Small-scale and short-term variability of ocean surface winds: Applications to objective analyses and ocean modeling

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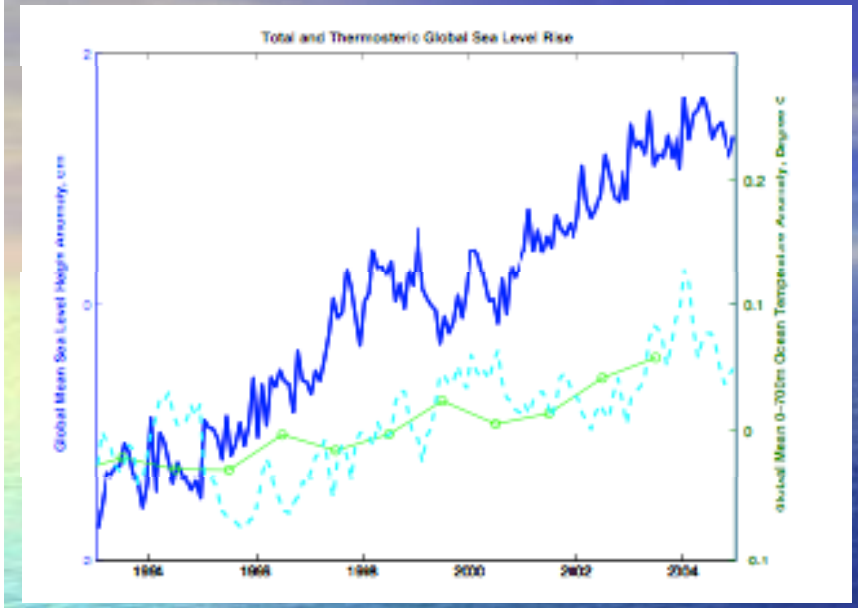
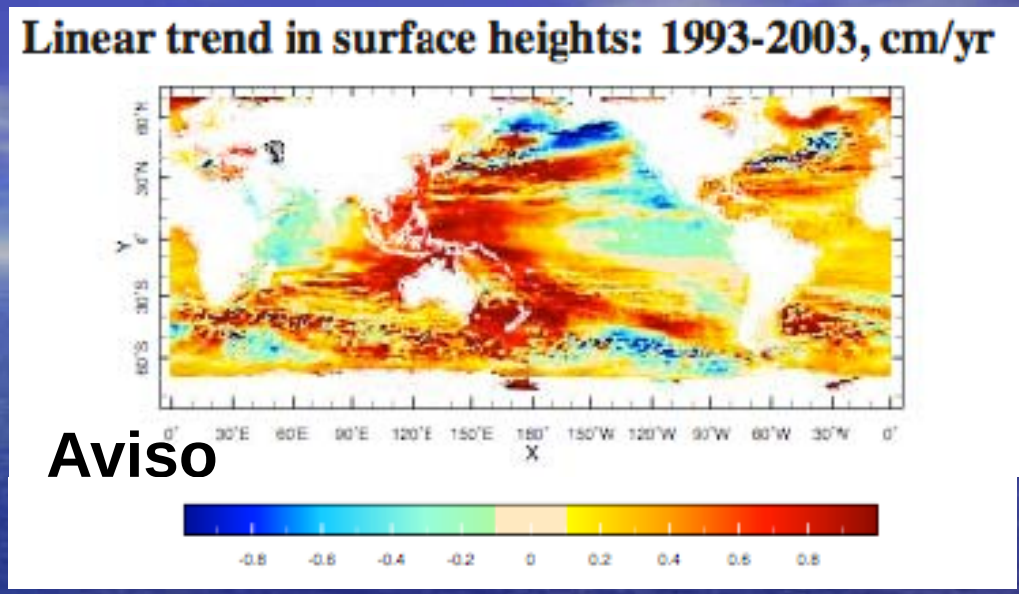
H.-P.Huang (ASU)

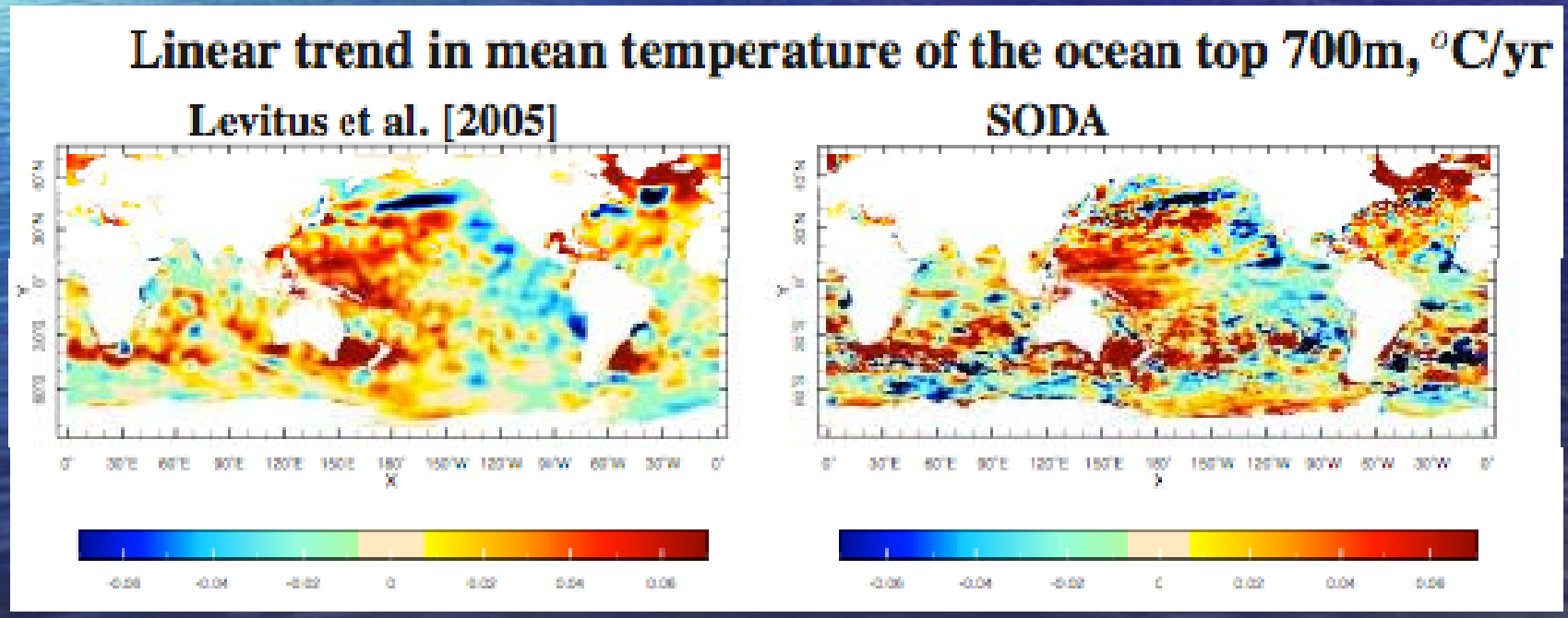
Importance of high-quality continuous wind products:

1. Major influence of wind forcing on the patterns of decadal-bidecadal sea level trends

Global vs Regional Sea Level Rise



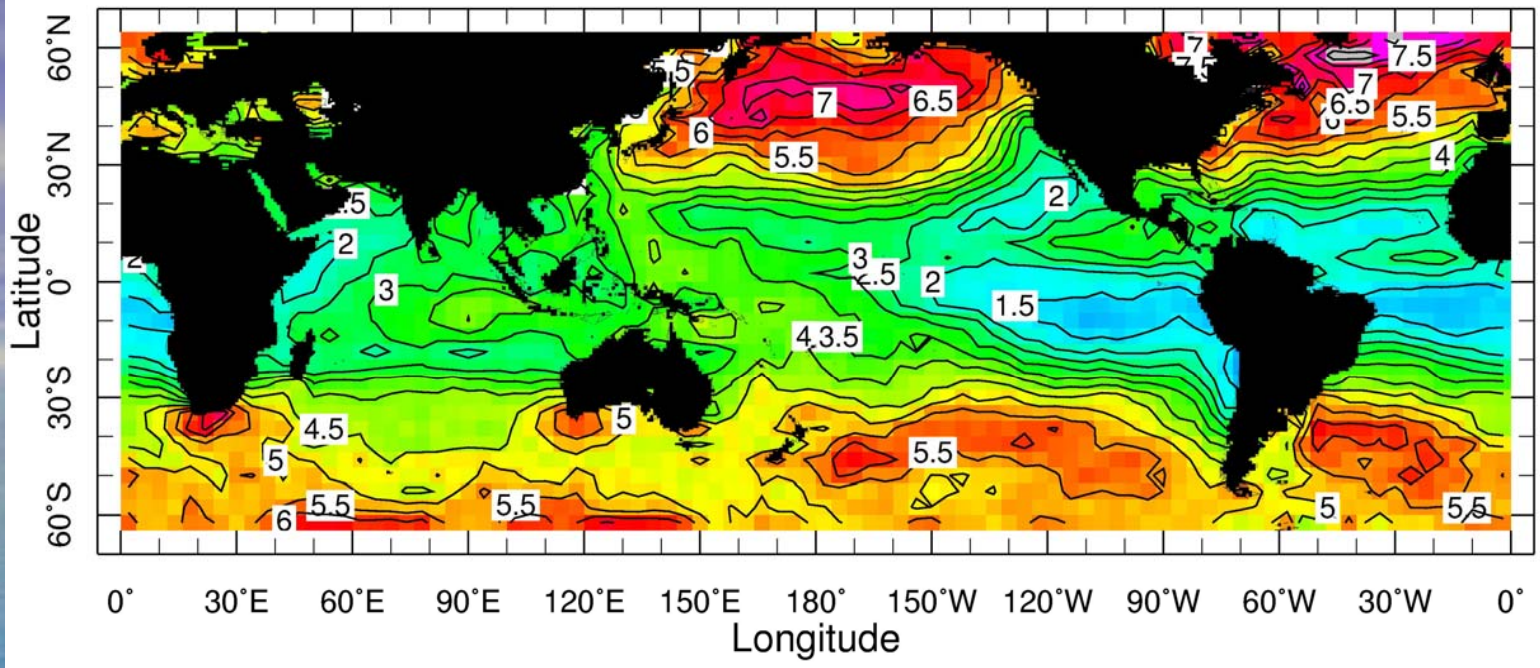




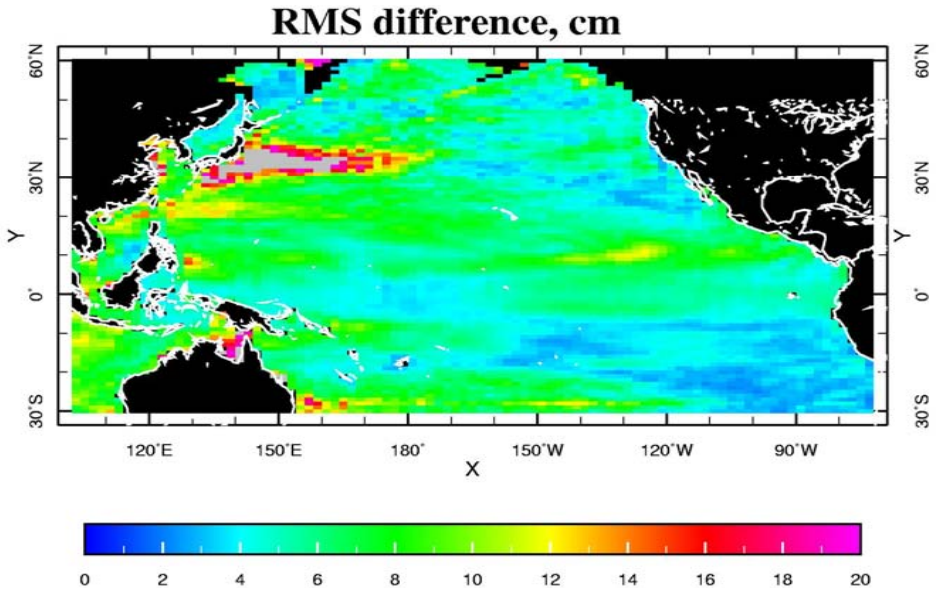
Importance of high-quality continuous wind products:

2. Ocean model responses to errors in winds

Zonal wind Variability Inside 4degx4deg x1mon bins (NSCAT)

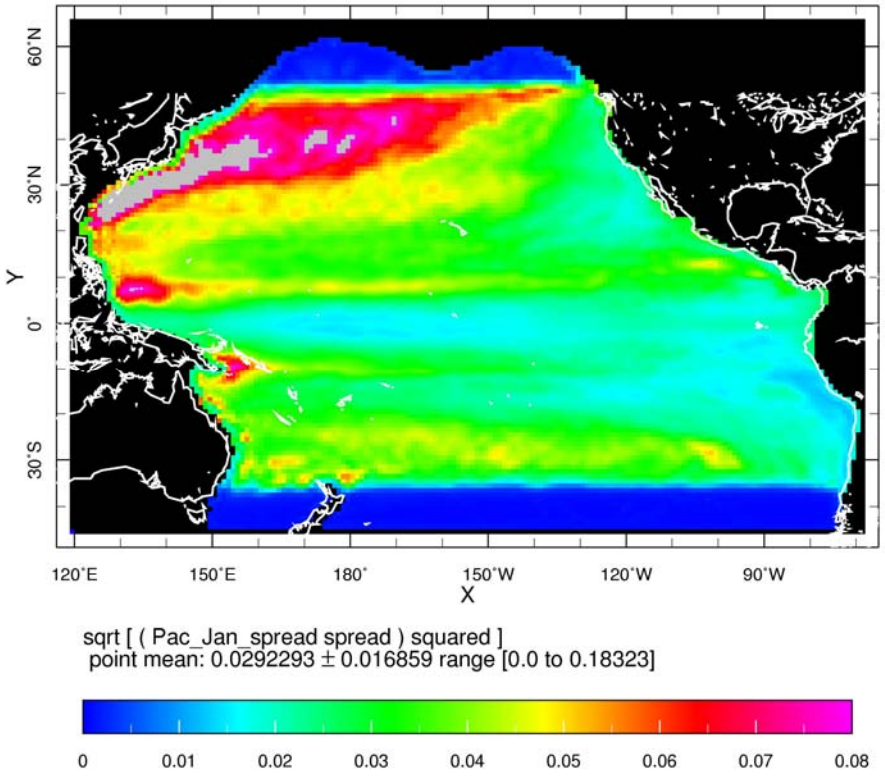


Comparison of sea level height deviation

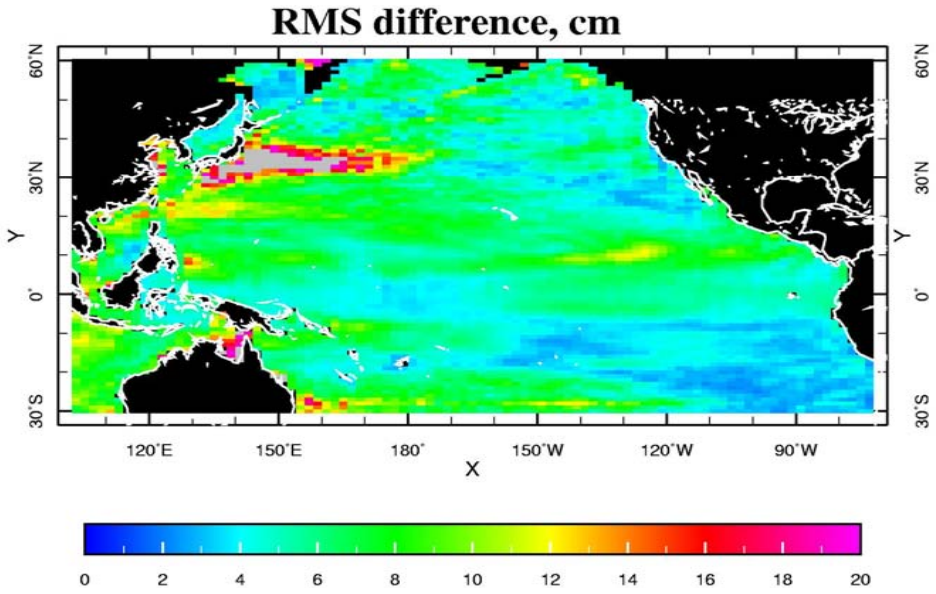


RMS SSH [Npac-DUACS], Curchitser et al. 2005

SSH response to perturbations from AMIP fluxes (GMAO Poseydon ocean model, Borovikov et al. 2005)



Comparison of sea level height deviati

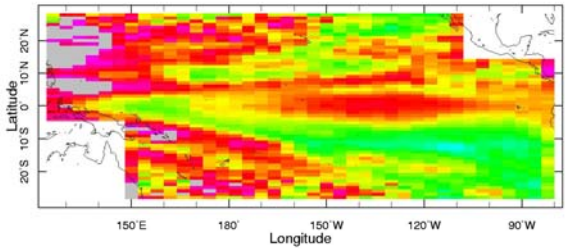


RMS SSH [Npac-DUACS], Curchitser et al. 2005

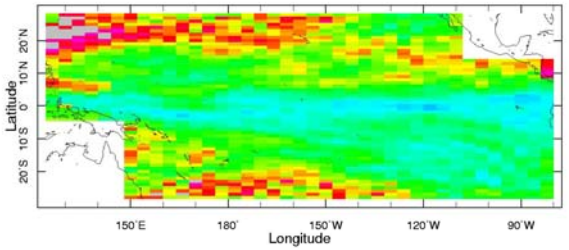
Sea level height anomaly: RMS[Topex – models], c

Linear model

No assimilation

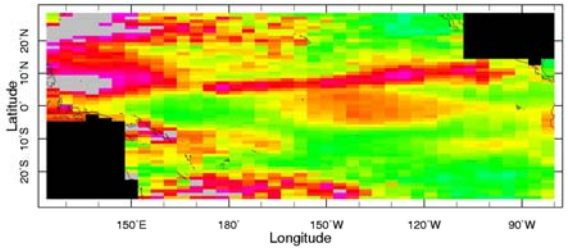


Altimetry assimilated

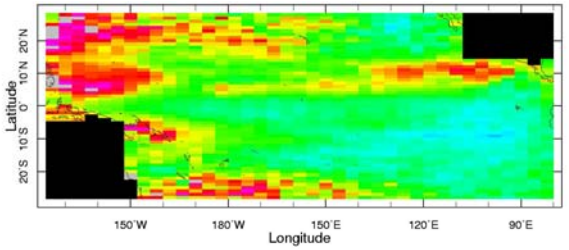


ECCO-1

No assimilation

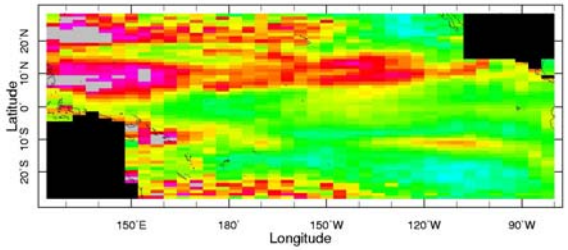


Everything assimilated

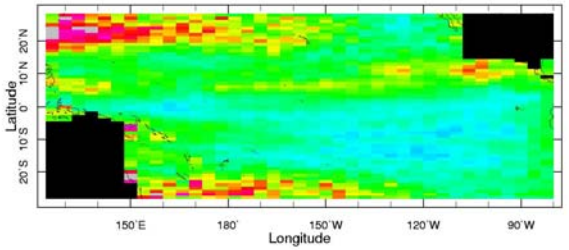


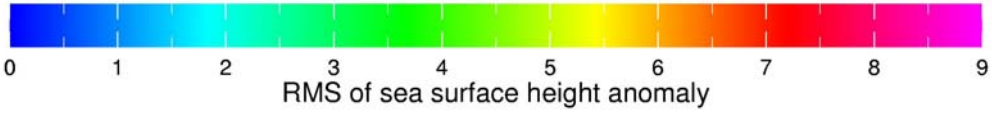
ECCO-2

No assimilation



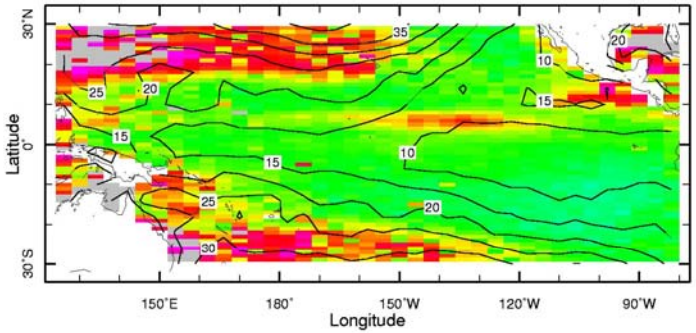
Topex assimilated



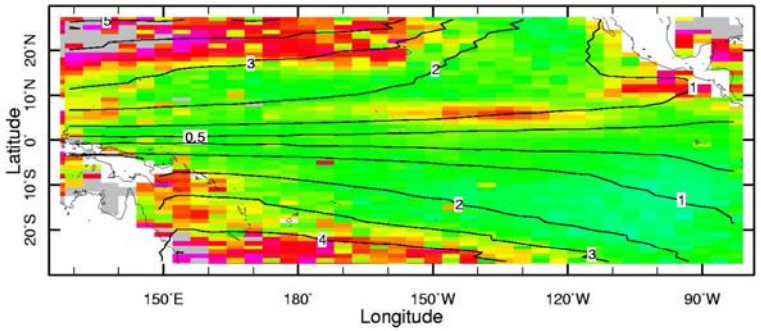


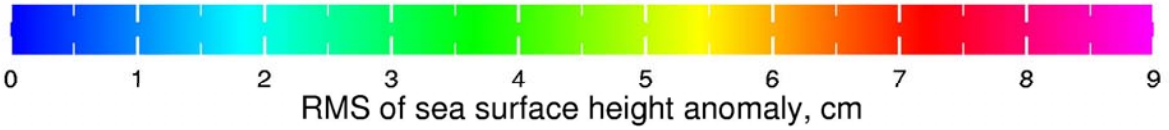
Small-scale variability in wind and sea level height

(a) SSV of zonal pseudostress



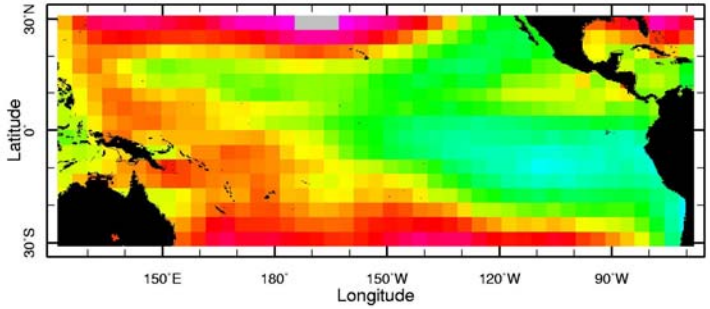
(b) Simulated sea level height SSV



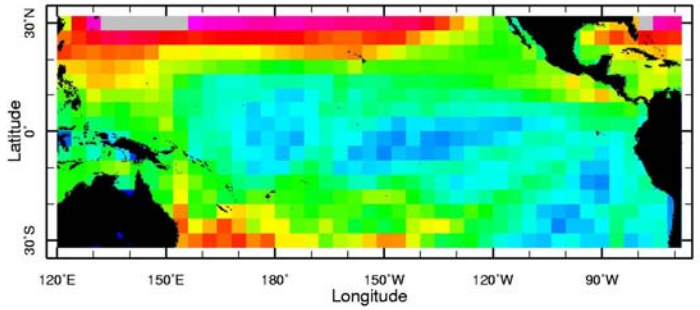


Small-scale variability in zonal wind $\sigma_{4^o \times 4^o \times 1 \text{ month}}$

(a) NSCAT



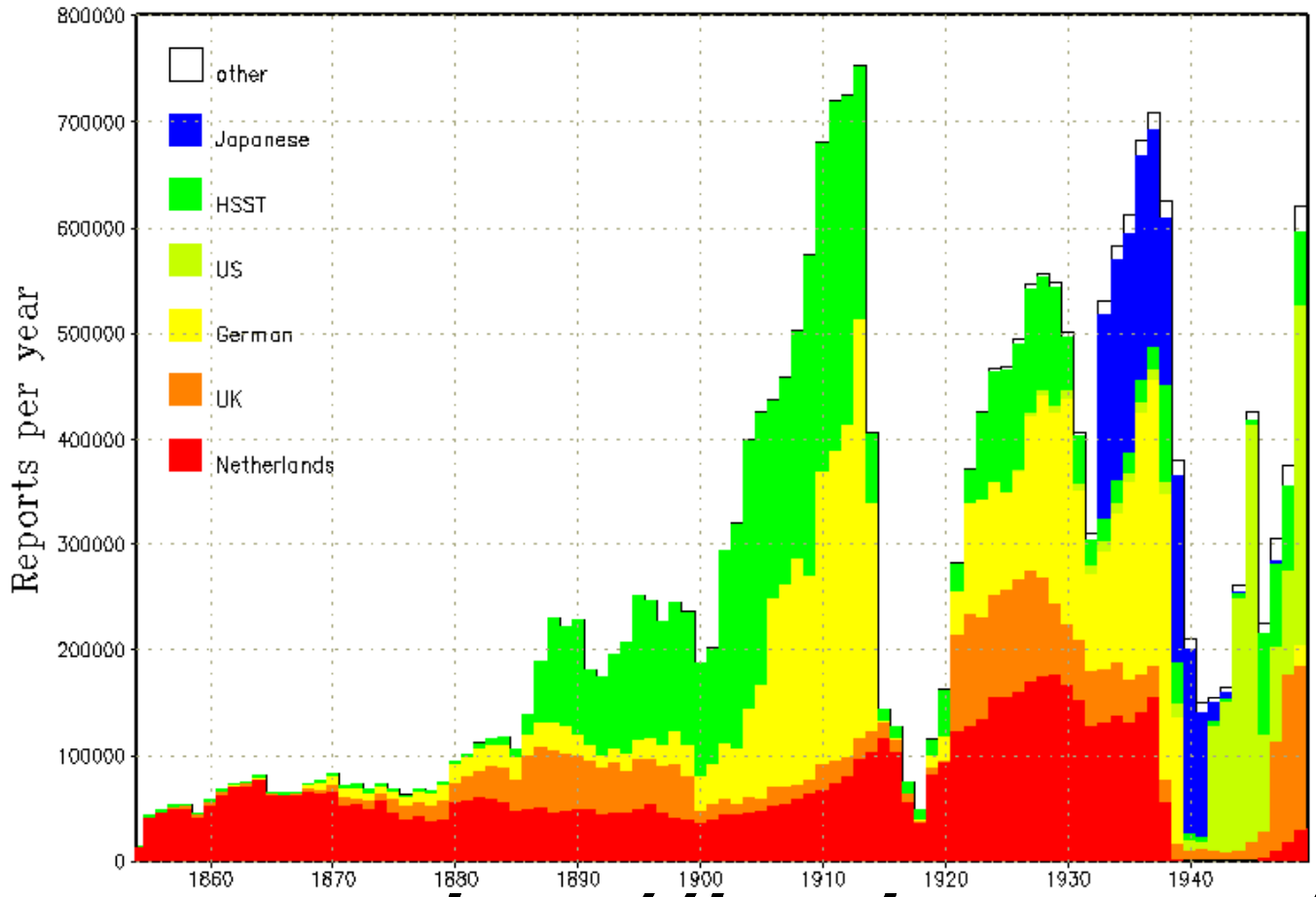
(b) COADS



Importance of high-quality continuous wind products:

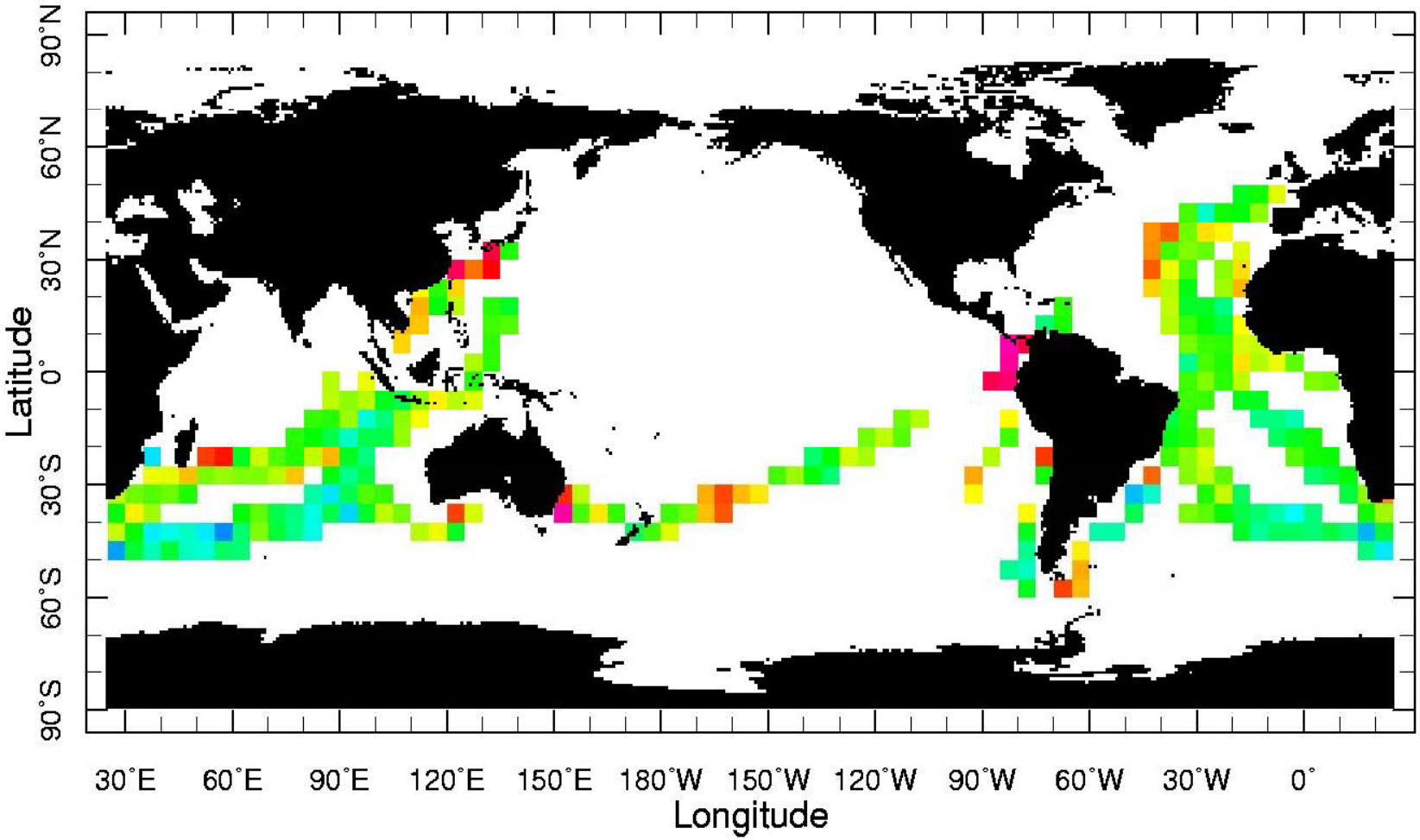
3. Learning relationships to constrain reconstructions of wind fields in pre-satellite era

Number of observations in ICOADS



http://icoads.noaa.gov/

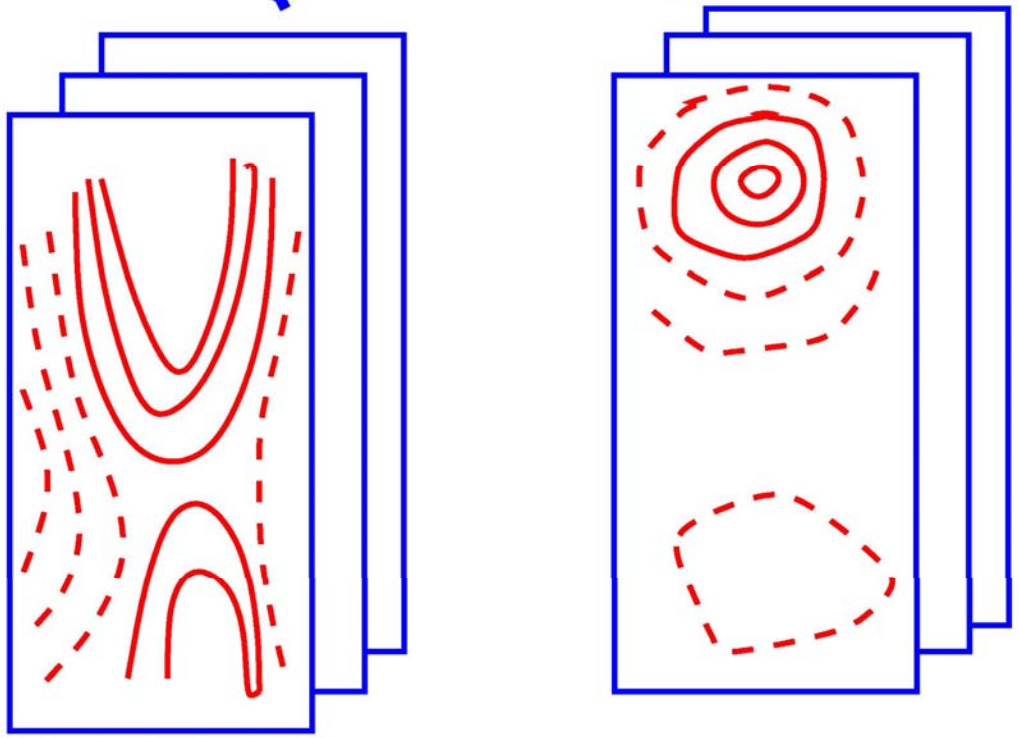
Dec 1868: Available observations



Dec 1868

APPROXIMATING COVARIANCE

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



Reduced Space Optimal Analysis

Kriging, Traditional OI

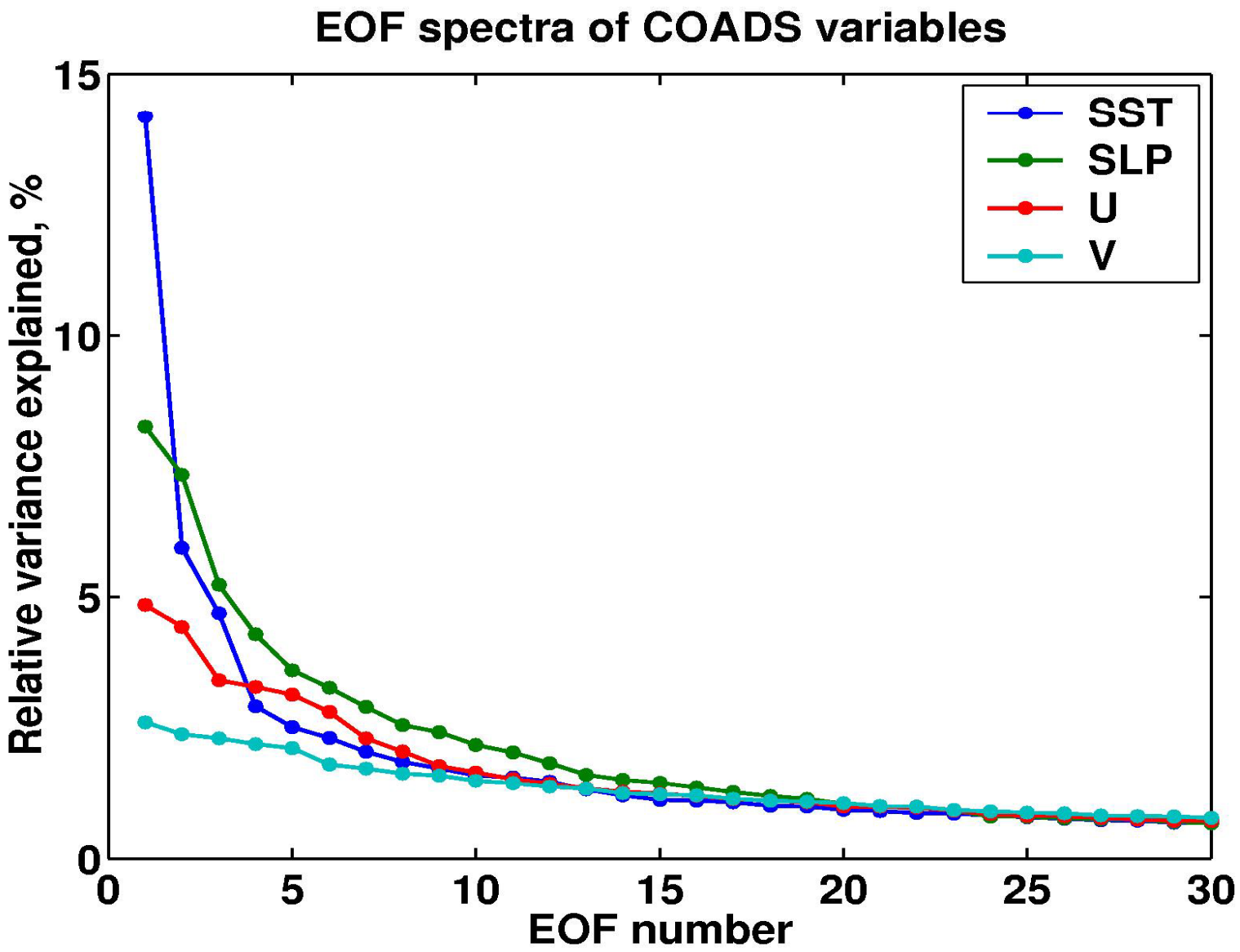


Figure 1: Eigenvalue spectra of climate variables from COADS, 1950-2000

EOFs of zonal wind anomaly

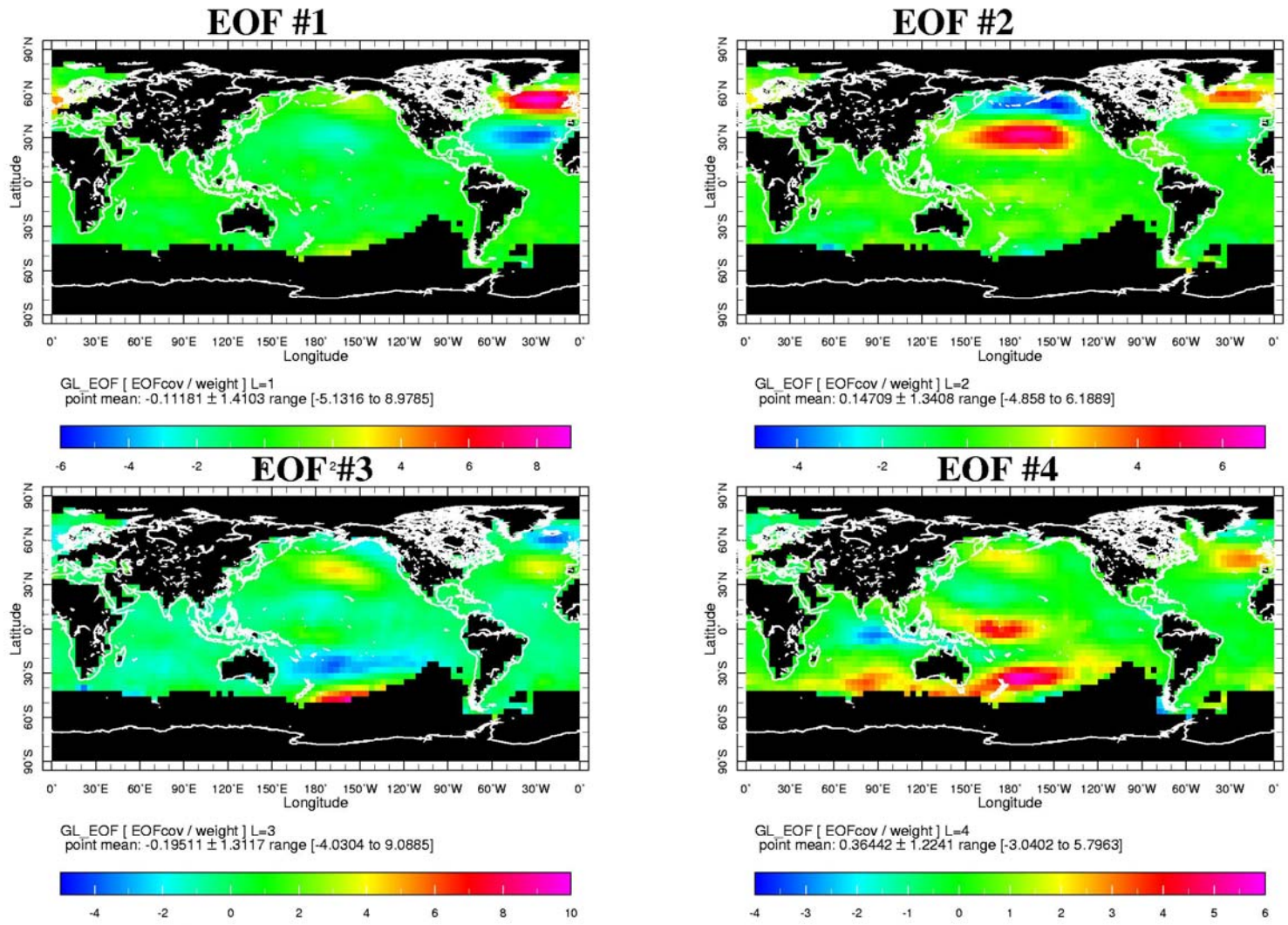
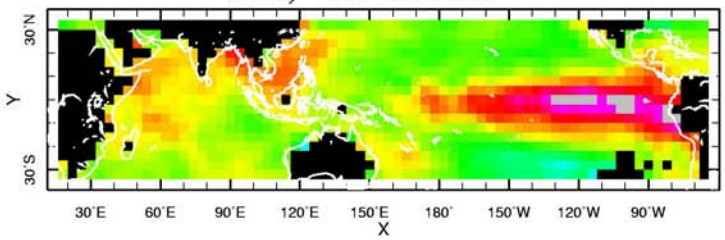


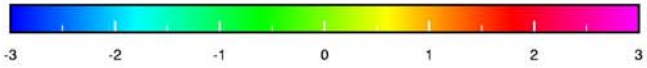
Figure 2: Leading EOF patterns of zonal wind anomalies from COADS, 1950-2000

El Niño of 1877-1878 in analyzed anomalies

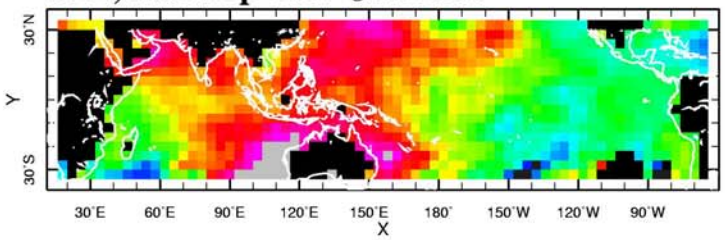
SST, °C: Dec 1877



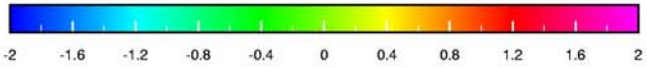
RSA_COADS_sstFP95 OS sstca T=Dec 1877
point mean: 0.45326 ± 0.81865 range [-1.7467 to 3.7493]



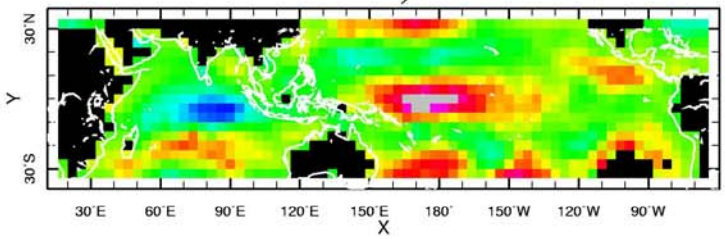
SLP, mb: Sep 1877-Jan 1878



RSA_COADS_slp OI mslpa T=Nov 1877
point mean: 0.26096 ± 0.97148 range [-3.1618 to 5.633]

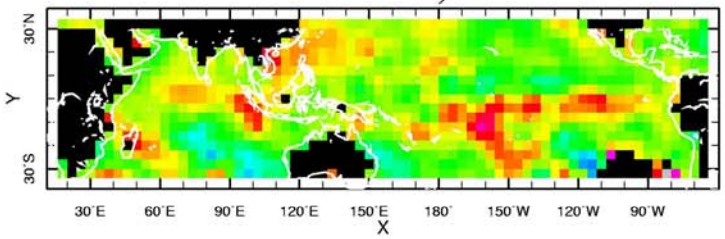


Zonal wind, m/s: Nov 1877

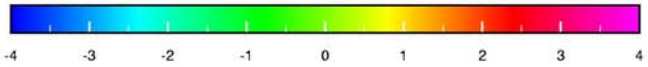


RSA_COADS_uwnd OI uwnda T=Nov 1877
point mean: 0.0229419 ± 1.4972 range [-4.8119 to 5.9475]
Reduced space (80 EOFs) analysis of COADS uwnd data

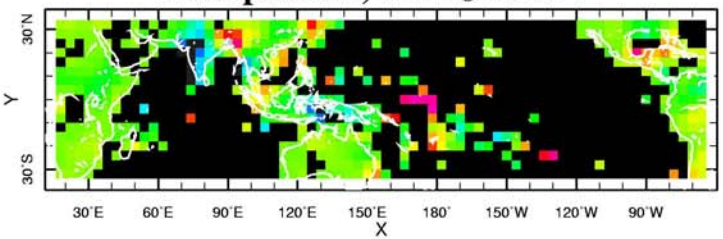
Meridional wind, m/s: Nov 1877



RSA_COADS_vwnd OI vwnda T=Nov 1877
point mean: 0.20265 ± 0.96678 range [-3.1376 to 4.5608]

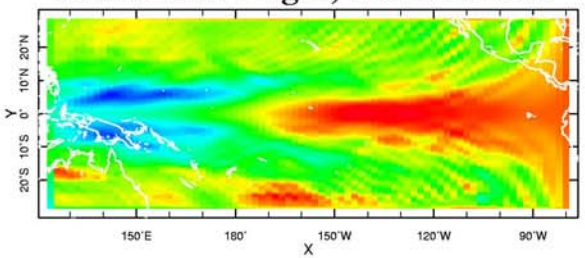


Precipitation, mm: Jul 1877

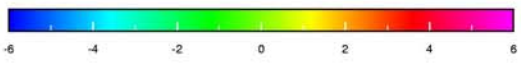


RSA_GHCN_prcp_anoml_cgrid OI prcpa T=Jul 1877
point mean: -9.2232 ± 53.891 range [-320.72 to 200.16]

Sea surface height, cm: Dec 1877



sl_OI Sea_Level Z=0 T=Dec 1877
point mean: 0.00201655 ± 1.9395 range [-5.8358 to 3.8843]



Independent ENSO Indices

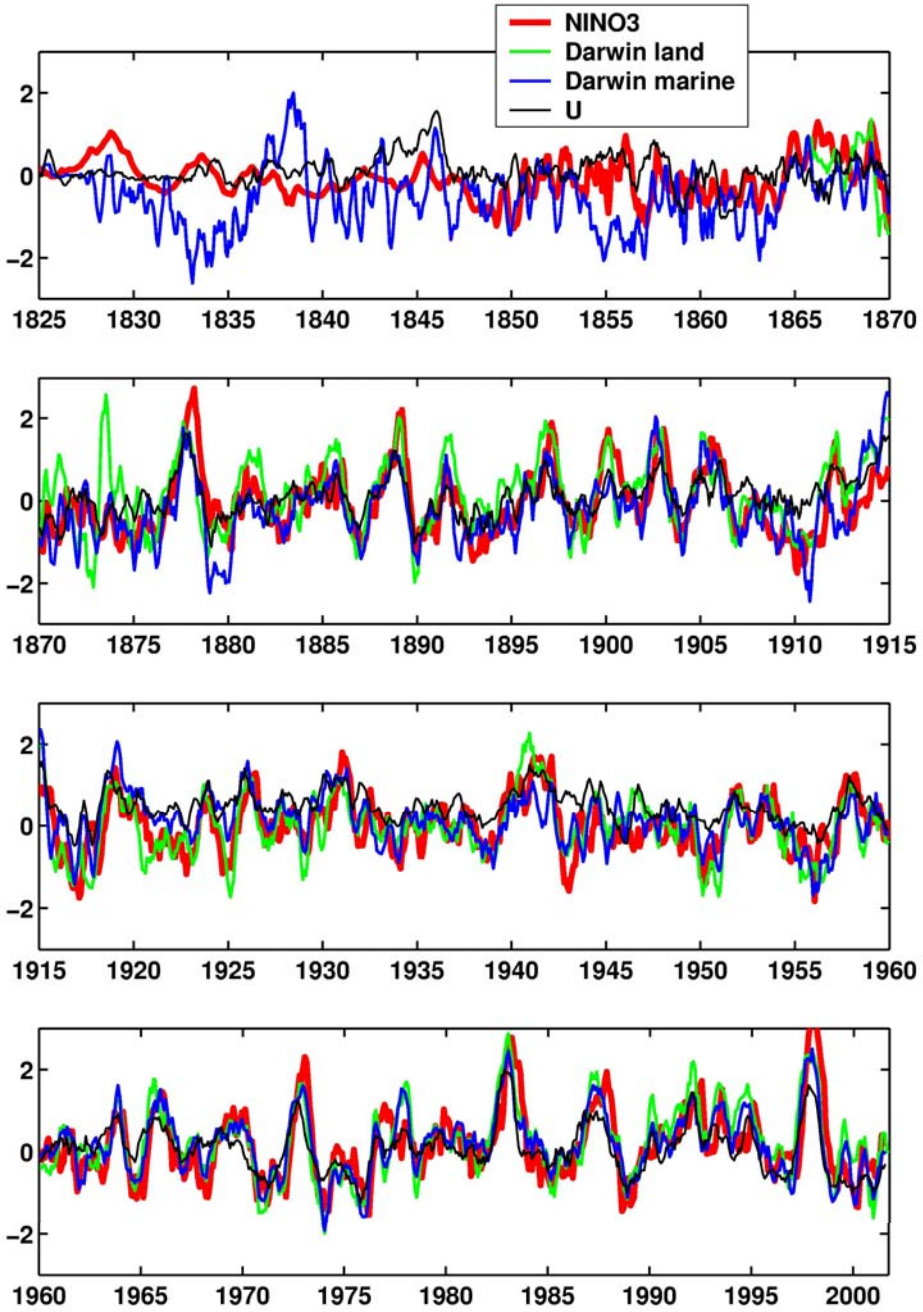
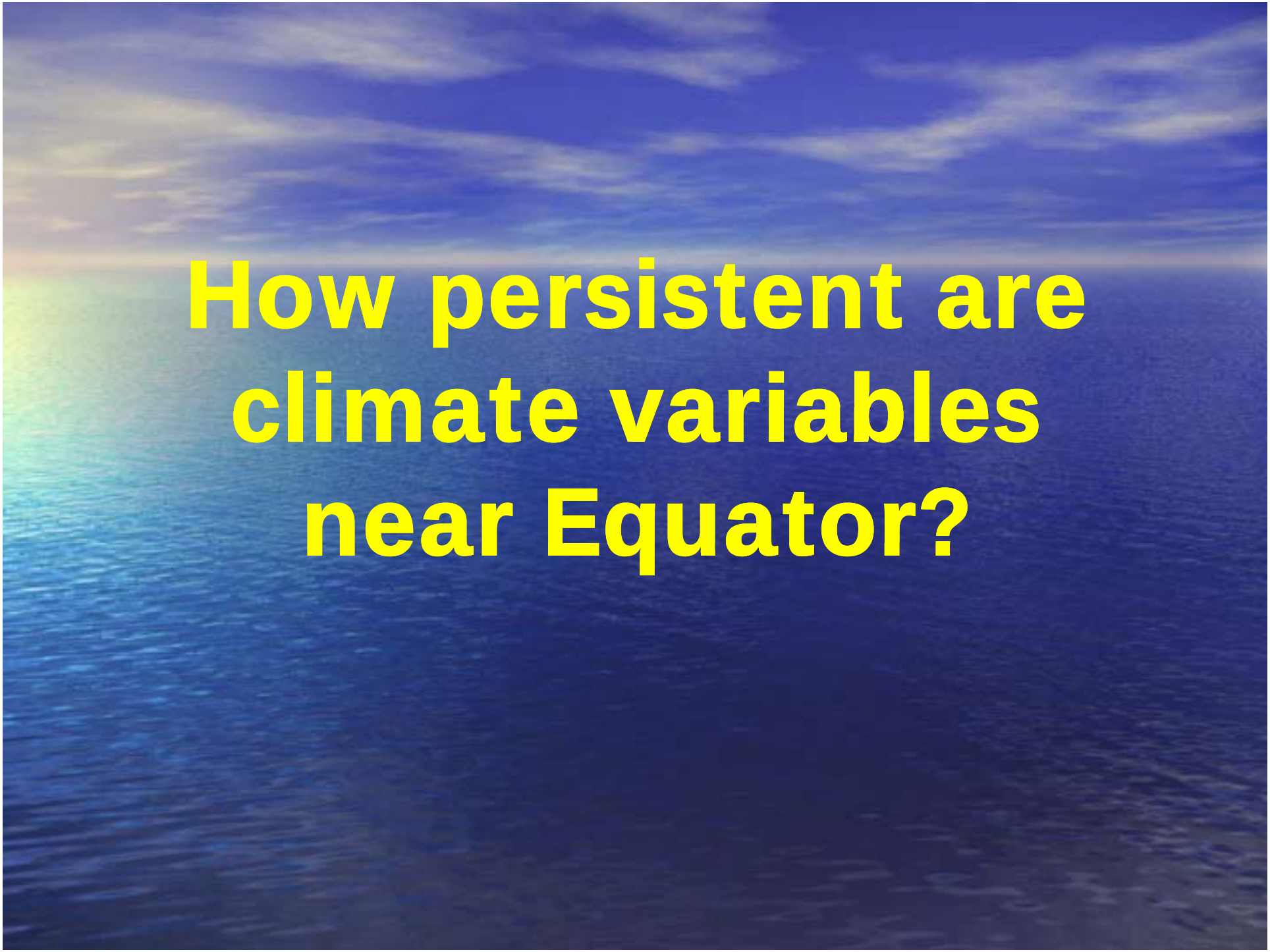
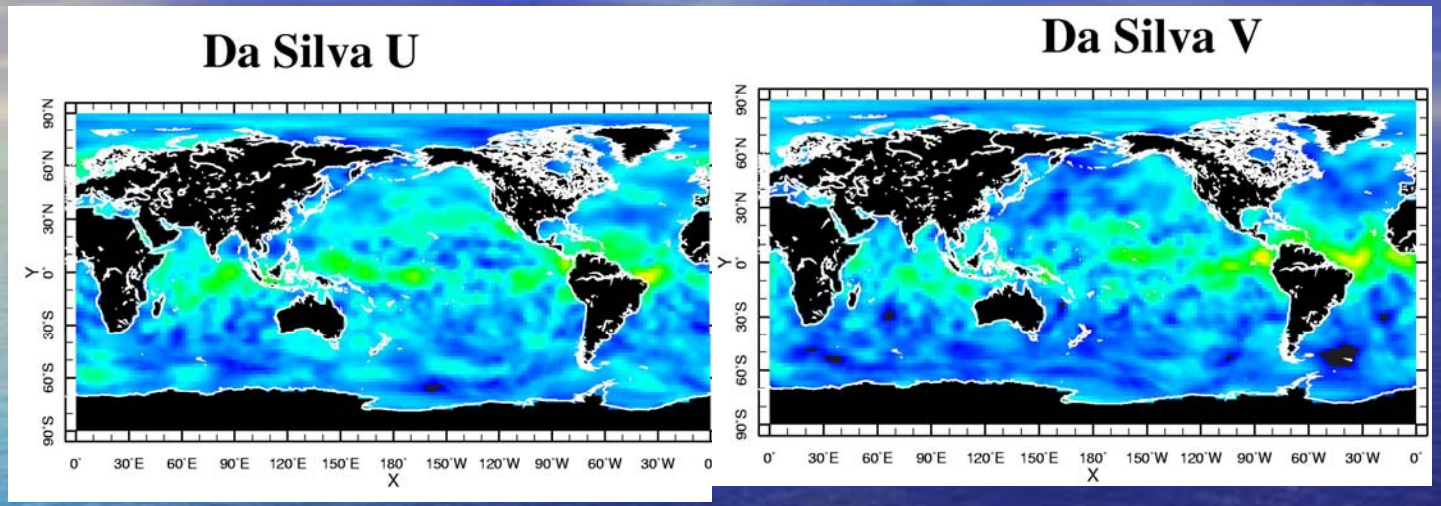
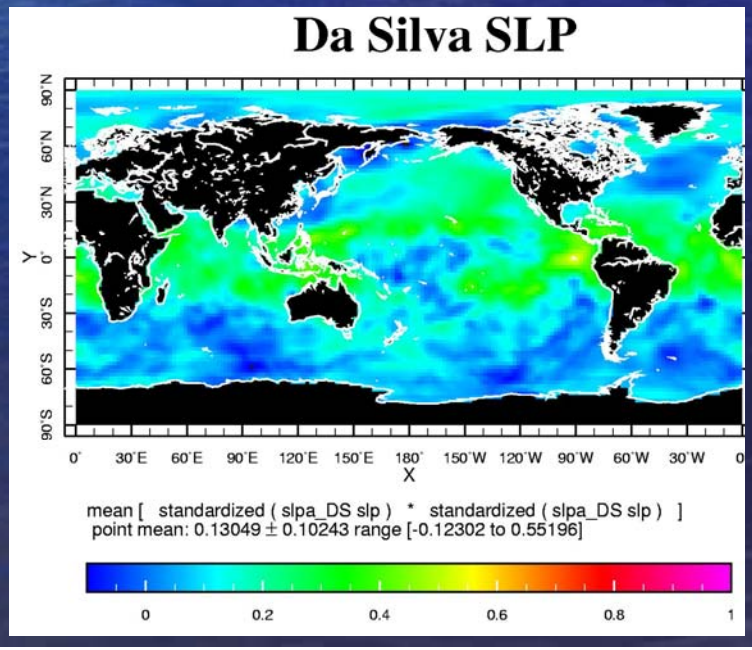


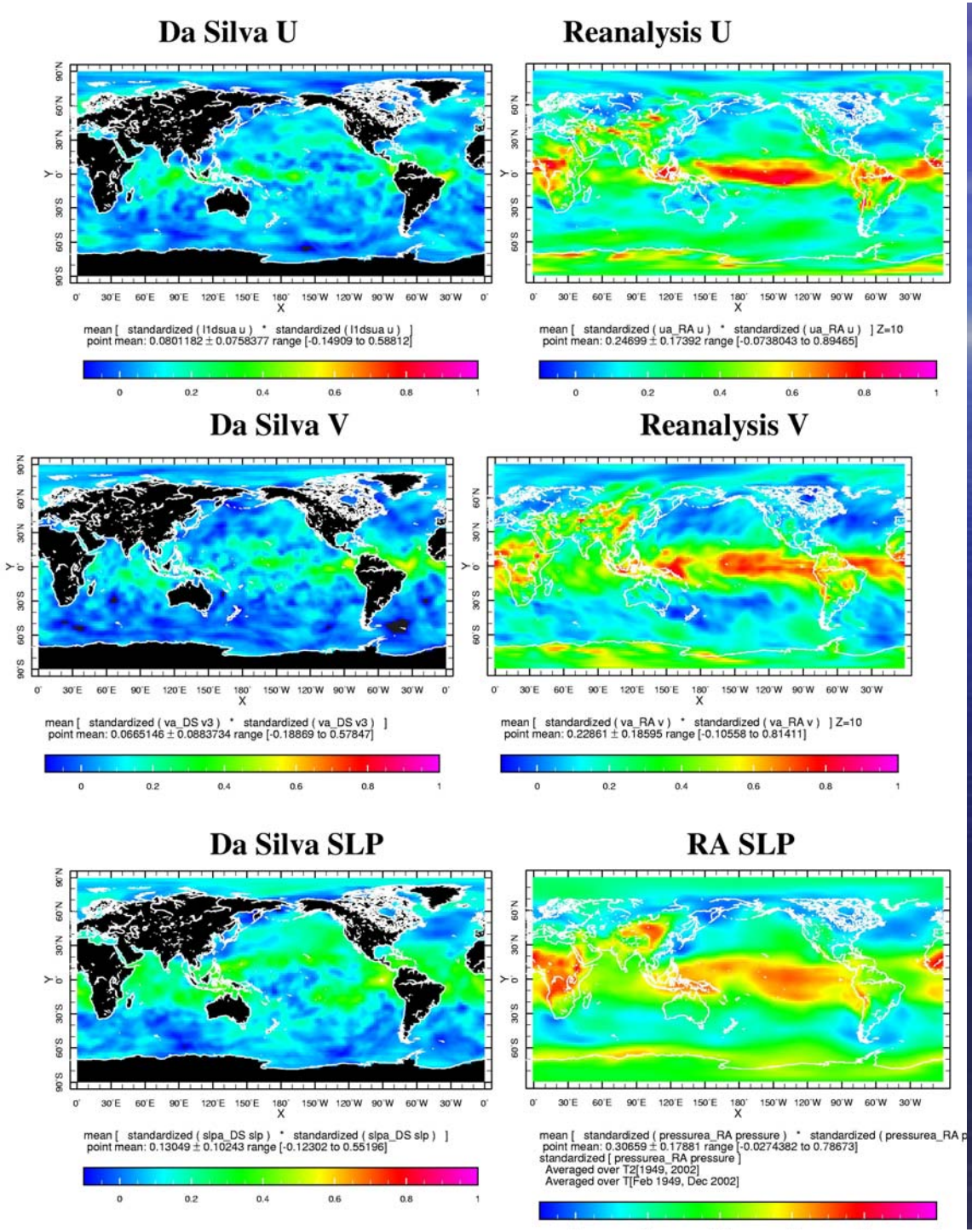
Figure 3: Intercomparison of ENSO indices: NINO3, ^{o}C, by *Kaplan et al.* [1998]; Darwin station SLP, mb, [*Allan et al.*, 1991; *Können et al.*, 1998]; Darwin area SLP estimate from ship-based RSOI, mb, [*Kaplan et al.*, 2000]; and Central Equatorial Pacific zonal wind anomaly (5^{o}N-5^{o},160^{o}E-120^{o}W),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


How persistent are climate variables near Equator?

Persistence: Anomaly autocorrelations with 1 month lag



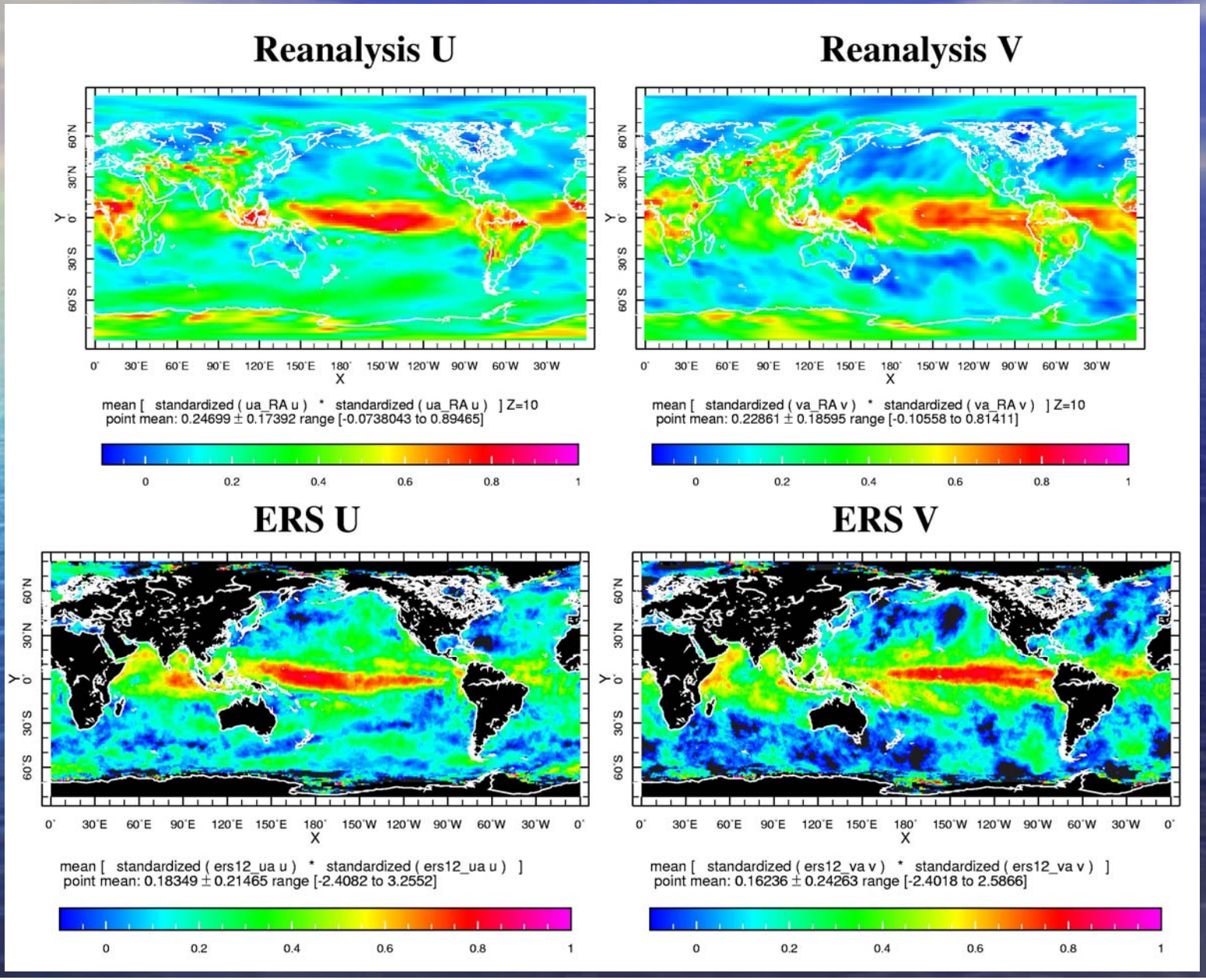




Persistence: Anomaly autocorrelations with

1 month lag

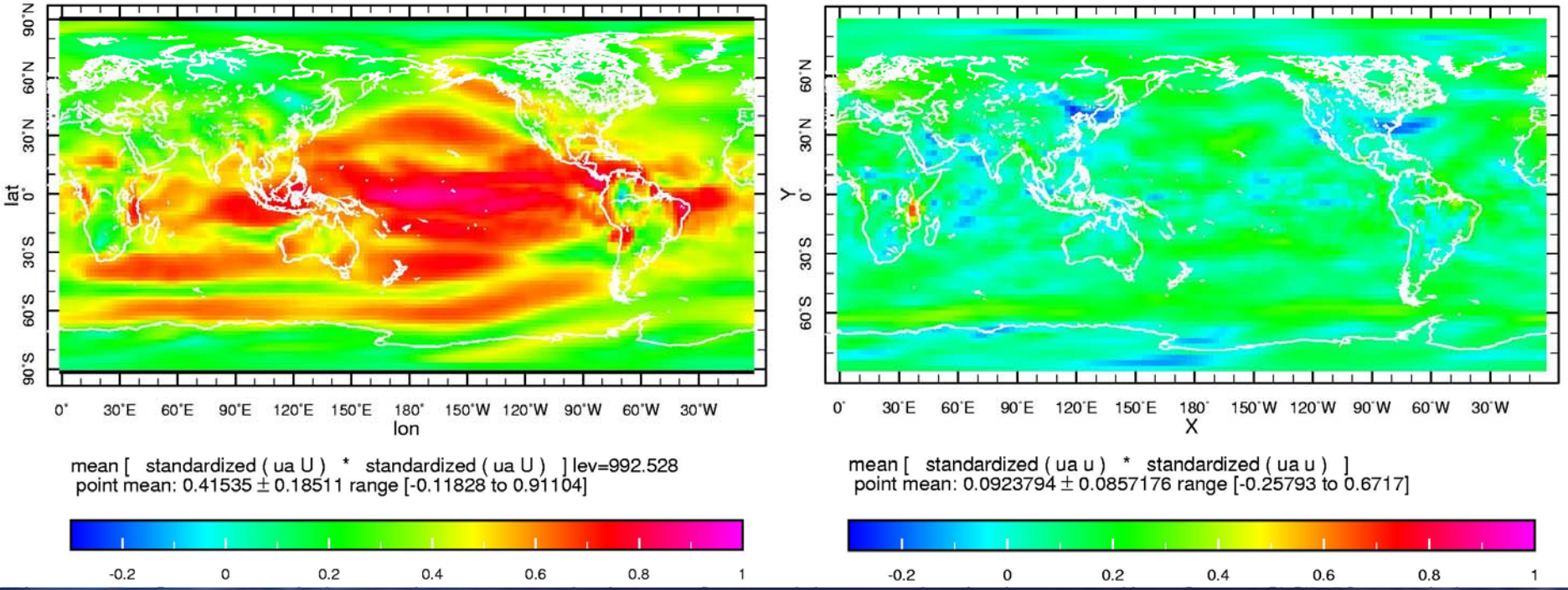
Verification from the satellite data



Persistence in AMIP experiments: zonal wind anomaly

CCM3 runs with boundary conditions of

Full SST | **SST climatology**

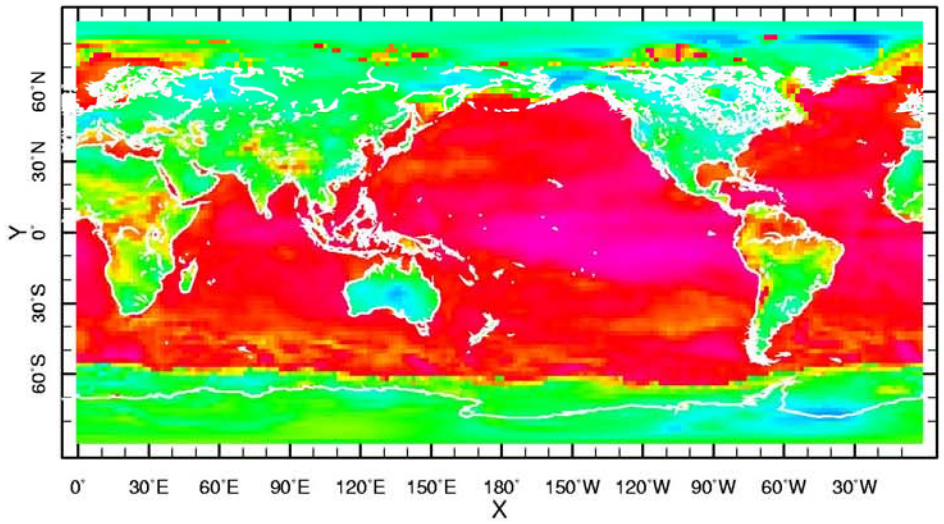


John Chiang et al [2001] approach to surface wind modeling:
Linearized dynamical core of a GCM [*Seager and Zebiak*, 1995] is set up to take both sea surface temperature and elevated atmospheric heating as forcing for the atmospheric dynamics. Elevated heating is parameterized via precipitation.

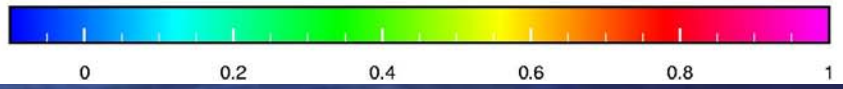
Persistence of the actual forcing

Lag-1 autocorrelations

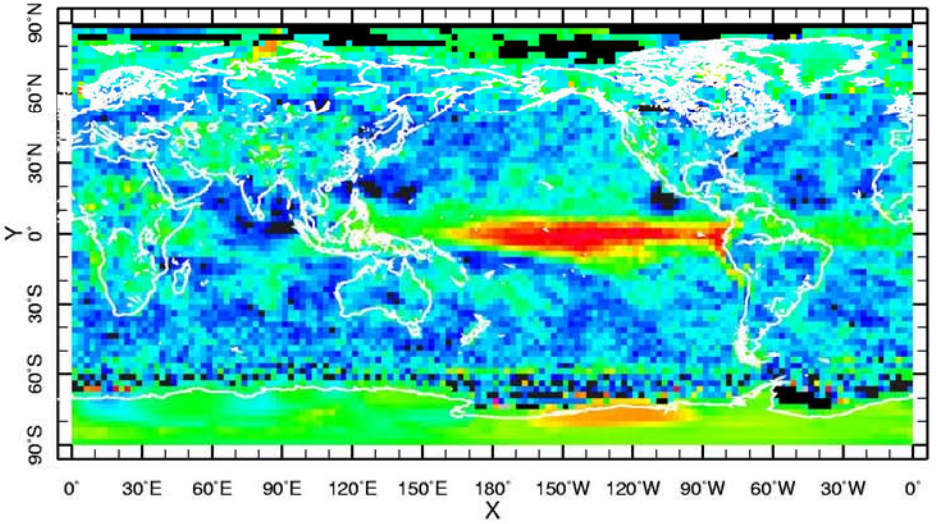
Surface temperature



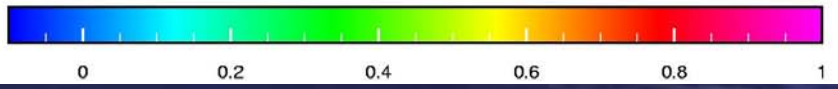
mean [standardized (tempa_RA temp) * standardized (tempa_RA temp)]
point mean: 0.55176 ± 0.27342 range [-0.0231465 to 0.95874]

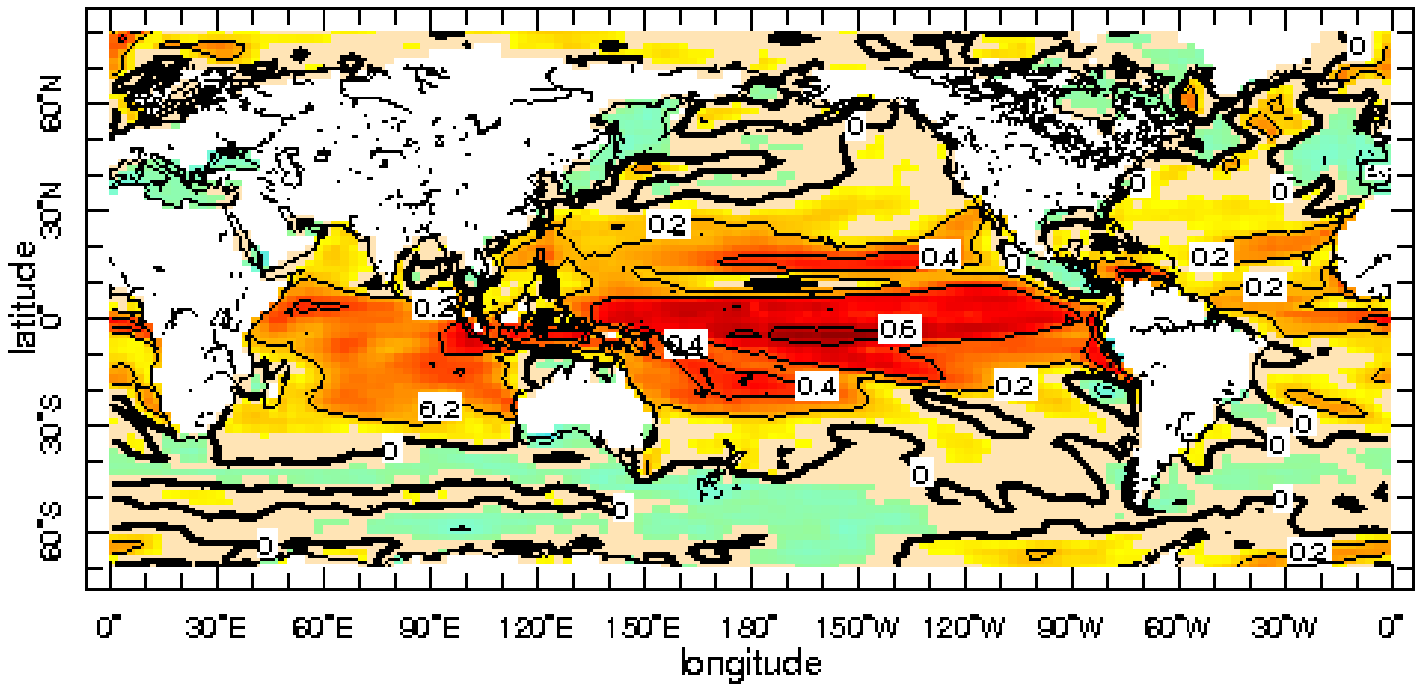


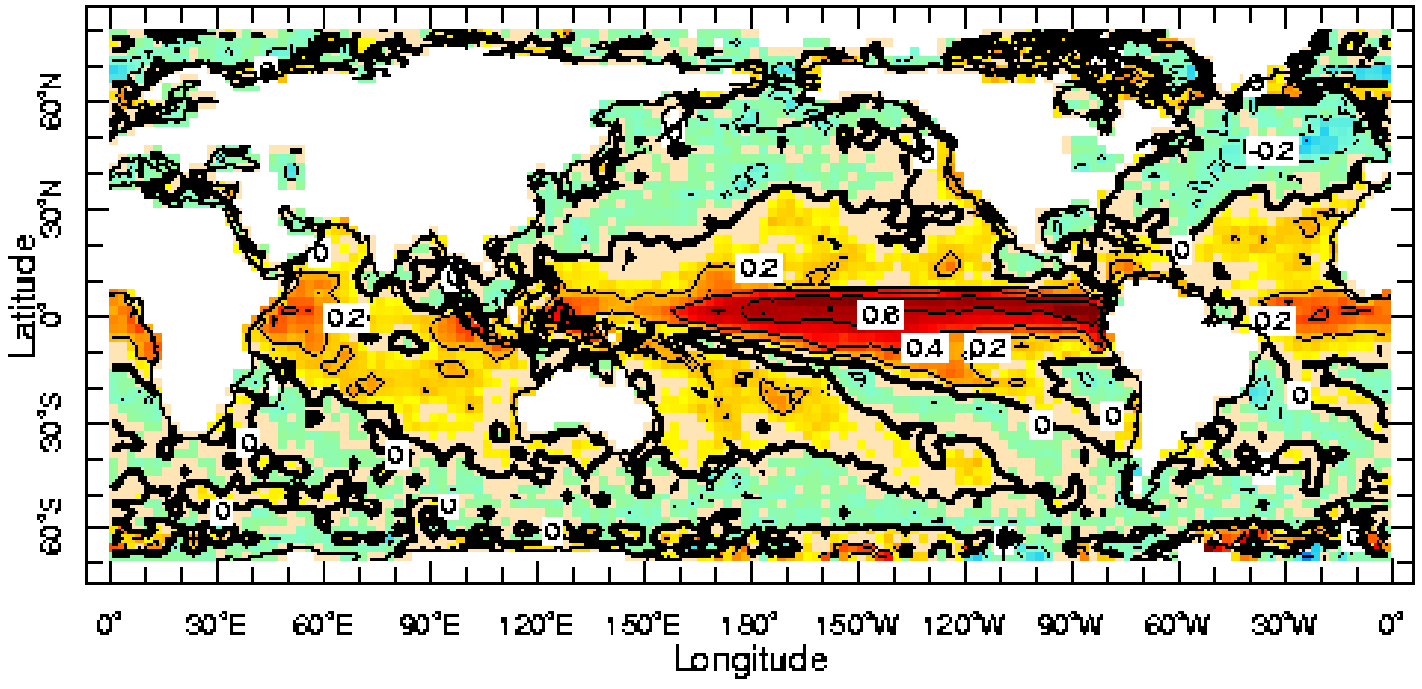
Precipitation [Xie and Arkin]



mean [standardized (prcpa_XieArkin prcp_est) * standardized (prcpa_XieArki
point mean: 0.15705 ± 0.17386 range [-0.73877 to 1.1561]







SST and Precip correlations

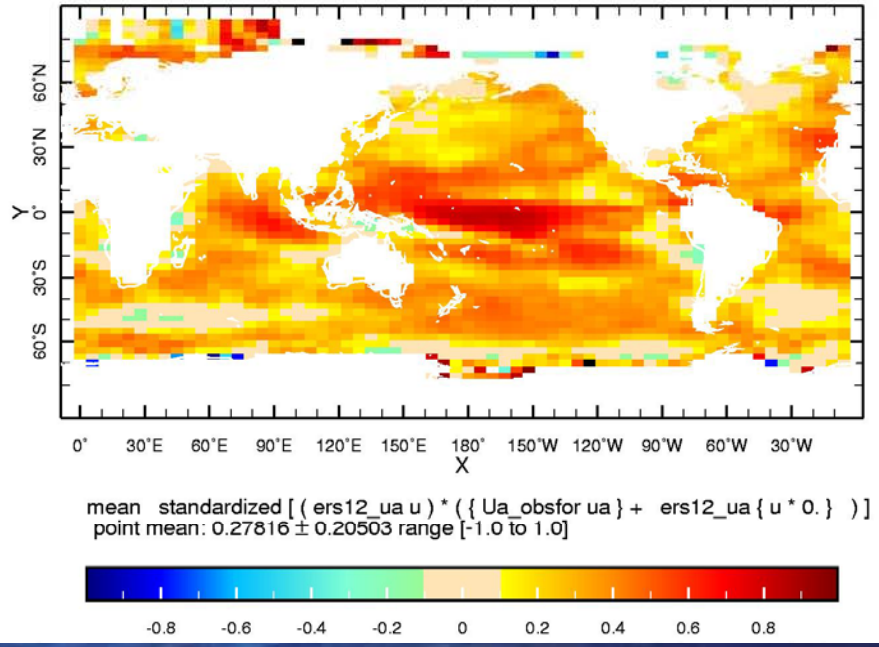
GFDL model (CM2.1)

Observations (NCEP OI and CMAP)

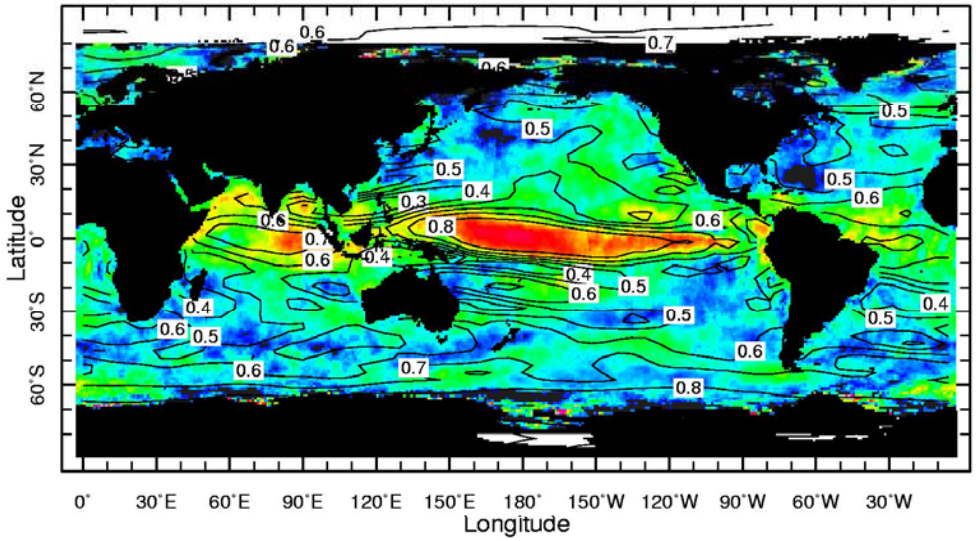
Simulation skill

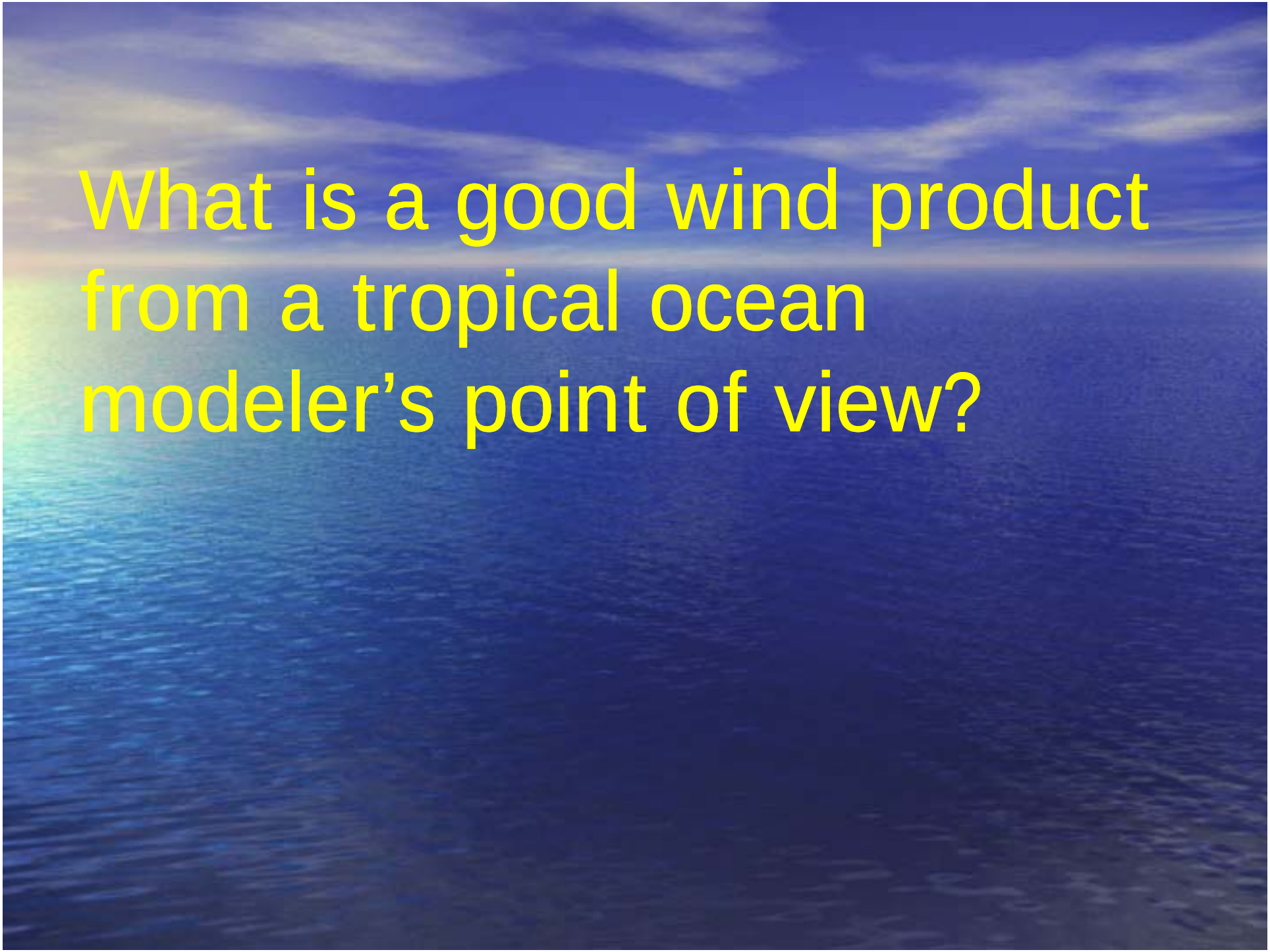
Consistency of persistence pattern in ERS (colors) and simulation (contours)

corr[model,ERS]

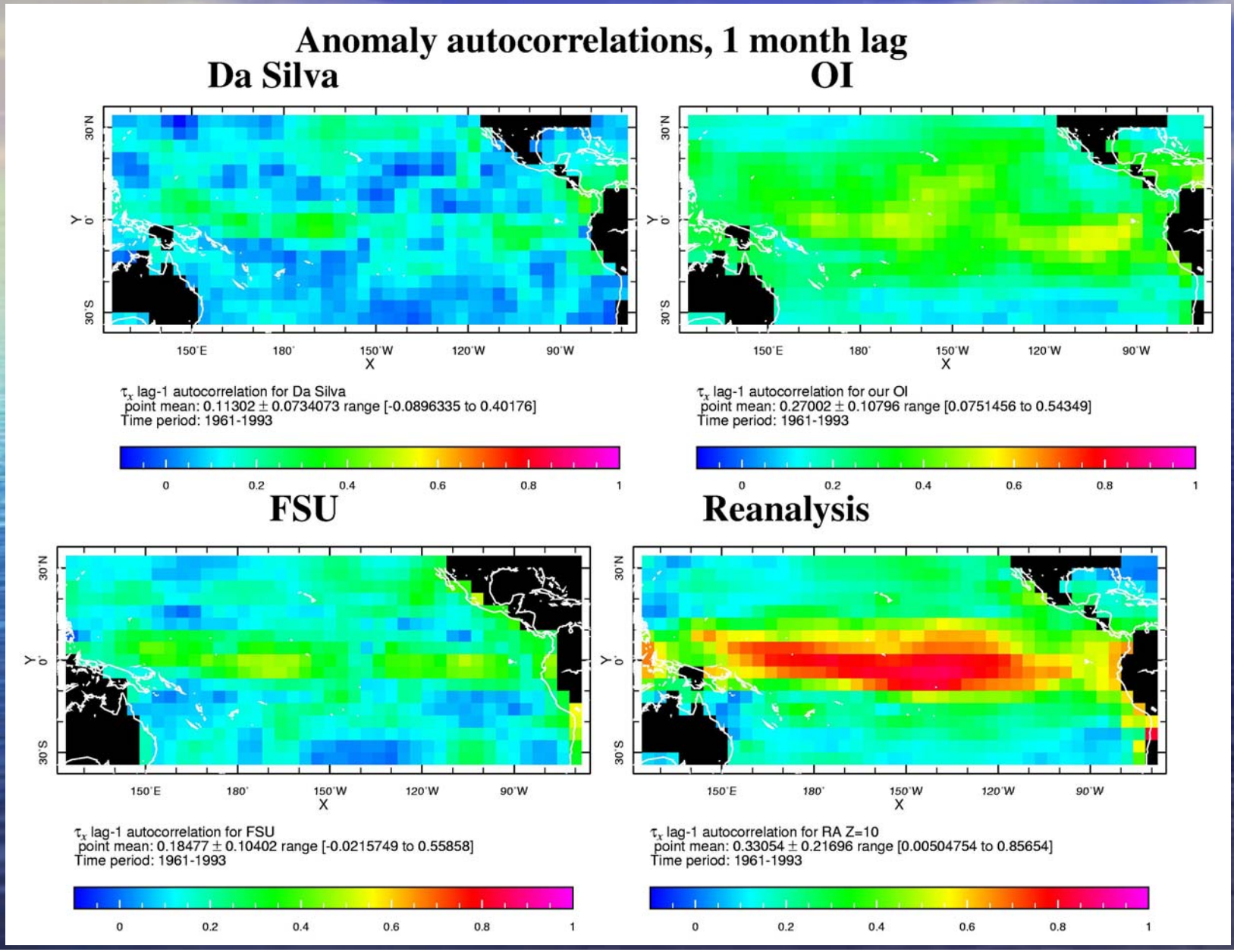


corr[model(t),model(t+1)]

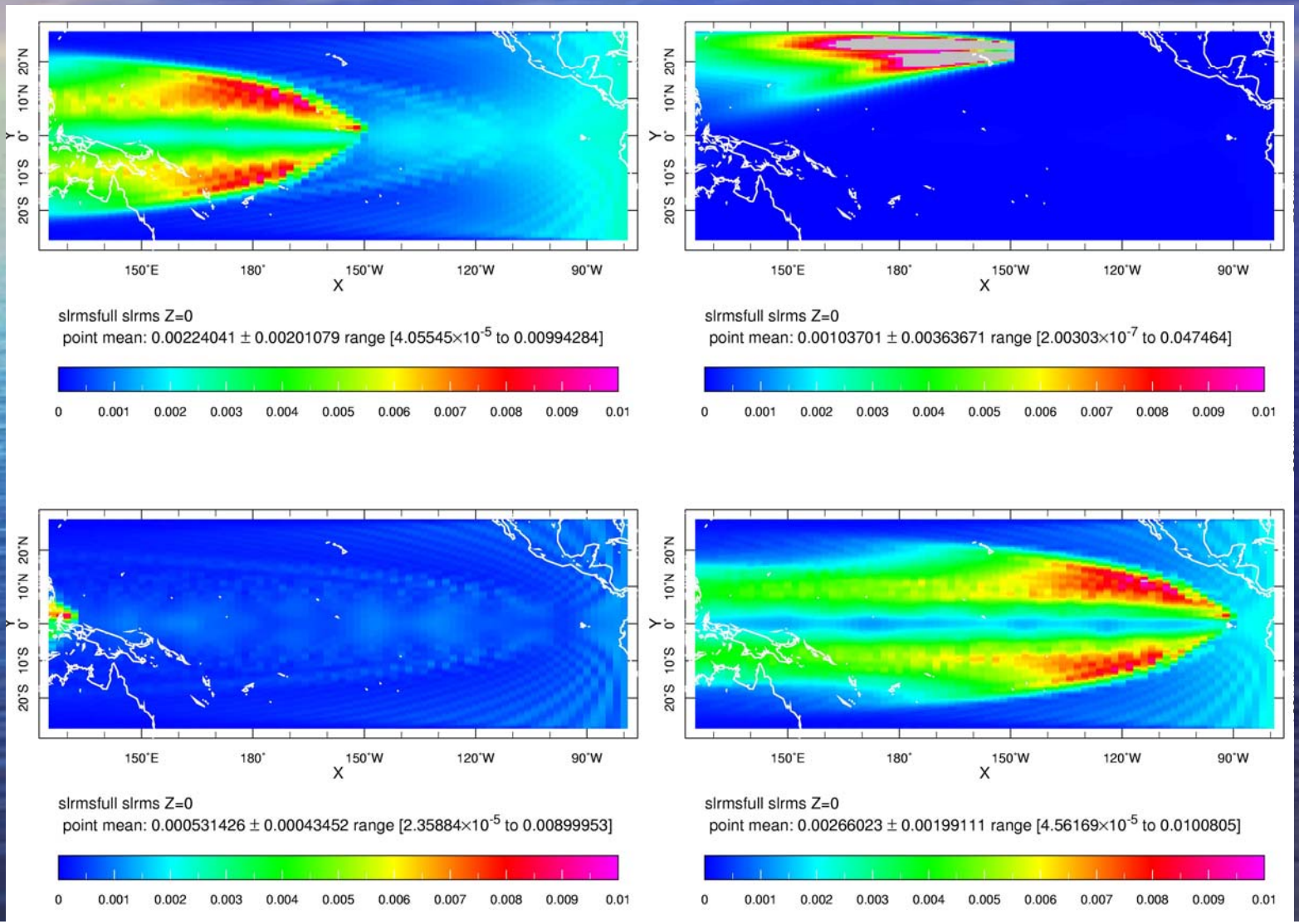



What is a good wind product from a tropical ocean modeler’s point of view?

Why equatorial persistence is so important?

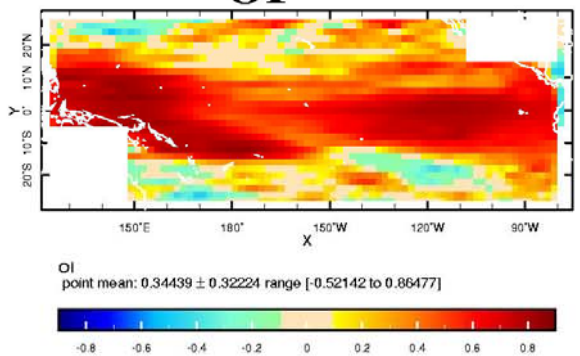


RMS of sea level response to the wind noise in a single location

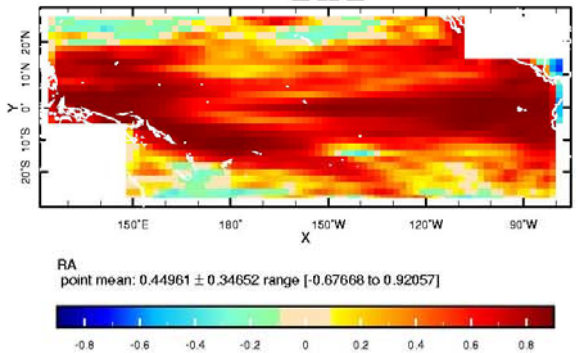


Correlation with TOPEX altimetry of ocean model sea level height responce to wind products

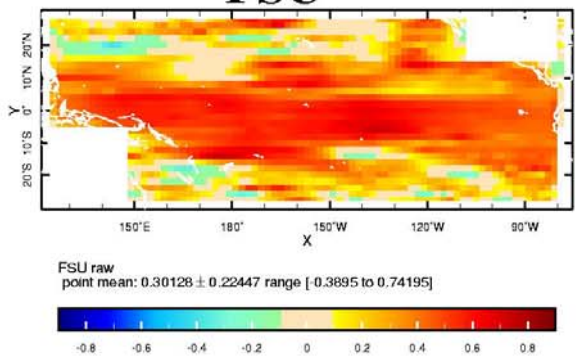
OI



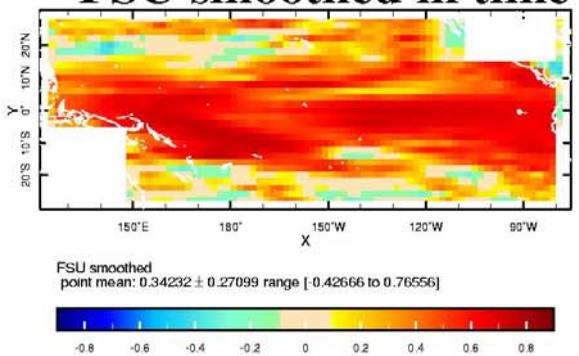
RA



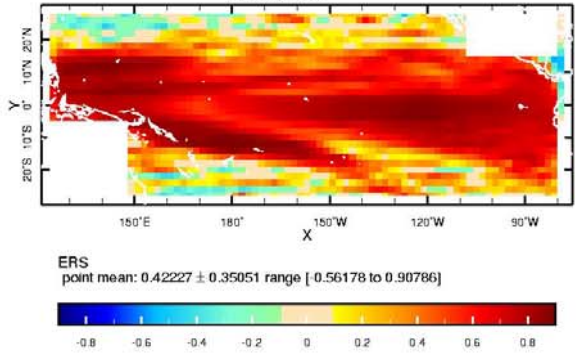
FSU



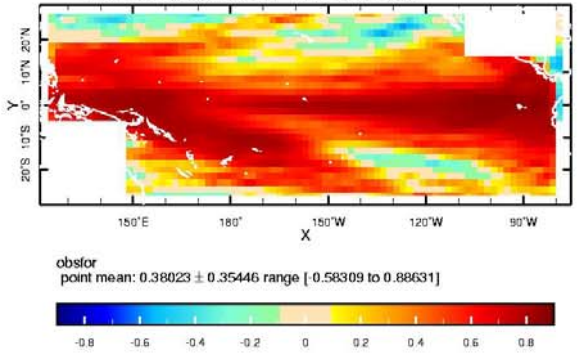
FSU smoothed in time



ERS



Modeled winds



Conclusions and Outlook

- Univariate statistical analyses of historical climate data sets 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.