Two different Hypoxic Cases:

Kangjin Bay, South Sea

Chunsu Bay, Yellow Sea, Korea

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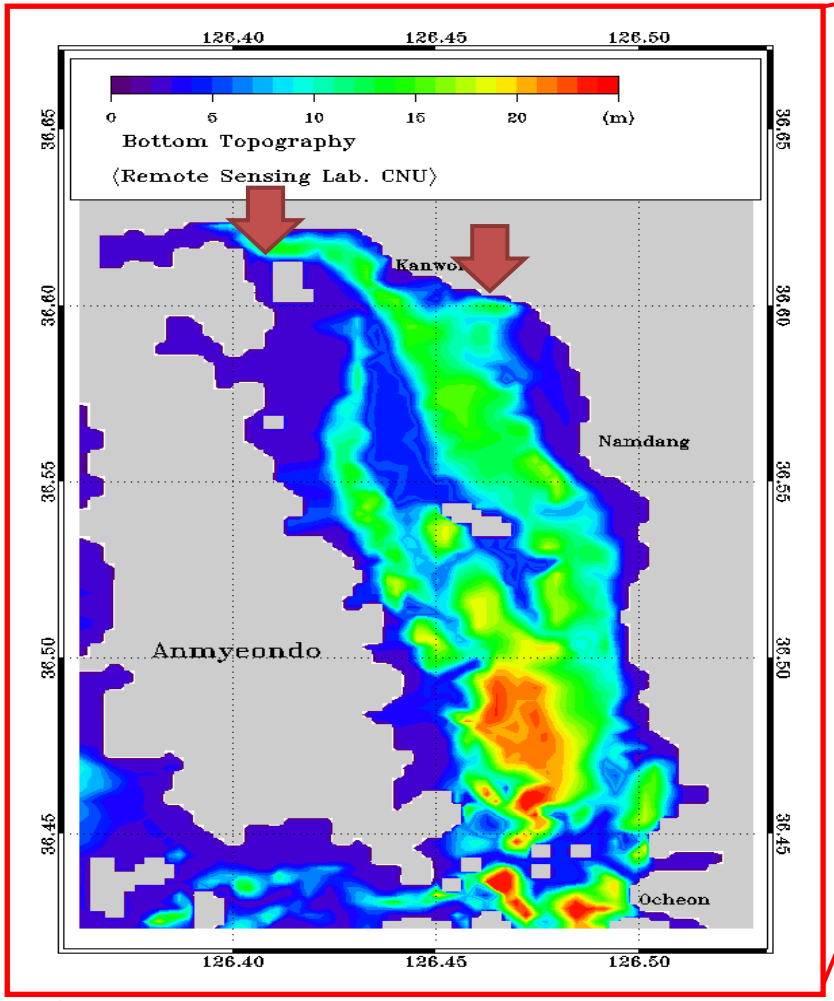
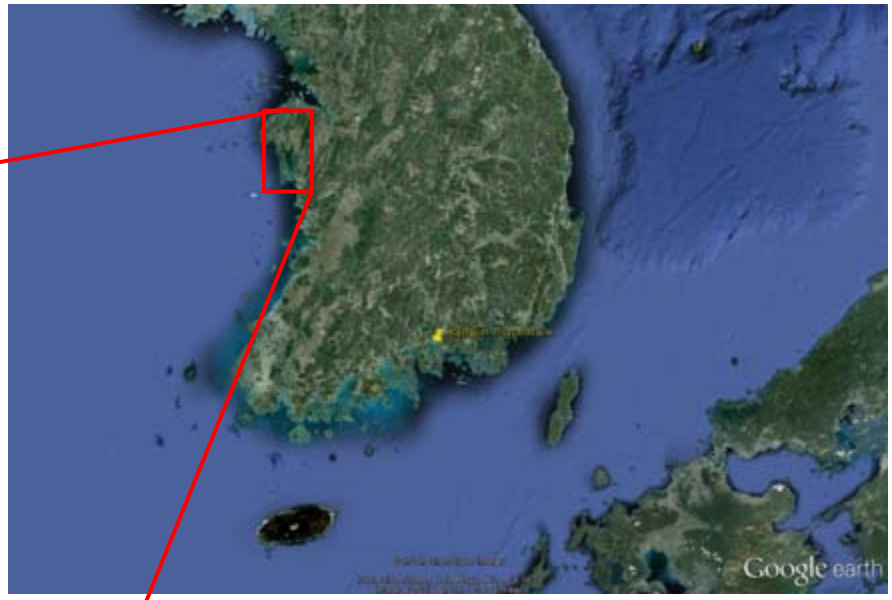
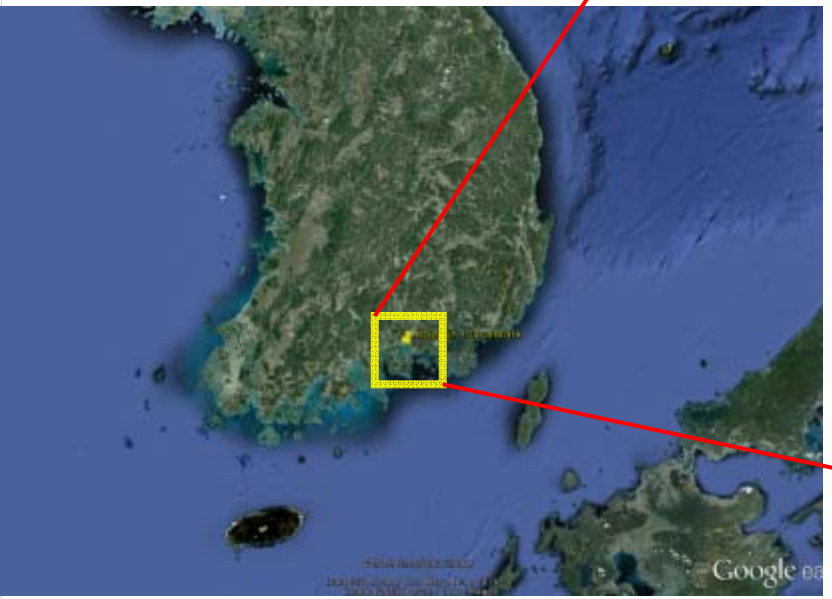
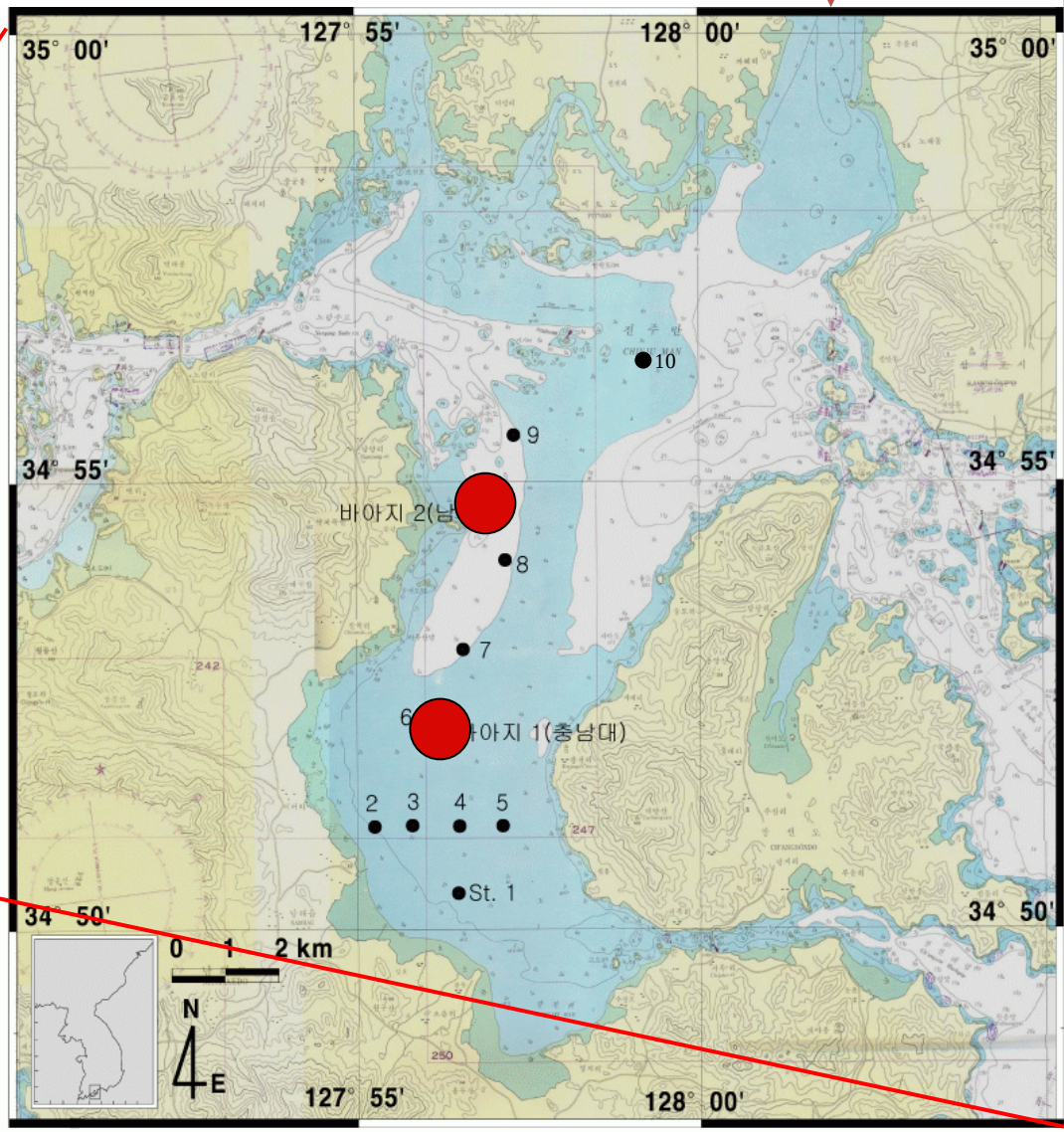
Chunsu Bay, Yellow Sea





Kangjin Bay, South Sea





Similarity

- Small Estuary (~ 10s Km)
- Strong Tidal Circulation
- Intermittent Dam Water Discharge

Differences

- Chunsu Bay
  - Eutrophic Turbid Water from Inland Lakes
  - Oxygen Consumption by bloom of micro-algae in the water column
- Kangjin Bay
  - Fresh Clean Water from NG Dam
  - Oxygen Consumption by SOD at bottom & no oxygen supply by stratification

Introduction, the Chunsu Bay

- Artificial Dyke Construction for Reclamation and Land Use → Northern Passage Blocked
- Tidal Circulation Change in the Chunsu Bay
- Pollutant Load and Reduced Dilution and Transport out of the CS Bay
- Frequent Hypoxia/Anoxia Occurrences in the Summer Time
- Reduced Fishery Production

So Many Issues with Questions

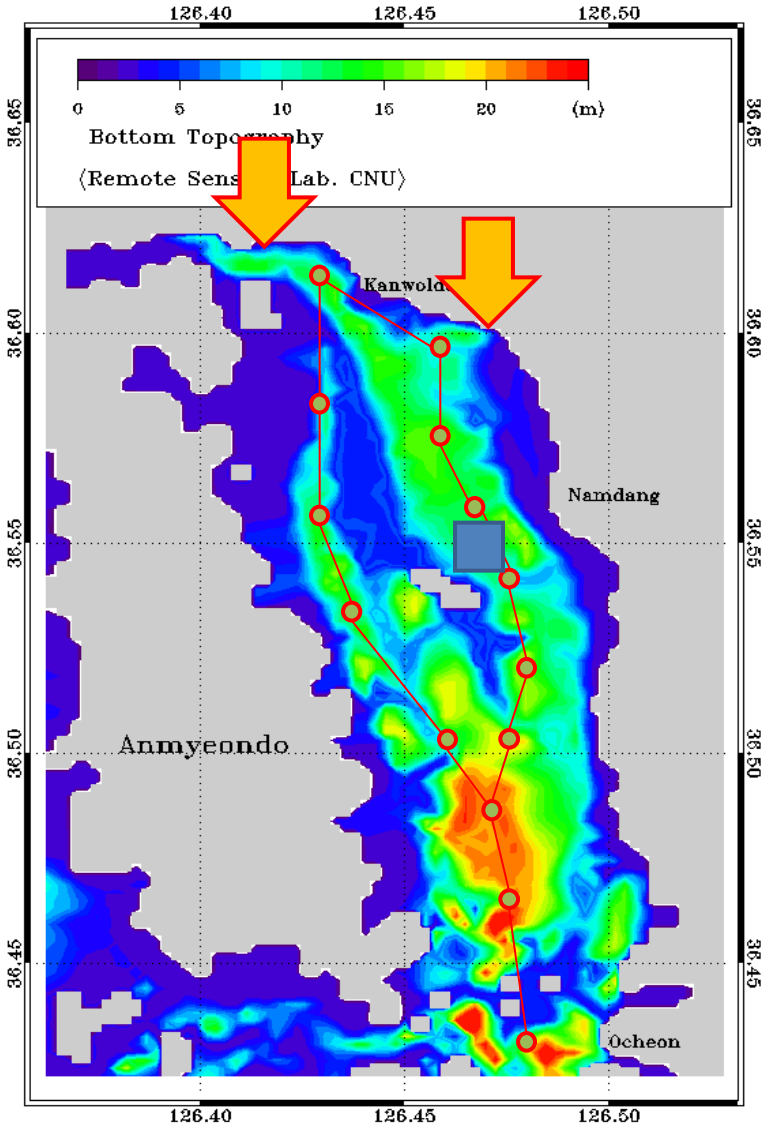
- Many Dam Constructions in the coastal Embayment in Korea since 1970s
  - Dam Water Discharge
  - Pollutant Load
  - Salinity Decrease and Stratification
  - Eutrophication → Red Tide
  - Hypoxia Formation
  - Reduced Ecosystem Health

Intensive Field Measurements

- **Current & direction(ADCP)**
  - Jul. 29~Aug.30, 2010 (32 days)
  - Current Speed and Direction
  - Sampling interval : 10 min
  - Obs. Layers : 14 (1 m)

- **Surveys**
  - N-S cross section

- **Seasonal and Summertime-monthly field works**
  - Temperature & Salinity
  - Dissolved Oxygen, pH, Turbidity, Chlorophyll
  - COD, DOC, C, TN, TP, Si, etc.
  - Total 27 water quality parameters

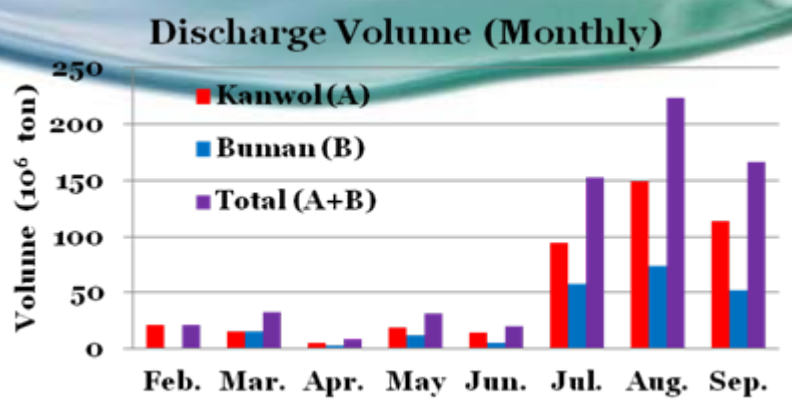


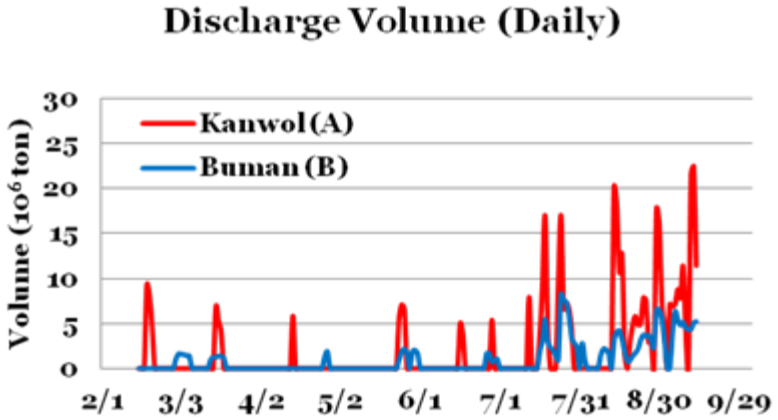
Discharge Information

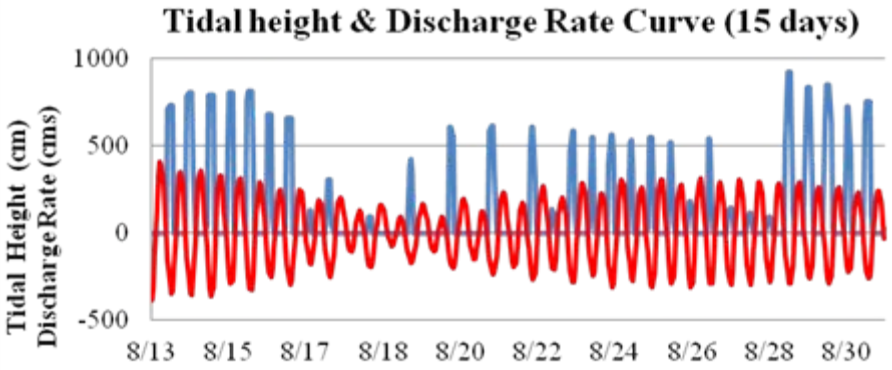
- **Total discharge volume (2010) : 700 million ton/year**
  - Kanwol A-district tide-embankment : 430 million ton/year
  - Bunam B-district tide-embankment : 260 million ton/year

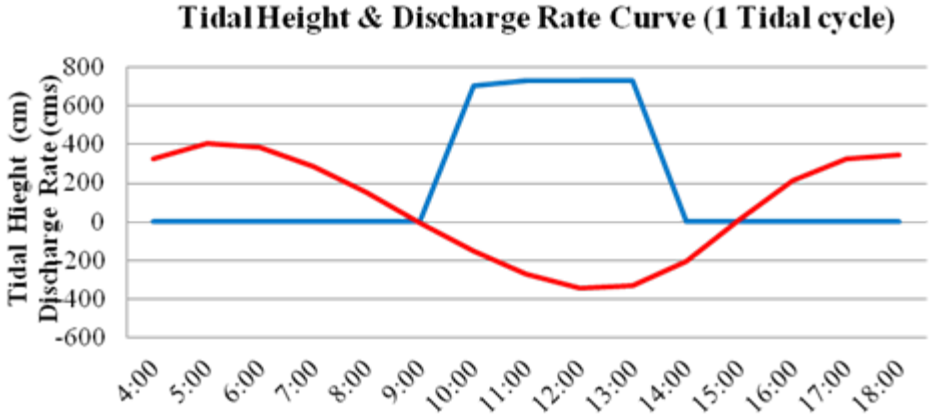
- Discharge took place for 3~4 hours
  - with discharge rate : 400 m^3/sec (KW), 200 m^3/sec (BN)
  - twice a day (during ebb~low tide)

Tide-Embankment	A-district	B-district
Length(km)	6,458	1,228
Floodgate	8 gates(102m)	4 gates (35.6m)
Open	4~6 gates	2~3 gates

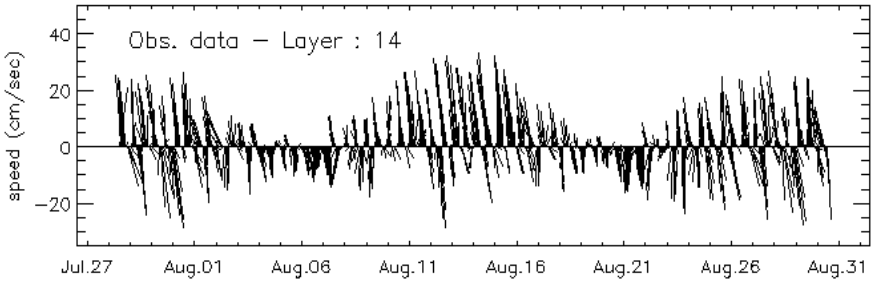




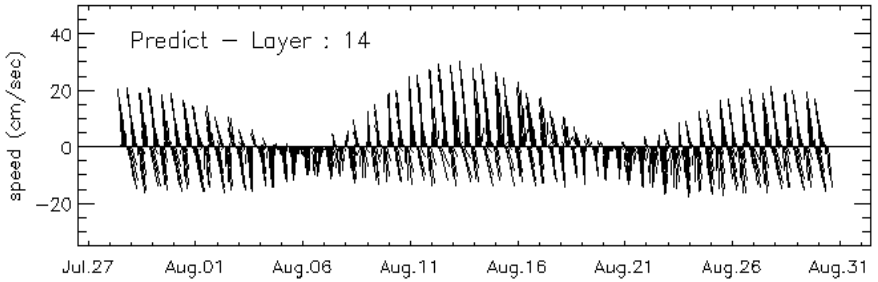




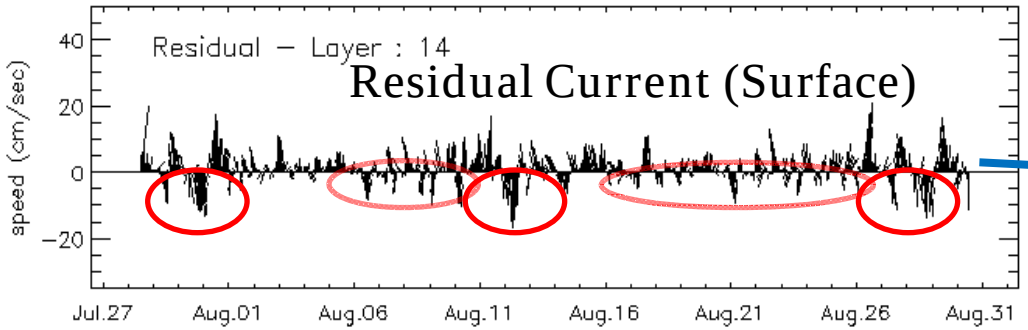
Observations: Result 1- Current

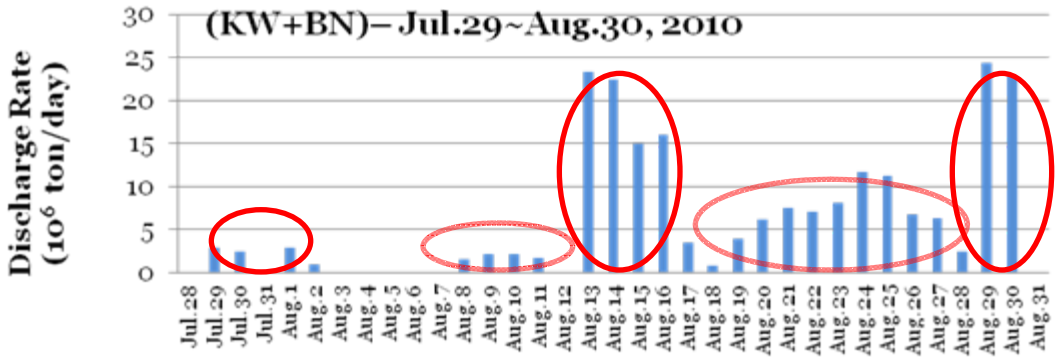


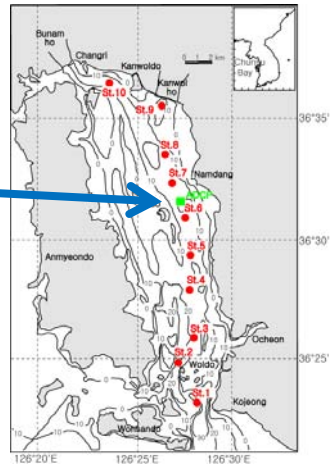
Observed Data (Surface)



Harmonic Analysis Result (Surface)

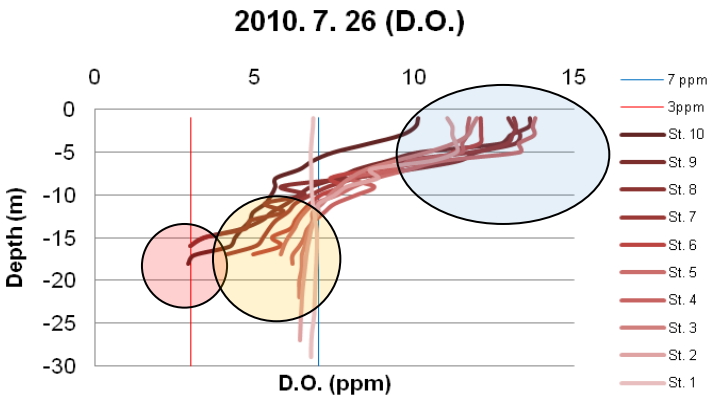


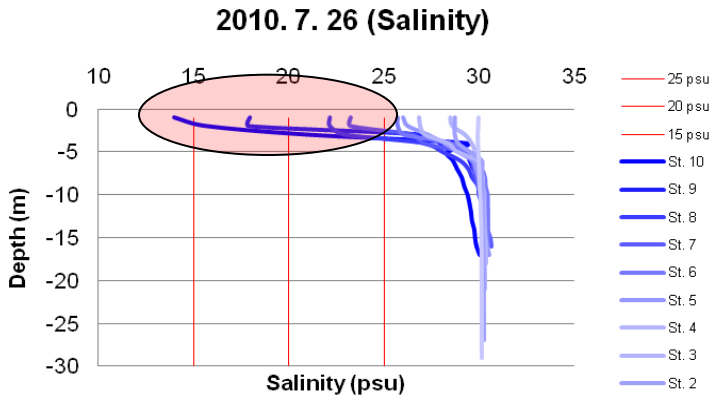


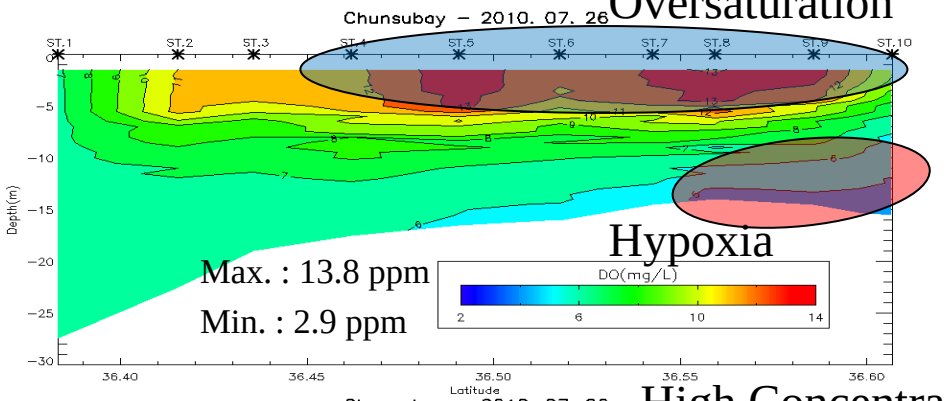


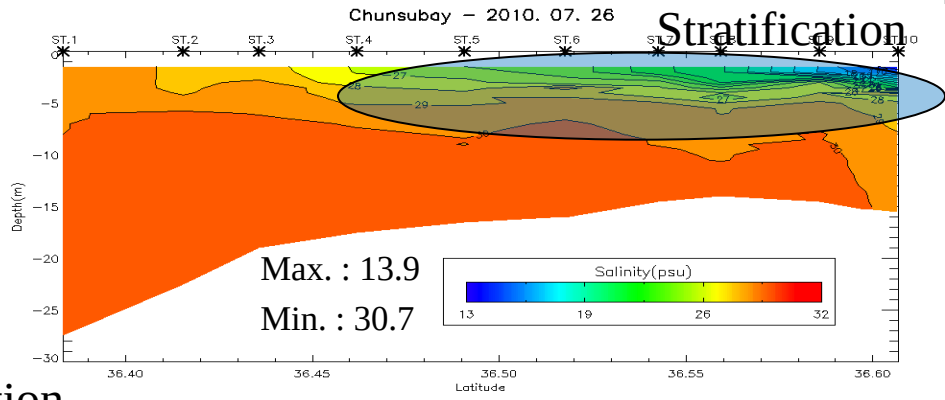
- ADCP mooring Info.
  - Jul. 29~Aug.30, 2010 (32 days)
  - Current Speed and Direction
  - Sampling interval : 10 min
  - Obs. Layers : 14 (1 m)

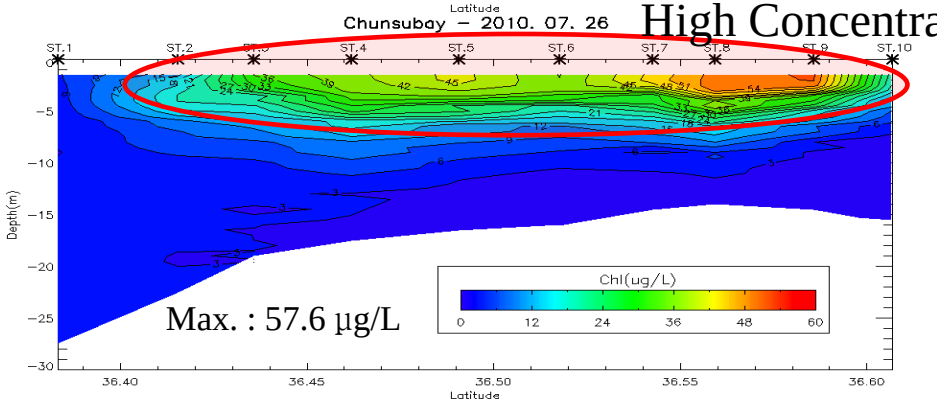
Obs. Result 2– Salinity, DO and Chlorophyll







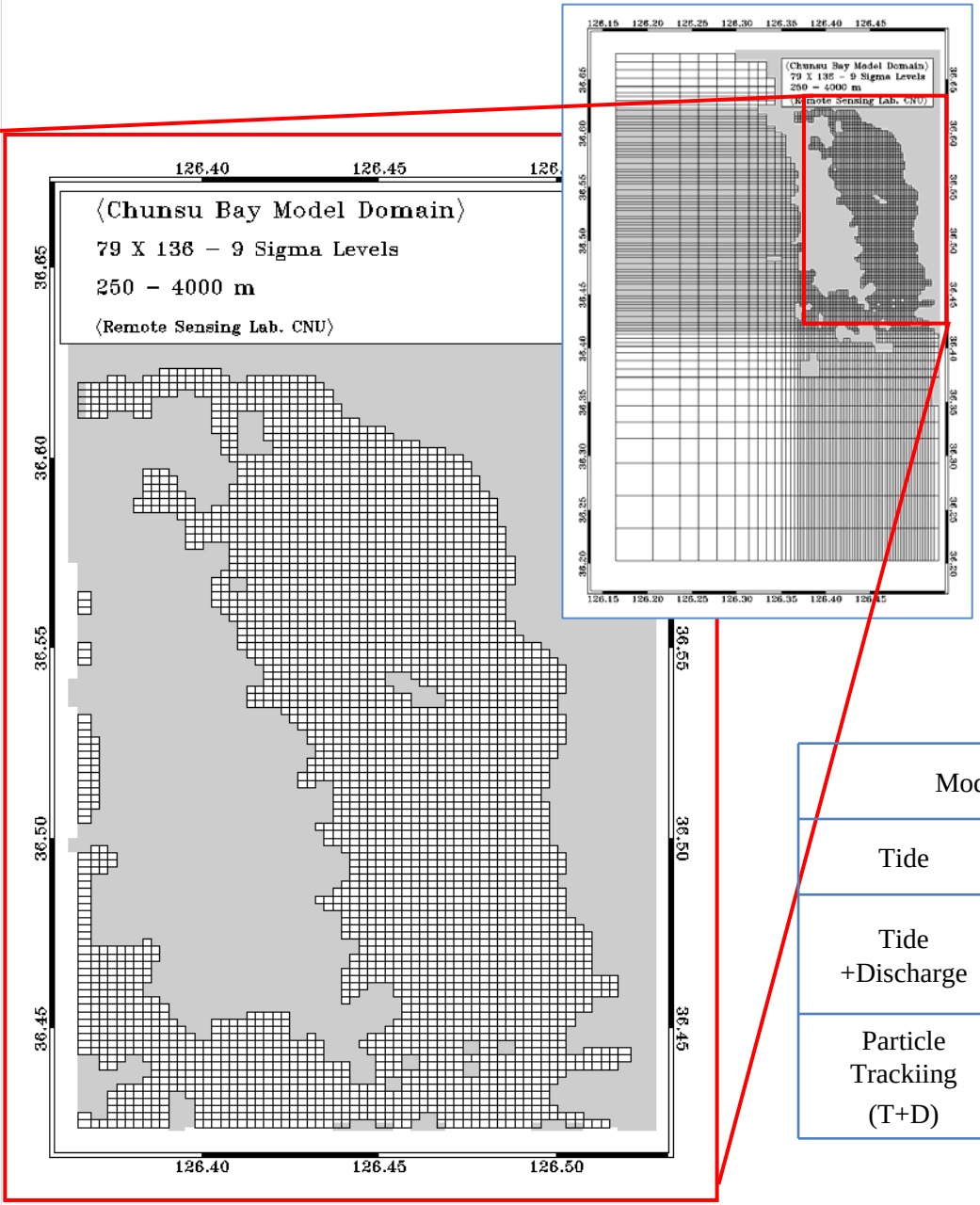




During Discharge : Kanwol & Bunam Lake
(7.24~26 : Total Discharge amount 5.4×10^7 ton)

- DO : Oversaturation at surface
  Hypoxia formation at Bottom
- Salinity : Strong Stratification
- Chlorophyll : high concentration at surface

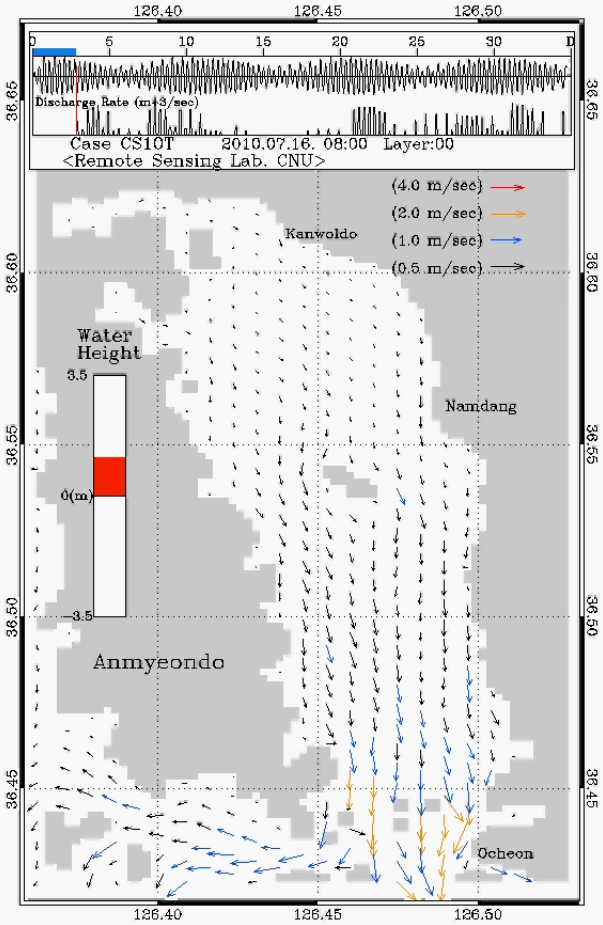
Model Specification and Modeling Cases



- **Model code :** ECOM3D (Hydroqual)
- **Grid system**
  - 79 X 136, 250~4000 m, 9 sigma levels
- **Time step**
  - Internal : 20 sec, External : 2 sec
- **Open boundary condition**
  - 4 major tidal constituents (M2, S2, K1, O1)
- **Rear dam discharge data**
- **Obs. Temp. & Salt. data**

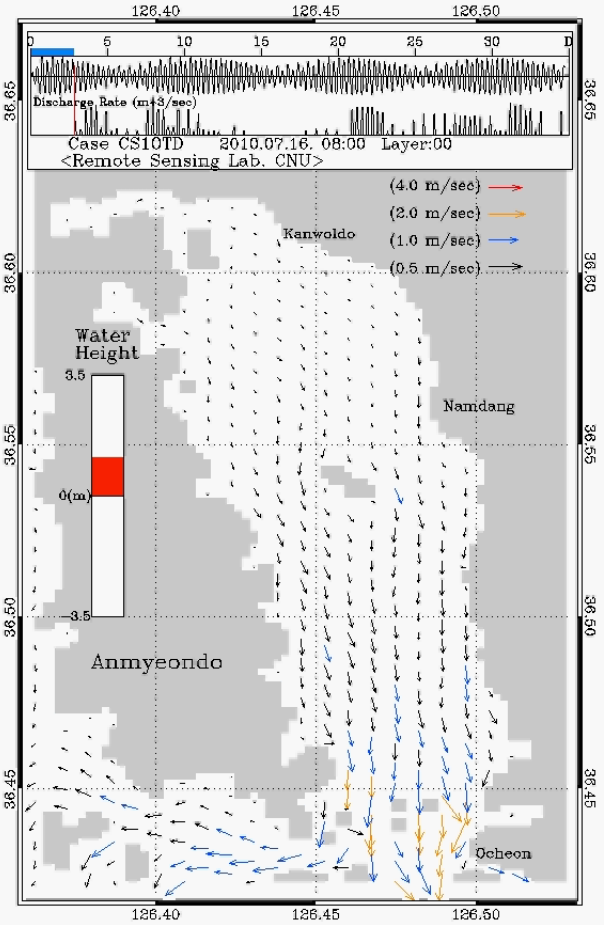
Modeling Cases		Out Forcing (Input Data)
Tide	Case-CS10T	4 Major Const. (M2, S2, K1, O1)
Tide +Discharge	Case-CS10TD	4 Major Const. + Real Discharge Data (28℃, 0 psu)
Particle Trackiing (T+D)	Case-CS-P10D-C Case-CS-P10D-R	4 Major Const. + Real Discharge Data (28℃, 0 psu)

Model Result – Current Field



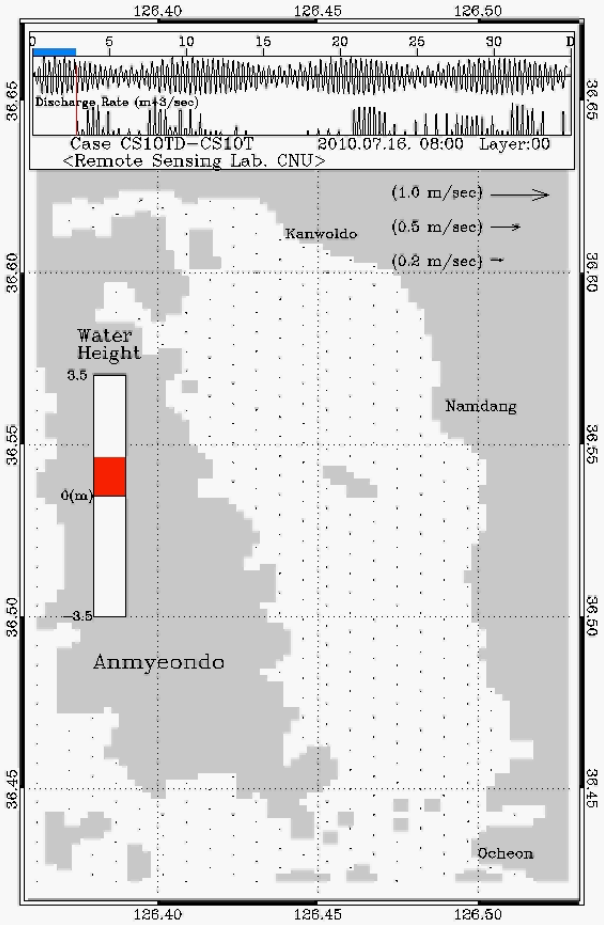
Case 10T

Only Tide



Case 10TD

Tide+Discharge

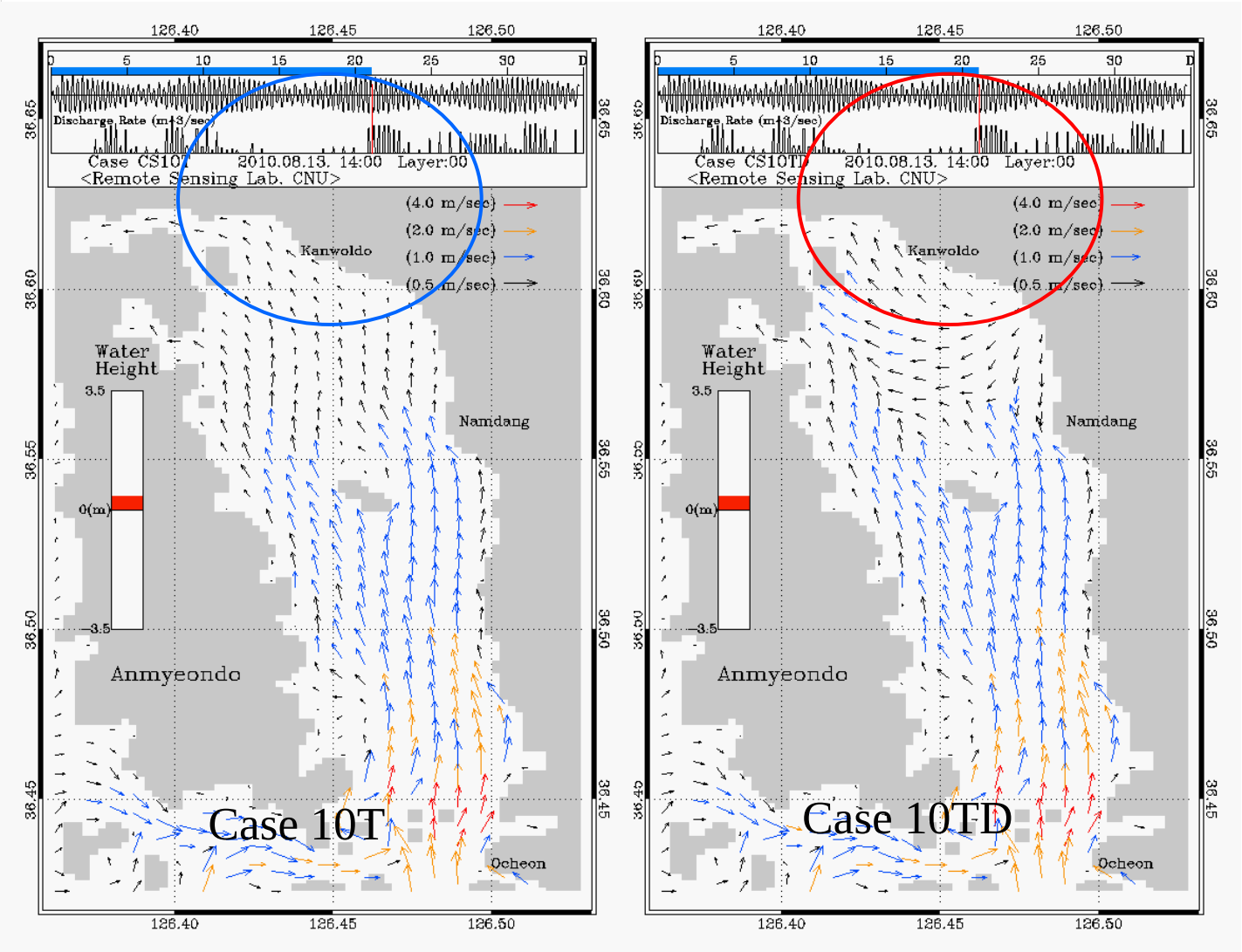


Case 10TD-10T

Discharge effect

(Density Current)

Model Result – Tidal Current (Spring / Flood)



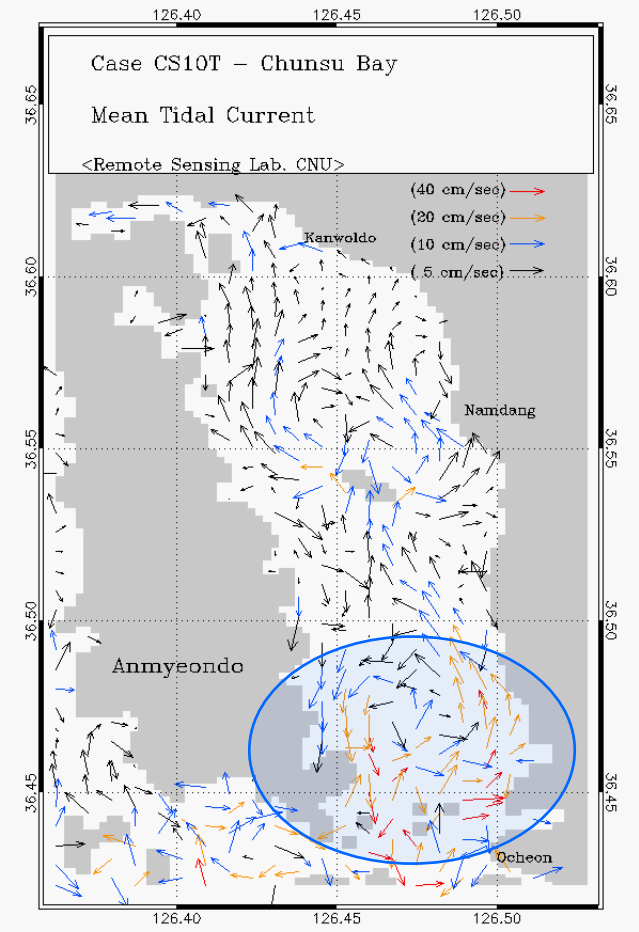
Northern part
: 0.2~0.5 m/s

Central Part
: 0.5~1.0 m/s

Southern Part
: 1.0~3.0 m/s

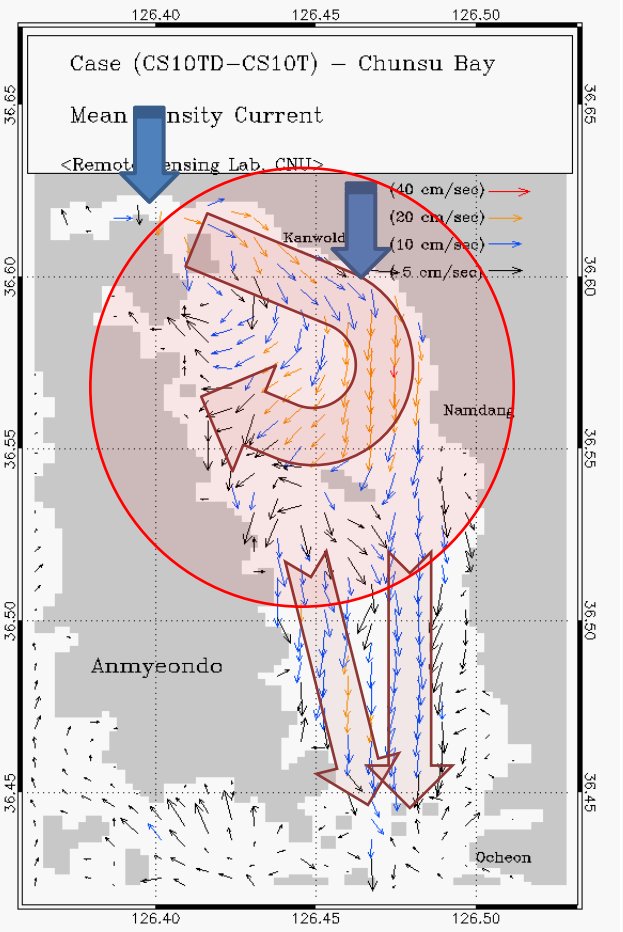
Discharge effect
: Northern Part
: Change Dir.
from N-S to E-W

Model Result – Residual Current



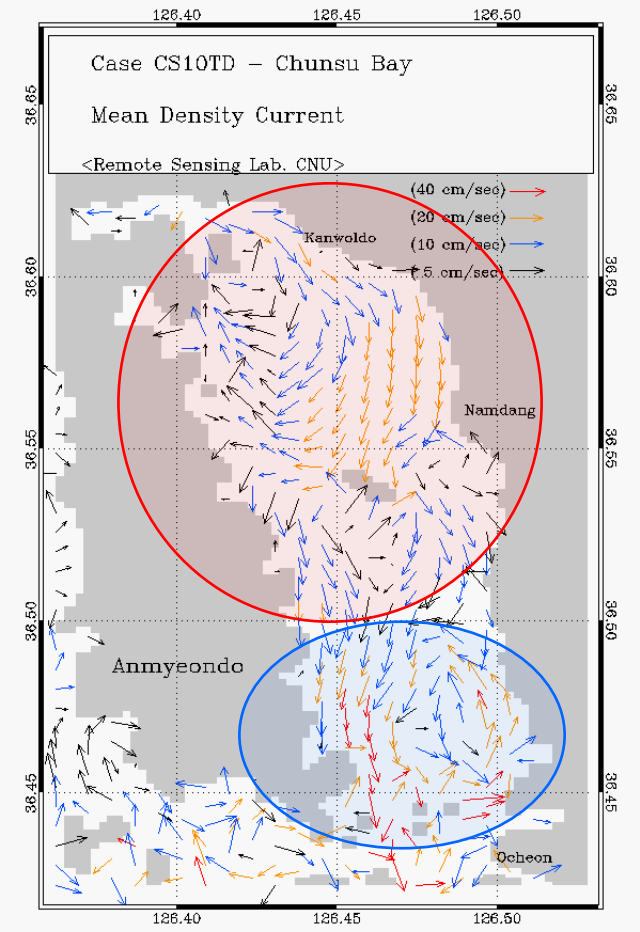
Tidal Residual Current

- Northern Part : 0~10 cm/s
- Southern Part : 20~50 cm/s



Density Current

- Northern Part : 10~40 cm/s
- Southern Part : 5~15 cm/s



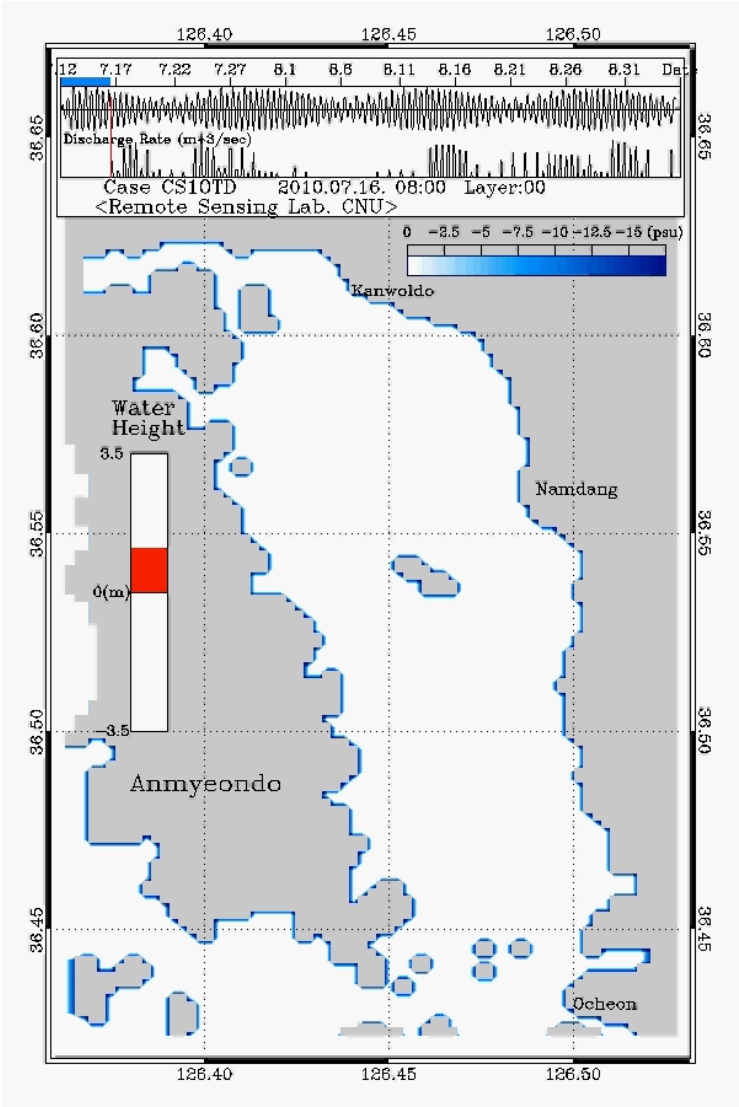
Tidal Residual + Density Current

- Northern Part : Density Current
- Southern Part : Tidal Residual Current

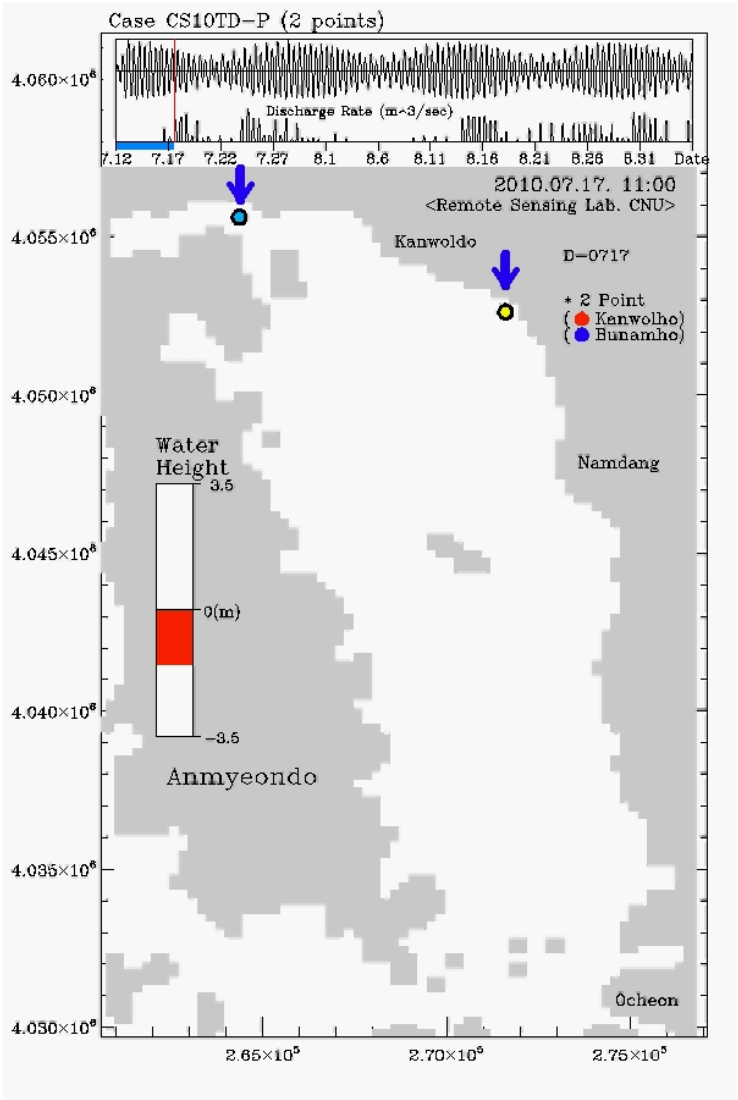
Model Result – Salinity Field (Surface)

Animation

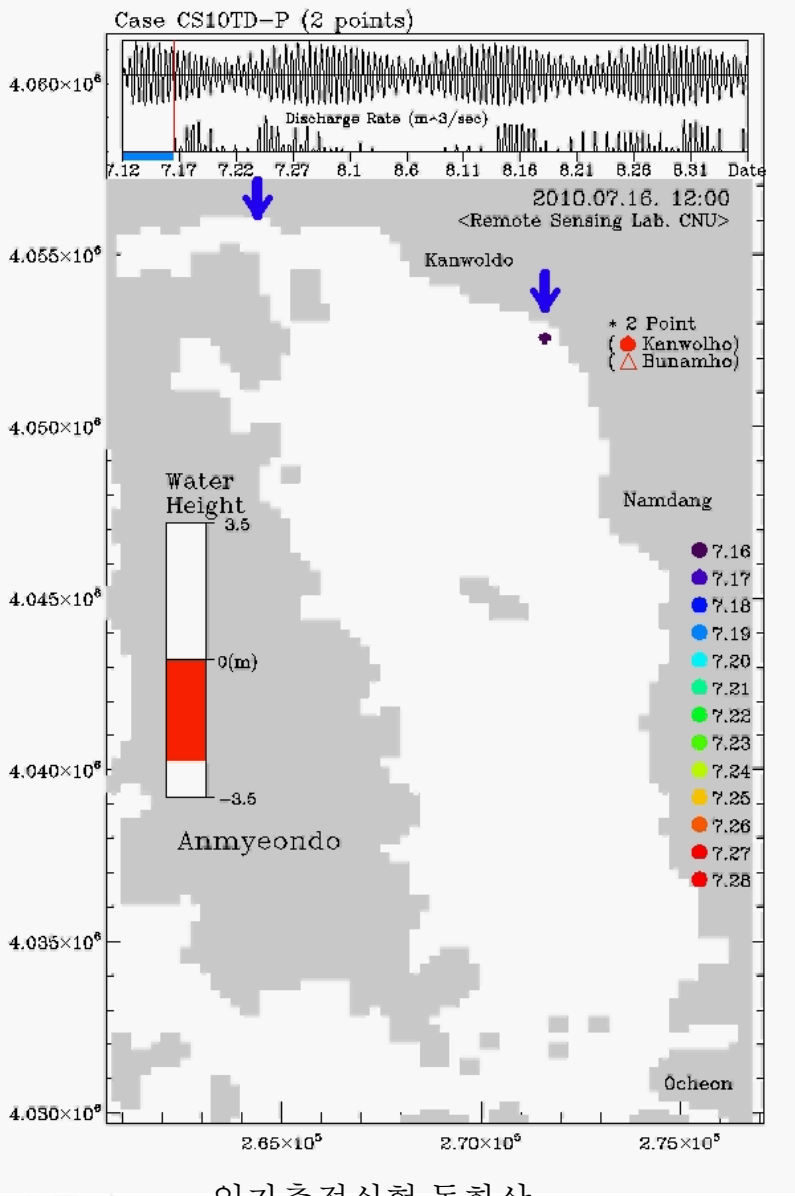
Salinity Change



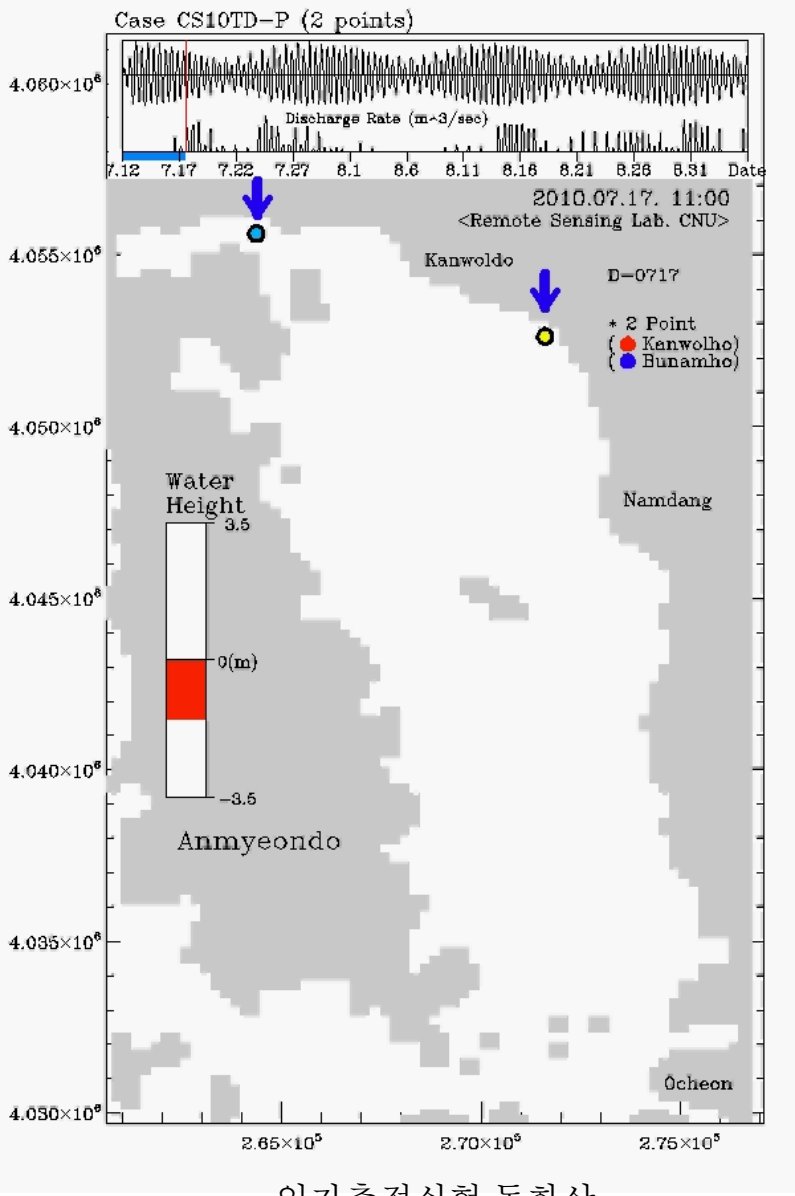
Particle Trtajectory



Model Result – Particle Tracking Exp.



입자추적실험 동화상



입자추적실험 동화상

Summary-1 : Field Observation

Obs. Results of WQ parameters in the Chunsu Bay

(1) Strong Stratification formed due to Dam Water Discharge

- Salinity drop by 13.9 psu
- Region of Influence down to the middle part of Chunsu Bay
  (5 psu difference between surface and intermediate layer)

(2) Hypoxia Formation : Jul. 26, 2010 / Aug.3,2011

- Raipd decrease of DO Conc. toward the Dam in the north
- Observed Hypoxia with 1~2 m thickness under 3 ppm at Bottom

(3) Increase of Chlorophyll in the surface layer

- Max. 57 μg/L Cha,
- Saturation DO: 120~160 %

ADCP measurement

- Residual current to the North
- Good agreement between Dam water discharge record and southward residual Current

Summary-2 Model Exp.

Circulation Modeling Exp.

- **(1) Tide Model**

  - Entrance: 2~4 m/sec strong tidal current
  - S. Jukdo~Entrance: moderate 0.5~1 m/sec
  - Kanwol/Bunam: weak current with 0.2~0.5 m/sec

(2) Tide+Discharge Exp.

- **SSS 2~15 psu Drop**
- **Bottom Salinity 1~3 psu** drop
- Change of circulation due to density driven current

(3) Particle Trajectory

- Kanwol Lake: realistic trajectory reproduced

10 day reached mouth of the CS Bay

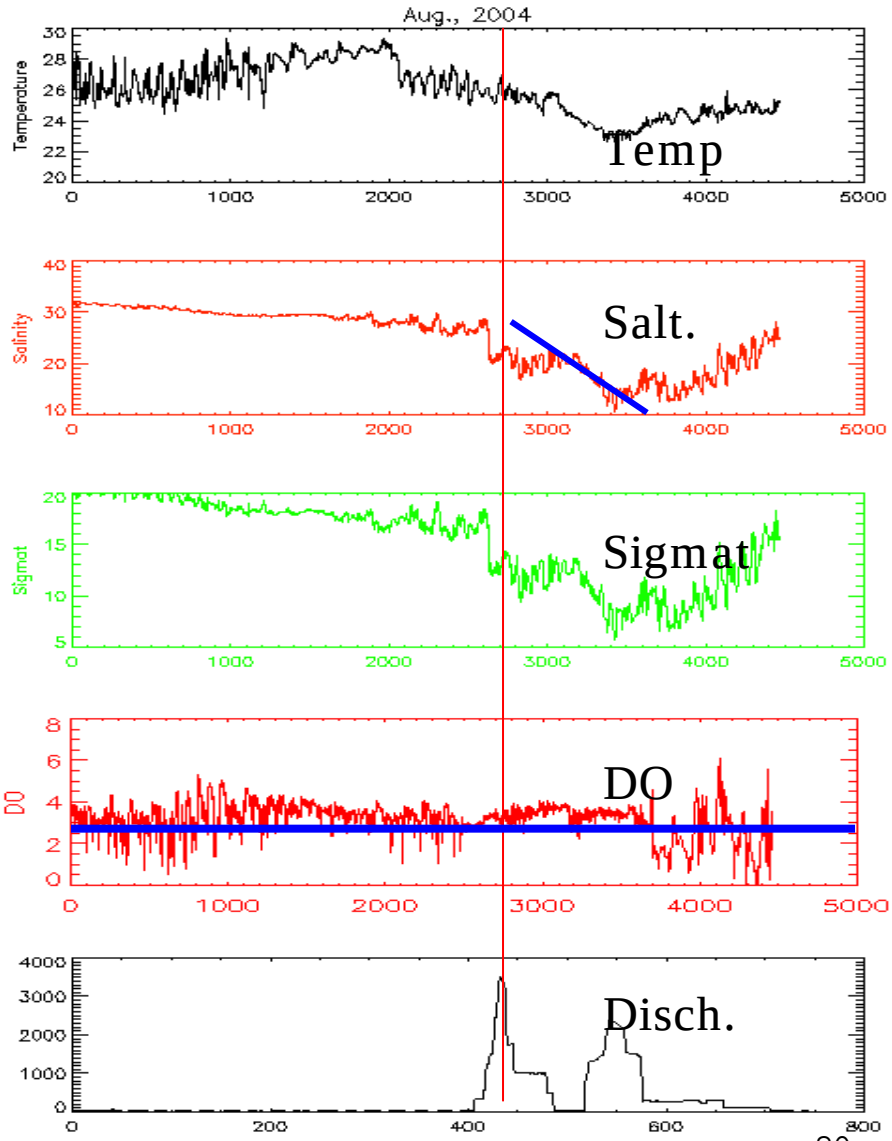
- Bunam Lake: 4~5 days to Jukdo Island

10 day reached mouth of the CS Bay

Hypoxia in the Kangjin Bay

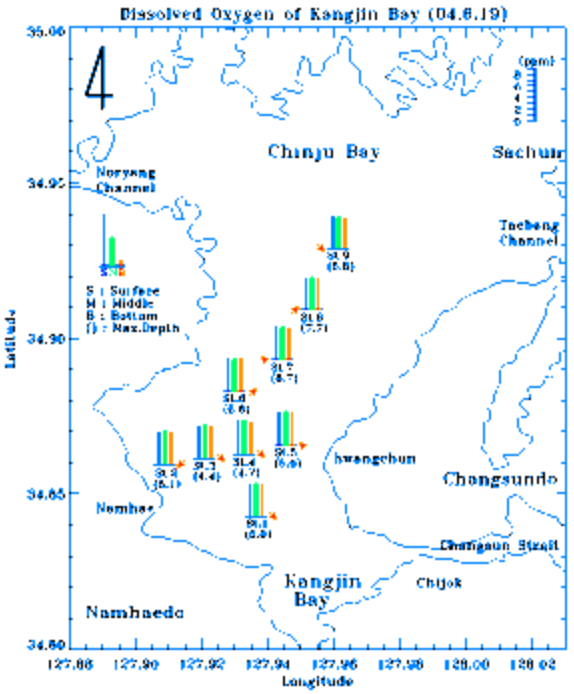
Time Series in Aug., 2004

- Start at 04/08/17 23:37 296.4 (cms)
- Peak at 04/08/19 01:38 3523.4 (cms)
- Ends at 04-08-30 11 37.03 49.0
- Total
  - Period ; 12 days 12 hours
  - Volume ; 830,176,000 ton (0.83 billion ton)
- Salinity Minimum occurred
  - on 8/24/04 19:17 (5 days and 17 hours later)
  - Salt = 10.63 (psu)
  - Temp= 22.66 do=6.22

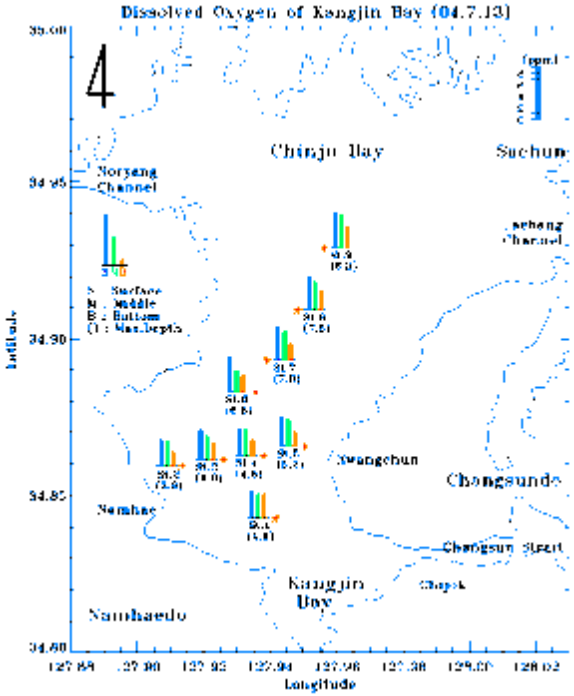


Vertical Profile of DO

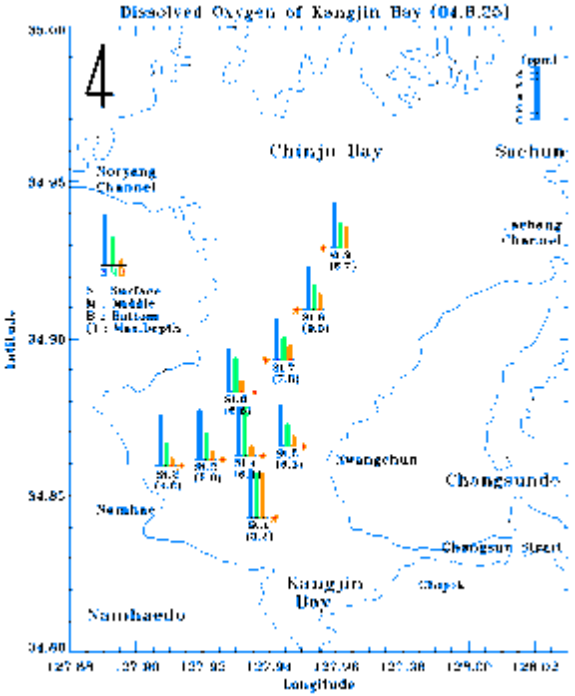
June, 2004



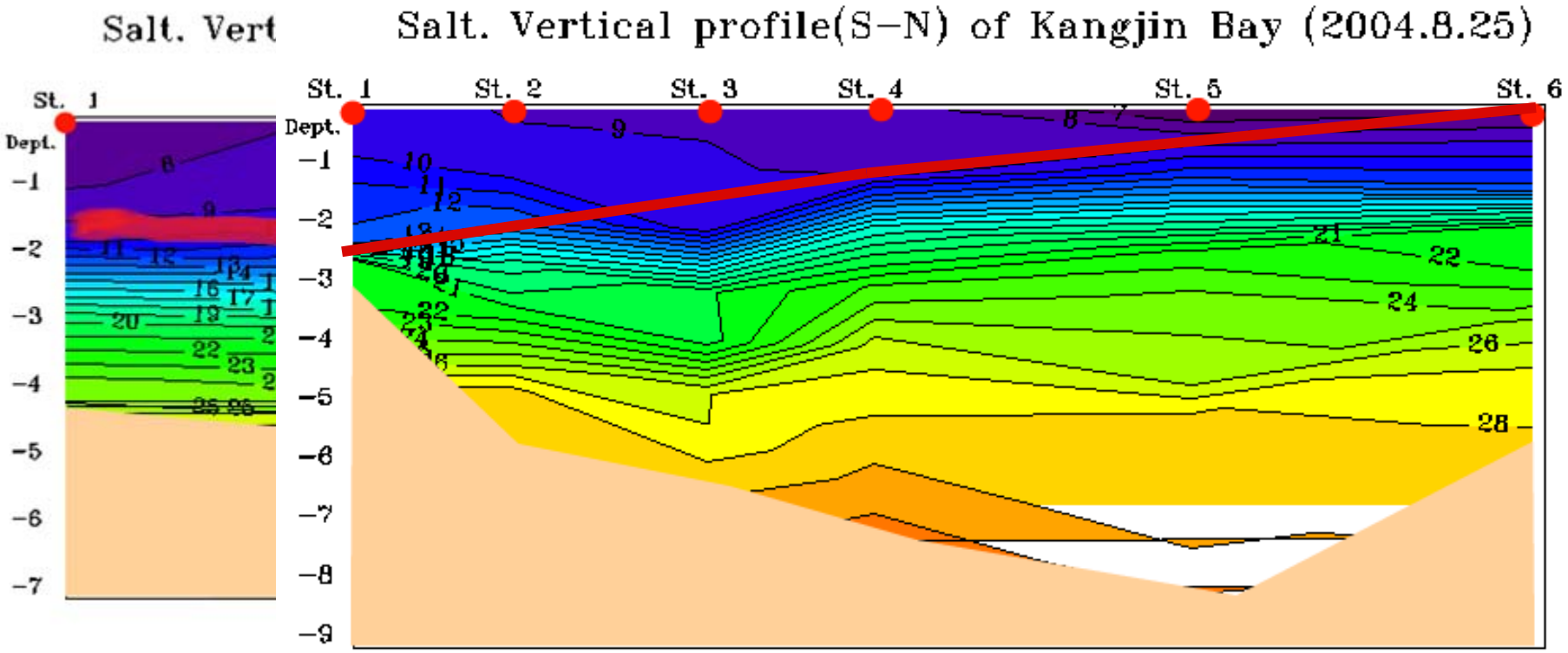
July, 2004



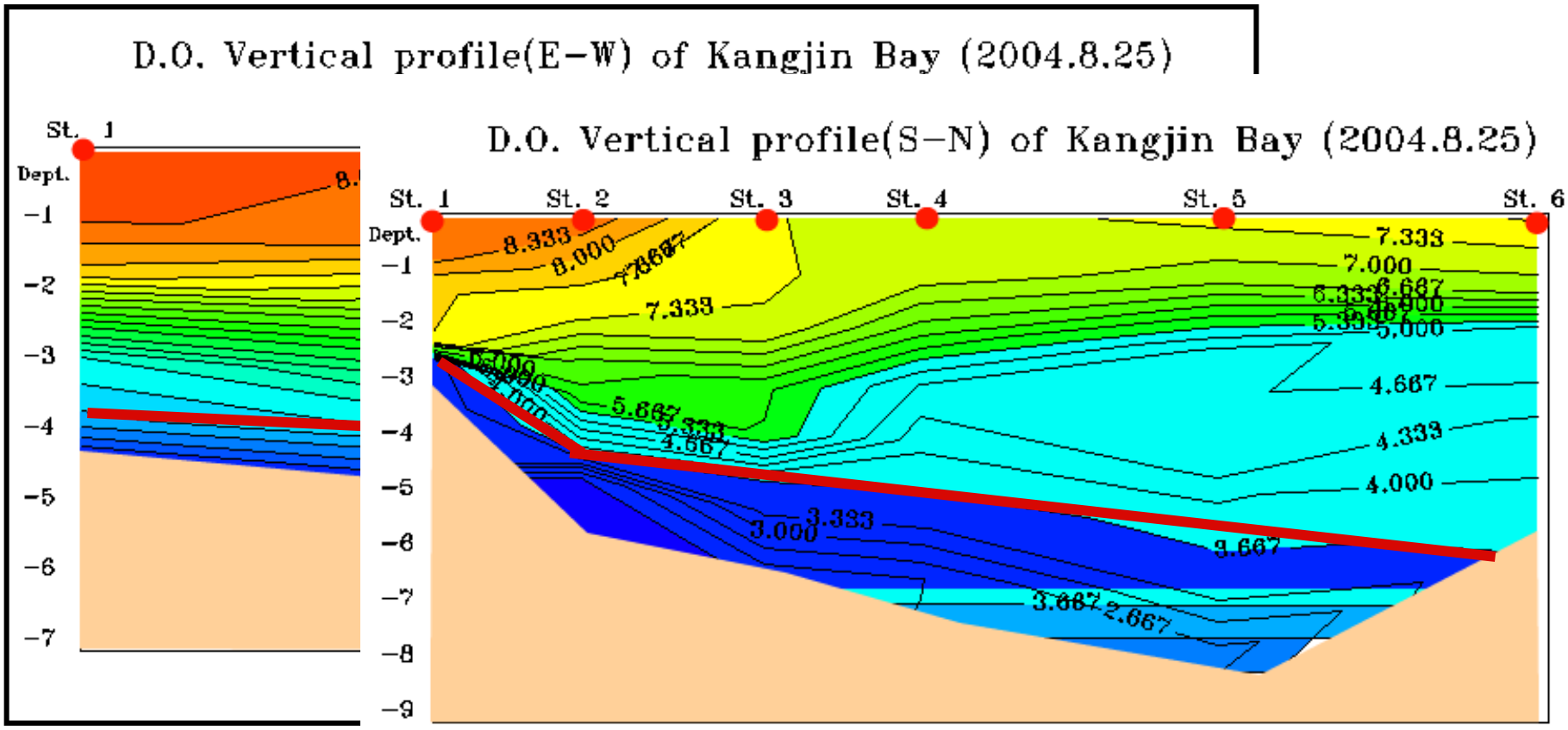
Aug., 2004



Cross sectional distri. of Salinity



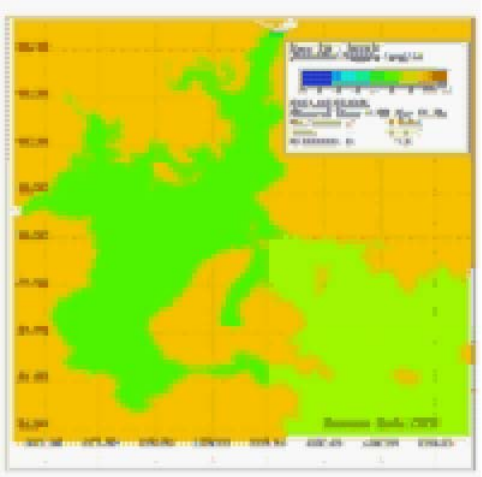
DO Cross Section in Summer, 2004

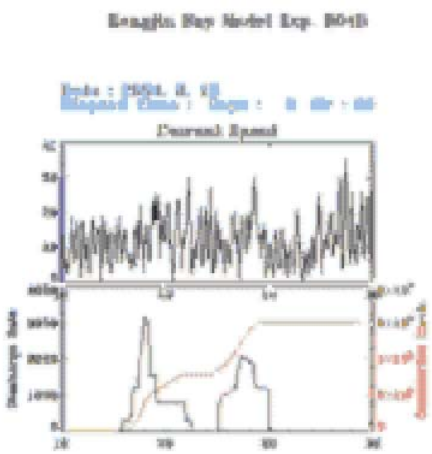


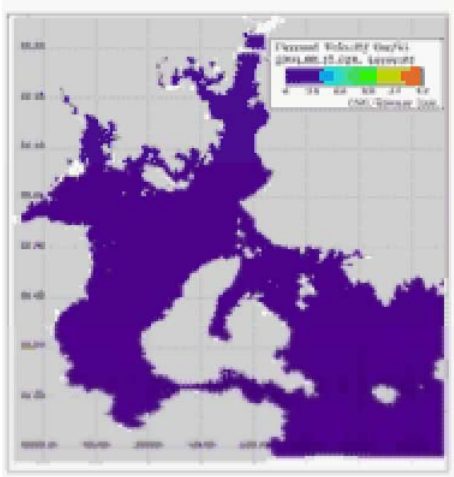
Hypoxic Events after Fresh Dam Water Discharge

DO & Salinity Change Animation

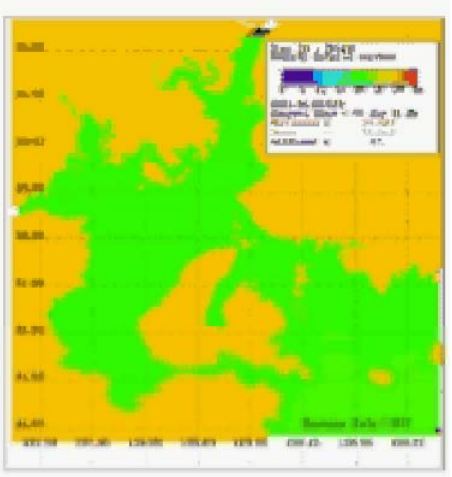
Dissolved Oxygen







Salinity



Implication to Ecosystem

- Physical Conditions
  - Water circulation by Tide
  - Fresh Water and nutrients Supply
  - Eutrophication vs Flushing of the Bay Water
  - Stratification and Strong Pycnocline
  - Oxygen Production vs Consumption
  - Hypoxia Formation
- Health of the Ecosystem
  - Dramatical Change in Salt, DO, etc
  - Large Mortality of Clam-shell (Scaborcha Brouhtonii)
  - Fishery Collapse

➢Tolerance for the dam water discharge

➢Smart Way to Release

➢How much water can be discharged without causing Hypoxia and Clam-Shell Fishery Collapse?

Thank you for Your Attentions !