Part I: Impact of ENSO on seasonal climate predictability and prediction
Part II: Attribution study of extreme North America winter storm season of 2013/14

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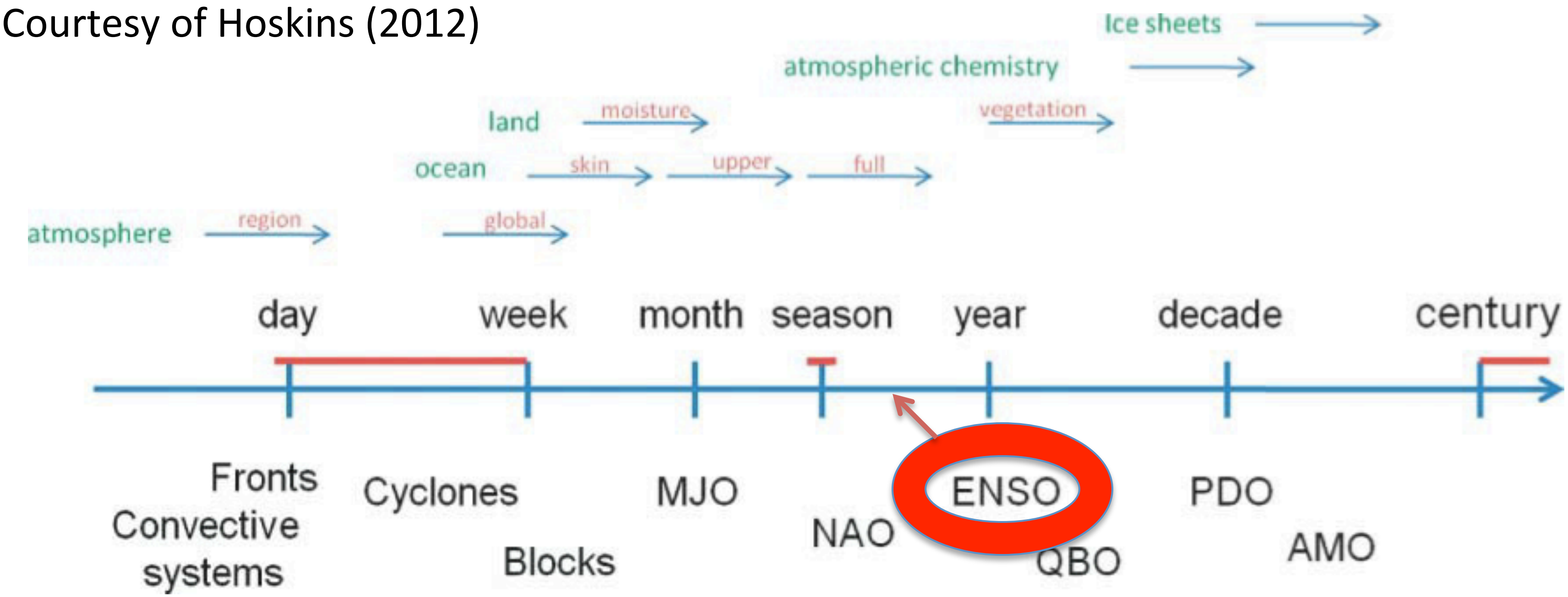
The seamless weather-climate prediction problem

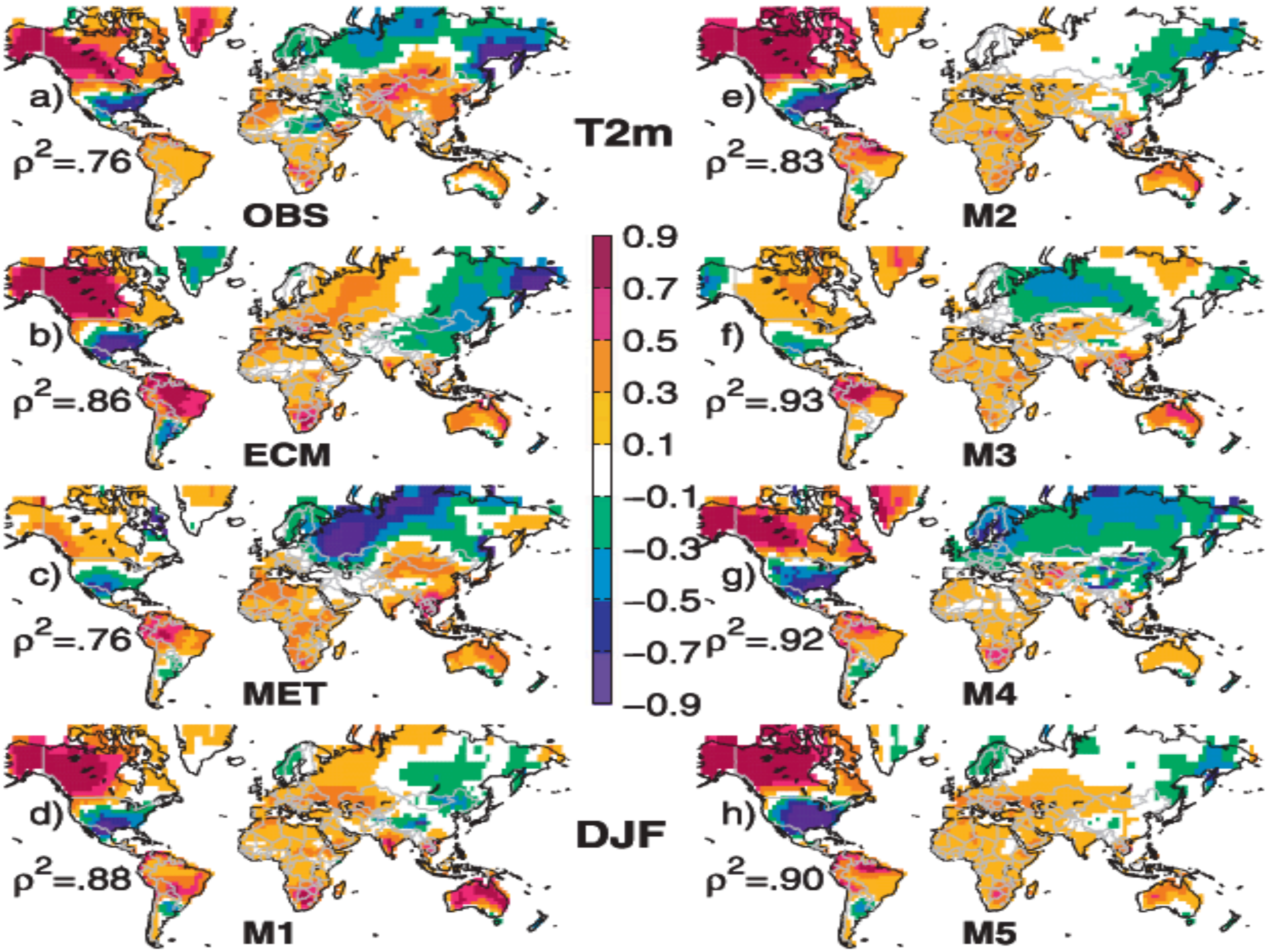
Courtesy of Hoskins (2012)



A seamless weather-climate seasonal prediction system:

- ENSO provides dominant source for skillful seasonal climate prediction over global land (Jia et al., J. Clim., 2015)
- Need a model representing ENSO and ENSO-induced variability to predict ENSO itself and its global impacts (regional, extremes)

Agreement between observed and modeled ENSO-teleconnection patterns differs among different models and regions



Yang and DelSole, J. Clim.,2012

Model development for seasonal climate prediction (GFDL)

- Built on GFDL-CM2.1 (~200x250km atmosphere/land, 1° ocean/sea ice, LM2 land model)
- Initialized using GFDL's ensemble coupled data assimilation
- Contributed to North American Multi-Model Ensemble (NMME)

However:

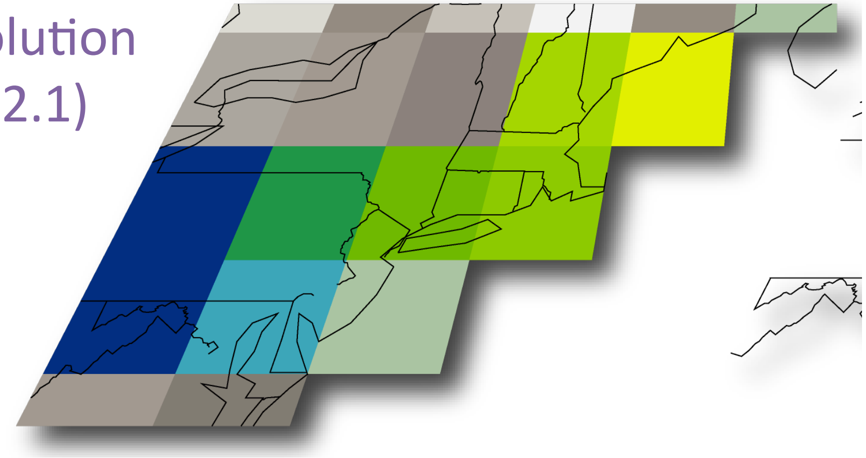
- Relatively low resolution atmosphere: can't directly get to extremes/ regional
- Large biases (processes poorly represented)
- ENSO and ENSO-teleconnection need improvement

GFDL FLOR (Forecast-oriented low ocean resolution):
Experimental high-resolution coupled prediction system

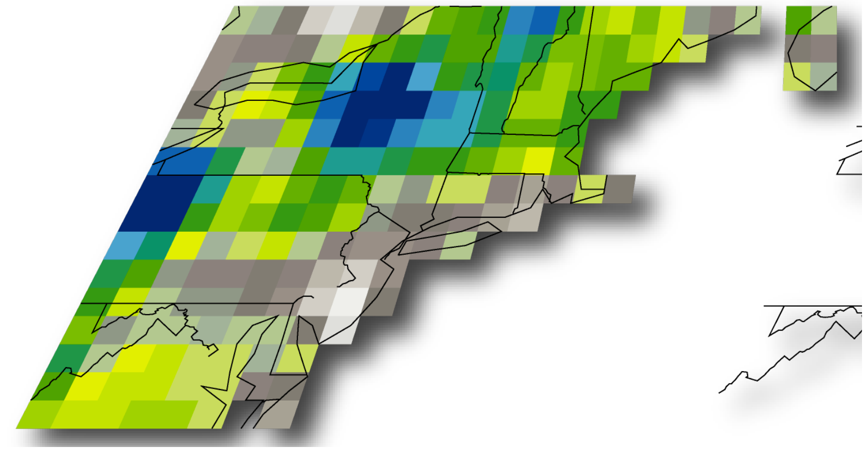
Goal: Build a seasonal to decadal forecasting system to:
- Yield improved forecasts of large-scale climate
- Enable forecasts of regional climate and extremes

Precipitation in Northeast USA

Medium resolution (CM2.1)



High resolution (GFDL-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)

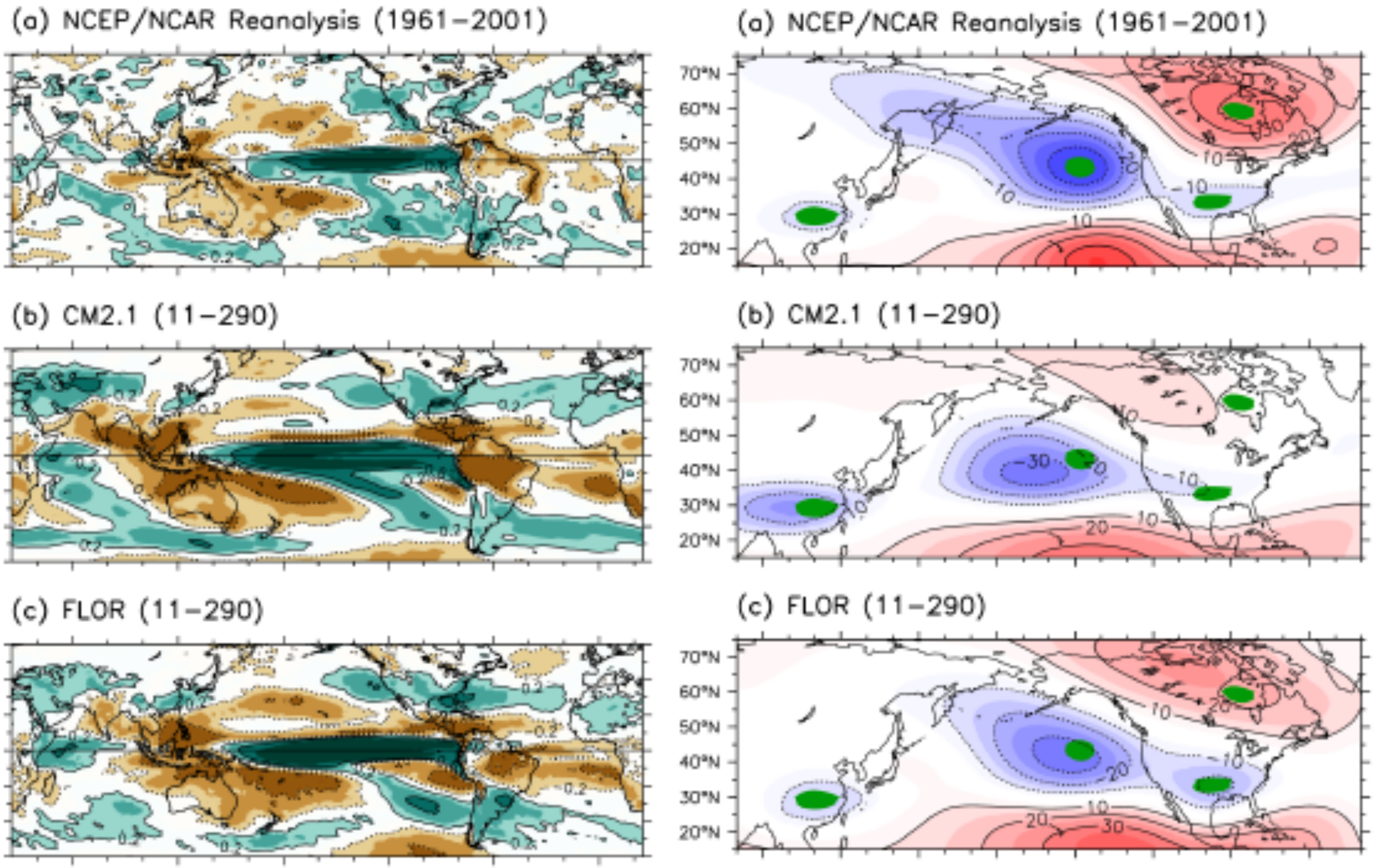
Increased atmospheric model resolution improves ENSO-teleconnection pattern

CORR(Precip, NINO3 SSTA) | Z200 regressed on NINO3 SSTA

Obs

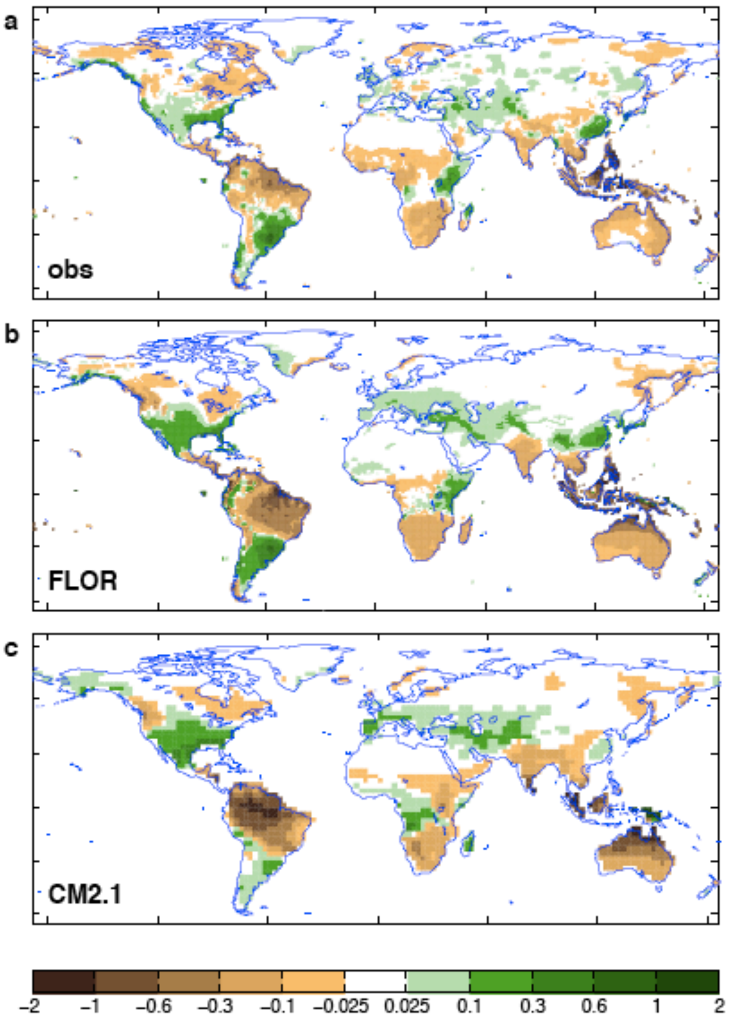
CM2.1 ~250km

FLOR ~50km

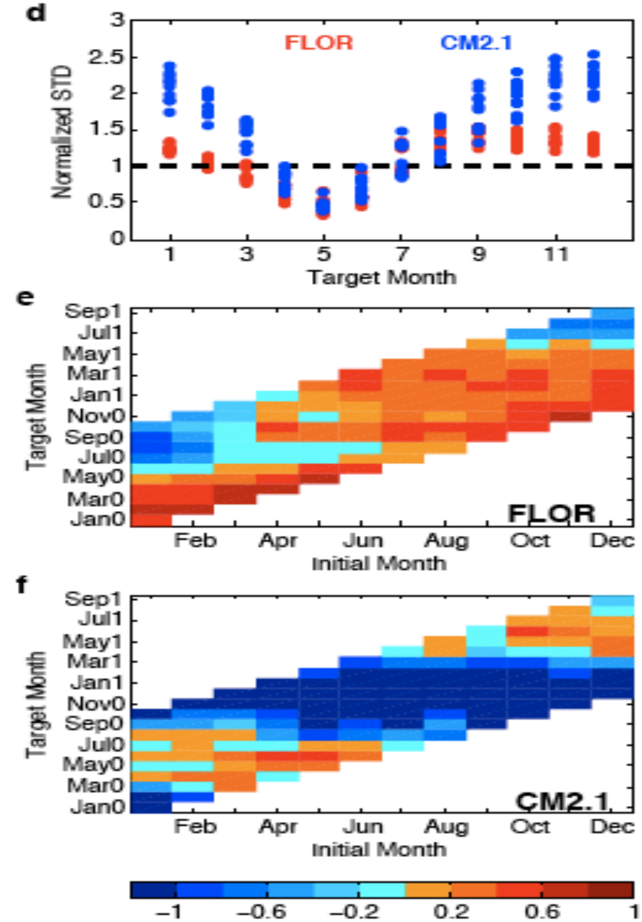


Courtesy of A. Wittenberg

GFDL's Seasonal prediction: ENSO-related predictable patterns of global land precipitation for FLOR and CM2.1



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



SESS

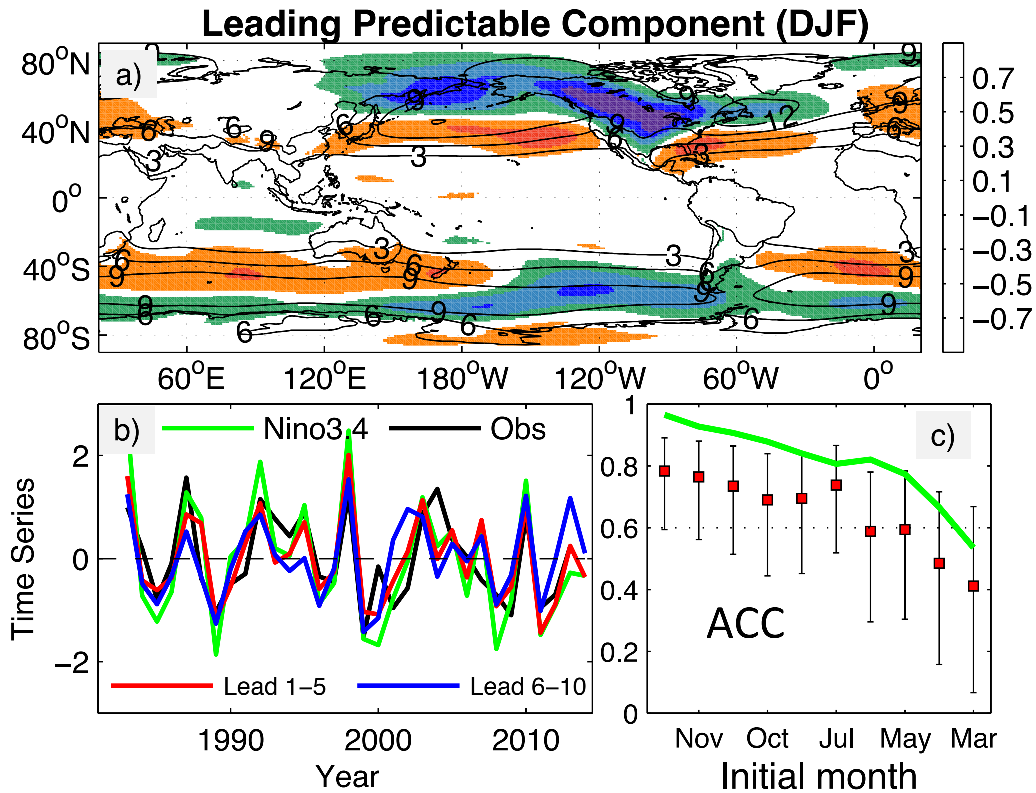
Regional patterns and predictive skill (FLOR > CM2.1)

Seasonal prediction of higher order statistical information

- **Traditional seasonal prediction products**
  - Seasonal mean precipitation, surface temperature (first moment)
  - Predictability analysis of land temperature and precipitation (Jia et al. 2015)
- Higher order products (second moment)
  - Extratropical storms (ETS) (Variance statistics)
  - Cause extreme weather and climate events
  - Useful information for the seasonal prediction
  - Are they predictable?

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

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

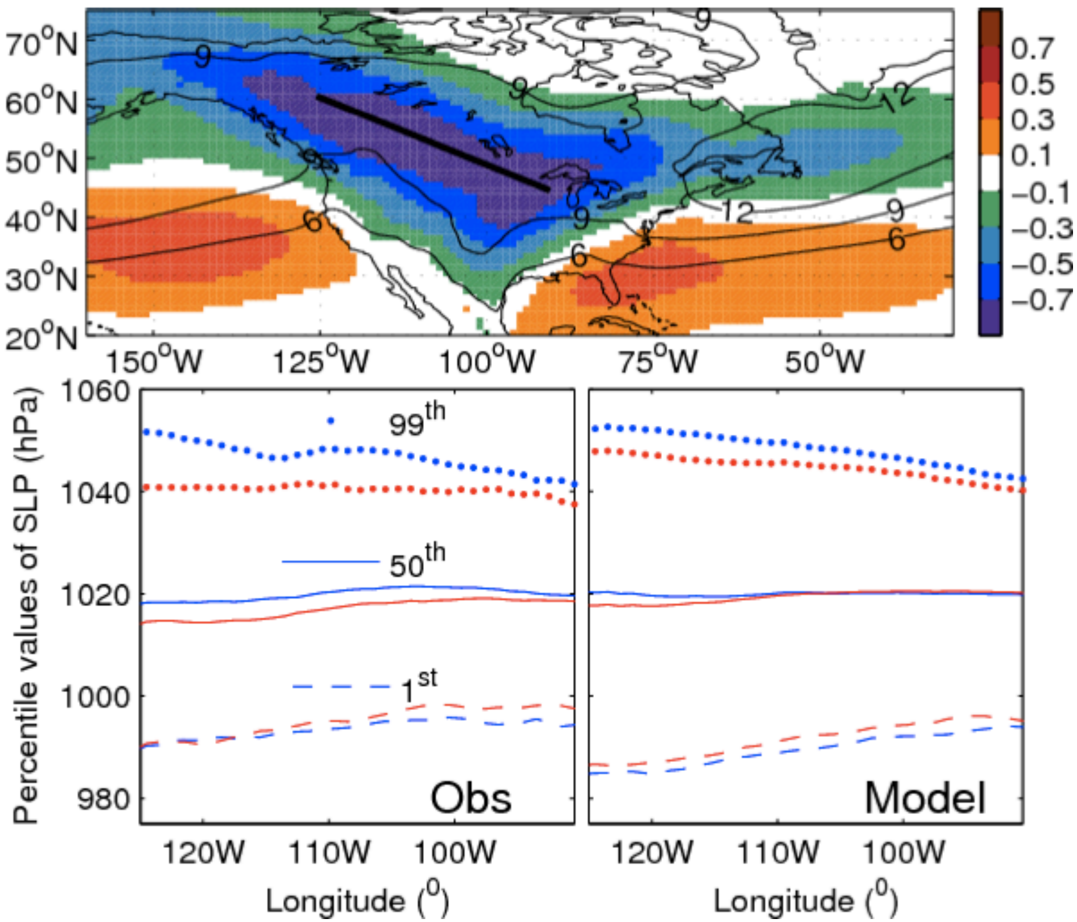


- Storm reduction over most North America
- Time series highly correlated with NINO3.4
- Skill is comparable with predicting ENSO

FLOR

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

ETS predictability: The model could predict the storm extreme changes associated with ENSO



Blue: La Niña composite Red: El Niño composite

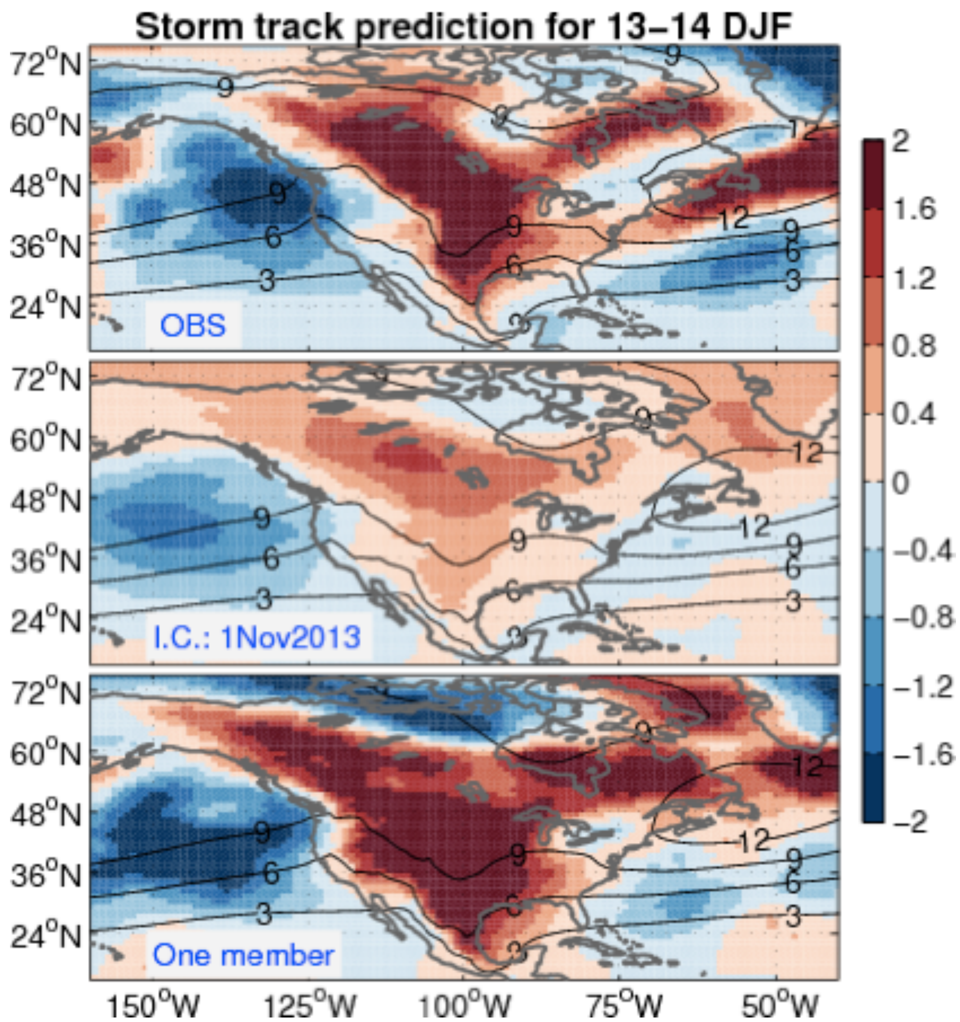
During El Niño years:

Reduced storm tracks → Reduced both anticyclones and cyclones → Smaller 99th percentile value and larger 1st percentile value (Narrower distribution width)

Vice versa for La Niña years

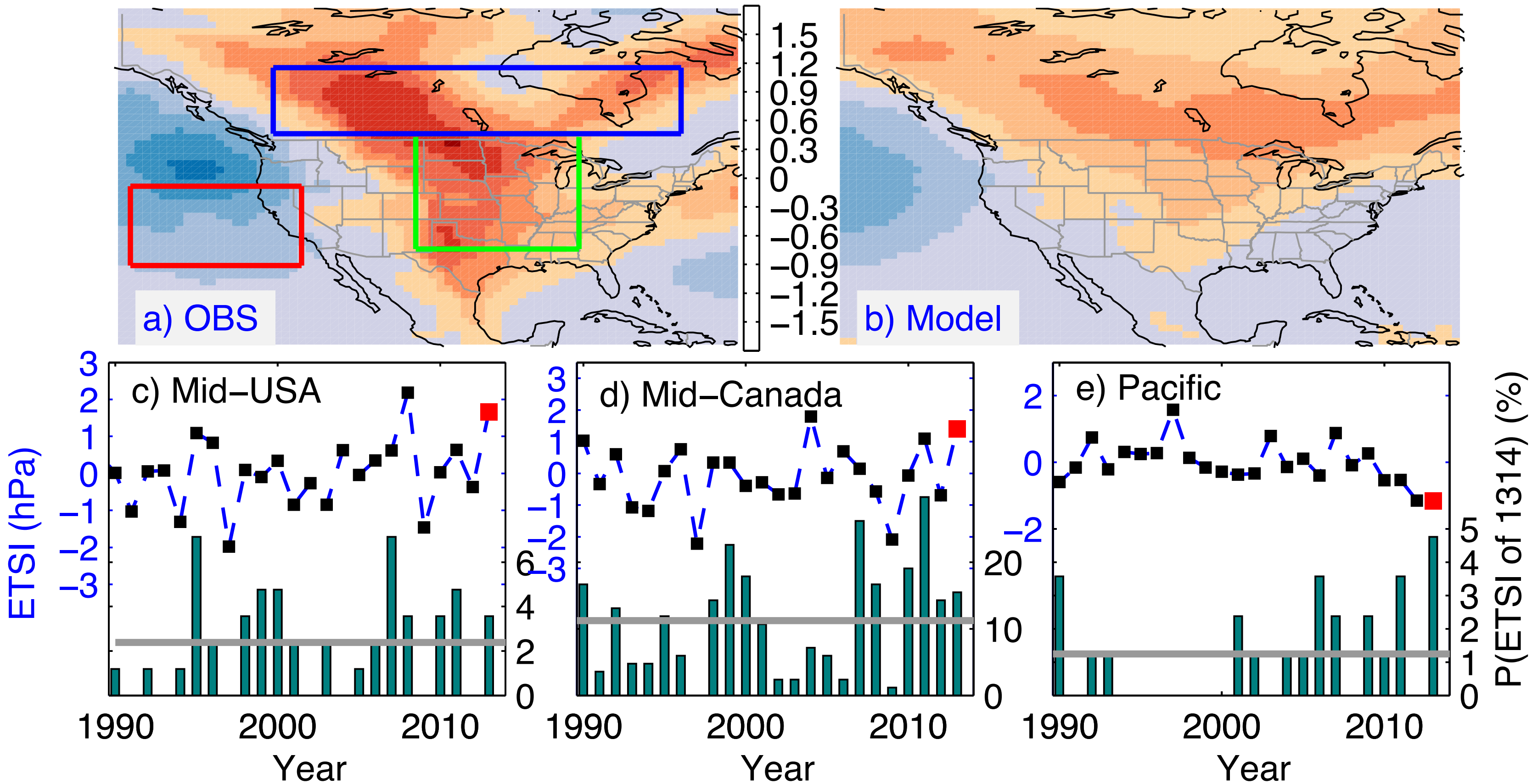
Model agrees well with Obs

ETS predictability: Storm track prediction for 2013-14 winter (non-ENSO year, an extreme year)



- Skill is limited to 1-2 months lead time
- Amplitudes are much weaker in prediction than in observation

Attribution study for 2013/14 winter ETS extreme event over North America: Probabilistic approach

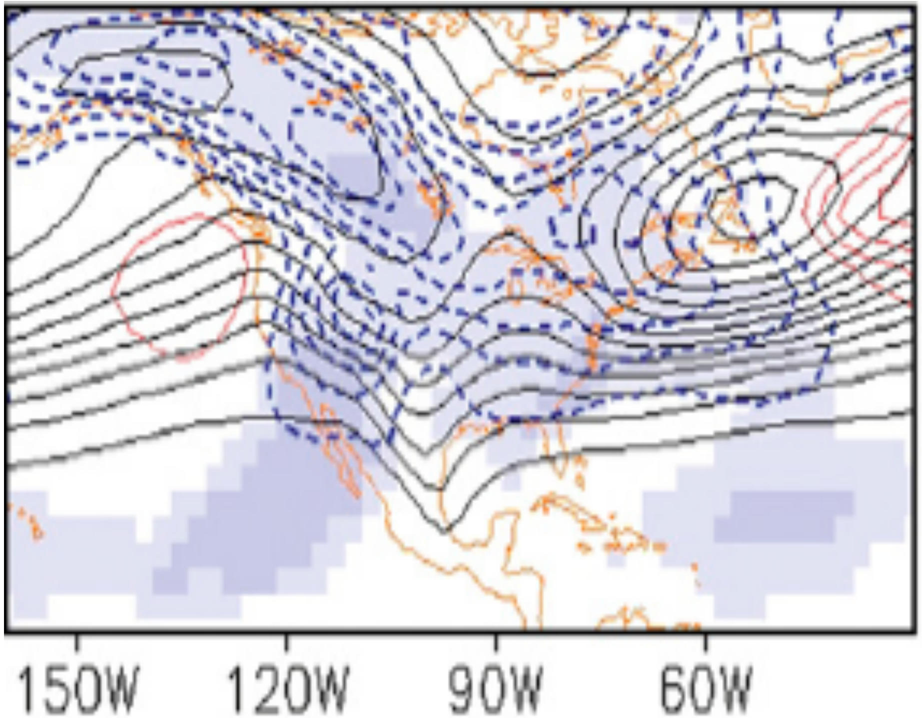


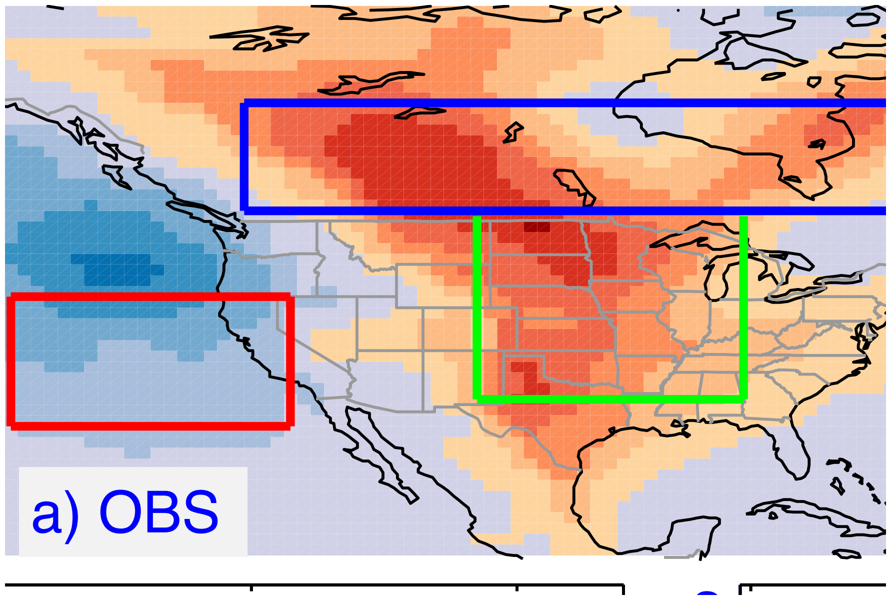
Extreme probability: P=(number of members > 2013-14 value) / total sample size

Climate drivers for this ETS extreme event : Global warming vs Global warming hiatus

Global warming: reduction of surface ETS over North America

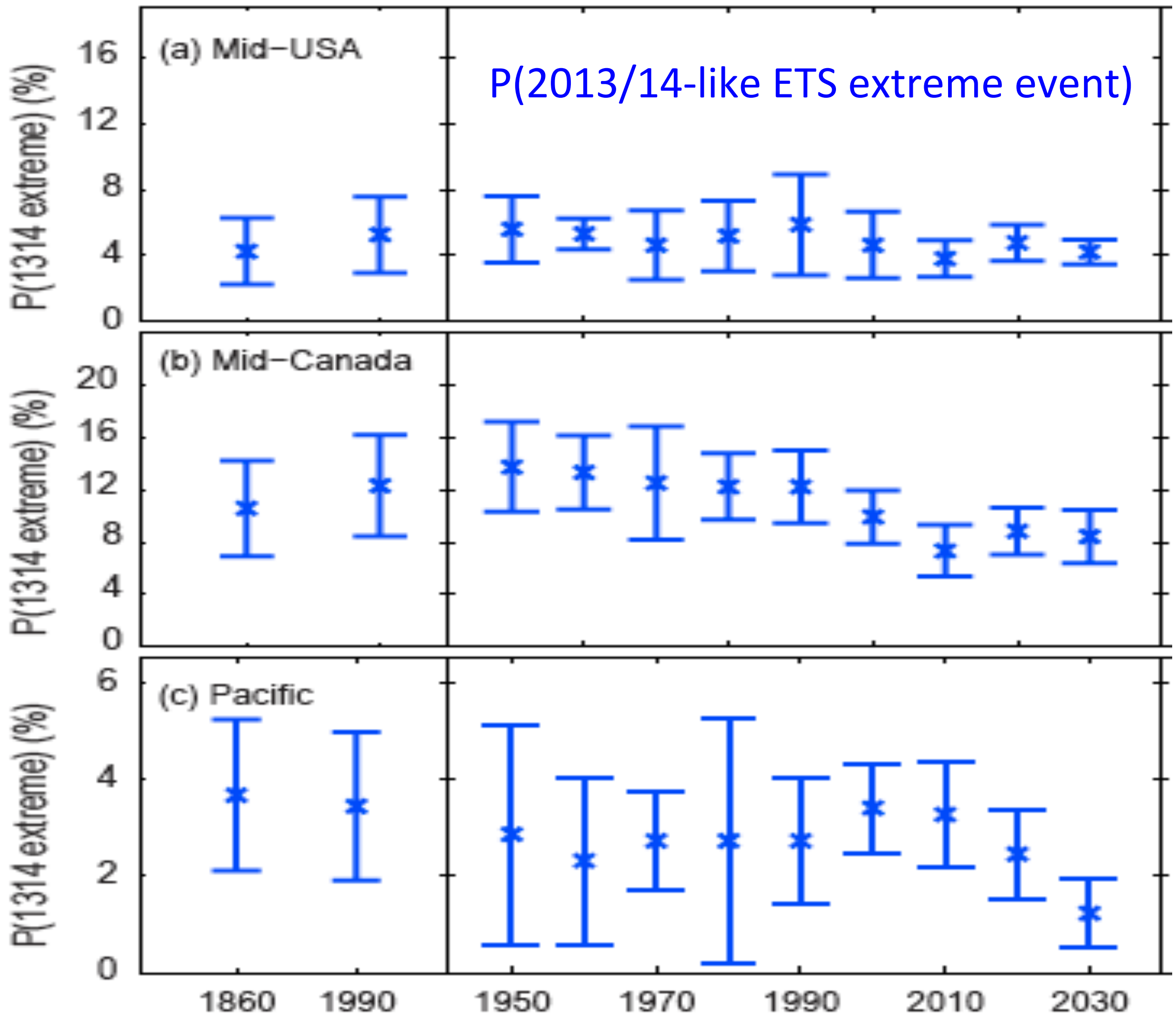
CMIP5 multi-model projection
(2081-2100 – 1980-99)





Chang (2013, J. Clim.)

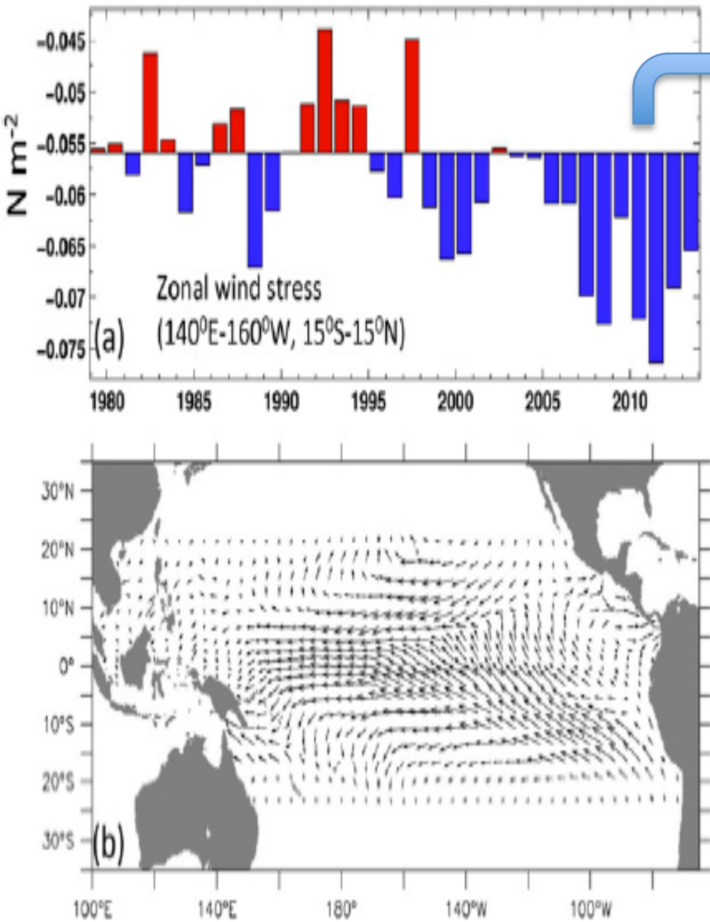
No evidence: global warming contributed to the 2013/14 extreme ETS event



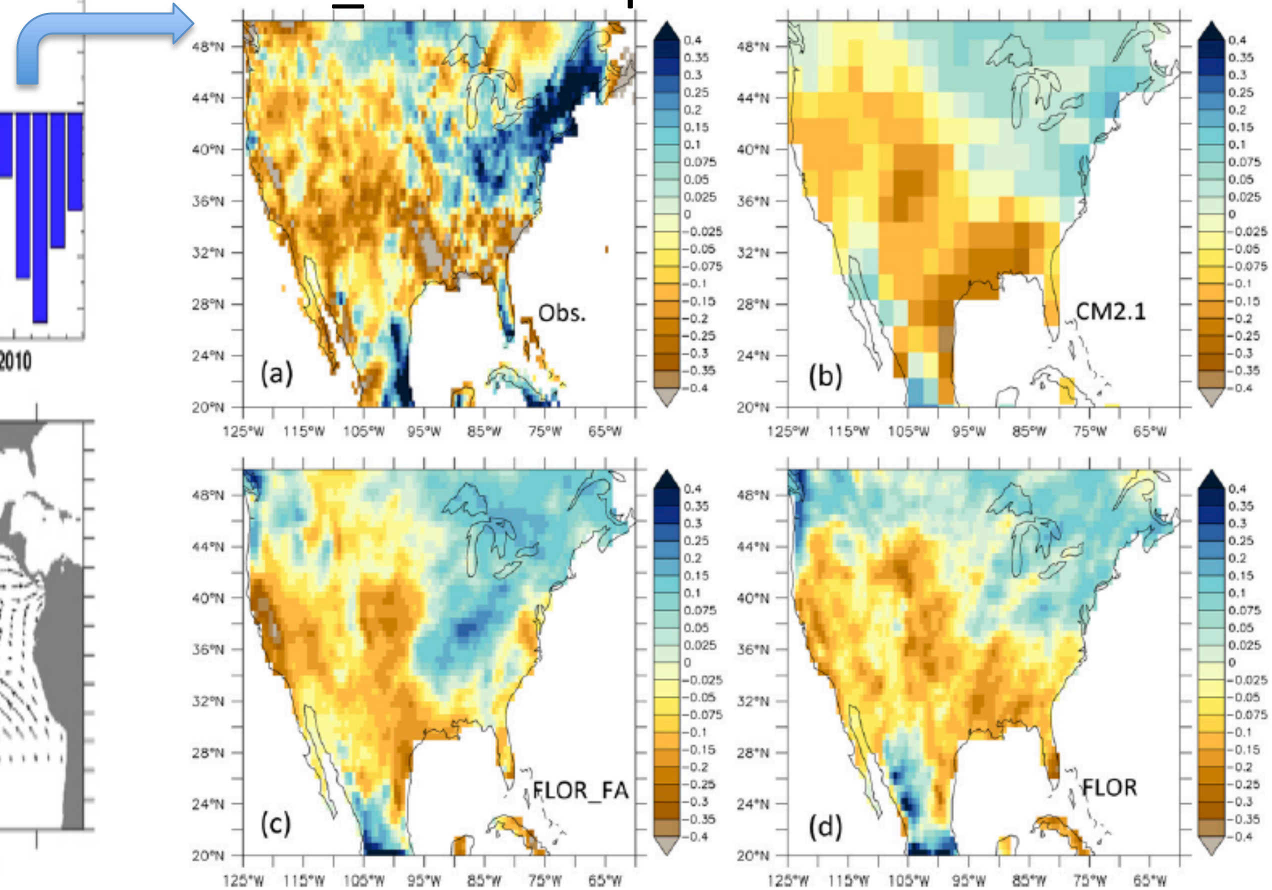
500 years 1860/1990 control runs

Large-ensemble (30) historical-forcing simulations

A link between the hiatus in global warming and North America drought



ALLFORC_STRESS Exp.



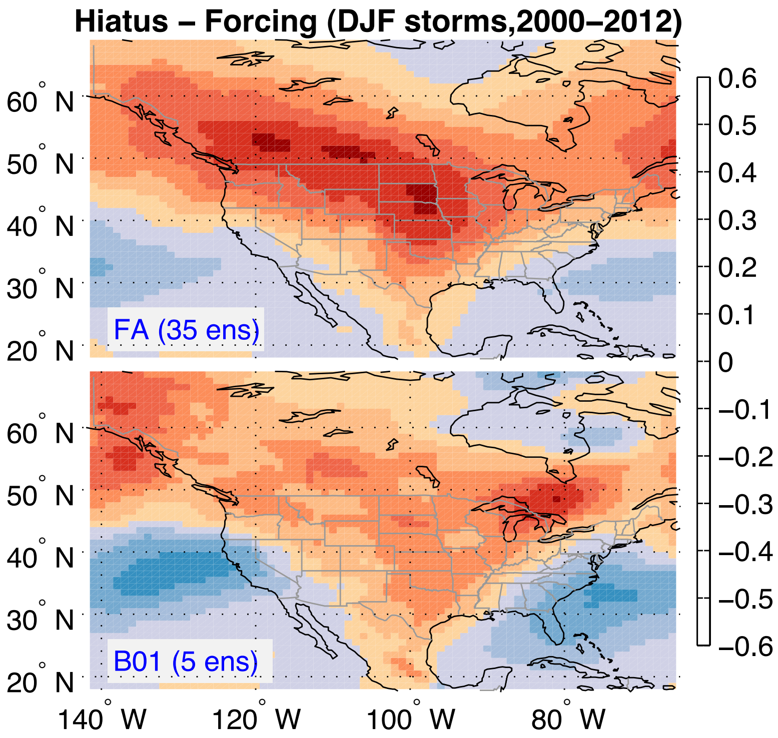
Connection between tropical Pacific SSTA and wind stress anomalies (Kosaka and Xie, 2013; England et al., 2014)

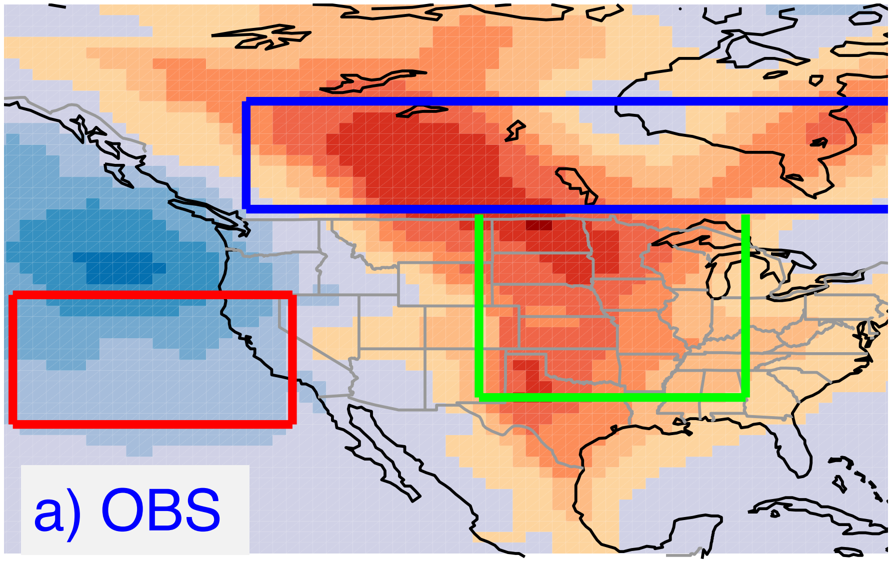
500 years 1860/1990 control runs

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

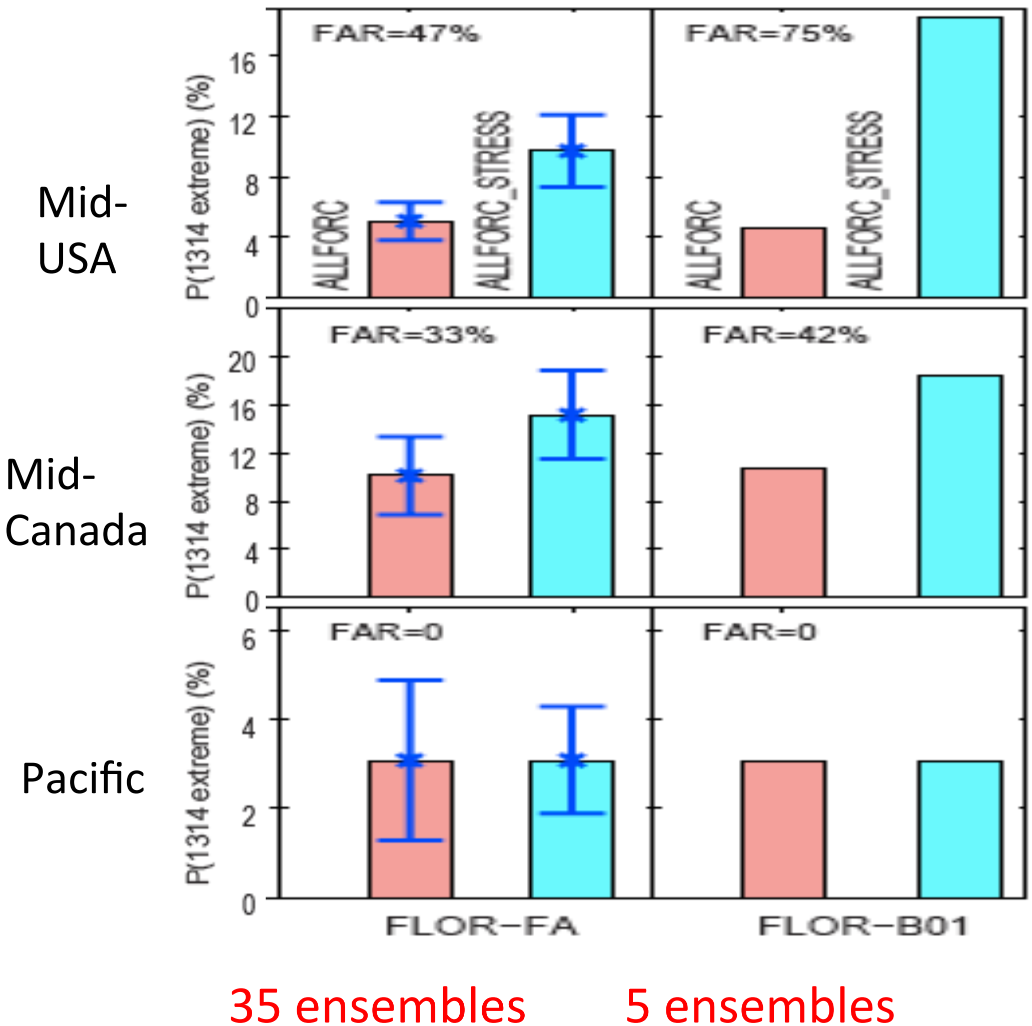
Global warming hiatus: increase of surface ETS over North America

Hiatus - Forcing (2000-2012)





Connection between global warming hiatus and the 2013/14 extreme ETS event over North America

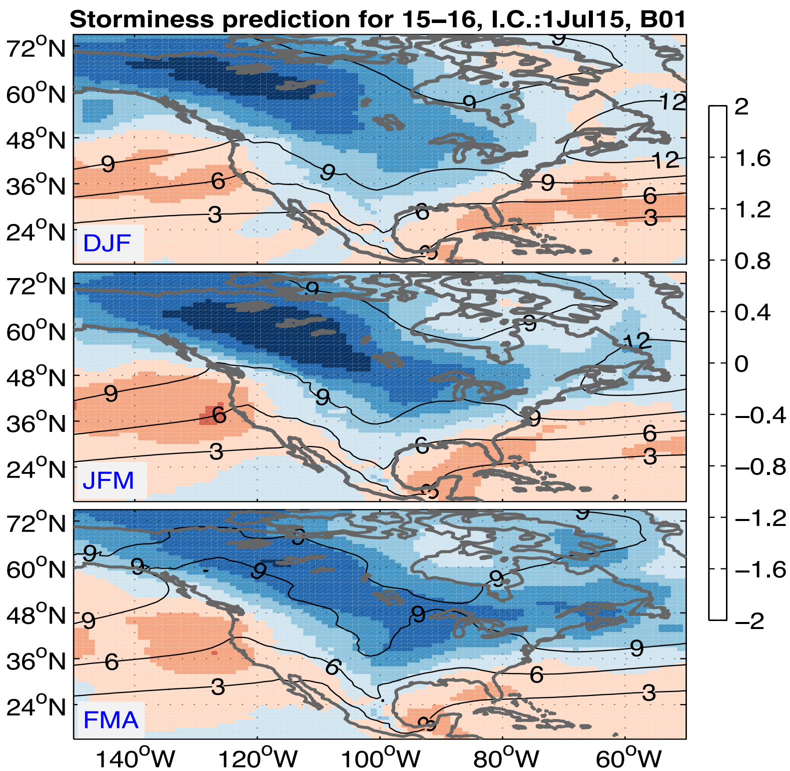


Pink shading: ALLFORC (global warming)
Cyan shading: ALLFORC_STRESS (hiatus)

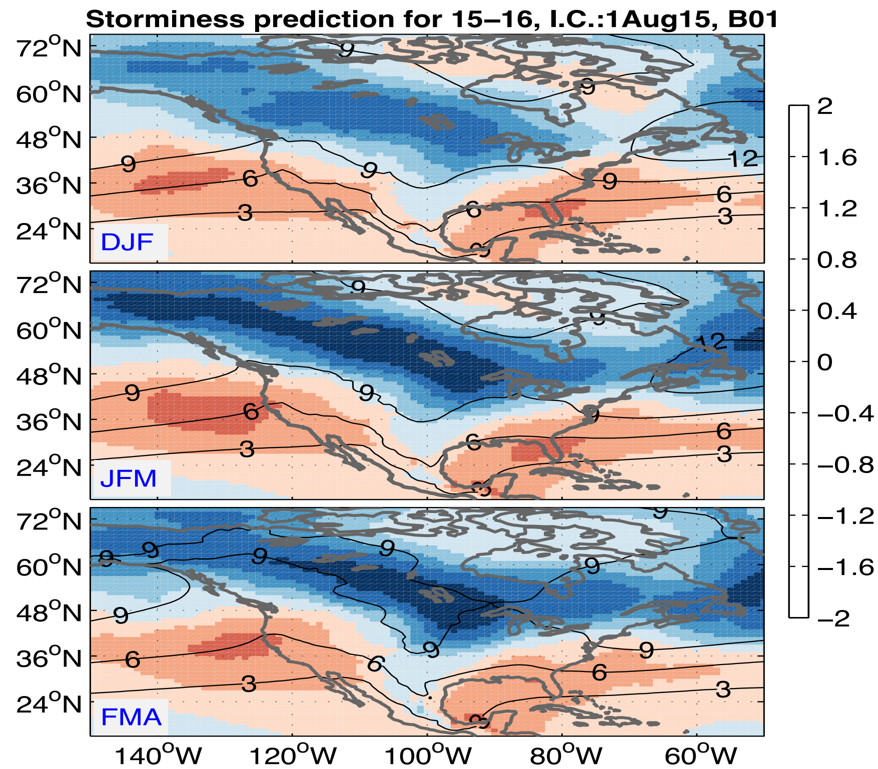
The recent multiyear increase in the strength of trade winds in the tropical Pacific Ocean that has been linked to global warming hiatus(Kosaka and Xie, 2013; England et al., 2014; Delworth et al., 2015) substantially increased the probability of the 2013/14 positive extreme ETS winter over much of North America.

Experimental prediction of 2015-16 winter ETS over North America using GFDL-FLOR

Forecast: 1Jul2015



Forecast: 1Aug2015



Reduced storms: Mid-USA, Northeast of USA and Canada
Increased storms: Southeast, Southwest of USA

Summary

High-resolution coupled models provide opportunity for improvement of ENSO-related regional climate variation and its predictive skill

- Increased atmosphere resolution substantially enhance seasonal predictive skill of ENSO-related precipitation anomalies
- ENSO-related extratropical storm pattern is predictable up to 9 month lead.
- The FLOR model could reproduce the observed extratropical storm extreme changes associated with ENSO

Attribution study of 2013/14 winter extratropical storm extreme event:

- Global warming does not contribute to the occurrence of 2013/14-like extreme event over North America
- The recent multiyear easterly wind anomalies in the tropical Pacific Ocean (linked to global warming hiatus) significantly increase the occurrence of 2013/14-like extreme ETS event over North America

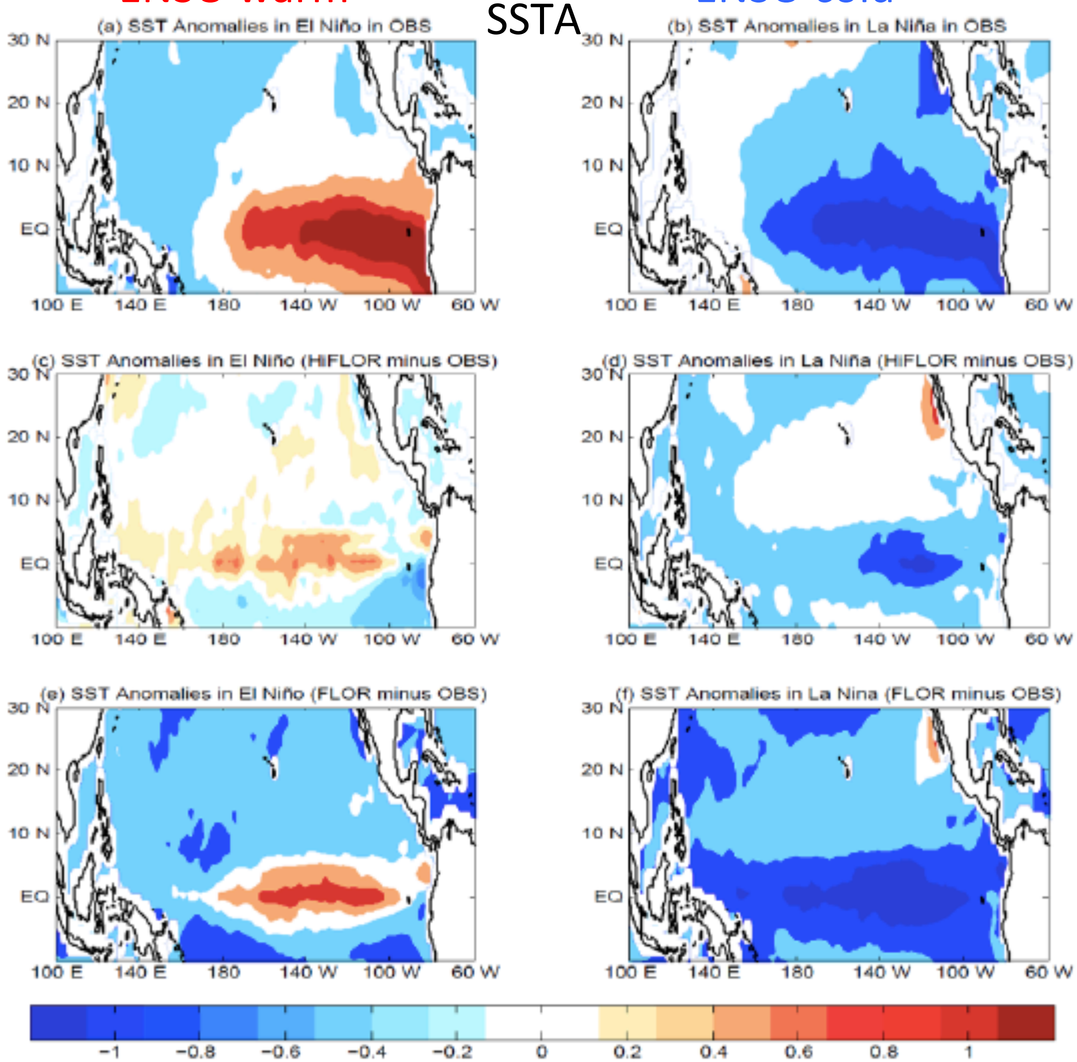
HiFLOR(25km): Further improves ENSO variability

ENSO warm SSTA ENSO cold

Obs

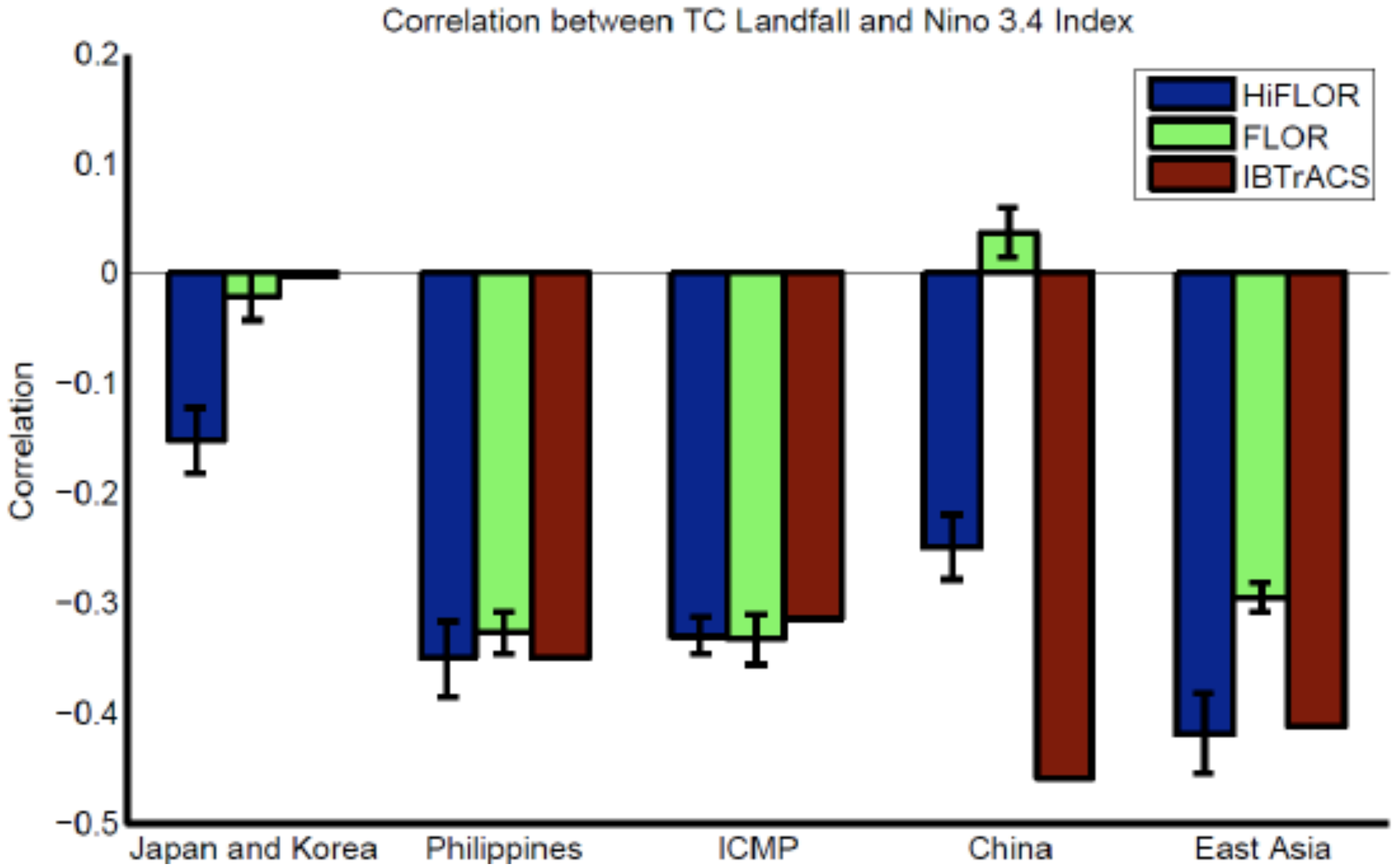
HiFLOR - Obs

FLOR - Obs



Murakami et al. (2015, J. Clim., in press; W. Zhang et al. (2015, J. Clim., submitted)

HiFLOR(25km): Improves relationship between ENSO and regional TC landfall in the Western North Pacific



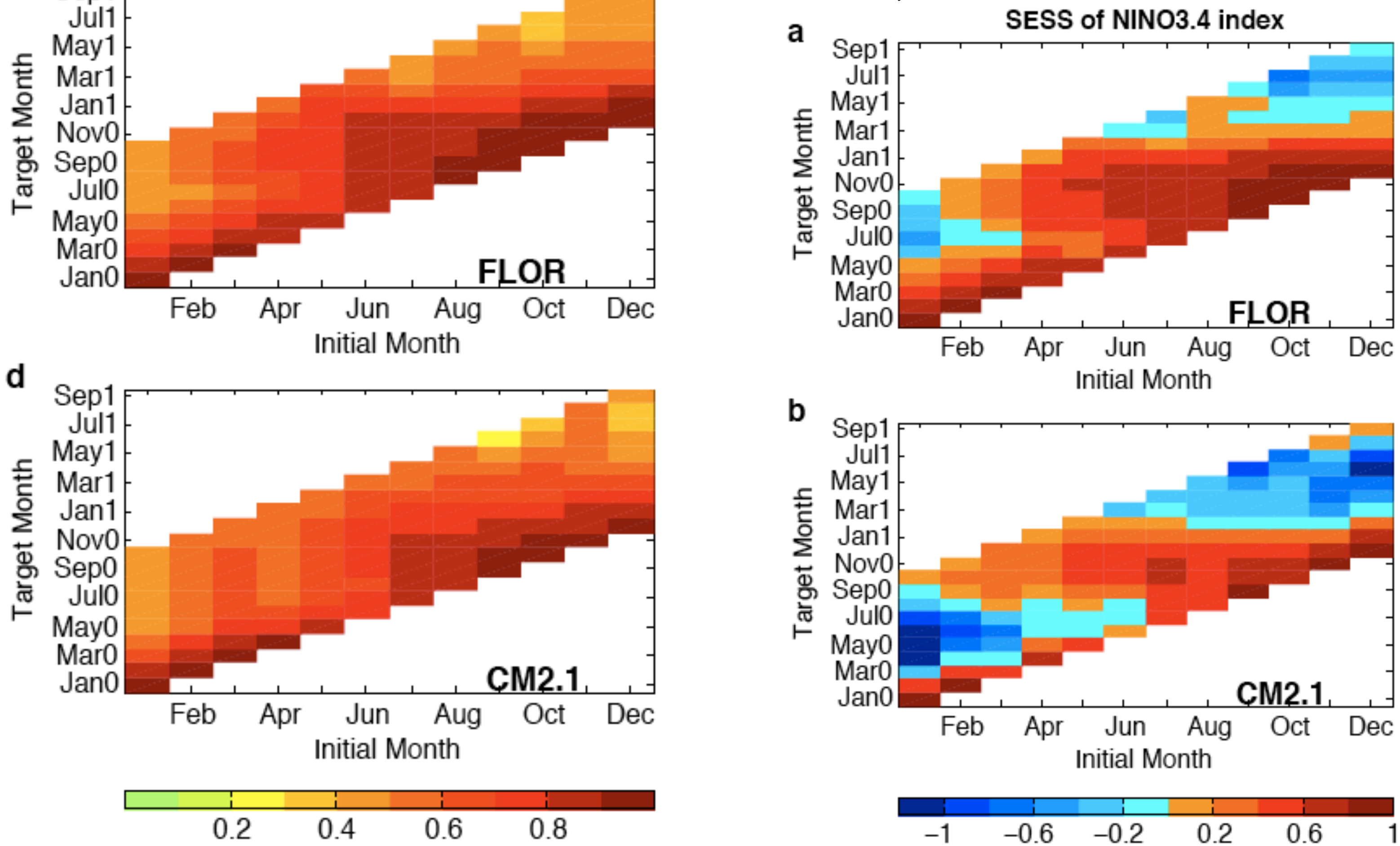
W. Zhang et al. (2015, J. Clim., submitted)

Seasonal predictability and predictions using GFDL-FLOR

- Seasonal predictability and predictions of extratropical storm tracks (Yang et al., 2015)
- Seasonal predictability and predictions of land temperature and precipitation (Jia et al., 2015).
- Seasonal predictions of Arctic sea ice extent (Msadek et al., 2014)
- Seasonal Forecasting of Regional Tropical Cyclone Activity (Vecchi et al., 2014)
- The Role of Sea Surface Temperature, Atmospheric and Land Initial Conditions in US Heat Waves (Jia et al., 2015)

GFDL's Seasonal prediction: Predictive Skill of ENSO (Nino3.4 SST)

$$SESS = 1 - \frac{\sum_i \left(f_i' - o_i'\right)^2}{\sum_i (o_i')^2}$$ Squared Error Skill Score



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