Establishment of Regional Environment Simulator at Faculty of Engineering, Hasanuddin University, Gowa Campus. Case Study Meteorological Simulation and Estuary Circulation

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Abstract

The increasing of natural hazards in Eastern Part of Indonesia (EPI) triggered the needs for a comprehensive understanding of the natural hazard itself along with the substantial causes. The best way for achieve a comprehensive understanding of it is by building and implementing an environmental simulator. Faculty of Engineering of Hasanuddin University (FoE-UNHAS) with the fund from JBIC Loan that based on the Enhancement Project of FoE-UNHAS, respond to this need by establishing the Regional Environmental Simulator at FoE-UNHAS new campus in Gowa, South Sulawesi Province, Indonesia.

This is the report of the training done by the author in Graduate School for IDEC, Hiroshima University during the 2013 Japan Short Term Visit, from June 24th to September 21st 2013. The training was focusing on the Meteorological Simulation using numerical code of Weather Research and Forecasting (WRF) and the Estuary Circulation using ECOMSED.

1. Introduction

The Enhancement Project of Faculty of Engineering at Hasanuddin University was initiated on 2006 at Makassar-Indonesia. The main idea is to move the faculty to another place and also build a-state-of-art modern campus including the up-to-date educational and modern research facilities. Due to that, it was also necessary to enhance the human resources by upgrading the academic staff by sending them to several universities in Indonesia and Japan; for master and doctor course, or even for postdoctoral scheme.

There are total 6 batches of Postdoctoral Scheme for academic staff of FoE-UNHAS, with almost a hundred person. From Batch 1 to 4, the scheme were in duration of six months, while on the last two (Batch 5 and 6) shrank to only three months. The last two batches are called 2013 Japan Short Term Visit. The corresponding author are in Batch 5 and sent to Faculty for IDEC, Hiroshima University; from June 24th to September 21st 2013.

For the corresponding author, the main focus of this 2013 Japan Short Term Visit is to train itself and be able to implement the Regional Environment Simulator for the FoE-UNHAS at new campus in GOWA.

2. The enhancement project of faculty of engineering, Hasanuddin University

To play a role as a center of technology, Hasanuddin University (UNHAS) has developed new Gowa Campus for Faculty of Engineering (FoE-UNHAS). The new campus is financed by JBIC – Yen Loan Project IP-541 for building construction, equipment procurement, and fellowship programs (doctoral program and short term research program). The JBIC-Yen Loan Project was also supported by joint implementation of JICA-Technical Cooperation Project (JICA-TCP) completed in the end of January 2012.

In accordance with the above role, the FoE-UNHAS will proactively establish mutual collaborations with industries, governments, and other universities. The improvement of faculty management and planning, and the optimal utilization of the infrastructures become FoE-UNHAS's development focus. Hence, the vision of FoE-UNHAS was reformulated and approved by Faculty Senate on September 2010; which is to be the center of excellence for global sustainability with the spirit of Maritime Culture. Based on that vision, the missions were also formulated as:

1. To develop engineering education, research and community service in the spirit of maritime culture,
2. To foster engineers with broad knowledge, advanced technology, and innovative capability,
3. To establish an excellent engineering center for sustainable development,
4. To disseminate the appropriate technology to improve the human quality of life and to sustain the potential of natural resources.

During February 2009 – January 2012 of JICA-TCP activities, internal improvement focusing on learning system had been carried out. The project produced four important documents namely FoE-UNHAS Strategic Plan 2011-2020, Guidelines for the Introduction of LBE, Research Roadmap 2011-2014, and Policy and Academic Standard. By referring to these documents, all engineering programs at FoE-UNHAS developed new curriculum based on LBE system that has been implemented since the first semester of 2011/2012. Furthermore, it has been established research laboratories besides educational (practical) laboratories. These efforts are mainly concern to improve faculty management to establish a new learning system and methodology. It is realized that to play a role as a center of technology requires improvement of faculty's capability in collaboration and cooperation with other faculties within UNHAS, other universities particularly related to engineering fields, local and national governments, and industries. The development of the new campus of FoE-UNHAS in Gowa consists of four packages, with Department of Naval Architecture and Shipbuilding Engineering (NASE-UNHAS) is one of them. NASE-UNHAS have three study program, which are Naval Architecture, Marine Engineering, and Ocean Engineering. One of the main and prime mission of this department is to develop a collaboration and cooperation with other educational and research units at universities all around the world, especially in the field concerning environmental dynamics phenomenon. To do so, NASE-UNHAS with the scheme of The Enhancement Project of FoE-UNHAS, is focusing to develop an environment simulator which is can be very useful for understanding several environment phenomenon itself, both local and regional. The simulator will cover phenomenon at the Sea, the Atmosphere, and the Land; and also the interaction between them.

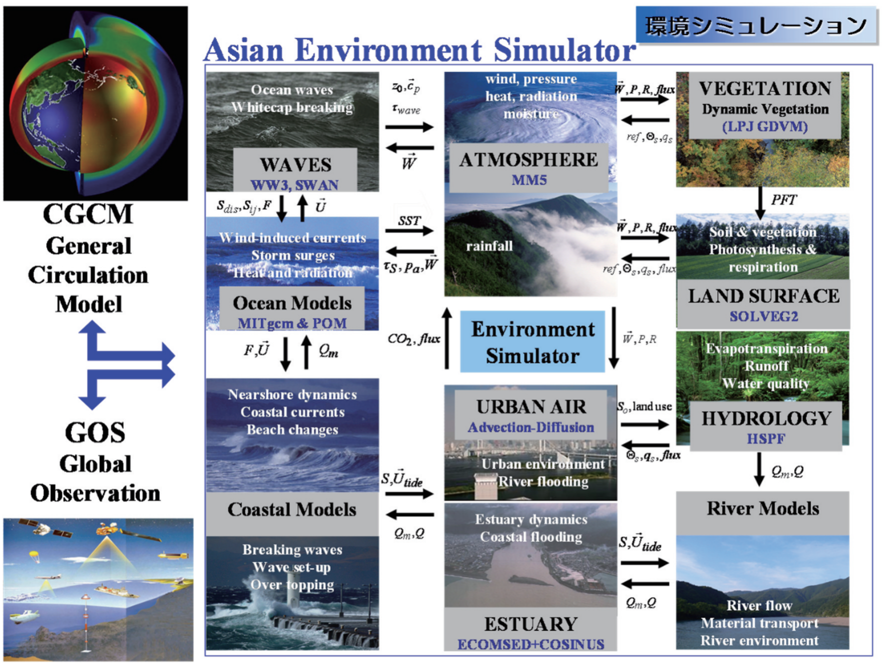

Figure 1. RES Schematic at IDEC, Hiroshima University

3. Regional environment simulator (RES)

Hiroshima University as one of the contributing university from Japan for The Enhancement Project of FoE-UNHAS, especially at Graduate School for International Development and Cooperation (IDEC), also have a very good experience in environmental simulation. At IDEC, the research group had developed numerical models named Regional Environment Simulator (RES) as a tool for research and education for assessing the environmental impacts due to natural hazards. Developed at IDEC, Hiroshima University, RES is a meso-scale numerical model system that can be used for regional simulation of natural disasters and environmental problems caused by water and heat circulation in the atmosphere, hydrosphere, and biosphere. RES has three components: i) atmosphere-surface waves-ocean part, ii) atmosphere-land surface process-hydrologic part, and iii) coastal and estuarine part. Each part is constructed with state-of-the-art public domain numerical models that are combined synchronously by an own-developed model coupler. Therefore, RES can provide detailed insights from various aspects of interaction processes between each component in the earth system. For instance, RES has been used for the study of storm surges and the abnormally high ocean waves caused by typhoons, cyclones, hurricanes, and winter monsoon winds in Asian region; dam lake circulation; air-sea interaction of momentum, heat, and tracer material exchange; heavy rainfall and runoff simulation; estuarine circulation with cohesive sediment transport; and wave overtopping in coastal regions.

In Eastern Part of Indonesia (EPI), almost all local government facing a lot of problems regarding environmental issues; i.e. several forms of sea hazards, heavy rainfall, and also the unstable estuarine circulation with cohesive sediment transport. All of these problems have cost a huge amount of losses, both material and immaterial. Due to those IDEC-Hiroshima University experiences combine with the environmental problems at EPI, emerge the needs and the possibility for establishing the same state-of-art Regional Environment Simulator in FoE-UNHAS, especially at NASE-UNHAS. For these needs, FoE-UNHAS in coordination with NASE-UNHAS, have been doing several actions. The first one is to select and then proposed the equipment for establishing RES by using the fund from the enhancement project of FoE-UNHAS. The equipment is a High Performance Computing System (HPCS), which is similar or maybe even better in specification than HPCS at IDEC, Hiroshima University. Secondly is the adaptation process, conduct by learning the numerical codes of the simulators and then implement them into some cases. Thirdly is implementing the numerical codes as components of RES to the HPCS at NASE-UNHAS. There are high hopes that RES can help local governments at EPI to overcome the environmental problems they had experienced over these past years; while also still maintain the research for educational purposes in campus.

4. Meteorological simulation of Hurricane Katrina (2005)

One of the main simulation in RES is Meteorological Simulation. In RES which developed by IDEC-Hiroshima University, the meteorological simulation hold an important role for the successfulness of other simulation, such as storm surges, forest fire, etc. In the beginning, for meteorological simulation, RES used MM5 numerical code. But since 2009, RES uses a new model called WRF (Weather Research and Forecasting) which is the successor of MM5.

The WRF is a fully compressible, nonhydrostatic model (with a hydrostatic option), which vertical coordinate is a terrain-following hydrostatic pressure coordinate. It uses grid staggering of the Arakawa C-grid, and also uses higher-order numerics that includes the Runge-Kutta 2nd- and 3rd-order time integration schemes, and 2nd- to 6th-order advection schemes in both horizontal and vertical directions.

The WRF code contains initialization programs (ideal.exe and real.exe), a numerical integration program (wrf.exe), and a program to do one-way nesting (ndown.exe). The WRF ARW model Version 3 supports a variety of capabilities. These include:

1. Real-data and idealized simulations
2. Various lateral boundary condition options for both real-data and idealized simulations
3. Full physics options
4. Non-hydrostatic and hydrostatic (runtime option)
5. One-way, two-way nesting and a moving nest
6. Applications ranging from meters to thousands of kilometers

The WRF can be used for idealized, real or even real cases with variation analysis. For almost all cases, which are real cases, WRF Simulation process divided into three steps.

WRF ARW Model + PostProcessing

WPS + WRF ARW Model + PostProcessing

WPS + WRF-Var + WRF ARW Model + PostProcessing

Figure 2. Three schemes of WRF

Firstly, the preparation step. It uses the WRF Preprocessing System (WPS). In this step, three important preparations being done by using three executional files, i.e. ungrib.exe, geogrid.exe and metgrid.exe.

The ungrib program reads GRIB files, “degribs” the data, and writes the data in a simple format called the intermediate format. The GRIB files contain time-varying meteorological fields and are typically from another regional or global model, such as NCEP’s NAM or GFS models. The ungrib program can read GRIB Edition 1 and, if compiled with a “GRIB2” option, GRIB Edition 2 files.

The purpose of geogrid is to define the simulation domains, and interpolate various terrestrial data sets to the model grids. The simulation domains are defined using information specified by the user in the “geogrid” namelist record of the WPS namelist file, namelist.wps. In addition to computing the latitude, longitude, and map scale factors at every grid point, geogrid will interpolate soil categories, land use category, terrain height, annual mean deep soil temperature, monthly vegetation fraction, monthly albedo, maximum snow albedo, and slope category to the model grids by default. Global data sets for each of these fields are provided through the WRF download page, and, because these data are time-invariant, they only need to be downloaded once. Several of the data sets are available in only one resolution, but others are made available in resolutions of 30", 2', 5', and 10'; here, " denotes arc seconds and ' denotes arc minutes. The user need not download all available resolutions for a data set, although the interpolated fields will generally be more representative if a resolution of data near to that of the simulation domain is used. However, users who expect to work with domains having grid spacing’s that cover a large range may wish to eventually download all available resolutions of the static terrestrial data.

The metgrid program horizontally interpolates the intermediate-format meteorological data that are extracted by the ungrib program onto the simulation domains defined by the geogrid program. The interpolated metgrid output can then be ingested by the WRF real program. The range of dates that will be interpolated by metgrid are defined in the “share” namelist record of the WPS namelist file, and date ranges must be specified individually in the namelist for each simulation domain. Since the work of the metgrid program, like that of the ungrib program, is time-dependent, metgrid is run every time a new simulation is initialized.

The second step is simulating the weather using WRF. This step uses files that have been prepared by WPS in form of metgrid files as input, and controlled them with “namelist.input” file. In “namelist.input” all the conditions parameters are set for the simulation. There are two executional files uses in this step, i.e. real.exe and wrf.exe. The “real.exe” is for interpolates vertically the data onto the model coordinates, and resulting two files, which are “wrfbody_d01” and “wrfinput_d01”. The “wrf.exe” then generates the model forecast using those two files, “wrfbody_d01” and “wrfinput_d01”. This step will resulting file(s) “wrfout_(dates)”, which will then be uses as an input for post processing.

The third step in simulation is the post processing the output of the second step, which in form of “wrfout_(dates)”. There are several codes that can be used for the post processing, one of them is ARWpost. In ARWpost, the parameters which will be shown are defined and controlled by changing the value of several items in “namelist.ARWpost” file. After adjusting the parameters, then the “wrfout_(dates)” will executed using an executional file called “ARWpost.exe”. The result will be two files, with an extension code “.ctl” and “.dat”. For displaying the results in figure with certain parameter(s), several programs can be used; which one of them is GrADS.

An example of weather simulation using WRF is the simulation of Hurricane Katrina. On August 28, 2005, Hurricane Katrina was in the Gulf of Mexico where it powered up to a Category 5 storm on the Saffir-Simpson hurricane scale packing winds estimated at 175 mph.

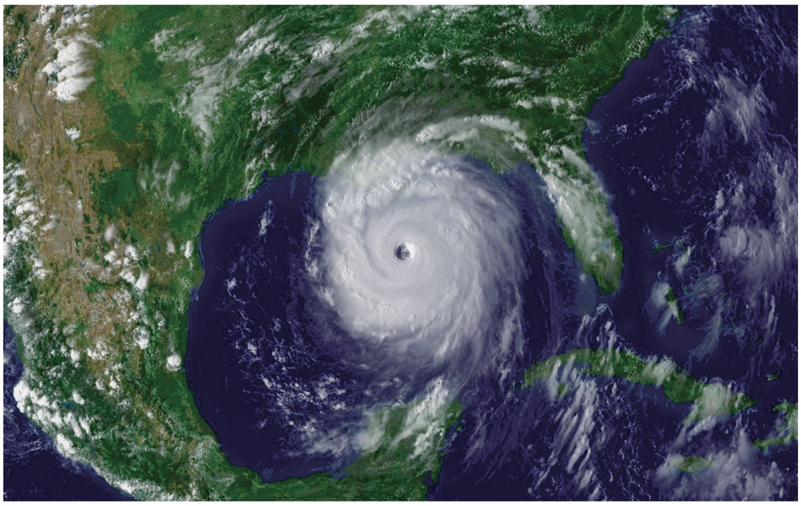

Figure 3. Aerial shot of Hurricane Katrina
Source: http://www.katrina.noaa.gov/satellite/satellite.html

At 7:10 a.m. EDT on August 29, Hurricane Katrina made landfall in southern Plaquemines Parish Louisiana, just south of Buras, as a Category 3 hurricane. Maximum winds were estimated near 125 mph to the east of the center.
Although Katrina will be recorded as the most destructive storm in terms of economic losses, it did not exceed the human losses in storms such as the Galveston Hurricane of 1900, which killed as many as 6,000-12,000 people, and led to almost complete destruction of coastal Galveston.

Hurricane Andrew, in 1992, cost approximately $21 billion in insured losses (in today's dollars), whereas estimates from the insurance industry as of late August 2006, have reached approximately $60 billion in insured losses (including flood damage) from Katrina. The storm could cost the Gulf Coast states as much as an estimated $125 billion.

The simulation process started by downloading 6hourly meteorological data in form of GRIB data, during August 28-30 2005 and also the daily SST data from August 27th to 31st, 2005. After linking them in to the WPS folder and adjusting the parameters in "namelist.wps", the "ungrib" process begin, resulting 9 intermediate files which every one of them contains 6hourly meteorological data; also 9 intermediate files of SST. After ungrib process finished, the "geogrid" process begins by adjusting the domains parameters at "namelist.wps"

This will resulting a file, called "geo_em.d01.nc". With this data, combined the intermediate files of ungrib process, then the "metgrid" process begin. The process will be resulting 9 metgrid files, called "met_em.d01.(date.time).nc". These files contain 6hourly interpolating data from August 28th 00.00 to August 30th 00.00 2005, which will be used to run the WRF simulation of Hurricane Katrina.

After finishing the preprocessing at WPS, then the simulation continued to WRF. For this simulation, the directory "run" in WRF folder will be used as the working directory, meaning all the metgrid data have to be linked to this directory. For controlling the process, several values of the parameters in "namelist.input" have to be adjust. For example; in time control, the run days sets to be 48 hours, and interval seconds sets to 21600. It means that the simulation will set for 48 hours with an interval of 21600 seconds. After the adjustment, then the simulation continued by executing the "real.exe" for interpolating the data onto the model coordinates, resulting two files, i.e. "wrfbody_d01" and "wrfinput_d01". Then running the simulation with "wrf.exe", and resulting "wrfout.d01.2005-08-28_00:00:00.nc" which contain all output data.

For post processing, the "wrfout.d01.2005-08-28_00:00:00.nc" then be copied to the directory of ARWpost. Before the process begin, several adjustment have to be done in "namelist.ARWpost", especially the name of input and output file. With this simulation, the name output file is "out-Katrina48hours". This process results "out-Katrina48hours.ctl" and "out-Katrina48hours.dat". With GrADS, the "out-Katrina48hours.ctl" then used and can produce several Figural output data, such like Wind Direction, Temperature, Pressure Perturbation, etc. In Figure 4, it displayed the wind direction of Hurricane Katrina during August 28th to 30th 2005.

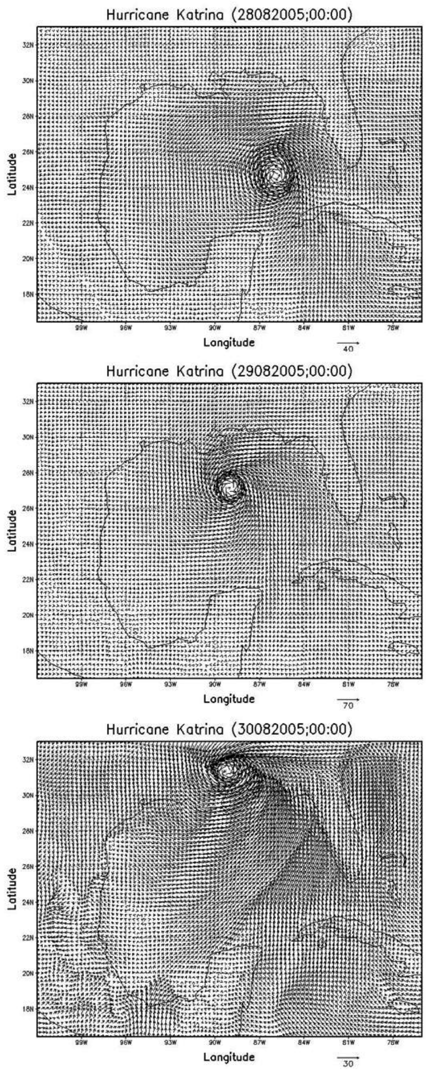

Figure 4. Meteorological simulation result of Hurricane Katrina

At Figure 4, showed the movement of the hurricane core from the East of The Gulf of Mexico on August 28th to the North and making a landfall on August 30th 2005. Comparing to the NOAA image at Figure 5, it showed the resemblance; making the simulation of Hurricane Katrina is well succeed.

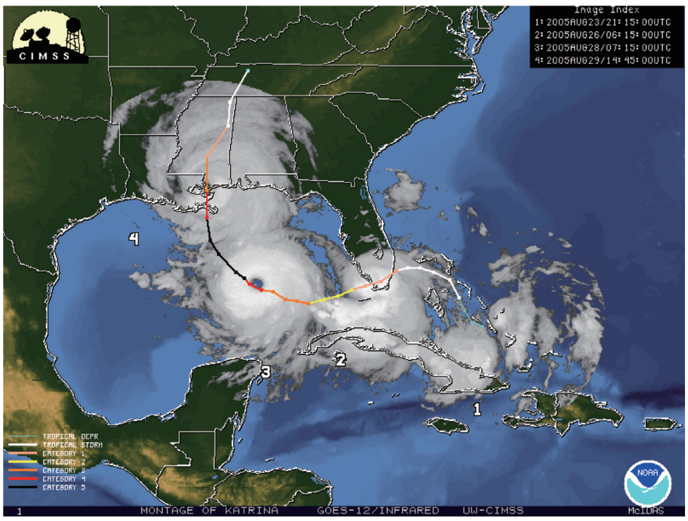

Figure 5. Hurricane Katrina track from NOAA
Source: http://www.earthlyissues.com/katrina.htm

5. Estuary water circulation with consideration of Kuroshio Current

Using ECOMSED and JCOPE (Japan Coastal Ocean Predictability Experiment) reanalysis data, a computation of estuary water circulation with consideration of Kuroshio Current was conducted in the Tone river estuary, Chiba Prefecture, Japan.

JCOPE is the Climate Variation Predictability and Applicability Research Program in Research Institute of Global Change, at JAMSTEC. It will be the best background data for the simulation of coastal ocean circulation. It is also possible to analyze the ocean climate in the North-West Pacific as shown in Figure 6 that depicts the surface currents including Kuroshio, and the surface temperature and surface water elevation.

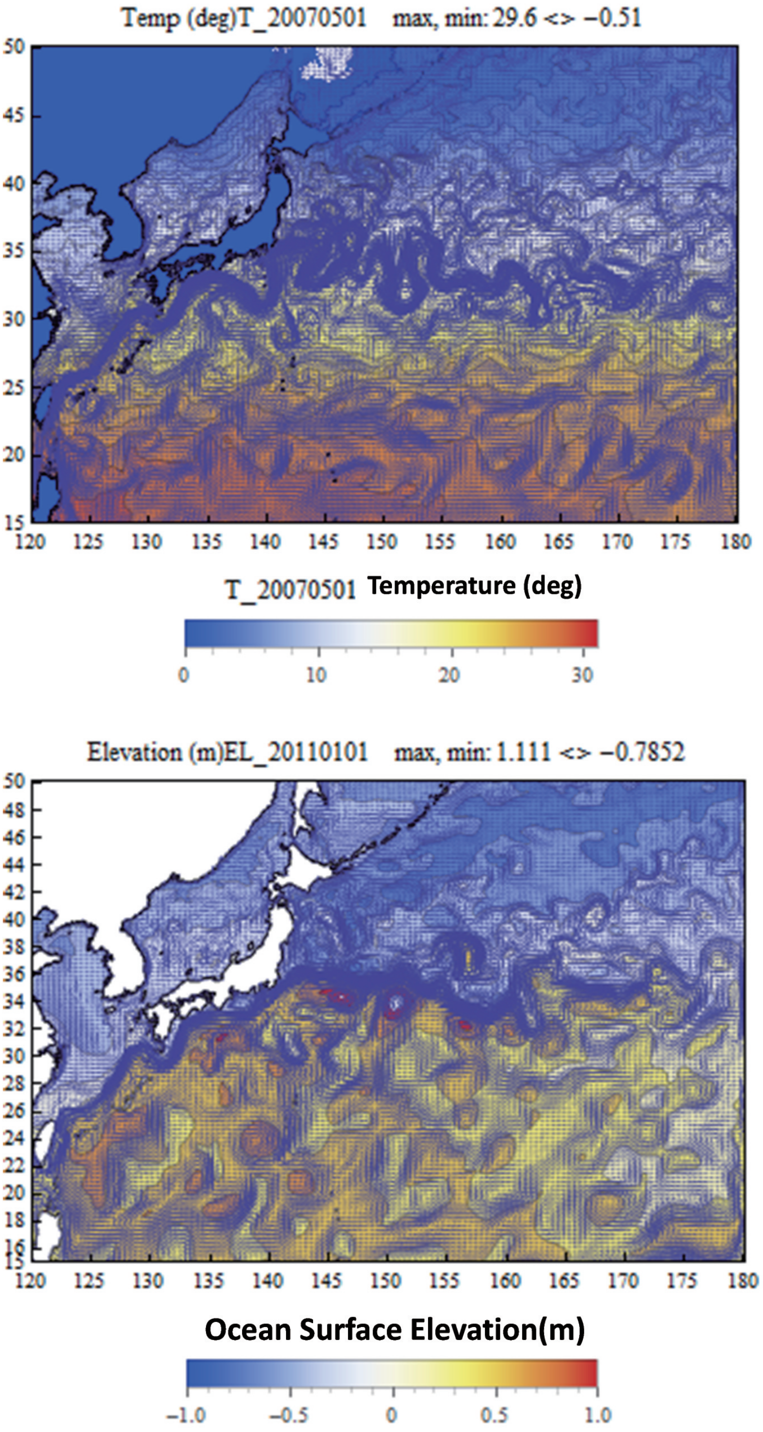

Figure 6. Surface currents and the surface temperature (upper) and surface water elevation (lower).

Figure 7 shows the relation of computational domains, JCOPE data and Estuary computation (450m meshes). S-coordinate system used in JCOPE analysis also indicated in the bottom of the figure. The fixed fine surface levels are introduced in this coordinate system.

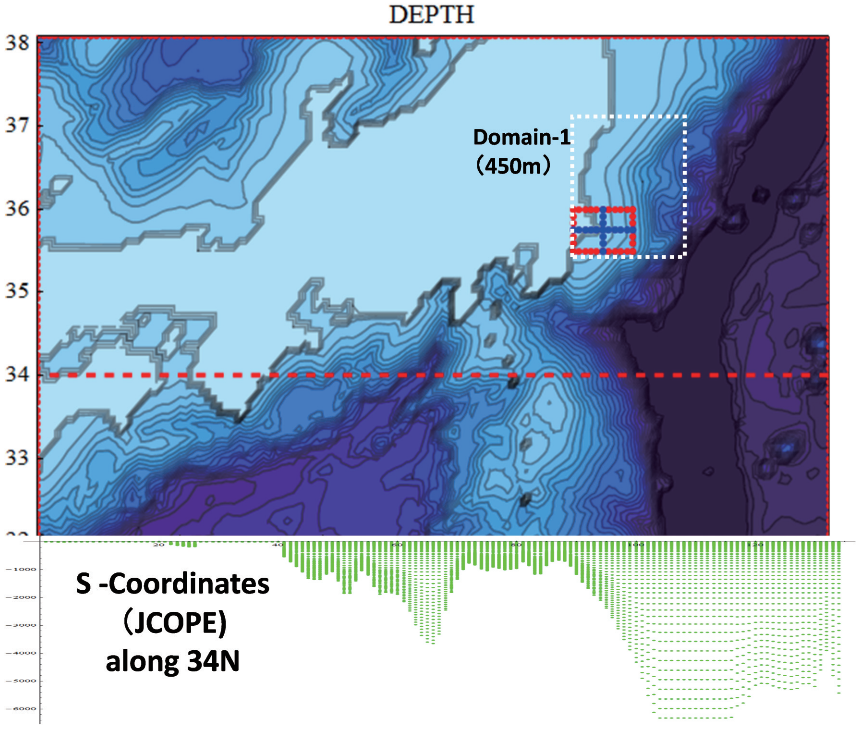

Figure 7. Computational domains, JCOPE data and Estuary computation (450m meshes).

Test computations executed with 450m horizontal meshes and 21 vertical layers of sigma-coordinates. JCOPE reanalysis data were employed as an initial and boundary conditions of estuary simulation.

Figure 8 shows a sample of output in the estuary computation domain. Left figure shows the current vector and salinity at the surface layer. Right figure shows the surface temperature with current vectors which clearly indicated the reproduction of Kuroshio off the Tone river mouth, the Kashima-Nada Sea. River fresh water flow into the ocean is also included in the computation.

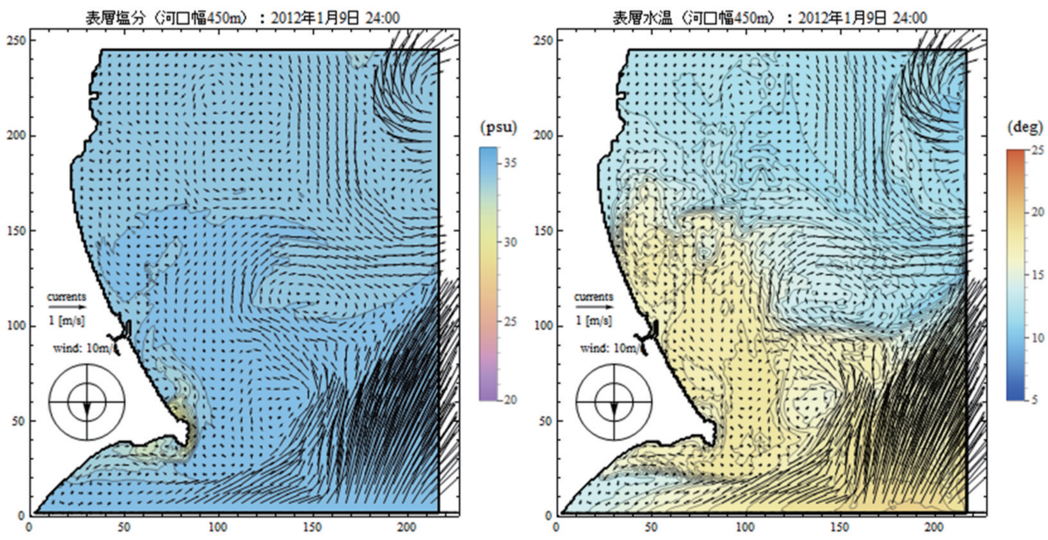

Figure 8. Surface salinity with current vectors (left), the surface temperature with current vectors right).

Figure 9 depicts the 3D current vector fields of the estuary simulations. Top figure is the bird view (from the sky) and the bottom is the fish view (from the ocean bottom). This also show the clear introduction of Kuroshio currents near the sea surface.

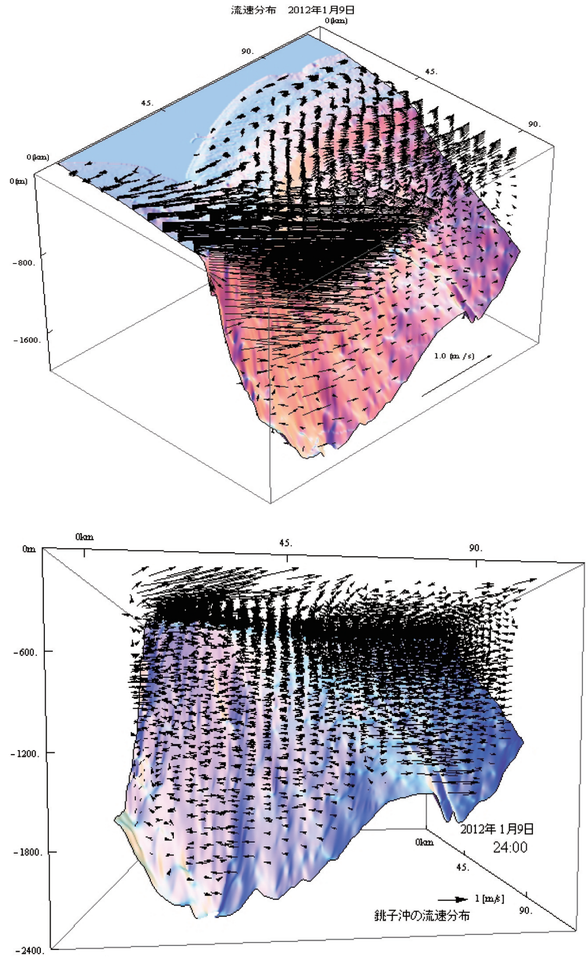

Figure 9. Three-Dimensional current vector fields. A bird view (top) and fish view (bottom).

6. Acknowledgement

This project would not have been possible without the support of many people. The author wishes to express his gratitude to Prof. Takao Yamashita who was abundantly helpful and offered invaluable assistance, support and guidance, and also for becoming the co-author on this report. Special thanks also goes to the JICA-Japan and PIU-GOWA Project UNHAS for the fund and all of their assistance to the author.

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Hurricane Katrina Track (downloaded from http://www.earthlyissues.com/katrina.htm)