GFDL's high-resolution seasonal climate prediction system: modeling, initialization and predictability

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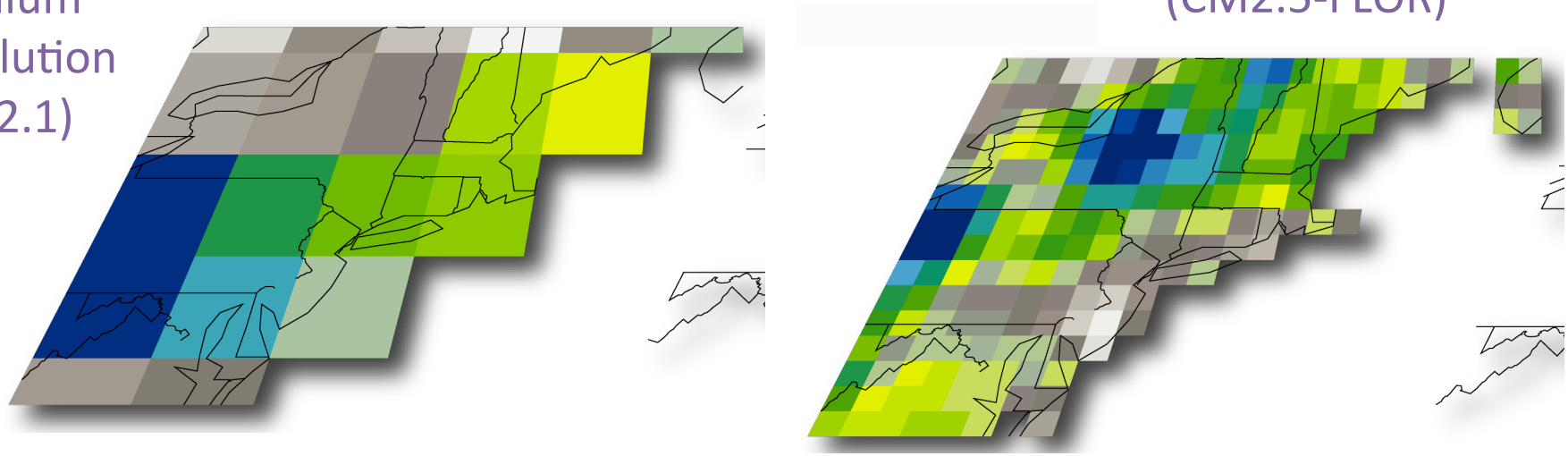
GFDL FLOR/HiFLOR: High-resolution coupled seasonal prediction system for regional climate and extremes (Vecchi et al. 2014, *Murakami et al. 2015*)

Precipitation in Northeast USA

Medium resolution (CM2.1)

High resolution (CM2.5-FLOR)



Delworth et al. (2012), Vecchi et al. (2014)

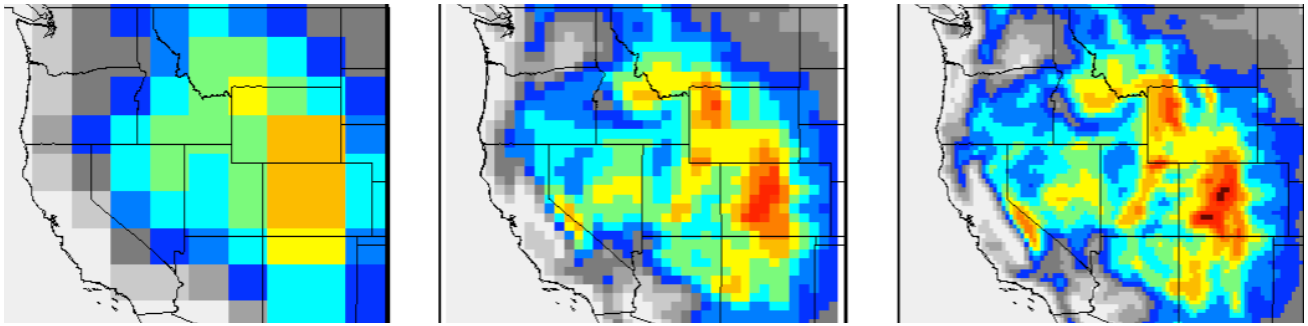
Modified version of CM2.5 (Delworth et al. 2012):

- 50km cubed-sphere atmosphere
- 1° ocean/sea ice (low res enables prediction work)

Contributed to NMME from March 2014

Computation cost

Model elevation



	CM2.1/LOAR	FLOR	HiFLOR
Atmospheric Grid Cell Size	*200 km (~160 miles)*	*50 km (~30 miles)*	*25 km (~16 miles)*
Computing Cost	*1*	*20*	*120*
Size of 5 Year of Daily Data File (ex: Total Precipitation)	*91 MB*	*1.5 GB*	*7.1 GB*

Tropical cyclones (TCs) and extratropical storms (ETSs) cause weather/ climate extremes for natural disasters (winds, flooding, blizzards)

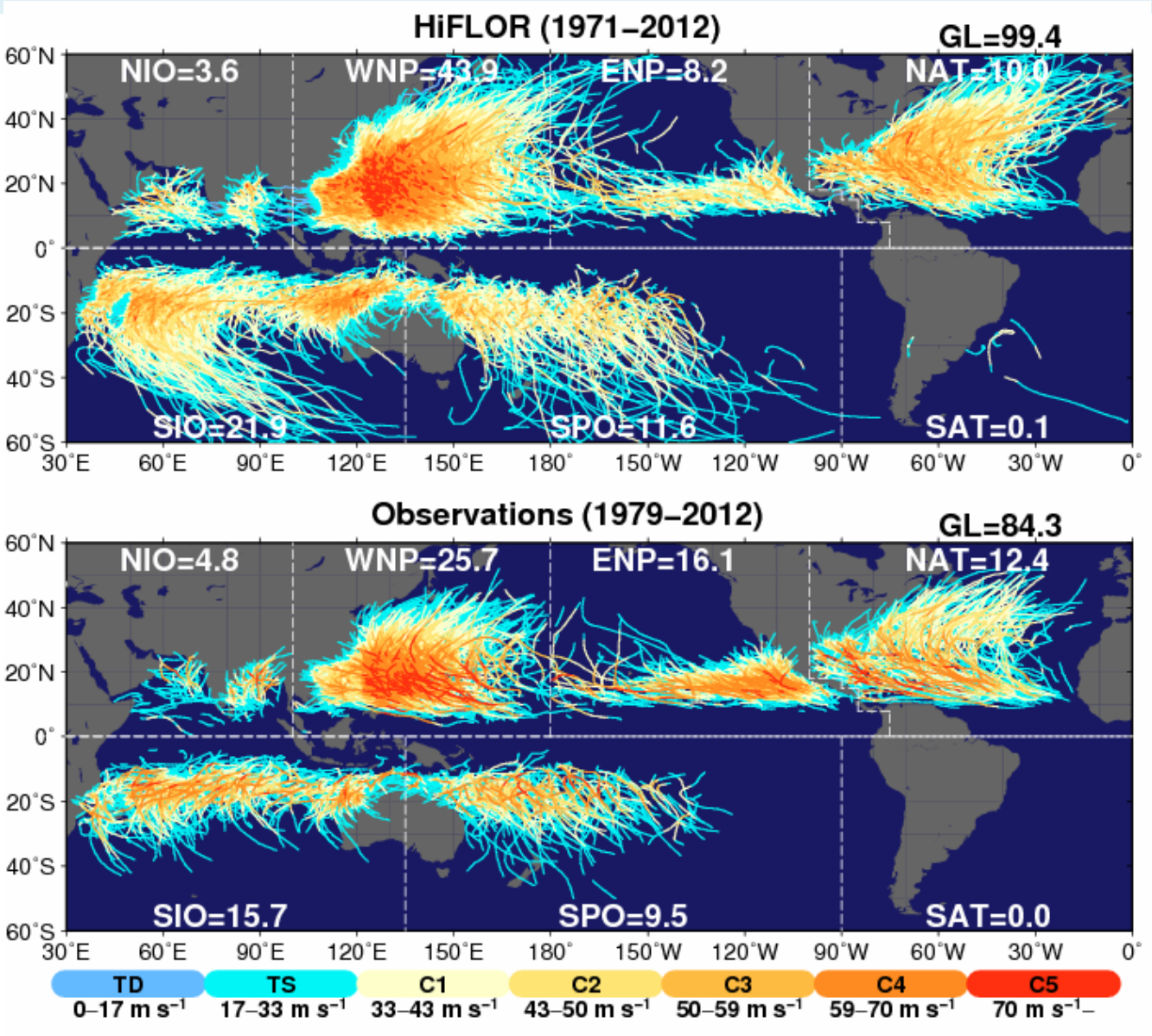
- **Hypothesis:** Enhanced resolution improves simulation (fidelity) and prediction of regional climate & extremes (TCs and ETSs).

- Tropical cyclones (TCs)

- GFDL-CM2.1 (~200x250km atmosphere/land, 1° ocean/sea ice): No-TC
- GFDL-FLOR (50km atmosphere/land): TC-permitting
- GFDL-HiFLOR (25km atmosphere/land): TC-category-resolving

- Extratropical storms (ETSs)
- All the three models resolve ETSs
- Can we still improve ETSs with high-res models?

HiFLOR: doubling atmospheric resolution of FLOR (cost 6x) allows model to simulate Cat. 4-5 TCs (most destructive storms)

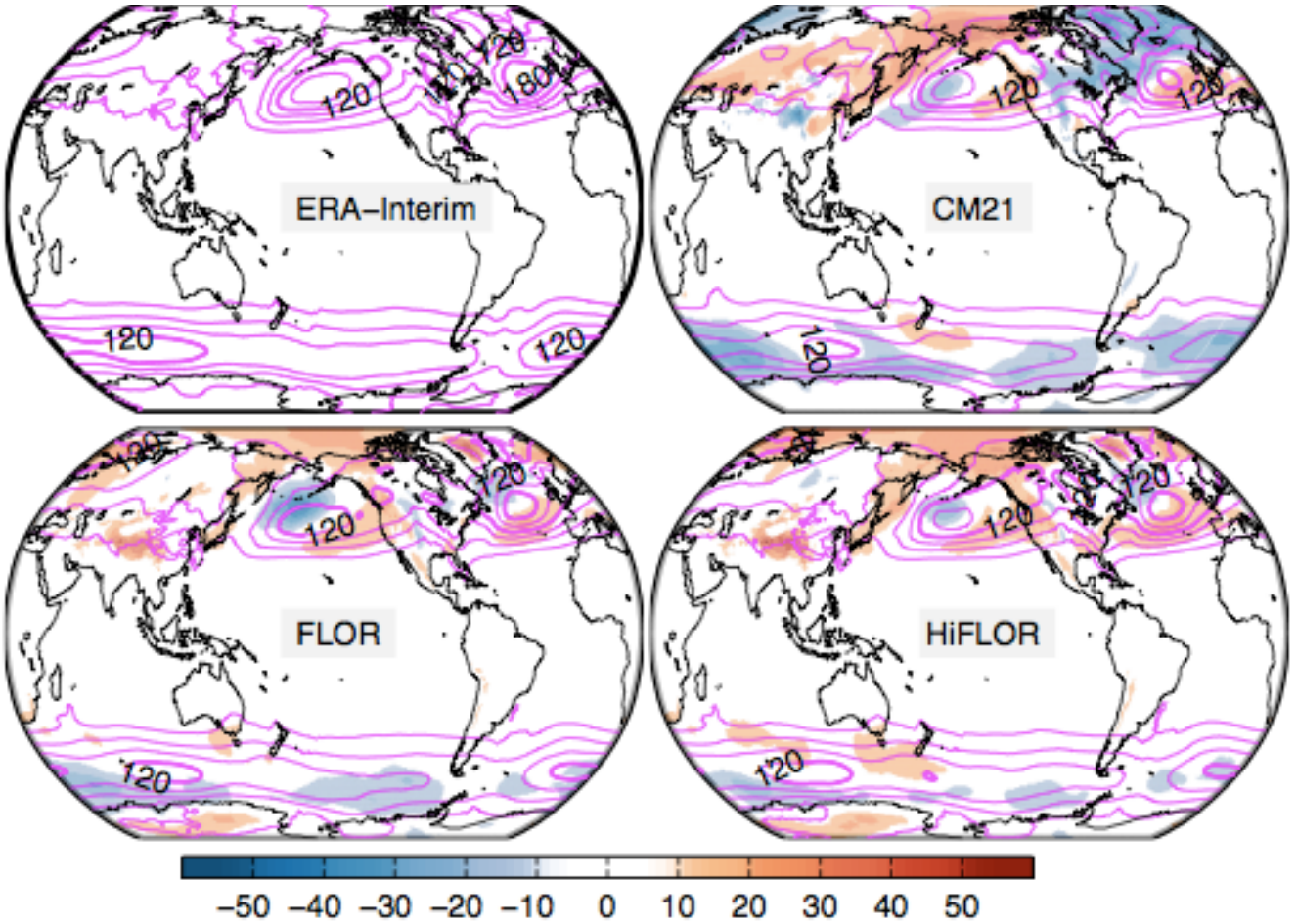


Murakami et al. (2015)

Fidelity of TCs

Model fidelity of ETS: Can we do it better using high-res?

DJF ETS: Var(filtered 6-hourly SLP)



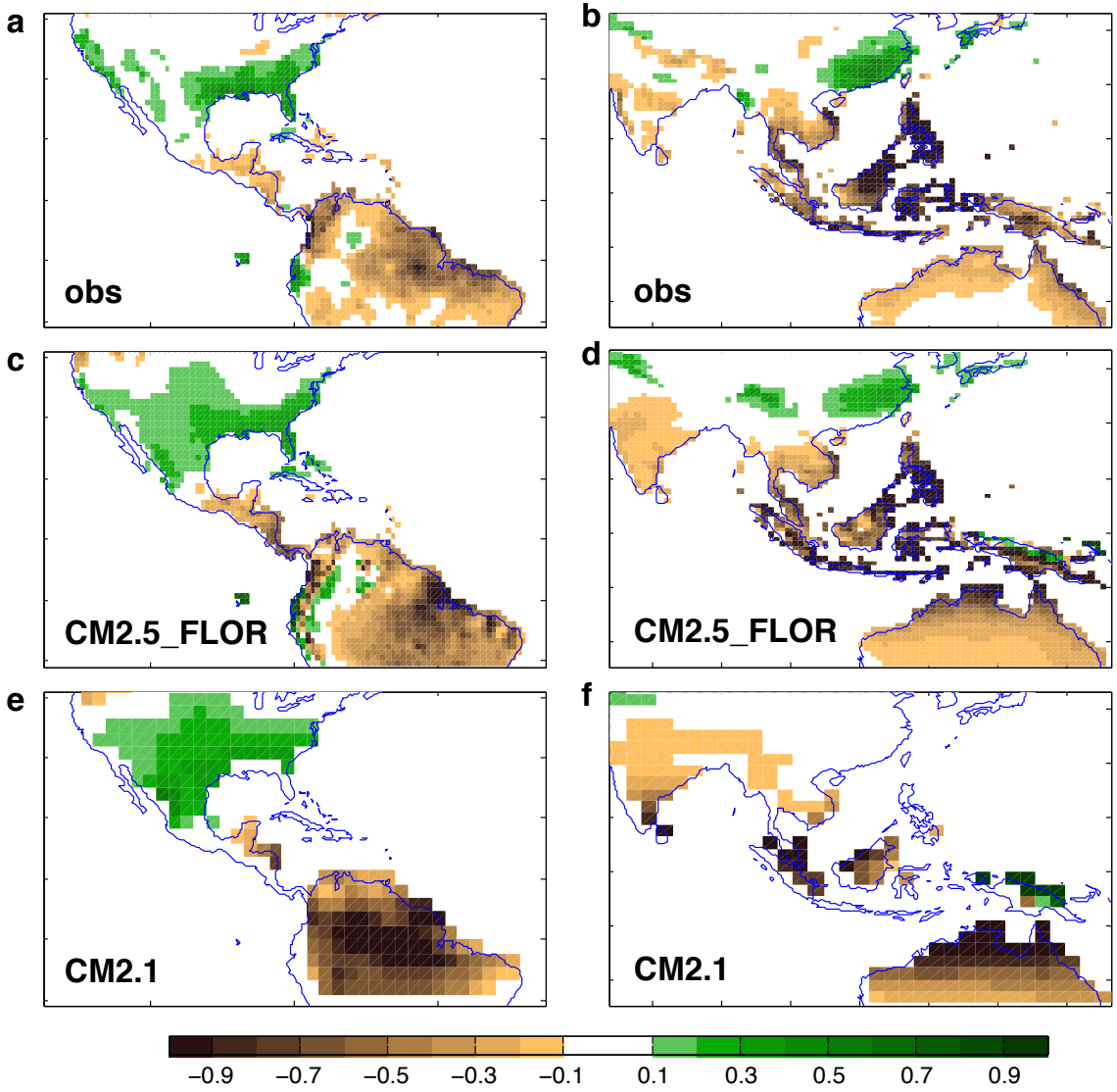
Contour: ETS climatology; Shaded: Model bias

FLOR/HiFLOR improves climatological ETS over North America, North Atlantic, Eurasia and Southern Ocean.

GFDL-FLOR initialization: Phase 1, NMME

- Ocean & sea ice initialized from CM2.1 V3.1 EnKF Assimilation
- Atmosphere and land initialized from ensembles of AGCM driven by observed SST (*i.e.,* only information contained in SST and radiative forcing in atmos/land ICs)
- Uncoupled initialization: high-res ensemble coupled data assimilation computationally expensive.
- References: Jia et al. (2014, J. Clim.), Msadek et al. (2014, J. Clim.), Vecchi et al. (2014, J. Clim.), Yang et al. (2015, J. Clim.), Murakami et al. (2015, J. Clim.)

Regional ENSO rainfall pattern improved in FLOR (skill up too)

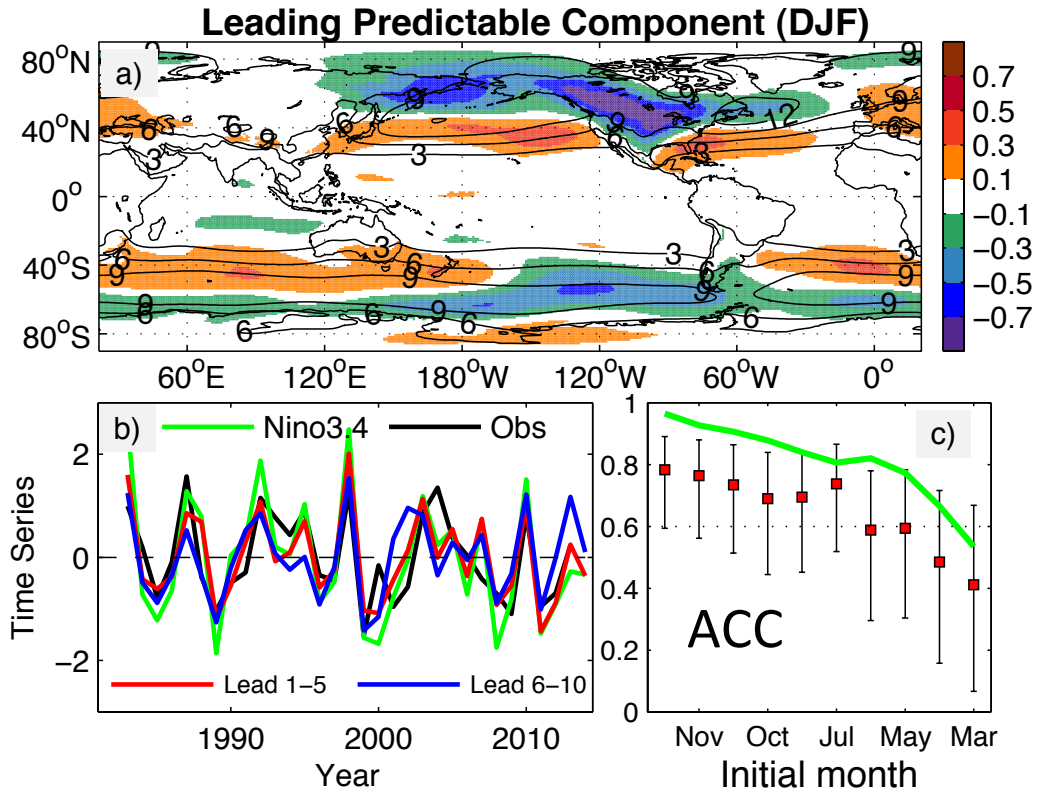


Most predictable precip pattern (mm/day)

(Jia et al. 2015, J. Clim.)

ETS predictability: Leading Predictable pattern of storm tracks is ENSO-related, and is predictable up to 9 month lead time.

Storm track (DJF) : std(24-hour difference filtered SLP)

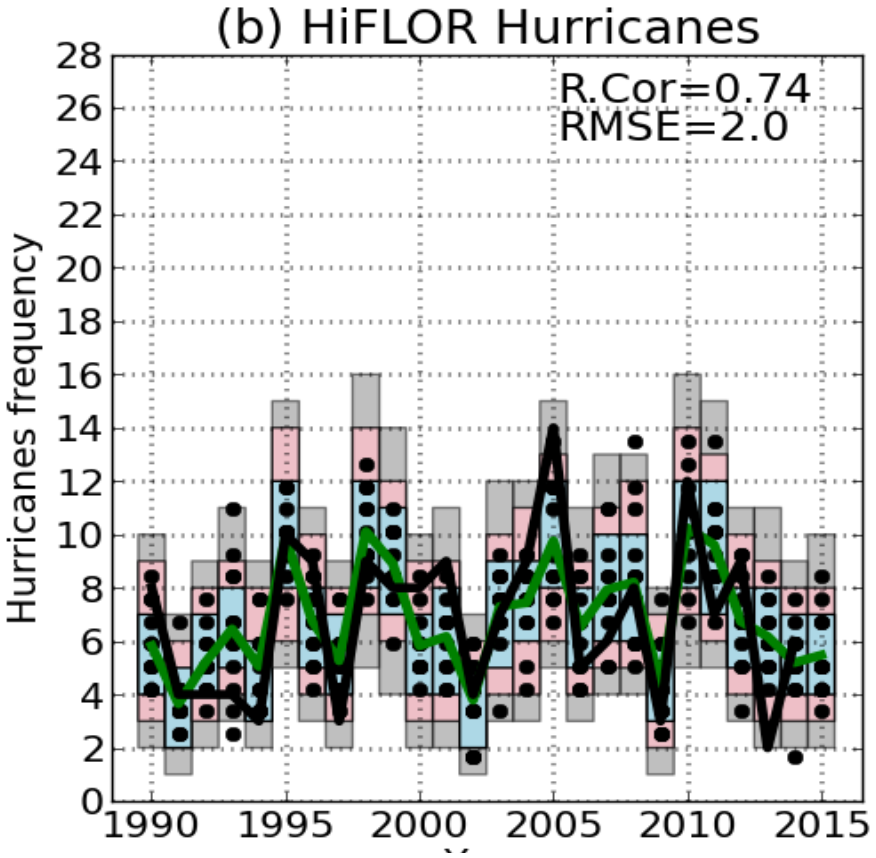


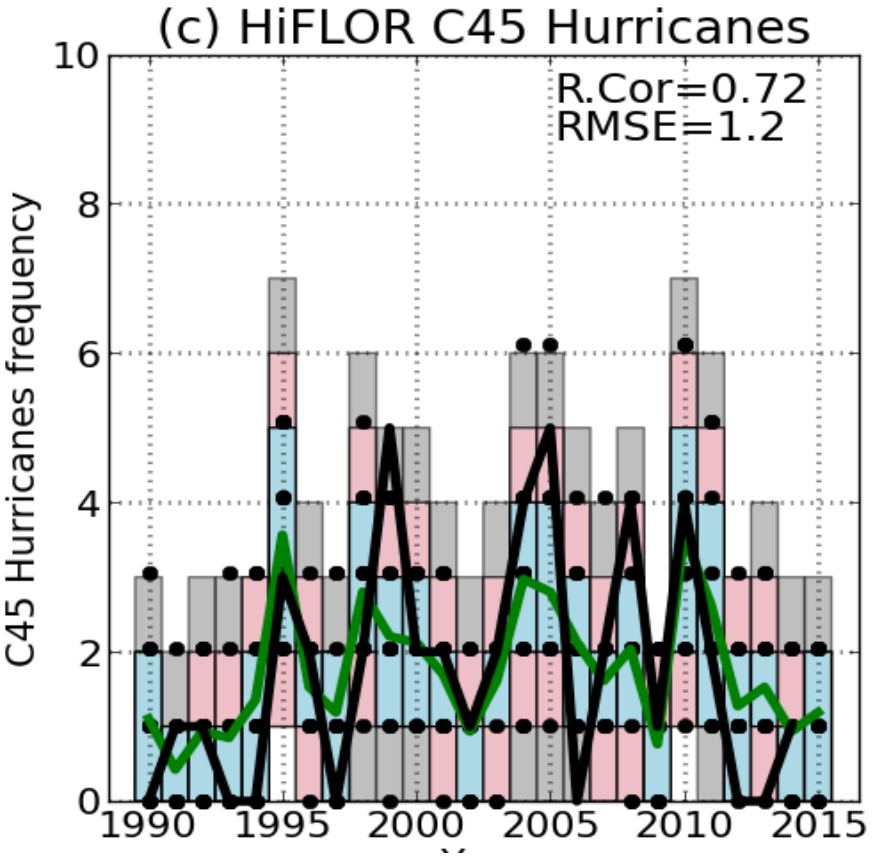
- Storm reduction over most North America
- Time series highly correlated with NINO3.4
- Skill is comparable with predicting ENSO

FLOR

Yang et al. (2015, J. Clim.)

1-July Initialized Retrospective NA TC forecasts with HiFLOR (25km FV3 atmosphere coupled to 1° MOM5)





Prediction of TCs

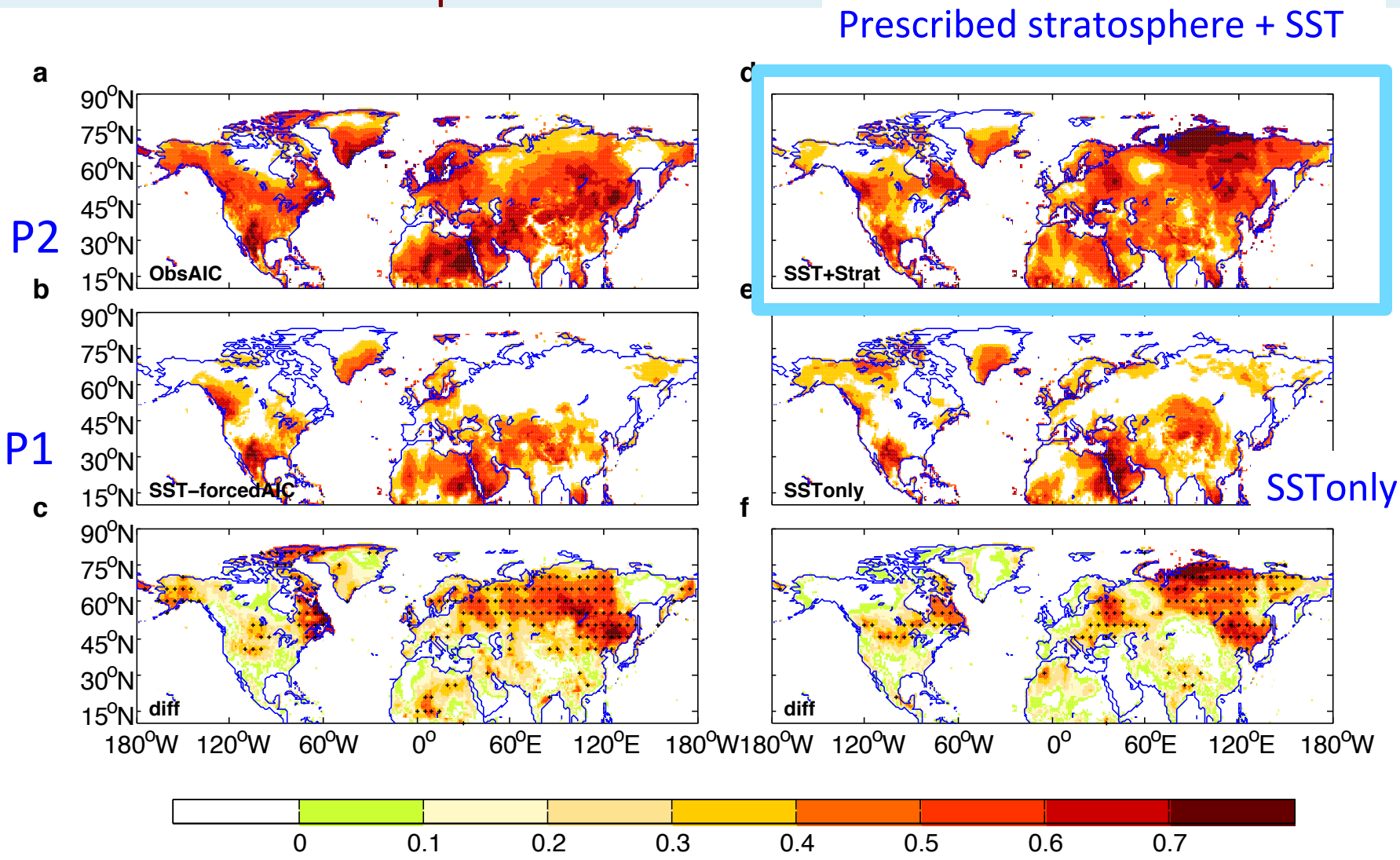
Murakami et al. (2016)

GFDL-FLOR initialization: Phase 2, research mode

- Ocean & sea ice initialized from CM2.1 V3.1 EnKF Assimilation
- Atmosphere and land initialized from a coupled FLOR simulations with atmosphere state relaxed to MERRA (CFSR) reanalysis , SST restored towards observed SST
- Predictability source arising from observed ocean/sea ice and atmosphere/land in P2
- References: Jia et al. (2016, J. Clim.), Jia et al. (2017, J. Clim.), Yang et al. (2017, J. Clim.)

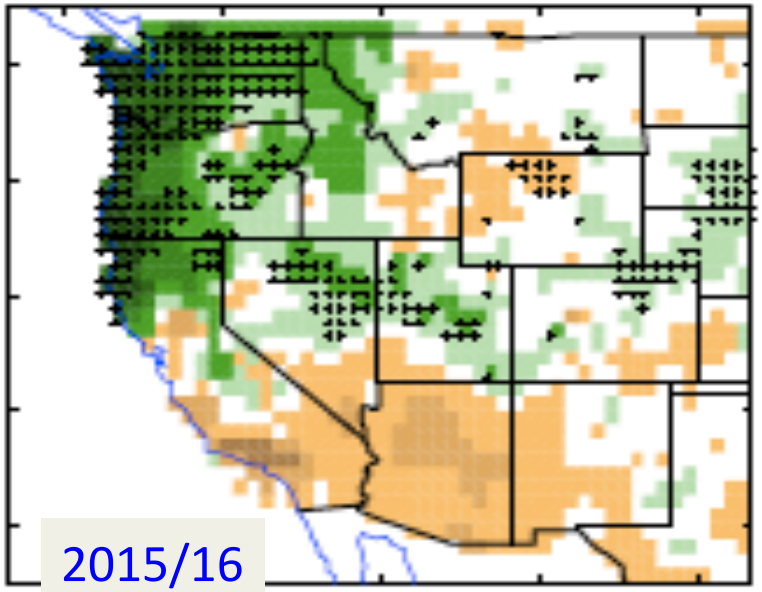
Seasonal (MAM) Temperature Prediction

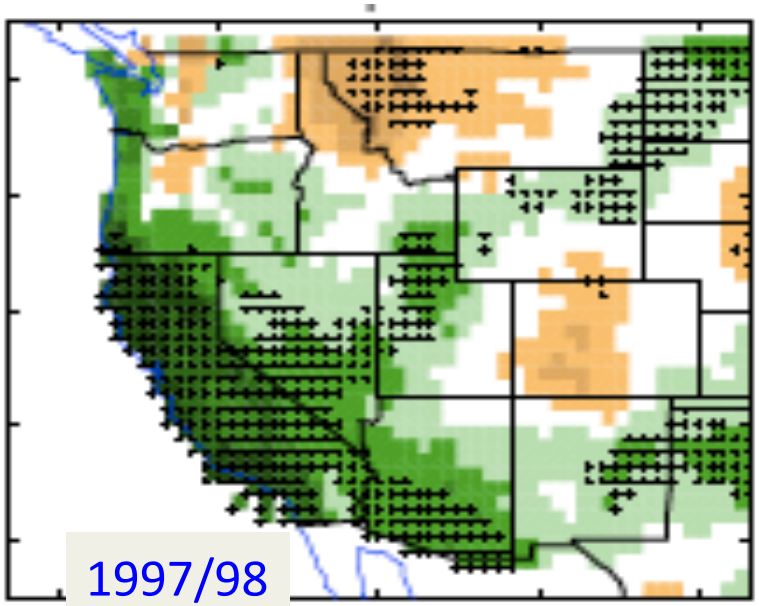
The Role of the Stratosphere

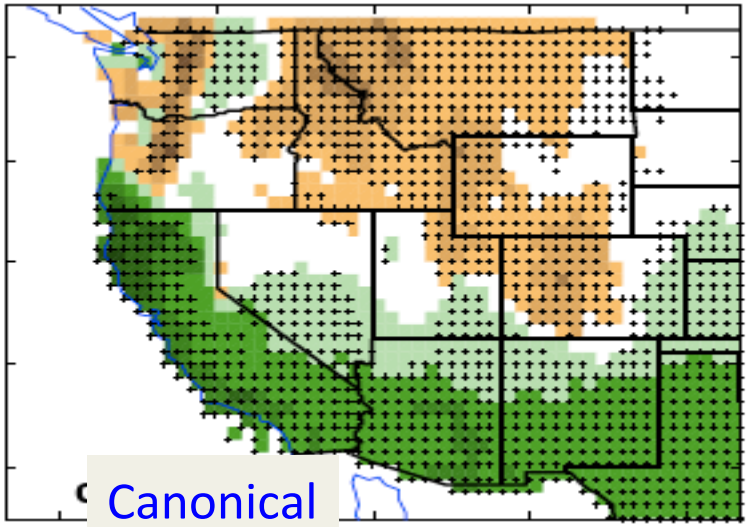


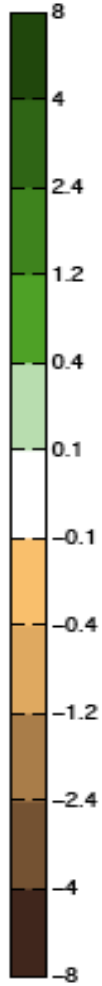
Source: Jia et al. 2017, Submitted

Flipped precipitation pattern over the Western US (WUS) during 2015/16 winter VS the canonical El Niño pattern







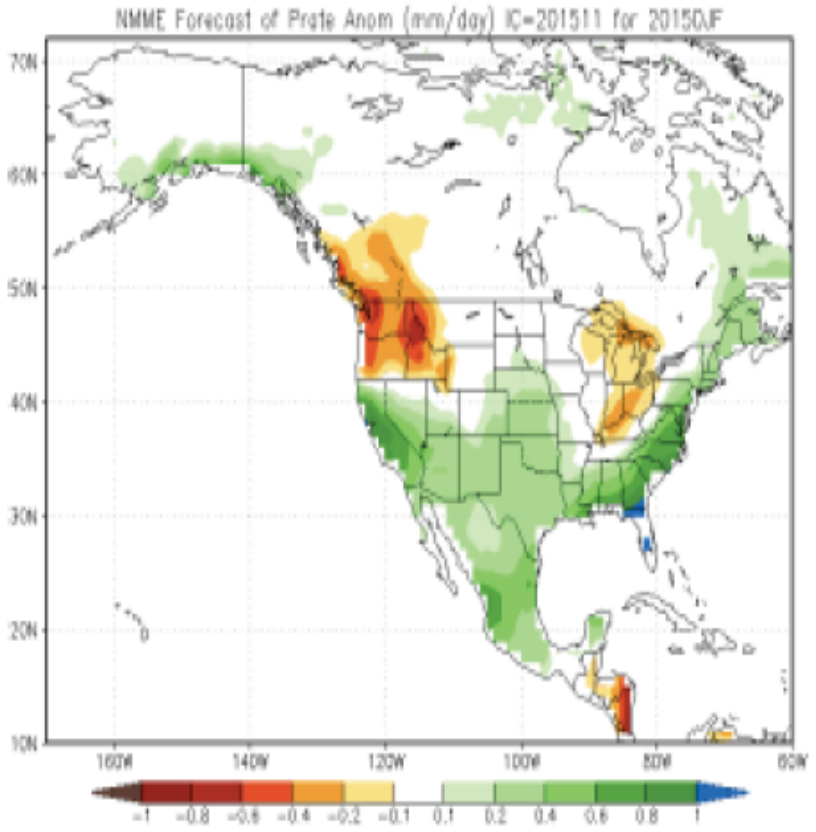


mm/day

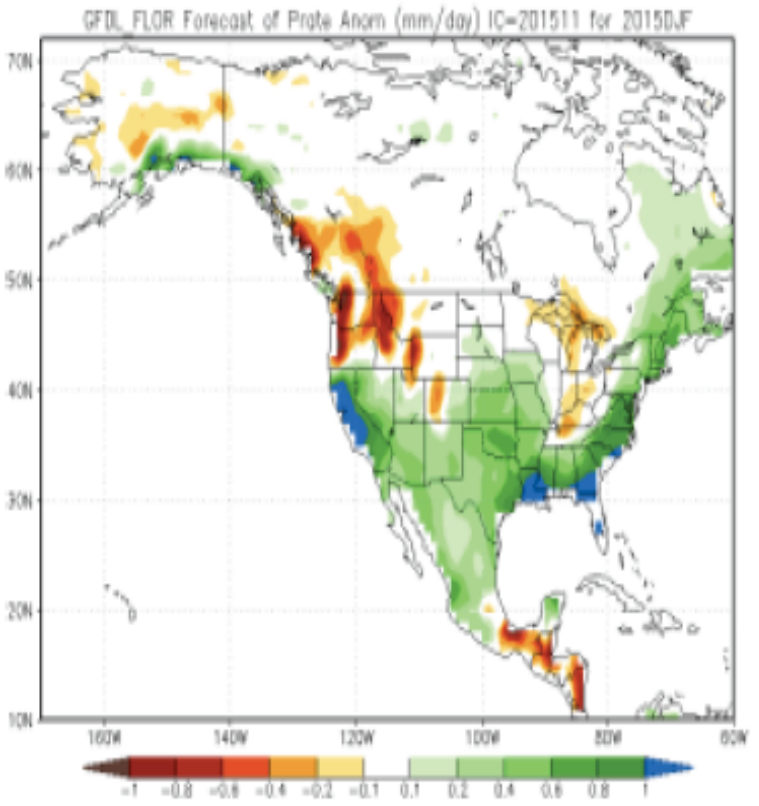
- The canonical El Niño pattern: wet (dry) over the southern (northern) half over the WUS.
- 2015/16: almost opposite to canonical pattern
- 1997/98: similar to the canonical pattern.

NMME models (including GFDL-FLOR) predicted a canonical El Niño precipitation pattern over the WUS.

NMME



GFDL FLOR



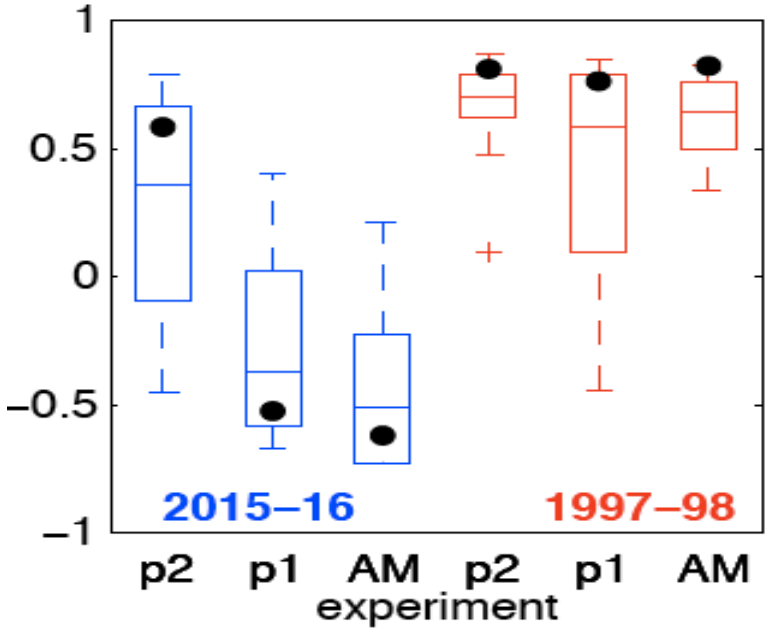
http://www.cpc.ncep.noaa.gov/products/NMME/

I.C.: 1Nov2015

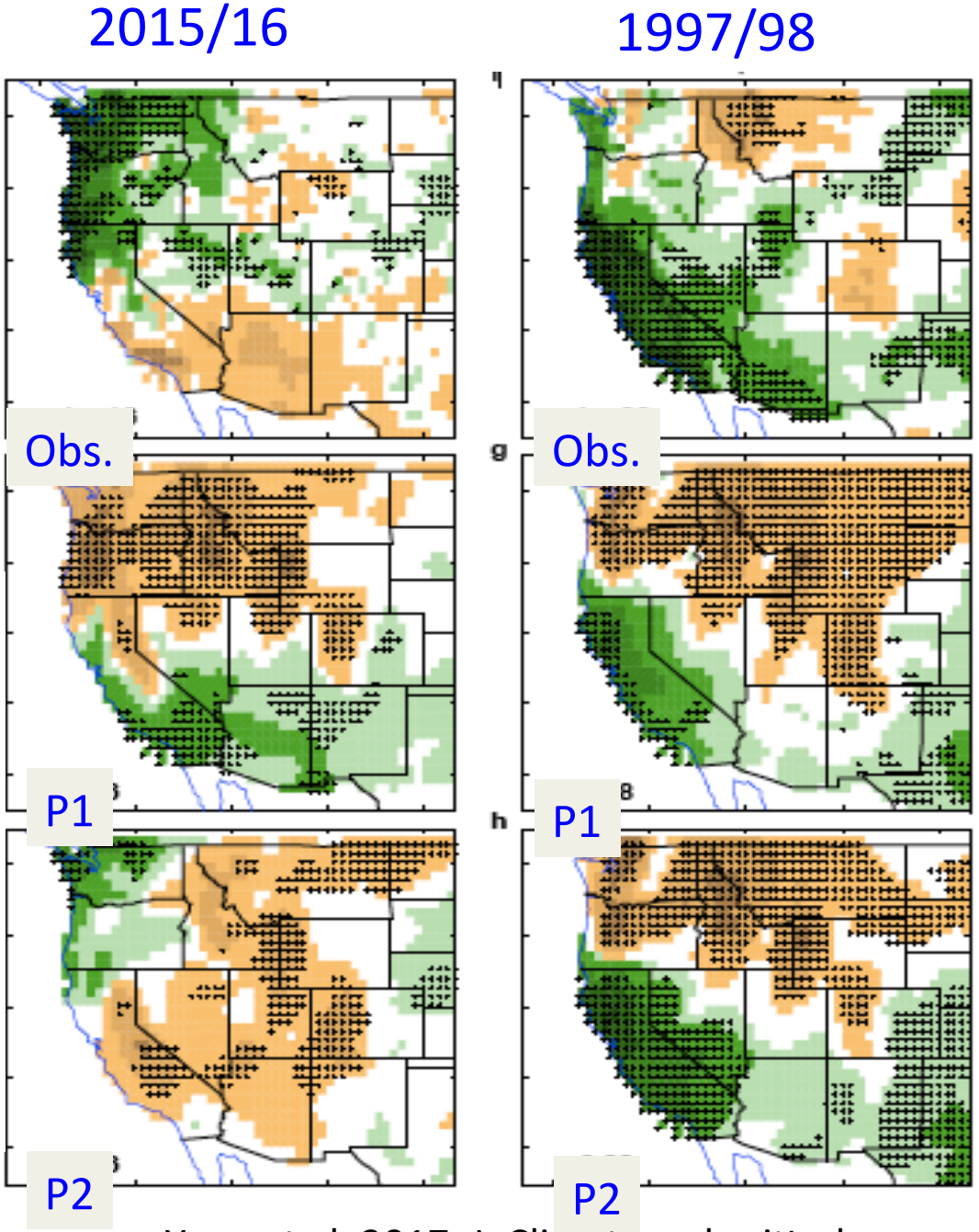
FLOR P1 and P2 hindcasts: 2015/16 and 1997/98

2015/16: Flipped pattern from P1 to P2 towards the observation

1997/98: P1 and P2 have similar skill.



Pattern Correlation Coef.

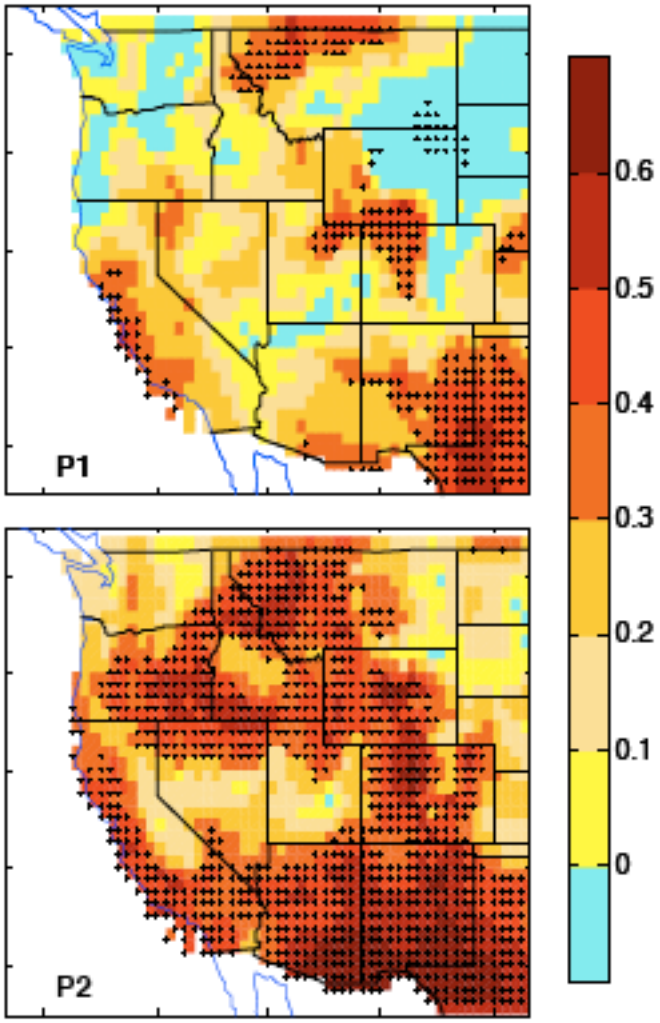


Yang et al. 2017, J. Climate, submitted

Impact of land and atmospheric states on winter precipitation skill during 1982-2016.

P1

P2



The ratio of the grid points with positive significant correlation to the total grid points:

P1: 17%

P2: 55%

Conclusions and discussions

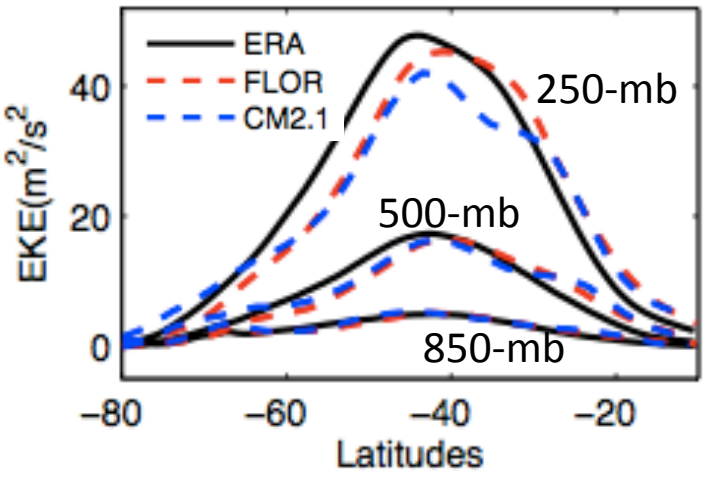
- High-res model substantially improves the regional climate prediction skill.
- Skillful seasonal prediction of extratropical storms, tropical cyclones as well as Category45 hurricanes
- Stratosphere plays important roles in the extratropical surface seasonal climate prediction, so accurately modeling and observing stratosphere could improve seasonal climate prediction.
- The appropriate initialization of atmosphere/land in addition to the ocean could substantially improve the seasonal precipitation prediction.
- Seasonal prediction for regional climate is a very challenge problem (modeling and initialization).
- Better skill is expected if the prediction model is initialized using coupled DA.

Model fidelity of ETS: mean and variations of eddy kinetic energy (EKE) simulated by high-res coupled models

SH baroclinic annular mode (BAM) (Thompson and Barnes, 2014):

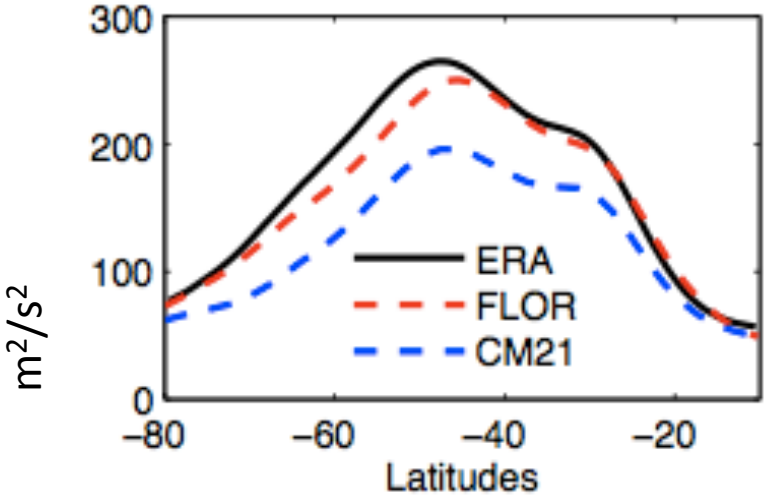
- Leading EOF mode of daily EKE
- Periodicity of 20-30 days

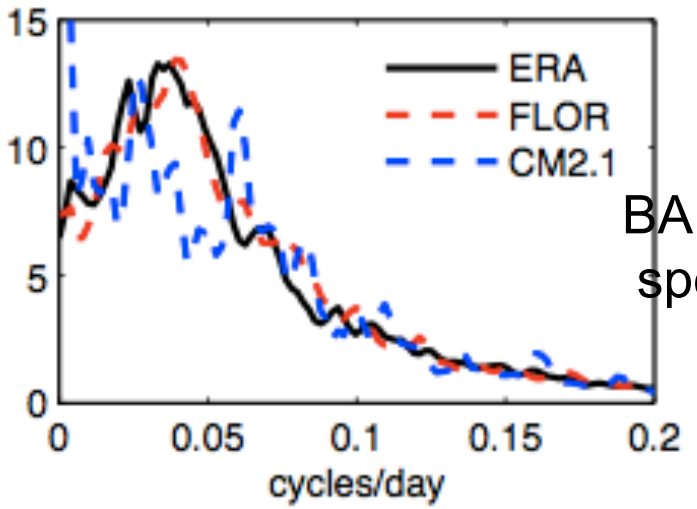
Subseasonal signal



Leading EOF daily EKE

Mean EKE at 250 mb



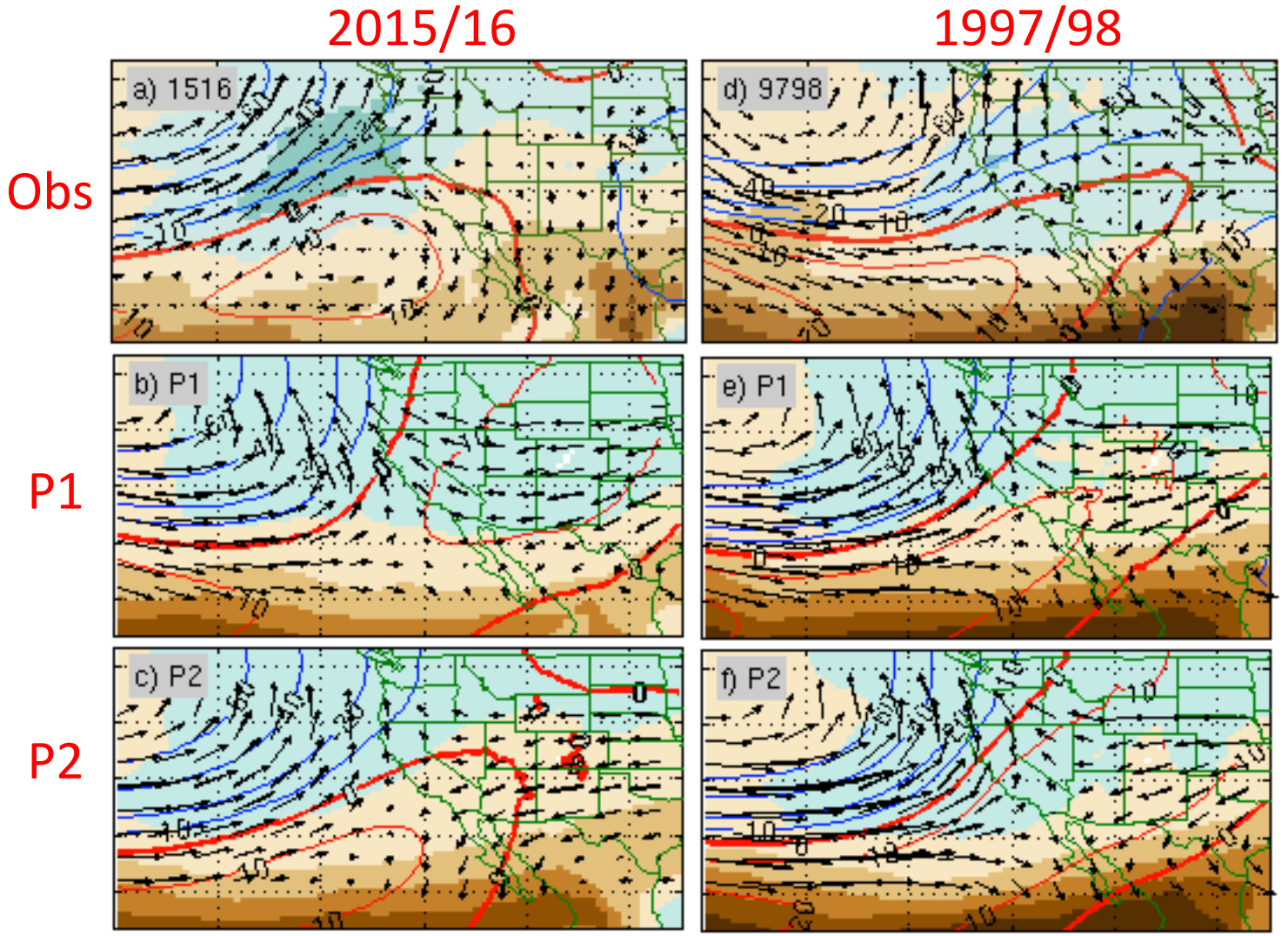


BAM spectrum

FLOR (1990-control) improves climatological SH EKE as well as spatial-temporal variations.

Fidelity of ETS

Predicted circulation anomalies for 2015/16 and 1997/98 from P1 and P2



700-hPa
Height: contour
Winds: vector
Moisture: shading

P2 predicted the observed local blocking high for 2015/16 winter