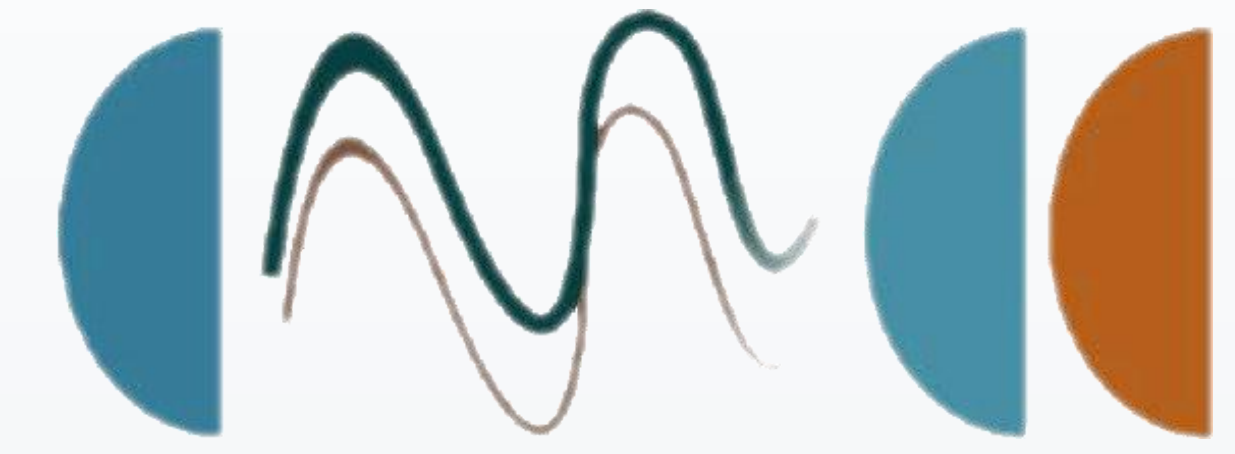


Teleconnections between the Indian Monsoon and the Mediterranean Sea as simulated by a coupled General Circulation Model

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Abstract

The teleconnection patterns between the Indian Monsoon and the Mediterranean Sea climate variability is examined using climate simulations generated by the INGV-SXG, a fully coupled Atmosphere Ocean General Circulation Model (AOGCM) [Scoccimarro et al., 2007, Gualdi et al., 2003a, 2003b]. The study is then validated using available data from ERA-40 reanalysis.

The model is able to reproduce the regions of ascendance/subsidence in general. Anomalies in ω , u , v , relative humidity and precipitation shows a circulation pattern governing both the regions, with its centre of ascendance over the south east Indian Ocean and subsidence over the Mediterranean region. The zonal wind anomalies over the south east Indian Ocean has a significant negative correlation ($r=-0.43$) with that over the Mediterranean region, confirming this relationship.

Background

Rodwell and Hoskins [1996, 2001] proposed that the adiabatic descent induced by the **remote thermal forcing** from the Indian summer monsoon intensifies the descent induced by radiative cooling over the Mediterranean region.

Ziv et. al. [2004] proposed that an intensification of the monsoon enhances both the subsidence over the Mediterranean, via the **circulation** connecting them, and the Etesian winds, due to the enhanced pressure gradient between the two regions.

Model components

Atmosphere: The atmospheric component is **ECHAM4** [Roeckner, 1996]. The release 4.6 used, is the MPI (Message Passing Interface) parallelized version.

Resolution:

Horizontal: Gaussian grid at triangular truncation T106 (about $1.125^\circ \times 1.125^\circ$).

Vertical: 19 hybrid sigma-pressure levels; top level at 10 hPa; 7 layers above 200hPa, 5 layers below 850 hPa.

Coupler: The software used to couple ocean and atmospheric components is **OASIS 2.4** [Valke, 2000]. Its tasks are synchronization of the models being coupled, and the treatment and interpolation of the fields exchanged between the models.

Ocean: The ocean component is **OPA 8.2** [Madec et al., 1999] in ORCA2 configuration.

Resolution:

Horizontal: quasi-isotrope tri-polar grid (2 poles in the northern hemisphere, one over Canada and the other over Siberia. 2° resolution Mercator grid with enhanced meridional resolution in the proximity of the equator and in Med and Red seas (1°).

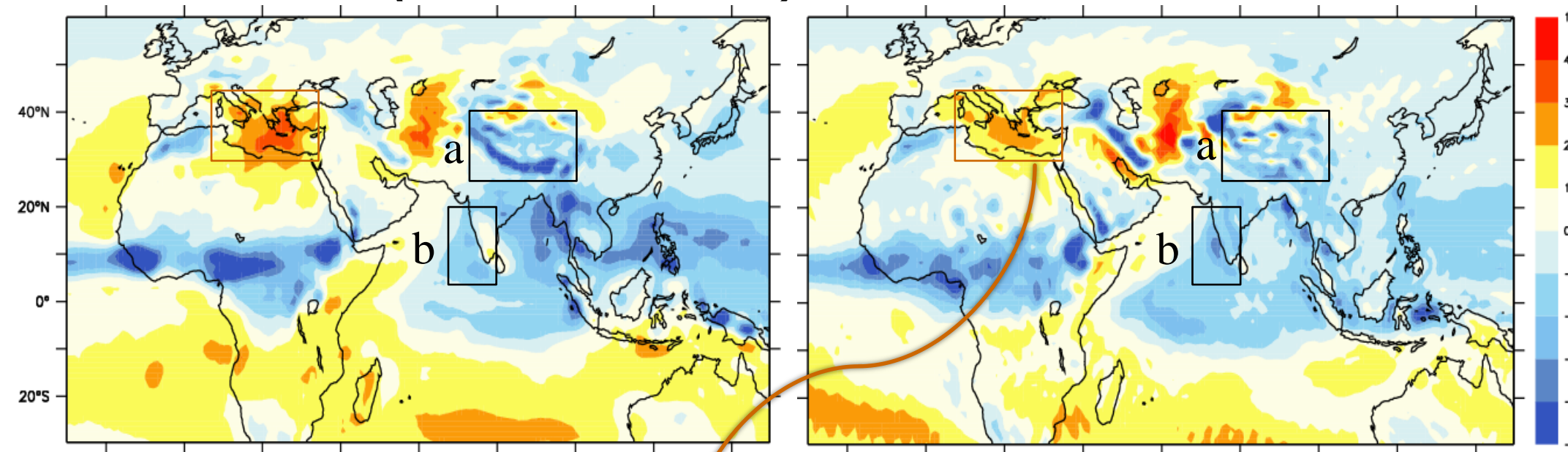
Vertical: 31 vertical levels with 14 levels lying in the top 150 meters.

Data validation

ERA-40: Reanalysis dataset, ERA-40 [Uppala et al., 2005], from the European Centre for Medium-range Weather Forecasting (ECMWF).

Teleconnection in the coupled GCM simulations

Fig.1. Vertical velocity, ω (500hPa), over the Mediterranean and the Indian subcontinent, for the model and observations (JJA 1979-2000).

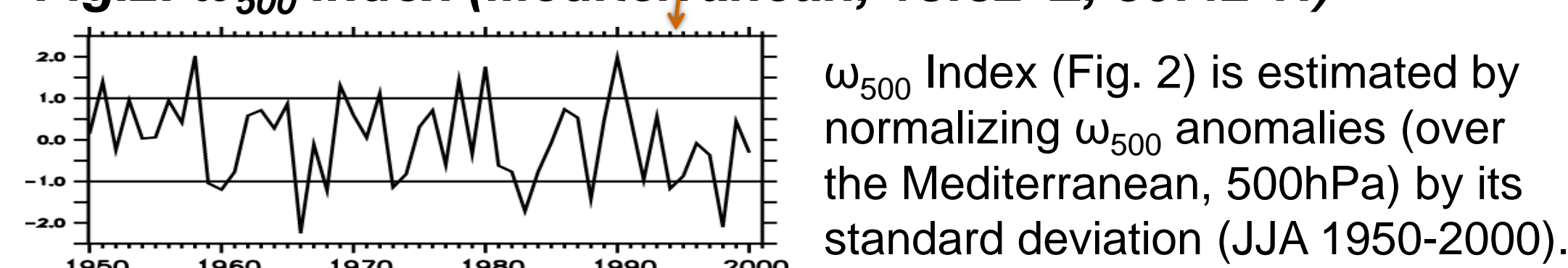


➤ Regions of ascendance/subsidence captured.

➤ The ascendance associated with regions of orographic uplift, (a) Himalayan mountain ranges (b) Western Ghats in the Indian subcontinent is underestimated. → Probably due to a failure of the model in taking care of the orography with respect to the monsoon circulation.

➤ The model simulates precipitation over the leeward side of the Western Ghats, instead of the windward side. However, the model is capable of simulating the precipitation due to the ocean-atmosphere coupling over the Arabian Sea which results in the observed precipitation over the Western Ghats [Roxy and Tanimoto, 2007].

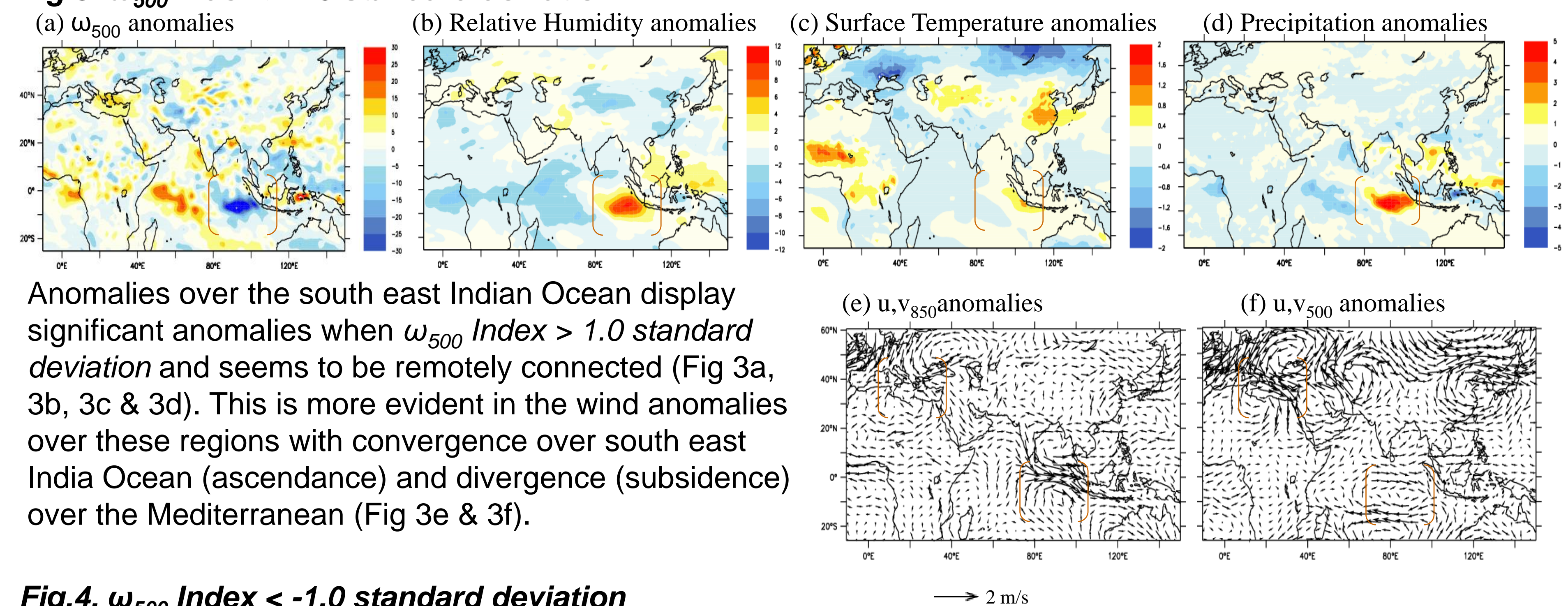
Fig.2. ω_{500} Index (Mediterranean, $18:32^\circ\text{E}$, $30:42^\circ\text{N}$)



ω_{500} Index (Fig. 2) is estimated by normalizing ω_{500} anomalies (over the Mediterranean, 500hPa) by its standard deviation (JJA 1950-2000).

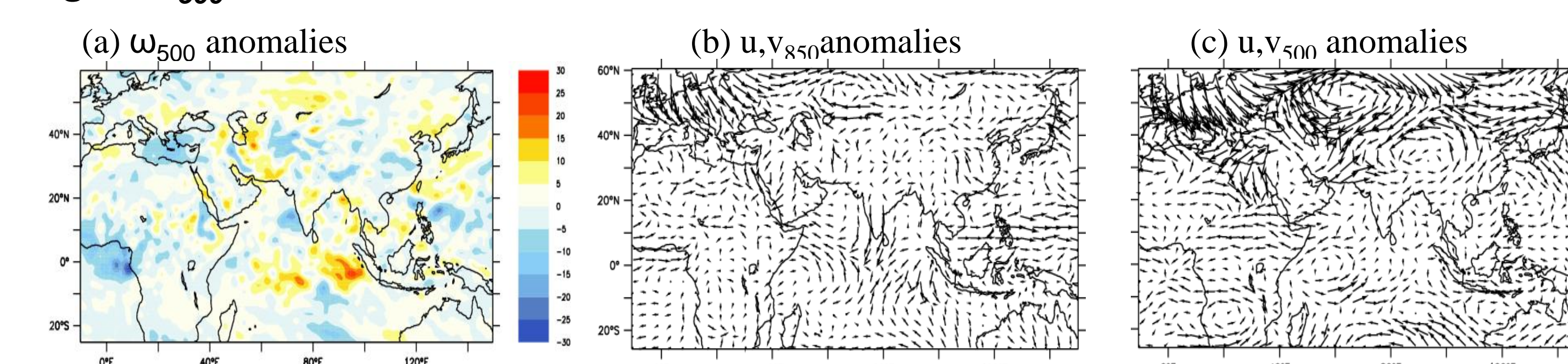
Composites for the atmospheric parameters are prepared for JJA mean for all years (1950-2000) when :

Fig.3. ω_{500} Index > 1.0 standard deviation



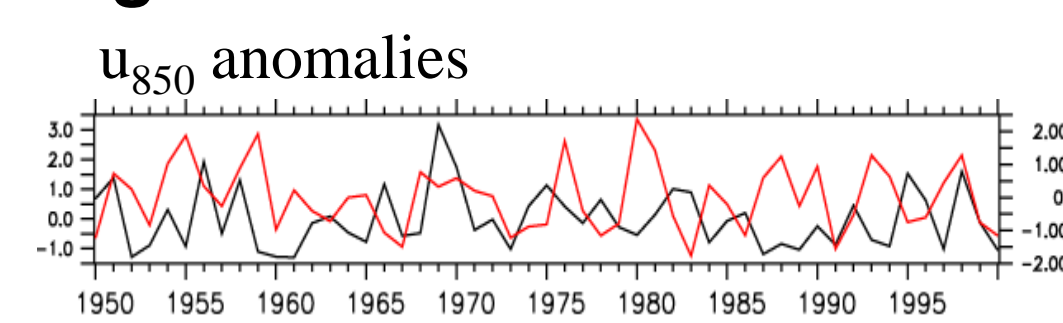
Anomalies over the south east Indian Ocean display significant anomalies when ω_{500} Index > 1.0 standard deviation and seems to be remotely connected (Fig 3a, 3b, 3c & 3d). This is more evident in the wind anomalies over these regions with convergence over south east India Ocean (ascendance) and divergence (subsidence) over the Mediterranean (Fig 3e & 3f).

Fig.4. ω_{500} Index < -1.0 standard deviation



In the central Indian Ocean, the climatological winds are southwesterly. When ω_{500} Index > 1.0 S.D., the anomalies are observed to be southwesterly (resulting in enhanced monsoon circulation) and when ω_{500} Index < -1.0 S.D. the anomalies are observed to be northeasterly (resulting in weakened monsoon circulation). This means that the strength of the monsoon circulation determines the observed anomalies and in turn remotely influences the subsidence over the Mediterranean region.

Fig.5. zonal wind anomalies over Mediterranean ($18:32^\circ\text{E}$, $30:42^\circ\text{N}$) & S.E. Indian Ocean ($85:100^\circ\text{E}$, $10^\circ\text{S}:0$)



The zonal wind anomalies over the south east Indian Ocean has a significant negative correlation ($r=-0.43$) with that over the Mediterranean region during 1980-2000, indicating a common circulation pattern governing these 2 regions.

Concluding Remarks

From the preliminary results, it appears that the model is able to reproduce the regions of ascendance/subsidence in general. Anomalies in ω , u , v , relative humidity and precipitation shows that the **strength of the monsoon intensifies the subsidence over the Mediterranean**, through a common governing circulation pattern, with its centre of ascendance over the south east Indian Ocean and subsidence over the Mediterranean region. Numerical experiments using coupled General Circulation Models may be used to further test the hypothesis suggested in this study and examine the process involved in the remote connection between the 2 regions.

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