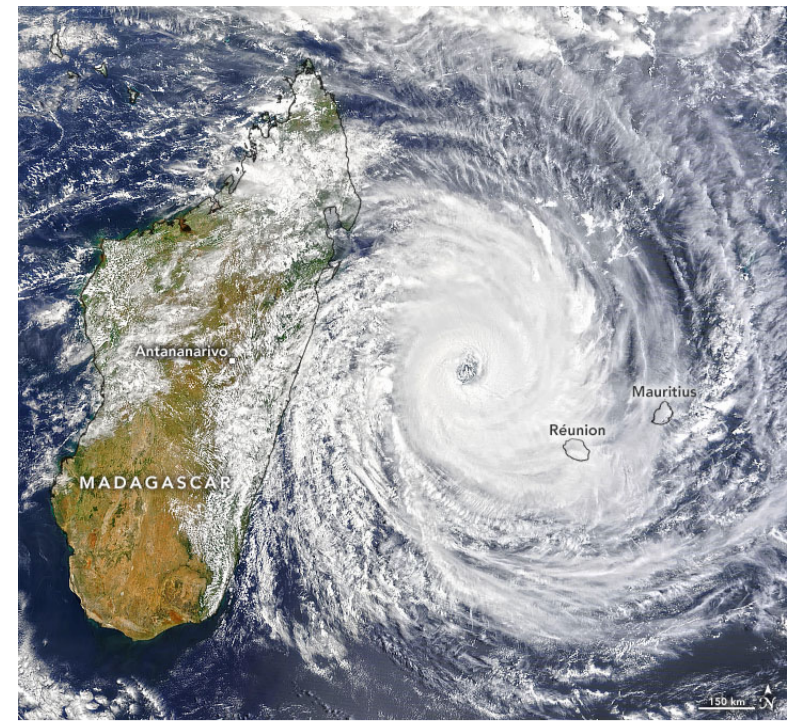


Hazard-focussed tropical cyclone diagnostics

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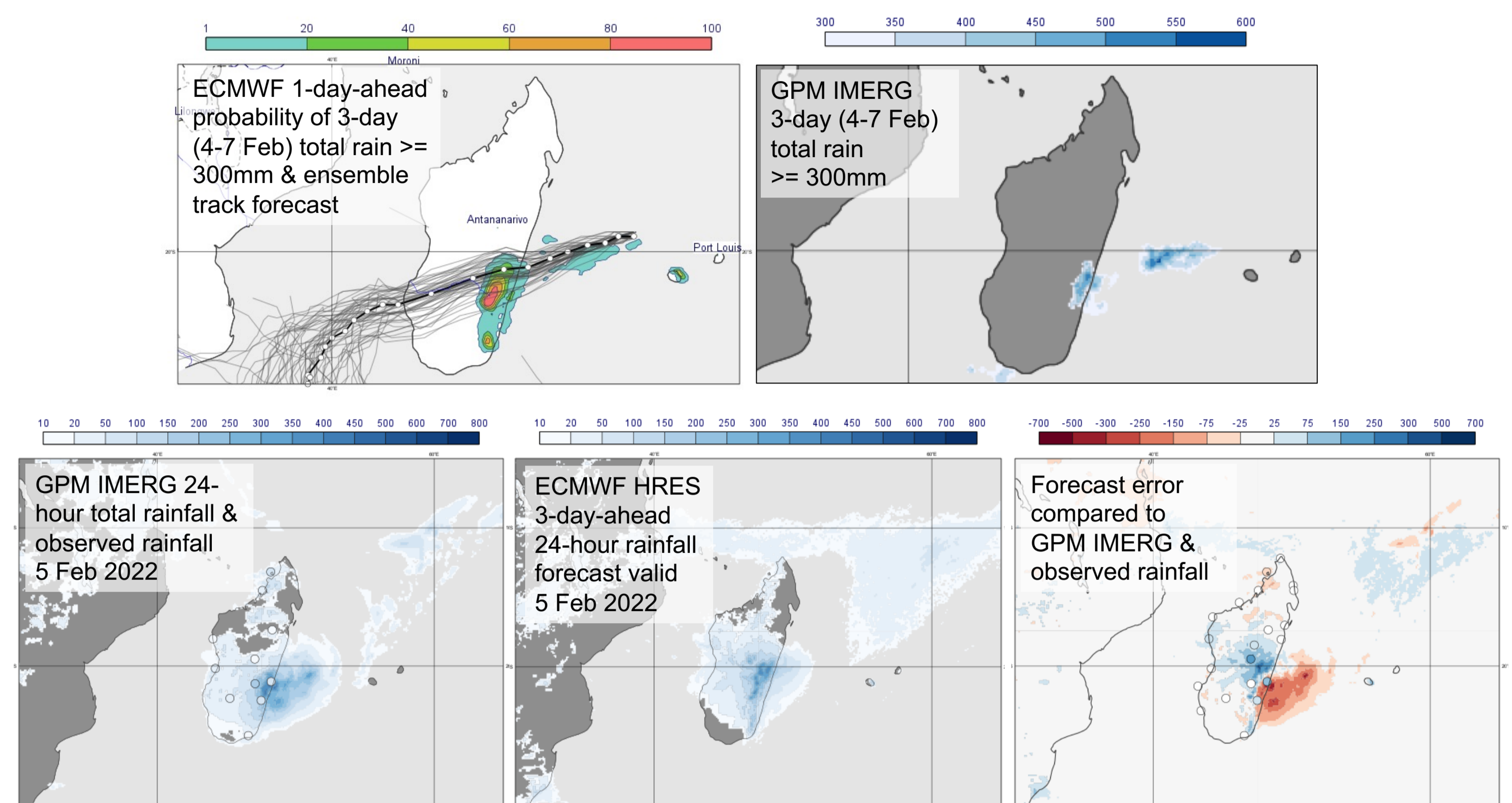


Shifting the focus for TC forecast evaluation

- Increasingly, forecast emphasis is moving towards **hazard- and impact-based forecasting**, aiming to narrow the gap between science and decision-making for early action based on forecast information
- Traditionally, investigation of tropical cyclone (TC) predictability and predictive skill focussed on track prediction, and moved increasingly towards intensity and other characteristics as model resolution increased
- It is imperative to also **understand the skill in forecasting TC hazards, alongside the track and intensity**: wind field, rainfall, flooding...
- For example, TC flooding relies on several factors: track, intensity, size, structure, and interaction with land & atmospheric circulation¹
- We highlight some examples of **new diagnostics being developed to better understand forecasts of TCs and their hazards**, encompassing the full chain of forecasts; track → flooding



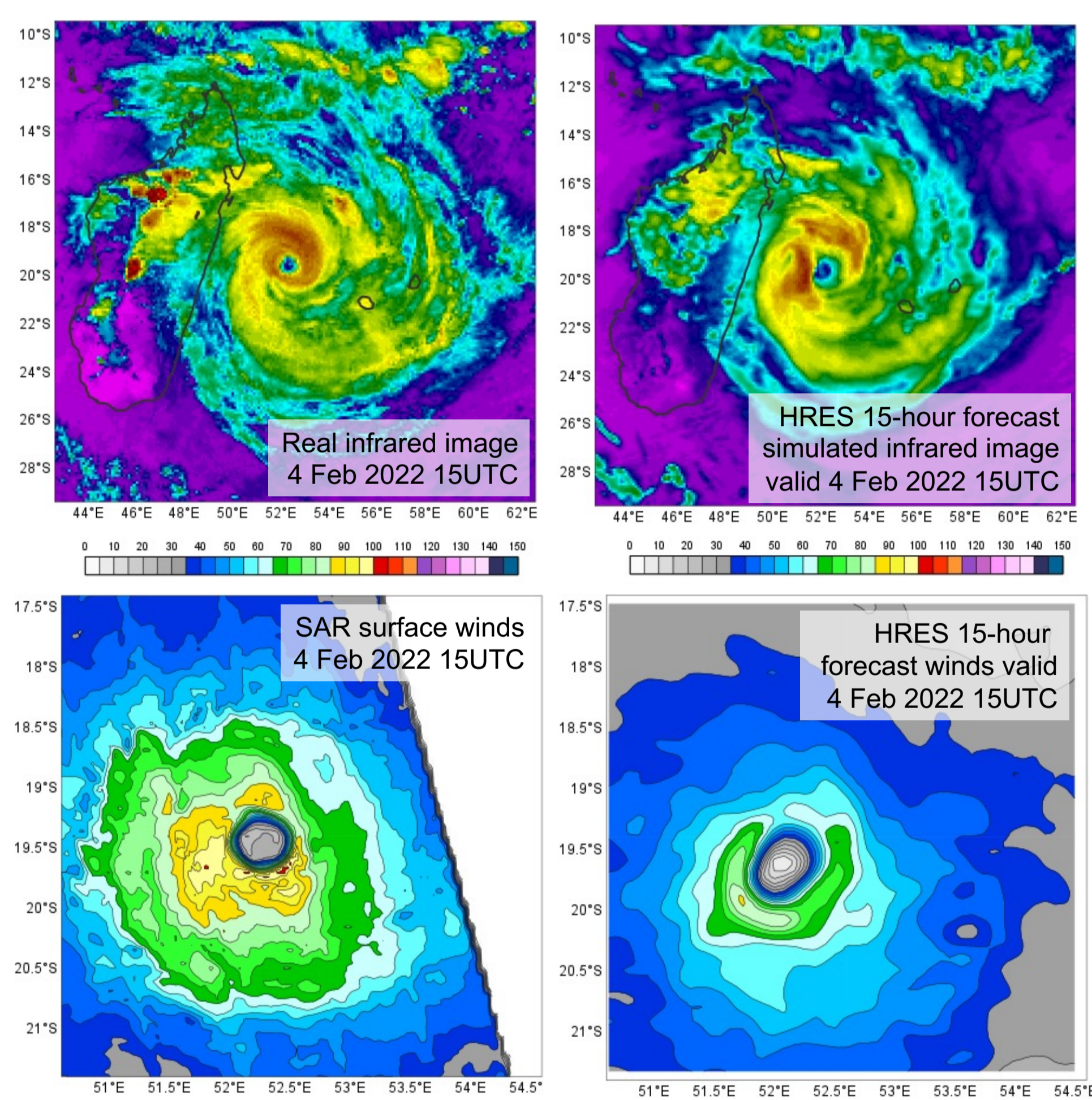
Tropical Cyclone Rainfall Prediction



Evaluating ECMWF high resolution & ensemble rainfall forecasts for tropical cyclones, using several datasets: ERA5, GPM IMERG, obs^{2,4}

- Examples shown for Cyclone Batsirai, Madagascar, February 2022
- Routine evaluation of TC rainfall forecasts is uncommon, but these forecasts are key for decision-making and disaster risk reduction efforts
- Rainfall forecasts are heavily influenced by the track forecasts, and the translation speed (over-estimation in the north-west, under-estimation in the south-east above)
- Previous work has evaluated the full chain of forecasts for tropical cyclones Idai and Kenneth (Mozambique, 2019) – from track to rainfall to flooding²
- Future work should include continued assessment of rainfall forecasts for individual TCs, and evaluate & diagnose systematic errors in TC rainfall forecasts in all basins

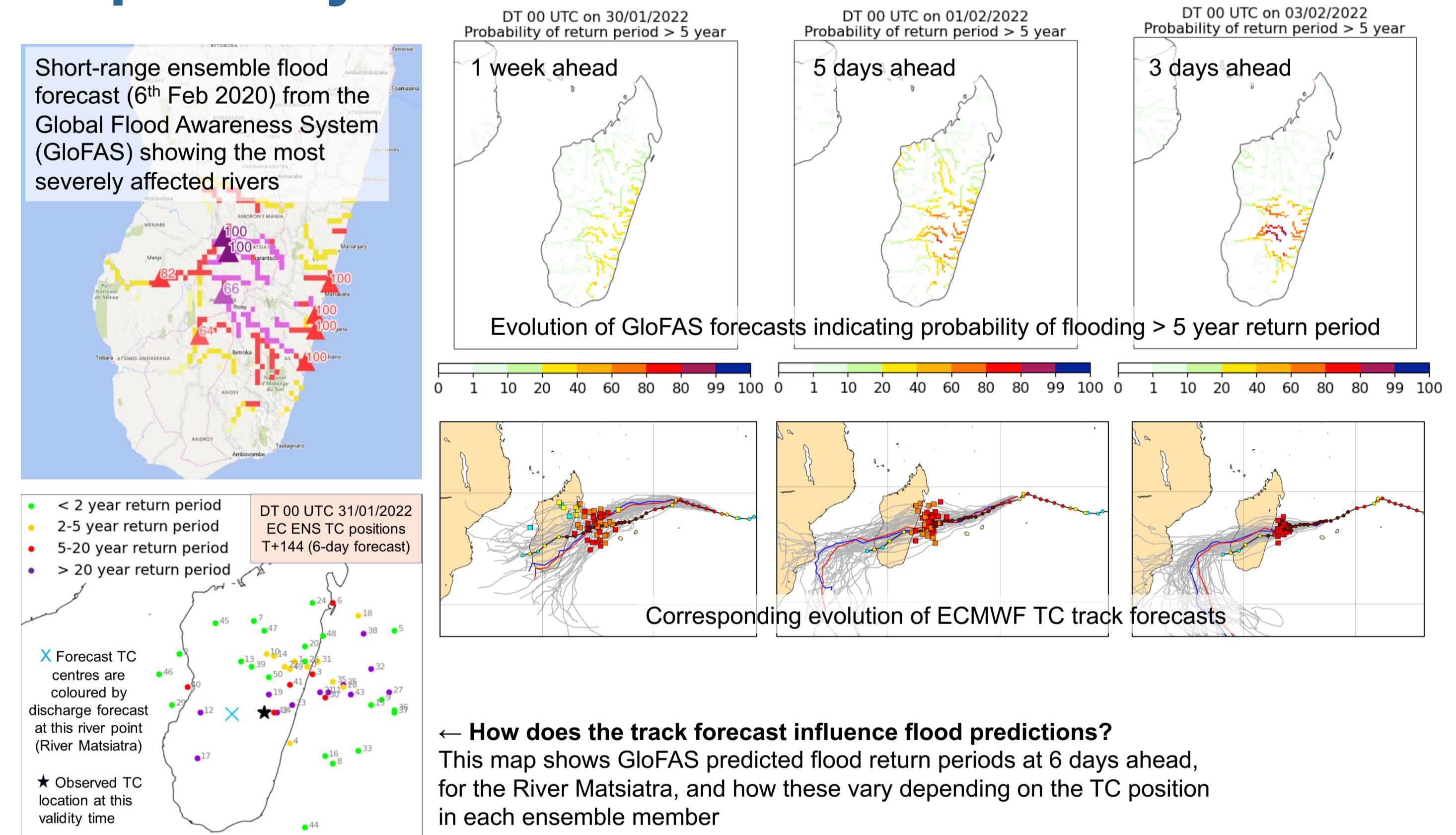
Tropical Cyclone Structure & Wind Field



Diagnosing TC structure and winds by comparing forecast wind fields & simulated infrared images with satellite satellite imagery^{3,4}

- Example shown for Cyclone Batsirai, ahead of landfall in Madagascar (4 February 2022)
- Meteosat-8 Infrared images (top left); Sentinel-1 SAR surface winds (bottom left)
- Forecast data from ECMWF's high resolution (HRES) 15-hour forecasts (right)

Tropical Cyclone Flood Prediction

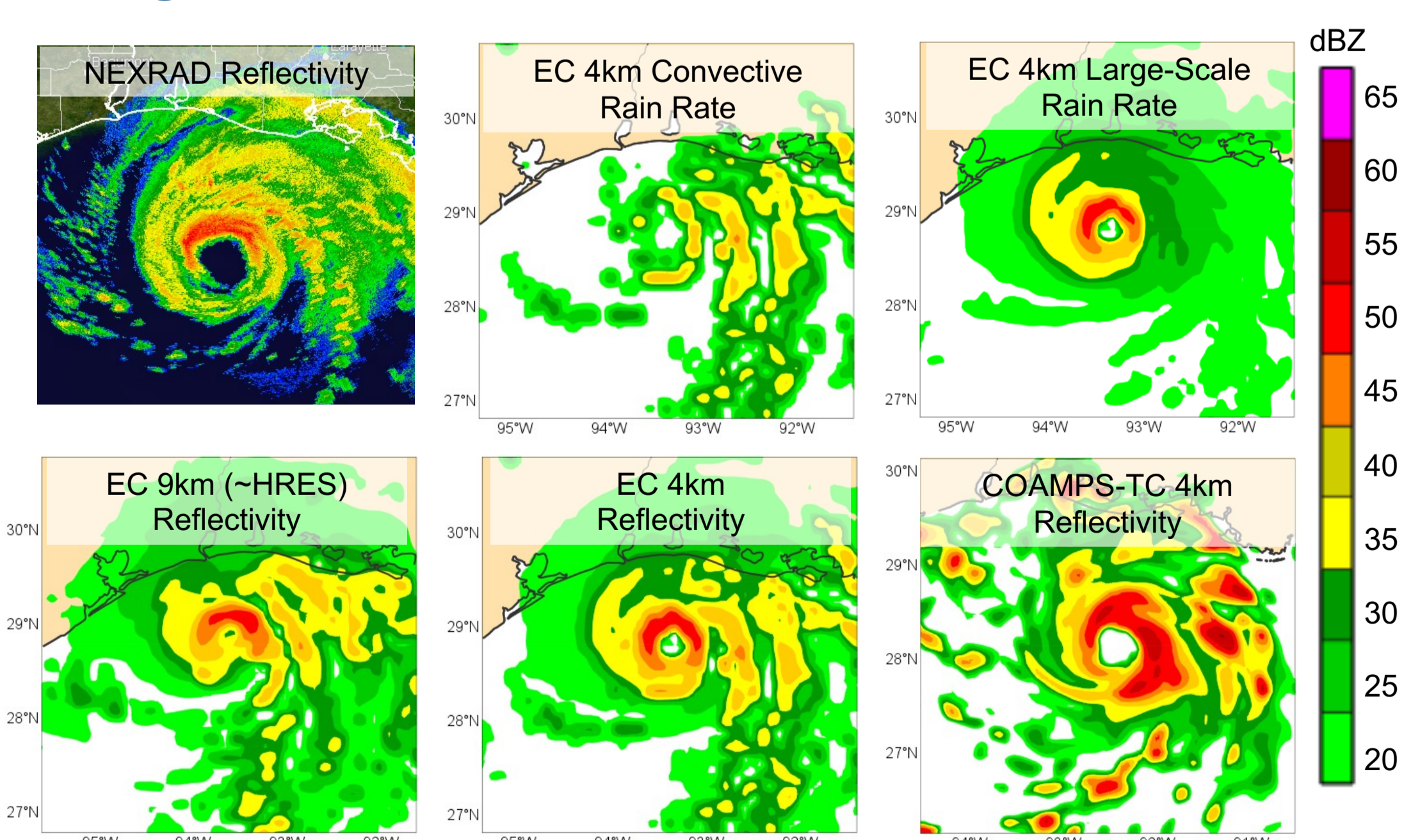


← How does the track forecast influence flood predictions? This map shows GloFAS predicted flood return periods at 6 days ahead, for the River Matsiatra, and how these vary depending on the TC position in each ensemble member

Diagnosing TC flood forecasts from the Global Flood Awareness System^{1,4}

- Examples shown for Cyclone Batsirai, Madagascar, February 2022
- GloFAS, the Global Flood Awareness System, is a Copernicus Emergency Management Service providing openly available 30-day ensemble flood forecasts & seasonal river flow outlooks for rivers worldwide, using ECMWF forecasts as input to a hydrological model (www.globalfloods.eu)
- Flooding is a major TC hazard; impacts can extend far inland and last long after landfall
- Location of track and rainfall important – too far north/south and the rain is falling on the wrong catchment and highlighting the wrong rivers to be at risk of flooding
- Ensemble forecast members can be tracked through the forecast process to evaluate the key controls on flood predictability e.g. diagnostic map (above left) for the River Matsiatra. This work adds a new hydrological perspective to the traditional methods of verifying ensemble TC forecast performance.

Tropical Cyclone Structure & Rain Rates



Using simulated radar reflectivity and forecast rain rates to investigate TC structure and intensity at different model resolutions^{3,4}

- Example shown for Hurricane Laura, ahead of landfall in Louisiana USA (August 2020)
- NEXRAD observed radar reflectivity (top left) (higher reflectivity = stronger rain rate)
- Bottom maps show **simulated radar reflectivity at 60 hours ahead** from ECMWF's HRES 9km forecast experiments (left), a 4km experimental version of ECMWF's forecasts (centre), and the US Naval Research Laboratory's 4km COAMPS-TC model
- Top centre and right maps indicate the proportion of the total rainfall in the model coming from the convection scheme (centre) and the large-scale cloud scheme (right)

Further Reading

- Titley, H. A., et al. (2021). **Key factors influencing the severity of fluvial flood hazard from tropical cyclones**. Journal of Hydrometeorology, 1(aop). <https://doi.org/10.1175/JHM-D-20-0250.1>
- Emerton, R. et al., (2020). **Emergency flood bulletins for Cyclones Idai and Kenneth: A critical evaluation of the use of global flood forecasts for international humanitarian preparedness and response**. International Journal of Disaster Risk Reduction, 50, 101811. <https://doi.org/10.1016/j.ijdrr.2020.101811>
- Majumdar, S. J., et al., (2022): **Advanced tropical cyclone prediction using the experimental global ECMWF and operational regional COAMPS-TC systems**. Monthly Weather Review, Under Review
- Magnusson, L. et al. (2021): **Tropical Cyclone Activities at ECMWF**, ECMWF Tech Memo, 888, DOI: <https://doi.org/10.21957/zxxzzygyvw>
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- WMO HIWeather Project: <http://hiweather.net/Lists/130.html>