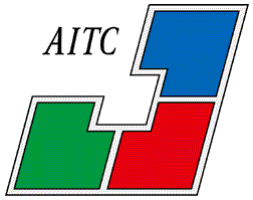
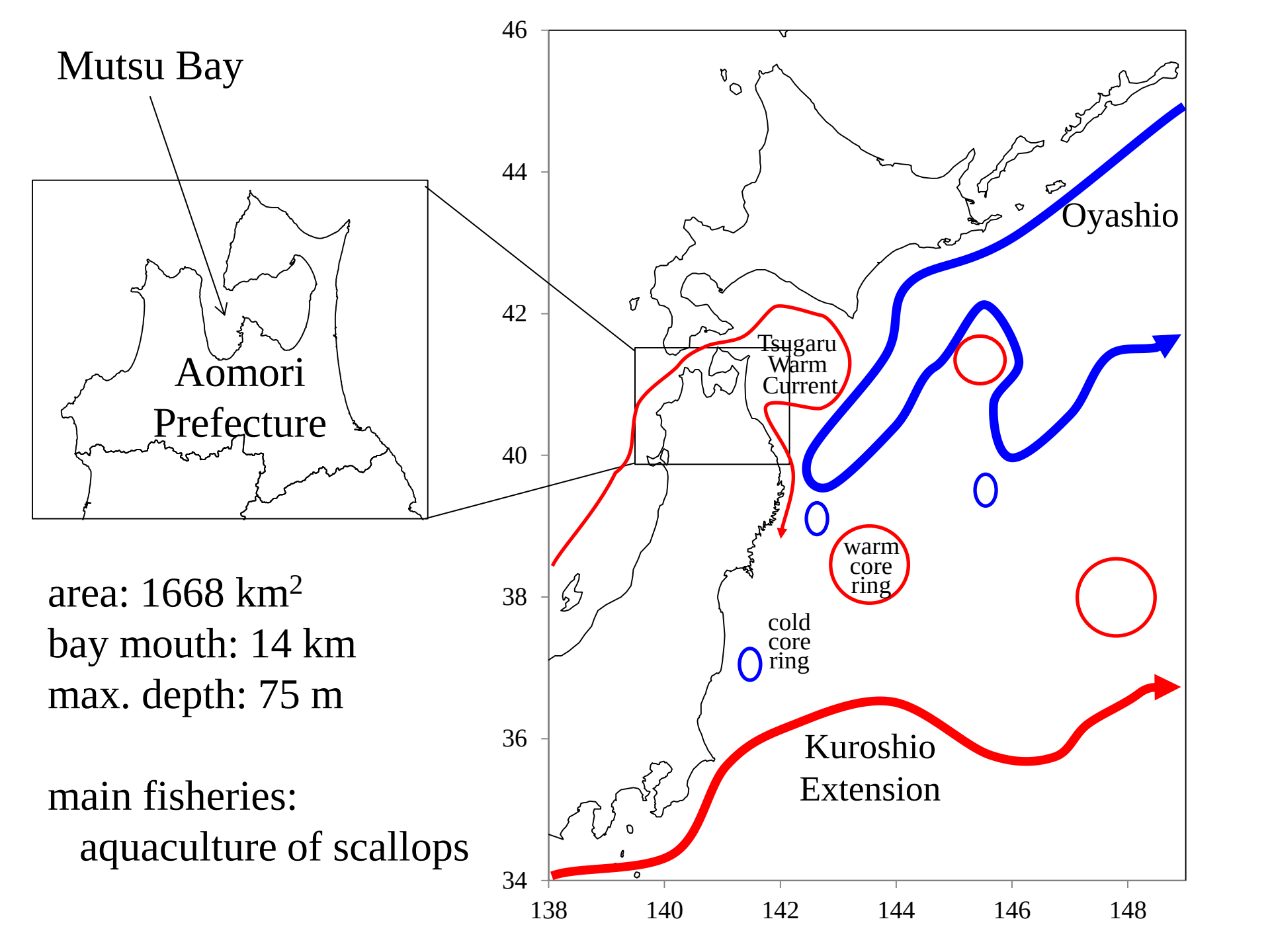
Water temperature forecasts to decrease megadeath of aquacultured scallops in Mutsu Bay, Japan.

Shin-ichi Ito[1], Masaki Seito[2], Tooru Yoshida[2], Kazuhiro Takeuchi[3], Shigeho Kakehi[1], Taku Wagawa[1], Yutaka Isoda[4], Hiroshi Kawamura[5]

[1] Tohoku National Fisheries Research Institute, FRA
[2] Fisheries Research Institute, AITC
[3] IDEA Consultants, Inc.
[4] Hokkaido University
[5] Tohoku University



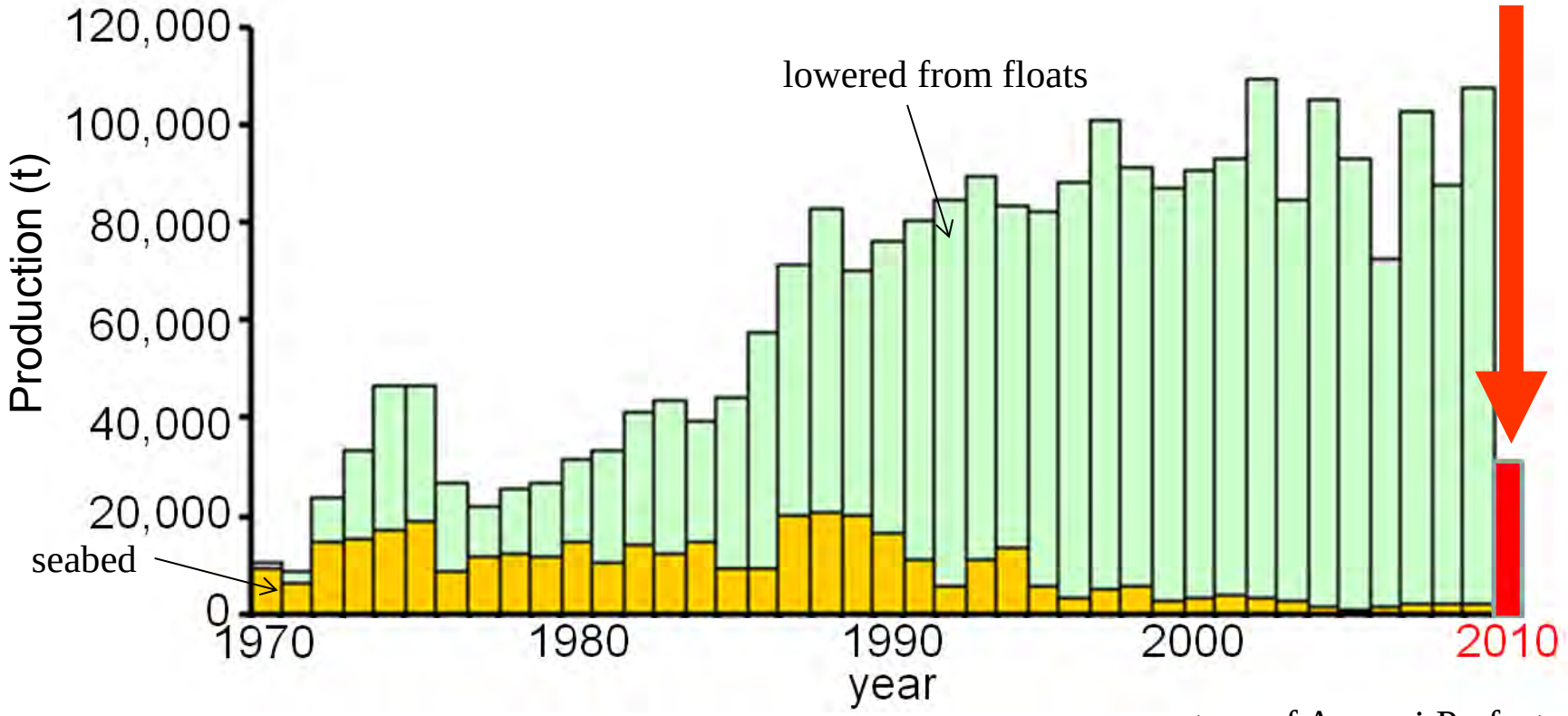
collaborators
Hiroshi Kuroda (FRA), Takashi Setou (FRA)



area: 1668 km^2
bay mouth: 14 km
max. depth: 75 m

main fisheries:
aquaculture of scallops

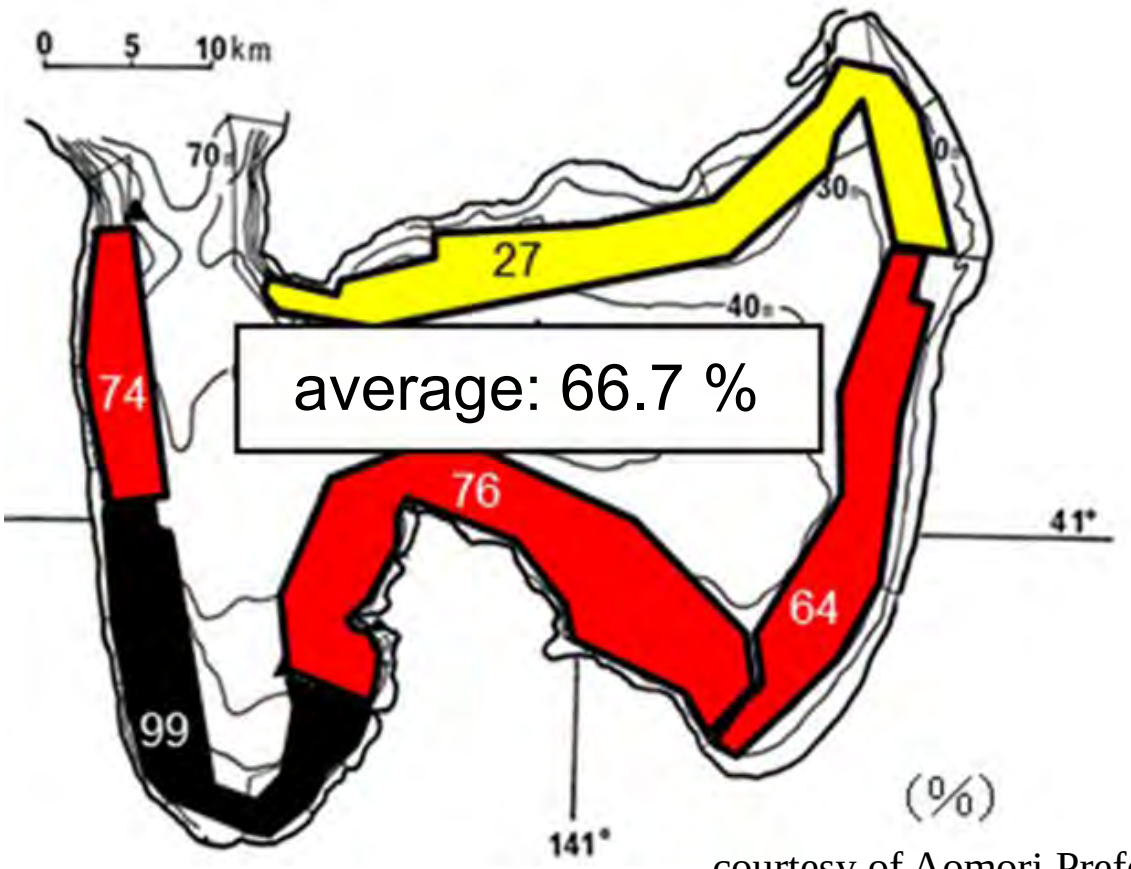
Production of scallops in Mutsu Bay



courtesy of Aomori Prefecture

production: 80,000 - 110,000 t
yield: 10 - 14 billion yens/year
2010 production: 33,000t
yield: 6 billion yens

Megadeath of aquacultured scallops in Mutsu Bay

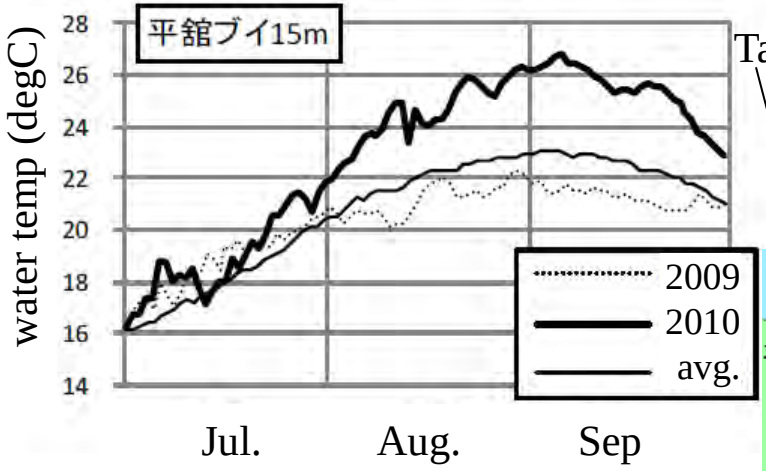


courtesy of Aomori Prefecture

mortality in 2010

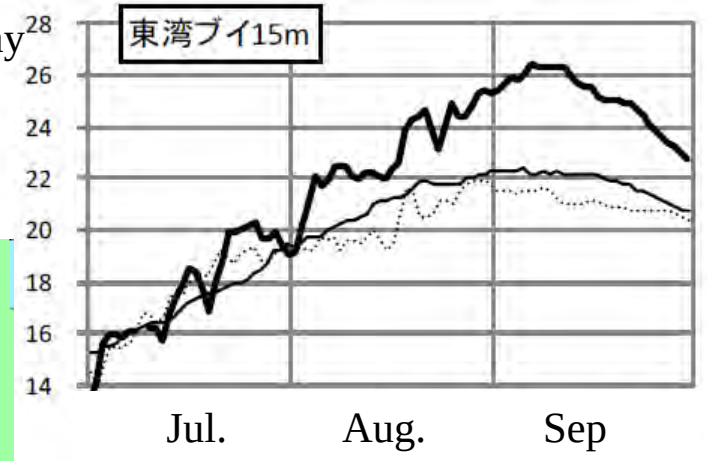
- Average mortality in the bay is 66.7%.
- The highest mortality was observed in the end of the west bay (99%).

Extreme hot event in 2010 summer



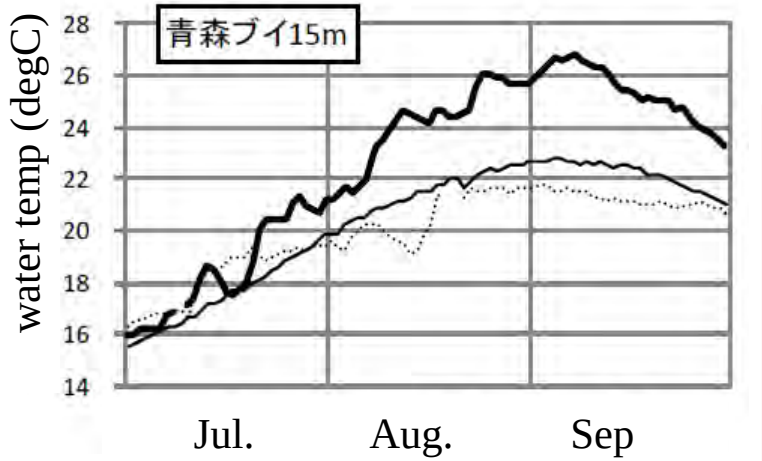
Tairadate

East bay



courtesy of Aomori Prefecture

Aomori



- Water temp. was much higher than climatology.
- 26.8 degC on 7th Sep. was the highest record (the former record was 25.1 degC).

- Scallops have trouble when T > 23 degC.
- The water temp. had excessed 23 degC for 54days.
- The water temp. was high even in the deeper layer.

MAFF Project on "Aquaculture production skill developments to decrease mortality of scallops in extreme hot summer"

target: decrease the mortality to the half of 2010

water temp. forecast

mechanism research

- heat budgets in air-sea interaction
- heat exchange with outside ocean
- regional model development
- heat budget analysis using regional model

forecasting system

- statistical forecasts of water temp. in the aquaculture fields

aquaculture skill

mechanism research

- tolerance for multiple stressors (temp., hypoxia, currents, waves, etc.)
- physiological response to extreme high temperature

skill developments

- aquaculture managements in semi-enclosed bays
- aquaculture managements in open bays
- developments of aquaculture facility to decrease mortality

mechanism research

salinity budget analysis (independent data with temp.)

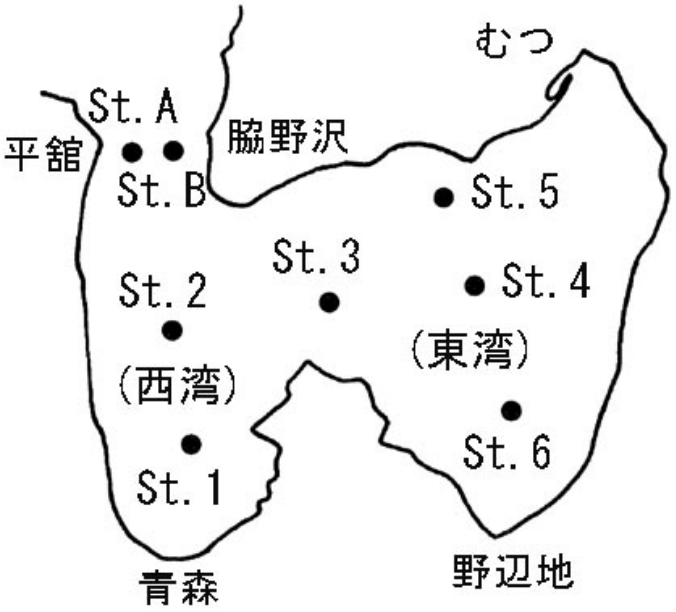
monthly monitoring data in the Mutsu Bay

Cluster analysis was applied for salinity data (2006-2011).

The data was divided to 5 (7) clusters.

upper, middle, lower layers in the bay month

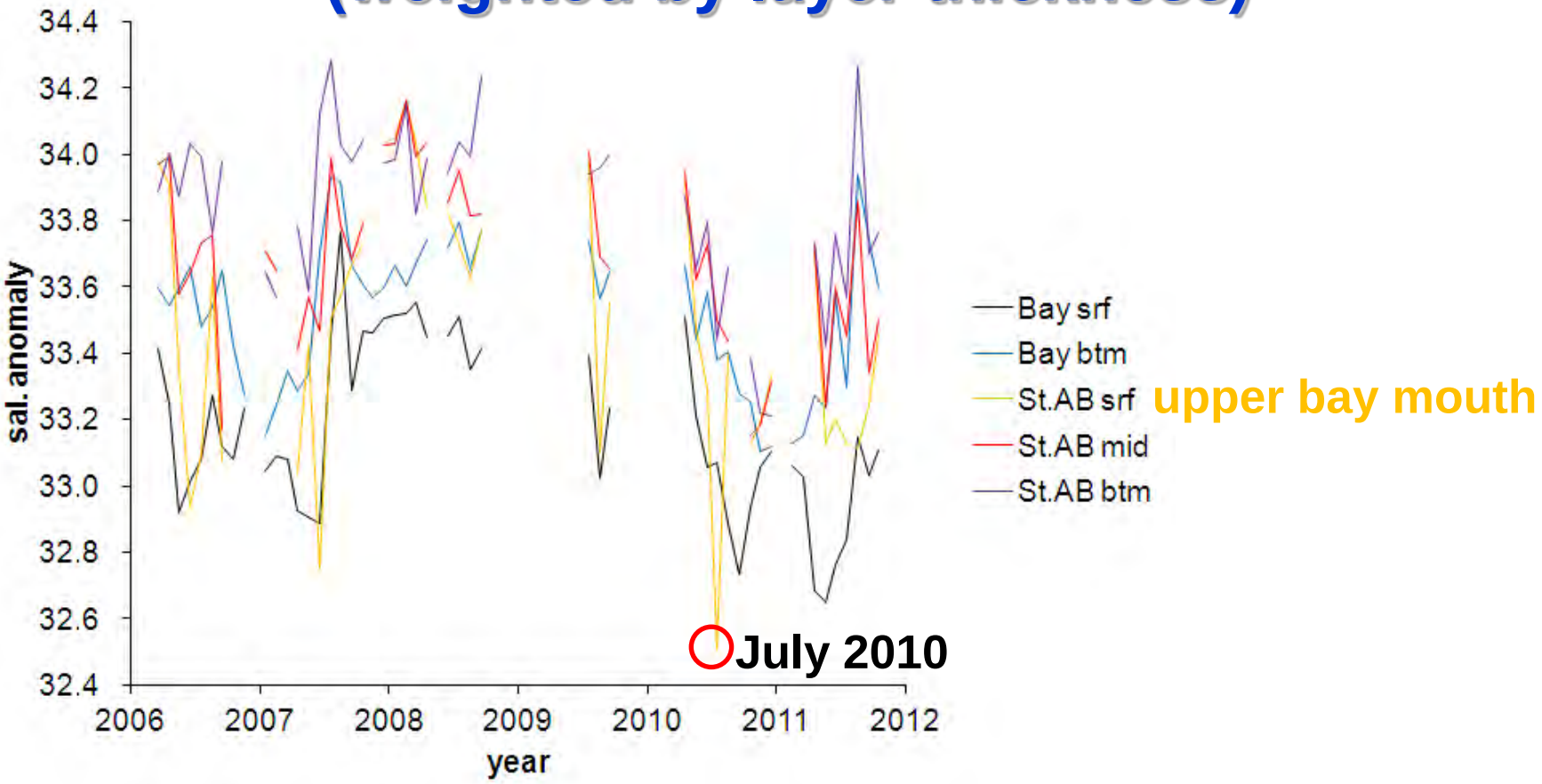
upper & lower layers in the bay



clusters for salinity data

St.A	St.B	St.2	St.1	St.3	St.5	St.4	St.6
0 m	0 m	0 m	0 m	0 m	0 m	0 m	0 m
5 m	5 m	5 m	5 m	5 m	5 m	5 m	5 m
10 m	10 m	10 m	10 m	10 m	10 m	10 m	10 m
20 m	20 m	20 m	20 m	20 m	20 m	20 m	20 m
30 m	30 m	30 m	30 m	30 m	30 m	30 m	30 m
40 m	40 m	40 m	40 m	40 m	btm	40 m	btm
50 m	50 m	btm	btm	btm		btm	
btm	btm						

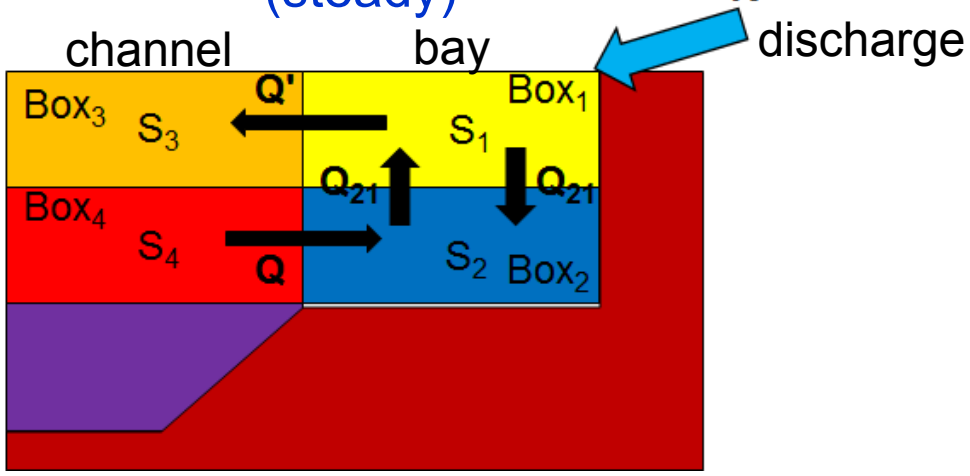
cluster averaged salinity (weighted by layer thickness)



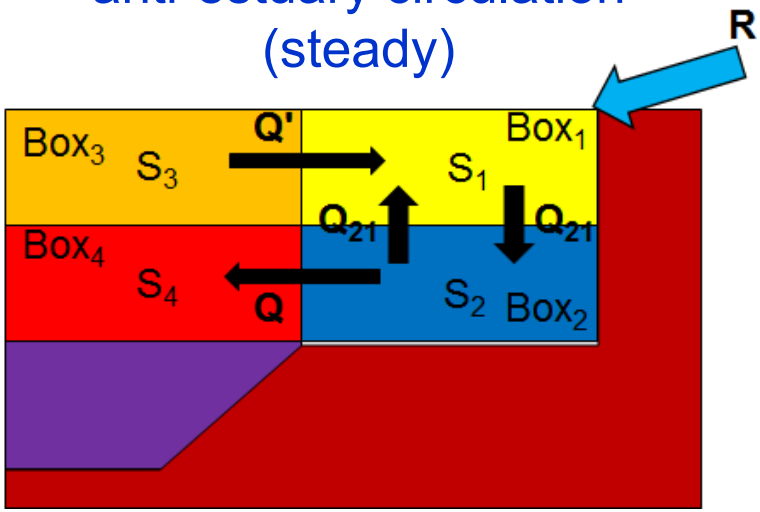
- Salinity in the upper layer of bay mouth anomalously decreased in July 2010.
- Similar salinity decreases were observed in June 2006, June 2007, August 2009. However the decrease in July 2010 was the largest.

box model analysis

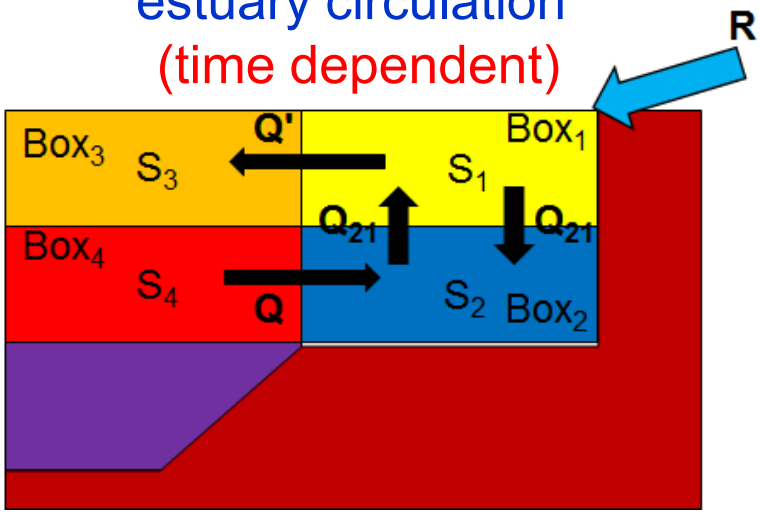
estuary circulation (steady)



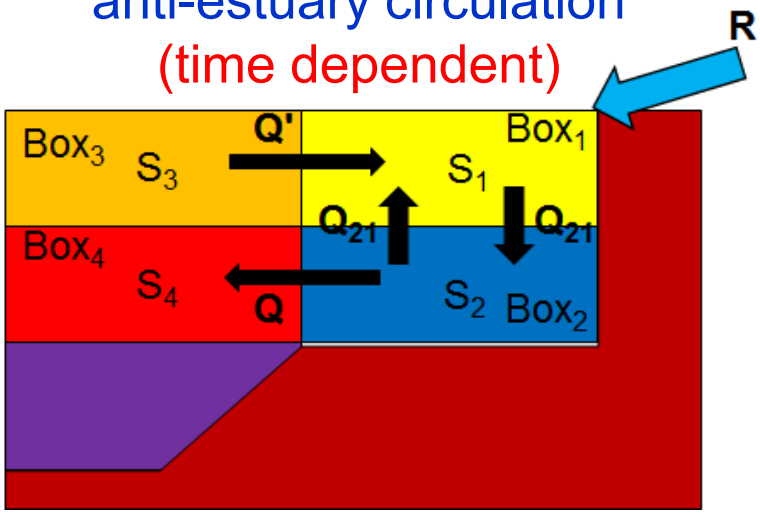
anti-estuary circulation (steady)



estuary circulation (time dependent)

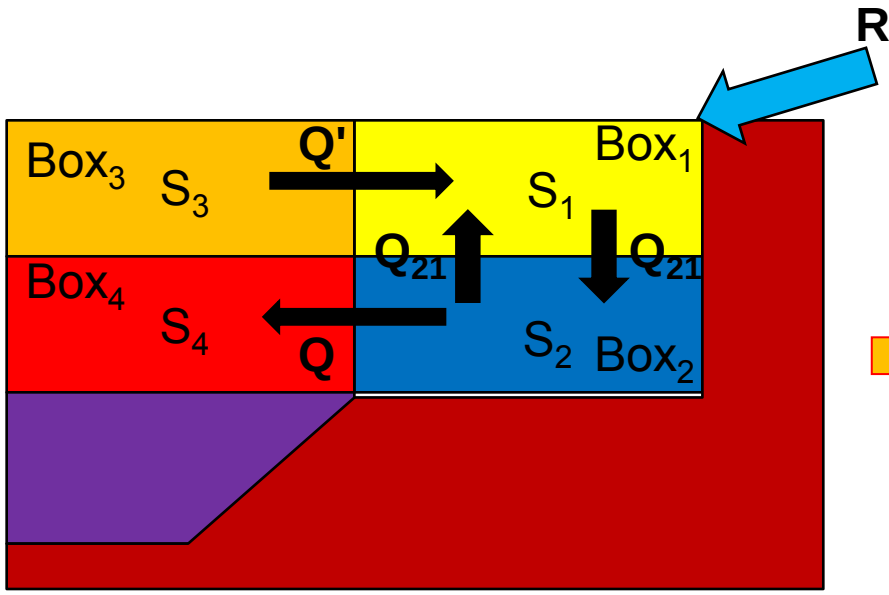


anti-estuary circulation (time dependent)



We applied four types of box models to explain salinity budgets in the bay.

anti-estuary circulation (time dependent)



water conservation

Box1&2: $R+Q'-Q=0$

salinity conservation

Box1&2: $(Q'*S_3-Q*S_2)*\Delta t=\Delta S_1*V_1+\Delta S_2*V_2$

$$Q=(\Delta S_1*V_1+\Delta S_2*V_2+R*\Delta t*S_3)/(S_3-S_2)/\Delta t$$

using state from Jun. to Jul. 2010

$R=44.0\ m^3s^{-1}$, $S_2=33.58$, $S_3=33.29$

$V_1=3.32\times10^{10}\ m^3$, $V_2=2.99\times10^{10}\ m^3$

$\Delta S_1=0.014$, $\Delta S_2=-0.202$

$\Delta t=60*60*24*30$ sec

$Q=2370\ m^3s^{-1}$

using $T_1=16.5$, $T_2=12.5$, $T_3=19.4$, $T_4=14.6$ in Jun. 2010

heat content increase in Box1&2 by advection

$Q'*T_3-Q*T_2=8.18\times10^3$ degC m^3S^{-1} :**+0.6 degC/month**

heat content increase in Box2 by advection

$Q*T_1-Q*T_2=3.56\times10^3$ degC m^3S^{-1} :**+0.8 degC/month**

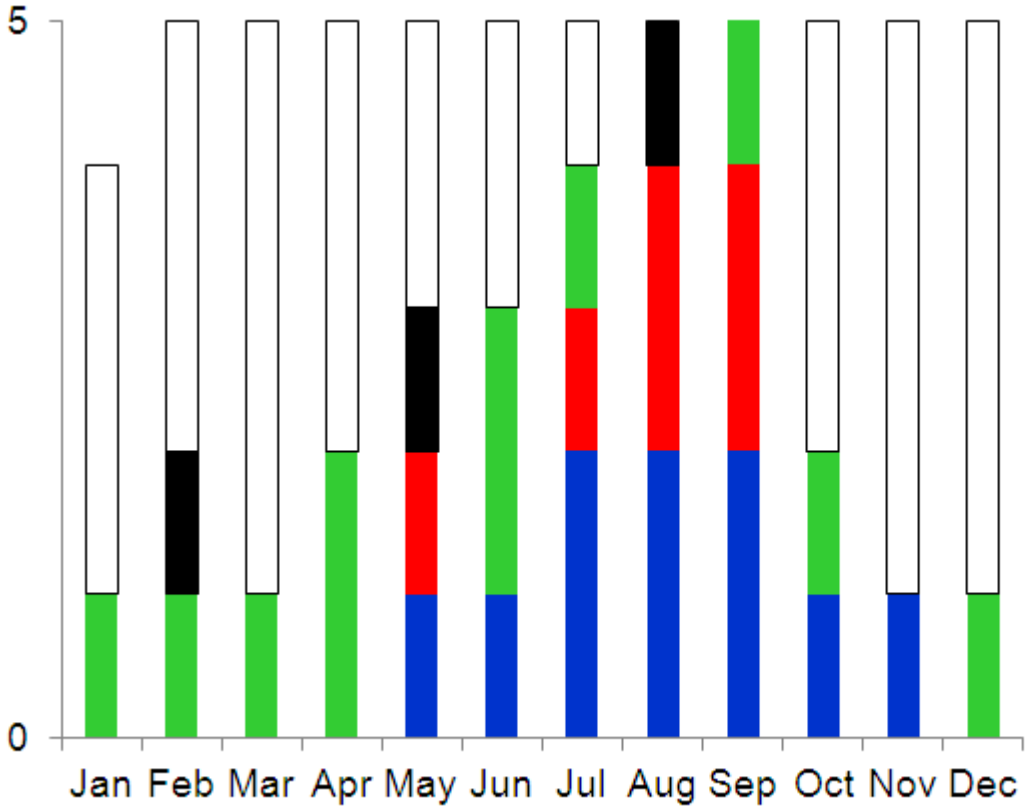
Anti-estuary circulation warmed up both upper and lower layers in Jul. 2010.

box model analysis (time dependent) for salinity budgets

Seasonal variability

Data: monthly salinity during 2006-2010.
Estuary circulation occurs in summer.
Anti-estuary circulation occurs in summer.

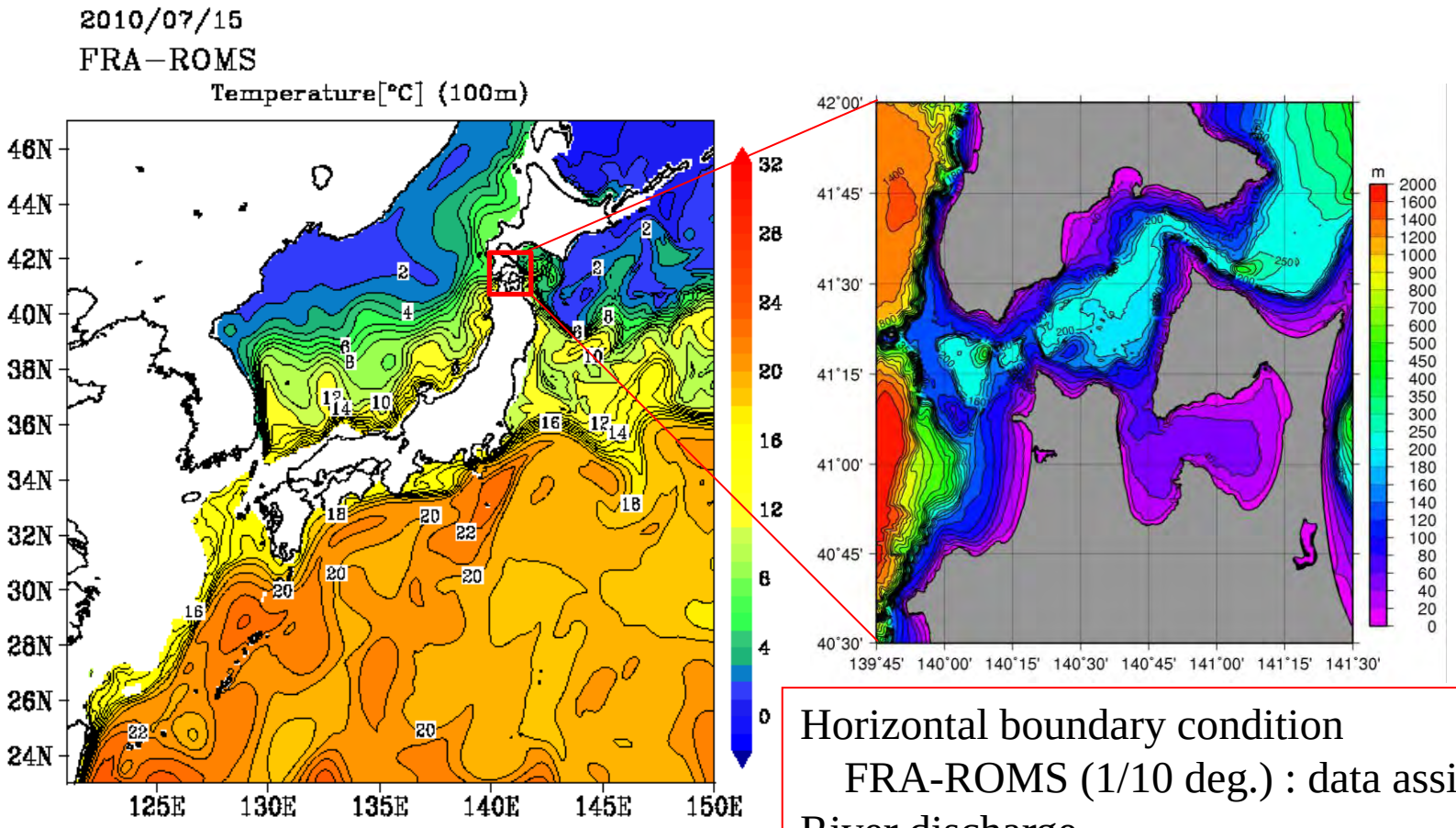
Yahaba et al. (2000)
Deformed estuary circulation is formed in summer.



Anti-estuary circulation was formed in May 2006, Sep. 2007, Aug. 2008, Jul. Aug. Sep. 2010.

Anti-estuary circulation had been kept for 3 months in 2010 summer.

ROMS in the Mutsu Bay



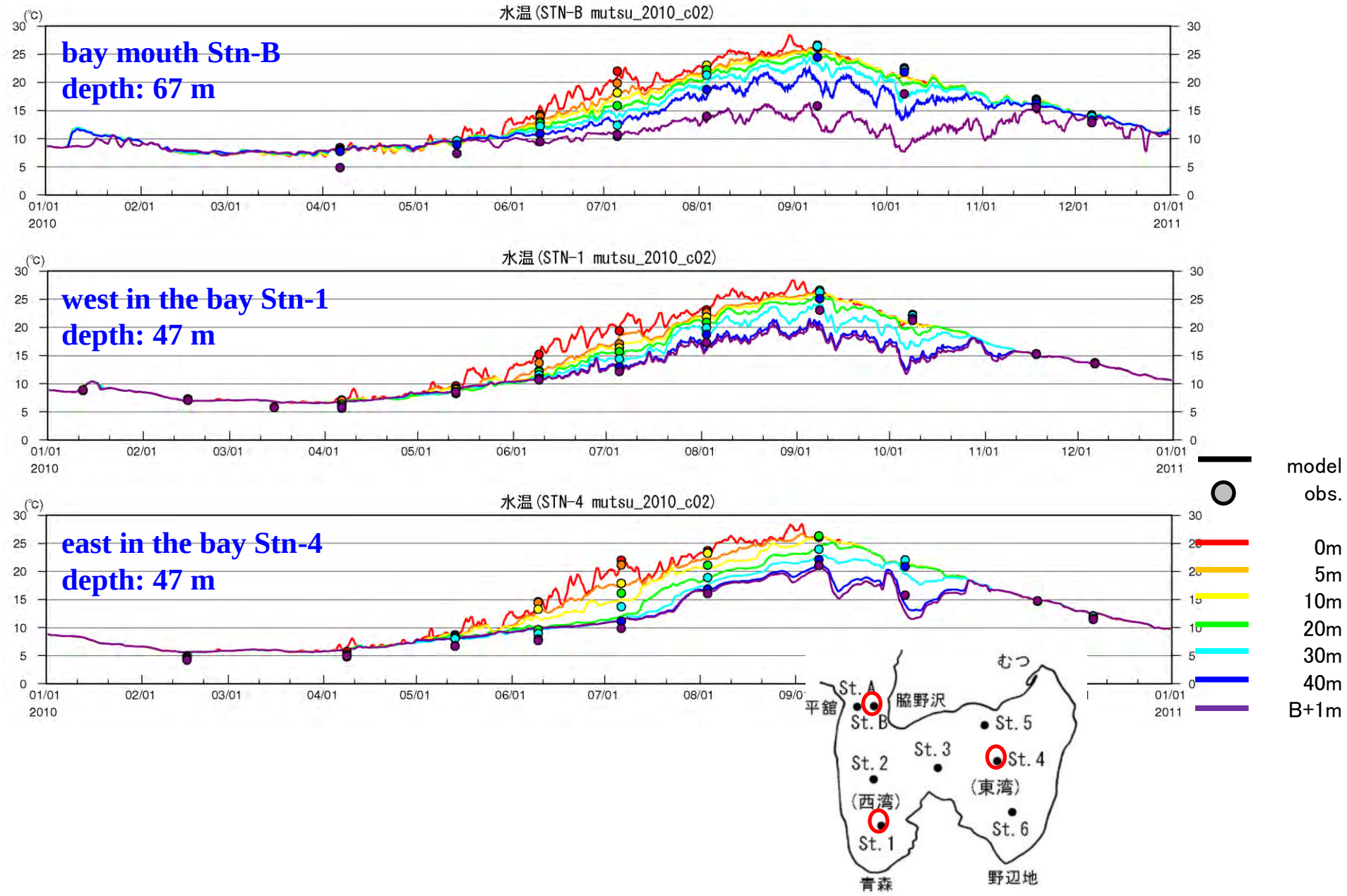
http://fm.dc.affrc.go.jp/fra-roms/index.html

Horizontal boundary condition
- FRA-ROMS (1/10 deg.) : data assimilation

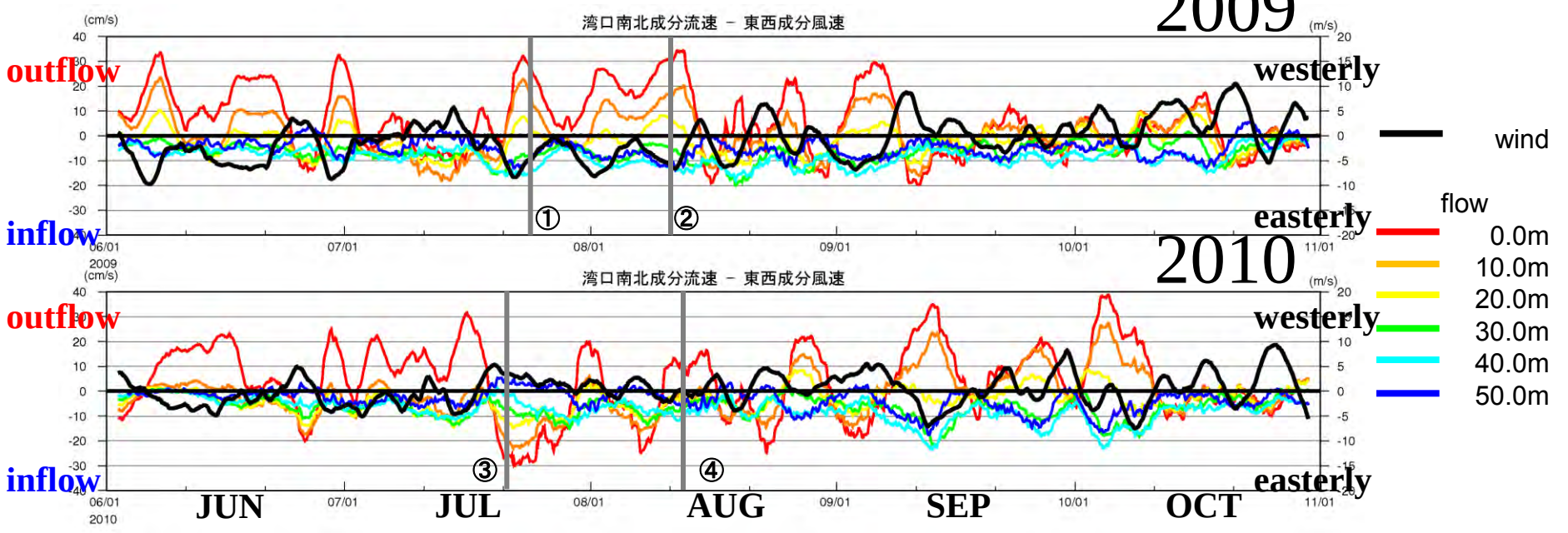
River discharge
- hydrological model (SWAT)

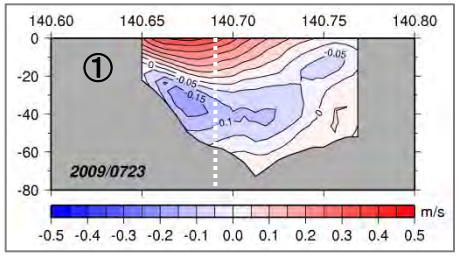
model resolution
- 1/160 deg. x 1/240 deg. x 25 level

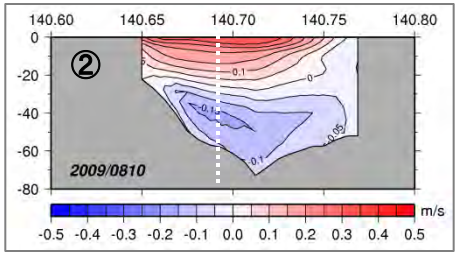
temperature in 2010

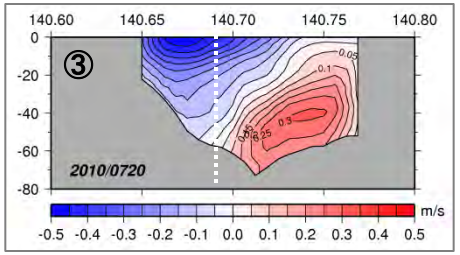


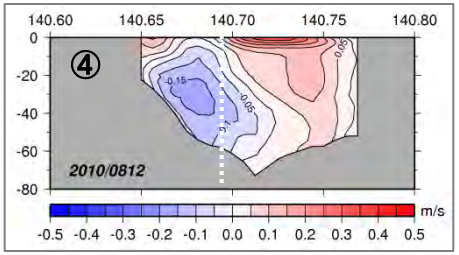
wind and outflow at the bay mouth







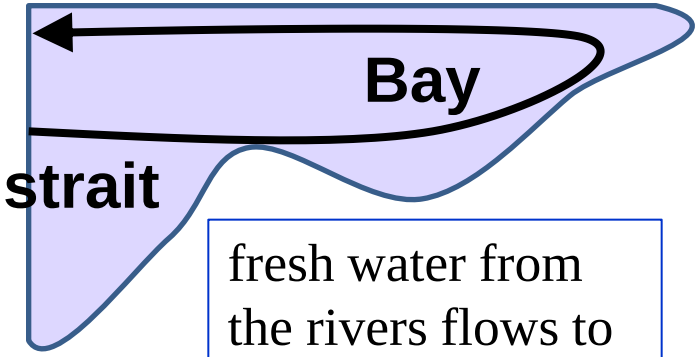




easterly positively correlated with surface outflow
negatively correlated with bottom outflow
higher surface inflow in 2010.
However, the duration is about half month.

2010 summer in the Mutsu Bay

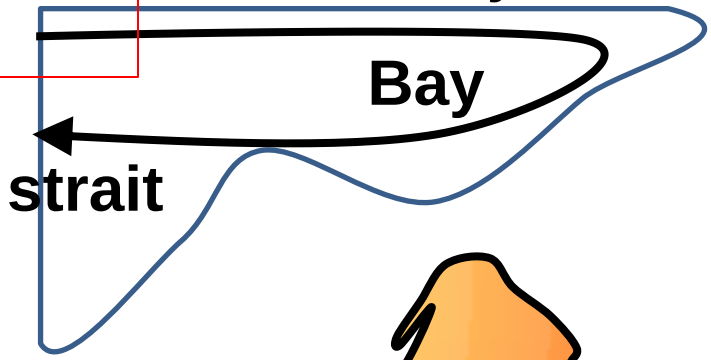
Normal year
estuary circulation

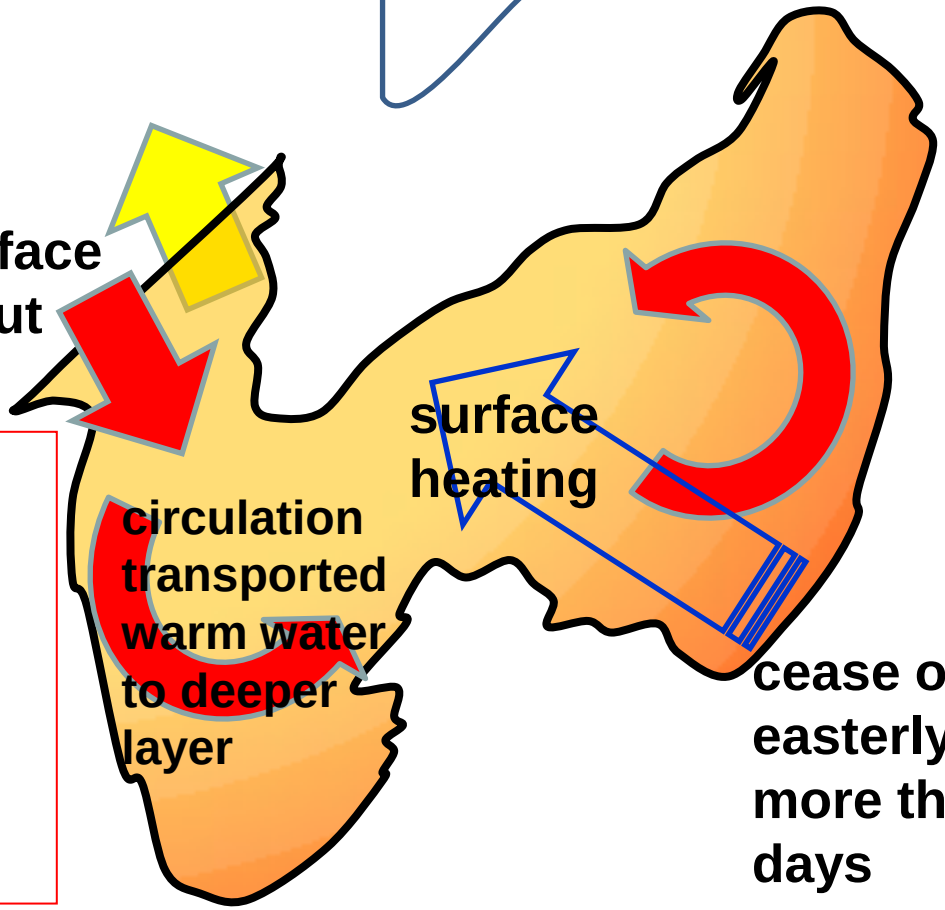


fresh water from the rivers flows to the offshore.

warm surface water from the strait

2010
anti-estuary





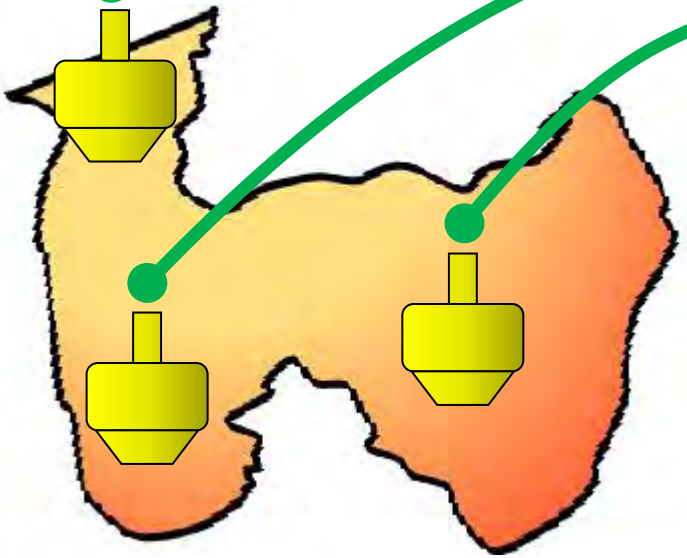
abnormal summer

Long cease of easterly wind heated the surface rapidly and also assisted anti-estuary circulation.
Anti-estuary circulation heated not only surface but also subsurface.

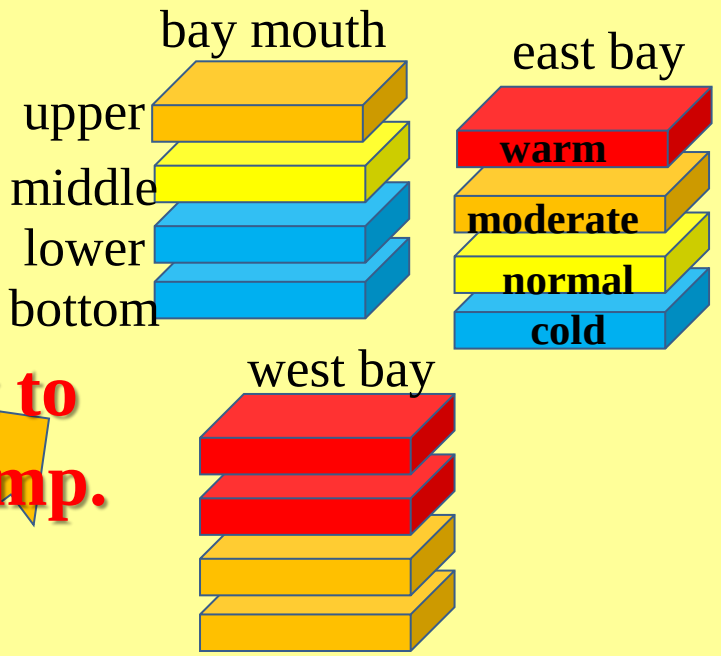
statistical prediction of water temp.

monitoring of temp.

realtime report



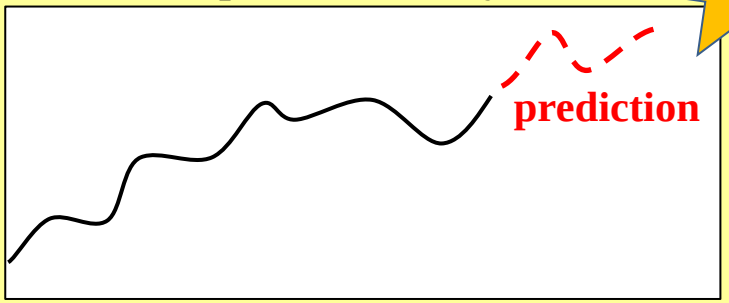
Principal component analysis



convert to water temp.

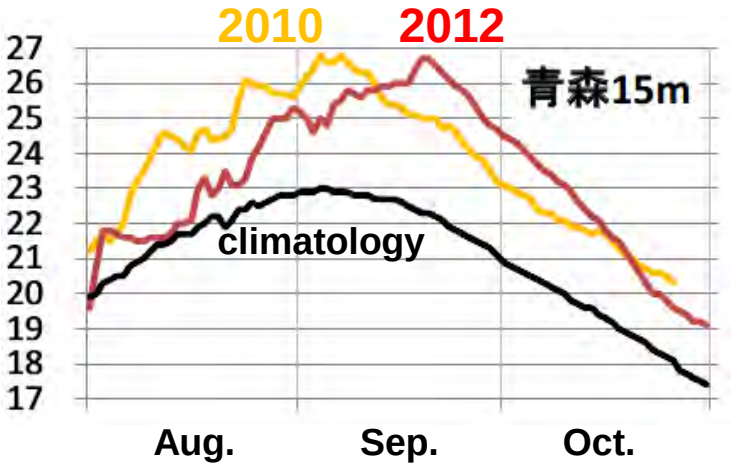
score prediction

score predic. = c1 x previous 5 days score + c2 x previous 10 days score...

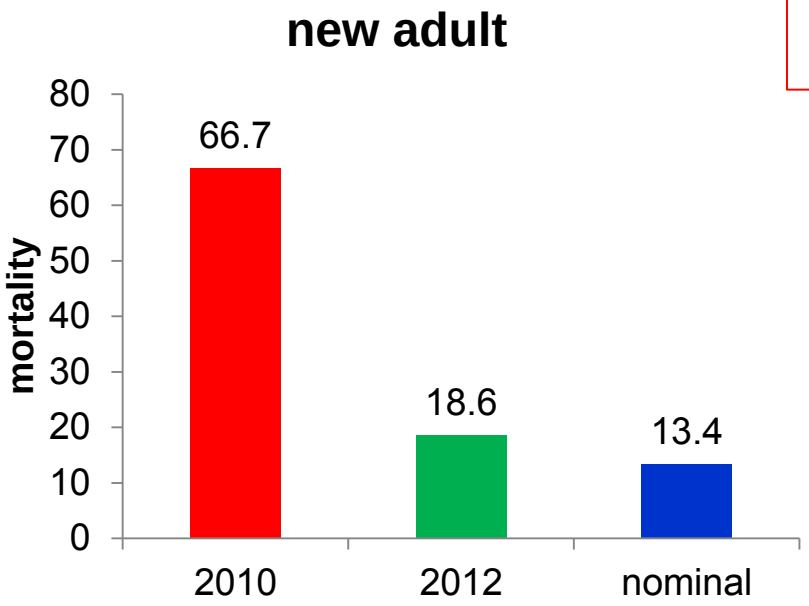


autoregressive model for score of PCs.

Extreme hot summer in 2012



- Another extreme hot event occurred in 2012.
- Statistical forecasts was used to advice fishermen not to disturb scallops during the hot event.
- As a result, the mortality was reduced less than half of the 2010 value.



This is a good example of scientific information delivery for management.

Our big challenge is to improve the accuracy of the prediction without higher computational cost.

courtesy of Aomori Prefecture