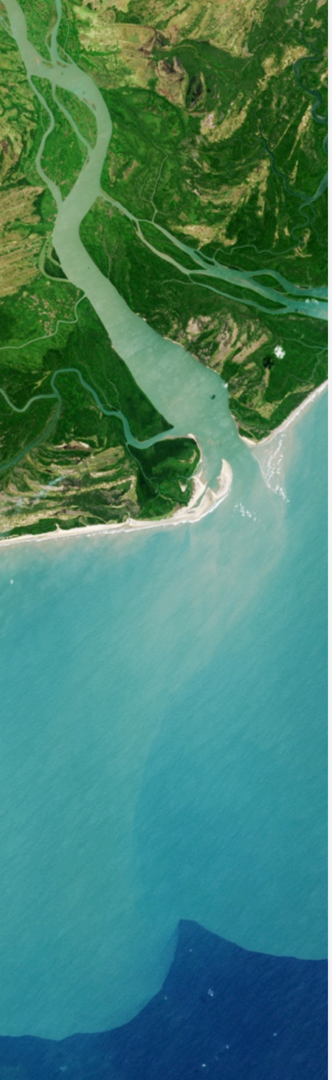


National Aeronautics and
Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Introduction to Remote Sensing for Ocean and Coastal Applications

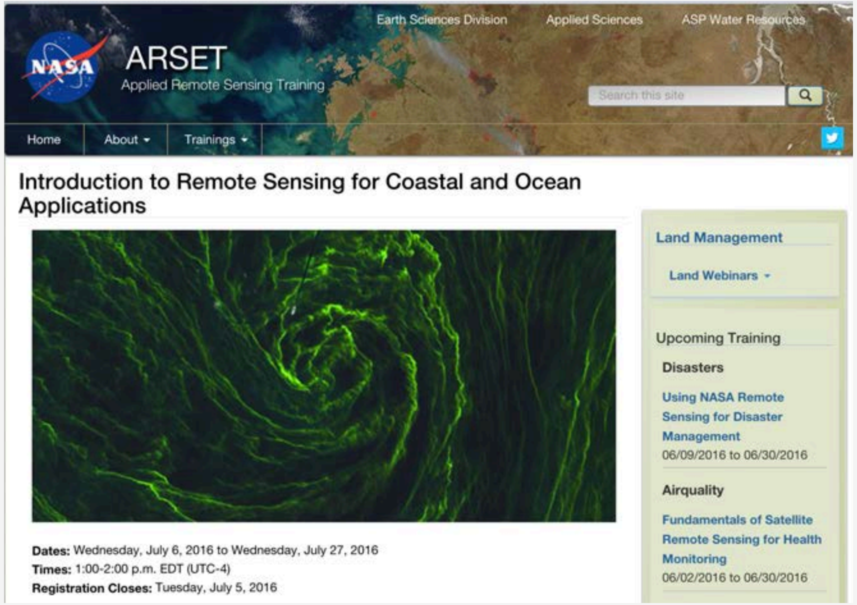
Week 3: Animal Movement and Migration

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)

Accessing Course Materials

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

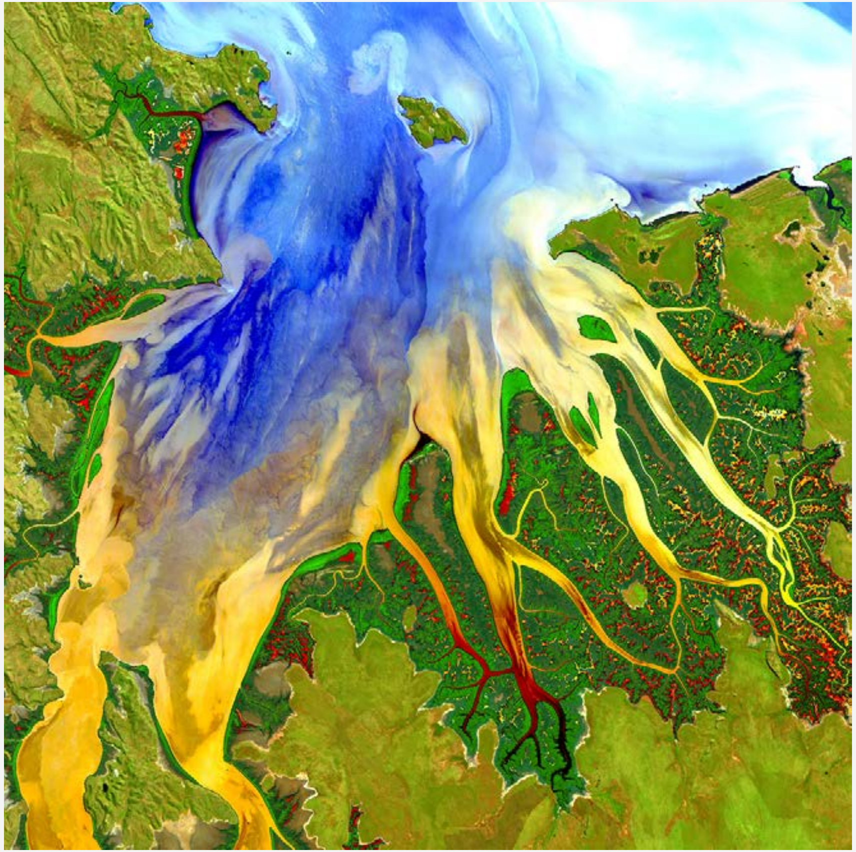
- Sherry Palacios: sherry.l.palacios@nasa.gov
- Amber McCullum: amberjean.mccullum@nasa.gov
- Cindy Schmidt: cynthia.l.schmidt@nasa.gov

- 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

Course Objectives

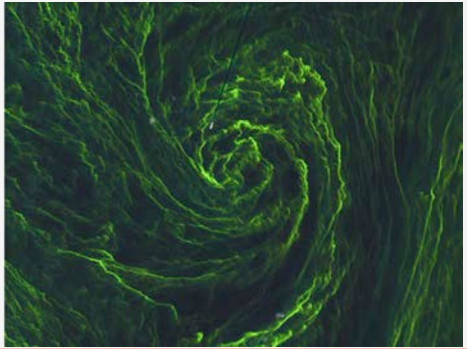
- Overview of NASA Earth Observation resources available for open ocean and coastal applications including:
  - A basic understanding of remote sensing of aquatic systems
  - How to access and visualize NASA Earth science data
  - How to use NASA Earth science data, tools, and products for ocean and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

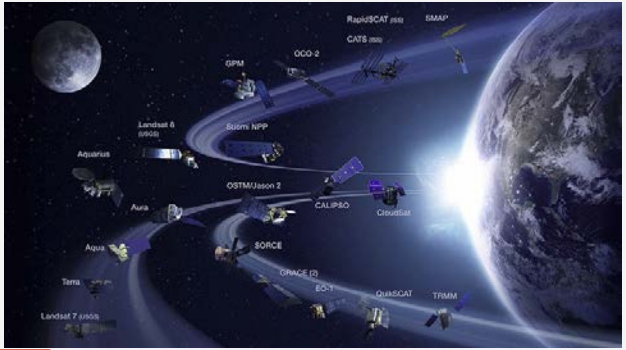


Credit: NASA/USGS Landsat; Geoscience Australia

Course Outline

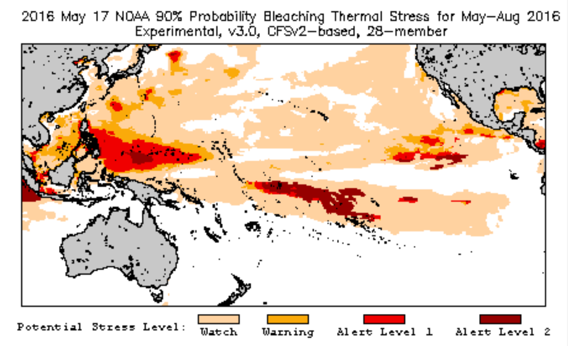
Week 1
Overview of Satellite Remote Sensing





Week 2
Platforms and Sensors for Ocean Observations

Week 3
Animal Movement



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

Review of Week 2

NASA Satellites & Sensors for Ocean and Coastal Systems

Satellite	Sensor	Parameter
Landsat Series (7/1972 - present)	• Thematic Mapper (TM) • Enhanced Thematic Mapper (ETM+) • Operational Land Imager (OLI)	• Spectral Reflectance
Terra (12/1990-present)	Moderate Resolution Imaging Spectroradiometer (MODIS)	• Spectral Reflectance • Chlorophyll-a Concentration • Temperature • Colored Dissolved Organic Matter (CDOM) • Turbidity • Euphotic Depth
Aqua (5/2002-present)		
Terra (12/1999 – present)	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)	• Spectral Reflectance • Temperature

NASA Satellites & Sensors for Ocean and Coastal Systems

Satellite	Sensor	Parameter
National Polar Partnership (NPP) (11/2011-present)	Visible Infrared Imaging Radiometer Suite (VIIRS)	• Spectral Reflectance • Chlorophyll Concentration
International Space Station	Hyperspectral Imager for the Coastal Ocean (HICO) (2009 – 2014)	• Spectral Radiance • Spectral Remote Sensing Reflectance
Plankton, Aerosols, Clouds, ocean Ecosystems, PACE (proposed for 2022 or 2023)	Ocean Color Instrument	• Spectral Reflectance • Optional Polarimeter being considered

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

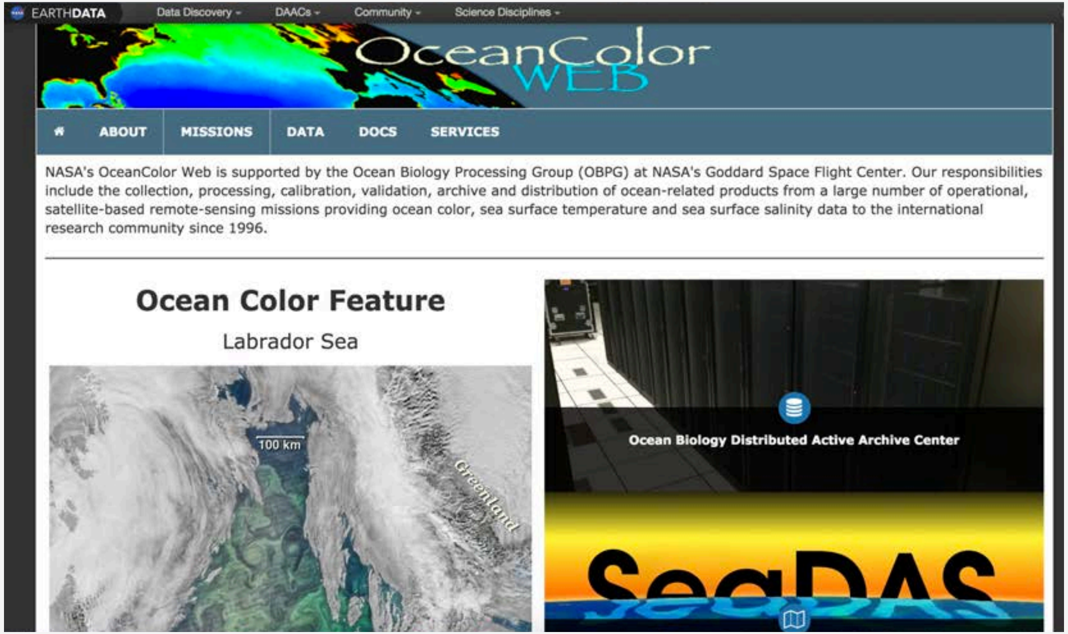
Harder to Use

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

Overview of Animal Movement & Migration

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

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credit: B. Mueller

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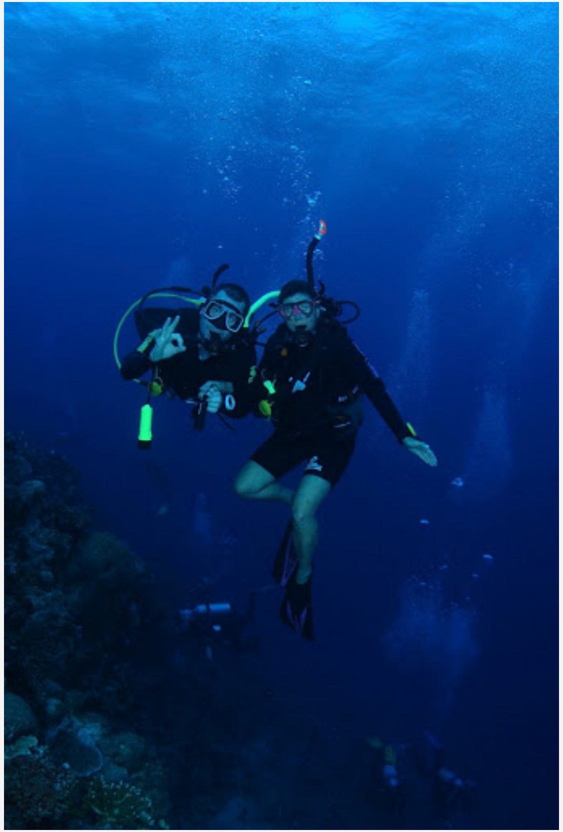
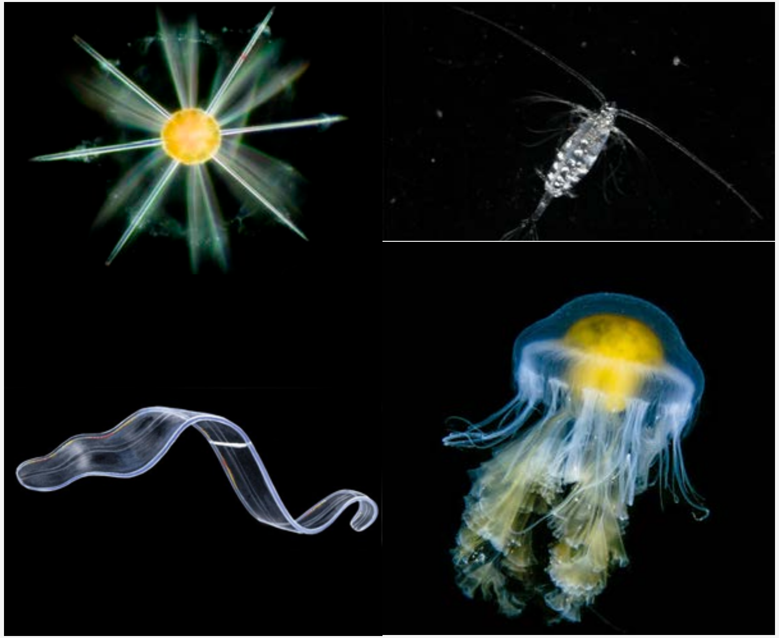


Credit: L. Buckingham

Life as Plankton or Nekton

Plankton: drifters
(usually microscopic)



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

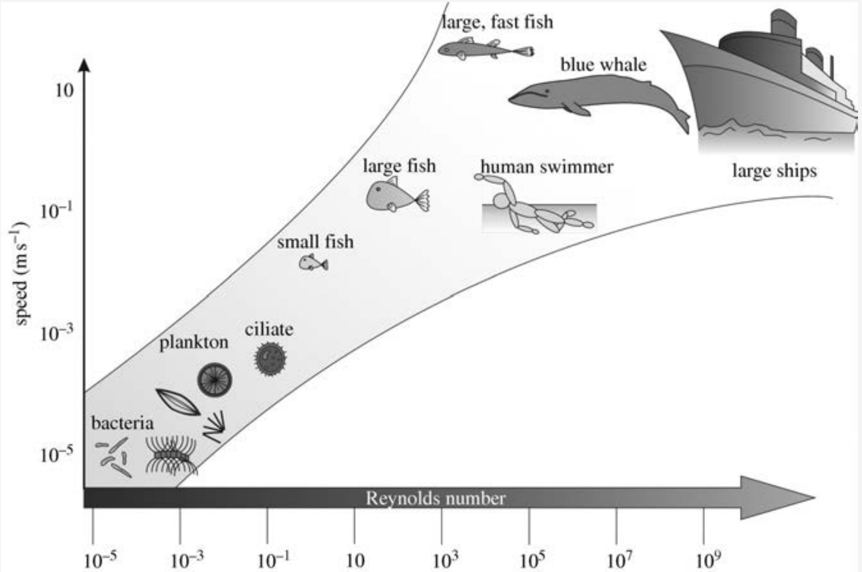
Nekton: swim freely
and independent of currents

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

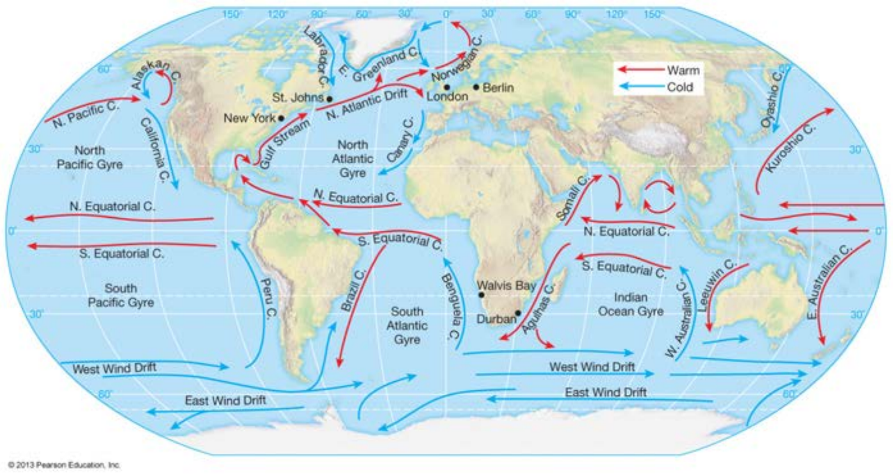


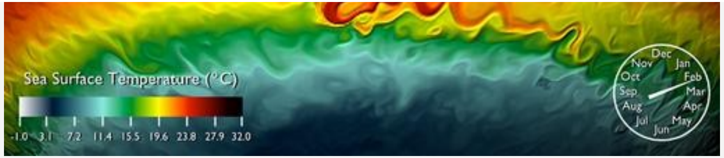
Credit: The Royal Society

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

Agulhas Current “Leaks” Salt into





Credit: NOAA/GDFL

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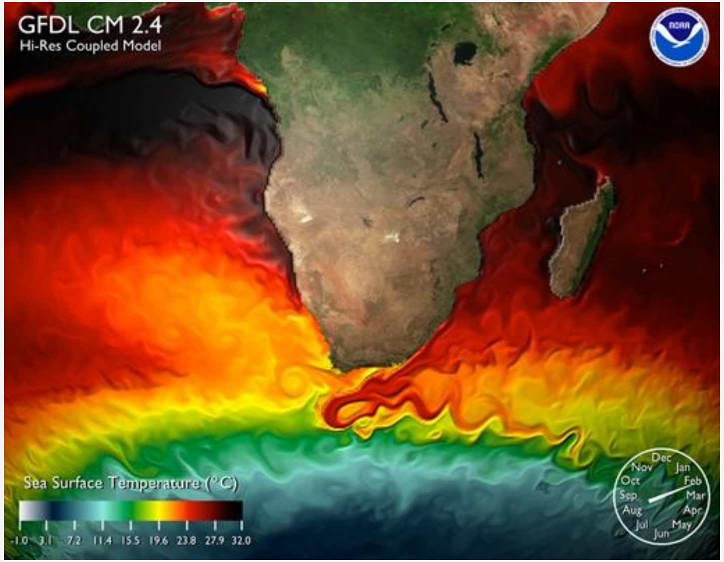
Agulhas Current "Leaks" Salt into South Atlantic from Indian Ocean



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, Inferometric 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

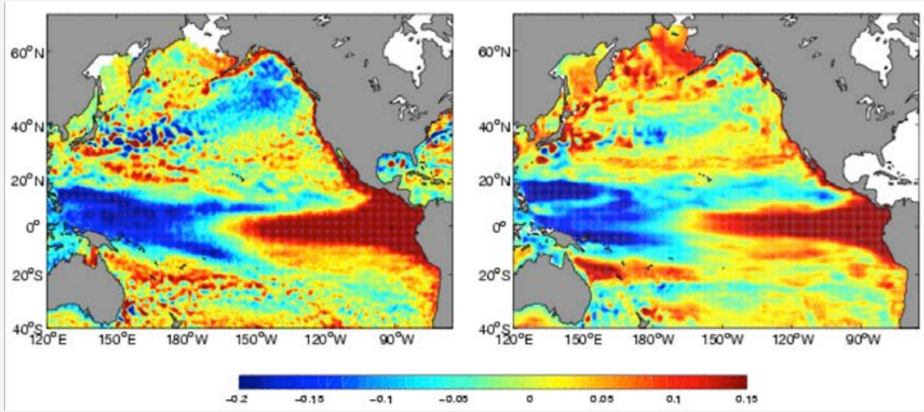
Models of a Moving Ocean

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)

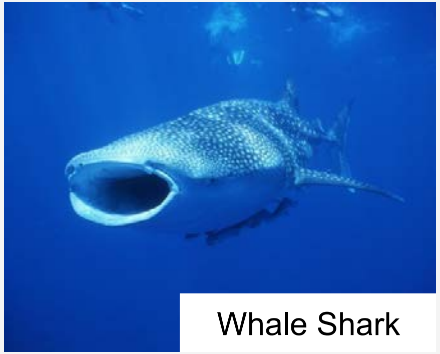


Credit: Center for Earth System Research, UC-Los Angeles
http://research.atmos.ucla.edu/cesr/index.html

Monitoring Animal Movement

Differences Between Land and Sea

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

Coupled Model and Remote Sensing Tools for Tracking Animal Movement

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

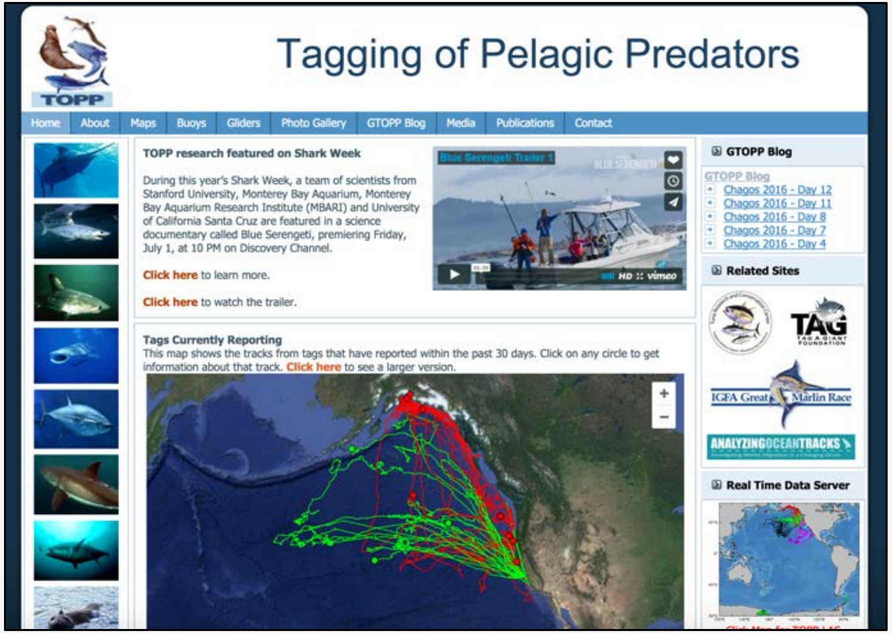
- Predictions of species distribution and abundance in year 2100

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

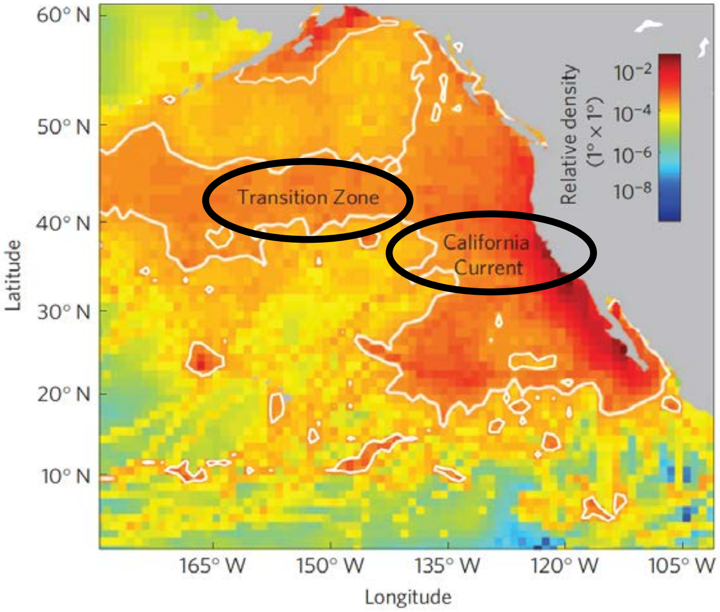
Credit: TOPP

Tag Data Informed Present Day Species Density

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

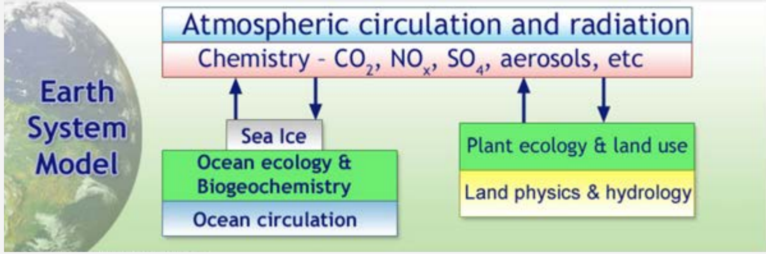
- Biological "hotspots"
  - Transition Zone
  - California Current
- Hotspots move with season
- Observed seasonal patterns suggest climate change may affect species distribution and abundance

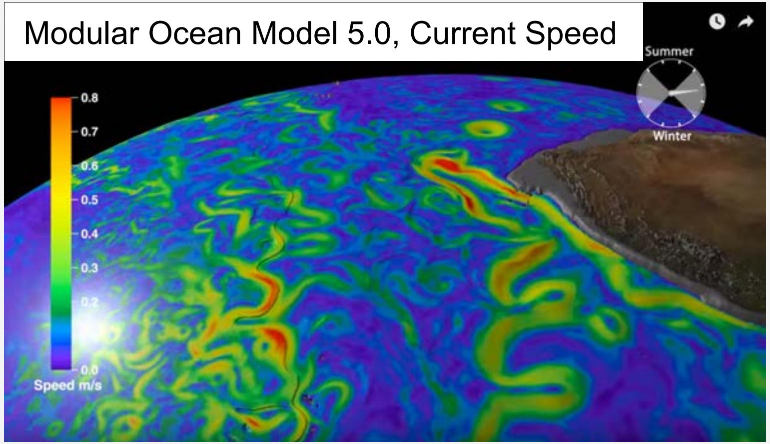
Density of Top Predator Species in the Eastern North Pacific



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

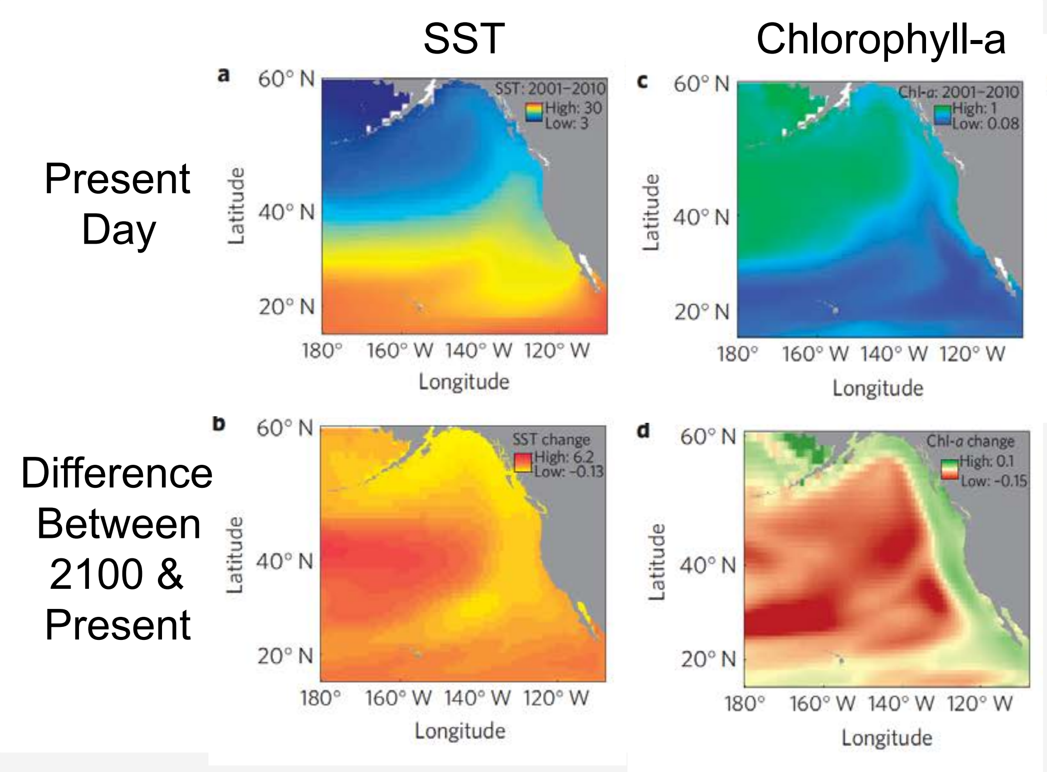




Southern Ocean Visualization: https://youtu.be/8VMSF28J9H4

How will SST and Chlorophyll-a Change?

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

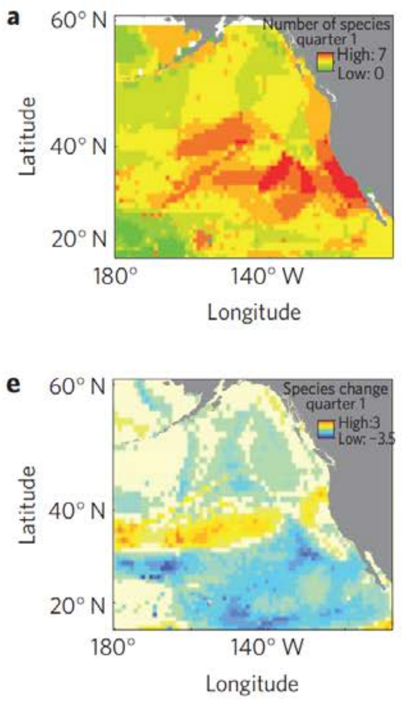


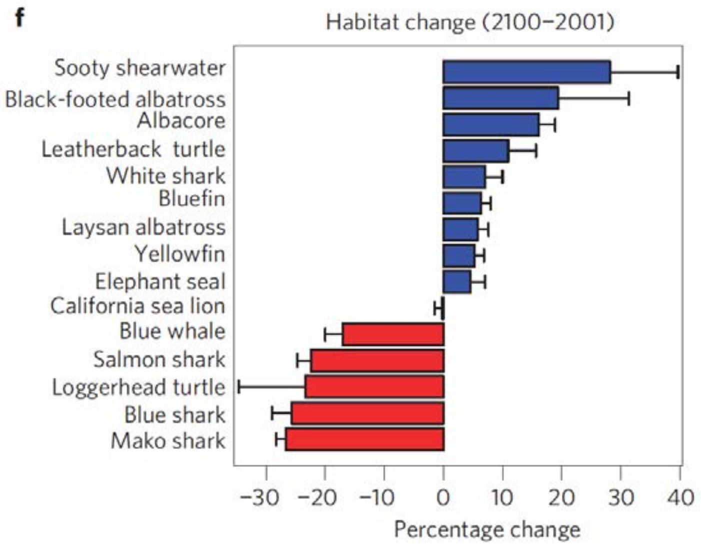
Habitat is Predicted to Decline by 2100

Some Species are Losers, Others are Winners

Present Day

Difference Between 2100 & Present





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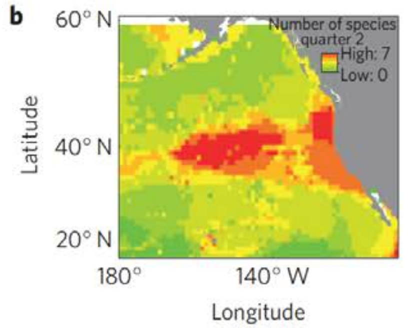

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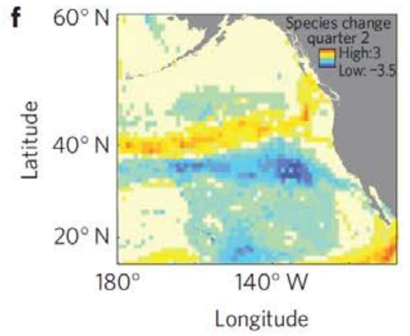

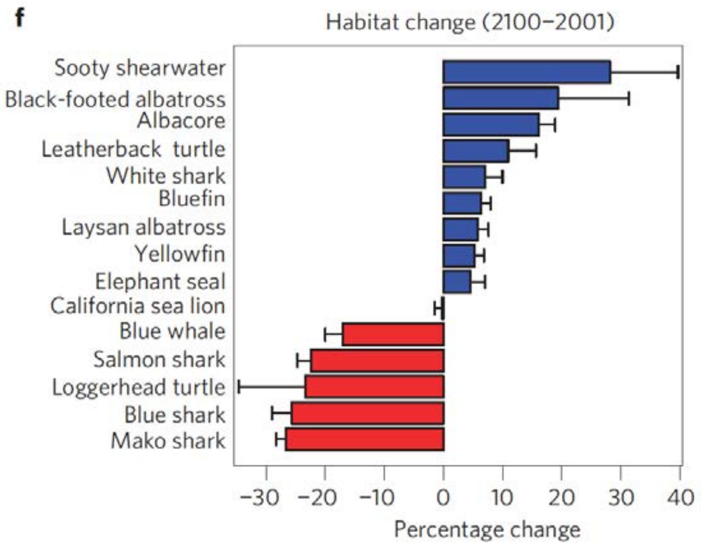

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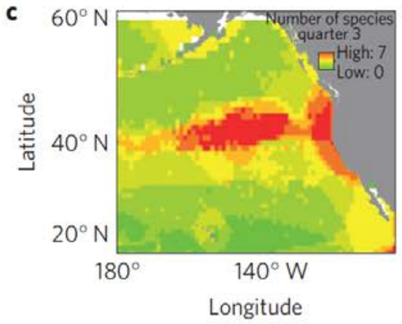

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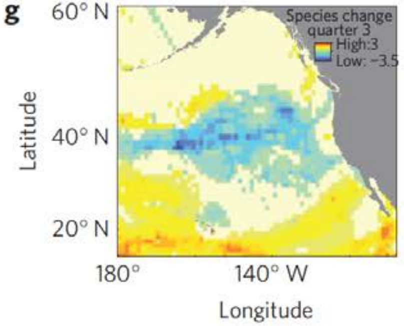

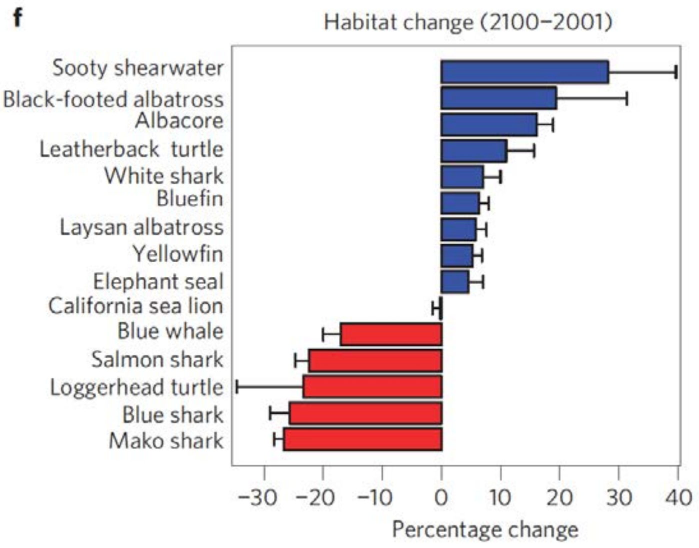

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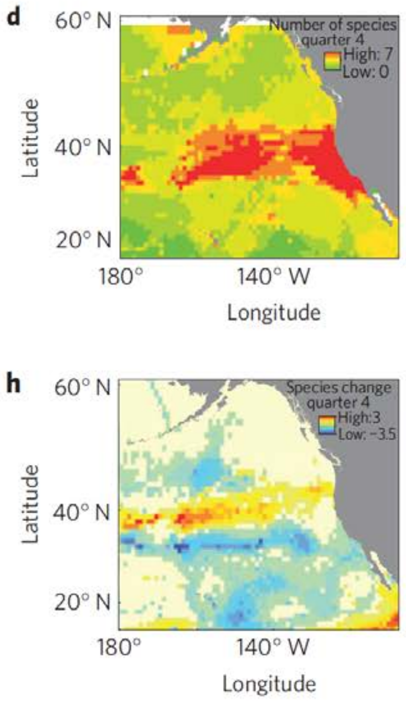

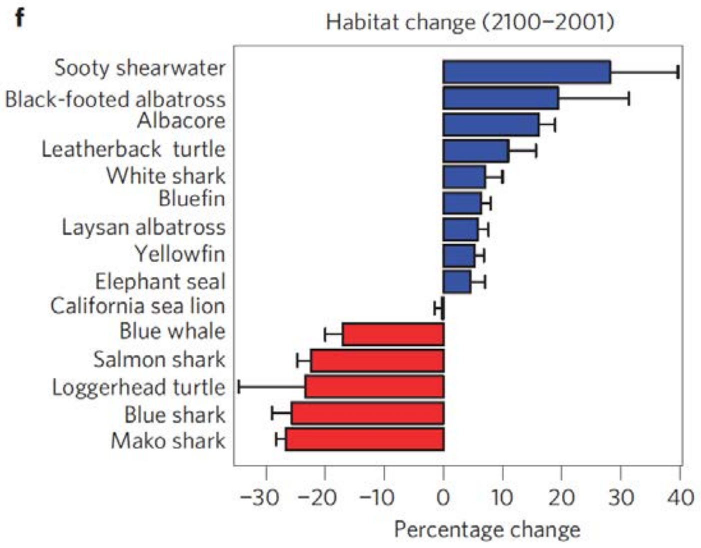

Examples of Remote Sensing Tools for Understanding Animal Movement

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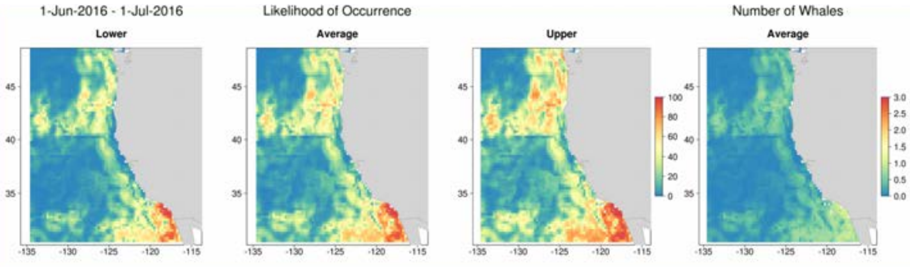
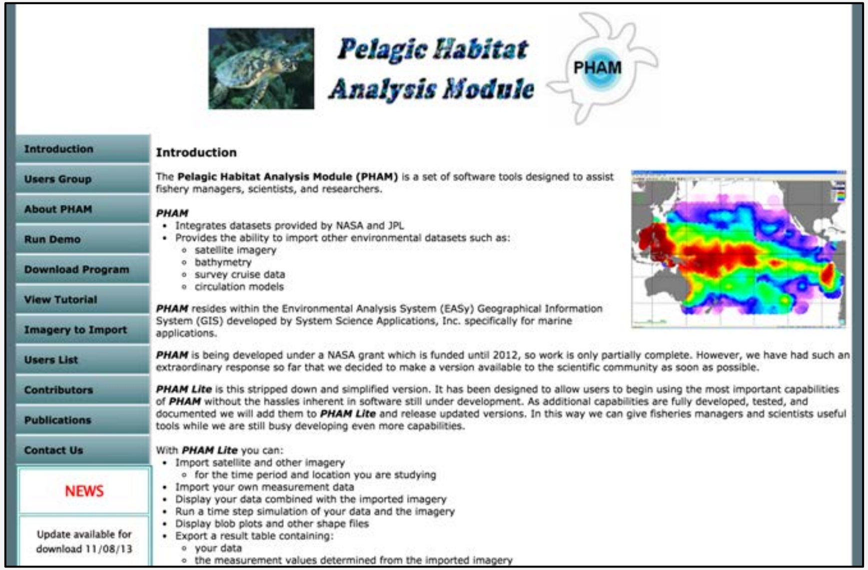
This month’s estimate of
Blue Whales off the US West Coast



Pelagic Habitat Analysis Module (PHAM)

http://www.phamlite.com/

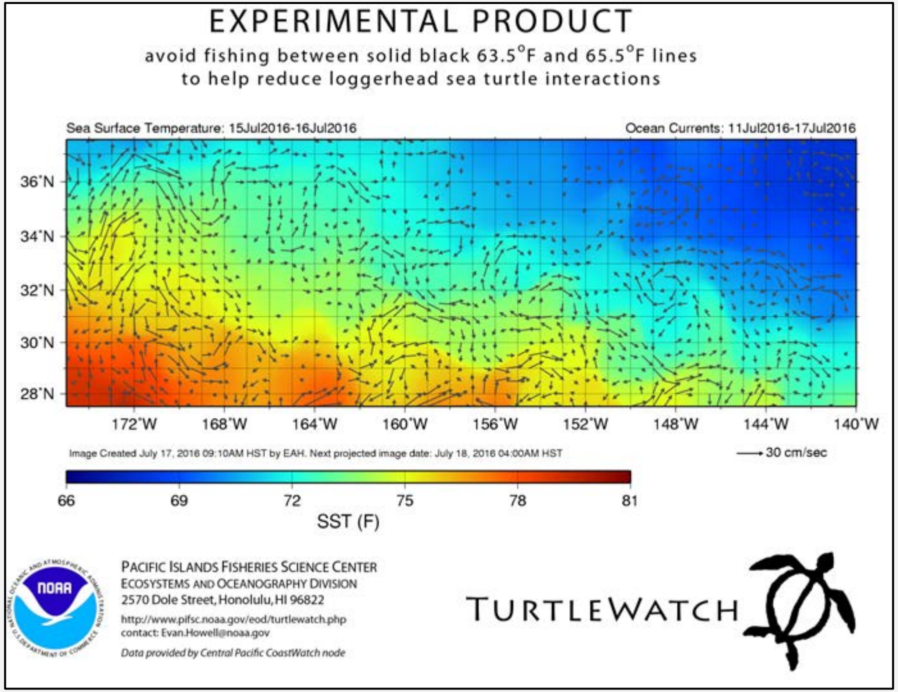
- GIS software tool for fisheries managers, scientists, and researchers to examine and predict pelagic ocean biota habitat
- Uses biota presence/absence or abundance data combined with environmental data (satellite imagery, bathymetry, survey cruises, and ocean circulation models)
- Freely available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



NOAA TurtleWatch

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

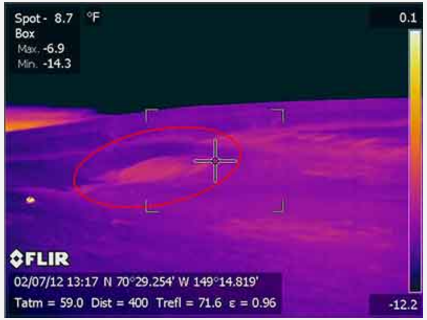
- Up-to-date information about thermal habitat of loggerhead sea turtles in the Pacific Ocean north of the Hawaiian Islands
- Created to reduce interactions between Hawaii-based long-line fishing vessels and loggerhead turtles
- Predicts the location of waters preferred by these turtles based on sea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



Remote Detection of Polar Bear Dens

http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.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/

Live Demo:
Roffer’s Ocean Fishing Forecasting Service


ROFFS™
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)

ROFFS™

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

ACKLOWLEDGMENT
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)
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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

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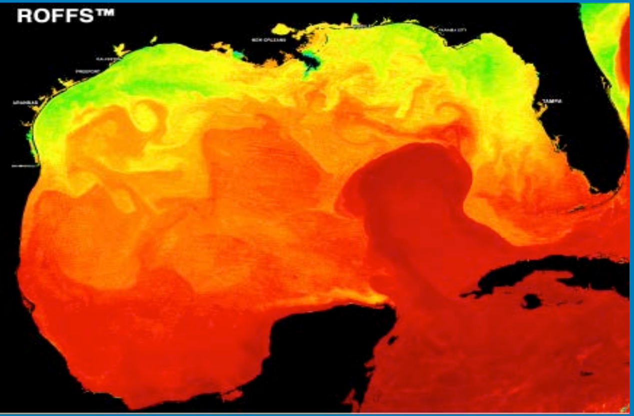
Gulf of Mexico & North Atlantic Ocean

Larvae and Adults



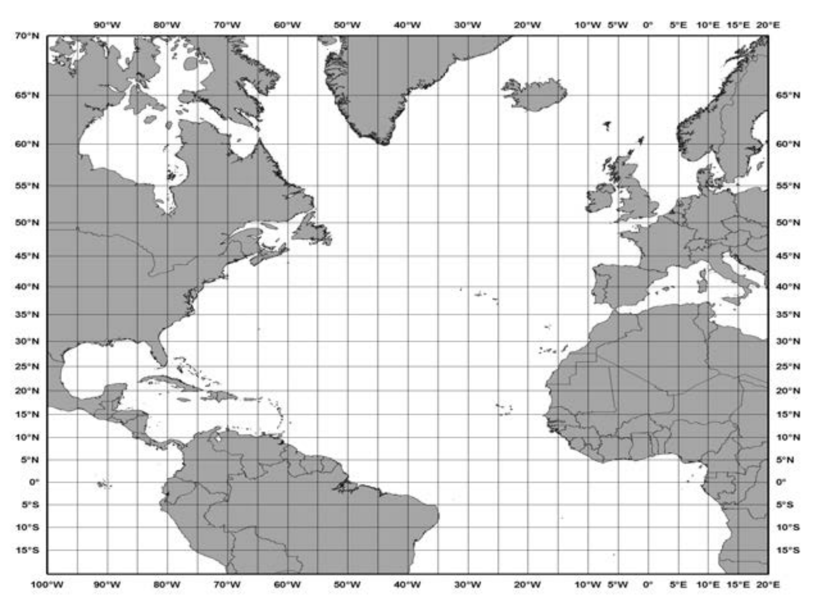
Infrared Image

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

Climate model domain
1000's km

6 mm

2 m



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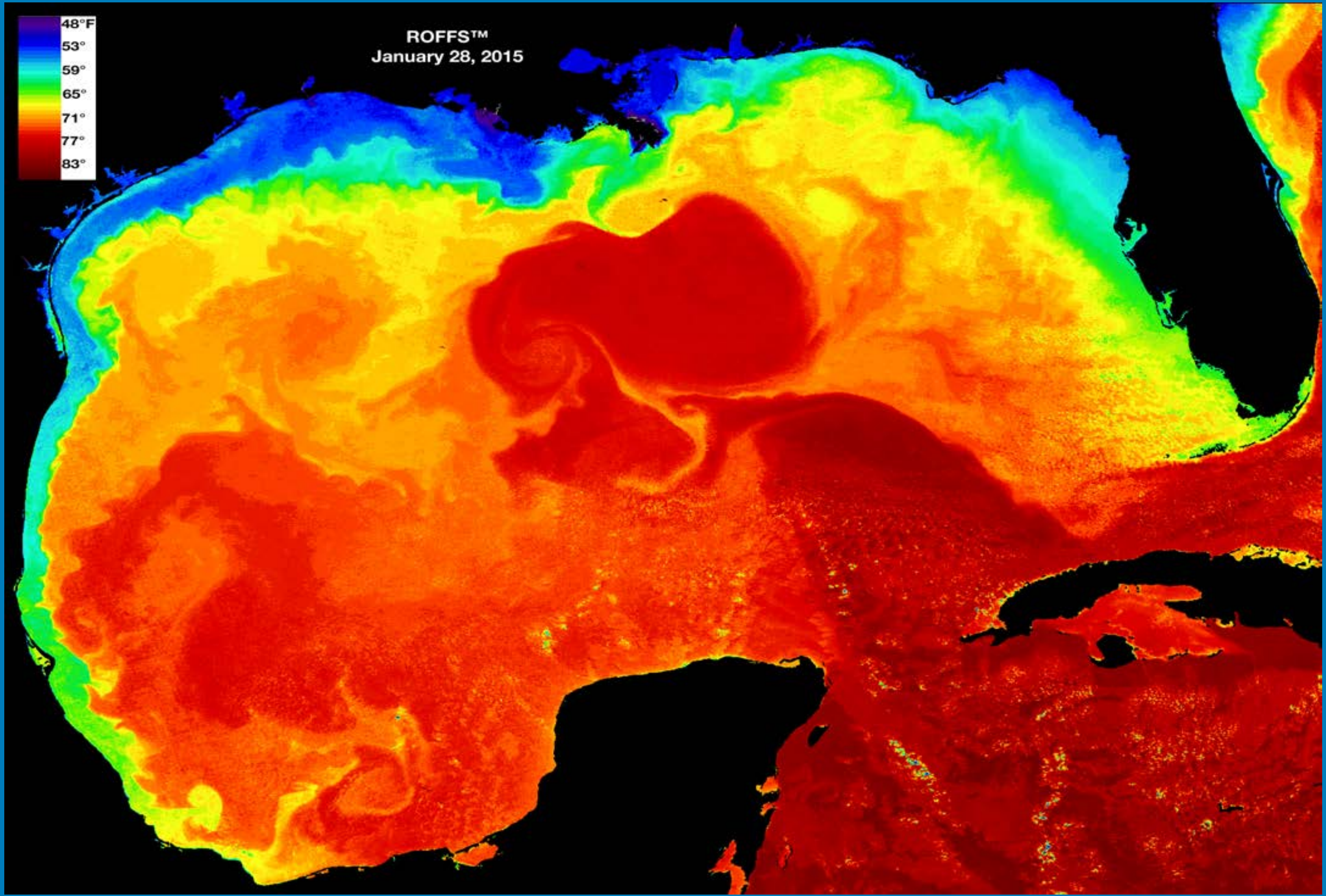
23 years commercial longline data (NOAA + ICCAT)

Infrared Visualization of the Currents



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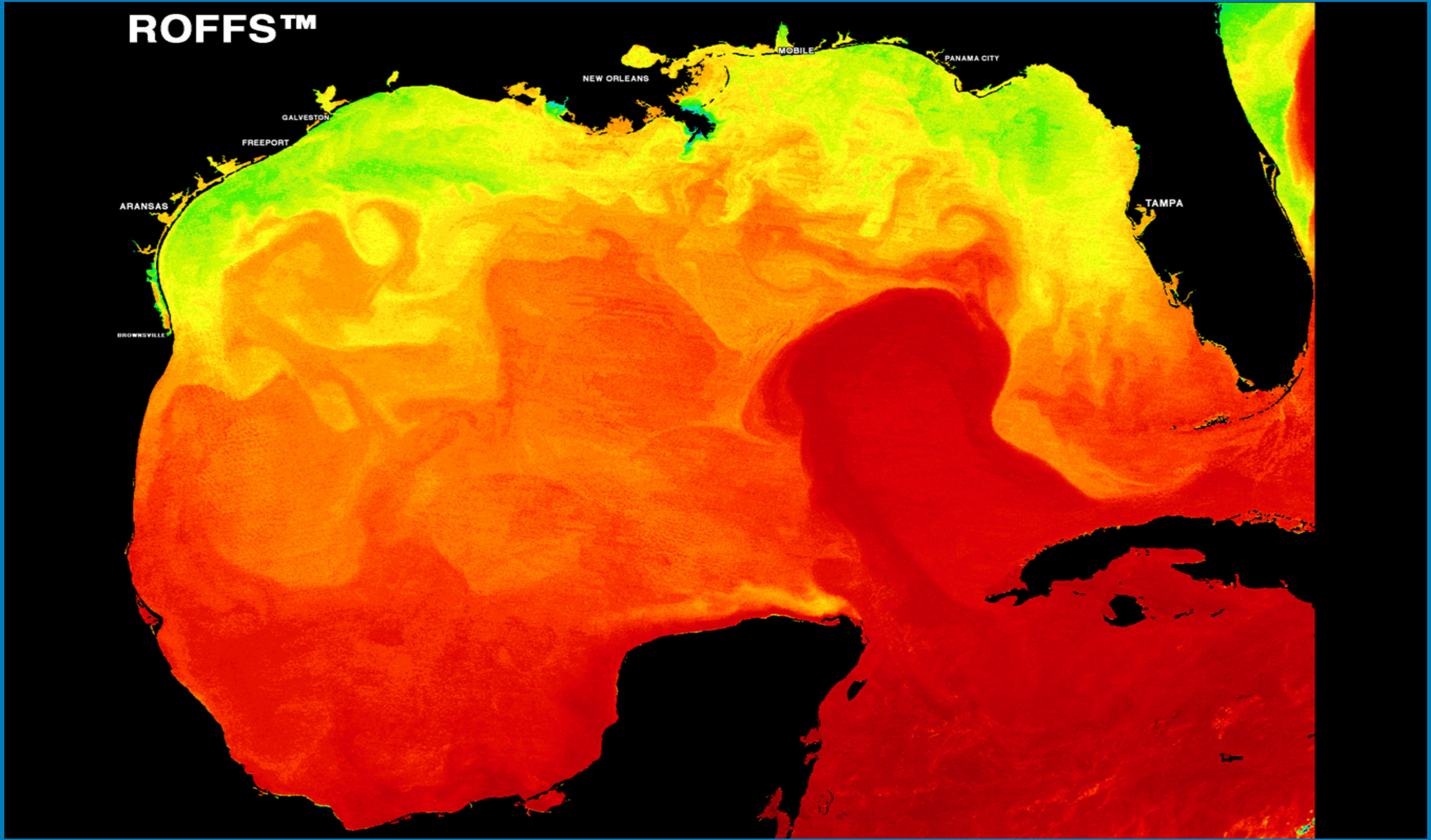
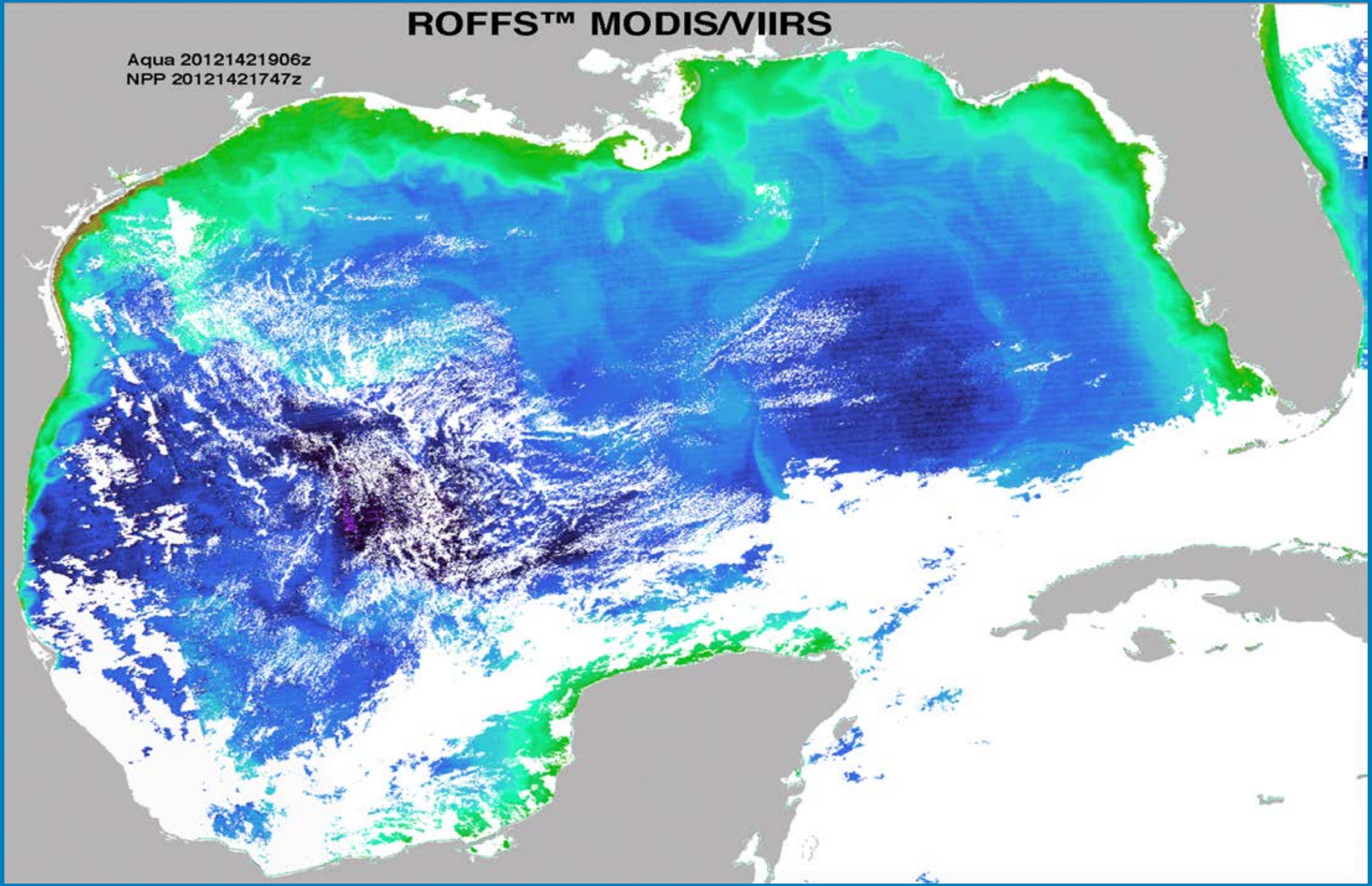
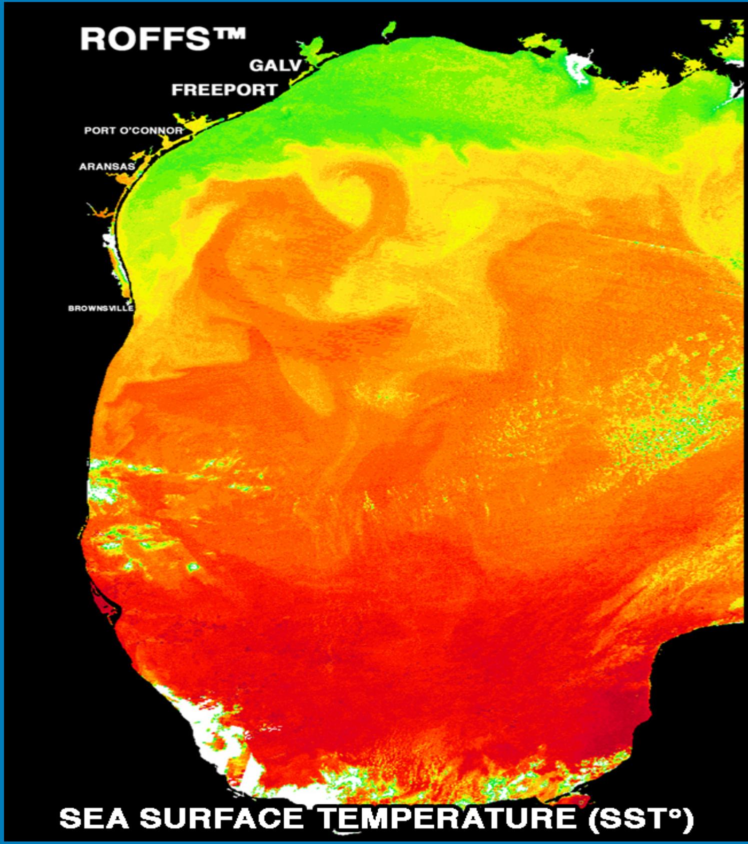
Infrared Visualization of the Currents



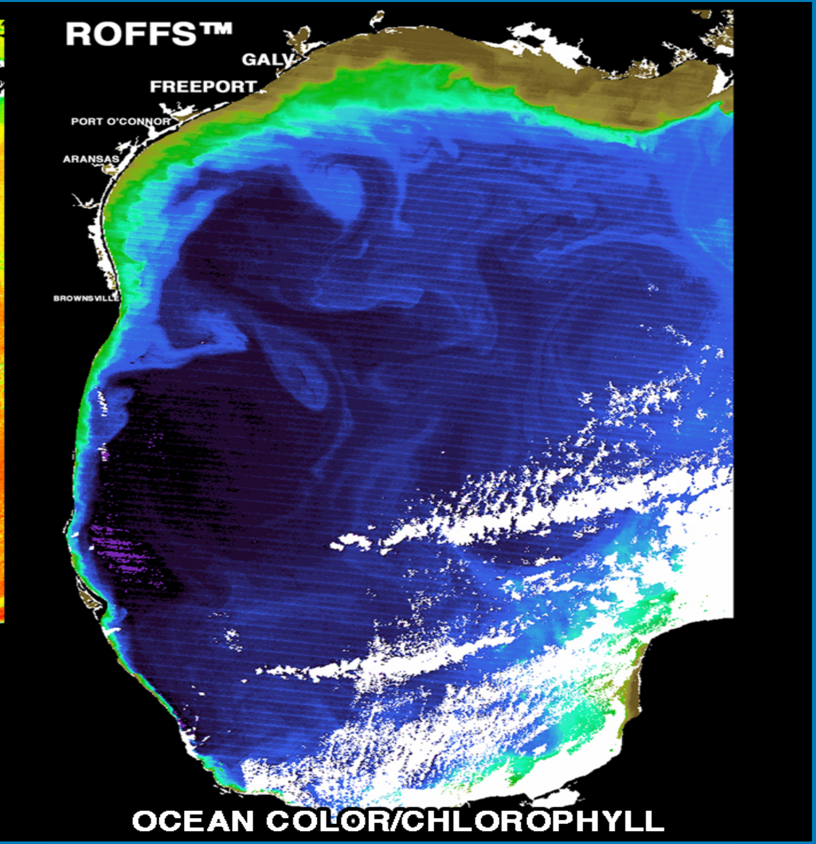
Ocean Color MODIS/VIIRS Composite



Infrared



Ocean Color



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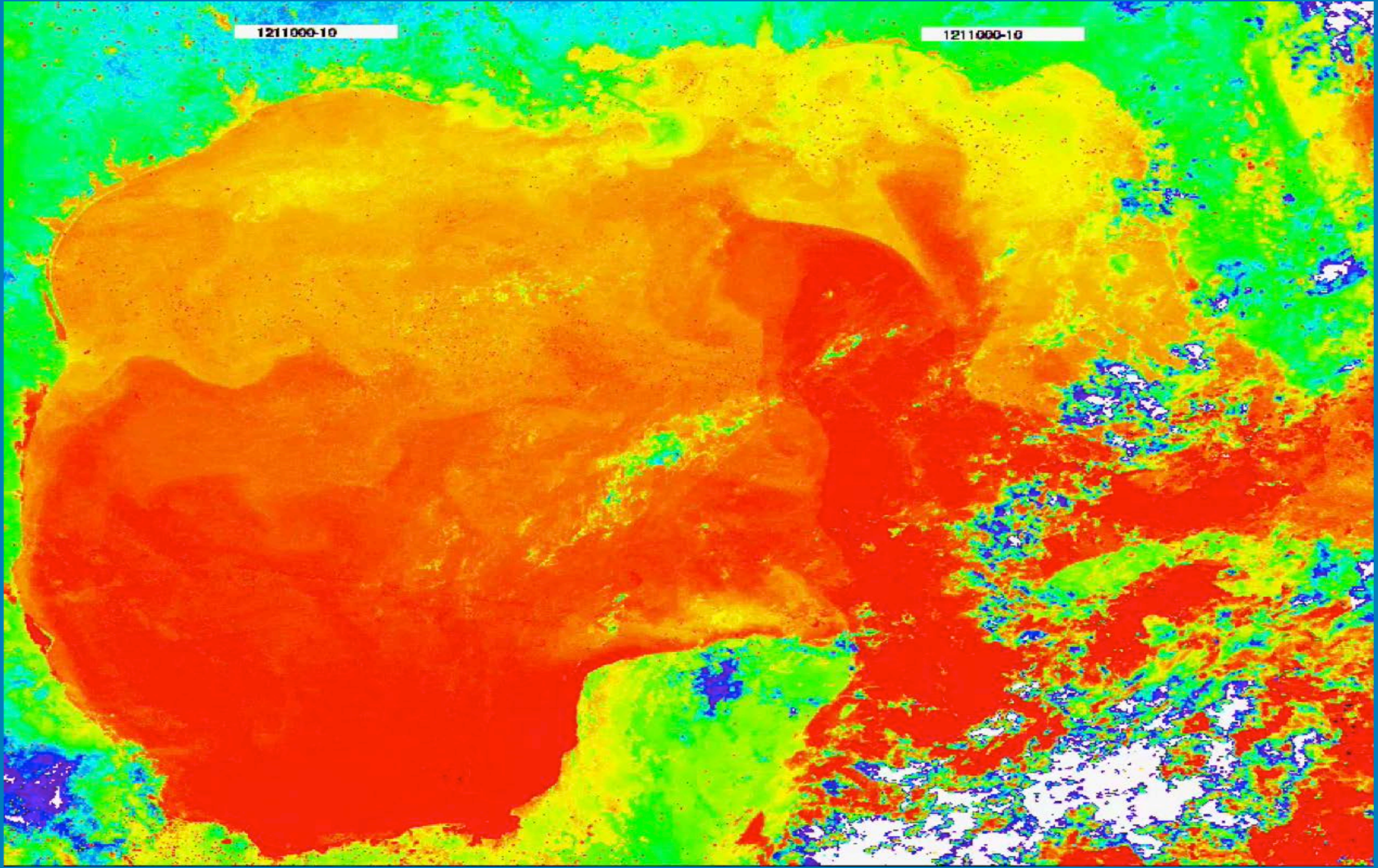
Motion is Critical



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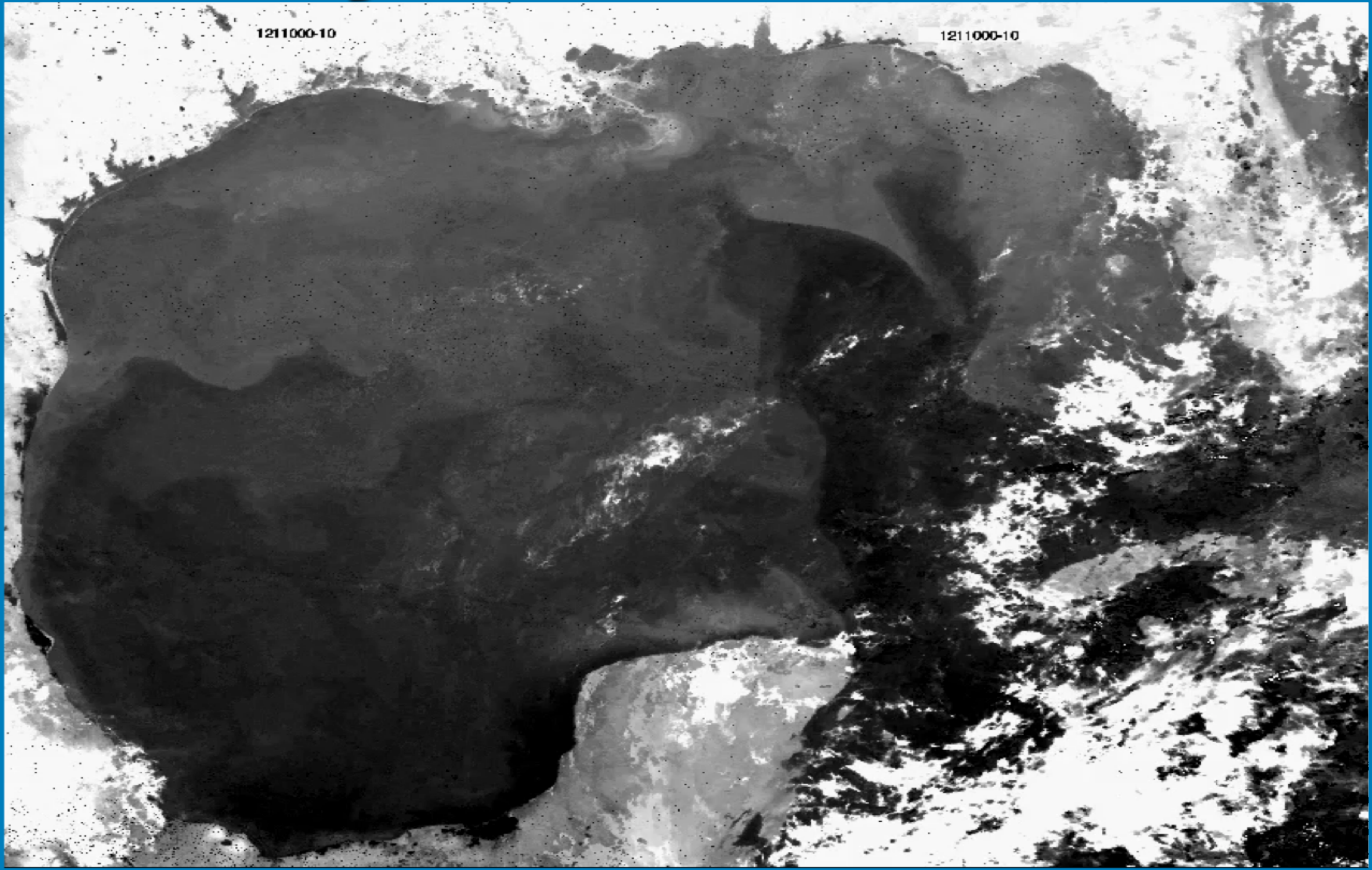
Graytone Is Useful



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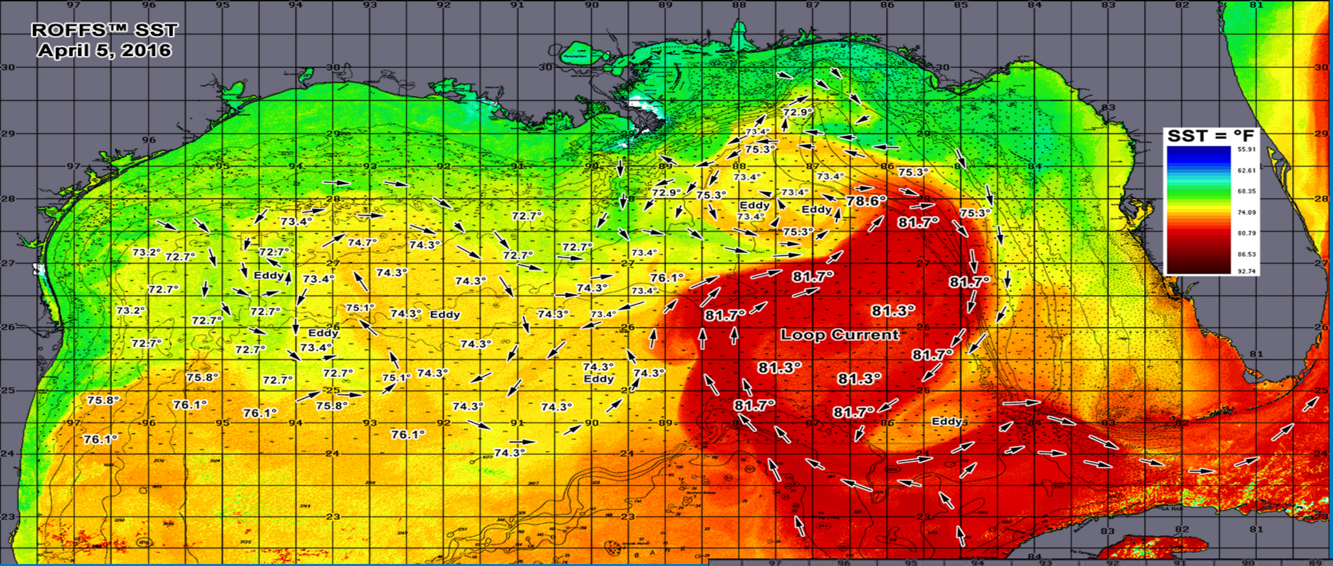
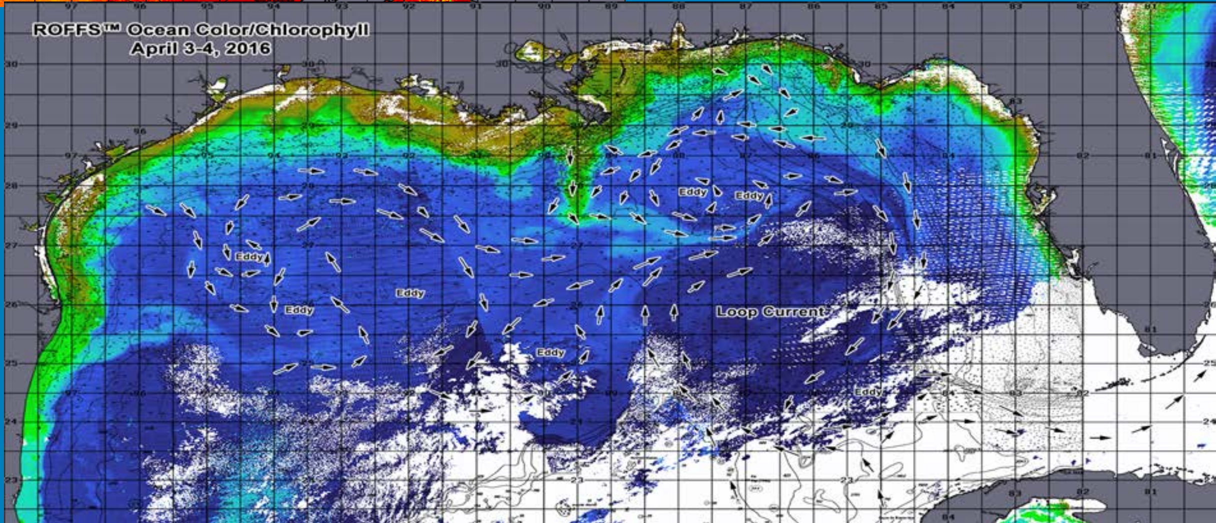


Analyses Are Made Using Both Data Types



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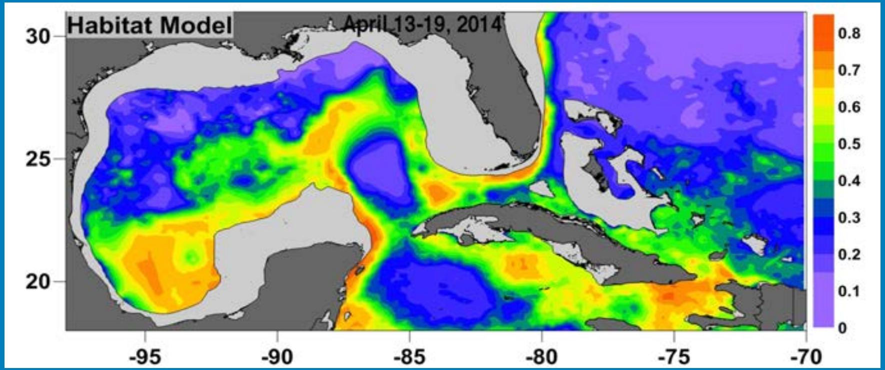
Research Tool Development

- 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)

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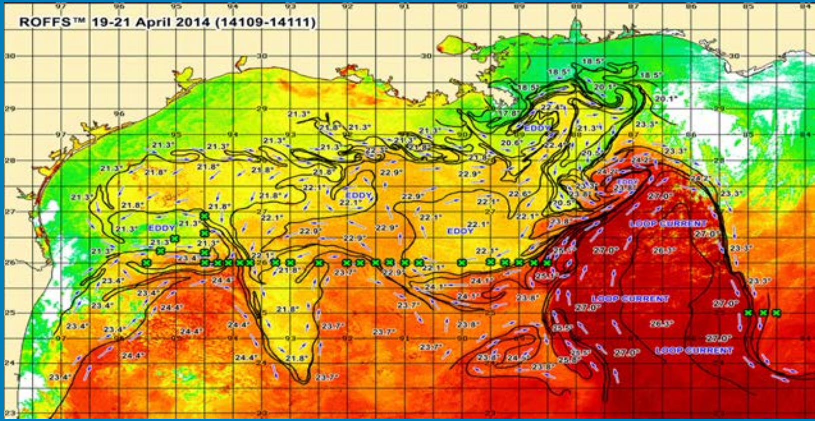
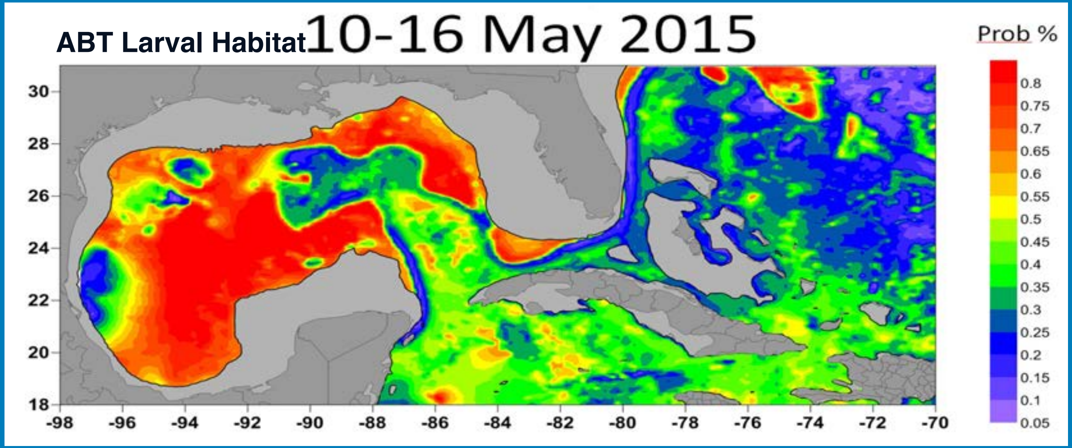
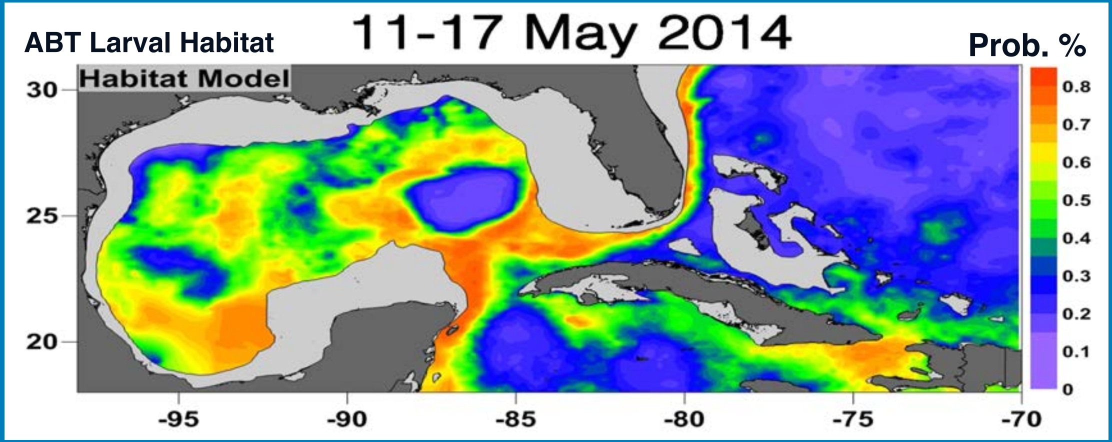
*Quantitative probabilities Used in larval assessment



Larval Habitat Variable





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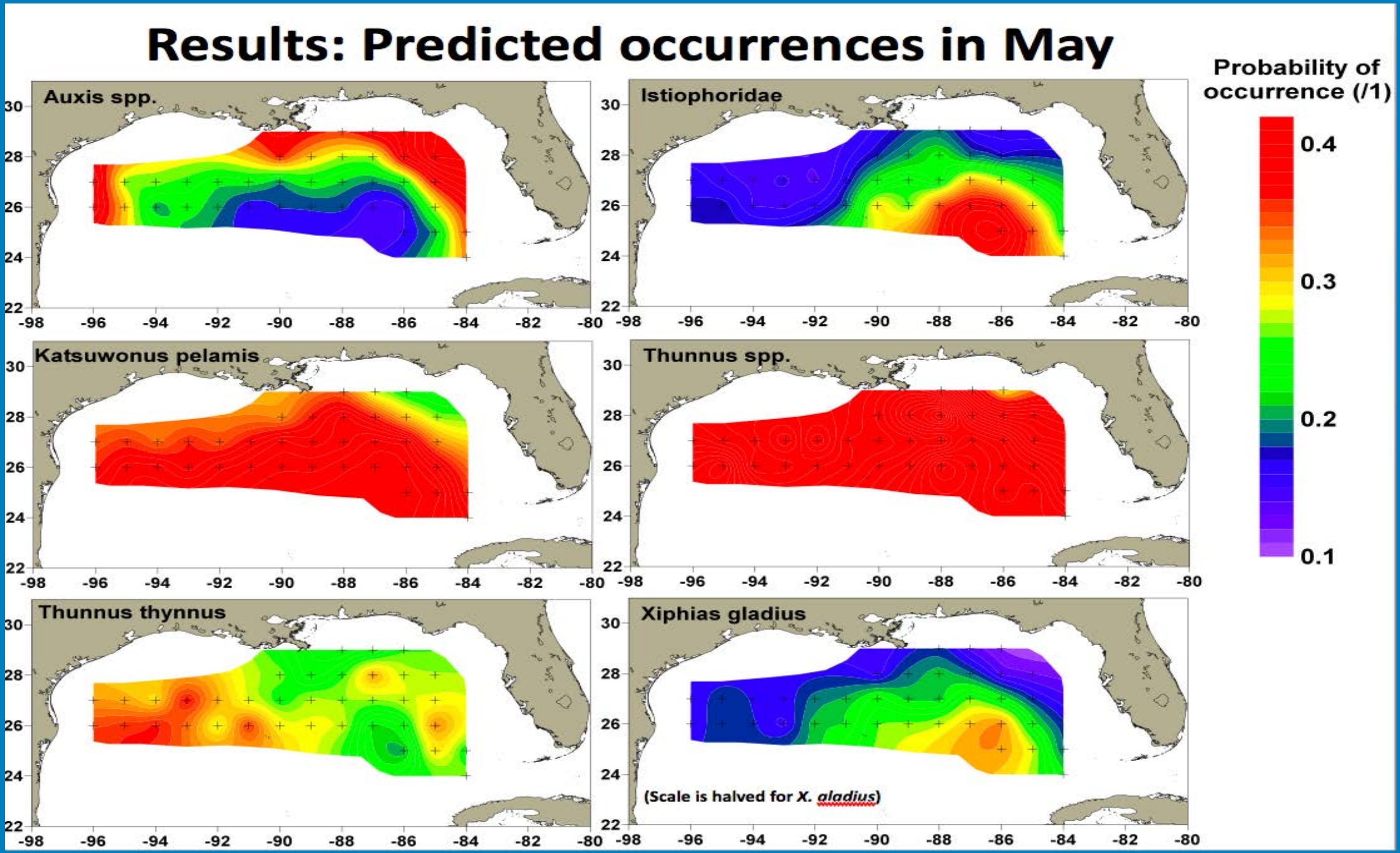
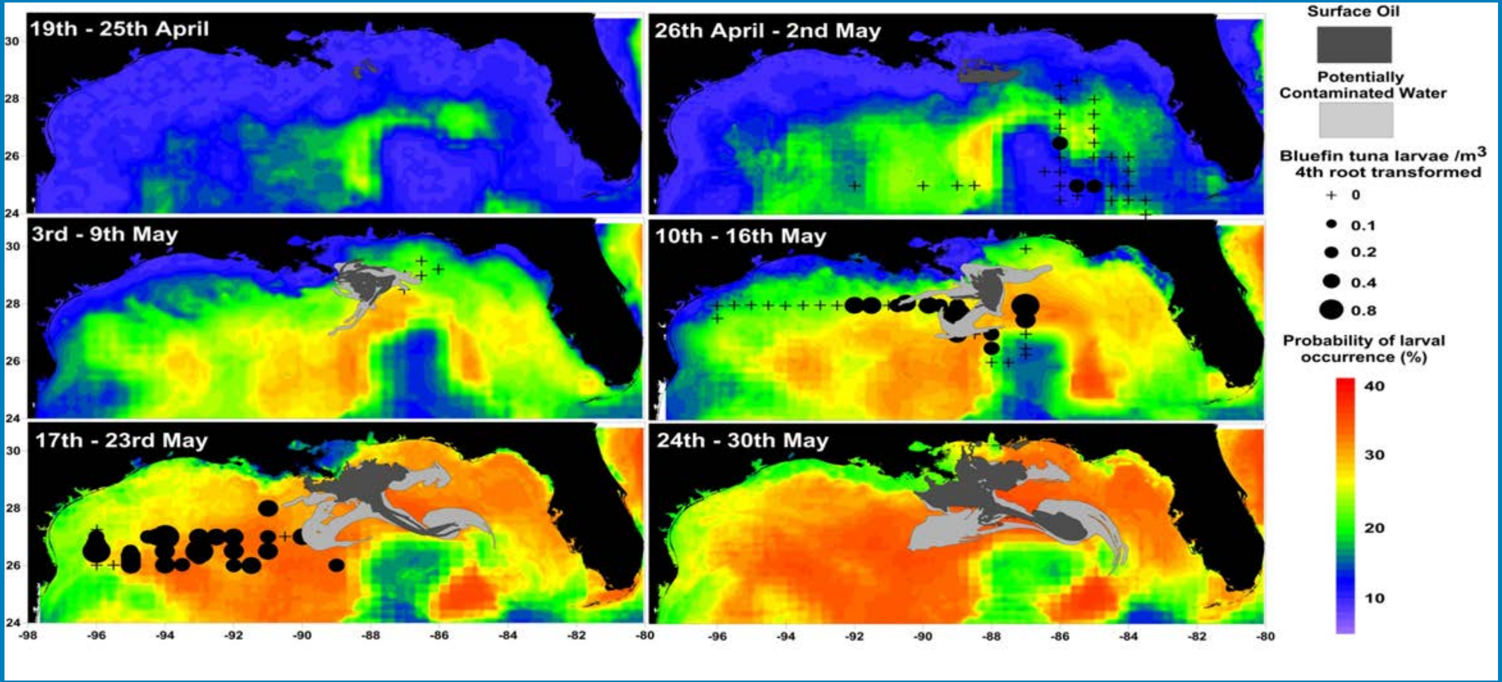
LARVAE HABITAT MODELING

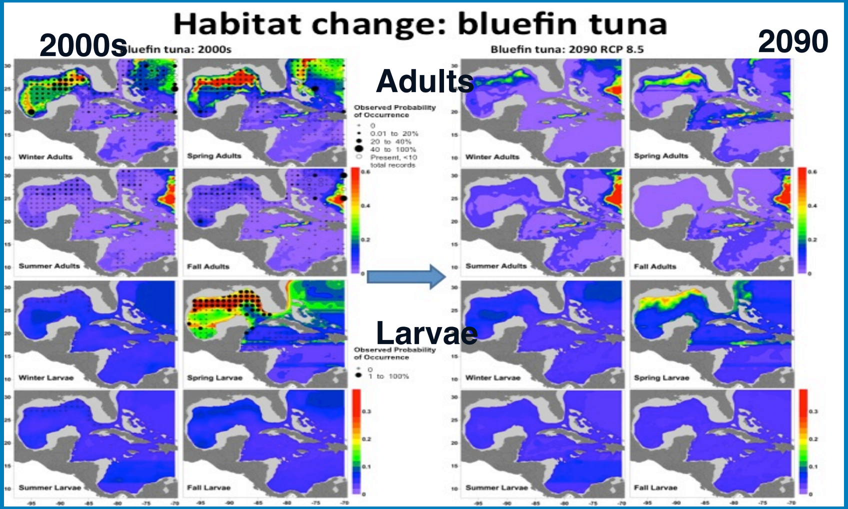


Bluefin Tuna and Deepwater Horizon Oil Spill



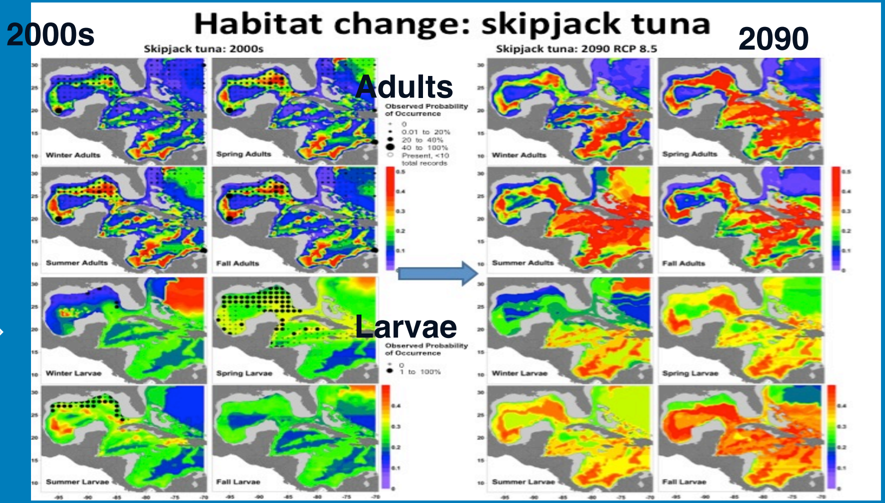
- Muhling, B.A., M.A. Roffer, J.T. Lamkin, G.W. Ingram, Jr., M.A. Upton, G. Gawlikowski, F.E. Muller-Karger, S. Habtes, and W.J. Richards. 2012. Overlap between Atlantic bluefin tuna spawning grounds and observed Deepwater Horizon surface oil in the northern Gulf of Mexico. Marine Pollution Bull. 64(4):697-687.

Climate Change & Fish



Some losers

Some winners



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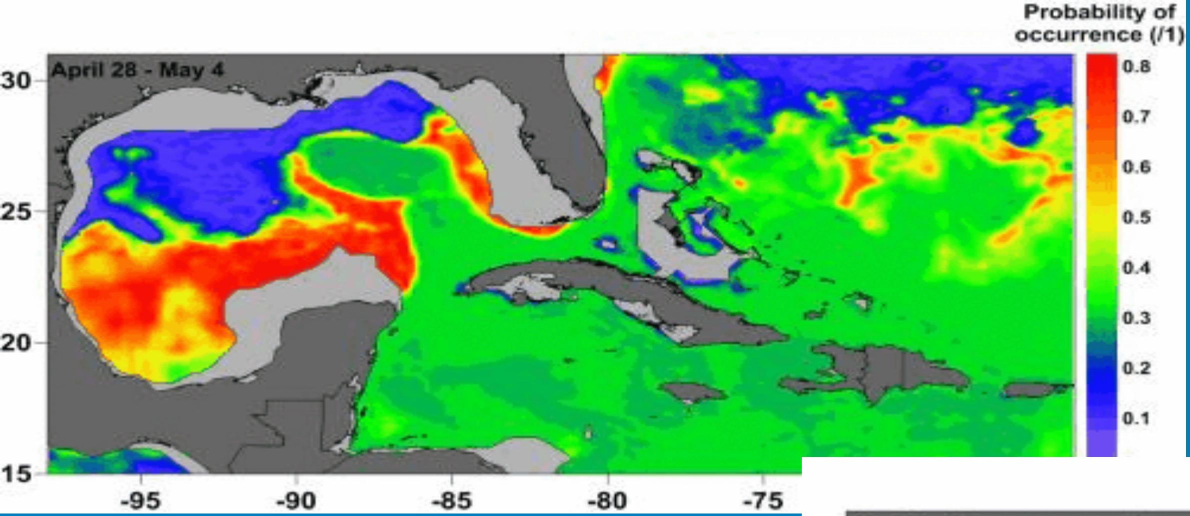
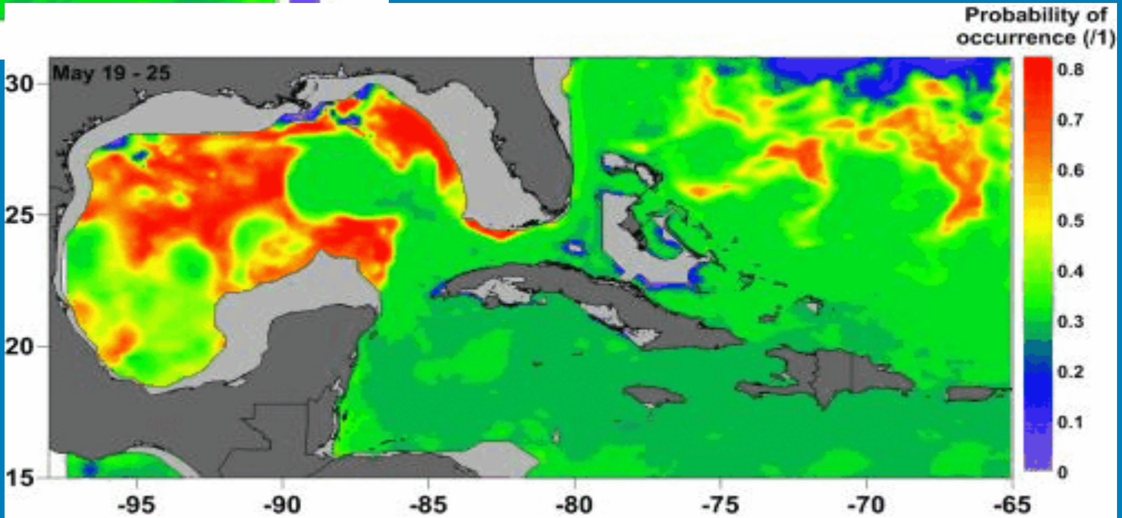
Muhling, et al., 2015. J. Mar. Syst. 148: 1-13.

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!



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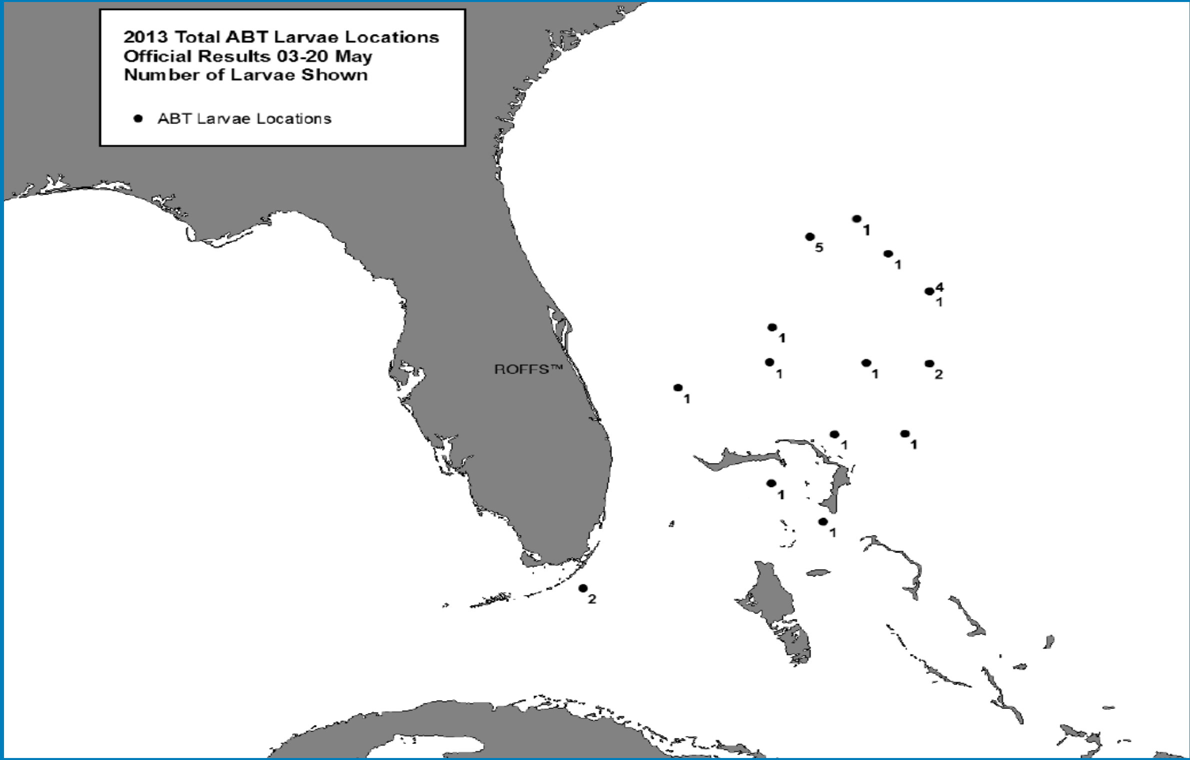
2013 Results for ABT
16 Positive Stations - 16.5%



Where were they spawned?

Not Satisfied with the High Resolution Circulation Models

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

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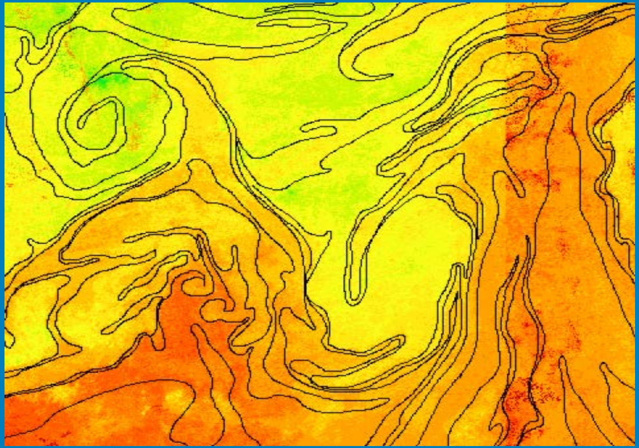
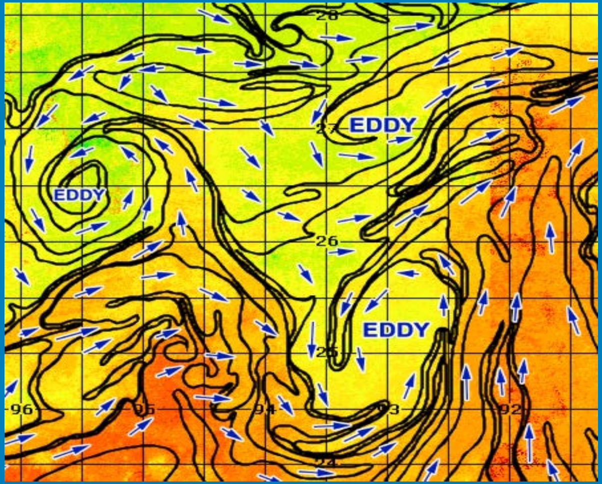
Lagrangian Coherent Structures

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.





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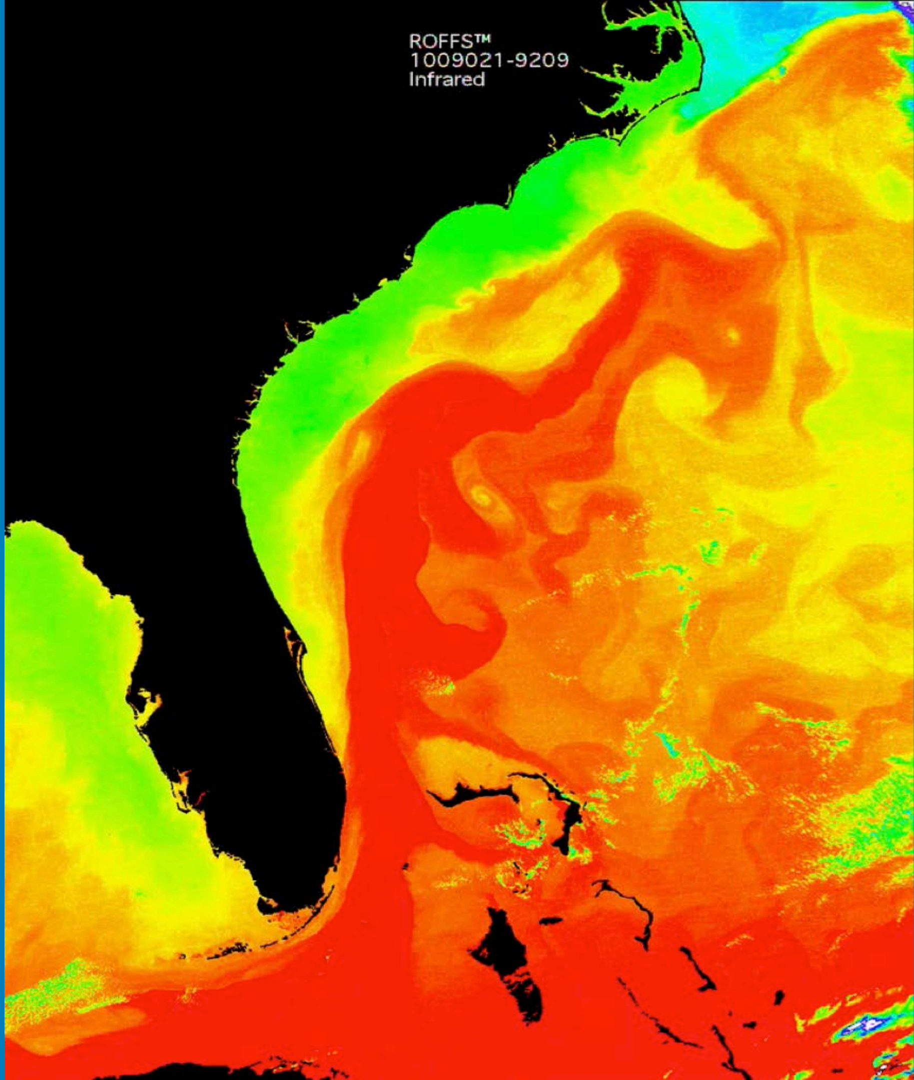
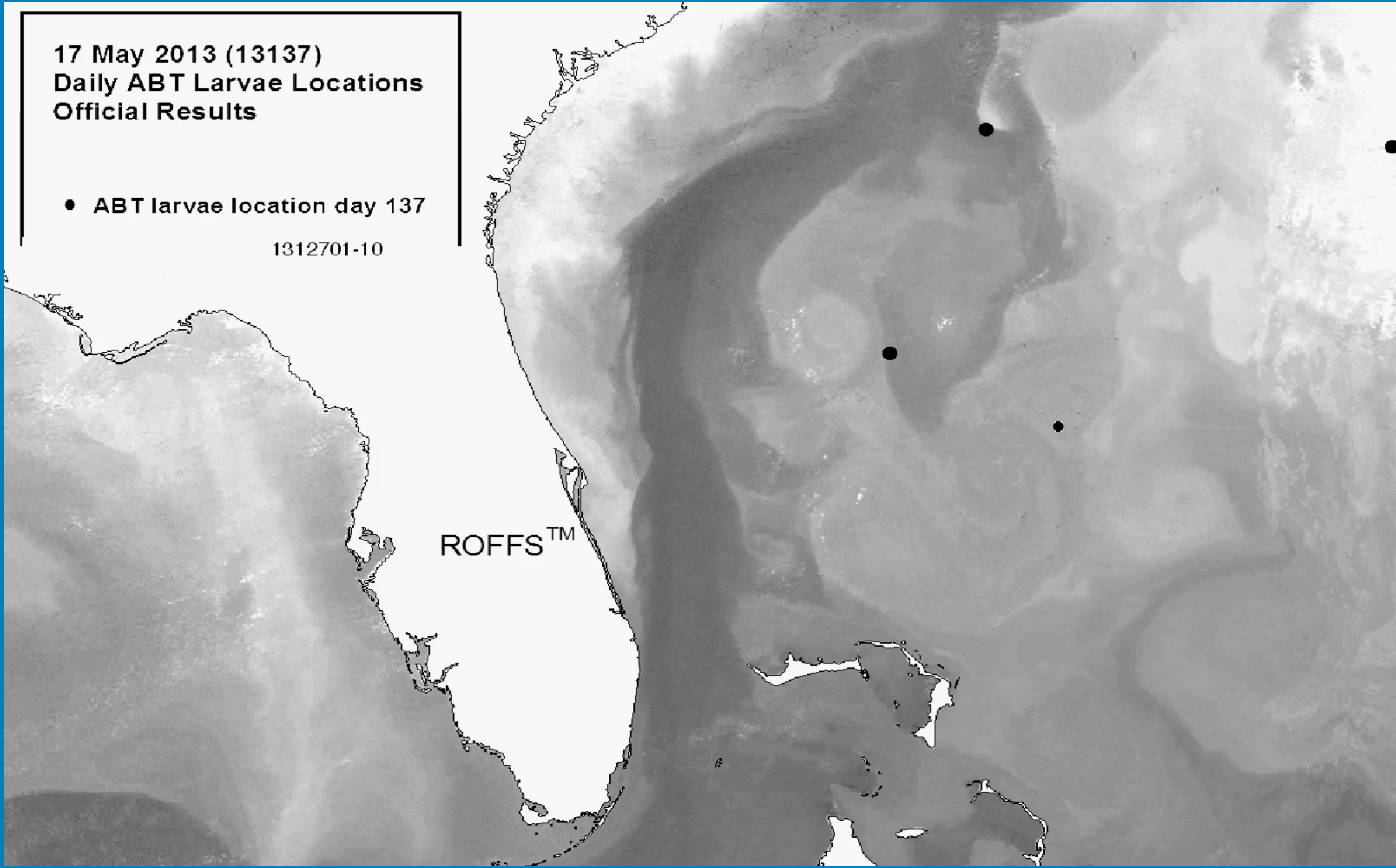
Ocean
Is
Dynamic

1 KM
~HOURLY
36HOURS
IR/SST




17 May 2013 (13137)
Daily ABT Larvae Locations
Official Results
ABT larvae location day 137
1312701-10
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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)

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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.

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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. Hooidonk, 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

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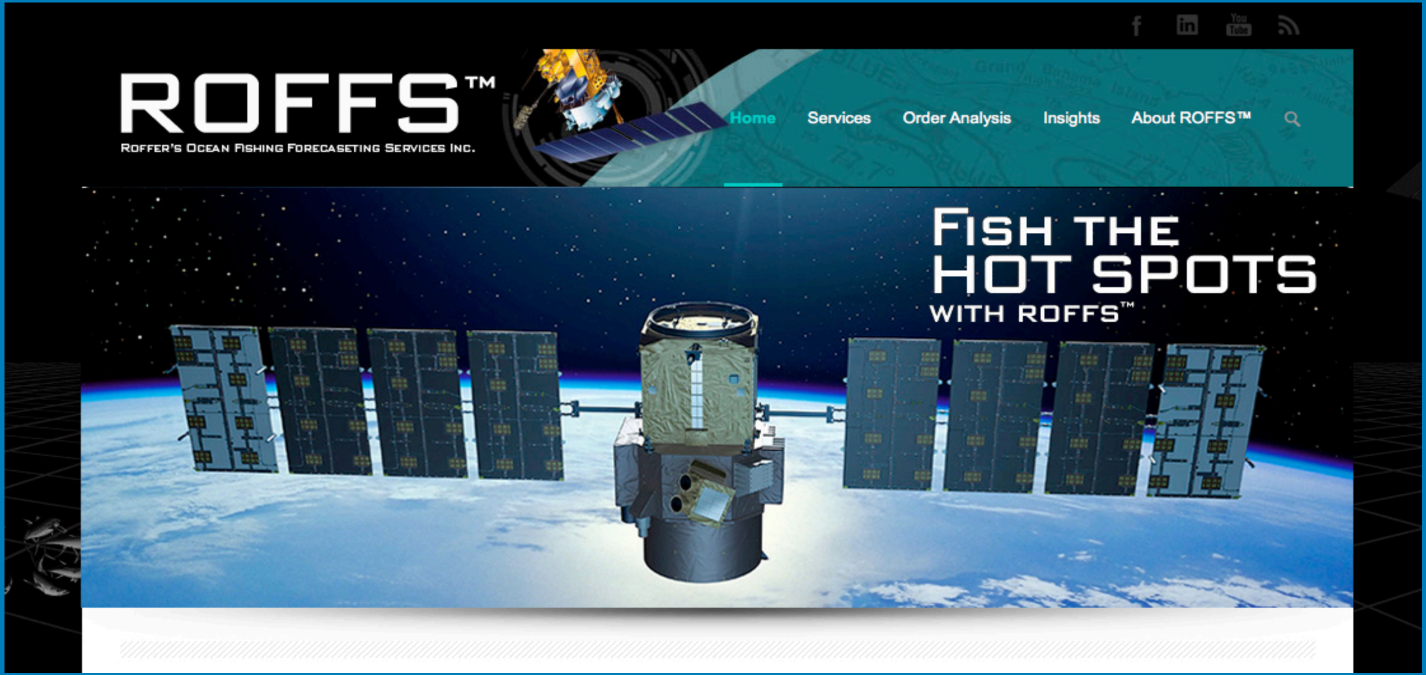
THANK YOU & LET THE FUN BEGIN
QUESTIONS



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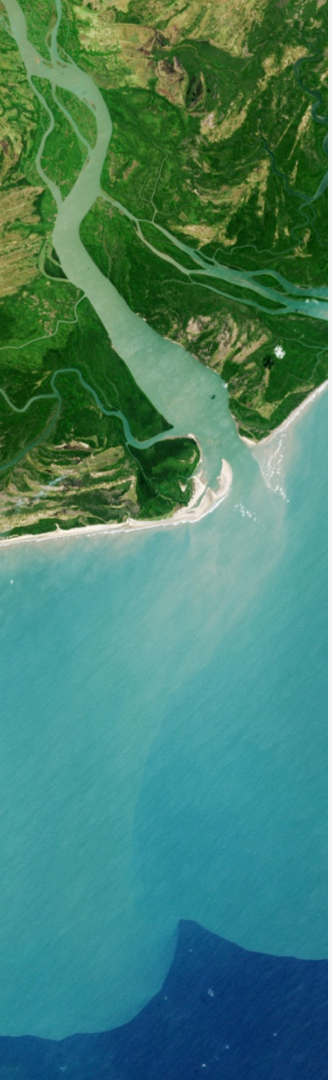
Facebook, Linkedin, Twitter, etc.

Week 3 Summary

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

Thank you!

Next Week:

Coral Reefs