Submesoscale to mesoscale variability in the California Current: Implications for SWOT

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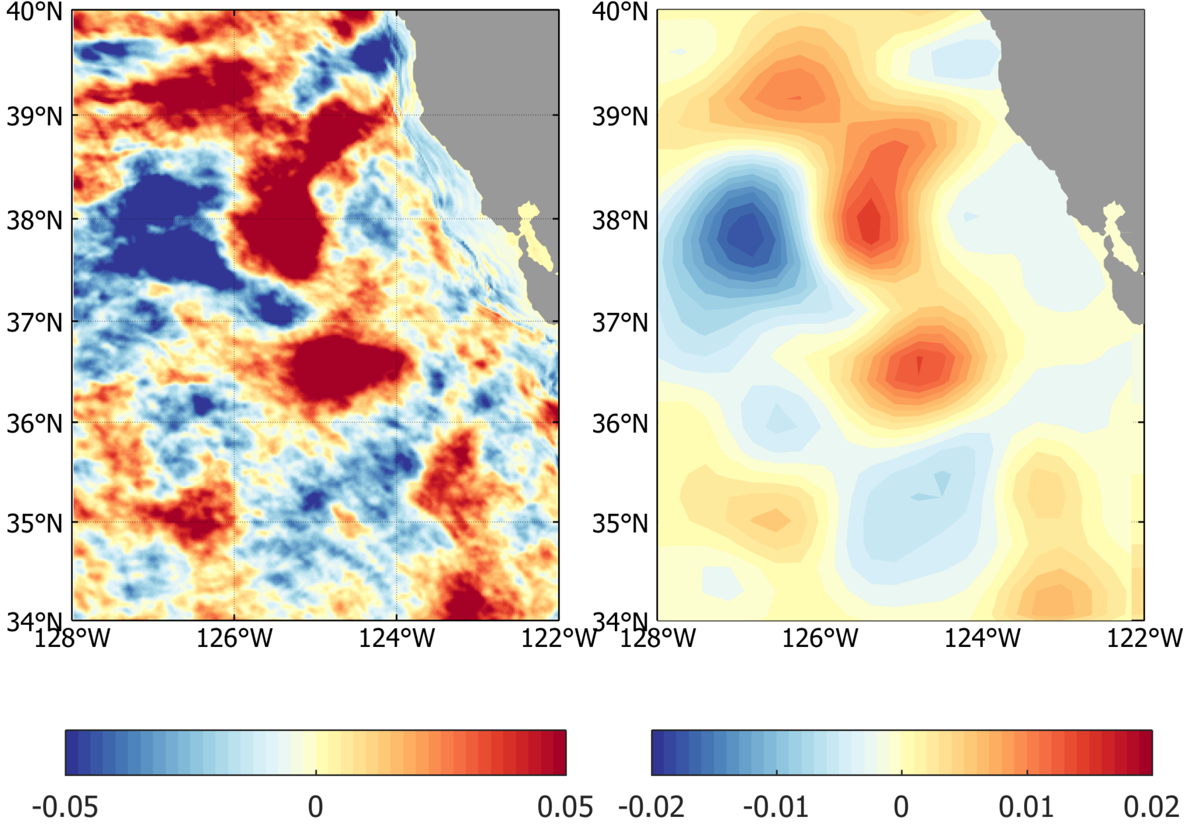
MITgcm 1/48° model

- llc4320 global ocean simulation
- 90 vertical levels
- Atmospheric + tidal forcing
- Run for ~14 months
- Good representation of SWOT-scale variability, but some issues (e.g., internal tides too energetic)

California Current region

- Strong sea surface height variability on SWOT scales
- SWOT cal/val campaign

Motivation: SWOT will allow the full range of mesoscale features to be detected & quantified



SSH snapshot from 1/48° model output (2 Sept 2012)

SSH smoothed to represent gridded AVISO products

SWOT will measure sea surface height (SSH) on ~**15-150 km wavelengths**: this includes the small end of the mesoscale.

Compare to ~150 km wavelength resolution of today's altimeter products such as AVISO.

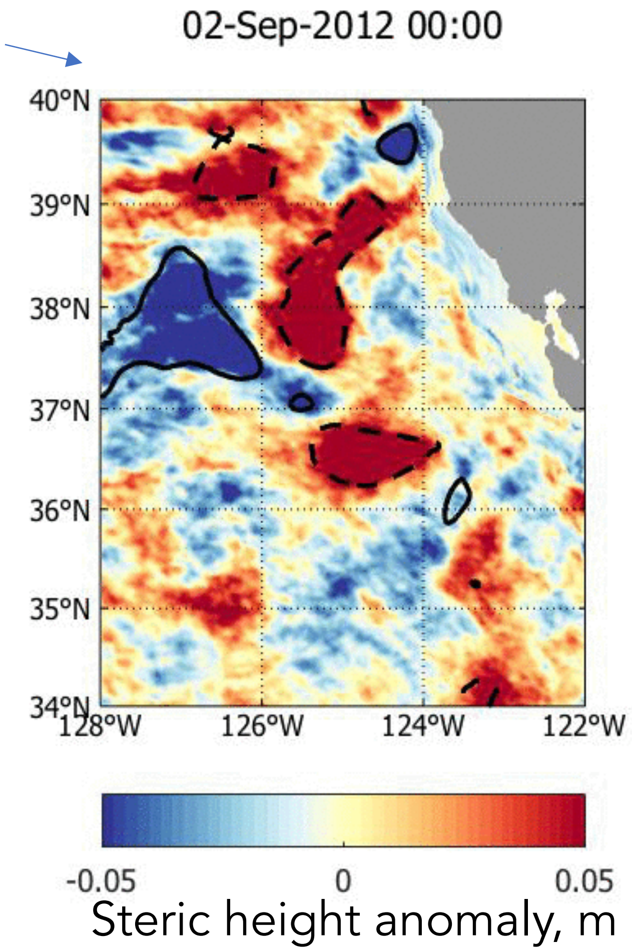
→ SWOT will improve **detection and quantification of small mesoscale features** (in terms of their size, shape, amplitude, location, etc.)

→ Valuable for **quantifying eddy impacts** (e.g., on fluxes, biogeochemistry, air-sea interaction)

Challenge 1: Interpreting SWOT data will require separating the mesoscale from other signals

Steric height from 1/48° MITgcm simulation

Mendocino escarpment: internal tides generated



SWOT measurements will represent:

- mesoscale features
- internal waves & tides
- submesoscale & smaller signals
  (*submesoscale will not be resolved by SWOT)
- noise + errors

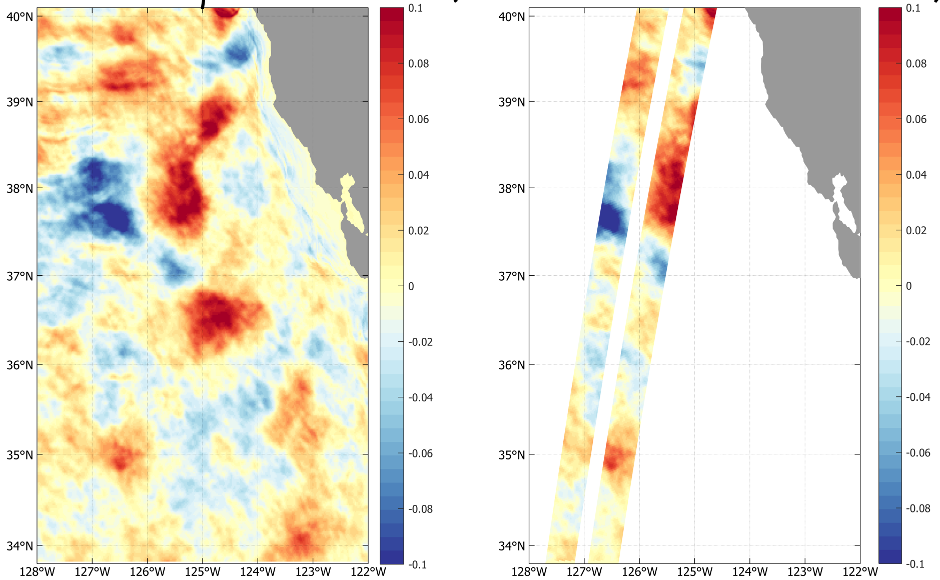
Untangling these signals to extract the mesoscale field will require a priori knowledge of these contributions to sea surface height (SSH).

Challenge 2: SWOT data will represent snapshots in time

- Small mesoscale features evolve faster than the 21-day exact repeat orbit
- SWOT swath width is similar to mesoscale (120 km with 20-km nadir gap)
- Noise + errors may be large.

SSH snapshot: Sept 02, 2012
Mesoscale features are evident

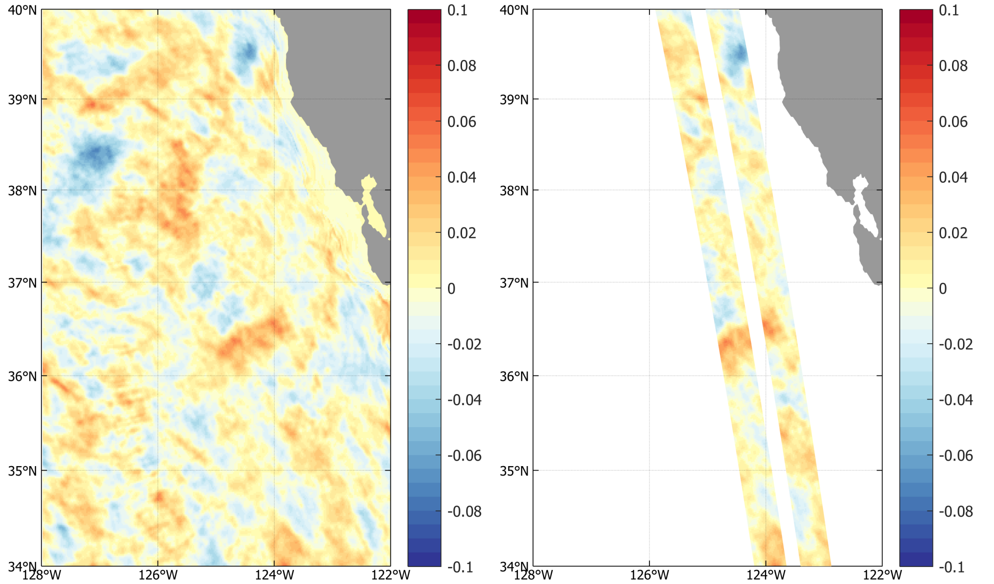
1/48° model output *Model sampled like SWOT (no noise/errors added)*



Steric height anomaly, m

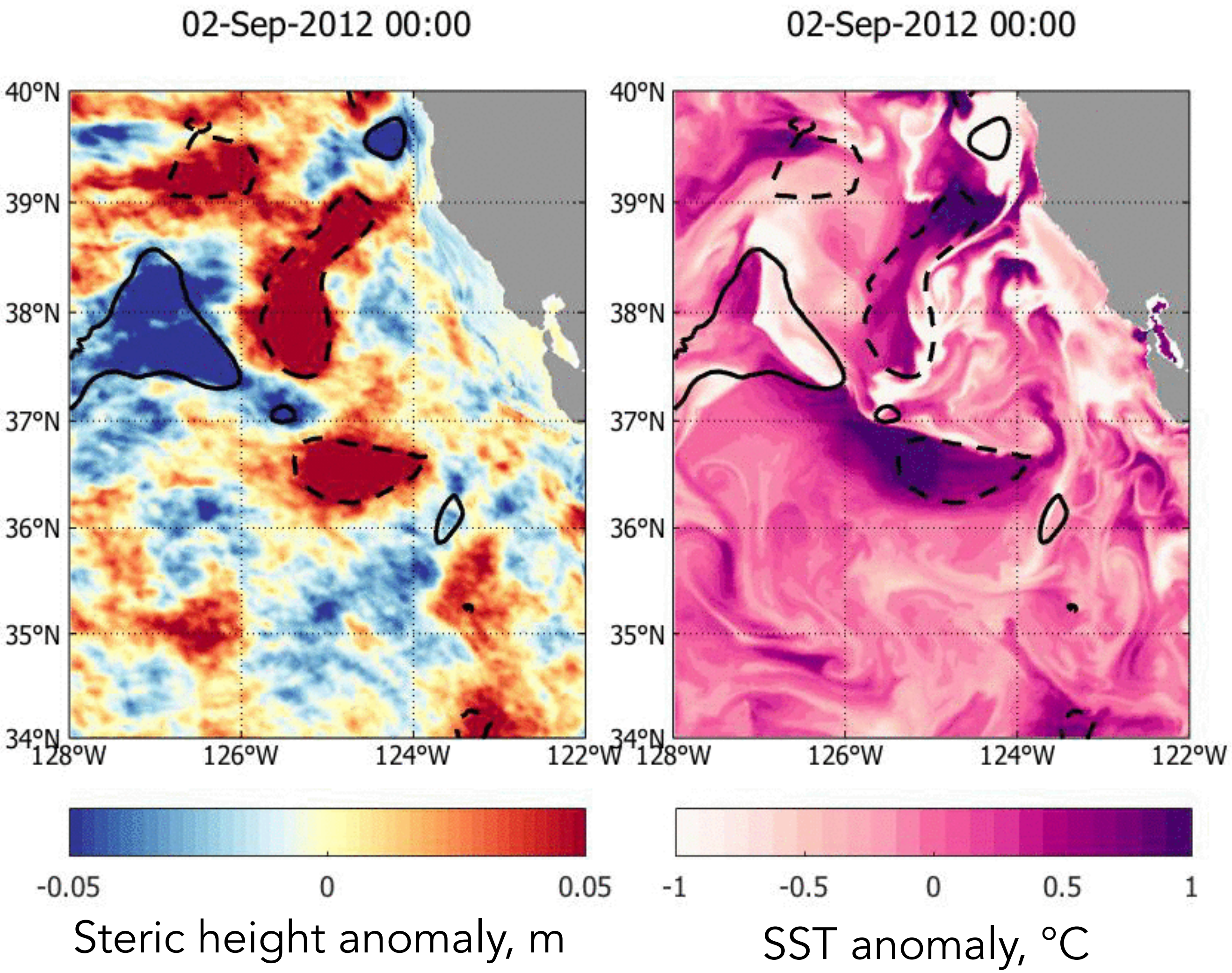
SSH snapshot: Sept 11, 2012:
Mesoscale indistinguishable from internal waves

1/48° model output *Model sampled like SWOT (no noise/errors added)*



Steric height anomaly, m

Opportunity: surface tracer variance can potentially be used to identify mesoscale features



Internal waves don’t have a signal in surface tracers.

Submesoscale tracer variability (1-10 km scales) is often strong at the edge of mesoscale features.

→ Surface tracer fields may be useful for identifying mesoscale features (e.g., fronts, eddies)

Objective: explore ways to extract mesoscale features from SWOT using what we know about variability on other scales

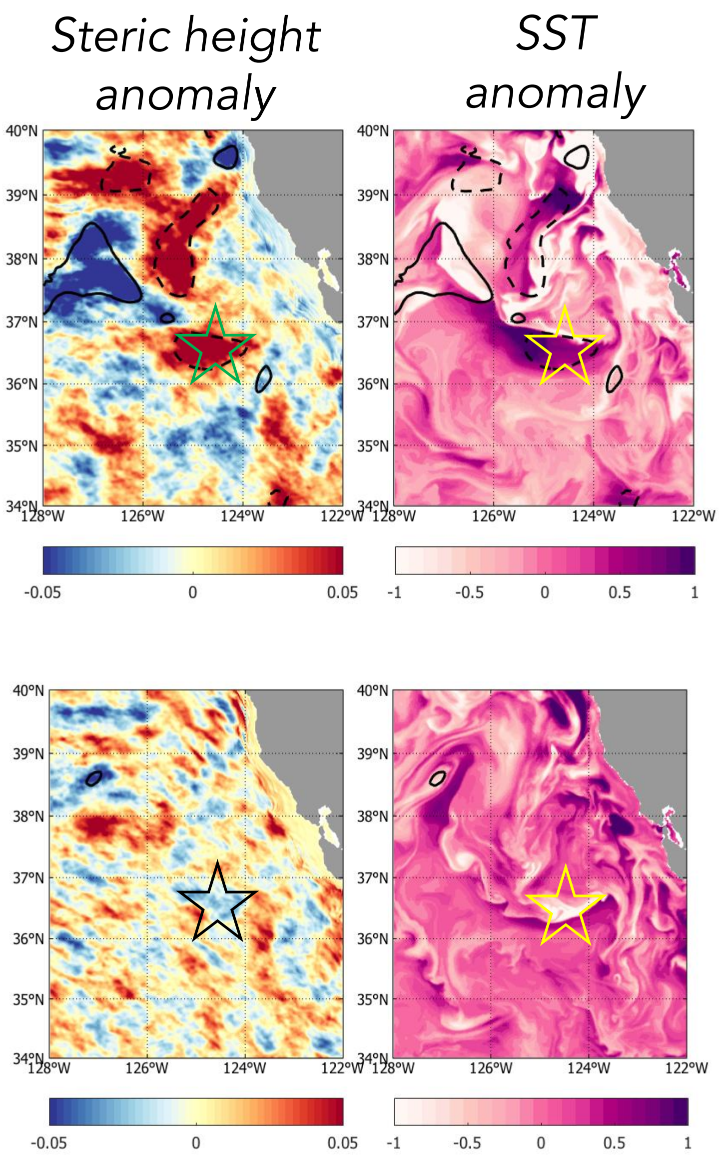
1) Quantify the contribution of **internal waves & tides, mesoscale features, and submesoscale signals** to SSH variability

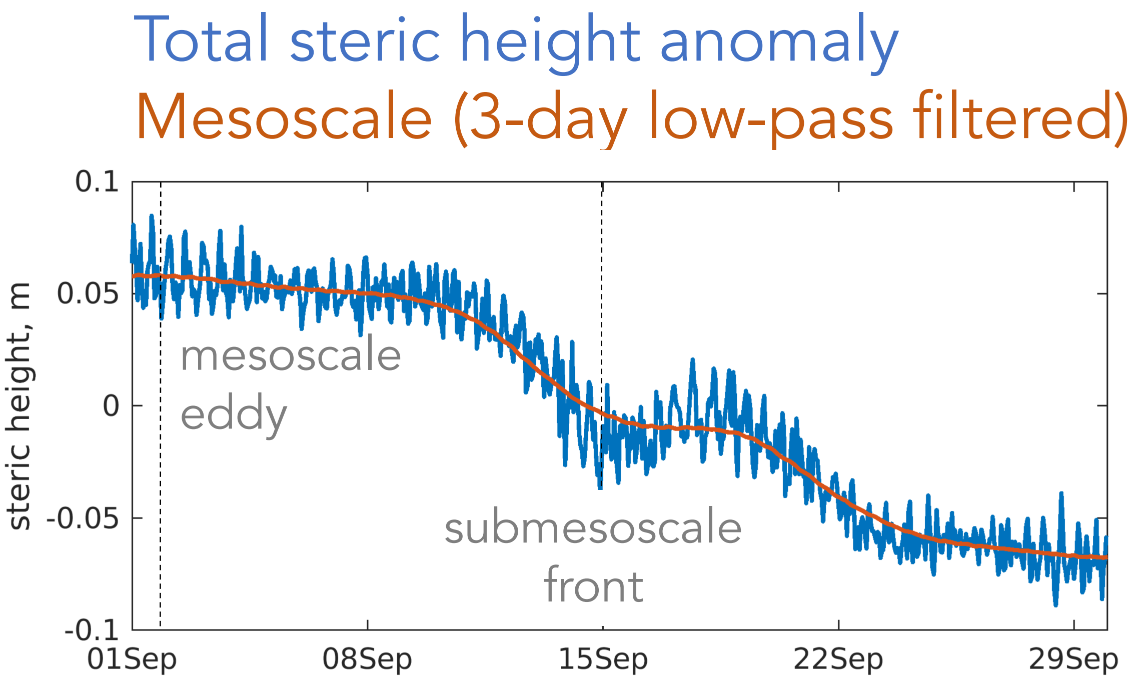
2) Explore the use of **sea surface temperature** (SST) to help extract mesoscale features from SWOT

Example: steric height at 36.4°N, 124.4°W during September 2012

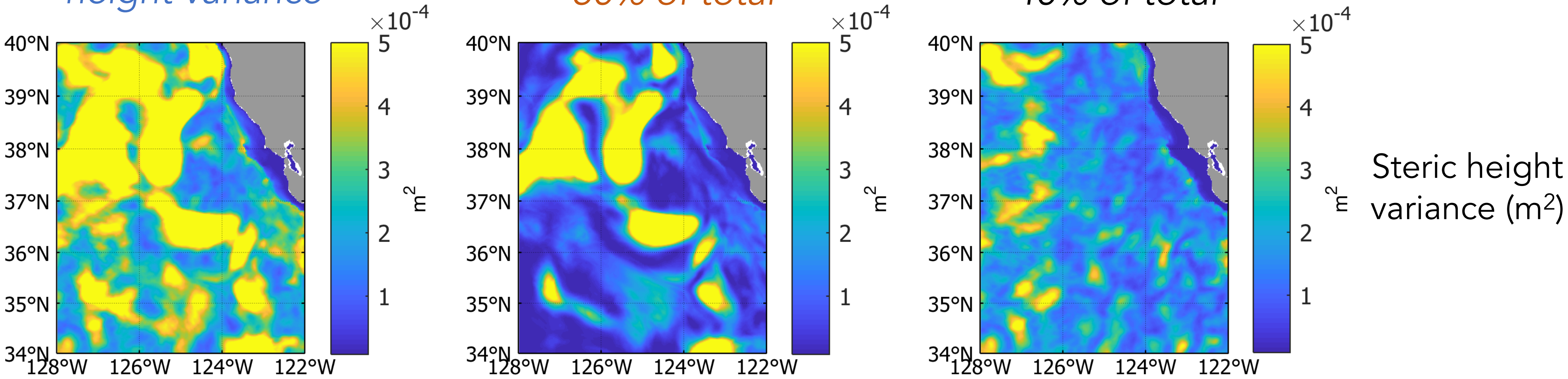
Sept 2:
mesoscale
eddy

Sept 15:
submesoscale
front





Steric height variance computed over 1 month (Sept 2012) within the California Current


Total steric height variance

Mesoscale SH variance: 60% of total

High-frequency SH var.: 40% of total

Steric height variance (m^2)

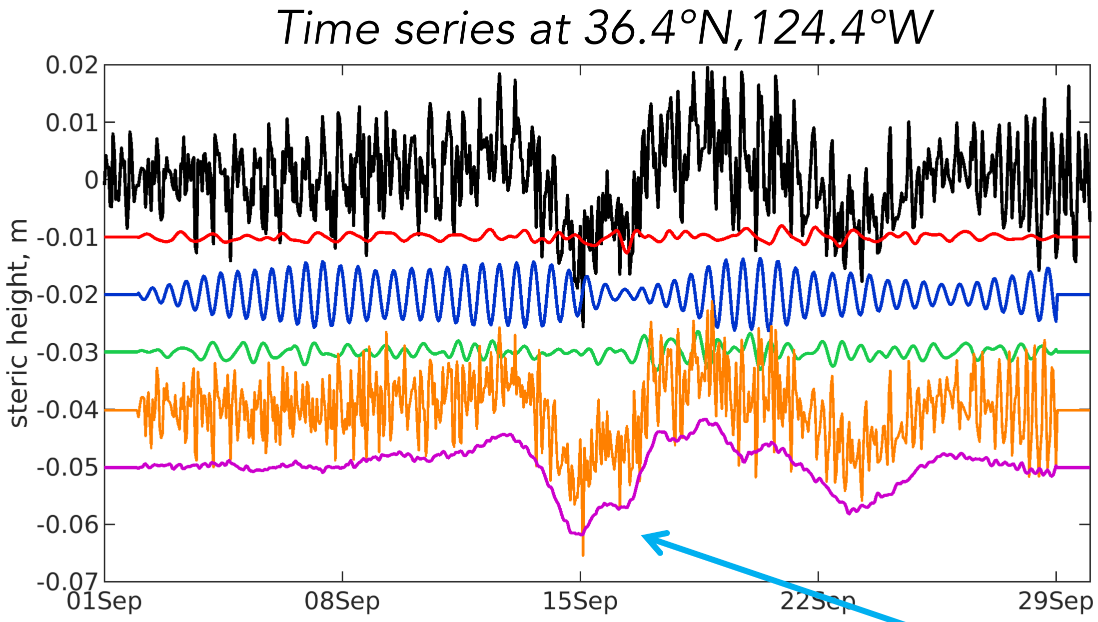
In the California Current, mesoscale variability generates ~60% of the SSH variance.

In winter, mesoscale is 55% of SH variance, high-frequency is 45% (not shown).

What high-frequency signals generate the other 40%?

Components of the high-frequency steric height signal

Obtained by fitting internal tide components over 3-day windows



High-frequency*

Diurnal (1%)

Semidiurnal (17%)

Inertial (2%)

Internal tide (20%)

Residual (80%): internal gravity waves + submesoscale + errors on fit

Sub-inertial residual** (30%) ≈ submesoscale

Around mesoscale eddies, submesoscale SSH variance can be as large as the internal tide signal.

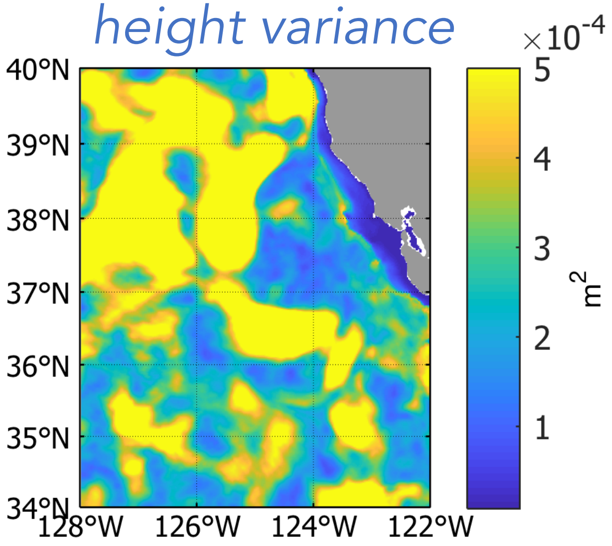
Internal tide

$$\text{* High-frequency} = \underbrace{\text{diurnal} + \text{semidiurnal} + \text{inertial}}_{\text{Internal tide}} + \text{residual}$$

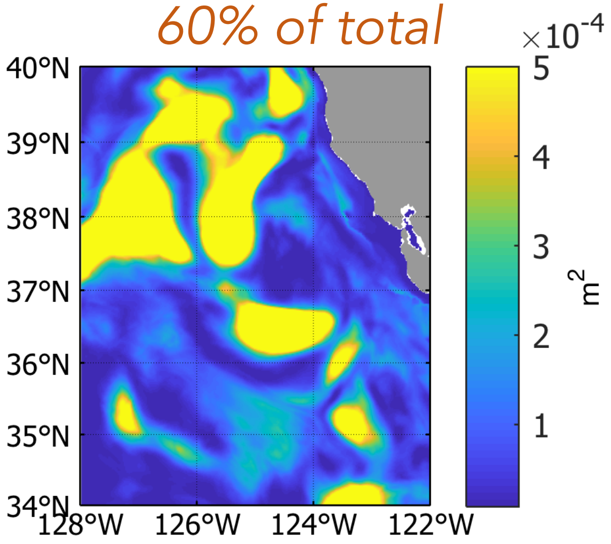
** Sub-inertial residual = filtered for frequencies lower than inertial

Steric height variance computed over 1 month (Sept 2012) within the California Current

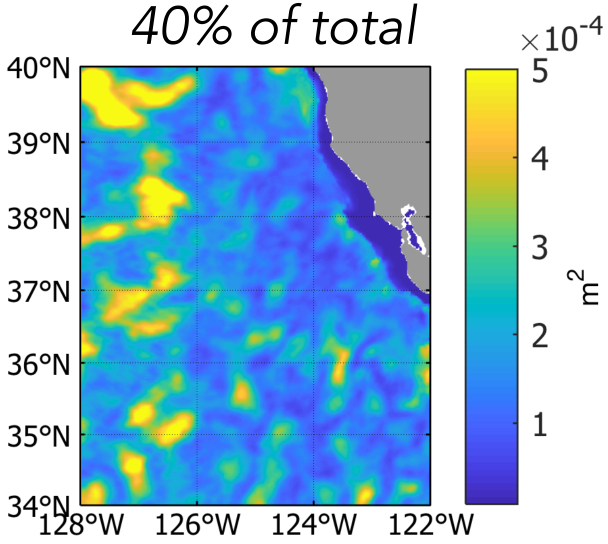
Total steric height variance



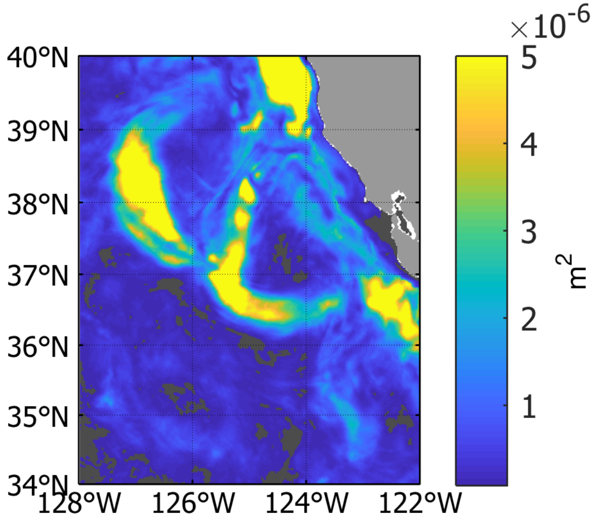
Mesoscale SH variance: 60% of total



High-frequency SH var.: 40% of total



Submesoscale (sub-inertial residual) SH variance: <1% of total

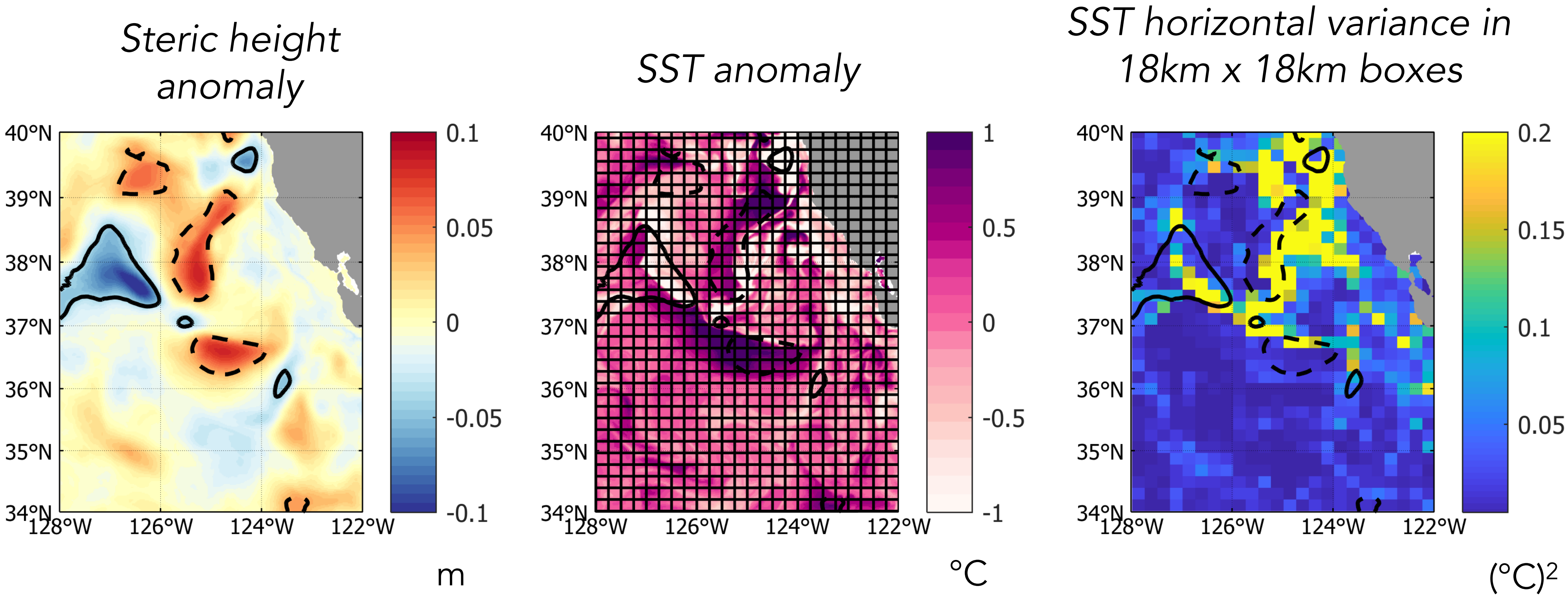


Submesoscale SSH variance is negligible on average, but has a strong correlation with the mesoscale.

→ Submesoscale information can help us identify mesoscale features.

Horizontal SST variance as a proxy for submesoscale variability?

Snapshots from Sept 2:


Steric height anomaly

SST anomaly

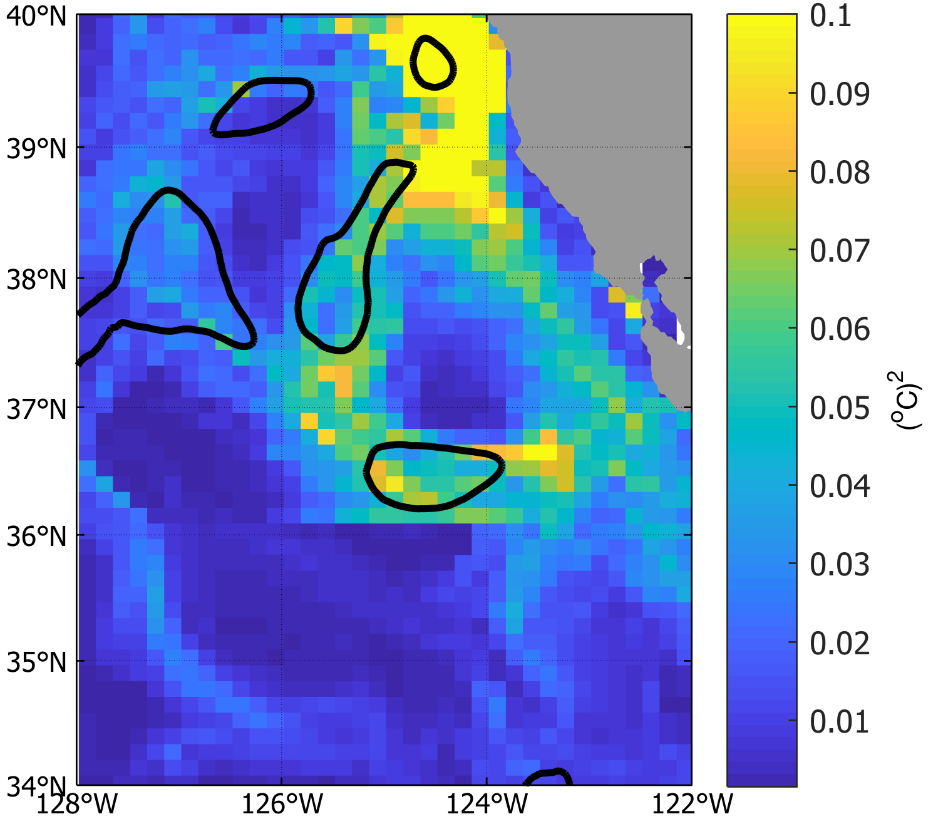
SST horizontal variance in 18km x 18km boxes

Something like this could be estimated from satellite SST (in clear skies)

Horizontal SST variance can be used to identify mesoscale features that are associated with strong submesoscale variability

Colors: Mean horizontal SST variance

Contours: mesoscale SH variance



SST variance ($°C^2$)

Satellite SST will be valuable for identifying mesoscale features in SWOT data.

Requires cloud-free conditions, when infrared SST measurements with ~1-10 km resolution are possible.

Summary

In the California Current region, **mesoscale features generate ~60% of the SSH variance**, in both summer/winter.

The rest of the signal is mostly internal waves and tides.

On average, **submesoscale SSH makes a negligible contribution** to total SSH variance

But at the edge of mesoscale features, it can be as strong as the internal tide contribution: *we might use this to our advantage, to identify likely submesoscale hotspots from SWOT data.*

High-resolution SST variability, observable from satellites, could help us identify mesoscale features in SWOT data.

SST variance strong around eddies but not internal waves.