Investigation of surface flux feedbacks for coupled atmosphere-ocean anomalies

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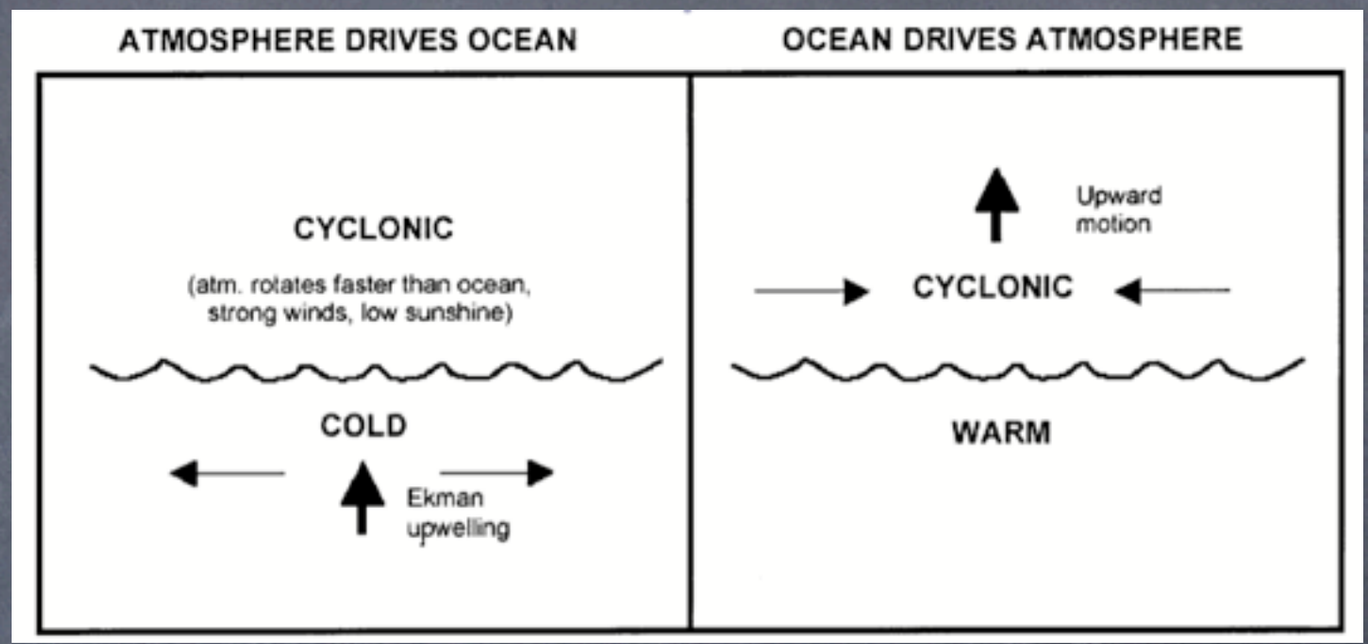
Outline

- Overview of dynamical coupling rules
- Data sets used for classification and compositing
- Statistics of coupling events
- Composite analyses
- Conclusions and further work

Coupled or Uncoupled?

- Difficult to determine directly from observations
- Statistical, Cross-Correlation Method (Czaja et al. 2003)
- Use dynamical rules for determining atmosphere vs. ocean forcing (Pena et al. 2004)



From Pena et al. (2004)

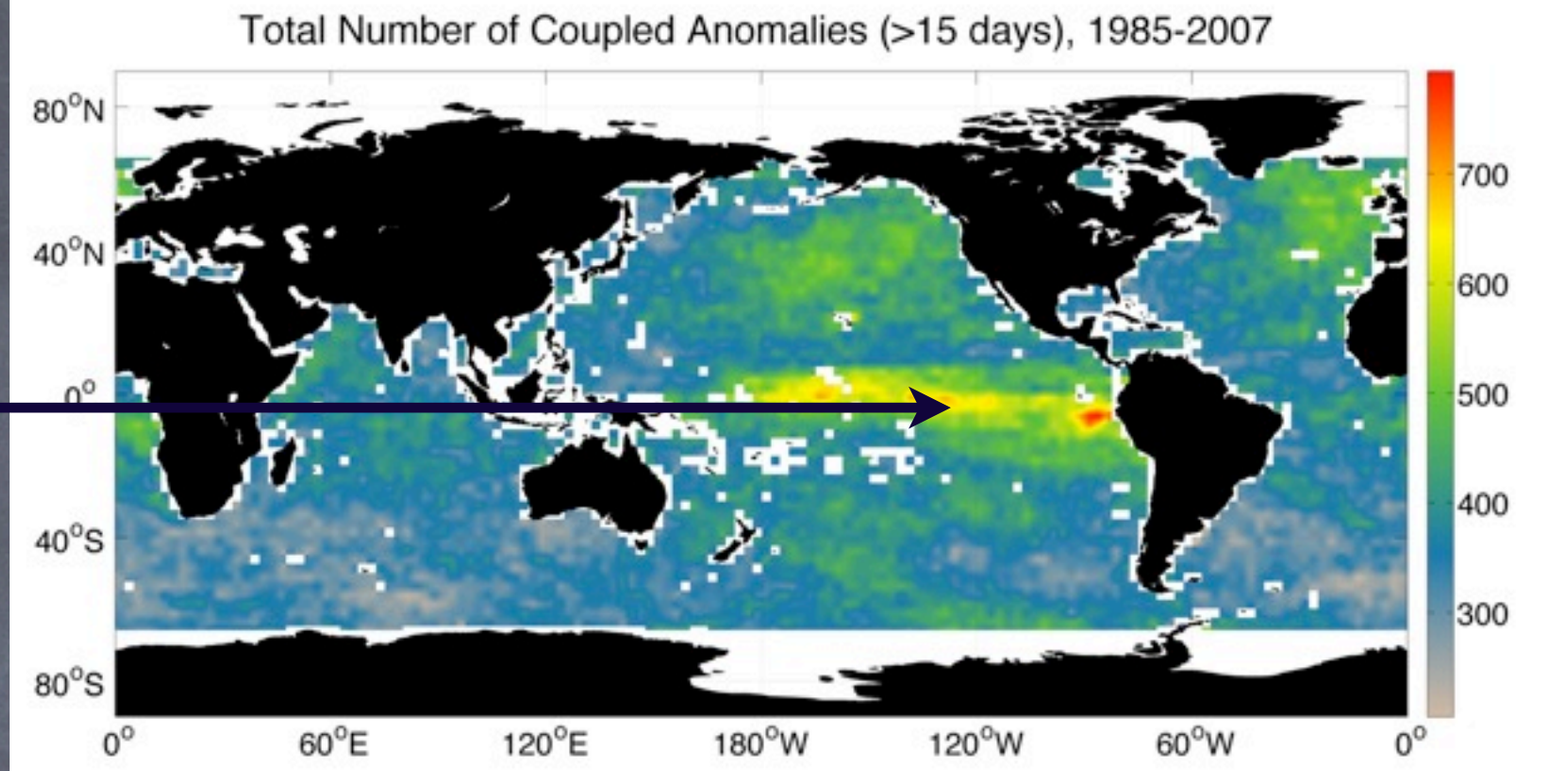
Data Sets

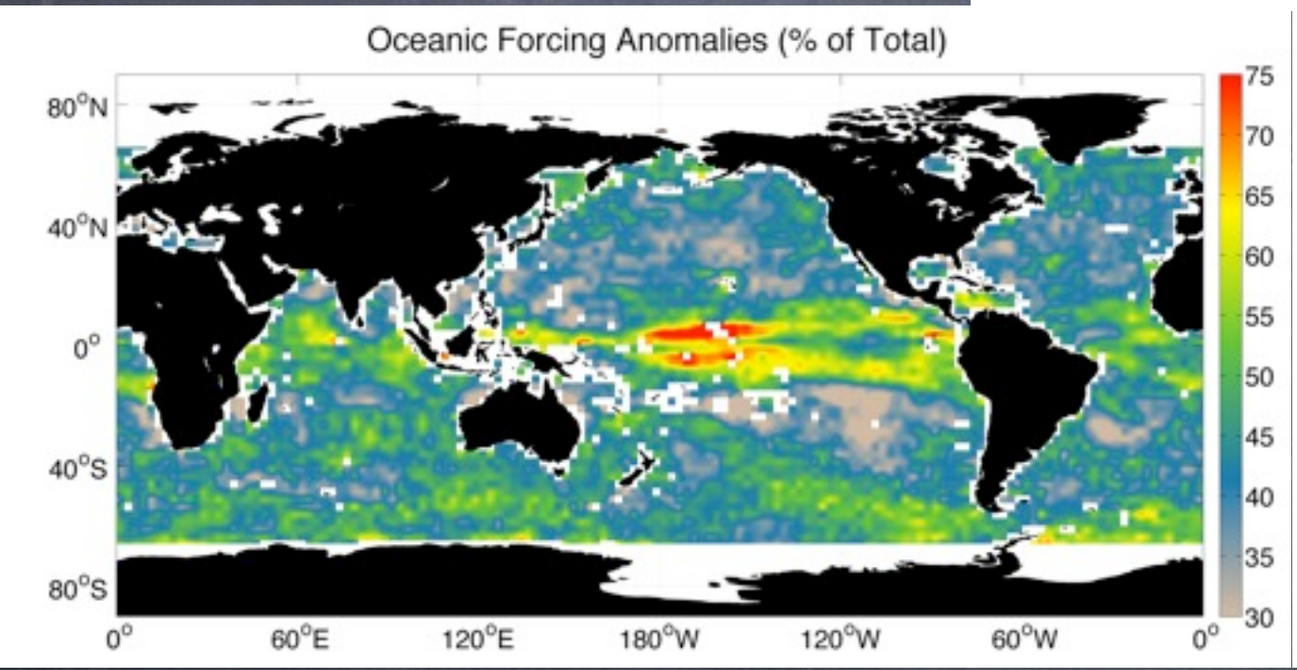
- Data Period: 1985-2007 (23 years)
- MERRA 850mb U,V winds
- Reynolds OISST AVHRR-only V2
- OAFlux v3.0 Turbulent Fluxes
- GEWEX-SRB Shortwave and Longwave Radiation Fluxes

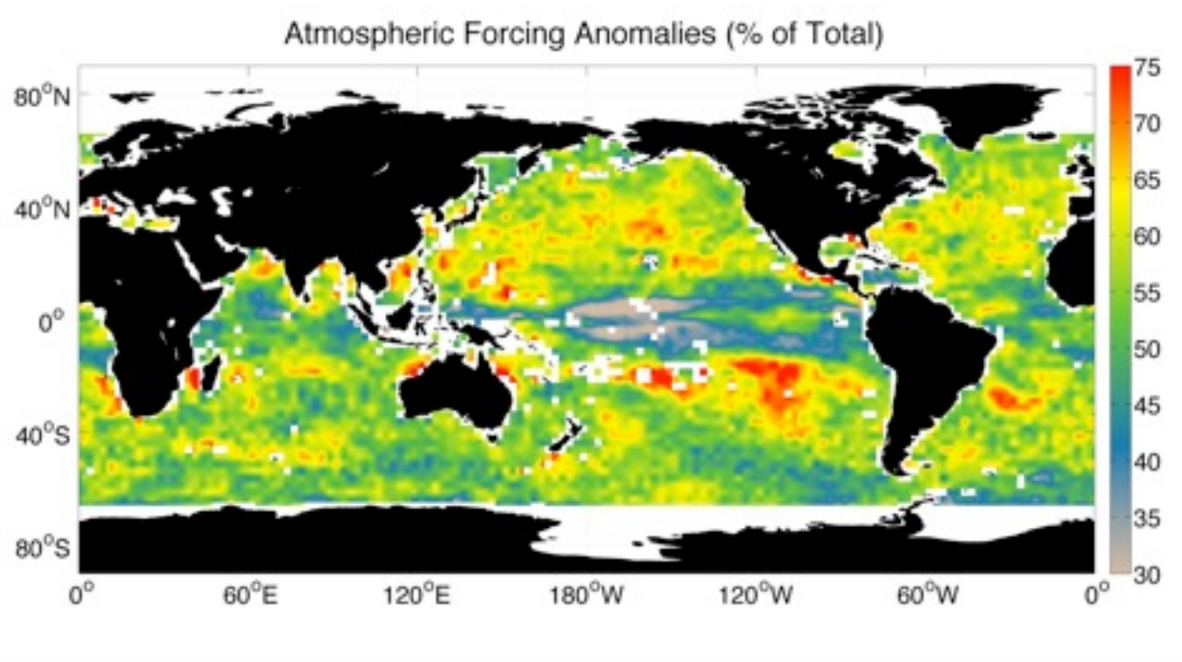
Methodology

- Interpolated all data onto 2.5 degree, pentad grids
- Removed mean annual cycle from each grid point
- Used dynamical rule for classifying coupled anomalies
- Coupled events longer than 3 pentads (15 days) were used for compositing surface heat budget terms

Largest absolute number of coupled "events" found in the tropics.

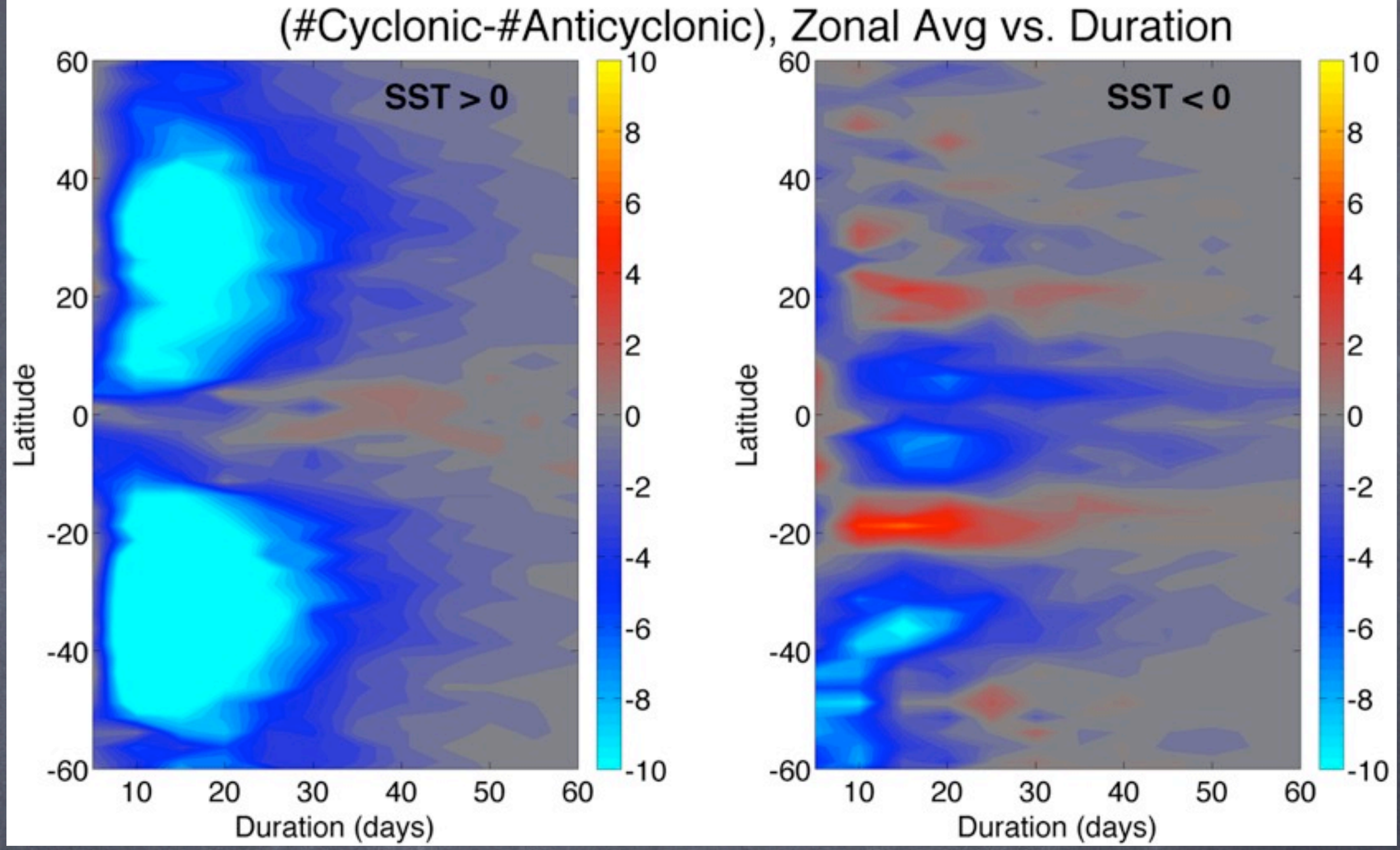






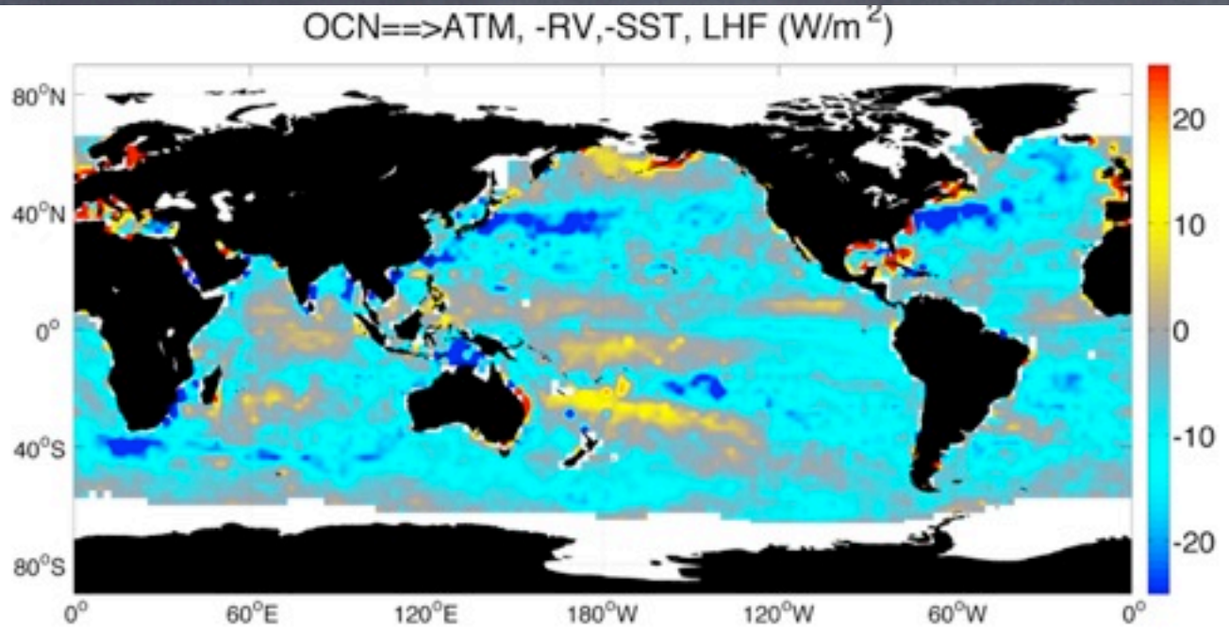
- Coupling in the extratropics: atmosphere-driving
- Coupling in the tropics : ocean-driving

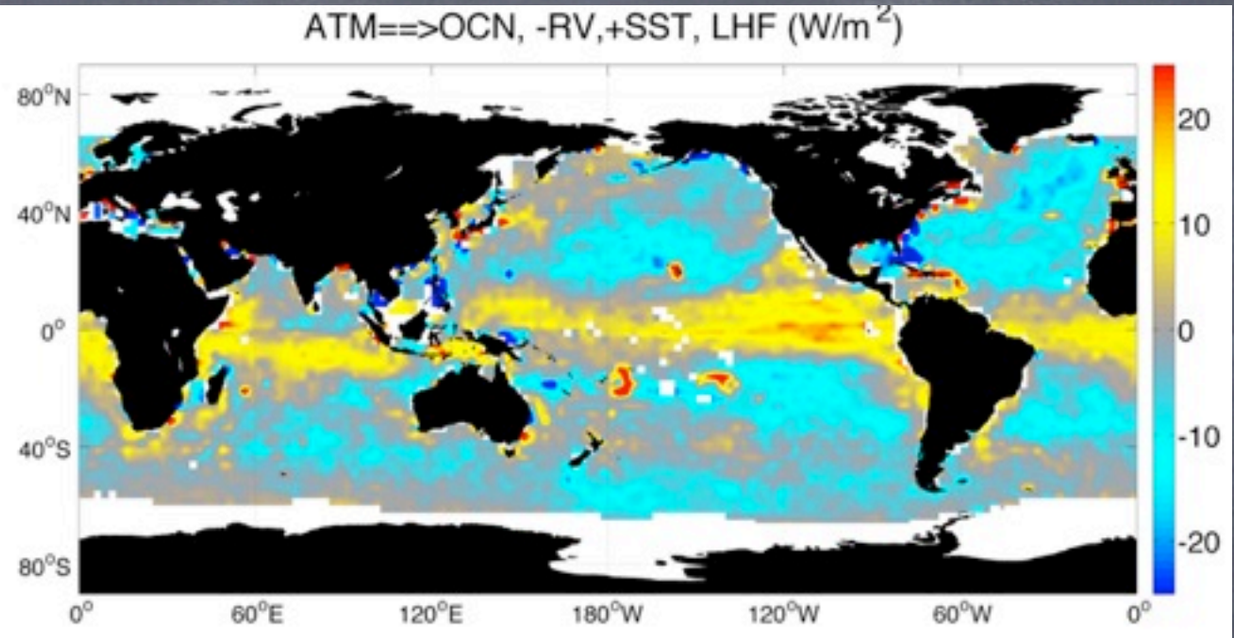
Duration of "Events"

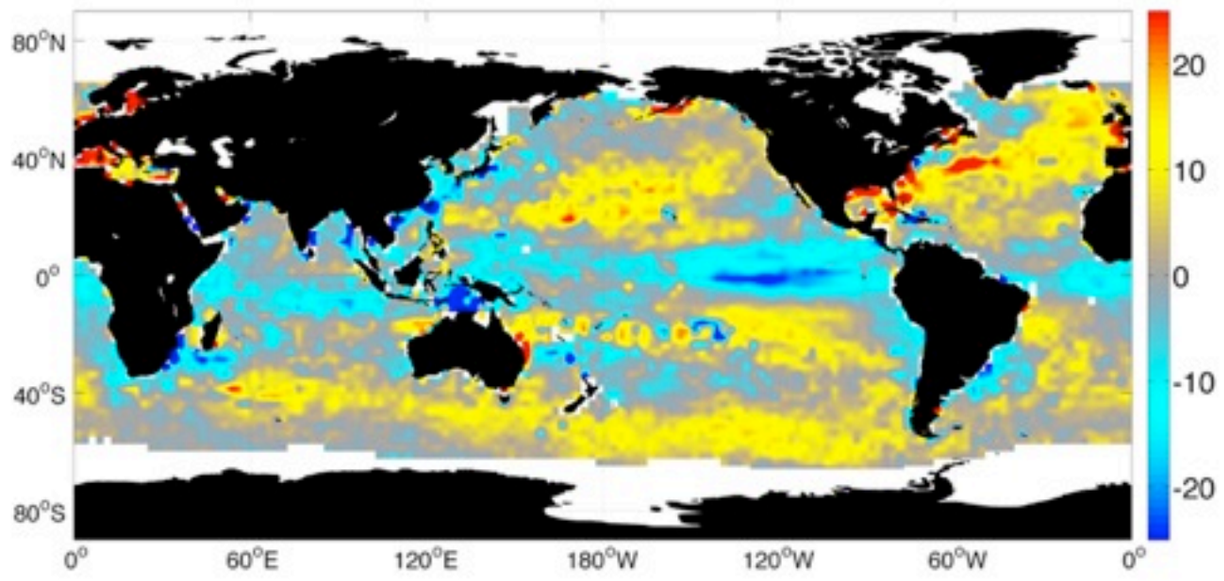


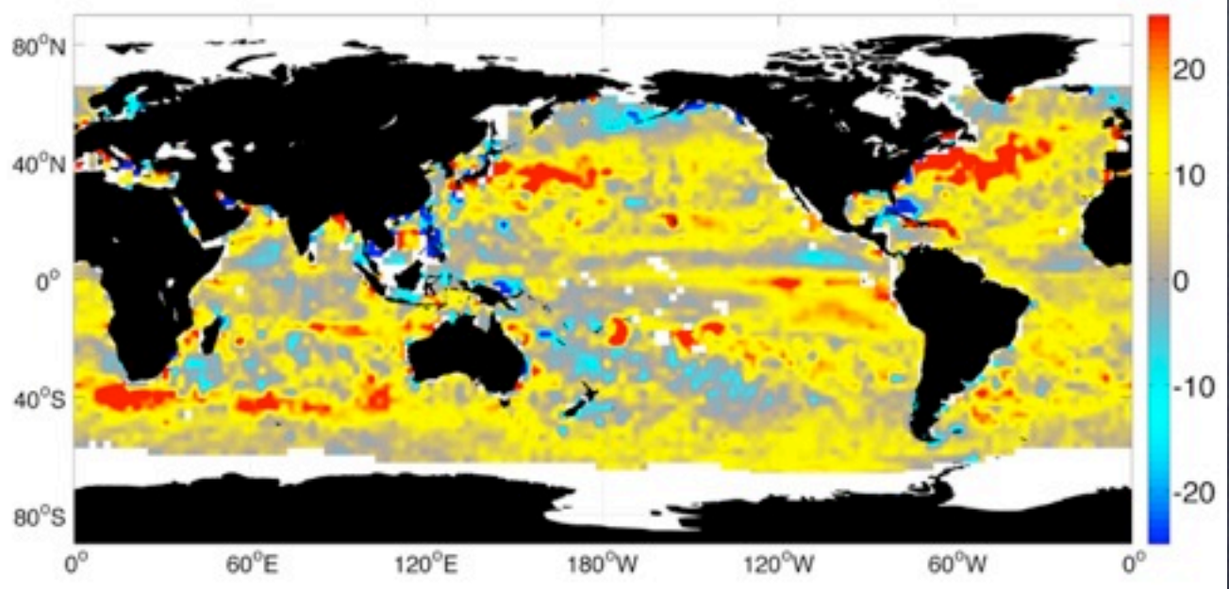
- The number of longer lasting anomalies in the tropics are same-sign -- OCEAN DRIVING
- The extratropics show opposite sign anomalies are longer lasting -- ATMOSPHERE DRIVING

Latent Heat Flux (about -25 to 25 W/m^2)



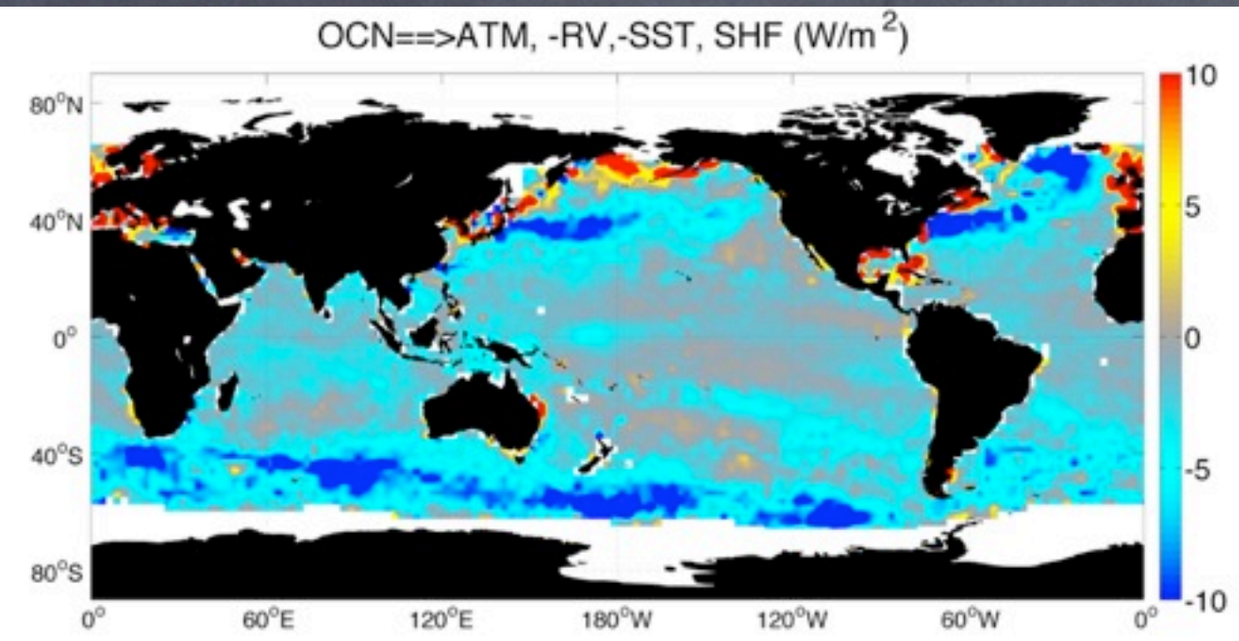


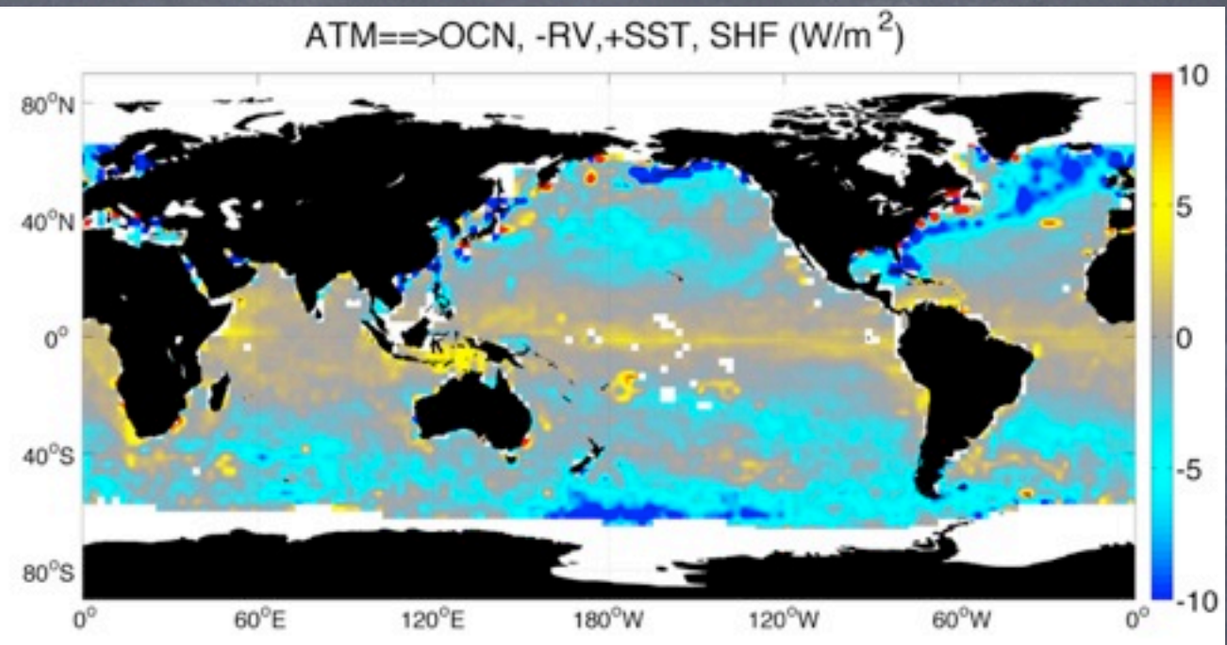


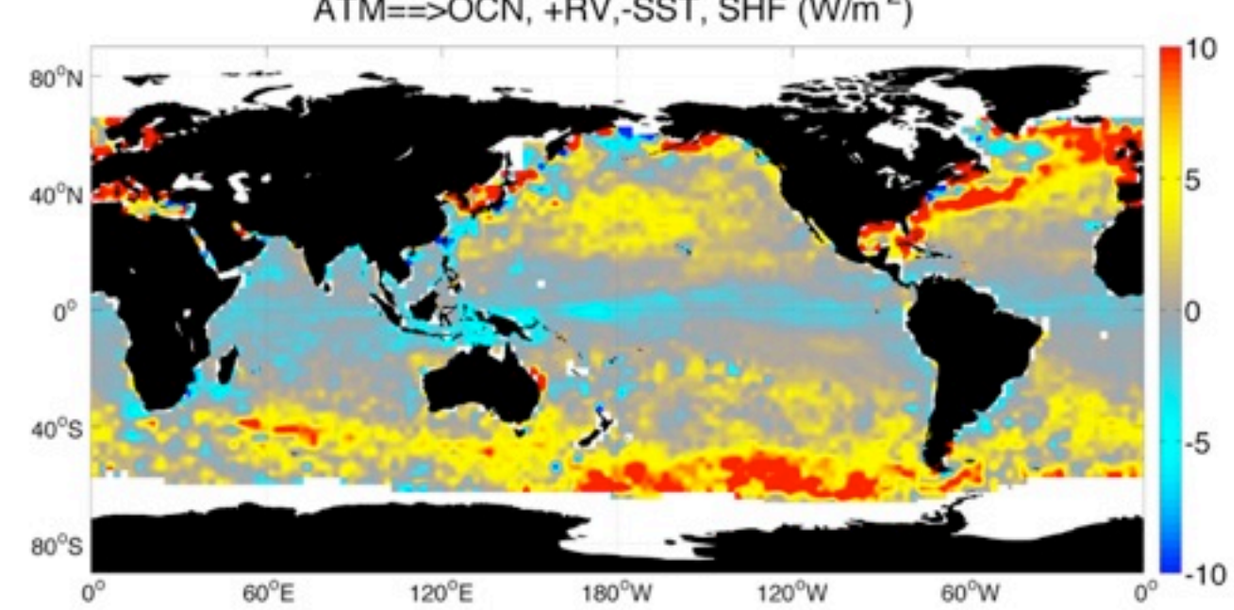


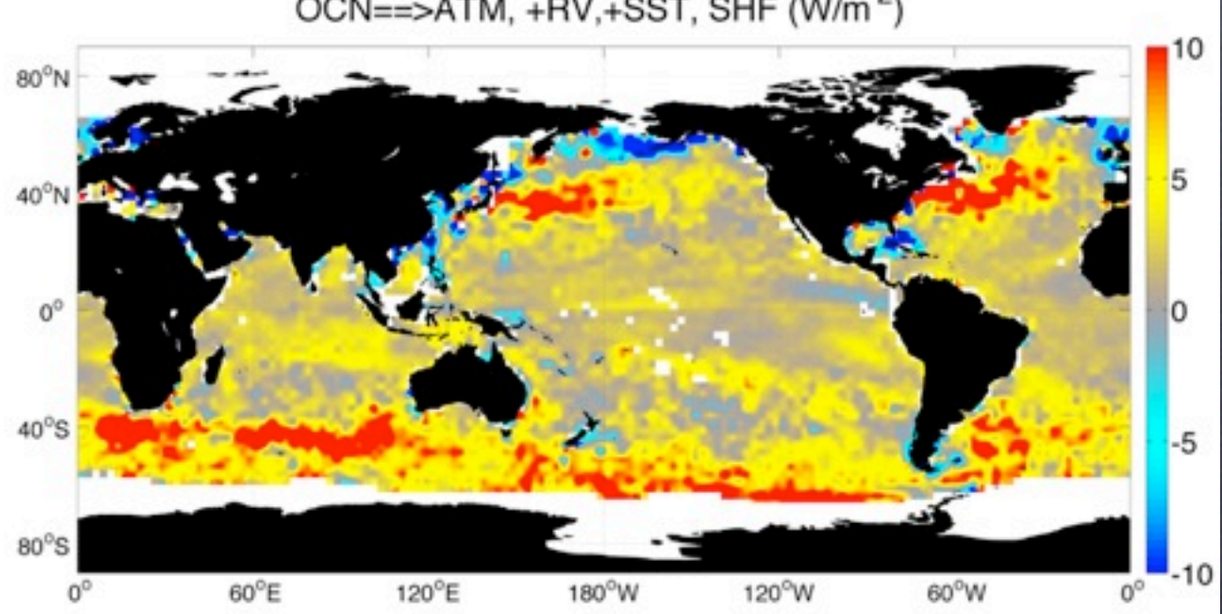
- Magnitudes appear to be stronger outside of the tropics
- The extratropical LHF appears to be "in-phase" with regards to the sign of the SST anomaly
- The tropical response appears to suggest a stronger connection to SST.

Sensible Heat Flux (about -10 to 10 W/m^2)



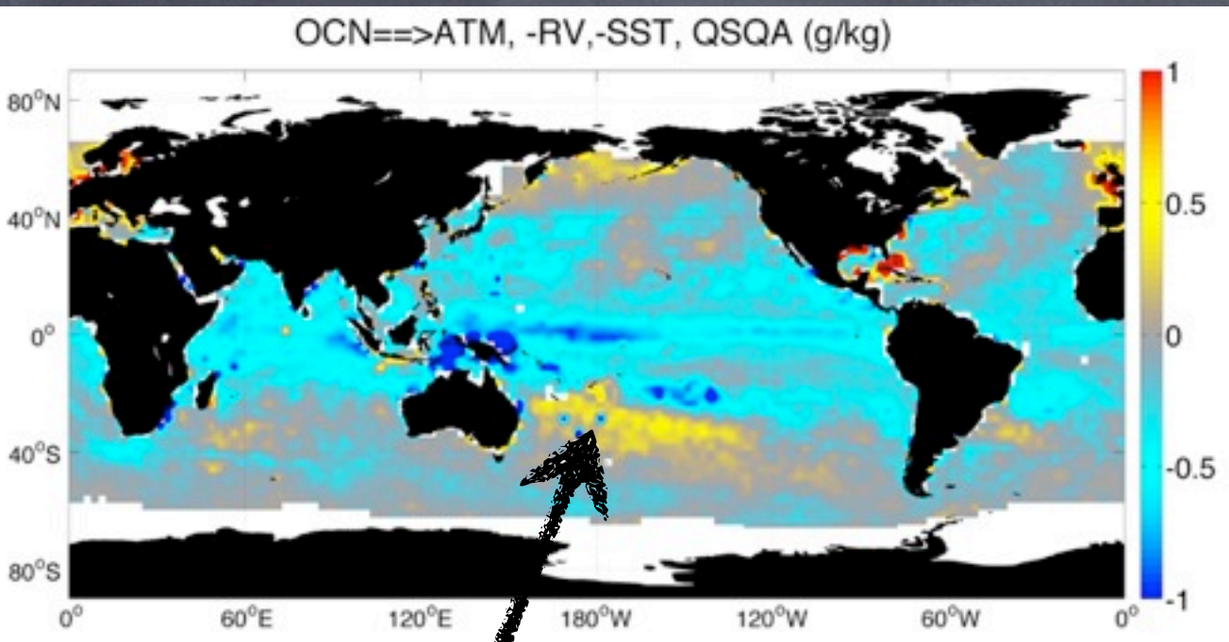


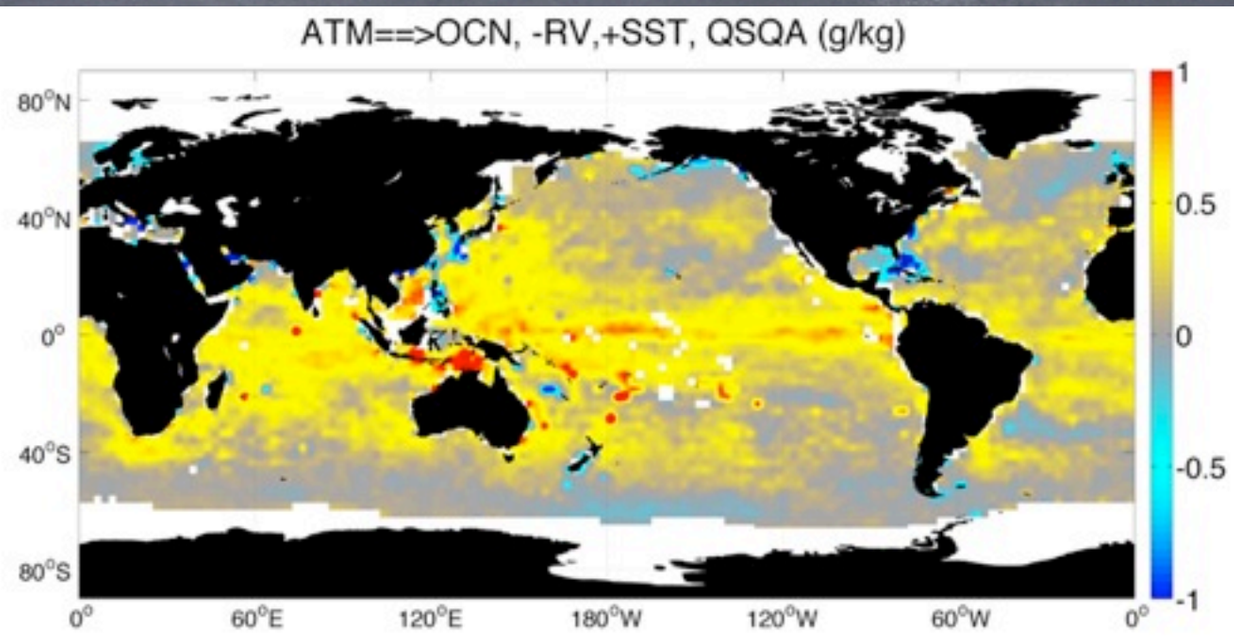


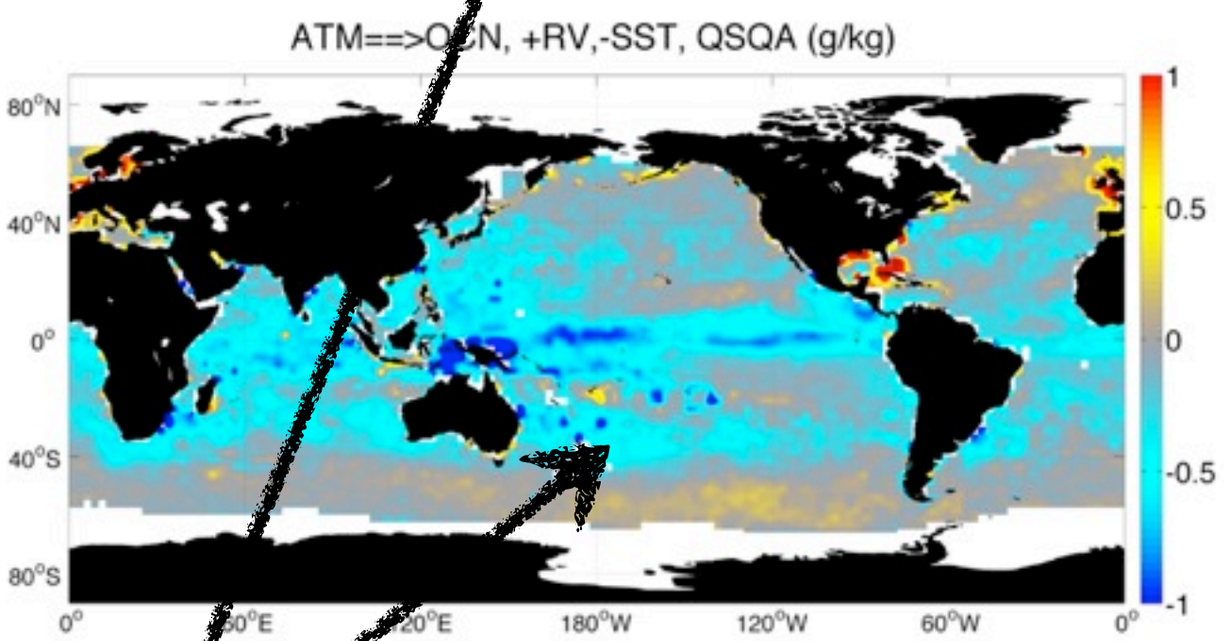


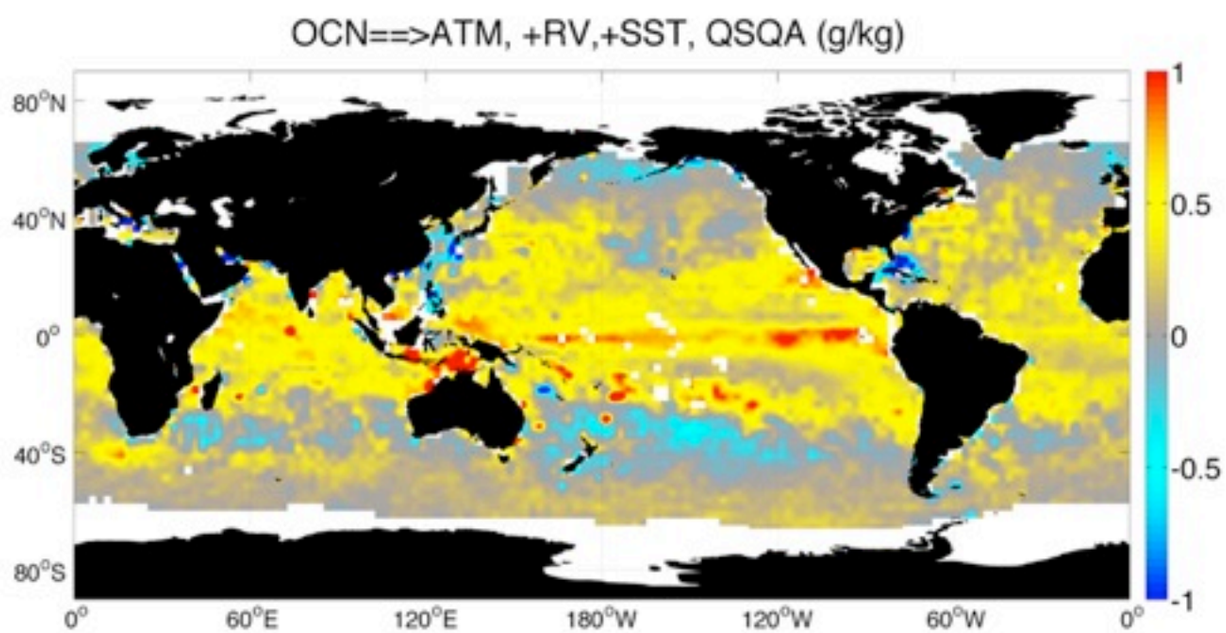
- SHF magnitudes only about half the size of the LHF; tropical response particularly muted.
- Extratropical Response appears connected mostly to wind speed.

QS-QA (about -1 to 1 g/kg)



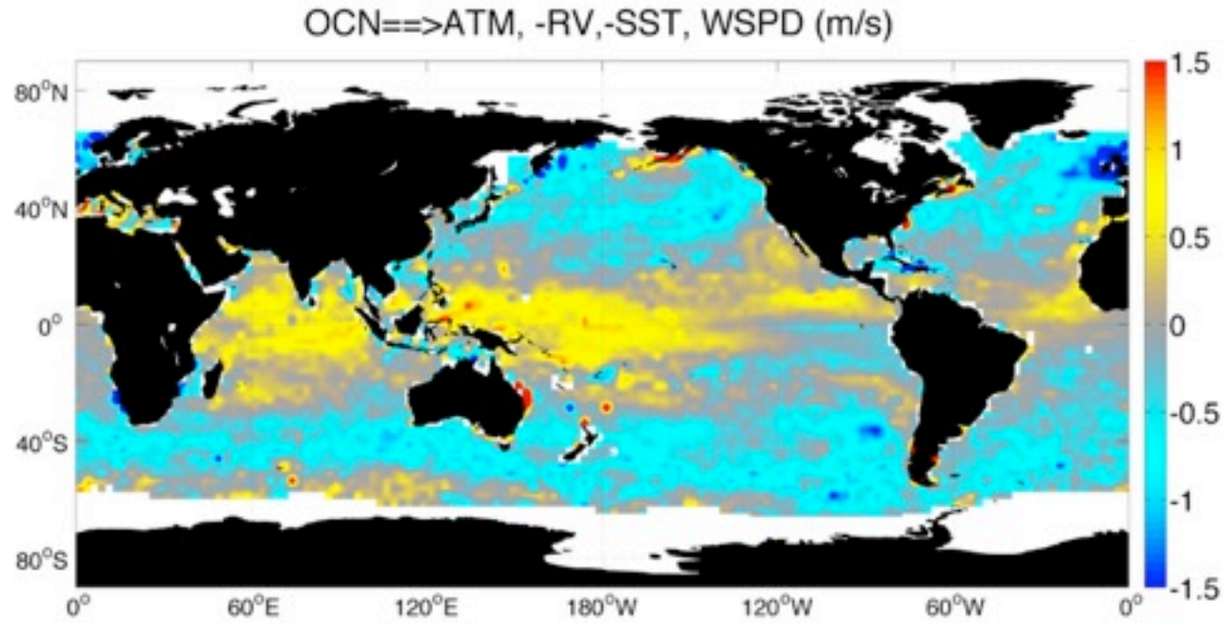


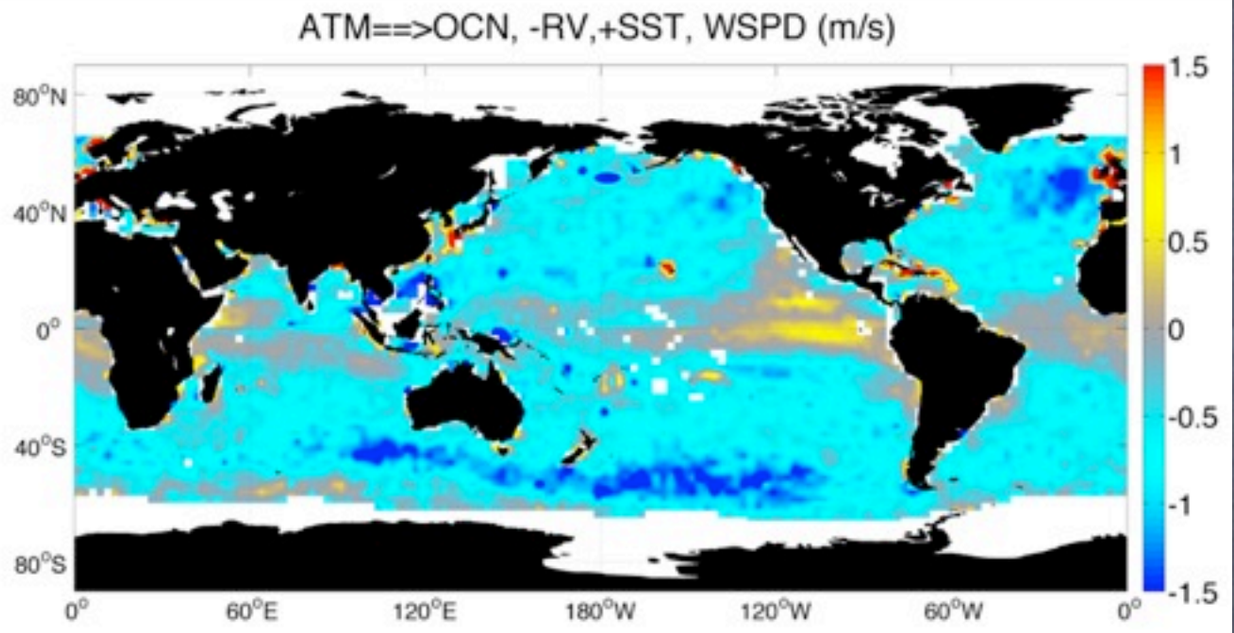


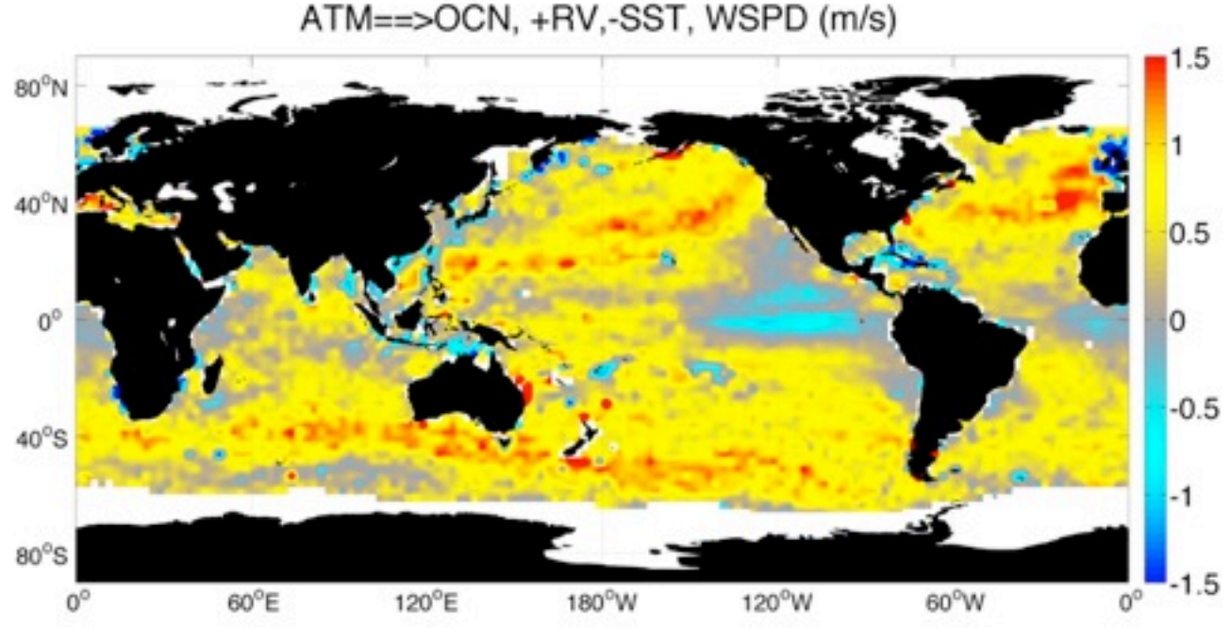


- Increase in QS-QA for SST>0 means QA does not increase as fast as QS. This also means that higher LHF is expected which would act to dampen the anomaly.
- Since Qa is normally lower than QS, a decrease in QS-QA as QS decreases is expected. An increase in QS-QA results if QA decreases faster than QS.
- How much can we trust Qa (or Ta) in the Southern Ocean … ??

Wind Speed (about -1.5 to 1.5 m/s)

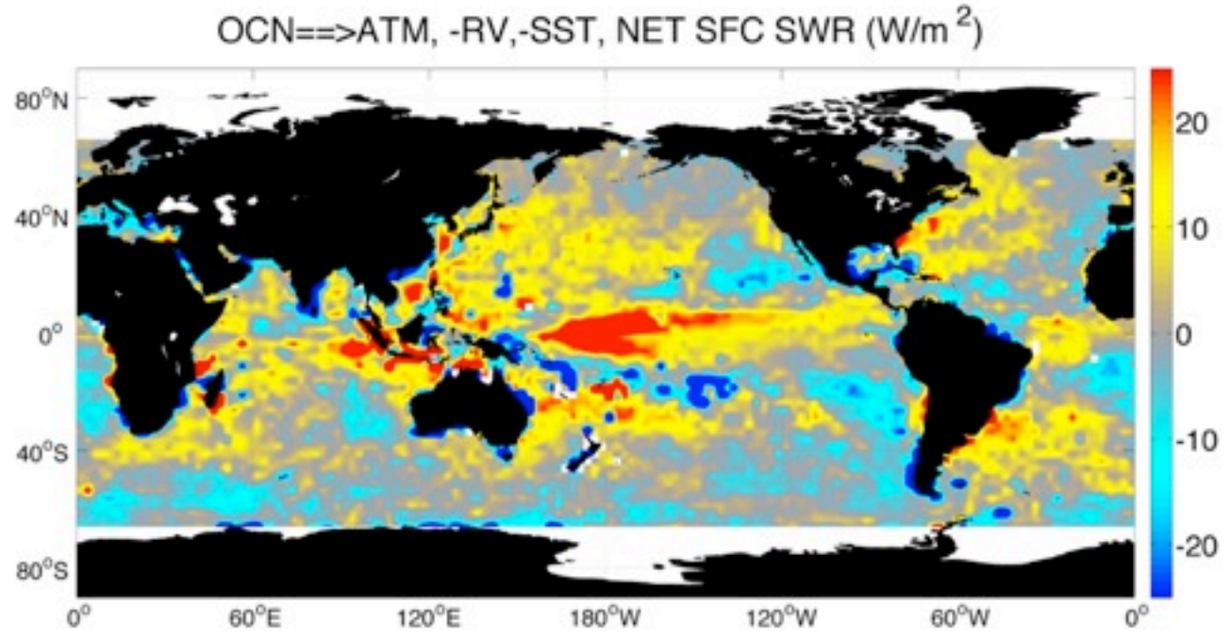


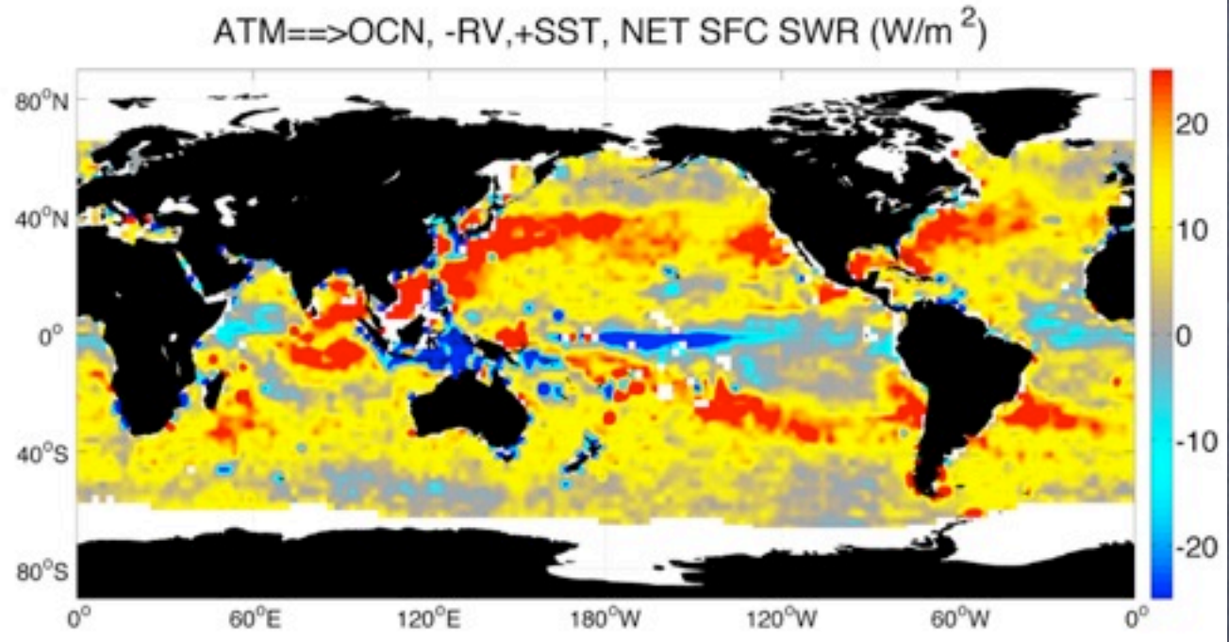


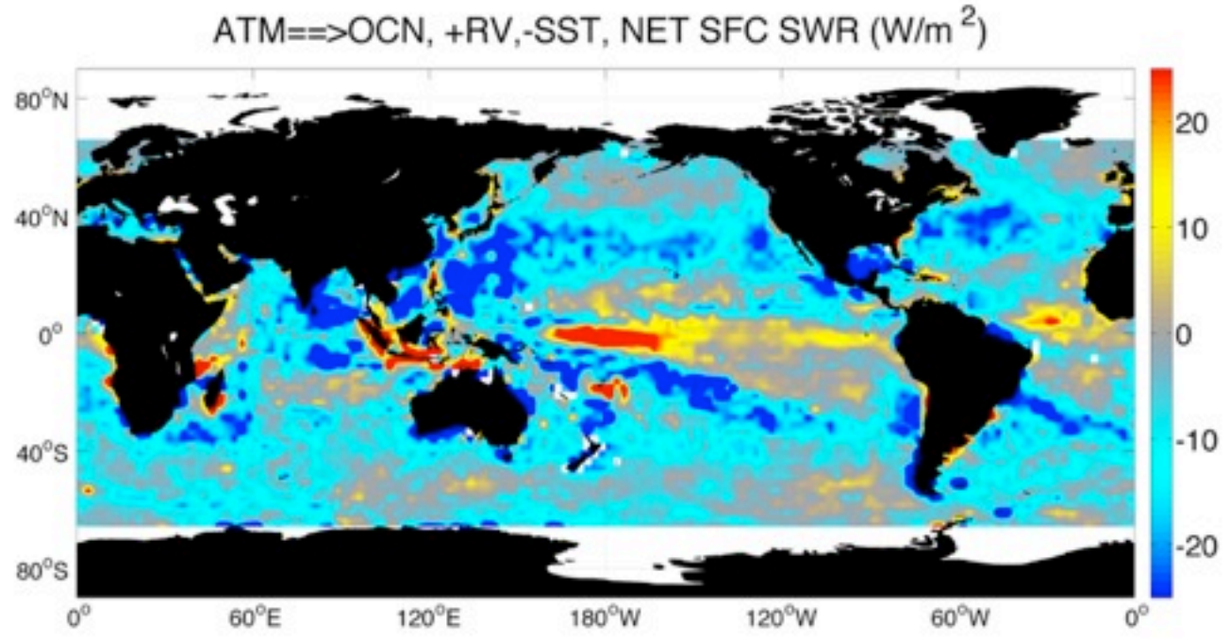


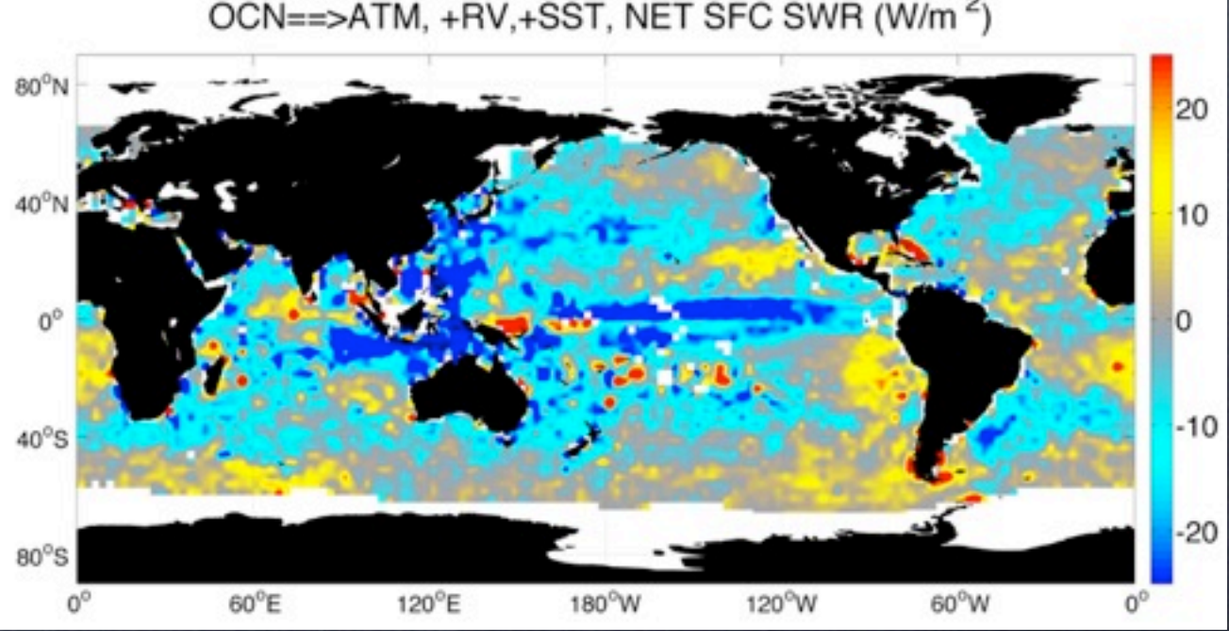
- Extratropics: Positive correlation between vorticity and wind speed; relationship less straightforward in the tropics.
- The wind speed response shows a positive feedback for parts of the tropical Pacific.
- Strongest wind speed response appears to be in the Southern ocean.
- Relationship in tropics perhaps related to differential changes in vorticity/pressure across the basin.

Net Shortwave Down (about -25 to 25 W/m^2)



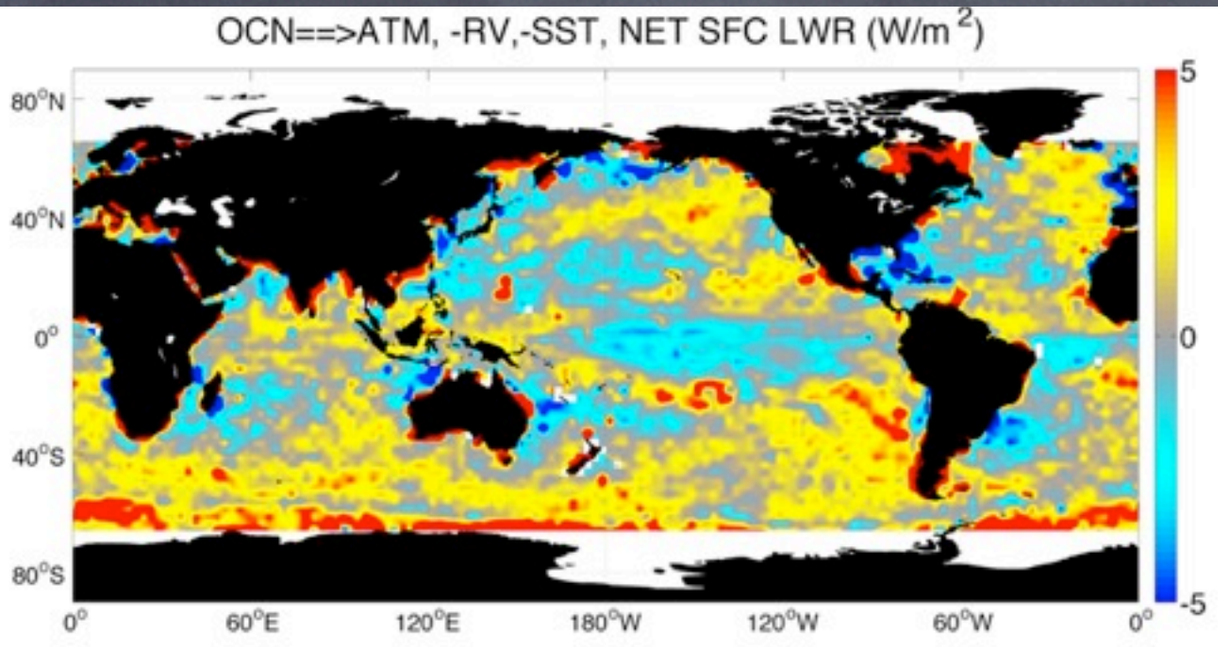


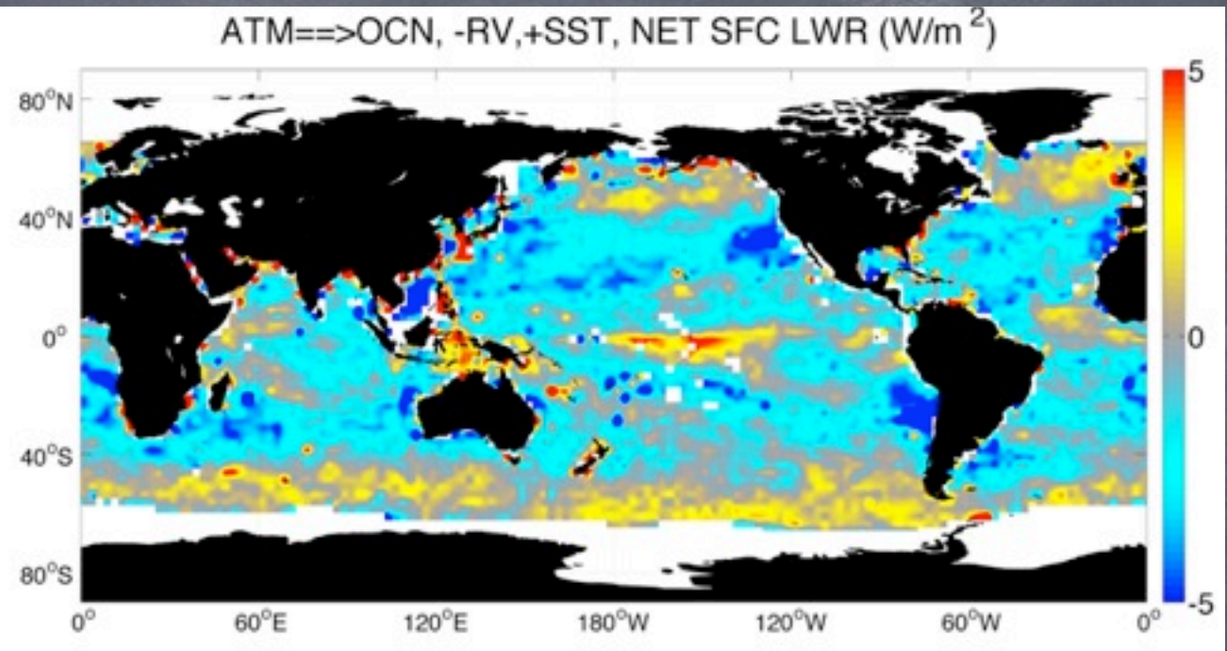




- Net Shortwave response is on par with the changes in LHF overall but stronger than LHF in the deep tropics.
- Positive feedbacks are seen for Ocean forcing cases in the stratus deck regions.
- Extratropics show the expected dynamical relationship: Cyclonic => More Clouds => Less Radiation

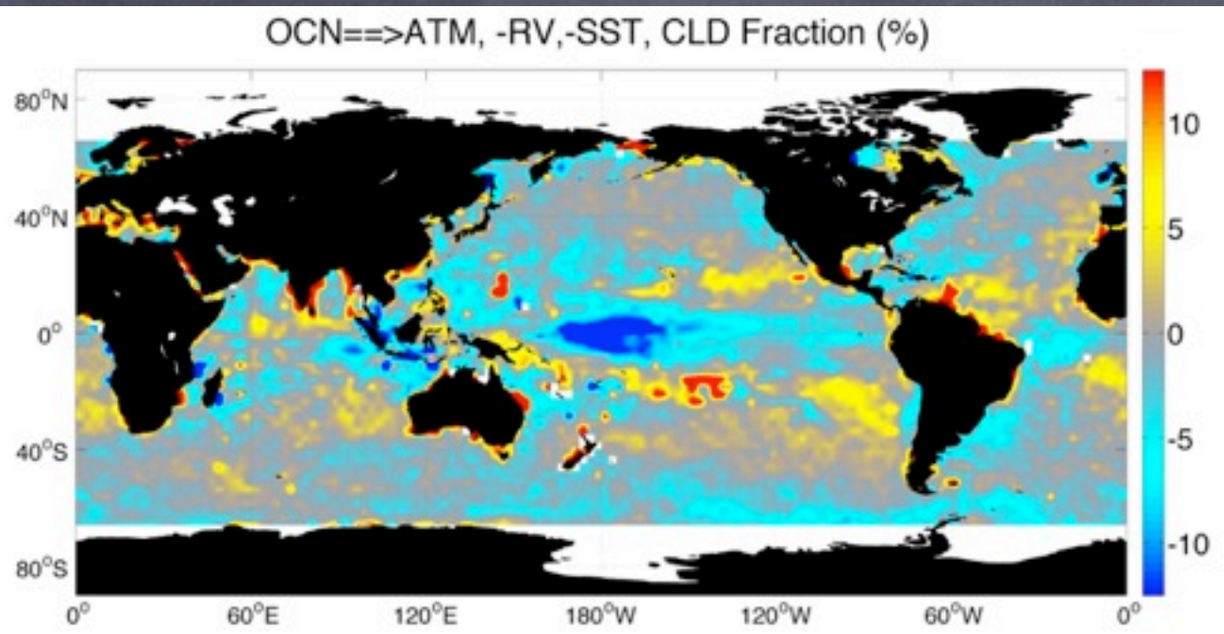
Net Longwave Down (about -5 to 5 W/m^2)

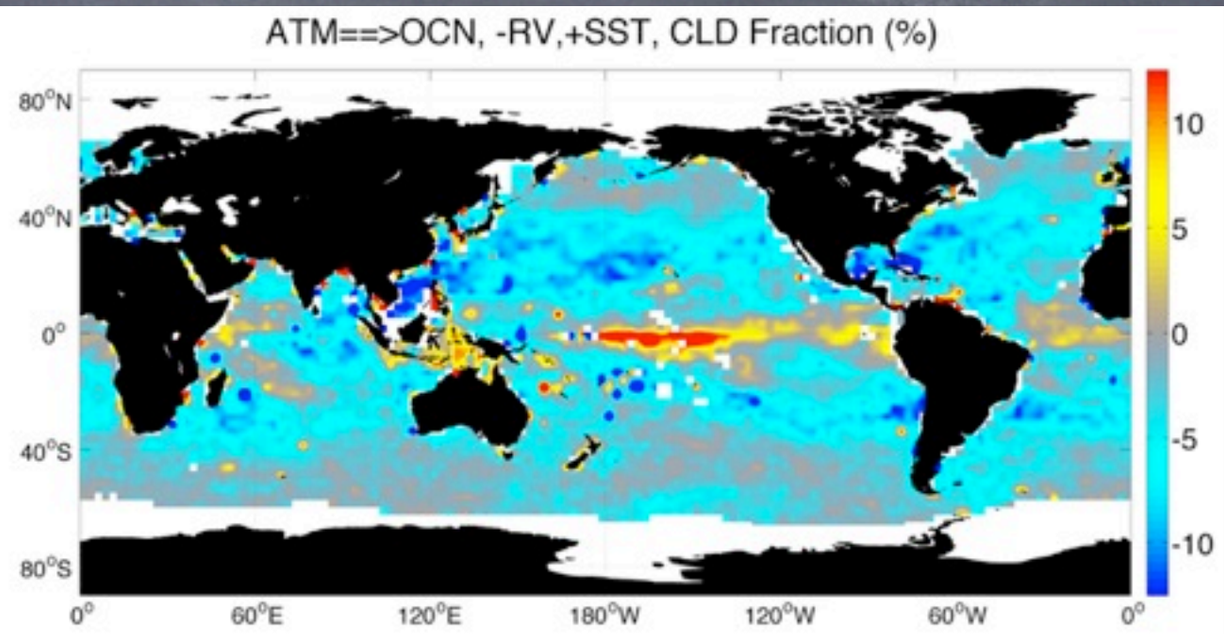


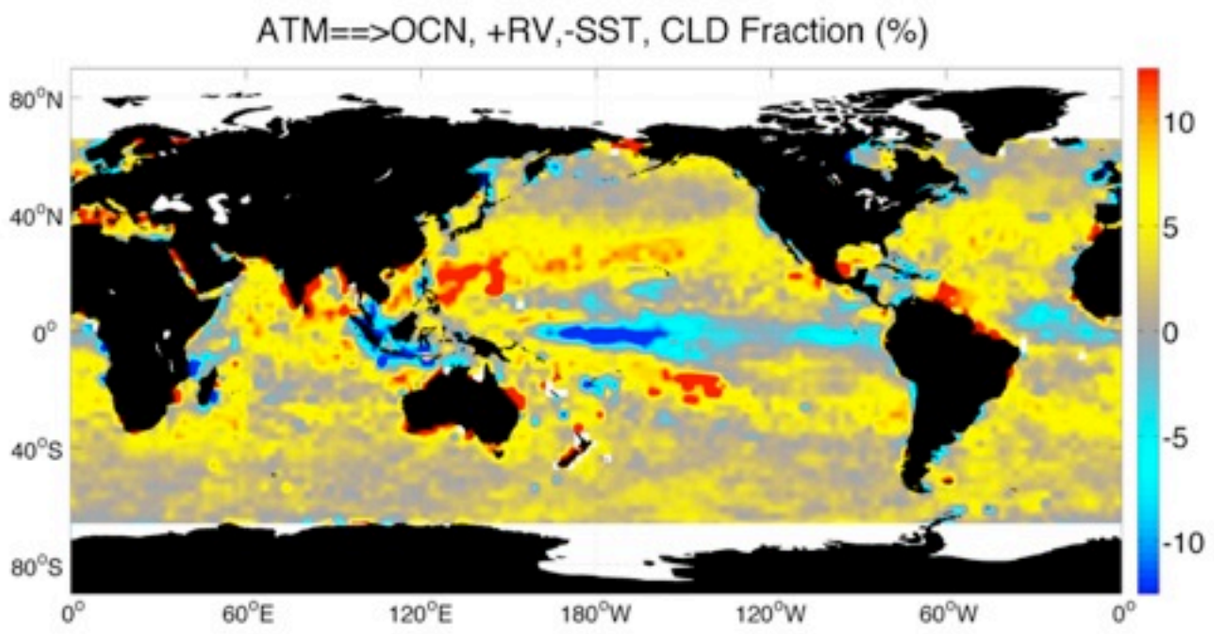


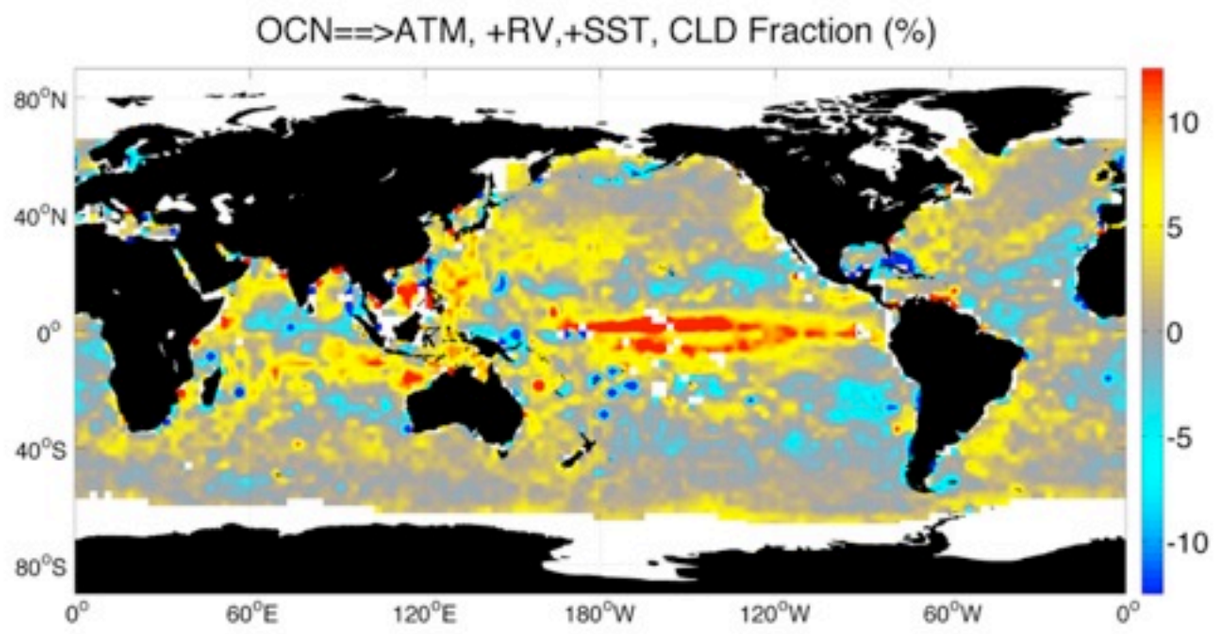
- Longwave response is more muted, mostly from a cancellation of the upwelling and downwelling components (not shown)
- Large region of positive feedback by LWR forcing in central Pacific, but remember this weak.
- Negative feedback in the extratropics of atmospheric forcing cases.

Cloud Fraction (about -10 to 35 W/m^2)









- Cloud fractions are as expected of the dynamical coupling rules in the extratropics but less so in the tropics
- The tropics generally show a much stronger coupling to the SST, regardless of the sign of the vorticity anomaly.

Summary

- The use of "dynamical coupling" rules allows for identifying coupled vs. uncoupled anomalies and one-way interaction
- Results of this study are consistent with those of Pena et al. (2003,2004) although using a more recent reanalysis at higher resolution.
- Find more atmosphere-forcing coupled anomalies in the extratropics and ocean-forcing anomalies in the tropics.
- The LHF and SWR show the largest magnitude anomalies in the composite analysis.
- The turbulent flux responses are due to interactions between the differing responses in wind speed and near-surface gradients.
- The radiative fluxes responses are primarily tied to changes in cloud fraction, as expected, though longwave response can be tied more to changes in the upwelling component.

Future Work

- Perform similar composite analysis to MERRA turbulent and radiative fluxes
- Use the CFSR to examine changes on the ocean side.
- Examine composite analysis using satellite-only based turbulent flux products.

References

- Frankignoul, C., Czaja, A., and L'Heveder, B. (1998). Air-sea feedback in the north atlantic and surface boundary conditions for ocean models. Journal of Climate, 11, 2310–2324.
- Pena, M., E. Kalnay, and M. Cai (2003): Statistics of locally coupled ocean and atmosphere intraaseasonal anomalies in Reanalysis and AMIP data. Nonlinear Process in Geophysics, 10, 245-251.
- Pena, M., M. Cai, and E. Kalnay (2004): Life Span of Subseasonal Coupled Anomalies. Journal of Climate, 17, 1597-1604.