
S04-17907

# TOWARD DISCERNING **SUBMESOSCALE COHERENT VORTICES** ORIGINATING FROM TOKARA STRAIT IN THE **UPSTREAM KUROSHIO**

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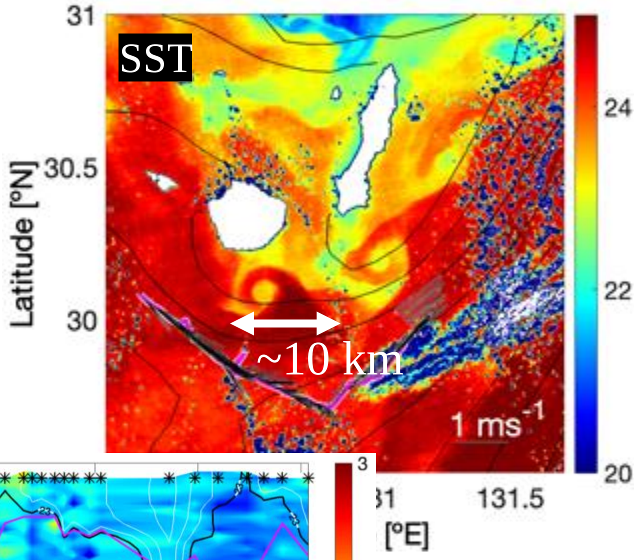
# **TOKARA STRAIT:** a mixing hotspot south of Kyushu

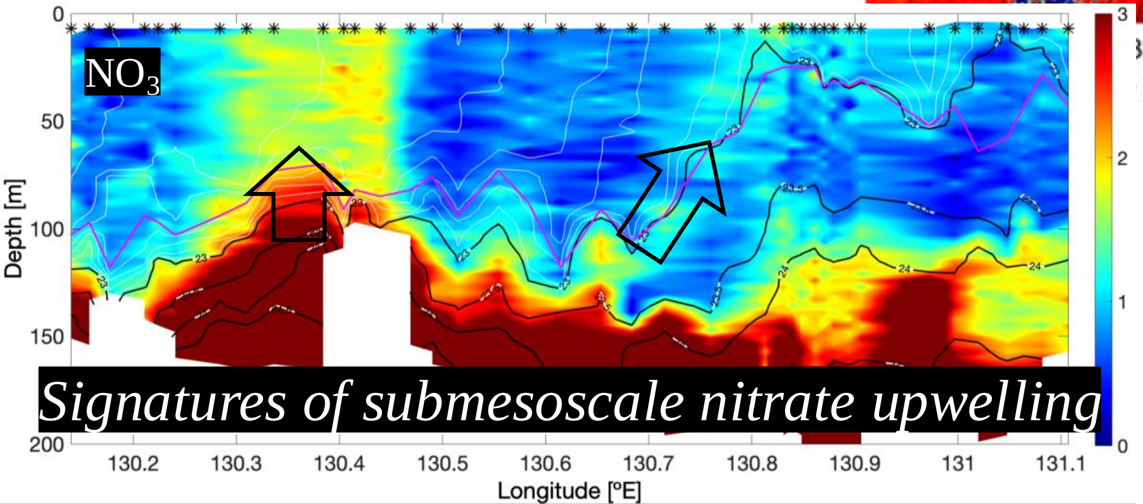
Tsutsumi et al. (2017), Nagai et al. (2017), Nagai et al. (2021), Hasegawa et al. (2021)

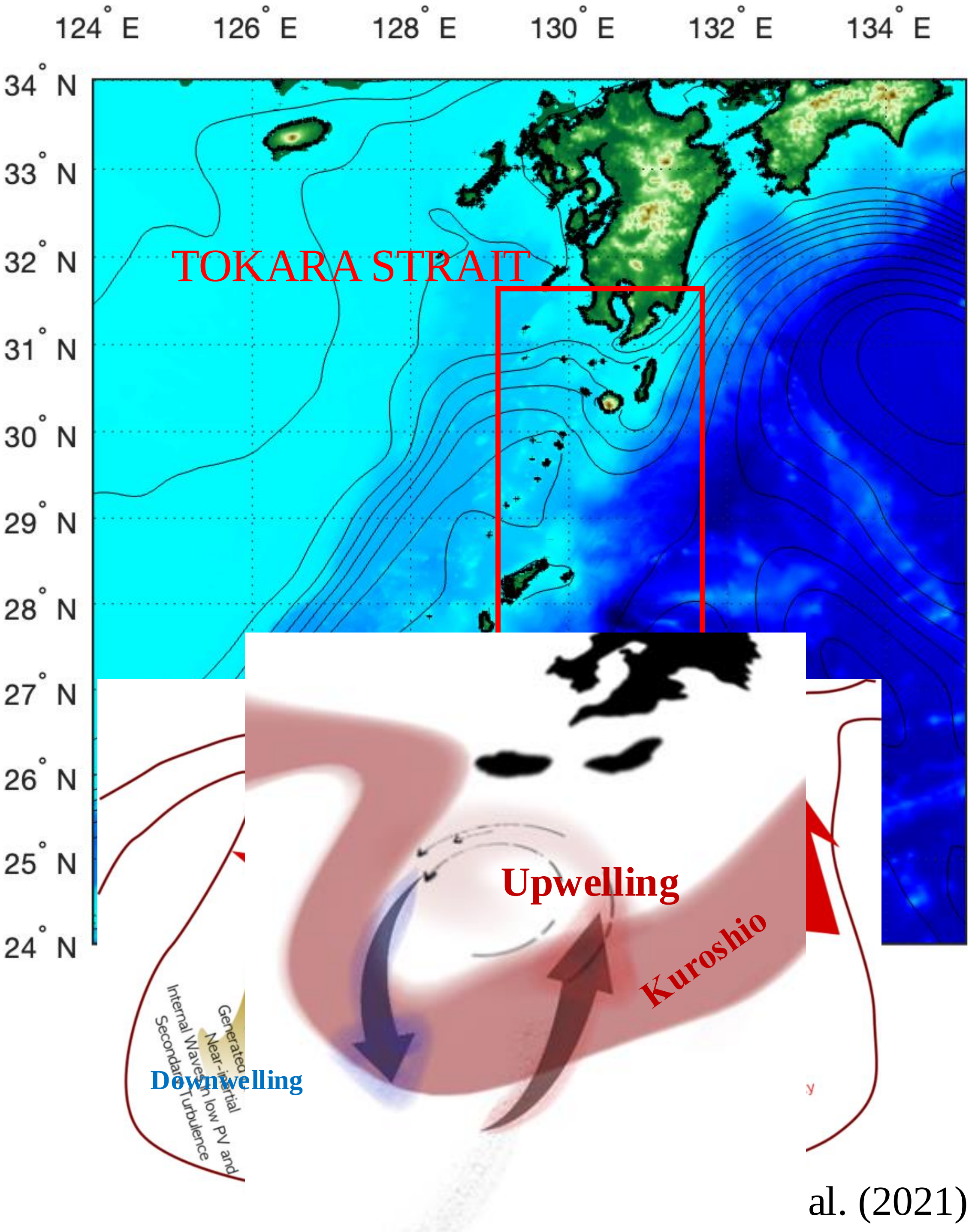
- SUBMESOSCALE EDDIES

Cyclonic eddies visible during winter season

Duran and Nagai (*Under review*)



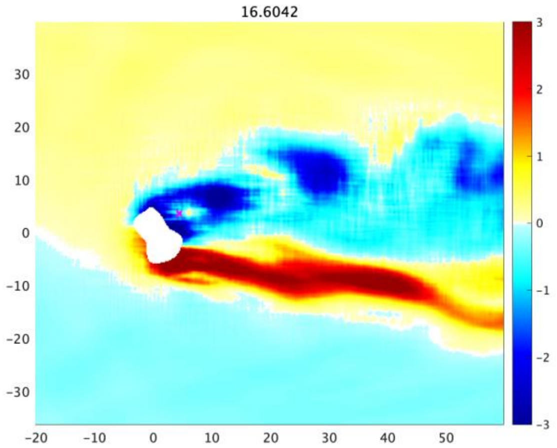




al. (2021)

# ANTICYCLONES IN SUBSURFACE LAYERS:

Vortex shedding (anticyclones $\zeta_z<0$) of 10-km scale behind Hirase seamount.

*Inoue et al (2024)*




# SUBMESOSCALE COHERENT VORTICES

- Retain water mass in their core
- Lifetime can be long
- They often move far from their origin: advected by mesoscale and/or mean current

*McWilliams (1985)*

## Flow–topography interactions

*SCVs in the Kuroshio-Oyashio Extension are mainly generated on the eastern continental slope of Japan through flow–topography interactions.*

*(Zhu et al. 2024)*

*Generation process of South China Sea SCV is similar to the island wakes.*

*(Zhang et al. 2022)*

# Objective

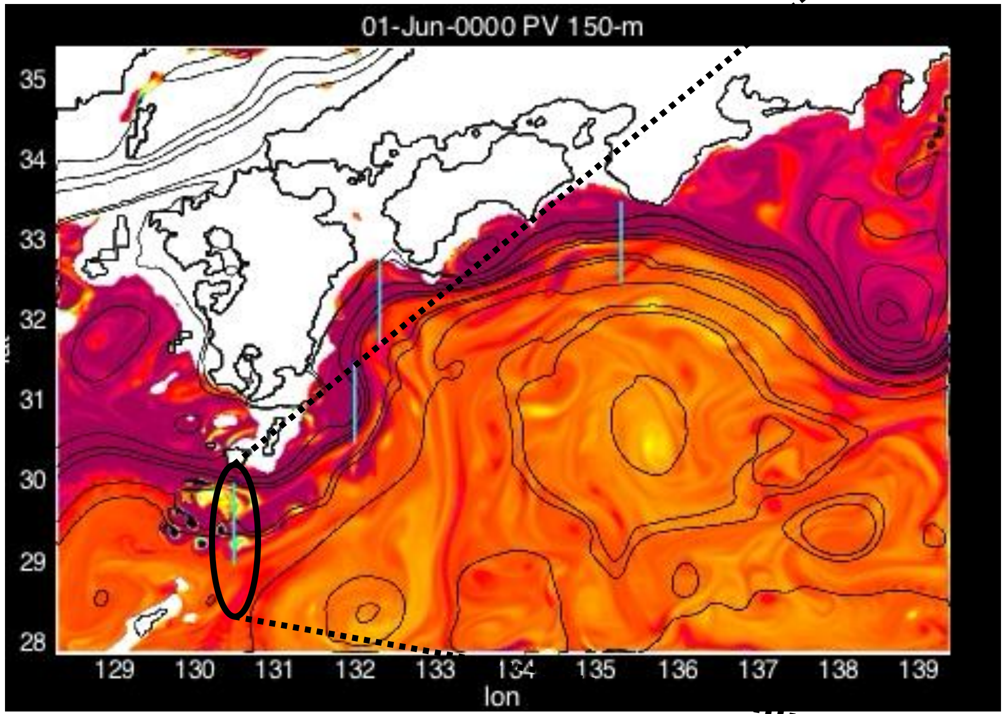
To discern the presence and/or generation of SCVs in the Tokara Strait behind the small islands in the Tokara Strait.

# STRUCTURES IN SIMULATION

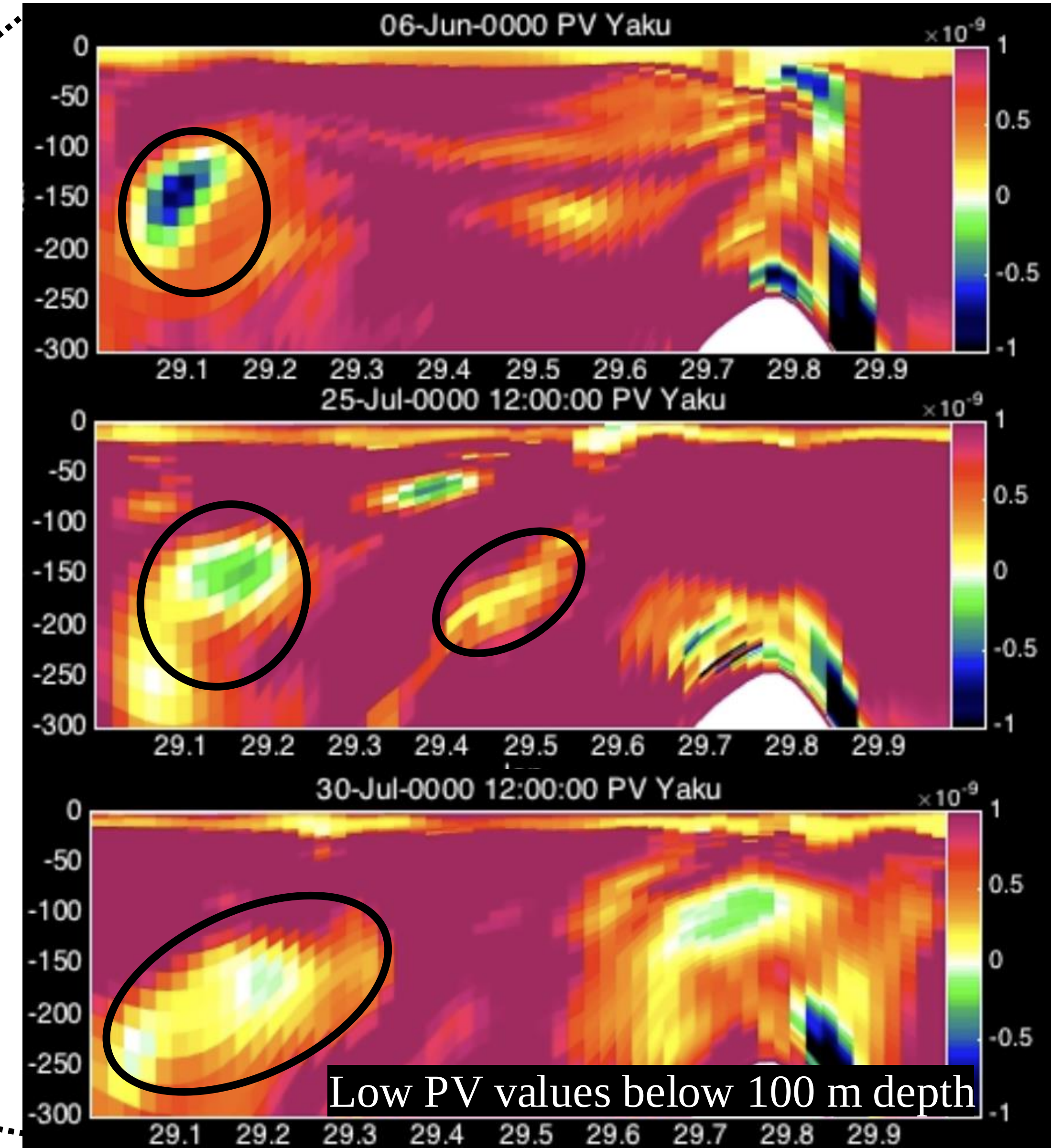
**Regional Oceanic Modeling System (ROMS)** - GRID 2 KM

- ✓ Monthly climatological wind from the Comprehensive Ocean - Atmosphere Data Set (COADS)
- ✓ No tide
- ✓ 500-m topography data
- ✓ K-Profile-Parameterization (KPP)

**Potential Vorticity (x10$^{-9}$)**




*Vortex shedding behind islands*

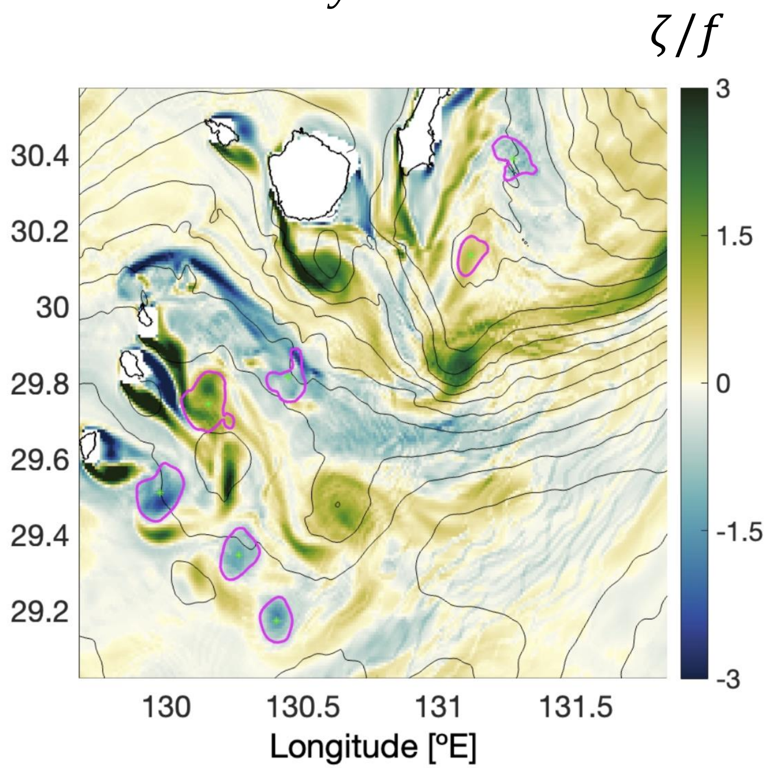


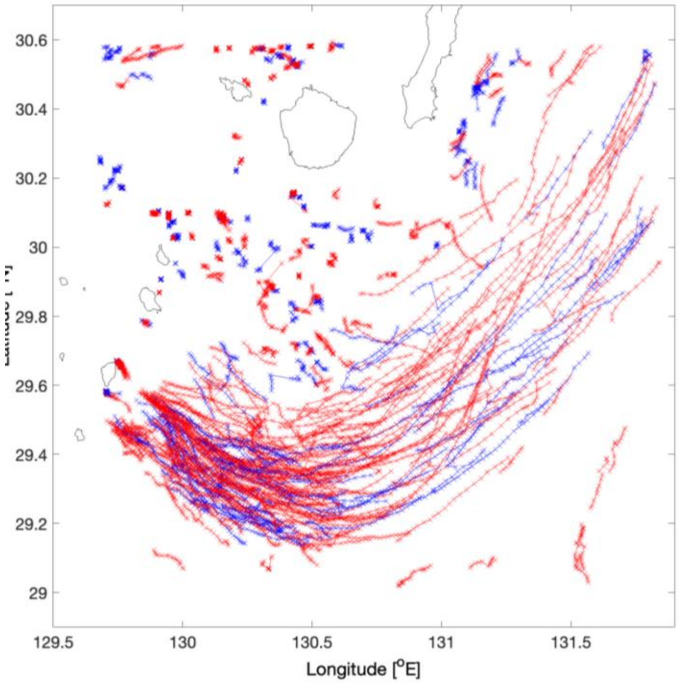
# STRUCTURES IN SIMULATION

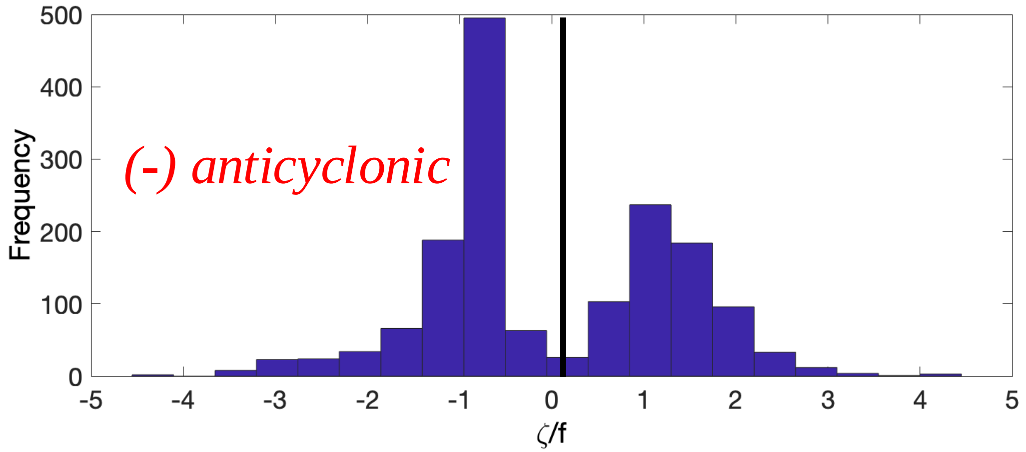
## **Regional Oceanic Modeling System (ROMS) -** GRID 700 m

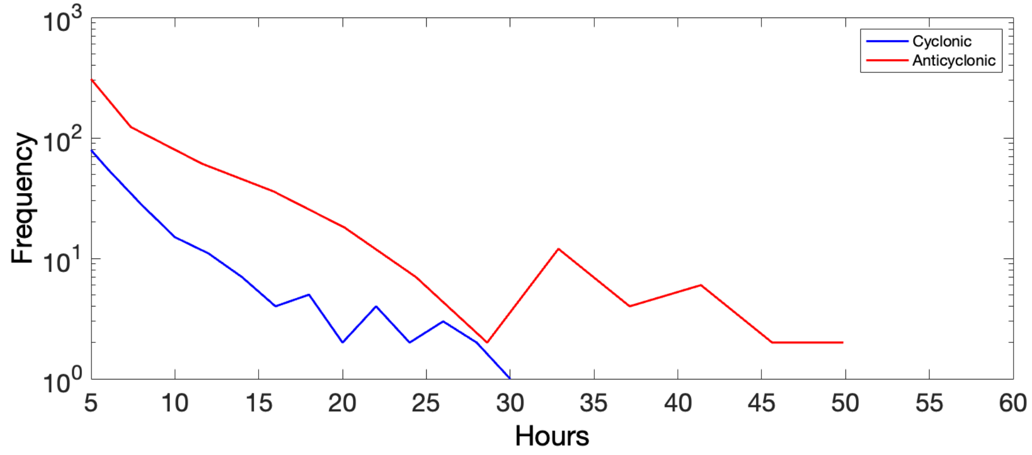
### Detection at Okubo-Weiss at $5 \times 10^{-10}$

*Smoothed every 3.5 km*



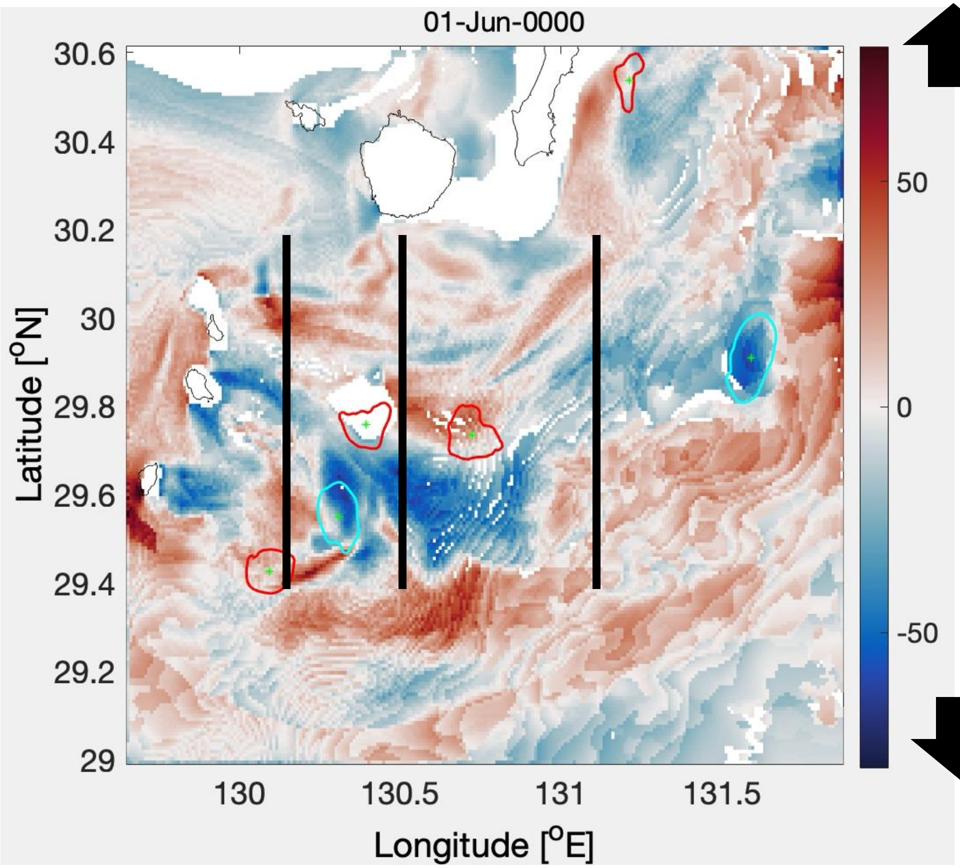

*Anticyclonics live longer*

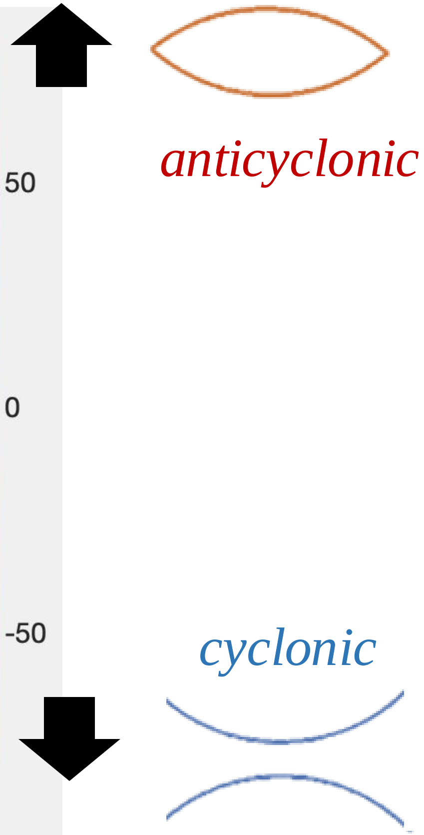
- Within isopycnals of $\sigma_\theta = 23.5 – 25\ kgm^{-3}$
- Ratio > 5 km

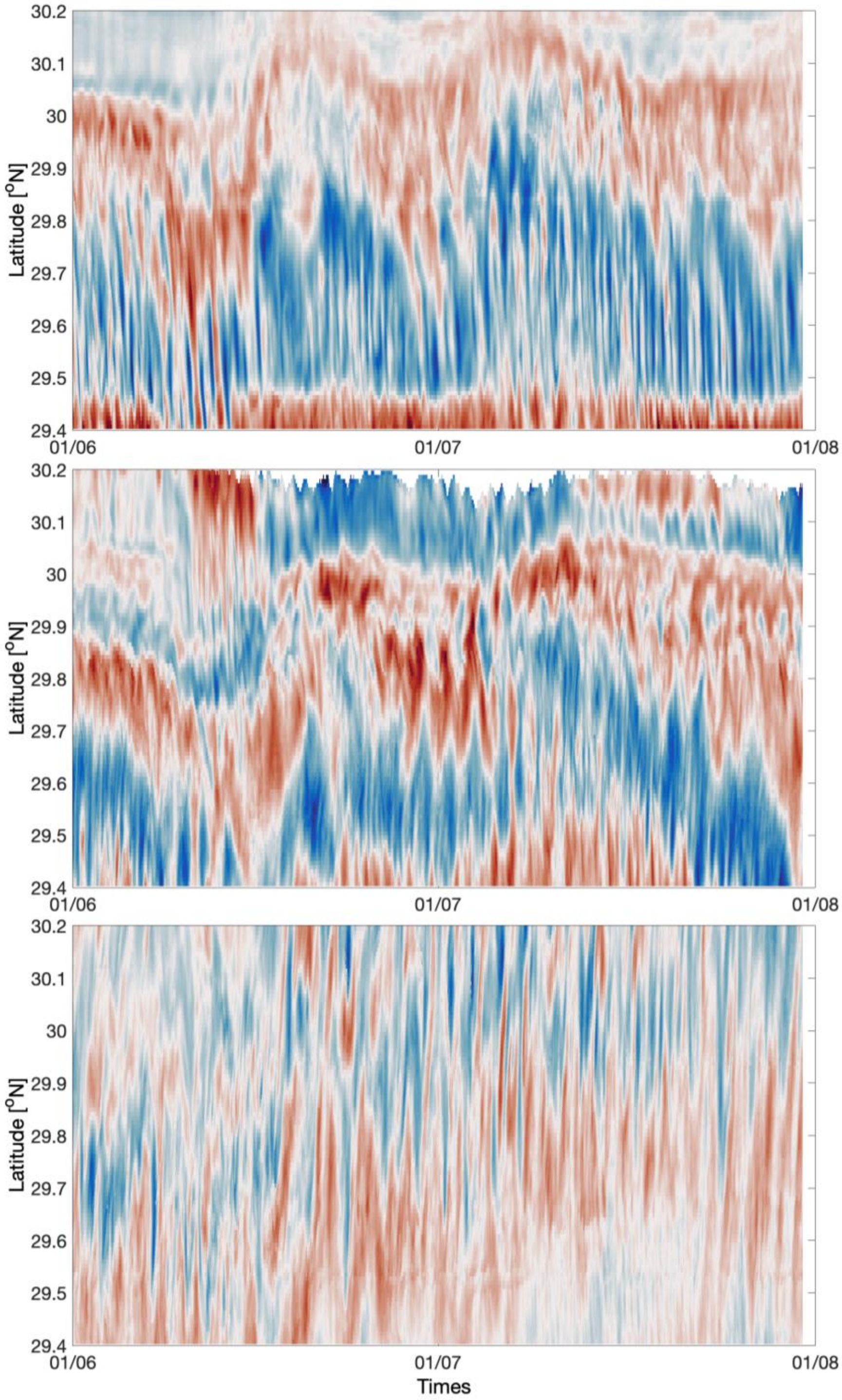
# STRUCTURES IN SIMULATION

**Depth variation of isopycnals:** $DZ_0 = \text{Depth } \sigma_{25} - \text{Depth } \sigma_{23.5}$

$$DZ = DZ_0 - DZ_{40km}$$



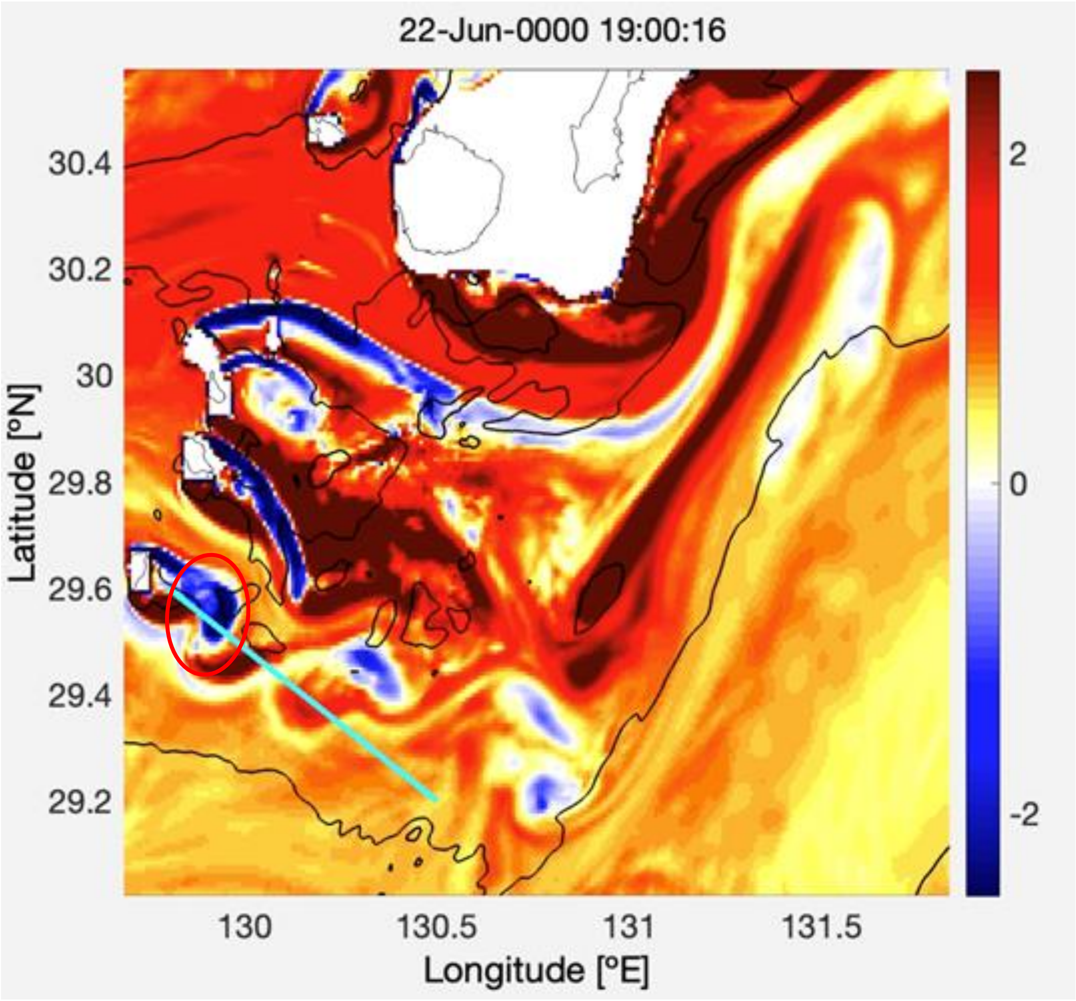



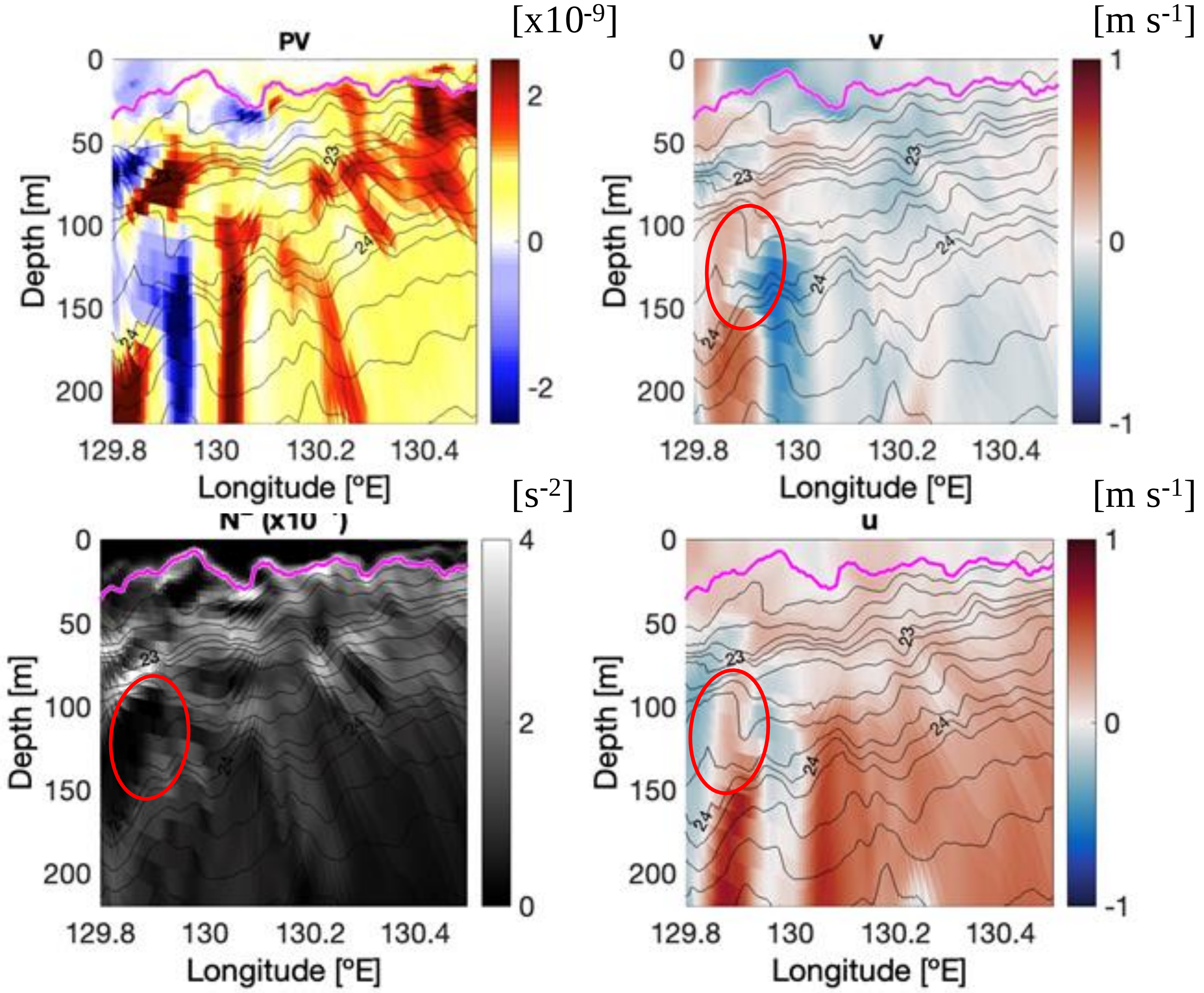



# STRUCTURES IN SIMULATION

## SNAPSHOT

- Vertical extent ~100 m
- Low PV values
- Low $N^2$ values
- Convex isopycnals



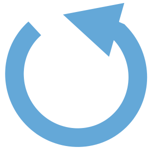



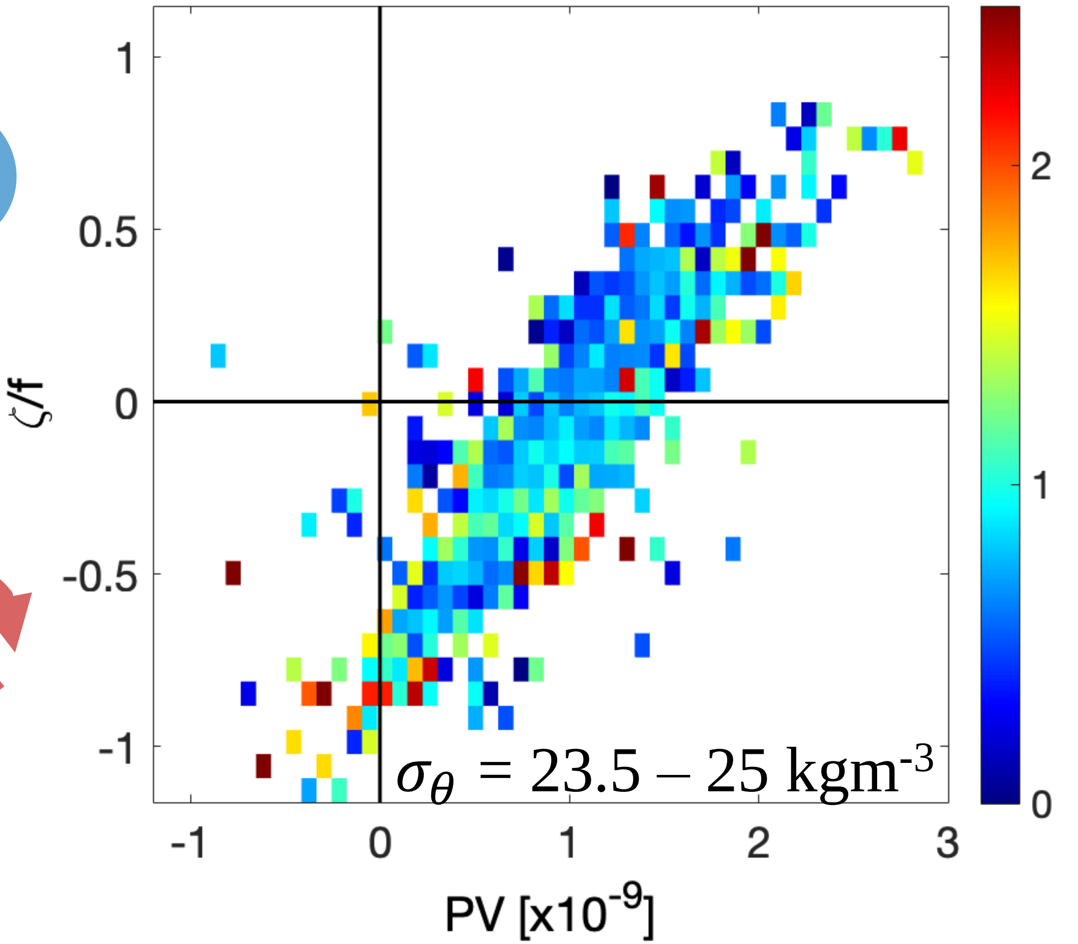
# RELATED TO VERTICAL MIXING?

Nitrate diffusive flux ($FNO_3$) within detected eddies:

$$\mathbf{NO_3\ Flux} = -\boldsymbol{Akt}\frac{\mathbf{dNO_3}}{\mathbf{dz}}$$

*Vertical diffusivity (KPP)*






⬆ $FNO_3$

**~ O(1) mmolm$^{-2}$day$^{-1}$**

(-) $\zeta/f$

*Low PV*

# POSSIBLE SOURCES OF SCVs

→ *Overbars: 1-month average*
→ *Primes: deviations from 1-month average*

**Horizontal Shear Production**

$$\mathrm{HSP} = -\overline{u'^2}\frac{\partial \bar{u}}{\partial x} - \overline{u'v'}\frac{\partial \bar{u}}{\partial y} - \overline{v'^2}\frac{\partial \bar{v}}{\partial y} - \overline{u'v'}\frac{\partial \bar{v}}{\partial x}$$

**Vertical Shear Production**

$$\mathrm{VRS} = -\overline{u'w'}\frac{\partial \bar{u}}{\partial z} - \overline{v'w'}\frac{\partial \bar{v}}{\partial z}$$

MKE → EKE

**Vertical Eddy Buoyancy Flux**

$$\mathrm{BF} = -\overline{w'b'}$$

EPE → EKE

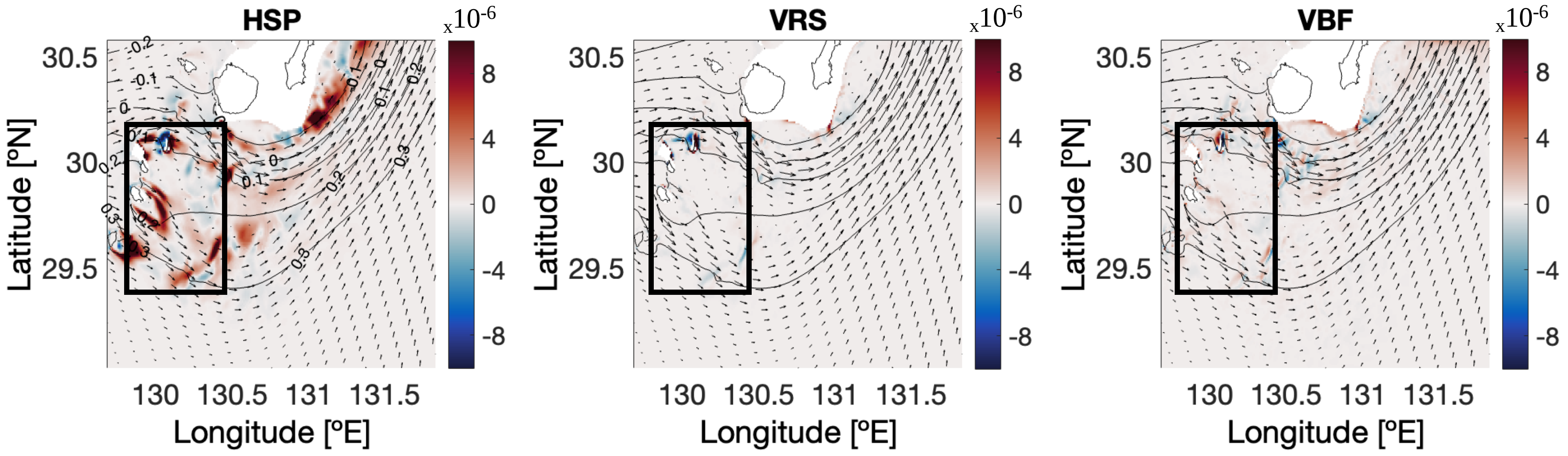
# POSSIBLE SOURCES OF SCVs

**Lateral shear (HSP)**

**>**

**Vertical shear (VRS)**

*From topography-induced island wakes*

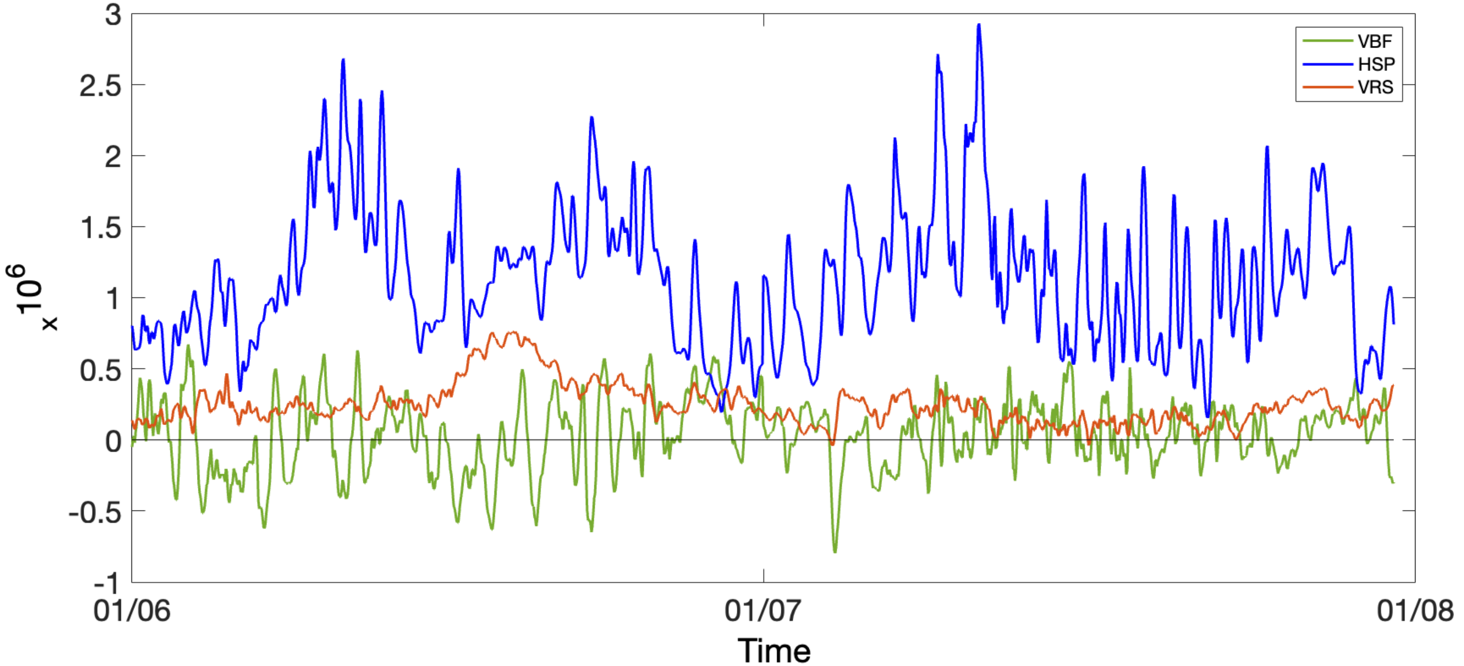



*Values between 150-200m depth*

➡ Centrifugal instability

➡ Turbulent Mixing & low PV lends generation

➡ SCVs generation



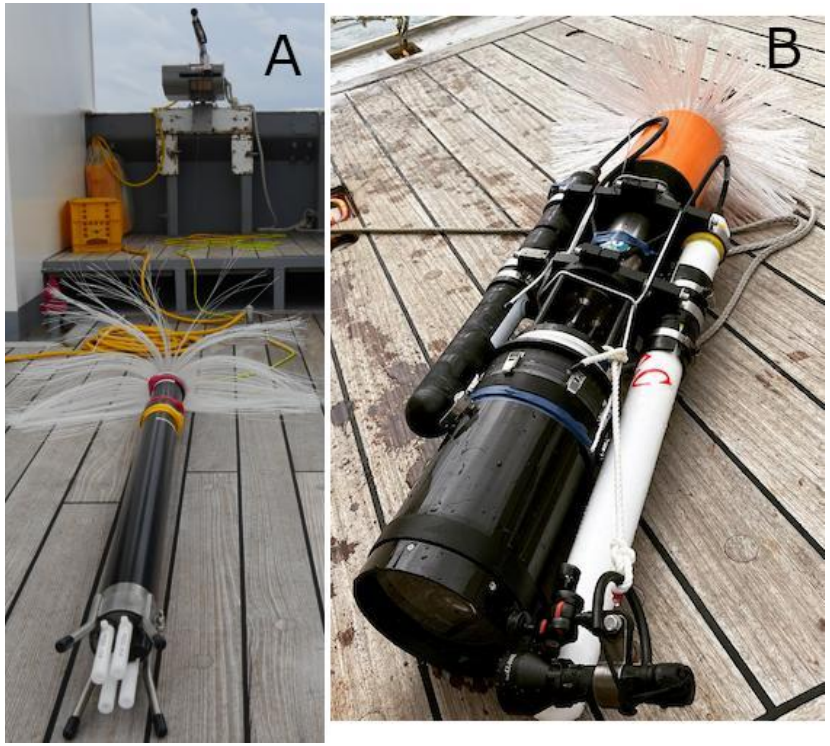
# IN-SITU OBSERVATIONS

- Transect on June & July, 2023 of ~12h
- **Tow-yo instruments:**

**A** UVMP: Underway Vertical Microstructure Profiler 250 $(\epsilon)$
**B** SUNADAYODA: CTD, a chlorophyll-turbidity sensor, a nitrate sensor

$$\mathrm{NO_3\ Flux} = -K_\rho \frac{dNO_3}{dz}$$

$$K_\rho = 0.2\frac{\epsilon}{N^2}$$




- Small values of Potential Vorticity ($PV_{2D}$) in the subsurface layers:

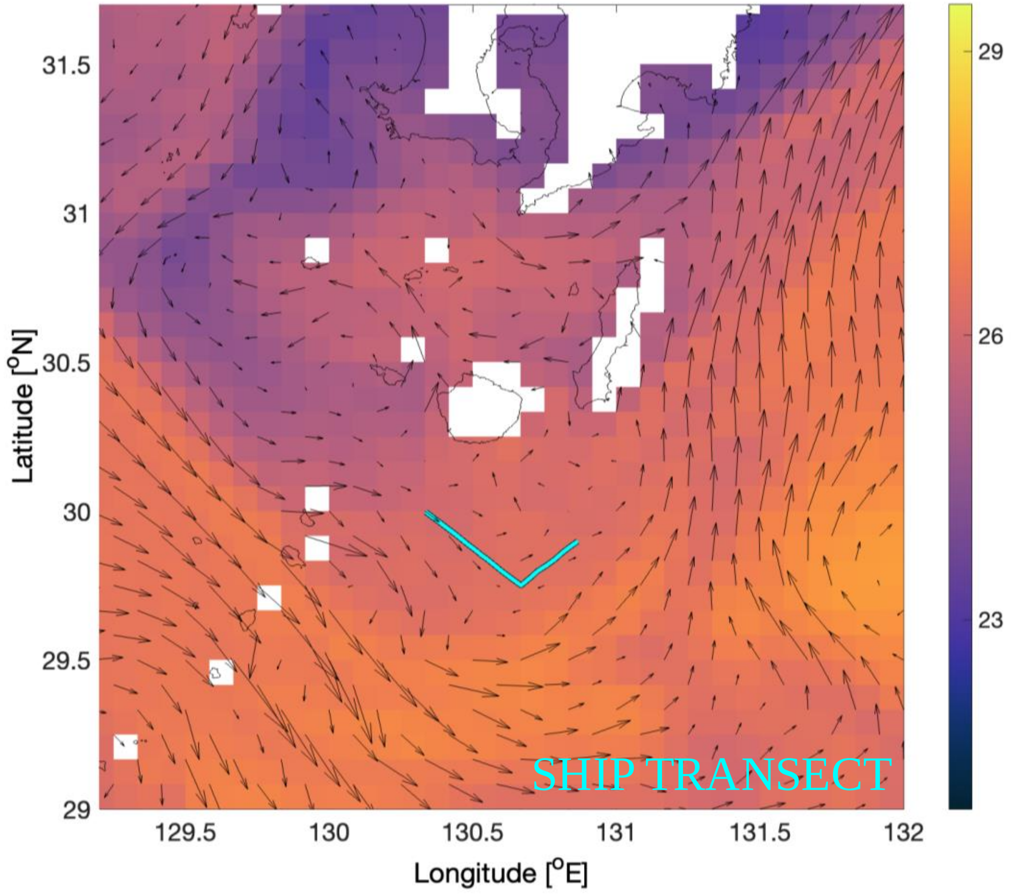
$$PV_{2D} = -\frac{1}{\rho_o}\left[\frac{\partial u}{\partial z}\frac{\partial \rho}{\partial y} + \left(f - \frac{\partial u}{\partial y}\right)\frac{\partial \rho}{\partial z}\right]$$

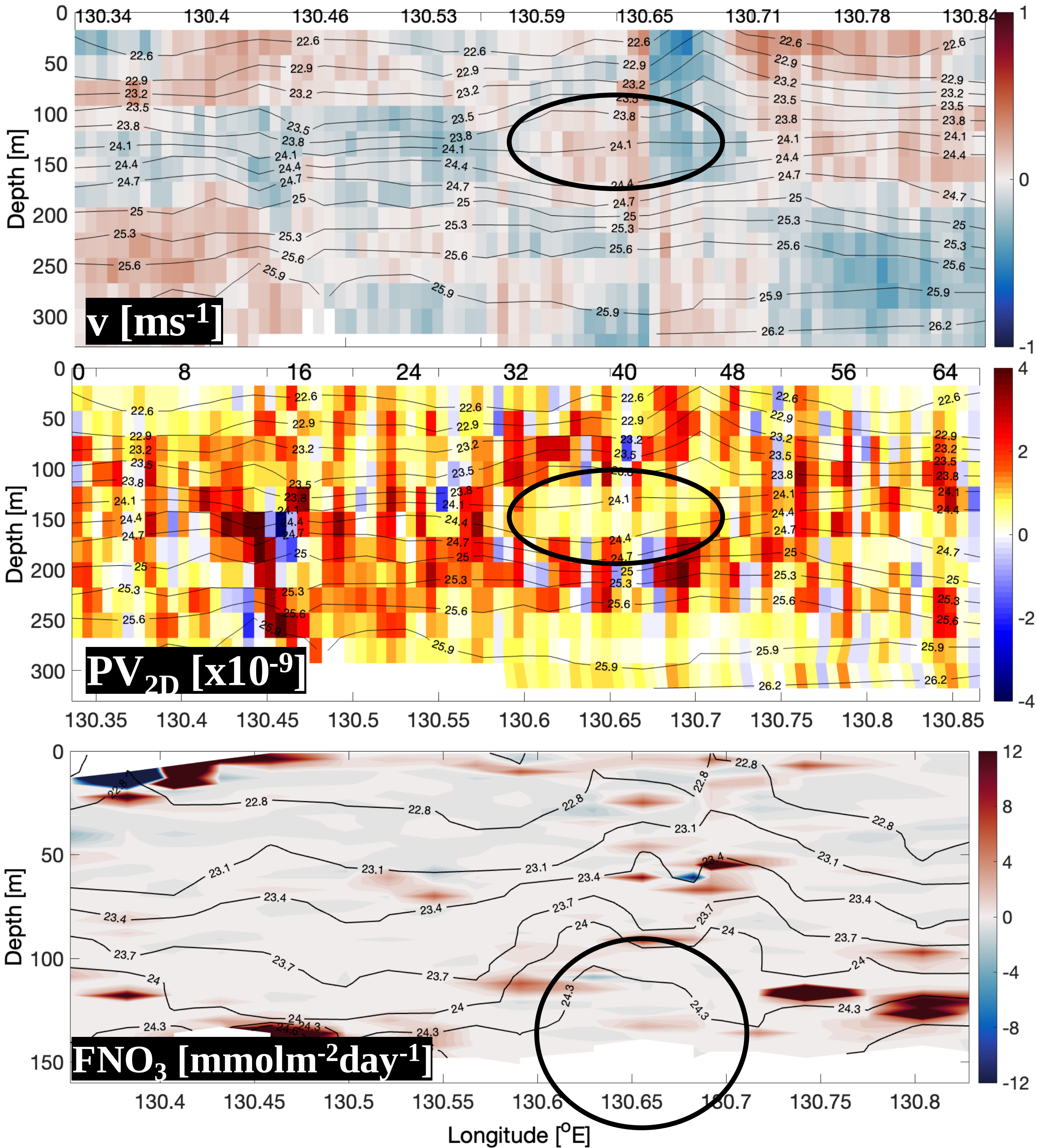
$f$ : Coriolis parameter
$\rho$: seawater density
$u$ & $v$: parallel and normal velocity components to the ship track ($y$ and $z$ coordinates)

# IN-SITU OBSERVATIONS

## JUNE 2023

*SST on June 14th, 2023 – CMEMS*



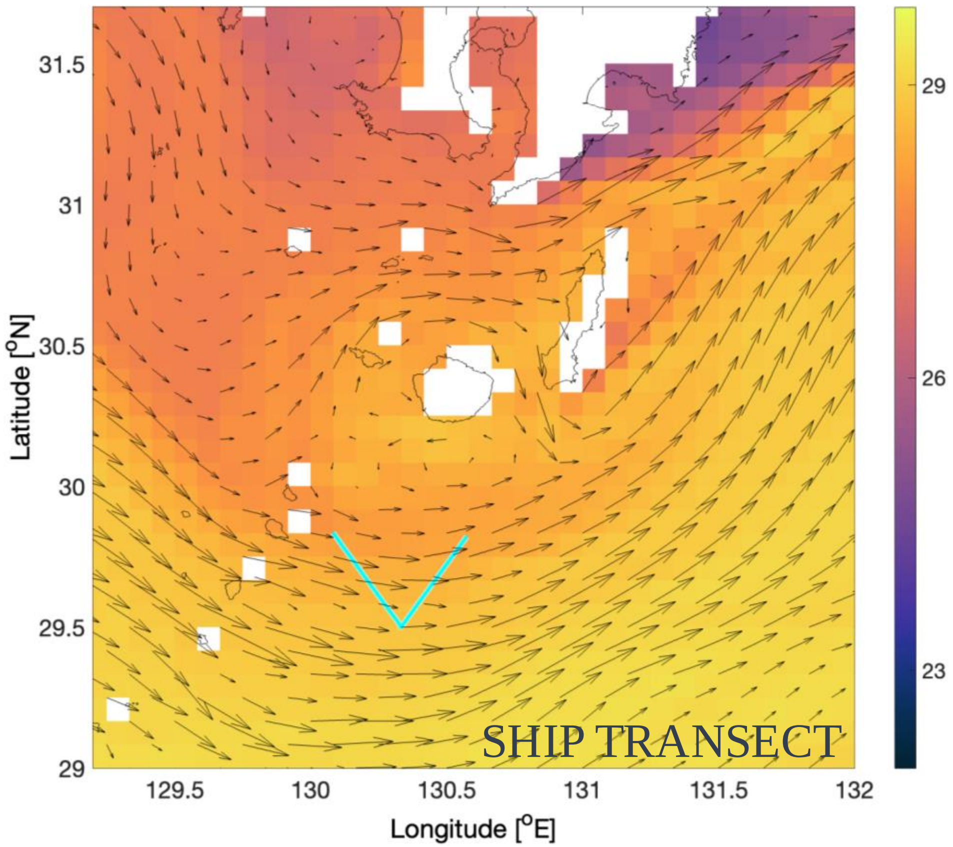




- Low $PV_{2D}$ values within convex isopycnal structures
- Dipole core (horizontal extent < 20 km)

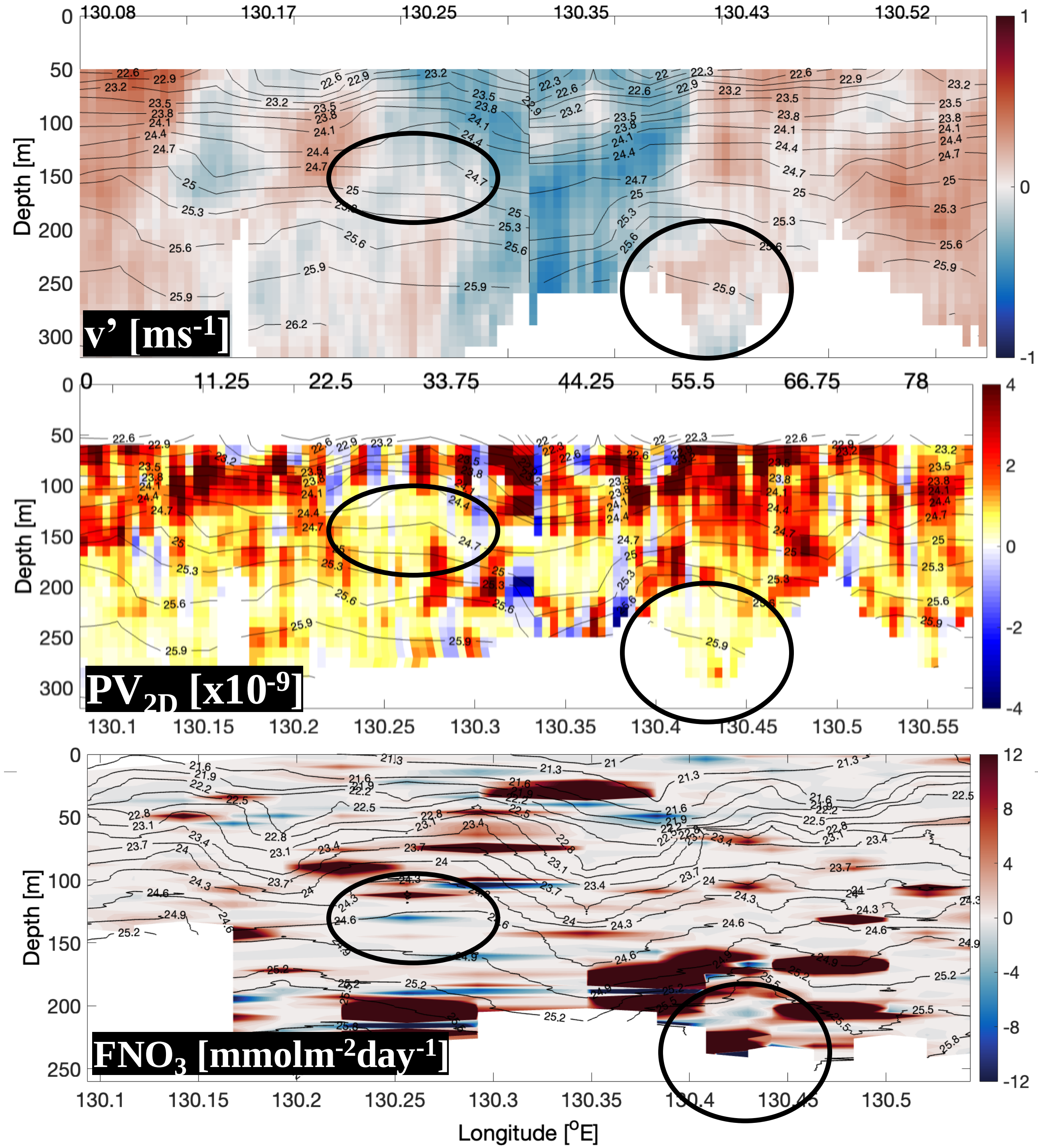
# IN-SITU OBSERVATIONS

## JULY 2023

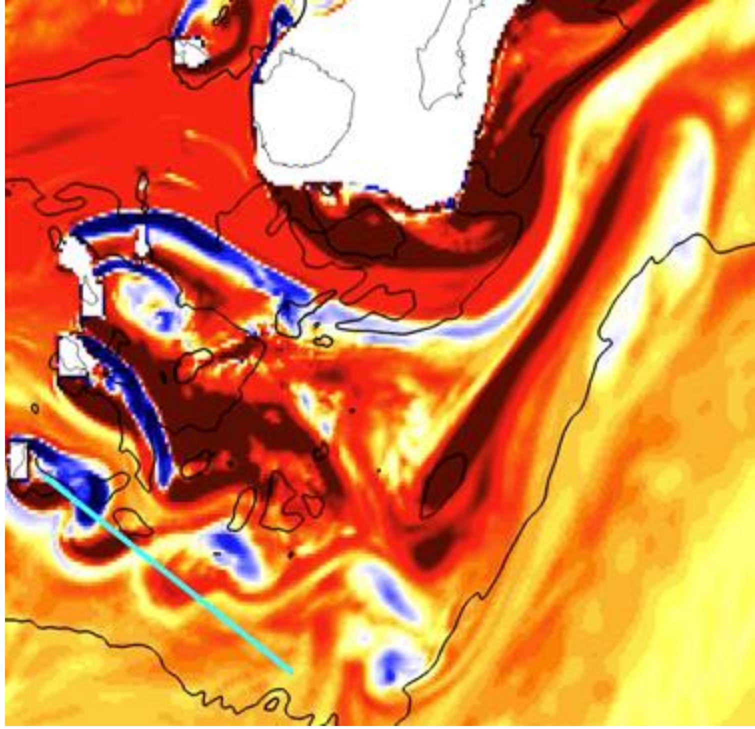
*SST on July 12th, 2023 – CMEMS*




- Low $PV_{2D}$ values below $\sigma_\theta$ = 24 kgm$^{-3}$
- Intense $FNO_3$ in the surrounding of low PV



# SUMMARY



**VORTEX SHEDDING** depends on **the Kuroshio axis position** in respect of small islands in the Tokara Strait

**Origin**: due to lateral shear (topography-current interaction)

**Effects**: Possible increase of nitrate diffusive fluxes

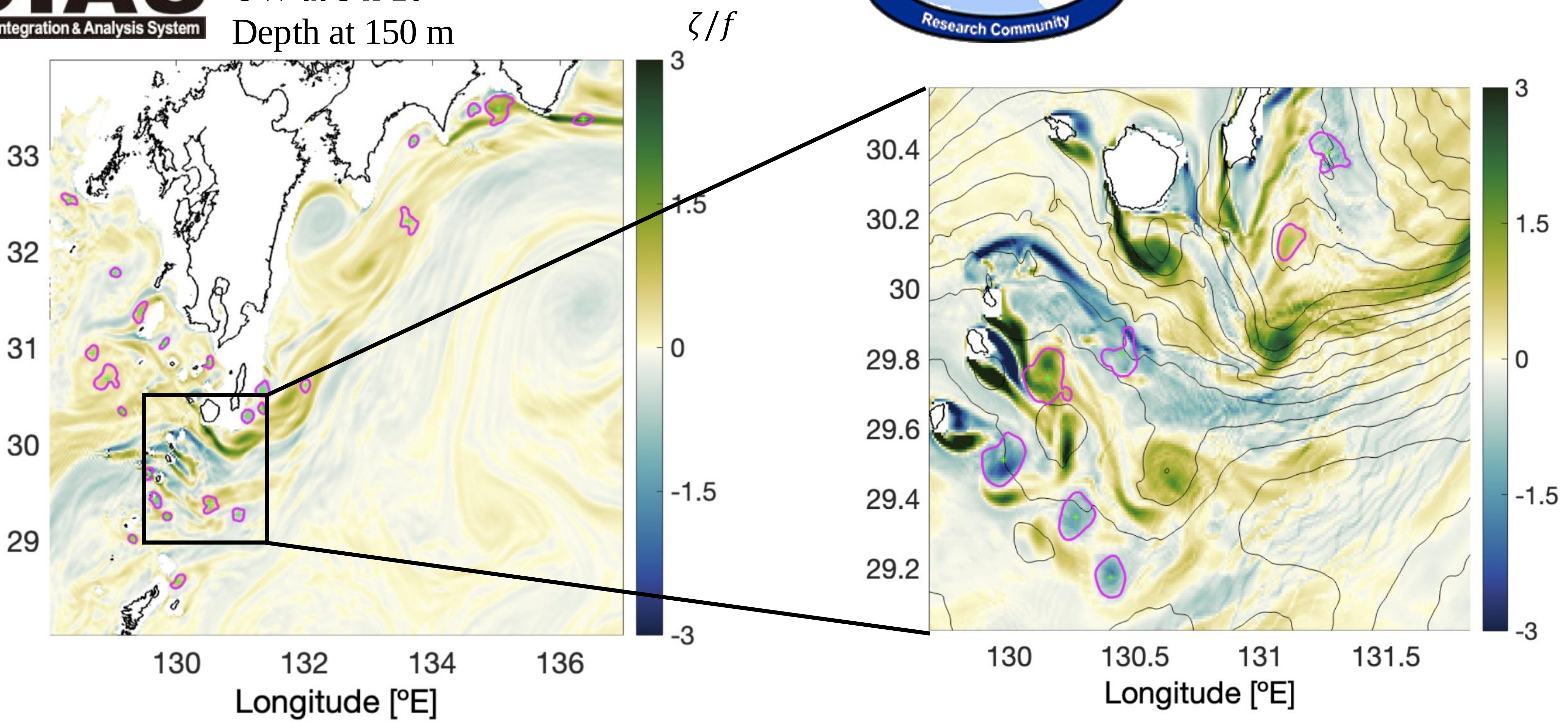
**$FNO_3$ ~O (1) mmol $m^{-2}$ $day^{-1}$**

**Observations**: lens of low $PV_{2D}$ related with dipole velocity cores at subsurface layers

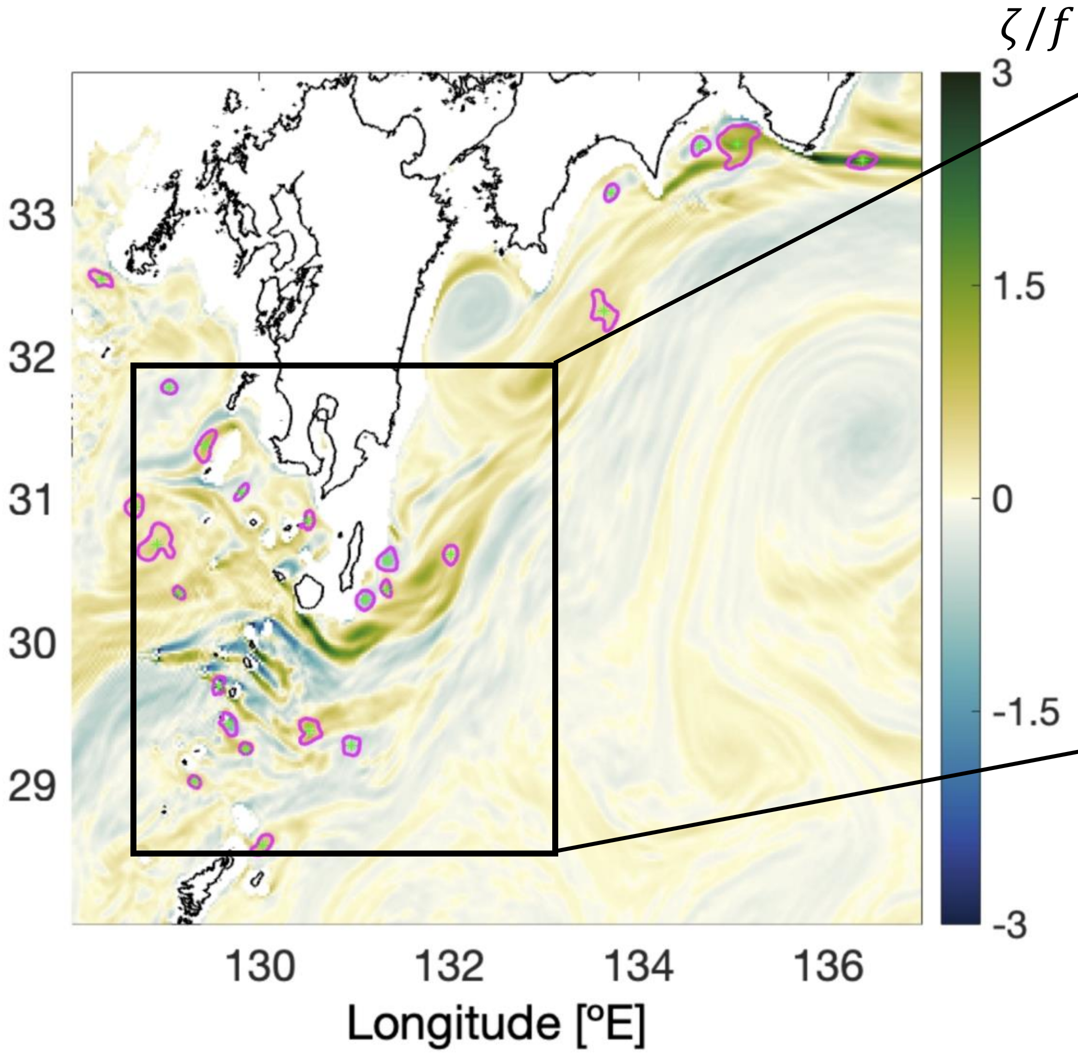
# NEXT STEP: DETECTION IN A WIDER IMAGE

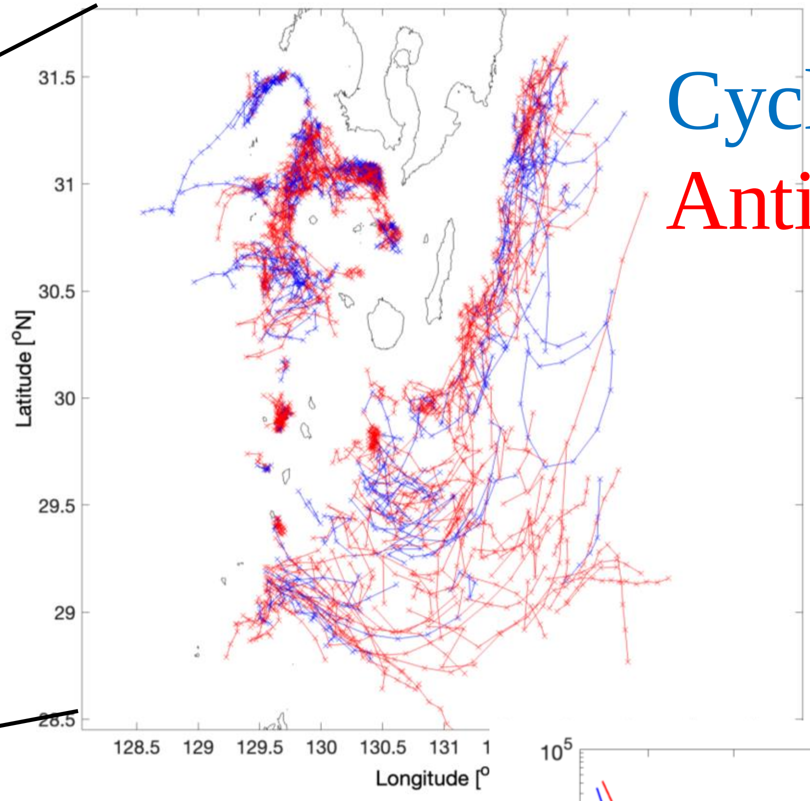
MOVE/MRI.COM-JPN (JMA)
2 km resolution
OW at 5 x $10^{-10}$
Depth at 150 m

700 m resolution
OW at 5 x $10^{-10}$



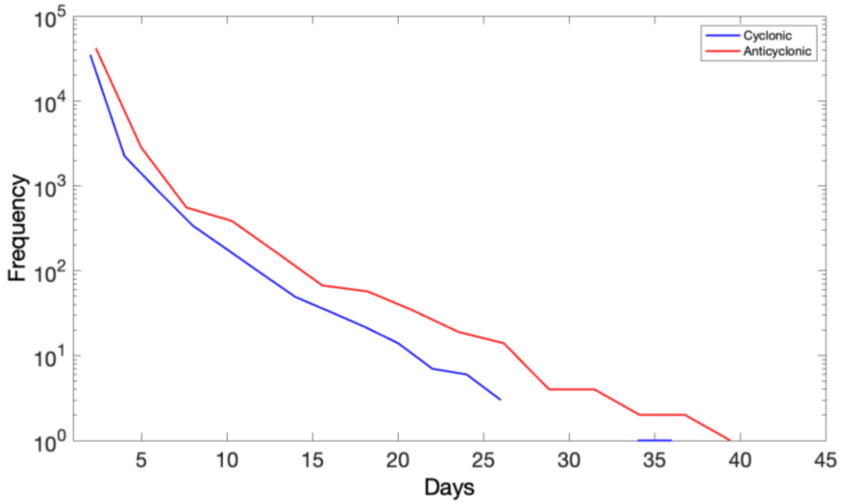
# NEXT STEP: DETECTION IN A WIDER IMAGE




Cyclonic: 47%

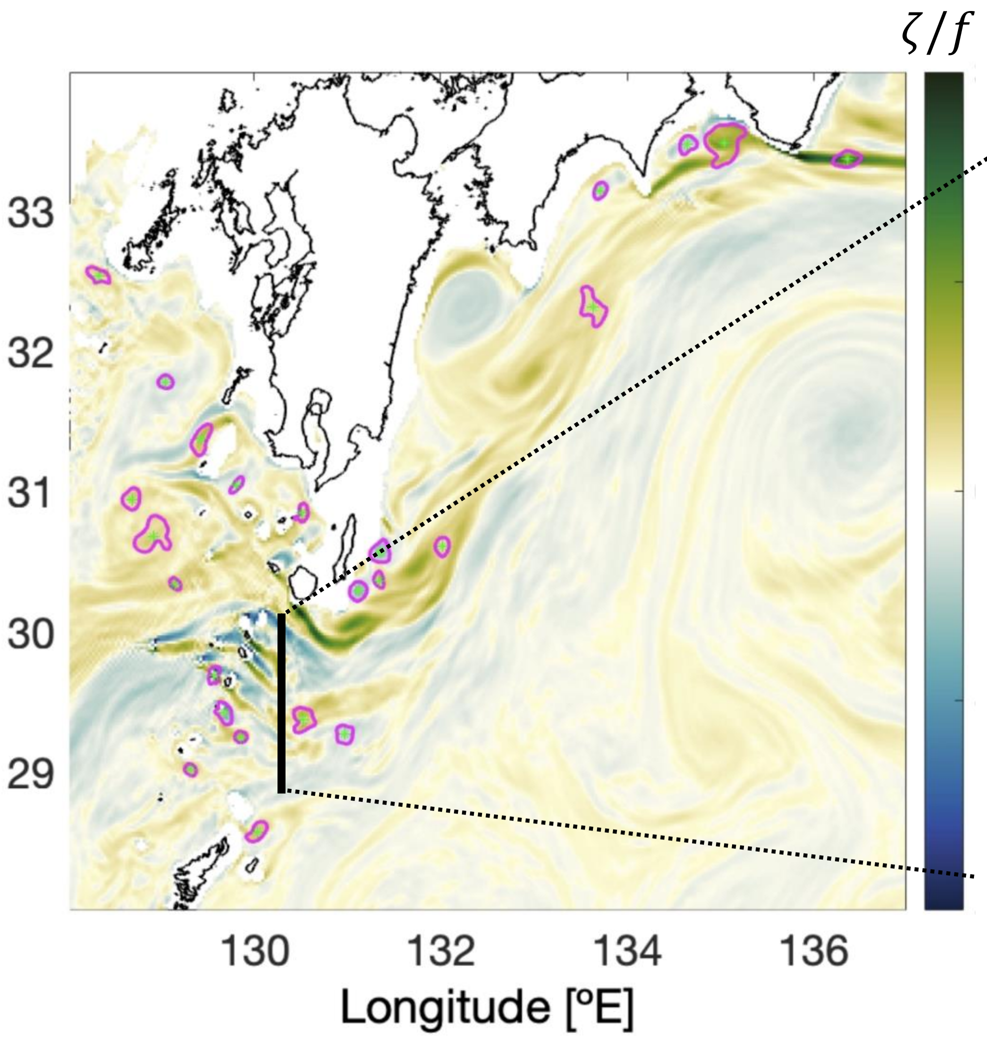
Anticyclonic: 53%

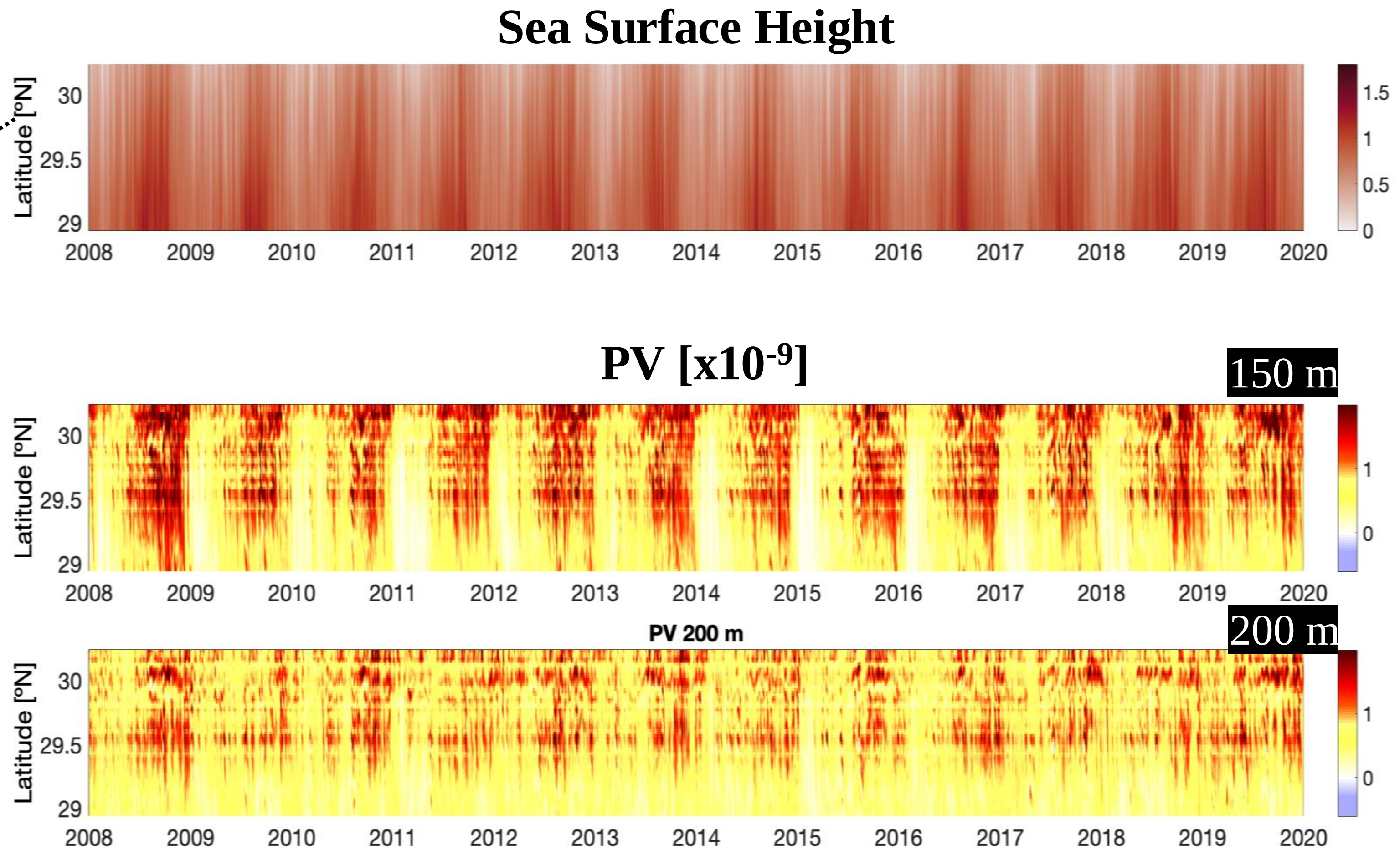



*Anticyclonic eddies live up to 40 days*

# NEXT STEP: DETECTION IN A WIDER IMAGE

Low PV lens variation behind small islands every year




*According to the current position in respect of the islands*

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