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Relationships between ocean conditions and interannual variability of habitat suitability index (HSI) distribution for neon flying squid in central North Pacific examined using new 4D-VAR ocean reanalysis dataset

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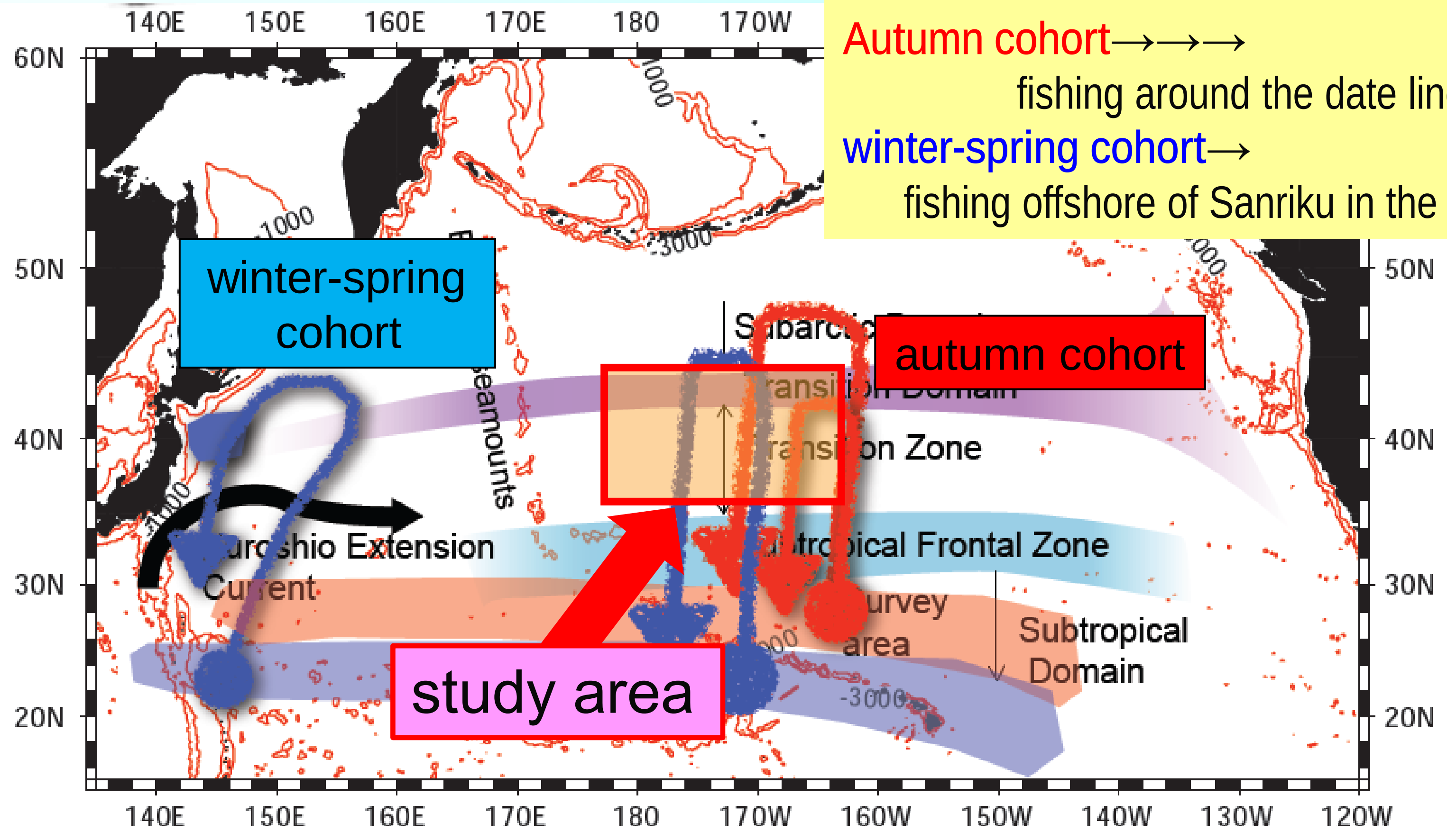
outline

1. Introduction
2. Purpose
3. Data and methodology
4. Results
5. Concluding remarks

neon flying squid
(*Ommastrephes bartramii*)

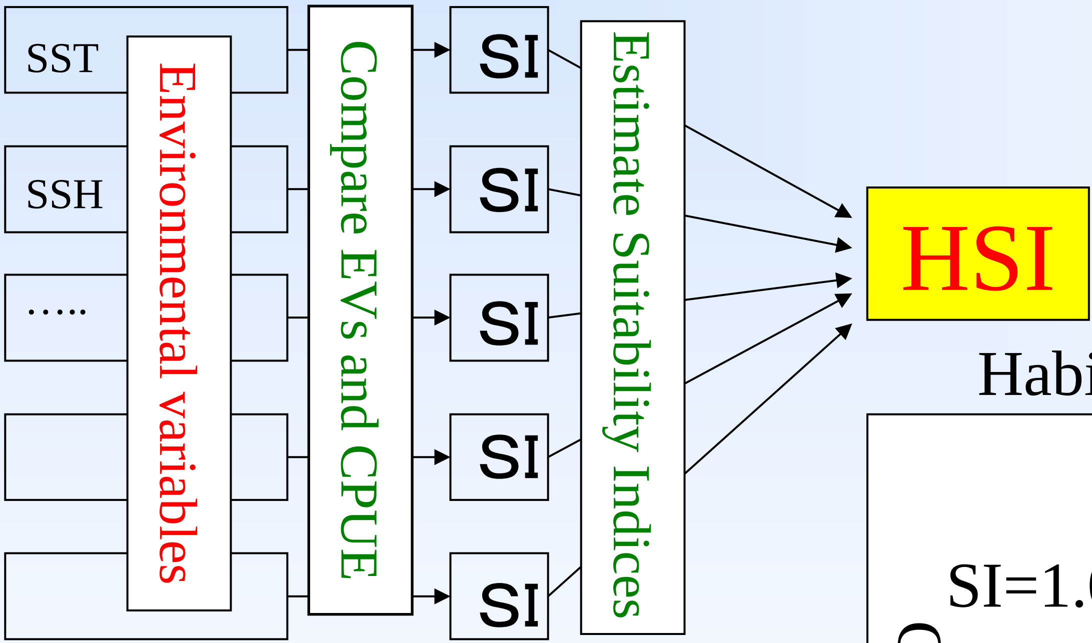
- widely distributed in the North Pacific
- 1-year lifespan and seasonal migration
- important for pelagic ecosystem and Japanese fisheries



Autumn cohort→→→
fishing around the date line in summer
winter-spring cohort→
fishing offshore of Sanriku in the next winter

Habitat Suitability Index(HSI)model

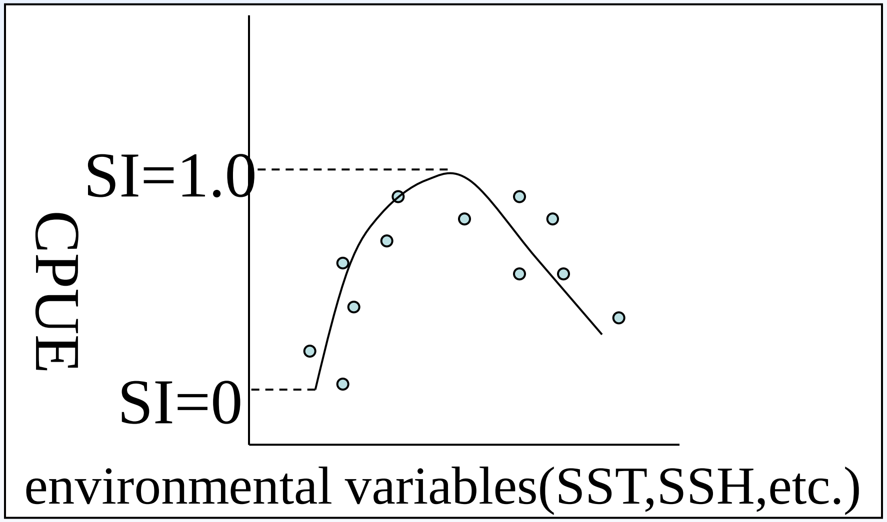
- is widely used as a tool for ecological impact assessment.
- describes the relations between fish abundance and environmental variables, estimates the level of habitat suitability as an HSI score ranging from **0 to 1**.



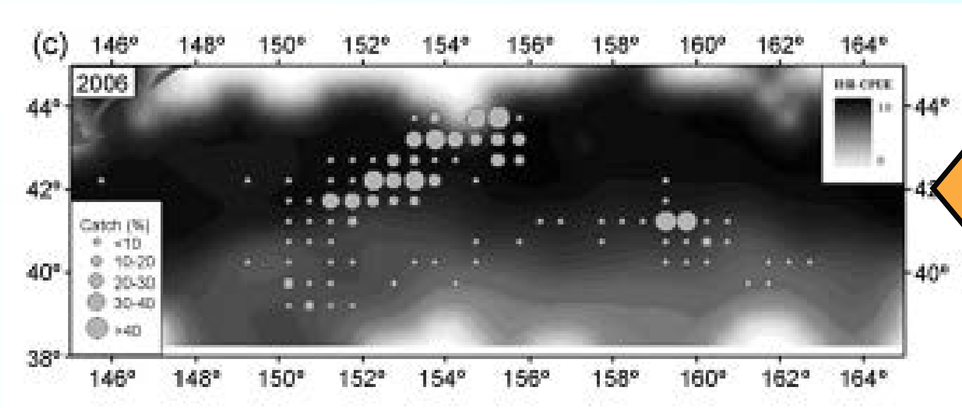
HSI=f(Si1, Si2, Si3,・・・)

SI: Suitability index

Habitat Suitability Index



Evaluating HSI for neon flying squid around Kuroshio extension region (Tian et al.,2009)



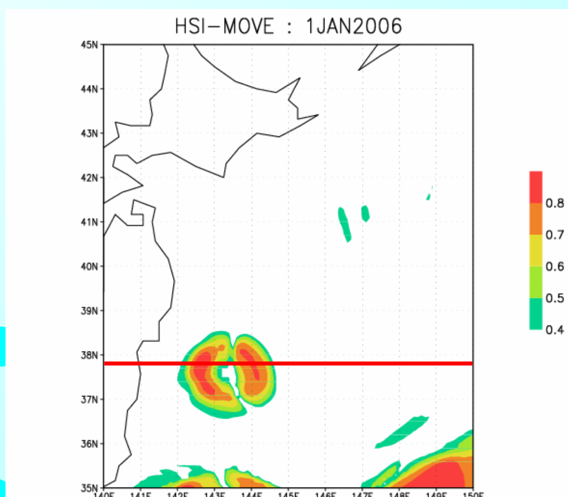
Estimated HSI distribution(gray scale) and catch observation(○) in 2006

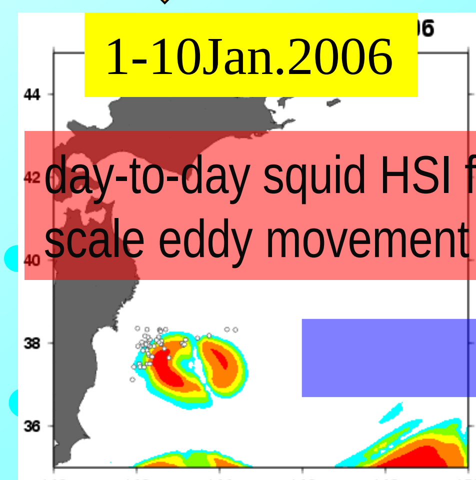
High HSI have little correspondence with high catch in the wide area.

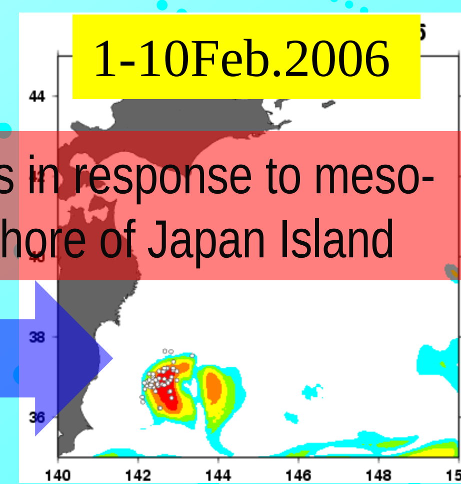
Monthly mean SST,T(35m),T(317m), SSS,SSH were used.

It is well-known that the meso-scale eddy activities strongly affect the ocean biogeochemical and fishery environments in this area, but this model doesn't have a potential to express them because of using just monthly mean values.

RECCA
Research Program on Climate Change Adaptation
(2010-2014)



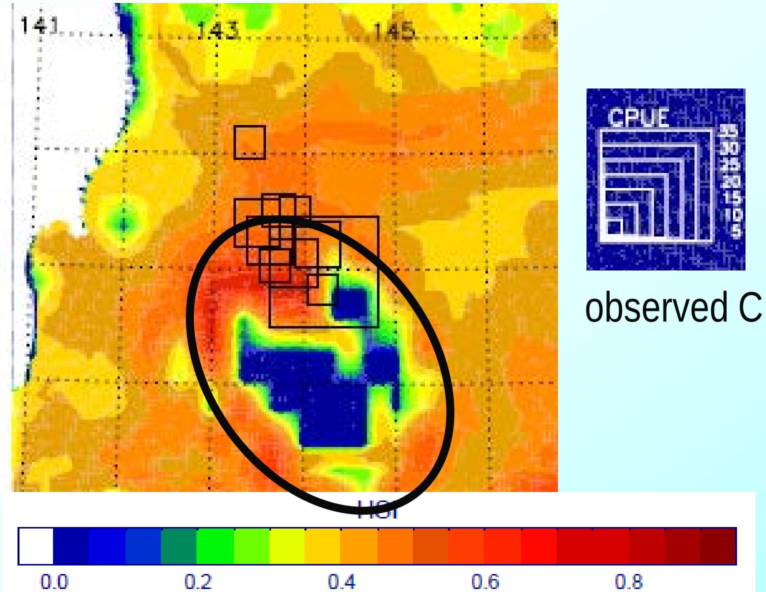




day-to-day squid HSI fields in response to meso-scale eddy movement offshore of Japan Island

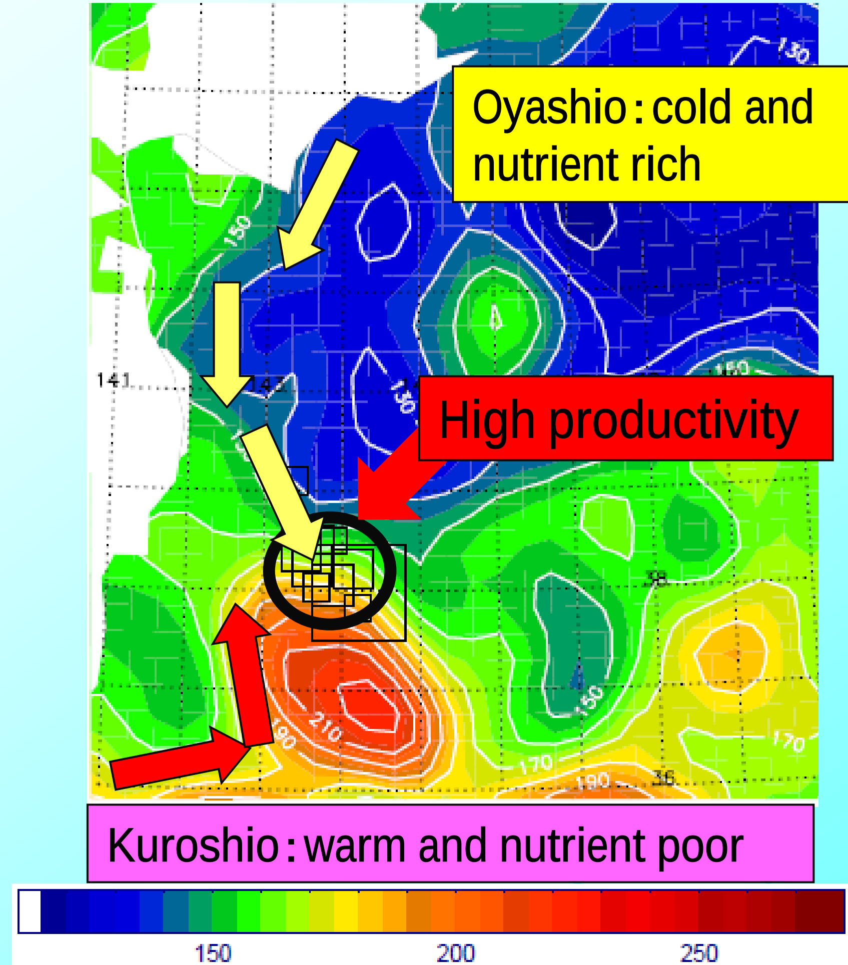
○:actual fishing point

winter fishing ground
(offshore of Japan Island)

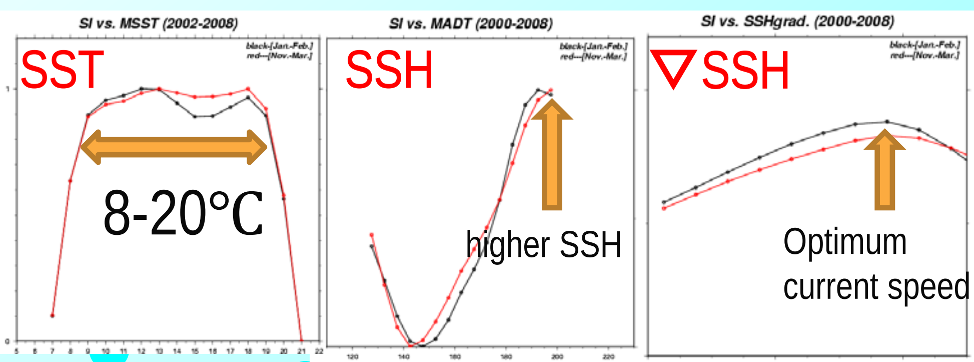


observed CPUE

HSI map(15Feb.2007)



SSH distribution（15Feb.2007）



SI curve of neon flying squid HSI model

The mixture of Oyashio and Kuroshio and the local upwelling leads to high-productivity and high squid abundance.

Fishing ground in the central North Pacific

- The accurate estimation of squid HSI fields is more difficult because the fishing ground is wider than that in winter and ocean environmental changes are more complicated.
- The relationship between squid habitat and a variety of ocean phenomena has not been examined.

【purpose】

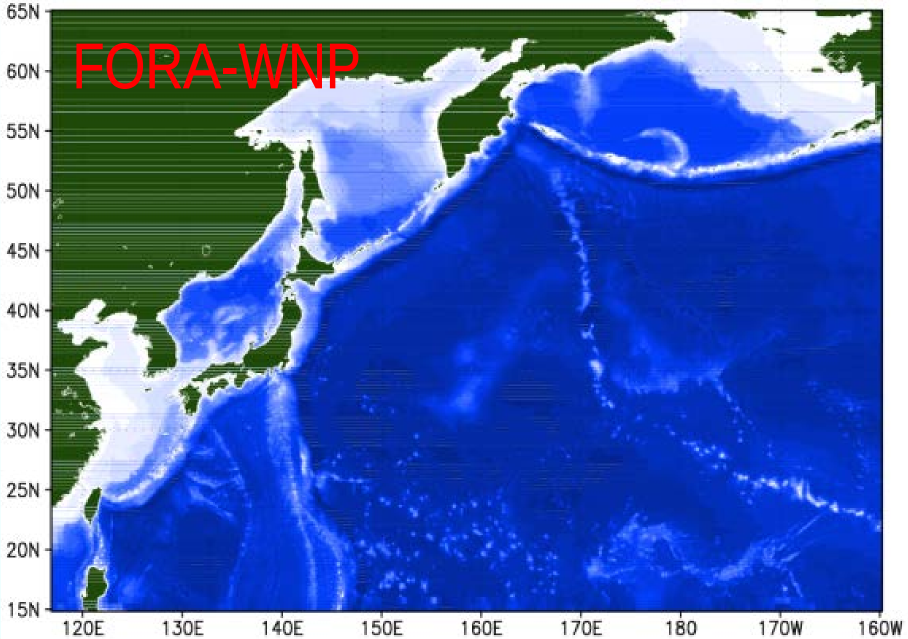
・In order to specify the typical spatial scales of the neon flying squid HSI variations, we developed an empirical weighted ensemble model from the six HSI models, and describes the characteristics of the HSI fields scale by scale by applying 2-D Fourier transform.

・Interannual variation in squid HSI was compared to that in the RMSE of the ensemble model and the seasonal mean squid CPUE.

data

Long-term ocean reanalysis dataset FORA (4-dimensional variational Ocean ReAnalysis)

JAMSTEC/CEIST and MRI/JMA have produced a new 4D-VAR ocean reanalysis dataset by using the Earth Simulator 3rd generation.



data period : 1982-2012, daily
data domain : 117-200E, 15-65N
resolution : horizontal 0.1*0.1° （1/6° north of 50N and east of 160E）, vertical 54 levels
atmospheric forcing: JRA55

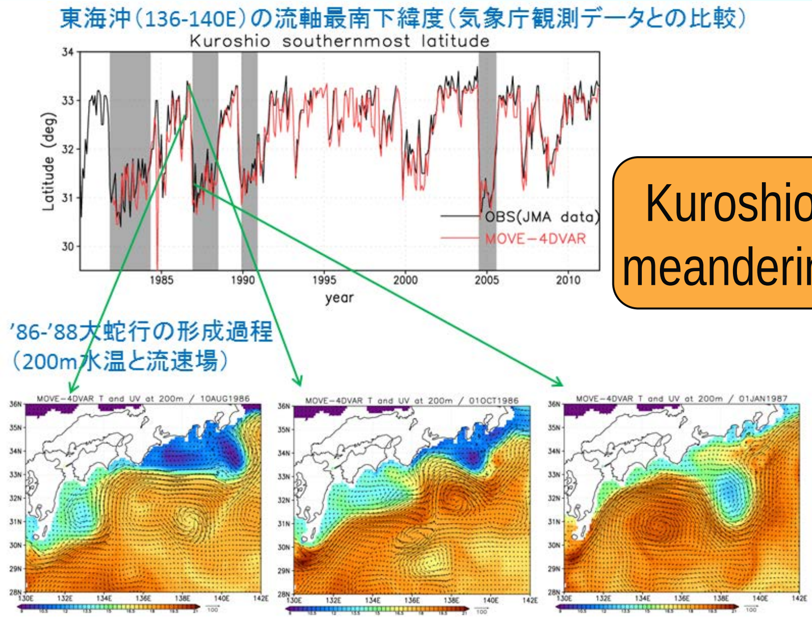
Variables: potential temperature, salinity, horizontal velocity, sea surface height, sea ice concentration

This dataset was produced by the state-of-the-art ocean data assimilation system MOVE-4DVAR developed by MRI/JMA, which can provide the best time-trajectory fit to observations and created a dynamically self-consistent dataset.

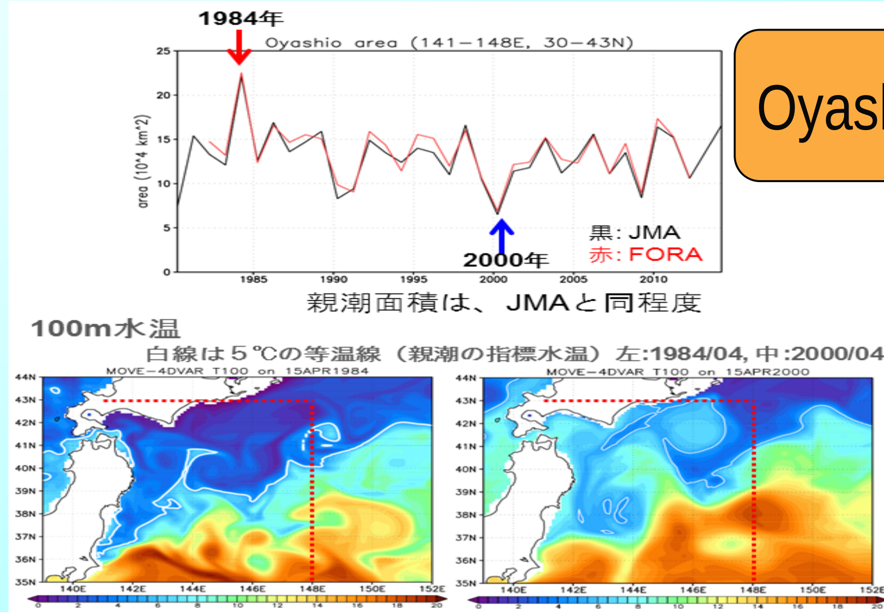
assimilation method : ４D-VAR
assimilation window : 10 days
optimization scheme : POpULar
Incremental Analysis Update(IAU) 3days
TS EOF mode

performance

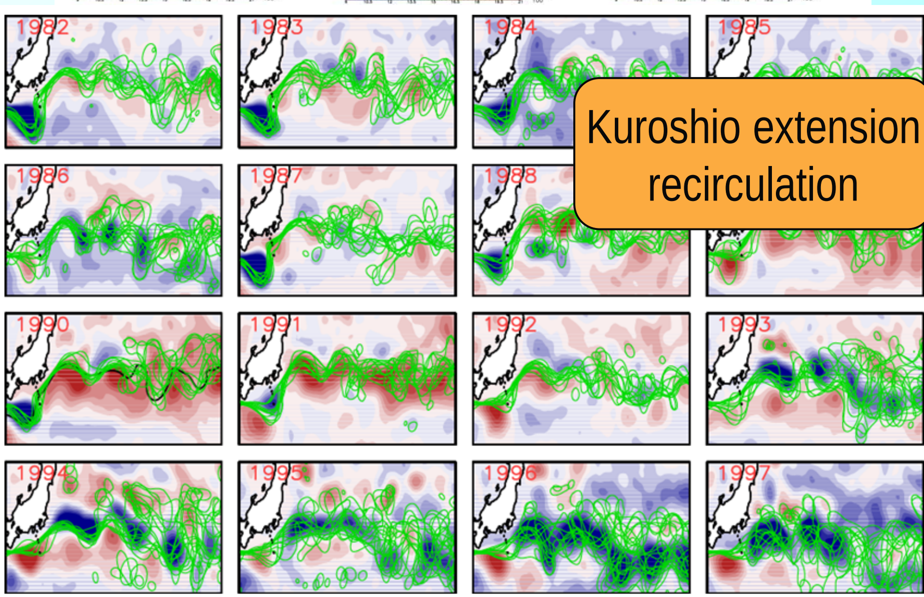
Long-term ocean reanalysis dataset FORA (4-dimensional variational Ocean ReAnalysis)



Kuroshio meandering



Oyashio



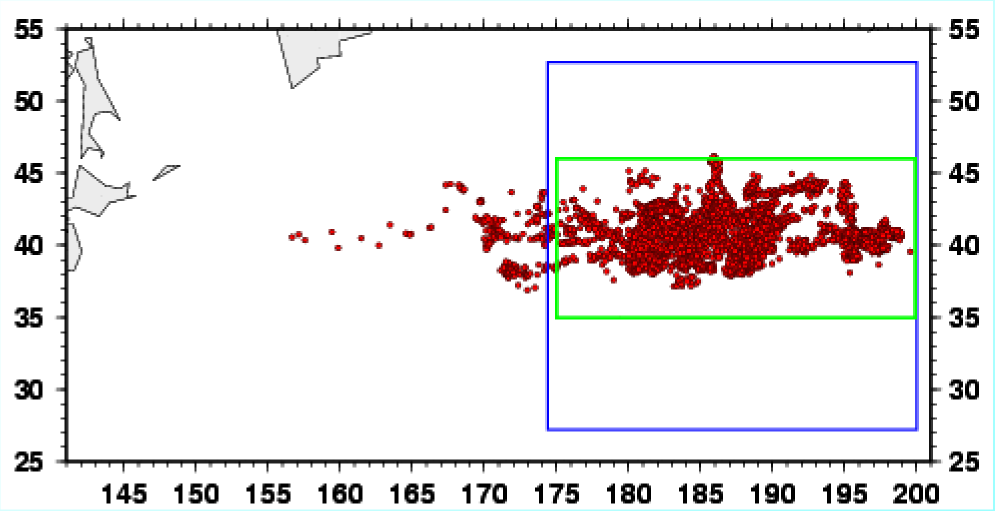
Kuroshio extension recirculation

FORA-WNP data release

FORA-WNP dataset is now provided to academic researchers for a broad range of ocean/climate research applications. Please contact us for using FORA dataset.

data

● : squid observation
□ : study area



- Fishery data
  Commercial fisheries data of neon flying squid from June to July during 1999–2012
  (by Aomori Prefectural Industrial Technology Research Center)
  the dates of fishing, fishing locations, CPUE(No./hour/machine)
- FORA-WNP dataset
  27.2–52.7N,174.4—200E (0.1*0.1 deg, 256*256 mesh)
  daily temperature, salinity, current velocity(U,V), SSH
  (vertical: upper 30 levels(1–780m))

methodology

- 6 models (HSI・GAM・neural network(NN)・MARS・Random Forest(RF)・Support Vector Machine(SVM)) were constructed.
- Multiple regression analysis were applied to top 50 components of each HSI models for making an "ensemble model".

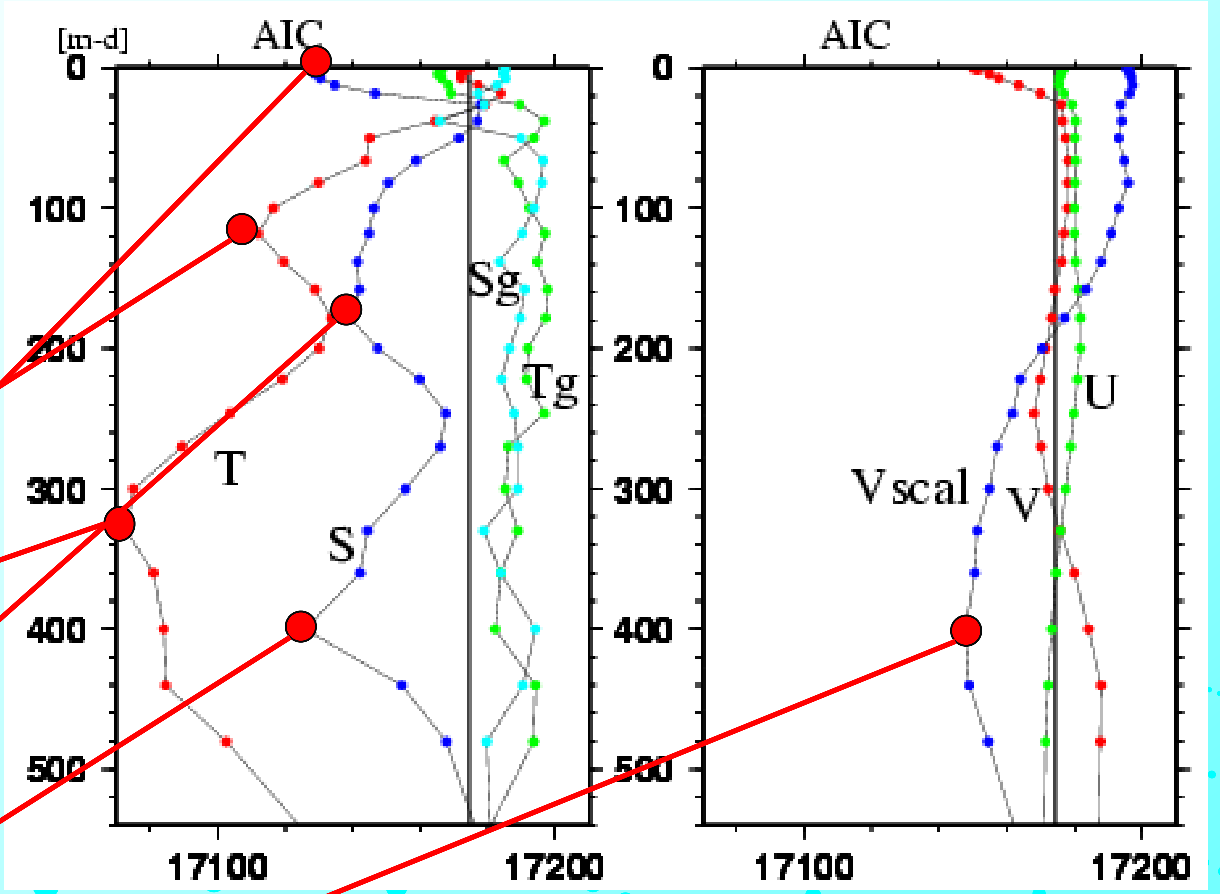
$$ln(CPUE) = a + \sum_{i=1}^{50} f_{1i} * (HSI_i) + \sum_{i=1}^{50} f_{2i} * (GAM_i) + \sum_{i=1}^{50} f_{3i} * (NN_i) + \sum_{i=1}^{50} f_{4i} * (MARS_i) + \sum_{i=1}^{50} f_{5i} * (RF_i) + \sum_{i=1}^{50} f_{6i} * (SVM_i) + \varepsilon$$

- 2-dmensional Fourier transform were applied to decompose the HSI fields of each model.
- Typical spatial scales were extracted from the ensemble model and their characteristics were described scale by scale.
- Interannual variation in squid HSI was compared to that in the RMSE of the ensemble model and the seasonal mean squid CPUE.

Parameters for making statistical models

selected 10 parameters

- SSH
- SSH gradient
- MLD
- SST
- T-118m
- T-330m
- SSS
- S-178m
- S-400m
- Vscal-400m



Vertical profiles of AIC of GAM constructed using SSH,∇SSH,SST and additional one parameter.

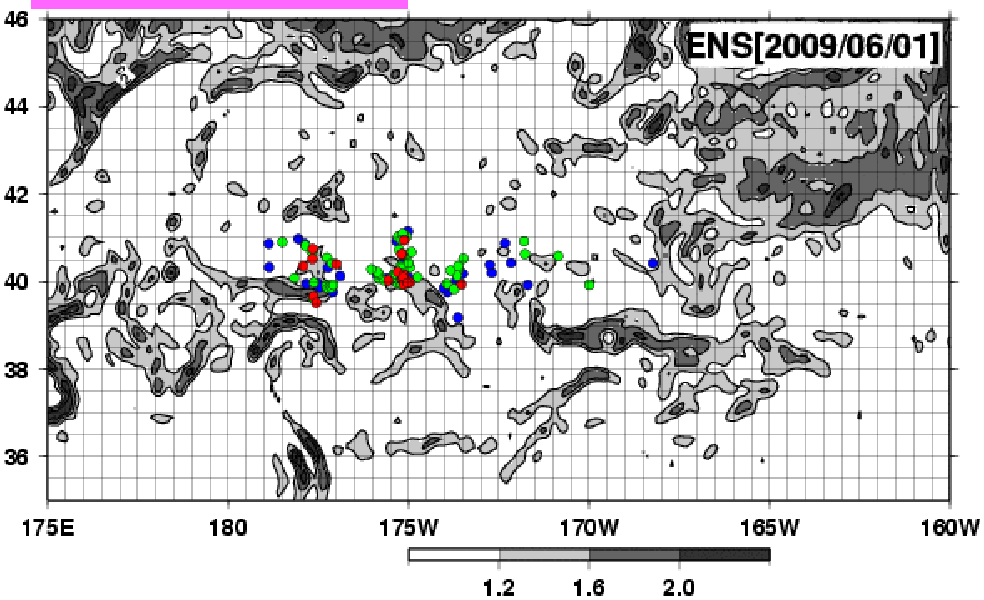
S:Salinity, T:Temperature, Tg:∇T, Sg:∇S,
U,V: horizontal velocity, Vscal: scalar velocity

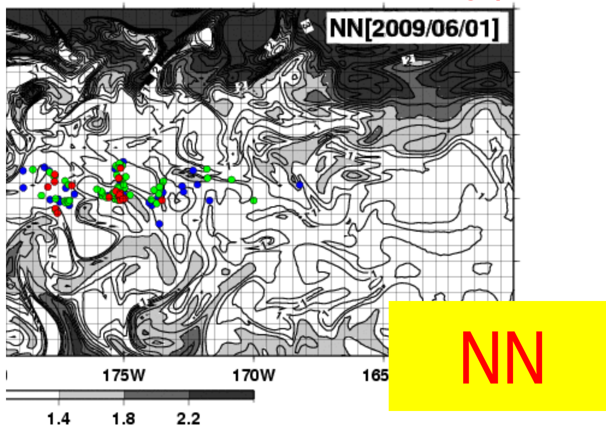
results

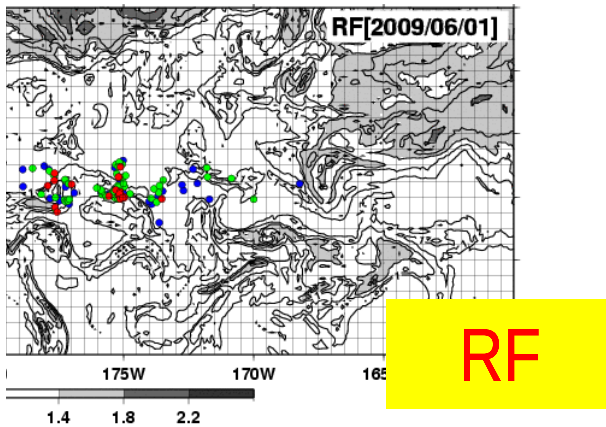
HSI distribution in 2009 June-July

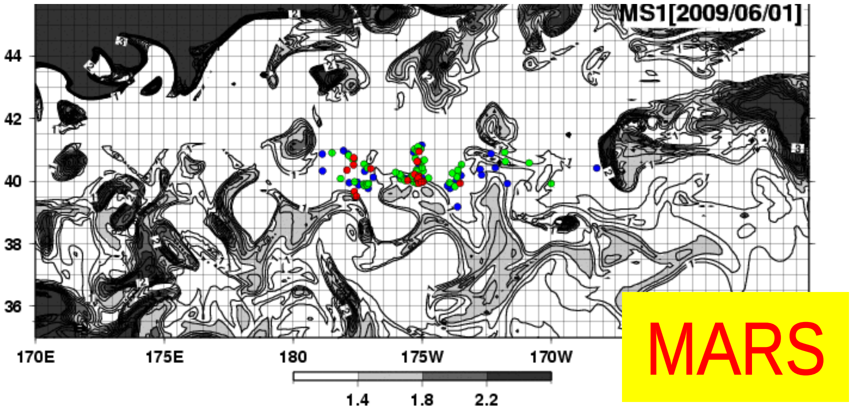
(●:actual fishing point)

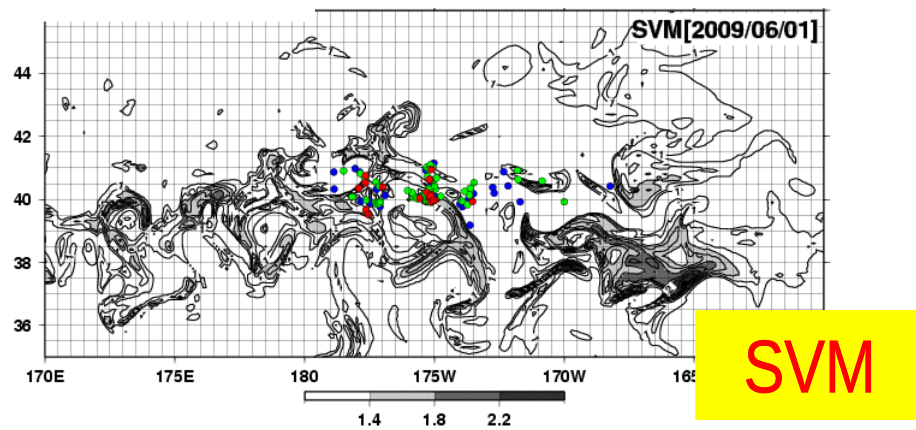
ensemble



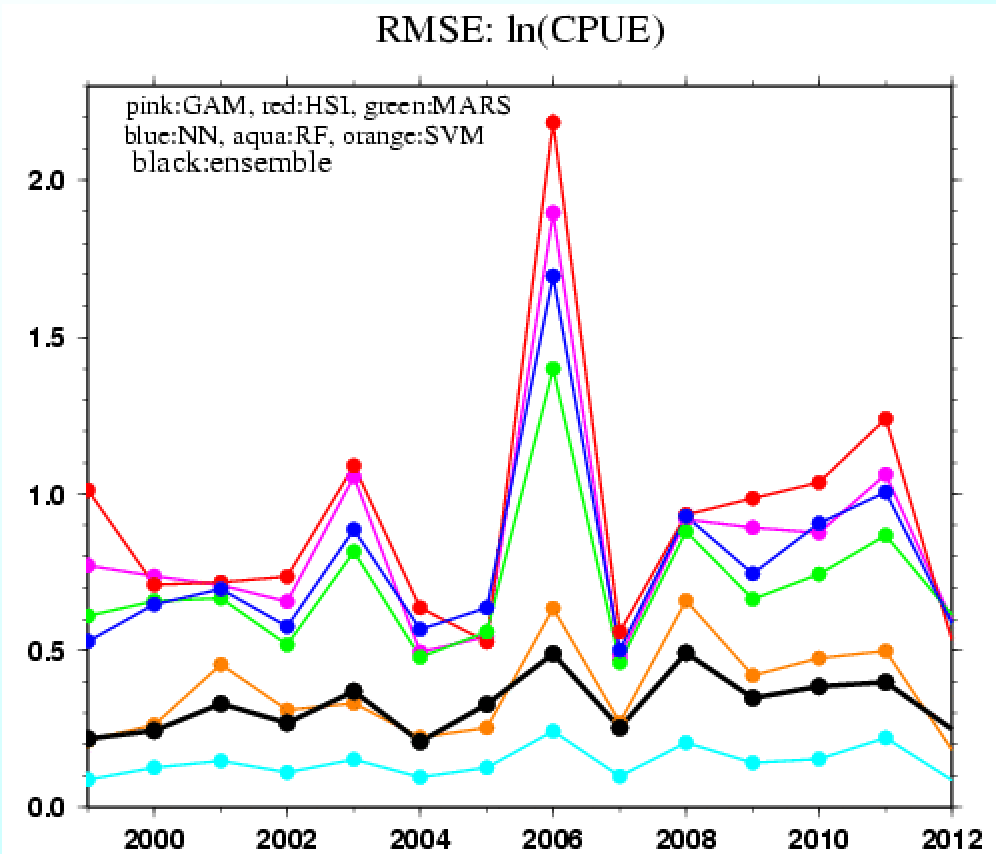








RMSE time series of HSI models



black line: ensemble model

1999-2012 mean

model	RMSE
GAM	0.793
HSI	0.861
MARS	0.686
NN	0.747
RF	0.142
SVM	0.390
ensemble	**0.332**

note : All results are fitting RMSE.
(not prediction RMSE)

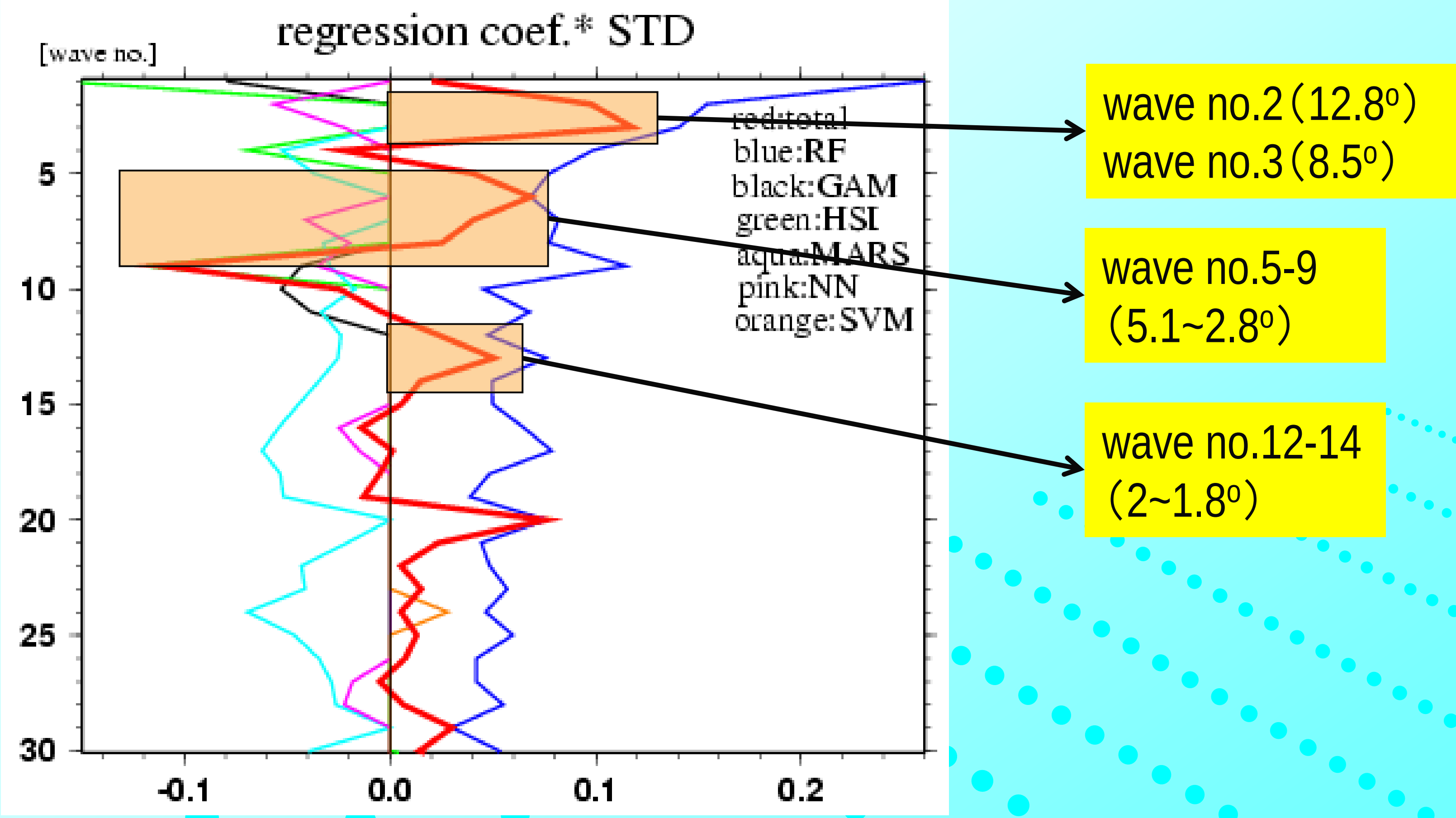
Fourier spectra of HSI models

$$ln(CPUE) = a + \sum_{i=1}^{50} f_{1i} * (HSI_i) + \sum_{i=1}^{50} f_{2i} * (GAM_i) + \sum_{i=1}^{50} f_{3i} * (NN_i) + \sum_{i=1}^{50} f_{4i} * (MARS_i) + \sum_{i=1}^{50} f_{5i} * (RF_i) + \sum_{i=1}^{50} f_{6i} * (SVM_i) + \varepsilon$$

( ) part : 2-D Fourier series

i: wave number

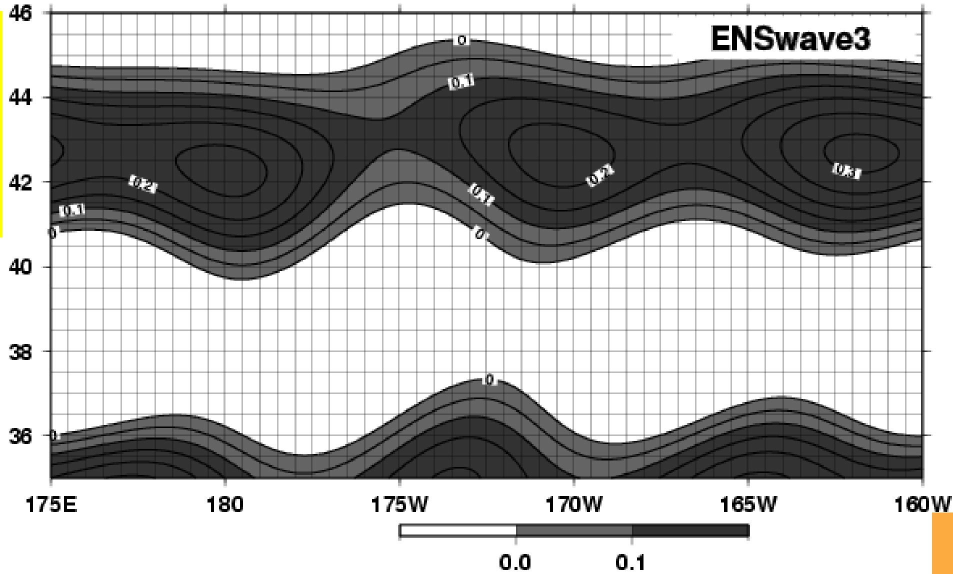
(i=1 → wave length=25.6°)



vertical axis: wave number, red line : ensemble model

HSI distribution :wave no.2 & 3

wave no. 3
(8.5°)



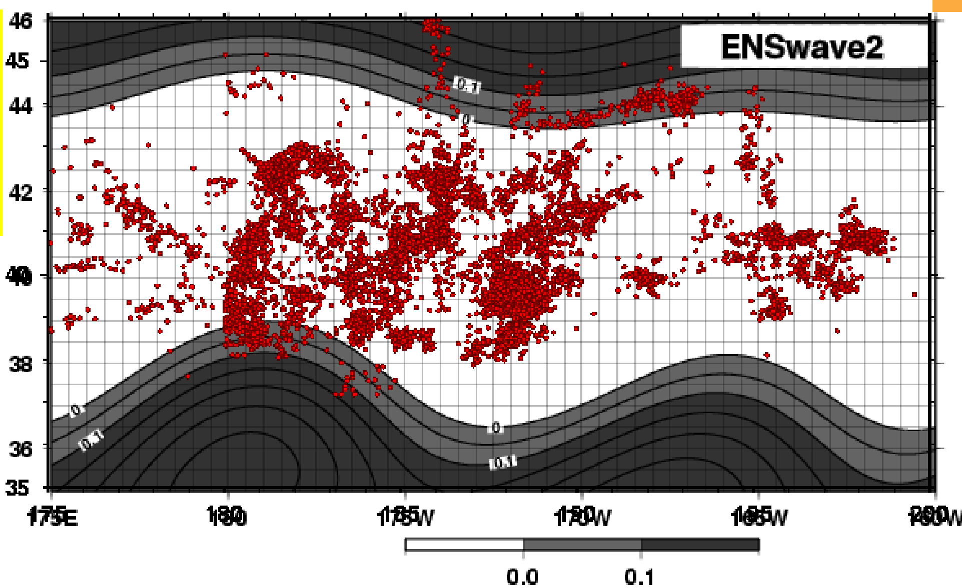
subarctic frontal zone（Roden,1991）
T_{100m}=7~10°C

north boundary ≒SST10°C
existence limit
（Ichii et al.,2006）

barrier for neon flying squid during northward migration
→ potential fishing zone

（●:actual fishing point）

wave no. 2
(12.8°)

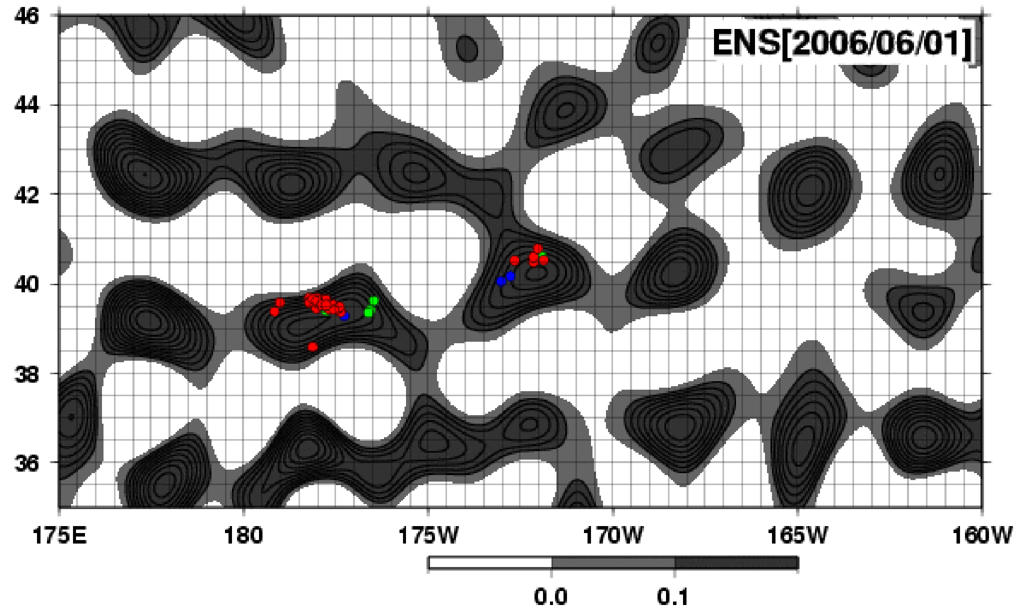


HSI : mainly south of 38°N
large variation at each case

important for
CPUE variation

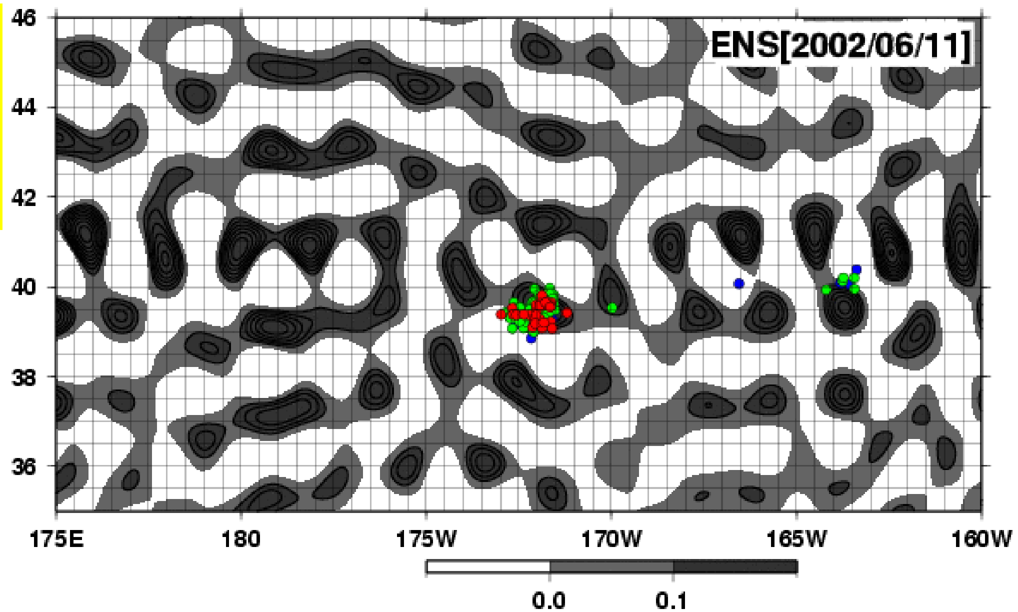
HSI distribution :wave no.5-9 & 12-14

wave no.5-9 (5.1-2.8°)



HSI varies with eddy activities

wave no.12-14 (2-1.8°)

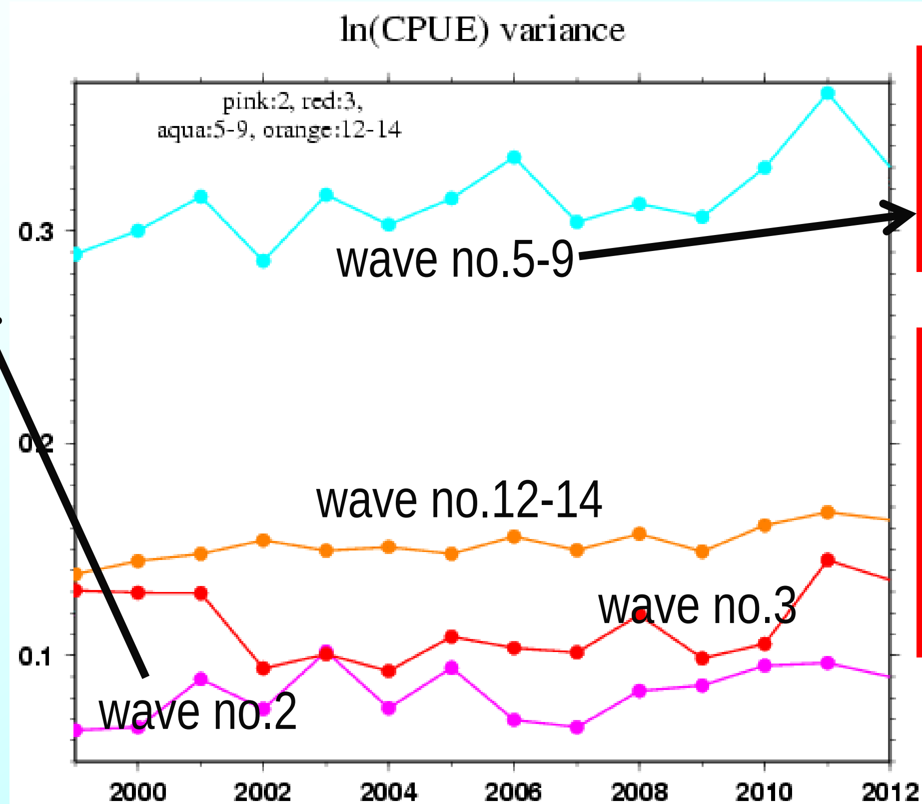


Potential fishing area forms south of 40°N

Interannual variation of HSI activity

Corr. with Wno.2
= -0.666
(significant at 1% level)

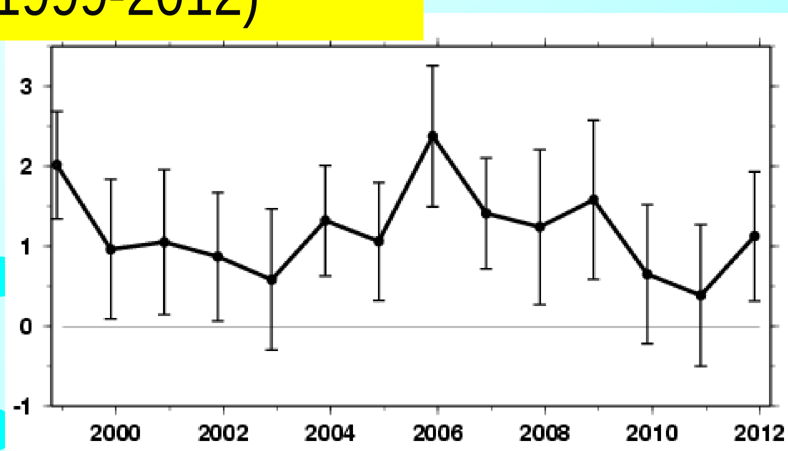
Corr. with Wno.5-9
= 0.570
(significant at 5% level)



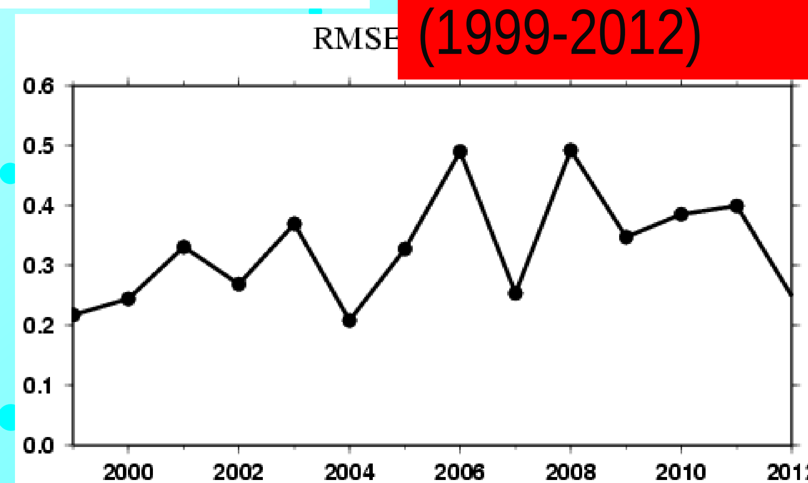
weaker activity of wave no.2
↓↓
higher CPUE

higher eddy activity
↓↓
worse model performance

CPUE time series (1999-2012)



RMSE time series (1999-2012)



concluding remarks

- A multimodel ensemble method was applied to estimating the potential habitat area of neon flying squid by using a new 4D-VAR ocean reanalysis dataset FORA.
- The four dominant spatial scales (wave no. 2, 3, 5-9, 12-14) were extracted from the squid HSI variations by applying 2-D Fourier transform.
- The results suggest that the HSI distribution of neon flying squid could be affected by the subarctic frontal zone (wave no.3) and meso-scale eddy activities (wave no.5-9, 12-14) in the fishing ground.
- The relationship between the interannual variation in the wave no.2 and the squid CPUE suggests that the dominance of the large-scale HSI component could prevent the neon flying squid from concentrating in local spots and result in the bad catch.

Thank you.