



National Aeronautics and  
Space Administration



## ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>



@NASAARSET

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# Introduction to Remote Sensing for Ocean and Coastal Applications

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## Week 3: Animal Movement and Migration

# Course Structure

- One lecture per week – every Wednesday July 6 – July 27
- 1:00 – 2:00 PM EDT (UTC-4)
  - Lectures
  - In-class demonstration
  - Homework exercises, due August 10th
- Webinar recordings, presentations, and homework assignments can be found after each session at:
  - <http://arset.gsfc.nasa.gov/land/webinars/coastal-oceans-2016>
- Q/A: Following each lecture and/or by email ([sherry.l.palacios@nasa.gov](mailto:sherry.l.palacios@nasa.gov))

# Accessing Course Materials

<http://arset.gsfc.nasa.gov/land/webinars/coastal-oceans-2016>

**ARSET**  
Applied Remote Sensing Training

Earth Sciences Division Applied Sciences ASP Water Resources

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## Introduction to Remote Sensing for Coastal and Ocean Applications

**Dates:** Wednesday, July 6, 2016 to Wednesday, July 27, 2016  
**Times:** 1:00-2:00 p.m. EDT (UTC-4)  
**Registration Closes:** Tuesday, July 5, 2016

**Land Management**

**Land Webinars**

**Upcoming Training**

**Disasters**

**Using NASA Remote Sensing for Disaster Management**  
06/09/2016 to 06/30/2016

**Airquality**

**Fundamentals of Satellite Remote Sensing for Health Monitoring**  
06/02/2016 to 06/30/2016

## Course Agenda:

[Agenda.pdf](#)

### Session One: Overview of Satellite Remote Sensing of Aquatic Environments

July 6, 2016

An overview of themes in coastal and ocean applied science, how remote sensing is used for coastal and ocean applied science, fundamentals of remote sensing (spatial, temporal, spectral resolutions), and the advantages and limitations of remote sensing in aquatic environments. View the recording »

- [Presentation Slides](#) »

### Session Two: Platforms and Sensors for Ocean Observations, Data Access, and Processing Tools

July 13, 2016

Satellites and sensors for coastal and ocean applications, satellite data processing levels, NASA satellite data access tools and data processing tools. View the recording »

- [Presentation Slides](#) »

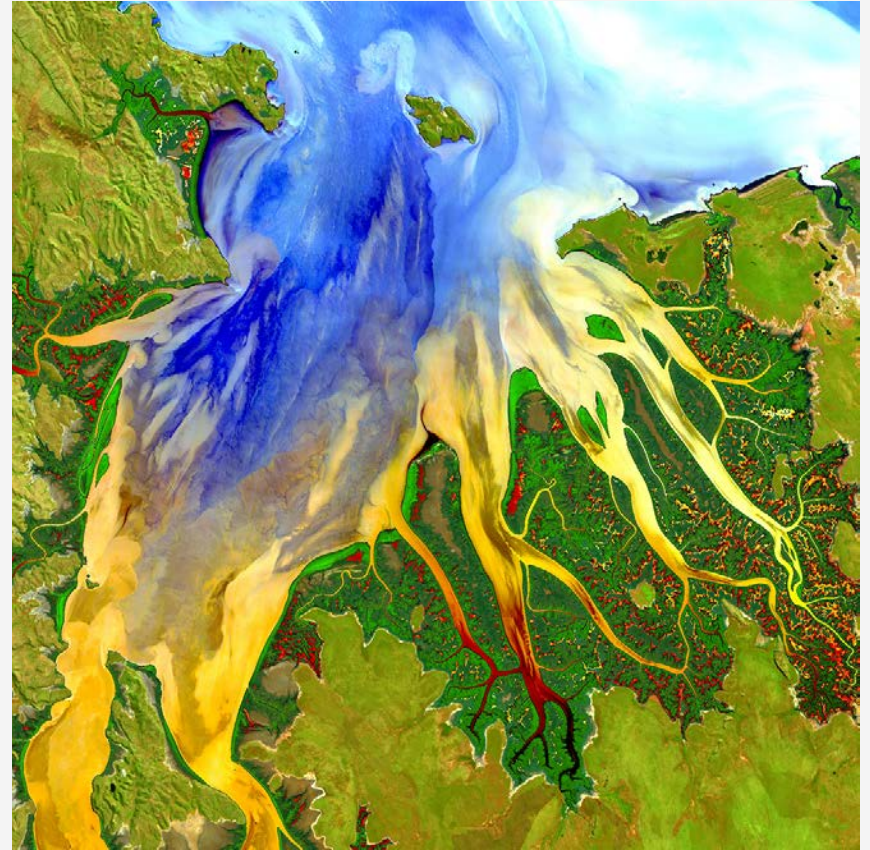
# Your Course Instructors

- Sherry Palacios: [sherry.l.palacios@nasa.gov](mailto:sherry.l.palacios@nasa.gov)
- Amber McCullum: [amberjean.mccullum@nasa.gov](mailto:amberjean.mccullum@nasa.gov)
- Cindy Schmidt: [cynthia.l.schmidt@nasa.gov](mailto:cynthia.l.schmidt@nasa.gov)
- Guest Speakers:
  - Mitchell Roffer, Roffer's Ocean Fishing Forecast Service (Week 3)
  - Mark Eakin, NOAA Coral Reef Watch (Week 4)
- General ARSET Inquiries
  - Ana Prados: [aprados@umbc.edu](mailto:aprados@umbc.edu)



# Course Objectives

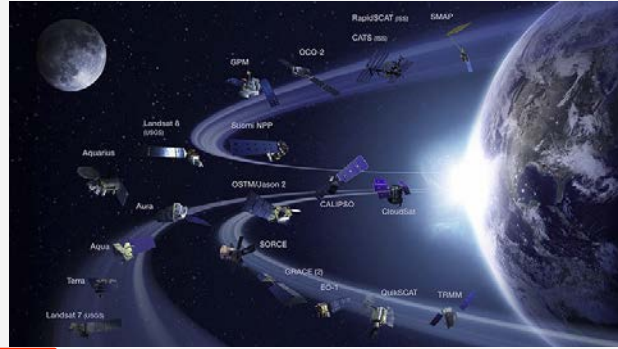
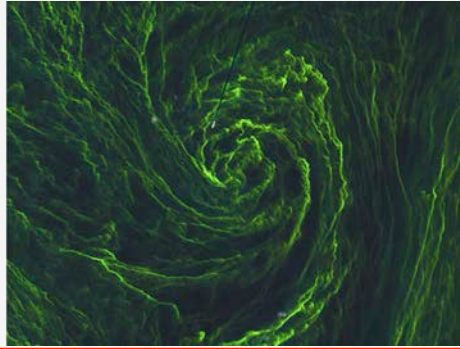
- Overview of NASA Earth Observation resources available for open ocean and coastal applications including:
  - A basic understanding of remote sensing of aquatic systems
  - How to access and visualize NASA Earth science data
  - How to use NASA Earth science data, tools, and products for ocean and coastal applied science issues
- Conduct live demonstrations of useful ocean and coastal applied science tools



Credit: NASA/USGS Landsat; Geoscience Australia

# Course Outline

## Week 1 Overview of Satellite Remote Sensing

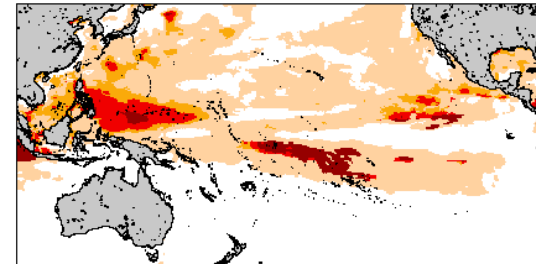


## Week 2 Platforms and Sensors for Ocean Observations

## Week 3 Animal Movement



2016 May 17 NOAA 90% Probability Bleaching Thermal Stress for May–Aug 2016  
Experimental, v3.0, CFSv2–based, 28–member



Potential Stress Level: Watch Warning Alert Level 1 Alert Level 2

## Week 4 Coral Reefs

## Week 3 Agenda

- Brief Review of Last Week
- Overview of animal movement & migration
- Overview of coupled model and remote sensing tools for tracking animal movement
- Examples of remote sensing tools for understanding animal movement
- Guest Speaker:
  - Dr. Mitchell Roffer: Roffer's Ocean Fishing Forecasting Service



An aerial photograph of a coastal region. In the top left, a river with a complex delta system flows into a body of water. The land is green with some brown patches, possibly indicating marshland or agricultural fields. The water transitions from a light turquoise near the shore to a deep blue further out. A large, semi-transparent white rectangle is overlaid on the right side of the image, containing the text 'Review of Week 2' and a horizontal line.

## Review of Week 2

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# NASA Satellites & Sensors for Ocean and Coastal Systems

Satellite	Sensor	Parameter
Landsat Series (7/1972 - present)	<ul style="list-style-type: none"><li>• Thematic Mapper (TM)</li><li>• Enhanced Thematic Mapper (ETM+)</li><li>• Operational Land Imager (OLI)</li></ul>	<ul style="list-style-type: none"><li>• Spectral Reflectance</li></ul>
Terra (12/1990-present)	Moderate Resolution Imaging Spectroradiometer (MODIS)	<ul style="list-style-type: none"><li>• Spectral Reflectance</li><li>• Chlorophyll-a Concentration</li><li>• Temperature</li><li>• Colored Dissolved Organic Matter (CDOM)</li><li>• Turbidity</li><li>• Euphotic Depth</li></ul>
Aqua (5/2002-present)		
Terra (12/1999 – present)	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)	<ul style="list-style-type: none"><li>• Spectral Reflectance</li><li>• Temperature</li></ul>

# NASA Satellites & Sensors for Ocean and Coastal Systems

Satellite	Sensor	Parameter
National Polar Partnership (NPP) (11/2011-present)	Visible Infrared Imaging Radiometer Suite (VIIRS)	<ul style="list-style-type: none"><li>• Spectral Reflectance</li><li>• Chlorophyll Concentration</li></ul>
International Space Station	Hyperspectral Imager for the Coastal Ocean (HICO) (2009 – 2014)	<ul style="list-style-type: none"><li>• Spectral Radiance</li><li>• Spectral Remote Sensing Reflectance</li></ul>
Plankton, Aerosols, Clouds, ocean Ecosystems, PACE (proposed for 2022 or 2023)	Ocean Color Instrument	<ul style="list-style-type: none"><li>• Spectral Reflectance</li><li>• Optional Polarimeter being considered</li></ul>

# Data Processing Levels

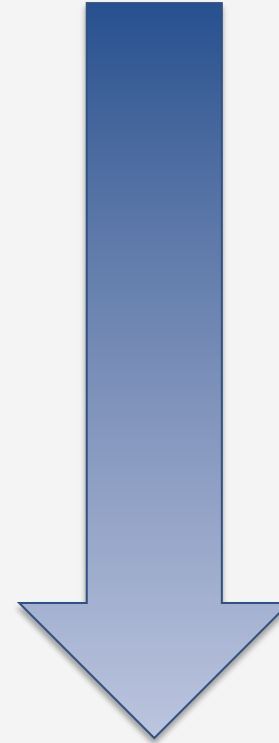
L0: Raw instrument data

L1: Geolocated and calibrated

L2: Products derived from L1B

L3: Gridded and quality controlled

L4: Model output: derived variables



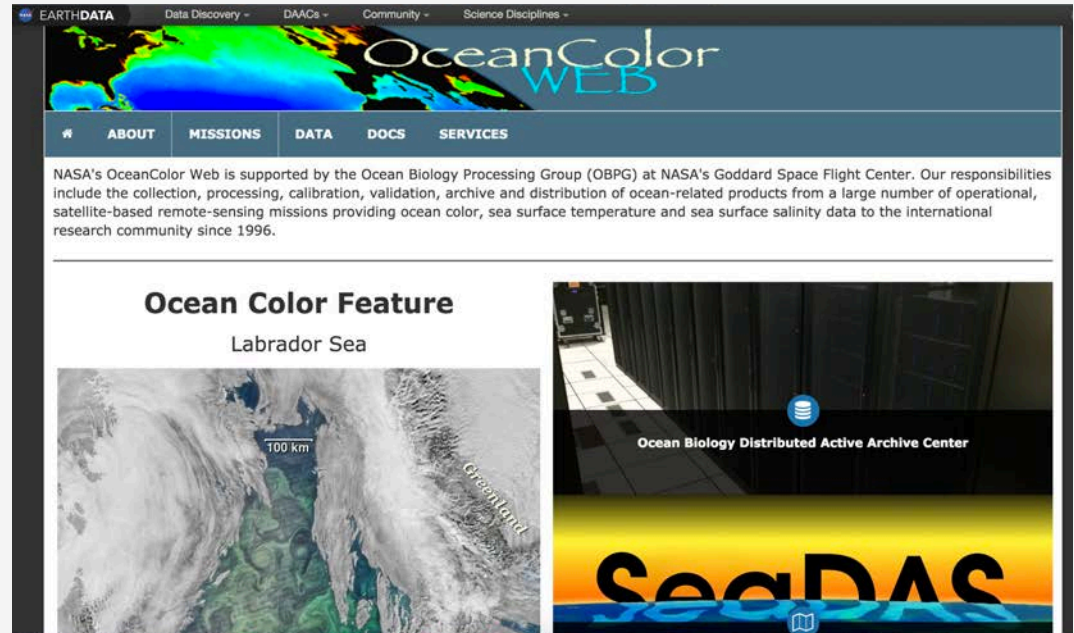
Harder to Use

Easier to Use

# NASA OceanColor Web

<http://oceancolor.gsfc.nasa.gov/>

- OceanColor Web is supported by the Ocean Biology Processing Group (OBPG) at NASA Goddard
- OBPG's duties include collection, processing, calibration, validation, archive, and distribution of ocean-related data products from a large number of satellite missions

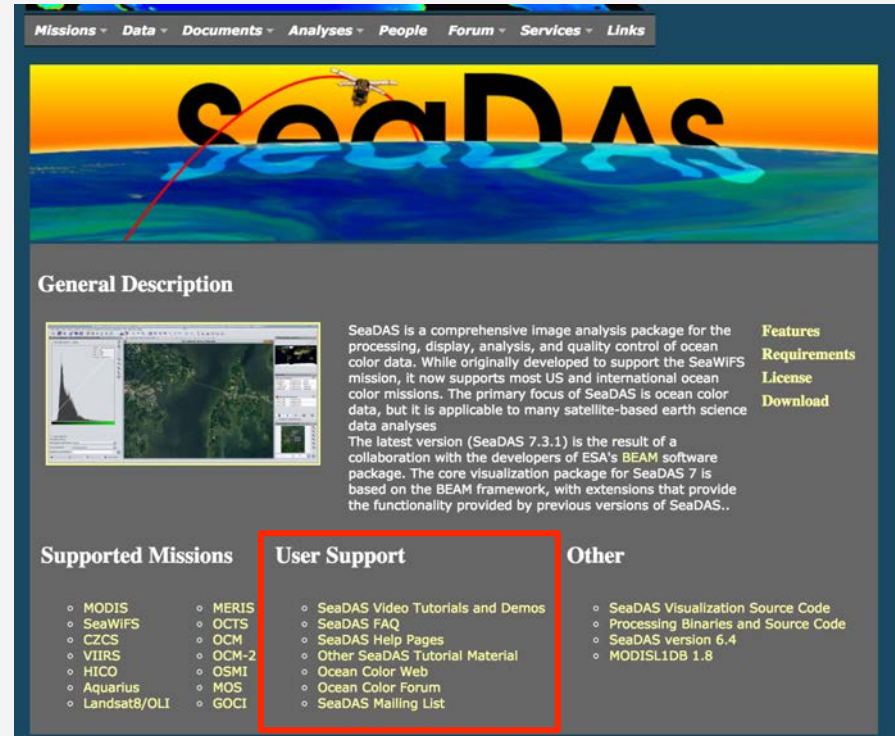




# SeaWiFS Data Analysis System (SeaDAS)

<http://seadas.gsfc.nasa.gov/>

- Image analysis package for the processing, display, analysis, & quality control of ocean color data
- Originally developed for SeaWiFS, but supports most U.S. and international ocean color missions
- Online tutorials, help pages, and an active user community in the Ocean Color Forum
- Attentive & friendly support team based at NASA Goddard



The screenshot shows the SeaDAS website homepage. At the top is a navigation bar with links: Missions, Data, Documents, Analyses, People, Forum, Services, and Links. Below this is a large banner image with the text 'SeaDAS' in a stylized font, overlaid on a satellite image of the ocean with a red orbital path. The main content area is divided into several sections. On the left, under 'General Description', there is a small thumbnail image of the SeaDAS software interface. To the right of this, there is a paragraph of text describing SeaDAS as a comprehensive image analysis package for ocean color data, mentioning its support for SeaWiFS and other missions, and its collaboration with ESA's BEAM software. Further right, there are links for 'Features', 'Requirements', 'License', and 'Download'. Below the 'General Description' section, there are three columns: 'Supported Missions' (listing MODIS, SeaWiFS, CZCS, VIIRS, HICO, Aquarius, Landsat8/OLI, MERIS, OCTS, OCM, OCM-2, OSMI, MOS, GOCI), 'User Support' (highlighted with a red box, listing SeaDAS Video Tutorials and Demos, SeaDAS FAQ, SeaDAS Help Pages, Other SeaDAS Tutorial Material, Ocean Color Web, Ocean Color Forum, and SeaDAS Mailing List), and 'Other' (listing SeaDAS Visualization Source Code, Processing Binaries and Source Code, SeaDAS version 6.4, and MODISL1DB 1.8).

**General Description**

SeaDAS is a comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data. While originally developed to support the SeaWiFS mission, it now supports most US and international ocean color missions. The primary focus of SeaDAS is ocean color data, but it is applicable to many satellite-based earth science data analyses.

The latest version (SeaDAS 7.3.1) is the result of a collaboration with the developers of ESA's BEAM software package. The core visualization package for SeaDAS 7 is based on the BEAM framework, with extensions that provide the functionality provided by previous versions of SeaDAS..

**Supported Missions**

- MODIS
- SeaWiFS
- CZCS
- VIIRS
- HICO
- Aquarius
- Landsat8/OLI
- MERIS
- OCTS
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**User Support**

- SeaDAS Video Tutorials and Demos
- SeaDAS FAQ
- SeaDAS Help Pages
- Other SeaDAS Tutorial Material
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- Ocean Color Forum
- SeaDAS Mailing List

**Other**

- SeaDAS Visualization Source Code
- Processing Binaries and Source Code
- SeaDAS version 6.4
- MODISL1DB 1.8

An aerial photograph of a coastal area. In the top left, a river flows through green fields and some buildings. The river meets a sandy beach, which is bordered by a strip of green vegetation. Beyond the beach is a shallow turquoise lagoon or bay, which transitions into a deep blue ocean. The sky is not visible.

# Overview of Animal Movement & Migration

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# The Ocean in 3-Dimensions

- Humans have a 2-dimensional bias
- There is more than just the surface
- Density governs vertical movement
- Aquatic creatures have adapted to life in 3-dimensions



Credit: L. Buckingham



# The Ocean in 3-Dimensions

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# The Ocean in 3-Dimensions

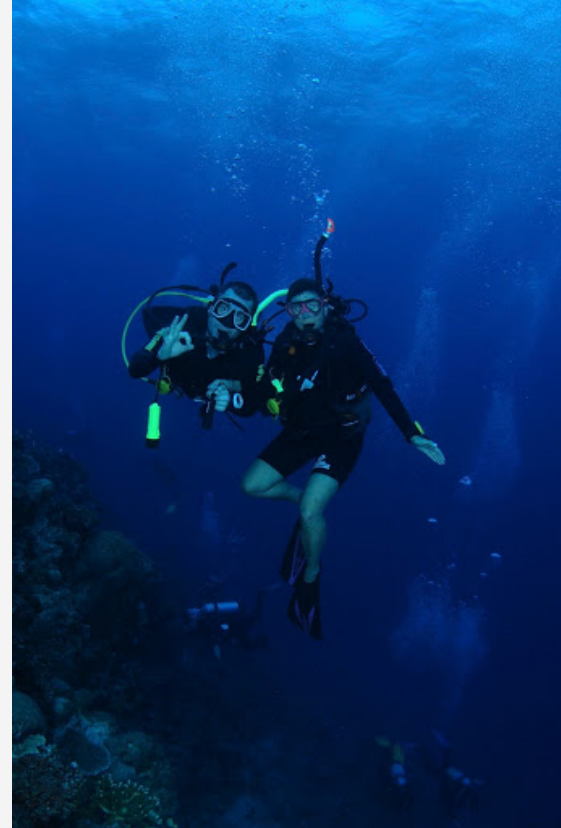
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credit: B. Mueller

# The Ocean in 3-Dimensions

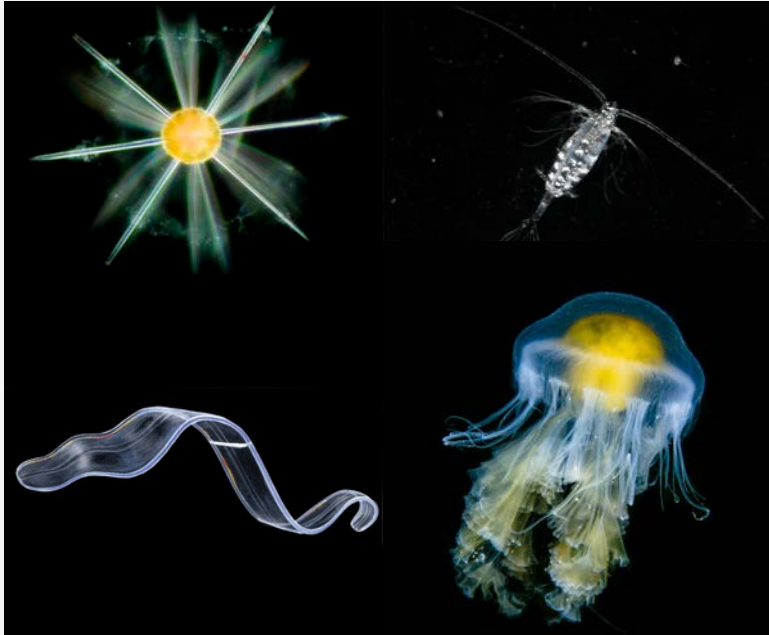
- Humans have a 2-dimensional bias
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Credit: L. Buckingham

# Life as Plankton or Nekton

*Plankton: drifters  
(usually microscopic)*



Credits: B. Walz, J. Trumpey, D. Collins

National Aeronautics and Space Administration

*Nekton: swim freely  
and independent of currents*

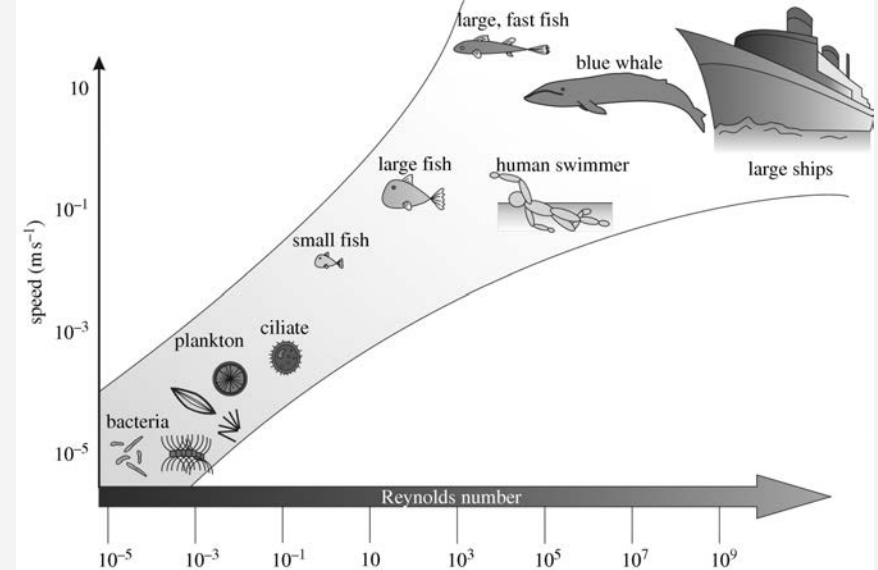


Credits: L. Buckingham, TOPP, MBARI, Sarasota Water Atlas

# Plankton or Nekton?

## A Function of Reynolds Number (Re)

- Re is the ratio of inertial and viscous forces
- Plankton have low Re
  - like living in jelly
- Nekton have higher Re
- Some animals spend larval stage in plankton and grow into nekton
- Copepods are special – they can use jet propulsion to increase Re



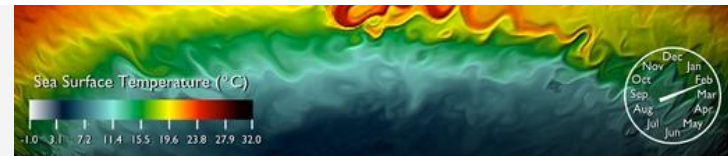
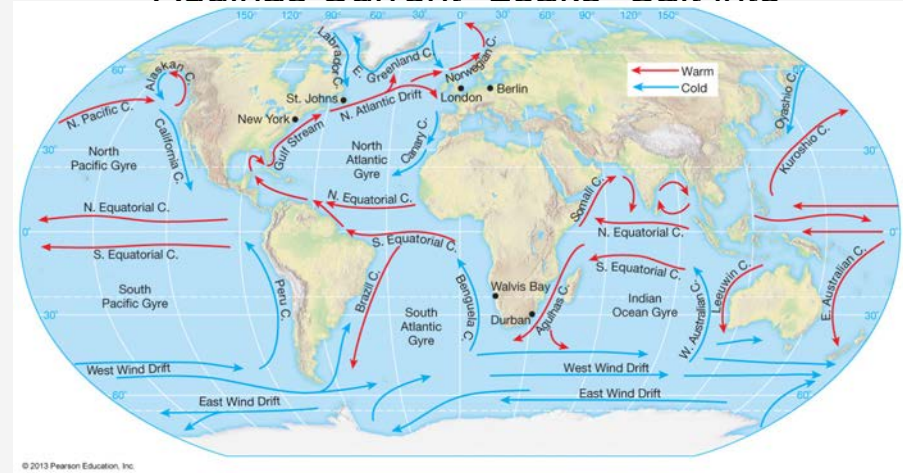
Credit: The Royal Society



# The Ocean as a Moving System

- Winds, friction, pressure gradients, and rotation of the earth contribute to major ocean current systems
- Plankton are carried along by ocean currents
- Nekton can swim independently of currents and may not follow them during migration
- Currents carry heat, salt, and momentum

## Aulhas Current “Leaks” Salt into

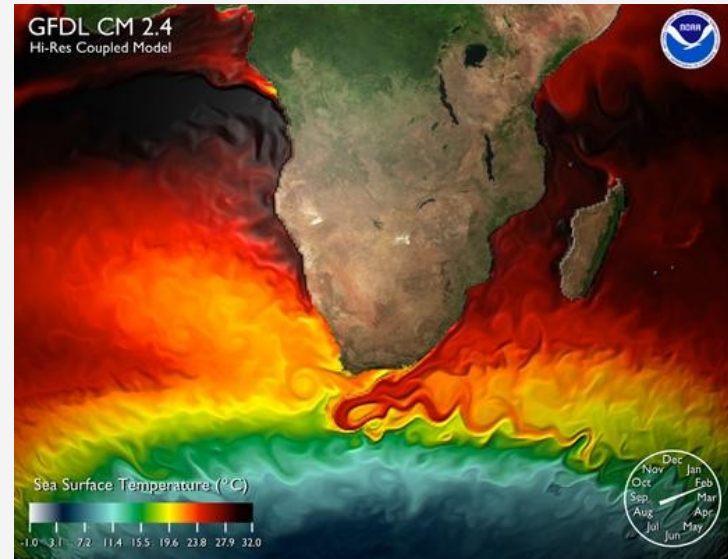


Credit: NOAA/GDFL

# The Ocean as a Moving System

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- Currents carry heat, salt, and momentum

## Agulhas Current “Leaks” Salt into South Atlantic from Indian Ocean



Credit: NOAA/GDFL

# Remote Observations of the Moving Ocean

From Klemas 2012

Science Objective	Satellite (S) or Shore-Based (SB)	Sensor	Measured or Derived Product
Current Flow Pattern	S	MODerate Resolution Imaging Spectrometer (MODIS), Advanced Very High Resolution Radiometer (AVHRR)	Sea Surface Temperature (SST)
Current Velocity & Feature Tracking	S	Synthetic Aperature Radar (SAR), AVHRR	Altimetry/Sea Surface Height (SSH), SST
Current Mapping by SAR	S	SAR, Interferometric SAR (InSAR), TerraSAR-X	SSH
Altimetry of Geostrophic Currents	S	SEASAT, ERS-1 & 2, TOPEX/POSEIDON, ENVISAT, JASON-1	SSH
Current Mapping	SB	High Frequency (HF) Radar	wave swell direction, height, period, and current velocity

# Models of a Moving Ocean

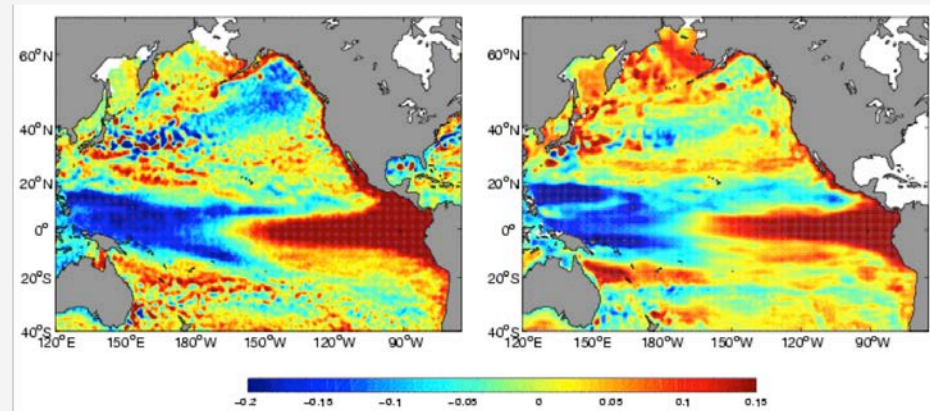
## Example: Regional Ocean Modeling System (ROMS)

- A free-surface, hydrostatic primitive-equation model discretized with a terrain-following vertical coordinate system
- Used to predict ocean conditions, including:
  - temperature & salinity
  - ocean currents
  - sea surface height
- Applied at many scales from global to estuarine

### Sea Surface Height

Measured (TOPEX/ERS)

Modeled (ROMS)



Credit: Center for Earth System Research, UC-Los Angeles  
<http://research.atmos.ucla.edu/cesr/index.html>

# Monitoring Animal Movement

## Differences Between Land and Sea

Gray Wolf



Blue Whale



N.Elephant Seal



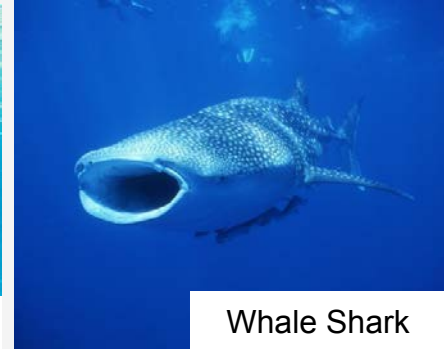
Mountain Lion



Blue Marlin



Whale Shark



Credit: M. Sloan, J. Yuskavitch

Credit: Tagging of Pelagic Predators (TOPP)



# Monitoring Animal Movement

## Technologies Used

- Telemetry tags glued to animal
  - time, location, speed, depth, temperature, salinity
- Archival tags surgically inserted into animal
  - time, depth, internal and external temperature, and ambient light
  - returned after catch



Credit: TOPP

An aerial photograph of a coastal area. In the top left, a river flows through green, marshy land. The river meets a sandy beach and the ocean. The ocean is a deep blue, with some whitecaps visible. A semi-transparent white rectangle is overlaid on the right side of the image, containing the title text.

# Coupled Model and Remote Sensing Tools for Tracking Animal Movement

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# Will Pelagic Predator Habitat Shift with Climate Change?

A Case Study (Hazen et al. 2012)

## Inputs

- Information from tagged predators
- Satellite remote sensing data
  - chlorophyll-a, sea surface temperature, sea surface height, wind stress, bathymetry
- Coupled general circulation model and biogeochemistry model
  - NOAA Geophysical Dynamics Lab's (FDL) Earth System Model (ESM2.1)

## Output

- Predictions of species distribution and abundance in year 2100



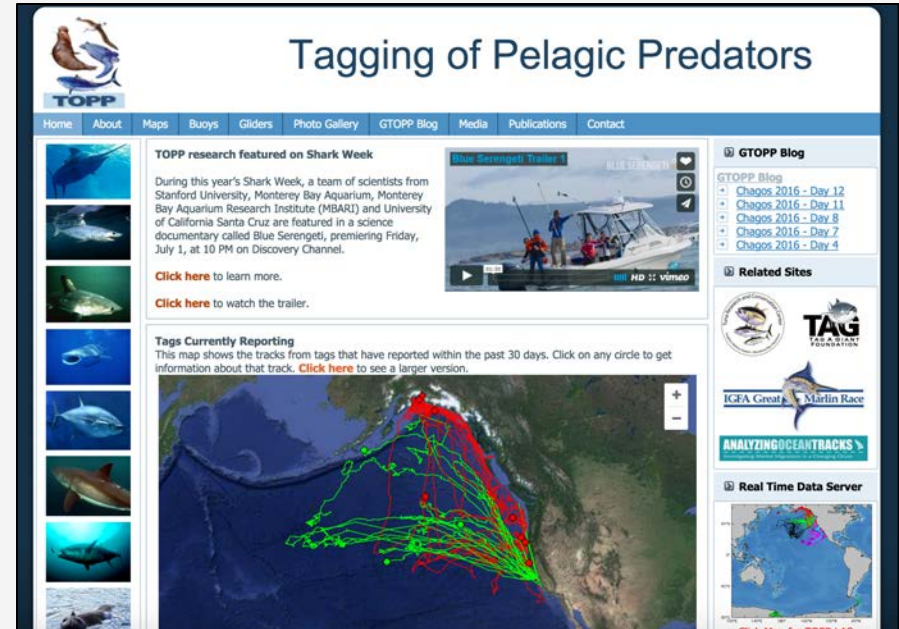
Credit: M. Conlin, Audobon Society, TOPP



# Tagging of Pelagic Predators (TOPP)

<http://www.topp.org/>

- International program to interact with tracking data & oceanographic datasets to observe marine megafauna
- To understand factors influencing animal behavior in blue ocean
- To use sensor data from animal tags to aid in climate models and a better understanding of ocean ecosystems



# TOPP Collects and Curates Data from Animal Tags

## Example Species



Northern Elephant Seal



Tagging Great White Shark



Laysan Albatross



Great White Shark

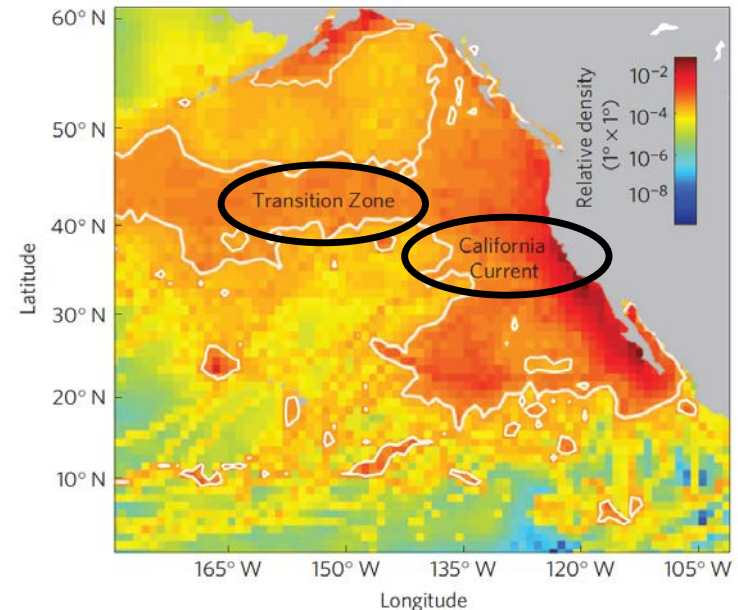
Credit: TOPP

# Tag Data Informed Present Day Species Density

Hazen et al. 2012, DOI: 10.138/NCLIMATE 1686

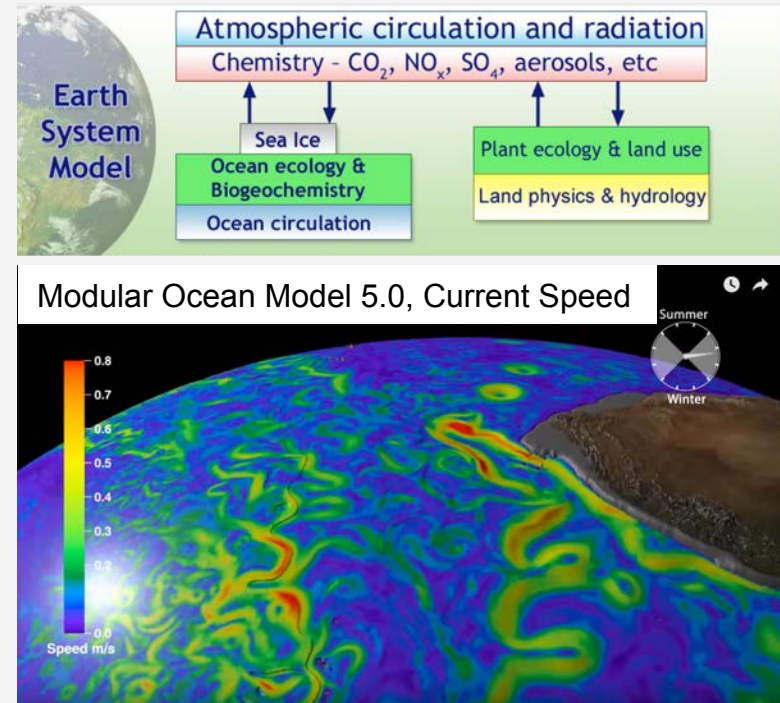
- Biological “hotspots”
  - Transition Zone
  - California Current
- Hotspots move with season
- Observed seasonal patterns suggest climate change may affect species distribution and abundance

Density of Top Predator Species  
in the Eastern North Pacific



# Coupled Ocean Models Predict Future Conditions

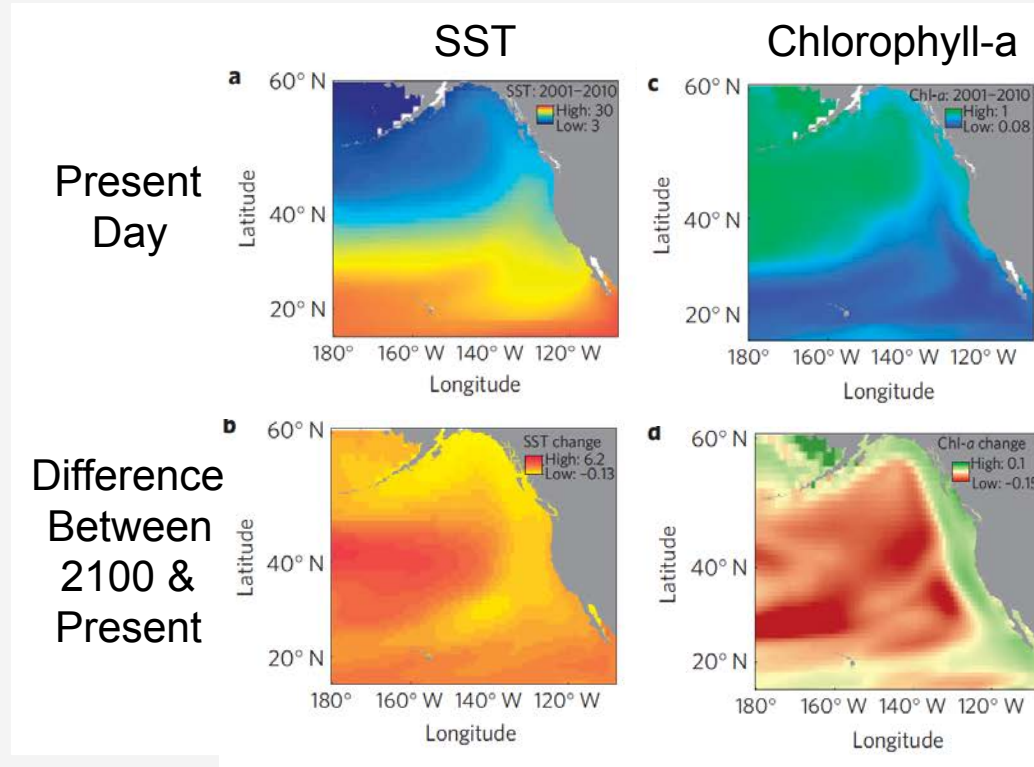
- NOAA's GFDL's ESM2.1 Model includes coupled models
  - The Modular Ocean Model (MOM)
  - A biogeochemical model
- Like ROMS, MOM simulates ocean circulation for climate and ecosystem studies



Southern Ocean Visualization: <https://youtu.be/8VMSF28J9H4>

# How will SST and Chlorophyll-a Change?

Warming of Ocean Gyre, and Compression of Productivity Close to Shore

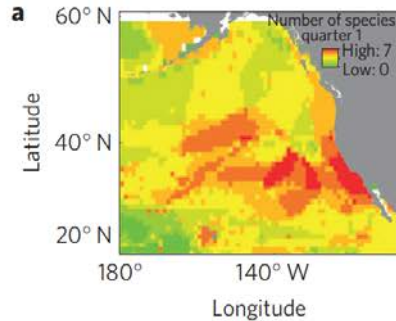




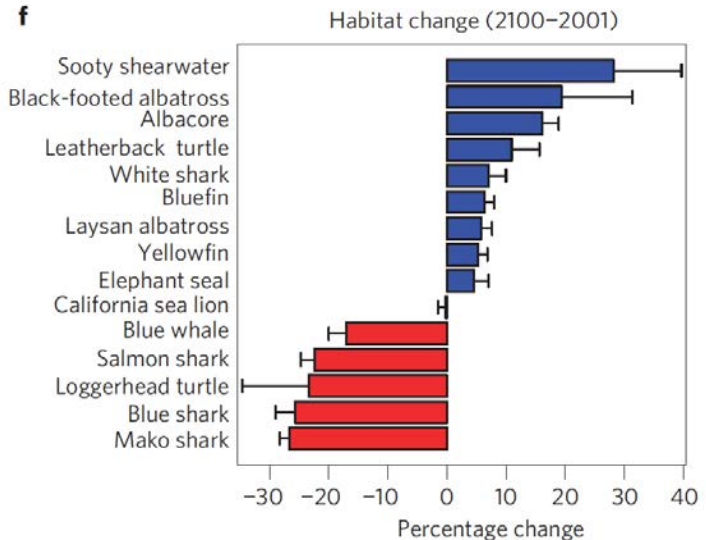
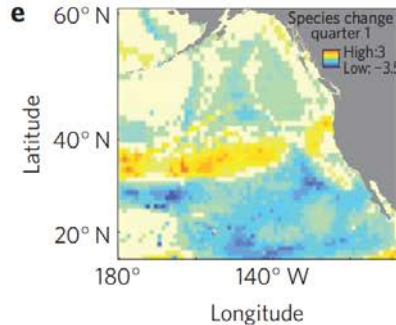
# Habitat is Predicted to Decline by 2100

Some Species are Losers, Others are Winners

Present  
Day



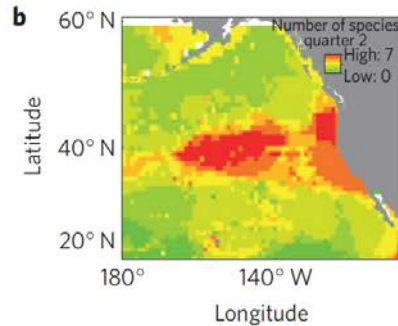
Difference  
Between  
2100 &  
Present



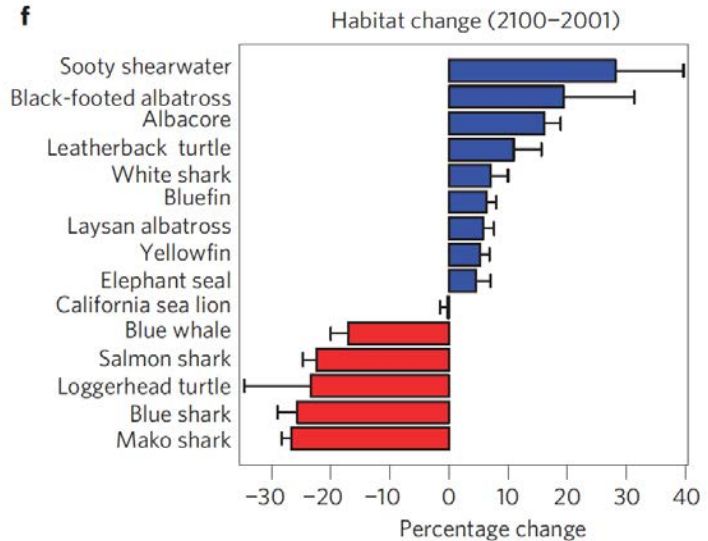
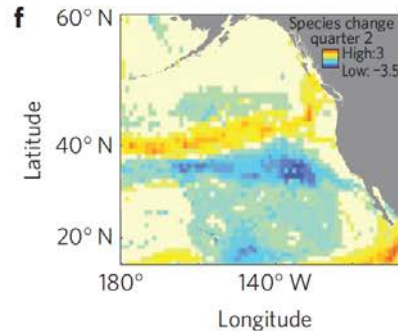
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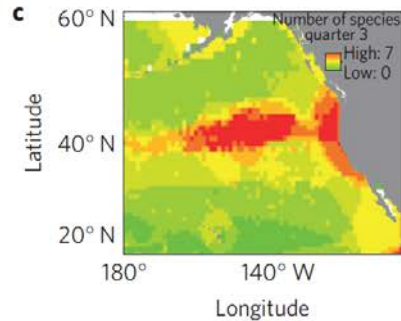
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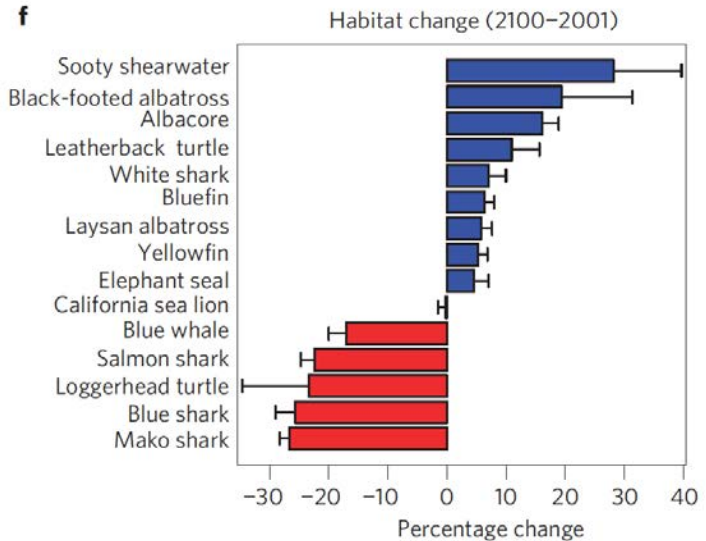
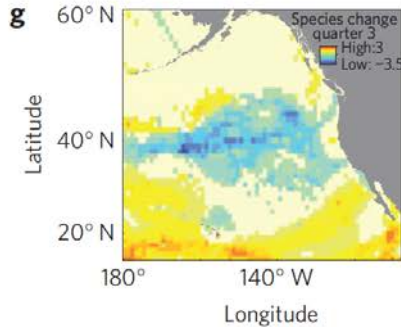
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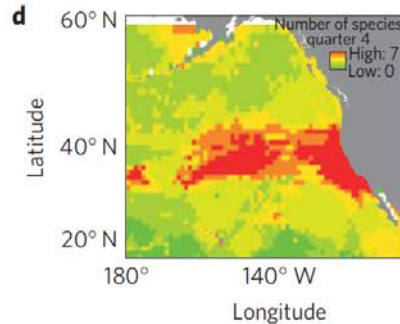




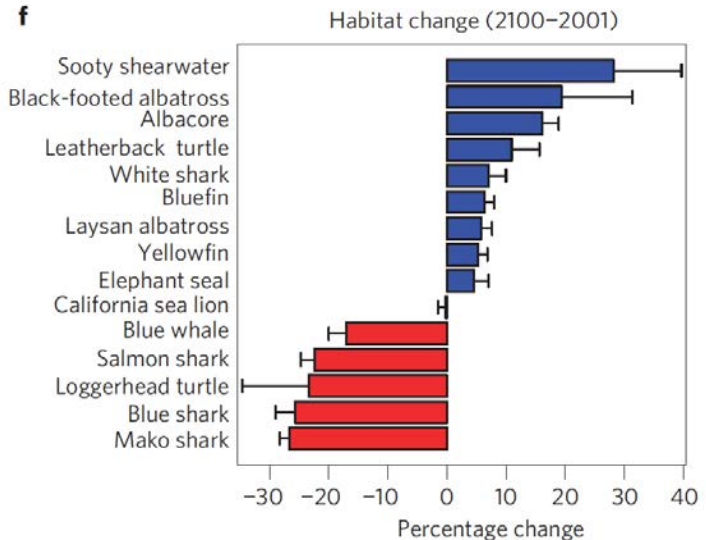
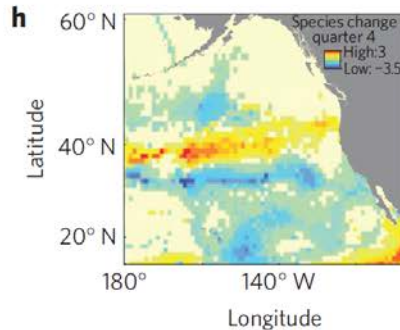
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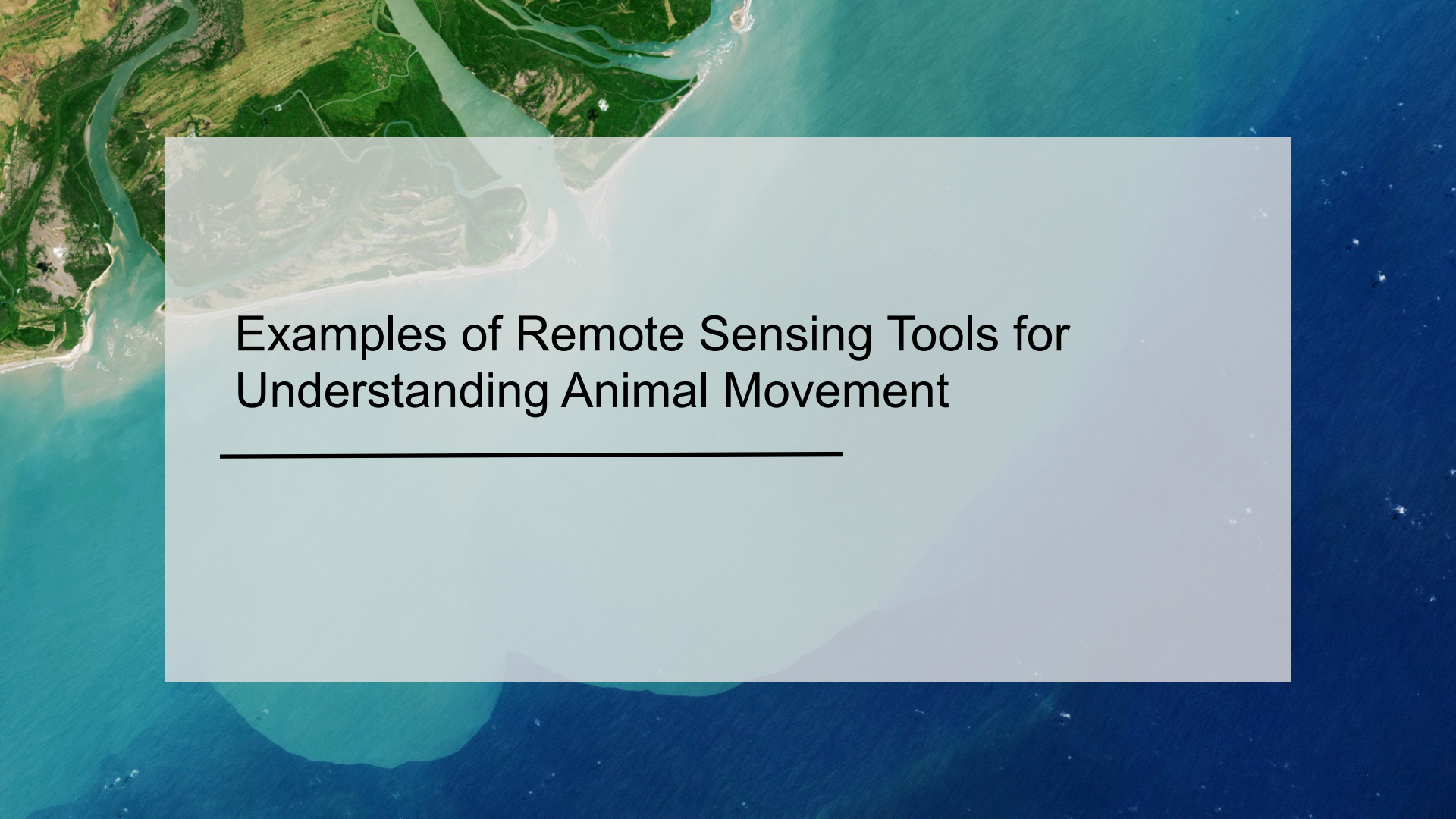
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Difference  
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An aerial satellite image of a coastal region. A river with a complex delta system flows from the top left towards the center. The land is green with some brown patches, indicating vegetation and possibly bare earth or sand. The river meets a body of water that transitions from a light turquoise color near the shore to a deep blue further out. A semi-transparent white rectangular box is overlaid on the right side of the image, containing the title text.

## Examples of Remote Sensing Tools for Understanding Animal Movement

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# NOAA Whale Watch

<http://www.westcoast.fisheries.noaa.gov/whalewatch/index.html>

- Whales are at risk from human encounters (e.g., ship strikes, entanglements, and loud underwater sounds)
- Goal: to reduce human impacts on whales by providing near real-time information on whale location
- Whale location estimated using coupled remote sensing and habitat-based model with satellite tracking of whales



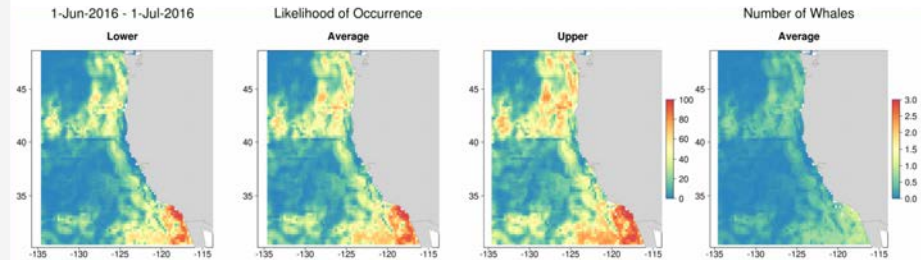


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## This month's estimate of Blue Whales off the US West Coast



# Pelagic Habitat Analysis Module (PHAM)

<http://www.phamlite.com/>

- GIS software tool for fisheries managers, scientists, and researchers to examine and predict pelagic ocean biota habitat
- Uses biota presence/absence or abundance data combined with environmental data (satellite imagery, bathymetry, survey cruises, and ocean circulation models)
- Freely available for download on website
- Tutorials & links to data provided



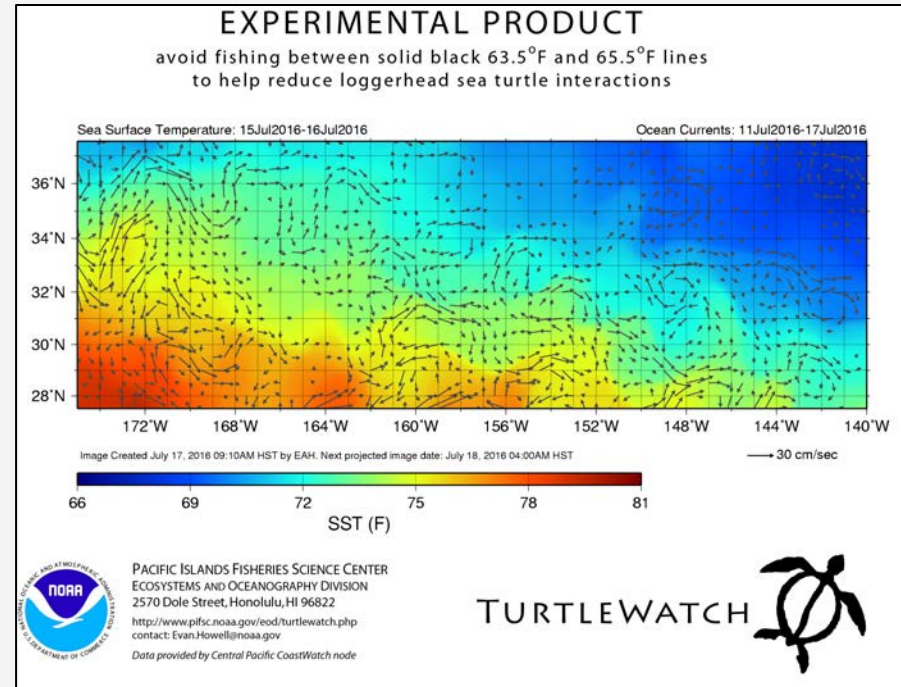
The screenshot displays the PHAM website interface. At the top, there is a header with a satellite image of the ocean, the title "Pelagic Habitat Analysis Module" in a stylized font, and a logo featuring a blue star-like shape with the text "PHAM" inside. Below the header, a left sidebar contains a navigation menu with links: "Introduction", "Users Group", "About PHAM", "Run Demo", "Download Program", "View Tutorial", "Imagery to Import", "Users List", "Contributors", "Publications", and "Contact Us". The main content area is titled "Introduction" and contains the following text: "The **Pelagic Habitat Analysis Module (PHAM)** is a set of software tools designed to assist fishery managers, scientists, and researchers." Below this, a section titled "PHAM" lists its capabilities: "Integrates datasets provided by NASA and JPL" and "Provides the ability to import other environmental datasets such as: satellite imagery, bathymetry, survey cruise data, and circulation models". Further down, it states: "PHAM resides within the Environmental Analysis System (EASy) Geographical Information System (GIS) developed by System Science Applications, Inc. specifically for marine applications." Another paragraph mentions: "PHAM is being developed under a NASA grant which is funded until 2012, so work is only partially complete. However, we have had such an extraordinary response so far that we decided to make a version available to the scientific community as soon as possible." A section titled "PHAM Lite" describes it as a "stripped down and simplified version" designed for users to begin using the most important capabilities of PHAM without the hassles of full development. It lists capabilities: "Import satellite and other imagery" (for time period and location), "Import your own measurement data", "Display your data combined with the imported imagery", "Run a time step simulation of your data and the imagery", "Display blob plots and other shape files", and "Export a result table containing: your data, the measurement values determined from the imported imagery". On the right side of the main content area, there is a map of the Western Hemisphere showing a color-coded heatmap of pelagic habitat, with a color scale legend on the right edge ranging from blue (low) to red (high). At the bottom left of the main content area, there is a "NEWS" section with the text: "Update available for download 11/08/13".



# NOAA TurtleWatch

<https://pifsc-www.irc.noaa.gov/eod/turtlewatch.php>

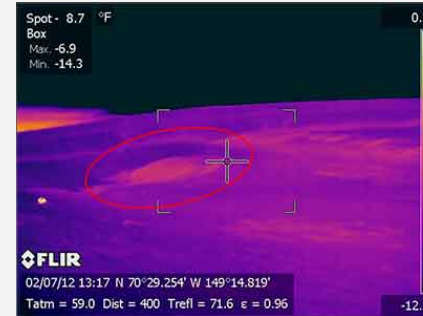
- Up-to-date information about thermal habitat of loggerhead sea turtles in the Pacific Ocean north of the Hawaiian Islands
- Created to reduce interactions between Hawaii-based long-line fishing vessels and loggerhead turtles
- Predicts the location of waters preferred by these turtles based on sea surface temperature and ocean current conditions



# Remote Detection of Polar Bear Dens

[http://www.adfg.alaska.gov/index.cfm?adfg=wildlifeneews.view\\_article&articles\\_id=708](http://www.adfg.alaska.gov/index.cfm?adfg=wildlifeneews.view_article&articles_id=708)

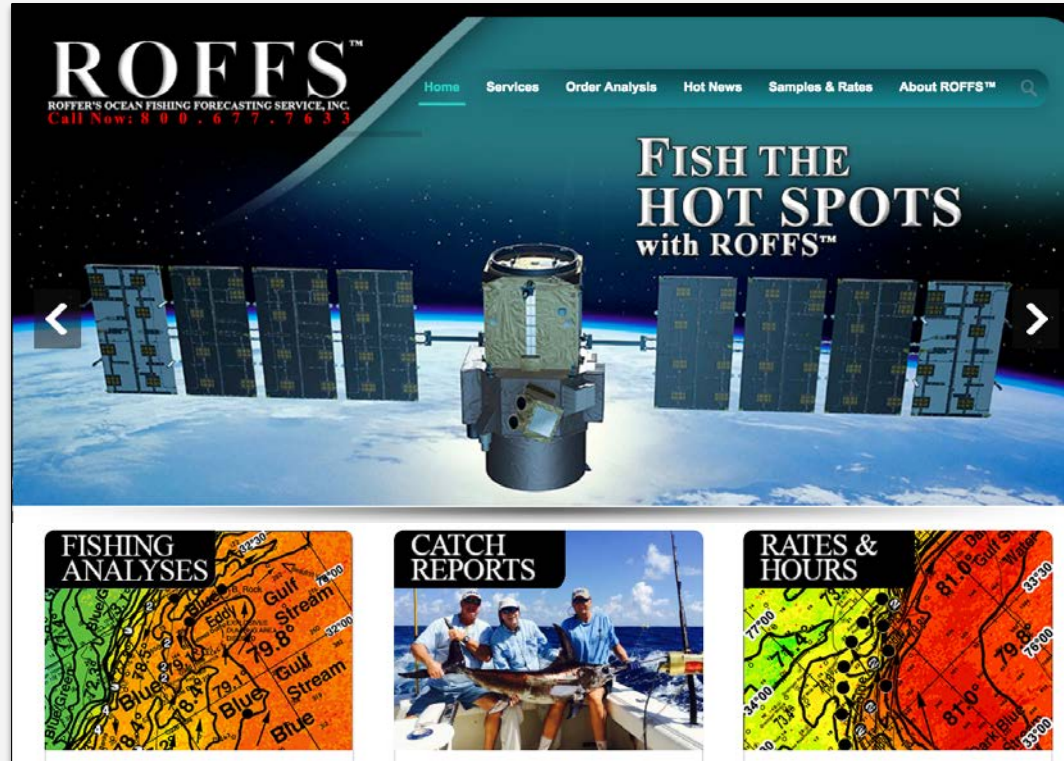
- Polar bear mothers near the Beaufort Sea can come ashore to build dens for winter. If disturbed they will abandon den
- Oil extraction activities occur during frozen winter to minimize impact to tundra
- Airborne Forward Looking Infrared Imagery (FLIR) is being used to thermally identify dens in the snow and reduce human-bear interactions



<http://bioscience.oxfordjournals.org/content/54/4/337.full.pdf+html>

# Special Guest: Dr. Mitchell Roffer

Roffer's Ocean Fishing Forecasting Service, Inc. <http://www.roffs.com/>





An aerial photograph of a coastal region. On the left, a river with multiple channels flows into the ocean, creating a delta. The land is green with some brown patches. The ocean is a deep blue with white-capped waves breaking near the shore. A semi-transparent white rectangle is overlaid on the right side of the image, containing the text.

# Live Demo: Roffer's Ocean Fishing Forecasting Service

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**ROFFER'S OCEAN FISHING FORECASTING SERVICE, INC.**





# **The Use of Satellites and Other Oceanographic Data To Provide Oceanographic Services and Products to the Fishing Industry, Oil and Gas Industry, as well as, Government and Academic Researchers**



**Mitchell A. Roffer (Ph.D.), President  
Roffer's Ocean Fishing Forecasting Service, Inc.  
West Melbourne, FL ([WWW.ROFFS.COM](http://WWW.ROFFS.COM))**



# Previous NASA - NOAA Project



## Improving The NOAA NMFS and ICCAT Atlantic Bluefin Tuna Fisheries Management Decision Support System.

PI: **M. A. Roffer** – ROFFS™

- Co-I: J.T. Lamkin (NOAA), F.E. Muller-Karger (USF), S-K Lee (UM CIMAS), B.A. Muhling (UM CIMAS)
- Other Investigator: Y. Liu (UM CIMAS), M.A. Upton, (ROFFS™) & G. Gawlikowski (ROFFS™), **G.W. Ingram (NOAA-NMFS Pascagoula)**
- **Other collaborators added: W. Nero (NOAA\_NMFS Stennis), J. Franks (USM), J. Quattro (USC)**  
D. Enfield (NOAA), John F. Walter (NOAA), A. Bakun (UM RSMAS), K. Ramirez (INAPESCA) A. Garcia (IEO) & F. Alemany (IEO).

Start date May, 2008 – End date May, 2012

Multi-sector, international and multi-disciplinary partnership,  
including government fishery scientists and managers





# ACKNOWLEDGMENT NASA - NOAA PROJECT



Management And Conservation Of Atlantic Bluefin Tuna (*Thunnus Thynnus*) And Other Highly Migratory Fish In The Gulf Of Mexico Under IPCC Climate Change Scenarios: A Study Using Regional Climate And Habitat Models.

- PI: M. A. Roffer – ROFFS™
- Co-I: **J.T. Lamkin** (NOAA), F.E. Muller-Karger (USF), S-K Lee (UM CIMAS), B.A. Muhling (UM CIMAS), G.J. Goni (NOAA)
- Other Investigator: Y. Liu (UM CIMAS), M.A. Upton, (ROFFS™) & G. Gawlikowski (ROFFS™), **G.W. Ingram (NOAA)**
- **Other collaborators added:** W. Nero (NOAA), J. Franks (USM), J. Quattro (USC)

D. Enfield (NOAA), John F. Walter (NOAA), **Michael Schirripa (NOAA)**; A. Bakun (UM RSMAS), K. Ramirez (INAPESCA), **F. Alemany (IEO)**, **A. Garcia (IEO)** **R. Laiz-Carrión, J. Llopiz, . . and growing**

Start date September 06, 2011 – End date September 05, 2016



# NASA - NOAA Research

- Focuses on **enhancing the science for management** of Atlantic bluefin tuna (*Thunnus thynnus*) and other highly migratory tunas and billfishes in the Gulf of Mexico and surrounding waters considering climate change.
  - Using data with differing scales.
    - MM's to M's to KM's to 1000's KM scales
    - Hourly to daily to 100 year time scales

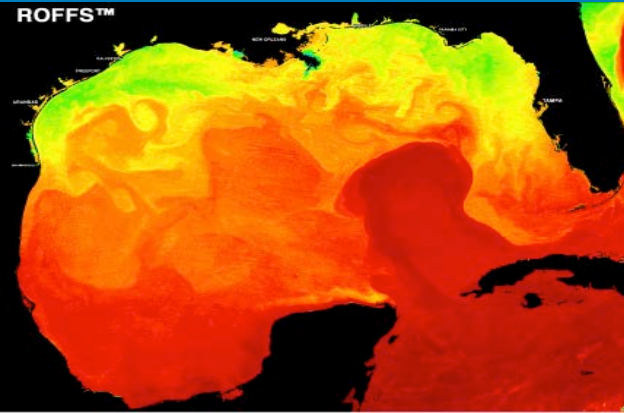


# Gulf of Mexico & North Atlantic Ocean

## Larvae and Adults

30+ years of NMFS larvae cruise data (larvae, in situ, satellite)

Climate model domain  
1000's km



Infrared Image

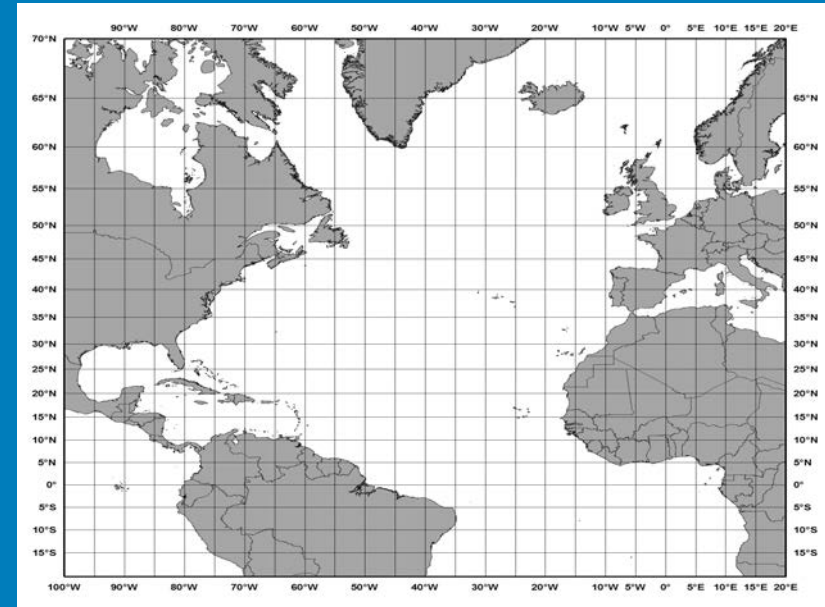
6 mm



2 m

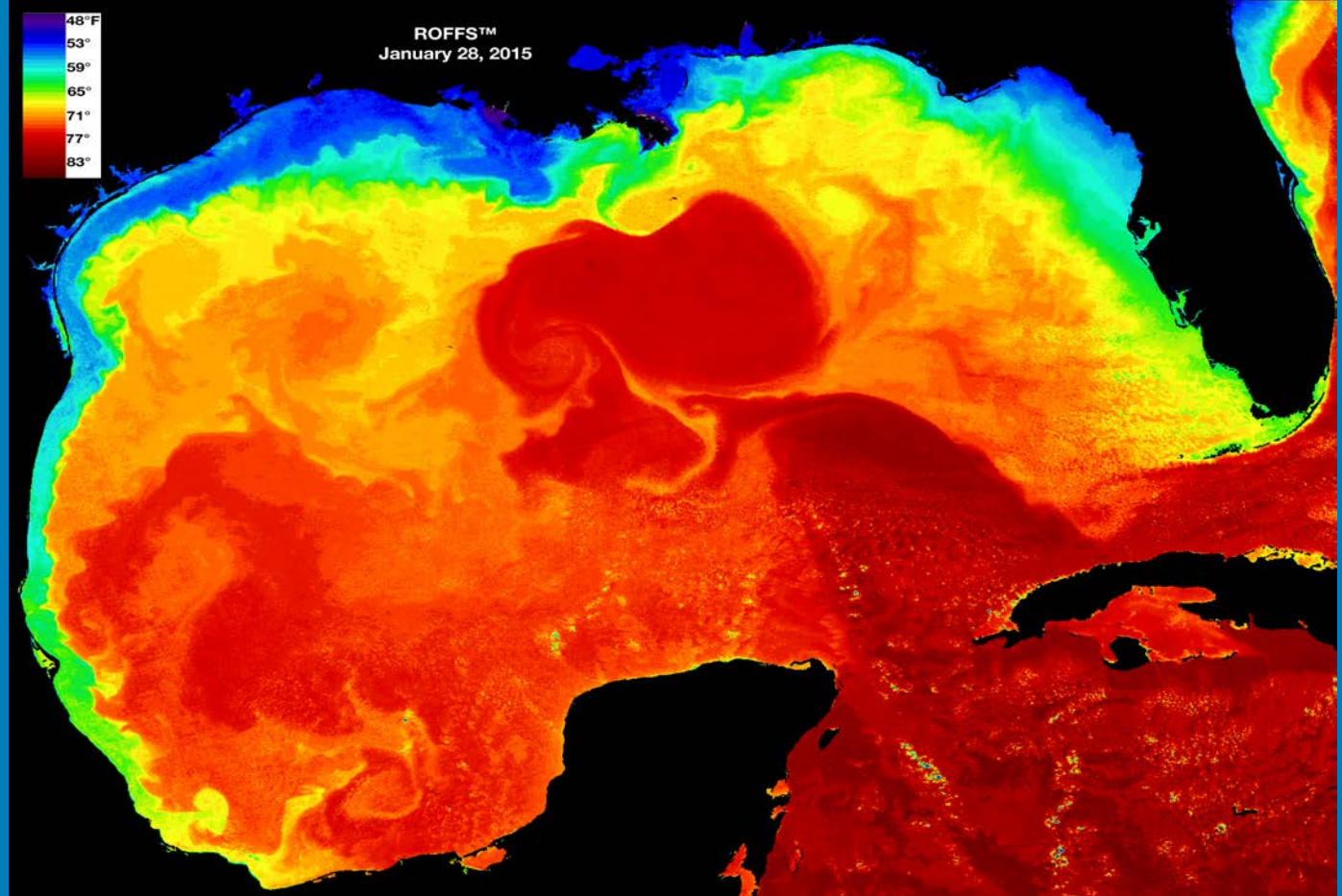


23 years commercial longline data  
(NOAA + ICCAT)

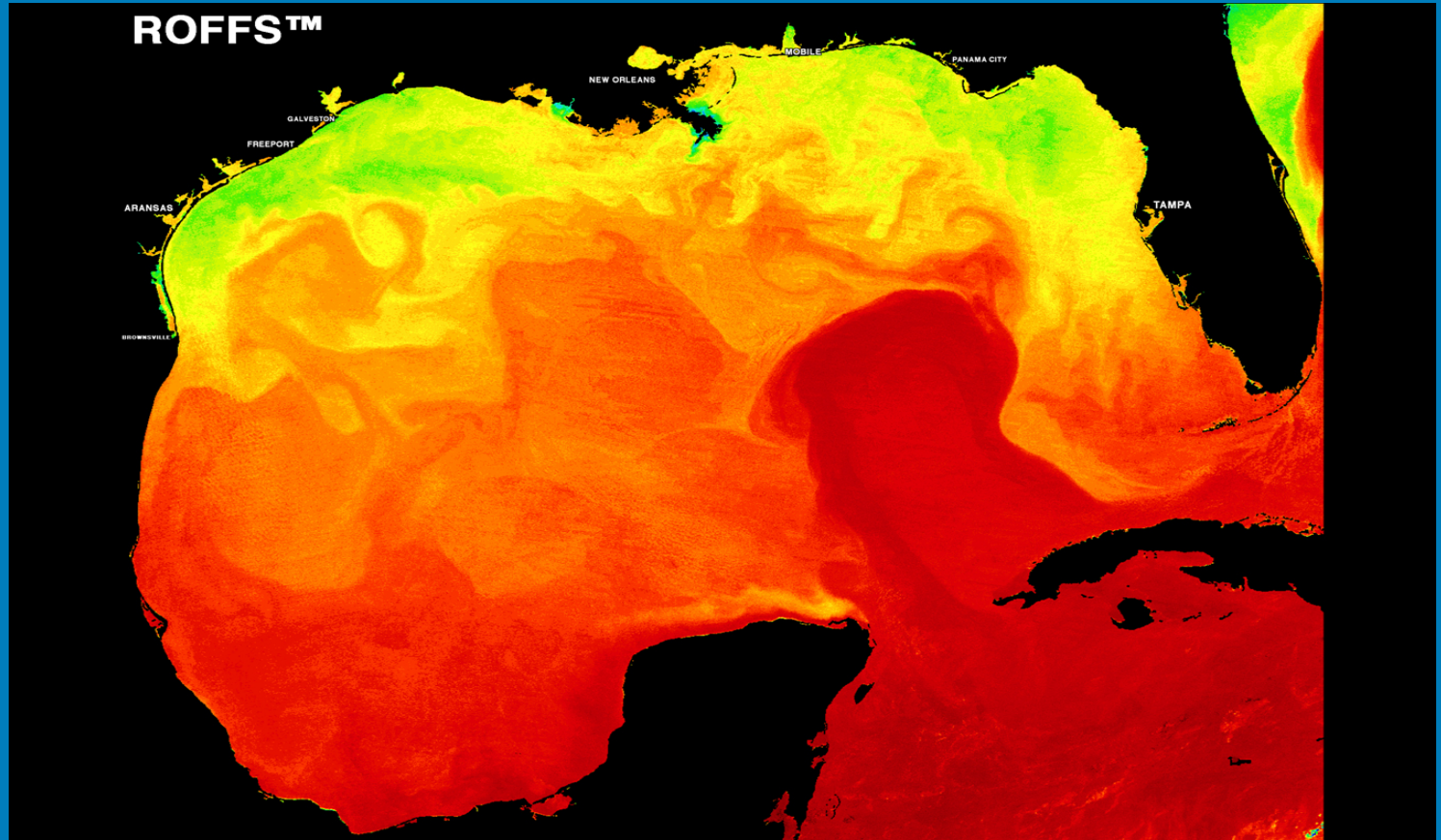




# Infrared Visualization of the Currents

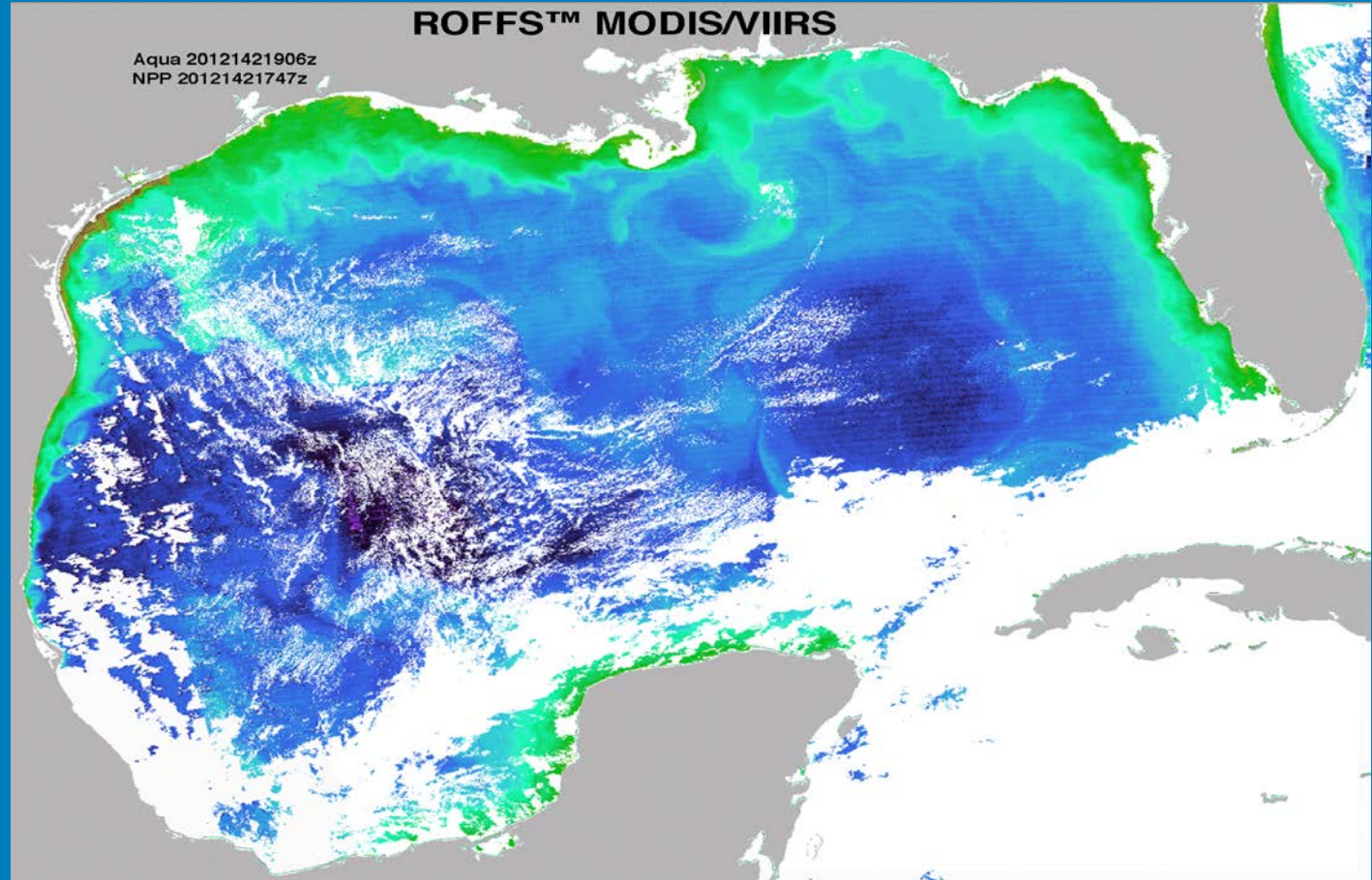


# Infrared Visualization of the Currents



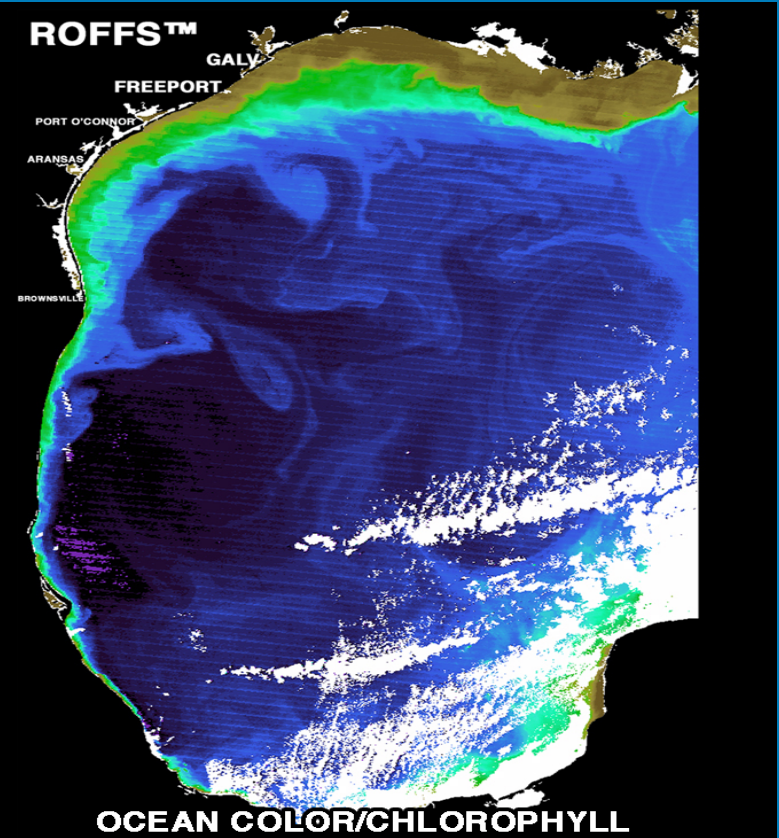
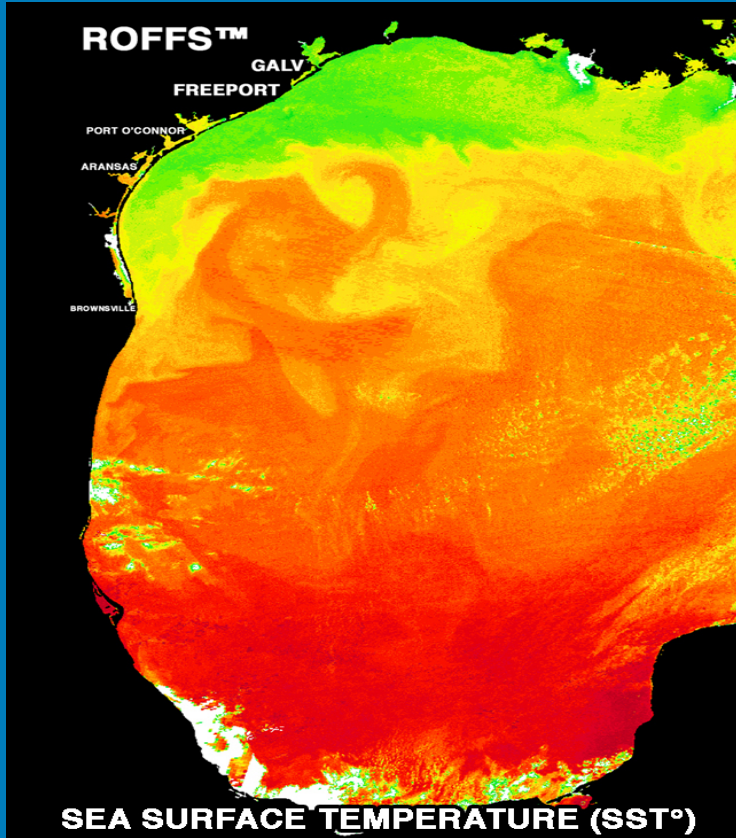


# Ocean Color MODIS/VIIRS Composite



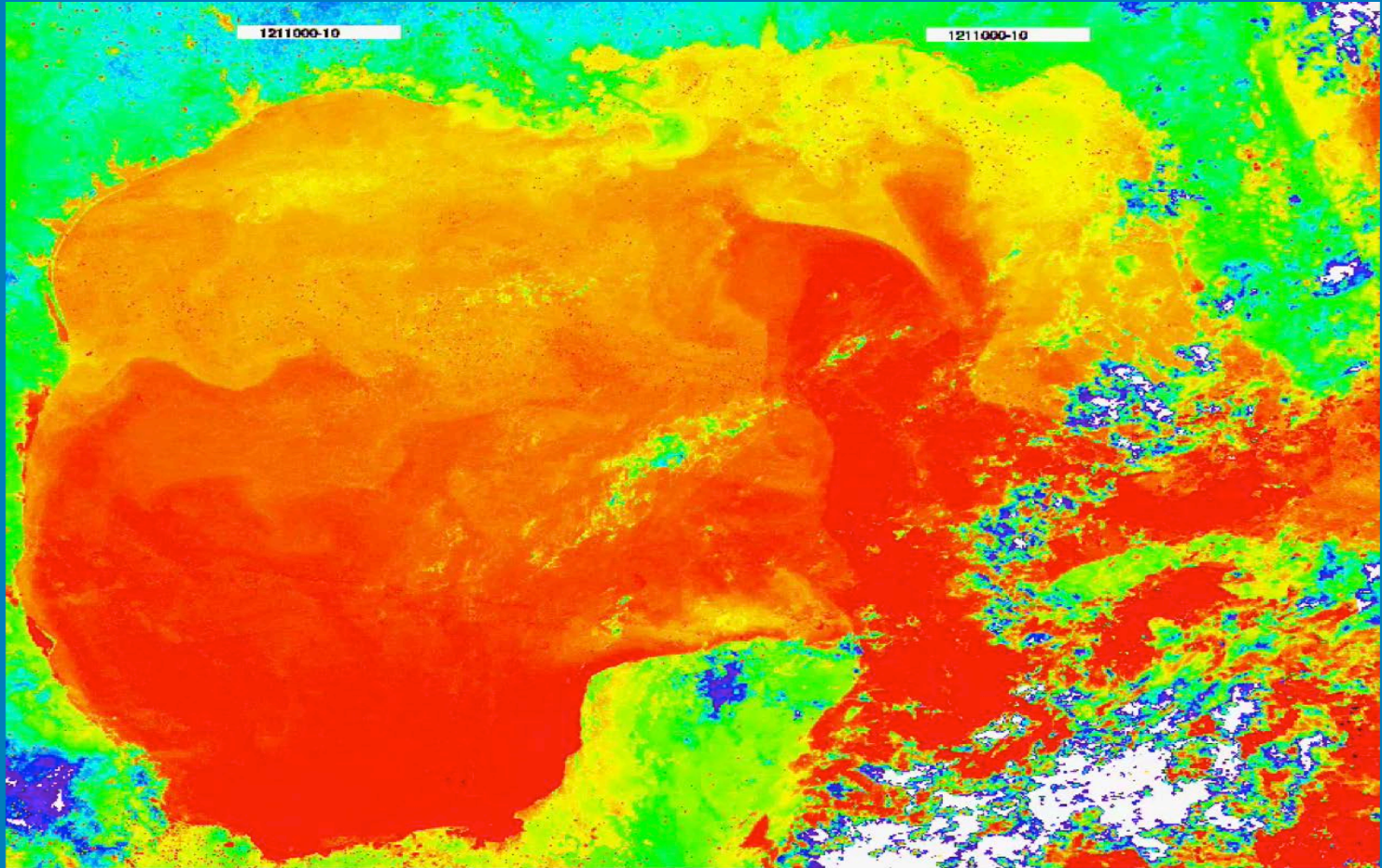
# Infrared

# Ocean Color



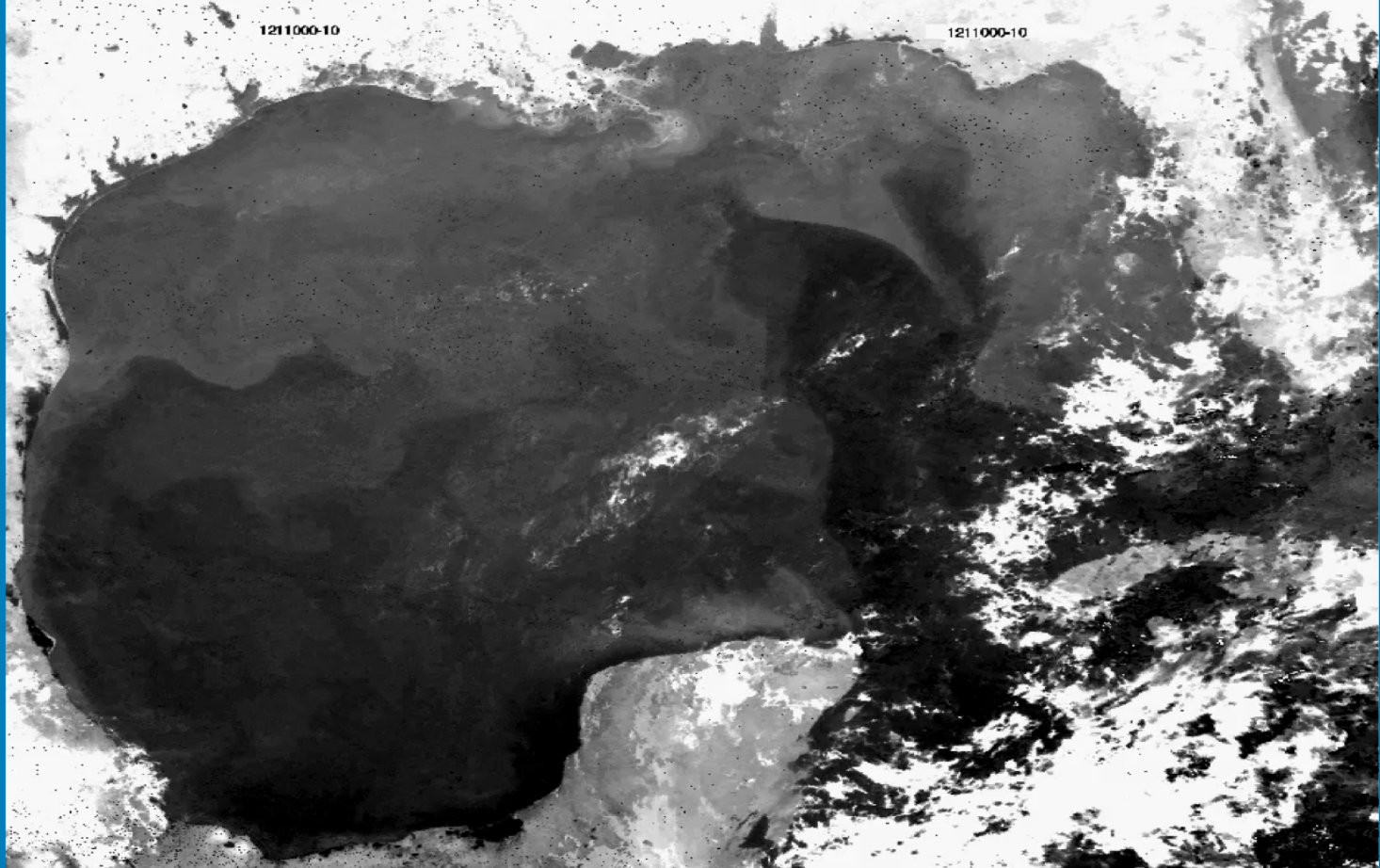


# Motion is Critical

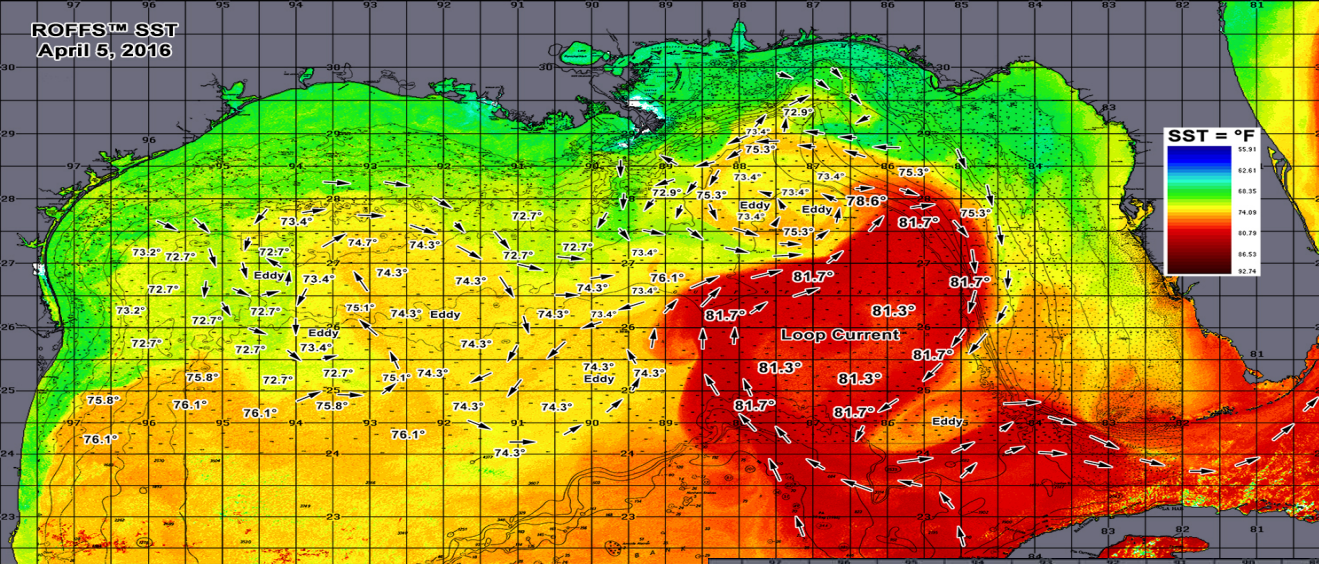




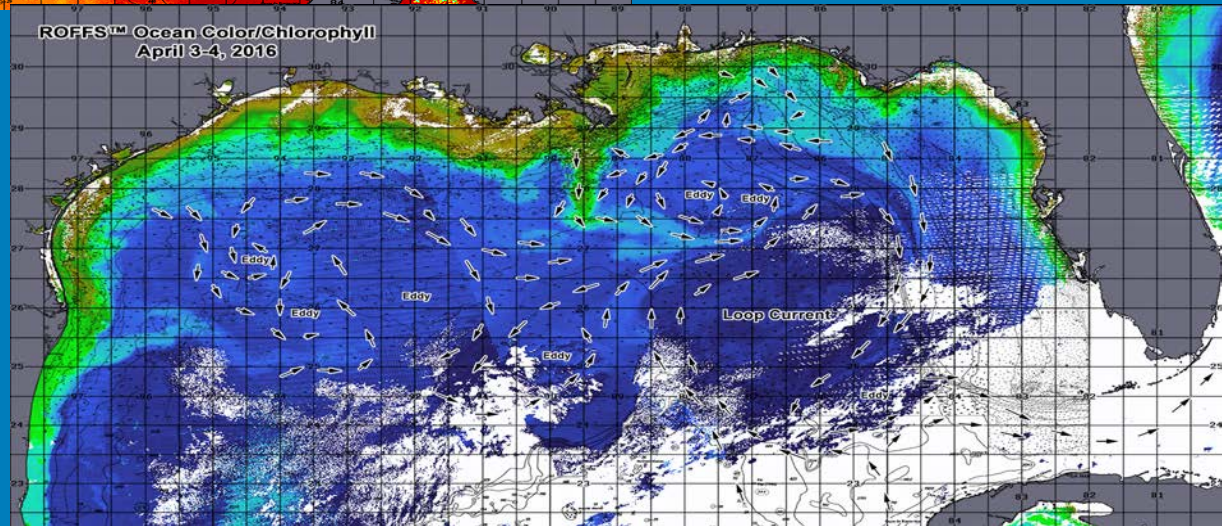
# Graytone Is Useful



ROFFS™ SST  
April 5, 2016



# Analyses Are Made Using Both Data Types

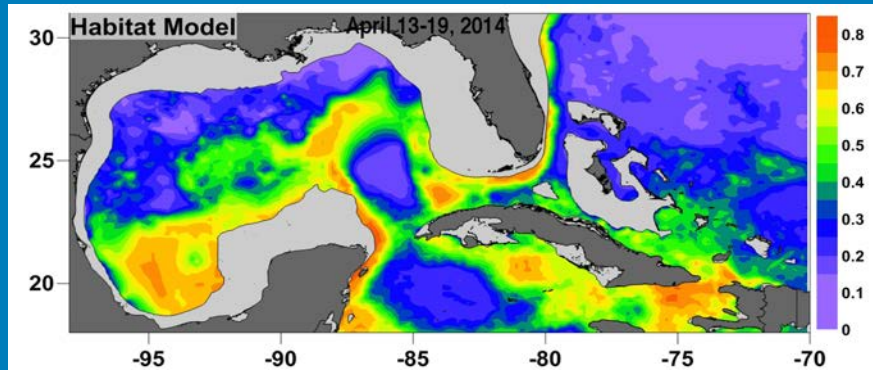




# Research Tool Development

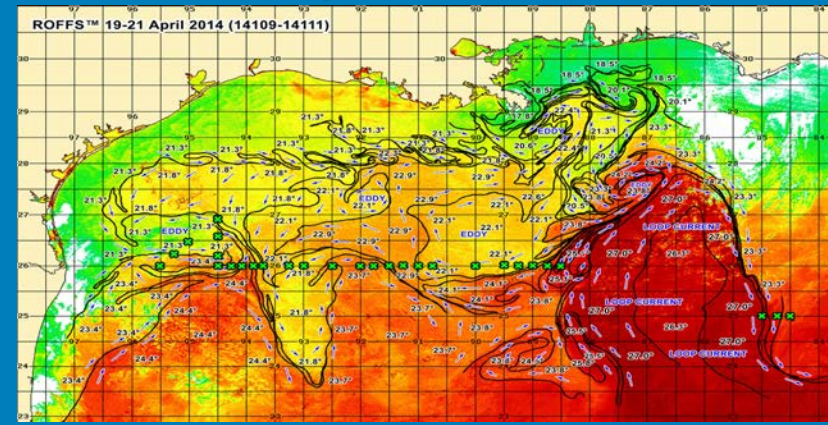
- Highly migratory species (larvae and adults), **habitat modeling\*** and climate change.

- **Habitat classification and neural networks.**



30+ years of NMFS larvae cruise data (larvae, in situ, satellite)

23 years commercial longline data (NOAA + ICCAT)

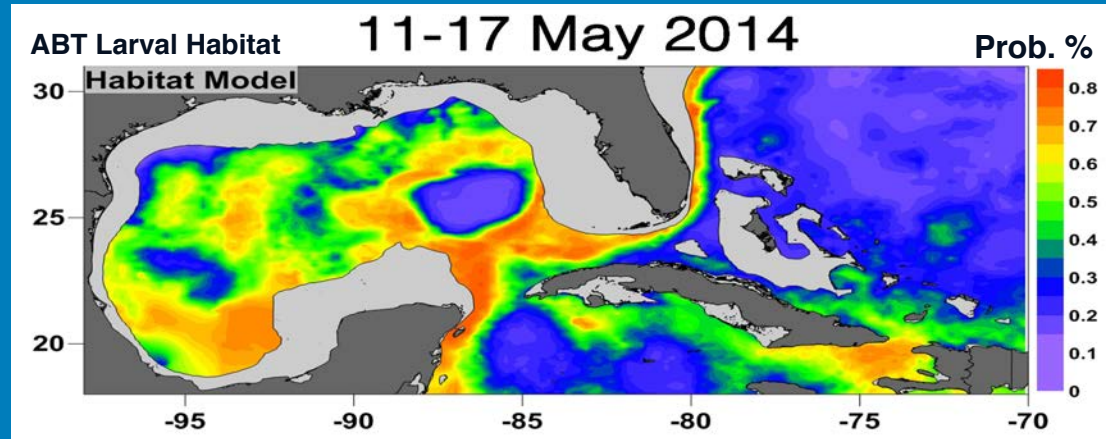
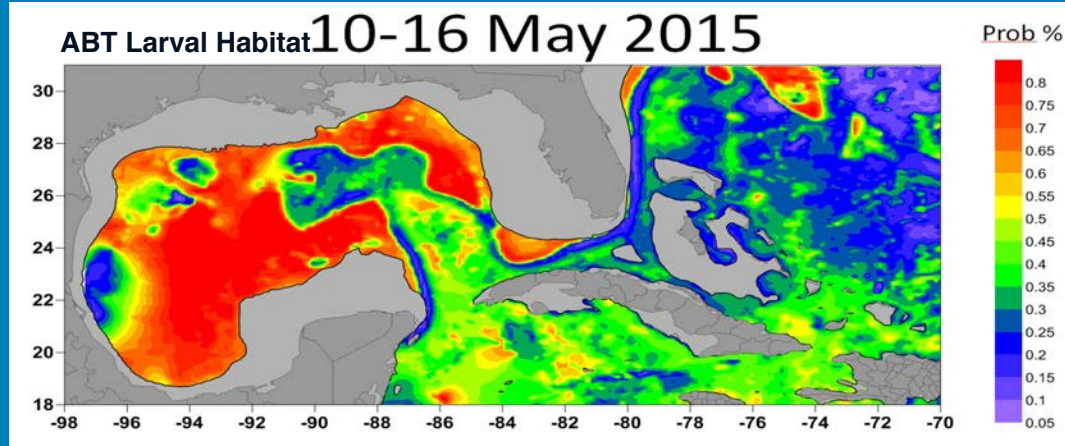


M. Roffer, J. Lamkin, B. Muhling, F. Muller-Karger, S K, Lee, Y. Liu, W. Ingram, G. Goni, D. Enfield and others  
2008 – 2016 (NASA & NOAA NMFS SEFSC support)

**\*Quantitative probabilities  
Used in larval assessment**

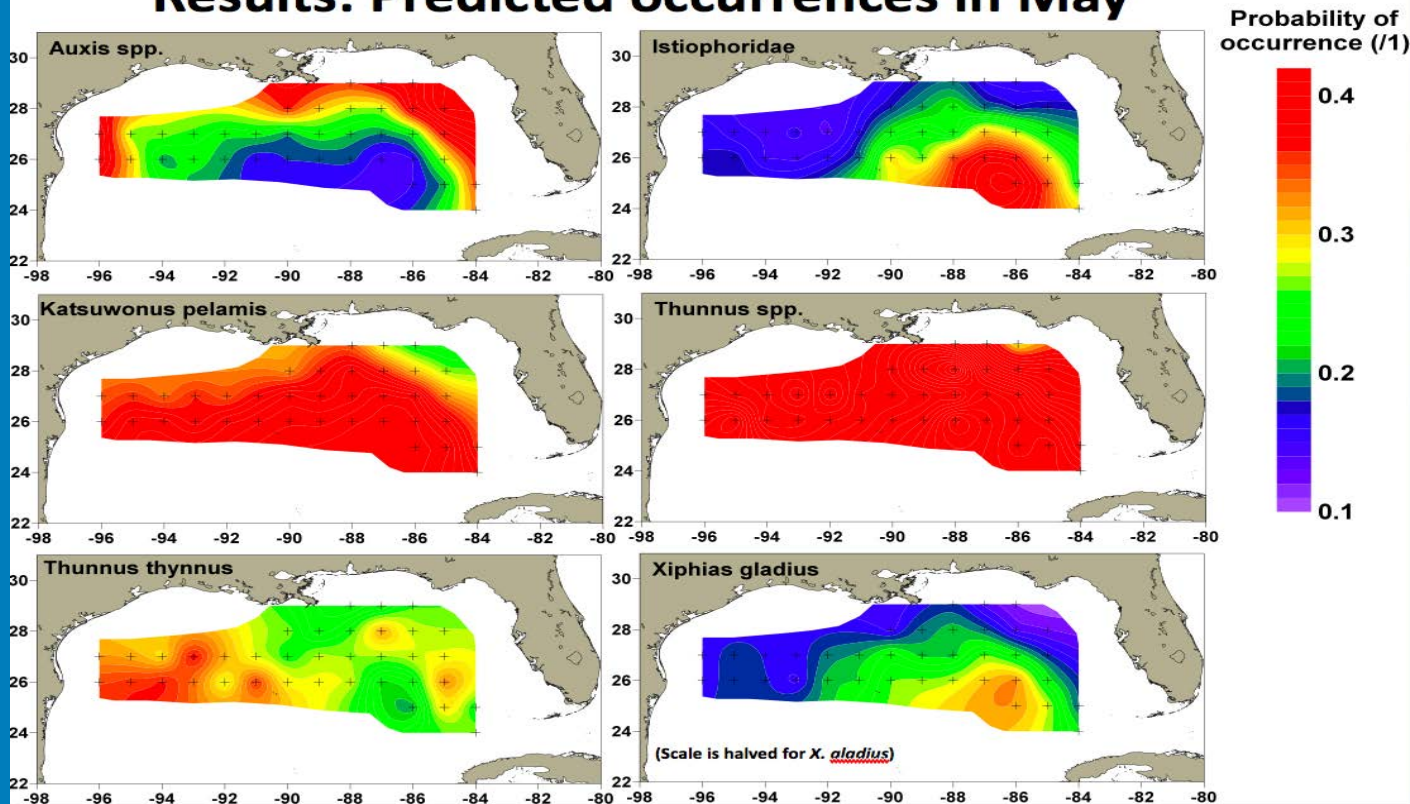


# Larval Habitat Variable



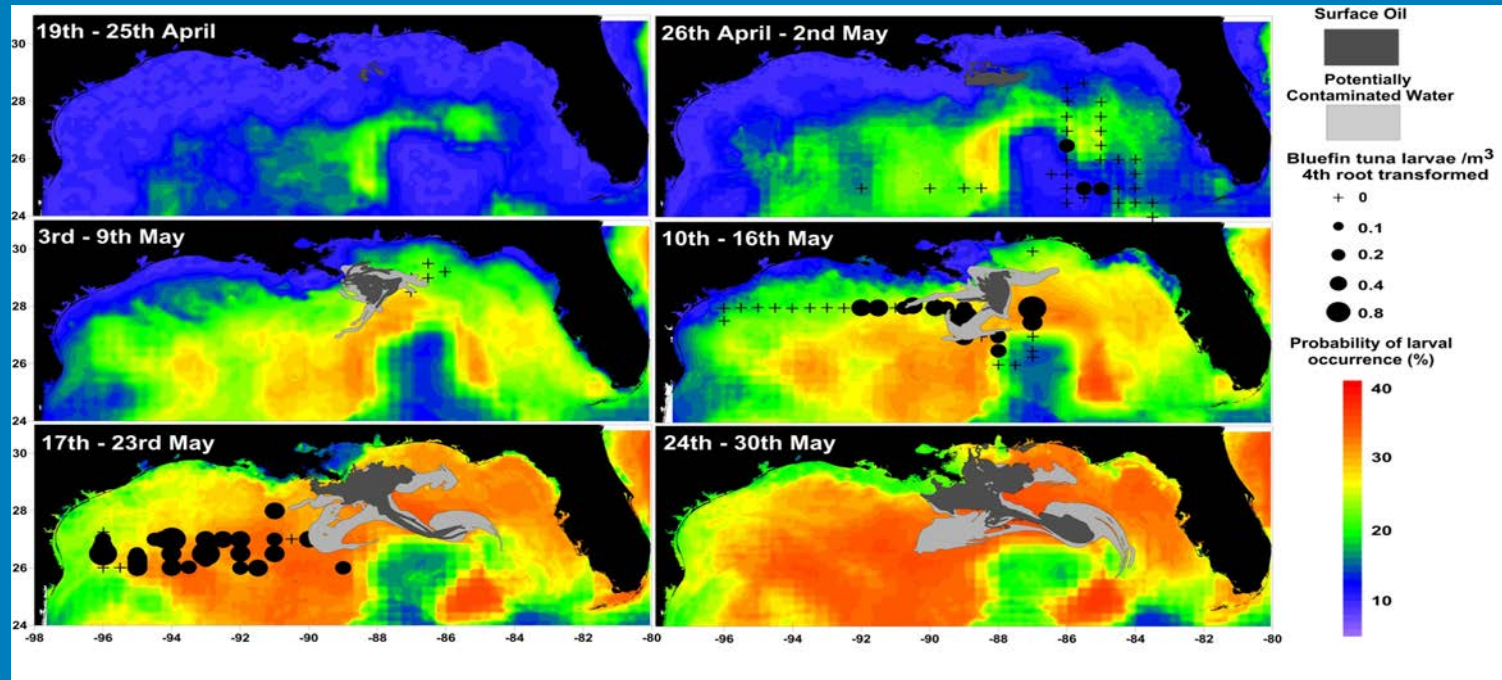
# LARVAE HABITAT MODELING

## Results: Predicted occurrences in May





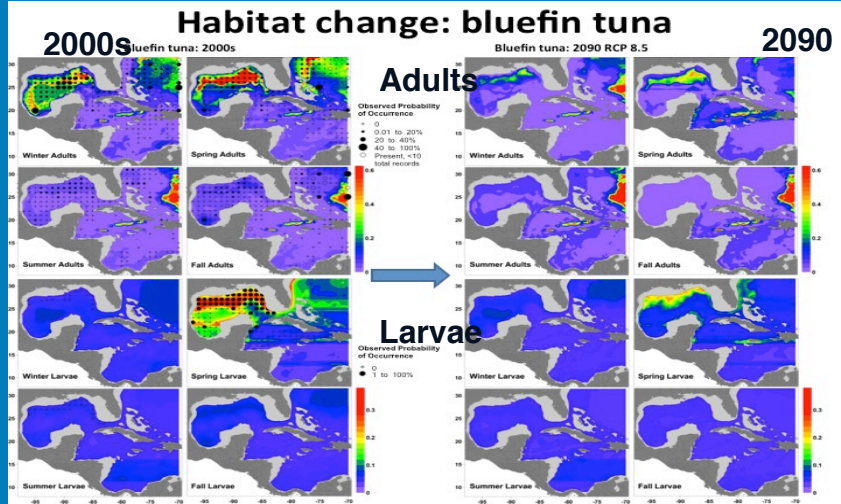
# Bluefin Tuna and Deepwater Horizon Oil Spill



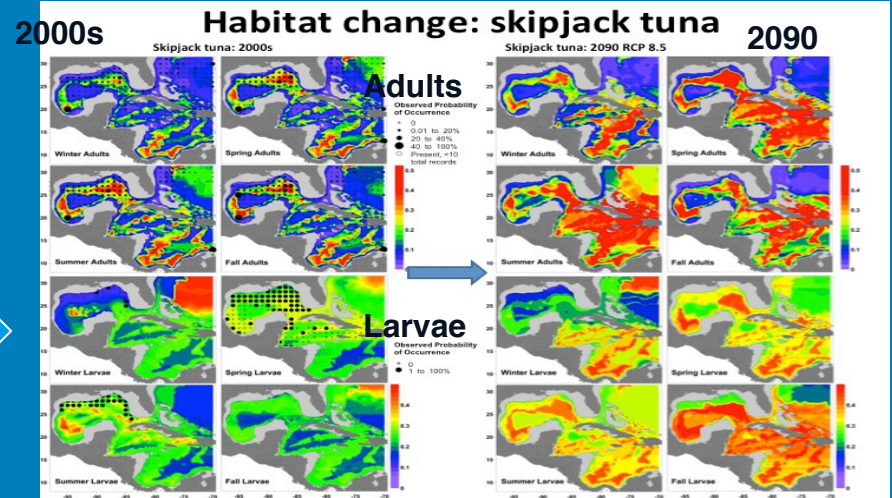
- Muhling, B.A., M.A. Roffer, J.T. Lamkin, G.W. Ingram, Jr., M.A. Upton, G. Gawlikowski, F.E. Muller-Karger, S. Habtes, and W.J. Richards. 2012. Overlap between Atlantic bluefin tuna spawning grounds and observed Deepwater Horizon surface oil in the northern Gulf of Mexico. *Marine Pollution Bull.* 64(4):697-687.



# Climate Change & Fish



Some losers

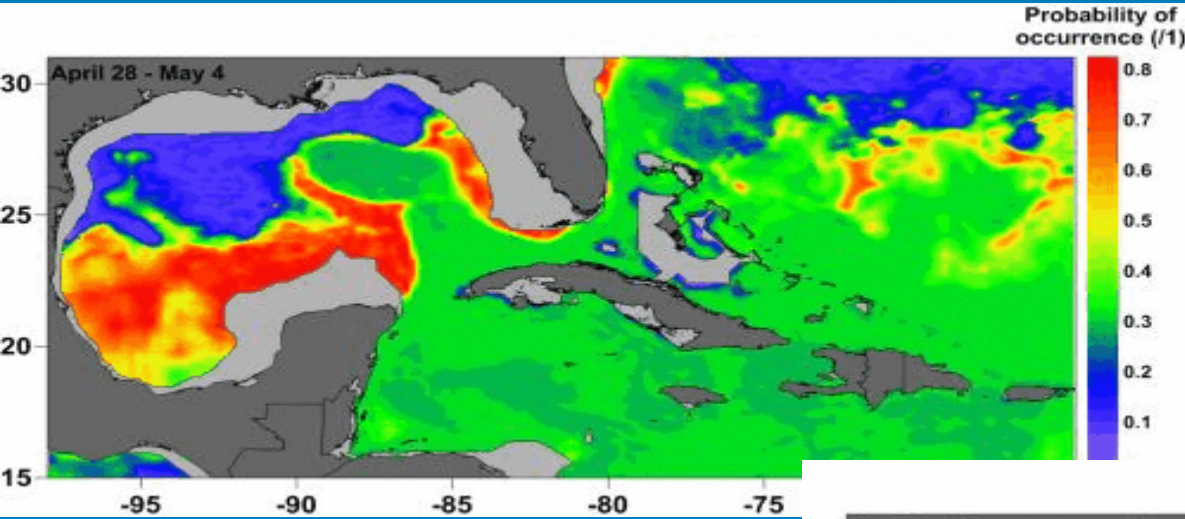


Some winners

Muhling, et al., 2015. J. Mar. Syst. 148: 1-13.

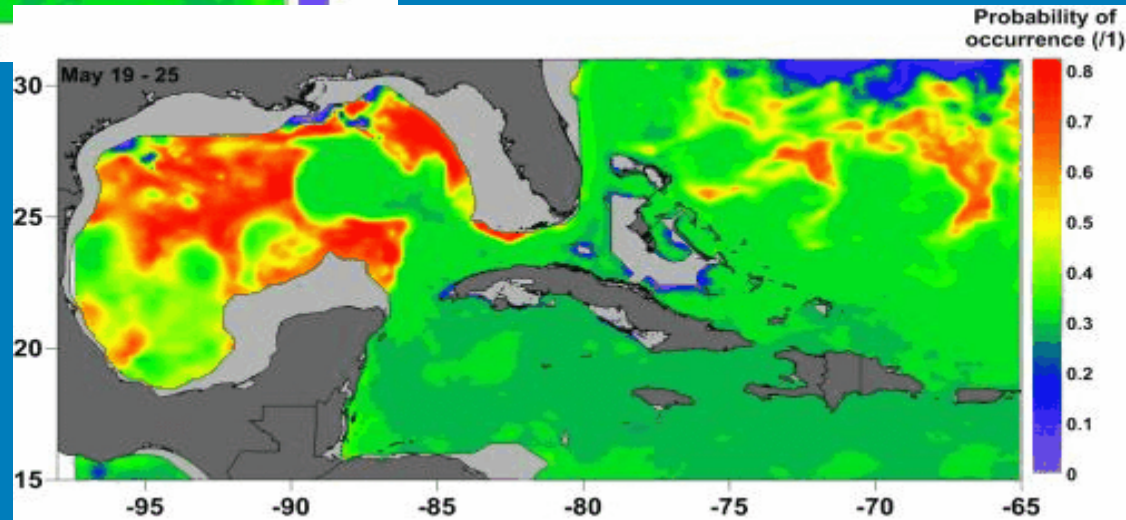


# Habitat in Gulf of Mexico, Bahamas, Caribbean 2013\*



Are bluefin tuna  
Spawning Outside  
Gulf of Mexico?

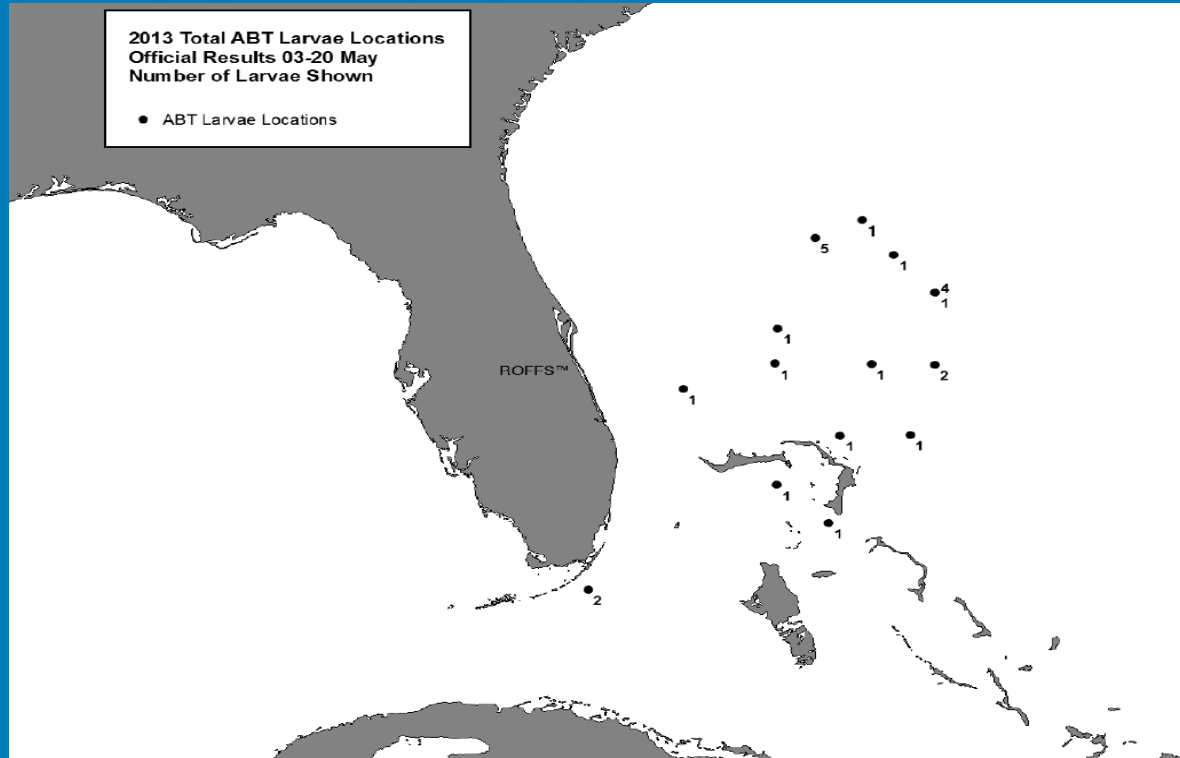
\*2013 habitat model May that  
was developed from Gulf  
Of Mexico data!





# 2013 Results for ABT

## 16 Positive Stations - 16.5%



Where were they spawned?



# Not Satisfied with the High Resolution Circulation Models

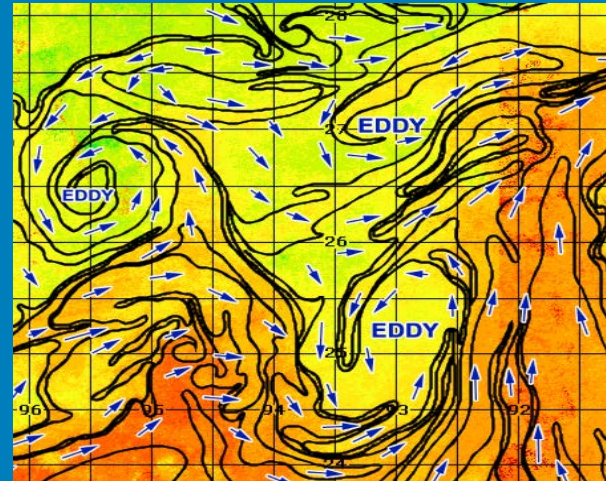
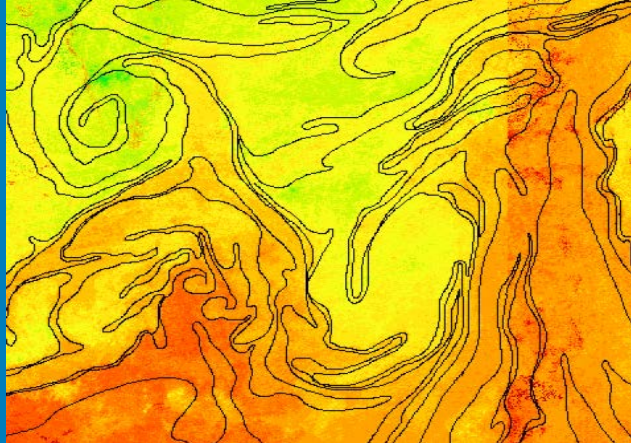


Warning if you use them:  
Know the Limitations  
Validation? – Calibration?



# Lagrangian Coherent Structures

1. LCS are structures which separate dynamically distinct regions in time-varying systems such as turbulent flows in fluid mechanics.
2. LCS divide dynamically distinct regions in the flow and reveal geometry which is often hidden when viewing the vector field or even trajectories of the system.
3. LCS often provide a nice tool in analyzing systems with general time-dependence, especially for understanding transport.

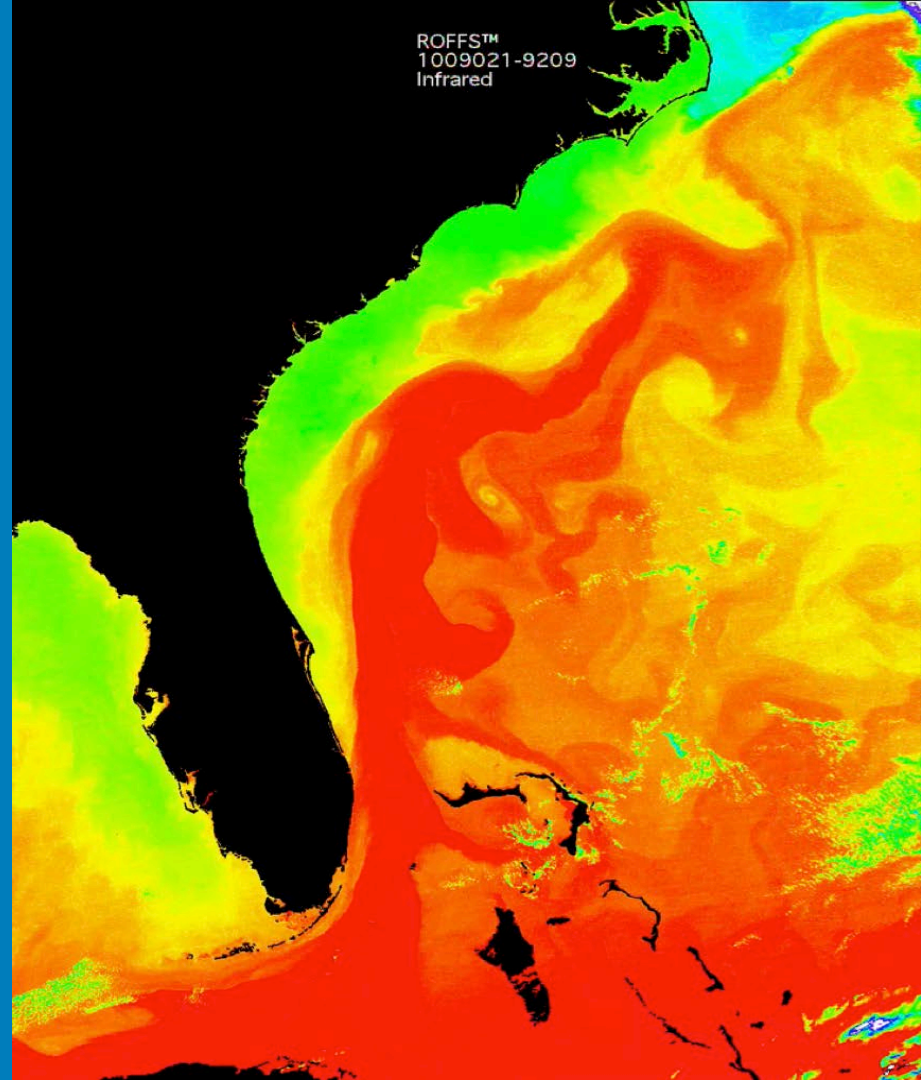


# Ocean Is Dynamic

**1 KM  
~HOURLY  
36HOURS  
IR/SST**



ROFFS™  
1009021-9209  
Infrared





17 May 2013 (13137)  
Daily ABT Larvae Locations  
Official Results

- ABT larvae location day 137

1312701-10

ROFFS™





# Are Bluefin Spawning Outside the Gulf of Mexico in Bahamas ?

- Based on our assumptions and tracking:
- 16 ABT definitely spawned in Bahamas
- 1 in the Gulf Stream
- 3 either the Gulf Stream or Bahamas
- 2 Gulf of Mexico

**YES bluefin tuna ARE spawning in Bahamas and north (east of northern South Carolina)**



We don't see good habitat every year  
Need to repeat routinely & expand area

# "Those who don't know history are doomed to repeat it." (Edmund Burke, 1729)

1. Liu, Y., S.-K., Lee, D.B. Enfield, B.A. Muhling, J.T. Lamkin, F.E. Muller-Karger, and M.A. Roffer. 2015. Impact of global warming on the Intra-Americas Sea: part-1. A dynamic downscaling of the CMIP5 model projections. J. Mar. Syst. 148:56-69.
2. Muhling, B.A., Y. Liu, S.-K. Lee, J.T. Lamkin, M.A. Roffer, F.E. Muller-Karger, and J.F. Walter III. 2015. Potential impact of climate change on the Intra-Americas Sea: Part-2. Implications for Atlantic bluefin tuna and skipjack tuna adult and larval habitats. J. Mar. Syst. 148: 1-13.
3. Lamkin J.T, B.A. Muhling, E. Malca, R. Laiz-Carrión, T. Gerard, S. Privoznik, Y. Liu, S.K.Lee, G.W. Ingram Jr., M.A. Roffer, F. Muller-Karger, J. Olascoaga, L. Fiorentino, W. Nero & W. J. Richards, 2014. Do Western Atlantic Bluefin Tuna Spawn Outside Of The Gulf Of Mexico? Results From A Larval Survey In The Atlantic Ocean In 2013. ICCAT SCRS/2014/176 12p.
4. Muhling, B.A., P. Reglero, L. Ciannelli, D. Alvarez-Berastegui, F. Alemany, J.T. Lamkin, and M. A. Roffer. 2013. A comparison between environmental characteristics of larval bluefin tuna (*Thunnus thynnus*) habitat in the Gulf of Mexico and western Mediterranean Sea. Marine Prog. Ser. 486:257-276.
5. Muhling, B.A., M.A. Roffer, J.T. Lamkin, G.W. Ingram, Jr., M.A. Upton, G. Gawlikowski, F.E. Muller-Karger, S. Habtes, and W.J. Richards. 2012. Overlap between Atlantic bluefin tuna spawning grounds and observed Deepwater Horizon surface oil in the northern Gulf of Mexico. Marine Pollution Bull. 64(4): 697-687.

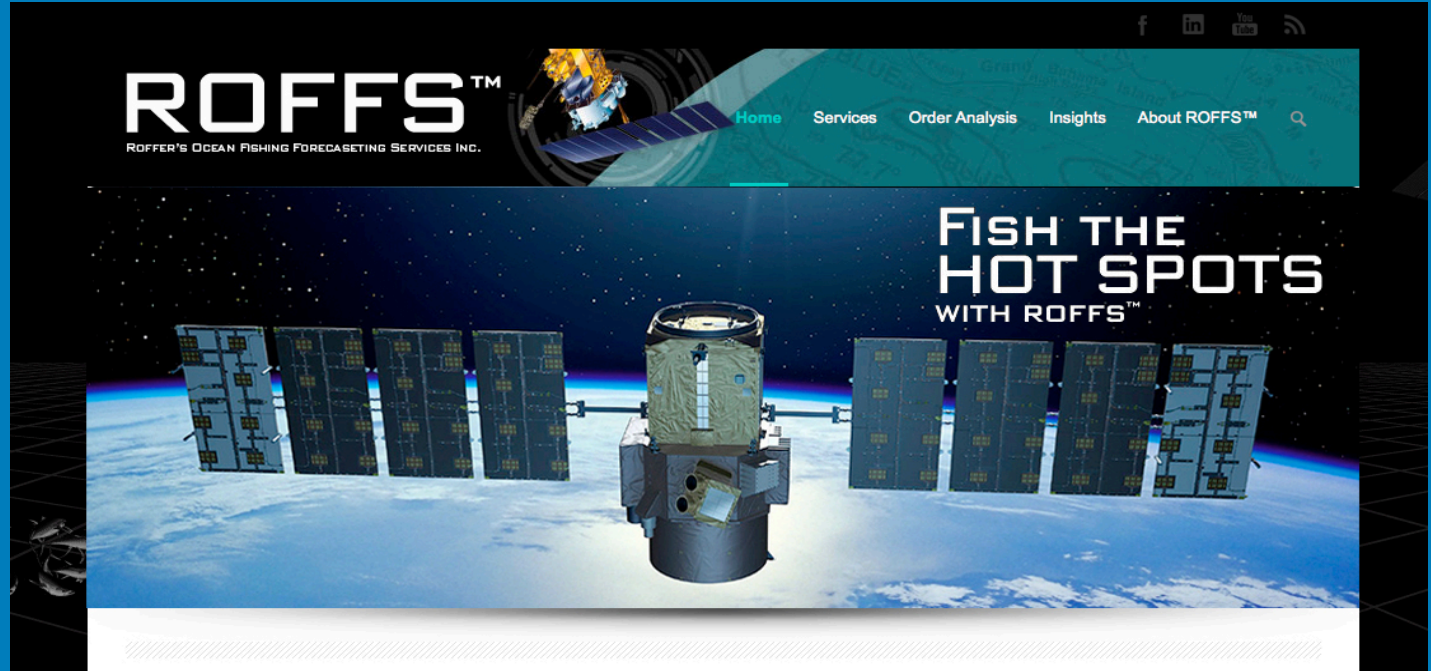


# Other Publications

1. Habtes, S., F.E. Muller-Karger, M. A. Roffer, J.T. Lamkin, and B. A. Muhling. 2014 A comparison of sampling methods for larvae of medium and large epipelagic fish species during SEAMAP ichthyoplankton surveys in the Gulf of Mexico. *Limnol. Oceanogr.: Methods* 12: 86-101.
2. Muhling, B.A., J.T. Lamkin, J.M. Quatro, R.H. Smith, M.A. Roberts, M.A. Roffer, and K. Ramirez. 2011. Collection of Larval Bluefin Tuna (*Thunnus thynnus*) Outside Documented Western Atlantic Spawning Grounds. *Bull. Mar. Sci. Bull. Mar. Sci.* 87(3):687-694.).
3. Muhling, B.A., J.T. Lamkin, and M.A. Roffer. 2010. Predicting the Occurrence of Bluefin Tuna (*Thunnus thynnus*) Larvae in the Northern Gulf of Mexico: Building a Classification Model from Archival Data. *Fish. Oceanogr.* 19:6, 526-539.
4. Muhling, B.A., Lee, S-K, Lamkin, J.T. (2011) Predicting the effects of climate change on bluefin tuna (*Thunnus thynnus*) spawning habitat in the Gulf of Mexico. *ICES Journal of Marine Science* 68: 1051-1062.
5. Liu Y., S.-K. Lee, B. A. Muhling, J. T. Lamkin and D.B. Enfield, 2012: Significant reduction of the Loop Current in the 21st century and its impact on the Gulf of Mexico. *J. Geophys. Res.*, 117, C05039, doi:10.1029/2011JC007555
6. Muhling, B.A., P. Reglero, L. Ciannelli, D. Alvarez-Berastegui, F. Alemany, J.T. Lamkin, and M. A. Roffer. 2013. A comparison between environmental characteristics of larval bluefin tuna (*Thunnus thynnus*) habitat in the Gulf of Mexico and western Mediterranean Sea. *Marine Prog. Ser.* 486:257-276.
7. Muller-Karger, F.; Roffer, M.; Walker, N.; Oliver, M.; Schofield, O.; Abbott, M.; Graber, H.; Leben, R.; Goni, G., 2013. "Satellite Remote Sensing in Support of an Integrated Ocean Observing System," *Geoscience and Remote Sensing Magazine, IEEE* , 1 (4):8-18, 2013 doi: 10.1109/MGRS.2013.2289656
8. Hoodonk, R.V., J.A. Maynard, Y. Liu, and S.K. Lee. 2015. Downscaled projections of Caribbean coral bleaching than can inform conservation planning. *Global Change Biol.* Doi: 10.1111/gcb.12901

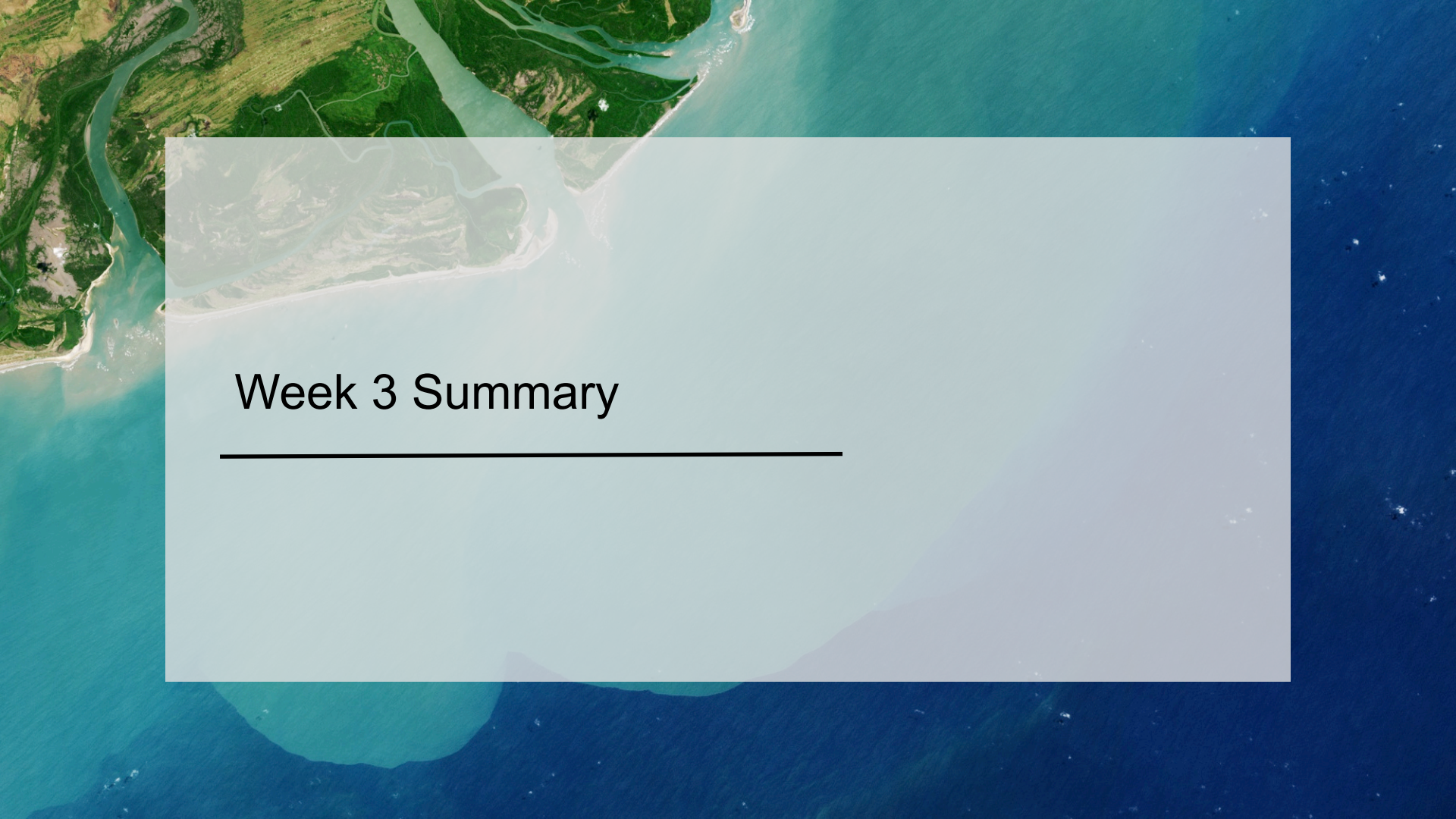


# THANK YOU & LET THE FUN BEGIN QUESTIONS



Facebook, LinkedIn, Twitter, etc.



An aerial photograph of a coastal region. In the top left, a river with a complex delta system flows into a body of water. The land is green with some brown patches, possibly indicating marshland or agricultural areas. The water transitions from a light turquoise near the shore to a deep blue further out. A large, semi-transparent white rectangle is overlaid on the right side of the image, containing the text 'Week 3 Summary' and a horizontal line.

## Week 3 Summary

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## Week 3 Agenda

- Brief Review of Last Week
- Overview of animal movement/migration
- Overview of coupled model and remote sensing tools for tracking animal movement
- Examples of remote sensing tools for understanding animal movement
- Guest Speaker:
  - Dr. Mitchell Roffer: Roffer's Ocean Fishing Forecasting Service



National Aeronautics and  
Space Administration



## ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>

 @NASAARSET

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# Thank you!

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Next Week:

Coral Reefs