Uncertainty in the Ocean-Atmosphere Feedbacks Associated with ENSO in the Reanalysis Products

Arun Kumar and Zeng-Zhen Hu

Climate Prediction Center, NCEP/NWS/NOAA, 5200 Auth Road, Camp Spring, MD 20746, USA

Main Results

- The overall structure and various ocean-atmosphere dynamical and thermodynamical feedback terms agree well in all the reanalyses
- On the other hand, there are substantial differences in the details of the spatial structures and strength of the ocean-atmosphere coupling related to ENSO

1. Motivations:

A. Various reanalysis data sets have been generated during the last decades. These reanalyses are treated as a proxy for "***observations***" and are widely used as initial conditions of predictions, hindcasts, simulations of GCMs, as well as for validating forecasts and GCM simulations .

B. To help validate ENSO simulations in coupled models, we assess the reproducibility of the air-sea interaction feedback associated with the ENSO.

2: Reanalysis and Verification Data

- **R1**: Kalnay, E., and co-authors, 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437-471.
- **R2**: Kanamitsu, Mand co-authors. 2002: NCEP-DOE AMIP-II Reanalysis (R-2). *Bull. Amer. Meteor.*, **83**, 1631-1643.
- **ERA**: Uppala, S. M., co-authors., 2005: The ERA-40 re-analysis. *Q. J. R. Meteor. Soc.*, **131**, 2961-3012, doi: 10.1256/qj.04.176.
- **JRA**: Onogi, K., co-authors, 2007: The JRA-25 Reanalysis. *J. Meteor. Soc. Japan*, **85**, 369-432.
- **ERSSTv3:** Smith, T. M., R. W. Reynolds, T. C. Peterson, and J. Lawrimore, 2008: Improvements to NOAA's historical merged land-ocean surface temperature analysis (1880-2006). *J. Climate*, **21**, 2283-2296.
- **MERRA**: Rienecker, M. M., co-authors, 2010. MERRA - NASA's Modern-Era Retrospective Analysis for Research and Applications. *J. Climate*, **24,** 3624-3648.
- **CFSR**: Saha, S., and Coauthors, 2010: The NCEP Climate Forecast System Reanalysis. *Bull. Amer. Meteor. Soc.*, **91**, 1015–1057. doi: 10.1175/2010BAMS3001.1.

- **CMAP Precipitation:** Xie P., and P. A. Arkin, 1997: Global precipitation: a 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteor. Soc.*, **78**, 2539-2558.
- **OAFlux Sensible and Latent Heat Flux:** Yu, L. and R. A., Weller, 2007: Objectively Analyzed air-sea heat Fluxes (OAFlux) for the global ocean. *Bull. Amer. Met Soc.*, **88**, 527-539.
- **ISCCP short-wave and long-wave radiation:** Zhang, Y., and co-authors, 2004: Calculation of radiative flux profiles from the surface to top-of atmosphere based on ISCCP and other global data sets: refinements of the radiative transfer model and input data. *J. Geophys. Res.*, **109,** D19105, doi:10.1029/2003JD004457.

3: SUMMARY

A. The overall structure and various ocean-atmosphere dynamical and thermodynamical feedback terms agree well in all the reanalyses.

B. On the other hand, there are substantial differences in the details of the spatial structures and strength of the ocean-atmosphere coupling related to ENSO among reanalysis products, demonstrating the level of uncertainty in current estimates arising from intrinsic differences among reanalysis systems.

C. If the biases in the estimates from different reanalyses is considered random, and to the extent they average out, the ensemble mean values for the wind stress and heat flux response is our best estimate of the air-sea feedback terms associated with the ENSO variability.

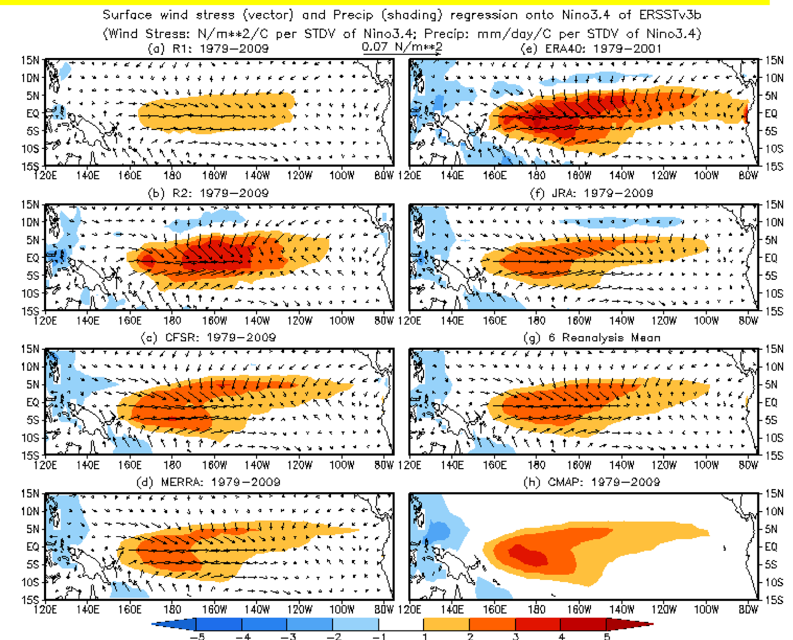
Citation: Kumar, A. and Z.-Z. Hu, 2012: Uncertainty in the ocean-atmosphere feedbacks associated with ENSO in the reanalysis products. *Clim. Dyn.*, DOI: 10.1007/s00382-011-1104-3 (published online).

Contact Information: **E-mail: Arun.Kumar@noaa.gov**

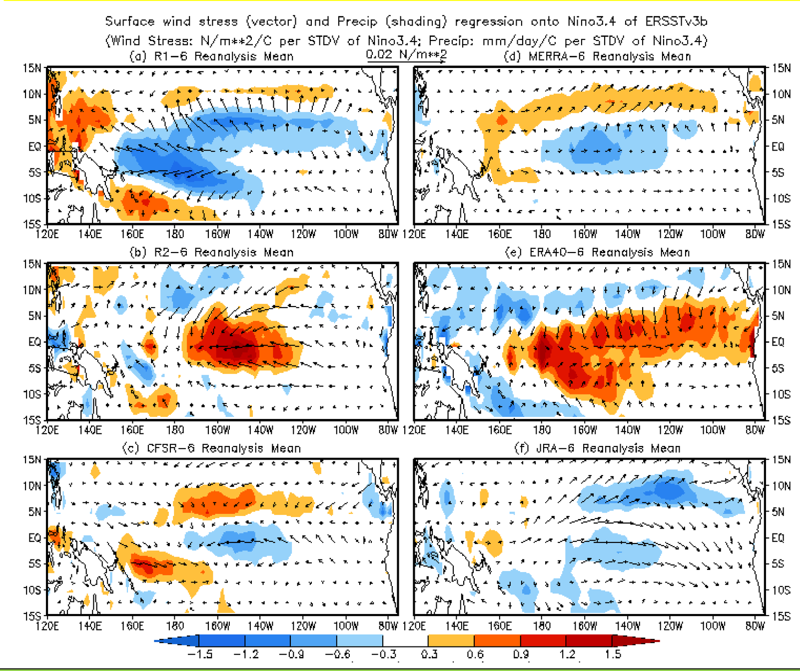
Acknowledgements: We appreciate the comments of Drs. Wanqiu Wang, Yan Xue, D. G. DeWitt, and two reviewers. Thanks also go to Dr. Li Zhang for managing the reanalysis data sets at CPC.

4: Dynamical Processes *(Not include thermocline, advection, Ekman feedbacks)*

Wind Stress and Precipitation Regression onto Nino3.4



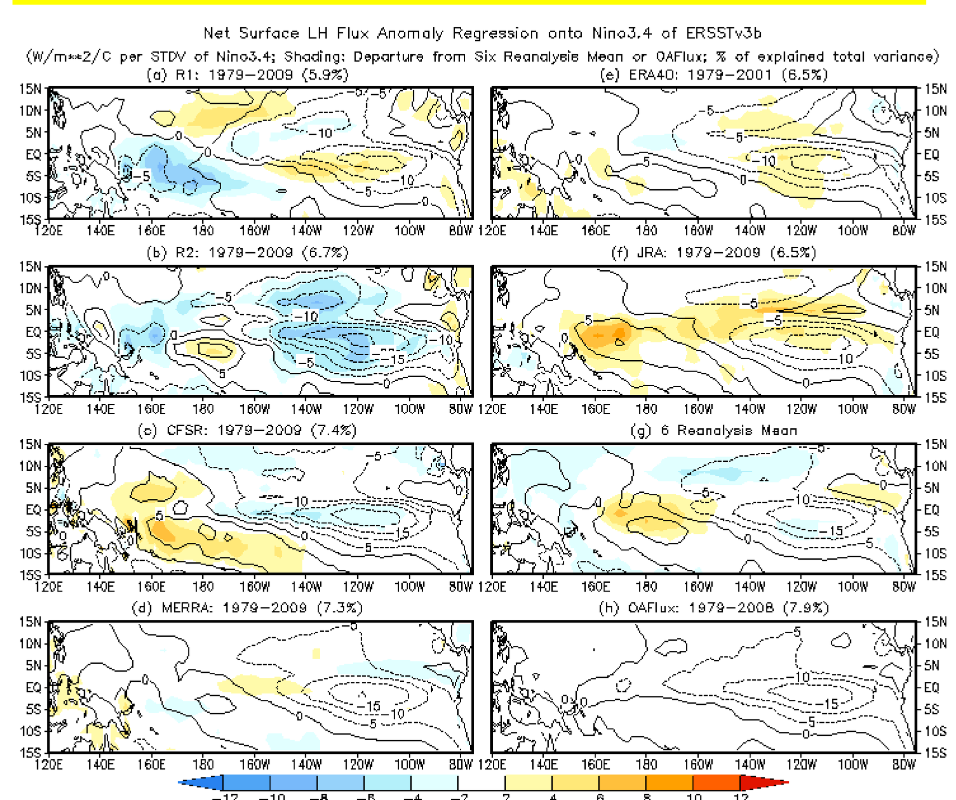
Wind Stress and Precipitation Regression onto Nino3.4: Departure from Mean Regressions



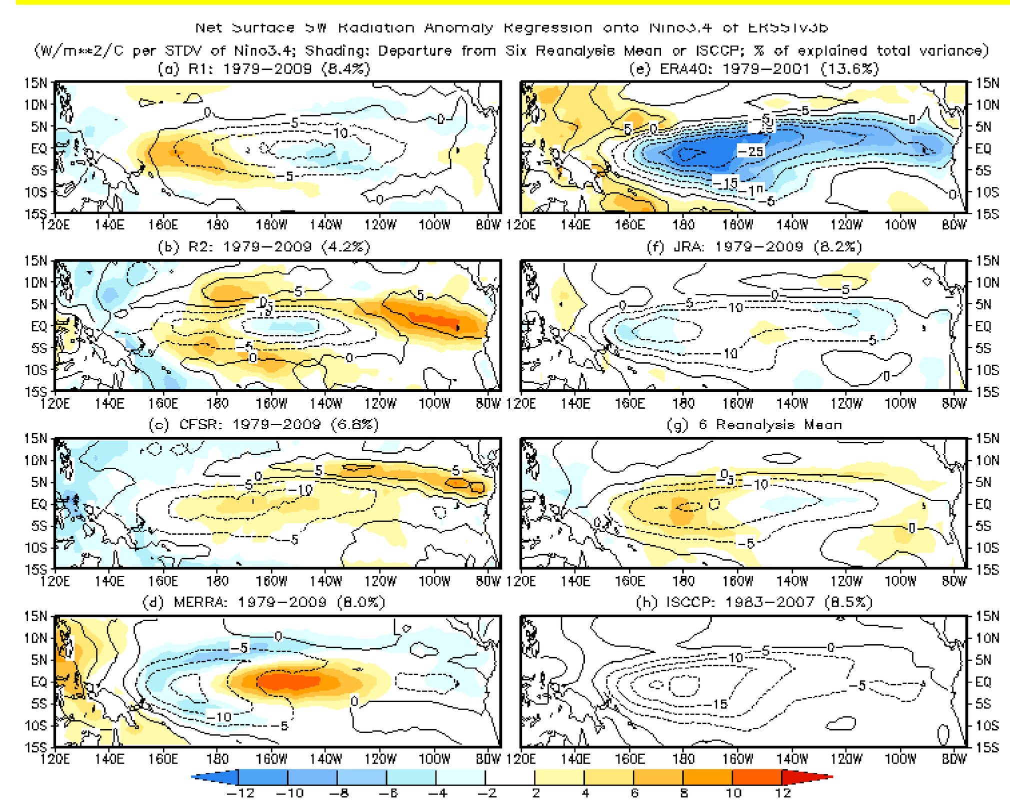
El Nino is associated with weakening of easterly tread winds and increase of precipitation in E. & C. tropical Pacific.
Divergence (convergence) is associated with decrease (increase) of precipitation. Also, both the zonal and meridional components are important for the precipitation.
Comma shaped pattern of precipitation is well simulated in all reanalyses, except R1 and R2.
Precipitation overestimated in ERA40 and R2, and underestimated in R1

5: Thermodynamical Processes

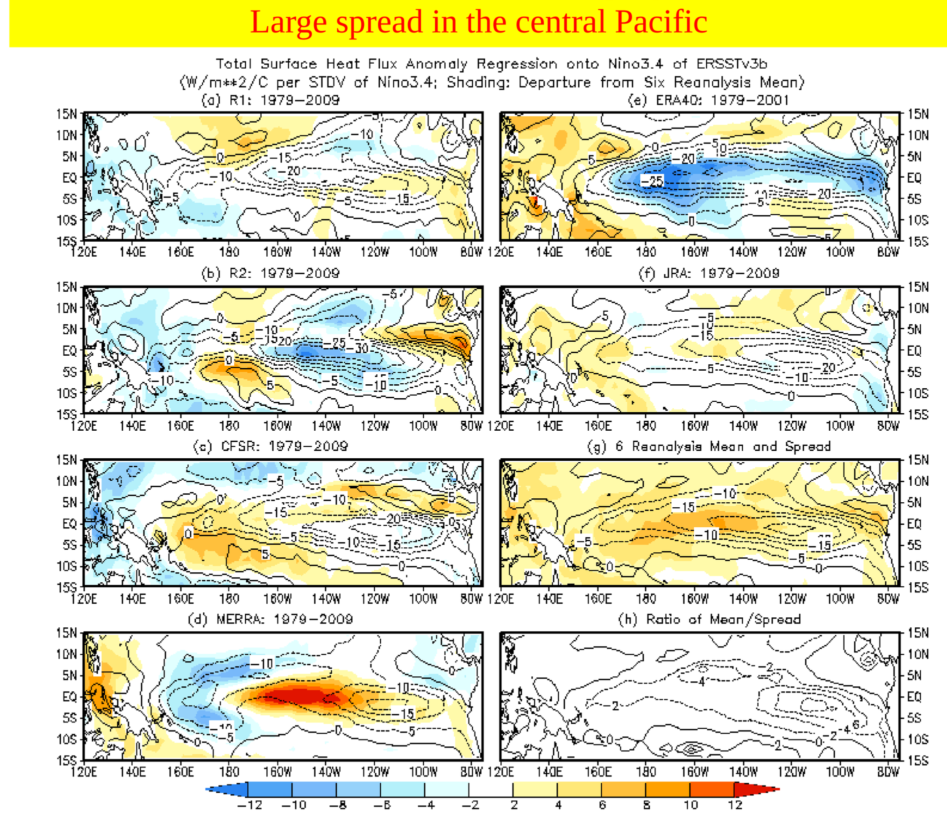
Net Surface Latent Heat Flux Regression onto Nino3.4:
Strong Damping
R2: Overestimated damping
JRA: Underestimated damping



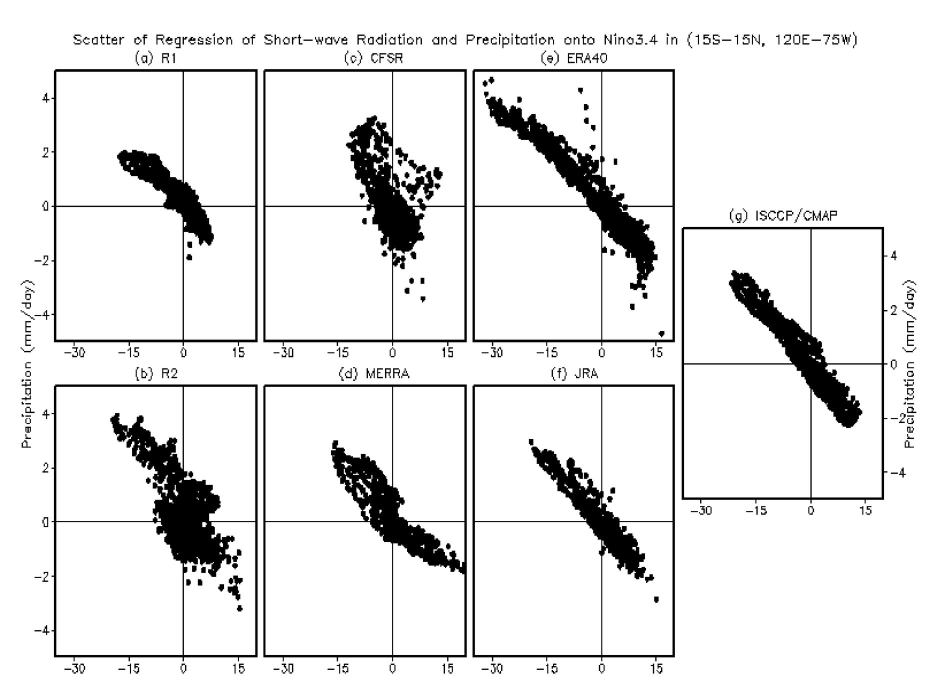
Net Surface Short-Wave Radiation Regression onto Nino3.4:
Associated with variations of cloud and precipitation (ITCZ)
ERA40: overestimates the damping
CFSR and MERRA underestimate the damping



Net Surface Total Heat Flux Regression onto Nino3.4:
Strong Damping
Overestimated total heat flux damping in R2 and ERA40
Underestimated total heat flux damping in MERRA
Large spread in the central Pacific

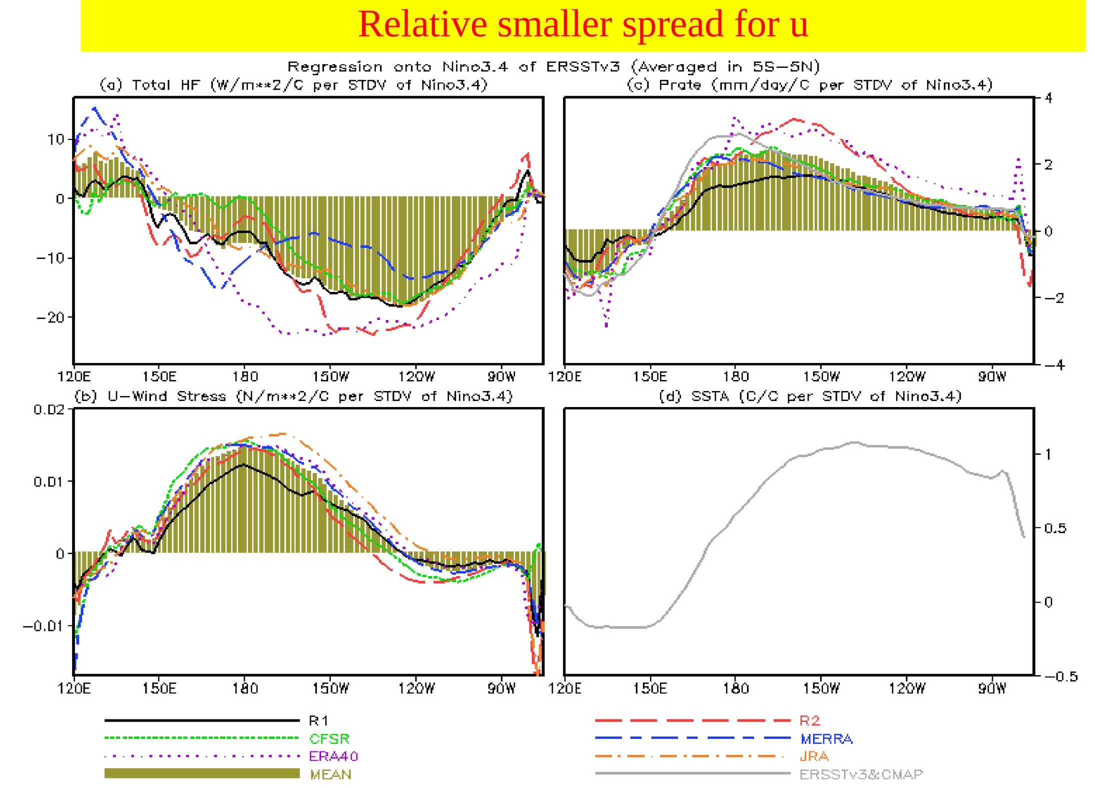


Regression Coefficients of Short-Wave Radiation and Precipitation onto Nino3.4 in Nino3.4 region:
Strong linear relation in observations (ISCCP/CMAP)
The linear relationship is generally reproduced in JRA, ERA40, and R1, but not well in R2, CFSR, and MERRA

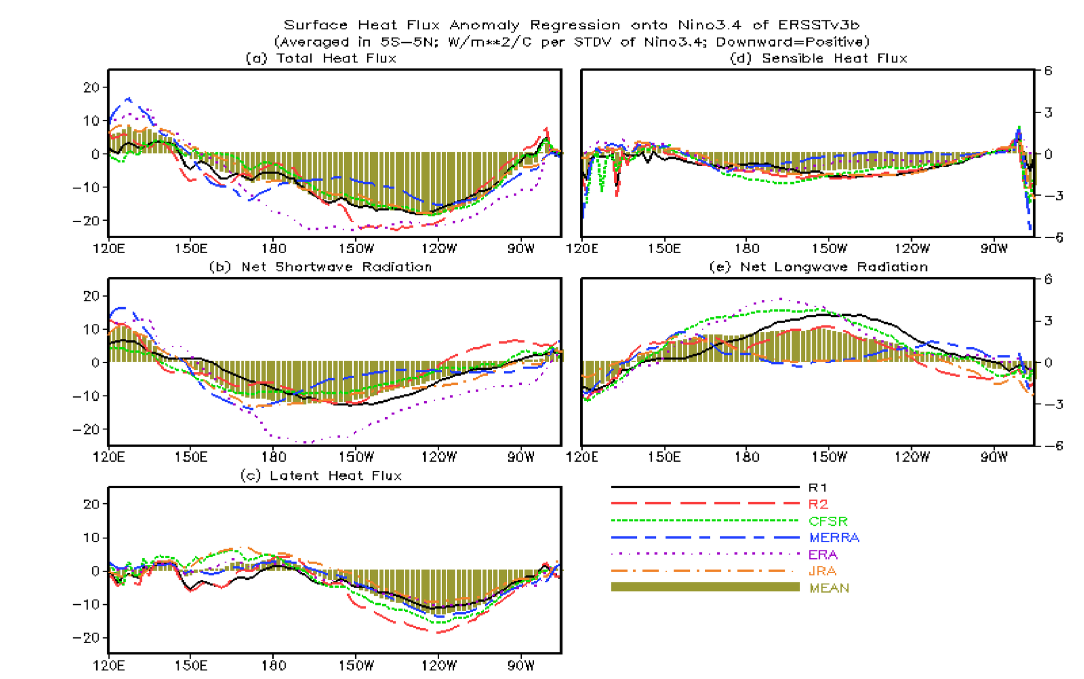


6: A Synthesis of Dynamical and Thermodynamical Feedbacks

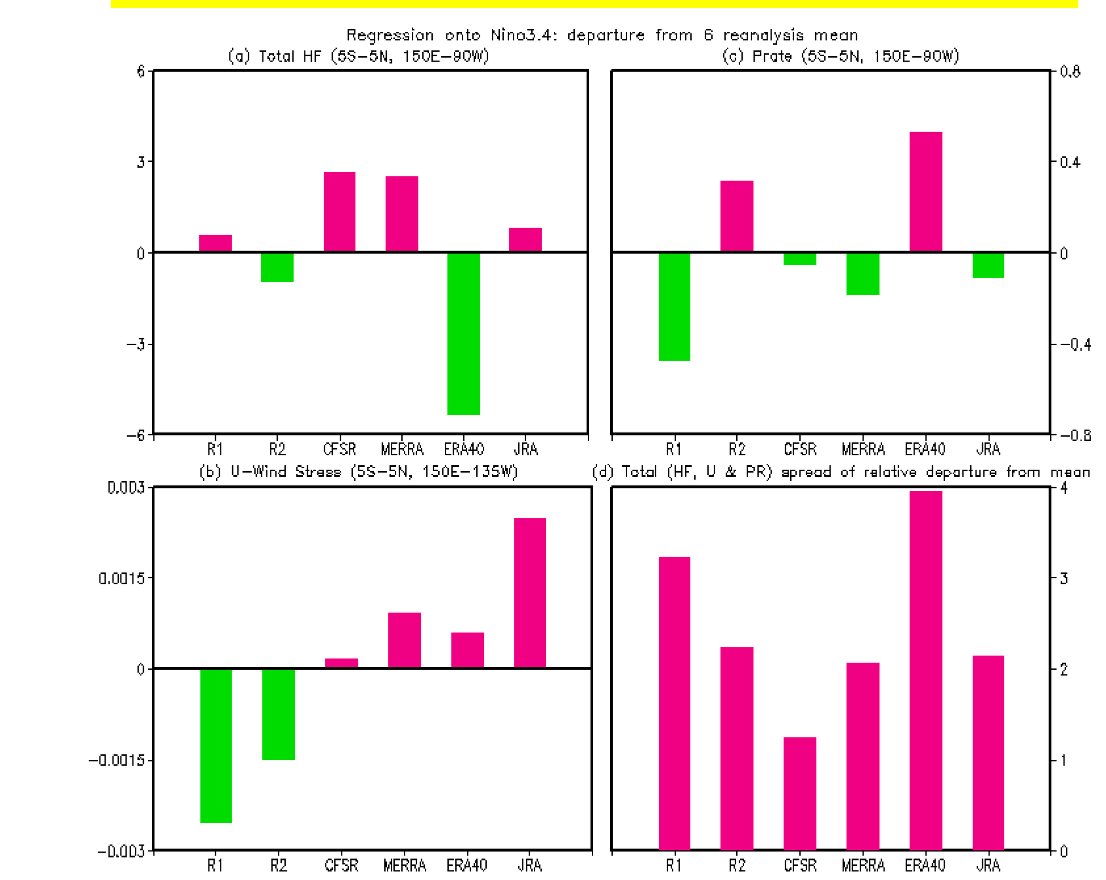
Regressions of Total Heat Flux, u, Precipitation on Nino3.4 along the Equator
Larger spread for total heat flux and precipitation;
Relative smaller spread for u



Regressions of Heat Flux Terms on Ninon3.4 along the Equator: Large Spread for Short-wave and Long-Wave Radiation



Overall Assessment



Total HF: R1, R2 and JRA closest to 6-reanalysis ensemble mean; ERA40 has largest departure.
U: CFSR closest to the mean; R1 and JRA have largest departure.
Rrate: CFSR closest to the mean; R1 and ERA40 have largest departure.
Overall: CFSR closest to the 6-reanalysis mean, and ERA40 and R1 have the largest departure.