Convectively Coupled Equatorial Wave skill in the Unified Forecast System

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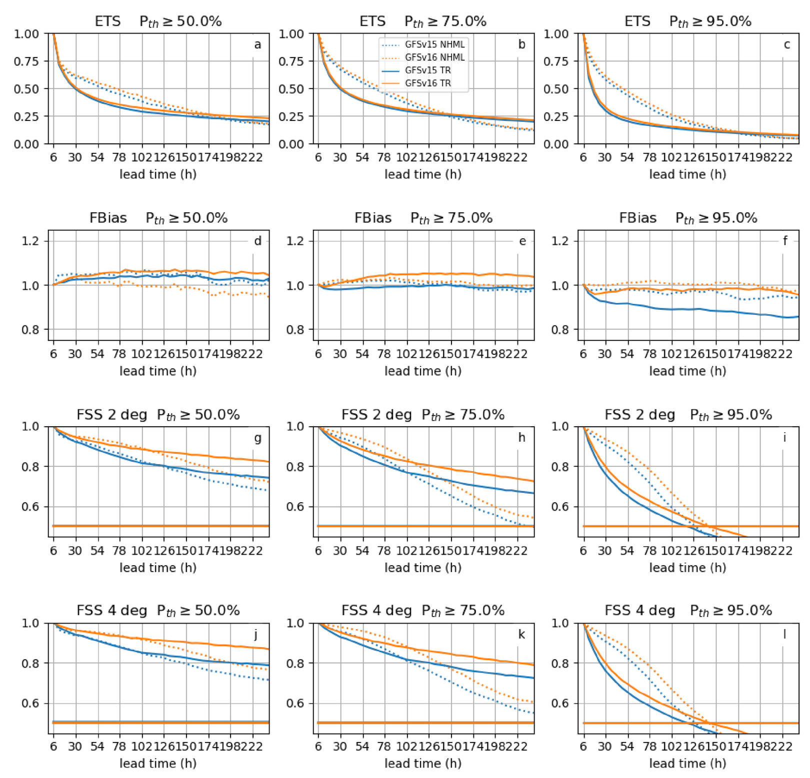
Introduction

Tropical precipitation and circulation are often coupled and span a vast spectrum of scales from a few to several thousands of kilometers and from hours to weeks. Current operational numerical weather prediction (NWP) models struggle with representing the full range of scales of tropical phenomena. Synoptic to planetary scales are of particular importance because improved skill in the representation of tropical larger scale features such as convectively coupled equatorial waves (CCEWs) have the potential of reducing forecast error propagation from the tropics to the midlatitudes.



NWP models tend to perform better in mid-latitudes than in the Tropics for lead times <4 days.
The underlying dynamics are different in the Tropics and mid-latitudes; Convection is main driver of precipitation in the Tropics and convective parameterization has a larger impact on precipitation in the Tropics.
There is evidence that better forecast skill in the Tropics can lead to improved forecasts in mid-latitudes.

Model Forecasts

Uncoupled **FV3GFS V15** operational (GFSv15) and **FV3GFS V16** parallel (GFSv16) runs initialized 6 hourly from April through October 2020 and run out to lead time 240h.

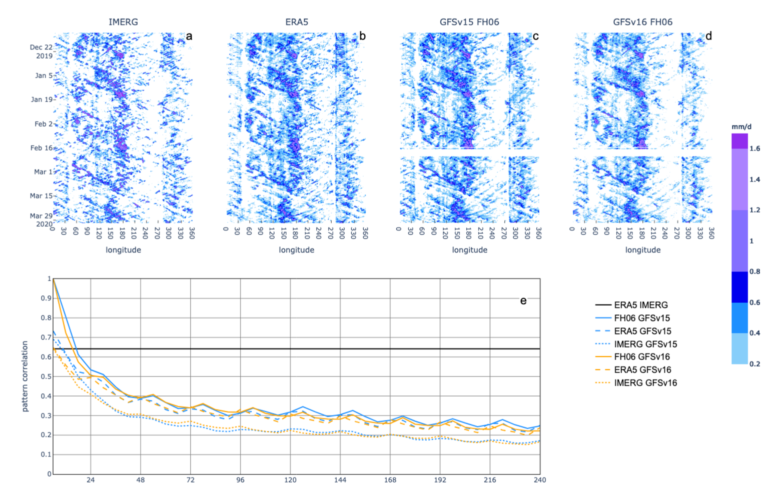
NOAA's Unified Forecast System (**UFS**) coupled prototype (P5,7,8) runs - 168 initializations, every 1st and 15th of the month between 20110401 and 20180315.

ECMWF S2S (2021 model version) (EC2021) database runs - only initializations within +-2 days of the UFS initializations.

More details on the GFS v15 and v16: `https://www.emc.ncep.noaa.gov/emc/pages/numerical_forecast_systems/gfs.php`
More details on the UFS prototypes: `https://registry.opendata.aws/noaa-ufs-s2s`
More details on the ECMFS S2S: `https://confluence.ecmwf.int/display/S2S/ECMWF+model+description`

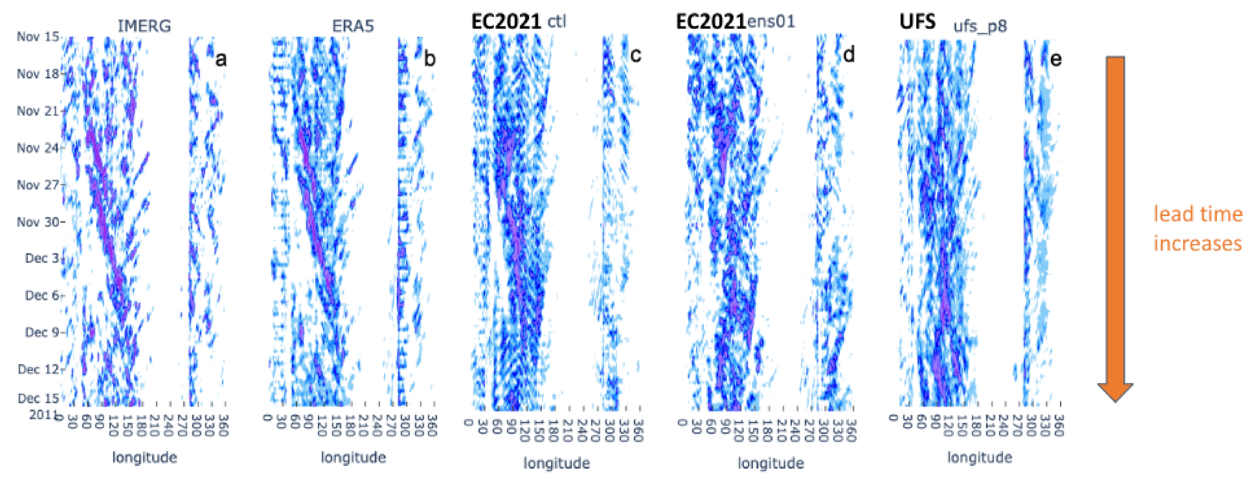
Results

Hovmoeller and Pattern Correlation



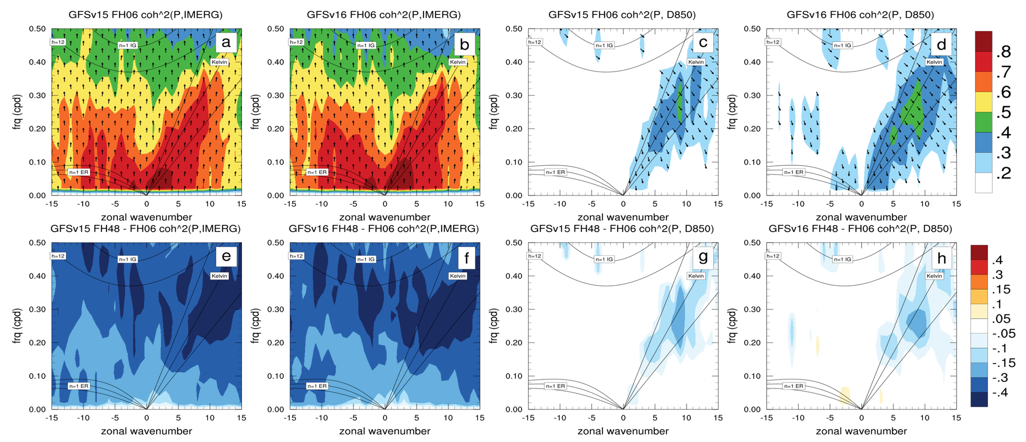
Hovmoeller diagram along a forecast for the coupled models. This forecast happens to be during the DYNAMO observing period and contains an MJO event. There is **a lot of variability among models and ensemble members**, with some showing an indication of enhanced convection during the observed MJO period and others not showing anything.

Hovmoellers are used to assess zonal propagation of precipitation features.Pattern correlation between forecast and 'truth' can be used as a skill score.
The correlation between model forecasts and verification is initially higher than the correlation between IMERG and ERA5. This indicates that the initialization and assimilation of fields relevant to precipitation are comparable or better than the reanlysis. The actual value of correlation being relatively low at 6h lead time shows that **much potential skill in precipitation forecasts is already lost during the first few hours after initialization.**



Space-time coherence spectra

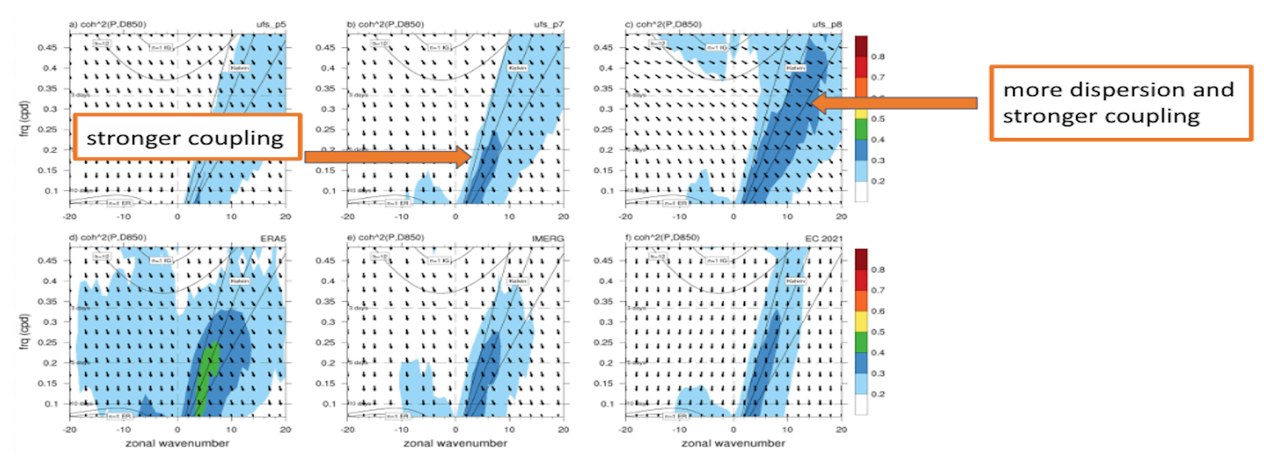
We compute space time coherence-squared spectra in zonal wavenumber and time. Regions in zonal wavenumber -frequency space where the two variables vary coherently will have higher coherence-squared values.
These spectra can be used to evaluate how well models initialize and propagate CCEWs. And they show regions of tropical variability and coupling without having to remove a background.



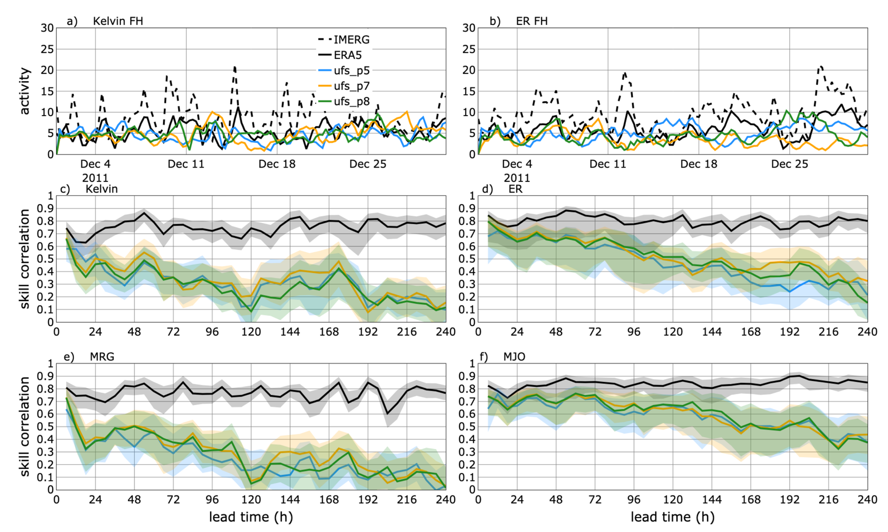
The coherence between modeled and verification precipitation initially has **larger coherence values that tend to be located near CCEW dispersion curves** and at lower frequencies and larger spatial scales. The **coherence decreases with lead time**, with larger decreases at higher frequencies/ wavenumbers. This indicates that models are either not able to initialize CCEWs at later lead times, or simply do no initialize CCEWs at the correct time.

The **strength of the coupling** between precipitation and low level divergence in the model is **weaker than observed** and decreases rapidly with lead time. Two days into the forecast the coherence-squared between model precipitation and D850hPa has decreased by about 50%. While the model is able to initialize CCEWs, it is **not able to keep the coupling strong enough to propagate the waves very far into the forecast**.

An application for the coherence spectra in model development is shown on the right. It has been shown that the EC model is too nondispersive in it's scales of coupling between low-level dynamics and convection. The **model changes made to the UFS prototypes during development** from P5 to P8 show first an **enhancement of the coupling and then an increase in the dispersion**. We also find that P8 has better precipitation variance than P7 and EC2021.



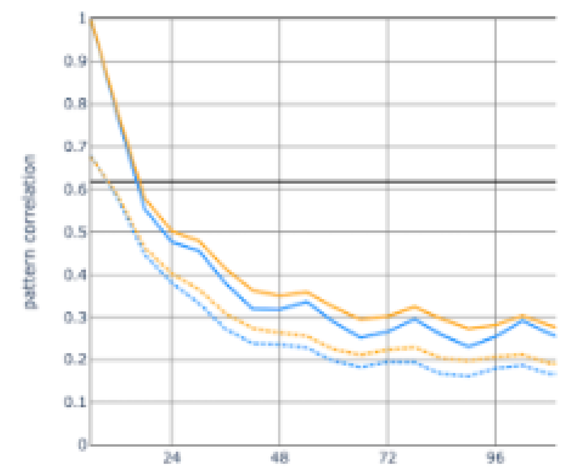
CCEW skill



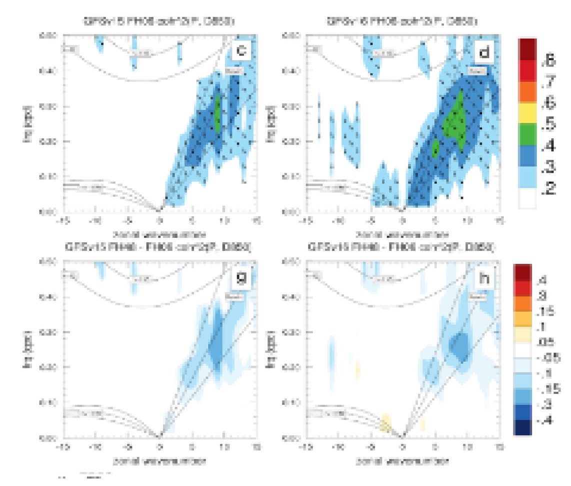
How long and how well can the model predict CCEWs?
Long time series (30+ years) of observed filtered precipitation are used to compute EOFs describing the CCEW signal. The model precipitation is then projected onto these EOF patterns at each forecast hour and a CCEW activity index is computed. The skill score is the anomaly correlation between the observed and model index.
Initial skill for MJO and ER are comparable to verification and the GFS is skillful in predicting the MJO (in this metric!) for about 5 days. Comparing UFS prototype to the EC skill for Kelvin waves, the EC is able to stay skillful for a few extra hours compared to the UFS. For ERs and the MJO, the UFS has skillful forecasts for much longer lead times.

Summary

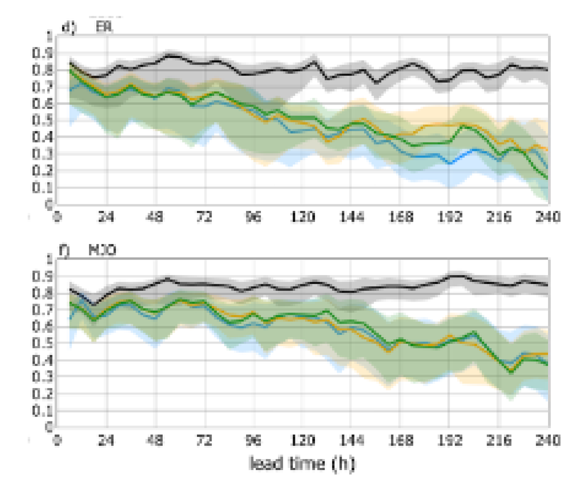
Here we consider skill metrics for tropical convection and in particular for CCEWs. We use these metrics to evaluate the UFS coupled prototype tropical variability compared to observations and ECMWF S2S model forecasts.



Much precipitation skill is lost in the hours immediately following initialization.



Coupling between convection and the circulation is improved (in terms of scales and strength) in the UFS coupled prototypes, but decreases rapidly with lead time.



The UFS coupled prototypes show skill at longer lead times for ERs and the MJO in a precipitation based metric.

Further investigation of the ER/ MJO skill in the UFS is currently underway.

A stand-alone python **GitHub** repository for these diagnostics (and more) exists (`https://github.com/NOAA-PSL/tropical_diagnostics`) and a release is public for testing.

METplus

Several of these diagnostics were included in the November beta release of METplotpy and METcalcpy of METplus. A recording of the presentation on METplus Use Cases for UFS P5 and P7 output can be found here `https://dtcenter.org/events/2022/2022-dtc-metplus-workshop/agenda-recordings`

Gehne M., B. Wolding, J. Dias and G. N. Kiladis (2022). Diagnostics of Tropical Variability for Numerical Weather Forecasts, Weather and Forecasting (`https://doi.org/10.1175/WAF-D-21-0204.1`)