Impact of stochastic physics in coupled simulations of the UFS and CESM

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Introduction

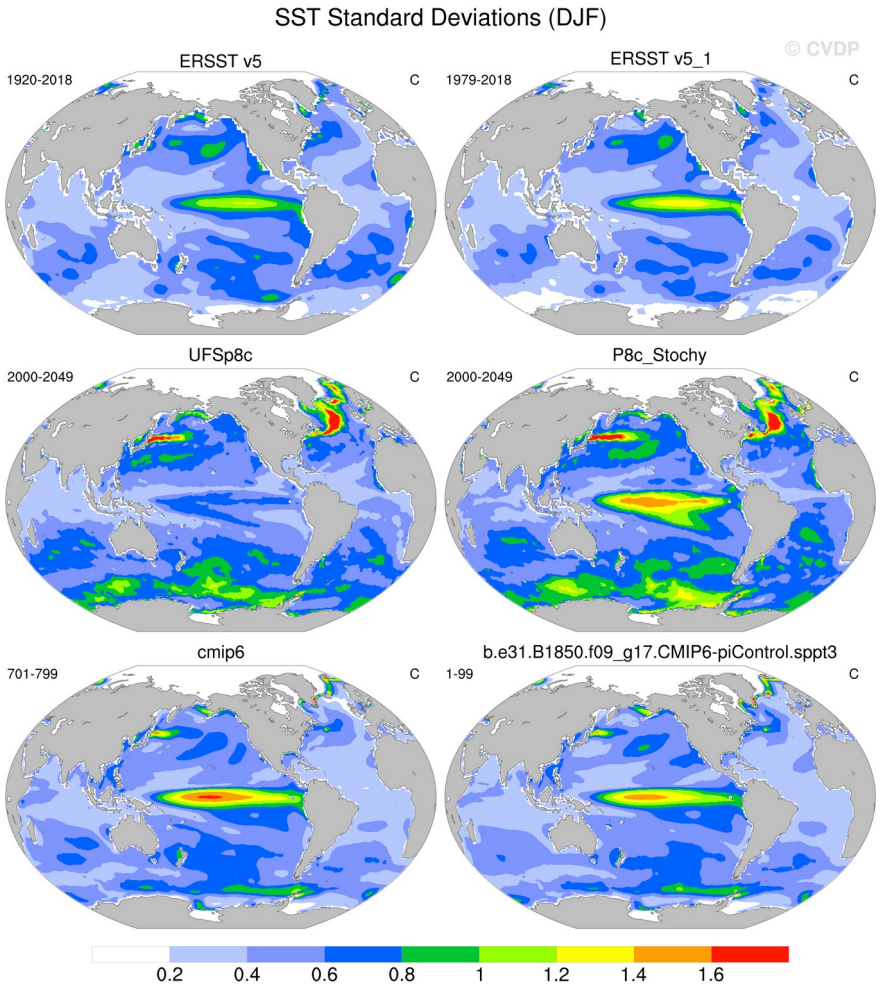
- The weather program office funded a project to study the **Benefits of Stochastic Parameterization on the Sub-Seasonal to Seasonal Timescale in Hindcasts with CESM and UFS**
- The goal of the project is to compare the impacts stochastic physics has in two different modeling systems **in initialized predictions** and **long climate simulations.**
- Ran both models through the **CVDP** plotting package (https://www.cesm.ucar.edu/projects/cvdp)
- Higher frequency UFS diagnostics were processed with **MDTF-Diagnostics** package (https://www.gfdl.noaa.gov/mdtf-diagnostics/) and the **Tropical Diagnostics** python package (https://github.com/NOAA-PSL/tropical_diagnostics)

Model setup

- **UFS**
  - coupled prototype 8 tag but without waves.
  - 1-degree horizontal resolution
  - 50 year simulations
  - Historical forcing forcing for first 21 years (2000-2020) then fixed at 2020 values.
  - Stochastic suite: SPPT (Stochastically Perturbed Physics Tendency)
    SKEB (Stochastic Kinetic Energy Backscatter)

- **CESM2**
  - Coupled Global Climate model, CMIP6 control tag
  - 1 degree horizontal resolution
  - 100 years, constant preindustrial forcing
  - Stochastic suite: SPPT

Interannual Results: SST variability



Observations (historical)

Observations (satellite era)

UFS-P8

UFS-P8-stoch

CESM2

CESM2-stoch

The UFS with deterministic physics lacks tropical variability. With stochastic physics the UFS has too much tropical variability.

CESM has the opposite problem. ENSO is too strong with deterministic physics, and is a little weaker with stochastic physics.

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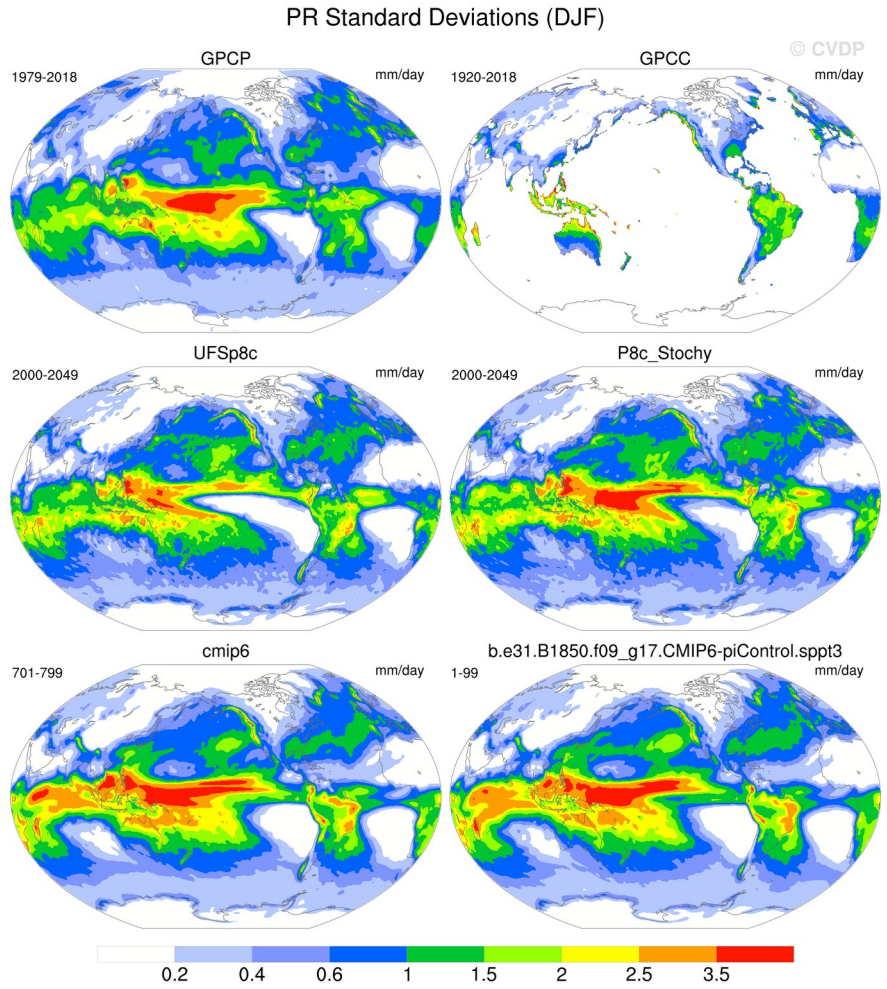
Interannual Results: Precipitation Variability



Observations (historical)

Observations (satellite era)

UFS-P8

UFS-P8-stoch

CESM2

CESM2-stoch

Stochastic physics has little impact to CESM2 on the inter-annual timescale, but a substantial impact in the UFS over the Tropical Pacific.

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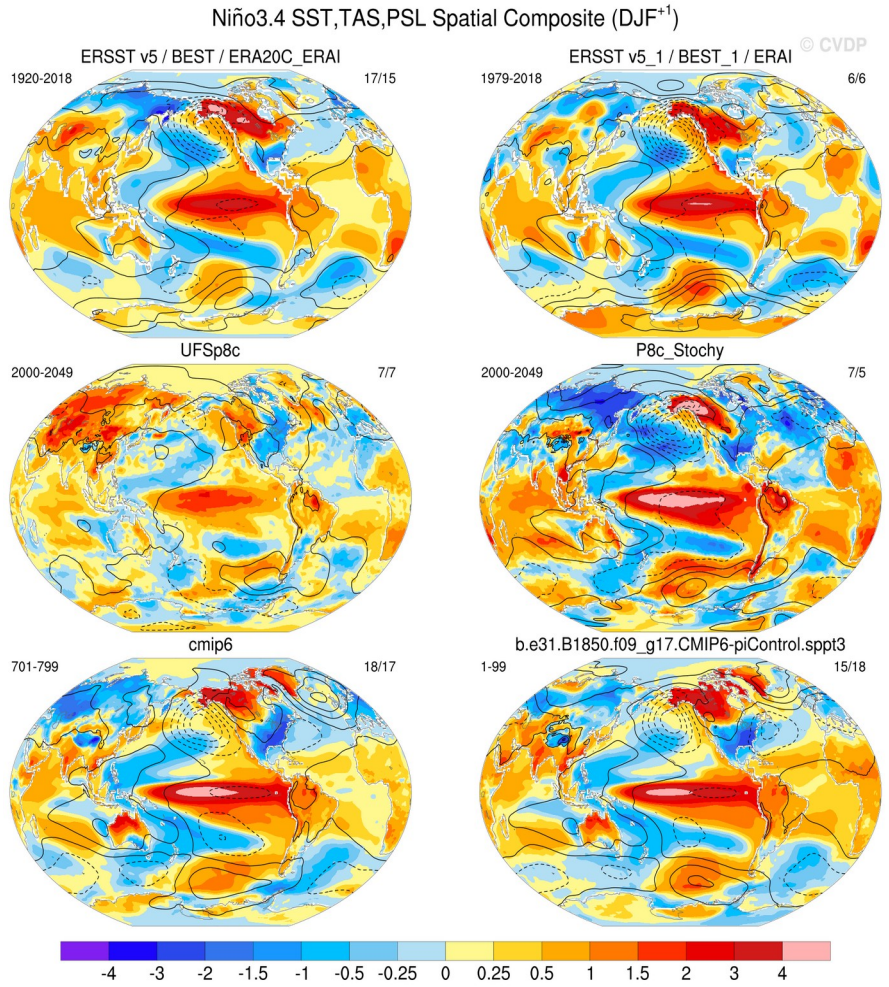
Interannual Results: ENSO and teleconnections



Observations (historical)

Observations (satellite era)

UFS-P8

UFS-P8-stoch

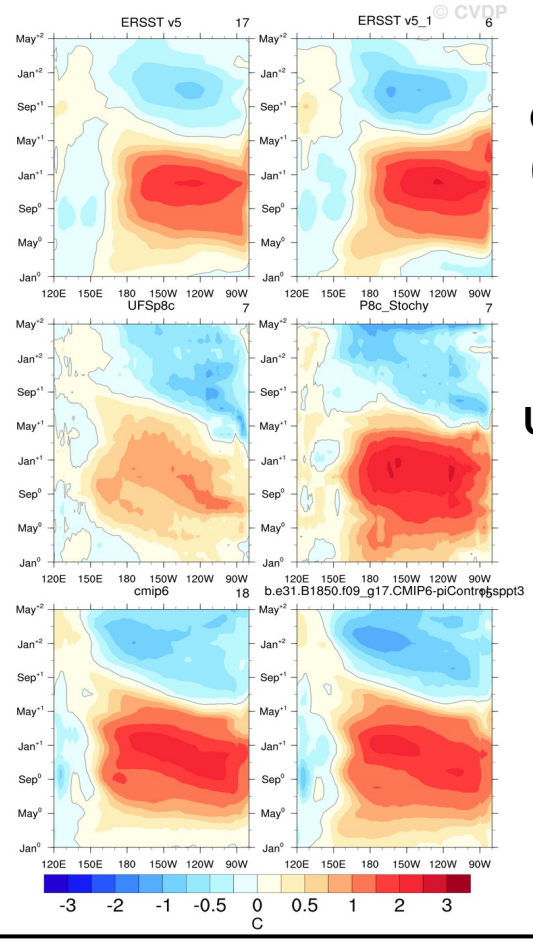
CESM2

CESM2-stoch

Stochastic physics improves ENSO teleconnections in the UFS. Both models have the strongest SST anomalies too far west, which is a common coupled model issue.

Composite ENSO Evolution

El Niño Composite (3°S:3°N)



Observations (historical)

Observations (satellite era)

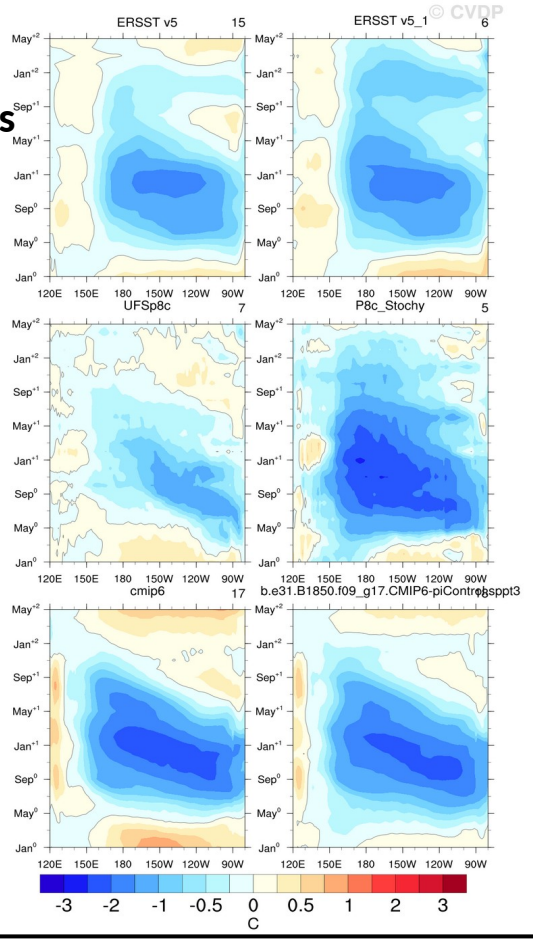
UFS-P8

UFS-P8-stoch

CESM2

CESM2-stoch

La Niña Composite (3°S:3°N)



Observations (historical)

Observations (satellite era)

UFS-P8

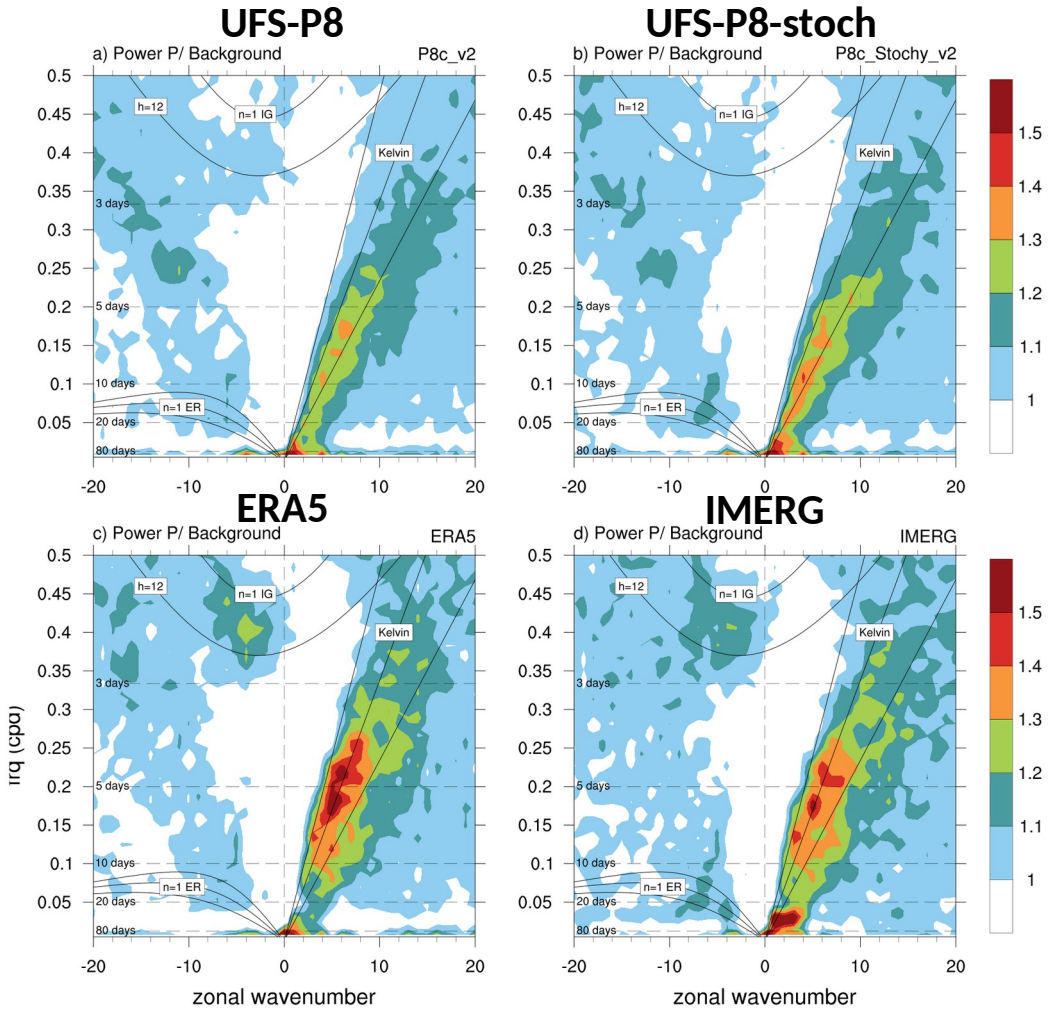
UFS-P8-stoch

CESM2

CESM2-stoch

UFS with stochastic physics exhibits too early of an ENSO onset, but shows a good decay phase, including the likelihood of a multi-year La Niña.

Subseasonal Results: Precipitation wavenumber-frequency



Stochastic Physics enhances the MJO and Kelvin wave activity although it is weaker than observations

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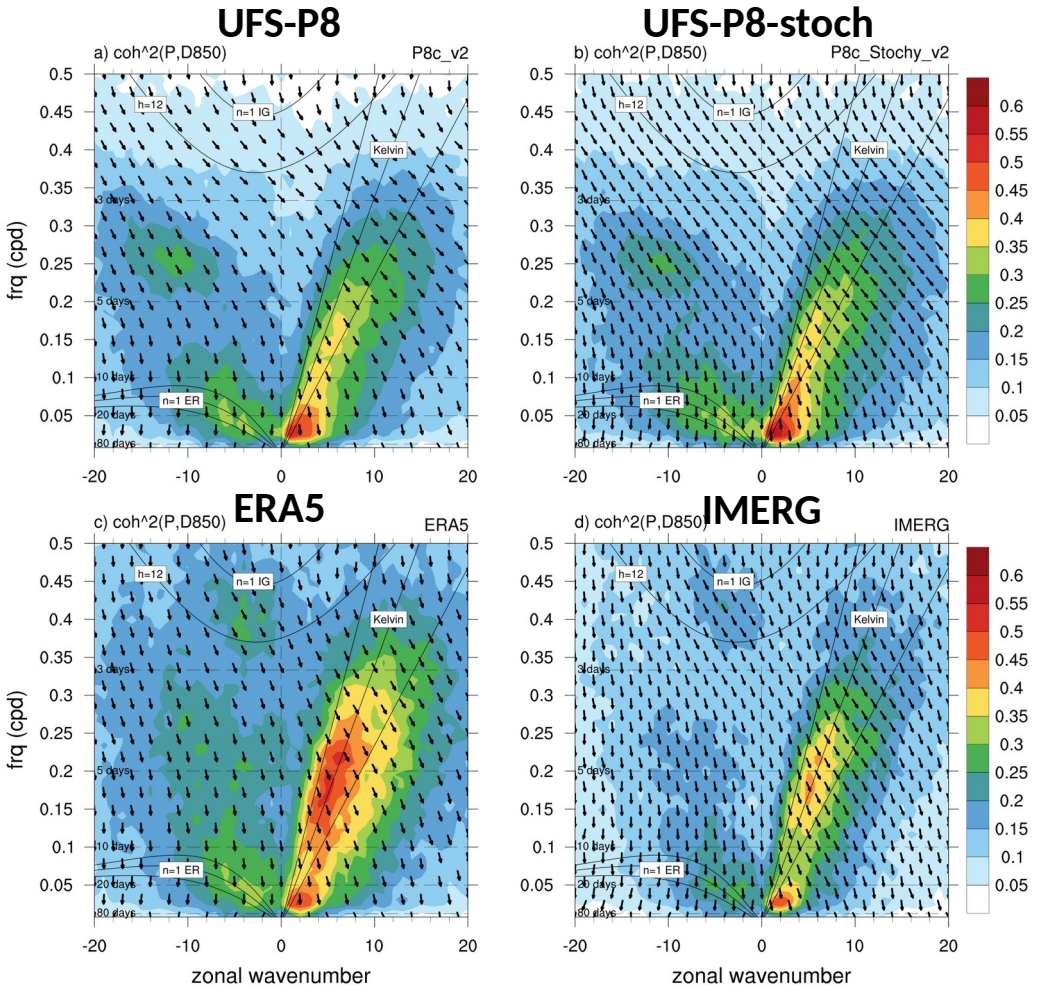
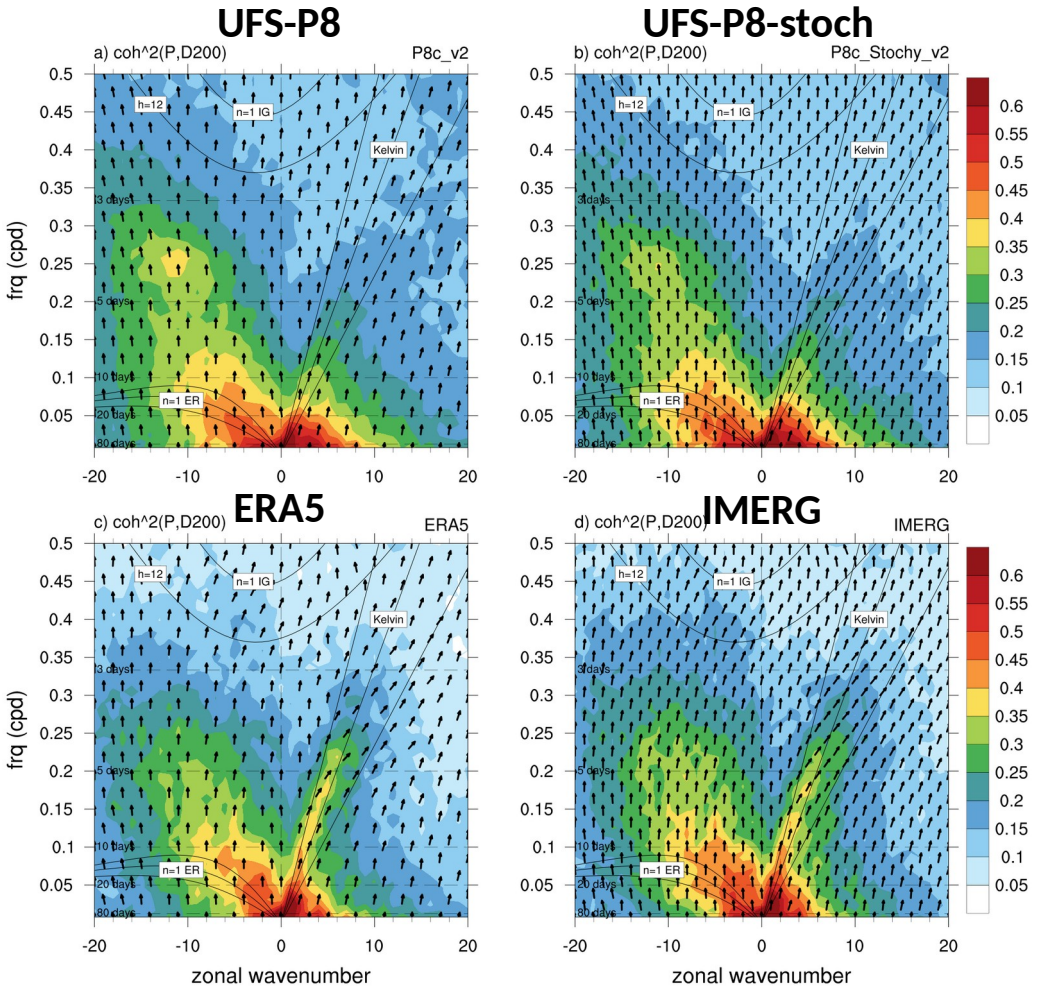
Subseasonal Results:
Coherence of Precipitation-Divergence at 850 hPa



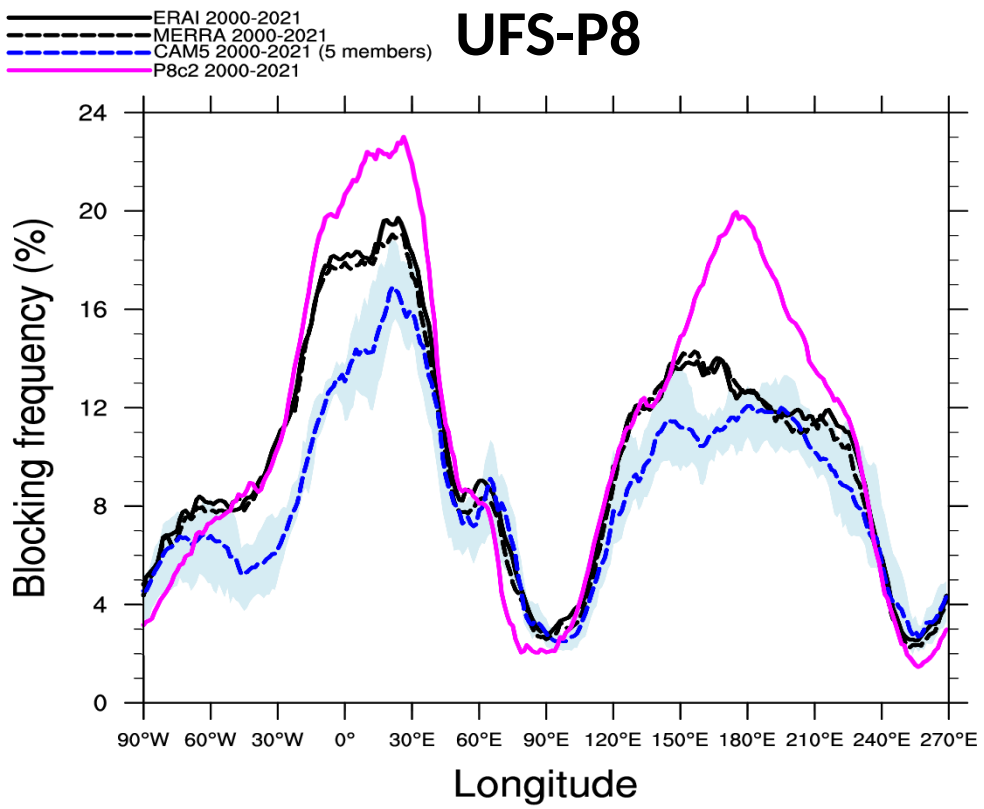
The coherence between low-level divergence and precipitation is well represented in the UFS. With the low-level convergence leading the precipitation by 1/8th of a cycle for eastward propagating waves.

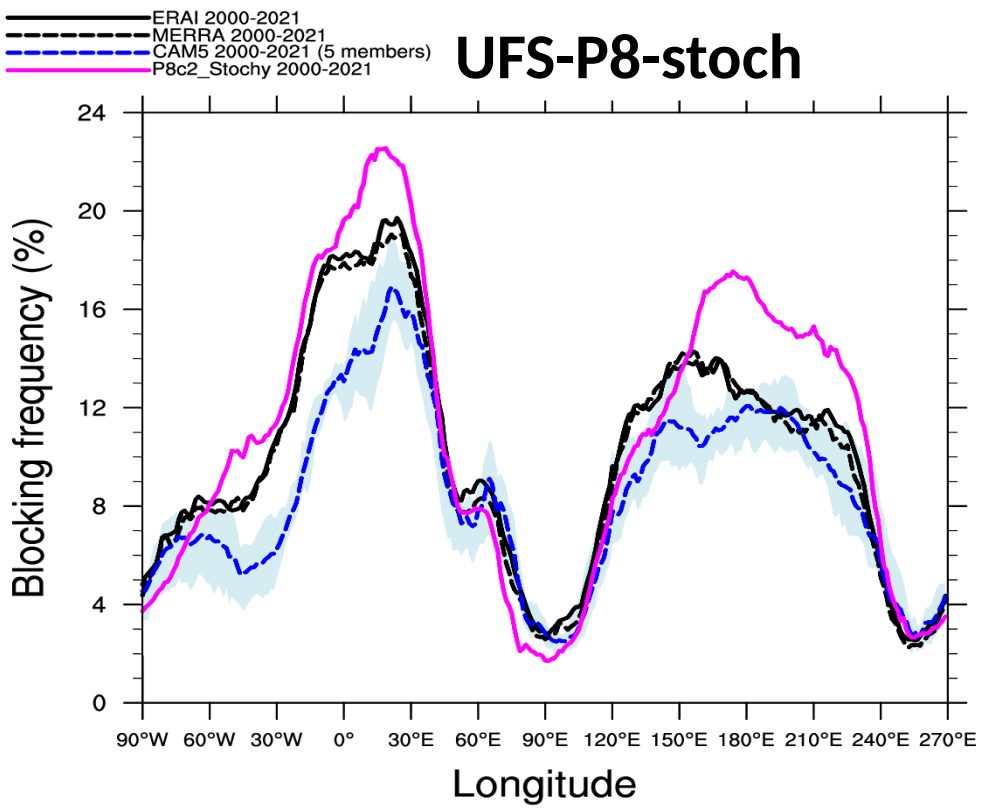
Subseasonal Results:
Coherence of Precipitation-Divergence at 200 hPa



But the upper-level divergence in response to the precipitation is weak in the kelvin wave band.

Subseasonal Results: N.H. Blocking frequency





UFS with deterministic physics had too much blocking over both the Atlantic and Pacific Sectors. Stochastic physics slightly improves the frequency over the Pacific.

Summary

- We have run a pair of 50-year UFS climate simulations that are directly compared to the NCAR's coupled climate model.
- In both models, stochastic physics improves the ENSO variability
- The primary 1-deg UFS lacks interannual variability in the tropics
- The UFS with stochastic physics exhibits a lot of good features that will enable it to be useful tool in the development of Seasonal Forecast System.