HOW WELL DO MODELS WITH TOPEX/POSEIDON ASSIMILATION SIMULATE THE SALINITY VARIABILITY IN THE EQUATORIAL PACIFIC?

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INTRODUCTION:

The variations in heat content of the tropical ocean are situated in the upper layer, mainly above the depth of the main thermocline This feature has been commonly used to infer their variations from the variability of sea level height observed from space. As stated as a proxy for the upper ocean heat content, altimeter data also represents a valuable constraint on the subsurface thermal structure for models that suffered from inaccuracy of the heat and wind forcing and from biases in their subsurface structure due to an inadequate representation of the physics.

Cross comparisons between altimeter and tide gauges data highlighted some residual errors in order of 5-10 cm in sea level variations reproduced by the assimilation system used at NCEP during 1996 (Ji *et al.*, 2000). These discrepancies could be interpreted as errors resulting from the salinity variability that was not accounted for in the analysis due to the absence of in situ salinity observations.

In the western Pacific warm pool, the salinity stratification is moreover suspected to play an important role in the onset of El Niño due to the presence of barrier layer (**Figure 1**). It has been also hypothesized that the barrier layer may influence the recharge and discharge of heat associated with the phases of the El Niño - Southern Oscillation (ENSO). Recently, the failure for ENSO to develop due to the removal of the barrier layer in a coupled model was demonstrated by Maes *et al.* (2002a). **Figure 2** shows the coupled response in SST when salinity barrier layer is taken into account or not in the warm pool during the development of a strong El Nino event.

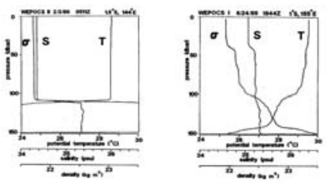

Figure 1: Vertical profiles of temperature, salinity and density in the western Pacific Ocean observed from oceanographic cruises (Lukas and Lindstrom, 1991). The left profiles display an homogeneous mixed layer deeper than 100 m whereas the right profiles show the presence of a salinity stratification within the quasi-homogeneous warm waters that controls the density profile. In such a case, the mixed layer is not deeper than 40 m and the difference between this layer and the depth of the isothermal layer (ΔT=0.5°C) defines the barrier layer thickness.

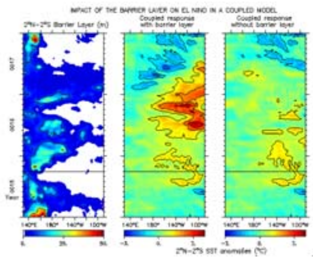

Figure 2: Longitude/time diagrams of barrier layer thickness (left) and SST anomalies in a coupled model. The middle panel shows the response with barrier layer whereas the right panel shows the response of the model when the barrier layer is destroyed (Maes *et al.*, 2002a).

METHODOLOGY:

Due to the present lack of salinity observations, an indirect estimation along the water column has been developed by Maes and Behringer (2000). This approach aims to reconstruct the salinity variability based on dominant statistical modes representing the joint variability of temperature and salinity derived from historical Conductivity-Temperature-Depth profiles. The description of the modes as well as their respective signature in sea level at the scale of the tropical Pacific is detailed by Maes *et al.* (2002b). The estimates are based on a least squares fit to temperature and to sea surface salinity (SSS) data when they are provided by the TAO/TRITON array (**Figure 3**). The computation of the statistical modes and the determination of the salinity variability have been derived to consider the conjoint variability of the sea level.

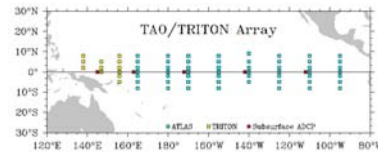

Figure 3: Position of the moorings in the tropical Pacific

MODELS

The complete description of the different models as well as of their assimilation methods is beyond the scope of this poster. The model physics, forcing fields and the assimilation techniques are all different. Some details are given in **Table 1**. The salinity information is considered either from synthetic salinity profiles based on a climatological T-S relationship (NCEP case) or from their contribution in the TOPEX/Poseidon sea level.

	Description	Forcing	Assimilation method & Data	Reference/ Contact
SODA (beta 7)	MOM 0.5° by 1° 20 levels monthly	COADS	Optimal Interpolation In-situ T and S, altimetry	Carton *et al.* (2000)
NCEP (GODAS)	MOM 0.3° by 1° 40 levels monthly	NCEP	3D-var by Derber and Rosati (1989) In-situ T and synthetic S	Behringer *et al.* (1998)
ECCO 2	MOM 0.3° by 1° 46 levels 10-day	NCEP/ COADS	Kalman filter Altimetry only	Fukumori *et al.* (1999)
MERCATOR GLOBAL MODEL (MGM)	OPA-ORCA 0.5° by 2° 31 levels 7-day	ECMWF	SOFA (O.I.) + Cooper and Haines (1996) Altimetry only	Nicolas Ferry (Mercator group)

Table 1: brief description of the different ocean data assimilation system.

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RESULTS

The variability in terms of SSS and barrier layer based on the indirect estimations has been previously detailed in Maes (2000) and has been extended to the 1993-2001 period in **Figures 4 and 5**. These results raise some questions about the potential impact of the barrier layer before the onset of the 1997-98 and 2001-02 El Niño events and they motivate, in large part, this comparison study.

Main points for SSS (Figure 4)

* The main features of the SSS are well reproduced with the presence of fresh waters in the warm pool and in the far eastern part of the basin separated by saltier waters in the central Pacific.

* The variability is often too weak in models and this is due, for a large part, to a strong damping toward climatological value. The front associated with the fresh-warm pool of the western Pacific is too diluted in some models and its variability is not necessary in phase with the displacements of the warmest waters (SST > 29°C).

Main points for Barrier Layer (Figure 5)

* If barrier layer could be evidenced in the different models, its spatio-temporal variability is not in agreement with the indirect estimate. For example, variability such as the eastward extension of the barrier layer during the mature phase of the 1997-98 El Niño is viewed by models only.

* Several models are able to simulate a reasonable barrier layer within the warm pool prior to the onset of the 1997-98 El Niño. The situation is less clear in 2001 where most of the models do not exhibit the presence of barrier layer.

SSS & BARRIER LAYER THICKNESS AT THE EQUATOR

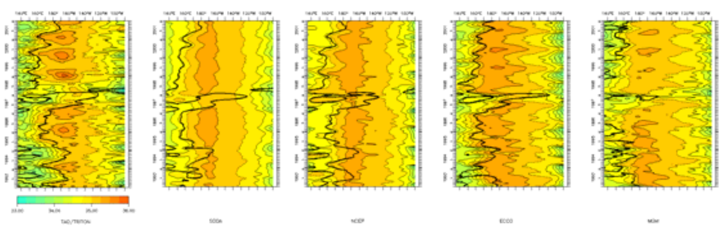

Figure 4: Longitude/time diagrams of SSS along the equator (ci = 0.25). The left panel shows the variability based on the indirect estimates whereas the right panels show the different model response. On each panel, the dark line represents the 29°C isotherm and the dashed line is the 35 isohaline.

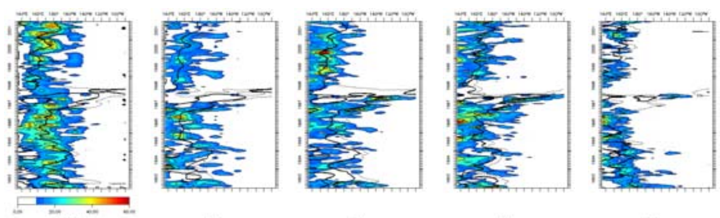

Figure 5: Longitude/time diagrams of Barrier Layer Thickness along the equator (ci = 10 m). The left panel shows the variability based on the indirect estimates whereas the right panels show the different model response. On each panel, the dark line represents the 29°C isotherm and the dashed line represents the 28°C isotherm.

CONCLUSIONS & PERPECTIVES:

The description of the barrier layer over the Pacific warm pool represents an important step to understand in the context of ENSO predictions. Barrier layer may affect the onset of El Niño through changes in mixed layer depth and SST. Nevertheless, due to the present lack of salinity observations, its role is not well accounted for, either in models or in predictions.

Inter-comparison between an indirect estimate and the salinity variability reproduced by different ocean data assimilation systems reveals that, if the SSS features are relatively well captured by models, the variability of the barrier layer is more problematic. None of the models considered in this study is able to reproduce the whole features of the fresh-warm pool of the western Pacific.

These results plead for the continued development of real time observations of in-situ salinity, especially at depth in order to properly estimate the salinity barrier layer.