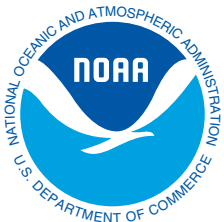
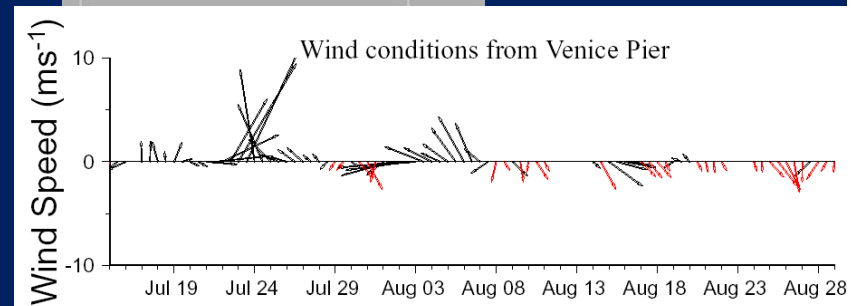
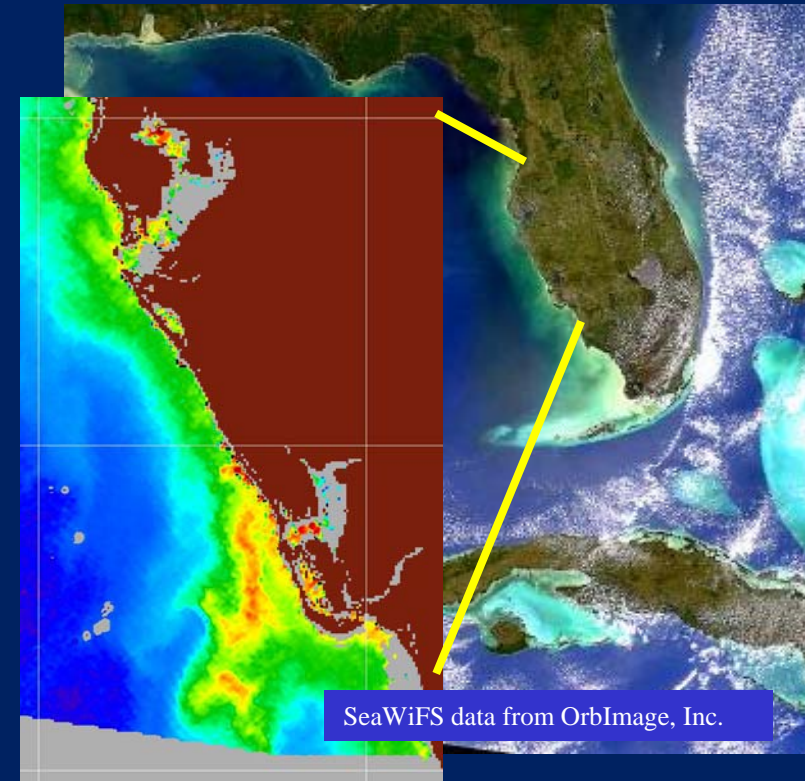
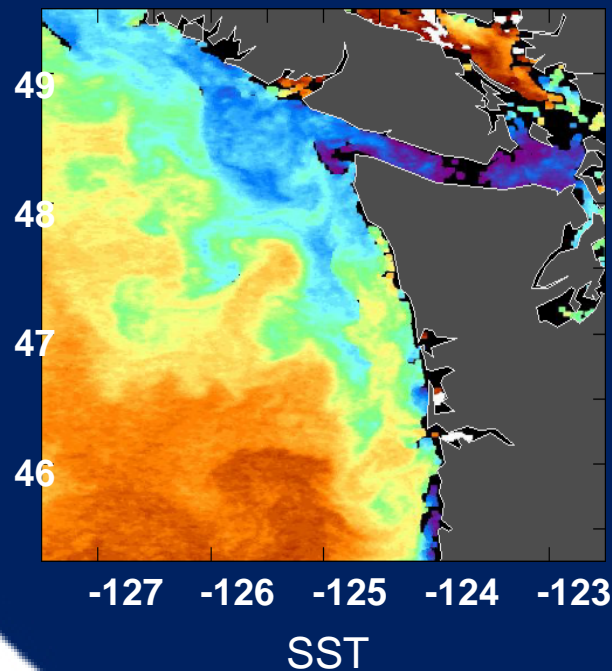


# The use of remote sensing and meteorological data for monitoring HABs through ecological associations

Shelly Tomlinson, Richard Stumpf,  
Timothy Wynne, Susan Dunham

NOAA National Ocean Service  
Silver Spring, MD

Dana Woodruff, Nathan Evans  
Pacific Northwest National Laboratory  
Sequim, WA

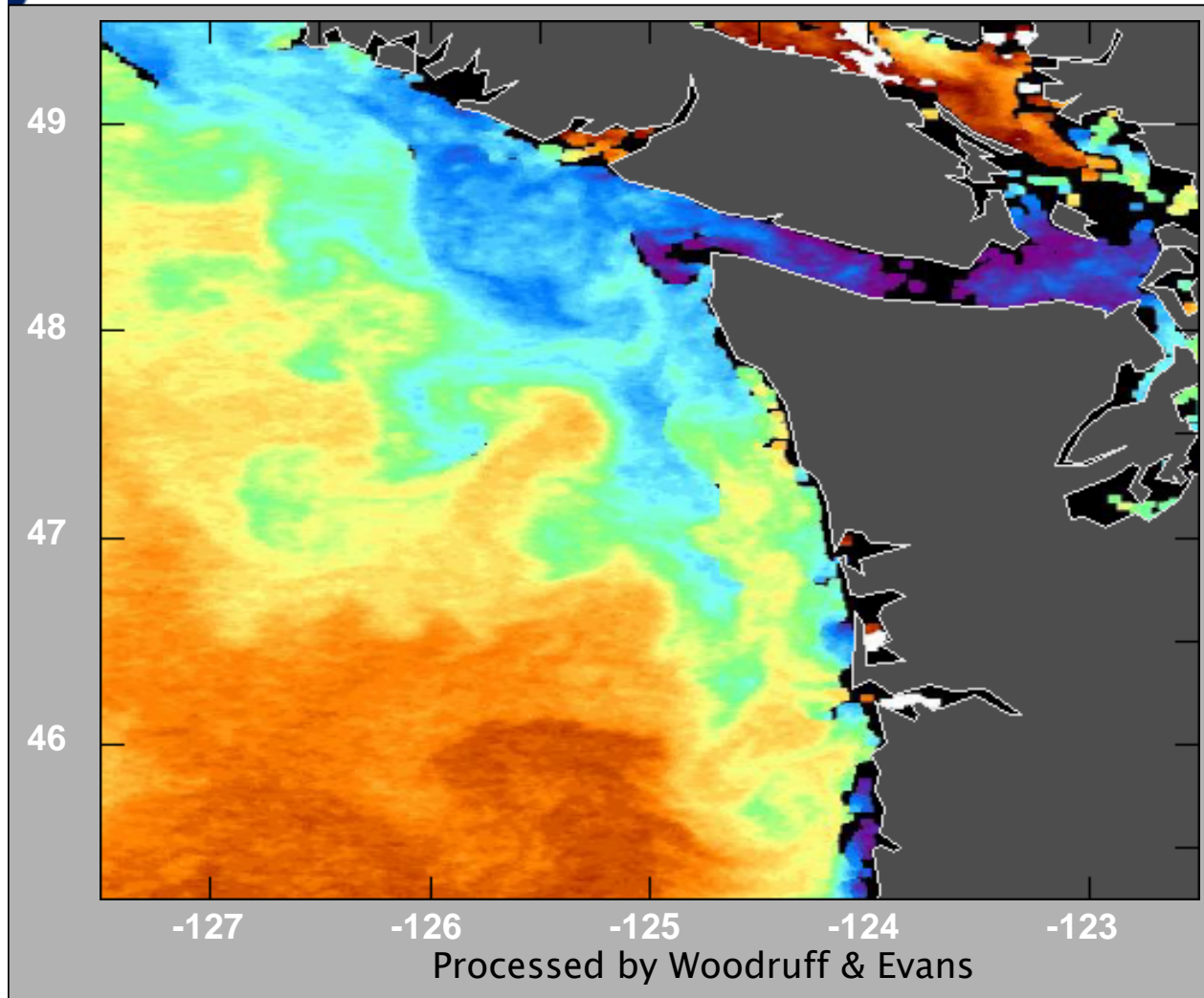


# SeaWiFS Ocean Color Sensor



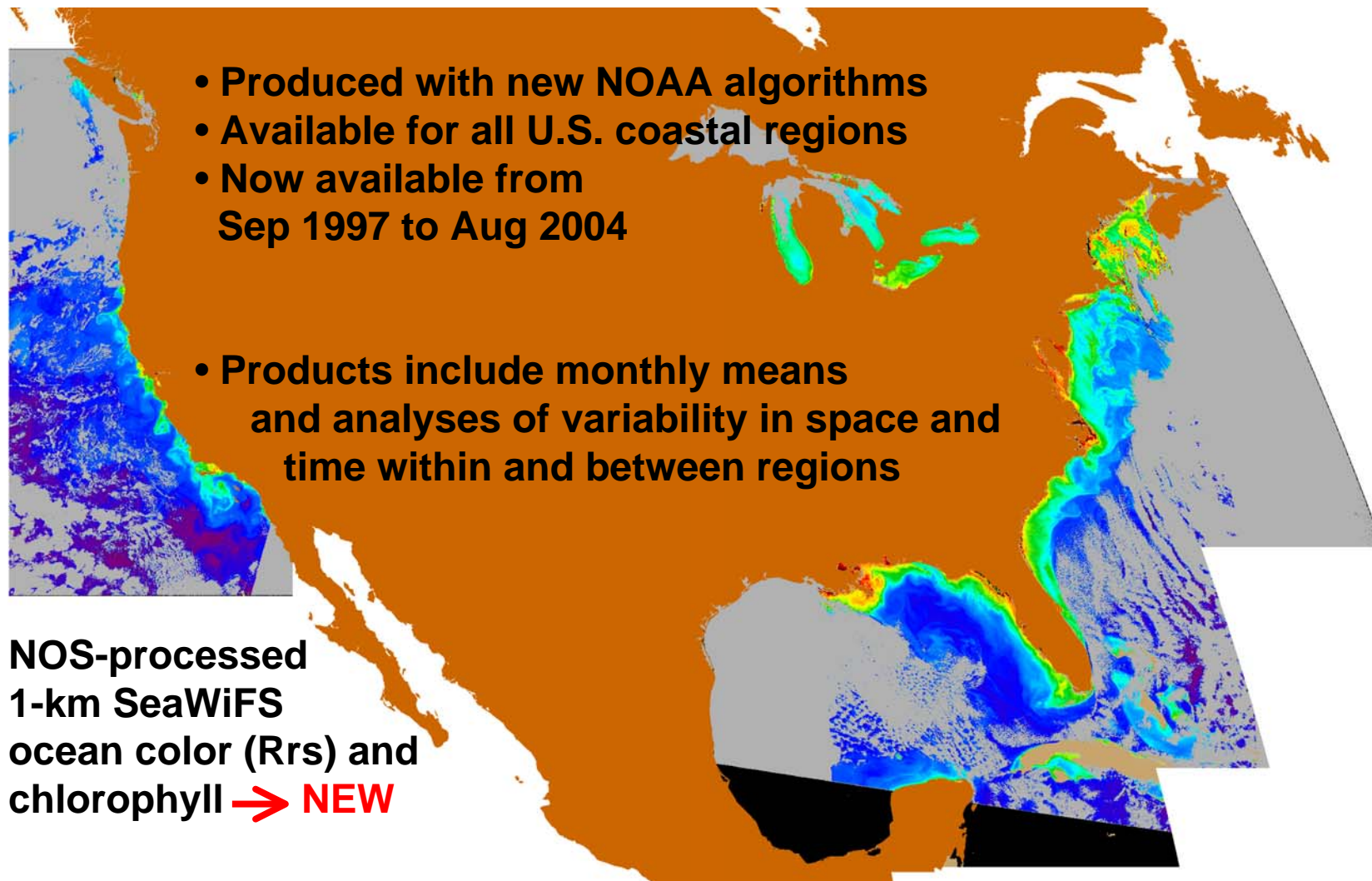
Operational SeaWiFS is limited to govt activity; 14-day delay for research. MODIS, with similar characteristics, will be operational soon.

# AVHRR SST



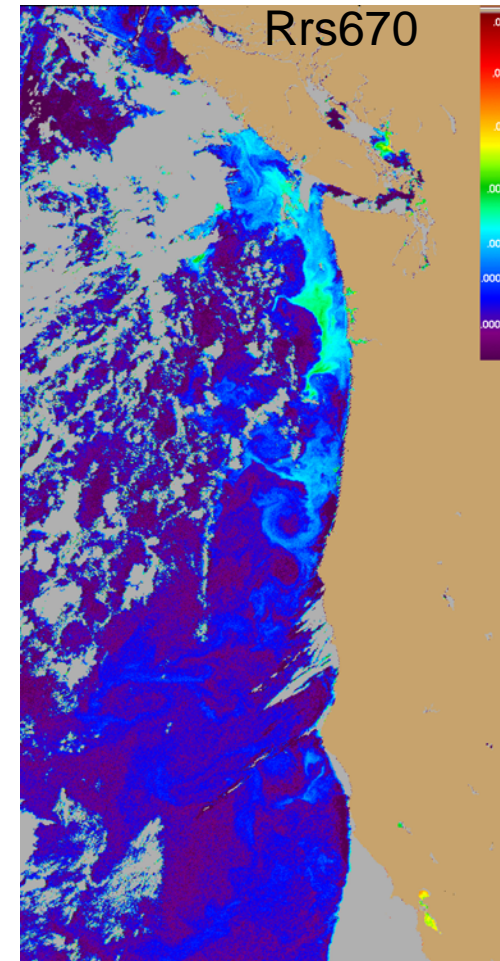
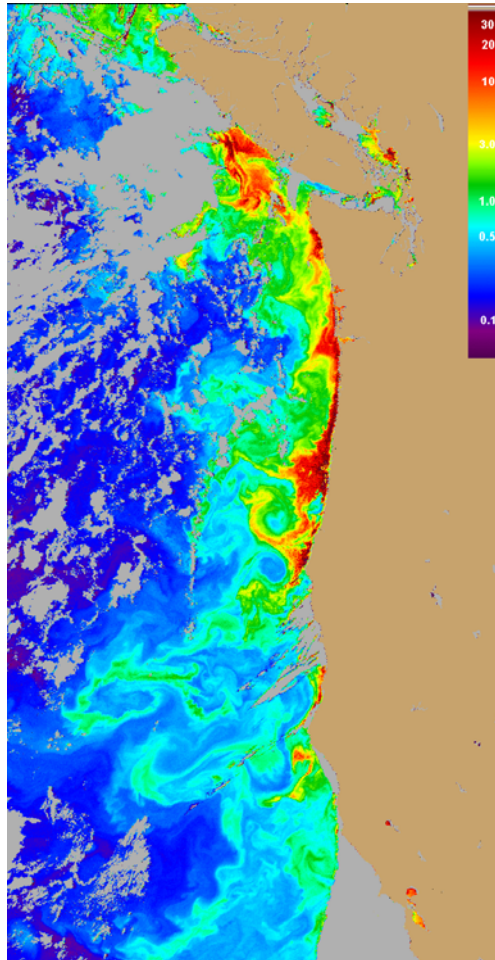
- Operational for 20 years
- 1.1 km field-of-view
- 2 Satellites, 1 primary and 1 secondary
- 2 passes per day per satellite

## Results of Improved SeaWiFS Algorithms: Accurate coastal data sets for climate and other studies

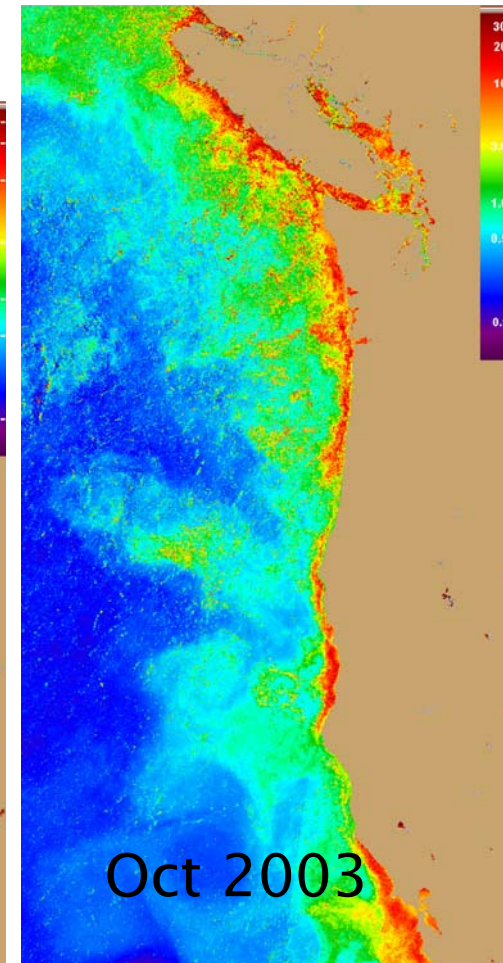
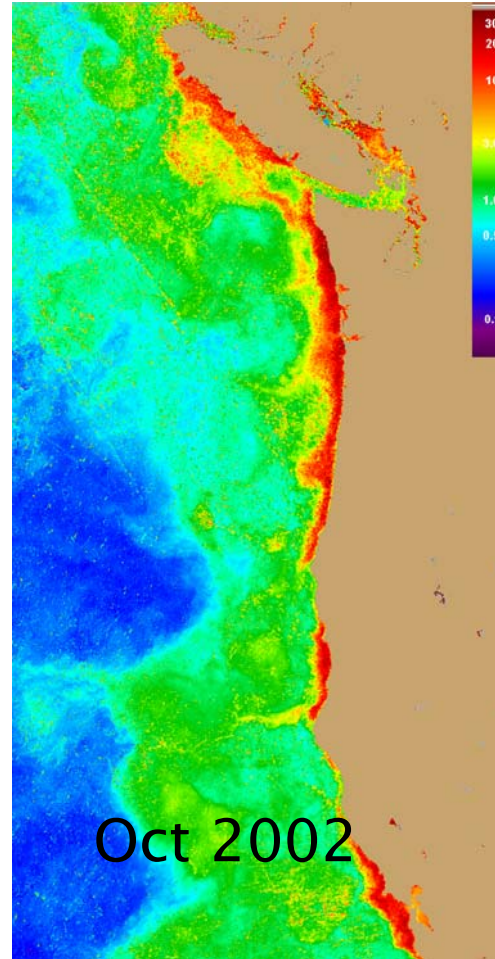
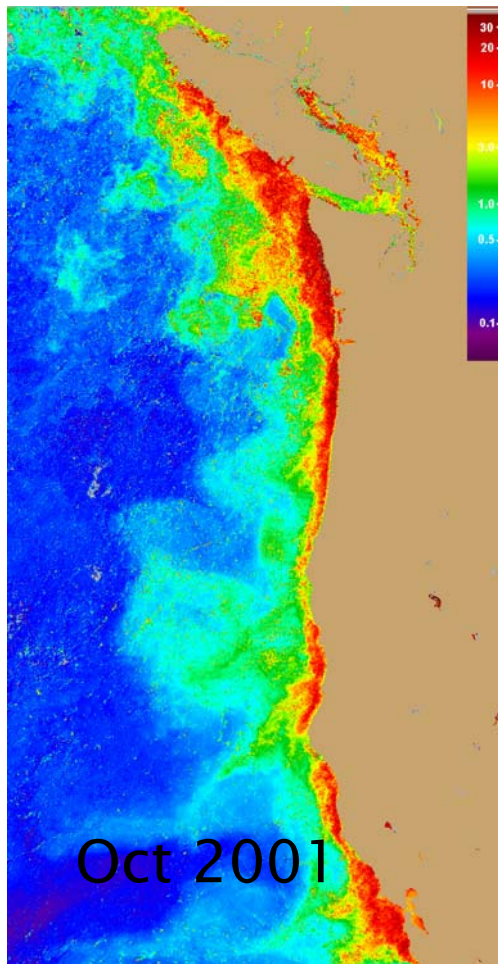




# Daily SeaWiFS image products



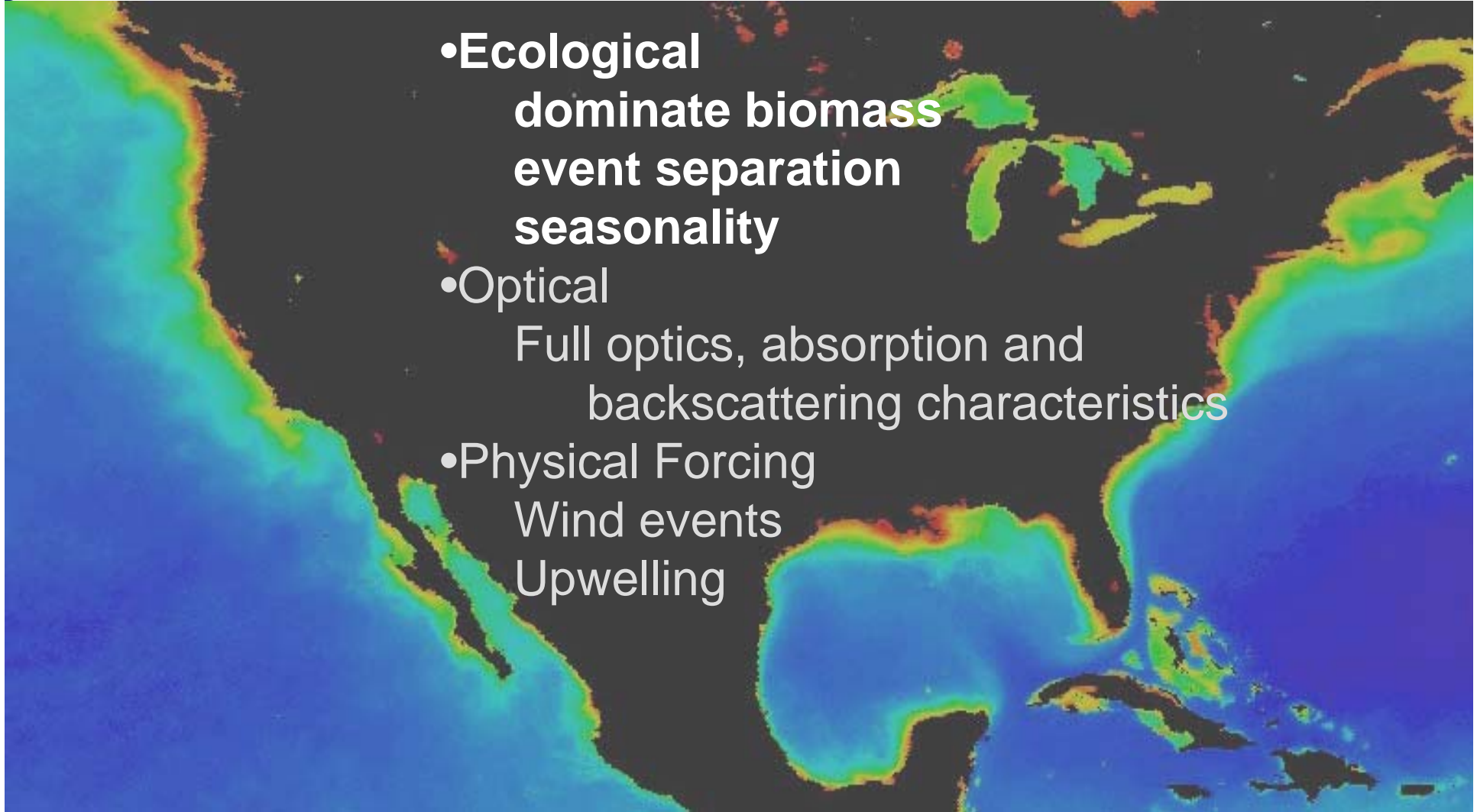
# SeaWiFS, monthly mean chlorophyll and Rrs; climatology from Sep 1997 to present



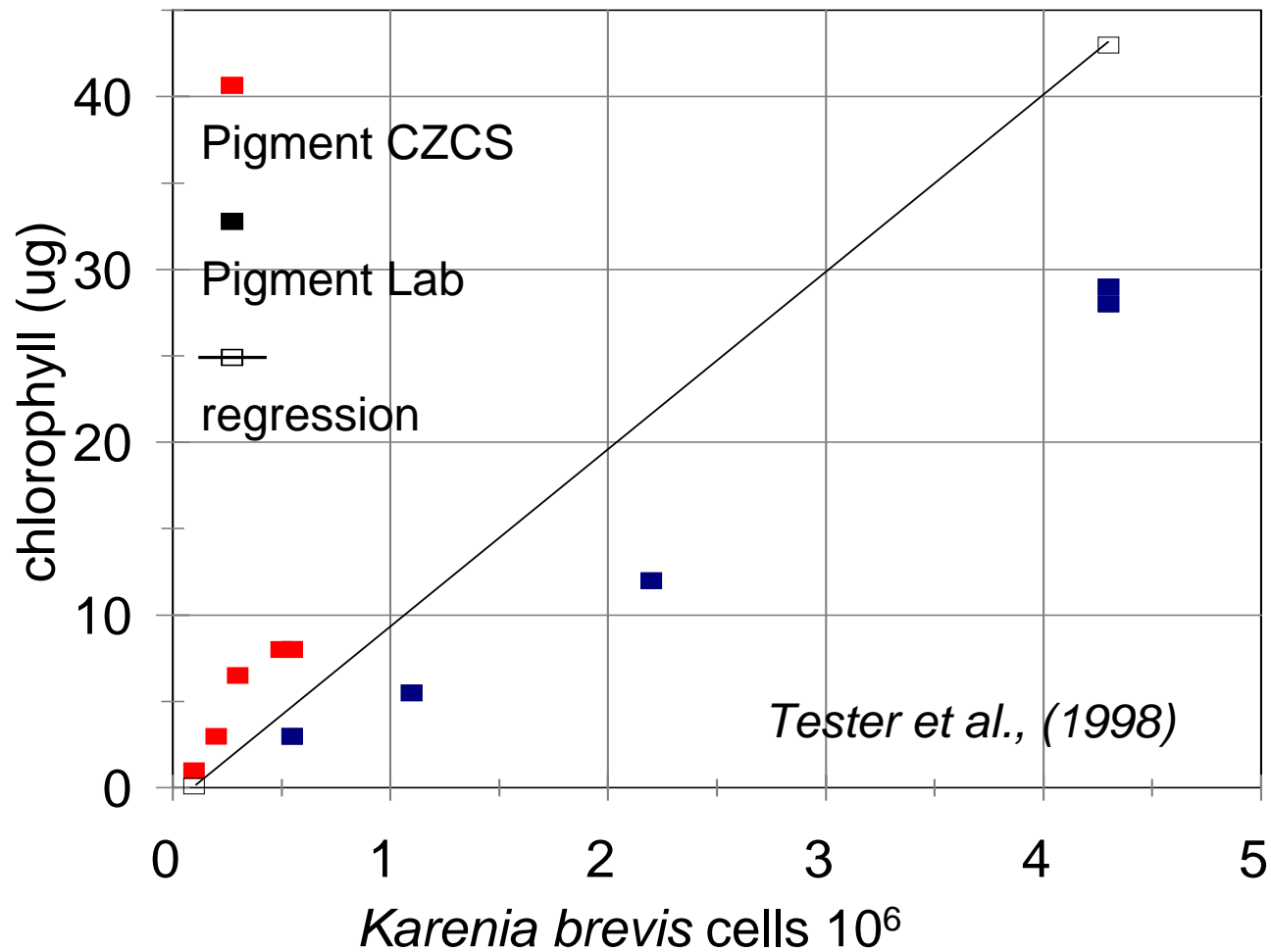


# Methods for detecting and monitoring HABs

- **Ecological**  
dominate biomass  
event separation  
seasonality
- **Optical**  
Full optics, absorption and  
backscattering characteristics
- **Physical Forcing**  
Wind events  
Upwelling



Laboratory chl/cell relationship needed for direct detection:  
convert satellite chlorophyll to cells or get % total biomass

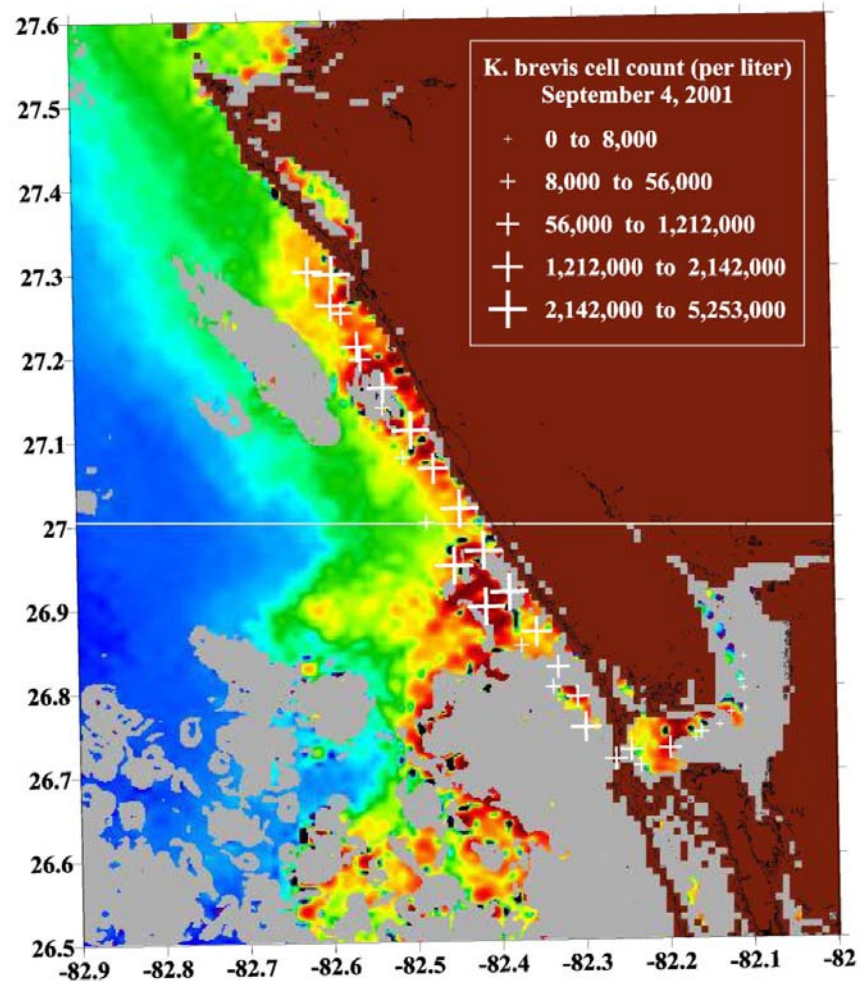




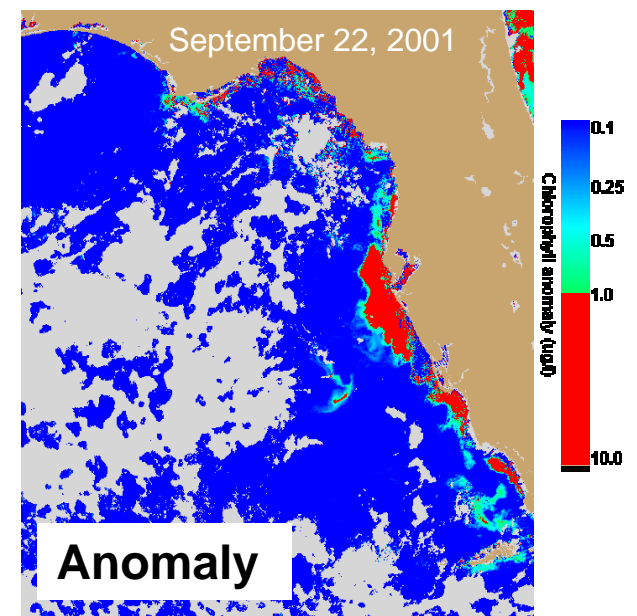
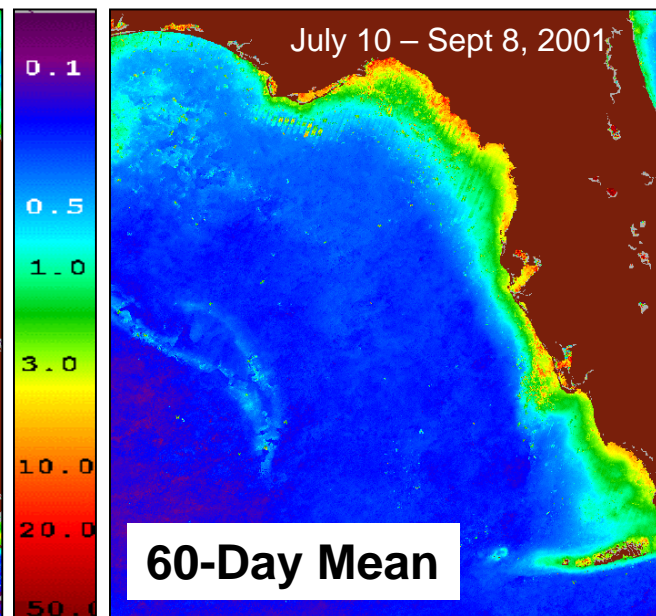
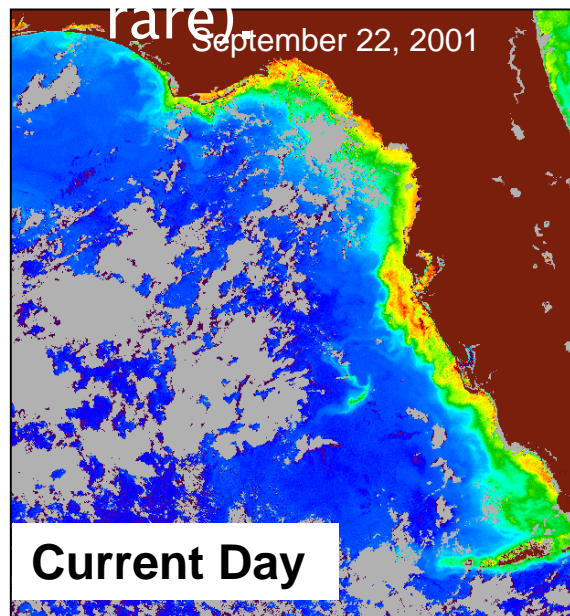
# SeaWiFS chl *a* & cell counts

## SW Florida: September 4, 2001

Chl <i>a</i> ( $\mu\text{g/L}$ )	Cells ( $\text{L}^{-1}$ )	Bloom intensity
>10	$10^6$	High
1-10	$10^5$ - $10^6$	Medium
<1	< $10^5$	Low

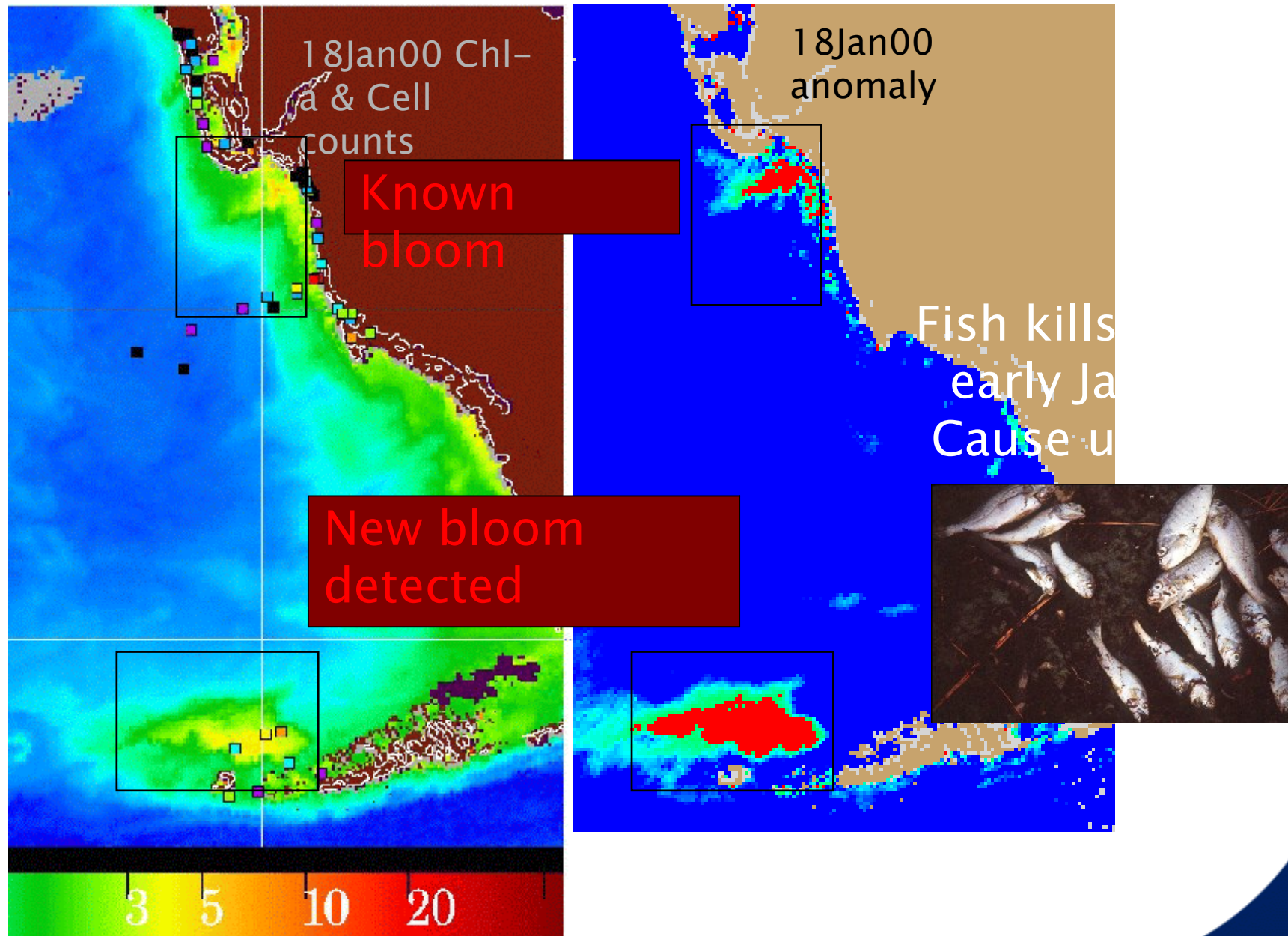


# Anomaly method for finding *Karenia brevis* blooms



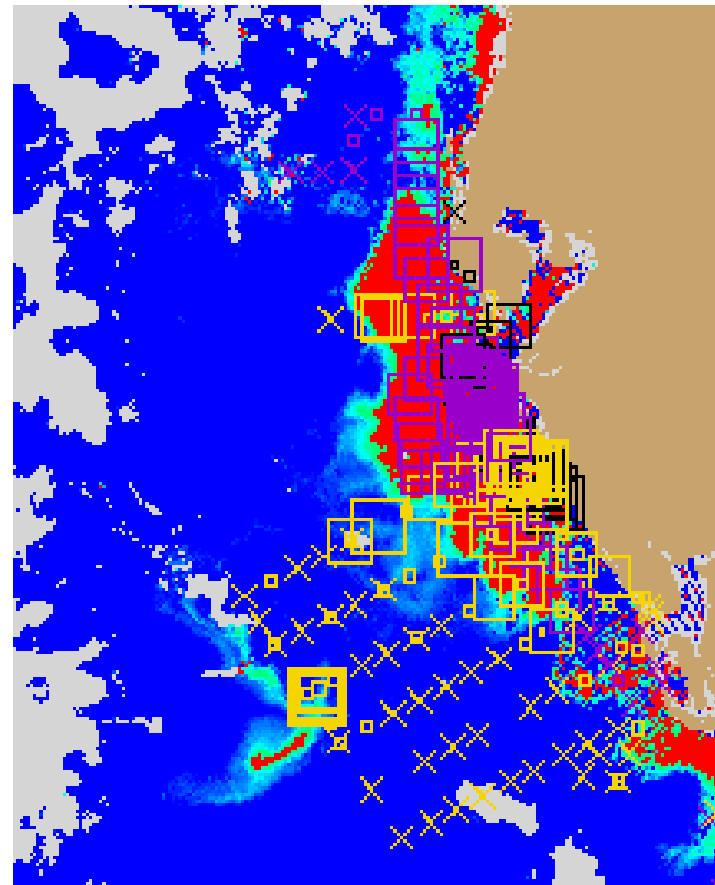
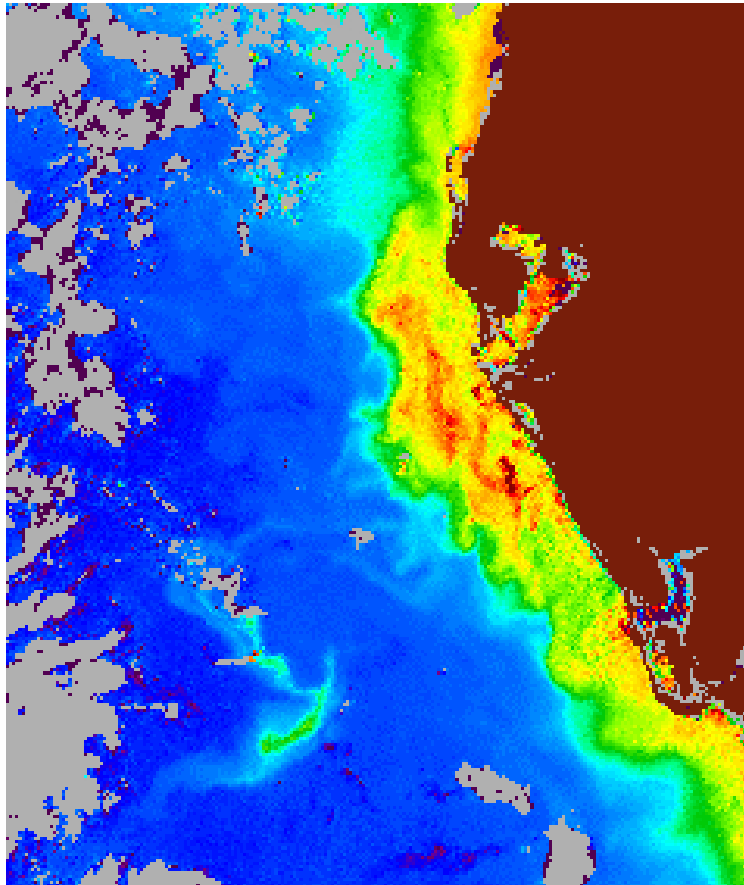
New Blooms

# First bloom detected from satellite



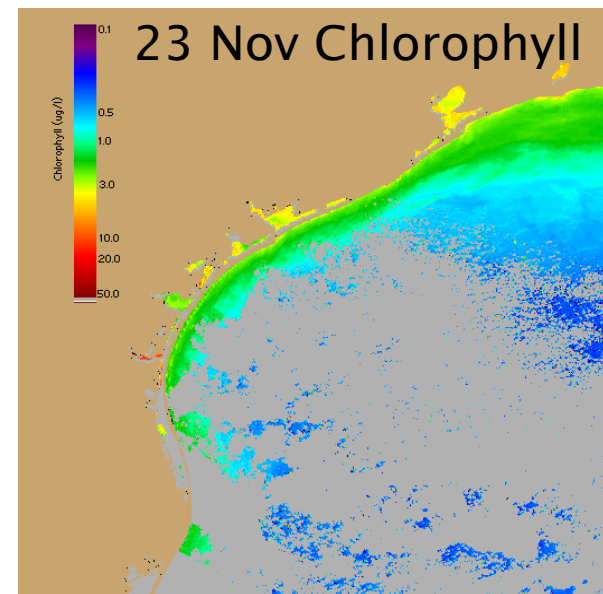
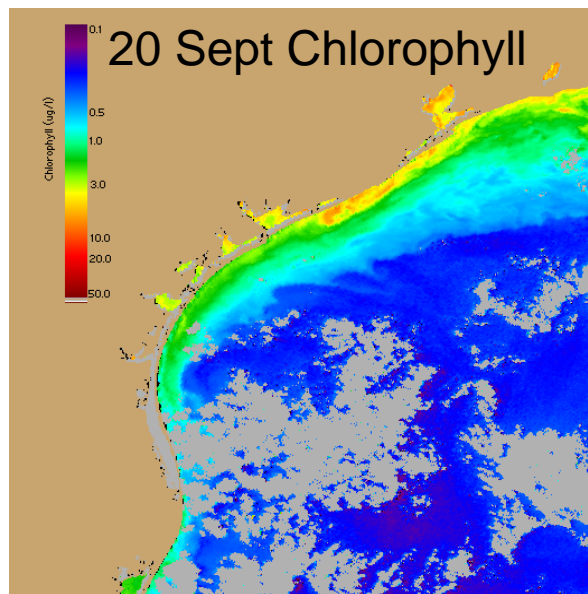
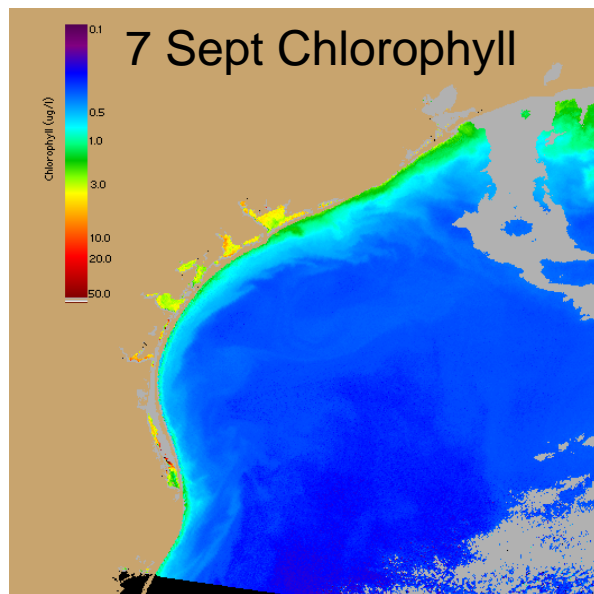
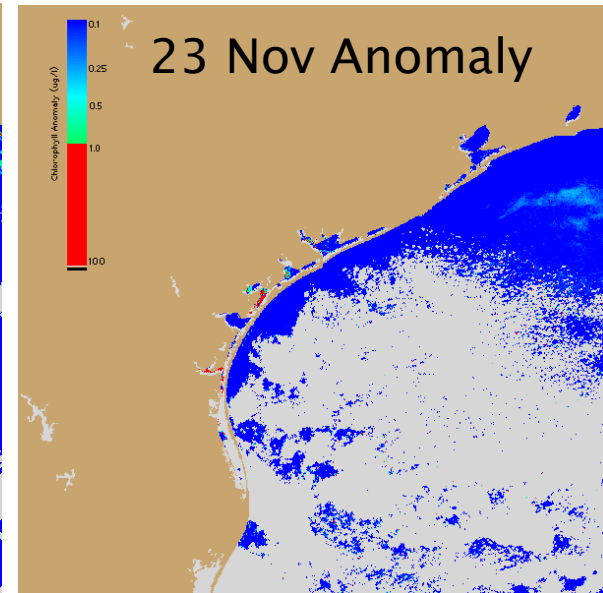
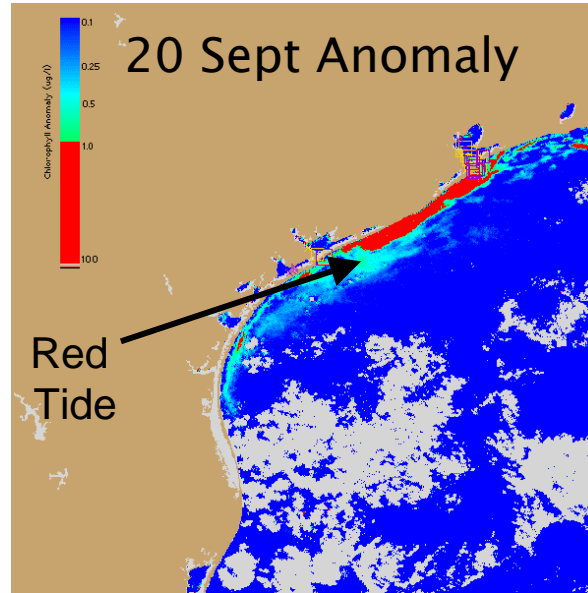
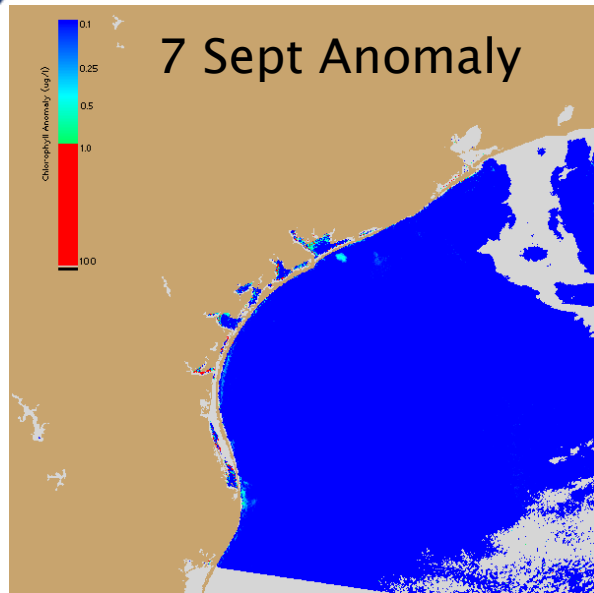


# After Tropical Storm Gabrielle

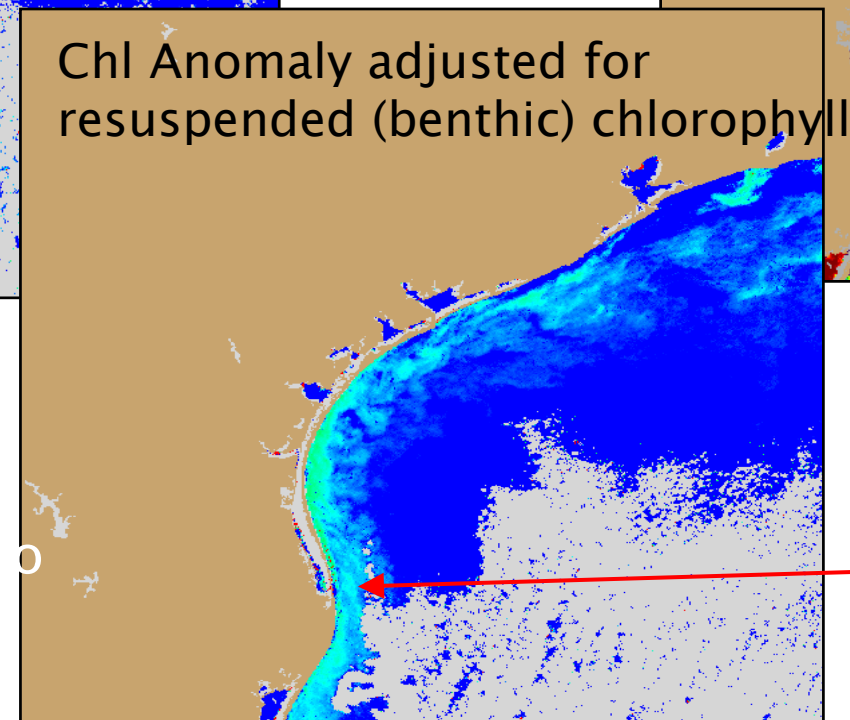
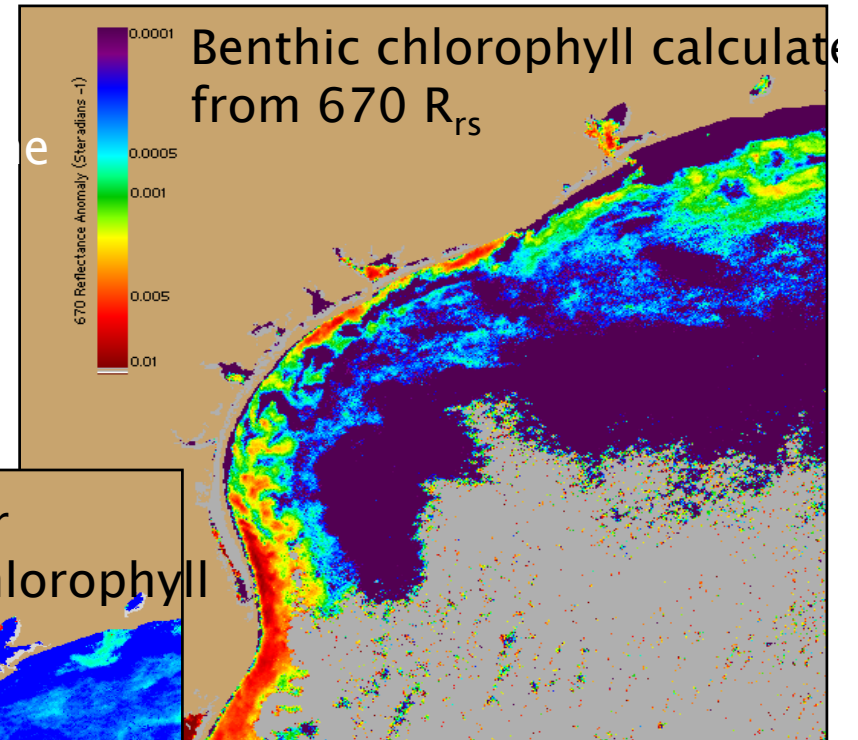
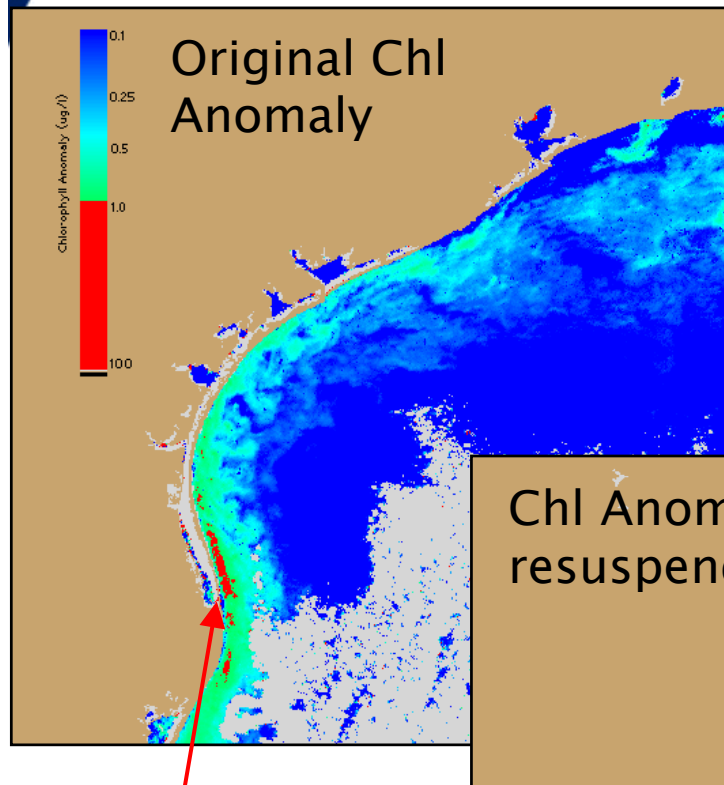


**Red = HAB**

# 2000 Texas Red Tide Event

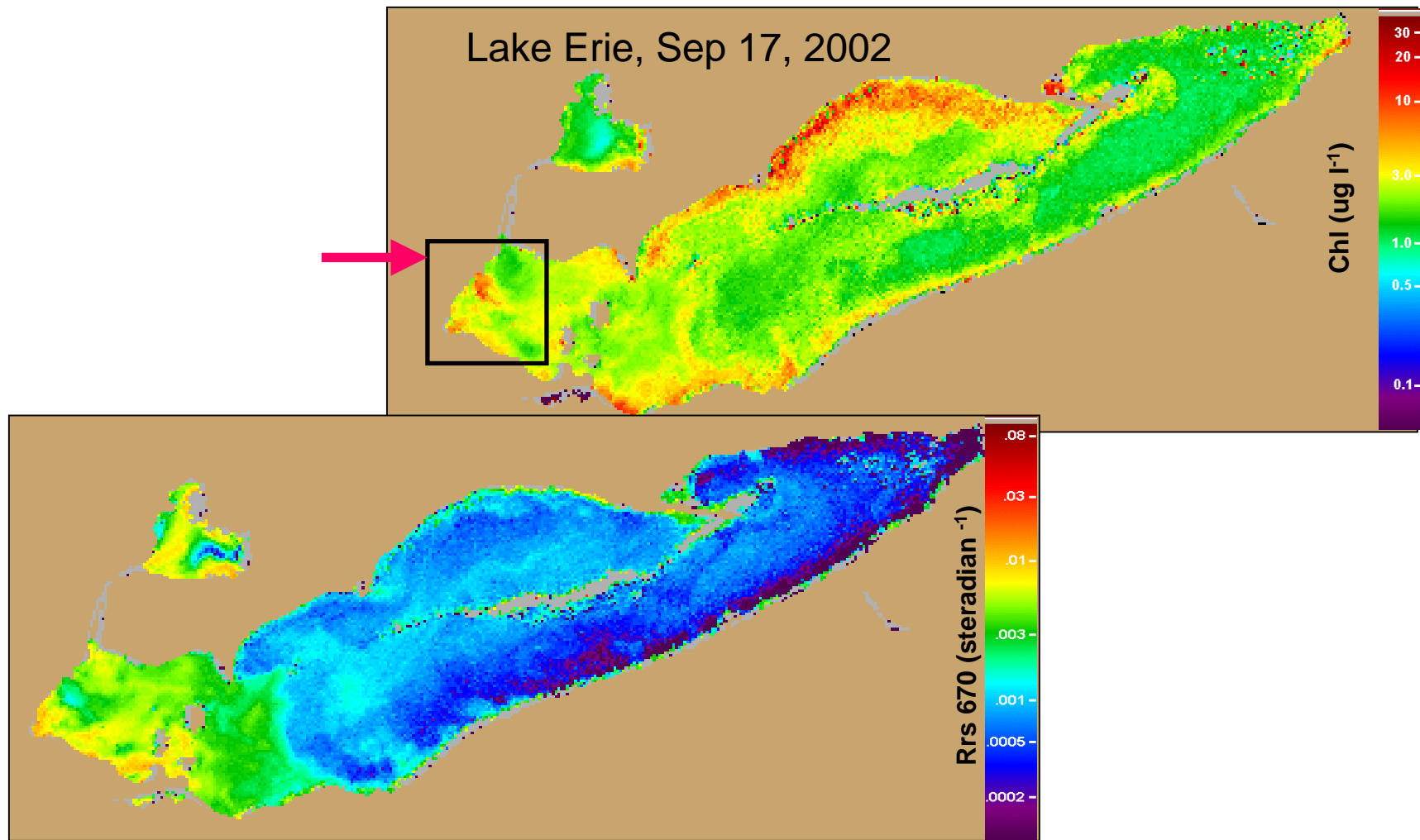


# Method to separate water column chlorophyll from resuspended algae

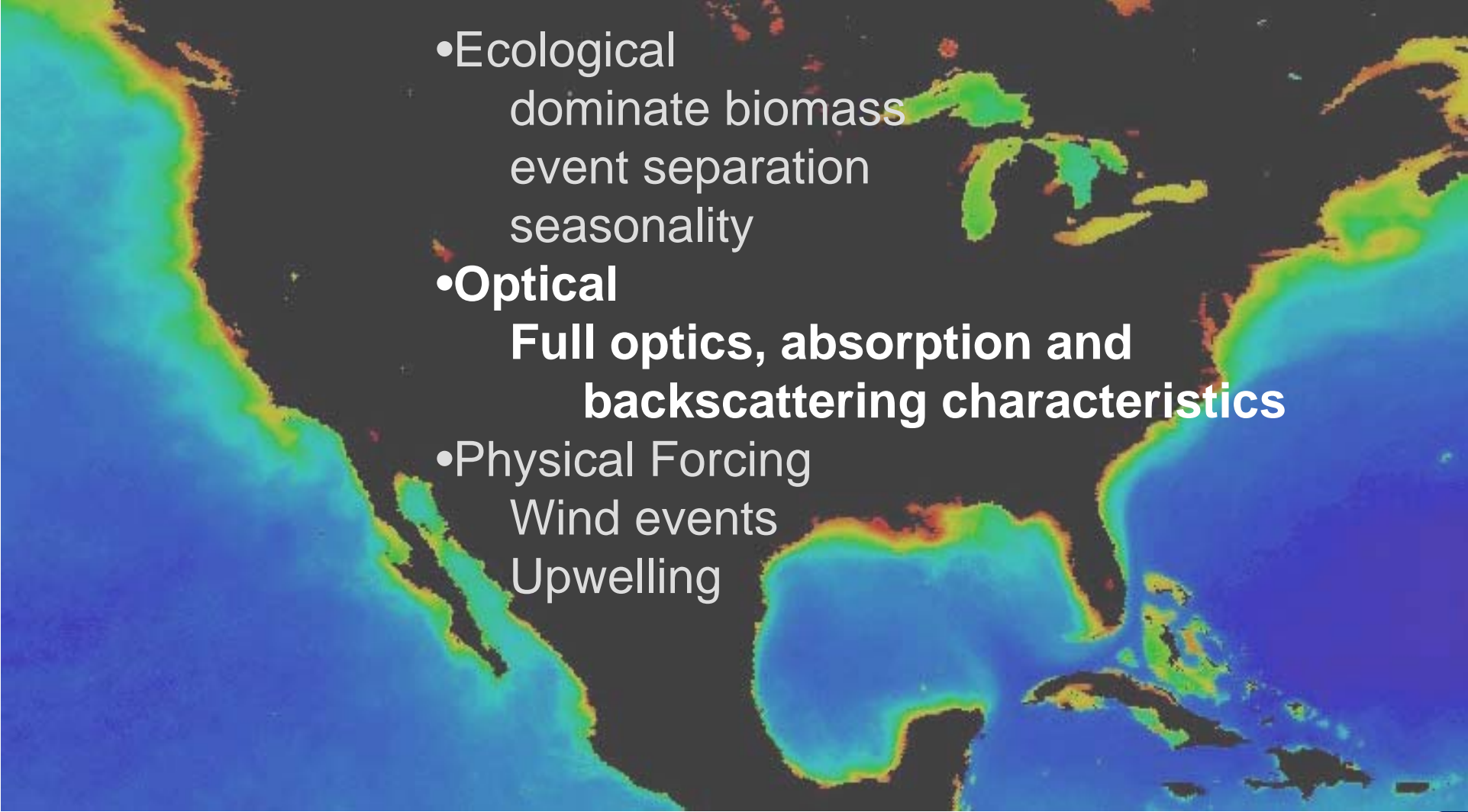




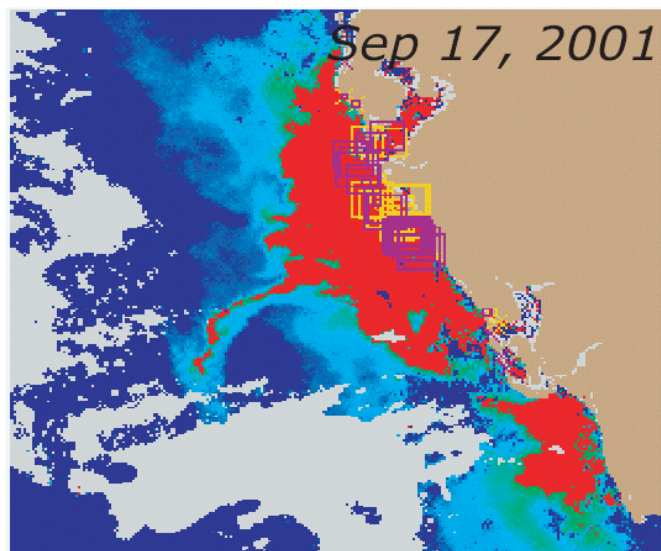
# Direct detection of toxic blooms



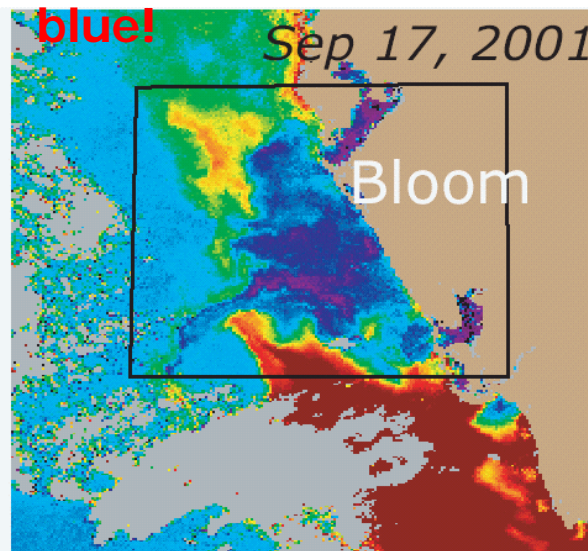
# Methods for detecting and monitoring HABs

- 
- A satellite map of the Pacific Ocean, showing the western coast of North America on the left and the eastern coast of Asia on the right. The map uses a color scale where blue represents deeper water, green and yellow represent shallower coastal waters, and red and orange indicate areas of high biomass or potential HABs. The text is overlaid on the map.
- Ecological  
dominate biomass  
event separation  
seasonality
  - **Optical**  
**Full optics, absorption and  
backscattering characteristics**
  - Physical Forcing  
Wind events  
Upwelling

# Potential HAB Flagging Enhancements

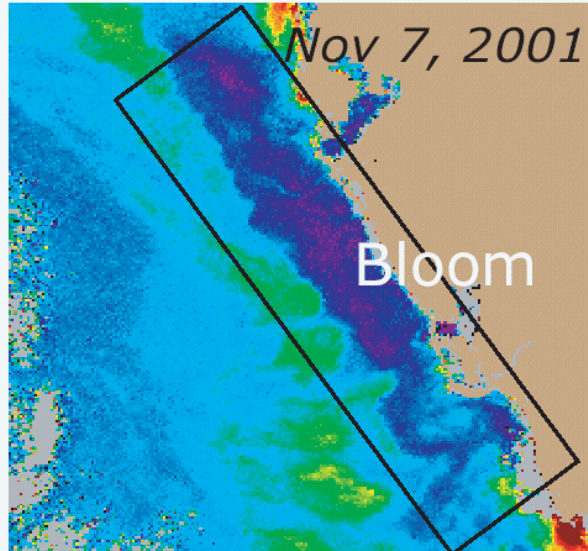
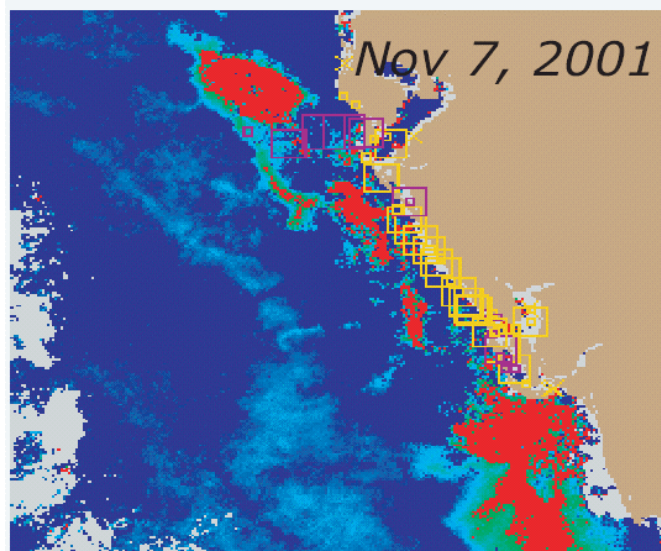


Low backscatter, High Chl in  
blue!



Anomaly

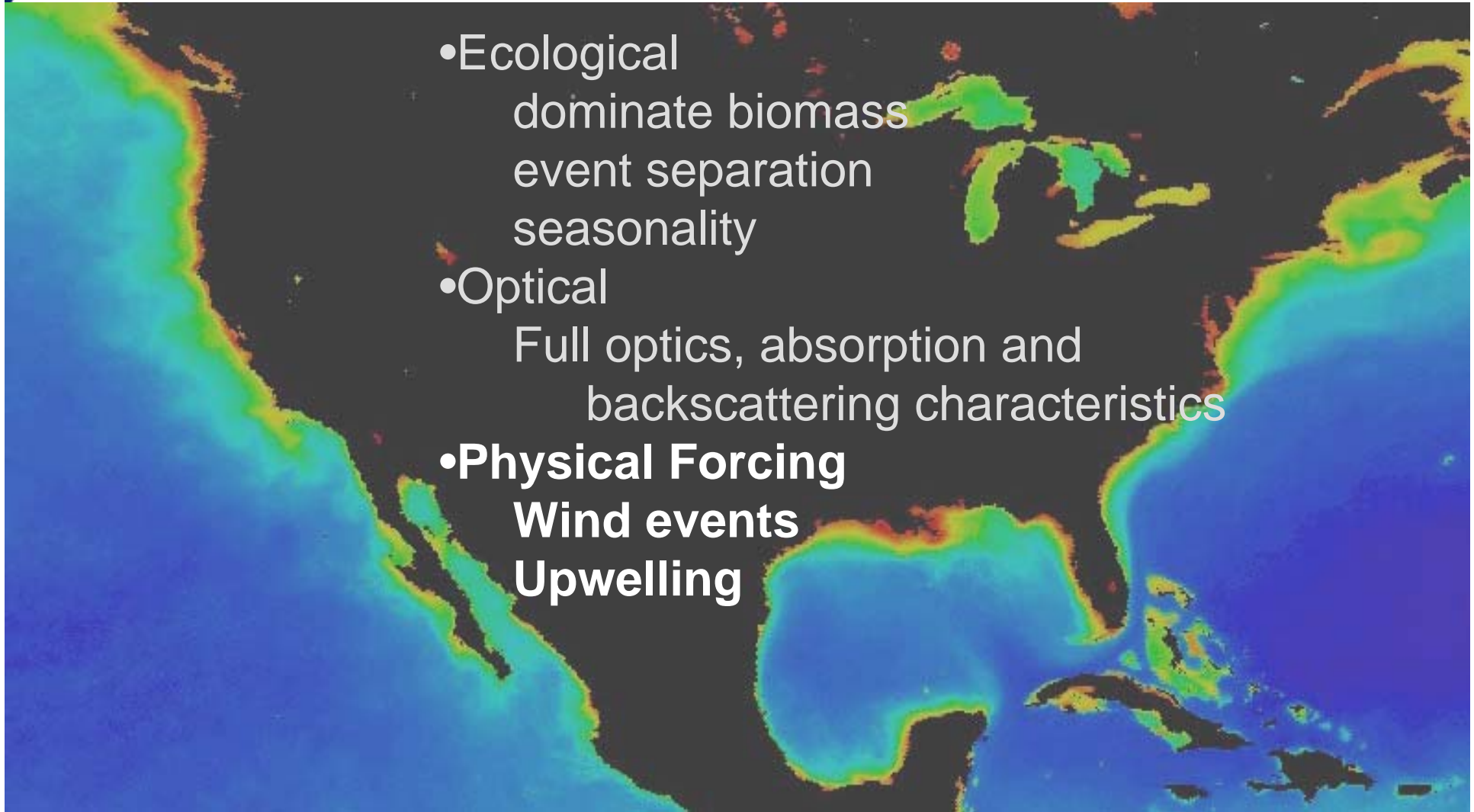
Backscatter



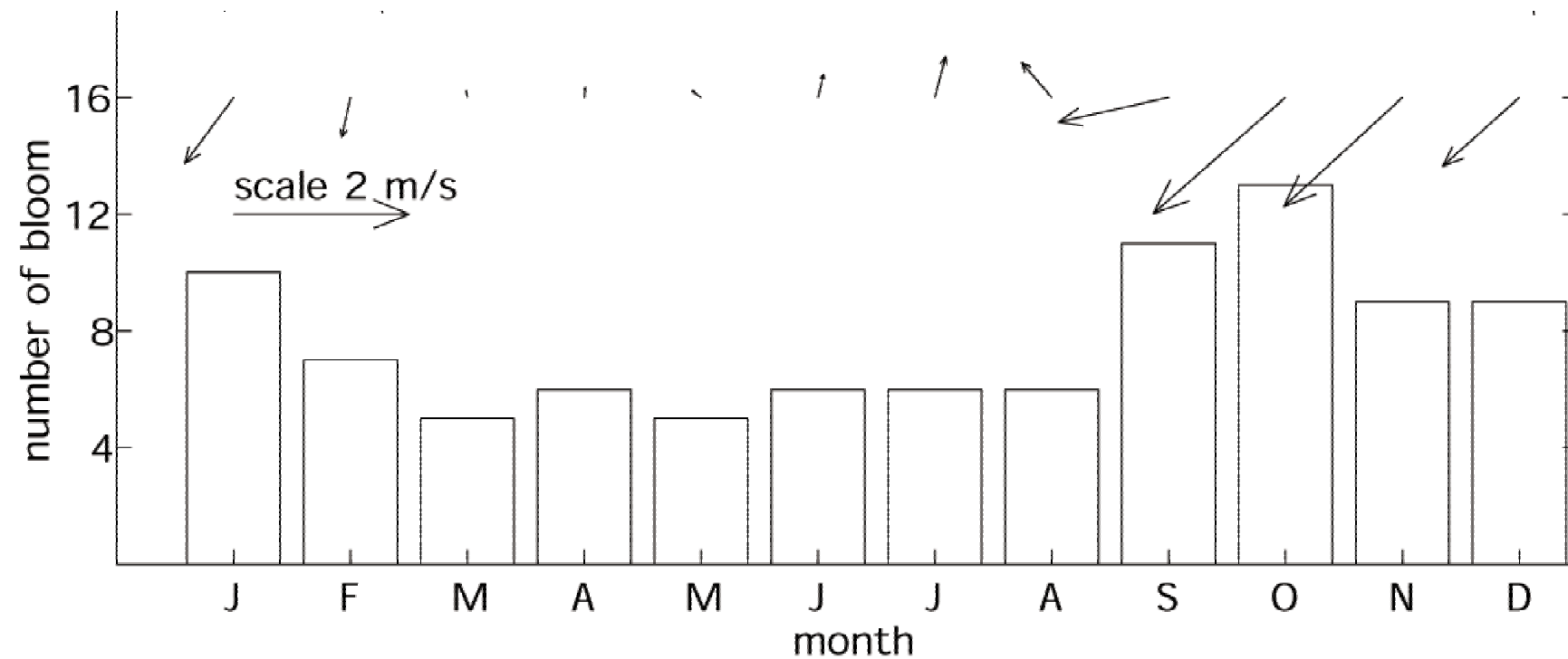


# Methods for detecting and monitoring HABs

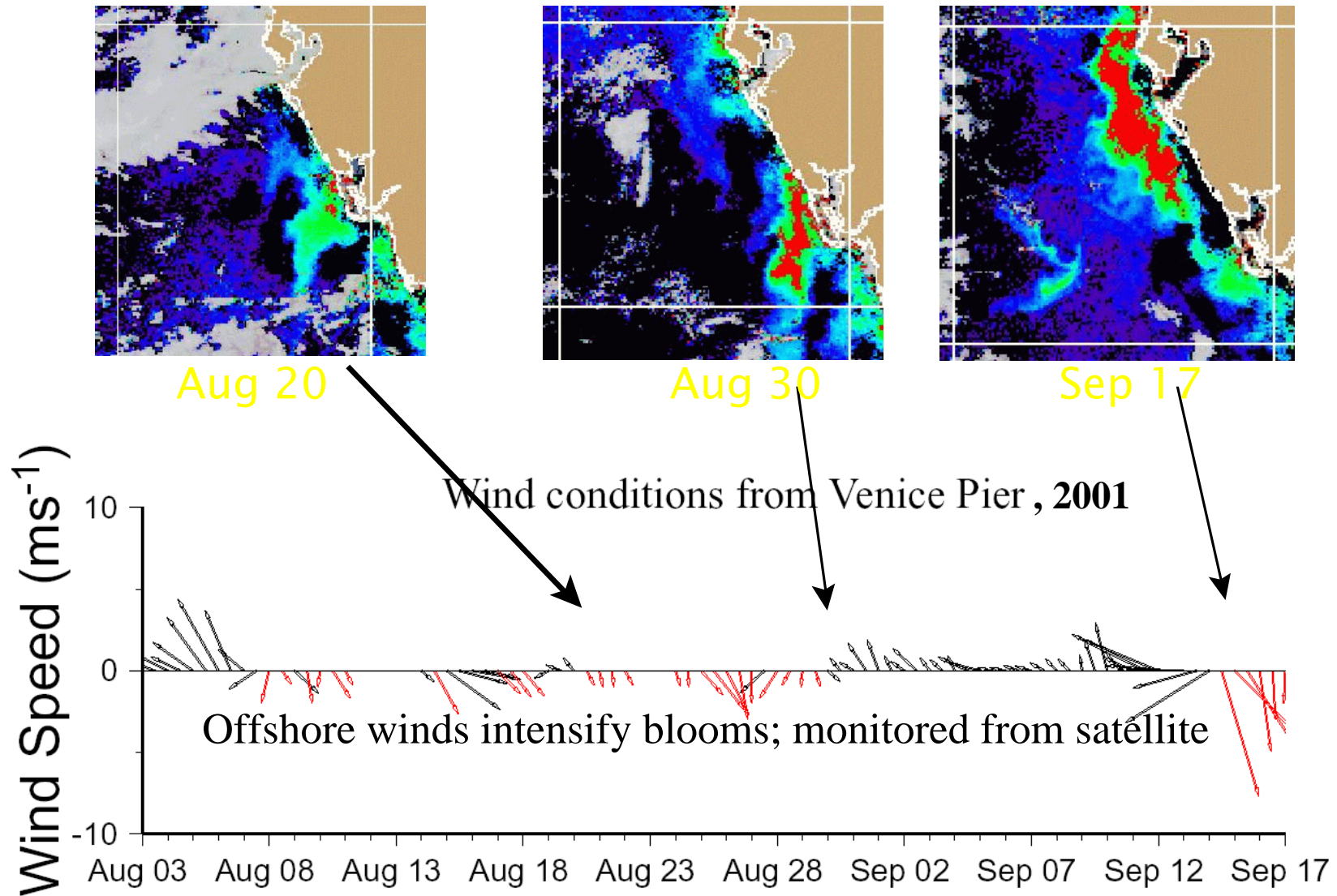
- Ecological
  - dominate biomass
  - event separation
  - seasonality
- Optical
  - Full optics, absorption and backscattering characteristics
- **Physical Forcing**
  - Wind events**
  - Upwelling**



# Physical Forcing: Upwelling and Bloom Initiation SW Florida Coast

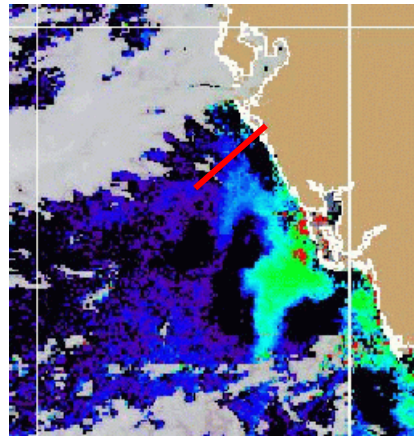


# Integrated data for forecasting

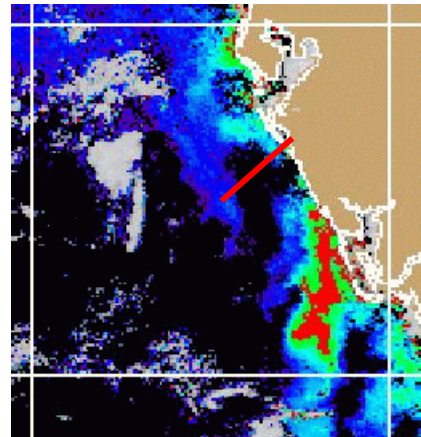




# HAB initiation from upwelling transport

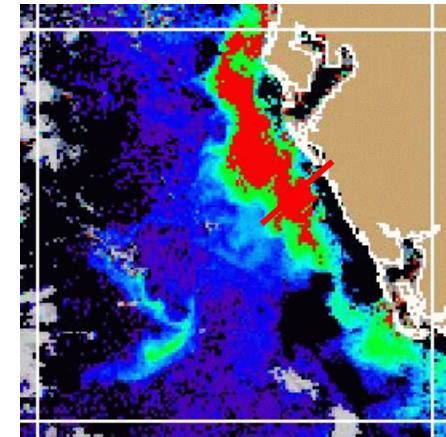


Aug 14



Aug 20

Aug 27

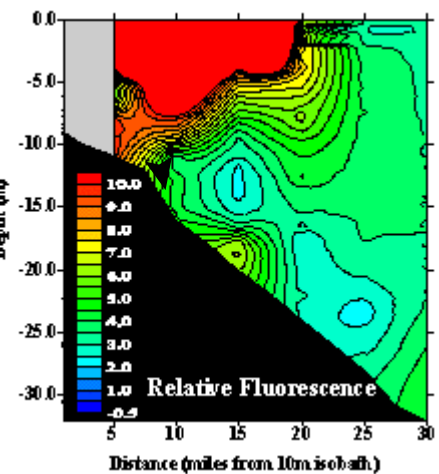
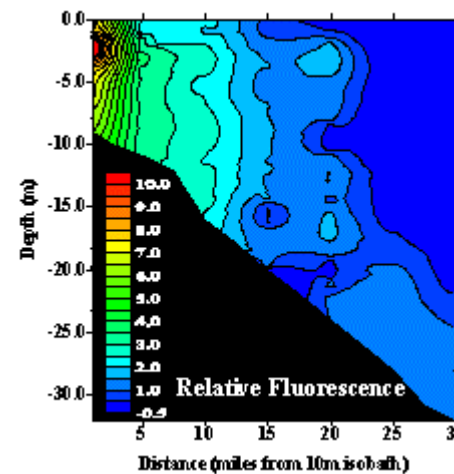
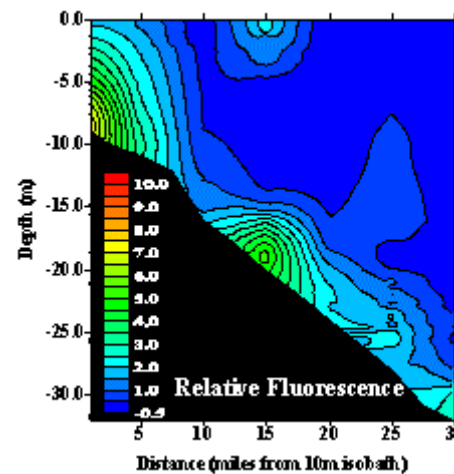
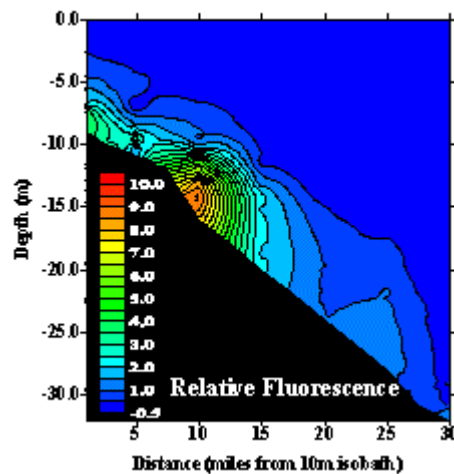


Aug 30

Sep 10

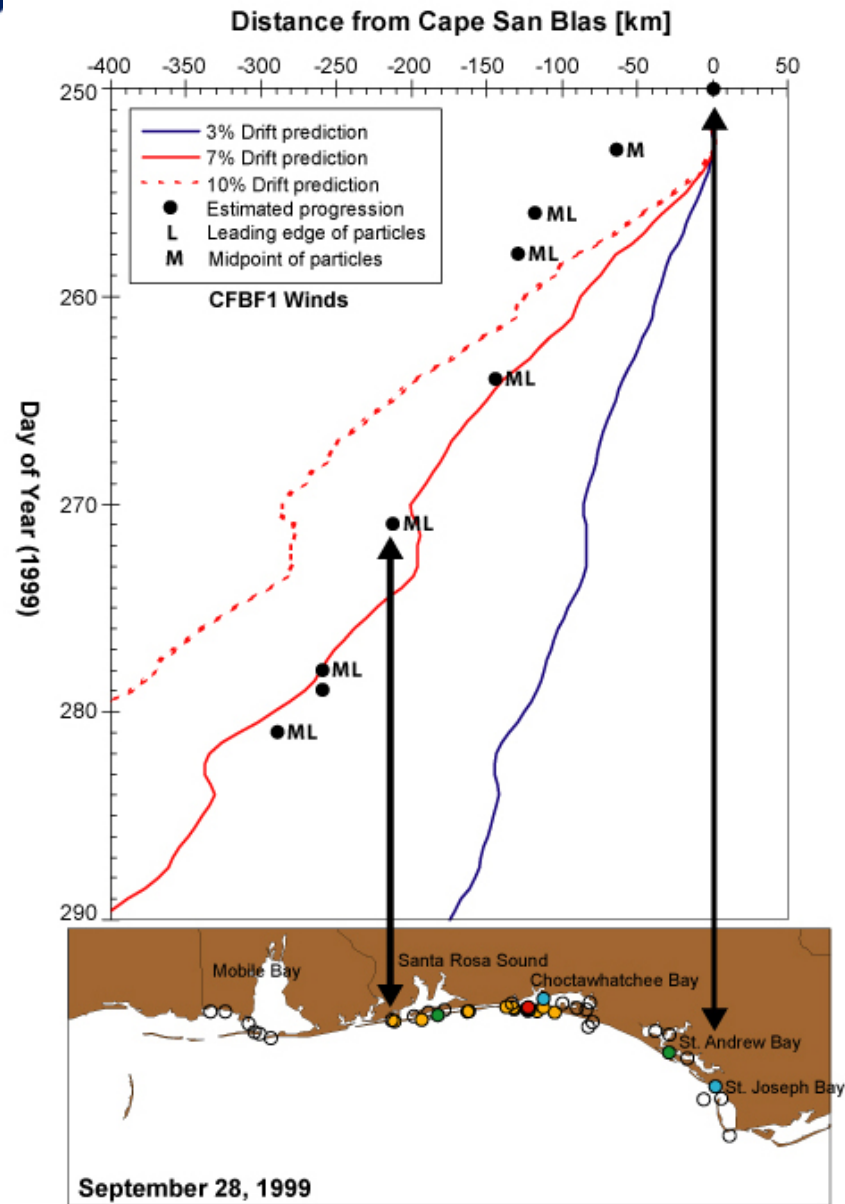
Sep 17

Sep 27

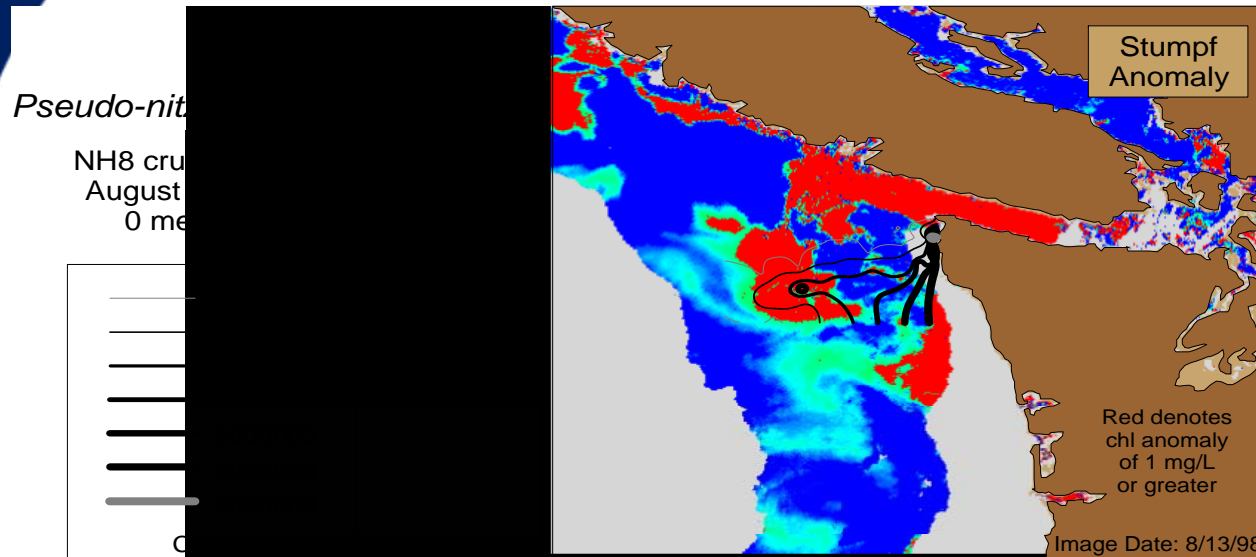


2001 ECOHAB Cruises  
(Kirkpatrick & Pederson)

# Forecasting Transport



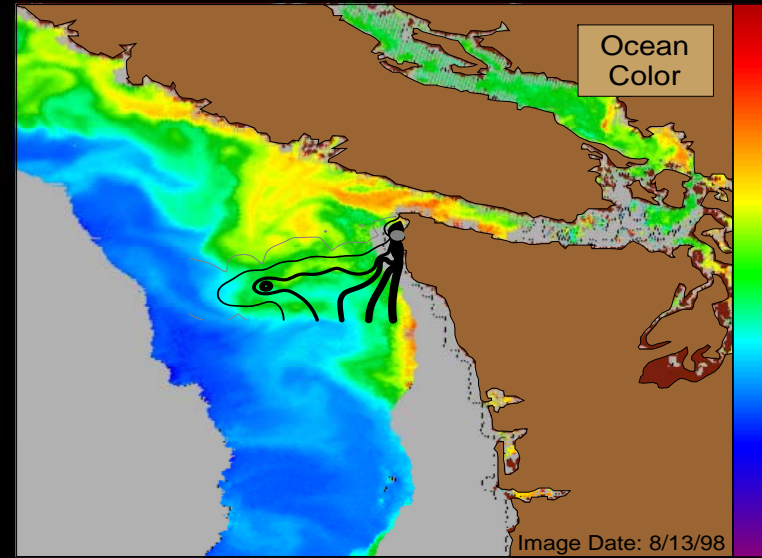
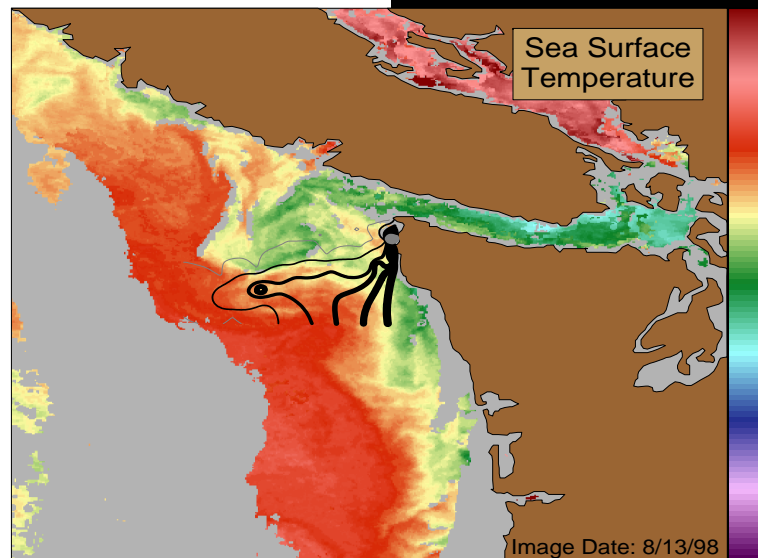
# Physical Forcing: Potential for *Pseudo-nitzschia* sp.



anomalies do not  
affect *Pseudo-nitzschia*  
**Does not dominate biomass!**

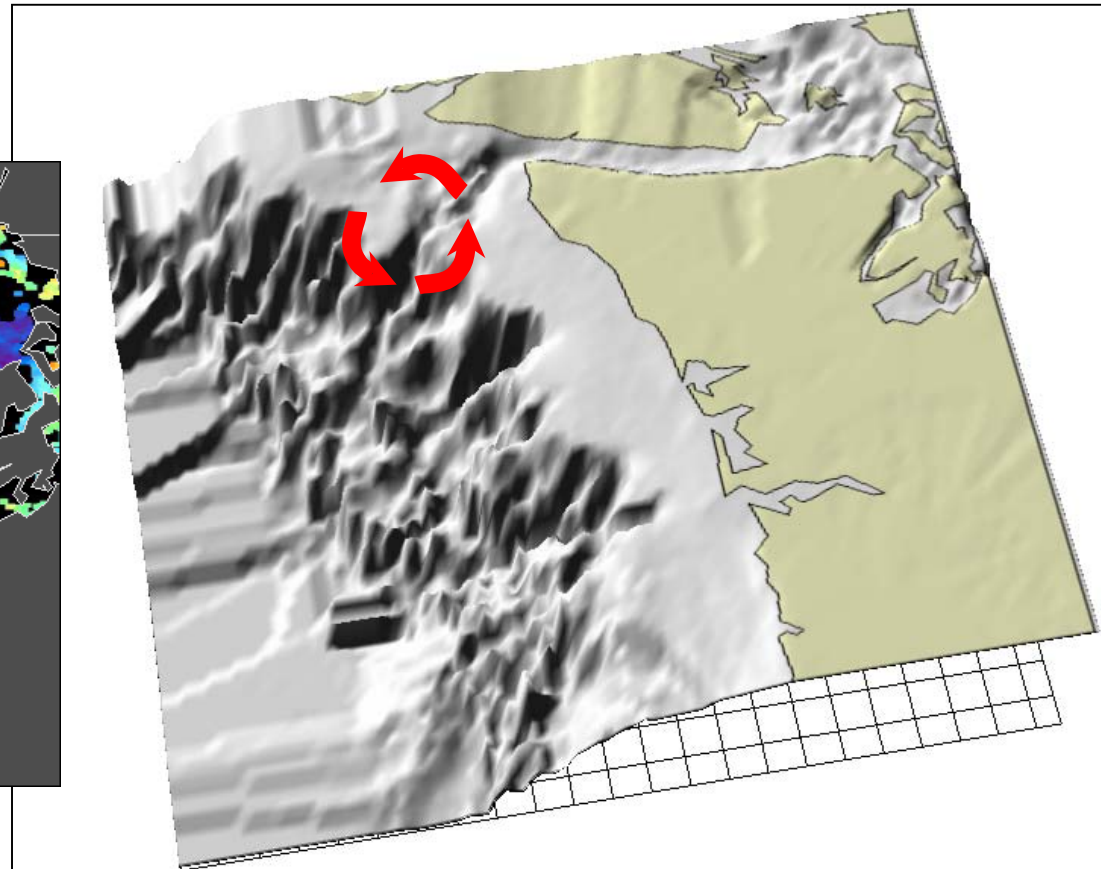
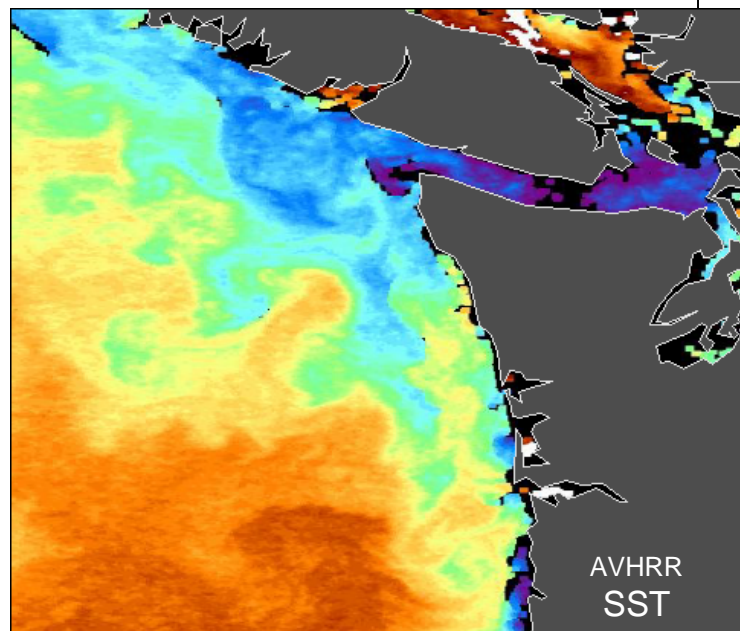
may help in feature  
tracking  
useful for front and  
detection, feature  
tracking

counts from ORHAB: Trainer et al.

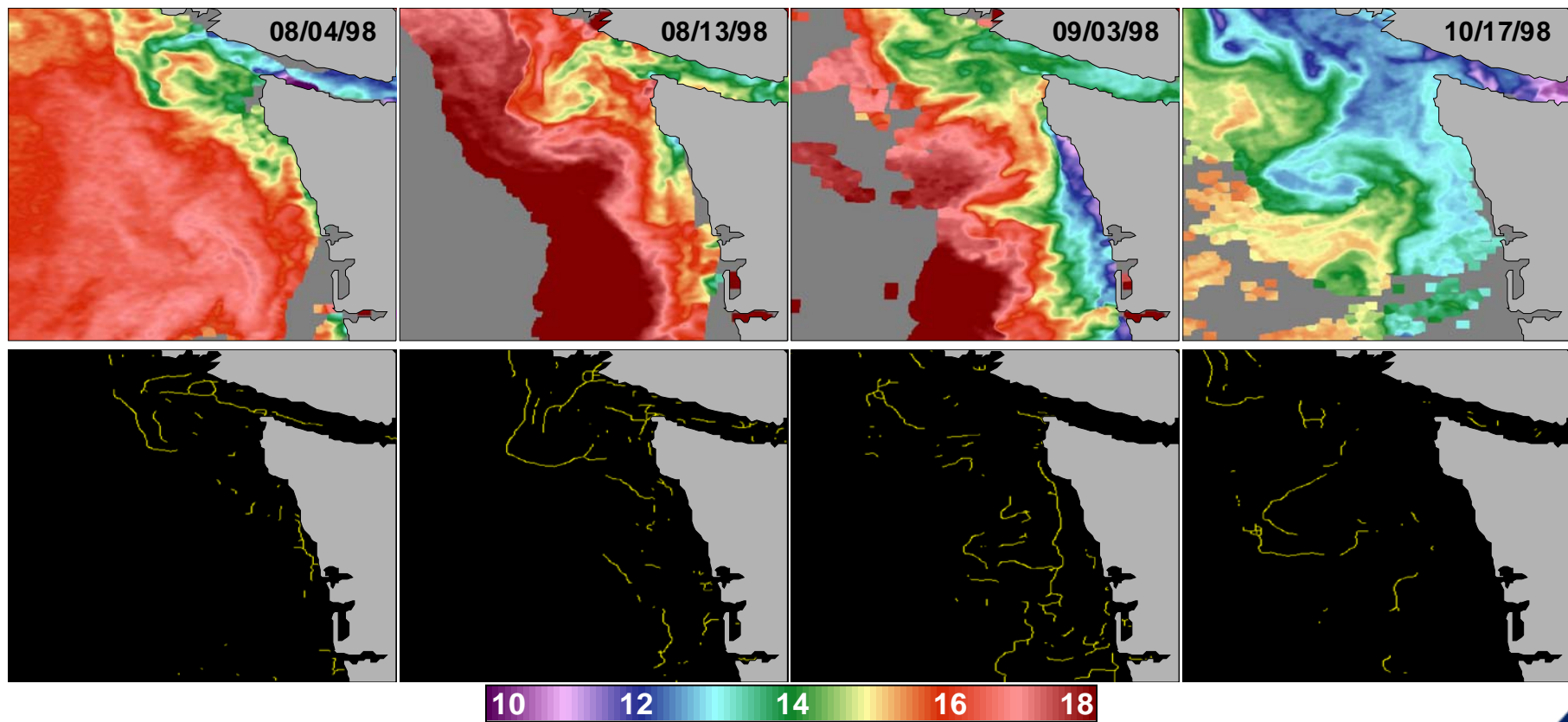




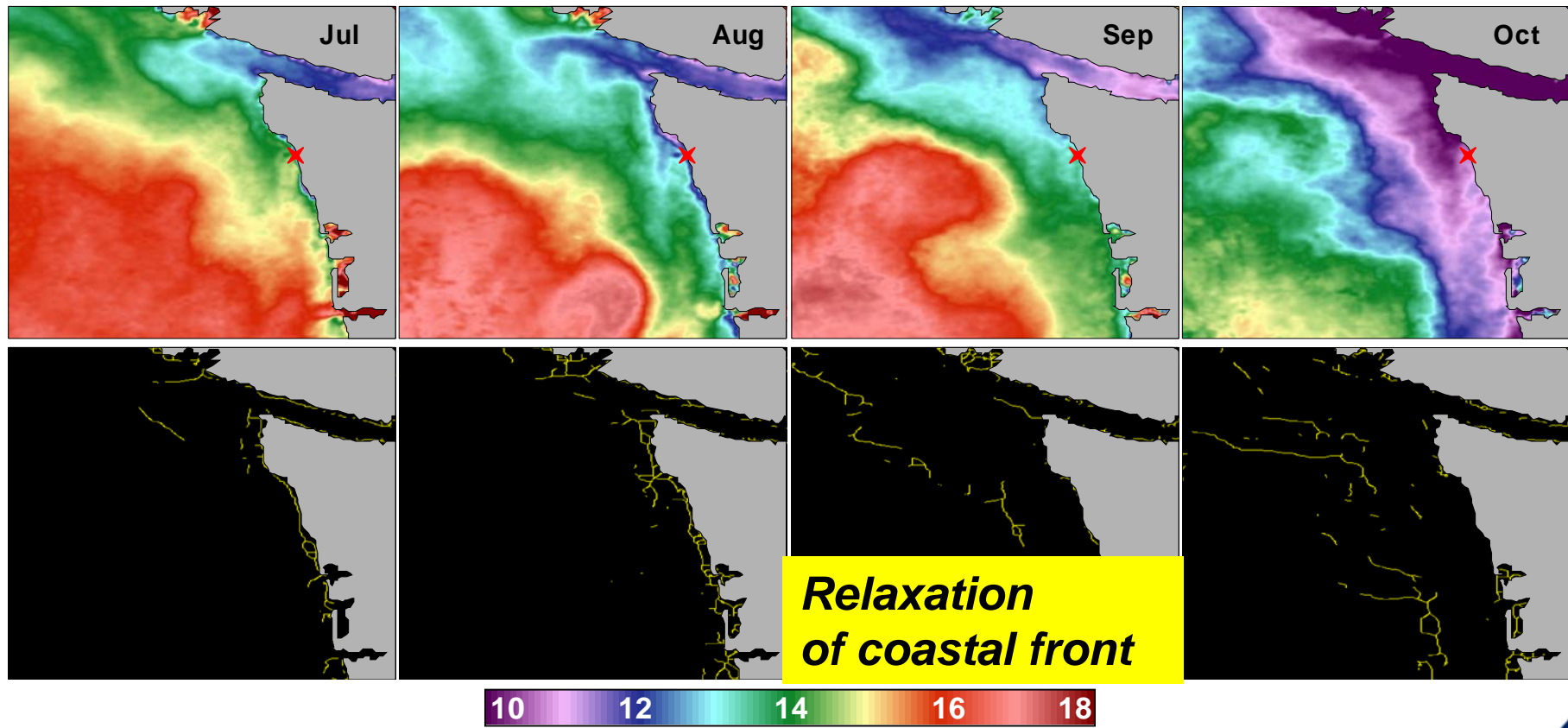
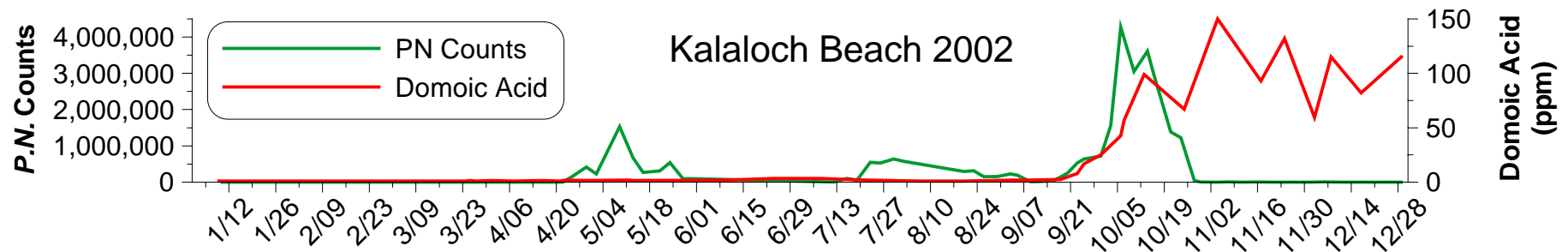
## Juan de Fuca Eddy



# Eddy Detection

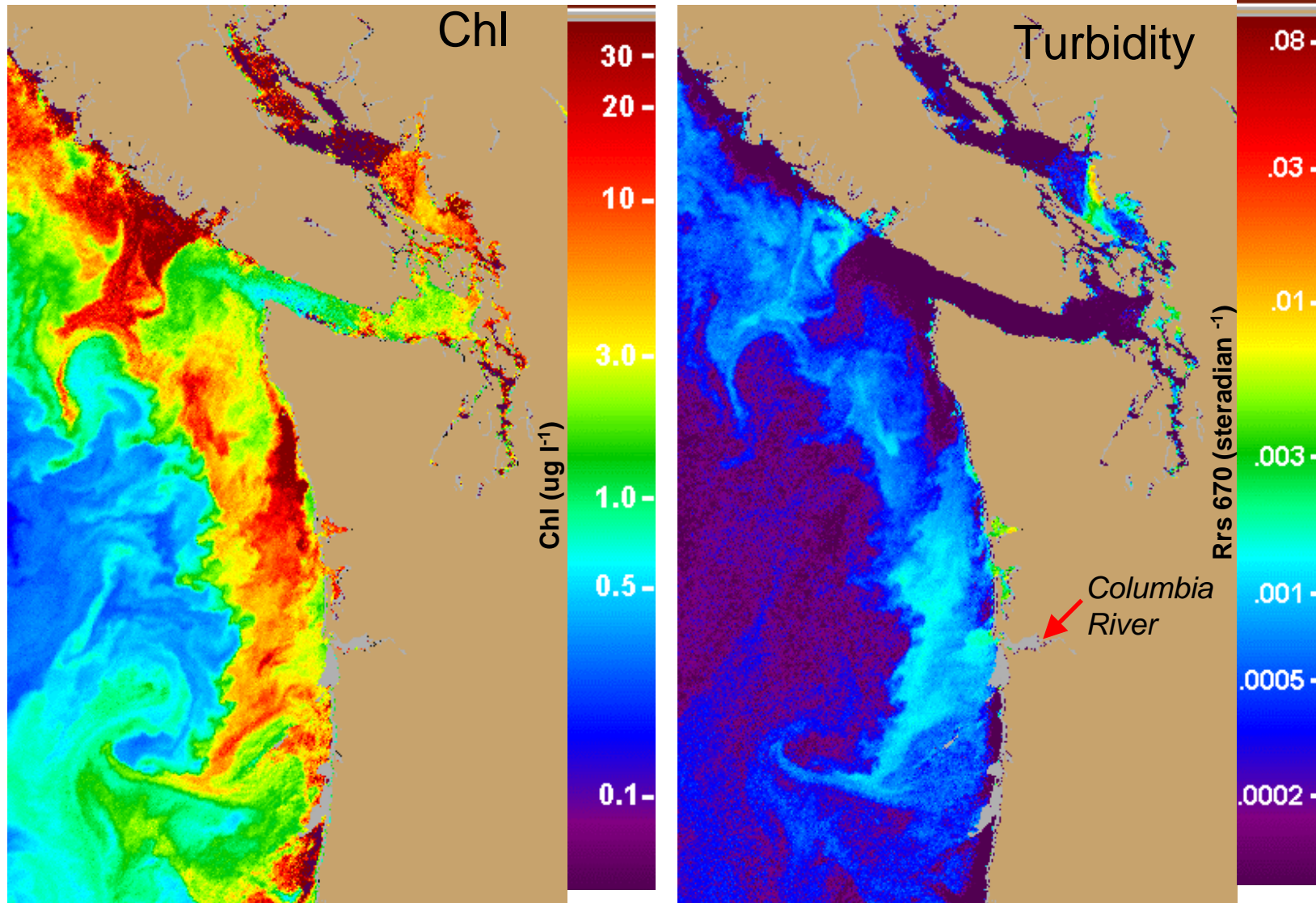


# Front detection and feature tracking for *Pseudo-nitzschia*





# Imagery for defining frontal boundaries, river plumes



# Examples of Remote Sensing from Elsewhere

## Biomass

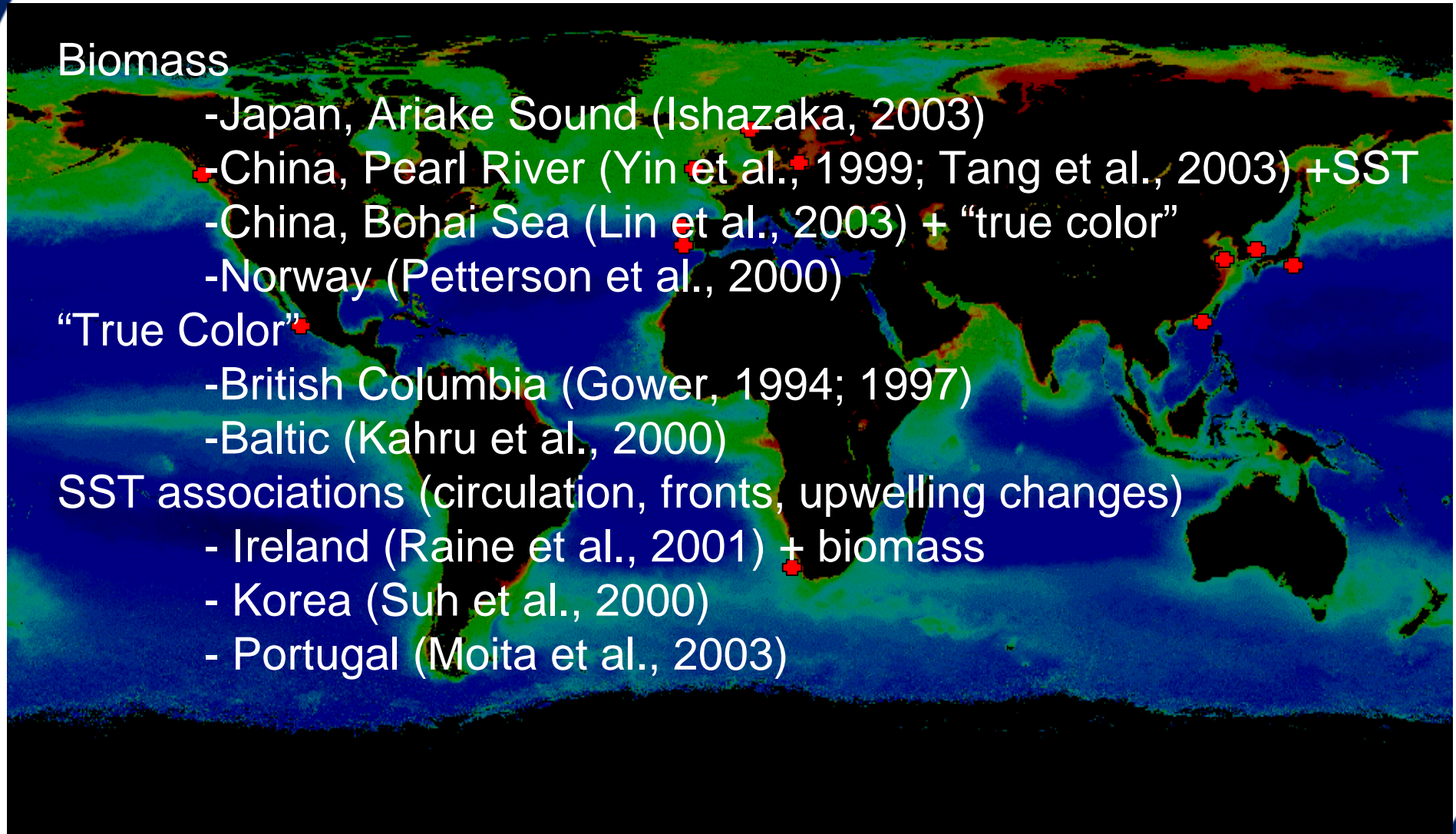
- Japan, Ariake Sound (Ishazaka, 2003)
- China, Pearl River (Yin et al., 1999; Tang et al., 2003) + SST
- China, Bohai Sea (Lin et al., 2003) + “true color”
- Norway (Pettersen et al., 2000)

## “True Color”

- British Columbia (Gower, 1994; 1997)
- Baltic (Kahru et al., 2000)

## SST associations (circulation, fronts, upwelling changes)

- Ireland (Raine et al., 2001) + biomass
- Korea (Suh et al., 2000)
- Portugal (Moita et al., 2003)





# Remote Sensing for HAB Detection and Transport

- Bloom Ecology

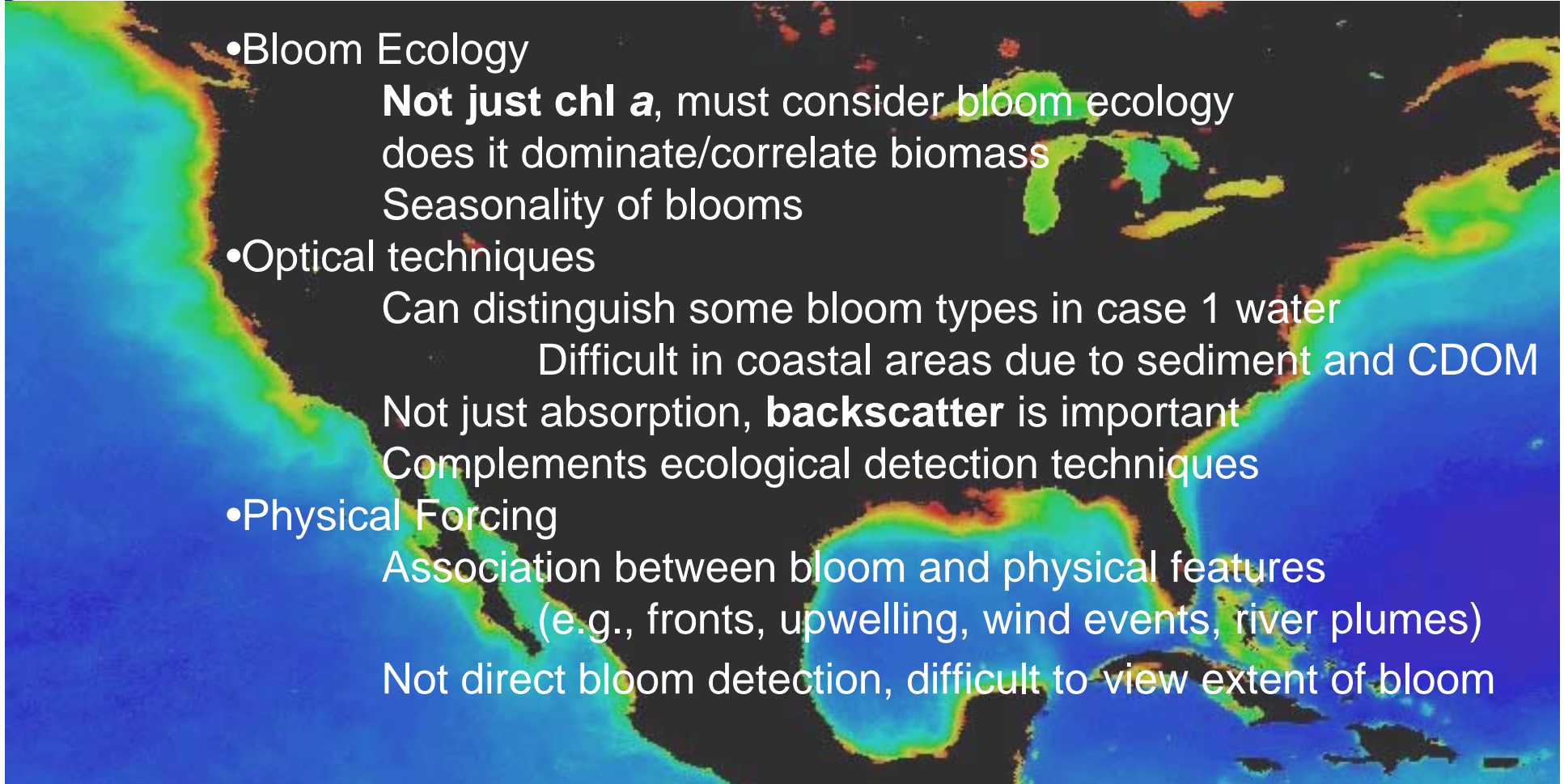
**Not just chl *a***, must consider bloom ecology  
does it dominate/correlate biomass  
Seasonality of blooms

- Optical techniques

Can distinguish some bloom types in case 1 water  
Difficult in coastal areas due to sediment and CDOM  
Not just absorption, **backscatter** is important  
Complements ecological detection techniques

- Physical Forcing

Association between bloom and physical features  
(e.g., fronts, upwelling, wind events, river plumes)  
Not direct bloom detection, difficult to view extent of bloom







# How Can Remote Sensing Address Management Needs?

- 

- 

-



# Characteristics of the Ideal Decision Support System – Migration of Research to Operations

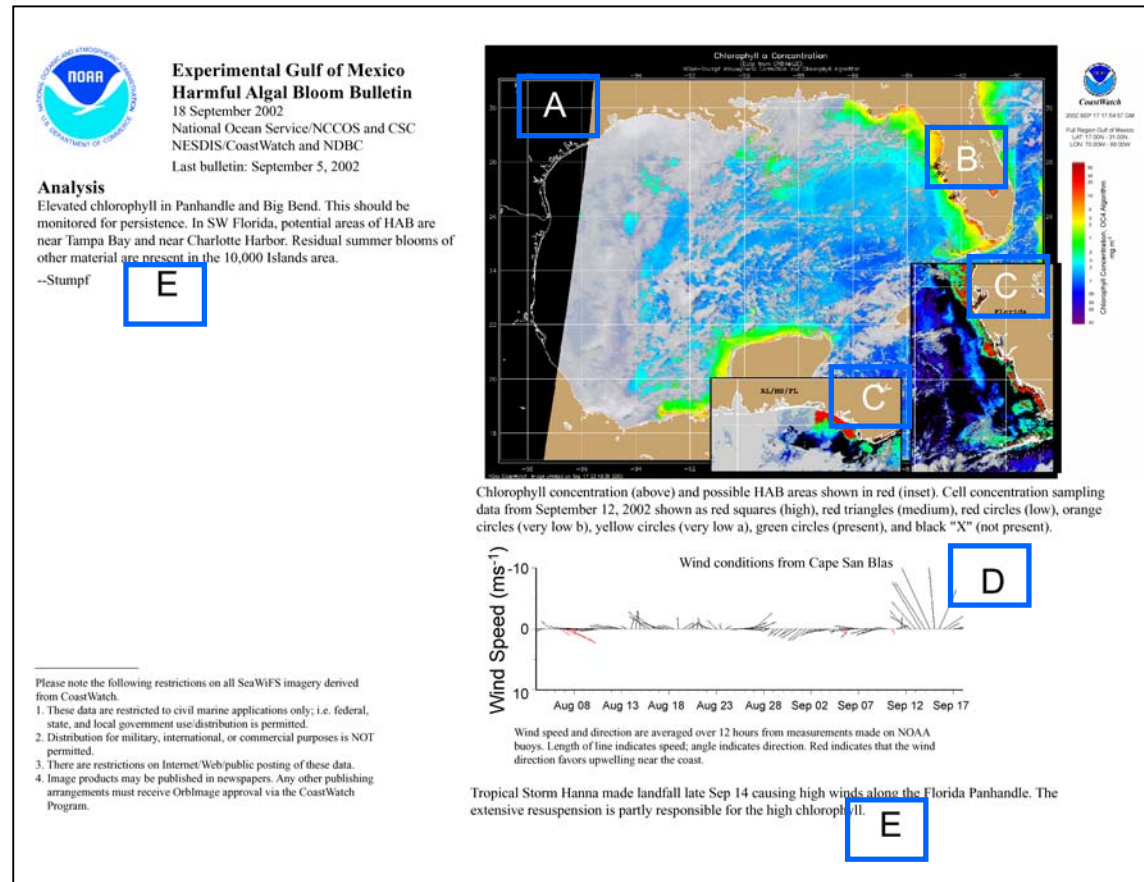


# Need for Timely Information

Warning Time	Management Options
seasonal	re-allocate resources alter monitoring schedules change harvesting policy
week – 3 days	alter monitoring schedules change harvesting policy alert businesses <u>prepare</u> for clean-up
24 hours	alter monitoring schedules alert businesses <u>prepare</u> for clean-up
none	extensive testing of harvested products initiate public health warnings divert resources to monitoring and clean-up

# Harmful Algal Bloom Bulletin

- Demonstration from 1999-2004
- Operational Oct 2004




National Center for Coastal Ocean Science; CoastWatch;  
Coastal Services Center; Center for Operational  
Oceanographic Products & Services



# Operational HAB Forecast System for Gulf of Mexico

## October 1, 2004



**Page 1**  
**Gulf of Mexico Harmful Algal Bloom Bulletin**  
 21 September 2004  
 National Ocean Service/NCCOS and CSC  
 NESDIS/CoastWatch and NDBC  
 Last bulletin: September 17, 2004

**Analysis**  
**HAB Forecast:**

No harmful algal blooms have been found along Florida's coast. Recent tropical storms have caused sediment resuspension and non-harmful blooms, which may cause discolored water.

**Analysis:**

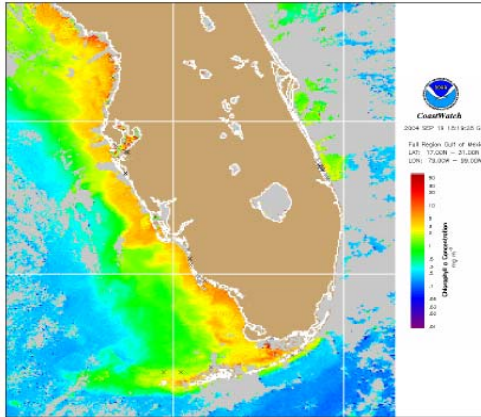
Samples taken last week from southwest Florida near Sarasota, Fort Meyers, and Naples showed no *Karenia brevis*. Imagery shows elevated chlorophyll along much of Florida's west coast: concentrations over 4 micrograms per liter off Cape San Blas and Cedar Key; over 5 micrograms per liter near Clearwater, Sarasota, Naples; and over 7 micrograms per liter Everglades City.

Winds have favored upwelling in southwest Florida for several days and are forecasted to continue for the rest of the week and through the weekend. These conditions are conducive to HAB formation, so this area should be monitored. Sampling here is recommended. Conditions in the panhandle don't favor HAB formation.

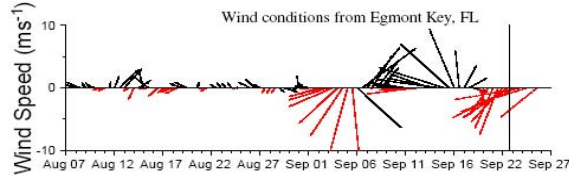
Bronder, Stolz

Please note the following restrictions on all SeaWiFS imagery derived from CoastWatch.

1. These data are restricted to civil marine applications only; i.e. federal, state, and local government use/distribution is permitted.
2. Distribution for military, or commercial purposes is NOT permitted.
3. There are restrictions on Internet/Web/public posting of these data.
4. Image products may be published in newspapers. Any other publishing arrangements must receive Orbimage approval via the CoastWatch Program.



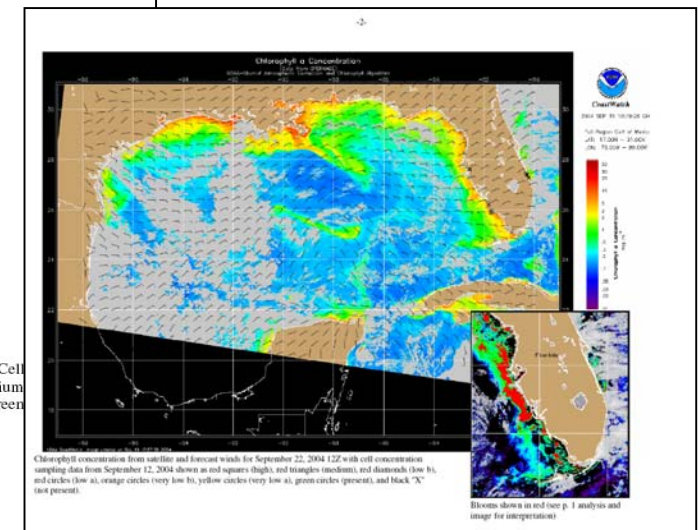
Chlorophyll concentration from satellite with possible HAB areas shown by red polygon(s). Cell sampling data from September 12, 2004 shown as red squares (high), red triangles (medium), red circles (low a), orange circles (very low b), yellow circles (very low a), green circles (present), and black "X" (not present).



Wind conditions from Egmont Key, FL

Wind speed and direction are averaged over 12 hours from measurements made on buoys. Length of line indicates speed; angle indicates direction. Red indicates that the wind direction favors upwelling near the coast. Values to the left of the dotted vertical line are measured values; values to the right are forecasts.

Southwest Florida: Winds have been northeasterly for the past few days, and are forecasted to shift to easterly then northeasterly over the next couple of days. The NWS Marine Forecast calls for easterly winds until Thursday, then northeasterly winds over the weekend. Florida Panhandle: Winds have been northeasterly for the past few days, and are forecasted to become easterly for the next couple of days.



2 components:

- Distributed to State/local/Fed Government to target sampling and management
- Public HAB condition report