chlorophyll and westerly wind events in the western tropical Pacific
a multi-sensor approach

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The western tropical Pacific: two main ecosystems

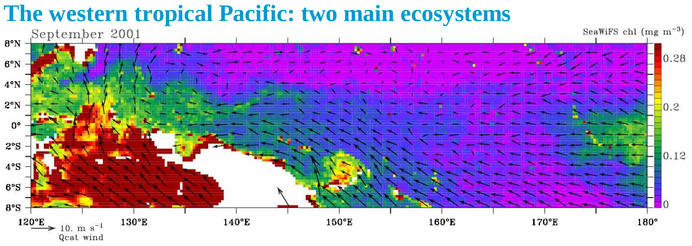


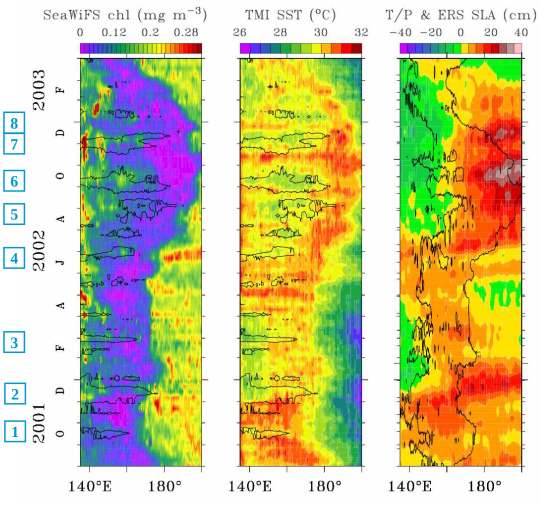
Fig. 1: September 2001: SeaWiFS chlorophyll (mg m^{-3}, color scale); QuikScat wind speed (m s^{-1}, vectors)

- **tip of the equatorial upwelling waters in the east**
  - cold and salty
  - High Nutrient-Low Chlorophyll (HNLC) characteristics (chl>0.1 mg m^{-3})
  - biological activity at intraseasonal (tropical instability waves, equatorial Kelvin waves) and ENSO time scales
- **western Pacific warm pool waters in the west**
  - warm (T>28°C) waters
  - oligotrophic characteristics (chl<0.1 mg m^{-3})
  - biological variability at intraseasonal scale associated with intraseasonal westerlies and interannual scale related to ENSO disruption.

The large scale context

general characteristics of westerly wind evnts (WWE)

- they episodically replace climatologically low winds over the warm pool;
- they generate intense eastward equatorial surface currents, SST decrease, deepening of the isothermal layer;
- they occur between November and April;
- they have a strong interannual variability:
  - strong and frequent WWE during El Niño
  - almost vanish during La Niña
- they are associated with the Madden-Julian Oscillation, cyclones, cold surges.



WWE during the 2002 El Niño event

- the intraseasonal activity was low in 1998-2001 and intensified during the 2002 El Niño;
- along the equator during the mild 2002 El Niño event:
  - eastward migration of the warm pool
  - SLA decrease in the west
  - SST decrease in the west
  - chl increase in the west
  - WWE move toward the central basin

Fig. 2: longitude-time diagrams of chlorophyll, SST, zonal wind, and SLA along the equator
The 5 m s^{-1} zonal speed is superimposed on chl and SST diagrams. The 0.1 mg m^{-3} chl isoline is superimposed on SLA.

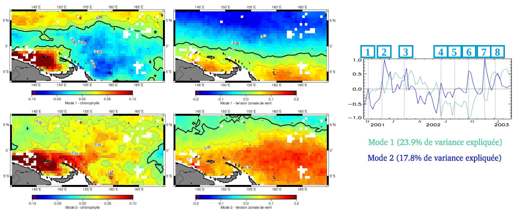
impact of WWE on surface chlorophyll

Fig. 3: **EOF analysis** SeaWiFS chl Qcat zonal wind stress

10/2001-02/2003

mode 1: seasonal cycle

mode 2: "advective type"



2 types of response:
- local processes: WWE # 1, 4
  - vertical mixing and/or vertical advection
- advective processes : WWE # 2, 3, 7
  - advection of nutriment and chlorophyll rich waters from the west

mode 2 of a multivariate EOF analysis captures the "advective type" response
- wind pattern = Harrison and Vecchi (1997) type C
  (5°N-5°S; 155°E-180°, mostly from November to January)
- chlorophyll pattern
  strong concentration north of Papua New Guinea
  associated with an eastward expansion of high concentrations

local type (WWE # 4 in June-July 2002)

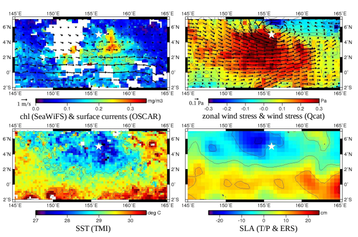


Fig. 4: weekly chl data are centered on 30 June 2002. Other data are from the closest date. The white star is the 156°E, 5°N TAO/TRITON mooring.

- cyclonic wind stress curl
  associated with local responses:
- SLA < 0
- surface chl increase
- SST decrease

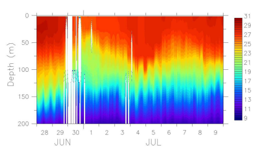


Fig. 5: hourly temperature profiles at the 156°E, 5°N mooring.

- westward wind: 28 June - 9 July
- 29-30 June
  - maximum wind speed
  - 70-80m thermocline (24°C) rise
  - eastward surface current
- 1-9 July
  - wind speed decrease
  - deepening of the vertical structure
  - south-eastward shift of the chl bloom

is wind responsible for the chl bloom?

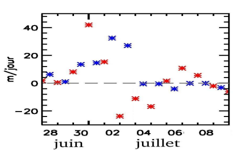


Fig. 6: Ekman pumping from daily Qcat wind stress curl (blue) and daily variations of the 24°C isotherm (red) at 156°E, 5°N.

- $-\partial h/\partial t = curl_z(\vec{\tau}/\rho f)$ relates the thermocline vertical displacements to wind stress curl
- Ekman pumping explains the thermocline uplift
- misfit for the deepening could be the consequence of other processes (advection?)

- local wind stress curl explains the uplift of the thermocline
  $\Rightarrow$ nutrient inputs in the euphotic layer
  $\Rightarrow$ chl bloom

advective type (WWE # 2 in December 2001)

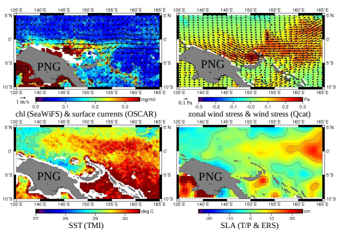


Fig. 7: weekly chl data are centered on 23 December 2001. Other data are from the closest date.

- upwelling north of Papua New Guinea
  - high chl, low SST, low SLA
- eastward surface current in the 0°-2°S band
- eastward spread of high chl and low SST in the 0°-2°S band

- such a chl pattern develops when nutrient and chl-rich waters north of PNG and eastward equatorial current occur concurrently (WWE # 2, 3, 7)

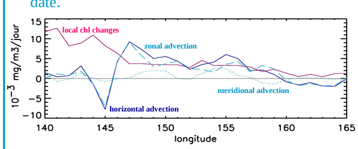


Fig. 8: partial chl budget (0°-2°S, 3-26/12/2002).

what is the part of horizontal advection in the chl increase?

- west of 145°E: no horizontal advection (consistent with upwelling processes)
- 145°E-155°E: zonal advection explains most of the chl variations.

- upwelling north of PNG drives high chl concentrations. Then, nutrient and chl-rich waters are advected eastward by the eastward surface current triggered by the wind.

conclusion

- **2 types of biological responses to WWE in the western Pacific warm pool:**
  - **chl increase associated with local vertical processes;**
  - **chl increase associated with advection of nutrient-rich waters from the west.**
- **a study is underway to study how the succession of WWE may contribute to maintain the well known positive anomaly of chlorophyll during El Niño events through interactions between ENSO basin scale modifications, biological consequences of the north-west monsoon, and local processes.**