oceanic response to northwest monsoon winds north of New Guinea

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1. Abstract

The SeaWiFS chlorophyll imagery suggests that advection of nutrient- and phytoplankton-rich waters from the west may explain the chlorophyll increase in the warm pool during the 2002 El Niño event. Therefore, the well known chlorophyll increase in the warm pool during El Niño would not be the result of local vertical processes alone. Instead, a succession of westerly wind events may contribute to maintain the positive anomaly of chlorophyll during El Niño events through interactions between ENSO basin scale modifications (east-west tilt of the thermocline/nutricline), local processes (Ekman pumping, vertical mixing) and biological consequences of wind forcing variability in the far western Pacific.

During austral summer, northwest winds blow parallel to the northern coast of New Guinea and a seasonal coastal upwelling develops. In order to investigate its structure and variability, we used multiple satellite data to infer the response of surface chlorophyll, sea surface temperature, and sea level anomaly to seasonal wind reversal. Results highlight differences between the two seasons. In austral winter, when south-east trade winds prevail, the surface current is north-westward and advection of cold and nutrient-rich water from the Solomon Sea may enhance phytoplankton growth downstream. In summer, current reverses during the north-west monsoon (November-March), which favors advection of cold water from the far western Pacific and upwelling along the New Guinea coast. The consequence is enhanced phytoplankton along the coast. Actually, this system is very dynamic as it is under the influence of rapid wind shifts.

Satellite data

- SeaWiFS
  - surface chlorophyll concentration
  - 8 days
  - 0.1°×0.1°
- TMI
  - sea surface temperature (SST)
  - 7 days
  - 1/4°×1/4°
- QuickSCAT
  - wind speed
  - 8 days
  - 1/2°×1/2°
- T/P and ERS altimetry product
  - sea level anomaly (SLA)
  - 7 days
  - 1/3°×1/3°

2. Along the equator

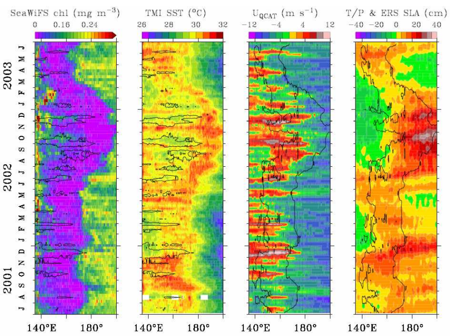

Fig. 1: longitude-time diagrams of chlorophyll, SST, zonal wind speed, and SLA along the equator. The 5 m s^{-1} zonal wind speed is superimposed on chlorophyll and SST diagrams. The 0.1 mg m^{-3} chlorophyll isoline is superimposed on zonal wind and SLA.

- The wind intraseasonal activity (westerly wind events) intensifies during the 2002 El Niño
- Along the equator during the mild 2002 El Niño event (fig. 1):
  - eastward migration of the warm pool
  - in the west: SLA and SST decrease, chlorophyll increase
- Chlorophyll increases and SST decreases are associated with westerly winds

➢ **Eastward advection driven by repeated westerly wind events along the equator during El Niño may contribute to maintain positive chlorophyll anomaly and SST cooling in the warm pool.**

3. The ocean north of New Guinea

The dynamics of this region close to the equator is under the influence of complex and steep bathymetry (narrow continental shelf and straits), and wind variations at the intraseasonal, monsoonal, and interannual scales

- Along the coast, the current system is narrow:
  - the surface New Guinea Coastal Current (NGCC) reverses following the monsoon winds:
    - northwestward during austral winter
    - weakens or reverses during austral summer
  - the subsurface New Guinea Coastal Undercurrent (NGCUC) flows northwestward
- Transport through the Vitiaz strait is predominantly from the Solomon Sea to the Bismarck Sea.

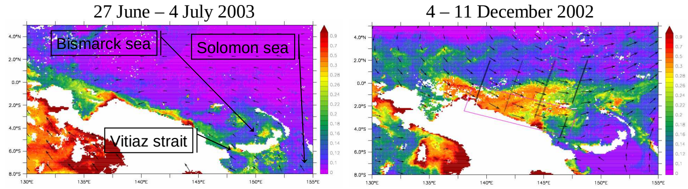

Fig. 2: snapshots of SeaWiFS chlorophyll (mg m^{-3}; colors) and QuickSCAT wind (m s^{-1}; vectors); left: trade wind season; right: NW monsoon season. The purple box is used in section 4. Black slanted lines are the 4 T/P and Jason tracks we use below.

- During the trade wind period (fig. 2, left), surface chlorophyll is low and the ecosystem is oligotrophic, as is usually found in the warm pool.
- During the NW monsoon (fig. 2, right), an upwelling with cold and chlorophyll-rich waters develops along the northern coast of New Guinea during the NW monsoon or during westerly wind events.

➢ **Upwelled waters are a potential pool of nutrient-rich waters likely to be advected in the warm pool.**

4. Along the New Guinea coast

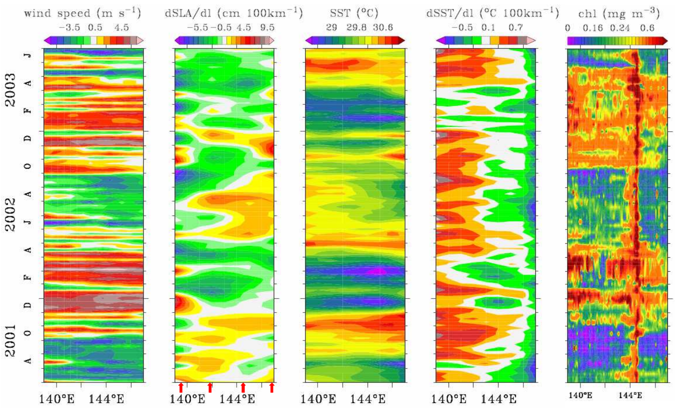

Fig. 3: longitude-time diagrams of along shore wind (Δ=1 m s^{-1}; negative is southeast wind), along track SLA gradient (Δ=1 cm 100km^{-1}; negative is low SLA at the coast), SST (Δ=0.2 °C), along track SST gradient (Δ=0.2 °C 100km^{-1}; negative is low coastal SST), and SeaWiFS chlorophyll.
Values are averaged in the purple box shown in Fig. 2, right panel, where the T/P and Jason tracks are also shown. Red arrows show the position of the altimetry tracks.

- Northwest winds prevail from October to February
  - Cold surface temperature and high surface chlorophyll along the coast
    - Note the high chl values at 144-145°E all the time and in the west in Jan.-Mar. 2002 and 2003 reflects the optically complex characteristics of river plume waters
  - Pulsing characteristics of the wind and of the oceanic response
  - The temperature signature of the upwelling is low (deep and warm isothermal layer?) and the cross shore SST gradient is weak (< 0.5°C 100km^{-1}), especially in the west
  - The cross shore SLA gradient is mostly negative (low SLA at the coast). It reflects both the dynamical and steric effects on SLA.
    - Note that gradient SLA of the west track, within 1° of the equator, does not reflect upwelling
- Southeast trade winds prevail in July-September
  - Surface water is cold in the east probably because of advection from the Solomon Sea through Vitiaz Strait and local processes in the Bismarck Sea

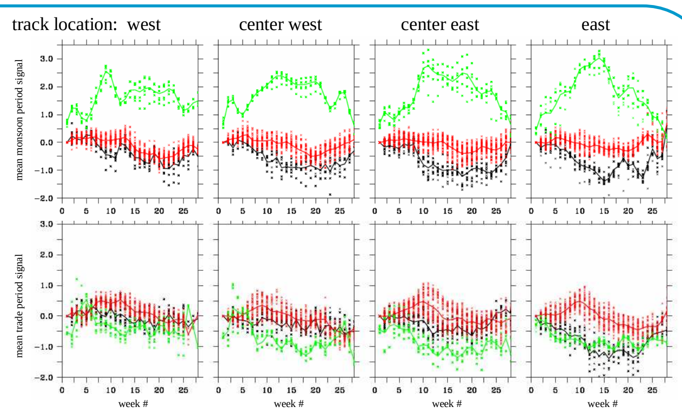

Fig. 4: synthetic **along shore wind (0.5×m s^{-1})**, **SST (°C)**, and **SLA (dm)** signal during 2002-2006 mean monsoon (upper panel) and trade (lower panel) wind period along the 4 tracks shown in Fig. 2, right panel.
SST and SLA anomalies are relative to the value of the 1st week.
Lines are averaged values, crosses are individual values.

- At the seasonal scale, synthetic monsoon and trade wind seasons have been constructed along the 4 altimetric tracks
  - Monsoon: about October-June each year
  - Trade winds: about May-October each year
  - SST and SLA anomalies are relative to the value during the synthetic season 1st week
- Monsoon season
  - SST decrease by 1°C or more in the center and eastern tracks
  - The amplitude of the SLA decrease is lower in the east than in the west. We do not separate dynamical and steric effects
- Trade wind season
  - Low wind speed, especially in the east, close to the equator
  - SST fall (> 1°C) is localized to the east (advection from the Solomon Sea)

➢ **Austral summer: NW monsoon winds**
  ➢ **Coastal upwelling: "low" SST, low SLA, high chl**
  ➢ **Advection from the west is likely**
➢ **Austral winter: SE trade winds and northwestward surface current**
  ➢ **Advection of cold water from the Solomon Sea**
➢ **Intraseasonal scale: westerly wind event**
  ➢ **The oceanic response is highly dynamic and satellite data do not fully resolve this issue**