

# The Effects of Vertical Mixing on Phytoplankton in Indian Ocean Regions

QuickTime™ and a  
YUV420 codec decompressor  
are needed to see this picture.

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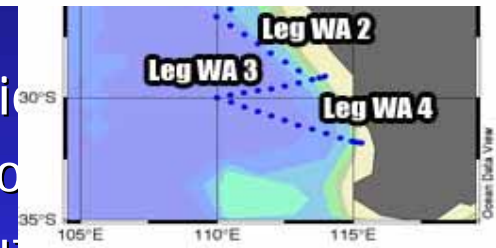
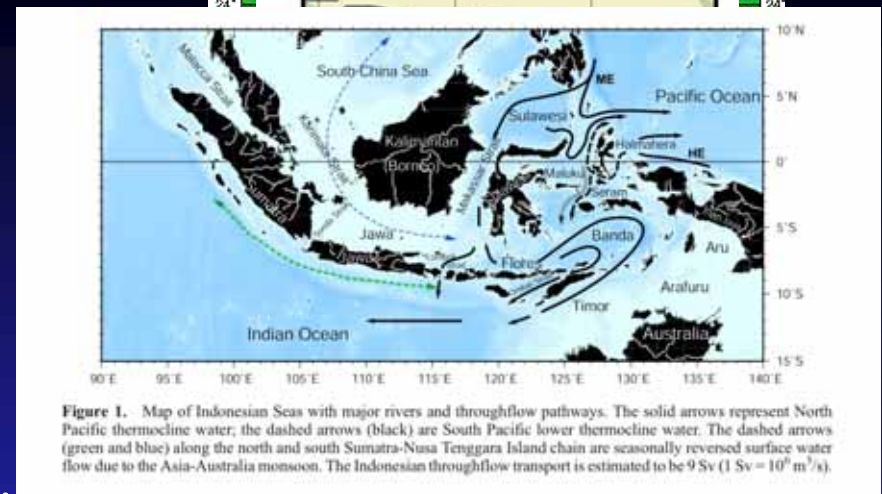
# Outline

## ■ Arabian Sea

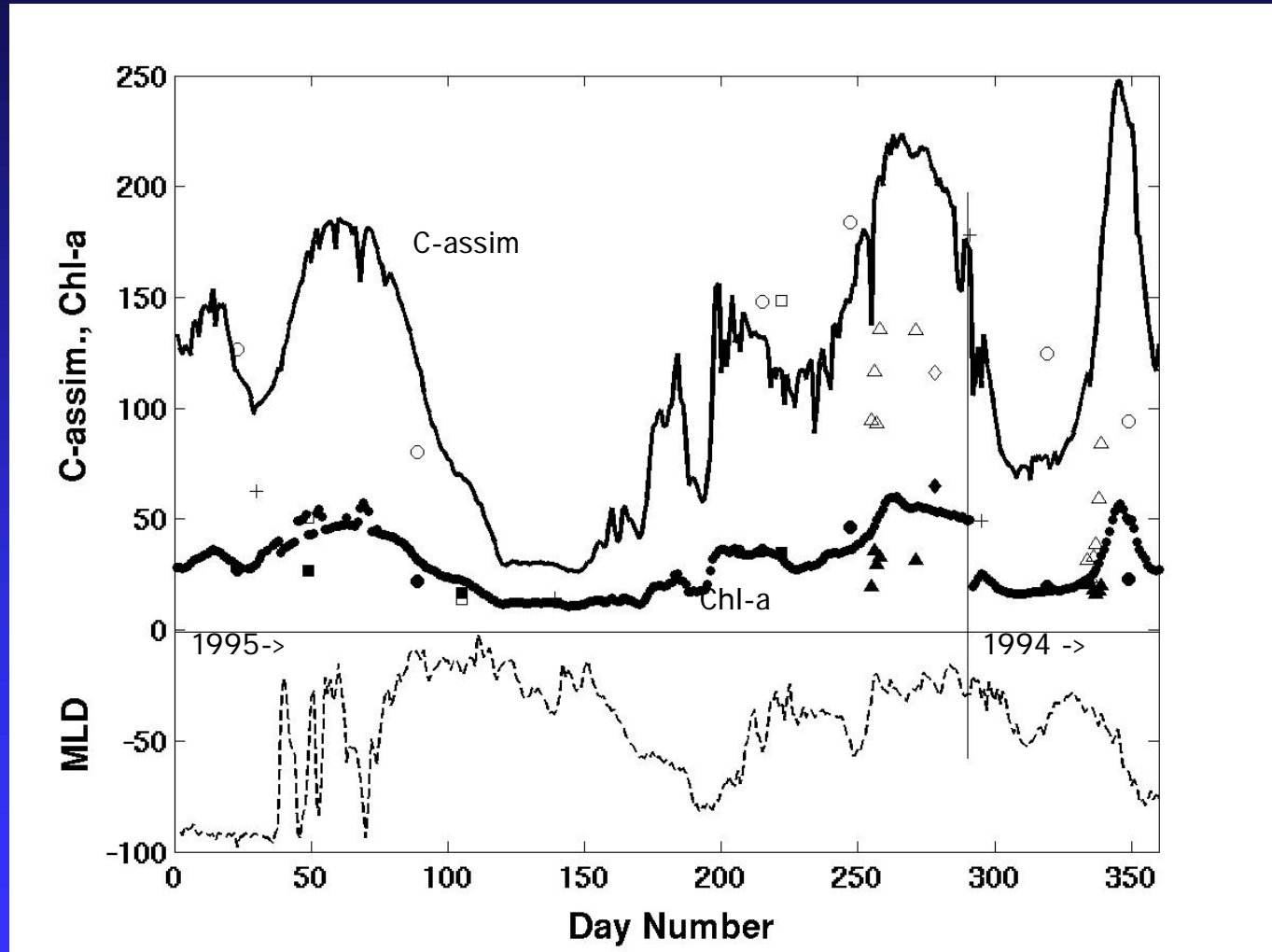
- ◆ Reconcile the observations that
  - ◆ Phytoplankton biomass variability
  - ◆ Grazing regulation would smooth biomass
- ◆ Hypothesis: Mixing produces dilution, at phytos and grazers alike, producing a temporal mis-match

## ■ Indonesian Throughflow: Island Effects

## ■ Leeuwin Current: Long-Lived Anti-Cyclonic Eddies

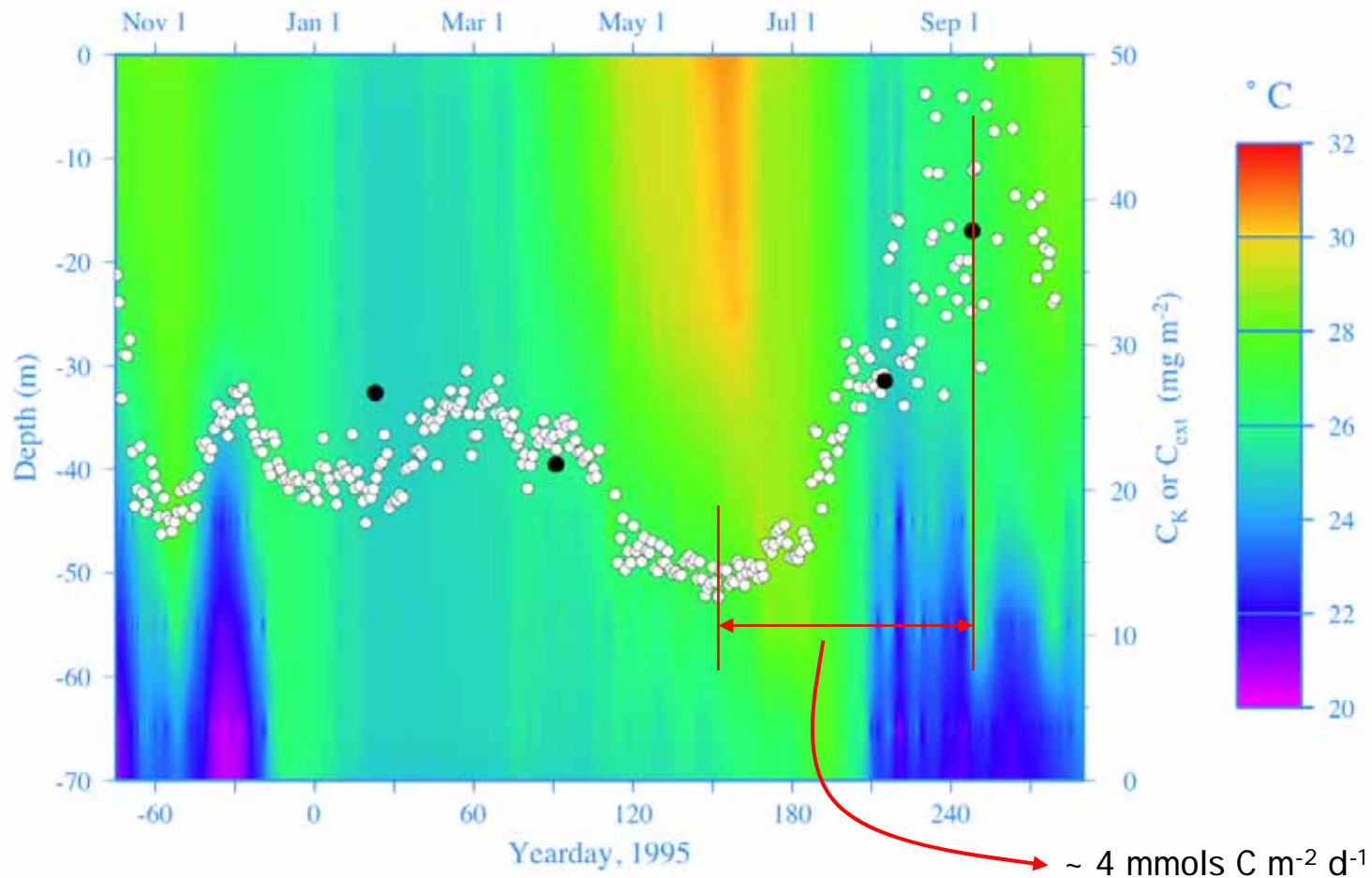


# Temporal Variability in Productivity, Phytoplankton, and Mixed Layer Depths

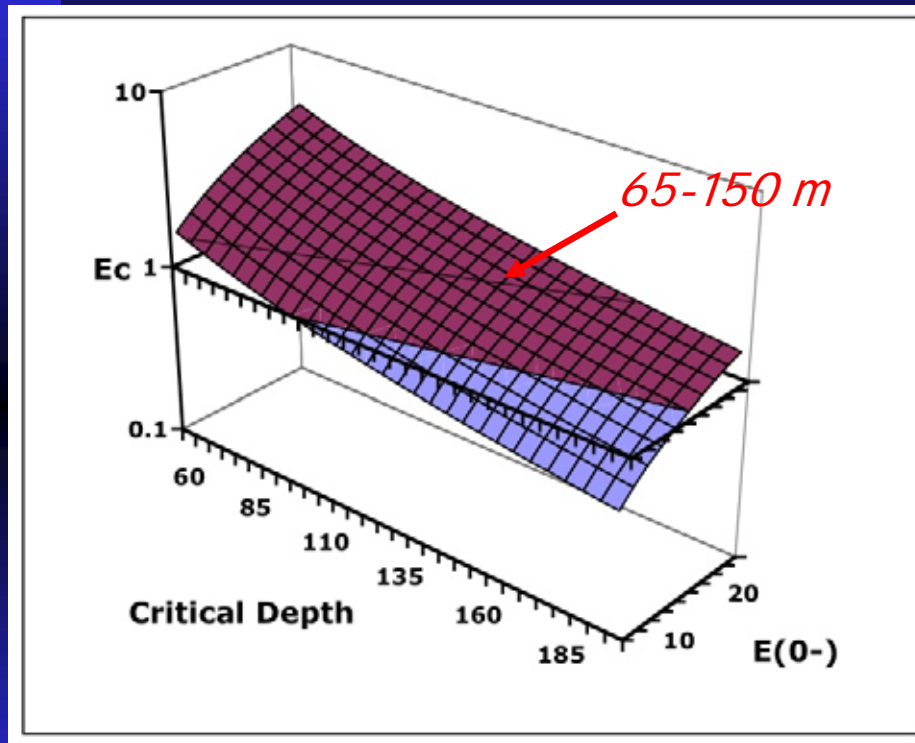


Mooring Location: 15°30'N, 61°30'E

# Temporal Variability of Areal Chl-a with Temperature



# Effects of Irradiance: Variability in the Critical Depth



$$\frac{Z_{cr}}{1 - \exp(k \cdot Z_{cr})} = \frac{E(0^-)}{E_c \cdot k}$$

- Calculate  $E_c$  from a range of  $Z_{cr}$ ,  $E(0^-)$ , and a high-average  $k$  ( $0.1 \text{ m}^{-1}$ ).
- For an  $E_c$  of  $1.6 \text{ mols m}^{-2} \text{ d}^{-1}$  (high!),  $Z_{cr}$  varies from 65-150 m at minimum.

*Phytoplankton are unlikely to be mixed to deeper than the critical depth*

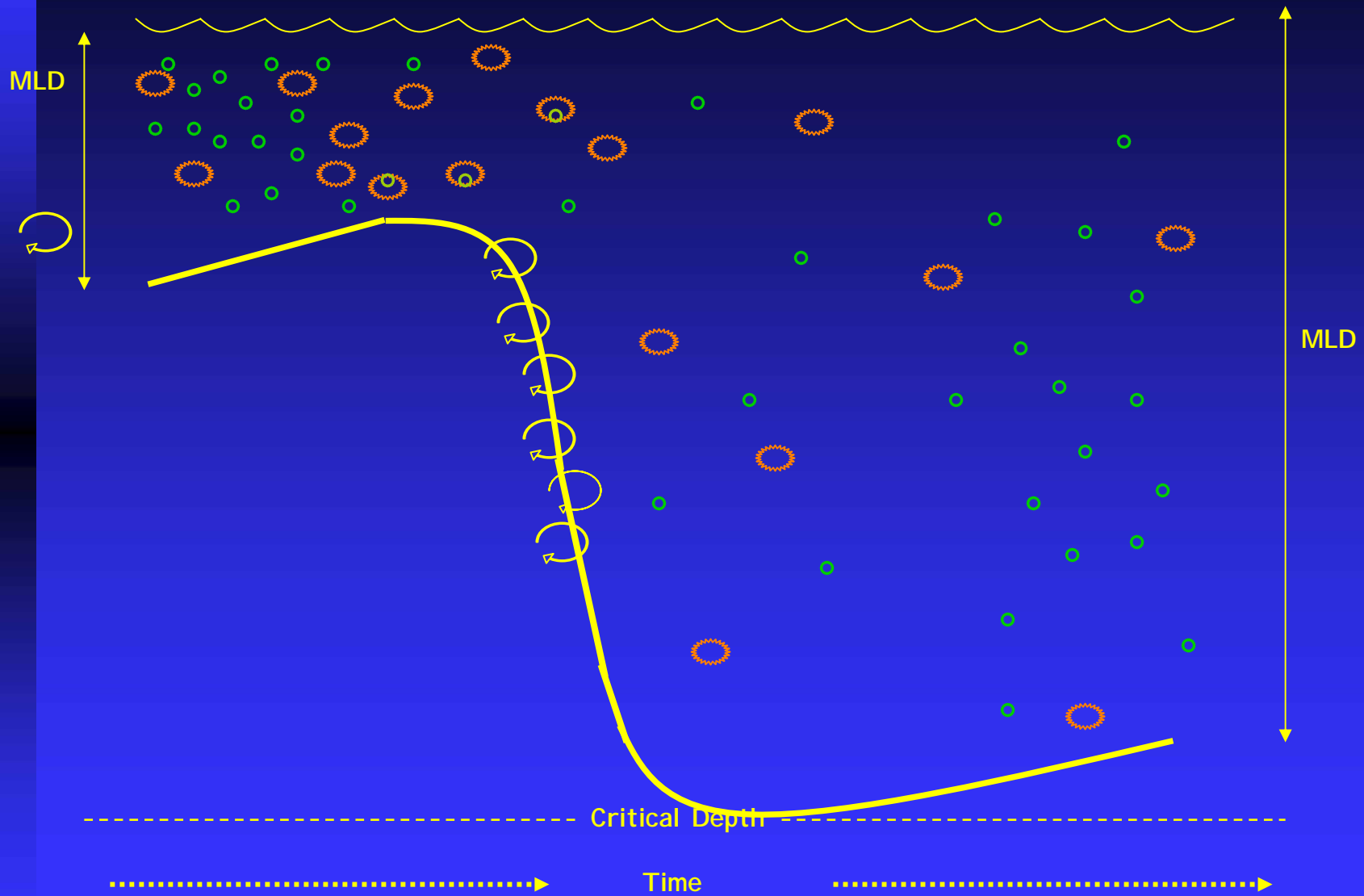
# Effects of Nutrients

- Phytoplankton have a very high affinity for  $\text{NH}_4$  and  $\text{NO}_3$  both in terms of uptake and growth ( $K_s$  values =  $0.1 \text{ mmol kg}^{-1}$ )
- Arabian Sea sometimes qualifies as a “High-Nutrient, Low-Chlorophyll” regime.

## *The situation thus far...*

1. Neither irradiance nor nutrients are likely to slow phytoplankton growth over the observed range of mixed layer depths
2. Mixed layer depths vary as a consequence of the monsoons and mesoscale processes
3. In situ increases in Chl-*a* are much, much slower than would be predicted from physiology or from C assimilation
4. ZP ingestion rates match phytoplankton growth rates

# The Dilution Hypothesis\*



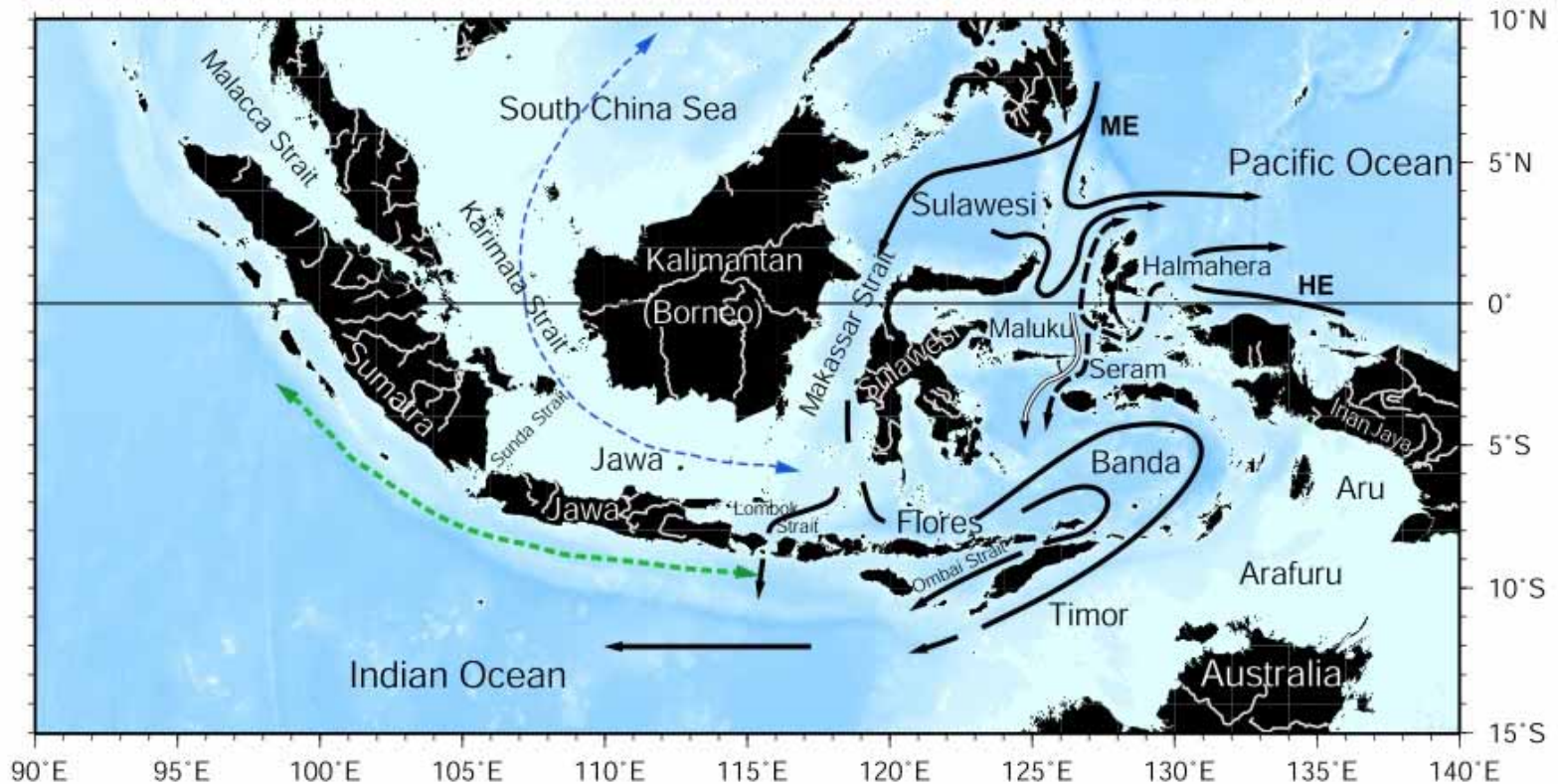
# Questions for the Future: “Top-Down” or Bottom-Up Regulation?

- Dilution hypothesis true? (Still bottom up)
- Micro-nutrient regulation (i.e., iron?)
- Phytoplankton community structure?
- Mesozooplankton?
- Spatial variability?

# The Eastern Boundary of the Indian Ocean

- Indonesian Throughflow into the Indian Ocean: Island Effects
- The Leeuwin Current near Australia

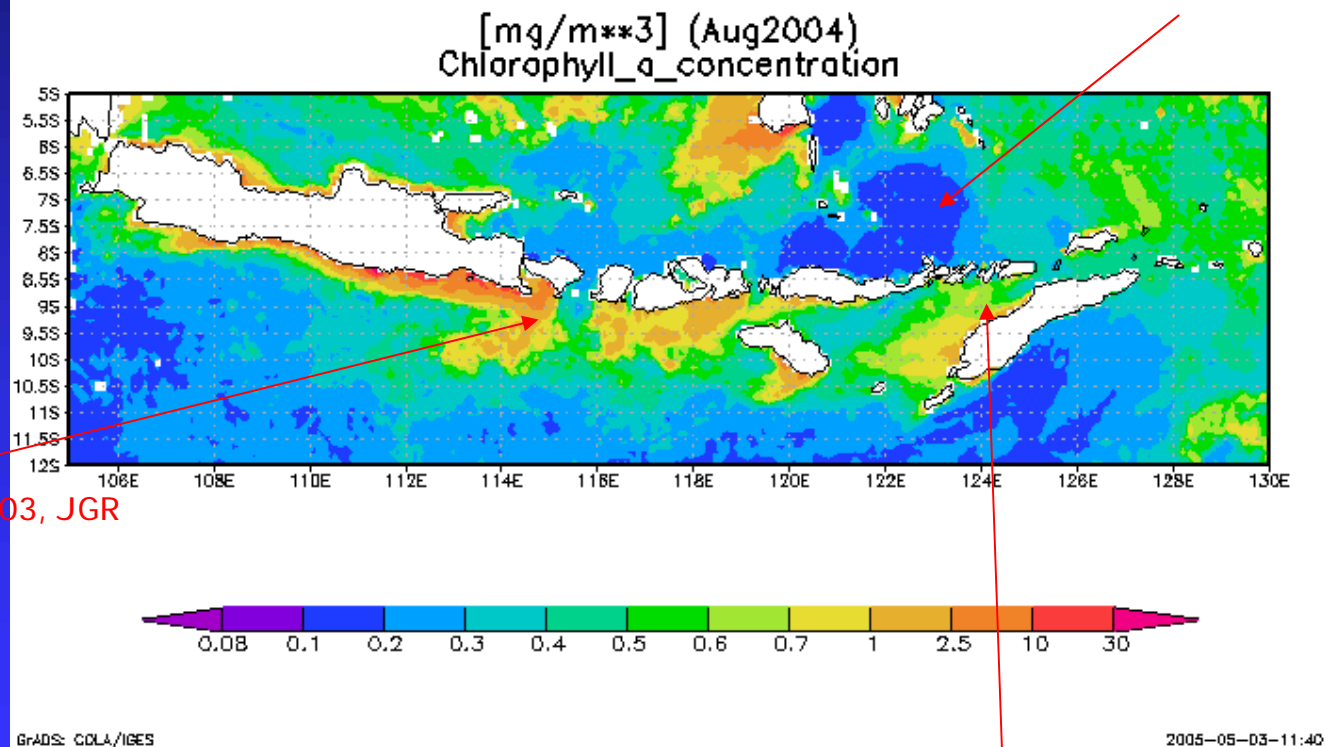
# The Indonesian Throughflow



**Figure 1.** Map of Indonesian Seas with major rivers and throughflow pathways. The solid arrows represent North Pacific thermocline water; the dashed arrows (black) are South Pacific lower thermocline water. The dashed arrows (green and blue) along the north and south Sumatra-Nusa Tenggara Island chain are seasonally reversed surface water flow due to the Asia-Australia monsoon. The Indonesian throughflow transport is estimated to be 9 Sv (1 Sv =  $10^6$  m<sup>3</sup>/s).

# Ocean Color Distributions During the SE Monsoon

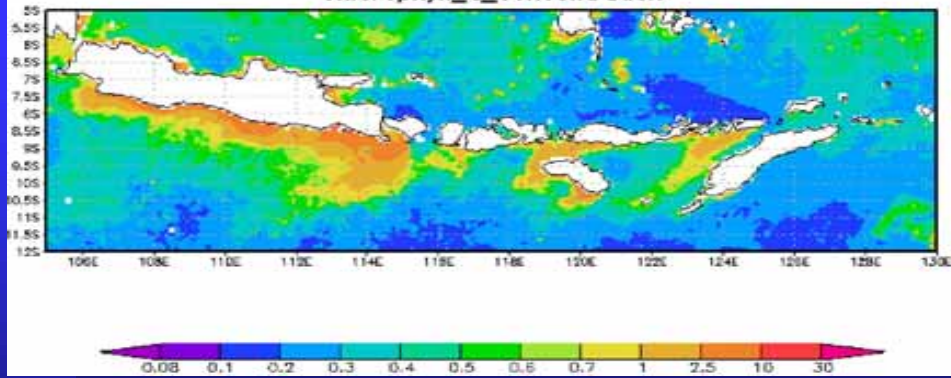
Susanto, Moore and Marra, 2006, G<sup>3</sup>



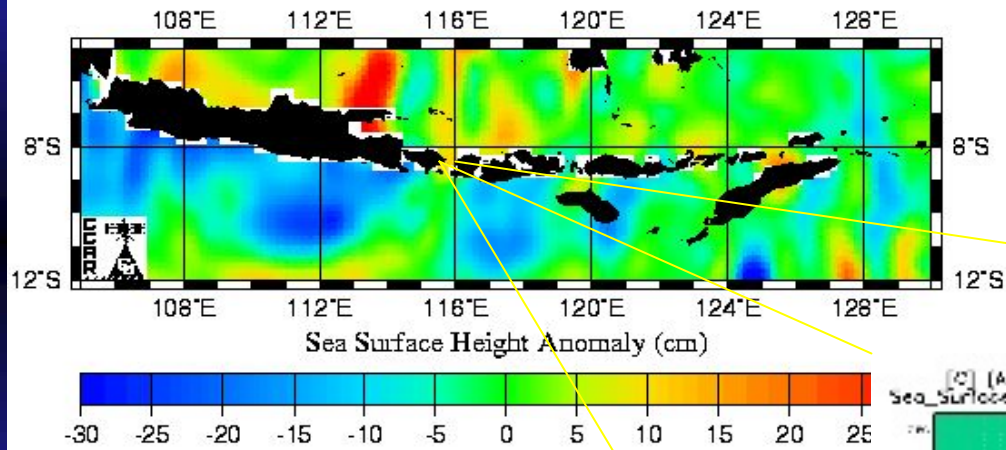
Asanuma et al., 2003, JGR

Moore and Marra, 2002, G<sup>3</sup>

[mg/m<sup>3</sup>] (Sep 1999)  
Chlorophyll\_a\_concentration

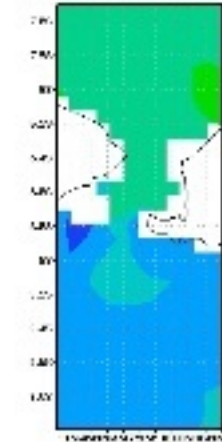


An attempt to relate color variability to sea-surface height...

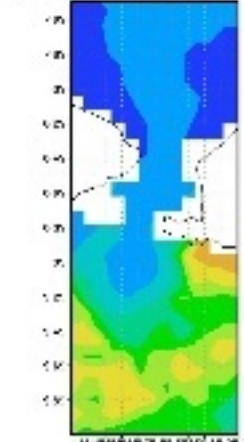


...and SST

[°C] (Aug 2003)  
Sea\_Surface\_temperature



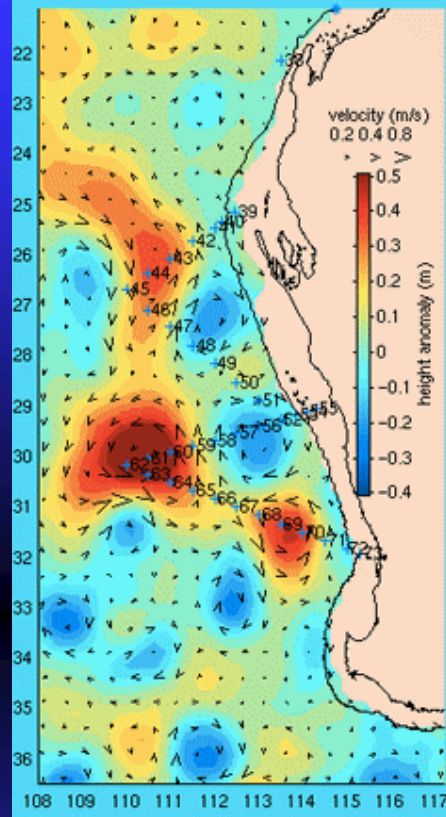
[mg/m<sup>3</sup>] (Aug 2003)  
Chlorophyll\_a\_concentration



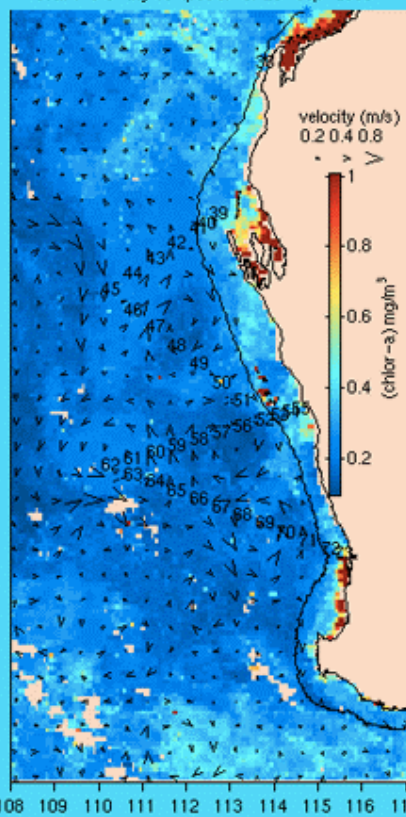
# Leeuwin Current Eddies

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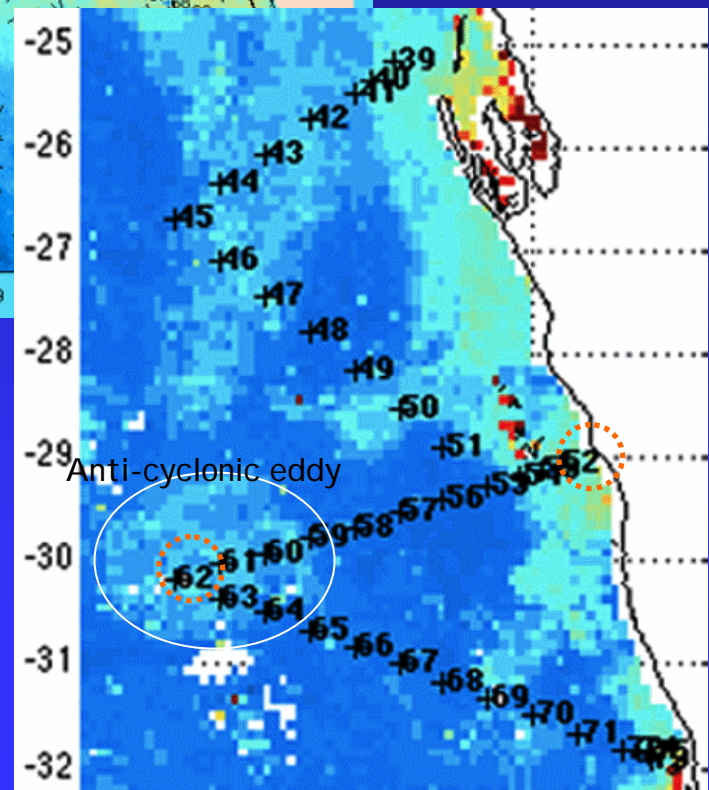
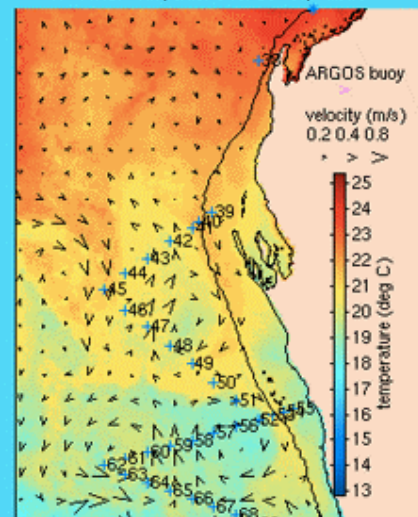
37  
Altimetric sea level and surface current for 30-Sep-2000



37  
Altimetric surface current for 30-Sep-2000  
SeaWiFS 8-day composite for 25-Sep-2000



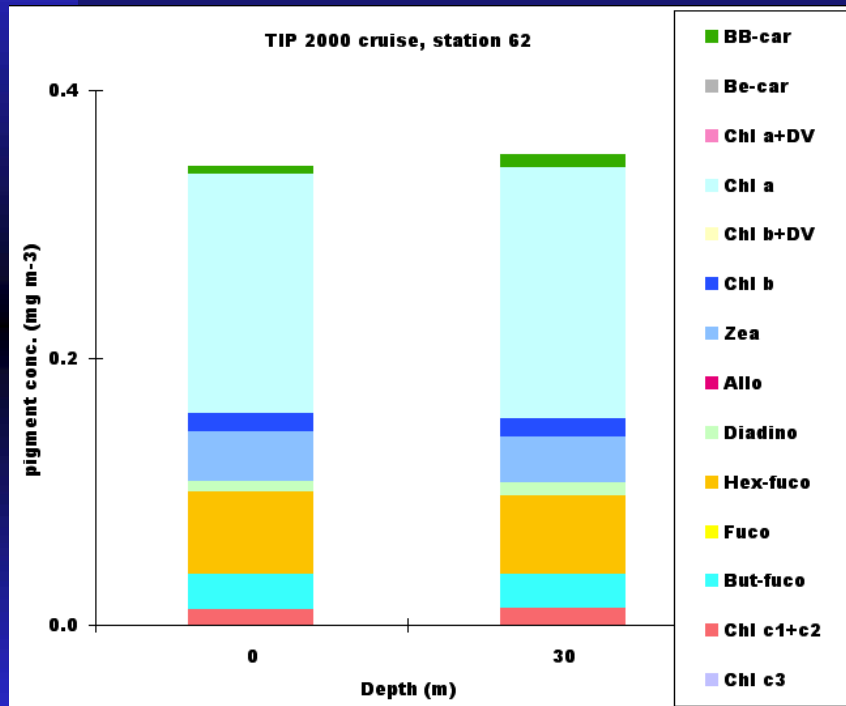
37  
Altimetric surface current for 30-Sep-2000  
sea surface temperature for 26-Sep-2000



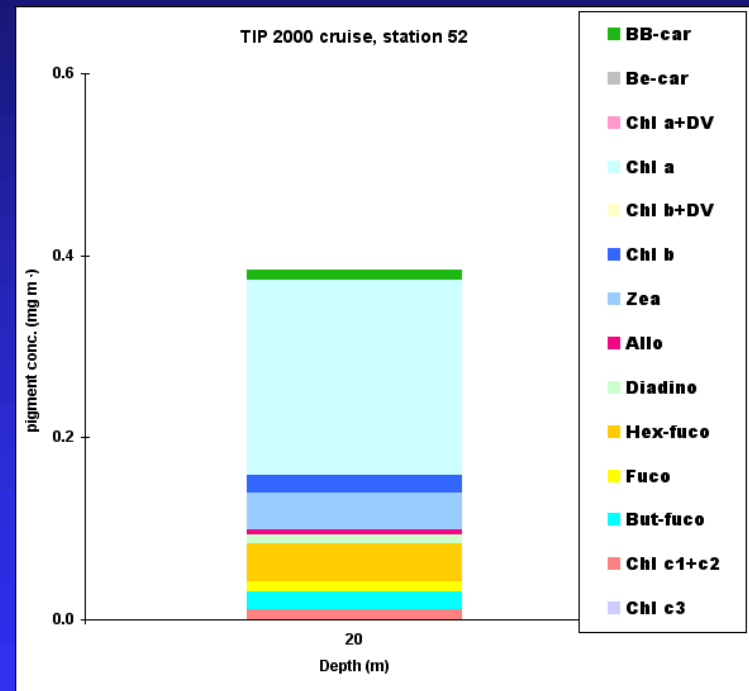
We then compared the pigment composition of coastal water and that in the eddy....

# Pigment analysis of coastal (Sta 52) and eddy (Sta 62) samples

## Coastal



## Offshore eddy, 3 months later



- Total quantity of pigment is the same
- Pigment composition nearly the same (addition of alloxanthin, fucoxanthin, loss of Chl c1+c2)

*Thanks!*