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Studying dynamic and thermodynamic influences on hurricane activity with a tropical cyclone emulator

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Global warming influences tropical cyclones (TC) and their impacts in different ways. Warmer sea surface temperatures (SST) are expected to lead to stronger intensification, the increased water holding capacity of warmer air increases the precipitation brought by TCs. These are thermodynamic changes that are rather well understood.

When it comes to the influence of circulation changes on tropical cyclone activity open questions remain: Will there be more or less TCs in a warmer world? And what would be the physical mechanism for a change in TC frequencies?

TC formation and intensification not only depends on the available energy but also on the large-scale atmospheric circulation. For instance, TC development is strongly hampered when the vertical wind shear (difference between upper and lower level wind speeds) is high.

Here we present a tropical cyclone season emulator for the Atlantic basin that produces TCs based on SSTs averaged over the Atlantic main development region and daily time series of weather patterns obtained from a self-organizing map clustering. The emulator is based on probabilities for storm genesis, storm length and intensity changes that were empirically assessed using the ERA5 reanalysis and IBTrACS TC observations.

We see different applications for this emulator:
1) While most global circulation models (GCM) fail to adequately simulate TCs, their projections for SSTs and large-scale weather patterns contains valuable information. Using our emulator, we could indirectly analyse TC activity projections for all available GCMs.
2) In the emulator thermodynamic (SSTs) and dynamic influences (weather patterns) are distinct inputs. This allows us to construct different counterfactuals to attribute changes in TC activity to thermodynamic or dynamic changes. For example, the emulator could be used to simulate TC seasons with large scale circulation as observed in 2017 but with preindustrial SSTs, so as to analyse the extent to which warming of the ocean surface had contributed to the extreme hurricane season of 2017.