Annual WWW Technical Progress Report

On the Global Data Processing and Forecasting System 2004

AUSTRALIA

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

1. SUMMMARY OF HIGHLIGHTS (2004):

Meteorological, Oceanographic and Computer Systems:

2 March:	MESO_LAPS_PT050 upgraded (featuring the 3 domains: SEQLD, SYDNEY and VICTAS).
15 March:	HP operational servers available for use at new Central Computing Facility (CCF), 700 Collins St., Melbourne.
26 March:	NEC SX-6 (18 nodes) and TX7s available for use at new CCF.
4 May:	Communications cutover to new CCF.
12 May:	Operational cutover to new CCF of rainfall analysis,verification, mof, EER, AAQFS and ADMS3 suites.
13 May:	Operational cutover to new CCF of GASP (GenSI), LAPS_PT375, MESO_LAPS_PT125 and MESO_LAPS_PT050 suites.
18 May:	FMD EER Exercise (Tasmanian RO)
20 May:	Operational cutover to new CCF of TLAPS and TC_LAPS suites.
26 May:	Operational HP servers at 150 Lonsdale St. Melbourne turned off.
31 May:	NEC SX-5 turned off at 150 Lonsdale St. Melbourne.
2 June:	EER Exercise (NSW RO)
5 July:	Air-borne virus EER Exercise (SA RO)
9 July:	Trial version of 33-level GASP system initiated.
2 August:	NMOC Personnel relocated to 700 Collins St. Melbourne.
12 August:	EER system upgraded to HYSPLIT Version 4.7.
17 August:	ADMS3 extended to SEQLD domain.
19 October:	Quality Control of TOVS data over tropics improved for ozone system.

18 November: EER Test (RSMC Melbourne: Lead Centre).

1 December: TXLAPS (featuring an extension of the tropical domain) operational.

8 December: LAPS_PT375 upgraded to GenSI.

26 December: Indian Ocean Tsunami.

2. EQUIPMENT IN USE AT CENTRE:

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

FUNCTION	COMPUTER	NO. OF CPUS	MEMORY	OPERATING SYSTEM	DISK STORAGE
Supercomputing (Assimilation and Prediction)	Multi-Node NEC SX-6	8 cpu / node 18 Nodes	64 GB / node	SUPER-UX 13.1 SX-6	14 TB (GFS) 133 GB (Local - total of all nodes)
Interface to Supercomputer	NEC TX7/i9510	12 cpu / node 2 Nodes	12 GB / node	NEC Linux R3.3	14 TB (GFS)
Communications / Message Switching	(i) HP RP7410 (ii) HP RP7410	(i) 4 (ii) 4	(i) 8 GB (ii) 8 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) 8 (ii) 8 (iii) 8	(i) 8 GB (ii) 8 GB (iii) 8 GB	(i) HP-UX 11.11 (ii) HP-UX 11.11 (iii) HP-UX 11.11	600 GB 10 TB (SAN)
Horace	(i) HP C3600 (ii) HP C3600 (iii) HP C3600	(i) 1 (ii) 1 (iii) 1	(i) 512 MB (ii) 512 MB (iii) 512 MB	(i) HP-UX 11.11 (ii) HP-UX 11.11 (iii) HP-UX 11.11	(i) 27 GB (ii) 35 GB (iii) 30 GB
RADAR and Visualisation	(i) SGI Octane (ii) SGI-O2	(i) 1 (ii) 1	(i) 512 MB (ii) 128 MB	(i) IRIX 6.5 (ii) IRIX 6.5	(i) 17 GB (ii) 8.5 GB
web / ftp	8 x Dell PowerEdge 2650	8 x 2	6 x 2 GB 2 x 6 GB	Linux RH ES 3.0	8 x 120 GB
MARS	2 x IBM p690	2 x 18 cpus (total) (MARS: 8 cpus)	128 GB (total) (MARS: 24 GB)	AIX 5.2	3 TB
Development	HP RP8400	8	8 GB	HP-UX 11.11	1.8 TB

Peripheral Equipment:

Magnetic Cartridge Archive System:

StorageTek Mass Store 9310 ACS (Automatic Cartridge System)
16 drives, for 9840 fibre channel tapes, in silo (4 for SAM-FS, 8 for MARS, 2 for backup and 2 others)
14 drives for 9940B tapes (6 for SAM-FS and 8 for backup)

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

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 operational NWP models are written mainly in Fortran, with many of the associated files having the NetCDF structure. Most displays are produced using the NCAR graphics package and IDL. The UK Met. Office's Horace (V3.8) system is used to prepare, in an on-screen mode, manual-computer products for: significant weather prognoses, Australian Region surface analyses and prognoses and Southern Hemisphere surface analyses. Sam-fs is currently being used for magnetic cartridge archives in the NMOC. The Meteorological Archive and Retrieval System (MARS from the ECMWF) is being gradually integrated into both research and operations.

Other Systems in use at Centre:
The DIFACS system is used to 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). 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.

3. DATA AND PRODUCTS FROM GTS 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 2004):

Observational Data Type or Report Type	Approximate number received during 24 hour period (unless otherwise stated)
SYNOP	47900
SHIP	7100
TEMP	1200
PILOT	750
BUOY	13700
AIREP / AMDAR	25100
SATOB	275900
SATEM	18000
ATOVS (BUFR)	86100
METAR	15600
CLIMAT	1800 / month
SATOB_SST	4200
BATHY	390
WAVEOB	750
TRACKOB	770
AMV	792900
TOVS1C	56100 (Jan-May)
SAT_ALT	9300
QUIKSCAT	1140300
JASON	64200
RA2_WWV	43900

The following Gridded Products are also received in NMOC Melbourne:

GRIB (ECMWF)
GRIB (EGRR)
GRIB (KWBC)
GRIB (JMA)
[GRID (ECMWF)]

4. 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.

5. QUALITY CONTROL SYSTEM:

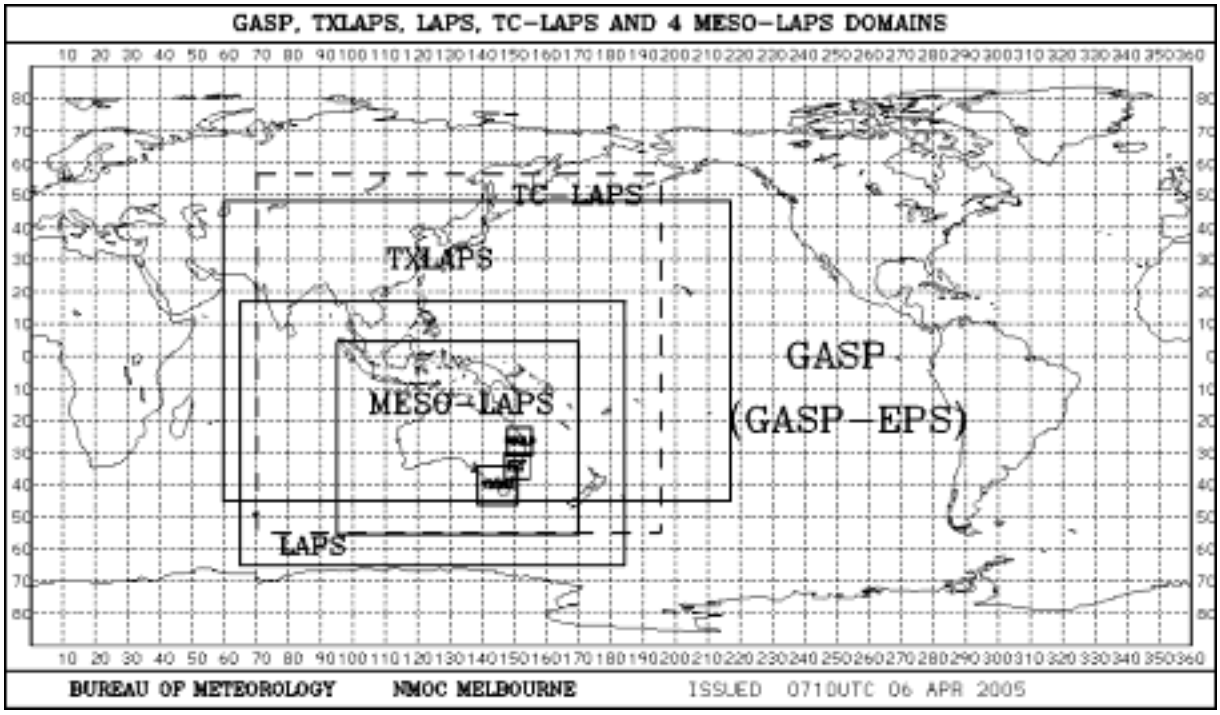
Validity checks are currently confined to within the respective assimilation or analysis schemes. Some gross checking outside these schemes may eventually be installed.

6. 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 prepared 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.

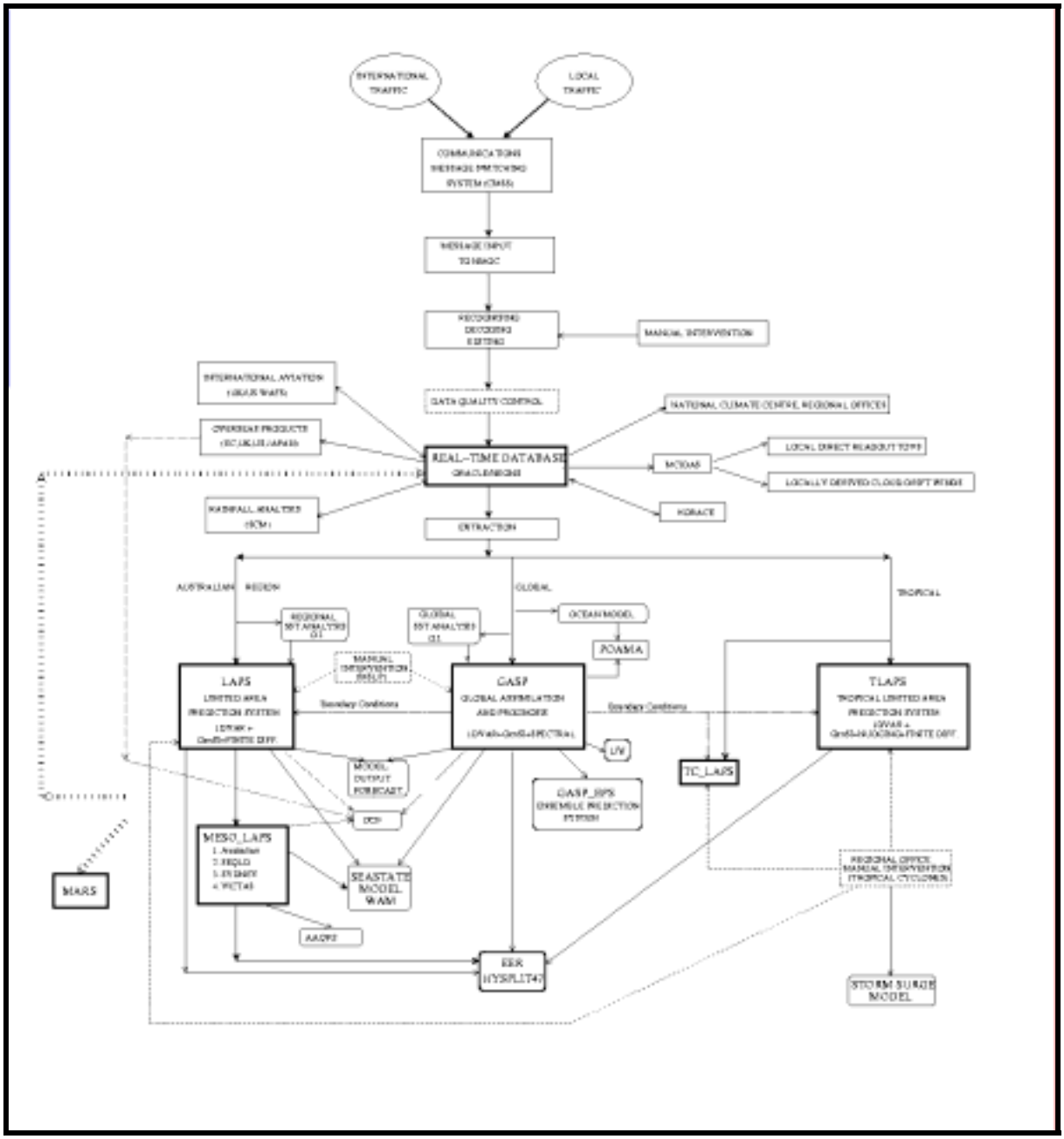
7. FORECASTING SYSTEM:

There are three major operational analysis and forecast systems (viz. the global GASP, regional LAPS and the tropical TXLAPS) in the NMOC Melbourne. A mesoscale version of LAPS, called MESO_LAPS, provides additional high resolution forecast products over 4 smaller domains (viz., Australia, SE Queensland, Sydney and Victoria/Tasmania). 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 4 MESO_LAPS systems are all nested in LAPS. An additional system, called TC_LAPS, is run to provide tropical cyclone, and other tropical guidance, for the region. (The possible lateral extent of this guidance is also depicted in the figure below.) Manual intervention is used for mean sea level pressure in both the global and regional systems. The resulting hemispheric "pseudo-observations" for mean sea level pressure are disseminated on the GTS. The tropical and Australian region limited area systems both use a tropical cyclone synthetic specification scheme. An additional feature of the tropical system is its dynamical nudging. Output from the global system is also used in the cold start procedure for the Australian region and tropical systems. It is noted that the MESO_LAPS systems do not have their own separate analyses but currently use initial (and boundary) conditions derived directly from LAPS.



Domains of the operational NWP systems in NMOC Melbourne.

The global, Australian region and mesoscale streams have associated sea-state systems. There are a large number of other parts to the basic scheme. These include systems for sea surface temperature analysis, environmental emergency response, generation of weather elements from model output (MOF), amendment and dissemination of aviation products, MCIDAS, archives, verification, display and dissemination of products. A schematic representation of the overall system is shown in the following figure.



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

7.1 System Run Schedule and Forecast Ranges:

At the present time, the centre produces major analyses at 00 and 12 UTC daily for the globe, Australian region and tropical domains. Global forecasts out to 10 days, Australian region and tropical forecasts out to 72 hours, mesoscale forecasts out to 48 hours for the Australian and 36 hours for the 3 other smaller domains, and special tropical cyclone forecasts out to 72 hours are produced off these major analyses. The ECMWF's Supervisor Monitor Scheduler is used to integrate 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 numerical systems is shown in the table below (with the times during the 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)
SSTANAL (REGIONAL)	1200	0100	0110	0
LAPS_PT375	0000	0145 (0045)	0215 (0115)	+72
MESO_LAPS_PT125	0000	0215 (0115)	0335 (0235)	+48
MESO_LAPS_PT050(VICTAS)	0000	0215 (0115)	0245 (0145)	+36
MESO_LAPS_PT050(SYDNEY)	0000	0215 (0115)	0230 (0130)	+36
MESO_LAPS_PT050(SEQLD)	0000	0215 (0115)	0250 (0150)	+36
EER PREP (LAPS)	0000	0215 (0115)	0220 (0120)	+72
WAVES (REGIONAL)	0000	0215 (0115)	0240 (0140)	+48
EER PREP (MESO_LAPS_PT050 SYDNEY)	0000	0230 (0130)	0235 (0135)	+36
EER PREP (MESO_LAPS_PT050 VICTAS)	0000	0235 (0135)	0240 (0140)	+36
TXLAPS	0000	0330	0435	+72
EER PREP (MESO_LAPS_PT125)	0000	0335 (0235)	0340 (0240)	+48
WAVES (MESO_LAPS_PT125)	0000	0340 (0240)	0435 (0335)	+48
TC_LAPS	0000	0400	0415	+72
EER PREP (TXLAPS)	0000	0440	0450	+72
GASP	0000	0545 (0445)	0800 (0700)	+240
GASP_EPS	0000	0620 (0520)	0710 (0610)	+240
EER PREP (GASP)	0000	0720 (0620)	0730 (0630)	+240
WAVES (GLOBAL)	0000	0810 (0710)	0830 (0730)	+96
LAPS_PT375	0600	1045 (0945)	1145 (1045)	+6
TXLAPS	0600	1045	1135	+6

TC_LAPS	0600	1100	1115	+6
GASP (EARLY)	0600	1200 (1100)	1220 (1120)	+24
LAPS_PT375	1200	1345 (1245)	1415 (1315)	+72
MESO_LAPS_PT125	1200	1415 (1315)	1535 (1435)	+48
MESO_LAPS_PT050(VICTAS)	1200	1415 (1315)	1445 (1345)	+36
MESO_LAPS_PT050(SYDNEY)	1200	1415 (1315)	1430 (1330)	+36
MESO_LAPS_PT050(SEQLD)	1200	1415 (1315)	1450 (1350)	+36
EER PREP (LAPS)	1200	1415 (1315)	1420 (1320)	+72
WAVES (REGIONAL)	1200	1415 (1315)	1440 (1340)	+48
EER PREP (MESO_LAPS_PT050 SYDNEY)	1200	1430 (1330)	1435 (1335)	+36
EER PREP (MESO_LAPS_PT050 VICTAS)	1200	1435 (1335)	1440 (1340)	+36
TXLAPS	1200	1530	1625	+72
EER PREP (MESO_LAPS_PT125)	1200	1535 (1435)	1540 (1440)	+48
WAVES (MESO_LAPS_PT125)	1200	1540 (1440)	1635 (1535)	+48
TC_LAPS	1200	1600	1615	+72
EER PREP (TXLAPS)	1200	1630	1640	+72
GASP	1200	1745 (1645)	2000 (1900)	+240
GASP_EPS	1200	1820 (1720)	1910 (1810)	+240
EER PREP (GASP)	1200	1920 (1820)	1930 (1830)	+240
WAVES (GLOBAL)	1200	2010 (1910)	2030 (1930)	+96
LAPS_PT375	1800	2245 (2145)	2345 (2245)	+6
TXLAPS	1800	2245	2335	+6
TC_LAPS	1800	2300	2315	+6
GASP (EARLY)	1800	0000 (2300)	0020 (2320)	+24
POAMA	(Daily)	0930	1530	+10 months
SSTANAL (GLOBAL)	(Mid-week)	2300 (Mondays only)	2345 (Mondays only)	0
SST (SUB-SURFACE)	(Monthly)	2205 (Tuesdays only)	2220 (Tuesdays only)	0
AD HOC (TOP PRIORITY): EER	ANYTIME	ANYTIME	ANYTIME + 30 mins	+72
TC_LAPS	0000 or 1200	ANYTIME	ANYTIME + 45 mins	+72

7.2 Medium-range Forecasting System (4-10 DAYS):

The acronym **GASP** is given to the **G**lobal **AS**imilation and **P**rognosis system, which produces medium-range forecast products out to 10 days. Post-processed products from this system are disseminated on the GTS in GRIB form, nationally through "DIFACS" and MCIDAS, and also via Radio-facsimile broadcasts (VMW, VMC and VLM).

7.2.1 Data Assimilation, Objective Analysis and Initialization:

Assimilated data: Mean sea level pressure (surface network, ships, drifting buoys), thickness (radiosondes, satellite retrievals), moisture (dew points, satellite precipitable water), wind (rawinsonde, aircraft, geostationary satellites, constant level balloons), cloud-clear radiances (from NOAA orbiting satellites).
Assimilation cycle, including cut-off time: 6 hourly cycling. H+6 cut-off.
Method of analysis: Generalised Multivariate statistical interpolation (GenSI) + univariate O.I. for moisture, one-dimensional variational retrievals (1DVAR).
Analysed variables: Geopotential, wind, moisture.
First guess: 6 hour forecast from previous cycle.
Coverage: Global.
Horizontal resolution: Triangular 239.
Vertical resolution: 29 sigma levels (0.991, 0.975, 0.950, 0.925, 0.900, 0.875, 0.850, 0.800,
0.750, 0.700, 0.633, 0.566, 0.500, 0.433, 0.366, 0.320, 0.290, 0.260, 0.230,
0.200, 0.170, 0.140, 0.110, 0.090, 0.070, 0.050, 0.030, 0.020, 0.010)
Initialization: Incremental non-linear normal mode.

7.2.2 Model:

Basic equations: Spectral primitive equations.
Independent variables: latitude,longitude,σ,t
Dependent variables: log p_*,T,q,vorticity,divergence.
Numerical technique:
horizontal: Spectral.
vertical: Finite difference.
time: Semi-implicit semi-Lagrangian.
Integration domain (in horizontal and vertical): Global, surface to 10 hPa (approx.).
Horizontal and vertical resolution, time step: Triangular 239, 29 sigma levels, 600 sec.(approx.).
Orography, gravity wave drag: Both included.
Horizontal diffusion: Included.
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 and shallow): Included.
Atmospheric moisture: Included.
Boundaries: Stand alone.
Albedo: Climatology.
SST Analysis: Weekly (1^0x1^0).

7.2.3 Numerical Weather Prediction Products:

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

Mean sea level pressure	Pressure at cloud top	Net solar radiation
Surface pressure	Temperature Tendency	Net downward radiation at surface
Temperature	Mixing ratio tendency	Outgoing longwave radiation
Wind	Radiative tendency	Albedo
Mixing ratio	Vorticity surface flux tendency	Surface wind stress
Geopotential height	Divergence surface flux tendency	Evaporation
Vorticity	Solar heating tendency	Roughness length at surface
Divergence	Precipitable water	Sub-surface temperature
Velocity potential	Soil moisture	Sensible heat flux
Precipitation	Snow depth, melt, cover	Latent heat flux
Stream function	Runoff	UV index
Cloud amount	Topography	

7.2.4 Operational Techniques for Application of NWP Products:

The 10 m wind field from GASP is used to drive a global sea-state model.

7.2.5 Ensemble Prediction System:

An Ensemble Prediction System based on the GASP system is currently being run in test mode in real-time in NMOC Melbourne. The 33-member ensemble system is running at the resolution: T119L19 (ie Triangular 119, 19 vertical levels), with a timestep of 1200 sec., and producing forecasts out to 10 days, off 00 and 12 UTC. Singular vectors are used to perturb the initial state derived from GASP. These perturbed states are then used as the initial conditions for each of the ensemble members.

7.3 Short-range Forecasting System (0-72 HRS):

The Australian region **L**imited **A**rea **P**rediction **S**ystem (**LAPS**), the **T**ropical e**X**tended domain **L**imited **A**rea **P**rediction **S**ystem (**TXLAPS**) and the **MESO**scale **L**imited **A**rea **P**rediction **S**ystem **(MESO_LAPS)** provide short-range forecasting guidance and products that are disseminated nationally through "DIFACS" and MCIDAS, and also via Radio-facsimile broadcasts (VMC, VMW and VLM). TXLAPS and TC_LAPS, for specific tropical cyclone guidance, are run on behalf of RSMC Darwin. Again it is noted that, at present, the 4 MESO_LAPS systems do not have their own assimilation, or analysis, but use an initial starting condition derived directly from LAPS. It is also noted that TC_LAPS runs in 2 basic parts. The first preparatory part produces analyses and prognoses over a large domain, or what is called the Large Scale Environment (LSE), and the second part then generates analyses and forecasts at a higher resolution on a relocatable domain centred on the tropical cyclone (and nested within the LSE part).

7.3.1 Data Assimilation, Objective Analysis and Initialization:

Assimilated data: Surface synop, ship, drifting buoy, radiosonde, rawinsonde, GTS TOVS, locally processed TOVS, GTS and locally derived GMS cloud drift winds, aircraft single level winds, bogus MSLP ("pseudo-observations"), tropical cyclone synthetic data, cloud-clear radiances (from NOAA orbiting satellites).

Assimilation cycle, including cut-off time: 6 hourly cycling; cut-off: LAPS: H+2 hr, TXLAPS: H+4 hr.

Method of analysis: Generalised Multivariate statistical interpolation (GenSI) + univariate statistical interpolation for moisture, one-dimensional variational retrievals (1DVAR).

Analysed variables: Geopotential, wind, moisture.

First guess: 6 hour forecast from previous cycle.

Coverage: LAPS: 17.125^0N-65.0^0S, 65.0^0E-184.625^0E

TXLAPS: 48.375^0N-45.0^0S, 60.0^0E-217.125^0E

TC_LAPS: 56.75^0N-55.0^0S, 70.0^0E-164.75^0W (LSE), 27.0^0x27.0^0 (Relocatable)

Horizontal resolution: LAPS and TXLAPS: 0.375^0

TC_LAPS: 0.75^0 (LSE) and 0.15^0 (Relocatable)

Vertical resolution: LAPS, TXLAPS, TC_LAPS: 29 sigma levels (0.9988, 0.9974, 0.9943, 0.9875, 0.9750, 0.9625, 0.9500, 0.9250, 0.9000, 0.8750, 0.8500, 0.8000, 0.7500, 0.7000, 0.6000, 0.5000, 0.4500, 0.4000, 0.3500, 0.3000, 0.2750, 0.2500, 0.2250, 0.2000, 0.1750, 0.1500, 0.1000, 0.0700, 0.0500)

Initialization: LAPS and MESO_LAPS: Digital filtering technique.

TXLAPS and TC_LAPS: diabatic dynamical nudging scheme incorporating GMS IR imagery.

(For Tropical Cyclones: Synthetic vortex specification.)

7.3.2 Model:

Basic equations: Grid primitive equations.

Independent variables: x,y,z,t

Dependent variables: P_*,T,q,u,v.

Numerical technique:

horizontal: Finite difference.

vertical: Finite difference.

time: Semi-implicit.

Integration domain (in horizontal and vertical):

LAPS: 17.125^0N-65.0^0S, 65.0^0E-184.625^0E, surface to 50 hPa (approx.)

TXLAPS: 48.375^0N-45.0^0S, 60.0^0E-217.125^0E, surface to 50 hPa (approx.)

MESO_LAPS:

Australian: 4.875^0S-55.0^0S, 95.0^0E-169.875^0E, surface to 50 hPa (approx.)

SYDNEY: 30.05^0S-38.00^0S, 147.00^0E-154.95^0E, surface to 50 hPa (approx.)

VICTAS: 34.05^0S-46.00^0S, 139.00^0E-150.95^0E, surface to 50 hPa (approx.)

SEQLD: 22.05^0S-31.00^0S, 148.00^0E-155.95^0E, surface to 50 hPa (approx.)

TC_LAPS:

LSE: 56.75^0N-55.0^0S, 70.0^0E-164.75^0W, surface to 50 hPa (approx.)

Relocatable: 27.0^0x27.0^0 , surface to 50 hPa (approx.).

Horizontal and vertical resolution, time step:

LAPS: 0.375^0 , 29 sigma levels, 40 sec

TXLAPS: 0.375^0 , 29 sigma levels, 40 sec
MESO_LAPS:
Australian: 0.125^0, 29 sigma levels, 10 sec
SYDNEY: 0.05^0, 29 sigma levels, 5 sec
VICTAS: 0.05^0, 29 sigma levels, 5 sec
SEQLD: 0.05^0, 29 sigma levels, 5 sec
TC_LAPS:
LSE: 0.75^0 , 29 sigma levels, 40 sec
Relocatable: 0.15^0 , 29 sigma levels, 15 sec.

Orography, gravity wave drag: Included.
Horizontal diffusion: Included.
Vertical diffusion: Included.
Planetary boundary layer: Included.
Treatment of sea surface, earth surface and soil: Included.
Soil moisture analysis: Included in LAPS, TXLAPS, TC_LAPS and MESO_LAPS.
Radiation: Diurnal cycle, diagnostic clouds, interactive optical properties.
Convection (deep and shallow): Included.
Atmospheric moisture: Included.
Boundaries: LAPS, TXLAPS and TC_LAPS (LSE): Lateral boundaries from GASP.
MESO_LAPS (4 domains): Lateral boundaries from LAPS.
TC_LAPS (Relocatable): Lateral boundaries from LSE TC_LAPS.
Albedo: Climatology.
SST Analysis: Weekly (1^0x1^0) - in LAPS, MESO_LAPS (Australian), TXLAPS and TC_LAPS.
Daily (0.25^0x0.25^0) - in MESO_LAPS (Melbourne and Sydney).

7.3.3 Numerical Weather Prediction Products:

The following table lists some of the post-processed fields that are available from the Limited Area Prediction Systems:

Mean sea level pressure	Stream function	Saturation deficit
Surface pressure	Wind shear	Cloud amount
Temperature	Boundary layer convective energy flux	Surface wetness
Wind	Shearing deformation	Atmospheric boundary layer height
Mixing ratio	Stretching deformation	Surface sensible heat flux
Geopotential height	Temperature gradient	Surface latent heat flux
Dew point temperature	Temperature advection	Surface wind stress
Dew point depression	Q vector	Surface total heat flux
Ageostrophic wind	Moisture convergence	Boundary layer convective energy flux
Potential temperature	Moisture advection	Skin temperature of boundary layer
Equivalent potential temperature	Wet bulb potential temperature	Pressure at cloud top
Wet bulb potential temperature	Total precipitation	Frontogenesis function
Layer thickness	Convective precipitation	Total totals index
Vorticity	Non-convective precipitation	Lifting index

Divergence	Lifting condensation level	Forest fire danger index
Vorticity advection	Topography	Grassland fire danger index
Relative humidity	Precipitable water	

7.3.4 Operational Techniques for Application of NWP Products:

The 10 m wind field from LAPS and MESO_LAPS are used to drive sea-state models for the Australian region and smaller domains. The Model Output Forecast (MOF) system, which is driven by LAPS and GASP, is used to produce numerous weather elements including temperatures (minimum, maximum, dry bulb, dew point, wet bulb and ground minimum), wind (speed and direction), precipitation, cloud amount, evaporation, sunshine and visibility. Meteograms, giving time series of meteorological variables, are also available. In addition, forecast guidance for thunderstorms (based on a decision tree approach) and cold-season tornadoes ("COLDIES"), with input from (the Australian domain) MESO_LAPS, was available during 2004.

7.4 Specialized Forecasts:

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

7.4.1 Sea Wave Models:

The following table summarises the characteristics of the seastate 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	GASP (10m)	LAPS_PT375 (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, buoys and satellite (ERS) altimeter data		

7.4.2 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.

7.4.3 Air Dispersion Model:

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 system consists of the Hybrid Single_Particle Lagrangian Integrated Trajectories (HY-SPLIT using Version 4.7) system, developed at the NOAA Air Resources Laboratory, with meteorological input from the operational NWP systems in NMOC (viz., GASP, LAPS, TXLAPS, and MESO_LAPS). Analysed backward trajectories, and retro-plumes, are also available from GASP, LAPS and TXLAPS in operations.

7.4.4 Solar Ultraviolet (UV) Radiation Forecast System:

Forecasts out to 36 hour forecasts of a UV index (defined as the product of the UV irradiance and a human skin response function) are produced operationally. The system analyses ozone concentrations, available from the global TOMS and 120 km GTS TOVS data, using 2-dimensional univariate statistical interpolation. Forecasts of the ozone distribution are then computed using isentropic fields derived from GASP output. From vertical profiles of temperature and ozone, the UV index is calculated. Currently, forecasts of the UV index (defined according to the WMO standard categories) are produced, once per day, after completion of the 1200 UTC run of GASP.

7.5 Extended-range Forecasts (10 - 30 DAYS): Not applicable yet.

7.6 Long-range Forecasts (30 DAYS - 2 YEARS):

A three-month rainfall seasonal climate outlook is prepared. Each month, a risk-assessment for three-month total rainfall across Australia is issued mid-month for the three-month period starting the following month. Probabilities are calculated for the three-month total rainfall being in the lowest one-third of historical falls (tercile 1), the middle one-third (tercile 2), and the upper one-third (tercile 3). 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 rainfall 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 tercile probabilities, computed across Australia on a $1^0 x 1^0$ grid are published in the form of contoured maps, tabulated averages for the 107 Australian rainfall districts, and tabulated interpolations for cities and towns around Australia. Similar outlooks are also provided for above/below median seasonal rainfall and additionally for both maximum and minimum (three-month average) temperatures (tercile and median probabilities).

Additional guidance at the rainfall district level is presented in the form of stratified rainfall climatologies based on recent values of the SOI (Southern Oscillation Index). Rainfall outcomes for eastern Australia, obtained from SOI analogues, are also described.

An ocean model for climate monitoring and seasonal prediction is run daily with forcing provided by GASP. Assimilation of ocean (sub-surface) observations is performed every three days.

7.6.1 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 interannual coupled ocean/atmosphere general circulation model known as POAMA (Predictive Ocean Atmosphere Model for Australia). Atmospheric initial conditions are obtained from the operational runs of GASP. The atmospheric component of the coupled system is essentially the same model as the operational GASP but run at the reduced resolution: T47L17 (ie Triangular 47, 17 vertical levels). Ten month forecasts are produced daily from this system and used as monthly, or last 30 day, ensemble forecasts for the seasonal outlooks.

8. VERIFICATIONS OF PROGNOSTIC PRODUCTS:

An annual summary of verification statistics for 2004, for the Australian regional and global schemes, is given in the following tables.

The following abbreviations have been used in the tables:
S1 - 30 day mean Teweles skill score over Australian verification area
r - anomaly correlation coefficient between forecast heights and climatology over Australian verification area
PERSIS - 24, 36 or 48 hour persistence prediction
REGN - Australian Regional LAPS (Limited Area Prediction System)
GASP - Global Assimilation and Prognosis model
RMSE - Root Mean Square Error

Note:
The LAPS and GASP results are with respect to their own analyses.

8.1 Skill Scores and Anomaly Correlation Coefficients:

24 HR VERIFICATION STATISTICS - AUSTRALIAN REGION 2004
BASE TIME: 0000UTC - VALID TIME: 0000UTC

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MSLP	S1	PERSIS	50	61	52	56	56	56	59	56	57	61	56	59
	S1	REGN	19	21	18	14	20	18	20	20	19	19	18	20
	r	REGN	.98	.97	.97	.99	.97	.98	.97	.97	.96	.98	.98	.97
500h heig	S1	PERSIS	41	43	49	53	49	44	47	45	47	46	48	47
	S1	REGN	12	12	14	12	13	11	13	13	12	12	12	13

pha t	r	REGN	.99	.98	.98	.99	.98	.98	.98	.98	.98	.98	.99	.98
250hpa height	S1	PERSIS	36	40	42	45	42	37	36	32	39	39	45	44
	S1	REGN	11	10	12	12	12	9	10	9	10	11	11	12
	r	REGN	.98	.98	.98	.98	.98	.98	.98	.97	.98	.98	.99	.98

36 HR VERIFICATION STATISTICS - AUSTRALIAN REGION 2004

BASE TIME: 1200UTC - VALID TIME: 0000UTC

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MSLP	S1	PERSIS	59	69	61	66	66	65	69	68	66	73	66	70
	S1	GASP	24	26	23	26	24	22	23	25	23	23	22	25
	r	GASP	.96	.95	.95	.96	.96	.96	.96	.96	.95	.96	.97	.95
500hpa height	S1	PERSIS	50	50	57	60	56	53	56	54	55	56	56	56
	S1	GASP	16	15	18	23	17	14	17	16	15	17	16	17
	r	GASP	.97	.97	.96	.97	.97	.97	.96	.97	.97	.96	.98	.97
250hpa height	S1	PERSIS	44	46	50	50	49	45	44	38	47	49	53	53
	S1	GASP	14	13	15	19	15	12	12	12	12	14	14	15
	r	GASP	.97	.98	.97	.97	.97	.97	.97	.96	.97	.97	.98	.97

48 HR VERIFICATION STATISTICS - AUSTRALIAN REGION 2004

BASE TIME: 0000UTC - VALID TIME: 0000UTC

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MSLP	S1	PERSIS	64	71	65	71	69	72	74	74	70	80	74	76
	S1	GASP	29	32	29	31	30	26	29	31	27	30	26	29
	r	GASP	.93	.92	.92	.93	.92	.94	.93	.93	.91	.93	.95	.93
500hpa height	S1	PERSIS	53	51	59	67	61	58	60	59	58	60	61	60
	S1	GASP	20	18	23	26	22	18	22	22	18	20	19	20
	r	GASP	.96	.95	.93	.95	.95	.95	.94	.93	.95	.94	.97	.95
250hpa height	S1	PERSIS	46	47	52	55	53	50	47	42	50	51	58	56
	S1	GASP	17	16	19	22	18	14	16	14	15	16	17	18
	r	GASP	.96	.95	.94	.96	.94	.96	.95	.93	.95	.94	.96	.94

8.2 Root Mean Square Errors (Annual 2004):

(a) Verification against analyses:

AREA	FIELD	RMSE or RMSVE UNIT	+24HR		+72HR		+120HR	
			00UTC	12UTC	00UTC	12UTC	00UTC	12UTC
Northern Hemisphere	**500 hPa Height**	**m**	15.5	15.4	41.3	41.3	68.8	68.4
	250 hPa Wind	**m/s**	5.6	5.6	11.7	11.7	16.8	16.7
Southern Hemisphere	**500 hPa Height**	**m**	19.4	19.2	51.5	50.9	81.2	80.5
	250 hPa Wind	**m/s**	6.0	5.9	12.9	12.8	18.3	18.2
Tropics	**850 hPa Wind**	**m/s**	3.0	3.0	4.8	4.8	5.5	5.5
	250 hPa Wind	**m/s**	5.2	5.2	8.3	8.3	10.0	10.0

(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**	17.2	17.3	43.9	44.8	73.1	72.7
	250 hPa Wind	**m/s**	8.3	8.2	14.6	14.4	20.2	19.8
Europe	**500 hPa Height**	**m**	21.7	20.3	45.6	45.5	79.5	79.4
	250 hPa Wind	**m/s**	7.5	7.1	13.2	13.2	19.9	19.6
Asia	**500 hPa Height**	**m**	21.2	21.2	42.2	42.5	60.7	62.1
	250 hPa Wind	**m/s**	8.1	8.2	13.5	13.7	16.9	17.2
Australia/NZ	**500 hPa Height**	**m**	17.2	16.7	32.6	34.7	49.7	53.5
	250 hPa Wind	**m/s**	7.8	7.7	12.2	12.3	16.8	16.6
Tropics	**850 hPa Wind**	**m/s**	4.6	4.6	5.7	5.6	6.3	6.2
	250 hPa Wind	**m/s**	6.9	7.2	8.6	8.9	9.9	10.1
Northern	**500 hPa**							

Hemisphere	**Height**	**m**	20.8	20.6	46.3	46.7	75.7	75.8
	250 hPa Wind	**m/s**	7.8	7.7	13.5	13.5	18.9	18.6
Southern Hemisphere	**500 hPa Height**	**m**	22.1	21.9	41.3	42.5	62.2	64.3
	250 hPa Wind	**m/s**	8.3	8.5	13.2	13.5	18.0	18.2

9. PLANS FOR THE FUTURE:

Plans for future operational systems in the NMOC Melbourne include:
. ongoing improvements to LAPS including: improvements to cloud and radiation parameterisations, more vertical levels (51 initially, followed by 60), full warm running, semi-implicit semi-Lagrangian formulation, and a non-hydrostatic formulation;
. the introduction of a Severe Weather relocatable (0.10x 0.10) version of LAPS;
. the introduction of a LAPS ensemble prediction system (using 2 physics schemes, with 16 members per scheme);
. the introduction of 3 new MESO_LAPS_PT050 domains (for Adelaide, Perth and Darwin);
. the introduction of a mesoscale assimilation system;
. enhancements to GASP incorporating: increased vertical resolution to 33 levels (and then 60 levels up to 0.1 hPa), ECMWF land/surface scheme, locally derived cloud drift winds and scatterometer winds, 3DVAR, 4DVAR;
. the operational implementation of the GASP Ensemble Prediction System;
. an upgrade of the rainfall analysis to use the Kriging method;
. the implementation of a rainfall verification scheme;
. introduction of a National Rainfall Forecasting System;
. introduction of a high resolution surface analysis;
. the implementation of the OCF (Operational Consenus Forecasts) system which combines direct model output with model output statistics to give forecasts of weather elements for various sites, and then later a gridded version;
. the introduction of the Graphical Forecast Editor (GFE) into NMOC and Regional Offices;
. a move to drive the storm surge model using meteorological input from TC_LAPS;
. an upgrade to the coupled ocean-atmospheric model (POAMA) for seasonal analysis and prediction, along with further development of products;
. an ongoing improvement to the operational Environmental Emergency Response System including the use of a unified wind input system and a full radionuclide database, and an extension to include a number of chemical transformations;
. the full implementation of a gaussian-type plume model (ADMS3) for the microscale;
. the operational implementation of an urban Australian Air Quality Forecasting System (AAQFS);
. the further development of the air-borne virus facility within the EER system and, eventually, its incorporation within the microscale dispersion and air quality systems;
. an ongoing improvement and generalization of data processing and graphical display (including the full integration of MARS and METVIEW and, eventually, a GIS);
. improvement in data monitoring systems;
. improvement in product dissemination methods.

10. REFERENCES:

Bourke W., Hart T., Steinle P., Seaman R., Embery G., Naughton M. and Rikus L. : "Evolution of the Bureau of Meteorology's Global Data Assimilation and Prediction System. Part 2: Resolution Enhancements and Case Studies." Australian Meteorological Magazine, 44, 19-40, 1995.

Bourke W., Buizza R. and Naughton M.: "Performance of the ECMWF and the BoM Ensemble Prediction Systems in the Southern Hemisphere." Monthly Weather Review, 132, 2338-2357, 2004.

Davidson N.E. and Puri K. : "Tropical prediction using dynamical nudging, satellite defined convective heat source and a cyclone bogus." Monthly Weather Review, 120, 2501-2522, 1992.

Davidson N.E. and Weber H.C.: "The BMRC high resolution tropical cyclone prediction system TC-LAPS." Monthly Weather Review, 128, 1245-1265, 2000.

Draxler R.R. and Hess G.D. : "An overview of the HYSPLIT_4 modelling system for trajectories, dispersion and deposition." Australian Meteorological Magazine, 47, 295-308, 1998.

Greenslade D.J.M.: "The assimilation of ERS-2 significant wave height data in the Australian Region." Journal of Marine Systems, 28, 141-160, 2001.

Hanstrum B.N.: "A national NWP-based thunderstorm and severe thunderstorm forecasting guidance system." BMRC (Australian Bureau of Meteorology) Research Report, 93, 7-12,` 2003.

Harris B.A. and Kelly G.: "A satellite radiance bias correction scheme for data assimilation." Quarterly Journal of the Royal Meteorological Society, 127, 1453-1468, 2001.

Le Marshall J., Mills G., Pescod N., Seecamp R., Puri K.K., Stewart P., Leslie L.M. and Rea A.: "The estimation of high density atmospheric motion vectors and their application to operational numerical weather prediction." Australian Meteorological Magazine, 51, 173-180, 2002.

Le Marshall J., Pescod N., Seaman R., Mills G. and Stewart P. : "An Operational System for Generating Cloud Drift Winds in the Australian Region and Their Imapct on Numerical Weather Prediction." Weather and Forecasting, 9, 361-370, 1994.

Le Marshall J.F., Riley P.A., Rouse B.J., Mills G.A., Wu Z.-J., Stewart P.K. and Smith W.L.: "Real-time assimilation and synoptic application of local TOVS raw radiance observations." Australian Meteorological Magazine, 43, 153-166, 1994.

Lemus-Deschamps L., Rikus L. and Gies P.: "The operational Australian ultraviolet index forecast 1997." Meteorological Applications, 6, 241-251, 1999.

Lemus-Deschamps L., Rikus L., Grainger S., Gies P., Sisson J. and Li Z.: “UV index and daily total UV dose distributions for Australia (1997-2001).” Australian Meteorological Magazine, 53, 239-250, 2004.

Mills G.A. and Colquhoun J.R.:” Objective Prediction of Severe Thunderstorm Environments: Preliminary Results Linking a Decision Tree with an Operational Regional NWP Model.” Weather and Forecasting, 13, 1078-1092 1998.

Puri K., Dietachmayer G.S., Mills G.A., Davidson N.E., Bowen R.A. and Logan L.W. : "The new BMRC Limited Area Prediction System, LAPS." Australian Meteorological Magazine, 47, 203-223, 1998.

Seaman R., Bourke W., Steinle P., Hart T., Embery G., Naughton M. and Rikus L. : "Evolution of the Bureau of Meteorology's Global Data Assimilation and Prediction System. Part 1: Analysis and Initialisation." Australian Meteorological Magazine, 44, 1-18, 1995.

Stewart P.K. : "RSMC Melbourne - Procedures, Standards, Results of Exercises and Ongoing Products." WMO Expert Team on Environmental Emergency Response. Beijing, China, 20-24 September 1999.

Woodcock F. and Engel C.: "Operational Consensus Forecasts." Weather and Forecasting, 20, 101-111, 2005.

Web References:

POAMA: http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA/index.htm
http://www.bom.gov.au/climate/coupled_model/poama.shtml