

# JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2015

Singapore

**Meteorological Service Singapore (MSS)**

## 1. Summary of highlights

MSS has been developing a convective scale NWP/Nowcasting system for Singapore based on the UK Met Office Unified Model with further developments and optimisations for equatorial tropical conditions. The real-time testing of the downscaler option of the system started in 2015.

MSS has implemented a customised and parallelised setup of the UK Met Office's Lagrangian particle dispersion model NAME which is used to inform operations and hazard assessments for transboundary haze from peatland fires in Southeast Asia.

In 2015, MSS as host of the ASEAN Specialised Meteorological Centre (ASMC) successfully coordinated two ASEAN Climate Outlook Forums, ASEANCOF-4 and ASEANCOF-5, in collaboration with regional and international partners.

## 2. Equipment in use

The main equipment for the meteorological data processing system includes:

- Cray XC-30 high performance computing system for the purpose of running NWP and climate models in research and operational mode. This system is configured with 336 Intel Xeon 2.6GHz (8 Cores, Sandy Bridge) processors and 10.7TB of total system memory, with a theoretical peak performance of 55.9 TF. The system uses Lustre file system with a usable storage space of 749TB.
- Set of p-series and x-series IBM servers running web, application server and database applications for processing of weather data (decoding, formatting and customization of data for forecasters and external users).
- 2 Windows Message Switching servers performing data reception and international message switching through the GTS/AFTN circuits and a set of 6 windows workstations for the purpose of processing/visualization of data from the GTS/AFTN.
- HP computing cluster with 22 nodes (14 nodes of AMD Opteron 8435 2.6GHz 8 Cores processors and 8 nodes of AMD Opteron 6272 2.1GHz 16 Cores processors), a Lustre filesystem with a usable storage space of 120TB and a total system memory of 1.7TB for the purpose of running NWP, atmospheric transport, wave and ocean models; and
- Various Windows/Unix Servers/workstations for data/image processing.

### 3. Data and Products from GTS in use

- Data - The following reports were received daily:

SYNOP, SHIP, PILOT, TEMP, AIREP, SATOB, AMDAR, DRIFTING BUOY REPORTS, SEA-LEVEL AND OCEANOGRAPHIC DATA

- Products

GRIB Data from KWBC, EGRR, ECMWF, JMA

### 4. Forecasting system

#### 4.1 System run schedule and forecast ranges

The general structure of the prognostic system, the models in operational, domain, resolution, frequency of run schedule and forecast ranges in hours.

Purpose	Model	Domain	Resolution	Frequency	Forecast
NWP	WRF	5.7S-8.1N, 94.6E-109.3E	4.5km	2	36 h
	WRF (nest)	0.9S-3.6N, 101.5E-106.1E	1.5km	2	36 h
Ocean Modelling	WaveWatch 3	Global	0.5 deg	2	72 h
	WaveWatch 3 (nest)	15S-30N, 90E-145E	1/6 deg	2	72 h
	WaveWatch 3 (nest)	4S-6N, 99E-109E	1/20 deg	2	72 h
	WAM	9S-24N, 99E-121E	1/12 deg	1	168h
	Southeast Asia Ocean Model (SEAOM, coupled with WAM)	9S-24N, 99E-121E	1/12 deg	1	168h

#### 4.2 Medium range forecasting system (4-10 days)

MSS does not run any in-house medium range forecasting system but has since April 2014 acquired ECMWF data catalogue. MSS is currently designing and developing forecast products derived from the ECMWF catalogue Set I (10-day high-res) and Set III (15-day low-res). These products will also be evaluated over time.

#### 4.3 Short-range forecasting system (0-72 hrs)

The WRF system is adapted and implemented for short range forecasting. This WRF model at MSS has a regional coverage that is centred over Singapore with a resolution of 4.5km and 1.5km. The WRF is driven by 0.1-deg ECMWF data.

Under a collaboration programme between MSS and the UK Met Office, MSS has been developing a convective scale NWP/Nowcasting system for Singapore. The system is based on the UK Met Office Unified Model, but further developed and optimised for the equatorial tropical conditions. At the end of 2015, the downscaler option of the system had undergone 3 major upgrades with focus on improving the convection modelling capability of the model. The data assimilation option of the system was also ready for real-time testing.

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

MSS started to build the initial capability of NWP based nowcasting system.

#### **4.5 Specialized numerical predictions**

MSS has implemented a customised and parallelised setup of the UK Met Office's Lagrangian particle dispersion model NAME (Numerical Atmospheric-dispersion Modelling Environment). Together with high resolution, satellite-based emission data retrieved through active fire detection, NAME is used to inform operations and hazard assessments for transboundary haze from peatland fires in Southeast Asia. Research into such hazards is ongoing in partnership with the UK Met Office and both Singaporean and international research institutes.

MSS in collaboration with the UK Met Office completed Singapore's Second National Climate Change Study (SCCS) in April 2015. This project produced an ensemble of downscaled climate and sea-level projections up to 2100 for Singapore and the wider Southeast Asia region. Two sets of future climate projections are produced at 12 km resolution using the Unified Model HadGEM3-RA, following the RCP4.5 and RCP8.5 scenarios and driven by 9 GCM outputs selected from the CMIP5 archive. End-of-century (2070-2099) changes are analysed relative to 1980-2009. Key results are summarised in the Stakeholder report and are fully described in the Science report, both publically available at <http://ccrs.weather.gov.sg/publications-listing-page>.

#### **4.6 Extended range forecasts (ERF) (10 days to 30 days)**

MSS does not run any in-house medium range forecasting system but has since April 2014 acquired the ECMWF data catalogue. MSS is currently designing and developing forecast products derived from the ECMWF catalogue Set VI (32-day low-res). These products will also be evaluated over time.

#### **4.7 Long range forecasts (LRF) (30 days up to two years)**

##### **4.7.1 Model products**

MSS currently assesses a number of dynamical products for long-range forecasts up to 6 months ahead. Seasonal outlooks are generated following consensus at an internal seasonal forecast forum held monthly. These are done for Singapore, and also for the Southeast Asia region on behalf of the ASEAN Specialised Meteorological Centre (ASMC). The ASMC also coordinates with the region's National Meteorological and Hydrological Services to organise the ASEAN Climate Outlook Forum (ASEANCOF), which is held

twice a year. ASEANCOF produces a regional consensus of temperature and precipitation outlook for boreal Summer (JJA) and Winter Monsoon (DJF) seasons. In 2015, ASMC successfully coordinated ASEANCOF-4 and ASEANCOF-5 in collaboration with regional and international partners.

MSS sources its multi-model dynamical products from the websites of the WMO Lead Centre, the APEC Climate Center (APCC) and International Research Institute for Climate and Society (IRI). For detailed analyses of seasonal outlook, MSS refers to a more comprehensive datasets from the ECMWF catalogue Set V (7-month low-res).

#### **4.7.2 Research performed in this field**

MSS is assessing the skill of ECMWF model in predicting rainfall over water catchment areas as well as its skill in forecasting dryness over key fire areas in the region for potential applications in water resource management and risk of trans-boundary haze respectively.

### **4.8 Wave and Ocean forecasts**

#### **4.8.1 Wave Models**

MSS has implemented the WAM and multigrid WaveWatch 3 from NOAA for various domains and resolutions for short term wave forecasting. The model outputs include wave forecasts up to 3 days. The skill of the various wave models from JMA, UK Met Office and WaveWatch 3 in the Asian region was assessed and found to be comparable with each other.

#### **4.8.2 Ocean Models**

Since 2006, MSS has been running the coupled ocean model, WAM-SEAOM to produce 3-day forecasts of currents, potential temperature and salinity at surface and various depths over the South China Sea. The ocean model is run at a resolution of 1/12 deg and comprises a wave model (WAM) coupled with an ocean circulation model which is adapted from the POM (Princeton Ocean Model).

Starting from 1 Sep 2013 MSS has extended the forecast time for wave and ocean products from 3 days to 7 days with the coupled WAM-SEAOM.

### **5. Verification of prognostic products**

The upgraded UKMO VER system was implemented in MSS by the end of 2015. The package is capable of verifying various NWP model products against analysis or observation in gridded or station format. It provides various scores including mean bias, RMS, threat score, fractional skill score, hit rate etc., for continuous or categorical variables.

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

#### **6.1 Development of the GDPFS**

MSS has started to prepare for an upgrade of the existing high performance computer, targeting a capacity increase from 55 TFLOPS to 212 TFLOPS.

## **6.2 Planned research Activities in NWP, Nowcasting and Long-range Forecasting**

### **6.2.1 Planned Research Activities in NWP**

MSS plans to further develop and tune the downscaler and data assimilation of the MSS NWP/Nowcasting system, adding local radar data and Himawari-8 data into the data assimilation. MSS also plans to introduce object based verification methods to evaluate the model performance in different perspectives of key weather systems, such as the statistics of storm cells, timing and location of the Sumatra squalls etc.

### **6.2.2 Planned Research Activities in Nowcasting**

New forecasting and assessment techniques are planned to be developed in the MSS nowcasting system to provide extended nowcasting up to 6 hours ahead over Singapore and the holding stacks for aviation. The enhanced nowcasting system will use real-time local observation data (e.g., radar reflectivity), NWP data assimilation results, and Himawari-8 observations.

### **6.2.3 Planned Research Activities in Long-range Forecasting**

MSS is planning to continue its research activities in long-range forecasting by assessing the seasonal models' skill (e.g. from GloSea5, ECMWF, and NCEP where available) over Singapore and the region. These include skill in forecasting probabilities of extreme rainfall thresholds as well as skill in predicting median, tercile and quintile categories of temperature and rainfall. MSS is also planning to investigate seasonal models' capabilities in capturing intra-seasonal wind variability, which has important applications in monsoon onsets and risk of trans-boundary haze. Research outcomes will be useful as inputs into MSS's activities as a contributing member of the planned WMO RA V Regional Climate Centre Network for Southeast Asia.

## **7. References**