MJOs and Ocean Processes

Physics, Low-Frequency Rectification, and Bio-Physical Feedbacks

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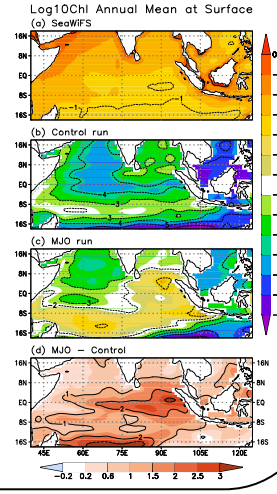
Introduction

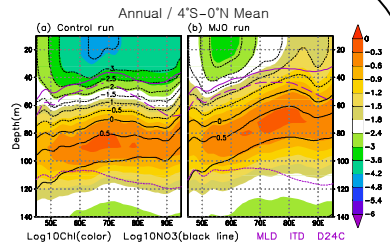
- **Chlorophyll-a (Chl) and Physical System**
  - Chl is an indicator of photosynthetic activity in the ocean
  - Chl absorbs light, and converts to heat; hence, changing vertical heat distribution
  - Chl can affect large-scale ocean dynamics and coupled climate system
- **Chl and Madden-Julian Oscillation (MJO)**
  - Jin et al. (2013): The MJO modulates observational surface Chl responses
  - Jin et al. (2012): Entrainment, detrainment, Ekman pumping, and seasonality play roles to modulate surface Chl, which is revealed from numerical simulations
- **Motivation: Does the MJO forcing increase mean Chl concentration? If so, how?**
- **Numerical Model**
  - Gent+Cane ocean circulation model in the tropical Indo-Pacific basin
  - 9-component ecosystem model is coupled (Christian et al. 2001)
- **MJO forcing**
  - MJO composite anomalies are weaved for 6-months (Nov-Apr and May-Oct)
  - Boreal summer and winter MJO forcings are concatenated
- **Experiments**
  - Control run: Climatological forcing only
  - MJO run: Climatological forcing + MJO anomalous forcing

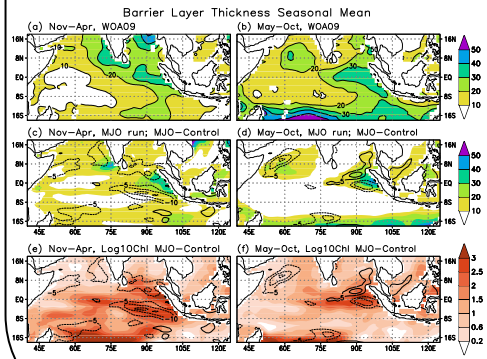


Result-1

- **Findings from Annual Mean Cross-section**
  - MLD, Isothermal depth (ITD), Nitrate isopleths all to be shoaled in annual mean
  - Particularly in the eastern equatorial Indian Ocean
  - Barrier layer* thickness (BLT) is also reduced

* Barrier layer is defined as ITD – MLD (Sprintall and Tomczak, 1992)

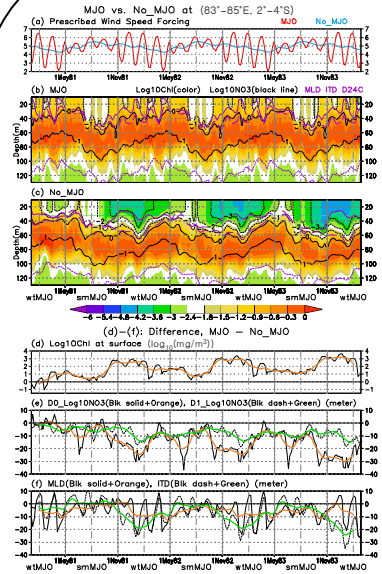




- **Why looking at BLT?**
  - Barrier layer is supposed to inhibit interactions between mixed layer and deeper ocean (Lukas and Lindstrom, 1991)
  - MJO signature on BLT is incontrovertible due to MJO-related wind and precipitation
- **BLT is improved by the MJO forcing**
  - The BLT seasonal mean in the MJO run becomes closer to the observations except in the Bay of Bengal
- **Improved BLT accompanies increased surface Chl concentration**
  - Compare color shadings and black contours in (e) and (f)

(a) and (b): BLT seasonal mean from World Ocean Atlas 2009 (WOA09)
(c), (d), (e), and (f) black contour: BLT seasonal mean difference, MJO-Control
(c) and (d) color shading: BLT seasonal mean for the MJO run
(e) and (f) color shading: Surface Log10Chl seasonal mean difference

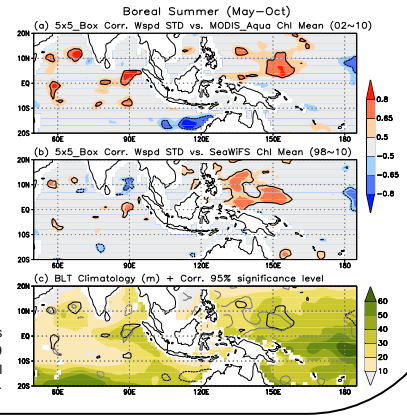
Result-2



- **No_MJO experiment**
  - Same as the control run except initial condition (climaological forcing only)
  - The initial condition is provided by the MJO run
- **Results of No_MJO run: Quick shift to the low mean surface Chl state of the control run**
  - Just in a few years without MJO forcing, ITD and nitrate isopleths are deepened
  - BLT is thickening and upper ocean becomes stratified
  - Surface Chl concentration is reducing due to less nutrients entrained

▪ *Observational Evidence* ▪

- **Correlation between surface Wspd and Chl concentration**
  - Wspd: band-pass time filtered (30-120days) STD for 6 months
  - Chl: 4-month mean** (Jul-Oct in this case)
  - Degree of Freedom: 9 (MODIS) and 13 (SeaWiFS)
- **Affirmative Signal in Boreal Summer**
  - Positive correlation coefficients locate in region of 20-40m of climatological BLT



D0_Log10NO3: The depth of nitrate isopleths, i.e. $\log_{10}NO_3$=0 ($\log_{10}$mmol/m³)
D1_Log10NO3: Same as D0_Log10NO3, but $\log_{10}NO_3$=1

5°×5° box smoothing was applied before calculating correlations
BLT climatology is based on WOA09

** The reason for later 4-month mean of Chl is because we assume that the Chl responses to the ISV events are not instantaneous.

Conclusions

- **MJO forcing maintains high concentration of surface Chl in bio-physical coupled numerical simulations**
  - MJO forcing means intraseasonal variability of oceanic vertical structure
  - Without MJO forcing, stratification and vertical stability are enhanced.
- **Rectification by the MJO forcing is due to non-linear responses**
  - Shoaling of MLD, ITD, nutrient isopleths etc. during calm wind regime is larger than deepening due to strong wind
- **Potential Bio-physical feedback is suggested**
  - The increased seasonal mean of surface Chl concentration means more shortwave radiation is absorbed in near-surface layer rather than penetrating into the deeper ocean
  - The effect of "modified heat distribution" on the physical climate system is being further examined

- **This content is from the "in press" manuscript in JGR-Oceans (DOI: 10.1029/2012JC008256)**

- **References**

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