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Diagnosis of the possible link between interannual variation of neon flying squid abundance in the North Pacific and the recent climate regime shift in 1998/99 by using 4DVAR ocean data assimilation product

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outline

- Introduction
- Purpose
- Data and methodology
- Results
    - correlation analysis between the neon flying squid CPUE and ocean environment
- Concluding remarks

Introduction

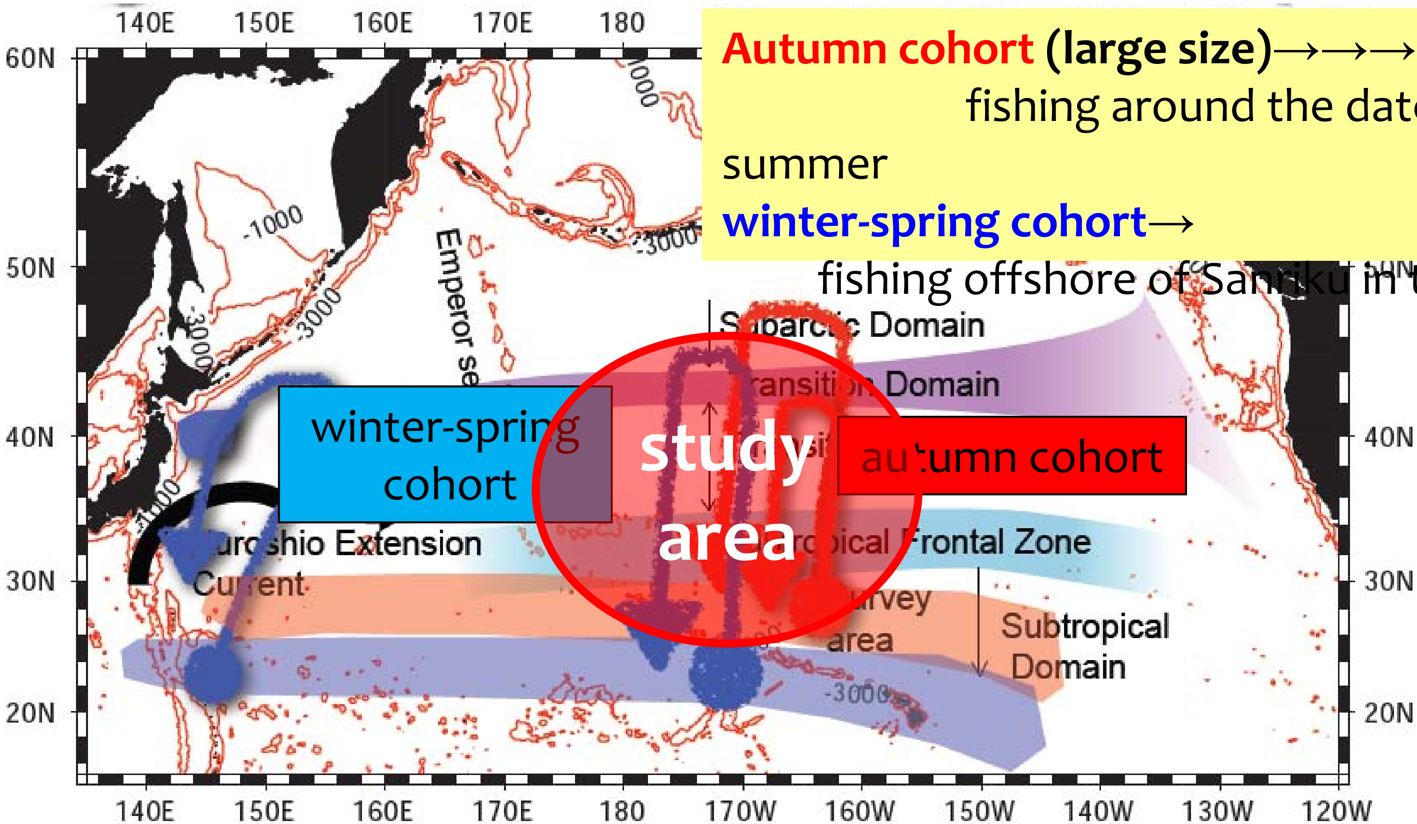
neon flying squid

(*Ommastrephes bartramii*)

- **widely distributed in the North Pacific**
- **1-year lifespan and seasonal migration**
- **important for pelagic ecosystem and international fisheries**

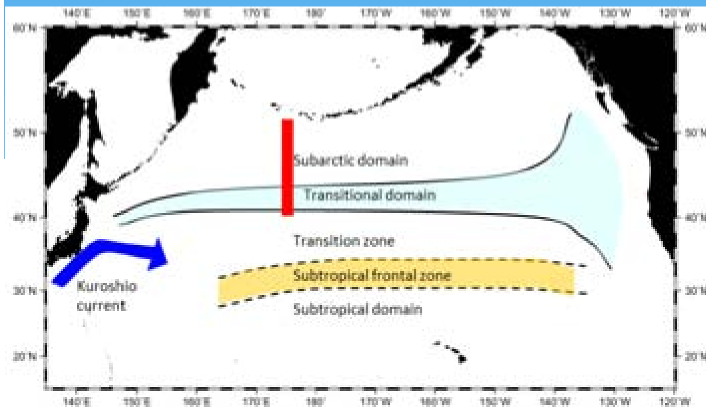
Autumn cohort (large size)→→→ fishing around the date line in summer

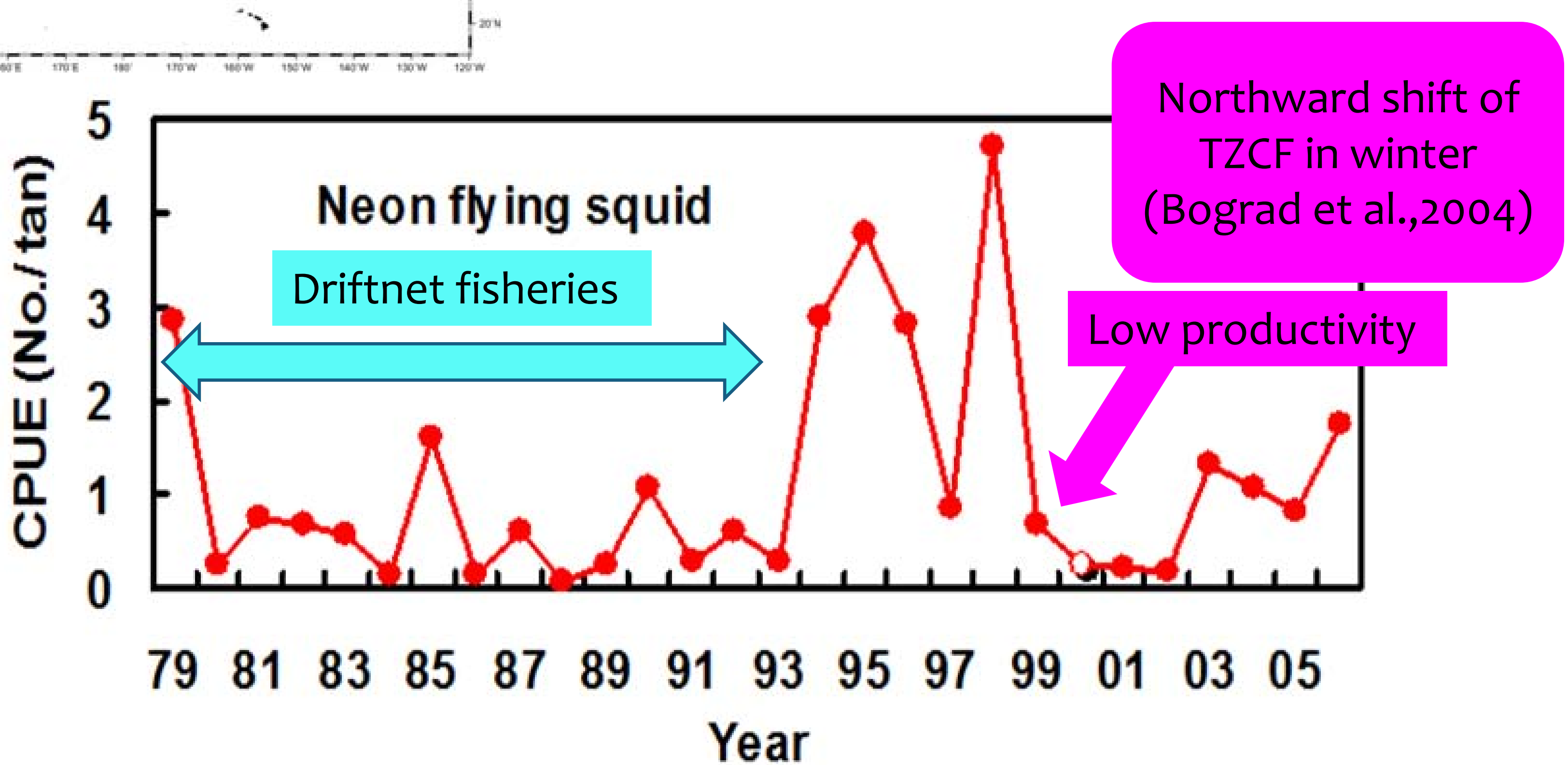
winter-spring cohort→ fishing offshore of Sanriku in the next winter

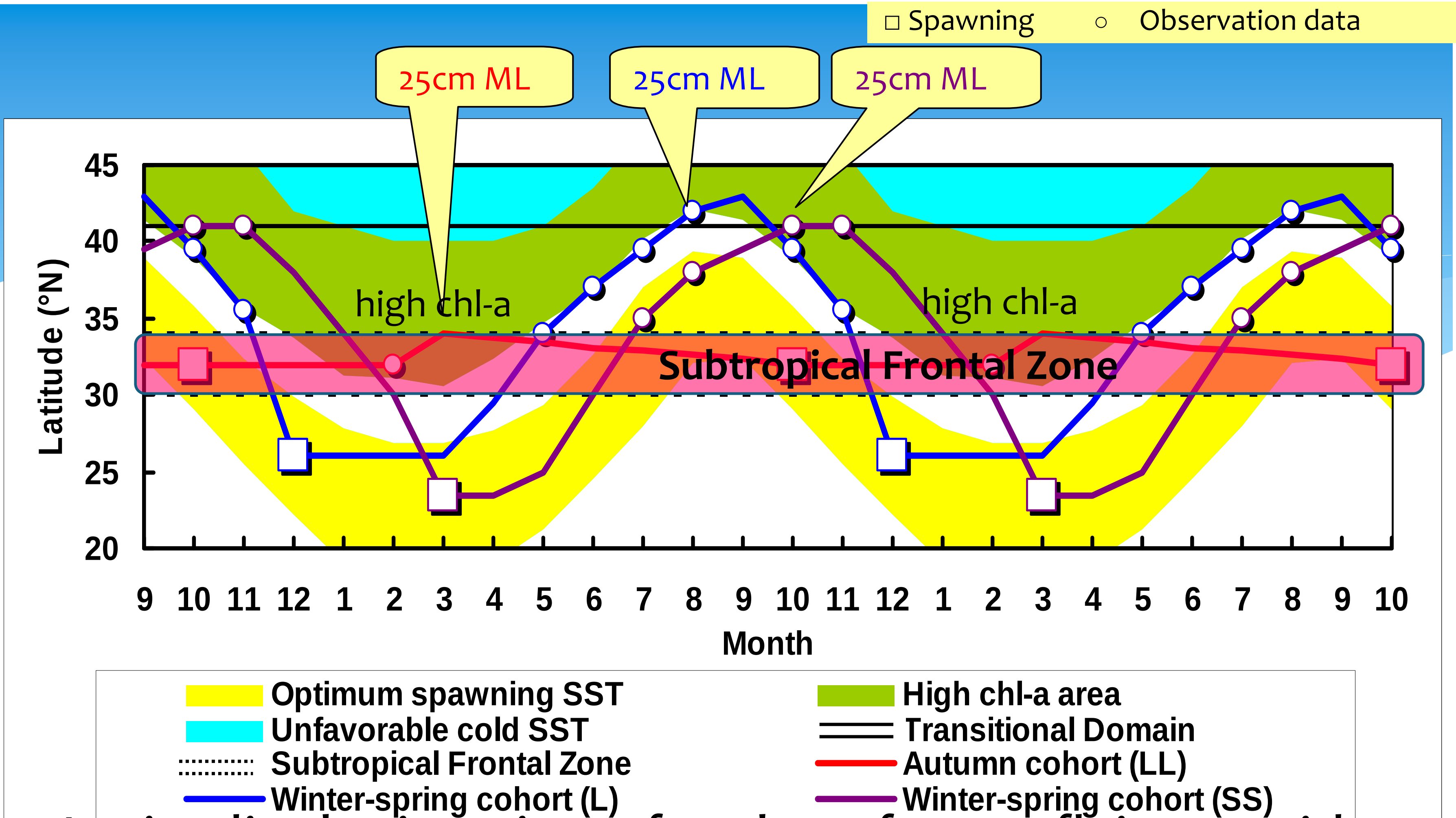


Interannual variation of neon flying squid stock in autumn cohort

(Ichii et al.,2011)







Ichii et al.(2011)

The experience of high chl-a concentration in nursery period is also important for the recruitment level and may possibly affect the interannual variation of the stock in the autumn cohort.

Relationship between squid CPUE and SSHA

Ichii et al.(2011)

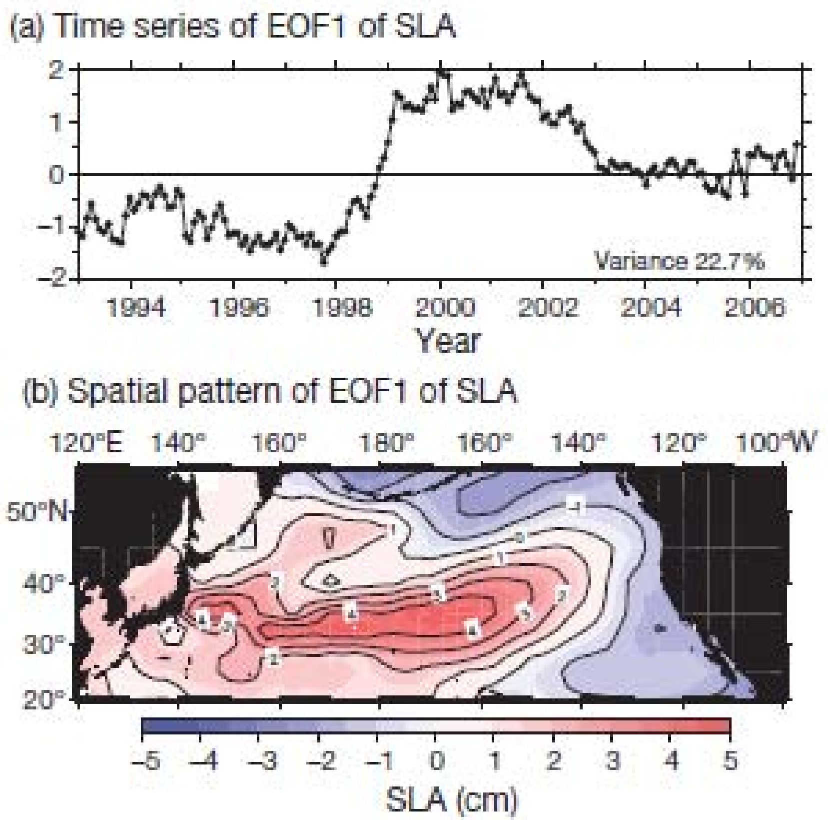


Fig. 9. (a) Time series of the first mode of the empirical orthogonal function (EOF) analysis of sea level anomaly (SLA) and (b) spatial pattern of the first mode of SLA EOF in the North Pacific. The high SLA period was observed during 1999 to 2002 and was followed by an intermediate SLA level in the STFZ and TZ

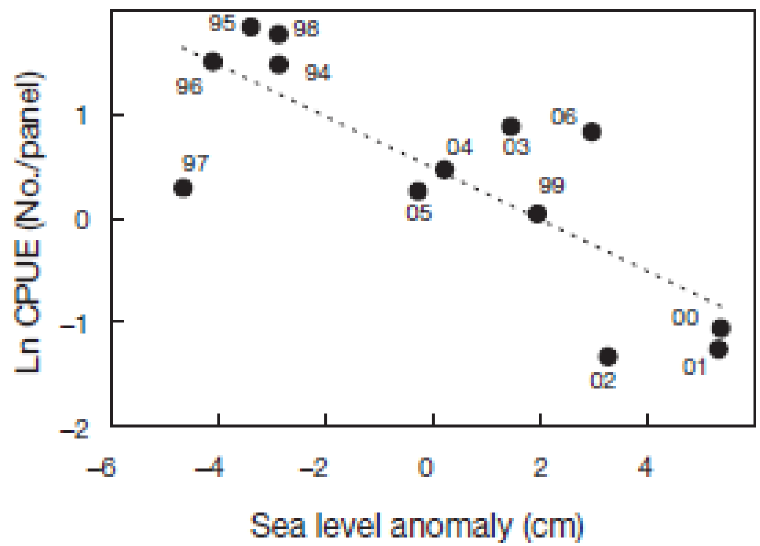


Fig. 10. *Ommastraphes bartramii*. Relationship between sea level anomaly (SLA) during the spawning and nursery period (October to March) and yearly stock level as survey driftnet ln(CPUE) of the autumn cohort of neon flying squid. Datapoints are marked with the years 1994 to 2006. The SLA had a significant correlation with the ln(CPUE) ($r = -0.79$, $t = -4.27$, df = 11, $p = 0.0013$)

purpose

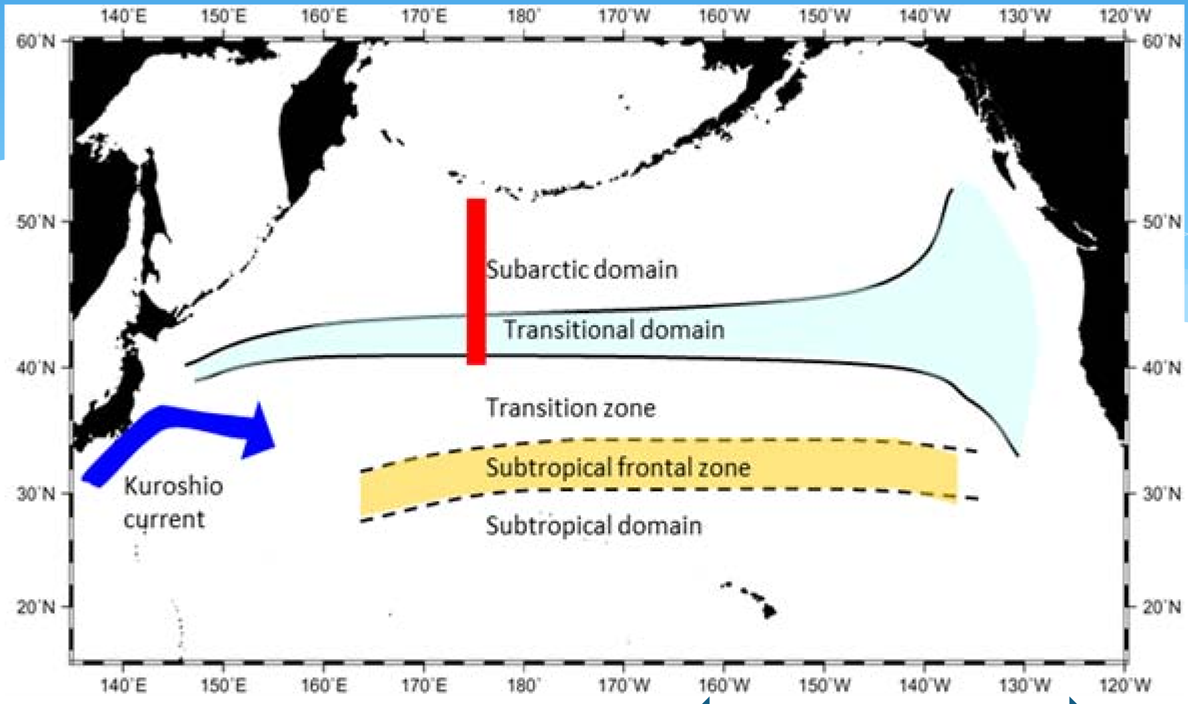
* To examine the relationships between squid catch and ocean environmental changes to investigate possible causes for the interannual variation in abundance of the autumn cohort of neon flying squid in the North Pacific, especially focusing on the **1998/99 regime shift**

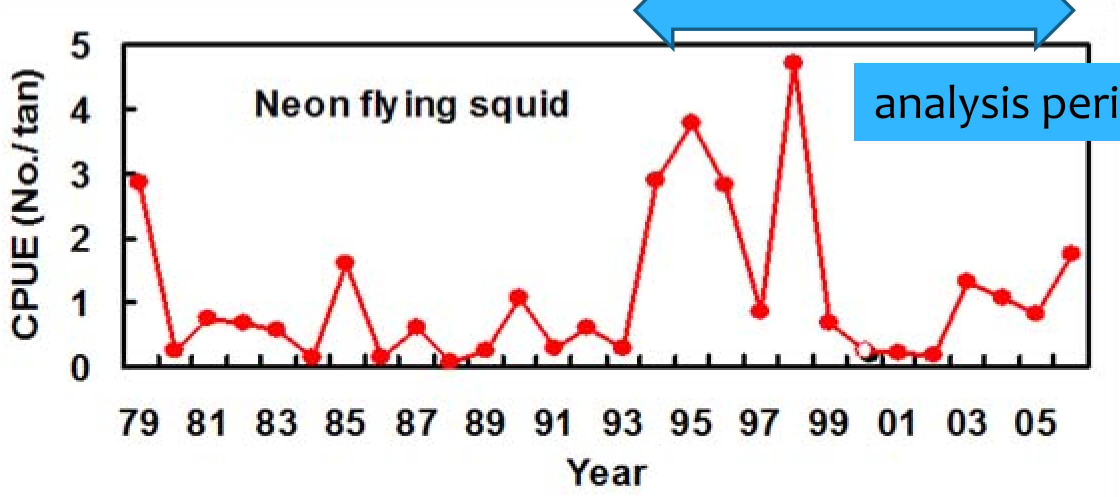
data

* **CPUE of neon flying squid (autumn cohort)**
  driftnet surveys by Hokkaido Univ. and NRIFSF collected annually from July to August at the nearly fixed sites along 175.5E and 180E longitudinal transects.
* **4DVAR Ocean data assimilation product**
  [3-D ocean temperature, current velocity]
* ERSST (Ver.3)
* NCEP/NCAR reanalysis (latent heat flux)
* Net primary production(NPP)
  [VGPM product(Behrenfeld & Falkowski,1997)
  by Dr. Mahapatra (Tokai Univ.)]

Squid catch data

Ichii et al.(2011)





analysis period:1994-2006

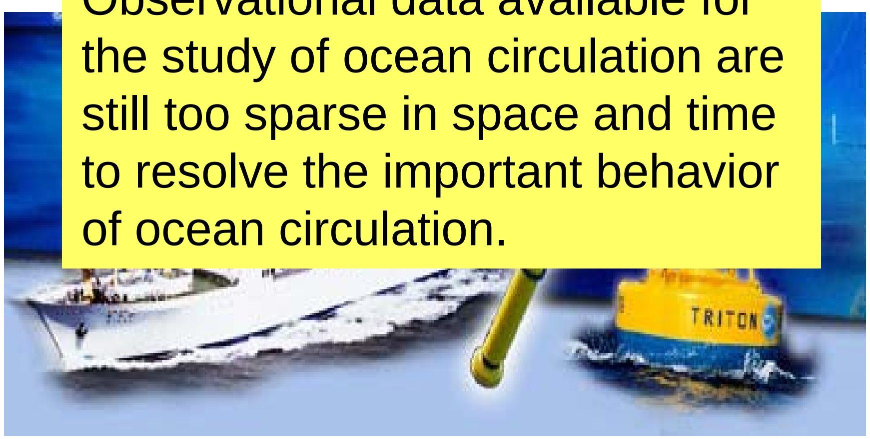
What is “Data Assimilation” ?

optimal synthesis of observation and model simulation

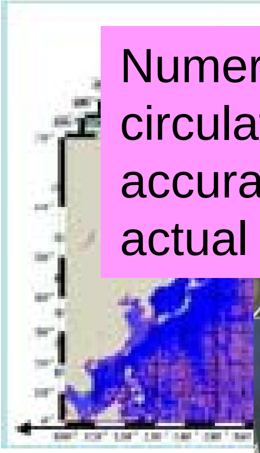
observation data **numerical model**

Pro: “truth” gridded, consistent

Observational data available for the study of ocean circulation are still too sparse in space and time to resolve the important behavior of ocean circulation.

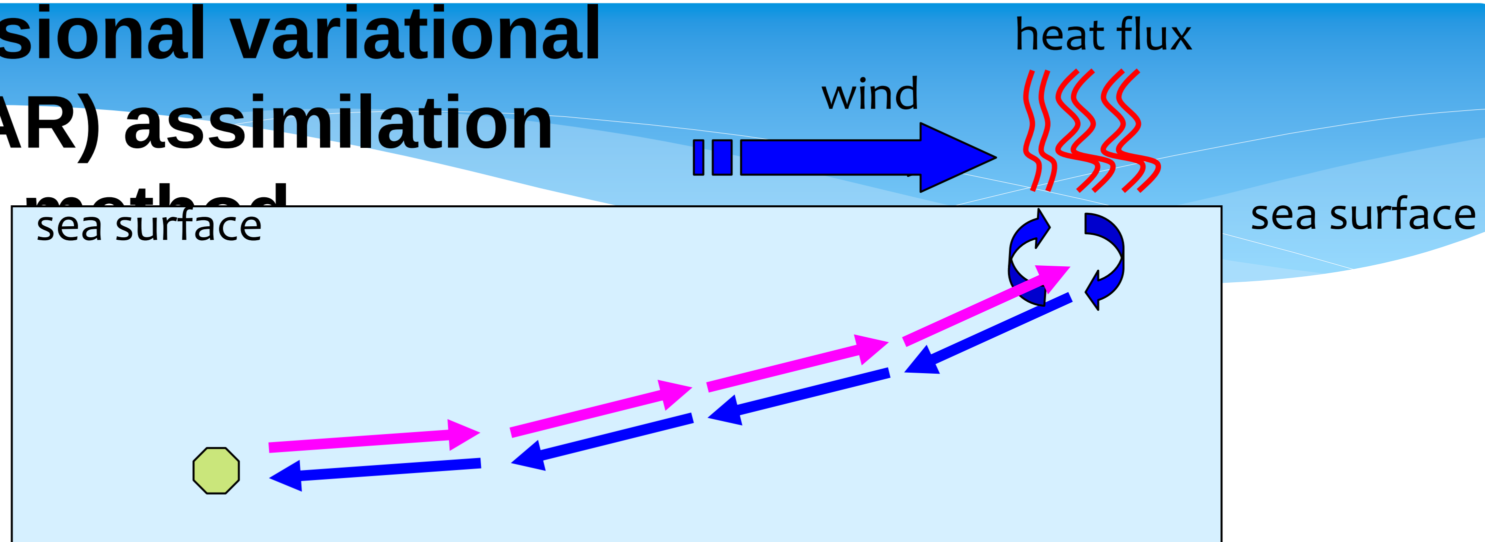


Numerical models of ocean circulation are unable to accurately quantify the actual ocean state.



4DVAR data assimilation method provides the best time-trajectory fit to the observations and can create a dynamically self-consistent dataset offering greater information and forecast potential using a state-of-the-art ocean GCM than do models or data alone.

4 dimensional variational (4DVAR) assimilation method



$$\Delta T = T_{\mathrm{model}} - T_{obs}$$

Forward model calculation
(first guess)

Detect the difference between
model and observation

Adjoint model calculation to correct the
control variables that causes the difference

Forward model calculation

4D Optimal synthesis

No artificial sources/sinks (Dynamically consistent)

4DVAR
Ocean Data Assimilation System

- General Circulation Model : **GFDL MOM3**
  75°S-80°N, 1°lat*1°lon, 45 levels
- Assimilation Method: **4DVAR adjoint method**
- Assimilation Period: **1957-2006 (50yr)**
- Assimilated Elements: AVISO altimeter data(10daily)
  EN3 data T,S (monthly) [WOD05, Argo, GTSPP etc.],
  TAO/TRITON, OISST (10daily)
- Control variables: surface fluxes [heat, fresh water, momentum]
  initial conditions [T,S,U,SSH]
- First guess forcing: NCEP/NCAR reanalysis dataset

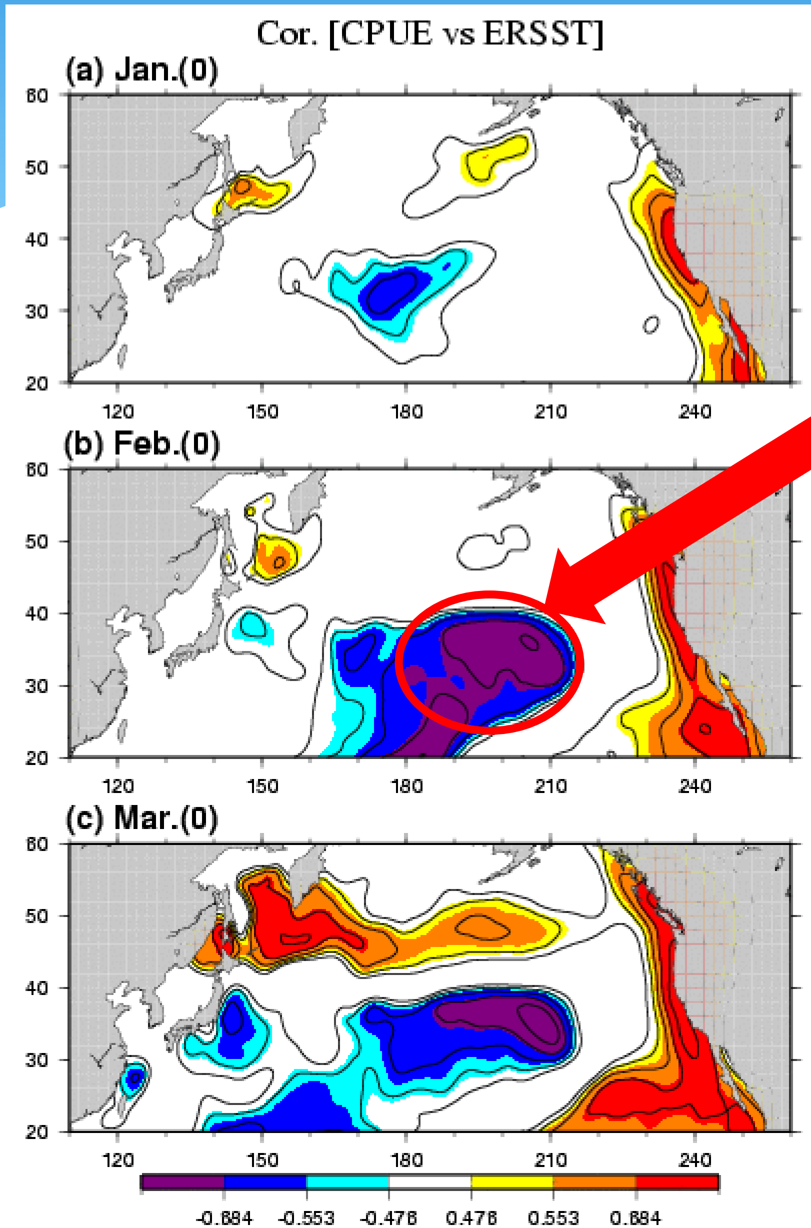
methodology

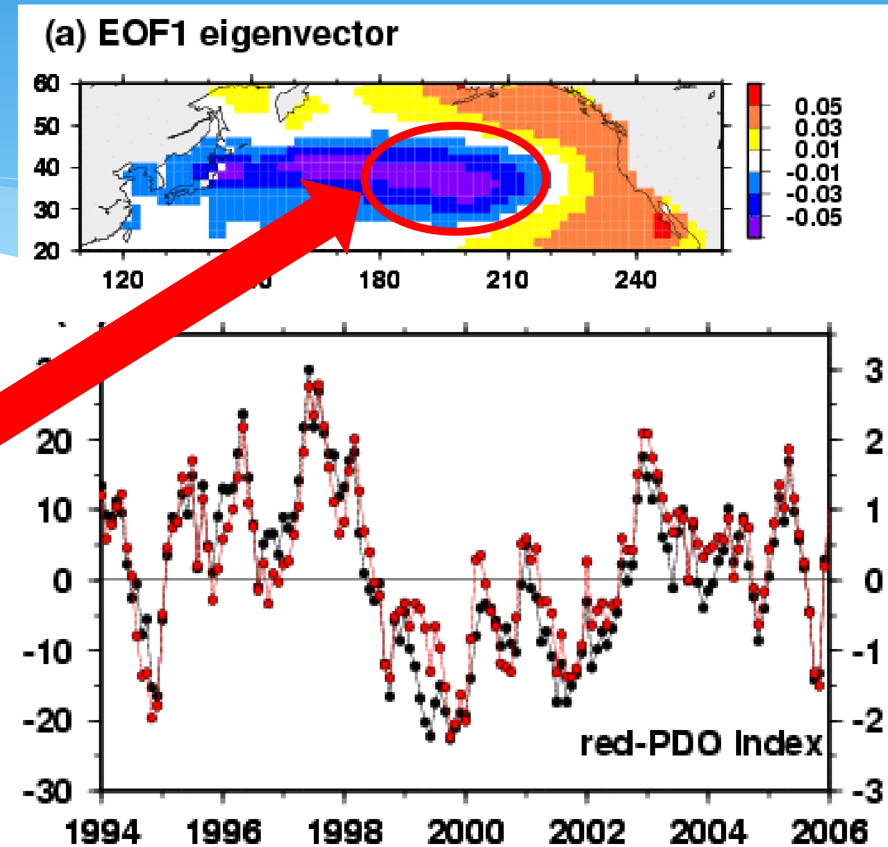
- **Correlation analysis**

We examine the statistical relationship between the CPUE time series of the autumn cohort of the neon flying squid and the ocean state variability in the North Pacific during 1994-2006 (after the international moratorium of the driftnet fishing), and try to detect a possible cause of the interannual variation of the squid stock.

results

Correlation maps [squid CPUE vs SST]



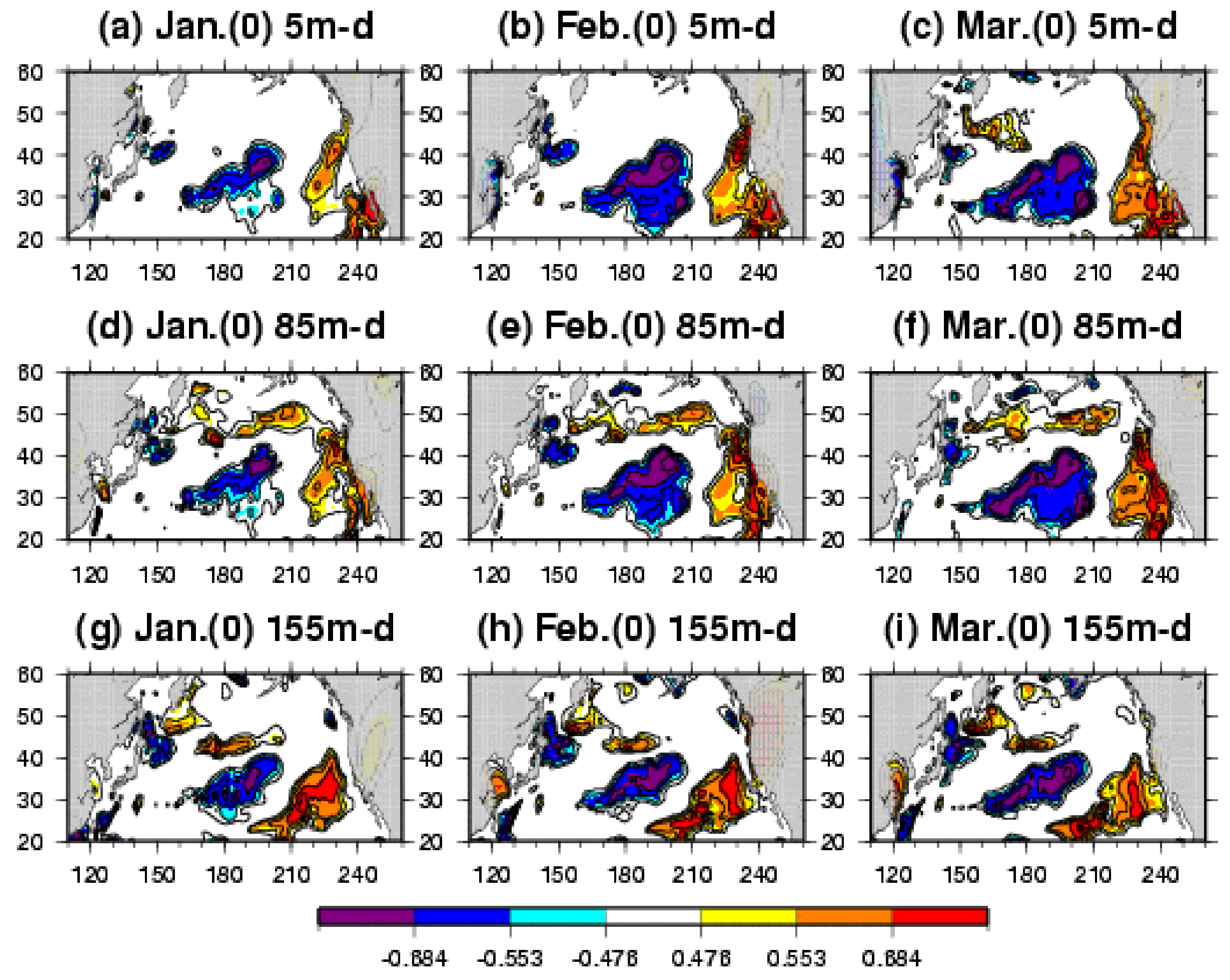


Negative correlation at 30-40N, 180-210E

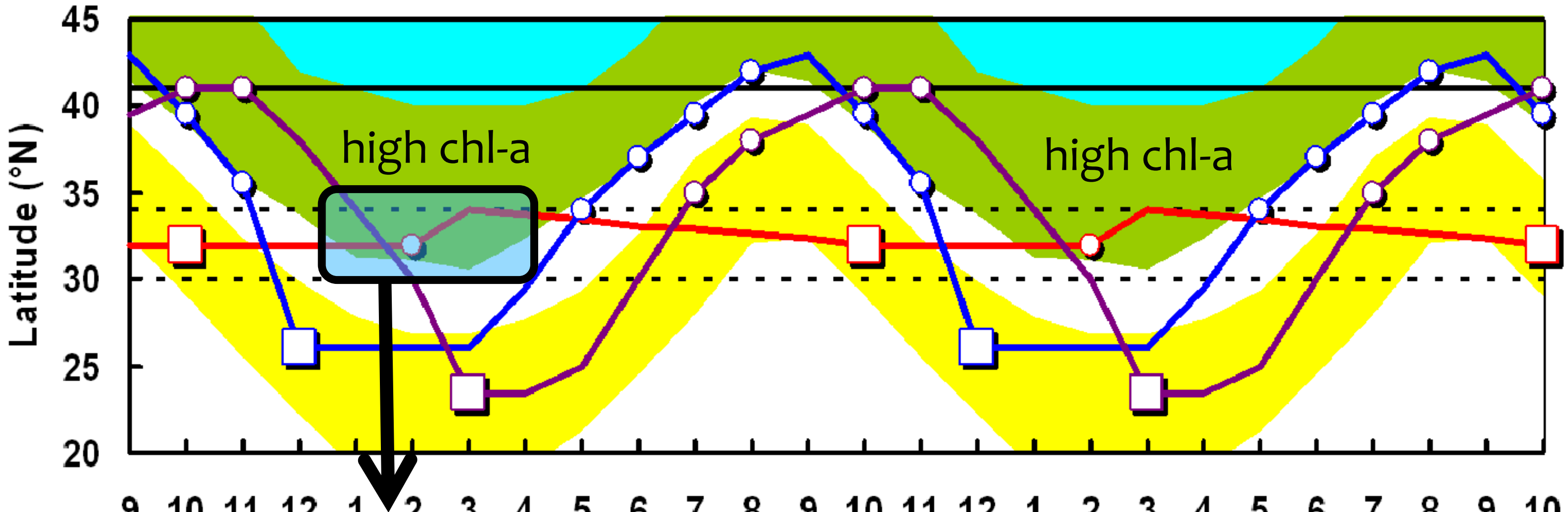
↓

Squid CPUE is correlated with winter PDO.
(Corr.=0.69)

Correlation maps between squid CPUE and winter temperature at 5m, 85m, 155m

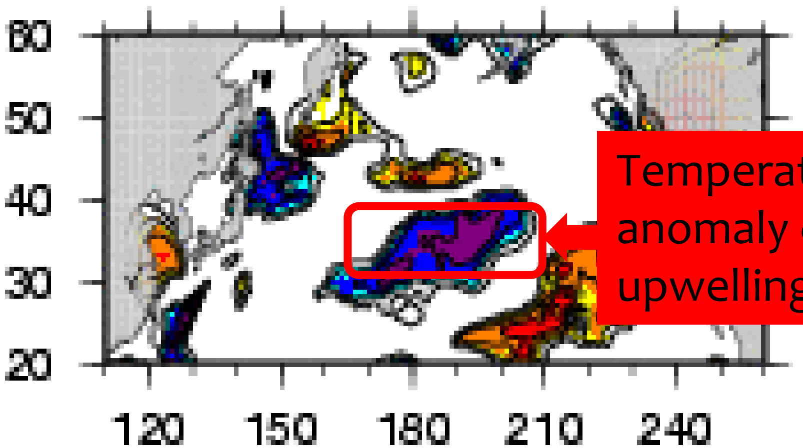


Life cycle of neon flying squid (male)

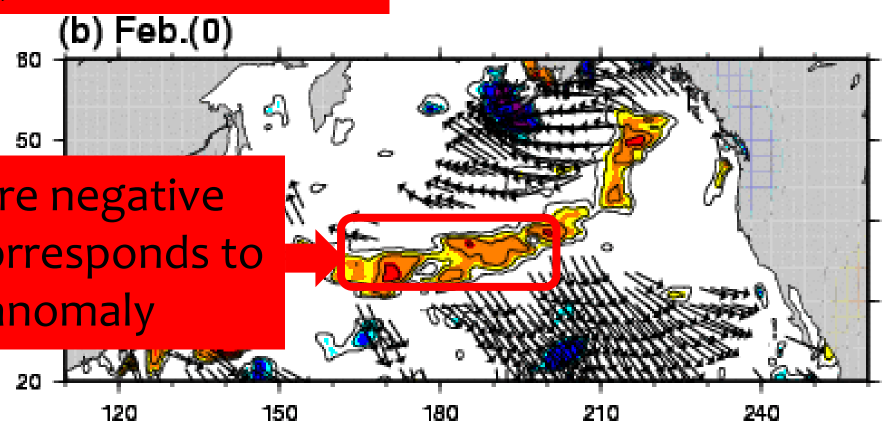


Autumn cohort

Seasonal southward shift of high chl-a zone in winter is important for the feeding condition of the autumn cohort juveniles.



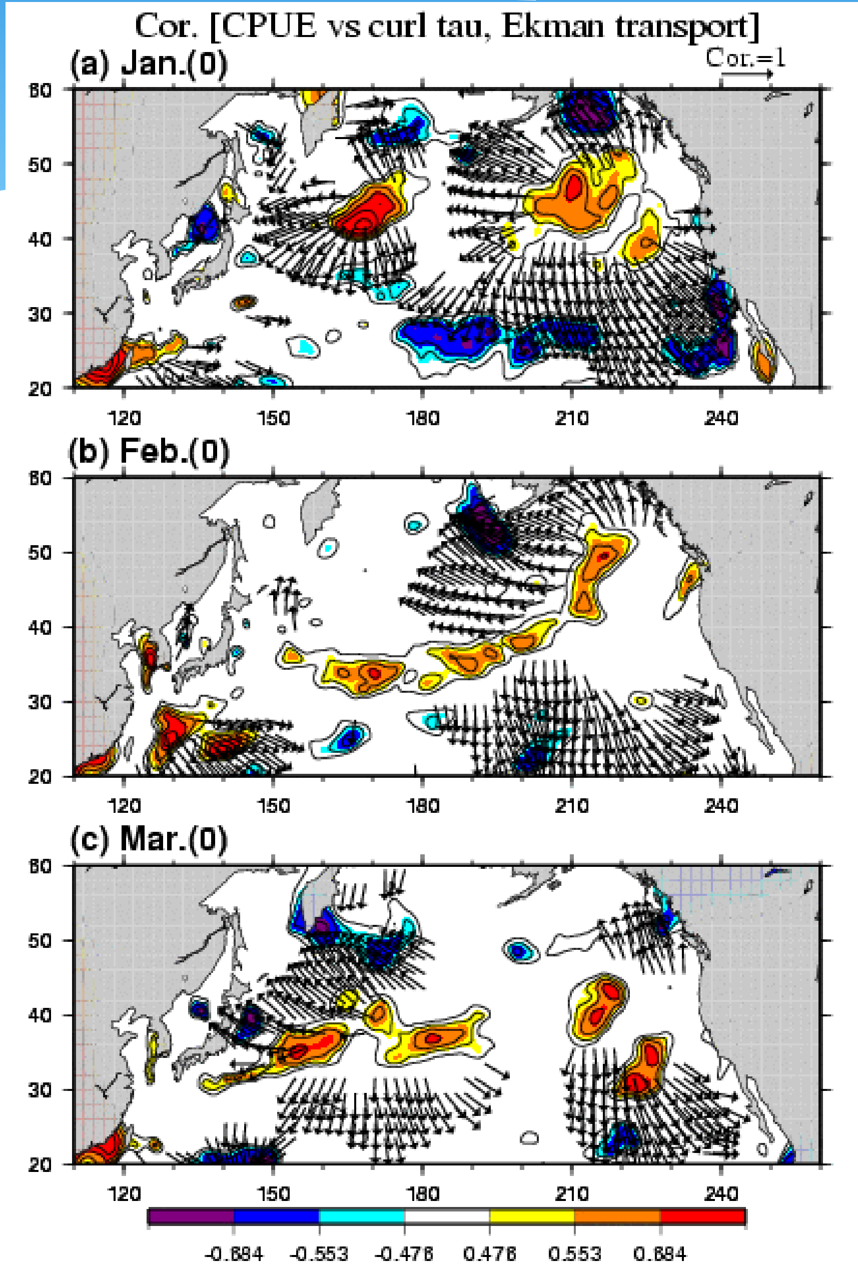
Temperature negative anomaly corresponds to upwelling anomaly



Correlation between CPUE and horizontal

Nutrient rich water supply from the subsurface and its divergence at the surface may control the productivity and the feeding condition of the autumn cohort.

Correlation maps [CPUE vs curlτ, Ekman transport]



The significant anomalous upwelling patterns and the corresponding divergence fields at the STFZ can be seen in February and March.
→→ weak !

estimation of entrainment rate

defined as the mass flux across the base of the mixed layer

$$ENT = (w_{mb} + \vec{u}_{mb} \cdot \nabla h_m + \frac{\partial h_m}{\partial t})$$

(Qiu and Huang,1995)

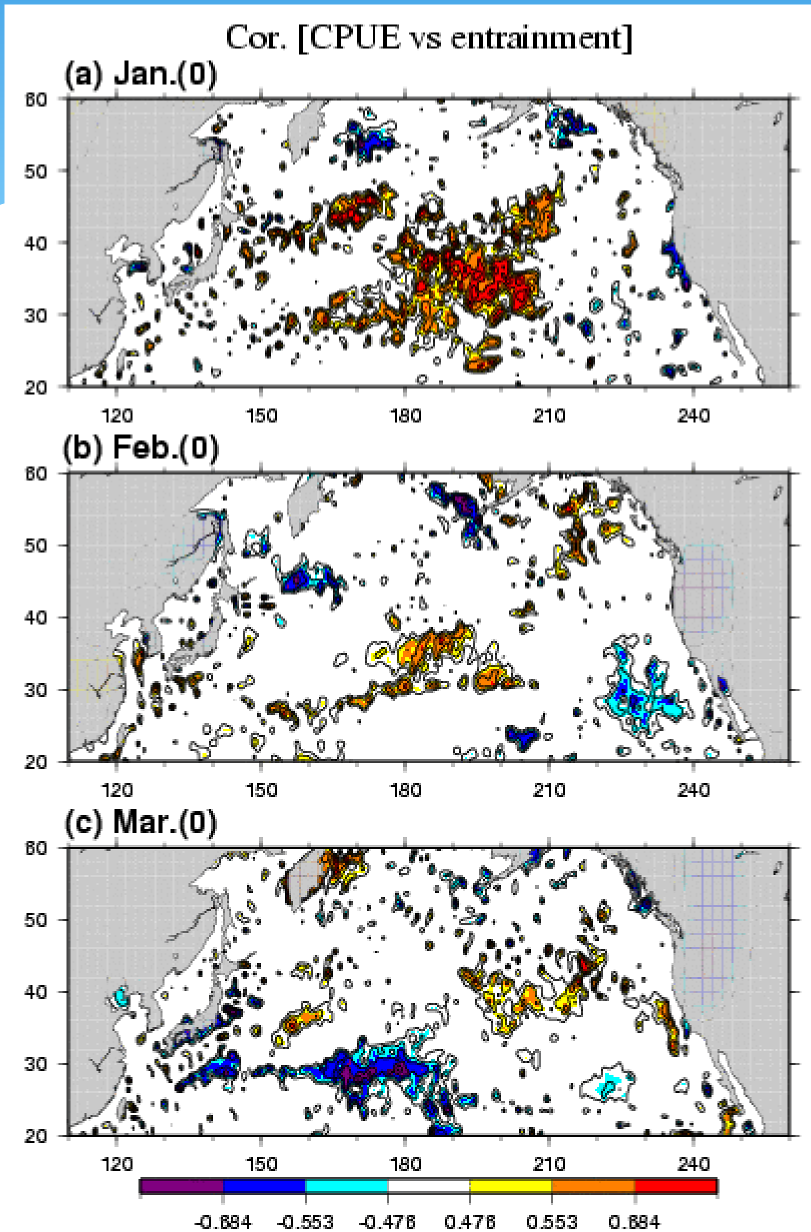
* W_{mb}: vertical velocity at the base of the mixed layer
* u_{mb}: horizontal verocity at the base of the mixed layer
* H_m: mixed layer depth

Here, we use the entrainment rate as a proxy of the nutrient rich water supply into the mixed layer.

↓

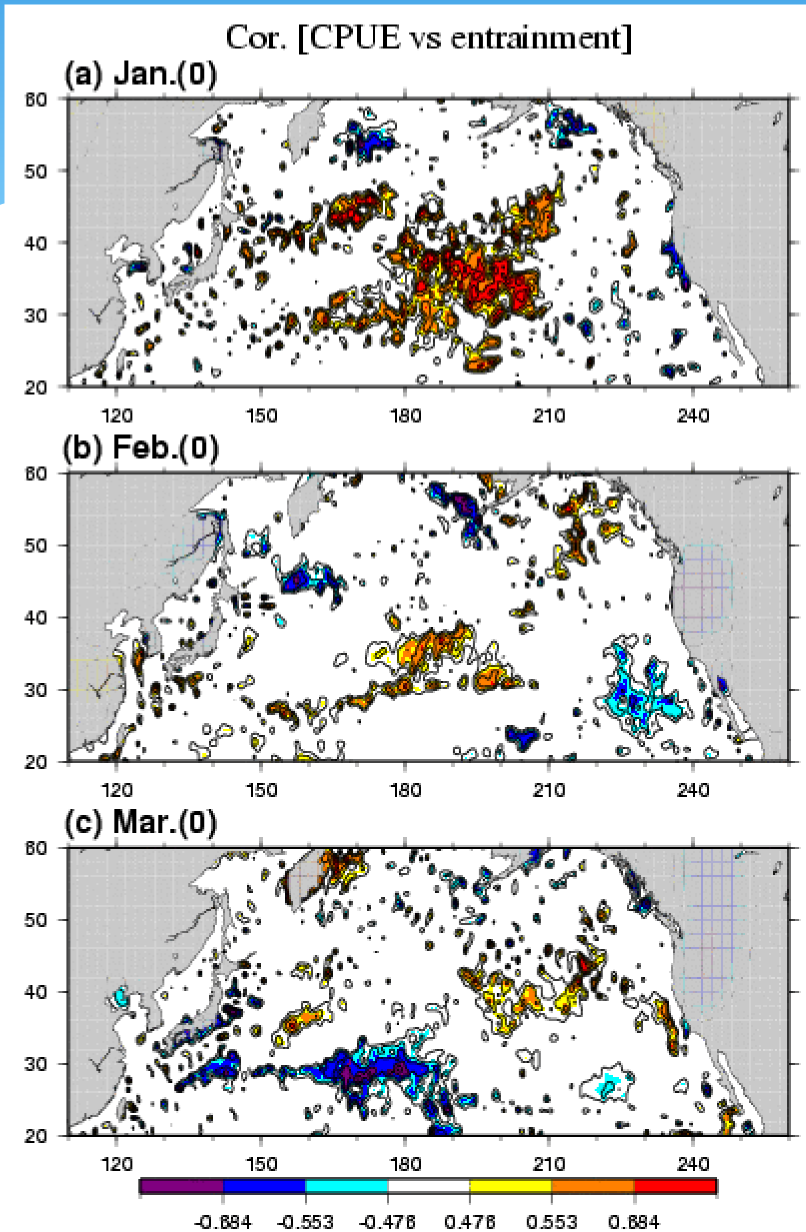
Correlation analysis with squid CPUE

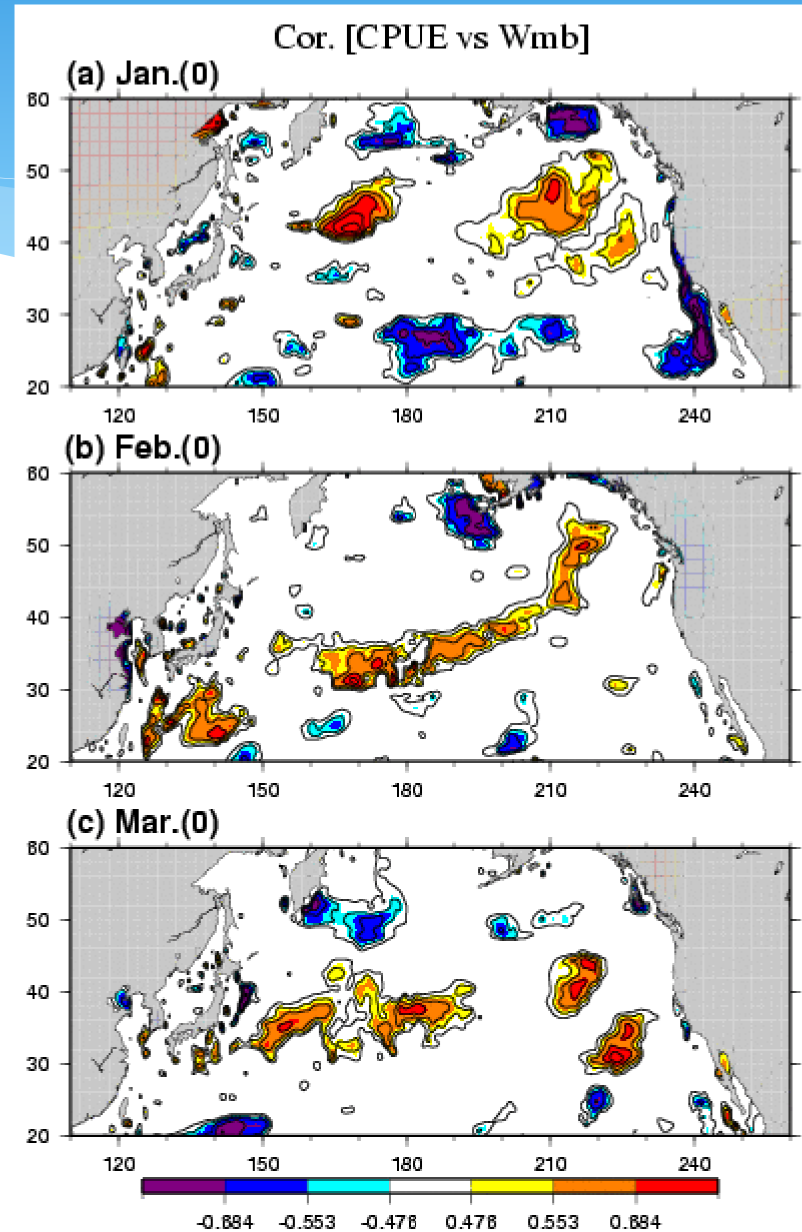
Correlation [CPUE vs entrainment]



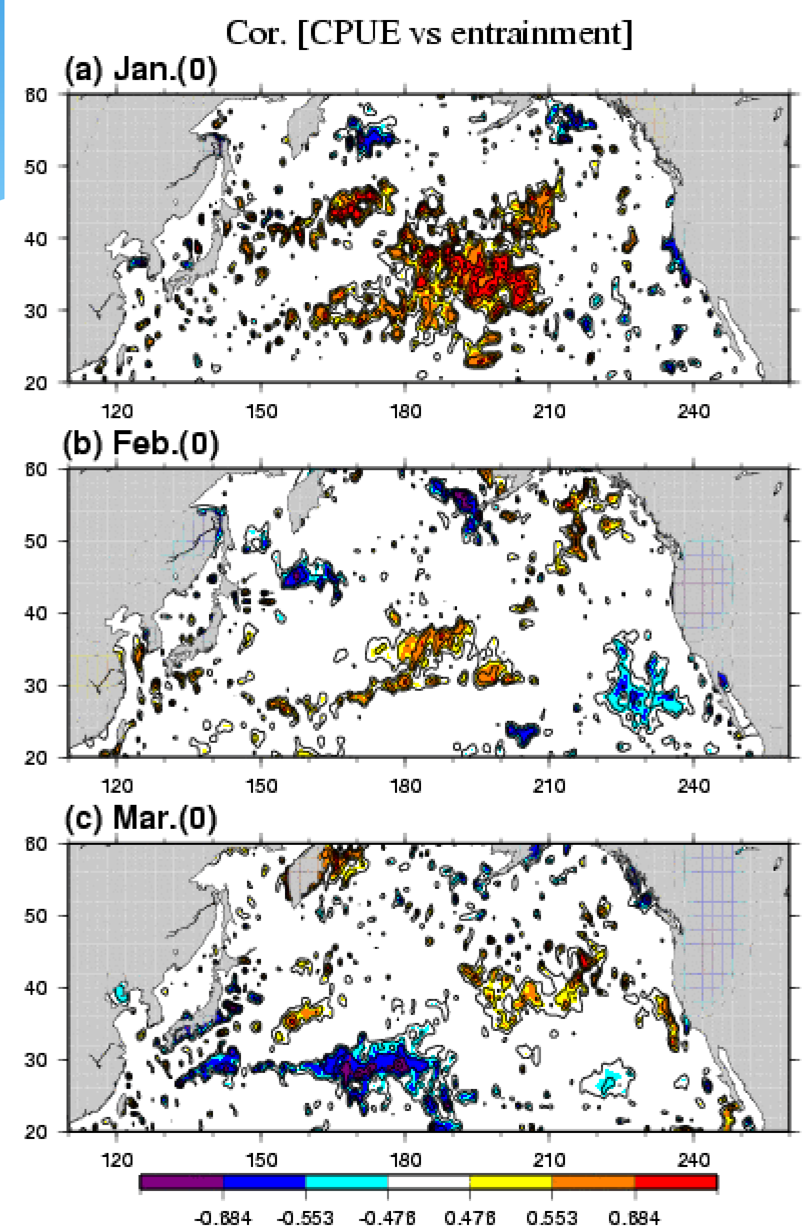
$$ENT = (w_{mb} + \vec{u}_{mb} \cdot \nabla h_m + \frac{\partial h_m}{\partial t})$$

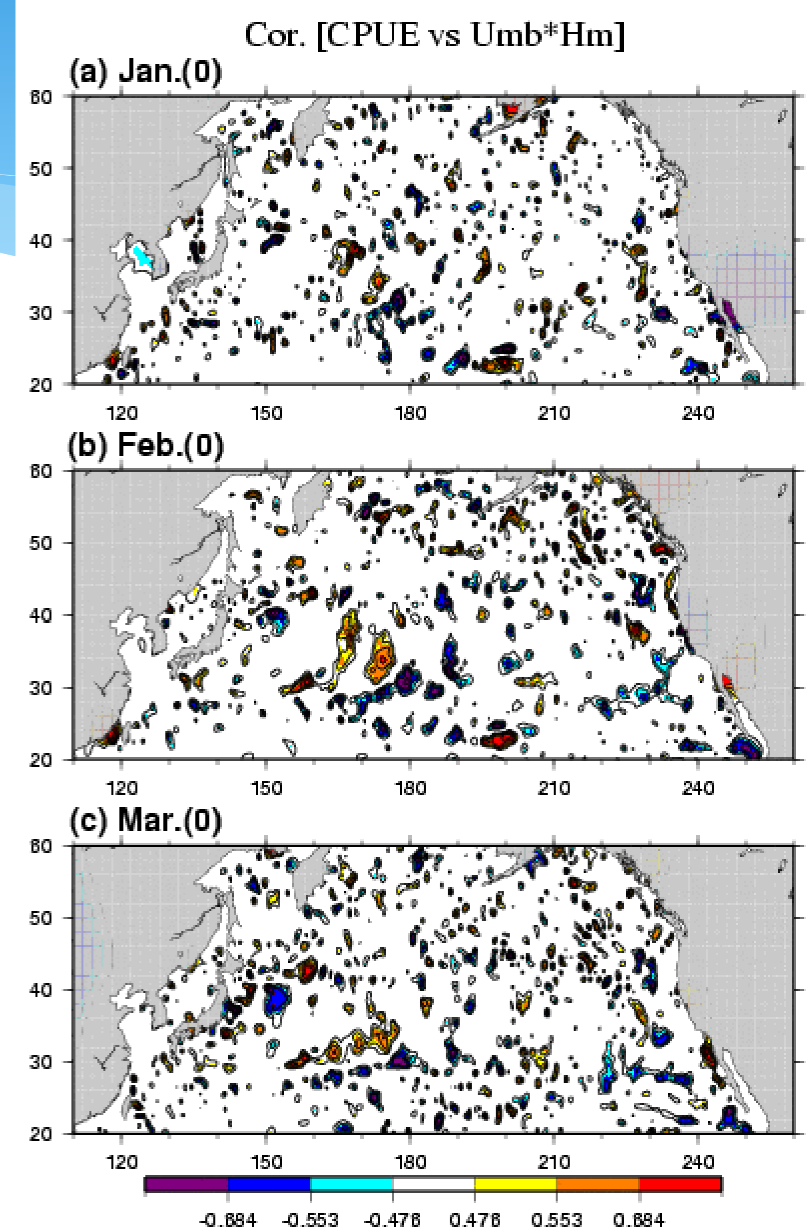
Correlation [CPUE vs upwelling term]



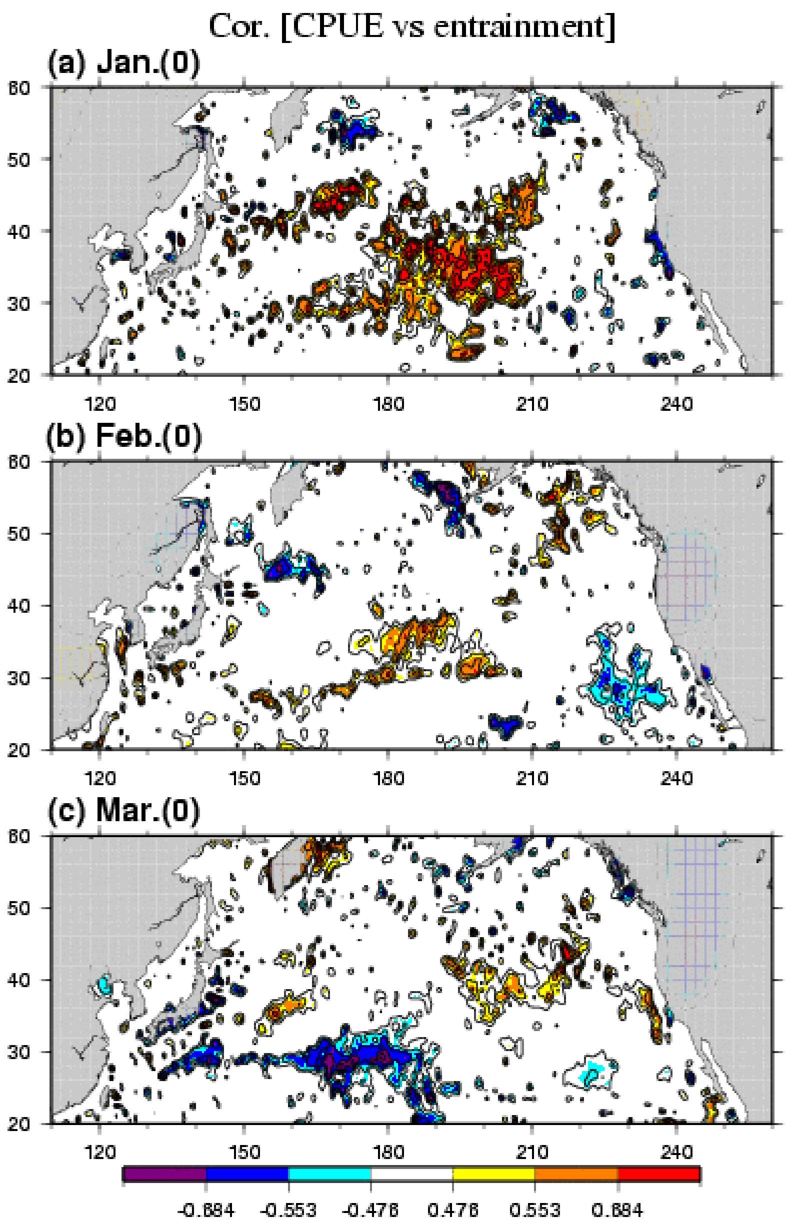


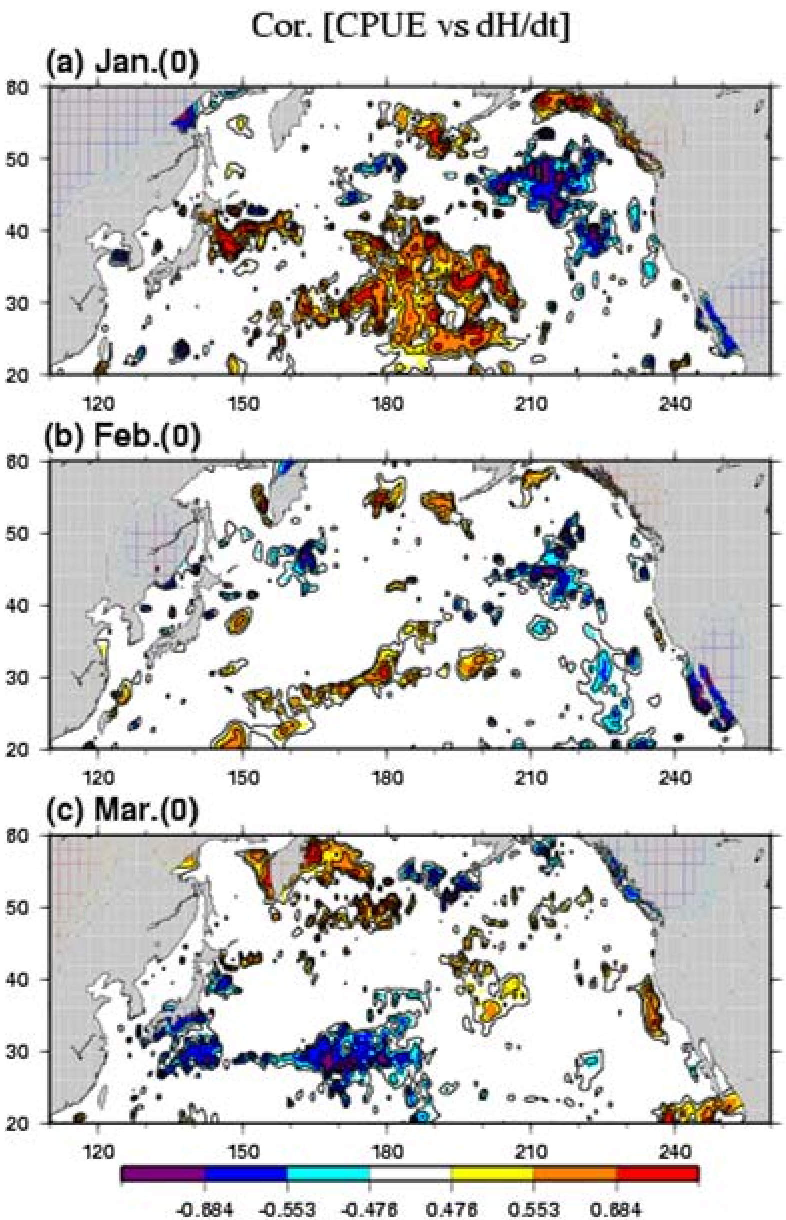
Correlation [CPUE vs advection term]



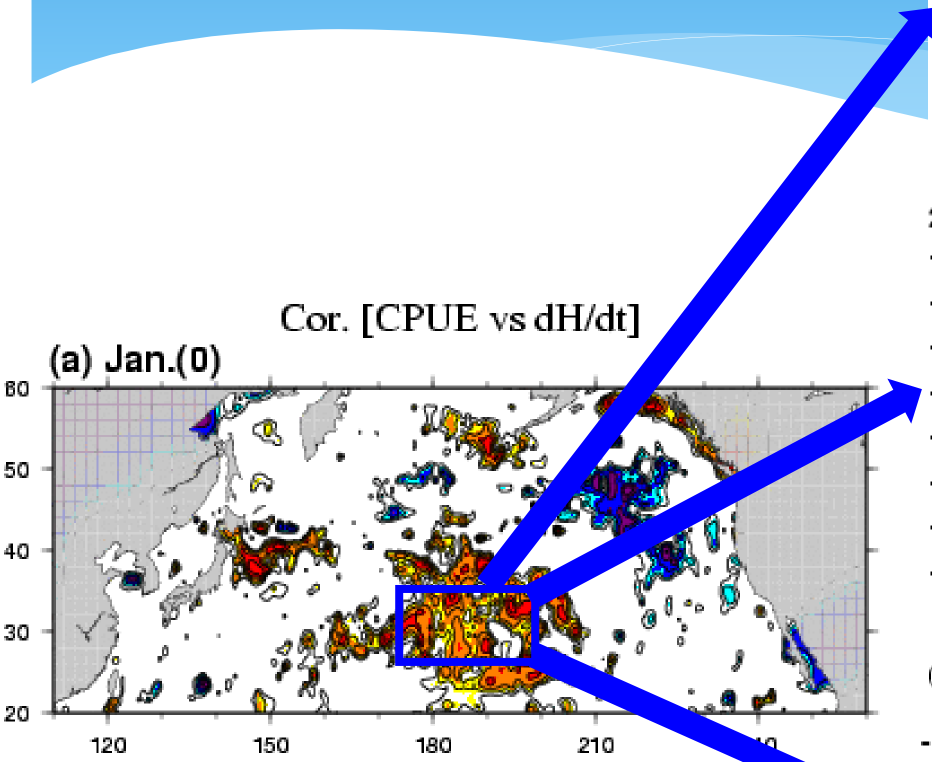


Correlation [vs MLD time tendency]

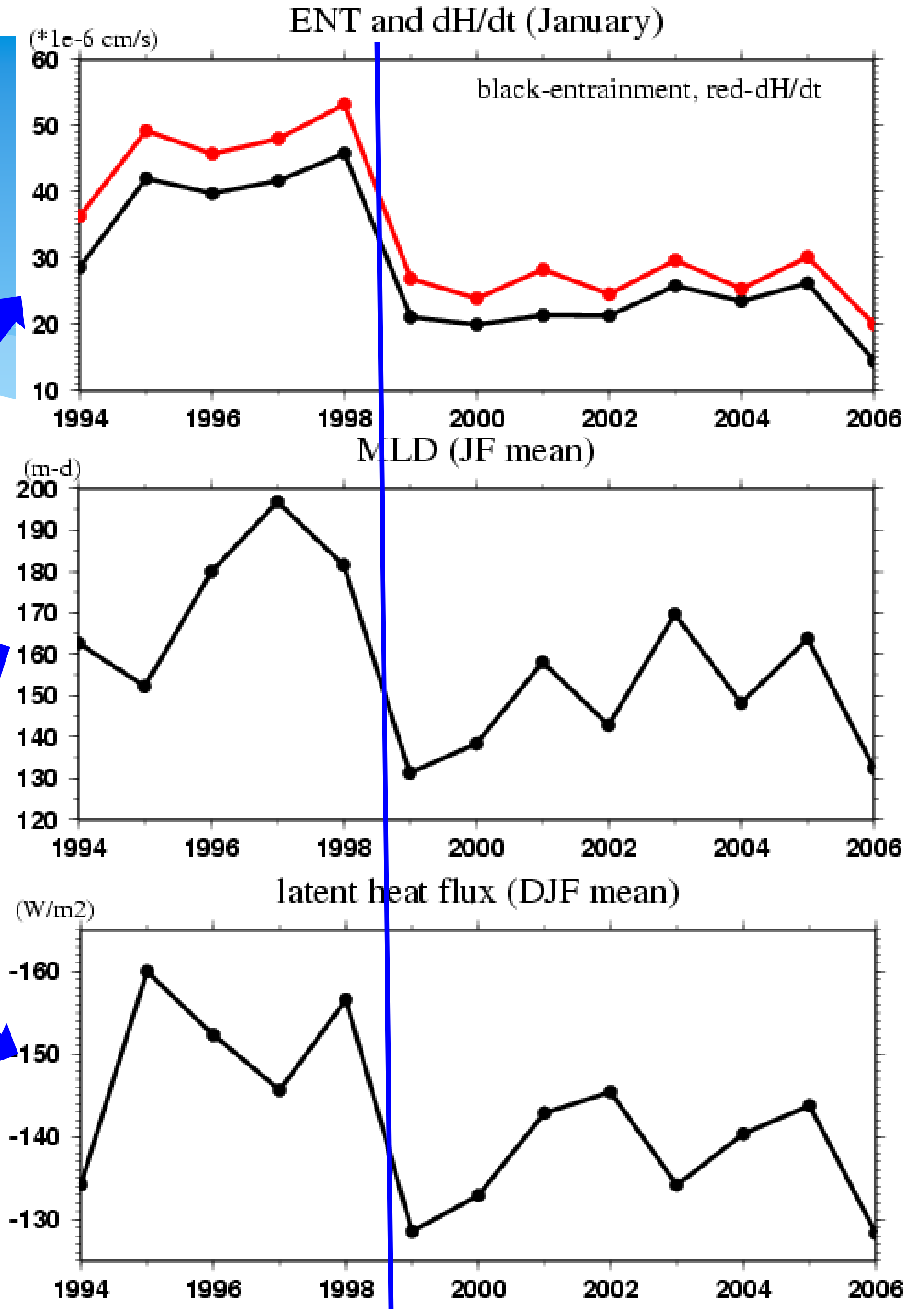




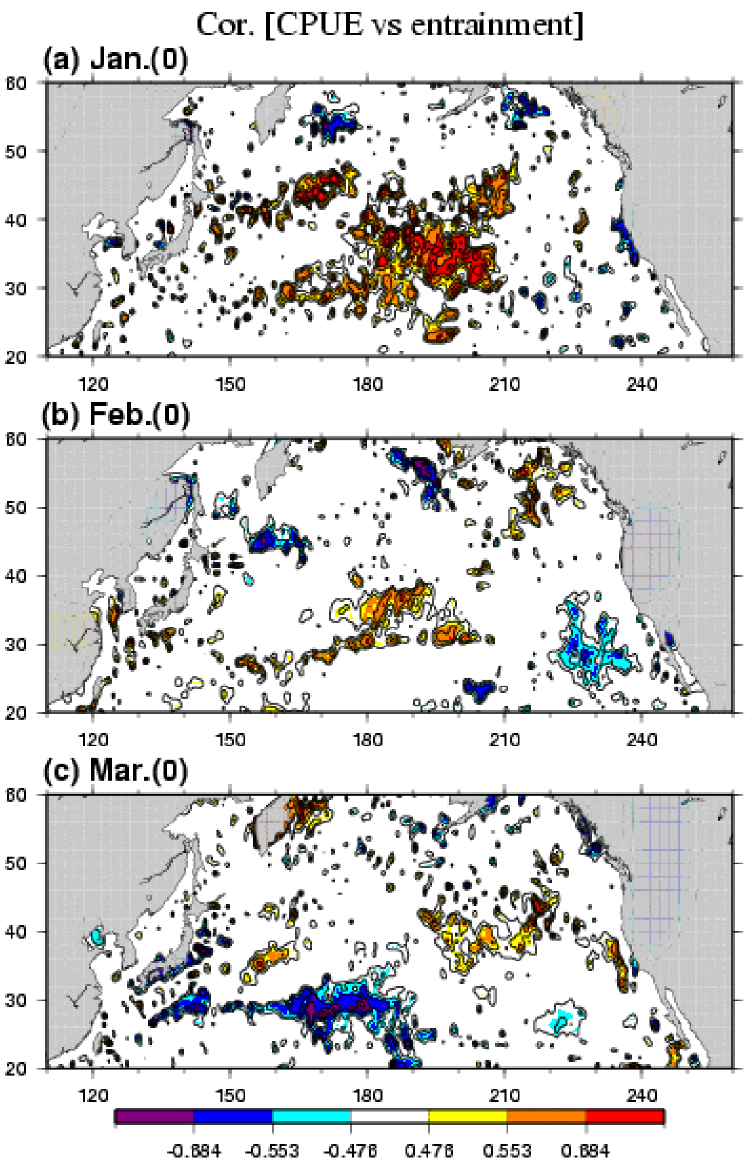
Time series of ENT,dH/dt, MLD and LH

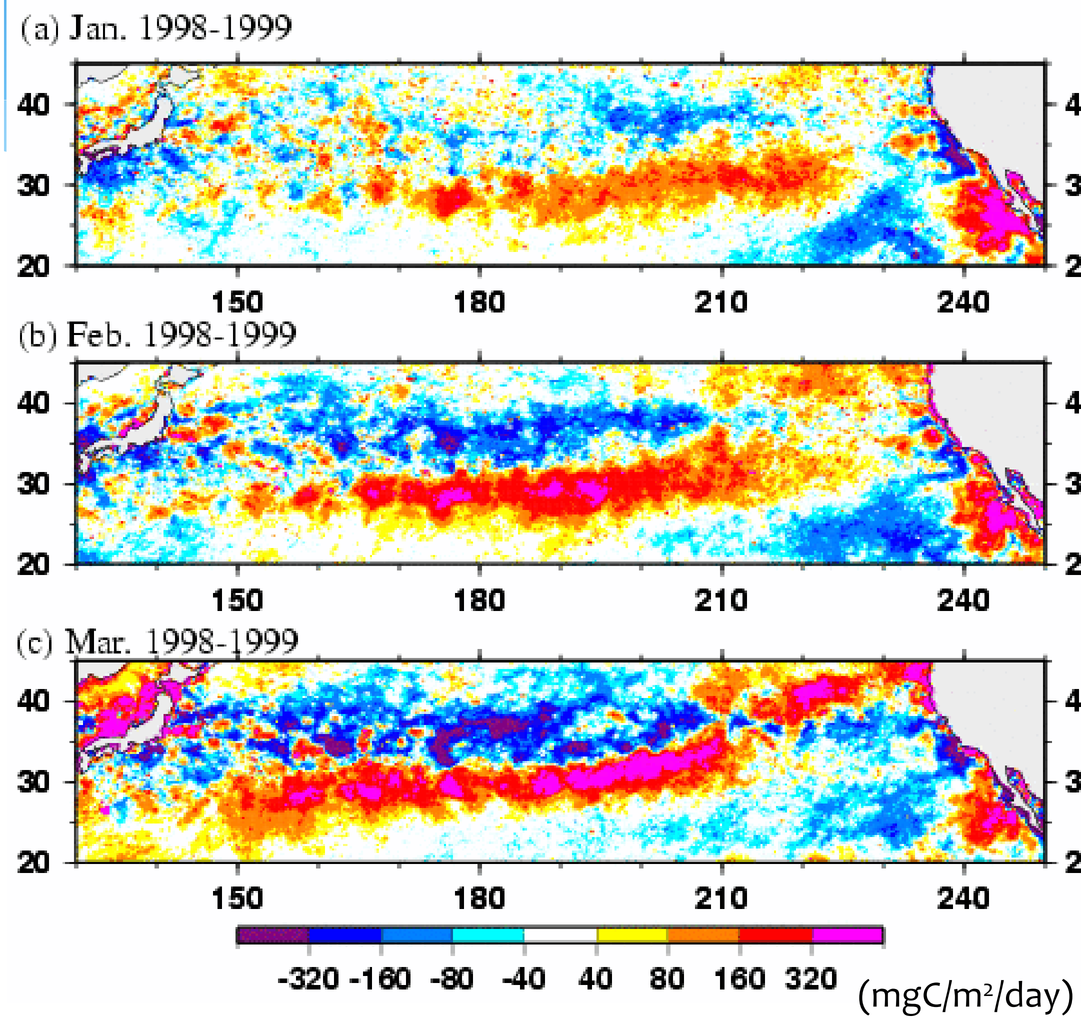


27-35N,177-200E

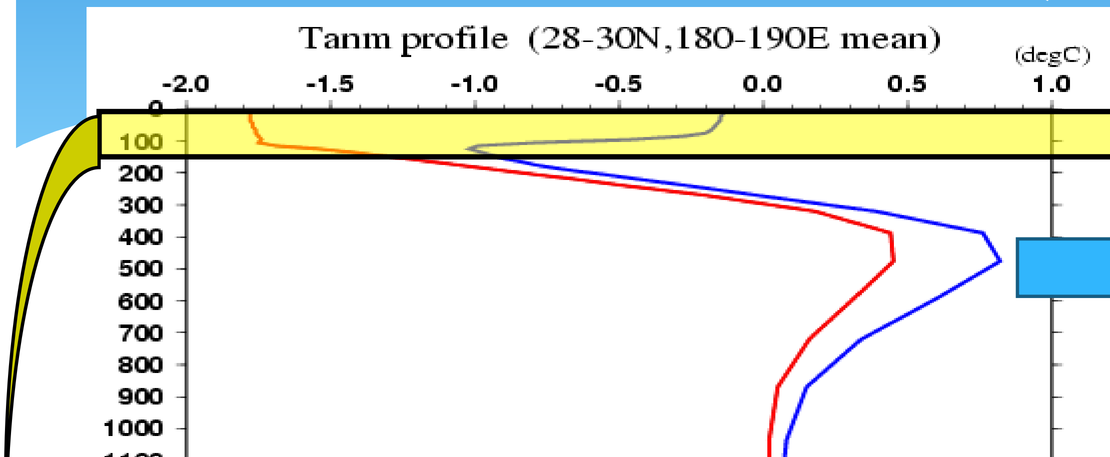


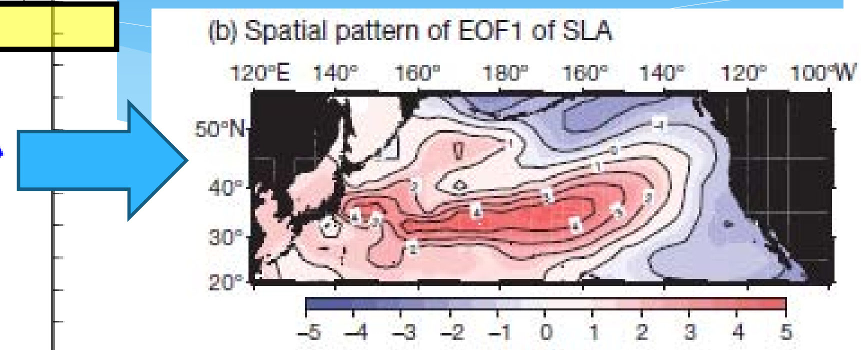
NPP difference (1998 minus 1999)



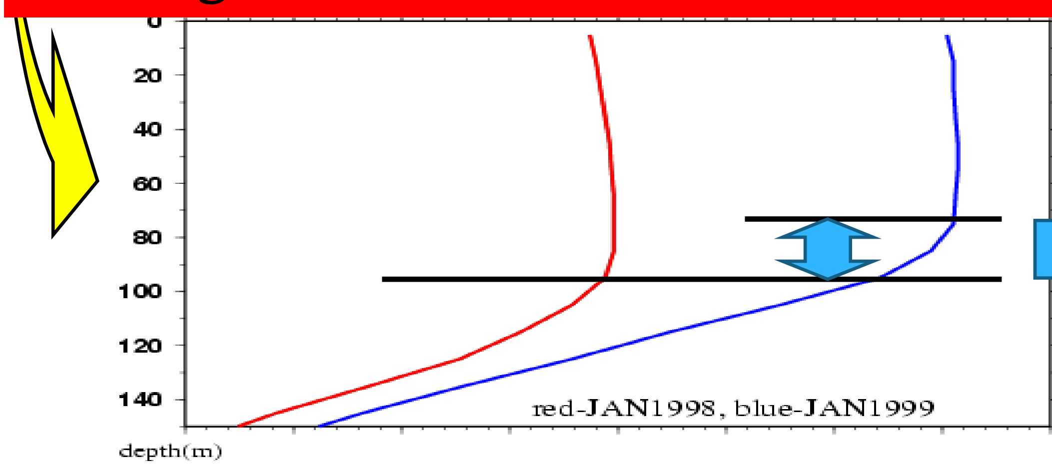


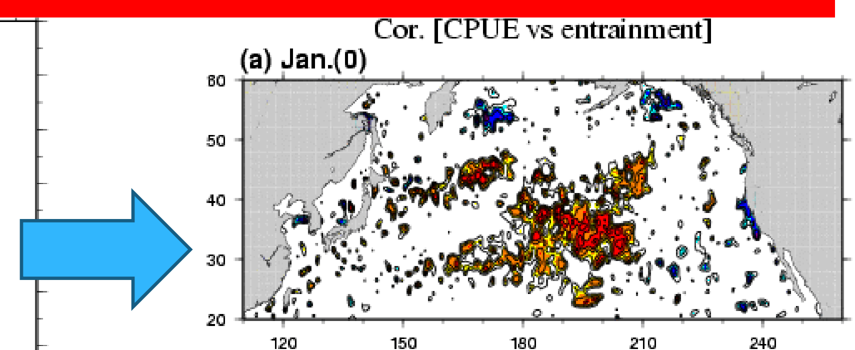
Vertical profiles of temperature anomalies in Jan 1998 and Jan 1999 (28-30N,180-190E)





These phenomena simultaneously occurred in the PDO mechanism. But the heat flux is more important to determine the nursery feeding condition for the autumn cohort.





Concluding remarks

* Statistical relationships between the interannual variation of the neon flying squid (autumn cohort) abundance in the North Pacific and the ocean state variability was investigated using the time series of the driftnet catch data and 4DVAR ocean data assimilation product.
* The abundance of the autumn cohort of neon flying squid was strongly affected by the large-scale ocean circulation in relation to Pacific Decadal Oscillation through the wintertime feeding condition.
* The amount of nutrient-rich water supply, important for the primary production activity, is tend to be affected by the local latent heat release during December to February and the resultant MLD variation in January.
* The accurate ocean state estimation can expect to provide us useful information for understanding the mechanism of fishery stock variation, better estimation, and effective stock management.

Thank you.

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