Historical marine sea level pressure and surface winds: How to constrain them?

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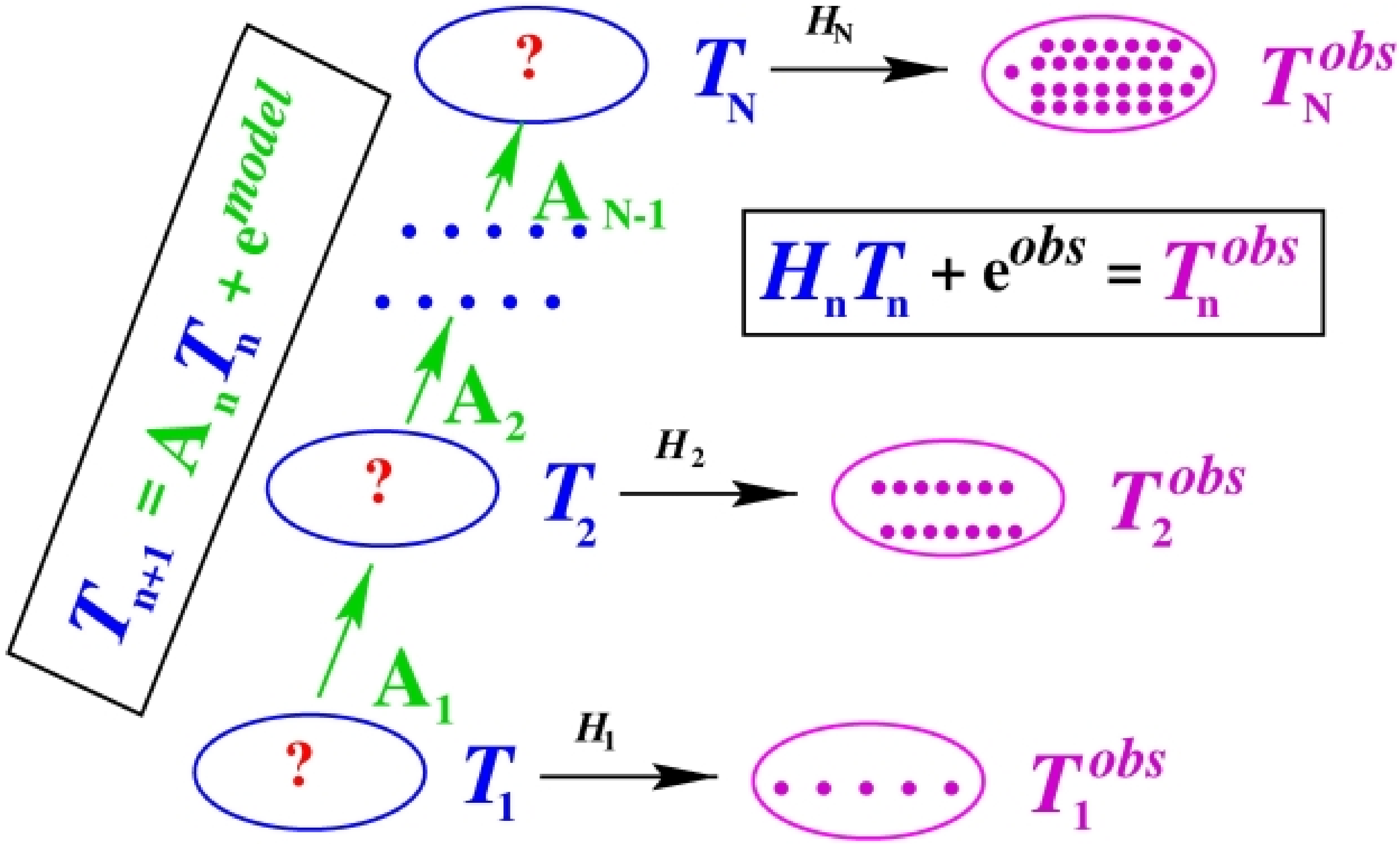
Outline

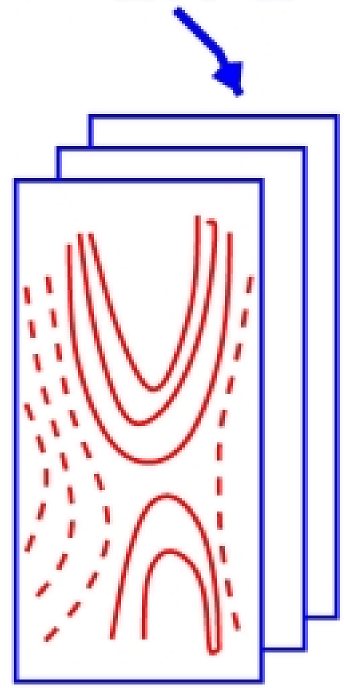
- Univariate analyses of I-COADS and GHCN: successes and challenges
- Additional constraints are crucial: geostrophy or… persistence?
- What drives the surprising persistence of tropical pressure and wind anomalies?
- Ocean modelers love equatorial wind persistence.
- New horizons open to us.

Generic problem of the analysis of time-evolving fields

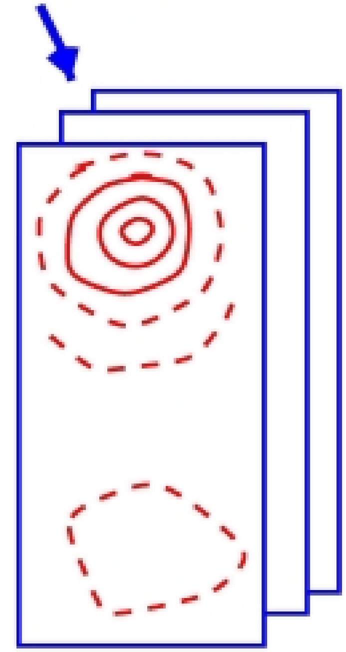


APPROXIMATING COVARIANCE

$$C = E\Lambda E^T + E'\Lambda' E'^T$$



Reduced space
optimal analysis



Successive corrections;
Kriging

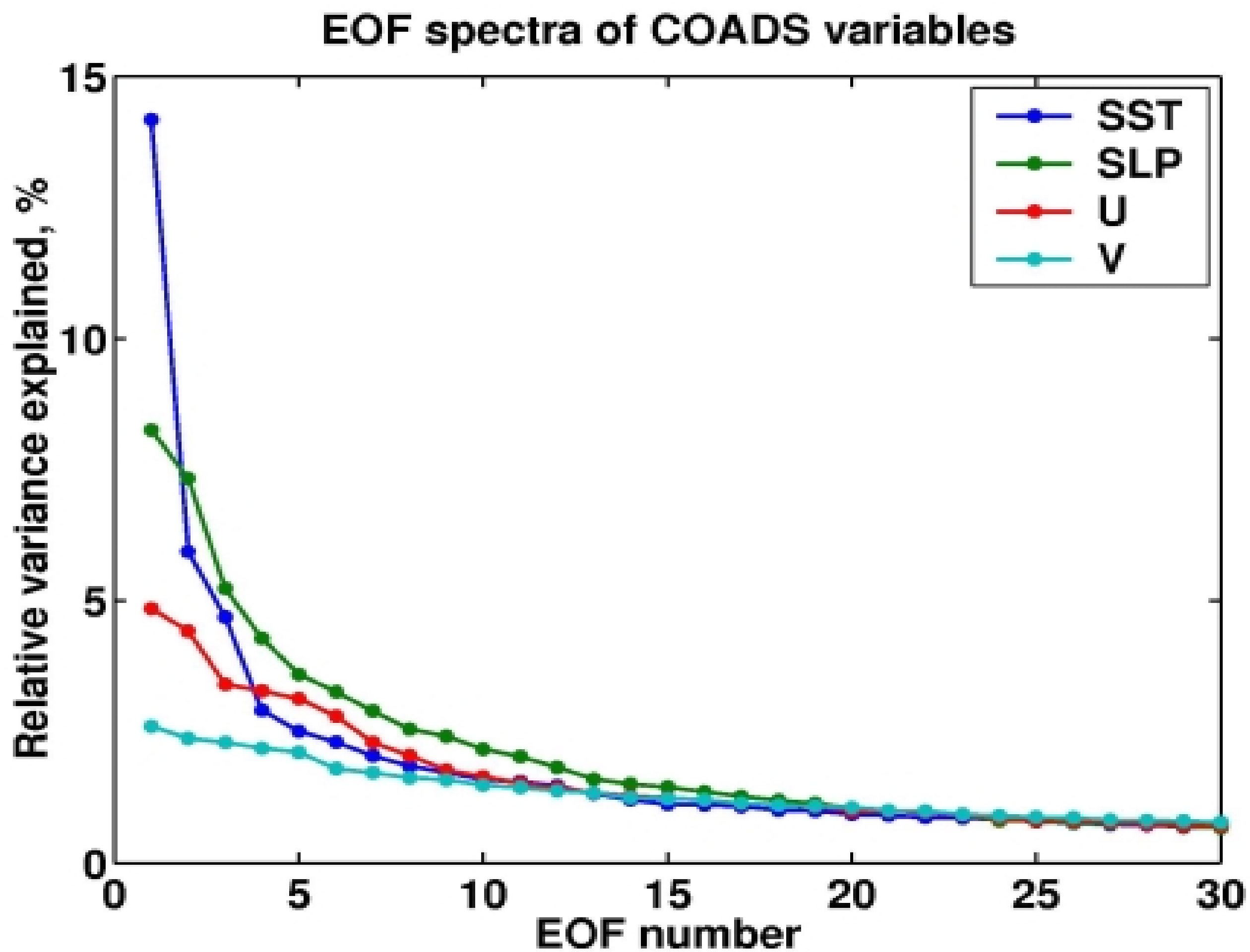


Figure 1: Eigenvalue spectra of climate variables from COADS, 1950-2000

EOFs of zonal wind anomaly

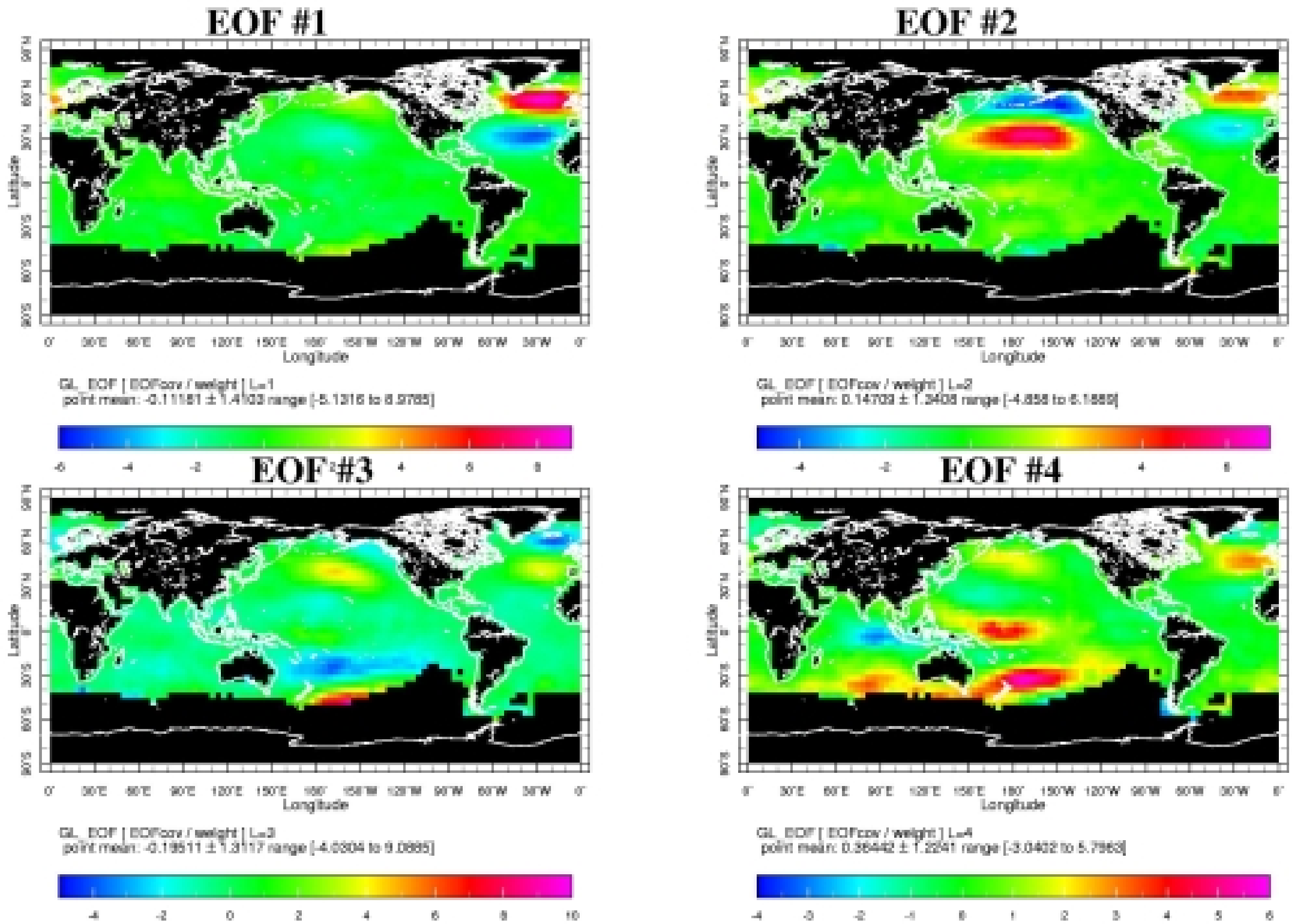
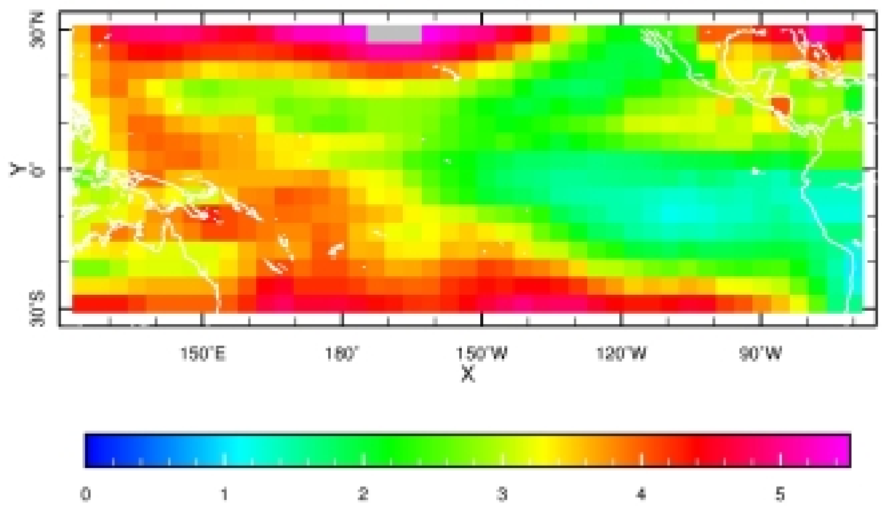


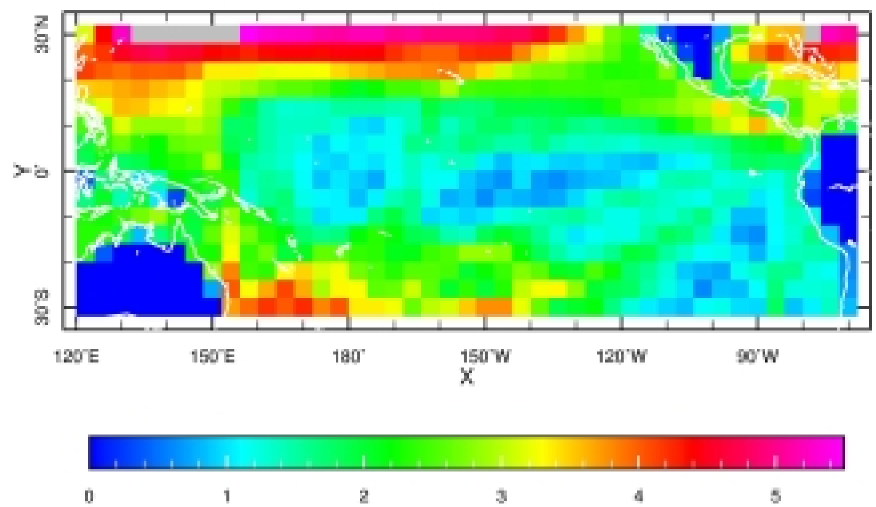
Figure 2: Leading EOF patterns of zonal wind anomalies from COADS, 1950-2000

Small-scale variability in zonal wind $\sigma_{4^o\times4^o\times1\ \text{month}}$, m/s

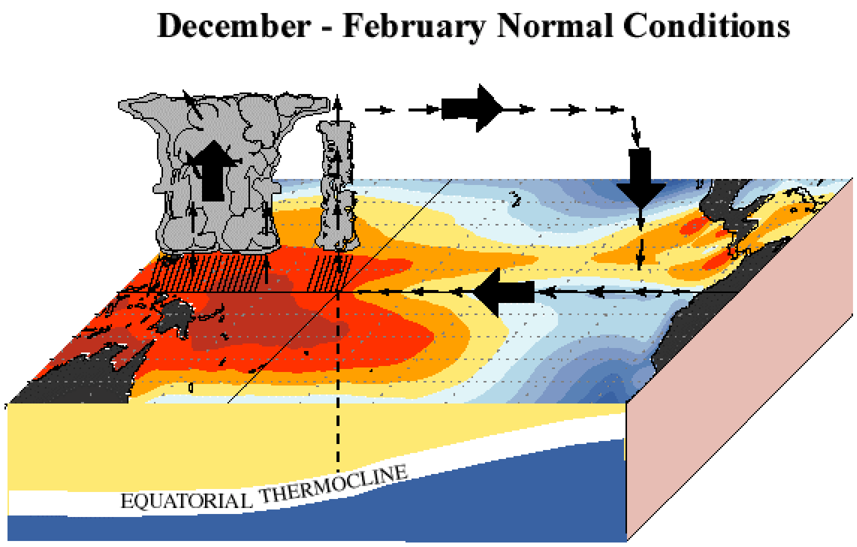
NSCAT

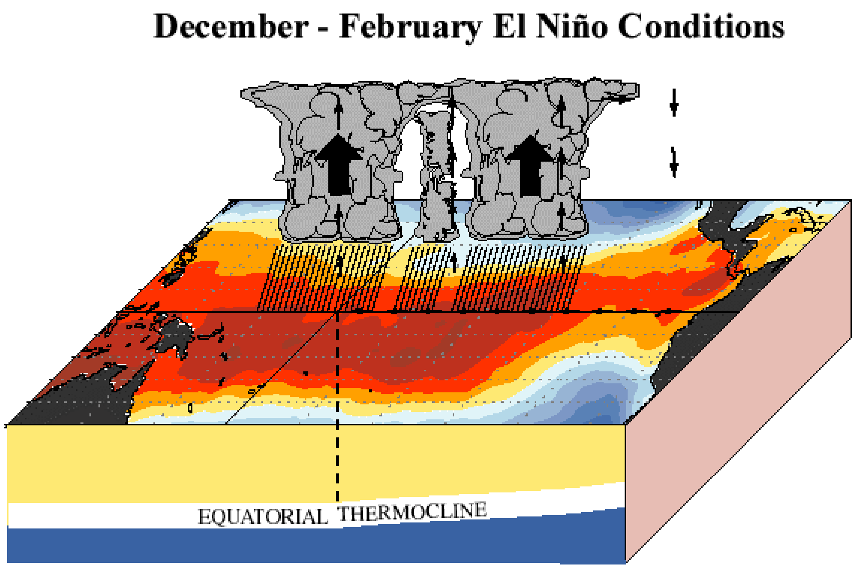


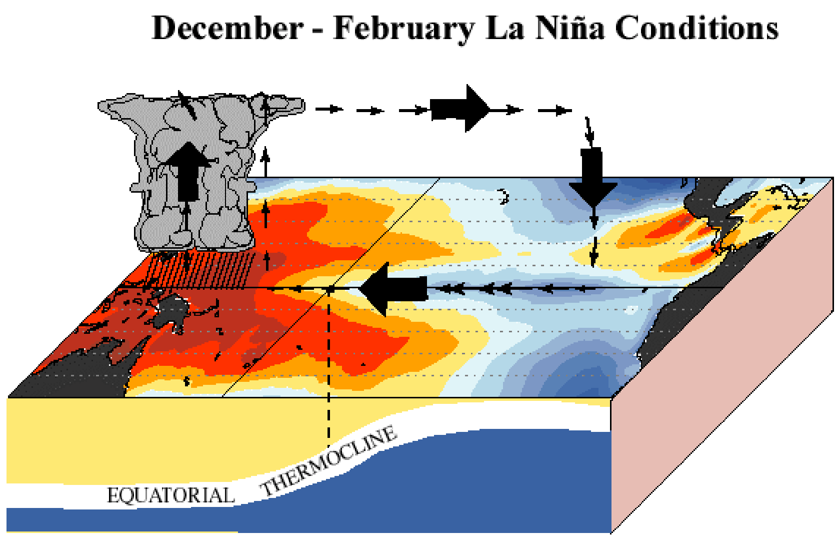
COADS



Dynamics of El Niño – Southern Oscillation







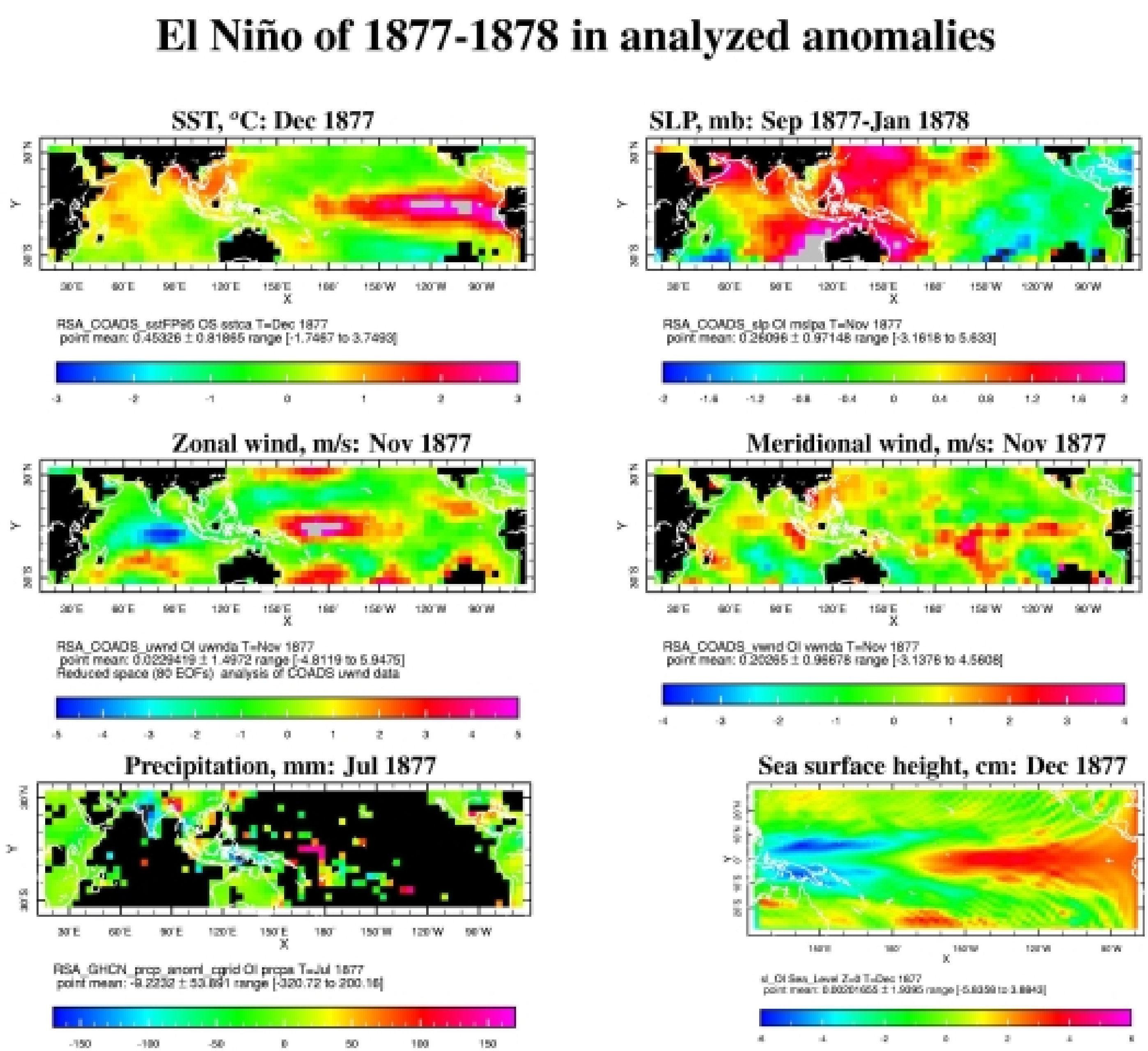


Figure 4: Anomalies of 1877-1878 El Niño illustrated by univariate reduced analyses by *Kaplan et al.* [2001b]

Independent ENSO indices

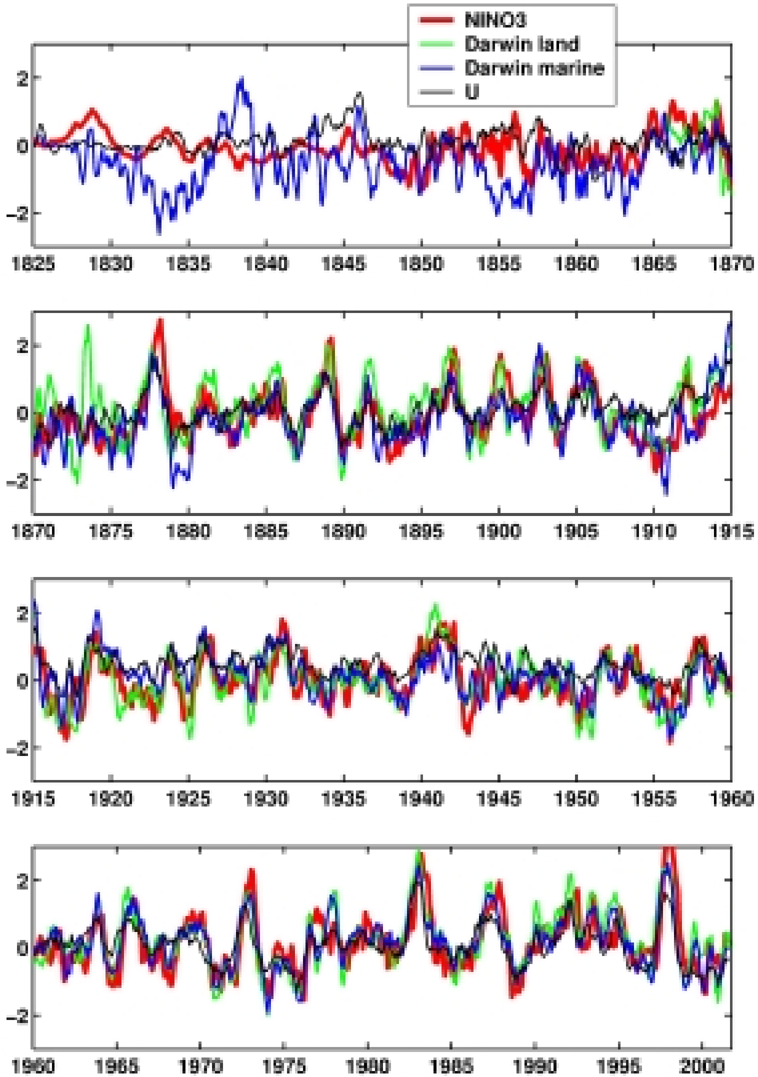
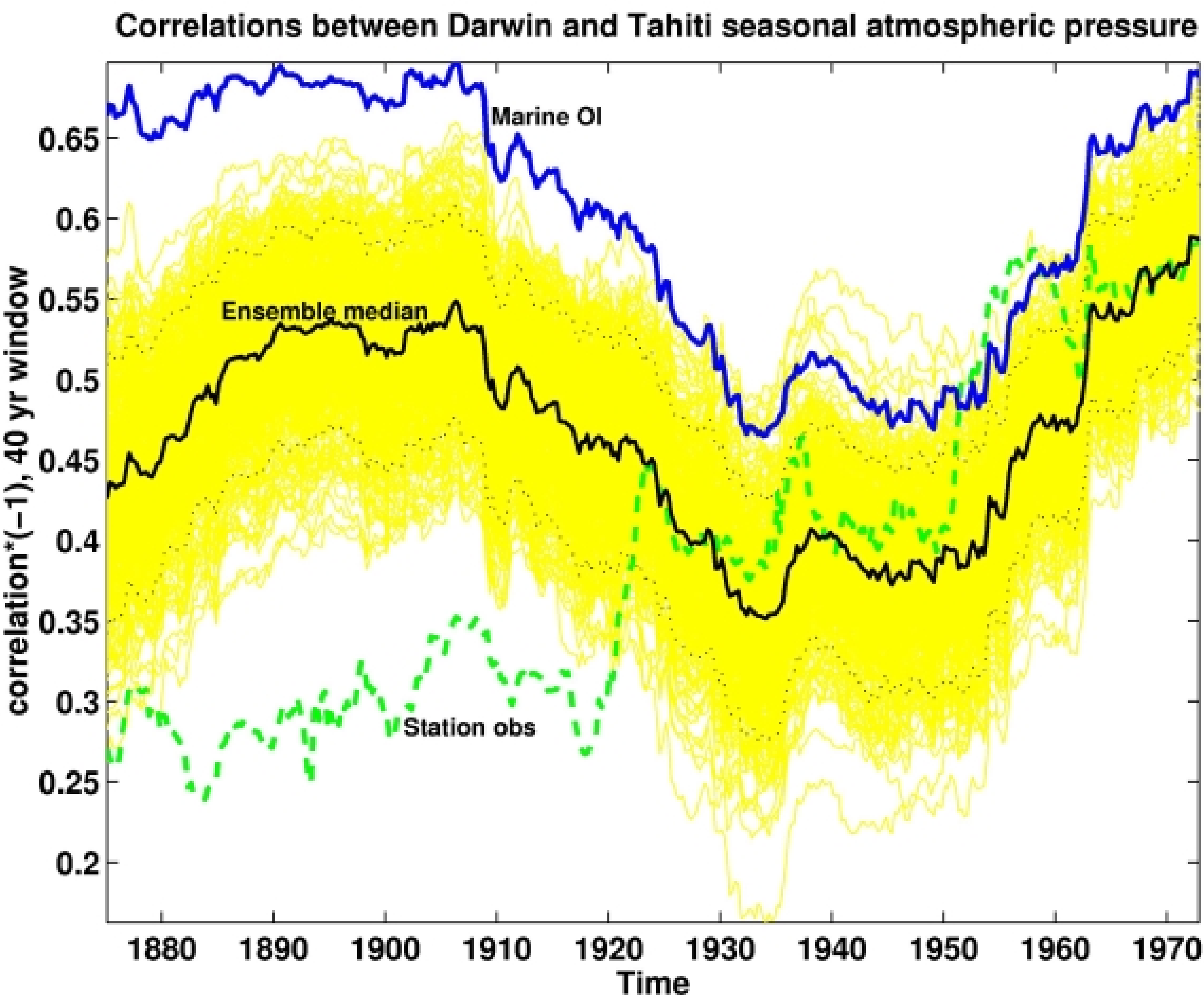


Figure 3: Intercomparison of ENSO indices: NINO3, °C, by *Kaplan et al.* [1998]; Darwin station SLP, mb, [*Allan et al.*, 1991; *Können et al.*, 1998]; Darwin area SLP estimate from ship-based RSOI, mb, [*Kaplan et al.*, 2000]; and Central Equatorial Pacific zonal wind anomaly (5°N-5°,160°E-120°W), 5m/s [*Kaplan et al.*, 2001]. Pressure and wind data are 5 month running means.


Correlations between Darwin and Tahiti seasonal atmospheric pressure
Marine OI
Ensemble median
Station obs
correlation*(−1), 40 yr window
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
Time

When data are sparse, additional constraints are absolutely necessary

Testing geostrophic constraint

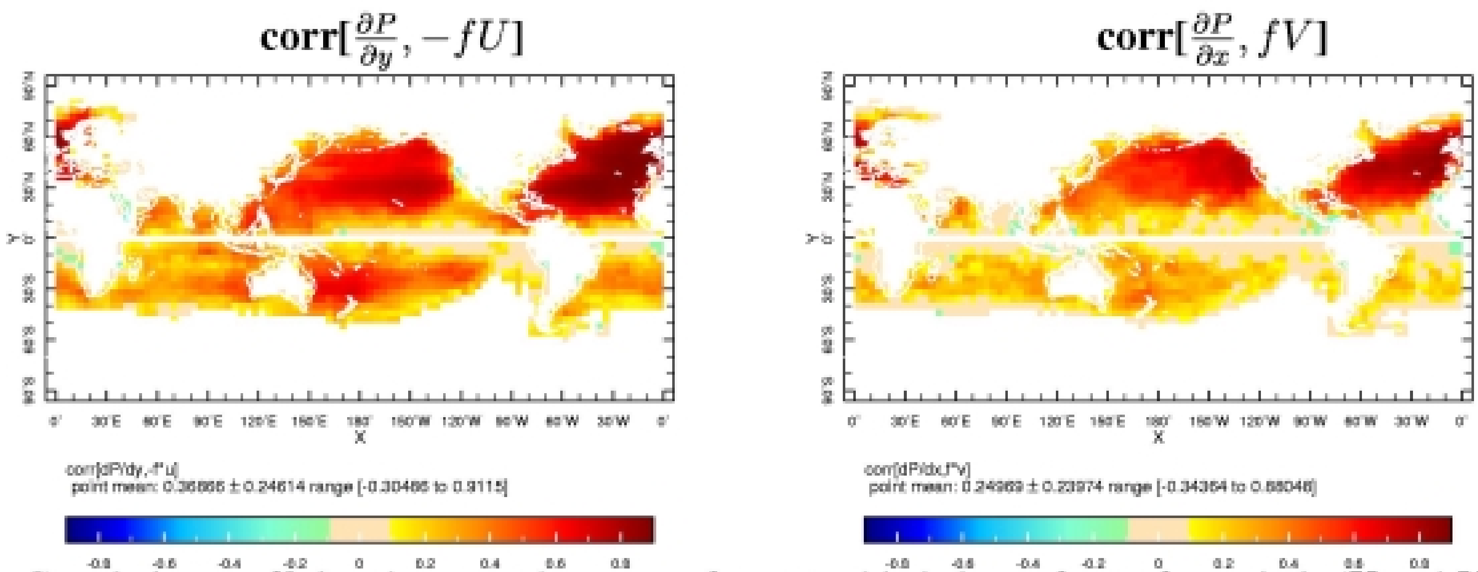


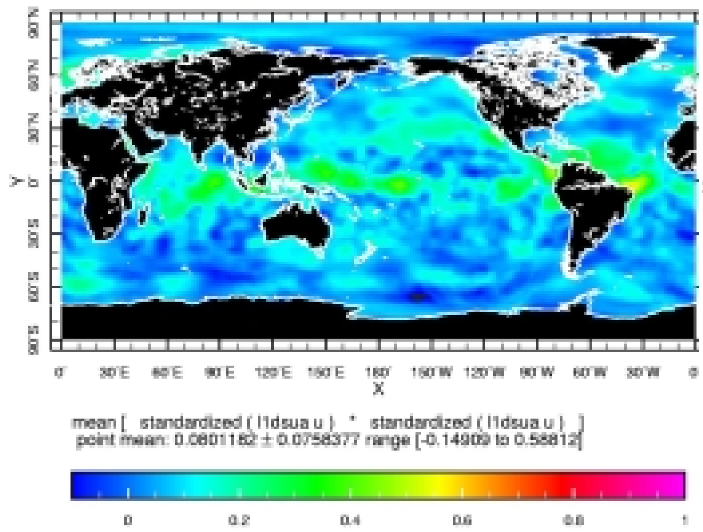
Figure 5: Correlation coefficient between the terms of geostrophic balance for surface winds (U and V) and sea level pressure P. Data comes from the univariate RS OI analyses of COADS data [*Kaplan et al.*, 2001]. Correlation coefficients are computed for all months from 1900 to 2000.

Persistence in SST anomalies is traditionally used to constrain historical analyses, but there is no persistence in monthly wind or pressure anomalies, right?

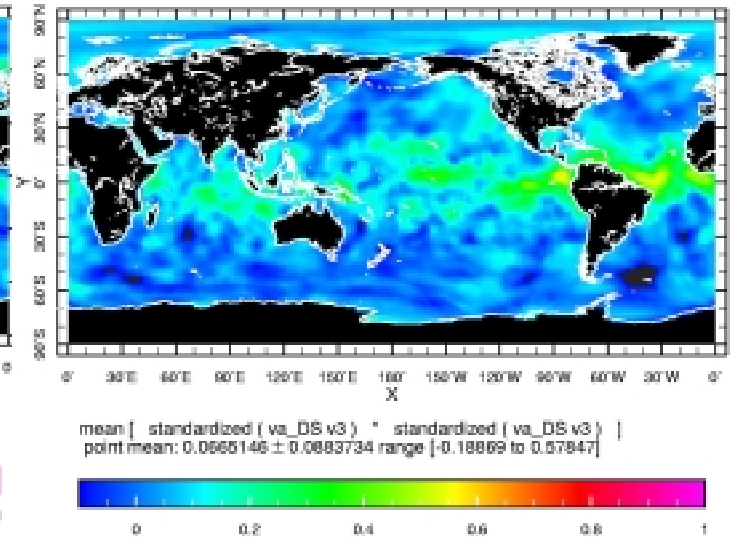
Data sets used below: Da Silva's successive-correction analyses of COADS data NCEP-NCAR Reanalysis; WOCE surface winds derived from the ERS Scatterometry; FSU subjective analysis of the tropical Pacific winds; Xie and Arkin precipitation analysis.

Persistence: Anomaly autocorrelations with 1 month lag

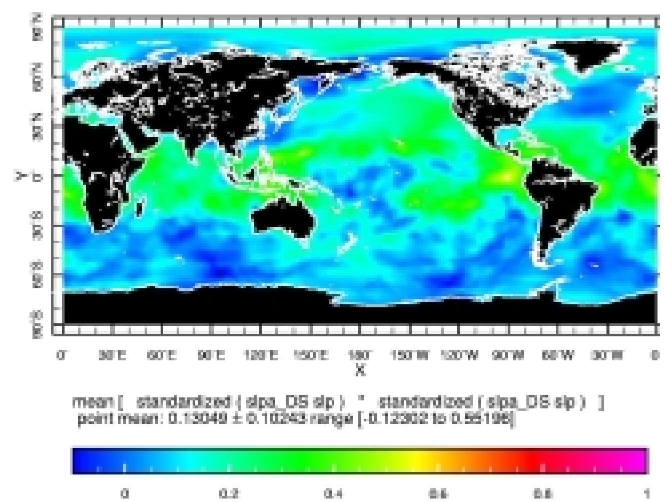
Da Silva U



Da Silva V



Da Silva SLP



Persistence: Anomaly autocorrelations with 1 month lag

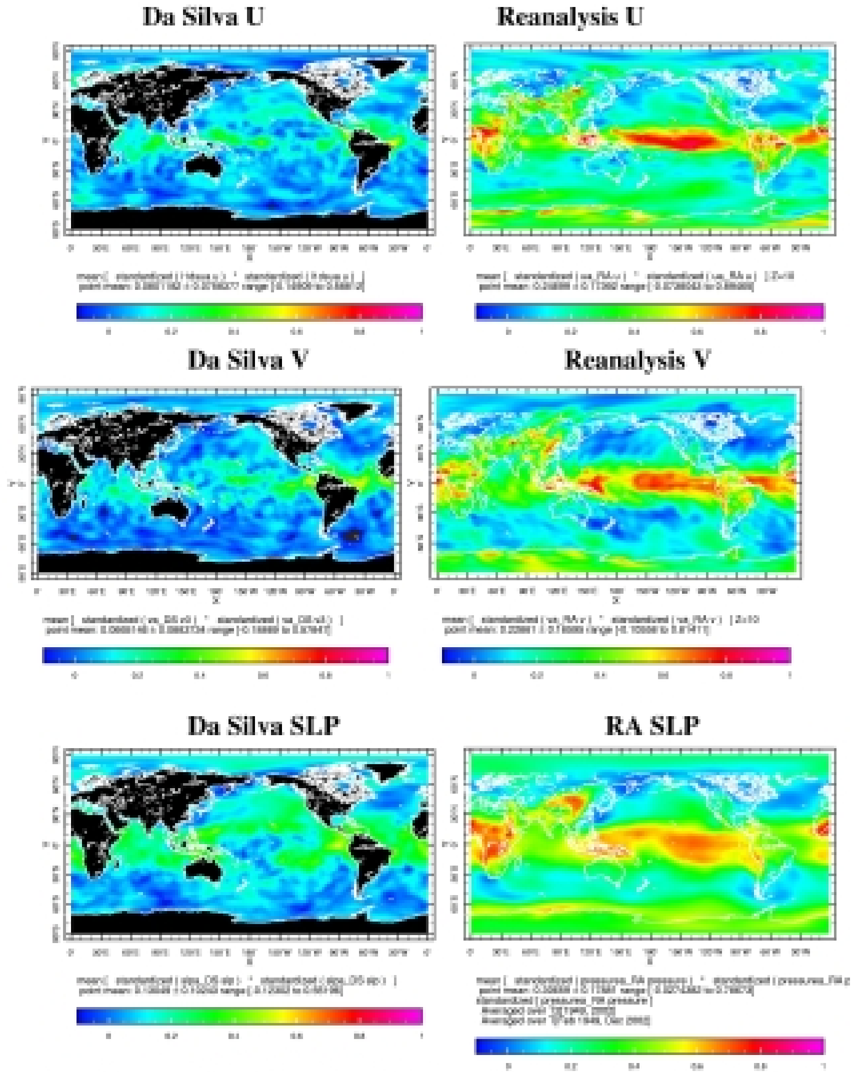
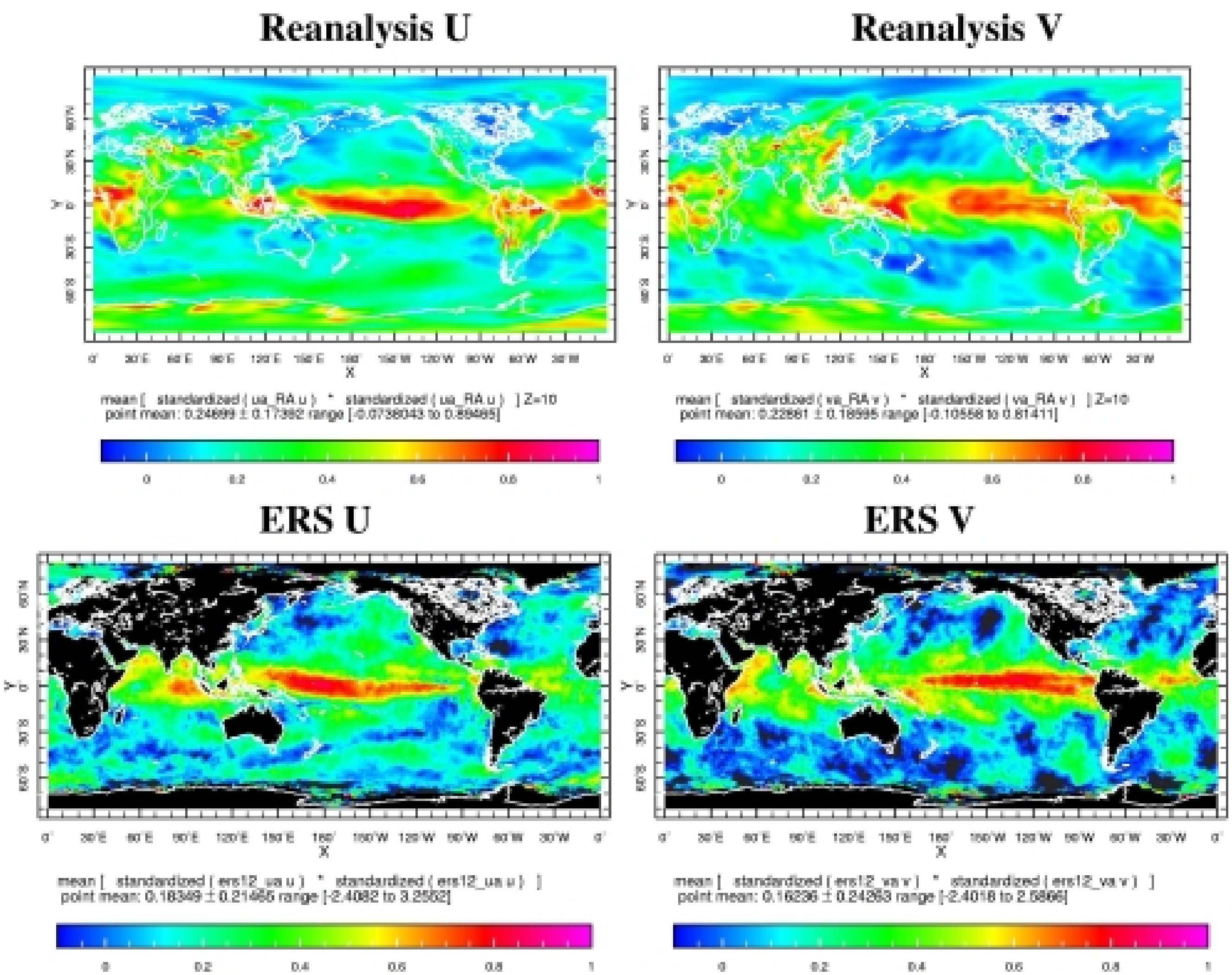


Figure 6: One month autocorrelation of monthly wind anomalies Da Silva et al [1994] and NCEP-NCAR reanalysis data sets

Verification by satellite data



John Chiang’s [*et al.,* 2001] approach to surface wind modeling: linearized dynamical core of a GCM [*Seager and Zebiak*, 1995] is set up to take both sea surface temperature and elevated atmospheric heating as forcings. The latter is parameterized via precipitation.

Persistence of the actual forcings

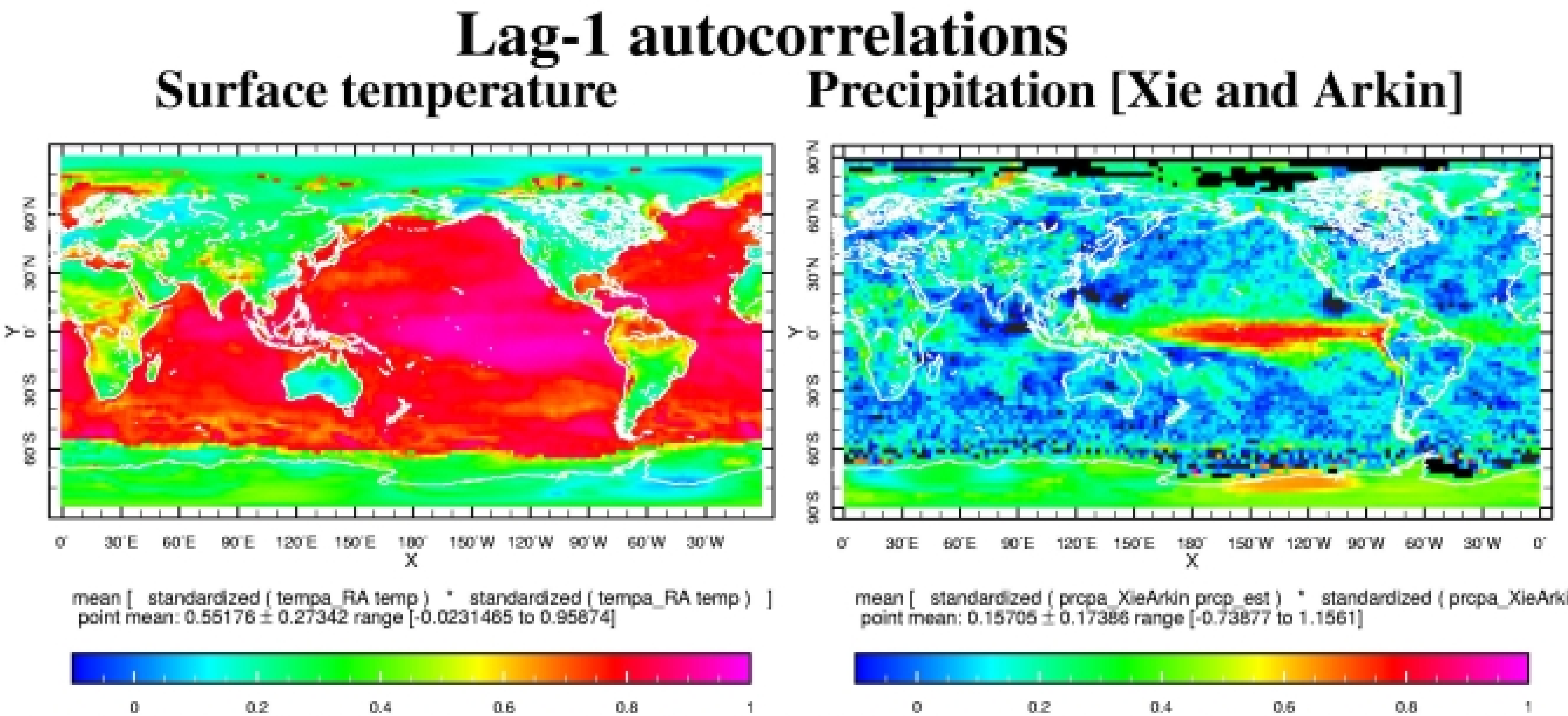


Figure 8: One month lagged autocorrelations of interannual monthly anomalies for RA surface temperature and for *Xie and Arkin* [1986] precipitation

Simulation skill

Consistency of persistence pattern in ERS (colors) and simulation (contours)

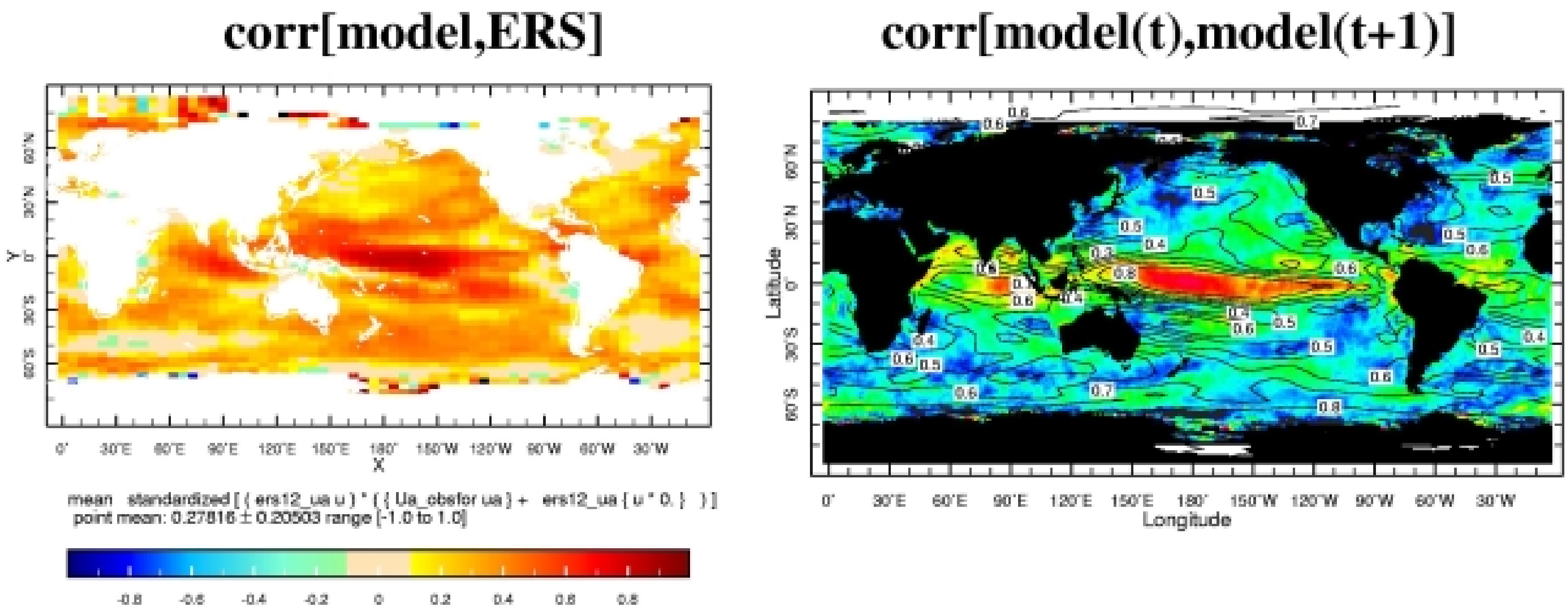
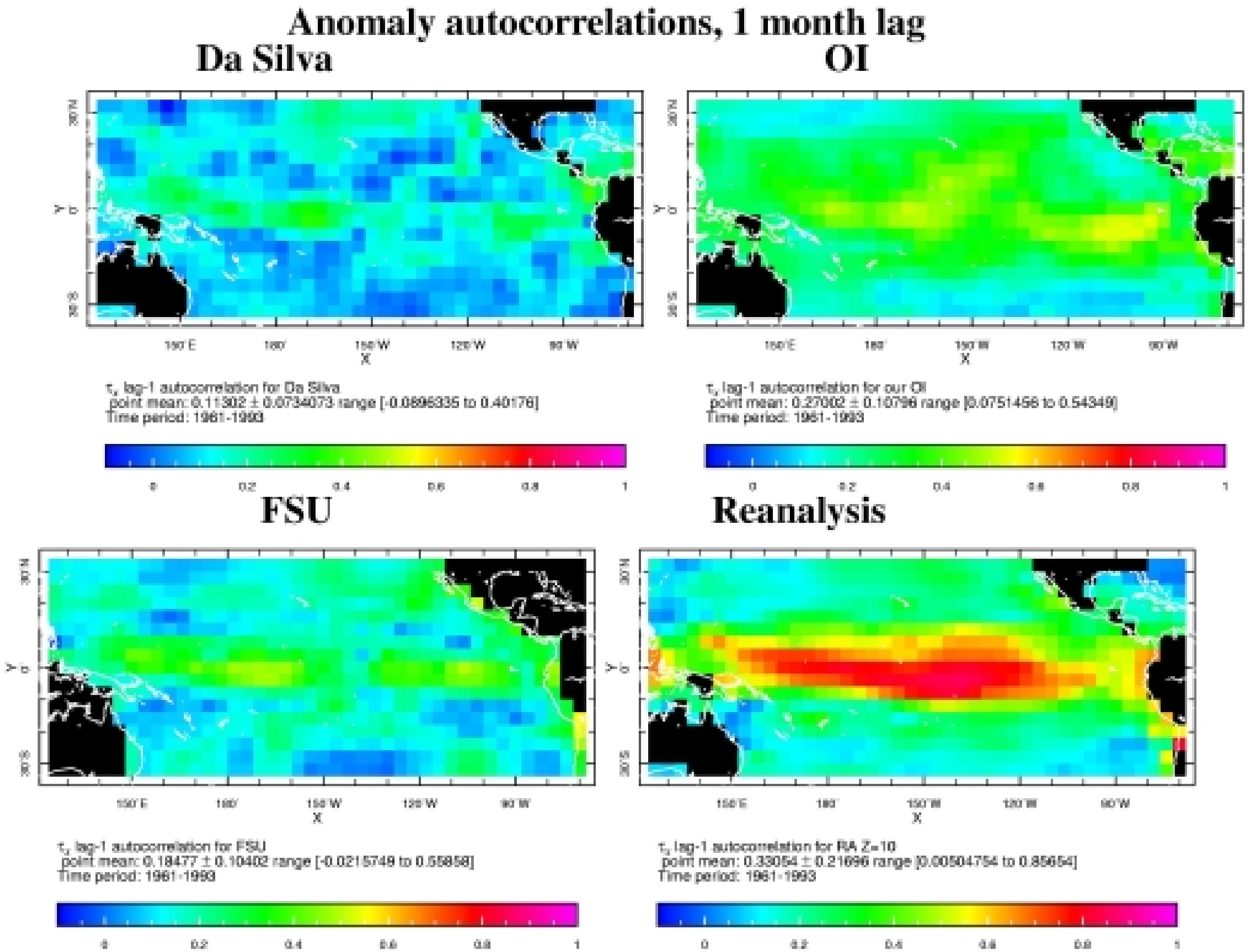


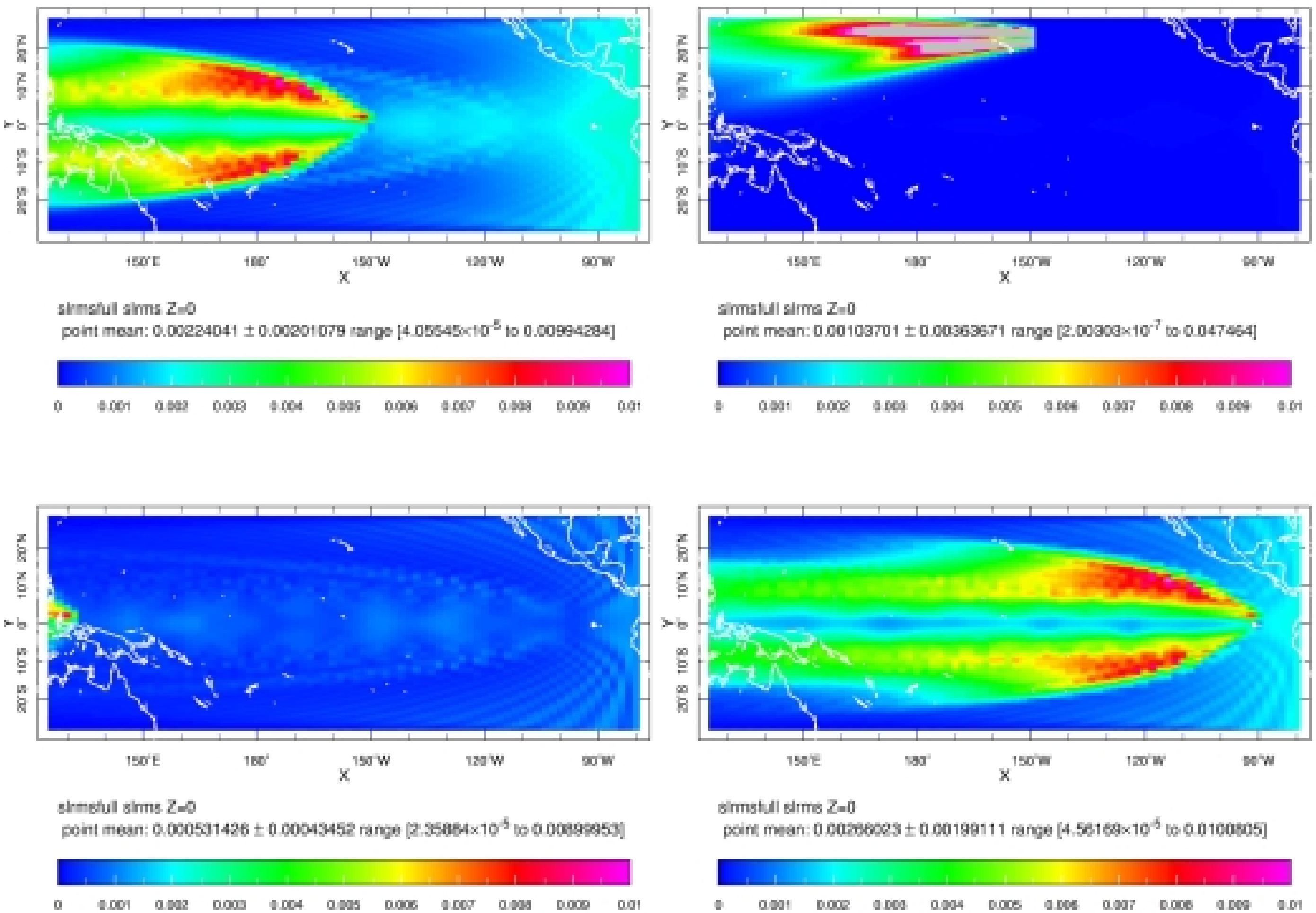
Figure 9: Use of *Chiang et al.* [2001] model to reproduce wind persistence. Zonal wind response of the model forced by observed SST and precipitation shows good correlation with ERS scatterometry in the tropics (left panel). Autocorrelations of model winds with 1 month lag (contours in the right panel), while generally higher than the autocorrelations in the ERS scatterometry data (colors in the right panel; same as bottom right panel in Figure 6) have a similar pattern in the tropics.

What is a good wind product from the tropical oceanographer's point of view?

Why equatorial persistence is so important?

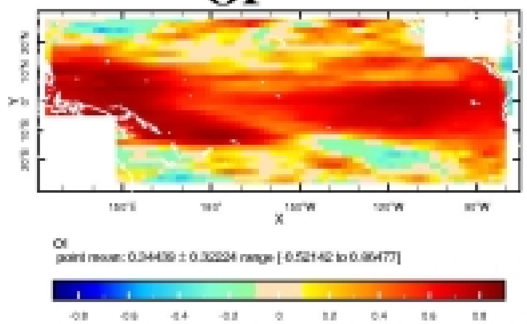


RMS of sea level response to the wind noise in a single location

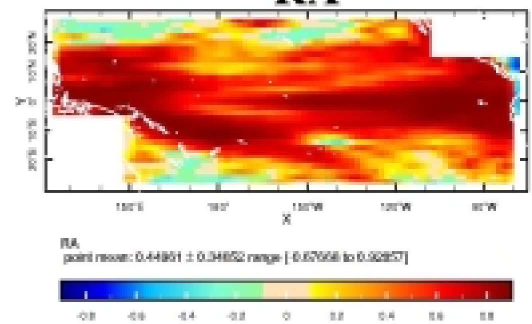


Correlation with TOPEX altimetry
of ocean model sea level height responce to wind products

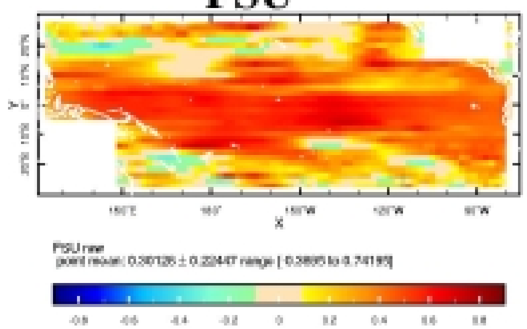
OI



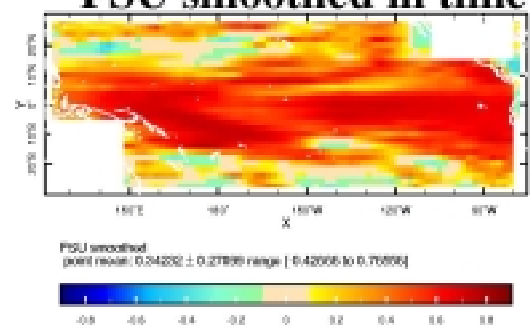
RA



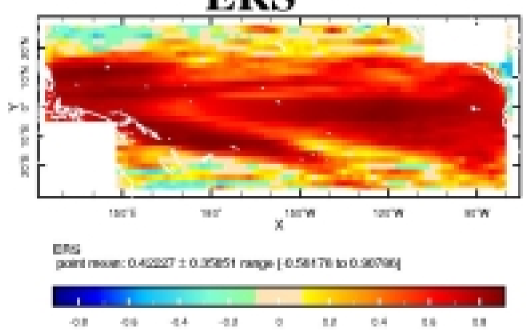
FSU



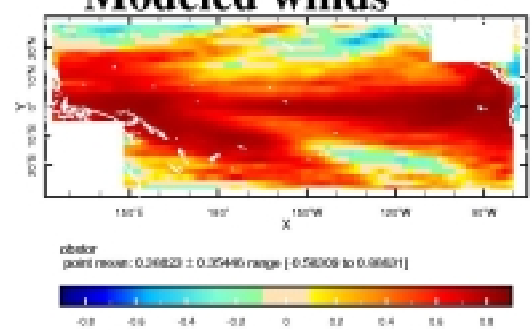
FSU smoothed in time



ERS



Modeled winds

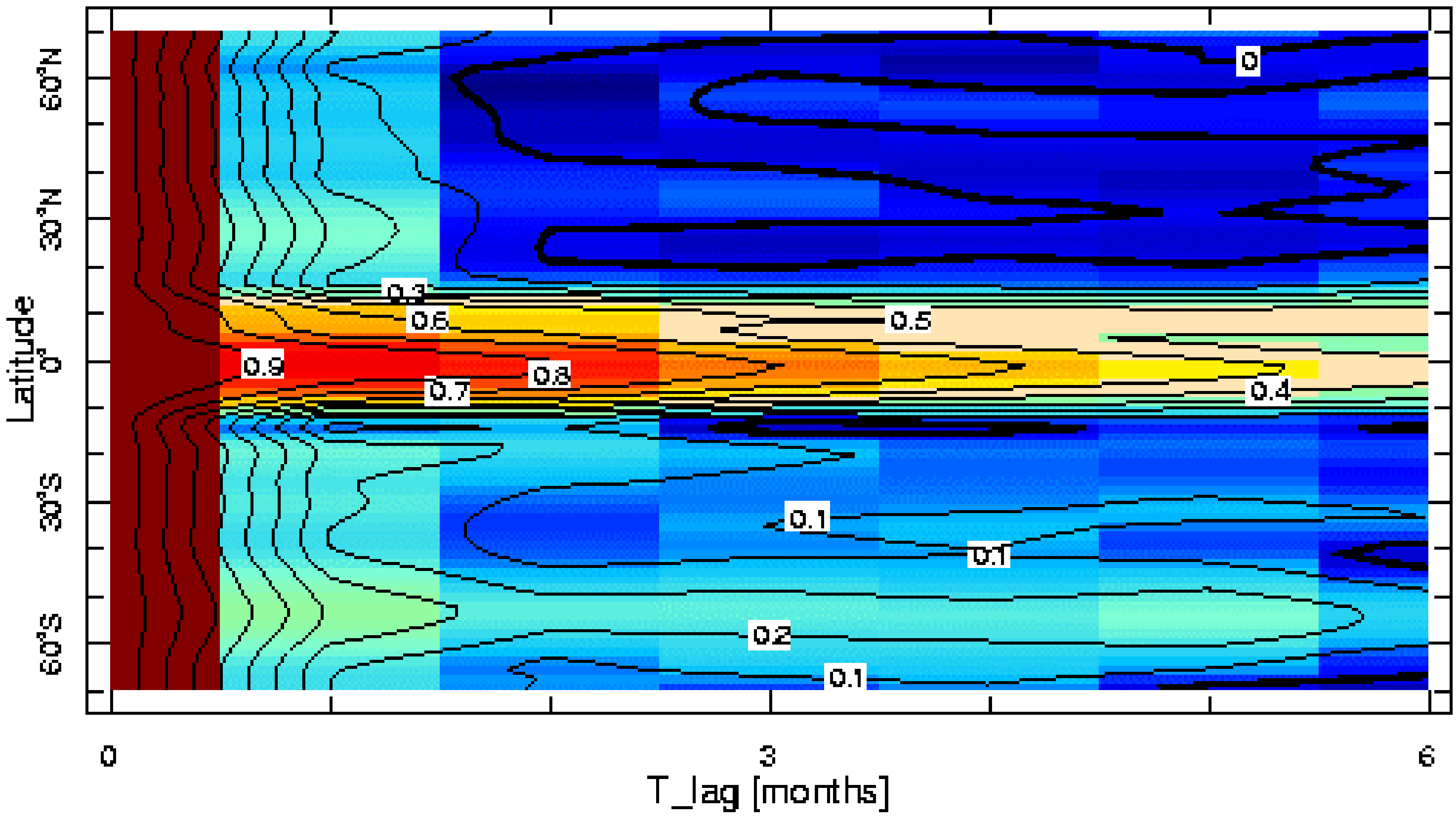


Conclusions

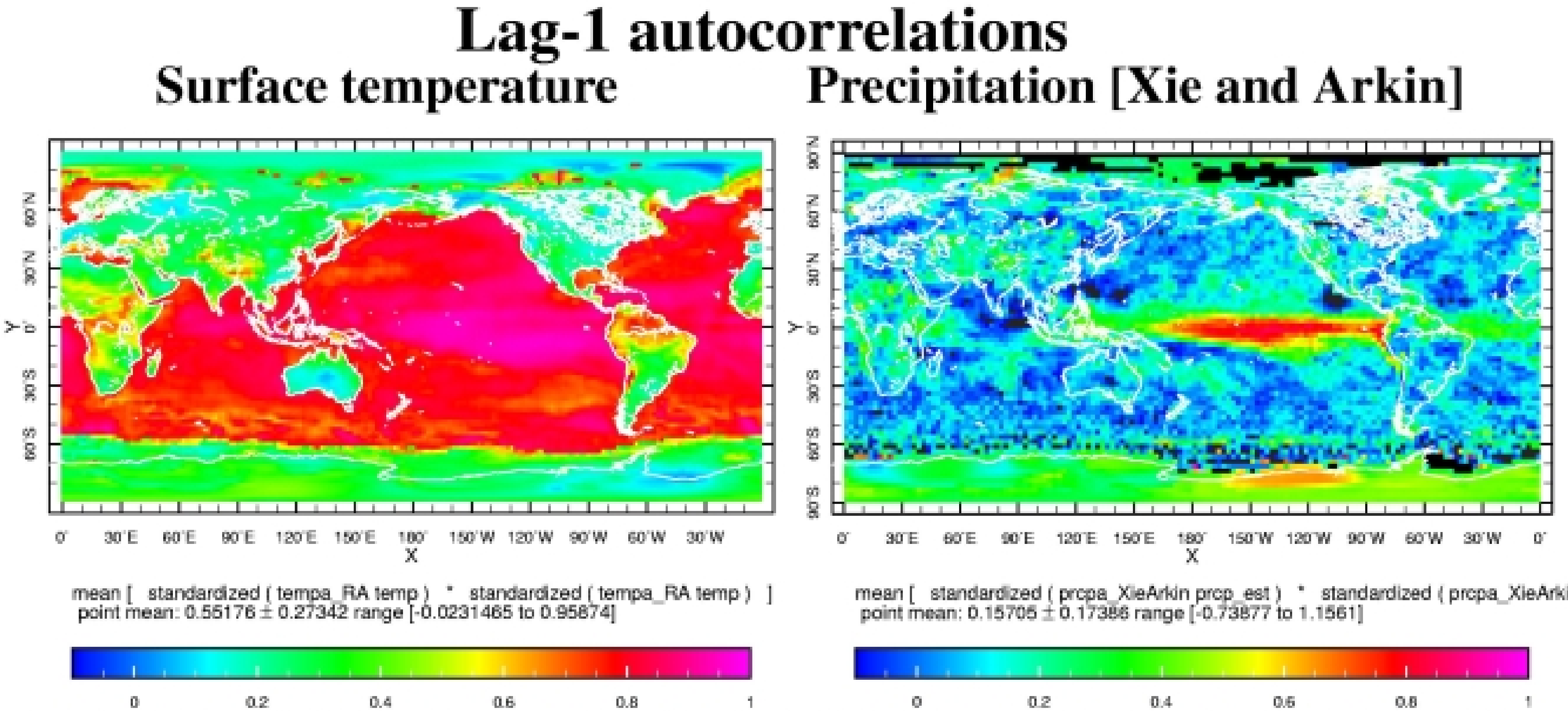
- Univariate analyses are useful but additional constraints are needed.
- Within ~10 degree of Equator there is a persistence of surface wind and pressure anomalies.
- It is driven by the persistence in SST and precipitation (via elevated heating).
- It can be used in historical analyses of instrumental data by either fitting AR model to the wind or pressure data or by including temperature and precipitation in the analysis.
- Wind analyses suitable for driving ocean models must be persistent near Equator.

Persistence with longer lags

Zonal wind in Reanalysis: 160E-120W averages



Persistence of the actual forcings



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