On the role of the MJO in exciting El Niño

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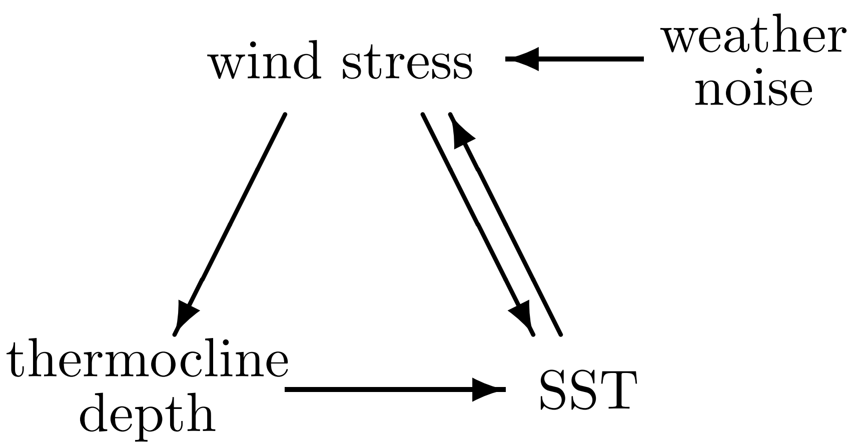
- Ideas
- A case study
- Statistics
- Model
- Predictability of ENSO
- Conclusions

Ideas

A schematic picture of the ENSO cycle



Wind stress anomalies on the equator in the western and central Pacific cause thermocline depth anomalies; wave dynamics transport these to the east where they are advected up as SST anomalies. These in turn affect the wind. Wind anomalies also influence SST directly, especially in the western and central Pacific.

MJO vs ENSO

- Is the weather noise related to the MJO?
- How can a 30–60 day oscillation force a 3-year phenomenon?
- How does the MJO affect the predictability of ENSO?

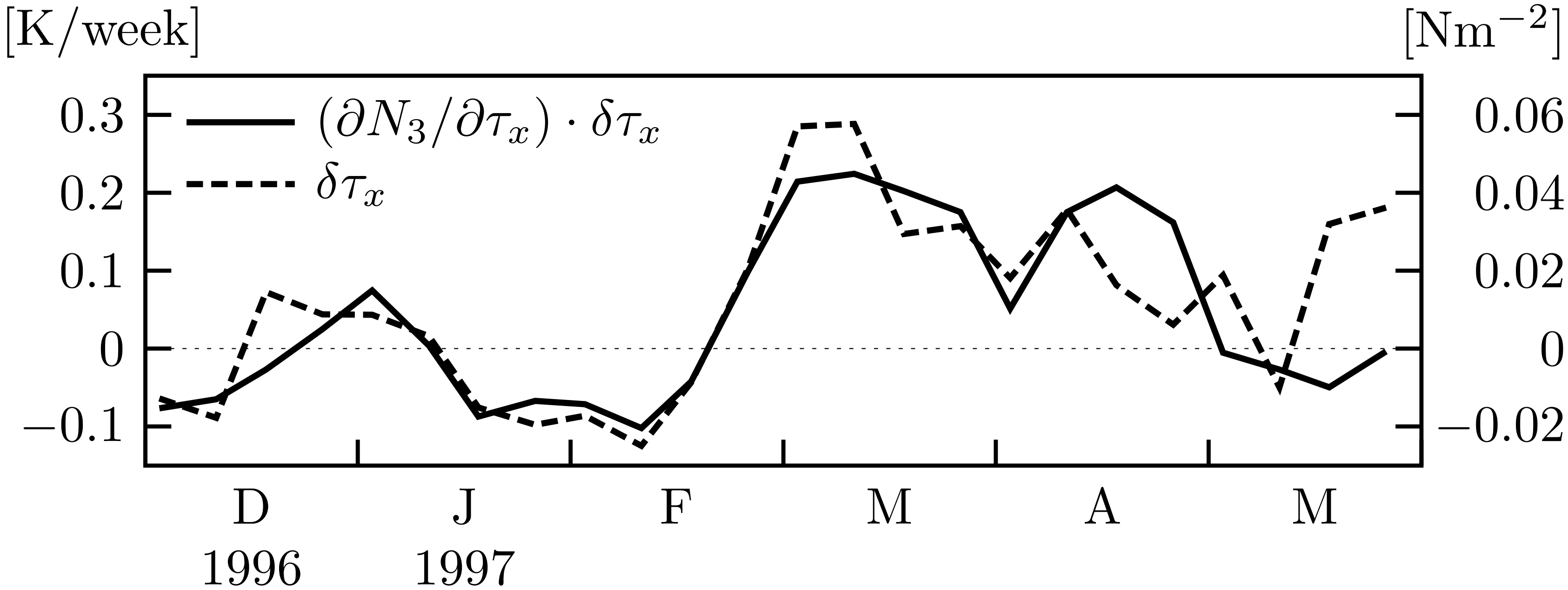
Case study: 1996/97

The extremely strong onset of the 1997/98 El Niño was associated with extraordinarily strong westerly wind events in the western and central Pacific in 1996/1997. An old study with an adjoint ocean model (adHOPE) tried to quantify the influence

$$\Delta N_3 = \int_0^T dt \frac{\partial N_2}{\partial \tau_x(t)} \cdot \Delta \tau_x(t) + \frac{\partial N_3}{\partial T_0} \cdot \Delta T_0 + \text{smaller terms} \qquad (1)$$

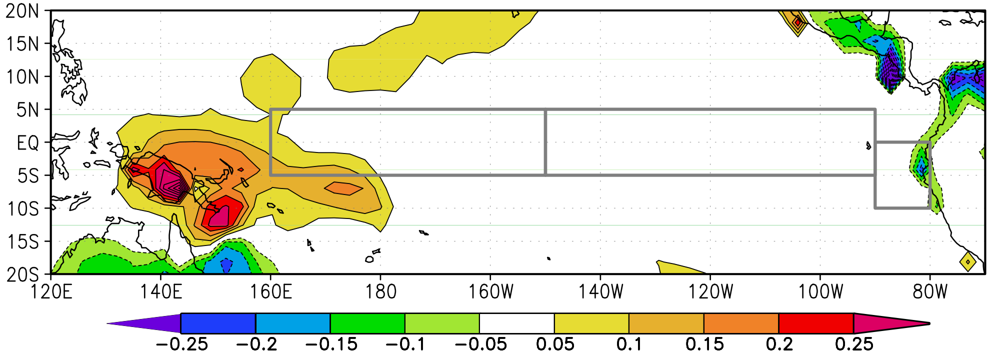
with N_3 the Niño3 index of SST in the eastern Pacific, τ_x the zonal wind stress over the duration of the forecast and T_0 the initial state temperature. The dots indicate integration over the surface and ocean volume respectively.

Effect of zonal wind stress

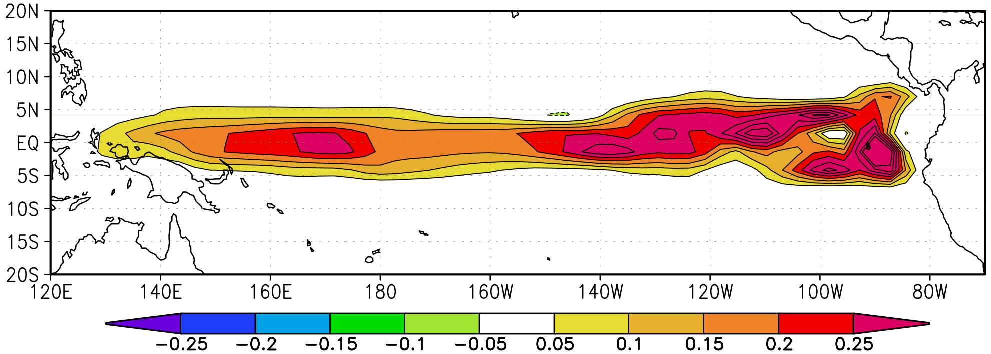


Within this model, zonal wind stress contributed about half the rise of the Niño3 index until June 1. The contributions are very similar to the zonal wind stress averaged over 130°E to 160°W, 5°S to 5°N (dashed line).

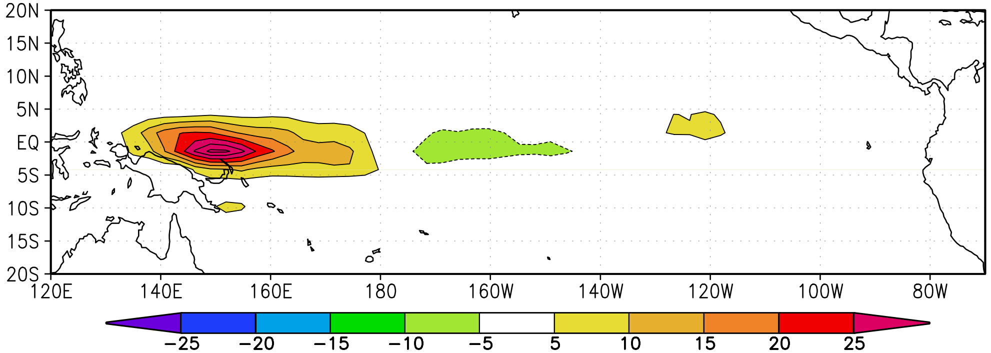
Effect of the March 1997 wind event



$\delta\tau_x$ [Nm^{-2}]

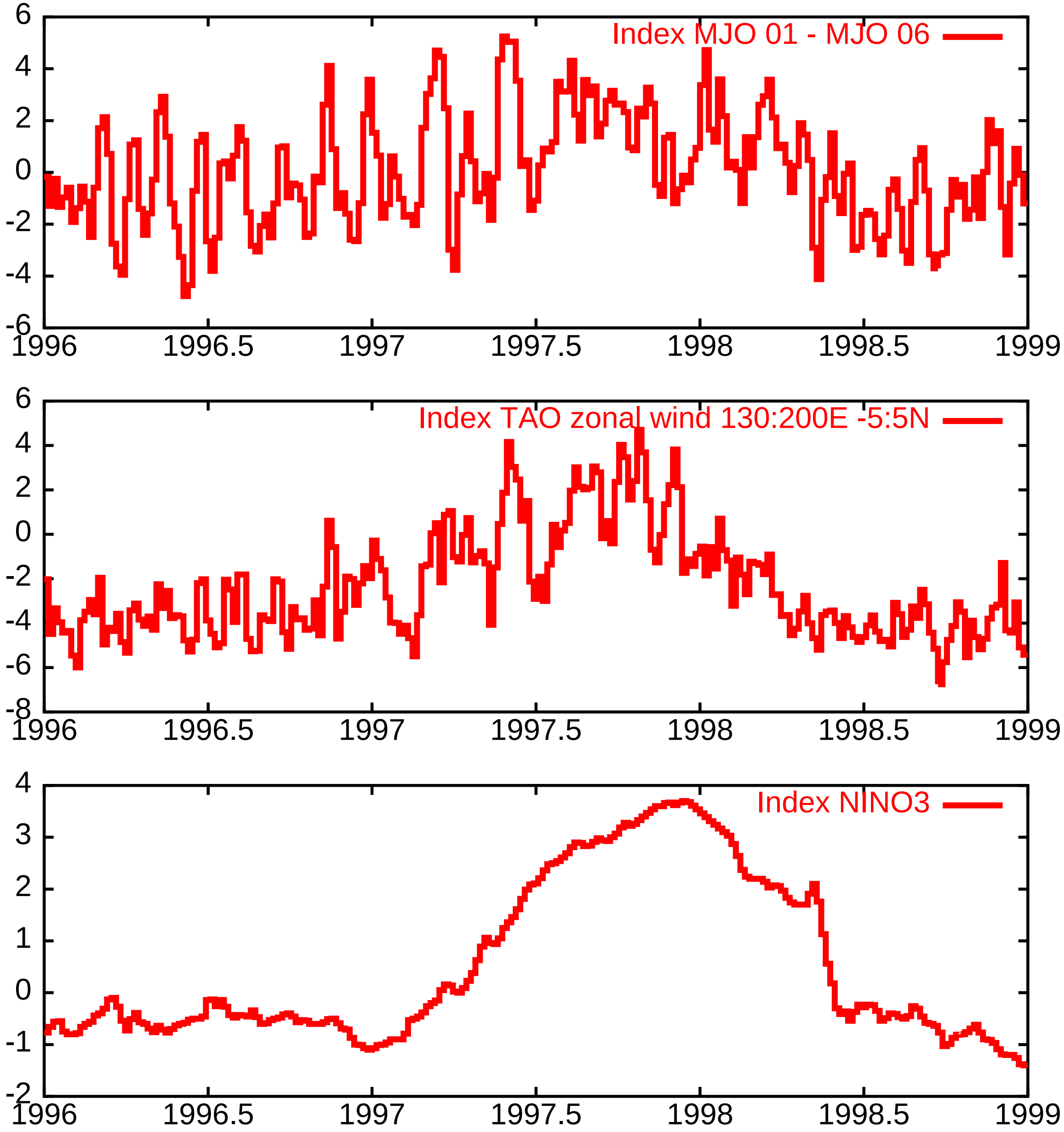


$\partial N_3/\partial\tau_x$ [$10^{-12}\ \mathrm{K(Nm^{-2})^{-1}m^{-2}day^{-1}}$]



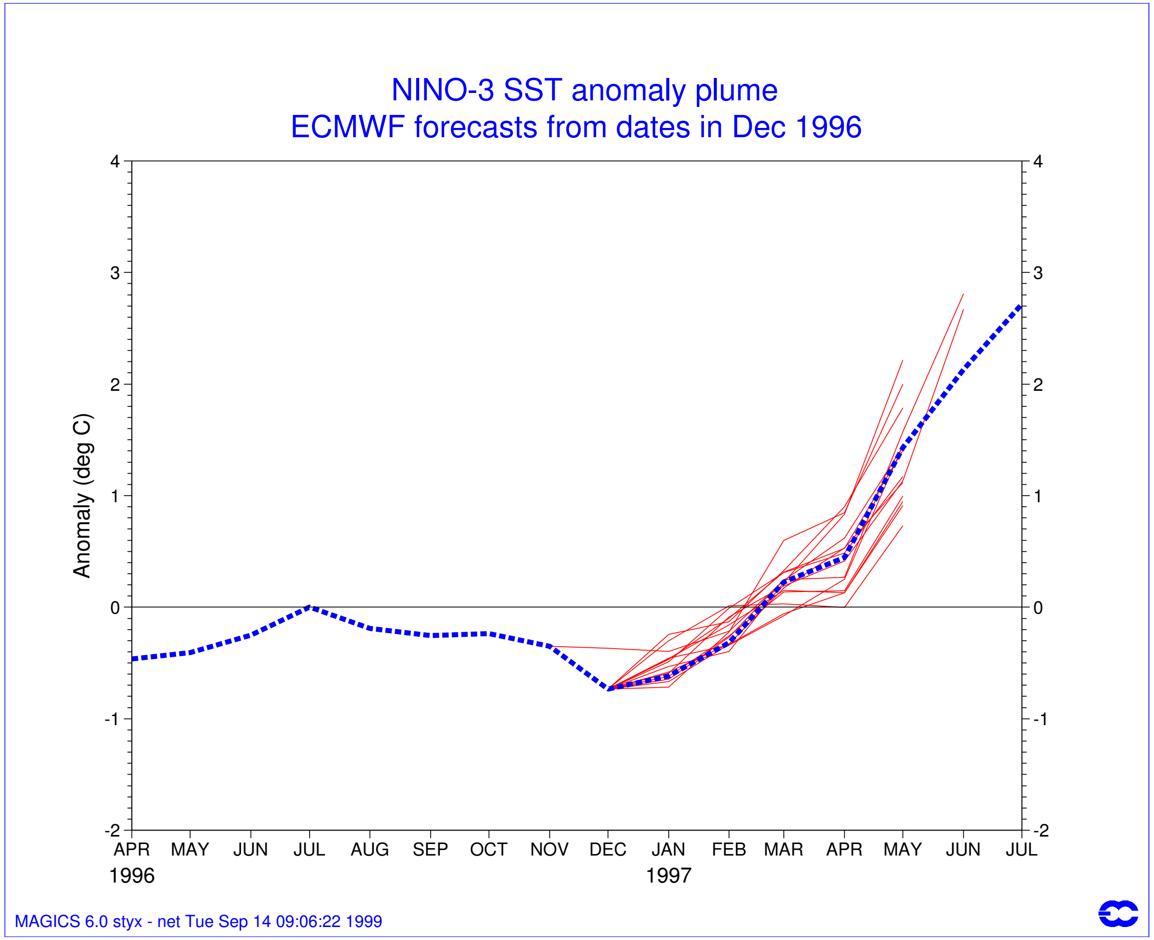
$(\partial N_3/\partial\tau_x)\cdot\delta\tau_x$ [$10^{-15}\ \mathrm{Km^{-2}day^{-1}}$]

Connected to the MJO?



However. . .

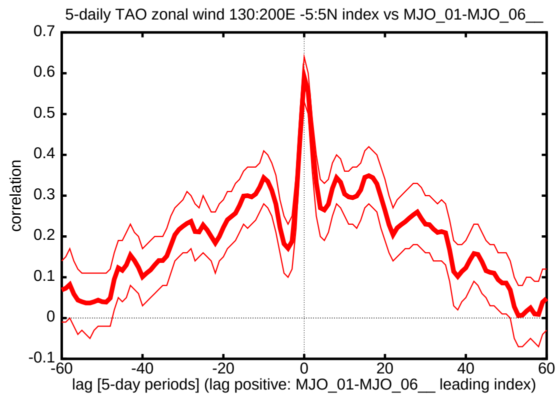
The ECMWF seasonal forecast model, with almost the same ocean model, managed to predict the 1997 onset quite well in forecast mode (and had no El Niño in the 1996 hindcasts)

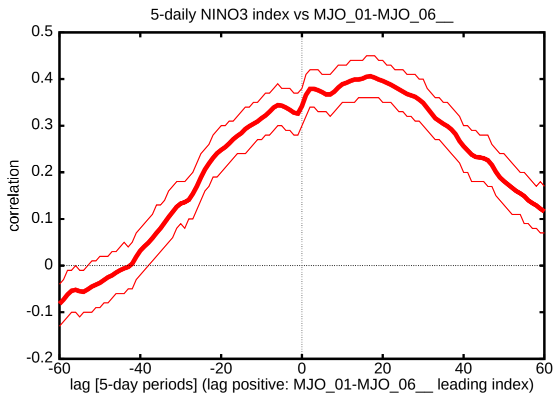


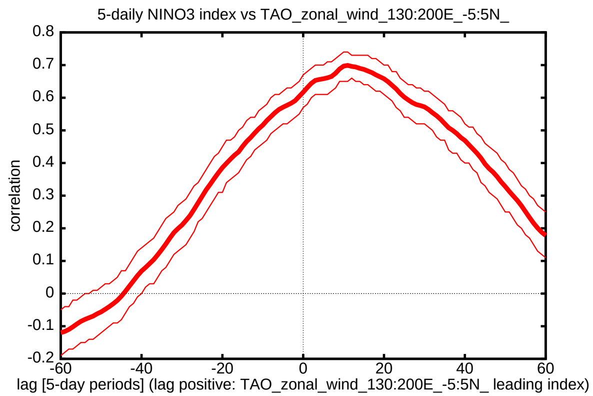
Statistics

Using 5-daily MJO indices from CPC 1978–now, weekly Niño3 from NCEP 1981–now, daily 4m wind from TAO 1990–now, all interpolated to 5-daily and monthly means.

Lag correlations: MJO vs zonal surface wind, wind vs ENSO, MJO vs ENSO.







Chicken and egg problem. . .

We only consider *changes* in Niño3 apart from damped persistence:

$$N'_{3,l}(t) = N_3 - \alpha(m,l)N_3(t-l)$$

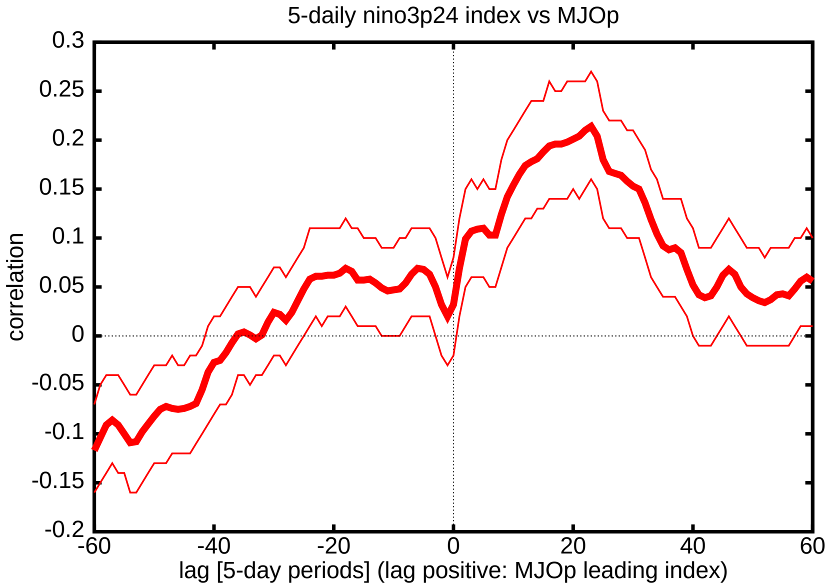
at lag 4 months, and the MJO and 4m zonal wind indices with the simultaneous influence of Niño3 subtracted:

$$\mathrm{MJO}'(t) = \mathrm{MJO}(t) - \beta(m)N_3(t)$$

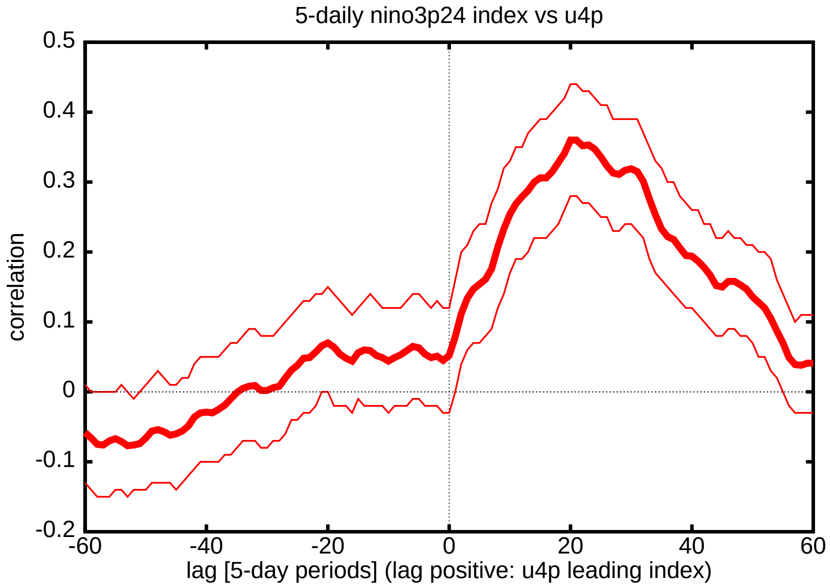
$$u'(t) = u(t) - \gamma(m)N_3(t)$$

These show clear relationships.

5-daily data

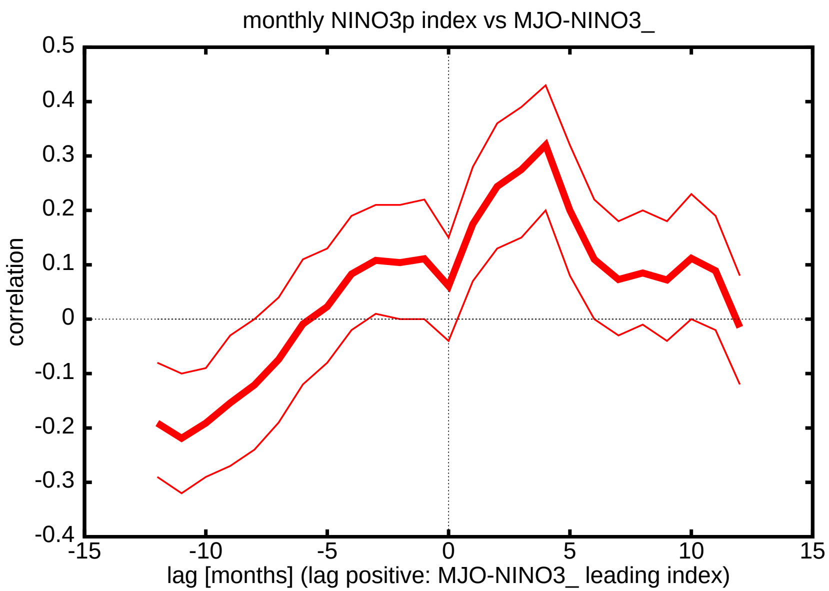


lag correlations of Niño3′ with MJO′

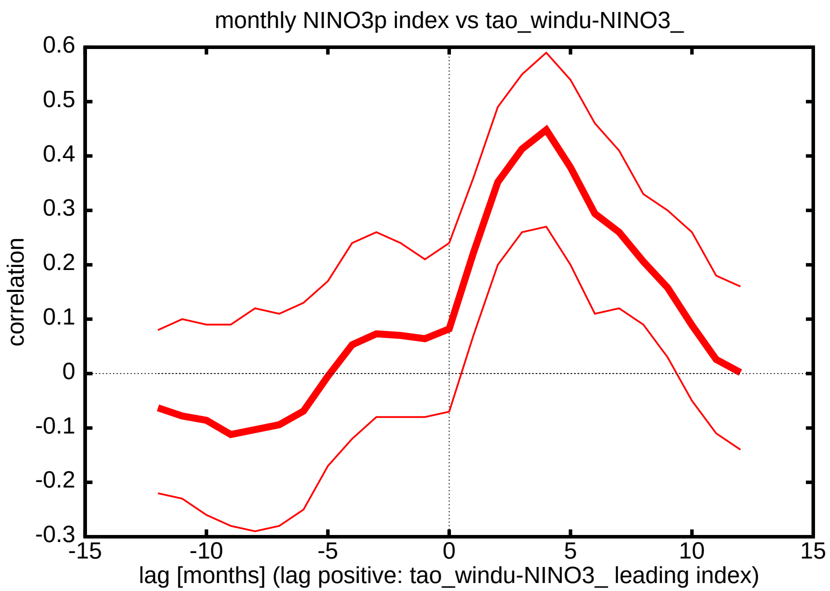


lag correlations of Niño3′ with u'

monthly data

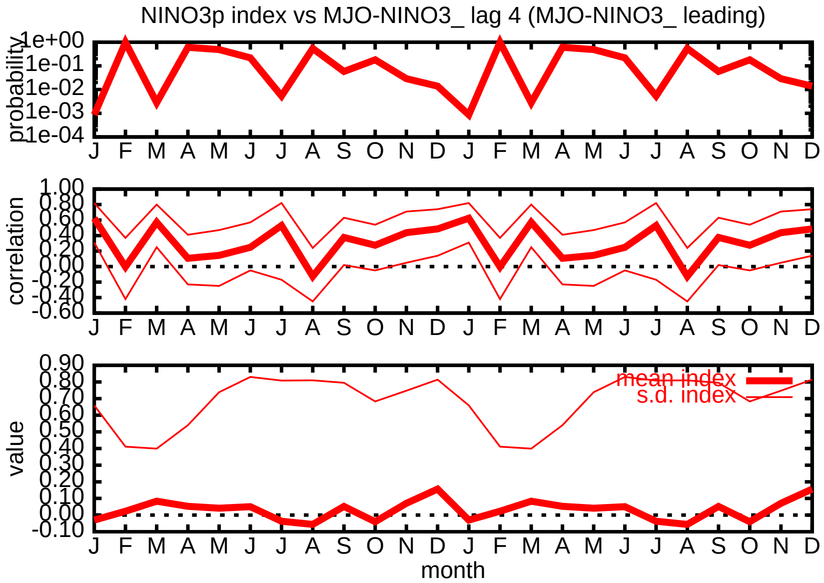


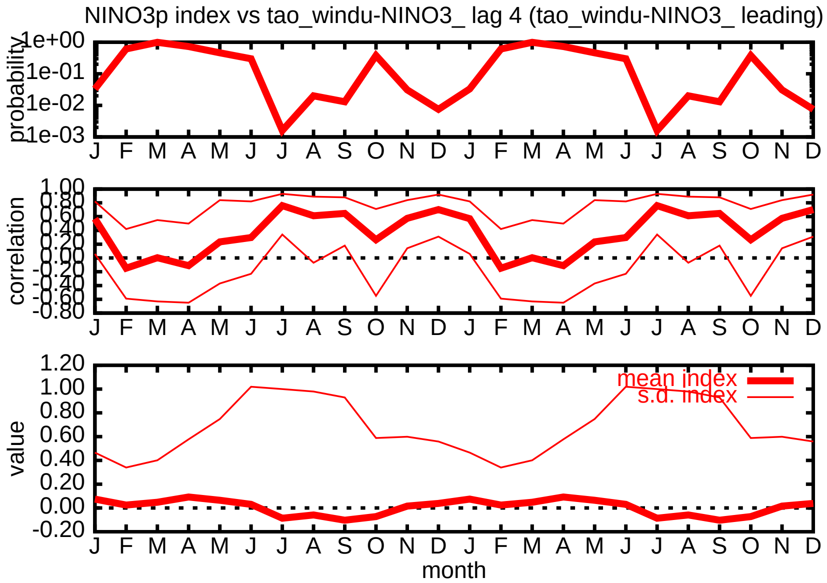
lag correlations of Niño3′ with MJO′



lag correlations of Niño3′ with u'

Seasonal cycle





lag-4 correlation of Niño3′ with MJO′

lag-4 correlation of Niño3′ with u'

Hypotheses

- Variations in the *mean* zonal wind stress in the equatorial wave guide that are independent of ENSO determine around 20% of the variations of Niño3 around damped persistence four months later,
- The effect is enhanced by its seasonality: 50% of July to January N_3', and virtually nothing the rest of the year, February to June.
- The long-term variations of the MJO *mean* determine around 30% of the variance of the zonal mean wind stress, more in June–August (when it is irrelevant), less the other months

Model results

- Ocean model: linear shallow water model (GMODEL)
- SST equation: linear tendencies proportional to thermocline depth (east) and wind stress (central) with stronger damping in the east, estimated from data and tuned to give good forced results,
- Atmosphere model: 2-parameter (N_3, N_4) statistical regression of zonal and meridional wind stress,
- Noise: residues of the zonal wind stress model projected on the N_3, N_4 patterns, amplitude from data, time structure either white noise or white noise with a red component deduced from observations.

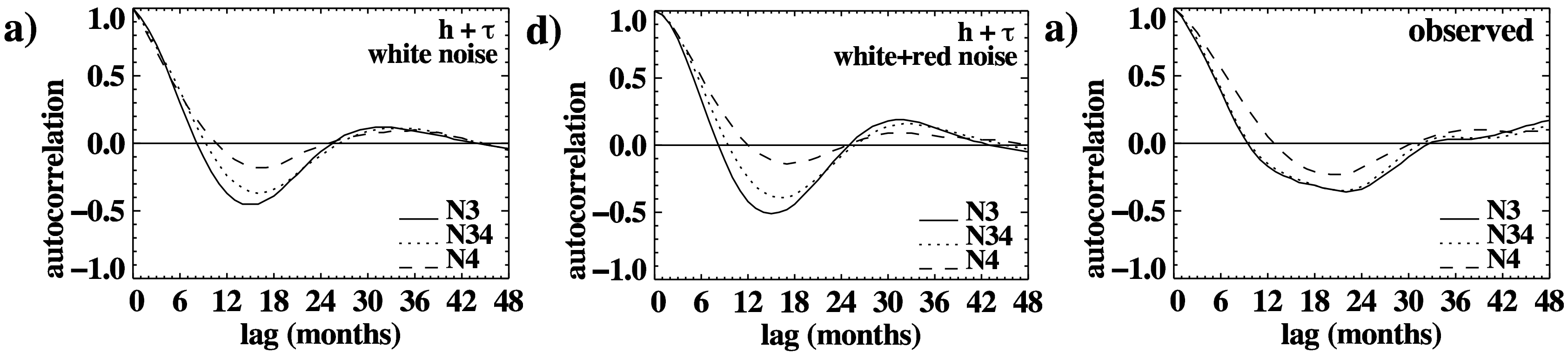
This model works according to the first hypothesis: ENSO is driven by the integrated white noise in zonal wind stress. This is almost equal to the Warm Water Volume.

Results

Amplitudes are very good with red noise

	white	white+red	obs
σ_{N3}	0.32	0.92	1.02
σ_{N34}	0.31	0.90	0.94
σ_{N4}	0.24	0.68	0.68
r(N3,N4)	0.78	0.80	0.75

although the autocorrelation function is too regular



white noise red+white noise observed

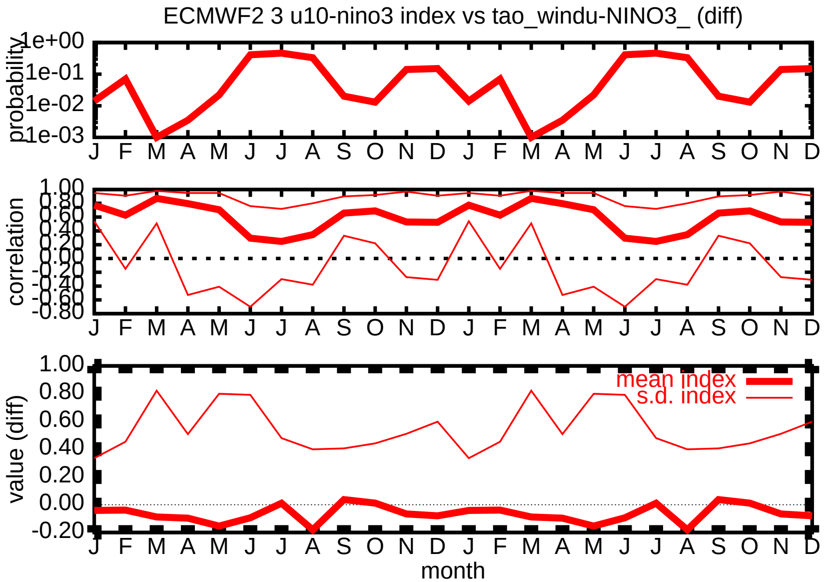
- Even without seasonal cycle, a linear ENSO model driven by observed amplitude high-frequency zonal wind variations gets the size of ENSO right by integrating the noise.
- Next project: seasonal dependence noise and model parameters.
- Next project: add essential non-linearities to the ocean model.

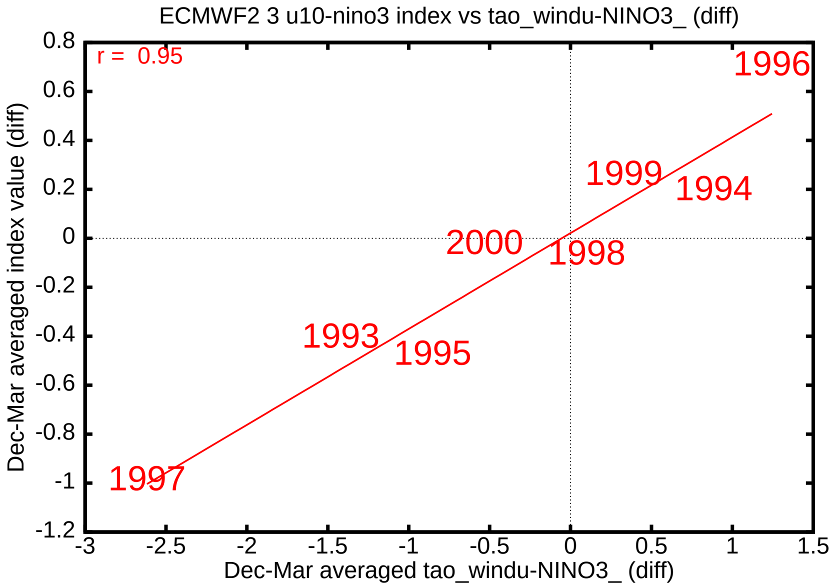
Predictability

Individual MJO oscillations or westerly wind events are unpredictable at seasonal time scales, but is the *average* zonal wind more predictable? That would explain the discrepancy between the adjoint model and forecast model results for spring 1997.

Model: ECMWF seasonal forecast model system-2, 15 years of hindcasts/forecasts 1987–2001 starts. Again we subtract the influence of (model) Niño3.

Seasonal predictability of U10 apart from ENSO

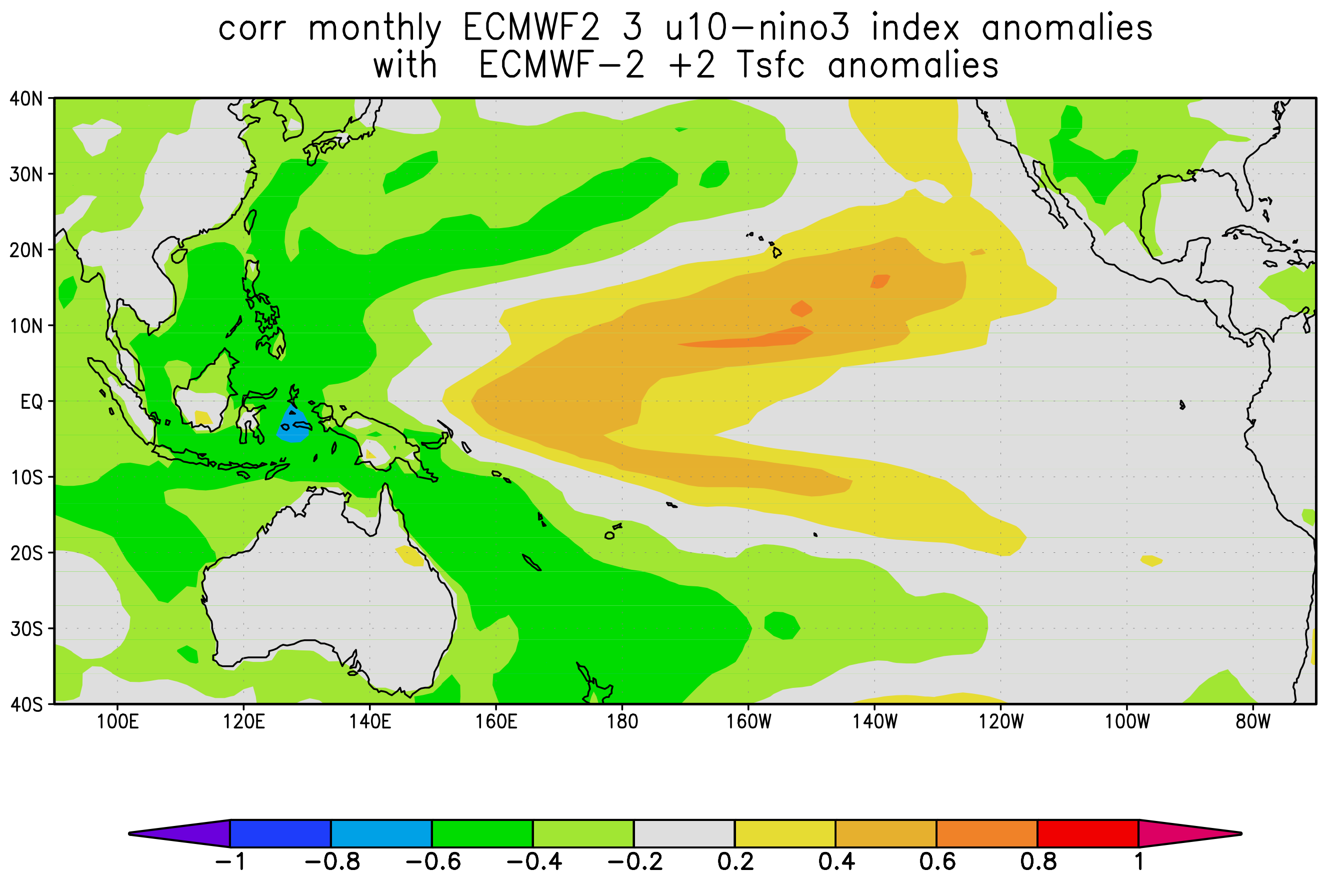




There was good seasonal predictability of the average zonal wind in the equatorial wave guide from September to May. In particular, December 1996 to March 1997 were *predicted* to have higher average zonal wind than Dec 1995 to March 1996.

SST pattern

The zonal wind in the equatorial wave guide in the model depends on the following pattern (apart from Niño3), this is known to be associated with non-ENSO predictability in the region.



Preliminary conclusions

- From July to January prior zonal wind variations perturb ENSO beyond damped persistence.
- The monthly mean of the wind is important, not the high-frequency variations; no scale interactions are necessary beyond the seasonal cycle.
- The monthly mean of zonal wind in this area is quite predictable due to non-ENSO SST variations, explaining the good ENSO forecasts through spring 1997.