

EGU22-11647

<https://doi.org/10.5194/egusphere-egu22-11647>

EGU General Assembly 2022

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Using Genetic Algorithms to Optimise Genesis Potential Indices for Tropical Cyclone Genesis

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Tropical cyclones (TCs) are one of the most devastating natural disasters worldwide, in terms of both economic damage (\$1100 billion in the last 20 years) and fatalities (210,000 in the last 20 years). The accuracy of TC track and intensity forecasts has been increasing steadily since the 1980s, but it remains difficult to predict how many TCs will form each year and where, as the physical processes that lead to the formation of TCs are still poorly understood. Several Genesis Potential Indexes (GPIs) have been proposed that predict the likelihood of formation and distribution of TC genesis given large-scale factors such as sea surface temperature and air humidity. These indices are constructed as the product of a number (typically 3-5) of dynamic and thermodynamic variables, each of which is assigned a coefficient and an exponent. Such indices serve not only to improve our understanding of TC formation by isolating the variables most linked to it, but also as a guideline for insurance companies and governments of how severe a TC season will be, and to predict how climate change will affect the frequency and severity of TCs in climate model simulations. Nevertheless, current GPIs have large margins of error, especially at the local scale and in terms of interannual variability.

In this work, we explore the search space for this type of index, intended as the space of variables and relative coefficients and exponents that can be used to structure a GPI. We begin by optimizing the coefficients and exponents of the well-known GPI developed by Emanuel and Nolan (ENGPI), and show that a simple genetic algorithm can lead to substantial improvements in spatial correlation between the index and observed data. However, we also show that interannual and spatial correlation may be conflicting objectives which cannot be optimized simultaneously. We then modify the structure of the ENGPI by introducing new variables used in other similar indices, some of which seem to lead to improvements. We then repeat the above experiments using different genetic algorithms, and find that different algorithms converge to different solutions with similar performance, indicating that there are many valid ways to structure a GPI; we offer an interpretation of this finding, which we believe to be relevant for future research. Finally, we show that thermodynamic variables tend to be discarded when optimizing interannual correlation, but not when optimizing spatial correlation; we offer a possible explanation of why this may be.