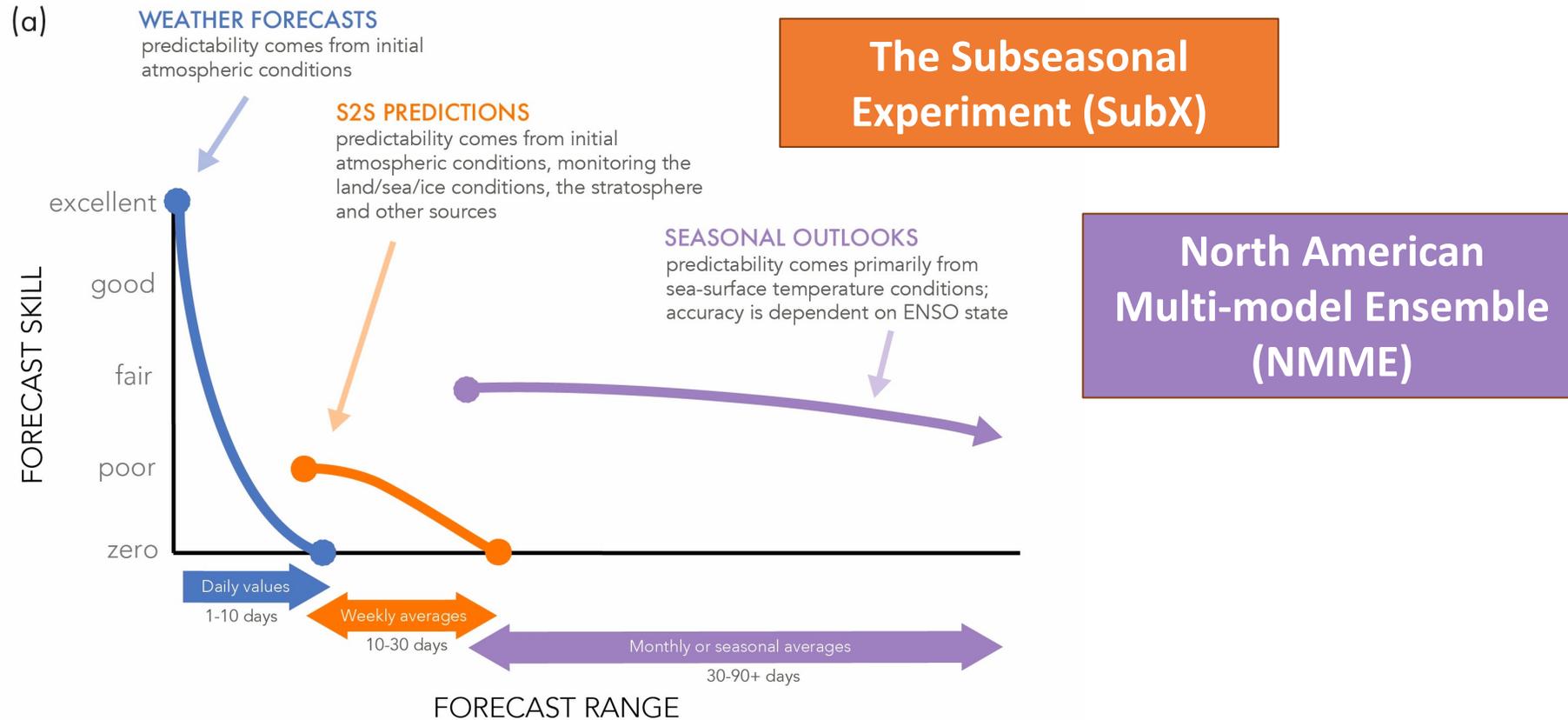


# Understanding Subseasonal to Seasonal (S2S) Predictability and Prediction using Multi-Model Ensembles



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# Why Multi-model?

- Why not?
- No single model is superior
- Better Representation of Uncertainty



*from Slingo & Palmer 2011*

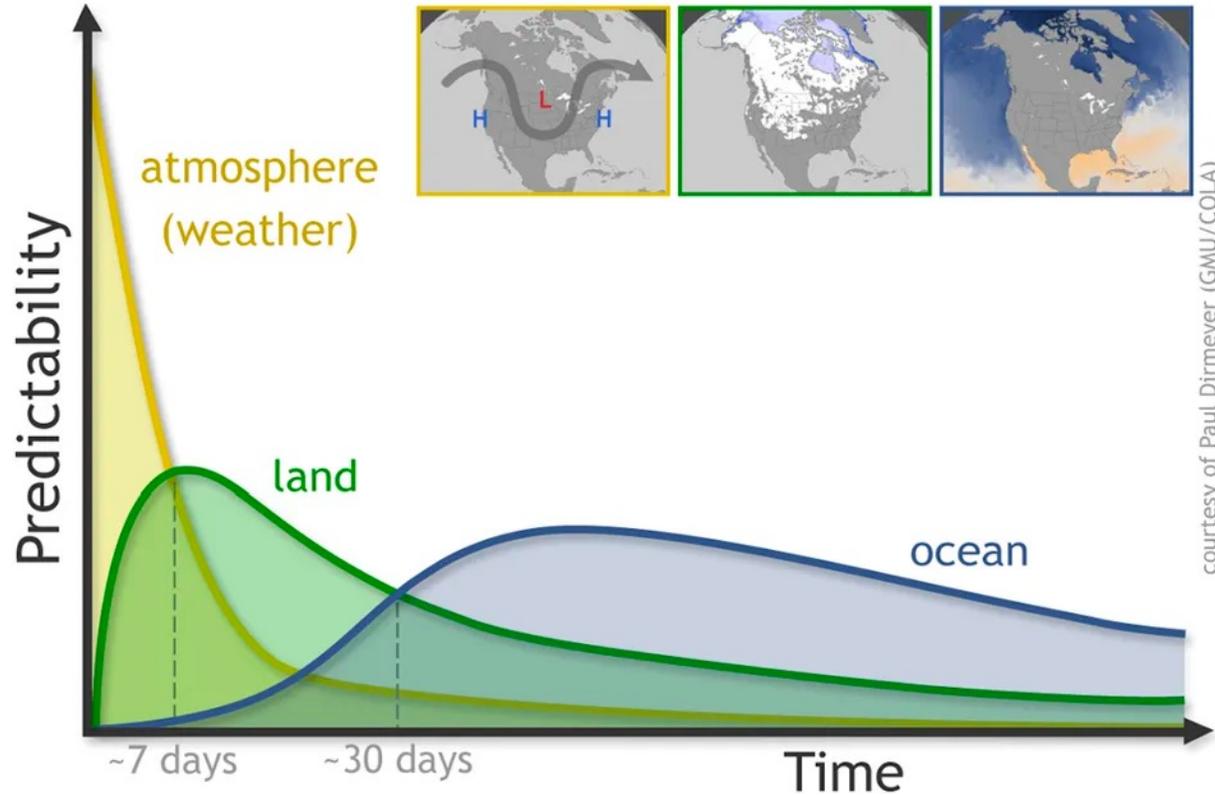


Why do we think we can predict beyond 2-weeks?

Predictability Varies

Why do we think we can predict beyond 2-weeks?

Slowly varying components of the climate system are sources of predictability



courtesy of Paul Dirmeyer (GMU/COLA)

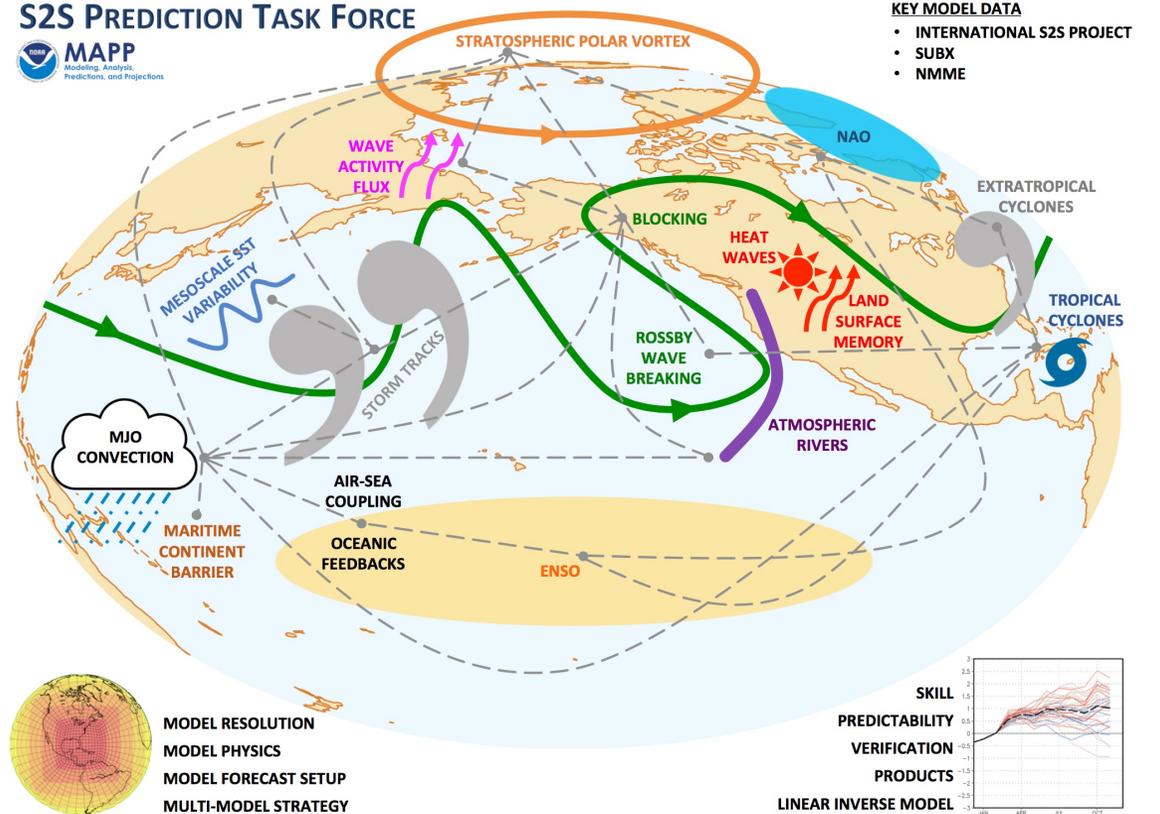
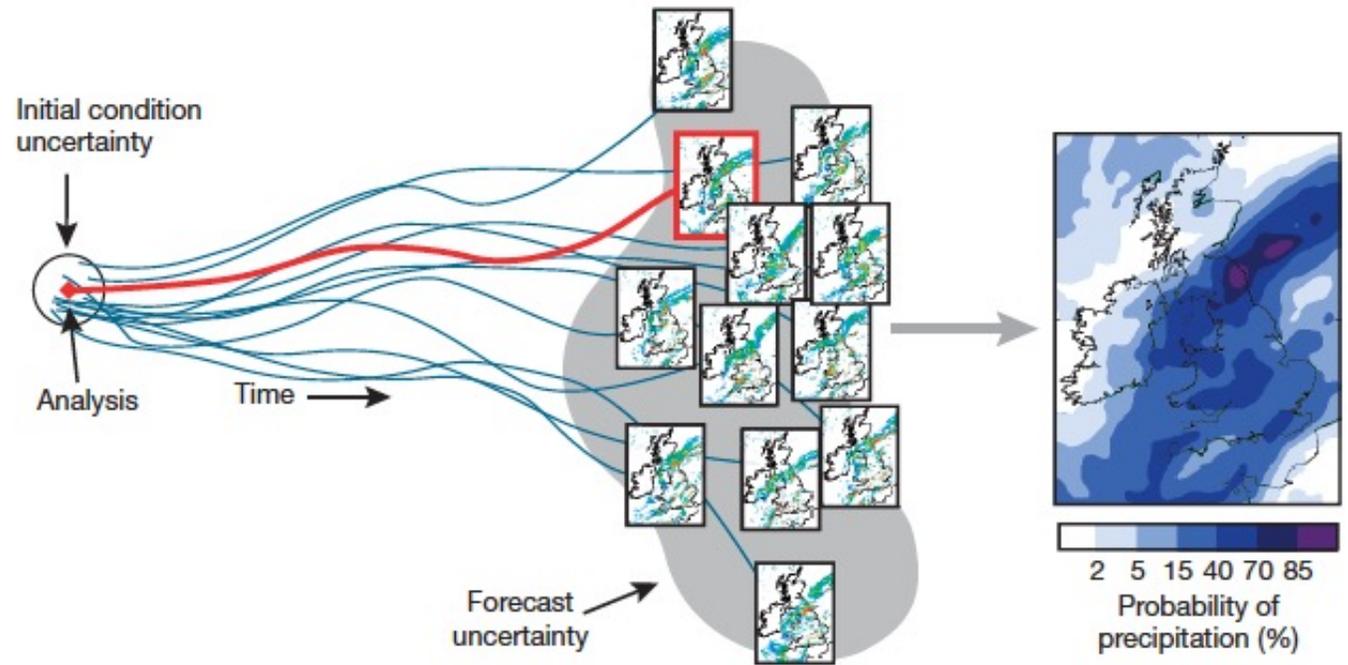


Image Credit: C. Baggett/MAPP S2S Task Force

# Uncertainty is Large!

- Use ensembles to account for initial condition uncertainty
- Use multiple models to account for model uncertainty



# SubX BY THE NUMBERS

**7** Global Models

**4+** Years of *weekly*  
*Real-time* Forecasts

**17** Years of *weekly*  
*Retrospective* Forecasts

**3-4** week guidance  
for Climate Prediction  
Center Outlooks

# SubX Protocol

---

Prediction System Details up to Provider

---

Real-time and retrospective systems identical

---

Re-forecast period: 1999-2015

---

At least 3 ensemble members

---

Minimum Length: 32 days

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Daily data on Uniform 1x1 grid

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Real-time forecast made available to NCEP/CPC every Thurs by 6am of every week.

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Re-forecasts and real-time forecasts made publicly available

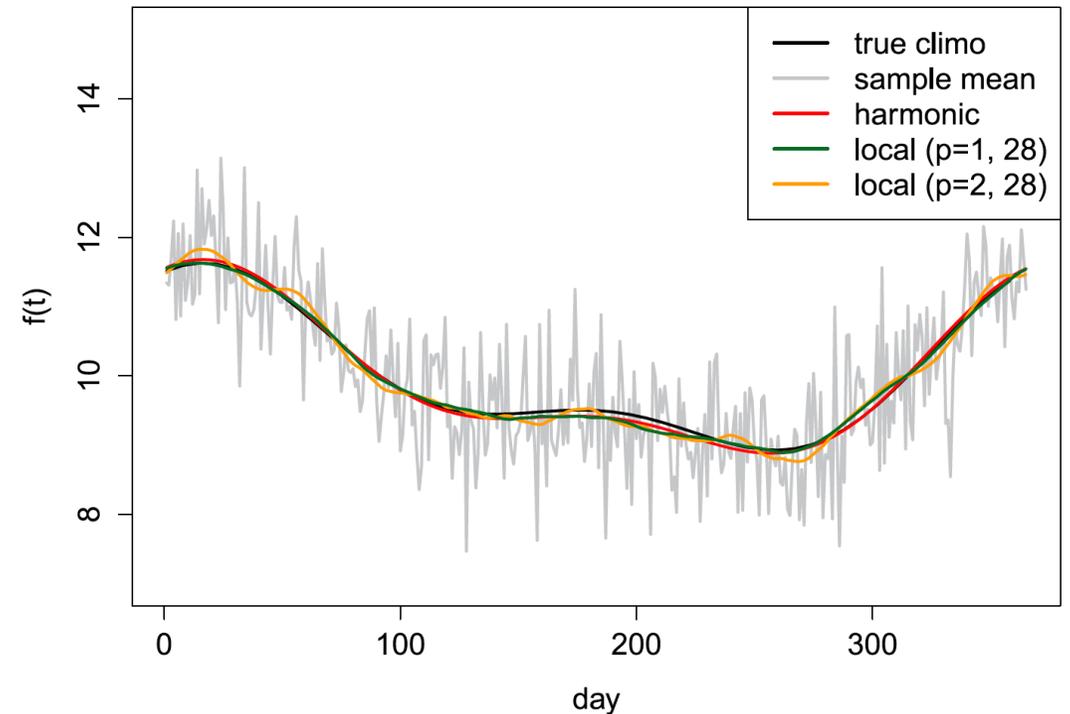
# Quantifying Skill

## Mean Bias Correction

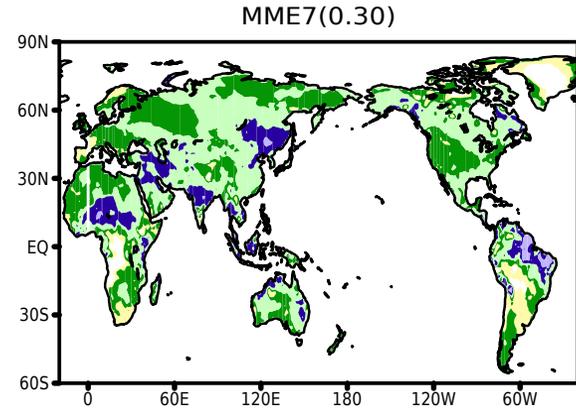
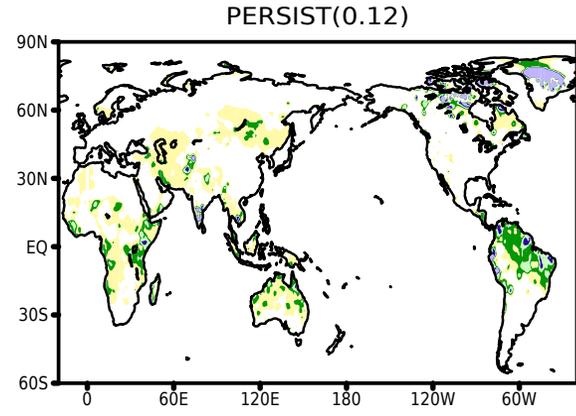
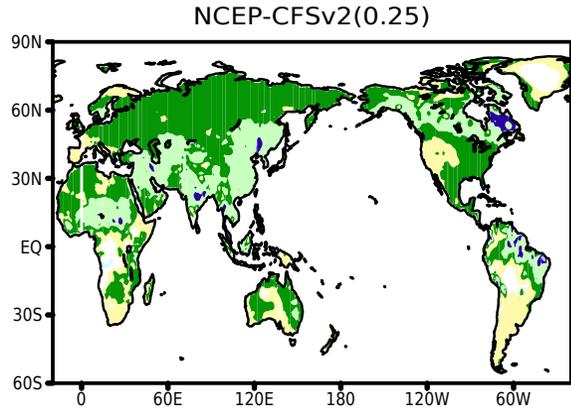
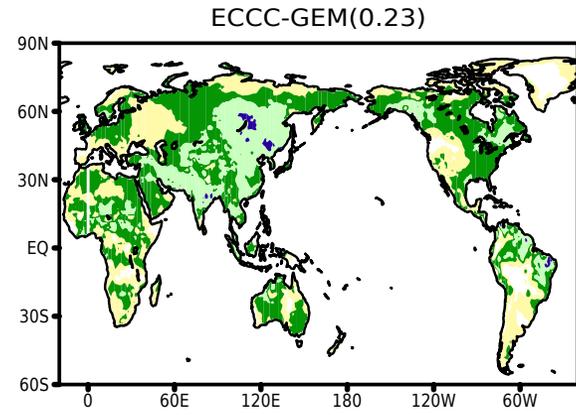
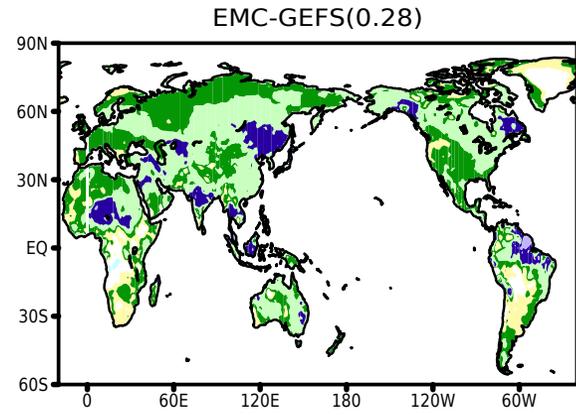
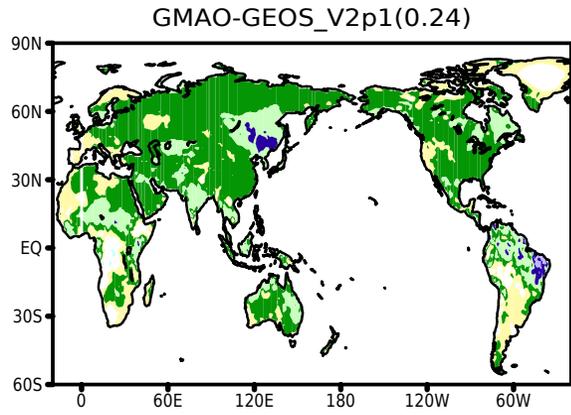
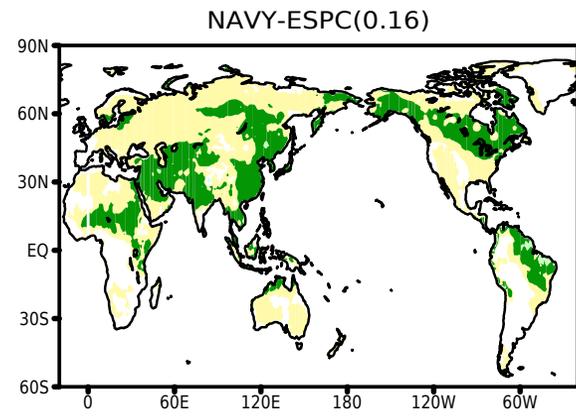
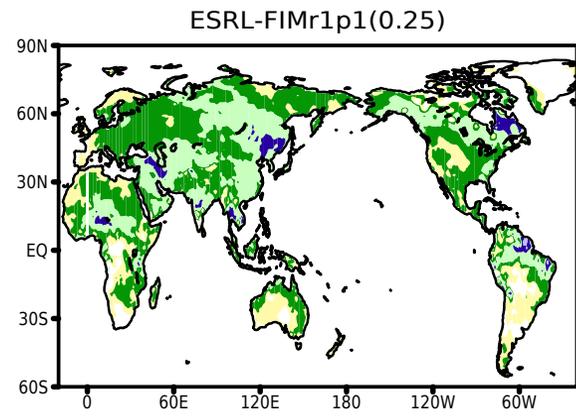
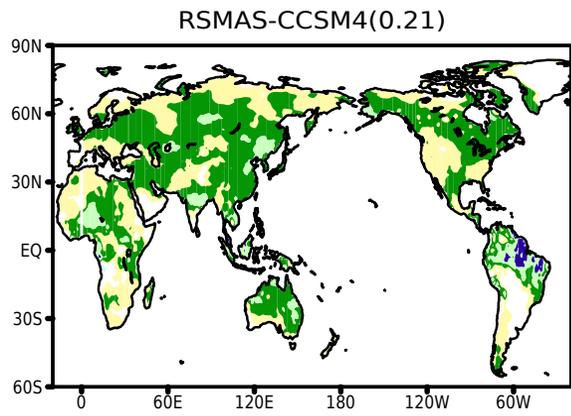
- Models have their own (erroneous) idea about what the climate looks like
- Calculate and remove model mean climatology
- Skill quantified using anomalies

## Anomaly Correlation Coefficient (ACC)

- Ensemble Mean
- How well does the variability of the model anomalies match with the verification anomalies?

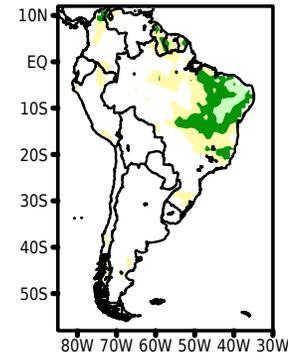


Anomaly  
Correlation  
Temperature  
Week 3

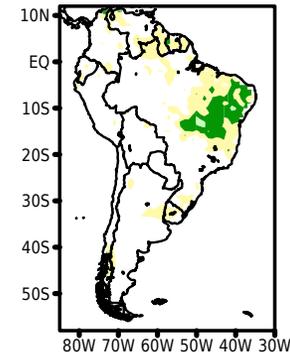


# Anomaly Correlation Precipitation Week 3

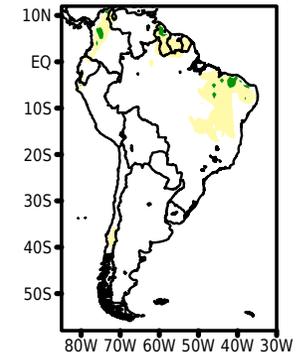
RSMAS-CCSM4(0.09)



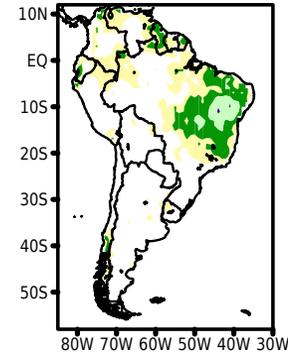
ESRL-FIMr1p1(0.08)



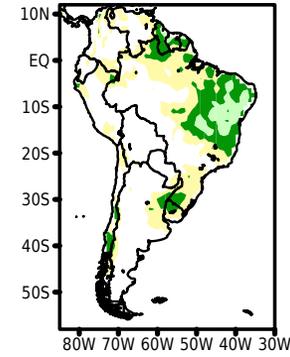
NAVY-ESPC(0.06)



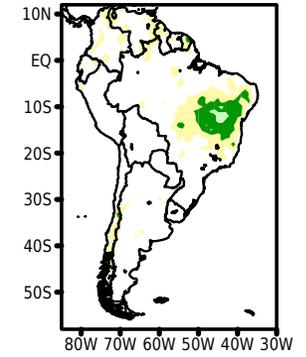
GMAO-GEOS\_V2p1(0.12)



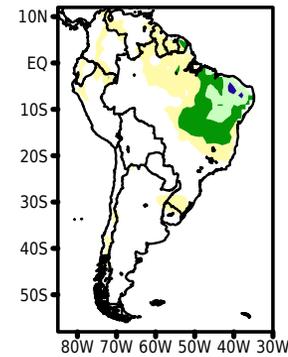
EMC-GEFS(0.12)



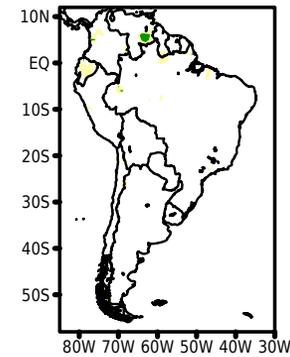
ECCC-GEM(0.08)



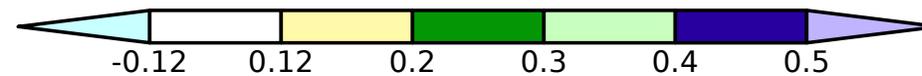
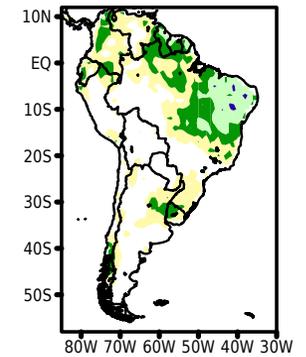
NCEP-CFSv2(0.11)



PERSIST(0.03)



MME7(0.15)

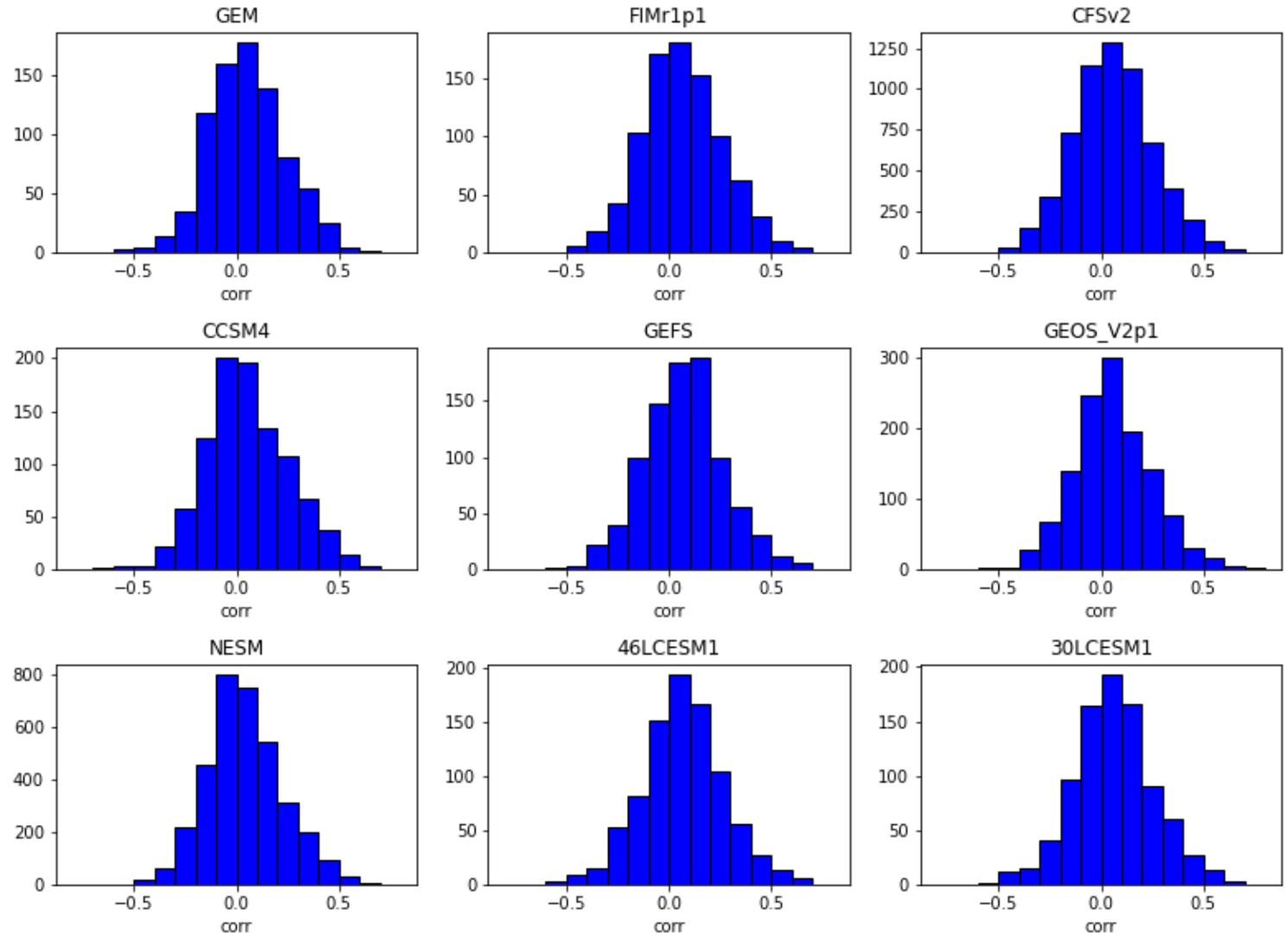


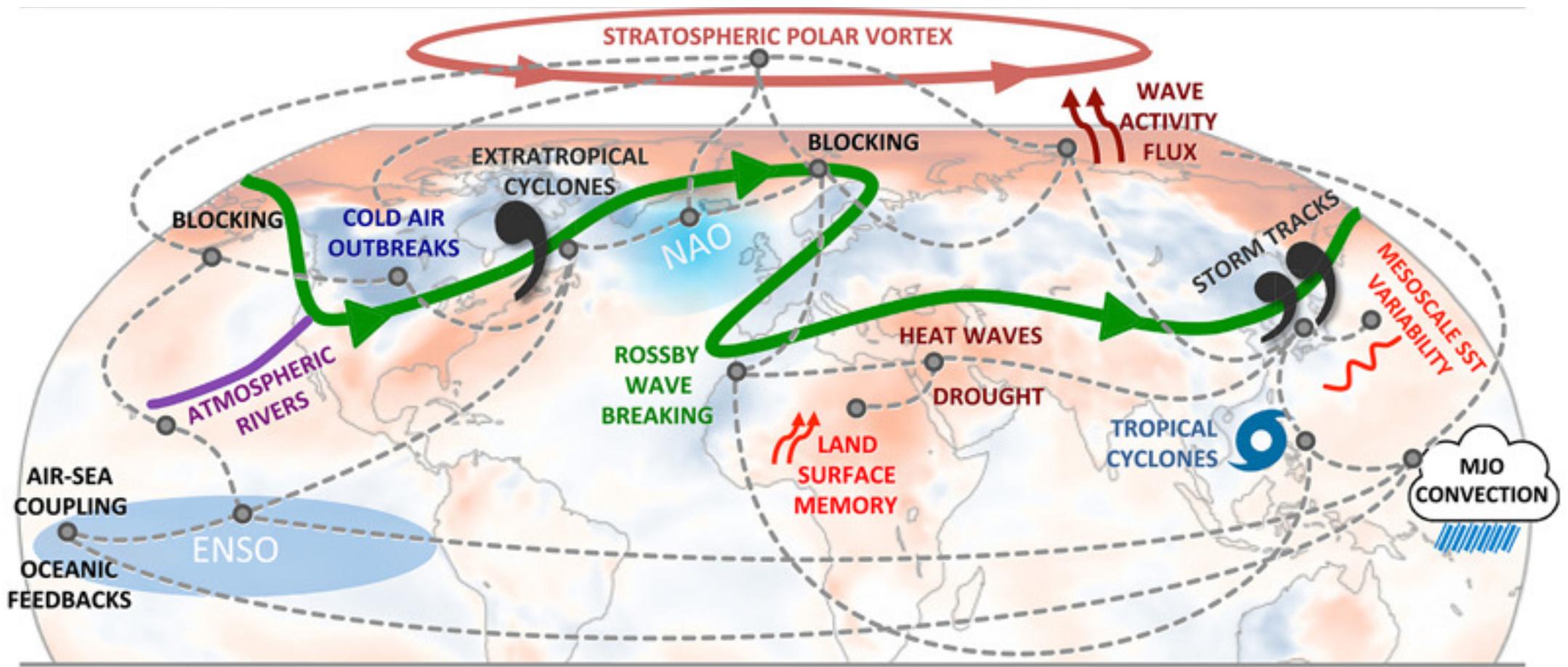
# Are these modest skill forecasts useful?

- Depends on the user & application
- They are overall better than persistence or climatology
- Some regions have more skill
- Some times are more skillful

**Forecasts of opportunity**

## Histograms of Week 3 Precipitation Pattern Correlation over North America





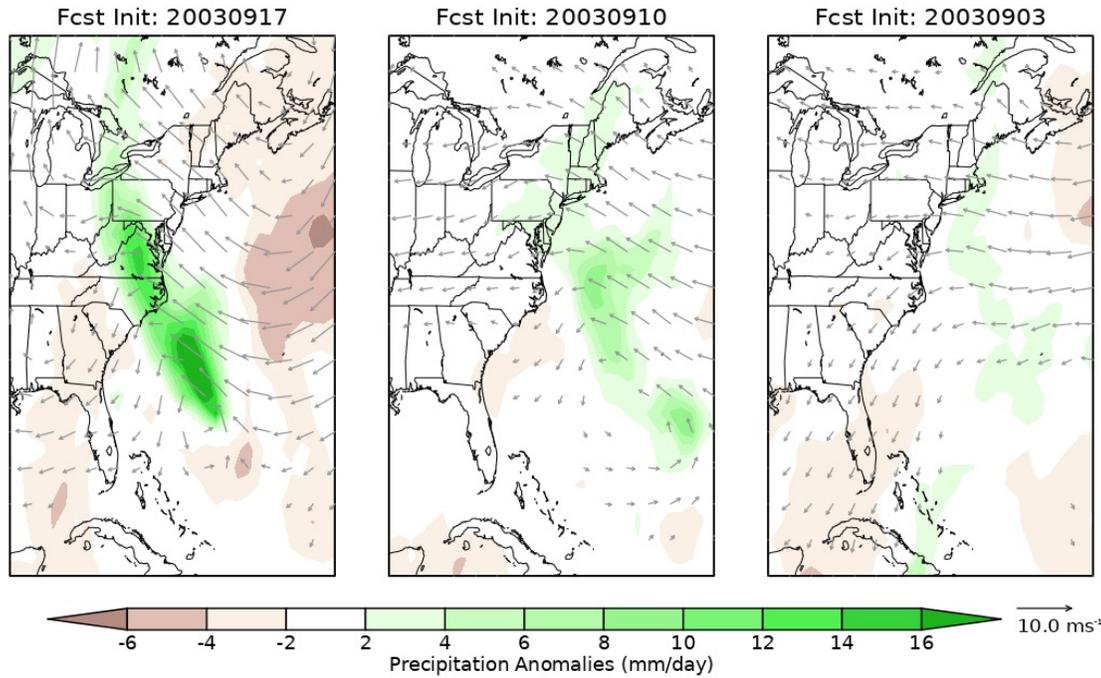
# Understanding Sources of Predictability

# Potential Hazardous and Extreme Weather

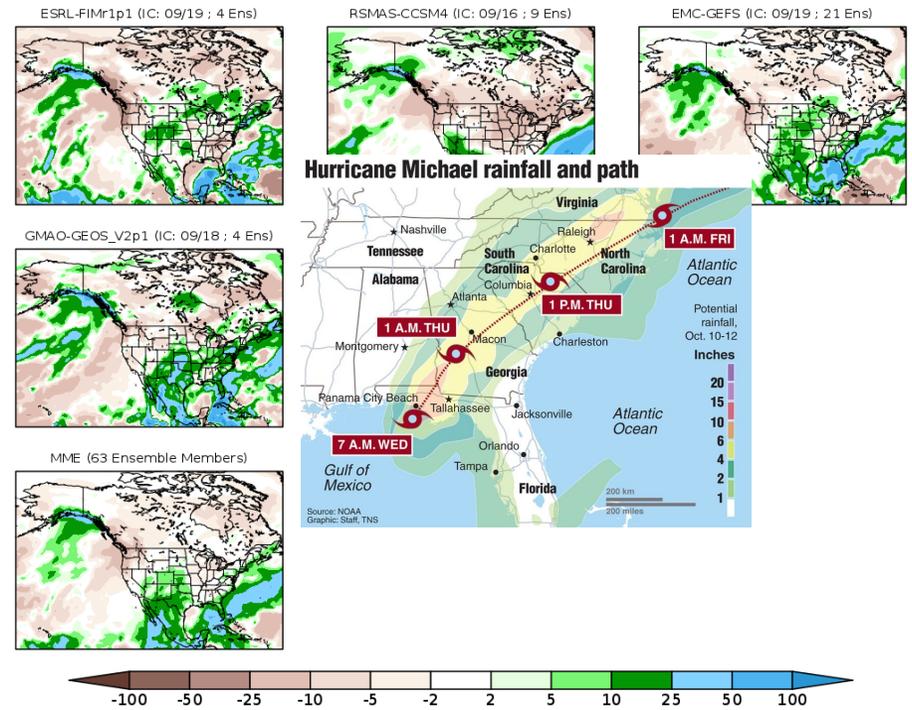
## Applications: Tropical Cyclones

### Hurricane Isabel Forecasted Precipitation & Wind Anomalies

Valid: Sep 17, 2003 - Sep 23, 2003

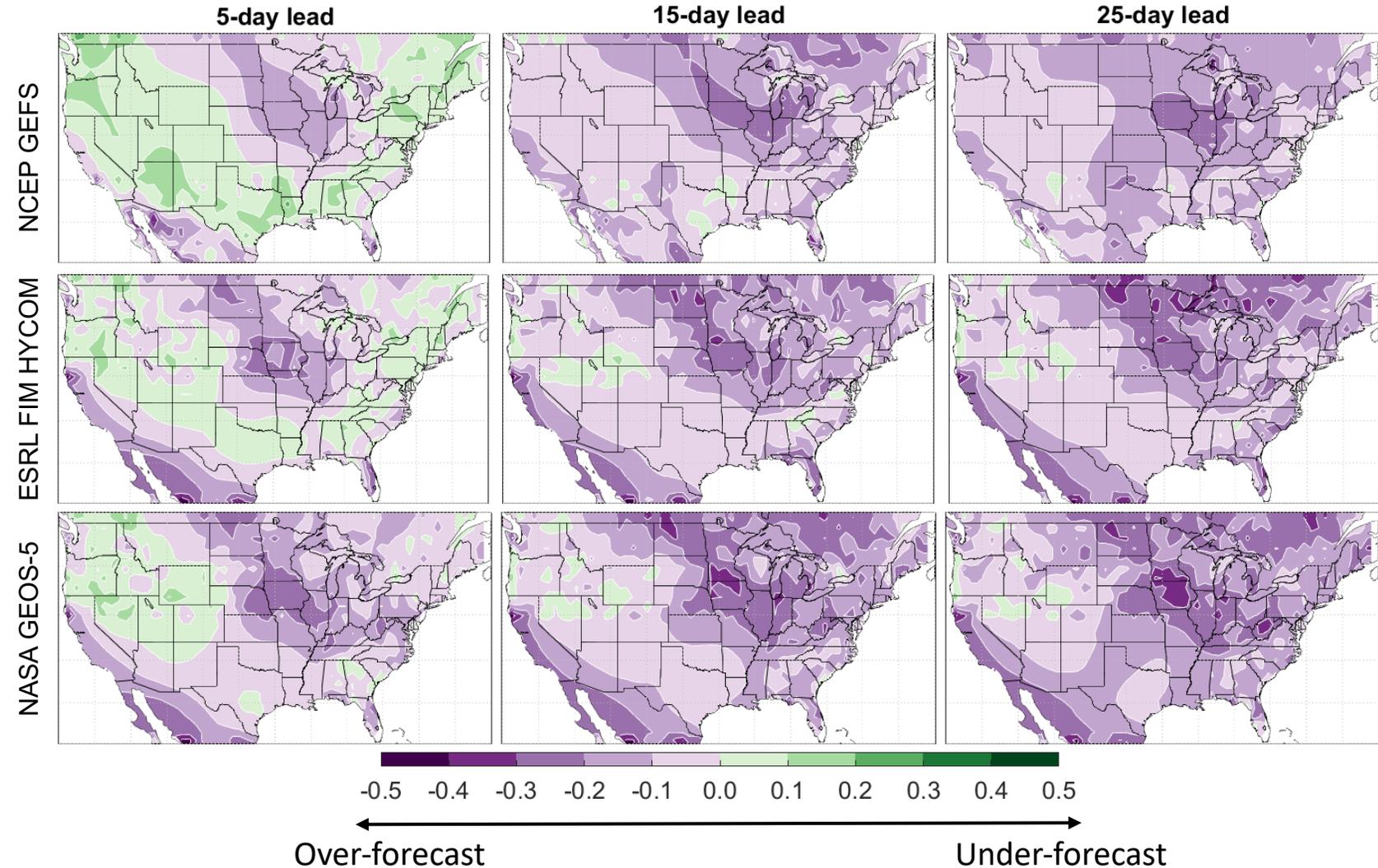


### SubX Week 3-4 Total Precipitation Anomalies (mm): Valid 2 weeks ending OCT 19



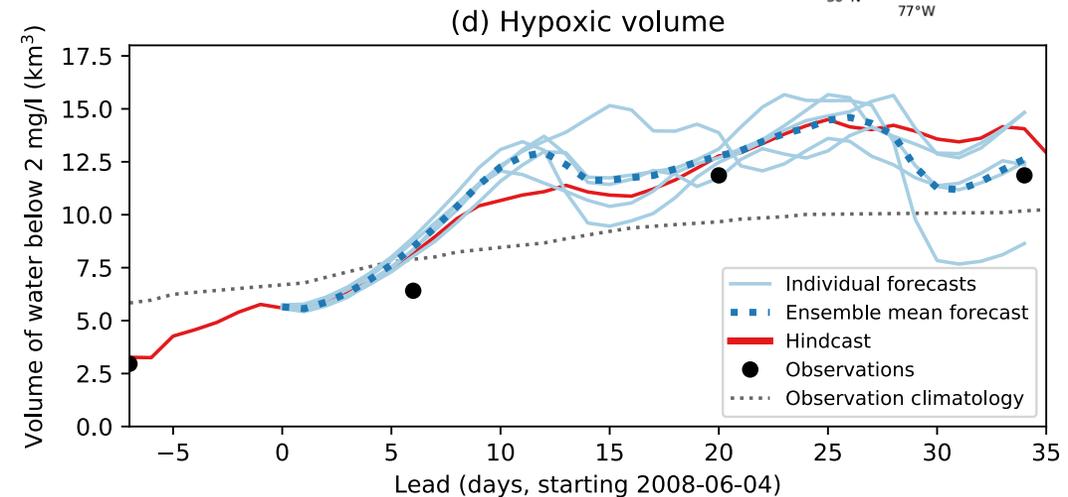
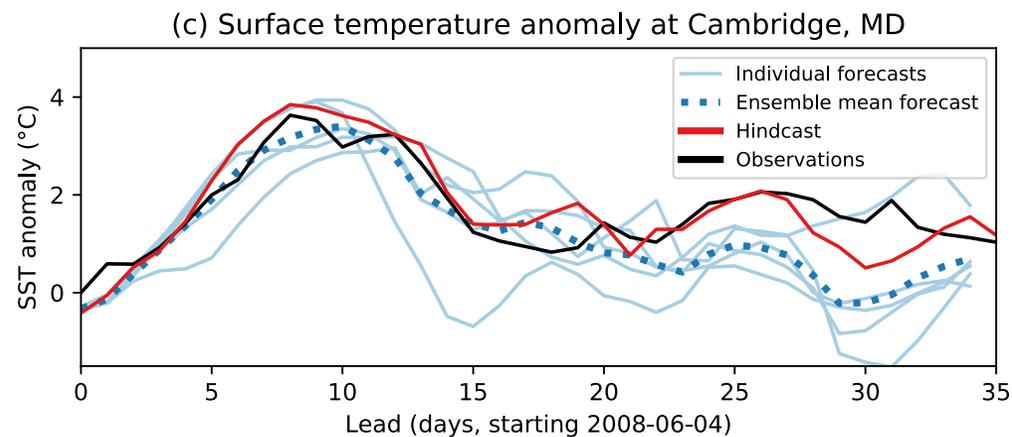
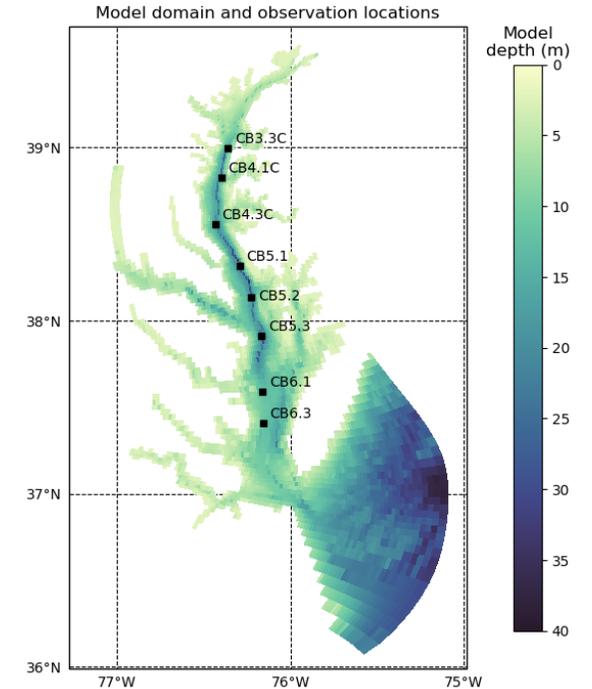
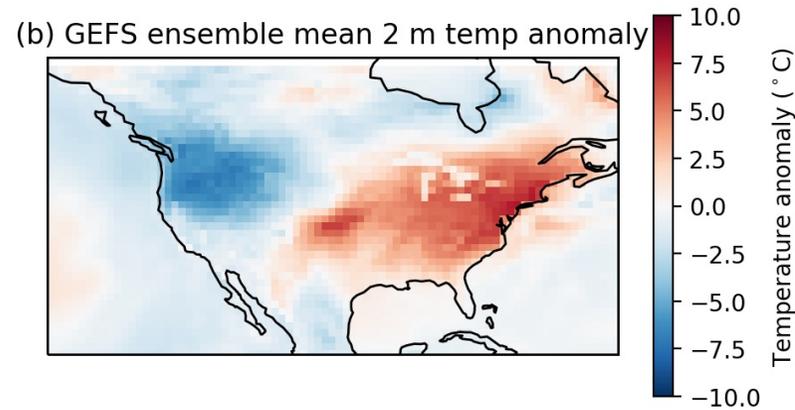
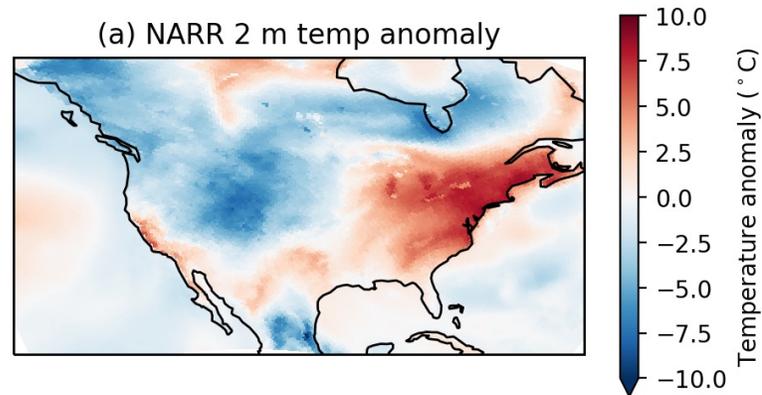
# Potential Hazardous and Extreme Weather Applications: Heat waves

Heat Wave Forecast Reliability -  $T_{MAX}$



- Models over-forecast heat waves across most of CONUS beyond 5-day lead
- Low forecast reliability in Midwest attributed to high frequency of false positive forecasts.
- Hot day persistence is underestimated in southern Great Plains (Texas).

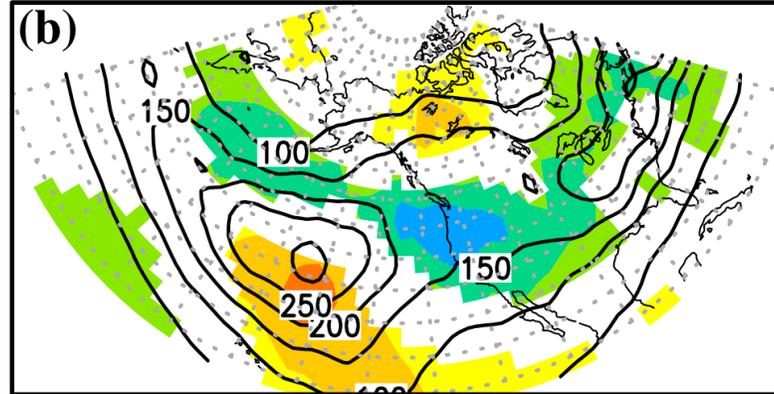
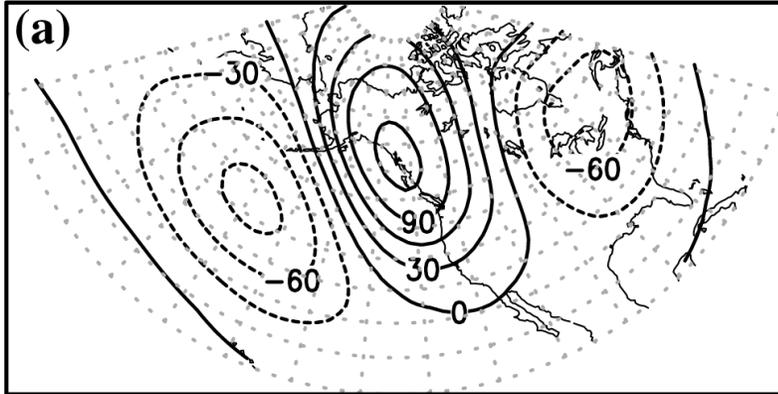
# Potential Hazardous and Extreme Weather Applications: Heat waves and their Impacts on Coastal Ecosystems



# Potential Hazardous and Extreme Weather Applications: Weather regimes and precipitation extremes

**Pacific Wavetrain 22%**

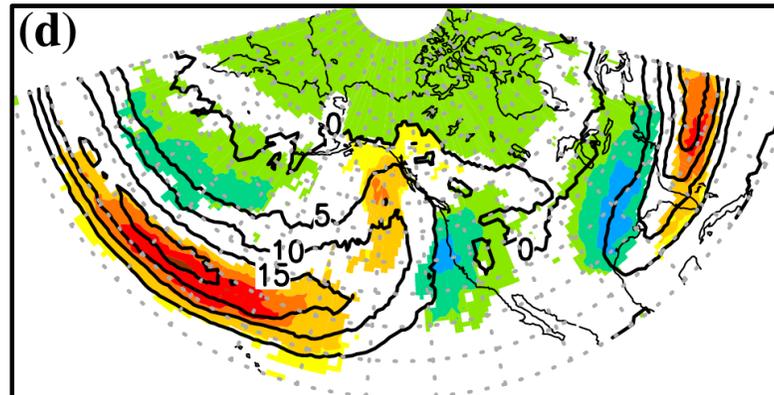
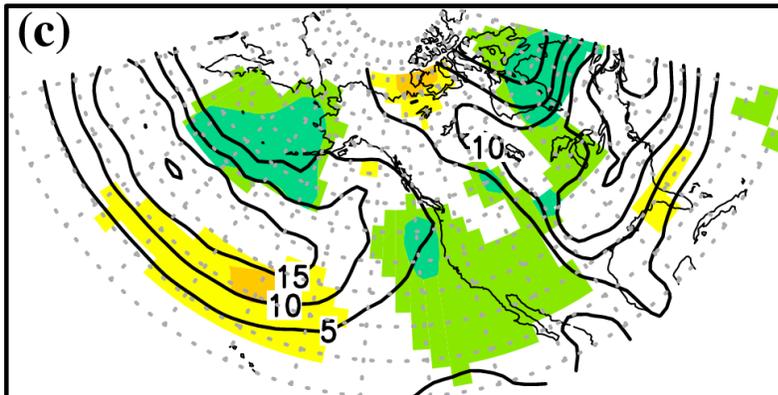
500 hPa  
Height  
Anomalies



300 hPa  $v'v'$



850hPa  $v'T'$



# Atmospheric  
Rivers per Season



# Other Potential Applications

Agriculture

Water Resources

Energy

Humanitarian Crises

Air quality, Fire, and Smoke

Public Health

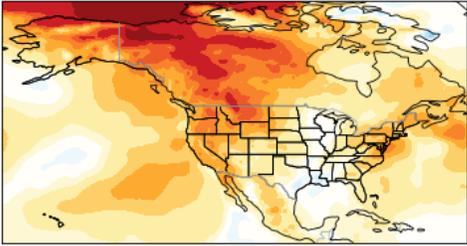
Health Equity

Optimizing military planning and intelligence

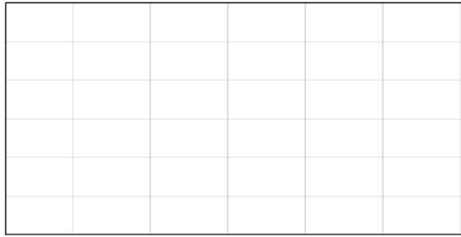
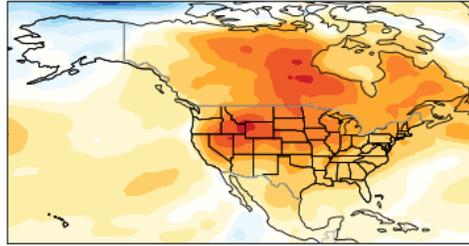
....

SubX Week 3-4 2m Temperature Anomalies (°C): Valid 2 weeks ending Oct 28

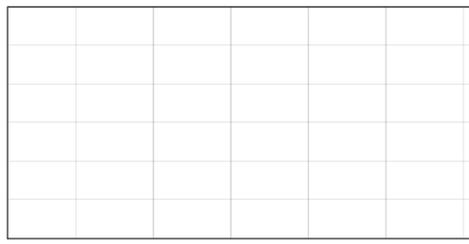
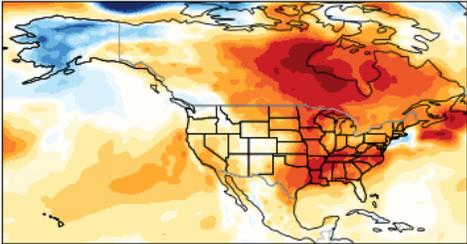
ESRL-FIMr1p1 (IC: 20220928; 4 Ens )



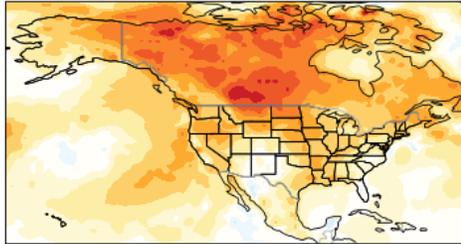
RSMAS-CCSM4 (IC: 20220925; 9 Ens )



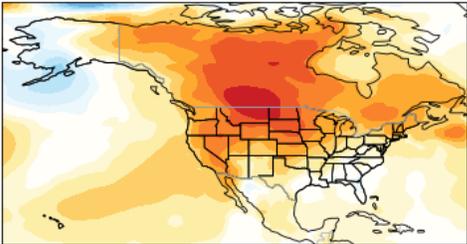
GMAO-GEOS\_V2p1 (IC: 20220928; 4 Ens )



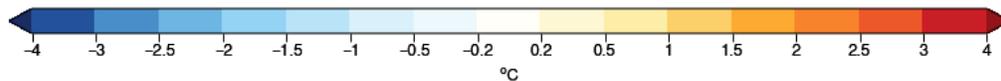
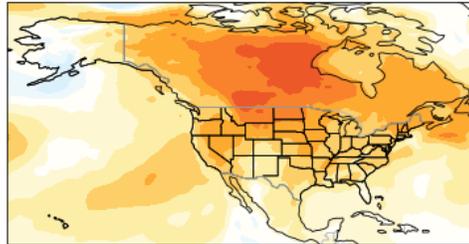
ECCC-GEPS7 (IC: 20220929; 21 Ens )



NCEP-CFSv2 (IC: 20220929; 16 Ens )



SUBX-MME (54 Ensemble Members)



**Project Website and Forecast Maps:**

<http://cola.gmu.edu/subx/>

**Data Library:**

<https://iridl.ldeo.columbia.edu/SOURCES/.Models/.SubX/>

**BAMS Paper:**

<https://journals.ametsoc.org/view/journals/bams/100/10/bams-d-18-0270.1.xml>

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