Impact of Observational Density on Tropical Cyclone Forecasts

Accurate forecasts of tropical cyclones are essential for early warning systems and risk management. Numerical weather prediction (NWP) models rely on atmospheric observations to produce accurate initial conditions, but observational coverage varies strongly across different regions of the world.

A unique set of forecast experiments performed with the ICOsahedral Nonhydrostatic (ICON) model is available in which the density and quality of assimilated pseudo-observations (PSOs) were systematically varied. The simulations cover September 2022 and include several notable tropical cyclones, such as Hurricanes Fiona and Ian as well as Typhoons Nanmadol and Noru.

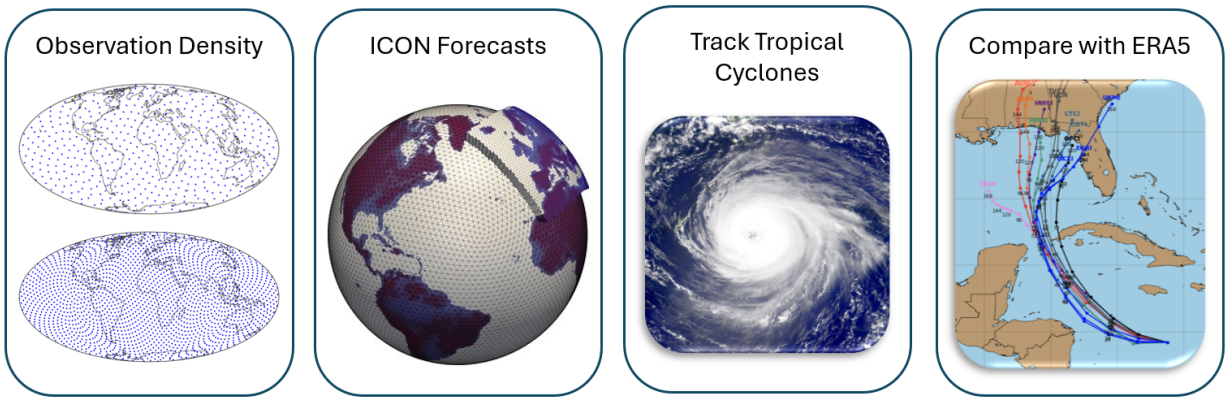

Figure 1: *Conceptual illustration of a possible analysis workflow for investigating the impact of observational density on tropical cyclone forecasts.*

Globe with ICON grid adapted from DWD, tropical cyclone image adapted from NASA, and cyclone tracks adapted from hurricanetracker.net.

Previous analyses of these experiments focused on forecast verification using spatially averaged metrics at the global scale and for the tropics and extratropics separately. These studies showed that increasing observational density generally improves forecast skill, particularly at short lead times, while observational quality has a considerably smaller impact.

This thesis extends the analysis from aggregated forecast scores to individual weather systems by investigating tropical cyclone track and intensity forecasts. Tropical cyclones will be identified and tracked in both the forecasts and the ERA5 reanalysis using meteorological indicators such as minimum sea-level pressure and relative vorticity, allowing forecast trajectory and storm intensity to be compared across experiments with different observational densities.

Possible research questions include:

- How does observational density and quality affect tropical cyclone track forecasts?
- How does observational density and quality influence cyclone intensity forecasts?
- How long do forecast improvements persist with increasing lead time?
- Do forecast improvements show signs of saturation at high observational densities?

The work will involve processing meteorological datasets in Python, identifying and tracking tropical cyclones, and evaluating forecast errors using established verification metrics.

Interested? Please contact cedric.froidevaux@kit.edu or peter.knippertz@kit.edu