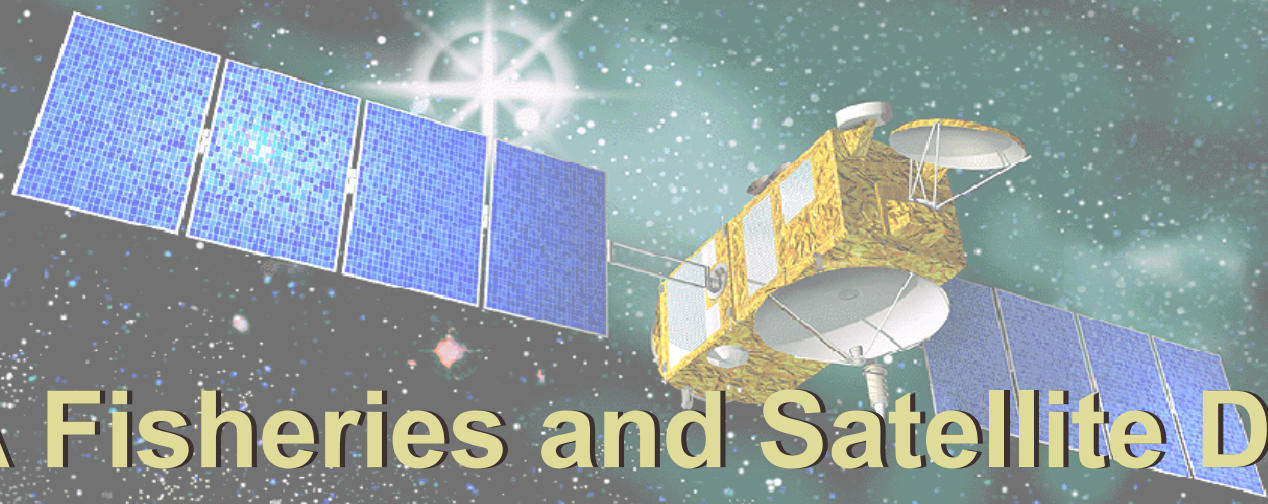
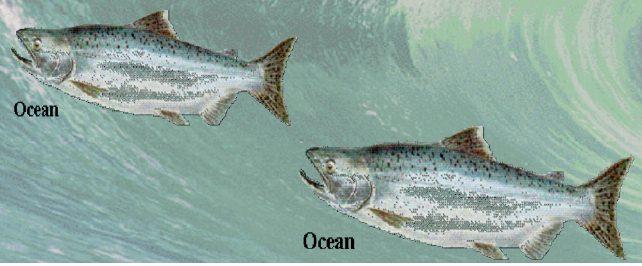


NOAA Fisheries and Satellite Data – Where are we and where are we going?

Cara Wilson
NOAA/NMFS/SWFSC
Environmental Research Division (ERD)



Contributors

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John Pereira	NOAA/NESDIS
Andrew Pershing	Cornell University
Franklin Schwing	NOAA/NMFS/SWFSC ERD
Ken Sherman	NOAA/NMFS/NEFSC
Rick Stumpf	NOAA/NOS
Andrew Thomas	U. Maine
Vera Trainer	NOAA/NMFS/NWFSC
Roy Torres	NOAA/OLE
Rick Wahle	Bigelow Laboratory
George Watters	NOAA/NMFS/SWFSC ERD
GOES-R COAST Team	

NMFS-Satellite group

- Satellite POCs for each science center (appointed by lab director)

AFSC	Jeff Napp (Seattle)
NEFSC	Jay O'Reilly (Narragansett)
NWFSC	Bill Peterson (Newport)
PIFSC	Jeff Polovina (Honolulu)
SEFSC	Tom Leming (Mississippi)
SWFSC	Cara Wilson (Pacific Grove)

At labs outside of the regional HQ

Objectives

- NMFS needs to better articulate its needs and requirements for satellite data

- As the NMFS representative on a number of satellite-related groups I would like to be better informed on:
  - how satellite data is being used within NMFS
  - what can be done to better facilitate satellite usage in NMFS

- Present some future directions of satellite data

Primary Objective: Initiate an intra-NMFS discussion of satellite issues relevant to NOAA and NMFS

Outline

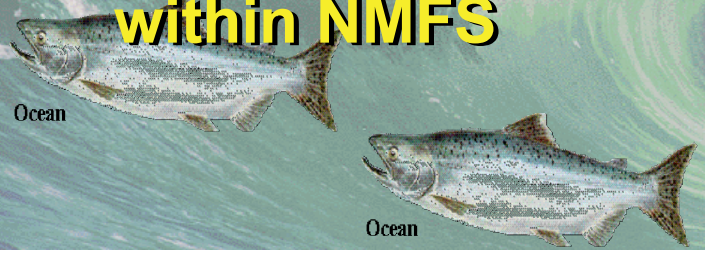
- Brief overview of satellite data

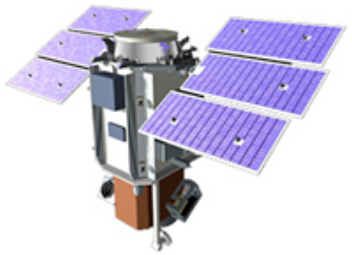
- Where are we going?

  An overview of the NOAA's current and future involvement with satellite data

- Where are we?

  An overview of the current uses of satellite data within NMFS





Different Types of Remotely Sensed Data (RSD)

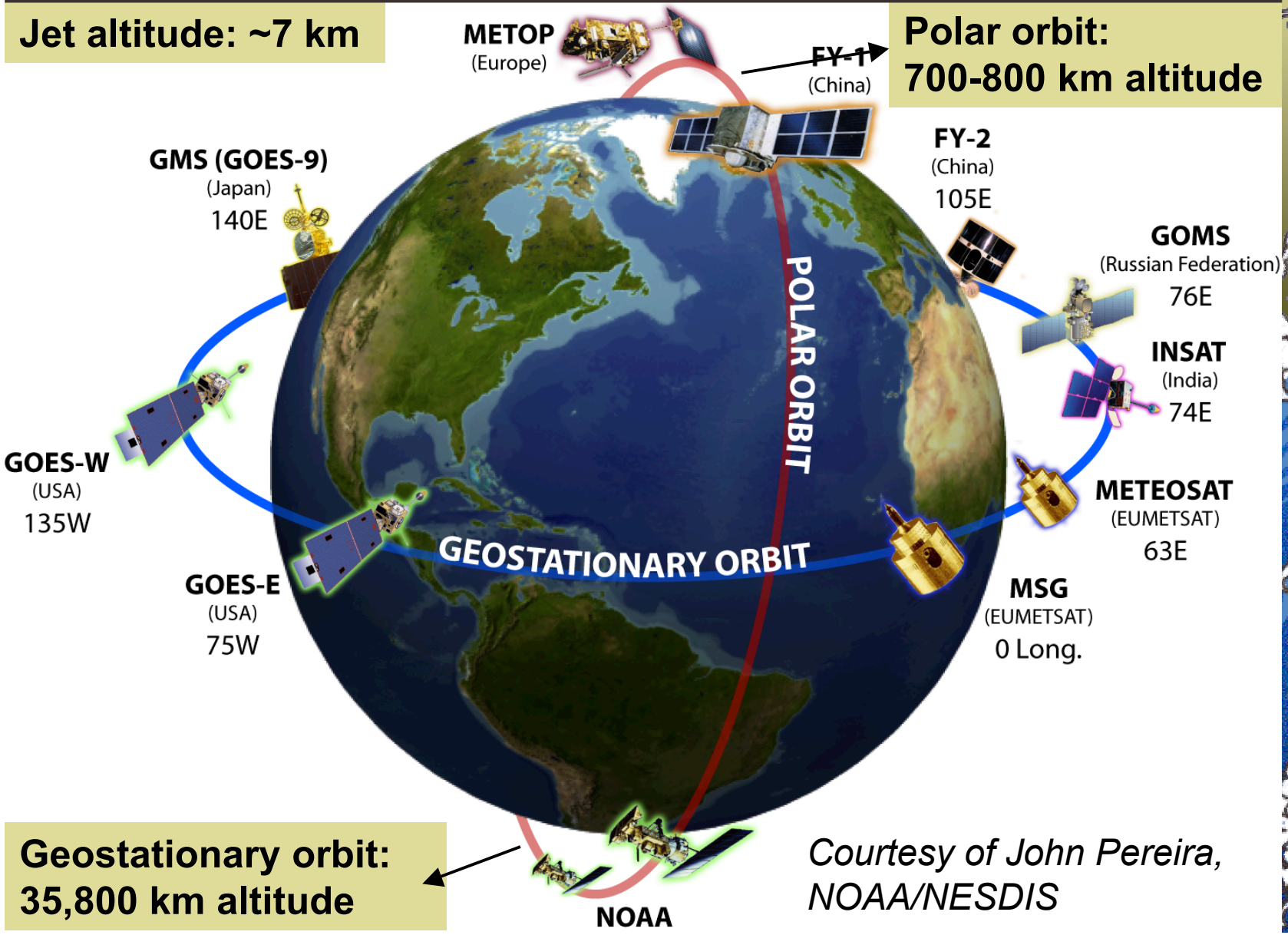
- *Satellite measurements*
  - *SST, SSH, ocean color, wind etc.*
- *Satellite-derived location information*
  - *tracking of fish, animals, fishing ships*
- *Aerial Surveys*
  - *Benthic habitat mapping*

Global Earth Observing System

Operational Satellite Component

Jet altitude: ~7 km

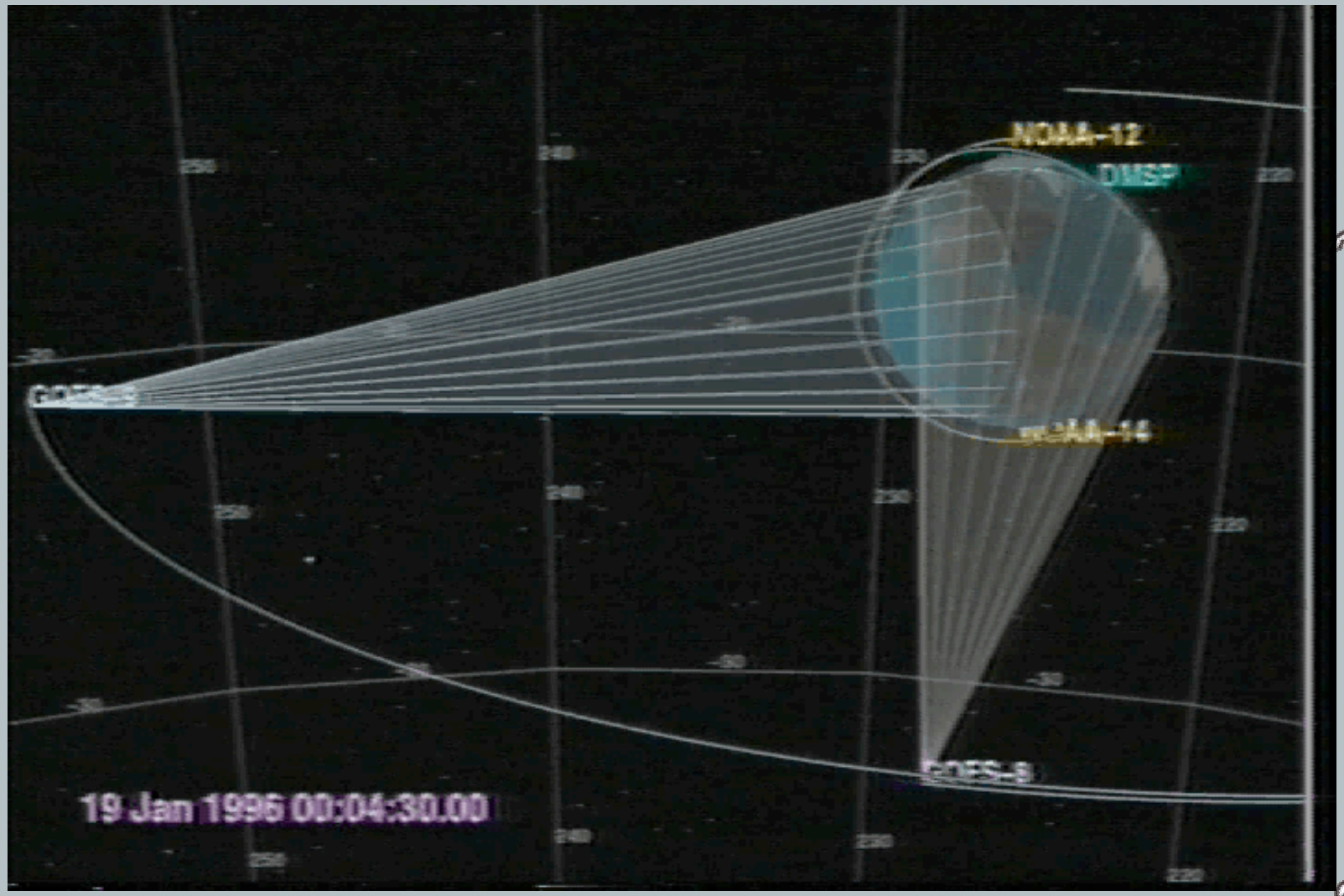
Polar orbit: 700-800 km altitude



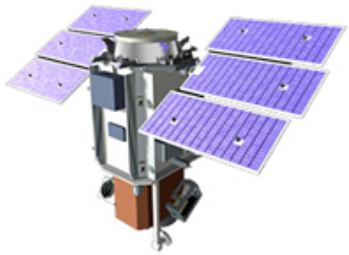
Geostationary orbit: 35,800 km altitude

Courtesy of John Pereira, NOAA/NESDIS

Polar versus Geostationary

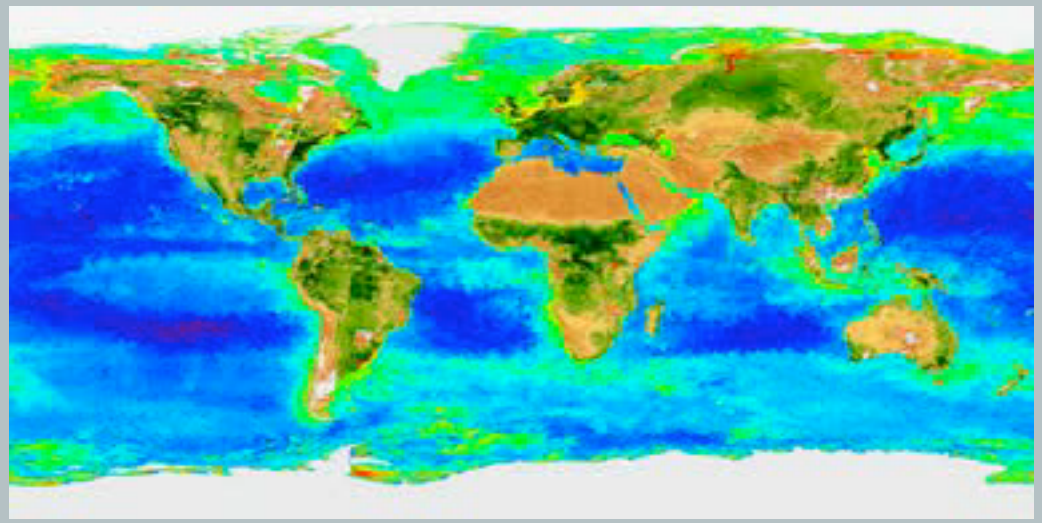


Courtesy of John Pereira, NOAA/NESDIS

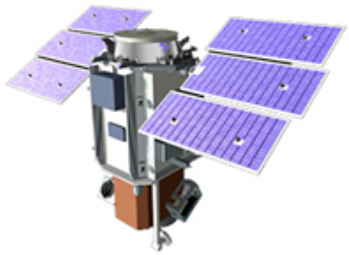


Chlorophyll

Animation of the first six years worth of biosphere data taken by the SeaWiFS satellite, Aug 1997 - July 2003.

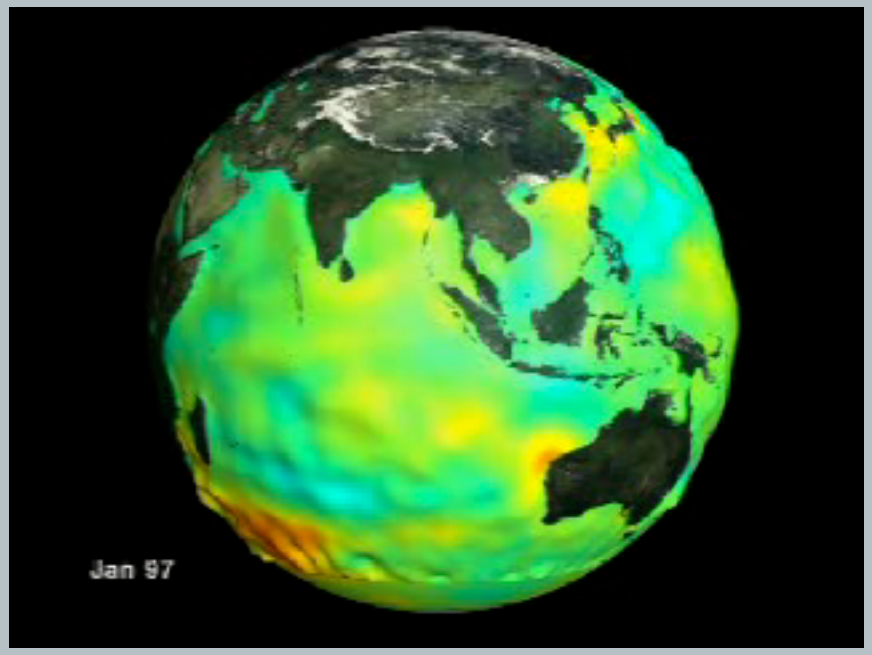


Animation by NASA Goddard's Scientific Visualization Studio

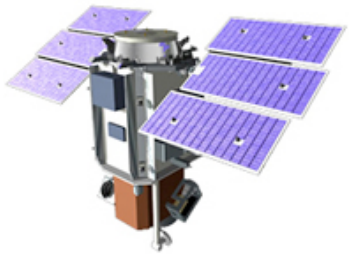


SSH and SST

Animation of SST anomalies superimposed on SSH anomalies from Jan 1997 through Feb 1998 showing the impact of the 97/98 El Niño



Animation by NASA Goddard's Scientific Visualization Studio



Sea Ice

Animation of daily AMSR-E sea ice concentrations from the Aqua satellite for the northern hemisphere during late 2002 and early 2003.

Animation by NASA Goddard's Scientific Visualization Studio

Where are we going?

Where are we going?

- Over the next few years the majority of research satellites currently operated by NASA will be transitioned over into NOAA's operation:
  - Ocean Color
  - SSH
  - Sea Surface Winds
- Future ocean color satellites:
  - VIIRS on the NPP satellite in 2007
  - HES-CW on NOAA's GOES-R satellite in 2012
- NMFS requirements for satellite data need to be articulated in these processes!

Research → Operations Transition (R2O)

Excerpt from -- Senate Report 108-344 – Departments of Commerce, Justice, and State, the Judiciary, and Related Agencies Appropriation Bill, 2005:

Satellite Oceanography/Transitioning Research to Operations

The United States Commission on Ocean Policy, National Academy of Sciences, and others have pointed to the United States' poor record on transitioning remote sensing research and development into operational Earth-Observing satellites. NASA is charged with Research and Development while NOAA is charged with flying operational satellites to acquire data on the Earth, the earth's atmosphere, and oceans. Little of the sensor technology developed by NASA has been picked up by NOAA, and NOAA's budget requests to Congress have been conspicuously absent requests to even acquire and process data from NASA satellites, such as ocean winds from ***scatterometers***, exact sea level and wave height from ***altimeters***, as well as other oceanic measurements such as coastal ***ocean color***. **As noted by the U.S. Commission on Ocean Policy, it is NOAA's mission to fly operational satellites, including ocean remote sensing technology, and to provide data continuity.**

R2O Strategic Approach

Near-Term

- Congress granted $4M in FY05 to NOAA to prepare an implementation plan for the Research to Operations Program (R2O Tiger Team)
- Transition “Research to Operations” into a NOAA Goal and engage in FY 2008 budget process

Longer-Term

- ~3-5 year: Establish plan to transition key space/data/modeling units from NASA to NOAA
- ~Decade: Engage in the NASA Strategic Roadmap process to identify and sustain key observations required for research and operational use

R2O Tiger Team

Membership:
Stan Wilson and John Pereira, leads, NESDIS
Cara Wilson, Jeff Polovina and Kenric Osgood, NMFS
Rick Stumpf, NOS
Marie Colton and Eric Bayler, NESDIS/ORA
Dave Behringer, Fred Toepfer, Kevin Schrab and David Green, NWS
Mike Johnson, Tony Rosati and Ants Leetmaa, OAR

Objective:
Prepare an implementation plan that will utilize NASA research data to improve NOAA operational products and services, with clear deliverables within FY05

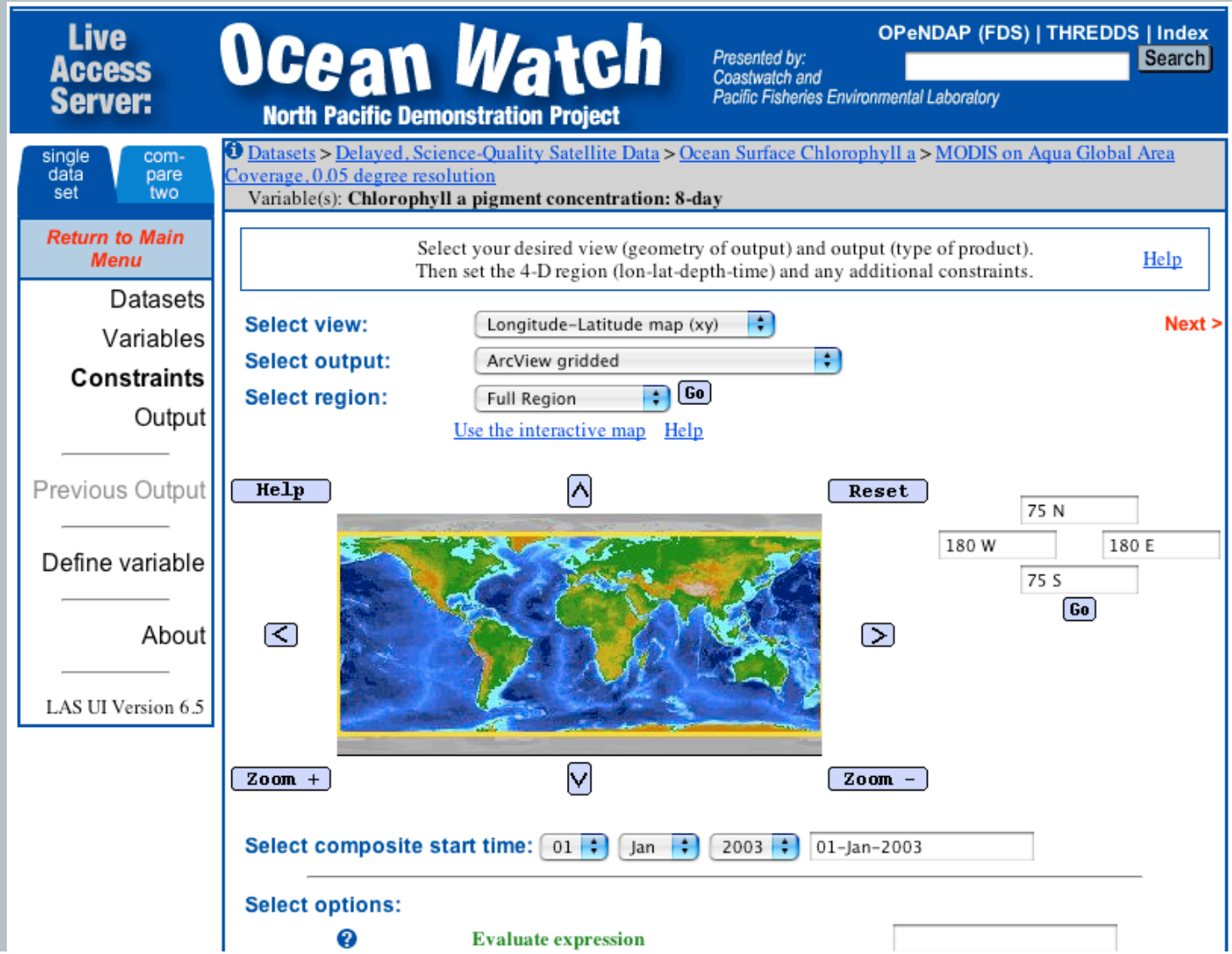
Accomplishment:
Identified 18 specific tasks to be accomplished, and established a timeline for their completion

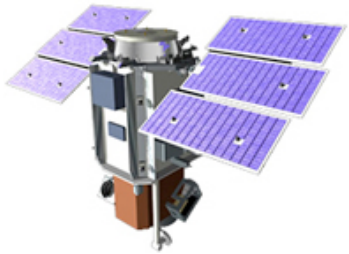
R2O
Ocean Color Tasks

1. **Continue SeaWiFS for MODIS evaluation and VIIRS overlap**
   NOAA contributed funds for the renewed contract with OrbImage to continue free research access to SeaWiFS data
2. **Fix MODIS deficiencies in coastal waters**
   MODIS data could be crucial for providing a continuous ocean color timeseries between SeaWiFS and VIIRS
3. **Develop a more robust in-situ oceanic calibration capability**
   The MOBY calibration platform needs to be established as an operational component for satellite ocean color
4. **Make a more effective case for climate-quality ocean color**
   Workshop sponsored by CIOSS (OSU) Aug 11-12, 2005
5. **Facilitate access to multiple satellite data sets to meet fisheries & IOOS needs**
   Expand PFEL's OceanWatch LAS to provide timeseries of satellite derived primary productivity and to improve access to other satellite datasets

OceanWatch LAS at ERD

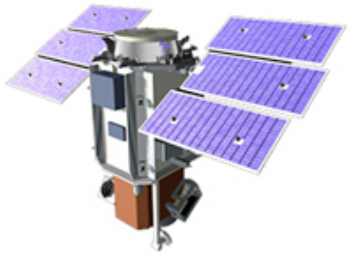
http://oceanwatch.pfeg.noaa.gov





Visible Infrared Imaging Radiometer Suite (VIIRS)

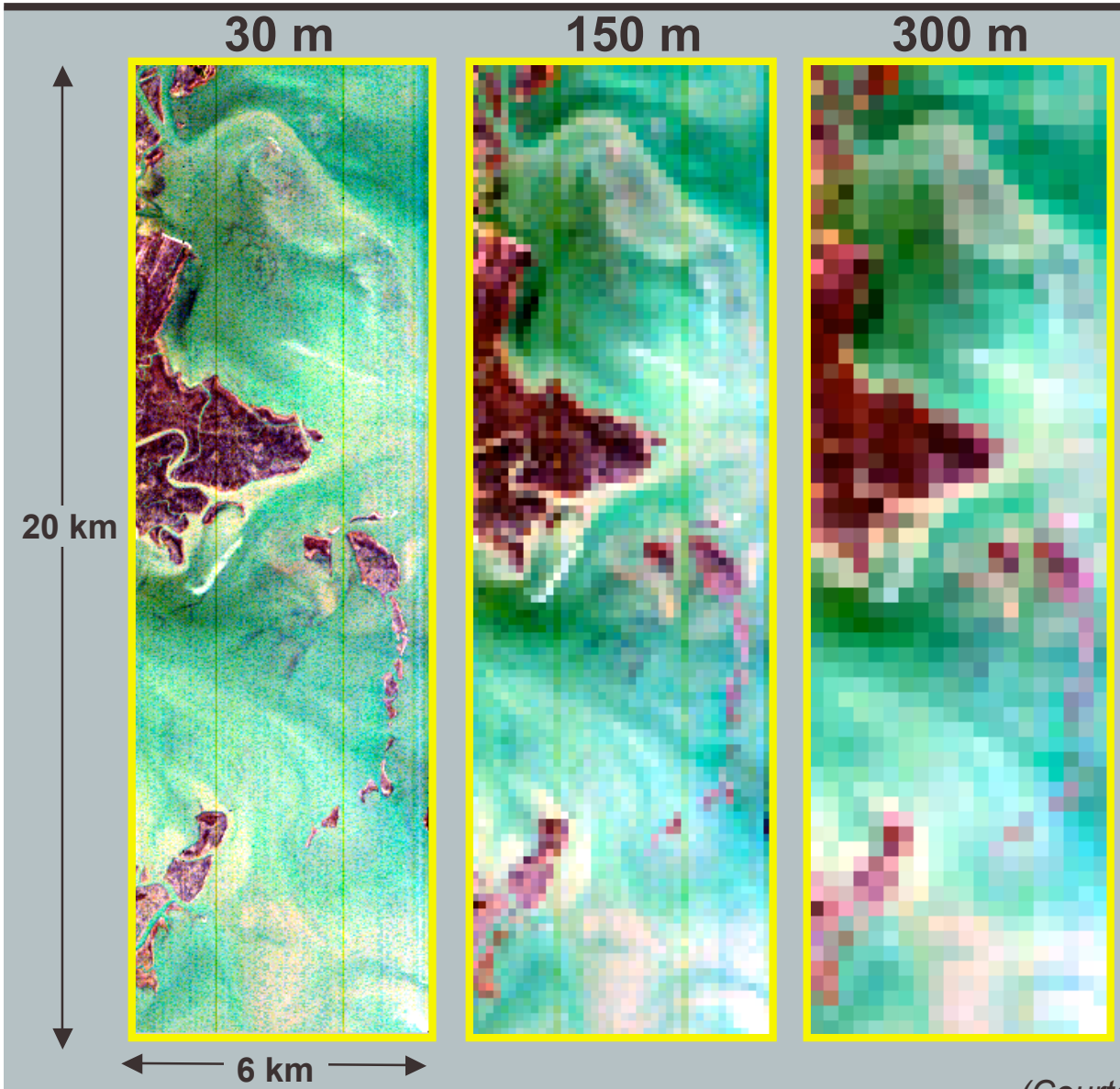
- SeaWiFS and MODIS heritage technology
- First flight on NPOESS Preparatory Project (NPP) in 2007
- NOAA NPOESS satellites starting in 2009
- 7 ocean color channels and 2 SST channels
- Approximately 1 km global spatial resolution
- Maximum revisit frequency of twice a day at 10:30 and 15:30



HES-CW on GOES-R

- Hyperspectral Environmental Suite with Coastal Water Imaging capability (HES-CW)
- Will be first ocean color sensor from geostationary orbit
- Sample all U.S. coastal waters (except Alaska) once every three hours (goal is hourly)
- 300 m spatial resolution at nadir; ~400-450 m in U.S. coastal waters
- 14 channels (visible & near IR), it could be hyperspectral
- Advanced Baseline Imager (ABI) could be used to selectively sample during cloud free periods
- A contractor will be selected to build HES in 2006
- GOES-R launch is planned for 2012

Spatial Resolution Comparison



The effect of spatial degradation from 30 m to 150 m and 300 m is illustrated

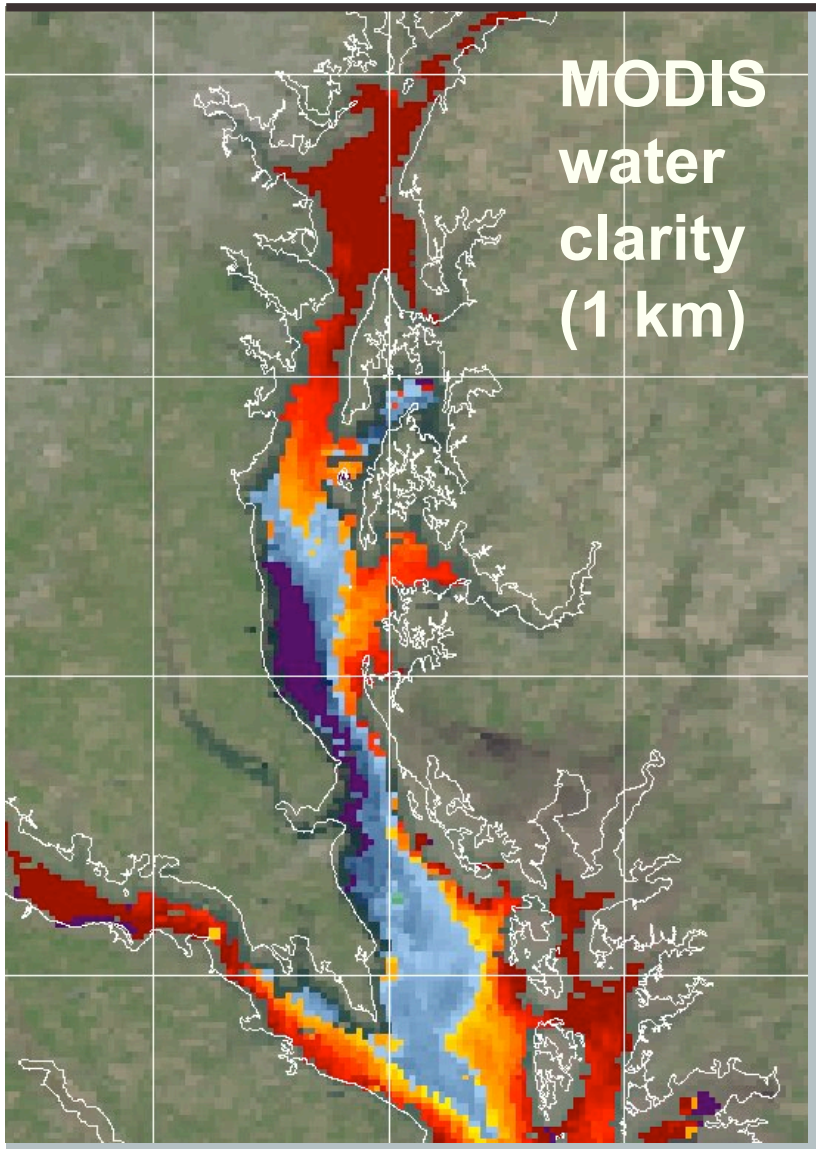
- Detailed coastal features are compromised at coarser resolutions
- Overall characteristics retained even at 300 m resolution

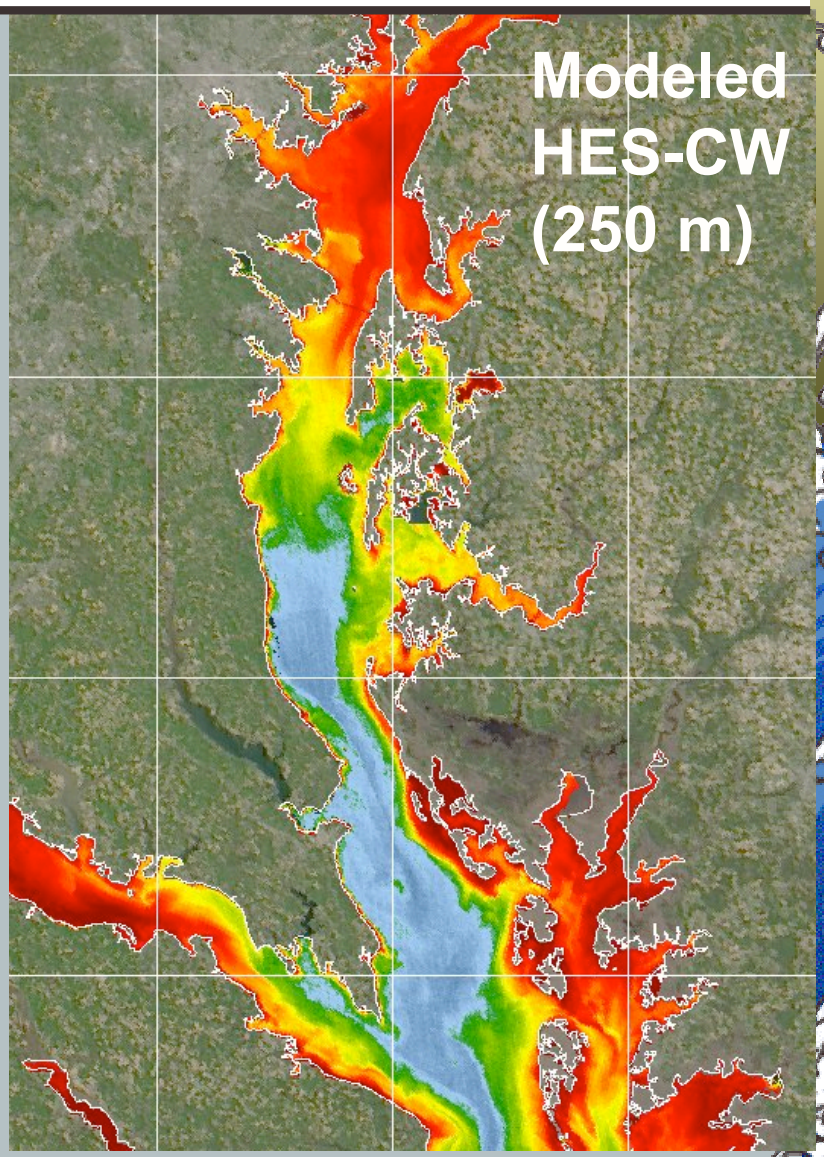
Hyperion Data RGB Composite

- 0.65 μm
- 0.55 μm
- 0.45 μm

(Courtesy Ed. Howard, NOAA)

Spatial Resolution Comparison

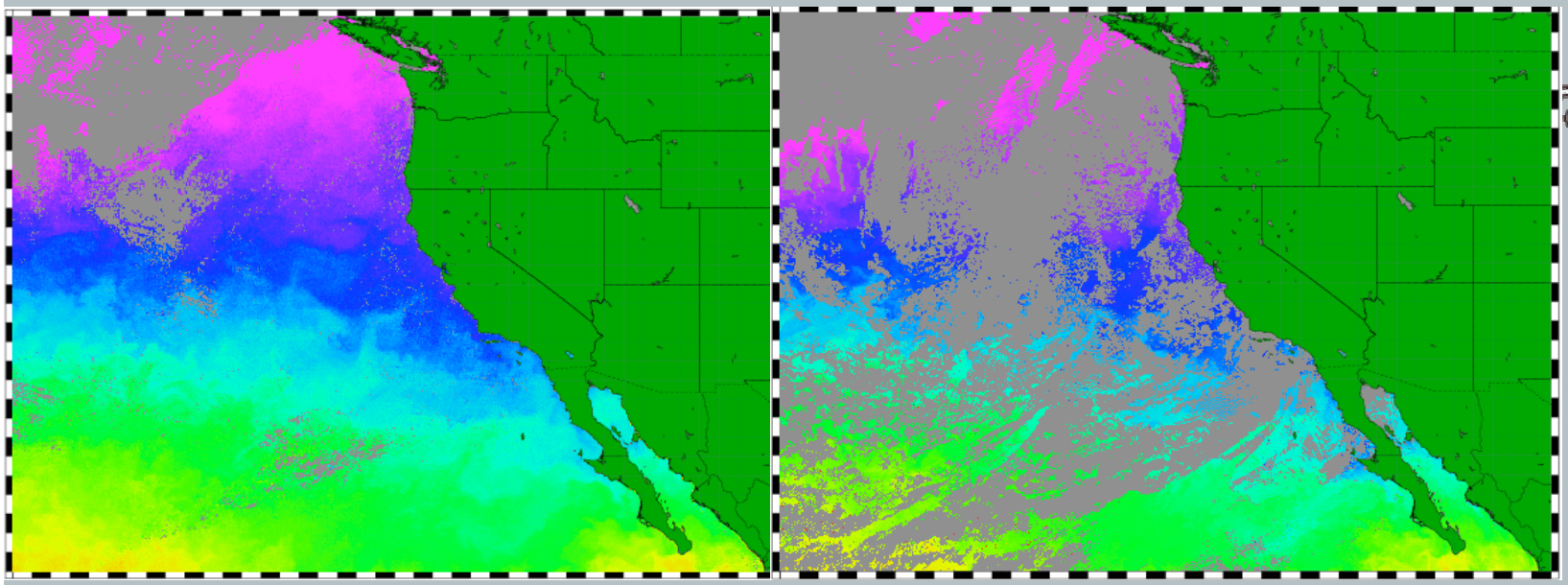




Courtesy of the GOES-R COAST team

Temporal Resolution Comparison

Increased temporal resolution will greatly increase data coverage in persistently cloudy areas



3 day composite of GOES SST

3 day composite of AVHRR SST

Image courtesy of NOAA CoastWatch, West Coast node at ERD

Fluorescence

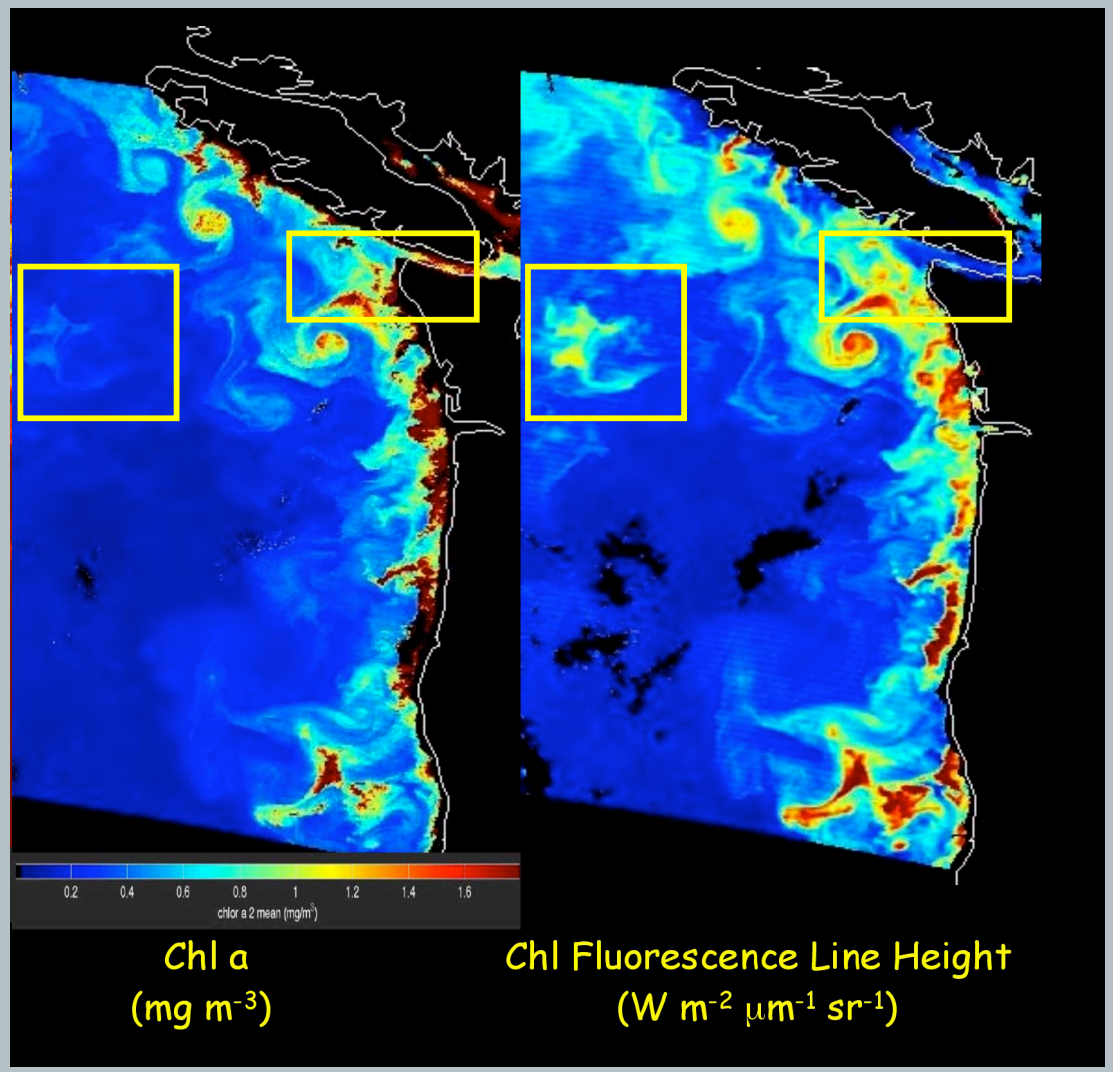


Image courtesy of the GOES-R COAST team

MODIS Terra scene from 3 Oct. 2001.

The ratio of fluorescence line height to chlorophyll changes as a function of the physiological state of the phytoplankton. This can be exploited to assess the health and productivity of the phytoplankton populations.

Fluorescence line height not available from VIIRS.

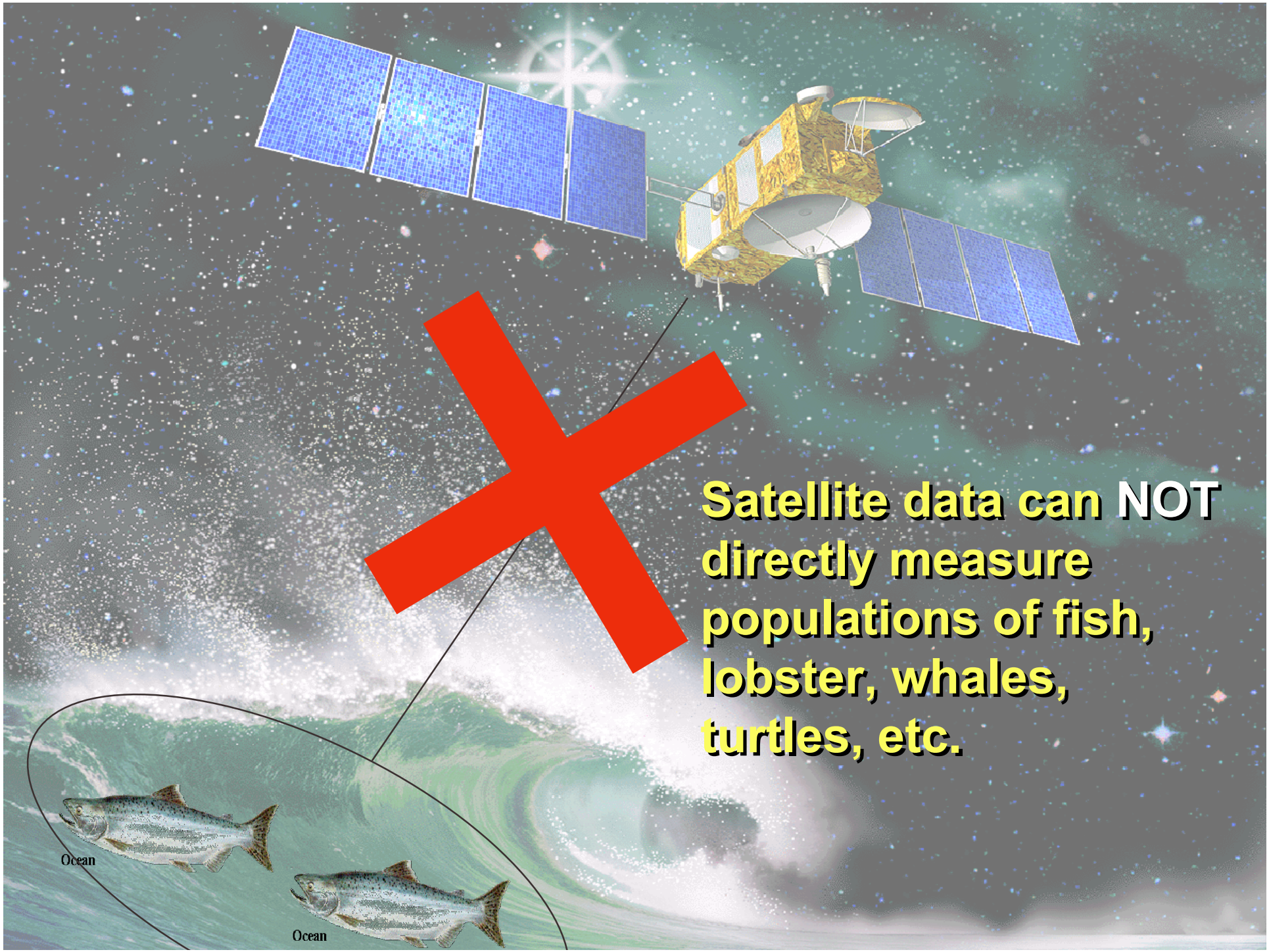
The Bottom Line…

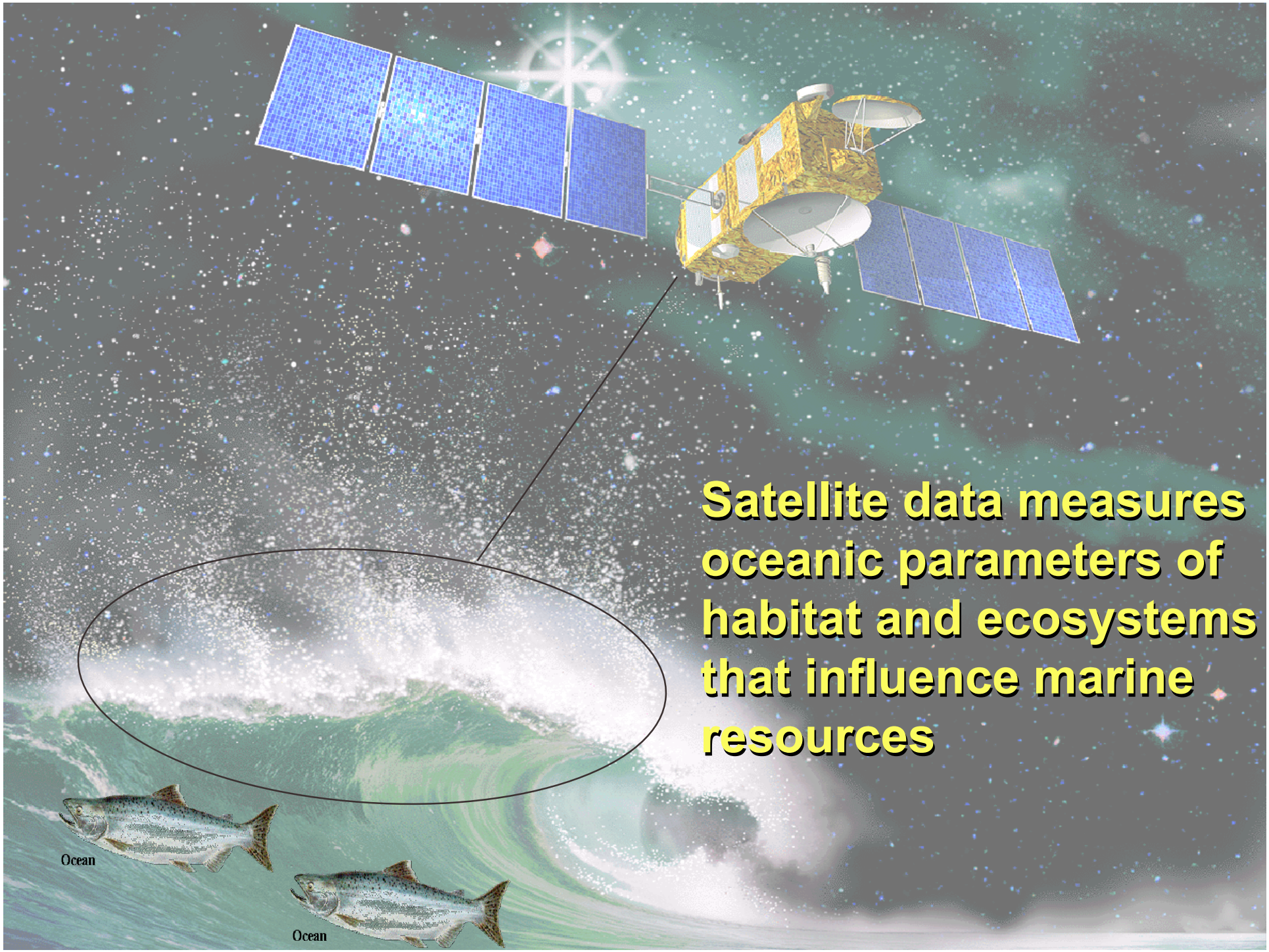
- NOAA will be taking over the operational acquisition of major satellite measurements such as SSH, ocean color and surface winds.
- In support of this, NOAA needs to demonstrate the ***operational use of these data*** within the agency.
- NMFS and NOS are the two NOAA LOs involved with the operational use of oceanic satellite data (ie non weather). **For the open ocean, NMFS is the only LO.**

Where are we?
Ocean
Ocean

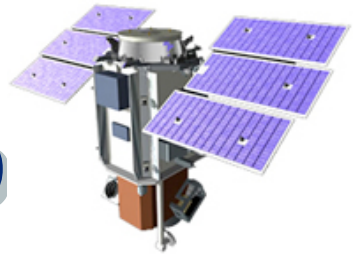
Operational?…

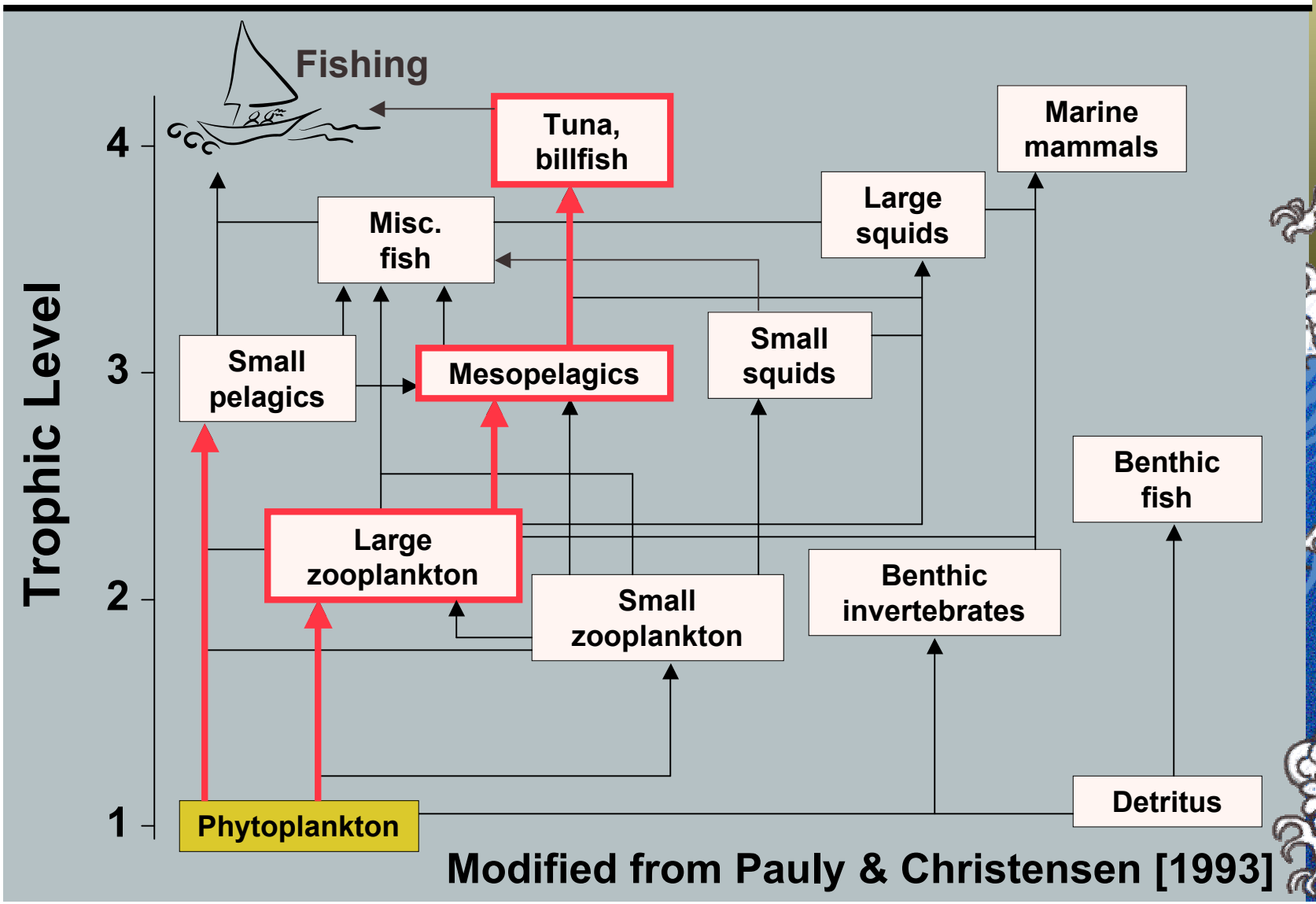
- "Operational" in the context of fisheries has a different temporal scale than for other uses such as the weather service, HAB monitoring etc.
- Linkages between satellite data and ecosystems are indirect, involving subsurface ocean dynamics and long-term climate variability. Understanding and monitoring these interactions requires continuous timeseries of high quality data.


Satellite data can NOT directly measure populations of fish, lobster, whales, turtles, etc.
Ocean
Ocean

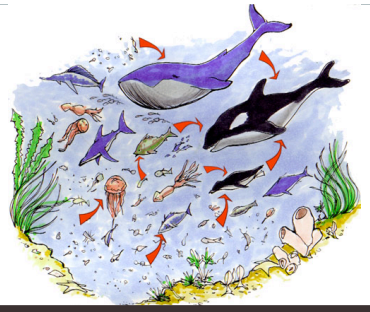

Satellite data measures oceanic parameters of habitat and ecosystems that influence marine resources
Ocean
Ocean

Oceanic Food Web

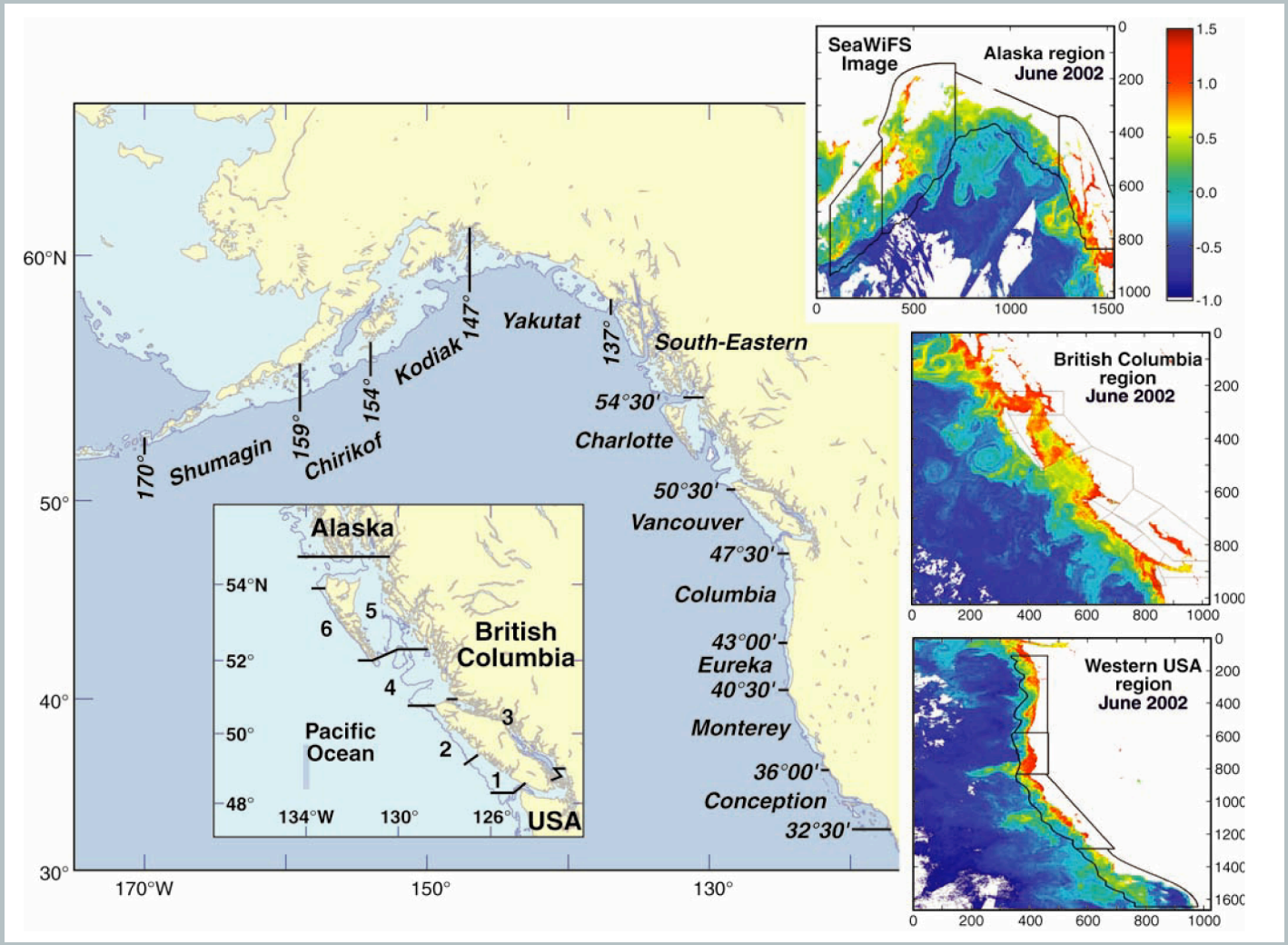




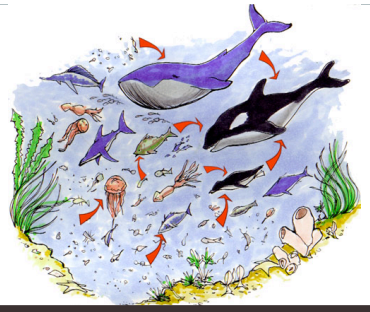
Modified from Pauly & Christensen [1993]



Linkages



Ware & Thomson [Science, 2003]



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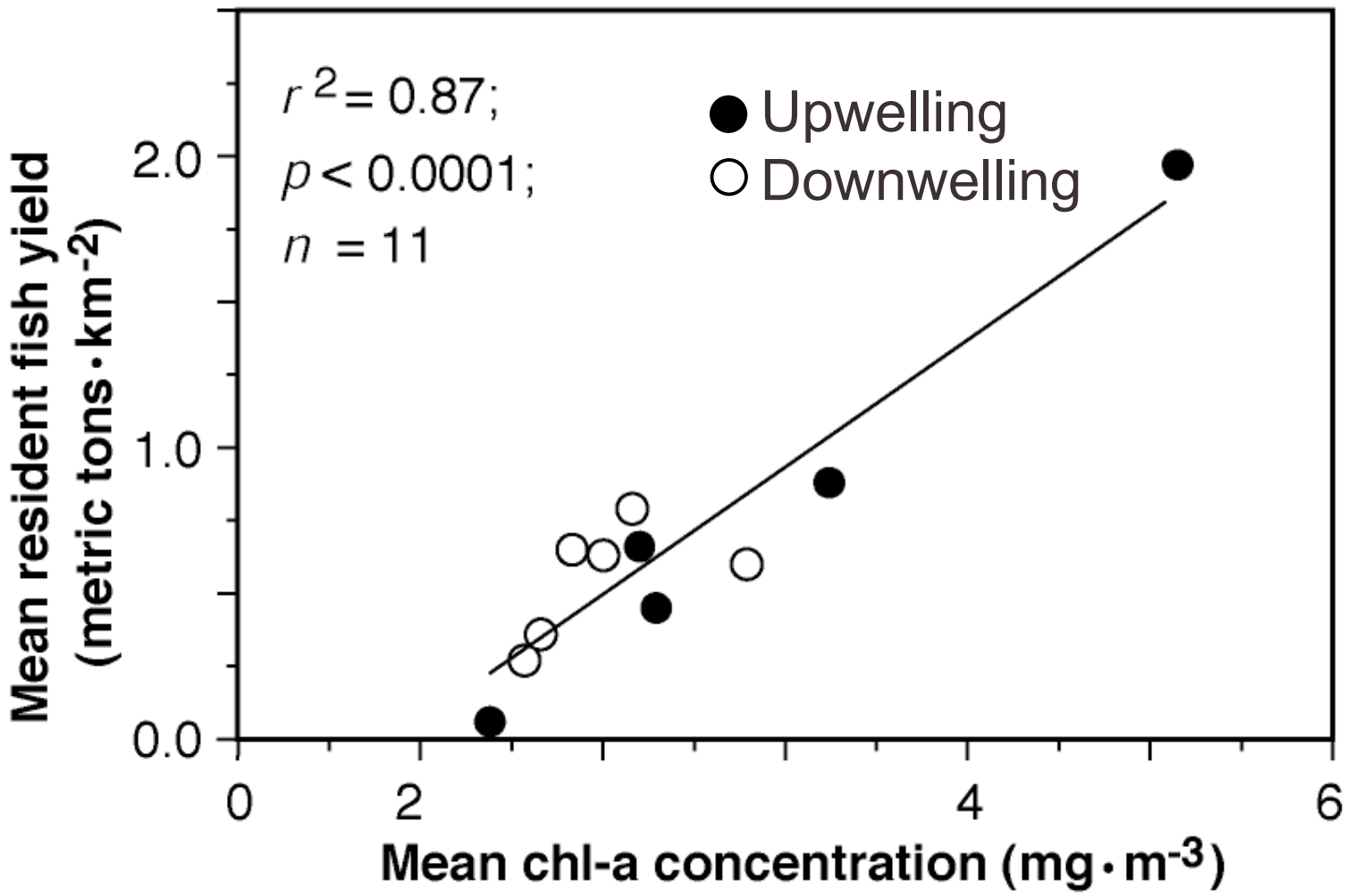

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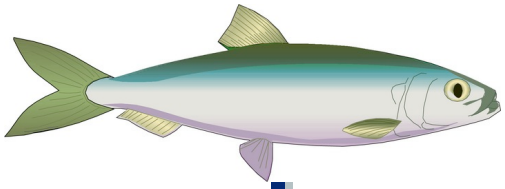
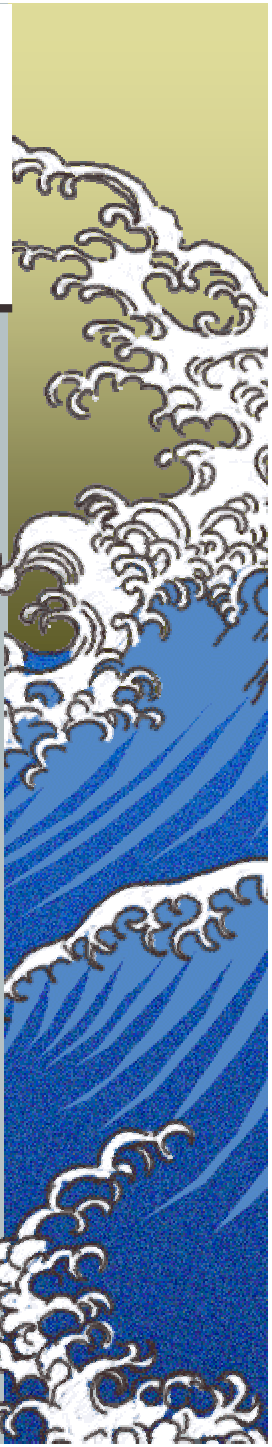


Ocean Features Important to Marine Resources

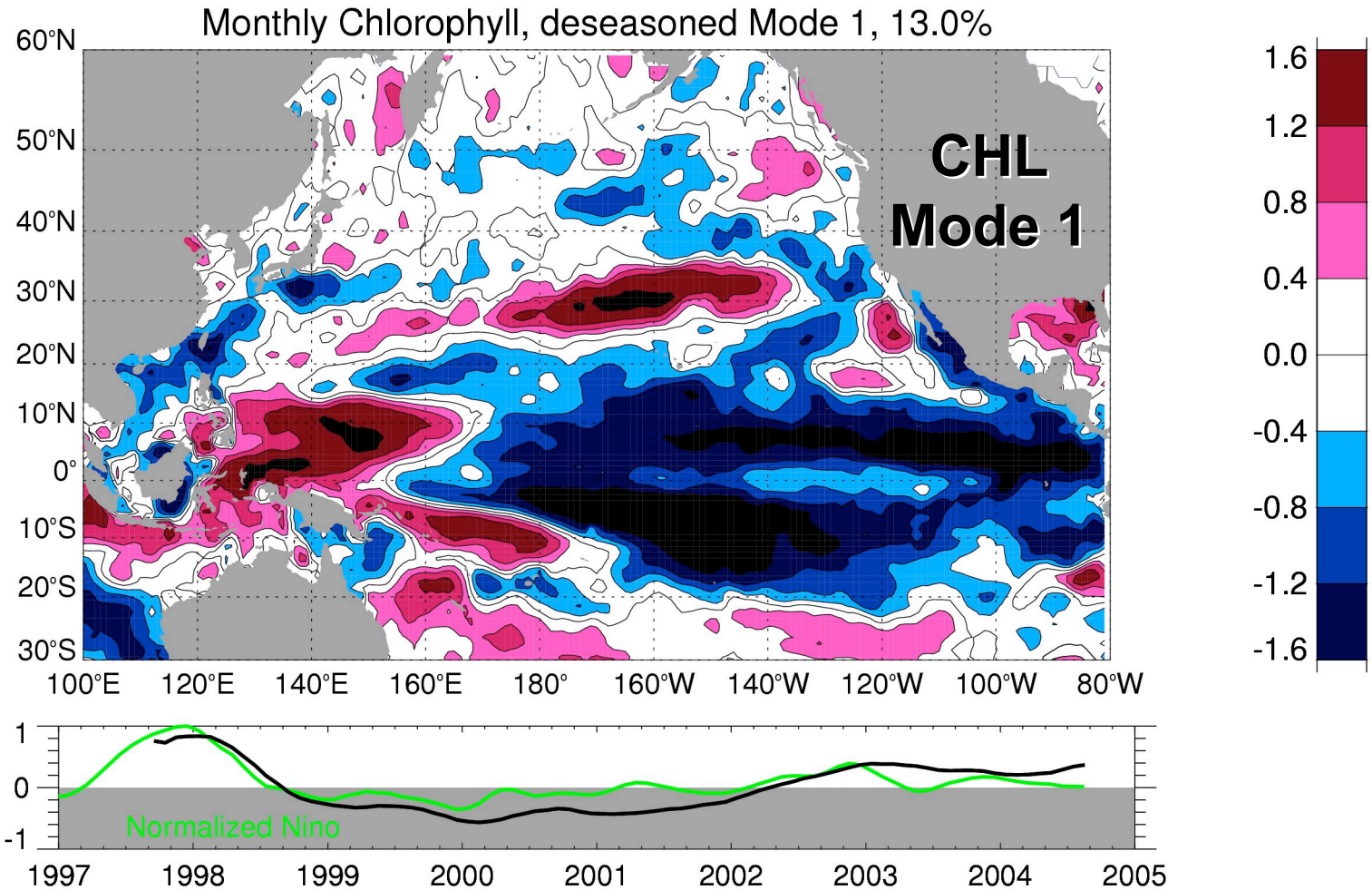
- *Ocean 'fronts', boundaries, 'edges'*
- *River plumes*
- *Coastal regions*
- *Mesoscale circulation patterns, e.g., eddies, meanders, 'loops'*
- *Convergence zones*
- *Subsurface thermal structure, e.g. MLD, thermocline*
- *Ocean surface winds*
- *Ocean currents*
- *Wave heights*



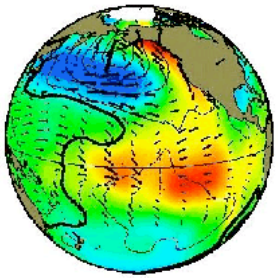
Temporal Events Important to Marine Resources

- *Upwelling*
- *Harmful Algae Blooms (HABs)*
- *Oil Spills*
- *Seasonal Transitions*
- *El Niño events*
- *Regime Shifts (i.e. PDO)*
- *Global Climate Change*

Chlorophyll Variability & El Niño



Wilson & Adamec [JGR, 2001]



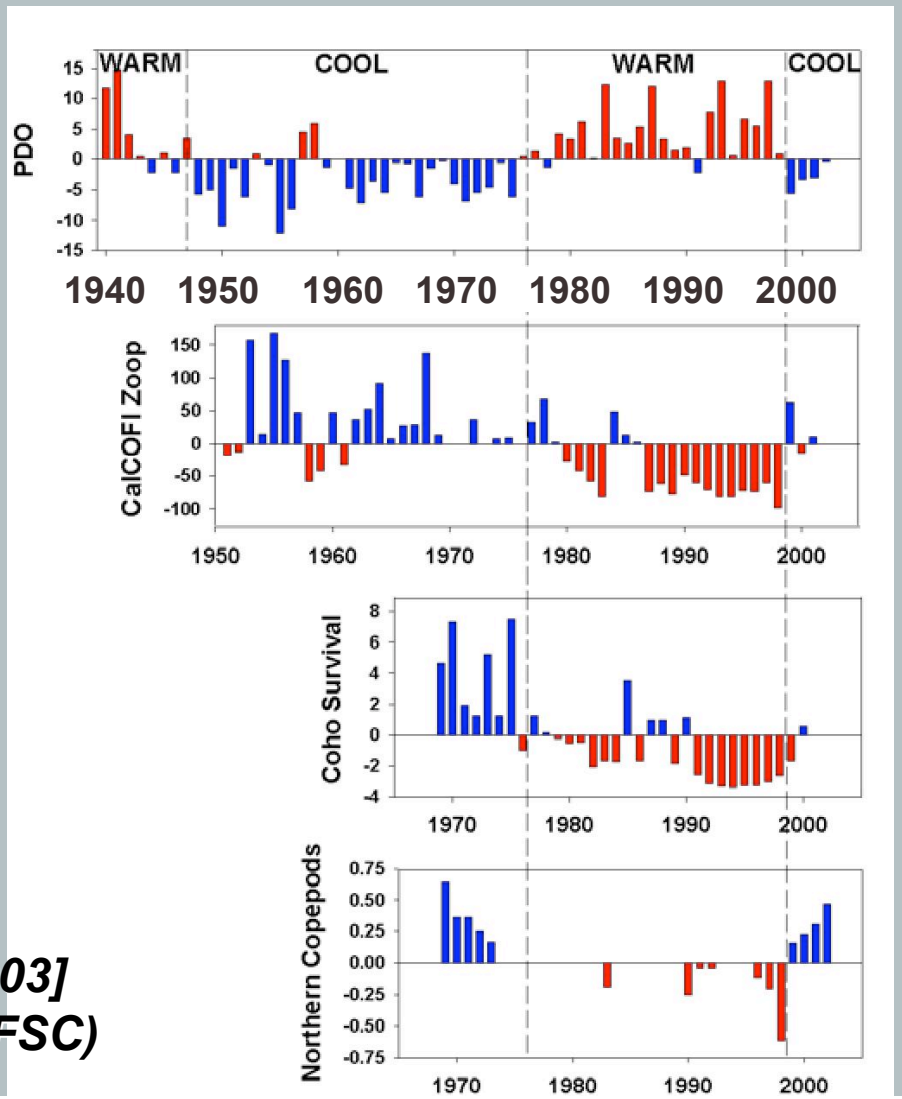
Regimes shifts

PDO

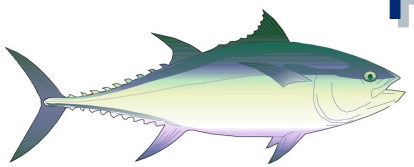
Zooplankton (CalCOFI)

Coho Survival

Copepods



Peterson & Schwing [GRL, 2003]
(NOAA/NMFS - NWFSC & SWFSC)



Fisheries Relevant Applications of 'Satellite' Data (RSD)

- *Benthic Habitat Mapping*
- *Land Cover Changes*
- *Oil Spill Detection and Monitoring*
- *Distribution of Tagged Living Marine Resources (LMR)*
- *Enforcement*
- *Harmful Algal Bloom (HAB) detection*
- *Coral Bleaching*
- *Optimize planning of fisheries research cruises*
- *Policy & Regulation*
- *LMR Strandings and Mortalities*
- *Pelagic Habitat Assessment*
- *Population Analysis of LMRs*

Benthic Habitat Mapping

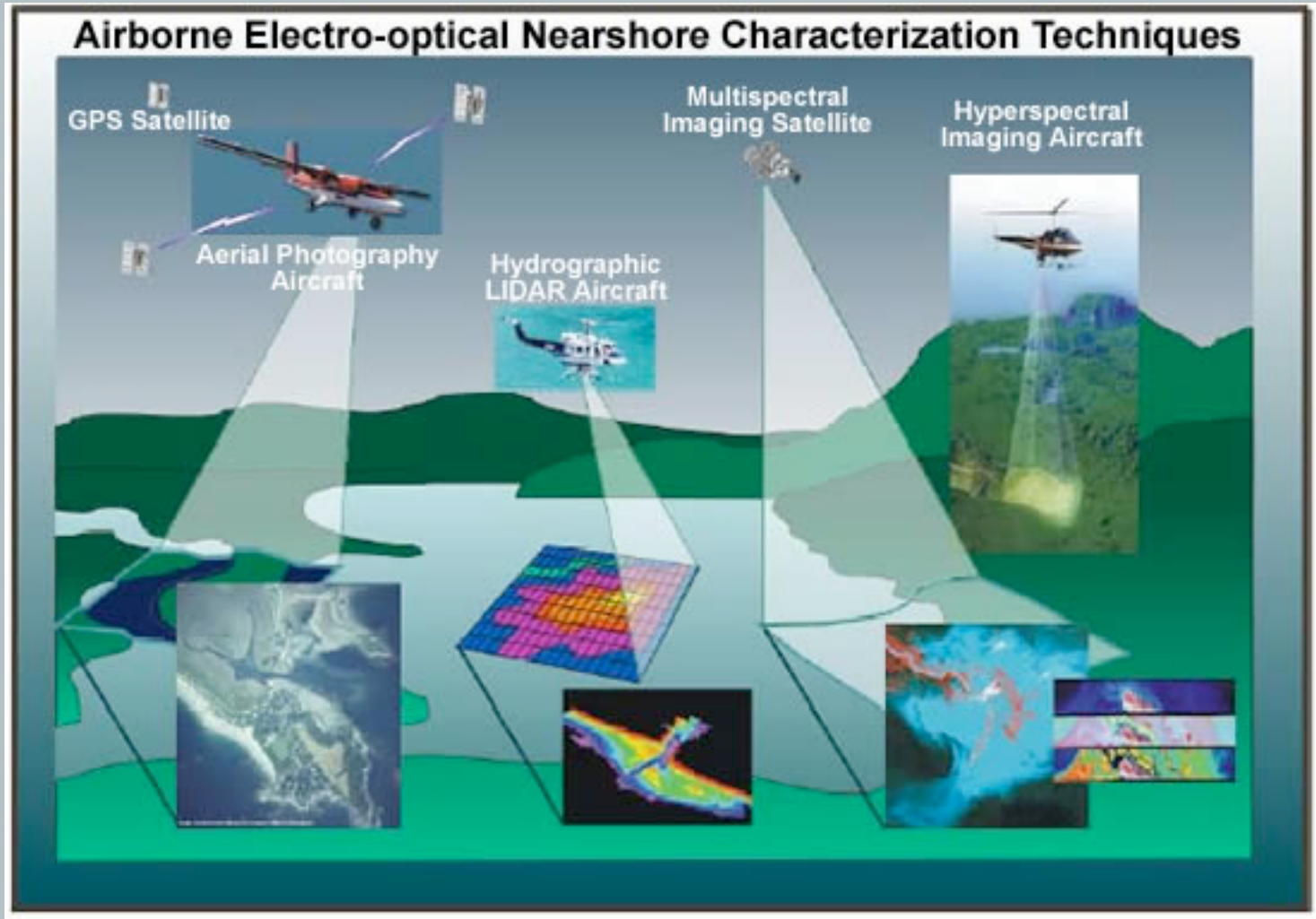
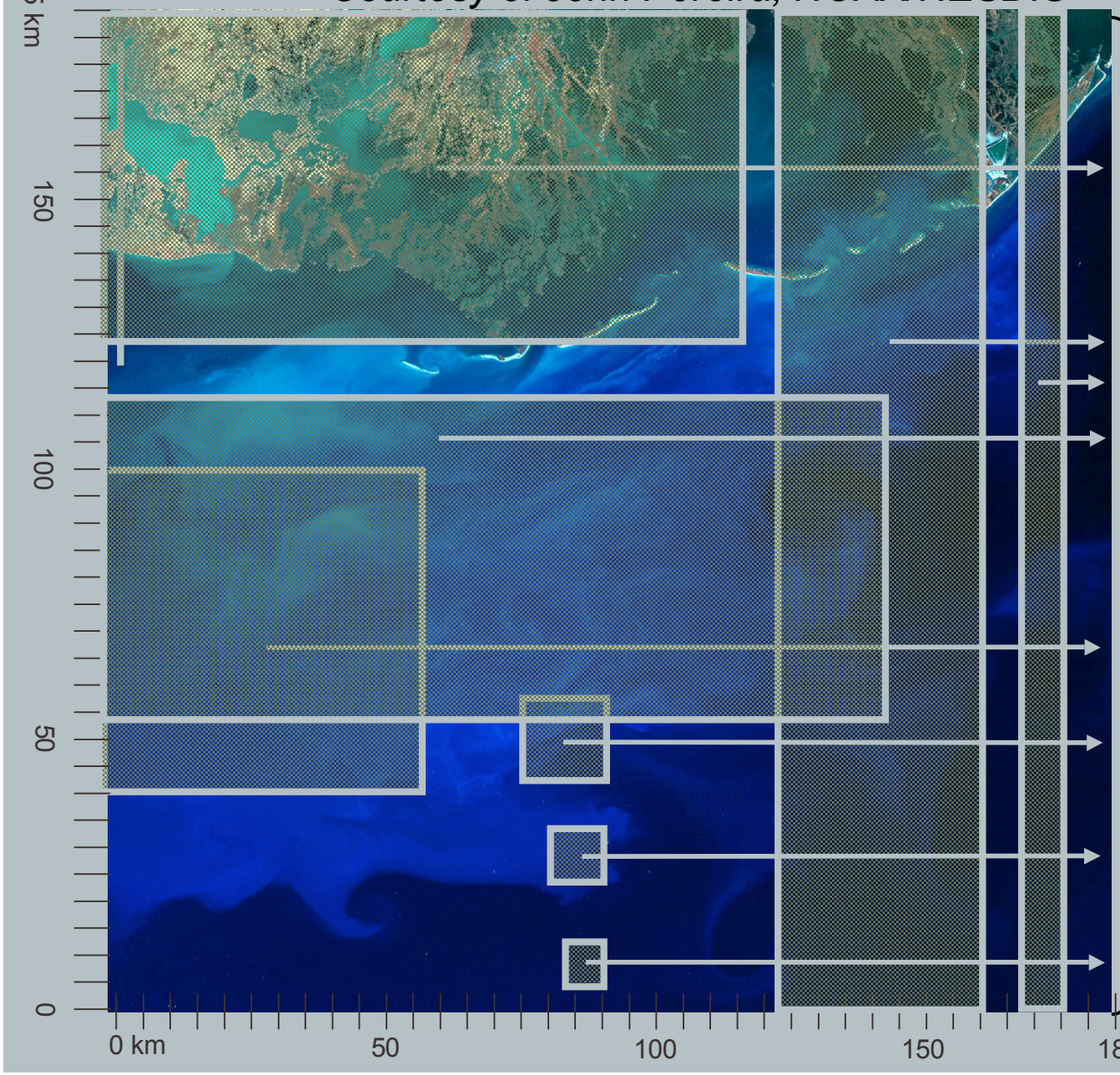


Image courtesy of Science Applications International Corporation

Spatial Coverage Comparisons

Courtesy of John Pereira, NOAA/NESDIS



SPOT
(10-m res.)

EO-1
-- ALI
-- Hyperion
(30-m res.)

RESOURCESAT
(23.5-m res.)

ETM+ (Landsat)
(30-m res.)

ASTER (Terra)
(up to 15-m res.)

QuickBird
(2.44-m res.)

IKONOS
(4-m res.)

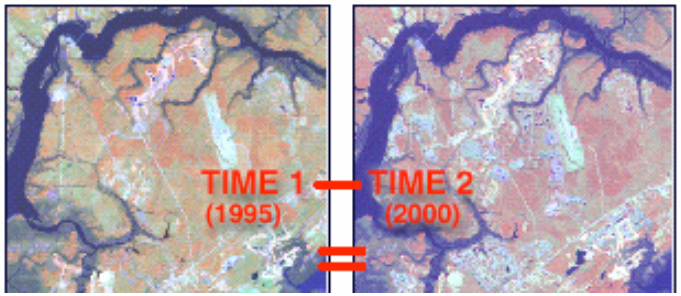
OrbView-3
(4-m res.)

Benthic Habitat Mapping

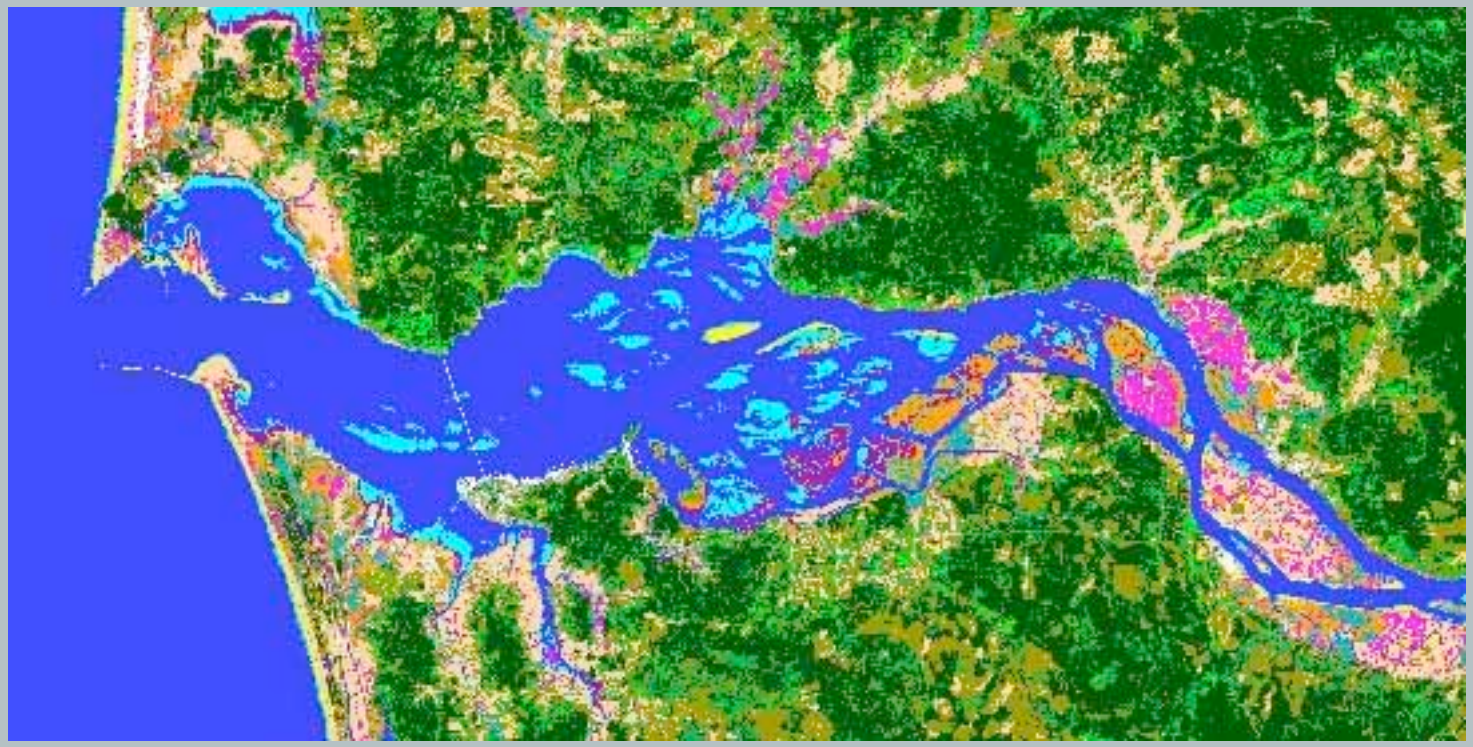
← Landsat image of the coral reefs off the Florida Keys.

Satellite image of nearshore coral reefs in the Philippines. →

Images courtesy of NASA



Land cover changes



Changes in land cover can significantly impact habitat, particularly for coastal fisheries. Satellite data is one of the most effective methods of monitoring land cover changes. These analyses need high resolution (<30 m) satellite data, most of which is commercial rather than government.

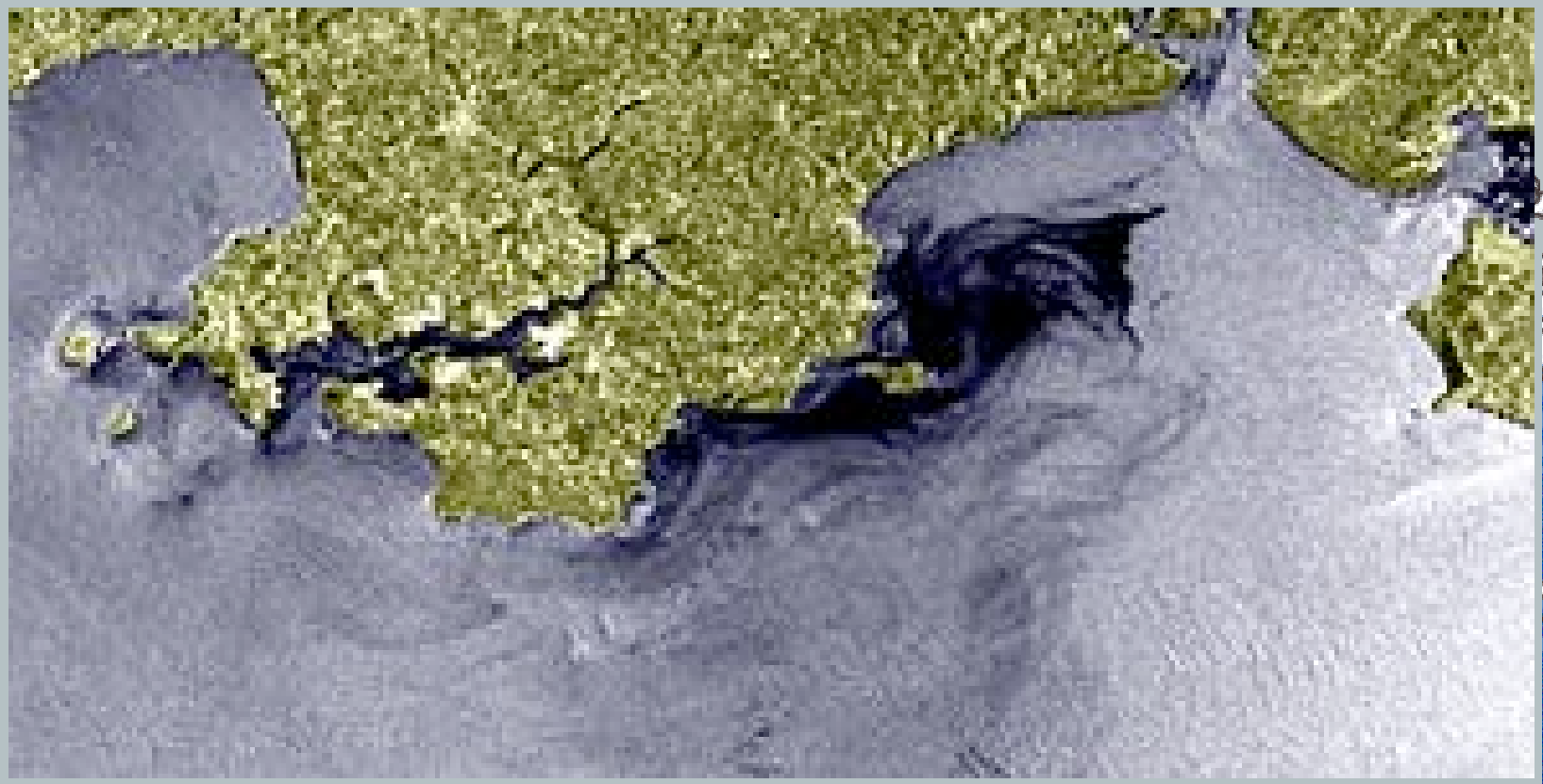
Oil Spill Detection and Monitoring

An oily sheen covers the surface of an intertidal habitat with aquatic plants following the *Exxon Valdez* oil spill. →

← Dead oiled sea otter.

Photos courtesy of the Exxon Valdez Oil Spill Trustee Council

Oil Spill Detection and Monitoring

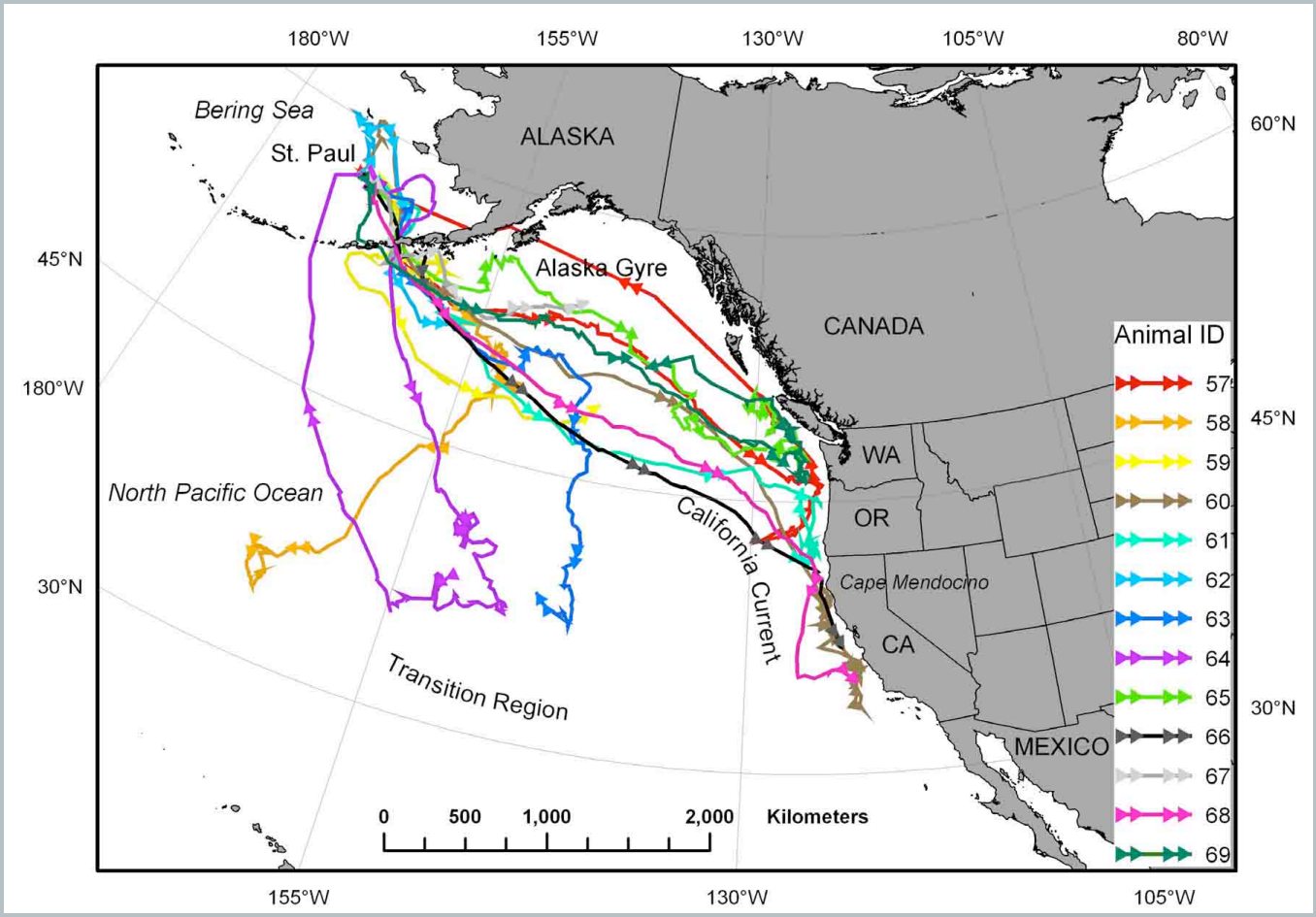


SAR (Synthetic Aperture Radar) image of an oil spill (black region) off of Wales in 1996.

Photo courtesy of Canada Natural Resources

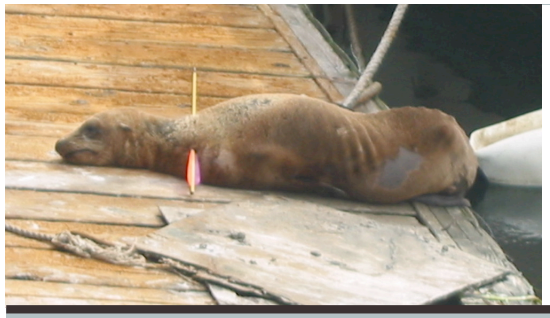
Telemetry of Tagged Living Marine Resources

Winter migration routes of 13 female northern fur seals



From Ream et al. DSR II, 2005

NOAA/NMFS/AFSC



Enforcement

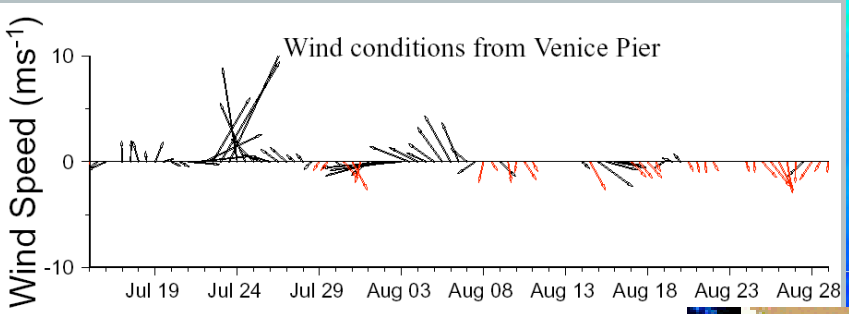
Satellite-based Vessel Monitoring System (VMS)

- Established in 1994
- In 2003 there were 1528 VMS systems in place
- Not every fishery uses VMS, but the list is growing
- SE: HMS Pelagic Longline Fishery and the S. Atlantic Rock Shrimp Fishery
- Alaska: Pollock, Pacific cod, and Atka mackerel (to protect Steller Sea Lion Habitat)
- NW: groundfish fishery

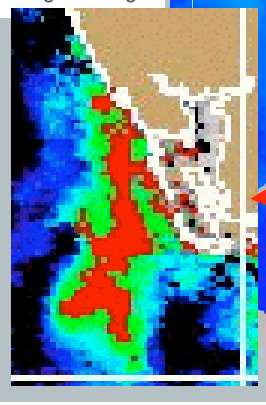
Harmful Algal Bloom (HAB) detection

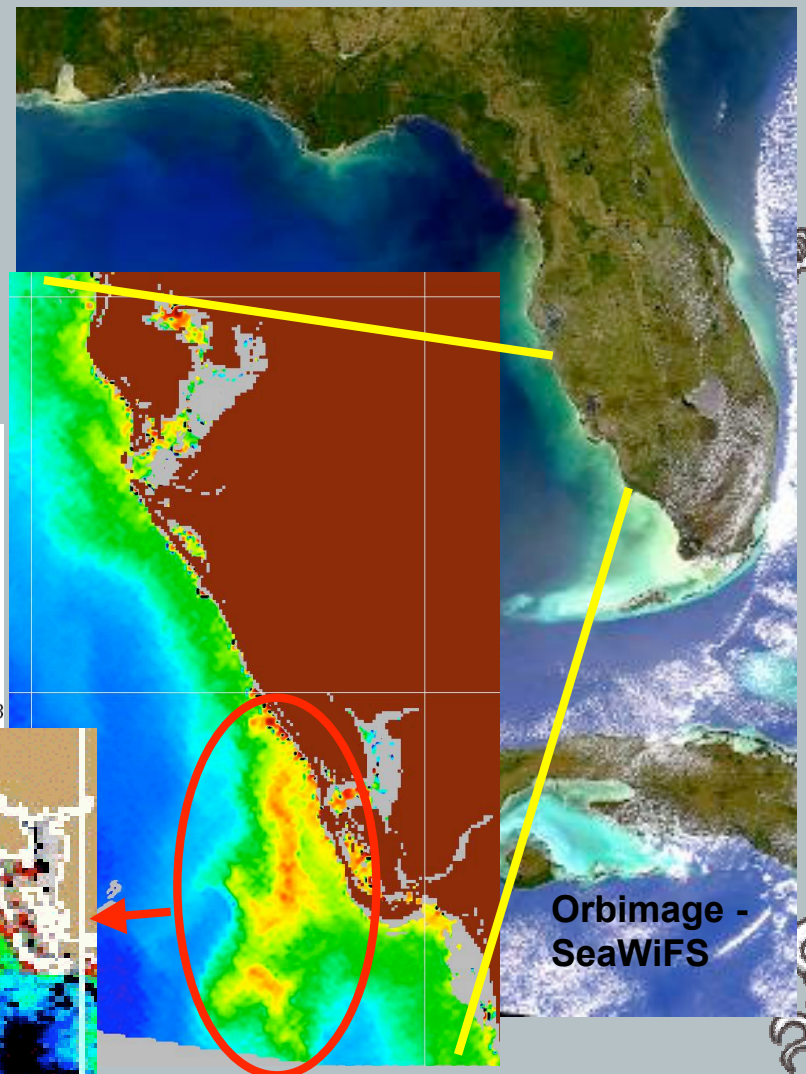
NOAA National Ocean Service

Operational Monitoring and Forecasting of HABs in the Gulf of Mexico



Courtesy of Rick Stumpf, NOS





Orbimage - SeaWiFS

Harmful Algal Bloom (HAB) detection

Distributed to Local/State/Federal Government

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:

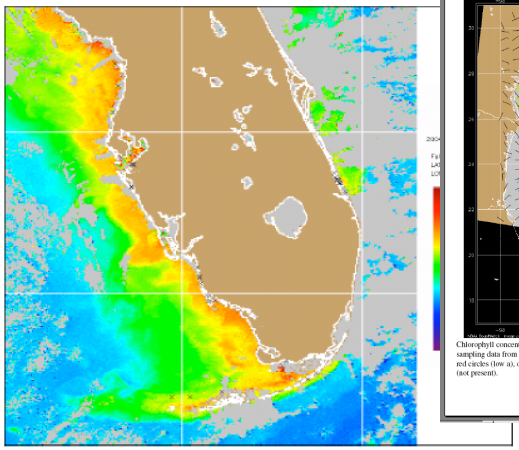
Samples taken last week from southwest Florida near Sarasota, Fort Meyers, and Naples showed no Karenia brevis. Imagery shows elevated chlorophyll along much of Florida's west coast: concentrations over 4 micrograms per liter off Cape San Blas and Cedar Key; over 5 micrograms per liter near Clearwater,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

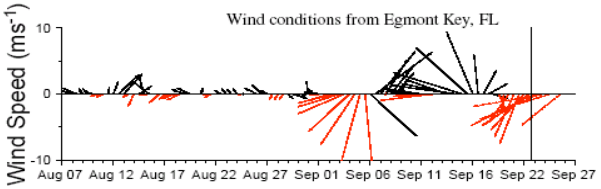
Bronder, Stolz

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.



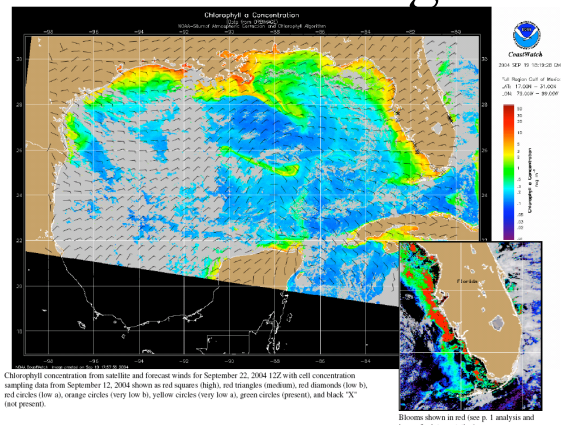
Chlorophyll concentration from satellite with possible HAB areas shown by red polygon(s). Cell concentration sampling data from September 12, 2004 shown as red squares (high), red triangles (medium), red diamonds (low b), red circles (low a), orange circles (very low b), yellow circles (very low a),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



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.

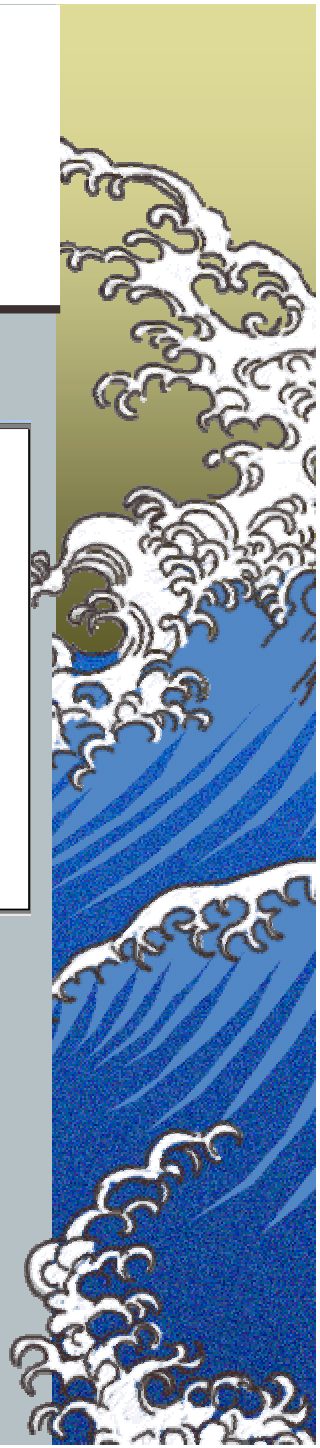
Page 2



Chlorophyll concentration from satellite and forecast winds for September 22, 2004 12Z with cell concentration sampling data from September 12, 2004 shown as red squares (high), red triangles (medium), red diamonds (low b), red circles (low a), orange circles (very low b), yellow circles (very low a), green circles (present), and black "X" (not present).

Blooms shown in red (see p. 1 analysis and image for interpretation)

Courtesy of Rick Stumpf, NOS

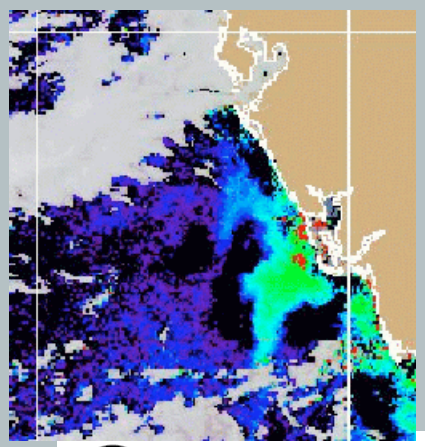


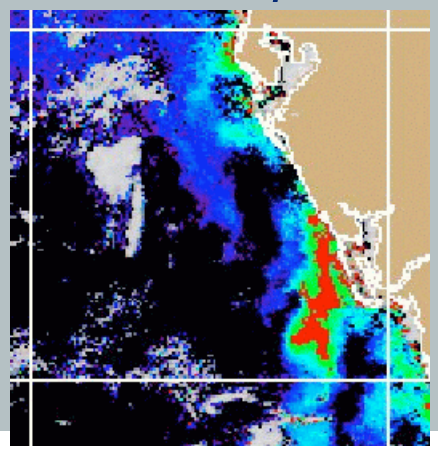
Harmful Algal Bloom (HAB) detection

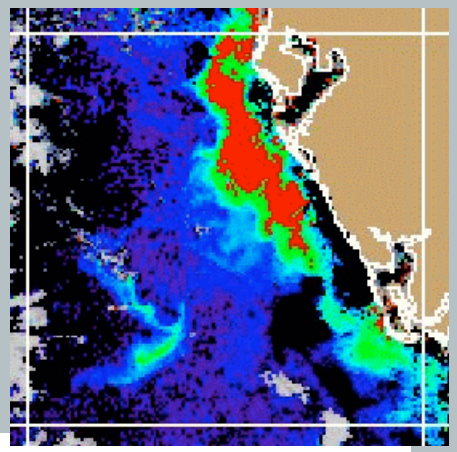
HAB initiation and intensification with upwelling

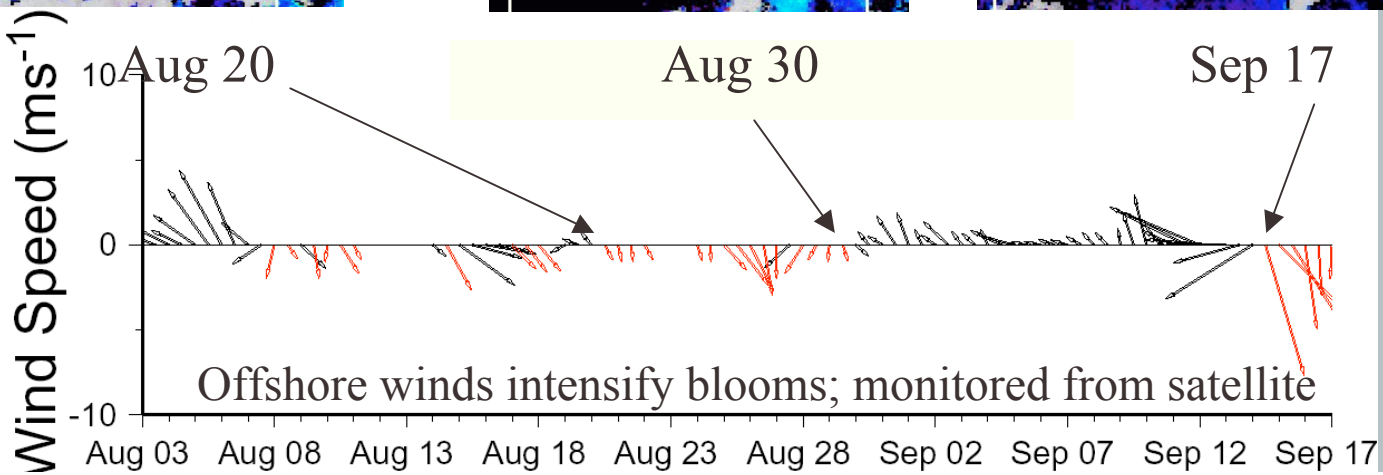
HAB-flags (Red is HAB, green is weaker HAB)

Courtesy of Rick Stumpf, NOAA NOS







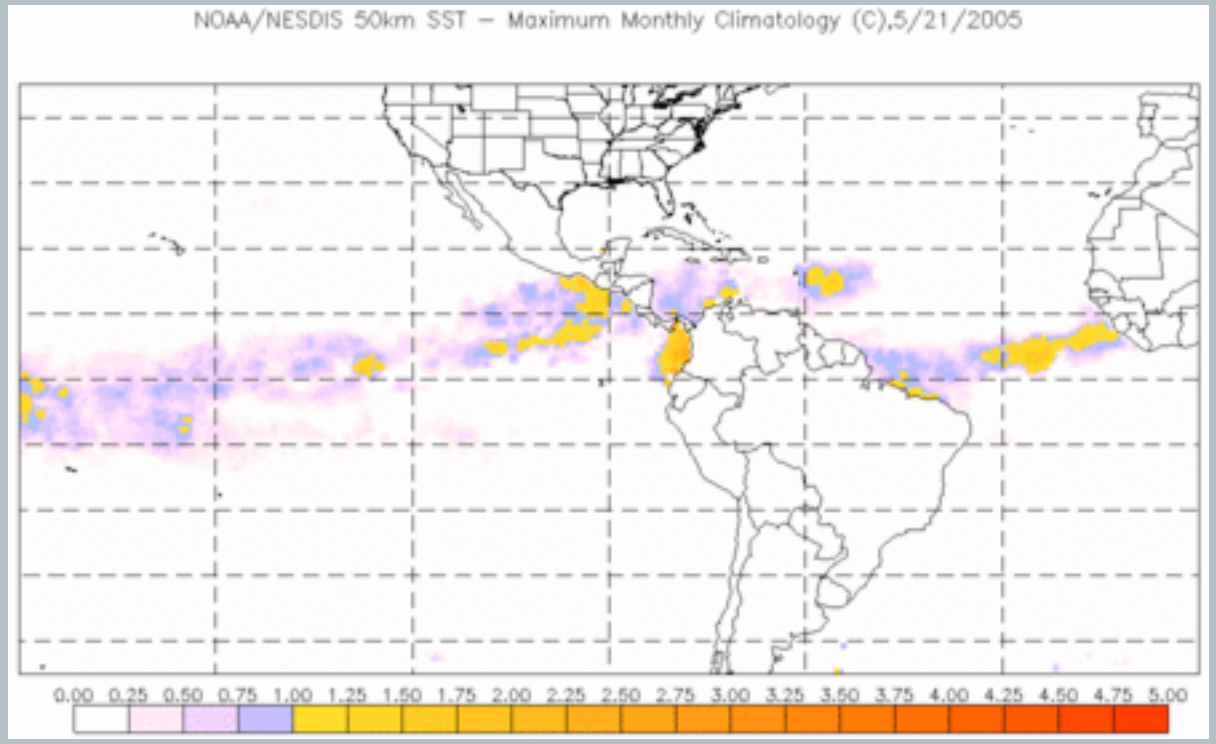


Coral Bleaching

NOAA's Coral Reef Watch Satellite Bleaching Alert became operational July 2005

Hot Spots

5/21-7/19 2005



http://coralreefwatch.noaa.gov

Optimize planning of fisheries research cruises

Ghostnet Program

Detection and tracking of marine debris in the North Pacific ocean using satellite and airborne remote sensing technologies

- Airborne Technologies Inc.
- NOAA Research/ETL
- NOAA Satellites and Information/ORA
- NOAA Fisheries/SWFSC/ERD (*Dave Foley*)

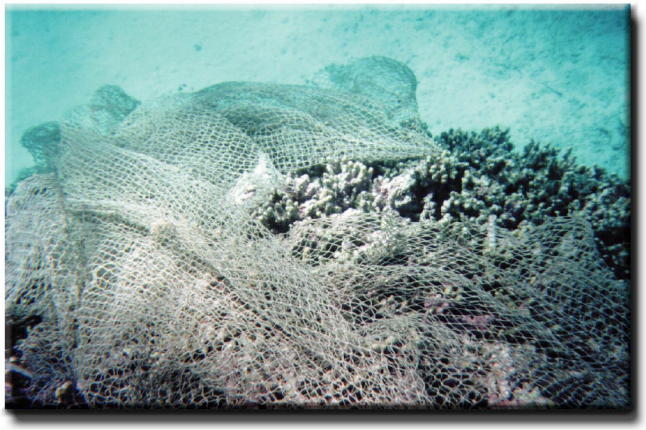
Ghostnet Program - Rationale

Minimize navigation hazards

Reduce wasteful “Ghost fishing”

Endangered Hawaiian Monk seal trapped in marine debris

Protect endangered species



Derelict fishing net anchored on coral

Maintain healthy coral reef ecosystems

Ghostnet Approach

Satellite data to identify convergence zones

- Infer with Ocean Color, SST, vector winds
- Observe with specially tasked SAR

Aircraft to confirm presence of debris

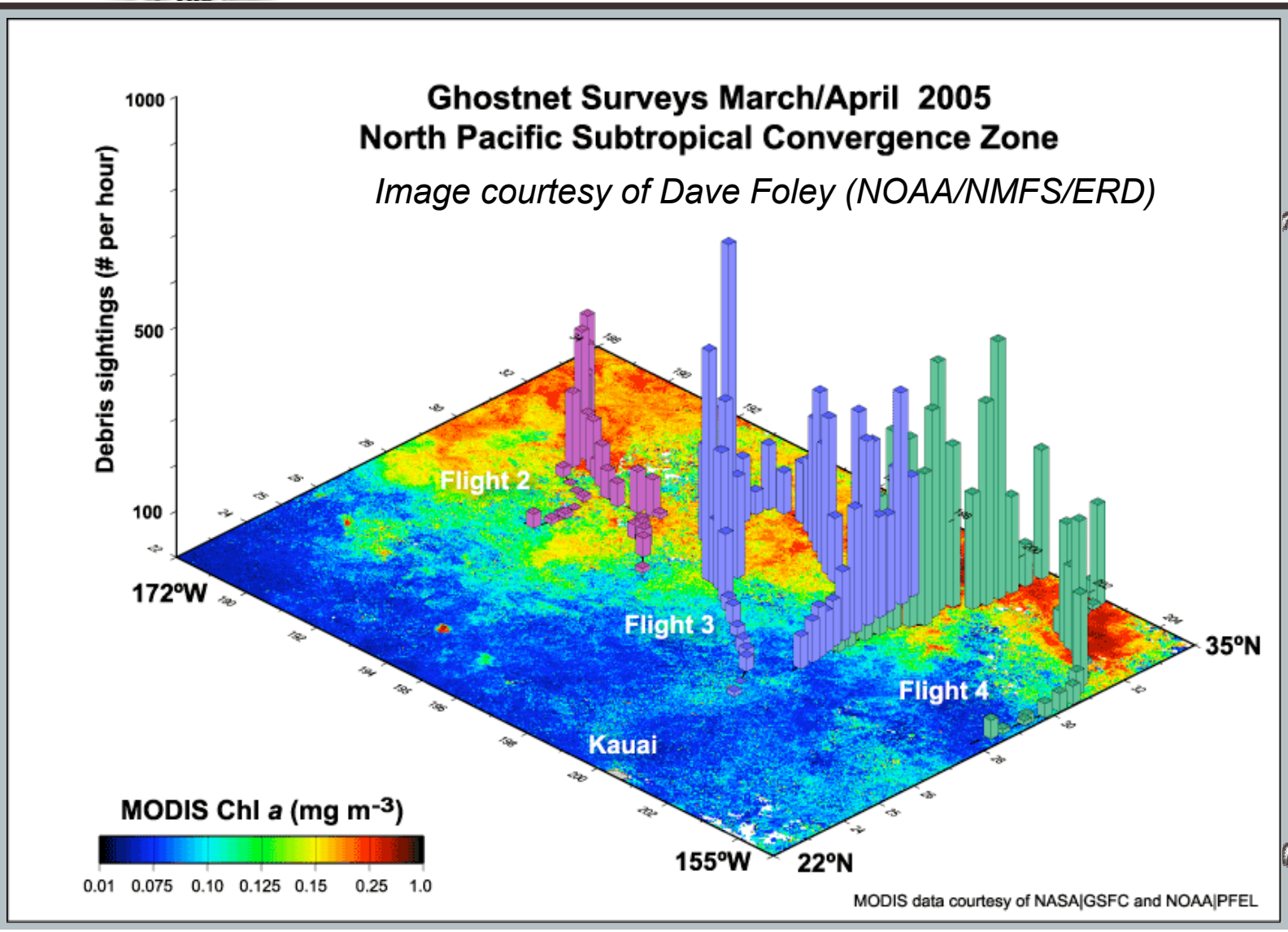
- Designating “hot spots”
- Deploy drifting buoys to track debris fields*

Interdiction with ships already on station*

- Possible use of helicopter to optimize collection

* Planned for FY06

Ghostnet Preliminary Results



Ghostnet Preliminary Results

Debris Density based on Observer Sightings per unit effort, and satellite-derived meaures of SST, Chl a, and Chl a Gradient

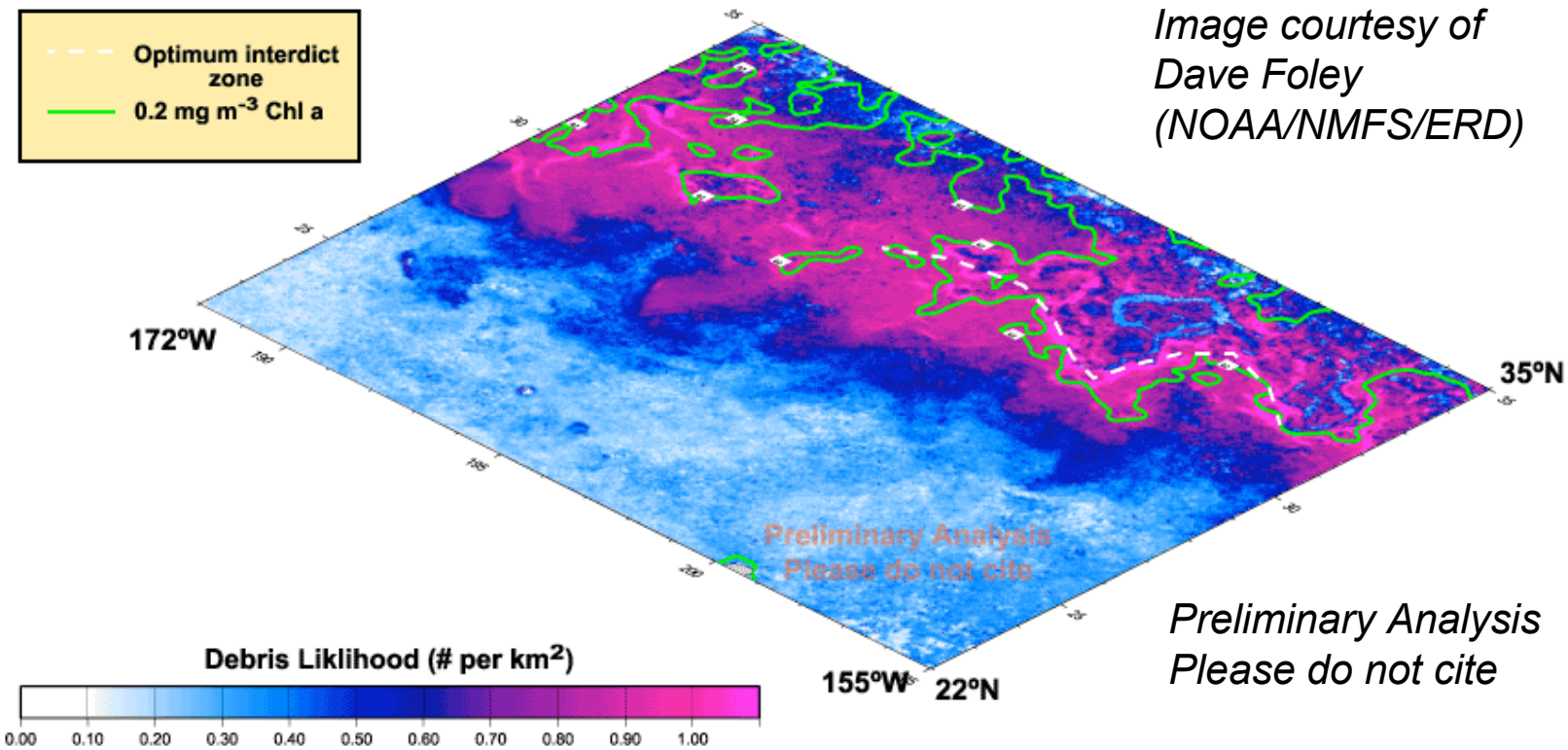
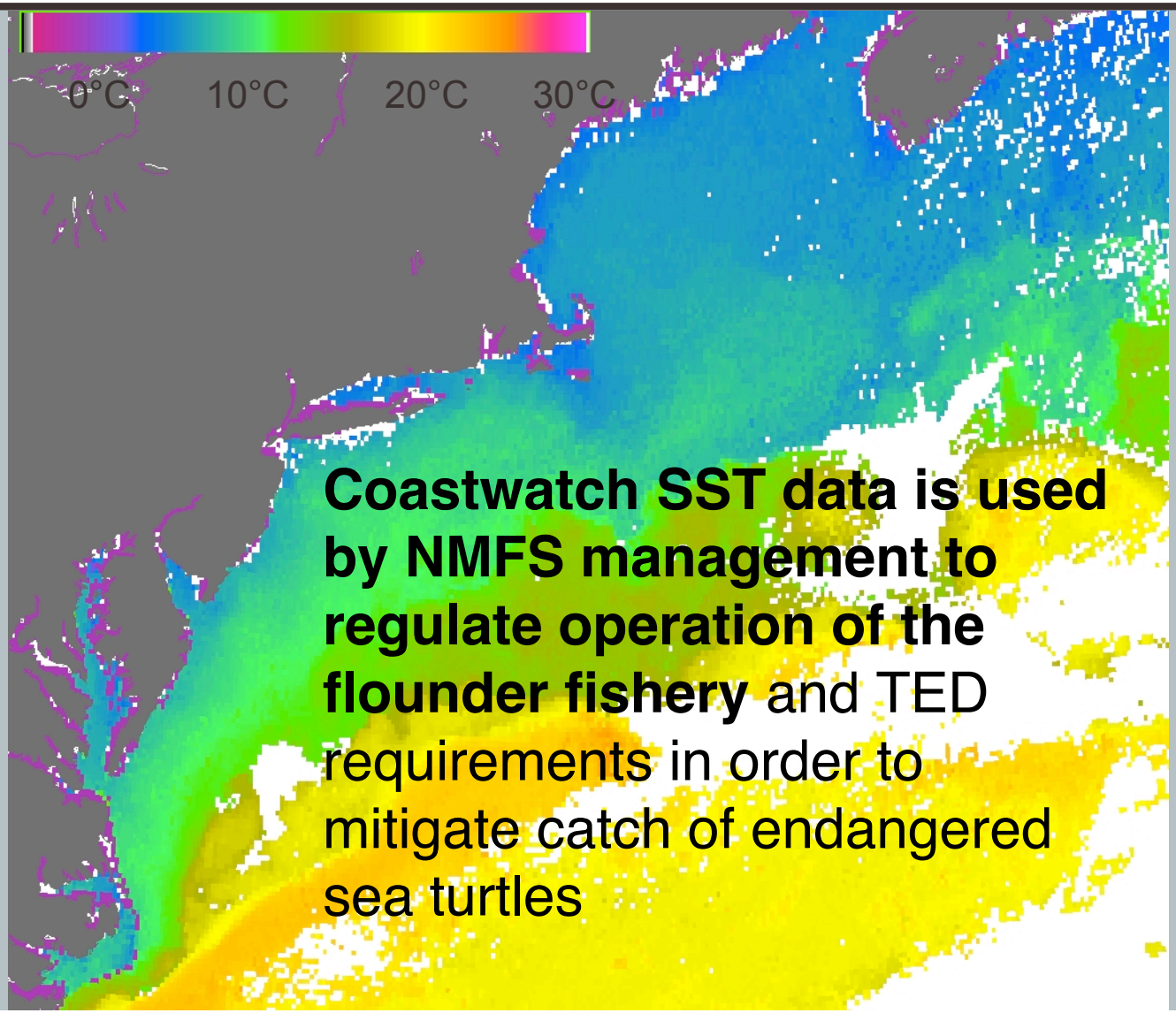


Image courtesy of Dave Foley (NOAA/NMFS/ERD)

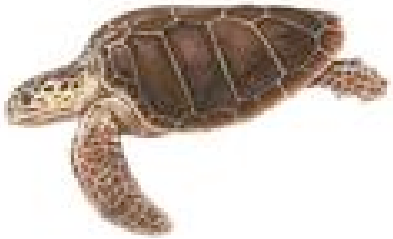
Preliminary Analysis
Please do not cite

NOAA/SWFSC/ERD

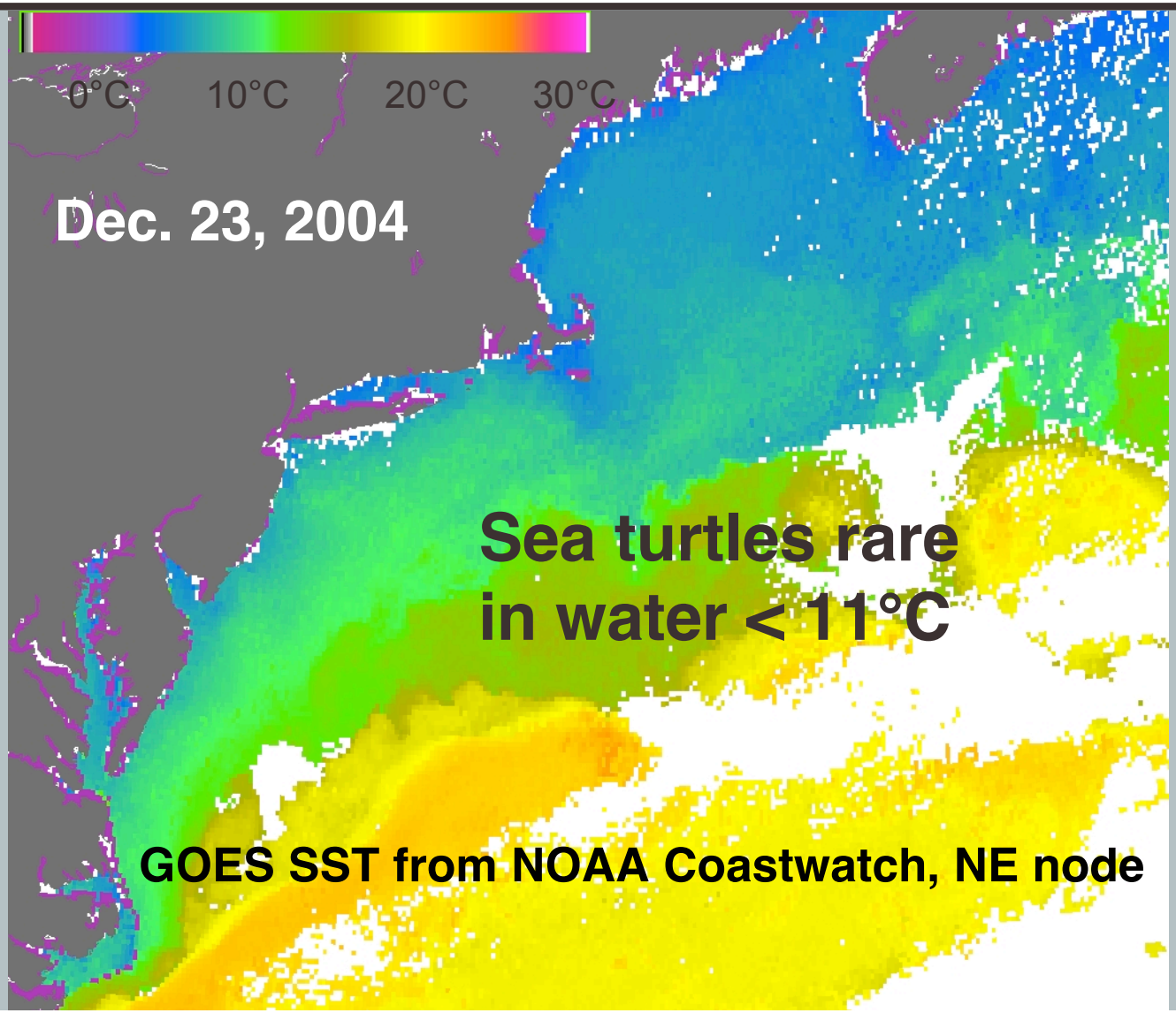
Policy & Regulation



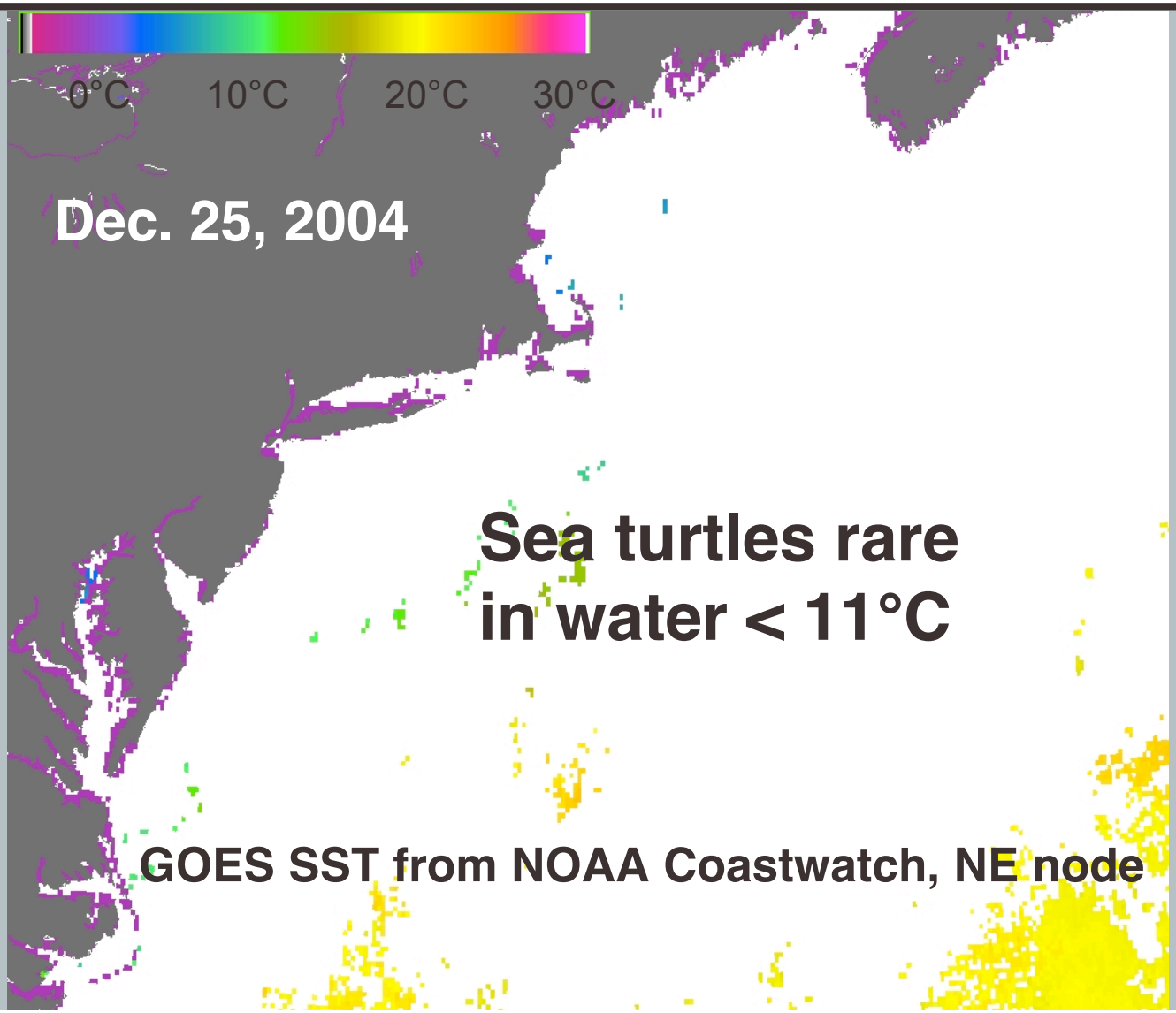
Coastwatch SST data is used by NMFS management to regulate operation of the flounder fishery and TED requirements in order to mitigate catch of endangered sea turtles



Policy & Regulation



Policy & Regulation

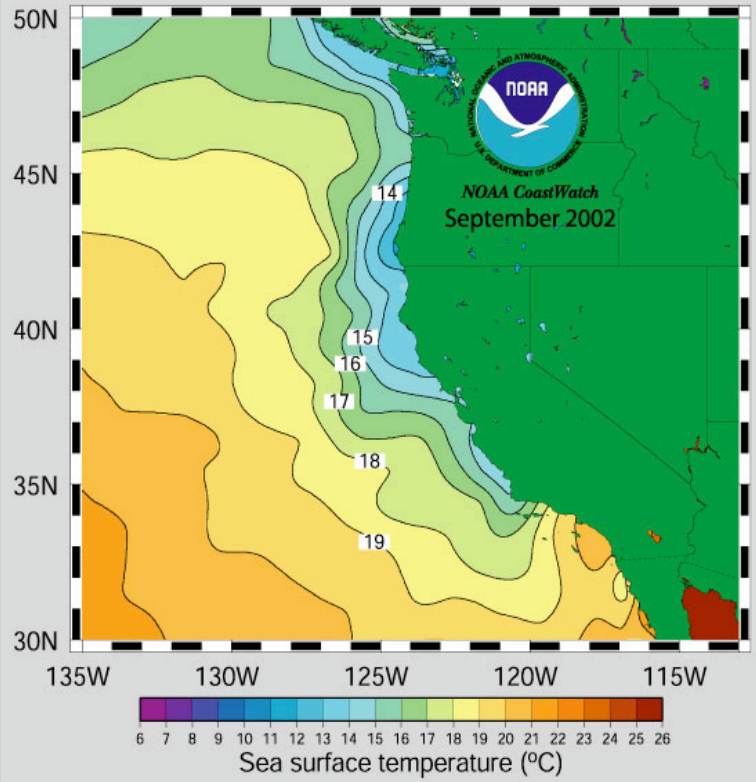


El Niño Watch

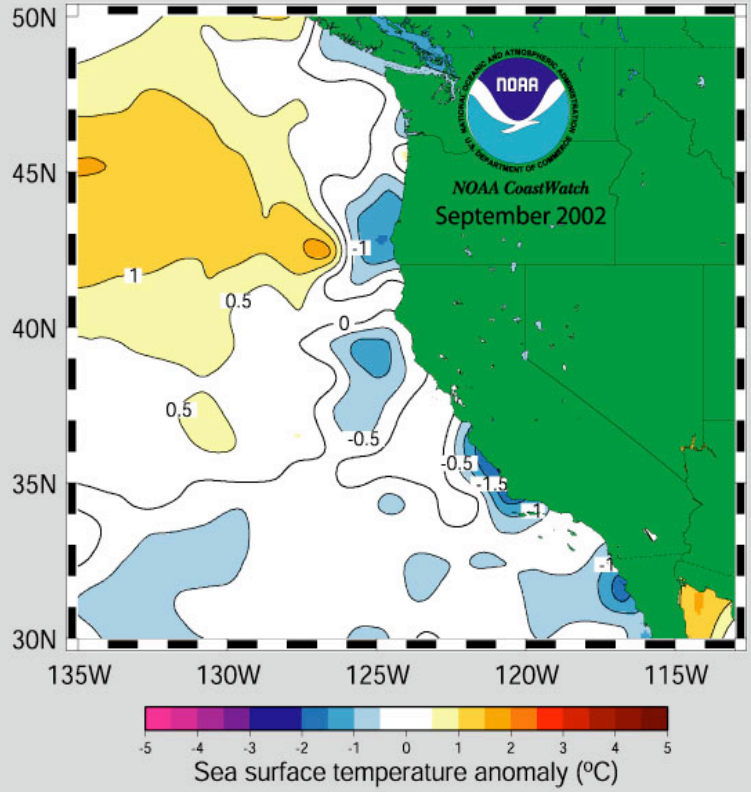
- Maintained by NOAA's west coast CoastWatch node
- Special SST data product prepared for NMFS SWR fishery managers, mandated for use in managing California fishery for large pelagic fishes
- First use of satellite data in management of West Coast Fisheries
- Generated monthly
- Complementary images of Chlorophyll and Wind Stress Curl now provided

El Niño Watch

SST



SST Anomaly



LMR strandings and mortalities

The Asahi, Feb 8, 2005

2005-2-8

朝日新聞

シャチ12頭、流氷で動けず

7日午前8時ごろ、北海道羅臼町役場に、知床半島の先端部近くの根室海峡に面した相泊漁港付近で、流氷に挟まれて動けないシャチがいると連絡が入った。職員が確認したところ、シャチ12頭が岸壁近くで流氷に挟まれていた＝写真、山中正実さん撮影。役場職員らが救出を試みたが、作業は難航、同日中の救出はできなかった。数頭はすでに死んだとみられる。

知床半島

同町環境課によると、シャチは体長6～8㍍のオス1頭、4～6㍍のメスとみられる6頭、1～3㍍の子どもが5頭。

シャチの尾びれにロープをかけて、8人くらいで引っ張ったが、びくともしなかったという。

羅臼海上保安署では「流氷は今朝、相泊に着岸した。流氷に追われて閉じこめられたのでは。非常に珍しい」と話している。

対処力優れるが

加藤秀弘・遠洋水産研究所鯨類生態研究室長の話

シャチは赤道直下から流氷帯までに生息し、環境への対処に優れており、氷に閉じこめられるのは非常に珍しい。この海域を頻繁に回遊している群れだとすると、氷の状況も熟知しているはず。急激に氷が動いたなど、環境に大きな変化があったのではないか。

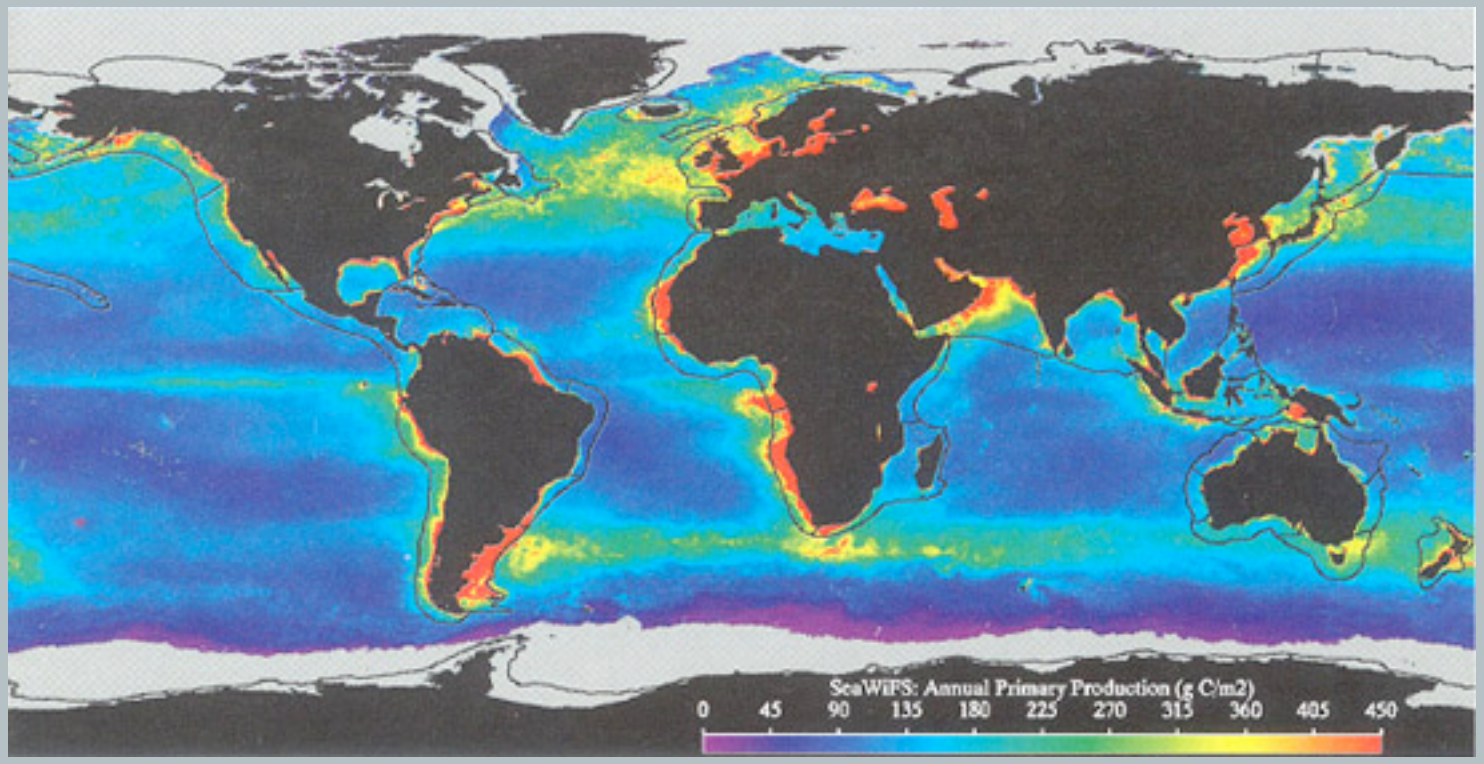
Images courtesy of Bob Brownell, NOAA/NMFS/SWFSC

Pelagic Habitat Assessment

- Typically a suite of satellite data, i.e. SSH, SST, ocean color, and wind data, is used synergistically to characterize LMR habitat.

- Marine ecosystems encompass vast areas of the ocean, both coastal and pelagic. The high temporal and spatial resolution of satellite data, as well as its continuity, makes satellite data a crucial component of monitoring and characterizing marine ecosystems.

Large Marine Ecosystems

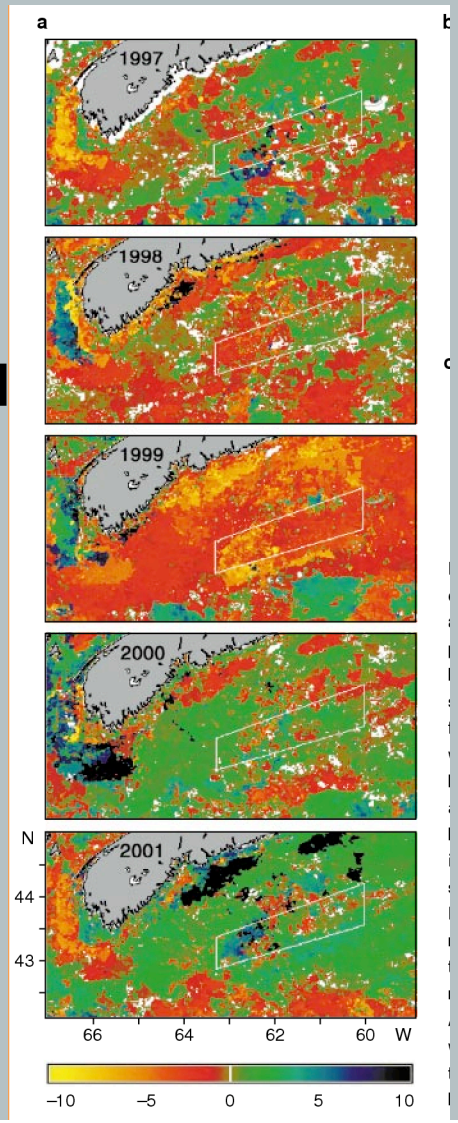


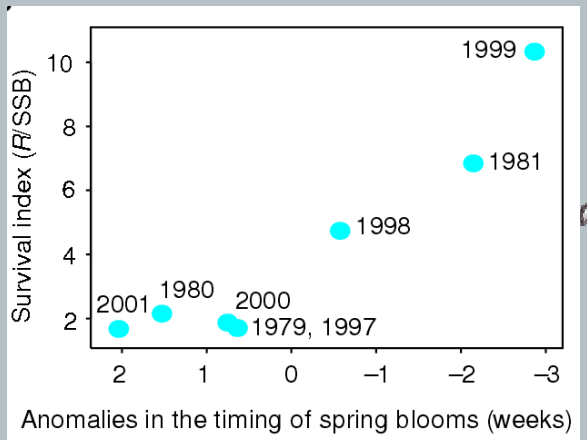
Average satellite-derived Primary Productivity and the outlines of the 64 defined Large Marine Ecosystems (LMEs)

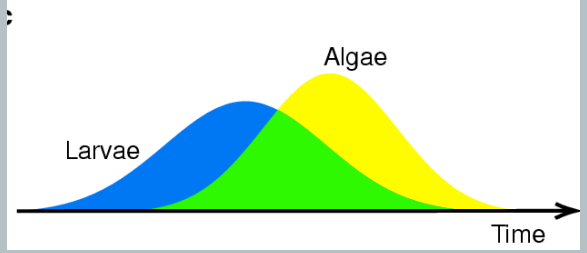
www.wdc.uri.edu/lme

Timing of the Spring bloom and Haddock Survival

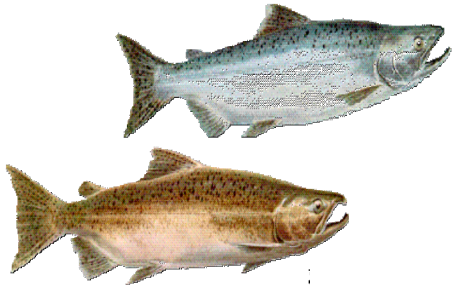
Contours of the annual anomaly in the timing of the spring bloom based on SeaWiFS chlorophyll data



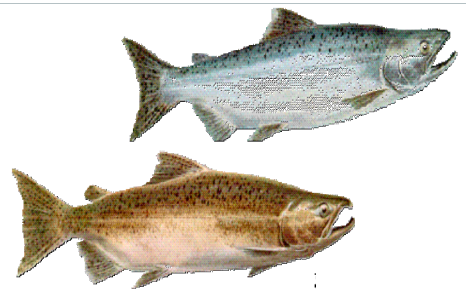




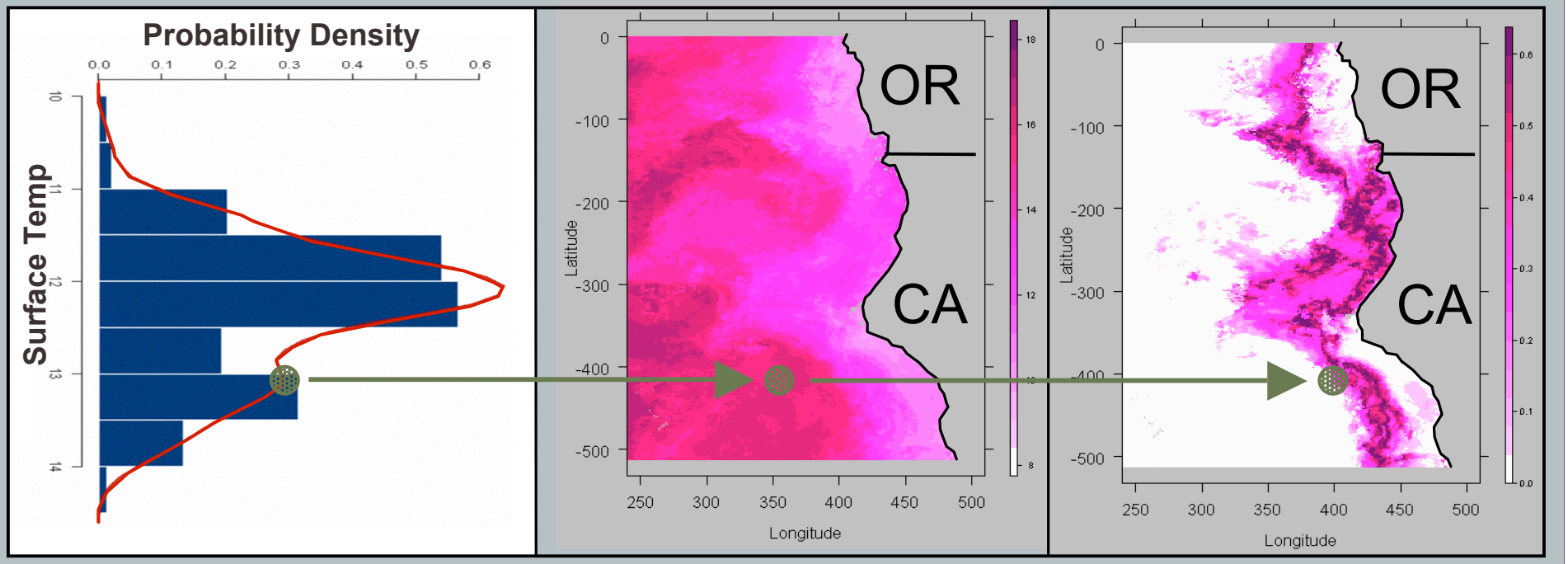
From Platt et al., Nature, 2003



Defining Salmon Ocean Habitat



Chinook Potential Habitat



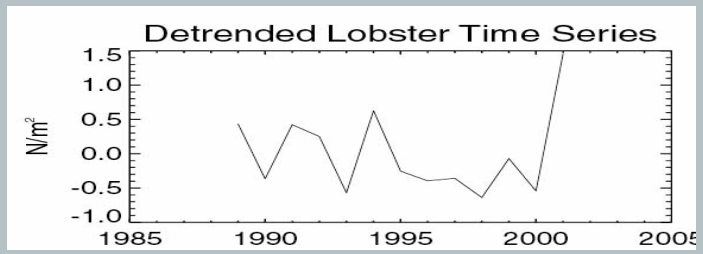
Density of fish's temperature experience at the surface from tag data

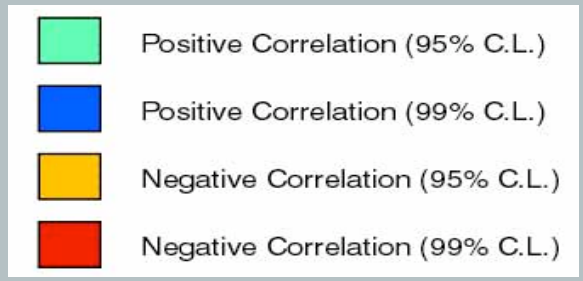
Satellite SST

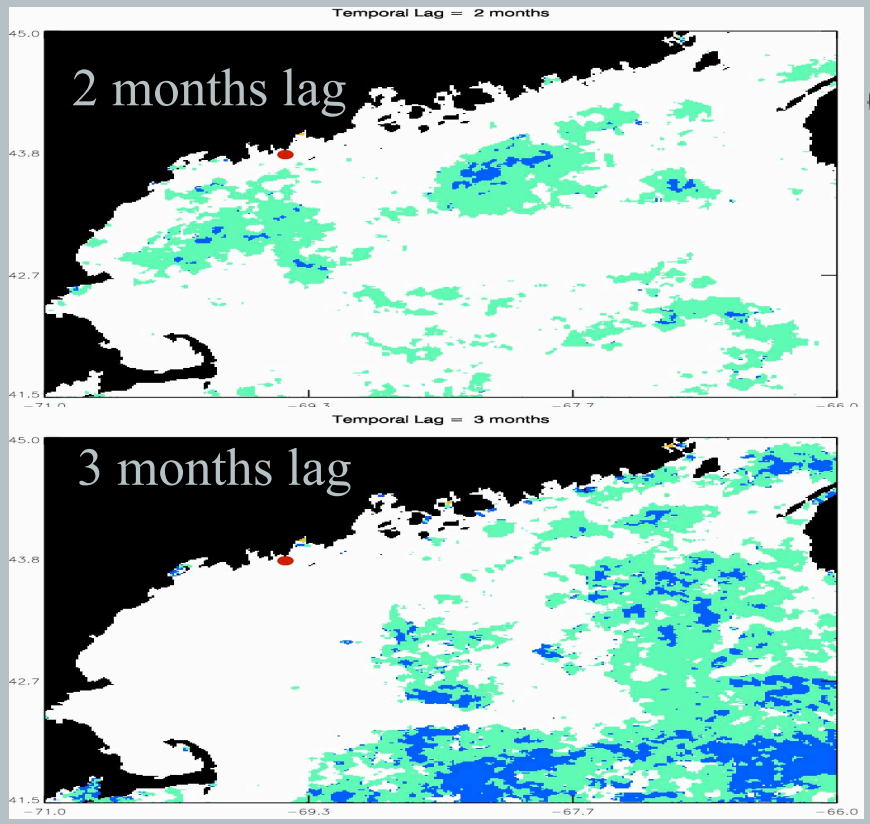
"Contours of utilization" – likely fish location

Lobster Larvae Study

September lobster # *vs* *prior* SST)







Data from A. Thomas, a NOAA/NESDIS funded project

THE UNIVERSITY OF MAINE

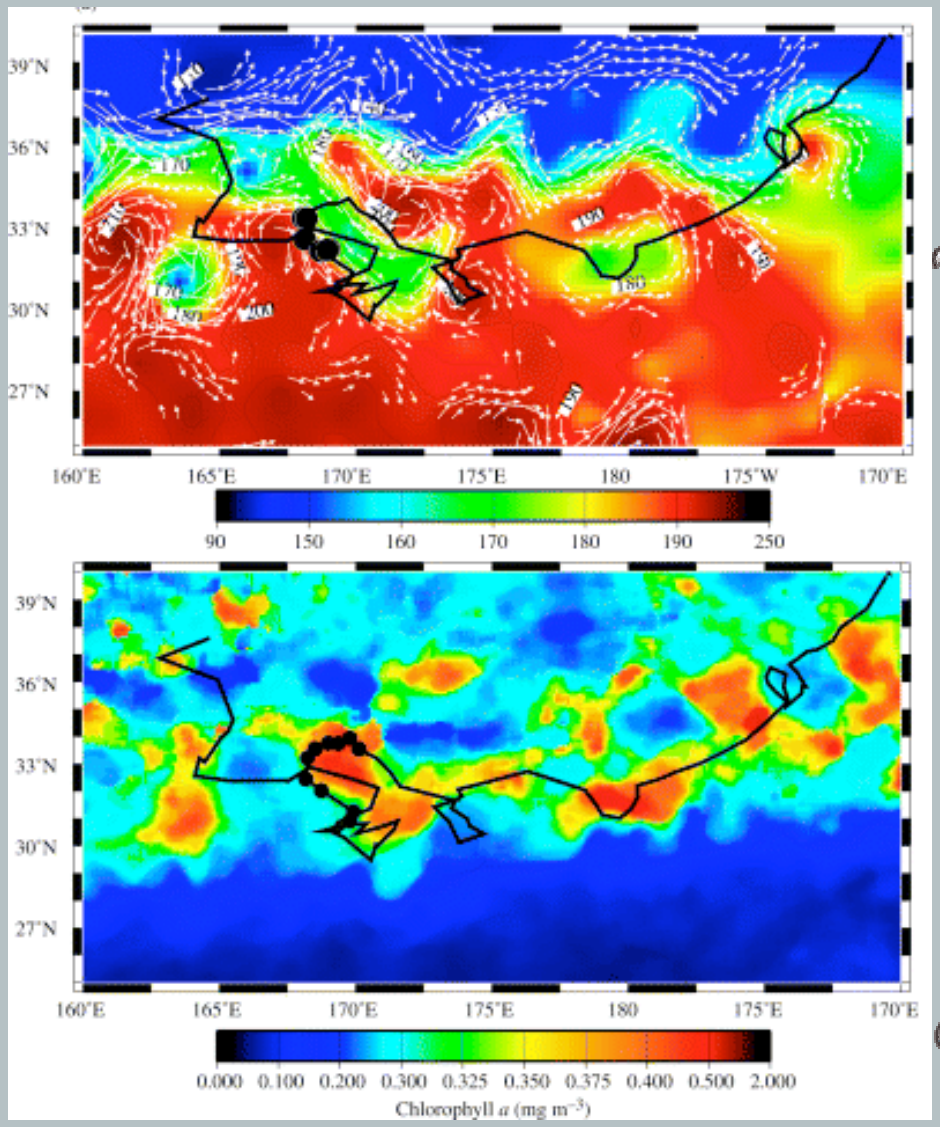
Characterizing Turtle Habitat

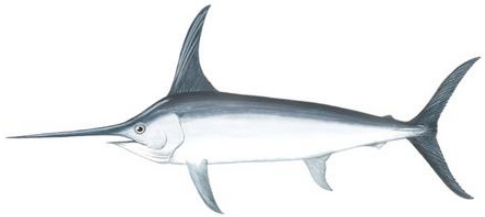
SSH

Loggerhead turtle tracks along the TZCF (Transitional Zone Chlorophyll Front) in the North Pacific during Feb. 2001

Chlorophyll

Polovina et al., Fish. Ocean., 2004
NOAA/NMFS/PIFSC

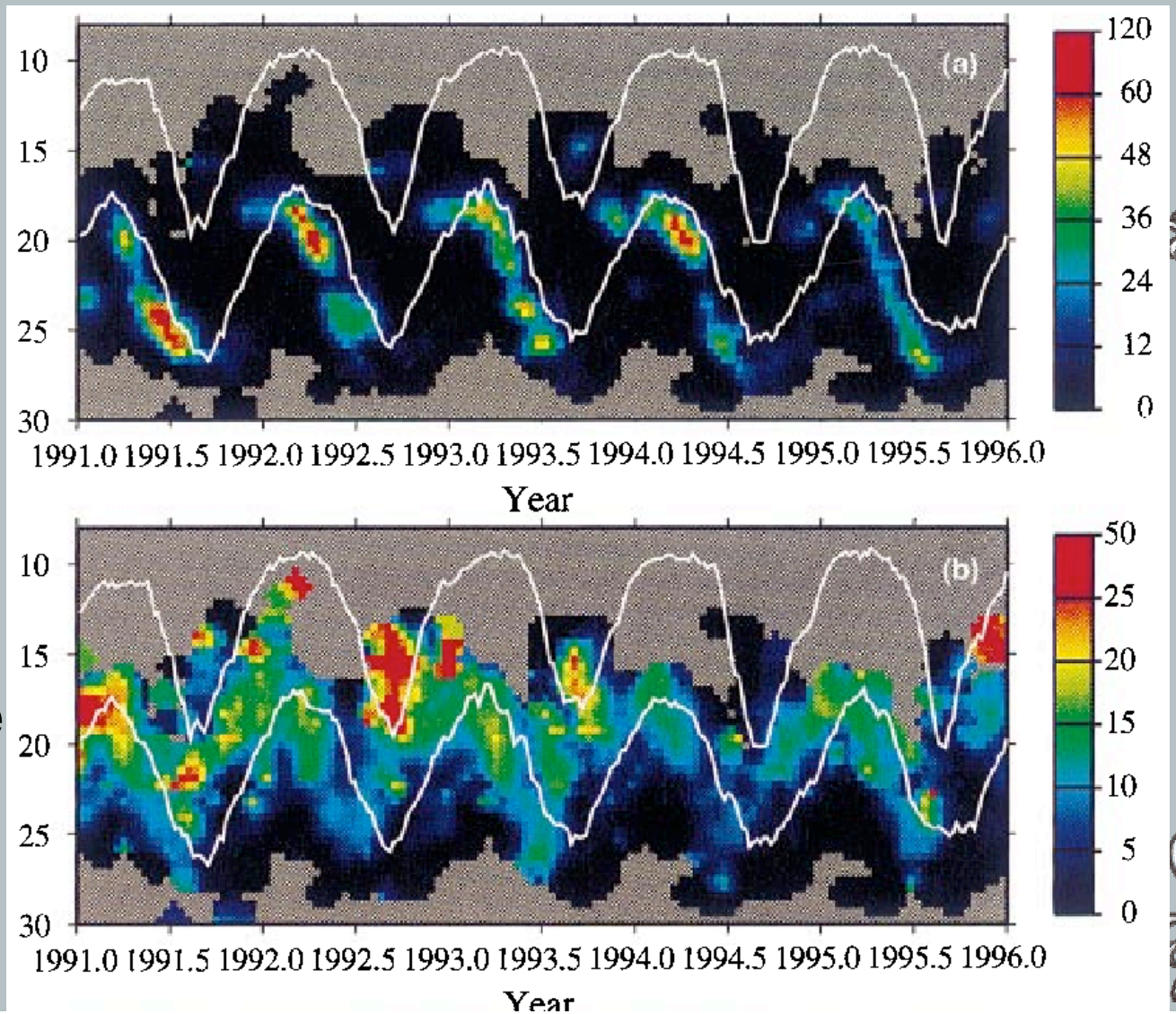




SST & Swordfish Catch

Effort

Catch rate

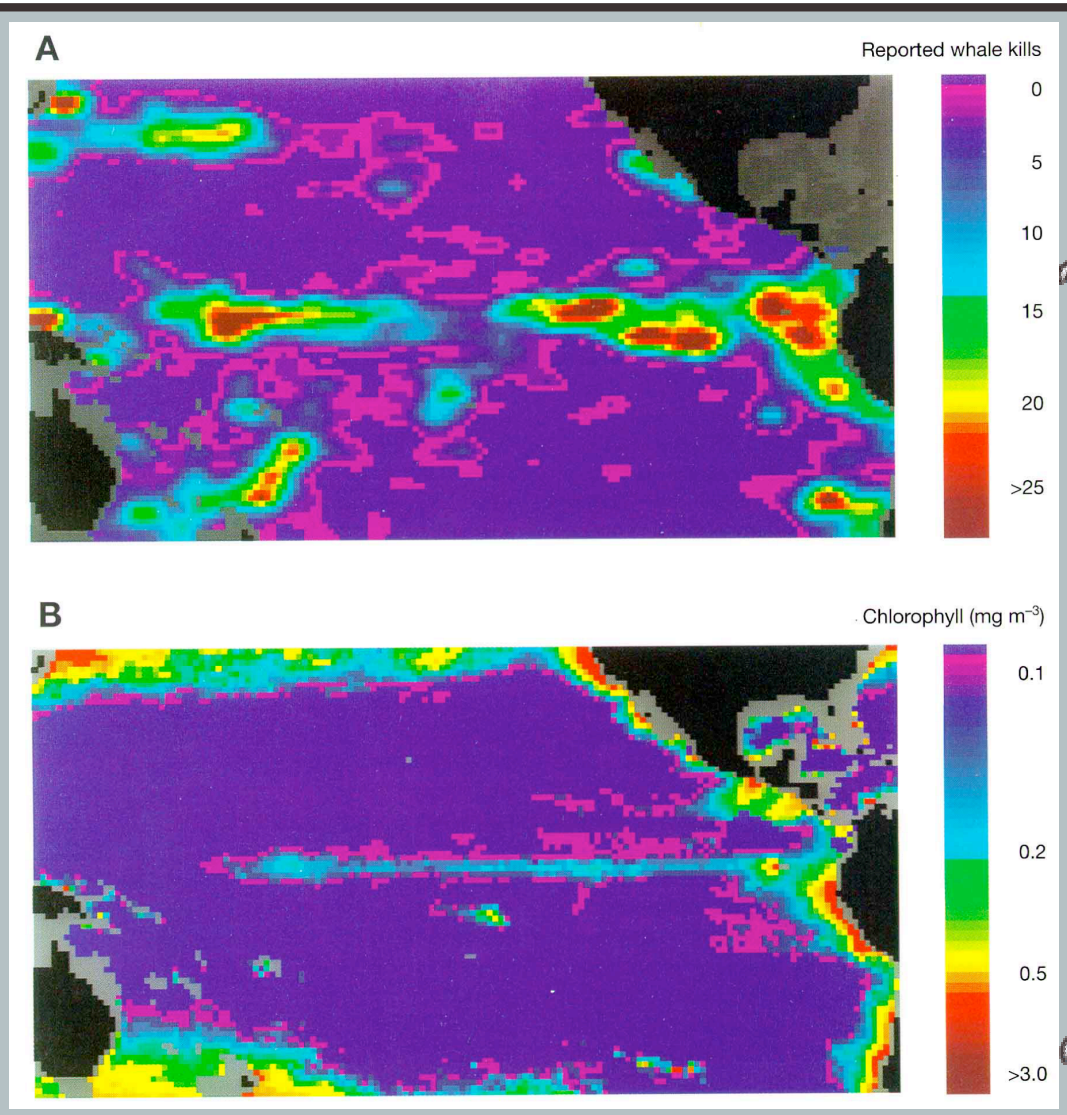


Bigelow et al., Fish. Ocean., '99 NMFS/PIFSC

Sperm Whale distribution

Historical whale kill distribution

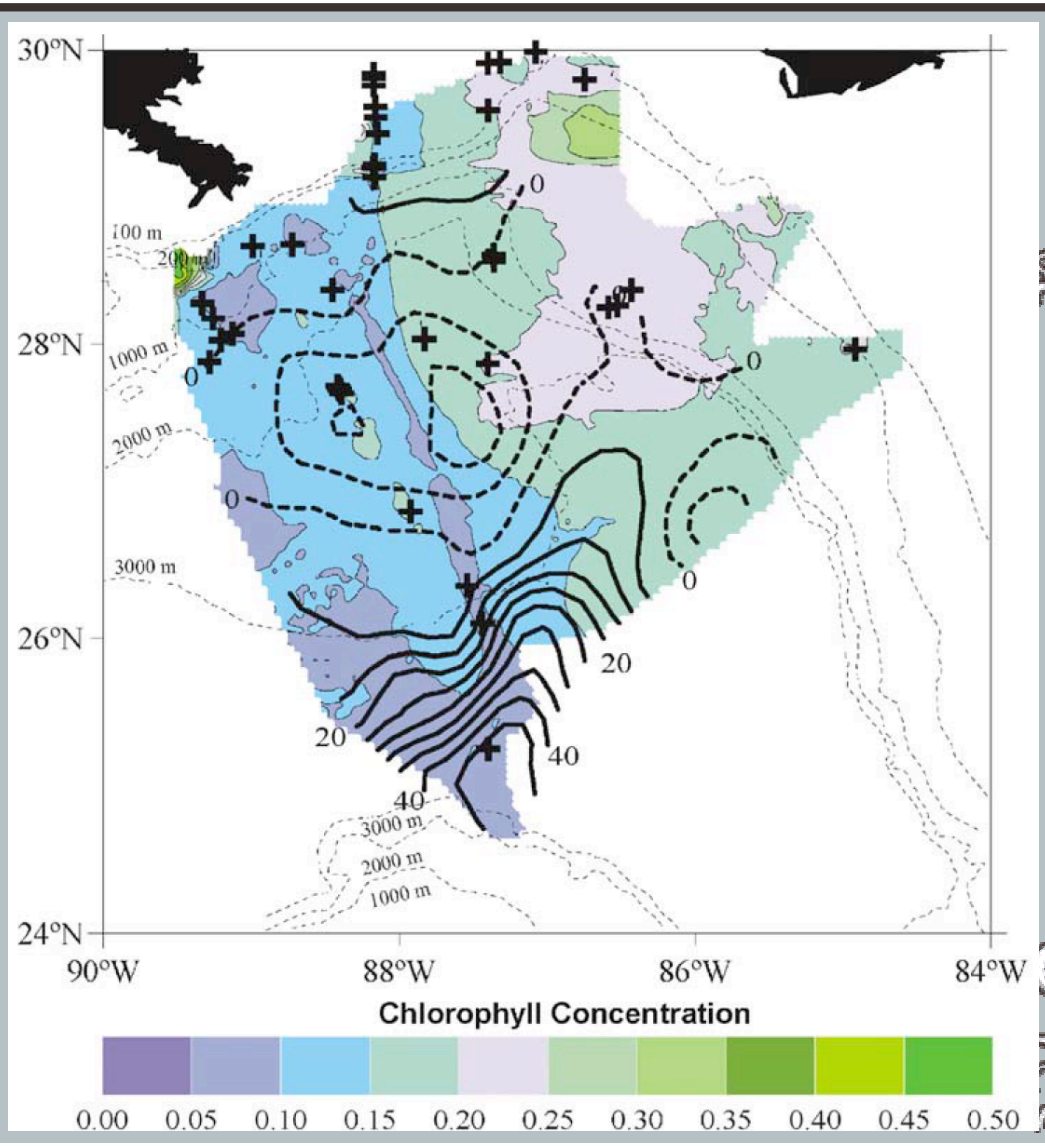
Climatological CZCS chlorophyll



Jaquet et al., MEPS 1996

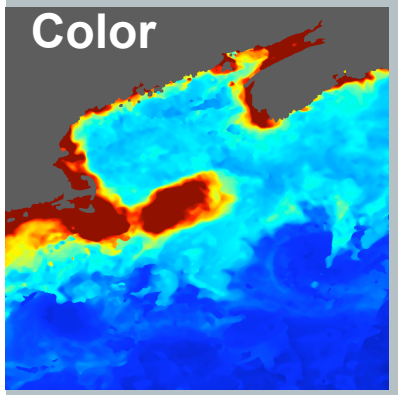
Sperm Whale distribution

Whale sightings (+) overlaid on surface chl (colors) and SSH anomaly (contours) in the Gulf of Mexico



Davis et al., DSR I, 2002

Right Whale Forecast



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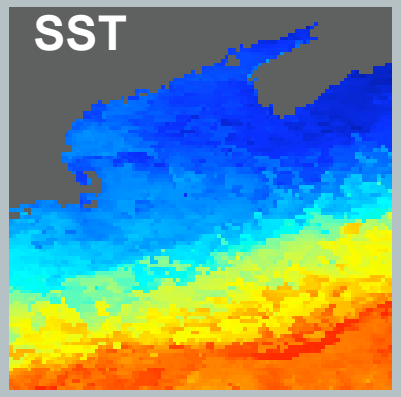

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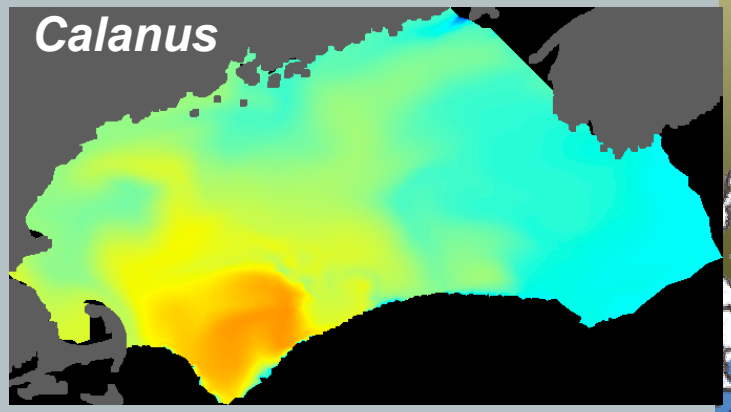

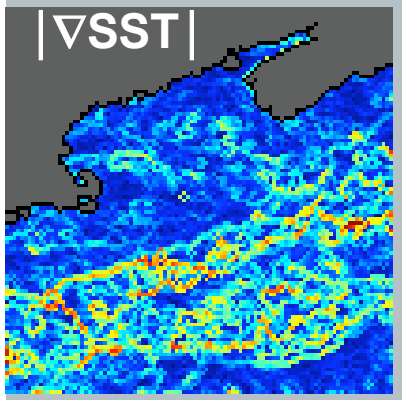

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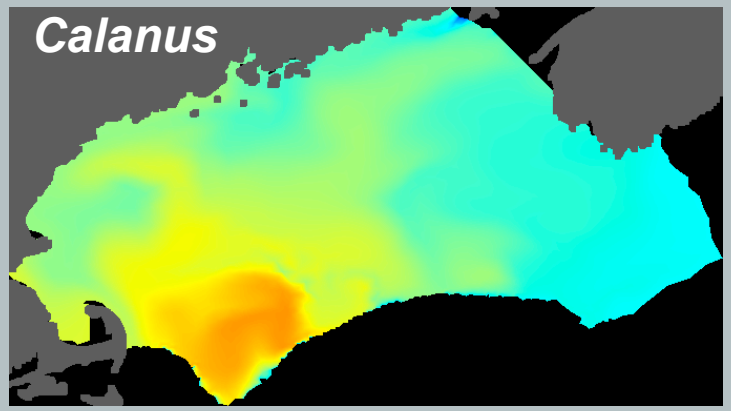

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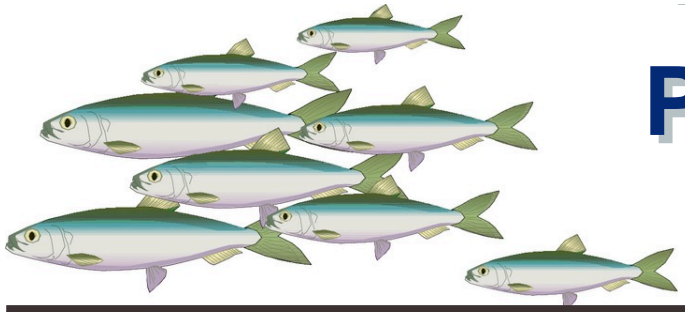
Whale feeding areas

Pershing and Monger, Cornell University
www.geo.cornell.edu/whales
Funded by NOAA's Right Whale Grants Program

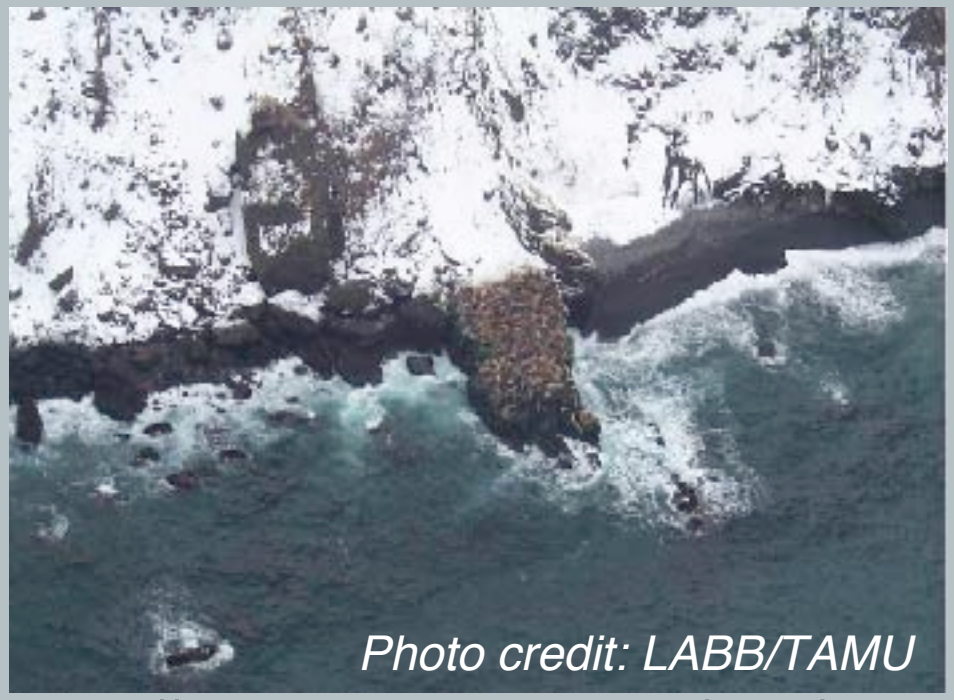


Population Analysis of LMRs

- Is satellite data currently being used in stock assessments or recovery plans of LMRs?
- Is VMS data being used to assess stock distributions?

Population Analysis of LMRs

Aerial photo of Steller sea lions hauled out at Billingshead, March 1999



http://www.tamug.tamu.edu/labb/

The only satellite data with enough resolution to do population analysis is classified military data. Getting access to this data is difficult to impossible.

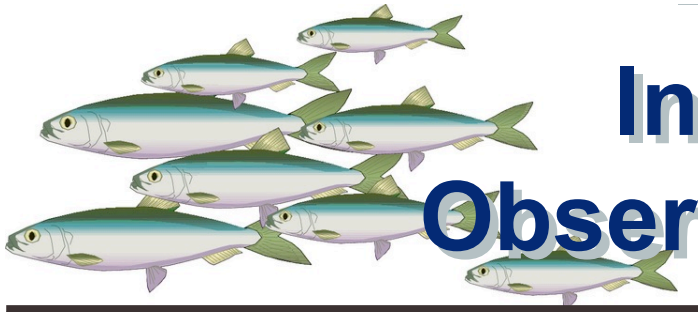
Whales from Space?

whale is 3-pixel gray smudge….

IKONOS satellite image of Shamu's tank at Sea World

Aerial photo of Shamu's tank at Sea World

From http://www.abileah.com/DigitalOcean/DigitalOcean.html



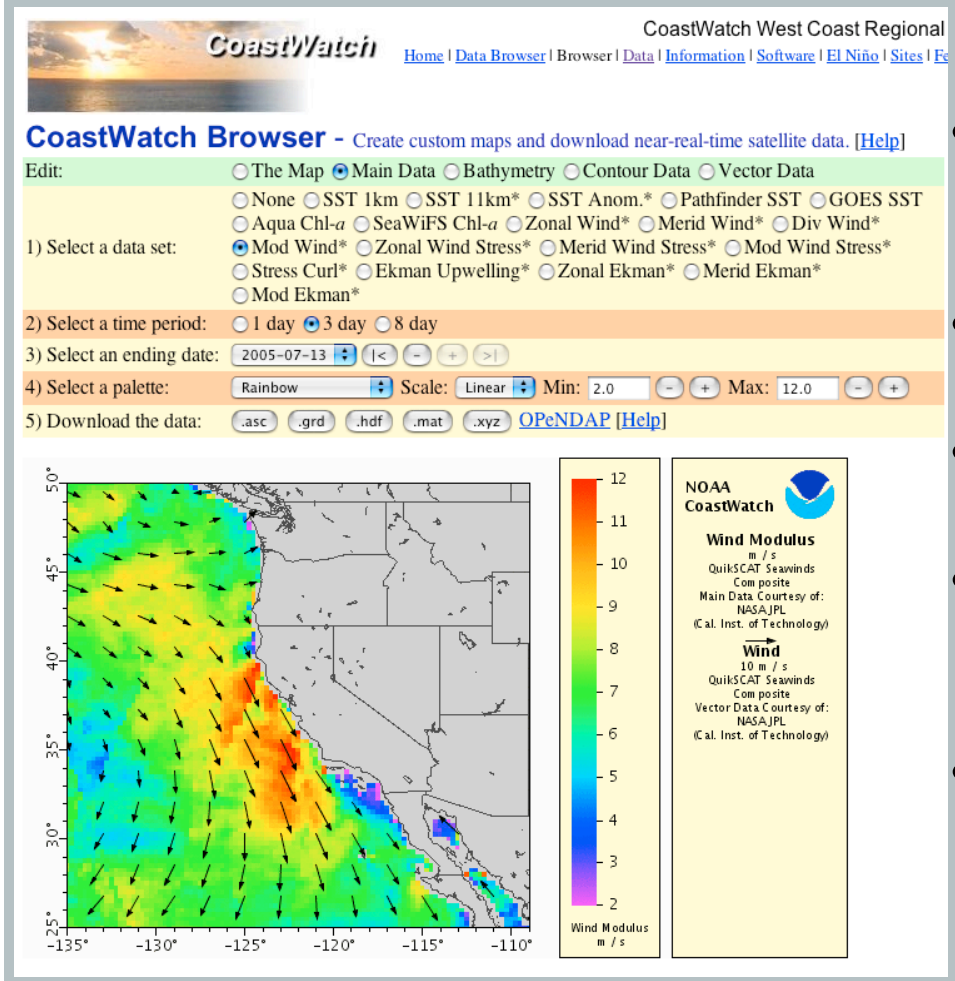
Integrated Ocean Observing System (IOOS)

- The IOOS development plan identifies a number of core ocean variables, many of which are directly derivable from current remote sensing missions:
  - Temperature
  - Ocean color
  - Sea level
  - Surface waves
  - Surface currents
  - Ice distribution

- NOAA's CoastWatch has been identified in the IOOS development plan as an operational part of the national backbone

New CoastWatch Browser at West Coast Node

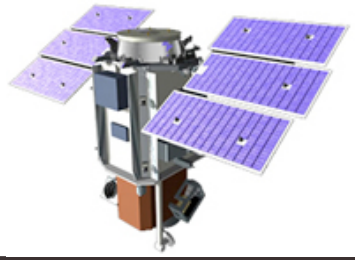
http://coastwatch.pfeg.noaa.gov/coastwatch/CWBrowser.jsp



- Designed to accommodate emerging west coast regional association of IOOS
- Beta version online since April 1, 2005
- Phase III modifications in progress
- Phase III will provide full compliance with NOAA data management requirements
- Many datasets served by OpenDAP

Summary

- Near real time (NRT) satellite data is crucial for optimizing sampling on fisheries research cruises.
- Timeseries of science quality satellite data are needed to understand linkages between climate and ecosystems, and to characterize and monitor ecosystems as part of an ecosystem based approach to fisheries management.



Feedback….

- **Are their applications that I missed, or that I should know more about?**
- **What future satellite data or products would you like to see developed?**
- **What could be done to make satellite data more accessible and/or useful?**
- **What benefits do you anticipate from the increased spatial and temporal resolution of future satellite sensors?**

Please feel free to contact me at cara.wilson@noaa.gov

Thank you…

Late summer chlorophyll blooms in the oligotrophic Pacific: What are their biological and physical forcings?

Cara WILSON

NOAA/NMFS/SWFSC Environmental Research Division

Corless Seminar Room

URI/GSO

Friday, Aug. 5

Noon