

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

Alexey Kaplan

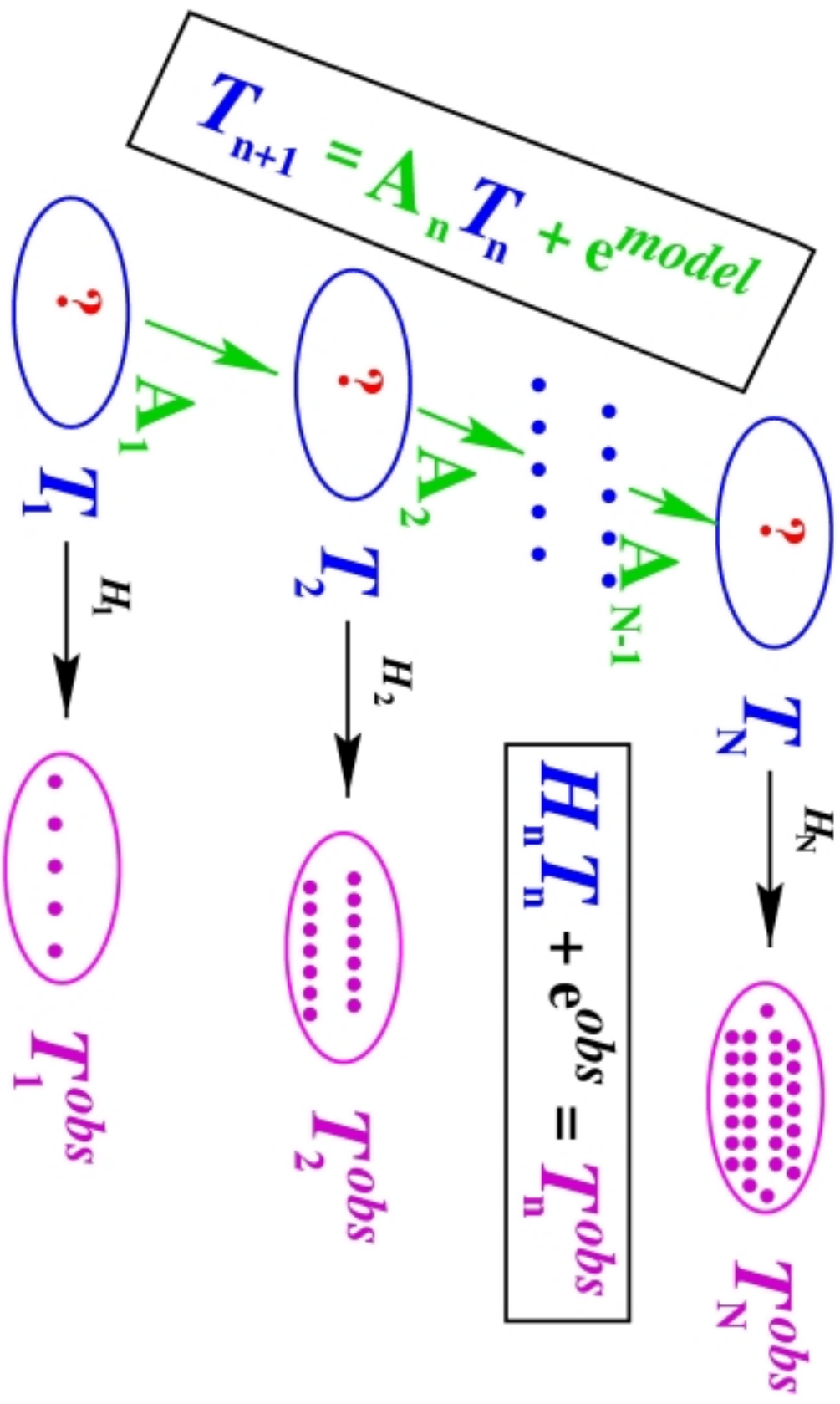
Lamont-Doherty Earth Observatory (LDEO) of Columbia University

In collaboration with : **D.Gombos (Cornell),
J.C.H. Chiang (U of CA, Berkeley),
M.A. Cane, Y.Kushnir, R.Seager, H.-P.Huang (LDEO)**

Outline

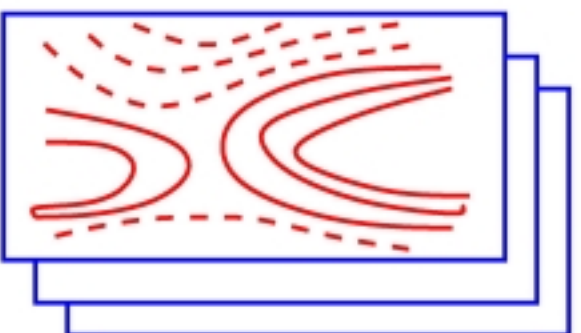
- Univariate analyses of I-COADS and GHCN: successes and challenges
- Additional constraints are crucial: geostrophy or... persistence?
- What drives the surprising persistence of tropical pressure and wind anomalies?
- Ocean modelers love equatorial wind persistence.
- New horizons open to us.

Generic problem of the analysis of time-evolving fields

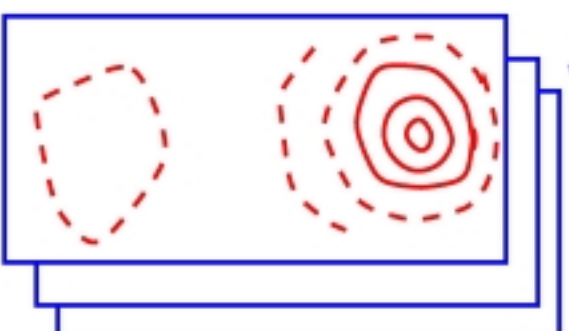


APPROXIMATING COVARIANCE

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



Reduced space
optimal analysis



Successive corrections;
Kriging

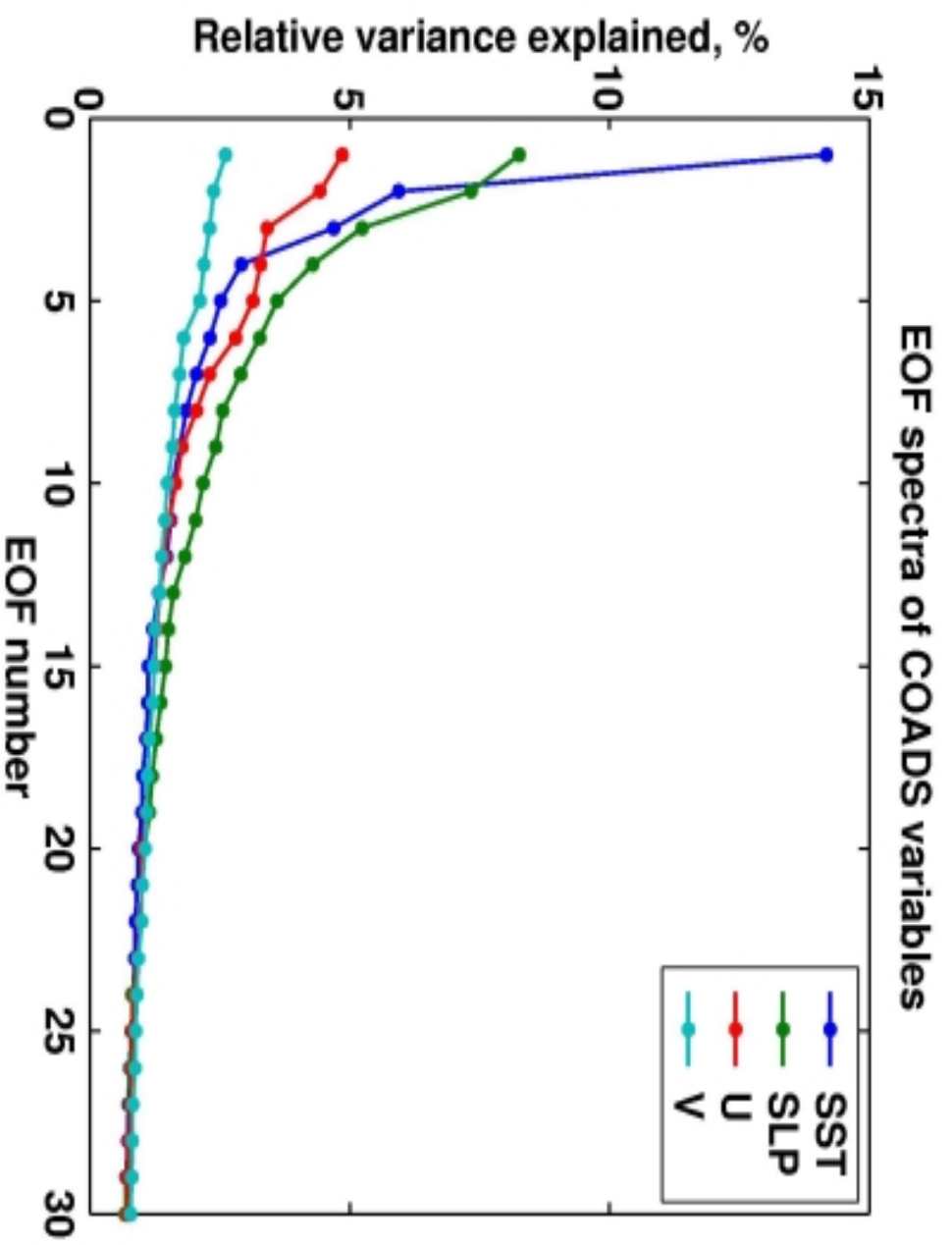


Figure 1: Eigenvalue spectra of climate variables from COADS, 1950-2000

EOFs of zonal wind anomaly

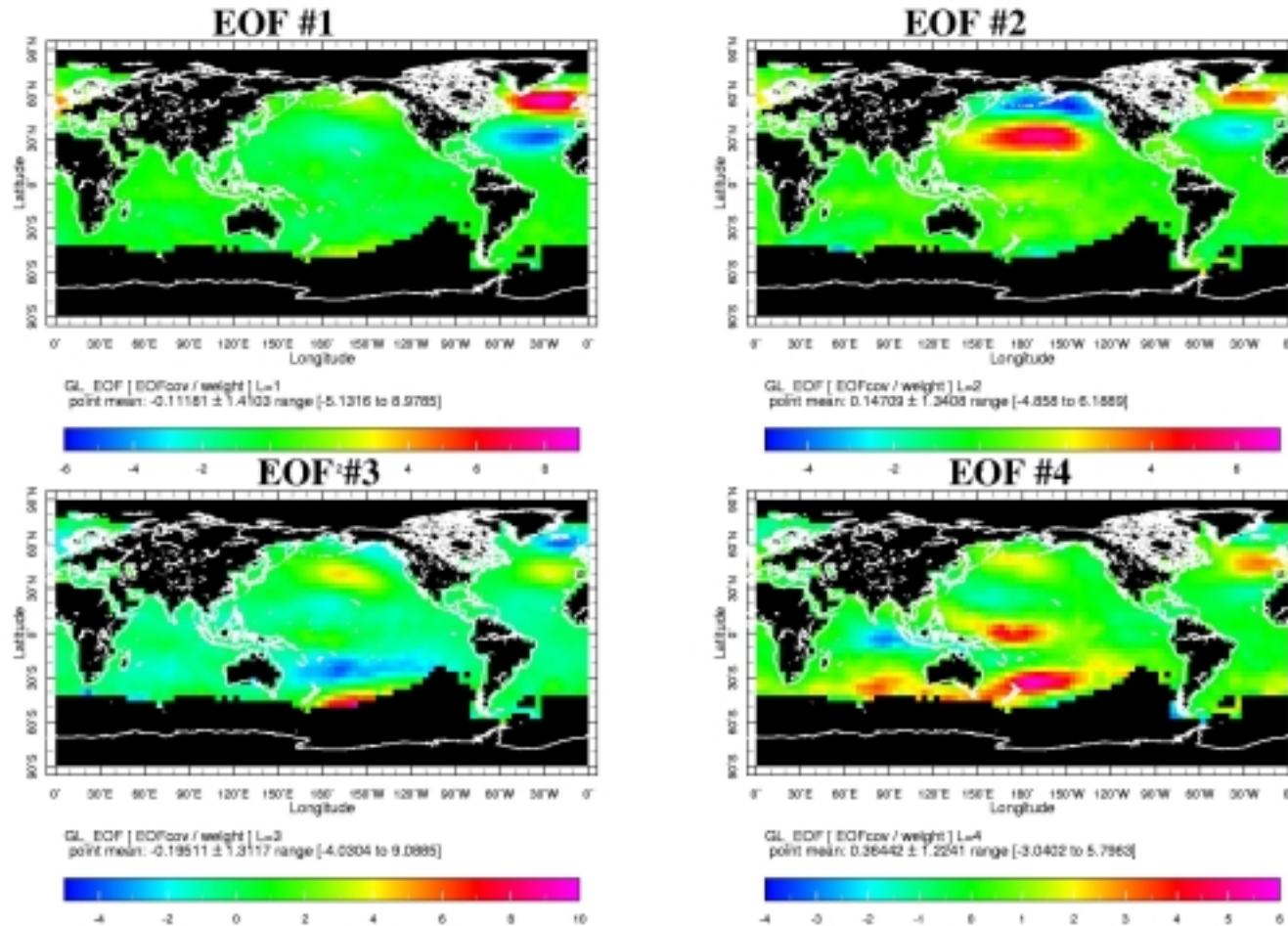
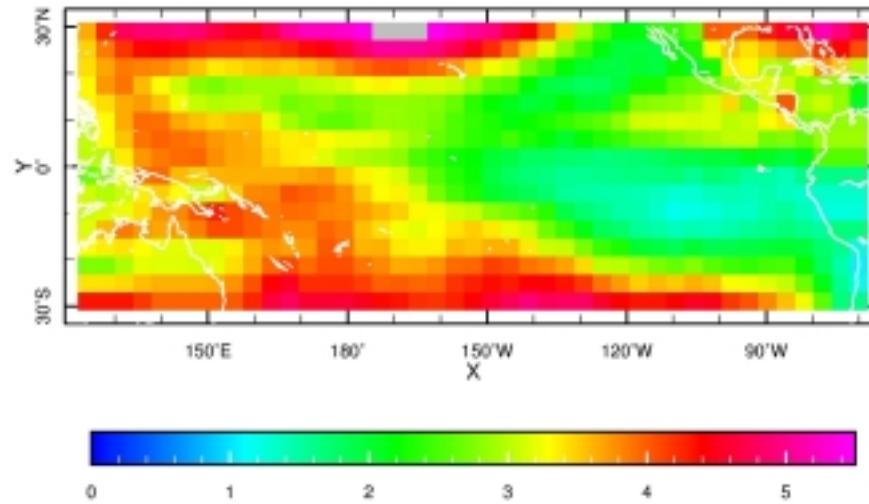


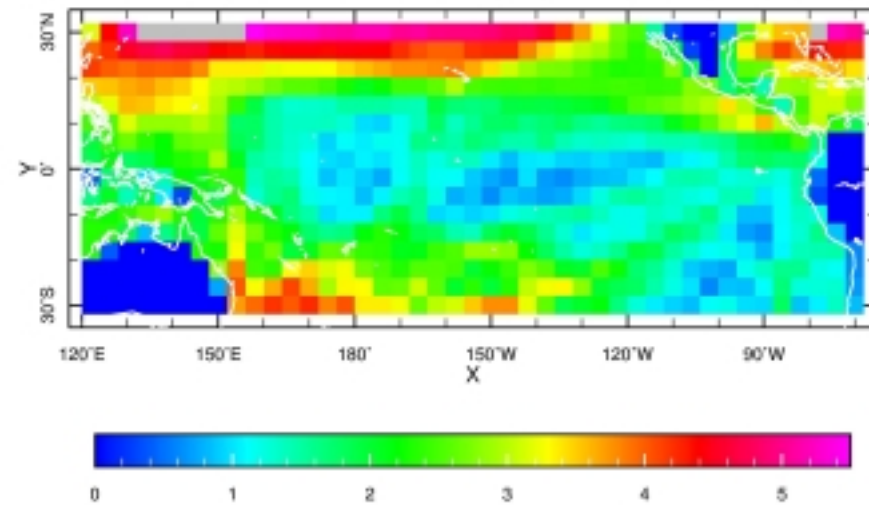
Figure 2: Leading EOF patterns of zonal wind anomalies from COADS, 1950-2000

Small-scale variability in zonal wind $\sigma_{4^{\circ} \times 4^{\circ} \times 1 \text{ month}}$, m/s

NSCAT



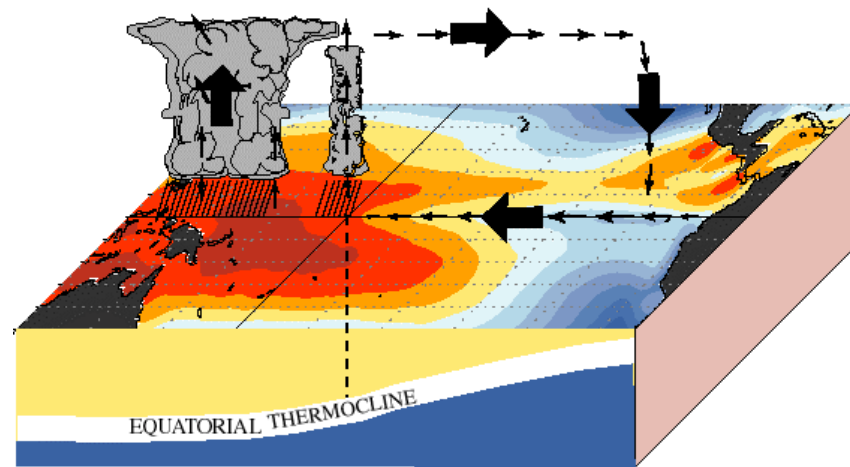
COADS



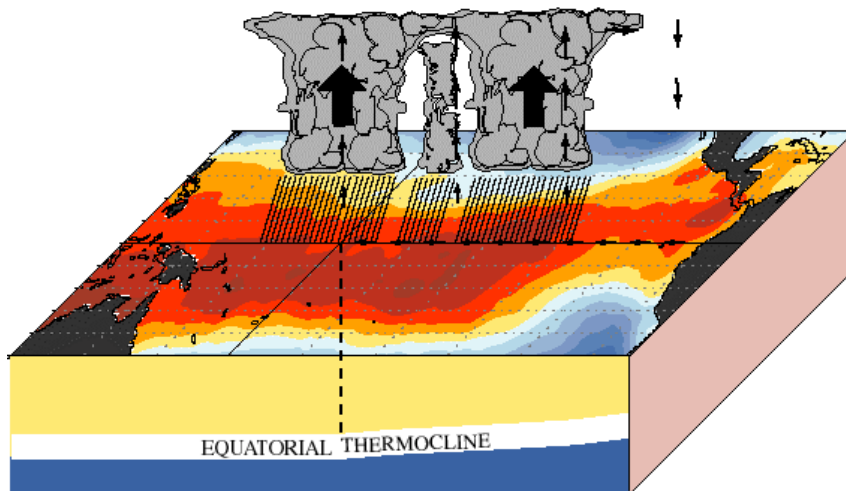
16/1/2004

Dynamics of El Niño – Southern Oscillation

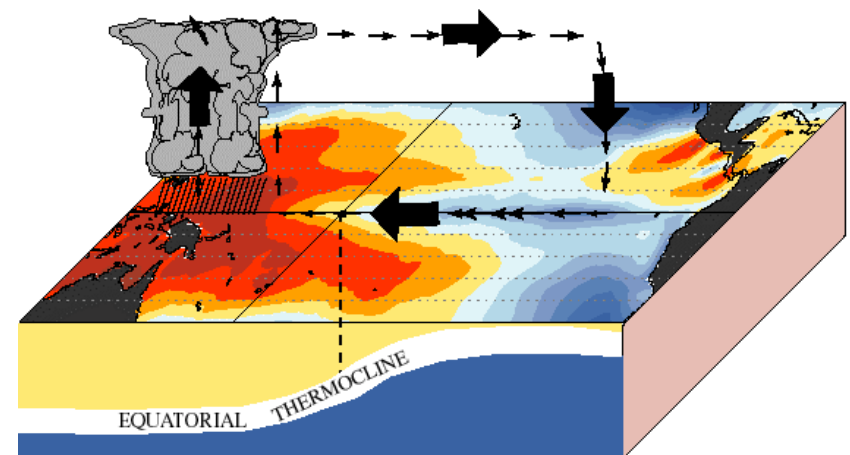
December - February Normal Conditions



December - February El Niño Conditions



December - February La Niña Conditions



El Niño of 1877-1878 in analyzed anomalies

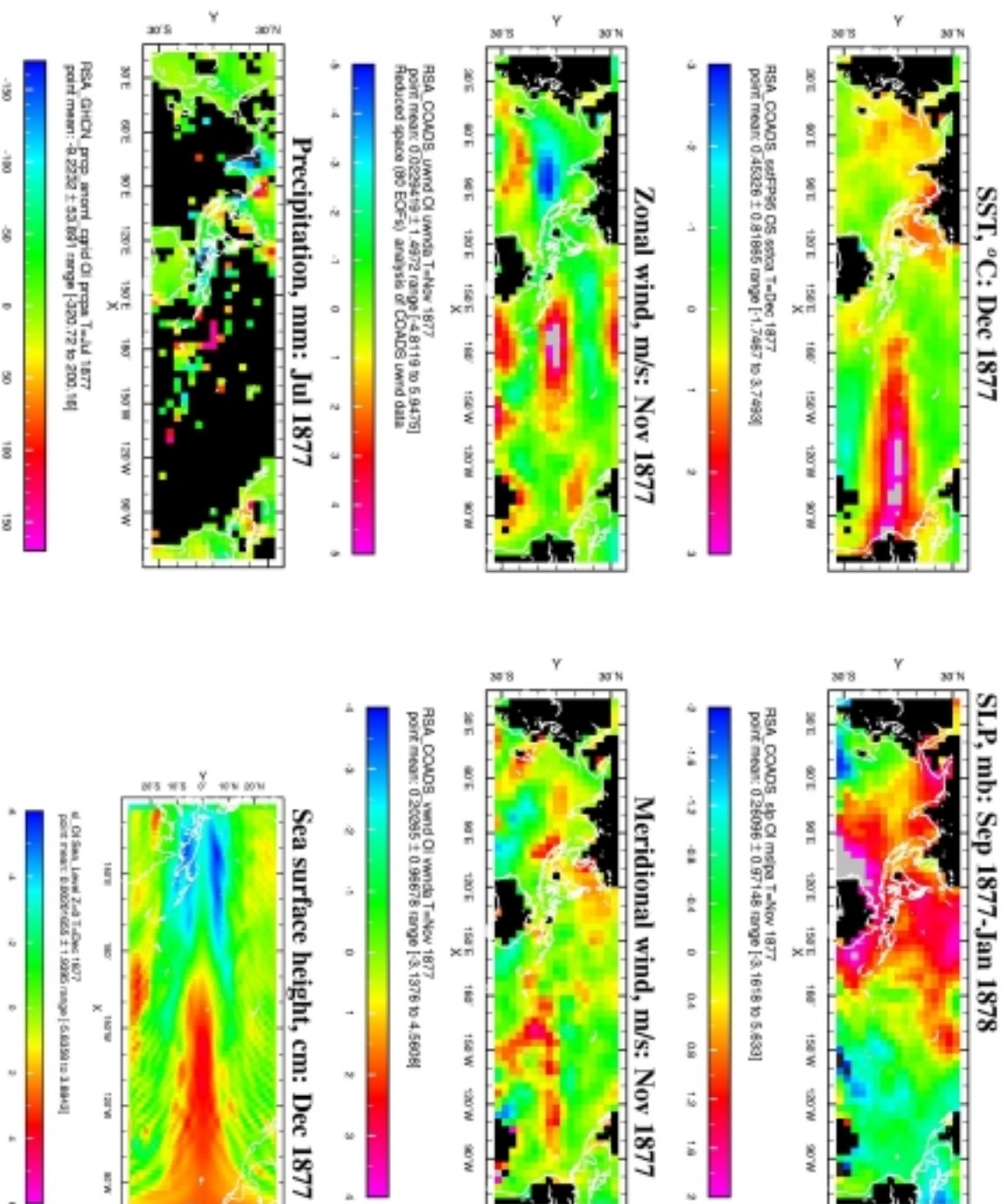


Figure 4: Anomalies of 1877-1878 El Niño illustrated by univariate reduced analyses by Kaplan *et al.* [2001b]

Independent ENSO indices

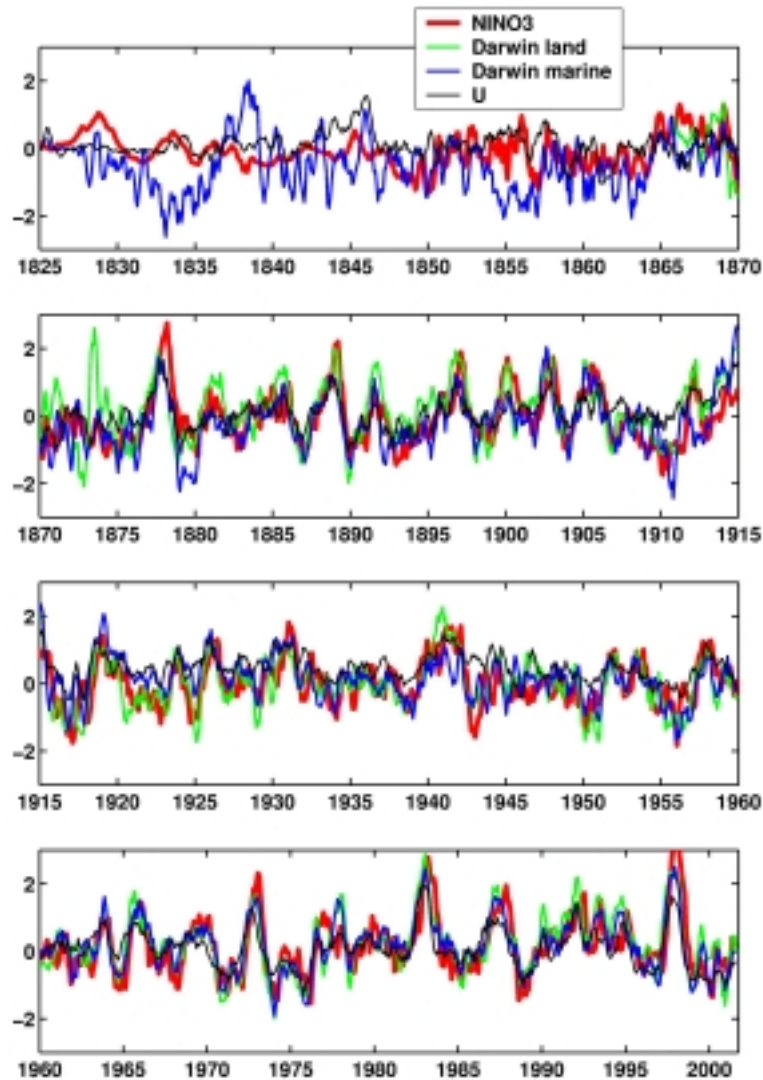
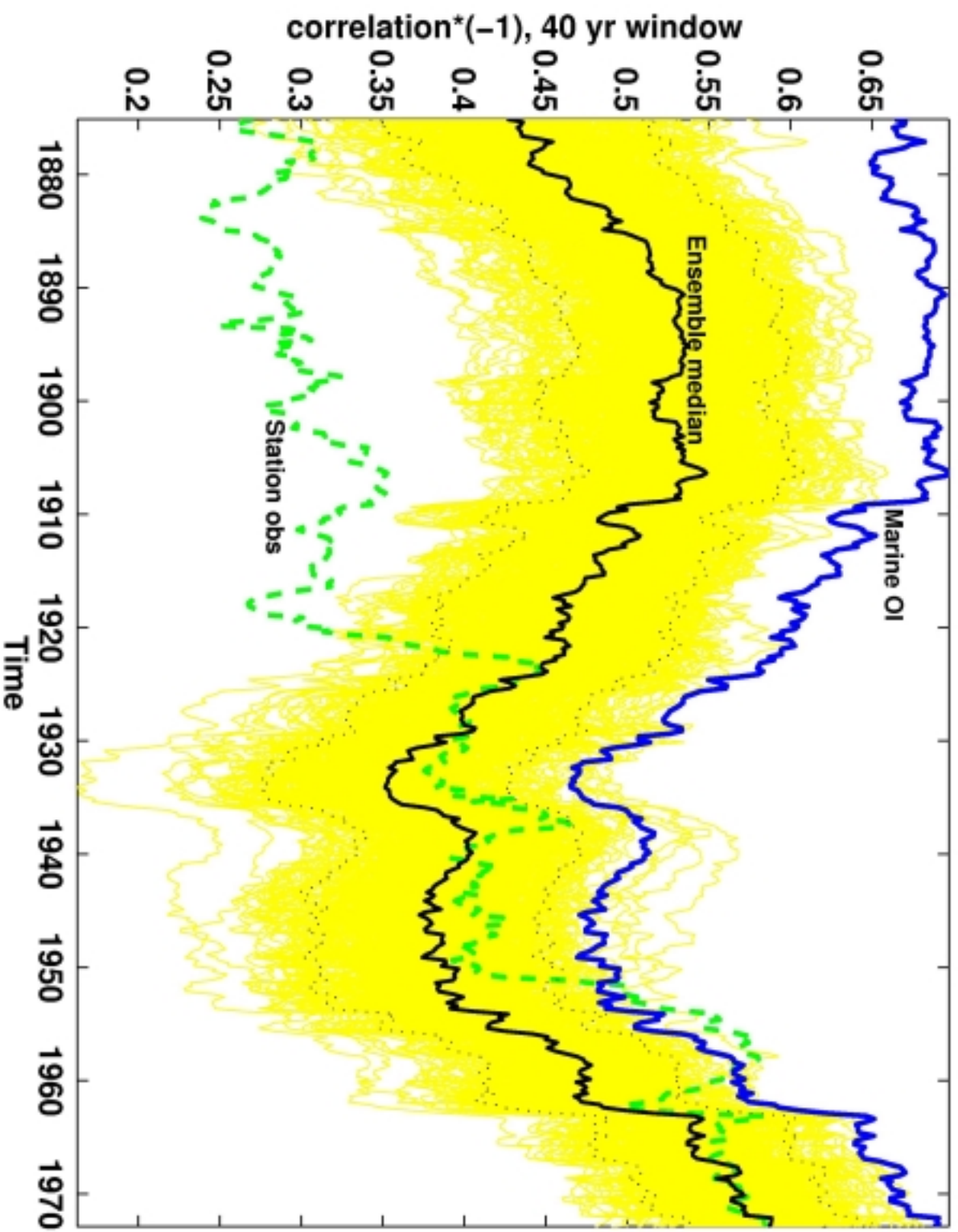


Figure 3: Intercomparison of ENSO indices: NINO3, °C, by Kaplan *et al.* [1998]; Darwin station SLP, mb, [Allan *et al.*, 1991; Rasmus *et al.*, 1998]; Darwin area SLP estimate from ship-based RSOL, mb, [Kaplan *et al.*, 2000]; and Central Equatorial Pacific zonal wind anomaly (3°N-5°S, 160°E-120°W),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

Correlations between Darwin and Tahiti seasonal atmospheric pressure



When data are sparse, additional constraints are absolutely necessary

Testing geostrophic constraint

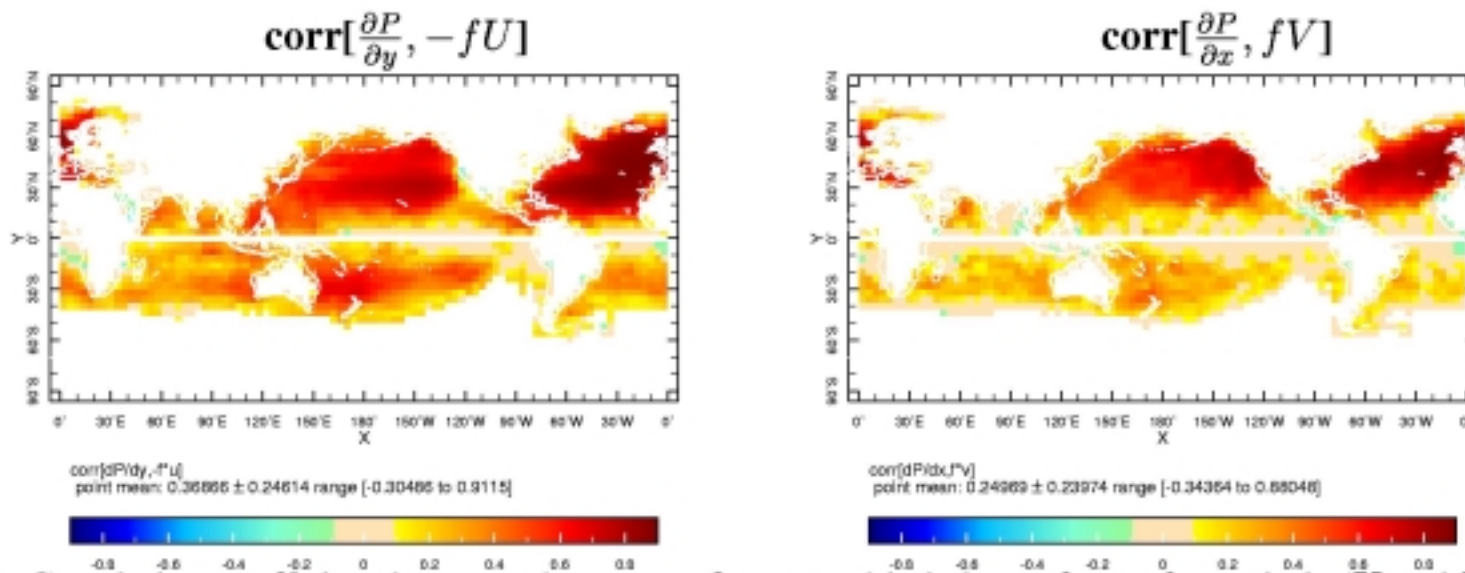


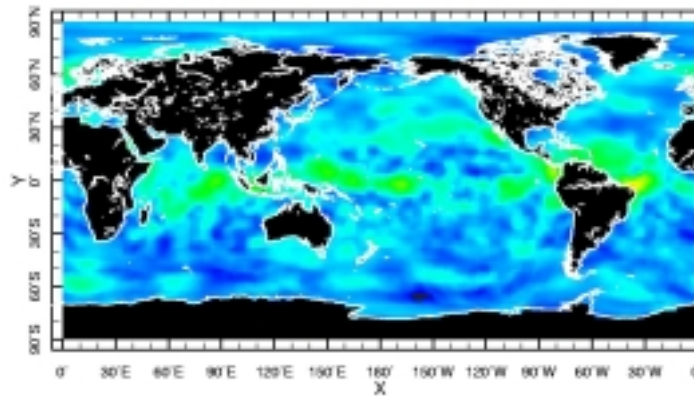
Figure 5: Correlation coefficient between the terms of geostrophic balance for surface winds (U and V) and sea level pressure P . Data comes from the univariate RS OI analyses of COADS data [Kaplan *et al.*, 2001]. Correlation coefficients are computed for all months from 1900 to 2000.

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

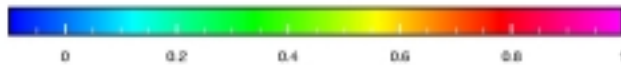
**Data sets used below: Da Silva's successive-correction analyses of COADS data
NCEP-NCAR Reanalysis; WOCE surface winds derived from the ERS
Scatterometry; FSU subjective analysis of the tropical Pacific winds;
Xie and Arkin precipitation analysis.**

Persistence: Anomaly autocorrelations with 1 month lag

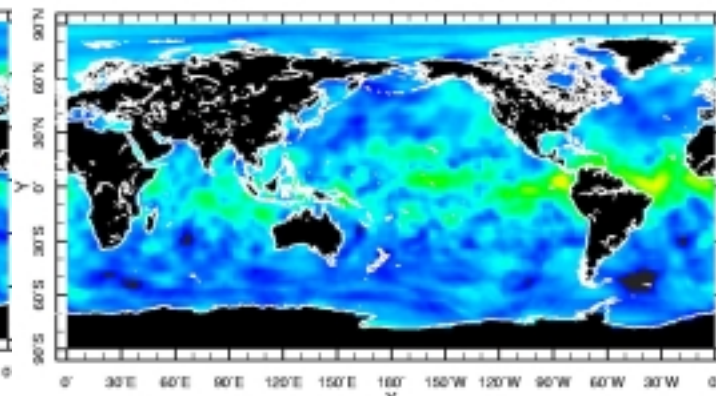
Da Silva U



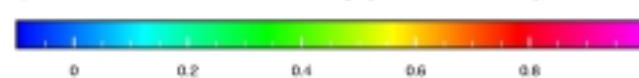
mean [standardized (l1dsua u) * standardized (l1dsua u)]
point mean: 0.0801162 ± 0.0758377 range [-0.14909 to 0.58812]



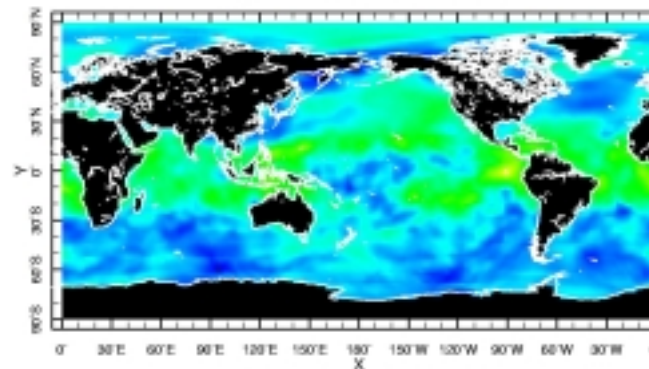
Da Silva V



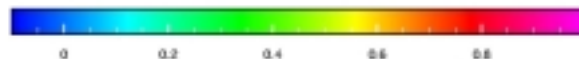
mean [standardized (va_DS v3) * standardized (va_DS v3)]
point mean: 0.0565146 ± 0.0883734 range [-0.18869 to 0.57947]



Da Silva SLP



mean [standardized (slpa_DS slp) * standardized (slpa_DS slp)]
point mean: 0.13049 ± 0.10263 range [-0.12302 to 0.55196]



Persistence: Anomaly autocorrelations with 1 month lag

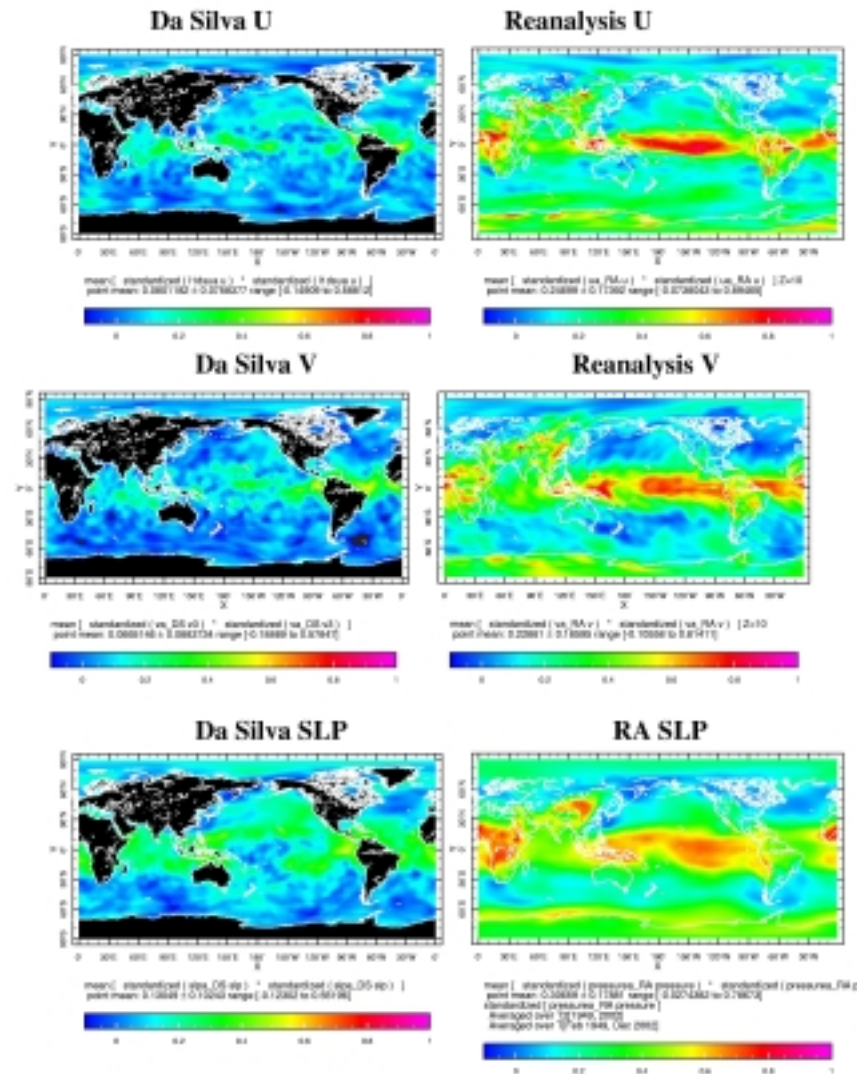
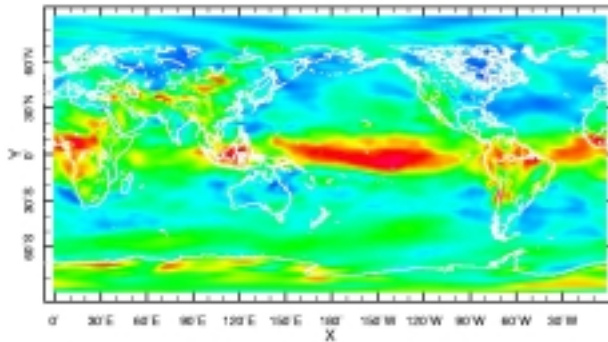


Figure 6: One month autocorrelation of monthly wind anomalies Da Silva et al [1994] and NCEP-NCAR reanalysis data sets

Verification by satellite data

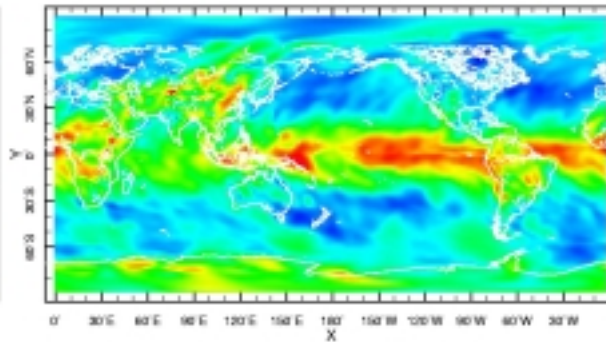
Reanalysis U



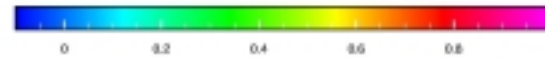
mean [standardized (ua_RA u) * standardized (ua_RA u)] Z=10
point mean: 0.24699 ± 0.17362 range [-0.0758043 to 0.89495]



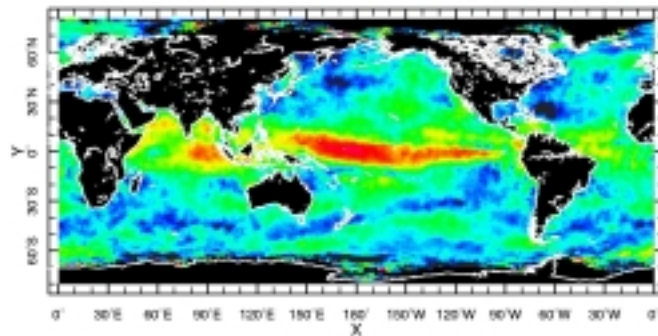
Reanalysis V



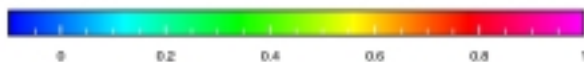
mean [standardized (va_RA v) * standardized (va_RA v)] Z=10
point mean: 0.22661 ± 0.18995 range [-0.10556 to 0.81411]



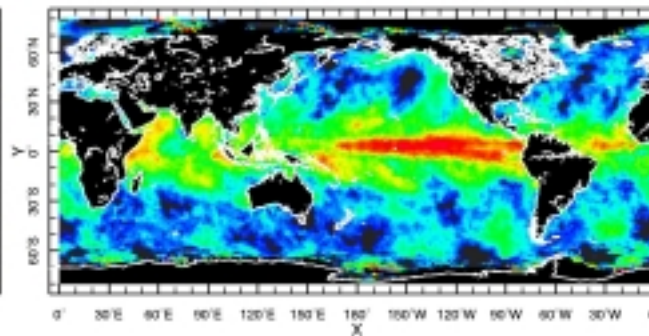
ERS U



mean [standardized (ers12_va u) * standardized (ers12_va u)]
point mean: 0.18349 ± 0.21465 range [-2.4082 to 3.2552]



ERS V



mean [standardized (ers12_va v) * standardized (ers12_va v)]
point mean: 0.16296 ± 0.24263 range [-2.4018 to 2.5866]



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

Lag-1 autocorrelations

Surface temperature Precipitation [Xie and Arkin]

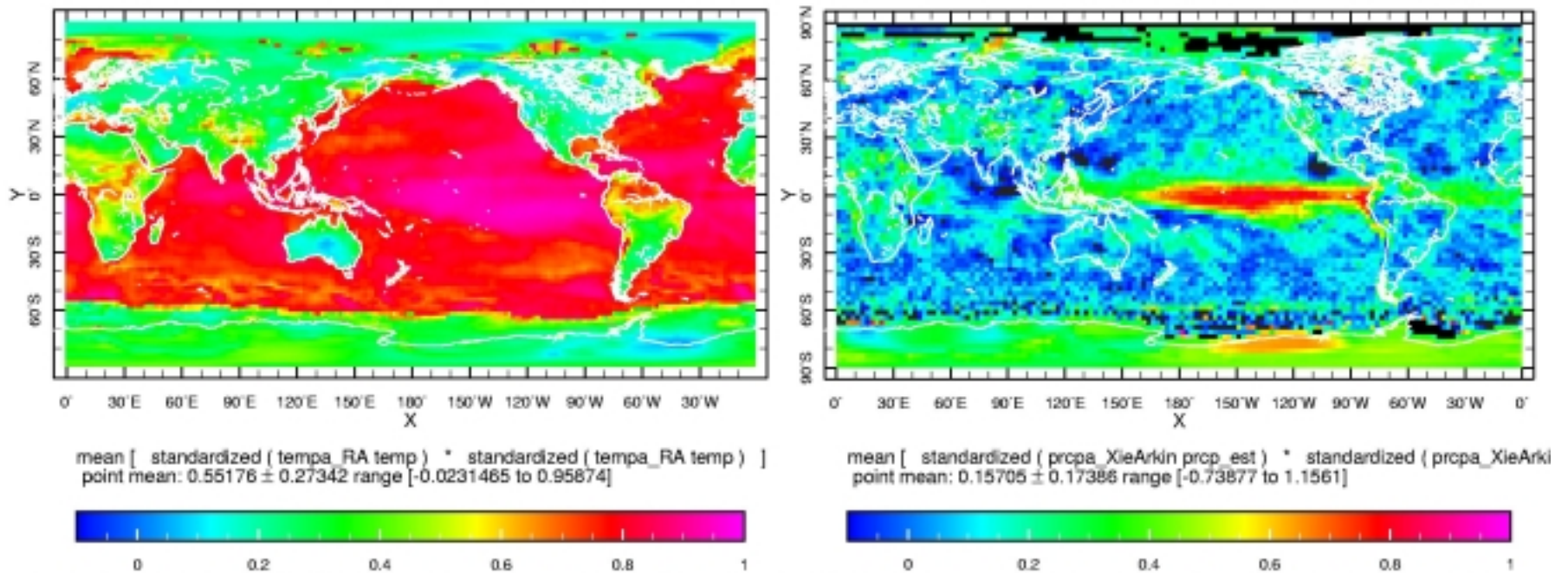


Figure 8: One month lagged autocorrelations of interannual monthly anomalies for RA surface temperature and for *Xie and Arkin* [1986] precipitation

Simulation skill

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

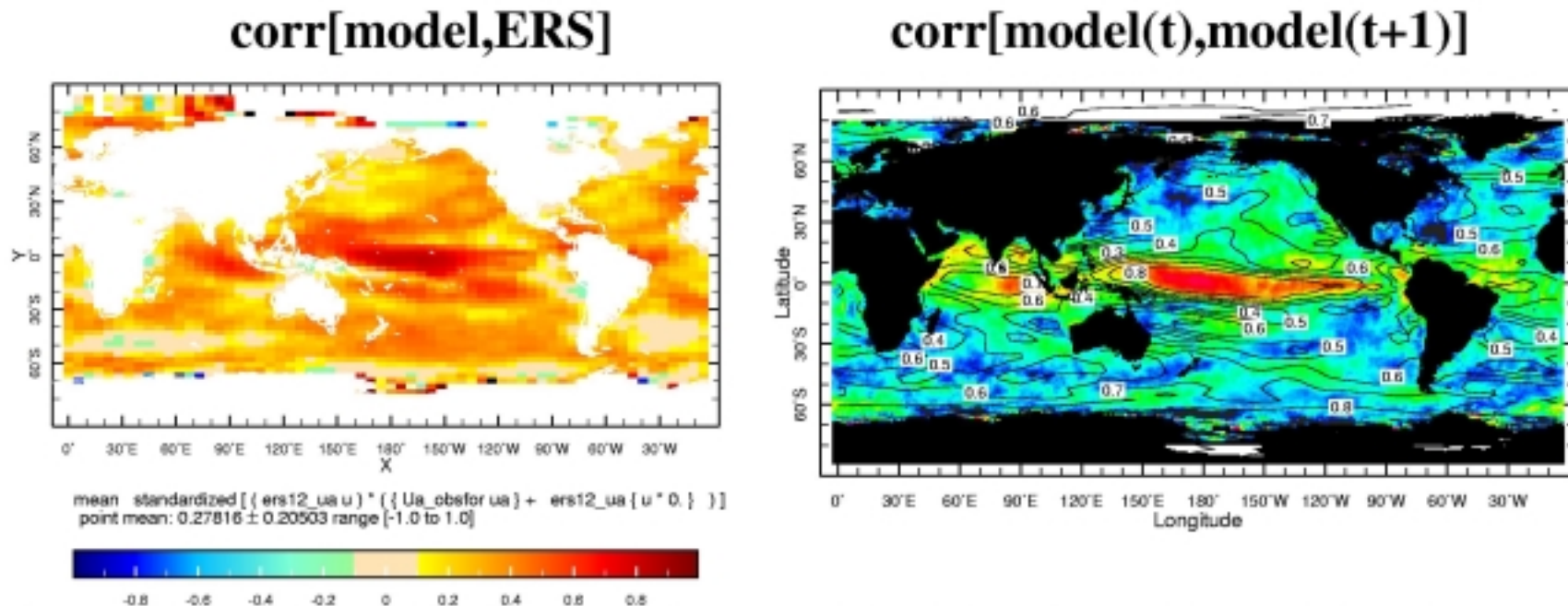
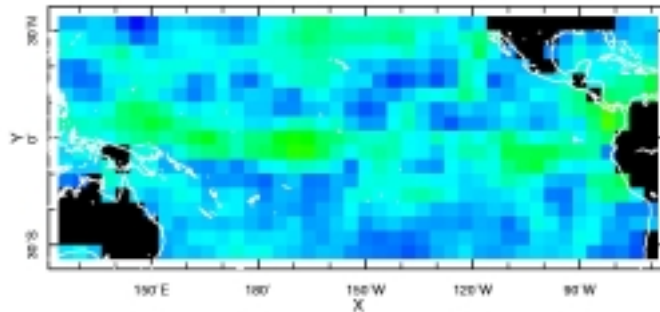


Figure 9: Use of *Chiang et al.* [2001] model to reproduce wind persistence. Zonal wind response of the model forced by observed SST and precipitation shows good correlation with ERS scatterometry in the tropics (left panel). Autocorrelations of model winds with 1 month lag (contours in the right panel), 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?

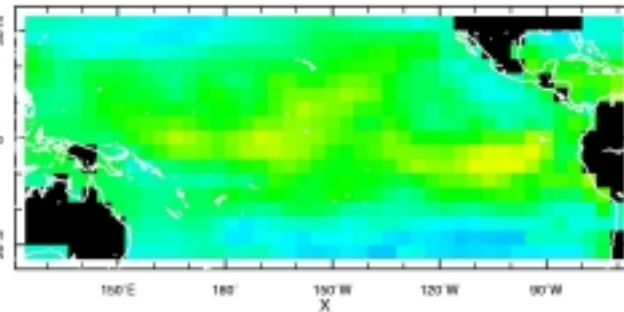
Anomaly autocorrelations, 1 month lag



τ_1 lag-1 autocorrelation for Da Silva
point mean: 0.11302 ± 0.0734073 range [-0.0896335 to 0.40176]
Time period: 1961-1993



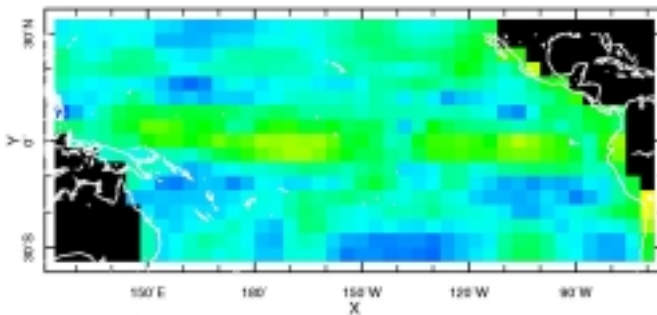
FSU



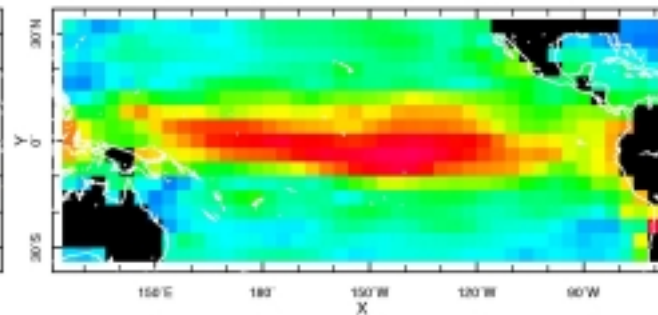
τ_1 lag-1 autocorrelation for our OI
point mean: 0.27002 ± 0.10796 range [0.0751456 to 0.54348]
Time period: 1961-1993



Reanalysis



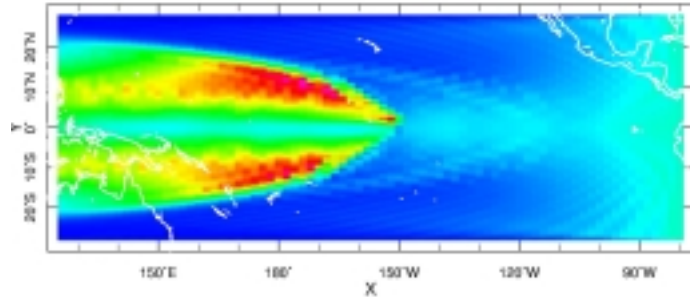
τ_1 lag-1 autocorrelation for FSU
point mean: 0.18477 ± 0.10402 range [-0.0215749 to 0.55858]
Time period: 1961-1993



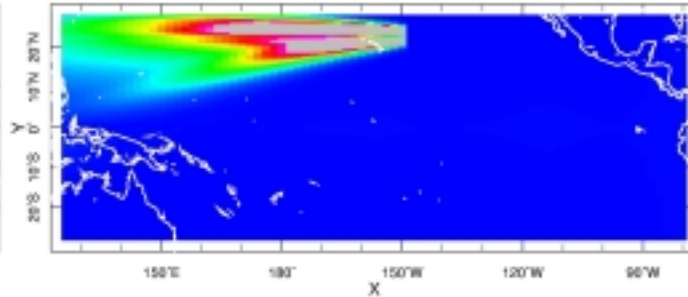
τ_1 lag-1 autocorrelation for RA Z=10
point mean: 0.33054 ± 0.21696 range [0.00504754 to 0.85654]
Time period: 1961-1993



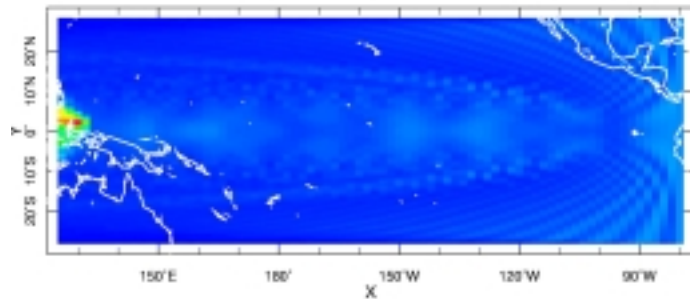
RMS of sea level response to the wind noise in a single location



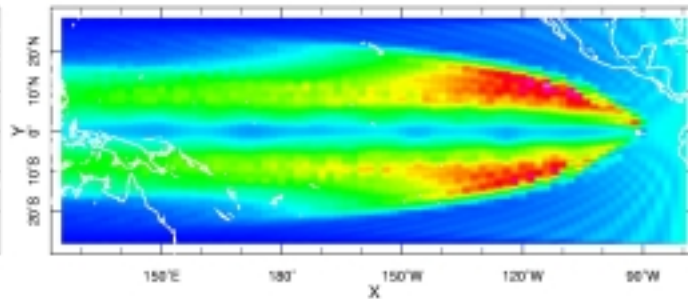
simstfl sims Z=0
point mean: 0.00224041 ± 0.00201079 range [4.05545×10⁻⁵ to 0.00994284]



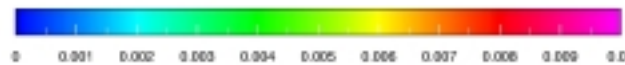
simstfl sims Z=0
point mean: 0.00103701 ± 0.00363671 range [2.00903×10⁻⁷ to 0.047464]



simstfl sims Z=0
point mean: 0.000531426 ± 0.00043452 range [2.35884×10⁻⁵ to 0.00899953]

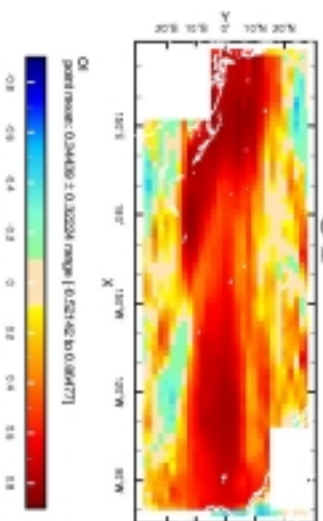


simstfl sims Z=0
point mean: 0.00266023 ± 0.00199111 range [4.56169×10⁻⁵ to 0.0100805]

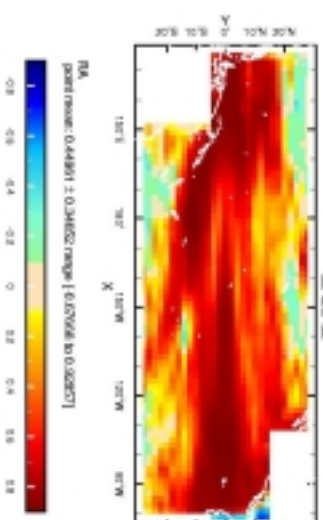


Correlation with TOPEX altimetry of ocean model sea level height response to wind products

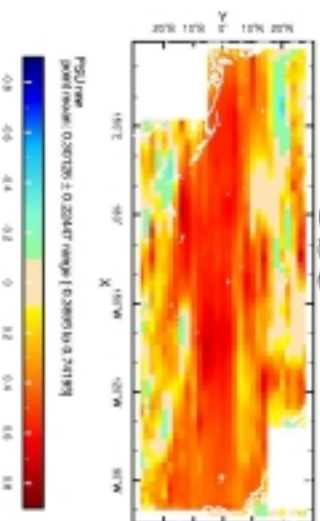
OI



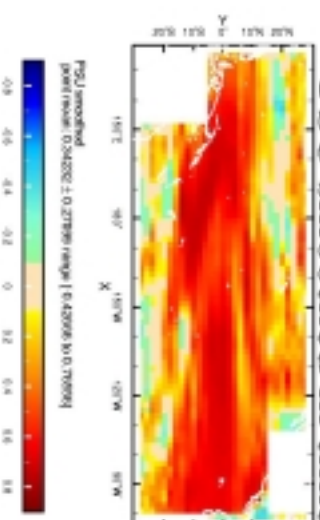
RA



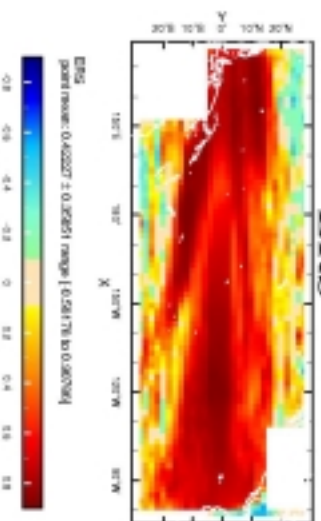
FSU



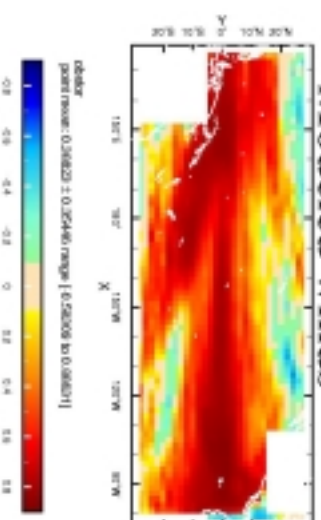
FSU smoothed in time



ERS



Modeled winds

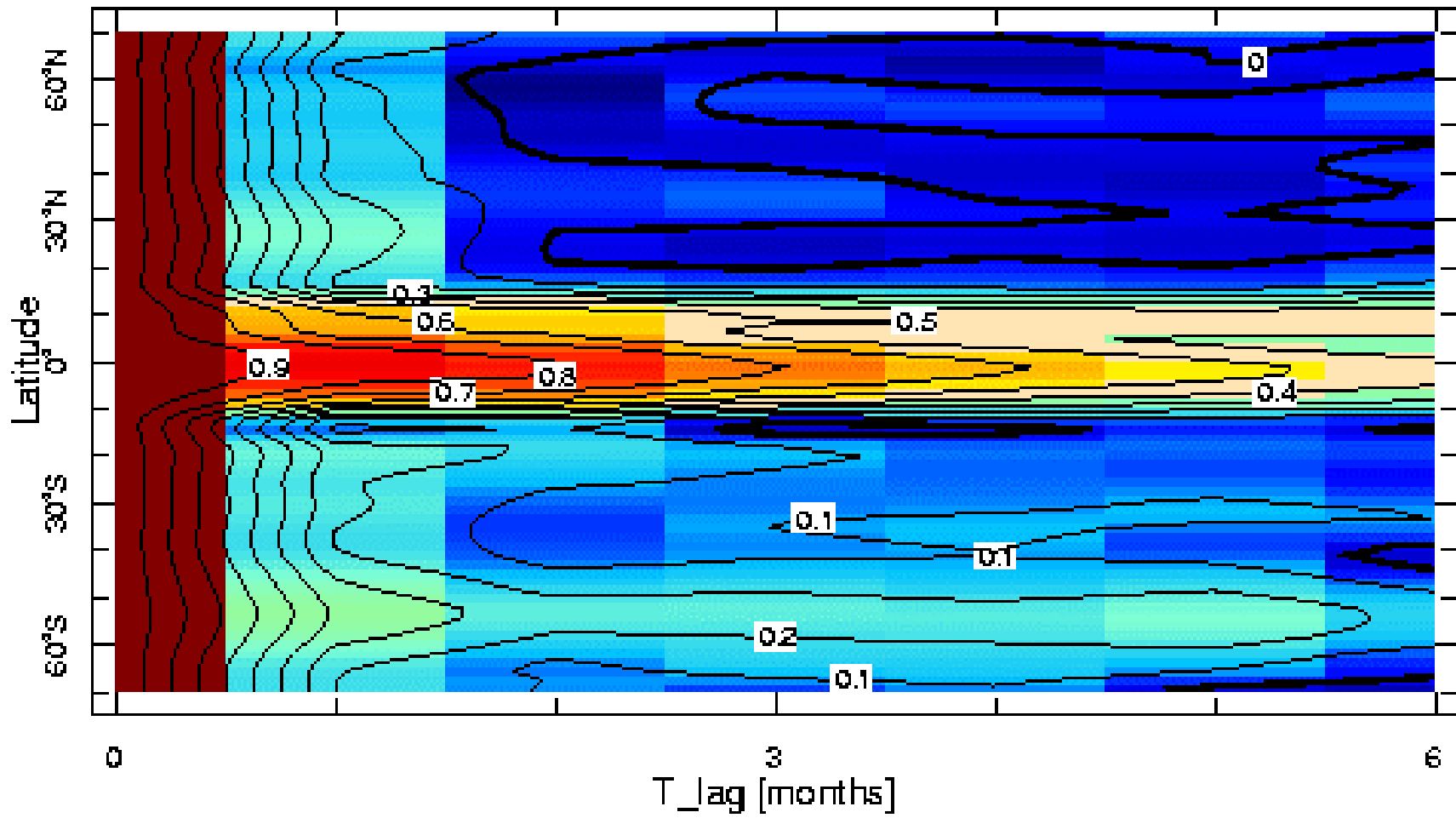


Conclusions

- 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

Lag-1 autocorrelations Surface temperature Precipitation [Xie and Arkin]

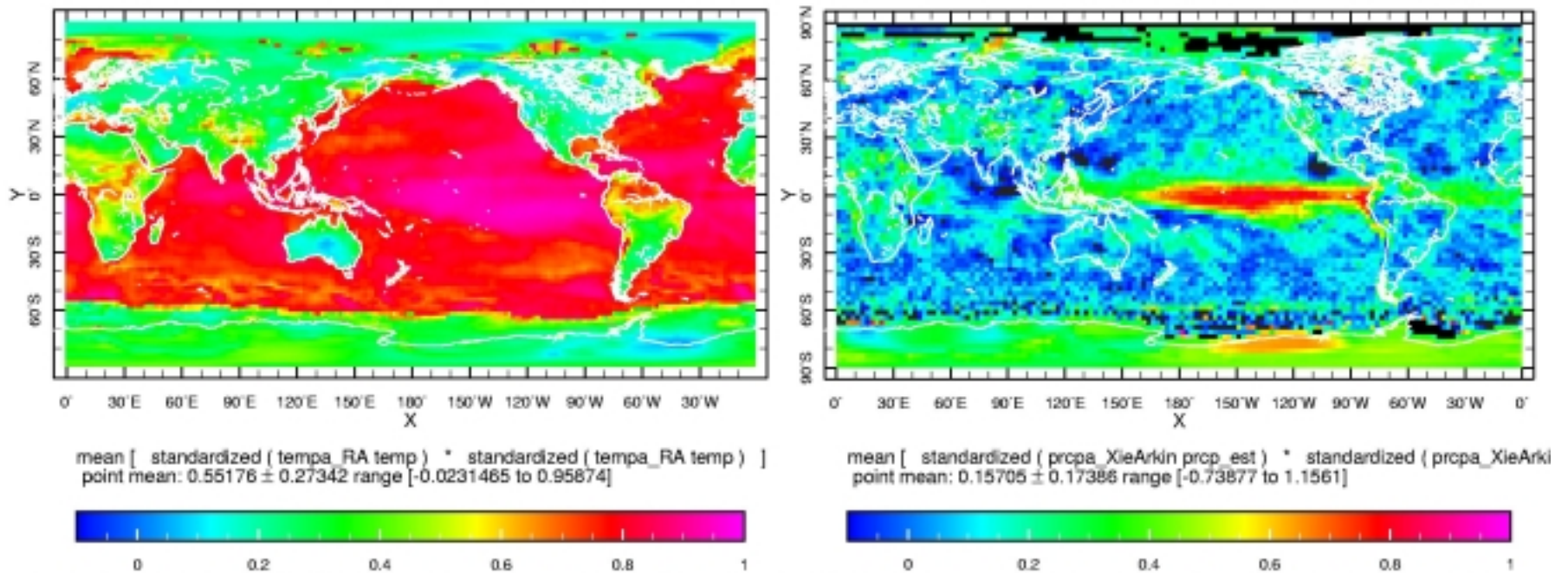


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