

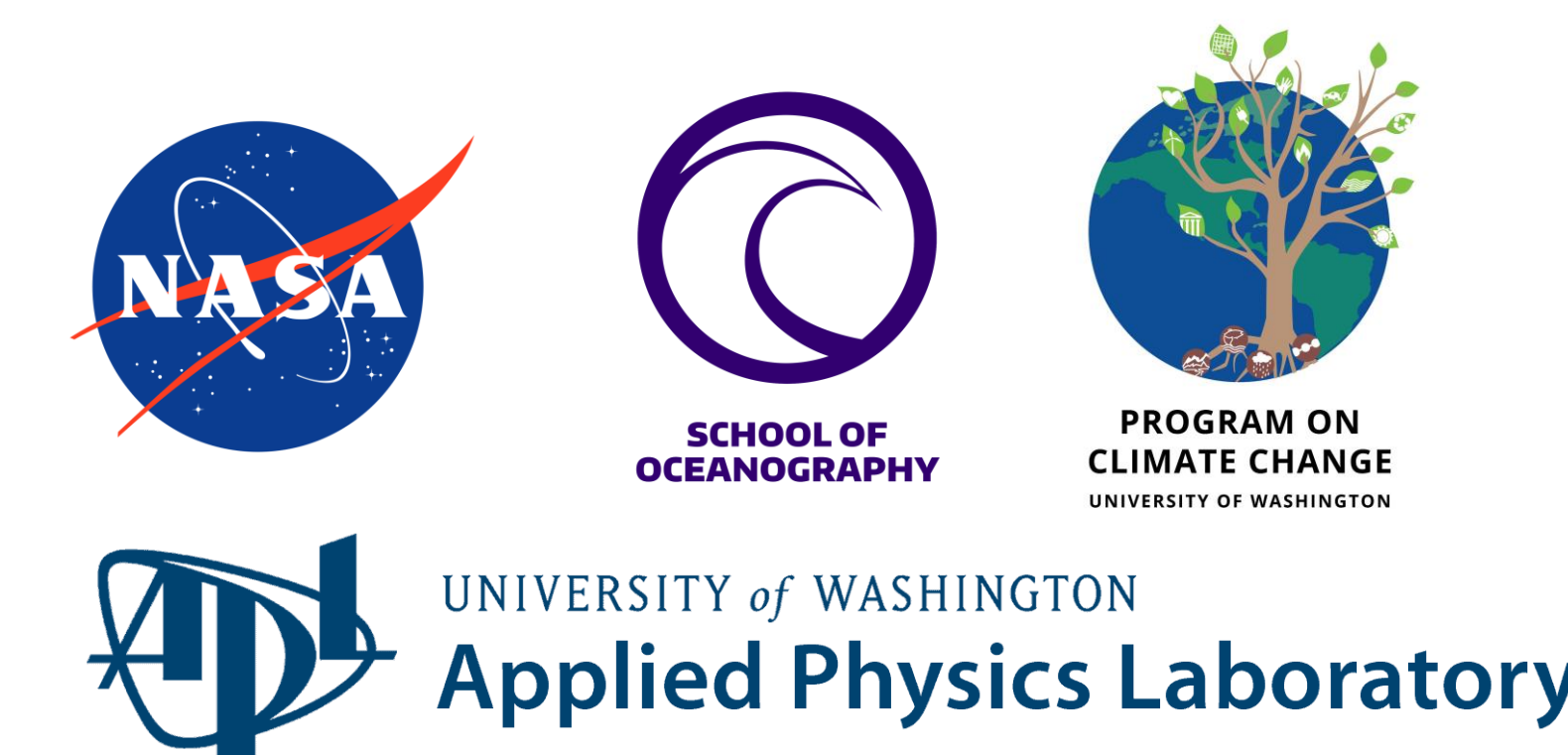
# Multi-Scale Ocean Variability in the Central California Current System

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## One-Sentence Summary

Bridging the gap between basin-scale weather and turbulence mixing, this research uses 15 years of autonomous glider data and satellite images to reveal how atmospheric rivers and mesoscale strain drive the submesoscale fronts that dissipate the ocean's energy.



$O(1000)$ km

## Macroscale

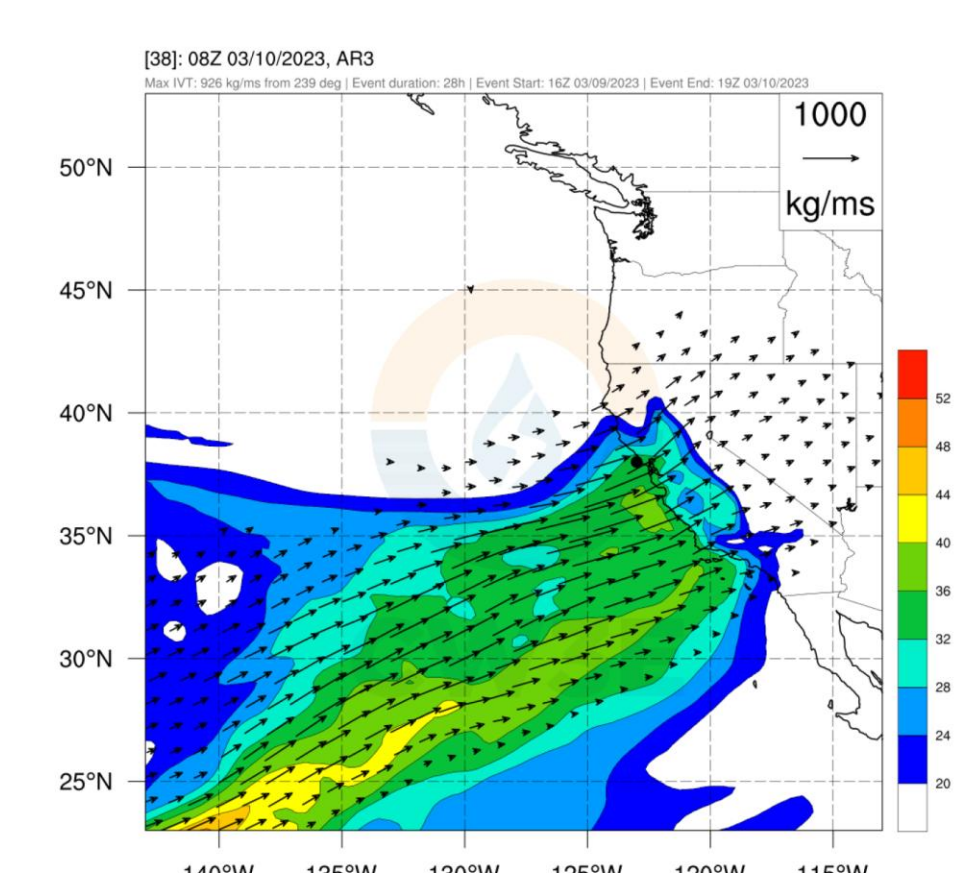
### The Engine

#### Forcing from Above:

Atmospheric Rivers inject massive pulses of freshwater buoyancy

AR event around IOPII: 9-10 March 2023, AR3

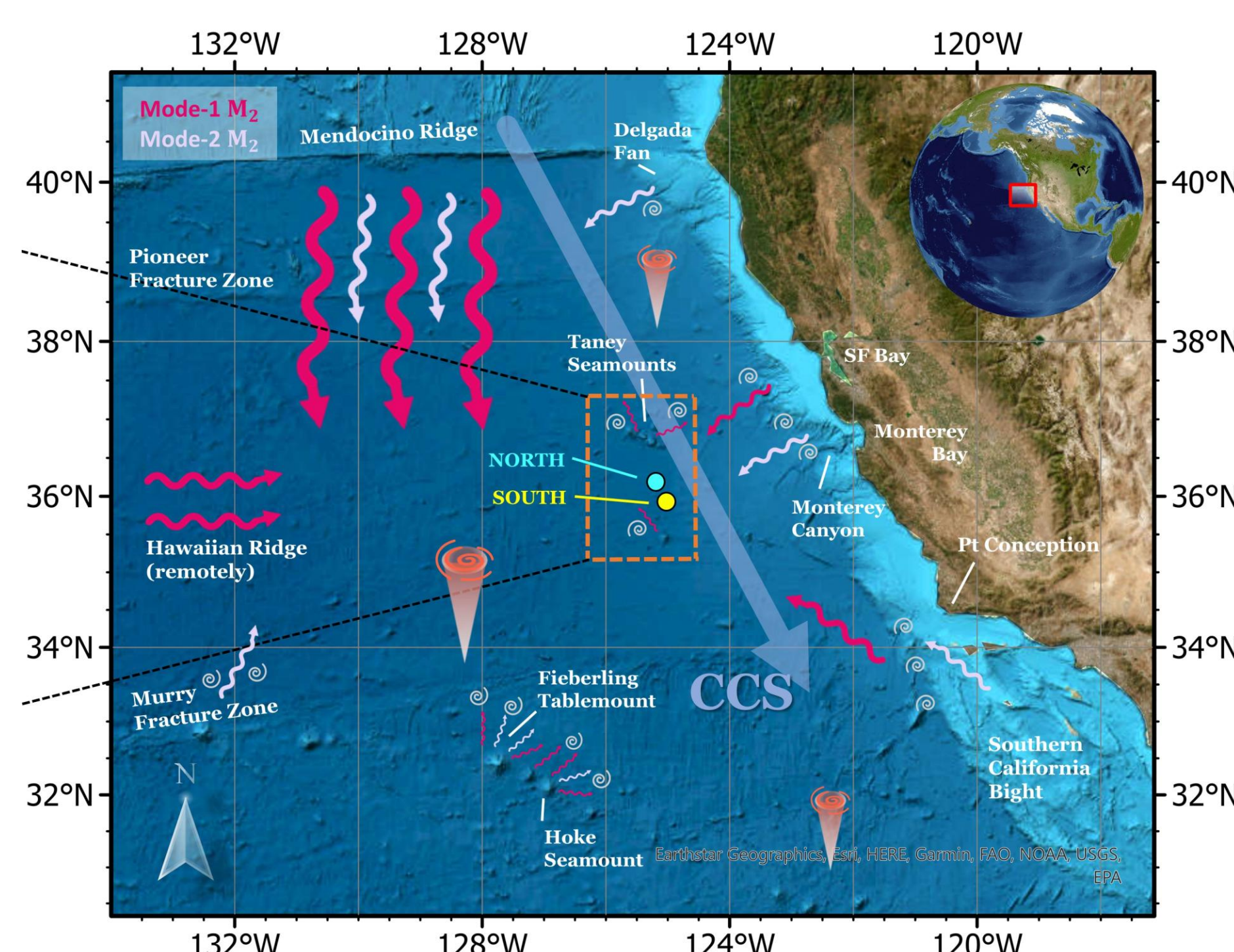
Integrated Water Vapor (mm) with IVT vectors



Integrated Water Vapor (IWV, color shading in  $\text{kg m}^{-2}$ ) and Integrated Vapor Transport (IVT, vectors) showing the moisture plume making landfall. Imagery supports FRO and California AR Programs at CW3E. Data source: ECMWF ERA5.

#### The stage is noisy:

Eddies and internal tides modulate the background environment



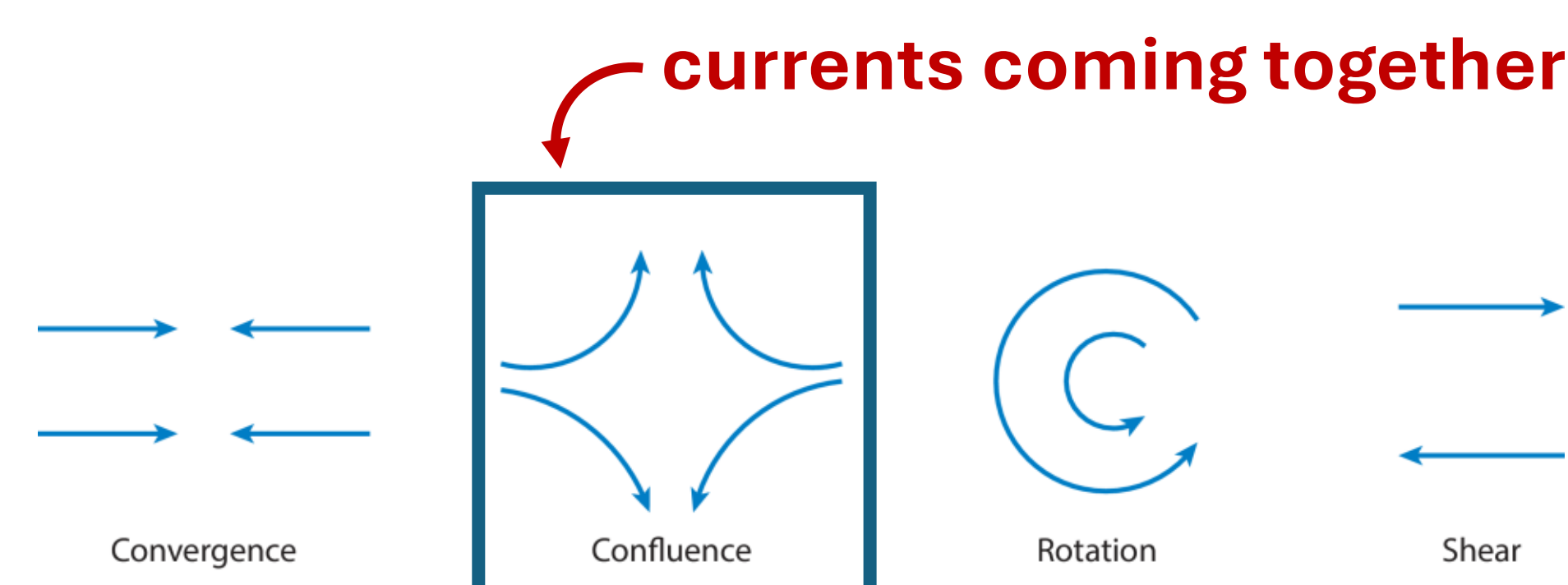
Spatially complex and temporal variable internal tidal field due to the interference of multiple seasonally-variable sources. Cai et al., 2014.

$O(100)$ km

## Mesoscale

### The Squeeze

#### The 2D Deformation Field



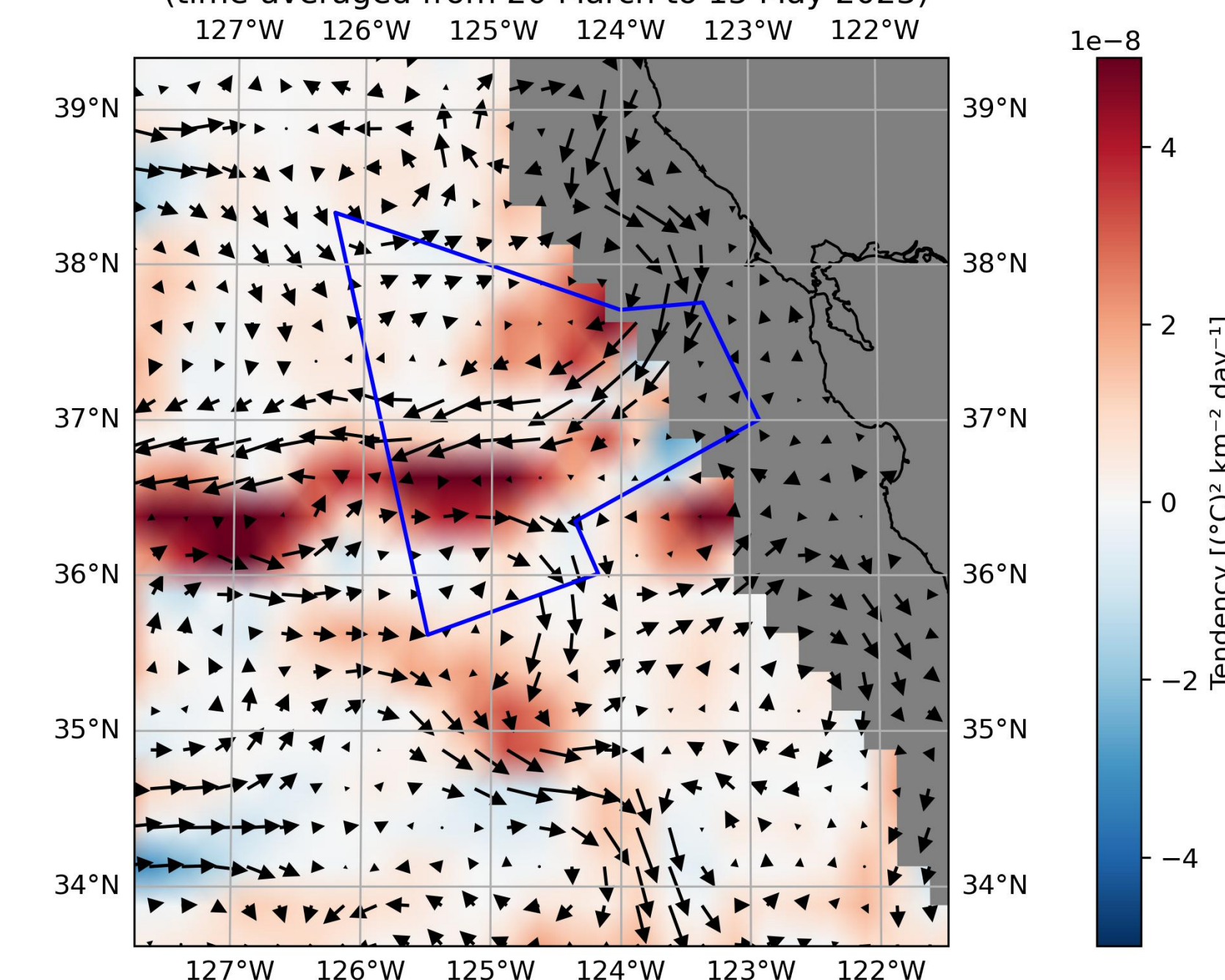
McWilliams JC, 2021  
Annu. Rev. Mar. Sci. 13:227-53

#### Frontogenesis (Mechanism)

$$\mathcal{F} = Q \cdot \nabla_h b$$

The Q-Vector measures the 'squeeze'. Mesoscale eddies strain broad gradients into sharp filaments, forcing energy down to smaller scales

Frontogenesis tendency (hori. deformation) calculated with RSS Microwave SST and Geostrophic Currents (time-averaged from 20 March to 15 May 2023)



2D frontogenesis diagnostics with the RSS Microwave SST and COPERNICUS-GLOBCURRENT Geostrophic Current in S-MODE IOPII

- Strong offshore band of frontogenesis (36–37.5°N)
- Confluent geostrophic flow strains and sharpens thermal gradients

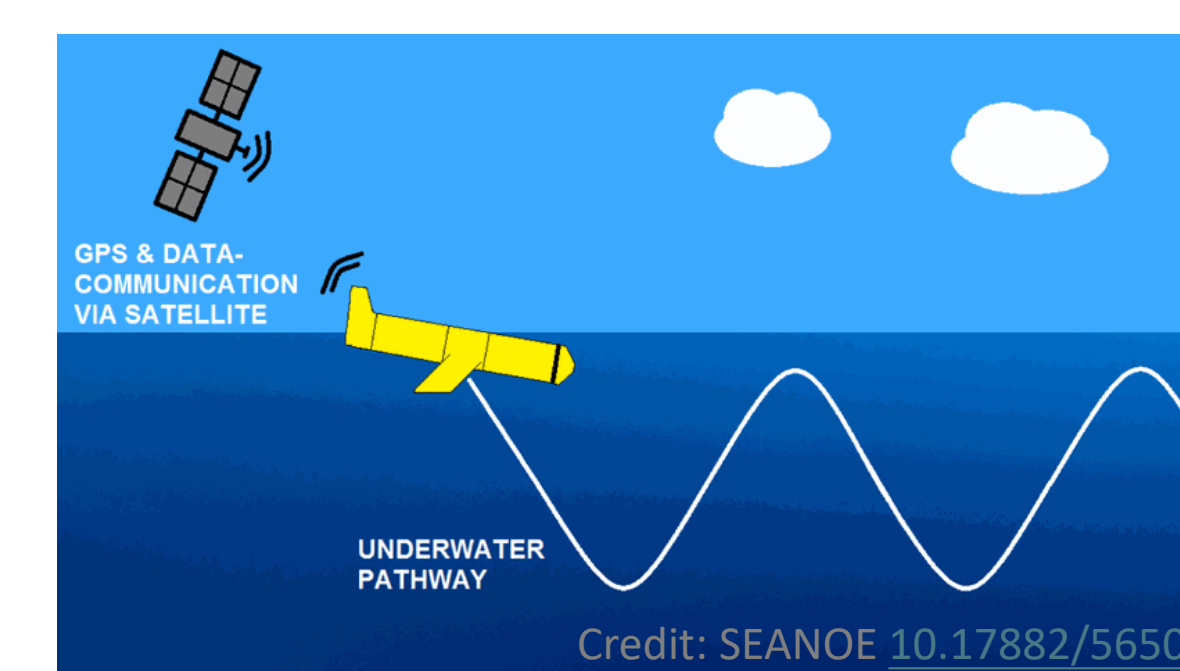
$O(10)$ km

## Submesoscale

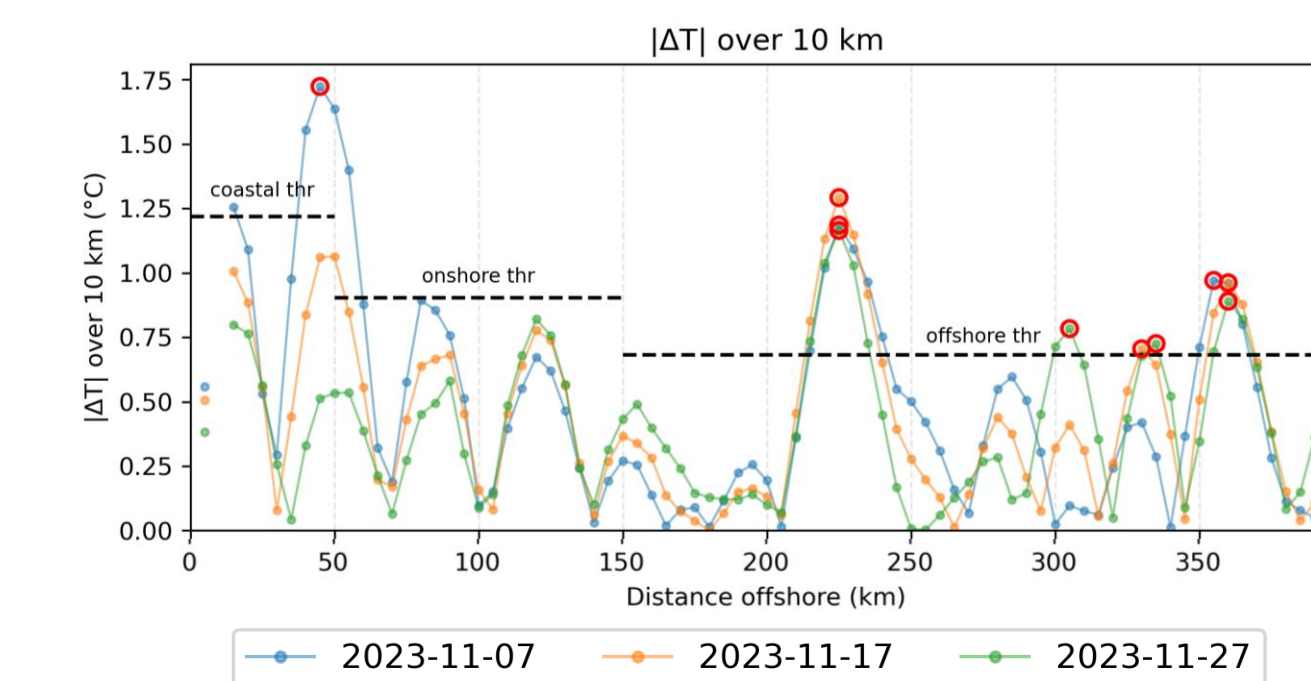
### The Leak

#### CUGN glider (2006-2024)

Provide high-resolution temperature, salinity, velocity data (~3km)



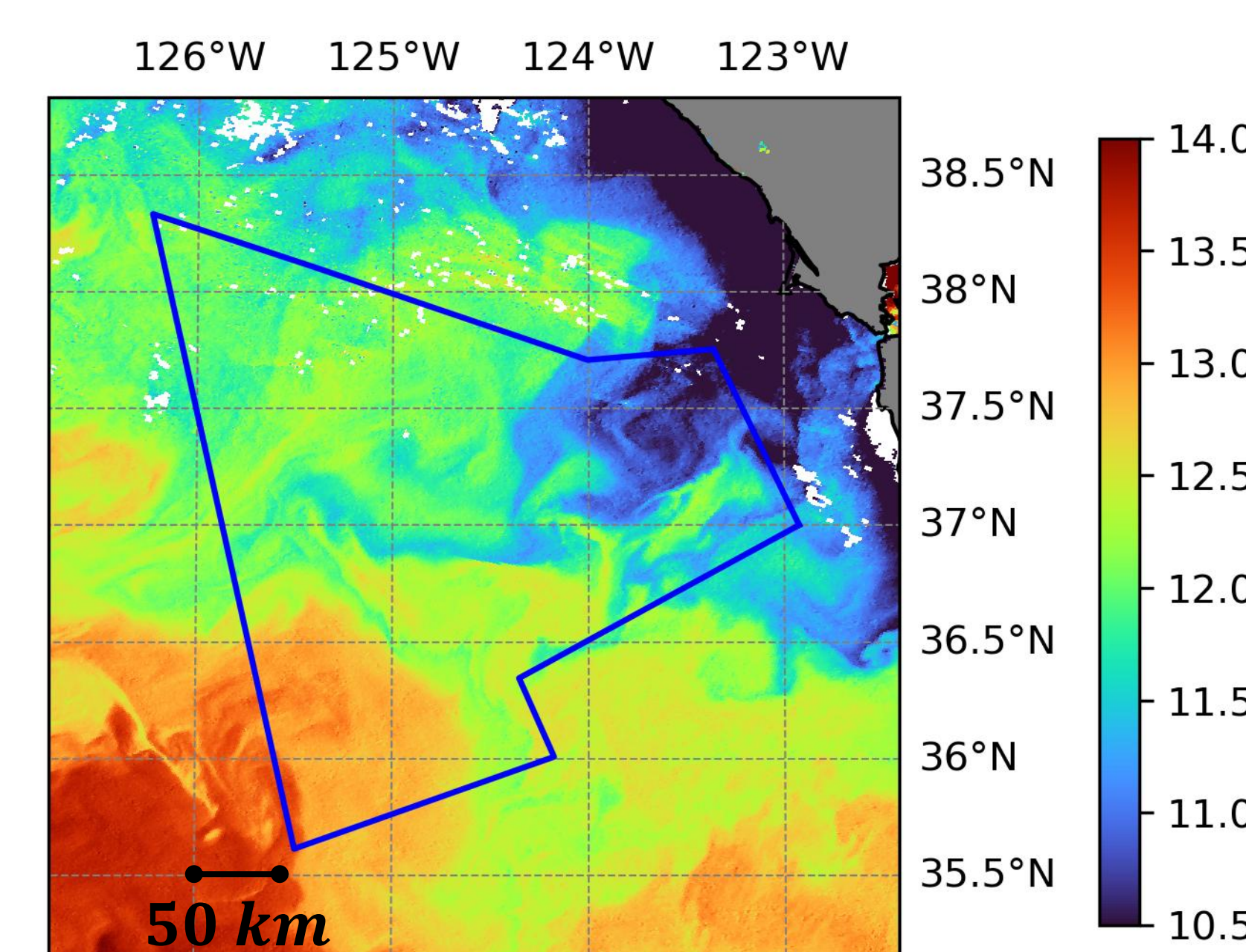
Identify submesoscale features along distance offshore for spatial variation



#### Satellite Inferred Image

Cold water come from the coast and get advected offshore

VIIRS NPP L2 SST on 2023-04-21 (750 m)



## Impact

### The Reality Check

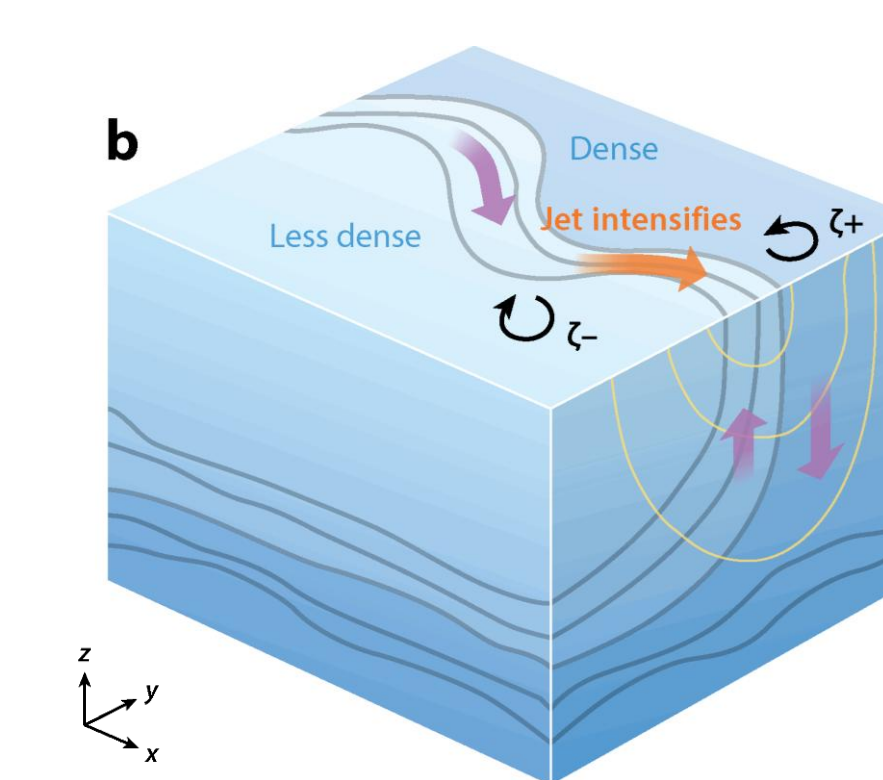
#### Do Climate Models See This?

#### VS GLORYS12V1 Reanalysis Model

Reanalysis models may miss submesoscale (salinity fronts) because they lack event-based river forcing (ARs)

#### Why does Submesoscale Matter?

The loss of geostrophic balance and strong vertical velocity



↑ Geostrophic flow  $u_y$   
↑ Vorticity  $\zeta = v_x - u_y$

$$Ro = \frac{\zeta}{f} \sim O(1)$$

Vertical velocity  $W \sim Ro\delta U$

Mahadevan, 2015

Implication to climate via Up-Gradient Vertical Heat Transport; **five times larger** than mesoscale

