



Representation of equatorial waves in state-of-the-art data-driven weather prediction models

Jasmin Haupt¹, Hyunju Jung¹, Marie Müller¹, Steffen Tietsche³, Tobias Selz¹, Peter Knippertz¹, and Julian Quinting²

¹Karlsruhe Institute of Technology, Institute of Meteorology and Climate Research, Karlsruhe, Germany
(jasmin.haupt@kit.edu)

²Institute of Geophysics and Meteorology, University of Cologne, Cologne, Germany

³European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom

Equatorial waves are a key process in shaping tropical weather and have been linked to tropical-extratropical teleconnections. Besides, they are one of the reasons for the higher predictability limit in the tropics compared to the extratropics. Yet, their correct representation in weather prediction models is a long-standing challenge, even at model resolutions on the km-scale, leaving substantial potential in global weather predictions unused.

In this study, we systematically quantify and compare the representation of equatorial waves in 10-day forecasts of operational deterministic state-of-the-art weather prediction models (numerical, hybrid, and data-driven). The forecast data initialized from 01 January 2020 to 16 December 2020 are provided by WeatherBench2 and dedicated experiments with AIFS from the European Centre for Medium-Range Weather Forecasts (ECMWF). Equatorial Kelvin, Rossby, and westward-moving mixed Rossby-Gravity waves have been identified based on 850-hPa winds and geopotential height using the approach of Yang et al. (2003). The filtered data-driven forecast data are evaluated against ERA5 and operational ECMWF analysis for wave amplitude and pattern correlation, and compared with the numerical weather prediction (NWP) model Integrated Forecasting System (IFS) from ECMWF.

The key finding is that for the period 2020, all data-driven weather prediction models outperform the NWP-based forecasts of the IFS model in representing equatorial wave patterns beyond 3 days lead time, evaluated with the Pearson Correlation Coefficient, except for the Rossby wave mode $n=1$, which is equally well represented by all models.

For Kelvin waves, the difference in forecast skill is most remarkable with an extension of the forecast horizon in most models from 8 to 10 days. In terms of Kelvin wave activity bias, ML-models exhibit a smaller systematic error than the IFS model, which locally underestimates the Kelvin wave activity by up to 30 % when evaluated against ERA5, with the highest underestimation in the Pacific. Interestingly, the equatorial wave representation in the data-driven model Pangu-Weather depends on the initialization dataset. We currently investigate the reason for this difference by systematically comparing ML-forecasts initialized from ERA5 and operational ECMWF analysis.

