Effect of eddy transport and blocking on migration of small pelagic fishes

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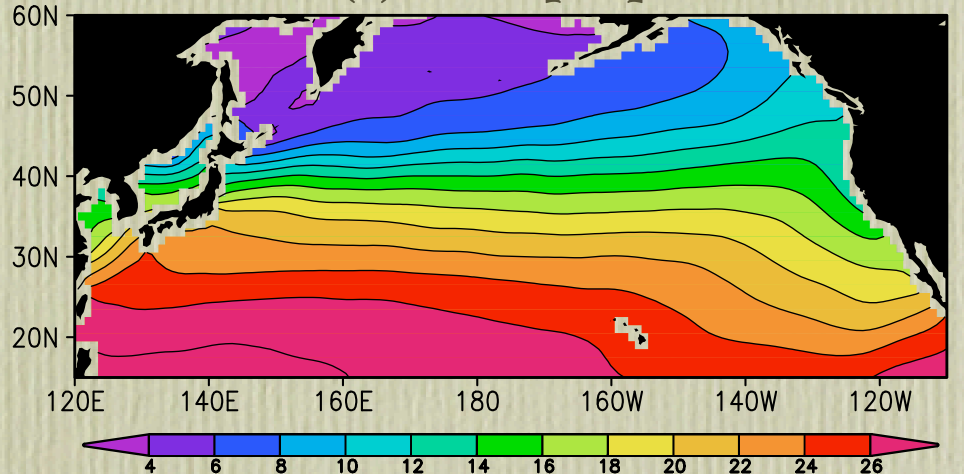
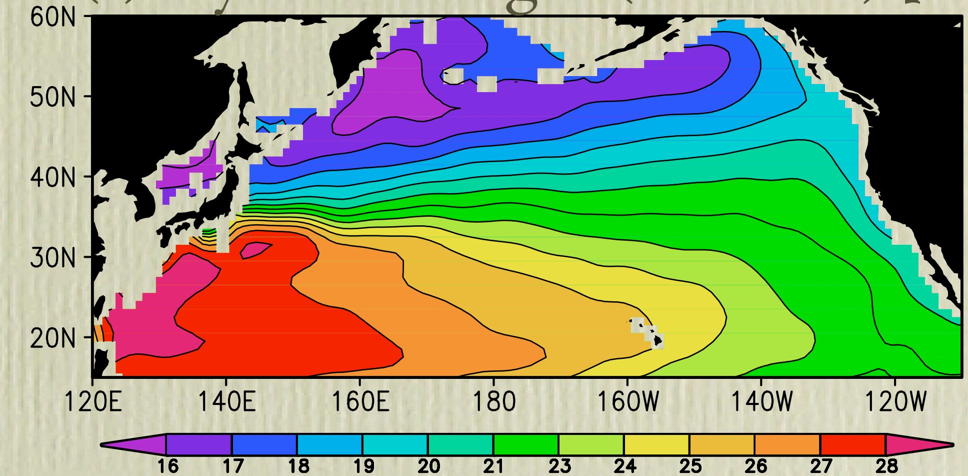
Subtropical and subarctic gyres

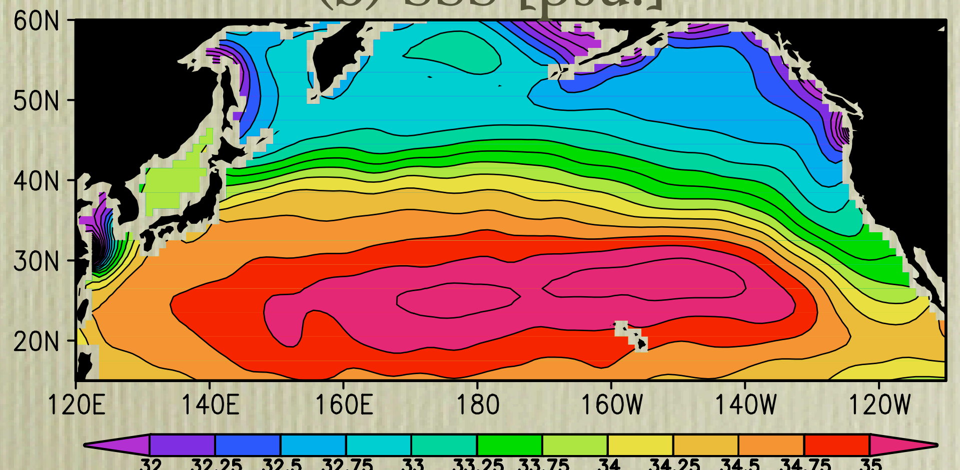
(a) SST [°C]



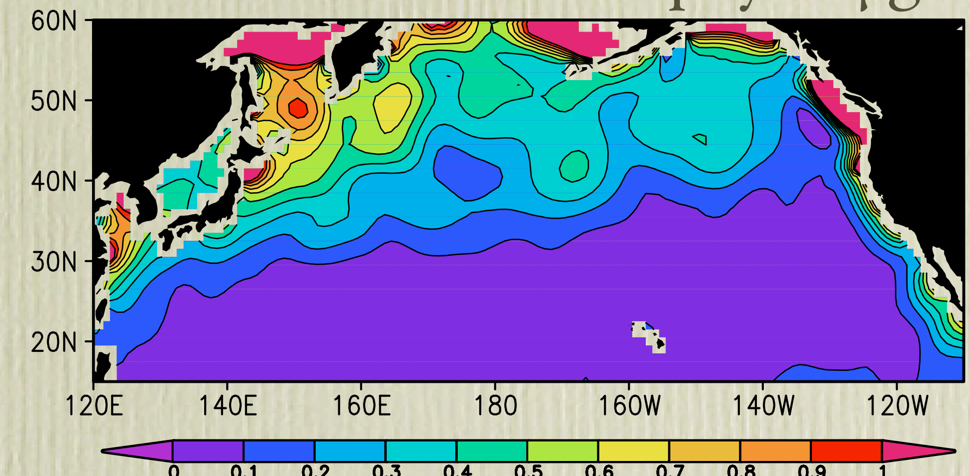
(c) Dynamic height (2000-db) [m]



(b) SSS [psu.]

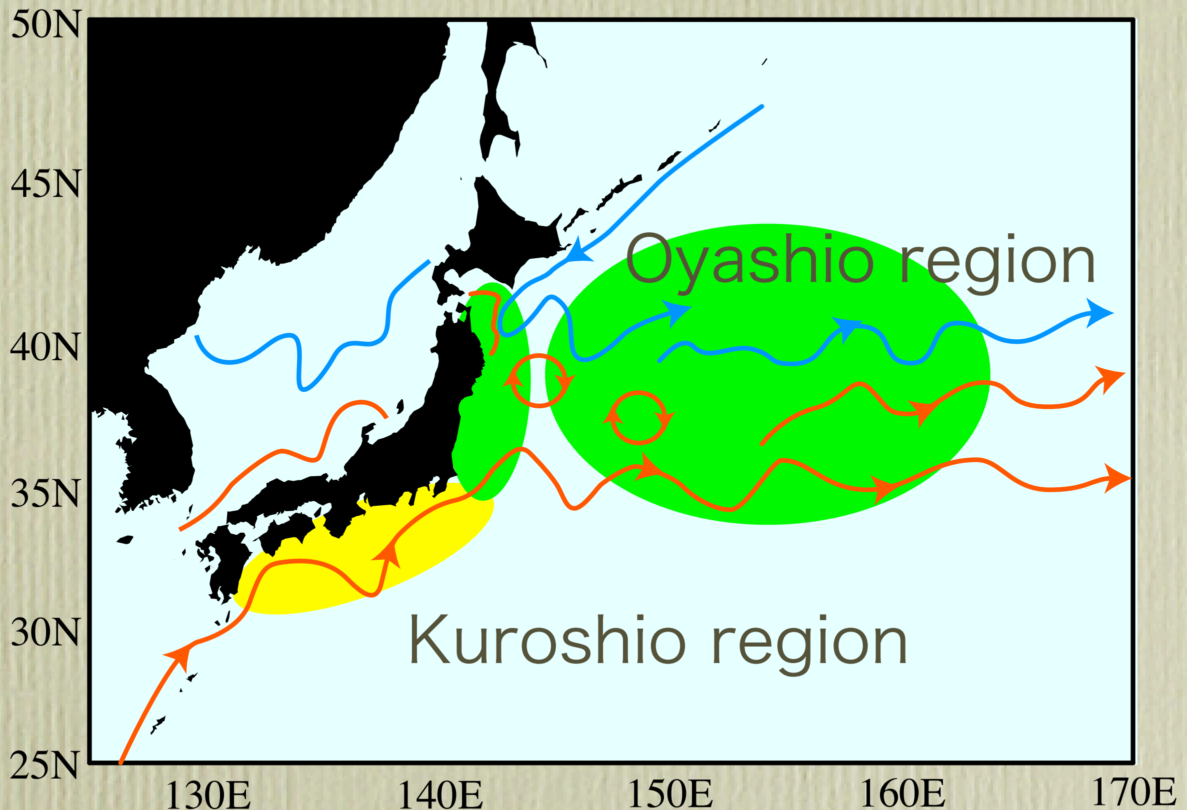


(d) Sea surface chlorophyll [μg/l]



(Data from World Ocean Atlas 2001)

Meridional migration of pelagic fishes in the Western North Pacific



Upper-layer oceanic/fishery condition

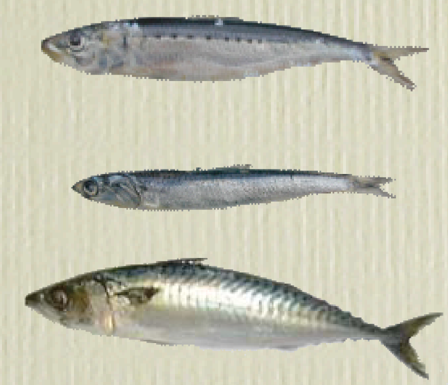
Spawning area (Over-wintering)

Feeding area

Northern coastal area

Kuroshio-Oyashio Transition region

Southern coastal area



sardine

anchovy

mackerels

Pelagic fishes in the Transition Region

Sardine	Importance of juvenile mortality (Watanabe *et al*. 1995)	
	Temperature criticality (Noto and Yasuda, 1999)	*Kuroshio Extension hypothesis*
Anchovy	Faster growth more survival (Takahashi, 2001)	
Mackerels	Largest young fish abundance in frontal areas (Kuroda *et al*, 1997)	

- **Importance of migration phase**
- **School concentration at fronts**

→ **Importance of fronts**

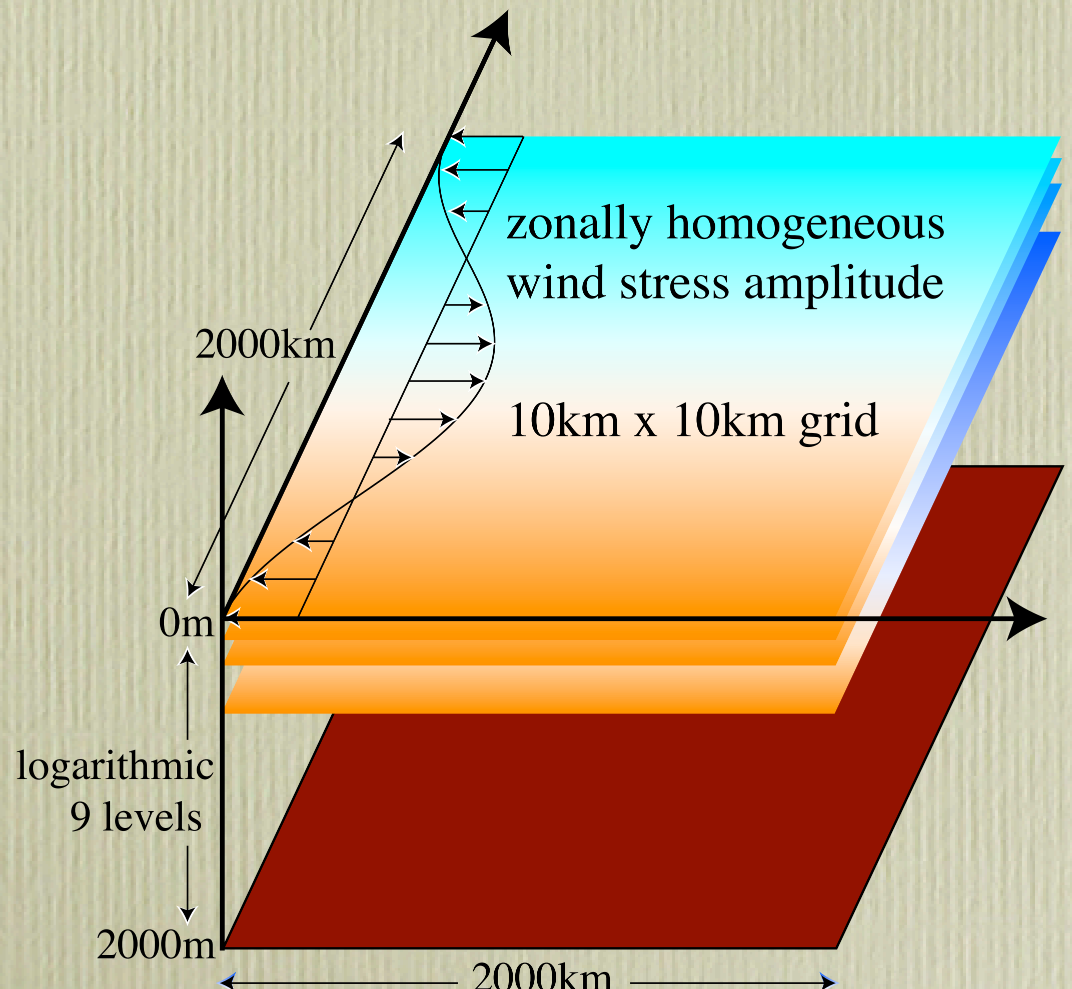
Eddies and fronts for small pelagic fishes

- High productivity and plankton convergence (Uda, 1960)
- Blocking migration (Uda, 1960)
- Transport/diffusion/retention

Modeling approach of this study

- Examine basic processes of eddies and fronts on the northward migration of fishes with small swimming ability
- Simple box-ocean (<=> realistic simulation)
- Migratory eulerian tracer

Physical model



Schematic diagram of model domain

- Wind-driven double-gyre ocean circulation model
- 2000-km x 2000-km closed flat domain
- Idealized wind stress and heating/cooling amplitudes
- 360-days period forcing (begins from spring)

Migratory eulerian tracer

$$\frac{\partial N}{\partial t} = -u\frac{\partial N}{\partial x} - v\frac{\partial N}{\partial y} - w\frac{\partial N}{\partial z} + A_H\left(\frac{\partial^2 N}{\partial x^2} + \frac{\partial^2 N}{\partial y^2}\right) - u_{mig}\frac{\partial N}{\partial x} - v_{mig}\frac{\partial N}{\partial y}$$

tendency | physical advection | physical diffusion | migration

Migration $\left(u_{mig}, v_{mig}\right)$

Direction northward

Speed limited by temperature gradient

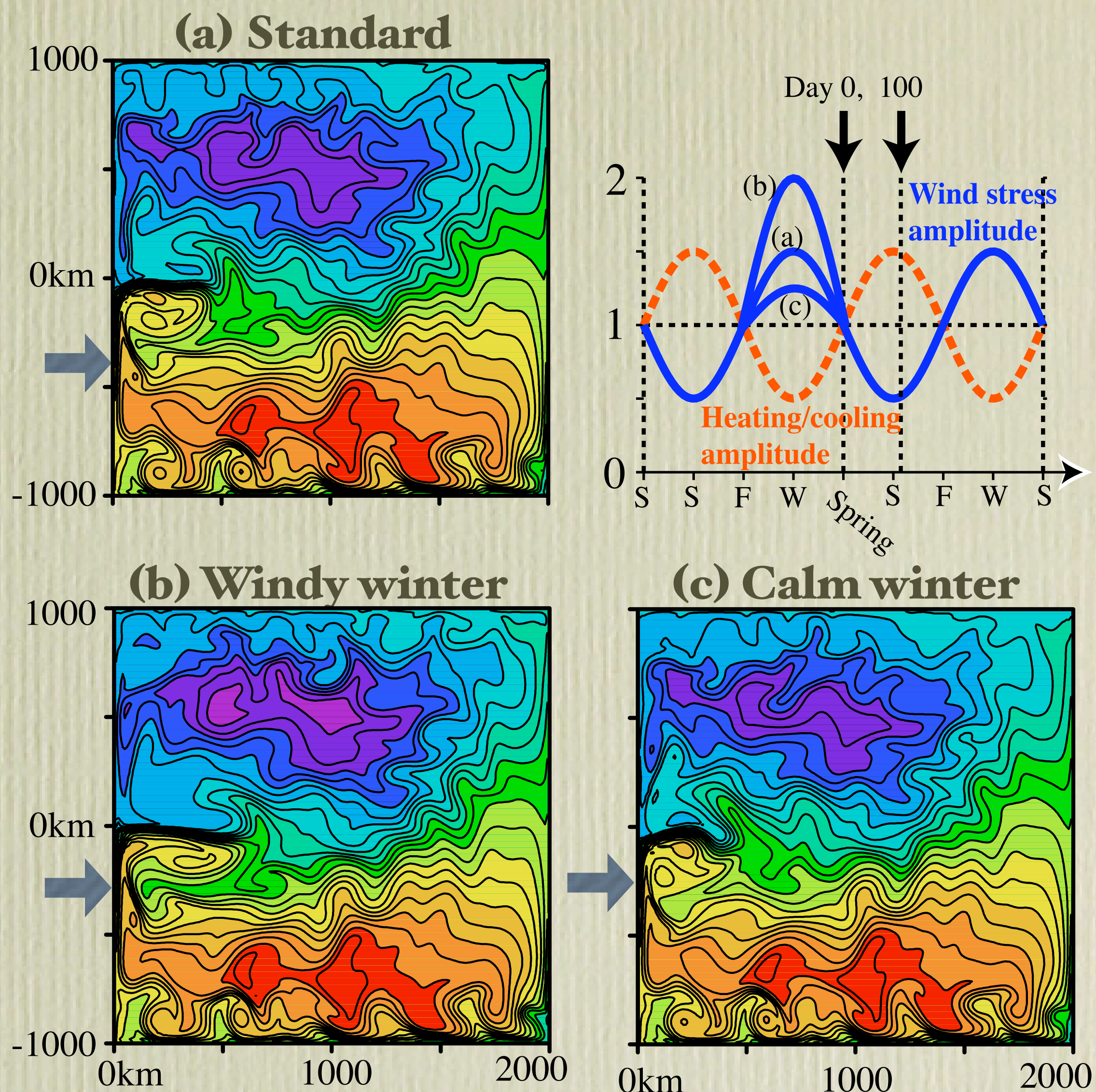
$$u_{mig} = 0,\ v_{mig} \le 0.1 \text{ m/s}$$

$$\left| T|_{y+v_{mig}\Delta t} - T \right| \le a\Delta t$$

$$a = 0.05 \text{ [°C/day]}$$

Settings and cases

- Tracer input
  - at the beginning of the seasonal cycle (Spring)
  - in 30m depth, 17°C latitude along the western boundary
- Three sets of 100 days calculation



30m temp. at Day 0 of the 1st year

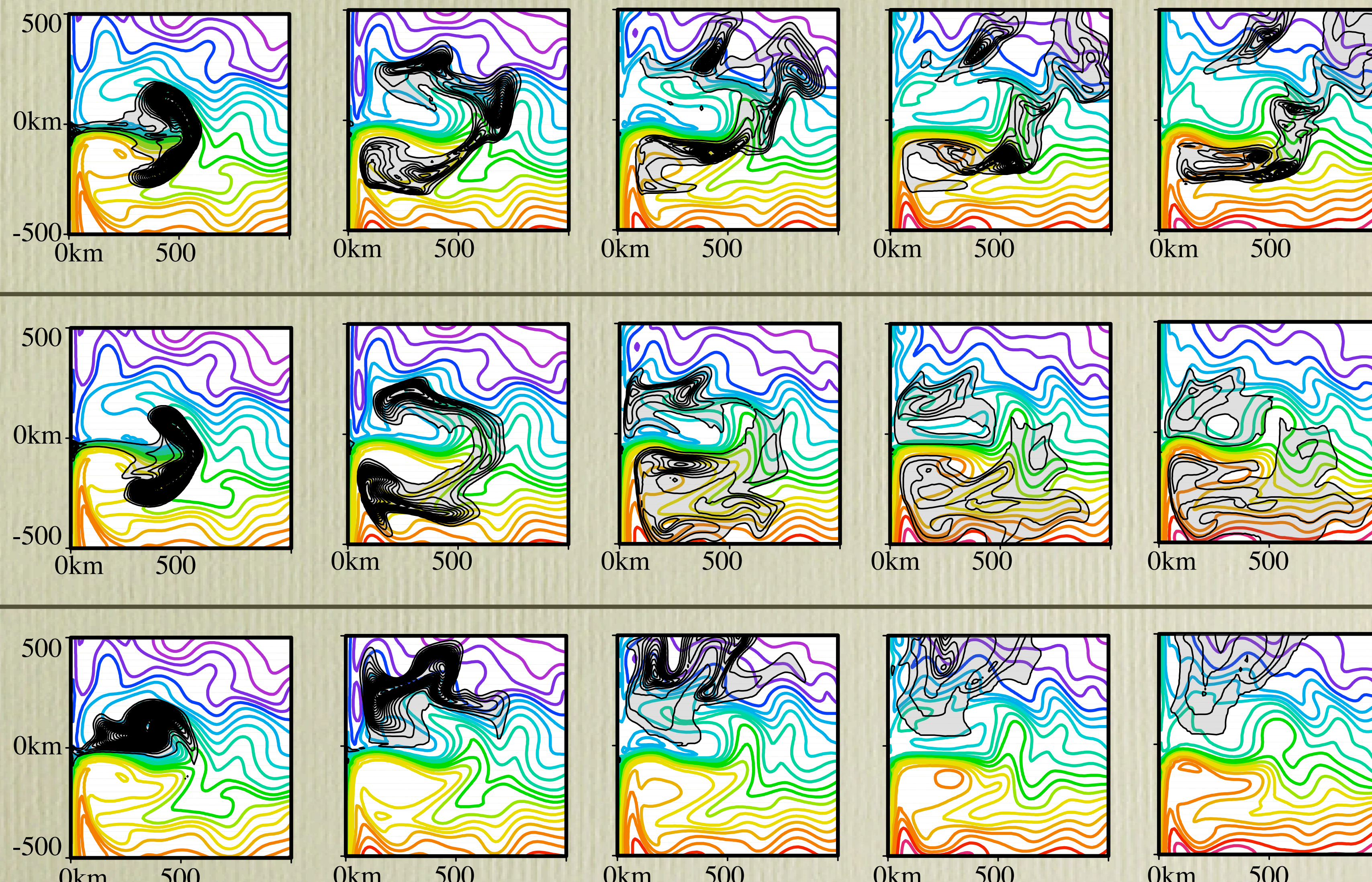
Basic cases

Day 20 | Day 40 | Day 60 | Day 80 | Day 100

Standard

No migration (Passive)

No blocking (constant migration)

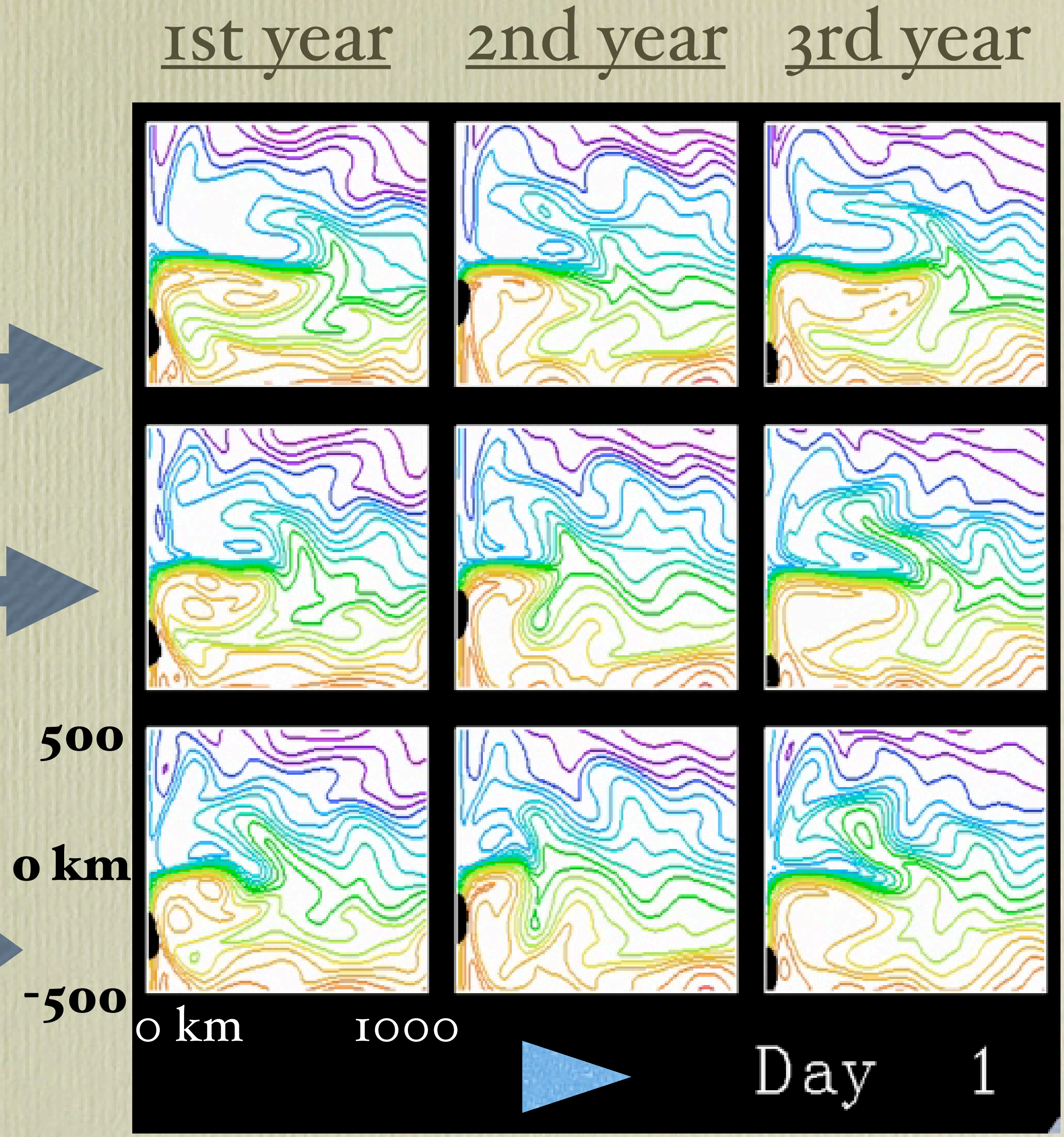


Change of wind in winter

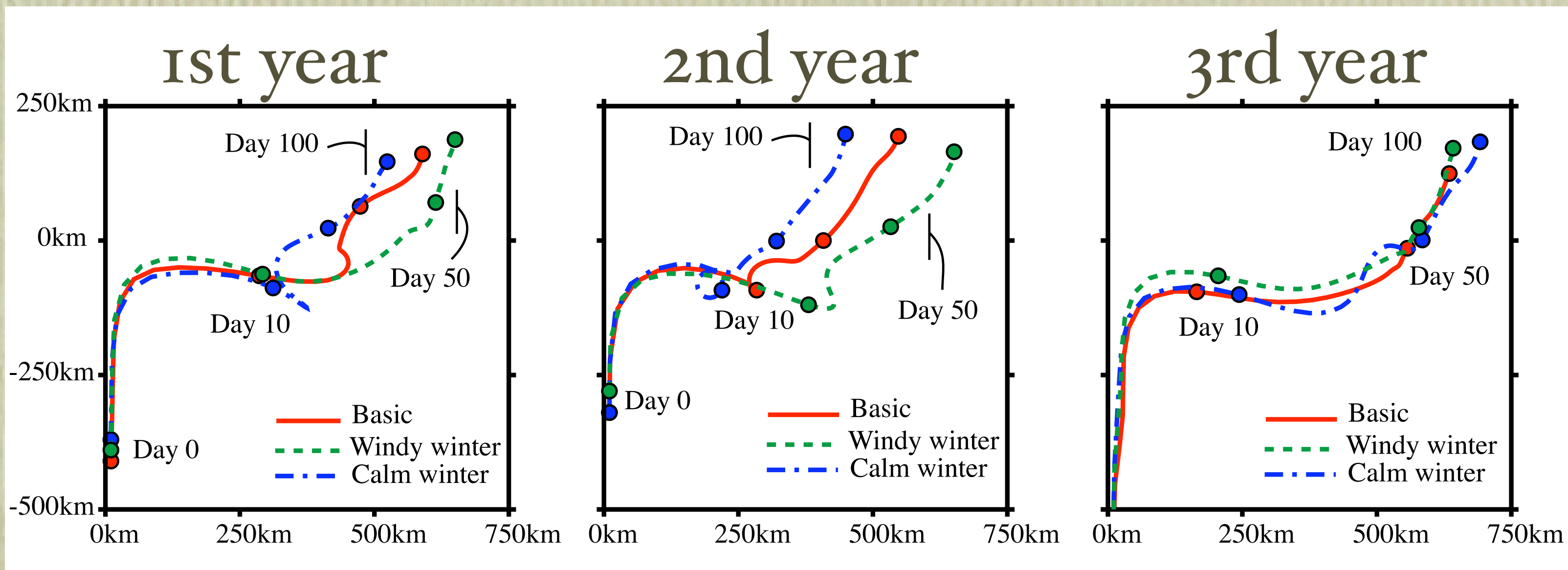
Windy winter

Constant wind stress amplitude (Standard)

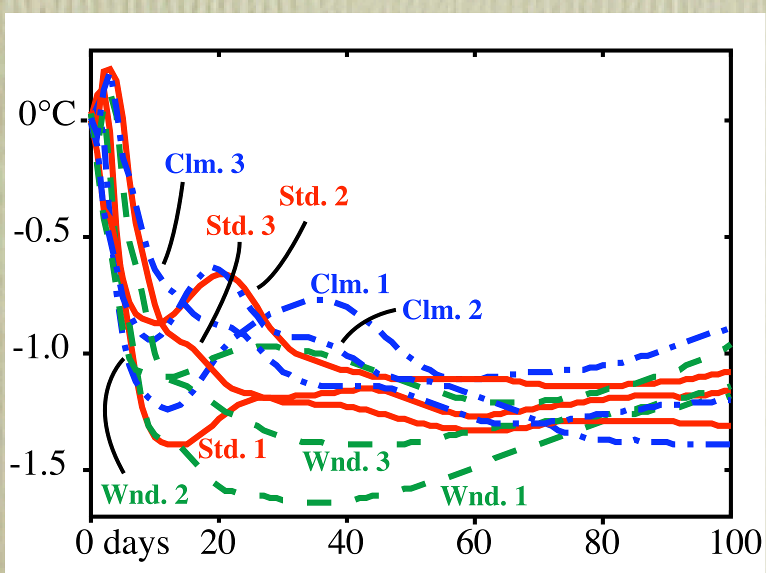
Calm winter



Average movement and temperature history

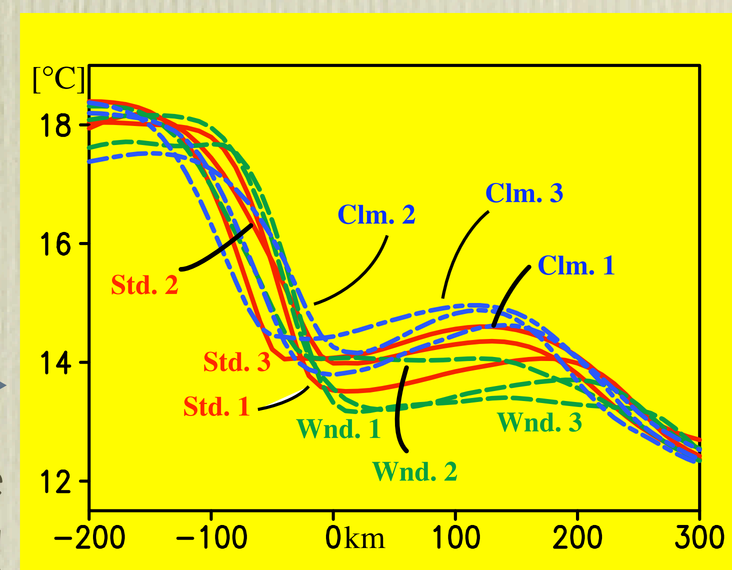


Average movement

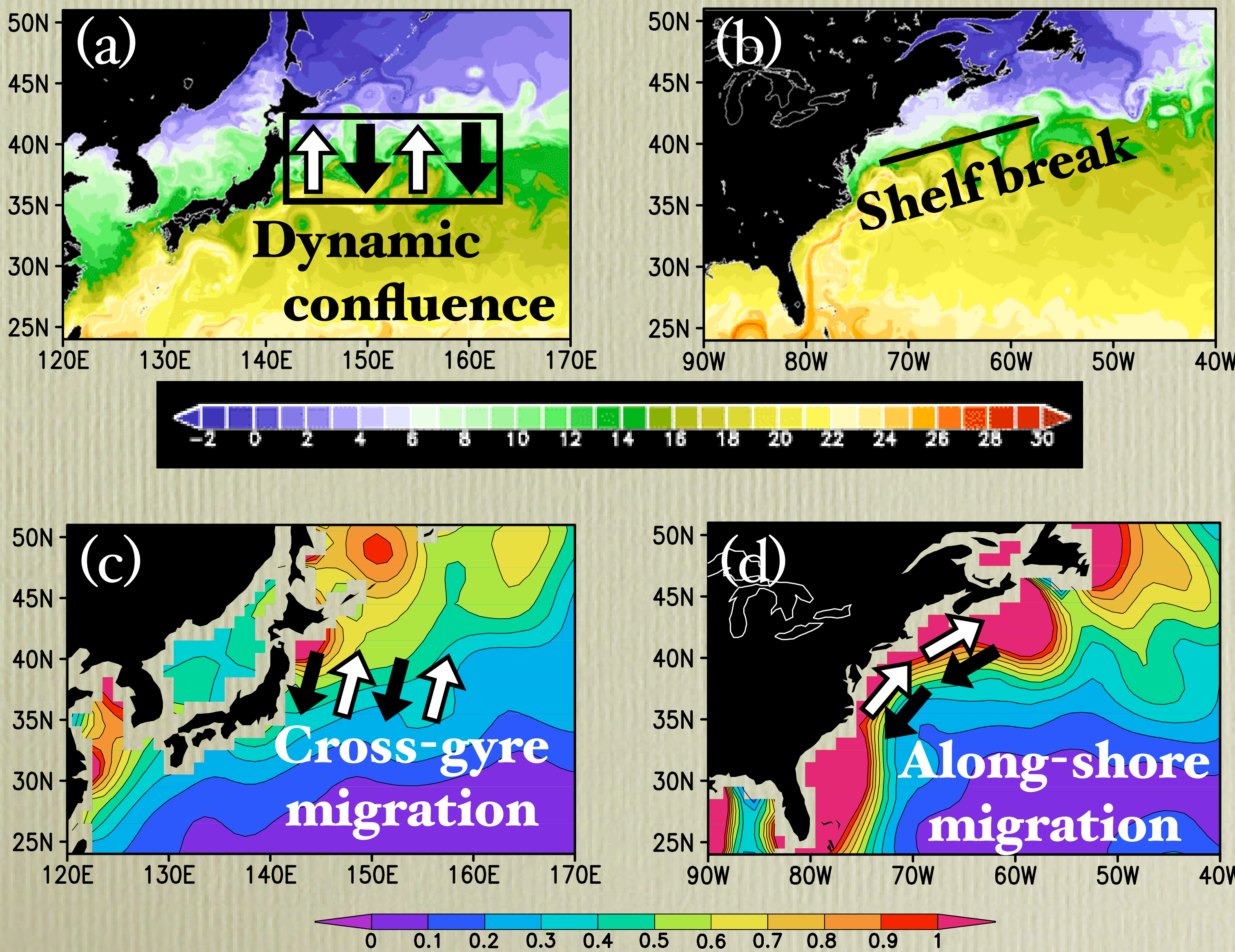


Average environmental temperature history

Average temperature filed



Latitudinally different waters and migration strategy



SST [°C] **snapshots by a simulation** (Earth simulator center)

SSC [μg/l] **climatology** (World Ocean Atlas 2001)

Summary

- Eddy transport and blocking of migratory tracer
  - Concentration at the ridge of water intrusions
  - Influences of warm eddy activity to the migration path and temperature history
- Meridional migration in the W.N.Pacific
  - Required to sustain large population
  - Utilizing eddy-intruding dynamic confluence

Thank you

Parameters examination

Average distance and increase/decrease of environmental temperature of tracer at Day 100 from the initial

Cases	X ± s.d. (km)	Y ± s.d. (km)	T ± s.d. (°C)
Standard	580 ± 243	571 ± 292	-1.3 ± 3.6
$V_{mig} \leq 0.20$ m/s	605 ± 225	758 ± 373	-1.8 ± 3.4
$V_{mig} \leq 0.05$ m/s	390 ± 159	378 ± 186	-0.4 ± 3.6
$a = 0.10$ °C	580 ± 216	768 ± 294	-1.8 ± 3.6
$a = 0.025$ °C	513 ± 266	436 ± 265	-0.6 ± 3.5
No heating	582 ± 249	545 ± 275	-3.2 ± 2.8