Book of Abstracts

Foreword

Thank you for attending the International Symposium on Weather Radar and Hydrology 2008.

This event belongs to a series of symposia originally called "Hydrological Applications of Weather Radar" that started in 1989 at the University of Salford, UK. This first symposium was followed by the Hannover (1992), Sao Paulo (1995), San Diego (1998), Kyoto (2001) and Melbourne (2004) editions.

The main objective of the symposium is to promote the use of quantitative precipitation estimates (QPE) and forecasts (QPF) derived from weather radar technology in hydrological sciences and their applications. The small change in the symposium name outlines the need for an increased synergy between radar physicists and hydrologists. The complexity of radar systems, the indirect nature of the measurement and the high variability of rainfall at all scales still make radar QPE and QPF very challenging tasks. However, weather radar networks offer unprecedented means for observing the space and time variability of rainfall, a critical point for improving our understanding of the hydrological cycle in the context of growing anthropic pressure and climate change impact on water resources.

The symposium is composed of two events:

- A 3-day conference held on **10-12 March 2008** in the Europole Congress Center in Grenoble, France.

  We are pleased to welcome 6 invited speakers: Isabelle Braud (Cemagref, France), Jim Freer (University of Lancaster, UK), Witold Krajewski (IIHR, USA), Alan Seed (BoM, Australia), Pierre Tabary (Météo-France), Isztar Zawadzki (McGill University, Canada). In addition, the programme is composed of 52 oral and 80 poster presentations covering the multiple aspects of radar physics, radar QPE and QPF and distributed hydrological modelling. This very rich scientific material is presented in the book of abstracts and the CDrom of the extended abstracts intended for use during and after the symposium. Demonstrations of a mobile weather radar system and an operational flood warning system are also proposed by two exhibitors.

- A 2-day workshop held on **13-14 March 2008** in a nearby mountainous village Autrans in the Vercors mountains.

  The workshop is dedicated to thematic discussions aimed at summarizing the conference results and defining future lines of research. Three themes have been chosen:

    - The most promising techniques for rainfall estimation
    - Rainfall re-analyses for hydrological sciences
    - Challenges in distributed hydrological modelling.

Selected contributions presented during the conference and summaries of the workshop thematic discussions will be published in a Special Issue Journal of Advances in Water Resources in order to increase the audience and impact of the symposium.

On behalf of the WRaH2008 organizing committee, I would like to thank all the institutions sponsoring this event and to wish all the attendees a fruitful, stimulating and pleasant stay in Grenoble and Autrans.

Guy Delrieu

WRaH2008 convener

ORAL SESSION : IMPROVING RAINFALL ESTIMATION IN OPERATIONAL RADAR NETWORKS

ORAL SESSION : OTHER PROMISING RAINFALL MEASUREMENT TECHNIQUES

ORAL SESSION : QUANTITATIVE PRECIPITATION ESTIMATION

ORAL SESSION : QUANTITATIVE PRECIPITATION FORECASTING

ORAL SESSION : DISTRIBUTED HYDROLOGICAL MODELING

POSTER SESSION : RADAR PHYSICS AND HYDROLOGY

POSTER SESSION : QUANTITATIVE PRECIPITATION ESTIMATION AND FORECASTING

POSTER SESSION : DISTRIBUTED HYDROLOGICAL MODELING

ORAL COMMUNICATIONS

O1-001

Quantitative Precipitation Estimation in the presence of ground and AP clutter - Polarimetric perspective

Dusan ZRNIC [1] *Valery MELNIKOV* [2] *Pengfei ZHANG* [2]

1 NOAA/National Severe Storms Laboratory 2 CIMMS/University of Oklahoma

Polarimetric radar offers several advantages for mitigating ground. Currently in the WSR-88D network (of non polarimetric radars) stationary clutter is recorded to create clutter map for a particular radar site. During radar operations, the map determines at what locations the clutter filter will be applied to eliminate most of the clutter power from the signal. We posit that in the polarimetric era the clutter map should be generated by analyzing the spectral densities of polarimetric variables in the narrow band of frequencies centered on zero Doppler. The clutter map generated that way will be robust, automated, and amicable to technicians. Moreover, the same method can produce instantaneous "adaptive clutter maps". These would be handy in situations where intermittent clutter due to anomalous propagation is present because it would target only these locations.

Whereas recognition and filtering clutter from the signal is straight forward, recovery of the precipitation part is not because the clutter residue often competes with the precipitation signal. A simplest approach is to apply existing classification schemes to the variables obtained from the filtered signal. Examples of such applications on the signals that have been altered by the clutter filter are given. A more complex approach involves further processing of the polarimetric spectral densities aimed at identifying contributions from precipitation. These and possibilities of further improvements are discussed.

O1-002

A VPR correction method based on separating precipitation types

María FRANCO[1] Rafael SÁNCHEZ-DIEZMA[1] Isztar ZAWADZKI[2] Daniel SEMPERE-TORRES[1]

1 Grup de Recerca Aplicada en Hidrometeorologia. Universitat Politècnica de Catalunya. Barcelona, Spain 2 J.S. Marshall Radar Observatory, Departament of Atmospheric and Oceanic Sciences, McGill University, Montreal, Quebec, Canada

One of the main errors affecting rainfall estimation by weather radar is due to the fact that radar does not scan the precipitation at ground level, but a certain height. Since different types of precipitation show different characteristic vertical profiles of reflectivity (VPR), this error strongly depends on the type of precipitation. In fact, only in case of stratiform rain it is possible to talk about systematic errors: the overestimation produced when radar measurements intercept the bright band, and the underestimation produced when radar scans precipitation in the form of snow.
Most of the techniques previously applied to extrapolate the observed reflectivity to the ground consist of applying the same representative VPR for the whole radar volume. However, it is very common to register different types of precipitation (with different characteristic VPR) in the same radar scan. So, an improvement in the QPE is expected if the radar volume is previously classified in zones with different types of precipitation, and the VPR correction is applied separately to these zones.
Accordingly, a method to correct the error related to the vertical variation of the reflectivity, based on separating convective and stratiform precipitation, is presented and evaluated. This evaluation has been carried out by comparing the obtained rainfall estimates against data from a dense raingauge network.

This work has been done in the framework of the EC projects FLOODSITE (GOCE-CT-2004-505420), HYDRATE (GOCE -CT-2006-037024) and EWASE (ERAC-CT-2004-515742)

O1-018

A storm classification approach for real-time rainfall estimation

Siriluk CHUMCHEAN[1], *Alan SEED*[2], *Ashish SHARMA*[3]

1 Department of Civil Engineering, Mahanakorn University of Technology, Thailand 2 Centre for Australian Weather and Climate Research, Bureau of Meteorology, Australia 3 School of Civil and Environmental Engineering, University of New South Wales, Australia

Radar rainfall is estimated by converting radar reflectivity (*Z*) into rainfall intensity (*R*) using an appropriate *Z-R* relationship. Even if there is no error in the measurement of either reflectivity or rainfall intensity, there is variability in the *Z-R* relation due to variability in the distribution of rainfall drop size caused by the effect of different storm types. This paper presents an approach to integrate a storm classification method into real-time radar rainfall estimation. A minor modification of a texturing classification algorithm proposed by Steiner et al. (1995) that can classify each pixel in the radar image as stratiform or convective is used to classify the instantaneous reflectivity field into convective and stratiform components. A method to derive climatological *Z-R* relations for convective and stratiform rainfall when only instantaneous radar reflectivity and hourly rain gauge rainfall are available is proposed. A classification algorithm that is designed to account for spatial and temporal variation of rainfall types within an hour is introduced to partition hourly rain gauge rainfall into convective and stratiform components. Vertical profiles of reflectivity are used to verify the accuracy of the storm classification. An alternative method for verification of a storm classification scheme based on differences between probability distribution functions of rain gauge rainfall of the two rainfall categories is also presented. A 6-month record of radar and rain gauge rainfall for Sydney, Australia for November 2000 to April 2001 is used for calibration and rainfall events during February 2007 to March 2007 are used to evaluate the efficiency and applicability of the proposed methods. The results show that the proposed integration of storm classification into real-time radar rainfall estimation offers significant improvements on radar rainfall estimates over the case where the rainfall is assumed to belong to one homogenous type.

O1-003

Provision of error estimates for rainfall derived from operational polarization radars

Anthony ILLINGWORTH[1] Robert THOMPSON[1] Jacqueline SUGIER[2]

1 University of Reading, UK   2 The Met Office, UK

This paper investigates how improved rainfall rates, accompanied by the quantified errors needed for accurate flood prediction and for use in data assimilation, can be derived operationally from the polarization parameters by better characterizing the raindrop size spectra and by correcting for attenuation. An accompanying paper (Sugier et al) demonstrates how polarization radar can improve data quality by better recognition and rejection of non-precipitation echoes and by using the redundancy of the polarisation parameters in rain to provide accurate calibration of Z. This work forms part of the trials currently underway to evaluate any improvements in rainrate estimates using the polarimetric C-band radar at Thurnham in Kent which is now part of the UK operational radar network. A major difficulty with using ZDR to infer the raindrop size spectra from operational radars is that the values of ZDR at each gate are very noisy and can take on unphysical negative values. To reduce the effect of this random statistical noise in ZDR, we examine the scatter of Z and ZDR over regions of about 5 by 5km and derive values of the normalized drop concentration, Nw, and its error. This value of Nw is then converted into the value of 'a' (and its associated error) which should be used in the $Z=aR^{1.5}$ relationship for the region. The use of a simple constant coefficient relating attenuation to differential phase shift has been widely proposed, but studies suggest that the value of this coefficient can vary by a factor or two depending on the temperature and the degree of Mie scattering in the rain. By the use of additional constraints we derive a value for this coefficient and its uncertainty and so compute a correction for attenuation accompanied by an error. Finally, both conventional rainfall rate, and the improved radar rainfall rate with its error using the polarisation parameters, are computed from the 12 low levels radar scans performed each hour which are then compared with the hourly rainfall recorded at tipping bucket rain gauges.

O1-004

Rainfall estimation algorithm for polarimetric NEXRAD

Alexander RYZHKOV[1] *Scott GIANGRANDE*[2]

1 CIMMS / NSSL, Norman, USA 2 CIMMS, Norman, USA

The paper contains description of the latest version of the rainfall estimation algorithm recommended for polarimetric WSR-88D radar. This version of the algorithm, called QPE v2, is planned for implementation during initial deployment of polarimetrically upgraded NEXRAD radars scheduled for 2009.
According to the algorithm, quantitative precipitation estimation is preceded by and is contingent on results of polarimetric hydrometeor classification. Polarimetric rainfall relations are utilized if the radar resolution volume is filled with rain (or rain and hail) and multiple R(Z) relations are used for different types of frozen hydrometeors. The intercept parameters in the R(Z) relations for each class are determined empirically from comparisons with gages.
An extensive 4 year dataset collected with the NSSL KOUN polarimetric radar in Oklahoma was used to validate the suggested algorithm. It is shown the polarimetric method exhibits better performance than the conventional WSR-88D algorithm with 1.5 to 2 times reduction in the rms error of one-hour rainfall estimates up to distances of 150 km from the radar.
Additionally, we will comment on possibilities of further algorithm refinements which might include polarimetric VPR based on the results of explicit microphysical modeling within the melting layer and on the analysis of the impact of beam broadening on vertical profiles of polarimetric variables.

O1-005

Evaluation of surface rainfall rate derived using data from the Thurnham dual polarisation radar

Jacqueline SUGIER[1] Miguel RICO-RAMIREZ[2] Robert THOMPSON[3] Anthony ILLINGWORTH[3] Ian CLUCKIE[2] Malcolm KITCHEN[1] Michael VAUGHAN[4] Turner RUSSELL[4]

1 UK Met Office 2 Bristol University 3 Reading University 4 Environment Agency

The C-band dual polarisation Thurnham radar is the first of its kind in the UK. It was introduced into the UK operational weather radar network in August 2006 in view of increasing the radar coverage over South-East England, and serving as a platform for evaluating the merits of dual polarisation technology to real-time weather and flood forecasting.

University groups at Reading and Bristol have been developing algorithms to produce rainfall rate estimates using dual-polarisation parameters. The expected improvement brought by those algorithms include better identification of spurious echoes (i.e. reduction of false alarms), better identification and correction of sectors affected by attenuation, and better adjustment of the Z-R relation for light to medium rainfall rate. These two sets of algorithms have been implemented into the Met Office real-time test system alongside the operational conventional radar processing chain which does not use dual-polarisation parameters.

All three chains produce real-time surface rainfall rate products at 1km, 2km, and 5km Cartesian resolution every 5 mins, which are evaluated using over 300 rain gauges located within 250 km of the radar.

The outcome of this evaluation is expected to form the basis to make recommendation to the operating authorities about the reliability and error characteristics of the dual polarisation rainfall estimation and informs decisions as to the roll-out of dual polarisation radars across the whole UK weather radar network in the medium/long-term.

O1-006

Validation of the rainfall estimation using the operational algorithm from C Band polarimetric radar

Eiichi NAKAKITA[1] *Hidenobu TAKEHATA*[2] *Katsuhiro NAKAGAWA*[3]

1 Disaster Prevention Research Institute, Kyoto University 2 Graduate School of Engineering, Kyoto University 3 National Institute of Information and Communications Technology

Improvement of quantitative precipitation estimation (QPE) is one of the primary benefi ts provided by dual-polarization radars. Dual polarimetric radar has been developed and partly utilized in meteorology and hydrology in these twenty years because its potential ability in estimating drop size distribution (DSD) and in discriminating precipitation type. Meantime, Ministry of Infrastructure, Land and Transportation (MILT) in Japan put Shakadake operational C band Radar practical use in 1992. However, large improvement had not been realized because of its initial technical stage(Yoshino et al. 1988). Under these circumstances, it is expected that C band is chosen for operational radars in Japan, but polatimetric radars for operational use have been not put. Therefore, this study aims at the construction of the new operational algorithm about the rainfall estimate using polarimatric parameters.

Two polarimetric variables are important for accurate rainfall estimation. Differential reflectivity ZDR is a good measure of the median drop diameter, which should be taken into account for more accurate rain measurements. Among the indisputable advantages of polarimetric rainfall estimation based on specific differential phase KDP is its immunity to radar miscalibration, attenuation in precipitation, and partial blockage of the radar beam (Zrnic and Ryzhkov 1996).

Four types of estimators are examined. The simplest and conventional rainfall algorithm is the R(ZHH) relation, and three polarimetric estimators are R(ZHH,ZDR), R(KDP) and R(KDP,ZDR)(Bringi et al. 2001).

In this paper, we use the C band polarimeteric radar named COBRA (CRL Okinawa Bistatic Polarimetric Radar) which located in Nago, Okinawa and operated by the National Institute of Information and Communications Technology (NICT). This paper presents various rain events, for example baiu front and typhoon. The ground data to validate is the data of AMeDAS, which is every 10 minutes data, in the observation range of the radar and the data of the optical rain gauge, which is every minute data, at Ogimi and Onna.

In summary, there are the merits of each polarimetric algorithm, so it is very important to choose the effectual estimator depending on rain intensity, rain type and so on. We show that even comparatively simple algorithm improve the rainfall estimate. Therefore it is expected that further improvement is enabled in the future.

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O1-007

The European Weather Radar Network (OPERA): An opportunity for hydrology!

Iwan HOLLEMAN[1] *Laurent DELOBBE*[2] *Anton ZGONC*[3]

1 KNMI, Netherlands 2 RMI, Belgium 3 EARS, Slovenia

The OPERA programme (Operational Programme for the Exchange of weather RAdar information, www.knmi.nl/opera) is the Weather Radar programme of EUMETNET, the Network of the European Meteorological Services (NMSs). The objective of OPERA is to harmonize and improve the operational exchange of weather radar information between national meteorological services. The third phase of the OPERA programme is a joint effort of 28 European countries, runs from 2007 till 2011, and is managed by KNMI. OPERA III is designed to firmly establish the Programme as the host of the European Weather Radar Network.

The first OPERA programme (1999-2003) put emphasis on the specification of the meteorological products to exchange, to their exchange format, as well as on the software to enable the data exchange. The second OPERA programme (2004-2006) built on these achievements. Its main goal was to increase the exchange and use of the weather radar data in Europe, and to produce a set of recommendations and algorithms for the production of high quality weather radar data, including both wind and precipitation products. A pilot of an European datahub for weather radar data was established at the UK Met Office during this programme.

The new OPERA programme will focus on the operational generation and quality control of an European weather radar composite, exchange of 3D radar reflectivity and wind data, exchange of quality information, and availability of radar data for official duties of NMSs and research. A Weather Radar Data Hub will be specified, developed, and operated during this phase of OPERA. This operational Data Hub is crucial for reaching the main objective of OPERA-3, i.e., establishing the weather radar networking as a solid element of the European infrastructure. In the presentation, the OPERA programme and its objectives will be discussed, and opportunities for use of European weather radar data in hydrological research and applications will be introduced.

O1-008

Recent advances in the use of X-band polarimetric radar as a hydrological sensor - Sensitivity of polarimetric variables and polarimetric rainfall estimators -

Masayuki MAKI [1], Sang-Goon PARK [2], V.N. BRINGI [3]

1 National Research Institute for Earth Science and Disaster Prevention, Tsukuba, Japan 2 Seoul National University, Korea 3 Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, USA

The variability of radar rainfall estimators and their estimation errors with temperature, elevation angle of radar antenna (incident angle of transmitted pulses), and drop shape are investigated for X-band polarimetric radar.

The scattering simulations are performed under various conditions with three different temperatures, five elevation angles, and three formulas for drop shape (or axis ratio). Four types of rainfall estimators $R(Z_H)$, $R(K_{DP})$, $R(Z_H,Z_{DR})$, and $R(K_{DP},Z_{DR})$ are considered, where R is rainfall rate, Z_H is radar reflectivity at horizontally polarized waves, Z_{DR} is differential reflectivity, and K_{DP} is specific differential phase. Two types of raindrop size distribution (DSD) models are used in the simulations. One is mono-disperse DSD model. The second is a total 7,664 one minute averaged raindrop size spectra.

Results of simulation for mono-disperse DSD model show that the sensitivity of the specific differential phase K_{DP} to the equivalent volume diameter at X-band wavelength is always larger than those at S- (10cm-) and C- (5cm-) band wavelengths. The effect of resonance on polarimetric variables is small at X-band wavelength compared to C-band wavelength. Temperature dependence of the effect of resonance is small at X-band wavelength while it is significant at C-band. The effect of backscattering differential phase at X-band wavelength becomes pronounced for raindrop diameters larger than 3 mm.

At X-band, a variation of temperature does not cause a significant change of the four types of radar rainfall estimators. The $R(K_{DP})$ estimator is largely affected by variations of elevation angle and drop shape while the $R(Z_H)$ estimator is immune to variations of these parameters. The $R(K_{DP})$ and $R(K_{DP},Z_{DR})$ estimators produce estimation error smaller than 10% for rainfall rates above 40 mm h^{-1}, when information on elevation angle and drop shape are exactly known a priori. Otherwise, the $R(K_{DP})$ and $R(K_{DP},Z_{DR})$ estimators can produce larger estimation error than that by conventional $R(Z_H)$ estimators (about 35%).

Disadvantages for rainfall measurements at X-band wavelength are discussed. Because polarimetric variables calculated from information of the back scattering signal amplitude such as the reflectivity factor Z_H and the differential reflectivity Z_{DR} suffer from attenuation caused by rainfall. Thus, the usage of Z_H and Z_{DR} at X-band wavelength for rainfall measurements requires information about the specific attenuation A_H and the differential attenuation A_{DP}. Relationships A_H-K_{DP}, and A_{DP}-K_{DP} are derived from the simulation using observed DSD spectra, which will be useful for attenuation correction of the variables Z_H, and Z_{DR}.

The other disadvantage at X-band wavelength is non-uniformity in the back scattering differential phase δ although experimental data of Matrosov et al.(1999, 2002) tends to discount this possibility at least in light-to-moderate rainfall events. The usage of K_{DP} at X-band wavelength for rain rate estimation and in attenuation correction schemes requires the correction of backscattering phase mainly for cases with large spatial gradients. Simulations show that a clear relationship between δ and Z_{DR} exists. Thus, the correction of the back scattering differential phase may be possible in those cases where large spatial gradients are present. This is a topic of our future experimental studies.

In conclusion, it is suggested that in real radar observation the $R(K_{DP})$ and $R(K_{DP},Z_{DR})$ estimators should be altered with elevation angle and the use of those estimators requires a careful attention in consideration of drop shape variation.

O1-009

Application of an Xband radar in Tropical Rain : Rainfall Monitoring over a small basin, in Bénin during the AMMA campaign . Part 1 : Experimental set up, global performances and QPE case studies

Marielle GOSSET[1] Frederic CAZENAVE[1] Josias DOSSOUGOIN[1] Augustin KADJO[1]

1 IRD/LTHE, Grenoble, France   2 IRD, Cotonou,Benin   3 Université Cocody, Abidjan, Cote d'Ivoire

An X-band polarimetric radar Xport, developped by the IRD/LTHE, has been installed in Djougou, in the northnern Benin, since June 2005. This radar was set up as part of the International African Monsoon Multidisciplinary Analysis (AMMA) Enhanced Observation Period (EOP) strategy. The primary objective of this radar experiment is to sample with a high spatial and temporal resolution the rain fields associated to the precipitating systems which are feeding with water the Ouémé water shed and its sub-catchment such as the densely equipped Donga water shed (a 600 km2 area). The main application of this radar is to derive from radar measurement the Quantitative Precipitation Estimates (QPE) which will be needed in turn as a forcing field to run hydrological models. The radar data is also useful for analyzing the structure and kinematics of the rain fields, these characteristics being important to assess the quality and the limitation of the rain estimation which can be obtained with the rain gage network, which unlike the radar is available in the area on a permanent basis and used for operational purposes.

Our presentation will discuss the global performances of our radar during the experiment. It is found that even in a tropical area characterized by heavy rainfall, an X-band radar with characteristics such as our X-port is well suited for the monitoring of a small basin and the occurrence of signal extension due to attenuation was extremely rare.. We will also present the results of radar QPE, on several case studies. The ground validation data available consists in optical disdrometers (installed about 10 km away from the radar) and a network of 40 raingages spread in the area. It includes 2 targets zones and in each one a cluster of 5 gages distant from about 200m. As the radar is equiped with dual polarization, several algorithm based or not on the polarimetric technics were implemented and can be compared.. We will discuss the benefit of the differential phase shift measurement (PHIdp), used to overcome the measurement bias introduced by the Xband attenuation, and show that the algorithms based on this variable perform well in the tropical rainfall we sampled.

O1-010

Experimental Results on Rainfall Estimation in Complex Terrain with a Mobile X-band Polarimetric Radar

John KALOGIROS [1] Marios ANAGNOSTOU [2] Michele TAROLLI [3] Emmanouil ANAGNOSTOU [4] Marco BORGA [3] Anastassios PAPADOPOULOS [2]

1 National Observatory of Athens, Institute of Environment and Sustainable Development, Athens, Greece 2 Hellenic Center for Marine Research, Institute of Inland Waters, Anavissos, Greece 3 University of Padova, Department of Land and Agroforest Environments, Padova, Italy 4 Hellenic Center for Marine Research, Institute of Inland Waters, Anavissos, Greece; and University of Connecticut, Civil and Environmental Engineering, Connecticut, USA

The performance of X-band dual-polarization radar rainfall estimation is evaluated on the basis of experimental measurements from a complex terrain setting in the Northeast Italian Alps. The data include volume scans from the National Observatory of Athens mobile X-band Polarimetric radar (X-POL) and coincident in-situ measurements from a dense network of high-resolution rain gauges ranging up to 50 km from XPOL. In this complex terrain setting X-POL measurements are affected by ground clutter, partial beam occlusion, and mixed phase contamination. Storms of varying intensity and spatio-temporal structure are included in the analysis. Algorithms are devised to correct for the various effects the significance of which are assessed in terms of improvements in attenuation correction and rainfall estimation. We assess different rainfall estimation algorithms through comparisons with rain gauge measurements at a range of time resolutions (5 min to storm totals). On this basis, the significance of polarization diversity parameters such as differential reflectivity and differential propagation phase shift is investigated for different storm cases and terrain complexities. Goal of this investigation is to evaluate/demonstrate the value of locally deployed low-power X-band radars in cases of complex terrain environment and/or cases where we need very-high resolution data to support hydrologic predictions.

O1-011

Synthetic retrieval study for polarimetric X-band radars based on a variational scheme

Lesya BOROWSKA[1] Alessandro BATTAGLIA[1] Dirk SCHÜTTEMEYER[1] Simmer CLEMENS[1]

1 Meteorological Institute, University of Bonn, Bonn, Germany

Polarimetric X-band radars promise improved QPE thanks to their better characterization of the drop size distribution (DSD) and the more reliable attenuation correction. In preparation to the installation of a polarimetric 9.5 GHz radar at the Bonn facilities -foreseen for early 2008 - an optimal estimation theory retrieval algorithm has been developed. The methodology, applied to the observations of reflectivity Zh, differential reflectivity Zdr and differential phase shift along a ray, produces DSDs and rain rate fields inclusive of error covariance matrices, accounting for many source errors (e.g. attenuation correction, inherent noise in Zdr and in differential phase shift, uncertainty in the relationship between dropsize and axial ratio).
The backbone of the algorithm is represented by a forward model based on precomputed look-up tables, which evaluates the radar measurable variables and their Jacobians respect to the parameters of the drop size distributions (parameterized by a Gamma function).
Time series of disdrometer data are exploited to evaluate the a-priori covariance matrix of the state vector and to simulate synthetic along-the-ray spatial DSD profiles. Sensitivity tests of the algorithm will be presented and compared with state of the art polarimetric algorithms with particular focus on the discussion of the relevance of the different sources of error.

O1-012

On the use of a mobile XPOL weather radar for flood warning

Augusto José PEREIRA FILHO[1] *Oswaldo MASSAMBANI*[1] *Ricardo HALLAK*[1] *Cesar BENETI*[1]

[1] University of São Paulo

This work is concerned with the application of operational mobile X-band polarimetric weather radar (MXPOL) for flash flood warnings in the Metropolitan Area of São Paulo (MASP). The MXPOL can be quickly moved from on place to another to monitor different weather systems in real time. It is used in conjunction with a mesoscale NWP model to anticipate types of weather systems; if convective, the MXPOL is placed nearby the MASP and, if long lived stratiform, by the coast area. Examples of the early detection of different precipitating systems with the MXPOL are shown.

O1-013

Mapping the precipitation from X-band weather radar

Emmanuel MOREAU[1] *Jacques TESTUD*[1] *Erwan LE BOUAR*[1]

1 NOVIMET, 10-12 av de l Europe, 78140 Velizy

Accurate estimation of rainfall is crucial for many purposes, as for crop yield assessment, water resource management and flood monitoring. The main objective of this paper is to validate X-band radar-derived rainfall estimate, with a special emphasis on the temporal and spatial variability of the rainfall.
Radar - rain gauge comparisons were systematically performed upon a one-year data base.
The radar data were collected by the X-band polarimetric HYDRIX radar located in Beauce region, processed in real time by ZPHI algorithm, and compared with 25 rain gauge network data. The statistics are computed in terms of spatial correlation, variogram, nash coefficient, bias and standard deviation. The various sources of uncertainties (instrumental, representativeness, and model) are then analyzed and quantified.

O1-015

Adjustment of C-Band radar with mobile vertical pointing X-band radar

Michael R. RASMUSSEN[1] *Flemming VEJEN*[2] *Rasphal GILL*[2] *Søren OVERGAARD*[2]

1 Aalborg University, Department of Civil Engineering, Aalborg, Denmark 2 Danish Meteorological Institute, Copenhagen, Denmark

Weather radar has a significant potential for improving the function of sewer systems and wastewater treatment plants by supplying distributed precipitation information for whole catchments (Einfalt et al, 2004). Information on both intensity and spatial distribution offers possibility for better real time control of the sewer system and wastewater treatment plant.

Traditionally, research within urban drainage has relied on rain gauges for precipitation data. The clear advantage of rain gauges is the simplicity and accuracy of the measuring technique. The primary disadvantage is the limited number of rain gauges. Often, there are only a few rain gauges in the catchments and sometimes there are none. Pedersen et. al, 2005 illustrated that spatial variation in the precipitation could have significant effects on the subsequent runoff, even for small urban catchments. For urban drainage application it is important that the radar is able to measure with as high spatial resolution as possible. Jensen and Overgaard, 2002 demonstrated that a local area weather radar based on a marine X-band system could measure with high spatial resolution. However, this is only possible in areas where these short range radars are installed. For most cities and for rural areas, the long range C-band radar is the preferred radar. In order to get most information from the C-band radar it is necessary to adjust it as accurate as possible. With only a few local rain gauges, this can be a serious challenge.

This study proposes to use a newly developed mobile vertical pointing X-band radar (VPR) to measure the local precipitation. By mounting the radar on a vehicle, measurements can be made in many places during the same storm event, thus improving the possibility for adjustment. The mobile VPR offers the possibility to study the accuracy of the stationary C-band radar at different distances. Also, the radar can be transported to interesting areas where it actually rains and not depend on chance, whether the thunderstorm moves above a fixed rain gauge. The VPR can also be fitted to busses or trains, which regularly travels along the same routes, thereby automating the procedure.

The measurements are performed by driving the vertical radar from Sindal in the northern part of Denmark to Rømø in the southern part of Denmark. In both ends, the Danish meteorological institute has two C-band radars. The direct distance between the two radars is 280 km. The VPR will measure the precipitation intensity every 10 second during the 4 hour long drive. This measuring campaign will offer the possibility to study effects of attenuation and variable sampling volume as a function of the distance from the radar. It will also be possible to study the overlapping area between the two C-band radars in greater detail.

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O1-016

Comparison rainfall maps from commercial microwave link measurements to operational weather radar data

Hidde LEIJNSE[1] Remko UIJLENHOET[2] Iwan HOLLEMAN[1]

1 Hydrology and Quantitative Water Management, Wageningen University, Wageningen, The Netherlands 2 Royal Netherlands Meteorological Institute, De Bilt, The Netherlands

Microwave links from commercial cellular communication networks have recently been suggested to be highly suitable for the estimation of path-averaged rainfall. Moreover, the high density of these existing networks over a large part of the continents (i.e. approximately 12,000 links with an average length of 3-4 km, in The Netherlands, which has a surface area of approximately 35,000 km2) make tomographic reconstruction of rainfall fields at a high spatial resolution possible. Operational weather radars are designed to provide just that: high-resolution rainfall fields. Because of the different measurement principles, scales, and resolutions (weather radars typically have a somewhat higher resolution than microwave link networks), rainfall fields derived from commercial microwave links will be different from those derived from weather radar data.

The two methods to derive rainfall maps (microwave link tomography and weather radar) are compared in a simulation framework. We use data from a high-resolution X-band radar to simulate microwave link signals and operational weather radar data. The rainfall fields resulting from the two methods can hence be compared to the true rainfall field. For this purpose, microwave link networks with different densities are generated stochastically. Thus, the effect of the density of the microwave link network can be analysed.

O1-017

Combining data from radars and microwave links

Rob CUMMINGS[1] Graham UPTON[2] Anthony HOLT[1] Kitchen MALCOLM[1]

1 Department of Mathematical Sciences, University of Essex, Colchester, Essex. CO4 3SQ, UK. 2 Observing Methods Technology Centre, Met Office, Exeter, Devon EX1 3PB, UK.

The final stage in the procedure currently used by the UK Met Office for producing a rainfield from the data collected by a weather radar consists of a comparison of raingauge information with the corresponding radar estimates. The question addressed here is whether raingauges (which require constant maintenance) might be replaced by a microwave link without loss of accuracy.
The results suggest that link-based adjustment of weather radars is certainly feasible and can improve on the existing gauge-based procedure. It is suggested that the procedure can be very cost effective and might be particularly useful in areas where gauges are difficult to position.

We are very grateful to the United Kingdom's Natural Environment Research Council for supporting this research under grant NER/D/S/2003/00703.

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O2-001

The AQUARadar field campaign - a comprehensive data set to improve areal precipitation estimation by weather radar

Martin HAGEN[1] Marco CLEMENS[2] Susanne CREWELL[3] Jan HANDWERKER[4] Martin LEEB[1] Gerhard PETERS[2] Joerg SELTMANN[5] Clemens SIMMER[6] Miklos SZAKALL[7] Peter WINKLER[5] Wenchieh YEN[1]

1 DLR Oberpfaffenhofen, Germany 2 University of Hamburg, Germany 3 University of Cologne, Germany 4 FZ Karlsruhe, Germany 5 DWD Hohenpeissenberg, Germany 6 University of Bonn, Germany 7 University of Mainz, Germany

The central objective of the project cluster AQUARadar funded by the German Science Foundation (DFG) since summer 2005 is to enhance the quality of radar derived area precipitation estimates by exploiting the spatial and temporal variability of the Radar signal on three different perspectives: by investigating (1) variations inside precipitation-filled vertical columns using the modes concept, (2) by analyzing the local 4D structure of radar data using physical reasoning, and (3) by exploiting complete events using Integral Radar Volume Descriptors of the 3D radar volume data. The project cluster will further explore the usefulness of polarisation weather radar and the polarimetric signatures of an improved description of the shape and behaviour of large falling raindrops obtained from experiments in a vertical wind tunnel.
In the frame of AQUARadar a 4-month field campaign was performed in summer 2006 in Southern Germany. Two clusters with each 5 vertical pointing micro rain radars were set up about 6 km apart. The clusters were complemented with a rain gauge, three disdrometers, one wind profiler, and a scanning cloud radar. The area was covered by three C-band weather radars, two of them polarimetric.
In the presentation we will show results from the campaign, including the temporal and spatial evolution of the drop size distribution, observations of rain drop shapes by different instruments, rain drop oscillation and the implication on polarimetric radar observations. The capabilities of polarimetric weather radars will also be shown. In summary it can be demonstrated that with the improved analysis methods it will be possible to reduce the error in rainfall rate estimation by conventional radars.

O2-002

Combining weather radar and raingauge data for hydrologic applications: from theory to practice

Ezio TODINI [1]

1 Department of Earth and Geo-Environmental Sciences, University of Bologna, Italy

In 2001 the paper titled "A Bayesian technique for conditioning RADAR precipitation estimates to raingauge measurements" (Todini, 2001) introduced a new technique based upon the use of block-Kriging and of Kalman filtering to combine, optimally in a Bayesian sense, areal precipitation fields estimated from meteorological radar to point measurements of precipitation, such as are provided by a network of rain-gauges. Block Kriging was used to estimate the average field over the radar pixels and its variance from the point rain gauge measurements, while a Kalman filter was taken to find the a posteriori estimates by combining the a priori estimates provided by the RADAR with the block Kriged measurements provided by the gauges, in a Bayesian framework.
The Bayesian combination technique, was first tested on theoretical synthetic data to assess its convergence to the true known solutions. Successively it was applied to real data and many new requirements had to be faced, such as non-negative weighting and incorporation of errors in gauge measurements, in order to respond to the request of more reliable quantitative and spatial descriptions of the rainfall field.
An original Block Kriging approach to the problem of spatial interpolation was introduced, which also included a new formulation of Kriging with uncertain point precipitation measurements. A Maximum Likelihood estimator was used at each step in time to estimate the semi-variogram parameters, while a new non negativity constraints were added to the Kriging system to prevent negative values in the Kriging weights. The proposed approach showed to be more effective in rainfall estimation than the traditional one, thus preventing the typical Kriging overestimations, smoothing and negative rainfall estimates.
Last but not least, the use of anisotropic variogram functions was incorporated to the Block Kriging formulation in order to better reproduce rainfall patterns.
The paper summarizes the new potentialities of the new system and shows the results obtained in real world applications.

O2-003

Quantitative precipitation estimation using radar, gauge and satellite for hydrometeorological applications in an operational center in the south of Brazil

Cesar BENETI[1] *Leonardo CALVETTI*[2] *Ieda PSCHEIDT*[1] *Augusto PEREIRA FILHO*[1] *Reinaldo SILVEIRA*[1]

1 SIMEPAR Technological Institute, Curitiba, Brazil 2 Atmospheric Sciences Department, University of Sao Paulo, Sao Paulo, Brazil

Quantitative Precipitation estimates (QPE) are, in general, performed with the spatialization of gauge data. Rain gauge networks measure rainfall directly, but usually have a low spatial density, unable to support hydrological requirements and flash flooding forecasts. Estimation from radar measurements has high spatial (1km2) and temporal (5 min) resolution but this need corrections in the intensities of precipitation. The development of improved methodologies to QPE merging radar and rain gauges data has been an objective from the initial studies of hydrometeorological applications.
In southern Brazil, rainfall is associated with extra-tropical cyclones, mesoscale convective systems, upper level jets, and frontal systems. However, mesoscale convective systems are responsible for a significant amount of the precipitation which occur in this area mainly during spring and summer.
More than 90% of the electric power generation in Brazil is produced in hydropower plants, and the south of Brazil is responsible for more than 30% of the energy production. Evaluation of QPE is fundamental to determine water volume available in reservoirs and basins for power generation. Also, hydric availability is an important information for agrobusiness, which is the major economic activity in the area.
To characterize and evaluate the precipitation in the region, a hydrometeorological system is used, with a S-Band Doppler weather radar, satellite information and a network of more than 80 automatic hydrometeorological stations (with hourly observations of precipitation and streamflow) in an area of around 200,000km².
A statistical objective analysis scheme was used to merge radar, gauge and satellite data, to improve QPE such that the error of the analyzed rainfall field becomes less than the least error among gauge, radar and satellite. To study the amplitude and phase of the precipitation in river basins, spatial averages in each sub-basin areas were used, in order to characterize surface and river draining. QPE were applied in a hydrological model to evaluate and compare the identification of the meteorological systems and their impacts in the streamflow in the basin.
With a set of observations covering the spring and summer season of 2003 to 2007, this paper presents the results which indicate that radar rainfall estimates provide better spatial and temporal resolution, while satellite estimates provide information in a larger area and raingauge measurements contribute to the adjustment of the amplitude of the precipitation estimation.
The results are used operationally in activities related to: preventing damages and injuries to people in areas prone to floodings; hydric balance estimates for agrometeorological models; input for hydrological models in hydropower plants and improvement of QPE with numerical models. With this work, we expect to

have a better understanding and improvement of our monitoring and forecasting abilities.

O2-004

Multi-sensor Precipitation Reanalysis

Brian NELSON[1] *Dongsoo KIM*[1] *Dj SEO*[2]

1 National Climatic Data Center - NOAA/NESDIS 2 NOAA/NWS/Office of Hydrologic Development, and University Corporation for Atmospheric Research

The archive of the Next Generation Radar (NEXRAD) Level II and Level III data at the National Climatic Data Center (NCDC) provides a unique opportunity for developing a high-resolution rainfall climatology suitable for regional applications. The data from almost all of the Weather Surveillance Radars 1988-Dopplers (WSR-88D) are archived and can be accessed via the High Density Storage System (HDSS) at NCDC. The Level III Digital Precipitation Array (DPA) for several radars over North and South Carolina are used to develop a merged radar and rain gauge rainfall product that has hourly temporal resolution and 4x4 km2 spatial resolution. The operational multi-sensor precipitation estimation algorithm of the NWS river forecast centers is adapted to work in a reanalysis mode. Six radars over North and South Carolina are selected for development of the multi-sensor precipitation reanalysis. Each radar has been operational prior to 1996 and thus provides for a 10-year data set through 2005. Ultimately, data sets that are monthly, yearly, and seasonal averages and accumulations will be developed for studying the rainfall variability over a relatively long period (Approx. 10 years) and large spatial extent. This presentation describes the science issues, such as reduction of long term radar-to-radar biases, reduction of local small scale biases, parameter optimization via cross validation, and merging of multi-sensor data sets. Initial results are shared in this presentation.

O2-005

Evaluation of several radar-gauge merging techniques for operational hydrological use in the Walloon region of Belgium

Laurent DELOBBE [1] Georges BASTIN [2] Philippe DIERICKX [3] Guillaume LECLERCQ [1] Luc MOENS [1] Marina THUNUS [1]

1 Royal Meteorological Institute of Belgium 2 Center for Systems Engineering and Applied Mechanics (CESAME), Université catholique de Louvain, Belgium. 3 Ministère de l'Equipement et des Transports de la Région wallonne, Namur, Belgium.

The Walloon region is 16842 square kilometers large and most of it belongs to the Meuse and Scheldt basins. The regional hydrological service (MET/DGVH) operates an automatic rain gauge network including about 90 stations which corresponds to a density of 1 gauge per 187 square kilometers. Radar observations are available from a C-band Doppler radar located in the south of the region and operated by the Royal Meteorological Institute of Belgium (RMI). The precipitation data ingested in the operational hydrological forecasting system are currently gauge observations only but a combined use of radar and gauge observations is planned in a near future.

In the present study, we evaluate several techniques for merging radar and gauge observations with various degrees of complexity. The merging techniques which have been implemented include (1) mean bias correction, (2) range dependant adjustment using a second order polynomial function, (3) range dependant adjustment complemented with a long term spatial adjustment aimed at correcting for beam blocking effects, (4) simple spatial adjustment through inverse distance weighting and (5) sophisticated merging based on geostatistical technique.

The verification of the precipitation field resulting from the merging will be based on the comparison with the 24h-accumulation gauge observations from the climatological network operated by RMI. This network includes 150 stations in the area of interest. Most of them are manual stations. Verification results will be presented for one year with the aim of selecting the most appropriate technique for operational use in the hydrological forecasting system.

O2-006

On the robust estimation of rainfall fields merging radar and rain gauges data in an operational context

Carlos VELASCO-FORERO[1] *Alan SEED*[2] *Daniel SEMPERE-TORRES*[1] *Geoffrey PEGRAM*[3]

1 Group of Applied Research on Hydrometeorology, Technical University of Catalonia (GRAHI-UPC), Barcelona, Spain 2 Centre for Australian Weather and Climate Research (CAWCR), Bureau of Meteorology, Melbourne, Australia 3 School of Civil Engineering, University of Kwazulu-Natal, Durban, South Africa

Techniques that are based on Kriging with an external drift or conditional simulation have been proposed in the literature as a means to combine radar and rain gauge data in an optimal manner, recognising that the gauge data provide un-biased observations at a point and radar data provide spatial information over a large domain. This paper evaluates the ability of these techniques to produce robust solutions in an operational context where the products need to be produced in near real-time using data that is frequently of a poor quality, where there are several restrictions on computation time and where a temporal consistence in the estimated rainfall fields is expected.
Both Kriging and conditional simulation require a model for the spatial correlation, which can be provided by either estimating parameters for a theoretical model or using the observed spatial correlation field directly. Additionally both techniques require a logarithmic transformation of the rainfall data, but the choice of how this is actually done has not received adequate attention to date.
This paper evaluates also the use of fast numerical techniques that are based on Fast Fourier Transformations to produce robust estimates of spatial correlation. The linear equations required to be solved in the Kriging estimations are not well conditioned and the use of Singular Value Decomposition to provide robust solutions to these equations is evaluated.
Case studies from the Catalan and Australian weather radar networks are used to evaluate the techniques and illustrate the difficulties that need to be overcome by an operational system.

O2-008

Merging radar and ground observations for operational quantitative rainfall estimation in four mountainous head catchments in Germany

Maik HEISTERMANN[1] Uwe EHRET[2] Axel BRONSTERT[1] Erwin ZEHE[1]

1 University of Potsdam 2 Water Management Agency Kempten

Flash floods in headwater catchments with areas typically around 500 km2 bear a high damage potential due to short lead times and a rapid increase in water levels. Given the typically low density of operationally available ground measurements of precipitation, weather radar is indispensable to attain the required spatial information on this scale (i.e. meso-gamma). However, ground observations are still needed to adjust for common and systematic errors in rainfall estimation by radar. In this study, we present an adjustment procedure which accounts for the most realiable information in both radar and rain gauge data and compare its performance to other benchmark methodologies by means of cross validation. Results will be shown for four head catchments in Germany (Upper Danube, Upper Iller, Goldersbach and Weißeritz).

The original procedure was proposed by Ehret (2002). Its philosophy is to preserve the mean rainfall field estimated from rain-gauge observations, but to imprint the spatial variability of the radar image. In a first step, we interpolate available gauge observations on a 1x1 km grid by means of ordinary kriging. Next, we imprint the spatial variability of the radar image: This variability is derived by comparing the original radar field with a mean radar field generated by kriging the rainfall observed by radar at our specific gauge locations. The resulting ratio between the original radar field and the mean radar field is then multiplied with our mean field from rain-gauge observations. In a final step, we mask out areas with zero rainfall. The procedure is implemented for an hourly time step, using national radar compositions on 1x1 km resolution, provided by the German Weather Service (DWD, 2005).

The described methodology is highly robust since the underlying mean field builds on gauge data in which we trust most to quantify precipitation intensity. The innovation in considering the spatial information from weather radar is to actually compare apples with apples (by comparing the original radar field with the mean radar field) - instead of comparing apples (radar) with oranges (rain gauges). Based on this procedure, we will investigate the following research issues: a) performance of our methodology against other benchmark methodologies. For this purpose, we use a selection of point and radar based interpolation techniques and cross validate them over a time period of four years (2004-2007) plus selected events between 2000 and 2004. Beyond, we compare cross validation performance subject to decreasing rain gauges density in order to study a method`s robustness under data scarce conditions; b) we estimate anisotropic variograms from radar images in order to improve the kriging interpolation of both rain gauge observations and radar rainfall oberservations at our gauge locations; c) we present strategies to consider spatial information on the quality of the radar observation in the course of the merging procedure.

These results are presented on behalf of the OPAQUE research project (Operationelle Abfluss- und Hochwasservorhersage in Quelleinzugsgebieten), funded by the Federal Ministry for Research and

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O2-009

Relevance of rainfall estimates from a dual polarized X-band radar

Stéphanie DISS[1] Jacques TESTUD[2] Jacques LAVABRE[1] Emmanuel MOREAU[1]

1 Cemagref aix en provence 2 Novimet

The goal of this paper is to evaluate rainfall measurement from two weather radars, a S-band radar (Météo France) and a dual polarized X-band radar (Hydrix). This work takes place in the European project FRAMEA (Flood forecasting using Radar in Alpine and Mediterranean Area). The two radars were localized near Collobrière at 4 km distance from each other, in the South East of France. For the validation we used as reference rainfall measurement from two rain gages network (Météo France, Cemagref). During the experiment, four significant rainfall events in spring 2006 were fully observed. We study the influence of the distance on the radar rain estimates. The results show a significant reduction of the statistical criteria beyond 60 km for both radars. For close range (< 60 km), the X-band radar shows better statistical results than the S-band radar compared to gages measurements.

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O2-010

Toward an Error Model for Radar Quantitative Precipitation Estimation in the Cévennes-Vivarais Region, France

Pierre-Emmanuel KIRSTETTER[1] Guy DELRIEU[1] Brice BOUDEVILLAIN[1]

1 Laboratoire d'étude des Transferts en Hydrologie et Environnement, Grenoble, France

Characterizing the error structure of radar quantitative precipitation estimates (QPE) is recognized as a major issue for applications in hydrological modelling. We want to "equip" radar QPE with a relevant description of uncertainties in terms of bias, variance and space-time structure.
Assuming the residual between radar and reference value to be a random variable, we will describe radar error by mean of probability distributions. We assess the radar QPE with respect to reference rain estimates derived from rain gauge networks. A geostatistical framework is proposed for the establishment of such reference estimates.
The model consists in an additive random error, described by a random distribution, to be associated to rainfall estimates to approximate true rainfall. The distribution of residuals is found conveniently approximated by a Gaussian model or better a Centred Exponential Model. It can be parameterized by the mean and the standard deviation of the residuals. This parameterization is found to be dependent on the rain rate, the integration time step and the distance from radar.
This preliminary investigation of the radar error model leans on radar and raingauge datasets of the Bollène 2002 Experiment aimed at assessing the interest of a volume-scanning protocol for radar QPE in the Cévennes-Vivarais region, France. We present here the results obtained with a preliminary version the new radar processing system (TRADHy) developed at LTHE. We plan to reprocess the radar datasets with an improved version and elaborate a new error model. We also plan to assess the impact of spatial bias correction on the space-time structure of such residuals.

The authors wish to thank Dr. Alexis Berne and Dr. Benoit Chapon for the helpful discussions and contributions.

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O2-011

A methodolgy to assess radar QPE uncertainties in real time. Generation of radar precipitation ensembles and their impact in hydrological modeling

Daniel SEMPERE-TORRES [1] *Xavier LLORT* [2] *Carlos VELASCO-FORERO* [3] *María FRANCO* [1] *Geoff PEGRAM* [1]

1 Group of Applied Research on Hydrometeorology (GRAHI). Universitat Politècnica de Catalunya. Spain 2 Group of Applied Research on Hydrometeorology (GRAHI). Universitat Politècnica de Catalunya. 3 Civil Engineering. University of Kuazulu-Natal. South Africa

In the last years, new comprehension of the physics underlying the radar measurements as well as new technological advancements have allowed radar community to propose better algorithms and methodologies and significant advancements have been achieved in improving Quantitative Precipitation Estimates (QPE) by radar. However, few of these algorithms and methodologies have been thoroughly tested, and the majority of them are essentially used in scientific studies or just applied by the same institutions that have developed them.

This work proposes a methodological framework to assess the associated uncertainties of a general QPE processing chain. This methodology could be used both, to provide quality metrics applicable to the inter-comparison of different algorithms and processing to evaluate their respective performances, as well as to assess the uncertainties of a QPE scheme to monitor and control its quality in real time.

The results obtained in the hydrometeorological observatory of Catalunya are used to show the potential of the methodology as well as the interest of the automatization of such a procedure in real-time QC management.

The methodology makes also possible to infer the 2-D error structure of the QPE estimates, and to generate multiple precipitation ensembles, compatible with the observed data and the infered error structure, as a way to represent the uncertainty associated to the precipitation estimates by radar.

The discussion of the results on a case study and their potential interest in hydrological applications are included here. Its use in a full hydrological application in the Besos basin is proposed in a related presentation.

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O2-012

Assessment of uncertainty in radar rainfall estimates

Daniele NORBIATO[1] *Marco BORGA*[1]

[1] Department of Land and Agroforest Environment, University of Padova, Agripolis, Legnaro (PD), Italy

Current systems for radar-based precipitation estimation consist of several interconnected algorithms, with a large number of (often nonlinear) functions and parameters controlling its performance. The parameter values of the system are often based on limited experimental studies and, more recently, on the implementation of calibration procedures aimed at identifying the optimal parameter set. This paper suggests, however, that there may be many parameter sets within an algorithm structure that are equally acceptable for rainfall estimation at the ground, and that these may come from very different regions in the parameter space. A methodology is proposed to take into account and assess the uncertainty arising from errors in parameter selection. The methodology, which is based on the GLUE (Generalised Likelihood Uncertainty Estimation), reformulates the algorithm calibration problem into the estimation of posterior probabilities of algorithm responses, thereby avoiding the idea that there is an optimum parameter set. The results of our preliminary studies are presented. Through an illustrative case study we show that the uncertainty assessment approach is not only practical and relatively simple to implement but can also provide useful information about the strength and limitations of the radar-rainfall estimation algorithm.

O2-013

Spatial structures and variability of intense Mediterranean precipitation

Alexis BERNE[1] *Guy DELRIEU*[2] *Brice BOUDEVILLAIN*[1]

1 EPFL, Lausanne, Switzerland   2 LTHE, Grenoble, France

The French Mediterranean regions are regularly affected by intense rainfall events which generate flash floods with catastrophic human and material consequences (e.g. Nîmes in 1988, Vaison-la-Romaine in 1992, Gard in 2002). The meteorological conditions favouring the occurence of such intense events are relatively well known at the synoptic scale, but the interactions of the atmospheric processes at the meso-scale is still an active research topic. The organization of intense Mediterranean events, through the identification of their characteristic space and time structures, is an important issue to further our understanding of the processes involved in order to better model and forecast these intense events, and to improve the management of hydrological hazards related to intense precipitation.
In this work, we focus on 2 particular events that occured in 2002: 8 September and 11 November 2002. They reflect the variety of the climatotlogy of intense Mediterranean rain events. Using a geostatistical approach, the characteristic scales are estimated at different time resolutions over a domain of about 100kmx150km. This approach makes it possible to analyze and quantify the characteristic scales and patterns of typical intense Mediterranean rain events, that are of primary importance for the generation of flash floods in this region.

O2-014

Weather Radar Derived Rainfall Areal Reduction Factors

Peter JOLLY[1] *Daniel JOBIN*[1] *Sid LODEWYK*[2]

1 Kije Sipi Ltd, 214, boulevard Saint-Joseph, Gatineau, Québec J8Y 3X4 Canada 2 City of Edmonton, Drainage Services, Asset Management & Public Works, 5th Floor Century Place, 9803-102A Avenue, Edmonton, Alberta T5J 3A3 Canada

Rainfall Areal Reduction Factors (ARF) are often used in hydrology to volumetrically adjust point-based rainfall statistics for application over large watershed surfaces. Existing ARF factors are derived using point-based rainfall data from meteorological stations and carry the inherent limitations associated with typically low density network data. This paper reports findings from analyzing seven years of gauge adjusted weather radar data in deriving ARFs and characterizing the spatial distribution of rainfall events occurring over and near the City of Edmonton, Canada. ARFs were derived from a pool of over 250 storm events and expressed as a function of the type of storm, duration, geographical extent and, maximum rainfall intensity. Furthermore, each storm event was identified and characterized according to a set of hydrological criterion from a 1km2 gridded, 15-minute radar database. Comparisons were completed with existing ARF relations and findings indicated the potential of creating higher spatial resolution ARF functions using weather radar data.

O2-015

Quantifying and Predicting the Accuracy of Radar-Based Quantitative Precipitation Forecasts

Frederic FABRY[1] *Alan w. SEED*[2]

1 McGill University 2 Australian Bureau of Meteorology Research Center

On the basis that hydrological users need to know the event-by-event forecast uncertainty, we computed distributions of radar rainfall forecast uncertainty as a function of forecast lead time, basin size, and forecasted rainfall intensity using data from the U.S. 3-D National Mosaic of radar data. Since these uncertainties are also weather dependent, we tried to find good predictors to help either reduce the forecast uncertainty or better define it. The value of some predictors was significant though modest, the predictors being more skillful at characterizing forecast uncertainty than at improving forecast accuracy. The value of predictors also depended on forecast lead time, basin size, and forecasted rainfall accuracy, different predictors performing best in different conditions.

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O2-016

Rainfall Nowcasting using Approximate Bayesian Inference

Remi BARILLEC[1] *Dan CORNFORD*[1]

1 Neural Computing Research Group, Aston University, Birmingham, UK

This work introduces a novel variational Bayes data assimilation method for the stochastic estimation of rainfall dynamics using radar observations for short term probabilistic forecasting (nowcasting). A spatial rainfall model based on the decomposition of the observed rainfall field using a basis function expansion captures the rainfall intensity from radar images as a set of "rain cells". The prior distributions for the basis function parameters are carefully chosen to have a conjugate structure for the rainfall field model to allow a novel variational Bayes method to be applied to estimate the posterior distributions in closed form, based on solving an optimisation problem, in a spirit similar to 3D VAR analysis. The rainfall field dynamics in the model are given by a vector field which advects the rain cells. A Gaussian process prior is chosen for the velocity field, which is tuned to have parameters that ensure the advection vectors are constrained to be smooth, and largely rotational in character. Estimation of the parameters for the basis functions is performed within a variational Bayes filtering framework: the optimal parameters minimise the Kullback-Leibler divergence, or relative entropy, between the true, but unknown, posterior distribution and a tractable, parameterised approximating distribution. A hierarchical Kalman filter is used to estimate the advection field based on the assimilated rainfall fields at two times. The model is applied to tracking rainfall dynamics in a realistic setting, using UK Met Office radar data from both a summer convective event and a winter frontal event. The performance of the model is assessed both traditionally and using probabilistic measures of fit based on ROC curves. The model is shown to provide very good assimilation characteristics, and promising forecast skill. Improvements to the forecasting scheme are discussed.

O2-017

Ensemble Kalman Fitler Assimilation of Doppler Radar Data Using the Cloud-Resolving Nonhydrostatic Model with An Aim to Introduce Polarimetric Radar

Kosei YAMAGUCHI[1] *Eiichi NAKAKITA*[2]

1 Graduate School of Engineering, Kyoto university, Japan 2 Disaster Prevention Research Institute, Kyoto university, Japan

It is important for short-term rainfall prediction to estimate initial state of variables in meso-scale atmospheric model. In recent years, the ensemble Kalman filter (EnKF) method has been proposed for performing the atmospheric 4-D data assimilation (e.g. Tong and Xue, 2005).
In this study, a performance of EnKF of Doppler radar data using the cloud-resolving nonhydrostatic model was demonstrated. EnKF method uses an ensemble of short-term forecasts to estimate the flow-dependent background error covariances required in data assimilation. The cloud-resolving nonhydrostatic model, called CReSS developed by Tsuboki and Sakakibara, was employed as a forecast model. Radial velocity and reflectivity were used as Doppler radar data observed on August in 2003. They are fit to be assimilated to resolve the moist convection; i.e. they provide sufficient temporal and spatial coverage. Moreover, the assimilation period, the number of ensembles, and the resolution of the forecast model were examined.
As a result, wind field was changed at the initial time for forecast by the assimilation of radial velocity, so a location of precipitation system predicted was corrected. The accuracy of predicted rainfall intensity was improved.
On the other hand, it is showed that polarimetric radar not only can retrieve raindrop size distributions but also can show promise in classifying hydrometeor (e.g. straka et al., 2000). Both information are key factors on QPF using an atmospheric model. This research proposes a method of assimilating the types of precipitation particles, such as raindrop, snowflake, ice crystal and graupel.

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O2-018

1D+3DVar assimilation of radar reflectivities for short-term high-resolution quantitative precipitation forecasts

Olivier CAUMONT[1] *Stéphanie PRADIER-VABRE*[1] *Véronique DUCROCQ*[1]

1 (Météo-France/CNRS), Toulouse, France

Through the Arome project, Météo-France aims at merging Aladin's dynamics and Meso-NH's microphysics into a kilometric-scale numerical weather prediction model capable of assimilating new high-resolution data.

In this framework, an original 1D+3DVar assimilation technique is being developed in order to assimilate volumes of radar reflectivities in the Arome model. The first step of the assimilation method itself consists in converting observed reflectivity profiles into humidity profiles with the help of background humidity and simulated reflectivity fields. Then, humidity profiles are assimilated as pseudo-observations with a 3DVar system.

The method improves drastically Meso-NH quantitative precipitation forecasts in comparison with reference runs without assimilation of radar data.

O3-001

Assimilation of radar-based QPE into distributed hydrologic model for monitoring and prediction of high-resolution hydrology and water resources information

Haksu LEE[1] Dong Jun SEO[1] Victor KOREN[2]

1 NOAA/NWS/Office of Hydrologic Development & University Corporation for Atmospheric Research 2 NOAA/NWS/Office of Hydrologic Development

With its high space-time resolution, radar-based QPE enables fine-scale distributed modeling to produce hydrology and water resources information, such as streamflow, runoff and soil moisture, at an unprecedented scale. It is well know, however, that radar QPE is subject to various sources of error which may greatly compromise the effective resolution and content of that information. It is also known, on the other hand, that the negative impact of certain types of error in radar QPE may be reduced significantly through real-time assimilation of hydrologic data, such as streamflow and soil moisture observations. In this work, we carry out a systematic assessment of the value of gridded radar-based QPE of varying quality to monitoring and prediction of high-resolution hydrology and water resources information as assimilated into the NWS operational distributed hydrologic model (1) using a 4DVAR technique (2) under varying levels of uncertainty in the QPE, in the initial soil moisture conditions, and in the streamflow and/or in-situ soil moisture observations. Also assessed from the experiment is the information content of the resulting hydrology and water resources variables, streamflow and soil moisture in particular, as a function of the upstream contributing area.

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O3-002

Distributed hydrological modelling using weather radar in gauged and ungauged basins

Steven COLE[1] *Robert MOORE*[1]

1 Centre for Ecology & Hydrology, Wallingford, Oxon, OX10 8BB, UK

Distributed hydrological modelling using space-time estimates of rainfall from weather radar provides a natural approach to area-wide flood forecasting and warning at any location, whether gauged or ungauged. However, radar estimates of rainfall may lack consistent, quantitative accuracy. Also, the formulation of hydrological models in distributed form may be problematic due to process complexity and scaling issues. The aim is to first explore new ways of improving radar rainfall accuracy through combination with raingauge network data. Integrated multiquadric schemes are developed as spatial estimators of rainfall using weather radar and raingauge data. Secondly, simple forms of physical-conceptual distributed hydrological model are considered, capable of exploiting spatial datasets on topography and, where necessary, land-cover, soil and geology properties. The simplest grid-to-grid model uses digital terrain data alone to delineate flow pathways and to control runoff production, the latter by invoking a probability-distributed slope-capacity relation. Model performance is assessed over nested river basins in northwest England, employing a lumped model as a reference. When the distributed model is used with the gridded rainfall estimators it shows particular benefits for forecasting at ungauged locations.

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O3-003

Using stochastic state-space modelling with radar input to specify and reduce hydrograph error

Chris COLLIER [1]

1 University of Salford

A Bayesian post-processor is used to generate a representation of the likely hydrograph forecast flow error distribution using raingauge and radar input to a stochastic catchment model and its deterministic equivalent. A hydrograph ensemble is so constructed. Experiments are analysed using the model applied to the River Croal in north-west England. It is found that for rainfall input to the model having errors less than 3 mm/h, corresponding to about a 15% error in peak flow, the stochastic model outperforms the determibnistic model. The implications for the use of radar data for flood forecasting are discussed. The range of hydrographs associated associated with the different model simulations and the measured hydrographs are compared. The significant improvement possible using a stochastic approach is demonstrated for a specific case study, although the mean hydrograph derived using the stochastic model has an error range associated with it. The uncertainty derived from the hydrograh ensemble is considered.

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O3-004

Flash-flood forecasting with the SURFEX/TOPMODEL coupled system

Béatrice VINCENDON [1] Ludovic BOUILLOUD [1] Katia CHANCIBAULT [2] Georges-Marie SAULNIER [3] Véronique DUCROCQ [1] Florence HABETS [4] Eric MARTIN [1] Joël NOILHAN [1]

1 GAME/CNRM (Météo-France, CNRS), Toulouse, France 2 LCPC,Nantes,France 3 EDYTEM,Université de Savoie,Le Bourget du Lac,France 4 UMR-SISYPHE ENSMP,Paris, France

The northwestern Mediterranean is prone to heavy rainfall events that lead to flash-floods over the small to medium basins of the region. The forecast of those flash-floods is difficult due to the spatial and time scales of these events. One action of the European Commission FP6 Integrated Project PREVIEW (PREVention, Information and Early Warning) is dedicated to the improvement of the Mediterranean flash-flood forecasting. It aims at developing and validating hydro-meteorological coupled systems based on kilometric-scale atmospheric models and hydrological models adapted to the fast hydrological response of Mediterranean catchments. In this framework, the hydrological model TOPMODEL (Beven and Kirkby, 1979) was coupled with the surface scheme (SURFEX) of the atmospheric MESON-NH and AROME models. Horizontal resolution of SURFEX and TOPMODEL models are 1 km and 50 m respectively. The hydrological model performs the lateral soil water distribution over the catchments and diagnosed saturated areas, from which the surface model, relying on the ISBA (Noilhan et Planton, 1989) scheme for natural land cover, simulates the surface run-off. Then, the surface run-off and deep drainage are routed on the hillslopes and in the river to the catchment's outlet to provide the total discharges.

Several flash-flooding events that occurred over Southeastern France since the year 2000 were used to validate the SURFEX/TOPMODEL coupled system. Both radar and raingauge data served to drive the hydrometeorological coupled system over three main medium watersheds of the French Cévennes-Vivarais region : Gardons, Ceze and Ardèche catchments. Sensitivity experiments to the water routing, the initial soil moisture, the profile of saturated hydraulic conductivity and the depth used for lateral transfers were conducted. As a result, an optimal configuration for the coupled systems was drawn.

In most of the cases, the coupled system caught well the peak flow both in time and intensity. The benefit of using the coupled SURFEX/TOPMODEL system against using SURFEX alone was clearly shown for both simulated discharges and soil water contents (the top of the catchments is dried whereas the soil is moistened near the hydrological network with the coupled system).

Then, high-resolution rainfall forecasts have been used as input to the coupled model. Hourly precipitation forecasts from 2.5 km MESO-NH simulations with various initial conditions were supplied to drive the SURFEX/TOPMODEL system. Better scores were obtained when the coupled system used as input the MESO-NH simulation starting from a mesoscale data assimilation instead of a large scale analysis. The study now focuses on how to evaluate the uncertainties of the forecasted rainfall and propagate them on the hydrological response.

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O3-005

Data assimilation and distributed hydrological flash flood modeling

Hélène BESSIERE[1] *Hélène ROUX*[2] *Denis DARTUS*[3]

1 PhD Student 2 Assistant Professor 3 Professor

Some parameters of hydrological models are not directly measurable and others need to be calibrated. As a consequence, all those parameters contain various sources of uncertainty and errors. The potential of variational data assimilation methods for parameter estimation can be exploited to improve parameter identification as well as prediction of the outlet flow.

The objectives of this study are first to improve the understanding of land surface hydrology and mechanisms of modeling process and secondly to reduce uncertainties linked to hydrological system characterization during flash flood generation. To achieve these objectives, an estimation of parameters involved in the calibration of the distributed MARINE (Modélisation de l'Anticipation du Ruissellement et des Inondations pour des événements Extrêmes) model was implemented. The estimation procedure is based on a variational data assimilation method called the adjoint state.

The MARINE model is a flash flood forecast model developed for real time exploitation of small watersheds. Inside this physically based model, the infiltration capacity is evaluated by the Green and Ampt equation and the surface runoff calculation is divided in two parts: the land surface flow and the flow in the drainage network both based on the hypothesis of the kinematic wave. In order to better represent the heterogeneities of the rainfall as well as the various behaviors of the land surface, the model is spatially distributed. The model requires a minimum numbers of data to run: the Digital Elevation Model, the rainfall data from meteorological radar, the land cover map and the description of the rivers.

The estimation process is applied on the Gardon d'Anduze catchment, located in southern France. It is a Mediterranean catchment, of 545 km² drainage area, often affected by flash floods. The goal is to determine the minimum set of parameters that better simulate the behavior of the watershed and effectively control the rate of infiltration and runoff for floods of different intensities.

The study shows that data assimilation techniques provide interesting contributions to data fitting in hydrological models. The estimated set of parameters allows simulating a hydrograph very similar to the observations. The evolution of the parameters values gives information about the importance of each parameter with respect to the modeling process. In order to match volume and peak discharge at the outlet, the results of the estimation process can be compared for different cost functions reflecting the objectives of the modeling. Consequently, the study contributes to a better understanding of the physical hypothesis on which the model is based.

Finally, from an operational point of view, the assimilation of observations during the rising flood phase, combined with the use of precipitation forecasts, allows anticipation, early identification and quantification of an imminent flood.

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O3-006

Accounting for uncertain radar rainfall estimates in distributed hydrological modelling

Kai SCHRÖETER [1] Xavi LLORT [2] Carlos VELASCO [2] Dirk MUSCHALLA [1] Manfred OSTROWSKI [1] Daniel SEMPERE-TORRES [2]

1 IHWB, TU-Darmstadt 2 GRAHI-UPC

Detailed information about spatial and temporal patterns of precipitation is crucial to adequately reproduce the dynamics of hydrological systems. Though, remarkable progress has been achieved in measuring precipitation fields using both radar and rain gages these data remain an important source of uncertainty in hydrological modelling.
Uncertain precipitation input is not only propagated through the hydrological model and in this way contributes to model predictive uncertainty but also affects the model parameters estimated in the calibration process.
It is expected that an explicit consideration of input uncertainty in the model calibration procedure yields more robust parameter estimates in the sense of physically and conceptually representing the hydrologic system behaviour which in turn increases the predictive capability of the model.
The objective of this work is to study the effect of uncertain precipitation input in spatially distributed hydrological models on model predictions and model parameter estimates.
For the analysis a distributed hydrological model (WBrM) (Klawitter, 2006; Lempert, 2000) is applied to the Besòs catchment (1024km², near Barcelona, Spain). Soil and land use patterns as well as precipitation input are represented on a 1km² grid resolution.
The representation of spatial detail in distributed models entails the consideration of spatial attributes of uncertainties inherent to input data. This requires the characterisation and quantification of uncertainties on the elementary model unit scale.
In this study the uncertainties associated to the observed precipitation field are quantified for each 10-minute time step in terms of a probabilistic ensemble (a set of equiprobable scenarios) of errors. The error is defined as the ratio in logarithmic scale between merged radar rain gages rainfall fields, which are assumed to represent the best available estimation of the 'true' precipitation field, and radar observations. Error fields for each time step of a complete rainfall event are analyzed to characterize their mean, variance and space-time correlation using Fast Fourier Transformation. Then, ensembles of error fields are generated for each time step via a probabilistic simulation approach using the previously inferred characteristics. Next, these perturbations are imposed to the observed radar precipitation field in order to generate an ensemble of rainfall fields.

This precipitation ensemble is used to drive the hydrological model. Forward propagation of uncertain input reveals the sensitivity of model predictions to input uncertainty. Model calibration is carried out for each member of the ensemble in order to evaluate the impact of uncertain input on parameter estimates.

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O3-007

Propagation of areal rainfall estimation errors into rainfall-runoff models

Eric GAUME [1] Leatitia MOULIN [2] Obled CHARLES [3]

1 Laboratoire central des Ponts et Chaussées, Nantes (France) 2 ENPC-CEREVE, Paris (France) 3 LTHE, Grenoble (France)

Among the various sources of uncertainties affecting the accuracy of rainfall-runoff (RR) simulations and limiting their operational use for flood forecasting issues, the areal rainfall estimation errors appear to play a major role. This is illustrated on a specific case study: the simulation of the flood hydrographs of various tributaries of the upper Loire river. This area is frequently exposed to flash floods and densely covered by an operational network of river and rain gauges. For technical reasons, no quantitative valuations of the radar measurements are possible for the moment. Areal rainfall estimation rely therefore only on the raingauge network.
An error model including temporal dependence has been calibrated and validated for the hourly mean areal rain rates over 11 watersheds of the region (combination of kriging and an autoregressive model). The efforts done to build a realistic error model is the main originality of the present work if compared of previous published results on the same issue. The propagation of these errors into calibrated rainfall-runoff models using Monte Carlo simulations shows that a large part of the RR simulation errors can be explained by the rainfall estimation uncertainties.
Two major conclusions can be drawn from this state of fact. These uncertainties should be taken into account and assessed by flood forecasting services. The reduction of the rainfall estimation uncertainties is a major concern for operational hydrology, the radar still being the most promising technology.

The work presented is part of the European research program Floodsite. It also benefited from the financial support of the Direction Régionale de l'Environnement Centre and of the Etablissement Public Loire.

O3-018

Sensitivity of the hydrological response of small ungauged catchments to the resolution of the rainfall fields in the context of flash floods

Claire MANUS [1] Isabelle BRAUD [2] Pierre VIALLET [3] Sandrine ANQUETIN [4] Brice BOUDEVILLAIN [1]

1 LTHE, Grenoble and UR HHLY, Cemagref, Lyon, France 2 UR Hydrologie-Hydraulique, Cemagref, Lyon, France 3 HYDROWIDE, Grenoble, France 4 LTHE, Grenoble, France

In September 2002 a flash flood killed 23 human lives and generated 1.2 billion Euros of damages in less than 24 hours over an area of 20000 km² located in the south of France. The Gard river basin was hit by a storm that locally received more than 600 mm in one day (Huet et al., 2003). This storm triggered catastrophic flash floods on many upstream tributaries as well as the most important flood ever reported of the major rivers (Gard, Ceze and Vidourle). Post-event hydrological investigation using interviews of witnesses and river cross-sections surveys allowed estimation of specific peak discharges of 17 watersheds, the size of which ranged from 10 to 100 km2. The estimation gave specific peak discharges of at least 5 m3.s-1.km2 and up to 20 m3.s-1.km2 in the 600mm area, whereas the 10 years return period discharge, in this region, is about 2 m3.s-1.km2 for such catchment sizes (Delrieu et al., 2005).

The prediction of such extreme events remains an open question due to scarcity of observations and the unknown individual hydrological behavior of very small basins. An analysis of casualties conducted by Ruin et al. (2007) showed that the reaction -and casualties- of these small catchments were spread over the whole duration of the event and not only at the beginning of the intense rainfall period. This let some hope for the efficiency of early warning in reducing the losses of lives.

In order to study the runoff generation on these small catchments, we implemented a physically based hydrological model based on the work of Varado et al. (2006) and developed under the numerical LIQUID platform (Viallet et al., 2006) on the Cévennes - Vivarais region. Soil characteristics were based on pedo-transfer functions applied to the soil profiles described in the Languedoc-Roussillon soil data base. We focused on 4 small catchments of less than 15 km2, where casualties occurred. We used the model to study the mechanisms responsible for runoff generation. We identified several behaviors which can be related to various soil characteristics. We found that some soils were prone to infiltration excess runoff (low surface hydraulic conductivity) whereas some other soils were prone to saturation excess runoff (shallow soils) (Braud et al., 2007). This study was conducted using the final radar product with a 1x1 km2 and 5 minute time step resolution. In the paper, our objective is to quantify the interest of improved radar based rainfall fields in the prediction of theses small ungauged catchments. For this purpose, we will analyze the response of the 4 small cachments mentioned above to the input rainfall fields. We will progressively degrade the quality of the rainfall fields by using the kriged maps derived from rain-gauges observations only and various radar maps, corresponding to various accuracy in the treatment of these images.

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O3-008

Comparative Analysis of Radar QPE Products Through a Distributed Hydrologic Prediction Context

Baxter VIEUX[1] *John IMGARTEN*[1] *Jonathan LOOPER*[1]

1 University of Oklahoma

Hydrologic forecast reliability in urban, rural, and mixed basins depends on the model hydraulics, antecedent soil moisture, and accuracy of quantitative precipitation estimates (QPE) derived from radar and rain gauge observations. Streaflow simulation experiments using radar QPE products for short-term prediction and long-term streamflow is analyzed to identify the limits to predictability. Radar derived QPE products can be tested to identify bias and random errors associated with operational radar data, such as the S-band (NEXRAD) or X-band radars developed as 'gap-filling' radars. Using radar QPE derived from the NEXRAD radars as input to a physics-based distributed hydrologic model, Vflo is used to simulate basins ranging from 10 to over 800 km2. Hydrologic forecast reliability due to model hydraulics and rainfall inputs are identified for individual hydrographs and for longer term simulations of streamflow and water balance.

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O3-009

Hydrologic and hydraulic distributed modelling with radar rainfall input - Reconstruction of the 8-9 September 2002 catastrophic event in the Gard region, France

Laurent BONNIFAIT [1] Guy DELRIEU [2] Matthieu LE LAY [3] Eric GAUME [4] Arielle MASSON [1] Philippe BELLEUDY [1] Georges-Marie SAULNIER [5]

1 LTHE, Grenoble, France 2 LTHE, Grenoble,France 3 LCPC, Bouguenais, France 4 Sogreah, Grenoble, France 5 EDYTEM,Université de Savoie,Le Bourget du Lac,France

This contribution follows the initial work realized by the research teams of the Cévennes-Vivarais Mediterranean Hydro-meteorological Observatory (Delrieu et al. 2005) on the 8-9 September 2002 catastrophic event in the Gard region, France. A distributed hydrologic and hydraulic modelling is implemented to put in coherence the various sources of data collected by the operational services and during the post-event field campaigns. Radar rainfall data (corrected for spatial bias at the event time scale) was used to force the n-TOPMODELs distributed hydrologic model over the Gardon watershed. The modelled discharge time series were compared to the peak discharge estimates collected during the post-event field campaign prior to be used as upstream boundary conditions for a hydraulic model built for the plain part of the Gardon watershed. The following results are obtained: (1) the response of the head watersheds is clearly very much influenced by the space-time distribution of rainfall with flash floods occurring in strong connexion with the trajectory of the convective part of the MCS; (2) due to the watershed geomorphological characteristics, the hydraulic model brings a clear improvement of the flood dynamics representation at the watershed outlet and the impact of the spatial distribution of rainfall remains significant at this scale. The potential of the implemented procedure for a critical analysis of the rating curves of the operational discharge stations is also illustrated.

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O3-010

Space-time rainfall variability and extreme flood response in the Sesia river basin,North Western Italy

Marco SANGATI[1] Marco BORGA[1] Davide RABUFFETTI[2] Bechini RENZO[2]

1 Department of Land and Agroforest Environment, University of Padova 2 ARPA, Regione Piemonte, Area Previsione e Monitoraggio Ambientale

A key question in hydrology is how spatial variability in rainfall and soil properties impacts on the flow response at various spatial scales. This question has important practical implications in terms of the accuracy of flood predictions from catchment runoff models which use data from weather radar. Such flood predictions may underpin flood warning procedures in real-time and form a key role in the design and planning of flood defence measures.

The purpose of this paper is to employ a unique dataset, encompassing rainfall and discharge data from an extreme flash flood event as well as from less intense events, together with a distributed rainfall-runoff model to investigate how spatial variability in rainfall and soil properties impacts on flood response at various catchment scales.

The hydrometeorological processes that control flash flooding are examined through analyses of space-time rainfall variability and flood response in the Sesia river basin, North Western Italy. The analyses focus on three flood events that occurred 4-5 June 2002, 2-3 August 2005 and 14-15 September 2006.

The analysis of the impact of different spatial aggregation scale for the two input variables (rainfall and soil properties) is performed by applying the same hydrological model, i.e. with the same model structure complexity. The gains thus obtained by taking into account such spatial variabilites is compared, thus allowing the ranking of their comparative significance.

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O3-011

Toward flash flood prediction in the dry Dead Sea region by utilizing radar rainfall information

Efrat MORIN [1]

1 Department of Geography, the Hebrew University of Jerusalem, Jerusalem, Israel

The objective of this study is to examine, through a case study, the effectiveness of a radar-based flash flood warning system for the dry region of the Dead Sea. The studied area is the Arugot catchment (235 squared km) with a sharp annual rainfall gradient that ranges from 700 mm in the west to less than 100 mm in the east (near the Dead Sea shore). Radar data adjusted by daily gauges were used as input to hydrological model. The model accounts for the processes of: infiltration, hillslope and channel routing and transmission loss. The model was calibrated based on four events that were found to have a sufficient data quality. The model application (after calibration) was done in a continuous mode for ten years period. For this period of simulation, the model was able to correctly detect eight flash flood events, but it missed two and wrongly detected three events. Considering the relatively unfavorable conditions (blocked radar, the small number of daily gauges, and fast hydrological response), the above scores are considered reasonable.

O3-012

Using radar observations for HBV rainfall-runoff simulations

Barbro JOHANSSON[1] *Jonas OLSSON*[1] *Günther HAASE*[1]

1 Swedish Meteorological and Hydrological Institute

Catchment response to rainfall depends on the initial conditions. It is thus important to know the amount of rain that has fallen during the period immediately preceding a forecast. Area estimates of precipitation from point observations may contain considerable errors, especially in near real-time situations when data are available only from a limited number of meteorological stations. Weather radars measure precipitation with a high spatial and temporal resolution, but data has been difficult to use due to unreliable estimates of actual precipitation amounts. However, in recent years data quality has improved and the number of weather radars has increased. This was considered justification for a new evaluation of the usefulness of radar observations in conjunction with flood forecasts in Sweden. The focus was on flood events caused by high rainfall over a few days.

For the evaluation, simulations were made with a hydrological model (HBV) over flood events in 17 catchments. Areal rainfall input was estimated from three sources: meteorological stations, radar observations and a combination of both. For most events, the combination or radar data and point observations provided the best results.

The evaluation showed that radar observations of good quality, contribute to better flood forecasts due to a better description of the initial conditions in the catchment. It was, however, necessary to modify radar data by means of point observations from meteorological stations.

O3-013

Prediction and Management of Flash Floods in Urban Areas: the URBAS project

Thomas EINFALT[1] *Fritz HATZFELD*[2] *Andreas WAGNER*[3] *Seltmann JOERG*[1]

1 Hydro & meteo GmbH & Co. KG, Breite Str. 6-8, D-23552 Luebeck 2 Hydrotec GmbH, Bachstr. 62-64, D-52066 Aachen 3 Deutscher Wetterdienst, Albin-Schwaiger-Weg 10, D-82383 Hohenpeissenberg

Recent studies about climate change indicate growing frequency and intensity of flash flood events in Western Europe. Precipitation of such events partly corresponds to return periods greater than 100 years and triggers flooding in urban areas. The URBAS project is being supported by the German Ministry of Research.

URBAS has as a main objective to increase the preparedness and the range of possible actions of urban actors (e.g. communities, public enterprises) before and during rare small scale flood events.

Little is known about distribution, frequency and damage of flash floods in urban areas. There are no adequate forecast or warning systems, poor knowledge about effective precautionary measures and disaster control.

Urban flash floods are flood events which cause damages in small catchment areas of less than 100 km² (and even less than 10 km²) and are caused by small scale rain events with volumes far above design rainfall for the concerned hydrological structures.

Since the impact of extreme events on a small area remains limited to a small part of an urban area, these events frequently are not widely publicised although they are - locally - causing considerable damage. The large number of such small events sums up the damage volume to several million ¤ per year only for Germany.

URBAS is producing a data base for Germany of urban flash floods and rainfall events since 1990.

Within URBAS meteorological parameters, runoff and damage of flash floods are investigated. Innovative and feasible actions and precautionary measures of a reasonable cost-value-ratio are to be developed.

For 15 municipalities, "interesting" / "representative" case studies are analysed. Assessment of damage at micro scale as well as ex-post-analysis of typical courses of action will be carried out. Based on these studies, forecast tools will be improved and recommendations will be given concerning information management, early warning, precautionary measures and disaster control.

Each case study has a particular focus which is being analysed in depth. These special investigations range from rainfall representativeness analyses via 2D hydraulic simulation to the improvement for operational warning systems and further to recommendations for city planning.

Common element for each case study is a radar based overview of the rainfall distribution in order to provide guidance to the investigation of rainfall and flow related aspects. These initial analyses comprise the application of radar data correction schemes as well as adjustment of radar data to raingauges.

The following results are expected:

-A database with flash floods and heavy rainfall events in Germany

-The improvement of the quality of flash flood forecasts

-detailed analyses of 15 case studies
-Hazard maps and risk maps for chosen case studies
-An approach to a flash flood hazard map for Germany
-The development of measures and recommendations for a preventive flood control of flash floods in urban areas.

O3-014

The relevance of attenuation corrected X- and C-band data for real-time applications

Hans-reinhard VERWORN[1] Norbert JARDIN[2] Frederik KÖHLER[1] Stefan KRÄMER[1]

1 Institute of Water Resources Management, Leibniz University of Hannover,Hannover, Germany 2 Ruhrverband,Essen, Germany

In RTC radar data are especially useful for nowcasting and short term forecasts of rainfall runoff processes in order to find optimal control decisions. In urban areas the processing of radar data has to be done instantly due to the short reaction times, which excludes calibration with ground gauges. To improve the quality even of data from heavy storm events a procedure has been developed to correct for clutter and attenuation and allow for R/Z variations [3,4]. This paper describes the application of in this way processed radar data for two RTC case studies and concentrates on the benefits in comparison to less processed radar data which are normally available. The focus is on the simulated and forecast runoff and the derived control decisions rather than just rainfall.

Case study A requires the control of two consecutive detention basins in an urban creek in order to avoid downstream flooding. The wet detention basins may be emptied in the prospect of heavy storm events to provide additional storage but should filled again at the end of the event.

In case study B the discharge to a river branch is to be controlled. Required to be as low as possible it has to be increased with the objetive to provide sufficient dilution of combined sewer overflow discharged into that river branch.

In both cases forecast runoff is required to find the appropriate control decisions. The simulated RTC is performed with a hydrodynamic rainfall runoff program package capable of simulating continously the on-going processes based on measured rainfall as well as repeatedly simulating forecast conditions based on forecast rainfall [1,2].

With the advanced processing [4], the radar reflectivity data of selected events are corrected for attenuation. The rainfall forecast is based on these data. Then the measured as well as the forecast refelctivities are transferred to rainrates with a quadratic R/Z relation, the parameters of which are continously derived from on-line available disdrometer data. To evaluate the benbefit of the advanced procedures all calculations are carried out with conventionally processed radar data as well. It is shown that with the advanced processing procedures the forecast runoff is more realistic and the derived control decisions are more effective. This not only holds for the X-band data which are more affected by attenuation, but for the C-band data as well.

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O3-015

Improving flood forecasting by coupling weather radar Quantitative Precipitation Estimation with distributed hydrological model

Yangbo CHEN[1] Qiwei REN[1] Jin HAN[1]

1 Lab of Water Disaster and Hydroinformatics, Sun Yat-sen University,China

Compared with rain gauge precipitation, weather radar quantitative precipitation estimation has advantages for river basin flood forecasting, such as providing high spatial resolution precipitation that can have a better representation of the precipitation spatial distribution, high observation reliability during extreme weather condition that secures the predictability of extreme flooding. For these reasons, there exists the potentiality to improve flood forecasting accuracy and reliability by coupling weather radar quantitative precipitation estimation with flood forecasting model. But the current operational flood forecasting models are mainly lumped models that have the river basin mean precipitation as the input for flood forecasting, thus can not utilize the advantage of high spatial resolution of weather radar quantitative precipitation estimation. Distributed, physically based hydrological models that utilize the grided terrain characteristics for rainfall-runoff simulation have the potential to couple the high resolution radar estimated precipitation. The purpose of this study is to explore the potentiality for improving the reliability and accuracy of river basin flood forecasting by coupling the radar estimated precipitation with distributed, physically based hydrological model.

This paper presents a distributed, physically based hydrological model for river basin flood forecasting that derives the model parameters from the terrain characteristics aided by GIS technique. The model has several components including Basin Digitization (BD), Precipitation Feeding (PF), Evaportranspiration (EV), Runoff Production (RP) and Runoff Routing (RR). In the BD, a squared-grid network DEM is employed to divide a study basin into a number of squared grid cells, and every cell is considered as a sub-basin (called unit-basin), which consists of three layers: Canopy Layer (CL), Soil Layer (SL) and Underground Layer (UL). For every grid cell, unique vegetation type and leaf area index are assigned. The flow direction, flow accumulation, slope, flow length for every grid cell is calculated based on the DEM. The PF treating precipitation information measured by digital weather radar assigns rainfall rate to each grid cell. The EV calculates the grid cell based evapotranspiration, which uses vegetation types and leaf area index as key parameters. The RP determines runoff production formed at the grid cell scale. The RR routes the runoff to the basin outlet. This model can couple the radar estimated high resolution rainfall.

In this study, attention was also paid to the weather radar quantitative precipitation estimation and an algorithm is proposed based on the CINRAD radar in China. This algorithm includes radar data quality control and precipitation estimation. The radar data, received at every 5-6 minutes, is quality controlled first to remove the data noises, the pre-processed radar data then is used to estimate the precipitation, in particular a procedure for correcting attenuation was presented and validated.

North river basin in Southern China with a drainage area of 46,710km^2 was chosen as the study case that is a flood prone area and frequent catastrophic flooding occurs in the past century, particularly a devastating flooding occurred in

2006 and caused severe damages to lives and properties due to lack reliable and in-time heavy rain observation and forecasting. Around North River two CINRAD weather radars were deployed and can fully cover the whole North River Basin. Unfortunately these two radars were not put into operational operation for precipitation estimation, so not be used for assisting flood forecasting, but the observed data were archived and can be retrieved. In this paper two severe storms and flooding occurred in North River in 2005 and 2006 were retrieved and simulated.

During these floodings, a major part of rain gauges were destroyed and were not be able to measure the precipitation, with the archived radar rain rate reflectivity, the precipitation during the flooding was estimated and it was found that the spatial distribution of the precipitation over the whole basin was highly uneven, the basin area mean precipitation of radar and rain gauges(part rain gauges still operated) was compared and the bias was obvious. From the results it was found that attenuation exists and is serious and needed to be corrected. In this study a correction factor was presented to correct this attenuation.

The estimated precipitation was coupled to the distributed model to simulate the flooding. The data in 2005 was used to validate the model, while the data in 2006 was used for simulation. The results shows that the simulated peak flow and the hydrograph are quite reasonable compared with the observed river discharge. The simulated peak flow is only one hour later than the observation, that is much better compared with the lumped model forecasting that is 9 hours later than the observation.

From this study it can be concluded that weather radar has advantages over rain gauges during extremely weather condition as it can provide reliable precipitation estimation and to better represent the spatial distribution of precipitation over the river basin. By coupling with the distributed hydrological model, the peak flow can be better predicted than the lumped model that is vital for river basin flooding management, particularly for devastating flood management, such as issuing evacuation warning and infrastructure operation for flood control. Works to be done include better attenuation correction method and parameter deriving methods for distributed, physically-based hydrological model.

O3-016

A study of a quantitative precipitation forecast-based real-time operation of a multipurpose multi-reservoir system

Oliver C. SAAVEDRA[1] *V. Toshio KOIKE*[2] *Kun YANG*[3]

1 Fellow Researcher, Department of Civil Engineering, University of Tokyo 2 Professor, Department of Civil Engineering, University of Tokyo 3 Associate Professor, Department of Civil Engineering, University of Tokyo

To capture the spatial variability of the quantitative precipitation forecast, a distributed hydrological model with an embedded dam network operation was coupled to a heuristic model. A meso-scale quantitative precipitation forecast at 0.125 degrees resolution issued every 6 hours was used. Since the actual quantitative precipitation forecast is not accurate enough to be used directly for water resource management, the standard deviation in the error forecast was introduced into the optimization scheme. The system attempts to 1) reduce flood peaks downstream and 2) replenish water levels in reservoirs after a flood event. The proposed scheme takes advantage of the heuristic algorithm to evaluate different release combination sets automatically based on stochastic seeding considering the dam constraints and objective function. The latter is defined to minimize the absolute difference between the forecasted flood volume at a protection point and the total released volume from reservoirs. To estimate the flood volume, a desirable discharge is set at the protection point. The desirable discharge is defined as the average of observed values exceeding the mean annual discharge; however, this can be modified according to flood warning levels and water resource management policies. The optimization variables are the release-inflow ratios. In addition, the standard deviation in the error forecast was introduced as a weight in the objective function. The developed system was applied to the upper Tone River in Japan using up to three multipurpose reservoirs. The efficiency of the system's response was evident in reducing the flood peaks and volume at the protection point comparing the optimized releases against observed data. This approach has shown the feasibility to be used by dam operators as a real-time reference tool for more efficient water resource management.

We would like to extend our thanks to the river section bureau of the Ministry of Land Infrastructure and Transportation (MLIT) for providing valuable data from operating dams in the Upper Tone river and observed stream flow at gauges managed by their river network.

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O3-017

Testing radar rainfall estimates in a flood forecasting operational system

Pier Paolo ALBERONI[1] *Silvano PECORA*[1] *Fabrizio TONELLI*[1] *Anna FORNASIERO*[1]

1 Servizio IdroMeteorologicoARPA Emilia Romagna

This paper presents an innovative flood forecasting system which is being developed for the Po River basin in Italy. The system collects telemetry data from the hydrometeorological gauges and precipitation field estimations from radar network across the whole basin. Forecasted meteorological conditions come from a non-hydrostatic model and from a number of ensemble members with the application of limited area models. All these data are the inputs for three parallel operational chains of coupled hydrological and hydrodynamic models, running on a cluster of computers.

The innovations of the system relies upon its modular and highly configurable nature and the implementation of ensemble forecast techniques useful in estimating the prediction uncertainty. In particular, some preliminary results are shown about the uncertainty of real time application of hydrological modelling gained using radar rainfall field estimates and point measurements from raingauges. The reduction of major sources of errors in capturing the spatial distribution of rainfall results in a better hydrological simulation and may improve the final forecast as well.

Radar data have been processed to remove artifacts like anomalous propagation clutter, bright band and to attenuate the beam blocking as results of the impact of orography on the radar propagation. The optimal configuration of radar data processing chain and the uncertainty related to radar QPE are analyzed in terms of hydrological response of the models used in the experiment.

Preliminary test, to evaluate the radar contribution, are carried out over a sub-catchment of the Po river.

This activity is partially carried on in the framework of projects PROSCENIO and "Mosaicatura radar" supported by National civil Protection Dept.

POSTER COMMUNICATIONS

P1-001

Radar monitoring of dam-induced rainfall lines at the west of the São Paulo State, Brazil

Mauricio DE AGOSTINHO ANTONIO [1]

1 UNESP-São Paulo State University; IPMet-Instituto de Pesquisas Meteorológicas; Caixa Postal 281; CEP 17096-370; Bauru-SP-Brazil

In some days of summer with convective activity, rain cells organized in lines of heavy showers form throughout the reservoir of the Porto Primavera Power Plant (width: 10-12 km; extension: exceeding 120 km), in the west of the São Paulo State, Brazil (Pontal do Paranapema region). The objective of the present work is to characterize with radar observations these lines of heavy showers. Two episodes of rain lines on the Pontal do Paranapanema, in January 23 and 31, 2007, are presented when one S-band weather radar located in Presidente Prudente (22.118o S; 51.384o W), recording rain data each 7.5 minutes, up to the ray of 240 km with resolution of 1 km2, showed organized echoes forming a line of about 100 km, at a distance of 5-10 km of the lake edge at the Pontal; the lines had dislocated for east, reaching 40-50 km of distance of the lake, lasting 4.5 hours in a case and 3.5 hours in another one. The maximum reflectivities of the echoes, were observed exceeding 56 dBZ and 51 dBZ, respectively. The maximum heights of the 20 dBZ echoes were below 13 km and above 14 km. Accumulated rain (using a Z-R relationship: Z=17R1.54) had exceeded 100 mm the first day, and 50 mm at the second, in isolated points. The lines of heavy showers alone had been observed in the area after 1999, when the lake was already formed. Previous observations using radar, between 1995 and 1998, had not indicated the occurrence of these lines, only isolated convective rain echoes. It must be considered that the occurrence of these heavy showers will be able to intervene with the regimen or in the characteristics of the precipitation of the region.

P1-002

Genesis of mesoscale cyclonic vortices over tropical Brazil: a case study using a single-doppler weather radar

Mauricio DE AGOSTINHO ANTONIO [1] *Luiz Carlos MOLION* [2] *Ricardo TENÓRIO* [1]

1 UNESP-São Paulo State University; IPMet-Instituto de Pesquisas Meteorológicas; Caixa Postal281; CEP 17096-370; Bauru-SP-Brazil 2 UFAL-Federal University of Alagoas; ICAT-Atmospheric Sciences Institute; Maceió-AL-Brazil

Prior to the existence of satellite and radar observations, the belief was that the hinterland southern Brazil was not affected by mesoscale cyclonic vortices and tornados. In fact, these phenomena have been observed, though their genesis not analyzed, and they seem to be relatively common, during the local spring and summer, associated with the passage of frontal systems. The purpose of this note is to report the results of a case study of the cyclonic vortex, with an estimated diameter of about 30-40 km, that occurred on February 4th and 5th, summer of 2005, over northwestern State of São Paulo. Data from the IPMET/UNESP S band single-Doppler weather radar (CAPPI), located in Bauru (22.358°S; 49.027°W), center of State of São Paulo, GOES satellite imagery and radiosoundings of São Paulo (SBMT), Rio de Janeiro (SBGL), Curitiba (SBCT) and Florianopolis (SBFL) were used for this analysis. In addition, composite 6-hourly NCEP Reanalysis data of wind vector, temperature, humidity and omega were used to plot charts at surface, 850, 700, 500 and 200hPa levels and a latitudinal vertical cross-section along 50°W for understanding the synoptic situation that generated the vortex. On Feb 5th 00Z, the remainings of a weak frontal system, that entered the region 3 days before, were apparent in the satellite images, associated with a strong wind shear, NE with SW winds, as shown in the simultaneous synoptic charts. The radiosonde data showed a marked wind direction shift, NE to SW, at about 700 hPa level, with dry air above, indicating that the system, in general, was relatively shallow. An inspection of previous 2 days soundings and satellite imagery revealed a southwesterly 200 hPa level subtropical jet, with core speeds over 35 m/s, located at 27°S approximately. The synoptic charts sequence induces one to conclude that the subtropical jet shifted northward and dived to lower levels over northwestern São Paulo, generating the vortex at approximately 22h local time on February 4th, as seen in the radar images animation. Rainfall intensity, as measured by radar echoes, exceeded 30 mm/h in some portions during the existence of the vortex, with surface winds over 15 m/s. Thus, wind shear, resulting from lowering of the southwesterly subtropical jet in conjunction with enhanced northeasterly winds, over hinterland southern Brazil in the spring and summer, seems to be a plausible cause of the severe weather, cyclonic vortices and tornadoes reported in the region. Fortunately, the center of this particular vortex was located over an agriculture area and no severe damage was reported.

P1-003

Raindrop Distribution in the Eastern Coast of Northeastern Brazil using Disdrometer Data

Ricardo TENORIO[1] *Byung KWON*[2] *Marcia MORAES*[3]

1 Universidade Federal de Alagoas - Brazil 2 Department of Environmental Atmospheric Sciences, Pukyong National University, South Korea 3 Fundação para Estudos Avançados no Trópico Semi-Árido - Brazil

The raindrop size distribution (RDS) and a Z-R relationship were developed for the Eastern Coast of Northeastern Brazil (NEB) using rainfall data collected with a disdrometer RD-69, aiming its utilization to start the operation of a weather radar system. In this initial part of the study, due to the operation and maintenance facilities, the disdrometer was installed in the Campus of the Universidade Federal de Alagoas (The Federal University of Alagoas) in Maceió in 2001, nearly two years before the complete installation of the radar system. The RDS was stratified by rainfall rate (R) classes, which were clearly dependent on the parameters of the analytical distribution functions used, and showed a marked monthly variability. The parameters of the frequency distributions were dependent on R. The forms of RDSs were similar and there was no agreement concerning the amount of droplets in each one. This may be due to the short period of data collection or possibly due to the intraseasonal rainfall variability. The correlation coefficients between R and the parameters of exponential and log-normal distributions were in good agreement with previously reported studies. The general relationship for the Eastern Coast of NEB was found to be Z = 176.5 R1.29, with correlation coefficient equal to 0.83. This equation is in accordance with the ones for stratiform rain reported in the literature. In addition, the convective rain observed was produced by convective cells usually imbedded into stratiform cloud layers.

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P1-004

Monsoon-Related Precipitation as observed by the MIT Doppler Radar in Niamey, Niger, during the AMMA SOP

Michel CHONG[1] *Frank ROUX*[2] *Earle WILLIAMS*[1]

1 Laboratoire d'Aérologie, Université de Toulouse - CNRS, France 2 Dept. of Civil & Environmental Engineering, Massachusetts Institute of Technology, Cambridge, USA

During the AMMA Special Observing Period (June-September 2006), the MIT C-band Doppler radar installed near Niamey, Niger, was operated continuously with 3 repetitive scanning modes at a time interval of ten minutes. A long-range (250 km) survey mode was first performed at a single elevation angle of 0.7°, followed by a medium-range (150 km) volume scan with 15 elevation angles, finally an optional RHI scan (in a selected azimuth at 150 km range) was conducted depending on the potential interest of the precipitation features. Elevation angles in the volume scan ranged from 0.5° to 29.2°, which allows to capture convective cells topping at 15 km altitude at a minimum horizontal distance of 30 km. Range and azimuthal resolutions are 250 m and 1°, respectively. Thanks to the high sensitivity of the radar, both clear air and precipitation signals could be detected.

A systematic analysis of the reflectivity and Doppler velocity data is performed to deduce the characteristics of the mean flow and precipitation at less than 150 km from the radar. Reflectivity and reflectivity-derived precipitation fields are investigated in terms of maximum intensity, cumulated intensity, mean horizontal and vertical dimensions, preferred location and motion. The high-resolution time series of volume observations will be analyzed over a long-term period so as to characterize the relationships between the characteristics of the West-African monsson flow and the occurrence of precipitation.

P1-005

Precipitation studies over the Clermont-Ferrand urban area

Joël VAN BAELEN[1] Yves POINTIN[1] Jacques FOURNET-FAYARD[1] Thierry COLLAY[2] Thierry DAUGE[2] Michel BOURDILLON[2] Philippe DARTIGUES[3]

1 Laboratoire de Météorologie Physique, CNRS/Univ. Blaise Pascal Clermont-Ferrand II 2 Direction de l'Eau et de l'Assainissement de la Ville de Clermont-Ferrand 3 Clermont Communauté

In this contribution, we will describe the experimental set-up which has been put together in order to study the precipitations over the Clermont-Ferrand basin within a collaboration between the Laboratory for Meteorological Physic of the University Blaise Pascal in Clermont Ferrand, the City of Clermont-Ferrand, and the agglomeration of Clermont-Ferrand. Overall, the system includes a high resolution X band precipitation radar (60 m. in range and 30 sec. in time), a vertically looking K band micro rain radar, and a network of 16 rain-gages and 2 disdrometers. The scientific objectives of the experimental set-up are the study of the heterogeneity and the dynamics of the precipitating structures, and the development of the corresponding adapted Z-R relationships for improved rain rate restitution. The community applications of this work deal with storm basins and runoff management.

P1-006

Simultaneous X-band and K-band study of precipitation heterogeneity and associated Z-R relationships

Joël VAN BAELEN [1] Yves POINTIN [1] Ludovic BRUCKER [1] Gerhard PETERS [2] Marco CLEMENS [2] Bernd FISCHER [2] Hans MUENSTER [3]

1 Laboratoire de Météorologie Physique, CNRS / Université Blaise Pascal Clermont-Ferrand II 2 Meteorological Institute, University Hamburg 3 Max-Planck Institute for Meteorology, Hamburg

A newly developed local area X-band radar and a set of Micro-Rain-Radars were been deployed during the two month period of the LAUNCH-2005 campaign which took place around Lindenberg Observatory during September - October 2005. The X-band radar used a fixed elevation of 11.2° and operated with a spatial resolution of 60m x 2° and a temporal resolution of 30s. The 13 MRR systems were aligned over a 6 km line at a distance comprised between 3.5 and 6 km from the X-band radar. The vertically looking MRR resolution was set to 20s and 100m. In this study, we will first compare the X-band and MRR reflectivity Z within their intersecting resolution volumes. Then, we will focus our attention on the internal heterogeneity of rain in space and time within the observed rain events, and consider the MRR disdrometer measurements in order to retrieve the rain rates R and compare them with the corresponding X band radar Z-R relationships. Finally, we will study the different Z-R relationships found with respect to the different rain regimes observed during the various case studies proposed.

P1-007

Precipitation monitoring at different spatial and temporal scales using an innovative raingage-disdrometer network: the X-band PLUDIX

Marco CASAZZA [1] Federico FASSIO [2] Angelo PIANO [3] Efisio SANTI [1] Prodi FRANCO [1] Torricella FRANCESCA [1] Caracciolo CLELIA [1]

1 Università degli Studi di Torino 2 CNR - ISAC, Bologna 3 Università degli Studi di Ferrara

Between October 2003 and August 2006 a field campaign has been held in three different locations in Southern Italy in order to evaluate the evolution of precipitation systems (using both an innovative raingage disdrometer, PLUDIX, in a network of three points)both from point measures and using satellite data.
The purpose of the study has been to evaluate the collected data respect to the most actual climatological studies in an area affected by the potential risk of desertification.

This work has been partially financed under the Italian national project RIADE.

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P1-009

Preliminary results on convective cells and rain fall studies during COPS 2007

Joël VAN BAELEN[1] Yves POINTIN[1] Frédéric TRIDON[1] Martin HAGEN[2]

1 Laboratoire de Météorologie Physique, CNRS / Université Blaise Pascal Clermont-Ferrand II 2 Institut für Physik der Atmosphäre, DLR - Oberpfaffenhofen

During the COPS (Convective Orographically-induced Precipitation Study) campaign that took place in summer 2007 between the Vosges and the Black Forest over the Rhine valley, the LaMP/OPGC X band local area precipitation radar and K band Micro Rain Radar were deployed in the foothills of the Vosges mountains in order to provide high resolution (60 m. in range and 30 sec. in time) observation of convective cells initiation and development. In this presentation, we will show preliminary results of the study of the heterogeneity of precipitating structures as well as illustrations of the time and space evolution of the internal distribution of such structures. Likewise, we will propose ways to provide adapted Z-R relationships for improved rain-rate estimations. Furthermore, in order to focus our study in the context of the lifecycle of the observed convective cells, the larger scale conditions and lifetime of the observed precipitating structures will be described by the nearby POLDIRAD measurements.

P1-010

On-Line Monitoring Of Weather Radar Antenna Pointing Using High-Resolution DTM and AI Techniques

Miguel RICO-RAMIREZ [1] *Ian CLUCKIE* [2] *Efren GONZALEZ-RAMIREZ* [1]

1 Water and Environmental Management Research Centre (WEMRC), University of Bristol, Bristol BS81UP, UK 2 Autonoma de Zacatecas, Zacatecas, Mexico, ZAC-98000.

This paper presents a novel tecnique to continuously monitor the azimuthal pointing accuracy of a weather radar antenna. The technique consists in cross correlating modeled and measured ground clutter signals in real-time at low elevation angles in precipitation and non-precipitation conditions. The azimuthal angle with maximum cross-correlation indicates the adjustment in antenna pointing accuracy. The modeled ground clutter echoes are obtained using high-resolution digital terrain elevation data whereas the measured ground clutter echoes can be obtained in real-time by using a bayes classifier, which identifies the clutter signals in the presence of precipitation.

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P1-011

Sea Clutter removal using radar elevation dependent second order texture parameters

Rashpal S. GILL[1] *Thomas BØVITH*[2] *Søren OVERGAARD*[1]

1 Danish Meteorological Institute 2 Danish Meteorlogical Institute

One of main problem in measuring precipitation with weather radars is the presence of false echoes. Of these false echoes, those that occur over the sea, called sea clutter, are perhaps the most difficult to eliminate as the radar returns from the sea can be of comparable strength and have similar doppler velocities to radar returns from precipitation regions. The studies that have been reported in the literature to address this problem can be split into three categories; (i) data classification schemes such as those based on fuzzy logics or neural networks using parameters derived from the radar moments Z, V, W, (ii) methods based predominately on thresholds applied on the Z gradients, Z differences between elevation scans or statistical parameters based on the vertical profiles such as the frequency of broken or unbroken profiles, and (iii) make use of data and products derived from other sensors such as satellites or numerical prediction models to identify and eliminate false echoes. The method described in here falls into the (ii) category and is based on an analogy with the second-order texture parameters derived from the Grey Level Co-occurrence Matrix (GLCM). However, the GLCM based texture parameters used to discriminate between sea clutter and precipitation are computed from the radar pseudo CAPPI products and do not contain the most important information concerning sea clutter, namely that it is confined to low elevation angles, typically Zmin. One of the features of the model is that the contribution to texture made by low reflectivity values, Z < Zmin, are also included. From the EDCM a number of second order texture parameters can be defined and these are used to determine their effectiveness at discriminating between clutter and precipitation. In the evaluation so far the texture parameters entropy, inertia, uniformity and inverse difference moment have been used. It was found that the parameter inertia is effective at discriminating between clutter and precipitation. However, a general clutter removal model that does not accidentally remove precipitation pixels is difficult. Thus to minimize the accidental removal of precipitation pixels, it is proposed to restrict the application of the current clutter removal model to specific geographical hot spots where clutter is frequently observed by the radar. One such model, to remove the sea clutter, has been developed for the Danish Meteorological Institute (DMI) radar at Stevns on the island Sjælland (55.326°N, 12.449°E). The evaluation of the model undertaken so far looks encouraging. Further tests of the model, during routine operations, are in progress. In this article the details of the method is described and some results of the evaluation are presented.

P1-012

Evaluation of a bright band identification algorithm using polarimetric radar data

María FRANCO [1] Monika PFEIFER [2] Daniel SEMPERE-TORRES [1] Martin HAGEN [1] Rafael SÁNCHEZ-DIEZMA [1]

1 Grup de Recerca Aplicada en Hidrometeorologia. Universitat Politècnica de Catalunya. Barcelona, Spain 2 DLR Institut für Physik der Atmosphäre. Oberpfaffenhofen, Germany

The classification of the rainfall field in function of the precipitation type (stratiform, convective or transition) is expected to improve several steps in the radar QPE chain. In particular, different types of precipitation show different characteristic vertical profiles of reflectivity (VPR). So it is important to use a representative VPR of each precipitation type to extrapolate the observed reflectivity to the ground.

Besides, several authors (Churchill and Houze, 1984; Steiner et al., 1995; Sempere-Torres et al., 2000) have emphasized the importance of using specific Z-R relationships for each kind of precipitation.

Different algorithms have been proposed to classify the precipitation, based on using conventional radar information or polarimetric. Here a new version of the bright band identification algorithm proposed by Sánchez-Diezma et al. (2000) is evaluated.

This algorithm is based on analyzing the radar volumes of reflectivity looking for VPR characteristics (maximum reflectivity peak and vertical reflectivity gradients) associated to the bright band profiles.

The evaluation has been realized using polarimetric radar data. It has been done taking advantage of the ability of the polarimetric radar variables to identify the type of precipitating particles

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P1-013

Performance of high-resolution X-band radar for rain measurementin The Netherlands evaluated using a multi-year data set

Remco VAN DE BEEK [1] Hidde LEIJNSE [1] Han STRICKER [1] Remko UIJLENHOET [1] Herman RUSSCHENBERG [2]

1 Wageningen UR 2 Delft University of Technology

Accurate measurements of the spatial and temporal variation of rainfall are of greatinterest for hydrology, meteorology and climatology. Traditionally rain is measuredusing rain gauge networks. The problem with gauges is that they provide point-scalemeasurements and that their network density usually is not enough to make accurateestimates of rainfall fields at the required short time scales. This study will focus onrainfall estimation using a high resolution X-band FM-CW (Frequency-ModulatedContinuous-Wave) Solid-State Weather Surveillance Radar, SOLIDAR, and on theassociated correction of ground clutter and rain-induced attenuation. The radar operated a resolution of 30 m, but due to computer capacity at the time this was reduced to 120 m. It operated at an elevation of 1.7º and had a maximum range of upto 16 km. Radar images were created every 16 seconds with an angular resolution of1.875º. Several gauges were installed in this area in a line configuration from 3 to upto 10 km distance from the radar for comparison and validation purposes. The entiredata set from this high-resolution radar covers a 7-year period, where focus will go to191 cases for which at least 30 minutes of continuous radar data are available. This offers a large amount of pseudo-climatological data as well as many individual rainevents, which will allow an assessment of the performance of X-band radar for rainmeasurement in The Netherlands. This is particularly relevant given the recentinstallation of SOLIDAR's successor, IDRA, at the top of the meteorological tower atCESAR (Cabauw Experimental Site for Atmospheric Research). In addition, this study provides an exploratory analysis for future research into the use of X-bandradar for ground validation of the upcoming Global Precipitation Measurementmission (GPM).

P1-014

Application of an Xband radar for Tropical Rain : Rainfall Monitoring of a small basin in Bénin during the AMMA campaign . Part 2 : A detailed analysis of Drop Size distribution variability in the region and link with radar measurements

Marielle GOSSET [1] Eric-Pascal ZAHIRI [2] Sounmaila MOUMOUNI [3]

1 IRD/LTHE, grenoble, France 2 Université Cocody,abidjan, cote d'ivoire 3 IRD/LTHE and Un Abomeay Calavi, Benin

To complement the weather radars set up in Djougou, Northern Benin (see part 1), in West Africa as part of the International African Monsoon Multodisciplinary Analysis (AMMA) program and field campaign, optical disdrometers were installed in their vicinity.
These rain Drop Size Distributions (DSD) measurements, carried out for the first time in Benin reveals some interesting characteristics of the DSD observed under Sudanese climate.. The 2005 and 2006 data sets (about 7000 one minute spectra) reveals some interesting characteristics of the DSD observed under Sudanese climate. Altogether about 40 rain events could be analyzed over the 2 years of operation, among which 7 well organized squall lines.
The double moment normalization method is found to be best suited and robust for the analysis of our data set. The observed DSD are well modelled by a gamma distribution with a shape parameter (μ) close to 5. The average normalized intercept parameter (N0*) is close to 2000 mm-1m-3, thus lower than the standard Marshall-Palmer value (8000 mm-1m-3) often used.
Convective and stratiform spectra are sorted out. As observed in other tropical area, a clear partition of DSD characteristics is found between the Convective and stratiform region of squall lines, with sharp change in N*0 value. It is found that 1/3 of the spectra could be classified as convective and they contribute to 75 to 80% of the annual rainfall.
Such DSD characteristics have consequences on the radar variables, including the polarimetric measurements and their relationships to rain. The consequences of the observed DSD variability on the X-band polarimetric measurements we performed in the area with the Xport radar (see part 1) and the effect on QPE accuracy are discussed. It il also interesting to compare the storm structure and physics analyzed from the radar data with the DSD below.

P1-015

Application potentiality of a cost-effective X-band weather radar for the quantification of precipitation in northern Italy

F. SALERNO[1] A.F.G. CEPPI,[1] D. DI PASQUALE[1] G. TARTARI[1]

1 Politecnico of Milan - D.I.I.A.R., Piazza Leonardo da Vinci, 32, 20133, Milan, Italy

In this paper setup, operational problems and a straightforward calibration approach for a cost effective X-Band radar are presented. The X-band Ellason E400 is based on conventional small airplanes radar technology which is adapted to register rainfall within a range of about 60 km with a spatial resolution of 500 m per pixel. The instrument does not offer Doppler processing, but uses several wide (vertical) beam. For the time being this radar, supported by satellite images and weather modelling, is used for nowcasting purposes. In fact it allows locating the precipitations, valuing their intensity and observing the direction and the speed of moving: important factors for example for the stormy cells. However the weather forecasting centres need more and more to reach a good degree of definition in time and space of the precipitations amount. Therefore a statistical analysis was carried out for the comparison between the reflectivity and measured rainfall, representing an example of the modern real-time technology used to establish the correlation between radar data and rainfall gauges.

The results obtained are related to:

- Temporal frequency of comparison that depends on rain gauges data archiving.
- Position of weather stations, because the calibration depends on location and distance of the rain gauge as regards the radar, due to the attenuation phenomena, typically of X-band weather radar.
- Precipitation magnitude that depends on the intensity of observed precipitation.

Generally the need to use simultaneously one rain gauge at least, shows how this radar can not substitute the usual ground weather measurements, but it ought to integrate the normal rain gauge measurements network.

A further application study will be performed to place side by side a rain gauge to the radar use and to evaluate its contribute for the description of rainfall spatial variability. This will be possible through the application of a hydrological model that simulates the daily river flow and provides

information about the real rainfall quantity over the examined drain basin.

P1-016

A new mobile polarimetric X-band radar for accurate precipitation measurements

Jörg BORGMANN[1] Ronald HANNESEN[1] Peter GÖLZ[1] Gekat FRANK[1]

1 Selex SI GmbH

X-band radars are ideal for mobile application and compact radar design. Due to the short wavelength spatial resolution and backscattering cross section for precipitation are increased. This allows better detection of meteorological targets. Furthermore, the contamination of ground clutter is smaller than for larger wavelengths (C- and S-band).
The integrated Meteor 50DX system is a new mobile compact X-band polarimetric weather radar, which can be set into operation in short time. It can monitor precipitation systems relevant for small river catchments, which makes it being an ideal instrument for flash flood warnings. It is specially designed to provide polarimetric data with high accuracy. The integrated data processing and display software package Rainbow corrects for attenuation effects from rain using the advanced radar's polarimetric data, which is superior compared to non-polarimetric radar.
Such corrected reflectivity data are used together with polarimetric rainfall relationships to improve the quantitative precipitation estimation. Furthermore, the polarimetric measurements are used to distinguish between meteorological and nonmeteorological targets and to classify the precipitation.

P1-017

The rain accumulation product from the X-band polarimetric radar HYDRIX

Erwan LE BOUAR[1] *Emmanuel MOREAU*[1] *Jacques TESTUD*[1]

1 Novimet

This paper describes how the surface rain product is processed from the hydro-meteorological radar HYDRIX, taking advantage of the radar technology (dual-polarisation, frequency band) and the scanning strategy (multi-PPI mode). The processing steps are typically:
- classification and quality control, using measured polarimetric variables;
- attenuation correction using ZPHI® algorithm, that also optimizes automatically the observation-to-rain estimate according to rain type;
- PPI merging from four low-elevation angles, selected to minimize ground-related artifacts and representativeness error;
- Generation of instantaneous rainfall rate and related quality index, cumulated rain.

The short dwell time required by the radar allows a cycle period of 2.5 min only, thus increasing the time resolution of available data. Owing to the visibility improvement allowed by the antenna of the radar, such products are also applicable for mountainous areas.

P1-019

Influence of Attenuation on Rainfall Estimation Based on Reflectivity and Differential Reflectivity at X Band

Eugenio GORGUCCI[1] *Luca BALDINI*[1]

1 Consiglio Nazionale delle Ricerche - Istituto di Scienze dell'Atmosfera e del Clima

Radar observations of reflectivity and differential reflectivity from a measurement volume are biased due to attenuation and differential attenuation in the presence of rainfall along the path between the measurement volume and the radar. The attenuation bias is typically fairly small at S- band frequencies, but not negligible at C-band and X-band. X-band systems have gained increasing interest due to their low cost and their suitability for some targeted applications.
The impact of attenuation and differential attenuation on the accuracy of rainfall estimation obtained using rain algorithms based on reflectivity and differential reflectivity measurements collected at X-band is studied. It is shown that the biases due to attenuation and differential attenuation nearly cancel each other when used in the rainfall algorithm that uses both reflectivity and differential reflectivity and result in small biases in the rainfall rate estimation. Theoretical and simulation analyses, based also on X-band radar profiles simulated from on S-band radar measurements, show that rainfall rate computed at X-band using reflectivity and differential reflectivity without attenuation correction, results in very small bias for certain underlying mean raindrop shape models.

P1-020

Mobile Weather Radar for Commercial Applications

Marcus POOL [1]

1 Selex SI

For Formula 1, construction sites, hydrographic applications or even military purposes accurate precipitation forecasts are very important. The desired range is about 50 - 70 km. Most of these applications need a radar system that is small and highly mobile.
The Rainscanner from Selex SI Gematronik is a product that fits these requirements. It offers a cost efficient and effective solution for short to medium range weather radar application. Simplicity and ease of use are the primary design features, permitting fast installation, easy radar control and data handling. The Rainscanner can be put into operation by only two persons in less than an hour. The entire system is lightweight and portable. It can be installed on a 16m telescopic mast easily. A setup can be seen on the poster.
The Rainscanner indicates precipitation areas, and classifies precipitation into levels. The transmitter is capable of delivering 25 kW power output, ideal for operation at ranges between 50 and 100 km, depending on environmental and meteorological conditions, e.g. intensity of precipitation. The antenna and pedestal combination is designed for exposed outdoor operation. Fast antenna scans provide quick updates of atmospheric situations. The modular design offers 3 reflector types, yielding in beam width of 1 to 4 degrees. Available are a 8 ft fan beam antenna or two parabolic dishes with 60 cm or 120 cm diameter. Depending on the reflector size and the environmental conditions, a suitable radome is also available.
The Rainscanner consists of a scanner unit, interface box and workstation. The scanner unit contains the transmitter, receiver and antenna unit. Analogue data (IF frequency and video signal) are feed directly from the scanner unit to the A/D converter in the interface box. The interface box comprises of a robust industrial signal processor and the interface unit. The interface unit is the interface between the radar system and the workstation through which the system is controlled. Using a modified marine radar and off the shelf components keeps initial and running expenses low. Due to the construction of the marine radar the waveguide runs are kept very short thus eliminating losses.
Data display as well as product and data archiving are provided with the real-time visualization software RainView. This software module is based on Gematroniks field proven software package Ravis. The real-time radar system and data visualization software Ravis forms an essential component of the full-size METEOR weather radar series.
Data transfer between the signal processor in the Interface Unit and the remote RainView PC can be provided via LAN or WLAN, etc. To plot the radar data on maps, different underlay functions are also available.

P1-021

Polarimetric WSR-88D Reflectivity and Differential Reflectivity Attenuation Correction for Tropical Rainfall

Terry SCHUUR[1] *Alexander RYZHKOV*[1]

1 University of Oklahoma/CIMMS

In the spring and summer of 2007, several precipitation systems that exhibited tropical characteristics passed over central Oklahoma, resulting in record rainfall. In this study, polarimetric WSR-88D data are examined for two of these systems: 1) a heavy rain event on March 29-30, 2007 in which an unprecedented differential phase (PhiDP) of nearly 500° was measured, and 2) the remnants of Tropical Storm Erin on August 18-19, 2007, which made landfall on the Texas coast and maintained a characteristic eye and rain band structure as it passed over central Oklahoma two days later. Both systems produced widespread rainfall and extensive flooding over central Oklahoma. Maximum rain accumulations for the two events, as measured by Oklahoma Mesonet rain gages, were approximately 125 mm and 250 mm, respectively.

Observations of these two rain events were made by the NOAA/National Severe Storms Laboratory polarimetric KOUN WSR-88D radar, which is located in Norman, OK. Using KOUN data, we examine polarimetric rainfall estimation for these two events with a particular focus on the use of PhiDP to correct for the attenuation of reflectivity (Z) and differential reflectivity (ZDR) for tropical precipitation. Coefficients currently in use for Z and ZDR attenuation correction at S-band frequencies were largely derived from observations of precipitation that originated primarily from ice microphysical processes, as is more typical in the midlatitudes. Scatterplots of PhiDP versus Z and PhiDP versus ZDR for these two systems, however, demonstrate that the coefficients currently in use may lead to an overcorrection of both Z and ZDR when applied to precipitation with more tropical characteristics. This finding has important implications for polarimetric rainfall estimation, especially considering the pending polarimetric upgrade to the entire U.S. WSR-88D radar network, thereby expanding polarimetric observations at S-band frequencies into climatic regimes with very different precipitation physics. Necessary adjustments to the coefficients for tropical precipitation will be discussed.

P1-022

Can we use polarimetric X-band radars for operational quantitative precipitation estimation in heavy rain regions ?

Pierre TABARY [1] Guy L'HENAFF [1] Pascale DUPUY [1] Jacques PARENT-DU-CHATELET [1] Jacques TESTUD [2]

1 Centre de Météorologie Radar - Météo France 2 NOVIMET

The aim of this paper is to assess the ability of dual-polarisation X-band radars to provide accurate quantitative precipitation estimations in regions prone to heavy rain events such as the Mediterranean area. The work is carried out in two parts. In the first part, we use real data and compare S-band and X-band measurements collected by two nearly collocated radars during several episodes of the fall of 2006. The S-band radar is an operational French conventional radar located in Collobrières (extreme southeast of France). The X-band radar is a polarimetric radar manufactured by NOVIMET. This radar has been purchased and deployed in the frame of the FRAMEA European project (INTERREG IIIA No 113). The two radars were scanning almost exactly the same elevation angles. In the analysis, the S-band data are considered as the reference against which both raw and attenuation-corrected X-band data were compared. Results are stratified according to distance, differential phase (an indication of the severity of attenuation) and S-band reflectivity. Because the results obtained in this first part are dependent upon the characteristics of the fall 2006 events (intensity, extension, duration, position with respect to the radars, ..), a simulation is done in a second part where S-band data collected by the Nîmes radar during a catastrophic rain event that took place in 2002 (the so-called "Gard event", 8 - 9 September 2002, Delrieu et al. 2005). Again the S-band data are considered as the reference, from which attenuated X-band measurements are generated (as in Chandrasekar et al. 2006). The simulation procedure starts by estimating the typical microphysical characteristics of the rain event (N0* parameter, Testud et al. 2001). Then, the relationships between specific attenuation at X-band (kX, in dB.km-1), reflectivity at X-band (ZX, in dBZ) and reflectivity at S-band (ZS, in dBZ) are computed and compared to previous results (e.g. Delrieu et al. 1999).. The attenuated and corrected X-band accumulations are finally compared to the S-band accumulations and the phenomenon of total extinction is quantitatively assessed. The simulation framework allows placing the X-band radar in various places and in particular in the region of maximum precipitation, i.e. in the worst case scenario.

P1-023

Comparison of two algorithms for quantitative precipitation estimations from operational polarimetric radars for hydrological applications

Pierre TABARY [1] *Marie-Laure SEGOND* [1] *Jacques PARENT-DU-CHATELET* [1] *Hervé ANDRIEU* [2]

1 Centre de Météorologie Radar - Météo France 2 LCPC

This paper is devoted to the comparative evaluation of two area / profile integrated polarimetric rain rate estimation techniques using Météo France C-band polarimetric Trappes radar. The ZPHI (Testud et al. 2000) method relies entirely on horizontal reflectivity (ZH) and differential phase (Φ_{DP}). ZPHI corrects for attenuation but performs the Nw adjustment only in case of attenuation (a minimum of 6° differential phase rotation is required). The Z/ZDR (Thompson, 2007) algorithm makes use of ZH and ZDR to derive the rainfall rate. The algorithm can be applied in moderate rain (ZH >20 dBZ) in case where there is no attenuation and no partial beam blocking. This is the reason why it can be considered as complementary with respect to ZPHI. The algorithm assumes a normalised gamma distribution (Illingworth and Johnson, 1999) to represent the drop size distribution and this is equivalent to estimating the parameter "a" in Z=aR1.5 over an integrated domain. Both algorithms have been applied on more than 20 rain episodes collected during the year of 2005. Calibration of ZH and ZDR (for Z/ZDR) is shown to be essential to take full advantage of the dual-polarisation measurements. Various approaches are tested to achieve the required accuracy. The effect of the radome on both ZH and ZDR is demonstrated. The polarimetric estimates are compared on an hourly basis against rain gauge measurements, the benchmark being the conventional estimator. We show that ZPHI is "triggered" in only 10 to 15% of the cases, though the most intense ones. The NW retrieved independently by the two algorithms are compared on a day-by-day basis. The radar - rain gauge comparison demonstrates the superiority of dual-polarisation algorithms, both in terms of bias and correlation.

P1-024

A rainfall estimation by radar calibrated against rain gauges : a response for the hydro-meteorological forecast and the management of crisis

Jean Paul MIZZI [1] *Anne-Marie FROMENTAL* [2] *Jacques LAVABRE* [3] *Jacques PARENT DU CHÂTELET* [4]

1 Météo-France Aix en Provence 2 Météo-France, Service de Prévision des Crues Méditerrannée-Est, Aix en Provence 3 Cemagref, Aix en Provence 4 Météo-France, Direction des Systèmes d'observation, Trappes

The rain is the major contributor to extreme weather events, more or less widespread in space and time, in South East of France. The aim of this paper is to show on real cases, the contribution of a rainfall estimator by radar calibrated by rain gauges to services in hydro-meteorological management. Most of the time, a real rainfall estimations from rain gauges, which are considered as the reference, fail due to under-sampling errors of convective phenomena : in space (due to the low geographical density of the network), or in time. The radar provides a complete space and time coverage but its measurements still suffer from numerous errors. It thus becomes essential to correct these measurements by adjustment against the rain gauges to reach the quality needed for hydrological operational use. The new Météo-France radar rainfall product (PANTHERE) incorporates an hourly radar/gauges adjustment to achieve this objective.

The resulting product is relevant for both meteorologists and hydrologists. This provides a spatially distributed rainfall estimation (for gauged and ungauged catchments) at time step short enough to capture the temporal variability of convective events. A quality index is associated with each pixel and each time step to take into account the real time measurement conditions. This information could be used to improve lumped or distributed rainfall-runoff models at a sub-hourly sampling rate. This has specific application in fast responding catchments : mountain catchments or urban areas.

Based on the case-studies in the South-East of France, the impact of the radar rainfall estimate hourly adjusted by the gauges, is positive. This rainfall product also benefits to AIGA, an integrated flood alarm system, jointly developed by Météo-France and Cemagref.

With this method, the quality of the radar rain product is statistically improved with respect to the classical gauge rainfall estimator. This is particularly true for heavy precipitations, without degrading weak precipitation.

P1-025

Towards Higher Precision Quantitative Precipitation Estimates from the United Kingdom Weather Radar Network

Dawn HARRISON[1] *Robert SCOVELL*[1] *Kitchen MALCOLM*[1]

1 Weather Radar Development, Met Office, Exeter, United Kingdom

Recent improvements in capacity of telecommunications links and a move to more centralised data processing have enabled radar composite products of quantitative precipitation estimates (QPE) to be generated with improved accuracy and higher horizontal resolution.

Since 2005, when the UK Met Office introduced its new radar data processing and product generation system, Radarnet IV, all quality control and correction to radar reflectivities has been carried out on polar data at 1° x 750 m resolution. Some of these processes, correcting for the effects of signal attenuation or partial beam blockages in particular, are more effective if they are carried out before any spatial averaging has been performed. This is a significant change from the previous configuration, where some quality control and correction (e.g. noise filtering and attenuation correction) was carried out at the radar site and the reflectivity data from each scan were converted from polar to Cartesian format before transmission to a centralised product generation system. The 1, 2 and 5km Cartesian products generated from each scan were limited in range to 50, 100 and 250 km from the radar site respectively. These limitations were imposed to facilitate real-time transmission within the available band-width and it was not thought that generating the higher resolution products to further range would yield significant benefit, since the radars' 1° beam-width would be a limiting factor.

The most recent development to the Radarnet IV system has been to begin generating composite products of QPE direct from the processed polar format data. This has the advantage that spatial averaging and reprojection of the data is performed just once in a single step. The polar-Cartesian conversion is performed using a method that weights individual polar cells according to distance from the centre of a defined Cartesian cell. Cells are only considered up to a maximum specified distance, this distance itself being a function of range. This method, and the functionality of the associated product generation software, means that products of any resolution and domain can be generated. In particular, it allows sub-1km QPE products to be routinely generated which may be of particular use in applications associated with urban hydrology.

This paper describes the methods by which high resolution composite QPE products are now generated, illustrates and compares the quality of products at different resolutions through case studies of intense rainfall and examines the some of the issues relating to temporal and spatial resolution of radar based QPEs from hydrological applications.

P1-026

Uncertainty assessment in the framework of radar quantitative precipitation estimate developed at ARPA-SIM

Anna FORNASIERO[1] *Roberta AMORATI*[1] *Chiara MARSIGLI*[1] *Pier Paolo ALBERONI*[1]

1 ARPA - Servizio Idrometeorologico Emilia Romagna

Uncertainty assessment in radar quantitative rainfall estimate is one of the most challenging tasks in radar hydrometeorology studies. Several sources of error affect the quality of radar data, like poor calibration, clutter, beam blocking, attenuation, anomalous propagation, variation of reflectivity with height etc. and their effects propagate along the data elaboration process up to the final product. In most cases well-constructed correction procedures are applied, which reduce the impact of these errors, but often the final reliability of the rainfall estimate is not described.

The scope of this work is the validation of the framework developed at ARPA-SIM for its regional radar network; the procedure corrects the Doppler filtered reflectivity data for beam blocking, anomalous propagation, clutter and performs vertical profile of reflectivity reconstruction, to finally estimate the precipitation rate at the ground level. The algorithm provides, in addition, a quality descriptor ranging from 0 to 1, which is the result of a priori considerations about the errors sources affecting the data.

Nevertheless the overall quality of radar quantitative precipitation estimate (QPE) is depending at least, on two further factors, which are not considered, at the moment, in the mentioned correction chain. These are errors in the radar calibration factor, as well as its possible time-drift, and variability in time and in space of the drop size distribution (DSD) and consequently the variability in the relationship between R and Z.

To investigate the relative importance and impact of these two factors we have selected data in a well defined situation, to minimize the impact of the other error sources, and we have analysed a way for separating calibration errors from errors due to other sources, especially from R-Z relation uncertainty.

Based on the obtained results, raingauge data have been used to evaluate radar products at different processing level and a spatial analysis of errors is carried out to describe the reliability of the radar QPE product.

This activity is carried on in the framework of projects PROSCENIO and "Mosaicatura radar" supported by National civil Protection Dept.

P1-027

Integration of radar microwave link and disdrometer data for improved quantitative rainfall estimation – Part I: attenuation analysis and correction methodology

Stefan KRAMER[1] Hans-Reinhard VERWORN[2]

1 Agricultural Hydraulic Engineering, University of Hanover, Germany 2 Institute of Water Resources Management, University of Hanover, Germany

The distribution of rainfall in space and time is important for meteorological and hydrological applications such as flash flood predictions and real time control of urban drainage systems. Weather radars provide this information, but with limited quantitative reliability. This is mainly due to attenuation of the radar signal which results in a measured reflectivity profile $Z_a(r)$ that underestimates the true (unknown) reflectivity profile Z(r) with increasing distance (r) from the radar. The attenuation phenomenon is severe for X-band, but it is also acute for C-band [1]. HITSCHFELD and BORDAN [3] addressed this problem and proposed an analytical solution which is often used in a modified version [4], where specific attenuation k is derived from reflectivity Z as $k = a \times Z_b$. The coefficients (a,b) have to be estimated before the correction is made. With the forward correction algorithm the calculated attenuation is added to the measured reflectivities step by step along the beam starting at the radar site. This methodology, however, easily becomes instable, when extreme reflectivities leading to high attenuation corrections produce even higher corrected reflectivities and so on. The backward correction algorithm is stable, but needs the total attenuation to be distributed along the beam which is generally not available. Therefore attenuation correction is not applied to operational weather radar systems and the "true" rainfall is continuously underestimated.

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P1-028

Integration of radar microwave link and disdrometer data for improved quantitative rainfall estimation – Part II: advanced attenuation correction and R-Z procedures

Hans-Reinhard VERWORN[1] Stefan KRAMER[2]

1 Institute of Water Resources Management, University of Hanover, Germany 2 Agricultural Hydraulic Engineering, University of Hanover, Germany

The correction of radar reflectivity profiles for attenuation is essential for quantitative precipitation measurements at X-band and C-band frequencies [2]. Attenuation corrections based on the Hitchfeld-Bordan approach suffer the problem of instability. Due to this attenuation correction is not applied to operational weather radar systems [3]. With the analysis of attenuation measurements with a 30 km microwave link parallel to one of the radar beams [4] demonstrates, that the problem of instability may be overcome when variable attenuation coefficients are used.

This paper describes the integration of the a priori knowledge derived from [4] and the implementation of an attenuation correction methodology to all radar beams of the radar scan.

With attenuation corrected reflectivity profiles the R-Z relation receives a completely new significance. With more realistic and less disturbed reflectivities the variation of the R-Z relation is no reduced to the influence of the drop size distribution. The improved rainfall estimation includes a new R-Z relation in consideration of its spatial and temporal variability.

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P1-030

Identification of temporal-constant Z/R relationships based on measurements using micro-rain radar

Marco CLEMENS[1] *Gerhard PETERS*[1] *Jörg SELTMANN*[2] *Peter WINKLER*[2]

1 Meteorological Institute, University of Hamburg, Germany 2 Meteorological Observatory Hohenpeißenberg, DWD, Germany

The functional connection between radar-reflectivity Z and rain rate R is the basis for the estimation of precipitation by the use of radar. Because in operational services mostly climatological relationships between the integral parameters Z and R are used, a comparison with precipitation measurements from the ground-based measuring net is necessary. Besides, radar- and ground precipitation show often large differences, so that suitable adjustment-factors become necessary. Nevertheless, these are not representative for all radar pixels and entail therefore locally strong over- or underestimates of the actual precipitation amount.
During an intensive measuring campaign of the DFG project AQUARADAR the changes of the drop spectra on their path downwards to the ground, as well as their temporal and spatial variability were examined with numerous vertically looking micro-rain radars. The results give insights in the different microphysical processes like coalescences and bursting of raindrops, which reflects in height-dependent Z/R relations. In addition, the measurements clearly show the influence of the so-called "drop-sorting" on the uncertainty of the estimation of empiric relations from integral parameters.
In the temporal domain the measurements with the micro-rain radar show rapid changes of the integral relations between the precipitation intensity R and the radar-reflectivity Z which are linked with instantaneous changes of the microphysical properties of precipitation. These appear in significant changes of the corresponding coefficient and exponent of the Z/R relationships. It is shown, that it is possible to divide precipitation events in periods with reduced scatter between Z and R by the use of correlation analysis. Afterwards, carried out regression analysis leads to new modal Z/R relations which shall lead to significant improvements of the estimates of the precipitation intensities by the use of the conventional radar. While these point measurements give detailed insight into the precipitation process, it is necessary to link these results to the measurements of horizontally pointing radars.

P2-001

Identification of Vertical Profiles of Reflectivity from Volume Scan Radar Data : Adaptation of an Inverse Method to Rainfall Typing

Pierre-Emmanuel KIRSTETTER[1] Hervé ANDRIEU[2]

1 Laboratoire d'étude des Transferts en Hydrologie et Environnement, Grenoble, France 2 Laboratoire Central des Ponts et Chaussées, Bouguenais, France

The aim of this paper is to present an operational methodology to correct the error of weather radar rainfall estimates related to the Vertical Profile of Reflectivity (VPR). Identifying the VPR is a key point in obtaining the rainfall estimate at the ground by radar. Since the measured reflectivity values are a convolution with the beam pattern, applying a direct method to identify the VPR is limited to the nearest area to the radar. Going further needs applying an inverse method to filter sampling effects and to retrieve the VPR. We consider separate domains for two types of precipitation, convective and stratiform.
The methodology is developed using the dataset of the Bollène 2002 Experiment (Delrieu, 2007), aimed at assessing the interest of a volume-scanning protocol for radar QPE in the Cévennes-Vivarais region, France.
We consider space-time domains extending over the one-hour period preceding the time of interest to stabilize the rain-typed VPR estimation.
The identification VPR procedure is decomposed in two steps. First, the shape of the apparent VPR is identified directly from the observed volume scans, by averaging the measured reflectivity values. Taking into account for the radar sampling properties in the averaging allows giving more weight to the radar measurements realized close to the radar site in order to limit the smoothing effect by the radar sampling.
Second, we consider the VPR inversion method proposed by Andrieu and Creutin (1995), which aims at recovering the most probable VPR compatible with radar measures using a statistical inverse method and allows to filtering the radar sampling effects in the VPR estimation. This methodology, initialised with the apparent VPR, allows the estimation of VPR shape in furthest areas to the radar. It is adapted to the case of time-varying geographical supports designed with preliminary rain typing (Chapon, 2006). In spite of a better satisfaction of the VPR homogeneity assumption by using a preliminary rain-typing algorithm, the application of the inversion technique in the case of variable geographical domains proved to be rather tricky because it faces to heterogeneous and contradictory information. Aggregating data from several successive time steps (one hour) was one of the keys together with the implementation of a ratio data censoring approach and a major reconsideration of the weighing of data in the calculation. The latter procedure brings a very significant gain in terms of computation cost and the new inverse method is found to be robust and reliable.
A better representation of the VPR computed with the inverse method compared to the apparent VPR, used as a priori information, is obtained. We plan to assess the impact of the VPR estimation method in terms of radar QPE. It is also of climatological interest to consider shapes and space-time domains of rain typed VPRs observed during the autumn 2002 rain events.

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discussions and contributions.

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P2-002

Adjustment of a robust Q-Z/R-relationship forhydrological modelling using observed riverdischarge data

Andreas MARX[1] Harald KUNSTMANN[2] András BÁRDOSSY[3] Joerg SELTMANN[1]

1 Karlsruhe Research Center, IMK-IFU, 82467 Garmisch-Partenkirchen, Germany 2 University of Stuttgart, Institute of Hydraulic Engineering, 70550 Stuttgart, Germany 3 German Weather Service, Meteorological Observatory Hohenpeissenberg, Germany

The quality of hydrological modelling is limited due to the availability of high resolution temporal and spatial input data such as precipitation. Rain gauge measurements give accurate information at a single point while radar measurements provide good spatial information. On the other hand, it is difficult to estimate areal precipitation from rain gauge measurements and absolute rainfall intensities from radar data.
In this study, a method to adjust a robust Q-Z/R-relationship to estimate rainfall intensities from radar reflectivities for hydrological modelling is presented. The coefficients of split, three-part, piecewise linear Z/R-relationship following the German Weather Service RADOLAN (Radar Online Adjustment) project are optimized using river gauge measurements from five catchments. The generated radar precipitation fields are used as input to the water balance model WaSiM to simulate river discharge for a three month period in summer 2001. On this base, the Nash-Sutcliffe efficiency (from observed and simulated discharge) is optimized and the final Q-Z/R-relationship estimated. The study is performed in the well known alpine Ammer watershed with very short reaction times of the river gauges to rainfall events. Results from the continuous, three month discharge simulations using radar derived precipitation fields (adjusted Q-Z/Rrelationship) are shown as well as the validation of the new found relationship against rain gauge measurements.

P2-003

Total rainfall estimation of a storm using Integral Radar Volume Descriptors

Silke TRÖMEL [1] Clemens SIMMER [1]

1 Meteorological Institute, University Bonn, Germany

Hydrology makes high demands on quantitative areal precipitation estimation. Significant improvements are required in a diverse array of hydrological applications like flash flood forecasting, the engineering design of flood control structures, operation and control of sewerage systems or water supply foerecasting. Nevertheless, the quality of the results is still unsufficient for the most urgent needs.

An improved Quantitative area Precipitation Estimation (QPE) with ground based radar will be achieved by exploiting the spatial and temporal variability of the radar signal. Therefore tracking of radar-detected precipitation-centroids is performed and rain events are investigated using Integral Radar Volume Descriptors (IRVD).

Our analyses start with the simplified method (Doneaud et al., 1981) for estimating convective rainfall by considering only the horizontal extent of the storms within a threshold radar reflectivity isopleth and the duration of the precipitation. Atlas et al. (1990) found that the method is based upon the existence of a well-behaved probability density function (PDF) of a single storm during its life. In other words, we assume that the distribution of individual rain rate values is very similar from one convective situation to the other. The relation between the total volume rainfall and the area time integral is then entirely determined by the climatological PDF of the regime in question.

Even though former publications describe the scatter from one storm to another as remarkably small, evaluation of the method reveals insufficient accuracy for precipitation estimation. The strategy pursued to achieve enhanced rainfall estimates is straightforward. Relevant information about the precipitation process hidden in the three-dimensional radar reflectivity volume`s structure shall condense in a small amount of integral radar volume descriptors to be included in the model.

Initially, the analyses shown are based on pseudo-radar data and modelled rain rates from a meso-scale weather prediction model (Lokal-Modell of the German Weather Service) in order to circumvent probable difficulties arising from an insufficient station network on the one hand or additional sources of error concerning the radar data like attenuation or shadowing effects on the other hand. As an example, the expected value of enclosed reflectivities of traced storm cells and the trend in the brightband fraction indicating the stage of evolution they undergo during observation are significant detected descriptors for the total rainfall of the system. Actually, 74 of 100 storms considered show relative errors of the rainfall estimate less than 10%.

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P2-004

Using a hydrometeor classification algorithm from two Doppler C-band radar data to infer snowfall areas in winter events

Miria CELANO [1] *Pier Paolo ALBERONI* [1]

1 ARPA - Servizio IdroMeteorologicoEmilia Romagna

A long standing problem in radarmeteorology is distinguishing between solid and liquid phase precipitation in order to achieve accurate rainfall and snowfall estimates during winter episodes. Polarimetric Doppler C-Band radar allows us to identify the prevailing hydrometeor type and thus they are strategic instrument for the characterisation of the precipitation phase in solid, liquid, and mixed. This can be extremely useful in supporting civil protection activities and road snow clearance locating areas of heavy snowfall.

The study is carried out using the polarimetric C-band radars located in the Po Valley of Northern Italy, the S. Pietro Capofiume and the Gattatico radars, both managed by ARPA Emilia-Romagna.

The radar observations are collected during winter storm episodes occurred in the region explored by the two radars. The microphysical properties are obtained by using a hydrometeor classification scheme developed at the National Severe Storms Laboratory (NSSL) (Zrnic et al., 2001) and extended from S-band to C-band radar data (Marzano et al., 2006). The scheme is based on a combination of weighting functions that map the reflectivity Z and differential reflectivity ZDR space and that are associated with a particular type of hydrometeor.

The environmental temperature is used to remove ambiguities in the decision process by introducing the additional constraint that every class of hydrometeors can only be found within a prescribed range of temperatures. The scheme makes use of a standard atmospheric profile of 6.5 km-1 starting from the surface temperature measured by local groundstation.

The comparison between a simple averaging and a more sophisticated analysis method to estimate surface temperature and the resulting impact on snowfall area identification will be presented here.

This activity is carried on in the framework of projects PROSCENIO and "Mosaicatura radar" supported by National civil Protection Dept.

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P2-005

Hydro-NEXRAD: Basin-Wide Precipitation Metadata Calculation Using NEXRAD Data

Piotr DOMASZCZYNSKI[1] *Witold KRAJEWSKI*[1] *Anton KRUGER*[1]

1 IIHR-Hydroscience and Engineering, University of Iowa, Iowa City, Iowa, USA

Hydro-NEXRAD is a prototype web-based system that allows hydrologists to obtain user-specified rainfall data for their research. These data are based on observations collected by the U.S. national network of WSR-88D radars, known as NEXRAD. Users interact with Hydro-NEXRAD through a web-based interface that has map-based components for spatial navigation, calendar- and time series plot components for temporal navigation and a menu-based component for selection of processing options.

In the system, radar based information is converted to point-, basin- or radar-based rainfall products such as reflectivity maps, rainfall maps and rainfall accumulation maps. These products are presented on several different grids and packed using formats allowing for convenient display and easy analysis of data with geographic information systems.

In the process of selection of data for analysis, users of the Hydro-NEXRAD system utilize pre-computed set of metadata. Time series of radar- and basin-based metadata can be visually inspected and provide information on variables such as: mean areal precipitation, maximum precipitation location, direction of advection, advection velocity, daily rain fraction and more. Rich set of metadata is helpful when selecting a dataset of interest for a particular hydrologic study.

Selected data subsets undergo conversion from basic volume scan reflectivity data to rainfall products with user-specified algorithms and parameters. Obtained products can provide basin rainfall information with high spatial and temporal resolution which can be further used as an input for hydrologic models. In the presentations authors provide an overview of Hydro-NEXRAD design, capabilities and discuss possible applications of system's products.

P2-006

Estimation of radar-rainfall error spatial covariance

Pradeep V.MANDAPAKA[1] Witold F. KRAJEWSKI[1] Grzegorz J. CIACH[1] Gabriele VILLARINI[1] James A. SMITH[2]

1 IIHR–Hydroscience & Engineering,The University of Iowa, Iowa City, IA 52242, USA 2 Department of Civil & Environmental Engineering Princeton University, Princeton, NJ 08544, USA

The study presents a theoretical framework for estimating the radar-rainfall error spatial correlation (ESC) using data from relatively dense rain gauge networks. The error is defined as the difference between the radar estimate and the corresponding true areal rainfall. The method is analogous to the error variance separation that corrects the error variance of a radar-rainfall product for gauge representativeness errors. The study demonstrates the necessity to consider the area-point uncertainties while estimating the spatial correlation structure in the radar-rainfall errors. To validate the method, the authors conduct a Monte Carlo simulation experiment with synthetic fields with known error spatial correlation structure. These tests reveal that the proposed method, which accounts for the area-point distortions in the estimation of radar-rainfall ESC, performs very effectively. The authors then apply the method to estimate the ESC of the National Weather Service's standard hourly radar-rainfall products, known as digital precipitation arrays (DPA). Data from the Oklahoma Micronet rain gauge network (with the grid step of about 5 km) are used as the ground reference for the DPAs. This application shows that the radar-rainfall errors are spatially correlated with a correlation distance of about 20 km. The results also demonstrate that the spatial correlations of radar-gauge differences are considerably underestimated, especially at small distances, as the areapoint
uncertainties are ignored.

P2-007

Bollène 2002 Experiment: Radar quantitative precipitation estimation in the Cévennes-Vivarais region, France

Guy DELRIEU[1], Brice BOUDEVILLAIN[1], John NICOL[1], Benoît CHAPON[1], Pierre-Emmanuel KIRSTETTER[1], Hervé ANDRIEU[2] and Dominique FAURE[3]

1 Laboratoire d'étude des Transferts en Hydrologie et Environnement, Grenoble, France 2 Laboratoire Central des Ponts et Chaussées, Division Eau, Bouguenais, France 3 ALICIME, Messimy sur Saône, France

The Bollène 2002 Experiment was designed to evaluate the benefit of a radar volume-scanning strategy for radar quantitative precipitation estimation (QPE) in mountainous regions. A number of innovative radar QPE algorithms aimed at a space-time adaptive radar data processing are proposed. Firstly, a ground clutter identification technique based on the pulse-to-pulse variability of the reflectivity is described and implemented to cope with the severe clutter experienced at S-band in such environment. Secondly, two rain-typing algorithms already proposed in the literature are adapted and coupled with the identification of the vertical profiles of reflectivity (VPR) for convective and stratiform precipitation. Two approaches are adapted to the case of time-varying geographical support for the VPR estimation: (1) a simple averaging of measured reflectivities close to the radar site and (2) an inversion technique aimed at filtering radar beam sampling effects. Various methods are considered for combining the corrected reflectivity measurements at the various elevation angles for estimating reflectivity at ground level prior to application of rain-typed Z-R relationships. Illustrations of the algorithms behaviour are given with the observations available for two selected time steps.
The radar and raingauge datasets collected during the Bollène-2002 Experiment for a series of intense Mediterranean precipitation events are used for assessing the new algorithms. Reference rainfall data is derived from a careful geostatistical analysis of the raingauge data. The new ground clutter identification and correction algorithm proves to work satisfactorily. Various time and space-time adaptive strategies are defined and implemented with focus on assessing a convective-stratiform precipitation separation method coupled with the vertical profile of reflectivity inference. The results indicate that good radar quantitative rainfall estimation is feasible within the 100-km radar range in mountainous regions by using well-sited, well-maintained radar systems and sophisticated physically-based radar data processing systems. Determining the radar detection domain, performing an efficient ground clutter processing, "capturing" the vertical structure(s) of reflectivity for the event of interest are the basic ingredients required. The radar performance depends on the rain types with very significant variations here between mesoscale convective systems, frontal and shallow convective events. The Bollène 2002 results indicate that the added value of the space-time adaptive processing is moderate. To be more specific, the radar raingauge scatter quantified by the determination coefficient remains basically unchanged for all the time and space-time adaptive processing strategies considered. A positive trend is observed however in terms of bias since the most refined space-time adaptive strategy presents systematically the lowest mean relative errors. This is attributed to a better estimation of the reflectivity at ground level by means of the typed VPRs. Adapting the separation method for radar network operation and documenting the Z-R relationships conditional on rain types

for Mediterranean intense rainfall are the two perspectives of this work.

P2-008

ANTILOPE: hourly rainfall analysis merging radar and raingauges data

Olivier LAURANTIN [1]

1 METEO FRANCE

Radar and raingauges data are combined to provide a rainfall analysis all over France on an hourly basis with a spatial resolution of 1 km. In order to achieve this, precipitation field is separated into small and large scale parts, which are respectively associated to stratiform and convective rainfalls. Small scale part is handled through a technique of convective cells detection in radar images. Then large scale part is obtained by kriging raingauges data whose convective part has been estimated and removed in case raingauges have been covered by at least one convective cell during the hour. A coherence control of those large scale raingauge svalues is computed prior to spatializing. The final estimation of precipitations is obtained by adding both large and small scale parts. An evaluation of this ANTILOPE analysis has been done versus a one-year set of hourly raingauge measurements, along with an evaluation of two other quantitative precipitation estimate, one derived from radar data only and one obtained by kriging raw raingauges data. Results show that all the three QPE underestimate precipitations, going along with a decreasing probability of detection as precipitation rate increases. A quite high false alarm rates are noticed, mainly due to remaining radar artefacts. ANTILOPE appears to provide the best estimation as it tends to behave like the best QPE for both small and large scale events, which is respectively the radar and the raw kriging QPE.

P2-010

Taking rain gauge errors into account in the calibration of a short range X-band weather radar

Toon GOORMANS[1] *Patrick WILLEMS*[1]

1 Hydraulics Laboratory, Katholieke Universiteit Leuven, Leuven, Belgium

In a research project of the Hydraulics Laboratory of the Katholieke Universiteit Leuven (K.U.Leuven) for the water company Aquafin, a small, short range, high resolution X-band weather radar called Local Area Weather Radar (LAWR, DHI) has been installed in the densely populated city centre of Leuven (Belgium). The radar beam has a horizontal opening angle of approximately 4 degrees, making quantitative precipitation estimation possible up to a distance of 15 km from the radar site. The radar data are being used to study the impact of the spatial variability of rainfall on sewer system design and operation.
Since weather radar measures the rain rate indirectly (through measurement of reflected energy), the system needs to be calibrated before quantitative precipitation estimation is possible. For this, data of a network existing of several well calibrated tipping bucket rain gauges are used. The calibration procedure of the rain gauges is based on the one described by Luyckx and Berlamont (2001), and consists of a dynamic calibration in the field, which takes the loss of water due to the tipping motion of the bucket explicitly into account.
In the radar calibration technique, the tipping bucket rain gauge errors are taken into account. It is assumed that these errors are mainly due to wind influences, the gauge resolution and errors in the gauge calibration. Errors in the near point (or small grid size) radar registrations are analyzed, and propagated to errors in the areal rainfall estimates.

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P2-011

Quantitative estimation of daily rain amounts over Mediterranean and dry climates using radar and rain gauge data

Efrat MORIN[1] *Marco GABELLA*[2]

1 Department of Geography, the Hebrew University of Jerusalem, Jerusalem, Israel 2 Dipartimento di Elettronica, Politecnico di Torino, Turin, Italy

The major objective of this paper is quantitative estimation of daily precipitation in Mediterranean and dry climatic regimes in Israel using weather radar data adjusted by rain gauges. Several radar-based gauge adjustment methods are considered. The first is the standard bulk adjustment, while the others correct not only the overall bias but also beam-broadening with distance, orographic and climatic influences (in the north-south direction) utilizing weighted linear regression technique. The method applies weighted regression of radar-to-gauge ratio (in dB) to the log of distance from radar, seems to provide relatively good results in general. In the mountainous area, however, the method that takes into account also topography performs better. In the dry climate areas, the standard bulk adjustment method performs equally to the more sophisticated methods. In the Mediterranean areas gauge interpolation provides rainfall estimates better than the radar-based estimates. In dry areas, however, gauge interpolation does not show better performance.

P2-012

Rain evaluation using weather radar in flood cases in urban area in the center of the state of São Paulo, Brazil

Mauricio DE AGOSTINHO ANTONIO[1] *Juliana ANDRADE*[2]

1 UNESP-São Paulo State University; IPMet-Instituto de Pesquisas Meteorológicas; Caixa Postal 281; CEP 17096-370; Bauru-SP-Brazil 2 USP-University of São Paulo; EESC-Escola de Engenharia de São Carlos; Caixa Postal 359; CEP 13560-970; São Carlos-SP-Brazil

This work presents three summer flood events in the urban catchment of the Gregorio creek basin in São Carlos, in the center of the São Paulo State, Brazil, and the rain evaluation performed with the Bauru weather S-band Doppler radar (22o21'30"S; 49o01'38"W). The radar data were collected each 7.5 minutes and the product used was the 3.5 km CAPPI. The radar rain quantification was made using a Z-R relationship derived from radar reflectivity and 30 minutes accumulated rain from raingage located in the creek basin, in these flood cases (Z=17R1.54). Diagrams from the radar accumulations for the rain events were made and compared with the surface measurements. The final differences were found to be lesser than 5% in all cases. Another radar rain quantification for those flood days was made using the Z-R Marshall-Palmer relationship (Z=200R1.6) and the differences considering the surface data were around 80%. The discrepancies between the Z-R relationships used in the comparisons with the surface data do recommend using a specific Z-R relationship for individual situations. The rain data from radar monitoring as input in flood forecast models can help the anticipation of flood episodes, to make possible previous warnings to save properties and reduction of damage.

P2-013

Quantitative precipitation estimation in north part of Serbia

Svetlana STEVANOVICH[1] *Zoran VUCINICH*[1]

1 Republic Hydrometeorological Service of Serbia

The Republic Hydrometeorological Service of Serbia has three Gematronik radars. One of them is placed on the mountain Fruska Gora near the city Novi Sad. This is the METEOR Dual-Polarization Doppler weather radar system together with the meteorological product generation software RAINBOW forms a unique remote sensing system which satisfies the most advanced requirements of modern meteorology and hydrology.

In our study case of quantitative precipitation estimation used range is 200 km and it is cover three rivers basins, Danube, Sava and Tisa in north part of Serbia.

We studied three cases:

1. Case of stratiform cloudiness;
2. Case of medium to strong convective cloudiness ;
3. Case of extreme convective cloudiness-supper cell.

Measurement are provided continually for period in wich cloudiness existed
in given range and compared with raingauge measurement .Comparison are provided for few points in target area in purpose to find acceptable accuracy.

[1] *Curich, Mladjen., Cloud Dynamics*
[2] *Curich, Mladjen., Weather modification*

P2-014

Comparison of MM5 output to adjusted radar rainfall data

Thomas EINFALT [1] Fatih KESKIN [1]

1 Hydro & meteo GmbH&Co. KG, Breite Str. 6-8, D-23552 Lübeck, Germany 2 Devlet Su Isleri, Investigation and Planning Department, Inönü Bulvari R-7, 06100 Yücetepe, ANKARA, Turkey

The first TEFER project [1] has been executed in the years 2002 to 2004. During this time, a large number of hydrometric measurement systems has been installed including three weather radars, a complete satellite based data transmission system and a model based flood warning system. Three years later, a considerable data base is now available, as well as MM5 NWP data.
A new project was started for the comparison of the now available MM5 data to adjusted radar and raingauge values. The frame for this project was the limitation to one hydrological basin - the West Black Sea basin - and to one month of data (November 2006).
For the selected month, a detailed data quality control was performed in order to first adjust the radar data to the raingauge values. This could be done successfully based on quality controlled data from eight raingauges. The adjustment factor of 3.0 was further applied to the radar data during a comparison between raingauge data, radar data and MM5 model results.
For the comparison, five subbasins were selected based on the criteria

- Choice from different basins
- Radar data coverage available
- Raingauge inside or close to subbasin
- Large and small basins
- Different topography
- Different land use patterns

The choice was made for the basins B1 and B8 in the Bartin basin, F1 and F12 in the Filyos basin, and M1 in the Melen area. For other choices higher up in the mountains no or no complete radar coverage was available.
As pointed out above, MM5 results were only available for the 00 hour simulation run. The daily values were compared to the sums produced by the raingauges and by radar.
Radar gaps with rainfall > 1 mm existed over the basins during the gap periods and have been filled with four alternative solutions.
The comparison procedure involved - on the daily basis - the direct comparison of the sums that were calculated for the five subbasins.
Furthermore, the data were analysed on an hourly level in order to quantify the effect of the radar nowcasting information in the processing chain. SCOUT nowcasts were included in the analysis if for the three hour nowcast at least one hour was forecast with more than 0.1 mm of rainfall.
For every hour during the day the MM5 values were used where no other information was available. At each hour, SCOUT performed a three hour forecast, and for every past hour, the adjusted radar measurements are also available through SCOUT. A spreadsheet table was computed for every day in November 2006, and for every basin.
The comparison results showed that

- MM5 is overestimating on average over the five basins by about 50%. This is mostly due to overestimations in the mountainous basins.

- The forecast sums have a larger variation for MM5 than for radar data.

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P2-015

Uncertainty analysis of interpolation methods in rainfall spatial distribution

Tao TAO[1] Bernard CHOCAT[2]

1 State key laboratory of Pollution Control and Resources Reuse, Tongji University, Shanghai 200092, China 2 U.R.G.C. Hydrology Urbane, I.N.S.A. de Lyon, 69621 Villeurbanne Cedex, France

Quantification of spatial and temporal patterns of rainfall is an important step toward developing regional water sewage models, the intensity and spatial distribution of rainfall can affect the magnitude and duration of water sewage. However, this input is subject to uncertainty, mainly as a result of the interpolation method and stochastic error due to the random nature of rainfall. In this study, we analyze some rainfall series from 30 rain gauges located in the Great Lyon, including annual, month, day and intensity of 6mins, aiming at improving the understanding of the major sources of variation and uncertainty in small scale rainfall interpolation in different input series. The main results show even if in the same research area, the different rainfall series, its model and the parameter choice of Kriging should also be different, and to the small region with deeply density rain gauges (15km2), the kriging method superiority is not obvious, IDW and the spline interpolation result maybe can be better, regarding the different research series, it will be suitable for the different method, and it must be determined by the data series distribution.

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P2-016

Is the variogram a good tool for assessing the spatial variability of vertical reflectivity profiles ?

Bernard MOHYMONT[1] *Laurent DELOBBE*[1]

1 Royal Meteorological Institute of Belgium

It is recognised that the dominant source of error affecting radar estimates of precipitation is produced by the vertical variations of reflectivity caused by the growth, transformation (melting) and evaporation of precipitation. Various methods have been proposed in the literature to correct the errors arising from nonuniform vertical profiles of reflectivity (VPR). Most of these methods require an assumption on the spatial homogeneity of the VPR over appropriate subdomains during a considered time step. In this paper we explore the ability of a geostatistical tool called variogram to assess the spatial variability of the VPR based on volume reflectivity files. We first describe for Belgium an adaptation of the Steiner algorithm aimed at separating convective from stratiform precipitation and present some results. Then we develop the theory related to variograms applied on VPRs. We restrict our analysis to VPRs measured inside stratiform zones. An analysis of two theoretical examples allows us to understand some difficulties arising in the calculation of the variograms. Furthermore an analysis of the variograms obtained for several selected observed situations is done. Particular attention is paid to the way of comparing two VPRs. Since these two VPRs are generally situated at different distances from the radar it may be appropriate to correct the closest one by an appropriate convolution in order to compare it with the furthest one. Variograms obtained with and without this type of correction are compared. Results concerning the decorrelation distance between VPRs are finally presented.

P2-017

Simulation of 2D fields of raindrop size distributions

Alexis BERNE [1] *Remko UIJLENHOET* [2]

1 LTE - EPFL, Lausanne, Switzerland 2 Hydrology and Quantitative Water Management Group, Wageningen University, The Netherlands

Quantitative applications of weather radar measurements require accurate and reliable rain rate estimates. For the conversion of measured radar reflectivities into rain rates, the raindrop size distribution (DSD in the following) plays a major role, as the parameters used in the Z-R relationship depend on the size and concentration of hydrometeors in the considered radar sampling volume. In addition, the shape of the drops (which depends on their size) is also relevant for the quantitative interpretation of polarimetric radar measurements. Hence, the variability of the DSD in space and time has to be taken into account to improve radar rain rate estimates.
The ability to generate a large number of 2D fields of DSD which are statistically homogeneous provides a very useful simulation framework that nicely complements experimental approaches based on DSD data, in order to investigate radar beam propagation through rain as well as radar retrieval techniques. In the present contribution, a stochastic simulator with such an ability is proposed. The approach is based on the Taylor's hypothesis of frozen turbulence (enabling to convert time into space), on the assumption that the exponential model fairly well describes measured DSD spectra, and on the assumption that the DSD model parameters are lognormally distributed. The first step is the simulation of bivariate Gaussian random fields with a given spatial structure (estimated from DSD measurements), that are then exponentiated in order to obtain 2D fields of the exponential DSD model parameters. The use of geostatistical tools makes it possible to simulate fields with the observed spatial structures. The generated fields are confronted to radar measurements in order to assess the quality of the simulations.

P2-018

Quality check of a gauge-based daily precipitation dataset: Using maximum rain rate given in the standard product 2A25 of TRMM/PR

Haruko KAWAMOTO[1] Akiyo YATAGAI[1]

1 Research Institute for Humanity and Nature, Kyoto, Japan

Some kinds of high resolution data set of precipitation were developed for the purpose of quantitative estimate of hydrological resources. However, these are not exactly sufficient in accuracy and horizontal resolution from the viewpoint of extremes analyses. On the basis of these problems, the present study created precipitation data set from daily rain-gauge within 65-155°E and 5-60°N, for a 26-yr period from 1978 to 2003. We improve them to high grid resolution and try collecting additional rain-gauge data, and release them freely on our web site (http://www.chikyu.ac.jp/precip/index.html).

It is important to distinguish an abnormal value from the amount of extreme values, because our data set sometimes includes huge value by original raw rain-gauge or calculating algorithm. This abnormal value problem has appeared by quality check system on collected gauge data that we got from some country. Therefore, we investigate quantitative quality to compare our gridded data with rain rate given in the standard product 2A25 of Precipitation Radar (PR) on board Tropical Rainfall Measuring Mission (TRMM).

In this study, the maximum rain rate derived from vertically series (pixels ~10km) of 2A25 is treated as the "likely-truth". The selected value is transformed to 0.05*0.05 degree grid box next. This analysis domain is restricted within 31.5-36.0°N, because of high dense of TRMM/PR observation. Normally, the number that TRMM/PR covered at same longitudinal position in this domain is 2 or 3 times a day. Next, the maximum value for a day in a 0.05 degree grid is selected as daily representative value in the grid.

The reason we choose not the surface but the vertical pixel is that our treating period is daily. It is not so important the instantaneous observations in small space such as 0.05 degree grid.

Meanwhile, our daily data set from rain-gauge is interpolated using the method of Shepard. We use their 0.05 degree format in intermediate process to compare with rain rate from 2A25.

We investigate the correlation between daily precipitation dataset and 2A25 data. And we attempt to remove the extremely high value from raw rain-gauge data, and go back to execute interpolate method again.

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P2-019

Extreme rainfall statistics based on rain gauges and radar measurements

Lisbeth PEDERSEN [1] *Niels Einar JENSEN* [2] *Henrik MADSEN* [3]

1 DHI & Institute for Informatics and Mathematical Modelling, Technical University Denmark 2 DHI 3 Institute for Informatics and Mathematical Modelling, Technical University Denmark

Most flooding in urban areas can be related to extreme rainfall events. The statistics for these rainfalls are of great importance, since they constitute the basis for the design criteria for future sewer systems. Up till now extreme value rainfall statistics have been based on rain gauge measurements, but since a gauge only represents a few hundred square centimetres, the extreme value statistics obtained for this small area may not be representative for the whole catchment.
Preliminary results have shown a great variation in the occurrence of extreme values at locations only a few kilometres apart, when analysing and comparing high resolution radar data with the recordings of nearby rain gauges. These preliminary results will be analysed further along with new data from a dense network of automatic rain gauges. As part of the DHI test bed for testing Local Area Weather Radars (LAWR), nine rain gauges have been placed symmetrically within a 500x500 meter area in order to quantify the variability within a single LAWR pixel. The rain gauge site is covered with 3 X-band radars less than 15 km from the site. The primary aim is to locate significant statistical properties of extreme rainfall events based on data from the nine gauges and the radars. The overall intent is to link the IDF curves with a spatial extent measure for the use of future design of urban drainage systems.

P2-020

A Novel Rain Gauge Network Design Methodology using Weather Radar and PCA

Michaela BRAY[1] *Dawei HAN*[1]

1 University of Bristol

Quality precipitation data are an important part of many water resource projects which are often derived from raingauge networks. Despite its importance; there is a lack of practical methodology to decide the optimum number of gauges needed and the ideal locations for them. This paper proposes a novel scheme to tackle this problem using Principal Component Analysis (PCA) and weather radar data. PCA provides useful information about the state of an existing rain gauge network, moreover for new network design, pixels from weather radar could be used for PCA analysis instead of an existing rain gauge network. If the number of linearly independent components are significantly less than the number of data values, it would indicate there are many redundant gauges in the network (i.e., they are highly correlated with each other) and further savings could be made by using fewer of them. On the other hand, if there are no near zero components, the network has no redundancy and may not be adequate. It is not straightforward to use PCA to pinpoint the suitable rain gauge locations; instead Cluster Analysis should be used to classify highly correlated pixels into distinctive groups indicated by the PCA information. The methodology has been studied using precipitation data from both weather radar and a dense raingauge network from the Brue Catchment in Southwest England and also using a synthetic rain field to simulate high to low quality weather radar data. This methodology works well and provides a quick way for users to explore different options for rain gauge network design, especially for multipurpose projects. However, it has been found that the existing radar data quality is too noisy and unable to coincide with the dense raingauge network. Nevertheless it is expected that with the advancement of radar technology, such a problem would be overcome

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P2-021

Developing a Method to Estimate Global Distribution of Temporal and Spatial Correlation Lengths of Instantaneous Rainfall Using Low Frequent Observation from Space

Eiichi NAKAKITA [1] *Lisako KONOSHIMA* [2]

1 Disaster Prevention Research Institute,Kyoto University 2 Graduate School of Engineering,Kyoto University

Estimating temporal and spatial correlation lengths in global scale from low frequent space observation (here TRMM/PR and TMI) is discussed. An application in Asian Monsoon areas as an example toward the global estimation is shown. Also validation with a continuous observation of ground radar is given.

The model used here, given by Nakakita et al. (2006) is outstanding in a point which the model estimates the population variance of monthly rainfall from the sample variance of monthly rainfall, and at the same time gives the temporal correlation lengths of instantaneous rainfall of the region, as stochastic parameters of precipitation characteristics, only from monthly rainfall data created from intermittent observation of TRMM.

In this research, based on the above model, the estimation method in lower latitude is focused, where the observation frequency is less than 15 times a month in average. Here, some solutions are studied to increase the observation frequency of the area. In particular, by respecting the spatial correlation into the model as spatial rainfall characteristics, revise the model function from point rainfall model to spatial (or area) averaged model which takes the footprint of the TRMM observation into account. This model enables to change the spatial domains (footprints) of the instantaneous rainfall samples and by enlarging them, increase the areal observation frequency in a month and estimate the parameters within all sizes (or footprints).

This model also made possible to incorporate TMI and PR observation of TRMM, which resolutions are quite different. Adding the TMI observation would make the model performance higher in estimating the global distributions.

This formulation also made the model accurate by considering the effect of the footprints as shown in the validation with the ground radar.

The TRMM PR and TMI products used in this research are provided from JAXA, the Japan Aerospace Exploration Agency. For the information of rain gauge of the Miyama radar, the MLIT, Ministry of Land, Infrastructure and Transport Japan provided us as research data sets. Here to state a great thanks to them.

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P2-023

Quantifying the diurnal cycle of precipitation to improve maple rainfall forecasts

Marc BERENGUER [1] *Isztar ZAWADZKI* [1]

1 J.S. Marshall Radar Observatory. McGill University, Montreal, Quebec (Canada)

Nowcasting based on extrapolation techniques using continental radar maps have shown their ability to produce forecasts of quality superior to numerical weather forecasts for lead times up to 6 hours. However, the main limitation of these techniques is their inability to capture the changes of precipitation patterns not detectable by echo motion. A particular case of change in area and intensity of precipitation may be associated to the diurnal cycle of precipitation.

In this work we propose a characterization of the diurnal cycle from radar composites with the aim of incorporating this diurnal component to improve the precipitation forecasts generated with MAPLE (the McGill Algorithm for Precipitation nowcasting by Lagrangian Extrapolation).

P2-025

A Comparative Study on Two Short-term Rainfall Forecasting Method Applied to Jungrang watershed, Korea

Seong-Sim YOON[1] *Deg-Hyo BAE*[2] *Gwangseob KIM*[3]

1 Ph.D Candidate Student, Depart. of Civil and Environmental Engr, Sejong Univ, 98 Kunja-dong, Kwangin-gu, Seoul 143-717, Korea 2 Prof., Depart. of Civil and Environmental Engr, Sejong Univ. 98 Kunja-dong, Kwangin-gu, Seoul 143-717, Korea 3 Assistant Professor, Department of Civil Engineering, Kyungpook National University, 1370 Sankyuk-dong, Bukgu, Daegu, 702-701, Korea

Recently, urban flood disaster is increasing mainly due to the increase of flood peak and reduction of concentration time. One of the counter-measures for reducing this disaster is to develop a flood forecasting system for the site-specific urban area. Rainfall forecasting is essential part of flood forecasting system. So, the improvement of the accuracy for rainfall forecasting is important. In this sense, the purpose of this study is to compare two different short-term rainfall forecasting method for the performance. The methods used for forecasting rainfall from radar data are Translation model and TREC (Tracking of Radar Echo with Correlation) technique. Translation model predict to move an initial echo by translation vector calculated by pattern matching method. TREC tracks echo movement by finding the maximum in cross-correlation function between two consecutive radar imageries. We attempt to compare the predicted radar rainfall by these methods and to analyze the performance of these methods in urban watershed, precisely in Jungrang watershed. In this study, the accuracy of rainfall prediction will be evaluated for with each method on urban watershed.

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P2-026

A Study of Combining Weather Radar and a Numerical Weather Model for Short-term Rainfall Prediction

Deg-Hyo BAE [1] *Seong-Sim YOON* [2]

1 Prof., Depart. of Civil and Environmental Engr, Sejong Univ., 98 Kunja-dong, Kwangin-gu, Seoul 143-717, Korea 2 H.D Candidate Student, Depart. of Civil and Environmental Engr, Sejong Univ., 98 Kunja-dong, Kwangin-gu, Seoul 143-717, Korea

The improvement of the accuracy of rainfall prediction is essential part for flood forecasting system. Both weather radar and numerical weather prediction (NWP) are two important sources for rainfall prediction. In general, no short-term rainfall prediction method using weather radar has been successful in predicting rainfall distribution approximately two hours ahead because the radar forecasting leaves the development/decay unresolved. Also, NWP model has a spin-up problem within 3hr leading time. However, in the case of river flow forecasting of a larger catchments, the longer leading time rainfall prediction is relevant. So, improving short-term rainfall prediction is necessary in order to increase the reliability of real-time flood forecasting. In this sense, we attempt to combine rainfall prediction from radar and NWP model (MM5) with high resolution for improves the short-term rainfall prediction. Predicted rainfall can be achieved by Translation model with weather radar data and by solving numerically the equations of a NWP model in this study. In this study, we will evaluate the improvement of short-term rainfall prediction by combine weather radar and NWP model.

This study was supported by the 2003 Innovation Project for Construction Technology(03-SANHAKYOUN-C01-01) through the Urban Flood Disaster Management Research Center in KICTTEP of MOCT KOREA

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P2-027

Accounting for the stochastic nature of rain field displacement by scale decomposition

Maik HEISTERMANN[1] *Erwin ZEHE*[1]

1 University of Potsdam

The extrapolation of rain field behaviour from subsequent radar images is common practice for precipitation nowcasting at meso-gamma scale, involving lead times of typically two to three hours. Field behaviour can be partitioned into advection and Lagrangian evolution (though we prefer the term 'displacement' to 'advection' if we do not exactly know the underlying processes). While several authors already addressed stochasticity in the evolutionary component (e.g. German and Zawadzki, 2002; Seed, 2003), uncertainty and stochasticity in field displacement have mostly been neglected, yet. In this study, we propose a method which considers the contribution of different spatial scales to the overall field displacement and the resulting impacts on displacement uncertainty. We distinguish between methodological and process-related uncertainty: the first reflects our limited ability to estimate the true displacement field from two subsequent radar images; the latter incorporates the uncertainty in the development of the displacement field over the forecast period.

We use radar compositions for Germany (900x900 km grid, 1x1 km resolution, available every five minutes). Field displacement is modelled by a simple Lagrangian advection scheme. Displacement vectors are derived from subsequent images by means of covariance maximisation, assuming perfect Lagrangian persistence. Now, consider two extreme approaches: first, we infer only one displacement vector for the entire grid. This vector would provide a reliable estimate of mean field displacement over the entire study area. But it would be of little value to forecast the movement of small meso-gamma cells in any sub-region of our grid. The other extreme would be to divide our grid into small blocks (e.g. 10 km edge length) and infer displacement vectors for every single block. This could allow us to predict the movement of individual cells. However, the information would be very uncertain (sample size, equifinality) and we would loose information about the general movement of squall lines or fronts. Our method assimilates these antagonising approaches by considering the contribution of different scales to the overall displacement field. For this purpose, we identify displacement fields resulting from increasing block sizes (i.e. scales). For each block at each scale, we generate a set of indicators to characterise the significance of our vector estimate. The final vector field is constructed by combining the results from each scale subject to estimation significance. Methodological uncertainty is accounted for by not only choosing the most significant result, but by setting a significance threshold. Process-related uncertainty is accounted for by analysing the decorrelation time (persistence) of displacement behaviour at each contributing scale. For this purpose, displacement is modelled as an auto-regressive process with a stochastic component, allowing us to generate ensembles of displacement fields.

These results are presented on behalf of the OPAQUE research project (Operationelle Abfluss- und Hochwasservorhersage in Quelleinzugsgebieten), funded by the Federal Ministry for Research and

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P2-028

Flood Prevention in Urban Area with Promising Rainfall forecasting Approach

Chi Dung DOAN [1] Shie-Yui LIONG [2] Eiichi NAKAKITA [1] Hoang Huy NGUYEN [1] Shan HE [1]

1 Disaster Prevention Research Insitute, Kyoto University, Japan 2 Tropical Marine Science Institute, National University of Singapore, Singapore

The paper presents an approach to nowcast rainfall with radar images. The forecasting time presented is up to 2 hours. The study uses the translation model (Shiiba et al., 1984; Takasao et al., 1994) with an added feature to better forecast rainfall on catchment under consideration. The rainfall amount forecasted by translation model is then further enhanced by Neural Network to yield higher agreement with the observed weighted average rainfall for the catchment. The proposed scheme is demonstrated on a catchment in Singapore with reasonably a high performance indicator even for a 2-hour lead time.

P2-029

A physically-based downscaling by a coupled land-atmosphere satellite data assimilation system

Souhail BOUSSETTA[1] Toshio KOIKE[2] Graf TOBIAS[1]

1 The University of Tokyo, Department of Civil Engineering, River & Environmental Engineering Lab 2 The University of Tokyo, Department of Civil Engineering, River & Environmental Engineering

This study developed a coupled land-atmosphere satellite data assimilation system as a new physical downscaling approach, by combining a mesoscale atmospheric model with a land data assimilation system (LDAS). The LDAS consists of a land surface scheme as the model operator, a radiative transfer model as the observation operator, and the simulated annealing method for minimizing the difference between the observed and simulated microwave brightness temperature. The atmospheric model produces forcing data for the LDAS, and the LDAS produces better initial surface conditions for the modelling system. This coupled system can take into account land surface heterogeneities through assimilating satellite data for a better precipitation prediction. 3-dimensional numerical experiments were carried out in a mesoscale area of the Tibetan Plateau during the first week of July as a wet monsoon season. The results from the new system showed significant improvement compared with the ones from a regional atmospheric model simply nested from the global model. The surface soil moisture content and its distribution from the assimilation system were more consistent to in-situ observations. These better surface conditions affect the land-atmosphere interactions through convection systems and lead to better atmospheric predictability as confirmed by satellite-based cloud observations and in situ sounding observations. It also showed that larger scale atmospheric conditions can in some cases enhance the surface induced local circulations. Through the use of satellite brightness temperature, the developed coupled land-atmosphere assimilation system has shown potential ability to provide accurate initial surface conditions and its inputs to the atmosphere and to improve physical downscaling through regional models. Even though, these results can be considered as a step toward better atmospheric predictability by improved initial surface condition, still this target can't be reached without improving the initial atmospheric conditions as well.

P2-030

Radar data interpolation for improvement of gauge adjustment techniques

Thomas PFAFF[1] Andras BARDOSSY[1]

1 Universitaet Stuttgart, Germany

Floodings in head catchments are connected with high damage potentials due to short lead times and rapid increases of the water level. Water management in such catchments requires precise operational forecasting of rainfall-runoff processes as well as corresponding control of reservoirs and retention basins. The OPAQUE project (Operationelle Abflussvorhersage in Quellgebieten - Operational runoff forecasting in head catchments [1]) is concerned with the development of such an operational system for small head catchments in Germany. Study catchments include the Upper Danube, Upper Iller, the Goldersbach and the Weißeritz.
An important aspect of the OPAQUE project is the improvement of real-time spatio-temporal rainfall estimation and the prediction of rainfall for the next 2-3 hours (now-casting). For this purpose, radar data (1° x 1 km azimuth and range) provided by the German Weather Service [2] is combined with rain-gauge measurements on the ground. Both estimation of current rainfall and now-casting are based on procedures developed by Ehret [3]. Real-time rainfall estimation is achieved by the so-called "merging" of radar and rain-gauge measurements. The merging preserves the mean rainfall field estimated by rain-gauge observations but imprints the spatial variability of the radar image.
One improvement to the merging routine is to correctly represent the spatial extent of the radar measurements using block kriging. For this purpose the correct point variogram has to be inferred from the experimental block variogram. Theoretical experiments with simulated fields show, that calculating the experimental variogram based on data from supports of varying size leads to random deviations from the original theoretical variogram. Therefore, experimental variograms should only be constructed from supports of similar geometry. This basically leads to as many experimental variograms as there are range bins in the radar data. These are then deregularized using the method given in [4]. From the resulting point variograms, a representative variogram is constructed for use in the kriging routines.
The presentation will show results for precipitation events in south-western Germany for August 2006.

OPAQUE is a project within the BMBF-National Research Programme "Risk Management of Extreme Flood Events" (RIMAX), funded by the German Federal Ministry of Education and Research (BMBF).http://www.rimax-hochwasser.deThe radar data is courtesy of the German Weather Service (DWD).

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P3-001

An approach to improve spatially distributed parameters for hydrological modelling using regionalization procedures

Felipe QUINTERO[1] *Carles CORRAL*[1] *Daniel SEMPERE-TORRES*[1] *Jaime I. VELEZ*[2]

1 Grup de Recerca Aplicada en Hidrometeorologia, Barcelona,Spain 2 Universidad Nacional de Colombia, Medellin, Colombia

One of the main challenges nowadays on hydrological sciences is the prediction of streamflow at ungauged sites, mainly considering the uncertainty related to regionalization process.
This study deals with the analysis of model structural error, taking into account the inherent uncertainty related to the parametrization in a classic calibration process against observed flows. Data from different instrumented watersheds in Catalunya region (Spain) have been used to infer relationships between model parameters and physical properties of the catchment, which have been used later to improve the spatial distribution of model parameters. Two distributed rainfall-runoff grid-based models: 1) DiChiTop, based on Topmodel and unit hydrograph routing; and 2) SHIA, based on a vertical tank structure and a geomorphological kinematic wave approach are tested to see differences between calibrated parameters, regionalization relationships and parameter distribution inside the catchments. Some conclusions about model structural error and regionalization are presented.

This work has been carried out in the framework of EHIMI project, funded by Agencia Catalana de l'Aigua.

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P3-002

A cell based physically based model to simulate stream flow using radar-based rainfall data applied to the Illinois River basin in Oklahoma, USA

Alireza SAFARI[1] *Florimond DE SMEDT*[2]

1 PhD student atDepartment of Hydrology and Hydraulic Engineering,Free University of Brussels, Belgium. 2 Professor at Department of Hydrology and Hydraulic Engineering,Free University of Brussels, Belgium.

This paper describes the application of a spatially distributed hydrological model WetSpa (Water and Energy Transfer between Soil, Plants and Atmosphere) using radar-based rainfall data provided by the United States Hydrology Laboratory of NOAAs National Weather Service for a distributed model intercomparison project. The physics based continuous hydrological model uses remote sensed and GIS data in order to simulate and predict hydrographs at the basin outlet or any converging point in a watershed. The model is applied to the Illinois River basin above Tahlequah hydrometry station in Oklahoma with a 30m spatial resolution and 1 hour time step for a total simulation period of 6 years. Rainfall inputs are derived from radar. The distributed model parameters are based on an extensive database of watershed characteristics available for the region, including digital maps of DEM, soil type, and landuse. An automated calibration scheme is employed to the WetSpa model to tune and adjust the global model parameters. The simulated hydrograph shows a good correspondence with the observed hydrograph indicating that the model is able to simulate the relevant hydrologic processes in the basin.

Keywords: WetSpa, Physically based Distributed Hydrological Model, DMIP, NEXRAD Stage III rainfall data, Streamflow Simulation, Automated Calibration, PEST, Illinois River basin.

P3-003

The hydrological study of the basin of Oued Ouahrane in Algeria

Bakhta CHENAOUI [1]

1 ENSEIGNANTE AU DEPARTEMENT D'HYDRAULIQUE.UNIVERSITE DE CHLEF. ALGERIE

The hydrological study of a basin is the set of physic, lithologie and hydroclimatic conditions which constitute principals parameters conditions the floods phenomenon.
The object of our work is the hydrological study of the basin of Oued Ouahrane and the estimation of peak flow by the influence of Mediterranean and semi arid climate.

Key words: hydrology, basin, flow, flood.

P3-004

Precipitation ensembles as input to hydrological models

Jan SZTURC[1] *Katarzyna OSRODKA*[1] *Anna JURCZYK*[1] *Leszek JELONEK*[2]

1 Institute of Meteorology and Water Management, Radar Centre, Waszawa, Poland 2 Institute of Meteorology and Water Management, Office of Hydrological Forecasts, Wroclaw, Poland

Radar-derived QPE and radar-based QPF constitute essential input to NWP and rainfall-runoff models. However the input data introduce a number of errors into final products. Thus their uncertainty should be determined to provide end-users with probabilistic forecasts as more reliable information.

The proposed idea is to use Quality Index (QI) scheme for some number of quality parameters assuming that: (1) relationship between the parameters and relevant quality indexes is linear; (2) averaged QI is a weighted average of all particular indexes (Friedrich et al., 2006; Szturc et al., 2006a; 2007a). The uncertainty parameters can be among others topography-dependent, parameters resulting from spatial and temporal distribution of data, etc.

Here it is proposed to take into account the uncertainty in precipitation using a PDF that is suitable to rainfall, i.e. gamma PDF (e.g. Amburn and Frederick, 2007). It is assumed that the PDF parameters are related to averaged QI, and this relationship can be experimentally determined.

The main characteristic of probabilistic QPE or QPF is that it is not a map of single values but map of precipitation PDF. Practically the probabilistic precipitation field consists of three values for each pixel: two PDF parameters and QPE/QPF. Next step is to produce a probabilistic precipitation field that is an ensemble of a few deterministic inputs (Germann et al., 2006; Szturc et al., 2006b) instead of only one. It may be done by selection of some characteristic maps, that can be chosen as the PDF quantiles.

Because of the ensemble of precipitation fields the hydrological model needs to be activated according to a number of input members (Szturc et al., 2006b). As output from rainfall-runoff model the same number of hydrographs is obtained defining classes of runoff forecasts uncertainty (Gouweleeuw et al., 2005; Roulin and Vannitsem, 2005).

This work has been carried out within the framework of the COST-731 Action "Propagation of uncertainty in advanced meteo-hydrological forecast systems" and supported by the Polish Ministry of Science and Higher Education.

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P3-005

Evaluation of several synthetic radar rainfall fields based on the runoff simulations using ModClark

Chulsang YOO[1] Byoungsoo KIM[1] Kyoungjun KIM[1] Jungsoo YOON[1] Jeongho CHOI[1]

1 Department of Civil & Environment Eng., Korea Univ., Seoul, Korea

Hydrological analysis considering rainfall spatial variability has been a major concern in water resources planning and management. Recently, the radar rainfall has become widely introduced for the hydrological analysis, which is believed to overcome the drawback of rain gauge rainfall. In fact, it is very rare for a basin to have enough number of rain gauges to accurately derive the spatial variability of rainfall fields. Economical consideration of maintaining many rain gauges may be another reason to introduce the radar system for rainfall observation.

This study focuses on the use of radar rainfall for the rainfall-runoff analysis. It is well known that the radar rainfall itself does not have enough accuracy for the rainfall-runoff analysis. Various correction methods have been introduced to improve the quality of the radar rainfall. Especially, in this study, G/R corrected radar rainfall data (Steiner et al., 1999), synthetic rainfall data of radar and rain gauge rainfall by co-Kriging (Seo, 1996), and synthetic rainfall data by the successive correction method (SCM; Cressman, 1957; Barnes, 1964) are compared by applying them to the rainfall-runoff analysis. Original radar rainfall data and distributed rain gauge rainfall by Kriging are also considered for the comparison. This study considers the typhoon Maemi during the summer of 2003.

The rainfall data prepared have all been applied for the rainfall-runoff analysis of the Chungju Dam Basin, located in the middle of the Korean Peninsula. Obviously, the true rainfall field is unavailable. In this study, however, the rainfall field generated by applying the block Kriging for the rain gauge rainfall was assumed the true rainfall field for the evaluation of the synthetic rainfall field generated. The number of rain gauges used for generating the true rainfall field is twice that for other cases of rainfall field generation or correction. The rainfall-runoff analysis model used in this study is the Modified Clark (ModClark; Kull and Feldman, 1998). The geomorphologic characteristics and other parameters required were all estimated using the HEC-GeoHMS.

Runoff results showed similar patterns of the rainfall data used. Especially, the original radar rainfall and the G/R corrected rainfall resulted in significant underestimates of the runoff observed. On the other hand, other synthetic rainfall data resulted in very comparable results with the observed. Especially, among the rainfall fields generated for the comparison in this study, the synthetic rainfall fields by the SCM gave the best results. The synthetic rainfall field by the co-Kriging also resulted in well matched runoff results with the observed. Considering that the SCM is a very simple and easily applicable data assimilation method, it may easily and effectively be applied for the rainfall-runoff analysis to the small urban basins with a short concentration time, where no time-consuming data correction method can be applied.

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P3-006

Contribution of the rain rate by radar in operational flood forecasting

Stéphanie DISS[1] Patrick ARNAUD[1] Jacques LAVABRE[1] Jacques TESTUD[2]

1 Cemagref Aix en Provence 2 Novimet

The goal of this paper is to appreciate the relevance of the use of weather radar information, and in particular Hydrix radar, compared to gages data in a rainfall runoff model. This work takes place in the European project FRAMEA (Flood forecasting using Radar in Alpine and Mediterranean Area). For this project dual polarized X-band radar (Novimet) was installed between February 2006 and March 2007 on the catchment of Réal Collobrier (South East of France). The dataset is composed of rain information from several sources, an S-band radar (Météo France), localized at 4 km range from the X-band radar, two dense gages network (Météo France and Cemagref) as well as flow measurements (Banque Hydro). This work aims to integrating the rain rate measured by the S-band radar, the X-band radar and the rain gages, into a rainfall runoff model. We used a spatialized version of the Gr3H model. The rain gages network, even very dense, cannot provide fully spatialization rain information and can miss very localized and intense rain events. Nevertheless, rain radar information will bring a better flow forecast only if the radar rain estimate is coherent with measurements on the ground.

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P3-008

Merging data from weather radar and raingauge networks: disagreements in the fractional coverage and implications for hydrological modelling

Javier GARCIA-PINTADO [1] Gonzalo G. BARBERÁ [2] Manuel ERENA [3] Victor CASTILLO [2]

1 Institute of Earth Sciences "Jaume Almera" (IJA-CSIC), Lluis Solé i Sabaris s/n, E-08028 Barcelona, Spain 2 Soil and Water Conservation Department (CEBAS-CSIC), Campus de Espinardo, E-30100 Murcia, Spain. PO BOX 164 3 Murcian Institute and Agricultural Development and Research (IMIDA), Mayor s/n, E-30150 La Alberca, Murcia, Spain

Theoretical and field studies have revealed that the spatial generation of runoff is strongly non-uniform. Thus, weather radar has been considered to be a powerful tool to provide rainfall data to drive hydrological models. Commonly, these are distributed models used for prediction of runoff production, assessing of flood risks, and planning of flood mitigation works. A number of studies are focused on quantitative precipitation estimation (QPE), merging meteorological radar and point measurements of precipitation such as are provided by a raingauge network. Other studies analyze the rainfall-runoff model sensitivity to rainfall temporal and spatial variability, including radar data. Here, we address the problem of dealing with consistent differences between the fractional coverage of rainfall as detected by radar and that recorded by the rain gauge network, and the implications of the corresponding data merging solutions for hydrological modelling. We analyze the response of a, physically based, distributed rainfall-runoff model to various approaches on the radar-gauge data merging under these disagreement conditions. The study area is a 556 km^2 semiarid watershed in a Mediterranean coastal area with high agricultural and urban pressures, where flash floods are commonly produced by large precipitation events with irregular spatial distribution. The model accounts for our perceptual hydrological processes in these specific environments.

P3-009

Flow forecasting in the Corumbatai river basin: radar rainfall characterization

Roberto CALHEIROS [1] *Augusto D OLIVEIRA* [2]

1 IPMet - UNESP 2 IBILCE - UNESP

While conventional estimates of precipitation with ground-based systems remain widely used for hydrological applications, radar rainfall utilization for, e.g., flow forecasting is ever growing. The radar use for that purpose is the object of many studies. On the other hand, the optimization of radar applications to hydrological prediction is being actively investigated.

The IPMet (Meteorological Research Institute) at Bauru, São Paulo, is implementing a new product in its operational practice providing precipitation over predefined sub-catchment(SRI: surface rainfall intensity and CATCH: subcatchment precipitation accumulation) areas under the coverage umbrella of the two radars run by the Institute (BRU: 22.36S, 49.00W, and PPR: 22.17S, 51.37W). Although the algorithms include some corrections to the radar rainfall field, outstanding issues such as Z-R relationships have to be approached locally.

This work is a pilot project dealing with the important Corumbatai River Basin, a catchment area situated at an average distance of approximately 130 km from BRU, which has been focused in many studies since long.The present research keeps similarities with the work carried out by Pessoa et al in 1993. In a first phase, rainfall over subcatchments of the Basin are being computed, for different characterizations of the radar field. Characterizations involve variations of the space and time resolution of the precipitation and, mainly, a set of Z-R relationships.

While relationships developed elsewhere are considered, focus is on specific Z-R conversion expressions derived for BRU, involving range corrections as well as an stratification by daily intervals. Computations are performed for selected events from both the dry-to-wet transition period, and the summer.

A comparison is made of the rain fields obtained with those shown in Pessoa et al (1993).

In continuation, the sensitivity of the flow forecast to the different radar rainfall characterizations will be investigated. To perform the forecast, the Hydrological Analysis and Simulation System - SASHI, presented by Rennó (2003) is being initially considered. This model has been tested in hydrological simulations in a subcatchment of the Corumbatai Basin.

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P3-010

Using weather radar measurements for real-time river flow forecasting

Guillaume LECLERCQ [1] Georges BASTIN [1] Luc MOENS [1] Laurent DELOBBE [2] Philippe DIERICKX [3] Marianna THUNUS [3]

1 Centre for Systems Engineering and Applied Mechanics (CESAME), Université Catholique de Louvain (UCL), Louvain-la-Neuve, Belgium 2 Royal Institute of Meteorology (RMI), Brussels, Belgium 3 Direction générale des Voies Hydrauliques, Walloon Ministry of Equipment and Transport, Namur, Belgium

This paper deals with the HYDROMAX real-time riverflow prediction system which has been developped by CESAME (Belgium) and is in permanent operation from 1995. HYDROMAX is based on a lumped grey-box rainfall-runoff model that requires only on-line rainfall and flow measurements in order to compute the riverflow predictions [1].
The goal of the paper is to give a systematic comparison of the HYDROMAX performance when alternative estimations of the average rainfall over a river basin are used as model inputs: estimations from pointwise rain-gauge measurements, estimation from weather radar measurements and estimations obtained by combining both measurement systems using geostatistical methods. It turns out that the flow predictions are almost not affected by the measurement bias which is known to be significative for raw radar measurements. This is due to the adaptation of the model parameters which are identified separately for each estimation method. We show that the predictions obtained with both types of measurements have the same level of accuracy despite the fact that quantitative radar measurements are much less accurate than rain-gauge measurements. Furthermore, it is shown that merging
both types of measurements do not significantly improve the prediction accuracy.
The analysis relies on application results on two river basins, tributaries of the Meuse river, in the Walloon part of Belgium : the Ourthe catchment at Tabreux (1608 square kilometers) and the Semois catchment at Membre (1229 square kilometers) . The rain-gage measurements are given by an automatic network operated in real-time by MET/DGVH. The radar measurements are provided by the Royal Institute of Meteorology (RMI), which operates the Wideumont radar, located in the south of Belgium.

[1] [1] C. Dal Cin, L. Moens, P. Dierickx, G. Bastin, Y. Zech,

P3-011

Hydrological modeling of the Ourthe catchment using both radar and raingauge data

Pieter HAZENBERG[1] *Hidde LEIJNSE*[1] *Remko UIJLENHOET*[1] *Laurent DELOBBE*[2]

1 Hydrology and Quantitative Water Management Group, Wageningen University, The Netherlands 2 Royal Meteorological Institute of Belgium

In the southern Ardennes region near the border of Luxembourg, the Royal Meteorological Institute of Belgium (RMI) installed a C-band Doppler radar at an elevation of 600 m in the year 2001. To assess the potential of the space-time structure of rainfall estimated using the radar for runoff modeling a collaboration with the Hydrological Service of the Walloon Region of Belgium (MET-SETHY), the RMI and Wageningen University was started.
The 1597 km2 Ourthe catchment lies within 50 km of the radar. Over the watershed ten raingauges are more or less equally distributed measuring at an hourly interval. Near the outlet discharge data are collected at the same time step.
A previous study (Berne et al., 2005) presented the first results of the radar application for six rainfall events. The spatial average values of a convective and stratiform event were used for runoff simulation in the lumped HBV model. It was shown that the predicted discharges were highly sensitive to the initial conditions, which are difficult to estimate for such event-based simulations.
In the current study six months of both radar and raingauge data over the period October 1, 2002 until March 31, 2003 are being compared. During this winter half year storm events are mainly stratiform giving rise to bright band effects which can decrease the performance of the radar. When modeling such continuous series the importance of accurate initial conditions becomes less important. To quantify the hydrological relevance of the high spatial resolution of the radar data as compared to the gauge data, both a lumped and distributed model are utilized.

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P3-012

The Use of Remotely Sensed Rainfall to Predict Floods in Small Mountainous Basins

Efthymios NIKOLOPOULOS [1] Emmanouil ANAGNOSTOU [2] Marco BORGA [3] Mekonnen GEBREMICHAEL [4]

1 Hellenic Center for Marine Research, Institute for Inland Waters, Anavissos, Greece 2 Hellenic Center for Marine Research, Institute for Inland Waters, Anavissos, GreeceandUniversity of Connecticut, Civil and Environmental Engineering, Connecticut, USA 3 University of Padova, Department of Land and Agroforest Environments, Padova, Italy 4 University of Connecticut, Civil and Environmental Engineering, Connecticut, USA

One of the main advantages of satellite and radar precipitation remote sensing is their ability to provide information over remote areas such as complex terrain where sparse, or no, in-situ observations are available. This study focuses on a well-instrumented small-scale mountainous basin (~116 km2) in the Northeastern Italy aiming at i) evaluating an array of remote sensing rainfall products through a comparison with dense rain gauge observations and ii) investigating whether rainfall retrievals from the various remote sensing precipitation datasets can be utilized to predict flood occurrences in such complex terrain basin. The precipitation estimates considered will vary from high-resolution precipitation fields (200-m by 200-m) retrieved from an locally deployed X-band dual-polarization radar to coarser resolution fields (1-km by 1-km) from a distant (>30 km) C-band single-polarization radar, and finally from a satellite retrieval that combines passive-microwave and Infrared observations. The error of the various remotely sensed rainfall estimates is statistically characterized and its propagation effect to the hydrologic prediction is evaluated by using a distributed hydrologic model to simulate the rainfall-runoff transformation and compare the results with discharge observations.

P3-013

What is the Ability of Distributed Hydrologic Models Driven by Radar-Precipitation Fields to Simulate Observed Scaling Characteristics of Spatial Soil Moisture Fields?

Mekonnen GEBREMICHAEL[1] Enrique R. VIVONI[1]

1 University of Connecticut; New Mexico Institute of Mining and Technology,USA

The purpose of this study is to evaluate the ability of simulated soil moisture fields to reproduce observed scaling properties, using a fully-distributed parameter, physics-based, hydrologic model. We employed the hydrologic model tRIBS (Tin-based Real-time Integrated Basin Simulator) that models the coupled surface and groundwater response to rainfall by tracking infiltration fronts, water table fluctuations and lateral moisture exchanges in the vadose and saturated zones. The soil moisture observations were derived from the airborne ESTAR L-band radiometer flown over the Little Washita basin during the SGP97 experiment conducted in June-July 1997. Our working assumption is that ESTAR-derived soil moisture maps represent realistic or plausible spatial patterns as characterized by scaling properties.

The results indicate that the distributed hydrologic models driven by radar precipitation fields have the ability to reproduce the major features of the scaling properties of soil moisture fields. Analysis of both simulated and observed soil moisture fields indicate that (i) the soil moisture obeys scale-invariance for moment orders of two or less, (ii) for moment orders exceeding three, the soil moisture does not obey scale-invariance particularly for wet land surface conditions, (iii) for moment orders exceeding two, the outliers can distort scaling parameters, and (iv) the scaling parameters show strong dependence on the e-folding distance

Properly-calibrated distributed hydrologic models driven by radar precipitation fields have the ability to reproduce the major features of scaling properties of soil moisture fields. Thus, hydrologic models can be used to characterize the space-time variability of soil moisture fields, which is crucially important in a number of applications, including validation of satellite soil moisture products.

P3-014

Examination of hydrologic and geomorphic response to an orographic thunderstorm in the Central Italian Alps

Paolo TAROLLI[1] Marco BORGA[1] Francesco ZANON[1] Pier Paolo MACCONI[2]

1 Department of Land and Agroforest Environment, University of Padova, Agripolis, Legnaro (PD), Italy 2 Provincia Autonoma di Bolzano, Bolzano, Italy

On 1 August 2005 an intense isolated thunderstorm affected a small catchment in the Anterselva River basin, in the Central Italian Alps, with duration of 75 minutes and rainfall accumulations up to 70 mm. The storms triggered an extreme debris flow, with a volume of about 100000 m^3. Rainfall and geomorphic impacts were concentrated in the ungauged 1.6 km^2 headwater catchment of Val Gole. The debris flow was triggered in a hollow draining a small steep rock basin. As such it exemplifies the characteristics of common debris flow events in the Central and Eastern Alps.

Detailed geomorphological field surveys and the application of a distributed hydrological model have made it possible to evaluate erosion processes and sediment supply to the channel network and to quantify water runoff and sediment volumes. The analysis of the rainstorm has been based on rainfall estimates from radar observations and data recorded by raingauge stations. Field surveys have permitted to assess the volume of eroded debris and to determine the space distribution of the sources of sediment. The accounts of eye-witnesses have provided useful elements for reconstructing the time evolution of the debris flow.

The objectives of this study are:

i) to explore the viability of using ground-based meteorological radar to examine geomorphic processes triggered by specific combination of high intensity rainfall cells and ground characteristics (distribution of rocky outcrops). Radar sensing of rainfall has the potential to be a powerful management and research tool. However, being an indirect measurement of rainfall, in addition to its advantages, this technology faces a unique set of limitations, particularly in an alpine context.

ii) To identify the aspects of storm structure, motion and evolution and its interaction with the impermeable portions of the headwater catchment that control the spatial and temporal distribution of extreme rainfall and runoff production;

iii)To compare the precipitation intensity-duration characteristics of the storm with existing debris flow triggering intensity-duration thresholds available for the Dolomites and surrounding regions;

iv) To assess the role of the initial conditions on the characteristics of the hydrologic and geomorphic response to the storm.

P3-015

The radar: an essential post-flood analysis tool

Eric GAUME[1] *Marco BORGA*[2]

1 Laboratoire Central des Ponts et Chaussées, Nantes, France. 2 University of Padova, Italy.

The availability of radar measurements has open new perspectives in hydrology. Post flood, especially post flash flood analysis is one of the domains where the gains due to the developments of rainfall radar measurement have been the most significant. The radar gives access to information about rainfall repartition at time and space scales in accordance with the spatial and temporal variability of the processes inducing flash-floods.
The usefulness of radar data as well as some limits will be illustrated on the basis of examples of analyses conducted after the Aude 1999 and the Gard 2002 floods. It will be shown how the available radar data enable a detailed analysis of (1) the spatial variability of the runoff, (2) the time sequence of the contributions of the tributaries to the main streams, (3) the rainfall-runoff dynamics of various sub-watersheds.

The work presented is part of the European Research project Floodsite.

P3-018

HowisErft - a radar based flood prediction and information system

Tilo KELLER [1] Dirk SCHÜTTEMEYER [2] Dirk MEETSCHEN [3] Oliver BUCHHOLZ [1] Ulrich KERN [1] Clemens SIMMER [1]

1 Erftverband, Bergheim, Germany 2 Meteorological Institute, University Bonn (MIUB), Germany 3 Hydrotec Ingenieurgesellschaft für Wasser und Umwelt mbH, Aachen, Germany

A key factor for various hydrological applications is to know accurate rainfall rate estimates. These estimates are utilized to drive hydrological models for e.g. flood forecasting. Radar based estimates of rainfall are increasingly applied for these applications, since it is possible to obtain higher coverage over a wide area with high temporal and spatial resolution compared to standard raingauge measurements.
Since floods cannot be prevented, it is crucial to limit flood damages. This is of rising concern since nowadays river dynamics are strongly influenced by human activities in the various catchments which affects the damage potential as well as the hydrological behaviour of the catchment. For these reasons the HowisErft project aims at improving the already existing flood warning system of the 1,800 km² catchment of the river Erft, Germany, to an integrated flood prediction and information system. HowisErft is a joint project of the water association Erftverband, the Meteorological Institute of the University of Bonn, Hydrotec Consulting Engineers, and the German Weather Service (DWD).
The HowisErft project is based on real-time acquisition and processing of high resolution precipitation data derived by the X band radar of the Meteorological Institute of the University of Bonn. To reduce the dependency on a single radar instrument and to create multi-view composites, additional radar data of the German Weather Service is merged with the Bonn radar data. Interpolated rainfall based on ground measurements alone can be used as an alternative data source, e.g. if radar data is temporarily unavailable. Precipitation forecast is derived from standard DWD numerical weather prediction products such as RADOLAN, COSMO-K and COSME-E. The different data sources are operationally combined and fed into NASIM, a distributed, physically based rainfall - runoff model to retrieve discharge predictions.
In flood cases, these predictions will be made available to FLIWAS (Flood Information- and Warning System), currently developed within the EU NOAH project. FLIWAS aims on supporting flood management by combining actual and prognosticated hydrometeorological data with pre-defined information such as inundation maps, flood risk maps and flood alarm plans.
This contribution describes the goals, the concept and some results of the HowisErft project. A special focus is on the comparison of hydrological simulations using (a) radar derived precipitation and (b)interpolated ground based measurements.

HowisErft is funded and supported by the State of North Rhine-Westphalia and the Bezirksregierung Köln

P3-019

Towards a radar-based operational warning system for a river catchment in Germany

Dirk SCHÜTTEMEYER [1] Dirk MEETSCHEN [1] Rene GRASSELT [1] Alessandro BATTAGLIA [1] Clemens SIMMER [1] Klaus WALBECK [2] Kirsten WARRACH-SAGI [3]

1 Meteorological Institute, University Bonn (MIUB), Germany 2 Aggerverband, Gummersbach, Germany 3 University Hohenheim, Germany

Weather radars provide unique information on quantitative surface precipitation. Due to their real-time capability they play an important role in forecasting and decision-making in many sectors of society. Especially in the field of water management there is a growing need to utilize radar data to better react to extreme events. Therefore it is crucial to build operational warning systems to react quickly to extreme situations in order to prevent severe damage related to heavy rainfall.

In the current study a simple fully automatic decision support system (DSS) was developed for a mesoscale river catchment covered by an X-Band Doppler precipitation radar, only based on radar based rainfall estimates with empirical consideration of hydrological particularities in the different river sub-catchments. Many precipitation events, which were followed by strong or severe flooding during the last years, were analyzed in order to calibrate and test the system. Based on the analyzed events empirical thresholds for the critical amount of precipitation in space and time were identified and installed. At present 15 thresholds for different integrations times in the different sub-catchments are used. When a threshold is reached, a message in form of e-mail, text message and/or fax is sent to the responsible people containing information about time, place and intensity of the identified precipitation events. These messages are not meant for direct action, but for providing further information to get the overall picture.

To also deal with situations where locally obtained radar data are not available e.g. due to malfunction, external data sources (other radars and rain gauge based systems) were integrated into the DSS to ensure the operational capability of the developed system.

Furthermore the soil vegetation atmosphere transfer (SVAT) model TERRA from the German weather service was coupled to a routing scheme to obtain deeper knowledge about rainfall-runoff relationships in the catchment under consideration. The model is operated in 1x1 km resolution and mainly fed by radar derived precipitation and local meteorological observations. Since the runoff is dependent on numerous parameters of the land surface, which also varying in time and space, crucial parameters (e.g. soil type, vegetation related parameters and topography) were adjusted to the local circumstances using locally obtained data as well as different kinds of databases. First results for an entire year show a reasonable performance also in comparison to available runoff measurements.

For the future extended tests for the decision support system in combination with the coupled model and radar data extrapolation techniques for nowcasting flood events will be undertaken. In addition to the current setup, use will be made of the newest advances in radar technology (extension of the current radar to polarimetry) to remove attenuation effects and obtain deeper knowledge about

the overall precipitation.

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P3-020

Estimating Quantitative Precipitation from Ground Based Radars and Rain Gauges as inputs for the Romanian DESWAT Hydrological Forecast Models

Saswati DATTA [1] *John MCHENRY* [2] *Robert IMHOFF* [1] *David WIDENER* [1] *Carlie COATS* [1] *Tom BURNET* [1] *Jeff VUKOVICH* [1] *Jerry CONDREY* [1]

1 Data and Image Processing Consultants 2 Baron Advanced Meteorological Systems

Precipitation estimation from microwave radars depends on several factors, the most important being the empirical relation used to translate the radar reflectivity (Z) to rain fall rate (R), which is the well known Z-R relationship(Atlas et al, 1997; Battan, 1973). The Z-R relationship varies for convective or stratiform precipitation types, as well as for solid and liquid precipitation. Further, there are uncertainties related to the vertical distribution of hydrometeors, beam blockage by the terrain, and other factors (Roy et al, 2000). In order to combat these uncertainties there have been attempts to correct or adjust the radar precipitation estimate with respect to surface rain gauge observations. There are several limitations to this adjustment approach (Datta et al, 2003; Habib and Krajewski, 2002), including the quality of the surface data, resolution difference between the two types of data, the density of surface gauge networks, etc. This becomes particularly problematic at longer radial ranges. However, comparing and combining the radar data with the surface observations gives the best possible quantitative estimate of high-resolution surface precipitation, at least within 100 km of the radar range. Keeping that in mind, a real-time radar-gauge algorithm is being implemented for the Romanian DESWAT project, in order to produce very high resolution inputs for the operational hydrological forecast models. This paper will discuss the state of the available data and describe the semi co-krieging technique developed to produce the hourly QPE. This paper will also discuss preliminary results on the performance of this algorithm and how a national mosaic of hourly QPE is produced for the forecast system.

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P3-021

Operational Forecaster Tools for DESWAT: Displays for Site-Specific Romanian flood data from radar, point observations and models

Tom BURNET[1] Greg WILSON[1] Dewey BURCHFIELD[1] David WIDENER[1] Pamela MCCOWN[2] John MCHENRY[1]

1 Baron Advanced Meteorological Systems   2 Education and Research Services

The Romanian DESWAT (Destructive Waters Abatement) project establishes a national integrated decision and informational system for flood forecasting. The DESWAT scope includes the deployment of hundreds of hydrological sensors, the integration of meteorological radar and point observations; the deployment of three real time hydrological models and a flash flood guidance model, the implementation of warning messaging, and the networking of the required data streams. In order to make the best use of the integrated observations and forecasts, DESWAT is deploying displays, installed throughout the country, that present the wealth of data in an easily comprehensible geospatial context for decision support. Two main display systems are being used: The Hydronet Briefing Terminal (HBT) for situational awareness, and the HydroThreatNet (HTN) for more configurable, in-depth analysis. Though these two display systems differ somewhat in content, they both share the same core data types: animated composite radar products, animated gridded distributed model land surface variables, and observed and modeled hydrographs and hyetographs. They also share storm tracking and the ability to send warning via fax, text message or email given triggering storm conditions. Both displays employ a GIS environment and have the ability to query and label pixels, streets and rivers. This talk will describe the display tools that support the forecaster in making critical real-time forecast decisions.

P3-022

The Distributed Hydrological Model Forecast System-Model Overview and DESWAT Implementation Strategy Utilizing Radar-based QPE/QPF

John MCHENRY [1] Carlie COATS [2] Matthew GARCIA [3] Dave GOCHIS [1] David YATES [1] Tom BURNET [1] Ted SMITH [1] Jerry CONDREY [1] Sujay KUMAR [1] Christa PETERS-LIDARD [1]

1 Baron Advanced Meteorological Systems 2 NASA Hydrological Sciences Branch 3 National Center for Atmospheric Research

Development, testing, calibration, and documentation of distributed hydrologic models (DHMs) has been going on for many years. Until recently, however, it was rare that these models were applied in operational forecast settings. Now, because of the increasing need to accurately forecast stream and river flooding at high resolution, the Destructive Waters Abatement (DESWAT) project has opted to include two such models among its suite of forecast tools. Both of these models utilize radar-based QPE and short-range QPF as precipitation inputs and run in both land-data-assimilation and forecast modes in real-time. This abstract describes these models and their implementation strategy for DESWAT. The first DHM is a catchment model that is based on the traditional TOPMODEL approach, but adds a soil-vegetation-atmosphere transfer (SVAT) scheme along with a unit-hydrograph to model catchments at or below the spatial scale of most lumped models. The TOPLATS-SMPV (Peters-Lidard, 1997, McHenry, 1999, Coats, 2004) resolves the coupled water and energy budgets (including runoff production) at resolutions of 100m or less while calculating baseflow and water-table responsivity at the catchment scale. Thus, the forecaster can determine the high-resolution location in space and time where runoff is expected to occur while at the same time examine the integrated runoff response of the small catchment using the unit hydrograph. The second DHM utilizes a more extensive grid-based approach with integrated/coupled explicit routing, and is fully distributed at the 100m scale. This model, the Baron-LIS, employs the NASA Land-Information System (LIS, Kumar et al., 2006) as the high-level system framework, while the Unified NOAH-distributed LSM (Gochis and Chen, 2004) is implemented as the operational land-surface model. NOAH-D has been further instrumented with explicit streamflow (Garcia et al., 2006) and lake-reservoir routing schemes, including classic approaches such as Muskingum, Muskingum-Cunge, Diffusive-wave, and Level-pool. Each routing scheme is independently calibratable on a per-reach basis, where reaches are classified as river/stream versus lake/reservoir and extend from downstream outflow to upstream junction. The Baron-LIS system is deployed over large basins that typify the size of RFC forecast areas in the United States, and it allows flow-time-series pixel query at the 100-meter scale for rivers, streams, lakes, and reservoirs across the whole of the large basin. This abstract will describe the core science behind the modeling system as well as the implementation strategy vis-à-vis radar-based QPE/QPF within the DESWAT project.

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P3-023

Quantitative precipitation forecasting applied in a hydrologic model for streamflow predictions in Iguassu River, southern Brazil

Leonardo CALVETTI[1] Cesar BENETI[2] Alex CONVELVAN[1] Augusto PEREIRA FILHO[1] Diogo STRINGARI[1]

1 SIMEPAR Technological Institute, Curitiba, Brazil 2 Atmospheric Sciences Department, University of Sao Paulo, Sao Paulo, Brazil

We will presents in this paper results from results of an atmospheric-hydrologic prediction system,which combines the Weather Research and Forecasting (WRF) model for rainfall forecasting with the Top Model hydrologic model used for short-term (1 to 48 hour) flood forecasting in the complex terrain of the Iguaçu Basin in Southern Brazil. This system was applied for hydropower operations of Parana State Power Company which drains an area of approximately 24211 square kilometers in Southern Brazil.

This paper presents results from the use of weather and streamflow forecasting in critical events of flood at Uniao da Vitoria, a city, upstream of the hydropower plant. In these events, the storms are produced by cold fronts and squall lines originated in the warm air near the front axis witch moves faster than the fronts itself. In these cases the streamflow was greater than 300% the normal condition. Model simulations and forecasts fom WRF were used as predictions of mean precipitation in the hourly Top Model forecasts. The streamflow hourly predictions were compared with observed streamflow data for the selected events. The predicted precipitation patterns are also compared directly with rain gauge bservations, radar and satellite data using integrated quantitative precipitation estimation (QPE), for the period of 2005 to 2007.

The results indicate an important improvement in the forecasting of fast increase of streamflow using information of atmospheric forecasting in the hydrological model. Also we discuss the aspects of the probability of detection and the false alarm of the forecasts.For rainfall periods we find no differences between 24 and 48 periods skills.

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