Centre Reports (Annex 2 to the WGNE-31 Final Report)

Météo-France centre report (F. Bouyssel)

The global and regional NWP systems have undergone significant changes, in two steps, in April and in December 2015.

The horizontal resolution of the global deterministic system is improved, from 10 to 7.5 km over Western Europe and from 60 to 36 km over Southern Pacific (spectral resolution Tl1198 linear grid with a stretching factor 2.2). The two minimizations resolutions in 4DVar analysis are now Tl149 and Tl399. The vertical resolution is increased from 70 to 105 levels, with a lowest model level at 10m.

Background error covariances used in the 4D-Var analysis are better sampled thanks to the implementation of a new version of the ensemble data assimilation (EDA), based on 25 members at uniform resolution Tl479 L105, with a temporal average reduced to one day and a half (instead of 4 days), and an update of correlations every 6 hours (instead of 24 hours).

The 35 members horizontal resolution of the global ensemble prediction system (EPS) is improved, from 15 to 10 km over Western Europe (spectral resolution Tl798 linear grid with a stretching factor 2.4) with 90 vertical levels. Background states and the mean of EDA are used for computing EPS initial conditions. A new set of 10 physical packages including a new prognostic convection scheme "PCMT" is being used to represent model errors.

The convective-permitting scale AROME-France system is now running at a horizontal resolution of 1.3 km, namely a halving relative to the previous version. Vertical resolution has also been increased, with a change from 60 to 90 levels with a lowest model level at 5m. Two of the most significant changes are a move towards a more continuous data assimilation process (1h instead of 3h time window) and a change in the spatial density (from 16 km to 8 km) of radar data (reflectivities and radial winds) used in the assimilation.

New observations are assimilated in these systems, such as 6 sounding channels of SAPHIR on Megha-Tropiques, surface winds from RapidSCAT, AMV and CSR data from Himawari 8, etc.

Two new systems have been introduced in the operational NWP suite for: i) nowcasting (called AROME-PI) with hourly analysis with 10' cut-off plus 6h short-range forecast with the same 1.3 km configuration than AROME-France, ii) weather forecasting over five overseas territorial collectivities (called AROME-OM) with configurations at 2.5 km running four times par day up to 48h range.

The upgrade of the BULL HPC (phase 2) is on-going. The first cluster is available including 1800 nodes with "Broadwell EP" cores. The second cluster will be available next autumn.

In 2016, the increase of computing resources will be used to put into operation a new numerical weather prediction system: the AROME Ensemble Prediction System (called

PEARO). The configuration of this system, currently developed, uses 12 perturbed forecasts of the AROME-France model with a 2,5km horizontal resolution and 90 vertical levels, coupled with the ARPEGE ensemble prediction system (PEARP). Each member is perturbed in order to represent the main sources of uncertainty, including the error on initial conditions, surface conditions, lateral boundary conditions and the model. The PEARO system will run twice a day, at 09 and 21 UTC, to provide forecasts up to a 45h range.

A new NWP e-suite (CY42_op1) is currently prepared. The most significant modifications will likely be the implementation of a new prognostic convection scheme, called "PCMT", and a surface model, called "SURFEX" in global systems based on ARPEGE model (deterministic, EDA and EPS). A parameterization of orography effects decreasing sky view factor on radiative fluxes will be introduced in AROME model. New observations will be assimilated: higher density of CSR of geostationary satellites, GMI/GPM data, first OPERA radars, etc.

In 2017/2018, several changes are foreseen such as the implementation of a regional EDA system based AROME 3DVar, the addition of 03 and 15 UTC production hours for PEARO and a resolution upgrade of global systems.

Council for Scientific and Industrial Research (CSIR, South Africa) Centre report
(F. Engelbrecht)

Development of the first African-based Earth System Model

The CSIR is working towards completion of the first African-based Earth System Model, the Variable-resolution Earth System Model (VRESM). The model development effort relies strongly on model development activities at the CSIRO and uses as atmospheric component the cube-based CCAM/VCAM model of the CSIRO. The CSIR has developed a cube-based ocean model VCOM as ocean component of VRESM, and is in the process of coupling this model to the PISCES biochemistry model PISCES. The land-surface component of VRESM is the CSIRO Atmosphere Biosphere Land Exchange (CABLE) model The CSIR intends to launch its DECK and ScenarioMIP simulations for CMIP6 in 2017.

Participation in CORDEX

The CSIR has completed a set of 50 km resolution global projections of future climate change for CORDEX, using the coupled CCAM-CABLE model to downscale six CMIP5 GCMs integrated for RCP8.5 (low mitigation), and similarly for RCP4.5 (modest-high mitigation). All these simulations were performed for the period 1961-2100. The CSIR is currently post-processing these projections toward delivery to the CORDEX Earth Systems Grid Federation (ESGF) data server.

Seasonal forecasting and AMIP simulations

The CSIR obtains an operational seasonal forecast system. The forecasts are issued twice a month, and consist of a 12-member ensemble initialized using a lagged-average forecasting approach. These forecasts rely on the CCAM model integrated globally at a resolution of 200 km in the horizontal. A set of hindcasts mirroring the operational system is available for the

period 1983-2012. These forecasts/hindcasts are atmosphere-only simulations forced at their lower boundary with predicted SSTs (the latter is obtained by combining the SST predictions of a number of CGCMs, with the latter obtained from the IRI).

Short-range forecasting

The CSIR obtains an operational short-range forecast system over southern Africa. Forecasts are initialised using the Global Forecast System (GFS), has a horizontal resolution of 15 km and extend 7 days ahead. These forecasts are obtained using the CCAM model and are issued four times a day (model initialisation takes place at 0 Z, 6 Z, 12 Z, and 18 Z).

Naval Research Laboratory Center Update (C. Reynolds)

For the global assimilation and forecasting system, a hybrid version of the 4D-Var data assimilation system, NAVDAS-AR, in which an ensemble-based background error covariance is ombined with the static background error covariance, has been delivered to Fleet Numerical Meteorology and Oceanography center and is expected to become operational in the next few months. This upgrade will also include ozone assimilation from OMPS and SPU/V, and MetOp A/B Global AVHRR Atmospheric Motion Vectors. New satellite assimilation components that became operational in late 2015 include CrIS radiances, geosationary clear sky radiances, SSMIS Upper Atmosphere Sounding (UAS) sounding channels, IASI/AIRS water vapor radiances and Himawari-8 Atmospheric Motion Vectors. The next Navy Global Environmental model (NAVGEM) upgrade, scheduled for summer 2017, will include an increase in resolution to T681L80 (19 km grid spacing) and 0.01 hPa model top from the current T425L60 (31 km grid spacing) with 0.04 hPa model top. NAVGEM has been coupled to the HYCOM ocean model, the Los Alamos CICE sea ice model, and Wave Watch 3 under the Earth System Prediction Capability effort. Preliminary multi-month ensemble forecasts from the summer of 2015 indicate a promising start in the prediction of El Nino and September arctic sea ice extent. NAVGEM physic improvements result in improved prediction of tropical phenomena such as the Madden Julian Oscillation. Planned spring 2016 upgrades to the Navy Global Environmental Model Ensemble Forecast System (EFS), include an increase in resolution (from T259L50 to T359L60) and upgrade in the model physical parameterizations, resulting in substantial improvements in fields such as 10-m temperature. The global Navy Aerosol Analysis and Prediction System (NAAPS) will begin assimilating MODIS Collection 6 aerosol optical depth assimilation in 2016. NAAPS will include organic aerosols by the fall of 2016, reducing biases in polluted areas and improving particle composition and properties. Assimilation of aerosol products from geostationary sensors is actively being developed at NRL.

For the mesoscale assimilation and forecasting system, the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), coupled to the NCOM ocean model and SWAN and WWIII wave models, has undergone several system upgrades including recent improvements to the boundary layer, and microphysical parameterizations. The COAMPS operational data assimilation will be upgraded from 3D-Var to 4D-Var in the fall of 2016. Recent improvements to the current 3D-Var scheme include an upgrade to increase the number of assimilated satellite Atmospheric Motion Vectors and add the capability to

assimilate AMSU-A radiances. The COAMPS-TC (tropical cyclone) ensemble continues to be a critical component of the NOAA Hurricane Forecast Improvement Project multi-model ensemble. The Atmosphere-Ocean coupled version of COAMPS-TC will be transitioned to operations this summer. COAMPS-OS (On Scene) operational upgrades include a ship-following COAMPS capability that is scheduled to become operational this summer. New capabilities to use WW3 curvilinear grids in COAMPS-OS are planned in the winter of 2016. Development continues on the Navy Environmental Prediction System Utilizing the NUMA Core (NEPTUNE) with a flexible cubed sphere or icosahedral grid and spectral element discretization. Recent capabilities added include improved physical parameterizations, a land surface model, and a physics grid that ensures consistent use of the physics package independent of the order of the basis functions in the dynamical core.

JMA Centre Report (Junichi Ishida)

A list of recent developments which are implemented to JMA global model (GSM) is as follows.

24 MAR 2016 : Major upgrade was made to the model. Major changes were,

- Land surface processes by introducing new land surface model,
- Upgrade of deep convection parameterization,
- Upgrade of cloud scheme,
- Upgrade of radiation scheme,
- Upgrade of treatment of sea ice,
- Optimization of Legendre Transform,
- Start of assimilation of the GPM Microwave Imager (GMI) data.

17 MAR 2016 : Assimilation of Himawari-8 AMV and CSR data was started. 08

OCT 2015 : Assimilation of METAR surface pressure data was started.

Usage of ASCAT ocean surface vector wind data was improved.

25 JUN 2015 : Assimilation of Megha-Tropiques/SAPHIR data was started.

The latest list is available by following webpage. http://www.wis-

jma.go.jp/ddb/latest_modelupgrade.txt

A list of recent developments which are implemented to JMA Meso Scale Model (MSM) with a horizontal resolution of 5km and Local Forecast Model (LFM) with a horizontal resolution of 2km is as follows.

24 MAR 2016: Assimilation of GPM DPR and GMI data for MSM was started.

Assimilation of GNSS Radio Occultation data for MSM was started. (GRACE-A,B/BlackJack, COSMIC/IGOR, Metop-A,B/GRAS, Terra-SAR-X/IGOR, TanDEM-X/IGOR)

17 MAR 2016 : Assimilation of Himawari-8 AMV data for MSM and LFM was started.

Assimilation of Himawar-8 CSR data for MSM was started.

24 DEC 2016: Major upgrade of MSM analysis was made. The changes are.

- Update of background error covariance,
- Start of assimilation of ASCAT ocean vector data,
- Improved usage of upper-air data at domestic radiosonde stations.

25 AUG 2016: Change of treatment of saturated vapour in LFM analysis.

05 MAY 2016: Major upgrade of MSM was made. The changes are

- Improvement of a planetary boundary layer scheme,
- Upgrade of diagnostic scheme of surface temperature over the sea.

A list of plan of upgrade of JMA GSM is as follows.

Improvement of land-surface model which was implemented in March 2016

Improvement of radiation scheme which was implemented in March 2016

Change of climatology of sea ice

Modification of roughness over the sea

Introduction of EDMF PBL scheme

Unifying weekly EPS and typhoon EPS to global EPS

Enhancement of forecast length of global EPS up to 18 days

Start of assimilation of Suomi-NPP/ATMS and CrIS data

Start of assimilation of SSMIS (183GHz) data

Start of assimilation of ISS/RapidSCAT data

Replacement to ROPP8

A list of plan of upgrade of JMA MSM and LFM is as follows

Introduction of new dynamical core "ASUCA" and physics package into MSM

Introduction of new variational DA system "ASUCA-Var" into MSM

Upgrade of ASUCA and physics package in LFM to the latest version.

Start of assimilation of Suomi-NPP/ATMS and CrIS data into MSM

Start of assimilation of SSMIS (183GHz) data into MSM

Start of assimilation of soil moisture retrieved from satellite data into MSM and LFM

Recent updates/upgrades at the Canadian Meteorological Centre (CMC) (Ayrton Zadra)

April 14th, 2016: Installation of the FireWork Prediction System for the Summer Season of 2016 - FireWork is a seasonal modelling system based on the Regional Air Quality Deterministic Prediction System (RAQDPS) which incorporates additional emissions from wildfire events over North America.

April 7th, 2016: Major Upgrade to the Regional Air Quality Deterministic Prediction System (RAQDPS) - This update includes the following changes new chemical lateral boundary conditions and updates to the chemistry module.

Wednesday March 16, 2016: Replacement of MTSAT-2 by Himawari-8 plus addition of AMV from NPP and ISS-RapidScat - Only the data assimilation component was modified with

- Replacement of AMV (Atmospheric Motion Vector) and CSR (Clear Sky Radiance) observations from the Japanese satellite MTSAT-2 by those from Himawari-8 in the GDPS and RDPS.

- Addition of AMV data from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on board the SUOMI National Polar-orbiting Partnership (NPP) satellite in the three systems GDPS, GEPS and RDPS;

- Addition of marine winds from the RapidScat Scatterometer mounted on the International Space Station (ISS) in the three systems GDPS, GEPS and RDPS.

- Regarding the CSR observations, the spatial thinning algorithm for geostationary satellite observations will be modified.

Tuesday December 15, 2015: Major Upgrade to Version 5.0.0 of the Global Deterministic Prediction System (GDPS) - Changes to the forecast model:

- Overlapping LAM domains (in Yin-Yang grid formation) replace a global uniform lat-lon grid (horizontal resolution remains at 25 km).

- Introduction of the trapezoidal method for trajectory calculation, combined with a cubic interpolation scheme.

- Addition of an extra momentum level to the vertical coordinate above 10 hPa to improve computing efficiency.

- Modification to the rate of flattening of the terrain-following levels.

- Addition of two diagnostic levels at 1.5 m and 10 m above model ground level.

Changes to the assimilation system and observations:

- Introduction of the same staggered vertical coordinate used by the forecast model.

- Addition of radiance observations from 17 channels of the Advanced Microwave Sounding Unit (ATMS).

- 103 additional Cross-track Infrared Sounder (CrIS) channels.

- More than 600 additional ground-based GPS sites (mostly in Europe).

- Introduction of inter-channel correlations for all infrared and microwave radiances.

December 15, 2015: Upgrade to Version 4.1.0 of the Regional Deterministic Prediction System (RDPS) - Changes to the forecast model:

- The horizontal grid spacing of the global driver model decreases from 33 to 25 km.

- The lateral boundary conditions of the driver model are now provided every 30 minutes (rather than every 60 minutes).

Changes to observations:

- Addition of radiance observations from 17 channels of the Advanced Microwave Sounding Unit (ATMS).

- 103 additional Cross-track Infrared Sounder (CrIS) channels.

- More than 600 additional ground-based GPS sites (mostly in Europe).

- Introduction of inter-channel correlations for all infrared and microwave radiances.

December 15, 2015: Upgrade to Version 4.1.1 of the Global Ensemble Prediction System (GEPS) - The changes included

- Numerical diffusion of the potential temperature field is now applied for all ensemble members (rather than only half the members).

- A damping gradient is applied to limit the diffusion of potential temperature near the poles.

- New observation errors for radiance data and GPS Radio-Occultation (GPS-RO) observations.

- Addition of radiance observations from the Advanced Microwave Sounding Unit (ATMS).

- Addition of GPS-RO observations from the TanDEM and GRACE-B satellites.

- The reforecast period is extended from 18 to 20 years.

December 15 2015: Upgrade to Version 4.1.0 of the High Resolution Deterministic Prediction System (HRDPS) - The changes included in this upgrade the use of an implicit convection scheme Kain & Fritsch and a correction for freezing rain events that were largely under-estimated in the HRDPS-4.0.0

September 17, 2015: The Canadian Meteorological Centre (CMC) installs its Regional Ice Prediction System (RIPS) version 2.2 - The major changes included

- Assimilation of AMSR2 data

- Assimilation of Canadian Ice Center regional (weekly) charts data

- Modifications to the passive microwave data processing:

- Thinning of SSMIS data along the satellite track (assimilate only 1 of 3 scan lines)

- Reduction of the observation-error standard deviation of SSMIS data from 0.1 to 0.05 (because of thinning)

- Reject all data over lakes (as in version 1.0)

- Wind filter to eliminate spurious ice concentration retrievals

June 23, 2015: Experimental Global Deterministic Wave Prediction System (GDWPS) - The development of the GDWPS was made through a partnership with NCEP/NOAA.

June 11, 2015: Upgrade to the Regional Air Quality Deterministic Prediction System (RAQDPS)– Included a new emissions set is based on the 2010 Canadian Inventory/2011 USA Inventory, updating from the 2006 Canadian Inventory/2005 USA Inventory.

June 03, 2015: Upgrade to the Regional Deterministic Precipitation Analysis (RDPA (CaPA)) version 3.1.0 - This version will lead mainly to the assimilation of a higher number of solid precipitation observations.

Met Office center report April 2016 (Keith Williams)

Over the last year there have been the following changes to the operational suite:

- Aug 2015: PS36 Port to new supercomputer (IBM Power 7 to Cray XC40). Largely science neutral (a few bug fixes)

- Mar 2016: PS37 Satellite package including introduction of variational bias correction (VarBC) and revised DA cov-stats for global model; routine science package for convective permitting models.

Presentations at WGNE30 showed the Met Office analysis to have a warmer lower troposphere over ocean regions than other analyses. From this initial state, the forecast would then cool such that the lower tropospheric temperatures several days into the forecast were more consistent with analyses/forecasts from other centres. The problem was traced to the bias correction being applied to the satellite data used in the data assimilation process and VarBC in PS37 goes a long way to address this. It was also found that as the cooling (from the overly warm analysis) was taking place through the forecast and geopotential heights falling, in certain situations mid-latitude synoptic systems could over-deepen with resulting double penalty problems. As VarBC largely addresses the problem, PS37 should bring improvements in CBS scores.

Planned operational suite changes for the coming year are:

- Sep 2016: PS38 Extend domain of regional model (UKV) and the regional ensemble and extend 00Z and 12Z runs to 5 days. Routine satellite changes for global model.

- Jan 2017: PS39 Implement GA7/GC3 science package in all global systems. Increase horizontal resolution of global deterministic model to around N1024 (~12km).

Global Atmosphere (GA) 7 is a reasonably large package of physics changes, primarily associated with clouds and radiation. It also includes a new multi-layer snow scheme. Global Coupled (GC) 3 uses the GA7 atmosphere and also includes multi-layer sea-ice along with a number of ocean improvements. The global deterministic model and NWP ensemble will implement GA7 whilst the seasonal and decadal systems will implement GC3.

For climate systems, GC3 will also form the physical model to be submitted to CMIP6, and will have earth system components (interactive chemistry, interactive land surface, etc.) built onto it to form UKEMS1 – the UK's Earth System Model to also be delivered to CMIP6, and hence used for climate change projections in the next IPCC report.

ECMWF Centre update

On 8 March 2016, ECMWF introduced a new model cycle of the IFS into operations. Cycle 41r2 represents a significant step forward in accuracy and resolution and it is currently the highest resolution global forecasting system in the world. The main change is an increase in horizontal resolution in most parts of the forecasting system. For HRES and ENS the grid point resolution is roughly doubled to 9 km and 18 km, respectively, while for the Ensemble of Data Assimilations (EDA) it is tripled to 18 km. In combination with several other scientific and technical changes, this has led to a significant increase in forecast accuracy and computational efficiency. The ENS was also improved by moving the step decrease in resolution of the forecast (going from 'medium range' at 18 km to 'monthly extension' at 36 km) from day 10 out to day 15, thus ensuring consistent high forecast resolutions throughout the medium range to 15 days. In more detail:

- Introduction of a new form of the reduced Gaussian grid, the octahedral Gaussian grid, for HRES, ENS and ENS Extended;

- Horizontal resolution of the HRES increased from TL1279 / N640 to TCo1279 / O1280, where subscript C stands for cubic and o for octahedral, with a model time step of 450s;

- Horizontal resolution of the ENS increased from TL639 / N320 to TCo639 / O640 for ENS (Days 0 - 15) with a model time step of 720s and from TL319 / N160 to TCo319 / O320 for ENS Extended (Days 16 - 46) with a model time step of 1200s;

- For the medium-range ENS there will no longer be a decrease of resolution at day 10: the ENS Days 11 - 15 will be run at the same TCo639 / O640 resolution as ENS Days 0 - 10;

- Increase of the HRES-WAM resolution from 0.25 to 0.125 degrees and the ENS-WAM Days 0 - 15 from 0.5 to 0.25 degrees;

- Horizontal resolution of the EDA outer loop is increased from TL399 to TCo639 with its two inner loops increased from TL159 / TL159 to TL191 / TL191, respectively;

- Horizontal resolution of the three 4DVar inner loops is increased from TL255 / TL255 / TL255 to TL255 / TL319 / TL399, respectively.

On 22nd November 2016 ECMWF introduced cycle 43r1. With this cycle upgrade, the medium-range ensemble and its monthly extension see a major upgrade in the dynamical ocean model (NEMO): the resolution is increased from 1 degree and 42 layers to 0.25 degrees and 75 layers (ORCA025Z75). Furthermore, NEMO model version v3.4.1 with the interactive sea-ice model (LIM2) is implemented. The ocean and sea-ice components of the ENS initial conditions are provided by the new ocean analysis and reanalysis suite ORAS5, which uses the new ocean model and revised ensemble perturbation method. In more detail:

- Introduction of the higher resolution ocean model with horizontal and vertical resolutions of the ocean model (NEMO v3.4.1) used by ENS increased from 1 degree and 42

layers to 0.25 degree and 75 layers (ORCA025Z75). An interactive sea-ice model (the Louvain-la-Neuve Sea Ice Model - LIM2) is introduced so that sea-ice cover evolves dynamically. Previously it was persisted for 15 days; over the next 30 days of the forecast, it was relaxed towards the climatology of the previous 5 years.

- A new ocean analysis/re-analysis (ORAS5), based on NEMOVAR with a higher-resolution version of the ocean model NEMO (0.25 degrees with 75 vertical layers: ORCA025Z75) has been implemented. This uses the same ocean model version (NEMO v3.4.1) as ENS. ORAS5 uses a new perturbation strategy for the surface fluxes and to simulate observation errors. It also includes an improved quality-control scheme for ocean observations. Sea ice is assimilated within NEMOVAR, with a weakly coupled assimilation to the ocean dynamics. The analyses have been run from 1975 and continue in real-time to provide initial conditions for the ENS forecasts and re-forecasts.

- The sea-surface temperature (SST) perturbations used in the EDA have been upgraded to a recently developed climatology based on the HadISST.2 dataset. This makes the perturbations statistically consistent with the error characteristics of the analysis cycles.

- The EDA-derived background error estimates used in 4DVAR are now computed at spectral resolution TL399 (previously TL159) and a new wavelet-based filtering algorithm is used to control sampling noise. The background error variance has been increased by ~16%.

- The weak constraint option of 4DVAR has been reactivated using a model error forcing term active in the stratosphere above 40 hPa and a new estimate of the model error covariance matrix.

- The land surface assimilation of SYNOP screen level observations now accounts for the vertical distance between the observations and model grid points. A new vertical structure function has been introduced that follows the approach used at Environment Canada and at Météo-France in MESAN-SAFRAN. The vertical correlation is expressed as a Gaussian function, consistent with that used for snow depth analysis. This gives more weight to observations from stations that are vertically closer to the model grid point (and less to observations less representative of the model altitude).

- Radiance assimilation will now take the viewing geometry more fully into account, by evaluating the radiative transfer along slantwise paths (instead of vertically). This is done for all clear-sky sounder radiances when interpolating model fields to observation locations.

- A better treatment of observation uncertainty for IASI and CrIS has led to updated observation error covariance matrices and a change of ozone anchor channels in bias correction.

- The channel selection for the hyperspectral infrared instrument CrIS has been revised and now uses 117 rather than 77 channels

- The aerosol detection scheme for IASI has been revised making it independent of the bias correction. The scheme is also applied to both CrIS and AIRS.

A new CAMS ozone climatology is now used, consisting of monthly means of a re-analysis of atmospheric constituents (CAMSiRA) for the period 2003 to 2014.

- Changes to boundary layer cloud for marine stratocumulus and at high latitudes.

- Modifications to surface coupling for 2 metre temperature.

- Assimilation of snowfall from the NEXRAD RADAR network over the USA.

- New model output fields include four cloud and freezing diagnostics (for aviation), a new direct-beam solar radiation diagnostic and improvements to the sunshine duration diagnostic.

- A global fix for tendency perturbations in the stochastic model error scheme SPPT to improve global momentum, energy and moisture conservation properties.