The role of the midlatitude ocean in sub-seasonal prediction

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CHAPTER

9

Midlatitude Mesoscale Ocean-Atmosphere Interaction and Its Relevance to S2S Prediction

R. Saravanan, P. Chang

The Gap between Weather and Climate Forecasting: Sub-Seasonal to Seasonal Prediction,
edited by Andrew W. Robertson and Frederic Vitart,
1st ed. Elsevier.

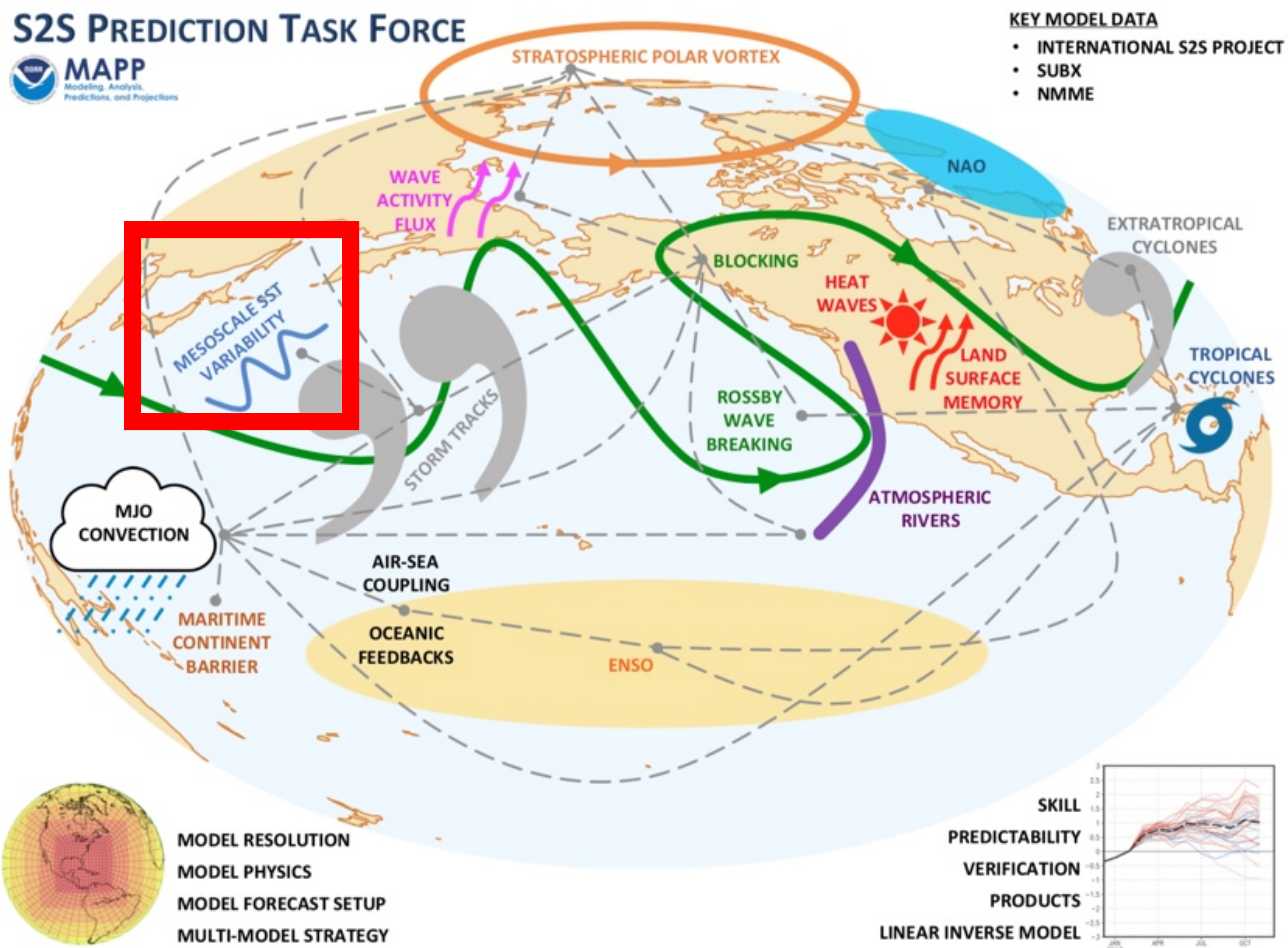
Fun Facts

- Heating due to warm SST anomaly
  - *Tropics*: balanced by vertical motion due to weak horizontal T gradients
  - *Midlatitudes*: can be balanced by horizontal advection due strong horizontal T gradients

- Baroclinic Rossby Radius in the midlatitudes
  - *Atmosphere*: O(1000km)
  - *Ocean*: O(100km)

insanity is doing the same thing
over and over again,
but expecting different results

S2S PREDICTABILITY
THE SEARCH FOR MEMORY



Frequency vs. power for SST in a coupled atmosphere-mixed layer model

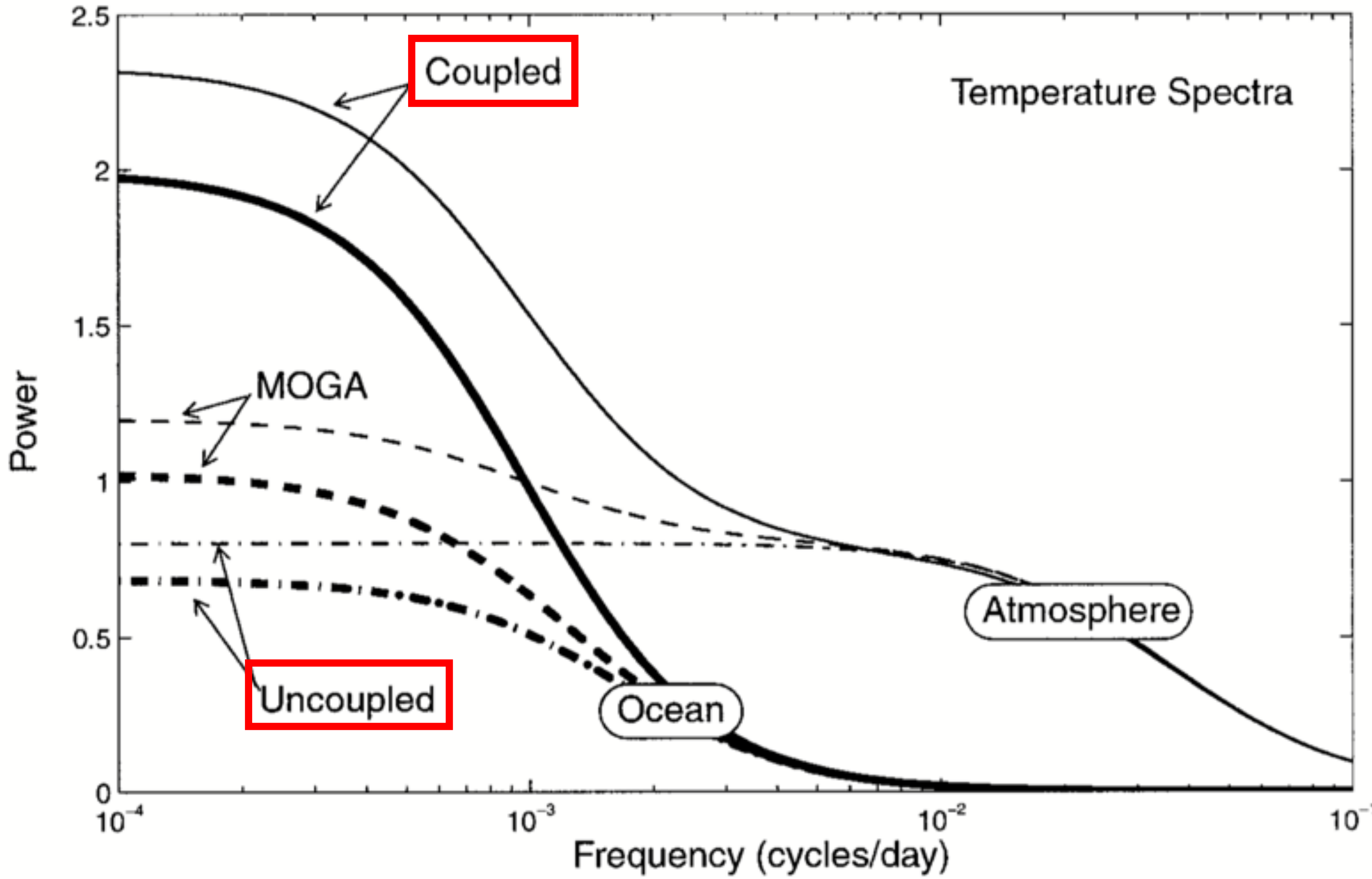
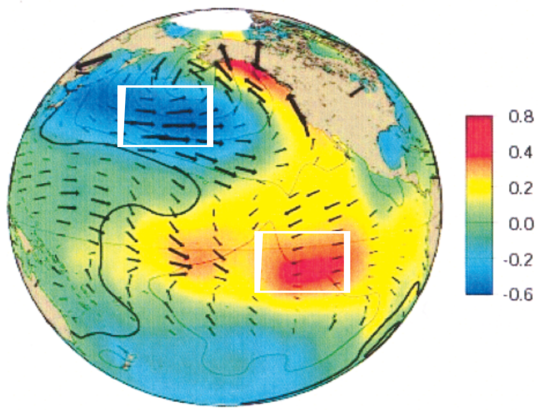
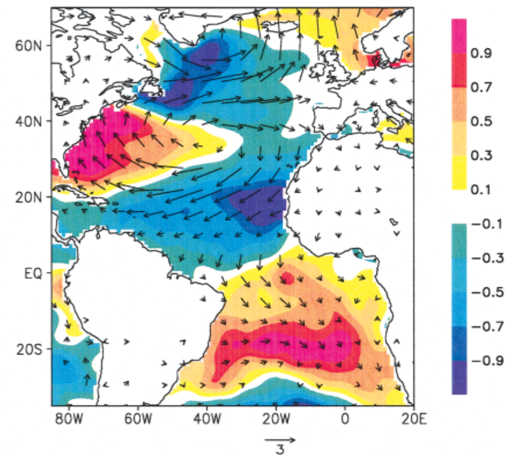


FIG. 4. Power spectra of atmosphere and ocean temperature for the coupled, MOGA, and uncoupled cases. The standard parameters (see Table 1) are used.

Correlation between surface wind speed and Sea Surface Temperature (SST): *observed*

Synoptic scale O(1000km): SST and wind are negatively correlated





Do basin-scale (1000km) midlatitititude SST anomalies affect the atmosphere?

1999

meeting summary

Review of WETS—The Workshop on Extra-Tropical SST anomalies

Walter A. Robinson
Department of Atmospheric Sciences, University of Illinois, Urbana–Champaign, Urbana, Illinois

2002

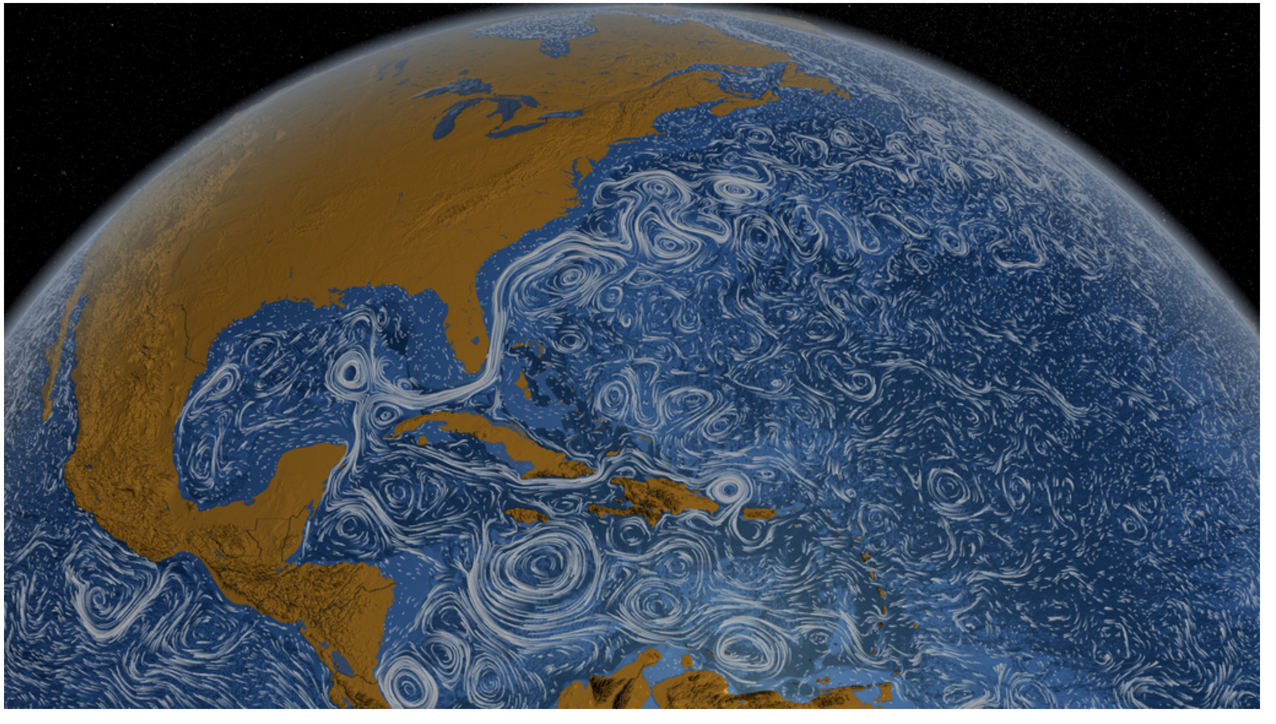
Atmospheric GCM Response to Extratropical SST Anomalies: Synthesis and Evaluation*

Y. Kushnir,+ W. A. Robinson,# I. Bladé,@ N. M. J. Hall,& S. Peng,** and R. Sutton++

First, we can now say with confidence that the extratropical ocean does indeed influence the atmosphere outside of the boundary layer, but that this influence is of modest amplitude compared to internal atmospheric variability. Taking a linear perspective, we can think of

Midlatitude dynamics

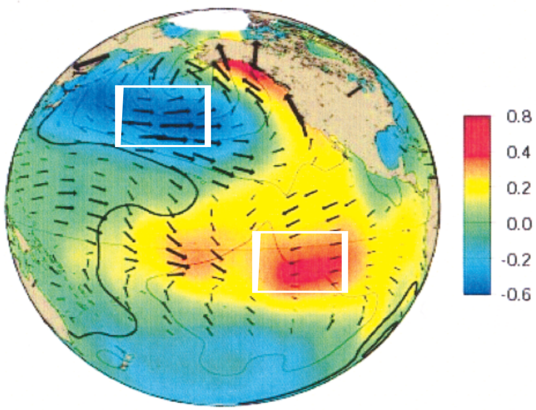
- Atmospheric weather – synoptic scales
  - Rossby radius O(1000km)
  - Baroclinic instability, 2-8 day timescale
- Oceanic weather – mesoscale eddies
  - Rossby radius O(100km) or less
  - Baroclinic/barotropic instability, 1 month timescale

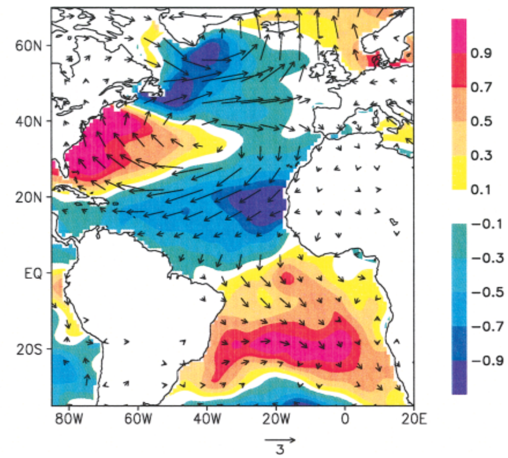


Do mesoscale (100km) midlatitititude SST anomalies affect the atmosphere?

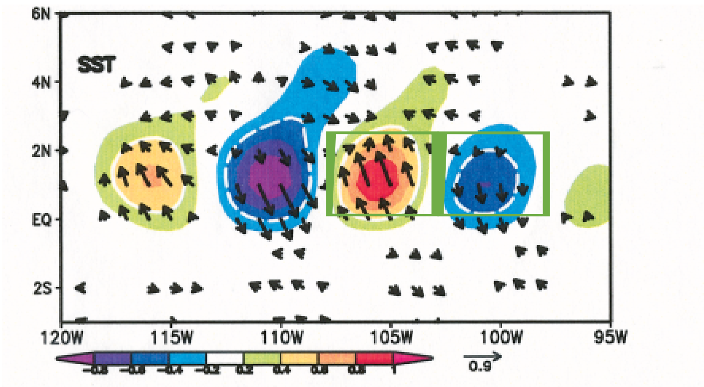
Correlation between surface wind speed and Sea Surface Temperature (SST): *observed*

Synoptic scale O(1000km): SST and wind are negatively correlated



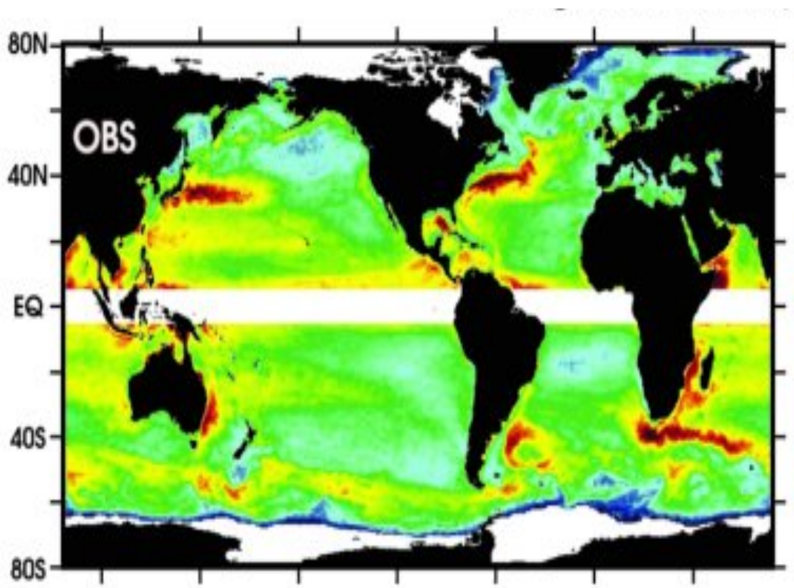


Ocean mesoscale O(100 km): SST and wind are positively correlated

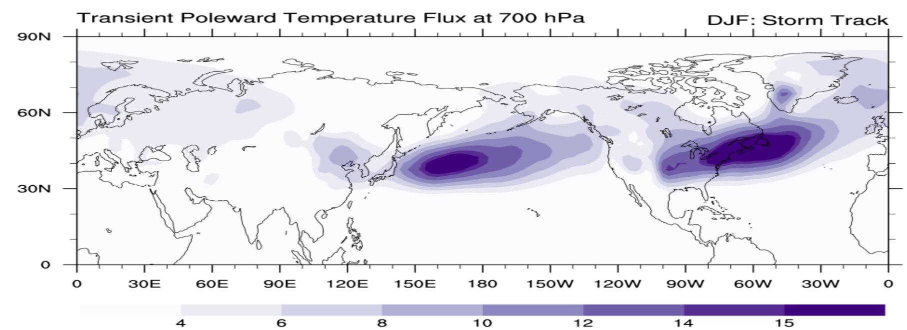


From Xie 2004

Where do the eddies occur?



Ocean Eddy Kinetic Energy
(Dixon et al., 2011, GFDL)

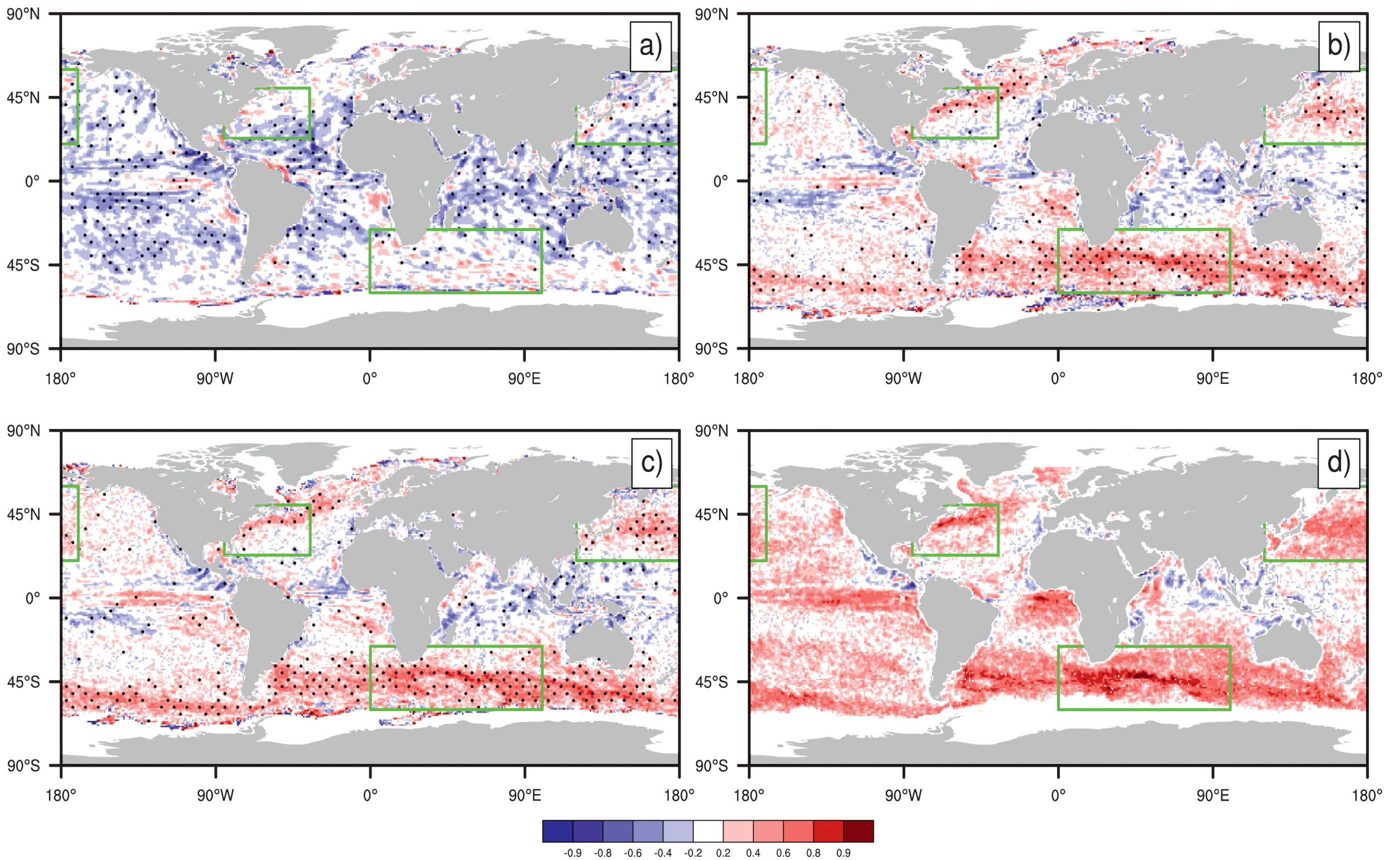


Atmospheric storm tracks
(S. Lubis)

Correlation between surface wind speed and SST - *simulated*

Bryan et al., 2010

1 deg OCN + 0.6 deg ATM **0.2 deg OCN + 0.6 deg ATM**



0.2 deg OCN + 0.26 deg ATM **OBS (AMSR+Quikscat)**

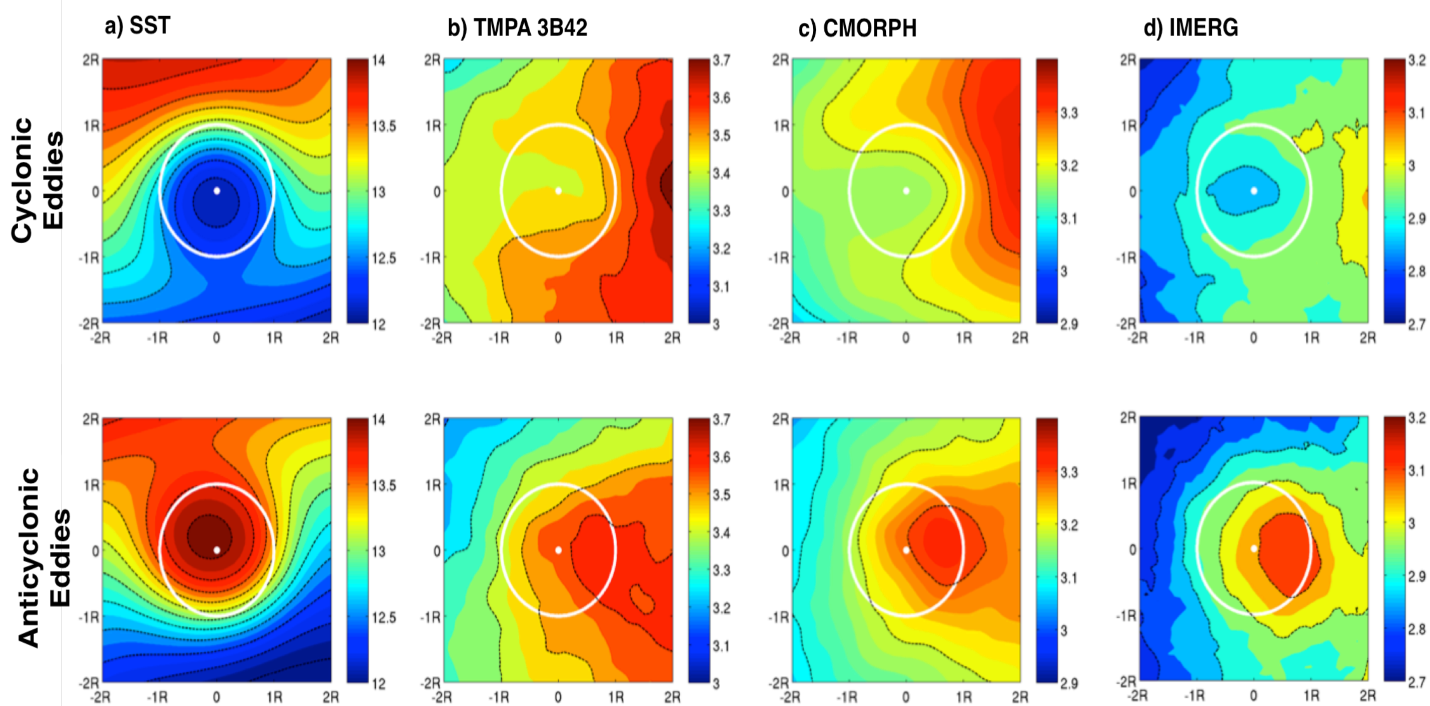
Satellite-Observed Precipitation Response to Ocean mesoscale eddies

Liu et al., *Journal of Climate* (2018)

SST

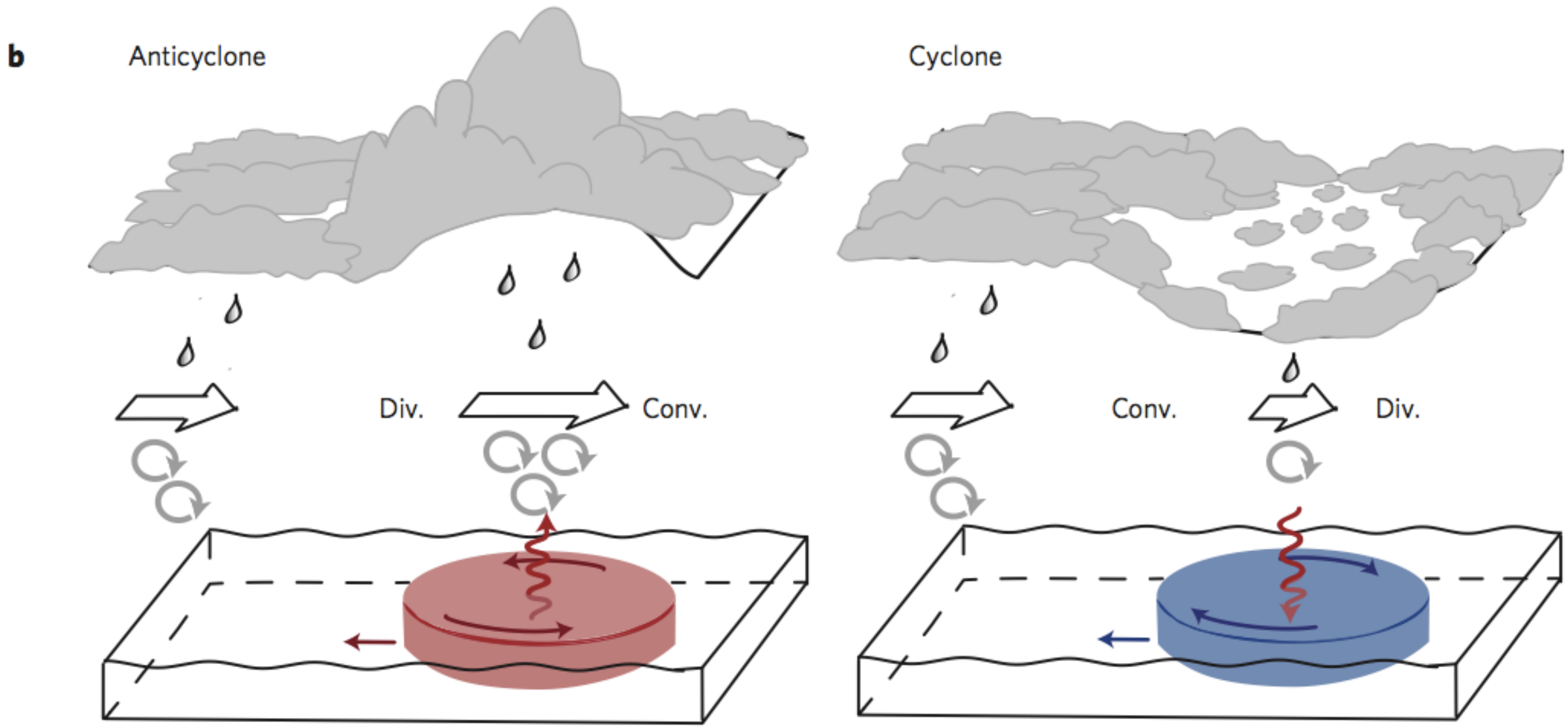
TRMM rainfall

GPM rainfall

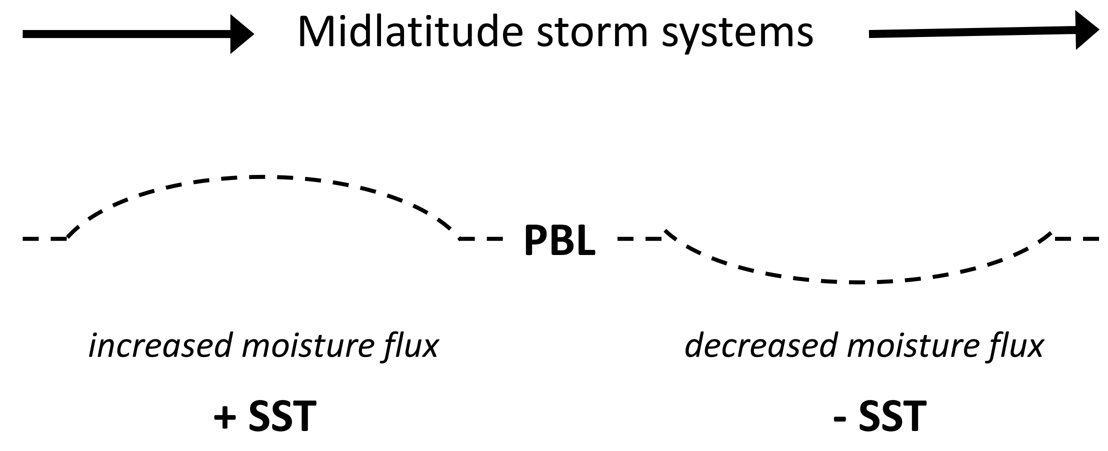


Imprint of Southern Ocean eddies on winds, clouds and rainfall

Frenger et al., 2013



Nonlinearity:
cold SST response is weaker



Distant Influence of Kuroshio Eddies on North Pacific Weather Patterns?

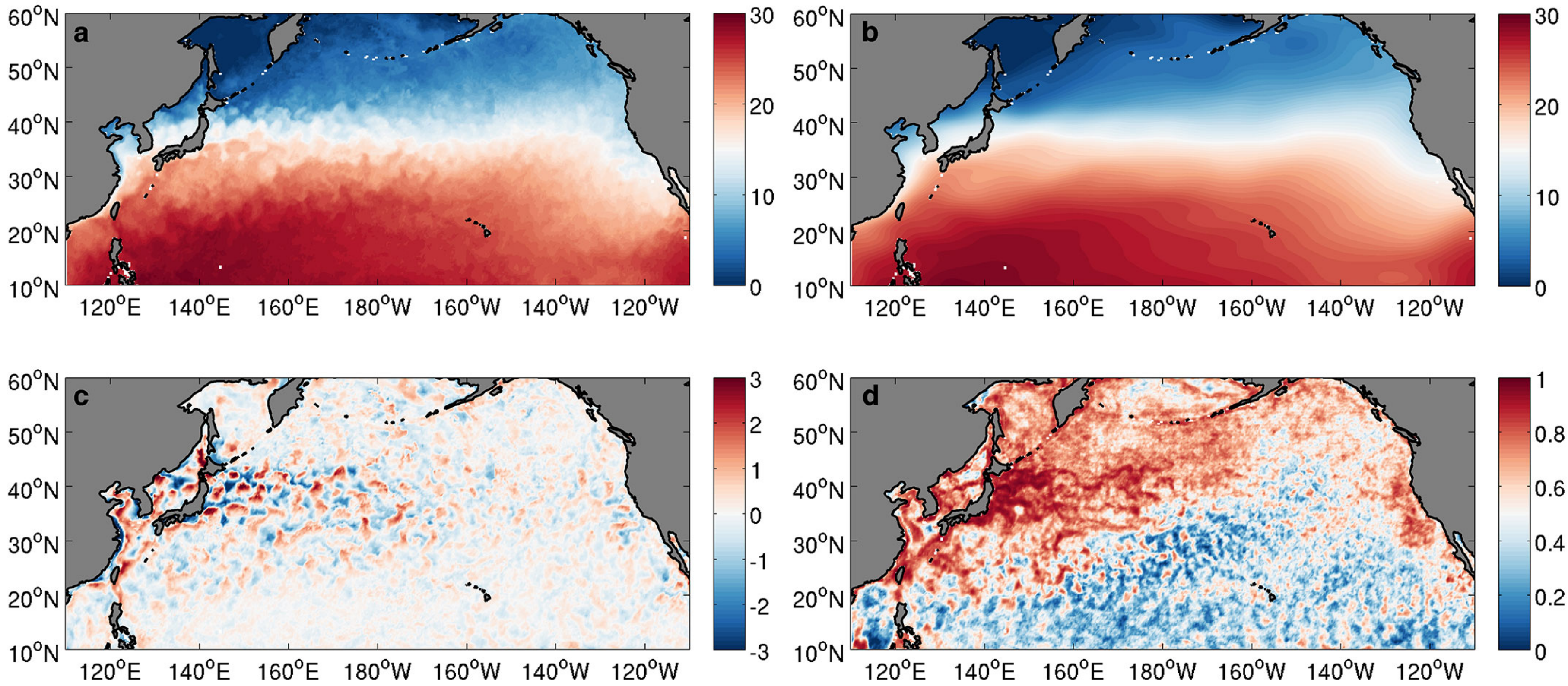
Ma et al., Scientific Reports (2015)

- **WRF Regional Atmospheric Model**
  - 27-km WRF, 30-Levels
  - 10-member ensemble
  - Seasonal (Oct. 2007 – Mar. 2008)
- **Control Simulation (CTRL)**
- **Smoothed Simulation (SMOOTH)**

Unfiltered vs. Filtered SST

Observed SST (CTRL)

Loess-Filter Filtered SST (SMOOTH)



Observed – Smoothed SST (Small-Scale)

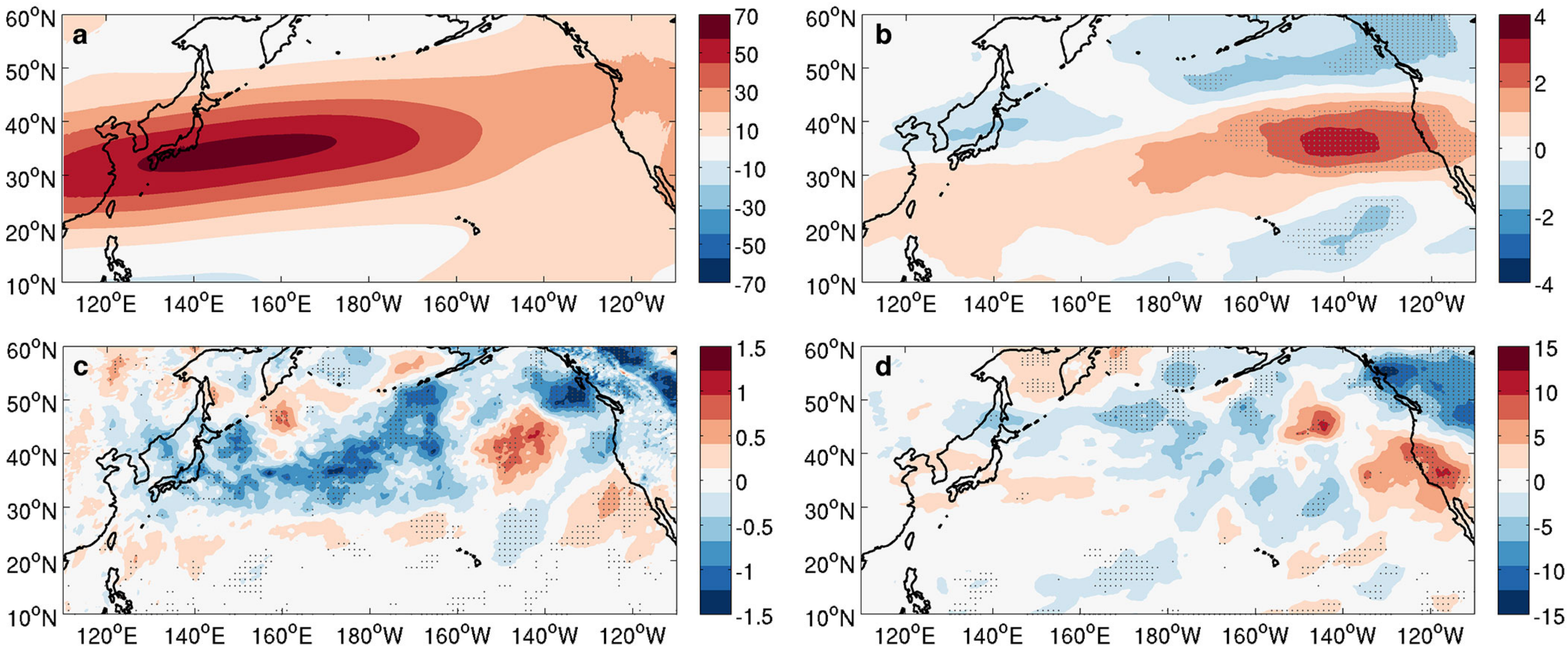
Variance fraction explained by Small-Scale SST

Ma et al., 2015, Sci. Rep.

Response to ocean eddies above Boundary Layer

U at 300 hpa (CTRL)

U Difference at 300 hpa (SMOOTH-CTRL)

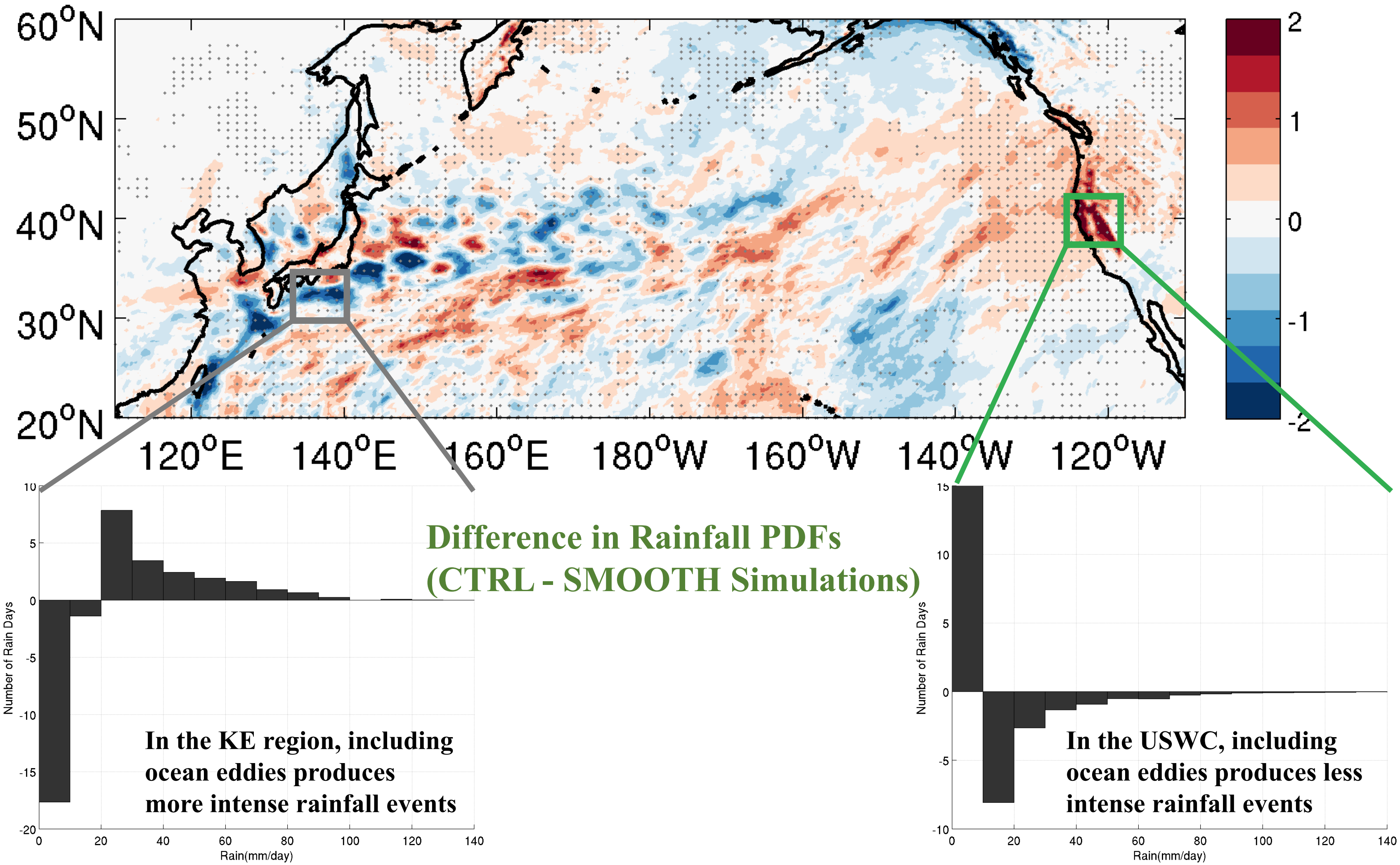


2-8 day <v'T'> at 850 hpa (SMOOTH-CTRL)

2-8 day EKE at 300 hpa (SMOOTH-CTRL)

Ma et al., 2015, Sci. Rep.

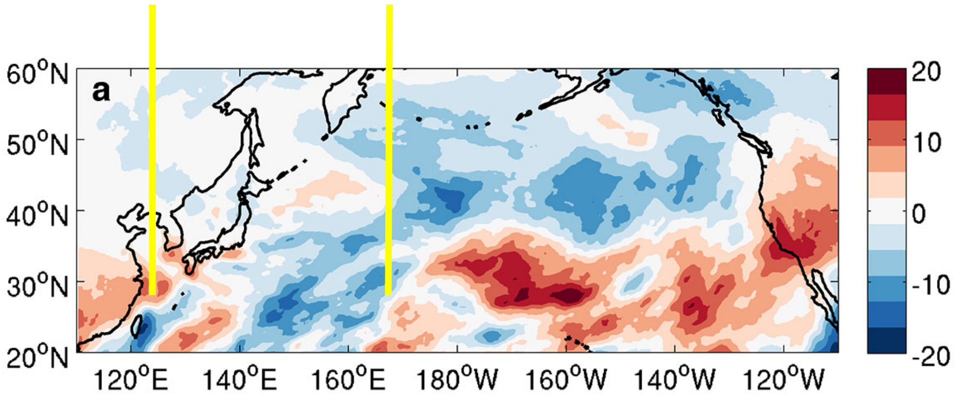
Simulated Rainfall difference (SMOOTH – CTRL)



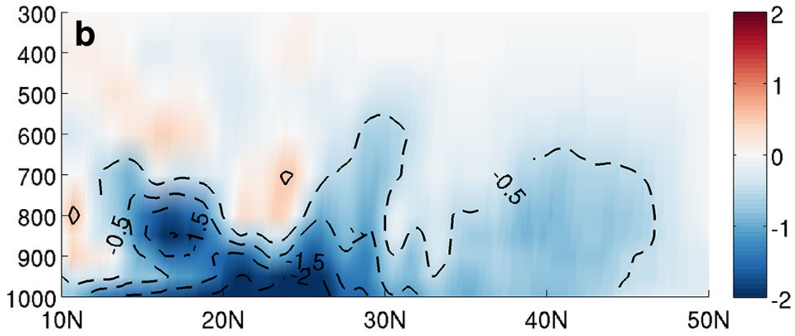
Ma et al., 2015, Sci. Rep.

Difference in Atmospheric Moisture (SMOOTH – CTRL)

Simulated Water Vapor Mixing Ratio Difference



Vertical Section of Water Vapor Mixing Ratio Difference

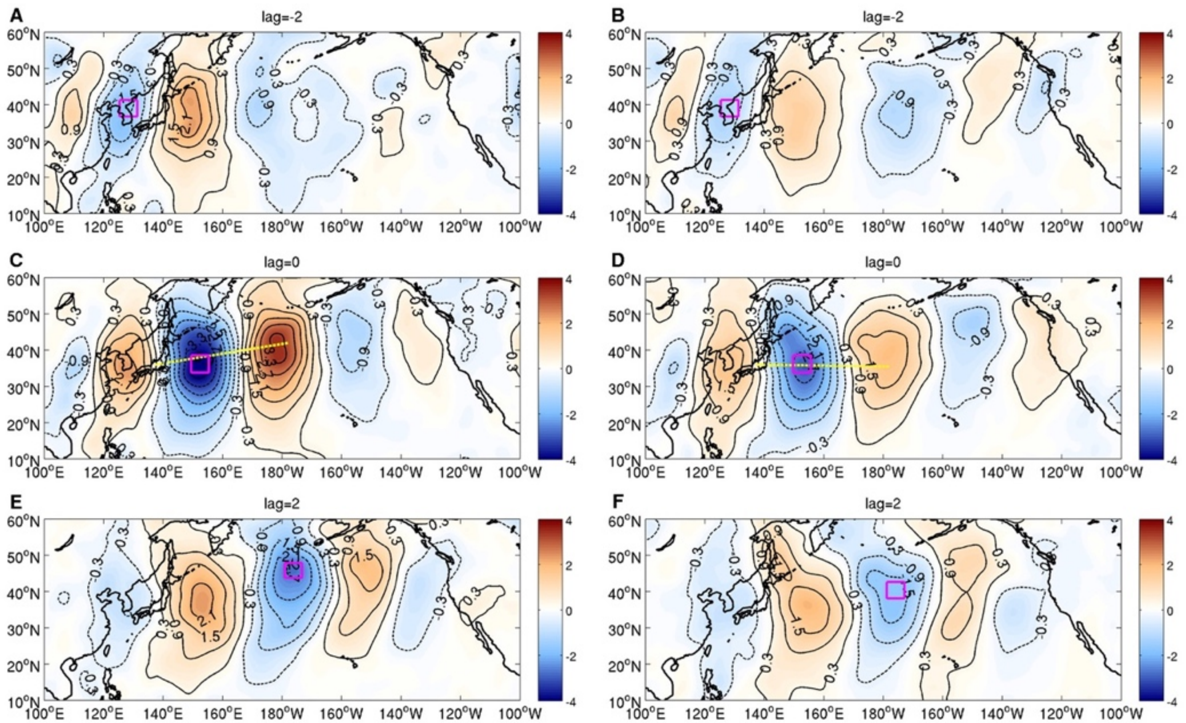


Ma et al., 2015, Sci. Rep.

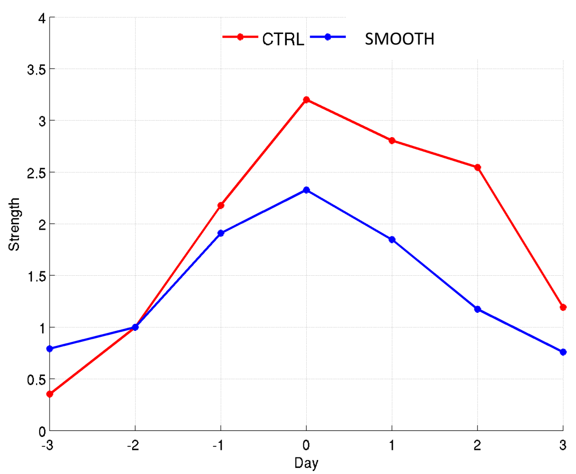
2-8 day V at 850 hpa storm lag-composites

CTRL

SMOOTH



Storm Amplitude Evolution



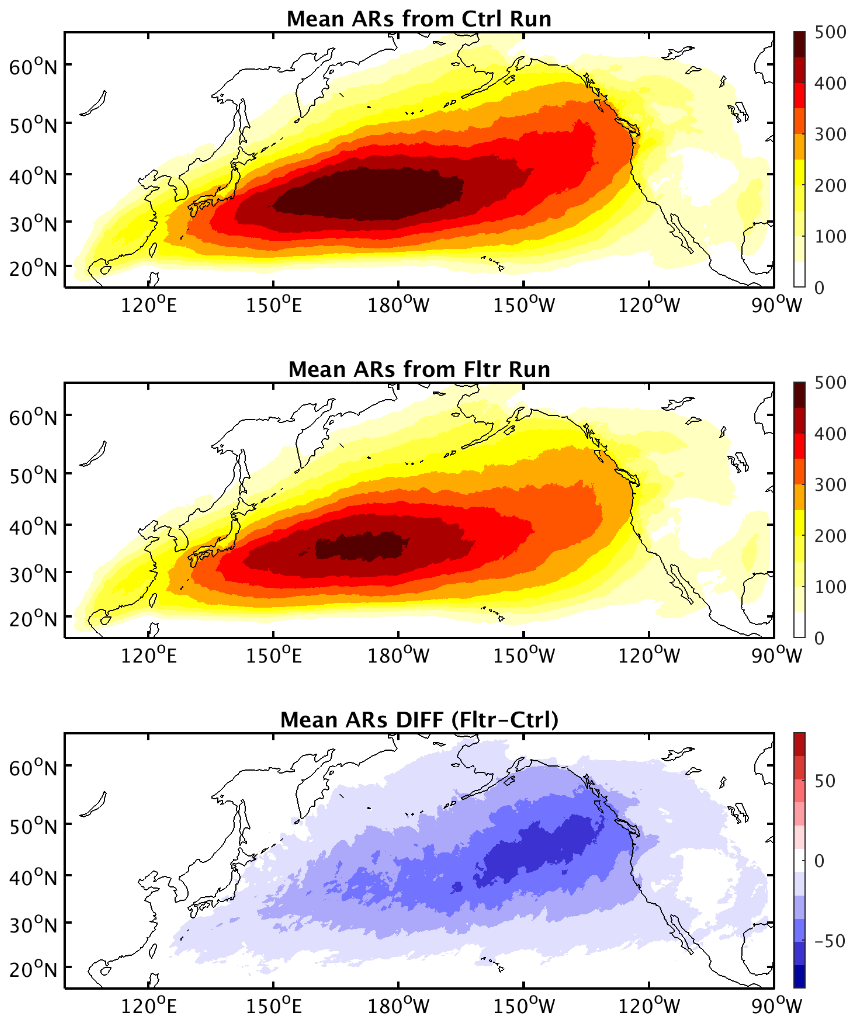
Ma et al., 2015, Sci. Rep.

Mesoscale eddy influence on biweekly timescales: Integrated Moisture transport associated with Atmospheric Rivers

CONTROL

SMOOTH

CONTROL-SMOOTH



Xue Liu, in preparation

Western boundary currents regulated by interaction between ocean eddies and the atmosphere

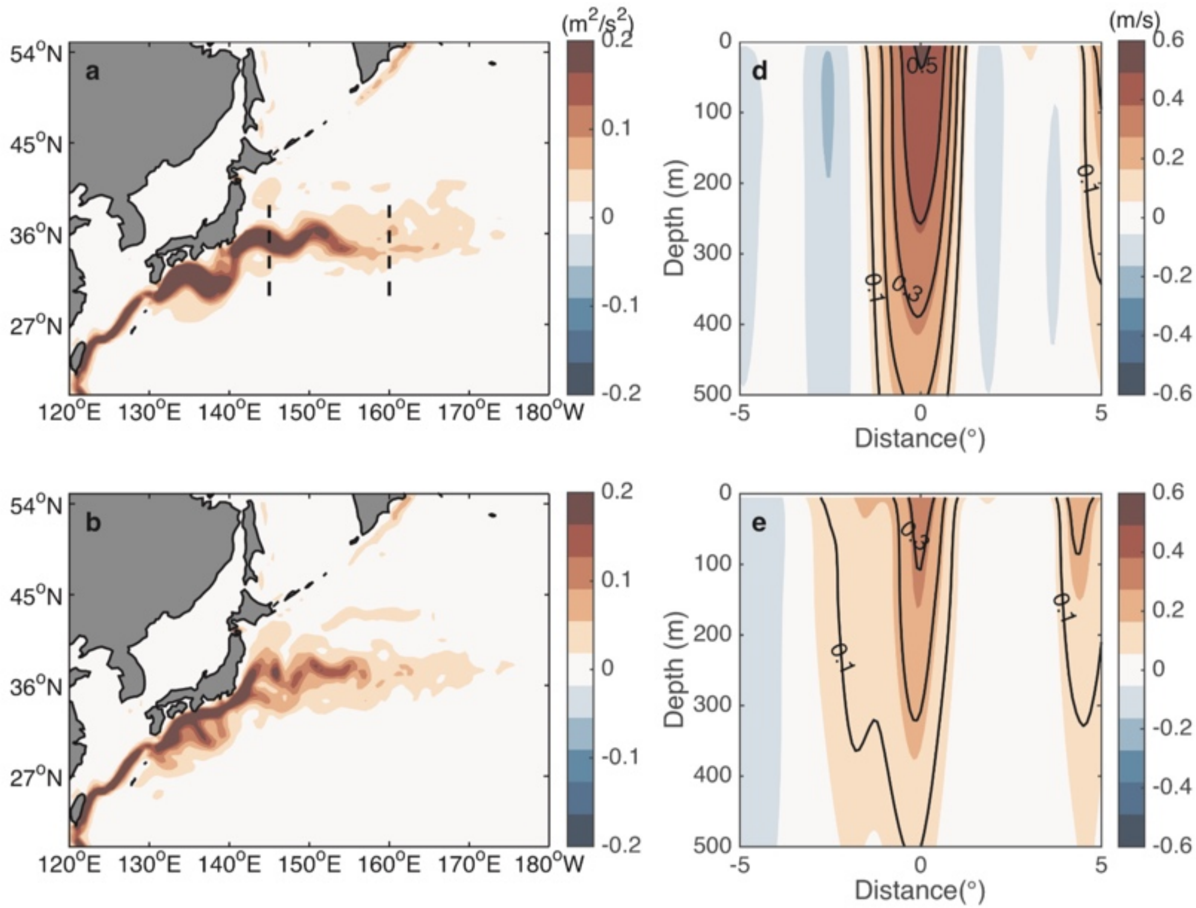
Ma et al., *Nature* (2016)

Eddy Kinetic Energy (upper ocean)

Zonal current

CONTROL

SMOOTH



Coupled Model: CESM with 0.25° deg. CAM5 and 0.1° POP2

Global S2S runs

- High-resolution (0.25°x0.25°) CAM5 coupled to a slab ocean model (CAM5-SOM):

$$\frac{\partial T_{mixed}}{\partial t} = \frac{1}{\rho c_0 h_{mixed}} \left(Q_{atm} + Q_{ocn}\right)$$

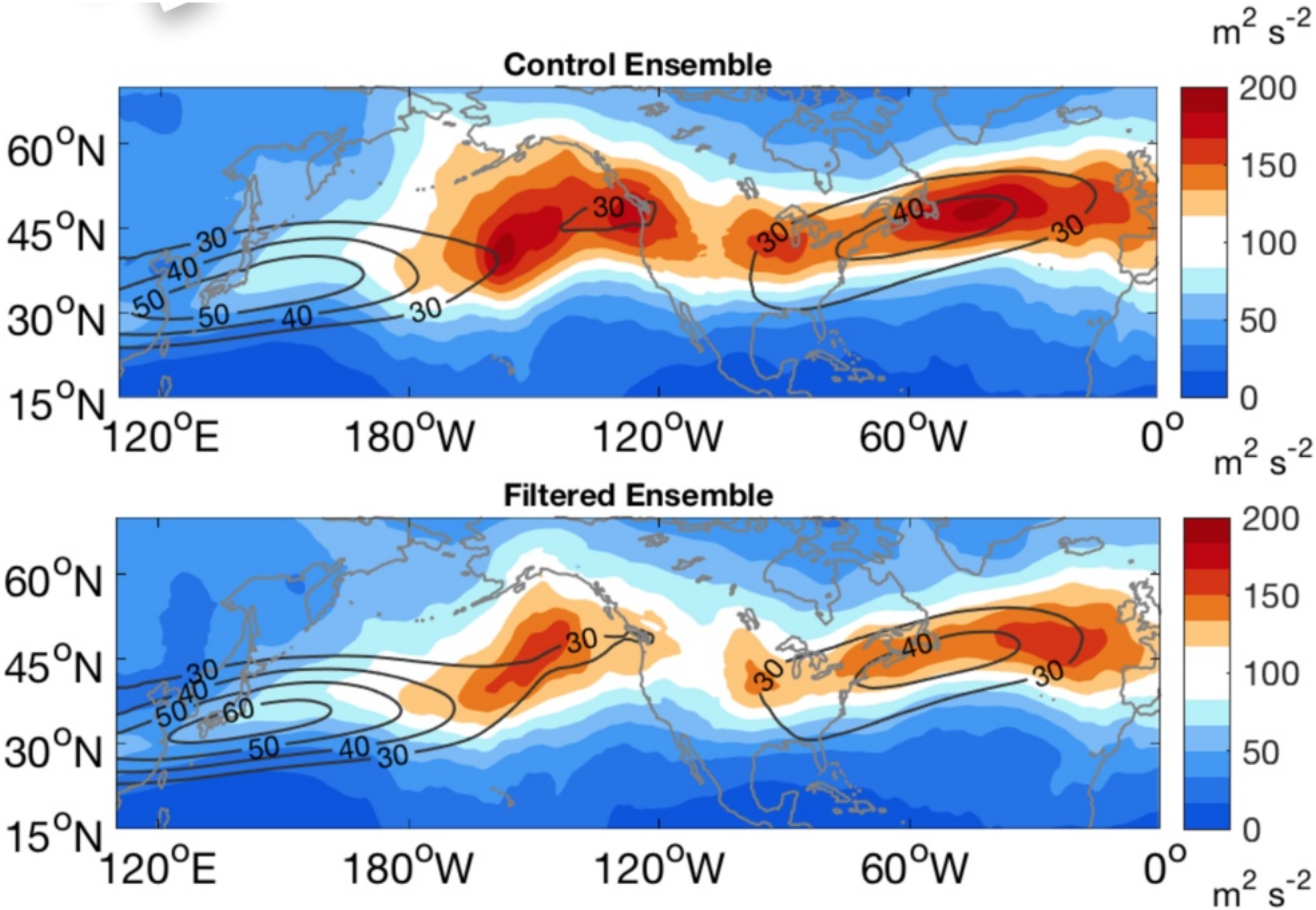
- Twin experiments: ensemble of thirty 30-day CAM5-SOM runs initialized with
  a. **CTRL**: high-resolution observed SST, and
  b. **FLTR**: spatial lowpass filtered SST (5°x5°)

Jia et al., submitted

200mb EKE

Color: EKE300

Contour: U300



Jia et al., submitted

Conclusions and Questions

- Oceanic mesoscale eddies ("ocean weather")
  - *Affect surface winds and boundary layer height*
  - *Nonlinear impact on moisture and rainfall*
  - *Impact above boundary layer on storm track?*
  - *Downstream remote effects?*
    - *Subseasonal, seasonal, ARs, extremes*
  - ***Tropical mesoscale eddies?***
  - ***Parameterized in coarse-resolution climate models?***

- Implications for S2S predictability
  - *Importance of model resolution (< 25km)*
  - *Importance of upper ocean conditions*
  - *Importance of coupling for damping of ocean eddies*