Constructing Oceanographic Data Sets for Biologgers: Successes, Failures and the Path Forward

Dave Foley
Joint Institute for Marine and Atmospheric Research
University of Hawaii
&
Environmental Research Division
NOAA Southwest Fisheries Science Center

(and many others ...)

PICES-2011
Khabarovsk, Russia
18 October 2011

Outline

- Goals
- Review basic data types
- Change perspective: measurement v. description of environment
- The artist's palette: distribution of different data sets via a uniform interface
- Derived products
- Thoughts on the future

Goals

- Develop quality descriptions of the marine environment
- Make these available and easily accessible to biologgers

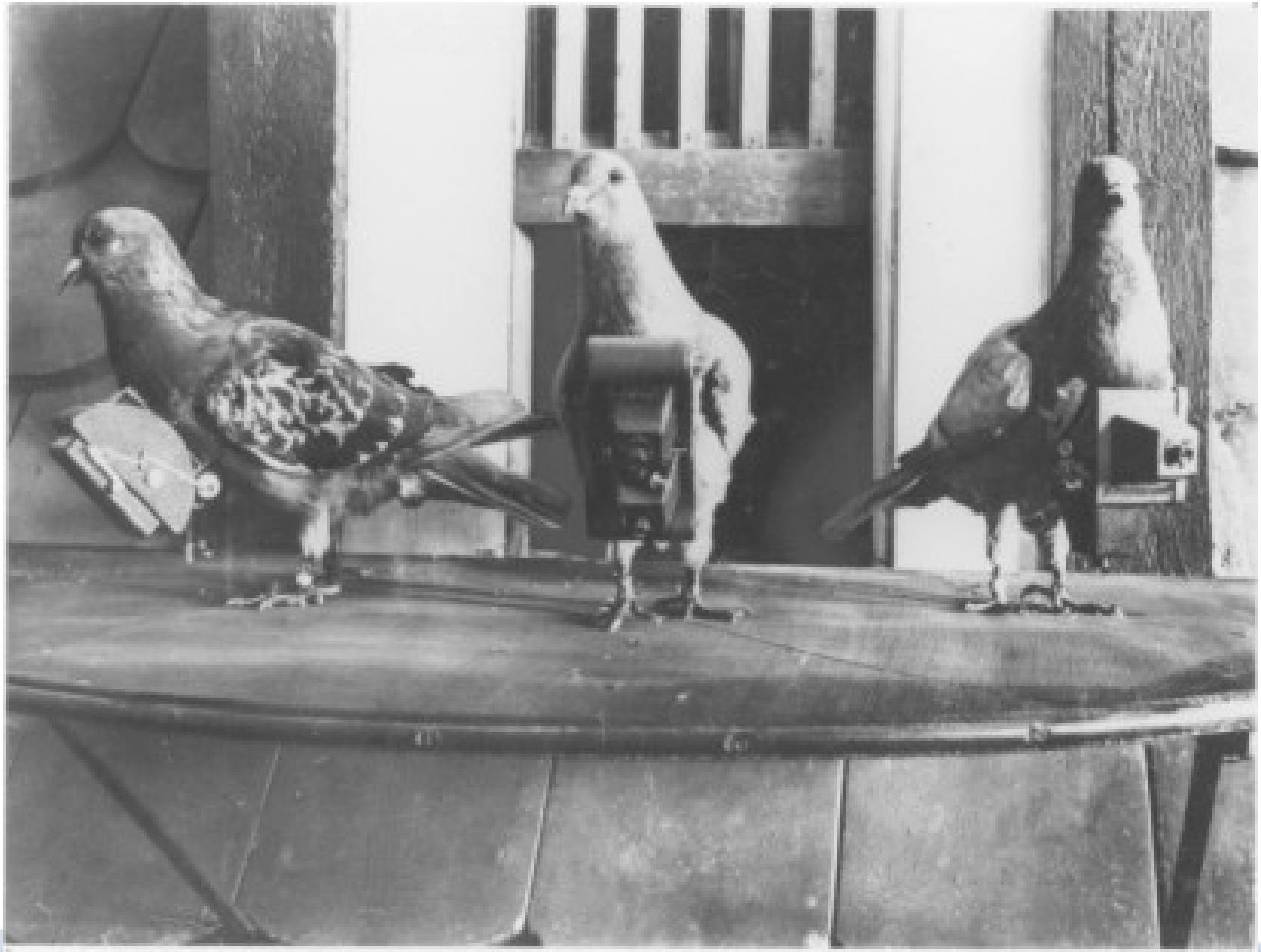
Data Management and Distribution

- Data and derived products made available by interoperable means
- Various access mechanisms
  - Browsers
  - Subsetting tools
- Choosing tools appropriate to the application
  - ArcGIS
  - R/Matlab
  - Google this and that

Shift Focus

- Satellite people focus on the actual measurement
- For Applications, we want to focus on the description of the marine environment.

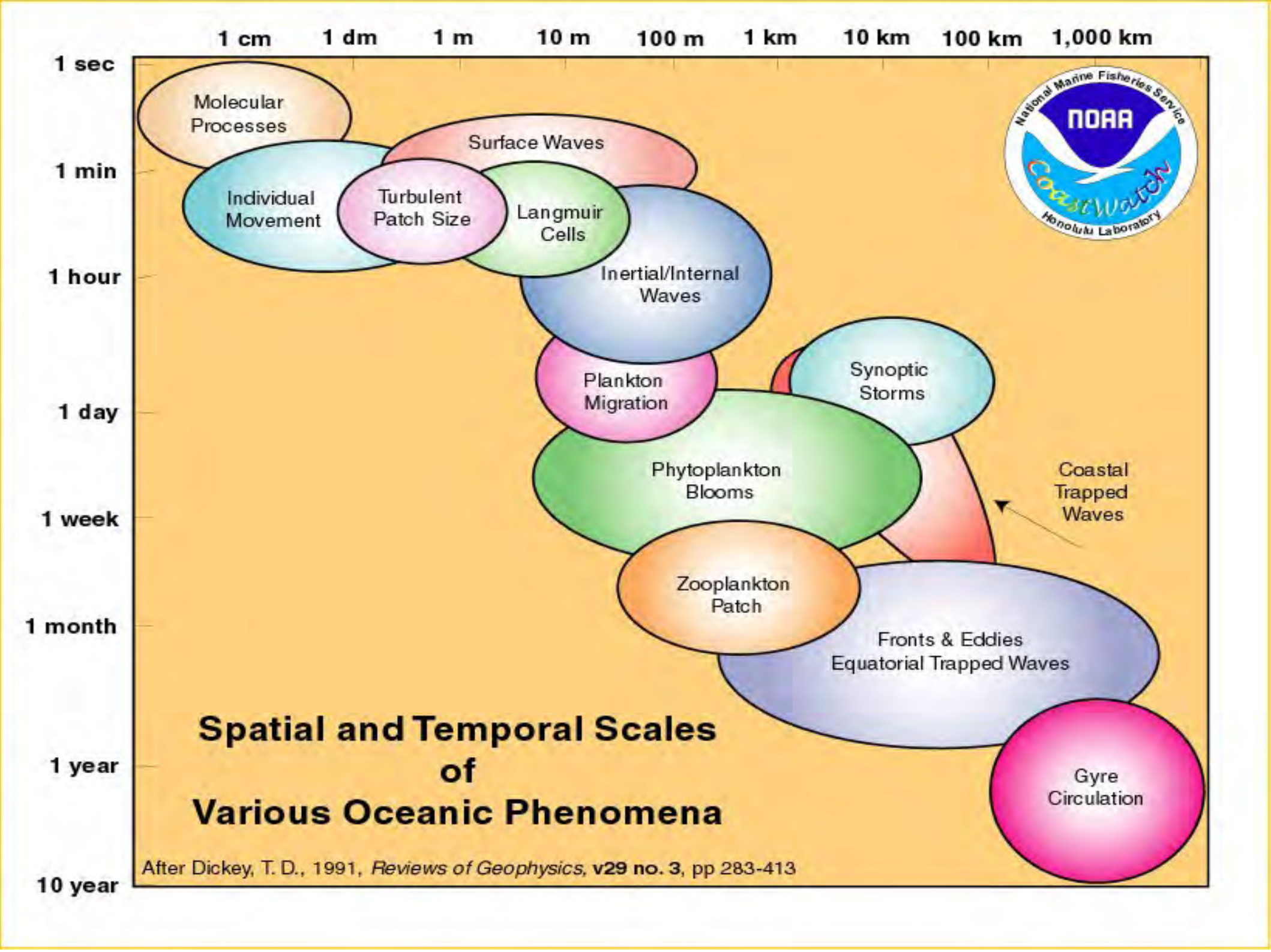
Early Autonomous Platforms



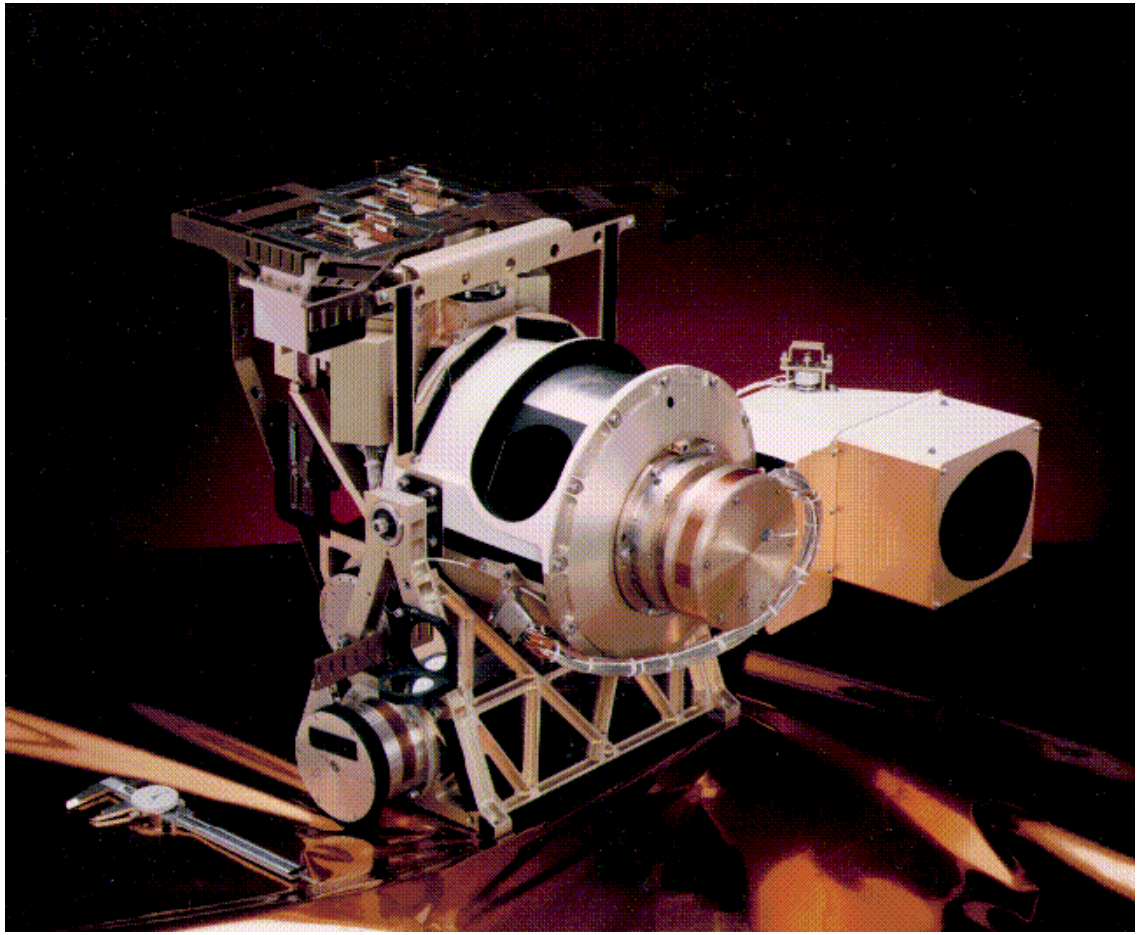
Composite product

Oceanic Features Important to Living Marine Resources

- Ocean ‘fronts’, boundaries, ‘edges’
- Mesoscale circulation patterns, e.g., eddies, meanders, ‘loops’
- Convergence zones
- Vertical thermal topography
- Ocean surface winds
- Wave heights


1 cm
1 dm
1 m
10 m
100 m
1 km
10 km
100 km
1,000 km
1 sec
1 min
1 hour
1 day
1 week
1 month
1 year
10 year
Molecular Processes
Surface Waves
Individual Movement
Turbulent Patch Size
Langmuir Cells
Inertial/Internal Waves
Plankton Migration
Synoptic Storms
Phytoplankton Blooms
Coastal Trapped Waves
Zooplankton Patch
Fronts & Eddies
Equatorial Trapped Waves
Gyre Circulation
Spatial and Temporal Scales of Various Oceanic Phenomena
After Dickey, T. D., 1991, Reviews of Geophysics, v29 no. 3, pp 283-413
National Marine Fisheries Service
NOAA
CoastWatch
Honolulu Laboratory

Modern Autonomous Platforms

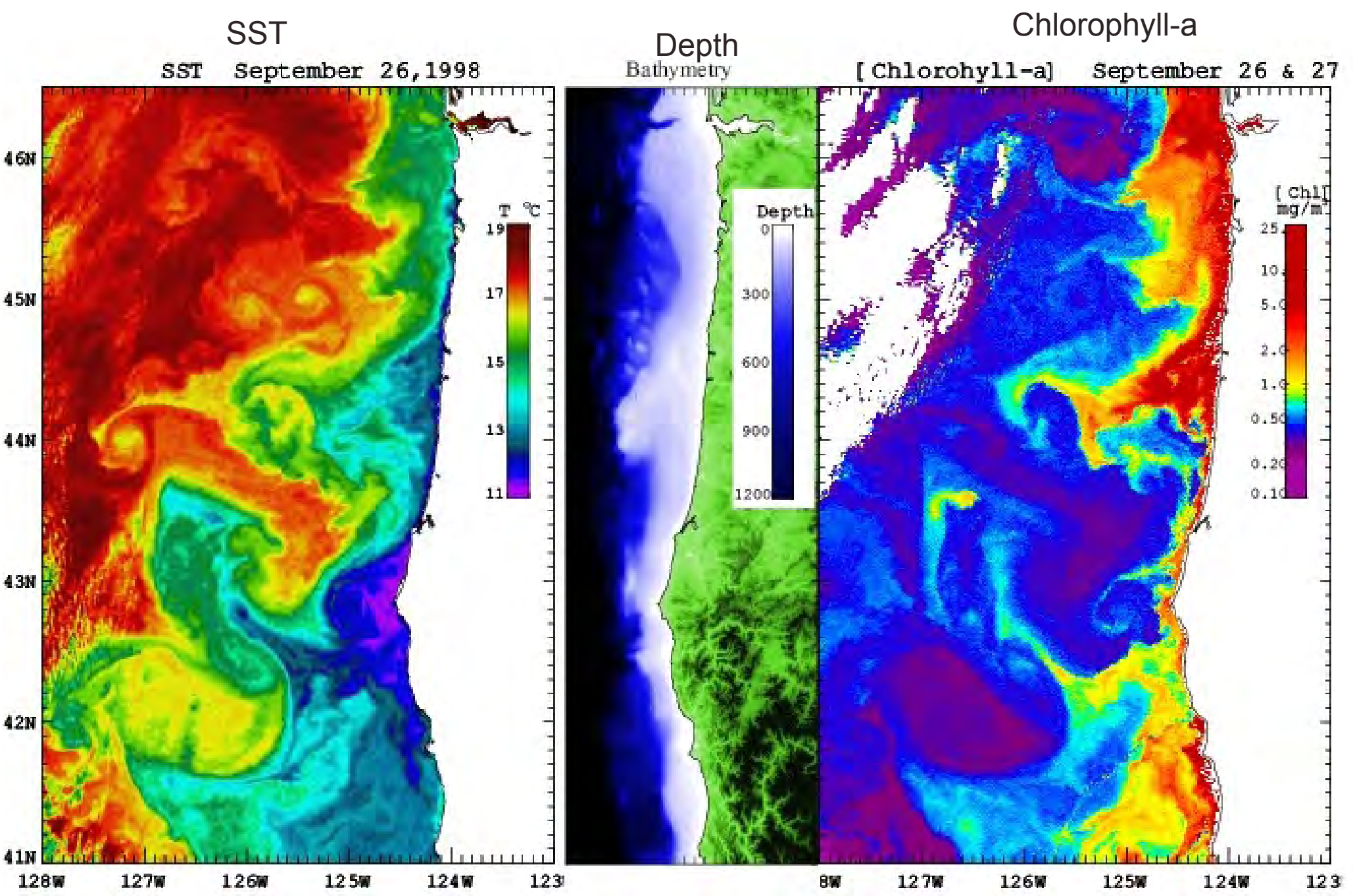


The instrument

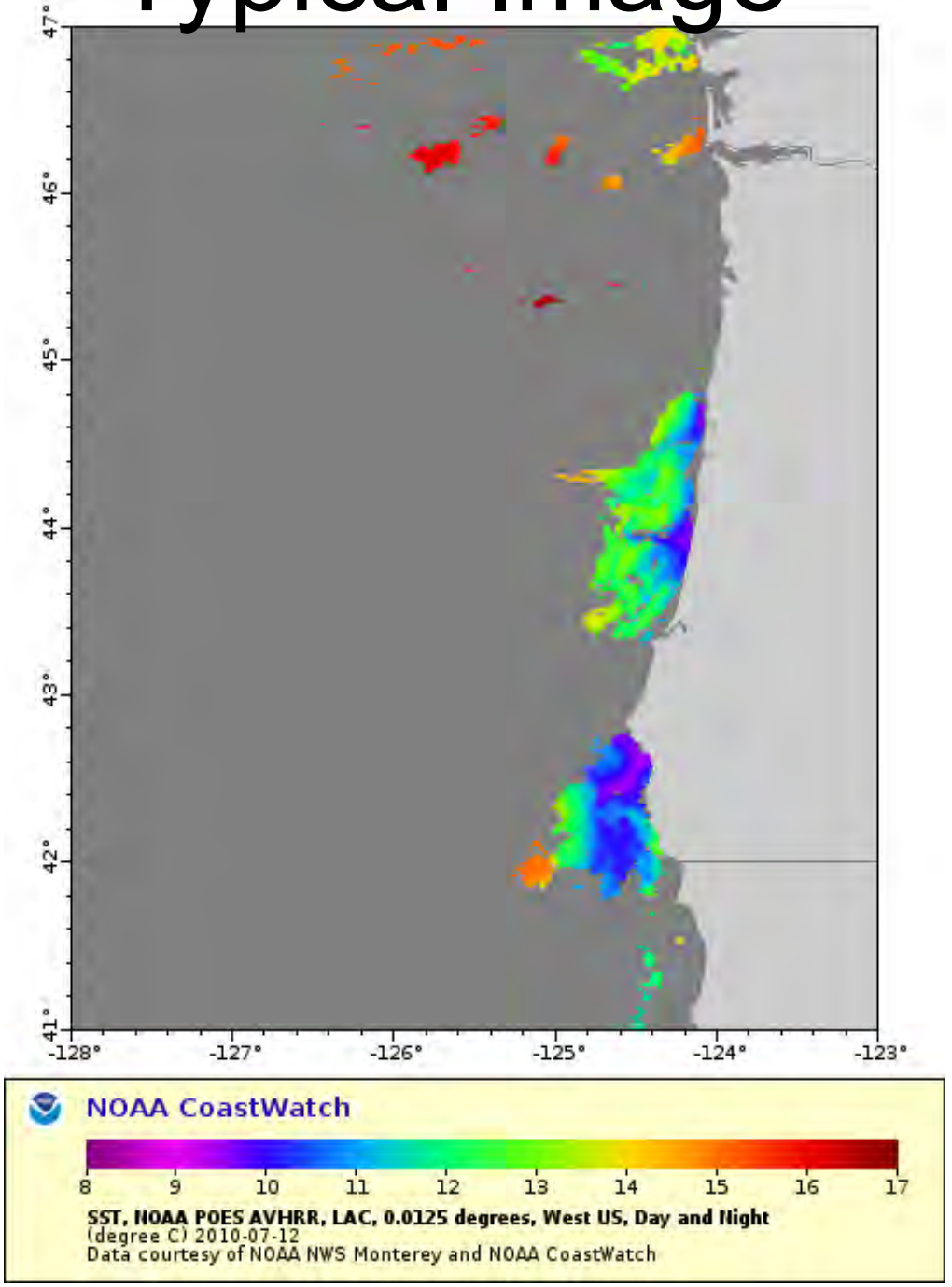
The satellite

Why use satellite

- Enhanced spatial coverage
- Resolves oceanic features at a variety of scales
- Democratization - data less biased to waters near wealthy nations


SST
SST September 26,1998
T °C
19
17
15
13
11
Depth
Bathymetry
Depth
0
300
600
900
1200
Chlorophyll-a
[Chlorohyll-a] September 26 & 27
[Chl]
mg/m
25
10
5.0
2.0
1.0
0.50
0.20
0.10
46N
45N
44N
43N
42N
41N
128W
127W
126W
125W
124W
123
8W
127W
126W
125W
124W
123

Typical Image

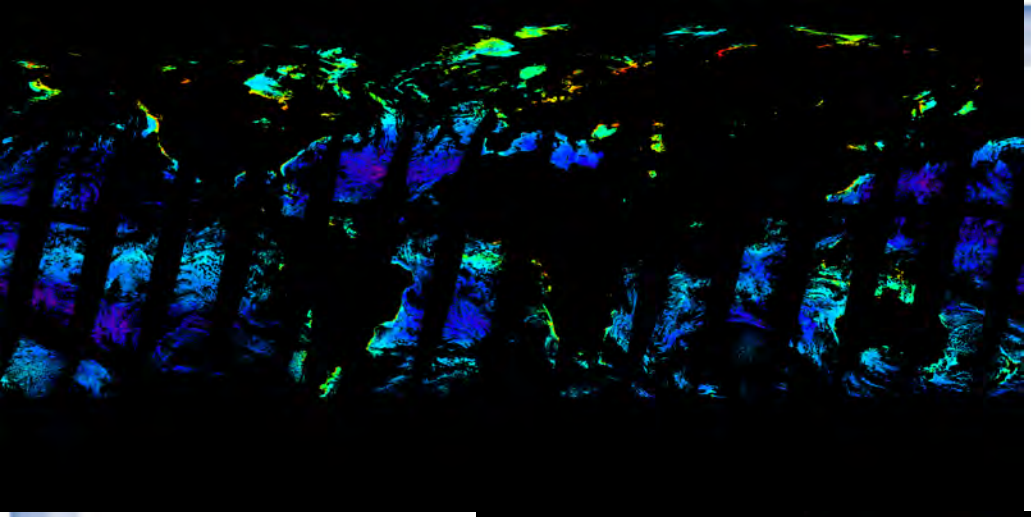


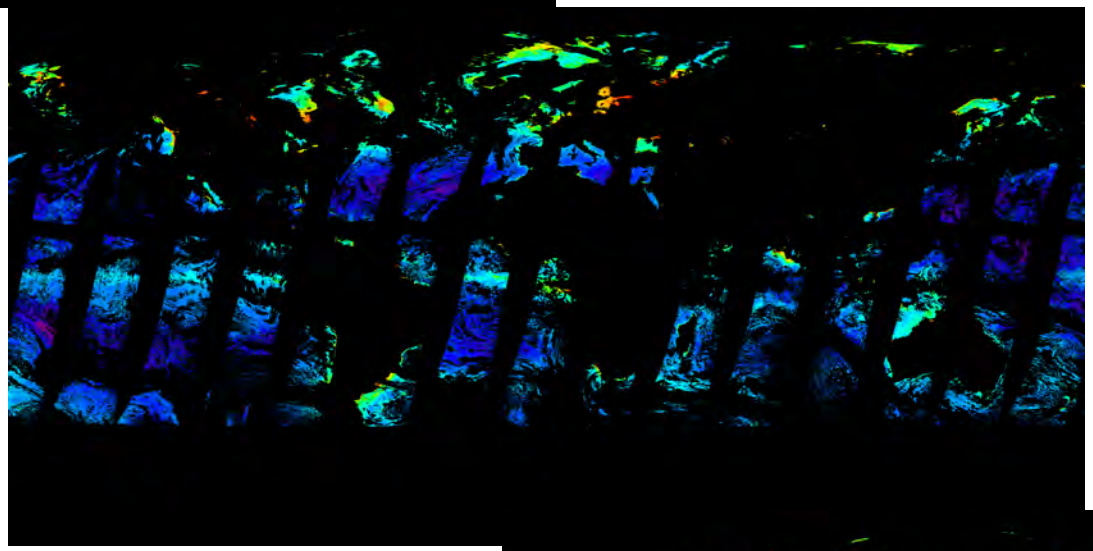
Problems with Satellite Measurements

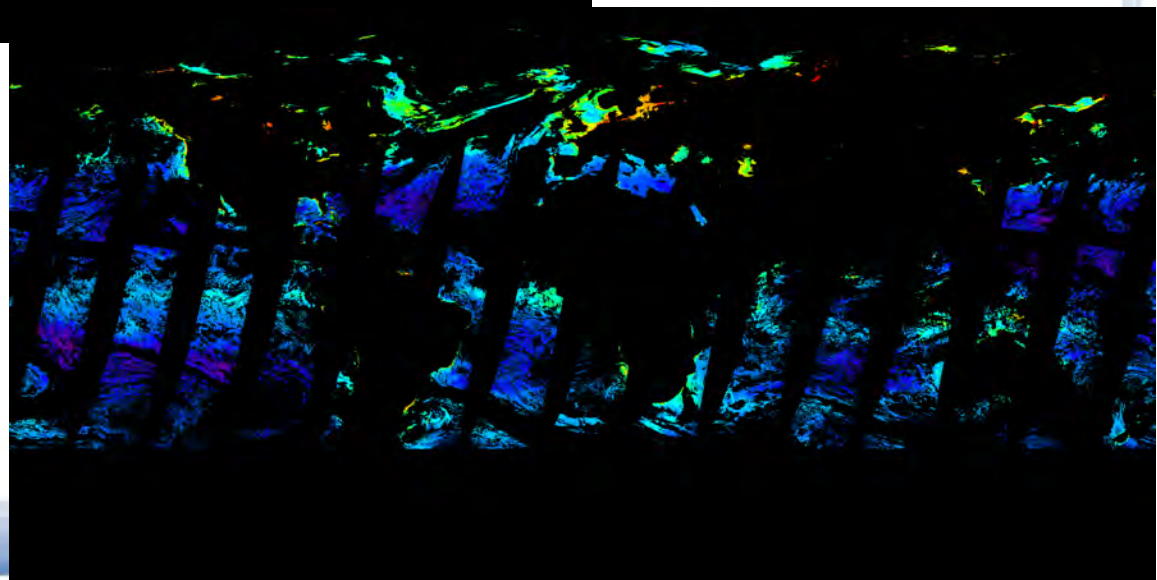
- Generally only see the very surface of the ocean
- Have to account for many factors in the measurement, many of which cannot be directly determined
- Can only derive very basic set of oceanographic parameters
- Clouds a problem for all Visible and Infrared measurements

Composite Images

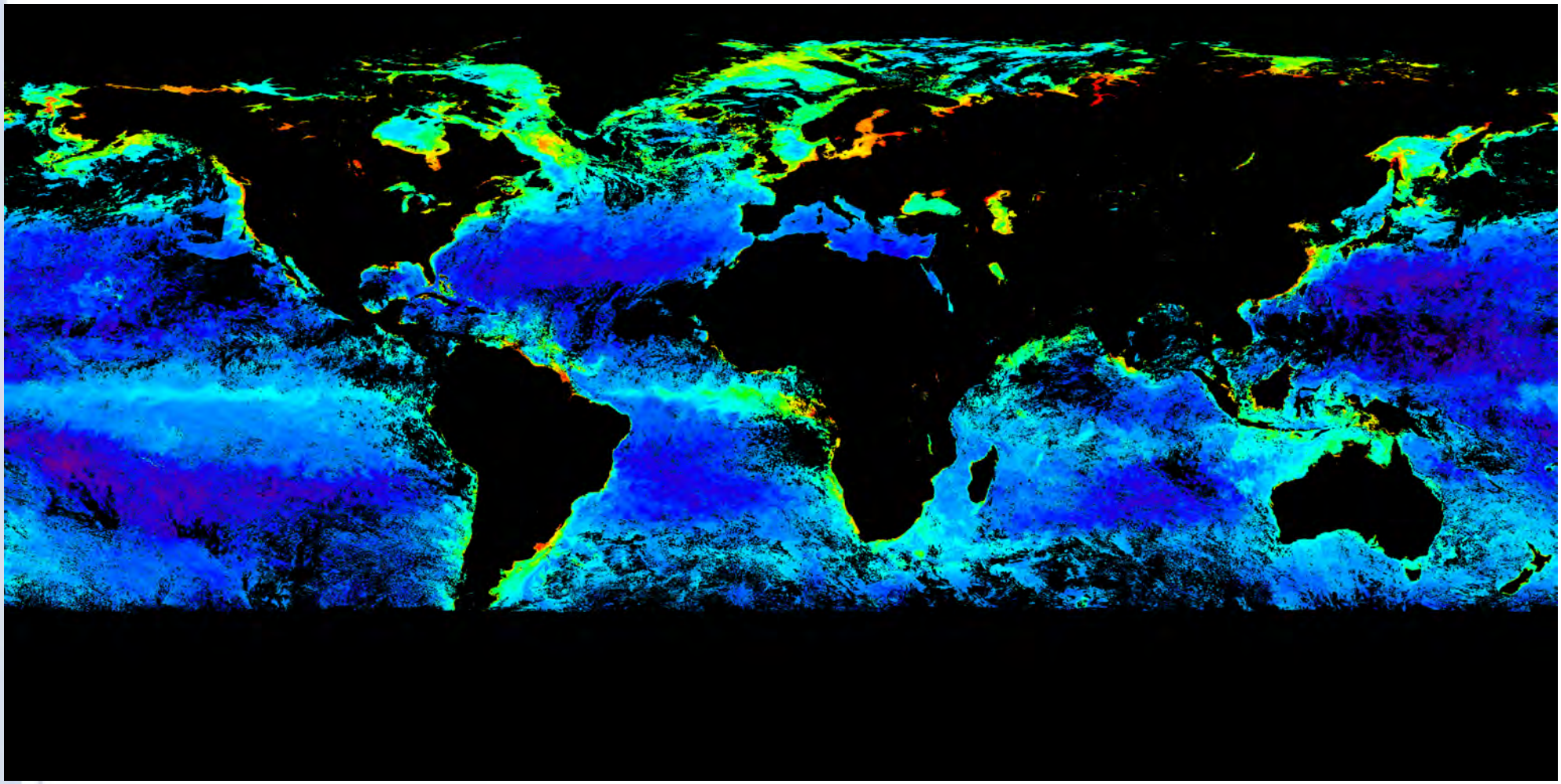
- Integrate across time on one platform to mitigate obscuring by clouds
- Integrate across sensors and platforms (e.g., microwave and Ifrared, polar-orbiting and geostationary)

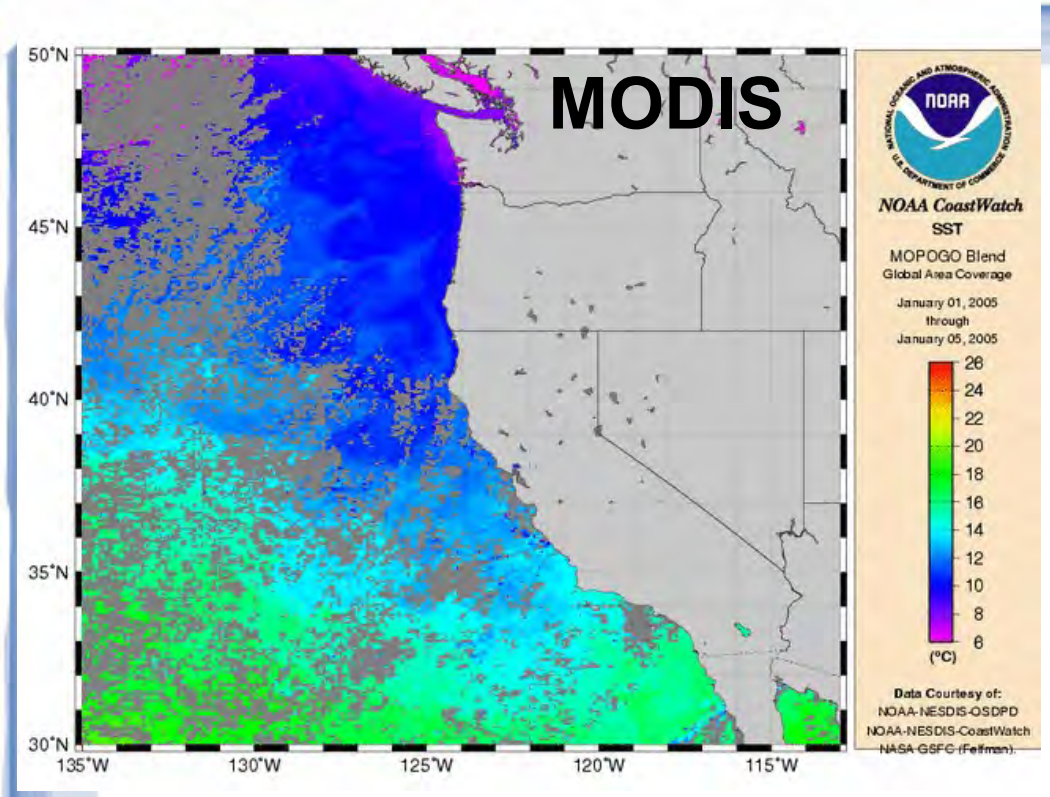


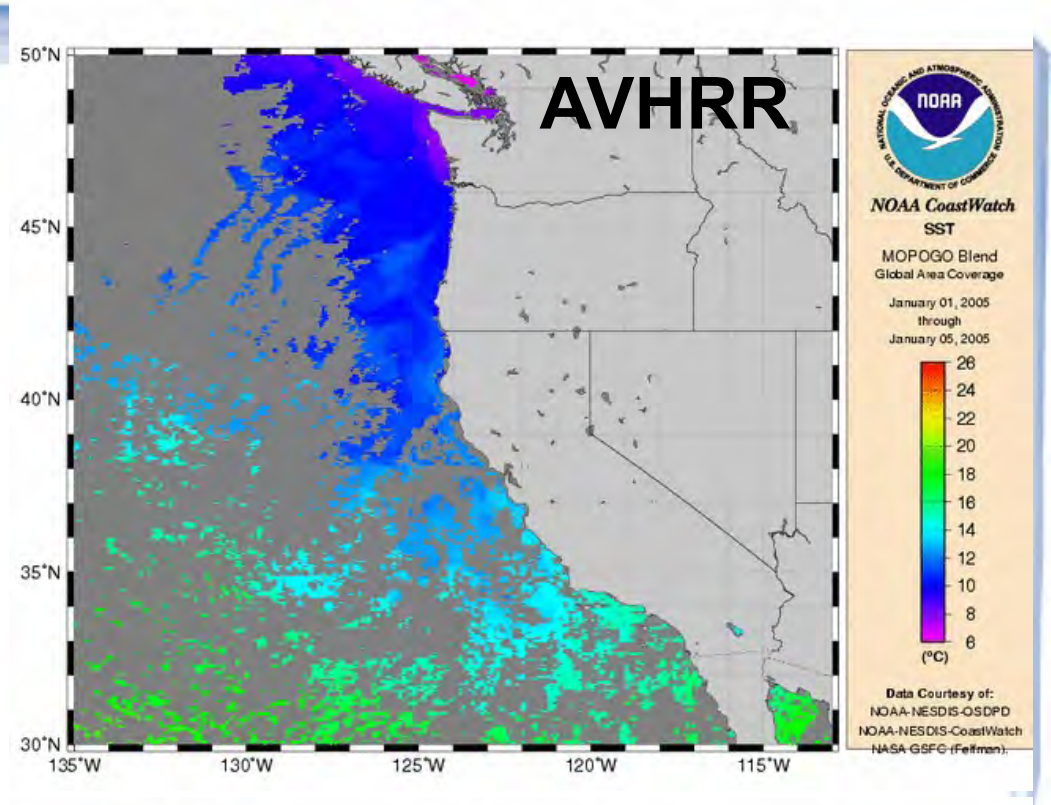


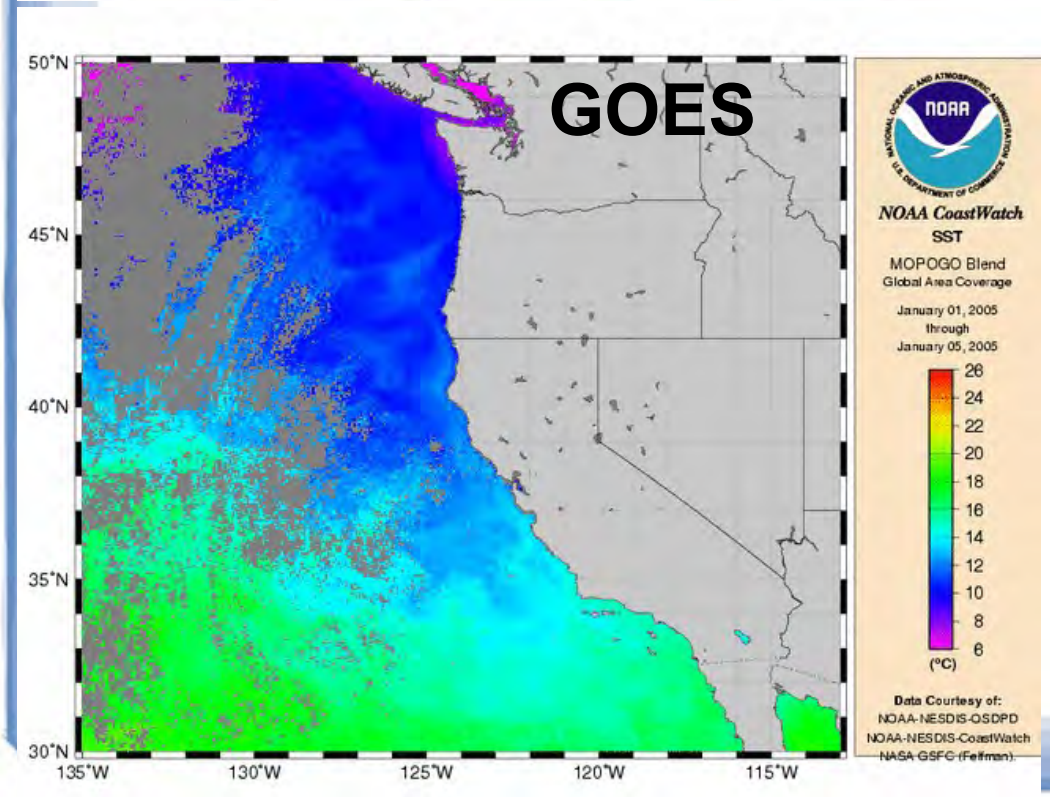


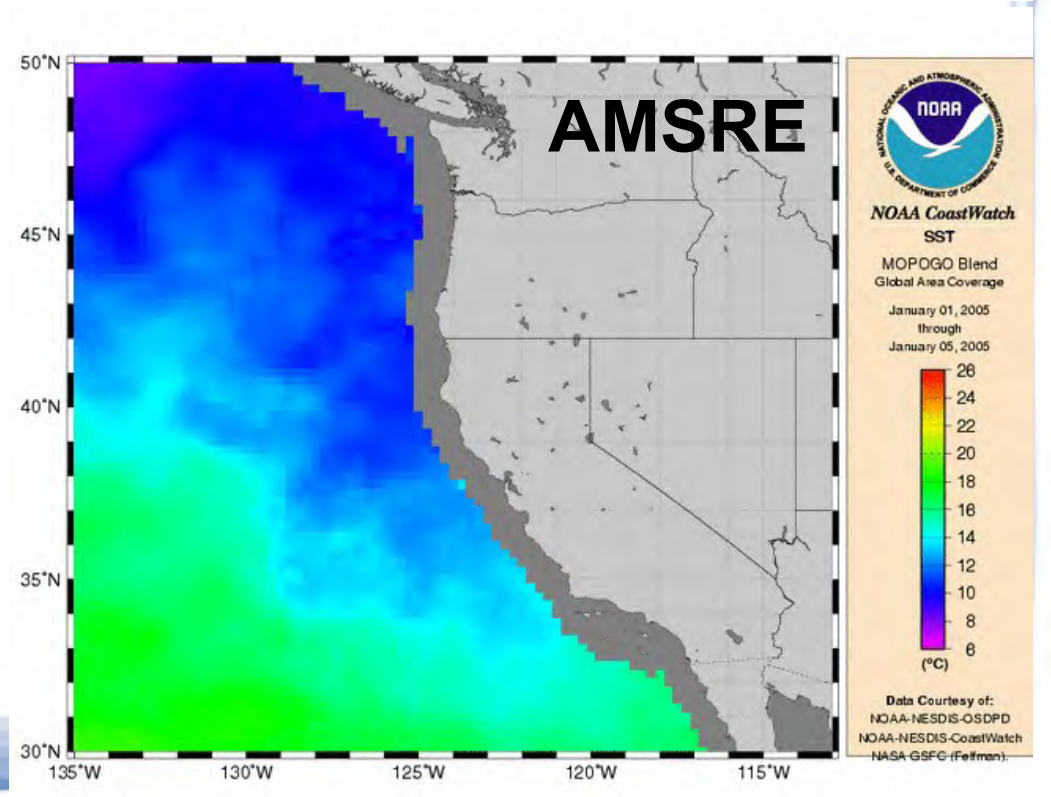
Composite (what we want to use)



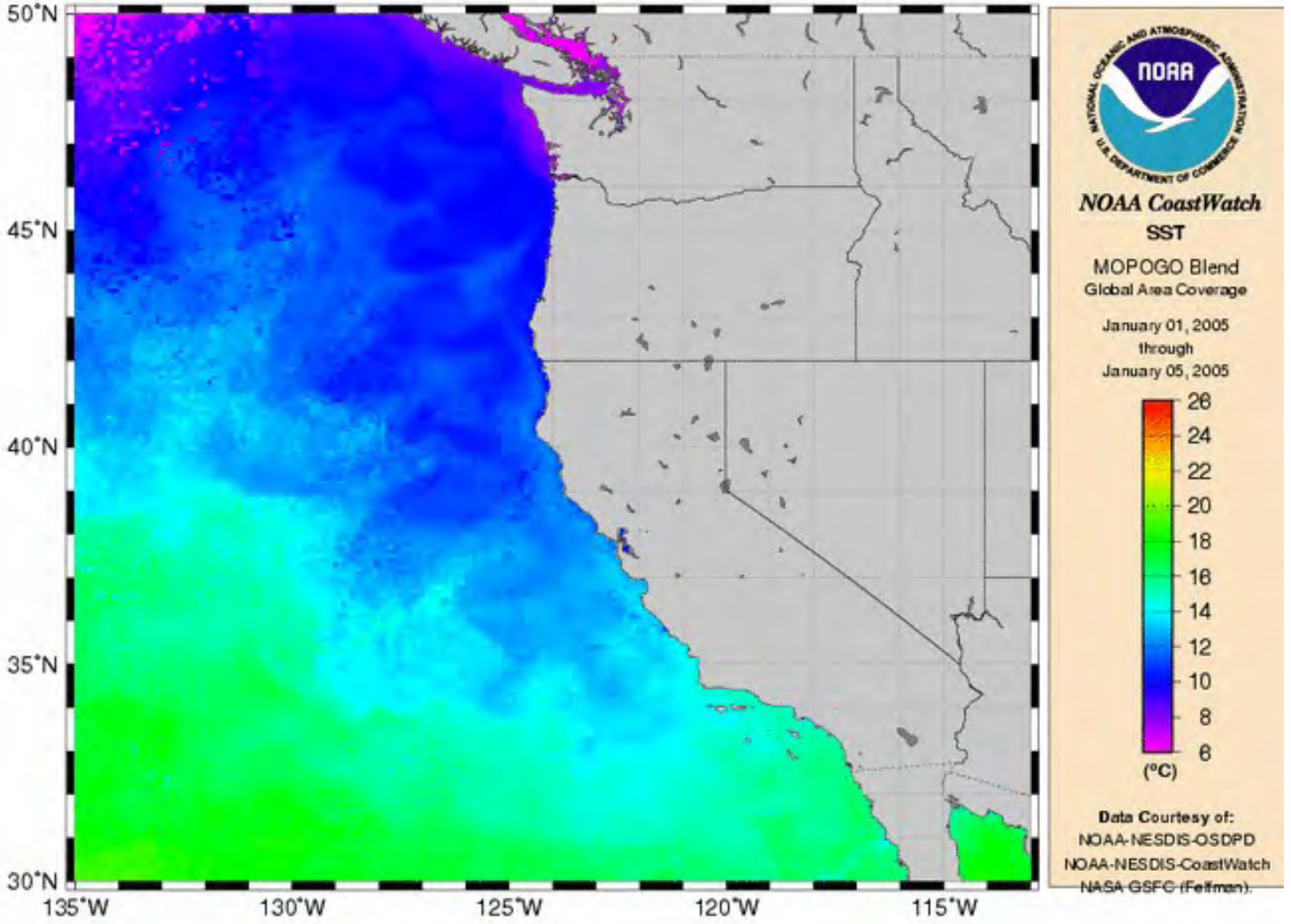

MODIS
50°N
45°N
40°N
35°N
30°N
135°W
130°W
125°W
120°W
115°W
NOAA CoastWatch
SST
MOPOGO Blend
Global Area Coverage
January 01, 2005
through
January 05, 2005
26
24
22
20
18
16
14
12
10
8
6
(°C)
Data Courtesy of:
NOAA-NESDIS-OSDPD
NOAA-NESDIS-CoastWatch
NASA GSFC (Feldman).


AVHRR
50°N
45°N
40°N
35°N
30°N
135°W
130°W
125°W
120°W
115°W
NOAA CoastWatch
SST
MOPOGO Blend
Global Area Coverage
January 01, 2005
through
January 05, 2005
26
24
22
20
18
16
14
12
10
8
6
(°C)
Data Courtesy of:
NOAA-NESDIS-OSDPD
NOAA-NESDIS-CoastWatch
NASA GSFC (Feldman).


GOES
50°N
45°N
40°N
35°N
30°N
135°W
130°W
125°W
120°W
115°W
NOAA CoastWatch
SST
MOPOGO Blend
Global Area Coverage
January 01, 2005
through
January 05, 2005
26
24
22
20
18
16
14
12
10
8
6
(°C)
Data Courtesy of:
NOAA-NESDIS-OSDPD
NOAA-NESDIS-CoastWatch
NASA GSFC (Feldman).


AMSRE
50°N
45°N
40°N
35°N
30°N
135°W
130°W
125°W
120°W
115°W
NOAA CoastWatch
SST
MOPOGO Blend
Global Area Coverage
January 01, 2005
through
January 05, 2005
26
24
22
20
18
16
14
12
10
8
6
(°C)
Data Courtesy of:
NOAA-NESDIS-OSDPD
NOAA-NESDIS-CoastWatch
NASA GSFC (Feldman).

Blended 5-dav SST



The GHRSST Advantage

- Standardized format with CF-compliance greatly reduces overhead to make data sets available to our users
- The provision of error fields allows users to better understand the data set
- Documentation is excellent.

Cetaceans and anthropogenic threats

Threats include

Ship strikes

Fishery bycatch

Naval activities

Anthropogenic sound

Cetaceans protected by US laws

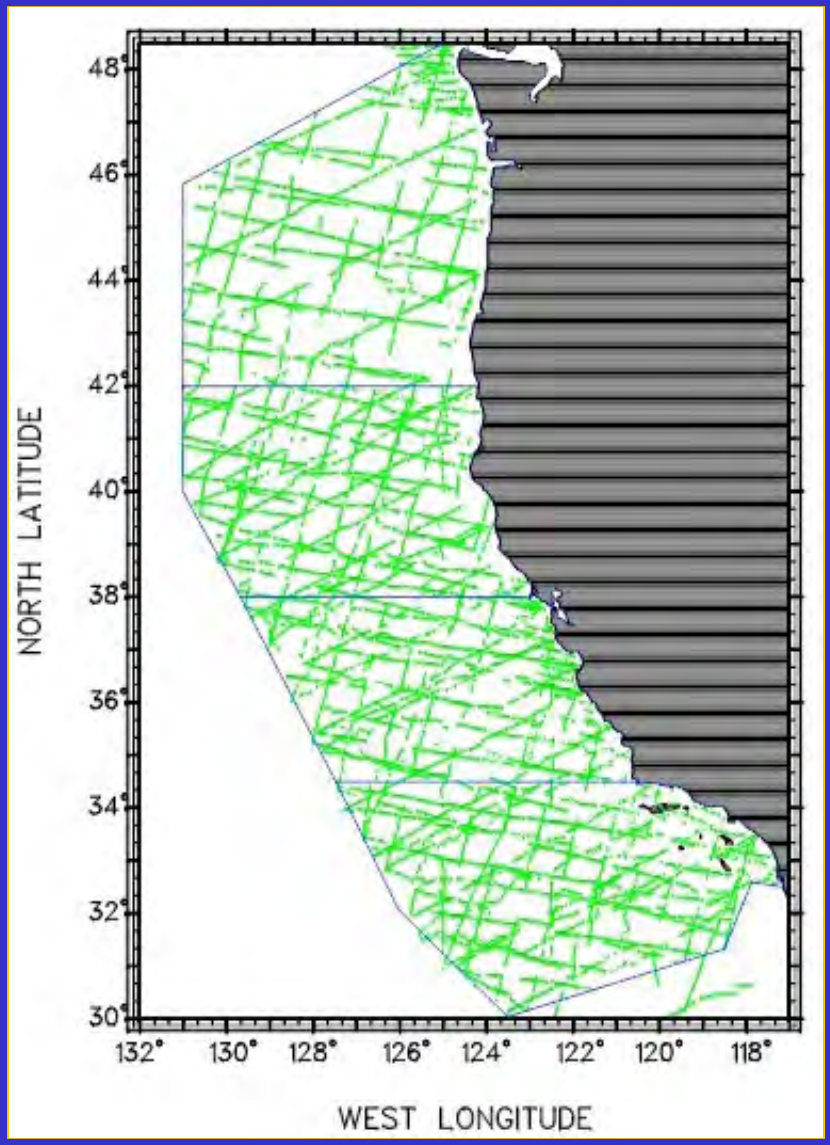
MMPA

ESA

SWFSC West Coast Shipboard Surveys

Cetacean surveys, summer & fall 1991, 1993, 1996, 2001, & 2005.

Systematic line-transect methods were used on all surveys.



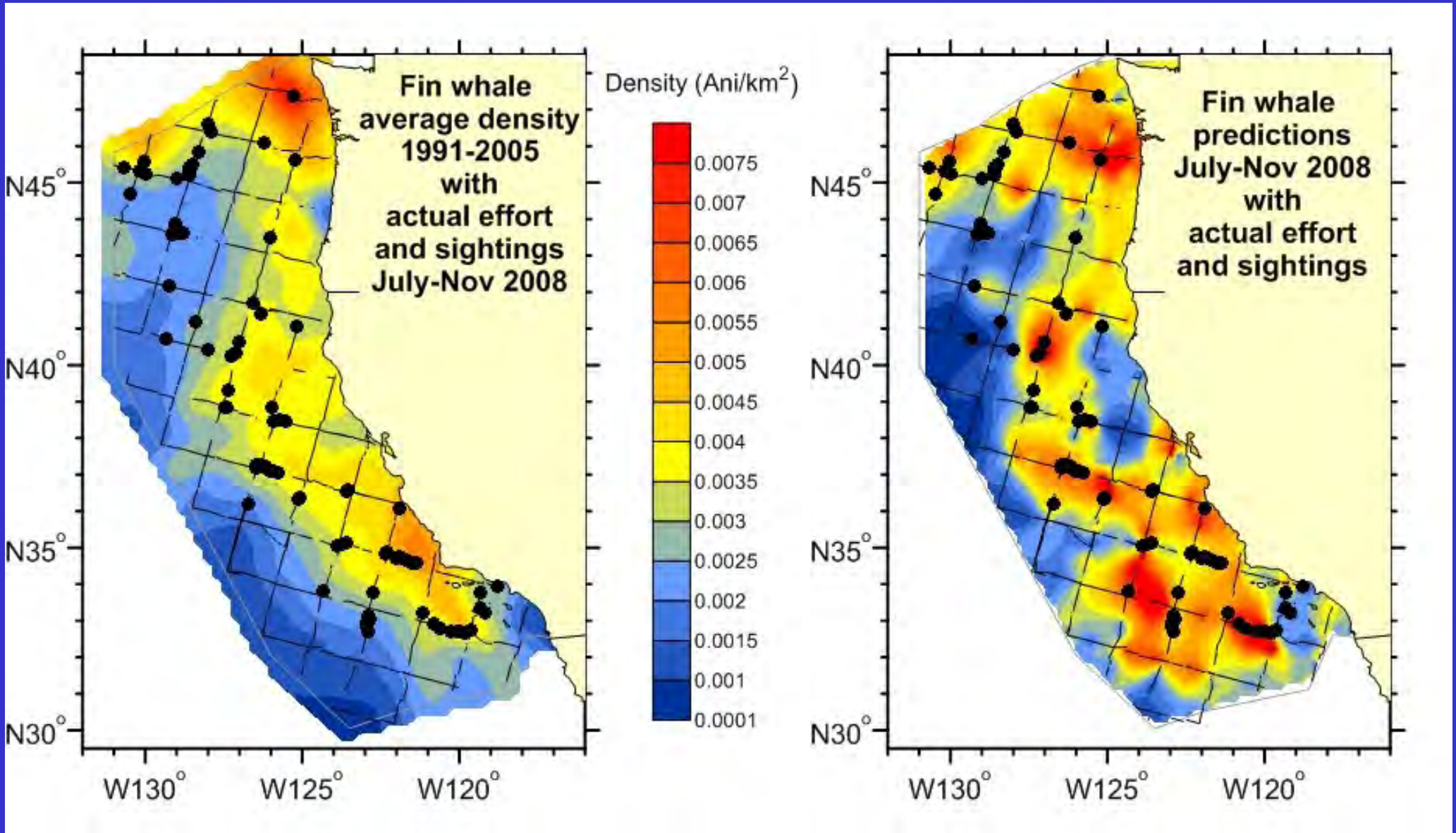
U.S. West Coast wide 'snapshot'

Completed transect lines 1991-2005

NOWCAST – Fin whale density for entire survey (July-Nov 2008)

Average 91-05

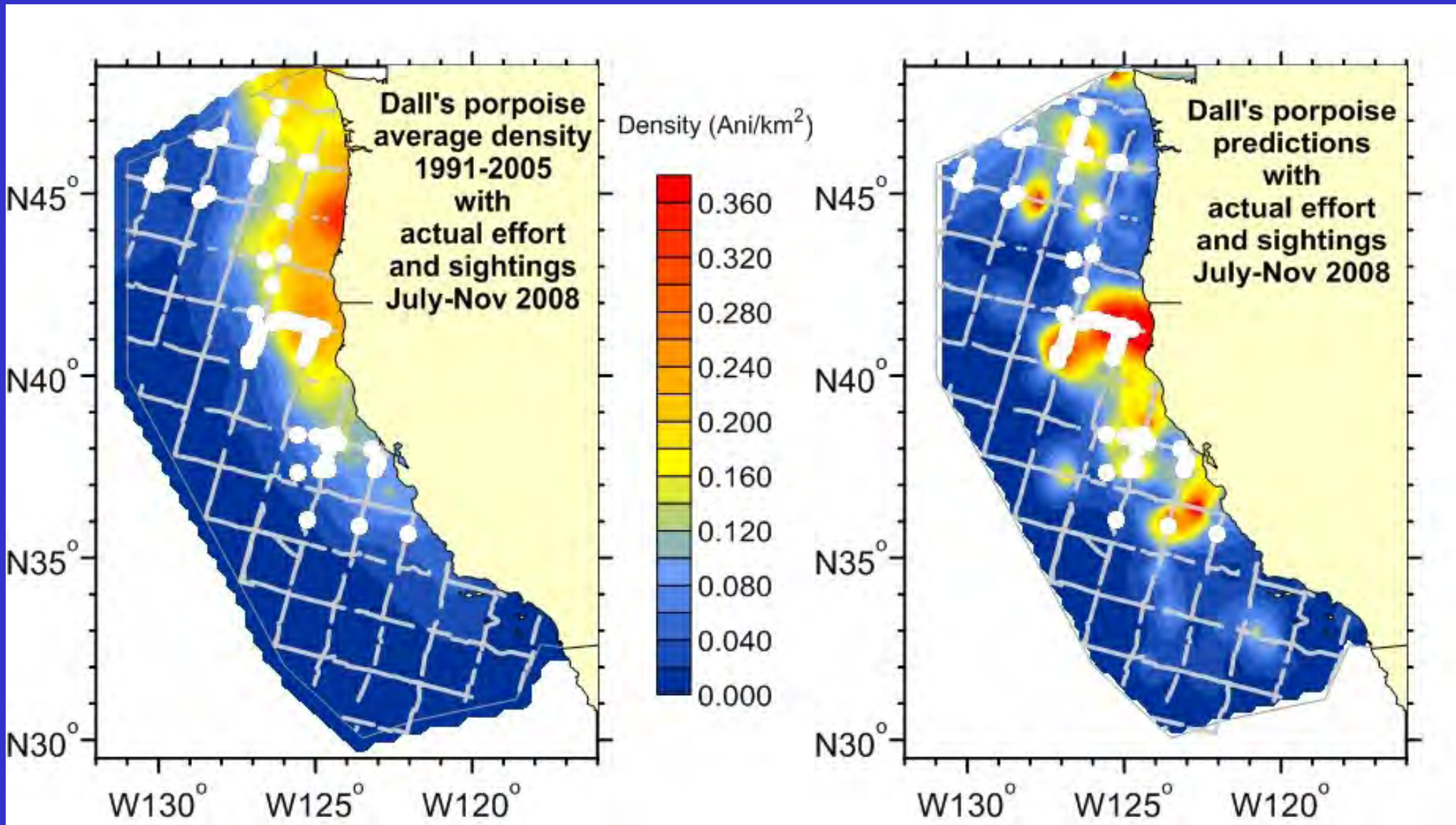
"Daily forecast"

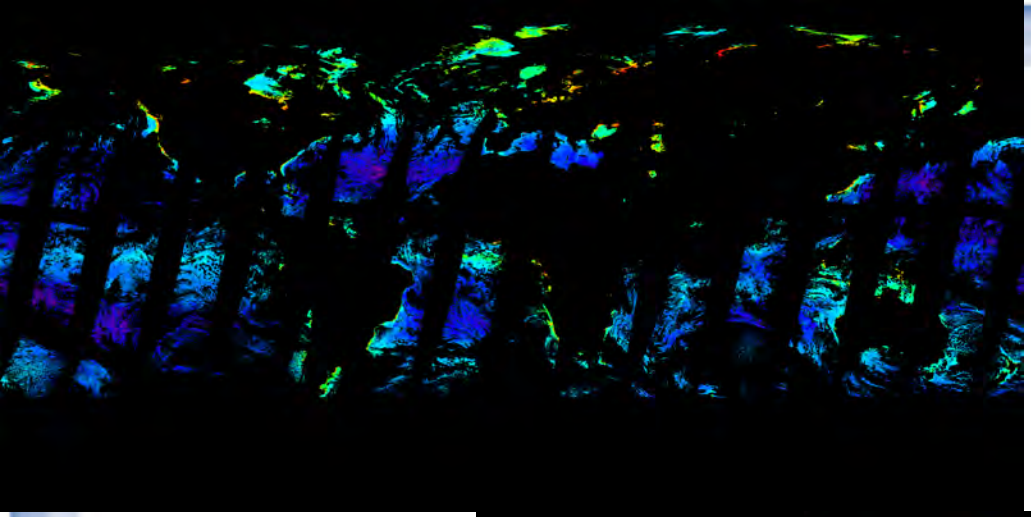


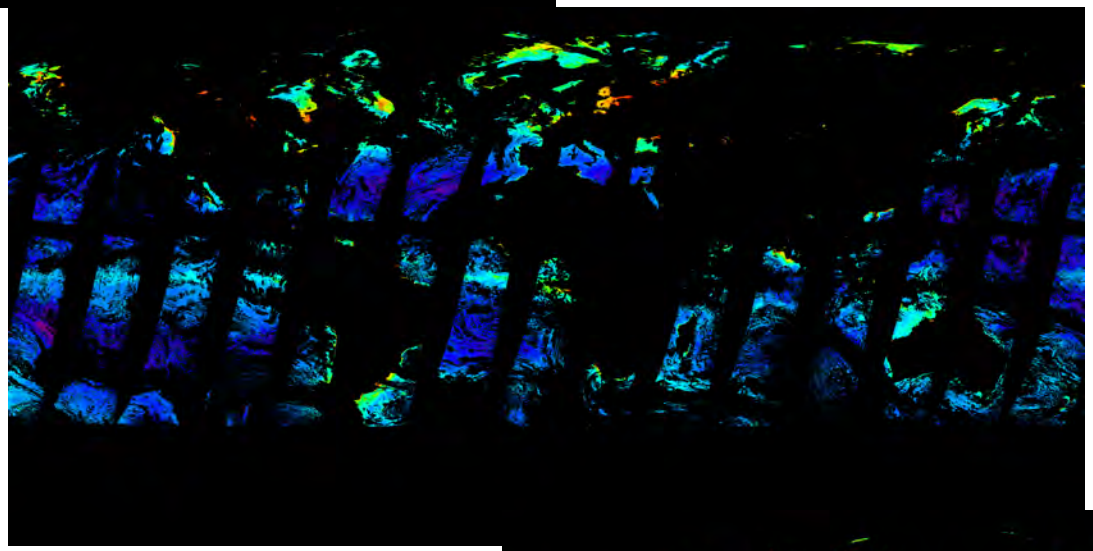
NOWCAST – Dall's porpoise density for entire survey (July-Nov 2008)

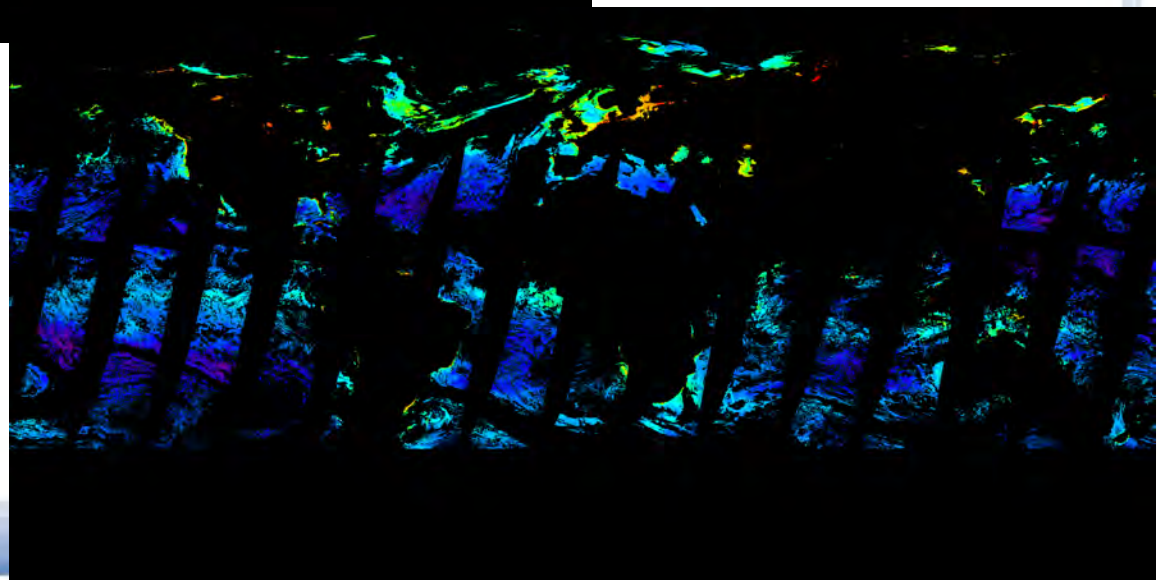
Average 91-05

"Daily forecast"

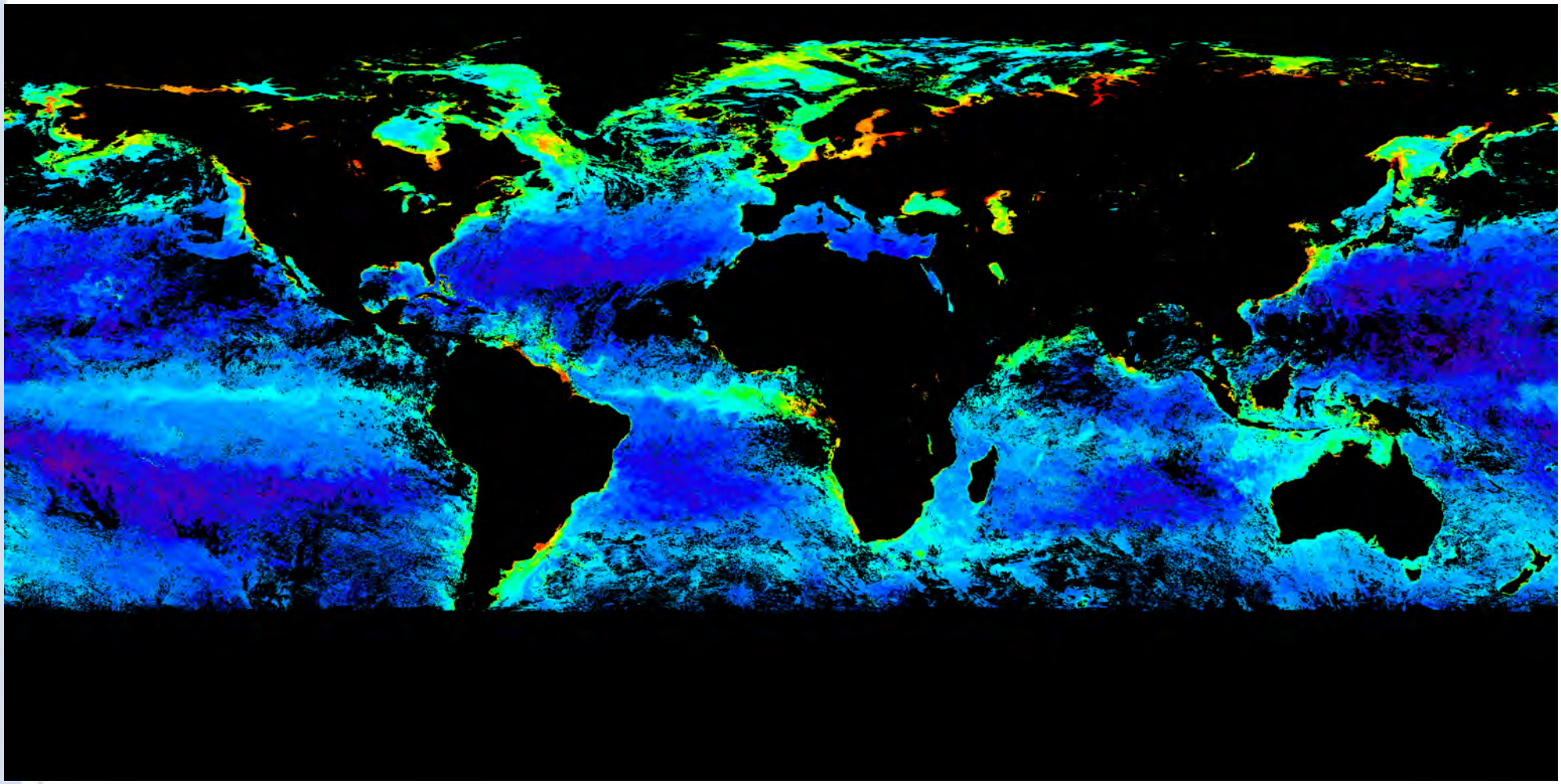




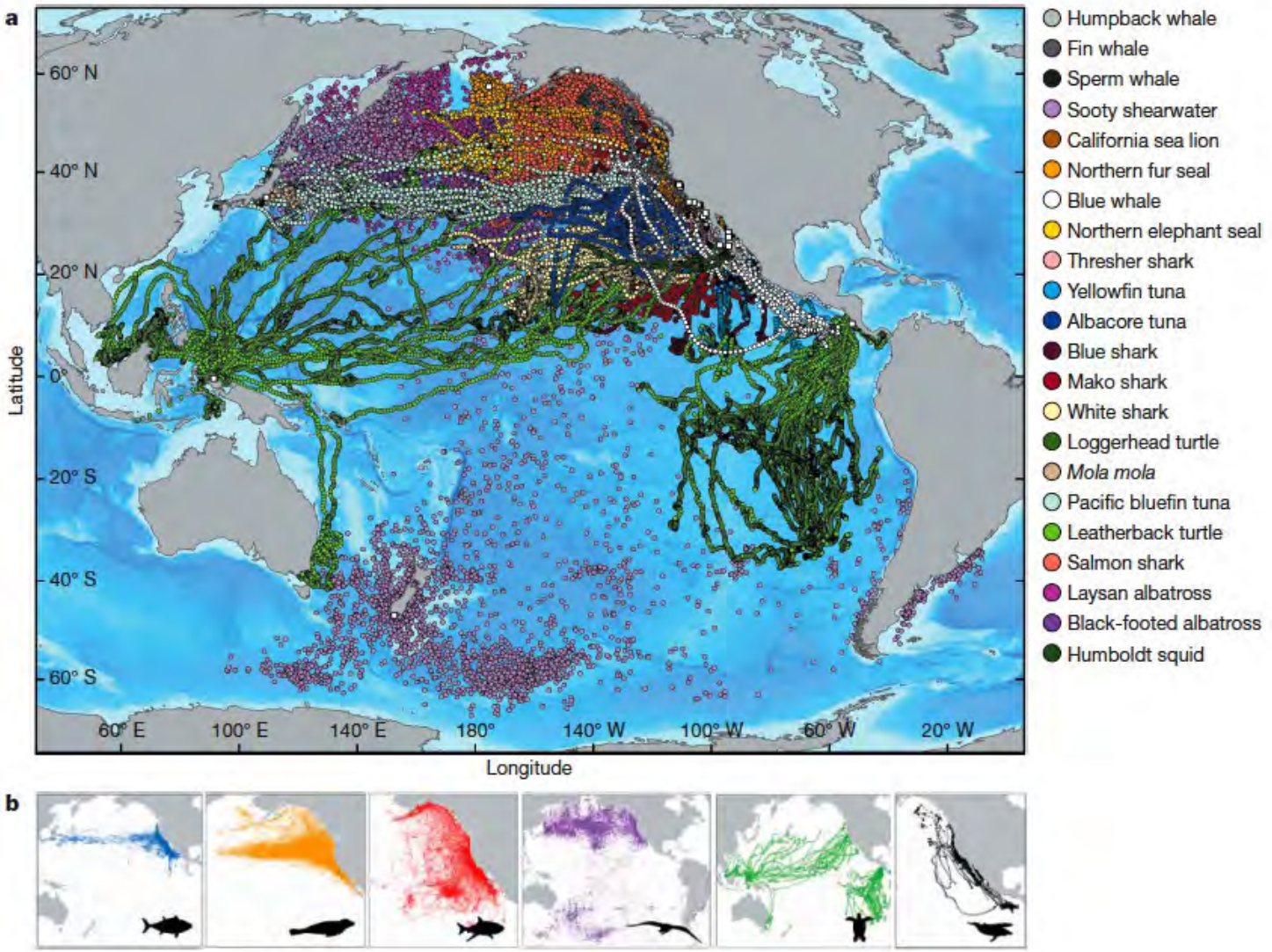




Composite (what we want to use)

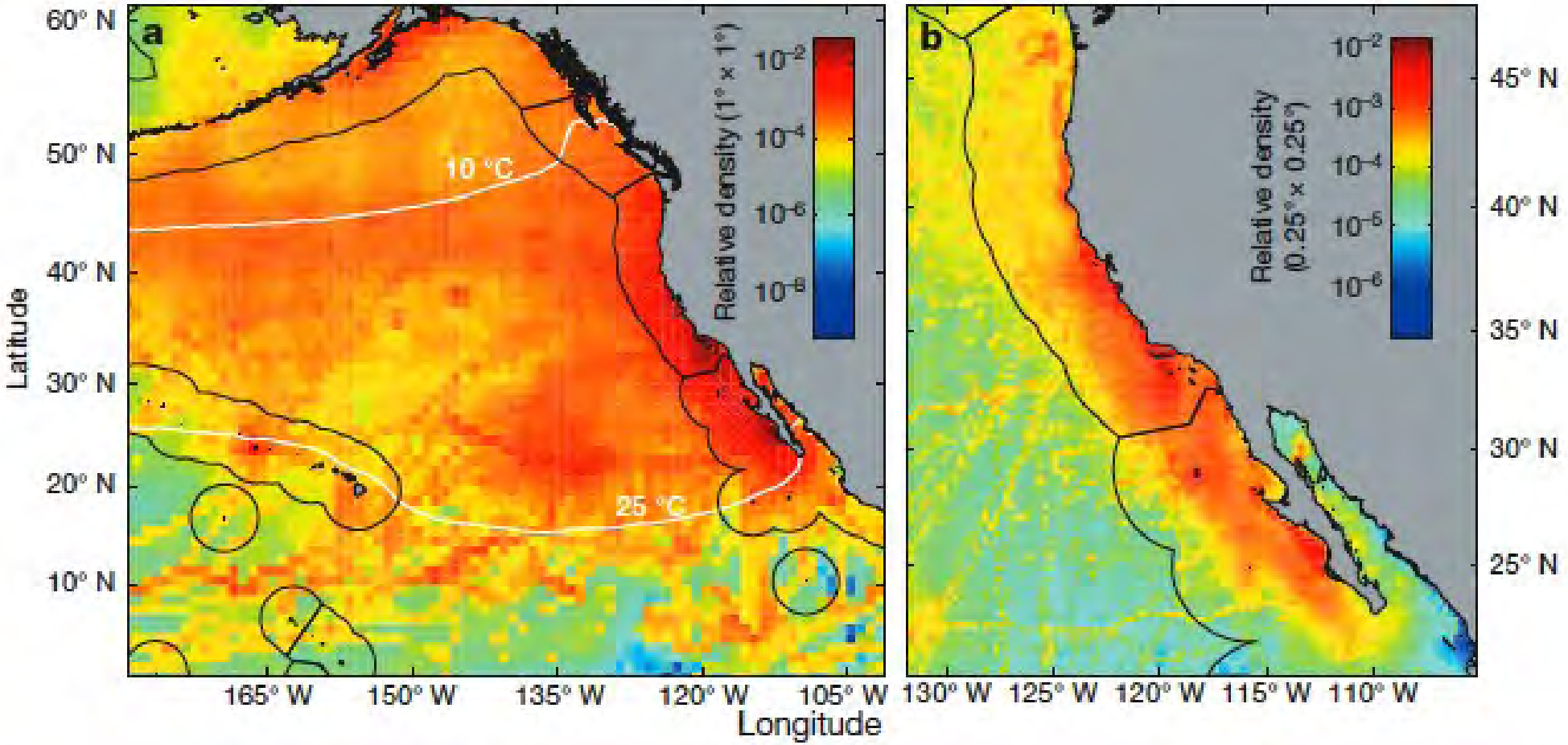


Tagging of Pelagic Predators (TOPP)



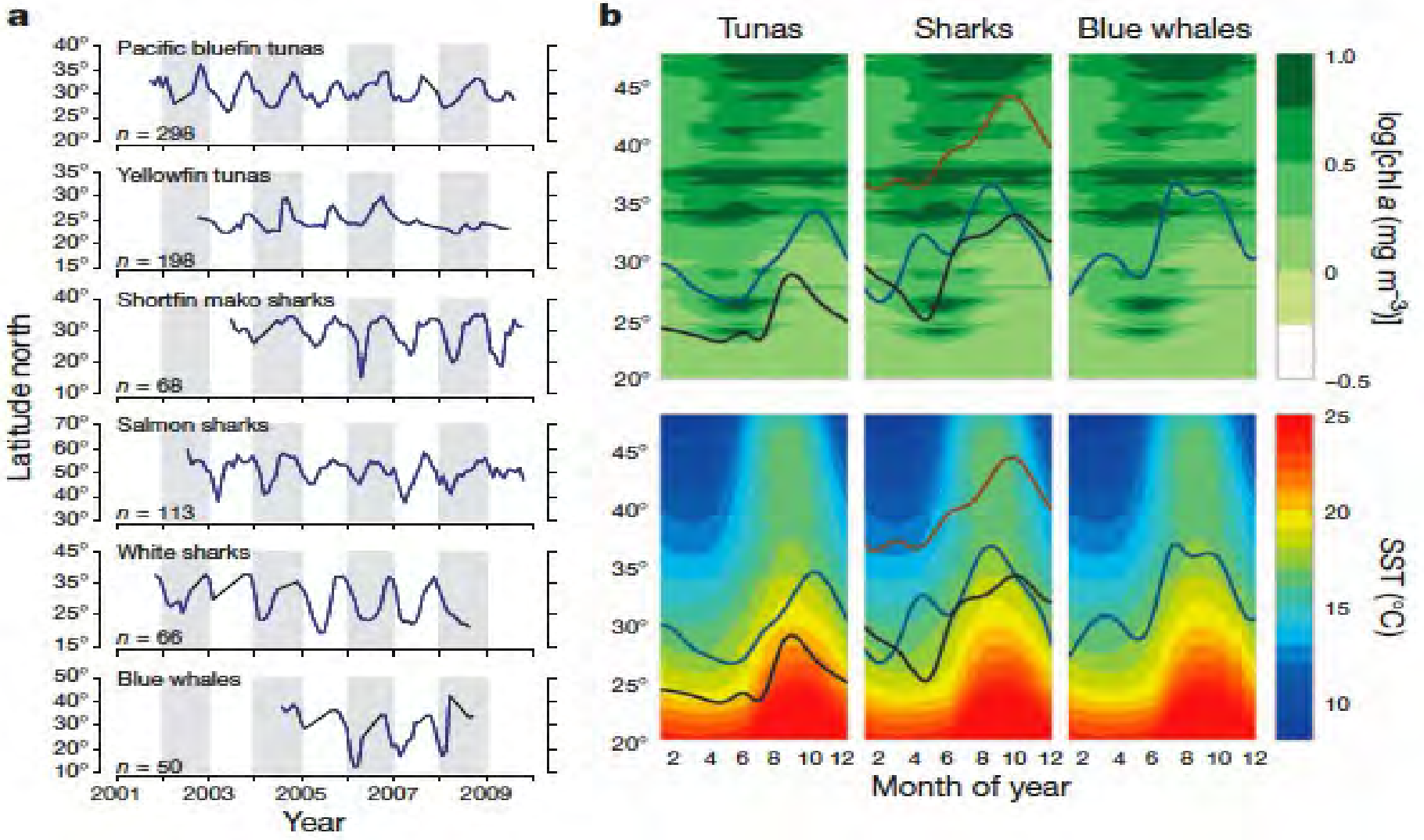
Block et al., Nature (2011)

Species Density Maps

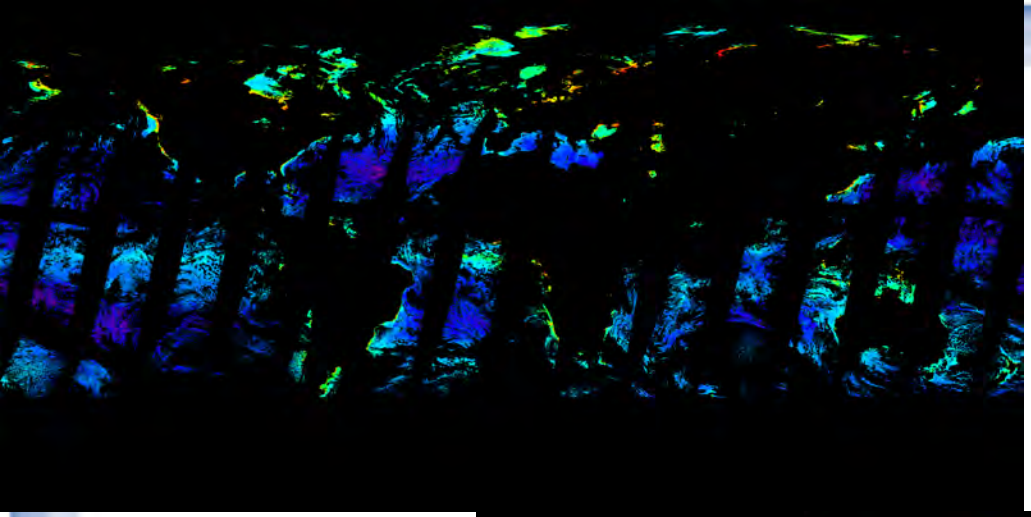


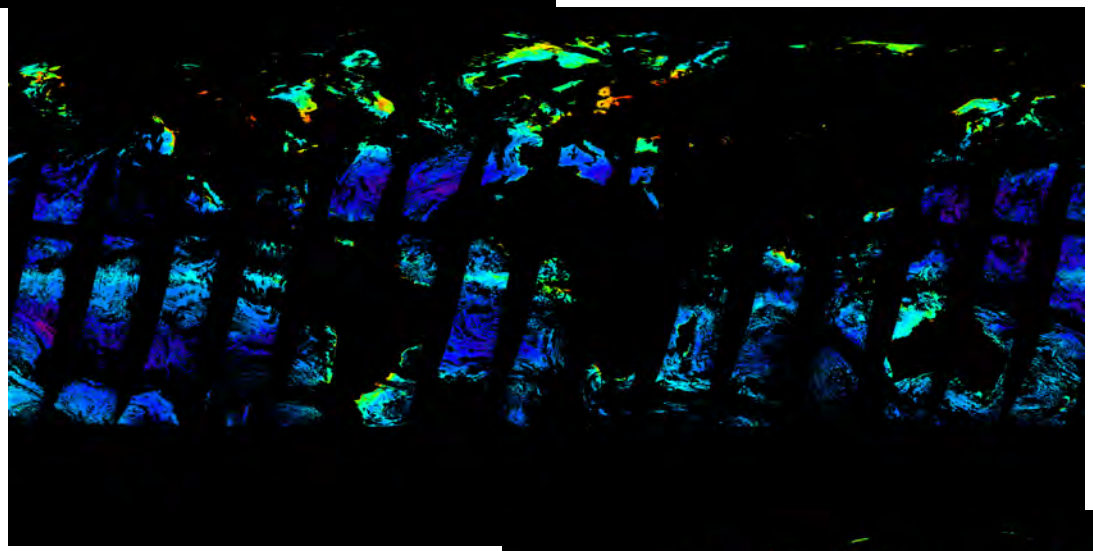
Block et al., Nature (2011)

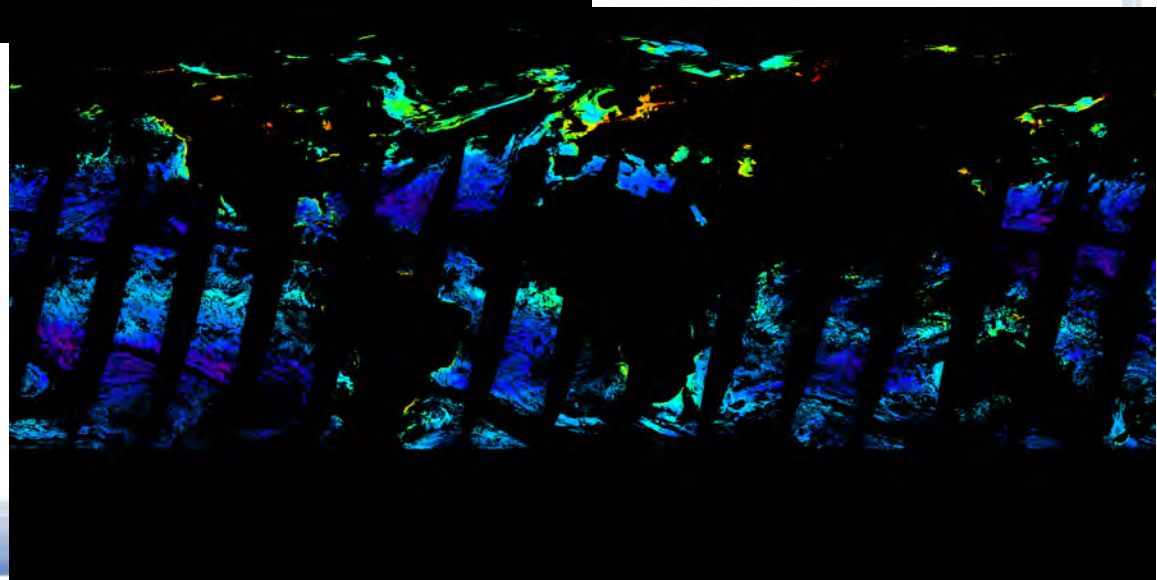
Seasonal Cycle of Hotspot



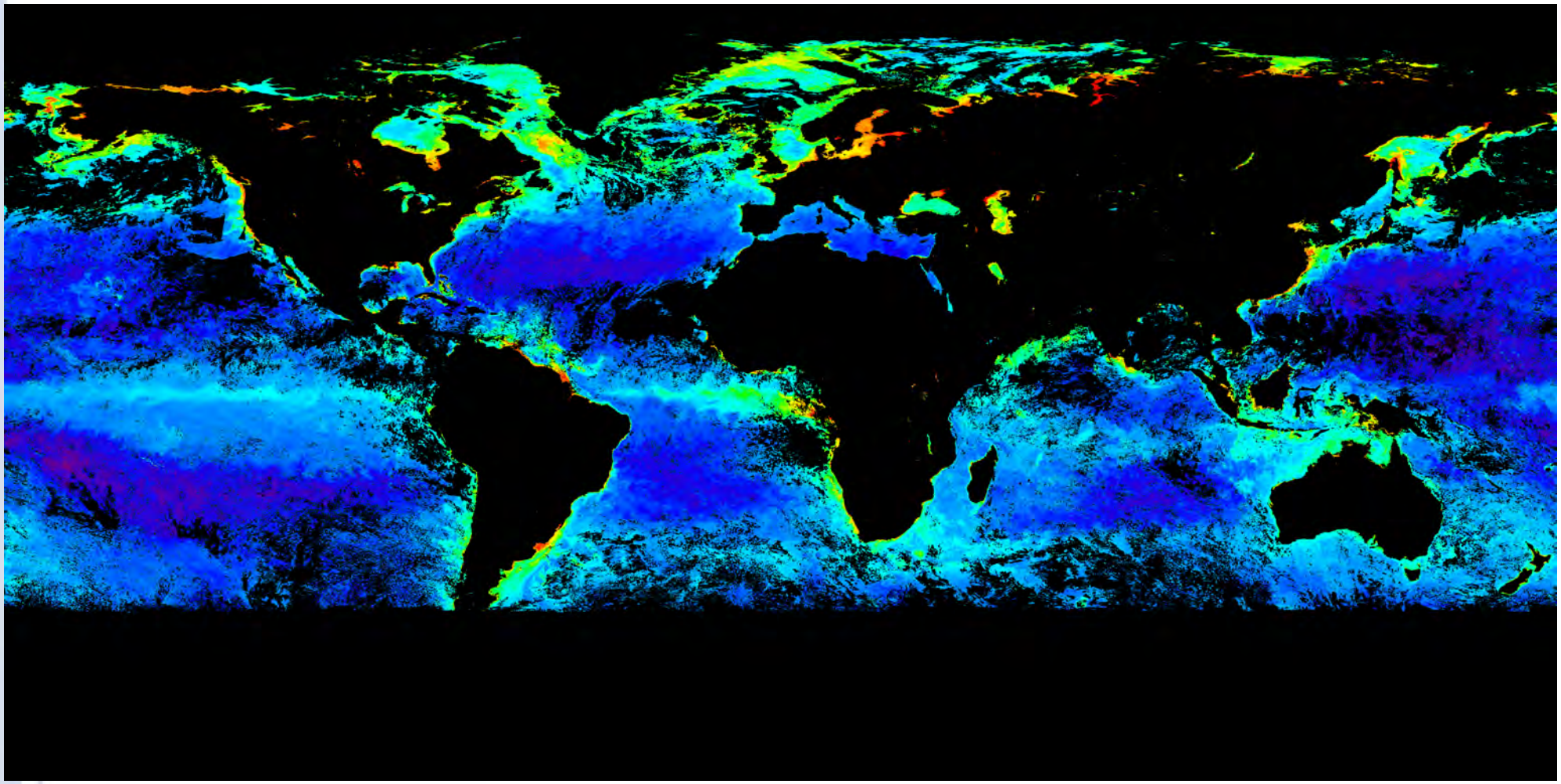
- Block et al., Nature (2011)





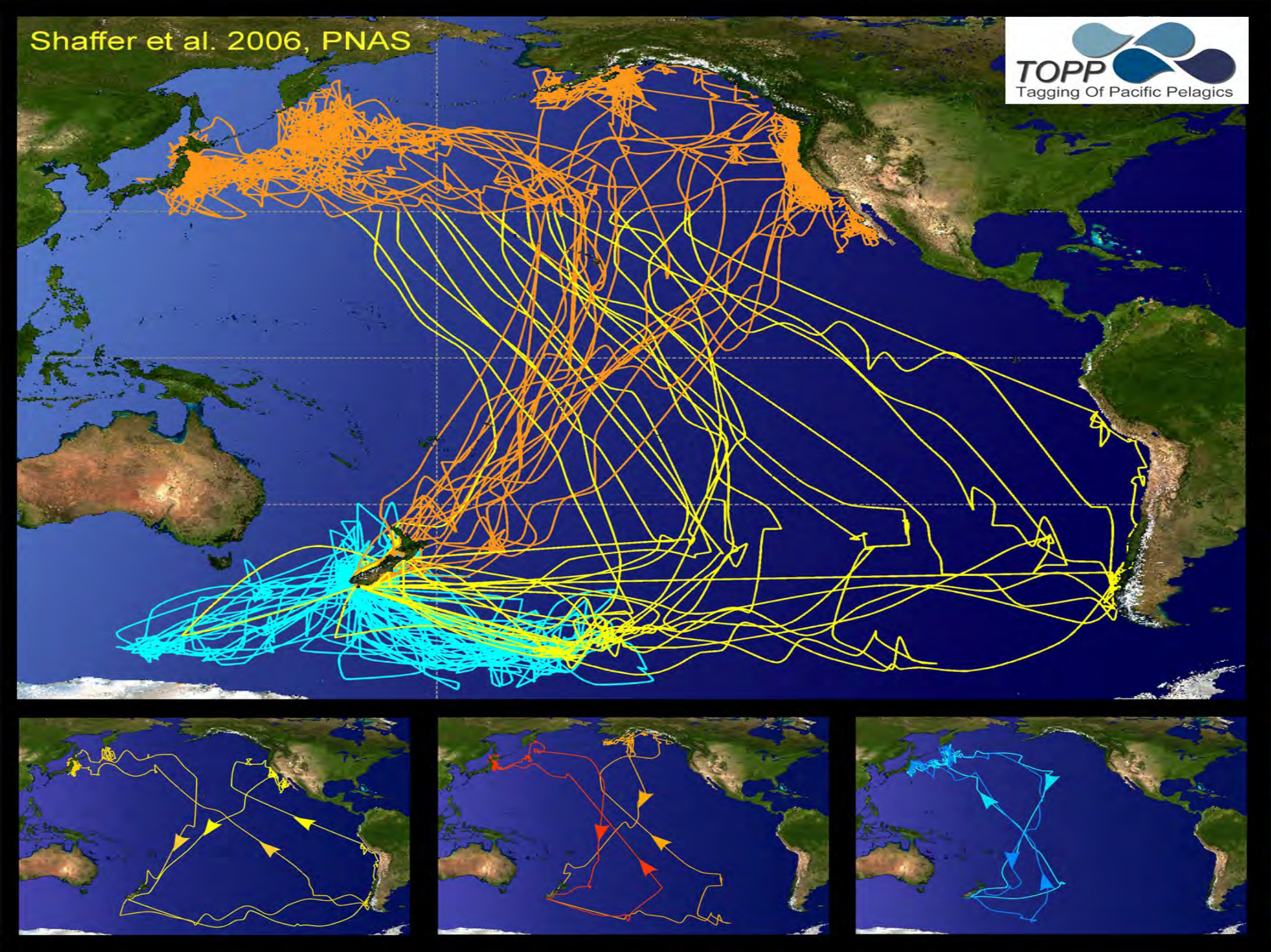


Composite (what we want to use)

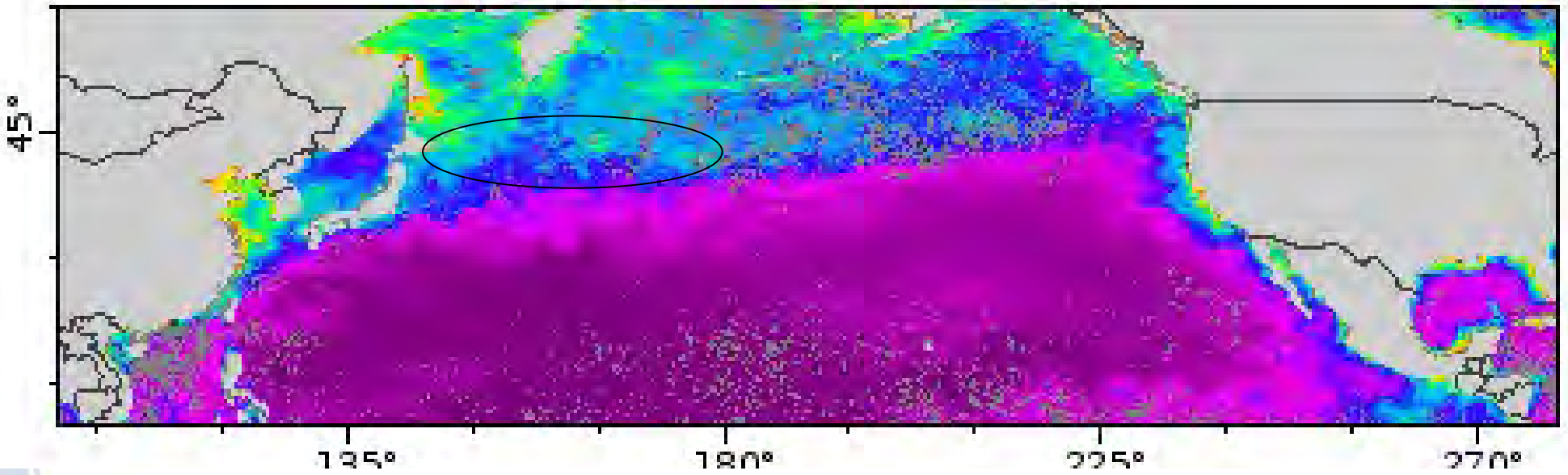


Going Beyond Chlorophyll

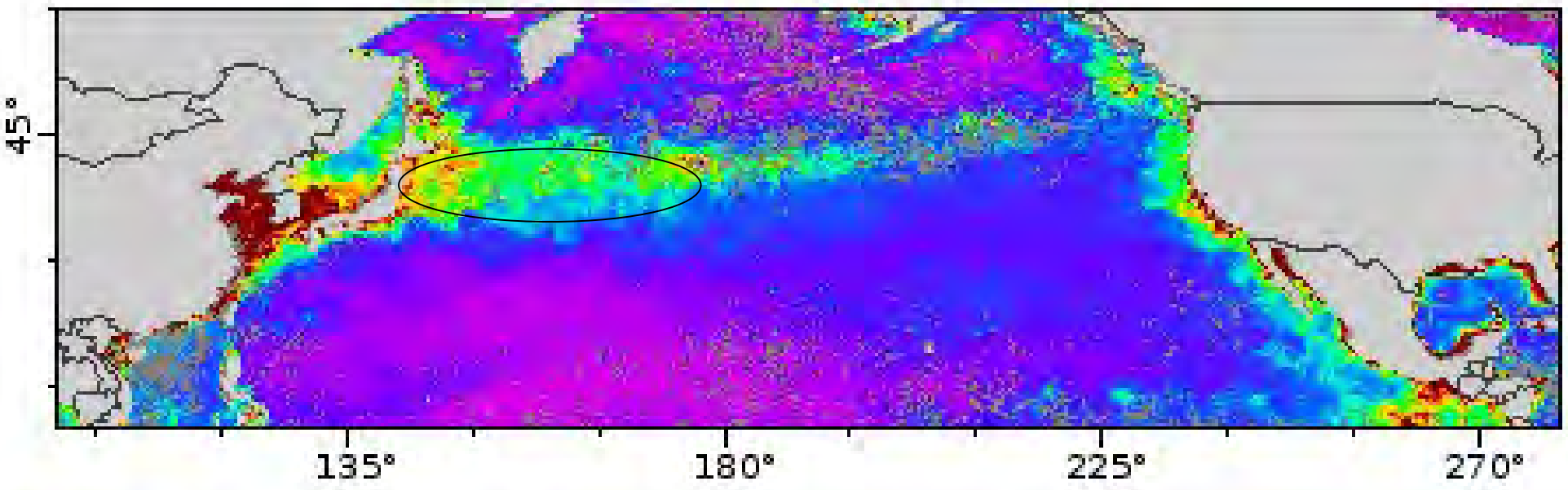
- Primary productivity
  - Chl
  - SST
  - Incident Light


Shaffer et al. 2006, PNAS
TOPP
Tagging Of Pacific Pelagics

Chlorophyll Image – Oct 2005

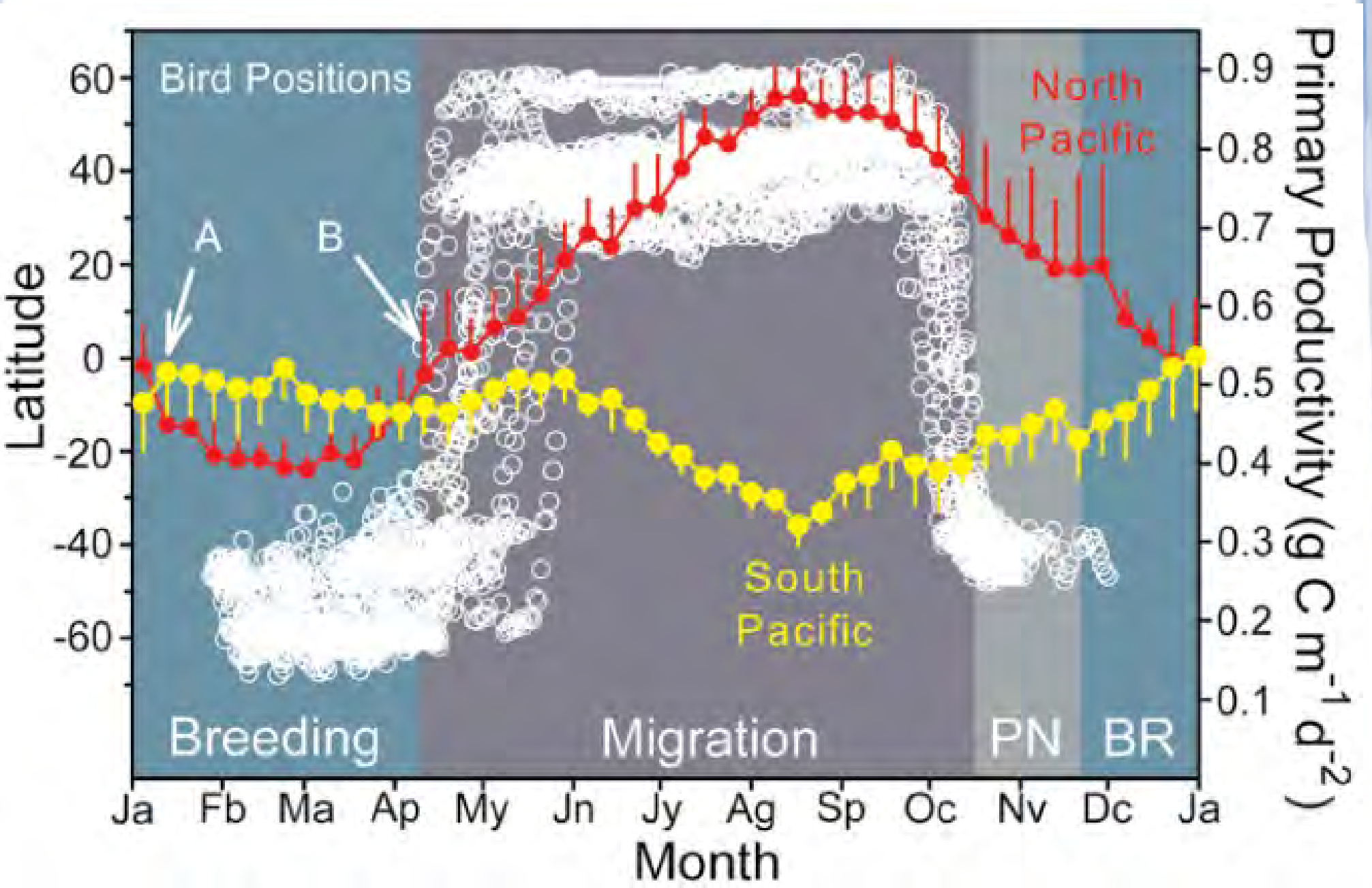


Productivity Image



NOAA CoastWatch

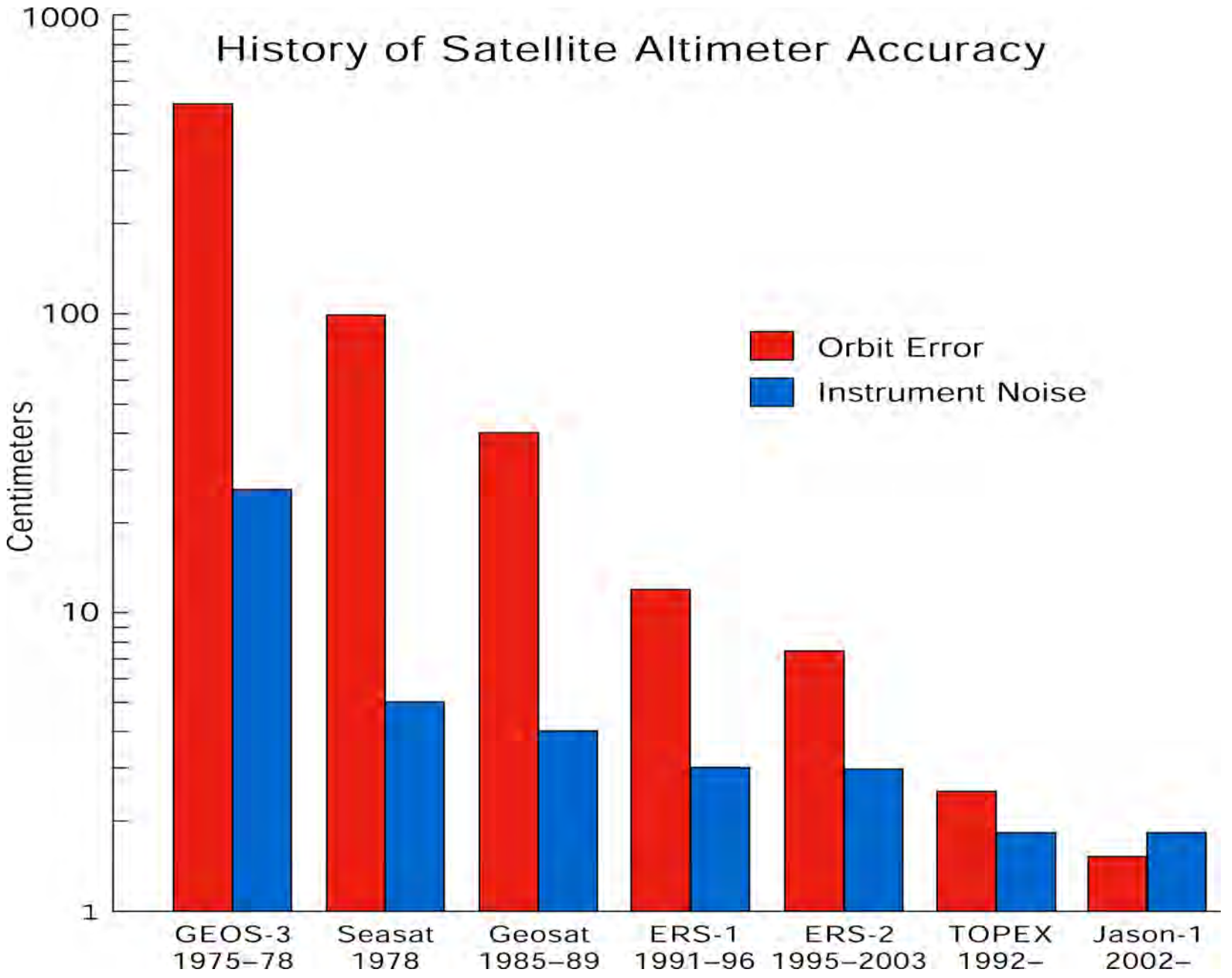
Bird Migration Linked to PP



The Immediate Future

- Frontal Indices or Gradients
- Merged Ocean Color products
- Feature ID & tracking
- Lagrangian Coherent Structure

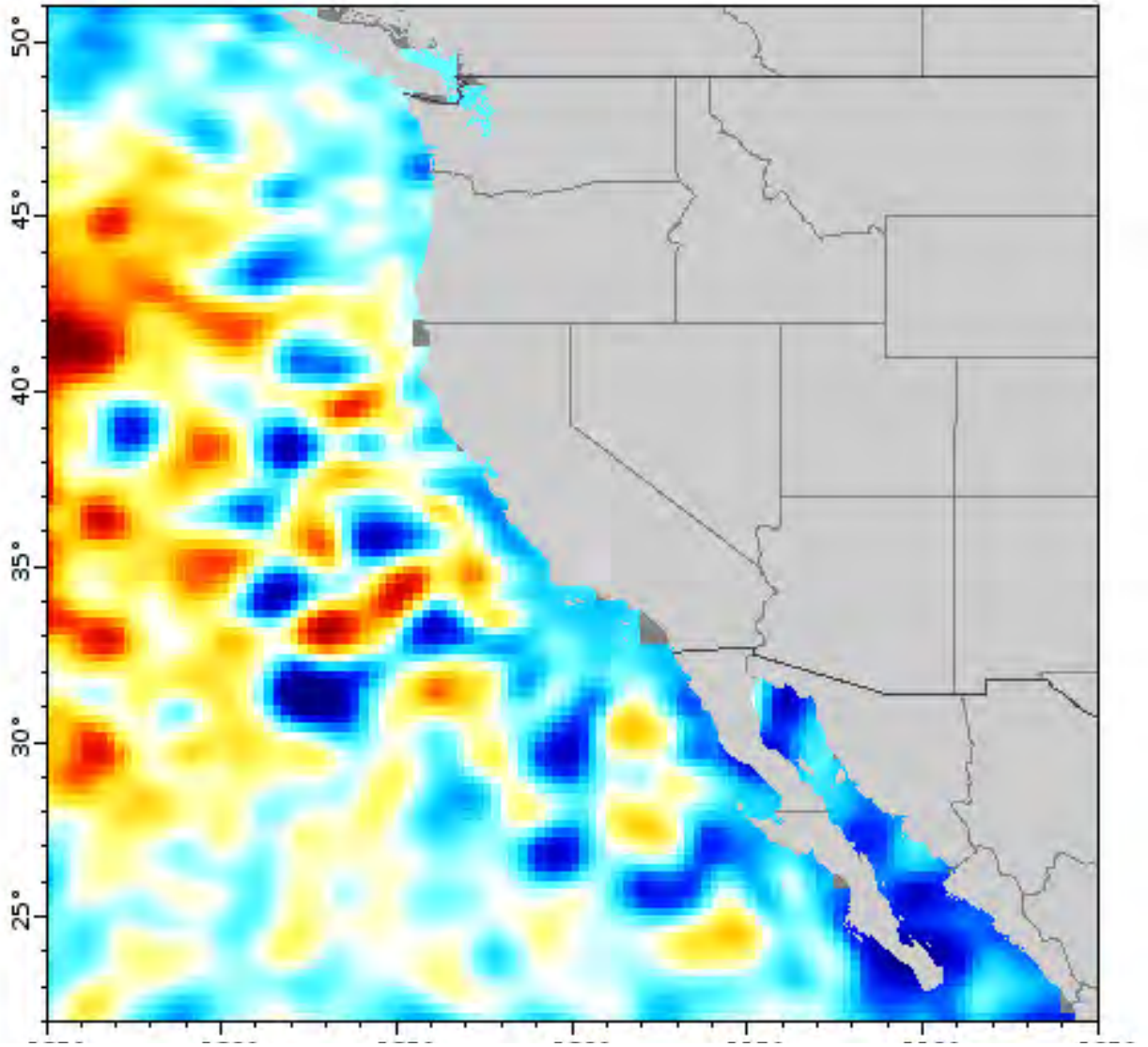
Reduction of error



Sea Surface Height Data Products

- Sea surface height “anomaly”
- Dynamic topography (actual “height”)

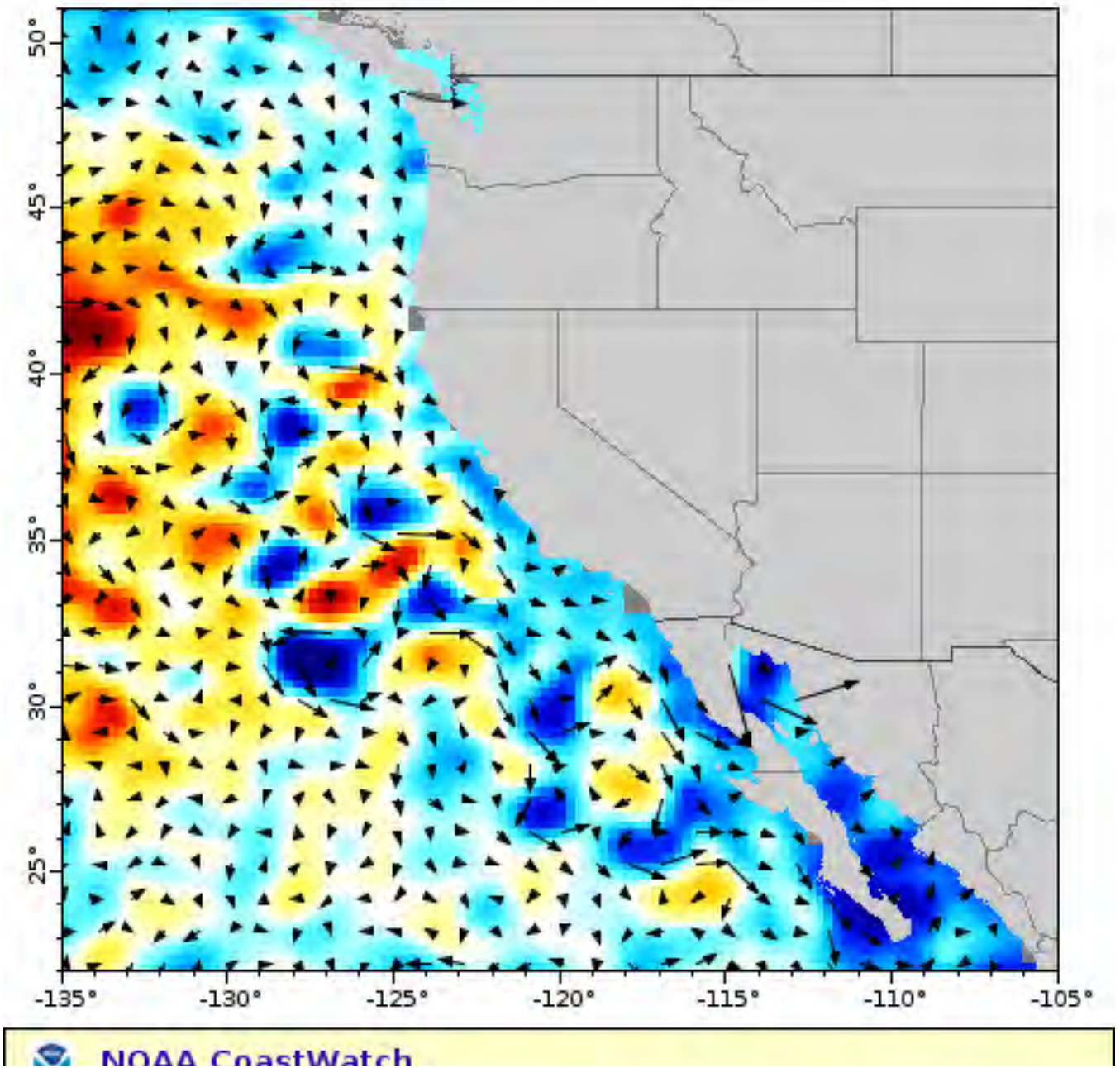
Sea Surface Height Deviation



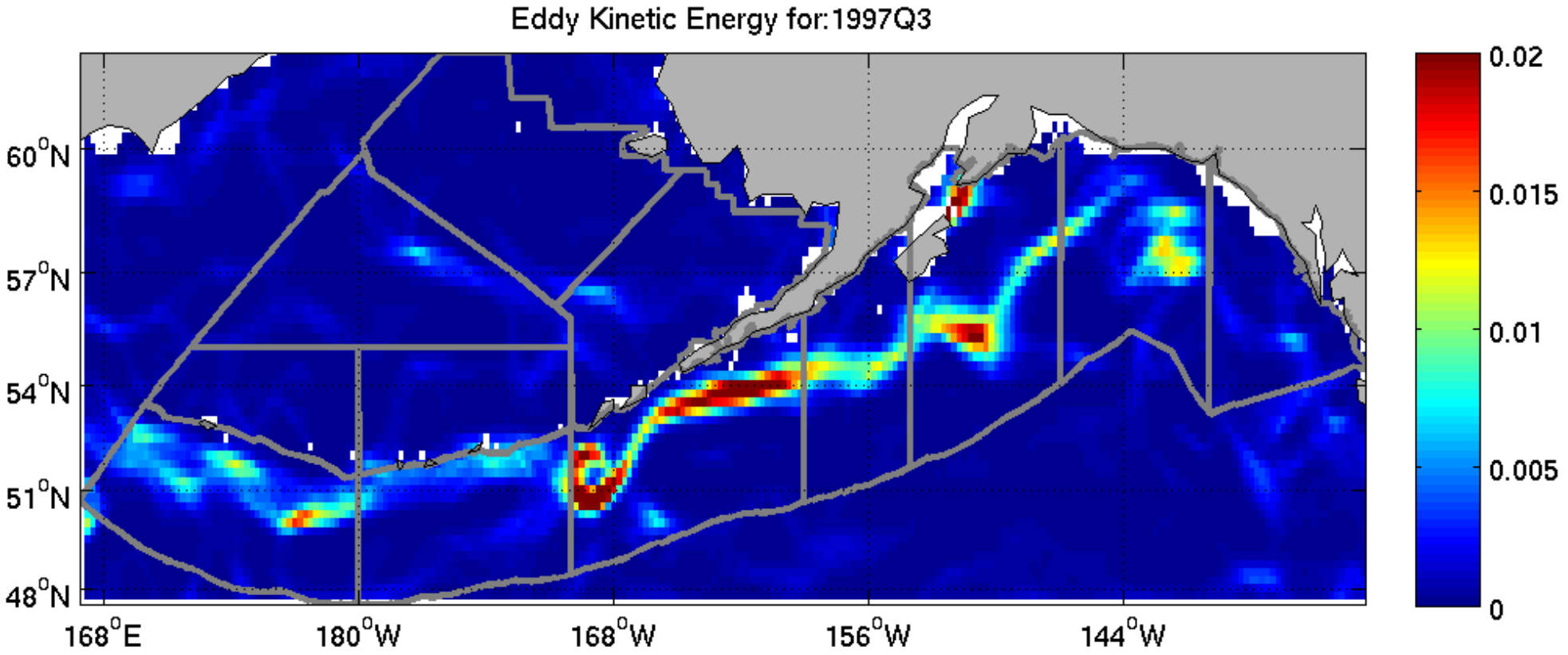
Derived Products

- Geostrophic Currents
- Eddy Kinetic Energy
- Feature ID & tracking
- Lagrangian Coherent Structures

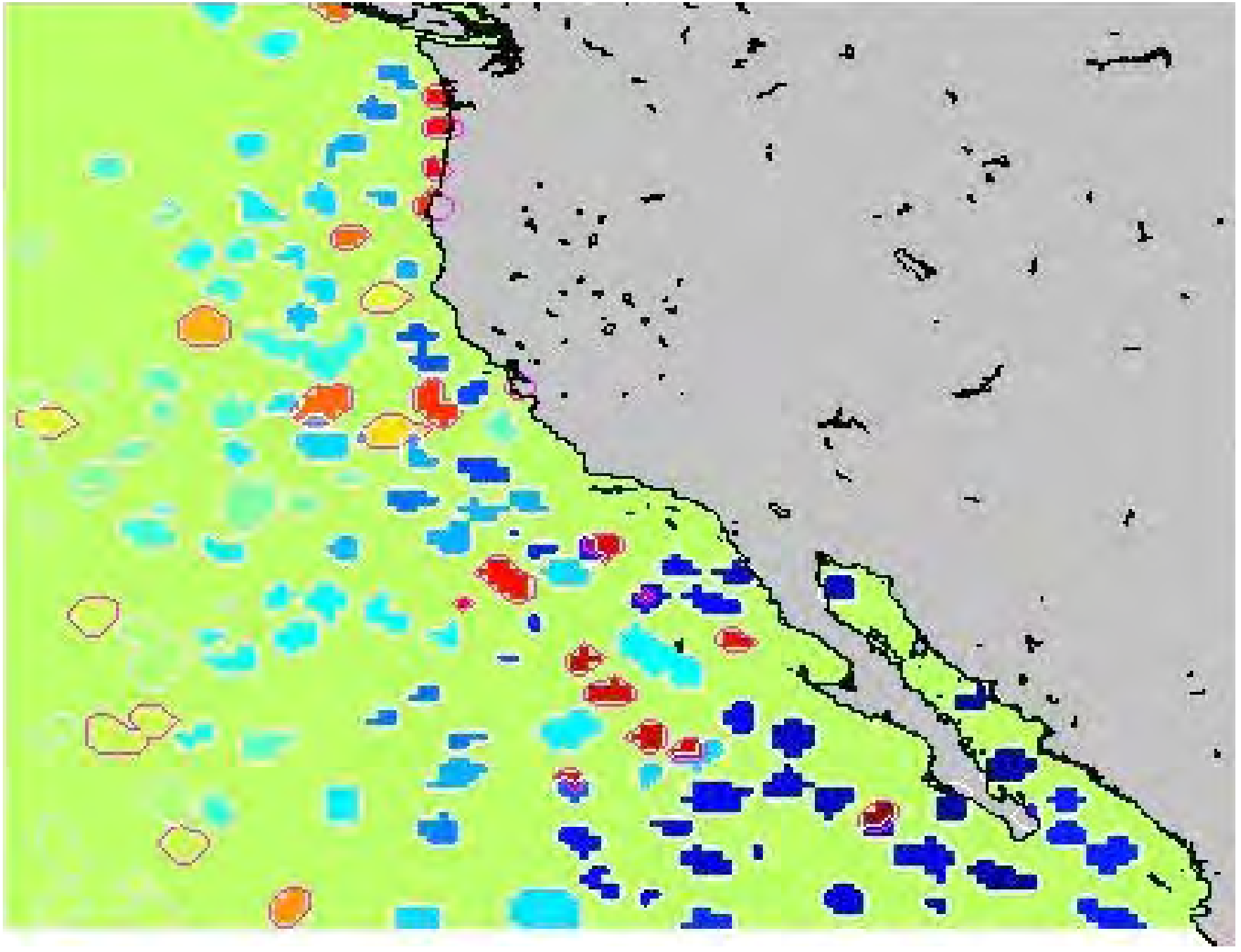
Geostrophic Currents



Eddy Kinetic Energy

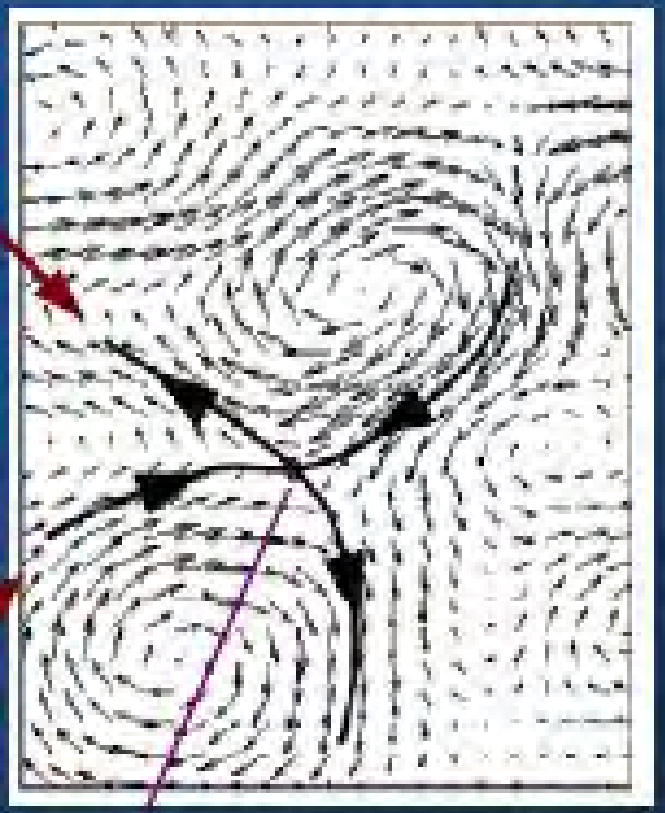


Feature Tracking - Eddies



Lagrangian Coherent Structures

Unstable Manifold



Stable Manifold

Hyperbolic point

Unstable manifolds (straining regions) can be identified as maxima in Finite-Size Lyapunov Exponents.

Unstable manifolds allow to predict structures below the resolution of the dataset because which result from the time-dependent evolution of the mesoscale flow

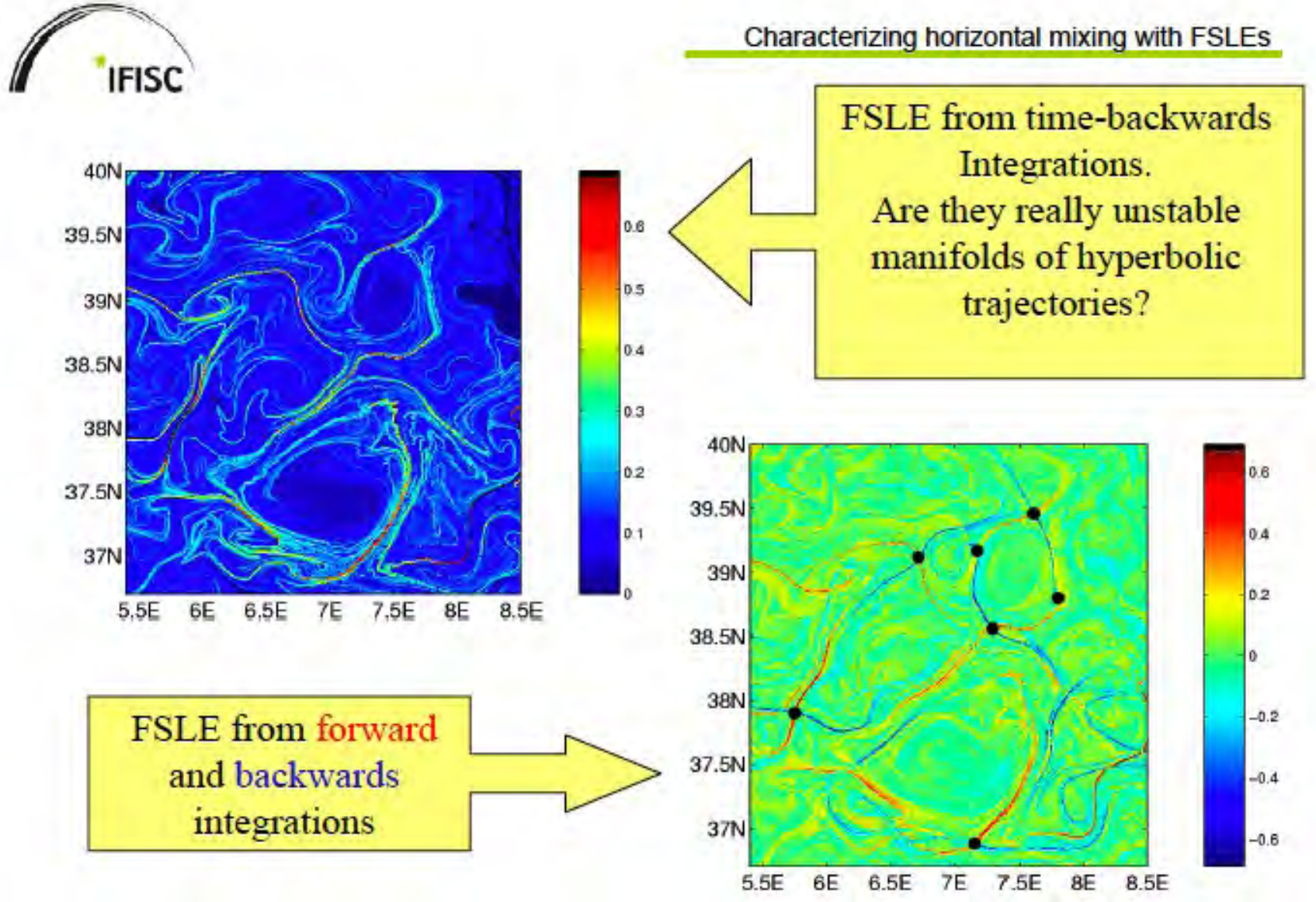
Act as transpor barriers, control the formation of fronts, exchange and mixing

$$\lambda(\mathbf{x}, t, \delta_0, \delta_f) \equiv \frac{1}{\tau} \log \frac{\delta_f}{\delta_0}.$$

deltaf=60km
delta0=0.01km

Courtesy of Paulo Calil, University of Hawaii

Characterizing These Zones: Lyaponuv



Application of LCS: Frigate Birds

Satellite transmitter and altimeter
(total weight : 1 to 3% mass of adults, max 45g)

8 birds (from Europa Island community) fitted with satellite transmitter and altimeter.

Followed for their foraging trips from August 18 to September 30, 2003.

1600 Argos from 50 trips positions, distributed into 17 long trips (> 614 km) and 33 short trips.

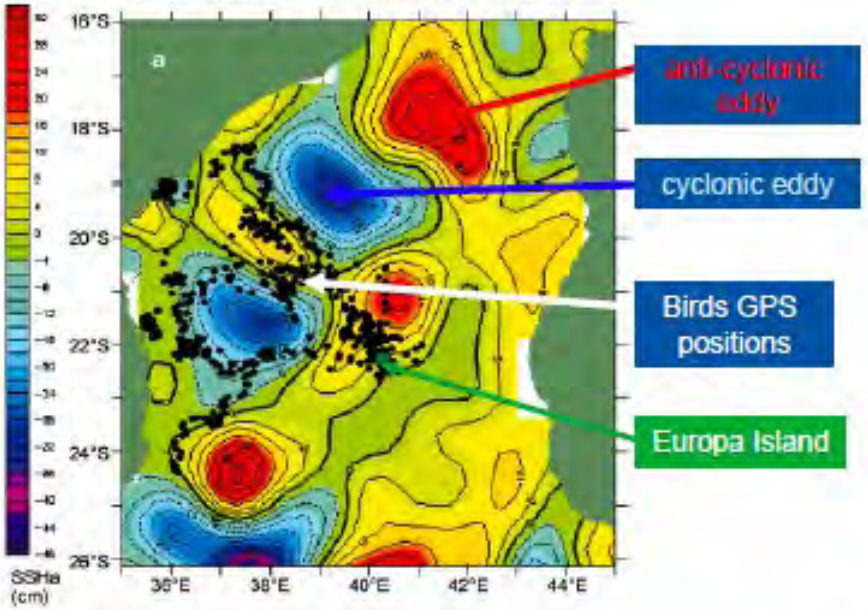
(Weimerskirch et al., 2004)

Foraging Trips - Submesoscale

IFISC

Frigatebirds and FSLE

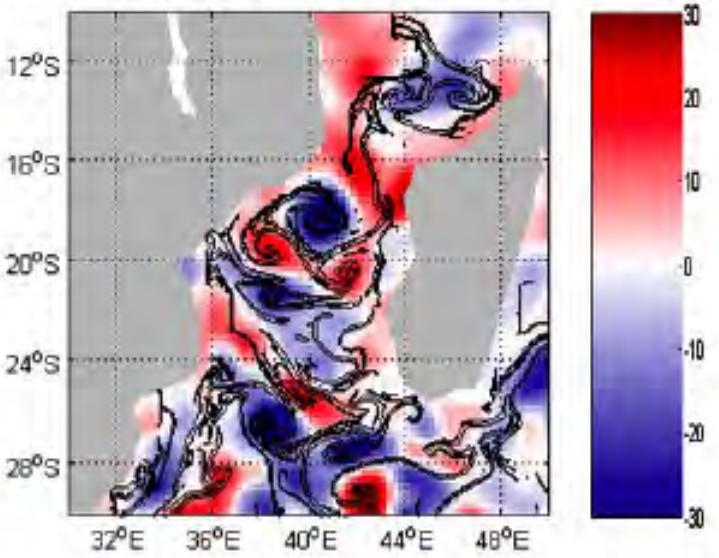
SSH (cm): Eulerian view



Weimerskirch et al,2004

Lagrangian FSLEs versus SSH

Overlay SLA-FSLE (backward) week of 27/08/2003



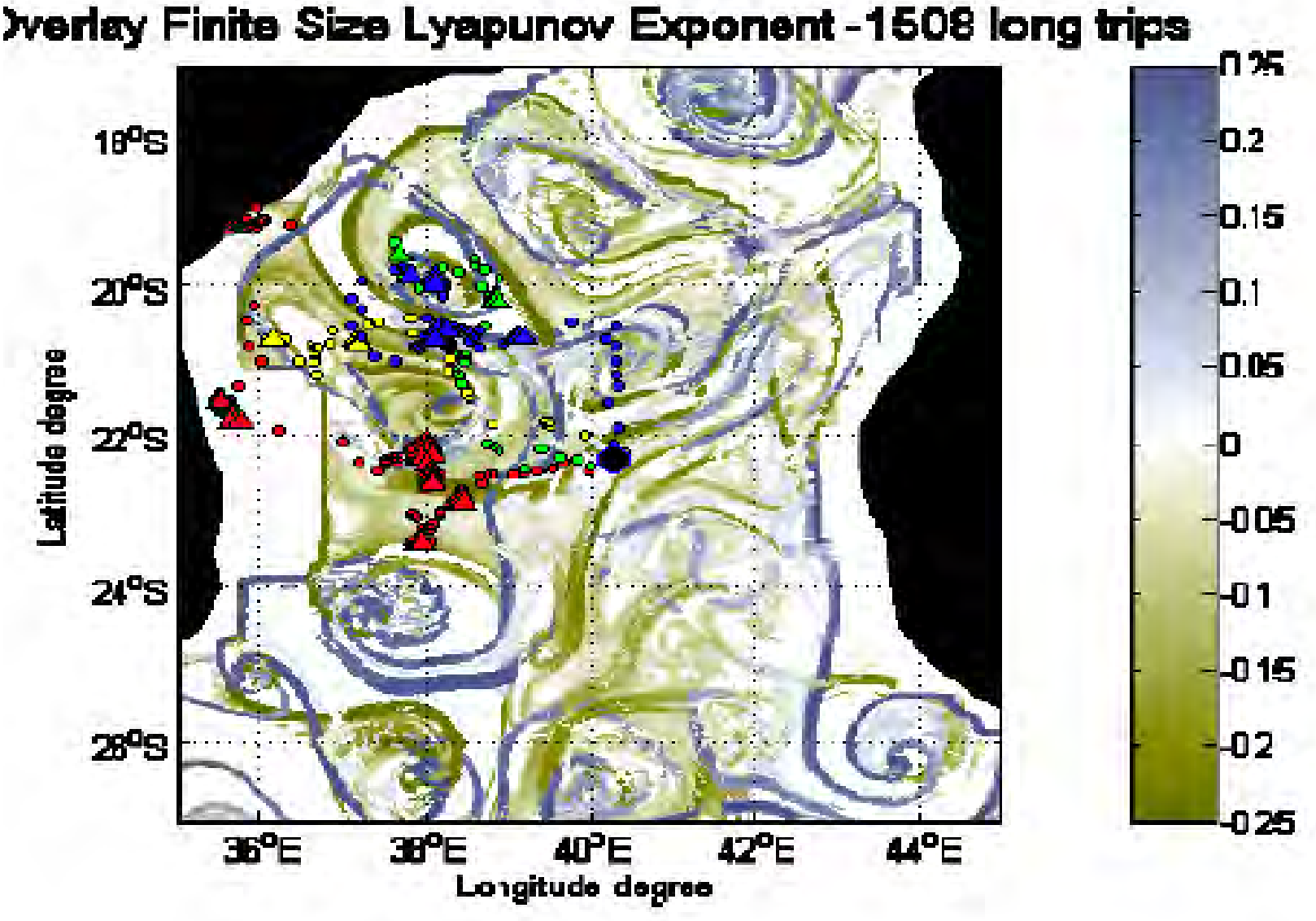
Sub-mesoscale: spatial resolution of FSLE: 2.5km

Dayly surface currents at ¼ degree resolution
from altimetry+scatterometter+mean topography

The Lagrangian FSLE gives access to submesoscale structures

Lagrangian Coherent Structures: $|FSLE| > 0.1\ day^{-1}$

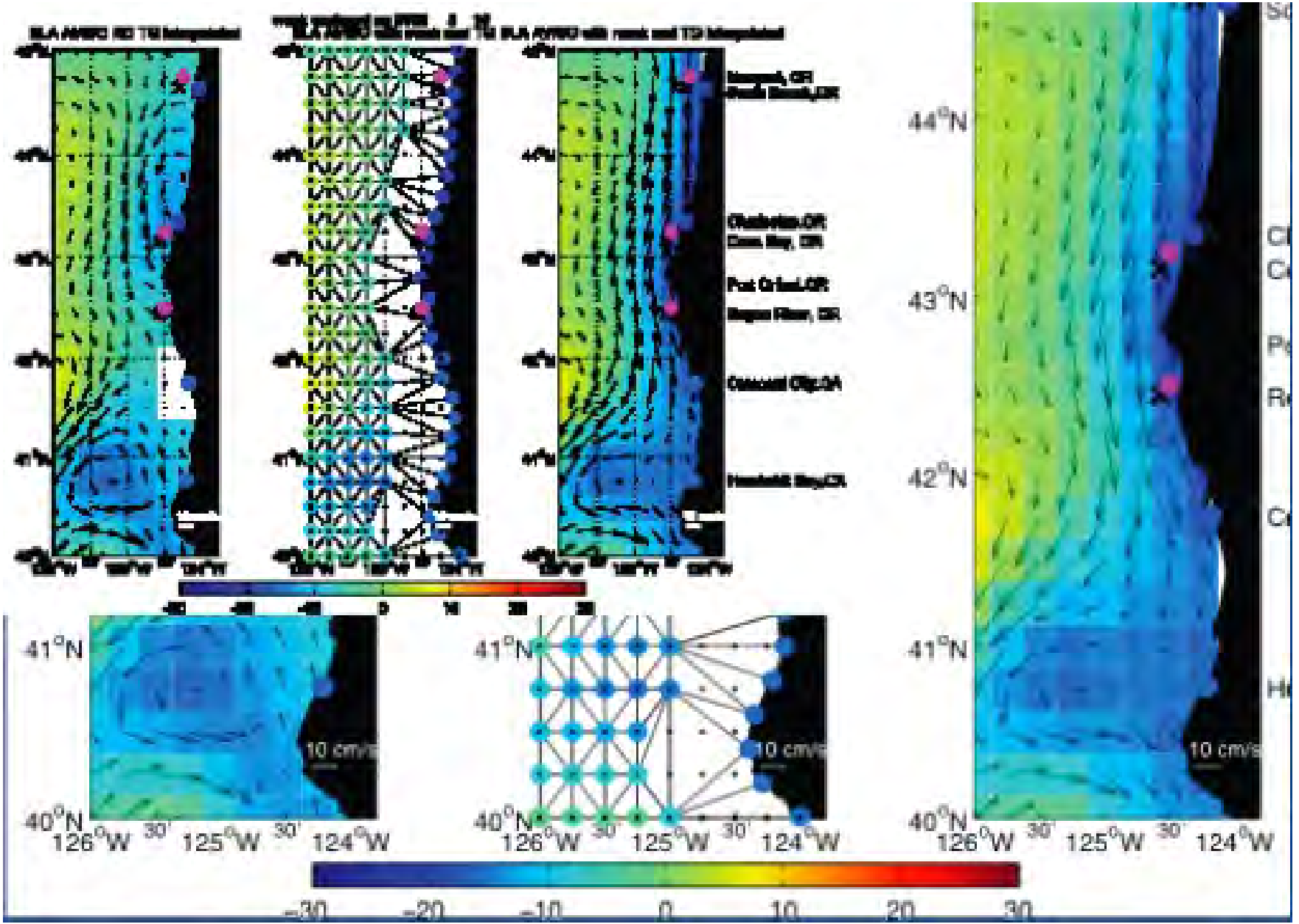
Bird Foraging Locations and FSLE



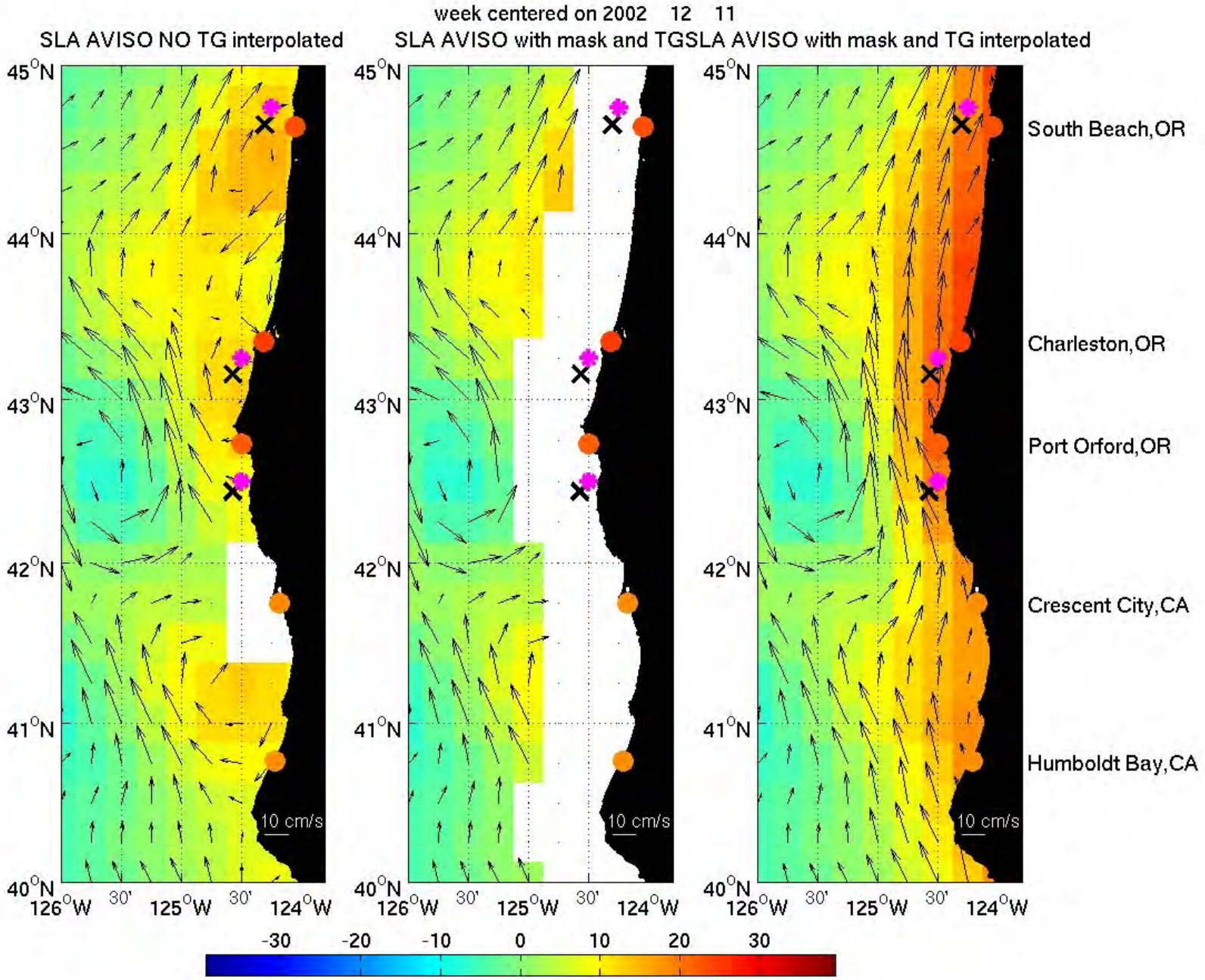
New Tricks

- Approaching the coast
  - Merge altimeter with tide gauges
  - Re-track altimeter data
- Inland Waterways
  - Bays
  - Estuaries
  - Large Rivers
- Synoptic measurements by SWOT

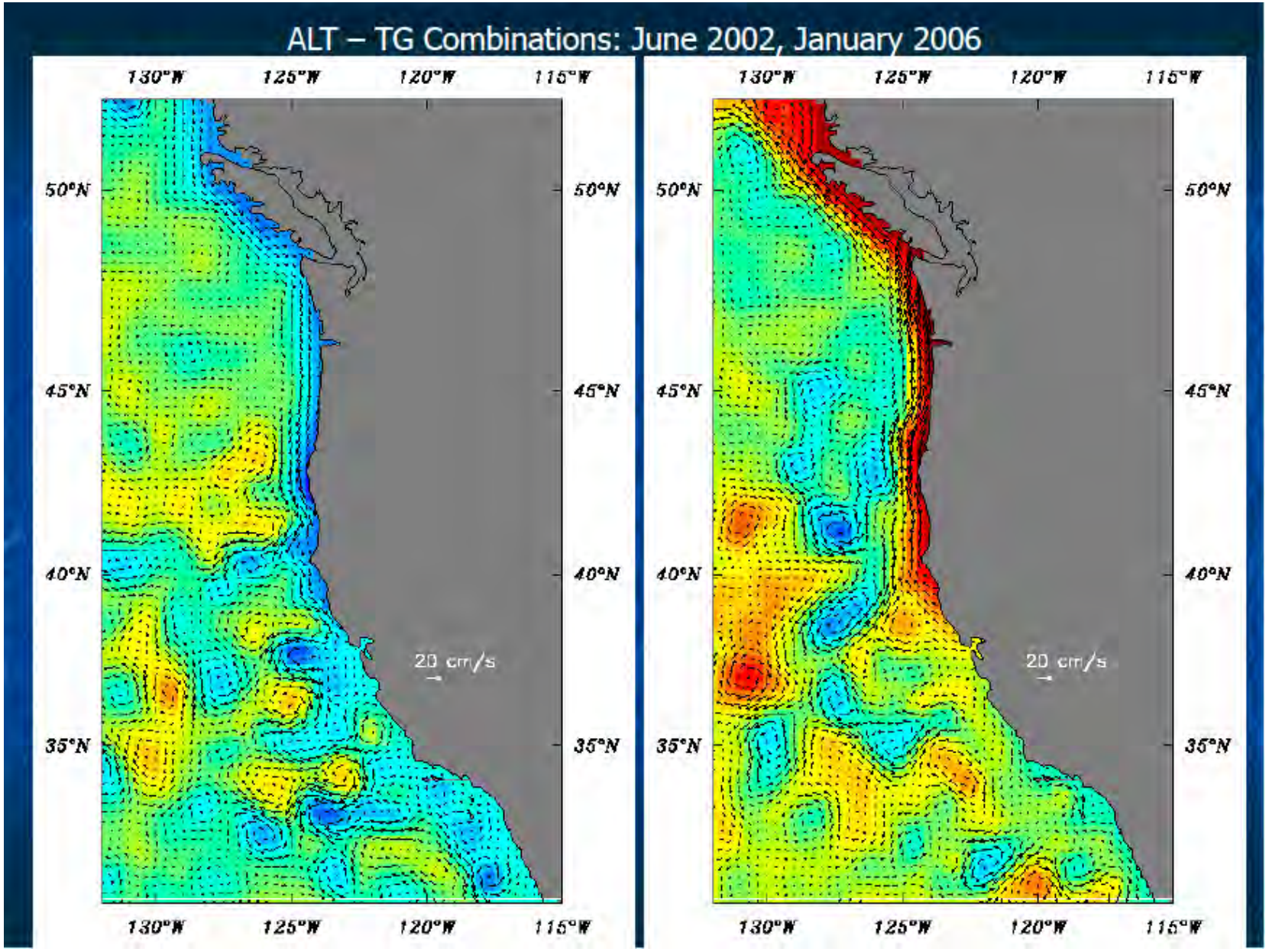
Process of Merging Data Sets



Comparison of SSH Products



End Product for TG+ALT



Reciprocation: Ground Truth

- Animals go places where there is little ground truth
- Will eventually be an element of the calibration and validation for past and future sensors.

Really Modern Autonomous Platforms

Body Size: 2.5 to 3.0 kg

Pop Center: NWHI

Est. Pop.: 590,000 pairs

Status: Vulnerable

Body Size: 3.0 to 3.5 kg

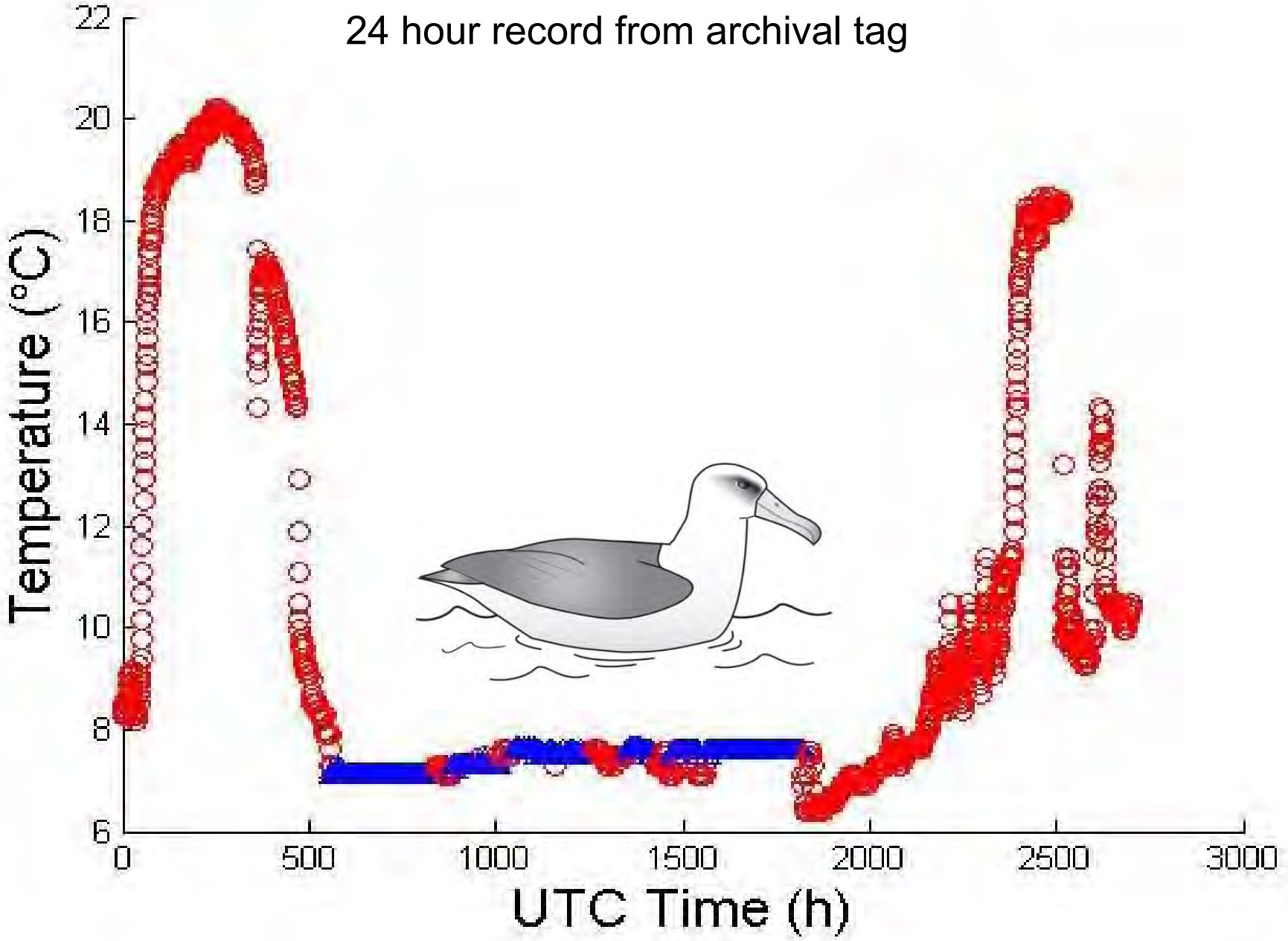
Pop Center: NWHI

Est. Pop.: 61,000 pairs

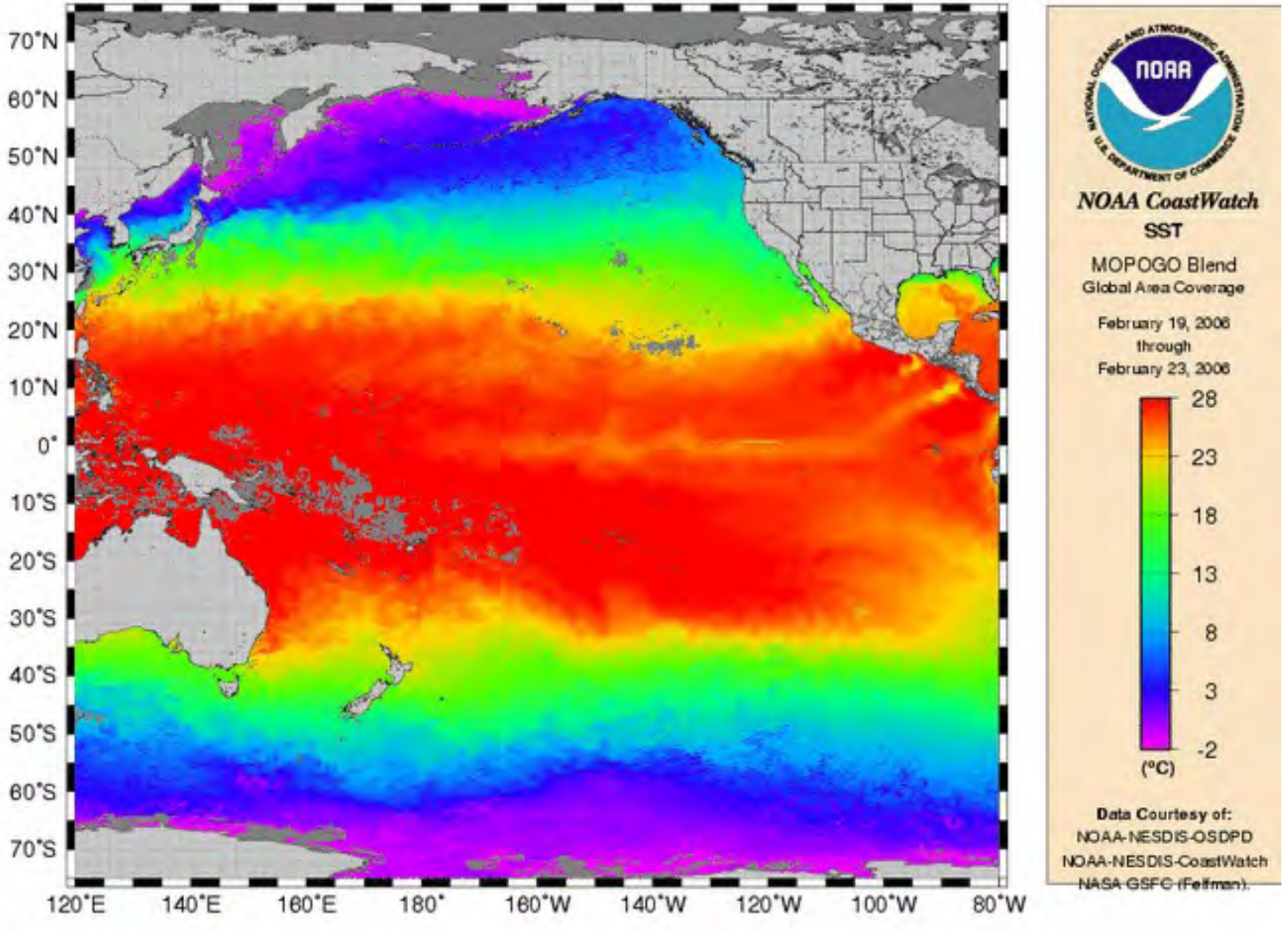
Status: Threatened

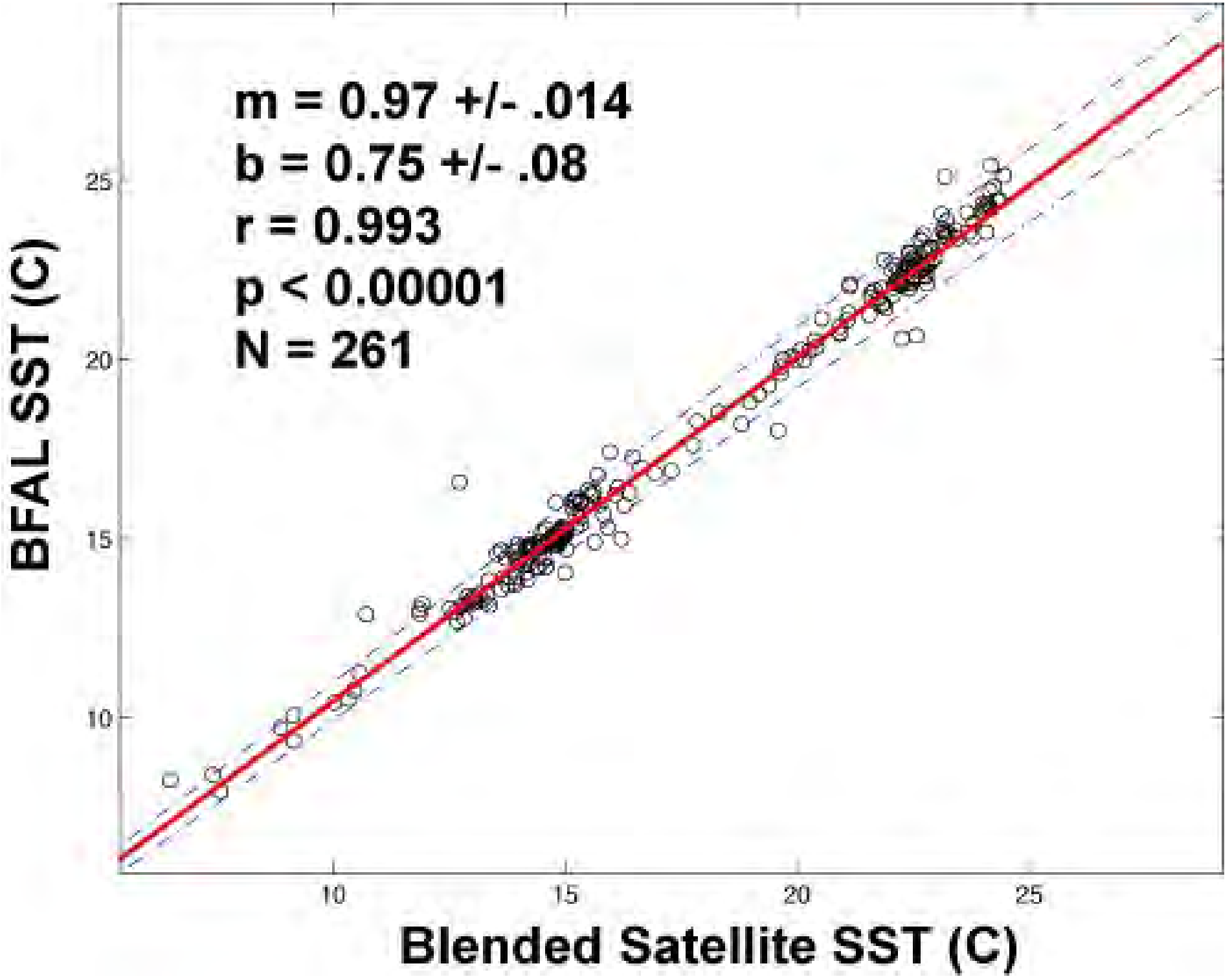
Bird Derived SST's

24 hour record from archival tag



Blended SST (5-day)



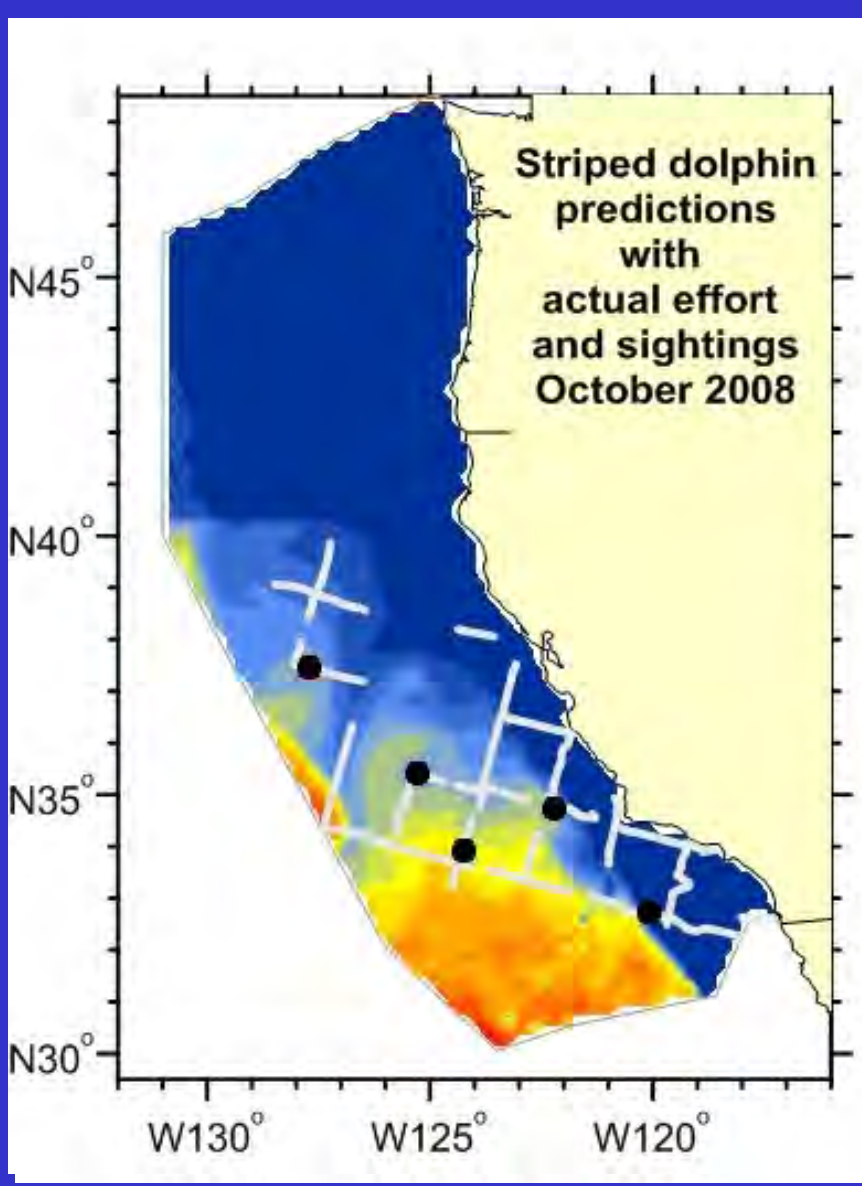

m = 0.97 +/- .014
b = 0.75 +/- .08
r = 0.993
p < 0.00001
N = 261
BFAL SST (C)
Blended Satellite SST (C)
10
15
20
25

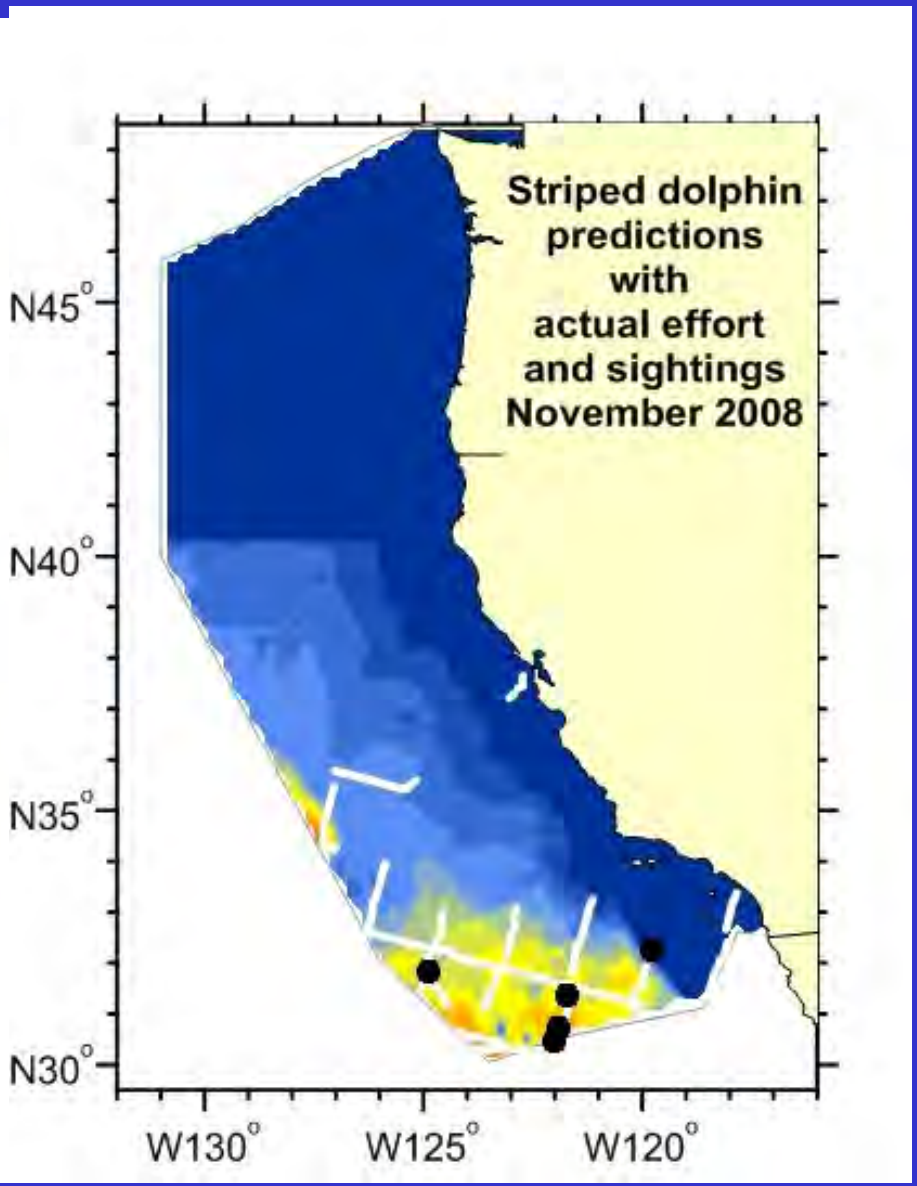
The Near Future

- Models (hindcast)
- Models (nowcast)
- Models (forecast)

FORECAST – Striped dolphin density

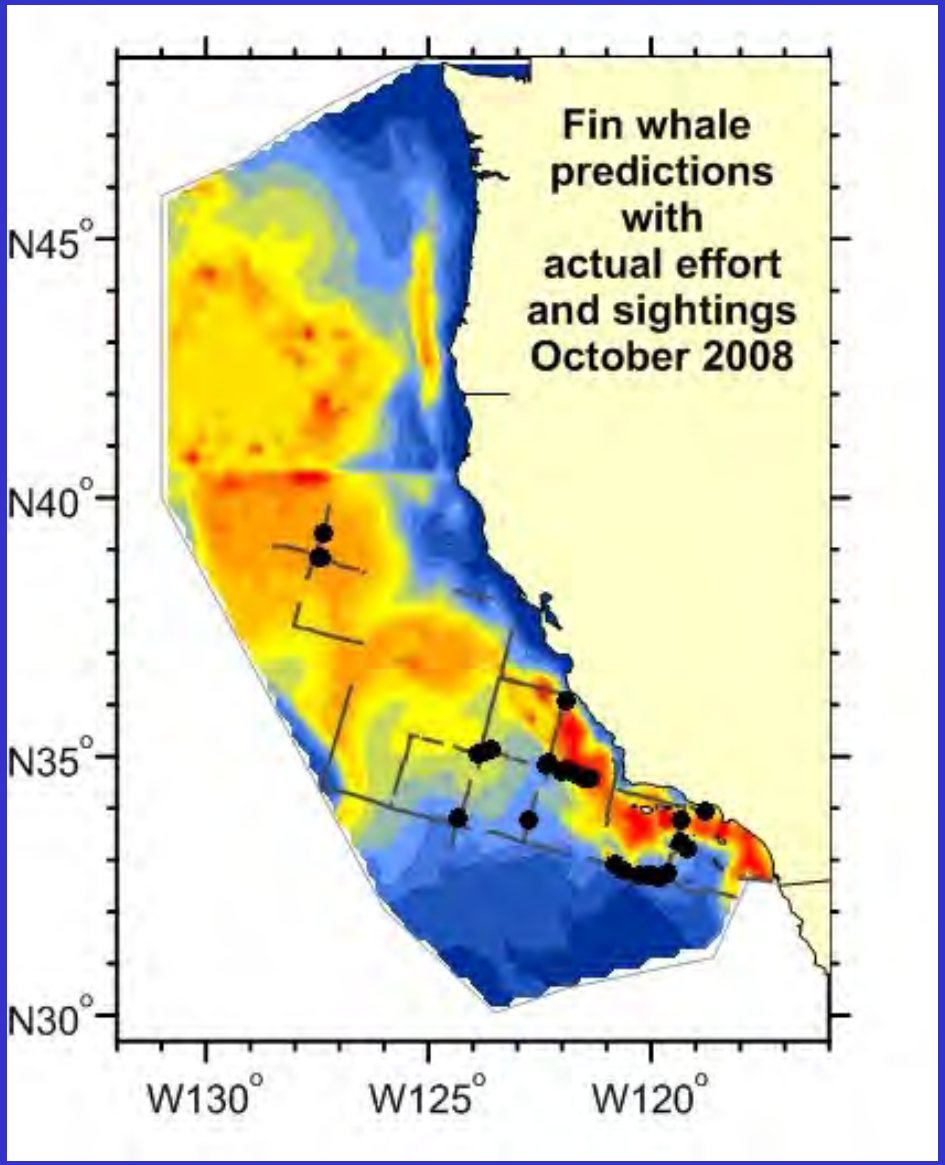
ROMS: July 2008 predictions for Oct/Nov 2008

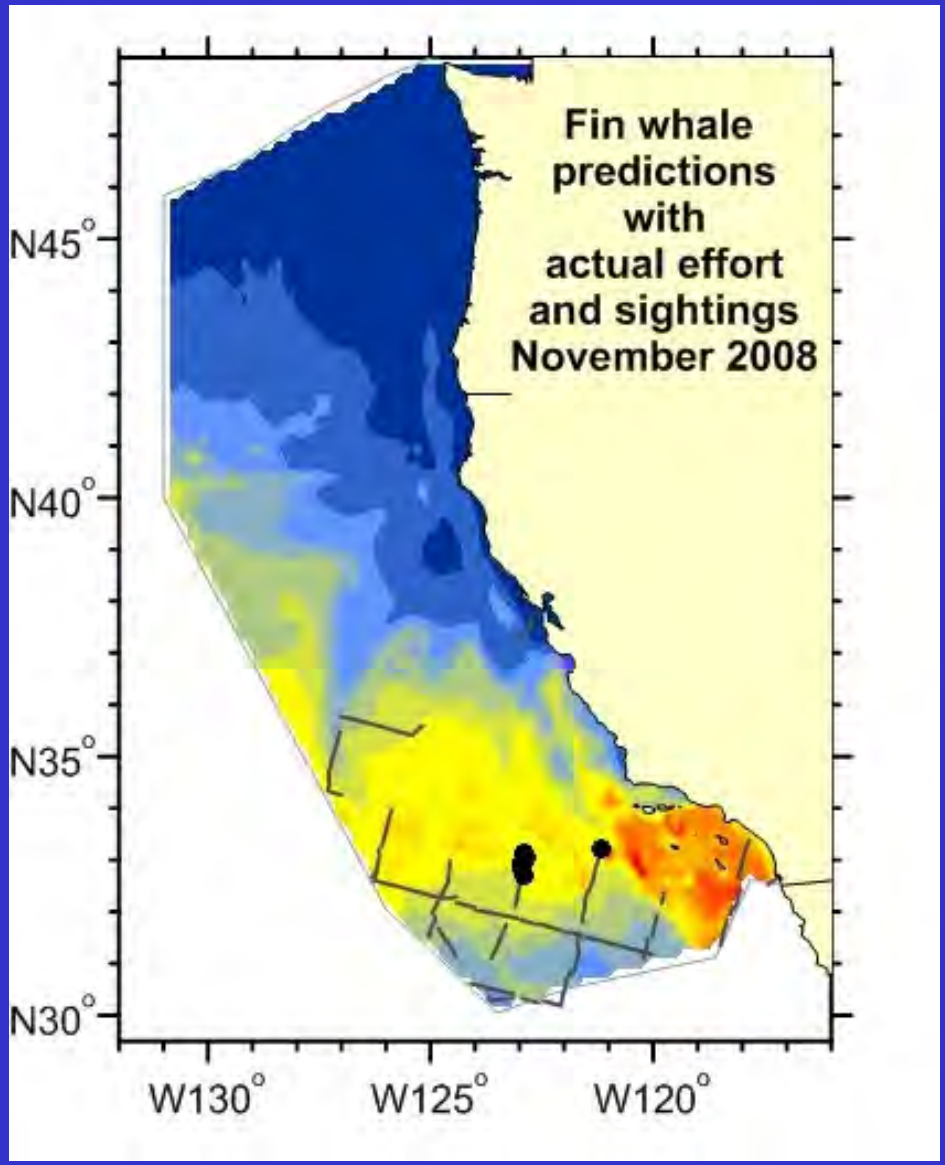




FORECAST – Fin whale density

ROMS: July 2008 predictions for Oct/Nov 2008





Contact Info:

Dave Foley
NOAA/SWFSC/ERD
1352 Lighthouse Ave.
Pacific Grove, CA 93950 USA

dave.foley@noaa.gov

coastwatch.pfel.noaa.gov
coastwatch.pfel.noaa.gov/erddap
oceanwatch.pfel.noaa.gov