JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2017

MALAYSIA, MALAYSIAN METEROLOGICAL DEPARTMENT

1. Summary of highlights

a) NWP Models

The resolution of the NWP models has increased from 3-km to 1-km. The forecast range has increased from 5-days (120-hours) to 7-days (168-hours). Update cycle of the models have increased from twice daily (00UTC and 12UTC) to four times daily (00UTC, 06UTC, 12UTC and 18UTC). The new system was fully operational beginning JUN 2017.

b) Wave Models

Operationalized the WAM cycle 4 wave model (The WAMDI Group1988) and Japan Meteorological-Meteorological Research Institute (MRI) third generation wave model (MRI III).

c) Storm Surge Model

Operationalized the Japan Meteorological Agency (JMA) Storm Surge Model.

d) Oil Spill Model

Operationalized JMA Oil Spill model.

2. Equipment in use

a) NWP System

The current operational NWP System being used is an 8288 core LENOVO NEXTSCALE NX 360 M5 Cluster with 100 T/Flops peak performance. The specifications are given in Table 1.

Table 1(a): Hardware and Software Specifications

Hardware specifications
296 node x INTEL XEON E5-2690 BROADWELL, 2.6GHz dual 14-core processors (Total: 8288 cores)
296 X 128GB ECC memory
INTEL OMNIPATH V10.2 Interconnect
6 PB On-line storage GPFS filesystem, 10 PB off-line storage. IBM Tape Library
Operating system
Red Hat Enterprise Linux 7.2
Message Passing Interface Library
Intel Parallel Studio v17 (Intel MPI , FORTRAN , C/C++ Compilers)
Post-processing utilities
RIP
NCAR GRAPHICS
Workload management system
Altair PBS Pro 13.1
NWP models
WRF – ARW v3.9 (Non-hydrostatic mode)

b) Marine Forecasting System

Table 1(b): Hardware and Software Specifications

Hardware specifications
2 X Intel Xeon E5-2643 v3 (3.4 GHz, 20 MB cache, 6 cores)
64 GB (4X16GB) DDR4-2133 ECC RAM
12 X 300GB 12G SAS (15k rpm), support RAID 6 and RAID 1
NVIDIA Quadro K620 (2GB) Graphic Card
Operating system
Fedora Core 24
Compilers
gcc Compiler
Post-processing utilities
GrADS Version 2.1.0.oga.1
Gnuplot Version 5.0
Generic Mapping Tools data processing and display software package (GMT) Version 4.5.15
Models
WAM cycle 4
JMA – MMD MRI III Wave Model
JMA – MMD Storm Surge Model
JMA – MMD Oil Spill Trajectory Model

3. Data and Products from GTS in use

- AMDAR
- BUOY

- SHIP
- SYNOP
- PILOT
- TEMP
- SATOB
- SATEM

4. Forecasting system

4.1 System run schedule and forecasting ranges

a) NWP Model

Two runs per day at 00 UTC , 06 UTC, 12 UTC and 18UTC with forecast range of +168 hours for the deterministic forecasts of WRF-ARW (non-hydrostatic mode). The forecast intervals are hourly, 3-hourly, 6-hourly and 24-hourly.

b) Marine Models

Two runs per day at 00UTC and 12UTC with forecast range of +192 (using NCEP GFS atmospheric forecast field) and +180 hours (using NAVGEM atmospheric forecast field) for the deterministic forecasts of wave model and storm surge. JMA-MMD Oil Spill will be executed on request basis with simulation up to 72 hours based on JMA-MMD MRI III (NCEP GFS) Wave Model output. HRM and the Ensemble Prediction System are run with a forecast range of +120 hours. The forecast intervals are hourly, 3-hourly, 6-hourly and 24-hourly.

4.2 Medium range forecasting system (4 – 7 days)

a) NWP Model

1-km WRF generated by MMD and also the 30-km National Center of Environmental Prediction (NCEP) Global Forecasting System (GFS) is used for the medium range forecast.

b) Marine Models

For official forecasting purposes National Center of Environmental Prediction (NCEP) Global Forecasting System (GFS) and Navy Global Environmental Model (NAVGEM). The GFS analysis and forecast for surface wind and pressure are retrieved using Open DAP server. While FTP protocol is used to download the NAVGEM surface wind and Mean Sea Level Pressure analysis and forecast. No research is performed in this field.

4.3 Short-range forecasting system (0 – 72 hours)

-Refer Section 4.1 (NWP Model)

4.3.1 Data assimilation, objective analysis and initialization

4.3.1.1 In operation

a) NWP Model

Data Assimilation has been switched off after the increase of the boundary condition resolution by the GFS global modal from 60 to 30 km.

b) Marine Models

- Both WAM and JMA-MMD MRI III Wave Model use NCEP GFS and NAVGEM surface wind as its forcing for 192 and 180 hours wave forecast respectively.

- The WAM and JMA-MMD MRI III wave models are configured to run on 2 domains namely coarse grid and fine grid with a one-way nesting option. Both wave models domains are configured with a resolution of 0.5 degree and 0.25 degree resolution for coarse and fine grid respectively. Domain for

coarse grid is set from 75°E – 135°E and 15°S – 35°N. Domain for fine grid is from 95°E – 124°E and 5°S – 17°N.

- The time step used for the WAM model are 1,800 seconds for the coarse domain and 900 seconds for the fine domain. Time step of 1,800 is used for fine grid in JMA-MMD MRI III Wave Model and 450 seconds for its fine grid domains.

- The WAM and JMA-MMD MRI III Wave Models are configured to perform two runs per day using 00UTC and 12UTC with forecast range of +192 hours for NCEP GFS wind forecast and +180 hours when using NAVGEM wind forecast. The interval of the main surface wave product output is 3 hour.

- The JMA-MMD Storm Surge Model uses NAVGEM surface wind and Mean Sea Level Pressure forecast to simulate sea level rise up to 180 hours ahead. The model utilizes two-dimensional shallow water equation which is solved by numerical integration using an explicit finite difference method. It uses Arakawa-C grid with horizontal resolution of 1 minute arc (1 nautical mile).

- The Models domains are configured from 93°E – 122°E and 0° – 20°N. Domain for fine grid is from 95°E – 124°E and 5°S – 17°N. The time step used for the JMA-MMD Storm Surge Model is set to 4 seconds.

- The JMA-MMD Storm Surge Model are configured to perform two runs per day using 00UTC and 12UTC with forecast range of +180 hours when using NAVGEM wind and mean sea level forecast as its forcing. The interval of the sea level elevation output is 1 hour.

- The JMA-MMD Oil Spill Model uses output from JMA-MMD MRI III (with NCEP GFS forcing) wave model as its input for 72 hour simulation of an oil spill incident.

- The simulation domain calculation is set within the boundary of 5°S – 17°N and 95°E – 114°E with horizontal resolution of 0.25 degree.

- The model uses GMT plotting package in C-Shell environment for post processing.

- The JMA-MMD Oil Spill Model need incident information such as time and position of incident, oil type, flow rate of oil spill and also spill source movement information. The model also capable to produce continuous run of oil spill trajectory and properties evolution in case of longer simulation.

4.3.1.2 Research performed in this field

a) NWP Model

Case studies were performed using the Grid point Statistical Interpolation (GSI) package from NCAR to assimilate GPS data.

b) Marine Models

Performance of the Princeton Ocean Model is currently being evaluated.

4.3.2 Model

4.3.2.1 In operation

a) NWP Model

- The operational NWP model which is used is the **WRF-ARW** non- hydrostatic model static.

- The WRF models are configured to run on 3 domains with a two-way nesting option. As indicated in the **Table 2** below:-

Table 2: WRF Domain Settings

	9km-3km-1km (nesting)	
Latitude	9km Domain	-10.8177 – 18.4874 (368 grid points)
	3km Domain	-3.1180 – 10.9063 (886 gridpoints)
	1km Domain	0.6311 - 6.9401(2197 gridpoints)
Longitude	9km Domain	86.6333 – 116.3327 (368 gridpoints)
	3km Domain	94.5586 – 108.7320 (442 gridpoints)
	1km Domain	98.6068 - 104.9428 (772 gridpoints)

- The adaptive time step was used for the WRF model. 36-108 seconds for the 9-km domain, 12-36 seconds for the 3-km domain and 4-12 seconds for the 1-km domain.
- The WRF model uses the initial and boundary data from the National Centers for Environmental Prediction Global Forecast System (NCEP GFS) at a resolution of 0.25° X 0.25° with an auxiliary initial and boundary data from JMA GSM at a resolution of 0.25° X 0.25°.
- The WRF model are configured to perform four runs per day at 00UTC, 06 UTC, 12 UTC and 18UTC with forecast range of +168 hours. The interval of the main NWP product output is 1 hour.

- **WRF-ARW** non-hydrostatic model is configured with 51 vertical levels. The cumulus parameterization schemes used are new Tiedtke for the 9-km and 3-km domain and explicit for the 1-km domain. The cloud microphysics options used are the Thompson scheme and the PBL scheme used is the Yonsei University (YSU) scheme.

b) Marine Models

- Both WAM and JMA-MMD MRI III Wave Model use NCEP GFS and NAVGEM surface wind as its forcing for 192 and 180 hours wave forecast respectively.

- The WAM and JMA-MMD MRI III wave models are configured to run on 2 domains namely coarse grid and fine grid with a one-way nesting option. Both wave models domains are configured with a resolution of 0.5 degree and 0.25 degree resolution for coarse and fine grid respectively. Domain for coarse grid is set from 75°E – 135°E and 15°S – 35°N. Domain for fine grid is from 95°E – 124°E and 5°S – 17°N.

- The time step used for the WAM model are 1,800 seconds for the coarse domain and 900 seconds for the fine domain. Time step of 1,800 is used for fine grid in JMA-MMD MRI III Wave Model and 450 seconds for its fine grid domains.

- The WAM and JMA-MMD MRI III Wave Models are configured to perform two runs per day using 00UTC and 12UTC with forecast range of +192 hours for NCEP GFS wind forecast and +180 hours when using NAVGEM wind forecast. The interval of the main surface wave product output is 3 hour.

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numerical integration using an explicit finite difference method. It uses Arakawa-C grid with horizontal resolution of 1 minute arc (1 nautica mile).

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  The JMA-MMD Oil Spill Model need incident information such as time and position of incident, oil type, flow rate of oil spill and also spill source movement information. The model also capable to produce continuous run of oil spill trajectory and properties evolution in case of longer simulation.

4.3.2.2 Research performed in this field

a) NWP Model

Study on the WRF model performance using GSI-ENKF to assimilate GPS Integrated Water Vapour (IWV) data over the Malaysia region has been performed.

b) Marine Model

Study of WAM model verification using observation data during a research vessel expedition had been conducted. Similarly a hindcast technique using ECMWF ERA-Interim data for the period January March 2015. The JMA-MMD MRI III significant wave height simulation was compared to those measured and derived using Aviso Satellite (Archiving, Validation and Interpretation of Satellite Oceanographic) and in situ observation by Buoy. Case study was also conducted to evaluate the JMA-MMD Storm Surge Model performance during Typhoon Vamei in December 2001 against the sea level rise observed by tide gauge by Department of Survey and Mapping Malaysia (JUPEM).

Operational available NWP products

a) NWP Model

- Temperature: 2m, 1000hPa, 850hPa, 700hPa, 500hPa, 200hPa
- Wind: 10m, 1000hPa, 850hPa, 700hPa, 500hPa, 200hPa
- Mean Sea Level Pressure
- Vorticity: 1000hPa, 850hPa, 700hPa, 500hPa, 200hPa
- Relative Vorticity: 1000hPa, 850hPa, 700hPa, 500hPa, 200hPa
- Geopotential Height
- Precipitation

b) Marine Models

- Significant Wave Height : Height (m), Direction and period (sec)

- Swell height : Height (m), Direction and period (sec)
- Wind Wave height : Height (m), Direction and period (sec)
- Friction Velocity
- Mean Period (sec)
- Peak Period
- Drag Coefficient
- Wave Stress
- Sea Level Rise (cm) : Horizontal map and time series
- Oil Spill Trajectory Map
- Coordinate and time of oil spill landing

4.3.3 Operational techniques for application of NWP products

4.3.3.1 In operation

NWP output visualization graphics are generated using RIP and NCAR graphics visualization software on Lenovo NextScale system. PBS Pro is utilized to control the workload to optimize processing time.

Wave and storm surge model output visualization graphics are generated using GrADS. Linux Crontab is utilized to control the execution of the marine models. Gnuplot is used together with bash script to plot the time series at any selected location. The NCEP g2grb tools is used to convert the product into GRIB2 format. GMT plotting package is used to plot the oil spill model output.

4.3.3.2 Research performed in this field

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4.3.4 Ensemble Prediction System

4.3.4.1 In operation

The NWP EPS System is currently being developed to run at 5-km resolution on the new High-Performance Computing System.

The Marine Model EPS is in operation. The details are as follows:

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- The JMA-MMD Storm Surge Model also accept best track data from RSMC Tokyo as its input. When a tropical cyclone (TC) exists around Malaysia a simple parametric TC model is also used.

- The parametric TC model (TC bogus) is introduced to take into account the error of TC track forecast and its influence on Storm Surge forecasting. To consider the influence of TC track uncertainty on the occurrence of storm surge, five runs of the storm surge model with five possible TC tracks were conducted. These TC tracks are prescribed at the centre and at four points on the forecast circle within which a TC is forecasted to exist with a probability of 70%. The following methods are used to make meteorological fields with the parametric TC model:-

    1. Centre track
    2. Fastest track
    3. Rightward biased track
    4. Slowest track
    5. Leftward biased track

- The simple parametric TC model utilizes the Fujita's formula (Fujita 1952) that represents the radial pressure distribution in a TC.

4.3.4.2 Research performed in this field

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4.3.4.3 Operationally available EPS Products

- In case of TC: 5 members of storm surge simulation based on 5 possible track of TC
- Ensemble mean of Storm Surge Forecast

4.4 Nowcasting and Very Short-range Forecasting Systems (0-6 hrs)

The Short-range Warning of Intense Rainstorms in Localized Systems (SWIRLS) nowcasting system was developed by the Hong Kong Observatory (HKO) and permission was given to the Malaysian Meteorological Department (MMD)to adapt it for local use. MMD has managed to tune the nowcasting system for the Malaysian region by blending in the new 1-km resolution WRF model output. The system is now called RaiNS short for radar integrated Nowcasting System.

4.5 Specialized numerical predictions

5. Verification and prognostic products

- Verification of the operational runs were performed from Jan 2018 onwards due to operational stability.
- Verification of 2-meter temperature and quantitative precipitation forecast against station observations has been carried out.
- Forecast verification has been performed for a period of 3 months obtained for the periods of January-February-March (JFM) 2018 to be included in this report.
- The BIAS scores for the forecast 2-meter temperature fields for the WRF-ARW are given in **Table 3**.

Table 3: BIAS for the 2-m Temperature Fields (ºC) for JFM 2018

Forecast	00UTC	06UTC	12UTC	18UTC
	BIAS	**BIAS**	**BIAS**	**BIAS**
24-hr	0.13	0.16	0.12	0.16
48-hr	0.24	0.22	0.26	0.23
72-hr	0.33	0.35	0.34	0.36
96-hr	0.39	0.36	0.38	0.34
120-hr	0.42	0.49	0.40	0.44
144-hr	0.49	0.48	0.43	0.42
168-hr	0.47	0.49	0.44	0.46

- The Equitable Threat Scores (ETS) for precipitation thresholds of 50mm, 75mm and 100mm for the quantitative precipitation forecasts are given in **Table 4**.

Table 4: ETS of quantitative precipitation Forecast for JFM 2018

Forecast	00UTC			06UTC			12UTC			18UTC		
	ETS			**ETS**			**ETS**			**ETS**		
Threshold (mm)	**50**	**75**	**50**	**75**	**75**	**100**	**50**	**75**	**50**	**75**	**75**	**100**
24-hr	0.31	0.33	0.34	0.36	0.33	0.38	0.25	0.39	0.28	0.37	0.33	0.38
48-hr	0.23	0.18	0.21	0.13	0.24	0.22	0.22	0.13	0.23	0.10	0.14	0.28

72-hr	0.10	0.11	0.11	0.11	0.15	0.12	0.10	0.10	0.13	0.15	0.12	0.12
96-hr	0.18	0.13	0.12	0.11	0.12	0.10	0.11	0.14	0.10	0.14	0.13	0.12
120-hr	0.19	0.15	0.11	0.11	0.11	0.11	0.10	0.10	0.12	0.12	0.18	0.16
144-hr	0.10	0.10	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.10	0.10
168-nr	0.11	0.12	0.11	0.10	0.10	0.09	0.09	0.10	0.10	0.12	0.11	0.10

- Verification of significant wave height of JMA-MMD MRI III Wave Model during validation period from January 2015 to March 2015 give an average Mean Absolute error of :

    - Against AVISO Altimeter Data : 0.14 m
    - Against Buoy Data : 0.18 m

6. Plans for the future (*next 4 years*)

- To include radar and satellite data assimilation in the operational NWP model
- To initialize the NWP models with the high resolution Lateral Boundary condition data from ECMWF.
- To create a short-range mesoscale multi-model ensemble prediction system
- Wave Model:
    - To run with multiple NWP forcing to create wave forecast consensus
    - High resolution wave model
    - Include Shallow water calculation
- Storm Surge Model

- To conduct more case study and verification/validation of the model
- To run with multiple NWP forcing to create storm surge forecast consensus
- To add astronomical tide to produce storm tide forecast

- Oil Spill Model
  - To run regional circulation model to better resolve the local current forecast for Malaysian Waters

- Nowcasting
  - To run integrated with other Radar in MMD Radar network to produce integrated SWIRLS nowcasting for Malaysia
  - SWIRLS incapability of predicting erratic rainstorm movement or accurate projection of rapidly growing or dissipating echoes. MMD aim to use SWIRLS nowcasting in conjunction with NWP forecasts. The combined NWP & SWIRLS forecast are produced by a weighted average of SWIRLS now-cast QPF together with NWP now-cast. The weighing factors are computed based on the best match between observed and forecast rainfall distribution in the past.

6.1 Development of GDPFS

No change

7. References

http://www.met.gov.my