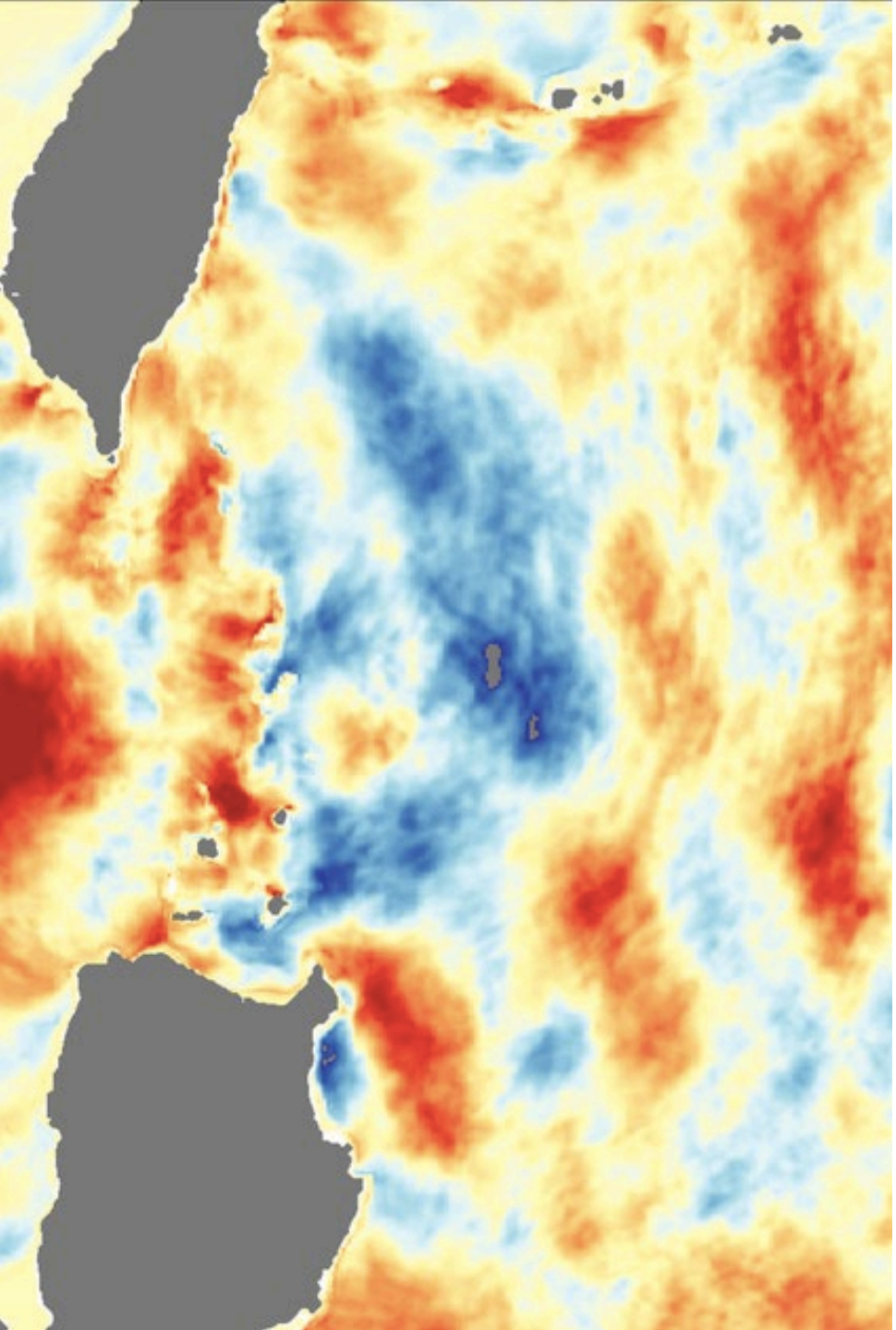


# Exploiting ocean observations to separate mesoscale and submesoscale variability

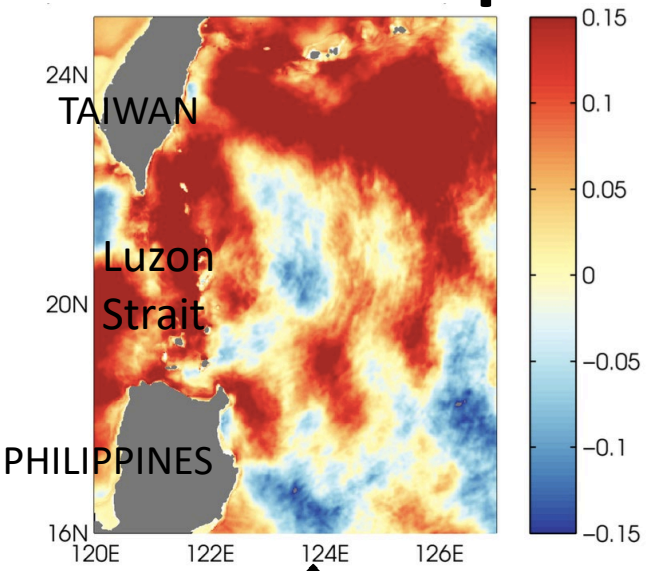
Kyla Drushka, Luc Rainville
*Applied Physics Laboratory, University of Washington.*

Dimitris Menemenlis
*Jet Propulsion Laboratory*

**Objective**: Develop tools to separate the internal wave signal from SWOT observations.

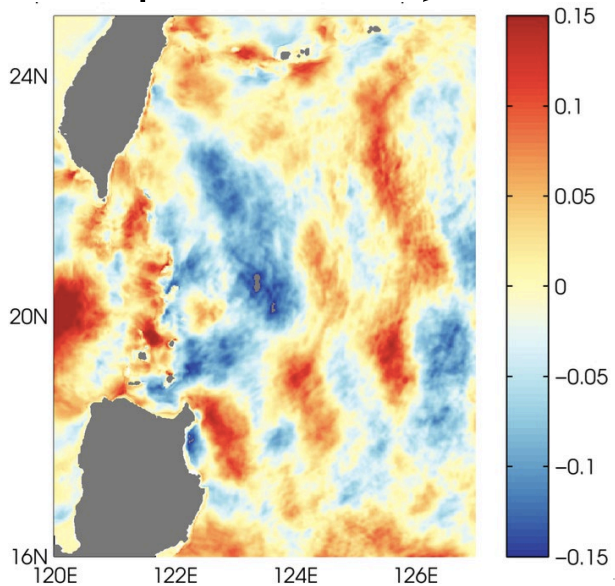
**Approach**: Exploit historical Seaglider data and a high-resolution model to characterize (sub)mesoscale ocean variability.

# What makes up the steric height signal?

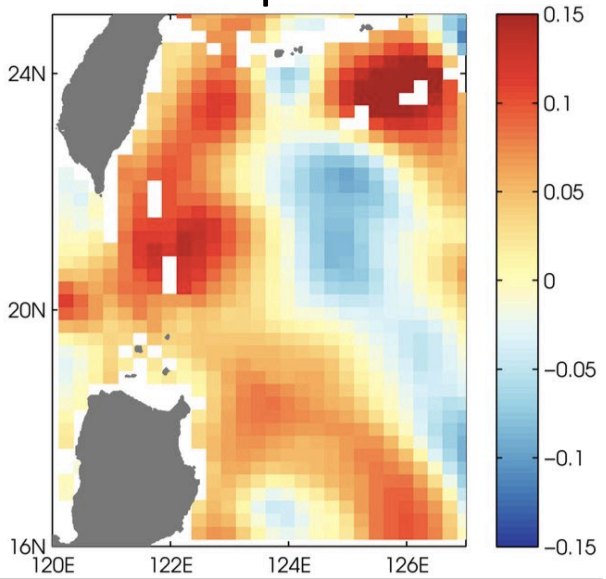



Snapshot of total steric height (m)

High-frequency component



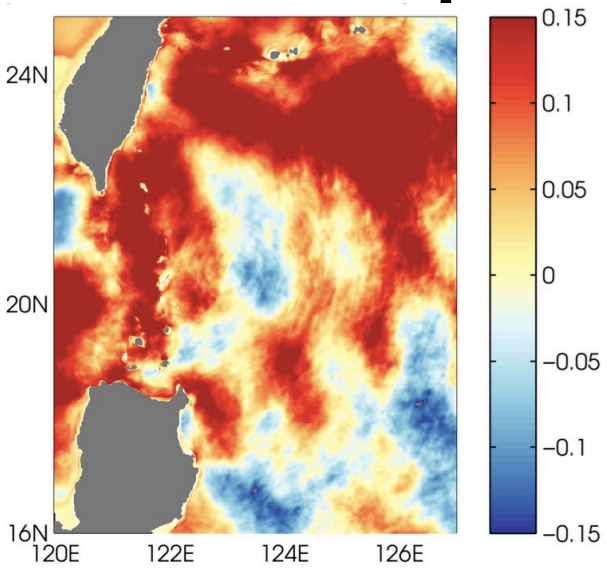

Mesoscale component




## MITgcm model

- LLC4320 simulation
- ECMWF surface boundary conditions
- 2.2 km horizontal resolution at equator
- 90 vertical levels
- Hourly outputs
- >1 year of output available (so far)
- Includes tides
- Not data constrained

# What makes up the steric height signal?

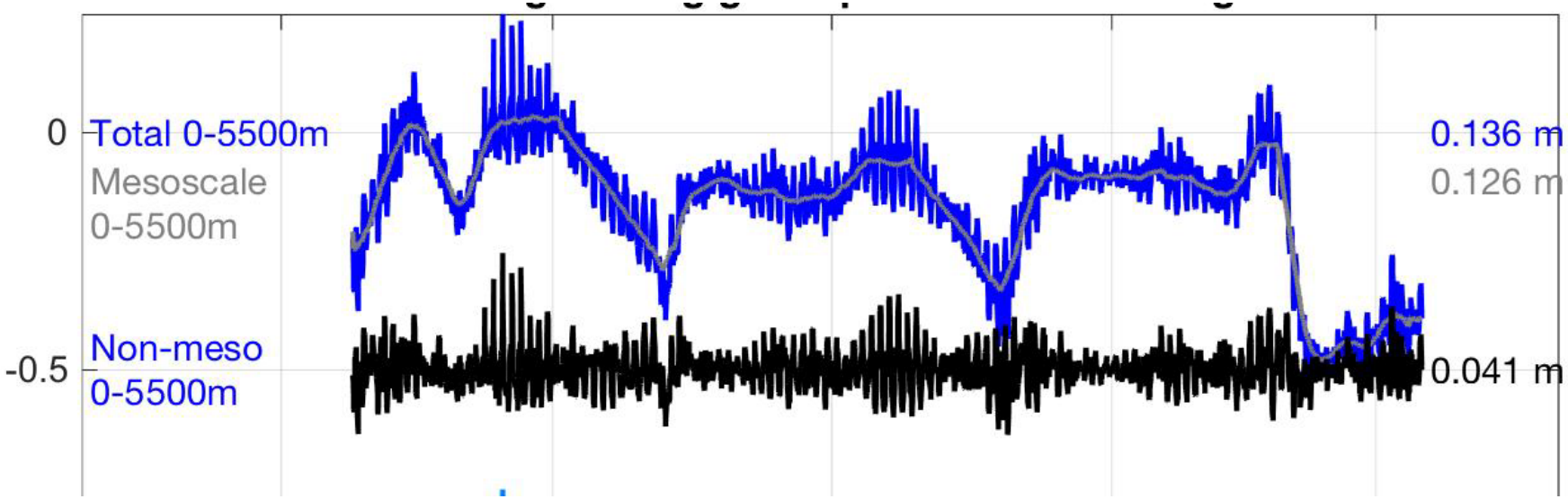



Snapshot of total steric height (m)

Total steric height (rms: 14 cm)

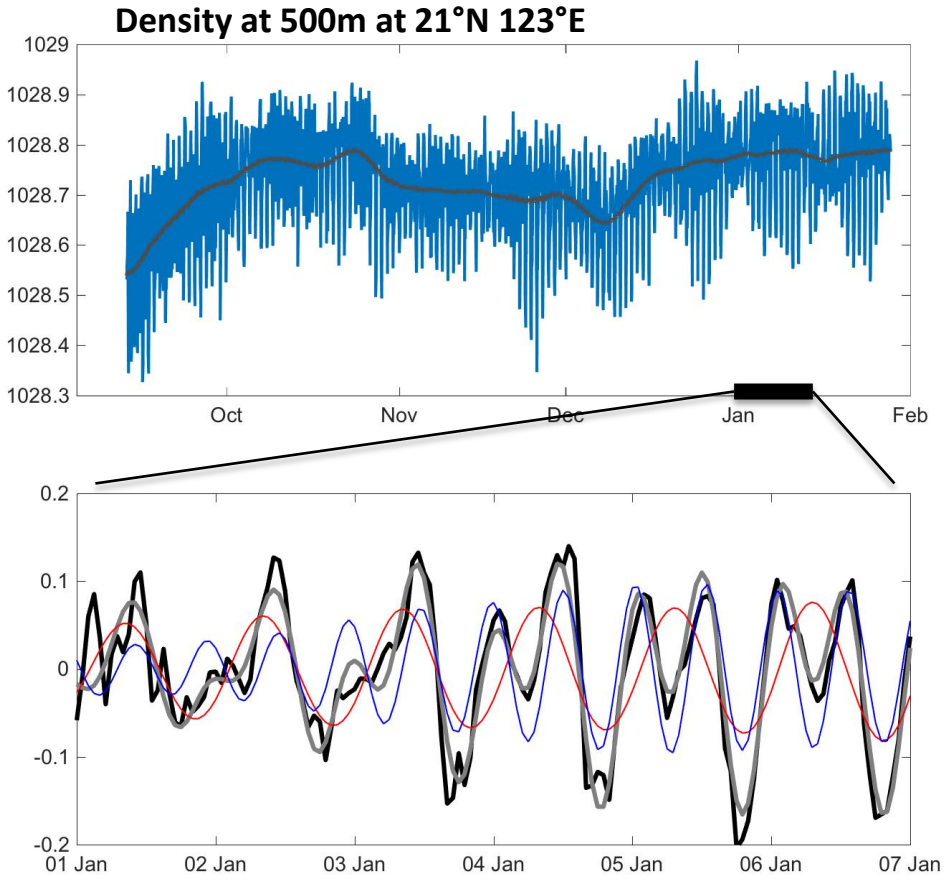
13 cm mesoscale,

4 cm high-frequencies



# What makes up the steric height signal?

Processes responsible for the steric height:




**Density time series at 500m**

**Mesoscale contribution**

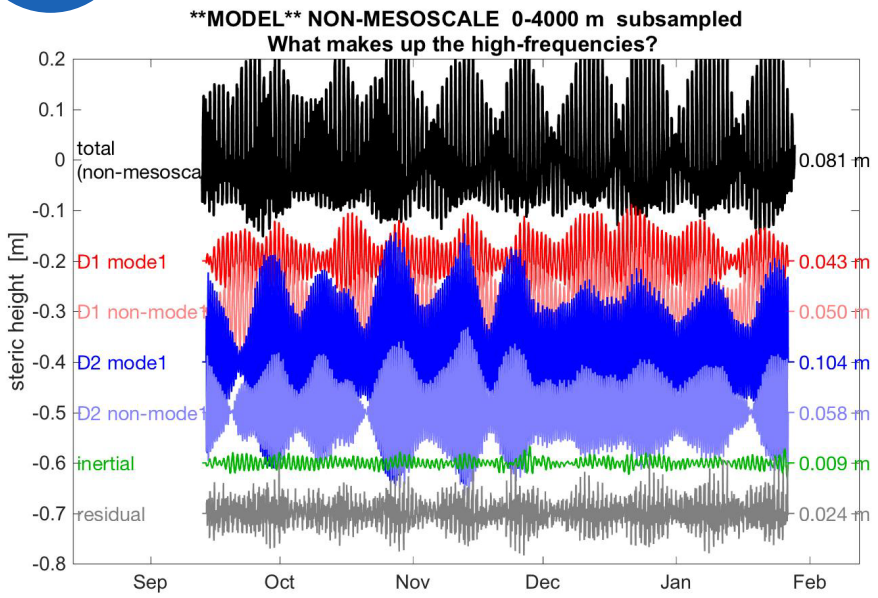
**High-frequencies** = all – mesoscale

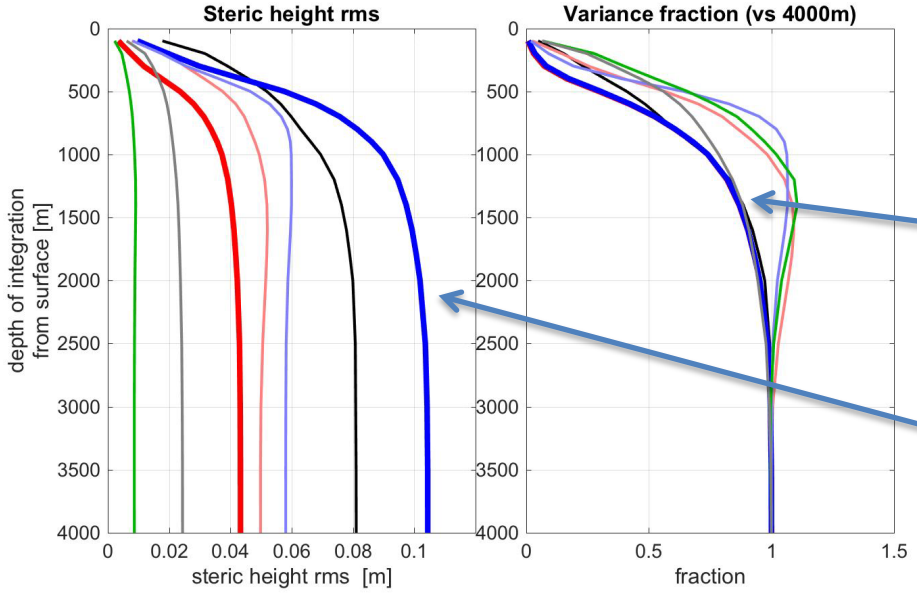
*Over a small time window (3 days), fit known frequencies:*

Semidiurnal + diurnal

*We can also fit all isopycnals together, using known vertical mode structures.*

# What makes up the steric height signal?




**21°N 123°E**

Non-mesoscale steric height (rms: 8.1 cm)

| | |
|---|---|
| Diurnal, mode 1 | (4.3 cm) |
| Diurnal, non-mode1 | (5.0 cm) |
| Semidiurnal, mode 1 | (10.4 cm) |
| Semidiurnal, non-mode1 | (5.8 cm) |
| Inertial motions | (0.9 cm) |
| Residual | (2.4 cm) |

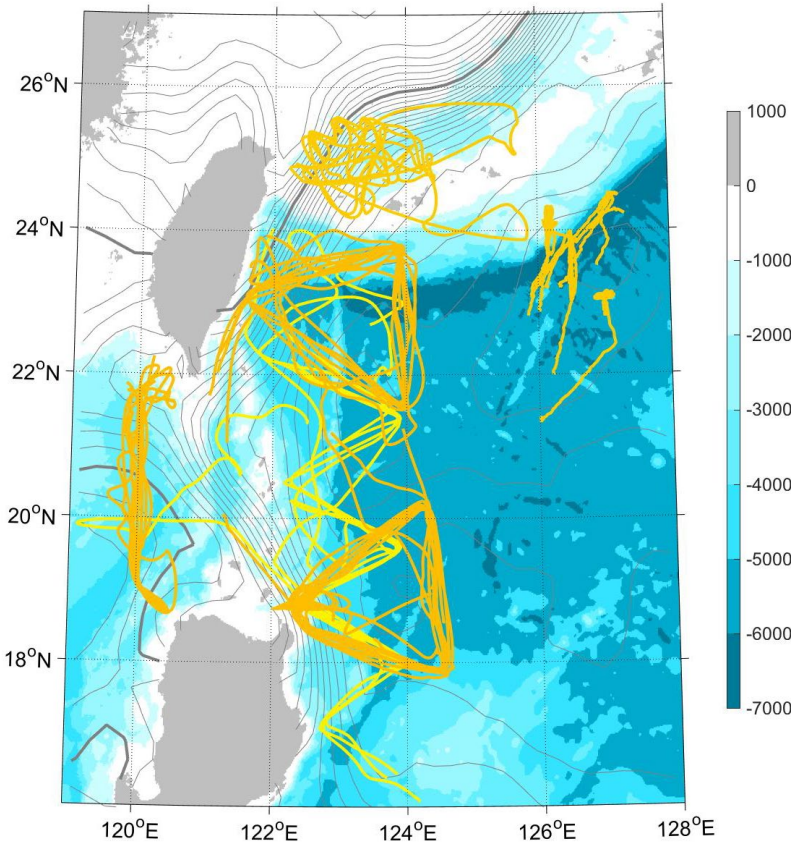
Where in the water column does the steric height come from?

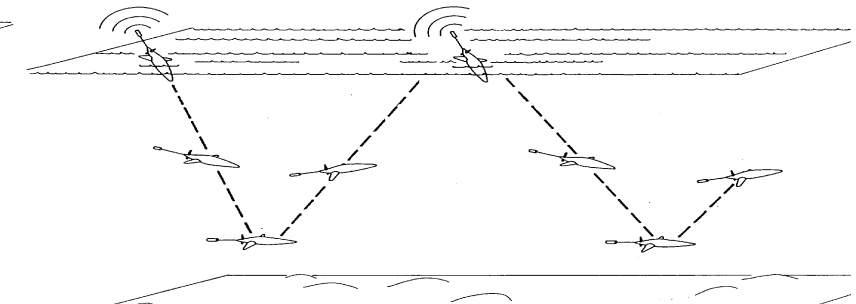
Most of steric height signal comes from the top 1000 m

Destructive interference causes semidiurnal > total

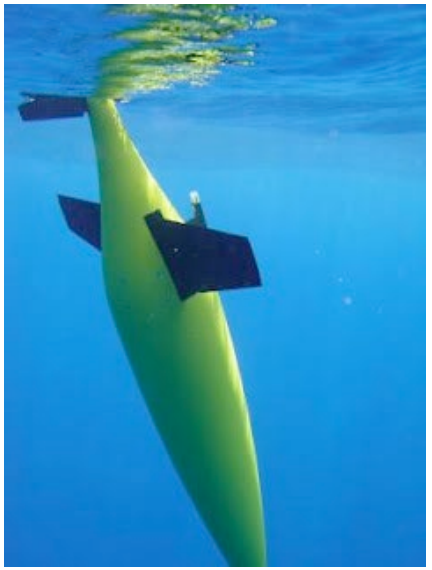
# Does the model get it right?

## Kuroshio 2007, ITOP 2010, OKMC 2012-2013



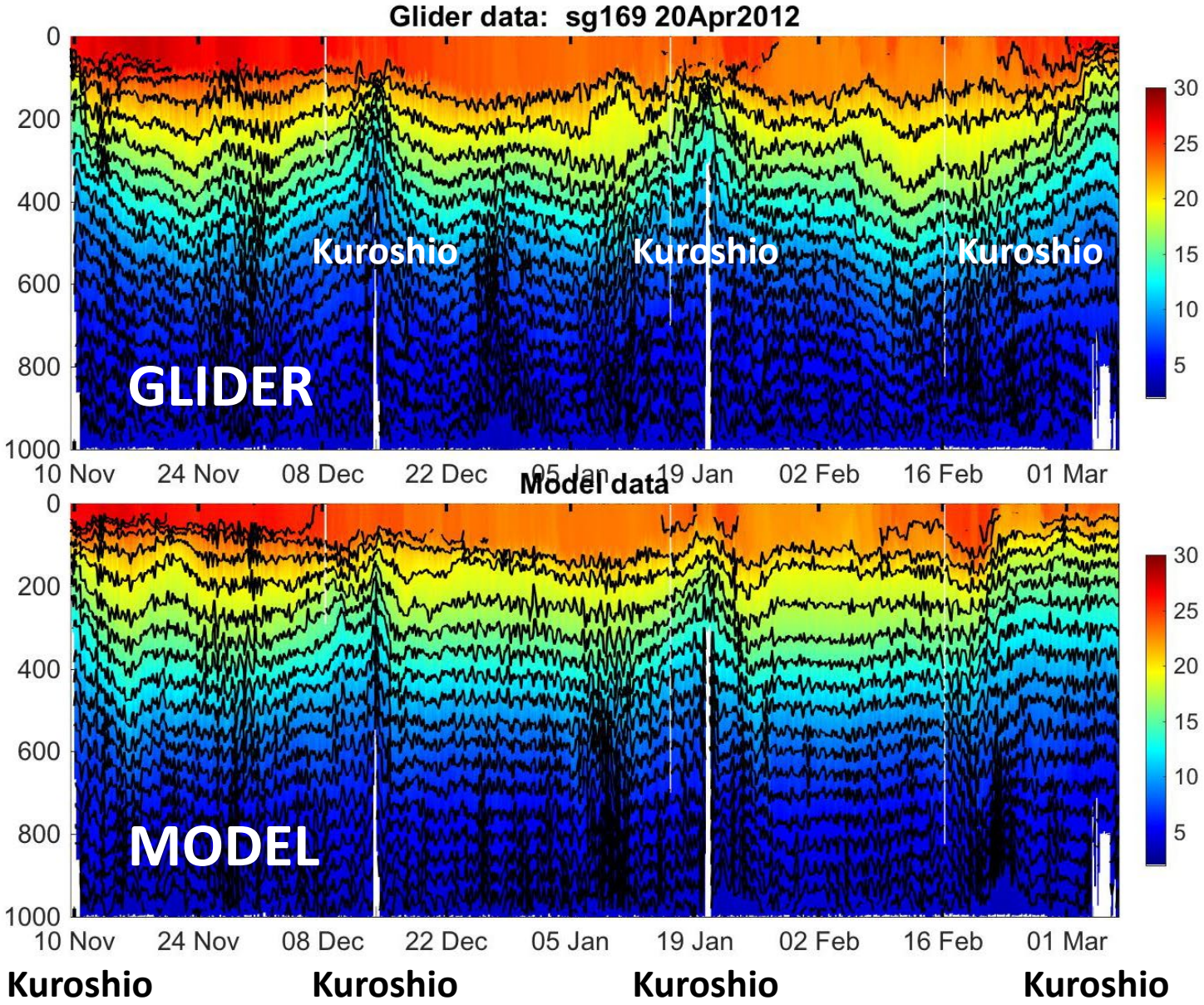
*Sampling the Kuroshio and understanding the circulation around Taiwan.*

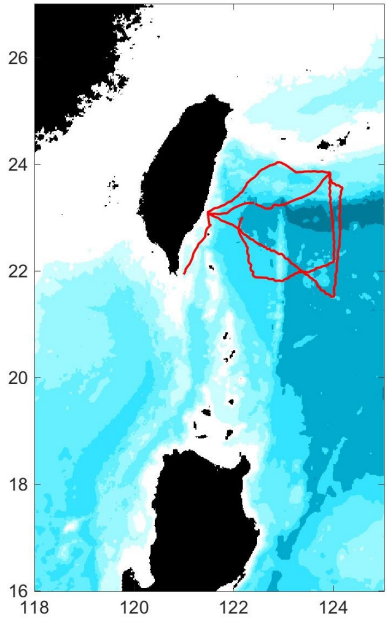


**Seaglider**

- profiles to 1000m 3-4 times / day
- real time data transmission
- travels 20 km / day
- 6-9 month deployments
- adaptive sampling

# Does the model get it right?

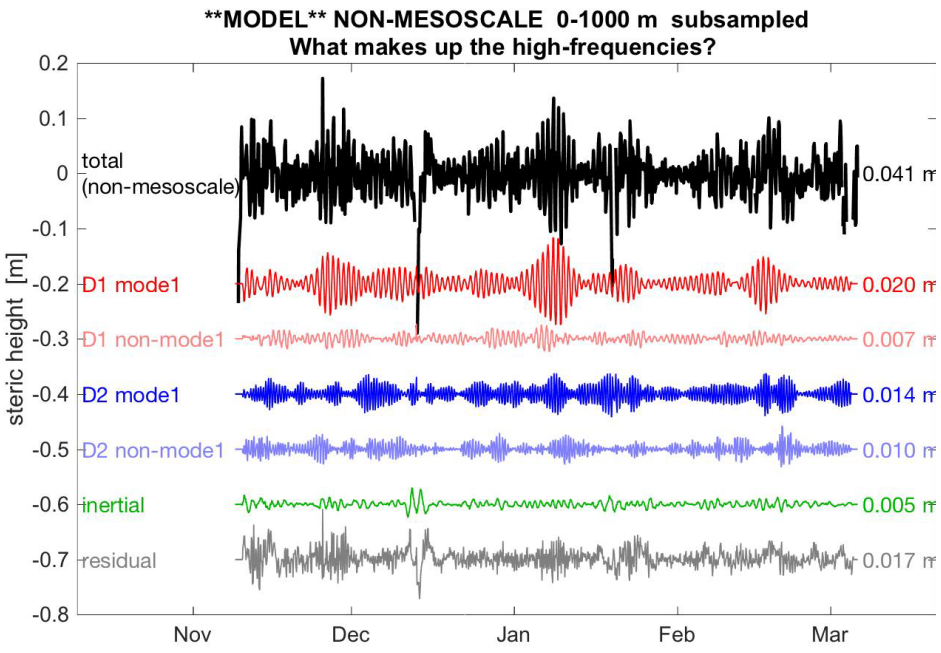


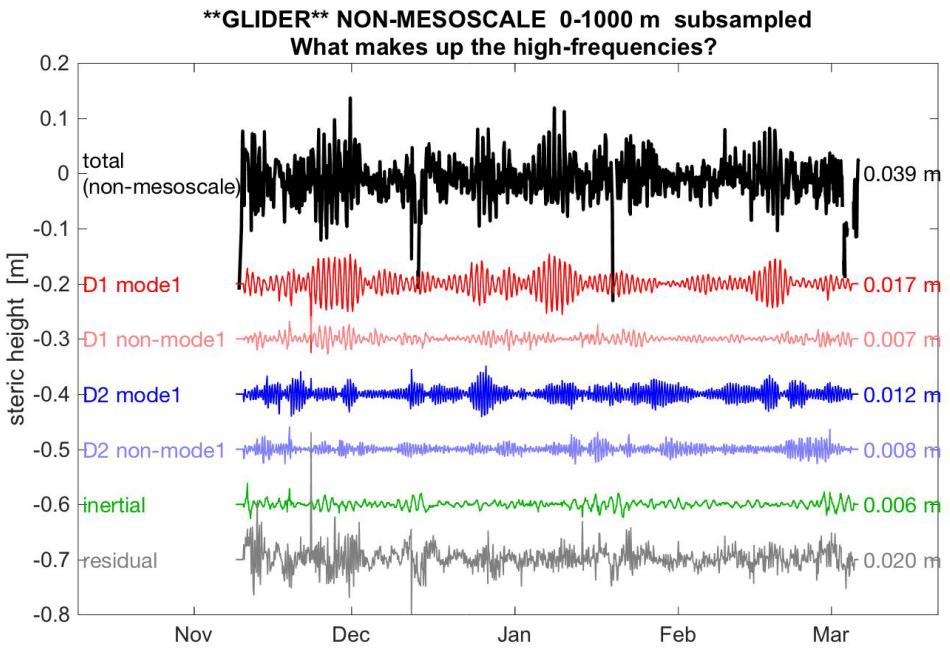




Temperature, °C

# Does the model get it right?

*Model subsampled like a glider…*




## MODEL

Non-mesoscale steric height (4.1 cm)

- Diurnal, mode 1 (2.0 cm)
- Diurnal, non-mode1 (0.7 cm)
- Semidiurnal, mode 1 (1.4 cm)
- Semidiurnal, non-mode1 (1.0 cm)
- Inertial motions (0.5 cm)
- Residual (1.7 cm)

## GLIDER

Non-mesoscale steric height (3.9 cm)

- Diurnal, mode 1 (1.7 cm)
- Diurnal, non-mode1 (0.7 cm)
- Semidiurnal, mode 1 (1.2 cm)
- Semidiurnal, non-mode1 (0.8 cm)
- Inertial motions (0.6 cm)
- Residual (2.0 cm)

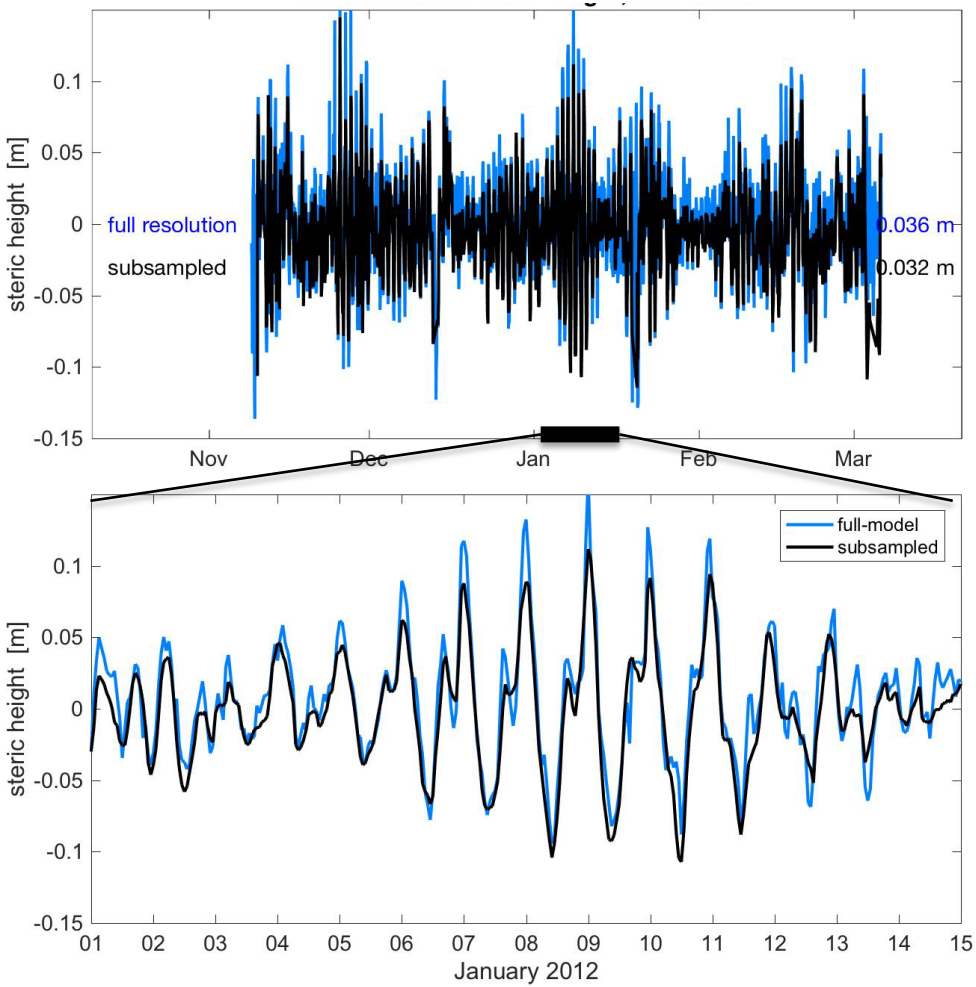
# Does a glider-type sampling work?

**YES!**

Subsampling (like a virtual glider) still captures most of the variance and important processes …

**Non-mesoscale, full res.: 3.6 cm**

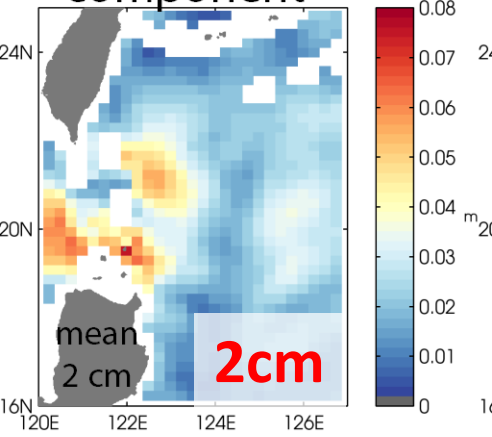
**Non-mesoscale, subsampled: 3.2 cm**



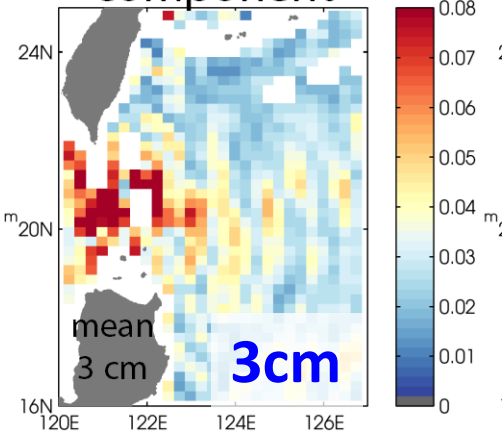

*and we can recover the full-depth, full time resolution steric height from the subsampled data, extrapolating mesoscale and mode 1.*

# Spatial maps (model)

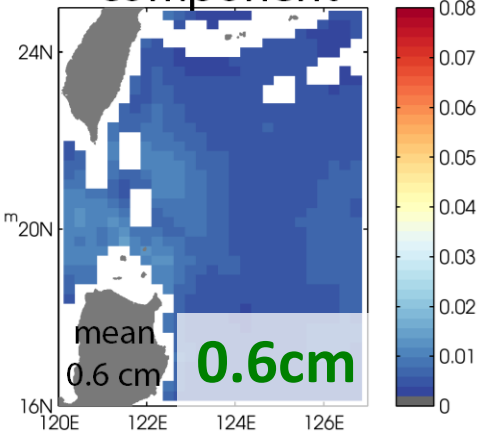
Diurnal SH component



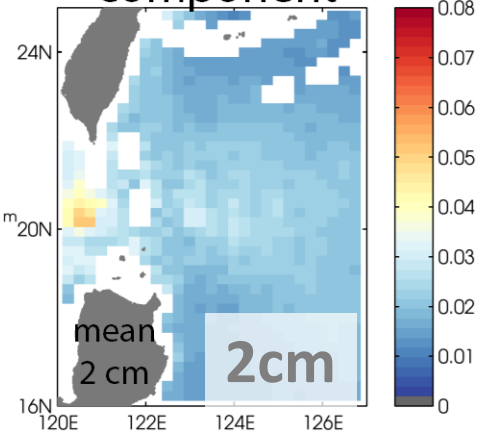

Semidiurnal SH component




Inertial SH component



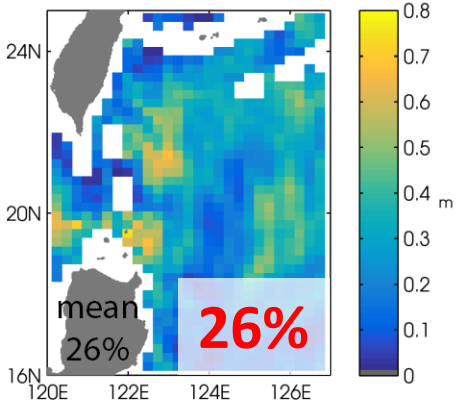

Residual SH component



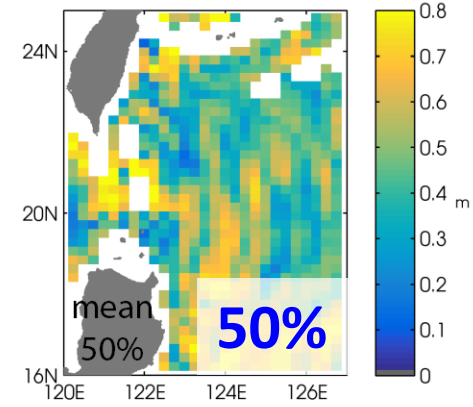

## Fraction of high-frequency SH variance:

(*note dif erent scales)

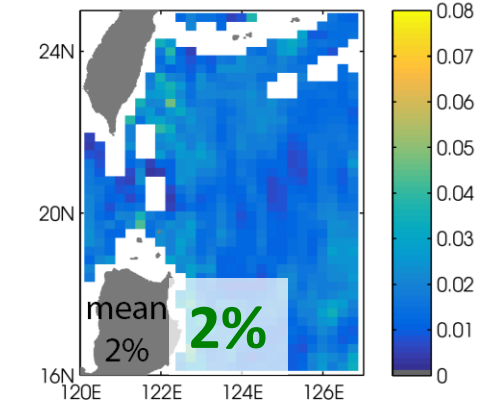
Diurnal



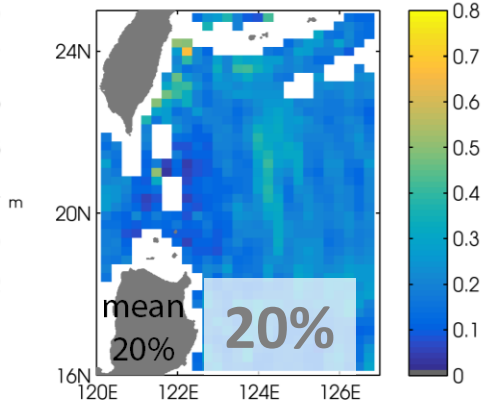

Semidiurnal



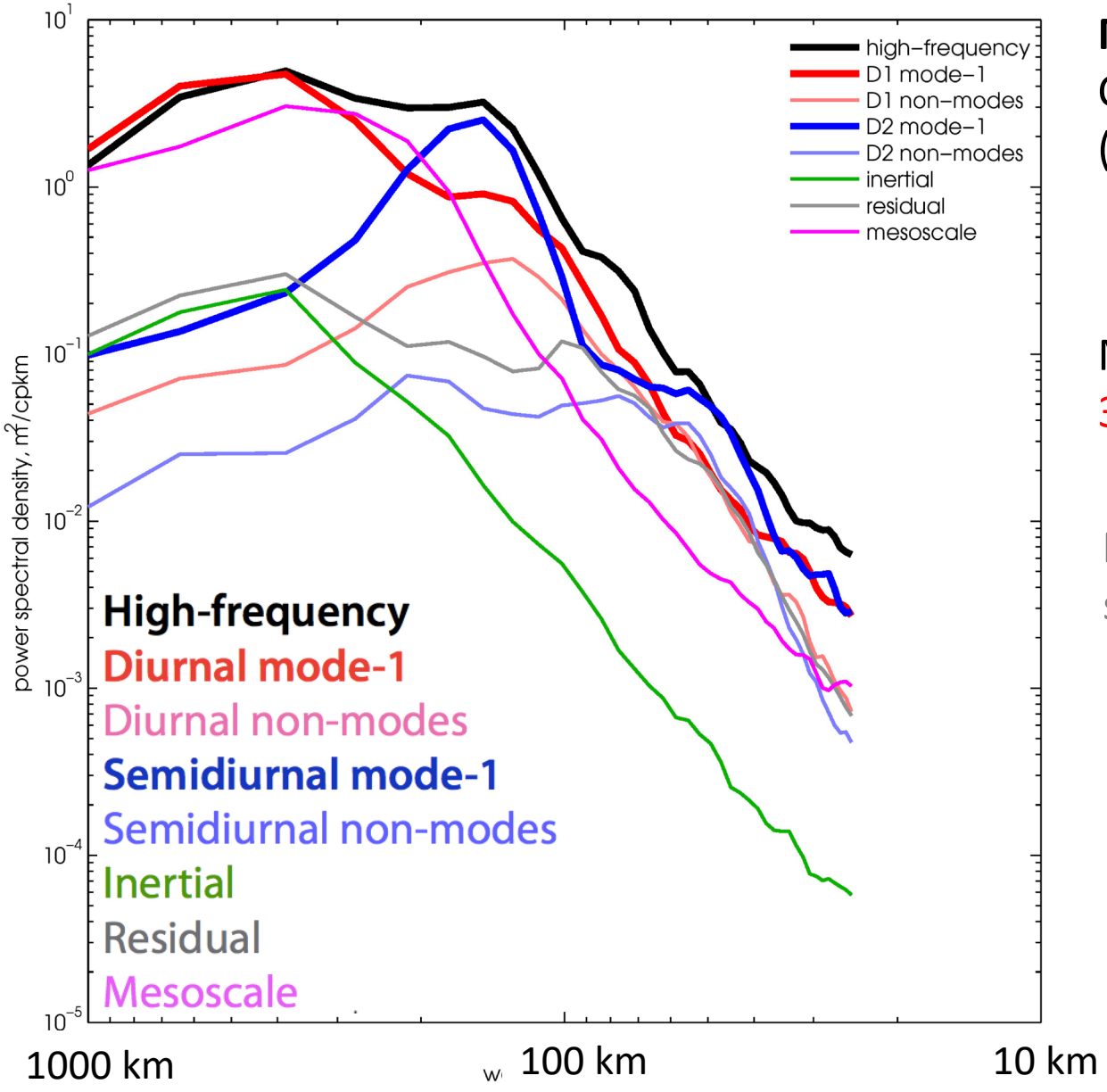

Inertial




Residual



# Wavenumber spectra




**MODEL, Luzon Strait**
Computed from snapshots (2D maps, many times).

Mode-1 wavelengths:
300km, 150km

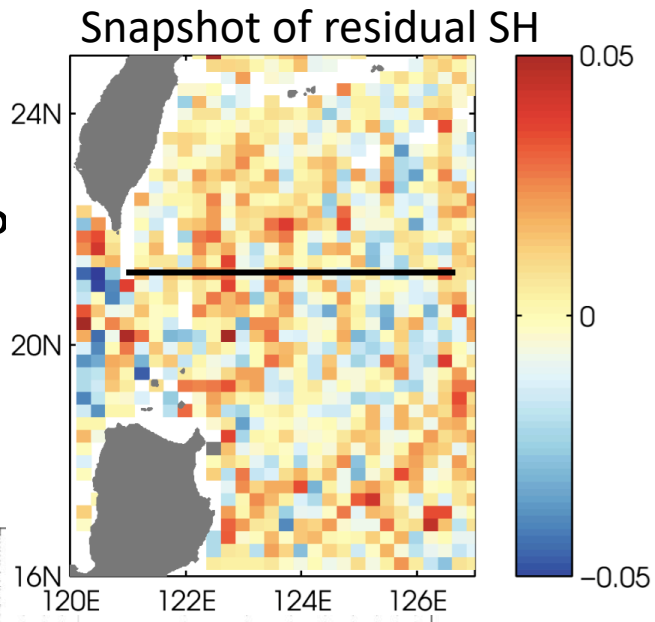
**Residual,** long and short wavelengths

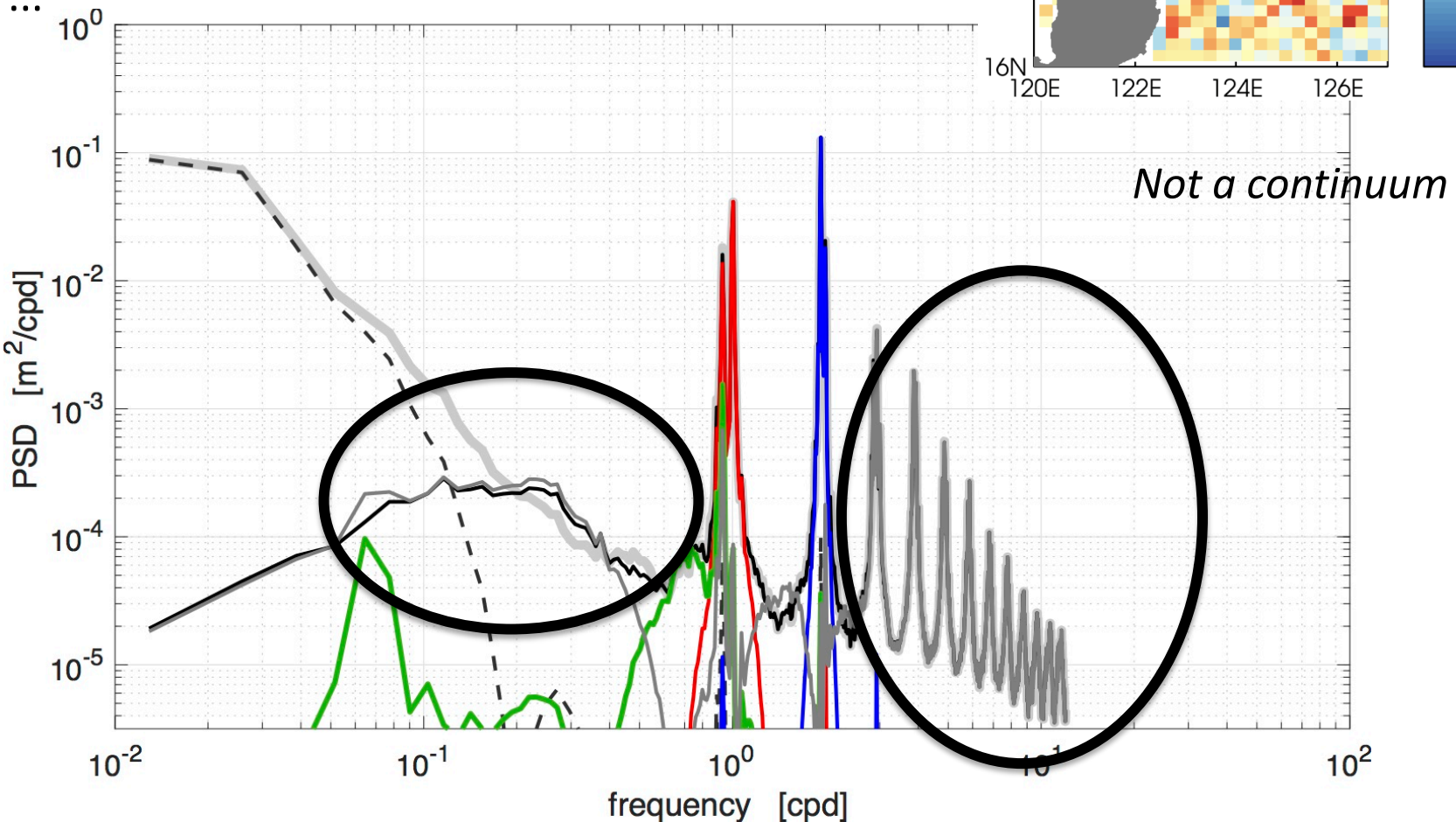
# Residual

Does the model have realistic sub-mesoscale?

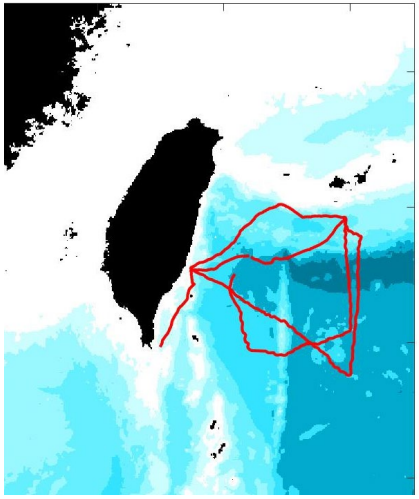
Likely contributors:

- Fronts (evolving on inertial time scales)
- Higher harmonics of tidal and inertial frequencies
- …



# Residual



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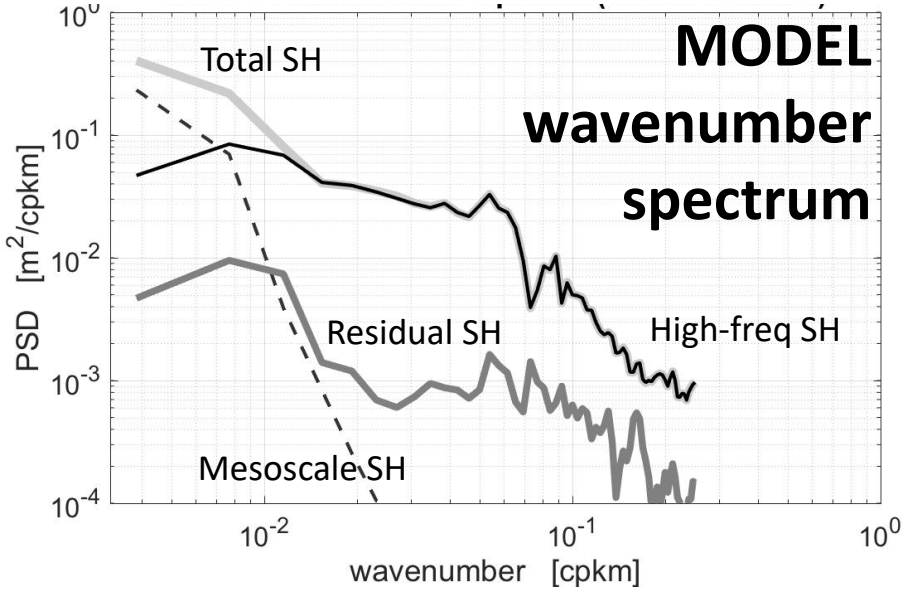
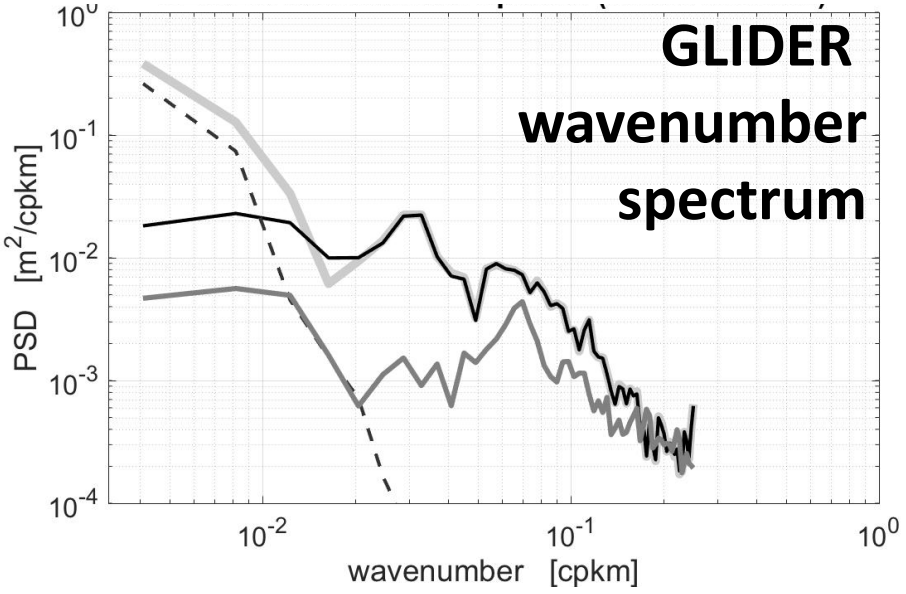
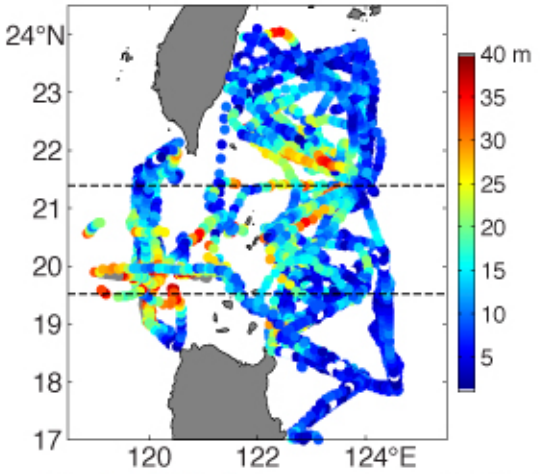



Model and observations are similar.

Likely a major science result from SWOT

# Summary and thoughts



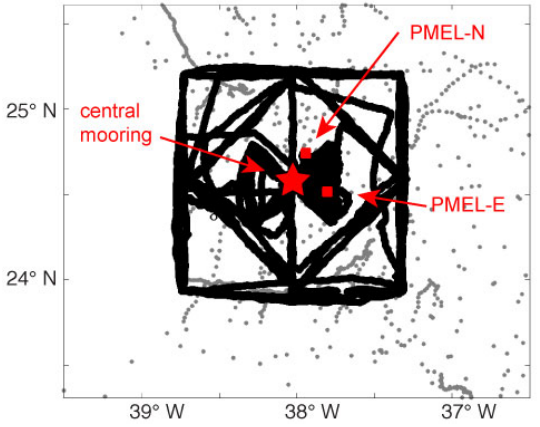

The MITgcm model is pretty good!

Sampling to 1000m (in deep ocean) is generally okay.

Gliders are slow, but they can capture important processes.

- Internal tides – stationary issues.
- In a given region, we can likely map low modes & non-mode 1 over a few days.

**SPURS-1**




**Ongoing and future efforts:**

- Understand residual: Higher harmonics vs sub-mesoscale (fronts, mixed layer eddies, etc.).
- Wavenumber & frequency spectra.
- Look at more regions.