平成20年度　第2回テクノフォーラム

環境アセスメントと大気・水災害予測

－地域環境シミュレーターの実用化に関する産学連携研究－

中国•三峡ダムの環境影響評価
Environment Impacts Assessment (EIA) of Three Gorges Dam (TGD), China

広島大学大学院国際協力研究科

(IDEC, Hiroshima University)

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- Modeling of hydrological and oceanic process
  - Preliminary results

Yangtze River and Three Gorges Dam

- Yangtze (Yangzi;揚子; Chang) Jiang
- The longest river (6,380km) in China and Asia, and the third-longest in the world after Nile and Amazon River

Three Gorges Dam(三峡ダム)

22,500MW
(Dec.1994 ~ 2009/2011)

Impacts of Three Gorges Dam

Environmental contribution of TGD (Positive?)

- **Direct reduction of air pollutant and greenhouse gas emission**

According to The National Development and Reform Commission of China, it takes 366 grams of coal to generate 1 kWh of electricity in China(2006).[1] Therefore, the TGD will potentially reduce the coal consumption by 31 million tonnes per year, cutting the emission of 100 million tonnes of greenhouse gas,[2] millions of tonnes of dust, 1 million tonnes of sulfur dioxide, 370 thousand tonnes of nitric oxide, 10 thousand tonnes of carbon monoxide and a significant amount of mercury into the atmosphere.[3] The elimination of the fossil fuel also reduces the energy consumption in mining, washing and transporting about 31 million tonnes of coal from northern China to the load centre in south and east China.

Since the dam started generating power on July 10, 2003, total power production is equivalent to 84 million tonnes of standard coal and reduces carbon dioxide emission by 190 million tonnes, sulfur dioxide by 2.29 million tonnes and nitroxides by 980,000 tonnes.[4]

- **Reduction of greenhouse gas due to navigation**

From 2004 to 2007 there were total of 198 million tonnes of goods passed through the Three Gorges Dam ship locks. The freight capacity of the river increased 6 times and the cost of shipping reduced by 25%, compared to previous years, which reduces carbon dioxide emission by 630,000 tonnes. Comparing to highway transportation, the amount of fuel that Three Gorges Dam project saved between the year of 2004 and 2007 is equivalent to 4,100,000 tonnes of standard coal. Thus it reduces carbon dioxide emission by 10 million tonnes.[4]

- **Waste management**

  Since the construction of the Three Gorges Dam, many waste water treatment plants have been completed to reduce the water pollution from the large populated city Chongqing and the suburban area around it. According to the ministry of environmental protection of PRC, until April 2007, there were more than 50 waste water treatment plants installed and the total capacity reached 1.84 million tonnes per day. More than 65% of the waste water is treated before being dumped into the Three Gorges Dam reservoir. About 32 land sites deposit were completed and could handle 7664.5 tonne of solid waste every day.[5][6]

- **Reforestation**

  The Three Gorges Dam pushes the Chinese government to think seriously about the environmental issues associated with the dam, such as deforestation and water pollution. “The FAO’s research suggests that the Asia-Pacific region will, overall, gain about 6,000 square km of forest in 2008. That is quite a turnaround from the 13,000 square km net loss of forest each year in the 1990s. The main reason is China’s huge reforestation effort. This accelerated after terrible floods in 1998 convinced the government that it must restore tree cover, especially in the mighty Yangtze’s basin” upstream of the Three Gorges Dam.[7]

Impacts of Three Gorges Dam

- ## Environmental impact

Environmental issues with the TGD, which is currently under construction on Yangtze River, include degraded water quality, detriments to wildlife, potential riverbank collapses, and potential silt related falling of coastal areas.

Currently, the quality of water in the higher banks of Yangtze is slowly worsening, due to the dam's preventing dispersal of pollutants; algal blooms have risen progressively since the dam's construction; and soil erosion has increased, causing riverbank collapses and landslides.[8] The report detailing this was officially released in September 2007.[9] Senior Chinese government officials and scholars said the dam could cause a "huge disaster ... if steps are not taken promptly."[8] The same scholars and officials previously had defended the Three Gorges Dam project.[10] However, the Chinese embassy in the United States has firmly promoted it.[11] Xinhua News Agency also reported that tens of billions of yuan had been spent to prevent pollution and geological disasters by tree planting, measures to maintain biodiversity, shutting 1500 polluting industrial and mining enterprises and building 70sewage and waste treatment plants, all of which are "progressing well."[10]

Of the 3,000 to 4,000 remaining critically endangered Siberian Crane, a large number currently spend the winter in wetlands that will be destroyed by the Three Gorges Dam.[12] The dam contributed to the functional extinction of the Baiji Yangtze river dolphin. Though it was close to this level even at the start of construction, the dam further decreased its habitat and increased ship travel, which are among the factors causing what will be its ultimate demise. In addition, populations of theYangtze sturgeon are guaranteed to be "negatively affected" by the dam.[13]

While logging in the area was required for construction which adds to erosion, stopping the periodic and uncontrolled flooding of the river will lessen bank erosion in the long run. The build up of silt in the reservoir will, however, reduce the amount of silt transported by the Yangtze River to the Yangtze Delta and could reduce the effectiveness of the dam for electricity generation and, perhaps more importantly, the lack of silt deposited in the peninsula could result in erosion and sinking of coastal areas.[14]

- ## Effect on local culture and aesthetic values

The 600 kilometer (375 mi) long reservoir has or will flood some 1,300 archaeological sites and alter the appearance of the Three Gorges as the water level rises over one hundred meters at various locations.[16] Cultural and historical relics are being moved to higher ground as they are discovered but the flooding of the Gorge will undoubtedly cover some undiscovered relics. Some other sites cannot be moved because of their location, size or design. For example the hanging coffins site high in the Shen Nong Gorge is inherently part of the sheer cliffs themselves.[17]

- ## Sedimentation

There are two hazards uniquely identified with the dam.[18] One is that sedimentation projections are not agreed upon, and the other is that the dam sits on a seismic fault.

The Three Gorges area currently has 10% forestation, down from 20% in the 1950s. At current levels 80% of the land in the area is experiencing erosion causing about 40 million tons of sediment to slide into the Yangtze annually.[15] The relocation of people from the reservoir area will cause further deforestation and erosion due to agricultural needs.

Excessive sedimentation can block the sluice gates which can cause dam failure under some conditions. This was a contributing cause of the Banqiao Dam failure in 1975 that precipitated the failure of 61 other dams and resulted in over 20,000 deaths. Critics believe that the Yangtze will add 530 million tons of silt into the reservoir on average per year; in time, this silt could accumulate behind the walls of the dam, clogging the turbines' entranceway. However, because China has began constructing four other megadams (see below) on the upstream of Yangtze since 2006, the sedimentation from upstream would be much less than originally predicted. But the absence of silt down stream would still have two dramatic effects:

Some hydrologists think that this could make downstream riverbanks more vulnerable to flooding.

The city of Shanghai, more than one thousand miles (1600 km) away from the dam, rests on a massive plain of sediment. The *"arriving silt -- so long as it does arrive -- strengthens the bed on which Shanghai is built... the less the tonnage of arriving sediment the more vulnerable is this biggest of Chinese cities to inundation..."*[19]

The Benthic sediment build up is a cause of biological damage and reduction in aquatic biodiversity.[20]

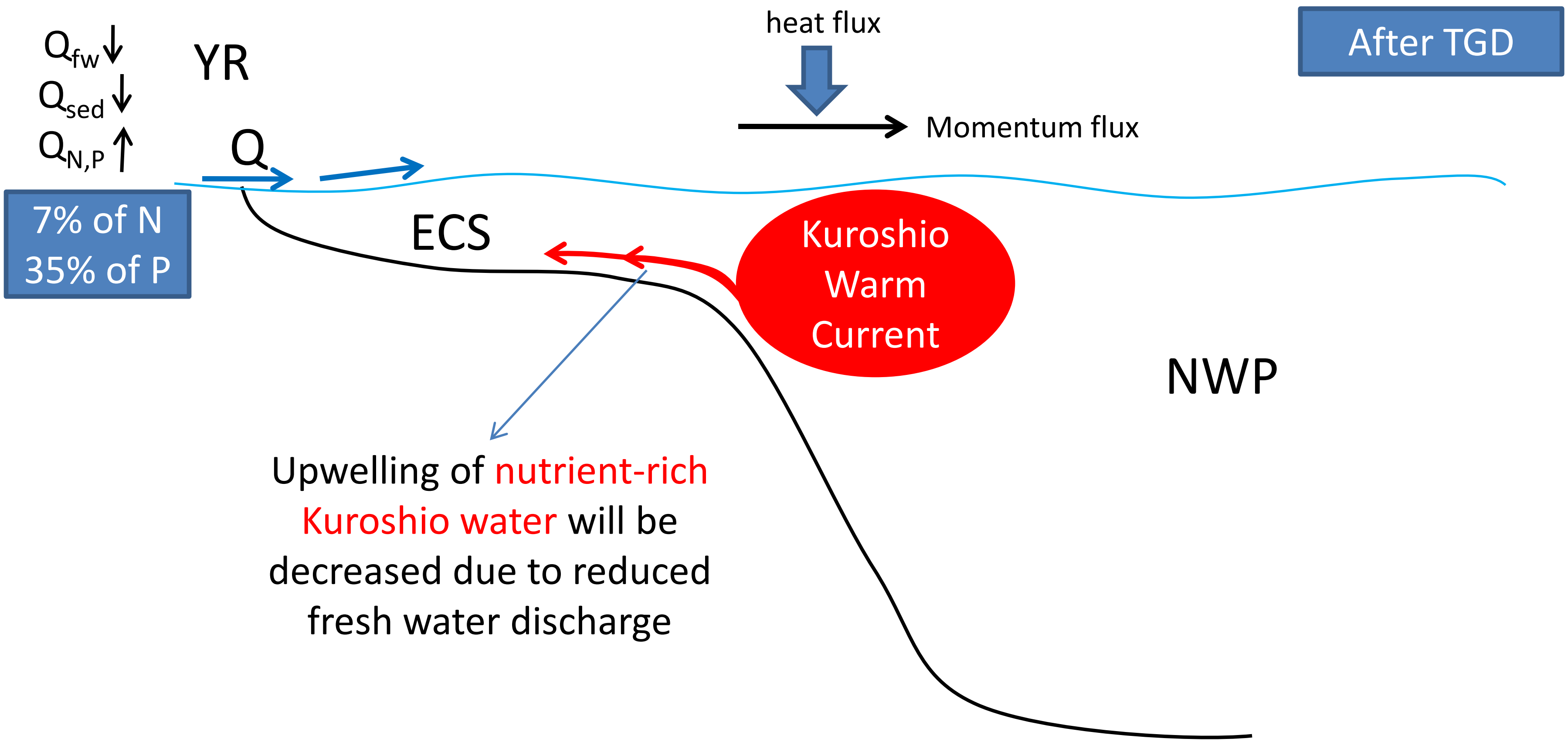
- ## National Security Concerns

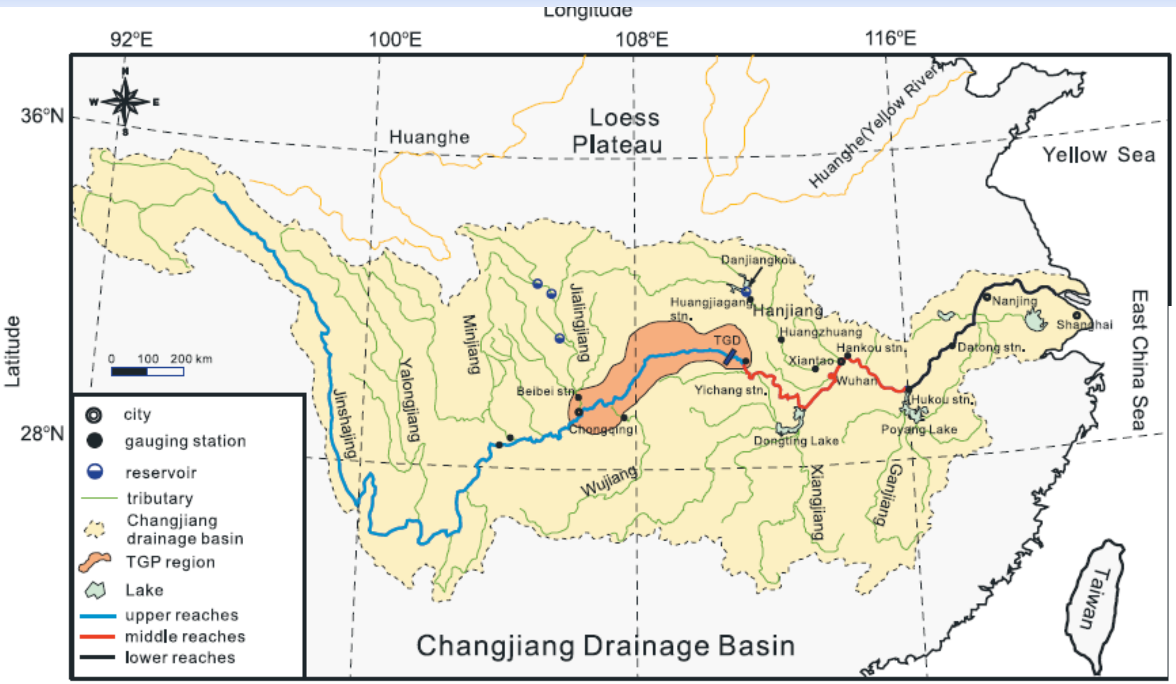
In an annual report to the United States Congress, the Department of Defense cited that in Taiwan, “proponents of strikes against the mainland apparently hope that merely presenting credible threats to China’s urban population or high-value targets, such as the Three Gorges Dam, will deter Chinese military coercion.”[21]

The notion that the Military of the Republic of China would seek to destroy the Dam provoked an angry response from the mainland China media. People’s Liberation Army General Liu Yuan was quoted in the *China Youth Daily* saying that the People’s Republic of China would be "seriously on guard against threats from Taiwan independence terrorists".[22]

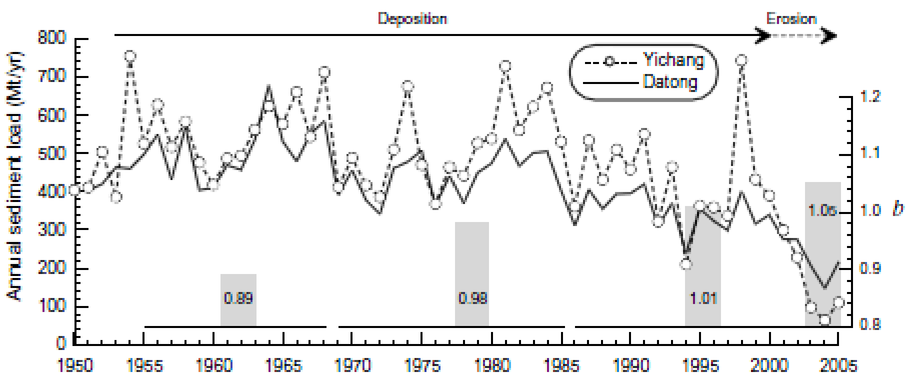
Impacts of TGD on the neighboring seas and river mouth, deltas

- Reducing the upwelling and thus productivity in the East China Sea (A. Chen, 2000)





Historical changes of Sediment flux



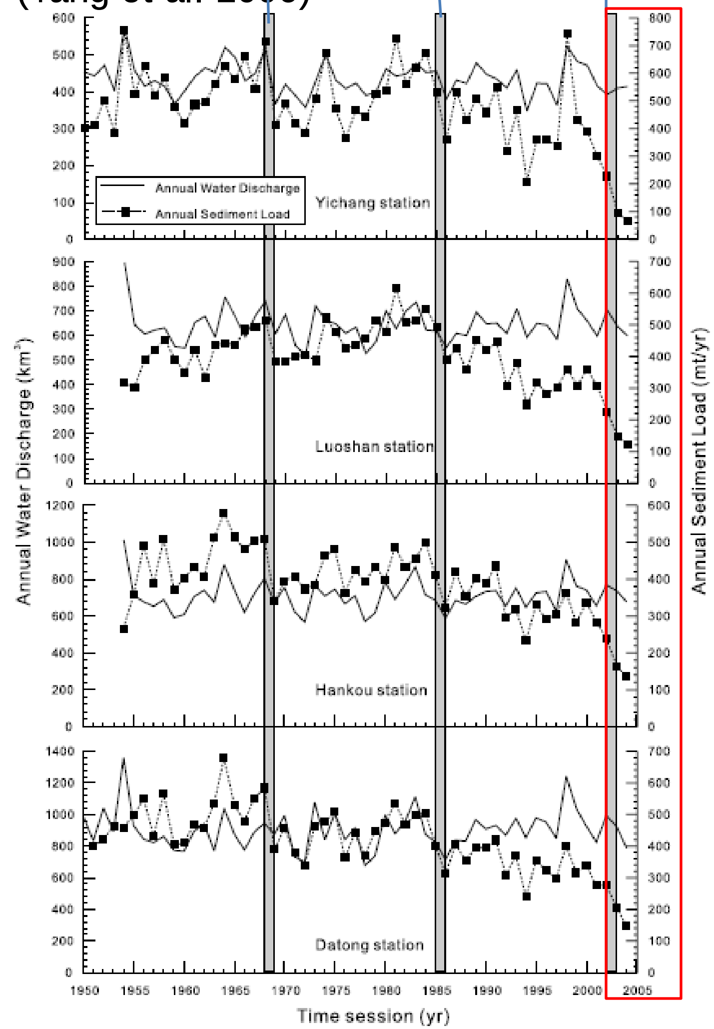
Annual sediment load at Yichang and Datong
(H. Wang et al. 2008)

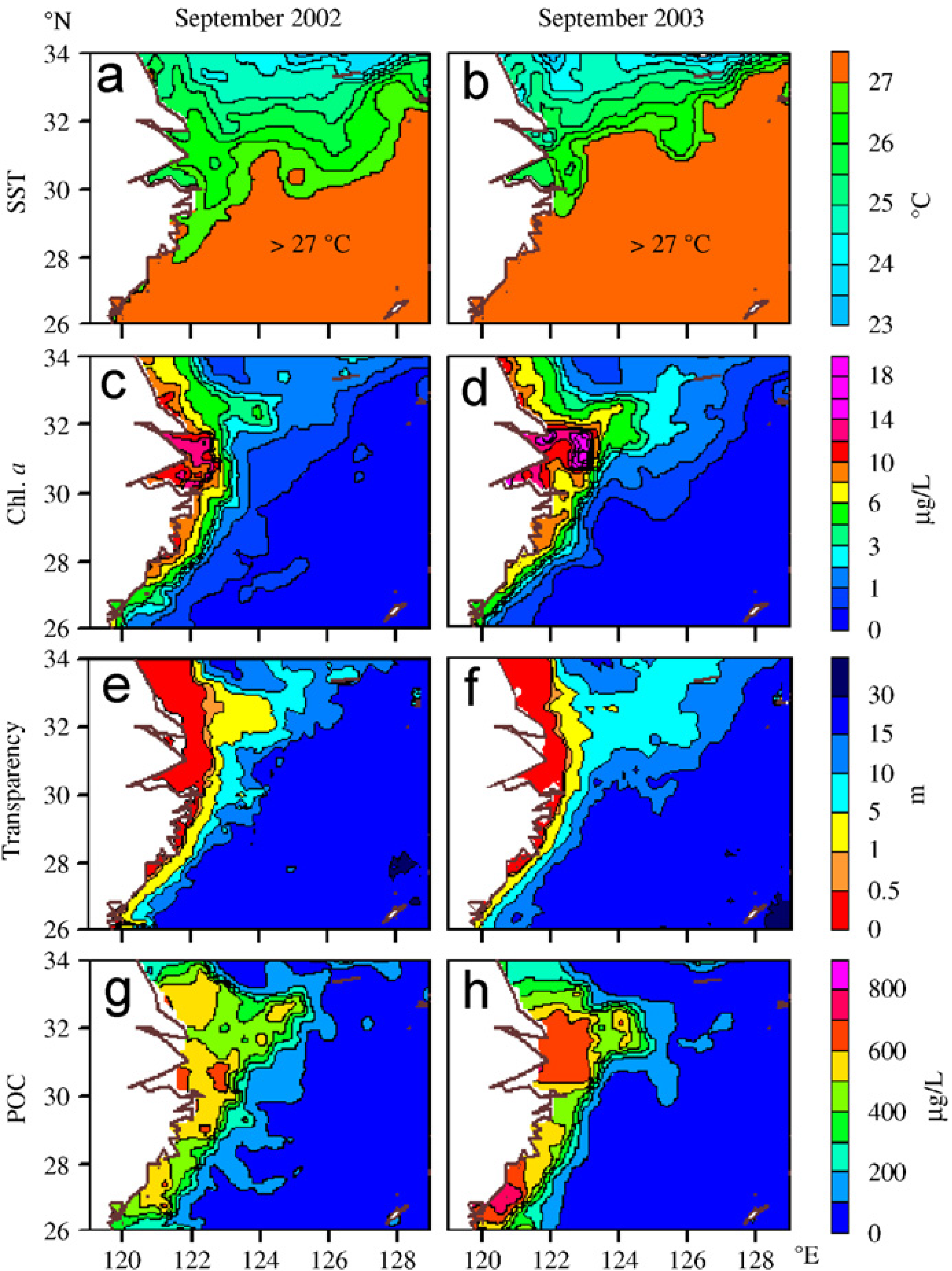
Completion of the Danjiangkou Reservoir in 1968

Soil conservation works in the upper reaches since 1980s

Operation of the Three Gorges Dam since 2003

(Yang et al. 2006)





Remote-sensing (MODIS and SeaWiFS) data-derived distribution patterns of
SST (a, b),
Chl. a (c, d),
transparency (e, f), and
POC (particulate organic carbon) (g, h)
in the
East China Sea
(left column: September 2002; right column: September 2003).
(Jiao et al. 2007)

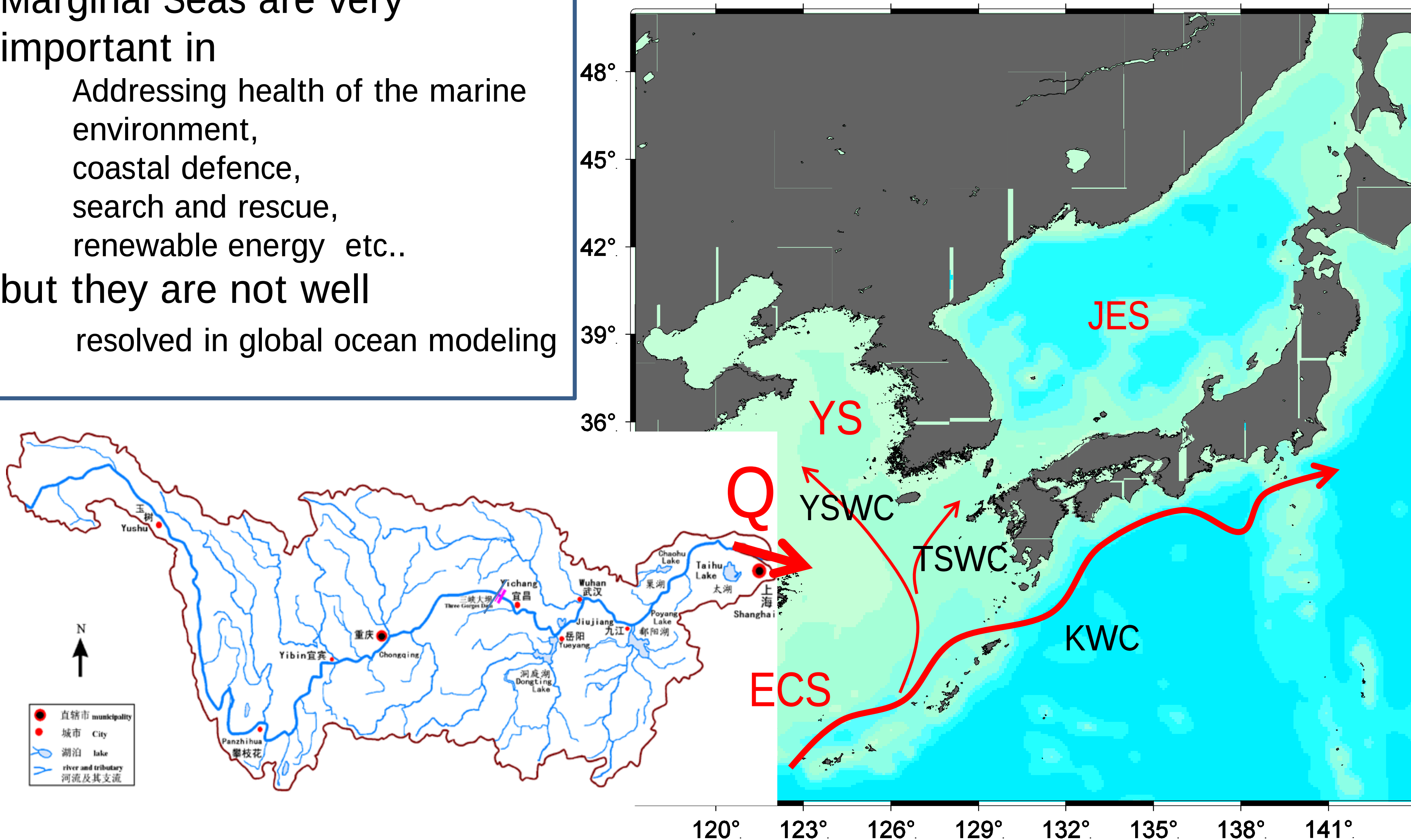
Objectives of this research

Marginal Seas are very important in

- Addressing health of the marine environment,
- coastal defence,
- search and rescue,
- renewable energy etc..

but they are not well

resolved in global ocean modeling



Numerical experiments of the TGD on

- Hydrological process in Yangtze River Basin
  - Fresh water, sediment and nutrients discharge

- Oceanic process in neighboring marginal seas
  - Influences of reduced fresh water, sediment discharge and increased nutrients on tracers such as T, S and ρ

Regional Environment Simulator (RES)

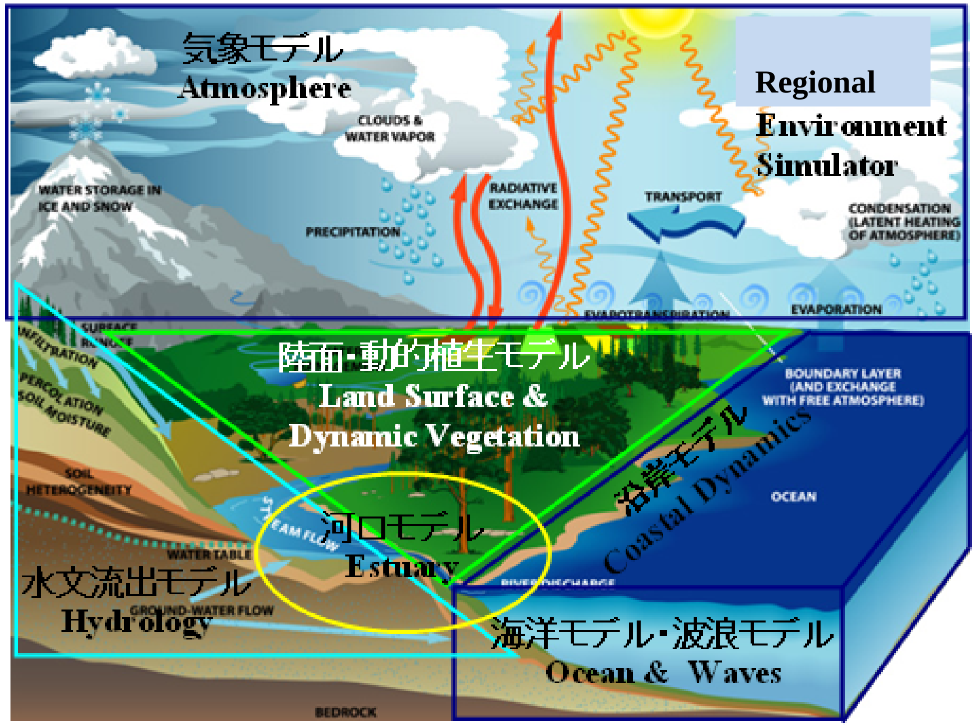
地球観測システム
Earth Observation System

Data assimilation ;
WINDAS,
QUICKSAT,
etc

RES

全球解析データ
Global Forecasting System

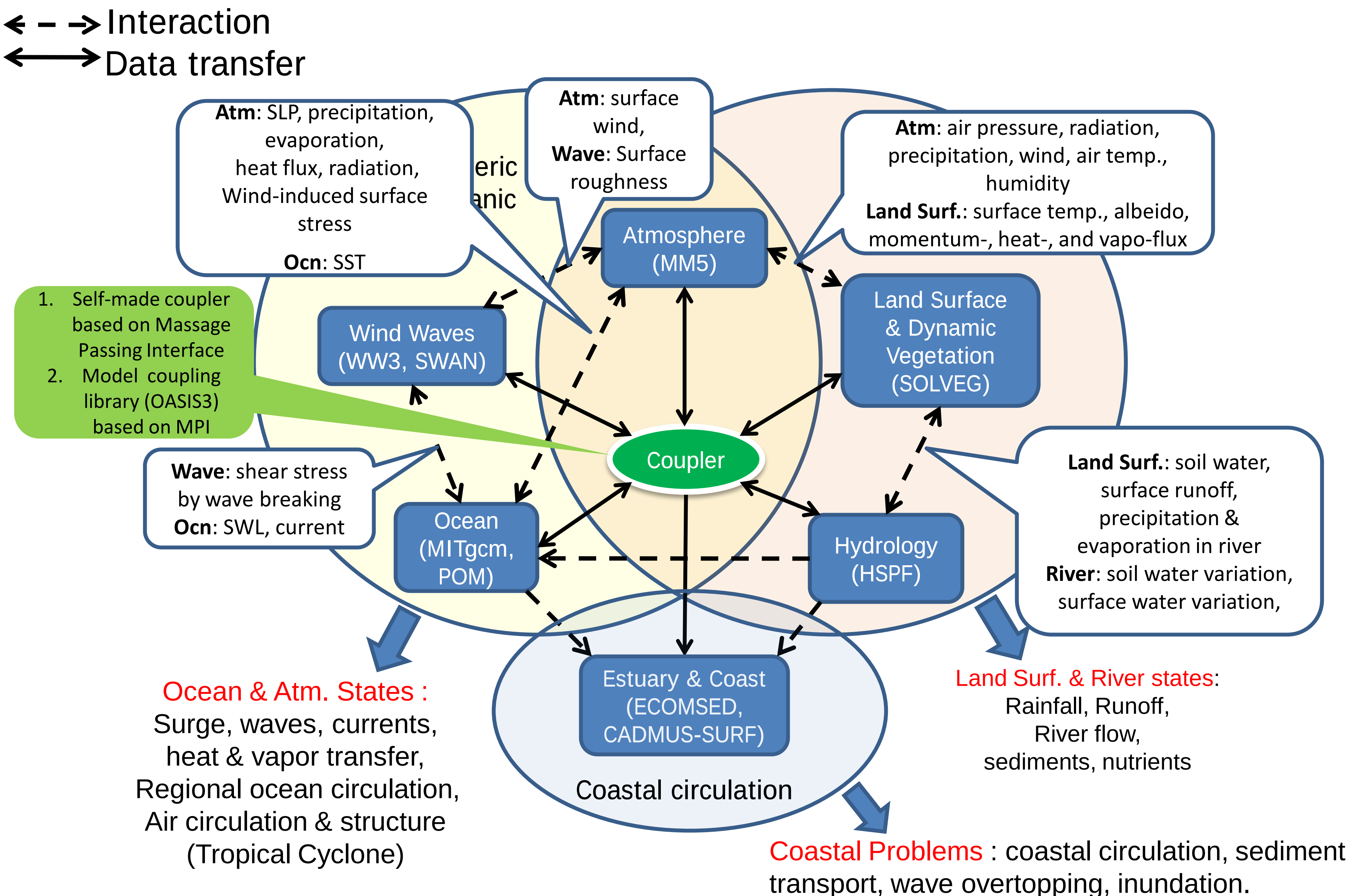
NCEP FNL from USA,
ECMWF ERA40 from EU,
JMA GPV from Japan,
etc.



RES : Water and heat circulation in environment in regional scale
→ Behaviour of Tracer gases and sediments in Environment

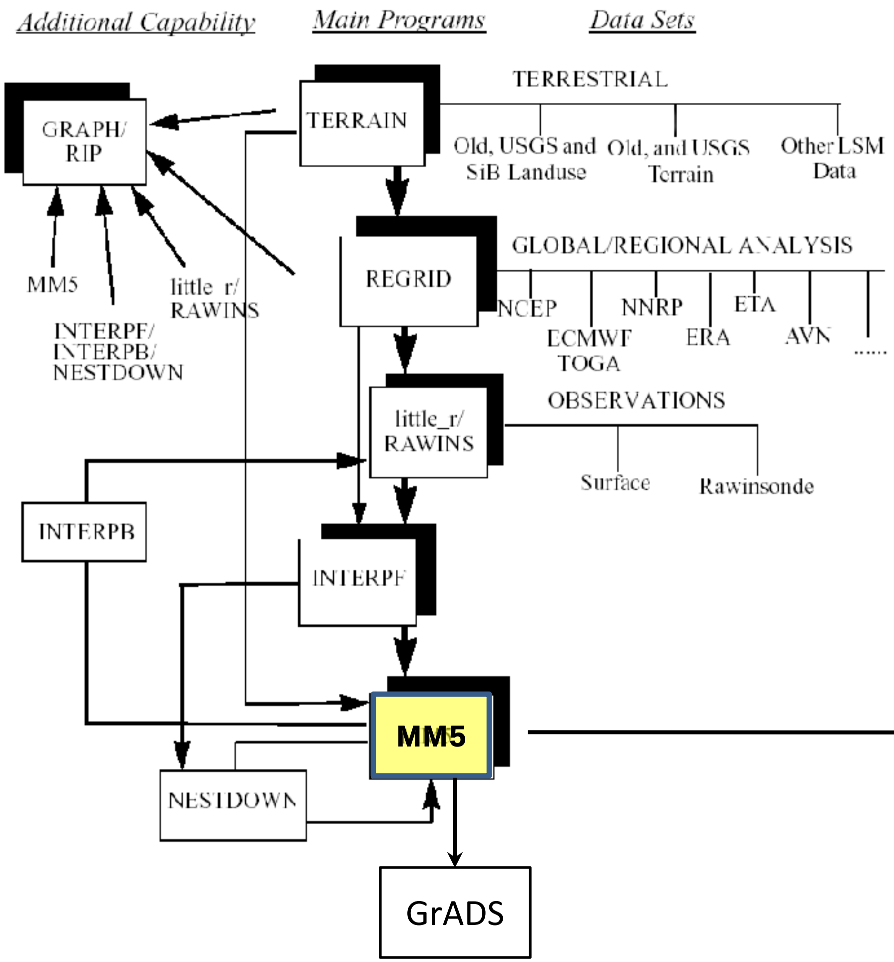
RES is a coupled system for computer simulations of Meteorology, Physical Oceanography, Land Surface Vegetation, Hydrology, Estuary and Coastal Dynamics and Urban Environment, which is mainly made use of natural environmental assessment against human activities. (Yamashita et al., 2007)

Component models and their interactions



MM5

3D non-hydrostatic meso-scale atmospheric circulation model
by Penn. State Univ. and
National Center for Atmospheric Research



Pre-processing

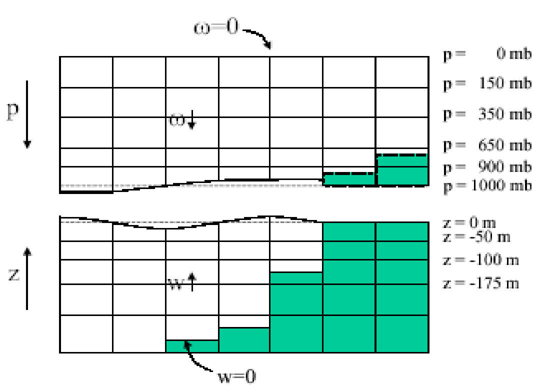
MM5

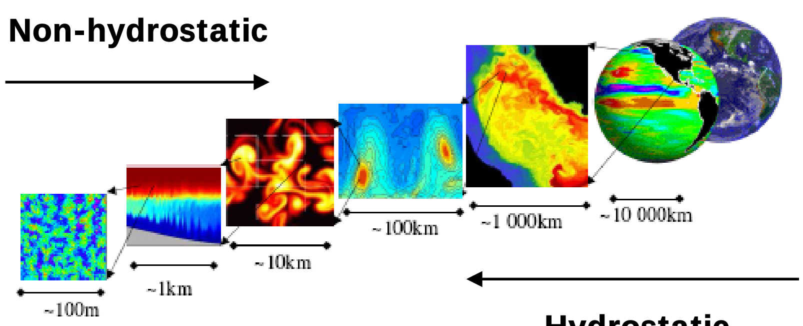
Physics parameterizations
- Cumulus scheme
- Microphysics
- PBL
- Atmospheric radiation

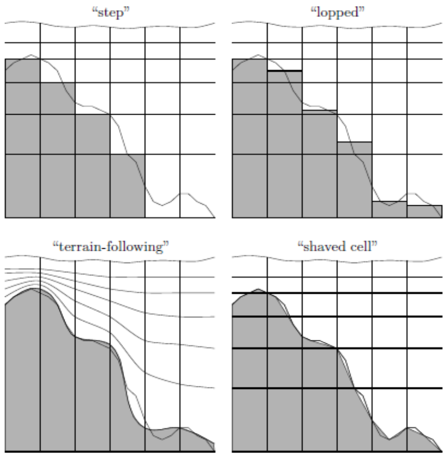
Post-processing;
Data analysis and visualization

MITgcm

- General Circulation Model developed at MIT
- Both atmospheric and oceanic circulation (incompressible N-S equations)
- Non-hydrostatic capability
- Horizontal orthogonal curvilinear coordinate
- Finite volume method for representing topography
- Wide range physical parameterization (Vertical mixing)
- Versatile computing using flexible domain decomposition





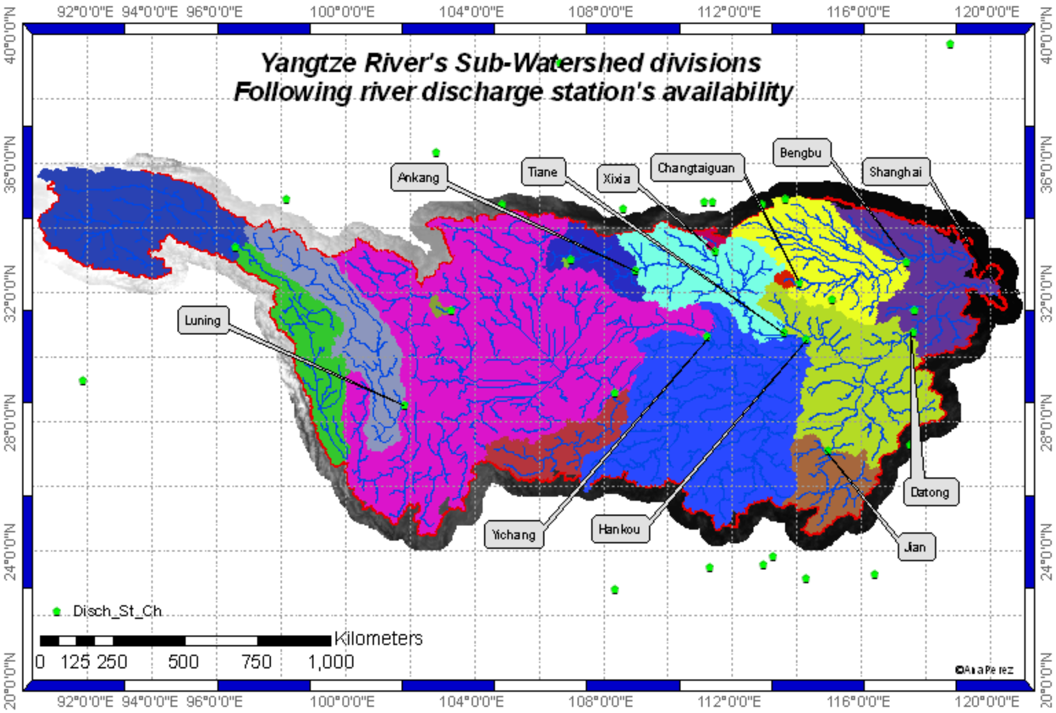


Hydrological Simulation Program Fortran (HSPF)

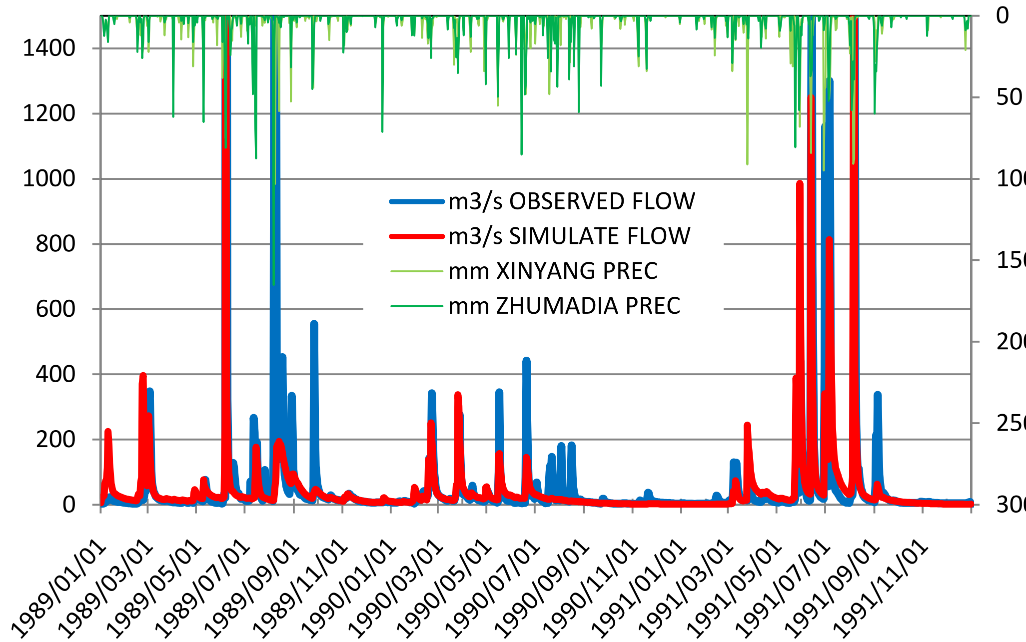
- HSPF is a continuous watershed simulation model design to reproduce water quantity and quality transformation processes occurring in a watershed. These processes include sediment transport and the movement of contaminants under the organic and inorganic effects as well as water discharge.

Modeling of hydrological process

- Meteorological conditions from MM5 simulation
  - Atmosphere temperature
  - Precipitation
- Modeling of hydrological process with HSPF
  - High resolution DEM : HydroSHEDS (3 arc second)
  - Updated land use : ALOS satellite
  - Observations of outflow, precipitation, temperature, sediments and water quality constituents for calibration process



Results of calibration processes for small watershed



Sub-watershed division by WMS

Modeling of oceanic process

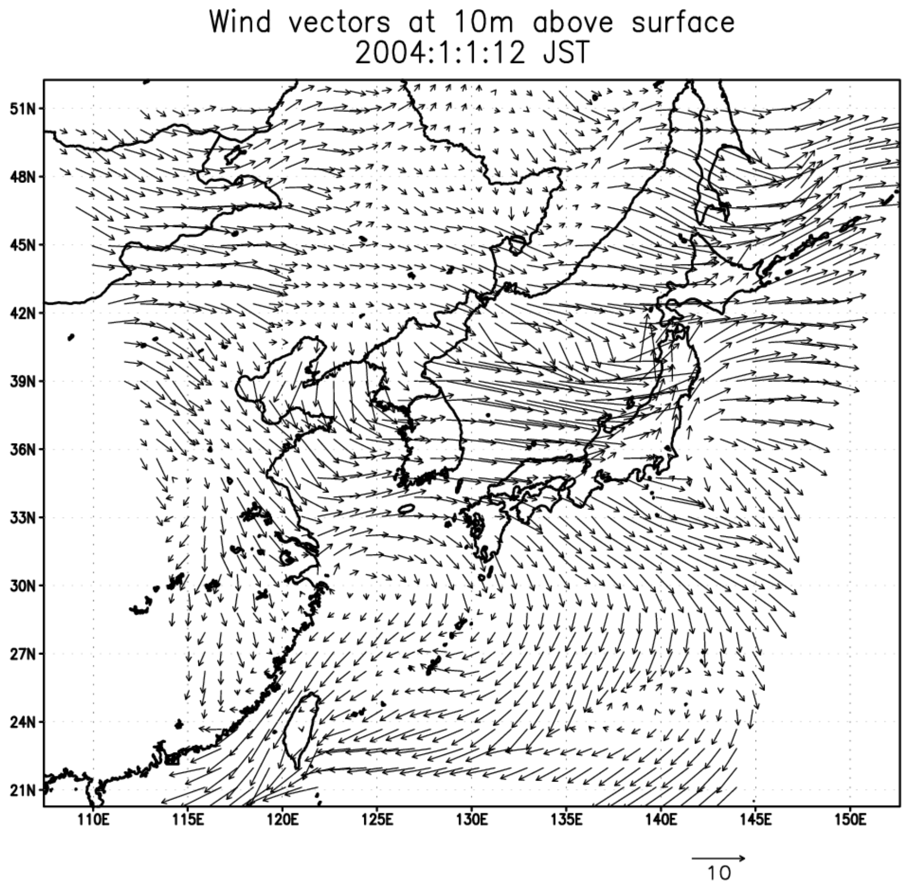
- Atmosphere modeling with MM5
  - Simulation period : Jan. 2004 (1 month)
  - Domain
  - Initial and boundary condition : NCEP FNL data
  - Physics parameterizations used :

    Mixed phase microphysics,

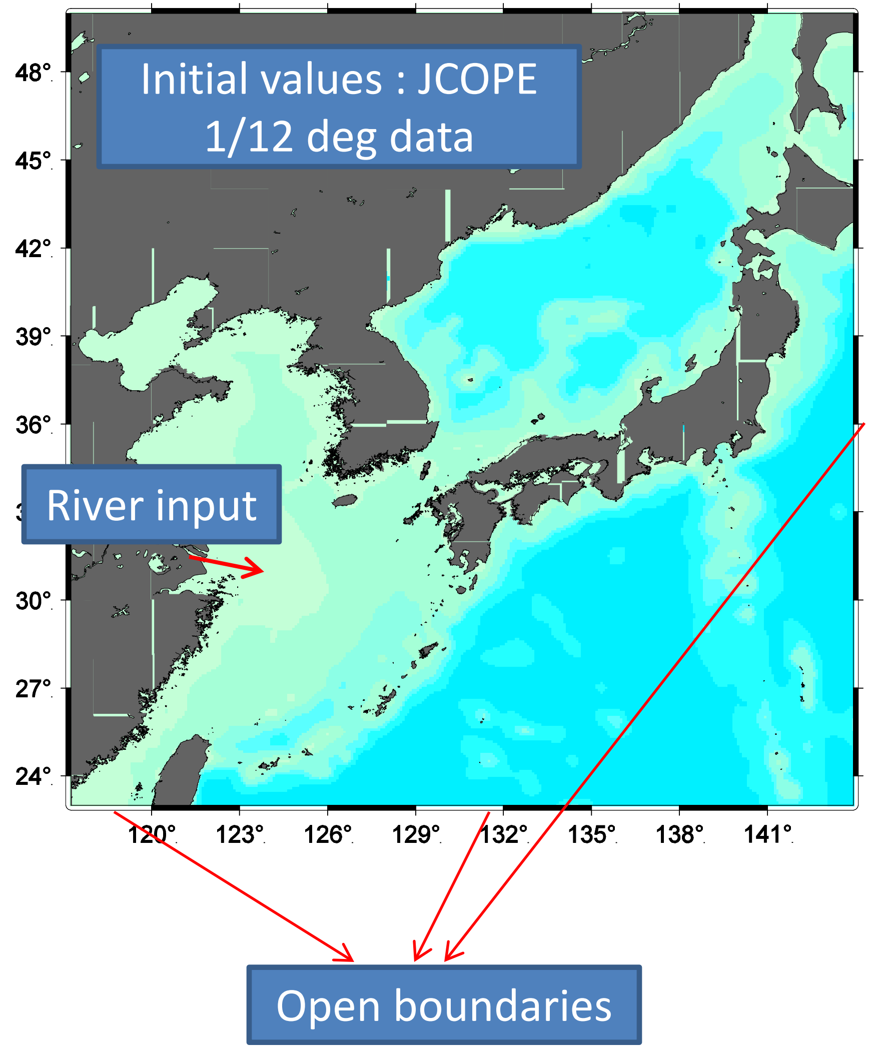
    Grell cumulus scheme,

    MRF PBL,

    Atmosphere radiation with cloud

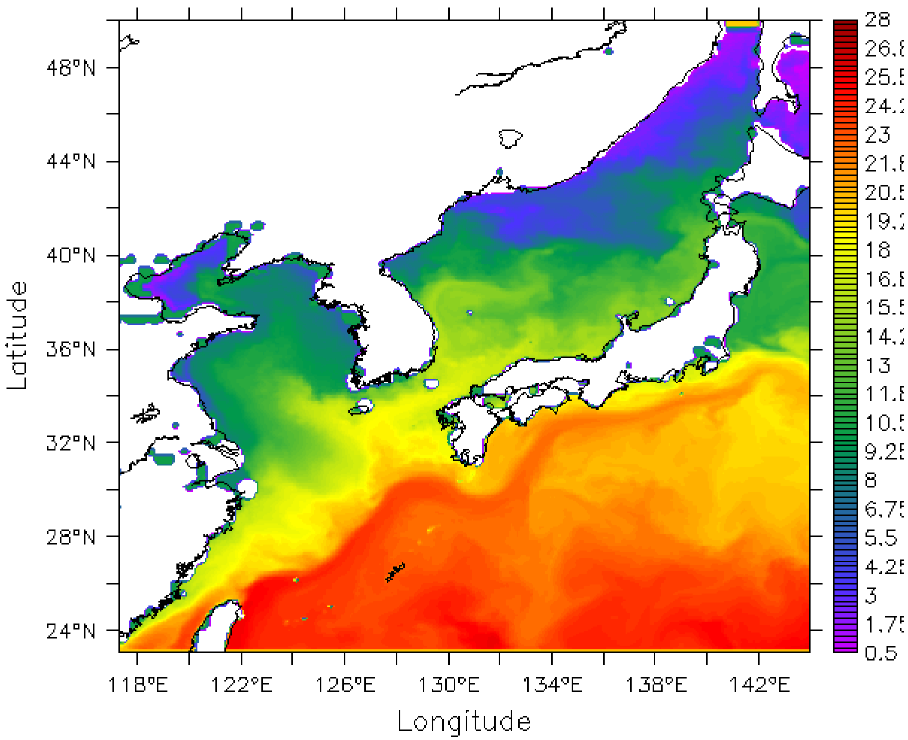


- Ocean modeling with MITgcm
  - Simulation domains and period
  - 321x325x50 (≃9km)
  - GEBCO 1-min bathymetry
  - No-slip bottom and
  - Free surface boundary condition
  - Surface forcing from MM5 (momentum and heat flux)
  - Initial and boundary conditions from JCOPE 1/12 deg data
  - No open boundary and river input → to be improved
  - MY(1982) turbulence model for vertical mixing and
  - Smagorinsky's nonlinear viscosity for lateral mixing

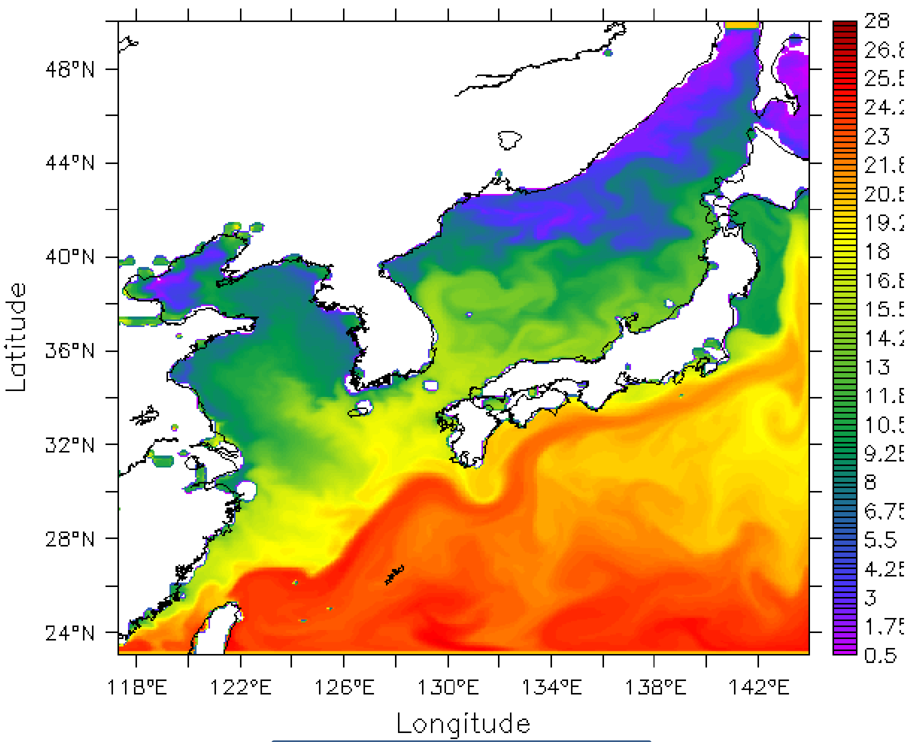


Preliminary results of ocean modeling

Sea surface temperature



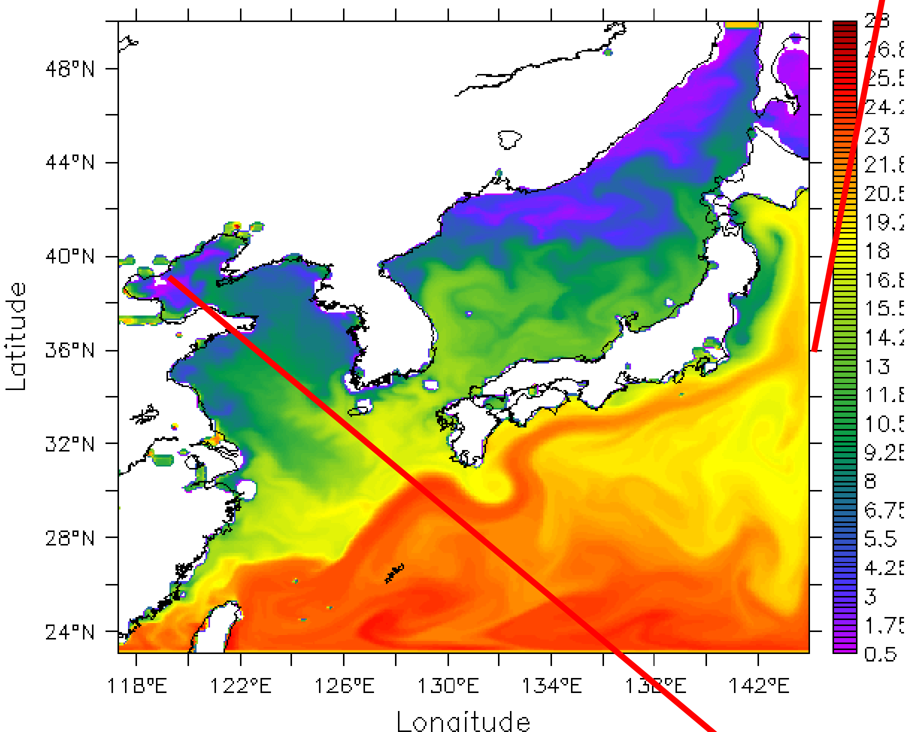
Jan.1.2004 00:00



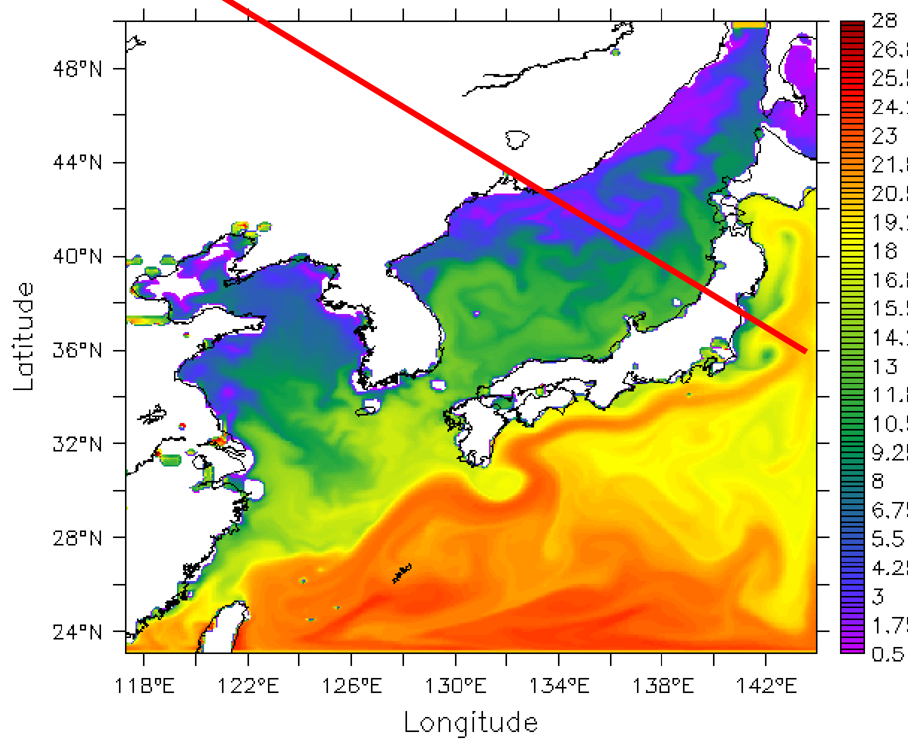
Jan.8.2004 00:00

Problem with boundaries

Sea surface temperature



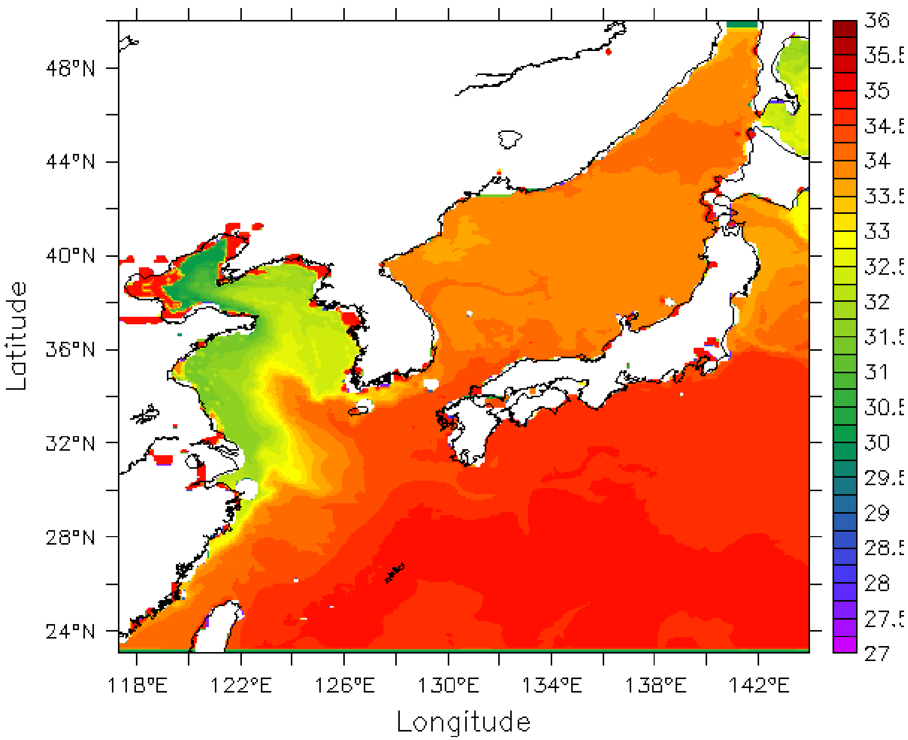
Jan.15.2004 00:00



Jan.22.2004 00:00

Initial value problem ?

Sea surface salinity



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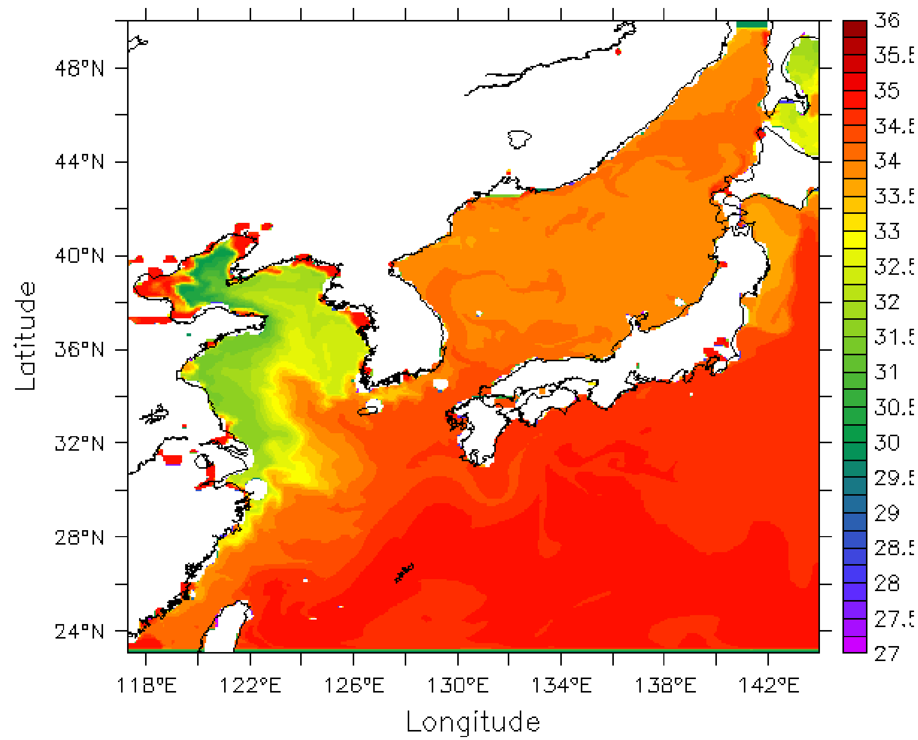

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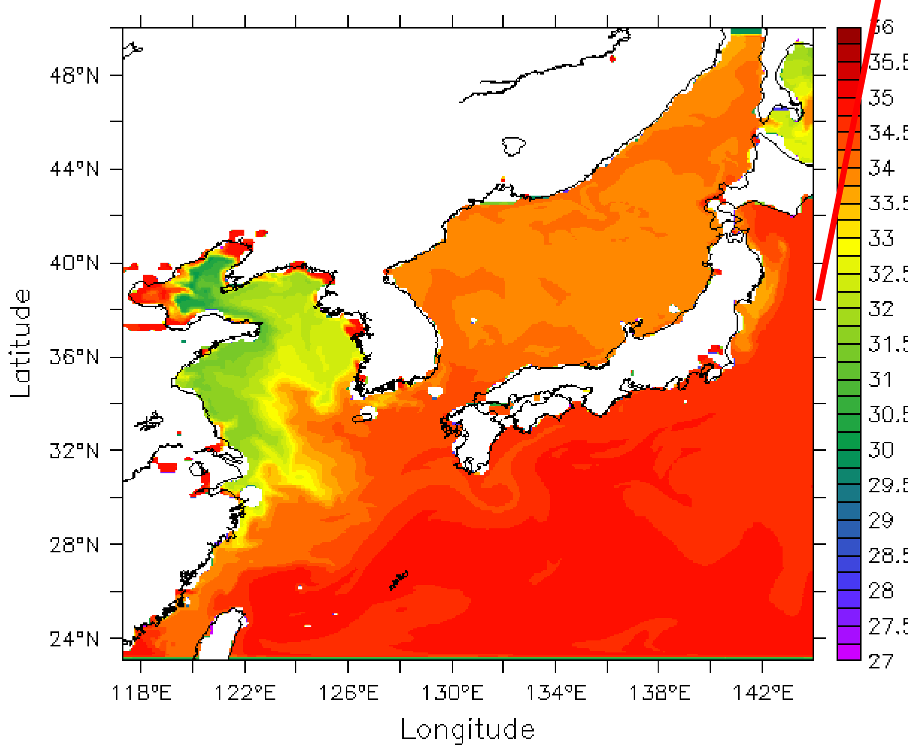
Sea surface salinity

Problem with boundaries



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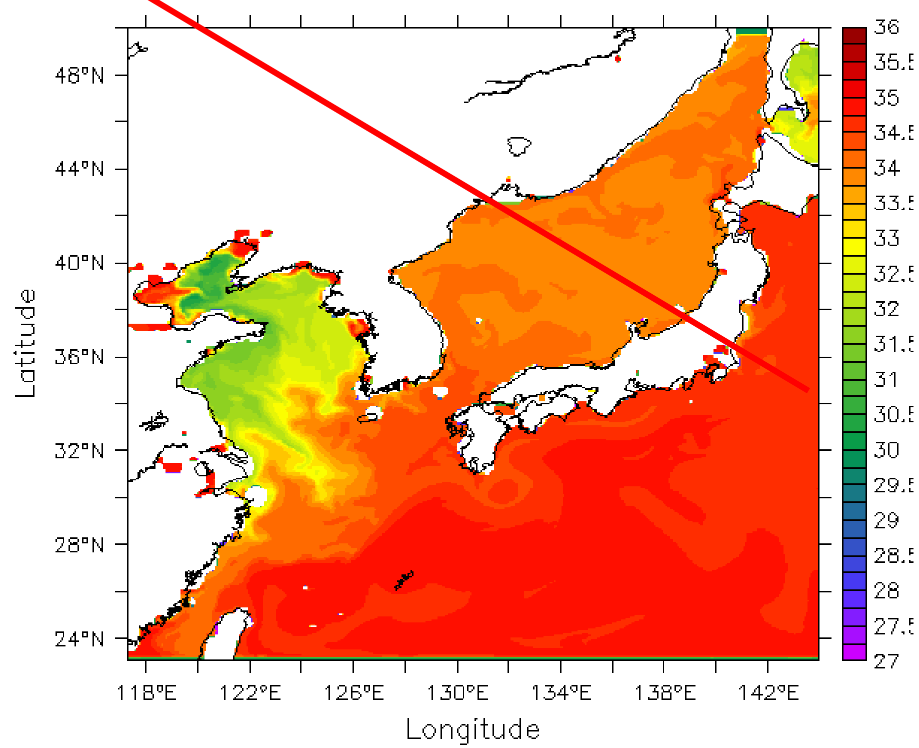
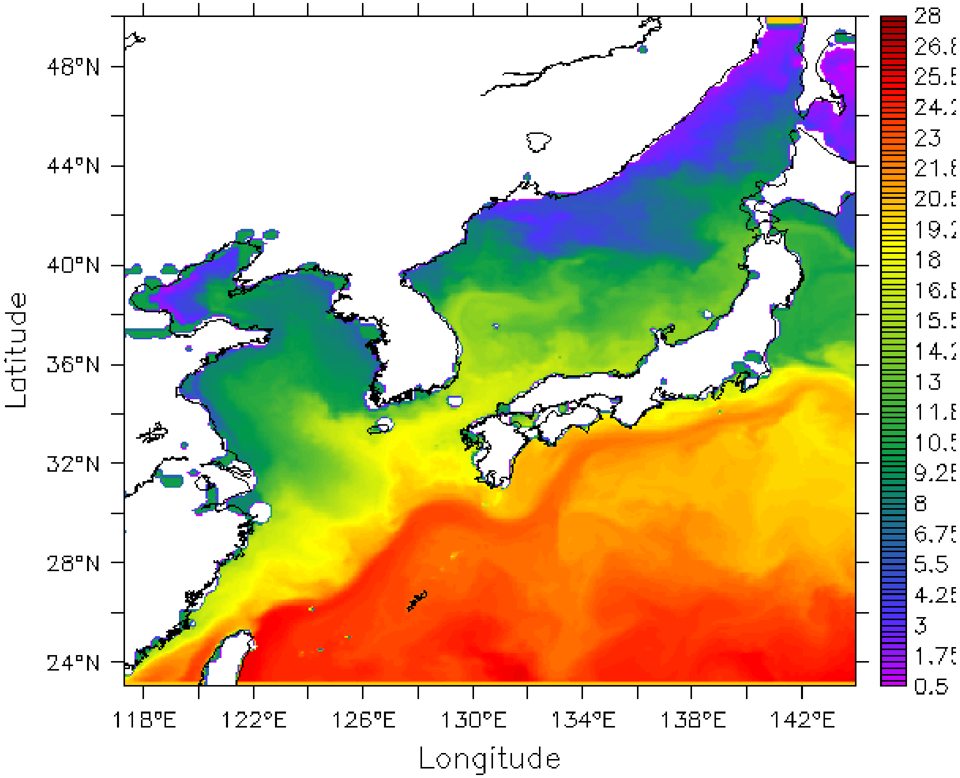
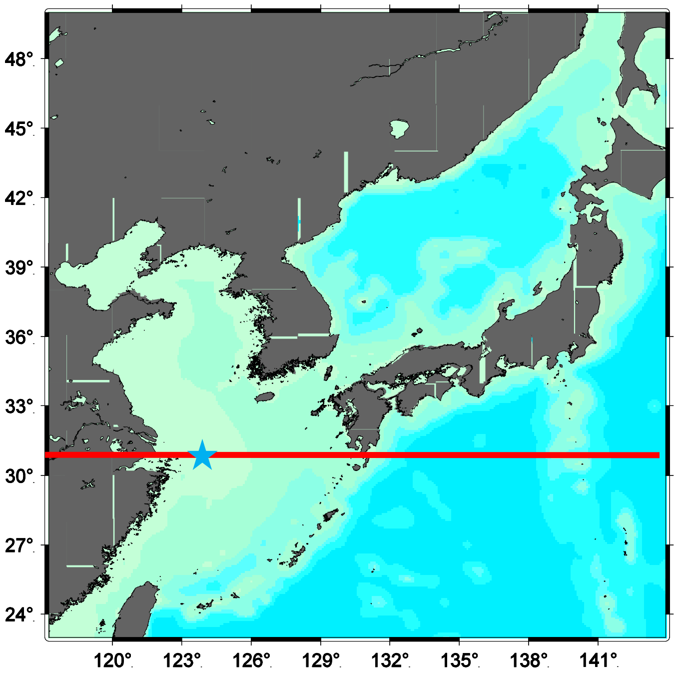
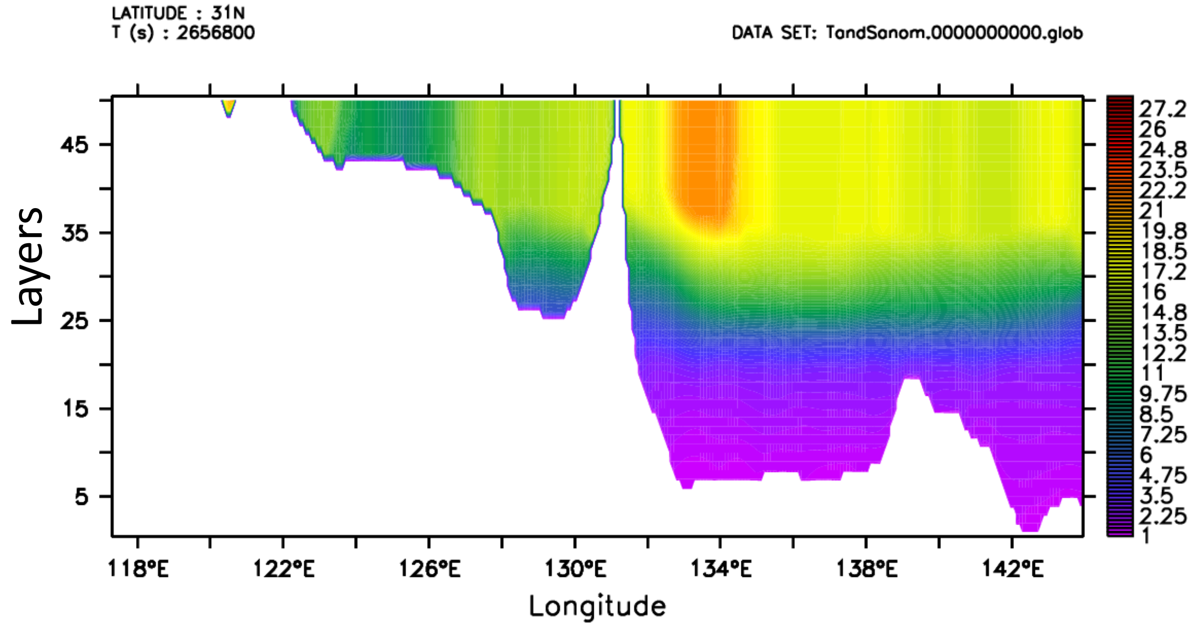


Jan.22.2004 00:00

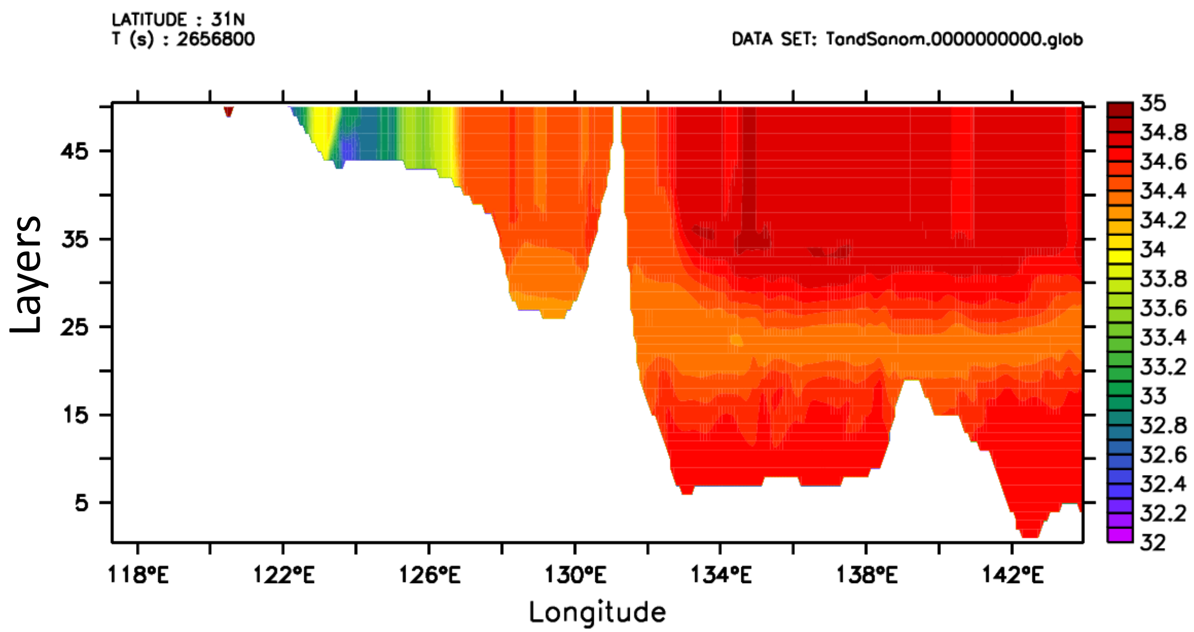
Sea surface temperature







THETA (degC)



SALTANOM+35

Concluding remarks

- Numerical experiments on the impacts of TGD and applicability of RES
  - Modeling of hydrological process
  - Modeling of oceanic process
- Ocean modeling with MITgcm
  - Instability with open boundary condition should be improved
  - Behaviour of passive tracers for nutrients

References

- **1** "Three Gorges Dam" (in Chinese), NDRC (2007-03-07). Retrieved on 15 May 2007.
- **2** "Greenhouse Gas Emissions By Country". Carbonplanet (2006). Retrieved on 2007-05-16.
- **3** "Three Gorges Dam" (in Chinese), TGP (2006-06-12). Retrieved on 15 May 2007.
- **4** "长江电力(600900)2008年上半年发电量完成情况公告 – 证券之星 (The Three Gorges sluice year transported goods volume may amount to 100,000,000 tons)", Xinhua (2007-01-23). Retrieved on 9 August 2008. translation
- **5** "重庆三峡库区污水和垃圾处理项目建设成效明显(Chongqing Three Gorges Reservoir Region sewage and the garbage disposal project construction result is obvious)" (2007-04-19). Retrieved on 9 August 2008. translation
- **6** "湖北省三峡治污项目三内投入约23.5亿元(In the Hubei Province Three Gorges anti-pollution project three years invest the approximately 2,350,000,000 Yuan)", Xinhua (2007-04-19). Retrieved on 9 August 2008. translation
- **7** Peter Collins "Falling here, rising there" Page 63,The World in 2008,The Economist
- **8** "China's Three Gorges Dam Under Fire", Time (2007-10-12). Retrieved on 13 January 2008.
- **9** "China dam to displace millions more", MWC News (2007-10-13). Retrieved on 13 October 2007.
- **10** Mary Ann Toy (2007-09-27). "Three Gorges Dam 'could be huge disaster'", The Age. Retrieved on 13 October 2007.
- **11** "People Are Better Off in Three Gorges Resettlement", Archive.org WayBackMachine. Retrieved on 15 January 2007.
- **12** "Three Gorges Dam Case Study", American University, The School of International Service. Retrieved on 20 January 2008.
- **13** Ethan Theuerkauf (2007-10-02). "Three Gorges Dam: A Blessing or an Environmental Disaster?", The Flat Hat, the College of William and Mary's student newspaper. Retrieved on 20 January 2008.
- **14** "Three Gorges Dam Project - Environmental Impact", ibiblio.org. Retrieved on 20 January 2008.
- **15** Qing, Dai, 9. The River Dragon Has Come!: The Three Gorges Dam and the Fate of China's Yangtze River and Its People (East Gate Book). Armonk, New York: M.E. Sharpe, 1997.
- **16** C.Michael Hogan. "Shen Nong Gorge Hanging Coffins", The Megalithic Portal. Retrieved on 20 January 2008.
- **17** Topping, Audrey Ronning. Environmental controversy over the Three Gorges Dam. Earth Times News Service.
- **18** Topping, Audrey Ronning. Environmental controversy over the Three Gorges Dam. Earth Times News Service.
- **19** Winchester, Simon (1998). *The River at the Center of the World*. New York: Henry Holt & Co. p. 228. ISBN 9780805055085.
- **20** Segers, Henrik; Martens, Koen (2005). *The River at the Center of the World*, Springer. p. 73. ISBN 9781402037450.
- **21** "Annual report on the military power of the People's Republic of China (.pdf)". *US Department of Defense*. Retrieved on 2007-01-28.
- **22** "Troops sent to protect China dam", BBC (2004-09-14). Retrieved on 28 January 2007.