Potential impact of ocean circulation on Japanese eel larvae migration

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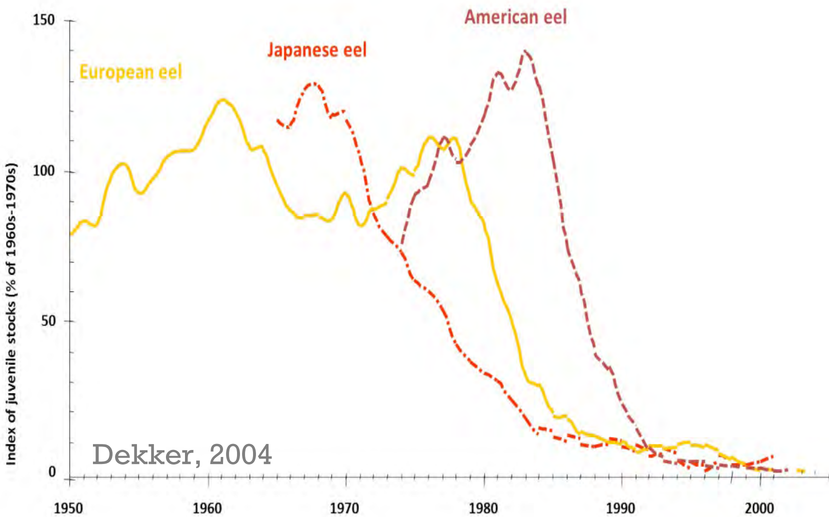
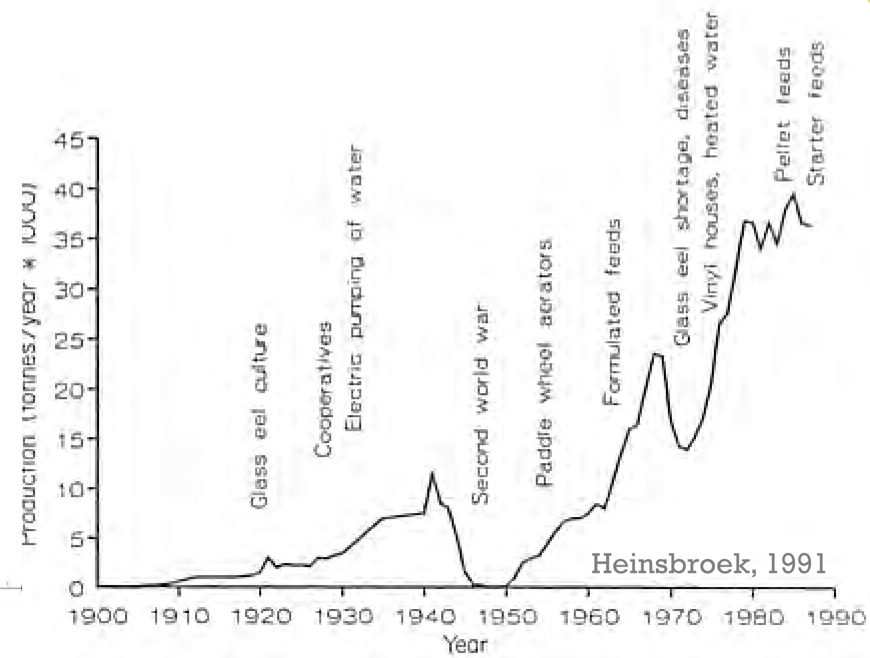
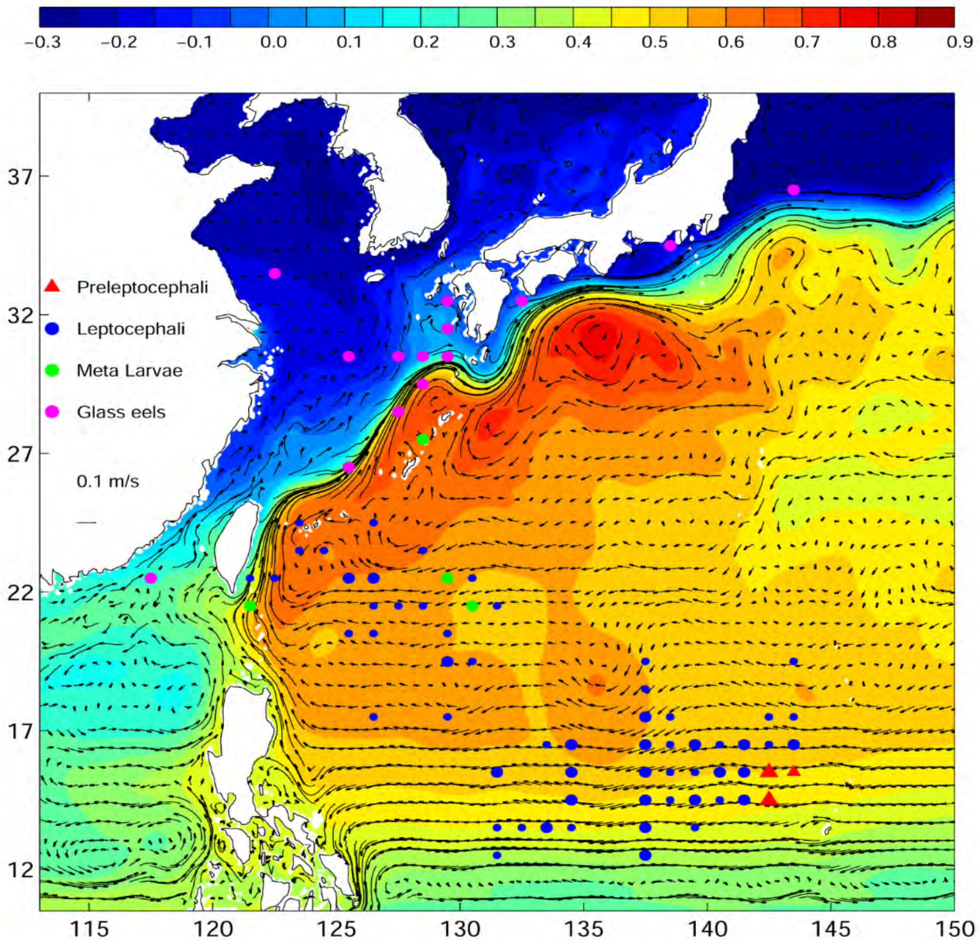
Japanese eel (*Anguilla japonica*)





- The Japanese eel is listed as endangered on the IUCN red list
- Japan consumes 75-80% of world eel production
- High prices of eel and declining catch that created interests in Europe in the culture of European eel in recent decades

Past 52 years observation [Shinoda et al., 2011]

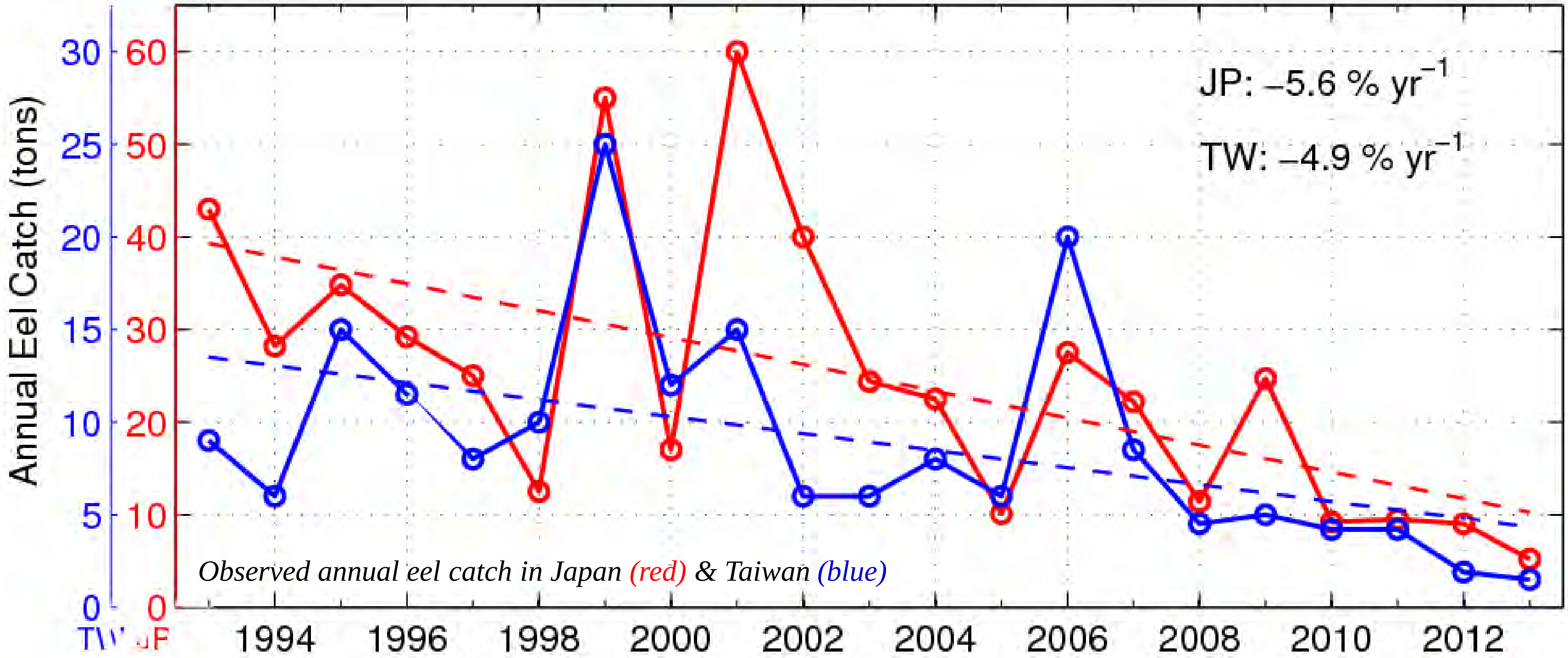


- Spawning area – Tsukamoto (1992)
- Eel larvae distribution is likely related to ocean circulation

Limitation of observation →Application of model simulation

- ➢ Seaward migration
- ➢ Migration swimming strategies
- ➢ Role of ocean current – affecting migration or recruitment?

Ocean circulation → declining of eel catch?



Reasons for recruitment decline:

- Overfishing and habitat loss

For variation:

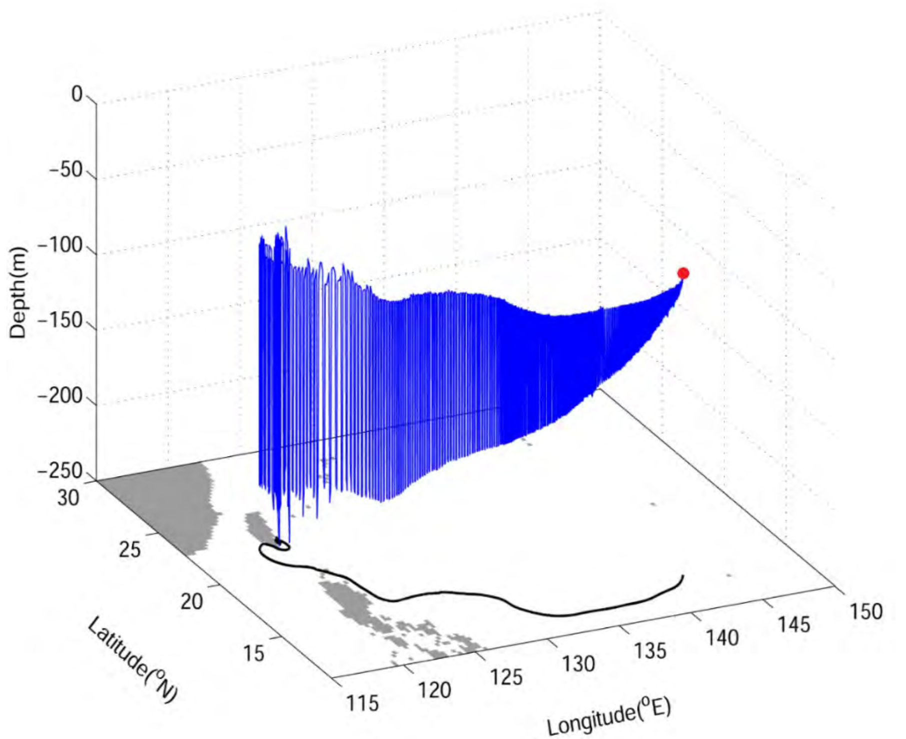
- Ocean-climate change (ENSO, PTO)

Present work proposed that ocean circulation also plays a role

Virtual eel simulation

Release plan

- Release area: 140-143E, 12-15N
- Release time: May-July, every 5 days
- Study period: 1993-2013
- Tracking: 240 days



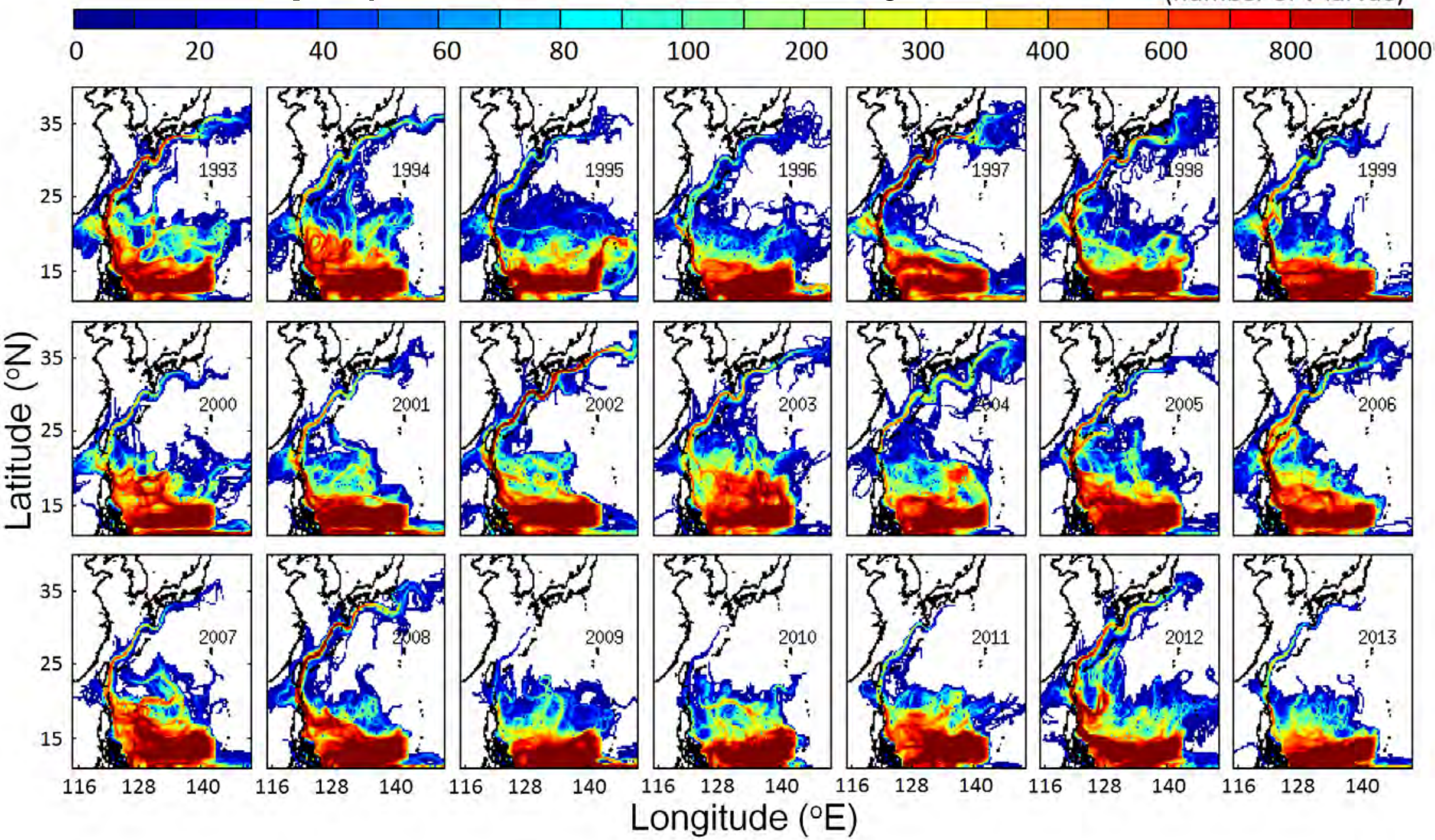
- Tracking scheme:
  3D particle tracking with 4th Order Runge-Kutta method
  (Ohashi & Sheng, 2015)

- Swimming behaviors:
  size dependent based on observation
  - horizontal swimming
    →0.0006×age (m/s)
    (0.06 m/s on day 100)
  - diel vertical migration
    →50m at night
    →50+0.75×age (m) daytime
    (125 m on day 100)

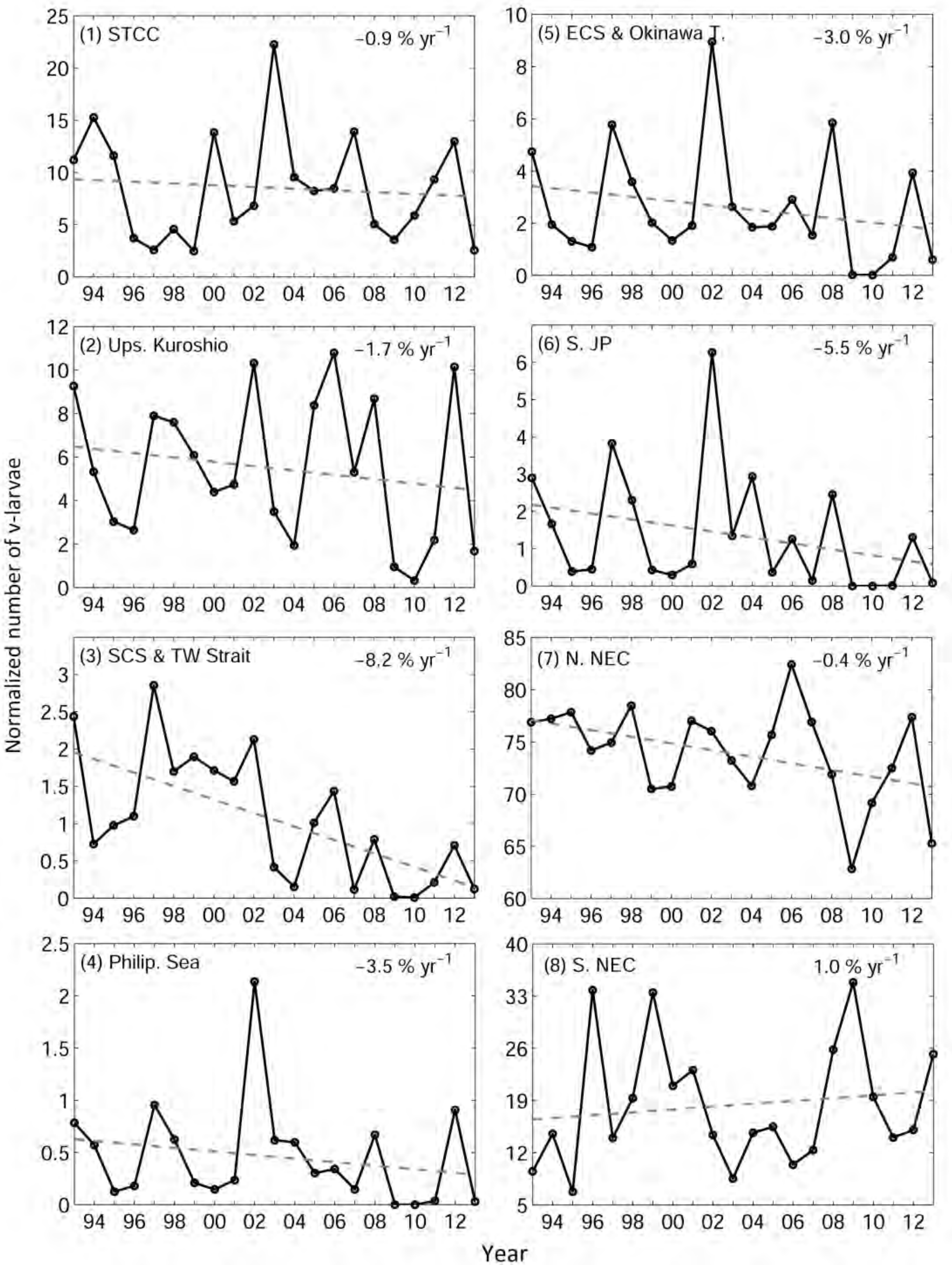
- Ocean currents:
  JCOPE2 (dx=dy=1/12°)
  (Miyazawa et al., 2009)

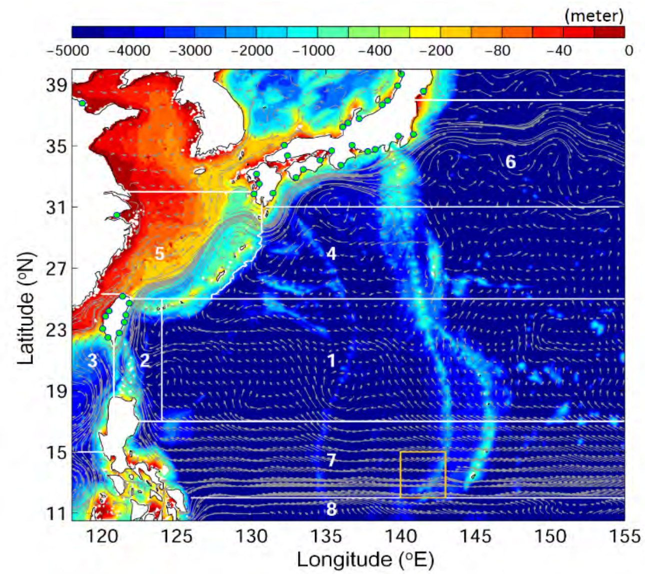
Visitation frequency (1993- 2013)

**Visitation frequency : number of v-larvae visited at each grid*



Visitation frequency in each sub-domain (Unit=20,000 v-larvae)



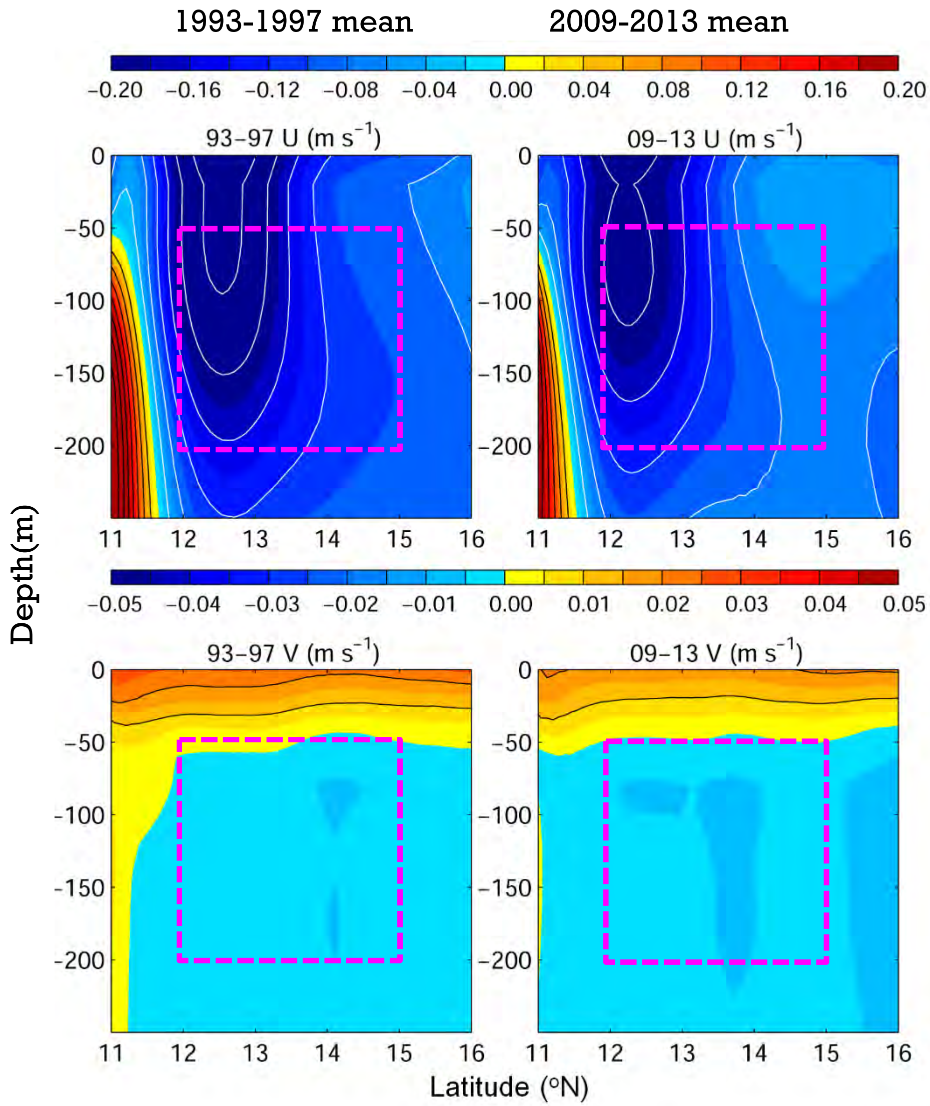


- Distribution of v-larvae decreases in all regions north of NEC; V-larvae move to south of NEC instead

→ V-larvae tend to move southward in recent years in comparison to early decade.

What had been changed in ocean circulation?

Change of North Equatorial Current (NEC)

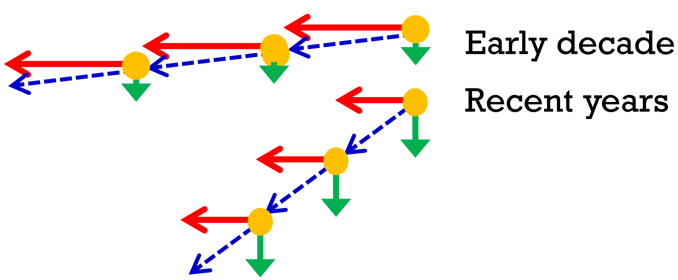


In past two decades:

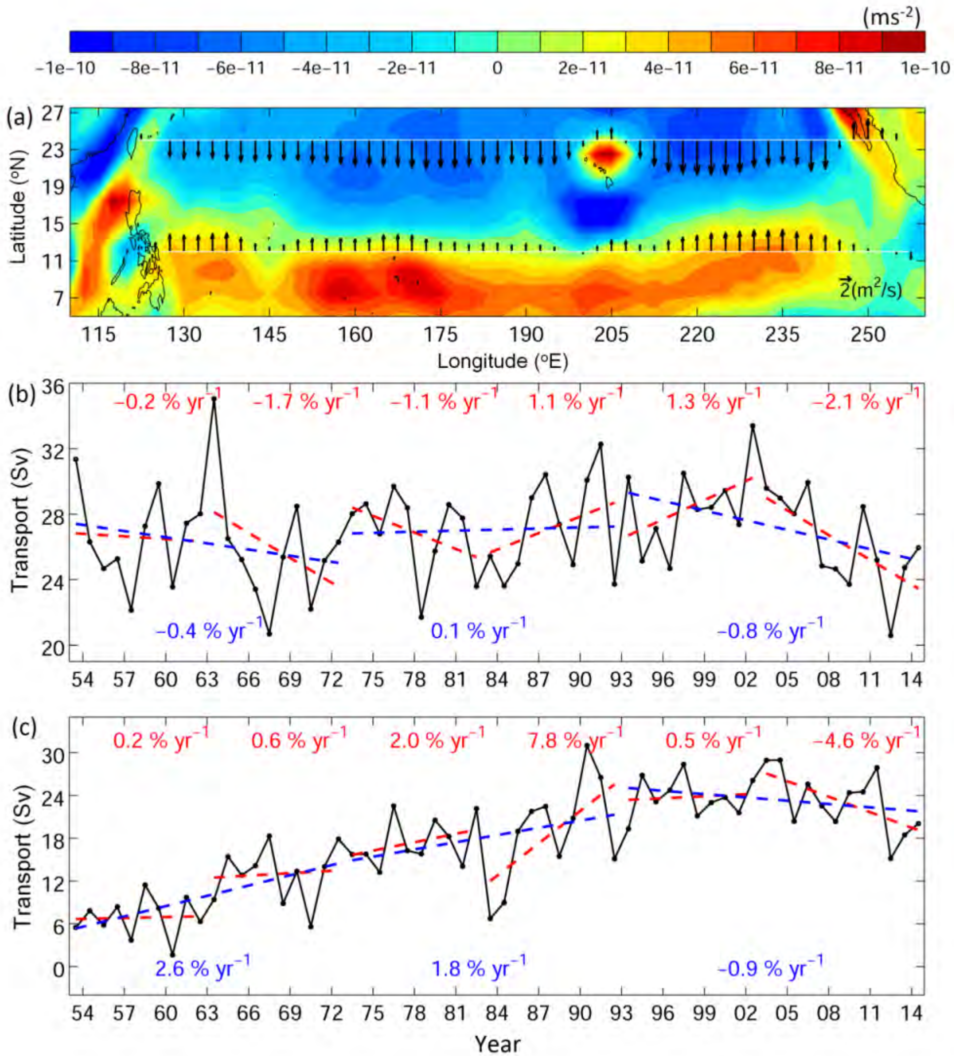
- NEC moves southward and gets weaker, so that westward current at 12-15N becomes weaker
- Subsurface (depth <50m) meridional current south of 14N gets more southward

Therefore:

The weaker westward flow makes v-larvae stay in NEC region longer, so that the southward current, although weak, can effectively brings more v-larvae southward.



Cause of changing ocean circulation: Large scale wind

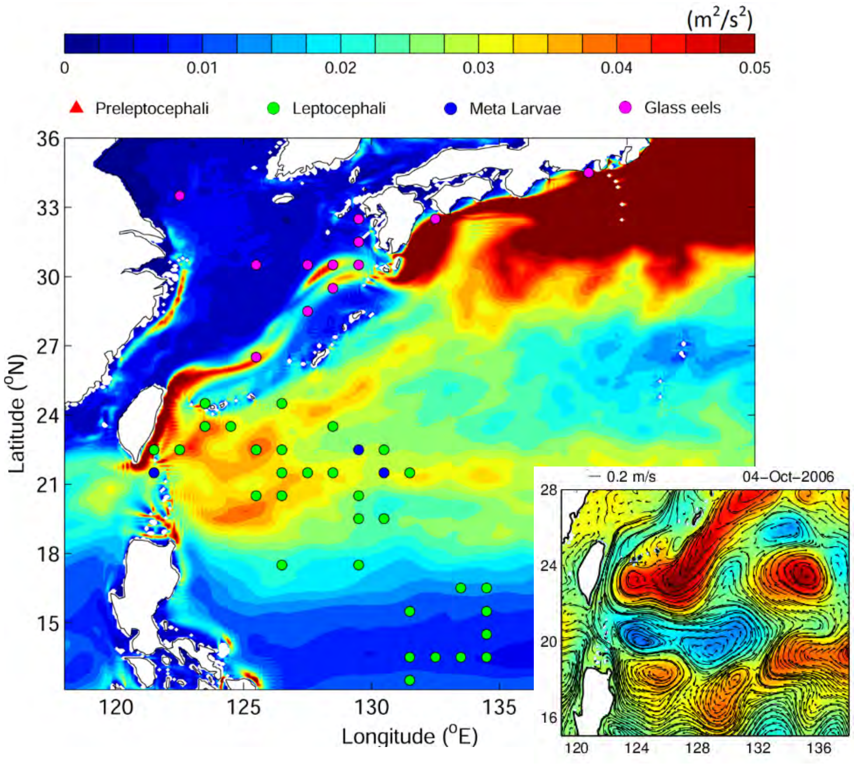


- Decadal variation is shown in past 60 years.
- The subtropical & tropical WSC and the corresponding Sverdrup transport are weakened in past 2 decades, especially after 2000

→ Weakening of NEC
→ Strengthening of southward subsurface current
→ Weakening of Kuroshio

Therefore, v-larvae distributed towards south, and eel catch in east Asia decreased

Fish larvae & mesoscale eddies



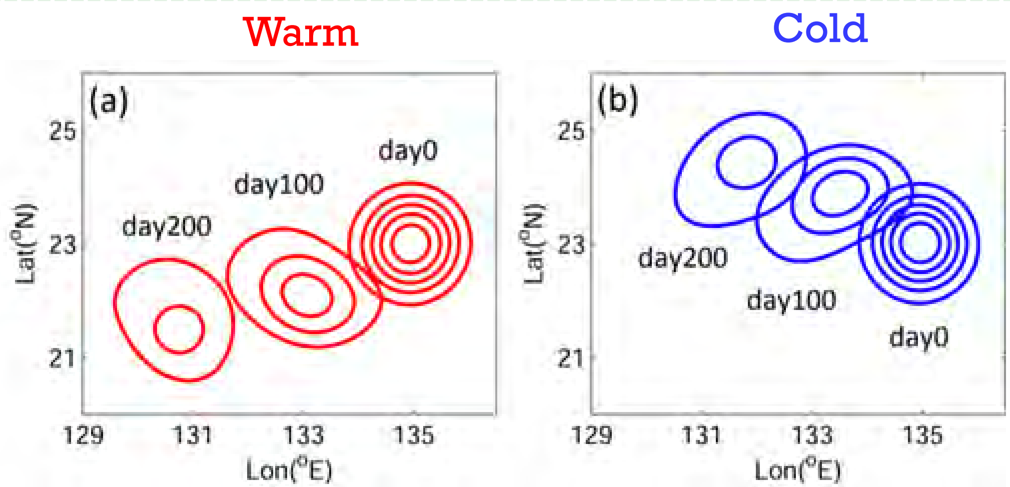
Biological:
Rich in nutrients, phytoplankton
→ Food source
→ fish larvae stay for feeding

Physical:
Eddies are nonlinear
→ Trap the material within eddies
→ Fish larvae are trapped passively

***Goal:** The combined contributions of passive physical trapping and active biological food-attraction of fish larvae to their migration in mesoscale eddies*

Idealized experiments based on bio-mpi-POM *(Huang & Oey, 2015)*

Case	SSHA	Domain & resolution	Eddy	note
Warm	0.1	X=2000km, Y=1000km H=1000m, dx=dy=0.1deg dz=10m (0-300m) 10m-30m (300m-1000m)	D=250km	T and bio parameters specified mean climatology from STCC region
Cold	-0.1			

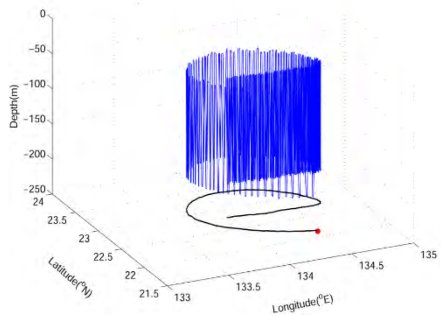


Meridional advection is caused by nonlinear self-advection due to β (Smith & O'Brien, 1983)

Release v-larvae:

→ Mean swimming direction is westward (towards East Asia)
→ Swimming speeds are set from 0.01 m/s to 0.06 m/s
→ DVM: night at 50m, day at 200m

Example of 3D trajectory in the warm eddy

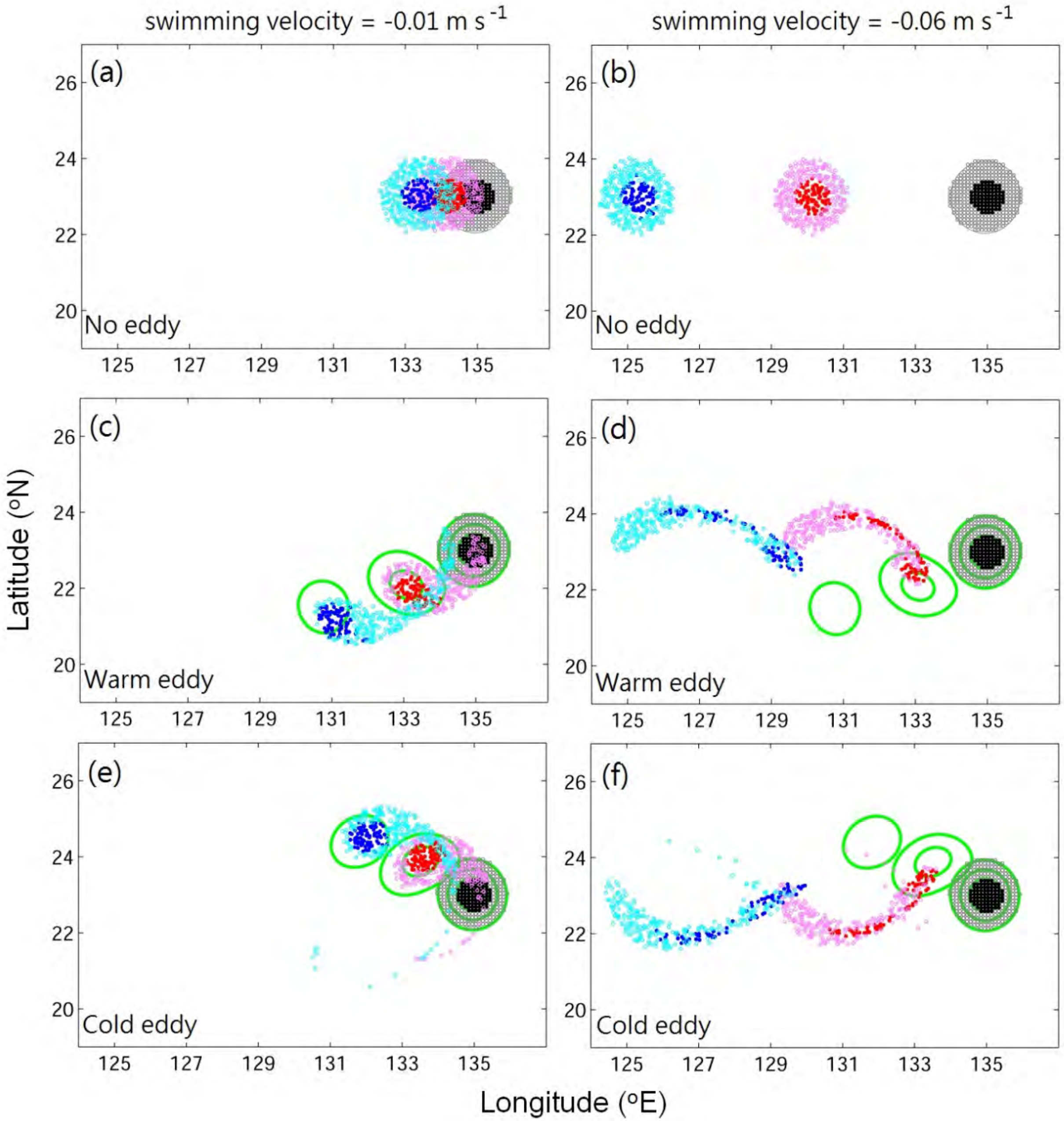


Distribution of v-larvae on day 0 (black), 100 (red), 200 (blue)

No Eddy

Warm Eddy

Cold Eddy



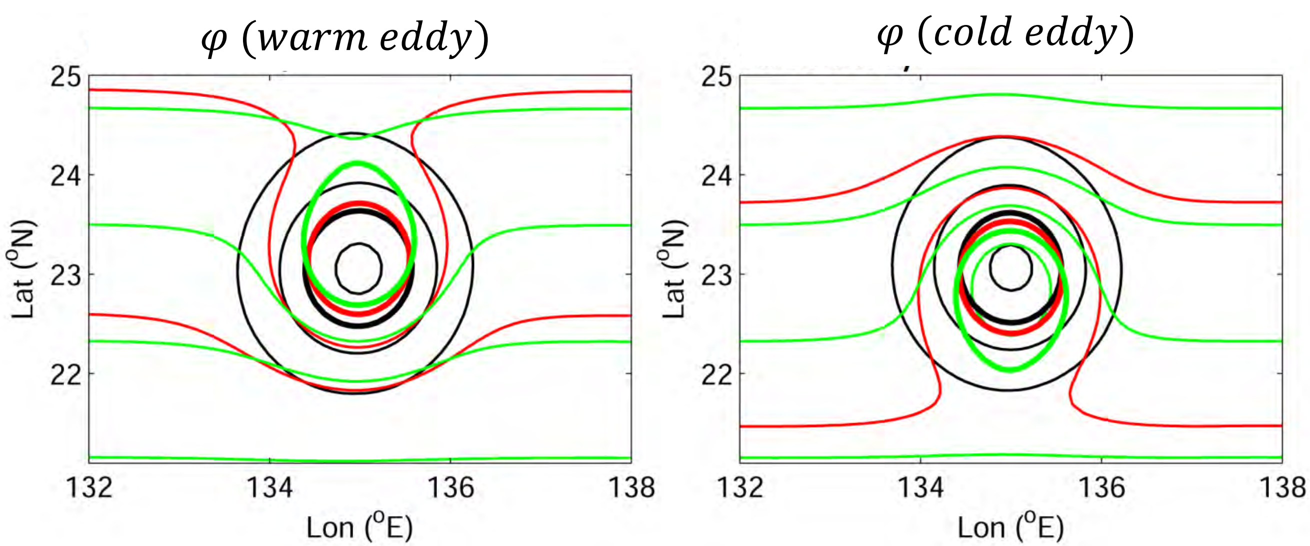
Difference of inner and outer eddy core

Stream function $\varphi : u = \partial\varphi/\partial y$

V-larvae is not the passive particles, the formula is modified to:

$$u = u_{eddy} + u_{eel} = \partial\varphi/\partial y$$

Black: u_{eddy} ; **Red:** $u_{eddy}+u_{eel}$ (-0.01 m/s) ; **Green:** $u_{eddy}+u_{eel}$ (-0.06 m/s)



Trapping depends on the two competing terms

→ u_{eddy} (closed streamline) & u_{eel} (open streamline)

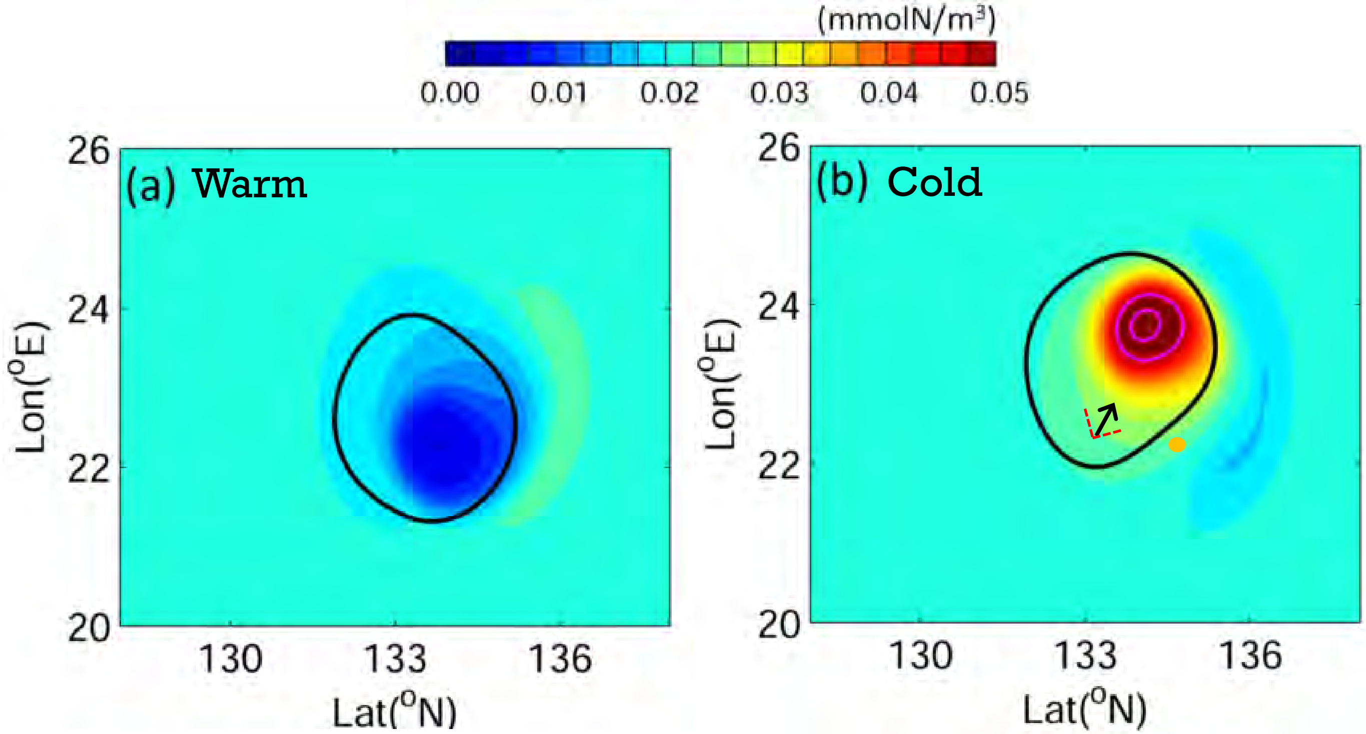
→ V-larvae can escape with the weakening of eddy (u_{eddy})

→ Faster swimming v-larvae (u_{eel}) can escape from eddy easier

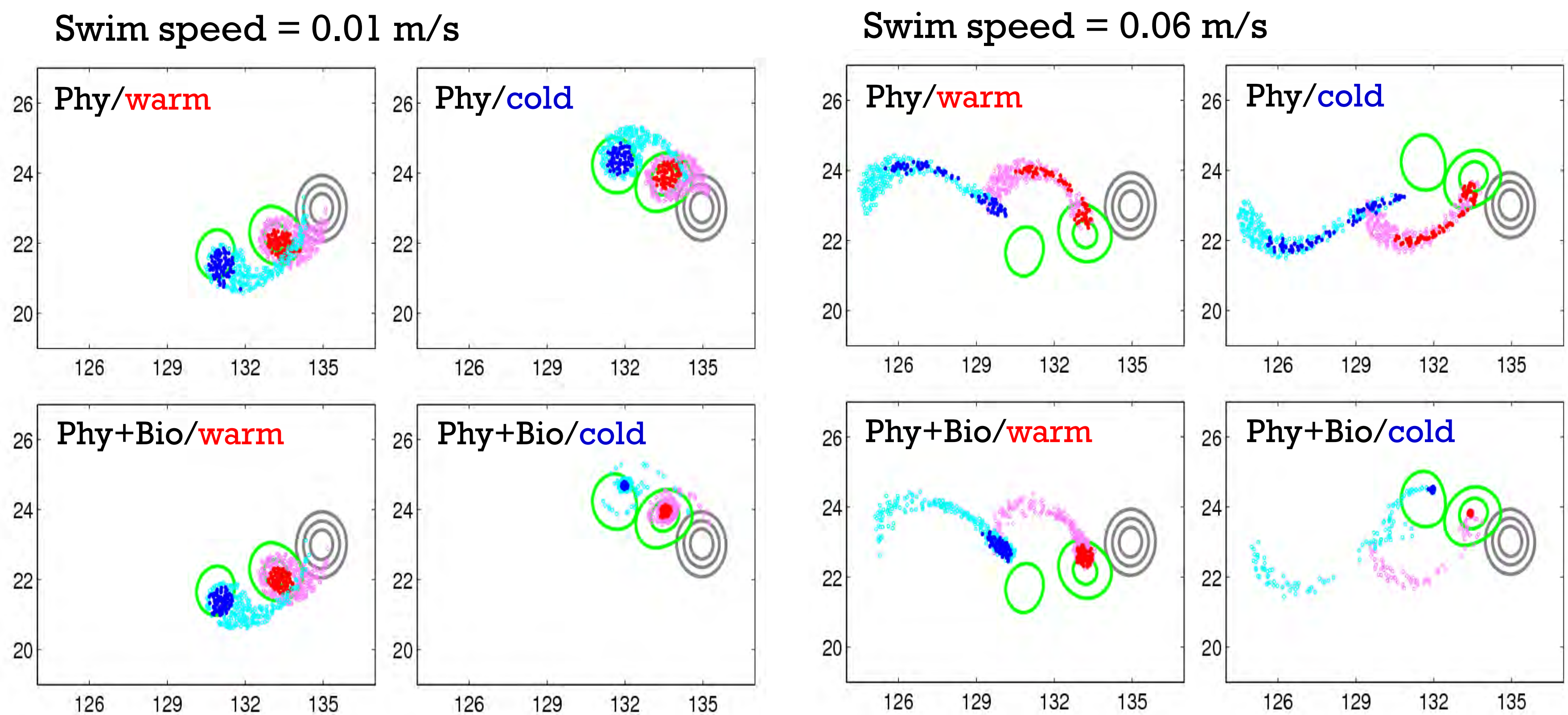
Biological Food-attraction included

- Japanese eel larvae feeds marine snow -> detritus is used as food indicator
- Food-attraction: meet the food (entering the eddy)->try to stay with the food -> changing swimming direction toward rich food zone

Top 200m integrated detritus

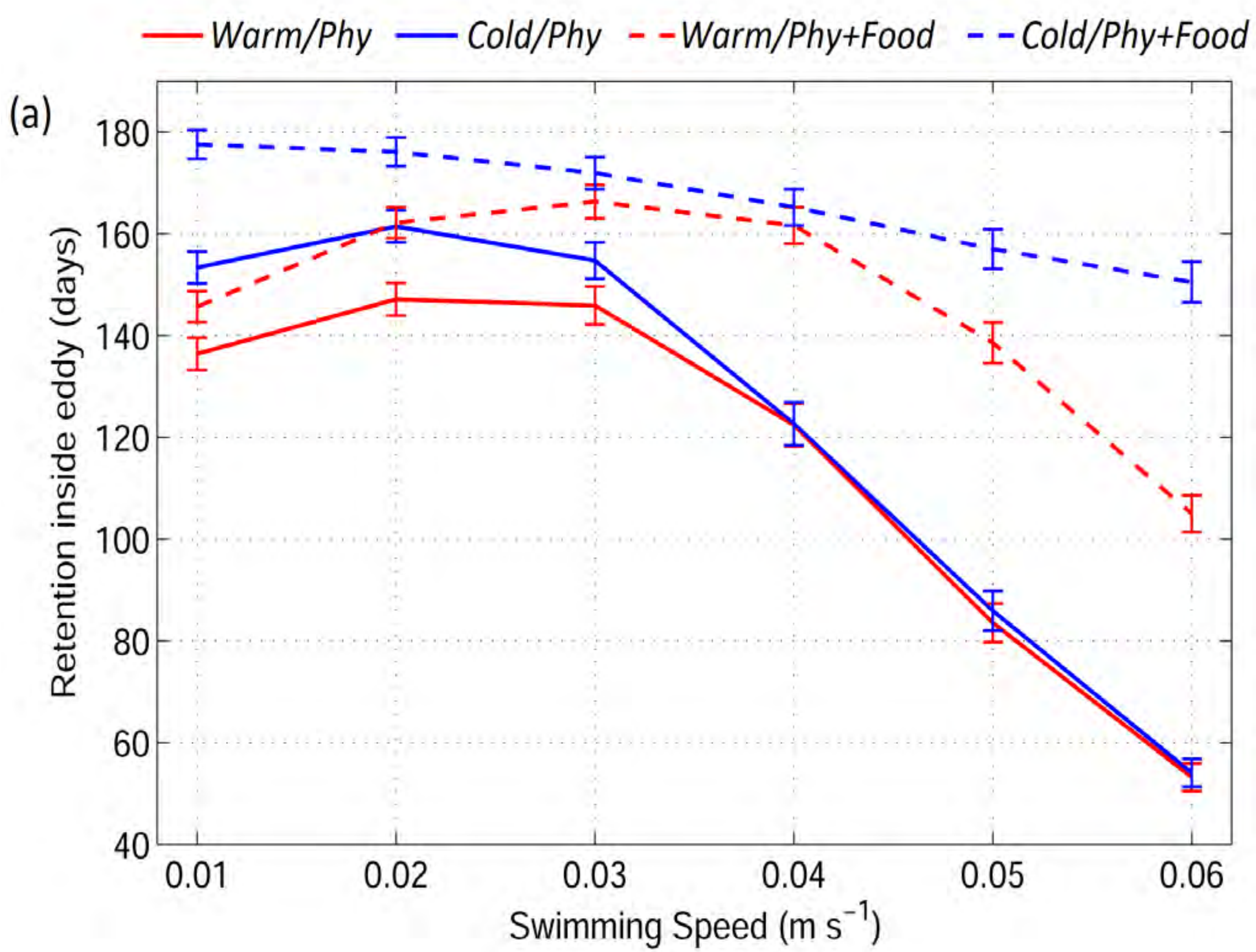


V-larvae distribution with/without food-attraction



- In the cold eddy: more v-larvae are able to stay in the eddy
- In the warm eddy: distributions are similar to physical trapping only

Retention time in eddies



Slow swimming — **Fast swimming**

Physical trapping — *Biological food-attraction*

Summary

Impact of ocean circulation on Japanese eel larvae migration are investigated based on a 3D particle-tracking method, in which swimming behavior are considered.

The ocean circulation plays a role in declining Japanese eel catch
Changes of wind → change of NEC → less larval transport toward East Asia

Physical and biological roles of eddies in fish larvae migration is investigated.

- The impact of eddies depends on the swimming speed of v-larvae relative to the eddy speed. Slow (fast) swimming v-larvae are accelerated (dragged) by eddies.
- Trapping depends on two competing terms: u_{eddy} & u_{eel}
- Physical trapping dominates the retention of slow-swimming v-larvae, whereas biological food-attraction takes over in fast swimming cases

Reference

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