PAKISTAN METEOROLOGICAL DEPARTMENT

ANNUAL JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA-PROCESSING AND FORECASTING SYSTEM (GDPFS) INCLUDING NUMERICAL WEATHER PREDICTION (NWP) RESEARCH ACTIVITIES FOR 2017

1 SUMMARY OF HIGHLIGHTS

Pakistan Meteorological Department (PMD) is both a scientific and a service department. It is responsible for providing meteorological service throughout Pakistan to wide variety of interest and for numerous public activities and projects which require climate information. PMD is currently processing 168 hours forecast and issues 72 hours as weather advisory to media and general public. The department post processes ICON model at 13km horizontal grid resolution for the domain spread over 30 – 100ºE and 0 – 55ºN that is able to capture both westerly and easterly systems that approach Pakistan. In addition to provide daily weather forecast, the NWP facility at PMD has been employed as early warning system in the last two years for issuing alerts against calamities like heatwaves, flash floods, glacier lake outburst floods especially in the high altitude regions of the country.

PMD started indigenous numerical weather forecast using High-resolution Regional Model (HRM) in 2006. HRM was hydrostatic regional weather forecast model with horizontal grid resolution flexible between 0.25° – 0.05° (~ 28 to 6 km) and hybrid vertical coordinate, 30 – 60 layers. Initially, the model was configured at 22km horizontal grid resolution and forecast was generated two times a day at 00:00 and 06:00 GMT using initial and boundary conditions from Global Model, GME by DWD (Deutscher Wetterdienst, German Weather Service). Later in September 2010 after successful deployment of powerful 256 cores High Performance Computing Cluster (Blade Servers) having peak performance of about 1.7 TFlops, HRM was configured at finer horizontal grid resolution of 11km and the forecast was generated three times a day 00:00, 06:00 and 12:00 GMT. PMD started simulating HRM with fine resolution initial and boundary conditions after the GME data resolution was improved from 30km to 20km in March 2012.

PMD switched from hydrostatic model HRM to non-hydrostatic Model COSMO (Consortium for Small-scale Modelling) in February 2014. The model was configured at horizontal grid resolution of 14km. On 20th January, 2015, DWD replaced the old global model GME with the new development, ICON. ICON (ICOsahedral Nonhydrostatic) modelling framework is a joint project between the Deutscher Wetterdienst (DWD) and the Max-Planck-Institute for Meteorology (MPIM) for developing a unified next-generation global NWP and climate modelling system.

Recently PMD has pursued on the hardware installation of a new NWP computational facility with more than 10 times the peak performance of its predecessor. It is anticipated that the new system will resolve sub-grid scale processes at finer resolution and will be operational by the end of year 2018. PMD is also in process to launch mobile-based application that will provide real-time weather forecast to public.

2 EQUIPMENT IN USE AT THE CENTRE

Pakistan Meteorological Department uses the following equipment for its numerical computations needs:

High Performance Computing Cluster (Rack mount Servers)

HP Proliant DL380 G4

Compute Nodes: 09 Nos.
Processor: 3.4 GHz Intel Xeon dual process each
RAM: 4 GB each

HP Proliant DL380 G5

Compute Nodes: 04 Nos.
Processor: 3.0 GHz Intel Xeon dual core dual processor each
RAM: 4 GB each

PowerEdge R720 Rack Server

Compute Nodes: 02 Nos.
Processor: Intel® Xeon® processor E5-2600
RAM: 8 GB each
Storage Capacity: SAS 12TB (5 SAS Drives of 2.4TB each)

PowerEdge R930 Rack Server

Compute Nodes: 04 Nos.
Processor: Intel® Xeon® processor E7-8800
RAM: 16 GB each
Storage Capacity: SAS 24TB (20 SAS Drives of 1.2TB each)
Storage:
DELL Power Vault MD1000 Direct Attached Storage
Capacity: 12 TB (12 SATA Drives of 1TB each)
Connectivity:
Gigabit Ethernet

High Performance Computing Cluster (Blade Servers)

Peak Computational Performance 1.7 TFlops

Dell Power Edge M600 Blade Servers

Compute Nodes: 32 Nos.
Processor: 3.33GHz 2 x Quad Core Intel Xeon Processors
RAM: 8 GB Each

Connectivity:

Infiniband Interconnect 20Gbps
Fiber Channel 8Gbps

Storage:

SAN Dell/EMC CX4-120 with Fiber Channel 8 Gbps Interconnect
12 TB SATAII (12 drives of 1 TB each)
FC 5.2 TB (13 Drives of 400 GB each)

In pursuit of coping with the current high resolution computational needs Pakistan Meteorological Department has recently deployed a new high performance computational facility with the following specifications:

Peak Computational Performance:	22 TFLOPS
Total No. of Cores:	672 Nos.
Total Memory:	3 TB
Connectivity:	
HPCC:	56 Gbps InfiniBand
Storage:	10 Gbps Ethernet
Management:	Gigabit Ethernet
Total Data Storage Capacity:	72TB

The newly installed facility will support weather guidance system that will enable an ensemble forecast of several models for operational needs.

3 DATA AND PRODUCTS FROM GTS IN USE

PMD is a part of WMO's Global Telecommunication System network and interconnect Tehran, Iran and New Delhi, India for round the clock reliable and near real-time collection and distribution of meteorological data. PMD is in process to deploy WMO Information System (WIS) to enhance data exchange capabilities. WIS at PMD will be operational by end of 2018.

4 FORECASTING SYSTEM

4.1 SYSTEM RUN SCHEDULE AND FORECAST RANGES

1. PMD post processes the ICON model forecast at 00 and 12 GMT to generate 168 hours of forecast. The forecast is generated at 13km horizontal grid resolution on 03 hourly intervals i.e. 00, 03, 06, 09, 12, 15, 18 and 21 GMT.
2. Global Forecast System (GFS) Model output from NOAA Operational Model Archive and Distribution System at 0.25^{o} horizontal grid resolution is used to generate short and medium range weather forecast for 7 days with an interval of 6 hours. GFS operates daily for 00UTC and 12UTC.
3. GSM is a global model of CMA. GSM provides short and medium range weather forecast for one week at almost 30km horizontal resolution. The model output is updated daily at 00UTC and 12UTC with an interval of 12 hours.
4. GFS maps of model analysis and forecasts for Central Asian domain (which encompasses the atmospheric dynamics of Pakistan) for 144 hours at daily intervals are also linked on the website of PMD.

4.2 SHORT-RANGE FORECASTING SYSTEM (0-72 HRS)

4.2.1 Data assimilation, objective analysis and initialization

In an operational NWP mode, initial conditions for the ICON model are produced by a data assimilation process. The data assimilation combines irregularly distributed (in space and time) observations with a short term forecast of ICON to provide a 'best estimate' of the current atmospheric state. For ICON, the 3D variational assimilation (3DVar) is applied.

ICONREMAP (ICOsahedral Nonhydrostatic model REMAPing) is used for (horizontally) interpolating ICON data onto regular grids and vice versa. ICONREMAP is part of the DWD ICON tools. The iconremap tool reads a data file with the unstructured ICON grid in GRIB2 or NetCDF file format or a data set on a regular grid, interpolates the data onto the target grid with special treatment of the wind fields (normal and tangential vector fields), and saves the resulting data in GRIB2 or NetCDF file format.

ICON is started in DWD initialization mode in which a first guess and an analysis file are loaded into the model at startup. ICON supports NetCDF and GRIB2 as input format for the DWD input fields.

4.2.2 Model

4.2.2.1 In operation

The primary model for operational purposes used by PMD is the ICON model. The ICOsahedral Nonhydrostatic model (ICON) is the global and regional numerical weather prediction model at DWD. It became operational at 2015-01-20, replacing the former operational global model GME. The ICON modelling system as a whole is developed jointly by DWD and the Max-Planck Institute for Meteorology in Hamburg (MPI-M). While ICON is the new working horse for short and medium range global weather forecast at DWD, it embodies the core of a new climate modelling system at MPI-M. ICON analysis and forecast fields serve as initial and boundary data for a couple of different limited area models. Since 2015-01-20, analysis and forecast fields of the deterministic forecast run at 13 km horizontal resolution serve as initial and boundary data.

Atmospheric analysis fields are computed every 3 hours (00, 03, 06, . . . 21 UTC) by the 3DVar data assimilation system, which has recently been upgraded to an En-Var system. Sea surface temperature and sea ice cover are provided once per day (00 UTC) by the SST-Analysis. A snow analysis is conducted every 3 hours, providing updated information on the snow height and snow age. In addition a soil moisture analysis (SMA) is conducted once per day (00 UTC). It basically modifies the soil moisture content, in order to improve the 2 m temperature forecast. For the 3-hourly assimilation cycle and forecast runs, ICON must be provided with 2 input files: One containing the first guess and the other containing analysis fields, only. Variables for which no analysis is available are always read from the first guess file. Other variables may be read either from the first guess or the analysis file, depending on the starting time.

4.2.2.2 Research performed in this field

Several studies have been conducted to evaluate the performance and fine tune the models for improved weather forecast. Some of these are listed as follows:

- Persistent Heavy Downpour in Desert Areas of Pakistan in South Asian Monsoon (Cheema, Zaman et al. 2012).
- Third Successive Active Monsoon over Pakistan – An analysis and Diagnostic Study of Monsoon (Faisal, Jameel et al. 2013).

- Diagnosis and Numerical Simulation of Heavy Rainfall Event in winter over upper parts of Pakistan (Zafar and Rasul 2009).
- Predictability of Summer Monsoon Rainfall using High-resolution Regional Model HRM (Mahmood and Rasul 2012).
- Heavy Rainfall forecast by High Resolution Regional Model (HRM) and its validation for Pakistan (Ali, Mahmood et al. 2014).

4.3 NOWCASTING AND VERY SHORT-RANGE FORECASTING SYSTEMS (0-12 HRS)

Presently, PMD has a network of seven radars to support flood early warning system. These radars are installed at Islamabad, Lahore, Sialkot, Karachi, Mangla, Dera Ismail Khan and Rahim Yar Khan. All these radars are operational and providing output for prediction of weather systems and issuance of warnings. The radars are both Quantitative Precipitation Measurement (QPM) and Doppler based over these districts.

Owing to the obsoleteness of the existing radars, PMD has submitted a comprehensive proposal to the government of Pakistan for the replacement of old radars as well as installation of new radars at 18 locations in the country. The replacements of old radars with new ones will help department to issue the weather predictions and warnings more effectively.

4.4 LONG RANGE FORECASTS (30 DAYS UP TO TWO YEARS) (MODELS, ENSEMBLE, METHODOLOGY)

4.4.1 In operation

Two statistical downscaling models are used for seasonal precipitation prediction at PMD:

1- Coupled Pattern Projection Model (CPPM), in which coupled patterns have been achieved from the covariance between each predictor and predictand and projected onto the predictor field and then calculating the value of predictand on local scale using single variable predictor.
2- Multiple Linear Regression Model (MLRM), in which more than one predictor is used to have predicted time series.

Now more recently two statistical approaches, the statistical regression method using pre-winter predictors and statistical downscaling, are employed to perform rainfall predictions for JA in Pakistan. Linear regression (LR) and optimal subset regression (OSR) are used for each approach. Data for large-scale variables from the NCEP–NCAR reanalysis and version 1.0 of the coupled atmosphere–ocean general circulation model from the Beijing Climate Center (BCC-CSM1.1) outputs are used as predictors for the statistical pre-winter method and statistical downscaling, respectively.

4.4.2 Research performed in this field

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2. Ding, T., Ke, Z., 2013. A comparison of statistical approaches for seasonal precipitation prediction in Pakistan. Weather Forecast. 28 (5), 1116–1132. http://dx.doi.org/10. 1175/WAF-D-12-00112.1.

5 PLANS FOR THE FUTURE (NEXT 4 YEARS)

5.1 PLANNED RESEARCH ACTIVITIES IN NWP, NOWCASTING, LONG-RANGE FORECASTING AND SPECIALIZED NUMERICAL PREDICTIONS

PMD is in process of establishing Specialized Medium Range Forecasting Center with acquisition of powerful High Performance Computing System having computing power of about 22 TFLOPS with following specifications.

Peak Computational Performance: 22 TFLOPS
Total No. of Cores: 672 Nos.
Total Memory: 3 TB
Connectivity:
HPCC: 56 Gbps InfiniBand
Storage: 10 Gbps Ethernet
Management: Gigabit Ethernet
Total Data Storage Capacity: 72TB

Numerical Weather Prediction capacity of PMD will be strengthened manifold by deploying Weather Forecast Guidance System that will incorporate inputs from multiple global and regional numerical weather prediction models. Few of the major SMRFC components are listed below.

- Acquisition and installation of Weather Surveillance Radars at Islamabad, Lahore, Karachi and Multan.
- SMRFC (Specialized Medium Range Weather Forecasting Center) High Performance Computing System for Weather Guidance and Numerical Weather Prediction.
- Meteorological Data Trunk Communication System at Islamabad, Lahore, Multan, Gilgit, Islamabad International Airport and Lahore International Airport
- Redundant GTS Message Switch System and deployment of WMO Information System (WIS)
- 2 Wind Profiler System in Islamabad and Multan

Future plan activities include:

Extending the scope of SMRFC to Long-range forecasting to improve monthly and seasonal prediction, particularly the monsoon rainfall which plays significant role in fulfilment of water needs but its fluctuation pose major threat in terms of droughts and flooding.

Enhancement of weather data/information provision capability to share upper-air observation data to SMRFC, WMO and the global communities through WIS.

Enhancement of the capability for downburst and wind shear monitoring.

Enhancement of Torrential Rain Prediction Capability by implementation of 0.5-1 hour very short range prediction for precipitation cloud movement by radar observation data in the radar detection range.

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PMD – Numerical Weather Products (http://www.pmd.gov.pk/rnd/rndweb/rnd_new/numerical.php)

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