Center Report from KMA
Forecasting System Operation & Research

Dong-Joon Kim
Numerical Prediction Office
Korea Meteorological Administration
Outlines

- KMA’s Operational NWP System Overview
  - Hardware and NWP Systems

- Major R&D Activities in 2014 and Performance
  - Operational NWP System upgrade
  - Verification Scores
  - KIAPS Development

- Further Development / Research Plans
Operational NWP Systems
Hardware (HPC) and Software
### Current Operational HPC (Cray XE6)

**Main System**  
(20 Cabinets, 379TFlop/s)

**Backup / R&D System**  
(20 Cabinets, 379Tflop/s)

<table>
<thead>
<tr>
<th>Refer</th>
<th>Main (HaeOn)</th>
<th>Backup (HaeDam)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Installation Year</strong></td>
<td></td>
<td>2010.12</td>
<td></td>
</tr>
<tr>
<td><strong>Core Number</strong></td>
<td>45,120</td>
<td>45,120</td>
<td>90,240</td>
</tr>
<tr>
<td><strong>Core Type</strong></td>
<td>AMD 2.1 GHz, 12 core</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Peak performance</strong></td>
<td>379 TF</td>
<td>379 TF</td>
<td>758 TF</td>
</tr>
<tr>
<td><strong>Main Memory</strong></td>
<td>60 TB</td>
<td>60 TB</td>
<td>120 TB</td>
</tr>
<tr>
<td><strong>Capacity of Disk</strong></td>
<td></td>
<td>4 PB</td>
<td></td>
</tr>
<tr>
<td><strong>Capacity of Tape drive</strong></td>
<td></td>
<td>8 PB</td>
<td></td>
</tr>
<tr>
<td><strong>OS</strong></td>
<td></td>
<td>Suse Linux 11</td>
<td></td>
</tr>
</tbody>
</table>
New HPC Introduction

- Contract: June 2014
- Installation of Initial Stage System: November 2014
- Installation of Final Stage System: Q4 2015

<table>
<thead>
<tr>
<th>System architecture</th>
<th>Peak Perf. (TF)</th>
<th>Processor type &amp; Memory</th>
<th># Nodes</th>
<th>Login nodes</th>
<th>I/O System</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRAY XC40-LC (3 cabinets)</td>
<td>447</td>
<td>Intel haswell 2.6GHz 24cores/node 128GB/node</td>
<td>computational (448nodes) Pre-post (12nodes)</td>
<td>4 set</td>
<td>3.3PB &gt; 50GB/sec</td>
</tr>
<tr>
<td>CRAY XC40-LC (16 cabinets*2set)</td>
<td>5,800</td>
<td>Intel haswell 2.6GHz 24cores/node 128GB/node(comp) 258GB/node(pre-post)</td>
<td>computational (2,904nodes<em>2set) Pre-post (56nodes</em>2set)</td>
<td>8 set</td>
<td>&gt; 13.5PB &gt; 248GB/sec</td>
</tr>
</tbody>
</table>

- The initial stage system (Uri) was ranked #148 on Top 500 list (Nov.2014)
 Operational NWP Systems

Global Medium-range Prediction
- Deterministic: UM 25km L70 / T+288hrs (00/12UTC), T+87hrs (06/18UTC) / Hybrid Ensemble 4DVAR
- Ensemble: UM 40km L70 / T+288hrs (00/12UTC) / 24 Members / Perturb.: ETKF, RP, SKEB2

Short-range Prediction (E-Asia)
- UM 12km L70 / T+87hrs (6 hourly) / 4DVAR / Deterministic

(Very) Short-range Prediction (Local)
- Deterministic: UM 1.5km L70 / T+36hrs (6 hourly) / 3DVAR (3 hourly)
- Ensemble: In preparation (Q3 2015)
# Operational NWP Models (March ’15)

<table>
<thead>
<tr>
<th>Model</th>
<th>Resolution</th>
<th>Target Length</th>
<th>Target / Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seasonal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GloSea5 (Global)</td>
<td>N215 (60km) L85</td>
<td>220 days (M2)</td>
<td>Seasonal prediction (~6 months)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60 days (M2)</td>
<td></td>
</tr>
<tr>
<td><strong>Medium-range</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDAPS (Global)</td>
<td>N512 (25km) L70</td>
<td>T+288 (00/12)</td>
<td>Global deterministic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T+87 (06/18)</td>
<td></td>
</tr>
<tr>
<td>Global EPS (Global)</td>
<td>N320 L70 M24</td>
<td>T+288</td>
<td>Global probabilistic</td>
</tr>
<tr>
<td><strong>(Very) Short-range</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDAPS (E.Asia)</td>
<td>12km L70</td>
<td>T+87</td>
<td>East Asia / Short-range</td>
</tr>
<tr>
<td>LDAPS (Korea)</td>
<td>1.5km L70</td>
<td>T+36</td>
<td>Korea / Short-range</td>
</tr>
<tr>
<td>KLAPS (Korea)</td>
<td>5km</td>
<td>T+12</td>
<td>Korea / Very short-range</td>
</tr>
<tr>
<td><strong>Application Models</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave Watch III</td>
<td>55km</td>
<td>T+288</td>
<td>Global</td>
</tr>
<tr>
<td></td>
<td>8km</td>
<td>T+87</td>
<td>Northeast Asia</td>
</tr>
<tr>
<td></td>
<td>1km</td>
<td>T+72</td>
<td>Coastal</td>
</tr>
<tr>
<td>ADAM (Dust &amp; Aerosol)</td>
<td>30km</td>
<td>T+72</td>
<td>Asia dust</td>
</tr>
<tr>
<td>DBAR (Typhoon)</td>
<td>35km</td>
<td>T+72</td>
<td>Track</td>
</tr>
<tr>
<td>Tide/Storm Surge</td>
<td>9km</td>
<td>T+87</td>
<td>Northeast Asia</td>
</tr>
</tbody>
</table>
**Operational NWP Models** (March ’15)

GloSea5 : UM (N216L85)+NEMO(ORCA025L75)
- 60 days prediction (2 Mem): weekly prediction (~ 8 weeks)
- 220 days prediction (2 Mem): monthly prediction (~ 6 months)
- Hindcast (42 Mem=3 Mem/yr): 1996~2009 (14 years)

- NWP
  - LDAPS
  - RDAPS
  - GDAPS
  - Global EPS

- Seasonal Prediction
  - GloSea5: UM (N216L85)+NEMO(ORCA025L75)
    - 60 days prediction (2 Mem): weekly prediction (~ 8 weeks)
    - 220 days prediction (2 Mem): monthly prediction (~ 6 months)
    - Hindcast (42 Mem=3 Mem/yr): 1996~2009 (14 years)

- Climate Research
  - Climate Models
  - Earth System Model
Major Upgrades in 2014 and NWP Performance
Operational System Upgrade (2014)

- Global NWP System (GDAPS)
  - No major upgrade in 2014
  - MetOp-B (ATOVS, IASI) data is used since Nov. 2013

- Regional NWP System (RDAPS)
  - Revision of **Background Error Covariance** for the East Asia domain
  - Software version upgrade of observation pre-processing (OPS), variational D.A. (VAR) and atmospheric model (UM)
  - Ancillary data (LAI) update: Heat/Moisture flux improved

- **T+12 Forecast Error**
  - Reduction of Continental (China) Warm Bias in the New D.A. System
Operational System Upgrade (2014)

- Regional NWP System (RDAPS) - continued

  Percentage Improvement (New vs. Oper.) / RMS Error / Verification against Analysis

- Local NWP System (LDAPS)
  - Software version upgrade of atmospheric model (UM)
  - Physics configuration update: Improvement of surface temperature and fog prediction performance
Operational Global Model Performance

Model: GSM T106, GSM T213, GSM T426, UM N320, UM N512

D. A.: 1dVar (TOVS), 3DOI, 3dVar, FGAT, 4dVar, Hybrid 4dVar

500 hPa Geopotential Height RMS Error / N.H.
Operational Global Model Performance

500 hPa Geopotential Height RMS Error / S.H.
Forecast Sensitivity to Observation

- FSO based on the operational global NWP system

Satellite Data 58%, Non-Satellite Data 42%

Impact of Synoptic Obs. (Sonde) is still dominant in the East Asia domain

Sonde >> GPS_RO > IASI (vertical sounding)
KIAPS Development

Major Achievement in 2014 (D.A.)

- Building 3DVAR System on a Cubed-Sphere
  - 3DVAR system on a cubed-sphere
    - Spectral filter and Eigenvalue analysis
    - Background error covariance
  - Variable transform method
  - Improvement of **cost-function** minimization
    - enhanced computational efficiency
  - Combination of 3DVAR system and KIM (KIAPS Integrated Model)
    - Successful generation of analysis field via 3DVAR
**Major Achievement in 2014 (Model)**

- **Building β-version of KIAPS global model**
  - Horizontal resolution: 25km (ne120np4)
  - 50 vertical layers / Top = 0.3hPa
  - Dynamical core: Hydrostatic/Non-hydrostatic system on a cubed sphere (based on CAM-SE HOMME)
  - Dynamical core and physics packages are successfully combined
  - Preliminary Evaluation
    - DCMIP (Dynamical Core Model Intercomparison Project) tests
    - Severe weather events
    - Medium-range (10-day) experiments
KIM Results

Typhoon Bolaven Case (August 2012)

- Initial Condition: GFS Analysis (No D.A.)
- Verification score from 10-day forecast for a month (July 2013)
- RMSE, AC are comparable to the reference model
KIAPS Development Plan for 2015

- Further development of β-version KIAPS NWP System
  - Complete building a 3DVAR-EnKF Hybrid D.A. cycling system
    - Design end-to-end system from observation data acquisition to post-processing/verification system
  - Refine dynamical core and physics package of KIM
    - More emphasis on non-hydrostatic version
  - (Near) real-time run and evaluation of KIM system

Operating Scripts (Python)
On-going Research/Development and Further Plans
Local ENsemble prediction System (LENS)

- Resolution : 3km (horizontal) / 70 vertical layers (~40km)
- Target length : T+45 hours (03/15UTC)
- # of Members : 11+1 (or 23+1)

- Initial Perturbation : from global EPS (LETKF to be tested)
- Model Perturbation : None (Random Parameter to be tested)

- Planned to be in Operation in Q4 2015
Convective scale EPS – Preliminary Evaluation

- Rank histogram and time series show **small ensemble spread**
  - Initial ensemble spread needs to be increased
  - Warm temperature bias and negative 10m wind bias

Ensemble spread needs to be increased by random parameter, etc.
Convective scale EPS – LETKF Initialization

OBS  ETKF_cntl  ETKF_ens_mean  LDAPS

T+05h  2012081418
T+12h  2012081500
T+18h  2012081506
+24h   2012081512

ETS

12h fcst

24h fcst

Threshold [mm h^-1]
Further Development of Local NWP System

- Expanding the outer (low-resolution [4km]) domain
  - Mitigating negative impact of lateral B.C. from global model which sometimes degrades the forecast accuracy

Typhoon NAKRI case (July 2014)
- 36hr accumulated rainfall amount
Further Development of Local NWP System

- Development of Atmosphere-Wave Coupled System
  - Coupling of LDAPS(UM) with WaveWatch III using OASIS-MCT coupler
    - Considering the air-sea interaction to enhance the short-range forecast performance
  - Optimization of physical parameterizations (especially microphysics scheme) using dual polarization radar and single column model
Future Plans (Development Strategy)

Medium-range NWP (Global Model)

• Collaboration among UM Community (UK Met Office, CAWCR, etc.)
• 17km resolution Global NWP System with ENDGame DyCore
  • Real-time run and evaluation (‘15)
  • Operational Implementation (‘16)
※ Use of additional observation (CrIS, ATMS, etc.)

Short-range NWP

• Tuning / Optimization of operational short-range NWP systems
  • LDAPS domain expansion (‘15)
  • Atmosphere-Wave coupled LDAPS (~’16)
• Local ensemble prediction system (LENS)
  • Operational implementation (‘15)
  • Enhancement of initial perturbation, etc. (‘16)
## Future Plans (summary table)

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPC</td>
<td>Cray XE6 Cray XC40 (1st stage)</td>
<td><strong>Cray XC40</strong> (final stage)</td>
<td></td>
</tr>
<tr>
<td>Short-range Deterministic</td>
<td>12km L70 / 4DVAR (East Asia Domain) [Frozen with minor upgrade (new observation, etc.)]</td>
<td>1.5kmL70 / 3DVAR (-&gt; 4DVAR?) Extended Domain / <strong>WW3 Coupled</strong></td>
<td></td>
</tr>
<tr>
<td>Short-range Ensemble</td>
<td>1.5kmL70 / 3DVAR Extended Domain</td>
<td>3kmL70 12M~24M (ETKF / Random Parameter)</td>
<td></td>
</tr>
<tr>
<td>Medium-range Deterministic</td>
<td>25kmL70 Hybrid 4DVAR</td>
<td><strong>17kmL70 (ENDGame core)</strong> Hybrid 4DVAR</td>
<td></td>
</tr>
<tr>
<td>Medium-range Ensemble</td>
<td>40kmL70 24M</td>
<td>32kmL70 (or 25km) 24(44)M (ENDGame core)</td>
<td></td>
</tr>
<tr>
<td>Seasonal Prediction</td>
<td>GloSea5 [60kmL85 (Atmos.) / 0.25deg L75 (Ocean)] Met Office – KMA joint seasonal prediction system</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>