JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2010

COUNTRY: **Australia**   CENTRE: **NMOC Melbourne**

1. Summary of highlights (2010)

8 June	Increase spatial resolution of gridded-OCF forecasts to 0.50°
22 June	Oracle "solar" supercomputer declared operational
29 June	ACCESS-G, ACCESS-R, ACCESS-T & ACCESS-A NWP models declared operational on solar
21 July	Cessation of ensemble-GASP system
11 August	POAMA v1.5 long range coupled ocean-atmosphere system declared operational on solar
12 August	ACCESS-C 5km city-based models declared operational on solar
17 August	Cessation of old GASP/LAPS/MESOLAPS/TXLAPS/TCLAPS NWP systems. Cessation of routine production and distribution of synthetic PAOBs. Decommissioning of old NEC sx6 supercomputer
19 August	Auswave wave model declared operational
1 September	GFE (known as NexGenFWS in Australia) went live in NSW Region
9 September	Commencement of new HYSPLIT 4.9 atmospheric transport modelling system using ACCESS input
13 December	New calibrated daily Poor Man’s Ensemble (PME) Probability of Precipitation (PoP) product became operational

2. Equipment in use

The following table shows the main computer systems used in NMOC Melbourne in late 2010, with their basic functions:

FUNCTION	COMPUTER	NO. OF CPUS	MEMORY	OPERATING SYSTEM	DISK STORAGE
Supercomputing (Assimilation and Prediction)	Sun Constellation System (Operational since 8 June)	8 - Intel X5570 (2.93Ghz) per/ node 576 Nodes	24 GB / node	Centos 5.3	105 TB (Lustre)
Frontend to Supercomputer	Oracle x4270 (Operational since 8 June)	8 – Intel L520 (.27GB) per node 4 nodes	24 GB / node	Centos 5.3	105 TB (Lustre)
Communications / Message Switching	(i) HP RP7410 (ii) HP RP7410	(i) 8 (ii) 8	(i) 16 GB (ii) 16 GB	(i) HP-UX 11.11 (ii) HP-UX 11.11	200 GB
Scheduling / Data Base / Satellite Post-Processing / Graphics	(i) HP RP8400 (ii) HP RP8400 (iii) HP RP8400	(i) 16 (ii) 16 (iii) 16	(i) 32 GB (ii) 32 GB (iii) 32 GB	(i) HP-UX 11.11 (ii) HP-UX 11.11 (iii) HP-UX 11.11	600 GB 10 TB (SAN)
RADAR and Visualisation OSA	(i) HP Compaq (ii) HP Compaq (iii) HP Compaq	(i) 1 (ii) 1 (iii) 1	(i) 2GB (ii) 2 GB (iii) 2 GB	(i) Linux Core2 (ii) Linux Core2 (iii) Linux Core2	(i) 300 GB (ii) 300 GB (iii) 300 GB
Web / ftp	6 x Dell PowerEdge 2950	6 x 2	8 x 16 GB	Linux RH EL 3	8 x 1.5 TB
MARS	2 x IBM p570	20 cpus (total) (MARS: 1+2 cpus)	136 GB (total) (MARS: 24 GB)	AIX 6.1	15 TB
Development	HP RP8400	16	32 GB	HP-UX 11.11	1.8 TB

Peripheral Equipment:

Magnetic Cartridge Archive System:

- Sun StorageTek Mass Store 8500, 10,000 slots
- 10 T100000A fibre channel tapes for MARS (500GB)
- 8 T10000B fibre channel tapes for SAM-FS (1000GB)
- 11 9940B tape drives (5 for SAM-FS, 6 for MARS), capacity (uncompressed): 200GB
- 14 LTO4 tape drives for backup (800GB)
- 4 LTO3 tape drives for backup (400GB)

Hardcopy Printers/Plotters:

- HP DesignJet 1055cm plus and 650C plotters
- HP LaserJet 5 SiMX printers
- HP LaserJet 8150DN
- HP Color LaserJet 5500dtn
- HP Color LaserJet 4500DN

Facsimile Machines:

- RICOH FAX 4420NF

Software in use at Centre:

The overall computer environment in the NMOC is mainly Unix. A real-time data base, currently using ORACLE 8.1.7.4.0, is used for storage of observational data and grids from the various NWP systems. The U.S. Navy's Environmental Operational Nowcasting System (NEONS) software is commonly used for accessing the data base. The ACCESS operational NWP models are written mainly in Fortran. ACCESS output files are in the UKMO UM dump file format, which are then converted to WMO GRIB1 format. The Meteorological Archive and Retrieval System (MARS from the ECMWF) is used for archiving of operational NWP gridded data. ACCESS model output data is written into MARS and not directly stored as files on SAM-FS, except for essential assimilation and restart files. SAM-FS is currently being used for magnetic cartridge archives in the NMOC. Most displays are produced using either the ECMWF MetPy graphics package, the NCAR graphics package or IDL. OSA (On Screen Analysis) is a system that is used to generate, in an on-screen mode, manual-computer products for: significant weather prognoses, Australian Region surface analyses and prognoses and Southern Hemisphere surface analyses.

Other Systems in use at Centre:

Both the intranet and the DIFACS system are used to disseminate a selection of basic analysis and prognostic charts, and some satellite imagery, to the Bureau's regional offices and some outside users. MCIDAS is used for comprehensive interaction and display of satellite imagery and products, observational and gridded data, and is also a major component of the Australian Integrated Forecast System (AIFS). The Next Generation Forecast and Warning System (NexGenFWS) project is in the process of being rolled out to the regional offices and is now used operationally in Victoria and New South Wales. The underlying forecasting system is the Graphical Forecast Editor (GFE) adapted from the version used operationally in the US National Weather Service. Kenny, a locally developed visualisation tool, is widely used within the regional offices at the present time. Products from the NWP systems are written to internal and external (www.bom.gov.au) web servers. Magnetic cartridge archives are kept of various numerical analysis and prognosis products with Australian region analyses available back to 1970 and Southern Hemisphere analyses back to 1972. Hard copy and microfilm archives of charts also exist.

An aviation system, which interacts with the WAFS data, is used to view and display the data and prepare the various flight and route forecasts. Regular statistics (including S_1 skill scores, root mean square errors and anomaly correlations), monitoring and comparing the performance of the NMOC's NWP systems (and also some NWP models from overseas centre), are also produced. An Automated Terminal Aerodrome Forecast Content Generator (AutoTAF) provides guidance data for temperature and QNH pressure values, which are included in Australian Terminal Aerodrome Forecasts. The guidance data is derived from an amalgamation of Operational Consensus Forecasts (OCF) data with the latest weather observations and is displayed as default values in the TAF forecast editor.

3. Data and Products from GTS and internet in use

The following table gives a list of the major observation report types used in the NMOC Melbourne and the approximate numbers received in a 24-hour period (during 2010):

Observational Data Type or Report Type	Approximate number received during 24 hour period (unless otherwise stated)
SYNOP	66,983
SHIP	6,241
TEMP	1,356
PILOT	747
BUOY	27,684
AIREP / AMDAR	60,798
ATOVS (BUFR)	137,933
METAR (Australian stations only)	24,630
SATOB_SST	1,336,937
BATHY	5,262
WAVEOB	626
TRACKOB	1,502
AMV	1,761,558
SAT_ALT	6,368
ASCAT (from Nov 2009)	103,000
JASON1/JASON2	70,391
HYREP	717
AIRS	350,000
TEN_MIN_AWS	17,448
MDF	4,626
MTSAT_MOIS	38,380
SEA_LEVEL	75,770
DARTBUOY	1,959
RA2_WWV	45,257

The following Gridded Products are also received in NMOC Melbourne:
GRIB (ECMWF, EGRR, KWBC, JMA, CMC, DWD)

Data Input Stream:
Automated. (Some manual intervention is available for correction of reports.) The observational data, along with NWP gridded data, is stored in a real-time relational data base system (ORACLE/NEONS). An increasing proportion of operationally-produced NWP gridded data is also being stored in MARS.

Quality Control System:

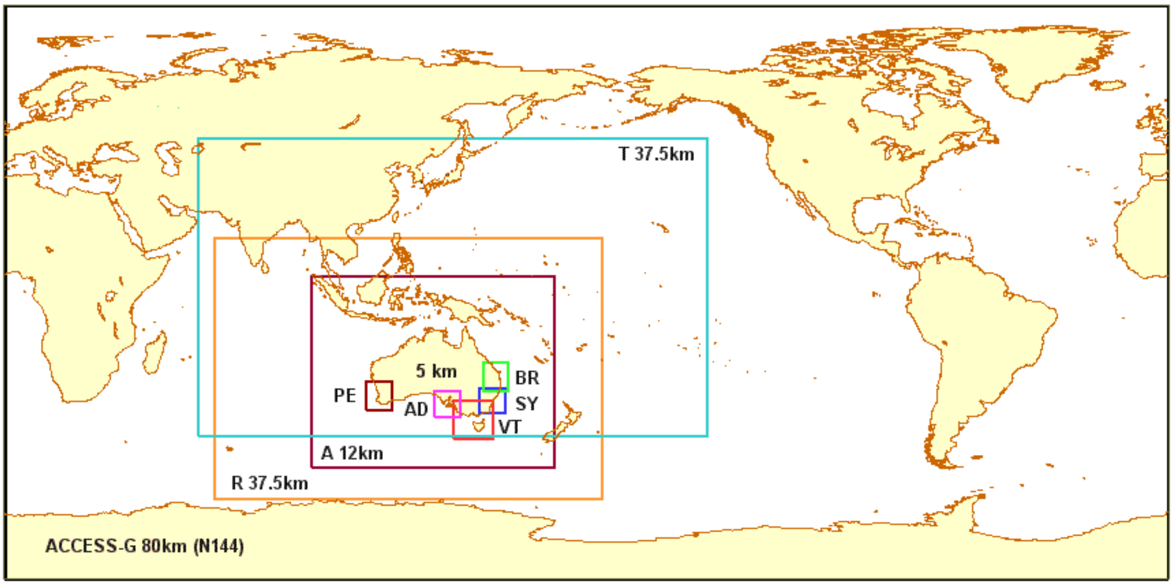
Validity checks are currently confined to within the respective assimilation or analysis schemes. Some gross checking outside these schemes may eventually be installed.

Monitoring of the Observing System:

Monitoring of the observing system is carried out. The quantity of data available is monitored in real-time to ensure that reports are being received reliably and are passed on to the operational systems. For the global system, statistics on the difference between observations and the first guess and analysis fields are routinely generated to identify any problems with either the analysis system or individual data types. Lists and displays of rejected data are also used to identify unreliable reporting from particular observing platforms.

4. Forecasting system

In December 2010 there were four major operational Numerical Weather Prediction (NWP) analysis and forecast systems run in the NMOC Melbourne, which all share the acronym of "ACCESS" (Australian Community Climate and Earth-System Simulator). These are the global ACCESS-G, regional ACCESS-R, tropical ACCESS-T and Australian mesoscale ACCESS-A systems. Additionally, high resolution forecast-only products are produced by the 5km resolution ACCESS-C mesoscale model over 5 smaller domains (viz., Brisbane, Sydney, Victoria/Tasmania, Adelaide and Perth). The domains for each of these systems are shown in the figure below. The regional and tropical systems are dependent on the global system for their lateral boundary conditions, whereas the 6 mesoscale systems are all nested in ACCESS-R. The ACCESS systems are based on the UK Meteorological Office Unified Model/Variational Assimilation (UM/VAR) system.

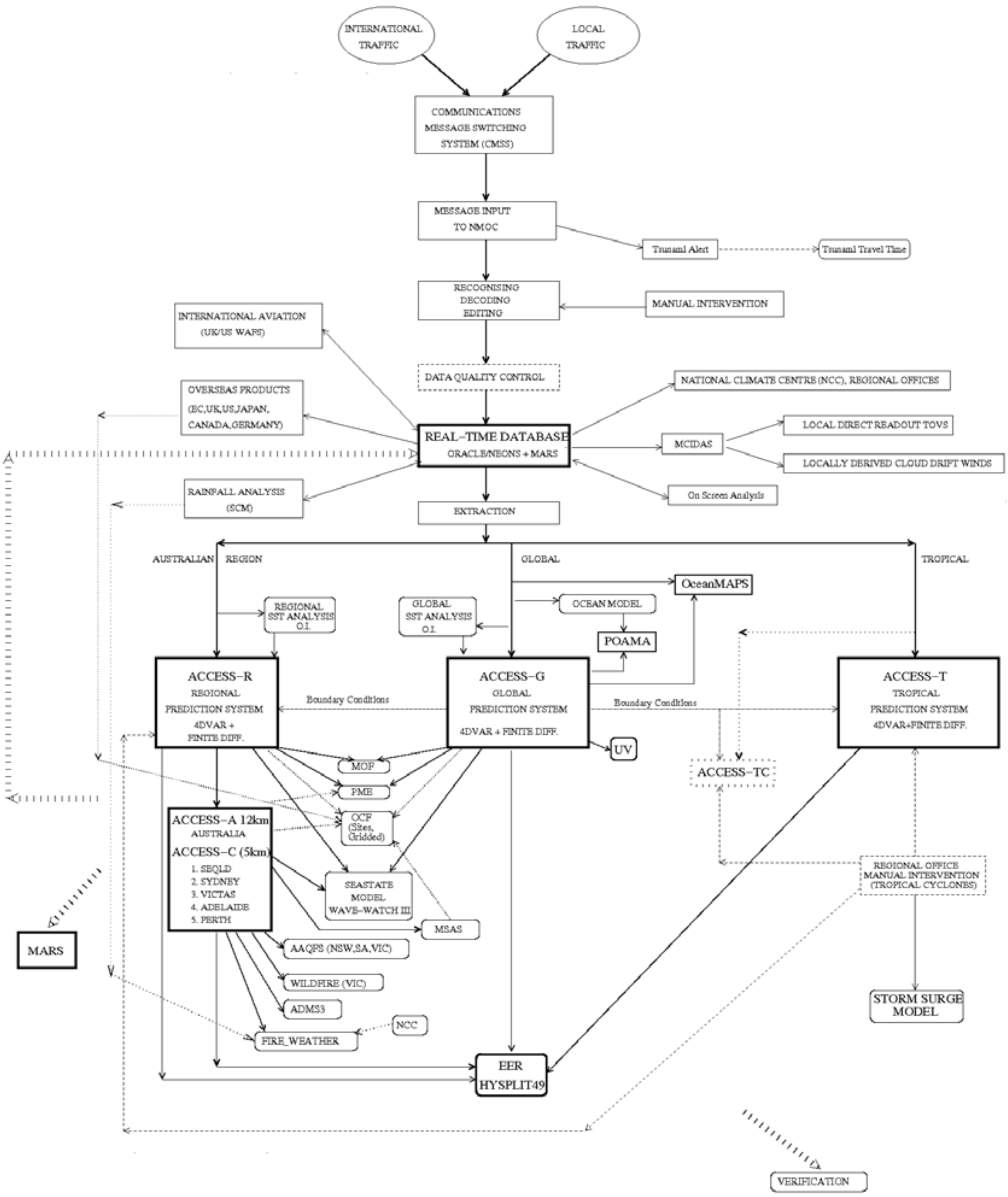


Domains of the operational NWP systems in NMOC Melbourne, 2010

The ACCESS NWP systems formally replaced all the Bureau of Meteorology's previous operational NWP systems (GASP, LAPS, TXLAPS and MESOLAPS) in August 2010 following the decommissioning of the Bureau's NEC sx6 supercomputer. The ACCESS model domains and spatial resolutions are generally similar to those of the previous GASP/LAPS systems. Further details on the operational ACCESS systems can be found at
http://web.bom.gov.au/nmoc/stan/opsbull/apob83.pdf

Schematic representation of the operational analysis and prediction system in NMOC.

The global, Australian region and mesoscale streams have associated sea-state systems. There are a large number of additional systems including sea surface temperature analysis, environmental emergency response (EER), generation of weather elements from model output (Operational Consensus Forecasts, OCF), amendment and dissemination of aviation products, MCIDAS, archives, verification, display and dissemination of products. The following schematic indicates the dataflows within the overall system:



4.1 System run schedule and forecast ranges

The following section is based on the system configuration in late 2010. The centre currently produces major analyses at 00, 06, 12 and 18 UTC daily for the globe, Australian region and tropical domains. Global forecasts extend out to 10 days, Australian region and tropical forecasts to 72 hours, mesoscale forecasts to 48 hours for the Australian and 36 hours for the 5 other smaller domains. The ECMWF's Supervisor Monitor Scheduler (SMS) is used to manage the major part of the operational system and to initiate and monitor the various tasks in the operational NWP suite. An approximate daily schedule for the main operational, and near-operational, numerical systems is shown in the table below (with the times during the Australian daylight saving months, November to March, shown in brackets).

System Run Schedule and Forecast Ranges

SYSTEM	**BASE TIME (UTC)**	**APPROXIMATE START TIME (UTC)**	**FORECAST AVAILABILITY (UTC)**	**FORECAST RANGE FROM BASE DATE/TIME (HRS)**
ACCESS-R (main)	0000	0155 (0055)	0235 (0135)	+72
ACCESS-C (VICTAS)	0000	0227 (0127)	0310 (0210)	+36
ACCESS-C (SYDNEY)	0000	0227 (0127)	0300 (0200)	+36
ACCESS-C (BRISBANE)	0000	0227 (0127)	0300 (0200)	+36
ACCESS-C (ADELAIDE)	0000	0227 (0127)	0300 (0200)	+36
ACCESS-C (PERTH)	0000	0227 (0127)	0300 (0200)	+36
EER PREP (ACCESS-R)	0000	0228 (0128)	0232 (0132)	+72
AUSWAVE (REGIONAL)	0000	0225 (0125)	0242 (0142)	+72
ACCESS-A (main)	0000	0230 (0130)	0415 (0315)	+48
EER PREP (ACCESS-C 0 5 DOMAINS)	0000	0300 (0200)	0310 (0210)	+36
ACCESS-T	0000	0330	0405	+72
FIRE_WEATHER (DROUGHT FACTORS)	0000	0315 (0215)	0355 (0255)	0
OCF (ACCESS-A)	0000	0345 (0240)	0400 (0255)	+48
OCF (DAILY COMPOSITE)	0000	0345 (0245)	0346 (0246)	+168
AUSWAVE (AUSTRALIA)	0000	0350 (0250)	0420 (0320)	+48
OCF (HOURLY COMPOSITE)	0000	0400 (0300)	0705 (0605)	+48
EER PREP (ACCESS-A)	0000	0405 (0305)	041 (0310)	+48
EER PREP (ACCESS-T)	0000	0410	0415	+72
RAINFALL_ANALYSIS	2300 (2200)	0500 (0400)	0510 (0410)	0
ACCESS-G	0000	0500	0530	+240
AUSWAVE (GLOBAL)	0000	0535	0600	+120
EER PREP (ACCESS-G)	0000	0535	0540	+240
OCF (ACCESS-G)	0000	0535	0540	+168
ACCESS-R (UPDATE ANALYSIS)	0000	0555 (0455)	0615 (0515)	+9
ACCESS-A (UPDATE ANALYSIS)	0000	0615 (0515)	0705 (0605)	+9
FIRE_WEATHER (DROUGHT FACTORS)	0000	0615	0630	0
GRIDDED OCF	0000	0650	0750	+216
PME	0000	0700	0715	+192
ACCESS-R (main)	0600	0755 (0655)	0835 (0735)	+72
ACCESS-A (main)	0600	0830 (0730)	1005 (0905)	+48
AUSWAVE (AUSTRALIA)	0600	0940 (0840)	1030 (0930)	+48
ACCESS-T	0600	1055	1120	+9
ACCESS-G (ANALYSIS)	0600	1125	1145	+9
ACCESS-R (UPDATE ANALYSIS)	0600	1155 (1055)	1215 (1115)	+9
ACCESS-A (UPDATE ANALYSIS)	0600	1215 (0515)	1305 (1205)	+9

ACCESS-R (main)	1200	1355 (1255)	1435 (1335)	+72
ACCESS-C (VICTAS)	1200	1427 (1327)	1510 (1410)	+36
ACCESS-C (SYDNEY)	1200	1427 (1327)	1500 (1400)	+36
ACCESS-C (BRISBANE)	1200	1427 (1327)	1500 (1400)	+36
ACCESS-C (ADELAIDE)	1200	1427 (1327)	1500 (1400)	+36
ACCESS-C (PERTH)	1200	1427 (1327)	1500 (1400)	+36
EER PREP (ACCESS-R)	1200	1428 (1328)	1432 (1332)	+72
AUSWAVE (REGIONAL)	1200	1425 (1325)	1442 (1342)	+72
ACCESS-A (main)	1200	1430 (1330)	1615 (1515)	+48
EER PREP (ACCESS-C 0 5 DOMAINS)	1200	1500 (1400)	1510 (1410)	+36
ACCESS-T	1200	1530	1605	+72
OCF (ACCESS-A)	1200	1545 (1440)	1600 (1455)	+48
OCF (DAILY COMPOSITE)	1200	1545 (1445)	1546 (1446)	+168
AUSWAVE (AUSTRALIA)	1200	1550 (1450)	1620 (1520)	+48
OCF (HOURLY COMPOSITE)	1200	1600 (1500)	1905 (1805)	+48
EER PREP (ACCESS-A)	1200	1605 (1505)	1610 (1510)	+48
EER PREP (ACCESS-T)	1200	1610	1615	+72
ACCESS-G	1200	1700	1730	+240
AUSWAVE (GLOBAL)	1200	1735	1800	+120
EER PREP (ACCESS-G)	1200	1735	1740	+240
OCF (ACCESS-G)	1200	1735	1740	+168
ACCESS-R (UPDATE ANALYSIS)	1200	1755 (1655)	1815 (1715)	+9
ACCESS-A (UPDATE ANALYSIS)	1200	1815 (1715)	1905 (1805)	+9
GRIDDED OCF	1200	1850	1950	+216
PME	1200	1900	1915	+192
ACCESS-R (main)	1800	1955 (1855)	2035 (1935)	+72
ACCESS-A (main)	1800	2030 (1930)	2205 2105)	+48
AUSWAVE (AUSTRALIA)	1800	2140 (2040)	2230 (2130)	+48
ACCESS-T	1800	2255	2320	+9
ACCESS-G (ANALYSIS)	1800	2325	2345	+9
ACCESS-R (UPDATE ANALYSIS)	1800	2355 (2255)	0015 (2315)	+9
ACCESS-A (UPDATE ANALYSIS)	1800	0015 (2315)	0105 (0005)	+9
MSAS	(Hourly)	Hour + 15 minutes	Hour + 25 minutes	0
SSTANAL (REGIONAL)	(Daily)	0130	0300	0
POAMA	(Daily)	1030	1600	+9 months
SSTANAL (GLOBAL)	(Daily)	0230	0330	0
SST (SUB-SURFACE)	(Daily)	2200	2225	0
AD HOC (TOP PRIORITY): EER	ANYTIME	ANYTIME	ANYTIME + 30 mins	+72
WILDFIRE (VICTAS)	ANYTIME	ANYTIME	ANYTIME + VARIABLE mins (dependent on number of fire sources)	+36
TSUNAMI ALERTS	(1-minute check)	ANYTIME		
ADMS3	ANYTIME	ANYTIME	ANYTIME + 30 mins	+24

4.2 Medium range forecasting system (4-10 days)

ACCESS-G is the global version of ACCESS. It produces medium-range forecast products out to 10 days. Post-processed products from this system are disseminated on the GTS in GRIB form, externally and internally via the web, "DIFACS" and MCIDAS, and also via Radio-facsimile broadcasts (VMC and VMW).

4.2.1 Data assimilation, objective analysis and initialization

4.2.1.1 In operation

ACCESS-G

Assimilated data: pressure, screen temperature, screen relative humidity and 10m winds (surface network, ships, drifting buoys), temperature (radiosondes and aircraft), relative humidity (radiosondes), wind (rawinsonde, profilers, aircraft, geostationary satellites , NASA Aqua and Terra polar orbiting satellites), radiances from ATOVS and AIRS (NOAA and NASA Aqua polar orbiting satellites respectively), ASCAT
Observation Reject List: Included.
(An intelligent thinning algorithm is used in the processing of satellite data.)
Assimilation cycle, including cut-off time: 6 hourly cycling. H+5 cut-off.
Method of analysis: four-dimensional variational analysis (4DVAR).
Analysed variables: temperature, wind, moisture, pressure
First guess: 6 hour forecast from previous cycle.
Coverage: Global.
Horizontal resolution: N108 (216 x 163 lat x lon gridpoints)
Vertical resolution: 50 hybrid levels (approximate height (m) of theta levels in absence of topography: 20, 80, 180, 320, 500, 720, 980, 1280, 1620, 2000, 2420, 2880, 3380, 3920, 4500, 5120, 5780, 6480, 7220, 8000, 8820, 9680, 10580, 11520, 12500, 13520, 14580, 15680, 16820, 18000, 19180, 20360, 21543, 22730, 23929, 25147, 26398, 27698, 29072, 30547, 32159, 33951, 35973, 38286, 40960, 44073, 47717, 51994, 57018, 62918)
Initialization: None

4.2.1.2 Research performed in this field

The main focus of research has been on preparing for the next upgrade, due in 2011. These improvements include

- Model resolution to N320 (~40km) and 70 levels
- VAR resolution N144 L70
- Use of IASI radiances and GPS radio occultation data
- Use of high resolution locally produced AMVs from MTSAT2
- Use of high resolution locally produced AMVs from MTSAT2
- A more frequent updating of satellite bias corrections – it has been changed from static to monthly cycling and will move to automated to update each analysis cycle during 2011
- There has also been a study of the value of extended range, high resolution, limited area prediction for major rainfall events. This has shown some encouraging results, but they are very dependent on the scale and nature of the event

4.2.2 Model

4.2.2.1 In operation

ACCESS-G.

Basic equations: Euler equations, in geometric terrain-following coordinates.
Independent variables: latitude, longitude, transformed (terrain-following) geometric height, time
Dependent variables: zonal, meridional and vertical wind ; density, potential temperature, mixing ratios of : water-vapour, cloud-liquid-water and cloud-frozen-water
Numerical technique: Non-hydrostatic
  horizontal: Finite difference.
  vertical: Finite difference.
  time: Semi-implicit semi-Lagrangian (although Eulerian for density)
Integration domain (in horizontal and vertical): Global, surface to 0.13 hPa (approx.).
Horizontal and vertical resolution, time step: N144L50 (217 x 288 lat x lon gridpoints = 0.8333° x 1.25°), 50 hybrid levels (approximate height (m) of theta levels in absence of topography: 20, 80, 180, 320, 500, 720, 980, 1280, 1620, 2000, 2420, 2880, 3380, 3920, 4500, 5120, 5780, 6480, 7220, 8000, 8820, 9680, 10580, 11520, 12500, 13520, 14580, 15680, 16820, 18000, 19180, 20360, 21543, 22730, 23929, 25147, 26398, 27698, 29072, 30547, 32159, 33951, 35973, 38286, 40960, 44073, 47717, 51994, 57018, 62918), timestep: 15 min
Orography, gravity wave drag: Both included.
Horizontal diffusion: Included in the model, but not active, except for local diffusion of moisture at a small number of points
Vertical diffusion: Included.
Planetary boundary layer: Included.
Treatment of sea surface, earth surface and soil: Included.
Radiation: Diurnal cycle, diagnostic clouds, interactive optical properties.
Convection (deep, mid-level and shallow): Included.
Atmospheric moisture: Included.
Boundaries: Stand alone.
Albedo: Climatology.
SST Analysis: GAMSSA Daily global 0.25° SST analysis

4.2.2.2 Research performed in this field

Main focus of research was model-tuning in support of the projected resolution increase noted in 4.2.1.2.

4.2.3 Operationally available Numerical Weather Prediction Products

Multilevel fields output from model: Temperature, Wind (U,V,W), Specific humidity, Pressure, Cloud amount , Convective cloud amount, Cloud liquid water content , Cloud ice water content.

Single level fields output from model include: Mean sea level pressure, Surface pressure, 10m wind (U,V), 10m wind gust, Precipitation (total, convective, large scale), Evaporation, 1.5m temperature, 1.5m dewpoint, 1.5m specific humidity, Surface temperature, Sub-surface temperature, Snow depth, Net solar radiation, Net downward LW radiation at surface, Net downward SW radiation at surface, Outgoing longwave radiation, Surface wind stress, Sensible heat flux, Latent heat flux, Soil moisture, Roughness length at surface, Boundary layer height, Topography, Sea ice fraction.

Additional post-processed fields generated include: Geopotential height, Dewpoint Temperature, Relative humidity, CAPE, DMAPE, Lifted Index, Precipitable Water.

A detailed description of gridded output fields available from the ACCESS models for external users can be found at http://www.bom.gov.au/nwp/doc/access/NWPData.shtml.

4.2.4 Operational techniques for application of NWP products *(MOS, PPM, KF, Expert Systems, etc..)*

4.2.4.1 In operation

ACCESS-G output fields are used to drive a number of systems including the global components of the sea-state and Environmental Emergency Response (EER) atmospheric transport modelling systems. In addition, ACCESS-G fields are used in the generation of OCF and meteogram products.

4.2.4.2 Research performed in this field

Research is being carried out on OCF (see Section 4.5.2.1), as described in Section 4.3.4.2. In particular, use of lagged model output is being investigated to improve the definition of the probability distribution function for probabilistic products in the medium range.

Sea Wave Models:

A multi-model technique for forecasting wave height and period at specific locations similar to OCF has been developed (Woodcock et al 2007)

4.2.5 Ensemble Prediction System (EPS)

4.2.5.1 In operation

An Ensemble Prediction System based on the GASP system (with the acronym GASP_EPS) had been run from July 2001 until July 2010 in a near-operational test mode in real-time in NMOC Melbourne. The 33-member ensemble system was running at the resolution: T119L19 (ie Triangular 119, 19 vertical levels), with a time step of 1200 sec., and produced forecasts out to 10 days, off 00 and 12 UTC. Singular vectors were used to perturb the initial state derived from GASP. These perturbed states were then used as the initial conditions for each of the ensemble members.

An ACCESS EPS system will be set up in 2013, resources permitting.

4.2.5.2 Research performed in this field

An ACCESS version of the UK Met Office MOGREPS ensemble system is under development (O'Kane et al., 2008). The global EPS has 24 members running with horizontal resolution of 90 km (N144) and 50 levels in the vertical; currently it is being run with a forecast period of 5 days, but the same system is run to 15 days by the Met Office, and KMA is also planning to run for this period. Initial condition perturbations are calculated using the local ensemble transform Kalman filter (Bowler et al., 2008); model uncertainties are represented through schemes which introduce stochastic perturbations to the parameterised model physics. In 2009 and early 2010, this system was run on the Bureau's NEC SX-6; in 2010 this system was ported to the Oracle Constellation computer, with the aim of progressing it to operational implementation.

Up until its cessation, Global EPS forecasts, from GASP_EPS, were produced for inclusion in the TIGGE program.

4.2.5.3 Operationally available EPS Products

Up until its cessation GASP_EPS, run in real-time mode in NMOC, generated the graphical products:
. rainfall probabilities - chance of exceeding certain (5mm, 20mm) thresholds;
. 850 hPa high and low temperature anomaly probabilities;
. 200 hPa and surface (10m) high speed wind probabilities;
. spaghetti diagrams (5600m contour);
. meteograms (of MSLP, total precipitation, 10m wind speed, 2m temperature) for Australian cities;
. tubing forecasts (MSLP/Thickness, precipitation);
. ensemble members: mean and thumbnails (MSLP/thickness and precipitation);
. standard deviations;
. comparisons with last 3 runs of system;
. ensemble spread plots;
. verification statistics.

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

The Australian regional domain ACCESS-R, the Tropical domain ACCESS-T and the Mesoscale Australian domain ACCESS-A, provide short-range forecasting guidance and products that are disseminated externally and internally via the web, "DIFACS" and MCIDAS, and also via Radio-facsimile broadcasts (VMC, VMW). ACCESS-T and TCLAPS (up until August 2010) for specific tropical cyclone guidance, are run on behalf of RSMC Darwin. Again it is noted that the 5 ACCESS-C 5km city-based systems do not have their own assimilation, or analysis but use an initial starting condition derived directly from ACCESS-R.

4.3.1 Data assimilation, objective analysis and initialization

4.3.1.1 In operation

<u>Regional ACCESS-R,T,A systems</u>

Assimilated data: pressure, screen temperature, screen relative humidity and 10m winds (surface network, ships, drifting buoys), temperature (radiosondes and aircraft), relative humidity (radiosondes), wind (rawinsonde, profilers, aircraft, geostationary satellites , NASA Aqua and Terra polar orbiting satellites), radiances from ATOVS and AIRS (NOAA and NASA Aqua polar orbiting satellites respectively), ASCAT
Observation Reject List: Included.
(An intelligent thinning algorithm is used in the processing of satellite data.)
Assimilation cycle, including cut-off time: 6 hourly cycling, cut-off: ACCESS-R: H+1:55 hr (H+0:55 hr during Nov-Mar), ACCESS-A: H+2:30 hr (H+1:30 hr during Nov-Mar), ACCESS-T: H+3:30 hr.
Method of analysis: four-dimensional variational analysis (4DVAR).

Analysed variables: temperature, wind, moisture, pressure
First guess: 6 hour forecast from previous cycle.
Coverage: ACCESS-R: -65.00°S to 17.125°N, 65.00°E to 184.625°E
ACCESS-T: -45.00°S to 55.875°N, 60.00°E to 217.125°E
ACCESS-A -55.00°S to 4.73°N, 95.00°E to 169.69°E
Horizontal resolution: ACCESS-R: 0.75°
ACCESS-T: 0.75°
ACCESS-A: 0.22°
Vertical resolution: 50 hybrid levels (approximate height (m) of theta levels in absence of topography: 20, 80, 180, 320, 500, 720, 980, 1280, 1620, 2000, 2420, 2880, 3380, 3920, 4500, 5120, 5780, 6480, 7220, 8000, 8820, 9680, 10580, 11520, 12500, 13520, 14580, 15680, 16820, 18000, 19180, 20360, 21543, 22730, 23929, 25147, 26398, 27698, 29072, 30547, 32159, 33951, 35973, 38286, 40960, 44073, 47717, 51994, 57018, 62918)
Initialization: None
Boundary conditions: ACCESS-R & ACCESS-T: previous ACCESS-G forecast
ACCESS-A: current ACCESS-R forecast

Additional High Resolution Analysis:

MSAS (Mesoscale Surface Analysis System):
Analysis Frequency: 1-hourly (15 minute cut-off)
Method of analysis: Optimum Interpolation
Analysed surface variables: pressure, temperature, dew point, wind
First guess: ACCESS-A (Australian)
Coverage: 45.125^{0}S - 8.917^{0}S, 109.875^{0}E - 156.083^{0}E
Horizontal Resolution: 0.0417^0

4.3.1.2 Research performed in this field

The main focus of research has been on preparing for the next upgrade, due in 2011. These improvements include:

- o Model resolution to 0.11^o km and 70 levels
- o VAR resolution 0.375^o L70
- o Use of IASI radiances, GPS radio occultation data
- o Use of high resolution locally produced AMVs from MTSAT2
- o Use of radiances from Asia Pacific Regional ATOVS Retransmission Service
- o A more frequent updating of satellite bias corrections – it has been changed from static to monthly cycling (based on the global system)
- o The value of tropical cyclone bogus data within 4dVAR. Experiments have shown that using only MSLP bogus data within 4dVAR produced better performance than using MSLP and upper air bogus data. With just MSLP data, 4dVAR was able to construct a more realistic vortex.
- o The introduction of some anisotropy into regional systems. This is done two ways, firstly by allowing for a latitudinal variation in the variances, which makes a significant impact on our large domain models. A second approach of allowing for horizontal structures that are rotated ellipses rather than circles also has shown positive impact.

There has also been research with a longer term view, including:

- o The testing of 0.0135^o systems for domains of the order 8^o x 8^o
- o The development of quality control and monitoring for radar based precipitation estimates and Doppler winds with a view to eventual assimilation

- o Following on from some earlier work on the feasibility of initializing soil moisture with AMSR-E data, work has commenced on assimilation ASCAT data, and the development of an Extended Kalman Filter for land surface assimilation.
- o A limited area coupled ocean-atmosphere system for tropical prediction has undergone initial testing.

4.3.2 Model

4.3.2.1 In operation

Basic equations: Euler equations, in geometric terrain-following coordinates.
Independent variables: latitude, longitude, transformed (terrain-following) geometric height, time
Dependent variables: zonal, meridional and vertical wind ; density, potential temperature, mixing ratios of : water-vapour, cloud-liquid-water and cloud-frozen-water
Numerical technique: Non-hydrostatic
horizontal: Finite difference.
vertical: Finite difference.
time: Semi-implicit semi-Lagrangian (although Eulerian for density)
Integration domain (in horizontal and vertical):
ACCESS-R: 65.00°S to 17.125°N, 65.00°E to 184.625°E, surface to 0.13 hPa (approx.)
ACCESS-T: 45.00°S to 55.875°N, 60.00°E to 217.125°E, surface to 0.13 hPa (approx.)
ACCESS-A 55.00°S to 4.73°N, 95.00°E to 169.69°E, surface to 0.13 hPa (approx.)
ACCESS-C
SYDNEY: 30.05^0S-38.00^0S, 147.00^0E-154.95^0E, surface to 0.13 hPa (approx.)
VICTAS: 34.05^0S-46.00^0S, 139.00^0E-150.95^0E, surface to 0.13 hPa (approx.)
BRISBANE: 22.05^0S-31.00^0S, 148.00^0E-155.95^0E, surface to 0.13 hPa (approx.)
ADELAIDE: 30.55^0S-39.50^0S, 132.00^0E-141.95^0E, surface to 0.13 hPa (approx.)
PERTH: 28.05^0S-37.00^0S, 112.00^0E-119.95^0E, surface to 0.13 hPa (approx.)
Horizontal and vertical resolution::
ACCESS-R: 0.375°, 50 levels
ACCESS-T: 0.375°, 50 levels
ACCESS-A: 0.11°, 50 levels
ACCESS-C
SYDNEY: 0.05°, 50 levels
VICTAS: 0.05°, 50 levels
SEQLD: 0.05°, 50 levels
ADELAIDE: 0.05°, 50 levels
PERTH: 0.05°, 50 levels
50 hybrid levels (approximate height (m) of theta levels in absence of topography: 20, 80, 180, 320, 500, 720, 980, 1280, 1620, 2000, 2420, 2880, 3380, 3920, 4500, 5120, 5780, 6480, 7220, 8000, 8820, 9680, 10580, 11520, 12500, 13520, 14580, 15680, 16820, 18000, 19180, 20360, 21543, 22730, 23929, 25147, 26398, 27698, 29072, 30547, 32159, 33951, 35973, 38286, 40960, 44073, 47717, 51994, 57018, 62918)
Orography, gravity wave drag: Both included.
Horizontal diffusion: Included in the model, but not active, except for local diffusion of moisture at a small number of points
Vertical diffusion: Included.
Planetary boundary layer: Included.
Treatment of sea surface, earth surface and soil: Included.
Radiation: Diurnal cycle, diagnostic clouds, interactive optical properties.
Convection (deep, mid-level and shallow): Included.
Atmospheric moisture: Included.

Boundaries: ACCESS-R, ACCESS-T: Lateral boundaries from ACCESS-G.
ACCESS-A and ACCESS-C (5 domains): Lateral boundaries from ACCESS-R.
Albedo: Climatology.
SST Analysis:
ACCESS-R,A,C: RAMSSA Daily regional 1/12° (~0.083°) SST analysis
ACCESS-T: GAMSSA Daily global 0.25° SST analysis.

4.3.2.2 Research performed in this field

Much of the research was in support of the projected resolution increases noted in 4.3.1.2, with particular emphasis on strong convective events. In addition to model-tuning, evaluation of the new prognostic cloud scheme ("PC2") was undertaken.

Boundary-layer processes also received attention. The new low-wind-speed parameterisation was tested in climate-mode (an important task, given our use of the Unified-Model across all scales), and the cause of surface-decoupling in boundary-layer transition periods was identified and ameliorated

4.3.3 Operationally available NWP products

The following table lists some of the post-processed fields that are available from the Regional ACCESS systems:

Multilevel fields output from model: Temperature, Wind (U,V,W), Specific humidity, Pressure, Cloud amount , Convective cloud amount, Cloud liquid water content , Cloud ice water content.

Single level fields output from model include: Mean sea level pressure, Surface pressure, 10m wind (U,V), 10m wind gust, Precipitation (total, convective, large scale), Evaporation, 1.5m temperature, 1.5m dewpoint, 1.5m specific humidity, Surface temperature, Sub-surface temperature, Snow depth, Net solar radiation, Net downward LW radiation at surface, Net downward SW radiation at surface, Outgoing longwave radiation, Surface wind stress, Sensible heat flux, Latent heat flux, Soil moisture, Roughness length at surface, Boundary layer height, Topography, Sea ice fraction.

Additional post-processed fields generated include: Geopotential height, Dewpoint Temperature, Relative humidity, CAPE, DMAPE, Lifted Index, Precipitable Water.

A detailed description of gridded output fields available from the ACCESS models for external users can be found at http://www.bom.gov.au/nwp/doc/access/NWPData.shtml.

4.3.4 Operational techniques for application of NWP products

4.3.4.1 In operation

ACCESS-R and ACCESS-A output fields drive the Australian region and Australian meso-scale domain wave forecast models respectively.

Output fields from ACCESS-A, ACCESS-T and the various city-based ACCESS-C systems, are used to drive the respective components of the EER atmospheric dispersion system, and are also used in the generation of OCF and meteogram products. Fields from ACCESS-A are used in the NTFGS decision tree system.

The Bureau of Meteorology has adapted the US developed Graphical Forecast Editor (GFE) for use as the main production engine for operational weather forecasts. Development work is continuing in preparation for a future national rollout (see section 4.3.4.2) but the GFE has been shown to lead to improved forecasts of temperature and rainfall in Victoria, where GFE has been running since October 2008, and in New South Wales, where it has been used operationally since Sep 2010.

4.3.4.2 Research performed in this field

OCF and GFE:

Sites based OCF is being updated to replace bias-correction of NWP predictions by a running least squares linear regression correction. Results so far have indicated better predictions at coastal and mountain sites.

The main research effort has been to improve the quantity and quality of gridded OCF daily and hourly forecasts that are used as first guess fields in a graphical editor. The Bureau of Meteorology has adapted the US developed Graphical Forecast Editor (GFE) for use as the main production engine for operational weather forecasts. Work has progressed on :

. developing gridded bias corrected consensus model forecasts of surface level temperature, dewpoint, MSLP, wind, multi-layer cloud cover, and precipitation as the first guess fields for the GFE;
- testing and evaluation of an OCF stratospheric ozone prediction system;
. through the use of "smart tools", improving the forecast process by which human forecasters modify the NWP derived grids in a systematic way to improve their utility as the basis of our suite of weather products;
. developing text formatters to produce high quality natural language text forecasts and warnings from the gridded numerical forecast database developed by forecasters within the GFE;

The introduction of the GFE has led to improved forecasts of temperature and rainfall in Victoria, where it has been running since October 2008. A national roll-out is now underway with New South Wales commencing operational use in Sep 2010.

4.3.5 Ensemble Prediction System

4.3.5.1 In operation

No regional EPS has been run in 2010.

4.3.5.2 Research performed in this field

An ACCESS version of the UK Met Office MOGREPS ensemble system has been implemented (O'Kane et al., 2008). The regional EPS has 24 members running with horizontal resolution of 37.5 km over the Australian Region domain (65S to 17N, 65E to 185E) and 50 levels in the vertical, nested within the global EPS, with a forecast period of 3 days. Initial condition perturbations are calculated using the local ensemble transform Kalman filter (Bowler et al., 2008); model uncertainties are represented through schemes which introduce stochastic perturbations to the parameterised model physics. In 2009 and early 2010, this system was run on the Bureau's NEC SX-6; in 2010 this system was ported to the Oracle Constellation computer, with the aim of progressing it to operational implementation.

4.3.5.3 Operationally available EPS Products

No regional EPS has been run in 2010

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

4.4.1 Nowcasting system

4.4.1.1 In operation

The Australian Nowcasting System is primarily based on radar data and comprises three components:

- A radar data serving infrastructure;
- A Nowcast Applications Server (NAS) which processes the radar data; and,
- Nowcast client applications that are used to display the radar data and information from the NAS and to generate end user products.

The NAS integrates several radar data processing applications, including the Thunderstorm Identification, Tracking, Analysis and Nowcasting (TITAN) application (Dixon and Wiener 1993), the Weather Decision Support System (WDSS) (Eilts 1997), and a quantitative rainfall application known as 'Rainfields'. These components identify and track 'storm' cells and associated parameters in the volumetric radar data and provide quantitative estimates of precipitation and make this information available for downstream applications.

The Bureau of Meteorology's operational radar data workstation is known as 3D-Rapic and this is the primary tool for forecasters when severe thunderstorms are possible. This application allows the display and analysis of the radar data together with guidance from the NAS and enables the forecaster to more quickly identify storm cells that may be associated with severe weather.

The Thunderstorm Interactive Forecast System (TIFS), (Bally 2004), is a graphical user interface used for the generation of graphical and text warning products for thunderstorms. Storm information from the NAS is displayed within TIFS together with lightning and selected NWP guidance and forecasters can generate a range of thunderstorm warning products in a time efficient manner.

The Automated Thunderstorm Alerting Service (ATSAS) has been developed to provide timely information on the presence of thunderstorms and associated lightning around major airports and enable airlines to manage the risk associated with lightning strikes for ground operations. Systems that support ATSAS take output from TITAN and a lightning sensor and generate end-user graphical and text products that show the location and movement of thunderstorm cells and the presence of lightning near the airport.

The Short Term Ensemble Prediction System (STEPS) (Bowler et al 2006), has been developed to generate ensembles of 0-6 hour rainfall forecasts. STEPS blends an advection forecast that is based on radar data with NWP rainfall forecasts and generates the ensemble by perturbing the blended forecast with a stochastic model of advection and NWP forecast error. The 50-member STEPS ensemble is updated at hourly intervals and generates forecasts with 2 km, 10 min resolution. STEPS is also used to generate ensembles for 0 – 90 minutes that are based only on perturbing an advection forecast. This version of STEPS generates a time-lagged ensemble with 30 members that is updated every 6 minutes and the forecasts have 1 km, 6 min resolution. The STEPS ensembles are used to estimate the probability that the rainfall accumulation in the next 60 minutes will exceed a range of thresholds.

4.4.1.2 Research performed in this field

Research and development activities include:

- Improvements to TIFS including trial production of probabilistic forecasts
- Work to improve the ATSAS products by improving the use of lightning data and to provide probabilistic forecasts on the likelihood of cells moving over the airport.
- Improvements to quantitative precipitation estimates and forecasts.
- Developing thunderstorm strike probability nowcasts based on TITAN tracks and historical track errors (Dance et al. 2010).
- Space-time models of rainfall and estimation errors for NWP and radar.
- Modelling the dependence of radar estimation error on the meteorology of the day and range from the radar.
- Generating ensembles of quantitative radar estimates and forecasts.

4.4.2 Models for Very Short-range Forecasting Systems

4.4.2.1 In operation

None at present.

4.4.2.2 Research performed in this field

Development of STEPS, a radar-mesoscale model ensemble blended forecast rainfall, is in progress (Bowler et al. 2006) and has been run in trial mode using ACCESS-A NWP forecasts.

4.5 Specialized numerical predictions

4.5.1 Assimilation of specific data, analysis and initialization (where applicable)

4.5.1.1 In operation

Rainfall Analysis:

A daily rainfall analysis is run for both an Australian (10.00^{0}S-44.50^{0}S, 112.00^0 E-156.25^{0}E) and a South East Australian (32.50^{0}S-44.00^{0}S, 134.50^0 E-152.40^{0}E) domain. The analysis uses a Barnes' successive correction method applied to observational data derived from SYNOP, telegraphic and AWS reports. The analysis is performed on a latitude/longitude grid at a horizontal resolution of 0.25^0 for the Australian and 0.10^0 for the South East Australian domains.

Ocean Model Analysis and Prediction System (OceanMAPS):

OceanMAPS, associated with the BLUElink> project (Brassington, 2007), is an ocean system that is used to analyse and forecast ocean temperatures, salinity and currents over most of the globe. The oceanic circulations are modelled spatially in 3 dimensions. Forecasts are produced out to 7 days, twice/week.

The horizontal latitude/longitude grid resolution varies between the 3 settings: 0.1^0, 0.9^0 and 2.0^0, according to geographical location, with the highest resolution of 0.1^0 being over an Australasian region (75S-16N, 90E-180E). The vertical resolution is currently set at 47 levels, extending from the surface to a depth of 5000m. The higher resolution in the Australasian region give the ability to resolve features such as eddies, mixed layers and thermoclines in the mesoscale.

Surface forcing for the system is provided by GASP, in the form of 3-hourly average surface fluxes. Observation data used by the system include in situ profile data (Argo and XBT) and remotely-sensed data (satellite altimetry sea level anomaly from JASON1, JASON-2 and Envisat, and satellite SST from AMSR-E and AVHRR). The BLUElink> Ocean Data Assimilation System (BODAS) is an ensemble-based, multivariate Optimum Interpolation scheme. (Use is made of a 72-member ensemble of anomalies from the seasonal cycle generated from a spin-up integration of OFAM - the Ocean Forecast Australian Model.) The basis of OFAM, the forecasting component of OceanMAPS, is the MOM4, Modular Ocean Model version 4p0d, from NOAA’s GFDL. The present implementation of OFAM does not include tides or a sea-ice model. The neutral physics is also not used.

4.5.1.2 Research performed in this field

Solar Ultraviolet (UV) Radiation Forecast System:

During 2010 an Ozone and UV analysis and forecasting system, based on the ACCESS framework, was continued to be developed (ACCESS-O3+UV; Lemus-Deschamps, 2009). ACCESS-O3 system has been running in research mode, in real near time, since May 2009. Interface to the UV component was also developed and tested. ACCESS-O3 performs three-dimensional variational assimilation (3DVar) of ATOVS radiances for ~80km resolution. Seven-ten days ozone forecast fields are generated from the atmospheric tracer transport within the UM model. Ozone analysis and forecast fields from ACCESS-O3 as well as the ACCESSS-G meteorological fields are input to the UV radiation scheme.

4.5.2 Specific Models (as appropriate related to 4.5)

4.5.2.1 In operation

National Thunderstorm Forecast Guidance System (NTFGS):

The NTFGS (Hanstrum, 2003) is a decision tree system that uses diagnostic fields derived from ACCESS-A together with defined thresholds to provide forecast guidance on likely storm or severe weather areas over Australia. Storm types considered include thunderstorms, super-cells and tropical squall lines. Severe weather classifications include events associated with large hail and heavy rain, tornadoes and severe convective gusts. The system is updated four times a day, after the runs of ACCESS-A.

Sea Wave Models:

The following table summarises the characteristics of the sea-state system in the NMOC:

Domain	Global	Australian Region	Australian MESO_LAPS Region
Numerical Scheme	Deep water 3rd generation (WAM)	Deep water 3rd generation (WAM)	Shallow water 3rd generation (WAM)
Wind data source	ACCESS-G (10m)	ACCESS-R (10m)	MESO_LAPS_PT125 (10m)
Grid	Latitude/ longitude	Latitude/ longitude	Latitude/ longitude
Resolution	1^0	0.5^0	0.125^0
Nesting	Stand alone	Within Global	Within Regional
Start time of forecast	00,12 UTC	00, 12 UTC	00, 12 UTC
Forecast Period	+96 hrs	+48 hrs	+48 hrs
Initial state	12 hr hindcasting and assimilation of satellite altimeter data		No assimilation
Model output	Wind and swell significant wave height, period and direction. Significant wave spectra and probabilities.		
Verification	With respect to rigs and buoys		

Specialized sea-state forecasts are provided for the North West Cape and Bass Strait gas and oil fields.

Storm Surge System:

A system capable of forecasting storm surges, caused by tropical cyclones, is currently driven by wind and pressure field distributions defined, according to the central pressure and maximum wind radius bogussed for tropical cyclones, by Darwin RFC.

Atmospheric Transport Model - EER System:

An air dispersion, or transport, system is available for running on demand and can produce forecast trajectories, concentrations (or exposures) and depositions for nuclear accident, volcanic ash, smoke, air-borne virus and other episodes. Currently, the operational Environmental Emergency Response (EER) system consists of the Hybrid Single Particle Lagrangian Integrated Trajectories (HYSPLIT) system Version 4.9, developed at the NOAA Air Resources Laboratory (Draxler et al, 1998), with meteorological input from the operational ACCESS NWP systems in NMOC.

Operational Consensus Forecasts (OCF):

The OCF system (Woodcock et al 2005) generates forecasts of weather elements using a consensus of direct model output and model output statistics. A bias correction (with a 30-day adaptation period) is applied to the component forecasts and then a composite forecast (based on the mean absolute error, using a weighted average algorithm) is generated. The system currently uses model output from ACCESS and overseas models from UK, USA, JAPAN, CMC and ECMWF. OCF is run in a daily (4 times per day) and an hourly (2 times per day) mode. For the daily mode, forecast elements include temperature (maximum, minimum, ground minimum), rainfall (amount and probability), sunshine hours and evaporation for approximately 800 sites covering Australian territories, Vanuatu and other locations of specific relevance, where the available forecast period can be up to 9 days, depending on the weather elements. For the hourly mode, the forecast weather elements produced include: screen-level air and dew point temperatures, relative humidity, QNH, wind speed and direction, and precipitation - with forecasts up to 48 hours for approximately 380 Australian stations. Gridded hourly OCF forecasts of temperature, dewpoints, MSLP, and sky cover are generated at 0.5º resolution (0.04º resolution for temperature) out to 8 days.

Poor Man's Ensemble (PME) Precipitation Forecasts:

PME (which is now part of the OCF suite) uses the precipitation forecasts from a number of models (ACCESS, CMC, DWD, UK, US, JAPAN and ECMWF) to generate mean precipitation fields and the probability of precipitation for various thresholds. It uses a probability-matched mean approach to combine the precipitation fields.

Fire Weather system:

The Fire Weather system (Finkele, 2006), in the NMOC operational context, uses the daily rainfall and (from the National Climate Centre) the maximum temperature analyses to generate a set of gridded soil moisture deficit (e.g. Keetch-Byram Drought Index and Mount's Soil Dryness Index) and associated drought factor fields, and other derivatives. These products are used to support fire weather services throughout the regions. By combining some of these products with output from ACCESS-A, ACCESS-C and OCF, a number of additional products (e.g. forest and grassland fire danger indices) are also made available.

Microscale Dispersion Modelling System:

The microscale dispersion system: ADMS3 (Atmospheric Dispersion Model Version 3), from CERC (UK), was relocated to an operationally supported platform, This system is a skewed Gaussian plume model, which has the capacity of allowing the definition of a variety of sources in terms of shape and pollution types. Currently, ACCESS-C (all 6 city based domains) provides the meteorological input for driving the system.

Tsunami Warning System:

The introduction and development of a tsunami operational modelling capability using scenario selection initially was implemented during 2007. There was a further enhancement made in October 2008 consisting of a Tsunami Decision Support Tool that uses this modelling output to generate national tsunami threat warnings.

4.5.2.2 Research performed in this field

Sea Wave Models:

The AUSWAVE model is based on version 3.14 of WAVEWATCH III® (WW3). It formally replaced the global WAM, Australian Region WAM, and Australian Mesoscale WAM models on 19 August 2010. Operational runs are performed using surface forcing data from the Australian Community Climate and Earth-System Simulator (ACCESS). The source terms employed in the latest WAM release (Bidlot et al. 2007) were chosen rather than the default source terms available within WW3 to produce the best results for the Australian region. The so-called Ultimate Quickest numerical scheme within WW3 was employed to alleviate the occurrences of the Garden Sprinker Effect and account for blocking of wave energy by unresolved islands at sub-grid scales. Verification of the trial AUSWAVE system against all buoys around the Australian coast shows significant improvement of root mean square errors over the legacy AUSWAM system, especially for the Regional and Australian domain systems.

Evaluation of the wave model WAVEWATCHIII™ against global satellite altimeter data and in situ buoy data in the Australian region has provided guidance as to the optimum choice of physics package for operational implementation. Research into error attribution has been performed. Initially, this has focussed on an evaluation of the errors in the forcing surface winds through comparison with satellite scatterometer data.

Tropical Cyclone Prediction:

ACCESS-TC has been configured for operational and research applications on Tropical Cyclones. The base system runs at a resolution of 0.11^0 and 50 levels, but higher resolution forecasts have also been made. The domain is re-locatable and nested in coarser-resolution forecasts. Initialization consists of 5 cycles of 4DVAR over 24 hours and forecasts out to 72 hours are made. Without vortex specification, initial conditions usually contain a weak and misplaced circulation. Based on estimates of central pressure and storm size, vortex specification is used to construct the inner-core of the storm, merge it with the large scale analysis at outer radii, and locate it to the observed position. Using all available conventional observations and only synthetic surface pressure observations, the 4DVAR can create (i) a good first approximation to the surface pressure field, and (ii) a balanced 3-D vortex at the observed location, with intensity near to the operational estimate. Objective verification for a limited number of storms is quite encouraging.

Solar Ultraviolet (UV) Radiation Forecast System:

The UVCODE scheme was run using as input total ozone amounts from ERA40 and TOMS/OMI for the period 1958-2007. Seasonal and Annual UV Index distribution were calculated for North, Central and South Australia. The UV Index deviations from the period (1960-1980) were obtained and compared with incidence of Melanoma skin Cancer. The results were presented at AMOS and NIWA UV Science Workshop 2010 (Lemus-Deschamps and Makin, 2010).

Tsunami warning system

Research in this area has included the assessment of numerical tsunami scenario forecasts for specific events (Uslu et al., 2011; Greenslade et al., 2010) and development of the amplitude threshold technique for threat assessment (Allen and Greenslade, 2010)

Research into the effect that linear scaling of pre-computed tsunami scenarios has on the propagation of tsunamis, and in particular their dispersion characteristics, has been performed.

4.5.3 Specific products operationally available

Rainfall Analysis:

Daily rainfall analysis products are generated for the Australian and South-east Australian domains.

Sea Wave Models:

Products from the sea wave models include:
. charts of wind wave and primary and secondary swell wave heights;
. significant wave spectra and probabilities.

Solar Ultraviolet (UV) Radiation Forecast System:

Forecasts for UV index and UV alerts are produced, once per day, based on the total ozone field obtained from the USGFS model. Diurnal UV Index forecast is available for all the Bureau of Meteorology's forecasting sites (more than 300 in number). UV Index forecast charts for Australia, and UV Index values for clear and cloudy sky conditions, are also produced daily.

Atmospheric Transport Model - EER System:

Products from the EER system include:
. forecast forward and backward trajectories and dispersion;
. analysed backward trajectories;
. analysed retro-plumes.

Dispersion products are available for different nuclear and non-nuclear scenarios (eg air-borne viruses, smoke and volcanic ash) and different domains ranging from the meso to the global scale. Forecast products out to 10 days ahead can be produced. Retro-plumes going back 30 days are available operationally. Products for external use are made available through a number of password-protected registered users.

National Thunderstorm Forecast Guidance System (NTFGS):

Graphical products, covering the Australian continent, are generated to depict areas of likely thunderstorms, severe convective weather, supercells and tornadoes.

Operational Consensus Forecasts (OCF):

Forecasts from OCF are generated for temperature (maximum, minimum, and ground minimum), rainfall (amount and probability), sunshine hours and evaporation, for a large number of sites (approximately 785) throughout Australia and areas of specific relevance. Hourly and daily gridded forecasts of temperature, dewpoint, wind, MSLP, low and medium level and total cloud cover, and precipitation out to day +8 are generated four times per day.

Fire Weather system:

Products generated by the operational FIRE_WEATHER system, for both Australian and South-East Australian domains, include:
. Keetch-Byram Drought Index;
. Mount Soil Dryness Index;
. low and high vegetation Soil Dryness indices;
. drought factors based on KBDI and SDI;
. forest fire danger indices based on KBDI and SDI;
. grassland fire danger index (100% curing factor).

Microscale Dispersion Modelling System:

Forecast dispersion plots for specific locations within the various ACCESS-C domains can be generated on demand. Horizontal domains are limited in extent to 1x1, 4x4 and 20x20 km^2. Plots are also available for horizontal and vertical spread, mean plume height, mean concentration at ground, and travel time against distance from the source.

Australian Air Quality Forecast System (AAQFS):

The AAQFS provided a facility for generating air quality forecasts for regions including and surrounding the Australian capital cities. The system features a Chemical Transport Model (using the Generalised Reaction Scheme), an emissions data base or inventory and, eventually, an evaluation module. The system is an Eulerian numerical forecasting system. Currently, the system is run over 6 airsheds: Sydney, NSW, Melbourne, Victoria, Adelaide and South Australia. Meteorological input to the system was provided by the 5km MESOLAPS models up until 16 August 2010.

Unfortunately, AAQFS ceased routine operational running when the NEC sx6 supercomputer was decommissioned on 16 August 2010 due to lack of resources for the task of porting the system to the new Oracle supercomputer using meteorological input from the ACCESS systems.

4.5.4 Operational techniques for application of specialized numerical prediction products *(MOS, PPM, KF, Expert Systems, etc..)* (as appropriate related to 4.5)

4.5.4.1 In operation

"[brief description of automated (formalized) procedures in use for interpretation of specialized NP output]"

4.5.4.2 Research performed in this field

"[Summary of research and development efforts in the area]"

4.5.5 Probabilistic predictions (where applicable)

4.5.5.1 In operation

PME uses the precipitation forecasts from a number of models (ACCESS, CMC, DWD, UK, US, JAPAN and ECMWF) to generate mean precipitation fields and the probability of precipitation for various thresholds. It uses a probability-matched mean approach to combine the precipitation fields.

4.5.5.2 Research performed in this field

CAWCR carried out research to improve the Probability of Precipitation products of the gridded OCF system. The existing poor man's ensemble model-counting technique was calibrated and a new Bayesian method, based on forecast rainfall amounts was investigated. Research also commenced into methods of predicting the expected error of gridded OCF products such as MSLP and 2 metre temperature.

4.5.5.3 Operationally available probabilistic prediction products

PME generates forecasts out to +8 days of simple ensemble means, probability-matched means, and probability of precipitation for thresholds of 1, 5, 10, 15, 25 and 50 mm/day.

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

4.6.1 Models

4.6.1.1 In operation

CAWCR continues to support real-time monitoring and empirical prediction of tropical convectively coupled wave modes, including the MJO (Madden Julian Oscillation).

CAWCR has started to contribute forecasts of the MJO to an international comparison project organized by the US CLIVAR MJO Working Group, and endorsed by the Working Group on Numerical Experimentation. These include a statistical forecast of the MJO (out to day 20), dynamical forecasts from the POAMA (Predictive Ocean Atmosphere Model for Australia) seasonal prediction system (out to day 40), and the GASP_EPS (out to day 10).

4.6.1.2 Research performed in this field

CAWCR has been involved in the US CLIVAR MJO Working Group, who have developed basic metrics of the MJO to be used for verification of model simulations and forecasts, and provided the framework for MJO forecast comparisons.

The POAMA dynamical seasonal prediction system has been extended to also provide meaningful predictions on shorter (~weeks) time scales. The key components leading to increased skill on these shorter time scales are the Atmosphere-Land Initialisation (ALI) scheme which allows the same land and atmosphere model to be used for initialisation and coupled forecasts and also allows consistency between real-time forecasts and hind-casts, the new state-of-the-art, POAMA ensemble-based ocean data assimilation scheme (PEODAS; Yin et al. 2011) that assimilates not only ocean temperature but also salinity and fully coupled initialisation scheme. A range of experimental products (e.g. fortnightly rainfall forecasts over Australia) have been developed.

4.6.2 Operationally available NWP model and EPS ERF products

Diagnostics and predictions associated with tropical convectively coupled wave modes, including the state of the MJO and its expected behaviour for the next 3 weeks, are made available on a web page and are updated in near real-time.

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

4.7.1 In operation

Three-month outlooks for rainfall and temperature across Australia are issued toward the end of each calendar month for the three-month period starting the following month.

Probabilities are calculated for the three-month total rainfall being above the long-term median based on the years 1950-1999. The technique used is discriminant analysis, with the inputs being derived from recent Sea Surface Temperature (SST) patterns. Subsidiary techniques involved in the forecast model include principal component analysis of SSTs for the Pacific Ocean, Indian Ocean and Southern Ocean, and principal component analysis of the rainfall and temperature patterns across Australia. SST EOF (Empirical Orthogonal Function) loadings, at one and three months lag, for the Pacific Ocean ENSO pattern and the Indian Ocean pattern are the current predictor inputs. The above-median probabilities, computed across Australia on a 1° x 1° grid are published in the form of contoured maps, together with commentary. Furthermore, the rainfall probability distribution is converted to show rainfall totals for the 25%, 50% and 75% probability levels as well as the chances for receiving various specified rainfall totals (e.g. 100 mm). This information is issued in both map and table format, the latter interpolated to numerous sites across the country.

In addition, the tercile category probabilities are derived from the above and published on the web for rainfall, maximum and minimum temperature. These data are tabulated as averages for the 107 Australian rainfall districts (rainfall only), and for cities and towns around Australia (all three variables).

The performance of seasonal forecasts is continually monitored and reported. The skills scores show a level of skill in the predictions that varies from season to season and from the place to place within Australia.

Ocean-Atmosphere Coupled Model:

The same ocean model, referred to above, is also used to provide the ocean initial conditions and ocean component of a seasonal to inter-annual coupled ocean/atmosphere general circulation model known as POAMA (Predictive Ocean Atmosphere Model for Australia). Atmospheric initial conditions are obtained from an initialization scheme that nudges the atmospheric model towards existing NWP analyses. The atmospheric component of the coupled system is the BoM Atmospheric Model version 3 (BAM3.0; Colman et al. 2005) which is essentially the same model as the legacy operational GASP but run at the reduced resolution: T47L17 (ie Triangular 47, 17 vertical levels). Nine month forecasts are produced daily from this system and used as monthly, or last 30 day, ensemble forecasts for the seasonal outlooks.

Operational products include forecasts of the sea surface temperature in the equatorial Indian Ocean and warnings of potential bleaching of coral in the Great Barrier Reef in the season ahead (Spillman and Alves, 2009).

4.7.2 Research performed in this field

The POAMA (Predictive Ocean Atmosphere Model for Australia; Alves et al 2003) system continues to be developed. The POAMA-1.5 system has been running operationally in the Bureau since Feb 2008and was ported to the new solar supercomputer in August 2010. A new version, POAMA-2 has been developed with improved physics. This includes a new

POAMA ensemble-based ocean data assimilation system (Yin et al. 2011) using variances calculated from a time evolving ensemble. Atmospheric initial conditions for POAMA-2 are provided by the same ALI system used in POAMA-1.5. ALI nudges the BAM3.0 atmospheric model toward global analyses of zonal and meridional winds, temperature, and humidity. For use in real time, ALI nudges to the analyses from ACCESS-G that are routinely produced at BoM in real time. The POAMA-2 version of ALI includes the BAM3.0 bug fix.

The forecast system comprises the BAM3.0 and the same ocean system, referred above coupled using the Ocean Atmospheric Sea Ice Soil (OASIS) coupling software (Valke 2000). This is the same system as POAMA-1.5, however, instead of the single instance of the system used in POAMA-1.5, three different versions of the configuration form a multi-model ensemble. The three versions differ in their inclusion of a bug fix and the implementation of flux correction, both in BAM3.0. The bug fix improves the atmospheric model physics associated with shallow convection, resulting in a reduction in the SST bias at longer lead times. POAMA-2.4a includes only the bug fix, POAMA-2.4b includes both bug fix and flux correction, and POAMA-2.4c includes neither. The three versions were found to have strengths and weaknesses in different areas. This makes them ideal for a multi-model ensemble. The model resolution of POAMA2 remains same as that of POAMA1.5 model.

A near-time trial system was set up and has been produced 60-member multi-model ensemble forecasts each month. Based on hindcast experiments conducted for the period of 1980-2006, POAMA2 system demonstrates a significant increase in SST skill in the Pacific and Indian Oceans. This system will be implemented operationally in 2011.

Development of the POAMA-3 system is also on the way, which includes a new coupled model based on the UKMO Unified Atmospheric model and the GFDL MOM4, to be run at higher resolution that the current system. The ocean data assimilation system is also being extended to include the atmosphere and land surface, which will result in a multi-variate ensemble coupled assimilation system.

4.7.3 Operationally available EPS LRF products

A comprehensive hind-casts set has been produced for the past 25 years from POAMA-1.5. For each month, a 10 member, 9-month forecast has been generated, thereby producing a hindcast set of some 27,000 months. Statistical calibration and bridging techniques have been developed as part of the South East Australian Climate Initiative that will deliver improved forecasts of SST, rainfall and other products. Operational trials started in June 2007 and the system went operational in February 2008.

Another focus of POAMA-1.5 is as a trial intra-seasonal forecast system. Because the hind-casts are initialised with true atmospheric and land states the system doubles as an intra-seasonal forecasts system. Skill has been explored on time scales of weeks and products have been made available, for example, for the Madden Julian Oscillation (MJO) and monsoon onset.

5. Verification of prognostic products

5.1 Annual Verification Summary

An annual summary of verification statistics for 2010, for the operational global schemes (GASP from January to June 2010, ACCESS-G from July to December 2010), is given in the following tables.

Root Mean Square Errors (Annual 2010):

Average of GASP (January to June 2010) and ACCESS-G (July to December 2010)

(a) Verification against GASP/ACCESS-G analyses:

AREA	FIELD	RMSE or RMSVE UNIT	+24HR		+72HR		+120HR	
			00UTC	12UTC	00UTC	12UTC	00UTC	12UTC
Northern Hemisphere	500 hPa Height	m	12.885	12.87	34.335	34.165	59.72	59.12
	250 hPa Wind	m/s	4.805	4.77	12.9	12.895	14.96	14.87
Southern Hemisphere	500 hPa Height	m	14.495	14.6	40.125	40.39	68.9	68.615
	250 hPa Wind	m/s	4.955	4.96	14.31	14.235	16.175	16.11
Tropics	850 hPa Wind	m/s	2.31	2.36	3.805	3.82	4.2	4.15
	250 hPa Wind	m/s	4.155	4.22	7.91	7.9	8.595	8.575

(b) Verification against radiosondes:

AREA	FIELD	RMSE or RMSVE UNIT	+24HR		+72HR		+120HR	
			00UTC	12UTC	00UTC	12UTC	00UTC	12UTC
North America	500 hPa Height	m	14.905	15.19	33.405	33.845	57.525	57.085
	250 hPa Wind	m/s	11.15	11.065	13.68	13.48	16.96	16.785
Europe	500 hPa Height	m	18.32	17.4	41.49	39.895	66.135	63.59
	250 hPa Wind	m/s	9.575	9.51	12.265	12.3	16.225	16.115
Asia	500 hPa Height	m	18.605	18.58	34.06	33.73	49.905	49.45
	250 hPa Wind	m/s	11.465	11.585	13.005	13.075	15.11	15.195
Australia/NZ	500 hPa Height	m	12.87	13.125	24.68	27.13	39.085	45.57
	250 hPa Wind	m/s	9.955	10.11	11.765	11.855	14.58	14.415
Tropics	850 hPa Wind	m/s	4.175	4.07	4.415	4.33	4.72	4.565
	250 hPa Wind	m/s	6.54	6.61	7.44	7.62	8.42	8.555
Northern Hemisphere	500 hPa Height	m	18.455	18.29	37.17	36.835	59.815	58.97
	250 hPa Wind	m/s	10.505	10.51	12.68	12.675	15.74	15.66
Southern Hemisphere	500 hPa Height	m	17.36	19.935	31.925	35.485	48.875	54.295
	250 hPa Wind	m/s	10.29	10.545	12.31	12.49	15.245	15.265

5.2 Research performed in this field

The use of neighbourhood techniques (Ebert 2008) to verify high resolution precipitation forecasts against radar and rain gauge observations is being investigated. The aim is to use objective methods to give credit to "close" forecasts at lead times exceeding the limit of deterministic predictability.

The Verify2008 system developed at ECMWF for the operational verification of global NWP has been implemented at the Bureau and is being adapted for global and regional verification of NWP and other gridded forecasts.

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

6.1 Development of the GDPFS

6.1.1 Major changes in the operational DPFS which are expected in this year

Plans for operational systems in the NMOC Melbourne include:

. the operational upgrade of ACCESS to the next version “APS1”

. increased use of the Meteorological Archival and Retrieval System (MARS) as the primary repository for gridded numerical model output and observational data

. the extension of OCF to provide sea-state forecast guidance is being implemented in 2011;

. increasing the spatial resolution of gridded OCF forecasts from 1.25º to 0.50º lat/lon (note: temperature fields are statistically downscaled to 0.05º resolution).

. a move toward the use of a Linux cluster infrastructure;

6.1.2 Major changes in the operational DPFS which are envisaged within the next 4 years

Long term plans for operational systems in the NMOC Melbourne include:

. Implementation of higher resolution ACCESS systems with rationalization of some domains

. the operational development and implementation, within the ACCESS framework, of global and limited area ensemble systems, an Antarctic regional modelling system, a very high resolution relocatable severe weather system, a TC-genesis system, and an associated storm surge system;

. an upgrade of the rainfall analysis to use the Kriging method;

. the implementation of a rainfall verification scheme;

. the rationalisation and upgrade of verification systems;

. the ongoing improvement and generalization of data processing and graphical display

. the improvement in data monitoring systems;

. the improvement in product dissemination methods.

. development of an assimilation and forecast system for tsunamis incorporating tsunameter gauge observations.

. assimilation of satellite altimeter wave height data into the WAVEWATCH III™ model**.**

6.2 Planned research Activities in NWP, Nowcasting, Long-range Forecasting and Specialized Numerical Predictions

6.2.1 Planned Research Activities in NWP

ACCESS:

Further increases in resolution are planned with the global system horizontal resolution going to 25km around 2012/13. The aim is also to implement both global and regional ACCESS-based ensemble systems, running at approximately half the resolution of their deterministic counterparts. Finally, progress towards radar-data assimilation (of both Doppler winds and reflectivities), at resolutions of 1.5km will be a major focus for several years. Associated with this is an investigation into the feasibility of a national 4km rapid update analysis.

With the major systems in place and integrated within the Bureau's operational forecast process a number of more major research activities have either commenced or are about to. These include:

- The development of an Extended Kalman Filter based land surface data assimilation scheme based on JULES to utilize the next round of satellites such as SMOS and SMAP.
- Further development of a regional coupled atmosphere land assimilation and prediction system
- Development of adjoint based observation sensitivity tools for operational use
- Use of diurnally varying SSTs
- Progress towards a hybrid ensemble/variational assimilation system
- Observation Impact experiments are currently under way on the effect of possible reconfigurations of the Australian radiosonde network, and on the impact of AMDAR data. This may be extended to other in situ observation in the future.
- Impact of dropsondes from Concordiasi.
- Building on experience from our climate-work, a prototype implementation of the "CABLE" land-surface scheme in a NWP framework.
- Evaluation of the "SES2" radiation scheme in full NWP (forecast plus assimilation) mode.
- Evaluation of the new low-wind-speed parameterisation in full NWP (forecast plus assimilation) mode.
- Continuing work on the impact of increased stratospheric resolution on forecast accuracy.
- Continuing development of the global and regional ensemble systems, with the general goal of keeping them at half the resolution of the deterministic systems.
- Continuing work on computational optimisation of the Unified-Model.

There is also a substantial amount of work in progress or planned on improving the use of satellite data, including:

- An intercomparison between cycling and variational bias correction for satellite sounders,
- Use of AIRS radiances from Asia Pacific Regional ATOVS Retransmission Service.
- Use of SSMI/S data, particularly its impact on tropical prediction.

- o Use of higher spectral and spatial resolution data from AIRS and IASI
- o Use of new satellite data as it becomes available: OceanSAT, geostationary radiances, WindSAT, NPP etc.

GFE and GRIDDED OCF:

Gridded OCF will increasingly be used to generate probabilistic predictions of wind, temperature, and other fields of interest such as derived products for fire weather. Optimal blending of bias-corrected multi-model output with NWP ensembles and methods of deriving expected errors in consensus forecasts and probabilities of exceedance of critical thresholds (for example, gale force winds) will be investigated.

Development will be completed with a progressive national rollout of GFE (known as NexGenFWS in Australia) occurring during 2010 to 2013/14. Rollout of will occur in Tasmania during June 2011, and South Australia in Sept 2011. The focus for system improvement during 2011 is on code quality improvements needed to support new forecasting functionality needed for implementation of the system in the tropics.

Tropical Cyclones:

Current and ongoing investigations include: (a) very high-resolution experiments on initialization and prediction of TC structure and intensity, with particular focus on rapid intensification, (b) basic research into initialization of realistic TC structures using the state-of-the-art 4-dimensional variational data assimilation system (4D-VAR) from ACCESS (Australian Community Climate and Earth System Simulator), which is an implementation of the UK Meteorological Office’s NWP system at the Australian Bureau of Meteorology, (c) diagnosis of the mechanisms of TC intensity and structure change (environmental influences, vortex structure, internal processes), and (d) transitioning of a validated TC assimilation and prediction system into operations, to provide forecast guidance on TC track, intensity and structure change.

Solar Ultraviolet (UV) Radiation Forecast System:

Research effort has been directed towards the interface of the Ozone and UV forecast system to the ACCESS framework. The ozone assimilation and forecast ACCESS-O3, integrated in the SCS (Suite Control System) job with OPS, VAR, and UM systems tailored for the inclusion of the ozone atmospheric tracer, has been successfully implemented on the Bureau’s computing environment and detailed testing was carried out. The ozone assimilation and forecast system (ACCESS-O3+UV) has been ported to the super computer and provided to NMOC.. The system is based on the ACCESS-G suite and on the Met Office’s 3DVar ozone assimilation. We developed and included the merging of ozone from 3DVar with ACCESS-G 4DVar meteorological fields to calculate ozone forecast fields. Both ACCESS-O3 and the UV radiation scheme form the basis of the Ozone and UV forecast system (ACCESS-O3+UV). The interface to the UV scheme has been completed and tested. The validation suite has been also upgraded. The ACCESS-O3+UV system has been provided to NMOC for implementation in 2010. The next upgrade to the system will be increased resolution N320 (40km) and investigation of inclusion ACCESS-O3 inside the ACCESS-G suite. We envision more upgrades to the ozone and UV Index validation suite and increased activity in the Antarctic ozone development and outlook.

Atmospheric Transport Modelling:

Verification studies will continue to ensure forecast accuracy is maintained in the operational smoke forecast system following the multiple changes made with the introduction of ACCESS NWP data and the implementation of HYSPLIT 4.9 as the operational EER model.

Dispersion modelling of other atmospheric particulates and gases, dust in particular, will be the focus of research effort in the next 4 years. One initial area of research will be the potential to assimilate observations into the model forecasts. Some preliminary investigations of a potential replacement for AAQFS have already begun.

In conjunction with several other agencies the Bureau of Meteorology is evaluating microscale models suitable for rapid response to (mainly) urban scale emergencies. The models chosen will ultimately provide a national emergency response capability.

Sea Wave Models:

Research into a data assimilation scheme that can treat wind-sea and swell separately is planned. Potential research is also planned to investigate techniques for correcting the wind fields prior to forcing the wave model.

Further evaluations of AUSWAVE are planned. This will involve research into how errors in the forcing wind fields are translated into the wave model.

Research into a data assimilation scheme that can treat wind-sea and swell separately is planned.

Tsunami warning system

Research in this area will include further evaluations of numerical tsunami forecasts as events occur. Research into the interaction between tsunamis and the Great Barrier Reef will also be performed through high-resolution modelling studies.

6.2.2 Planned Research Activities in Nowcasting

Nowcasting:

Planned research, associated with the use of radar, includes:
. improved identification and removal of anomalous propagation in radar data
. developing techniques to mosaic multiple radars together including:
- real-time indicators of radar rainfall accuracy
- improved techniques to blend radar rainfall estimates with rain gauge observations
- improved representation of orographic effects in ensemble rainfall nowcasts

. ensemble thunderstorm tracking
. phenomena probability forecasting based on radar algorithm output.
Objective analysis system for radar Doppler wind components
Develop decision support tools to make optimum use of networked radar information streams
. develop automated polarimetric hail detection techniques
Work is underway to operationalise generation of “THESPA” strike probability products (Dance 2010) in the TIFS operational Nowcast system.

Meso-Scale Assimilation:

(c.f. section 6.2.1) A national, 4km rapid update system, assimilating radar reflectivity and Doppler winds will be explored over the next 4 years, along with 1.5km systems over the major cities. A 1.5km relocatable system for use in high impact weather events outside of the city-based domains is also planned.

6.2.3 Planned Research Activities in Long-range Forecasting

A new version of the POAMA system (POAMA-3) is being built from components developed as part of ACCESS. ACCESS aims to develop an Australian earth system model for a range of applications, including seasonal prediction. New components developed by the ACCESS project include a new atmospheric model based on the UK Met Office atmospheric model and the CABLE land-surface model. The exact configurations of these systems remain to be decided and will depend on computational costs and scientific performance. The ocean model developed as part of the ACCESS project will be based on the GDFL MOM4 code and will have a configuration called AusCOM (Australian Climate Ocean Model) which will be used for a range of climate studies.

In the longer term there will be a focus on coupled data assimilation, with ocean data being assimilated directly into the coupled model using the PEODAS approach while, at the same time, assimilating atmospheric fields from a re-analysis or operational NWP analysis.

6.2.4 Planned Research Activities in Specialized Numerical Predictions

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