Indian Ocean variability

Albert S. Fischer
LODYC, IPSL, UPMC, Paris, France
(now at IOC/UNESCO)
a.fischer@unesco.org

Pascal Terray, Jean-Philippe Boulanger,
Sébastien Masson, Matthieu Lengaigne

LODYC

UNIVERSITE PIERRE & MARIE CURIE
LA SCIENCE A PARIS

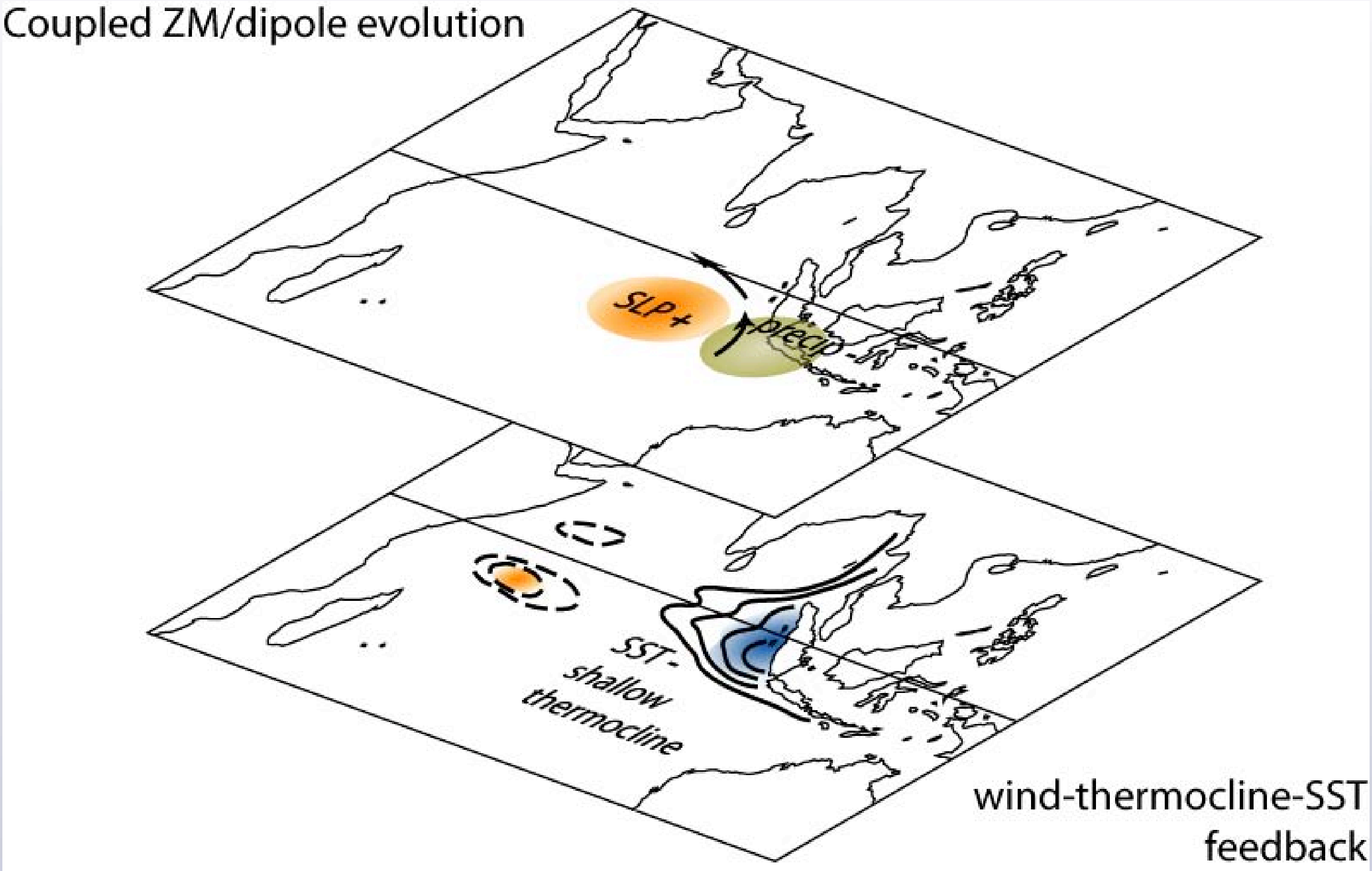
CNRS
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

IRD
Institut de recherche pour le développement

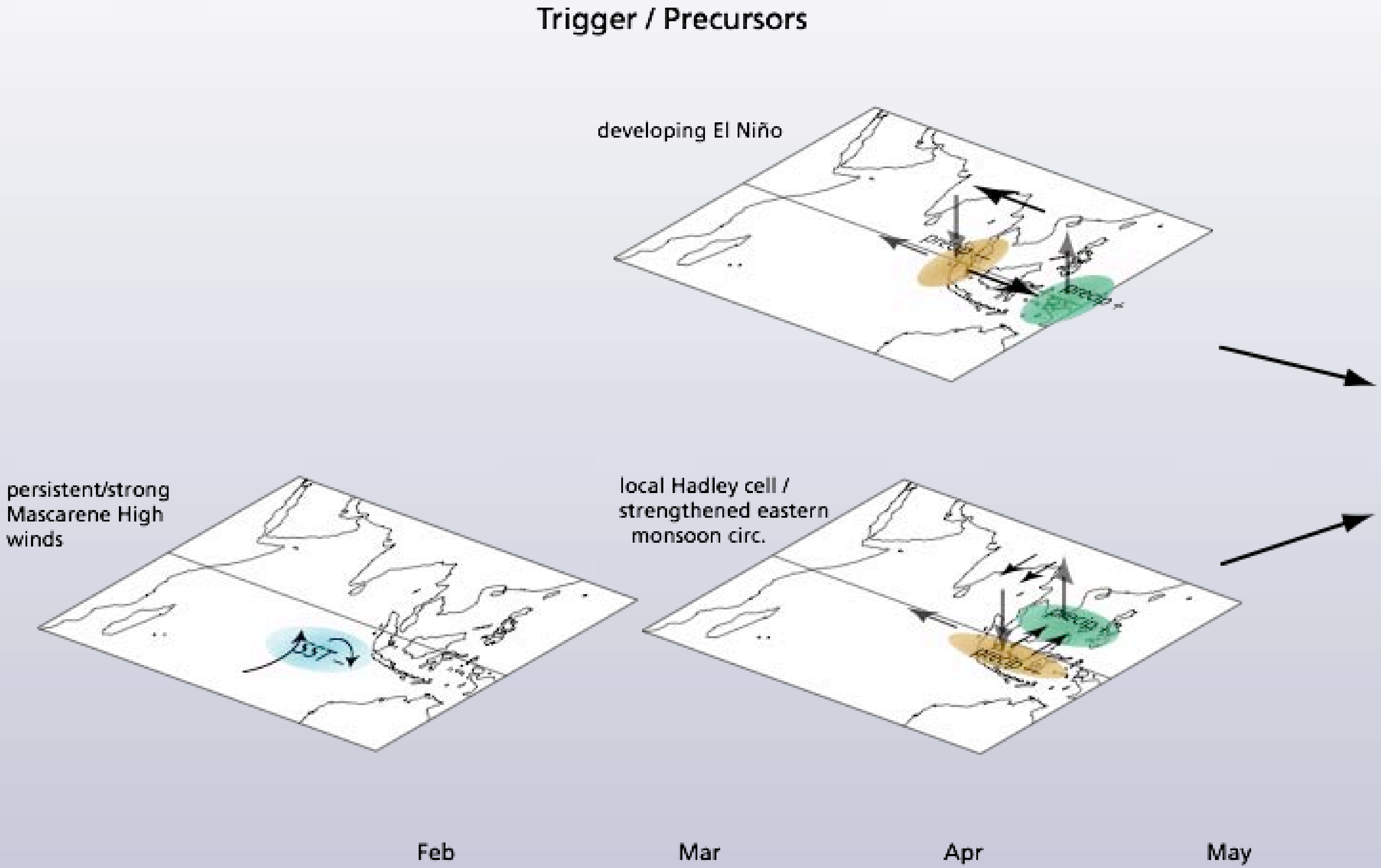
Outline

- Quick introduction to coupled feedbacks and the atmospheric response to heating
- What is the Indian Ocean dipole / zonal mode ?
- The IOD and ENSO
  - Experimental approach : removing ENSO from the coupled system
  - The intrinsic Indian Ocean variability
  - Triggers and the link to ENSO
- The dipole in the context of other Indo-Pacific modes of variability
- A complication: intraseasonal and interannual scale interactions

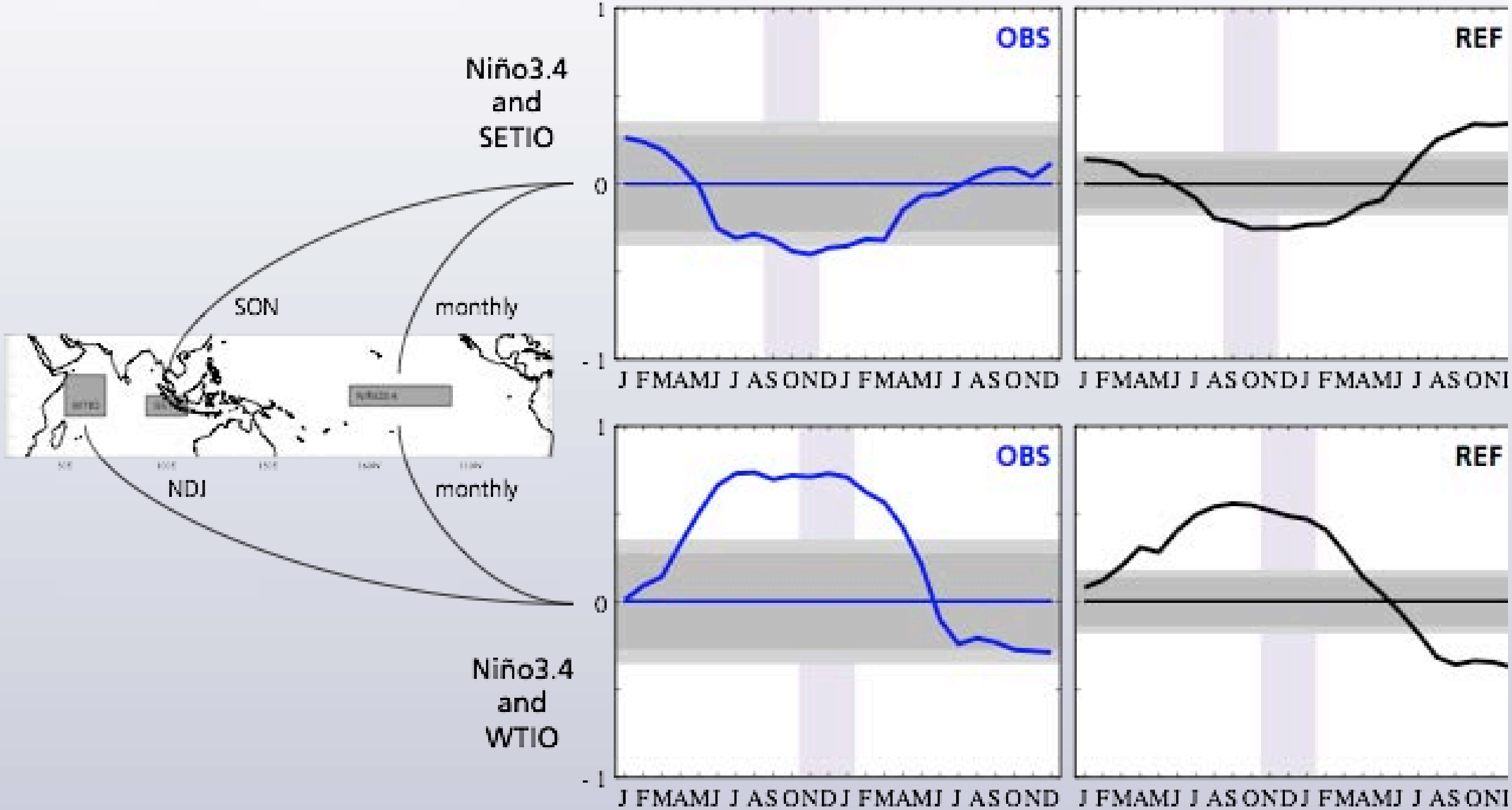
Coupled dipole / zonal mode evolution



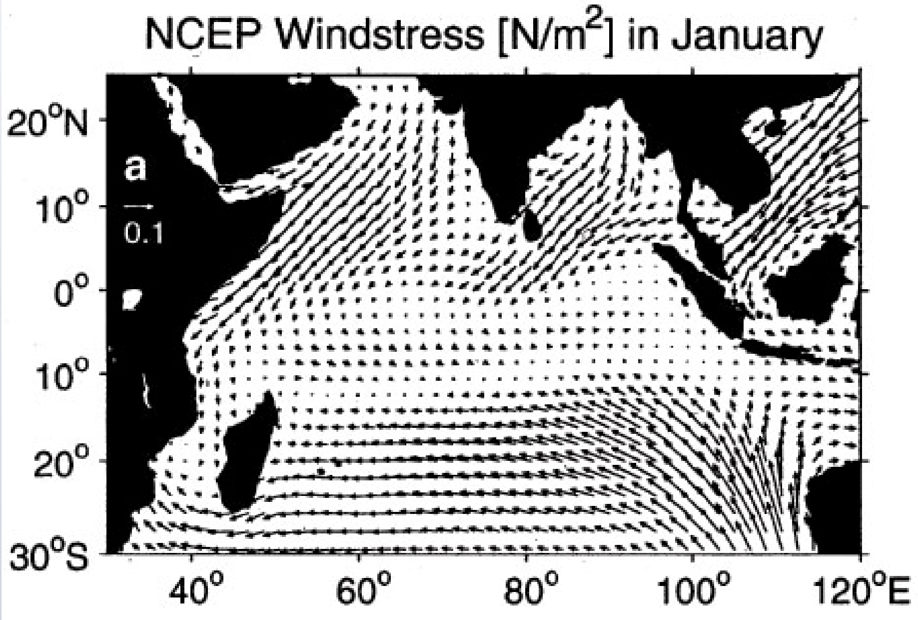
Coupled dipole / zonal mode evolution

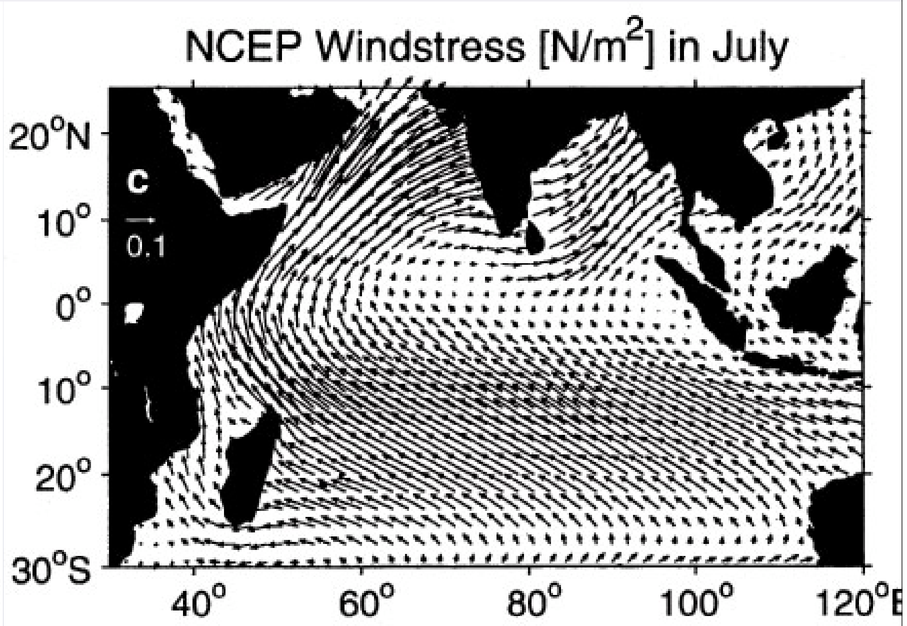


ENSO and the Indian dipole: loosely coupled, often phase-locked



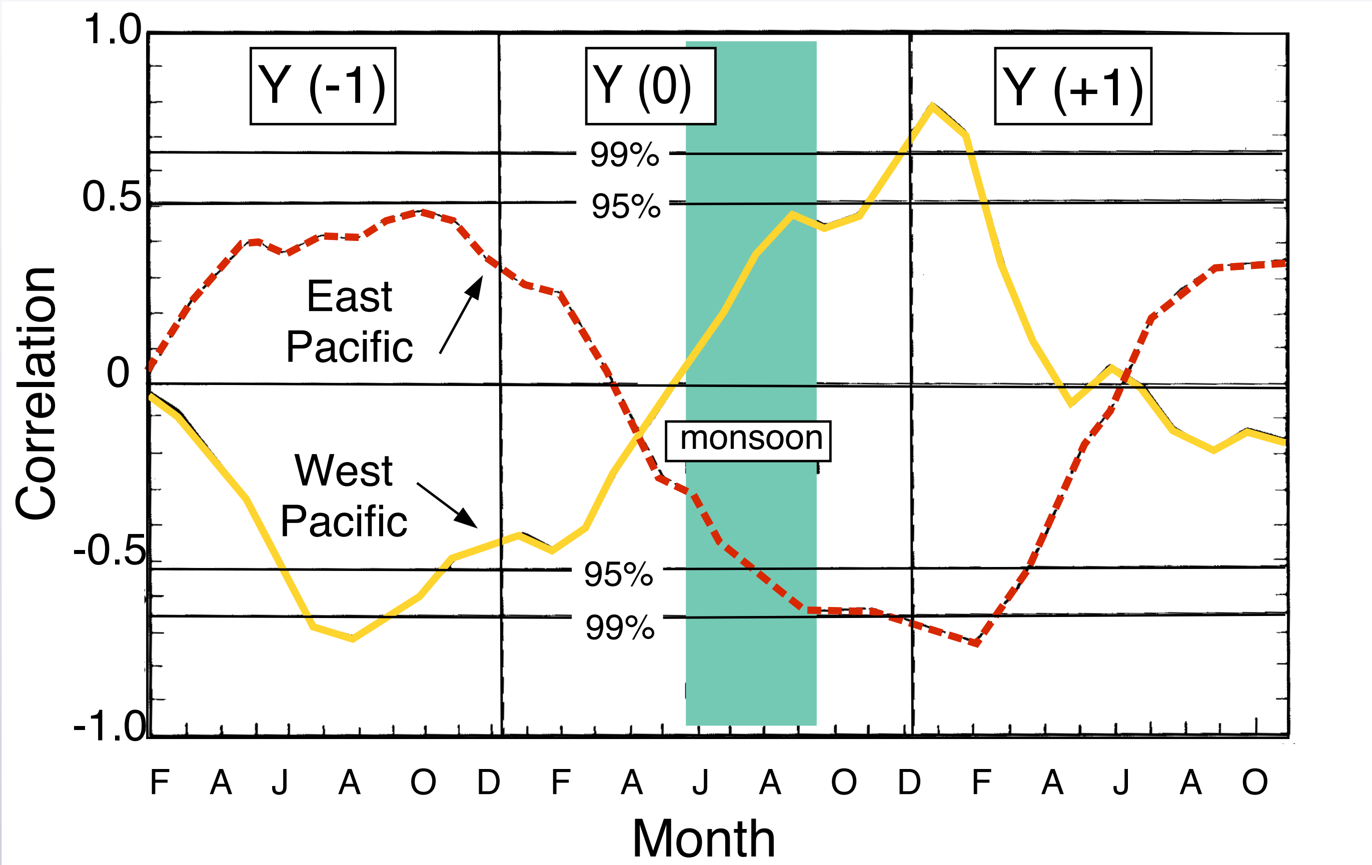
Indian Ocean: monsoon





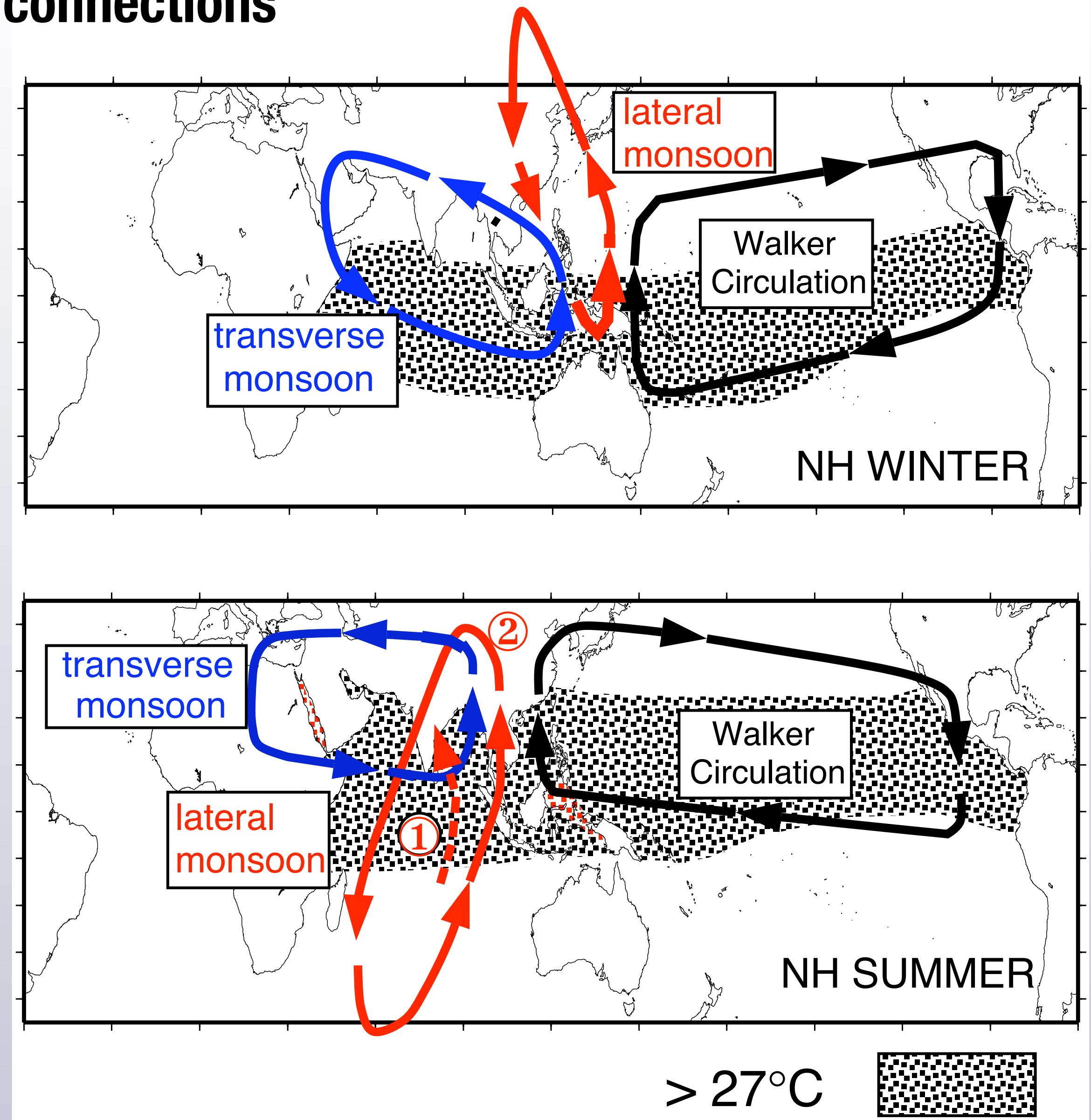
(Schott and McCreary, 2001)

ENSO-Monsoon connections



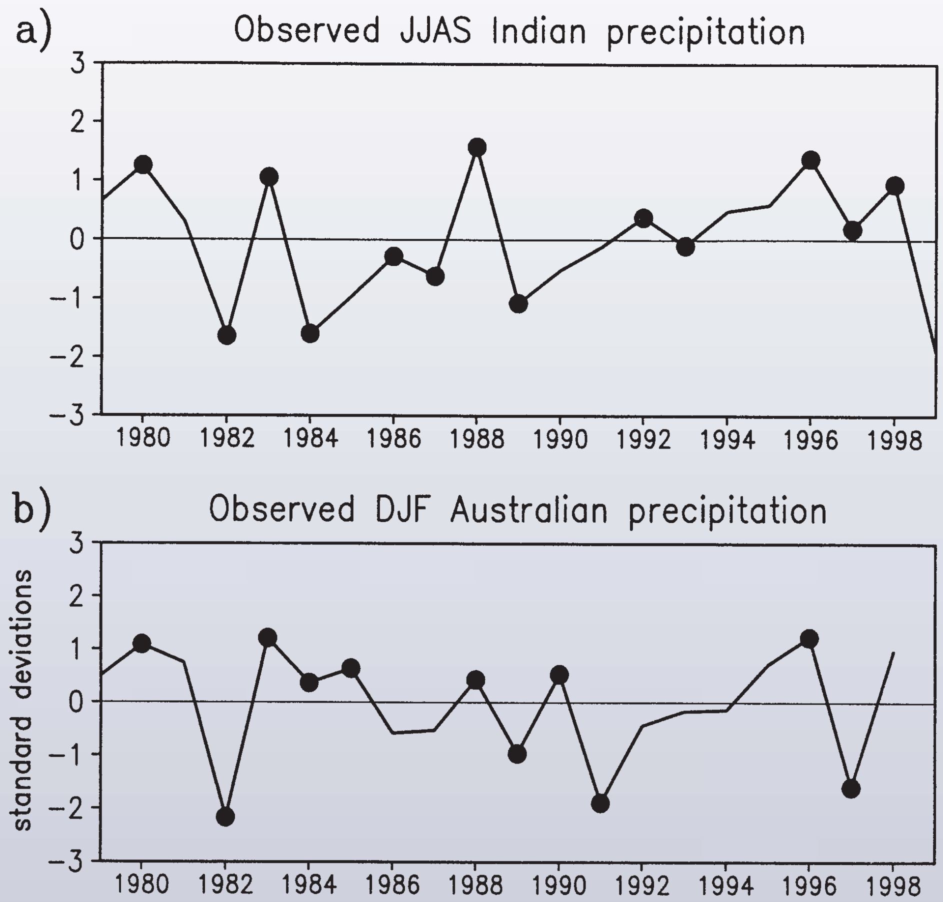
(Yasunari, 1990)

ENSO-monsoon connections



(Webster, 1997)

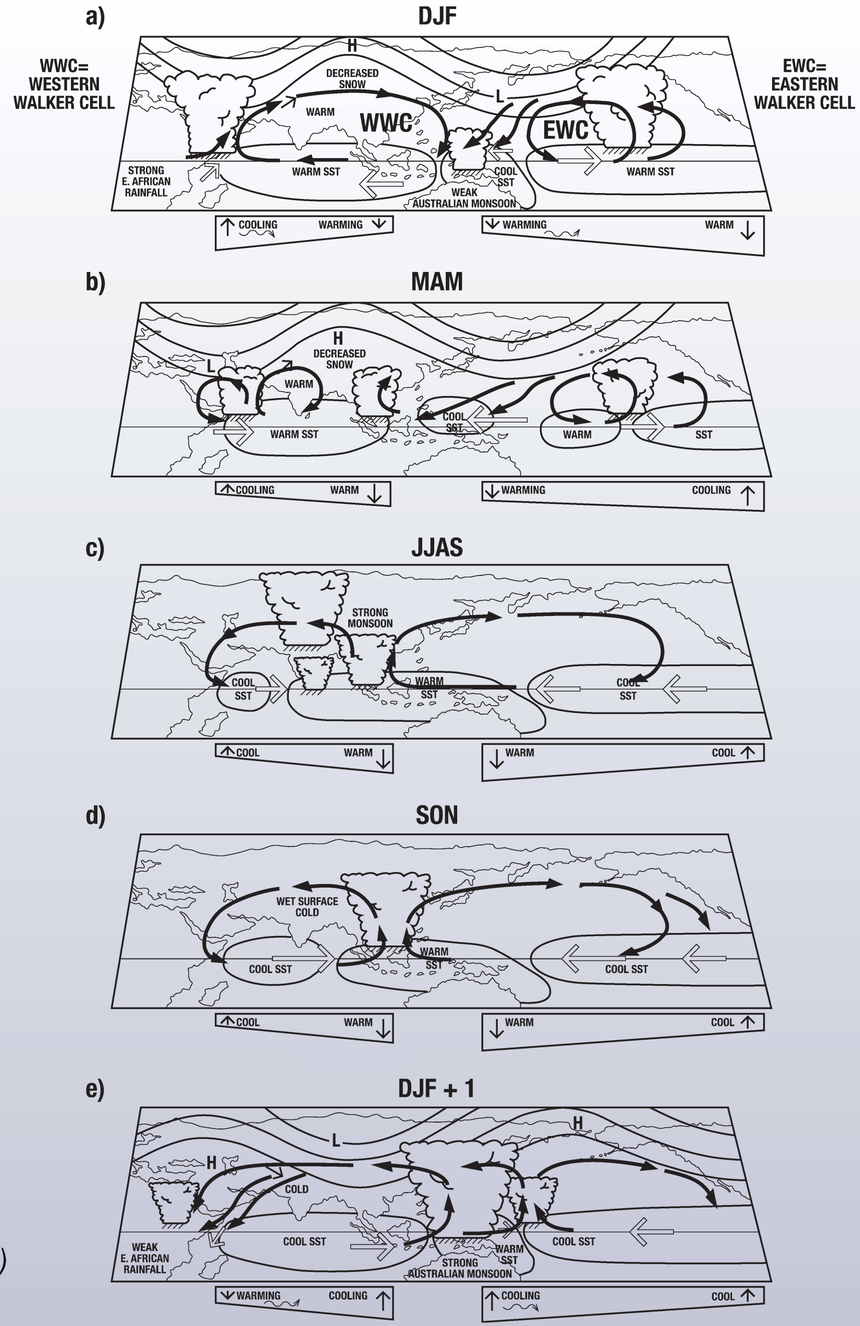
Biennial variability in the monsoon



(Meehl and Arblaster, 2002)

TBO: modes of the Indo-Pacific region

Towards a "Grand Unified Theory" for Indo-Pacific tropical variability



(Meehl and Arblaster, 2002)

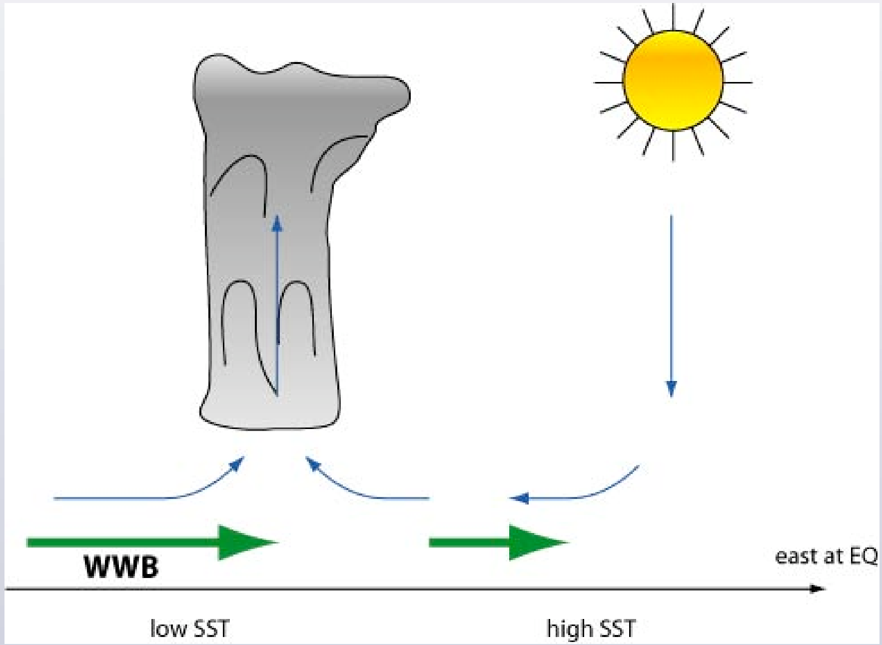
Relationships between modes of Indo-Pacific tropical variability

- The southern Indian Ocean and shifts in the Mascarene high appear to be a key common indicator of Indo-Pacific variability, and transitions in the state of the system

- The coupled models we have examined do not exhibit the same relationships - Order 0 requirement for study

- Promising avenues for further research, and for predictability of the system

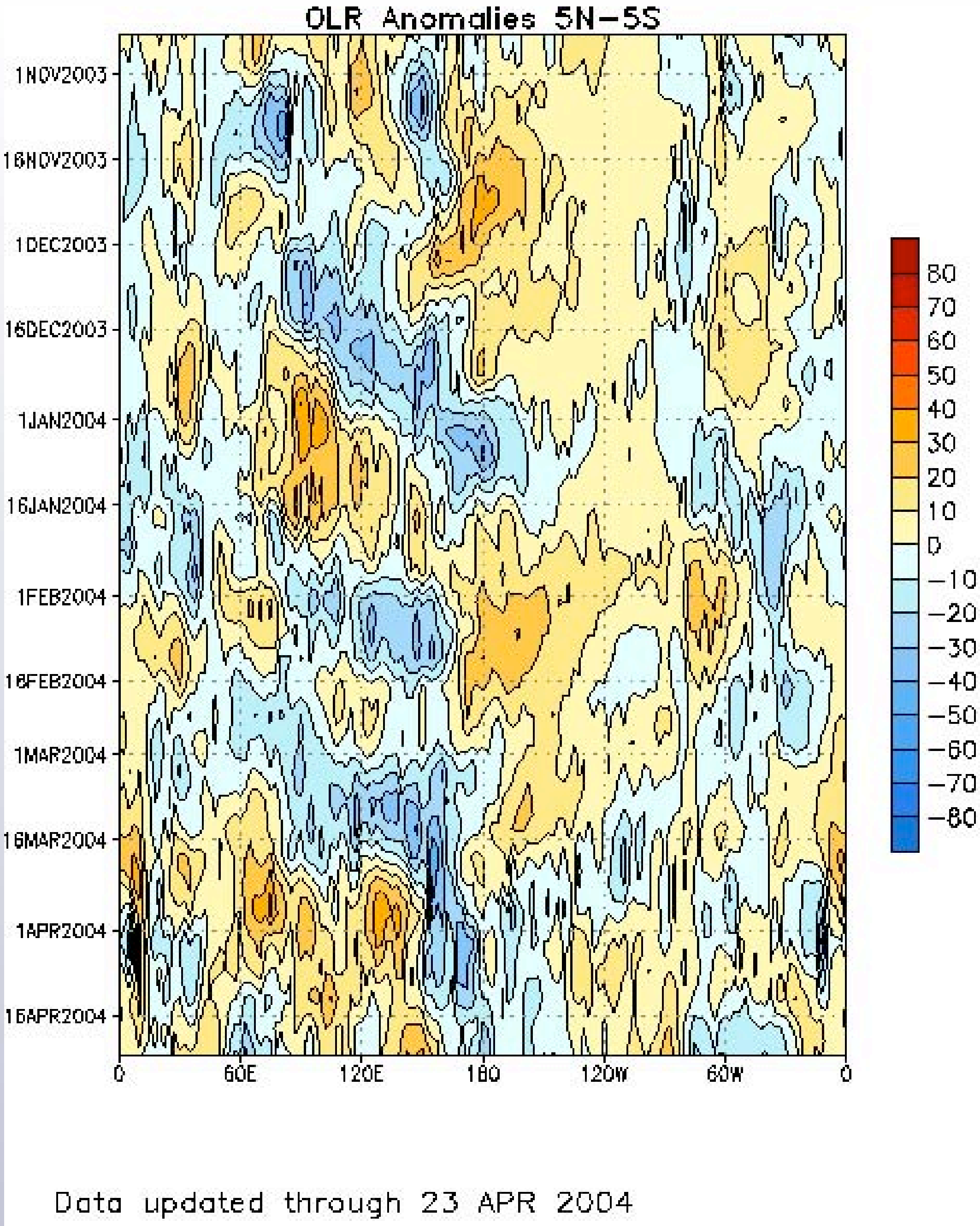
A potential complication: intraseasonal oscillations



- 30-60 day oscillation convective-dynamic instability
- Eastward propagation in the Indian and Western Pacific
- Prediction on more than 30-day timescales is difficult

- Westerly wind burst at the equator - provokes an oceanic wave response

The Madden-Julian oscillation: eastward propagation



(Climate Prediction Center / NCEP / NOAA)

MJO

3-D Structure of the MJO

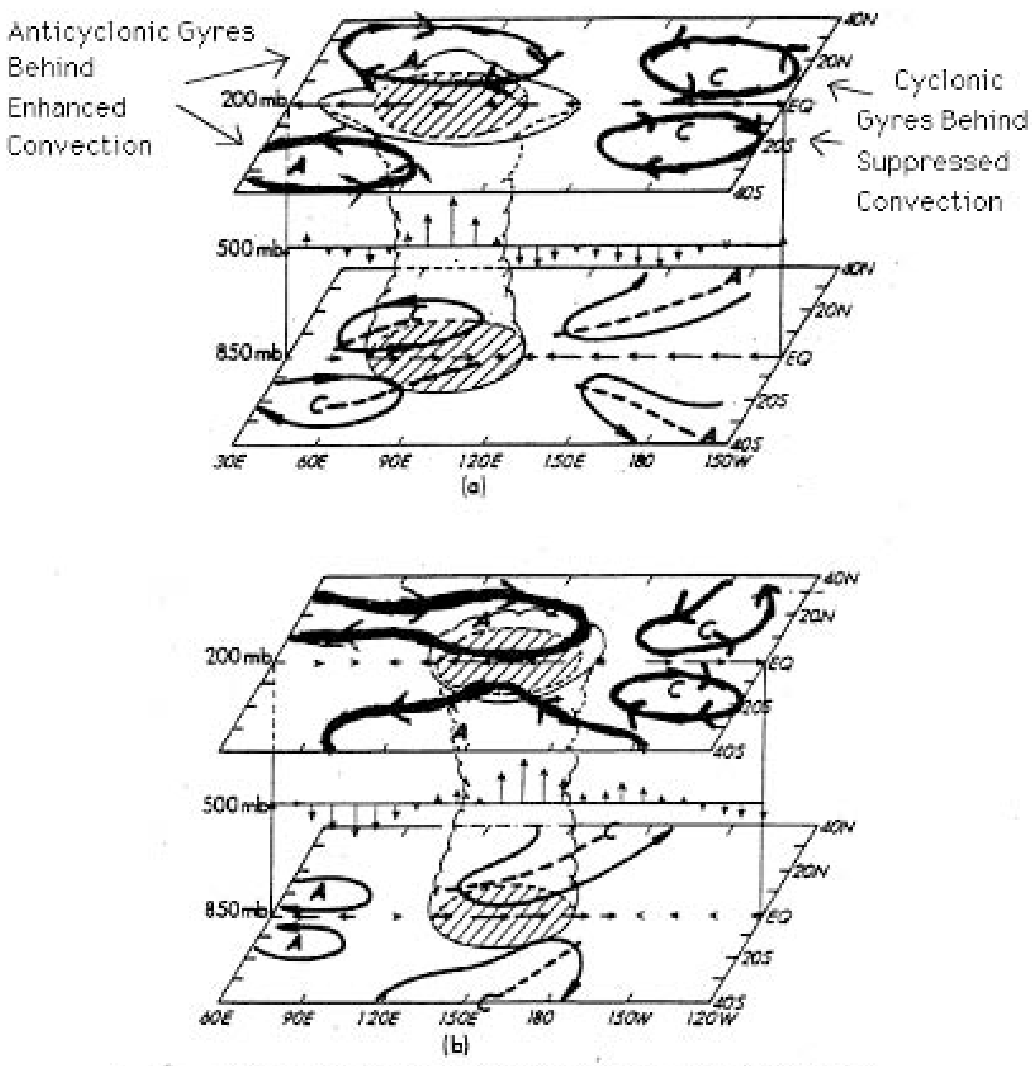
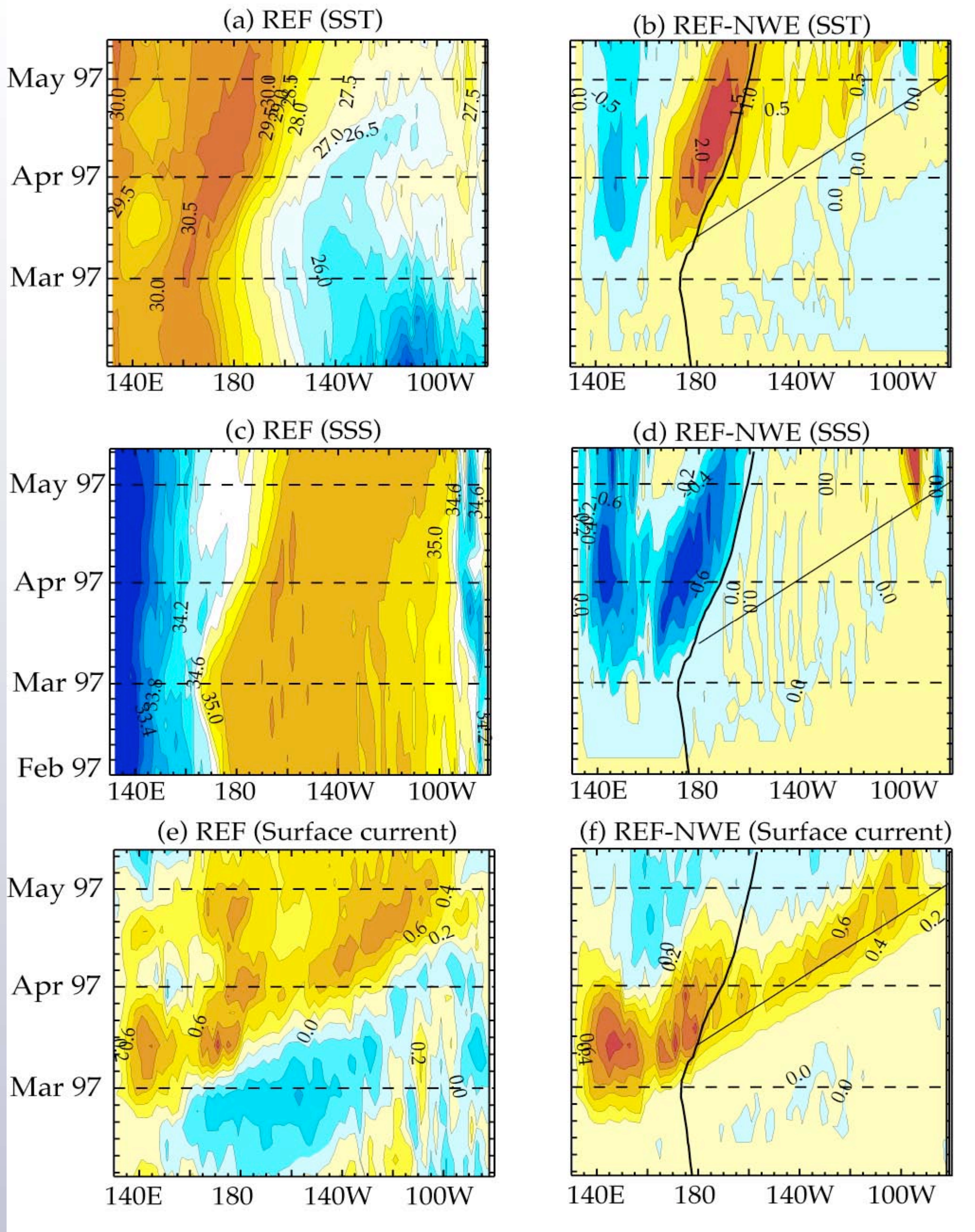


FIG. 8. Schematic depiction of the characteristic structure of the intraseasonal low-frequency waves at (a) phase 3, and (b) phase 5. The shaded regions correspond to areas where OLR anomalies are less than −7.5 W m^{-2} in Figs. 3c, e. The zonal wind and vertical velocity anomalies in the equatorial zonal plane are the same as those in Figs. 3c, e except the scaling. Bold letters A and C represent anticyclonic and cyclonic circulation centers. The circulation cells highlight characteristic wind anomalies associated with the convection anomalies in Figs. 5c, e and Figs. 6c, e.

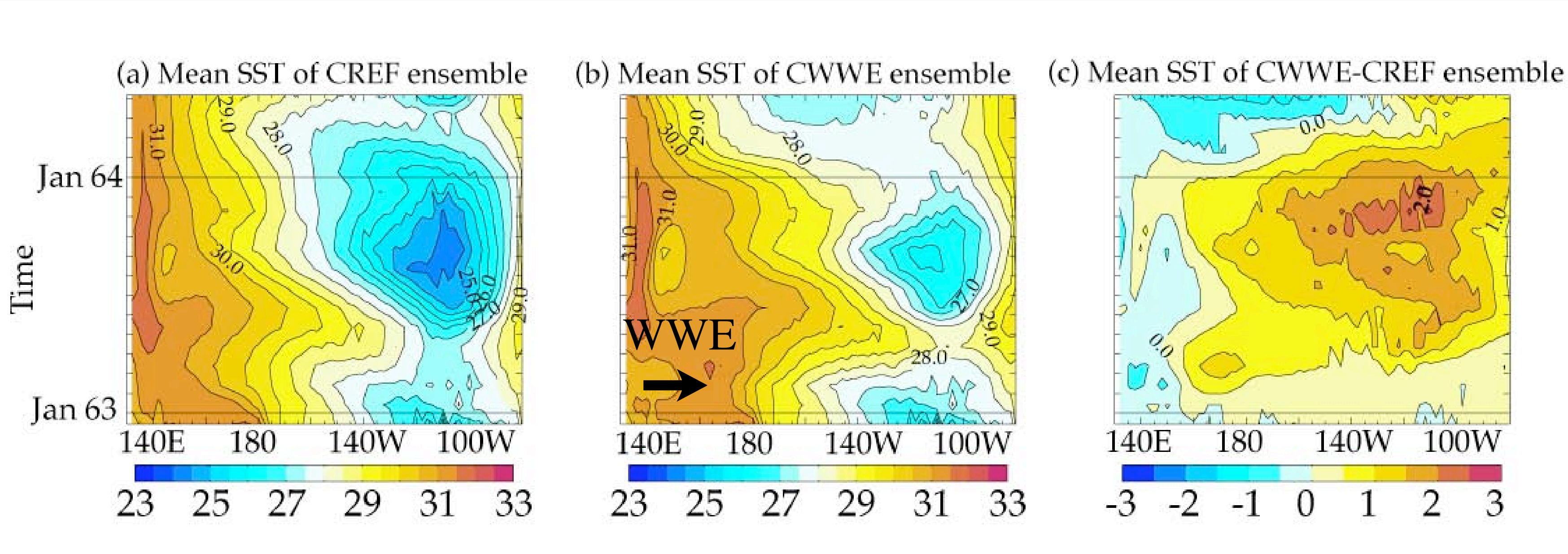
(From Rui and Wang, 1990)

The MJO and El Niño: a potential trigger

- Lengaigne, 2003;
  Kessler and Kleeman, 2000
- Two forced ocean experiments
  - with observed March 1997 WWB
  - without
- displacement of warm pool, warming along Kelvin wave path

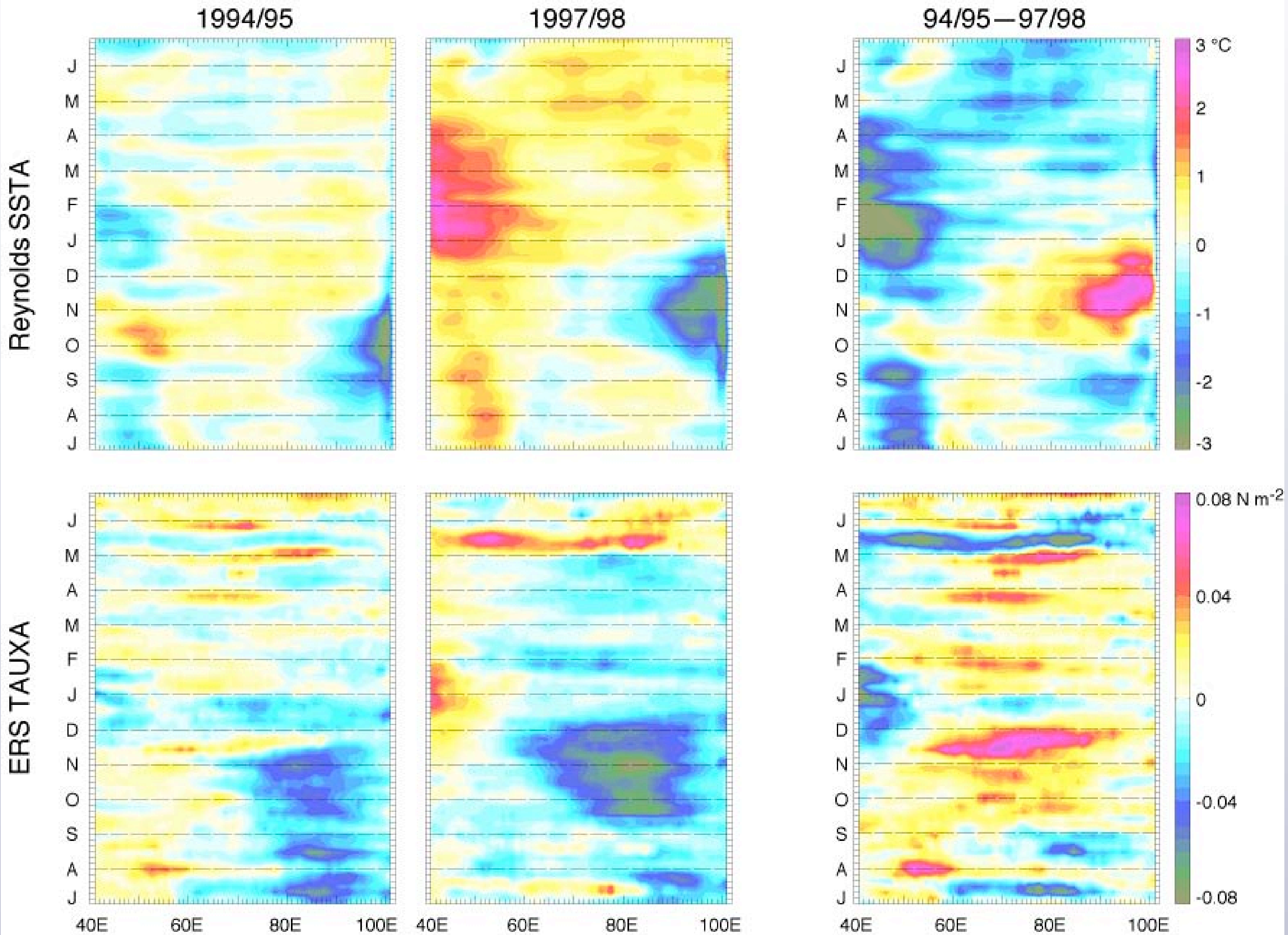


The MJO and El Niño: a potential trigger



- Lengaigne, 2003
- Insertion of a westerly wind burst into a coupled model (ensemble) provokes a Niño-like warming

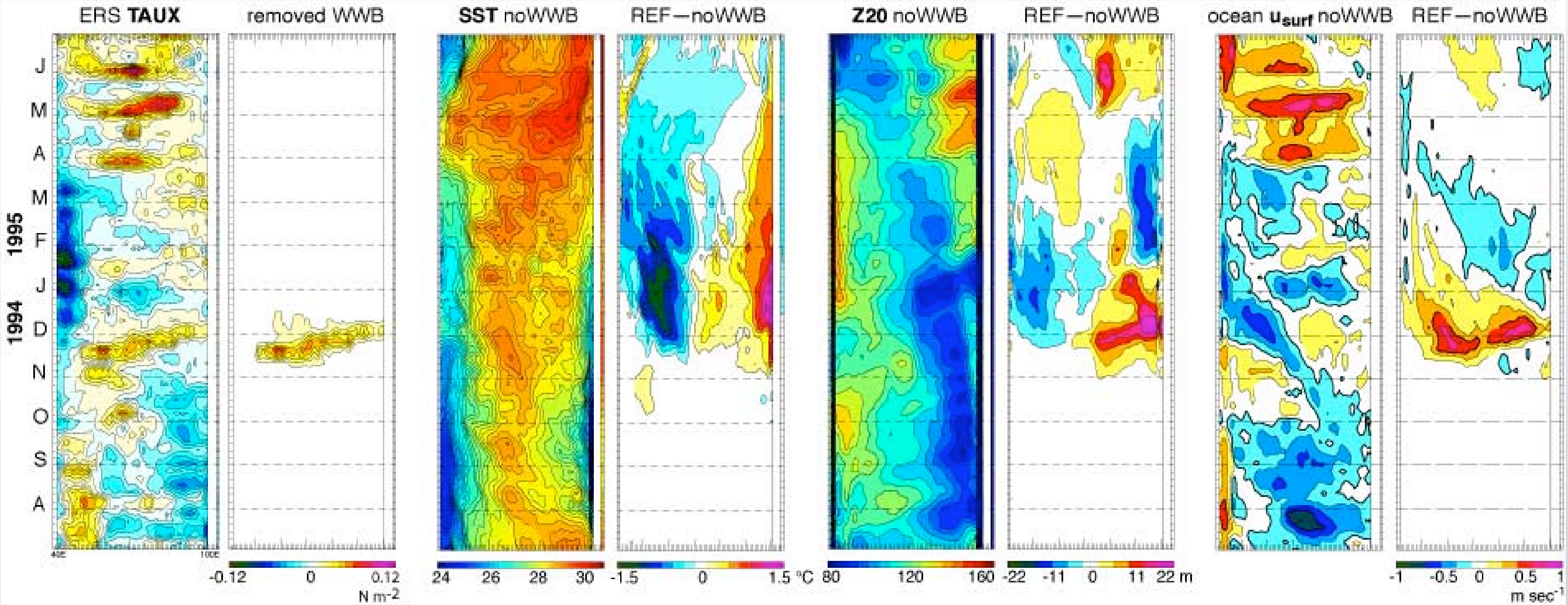
Observed difference between the 1994 and 1997 Indian Ocean dipoles



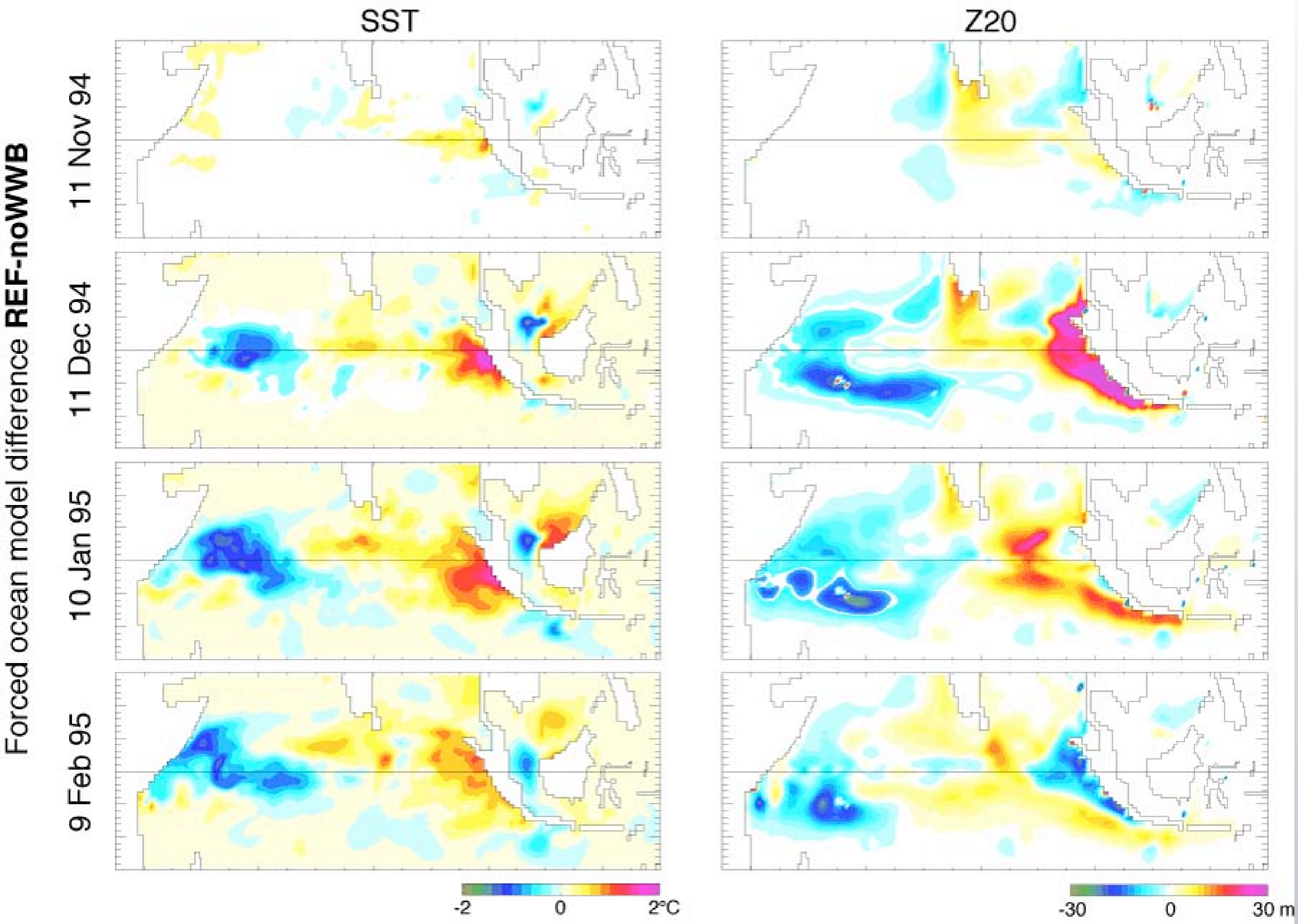
Forced ocean experiment: did the November 1994 WWB provoke the end of the IOD event?

- Two forced ocean simulations
  - **REF** : forced with observed winds (ERS scatterometer), and a surface flux restoring term
  - **noWWB** : only difference is removal of Nov 1994 WWB; surface flux stored from REF - isolating dynamical effect of the WWB
- OPA ocean model in TOTEM configuration
  - higher resolution (to 0.3°) tropical configuration

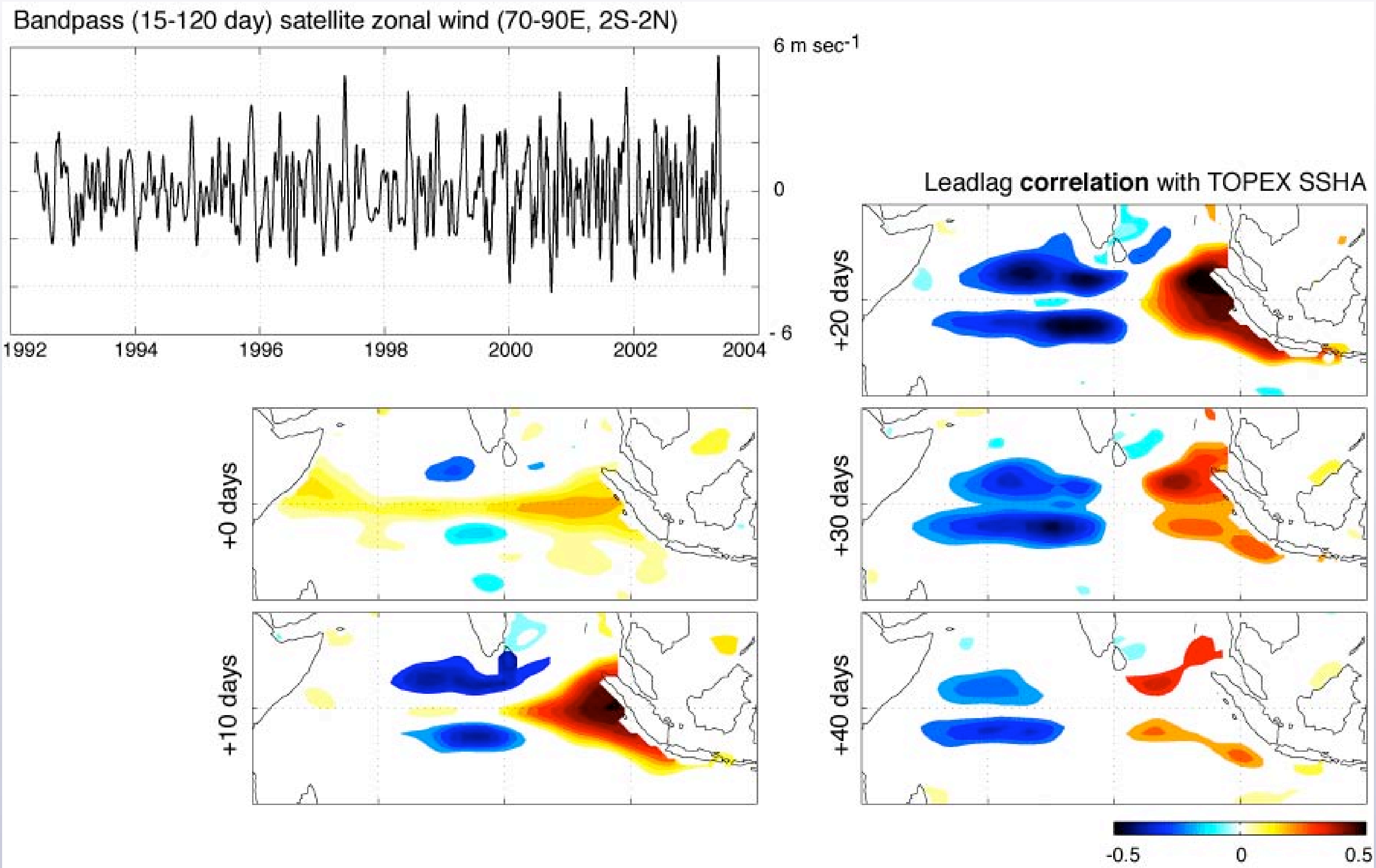
The effect of the WWB on the oceanic evolution



Modeled ocean wave and SST response to the WWB



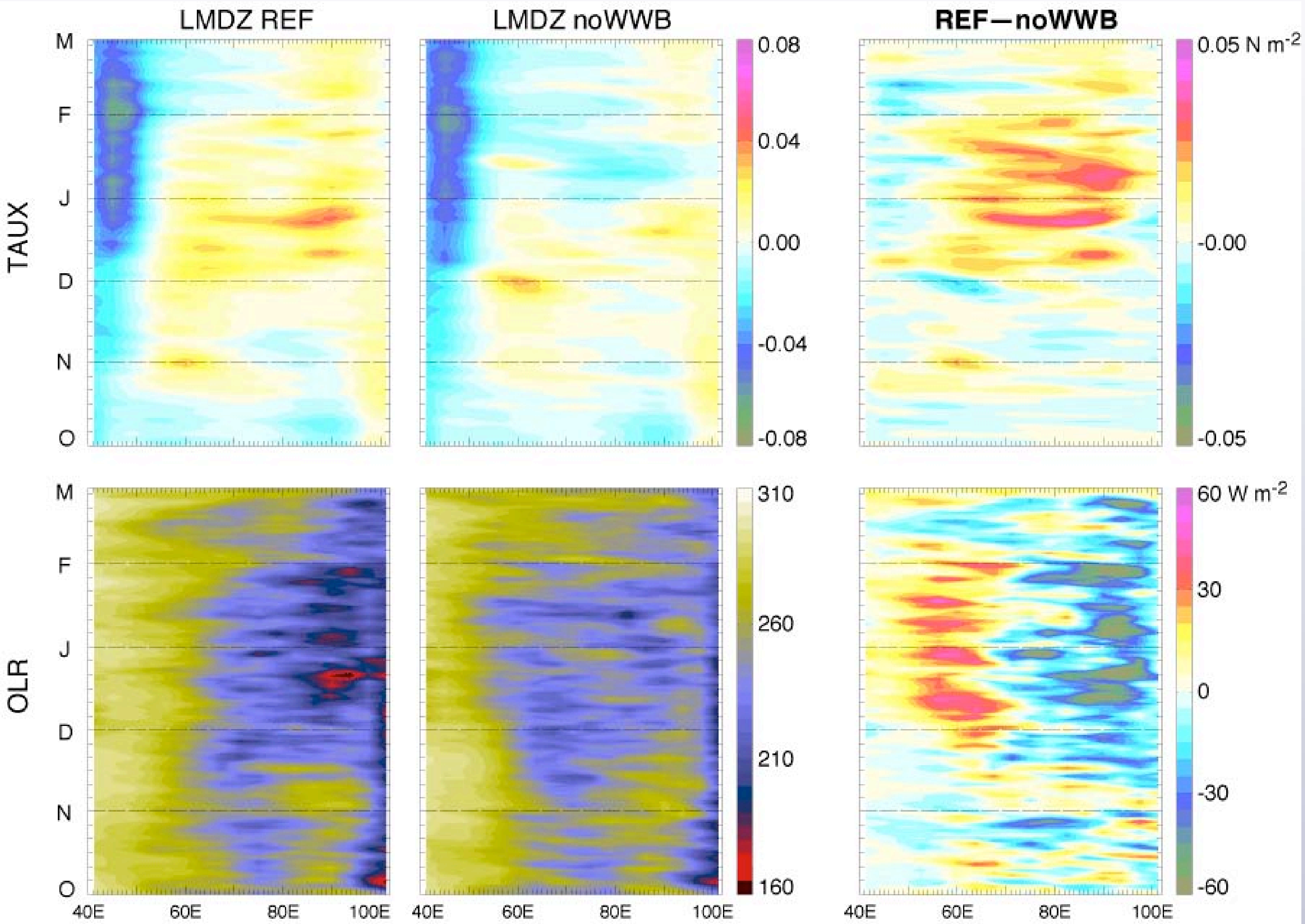
Observational evidence of this wave response



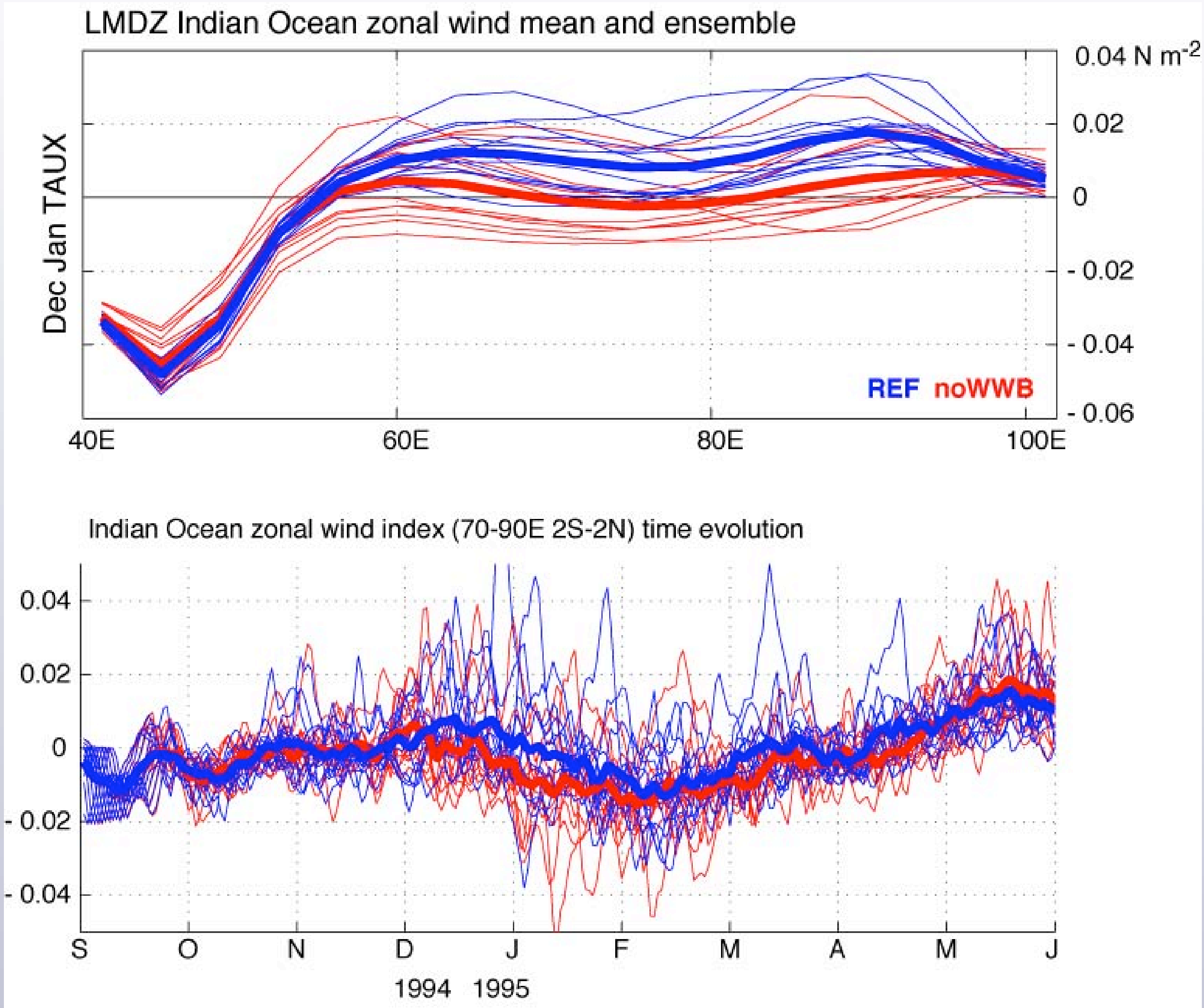
Is the atmospheric feedback positive?

- Two ensembles of simulations
  - **REF** forced by ocean REF SST
  - **noWWB** forced by ocean noWWB SST
  - 12 runs per ensemble, differing only in initial condition (1 day delay)
- LMDZ atmospheric model (climate resolution)
  - 3.75° longitude x 2.5° latitude

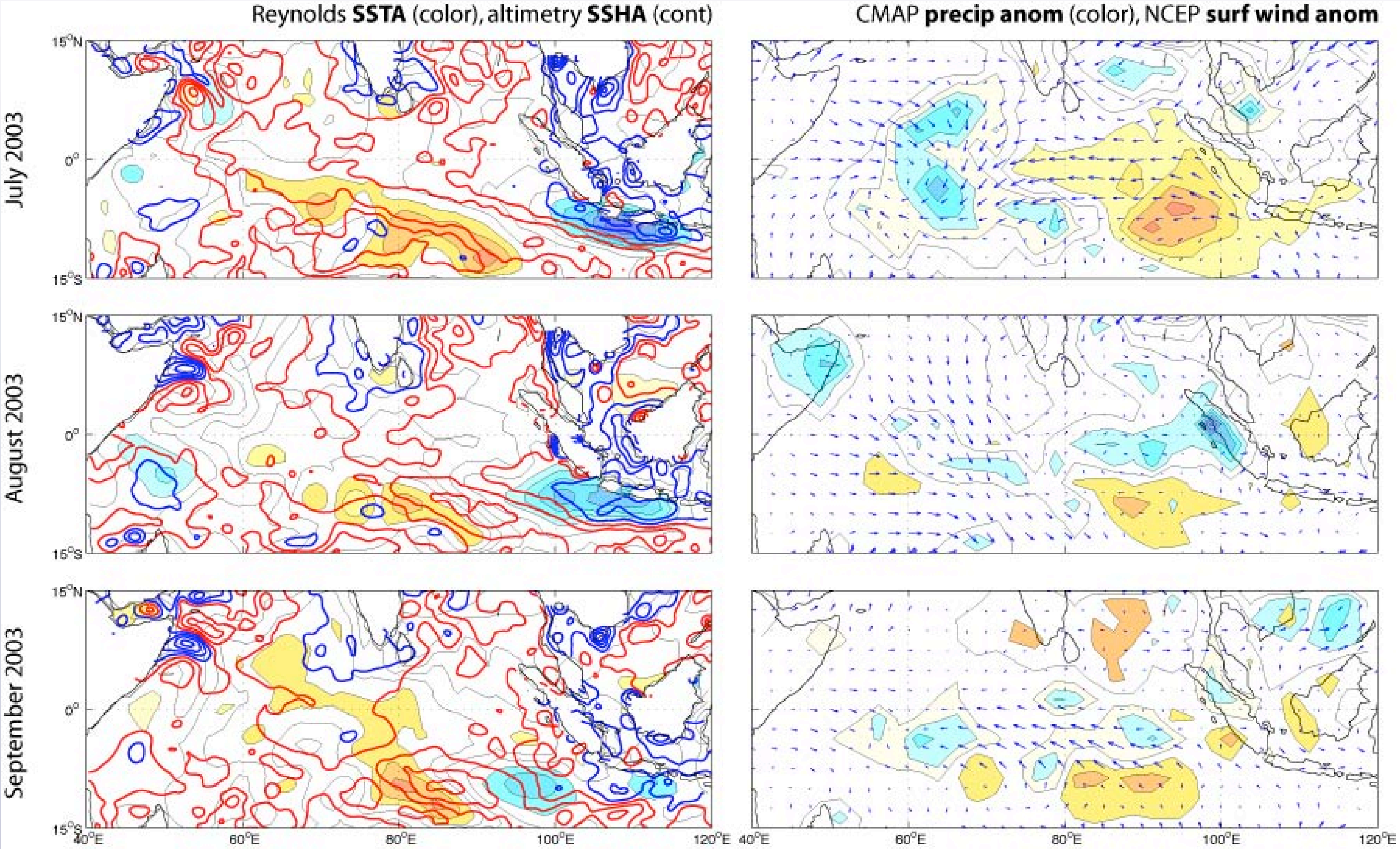
(Yes) the atmospheric feedback is positive



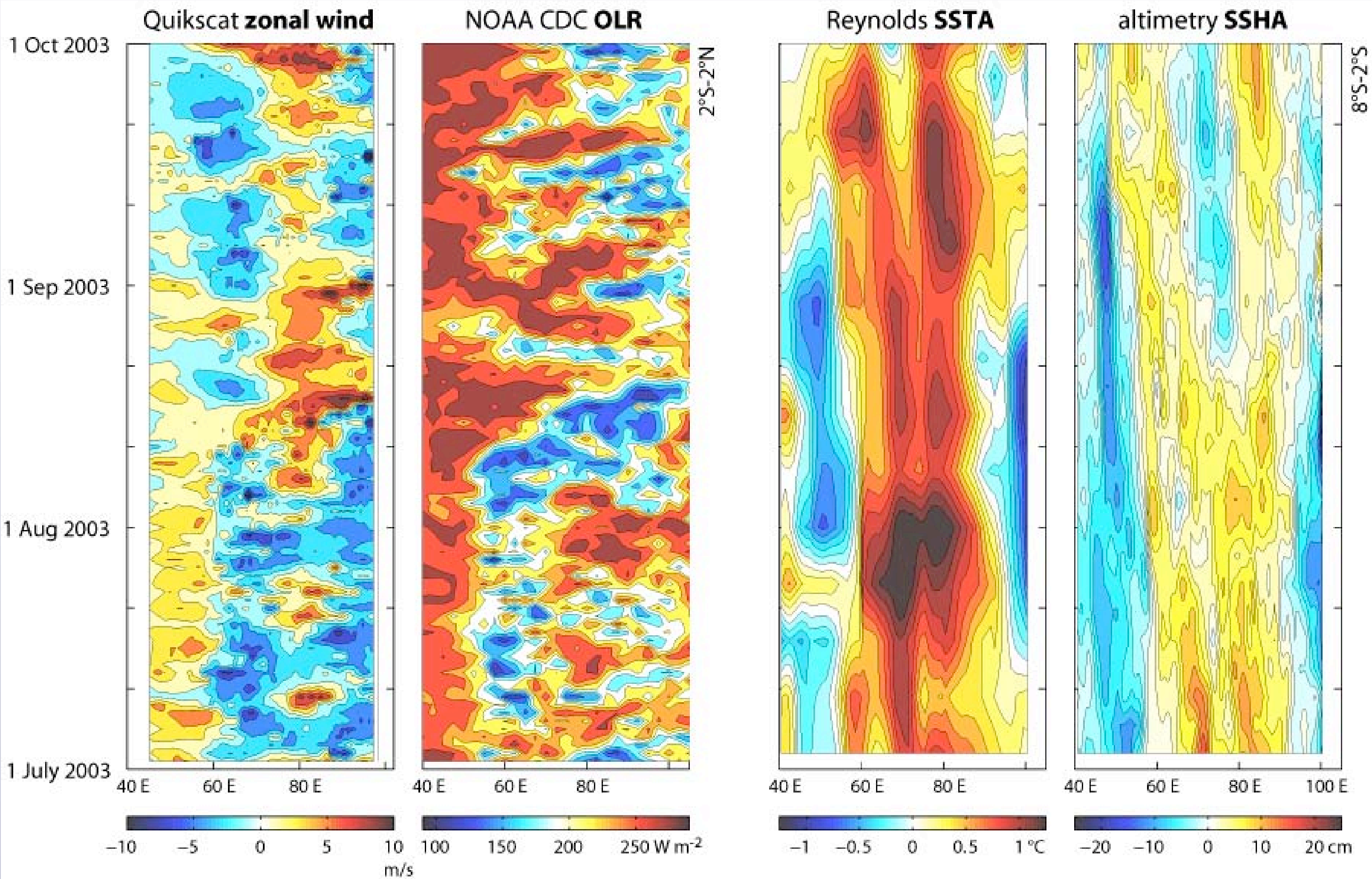
Ensemble dispersion: difficulties for prediction



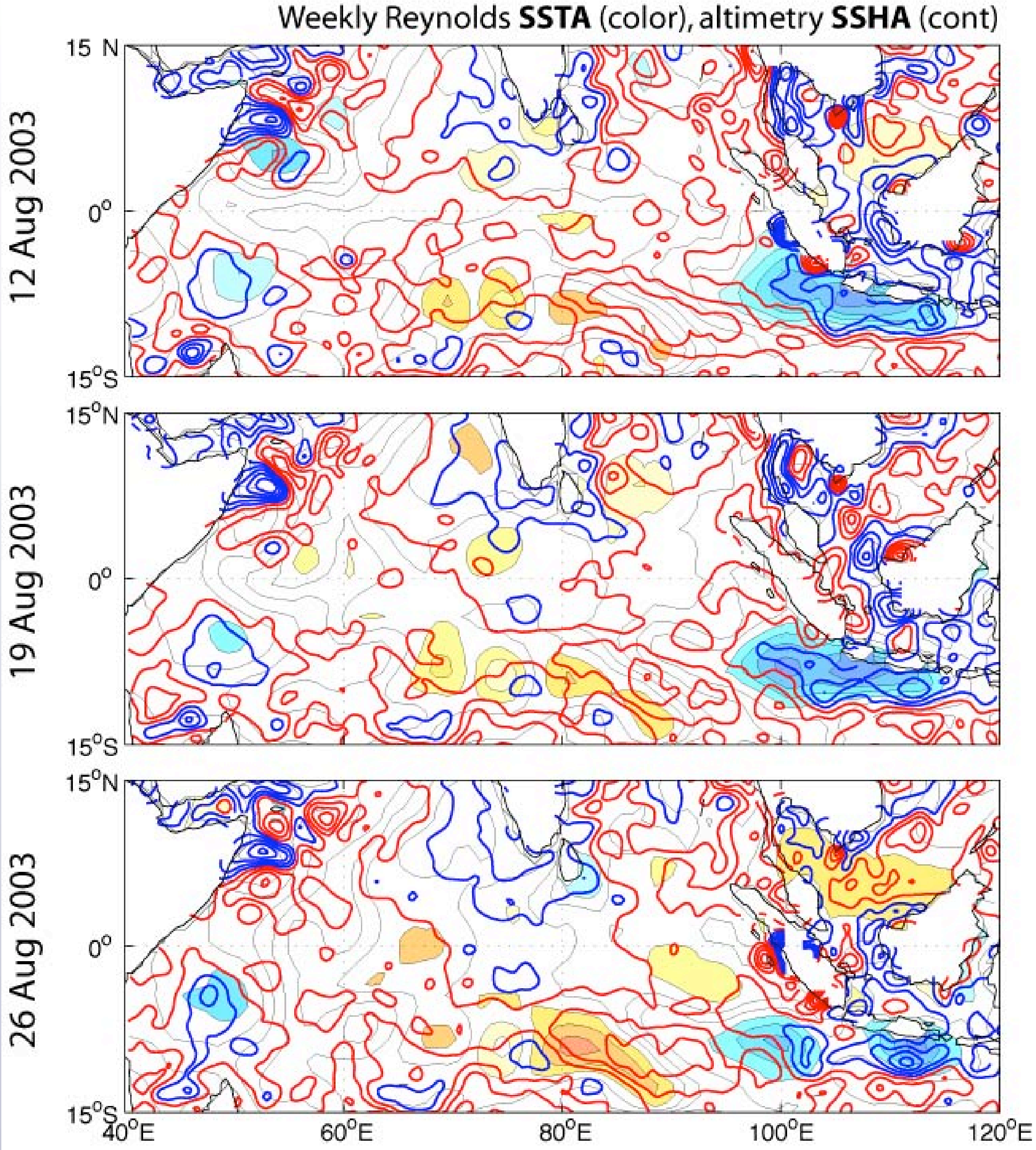
How last year's Indian dipole disappeared...



WWB and response : 12-18 August 2003



Shutdown of Sumatra upselling in August 2003



Summary

- The November 1994 wind event (WWB/MJO) accelerated the end of the dipole event
- The simulated and observed ocean wave response are similar
- The atmospheric response to the changed ocean state would have brought a positive feedback
  - But the large ensemble dispersion suggests that even with perfect predictions of the MJO, the coupled dipole evolution might be difficult to predict
- The 2003 dipole was interrupted by a WWB/MJO
- Intraseasonal-interannual scale interactions: a challenge for prediction