A multi-model ensemble prediction of habitat suitability index (HSI) models for neon flying squid in central North Pacific by using 3-D ocean data assimilation product

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RECCA
Research Program on Climate Change Adaptation

outline

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

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Introduction

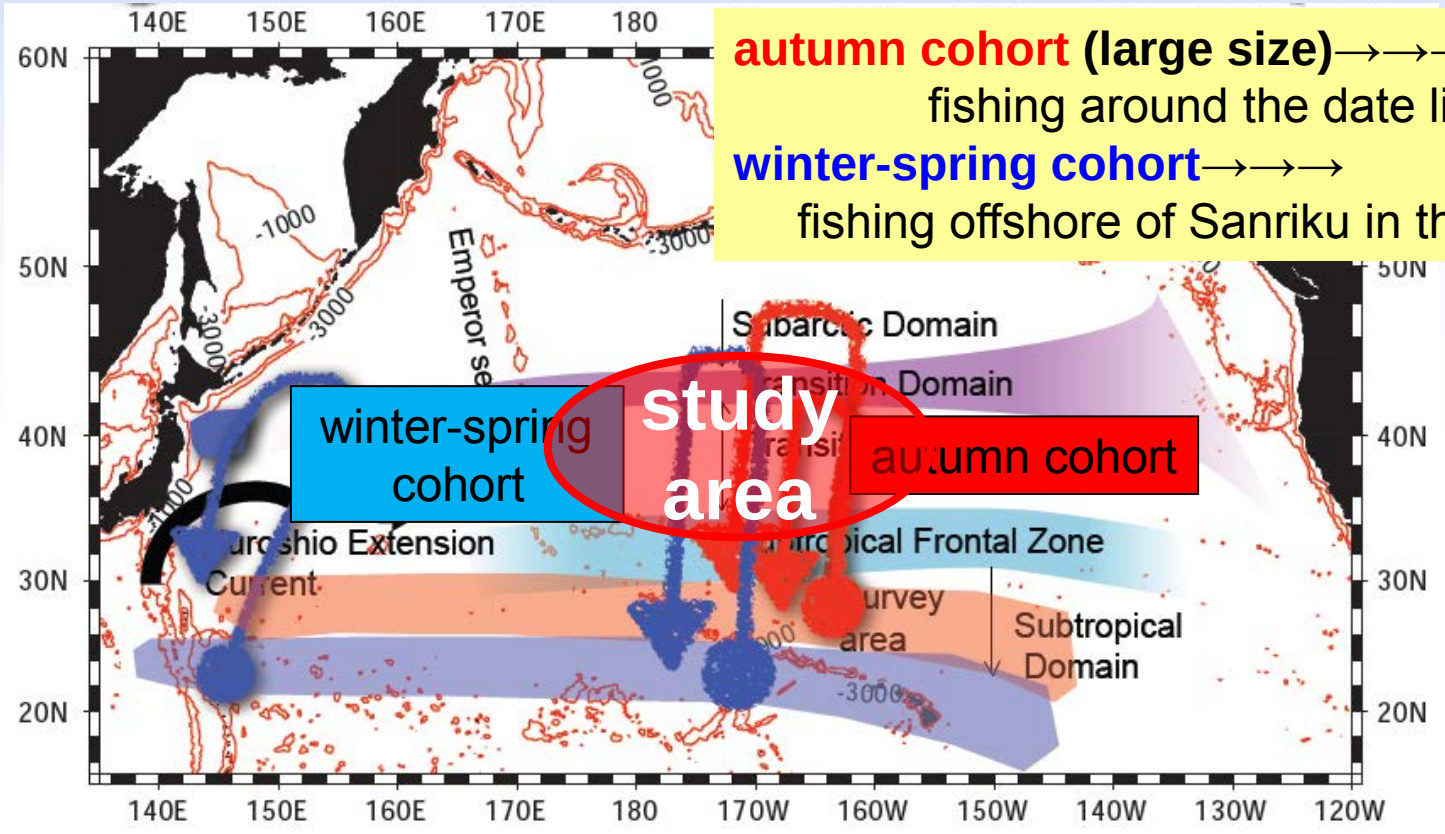
neon flying squid

(*Ommastrephes bartramii*)

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

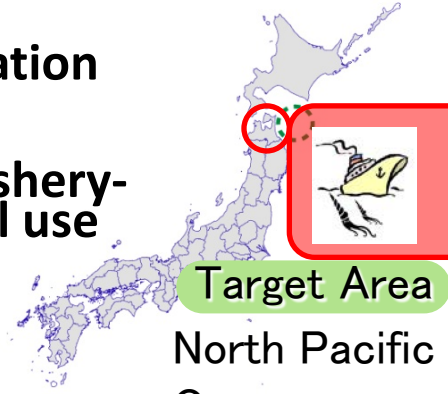
autumn cohort (large size)→→→
fishing around the date line in summer

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



RECCA Research Program on Climate Change Adaptation

An innovative method of forecasting ocean circulation and fishery-resource variabilities linked to climate change for operational use

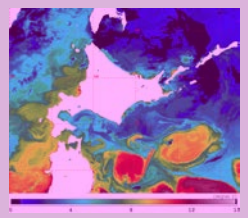


The goal of this project is to develop the new integrated atmosphere-ocean-marine ecosystem data assimilation system and the downscaling approach toward the better understanding and prediction of the linkage between ocean/climate variations and biogeochemical and fishery environments to the level of practical use for optimal fishery stock managements and adaptive fishing operations with low cost and low CO_2 emission leading to a sustainable fishery activity.

Target fish

New fishing ground survey method

- a high-resolution downscaling technique using the incremental 4DVAR
- Habitat Suitability Index (HSI) model for neon flying squid



Develop a medium-range pinpoint-like fishing ground survey

Long-term estimation of fishery resources

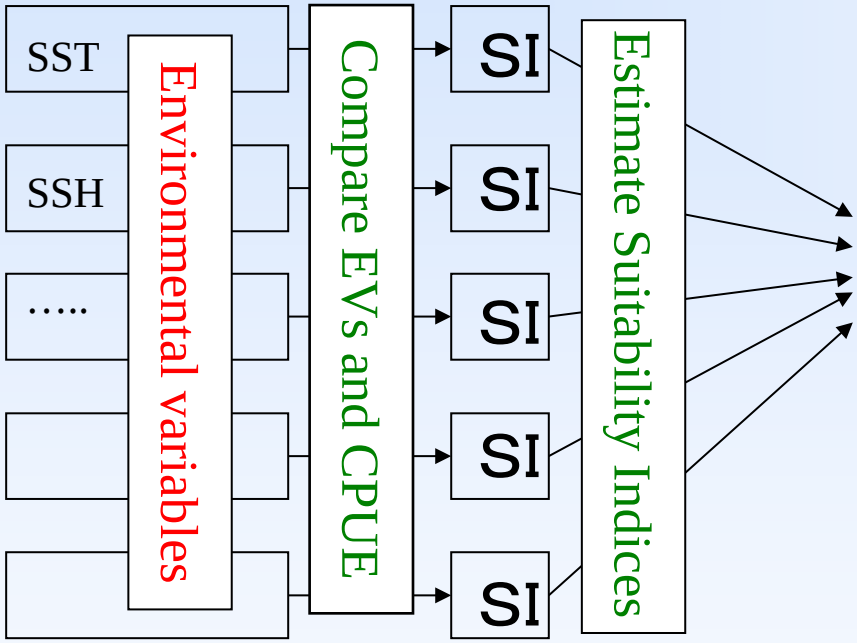
- a coupled data assimilation system for atmosphere-ocean-lower trophic level ecosystem interactions
- robust estimates of long-term fishery-resource variabilities

Establish a robust method of fishery-resource estimation

For fishery-resource savings for stable food supply, and promotion of efficient and environmentally-friendly sustainable fishery

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.

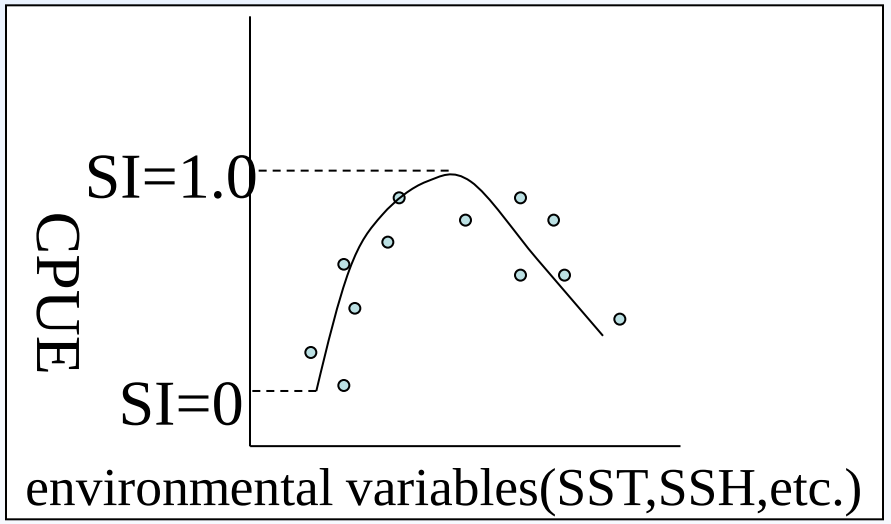


SI : Suitability index

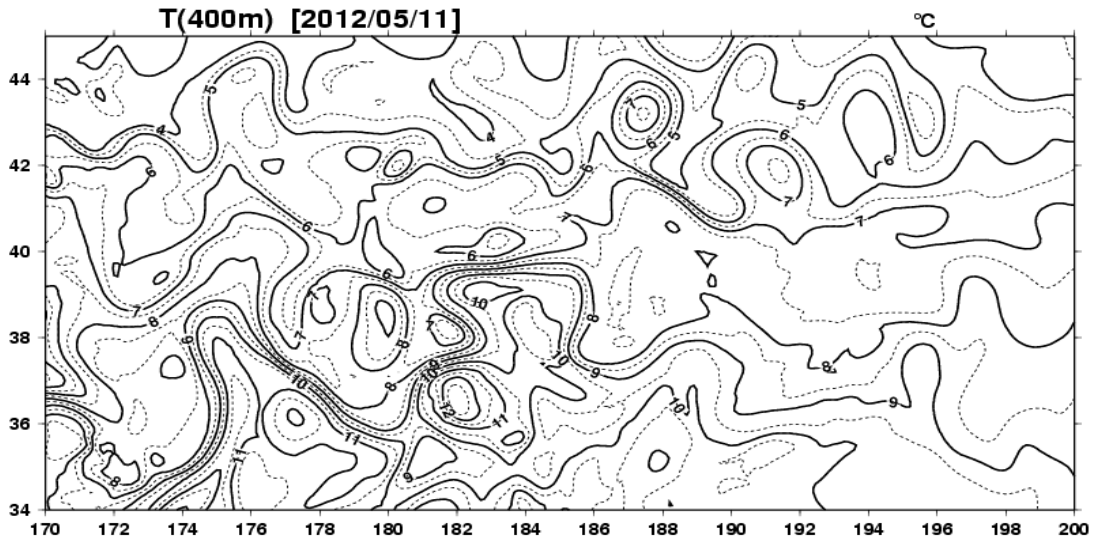
HSI

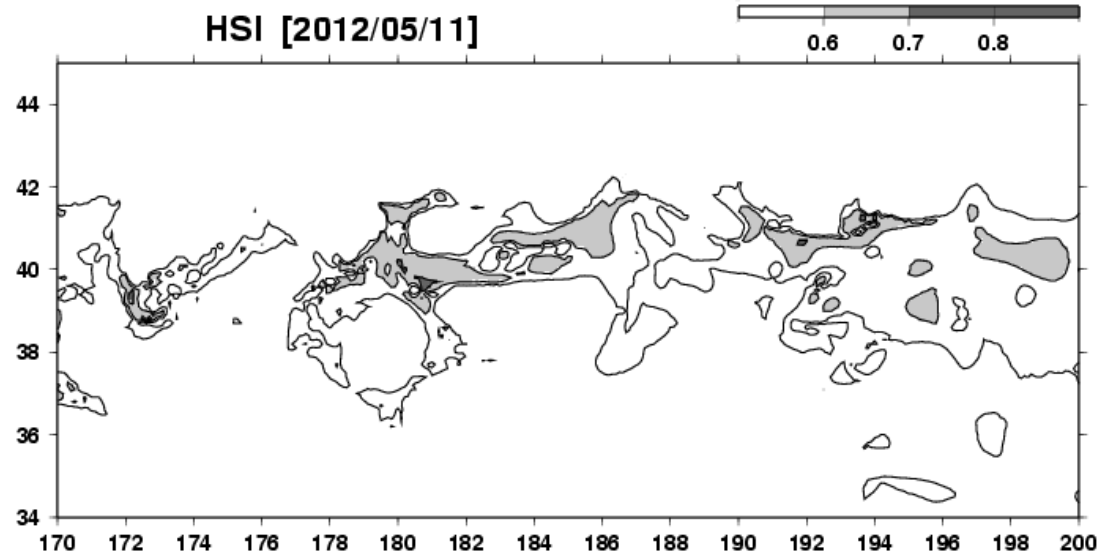
HSI=f(Si1, Si2, Si3, ・・・)

Habitat Suitability Index



400m-d temp. & HSI map

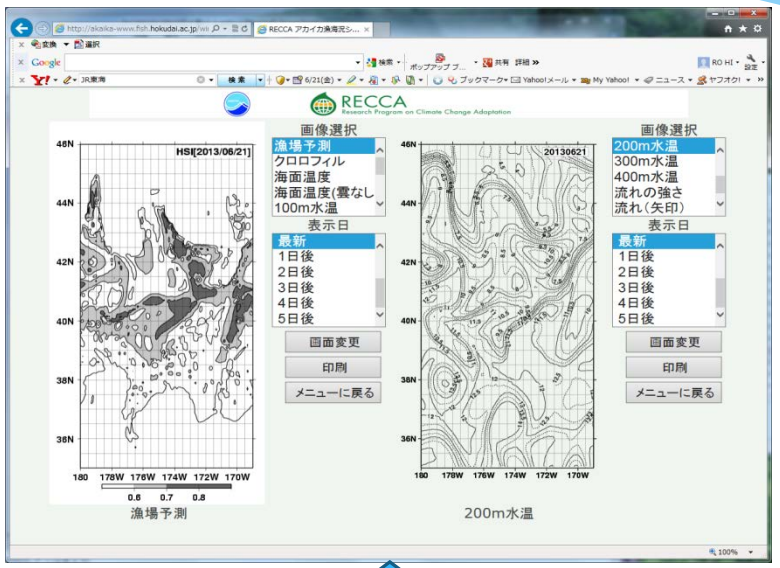


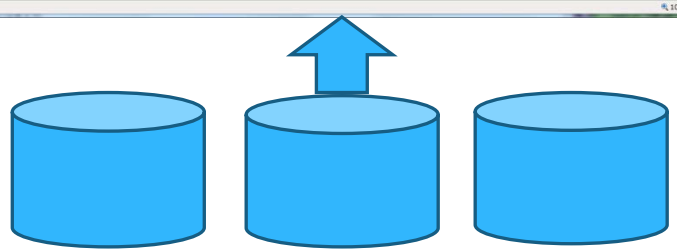


June-July 2012

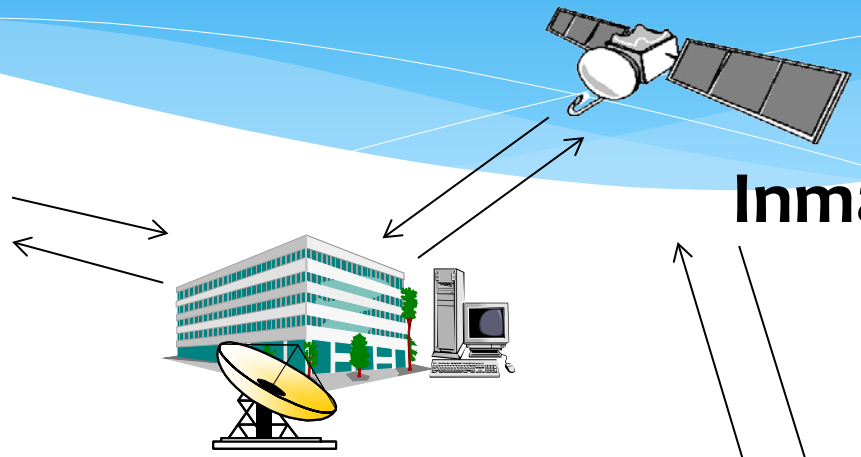
Web delivery by Inmarsat satellite communication

RECCA web site

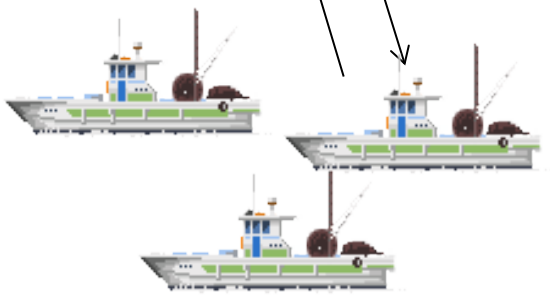




Satellite-derived SST, SSH, chl-a
MOVE subsurface temperature
Estimated daily HSI map



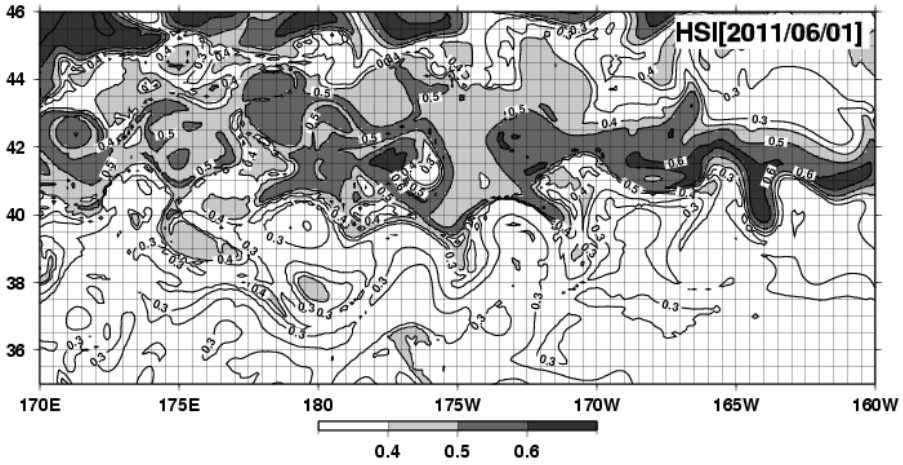
Inmarsat



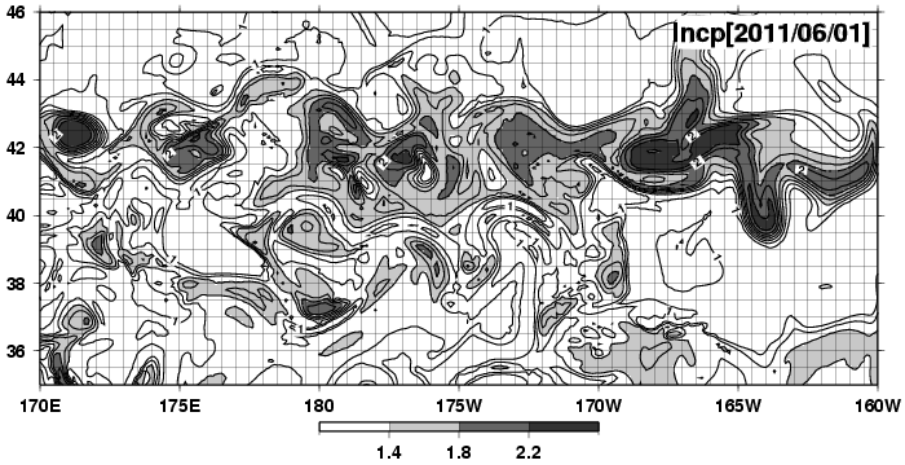
Japanese commercial fishing vessels

four statistical models

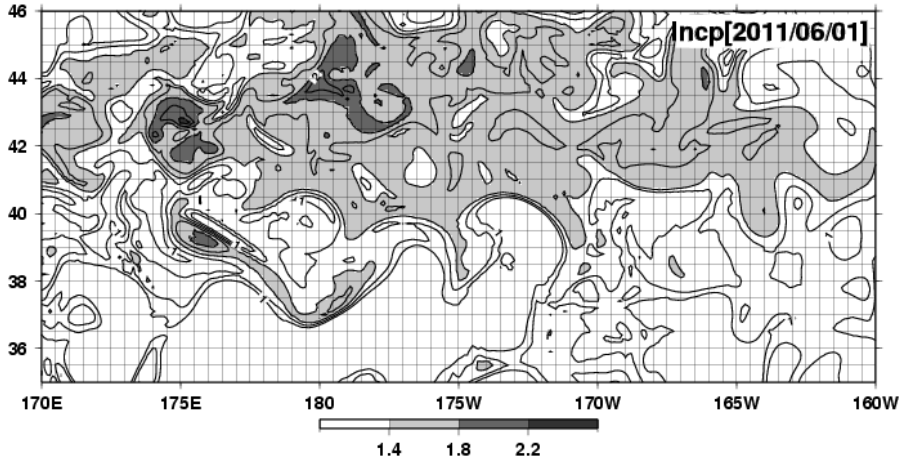
HSI



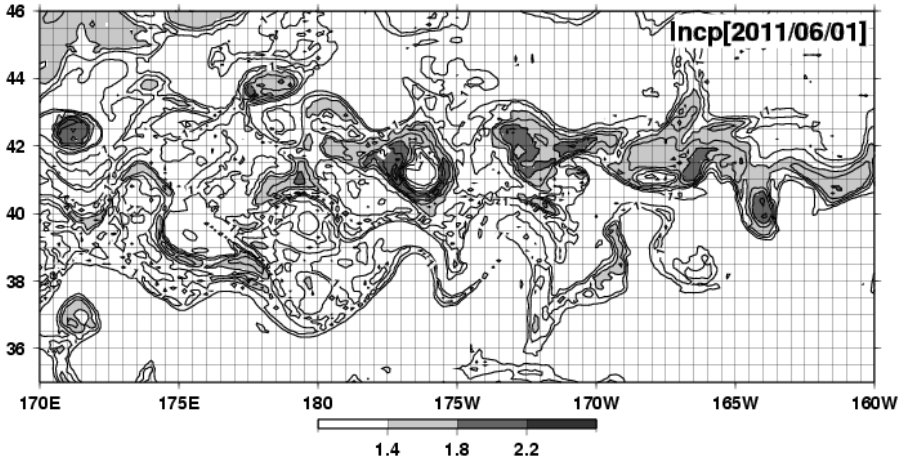
SVM



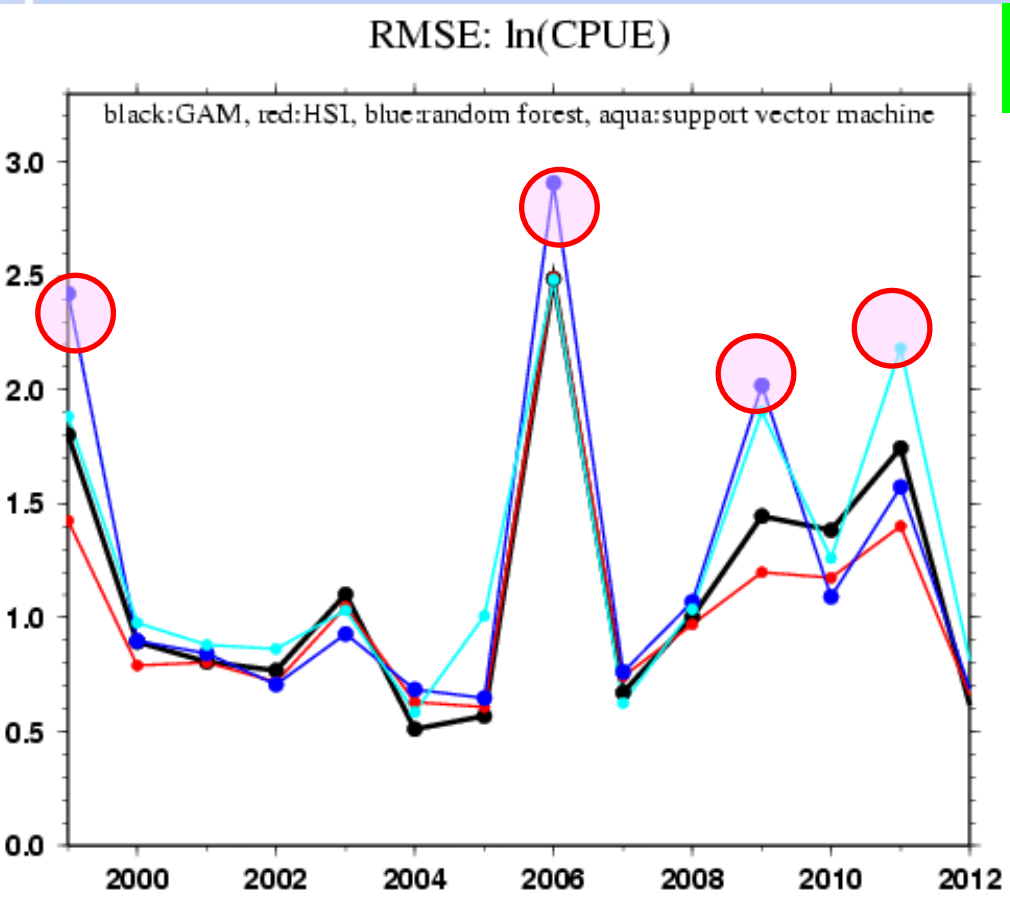
GAM



RF



validation of model performance



HSI < GAM < RF < SVM

Interannual variation of RMSE is larger than model differences.

Time series of the RMSE of GAM, HSI, RF and SVM.

purpose

In order to improve the HSI model performance, we applied an **empirical weighted multi-model ensemble (superensemble) method** to estimating the potential habitat area of neon flying squid by using four different statistical models (HSI, GAM, RandomForest, Support Vector Machine) as ensemble members.

data

- **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)

- **3D-VAR data assimilation product**

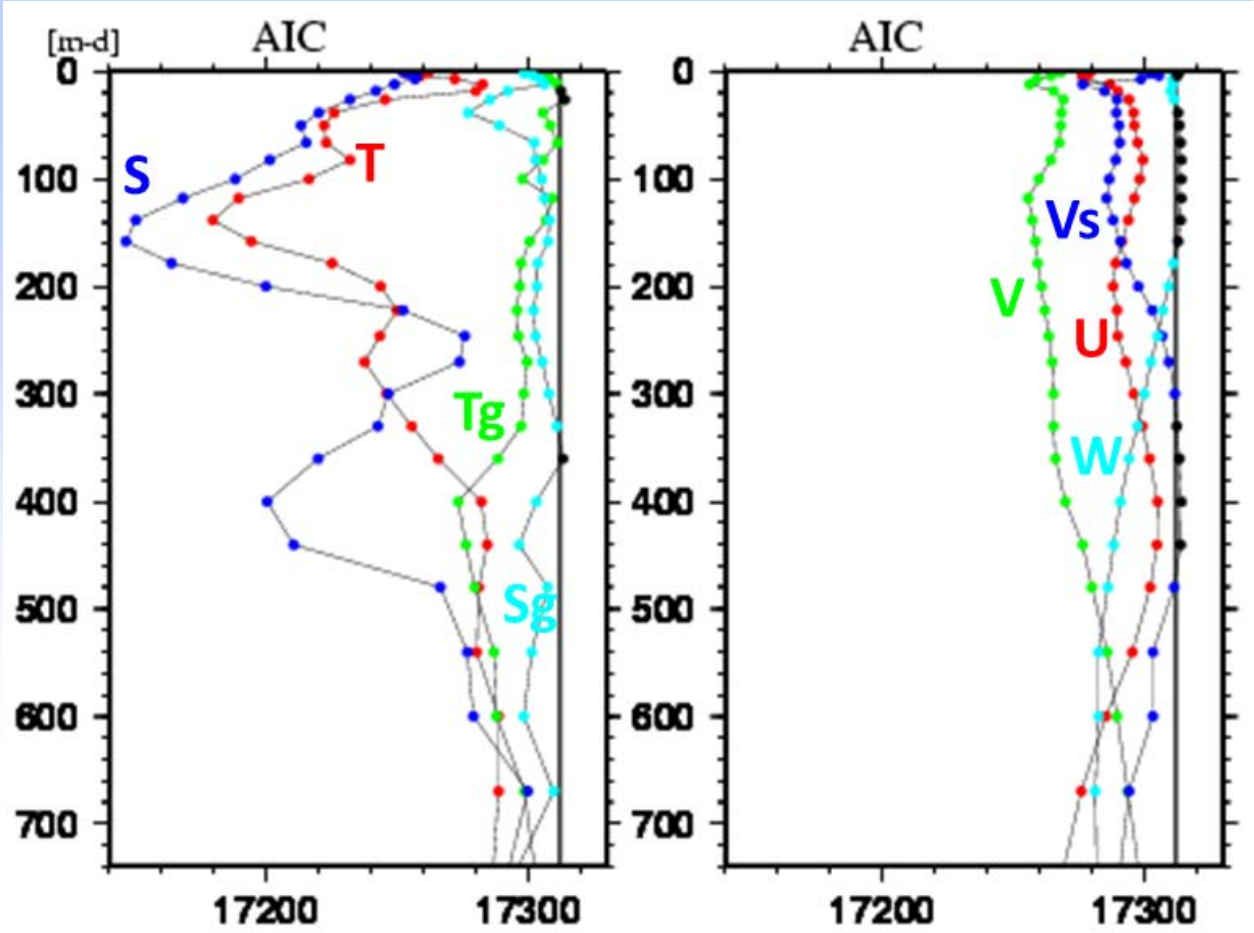
  MOVE(MRI Multivariate Ocean Variational Estimation)

  (by Meteorological Research Institute, JMA)
  Temperature, Salinity, Current velocity(U,V,W),SSH

  (0.1deg, vertical **54** levels, **5**-days → daily interpolated)

parameters for making statistical models

- SSH
- SSH gradient
- SST
- T15(158m)
- T21(300m)
- SSS
- S14（138m）
- S25（440m）



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

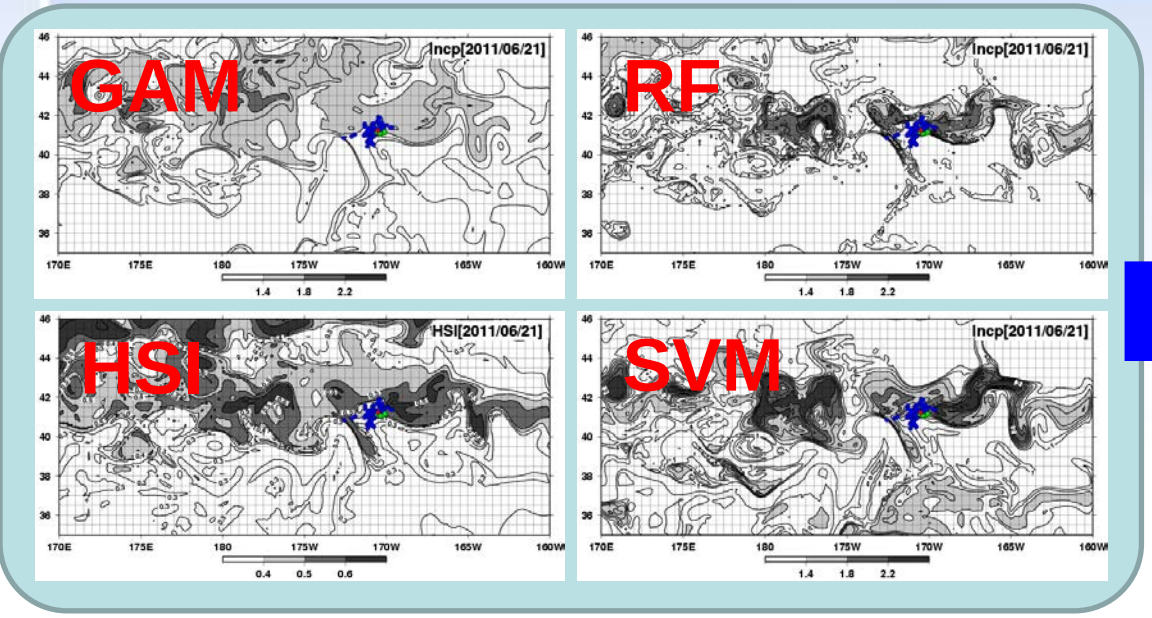
S:Salinity, T:Temperature, Tg:∇T, Sg:∇S,
U,V: horizontal current, W: vertical current

methodology

multimodel ensemble

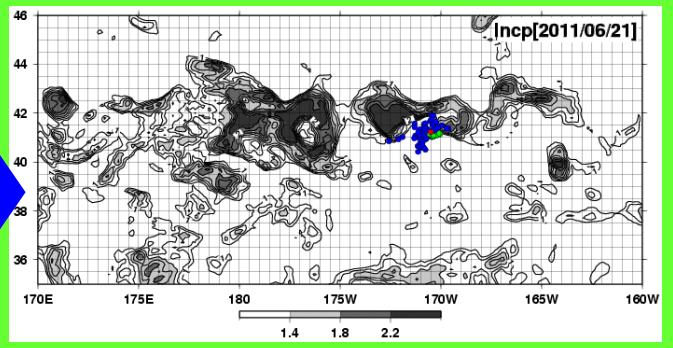
- **Multimodel ensemble methodology** utilizes a vast collection of past forecasts by member models to assess their collective biases. The statistics generated are used toward the correction of future model forecasts.

Krishnamurti et al.(2006)



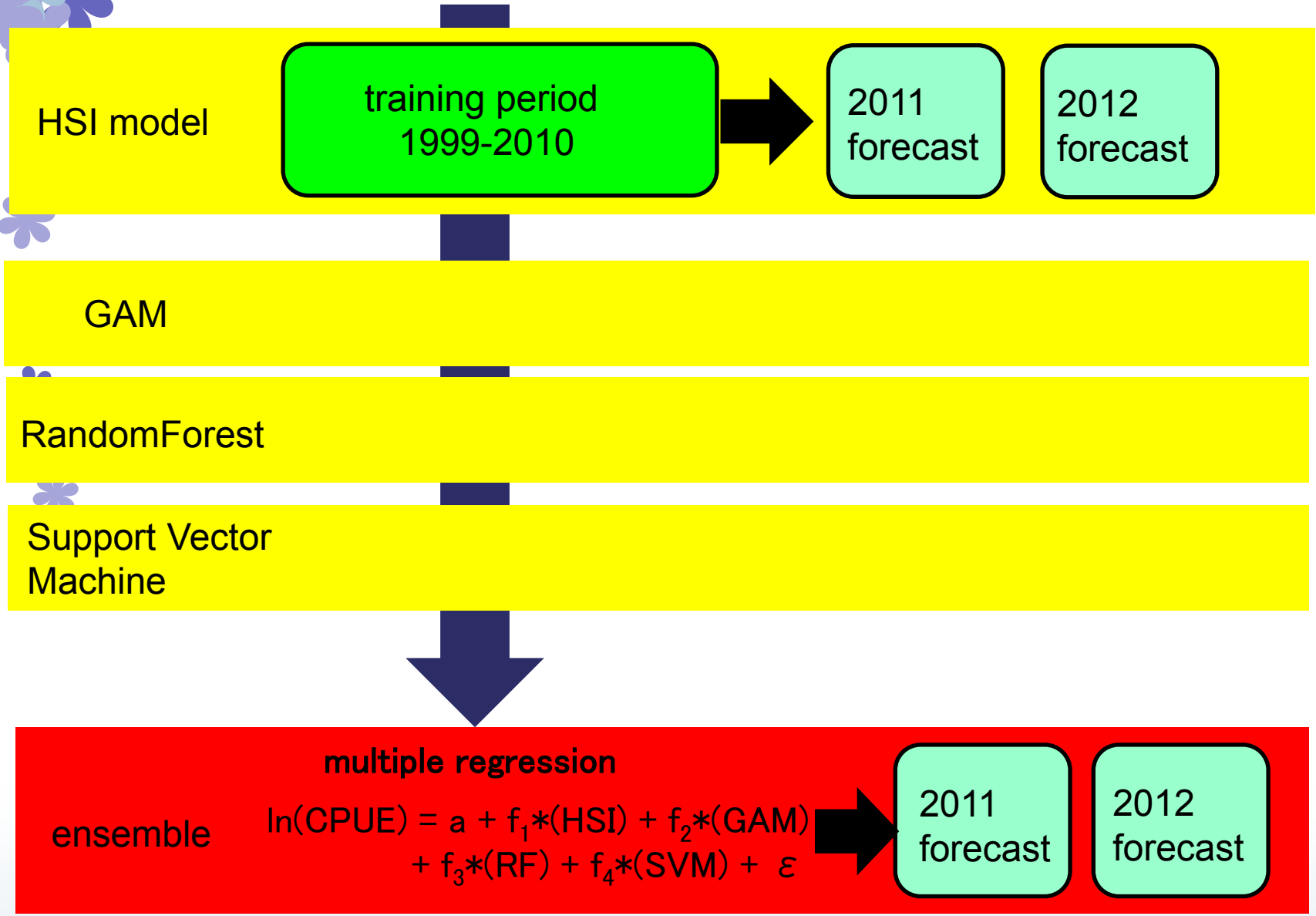
four member models

ensemble



It produces a single consensus forecast derived from a multimodel set of forecasts using a multiple linear regression technique.

Procedure of ensemble calculation



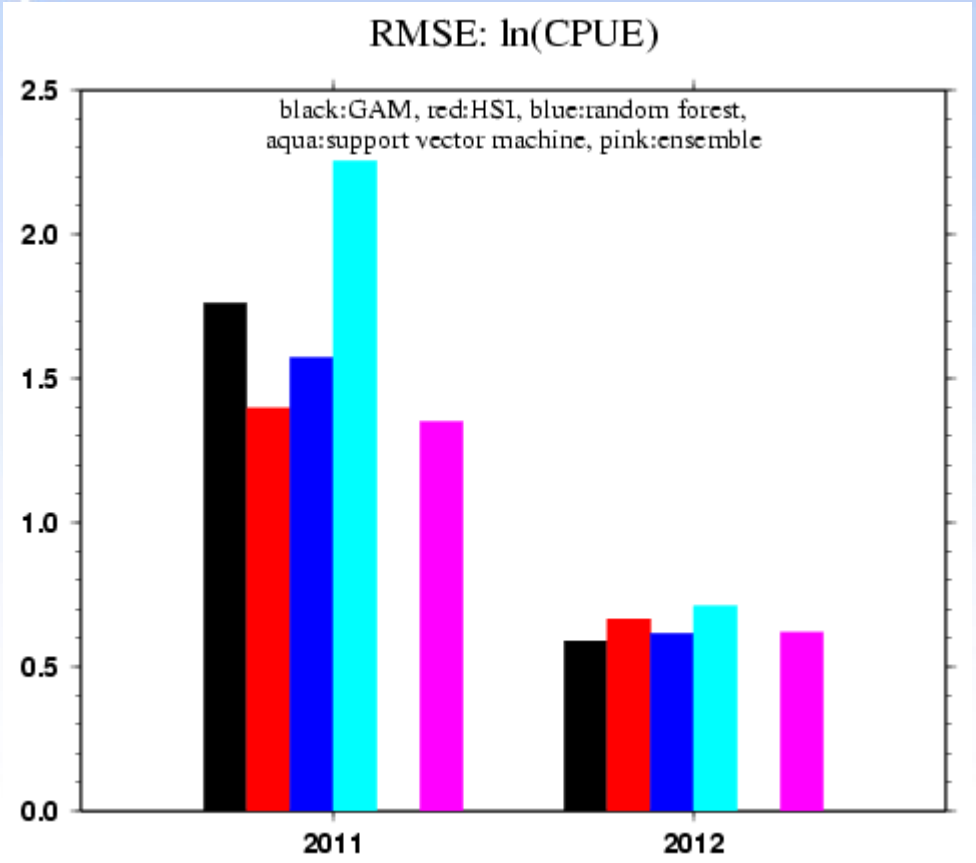
EOF decomposition

$$\ln(CPUE) = a + \sum_{i=1}^{20} f_{1i} * (HSI_i) + \sum_{i=1}^{20} f_{2i} * (GAM_i) + \sum_{i=1}^{20} f_{3i} * (RF_i) + \sum_{i=1}^{20} f_{1i} * (SVM_i) + \varepsilon$$

Predicted HSI fields of all member models were decomposed by Empirical Orthogonal Functions (EOFs), and the 20 leading EOF modes were used for constructing the ensemble model.

results

RMSE in 2011,2012

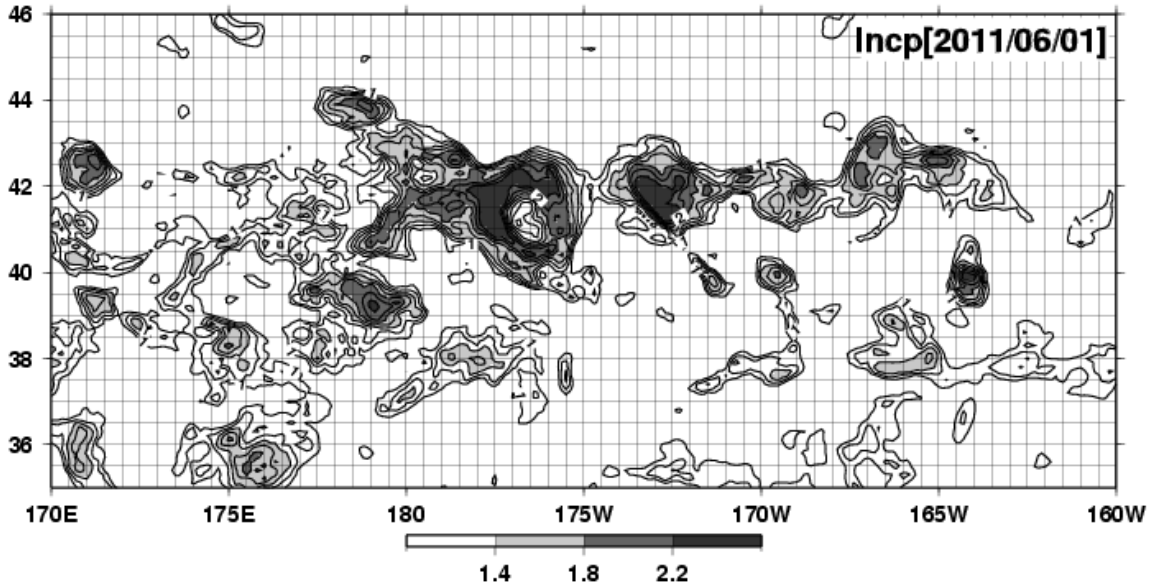


	2011	2012
GAM	1.76	0.59
HSI	1.40	0.66
RF	1.57	0.61
SVM	2.25	0.71
ensemble	1.35	0.62

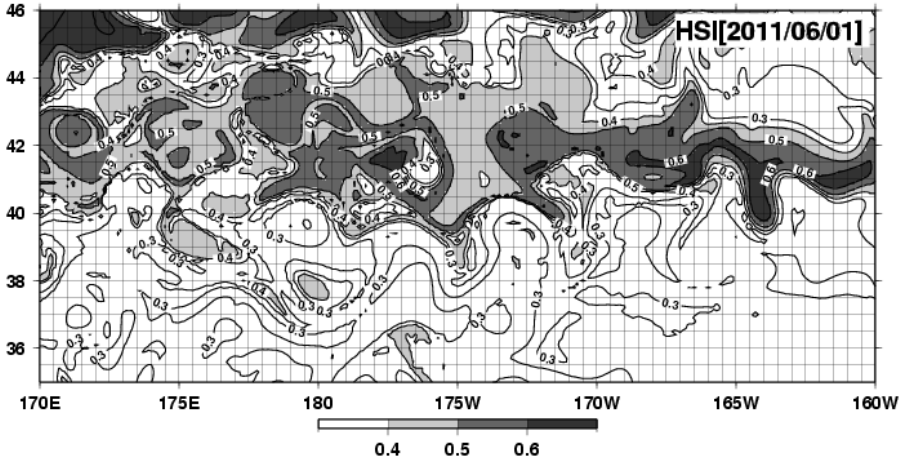
2011: poor catch, large RMSE
2012: good catch, small RMSE

daily HSI distribution 2011

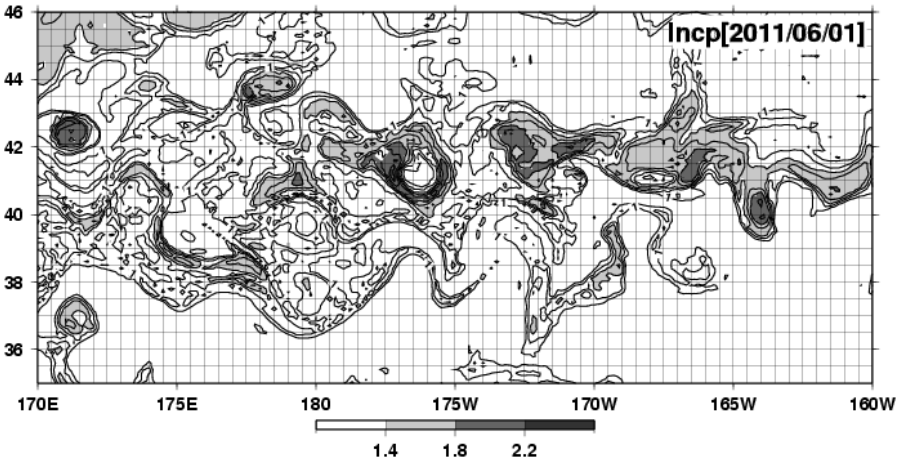
ensemble



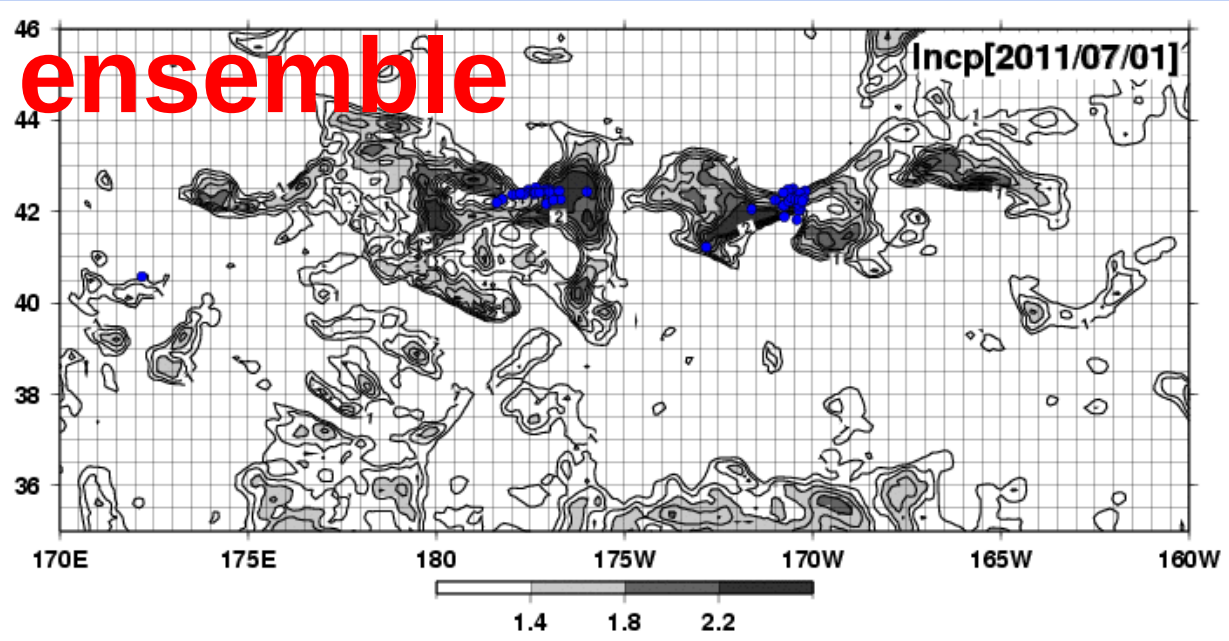
HSI



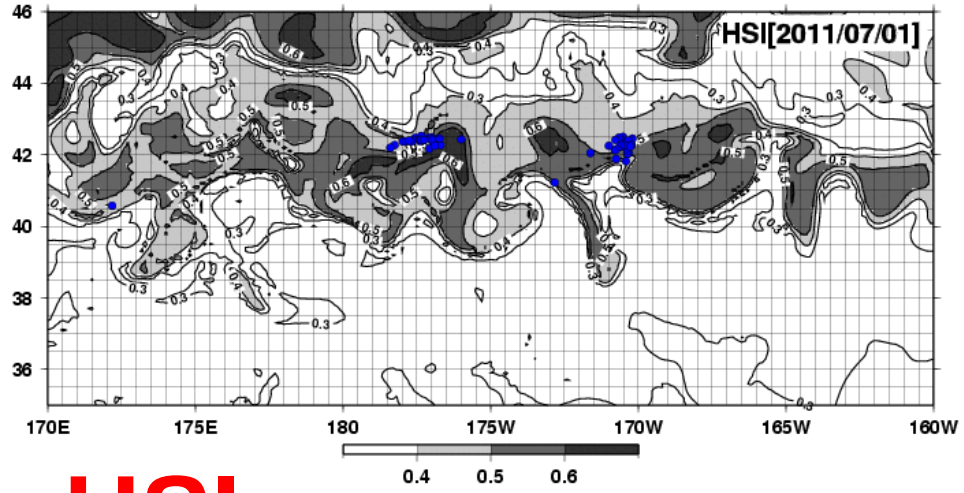
RF



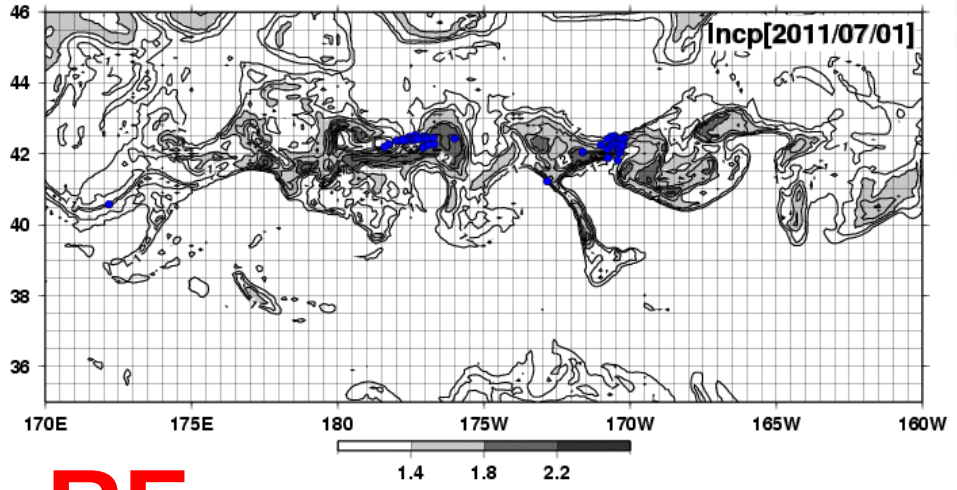
HSI : July1,2011



blue dot:
actual fishing point
(July1-10,2011)



HSI



RF

***: 1%
** : 5%
* :10%

significance level of correlation with ln(CPUE)

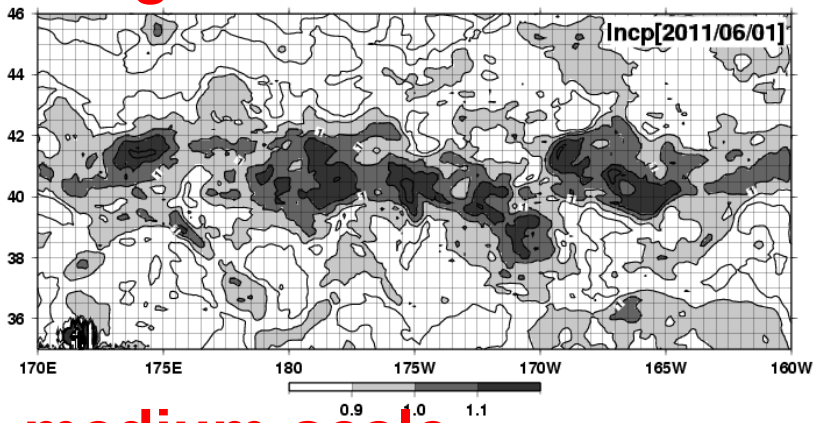
	HSI	GAM	RF	SVM
EOF1	**			
EOF2	**		***	***
EOF3				
EOF4			**	
EOF5			***	
EOF6		***		
EOF7	***			*
EOF8	***			
EOF9			*	
EOF10	**	**		
EOF11	**	***		
EOF12		**		***
EOF13	***		***	**
EOF14			**	***
EOF15				
EOF16				
EOF17				
EOF18		*	**	**
EOF19		**		
EOF20				

large-scale variation

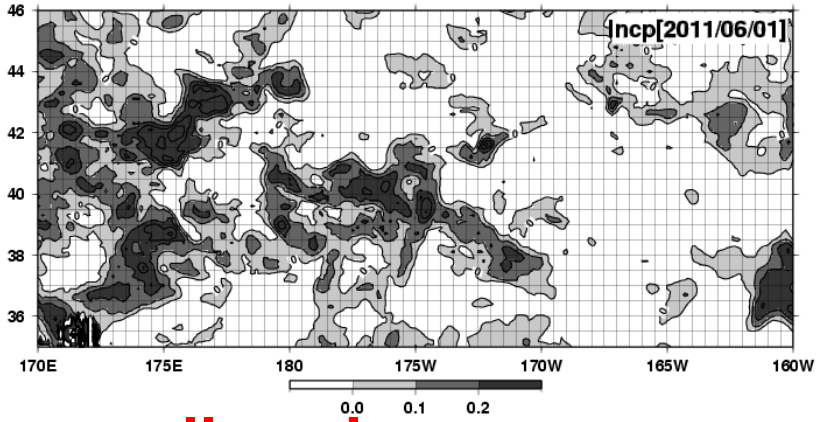
medium-scale variation

small-scale variation

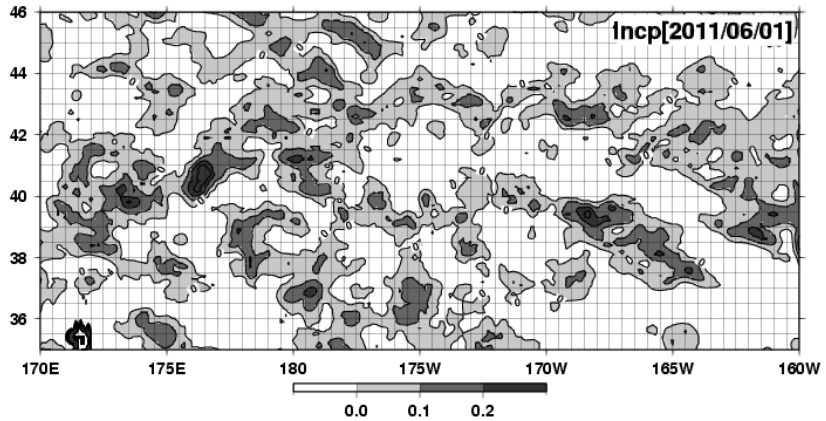
large-scale



medium-scale



small-scale

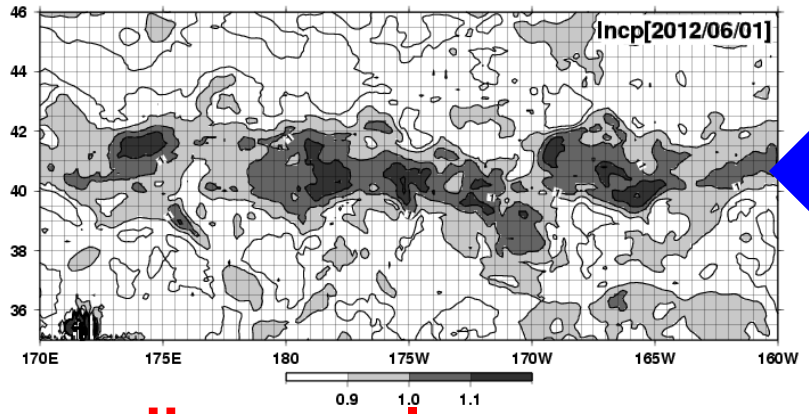


2011
poor catch
large RMSE

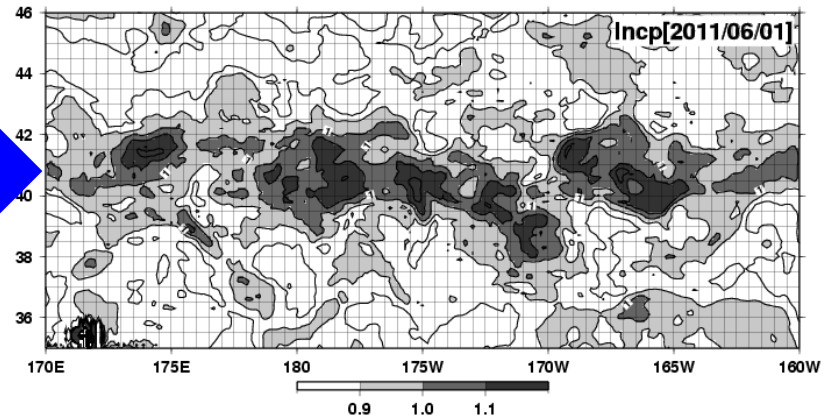
large-scale variation:
seasonal evolution

small-scale variation:
meso-scale eddies

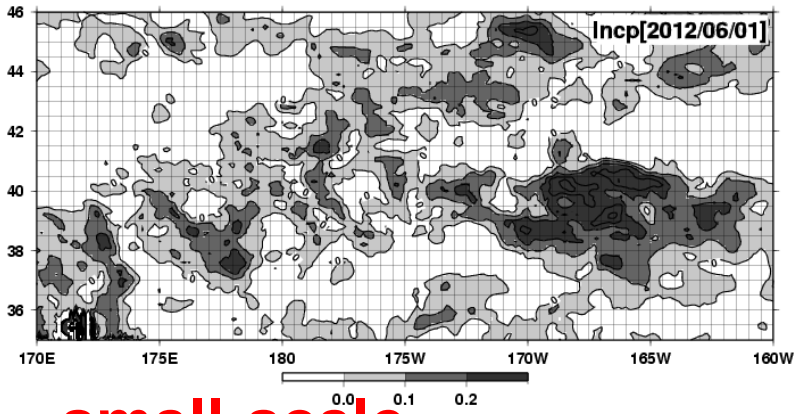
large-scale 2012



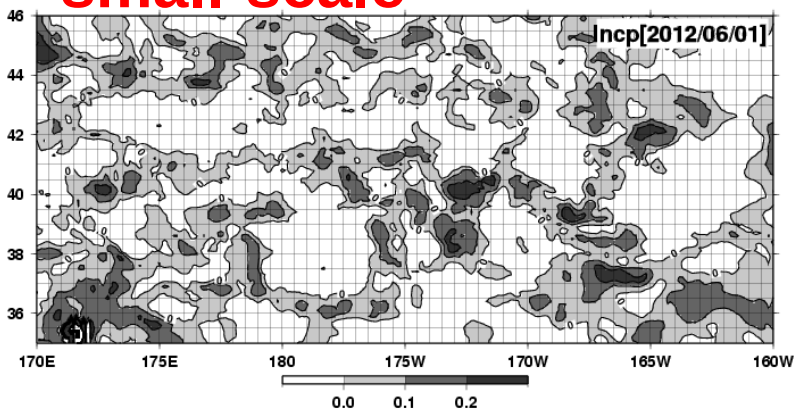
large-scale 2011



medium-scale



small-scale



Variance of large-scale component in 2012 is much smaller than that in 2011.

↓

- neon flying squid exists densely
  → form a good fishing point
- better model performance

Multimodel ensemble method improved the skill in 2011 by amplifying the medium and small scale components.

concluding remarks

- An empirical weighted multi-model ensemble method was applied to estimating the potential habitat area of neon flying squid by using four different statistical models.
- The results show better performance of HSI prediction by multi-model ensemble method in 2011(worse skill by a single model).
- In 2012, the fact that the large-scale component of the HSI variation is small suggests that neon flying squid exists densely in small areas and forms good fishing points. In this case, HSI model shows better performance than normal.
- Multi-model ensemble method improved the skill in 2011 by amplifying the medium and small scale components.

Thank you

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