# Mixing, stratification and the spring bloom in an oligotrophic sea

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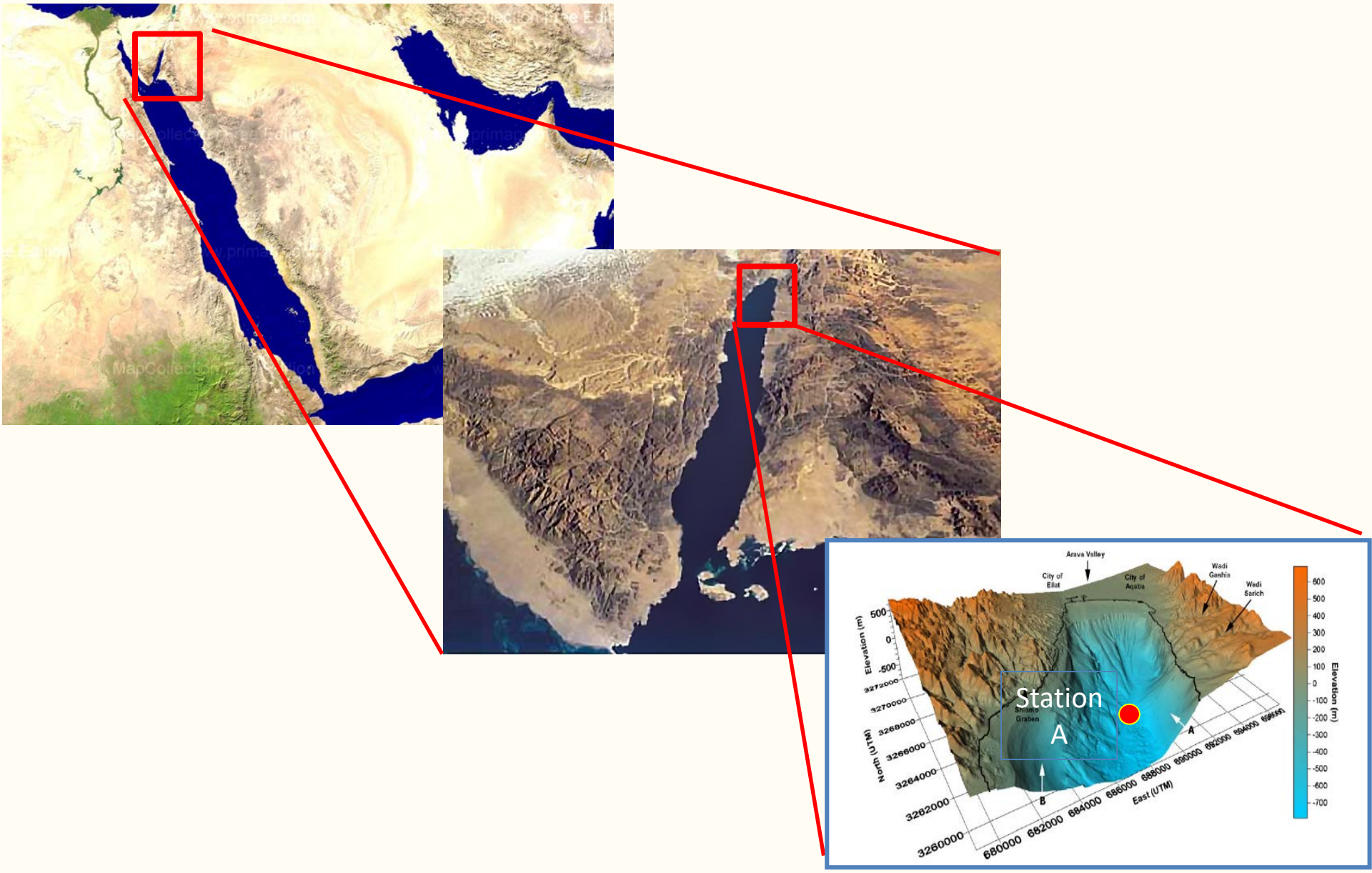
Margarita Zarubin, Yoav Lindemann

[Zarubin, Lindemann and Genin *(2017) Prog. Oceanogr.*]



*PICES-2018 Yokohama*

# Study Site: “Station A”, 750 m deep, northern Gulf of Aqaba, Red Sea



# Database

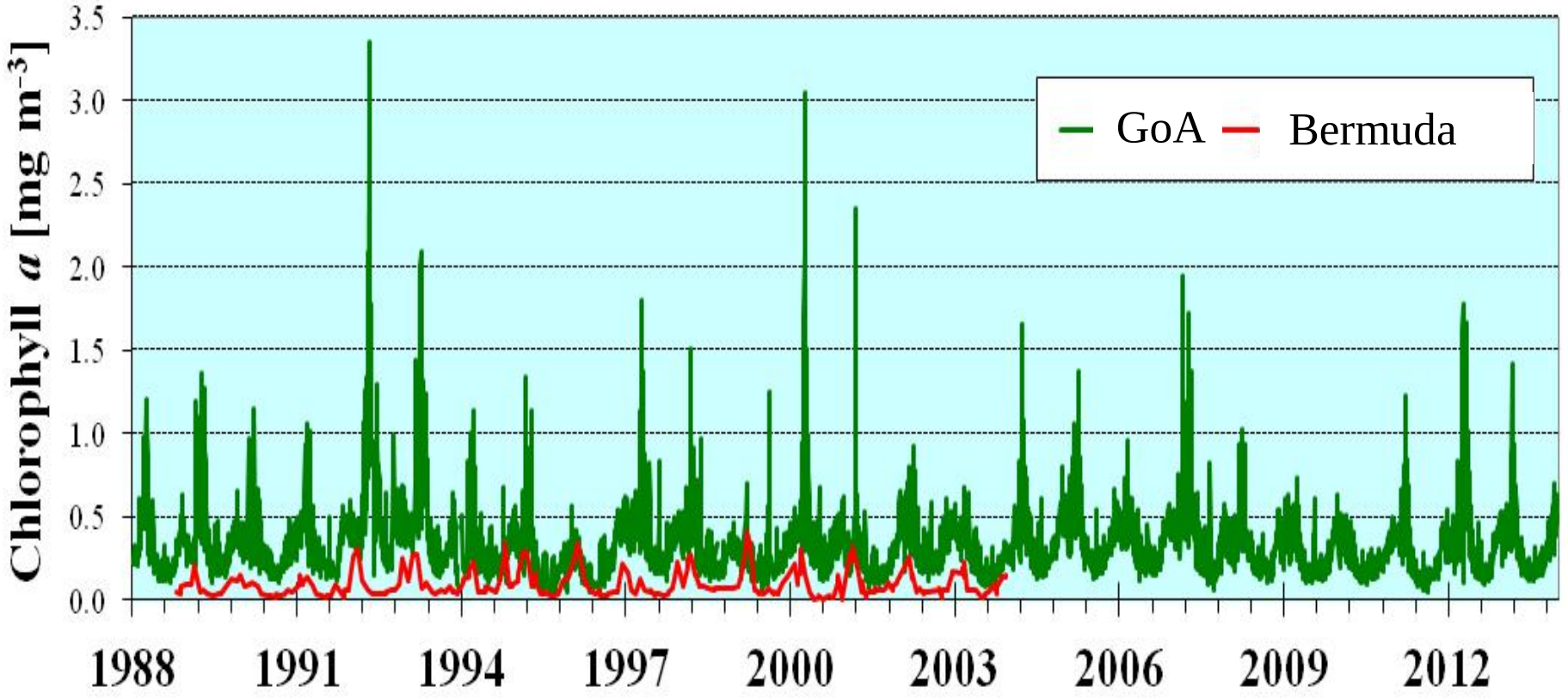
SST, Chlorophyll - since 1988

Profiling (CTD, phytoplankton, nutrients, and more) - since 2004

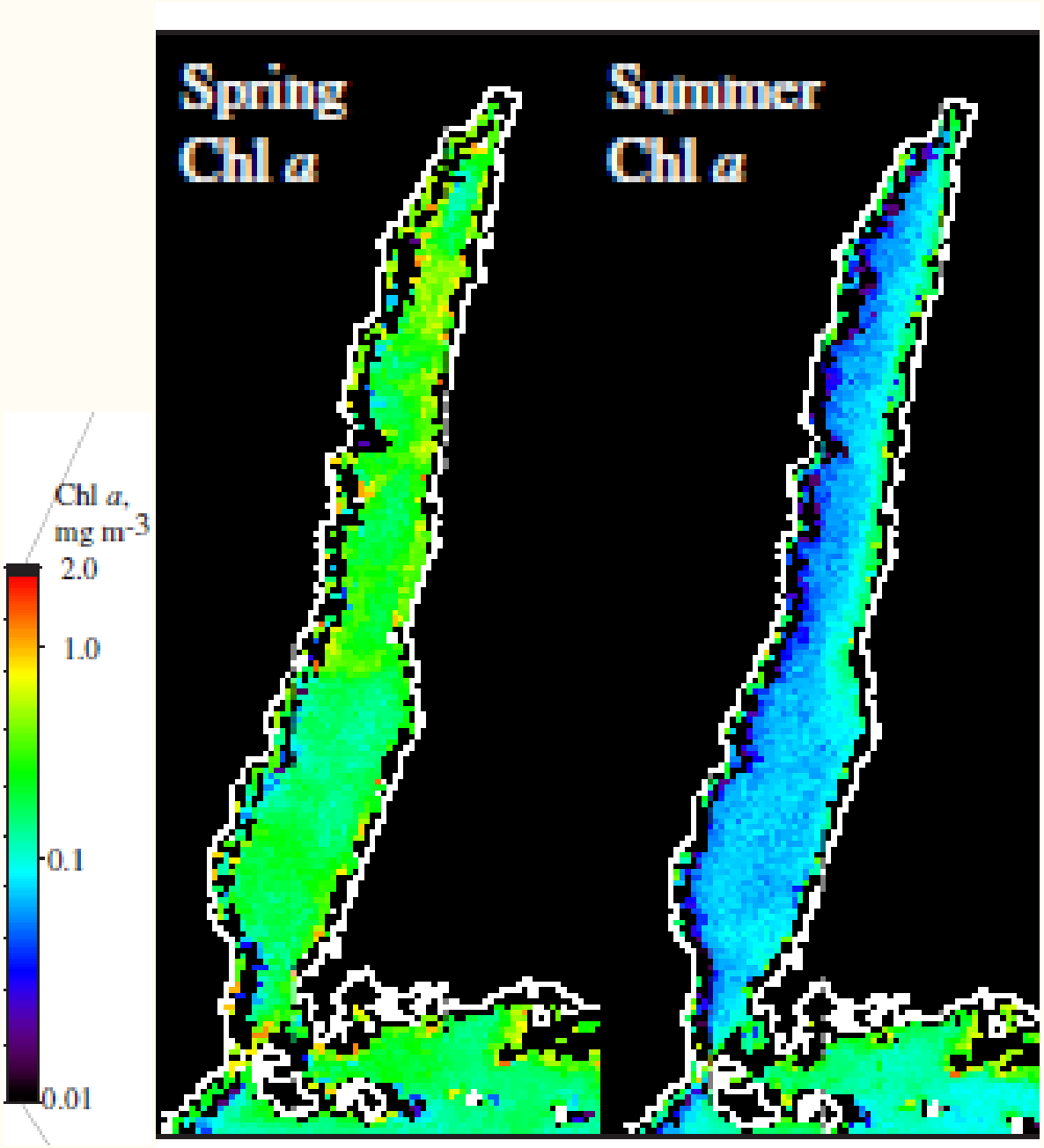
The National Monitoring Program

*http://www.iui-eilat.ac.il*

# Spring bloom (exceptional for a subtropical sea)

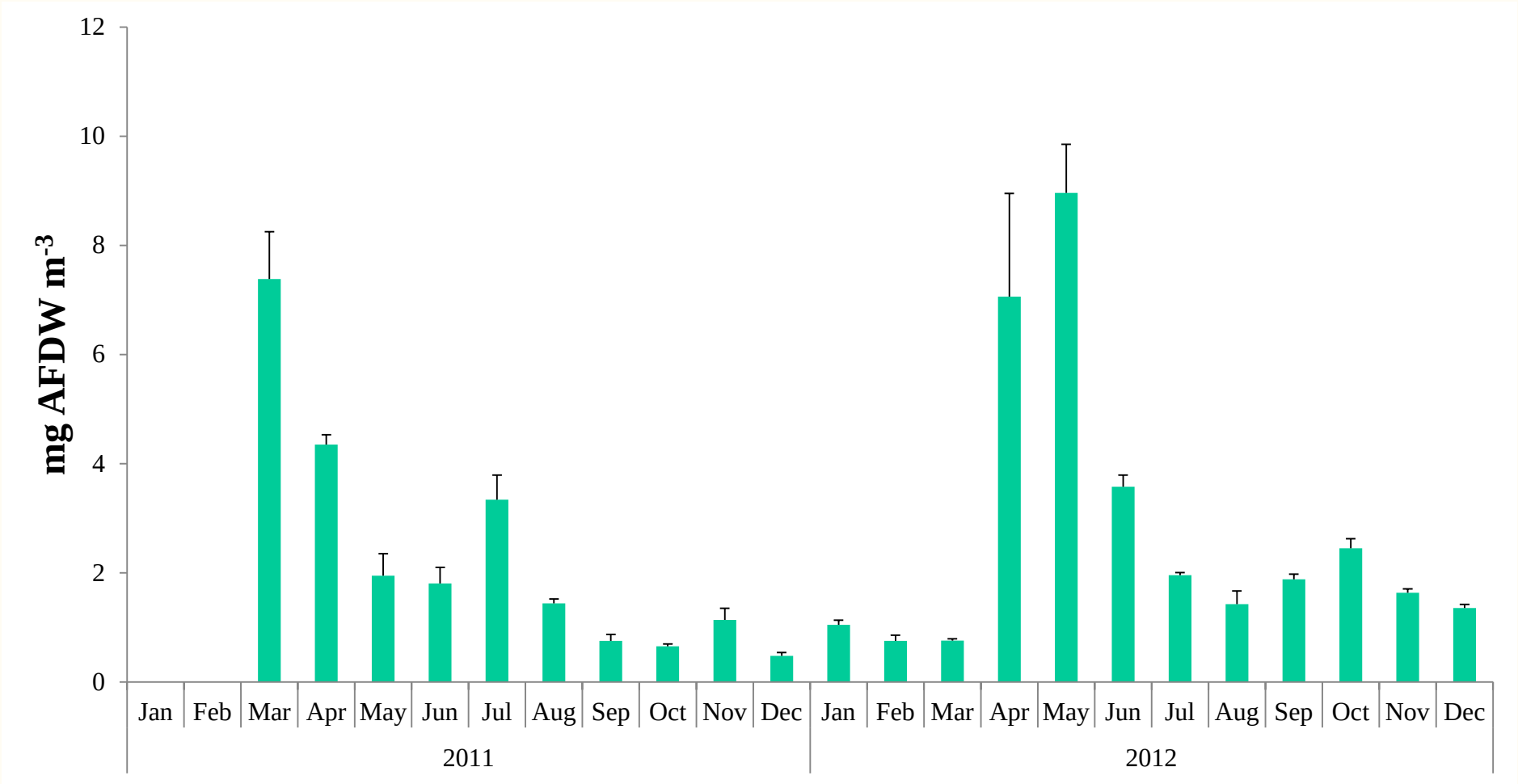


# The Spring Bloom is seen throughout the Gulf




Labiosa et al. 2003

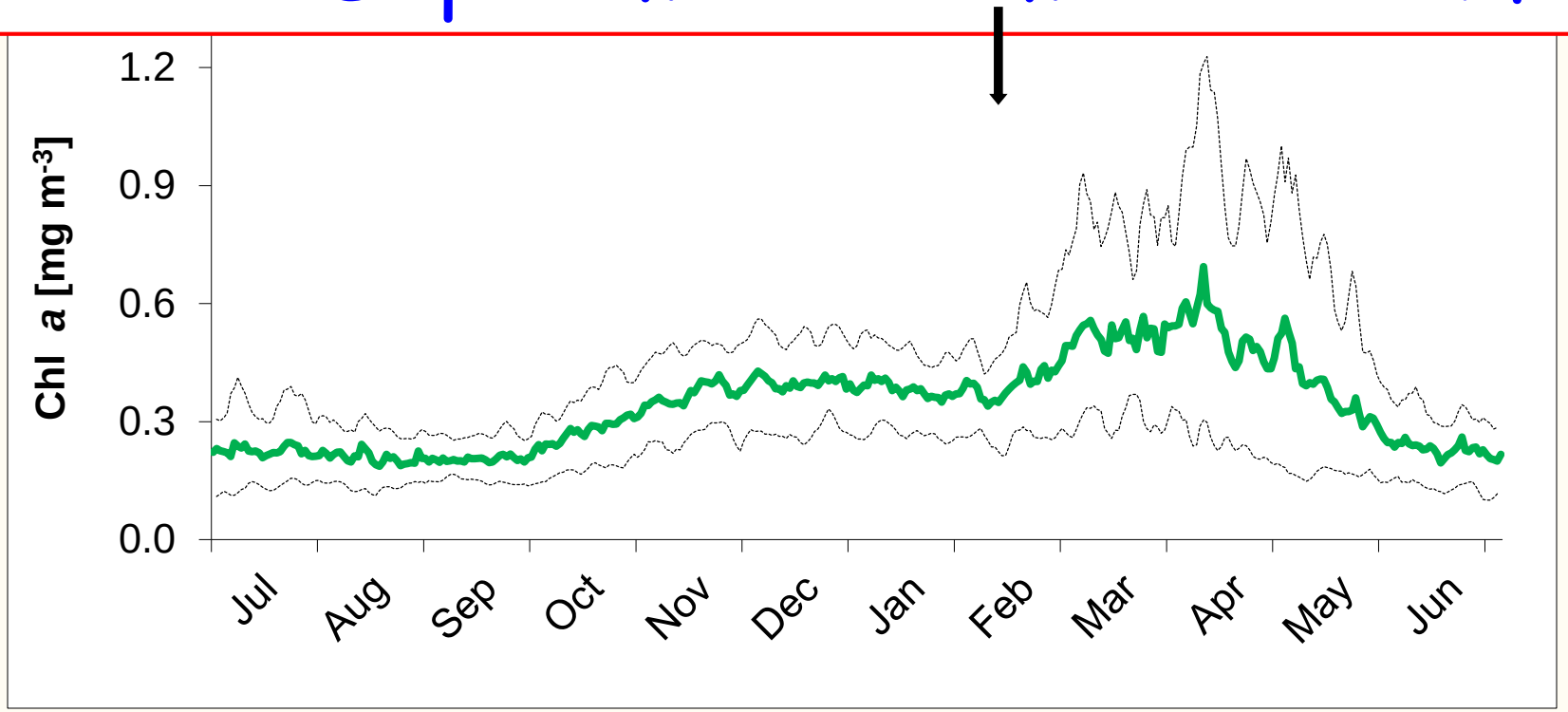
# Cascading effect: zooplankton "bloom"



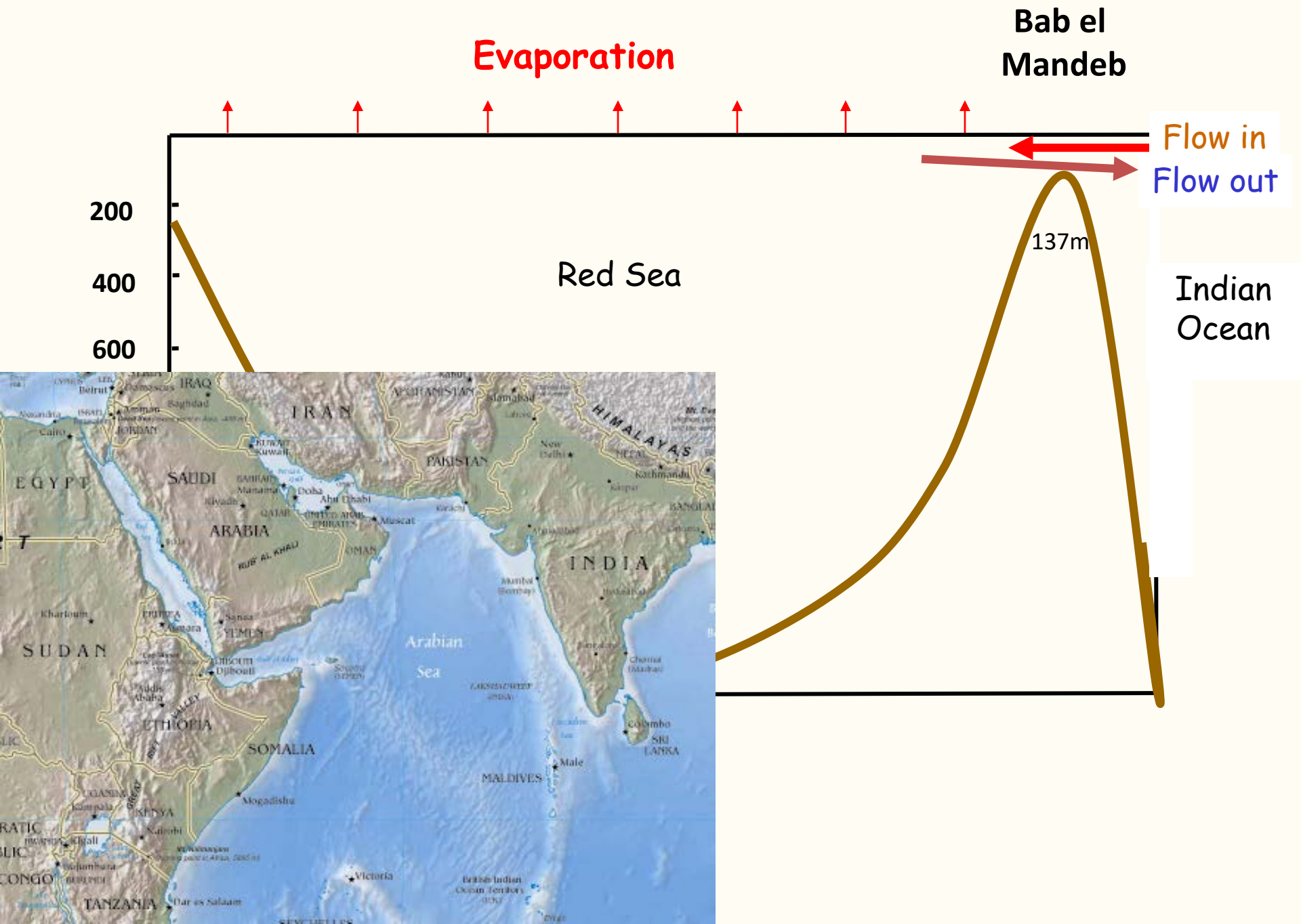
# Objectives:

(1) Find cause(s) for the strong bloom

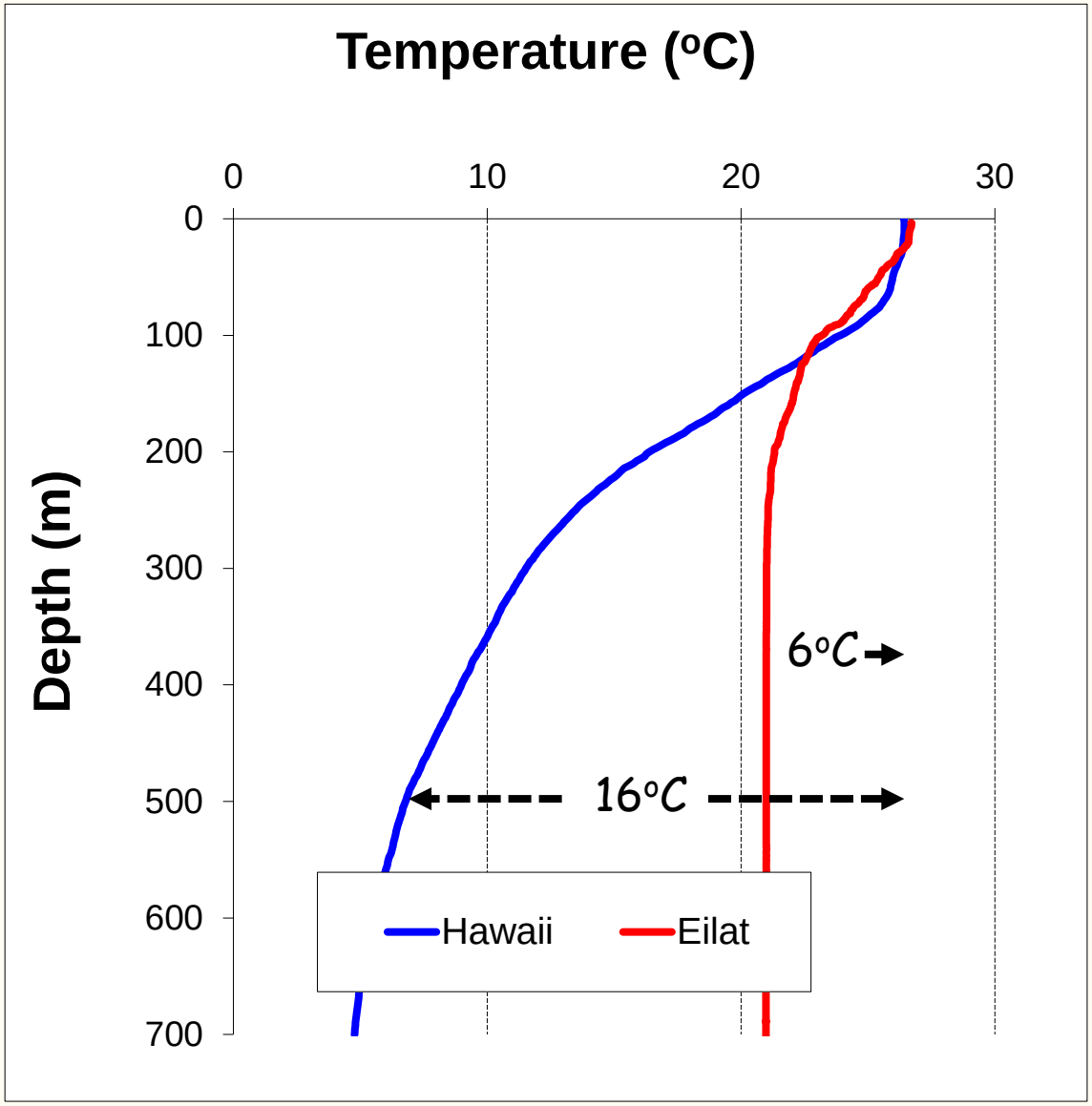
(2) Assess the relevance of Sverdrup's Critical Depth mechanism in the Gulf



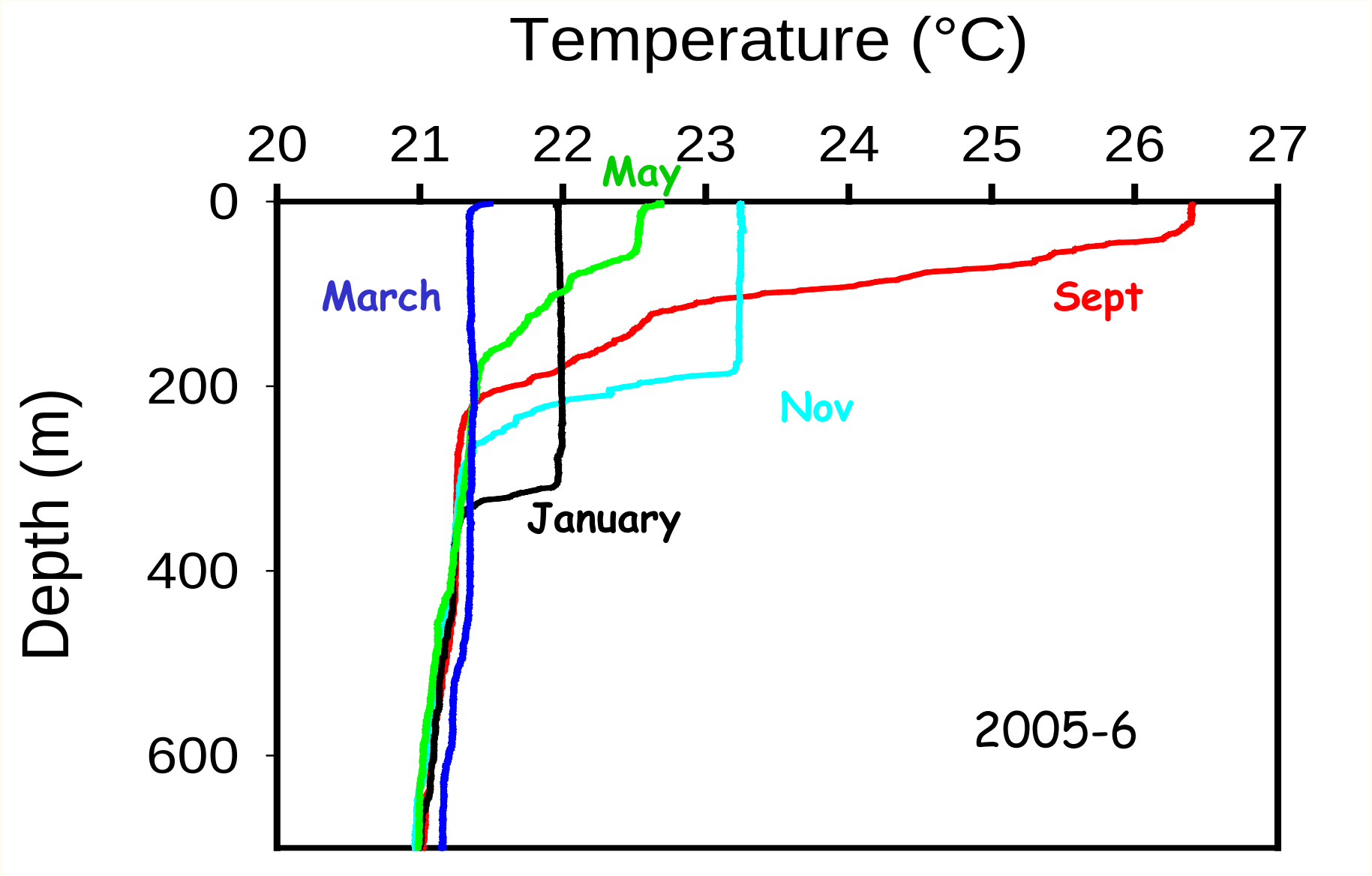
# A key feature of the Red Sea: the shallow sill near Bab el Mandeb


Evaporation
Bab el Mandeb
Flow in
Flow out
200
400
600
Red Sea
137m
Indian Ocean
IRAQ
IRAN
AFGHANISTAN
PAKISTAN
HIMALAYAS
EGYPT
SAUDI ARABIA
INDIA
SUDAN
ETHIOPIA
SOMALIA
MALDIVES
Arabian Sea
TANZANIA

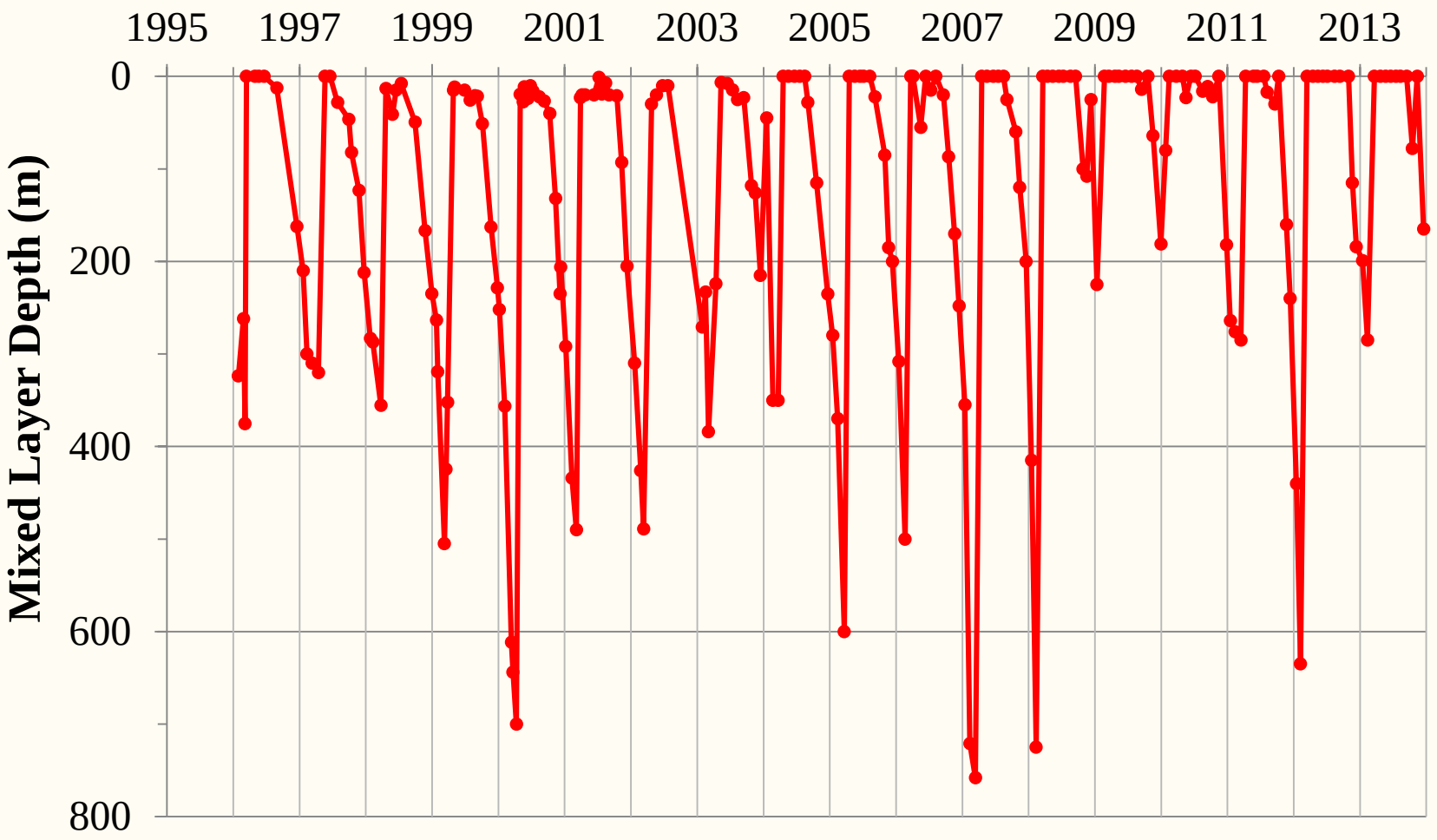
# Eilat vs. Hawaii



# Weak stratification → deep mixing

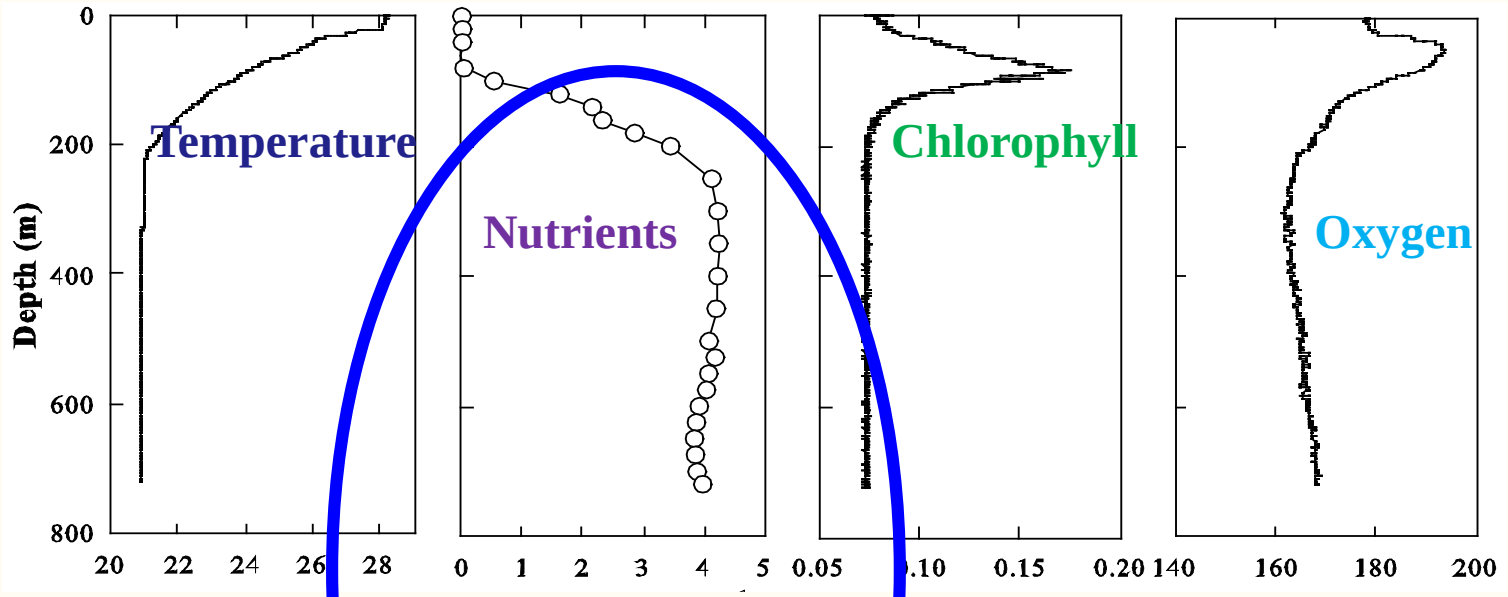


# The deepest convective mixing in the world's warm oceans

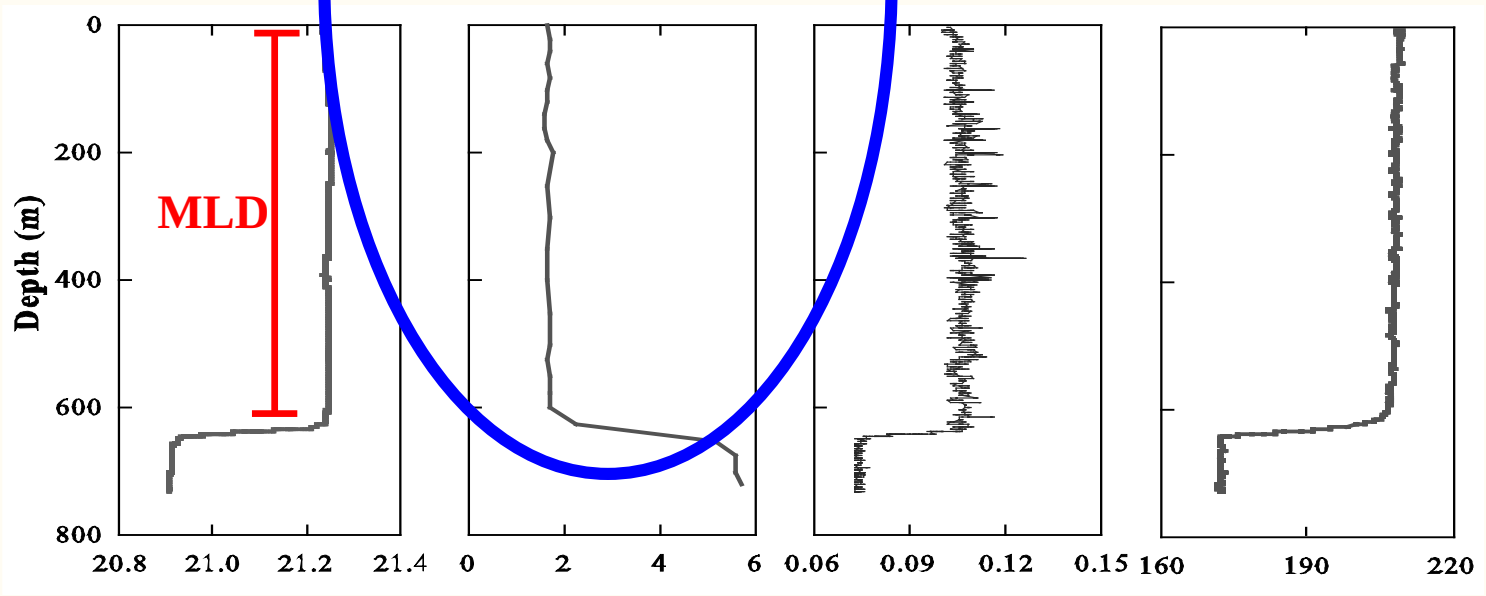


# "Mixed" layer = "Mixing" layer

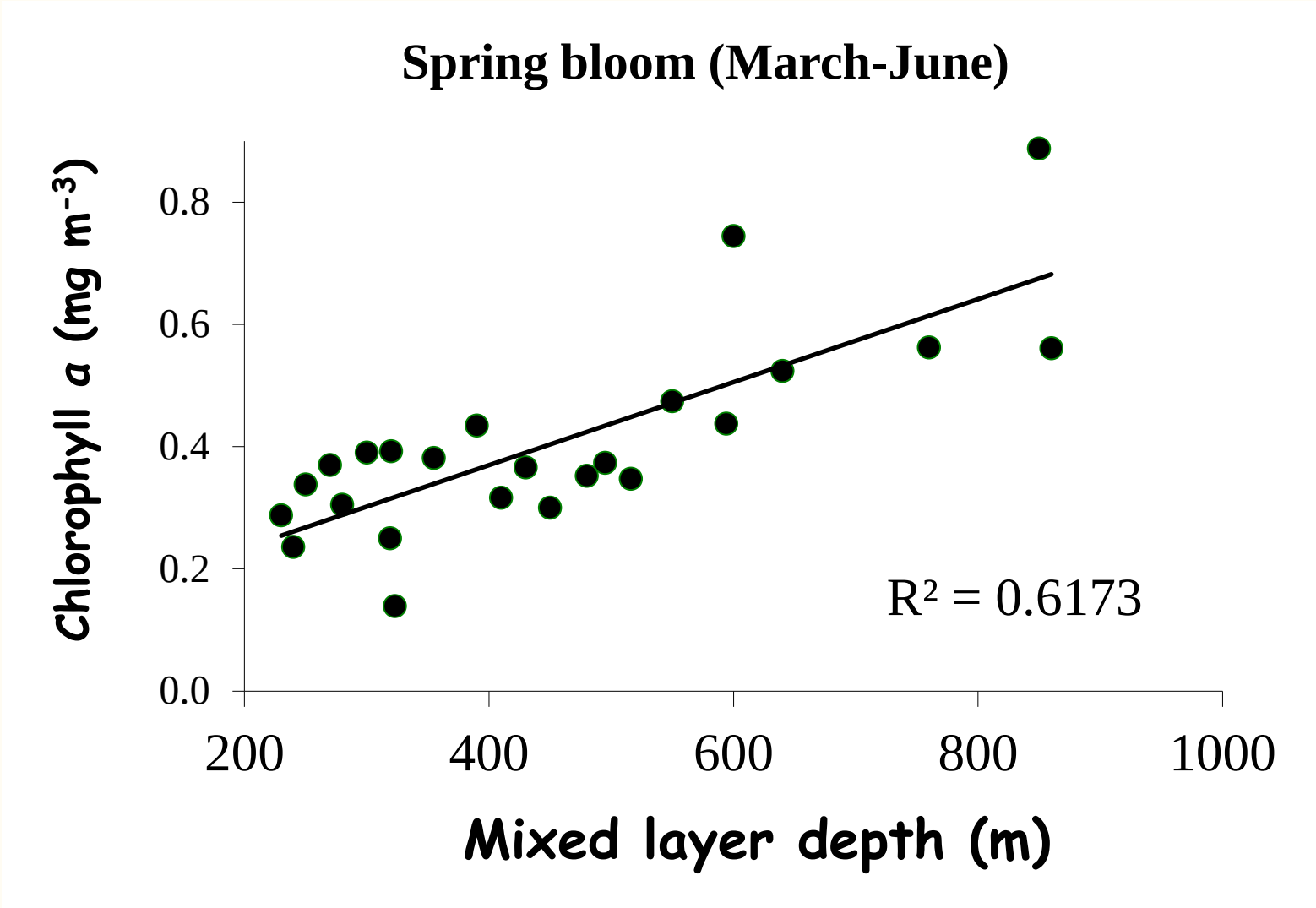
**Summer**
(Aug. 2012)



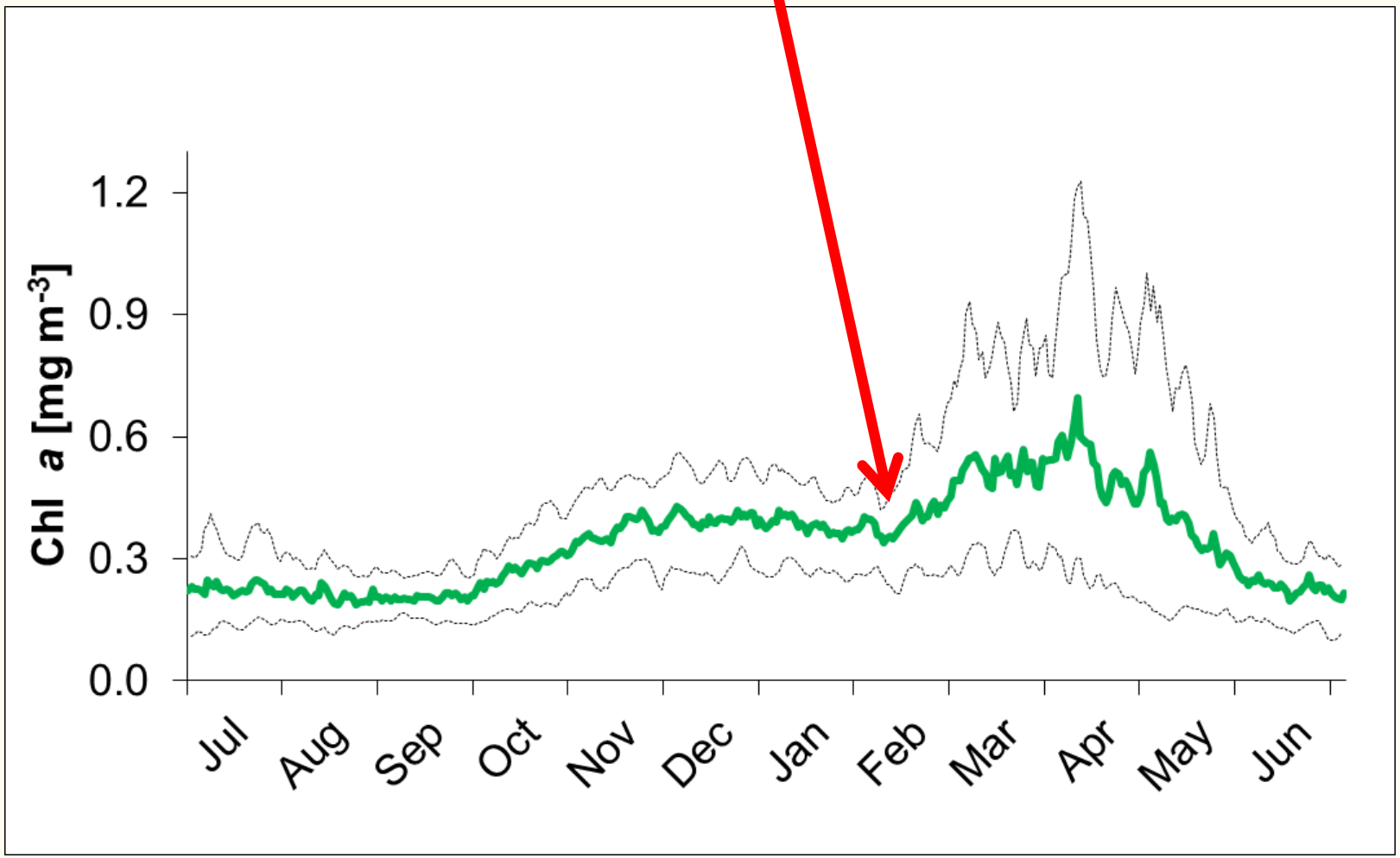

**Winter**
(Feb. 2012)



# Mixed Layer Depth (MLD) and bloom magnitude

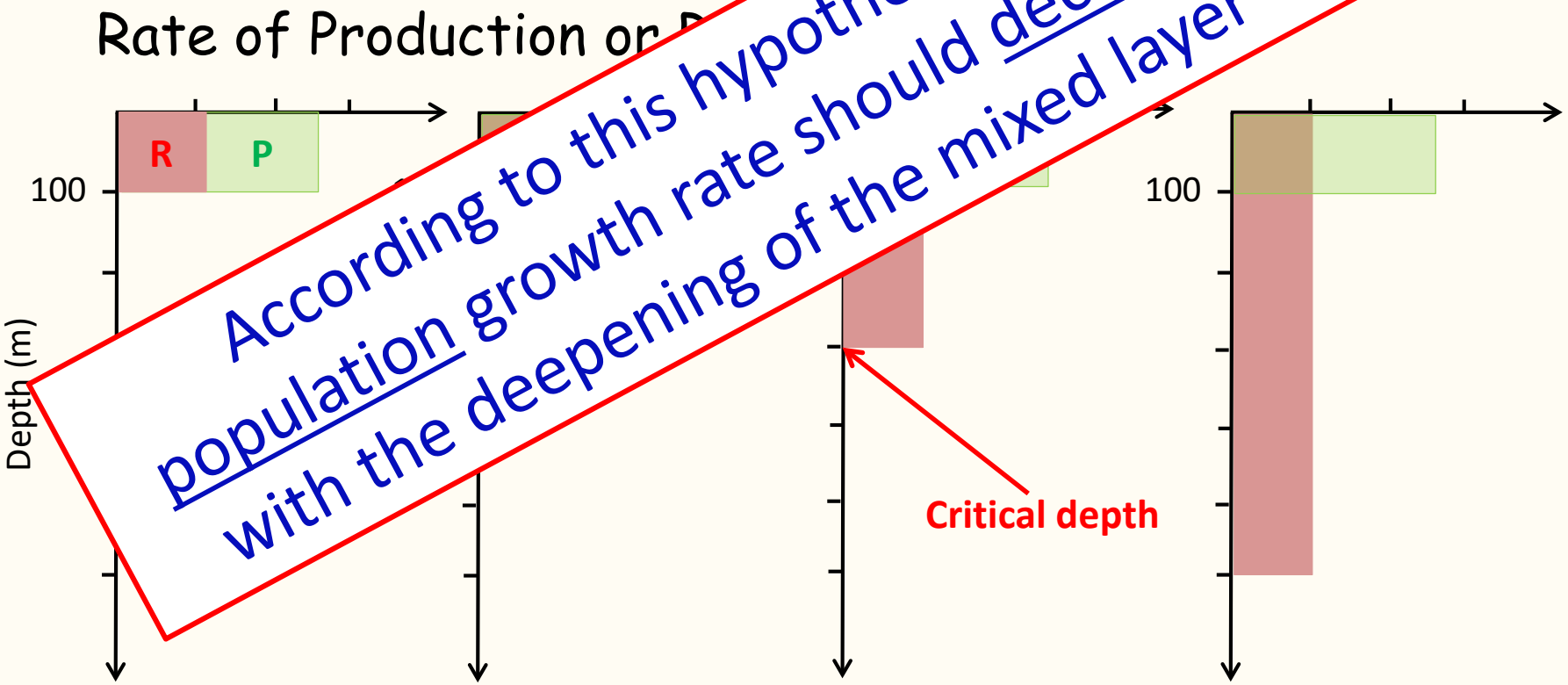


# Why does it start here?
# (and not earlier when nutrients peak)



# Sverdrup's Critical Depth Hyp thesis

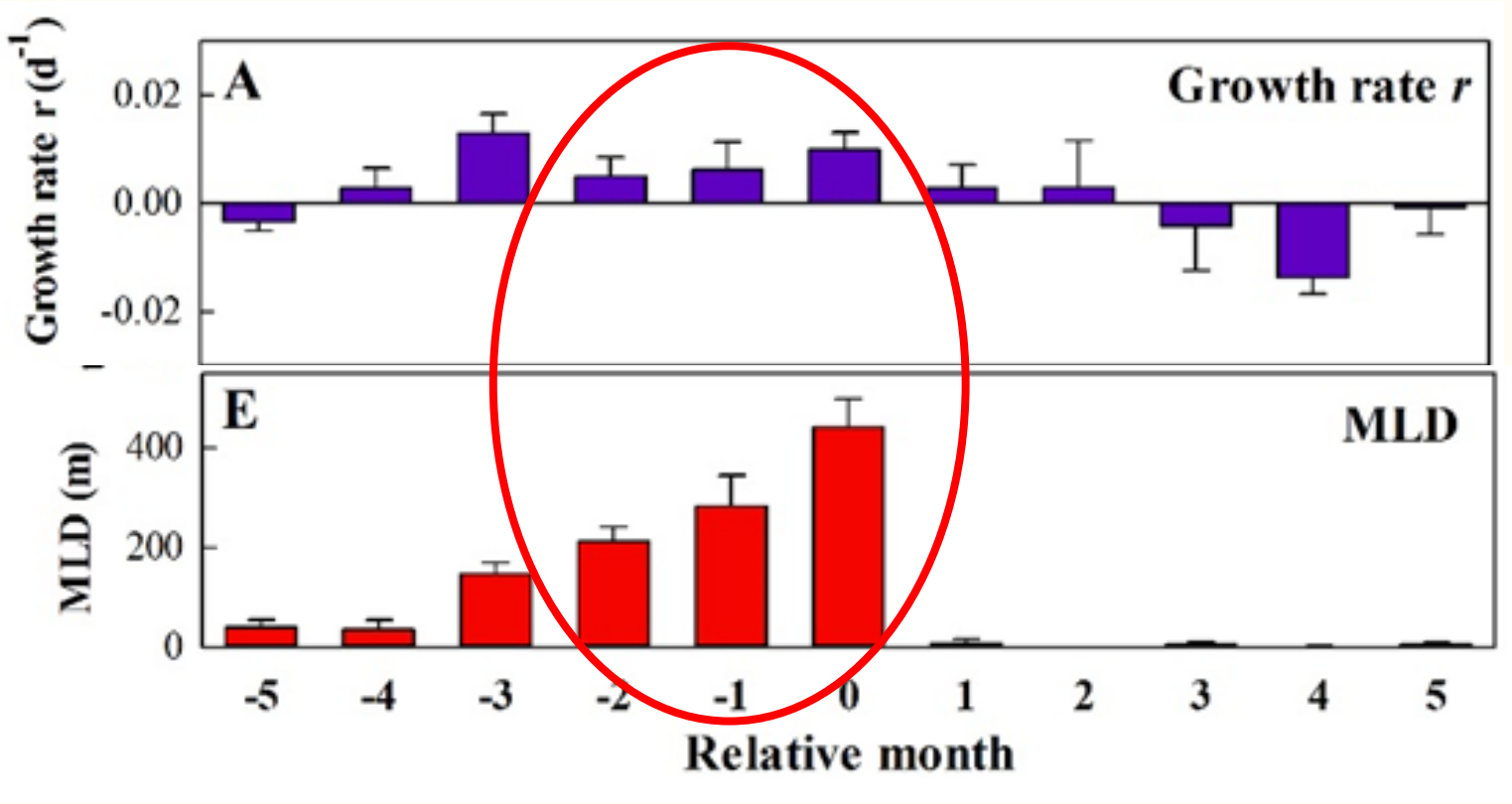
(a schematic descri




According to this hypothesis the population growth rate should decrease with the deepening of the mixed layer

Critical Depth: a depth of the mixed layer down to which the total (water-column integrated) photosynthesis by phytoplankton equals the total (column integrated) respiration

# Net population growth and mixing depth




Hence, the Critical Depth Hypothesis cannot explain the bloom initiation in GoA

# …as was reported for the N. Atlantic by Behrenfeld (2010) and Boss & Behrenfeld (2010)

*Ecology*, 91(4), 2010, pp. 977–989


## Abandoning Sverdrup's Critical Depth Hypothesis on phytoplankton blooms

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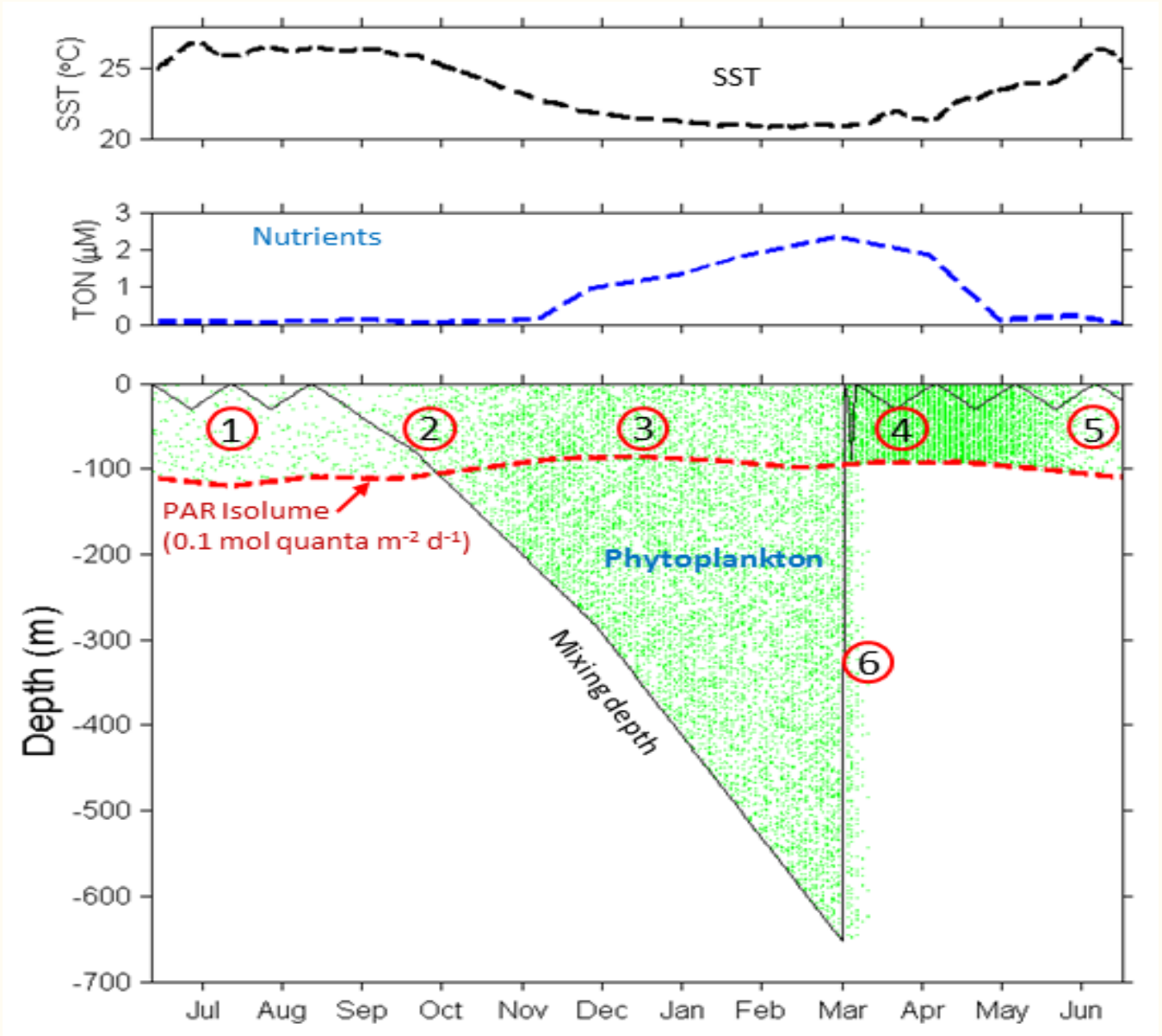
*Abstract.* The Critical Depth Hypothesis formalized by Sverdrup in 1953 posits that vernal phytoplankton blooms occur when surface mixing shoals to a depth shallower than a critical depth horizon defining the point where phytoplankton growth exceeds losses. This hypothesis has since served as a cornerstone in plankton ecology and reflects the very common assumption that blooms are caused by enhanced growth rates in response to improved light, temperature, and stratification conditions, not simply correlated with them. Here, a nine-year satellite record of phytoplankton biomass in the subarctic Atlantic is used to reevaluate seasonal plankton dynamics. Results show that (1) bloom initiation occurs in the winter when

- Behrenfeld (2010) proposed an alternative mechanism, relating the bloom initiation to reduced grazing by zooplankton.

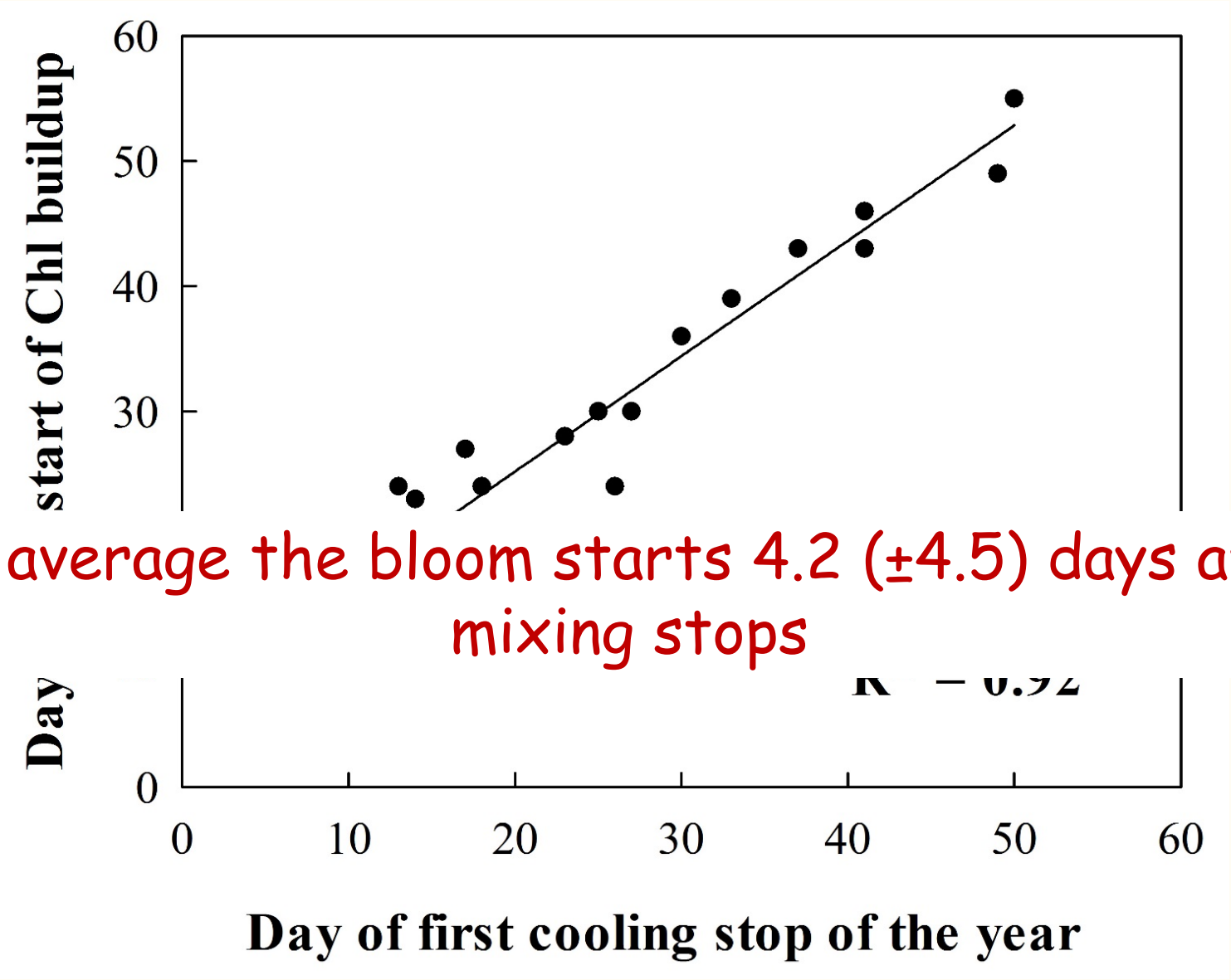
- That alternative hypothesis is not supported by experiments in the Gulf of Aqaba (Zarubin et al. 2017, *Prog. Oceanogr.*)

# The Dispersion-Confinement Hypothesis

(following Huisman et al., 1999, L&O)

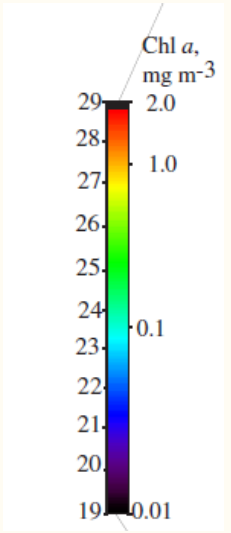


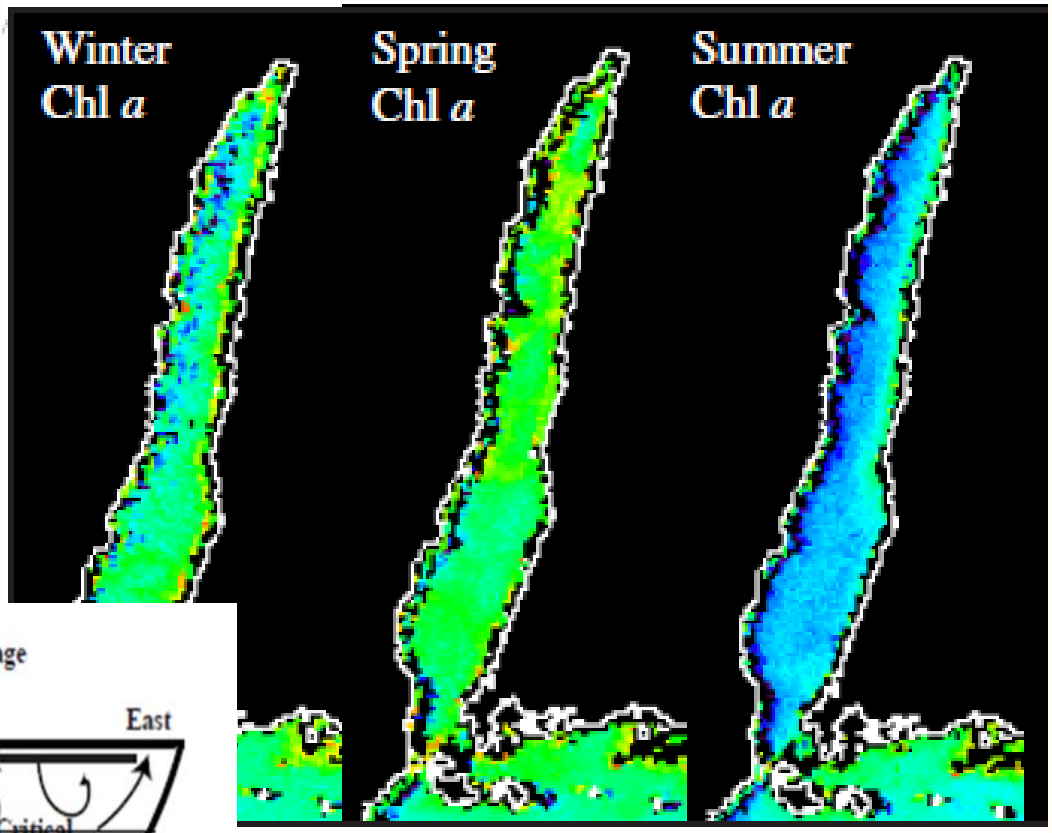
# Re-stratification and bloom onset

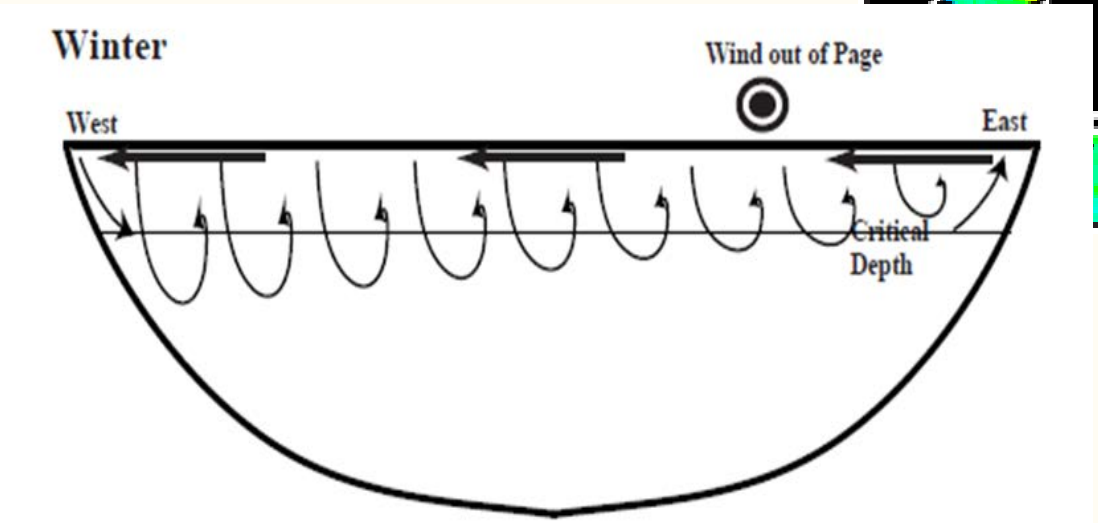



On average the bloom starts 4.2 (±4.5) days after mixing stops

# Corroboration of the Dispersion-Confinement model: remote sensing data:




Labiosa et al. 2003 *L&O.*

# Summary

Phytoplankton dynamics in GoA is determined by:

(1) Nutrient-limited production in the illuminated layer.

(2) Simple dispersion (dilution) by convective mixing (rather than respiration/production balance).

(3) The bloom appears once the dilution stops (phytoplankton produced remains in the photic layer).

(Can it also explain the N Atlantic bloom….?)

……and it is all (ultimately) because of the shallow sill at the opening of the Red Sea

Thank you!