Enabling NASA's Mission

Luc Rainville (APL-UW)

Eric Lindstrom (NASA)
Paula Bontempi (NASA)
…and NASA-supported investigators (SPURS, Science Teams)

SPURS campaigns
EXPORTS plans
Enabling Science Teams:

- SWOT Cal/Val *(Farrar et al.)*
- OSTST: Boundary current and eddies *(Castelao et al.)*
- SWOT: Fine-scale dynamical height *(Druska et al.)*

Vision and Mission

Our Vision

We reach for new heights and reveal the unknown for the benefit of humankind.

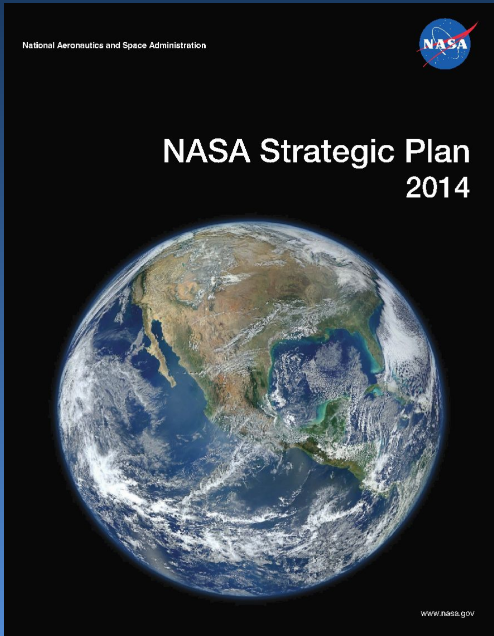
Our Mission

Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth.

NASA strategic goals are:

1. Expand the frontiers of knowledge, capability, and opportunity in space.
2. Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.
3. Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure.

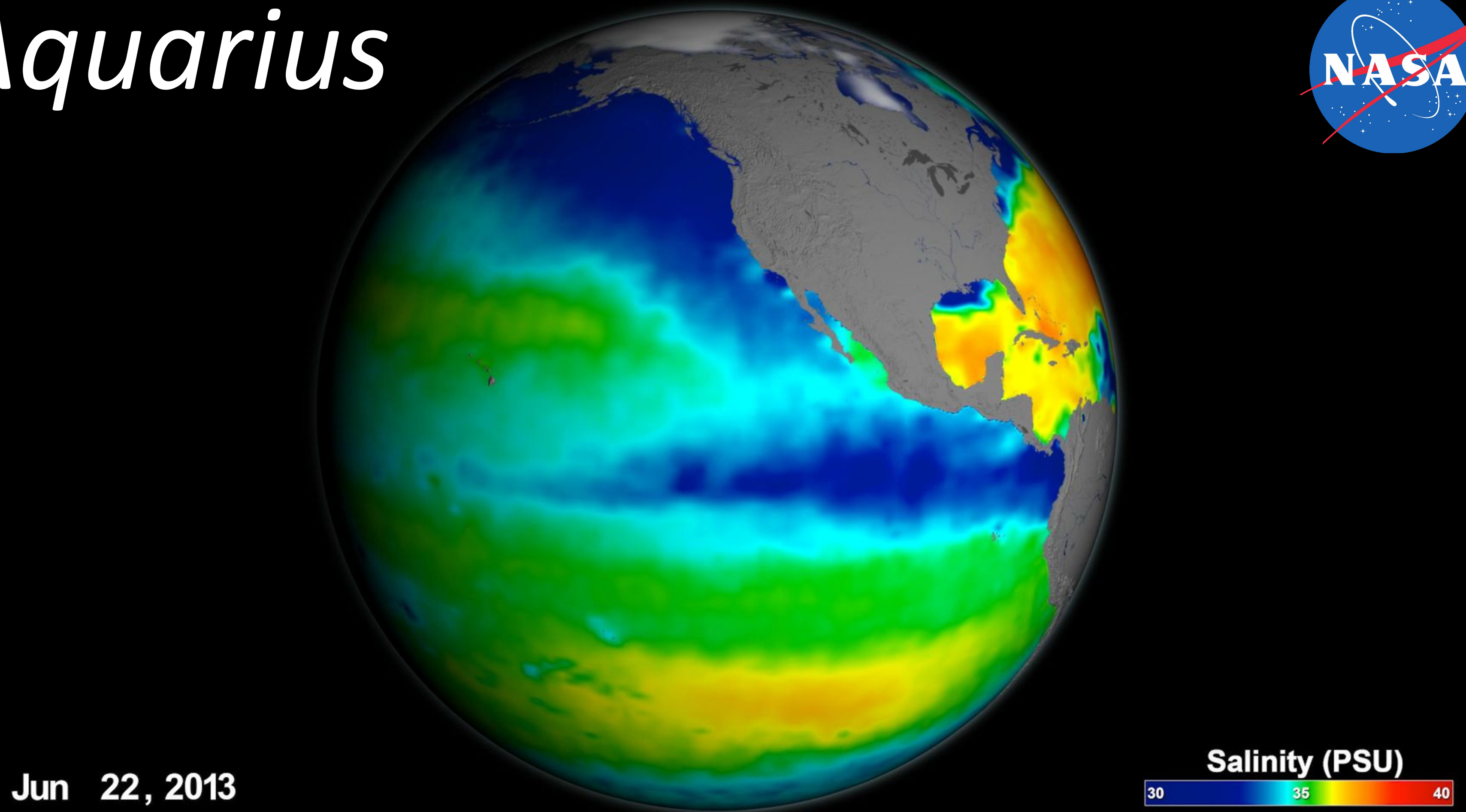
Charles F. Bolden Jr., Administrator



Enabling NASA's Mission

- Gliders are used as part of long-term autonomous arrays to capture important processes occurring on a variety of time and spatial scales
- NASA has been a supporter of glider technology development, and sensor development, in particular for interdisciplinary science (Ocean Color, etc.).
- Gliders are used as one of the tools to validate satellite and meet mission requirements.
- Glider data are often an important link between the components of large programs (e.g., modeling, Eulerian / Lagrangian arrays, etc.).

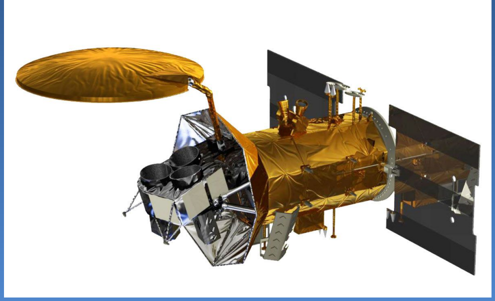
Aquarius



NASA's Goddard Space Flight Center Scientific Visualization Studio

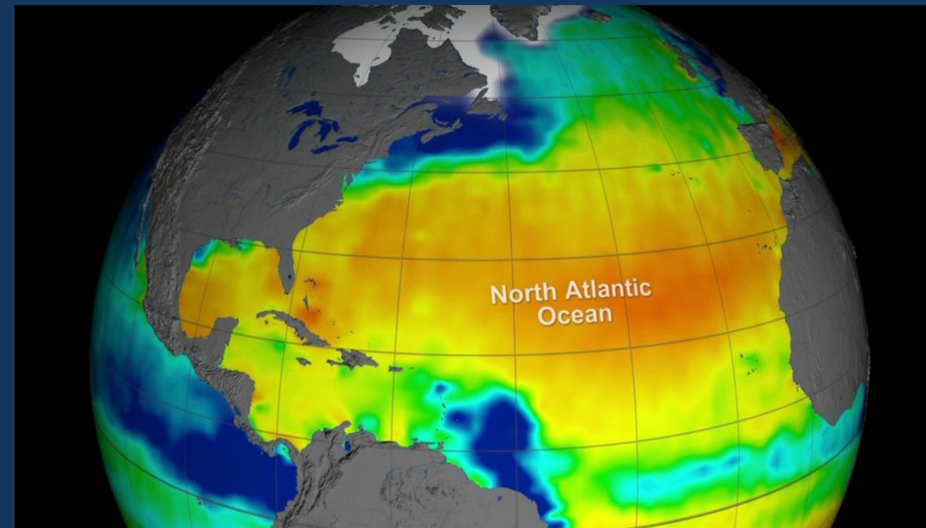
First space-based global observations of ocean surface salinity.
25 August 2011 through 7 June 2015

Currently, global salinity is retrieved from SMAP measurements



SPURS-1

What are the physical processes responsible for the location, magnitude, and maintenance of the subtropical Atlantic sea surface and subsurface salinity maximum?



NASA's Goddard Space Flight Center Scientific Visualization Studio

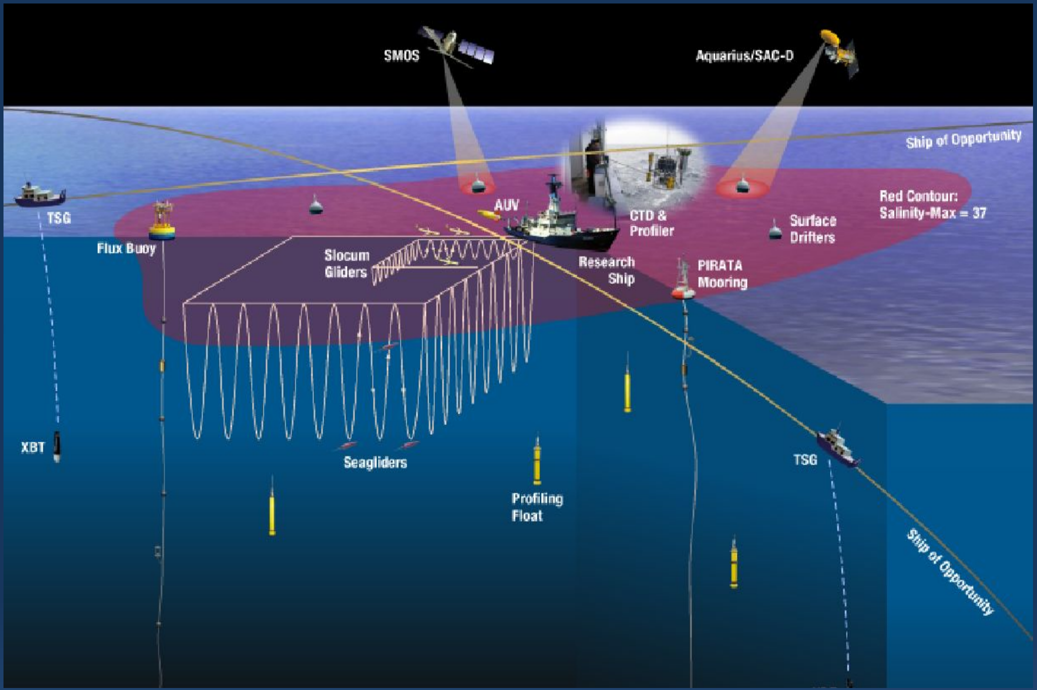
SPURS-1 involves coordinated field work, numerical models, and remote-sensing:

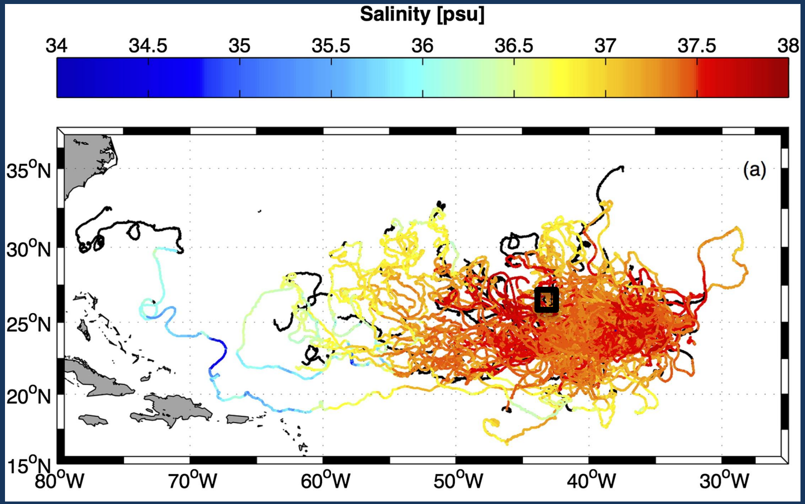
Towed Surface Salinity Profiler, Asher et al., University of Washington
SPURS Data Management System, Bingham et al., University of North Carolina Wilmington
Multi-scale Modeling and Data Assimilation, Chao et al., Remote Sensing Solutions, Inc.
Near-surface Turbulence: Lagrangian Floats, D'Asaro et al., University of Washington
Toward a Salinity Budget (flux mooring), Farrar et al., Woods Hole Oceanographic Institution
Multiscale Autonomous Surveys, Fratantoni et al., Woods Hole Oceanographic Institution
Characteristics SSS Fluctuations, Gordon et al., LDEO, Columbia University
Upper Ocean Salinity from Glider Surveys, Lee et al., University of Washington
Multi-Scale Modeling and Data Assimilation, Li et al., Jet Propulsion Laboratory
Measurements of T, S, Wind Speed, and Rainfall (floats), Riser et al., University of Washington

Microstructure and Mixing, Schmitt et al., Woods Hole Oceanographic Institution (NSF)
SSS Drifters for SPURS, Centurioni et al., Scripps Institution of Oceanography (NOAA)
Prawler Mooring, Kessler et al., NOAA/PMEL (NOAA)
Sustained Ocean Observations, Goni et al., NOAA/AOML (NOAA).

SPURS

Salinity Processes in the Upper Ocean Regional Study



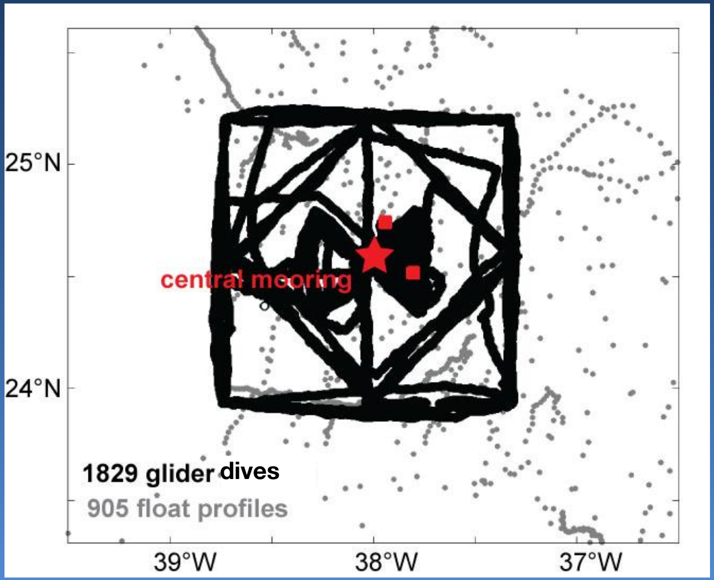


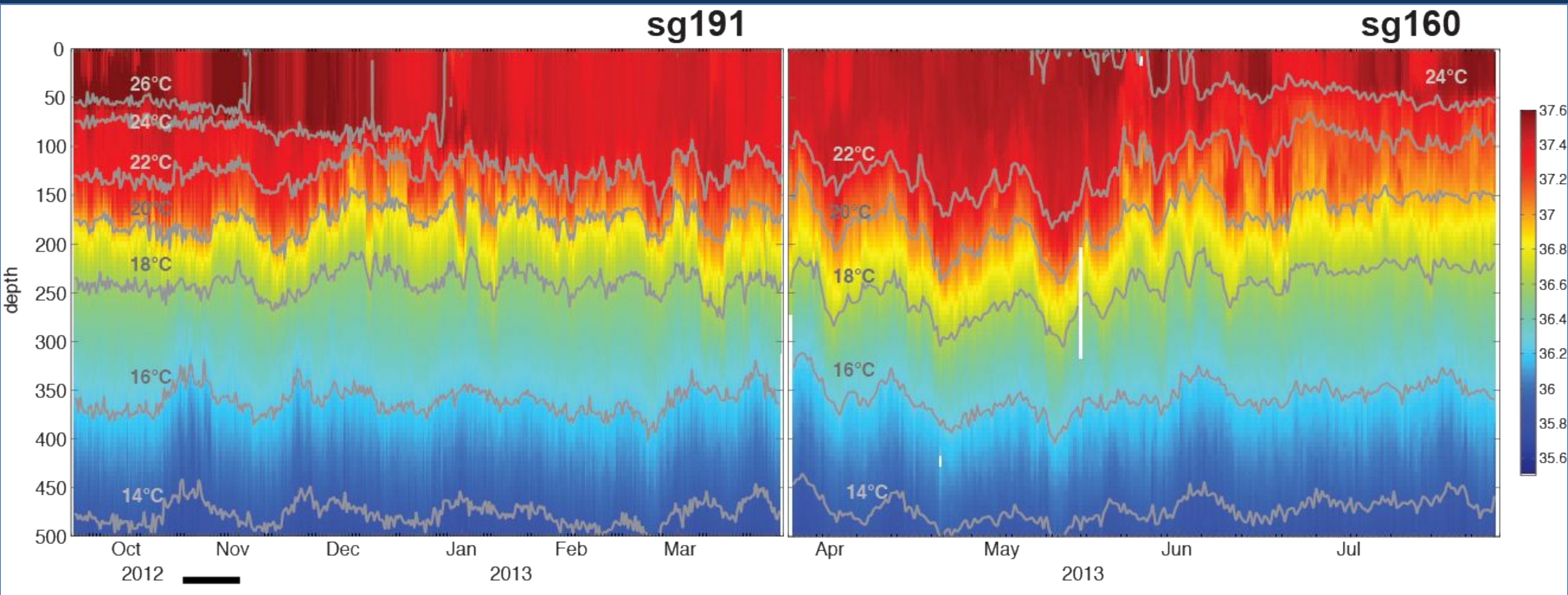
Centurioni et al.: 88 SVP-S and 56 SVP

Hormann et al., 2015

Autonomous platforms (Wave Gliders, floats, drifters, Seagliders) and ships sampled around the central (air-sea flux) mooring array with dense sub-surface measurements.

Unique perspective on the surface and sub-surface evolution of the salinity field.





one year

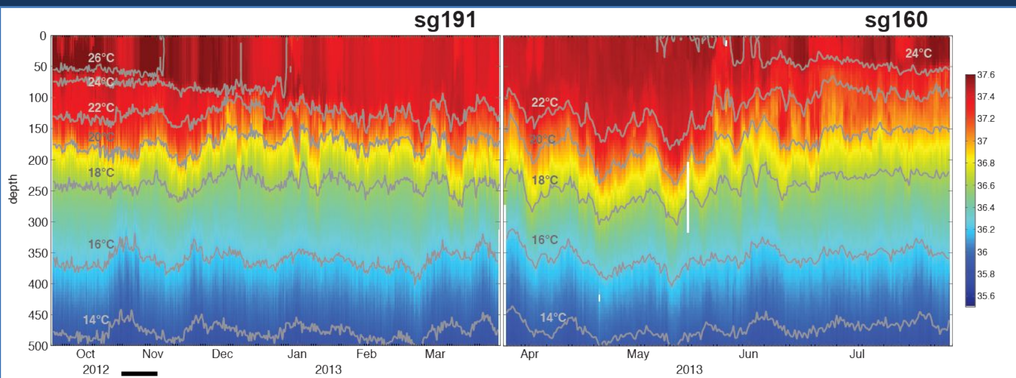
October 2012 — September 2013

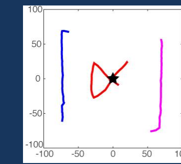
Fall to Winter:
Cooling, deepening of mixed layer.

Spring to Summer:
Restratification. Warming. Evaporation.

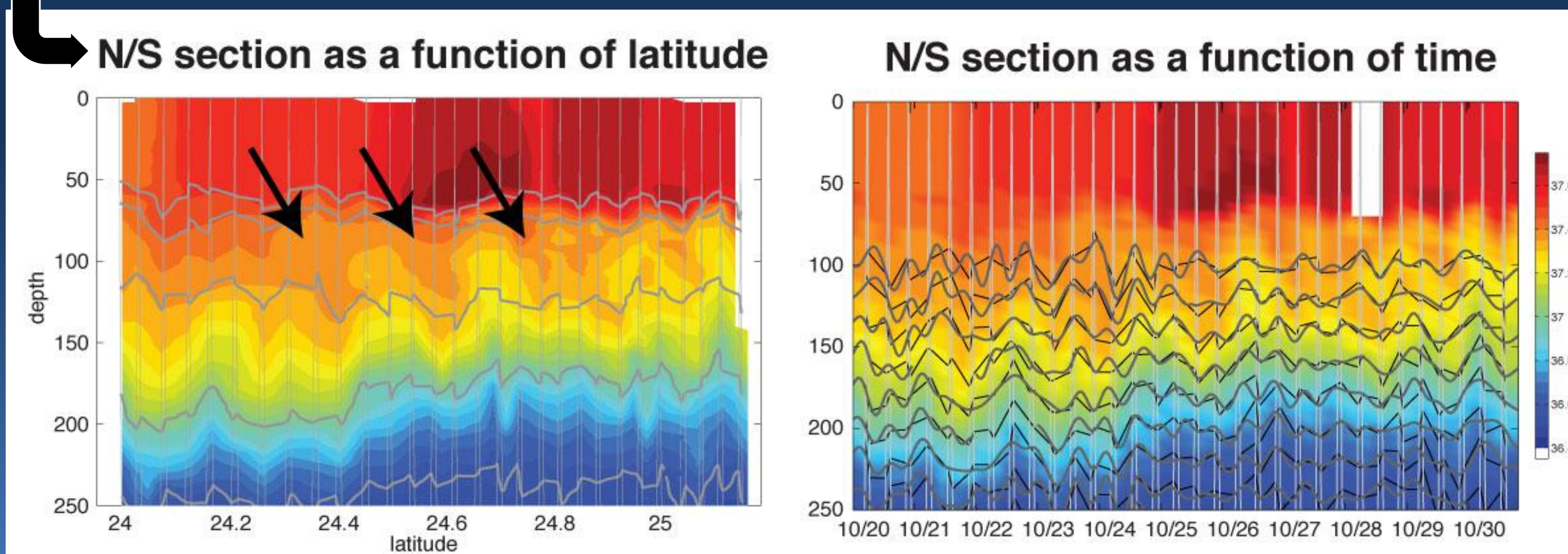
SPURS

Salinity Processes in the Upper Ocean Regional Study





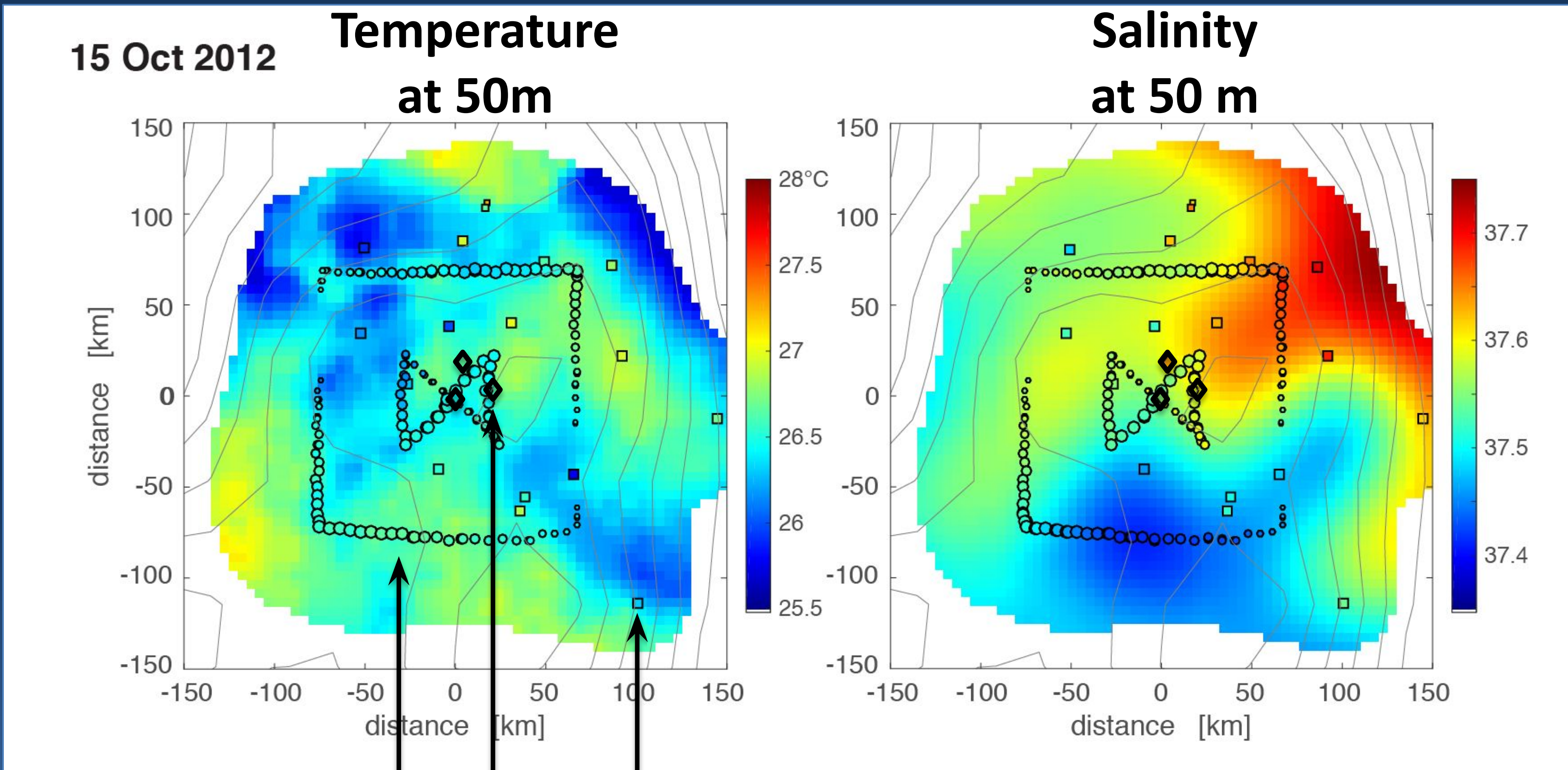
Single section from glider, collected over 1 week, showing complex intrusions, internal waves, mesoscale eddies, etc.



High salinity intrusion at the base of the surface mixed layer.

Semidiurnal displacements: +/- 20 m

Inertial displacements: +/- 15 m



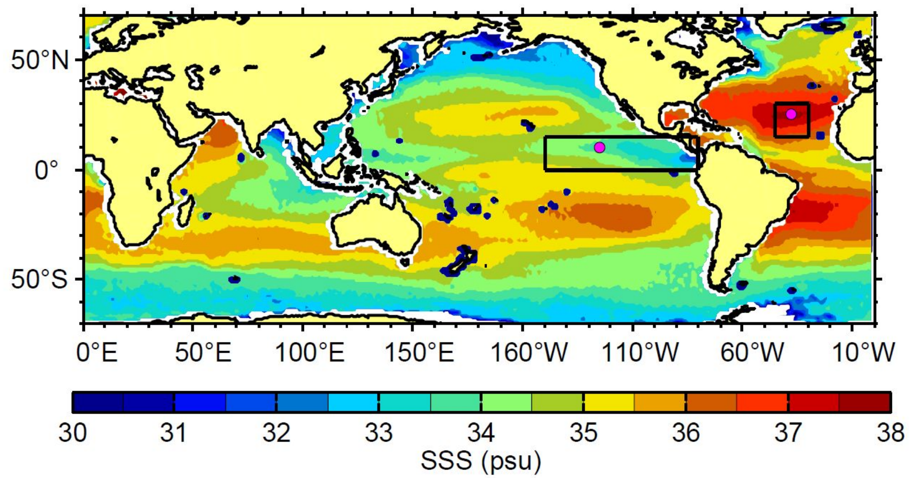
- Moorings
- Seagliders
- Argo floats
- UCTD

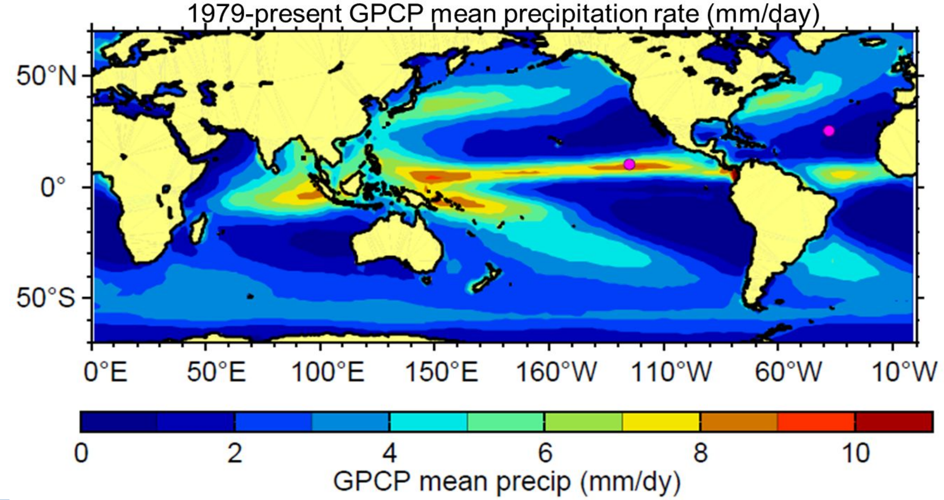
Decorrelation scales: 75 km and 5 days
mapped as perturbations from previous depth

Note: Size of data marker is scaled by when it was collected relative to the map time.

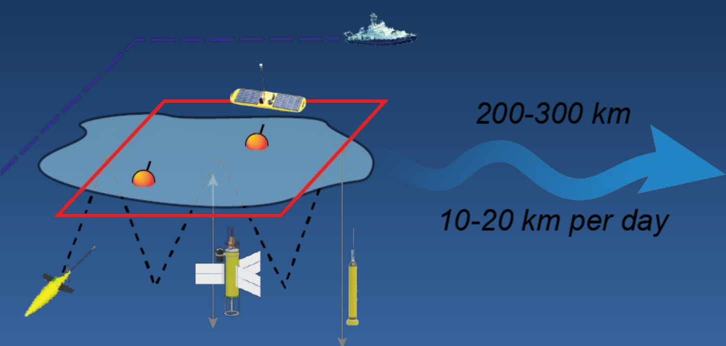
SPURS - 2

Salinity Processes in the Upper Ocean Regional Study





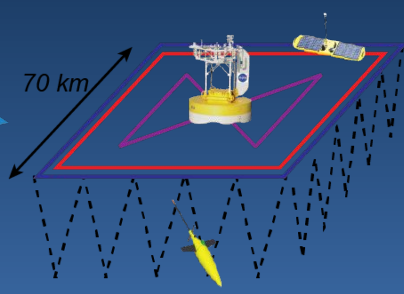
Lagrangian component



- Salinity drifters
- Lagrangian float (MLF)
- Profiling (APEX) floats
- Seaglider*
- Waveglider*
- Shipboard/SSP surveys

* return to mooring after ~2 weeks

Eulerian component



- Moorings
- Seagliders
- Wavegliders

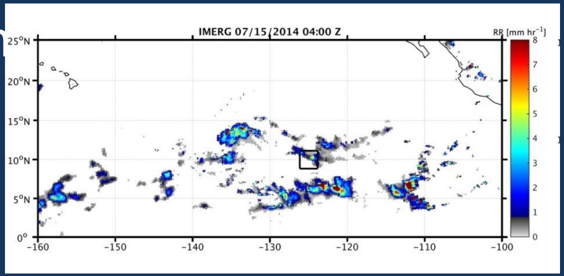
PIs

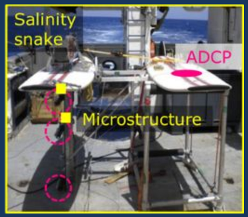
- Andrey Shcherbina, Eric D'Asaro, Ramsey Harcourt, Nikolai Maximenko
- Ben Hodges, Ray Schmitt
- Bill Asher, Andrew Jessup, Kyla Druska
- Carol Anne Clayson, Jim Edson
- Frederick Bingham, Peggy Li, Zhijin Li
- Janet Sprintall
- Julian J Schanze
- Luca Centurioni, Yi Chao, Nikolai Maximenko
- Luc Rainville, Charles Eriksen, Kyla Drushka, Craig Lee
- Steve Riser, Jie Yang
- Tom Farrar, Al Plueddemann, Jim Edson, Chidong Zhang, Jie Yang, William Kessler
- Zhijin Li, Frederick Bingham, Peggy Li
- Billy Kessler

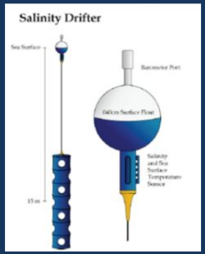
SPURS - 2

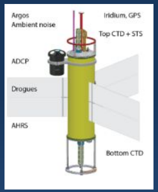
Salinity Processes in the Upper Ocean Regional Study

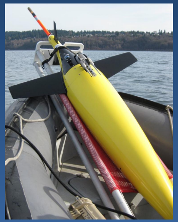
The overall goal of the SPURS-2 field program is to understand the structure and variability of upper- ocean salinity un

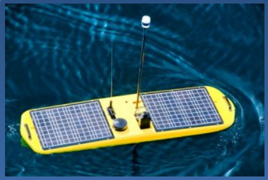


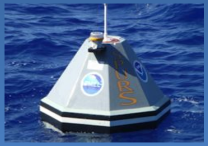












What governs the structure and variability of upper-ocean salinity near the ITCZ?

Where does the fresh water go, and how does the ocean distribute it from the small scales of the input (clouds) to the regional scale of the east Pacific fresh pool?

What local and non-local effect does the freshwater flux have on the ocean?

How does ocean salinity feedback on the atmosphere?

SPURS - 2

Salinity Processes in the Upper Ocean Regional Study

Use of schooner *Lady Amber* for SPURS-2

A novel and flexible observational approach, motivated by a need to capture the highly dynamical oceanic circulation at the isolated SPURS-2 site.

April 2016 to December 2017

9 cruises, every 2 months for 1.5 years.

- Deploy surface drifters and floats every 2 months,
- Recover, service, and redeploy autonomous instruments (Wave Gliders, Seagliders, MLF, etc.)
- Near-surface and atmospheric measurements during regular visits to the site.

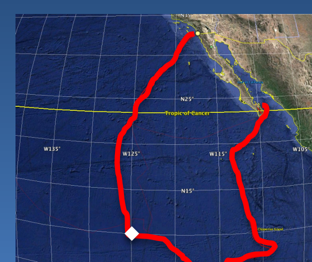
1st cruise:
9 Jun – 5 Jul 2016

- Deployed 15 surface drifters

2nd cruise:
29 Aug – 25 Oct 2016

- Deploy 15 surface drifters
- Serviced Wave Glider
- Underway sampling (T,S, atmos.)

3rd cruise:
1 Dec 2016 – 15 Jan 2017



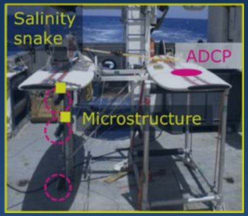
- Deployed 15 surface drifters
- Recovered Mixed Layer Lagrangian Float
- Recovered 2 Wave Gliders, deployed one.
- Underway sampling (T,S, atmosphere)

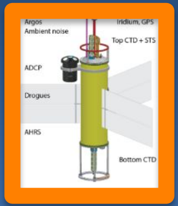
4th cruise:
Feb-March 2017

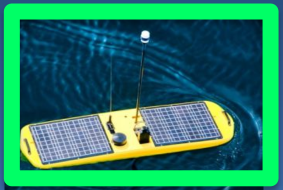
- **Recover 3 Seagliders**
- **Deploy 3 Seagliders**
- Deploy 15 surface drifters
- Deploy MLF
- Service Wave Gliders

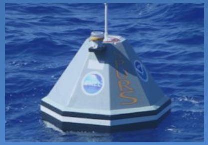
SPURS - 2

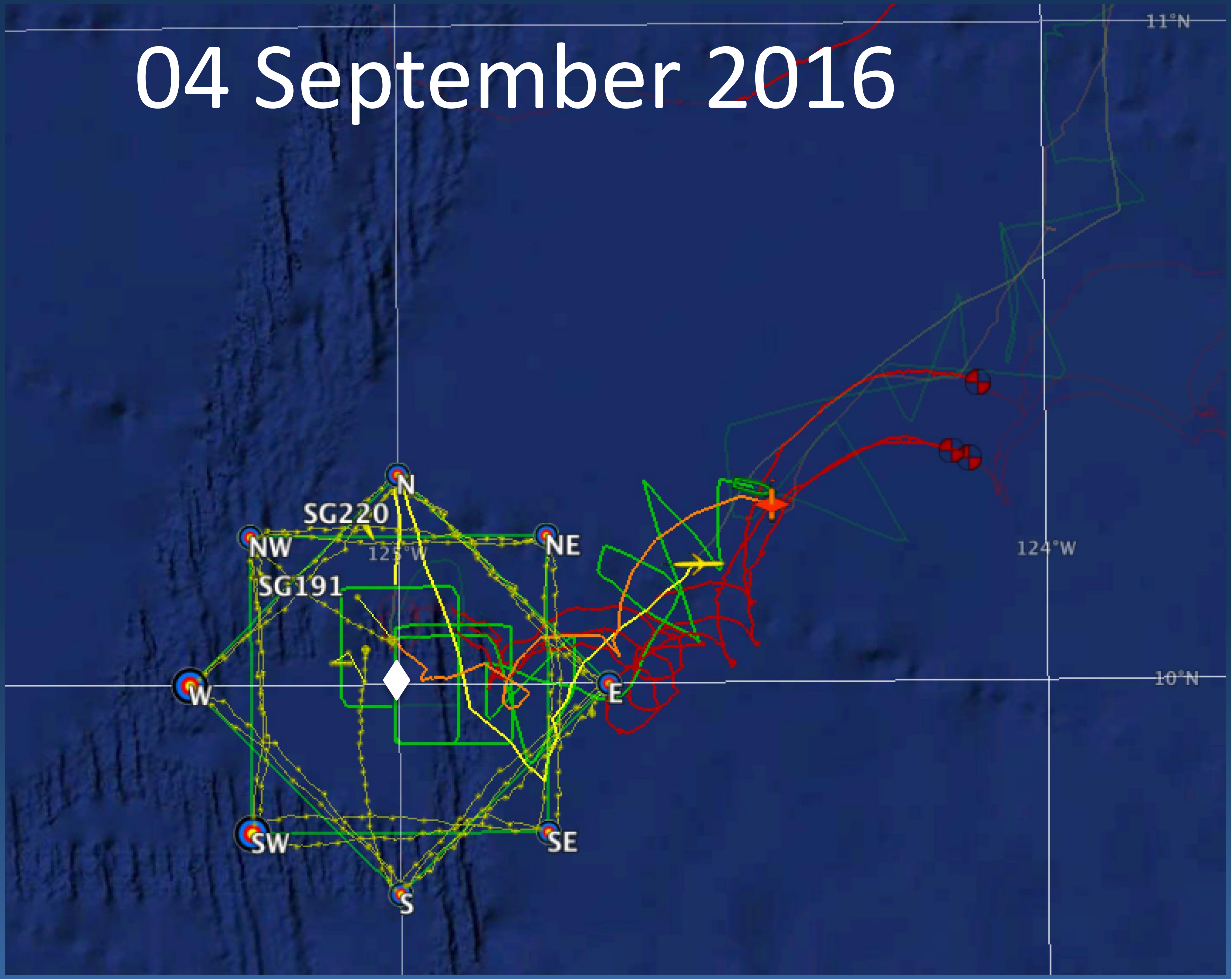
Salinity Processes in the Upper Ocean Regional Study







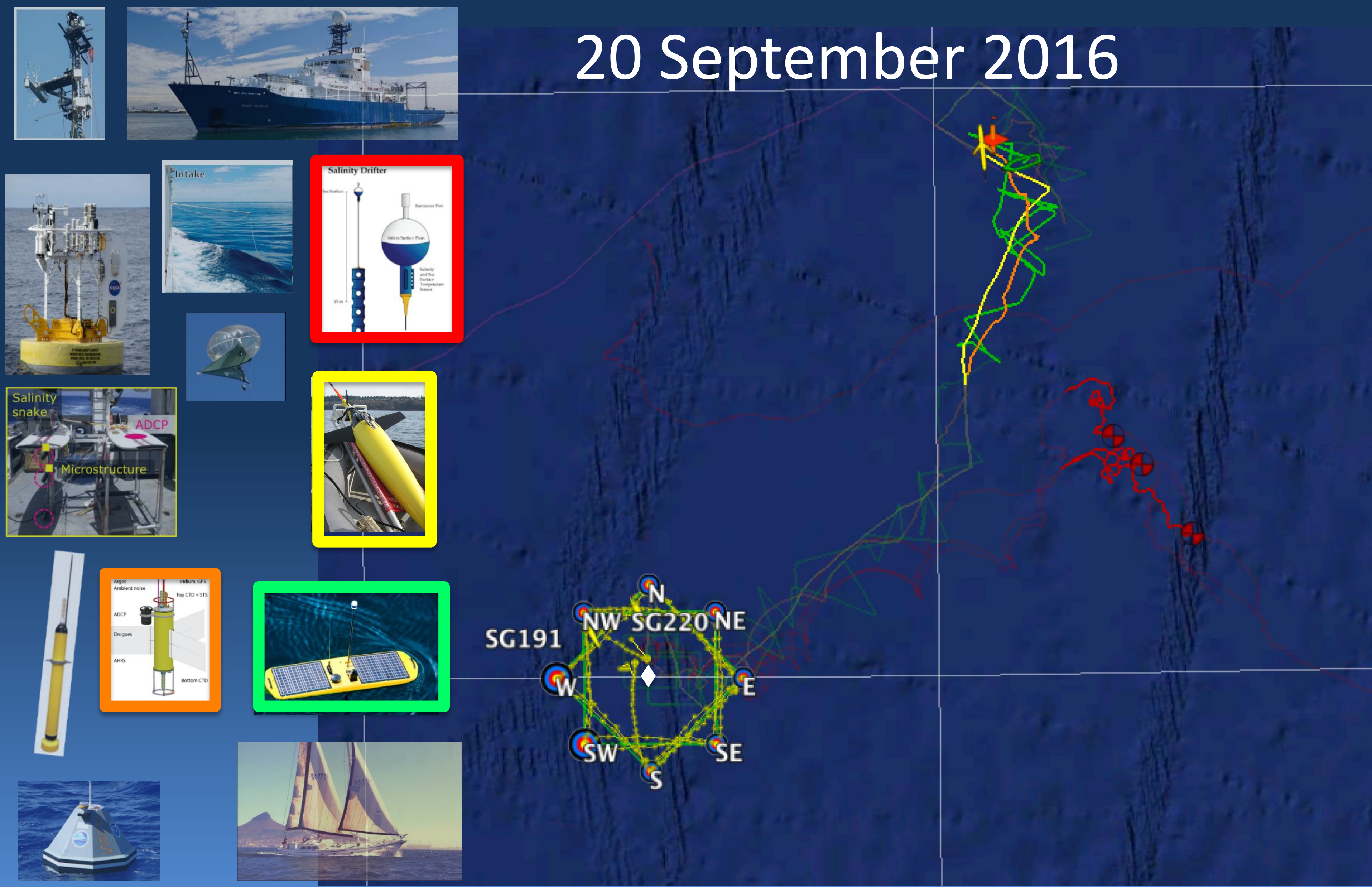




SPURS - 2

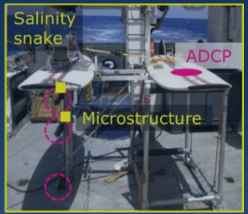
Salinity Processes in the Upper Ocean Regional Study

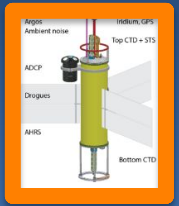
20 September 2016

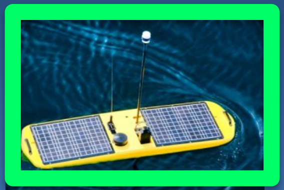


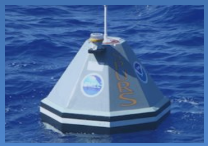
SPURS - 2

Salinity Processes in the Upper Ocean Regional Study

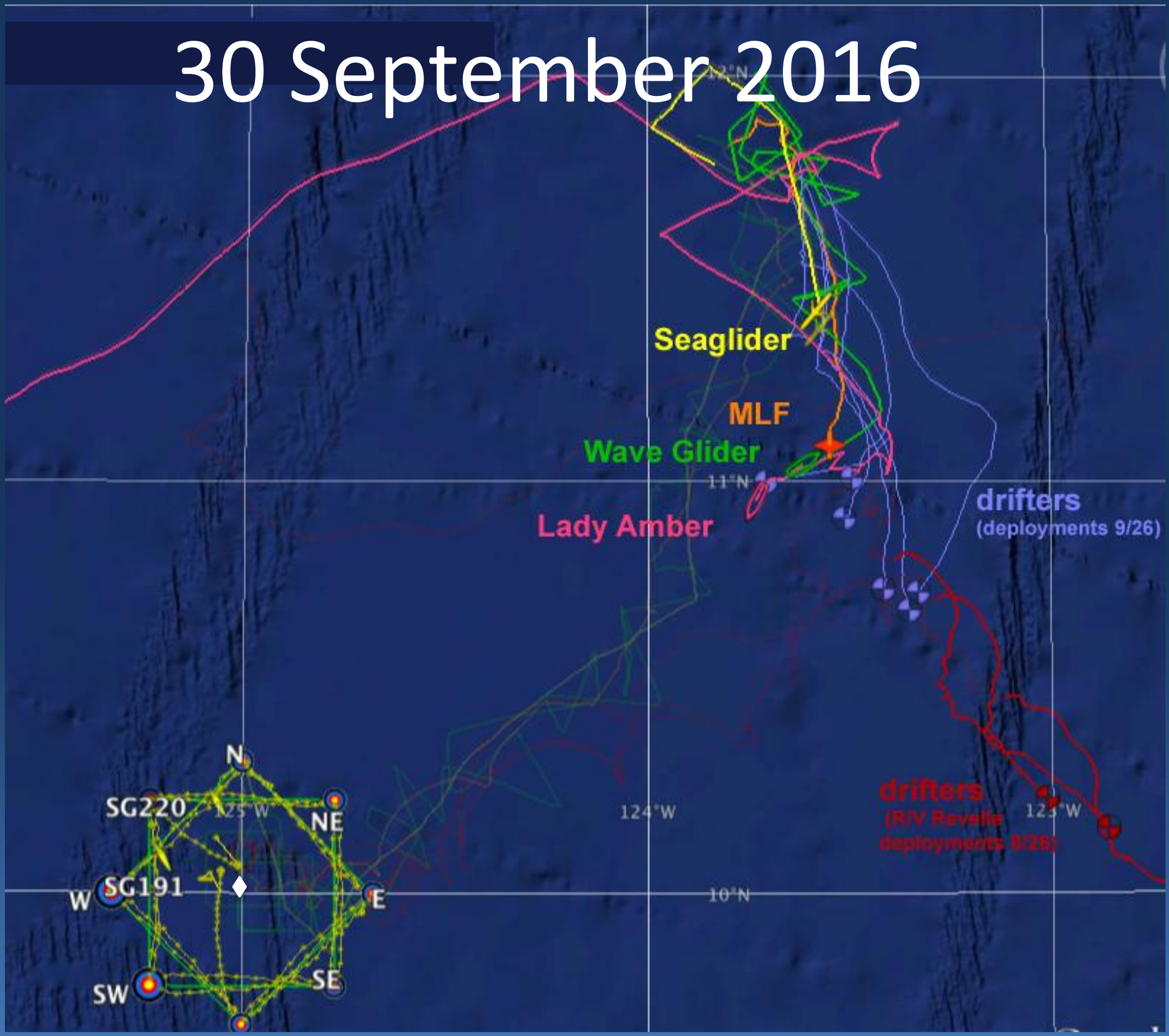


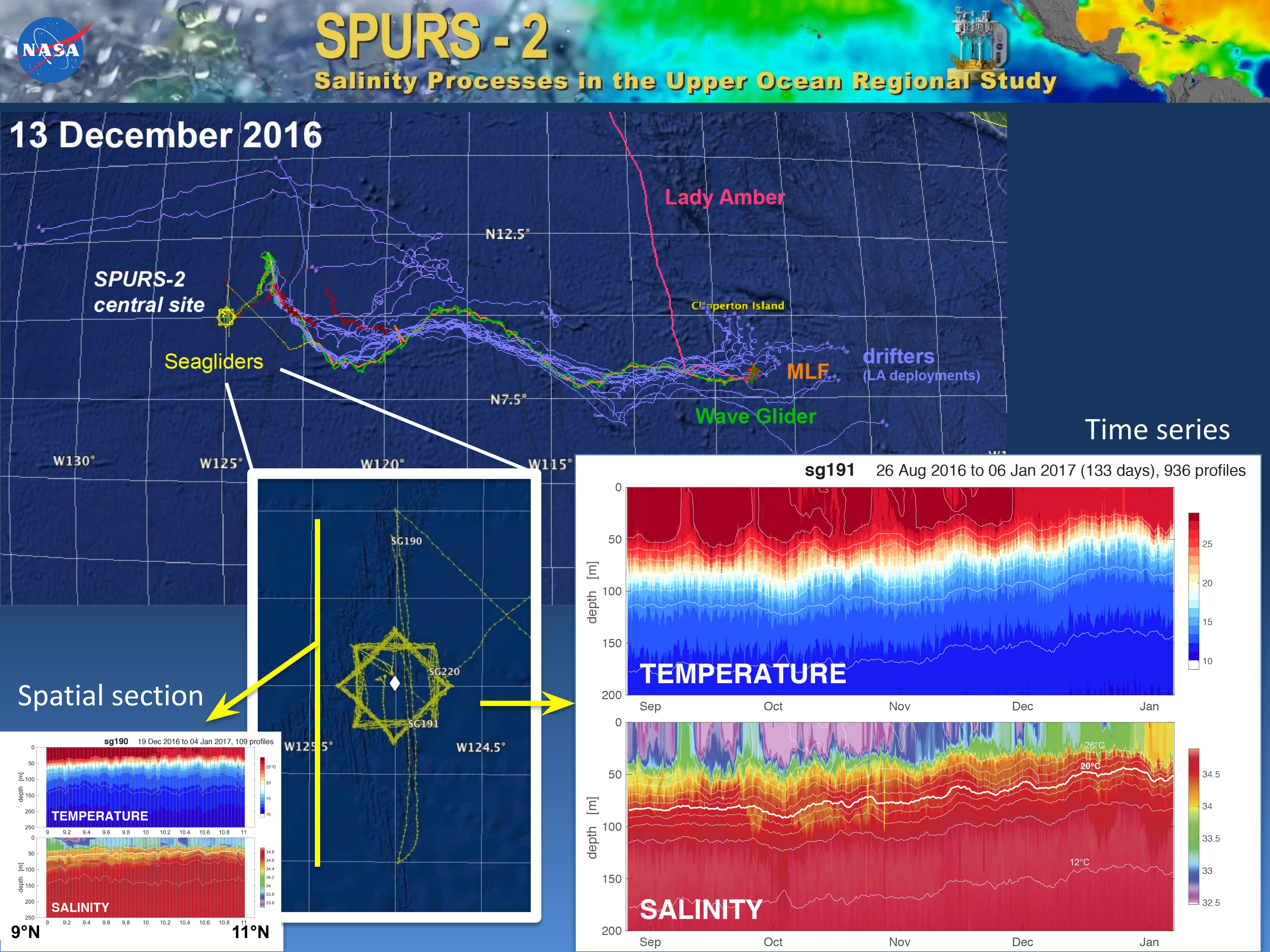






30 September 2016




SPURS - 2
Salinity Processes in the Upper Ocean Regional Study
NASA
13 December 2016
Lady Amber
N12.5°
SPURS-2
central site
Clipperton Island
Seagliders
MLF
drifters
(LA deployments)
N7.5°
Wave Glider
W130°
W125°
W120°
W115°
Time series
SG190
SG220
SG191
W125.5°
W124.5°
sg191 26 Aug 2016 to 06 Jan 2017 (133 days), 936 profiles
depth [m]
TEMPERATURE
Sep
Oct
Nov
Dec
Jan
25
20
15
10
SALINITY
26°C
20°C
12°C
34.5
34
33.5
33
32.5
Spatial section
sg190 19 Dec 2016 to 04 Jan 2017, 109 profiles
TEMPERATURE
SALINITY
9°N
11°N

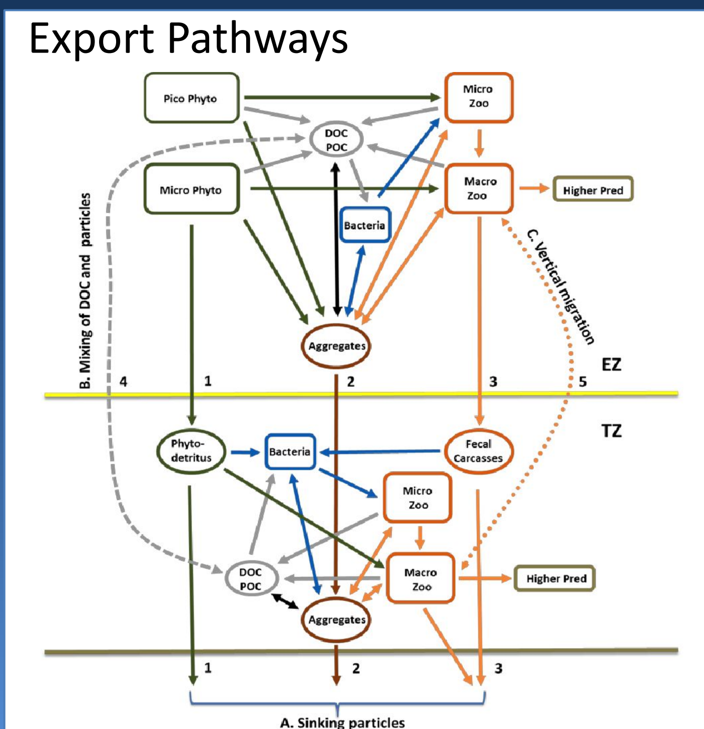
EXPORTS
EXport Processes in the Ocean from RemoTe Sensing

OCEAN BIOLOGY & BIOGEOCHEMISTRY PROGRAM

To develop a predictive understanding of the export and fate of global ocean net primary production and its implications for the Earth's carbon cycle in present and future climates

Plankton ecosystem characteristics include food web structure and their spatiotemporal variability in the environment

Recent advances in the remote sensing of plankton patterns (PFT, PSD, etc.) & autonomous in situ tools make achieving our goal possible



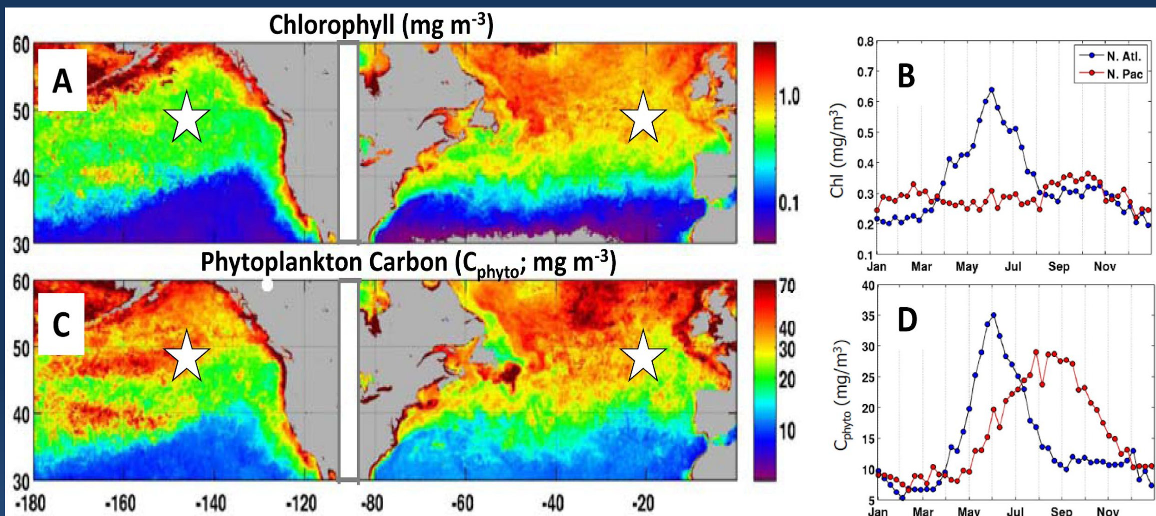
Q1: How do upper ocean ecosystem characteristics determine the vertical transfer of organic matter from the well-lit surface ocean?

Q2: What controls the efficiency of vertical transfer of organic matter below the well-lit surface ocean?

Q3: How can this knowledge gained be used to reduce uncertainties in contemporary & future estimates of export & fates of NPP?

EXPORTS Science Definition Team

Suggested field campaign: *2 NE Pacific & 2 NE Atlantic field deployments*



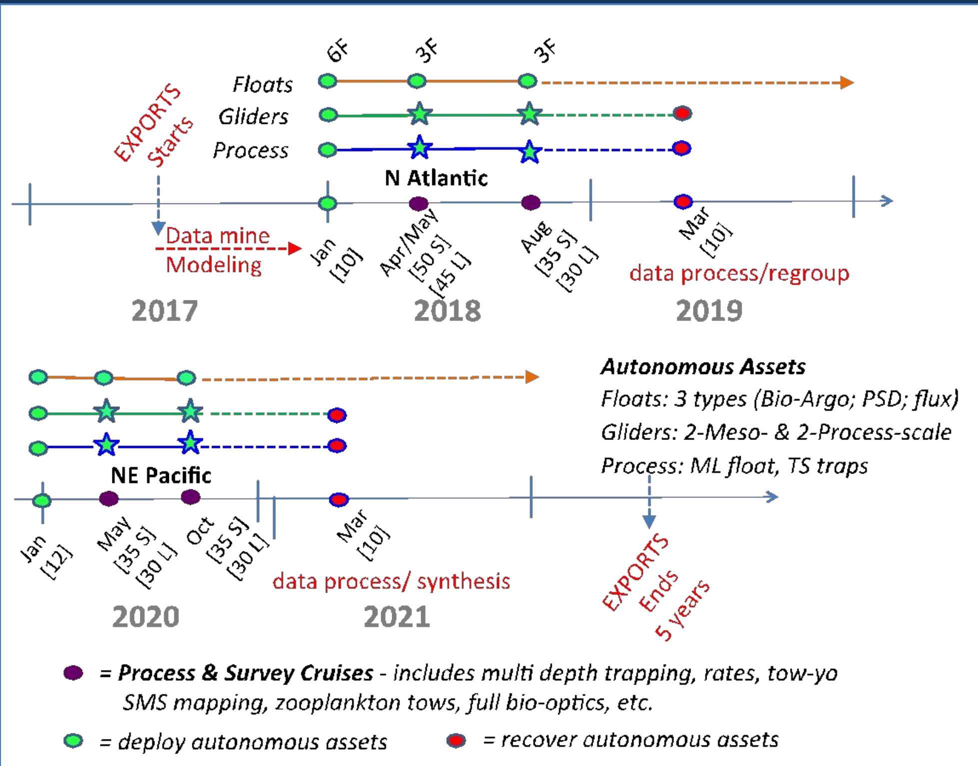
Sites have high signal and variability, increasing the range of ecosystem / C cycling states observed & low mean advection.

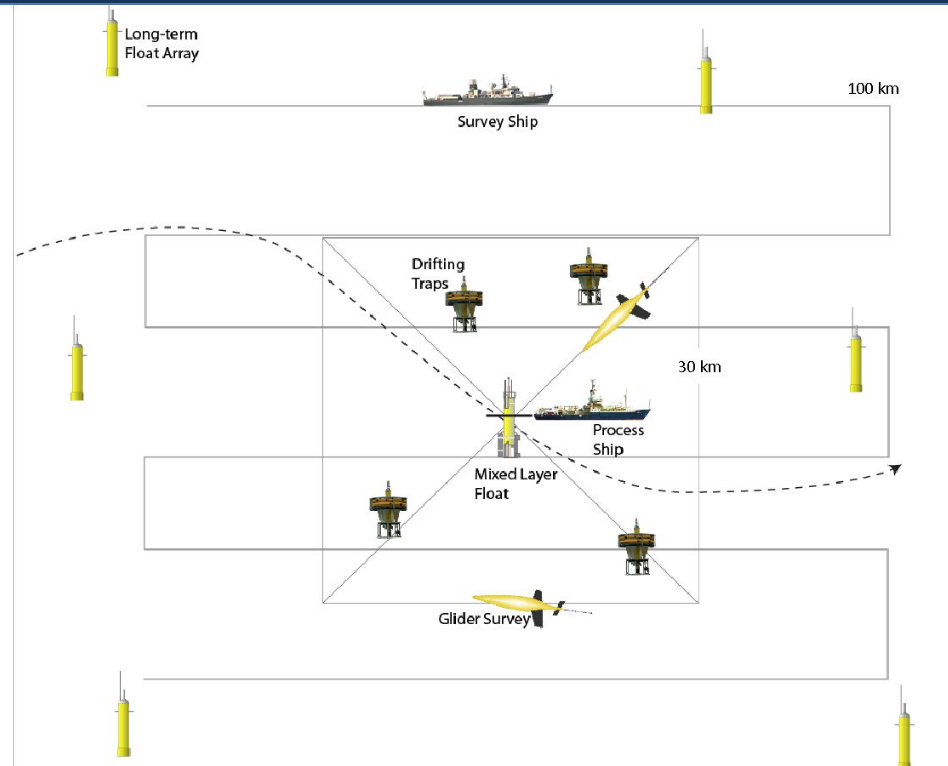
Long-term time-series programs, such as BATS and HOT, provide sufficient data for characterizing end-member conditions for oligotrophic sites.

For each cruise…

- A **process ship** measuring rates and time series of stocks following a sub-surface Lagrangian **float**.
- A **survey ship** provides spatial information on biogeochemistry as well as detailed submesoscale physical oceanographic surveys.
- Spatial observations supplemented by **gliders** & **satellites**
- Long-term context from **profiling floats**.

EXPORTS Field Program requires multiple ships (process, survey & vehicle launch/retrieval), autonomous platforms (gliders & floats) within a framework of remote sensing & modeling.





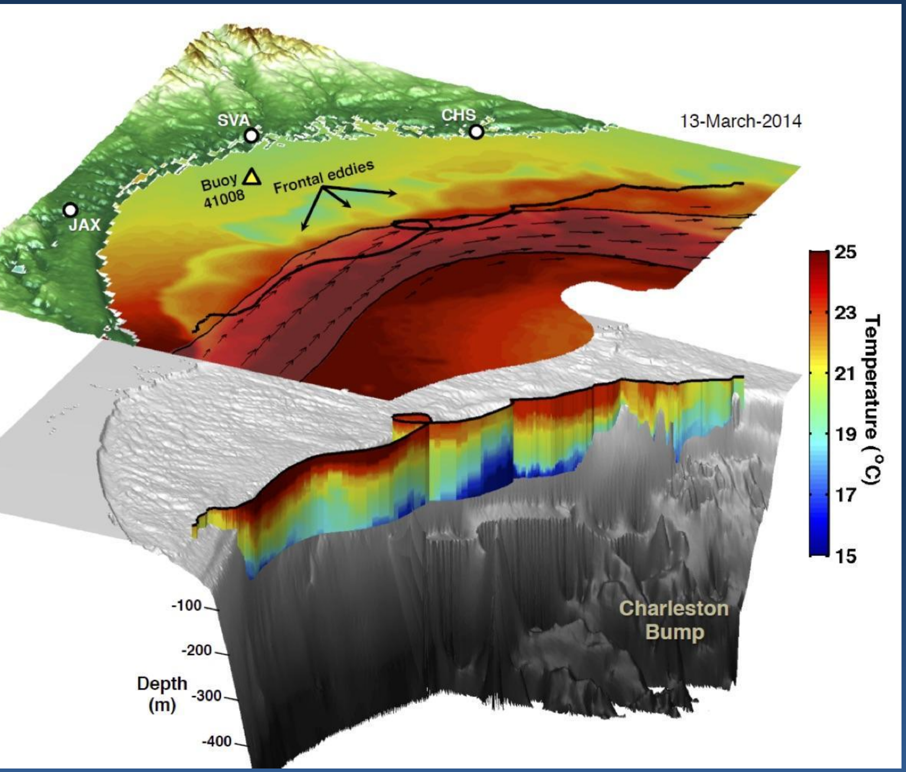
<u>Required Measurements</u>: Water Column Characterization, Food Web Structure, Carbon Flows, Export Paths

- Phytoplankton (C stock, size, PFT, NPP, ...)
- Particles (export w/ vertical profile, PSD, sinking rate, turnover rate, ...)
- Biogeochemistry (O_2, P/DIC, Nuts, P/DOC, ...)
- Food Web Interactions (grazing, fecal flux, sinking particle degradation, energy flow, ...)
- Scales (patch to experimental, trap funnels, ...)
- Context (R_{rs}(l), IOP's, physics, ...)

The Impact of Western Boundary Current and Eddies on the Across-Shelf Exchange in the South Atlantic Bight: an Integrated Study Using Satellite Altimeters Time Series, In-situ Observations, and Data Assimilative Numerical Modeling

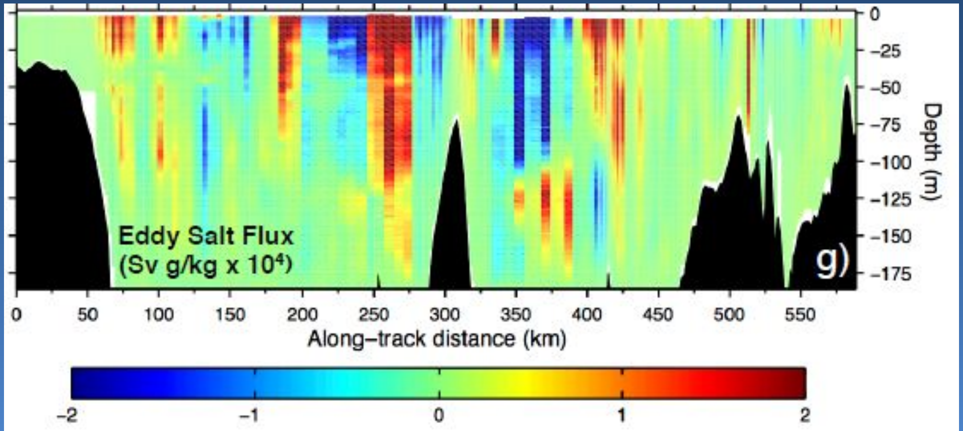
Renato Castelao (UGA) and Ruoying He (NCSU)

Supported by NASA Ocean Surface Topography Science Team



Example of observed potential temperature along the path of a glider in the South Atlantic Bight, March 4-17, 2014. AVHRR SST for March 13th is shown on top panel. Mean location of Gulf Stream core (from altimetry) during deployment is also shown.

- Gliders are providing information about subsurface slope water intrusions onto the shelf
- ROMS 4DVAR implemented assimilating glider data, SSH from altimeters, and SST --> currently being used to investigate along-shelf and cross-shelf exchanges associated with Gulf Stream dynamic



National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Surface Water and Ocean Topography (SWOT) Mission

SWOT Science Team Meeting
January 13-15, 2016

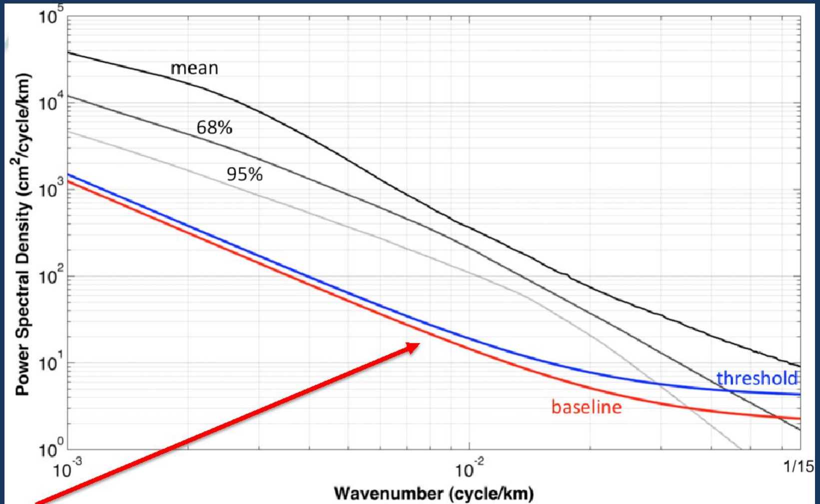
Cal/Val Overview

SWOT Cal/Val Team!

SWOT will provide high-spatial resolution, global measurements of ocean surface topography.

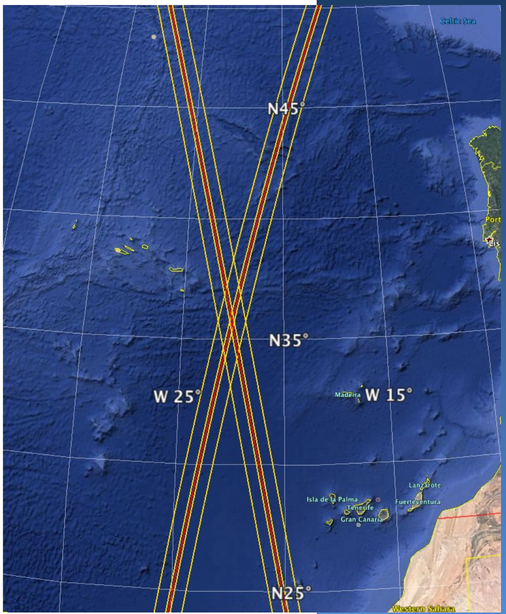
SWOT Validation requires to validate the measurements of entire SSH signature, including tides, internal waves, geostrophic, etc.

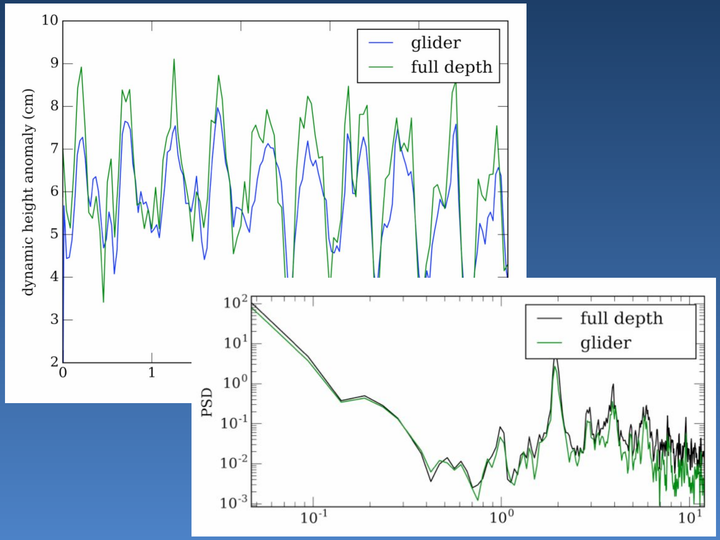
Need to measure the horizontal wavenumber height spectrum.



The spectrum of the *difference* between measured and truth SSH needs to be characterized synoptically at scales between 15 km and ~150 km wavelengths

OSSE using high-resolution models, to evaluate sampling strategies

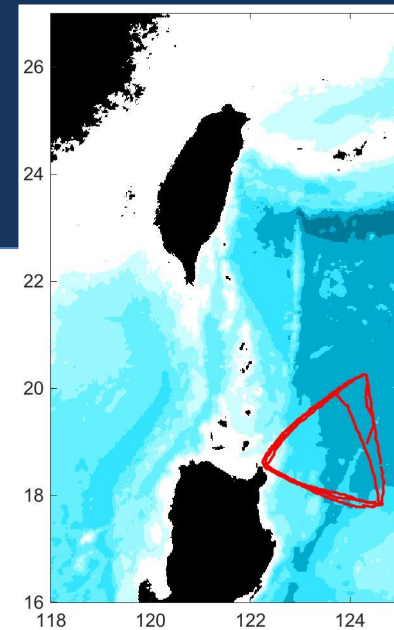




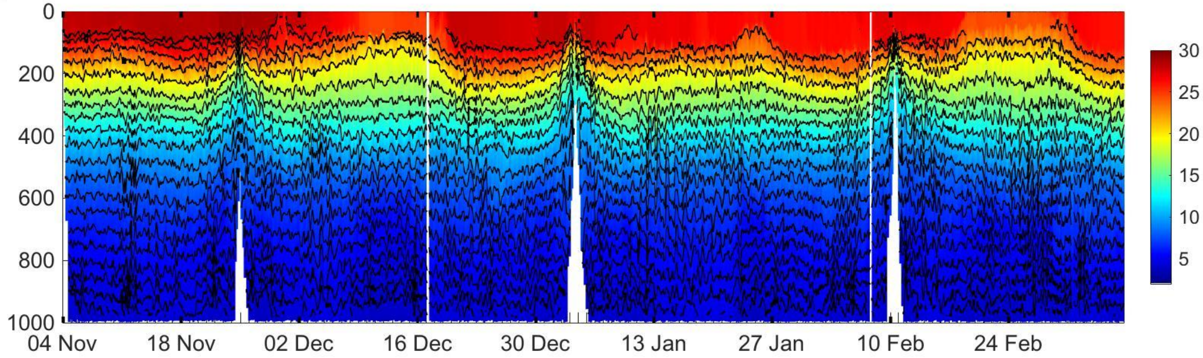
Gliders (time and space)
PIES (mesoscale structure)
Underway-CTD
Towed-body from ship
…

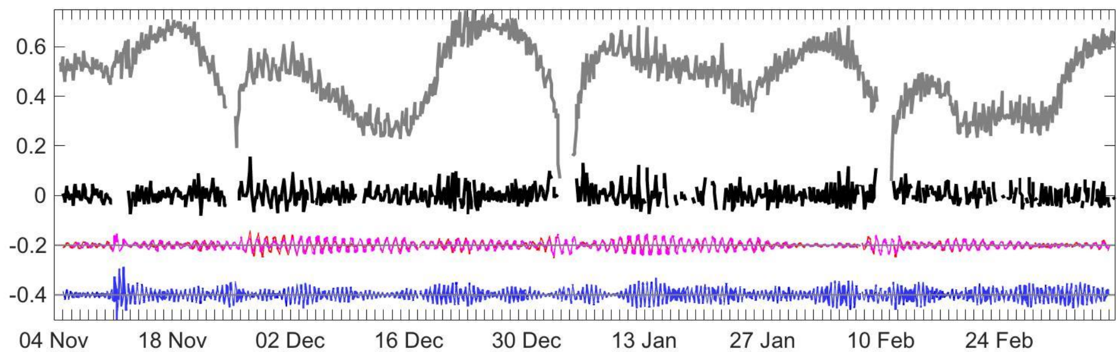
J. Wang, T. Farrar, L. Fu, E. Rodriguez, etc.

Dynamical height estimates from gliders



Temperature and isopycnal displacements from glider





Total steric height (0 < z < 1000m)

ssh with periods < 3-day

diurnal internal tide ssh

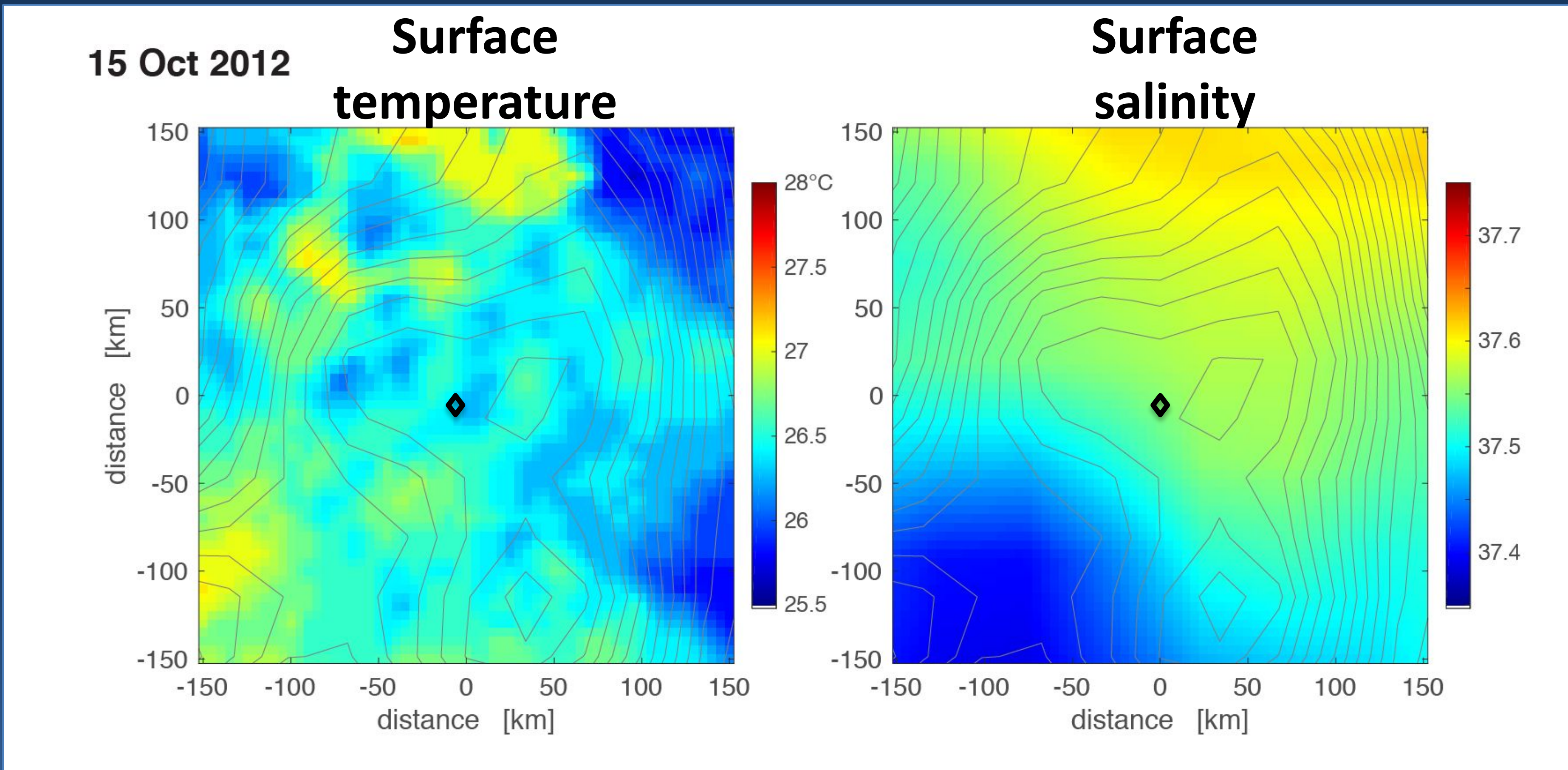
semidiurnal internal tide ssh

The persistence of gliders allows us to estimate the contribution to SSH from internal waves of *different frequencies*, and of different *vertical structures*, on a *regional scale*.

K. Drushka, L. Rainville

Enabling NASA's Mission

- Gliders are used as part of long-term autonomous arrays to capture important processes occurring on a variety of time and spatial scales
- NASA has been a supporter of glider technology development, and sensor development, in particular for interdisciplinary science (Ocean Color, etc.).
- Gliders are used as one of the tools to validate satellite and meet mission requirements.
- Glider data are often an important link between the components of large programs (e.g., modeling, Eulerian / Lagrangian arrays, etc.).

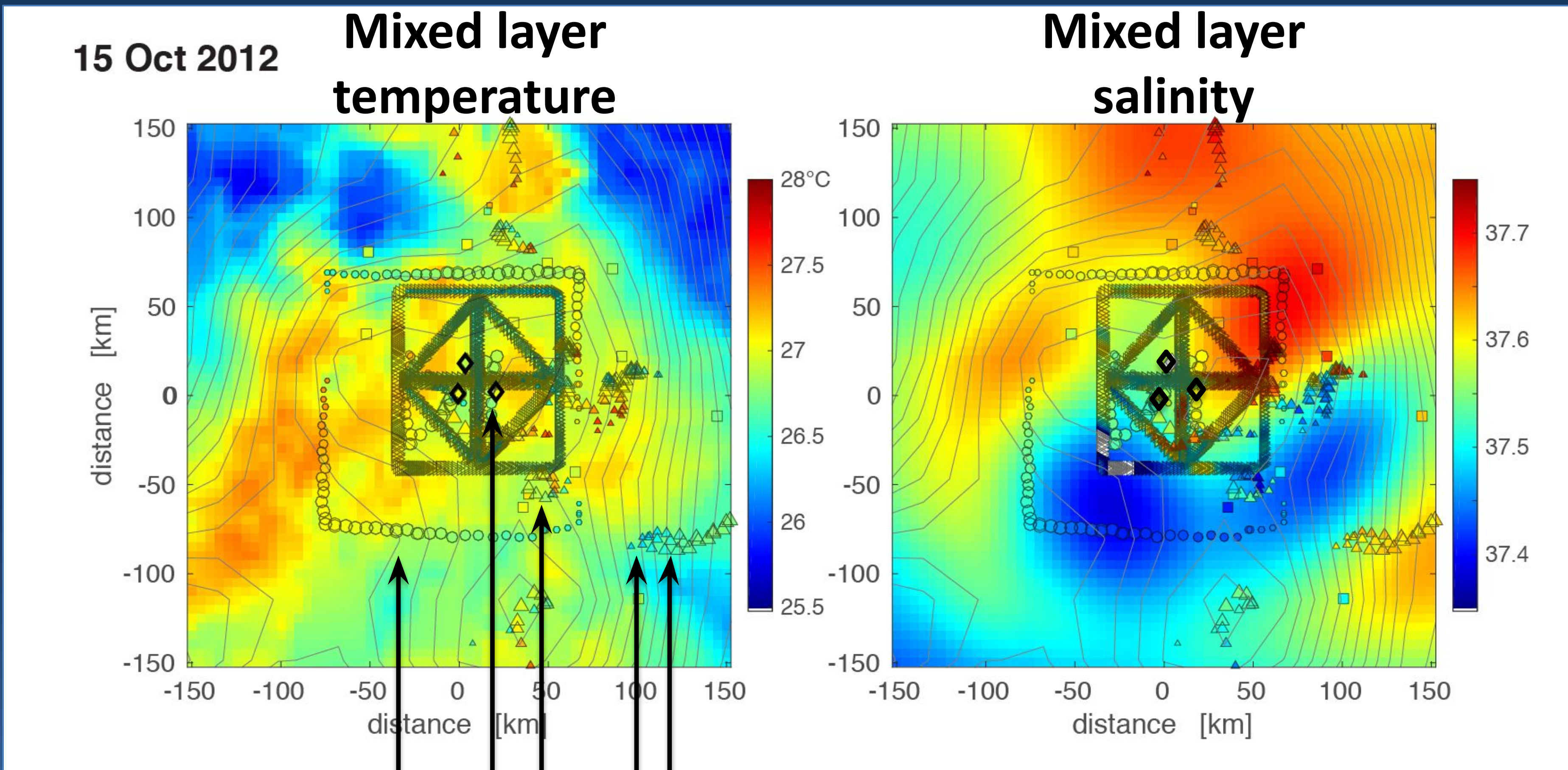


microwave (MW) and infrared (IR) SST
Optimal Interpolation
(Remote Sensing System)

Aquarius SSS
Optimal Interpolation
(Melnichenko et al.)

SPURS

Salinity Processes in the Upper Ocean Regional Study



- Moorings
- Drifters
- Seagliders
- Argo floats
- Wave Gliders

Decorrelation scales: 75 km and 5 days mapped as perturbations from remote sensing

Note: Size of data marker is scaled by when it was collected relative to the map time.