Connections Between the Madden-Julian Oscillation and Extratropical Regions of the Global Ocean and Atmosphere

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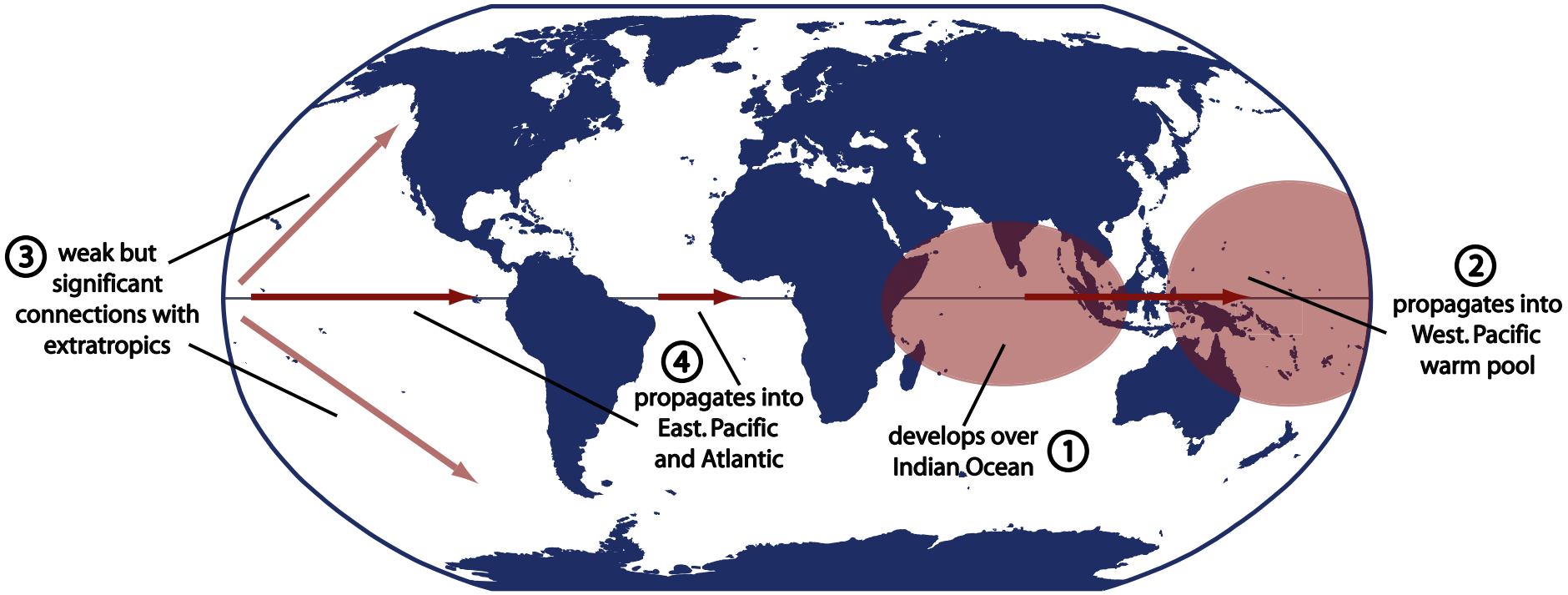
Background and Motivation

- There is growing interest in extending range of weather forecasts and developing a seamless scheme that bridges both weather and climate.
- Main prospect for predictability on intraseasonal timescales is the poorly understood **Madden-Julian Oscillation (MJO)**.
- We start by extending the work from a previous study which examined the connection between the MJO and high-latitude surface air tempurature (**SAT**).
- Then we explore the relationship between the MJO and global fields of oceanic data: sea surface temperature (**SST**) and sea level anomaly (**SLA**).

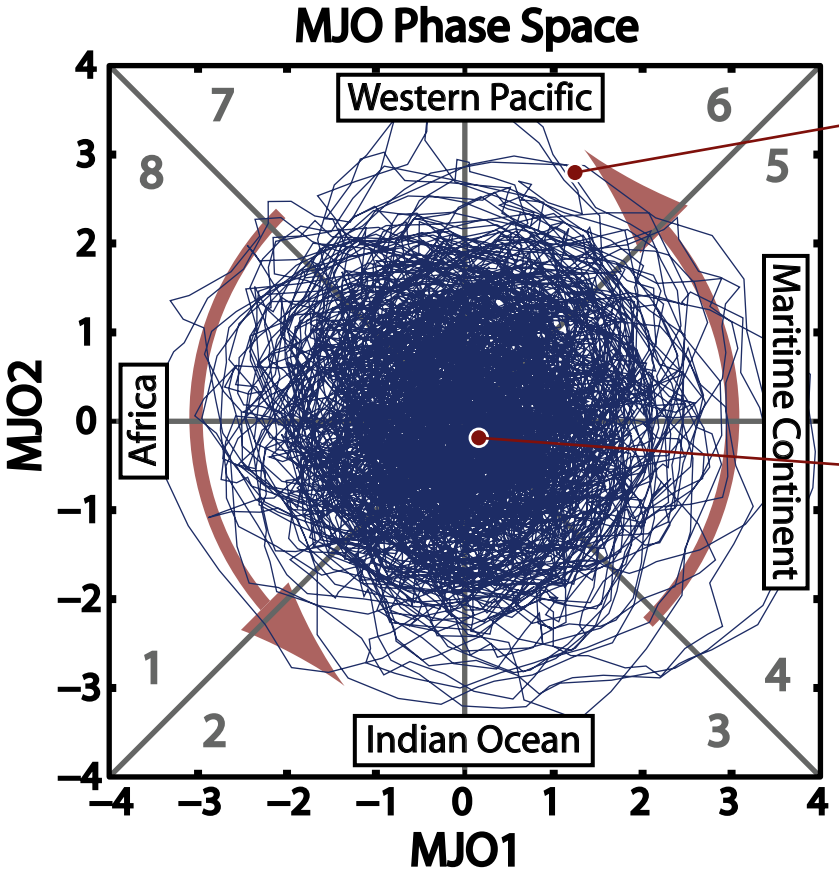
The Madden-Julian Oscillation

- MJO is dominant mode of atmospheric variability in the tropics on intraseasonal time scales (**30-90 days**)
- Eastward propagating disturbance detectable in tropical OLR/precipitation and zonal wind
- Shows promise for enhancing predictability over weeks to months



Monitoring the MJO

- Daily bivariate MJO index: MJO1 and MJO2, first two PCs of EOF analysis [1]
- Indices in quadrature so can generate "MJO phase spase":



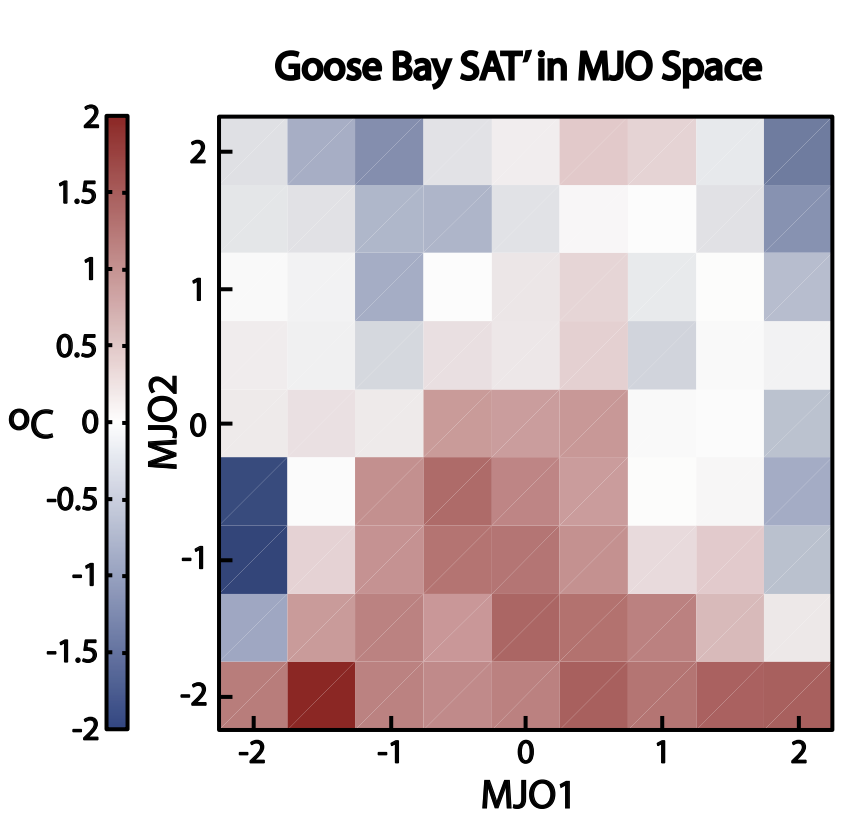
Strong MJO in phase 6
(active over Western Pacific)

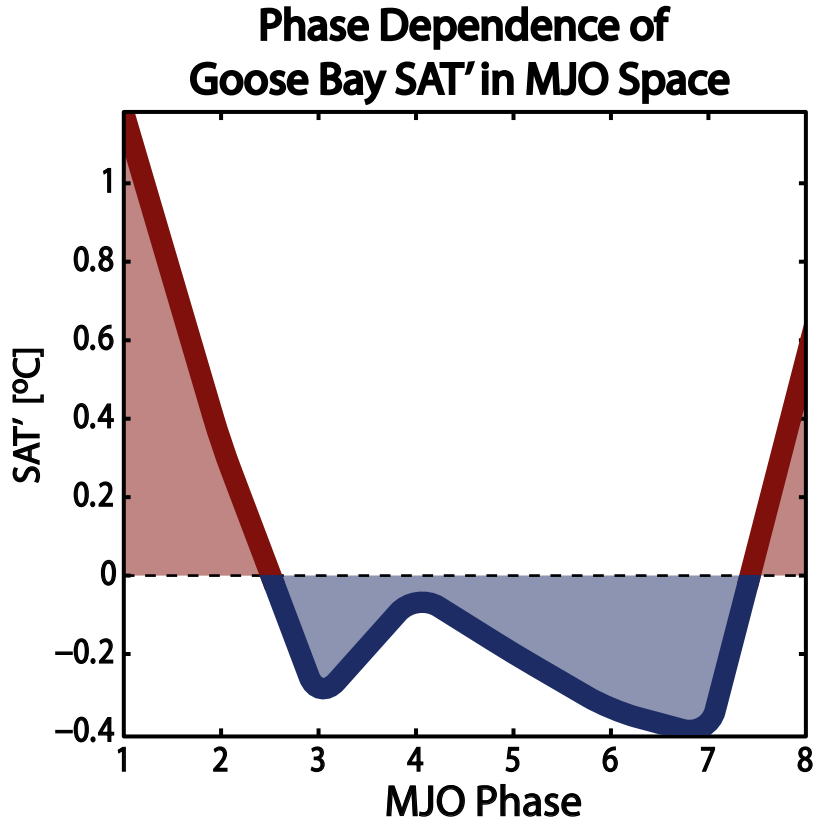
Weak MJO in phase 3
(active over Indian Ocean)

[1] Wheeler, M. C. and Hendon, H. H. ``An All-season Real-time Multivariate MJO Index". http://www.bom.gov.au/bmrc/clfor/cfstaff/matw/maproom/RMM/index.htm, March 20 2008

Goose Bay: A High-latitude Connection

- Relationship between MJO and Goose Bay computed by compositing SAT with the MJO. Allows for a nonlinear relationship.
- SAT varies O(1) ^{o}C throughout the MJO cycle effectively **linearly**. Amplitude consistent with that found by Vecchi and Bond [2]

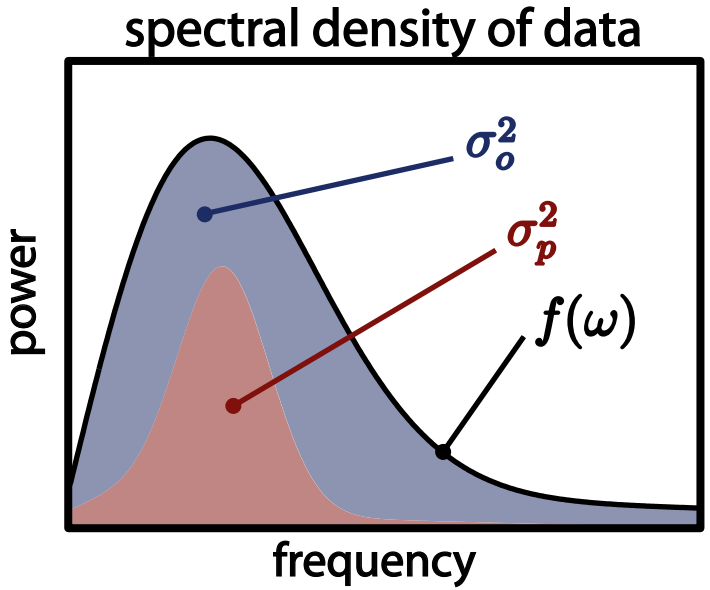




[2] G.A. Vecchi and N.A. Bond. The Madden-Julian Oscillation (MJO) and northern high-latitude wintertime surface air temperatures. Geophys. Res. Lett., 31, 2004

Quantifying a Relationship with the MJO

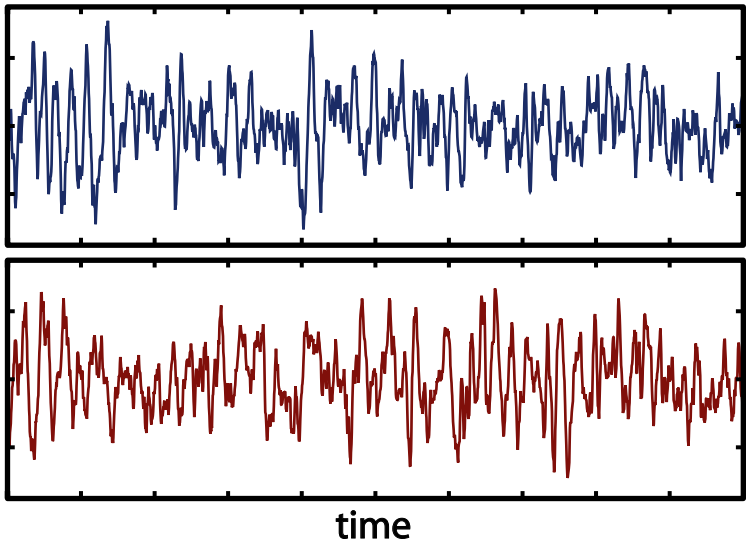
- The area under the curves represent the variance of the observed signal (**blue**) and that predicted by the MJO (**red**):

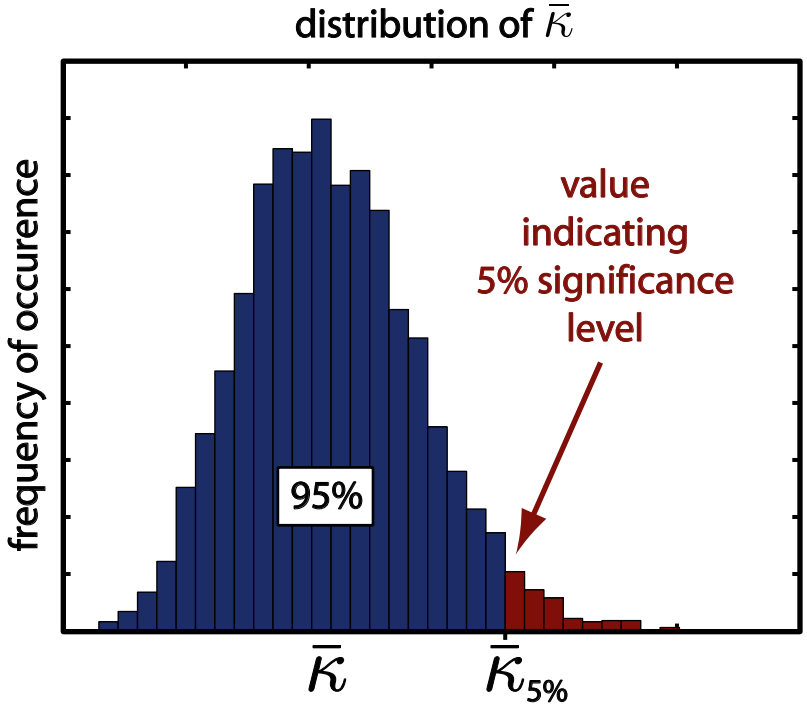


- Assuming **linearity**, the following represents the proportion of variance predicted by the MJO:

$$\bar{\kappa}^2 = \frac{\int \kappa^2(\omega) f(\omega) d\omega}{\int f(\omega) d\omega} = \frac{\sigma_p^2}{\sigma_o^2}$$

Testing Statistical Significance



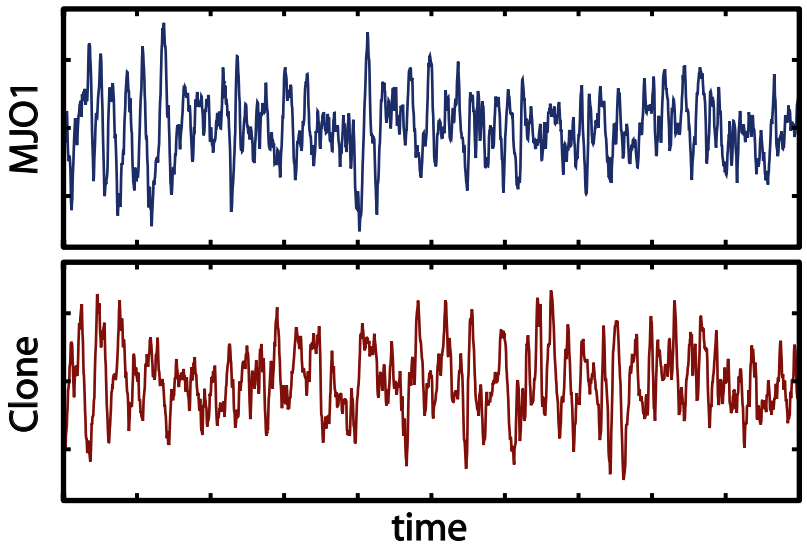


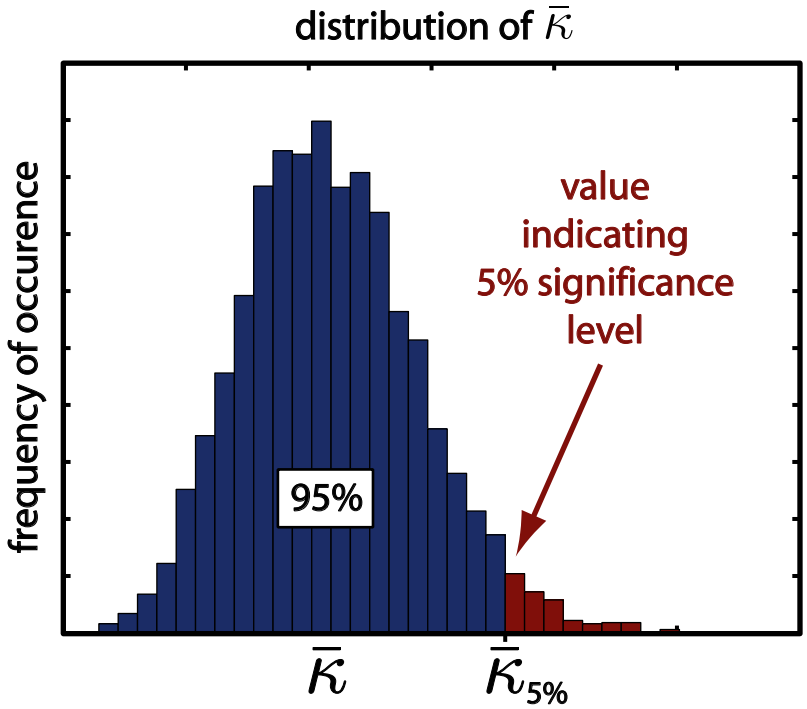
- We have a nonstandard statistical metric. How to determine statistical significance?
- Generate a clone time series that has the same mean, variance and spectral density but randomized phases by manipulating the fourier transform:

$$\underbrace{f_{\mathrm{MJO}}}_{\text{FFT of clone MJO index}} = \underbrace{|f_{\mathrm{MJO}}|}_{\text{retain the original spectral density}} \underbrace{\exp(i\theta)}_{\text{randomize the phases}}$$

- Can generate a sample distribution for $\bar{\kappa}$ (assuming no relationship) using a large number of these time series
- If the value of $\bar{\kappa}$ is greater than $\bar{\kappa}_{5\%}$ then it is statistically significant at the 5% significance level

Testing Statistical Significance





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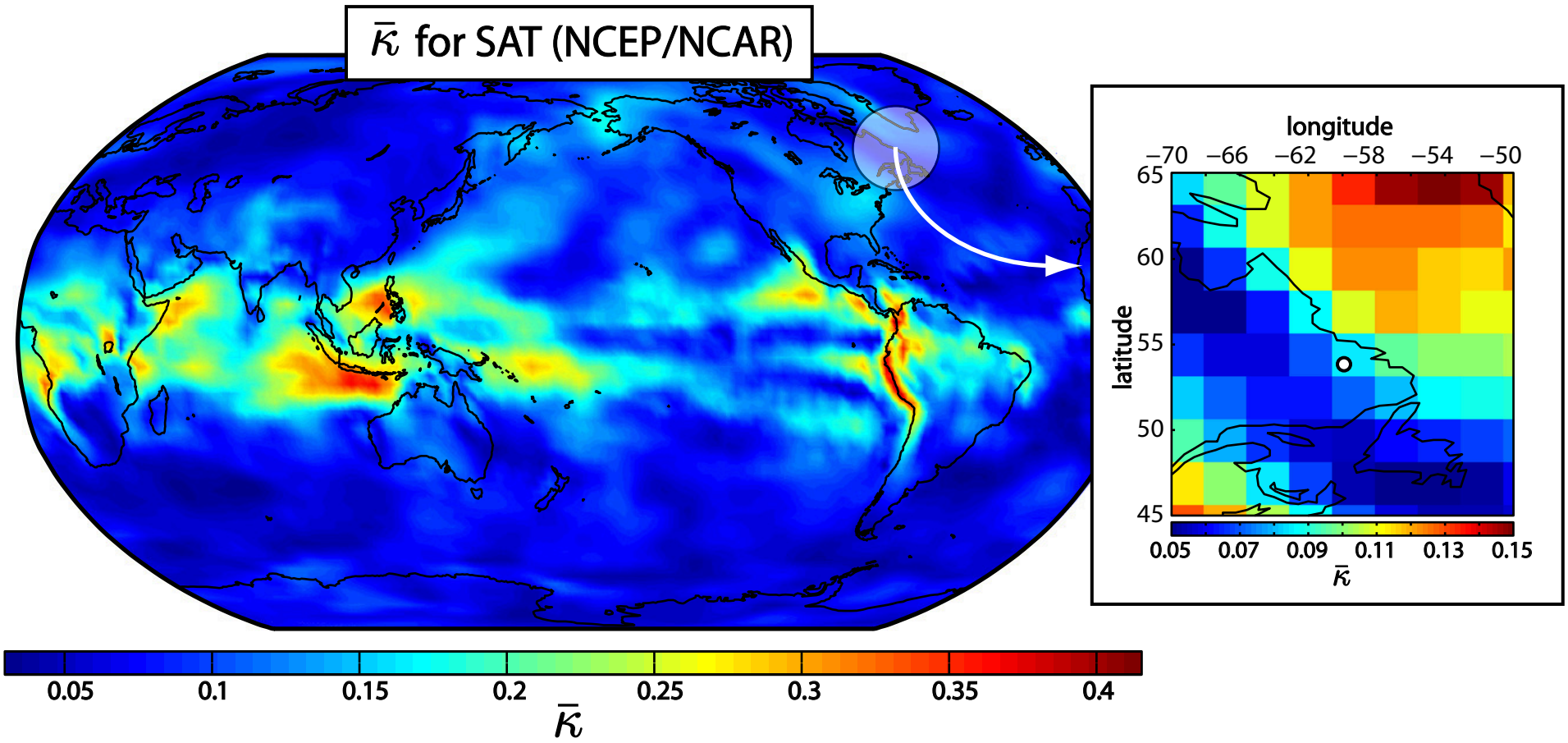
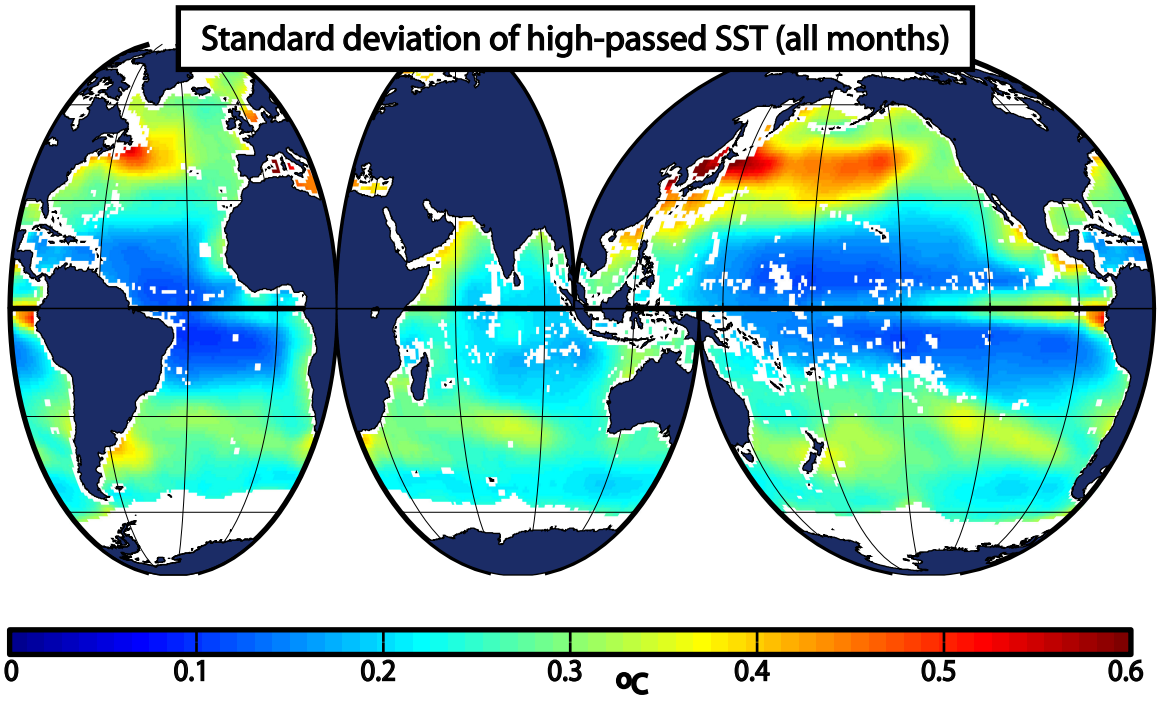
From Points to Fields: Global SAT

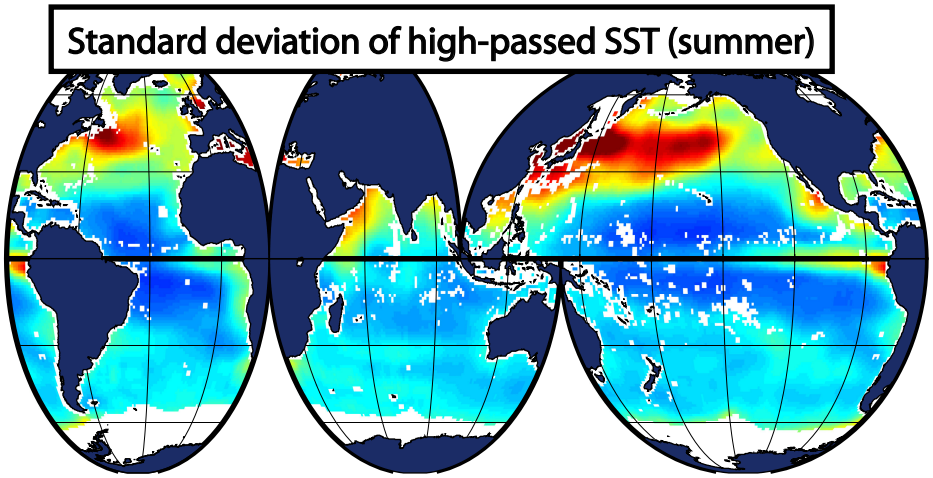
- For Goose Bay SAT: $\bar{\kappa} = 0.124$ with a *p*-value of 17.2%
- Consistent with analysis of global fields of SAT (from NCEP/NCAR)
- Consistent with high latitude analysis by Vecchi and Bond

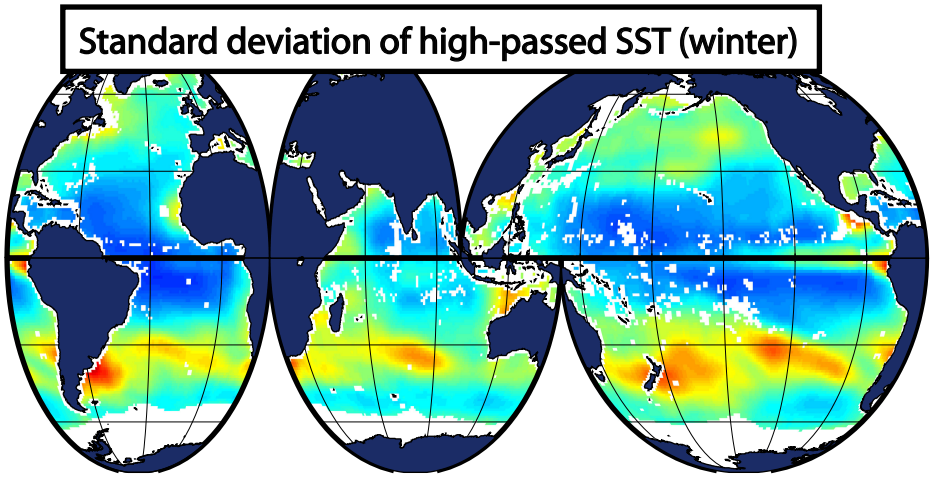


Global Distribution of SST Variability

- We used satellite-based measurements of SST and SLA (sea surface tempurature and sea level anomaly)
- The data is highpass filtered with a 120-day cutoff. We can stratify the data by season (defined as 181 days centred on July 15 for Summer and January 15 for Winter)

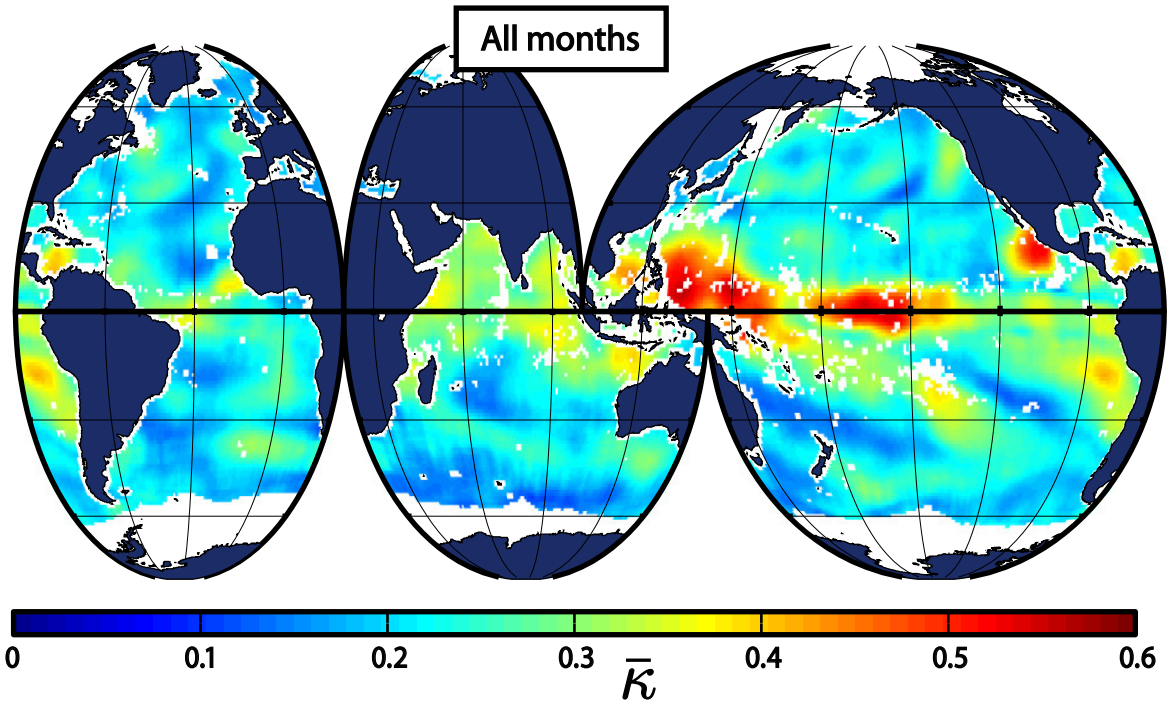


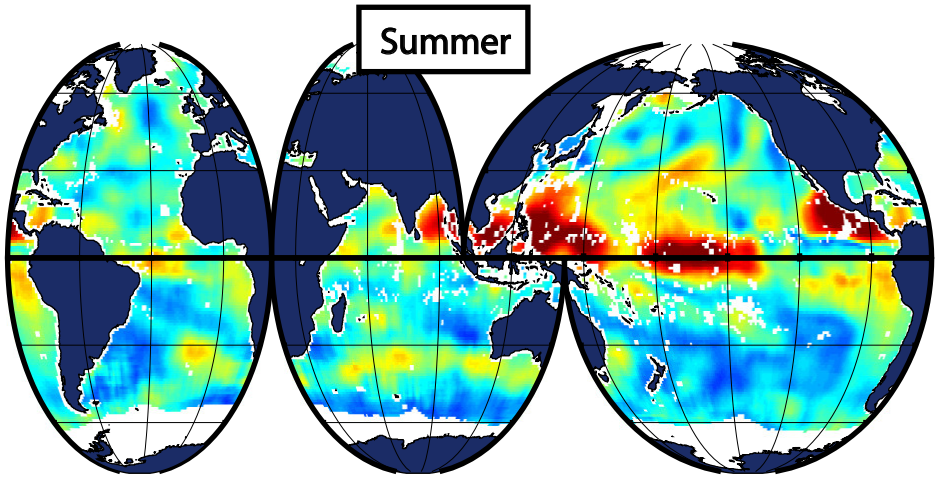


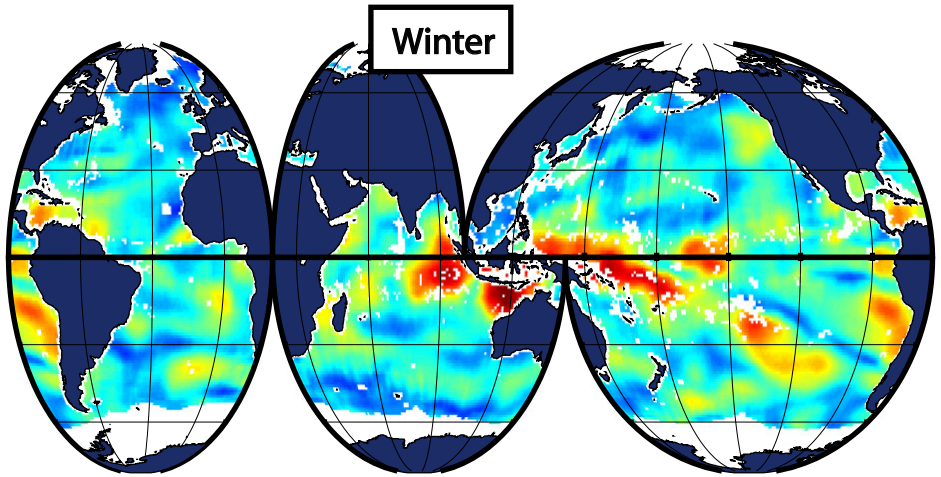


MJO and Global SST Variability

- Calculated $\bar{\kappa}$ for SST
- 5% significance level is ~0.3 (anything green, yellow and red is statistically significant at this level)
- Hemispheres alternate in importance when stratified by season and show **significant extratropical signatures**





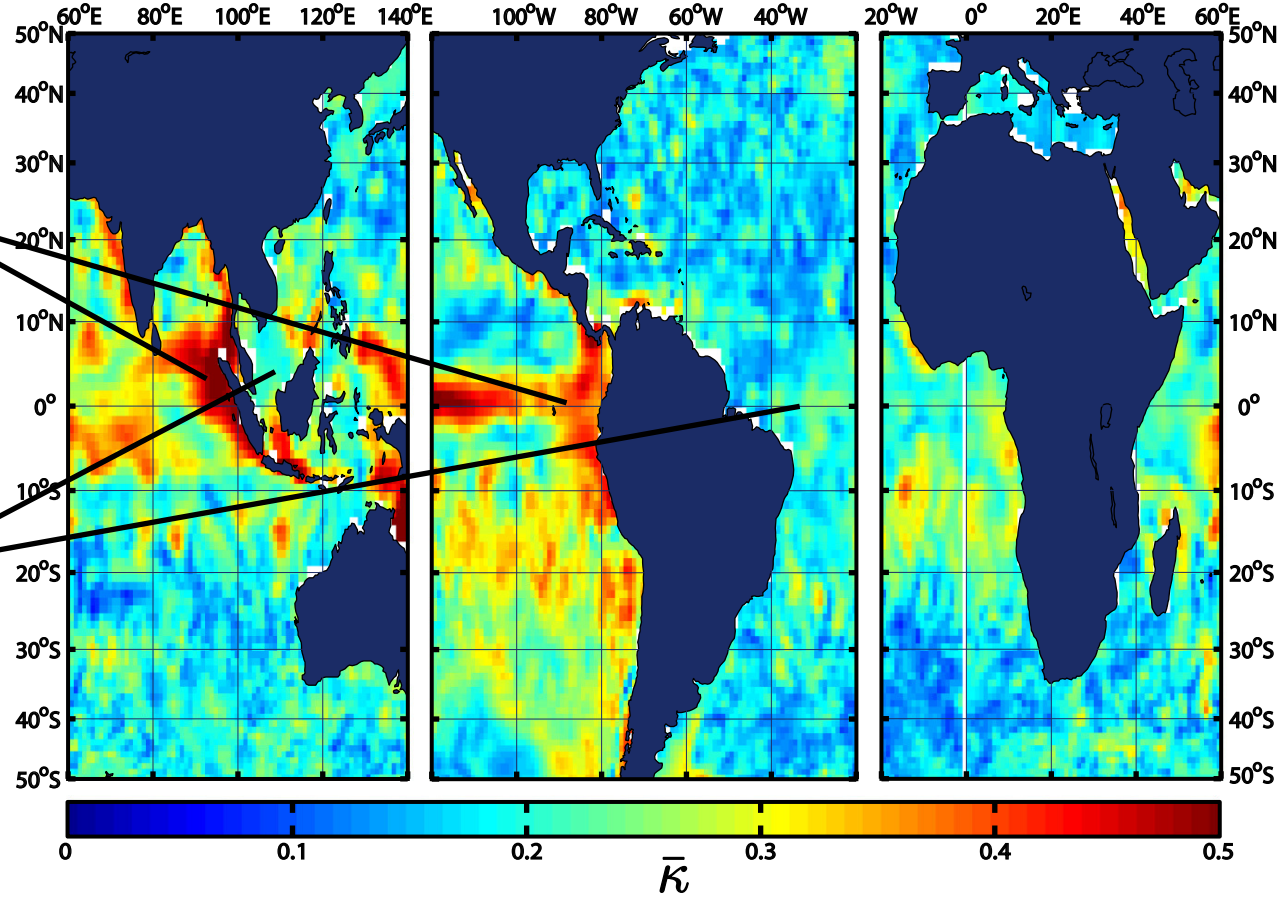


Sea Level Response to the MJO

- Strong evidence of coastally trapped signals related to MJO
- Eastward propagating MJO excites response in sea level on western coasts of the continents

Strong coastal response (west. coasts)

Weak coastal response (east. coasts)



Conclusions and Future Work

- MJO provides a mechanism for enhancing predictability on intraseasonal times-cales (weeks to months)
- We have devoloped tools to assess the relationship between a geophysical time series and the MJO including tests for nonlinearity and measures of statistical sig-nificance
- We have found linear seasonally modulated extratropical response to the MJO in extratropical Pacific SST (and possibly extratropical Atlantic SST)
- We have also found a response in coastally trapped sea level which extends into the extratropics
- To physically interpret the results we will move towards incroporating knowledge gained from looking at observations of the MJO and its extratropical expression into global coupled atmosphere-ocean models (*i.e.*, NEMO-GEM)

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