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Operational Guide JMA - MMD Storm Surge Model

Version 1

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1.0 Introduction

This document describes on how to run the JMA Storm Surge Model (SSM) Malaysian Meteorological Department from setting up the platform and collect data input to produce the graphical output. The document is meant to describe how to operate SSM at Malaysian Meteorological Department and National Hydrographic Centre. There are 5 essential steps involved in running the SSM:

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ii. Environmental setting in Fedora.
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1.1 Storm Surge Model (SSM)

Storm surges is the abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide. The surge is caused primarily by a storm's winds pushing water onshore. Malaysian Meteorological Department (METMalaysia) adopted the Japan Meteorological Agency (JMA) Storm Surge Model and operationalized it since March 2009. Although Malaysia is not located in the direct typhoon path but strong typhoon occurrence in Malaysia adjacent waters can cause the wind and mean sea level pressure fluctuation which can result in sea level rise due to wind and pressure setup. In addition to this, during the Boreal Winter season, strong north-east winds become predominant in south-east Asia region especially in the east coast of Peninsular Malaysia. Thus, the continuous run of the JMA-METMalaysia storm surge model is essential to monitor and forecast sea level rise which can affected low lying coastal areas during typhoon or winter monsoon season.

METMalaysia runs a JMA Storm Surge Model on operational mode since July 2007. It is a numerical model developed by JMA to simulate and predict storm surges, especially those caused by tropical cyclones. MetMalaysia refers to RSMC Tokyo-Typhoon Center, JTWC and RSMC Tropical Cyclones New Delhi for TC forecasts. The numerical scheme of the model is based on the shallow water equations and thus this model is two-dimensional. The model has features as listed below:

a) It computes storm surges due to wind setup and inverted barometer effect where 1hPa pressure drop equal to 1cm sea level rise.

b) Accepts two types of meteorological forcing data which is GRIB format files containing surface wind and pressure fields of NWP Models from Atmospheric Model such USGODAE and Tropical Cyclone Best Track Data provided by the Regional Specialized Meteorological Centre Tokyo - Typhoon Centre.

c) Writes the storm surge calculation results in a GRIB file using FORTRAN and displays using Grid Analysis and Display System (GrADS).

d) Grib is the one of binary file format to store the analysis and forecast data in structured manner. ctl means control file in ascii format. We can read it. Both these formats are usually used in atmospheric and meteorological departments. The generated ctl files can be read and visualized by GRADS and other meteorological software.

e) The model calculates the storm surges anomaly every hour. However, the model output is displayed at 6-hourly interval together with wind field map up to 7 days forecast.

f) Outputs calculated storm surge fields in GRIB format and timeseries at given coastal points.

1.2 **Dynamics**

Storm surges are mainly caused by the effects of wind setup due to strong onshore winds over the sea surface and the inverted barometer effect associated with pressure drops in low-pressure systems. To predict temporal and spatial sea level variations in response to such meteorological disturbances, JMA's storm surge model utilizes two-dimensional shallow water equations consisting of vertically integrated momentum equations in two horizontal directions:

$$\begin{aligned}\frac{\partial M}{\partial t} - fN &= -g(D+\zeta)\frac{\partial(\zeta-\zeta_0)}{\partial x} + \frac{\tau_{sx}}{\rho} - \frac{\tau_{bx}}{\rho} \\ \frac{\partial N}{\partial t} + fM &= -g(D+\zeta)\frac{\partial(\zeta-\zeta_0)}{\partial y} + \frac{\tau_{sy}}{\rho} - \frac{\tau_{by}}{\rho}\end{aligned} \qquad (1)$$

and the continuity equation:

$$\frac{\partial \zeta}{\partial t} = -\frac{\partial M}{\partial x} - \frac{\partial N}{\partial y} \qquad (2)$$

where M and N are volume fluxes in the x- and y-directions, defined as:

$$\begin{aligned}M &= \int_{-D}^{\zeta} u\,dz \\ N &= \int_{-D}^{\zeta} v\,dz\end{aligned} \qquad (3)$$

f is the Coriolis parameter; *g* is the gravity acceleration; *D* is the water depth below mean sea level; ζ is the surface elevation; ζ_0 is the inverted barometer effect converted into an equivalent water column height; ρ is the density of water; τ_{sx} and τ_{sy} are the x- and y-components of wind stress on the sea surface; and τ_{bx} and τ_{by} are the stress values of bottom friction. For computational efficiency, non-linear advection terms are omitted. The equations are solved by numerical integration using an explicit finite difference method. (Masakazu, 2009)

1.3 Meteorological Forcing

A storm surge model requires fields of surface wind and atmospheric pressure as external forcing, and these fields – especially wind – have the greatest impact on the performance of storm surge prediction. In the operation of JMA's storm surge model, two kinds of meteorological forcing field are used; one is a simple parametric model of TC structure and the other is the prediction of the operational JMA nonhydrostatic mesoscale model (referred to below as MSM) (Saito et al., 2006).

The parametric TC model is introduced to take into account the errors of TC track forecasts and their influence on storm surge forecasting. Although the performance of TC forecasts has gradually improved, their mean position error remains around 100 km for 24-hour forecasts at present (JMA, 2008). This implies that there is a large spread of possible forecast values for surface wind and atmospheric pressure at a certain location, making accurate storm surge prediction difficult even for 24-hour forecasts. Figure 1 demonstrates how differences in the path of a TC change storm surge occurrence. If the typhoon veers left of the forecast track, a storm surge will occur in Osaka Bay (the western bay in the area shown in the figures) (Figure 1(b)), while a surge would occur in Ise Bay (the eastern bay in the figures) if the typhoon veers right (Figure 1(c)).

To consider the influence of TC track uncertainty on the occurrence of storm surge, we conduct five runs of the storm surge model with five possible TC tracks. These five tracks are prescribed at the center and at four points on the probability circle within which a TC is forecast to exist with a probability of 70% (Figure 2) and are used to make meteorological fields with a parametric TC model. The simple parametric TC model used by Konishi (1995) based on Fujita's empirical formula (Fujita, 1952) is adopted. The radial pressure distribution of the simple parametric TC model is represented as follows:

$$P = P_{\infty} - \frac{P_{\infty} - P_c}{\sqrt{1 + (r / r_0)^2}} \qquad (4)$$

and is related to the gradient wind as follows:

$$-\frac{v^2}{r} - fv = -\frac{1}{\rho}\frac{\partial P}{\partial r} \qquad (5)$$

In Eqs. (4) and (5), P is the atmospheric pressure at distance r from the centre of the TC, $P\infty$ is the atmospheric pressure at an infinitely distant point, Pc is the pressure at the TC centre, $r0$ is the scaling factor of the radial distribution of pressure, and v is the gradient wind speed. The wind vectors are rotated inward 30 degrees to approximate the inflow in a TC. For the asymmetry of the wind field in a TC, the moving velocity vector of the TC multiplied by a weight that decays exponentially with the distance from the TC

centre is added to the wind vector. The resulting wind and pressure fields are applied to the storm surge model as external forcing. (Masakazu, 20

These formulas diagnose wind and pressure fields at each point in time using the necessary input of forecast values as below and all these values are obtained from the tropical cyclone advisories issued by the RSMC Tokyo – Typhoon Center.

- The location (longitude and latitude) of the TC centre.
- The minimum pressure at the TC centre.
- The maximum sustained wind speed.
- The radius of 50 kt wind speeds (if present).
- The radius of 1 000 hPa.

1.4 Advantage & Disadvantage of using RSMC Best Track Data

Advantage:

a. Tropical Cyclone Best Track Data provided by RSMC Tokyo uses Parametric Tropical Cyclone (TC) Model where is good for ensemble surge forecast due to the uncertainty of forecast typhoon track.

b. Time taken to run the model to the output product is short.

c. Where we can use as a backup input data if NAVGEM data unavailable.

d. Knowing fast the possibility of risk area.

Disadvantage:

a. Always overestimate the wind speed when TC hit Land where there is no dampening of wind speed due to topographic effect.

b. Base on few research made: The output value of the sea level rise was much overestimate between the real situation on ground. (Differentiate data by sea level recorder).

c. Could prejudice the effect to the risk area with over sea level rise.

2.0 ENVIRONMENT AND SOFTWARE SETTING

SSM is fully written in FORTRAN 90. SSM uses gfortran compiler in Linux Fedora Core 24 operating system. The operating system in the Linux Fedora should be installed with library and system to support the process of SSM.

2.1 Download and install Linux Operating System

a. Download the Linux OS for example, Ubuntu or CentOS but in this guide use Fedora. Go to https://getfedora.org/en/workstation/download/ and click on the download button for the DVD ISO file.

b. Start the Linux OS and the installation process of Fedora Workstation in the Linux OS.

2.2 Environmental setting in Fedora

a. There are few programs need to be checked or installed in the operating system to ensure the system can operate the SSM.

b. GrADS is useful to make distribution maps of storm surge as it can access GRIB files directly. With gnuplot, users can plot storm surge time-series easily.

$ which grads - check the program has been installed in the system or not

c. Install grads, gnuplot, gfortran, gcc*, Perl5, wgrib, unrar and crontab in the terminal by using sudo yum install:

$ sudo yum install grads - (Grid Analysis and Display System) an interactive desktop tool that is uses for easy access, manipulation and visualization of earth science data.

$ sudo yum install gnuplots - a portable command-line driven interactive data and function plotting utility.

$ sudo yum install gfortran - GNU Fortran compiler.

$ sudo yum install gcc* - GNU Compiler Collections which used to convert programs written in C programming language into binary executable on computer.

$ sudo yum install perl - a C line interpreter language, required by grib2ctl.pl (usually bundled in Linux).

$ sudo yum install wgrib - GRIB file manipulating program (bundled in GrADS).

$ sudo yum install gribmap - a utility making a index file for GrADS (bundled in GrADS).

$ sudo yum install unrar - used to extract, list or test archive files only.

$ sudo yum install crontab - a list of commands that you want to run on a regular schedule.

d. grib2ctl.pl is a tool to make GrADS control file for GRIB files. Download the file g2ctl and grib2ctl.pl perl source code from the link website below https://www.cpc.ncep.noaa.gov/products/wesley/g2ctl.html and copy both file into /bin.

2.2.1 Create new user and password for Storm Surge Model as ssm:

$ adduser ssm

$ psswd ssm **(insert password)**

2.2.2 Log in into SSM user:

$ su ssm

Password: **(Insert password)**

2.2.3 Copy the model source, binary and data needed in SSM_PHN_20210721.tar file.

a. All the files needed for the model run are included in the SSM_PHN_20210721.tar

b. Copy the file and paste to the drive of the Linux workstation.

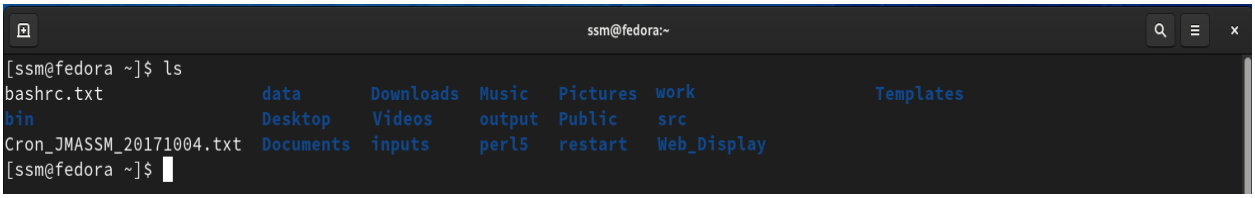
c. Unrar the SSM_PHN_20210721.tar file

$ unrar x SSM_PHN_20210721.tar

2.3 Folder and Data Setup

a. List the directory structure of **/home/user/ssm**

b. Directories appeared likely as picture below: (Must appear all off the blue colour directories file).



2.3.1 Here is brief explanation for the directories structure in ~/ssm:

bin/	: binary executable and scripts
bst.job	: execute JMA Strom Surge model using Best Track Data (BST)
jma_ssm	: binary executable of the model for Linux
all file (.sh)	: script for model run
surge.gs	: a GrADs script that display result of making storm surge maps
timeseries.sh	: a script to draw timeseries graphs of storm surge model output with gnuplot.
src/	: all the source codes for model
gribw/	: source of a GRIB library “gribw”
data/	: all the needed data for model run
ETOPO.DAT	: bathymetry data for East Asian area
station.txt	: a sample of station file
navgem	: 180 data downloads of uwind, vwind and mslp from usgodea.org into the file date.
TCbesttrack	: data download from RSMC Best Tack Data (Text).
input/	: file (.in) to be run JMA SSM using BST
output/	: all the result after the successful run create in “map” and “ timeseries”
work/	: temporary place during the model execution
restart/	: file use for others as a restart field for a continuous run

3.0 MODEL SETUP

3.1 **Compiling all the FORTRAN 90 source code below using gfortran to produce executable binary**

a. Change directories to src:

$ cd src/

b. Compile source code:

$ gfortran -o date_wam.o date_wam.f90

program write calendar date in Julien date

$ gfortran -o Cold_ssm.0 Cold_ssm.f90

create jma_surge.in for navgem data input

$ gfortran -o ssm_ctl.o ssm_ctl.f90

create control file to convert date to Julien day

$ gfortran -o Cold_hind_ssm.o Cold_hind_ssm.f90

create a restart field with 12-hour simulation

$ gfortran -o jma_ssm_restart.o jma_ssm_restart.f90

create a continuous start run from previous restart field created

$ gfortran -o jma_ssm_Hot.0 jma_ssm_Hot.f90

auto run ssm simulation

$ gfortran -o compare_date.o compare_date.f.90

program check difference in date.

3.2 Create executable file using make file

a. Directories remain at *src/*

$ make clean : To remove old object file

$ make : Compiling by run make and an executable for the program will be created in directory inside the source code directory

$ make install : To install the program and create the output file of *jma_ssm, mktopo.o, ensemble.o* in the *bin*

jma_ssm : binary executable of the model for Linux

mktopo : make a topography file topo.dat for storm surge model

ensemble : simulate ensemble manipulation with TC best track data

3.3 View or Editing script

$ vi Makefile : view script data by use “vi” and select any script

Press “i” letter : if we want to edit the script

Press “esc” : after editing script

Press :wq! :to exit from viewing the script, save the file and back to directories before.

3.4 Run File in *bin* directory

a. Change directory to *bin/*

$ cd bin/ : change directory to *bin/*

$ ls : view list file in directory

b. Should have all these run file:

i. ***bst.job***
- execute JMA SSM mode using the Best Track Data

ii. ***Manual_ftp_NAVGEM.sh***
- download 183 file NAVGEM data of uwind,vwind and mslp

iii. ***Adhoc_ssm.sh***
- execute JMA SSM using NAVGEM data

iv. ***restart_12_ssm.sh***
- run 12-hour simulation to create restart field for a continuous run

v. ***Adhoc_ssm_cold.sh***
- execute JMA SSM from zero state

vi. ***Adhoc_ssm_Hot.sh***
- execute JMA SSM from previous restart filed

vii. ***auto_ssm_run.sh***
- fully automated the data downloading and continuous execution of the model

viii. ***Sejuk_WGET_NAVGEM.sh***
- execute auto run SSM computation from static condition on the selected date by getting a NAVGEM data from server and created a restart field for next continuous run

ix. ***Sejuk_lftp_NAVGEM.sh***
- execute auto run SSM computation from static condition on the selected date by downloading NAVGEM data from usgodae.org website and created a restart field for next continuous run

4.0 MODEL EXECUTION

On model execution in this document will give a detail of procedure on how to run SSM from a Best Track Data and NAVGEM Meteorological data to produce the graphical output. The SSM requires four kinds of input data:

a. Meteorological input.

b. Parameter file.

c. Bathymetry.

d. Station file.

4.1 Meteorological Input

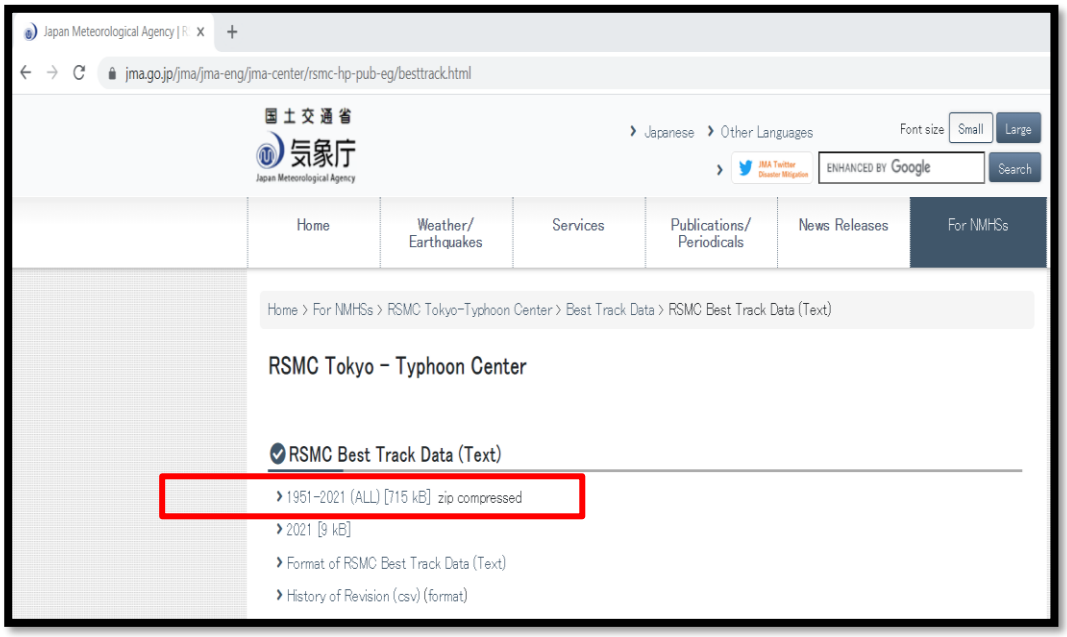
a. SSM execution depends on the input data from Regional Specialized Meteorological Center (RSMC) Tokyo Best Track Data or NAVGEM data. So we can choose which input data that we want to run in the SSM. Below is the explanation on how to download data from RSMC and NAVGEM data.

4.2 Download RSMC Best Track Data

a. Best Track data of RSMC Tokyo - Typhoon Center. They contain tropical cyclone parameters such as the centre position, central pressure, and maximum sustained wind for every 6 hours analysed by RSMC Tokyo-Typhoon Center in JMA. The format of the data is described in Appendix I of this document. Users can choose these data as input of the storm surge model by specifying the variable “N_TYPH” or “TYNAME” in the parameter file of the model. When users choose Best Track data as input, the model calculates wind and pressure fields using an empirical formula of pressure distribution and gradient wind relation.

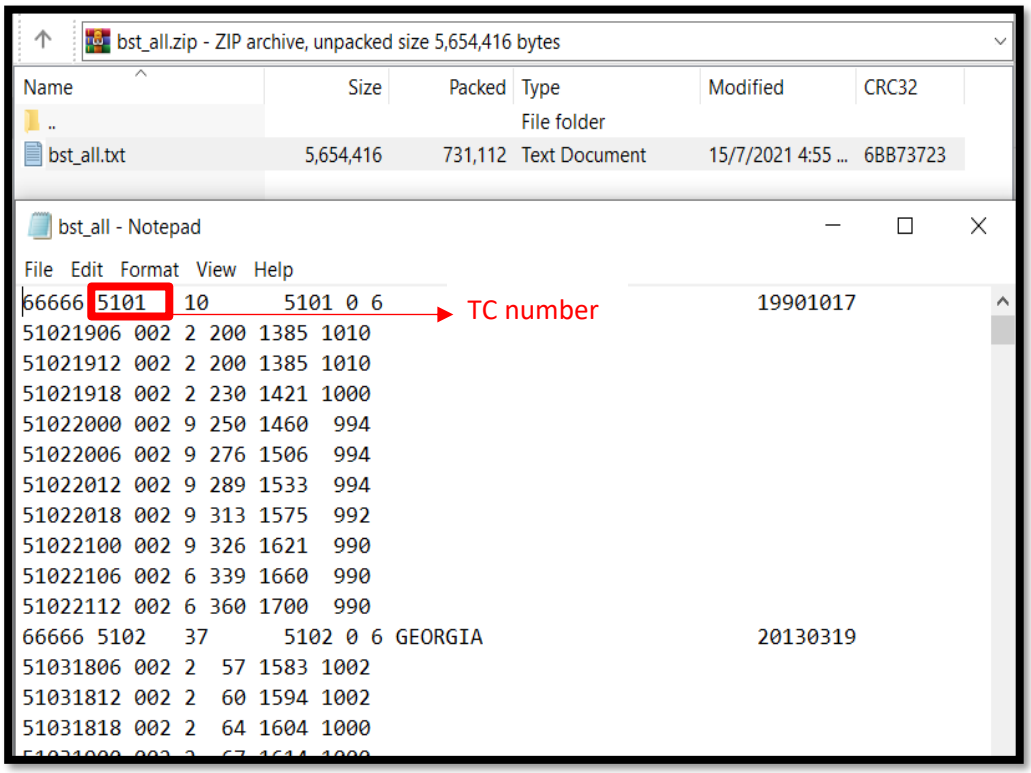
b. Open website RSMC Tokyo-Typhoon Center > Best Track Data > RSMC Best Tack Data (Text) or by clicking this link https://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/besttrack.html

c. Download 1951-2021 (ALL) [715kB] zip compressed and extract the file



d. These files include the following analysed values:

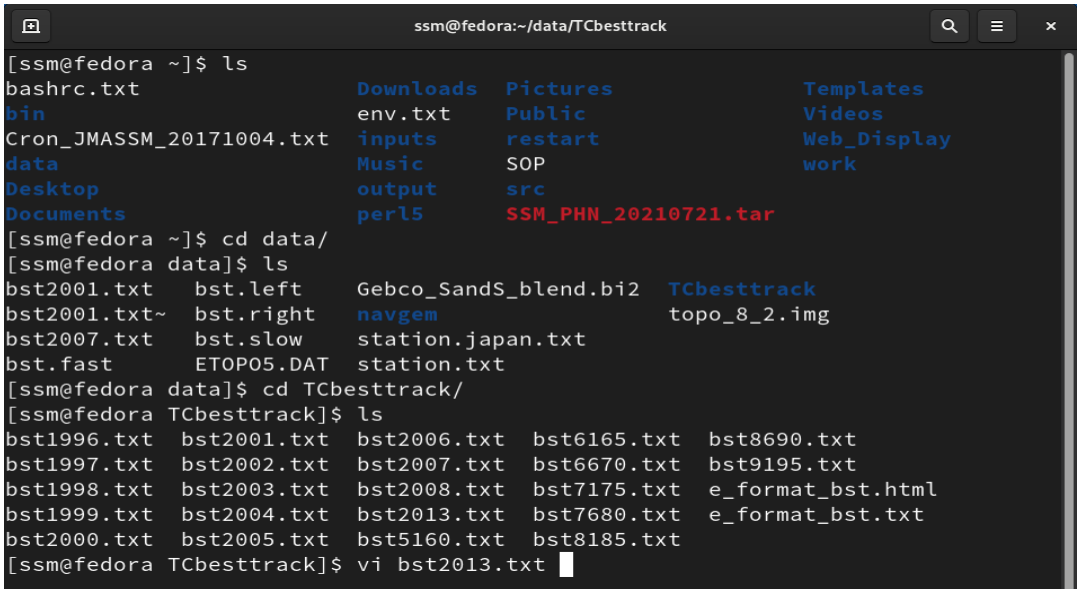
i. Position of TC
ii. Minimum pressure
iii. Maximum wind
iv. Radius of 50kt wind
v. Radius of 30kt wind



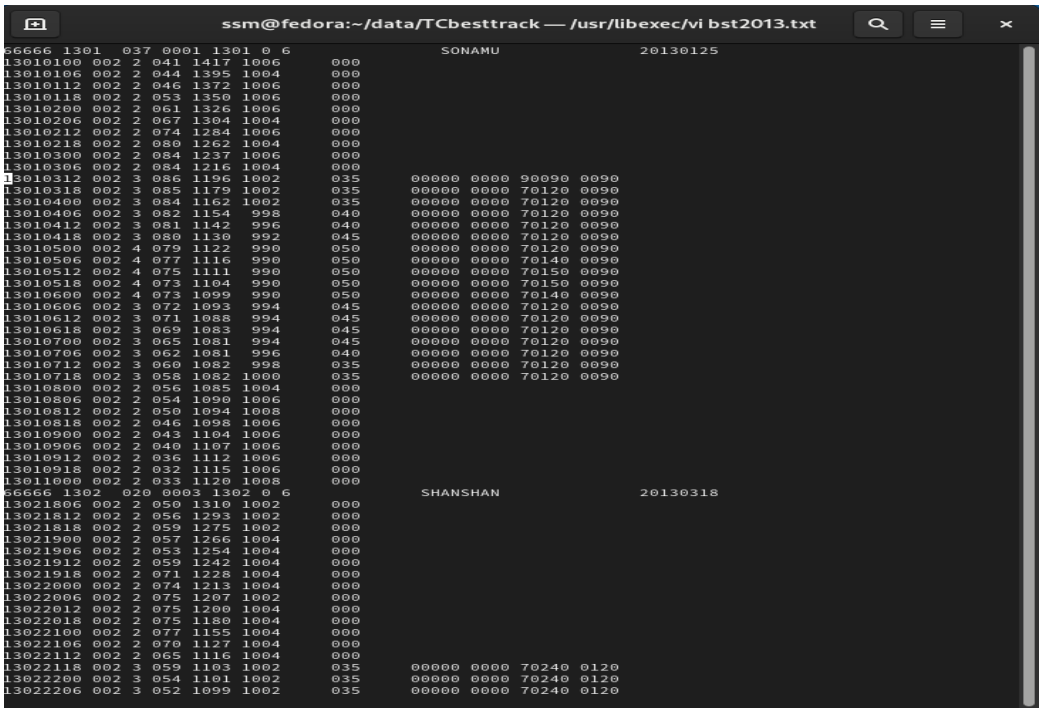
e. Select the data by year such as in year **2013** and paste into the new file create '**bst2013.txt'** inside the folder data > TCbesttrack.

$ cd data/TCbesttrack/ : change directory to TCbesttrack

$ vi bst2013.txt : create file bst2013.txt

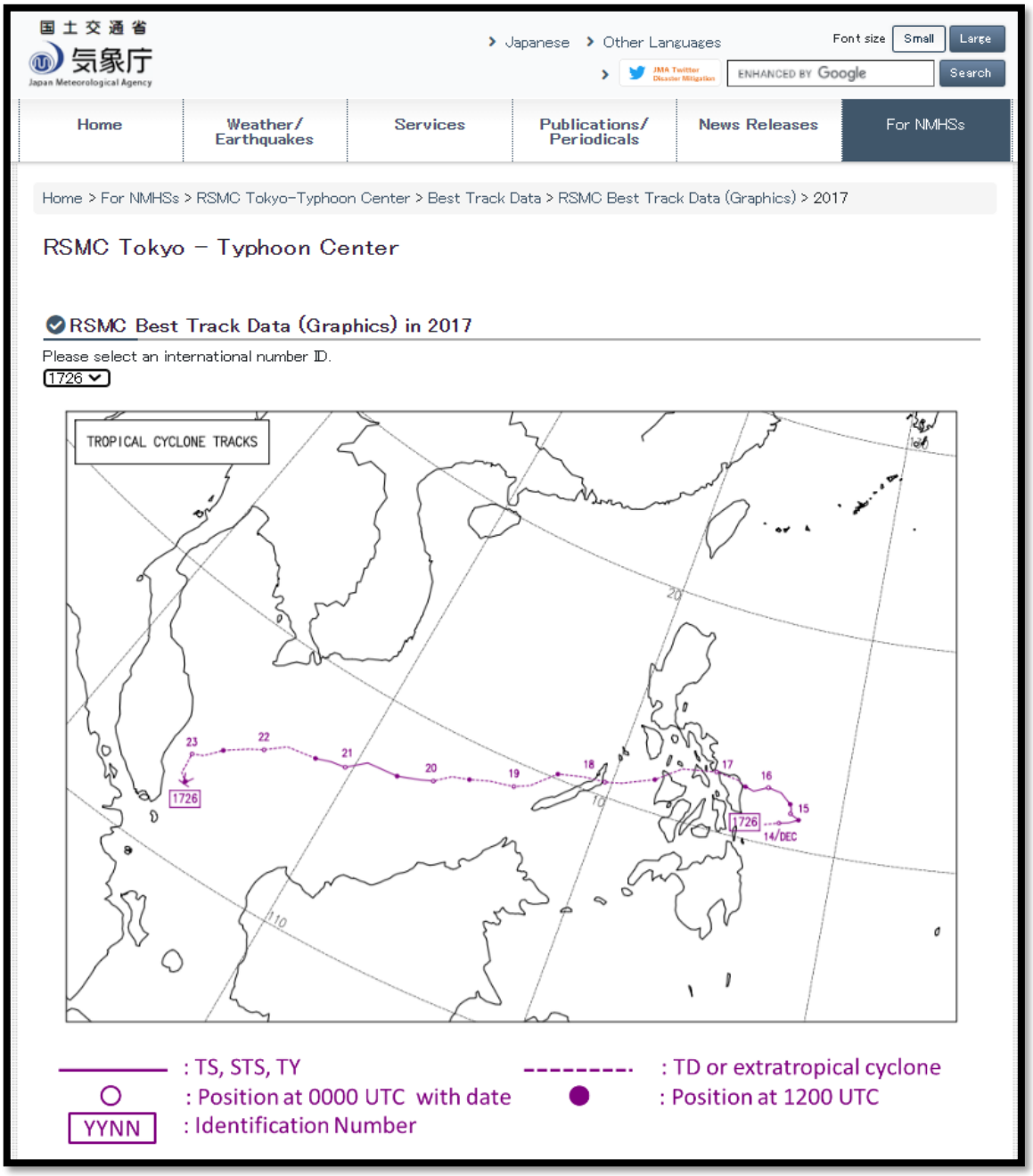


f. Push button 'i' to insert any numbers of letters in the file. Paste of selected 2013 data into the file bst2013.txt



g. Press 'esc' and then type ':wq!' to save and quit file. Back to TCbestrack directories.

h. Note: We just create data in bst.txt by year chosen where the most Tropical Cyclone (TC) nearest to Malaysia or where the possibility of impacting our sea is high. We can track the movement of the TC base on graphic at link https://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/bstve_2013_m.html. From here we can choose which TC is closer to Malaysia and then we could select the data base on the TC year and name the parameter file.in with the name of TC.



Example of Graphics Data of Tropical Storm Kai-Tak (1726)

$ cd : Change directory back to home

4.3 Download NAVGEM Data from usgoae.org

a. The Global Ocean Data Assimilation Experiment (GODAE) is a practical demonstration of near-real-time, global ocean data assimilation that provides, regular, complete descriptions of the temperature, salinity and velocity structures of the ocean in support of operational oceanography, seasonal-to-decadal climate forecasts and analyses, and oceanographic research. The GODAE Monterey Server, sponsored mainly by the Office of Naval Research (ONR), is intended to be a principal node in the GODAE architecture.

b. Navy Global Environmental Model (NAVGEM) is a global numerical weather prediction computer model with four times daily global forcing fields from the US Navy NAVGEM model. Format: GRIB.

c. From here we will download 60 times of uwind data, 60 times of vwind and 60 times of mean sea level pressure (mslp).

$ cd bin/ : change directory to bin

$ manual_ftp_NAVGEM.sh 2021072000 : insert the date of which day we want to download the data of uwind, vwind and mslp from

```
2021
For PHN-RMN Usage ONLY!
This is a Storm Surge Computation from Static condition...
Directory /home/ssm/data/navgem/2021072000 exists
Do you want download the 2021072000 data? <y/n----case sensitive>y
Set of data to be downloaded is 2021072000
ftp://anonymous:mat%40met.gov.my@199.9.2.160/pub/outgoing/fnmoc/models/navgem_0.5/2021/2021072000
```

usgodae.org

d. Click ‘y’ to download the data and to view the NAVGEM data which has been downloaded.

$ cd ../data/navgem : change directory to navgem
$ ls : to view list of file

It will appear the file with date where we choose the data to be downloaded. Then insert of the date file there should be 183 file of data which has been downloaded

$ cd 2021072000 : change directory to file date <yyyymmddhh>

$ ls : to view list of file in <yyyymmsdhh> directories

```
jma_surge.grb
US058GMET-GR1mdl.0018_0056_09000F0RL2021072000_0105_000100-000000wnd_vcmp
US058GMET-GR1mdl.0018_0056_00000F0RL2021072000_0105_000100-000000wnd_ucmp
US058GMET-GR1mdl.0018_0056_09300F0RL2021072000_0102_000000-000000pres_msl
US058GMET-GR1mdl.0018_0056_00000F0RL2021072000_0105_000100-000000wnd_vcmp
US058GMET-GR1mdl.0018_0056_09300F0RL2021072000_0105_000100-000000wnd_ucmp
US058GMET-GR1mdl.0018_0056_00300F0RL2021072000_0102_000000-000000pres_msl
US058GMET-GR1mdl.0018_0056_09300F0RL2021072000_0105_000100-000000wnd_vcmp
```

$ ls US* -1|wc -l : to check the amount of the data is 183 file

$ cat US* > jma_surge.grb : to get all the data of 60 x ucmp, 60 x vcmp and 60 x mlp into the jma_surge,grb file.

$ cd : Change directory back to home

4.4 Parameter File

a. Parameter file to run SSM with RSMC Best Track Data input.

b. Specify the period of model run, model area, the names of files to be used in this file.

$ cd input/ : change directory to *input/*

$ vi Pabuk.in : create file .in with name of Tropical Cyclone we choose to be run.

c. Parameters necessary for a model run with TC Best Track Data to be insert of "**Pabuk.in**"

Push button 'i' to insert all the text below:

```
&N_PARM

IT_BGN = 2013092100
IT_END = 2013092600
INTMET = 10
INTSRG = 60
DT     = 10.
LAT_S =   0.
LAT_N =  20.
LON_W =  93.
LON_E = 122.
DLON  =   1.
DLAT  =   1.
N_TYPH = 1320
/
```

Press 'esc' and then type ':wq!' to save and quit file. Back to input file directories.

TYNAME : the name of the typhoon concerned.

IT_BGN : the start time of this model run in the format of YYYYMMDDHH where YYYY, MM, DD, HH indicate year, month, date of month and hour in UTC, respectively. This time should be more than 24 hours earlier than the landing of the target typhoon for spin-up of the model.

IT_END : the end time of the model run.

DT: : time step of numerical integration [seconds], default = 8 seconds. The appropriate value for this variable depends on the horizontal resolution. As the resolution of current version of the model is fixed to 2 minutes, users should specify 20 seconds in a usual case.

LAT_N, LAT_S : the northern and southern limit of the model area. These values must be within the range of -15 (15 S) to 50 (50 N).

LON_W, LON_E : the western and the eastern limit of the model area. These values must be within the range of 85-155 (E).

N_TYPH : the serial number of the typhoon concerned

4.5 **Bathymetry**

a. Bathymetric data are obtained from open source where we can download directly from NOAA or GEBCO website or from the link https://topex.ucsd.edu/WWW_html/mar_topo.html. Data values are in whole meters representing the elevation of the CENTER of each cell.

b. Global Digital Elevation Model (ETOPO1) is a 1 arc-minute global relief model of Earth's surface that integrates land topography and ocean bathymetry. Horizontal datum: WGS 84 geographic. Vertical datum: sea level. More specific vertical datums, such as mean sea level, mean high water, and mean low water, differ by less than the vertical accuracy of ETOPO1 (~10 meters at best), and are therefore effectively equivalent.

c. Global Digital Elevation Model (ETOPO2) represents gridded (2 minute by 2 minute) elevation and bathymetry for the world. These data were derived from the National Geophysical Data Center (NGDC) ETOPO2 Global 2 Elevations data set from September 2001.Bathymetric data are obtained from the Smith and Sandwell 2 minute bathymetry data.

d. Earth topography five-minute grid (ETOPO5) is a gridded data base of worldwide elevations derived from several sources at a resolution of 5 minutes of latitude and longitude. Data are also available for on-line searching through the NGDC server at URL https://www.ngdc.noaa.gov/mgg/global/global.html.

e. Data downloaded (.dat) will be put it into the *ssm/data* directory.

4.6 Station File

a. This file is used to specify the locations at which time series of calculated storm surge are recorded.

b. List of station use for timeseries plot inside of folder data. Add any station but more reliable if the station is having water level recording where it can be used for data comparison. Note that the station location (latitude and longitude in degree & minute) must at least 1.8km away from land.

$ vi station.txt : insert list of station in the file station.txt created

c. Below is the sample of the station file. A line starting with "#" is regarded as comment. Users can add locations by specifying the name, latitude and longitude of the location. (The other parameters are not necessary). When a point is located on land area or outside of the model area, it will be disregarded.

Push button 'i' to insert all the station

```
# station list derived from the UHSLC JASL sea level archive
#                                          lati.  long.
033A Pxxx 069  Bitung           Indonesia   01-26N 125-12E 1986-1990
320A Pxxx 293  Cendering        Malaysia    05-16N 103-11E 1984-2006
321A Pxxx xxx  Johor Baharu     Malaysia    01-28N 103-48E 1983-2006
322A Pxxx xxx  Kuantan          Malaysia    03-59N 103-26E 1983-2006
323A Pxxx xxx  Tioman           Malaysia    02-48N 104-08E 1985-2006
324A Pxxx xxx  Sedili           Malaysia    01-56N 104-07E 1986-2006
325A Pxxx xxx  Kukup            Malaysia    01-20N 103-27E 1985-2006
326A Pxxx xxx  Geting           Malaysia    06-14N 102-06E 1986-2006
327A Pxxx 044  Keppel Harbour   Singapore   01-16N 103-49E 1981-1990
328A Pxxx 039  Ko Lak           Thailand    11-48N 099-49E 1985-2002
               Lam Sing         Thailand    12-28N 102-04E
               Ko Matapon       Thailand    10-27N  99-15E
329B Pxxx 077  Hong Kong        China       22-18N 114-13E 1986-2000
337A Pxxx 044  Victoria Dock    Singapore   01-16N 103-49E 1972-1981
340A Pxxx xxx  Kaohsiung        Rep. of China 22-37N 120-18E 1980-1999
341A Pxxx xxx  Keelung          Rep. of China 25-09N 121-45E 1980-1999
370A Pxxx 073  Manila           Philippines 14-35N 120-58E 1984-1997
371A Pxxx 072  Legaspi          Philippines 13-09N 123-45E 1984-1997
372A Pxxx 071  Davao            Philippines 07-05N 125-38E 1984-1997
373A Pxxx 070  Jolo             Philippines 06-04N 121-00E 1984-1995
376A Pxxx 247  Xiamen           China       24-27N 118-04E 1954-1997
385A Pxxx xxx  Tawau            Malaysia    04-14N 117-53E 1987-2006
386A Pxxx xxx  Kota Kinabalu    Malaysia    05-59N 116-04E 1987-2006
387A Pxxx xxx  Bintulu          Malaysia    03-15N 113-03E 1992-2006
388A Pxxx xxx  Miri             Malaysia    04-24N 113-58E 1992-2006
               OFB              Malaysia    02-56N 101-00E
389A Pxxx xxx  Sandakan         Malaysia    05-49N 118-04E 1993-2006
630A Pxxx 079  Dalian           China       38-56N 121-40E 1975-1990
631A Pxxx 079  Laohutan         China       38-52N 121-41E 1991-1997
632A Pxxx 094  Kanmen           China       28-05N 121-17E 1975-1997
633A Pxxx 283  Lusi             China       32-08N 121-37E 1975-1996
635A Pxxx 078  Zhapo            China       21-35N 111-50E 1975-1997
636A Pxxx xxx  Beihai           China       21-29N 109-05E 1975-1997
637A Pxxx xxx  Dongfang         China       19-06N 108-37E 1975-1997
638A Pxxx xxx  Haikou           China       20-01N 110-17E 1976-1997
639A Pxxx xxx  Lianyungang      China       34-45N 119-25E 1975-1997
641A Pxxx xxx  Shanwei          China       22-45N 115-21E 1975-1997
642A Pxxx xxx  Shijiusuo        China       35-23N 119-33E 1975-1997
650B Pxxx xxx  Hon Dau          Vietnam     20-40N 106-49E 1995-1995
651A Pxxx xxx  Vung Ang         Vietnam     18-05N 106-17E 1996-1997
652A Pxxx xxx  Vung Tau         Vietnam     10-20N 107-04E 1992-1992
699A Pxxx 044  Tanjong Pagar    Singapore   01-16N 103-51E 1988-2001
107A Ixxx 045  Padang           Indonesia   01-00S 100-22E 1986-1990
134A Ixxx xxx  Hiron Point      Bangladesh  21-47N 089-28E 1977-2000
135A Ixxx xxx  Khal #10         Bangladesh  22-16N 091-49E 1983-1992
136A Ixxx xxx  Cox's Bazaar     Bangladesh  21-27N 091-50E 1983-2000
137A Ixxx xxx  Teknaf           Bangladesh  20-53N 092-18E 1983-1988
138A Ixxx 036  Charchanga       Bangladesh  22-13N 091-03E 1980-2000
139A Ixxx xxx  Khepupara        Bangladesh  21-50N 089-50E 1987-2000
140A Ixxx xxx  Kelang           Malaysia    03-03N 101-22E 1983-2001
141A Ixxx xxx  Keling           Malaysia    02-13N 102-09E 1984-2001
142A Ixxx xxx  Langkawi         Malaysia    06-26N 099-46E 1985-2001
143A Ixxx 043  Lumut            Malaysia    04-14N 100-37E 1984-2001
144A Ixxx xxx  Penang           Malaysia    05-25N 100-21E 1984-2001
148A Ixxx 042  Ko Taphao Noi    Thailand    07-50N 098-26E 1985-2002
158A Ixxx xxx  Meneng           Indonesia   08-07S 114-23E 1987-1989
159A Ixxx xxx  Pari             Indonesia   05-51S 106-37E 1987-1990
160A Ixxx 292  Surabaya         Indonesia   07-13S 112-44E 1988-1990
161A Ixxx xxx  Jakarta          Indonesia   06-06S 106-53E 1984-1985
163A Ixxx 049  Benoa            Indonesia   08-45S 115-13E 1988-1990
```

Press 'esc' and then type ':wq!' to save and quit file. Back to input file directories.

$ cd : Change directory back to home

5.0 POST PROCESSING

We may choose which type of run SSM we would like to execute base on below steps.

5.1 Run SSM with RSMC Best Track data

$ cd bin/ : change directory to *bin/*

$ bst.job ~/inputs/Pabuk.in : execute JMA SSM mode using the Best Track Data. Insert the which file (.in) we want to run inside the input directory where we have made before in parameter prepare.

The program will run the SSM and shown as script below:

```
Creating new directory for BST output.....
Entering Output directory.....
********** mktopo **********
 make a topography file topo.dat for storm surge model
berjaya topo!!!
 ********* JMA-MetMalsysia Storm Surge Model *********
 read Sea Bottom Topography Data
 read Station List
 read TC best track file
  TY 0126 found in this best track file.
  time(UTC)    R0 [m]       Coef          Dp [Pa]
  2001122612   5003.0518    0.89999998    300.00000
  2001122618   5003.0518    0.89999998    300.00000
  2001122700   72000.000     1.3973582    500.00000
  2001122706   54000.000     1.4079193    700.00000
  2001122712   100000.00     1.2891532    500.00000
  2001122718   5003.0518    0.89999998    300.00000
  2001122800   5003.0518    0.89999998    300.00000
 start Storm Surge Computation
  period = 2013/09/21 12:00 - 2013/09/26 00:00
  time   = 2013/09/24 12:00
  time   = 2013/09/24 13:00
  time   = 2013/09/24 14:00
  time   = 2013/09/25 20:00
  time   = 2013/09/25 21:00
  time   = 2013/09/25 22:00
  time   = 2013/09/25 23:00
  time   = 2013/09/26 00:00
 The storm surge model exits successfully.
real    3m56.525s
user    3m55.537s
sys     0m0.986s
gribmap: opening GRIB file jma_ssm.grb
gribmap: reached end of files
gribmap: writing the GRIB1 index file (version 5)
Drawing maps.....
           Welcome to the OpenGrADS Bundle Distribution
           -------------------------------------------
For additional information enter "grads --manual".
Starting "/opt/opengrads/Contents/Linux/Versions/2.2.1.oga.1/x86_64/grads  -blc 'run /home/ssm/bin/surge.gs' " ...
Grid Analysis and Display System (GrADS) Version 2.2.1.oga.1
Copyright (C) 1988-2018 by George Mason University
GrADS comes with ABSOLUTELY NO WARRANTY
See file COPYRIGHT for more information
Config: v2.2.1.oga.1 little-endian readline grib2 netcdf hdf4-sds hdf5 opendap-grids,stn athena geotiff shapefile
Issue 'q config' and 'q gxconfig' commands for more detailed configuration information
Loading User Defined Extensions table </opt/opengrads/Contents/Linux/Versions/2.2.1.oga.1/x86_64/gex/udxt> ... ok.
GX Package Initialization: Size = 11 8.5
Running in Batch mode
GX Package Terminated
Drawing timeseries.....
```

$ cd : change directory back to home

5.2 Run with NAVGEM data

$ cd bin/ : change directory to *bin/*

$ Adhoc_ssm.sh 2021072000 : execute JMA SSM using NAVGEM data by inserting the same date of data downloaded.

$ cd : change directory back to home

5.3 Creating a restart filed for a continuous run

$ cd bin/ : change directory to *bin/*

$ restart_12_ssm.sh 20210720 : run for 12-hour output to create as a restart field for continuous run and the file created save in restart directory

$ cd : change directory back to home

5.4 Run SSM from zero condition state

$ cd bin/ : change directory to *bin/*

$ Adhoc_ssm_cold 20210720 : execute JMA SSM from zero state

$ cd : change directory back to home

5.5 Run SSM with continuous restart filed

$ cd bin/ : change directory to *bin/*

$ Adhoc_ssm_Hot 20210720 : execute JMA SSM from previous restart filed which has been created insert of restart directory

$ cd : change directory back to home

5.6 Created auto run by crontab

To run the program of SSM automatically, the crontab need to be set up.

$ crontab -e : execute auto run file base on time set (min hour day month day of week)

insert all the script below: (Find the directories location of GADDIR, GASCRP and PATH exit after completing.

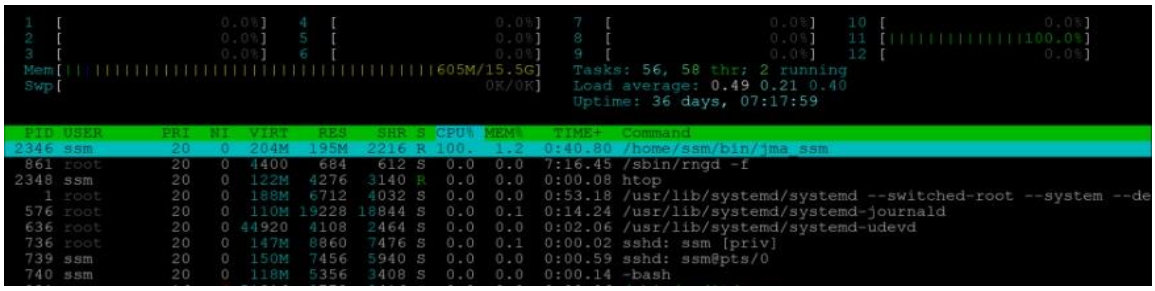
```
GADDIR=/opt/opengrads/Contents/Resources/SupportData
GASCRP=/opt/opengrads/Contents/Resources/Scripts
PATH=/home/ssm/perl5/bin:/usr/local/bin:/usr/bin:/usr/local/sbin:/usr/sbin:.:..:/opt/opengrads/Contents:/home/ssm/.local/bin:/home/ssm/bin
#
#
50 05,07,11,15,19,23  * * * /home/ssm/bin/auto_ssm_run.sh > /home/ssm/bin/auto_ssm_run.log
```

$ crontab -e
: installing new crontab : the program will execute auto run base on time had been set in the crontab.

explanation details of the crontab format:

```
*     *     *   *    *        command to be executed
-     -     -   -    -
|     |     |   |    |
|     |     |   |    +----- day of week (0 - 6) (Sunday=0)
|     |     |   +-------- month (1 - 12)
|     |     +---------- day of        month (1 - 31)
|     +------------ hour (0 - 23)
+-------------- min (0 - 59)
```

$ htop : command line utility that allows the user to interactively monitor the server's processes in real time so that we can confirm check our crontab successfully run by the time set



5.7 Auto run by getting the data from the server on any date selected by user

$ cd bin/ : change directory to *bin/*

$ Sejuk_WGET_NAVGEM.sh 20210720 : execute auto run SSM computation from static condition on the selected date by getting a NAVGEM data from server and created a restart field for next continuous run

$ cd : change directory back to home

5.8 Auto run by downloading the data from usgodae.org on any date selected by user

$ cd bin/ : change directory to *bin/*

$ Sejuk_WGET_NAVGEM.sh 20210720 : execute auto run SSM computation from static condition on the selected date by downloading NAVGEM data from usgodae.org website and created a restart field for next continuous run

$ cd : change directory back to home

6.0 OUTPUT CHECK

6.1 Output Files

The model outputs a GRIB file including storm surge for a given interval and a file of sea level anomaly time-series for locations specified by an input file. When you use the script “ssm_run.sh”, this script makes a working directory and the model outputs are put into this working directory. The following files will be made in the working directory:

work.DD_HHMMSS/	: working directory (DD_HHMMSS means date and time)
jma_ssm.grb	: GRIB output containing calculated storm surge fields
jma_ssm.out	: text output including constants and time-series

The script “ssm_run.sh” also creates files required for GrADS to access the GRIB output.

jma_ssm.ctl	: GrADS control file
jma_ssm.grb.idx	: GRIB index file used by GrADS

6.2 View data output from program run by RSMC Best Track Data input

$ cd output/BST/ : change directory to *BST/*

$ ls -lrta : to view list of file and sort by date and time

```
$ ls -lrta
total 4
drwxrwxr-x  2 ssm ssm    6 Jul 21 15:21 work.21_1521
drwxrwxr-x  3 ssm ssm   17 Jul 21 15:21 ..
drwxrwxr-x  2 ssm ssm  122 Jul 21 15:22 work.21_1522
drwxrwxr-x  2 ssm ssm  122 Jul 21 15:37 work.21_1537
drwxrwxr-x  4 ssm ssm  158 Jul 21 16:06 work.21_1548
drwxrwxr-x  4 ssm ssm  124 Jul 28 14:38 work.28_1438
drwxrwxr-x  4 ssm ssm  157 Jul 28 14:52 work.28_1448
drwxrwxr-x 29 ssm ssm 4096 Jul 28 15:20 .
drwxrwxr-x  4 ssm ssm  159 Jul 28 15:29 work.28_1520
```

$ cd work.28_1520/ : select the lastest file created work.28_1520

$ ls : list file in directories work.28_1520

```
$ ls
Pabuk.in  fn  jma_ssm.ctl  jma_ssm.grb  jma_ssm.grb.idx  jma_ssm.out  map  timeseries  topo.dat
```

$ cd map/ : change directory to *map/*
$ ls : list file in directories map

```
$ ls
surge001.png  surge005.png  surge009.png  surge013.png  surge017.png  surge021.png  surge025.png
surge029.png  surge033.png  surge037.png surge002.png  surge006.png  surge010.png  surge014.png
surge018.png  surge022.png  surge026.png  surge030.png  surge034.png surge003.png  surge007.png
surge011.png  surge015.png  surge019.png  surge023.png  surge027.png  surge031.png  surge035.png
surge004.png  surge008.png  surge012.png  surge016.png  surge020.png  surge024.png  surge028.png
```

$ eog surge130.png : view the image created by selecting any file.png

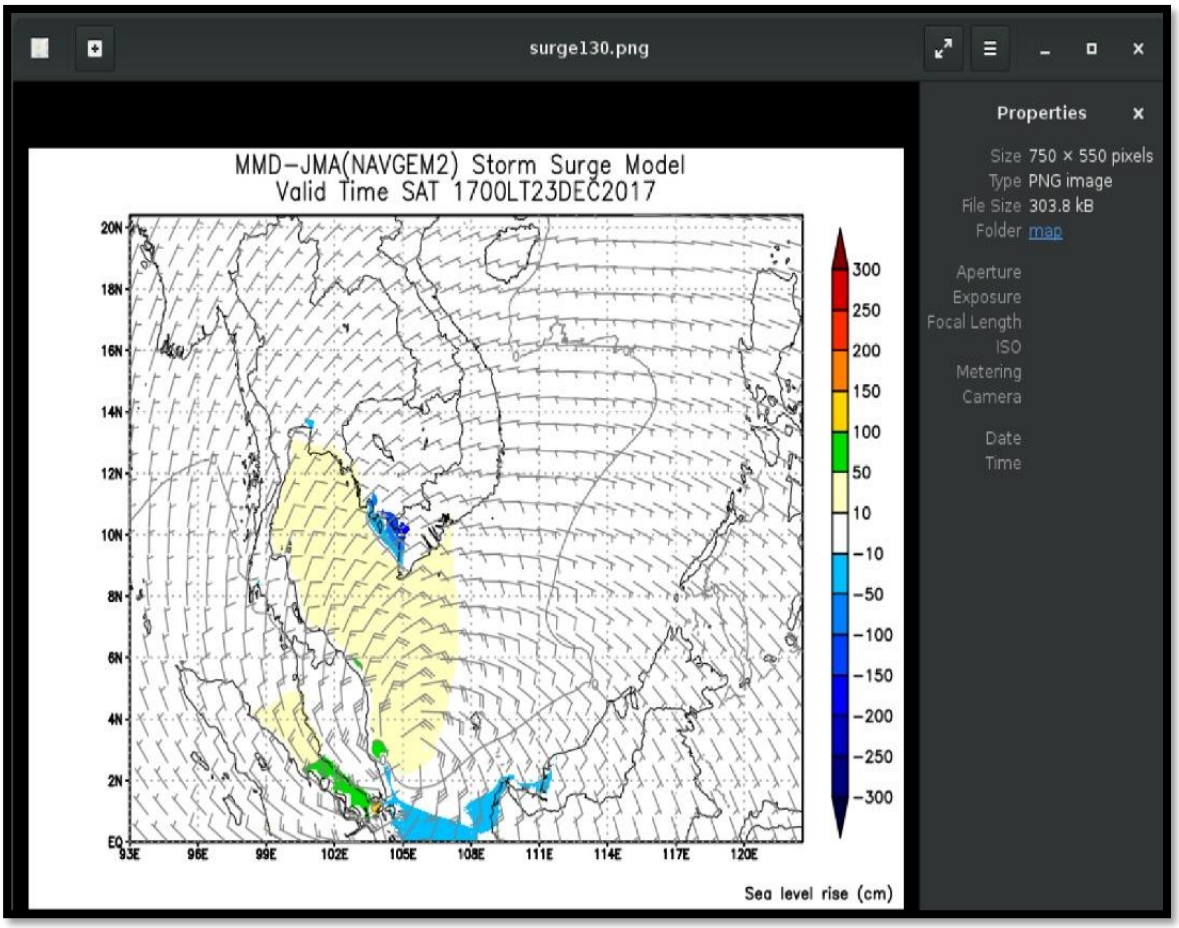


Figure 1: Sea Level Rise Map in Centimetre (cm)

$ cd ../timeseries : change directory to timeseries

$ ls : list file in directories timeseries to view the png and txt file

```
$ ls
10.png  11.txt  13.png  14.txt  16.png  17.txt  19.png  1.txt   21.png  22.txt  24.png  25.txt  27.png  28.txt
3.png  4.txt  6.png  7.txt  9.png 10.txt  12.png  13.txt  15.png  16.txt  18.png  19.txt  20.png  21.txt  23.png
24.txt  26.png  27.txt  2.png   3.txt  5.png  6.txt  8.png  9.txt 11.png  12.txt  14.png  15.txt  17.png  18.txt
1.png   20.txt  22.png  23.txt  25.png  26.txt  28.png  2.txt   4.png  5.txt  7.png  8.txt10.txt  12.png  13.txt
15.png  16.txt  18.png  19.txt  20.png  21.txt  23.png  24.txt  26.png  27.txt
```

$ eog 5.png : view the image created by select any file.png

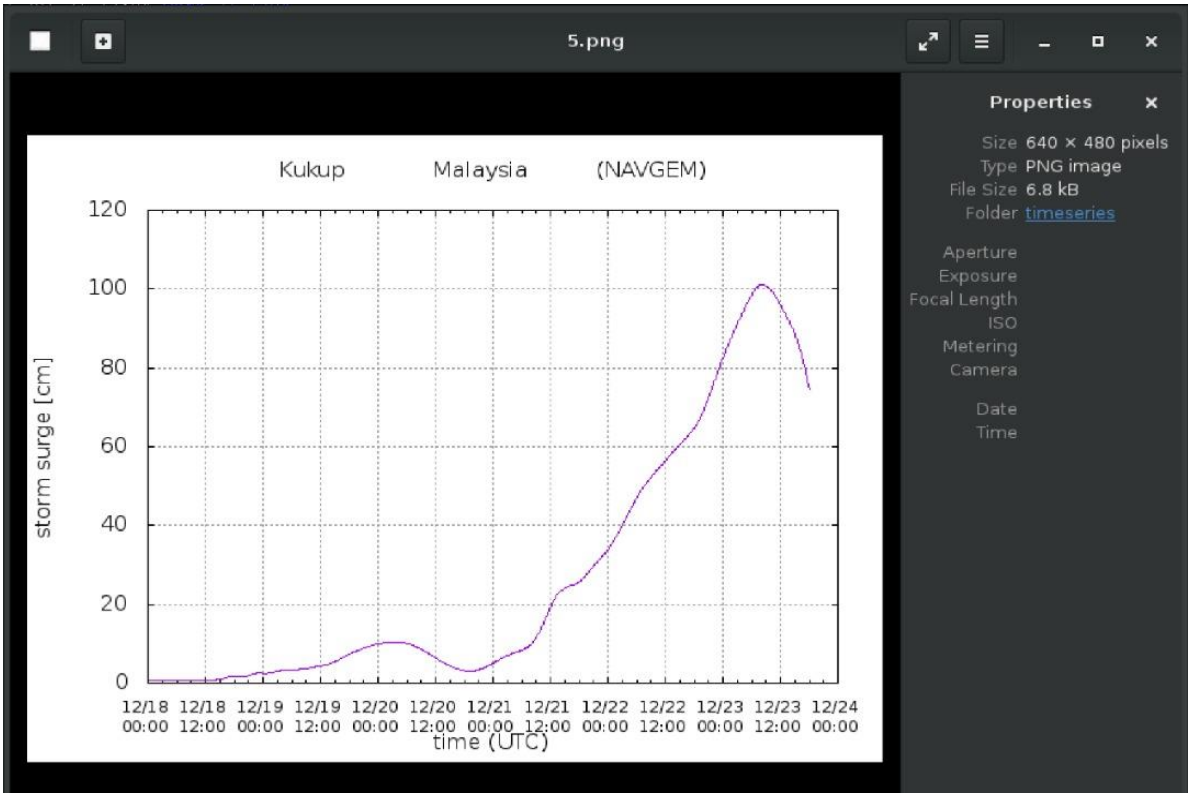


Figure 2: Time Series of Sea Level Rise at Kukup Station

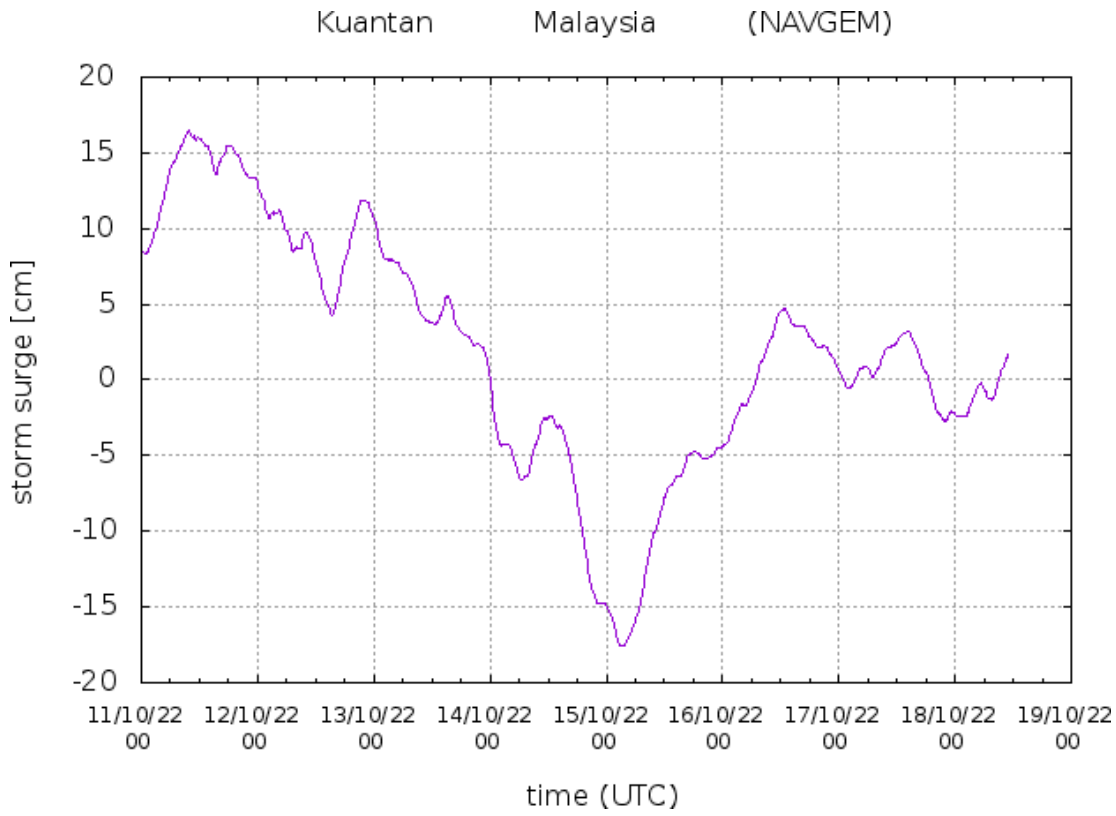


Figure 3: Time Series of Sea Level Rise at Kuantan station

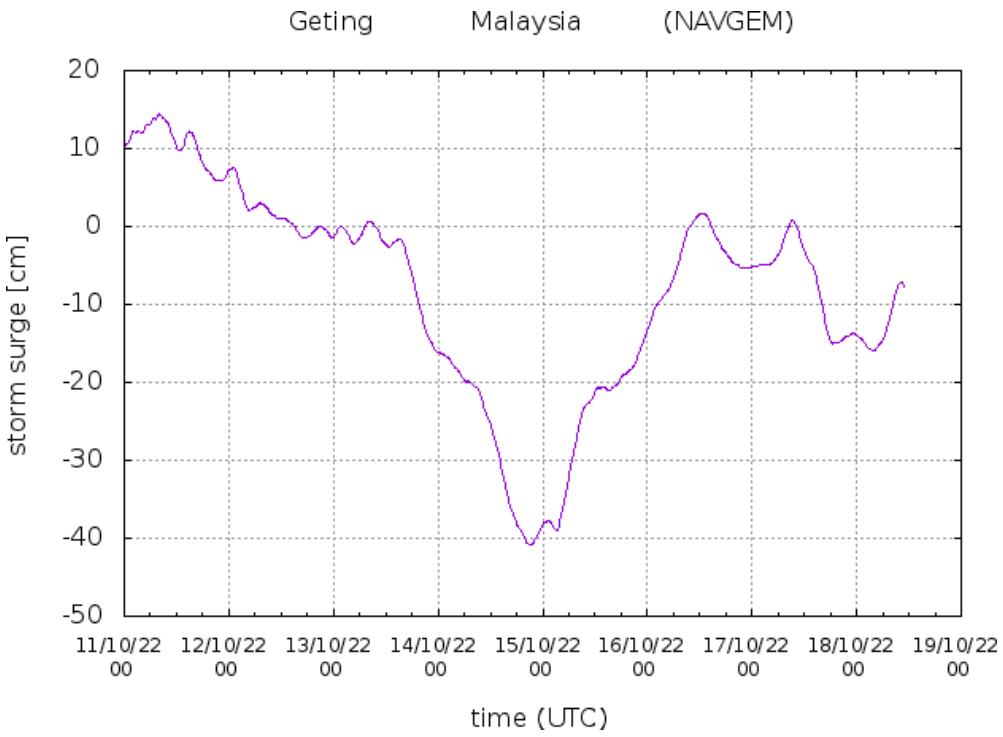


Figure 4: Time Series of Sea Level Rise at Kuantan station

Note: Check the date at the title top of the picture.

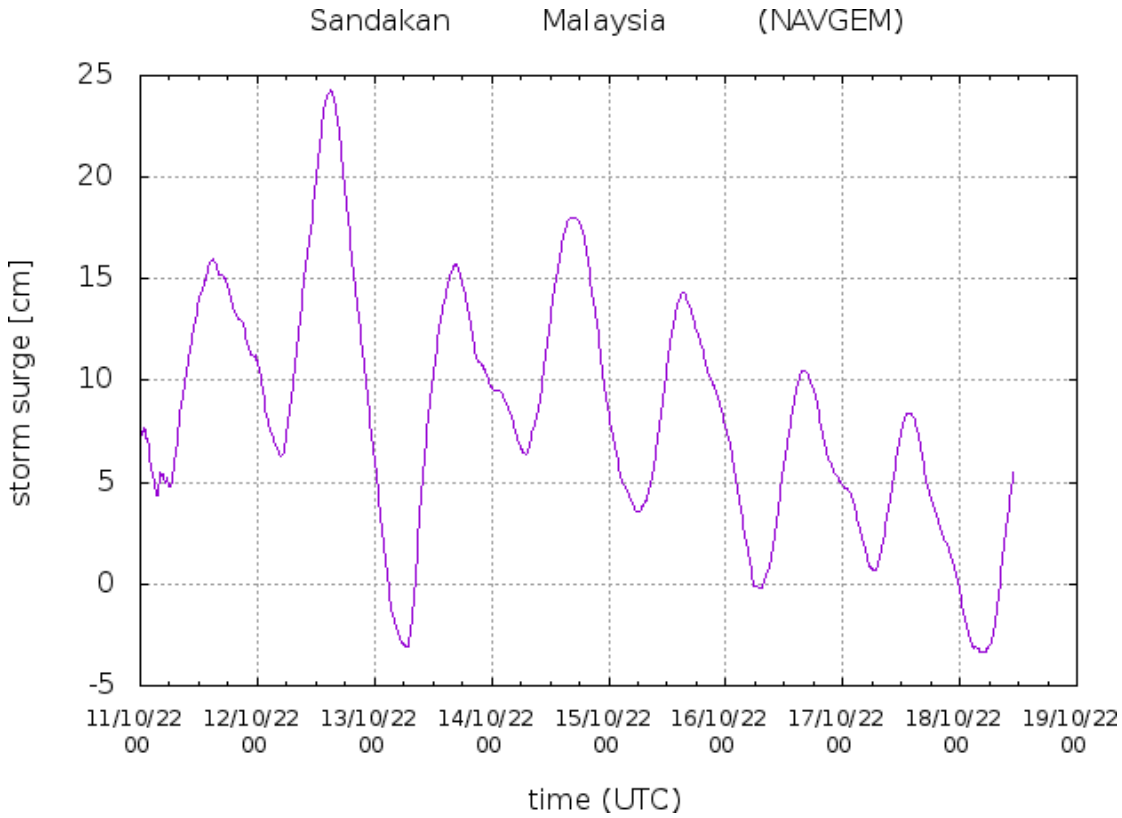


Figure 5: Time Series of Sea Level Rise at Sandakan station

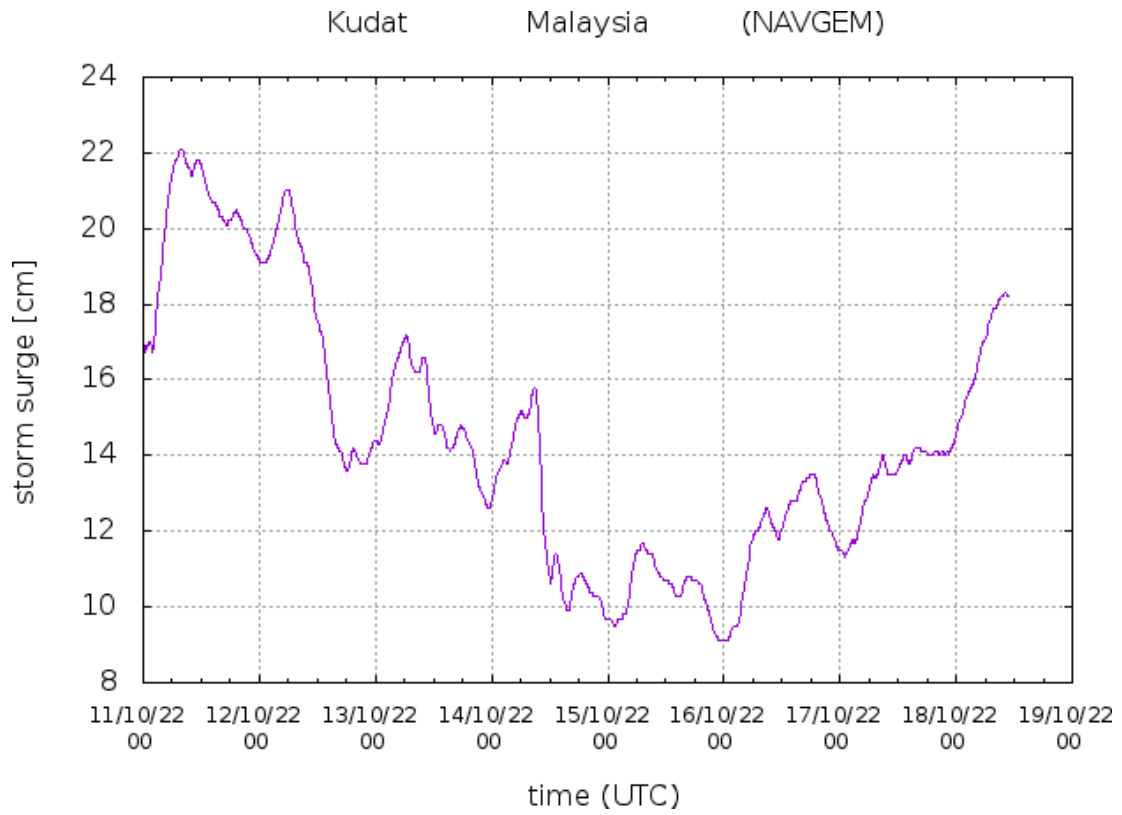


Figure 6: Time Series of Sea Level Rise at Kudat station

Note: Check the date at the title top of the picture.

$ cd : change directory back to home

6.3 View data output from program run by NAVGEM data

$ cd output/NAVGEM/	: change directory to *NAVGEM/*
$ ls	: to view list of file in NAVGEM directories
$ cd 20210720	: change directories to the date created in file yyyymmddhh
$ cd map/	: change directory to *map/*
$ ls	: list file in directories map
$ eog surge001.png	: view the image created by selecting any file.png

Note: The 3 digit number represent the number of forecast hour from the initial time

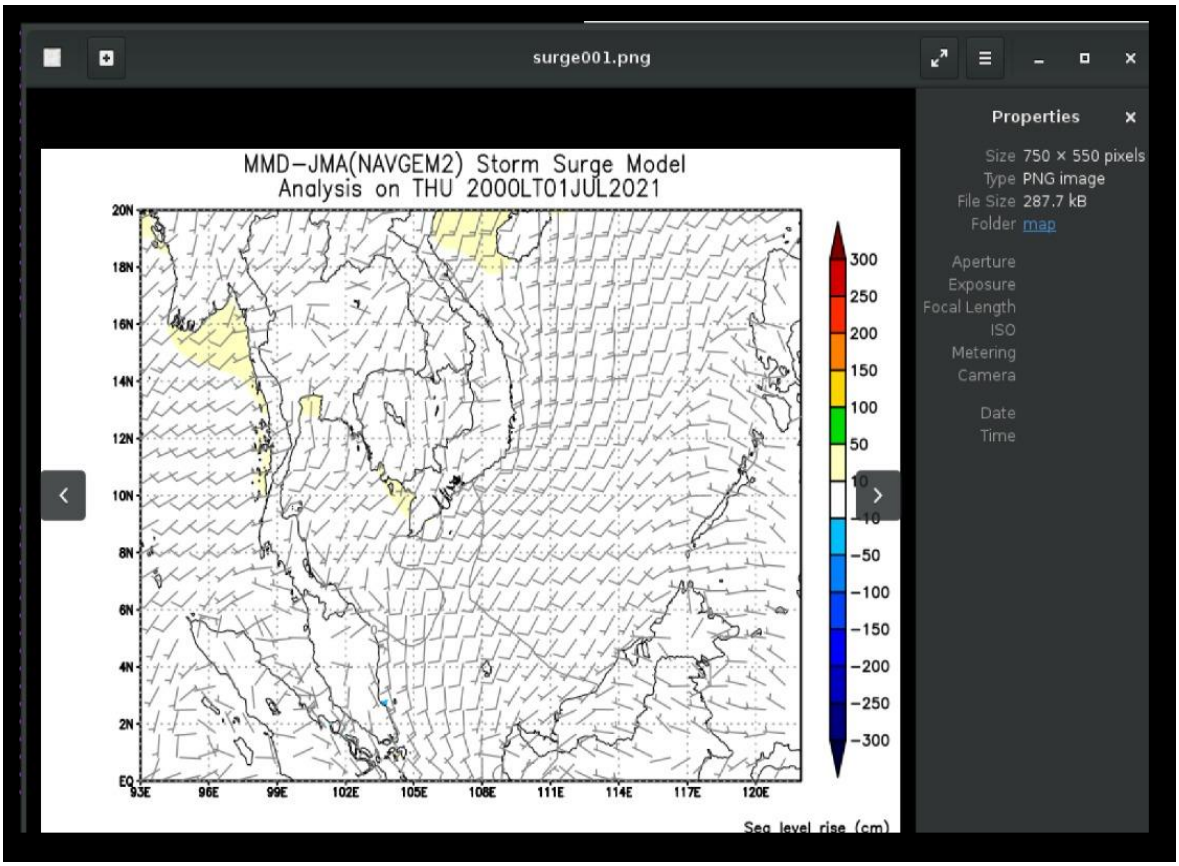


Figure 7: Sea Level Rise Map in Centimeter (cm)

$ cd ../timeseries : change directory to timeseries

$ ls : list file in directories timeseries to view the png and txt file

$ eog 15.png : view the image created by select any file.png

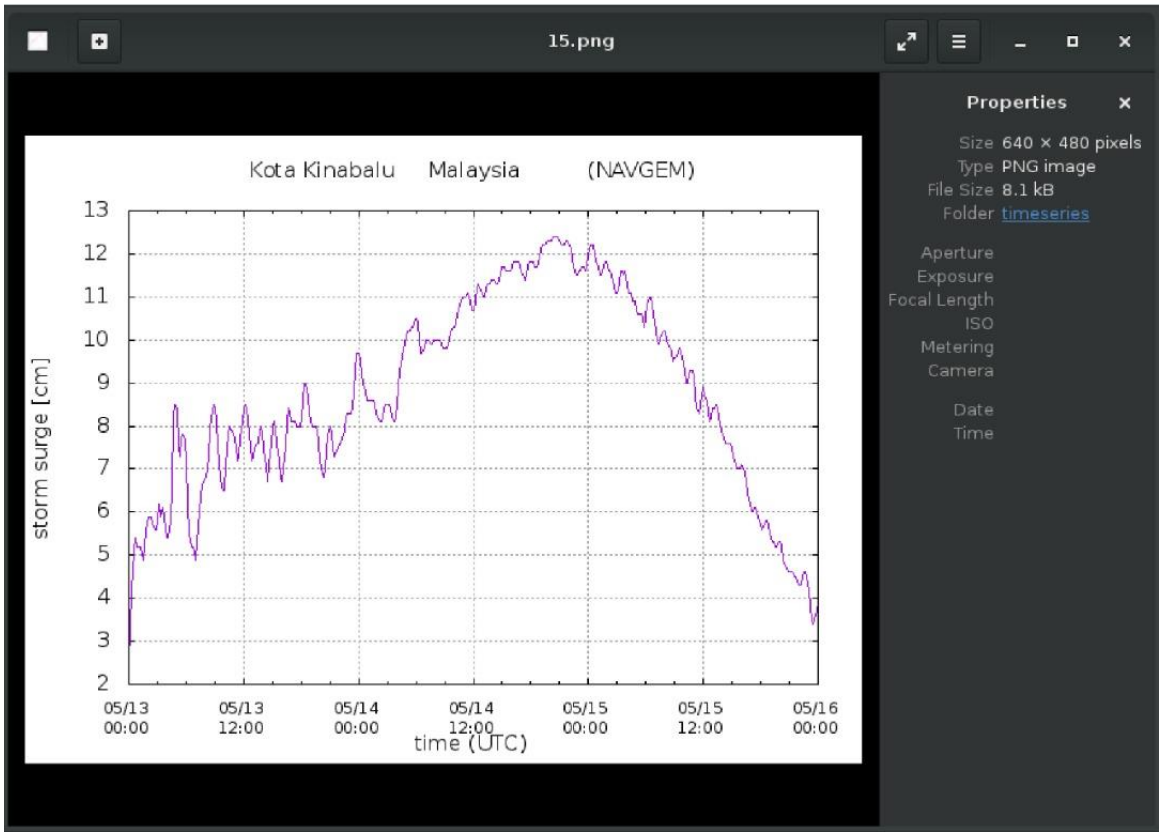


Figure 8: Time Series of Sea Level Rise at Kota Kinabalu Station

Note: Check the date at the title top of the picture.

$ cd : change directory back to home

7.0 Summary SSM Execution

7.1 Use Best Track Data (BST) Input

i. Download BST data (Text) from RSMC website and unzip the file.
ii. Create station file.txt and BST data file.txt by year in data directories. (Example: station.txt and bst2003.txt)
iii. Create file (.in) in the input directories with the format given and include the date begin, date end and TC number. (Example: Pabuk.in)
iv. Run model in bin directories. $ bst.job ~/inputs/Pabuk.in
v. Check output data inside output/BST/latest date file created/ directories.
vi. Select map or timeseries. Type eog and select the image to view the output.

7.1 Use NAVGEM Data Input

i. Download NAVGEM data in bin directories based on user choosing date.
$ manual_ftp_NAVGEM.sh 2021072000
ii. Check the data base on the date selected file inside data/navgem directories and compile all the data into the jma_surge.grb
$ cat US* > jma_surge.grb
iii. Execute by inserting the same date of data downloaded (yyyymmddhh)
$ Adhoc_ssm.sh 2021072000
iv. Check output data inside output/navgem/latest date file created/ directories.
v. Select map or timeseries. Type eog and select the image to view the output.

8.0 Reference

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