# Subseasonal Prediction over the Western U.S. (and elsewhere)

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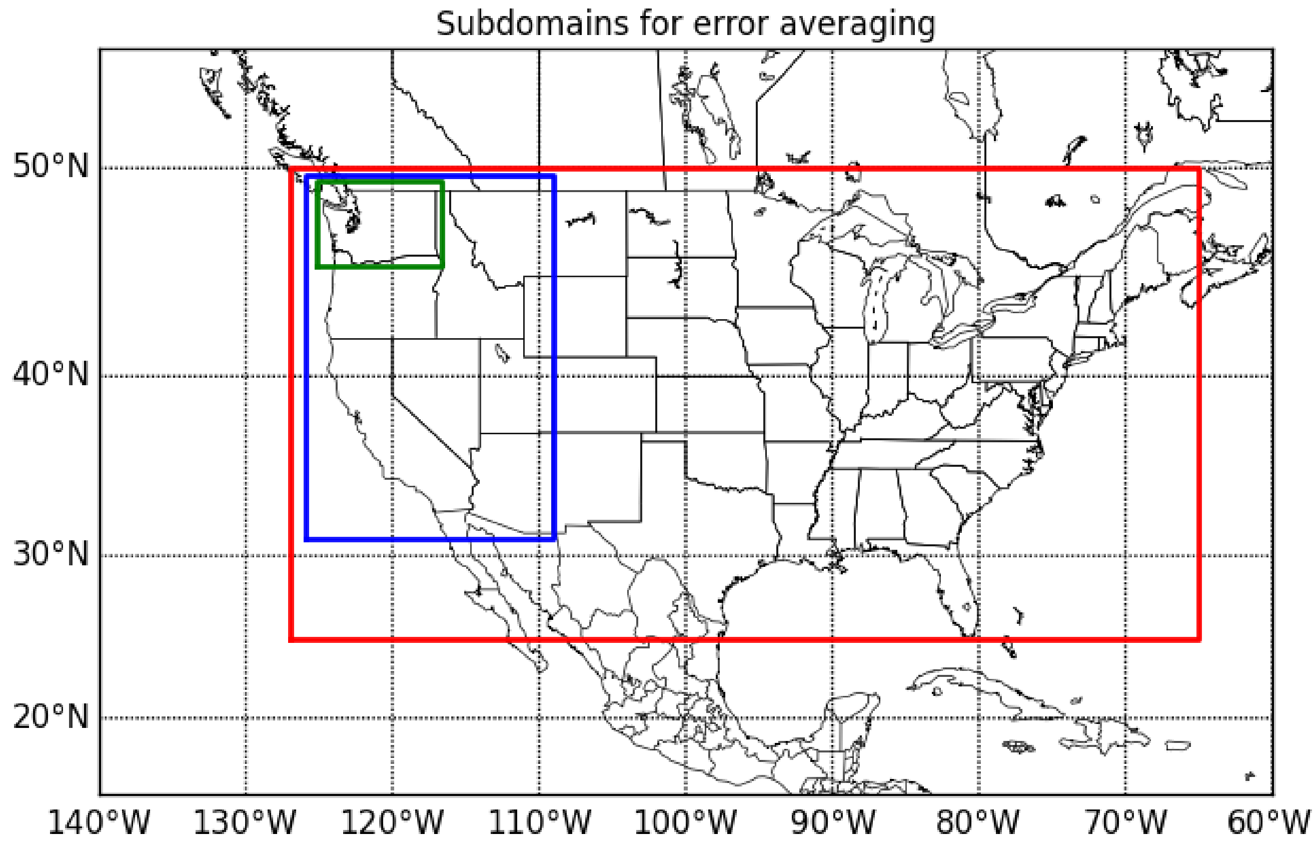
# Some Questions

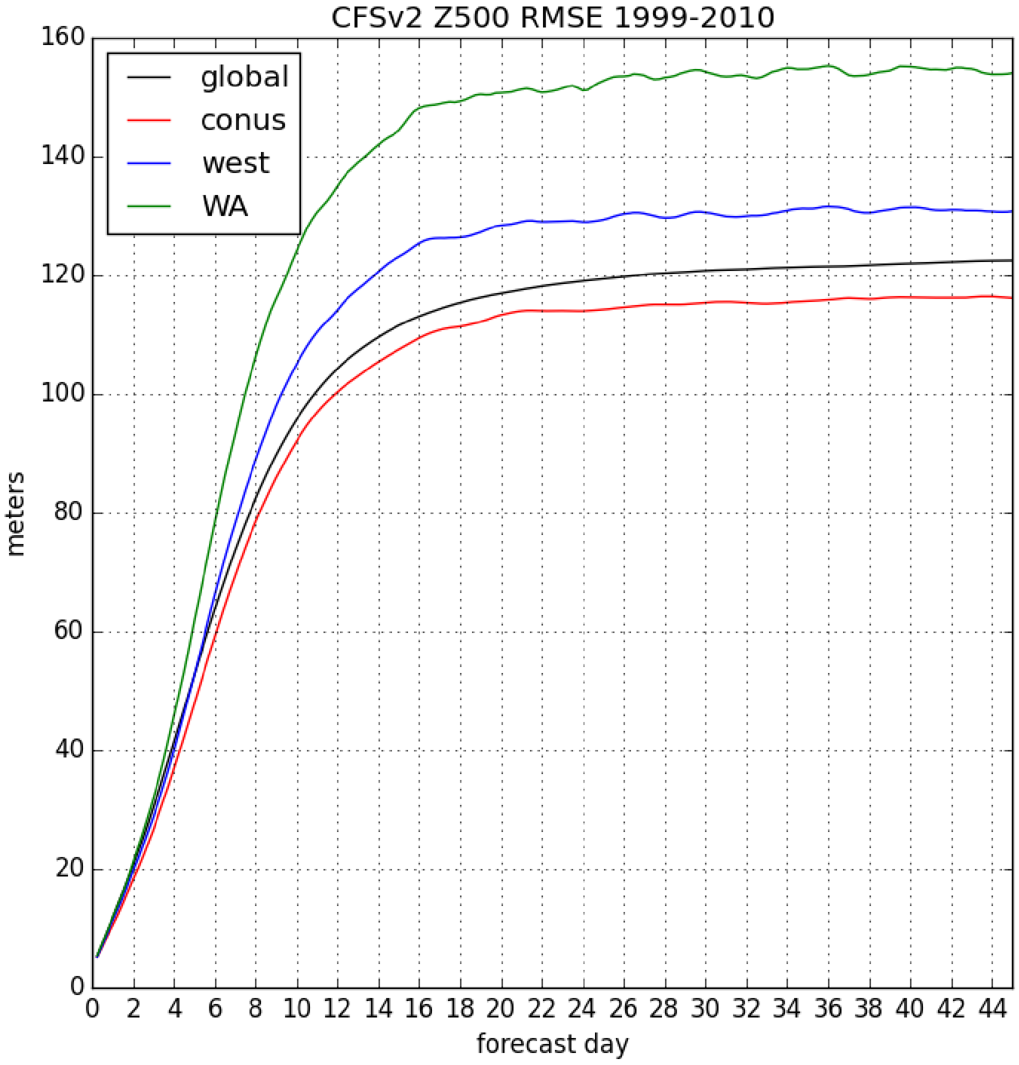
- What is the synoptic skill of the Climate Forecast System (CFS) over the West Coast (and elsewhere) for the subseasonal time range?
- How does temporal averaging affect skill?
- Is the skill good enough for high-resolution downscaling?
- Can ensemble forecast adjustment (EFA) help?
- If skill is poor, what are the failure modes and how can they be addressed by NOAA/NCEP?

# Last Year I Showed the Fade of CFS Skill over the Western U.S. over 1-3 weeks

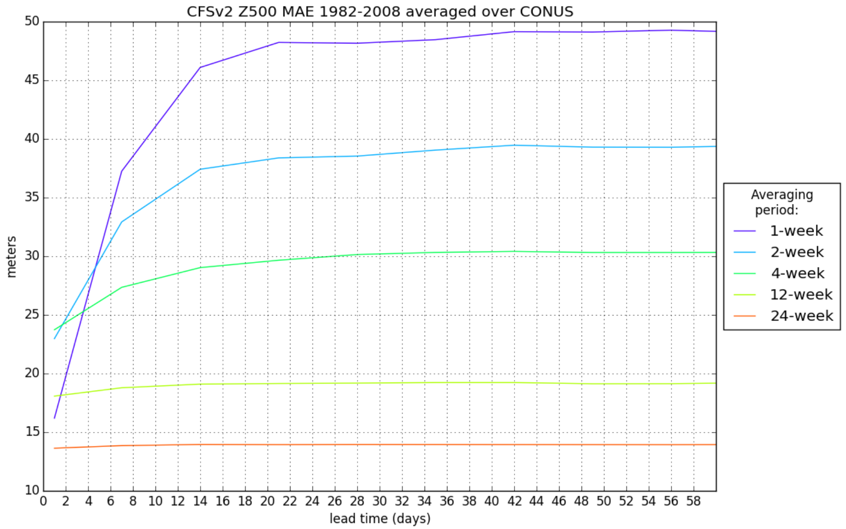

Subdomains for error averaging
50°N
40°N
30°N
20°N
140°W
130°W
120°W
110°W
100°W
90°W
80°W
70°W
60°W

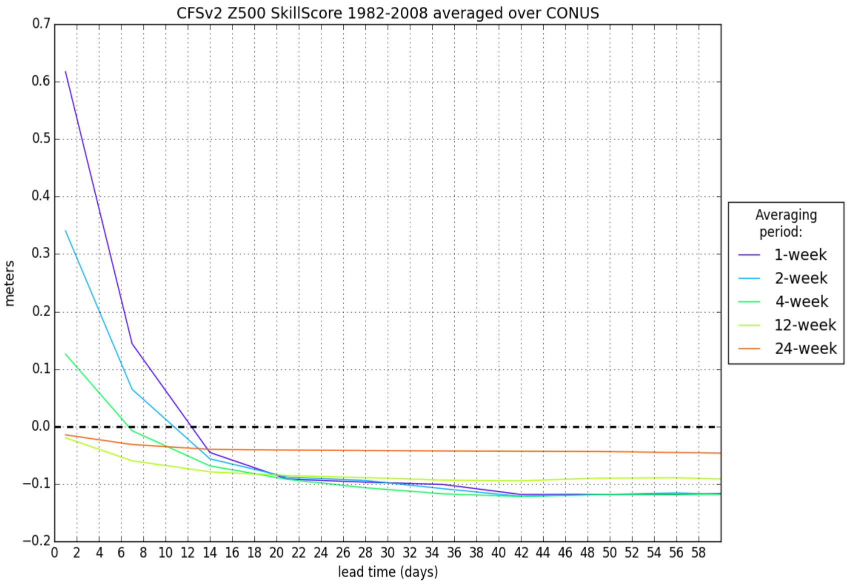
# Errors Saturate After Roughly Three Weeks

Little skill after two weeks



# 500 hPa heights (various averaging periods) for CONUS




- errors saturate at a ~2-3 week lead
- increasing the averaging period reduces the error
- little/no extension of error growth at longer averaging periods

- skill score computed with RMSE w.r.t. climatological forecast tells similar story to MAE chart

**What is the global context of the western U.S. verification scores for CFS?**

**Can we understand why CFS skill fades by 2-3 weeks even with averaging?**

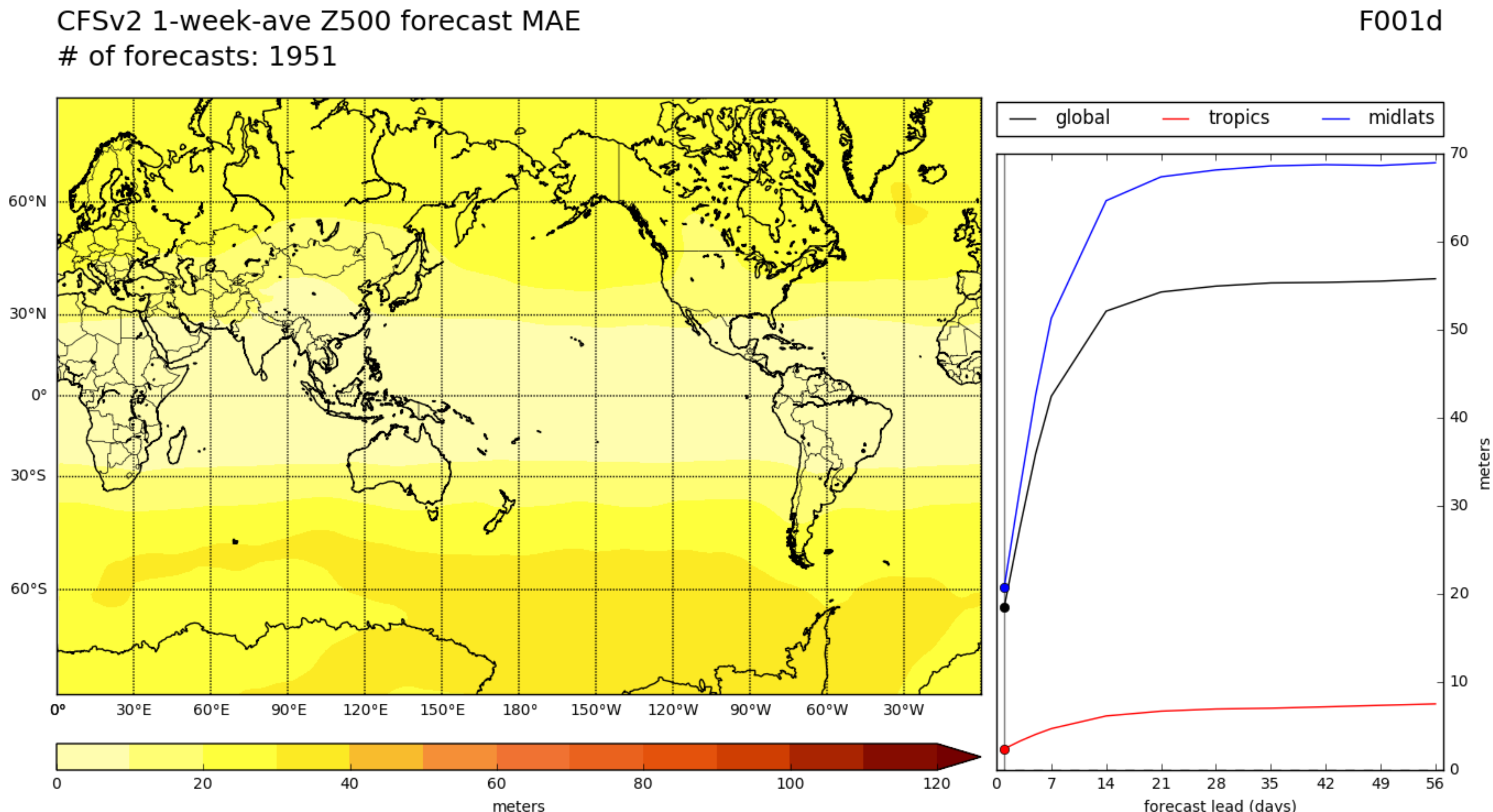
# How Far Into the Future Does CFS Have Synoptic Skill?

Will Show One-Week Averages

# CFS Synoptic Verification

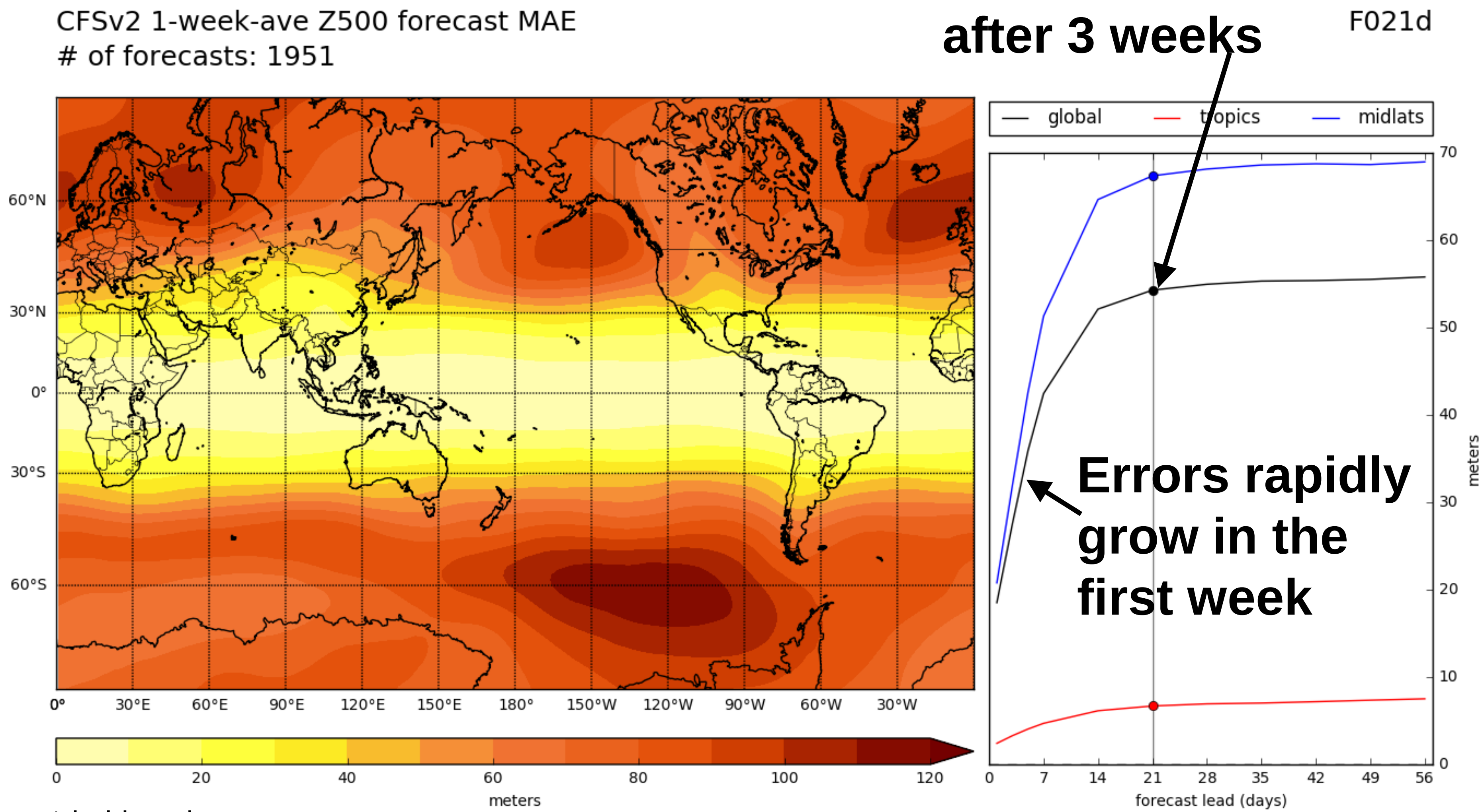
- Forecasts used
  - 4-member CFSv2 reforecast ensemble mean
  - Initialized every 5 days from 1982 through 2008
- Verification (analysis) dataset:
  - GDAS analyses
- Parameters examined:
  - 500-hPa height (Z500)
  - SST
  - 200 hPa velocity potential (CHI200)
- Averaging intervals examined
  - 1 day, 1 week (shown here), 4 week, 12 weeks

# Z500 MAE - week 1



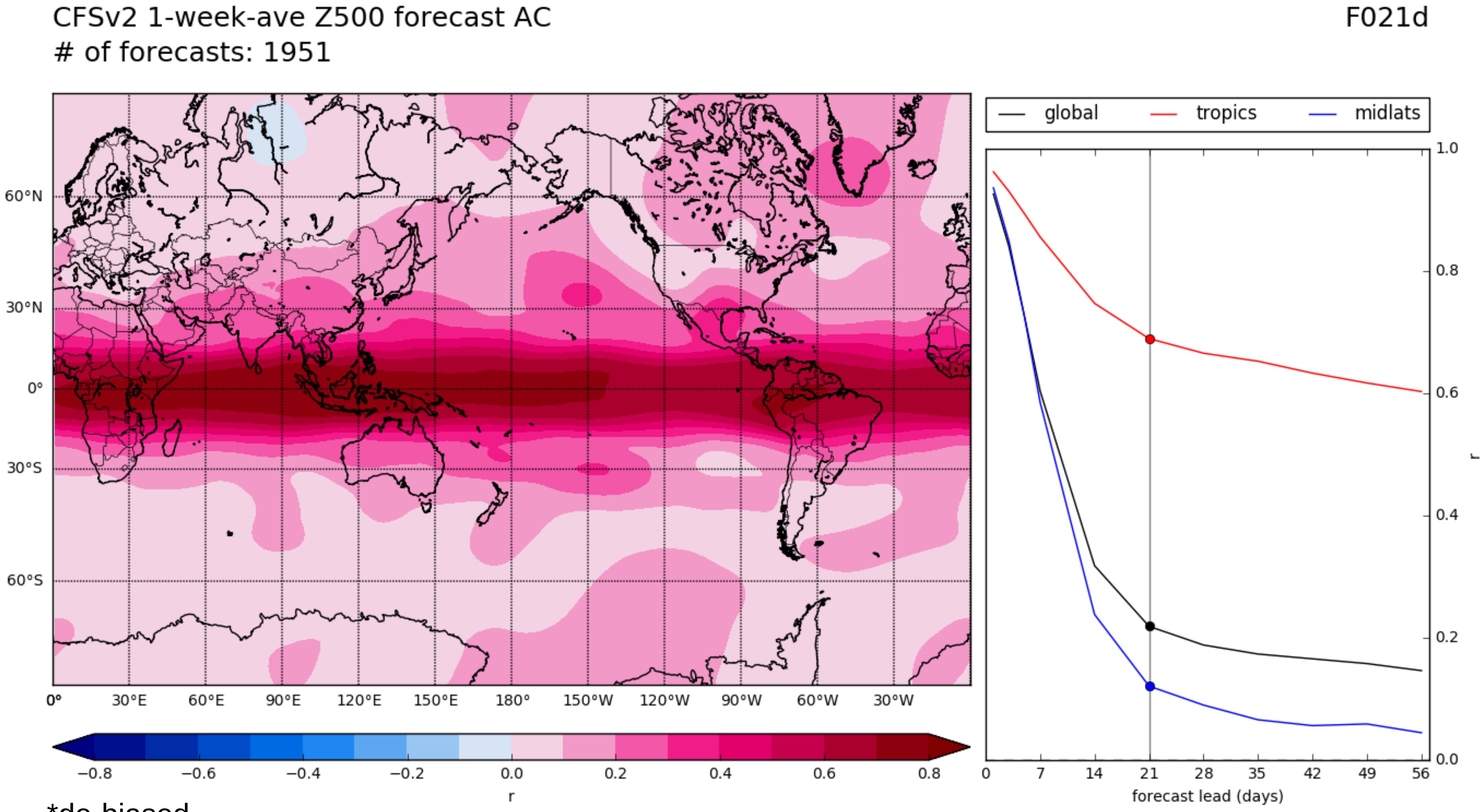

*de-biased

# Z500 MAE - week 4




*de-biased

# Z500 AC - week 4

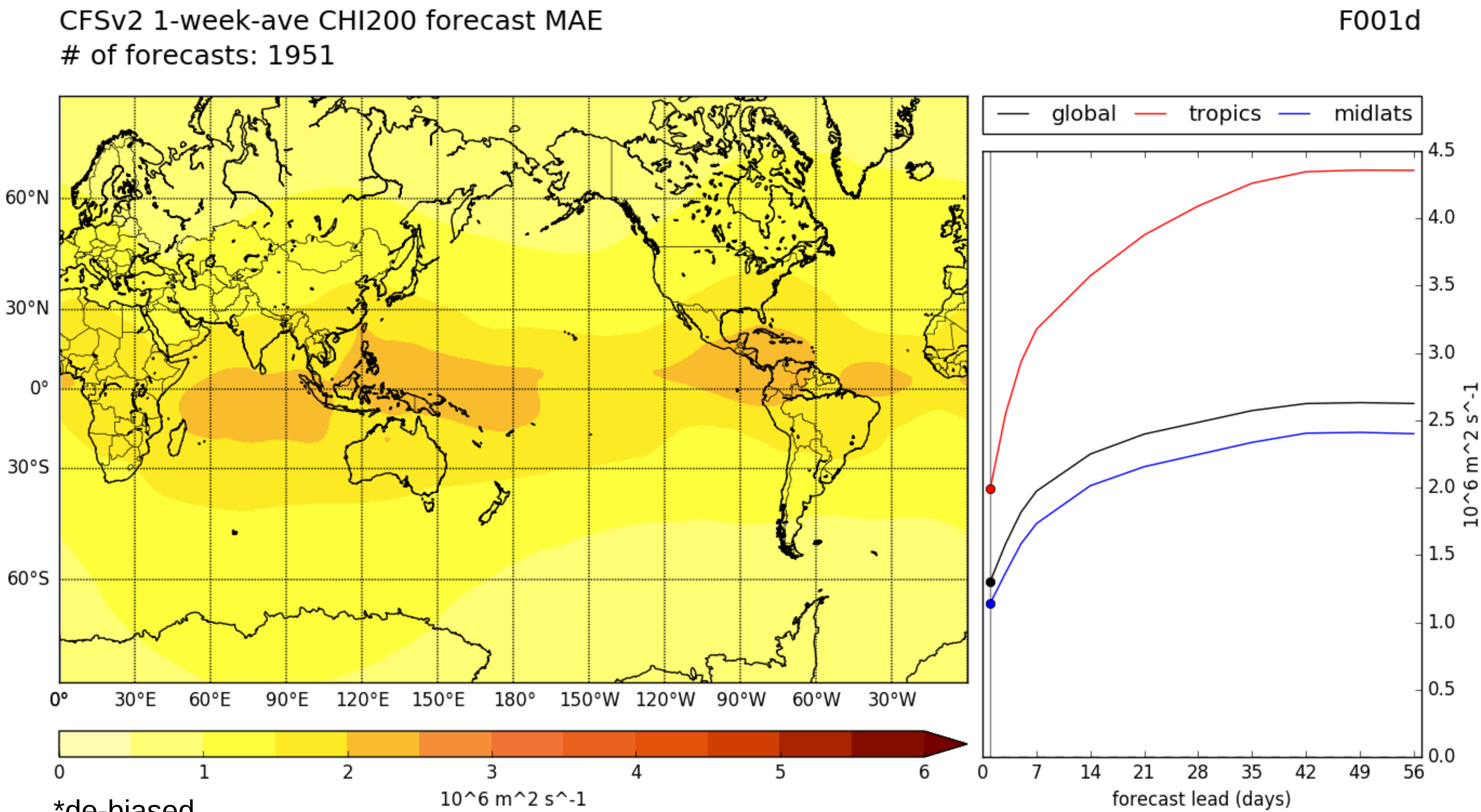



*de-biased

# 200 hPa Velocity Potential: CHI200

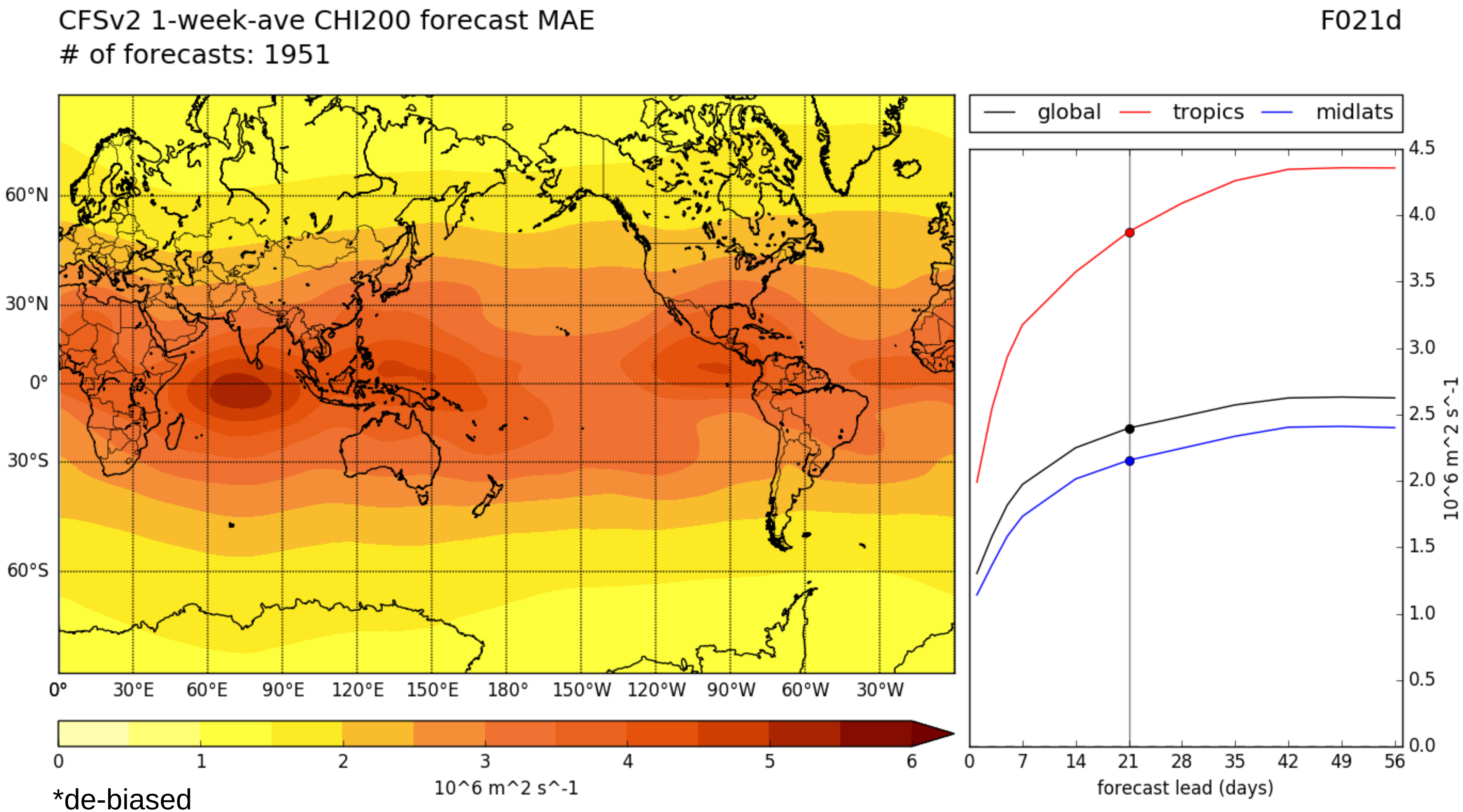
Again, 1-week average

# CHI200 MAE - week 1



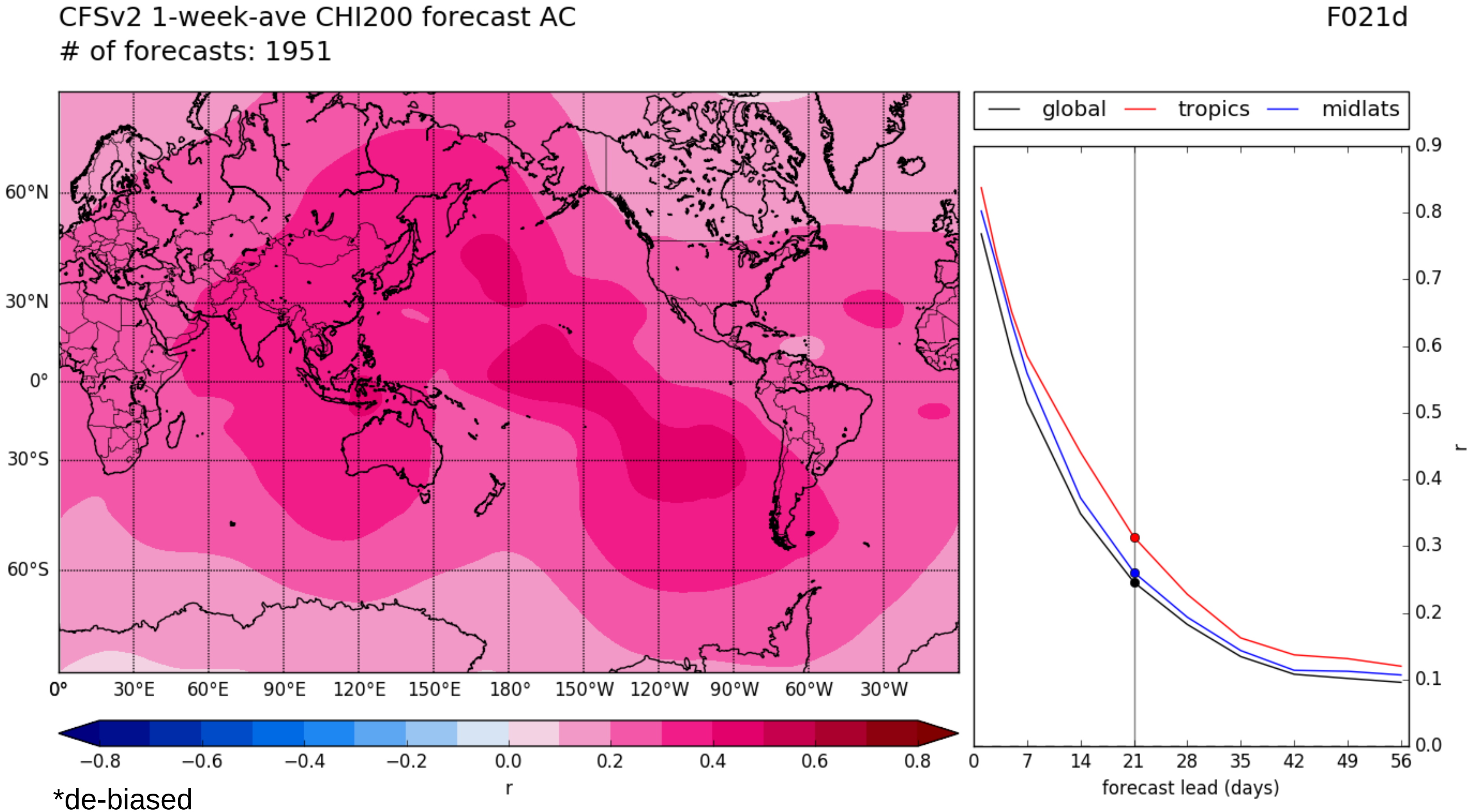

*de-biased

# CHI200 MAE - week 4



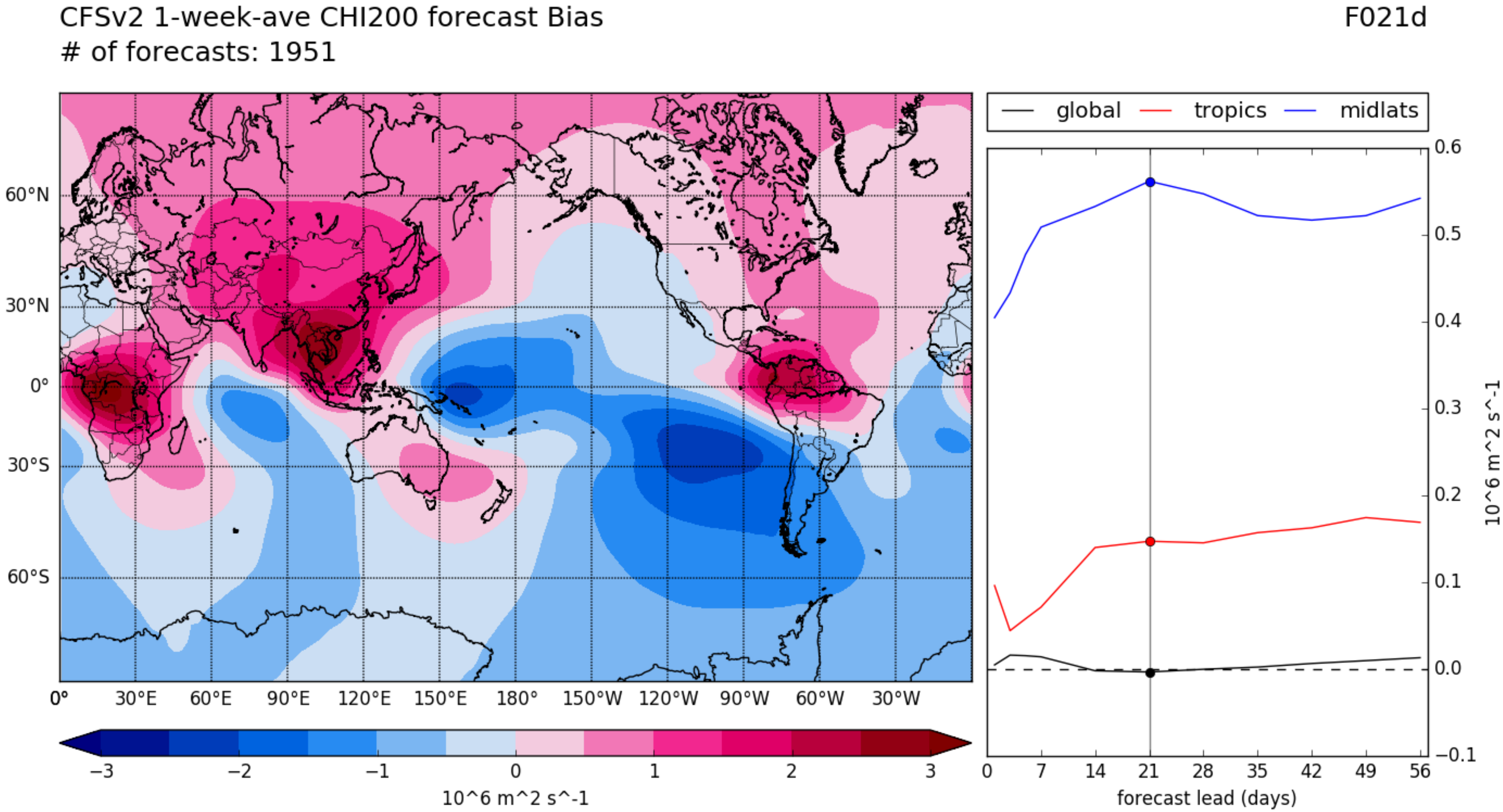

*de-biased

# CHI200 AC - week 4



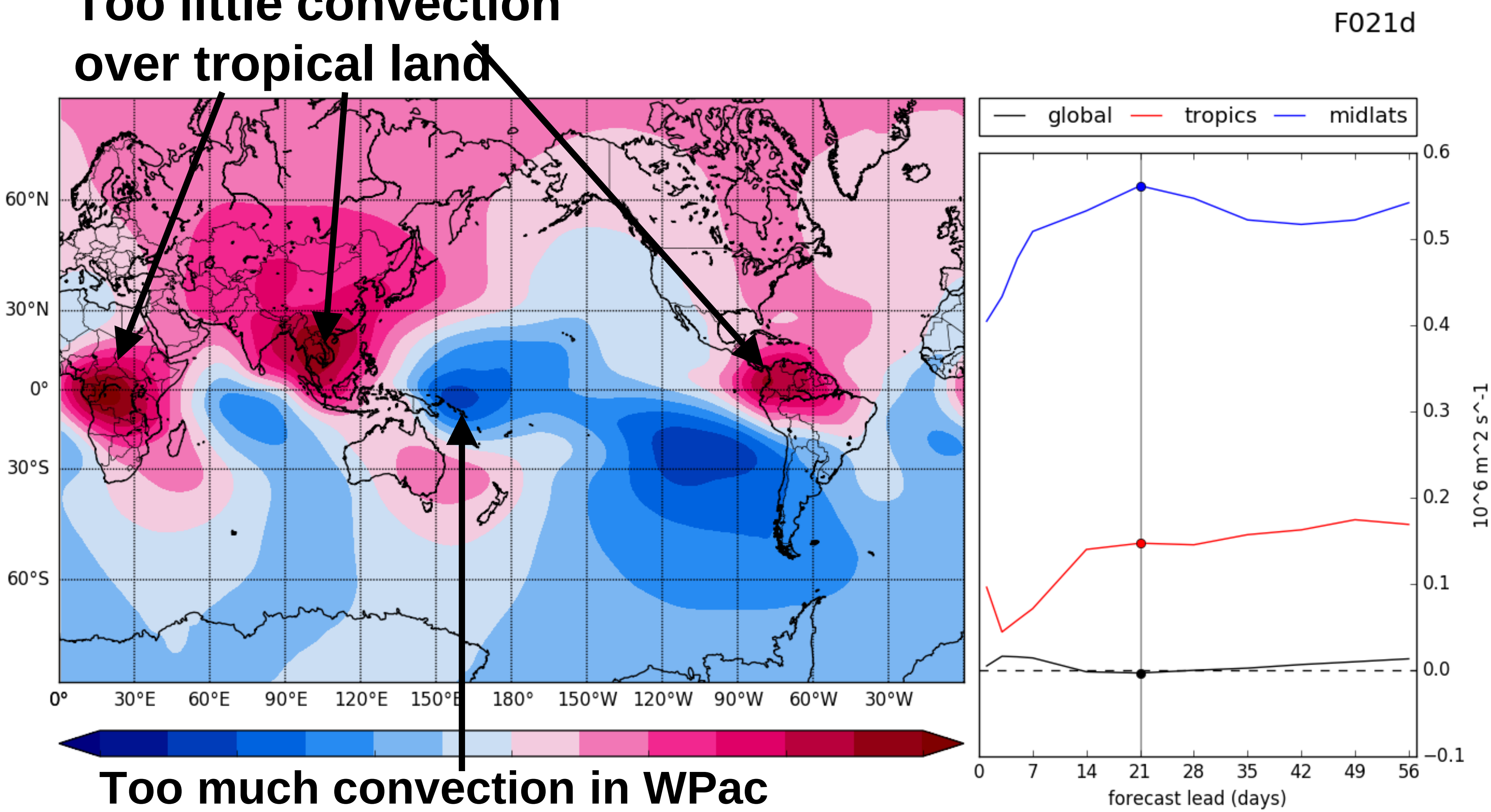

*de-biased

# CHI200 bias - week 4



# CHI200 bias - week 4

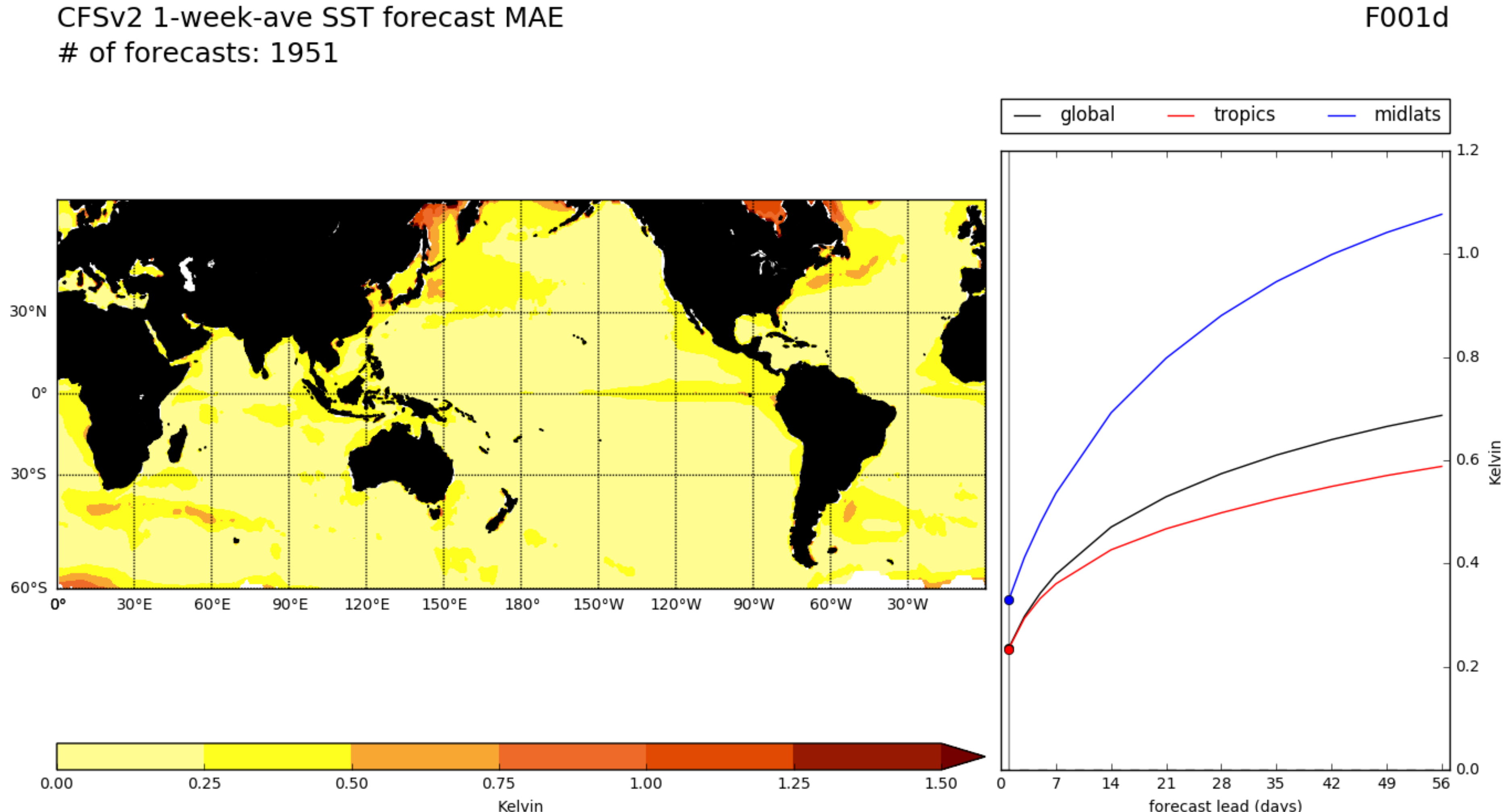
**Too little convection over tropical land**




**Too much convection in WPac (not good for MJO development)**

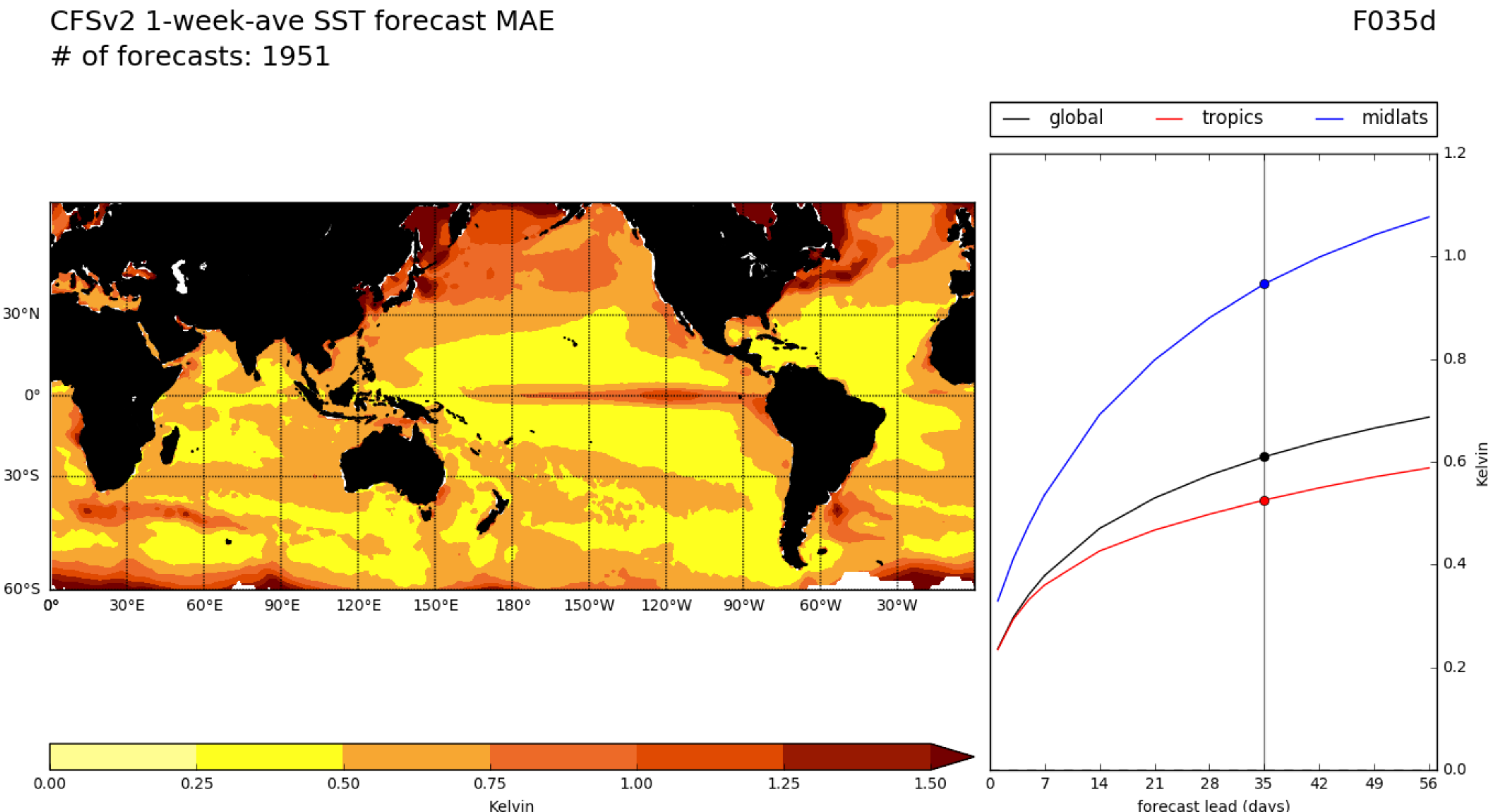
# SST

# SST MAE - week 1




*de-biased

# SST MAE - week 6



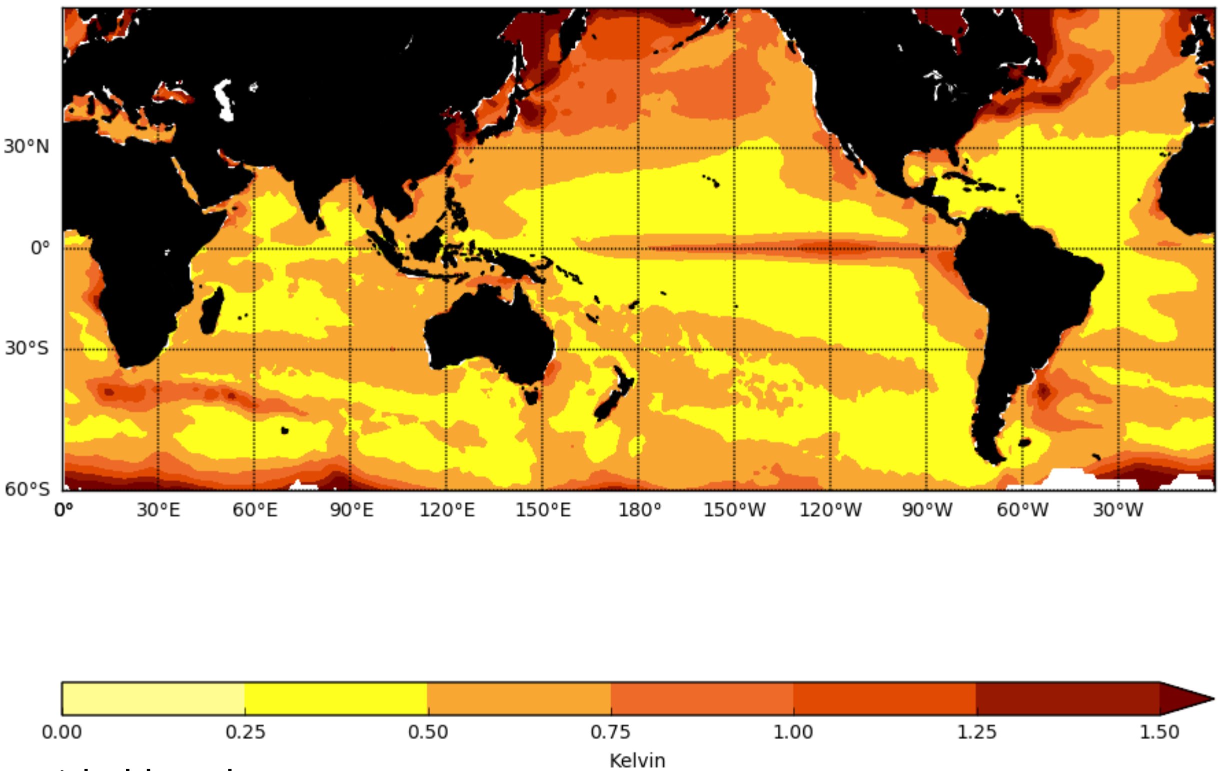

*de-biased

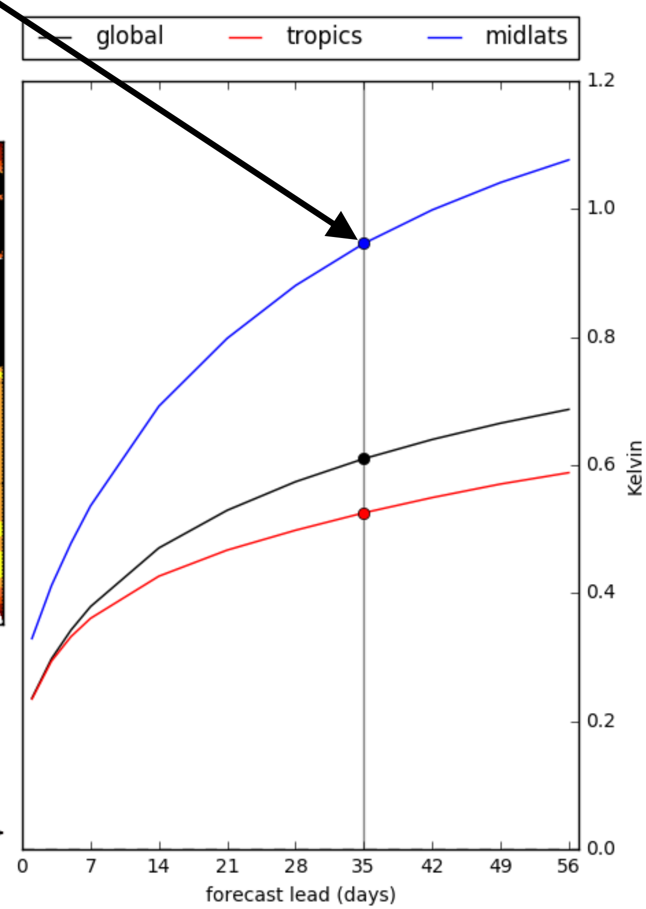
# SST MAE - week 6

CFSv2 1-week-ave SST forecast MAE
# of forecasts: 1951

**Slower error growth than other fields**

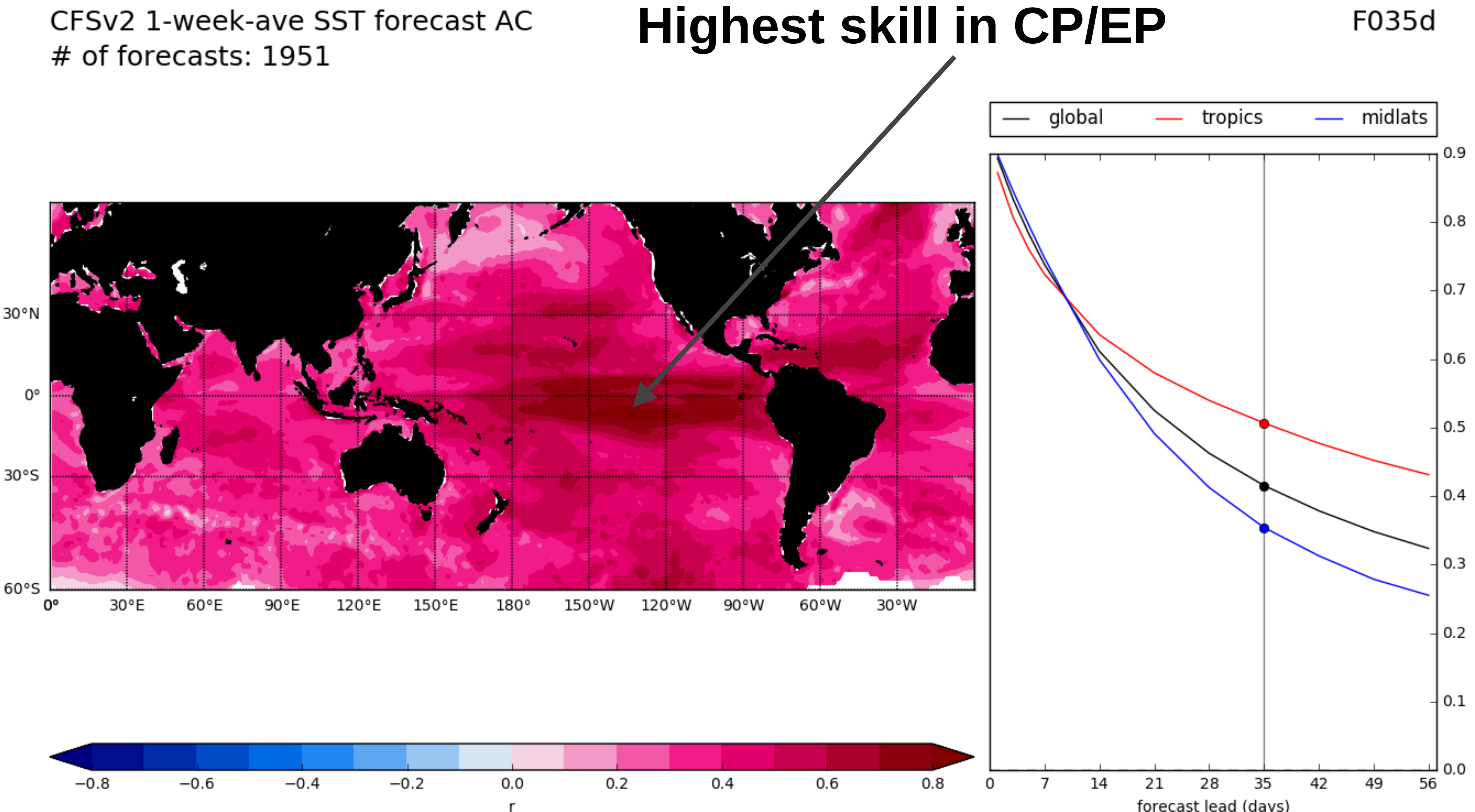
F035d




*de-biased

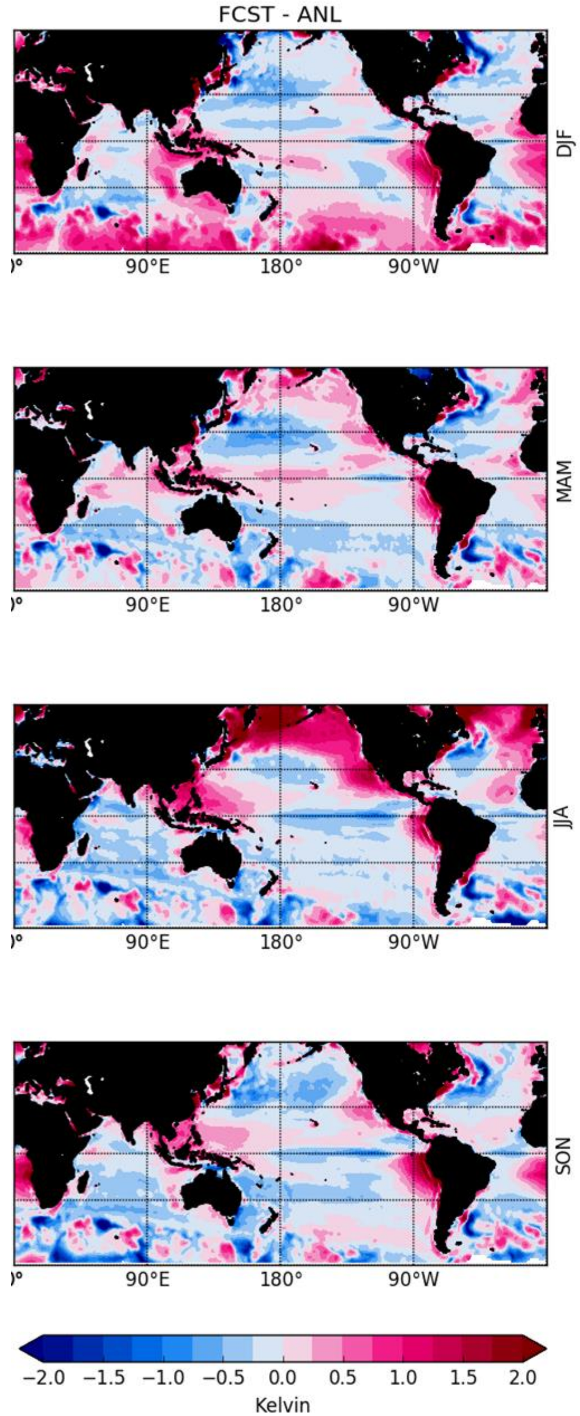
# SST AC - week 6




*de-biased

# SST bias - week 5

Major bias over north and NE Pacific in summer




Winter

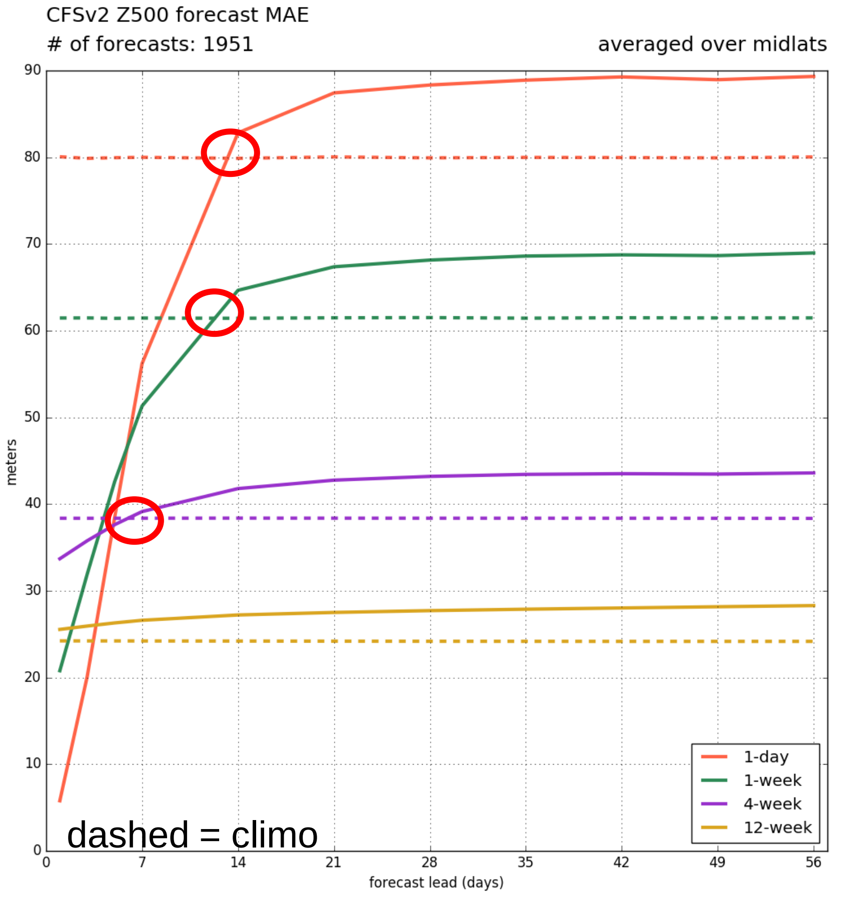
Spring

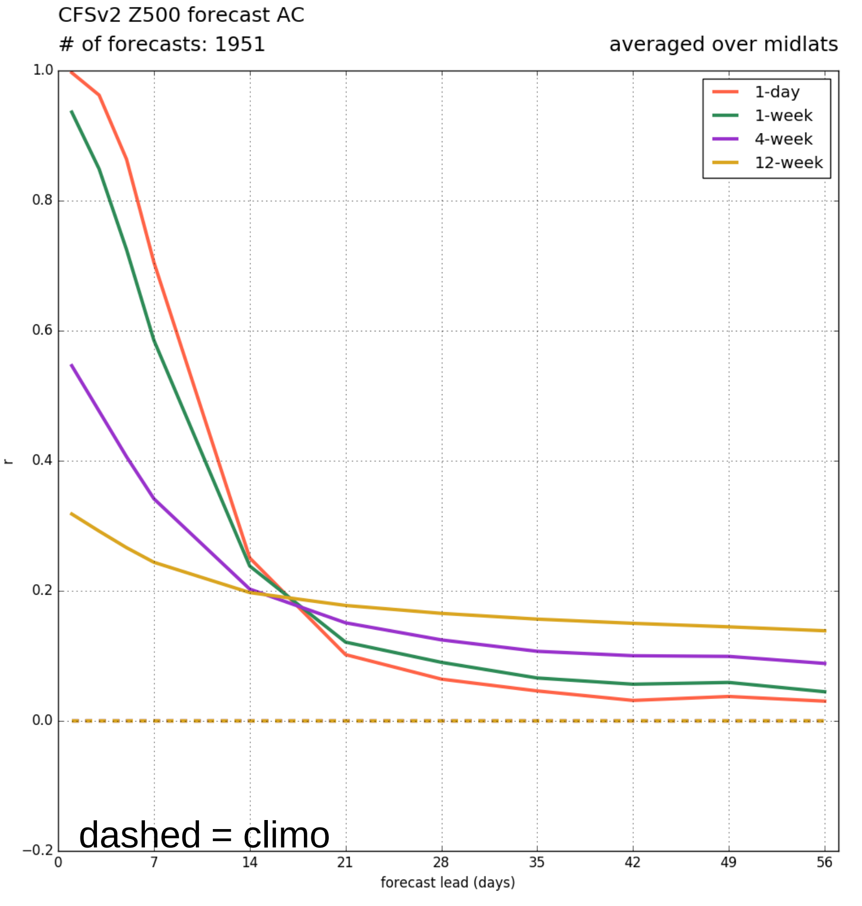
Summer

Fall

# How does skill vary with averaging time?

# Mid-latitude Z500 MAE and AC




Longer averaging periods:

**reduces** skill at shorter lead times

**increases** skill at longer lead times

* skill over climatology fades between weeks 1 and 2, at all time scales

Why does skill fade so quickly? Why doesn’t extended SST skill extend to other variables?

# The nature of simulated tropical convection

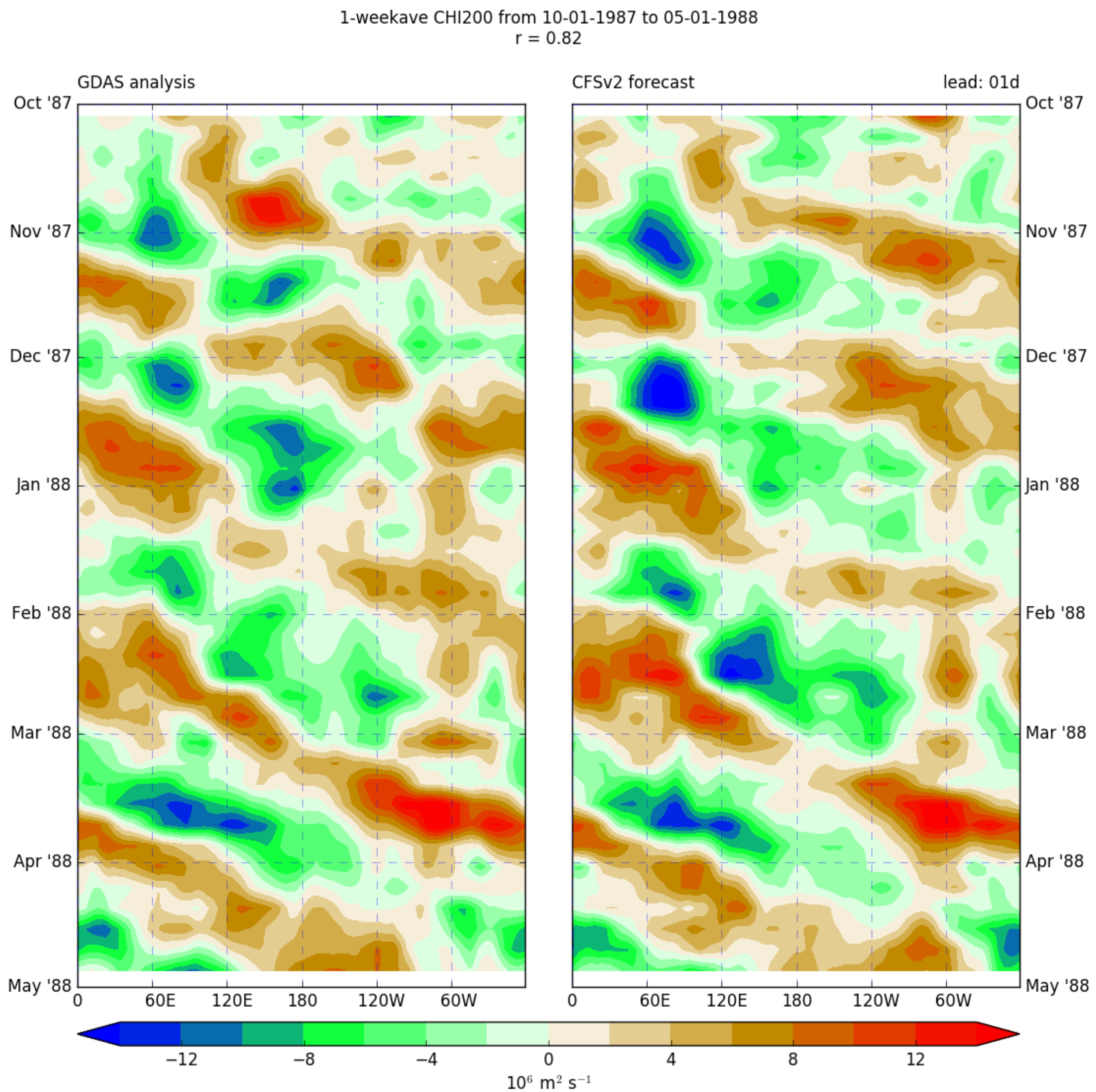
and how it evolves with lead time

# Hovmoller comparison: analyses vs CFS forecasts at different lead times

-5S to 5N

# CHI200 Hovmoller: analysis vs week-1 forecasts

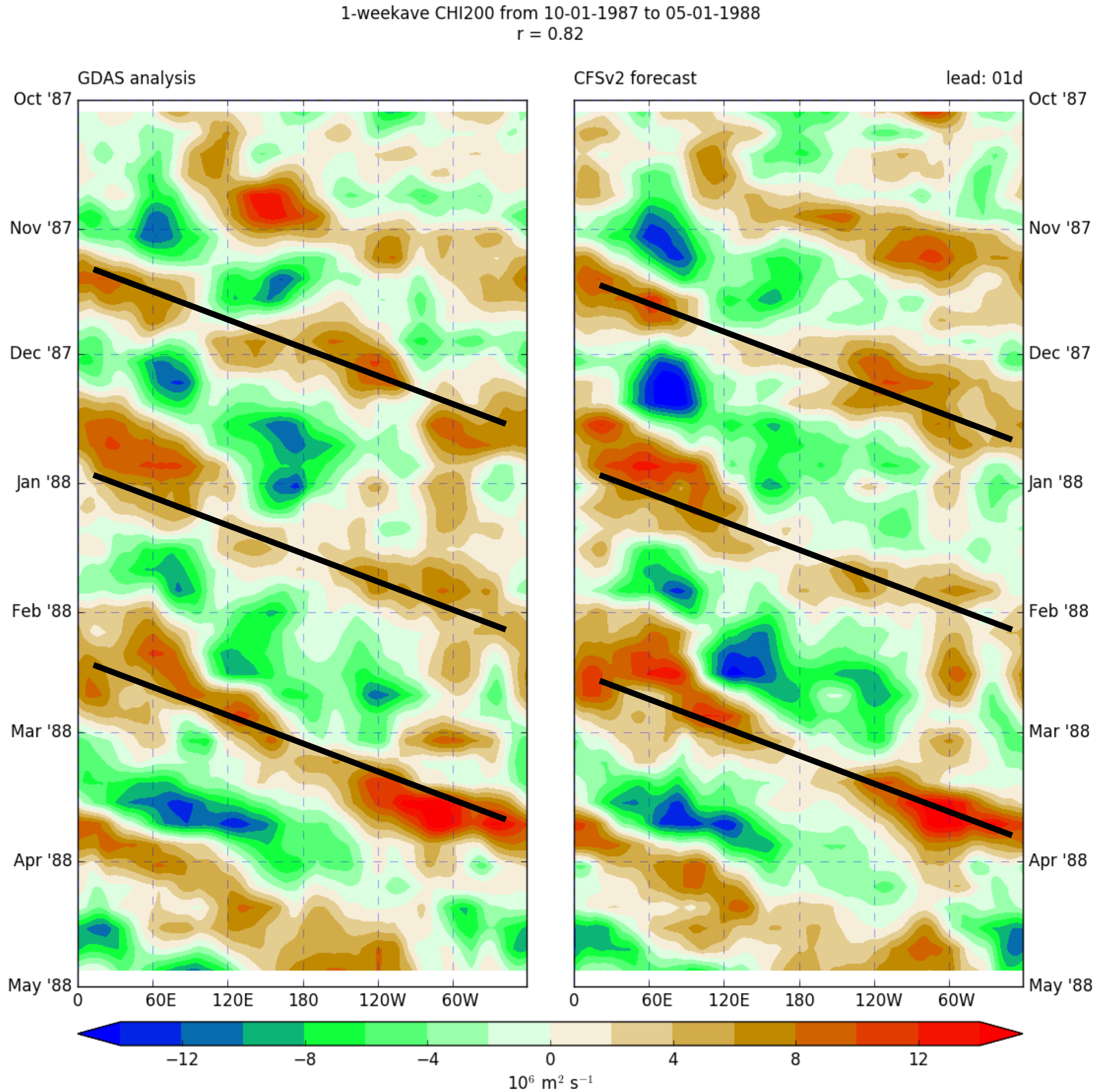
Winter/Spring '87-'88




*single-member forecasts

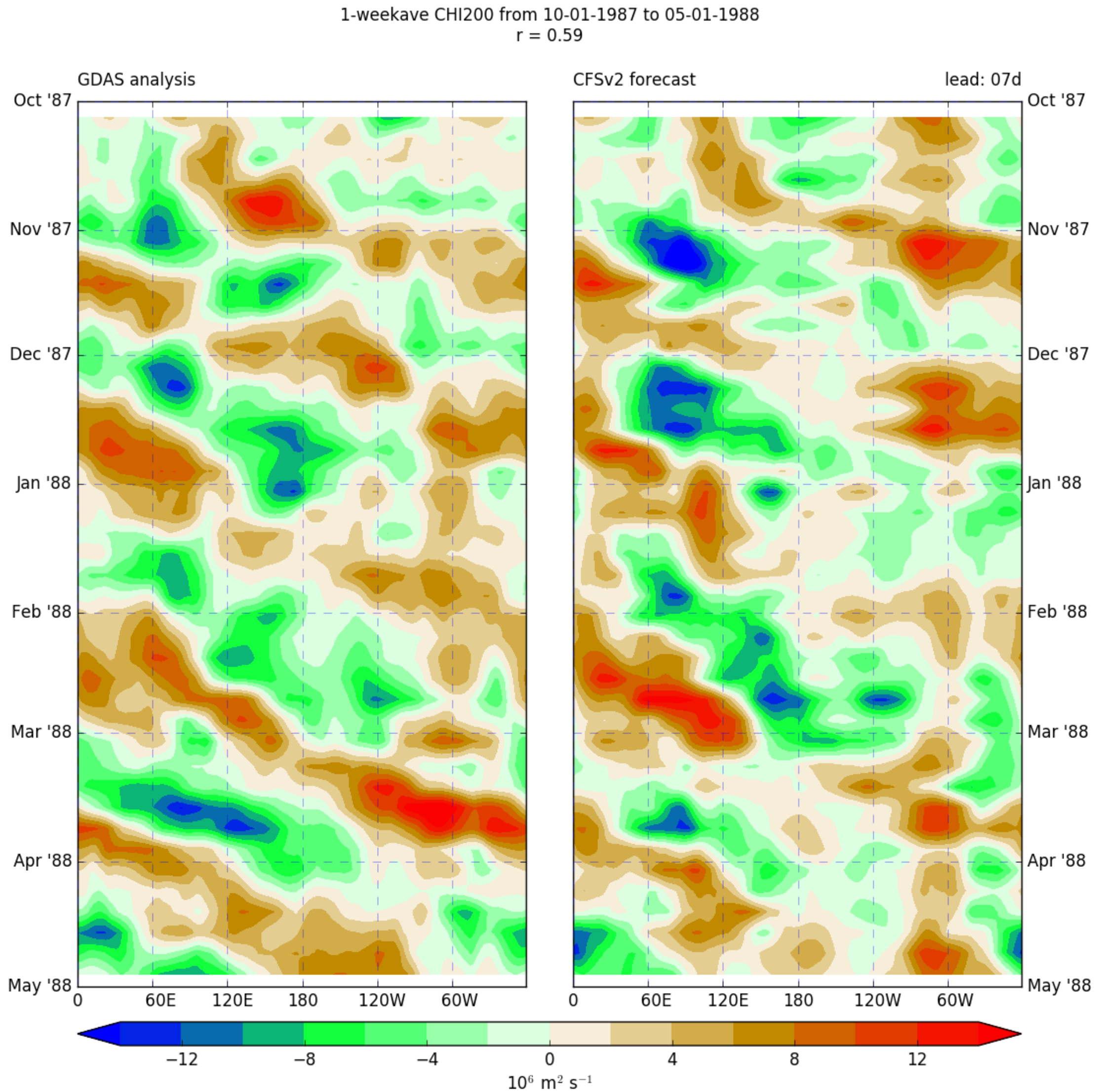
# CHI200 Hovmoller: analysis vs week-1 forecasts

Wave propagation in both analyses and forecasts



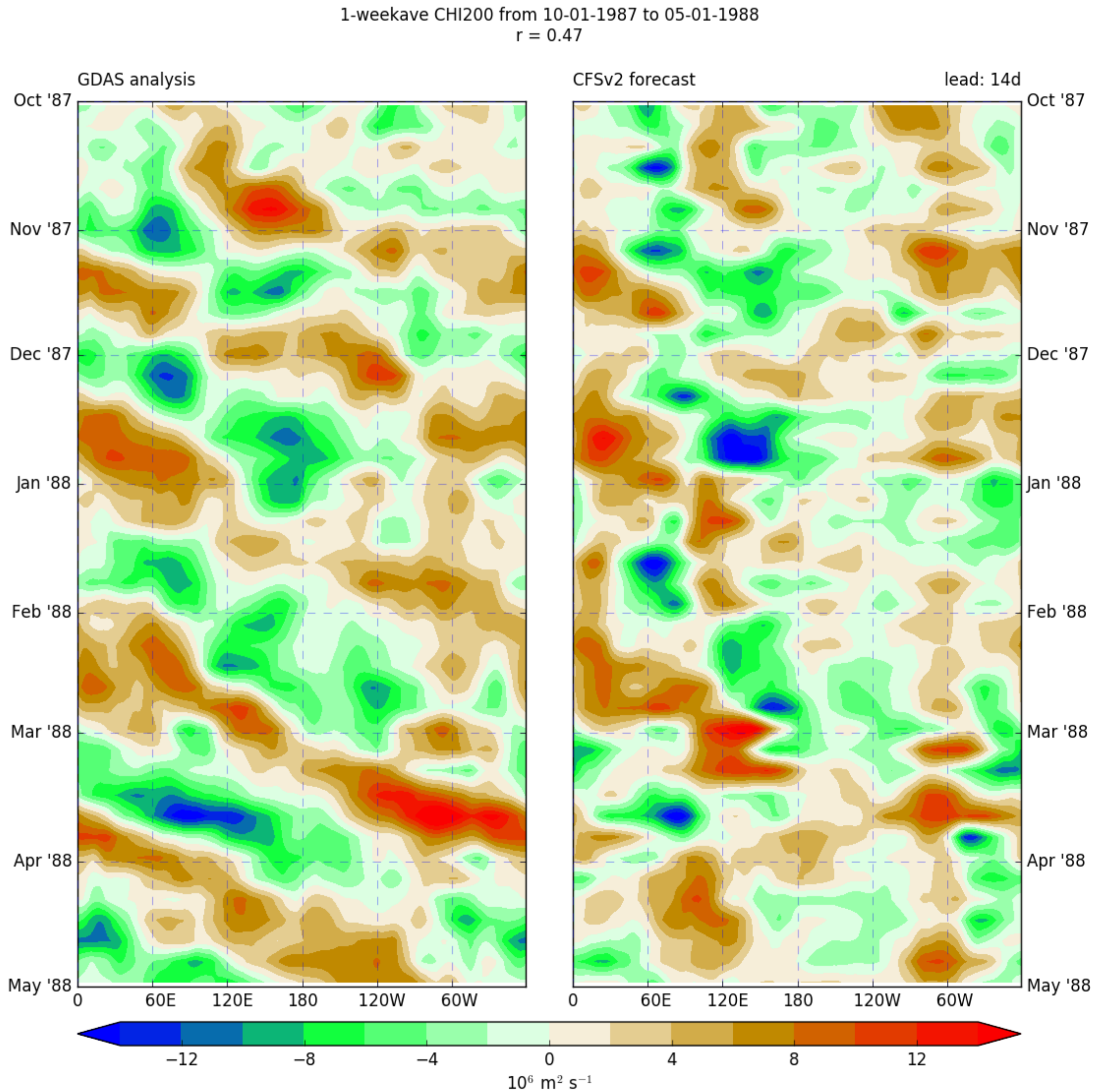

*single-member forecasts

# CHI200 Hovmoller: analysis vs week-2 forecasts



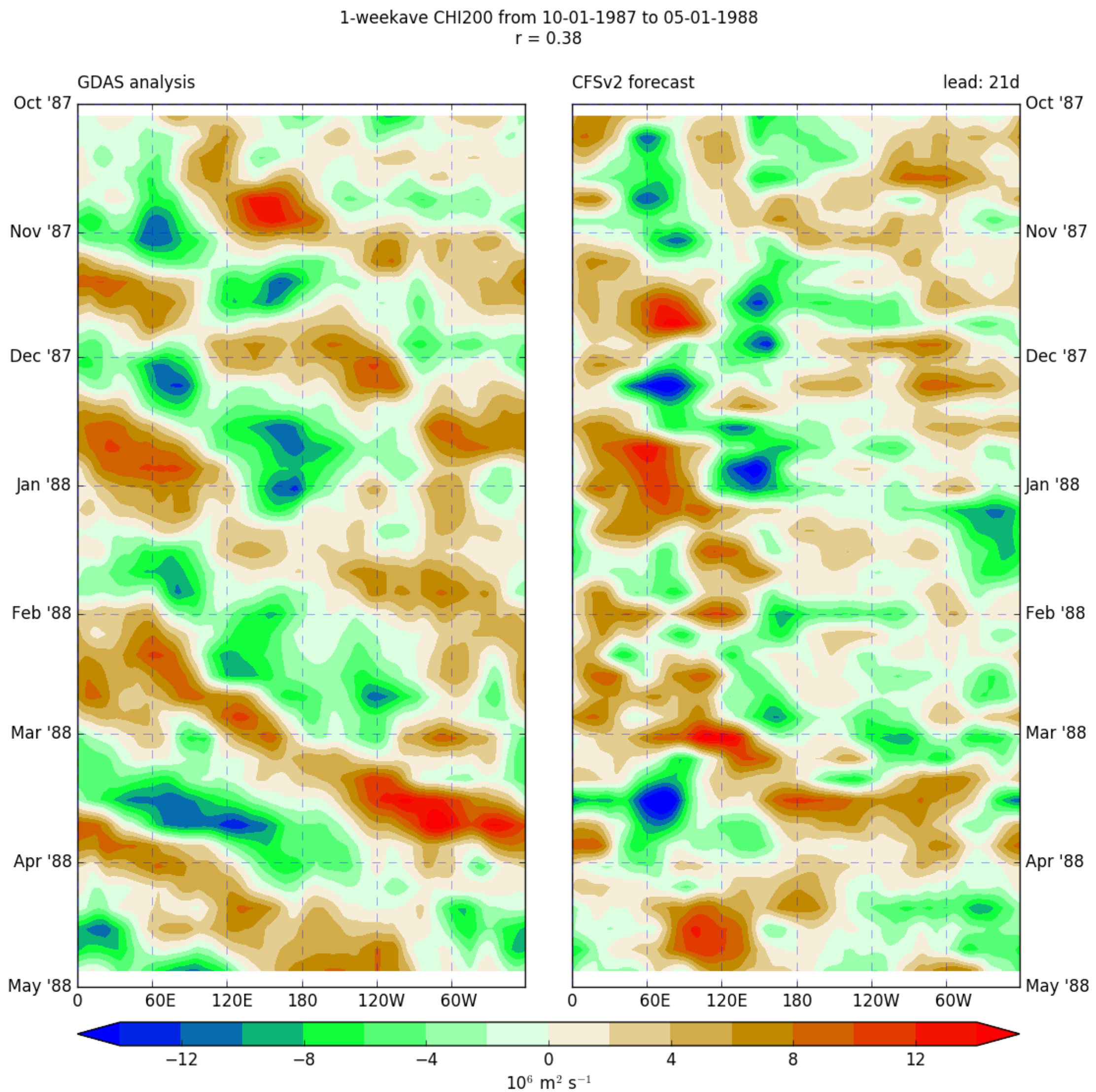

*single-member forecasts

# CHI200 Hovmoller: analysis vs week-3 forecasts




*single-member forecasts

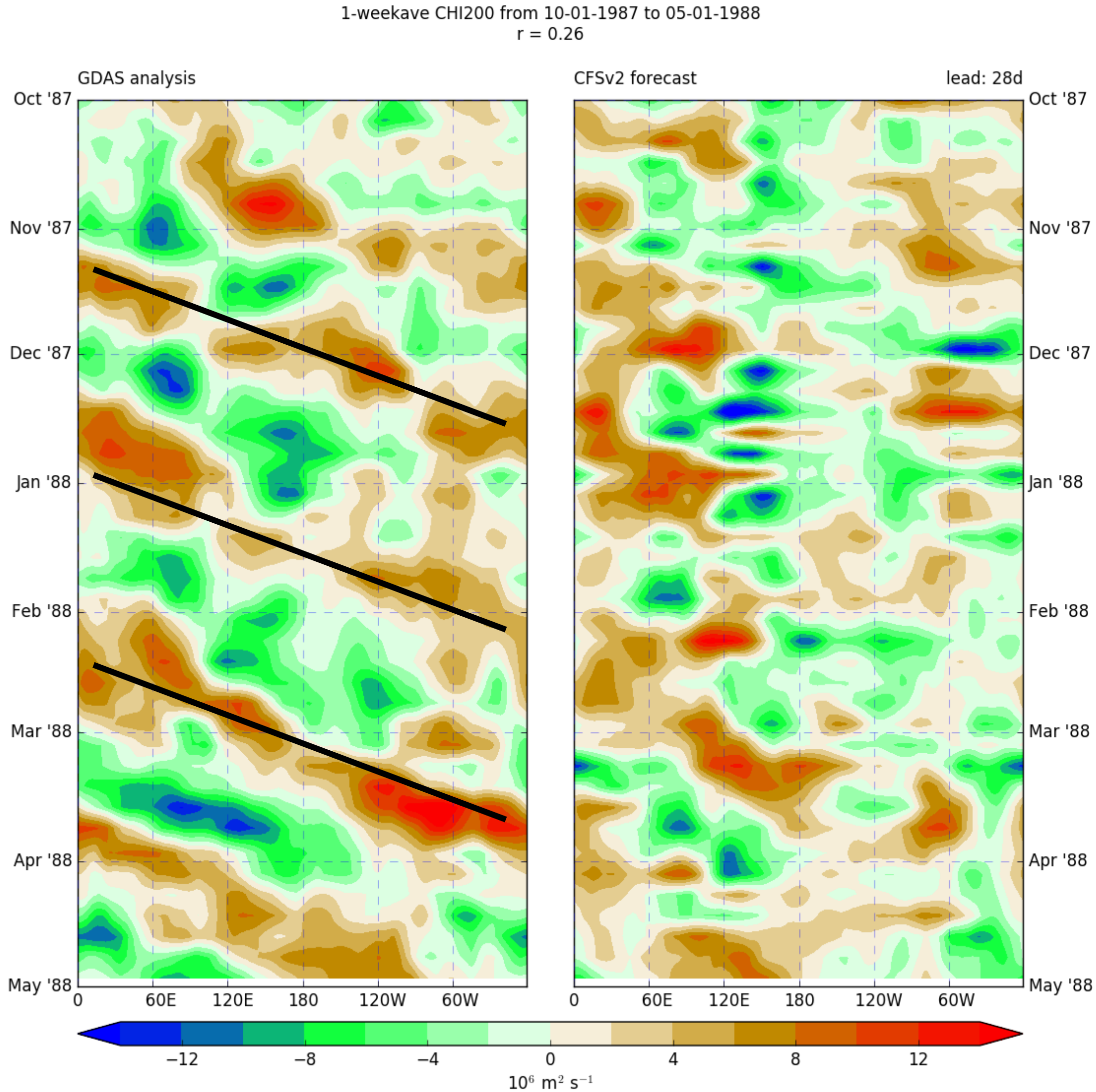
# CHI200 Hovmoller: analysis vs week-4 forecasts




*single-member forecasts

# CHI200 Hovmoller: analysis vs week-5 forecasts

Coherent propagating structures are lost as lead time increases!

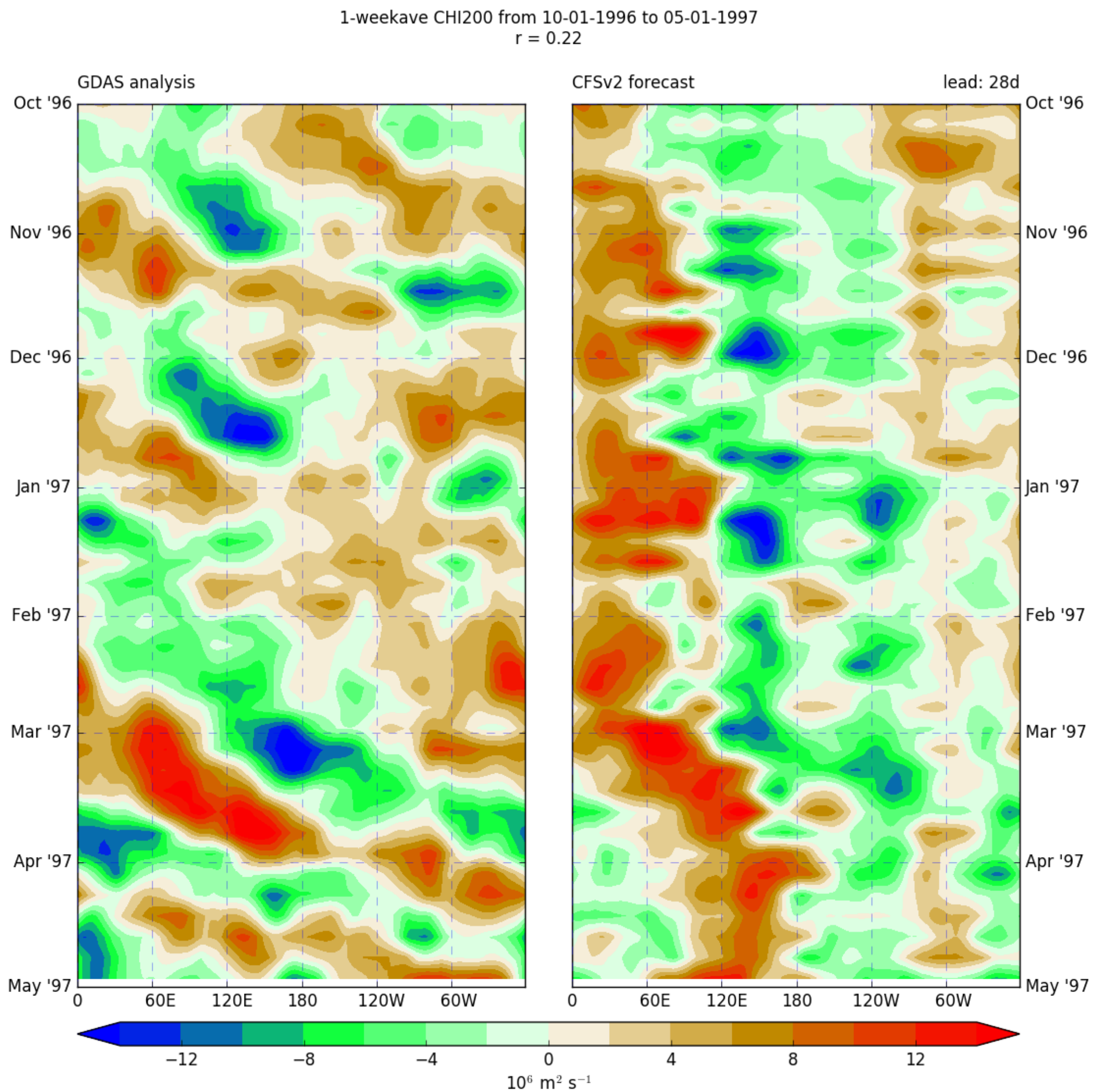



More stationary features take over

*single-member forecasts

# CHI200 Hovmoller: other examples

Winter/Spring
'96-'97

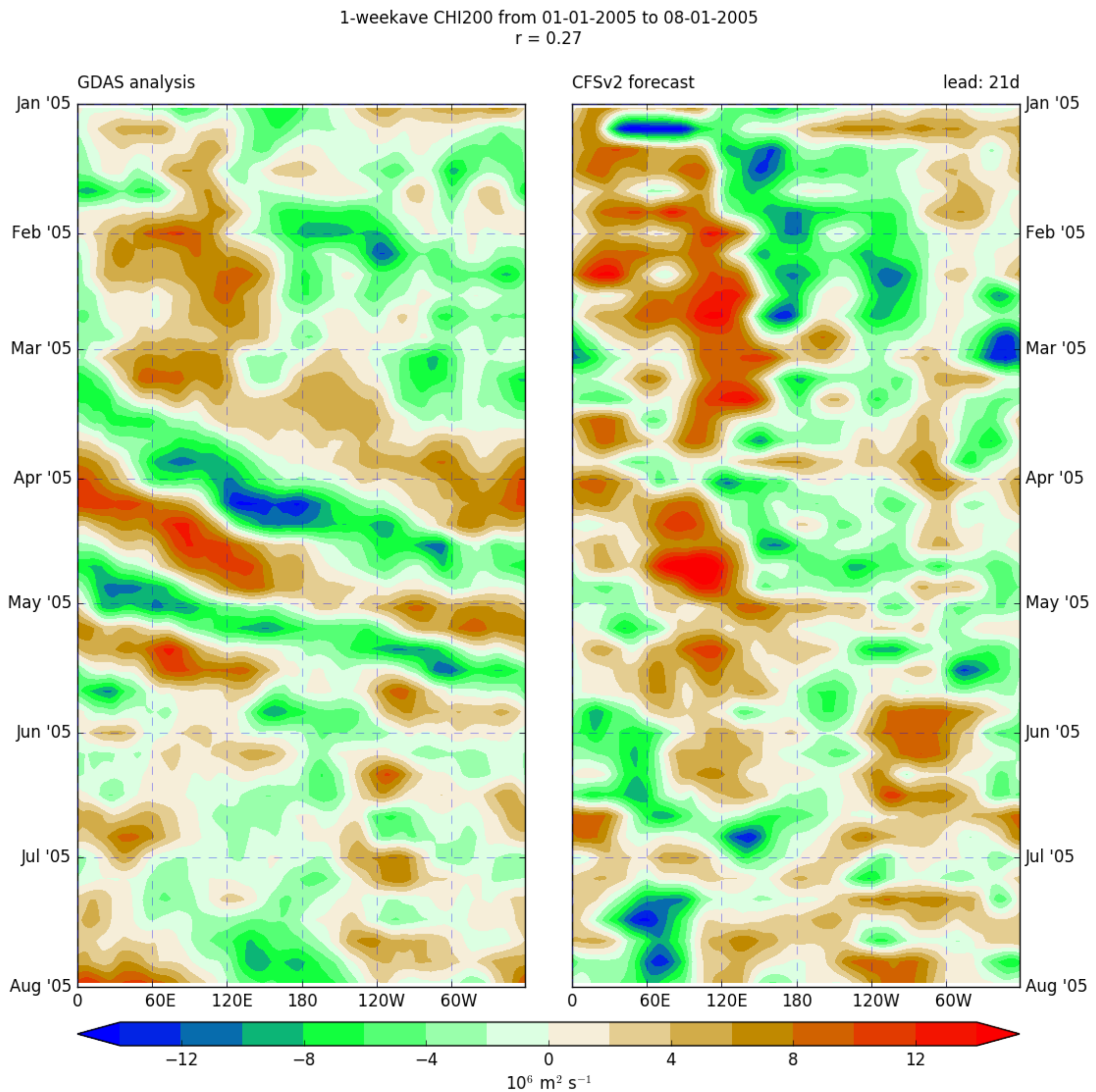



Week-5
forecasts

*single-member
forecasts

# CHI200 Hovmoller: other examples

Spring/Summer '05



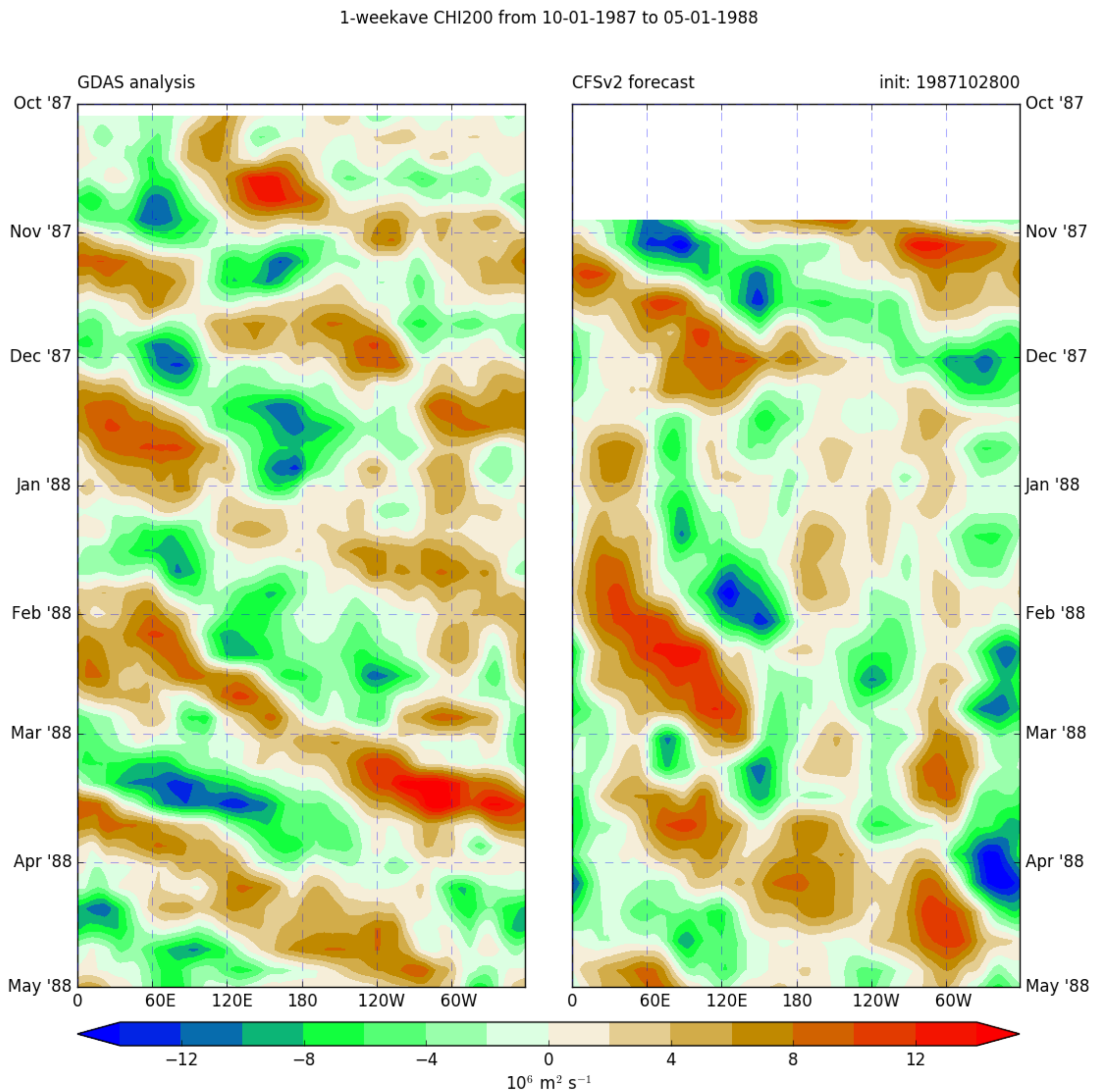

Week-4 forecasts

*single-member forecasts

# Hovmoller comparison: analyses vs a single CFS forecast

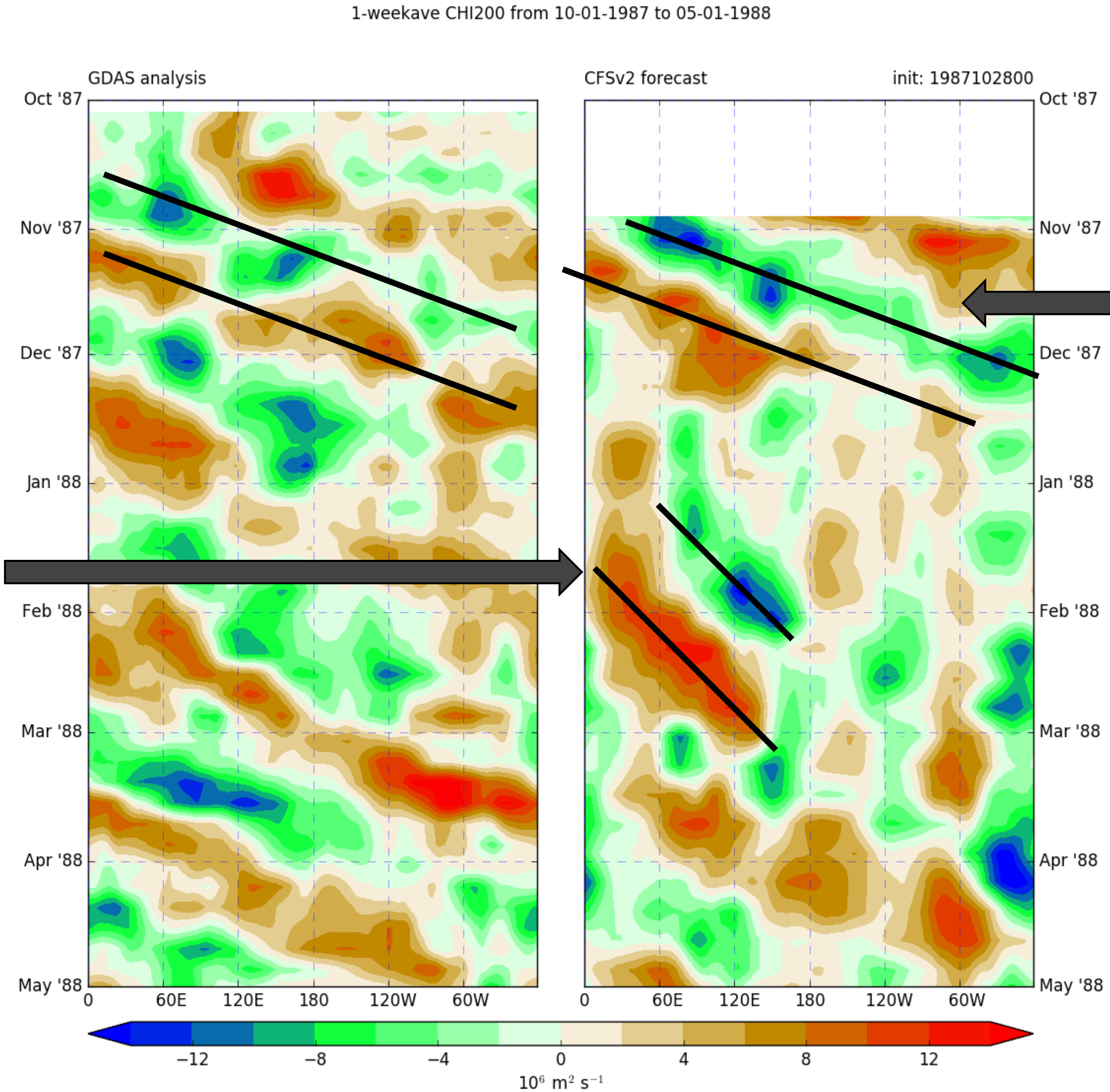
# CHI200 Hovmoller: analysis vs single forecasts

Winter/Spring
'87-'88




*single-member forecasts

# CHI200 Hovmoller: analysis vs single forecasts




**Short leads:**
Good phase speed

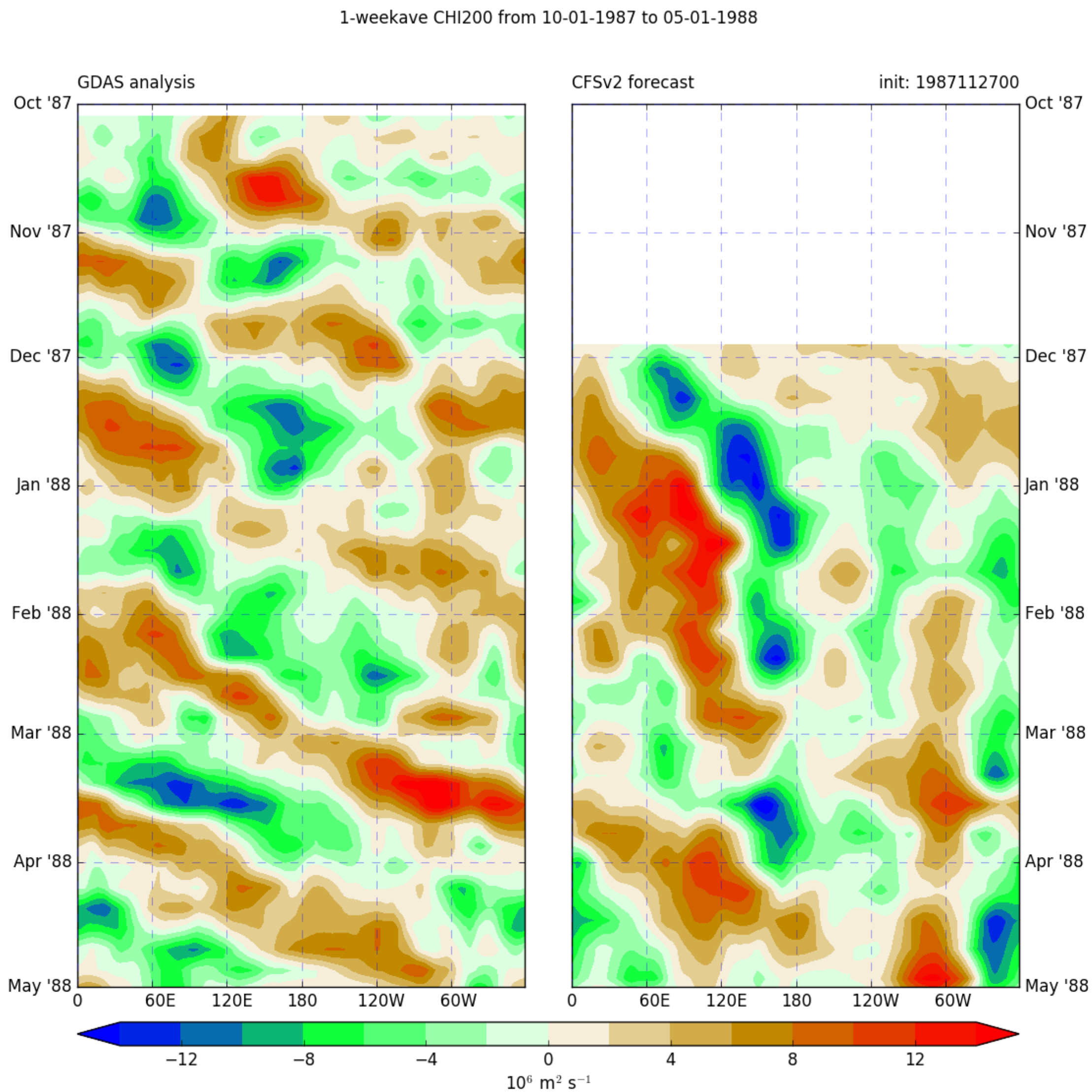
**Long leads:**
Phase speed often gets much slower

**Long leads:**
Propagation often impeded by the "Maritime Continent Barrier"

*single-member forecasts

# CHI200 Hovmoller: analysis vs single forecasts

A different forecast:

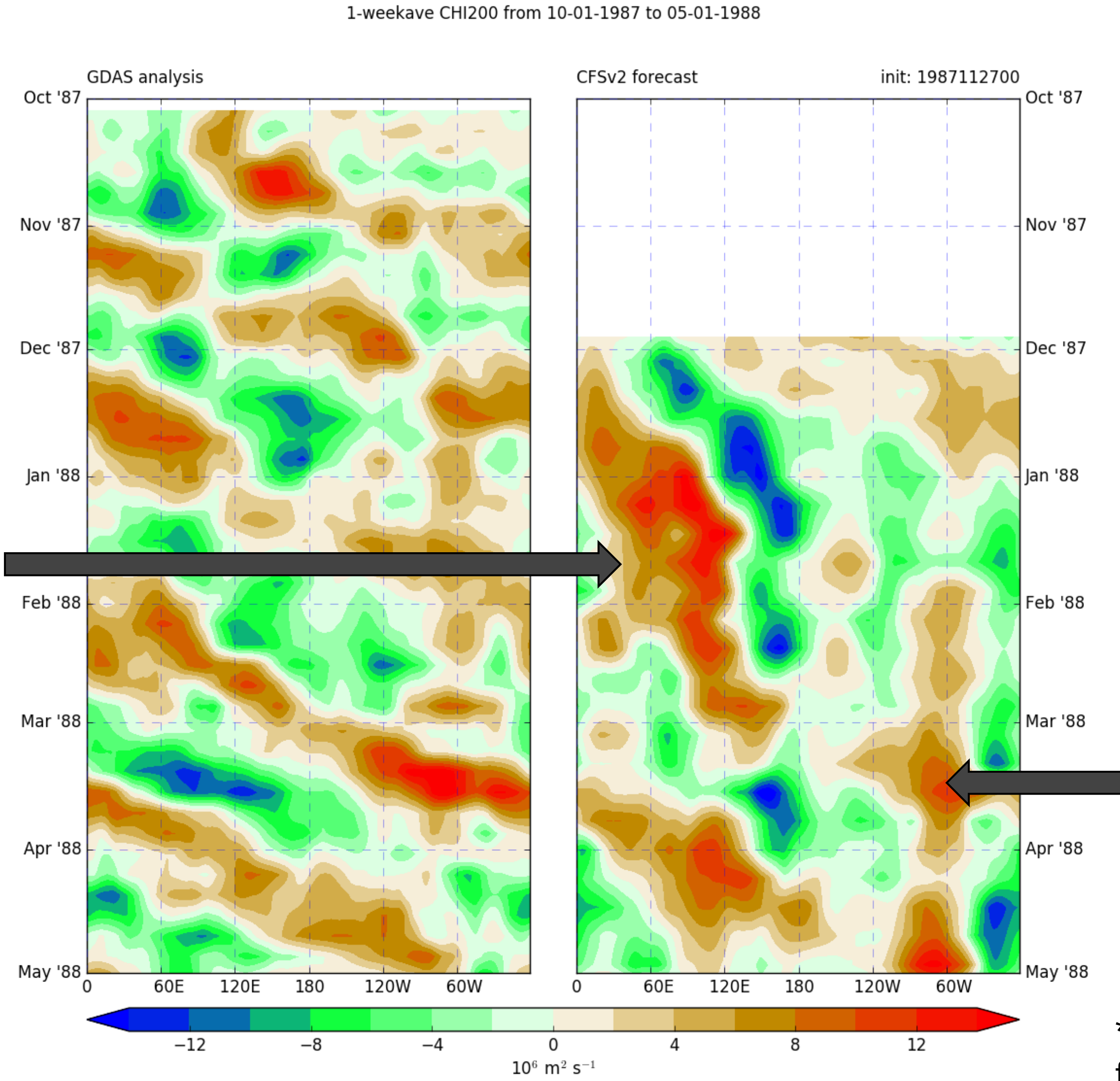



*single-member forecasts

# CHI200 Hovmoller: analysis vs single forecasts

A different forecast:

Propagating features often devolve into stationary ones



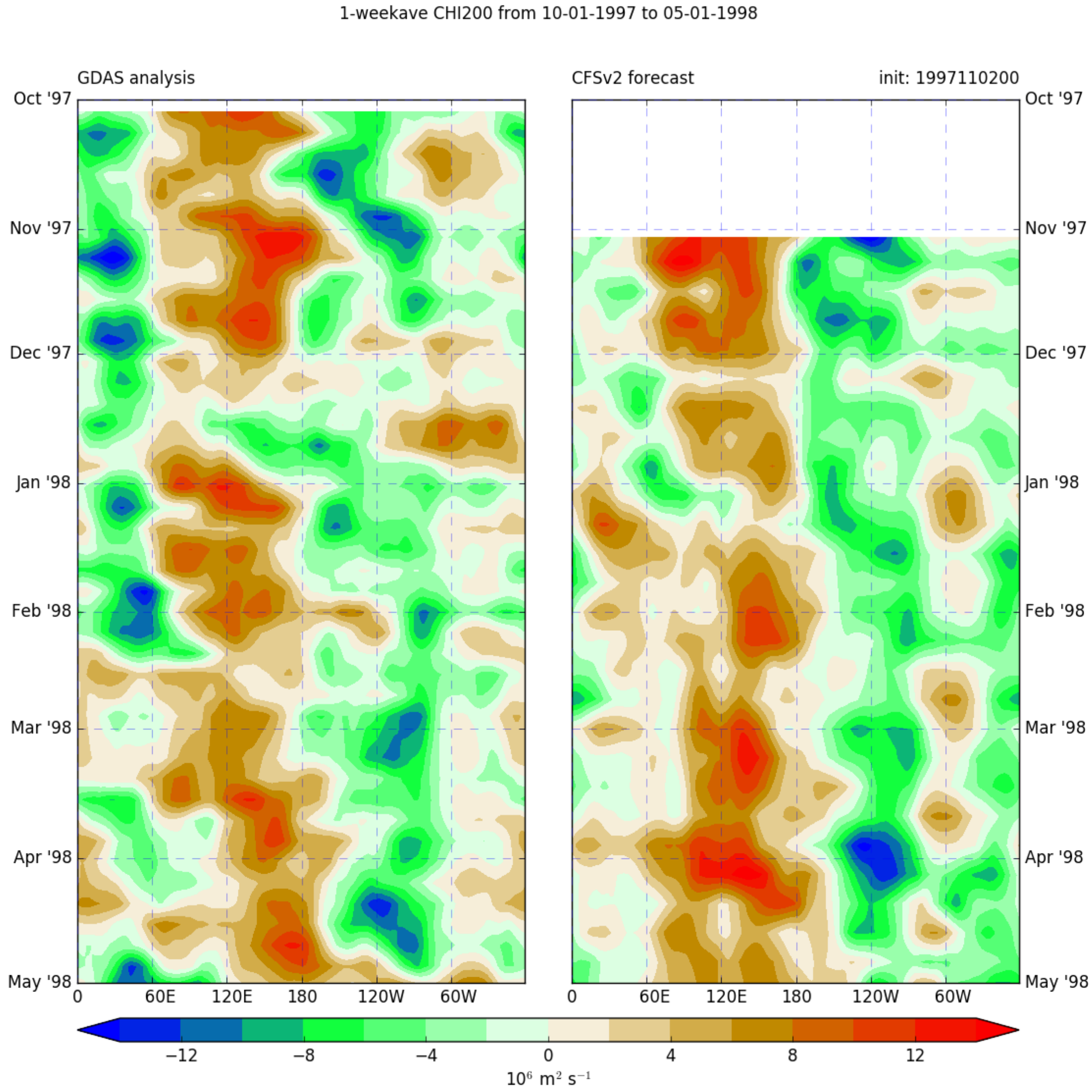

Dry land bias becomes more evident at longer lead times (e.g., South Amer.)

*single-member forecasts

# CHI200 Hovmoller: analysis vs single forecasts

Forecasts are *much* better during **strong El Niño** events

Winter/Spring '97-'98

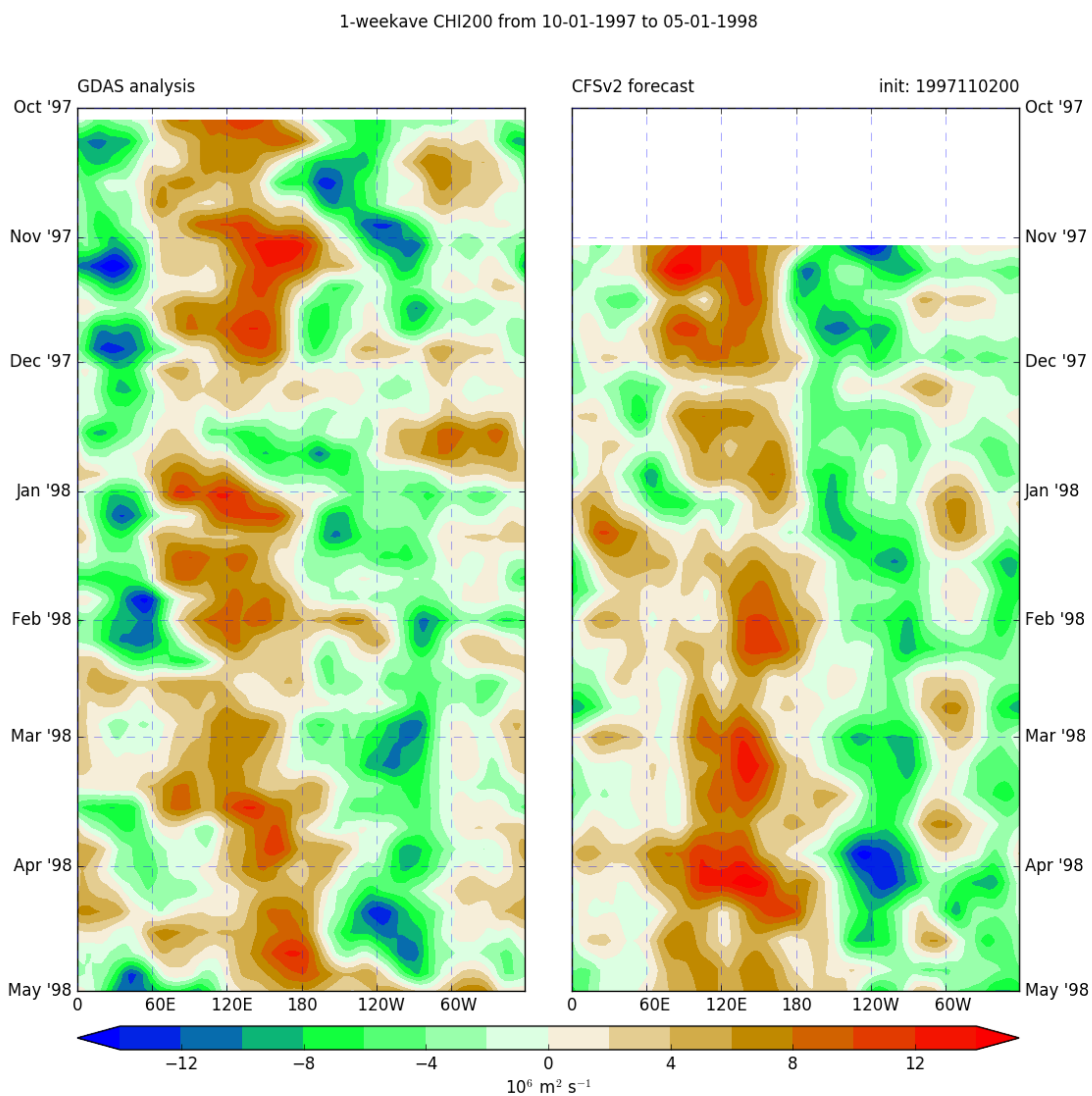



*single-member forecasts

# CHI200 Hovmoller: analysis vs single forecasts

Forecasts are *much* better during **strong El Niño** events

Winter/Spring '97-'98



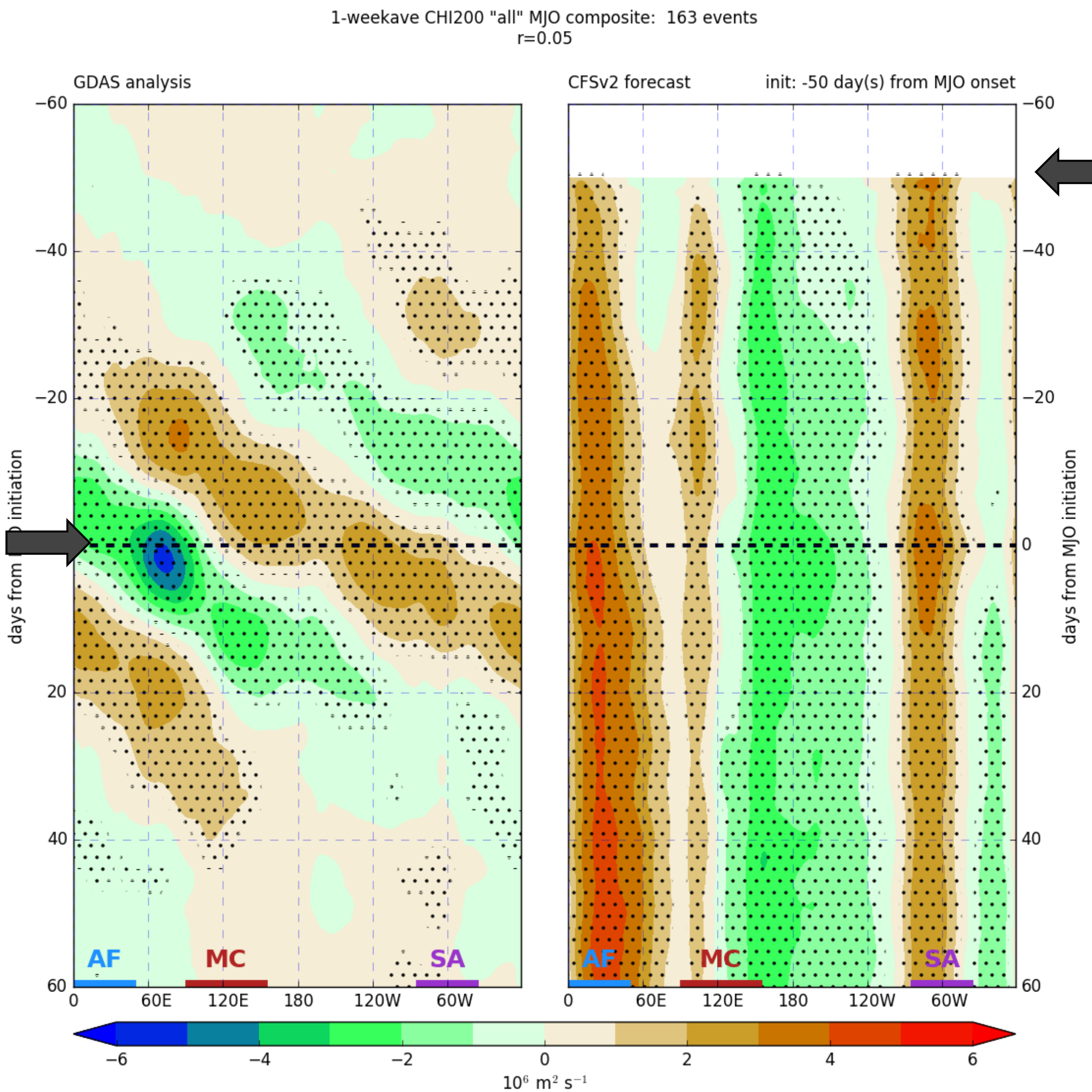

Propagating features are dwarfed by the ENSO signal

*single-member forecasts

# MJO Hovmoller composites

# CHI200 MJO composite

MJO initiation (as determined by an Indian Ocean convection index)



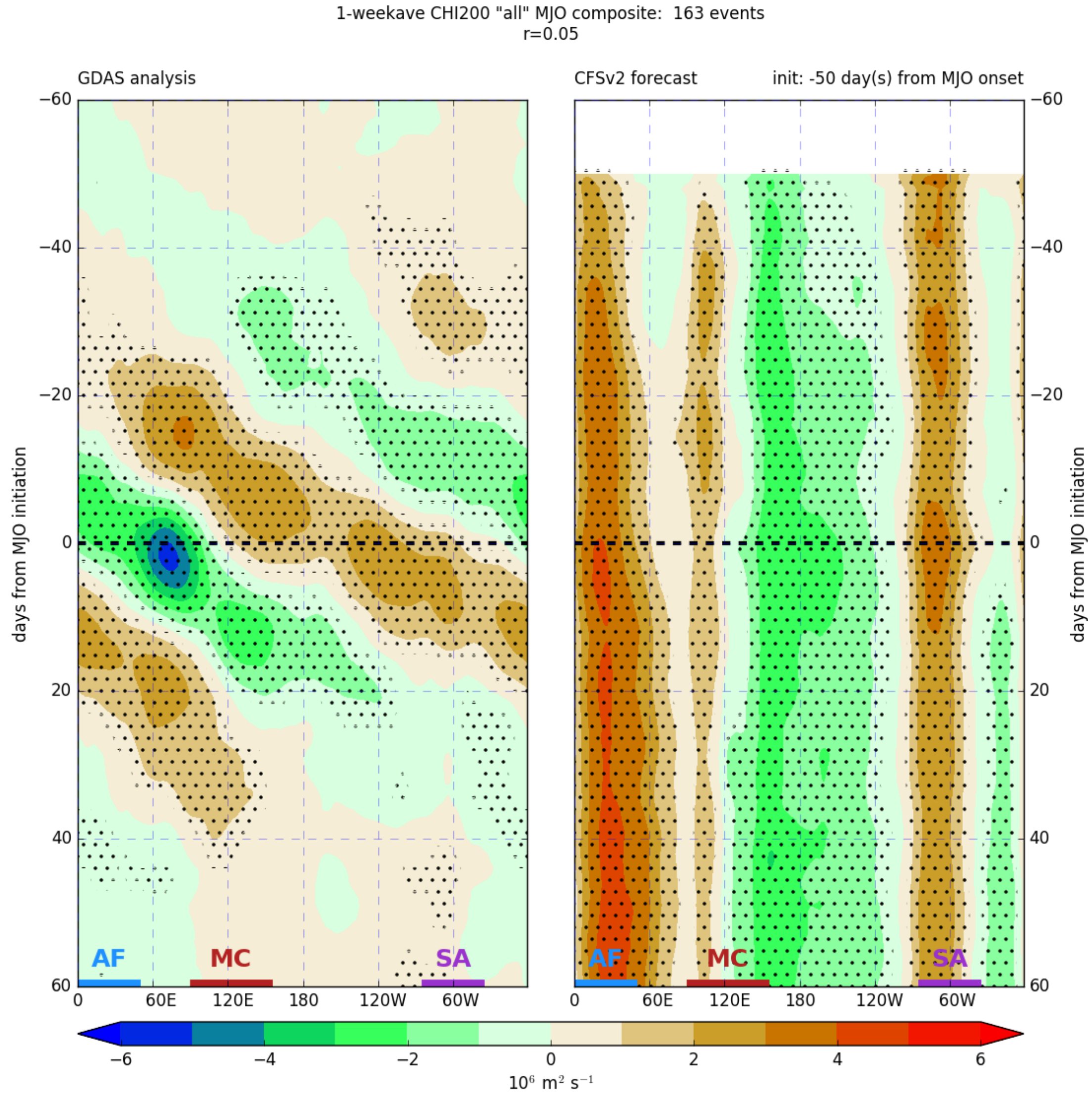

Forecasts initialized

Anomalies computed from 30-year CFSR climatology

Stippling = 95% significance

*single-member forecasts

# CHI200 MJO composite: raw forecasts

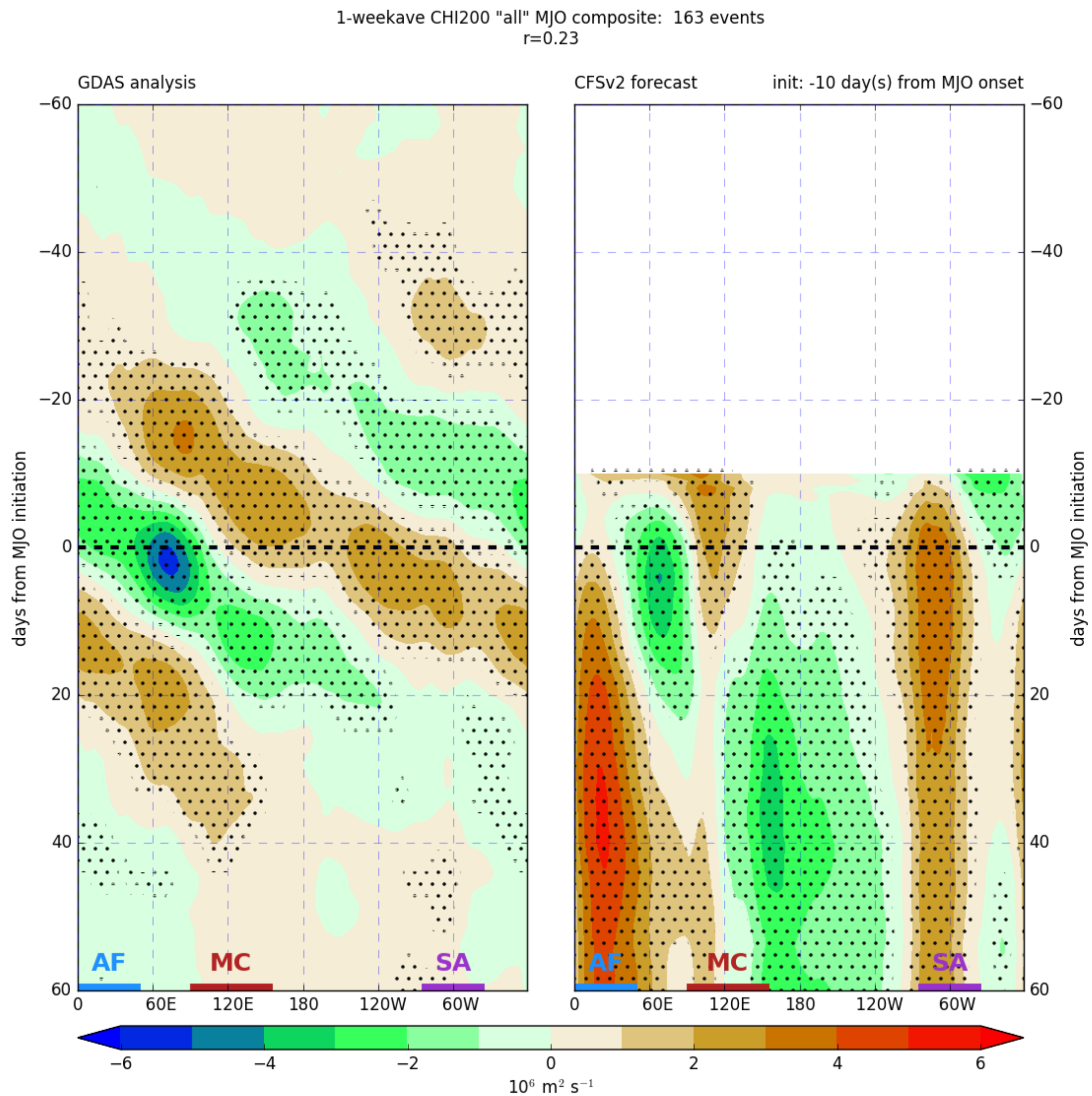



**Long leads:**
No MJO signal.

Model biases dominate:
- dry equatorial land
- wet W. Pac.

*single-member forecasts

# CHI200 MJO composite: raw forecasts




**Shorter leads:**

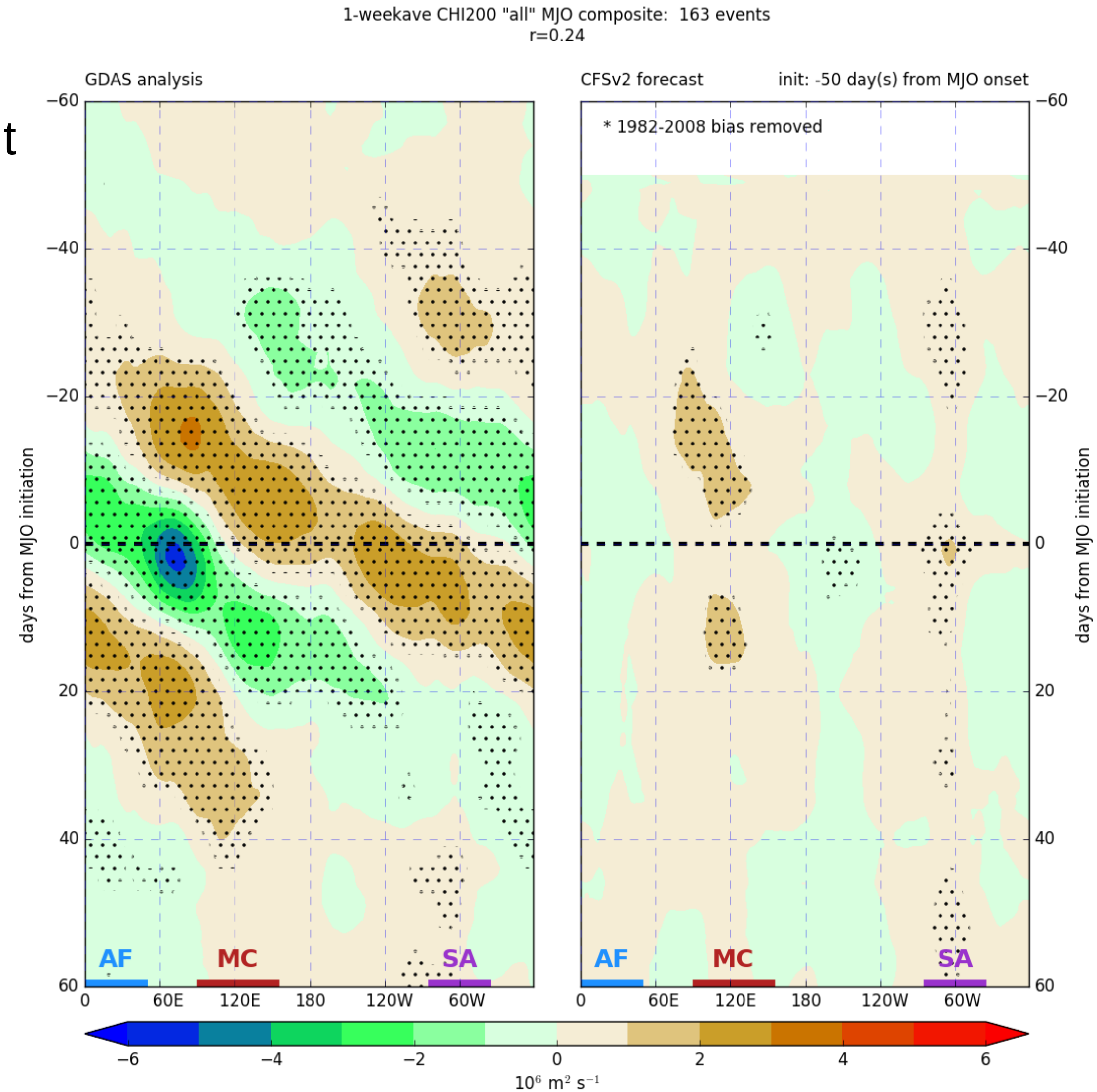
Weak MJO signal.

Model biases dominate take over ~20 days into the forecast

*single-member forecasts

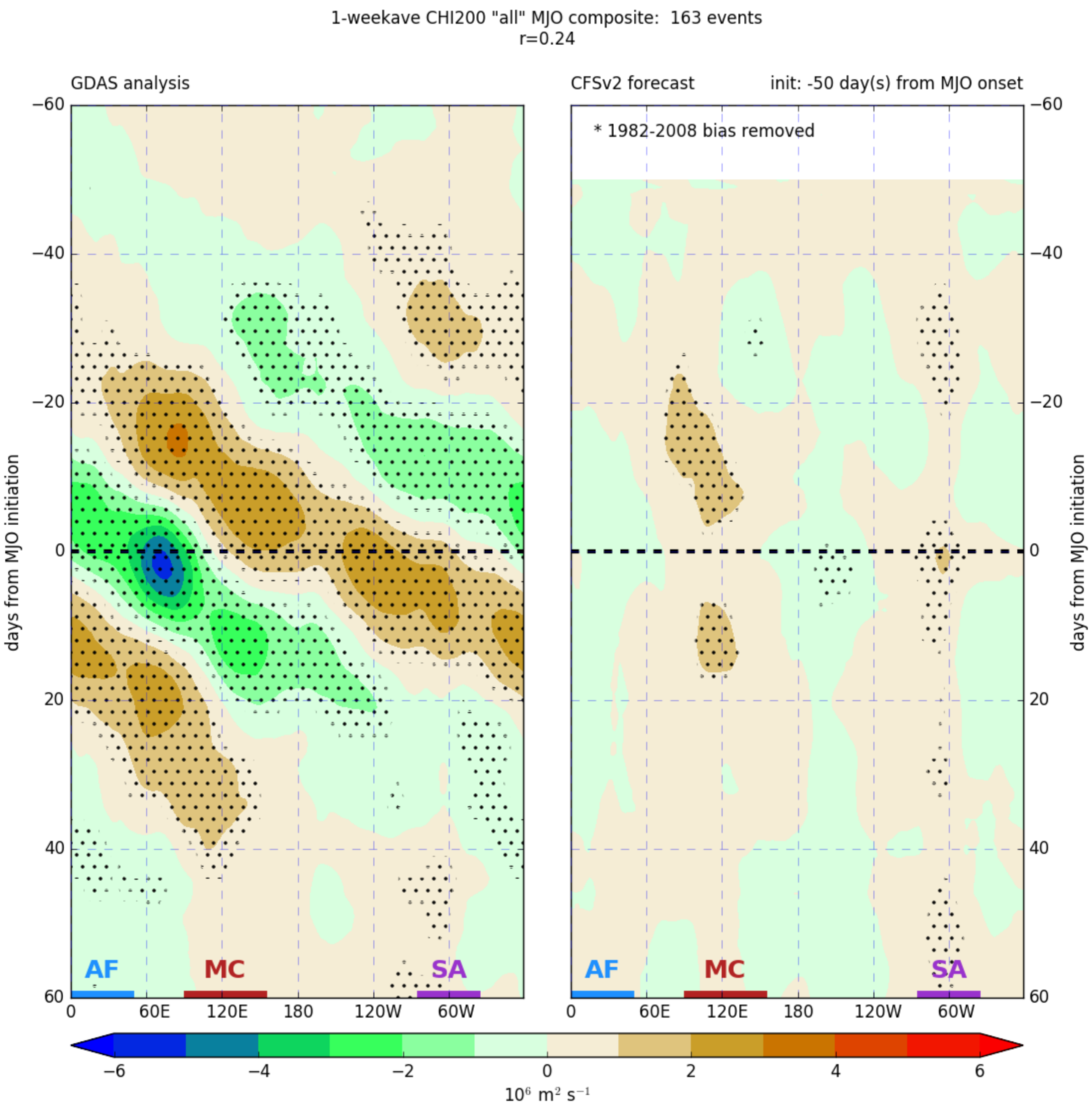
# CHI200 MJO composite: **de-biased** forecasts

Lead-dependent 1982-2008 bias removed from forecasts!




*single-member forecasts

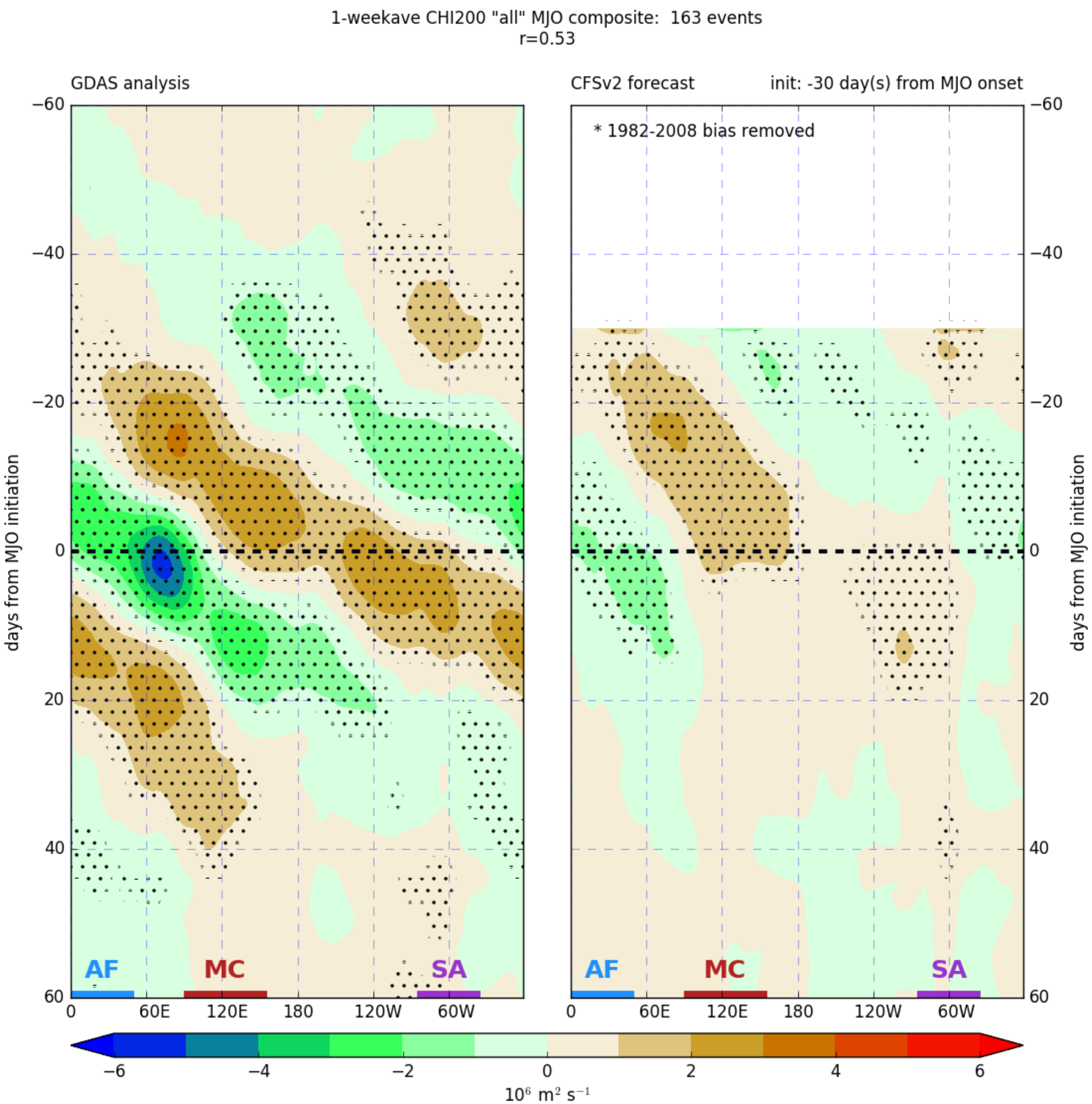
# CHI200 MJO composite: **de-biased** forecasts




**<u>Long leads:</u>**
No MJO signal.

*single-member forecasts

# CHI200 MJO composite: **de-biased** forecasts



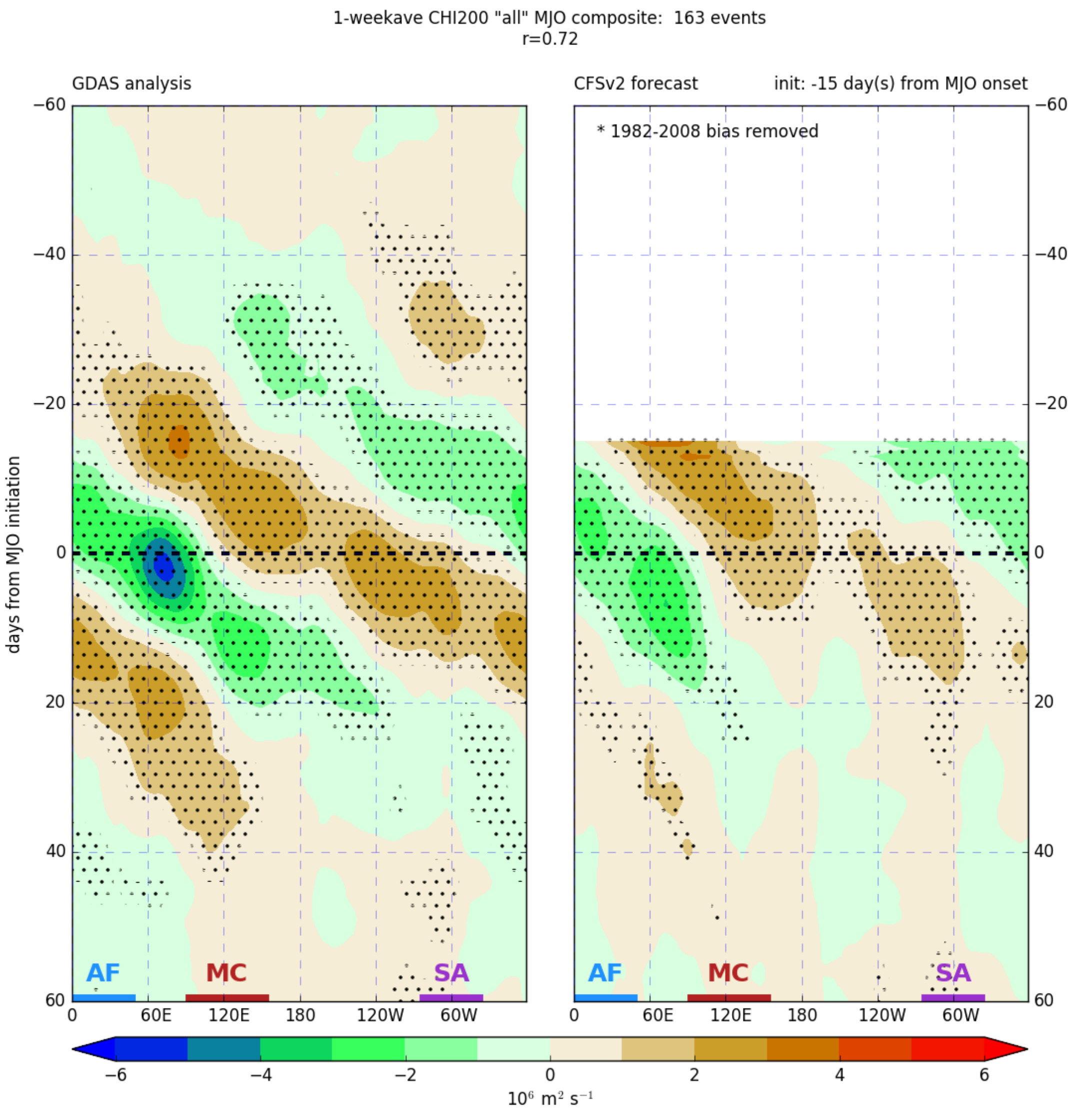

**~30-day lead:**

Very weak MJO-esq signal begins to appear

- phase speed too slow

*single-member forecasts

# CHI200 MJO composite: **de-biased** forecasts




**<u>~15-day lead:</u>**

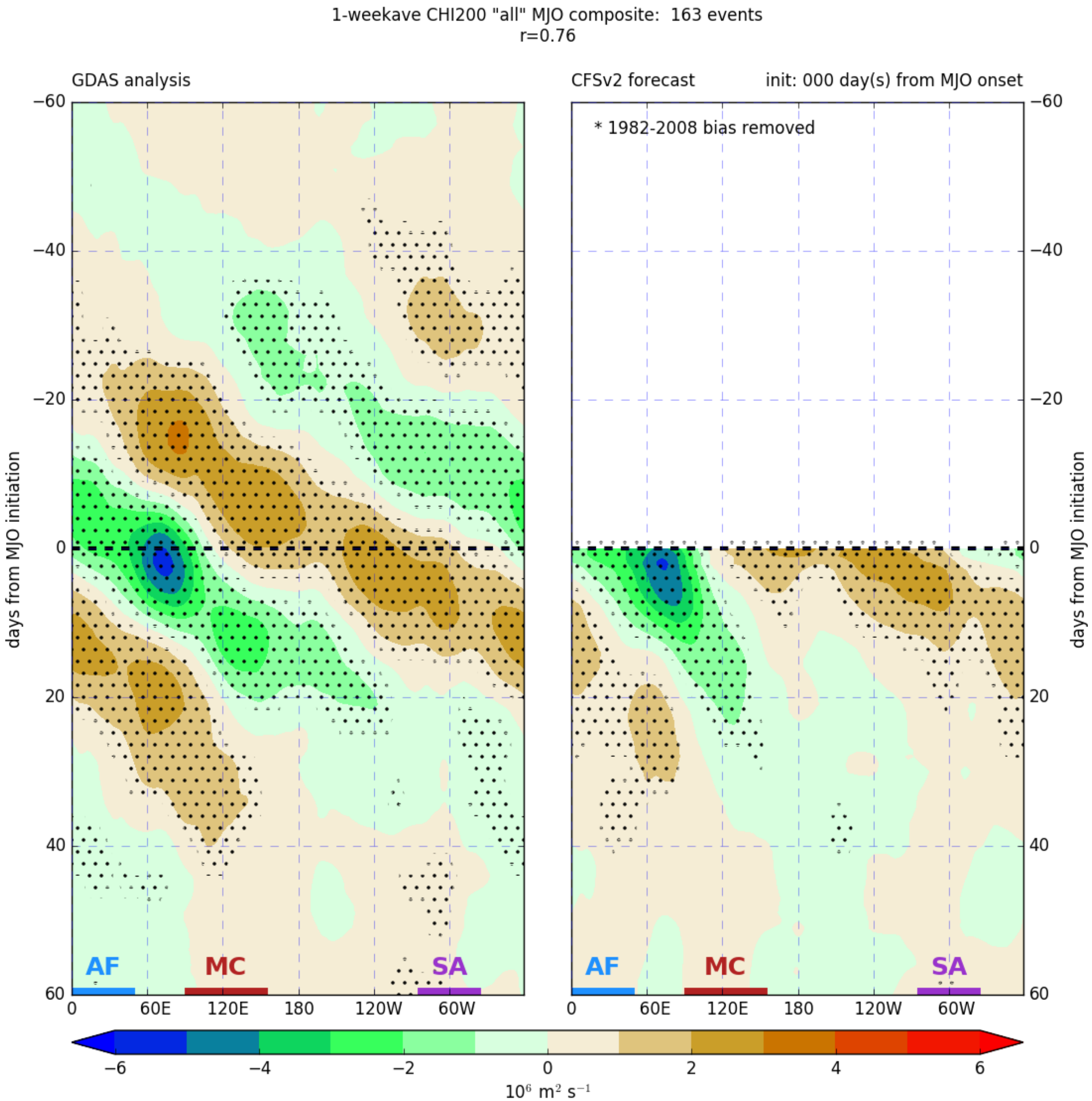
MJO still too weak

Improved phase speed

Maritime Continent Barrier

*single-member forecasts

# CHI200 MJO composite: **de-biased** forecasts




**<u>~0-day lead:</u>**
Convection strength is captured

MC Barrier and phase speed still an issue

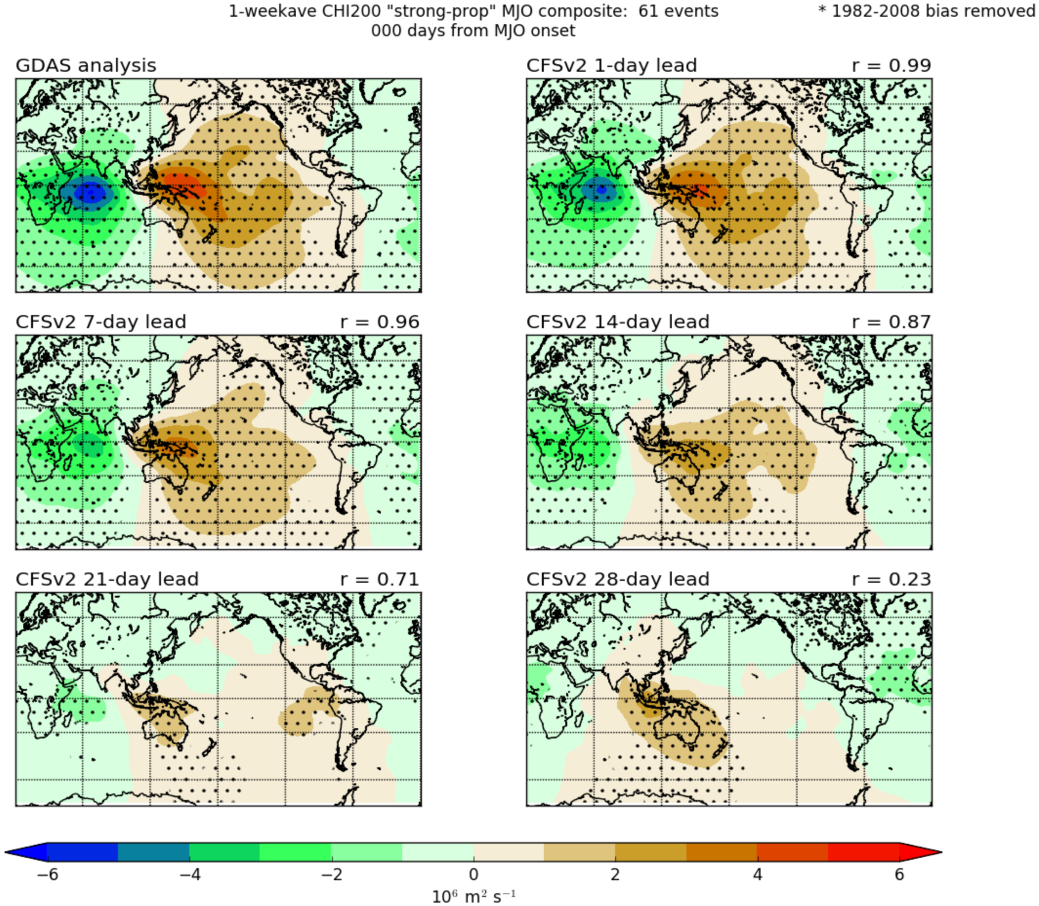
*single-member forecasts

# MJO composite maps: teleconnections

# MJO composite: **de-biased** forecasts

0 days **before** convective maximum

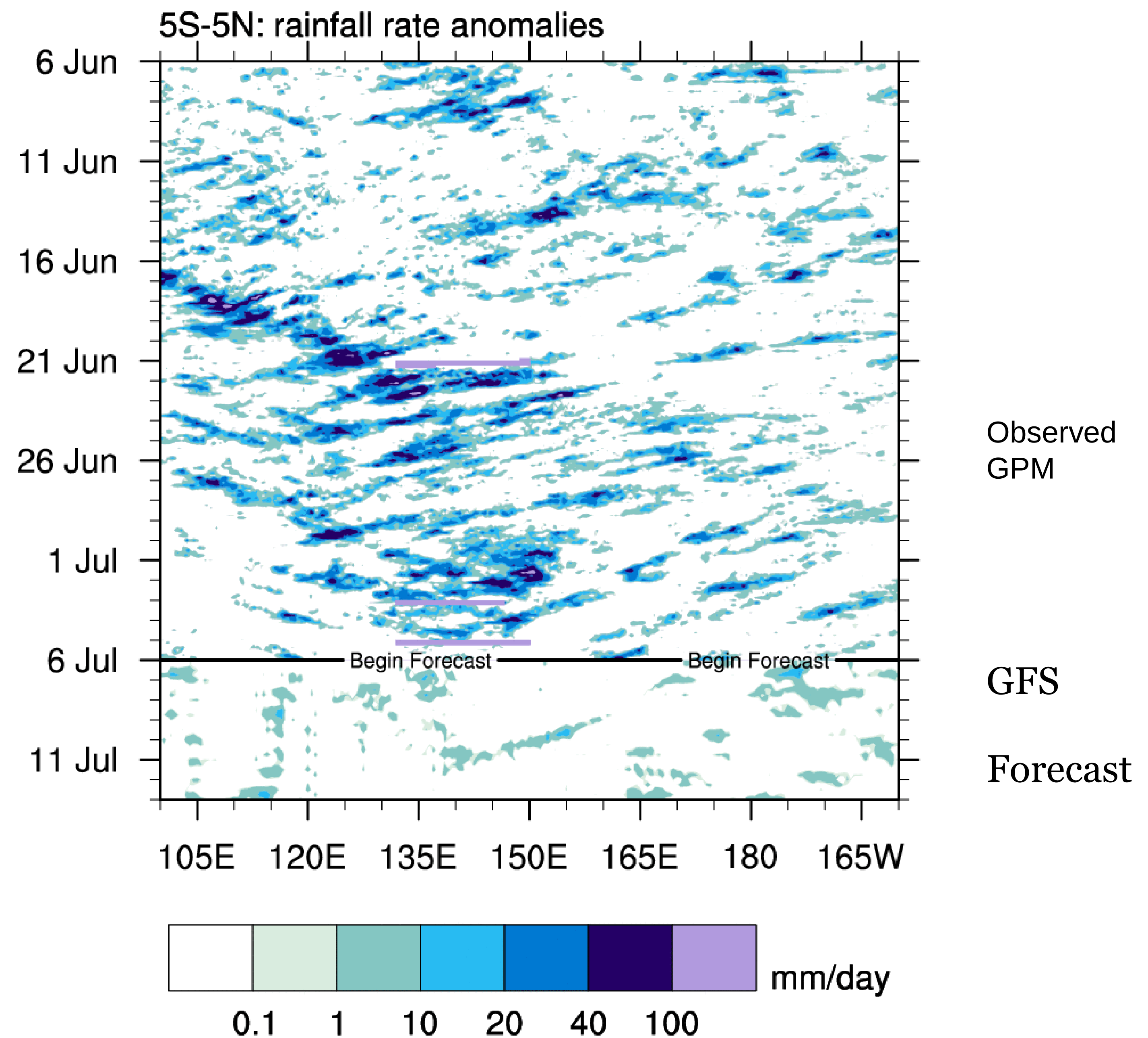
CHI200

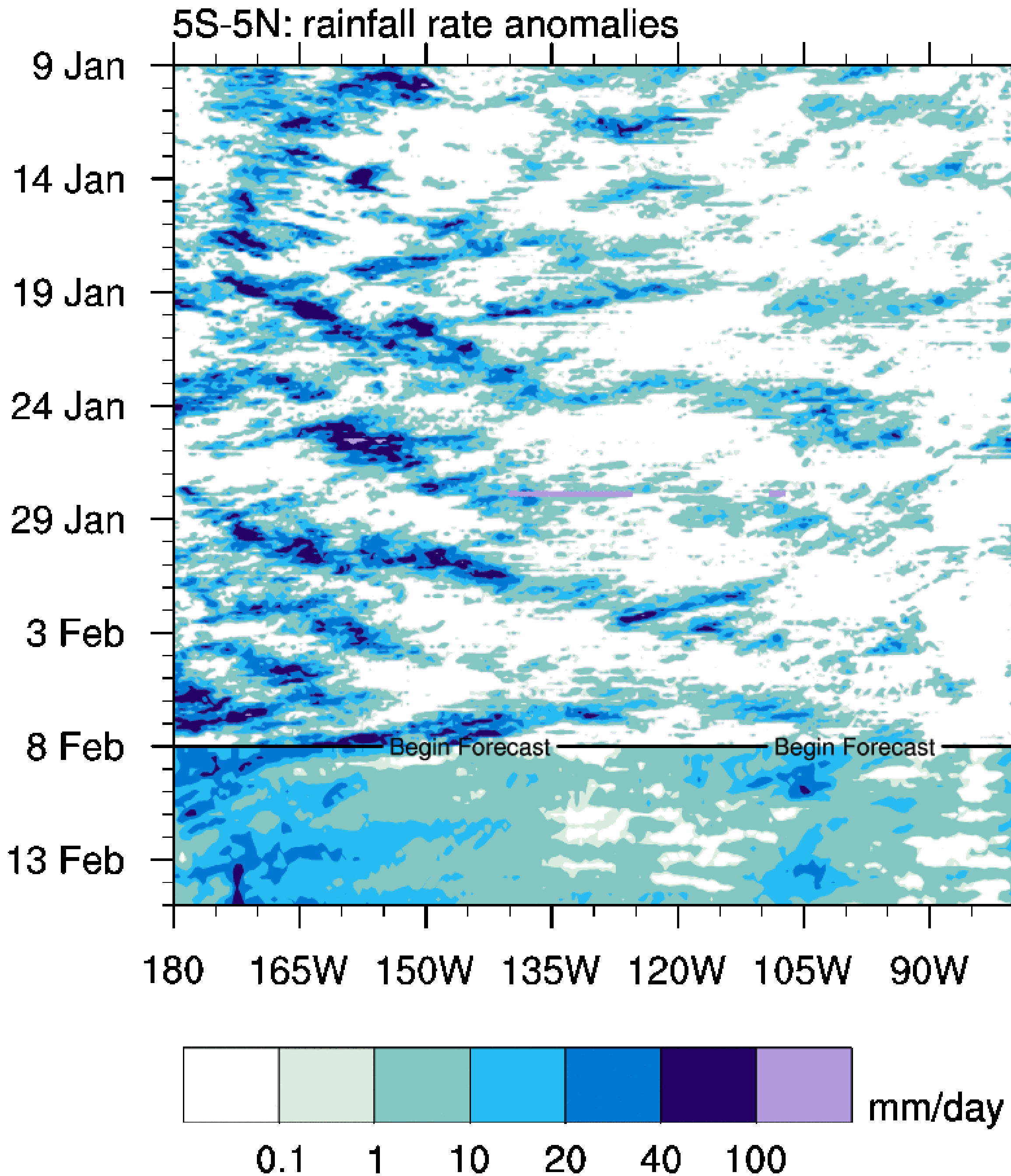


# Tropical Convection Failure Mode of CFS

- For short lead times, eastward-propagating tropical waves are accurately produced by the model
- But at longer lead times, the *nature* of modeled tropical convection degrades
  - Stationary features or **slowly** propagating waves take the place of realistic eastward-propagating tropical waves
  - Poorly defined or no MJO away from initialization time

# Hovmoller Diagrams in the Tropics Show the Problem

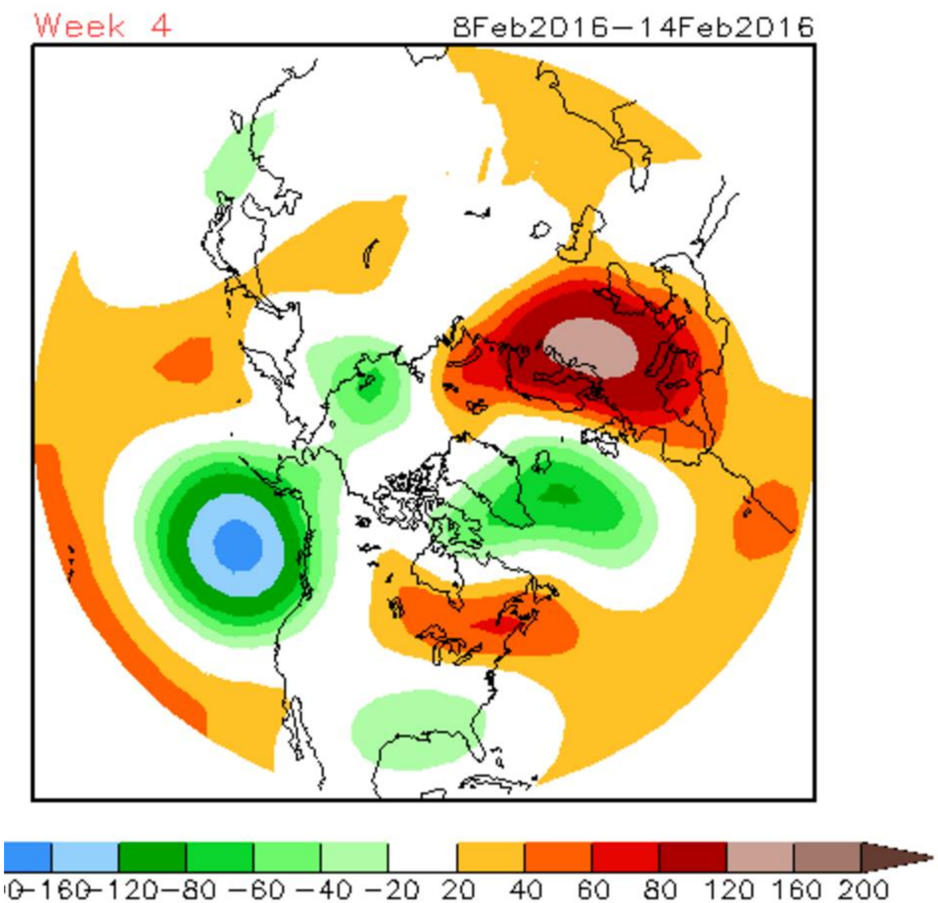

5S-5N: rainfall rate anomalies
6 Jun
11 Jun
16 Jun
21 Jun
26 Jun
1 Jul
6 Jul
11 Jul
Begin Forecast
Begin Forecast
105E
120E
135E
150E
165E
180
165W
0.1
1
10
20
40
100
mm/day
Observed
GPM
GFS
Forecast

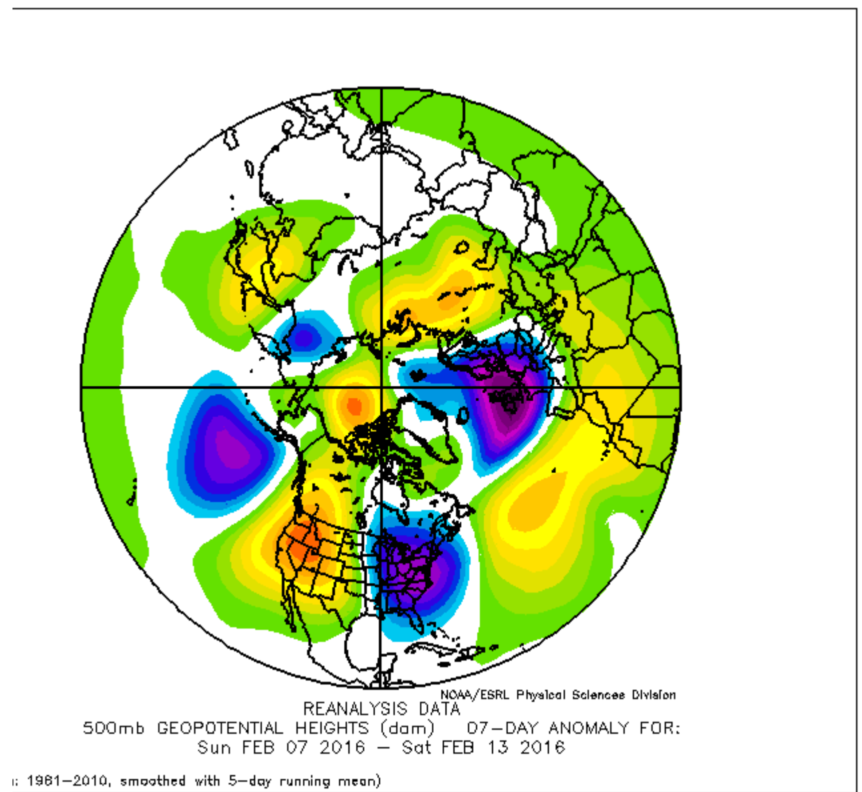

5S-5N: rainfall rate anomalies
9 Jan
14 Jan
19 Jan
24 Jan
29 Jan
3 Feb
8 Feb
13 Feb
Begin Forecast
Begin Forecast
180
165W
150W
135W
120W
105W
90W
0.1
1
10
20
40
100
mm/day

# Hypotheses

- CFS fails to produce propagating features because the CFS convective parameterization is unable to generate realistic convection and convectively-coupled waves
- Model biases, in particular, the wet bias in the West Pacific, may explain the slow MJO propagation  and the "Marine Continent Barrier"
- CFS subseasonal prediction and the ability to get realistic midlatitude teleconnection is undermined by its inability to produce realistic convection and convective propagation in the tropics.

# Is poor CFS convection and thus problematic teleconections the reason why CFS has constantly gotten sustained amplified wave patterns wrong over North America during the past several years?



# Hypotheses

- Such problems could be improved partially by improved convective parameterization.
- **The real solution is probably explicit simulation of convection with global models having convective-allowing resolution in the tropics**. This hypothesis should be tested.

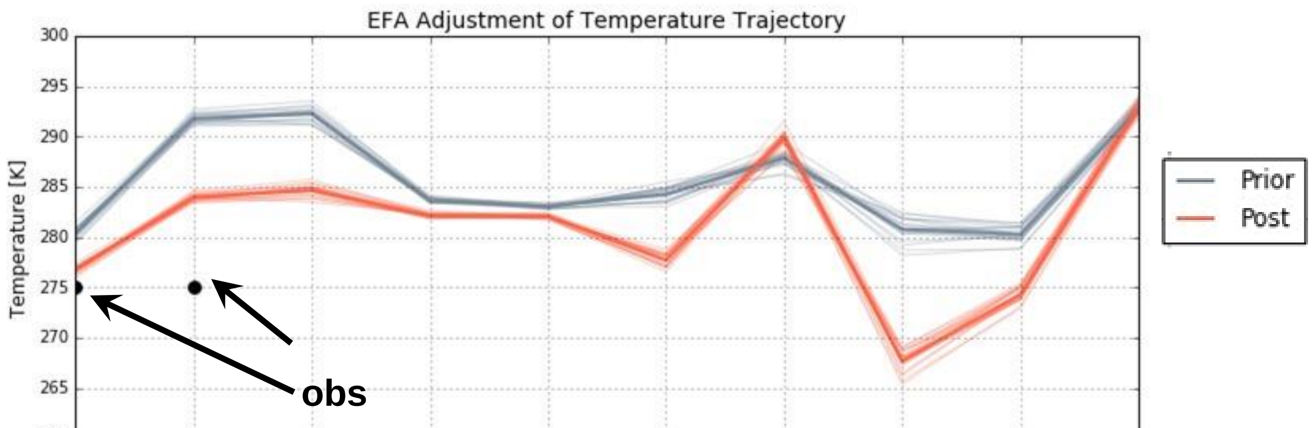
Anything we can try in the interim?

# Ensemble Forecast Adjustment
# EFA

Can we correct some of the CFS deficiencies statistically using ensemble temporal correlations?

# What is EFA?

**Ensemble forecast adjustment:** An offline data assimilation technique that uses *temporal* covariances in addition to spatial covariances to adjust the entire forecast using observations at one time (or several times).




**Can use temporal correlations for either averaged or non-averaged fields.**

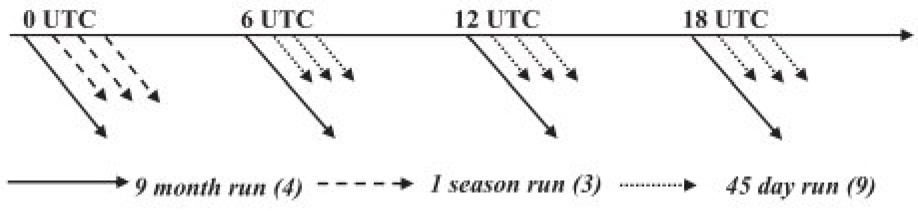
**Initial dataset:** The *operational* CFSv2 forecasts
- 16 members per day (rather than the 4 in the reforecast)
- specifically, the forecasts from DJF 2015-2016

# EFA dataset

**Forecasts used:**

CFSv2 ***operational*** forecasts from DJF 2015-2016.

- Initialized 4x daily with 4 ensemble members
  - **16 members per day**
- Lagged ensembles are assembled with members from the previous days' forecasts
  - **e.g., a 48-member ensemble contains members from the past 3 days**

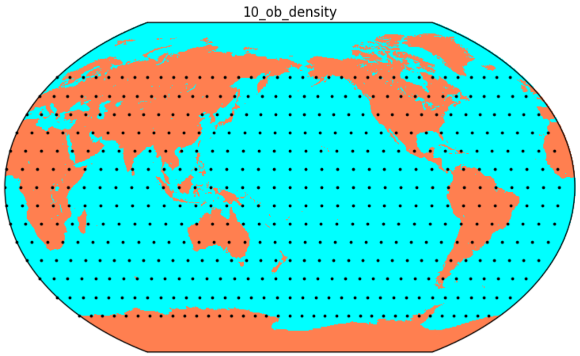


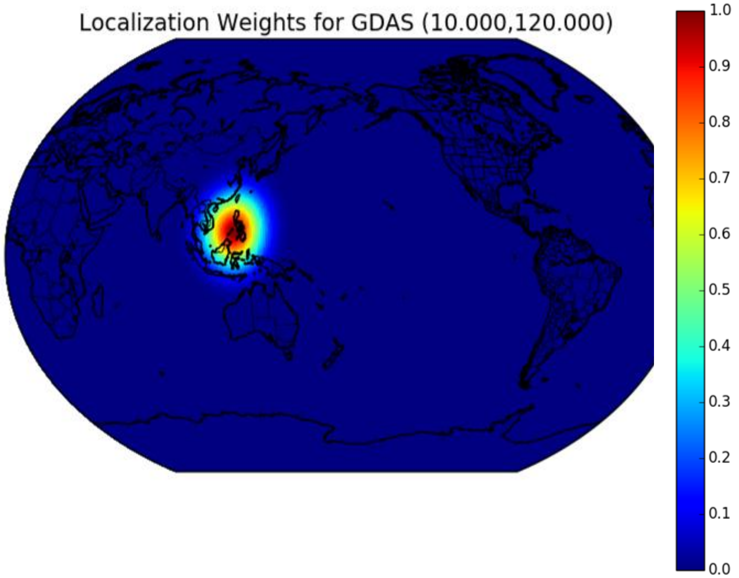

**Verification:**

GDAS analyses

# EFA: first experiment

- Adjusted a 21-day, unaveraged CFSv2 forecast using different lagged ensemble sizes
- Used GDAS analysis as "observations" by sampling every 10 grid points
- Assimilated observations at initialization time: December 01, 2015 00:00Z
- Evaluated forecasts of Z500 and CHI200
- Used Gaspari-Cohn spatial localization with a 2000 km half-width
- No temporal localization



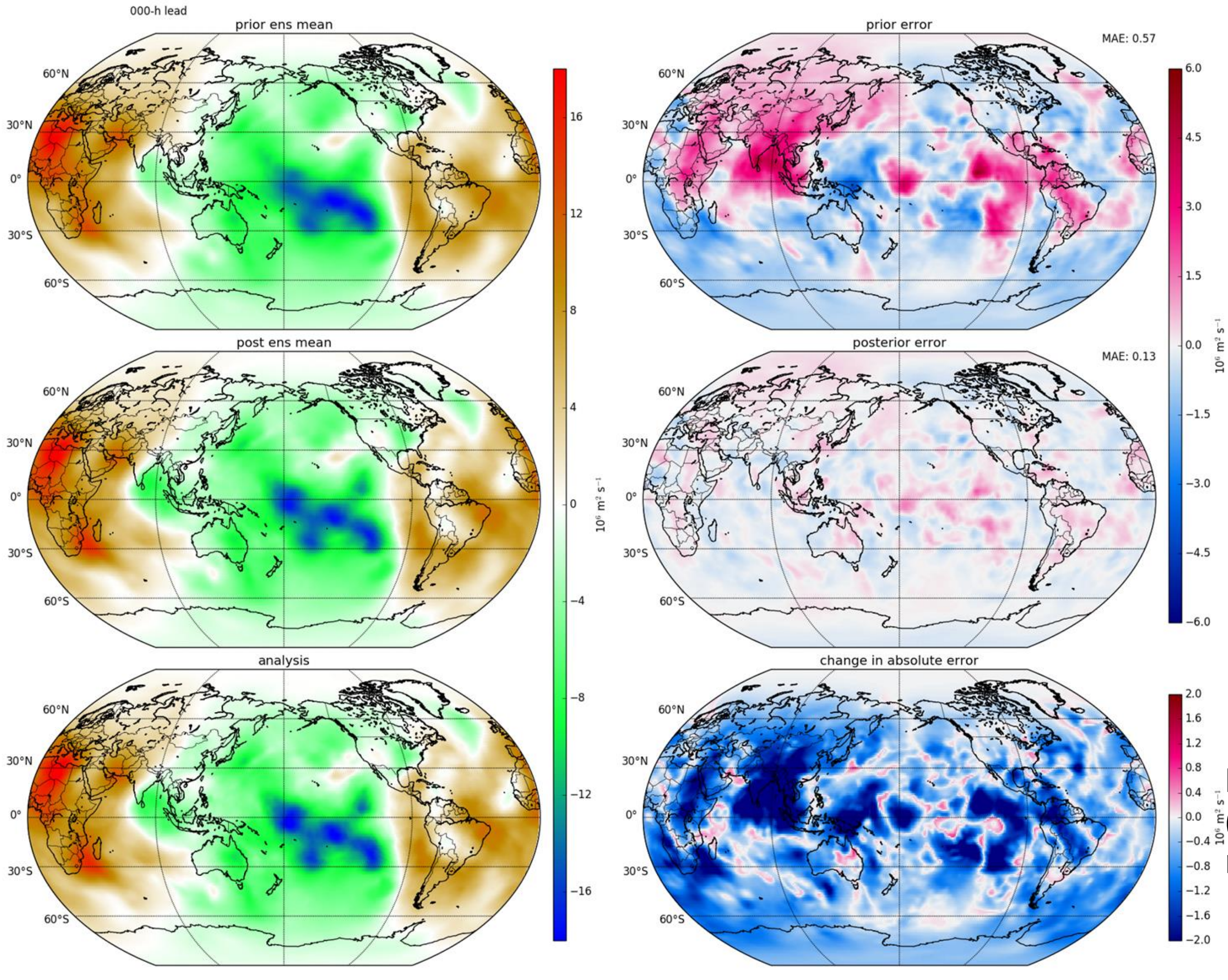
# EFA: first experiment: Can we improve the initial state from a lagged ensemble?

**CHI200** **F00 (days)**

Prior

Post

GDAS

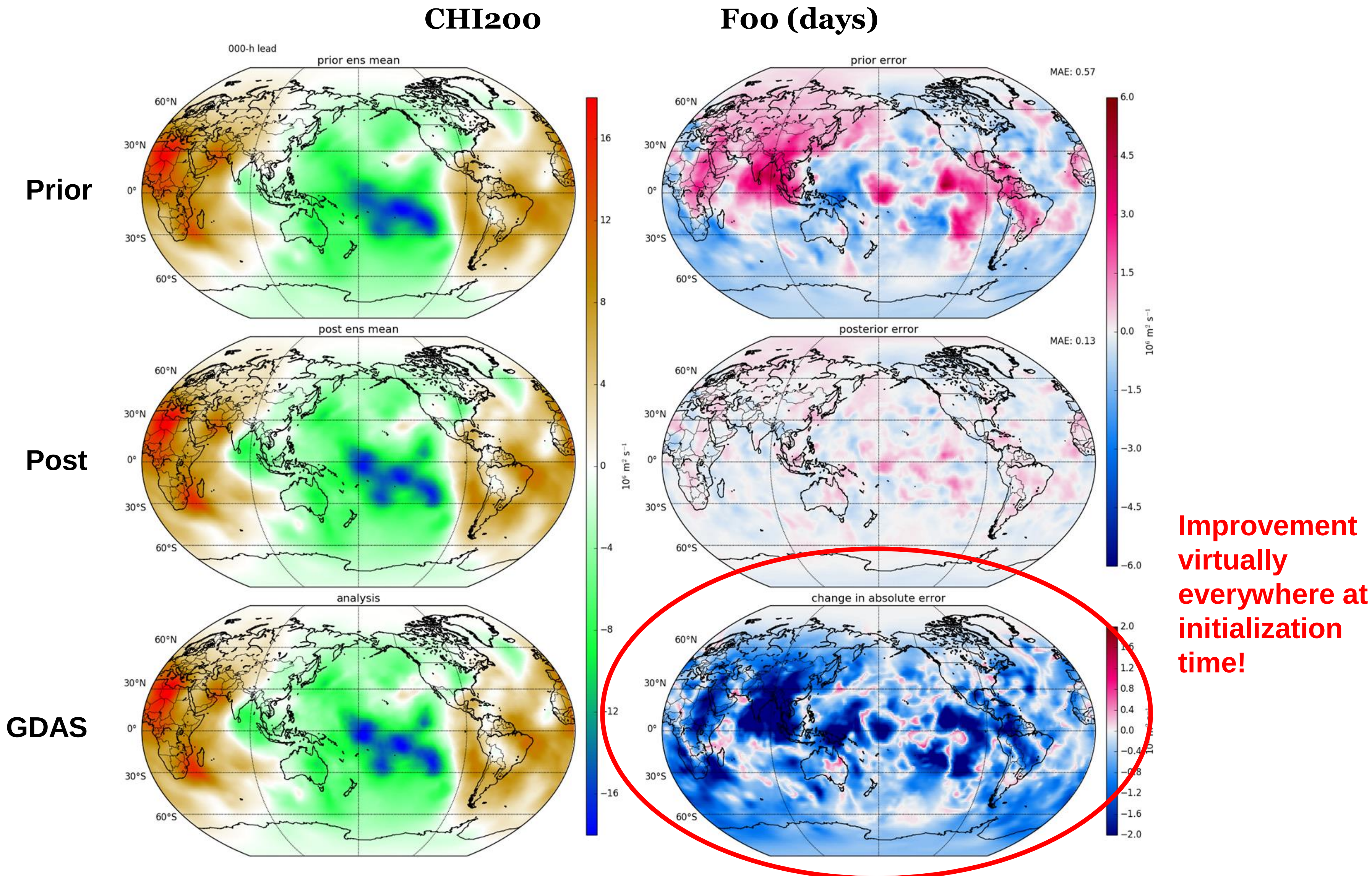



Prior - GDAS

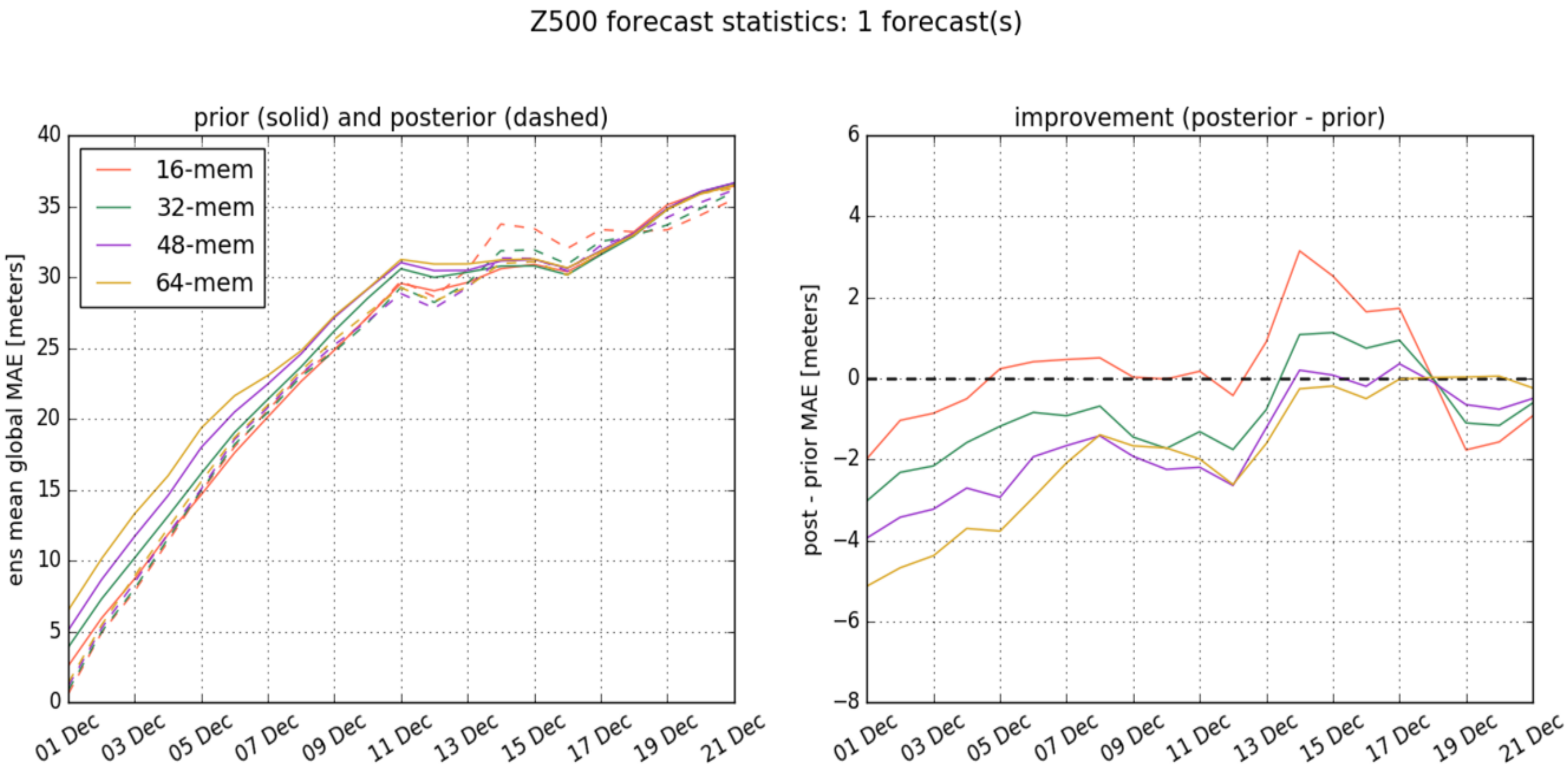
Post - GDAS

Improvement (blue = error reduction)

# EFA: first experiment: Improve the initial state?



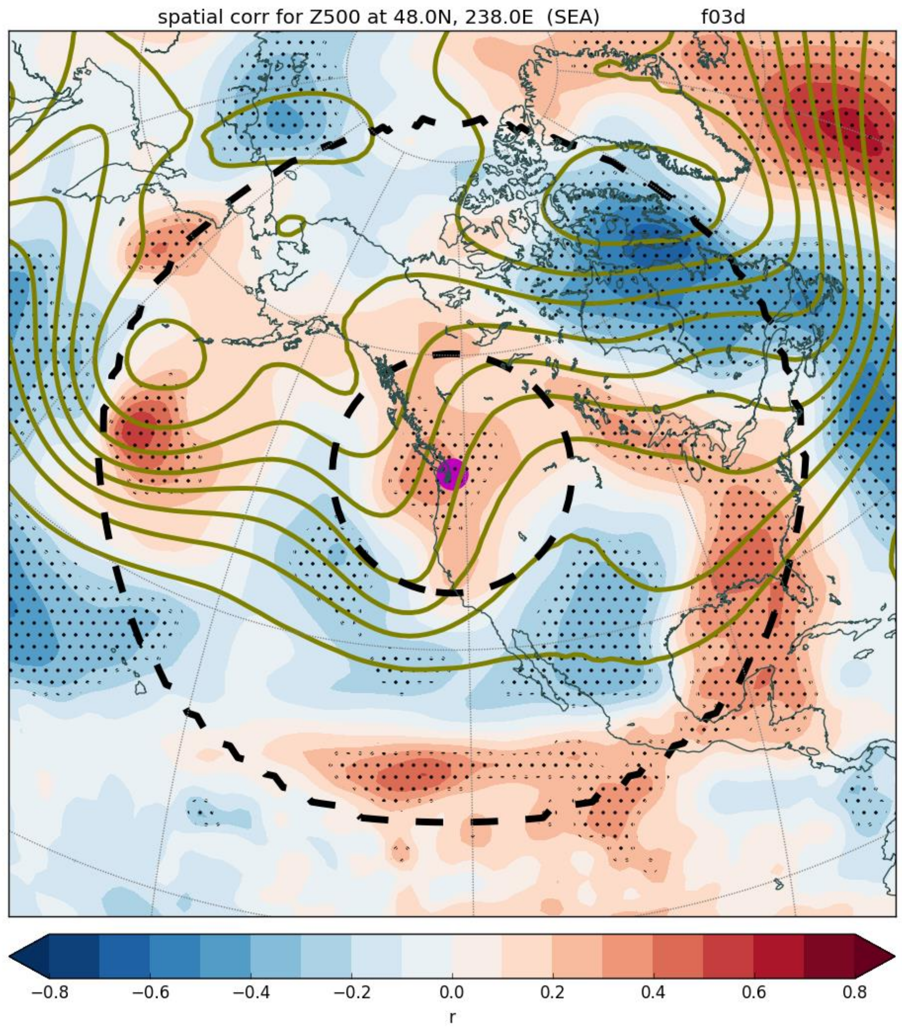
# EFA first experiment: Global MAE at 500 hPa: Some Improvements




Bottom line: We can improve a lagged ensemble but only for the first two weeks..

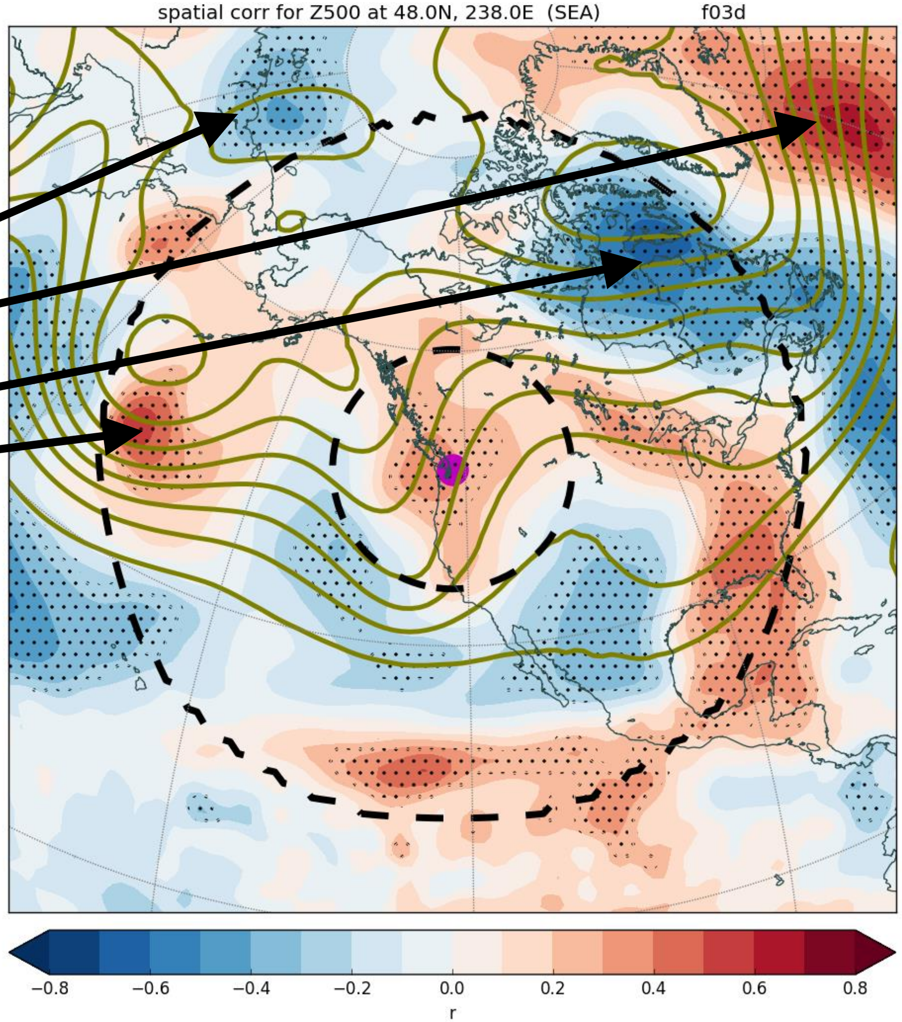
# Next step: significance-based localization of our modifications

Spatial localization (e.g., Gaspari-Cohn) misses statistically significant covariances outside the localization radius



# EFA: significance-based localization

Only update the points that are significantly correlated with the observation



## EFA development and testing. Upcoming work:

- **Adjust prior ensemble inflation and observational error to optimize skill improvement**
- **Do assimilation with observation localization based on statistical significance**
- **Process all the forecasts for DJF ‘15-’16**
- **Temporally average the forecasts prior to assimilation → averaged forecasts should have higher temporal covariances**

If EFA works in enhancing subseasonal prediction, can go forward with with higher resolution downscaling over the western for weeks 3-4.

If not, since it does appear to help with weeks 1-2, could use to drive downscaling for that period (particularly week 2)

But since poor convective propagation is obviously a major issue, why not fix that in the best way possible?

# A proposal: **the grand experiment for subseasonal forecasting**

- Run an extended global forecasting experiment with convection-allowing resolution (2-4 km) over the tropics.
- 1-2 month simulation
- CRAY has offered the computer time.

# Grand Experiment

- Hypothesis:  such a simulation will produce far better convection and propagation in tropics and will greatly enhance the fidelity of midlatitude teleconnections and thus subseasonal prediction.
- Ready to do this now, with support of a grad student.
- The operational computer power to do this will soon (or is) available.

# It is the Apollo Project of UW NWP. But much less expensive

# The End