# El Niño Preconditioning During the 2000's

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## Introduction

**Long time series of high quality ocean surface topography (SL from TOPEX/Poseidon and Jason 1), sea surface temperature (SST), subsurface temperature ($T_z$) and salinity ($S_z$) observations allow a thorough comparison between distinct El Niño conditions. In this study, these data are assimilated using the Ensemble Reduced-Order Kalman Filter (EROKF) technique to improve the initial state of the ocean for November of each year. Ocean model experiments are then used to isolate differences between initial states of the system for El Niño/non-El Niño development for each year, 2001-2007 and the big 1997 event is included for comparison purposes. A statistical atmospheric model is utilized to highlight the atmospheric response to anomalous SST fields. The 1997 El Niño showed a strong ocean-atmosphere coupled system which propagated from west to east leading to an intense El Niño. The weaker 2002 and 2006 events developed later in the calendar year and showed strongest anomalies near the dateline which shifted east in July. Strong easterlies to the east of the westerly wind region served to cap both the 2002 and 2006 events. For the 2007 forecast, our analysis shows a gradual weakening of the mild SST anomaly associated with the 2006 El Niño to near neutral conditions.**

## Methodology

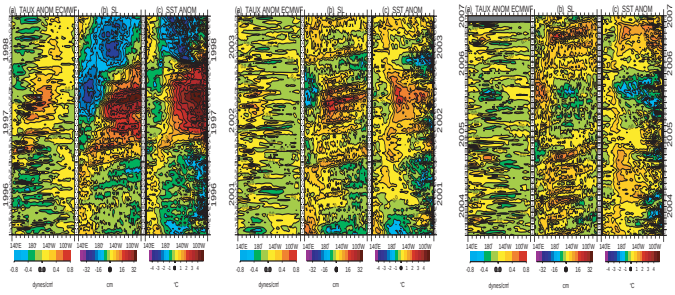
Isolation of Initial Conditions

| EXPERIMENT NAME | INITIAL CONDITIONS | FORCING |
|---|---|---|
| $IC_{96}$–$FOR_{CLIM}$ | Nov 96 Data Assim Results ($IC_{96}$) | Climatological ($FOR_{CLIM}$) |
| $IC_{01}$–$FOR_{CLIM}$ | Nov 01 Data Assim Results ($IC_{01}$) | Climatological ($FOR_{CLIM}$) |
| $IC_{02}$–$FOR_{CLIM}$ | Nov 02 Data Assim Results ($IC_{02}$) | Climatological ($FOR_{CLIM}$) |
| $IC_{03}$–$FOR_{CLIM}$ | Nov 03 Data Assim Results ($IC_{03}$) | Climatological ($FOR_{CLIM}$) |
| $IC_{04}$–$FOR_{CLIM}$ | Nov 04 Data AssimResults ($IC_{04}$) | Climatological ($FOR_{CLIM}$) |
| $IC_{05}$–$FOR_{CLIM}$ | Nov 05 Data Assim Results ($IC_{05}$) | Climatological ($FOR_{CLIM}$) |
| $IC_{06}$–$FOR_{CLIM}$ | Nov 06 Data Assim Results ($IC_{06}$) | Climatological ($FOR_{CLIM}$) |
| $IC_{CLIM}$–$FOR_{CLIM}$ | Nov Climatological ($IC_{CLIM}$) | Climatological ($FOR_{CLIM}$) |

El Nino experiment pairs:
1997: $IC_{96}$–$FOR_{CLIM}$ - $IC_{CLIM}$–$FOR_{CLIM}$
2002: $IC_{01}$–$FOR_{CLIM}$ - $IC_{CLIM}$–$FOR_{CLIM}$
2006: $IC_{05}$–$FOR_{CLIM}$ - $IC_{CLIM}$–$FOR_{CLIM}$

**Experiment pairs are used to isolate the role of the initial state for all Novembers from 2001 until 2006. First a model experiment is forced by climatological (ECMWF) winds for 14 months using November initial conditions derived from data assimilation (SL, SST, $T_z$, and $S_z$). Next a similar experiment is started from the climatological November state. The climate experiment is then subtracted from the experiment initiated from the real November state. Since the only difference between the two experiments is the initial conditions, the role of the initial state of the ocean can thus be isolated. Experiment pairs which highlight the role of the initial state for El Niño years are underlined in red in the Table to the left.**

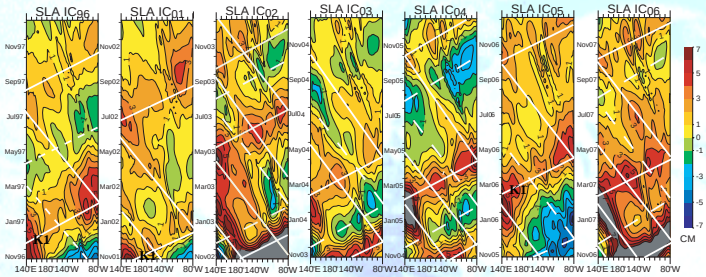
## Background Observations



**Equatorial longitude versus time plots for observed zonal wind stress anomaly from ECMWF (left), SL anomaly from TOPEX/Poseidon and Jason 1 (middle) and SST anomaly (right) for the periods 1996-1998 (left group of three columns), 2001-2003 (middle group) and 2004-present (right group of three). For all three El Niño events (1997, 2002, 2006) westerly wind anomalies in the western Pacific are followed by positive SL anomalies moving from west to east (ie. downwelling Kelvin waves) leading to warming in eastern Pacific SST. Note that the 1997 event shows the anomalous westerlies propagating to the east leading to this unusually strong event. This contrasts with 2002 and 2006 since westerlies are generally limited to west of the dateline for these events. Also note the weak La Niña developing in 2005.**

## Role of Isolation of Initial Conditions

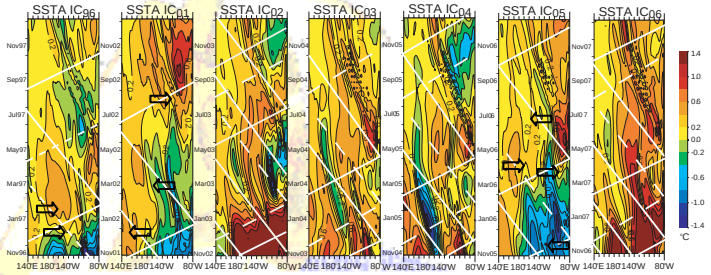
### Sea Level



**Equatorial longitude versus time for SL anomalies from experiments designed to isolate the role of the initial conditions. The starting year for each experiment is indicated at the top of each figure. El Niño years are $IC_{96}$, $IC_{01}$ and $IC_{05}$. SL anomalies are converted to Kelvin and Rossby waves using the technique of Delcroix et al., 1994. Solid (dashed) lines represent downwelling (upwelling) Kelvin (positive slope) and Rossby (negative sloping lines), respectively. The timing of the original downwelling Kelvin wave (K1) leaving the eastern boundary changes for the different events (Dec 96, Oct 01 and Mar 06) due to varying arrival times of the downwelling Rossby waves present in the initial conditions. Strong upwelling early in the 2006 event differentiates this event from the 1997 and 2002 El Niños. Also note that this methodology correctly simulates the 2005 La Niña which developed from the $IC_{04}$ initial state.**

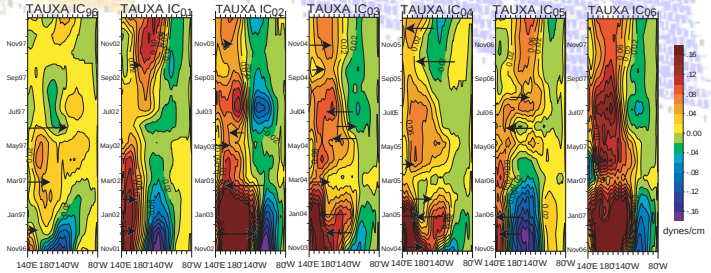
## Role of Isolation of Initial Conditions

### Sea Surface Temperature



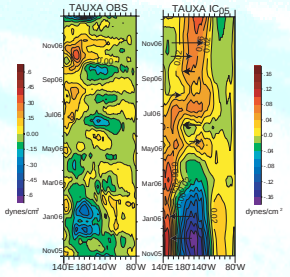
**Same as previous but for SST. Prior to Jun 97, downwelling Kelvin (DK) and upwelling Rossby (UR) waves move warm SST to the east for the $IC_{96}$ case. For $IC_{01}$, downwelling Rossby (DR) waves arriving at the WB in Feb 02 and Jun 02 bottled up warm SST in the west until Jul 02 when the DK wave allowed escape of warm SST to the east. The $IC_{04}$ UK wave arriving in Nov 05 signals the correct timing for the start of the 2005 La Niña. However, cold filaments stretching from 140°W for November IC to around 180°W in May are consistent with the speed and spatial scale of Tropical Instability Waves (see especially $IC_{04}$). For $IC_{05}$, an upwelling Kelvin (UK) wave arriving at the EB in Dec 05 serves to cool the eastern Pacific until the combined effects of the DK (WB-Mar 06) and UR waves (EB-Dec 05) allow eastward migration of warm SST. The westward advection of cold water due to DR wave starting from the EB in May 06 stunts the development of this event. Warm SST gradually cools signaling a relaxation of the 2006 El Niño (similar to $IC_{02}$ experiment). Arrows indicate current direction associated with K/R waves.**

## Zonal Wind Stress



**Longitude/time of zonal wind stress anomaly resulting from the statistical atmospheric model forced by anomaly SST from above. Arrows indicate observed wind anomalies. For $IC_{96}$, initial conditions alone provided favorable conditions for westerlies to migrate east between Jan and Jun 97 setting the stage for the intense event. For $IC_{01}$ and $IC_{05}$, strong easterlies to the west of 180° limited the growth of the 2002 and 2006 El Niños by destructive interference until the characteristic eastward jump of the westerlies occurred in July. For $IC_{04}$ (La Niña year), the easterly patch at the dateline between Jan-Mar 04 corresponds with the cold SST filament shown in previous figure, bifurcates strong westerlies, and may be significant for La Niña prediction. $IC_{02}$ and $IC_{06}$, initiated from El Niño conditions, shows capping easterlies to the east of the warmest anomaly with $IC_{06}$ displaced east by 20°.**

## Zonal Wind Stress – 05 Forecast versus Observed



**The forecast for the 2006 El Niño is highlighted in this figure. The left panel shows the observed zonal wind anomaly for Nov 05-Dec 06. The right panel is a repeat of the $IC_{05}$ zonal wind stress results. Note the close correspondence between the observed and forecast for the major wind events – easterlies Nov 05 to Apr 06 near the dateline, westerlies 180-120°W in May 06 and easterlies in the same region in Jun 06, and the increasing fetch of the westerlies in Aug 06. The good correspondence between observed and forecast zonal wind stress demonstrates the potential of the isolation of the initial state technique.**

## CONCLUSIONS

- **Using data assimilation, initial states of the system ($IC_{96}$, $IC_{01}$ and $IC_{05}$) are predisposed to induce subsequent El Niño events – *predictable 14 months in advance***
- **The initial state induces an eastward propagating wind field which leads to an intensification of the 1997 event whereas the capping easterlies, inherent in the IC for 2002 and 2006, serves to limit El Niño growth**
- **In La Niña/Neutral years (especially $IC_{04}$) cold water filaments (with same scale and speed as TIW) and concomitant easterly anomalies serve to disrupt westerly signals**
- **Wind patterns of big El Niño (ie. 1997), moderate El Niño (2002, 2006), La Niña (2005) and non-El Niño years derived from experiments using the initial state *are distinct, reproducible and easily recognized well in advance of the event***
- **Application of this technique improves the outlook for coupled model ENSO forecasts *and should be incorporated as a forecast tool***

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