A pair of notional SWOT science campaigns

(“Notional” means “existing only in theory or as a suggestion or idea”)

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Francesco d’Ovidio

SWOT ST meeting, 28 June 2018

SWOT will reveal an exciting new view of 10-100km SSH variability

The primary oceanographic motivation for the SWOT mission is to *enable progress on several important science questions related to mesoscale and submesoscale variability.*

Preparation for SWOT has stimulated a whole new set of important science questions, related to interpretation and use of SWOT measurements.

SWOT will reveal an exciting new view of 10-100km SSH variability

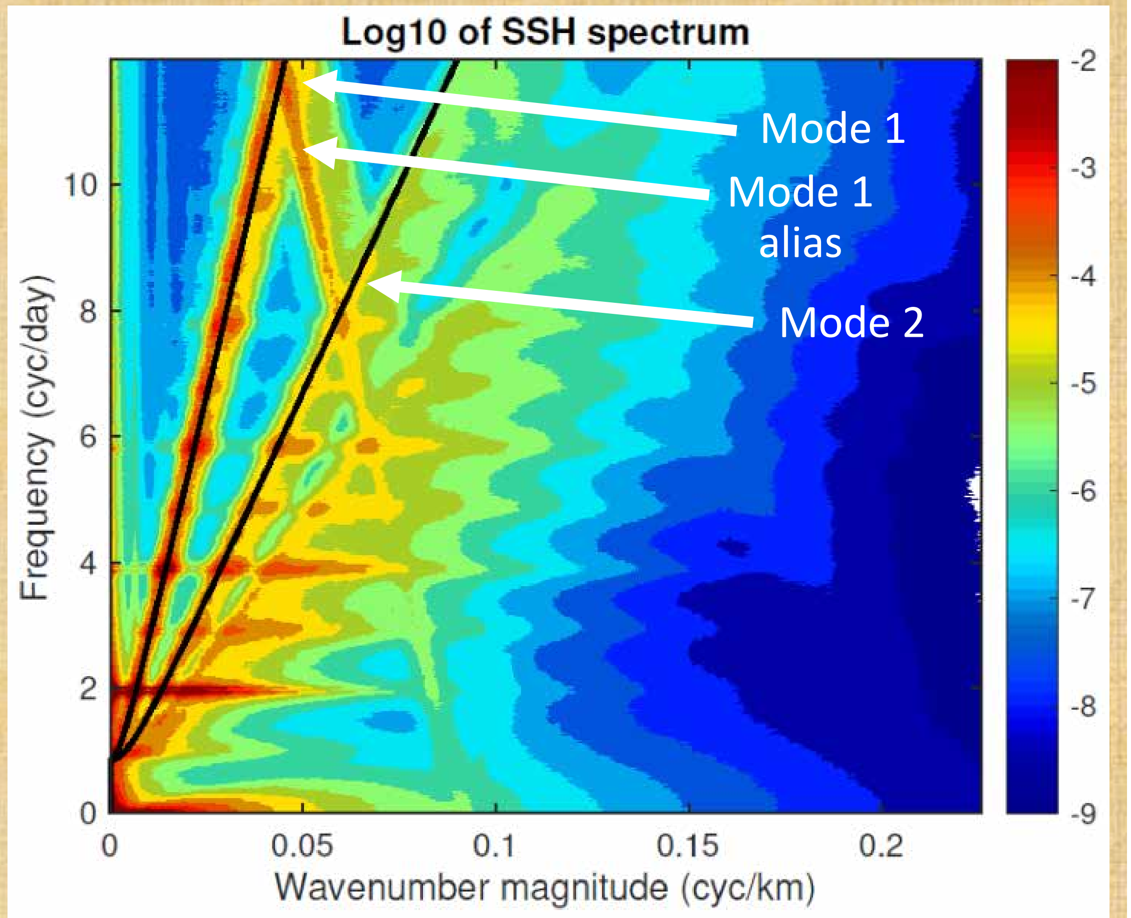
A coordinated field campaign would speed progress on the underlying scientific questions and questions related to use and interpretation of SWOT data.

This talk:

1. Motivating scientific questions
2. A proposal for a two SWOT oceanographic campaigns
3. Moving forward (dedicated workshop, Fall 2018)

Motivating scientific questions

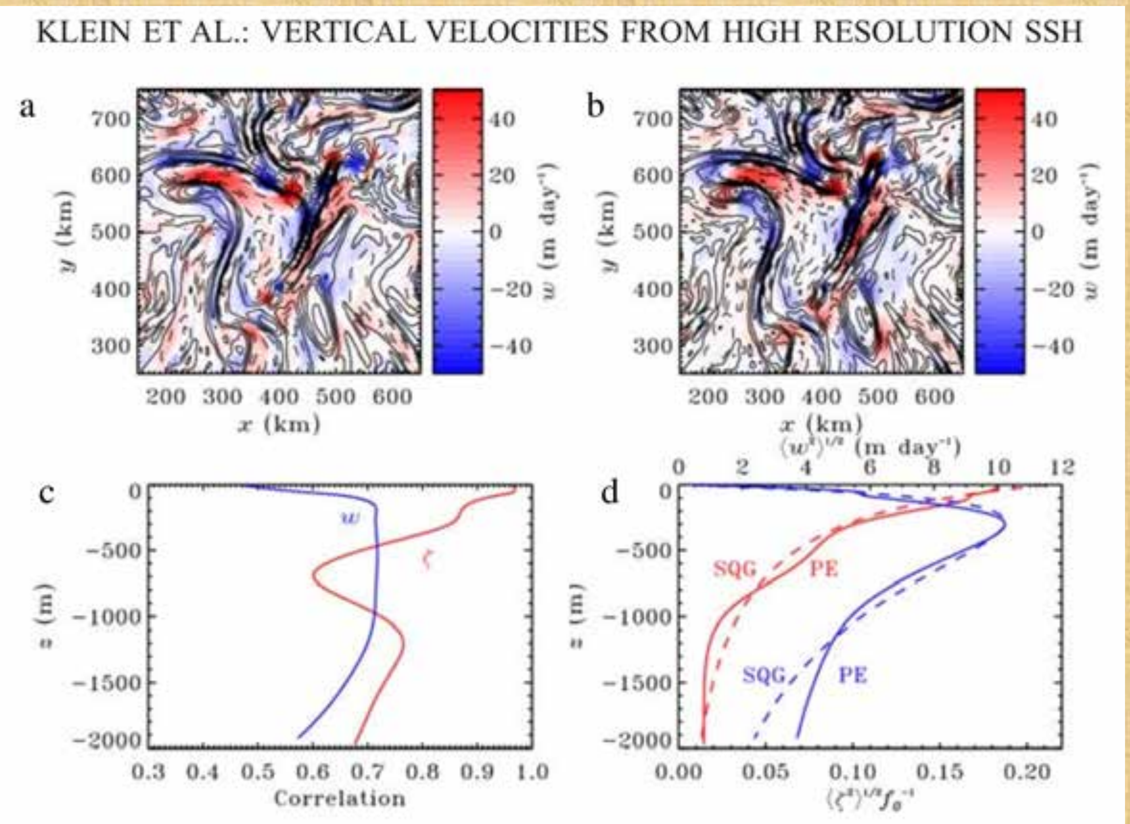
(1) What is the 4D (x,y,z,t) spectrum of ocean variability at 1-200 km scales? What are the physical processes that produce the SSH variability on these scales?



SSH spectrum from MITgcm

Motivating scientific questions

(2) How much of the upper-ocean variability at 1-200 km scales can be observed and constrained using only surface observations of SSH and buoyancy (SST, SSS)? Can tracer fields (SST, SSS, chlorophyll) be used to infer SSH structure at these scales?



Motivating scientific questions

(3) How is energy removed from the large-scale ocean circulation and mesoscale eddy field? That is, how does the ocean energy cascade work, and what are the relative roles of submesoscale variability, internal waves, and other ageostrophic variability in removing energy from the larger scales?

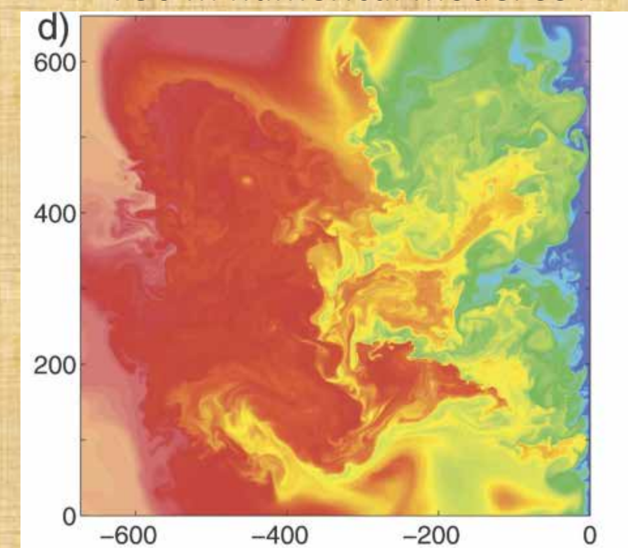
Motivating scientific questions

(4) How do the balanced motions interact with the internal tides and waves? How can we separate these two kinds of motions in the SWOT SSH observations? What is the transition scale between these regimes? Can other measurements be used together with SSH to distinguish between balanced and unbalanced motions?

Motivating scientific questions

(5) How do dynamics at 1-200 km scales contribute to vertical and horizontal transport in the upper ocean?

750 m numerical model SST



Capet et al. (2008)

L14607 RUIZ ET AL.: VERTICAL MOTION AND NEW TECHNOLOGIES L14607

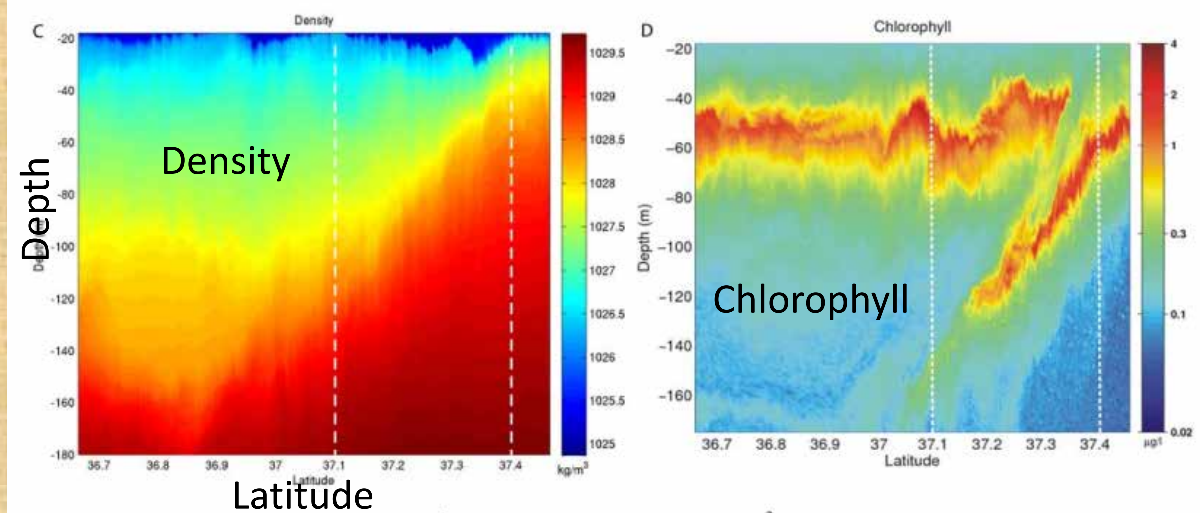


Figure 2. Vertical section of temperature (°C), salinity (PSU), density (kg/m^3) and chlorophyll (μg/l) from glider section 2 (dashed magenta in Figure 1). White dashed lines define sub-section in the northern part of the domain.

Notional SWOT science campaigns

Campaign #1: *A wavenumber-frequency view of ocean variability*
Campaign to resolve 4D spectrum of ocean variability in pressure and velocity at scales of 10-200km. This campaign would capitalize on the existence of the SWOT fast-repeat orbit and the existence of an in situ cal/val array designed to resolve 20-100km

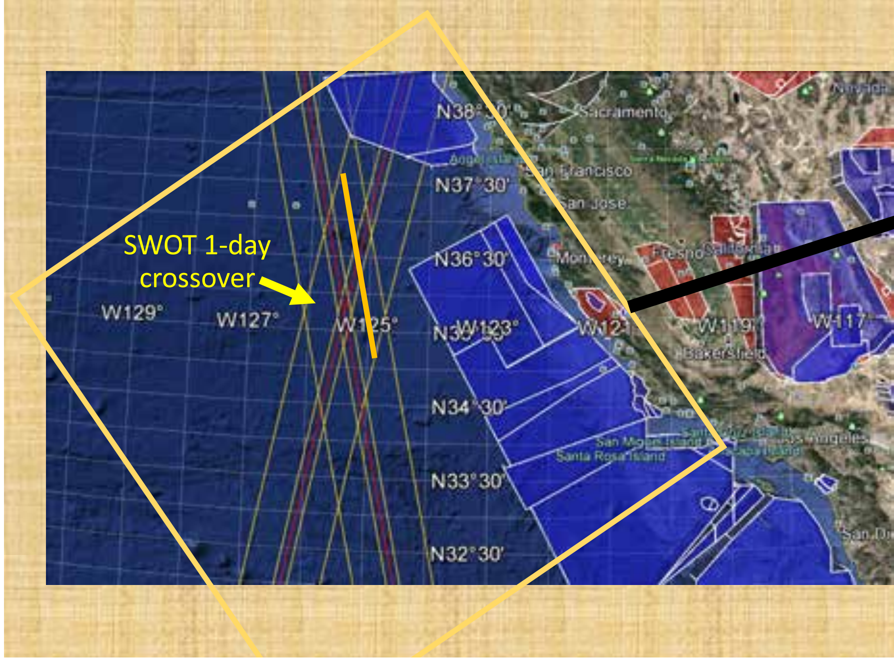
Campaign #2: *A time-space view of submesoscale variability near a front*
Frontal/submesoscale campaign with intensive measurements of submesoscale eddies and fronts. Scientific focus on dynamical processes and vertical transport in the upper ocean.

Campaign #1: Resolve 4D spectrum of ocean variability in pressure and velocity at scales of 10-200km.

Assume the baseline cal/val system consists of a horizontal array of time series measurements (e.g., moorings or gliders) and airborne LIDAR flights to validate the SSH measurement wavenumber spectral requirement during the SWOT fast-repeat orbit phase.

Campaign #1: Resolve 4D spectrum of ocean variability in pressure and velocity at scales of 10-200km.

The prospective California cal/val site is in a canonical submesoscale study region



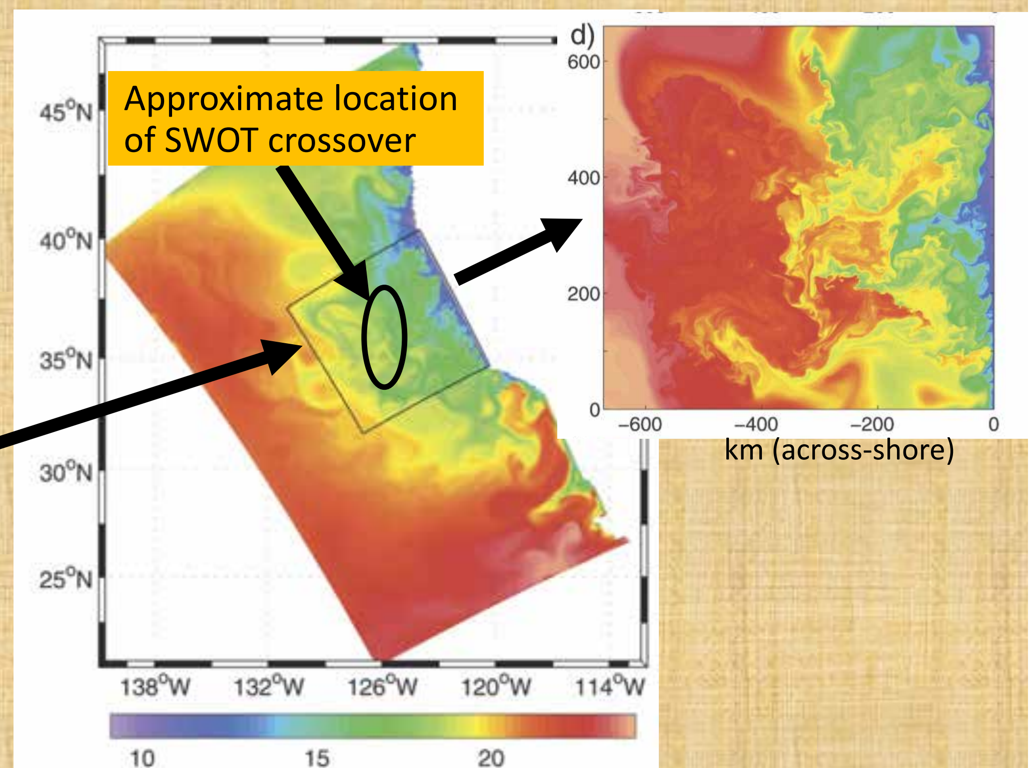
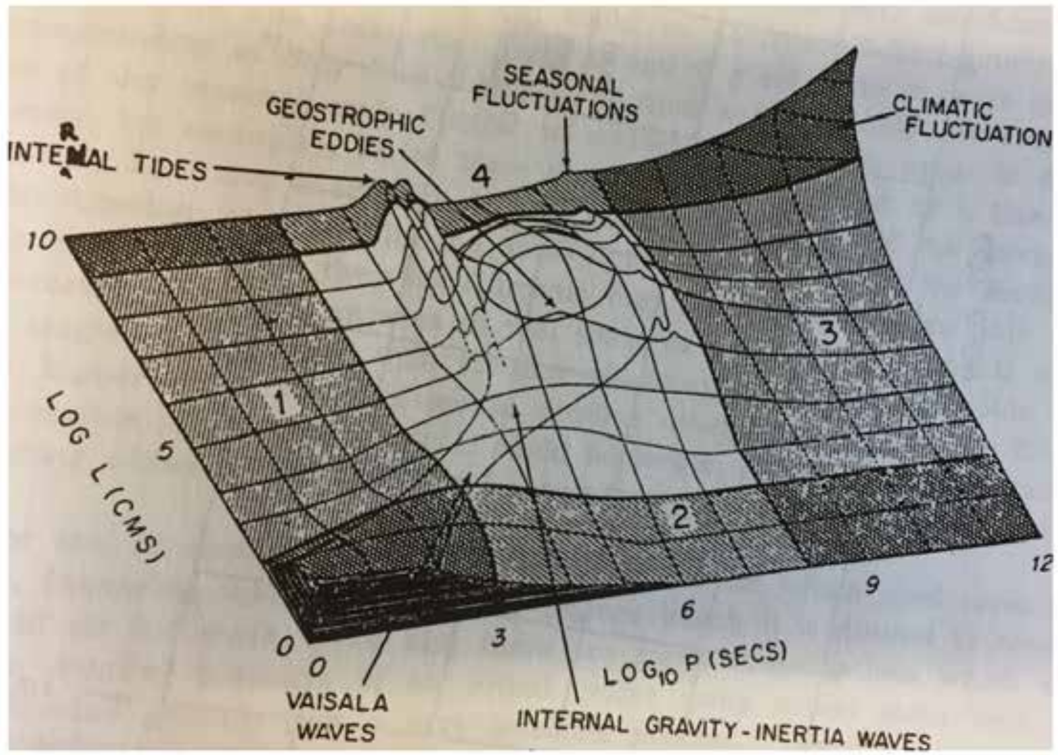


FIG. 1. Instantaneous SST at t = 30 days. The SST computed from ICC3 is superimposed onto the full USW12 field. The boundaries of the ICC domains are delineated by black lines.

Capet et al. (2008)

Campaign #1: Resolve 4D spectrum of ocean variability in pressure and velocity at scales of 10-200km.

Stommel's (1963) conceptual spectrum of dynamic height



Schematic wavenumber-frequency spectrum by Stommel (1963)

(Courtesy of Cesar Rocha)

Campaign #1: Resolve 4D spectrum of ocean variability in pressure and velocity at scales of 10-200km.

VOL. 80, NO. 27 JOURNAL OF GEOPHYSICAL RESEARCH SEPTEMBER 20, 1975

Preliminary Results From the Trimoored Internal Wave Experiment (IWEX)

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A three-dimensional array of 20 current meters, temperature sensors, and vertical temperature gradient sensors was successfully deployed for 40 days in late 1973 in the main thermocline over the Hatteras Abyssal Plain southeast of Bermuda. Sensor spacings in the main array were 1.4–1600 m in the horizontal, 2.1–1447 m in the vertical. The minimum sampling interval was 225 s. The ultimate purpose of the experiment was to estimate a vector wave number–frequency spectrum of internal waves without the usual assumptions of simple modal structure, horizontal isotropy, and linearity. The purpose of this paper is to describe some of the early results. Autospectra from the array normalize quite well in depth according to

Campaign #1: Resolve 4D spectrum of ocean variability in pressure and velocity at scales of 10-200km.

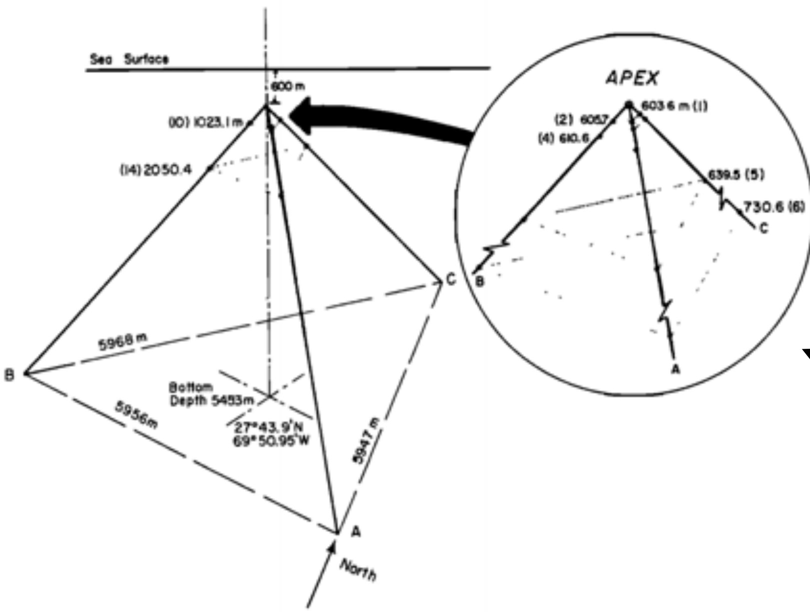


Fig. 2. Trimoor geometry, approximately to scale. Numbers in parentheses are level numbers. Depths are nominal. Each leg is nominally 5964 m long. Compare with Table 1.

BRISCOE: IWEX

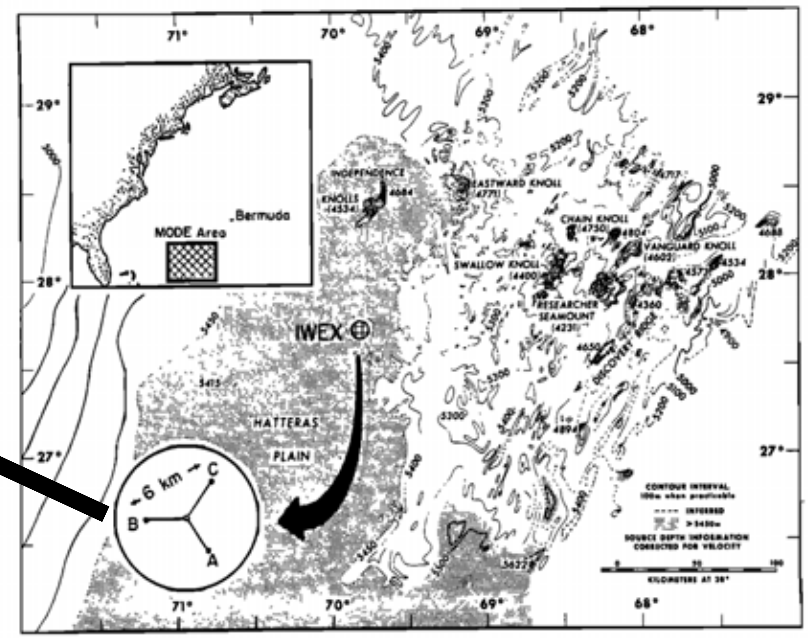
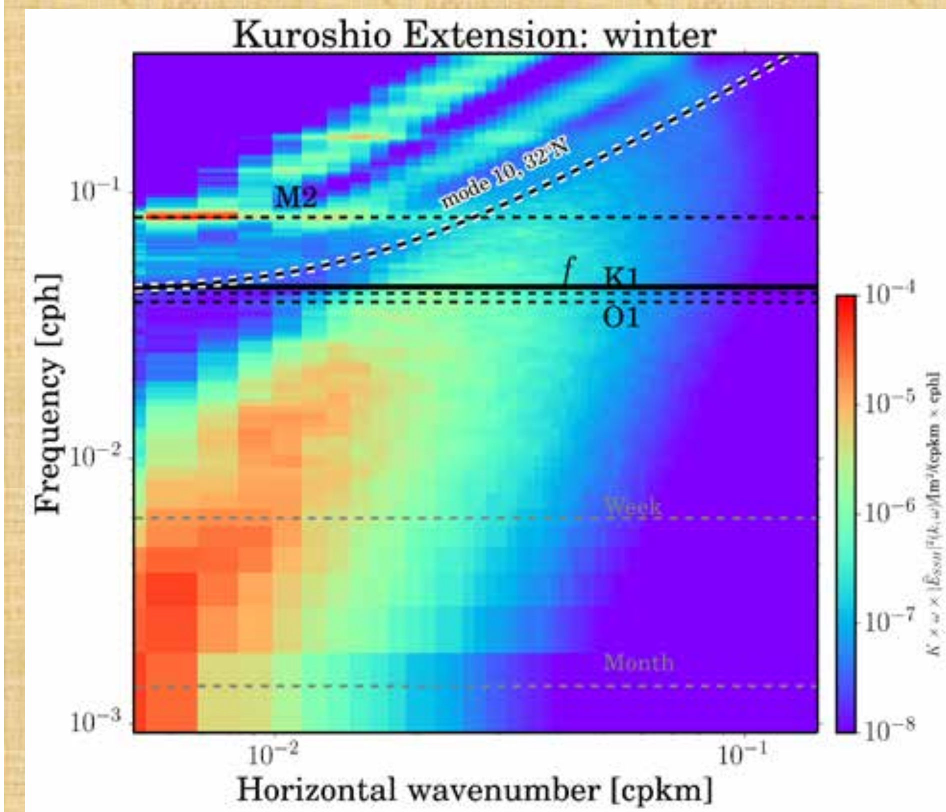


Fig. 1. Trimoor site on the Hatteras Abyssal Plain. Chart compiled by Patricia A. Bush, Atlantic Oceanographic and Meteorological Laboratory/NOAA, Miami, Florida 33149.

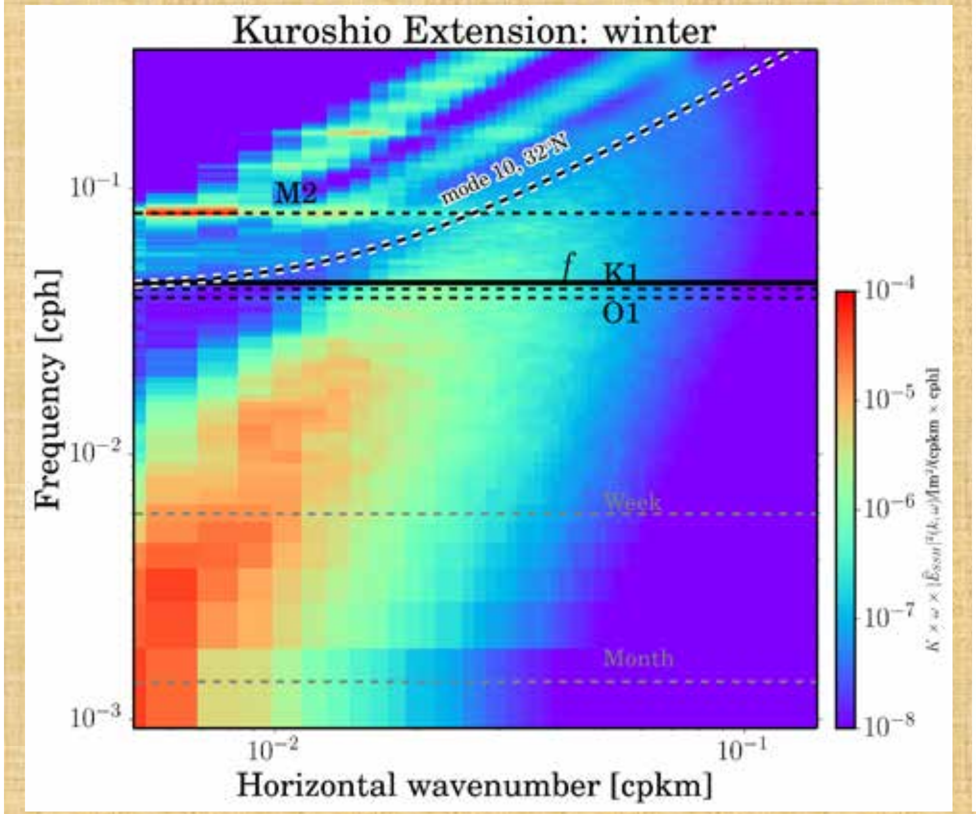
Campaign #1: Resolve 4D spectrum of ocean variability in pressure and velocity at scales of 10-200km.



(Courtesy of Hector Torres)

State-of-the-art wavenumber-frequency spectrum from GCMs with realistic tide and surface forcing

Campaign #1: Resolve 4D spectrum of ocean variability in pressure and velocity at scales of 10-200km.



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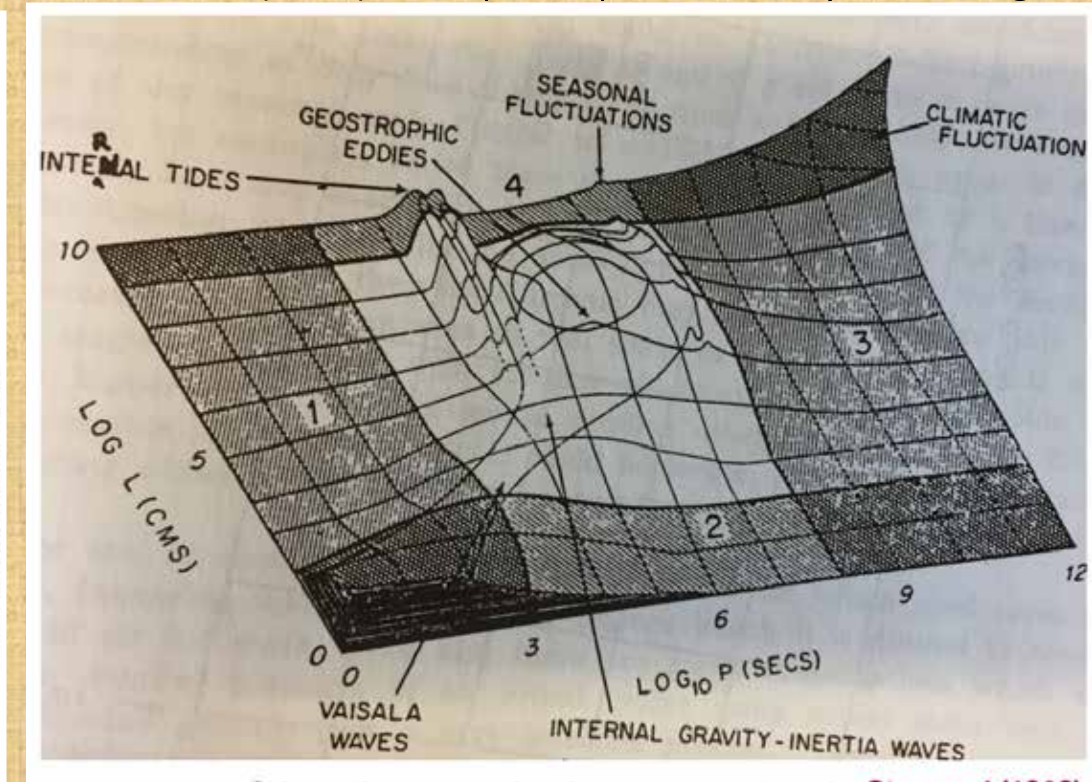

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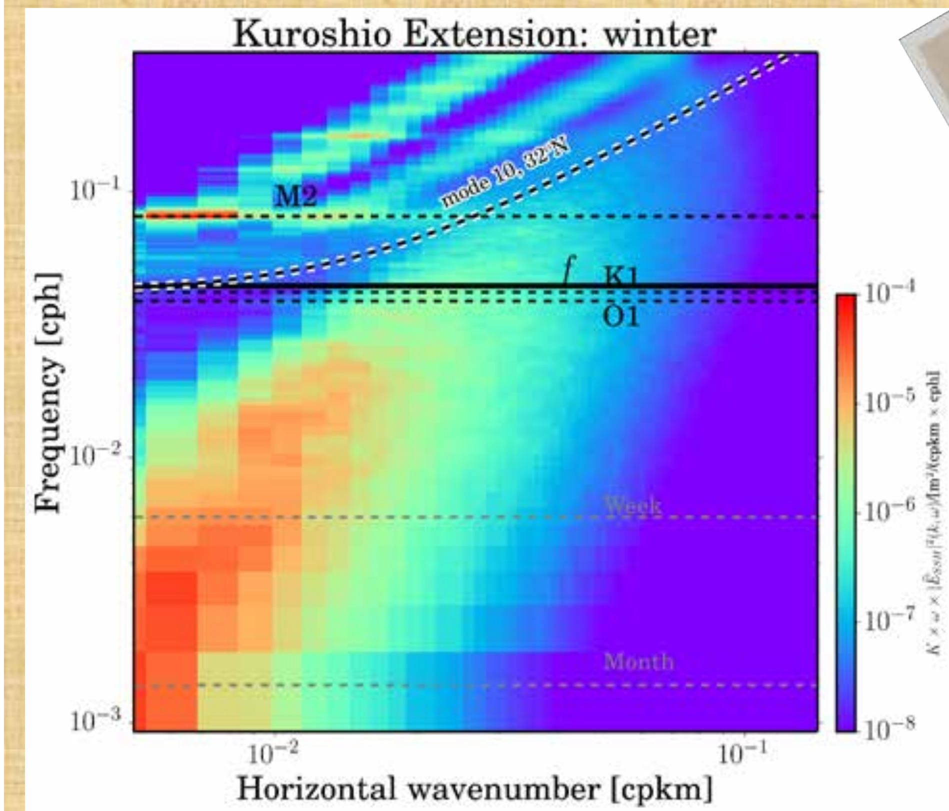

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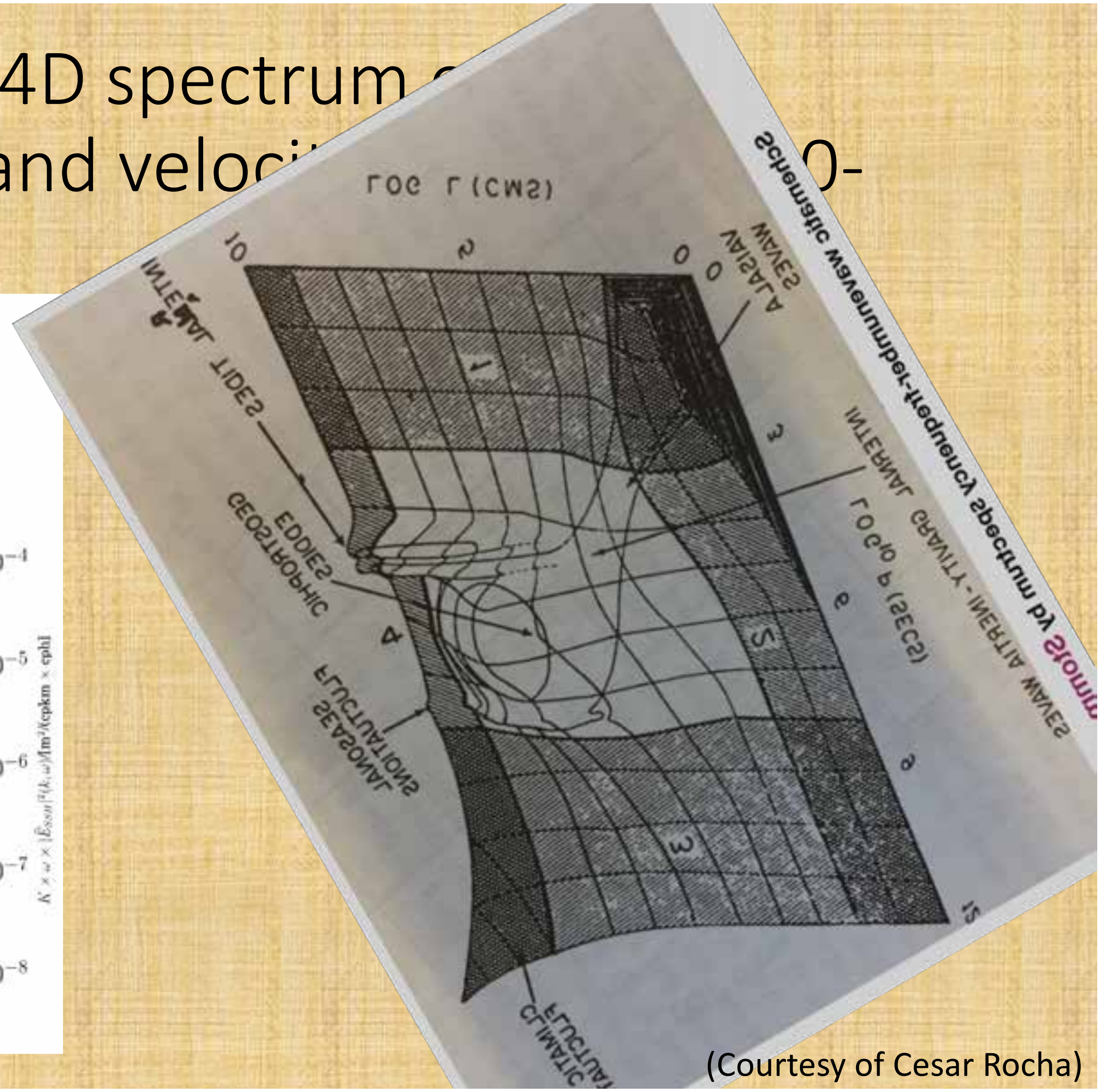


(Courtesy of Cesar Rocha)

Campaign #1: Resolve 4D spectrum of ocean variability in pressure and velocity at scales of 10-200km.

Logistics/notes:

a. Complement existing cal-val measurements to better resolve 4D structure of multiple variables (temperature, salinity, velocity)
b. Aim for deployment of all assets 4 months after nominal time of launch (mitigates risk of delay of launch by up to 3 months)
c. Rely heavily on autonomous assets; arrange deployment strategies to be able to adjust for delay of launch and implementation of cal-val array
d. Has synergy with proposed DopplerScatt Earth Ventures Suborbital mission

Sub-Mesoscale Ocean Dynamics Experiment (S-MODE), proposed EVS Experiment

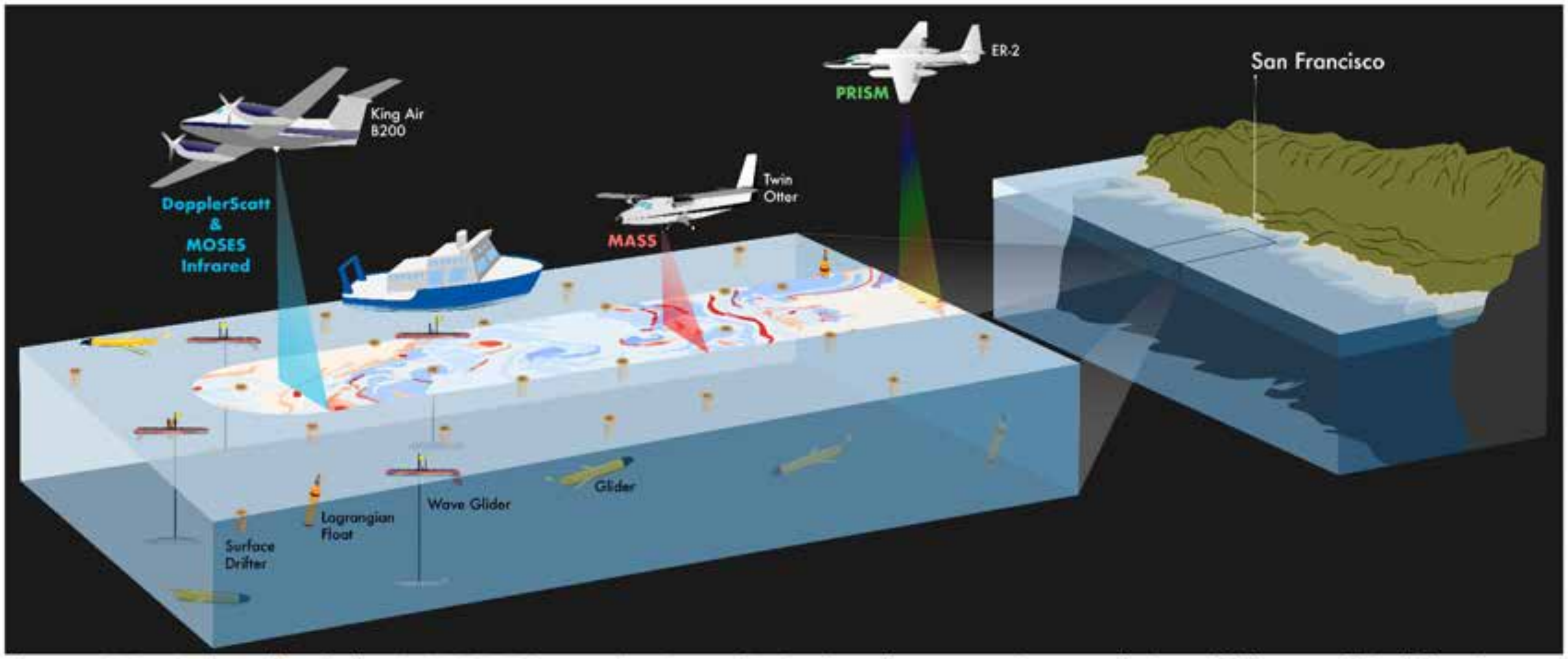


Figure 1.1: A sketch of the S-MODE investigation, depicting the experimental site offshore of California and the platforms and aircraft instruments that will be employed. The experimental plan involves a two-week pilot campaign and two, 25-day intensive operating periods during spring and fall of 2021, with 10-15 flights in each period. The nominal site is 300 km from San Francisco.

Campaign #2: Frontal/submesoscale processes campaign

- Scientific focus on dynamical frontal/submesoscale processes and vertical transport in the upper ocean (important for ocean physics, biology, chemistry).

- Would be set in a “high-signal” environment, i.e., features observable in SWOT data. (SWOT random noise is ~2.7 cm at 1-km resolution)

- Location could be anywhere– preferably easily accessible from Europe

Campaign #2: Frontal/submesoscale processes campaign

AirSWOT Monterey campaign in April 2015: Illustration of "high-signal environment"

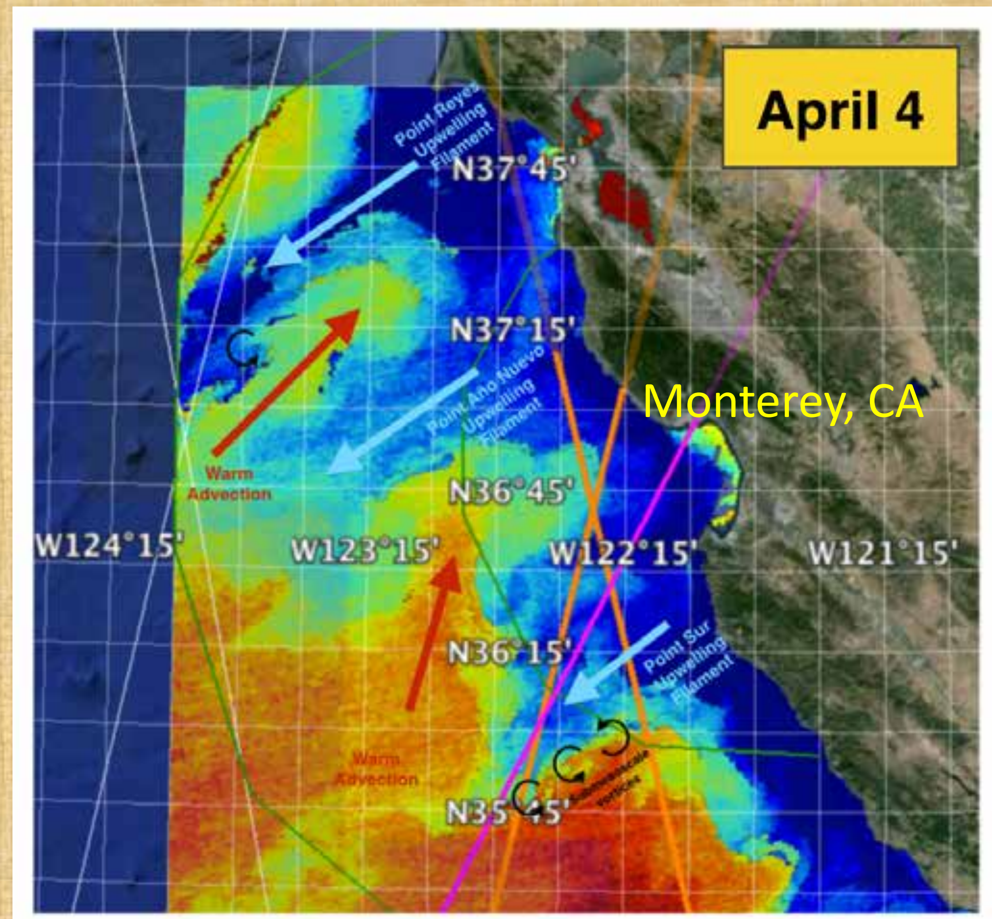


Figure courtesy James Girton, UW-APL

Campaign #2: Frontal/submesoscale processes campaign

AirSWOT Monterey campaign in April 2015: Illustration of “high-signal environment”

Underway CTD section measured along this AltiKa altimeter track

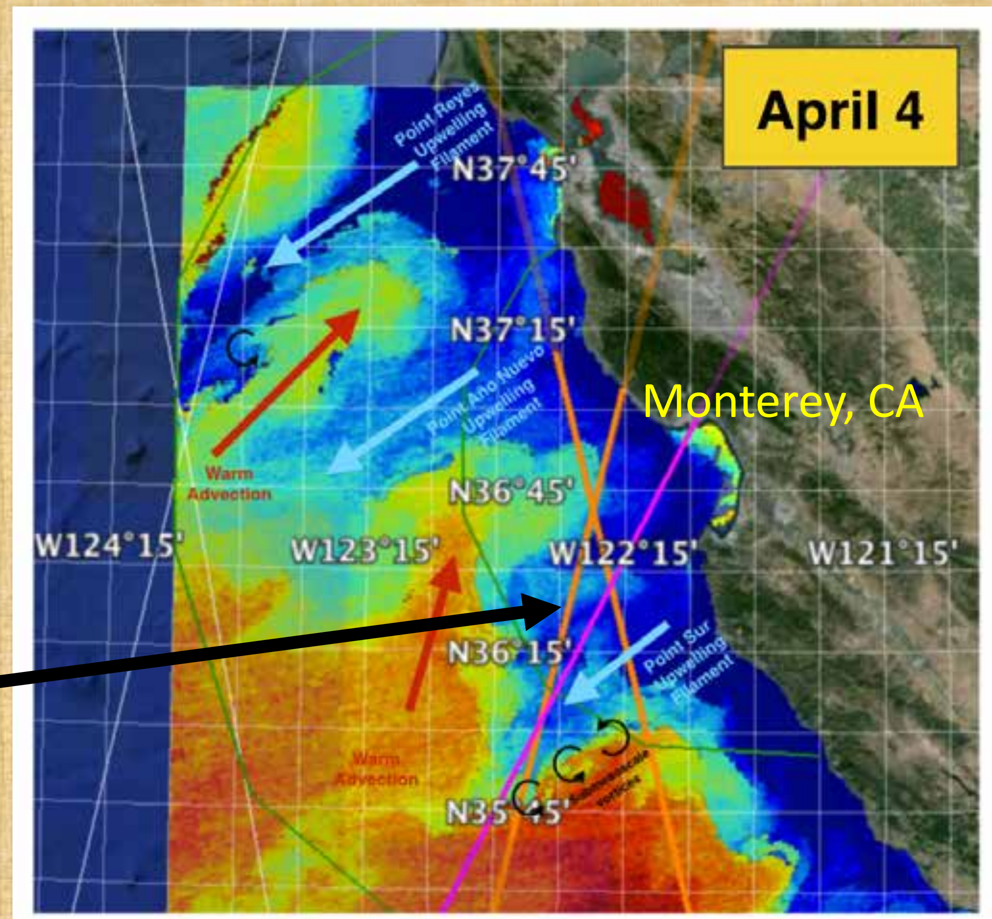


Figure courtesy James Girton, UW-APL

Campaign #2: Frontal/submesoscale processes campaign

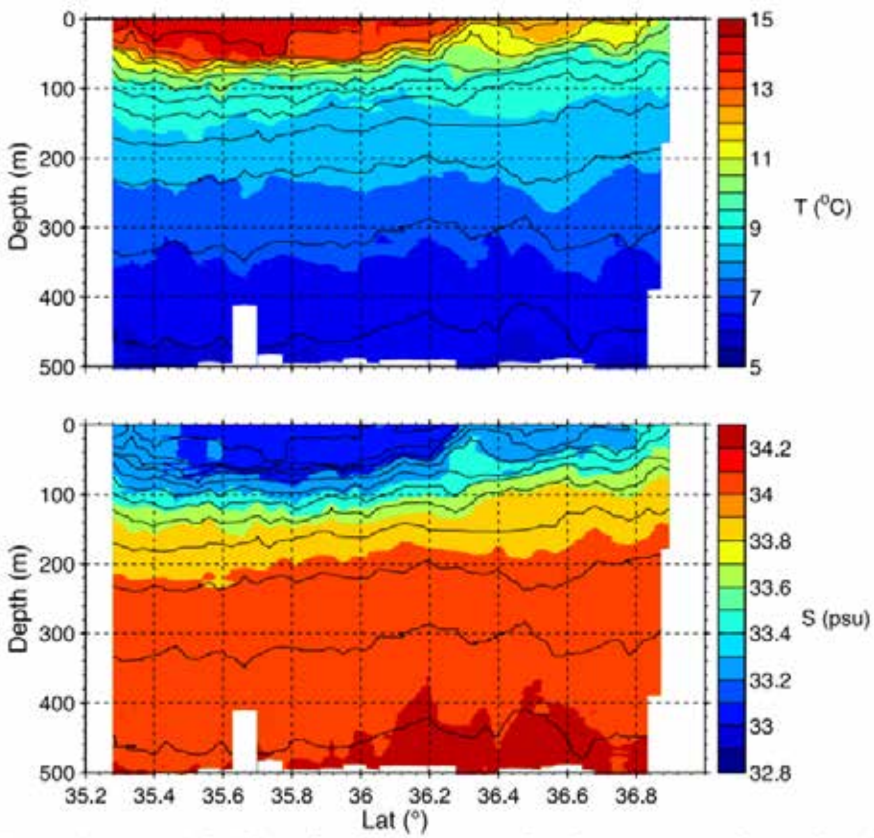
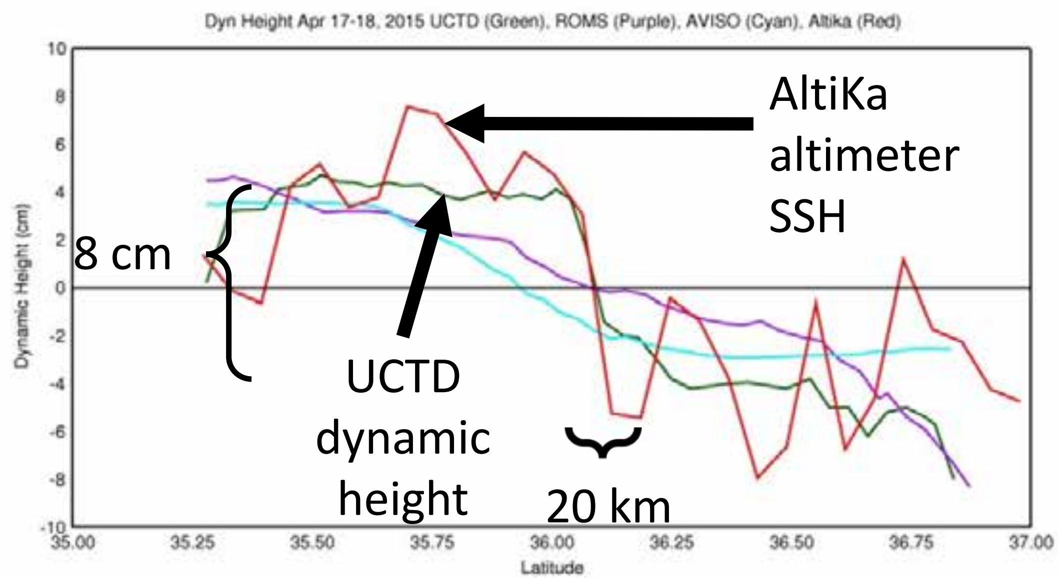


Figure 8: Dynamic height referenced to 400 m (top), temperature (center) and salinity (bottom) for UCTD section 1 (long transect in Fig. 1).



→Long section coincident with AltiKa altimeter pass
→Front has 8 cm SSH change over ~20km– easily observable in SWOT data

Campaign #2: Frontal/submesoscale processes campaign

Submesoscale and small-mesoscale fronts and eddies are not static or long-lived features, and they are rapidly swept around by the larger-scale flow field. This has important implications for a campaign:

a. Features would only remain in a fast-repeat crossover for ~5 days, so this kind of campaign might be better suited to 21-day orbit phase.
b. Features are most easily studied in a reference frame that moves with the features of interest (i.e., using mobile or Lagrangian measurement platforms).
c. Not being tied to the cal/val location, the study region could be in the eastern Atlantic or Mediterranean to encourage European participation.

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c. **Not being tied to the cal/val location, the study region could be in the eastern Atlantic or Mediterranean to encourage European participation.**

Conclusions (1): Summary

Coordinated augmentation of SWOT satellite and cal/val measurements will allow:

1. Better interpretation and use of SWOT data
2. Significant advances on the important science questions that motivated the SWOT mission.

Notional plan meant to stimulate discussion and better ideas :

1. Wavenumber-frequency spectrum campaign aligned with cal/val and SWOT fast-repeat phase
2. Campaign focusing on frontal/submesoscale features, with scientific goals and a study region that encourage European participation

Conclusions (2): Moving forward

The timeline for action is driven by the SWOT launch (Fall 2021).

(1) For fieldwork in Fall 2021/Winter 2022 (SWOT fast-repeat), investigators would need funds by Fall 2020. A proposal for US ship time must be made by August 2019.

(2) NASA's October 2020-September 2021 budget planning begins March 2019.

We need a dedicated workshop this fall (by November 2018) to:

(1) Develop a vision that is of interest to funding agencies in Europe and the US– it must be centered on the science, not SWOT.

(2) Better define the rationale and plan to inform NASA budget planning.

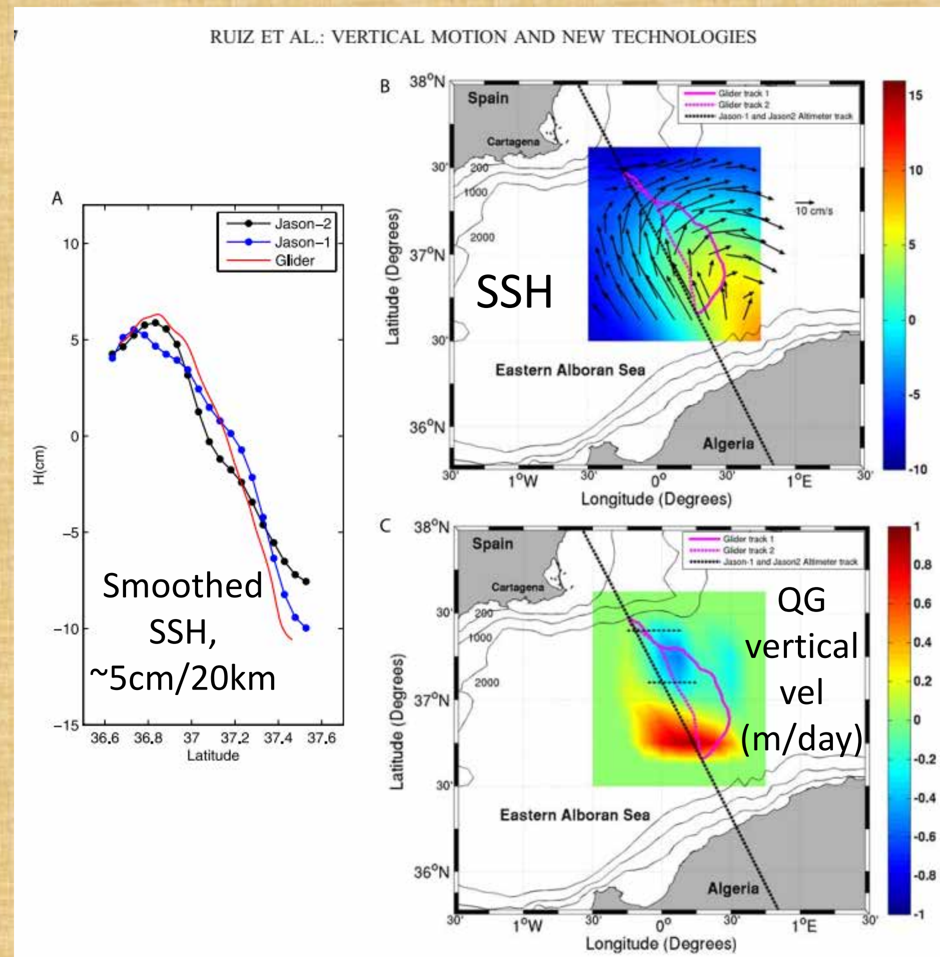
Please let me know if you are interested in participating in the workshop. All aspects of the notional campaigns are open for discussion.

Backup slides

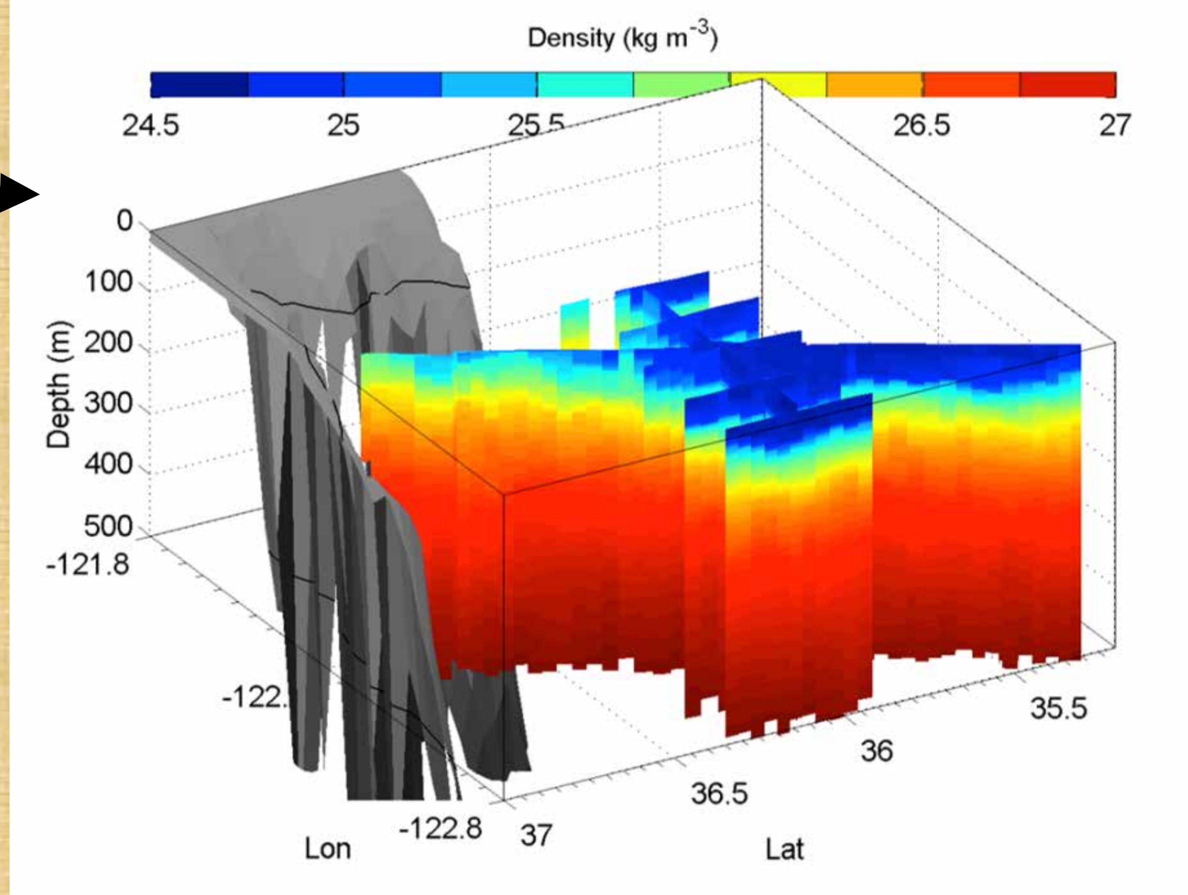
Campaign #2: Frontal/submesoscale processes campaign

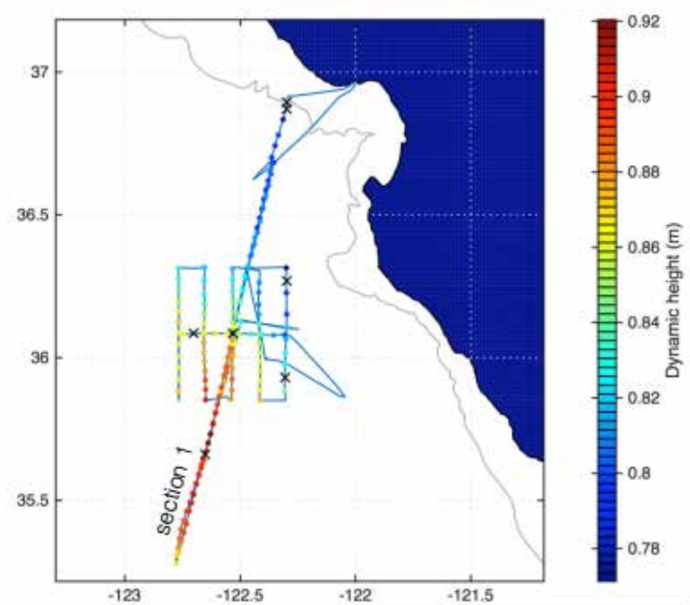
Another "high-signal" environment: Alboran Sea in the Mediterranean

Mediterranean site might facilitate international collaboration



3D view
looking east





UCTD Survey track, April 17-21, 2015