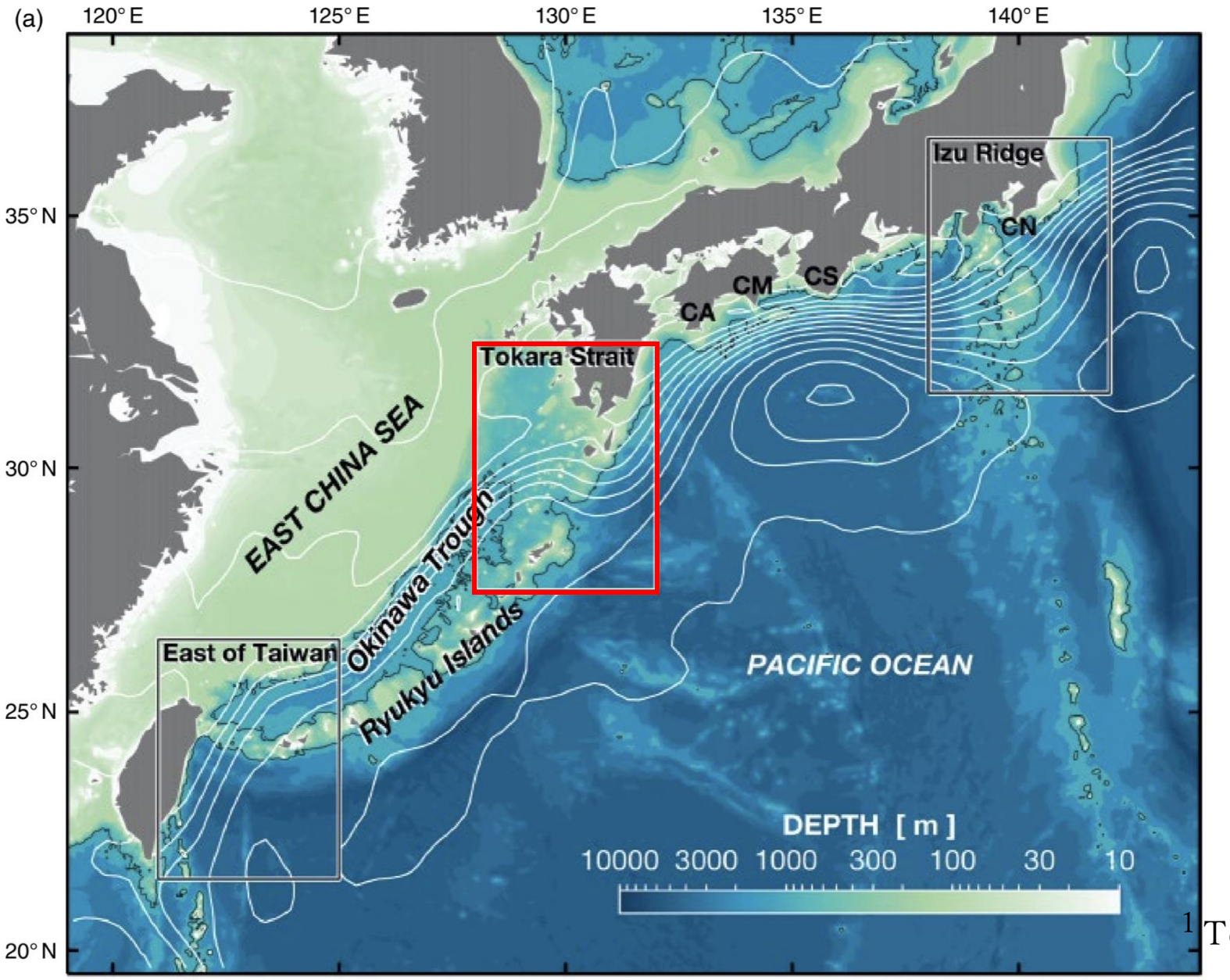

TUMSAT

PICES-2025
Nov 8-14, 2025 | Yokohama, Japan

S10-18336

Submesoscale Coherent Vortices (SCVs) in the upstream Kuroshio: Insights from high-resolution no tide/tide simulations and in-situ observations

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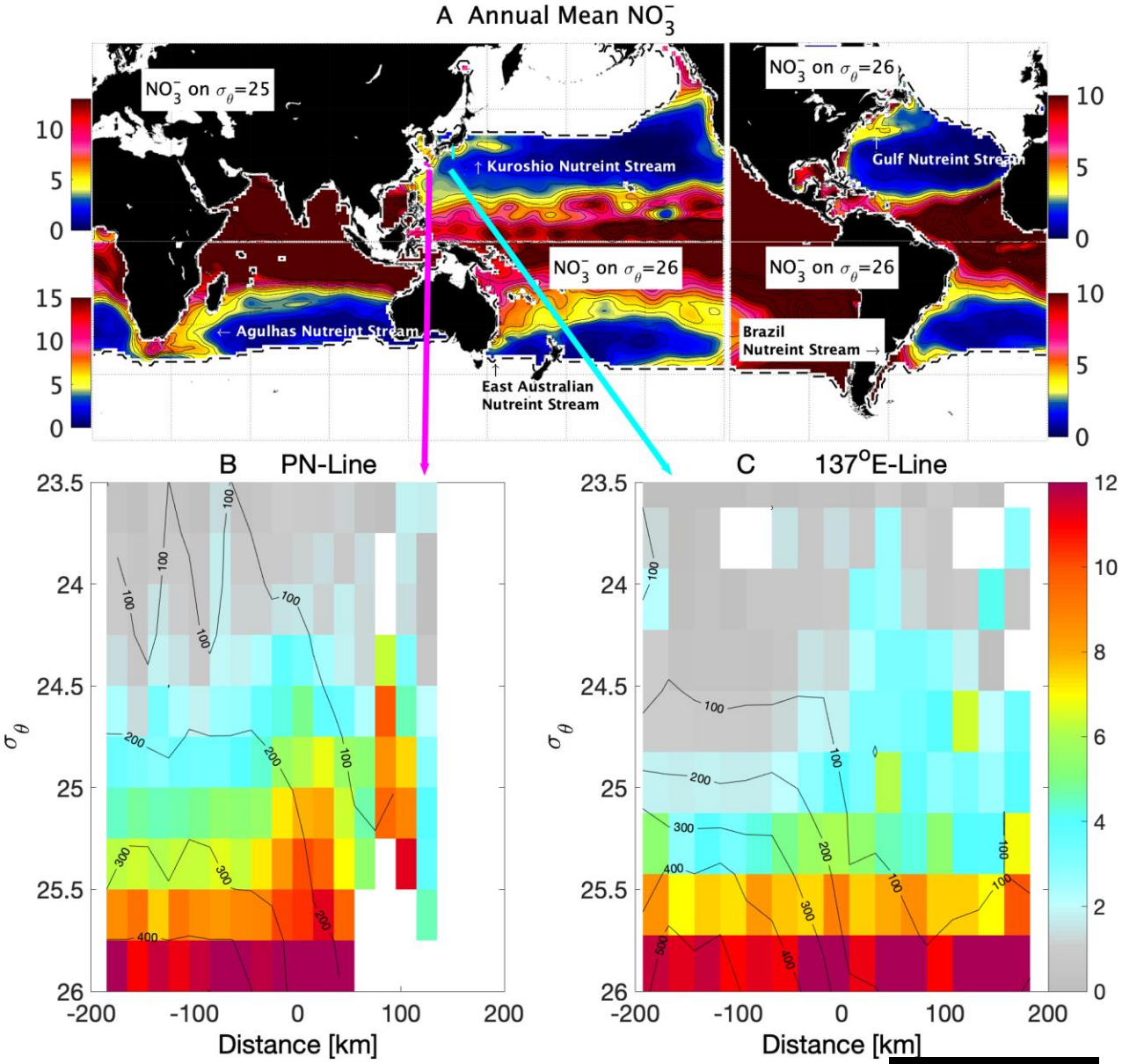
Takeyoshi Nagai[1]

[1] Tokyo University of Marine Science and Technology

Tuesday, 11th November 2025

THE KUROSHIO CURRENT

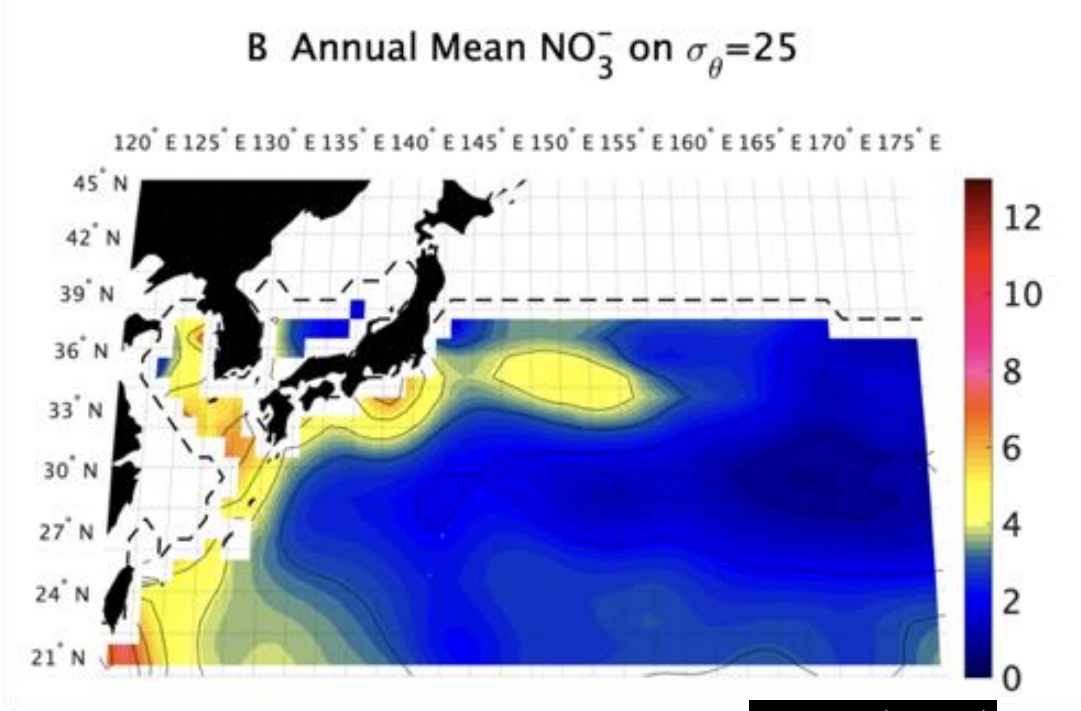


Source: JMA

Kuroshio Paradox (Saito 2019)

Abundant biodiversity despite its oligotrophic surface waters

Fishing industry, local weather, major carbon dioxide sink



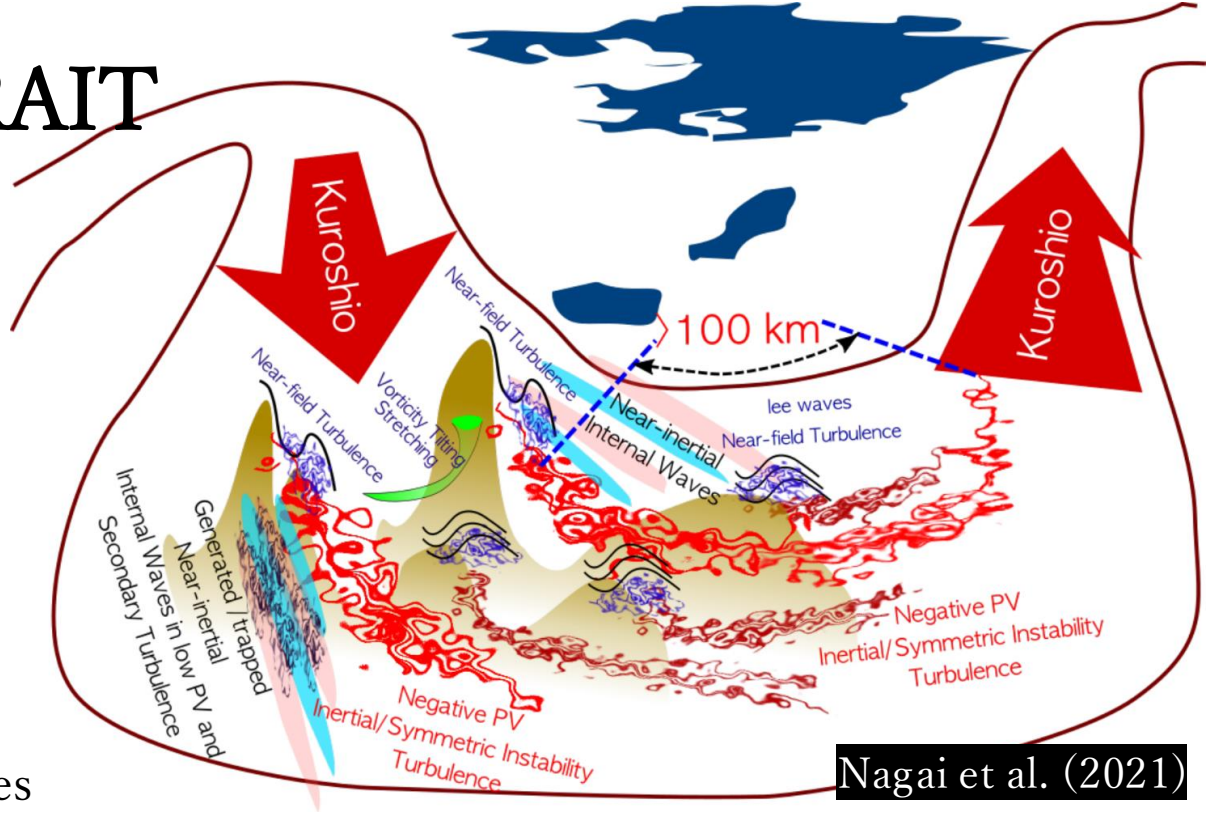
WOA (2023)

STUDY REGION: TOKARA STRAIT

Kuroshio – topography interaction

Strong turbulent mixing
~ enhanced FNO_3
O(1-10) mmol N m^{-2} day^{-1}

Formation of submesoscale structures
subsurface eddies: SUBMESOSCALE COHERENT VORTICES SCV
~ lateral advective transport



Nagai et al. (2021)

SCV: long lifetime and move far from their origin with water mass in their core (McWilliams, 1985)
South China Sea SCV (Zhang et al. 2022) / Kuroshio-Oyashio Extension (Zhu et al. 2024)

OBJECTIVE:
Examine the occurrence (seasonality) and advective transport of nutrients associated with subsurface submesoscale coherent vortices (SCVs)

Extra: To evaluate the potential in capturing SCVs from in-situ observations

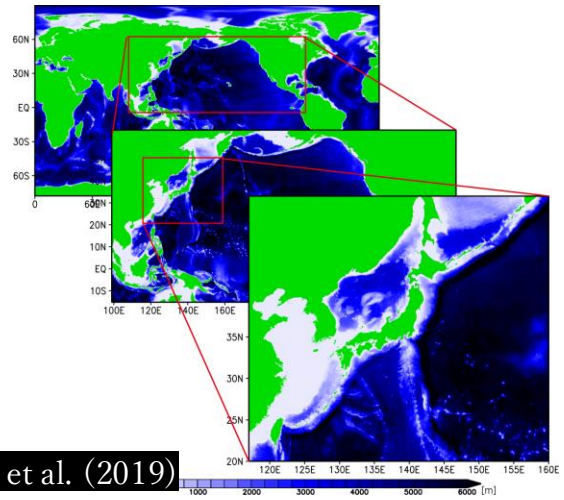
DATA & METHODS

Reanalysis data

DIAS
Data Integration & Analysis System

MOVE/MRI.COM-JPN

- ✓ **Dataset from 2008 ~ 2019**
- ✓ Horizontal grid of 1/33° × 1/50° **(~2 km)**
- ✓ Vertical turbulent mixing - General Length Scale (GLS) parameterization
- ✓ Includes eight major tidal constituents



Sakamoto et al. (2019)

Simulations

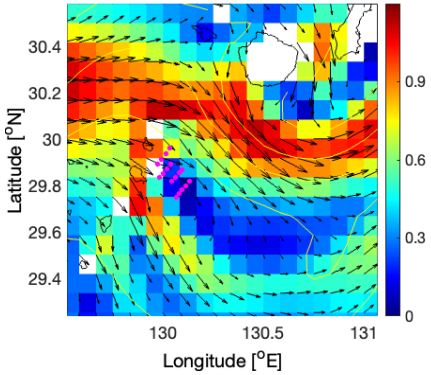
CROCO
Coastal and Regional Ocean COmmunity model

- ❑ Monthly climatological wind from the Comprehensive Ocean - Atmosphere Data Set (COADS)
- ❑ K-Profile-Parameterization (KPP)
- ❑ Horizontal resolution **~700m grid**
- ❑ CASES: w/ TIDAL FORCING
  NO TIDAL FORCING

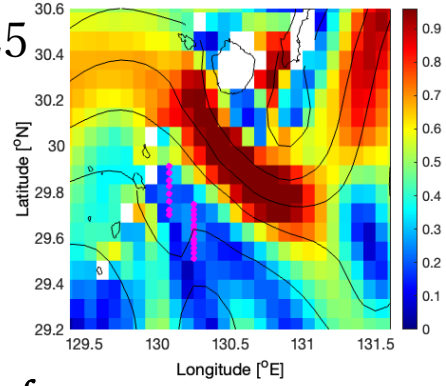
In-situ observations

Transects on:

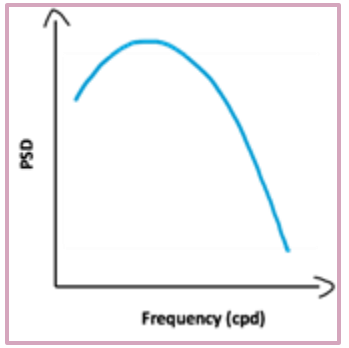
- Jan 3rd, 2025



- Oct 17th, 2025

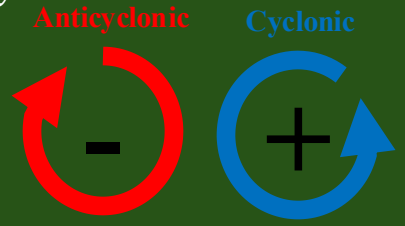


Wavenumber spectra for observations:
Horizontal wavenumber spectra calculated using velocity from shipboard ADCP measurements

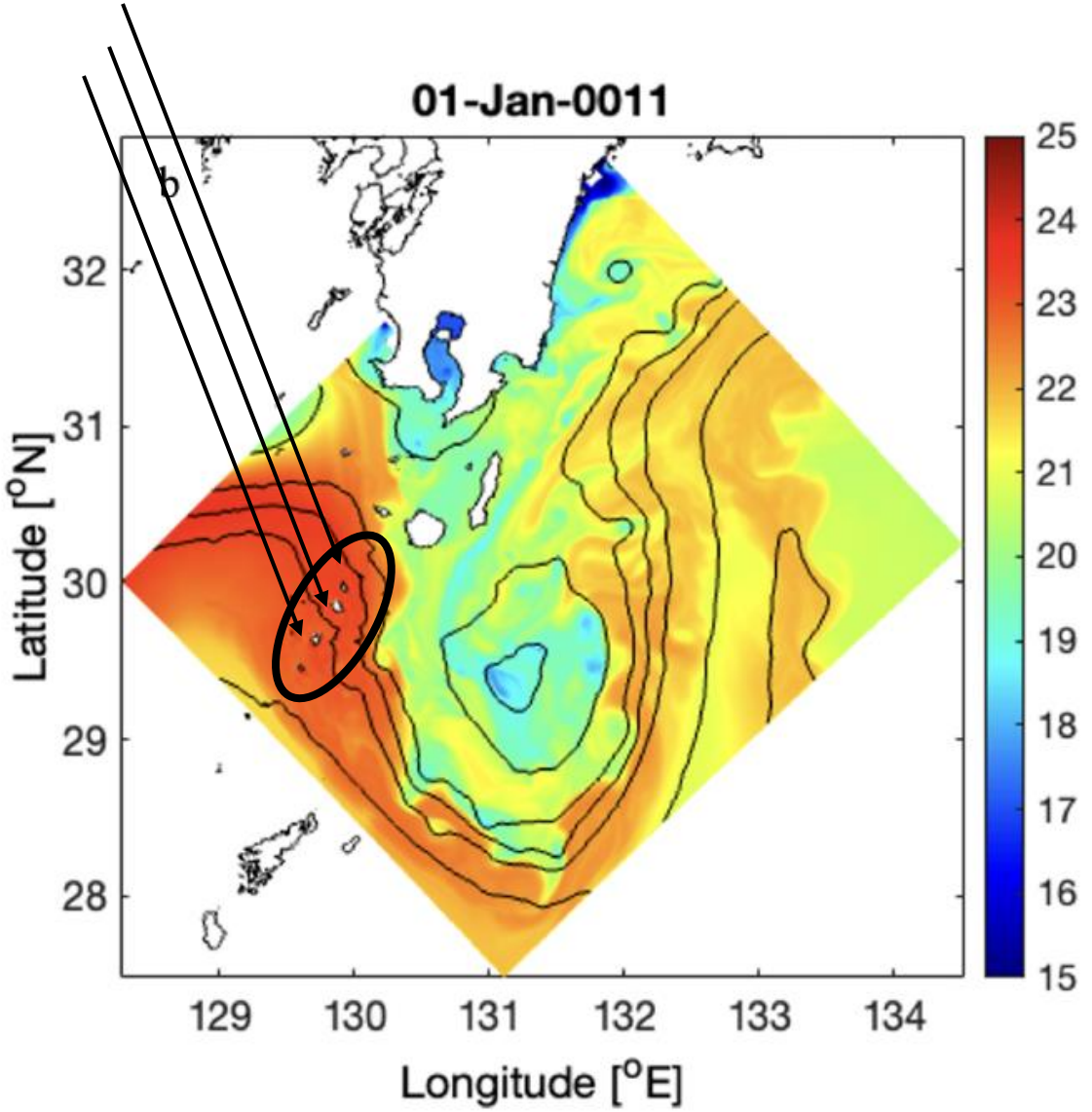


DETECTION & TRACKING OF EDDIES – 200m depth

- Okubo-Weiss parameter OW = -5 x 10^{-10} (smoothed over 3.5km)
- Relative vorticity: cyclonic – anticyclonic



- During tracking, an eddy/SCV is defined if it lasts more than 3 days (MOVE/MRI.COM) or 20h (CROCO)



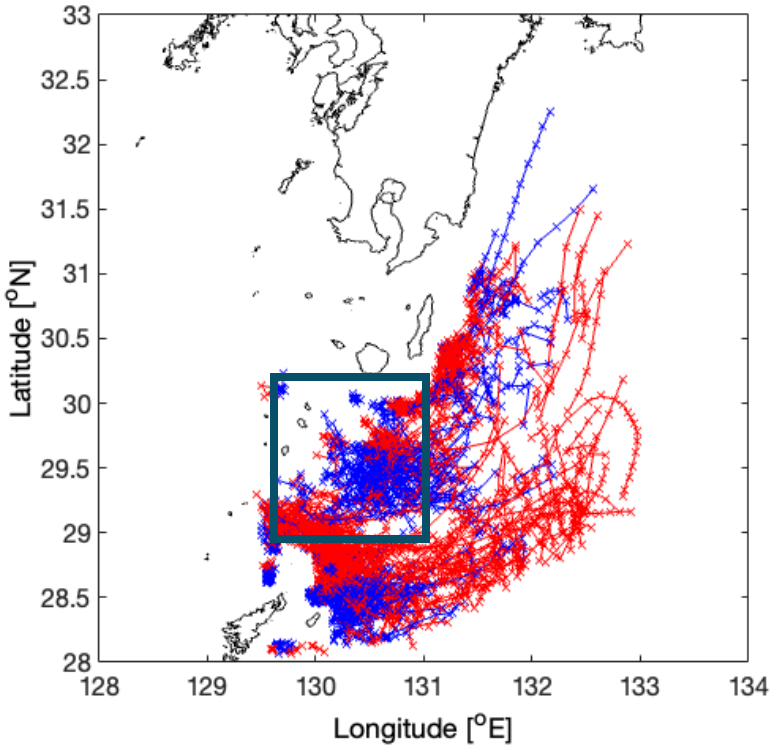
Horizontal resolution ~2km grid

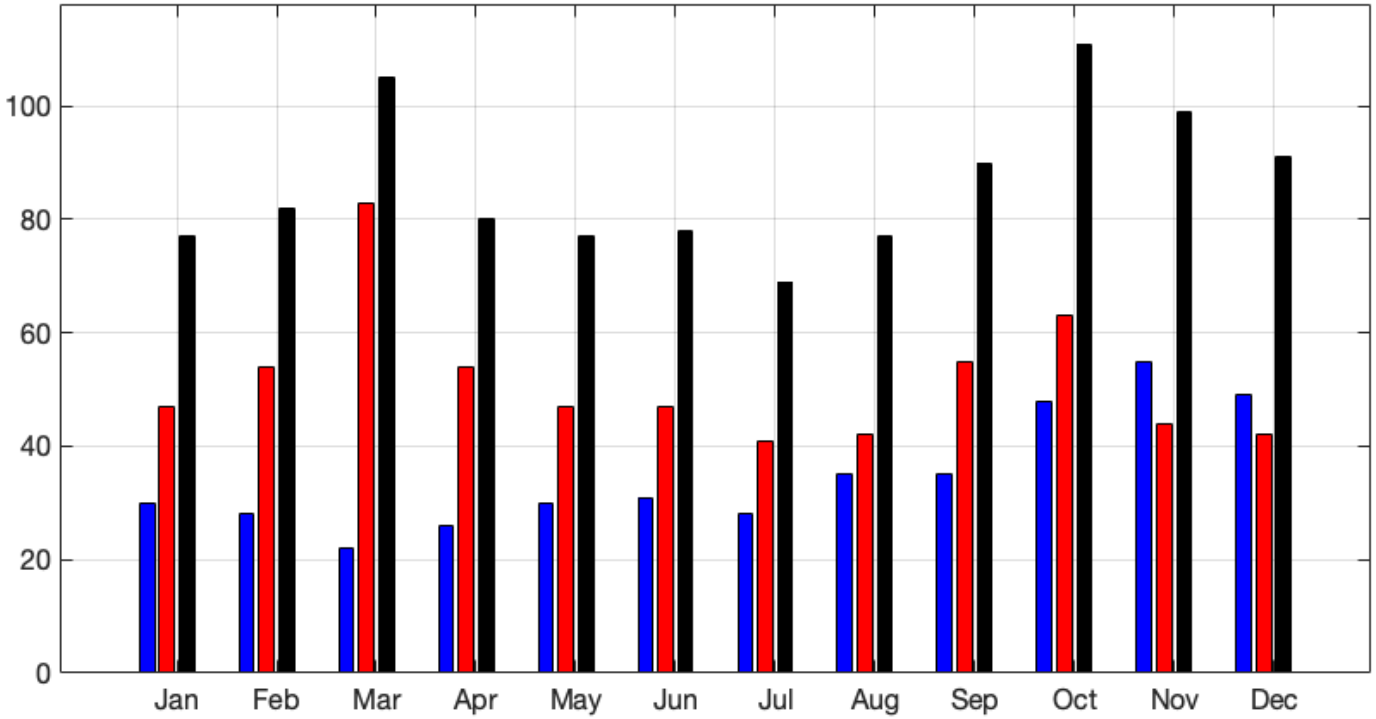
Long-term variation of eddies at subsurface layers – OW = -5×10^{-10}

Climatology (2008-2019) of occurrence (#count)

Anticyclonic ~59%

SUBSURFACE EDDIES (SCVs) – 200m





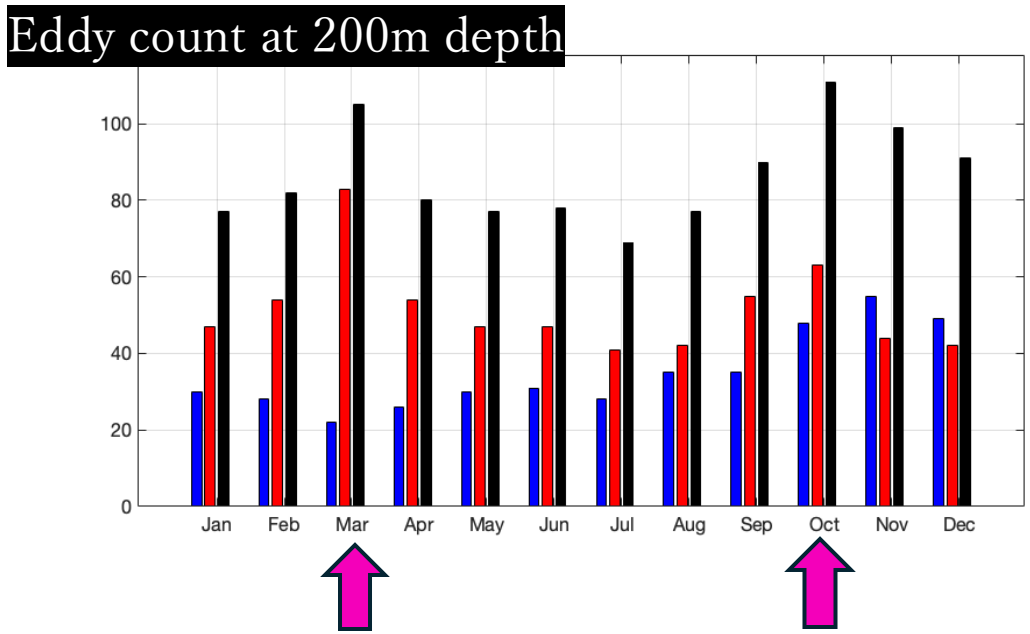
15% of all eddies along japanese coast

- Although subsurface eddies are less in number (#surface=3x#subsurface), their importance rely on how they can carry nutrient-rich waters

Examine **THE OCCURRENCE** and advective transport associated with SCVs

MOVE/MRI.COM-JPN

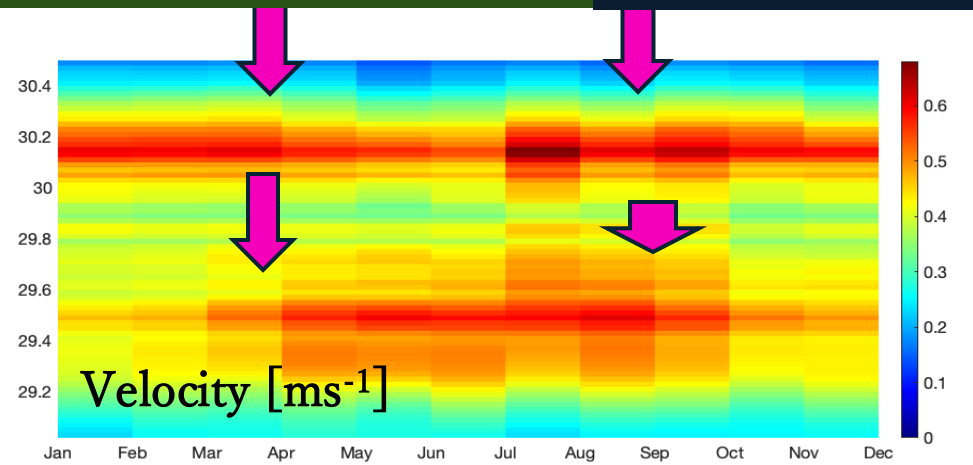
Climatology (2008-2019) of the Tokara Strait at 200m depth:

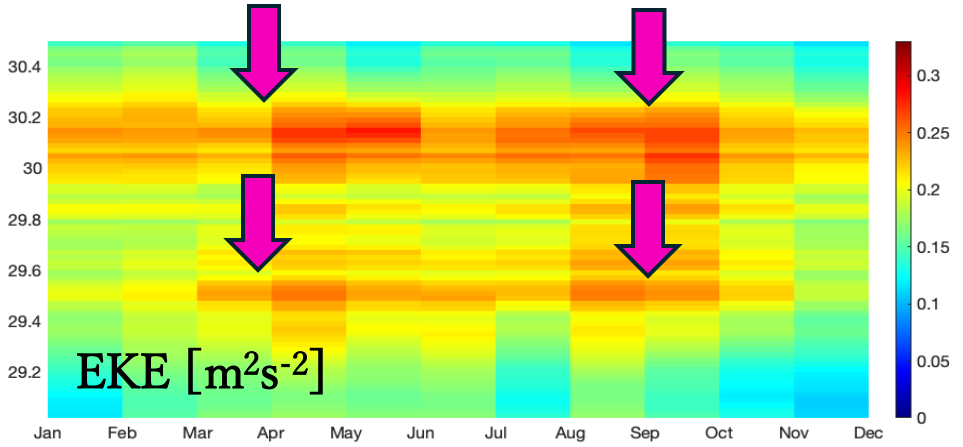


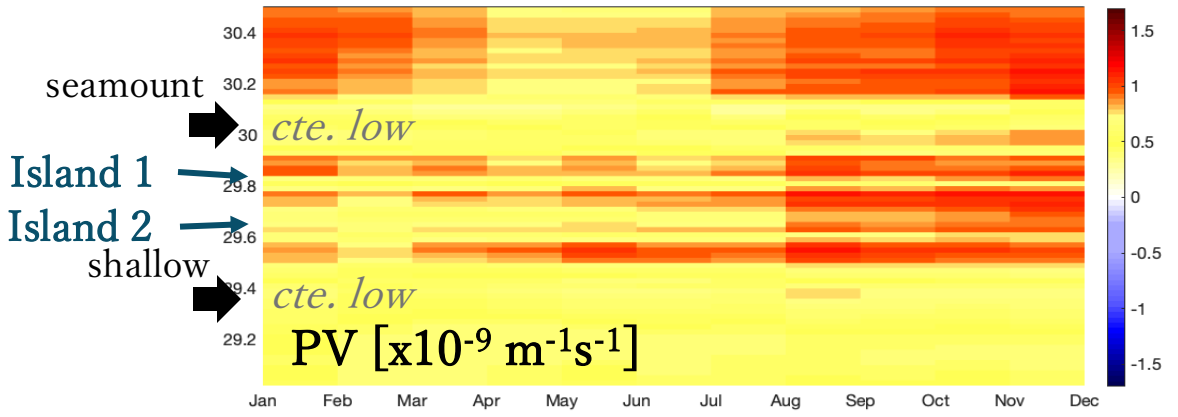
High velocity → High EKE → Low PV

Two peaks #subsurface eddies & velocity/EKE

When the Kuroshio flows directly through the islands (southward shift), it promotes SCVs formation mainly in March and October







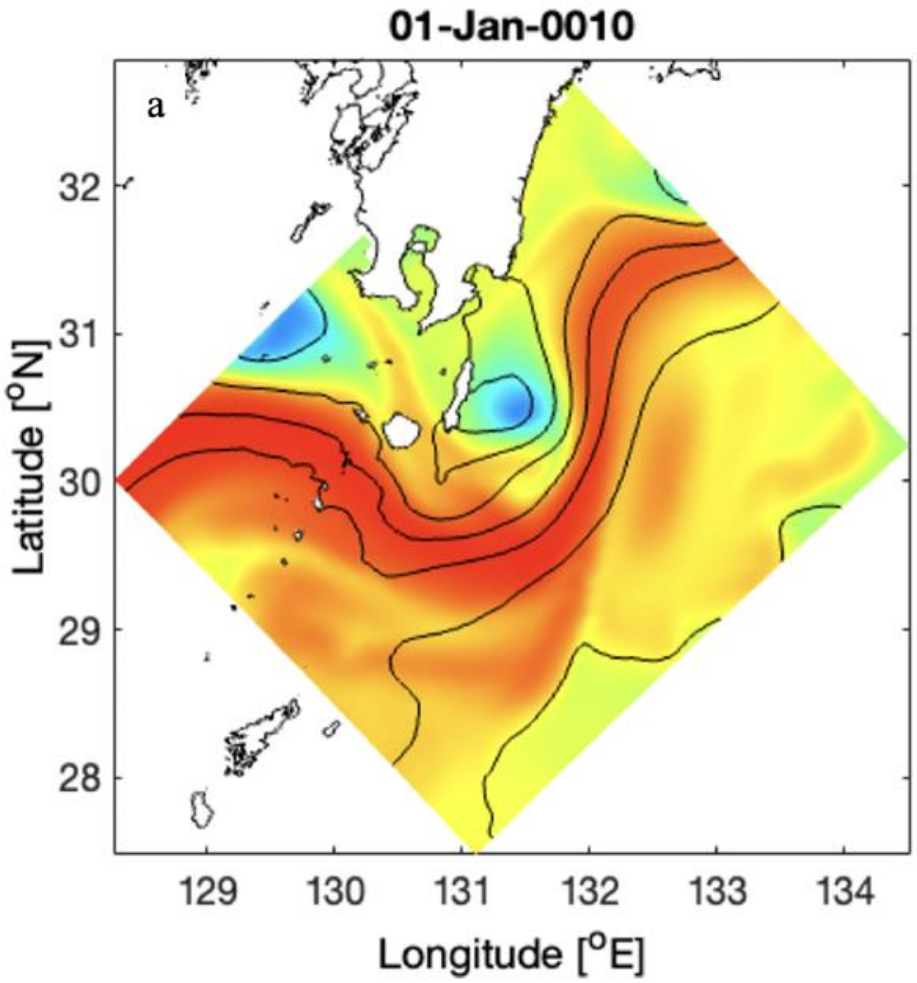
Examine **THE OCCURRENCE** and advective transport associated with SCVs

CROCO
Coastal and Regional Ocean COmmunity model

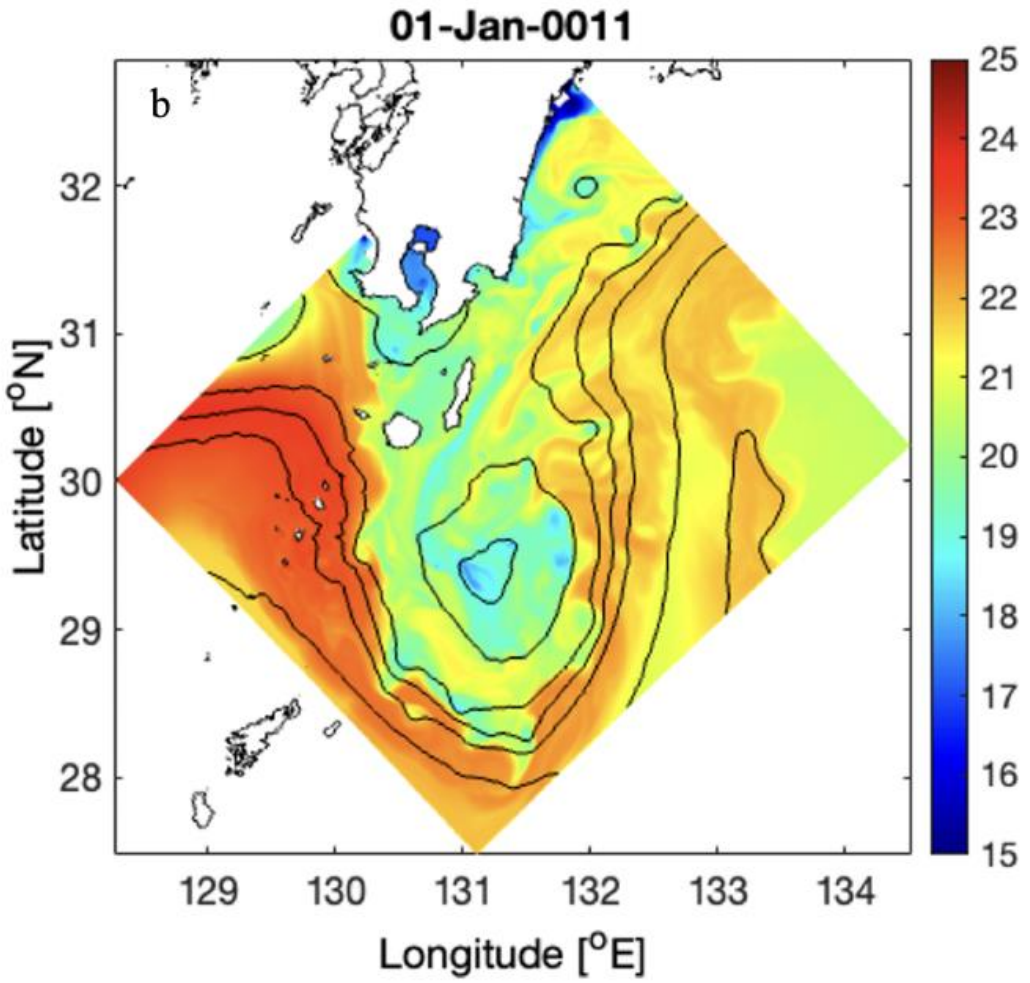
Horizontal resolution ~700m grid

Occurrence (#count) of SCVs at subsurface layers (180 - 220m depth)

NO TIDAL FORCING



UNDER TIDAL FORCING



Q3: Examine THE OCCURRENCE and advective transport associated with SCVs

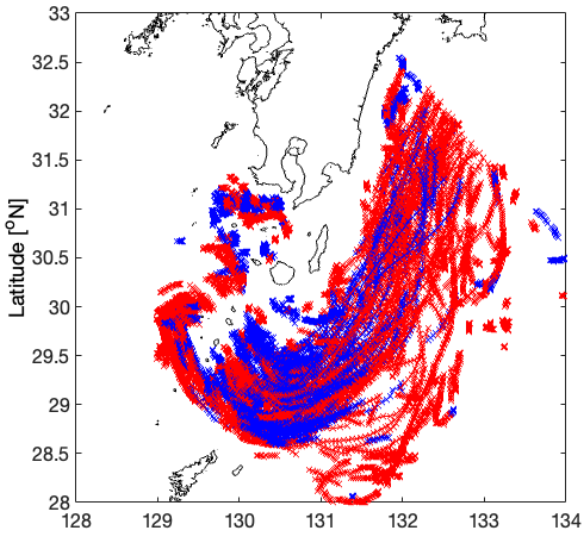
CROCO
Coastal and Regional Ocean COmmunity model

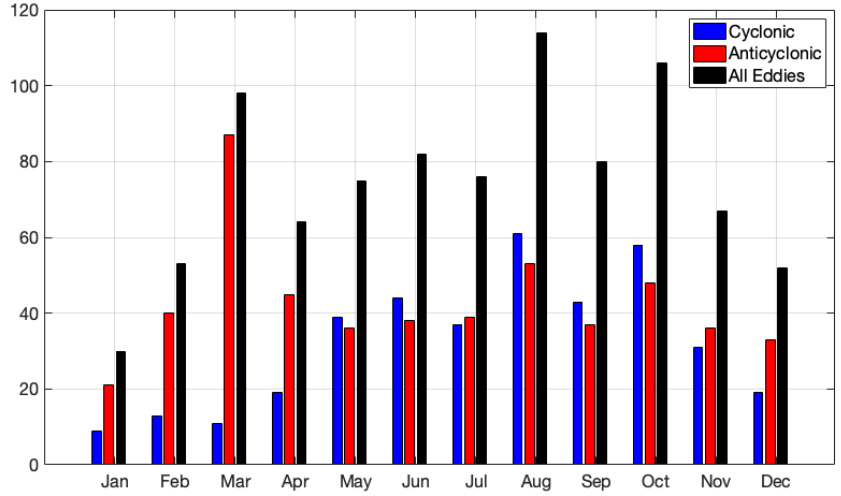
Horizontal resolution ~700m grid

Occurrence (#count) of SCVs at subsurface layers (180 - 220m depth)

NO TIDE

Anticyclonic 57%



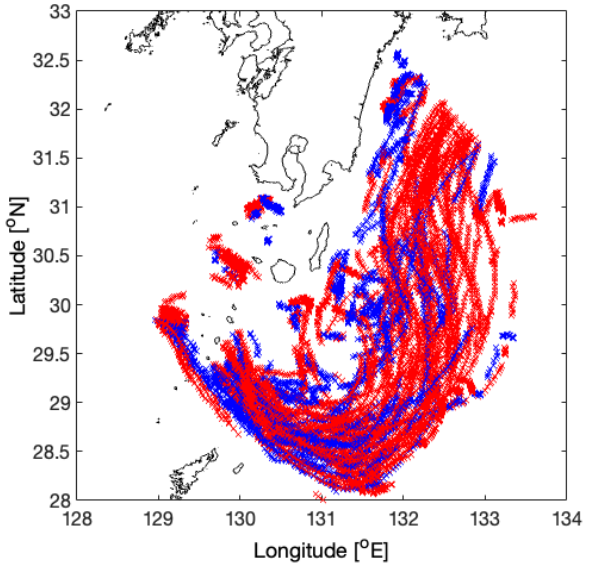


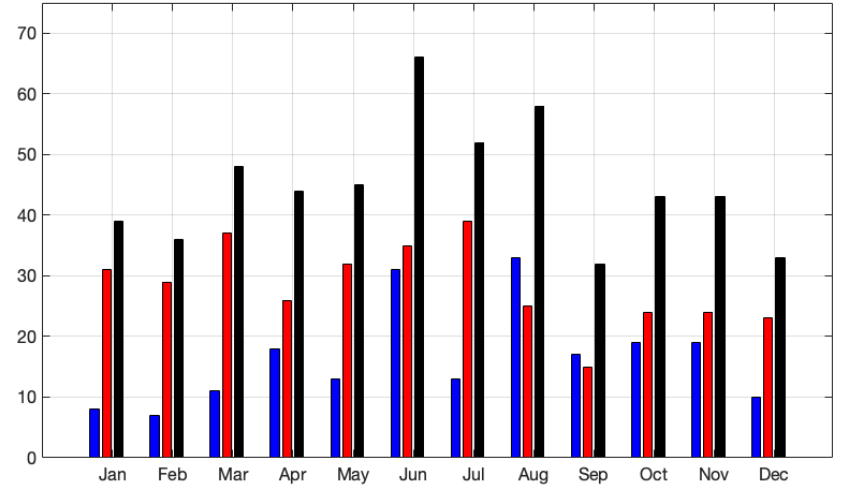
No tide scenario

- Present more subsurface eddies (near double)

TIDE

Anticyclonic 63%





Tide scenario

- Southward shift of SCV trajectories

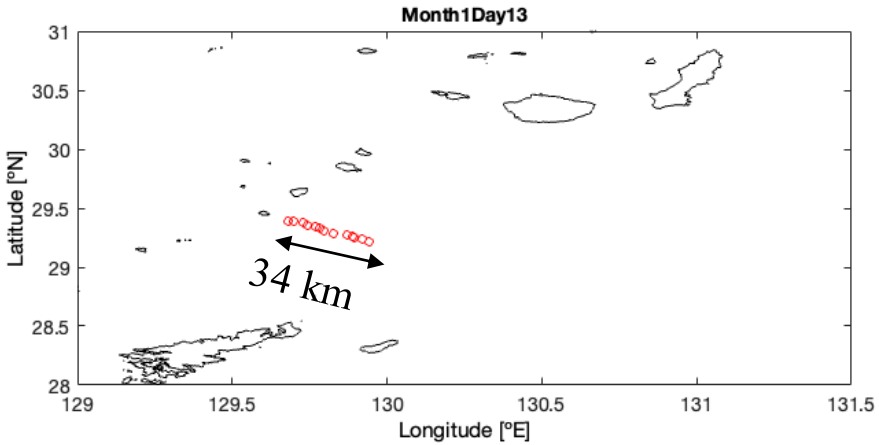
Forced climatological boundary and surface conditions; they cannot explicitly capture interannual variability

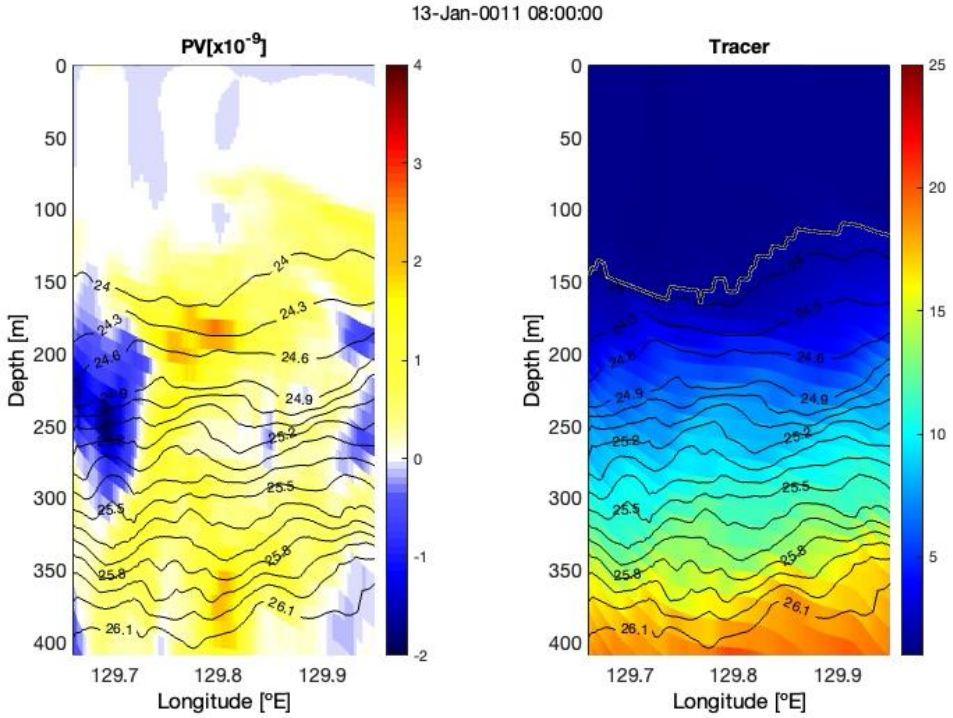
Q3: Examine the occurrence and **ADVECTIVE TRANSPORT** associated with SCVs

CROCO
Coastal and Regional Ocean COmmunity model

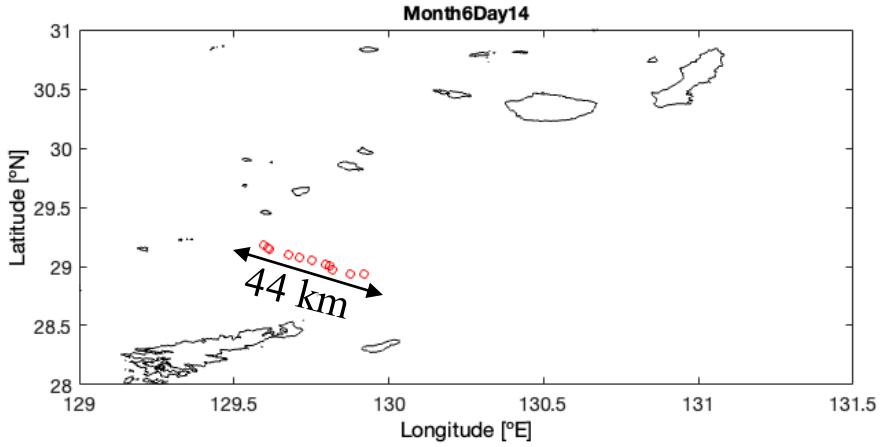
Horizontal resolution ~700m grid

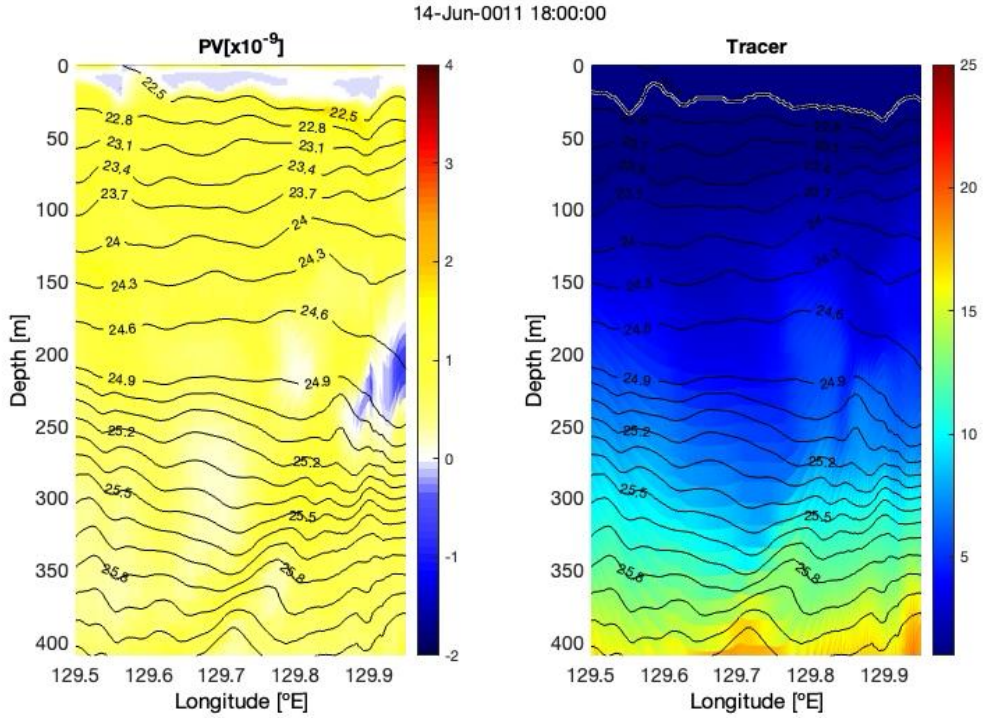
Anticyclonic





Cyclonic





CROCO
Coastal and Regional Ocean COmmunity model

Horizontal resolution ~700m grid

PASSIVE TRACERS

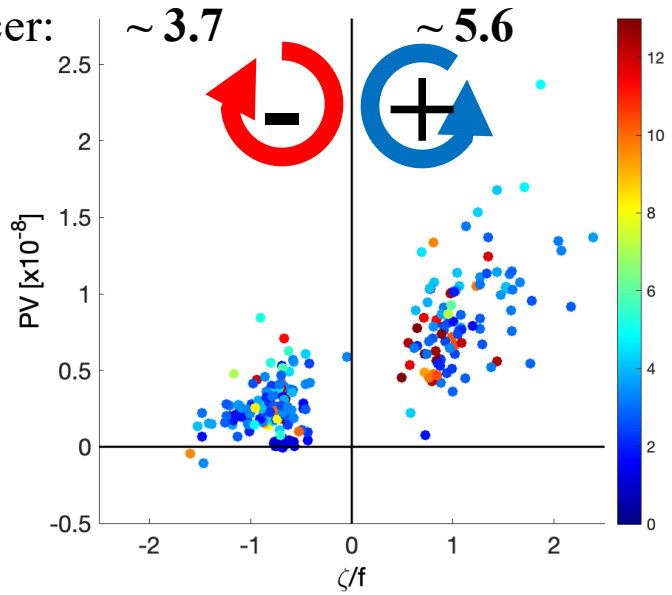
- Initial and boundary conditions: derived from **nitrate distribution** of the ecosystem model, BioEBUS in the parent grid, interpolated onto the nested child grids

- Tracer evolve passively without any biogeochemical sources or sinks

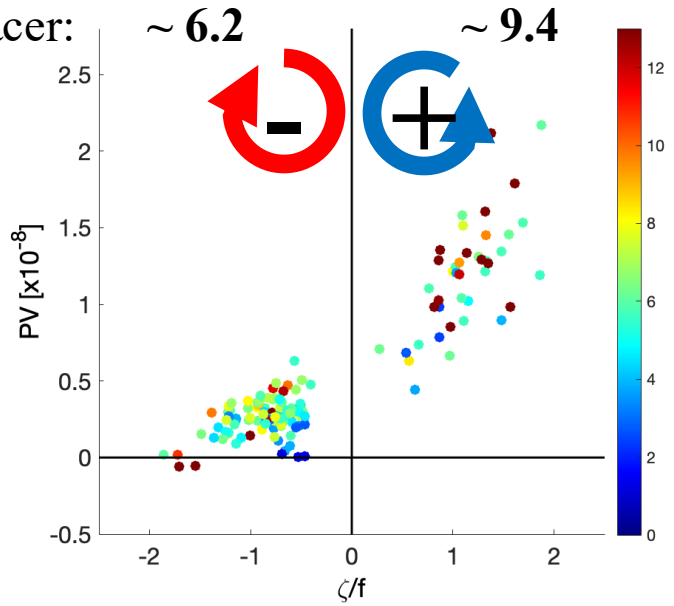
Q3: Examine the occurrence and **ADVECTIVE TRANSPORT** associated with SCVs

CROCO
Coastal and Regional Ocean COmmunity model

NO TIDE



TIDE



- Values remain similar from the start (first 8hours) to end (last 8hours) of the eddy
- Tracers injected **under tide scenario** are higher

Kuroshio – island topography interaction

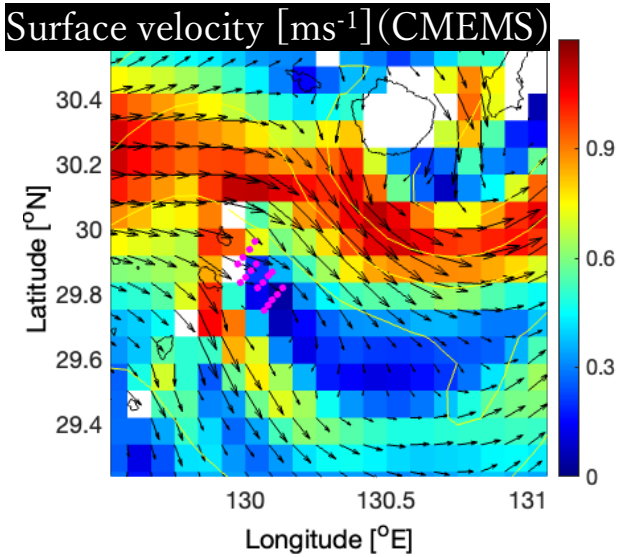
→ SCV formation:
Although tidal flows may inhibit them but enhance tracer injection when SCVs do form

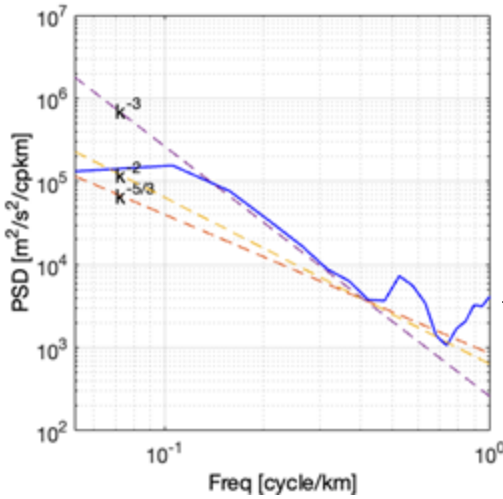
→ nutrient-rich subsurface waters entrained within SCVs and are advected downstream

EXTRA: Potential for capturing SCVs from in-situ observations

January 3rd, 2025

35 km distance
Duration of ~7[h]

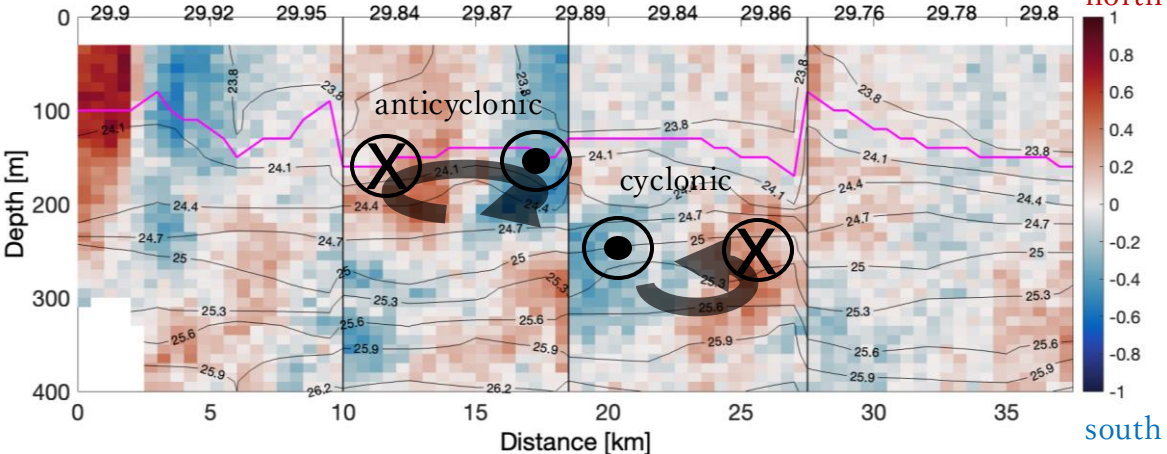




Wavenumber spectrum(150-350 m):

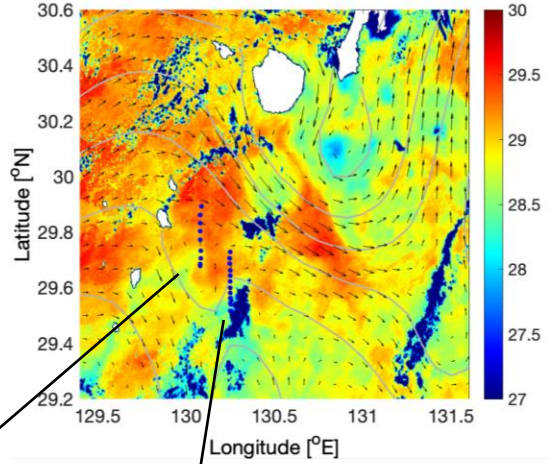
k^{-2} → $k^{-5/3}$ at higher wavenumber 1–10 km
By submesoscale and ageostrophic flows
(possibly internal waves too)

Velocity [ms^{-1}]: meridional component

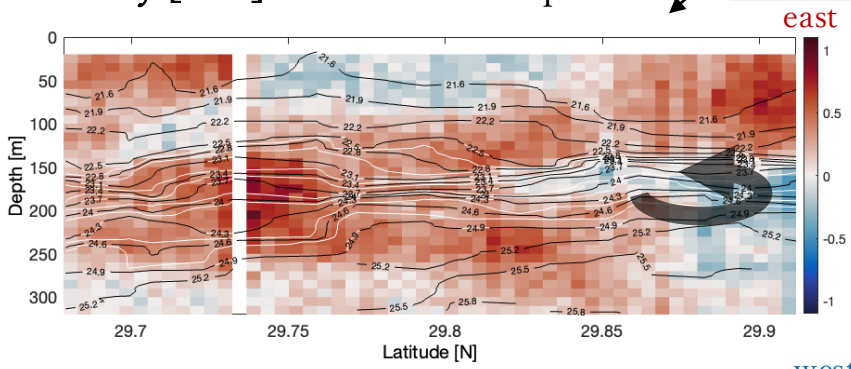


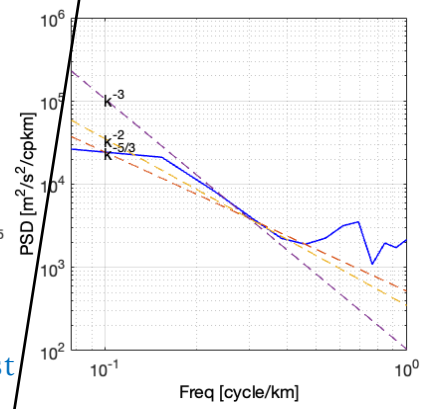
October 17th, 2025

~26 km distance
& duration of ~4-5[h] /each transect

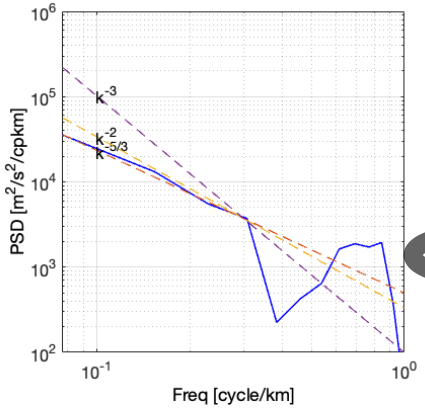


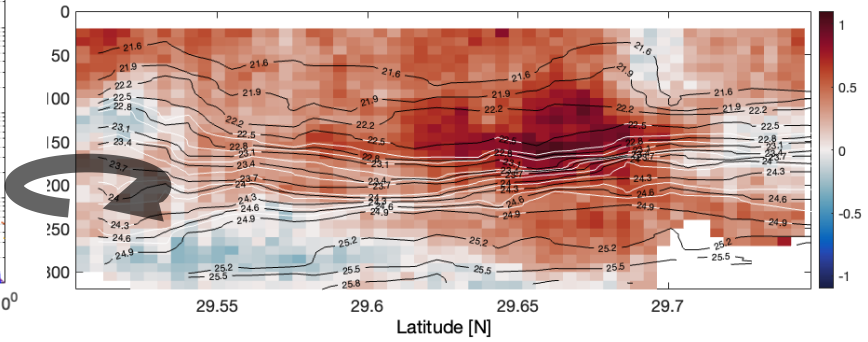
Velocity [ms^{-1}]: meridional component





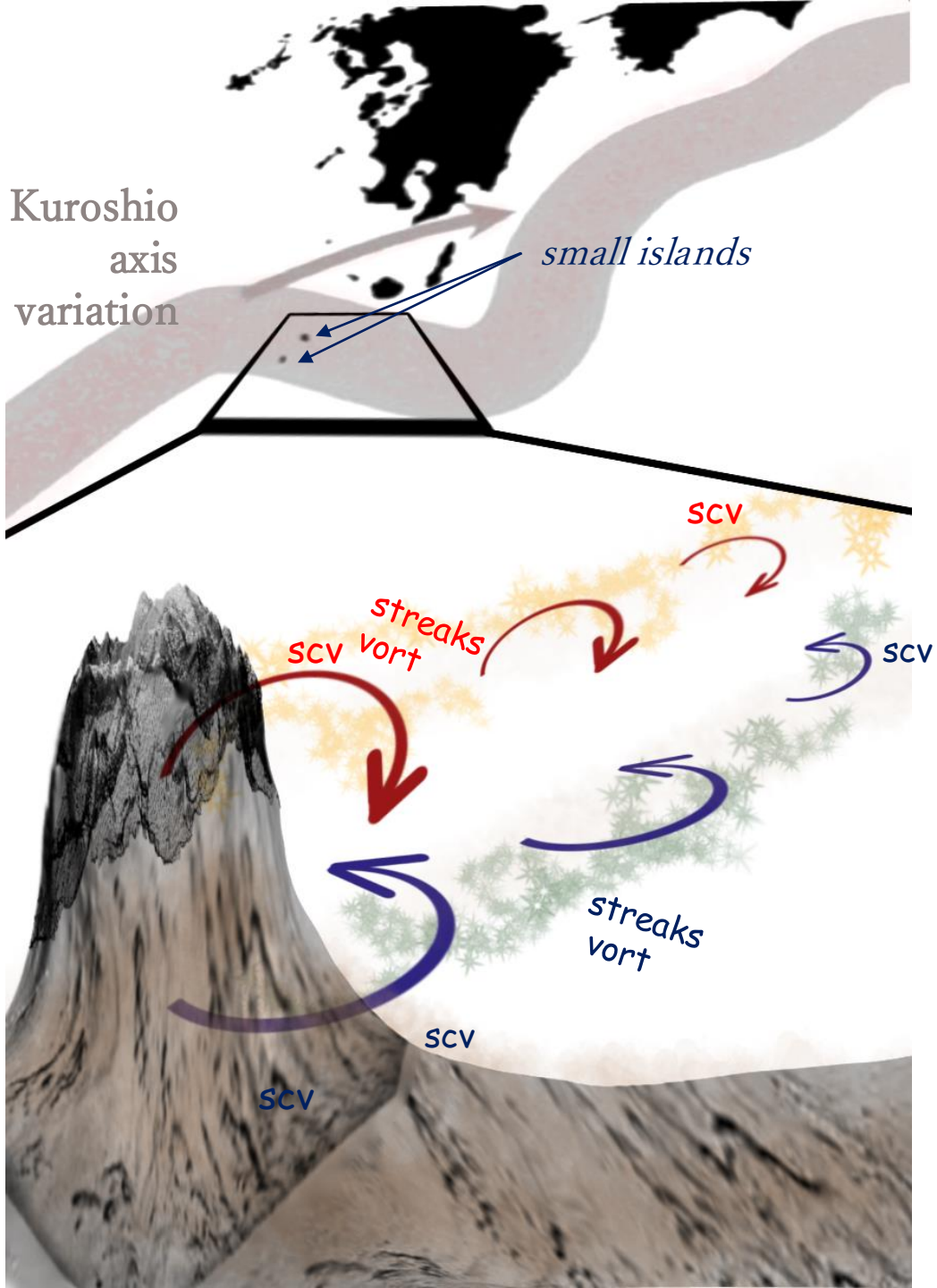
Wavenumber spectrum(100-300 m)





CONCLUSIONS

Examine the occurrence and advective transport of nutrients associated with SCVs



scv