



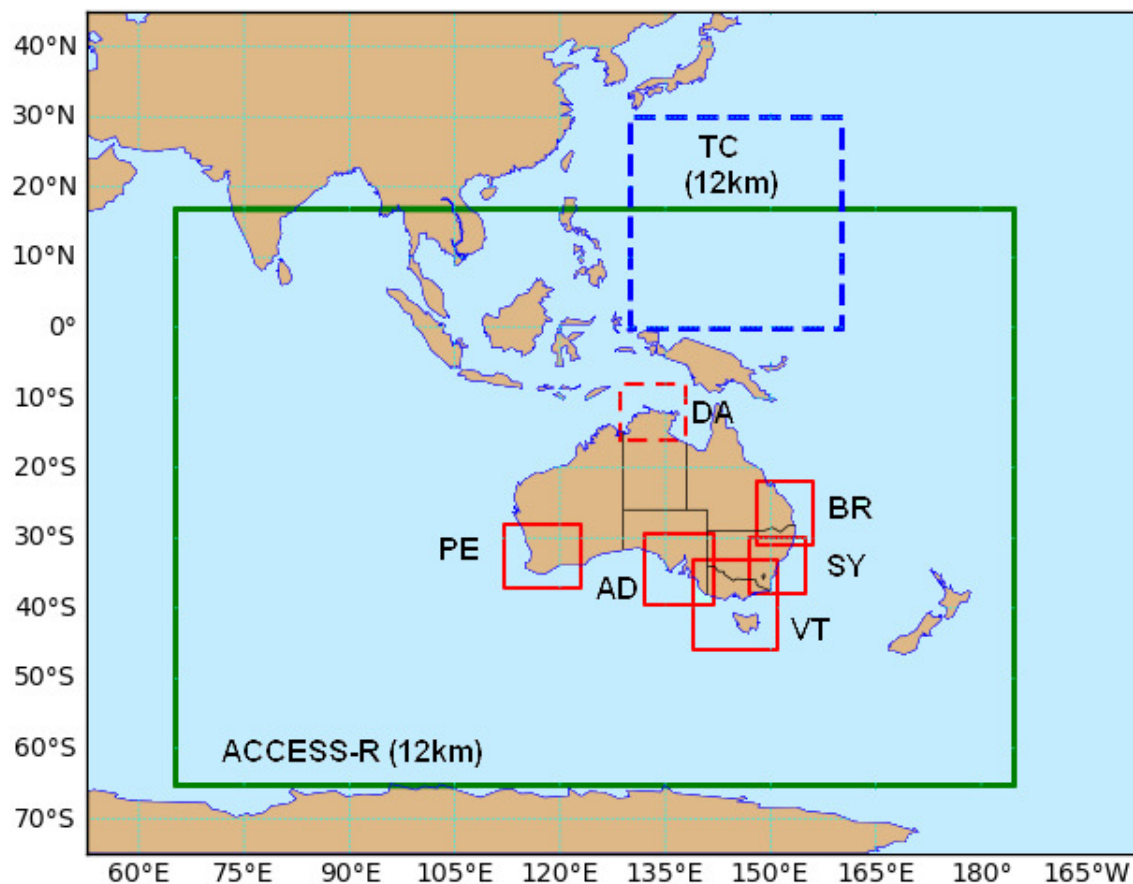
Australian Government
Bureau of Meteorology

National Meteorological and Oceanographic Centre

Operations Bulletin Number 98

APS1 upgrade of the ACCESS-R Numerical Weather Prediction system

21 August 2013



Executive Summary

The Bureau of Meteorology's 'ACCESS-R' numerical weather prediction system was operationally upgraded in April 2013. The model complements the Bureau's global suite ('ACCESS-G') by providing high resolution forecasting guidance over Australia and surrounding regions, with the model domain extending from the Antarctic coast to the northern Philippines, and eastwards to Fiji. Significant changes include:

- an improvement to the model grid spacing from 0.375° to 0.11° (approximately 12km),
- an increase in the number of model atmospheric levels from 50 to 70,
- an increase in remote sensing observation assimilation (additional new IASI & GPS-RO satellite observation types), and the use of updated software.

As a result of these changes the forecast skill of the ACCESS-R system has improved, with model versus analysis verification results indicating an improvement in the APS1 forecast skill of approximately 12 hours relative to the previous APS0 ACCESS-R system at forecast lead times of 2 to 3 days.

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1 Introduction

On 17 April 2013, a new version of the Bureau of Meteorology's ACCESS-R (the Australian Regional domain of the "Australian Community Climate and Earth-System Simulator") Numerical Weather Prediction (NWP) system was declared operational within the National Meteorological & Oceanographic Centre (NMOC). This new version is designated as "Australian Parallel Suite 1" (APS1) and represents the first major upgrade to the ACCESS-R system since operational running commenced in September 2009 and follows a similar APS1 upgrade to the global ACCESS-G in March 2012. The upgrade incorporates improvements by the UK Meteorological Office (UKMO) to the Unified Model/Variational Assimilation (UM/VAR) system upon which ACCESS is based. Local research, development, testing and initial implementation of APS1 was performed by research staff in the Earth System Modelling Programme of the Centre for Australian Weather and Climate Research (CAWCR) and the operational implementation was performed by the Operational Development Section of NMOC.

Significant changes for this upgrade include:

- a decrease in model grid spacing from 0.375° to 0.11° (approximately 12 km),
- an increase in the number of model atmospheric levels from 50 to 70,
- assimilation of additional new IASI & GPS-RO satellite observation types,
- use of more recent versions of the UM/VAR software.

As a result of these changes the forecast skill of the ACCESS-R system has improved, with model versus analysis verification results indicating an improvement in the APS1 forecast skill of approximately 12 hours relative to the previous APS0 ACCESS-R system at forecast lead times of 2 to 3 days.

The geographical domain of the new APS1 system remains essentially the same as the APS0 ACCESS-R system. The domains of the APS1 limited-area ACCESS models are illustrated in Figure 1 below, with details listed in Table 1. The increased horizontal resolution means that ACCESS-R now has a resolution equivalent to that of the previous APS0 Australian-region ACCESS-A model, albeit over a much larger domain, and as a result the APS0 ACCESS-A system was discontinued from 9 May 2013. However, the APS0 versions of ACCESS-R and ACCESS-G have continued to be run in parallel in NMOC in order to provide boundary conditions required for the nested APS0 city-based ACCESS-C models until the ACCESS-C models are also upgraded to APS1 versions in August/September 2013.

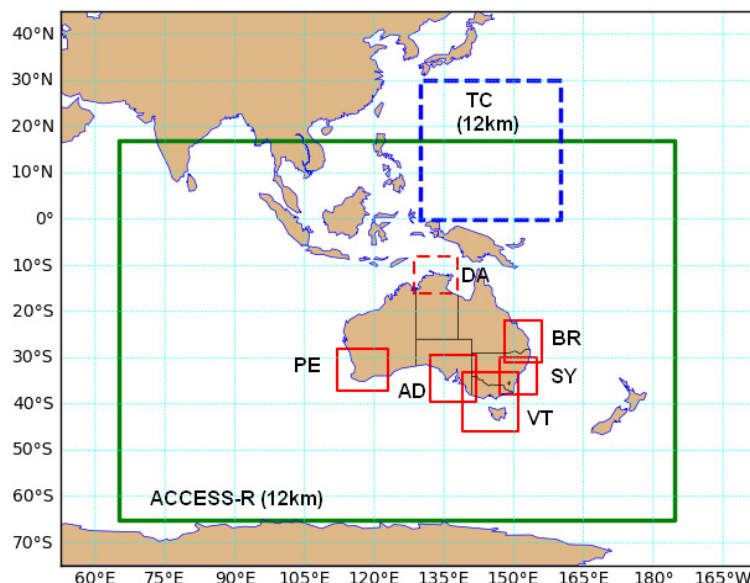


Figure 1: Domains of APS1 limited-area ACCESS models

NWP system	Domain	Type	Resolution	Grid size (lat x lon)	Domain limits (S-N, W-E)	Duration (hours)	Runs (UTC)
ACCESS-G	Global	Assim +Forc	N320 0.375°x0.5625° (~40km)	481x640	-90.0°S to 90.0°N 0.0°E to 359.44°E	+240	00, 12
						+78	06, 18
ACCESS-R	Regional	Assim +Forc	0.11° (~12 km)	746x1088	-65.0°S to 16.95°N 65.0°E to 184.57°E	+72	00, 06, 12, 18
ACCESS-C	Brisbane	Forc	0.036° (~4 km)	250x224	-31.0°S to -22.04°S 148.0°E to 156.03°E	+36	00, 06, 12, 18
	Perth	Forc	0.036° (~4 km)	250x306	-37.0°S to -28.04°S 112.0°E to 122.98°E		
	Adelaide	Forc	0.036° (~4 km)	278x306	-39.5°S to -29.53°S 132.0°E to 141.98°E		
	VICTAS	Forc	0.036° (~4 km)	364x334	-46.0°S to -33.04°S 139.0°E to 150.99°E		
	Sydney	Forc	0.036° (~4 km)	224x224	-38.0°S to -29.98°S 147.0°E to 155.03°E		
	Darwin	Forc	0.036° (~4 km)	224x264	-16.0°S to -7.97°S 128.5°E to 137.97°E		
ACCESS-TC	Tropical Cyclone	Assim +Forc	0.11° (~12 km)	300x300	33°x33° relocatable within the ACCESS-G domain	+72	00, 12

Table 1: ACCESS APS1 model domains & resolutions.

This Bulletin provides an overview of the changes involved with the upgrade to the APS1 ACCESS-R system and presents verification results from the parallel trial for this system. In addition, general plans for the forthcoming APS1 upgrades of the other operational ACCESS NWP systems run in NMOC are briefly outlined.

2 Changes associated with the APS1 ACCESS-R upgrade

A detailed overview of all the original APS0 ACCESS systems was presented in NMOC Operations Bulletin No. 83 (NMOC, 2010 henceforth referred to as NOB83). The global ACCESS-G system was subsequently upgraded to APS1 in March 2012 and the changes involved in that upgrade were described in NMOC Operations Bulletin No. 93 (NMOC, 2012 henceforth referred to as NOB93). Since the underlying assimilation and forecasting systems are very similar between ACCESS-G and ACCESS-R, users should refer to that bulletin for a general overview of the APS1 upgrade. Details specific to the ACCESS-R upgrade are described below.

A brief summary of the APS1 ACCESS-R system specifications and super computer resources used are listed in Table 2 below.

UM horizontal resolution (lat x lon)	746x1088 (0.11° x 0.11°)
UM horizontal domain	65.0°S to 16.95°N, 65.0°E to 184.57°E
Analysis horizontal resolution (lat x lon)	250 x 360 (0.33° x 0.33°)
Vertical resolution	L70, top level at approximately 80km (~0.009 hPa)
Frequency of data assimilation	6-hourly for base times 00, 06, 12 and 18 UTC
Observational data used (6hr window)	AIRS, ATOVS, ASCAT, AMV, IASI, GPSRO, SYNOP, SHIP, BUOY, AMDARS, AIREPS, TEMP, PILOT
Sea surface temperature analysis	RAMSSA Daily Australian Region 0.0833° SST analysis (Beggs et al. 2011)
Sea ice analysis	Not used in this system as the domain southern boundary is at 65.0°S.
Soil moisture analysis	Reconfigured from global soil moisture analysis Once every 6 hours
Snow amount	Warm running from previous model first guess
Internal model time step	5 minutes (288 time steps per day)
Analysis time step	15 minutes
Software suite details	<ul style="list-style-type: none"> • Suite Control System (SCS) v18.2 • Unified Model (UM) v7.5 • 4DVAR analysis System (VAR) v26.1 • Observation Processing System (OPS) v26.1 • Surface Fields Processing (SURF) v18.5 (using v18.3 for ACCESS-G APS1)

Table 2: ACCESS-R system specifications.

2.1 Model resolution and domain

For the APS1 upgrade, the horizontal resolution of ACCESS-R has been increased from 0.375° to 0.11° giving a nominal grid spacing of approximately 12km. This is the same as the resolution of the old APS0 ACCESS-A system, which thus became redundant and has been discontinued.

The change in model resolution has necessitated a slight change in the boundaries of the model domain. Boundary extremes are now -65.0°S to 16.95°N, 65.0°E to 184.57°E (in comparison, the previous APS0 ACCESS-R boundary were -65.0°S to 17.125°N, 65.0°E to 184.625°E and the APS0 ACCESS-A boundaries were -55.0°S to 4.7°N, 95.0°E to 169.69°E).

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APS1 Level index	η at theta levels	Height (m)	Press (hPa)	η at rho levels	Height (m)	Press (hPa)		APS0 Level index	η at theta levels	Height (m)	Press (hPa)	η at rho levels	Height (m)	Press (hPa)
70	1.000000	80000	0.009	.9508334	76066	0.017								
69	.9016668	72133	0.033	.8582535	68660	0.057								
68	.8148403	65187	0.096	.7765451	62123	0.150		50	1.000000	62918	0.134	0.9531141	59968	0.204
67	.7382500	59060	0.231	.7044966	56360	0.333		49	.9062281	57018	0.305	0.8662998	54506	0.426
66	.6707432	53659	0.476	.6410096	51281	0.646		48	.8263715	51994	0.590	0.7923848	49855	0.773
65	.6112759	48902	0.872	.5850902	46807	1.14		47	.7583982	47717	1.01	0.7294412	45895	1.28
64	.5589045	44712	1.48	.5358422	42867	1.89		46	.7004842	44073	1.61	0.6757434	42516	1.98
63	.5127798	41022	2.42	.4924589	39397	3.01		45	.6510026	40960	2.44	0.6297574	39623	2.92
62	.4721379	37771	3.77	.4542161	36337	4.62		44	.6085122	38286	3.51	0.5901292	37130	4.13
61	.4362943	34903	5.67	.4204658	33637	6.81		43	.5717462	35973	4.86	0.5556734	34962	5.62
60	.4046373	32371	8.21	.3906297	31250	9.71		42	.5396007	33951	6.51	0.5253624	33055	7.42
59	.3766222	30129	11.5	.3641936	29135	13.4		41	.5111240	32159	8.48	0.4983146	31353	9.56
58	.3517651	28141	15.5	.3407014	27256	17.8		40	.4855051	30547	10.8	0.4737836	29810	12.0
57	.3296378	26371	20.3	.3197505	25580	23.0		39	.4620621	29072	13.5	0.4511468	28385	15.0
56	.3098631	24789	25.9	.3009862	24079	28.9		38	.4402316	27698	16.6	0.4298941	27048	18.3
55	.2921094	23368	32.3	.2840981	22728	35.7		37	.4195567	26398	20.3	0.4096167	25772	22.3
54	.2760868	22086	39.5	.2688150	21505	43.2		36	.3996766	25147	24.5	0.3899956	24538	27.0
53	.2615432	20923	47.3	.2549014	20392	51.5		35	.3803146	23929	29.6	0.3707909	23329	32.5
52	.2482597	19860	56.0	.2421538	19372	60.4		34	.3612672	22730	35.7	0.3518300	22136	39.1
51	.2360480	18883	65.3	.2303973	18432	70.1		33	.3423928	21543	43.0	0.3329966	20951	47.1
50*	.2247466	17979	75.3	.2194822	17558	80.5		32	.3236004	20360	51.7	0.3142195	19770	56.8
49	.2142178	17137	86.0	.2092815	16742	91.5		31	.3048386	19180	62.3	0.2954611	18590	68.4
48	.2043451	16347	97.4	.1996879	15975	103.3		30*	.2860837	18000	75.0	0.2767065	17410	82.4
47	.1950307	15602	109.5	.1906118	15249	115.8		29	.2673293	16820	90.4	0.2582700	16250	98.9
46	.1861929	14895	122.4	.1819786	14558	129.1		28	.2492107	15680	108.2	0.2404693	15130	118.0
45	.1777643	14221	136.2	.1737269	13898	143.3		27	.2317278	14580	128.7	0.2233042	14050	139.9
44	.1696895	13575	150.7	.1658067	13264	158.4		26	.2148807	13520	152.1	0.2067749	13010	164.8
43	.1619238	12953	166.3	.1581776	12654	174.4		25	.1986692	12500	178.6	0.1908814	12010	192.9
42	.1544313	12354	182.8	.1508076	12065	191.3								
41	.1471838	11774	200.3	.1436715	11494	209.4		24	.1830936	11520	208.5	0.1756236	11050	224.5
40	.1401592	11212	218.8	.1367499	10940	228.5								
39	.1333406	10667	238.4	.1300280	10402	248.5		23	.1681536	10580	241.7	0.1610016	10130	259.1
38	.1267154	10137	258.8	.1234950	9879.6	269.3								
37	.1202745	9622.0	280.0	.1171429	9371.4	290.8		22	.1538495	9680	277.6	0.1470152	9250	296.1
36	.1140113	9120.9	301.9	.1109663	8877.3	313.1								
35	.1079213	8633.7	324.5	.1049615	8396.9	336.0		21	.1401810	8820	315.7	0.1336647	8410	335.3
34	.1020017	8160.1	347.8	.0991261	7930.1	359.6								
33	.0962505	7700.0	371.7	.0934586	7476.6	383.8		20	.1271483	8000	356.0	0.1209498	7610	376.5
32	.0906668	7253.3	396.2	.0879584	7036.6	408.5		19	.1147514	7220	398.0	0.1088707	6850	419.3
31	.0852500	6820.0	421.1	.0826250	6610.0	433.7		18	.1029901	6480	441.6	0.0974274	6130	463.4
30	.0800000	6400.0	446.5	.0774583	6196.6	459.2								
29	.0749167	5993.3	472.2	.0724583	5796.6	485.1		17	.0918647	5780	486.2	0.0866198	5450	508.4
28	.0700000	5600.0	498.3	.0676250	5410.0	511.2								
27	.0652500	5220.0	524.5	.0629583	5036.6	537.6		16	.0813749	5120	531.6	0.0764479	4810	554.0
26	.0606667	4853.3	550.9	.0584584	4676.6	563.9								
25	.0562500	4500.0	577.3	.0541250	4330.0	590.4		15	.0715209	4500	577.3	0.0669118	4210	599.7
24	.0520000	4160.0	603.6	.0499583	3996.6	616.7		14	.0623027	3920	622.9	0.0580114	3650	645.0
23	.0479167	3833.3	629.9	.0459583	3676.6	642.8								
22	.0440000	3520.0	655.9	.0421250	3370.0	668.7		13	.0537202	3380	667.9	0.0497468	3130	689.5
21	.0402500	3220.0	681.7	.0384583	3076.6	694.3								
20	.0366667	2933.3	707.0	.0349583	2796.6	719.4		12	.0457734	2880	711.8	0.0421179	2650	732.8
19	.0332500	2660.0	731.9	.0316250	2530.0	744.0		11	.0384624	2420	754.4	0.0351247	2210	774.4
18	.0300000	2400.0	756.2	.0284583	2276.6	768.0								
17	.0269167	2153.3	779.9	.0254583	2036.6	791.3		10	.0317871	2000	795.0	0.0287673	1810	813.8
16	.0240000	1920.0	802.9	.0226250	1810.0	813.9								
15	.0212500	1700.0	825.0	.0199583	1596.6	835.6		9	.0257475	1620	833.2	0.0230456	1450	850.8
14	.0186667	1493.3	846.2	.0174583	1396.6	856.3								
13	.0162500	1300.0	866.5	.0151250	1210.0	876.1		8	.0203437	1280	868.6	0.0179597	1130	884.7
12	.0140000	1120.0	885.7	.0129583	1036.6	894.8		7	.0155757	980	900.9	0.0135095	850	915.2
11	.0119167	953.3	903.8	.0109583	876.6	912.3								
10	.0100000	800.0	920.8	.0091250	730.0	928.6		6	.0114433	720	929.7	0.0096951	610	942.1
9	.0082500	660.0	936.4	.0074583	596.6	943.6								
8	.0066667	533.0	950.8	.0059583	476.6	957.3		5	.0079468	500	954.6	0.0065164	410	965.0
7	.0052500	420.0	963.8	.0046250	370.0	969.6								
6	.0040000	320.0	975.4	.0034583	276.6	980.5		4	.0050859	320	975.4	0.0039734	250	983.6
5	.0029167	233.3	985.5	.0024583	196.6	989.8		3	.0028608	180	991.8	0.0020662	130	997.7
4	.0020000	160.0	994.2	.0016250	130.0	997.7								
3	.0012500	100.0	1001.3	.0009583	76.6	1004.1		2	.0012715	80	1003.7	0.0007947	50	1007.3
2	.0006667	53.3	1006.8	.0004583	36.6	1008.9								
1	.0002500	20.0	1010.8	.000125	10.0	1012.0		1	.0003179	20	1010.8	0.0001589	10	1012.0

Table 3: Comparison of APS1 (left) and APS0 (right) model vertical levels and equivalent heights in the absence of topography and International Standard Atmosphere pressure at this geopotential height (ISA $P_0 = 1013.25$ hPa). The lowest “constant height” rho levels (level 50 in APS1 and level 30 in APS0) are indicated with asterisks.

The number of vertical levels increases from 50 to 70. Most of the additional levels have been added throughout the lower troposphere, with a few additional upper levels added to lift the top level from 63km to 80km. The full distribution of APS0 versus APS1 ACCESS vertical levels is listed in Table 3 above. It is worth noting that, apart from the bottom level, very few specific model levels are common between the two versions.

2.2 UM Model changes

Most APS1 ACCESS systems use version 7.5 of the Unified Model (ACCESS-C uses 7.6). This corresponds to the version used in the UKMO's parallel suite PS24. Significant changes to the ACCESS-G model and parameterisation setup between APS0 and APS1 are outlined in Section 2.1 of NOB93 so only particular changes unique to APS1 ACCESS-R are discussed below. Users requiring further detail on the UM/VAR physical parameterisations should also refer to NOB83, Walters et al. (2011) and Puri et al (2012).

Generally speaking, the model dynamics and physics in APS1 ACCESS-R are the same as those in APS1 ACCESS-G. However, there are notable exceptions. These have arisen primarily because the configuration of the APS1 ACCESS-R system is based on that of the UKMO North Atlantic European model (NAE) and there has been little development of the NAE in recent years. Whilst at the same time the UKMO global model, upon which ACCESS-G is based, has continued to develop. Major differences between APS1 ACCESS-G and APS1 ACCESS-R are noted below.

Perhaps the most significant difference between the two systems is that ACCESS-R retains the Smith diagnostic cloud scheme which was used in the APS0 suite (see NOB93) whereas APS1 ACCESS-G has moved to the PC2 prognostic cloud scheme as described in section 2.2.3 of NOB93.

APS1 ACCESS-G has a "full" radiation simulation, which is performed every three hours, with the less accurate (but computationally faster) "diagnostic" simulations performed at the intervening hours. ACCESS-R has full radiation applied hourly hence no diagnostic scheme is required.

There are a number of configuration differences in the convective parameterization scheme between ACCESS-R and ACCESS-G which reflect their different horizontal resolutions. Firstly the CAPE reference time-scale (time scale over which convection brings the environment back to equilibrium) is shorter in ACCESS-R (720 seconds) than ACCESS-G (1800 seconds). The convection scheme is called twice per model time-step in ACCESS-G compared with four times in ACCESS-R. These differences result in the damping effect associated with convective parameterisation being greater in ACCESS-R compared to ACCESS-G.

Both models use "targeted diffusion" to suppress numerical instability associated with unphysical "grid-point storms". In this approach, the moisture field is heavily smoothed at points in which the vertical velocity exceeds a critical value: 1.5 m/s ACCESS-G and 5.0 m/s ACCESS-R. The different critical values reflect the difference in horizontal resolution. The grid-point storm phenomenon occurs when the model initiates convection, usually at a single grid point, but due to the model resolution the model convection is not subject to dampening which occurs in the real world thus resulting in physically unrealistically high vertical velocities and rainfall.

Targeted diffusion cannot be applied over steep topography, because diffusion is calculated on model, rather than horizontal surfaces, which would result in spurious vertical transport of moisture that itself would be de-stabilising. The model automatically turns off this diffusion over steep topography, which meant that in preliminary APS1 ACCESS-R testing there were a significant number of grid-point storms over mountainous regions such as New Guinea. These grid point storms were subsequently eliminated by the introduction of a light degree of filtering of the topography for land-points north of mainland Australia. As a last defensive measure against grid-point storms, "vertical velocity capping", a new facility in UM 7.5, was also activated. This feature scans for extreme vertical velocities in the model and simply reduces them to some limit-value.

Tests were conducted for several limiting values, and they showed impact only on grid-point storms, with the surrounding larger-scale flow untouched. They also showed that the limiter was being applied only for a very small number of grid-points.

Both models include parameterisation of orographic gravity-waves, but ACCESS-G (alone) also uses a spectral gravity-wave scheme which has been shown to have significant positive impact at high latitudes on features such as the southern winter jet.

2.3 Observational data assimilation changes

As was noted in NOB93, two significant new sources of satellite data are being assimilated in APS1 systems:

1. Infrared radiances from the Infrared Atmospheric Sounding Interferometer (IASI) (Pavelin 2008, Hilton 2009) which flies on the ESA MetOp polar orbiters.

2. GPS Radio Occultation (GPS-RO) bending angles (Rennie 2008, 2010): GPS radio signals passing through, and being refracted by, the Earth's atmosphere are detected by receivers carried on a constellation of low Earth orbiting satellites. The bending angle so measured is a function of the temperature and moisture along the path travelled by the radio signal. The high quality and unbiased nature of the GPS-RO data provides not only direct improvement of upper atmosphere analysis, but also significantly improves the use of satellite soundings.

An additional data type capable of being assimilated by the APS1 system is the RARS "Regional ATOVS Retransmission Service" data. This data is processed within the Australian Bureau of Meteorology and provides more timely ATOVs data in the Australian region. This allows the assimilation of significantly more ATOVS data for the short data cut-off window of the APS1 ACCESS-R system, as shown below in Figure 2.

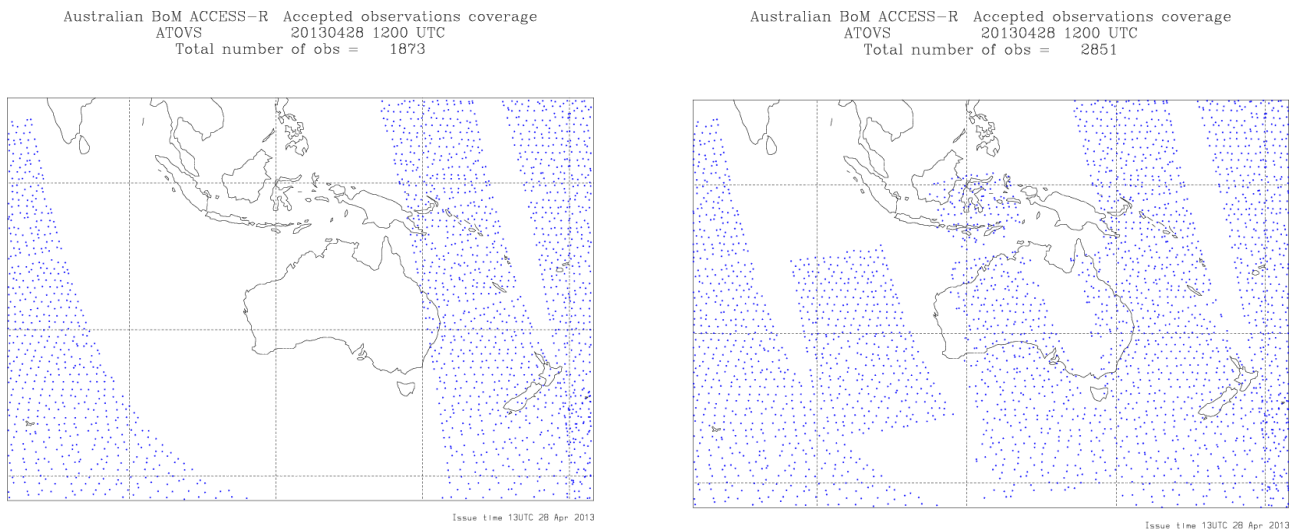


Figure 2: Comparison of accepted ATOVS observations for APS0 ACCESS-R (left) and APS1 ACCESS-R (right) for the assimilation basetime of 1200UTC 28 April 2013, illustrating the increased number of observations provided by the assimilation of RARS data

2.4 Changes in model output fields

APS1 ACCESS models (including ACCESS-R and ACCESS-G) introduce the following new single-level output fields:

- snow amount over land [kg m⁻²]
- total surface moisture flux [kg m⁻²]
- average outgoing short-wave radiation flux [W m⁻²]
- 8 new fields depicting cloud base heights for cloud-cover greater than various thresholds (0.1, 1.5, 2.5, 3.5, 4.5, 5.5, 6.5 & 7.9 oktas) [kft]

In addition, APS1 includes a fix for three shortwave surface radiation fluxes (direct, diffuse and net) [W m⁻²] (the calculations have been corrected for the solar zenith angle that is valid for the model time-step).

2.5 Changes in product availability time

ACCESS-R data assimilation is performed 4 times per day at the nominal assimilation basetimes of 00, 06, 12 and 18 UTC. The commencement time for the main data assimilation is 5 minutes earlier than APS0, i.e. at H+1:50 hr, where H is the nominal analysis basetime. This is shifted to H+0:50 hr during the summer daylight saving period to fit in with forecasting deadlines. A secondary “update” assimilation is also performed 4 hours later to include any data that was omitted from the earlier main assimilation run.

Model forecasts out to +72 hours are performed 4 times daily from the main analyses. Because of the increased resolution of APS1 ACCESS-R the model integration takes significantly longer to complete compared to the previous APS0 ACCESS-R and the full VAR+UM system now takes approximately 110 min to complete (actual timing is heavily dependent on the Solar disk I/O load at the time of running) compared to 35 min for the previous APS0 ACCESS-R system. The final post-processed output is not available to users until approximately H+4:15 hr (H+3:15 during the summer daylight saving period). However, the data availability times are slightly earlier for APS1 ACCESS-R than was the case for APS0 ACCESS-A (which was nested within APS0 ACCESS-R and could only commence after ACCESS-R had completed).

Typical timings for the APS1 ACCESS-R assimilation and forecast completion and +72hr forecast data availability as of mid-May 2013 are shown in Table 4 below.

Basetime	Obs data extraction	Completion time		Final (+72hr) gridded product delivery times to external ftp server
		Assimilation	Forecast	
00 UTC	0150	0215	0345	0415
06 UTC	0800	0825	0955	1015
12 UTC	1350	1415	1545	1610
18 UTC	1950	2015	2145	2200

Table 4: Typical ACCESS-R runtimes and data availability times (UTC). (These times are shifted 1 hour earlier during the summer daylight saving period to fit in with forecasting deadlines.)

3 Forecast performance

Testing and evaluation of APS1 ACCESS-R commenced in the Bureau in early 2012, initially within CAWCR on their research development system and then within NMOC on the operational trial system. An official parallel trial using the final system configuration was performed between September 2012 and March 2013, the results of which are presented below. Overall, there has been a significant improvement in model forecast skill compared to APS0 ACCESS-R with a smaller improvement when compared with APS0 ACCESS-A.

3.1 Verification of model forecasts versus own analysis

Comparisons of APS1 ACCESS-R verification scores against APS1 ACCESS-G, and APS0 ACCESS-R and ACCESS-A for the period 1 September 2012 to 31 March 2013 over the Australian Region are shown in Figures 3 and 4.

In Figure 3 MSLP verification scores are compared. The APS1 models have better (lower) root mean square (RMS) errors than the APS0 models for all leadtimes. APS1 ACCESS-G S1 skill scores and RMS errors are better (lower) than those of APS1 ACCESS-R for all leadtimes. For leadtimes of 2 days there are improvements of about 12 hours in APS1 ACCESS-R RMS errors compared with the APS0 models. At leadtimes of 2 to 3 days APS1 ACCESS-R has a 12-18hour improvement in RMS errors compared with APS0 ACCESS-R. For the S1 skill score APS1 ACCESS-R beats APS0 ACCESS-R at all leadtimes; and beats APS0 ACCESS-A for leadtimes of 36hr-48hr. APS1 ACCESS-R has a pronounced positive MSLP bias that is of similar magnitude to the negative bias for APS1 ACCESS-G and APS0 ACCESS-A.

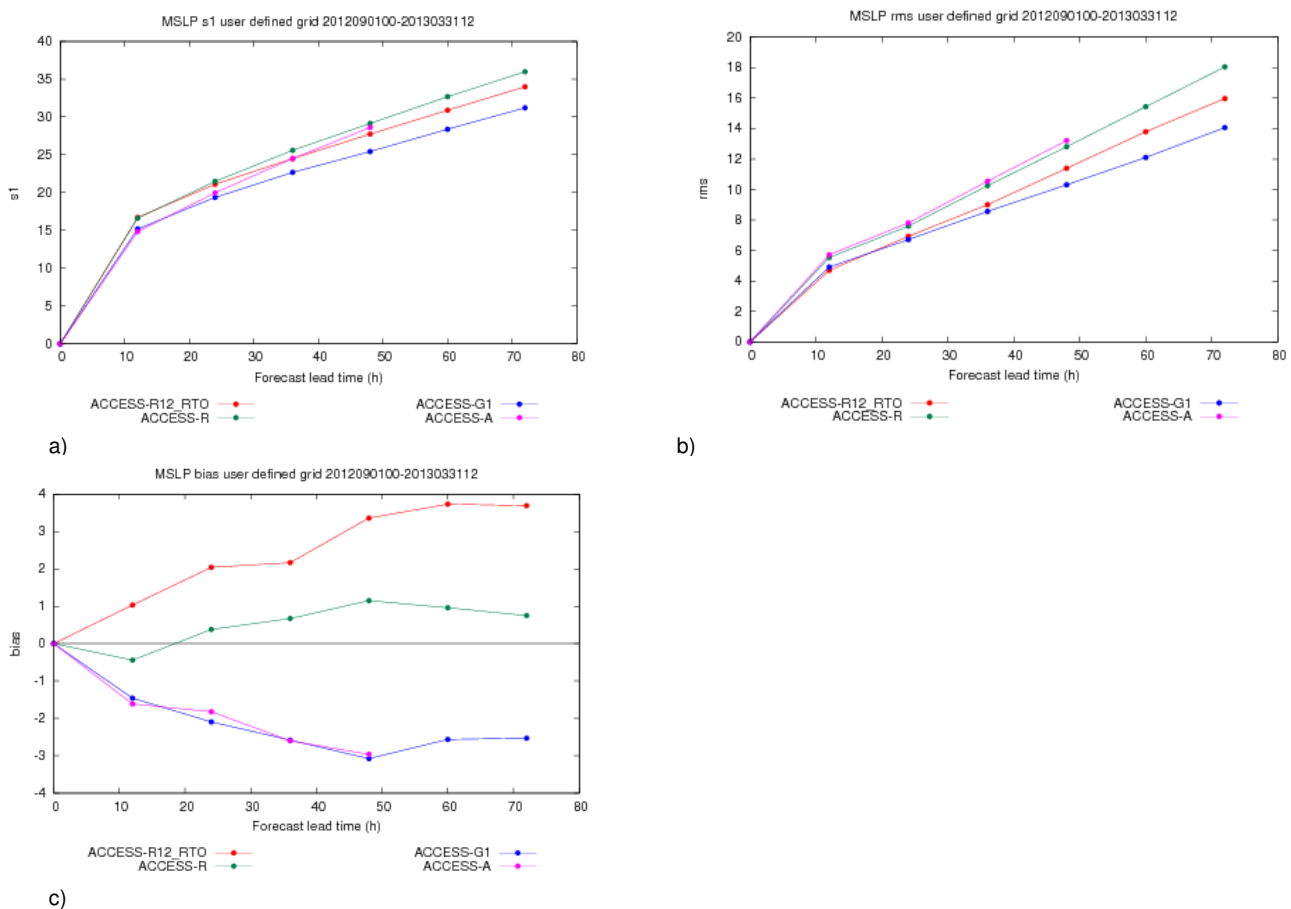


Figure 3: Comparative MSLP verification scores APS1 ACCESS-R (*ACCESS-R12_RTO*) and ACCESS-G (*ACCESS-G1*); and APS0 ACCESS-A and ACCESS-R 00-72hr forecasts for the Australian Region averaged over the period 1 Sep 2012 to 31 Mar 2013 for APS0 ACCESS-R for a) S1 skill Score, b) RMS error, c) bias. All fields are self-verified, i.e. the forecasts from each system are compared to the system's own analysis. Calculations have been performed on a $1^\circ \times 1^\circ$ grid, from 45°S to 10°S , and 110°E to 155°E .

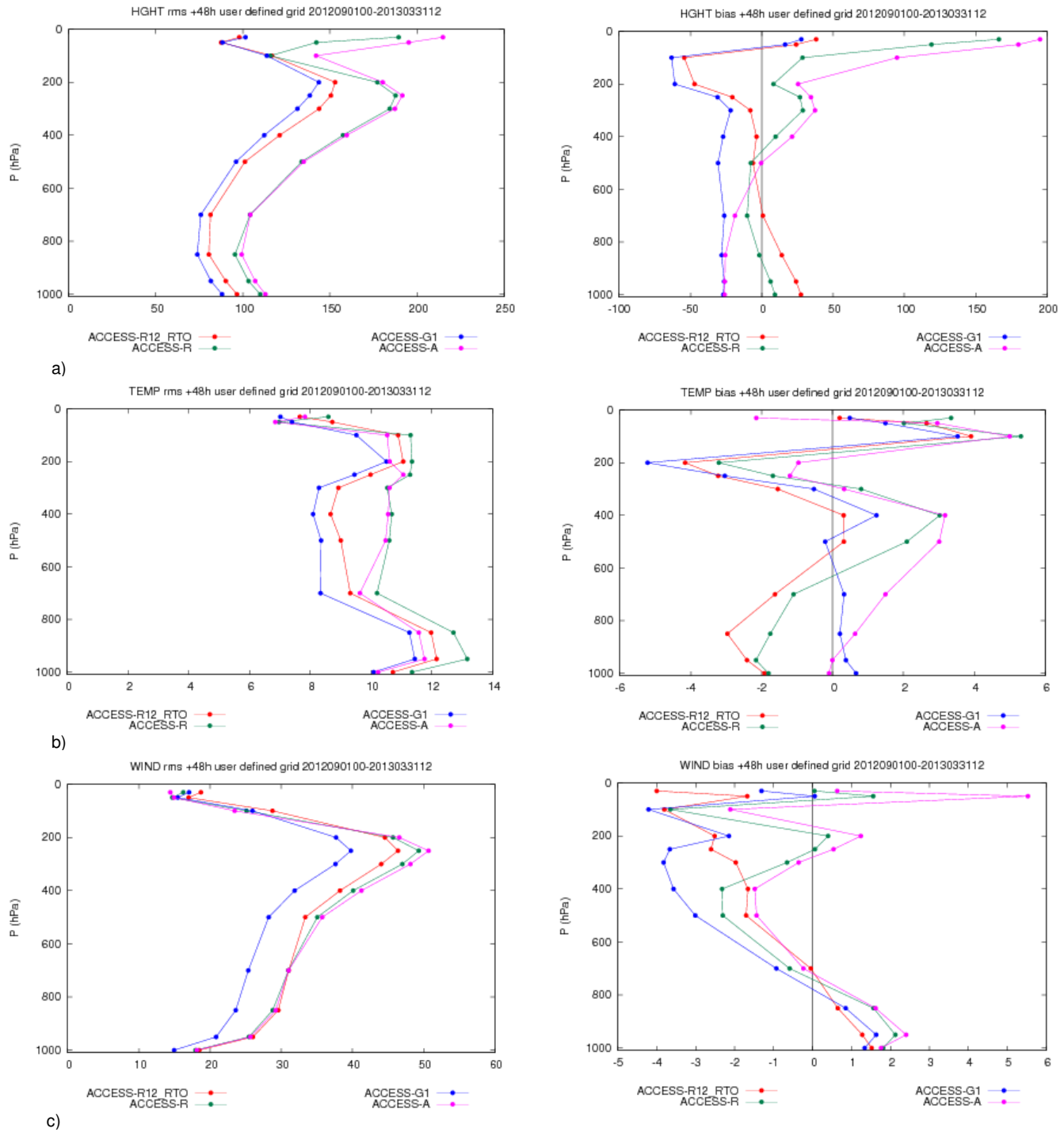


Figure 4: Comparative verification scores for APS1 ACCESS-R (*ACCESS-R12_RTO*, red) and APS1 ACCESS-G (*ACCESS-G1*, blue); and APS0 ACCESS-A (pink) and APS0 ACCESS-R (green), for 48 hour forecasts averaged over the Australian Region averaged and the period 1 Sept 2012 to 31 Mar 2013. Individual panels are: a) geopotential height (units=0.1m), b) temperature (units=0.1°C), and c) wind speed (units=0.1msec⁻¹). RMS error is shown on left, bias on right. All fields are self-verified, i.e. the forecasts from each system are compared to the system's own analysis. Calculations have been performed on a 1° x 1° grid, from 45°S to 10°S, and 110°E to 155°E.

In Figure 4 geopotential height, temperature and wind speed RMS and bias verification scores at model levels for 2 day lead times are compared. The RMS errors for all parameters show similar trends with height for all of the models. Likewise the trends in the biases with height for the individual models show similar trends, though not as consistently across the models as for the RMS errors.

The APS1 model RMS errors for all the parameters are mostly better compared to those for the APS0 forecasts, particularly for geopotential heights above 100hPa. The results of the geopotential height biases are mixed. The APS1 models have significantly better bias scores above 100hPa than the APS0 models. These better verification scores at high levels are consistent with the APS1 having extra model levels above 60,000m. The geopotential height bias for the APS1 models is mostly negative. By comparison the APS0 models have a positive bias in the middle to high levels. At middle to low levels APS1 ACCESS-R has a positive geopotential height bias compared to negative values of slightly larger magnitude for APS0 ACCESS-A. The APS1 ACCESS-R model has a significant negative temperature bias in the middle to low levels, while APS1 ACCESS-G has very little bias over the same levels; and APS0 ACCESS-A has a significant positive middle level bias. APS1 ACCESS-G has a significantly better wind speed RMS errors below 200hPa compared with all the other models. Between 400-100hPa the APS1 models have negative wind bias of larger magnitude than that of the APS0 models.

The long term improvement in the Bureau's regional model performance since 1971 is shown in Figure 5.

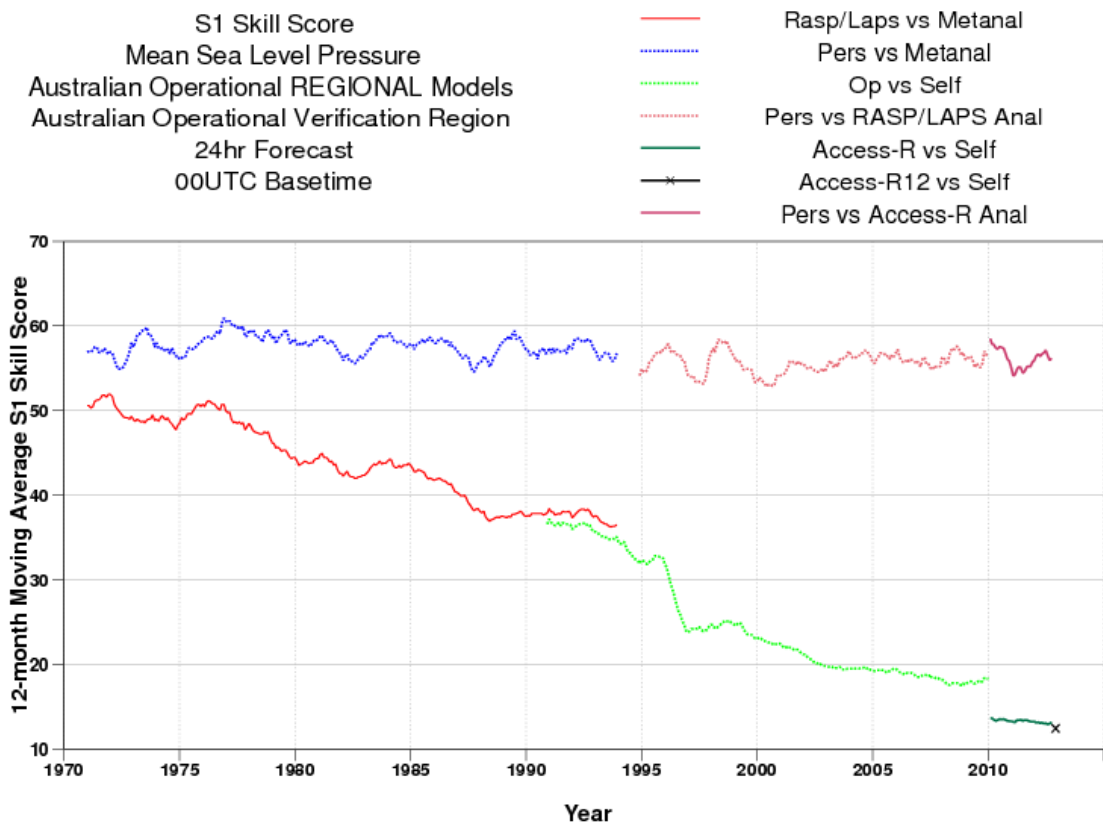


Figure 5: Long term time series showing S1 Skill Scores for the +24 hour forecast MSLP over the Australian Verification Region. The curves show time-filtered values with the plot centred on the sixth month of a twelve month running mean. The new APS1-ACCESS-R result ("ACCESS-R12", black cross) is a six month mean for the period October 2012 to March 2013. The upper curves show the skill of a persistence forecast whereas the lower curves show the skill of the various Bureau's regional forecast models (RASP, LAPS and ACCESS-R) over the years. Verification was against Metanal analyses till 1995, then against the models' own analyses after that.

3.2 Rainfall verification

Rainfall verifications have been performed using the RAINVAL statistical verification package, which verifies daily quantitative precipitation forecasts for NWP models against daily rainfall analyses. RAINVAL was developed by Beth Ebert and John McBride of CAWCR (McBride & Ebert, 2000). Various statistical scores are available from this system for judging aspects of rainfall forecast performance. Further details, including a glossary that explains the strengths and weaknesses of the various statistical scores presented here, can be found at

http://www.bom.gov.au/bmrc/mdev/expt/rainval/rainval_gui/rainval_gui.shtml.

In brief, ideal values for the RAINVAL statistics presented below are as follows: Rain area, average and maximum intensity, and volume should be the same as observed; the mean absolute error, RMS error and False Alarm Ratio should be 0 (i.e. the smaller the better); and the Correlation Coefficient, Critical Success Index, Hanssen & Kuipers Score and Equitable Threat Score should be 1 (i.e. the larger the better). The Bias Score measures the relative rainfall area – the closer to 1 the better. The bias-adjusted ETS (Mesinger, 2008) attempts to account for the impact of forecast bias on the skill (over-forecasting can artificially improve the standard Equitable Threat Score).

General Summary

Table 5 below presents rainfall statistics averaged over the Australian domain for the period 1 October 2012 to 31 March 2013. APS1 ACCESS-R results are colour coded bold blue font when they are better than the corresponding APS0 ACCESS-A results, whereas italicized red font indicates that the APS1 ACCESS-R results are worse.

	Observed	APS0 ACCESS-A			APS1 ACCESS-R				
		00-24 hr	12-36 hr	24-48 hr	00-24 hr	12-36 hr	24-48 hr	36-60 hr	48-72 hr
Rain Area (km ² ×10 ³)	1247	1315	1363	1333	<i>1380</i>	<i>1448</i>	<i>1458</i>	1475	1455
Avg Intensity (mm/d)	6.0	4.4	4.8	4.7	<i>3.6</i>	<i>4.0</i>	<i>3.9</i>	4.1	4.0
Rain Volume (km ³)	11.8	9.4	10.4	10.1	<i>8.5</i>	<i>9.4</i>	<i>9.4</i>	9.9	9.7
Max Intensity (mm/d)	75.6	212.2	236.5	228.4	125.4	137.1	137.0	145.4	155.5
Mean Abs Error (mm/d)		1.74	1.89	1.93	1.72	1.84	1.89	2.01	2.08
Pooled RMS Error (mm/d)		5.29	5.79	5.96	5.04	5.36	5.45	5.87	6.16
Pooled Correlation		0.46	0.44	0.41	0.47	0.45	0.43	0.40	0.38
Bias Score		1.06	1.09	1.07	<i>1.11</i>	<i>1.16</i>	<i>1.17</i>	1.19	1.17
Probability of Detection		0.66	0.67	0.65	0.68	0.69	0.68	0.68	0.65
False Alarm Ratio		0.37	0.39	0.40	<i>0.38</i>	<i>0.40</i>	<i>0.42</i>	0.43	0.44
Critical Success Index		0.48	0.47	0.45	0.48	0.47	0.46	0.45	0.43
Hanssen & Kuipers Score		0.56	0.56	0.54	0.57	0.57	0.56	0.55	0.52
Equitable Threat Score		0.38	0.37	0.35	0.38	0.37	0.36	0.34	0.33

Table 5: APS1 ACCESS-R and APS0 ACCESS-A RAINVAL statistics averaged over Australia between 1 October 2012 to 31 March 2013 for 0.11 grid resolution. Statistics are only for those days common to all QPFs. The number of days common to all QPFs is 197.

Generally speaking APS1 ACCESS-R forecasts tend to be marginally more skilful than the APS0 ACCESS-A forecasts, with improved maximum precipitation intensity and probability of detection. However, there is a tendency for APS1 ACCESS-R to over-forecast the total rain area, and to underestimate both the average rainfall intensity and the rain volume. This results in higher bias scores and slightly increased false alarm ratios for APS1 ACCESS-R. Unfortunately, estimates of the statistical significance of these results are not available.

Figure 6 below is a comparison of 00-24 hour forecast rainfall threshold statistics for APS1 ACCESS-R and APS0 ACCESS-A, once again averaged over the Australian domain for the period 1 October 2012 to 31 March 2013. While in general the two sets of plots are fairly similar there are some notable differences. The blue bias plot indicates that APS1 ACCESS-R appears to overestimate light rainfall events (less than 2mm/day) slightly more than APS0 ACCESS-A, this is consistent with the over estimation of rain areas in Table 5. This overestimation in APS1 ACCESS-R is not as pronounced as for APS1 ACCESS-G which is using the new PC2 prognostic cloud scheme. APS1 ACCESS-R also has a slightly larger tendency to underestimate rainfall days of between 10-20mm compared to APS1 ACCESS-A. The probability of detection (false alarm ratio) at low thresholds is slightly better (slightly worse) for APS1 ACCESS-R than for APS0 ACCESS-A and fairly similar at other threshold values. The other statistical measures have similar results across all threshold values.

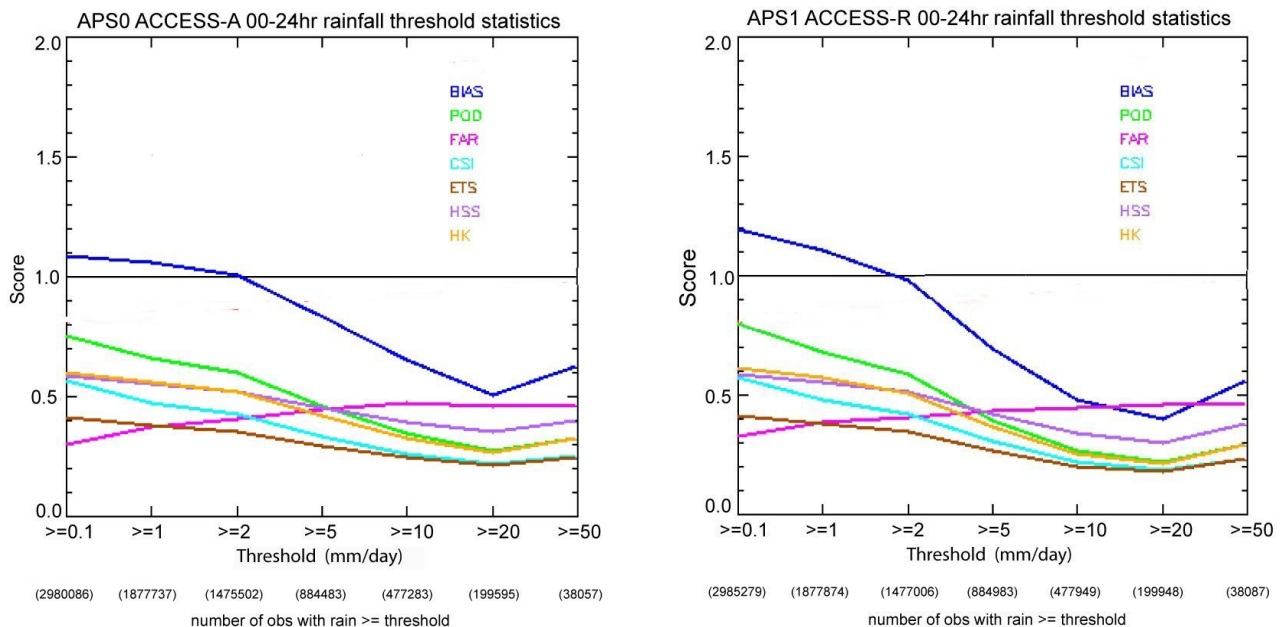


Figure 6: Rainfall threshold statistics for the 00-24 hour forecasts from APS0 ACCESS-A (left) and APS1 ACCESS-R (right) averaged over the period 1 October 2012 and 31 March 2013.

3.3 Surface Weather Element Verification

The European Centre for Medium-Range Weather Forecasting (ECMWF) verification system, VERIFY, was used to compare APS1 ACCESS-R forecasts to observational data across Australia. APS0 ACCESS-R and ACCESS-A were also verified. Model screen temperature, screen dew point and 10m wind speed were compared to data from the metar/metaraws dataset from over 480 stations Australia-wide. Only observations within 30 minutes of the model valid time were used. All datasets were verified for the period 10 March to 25 April 2013. Overall the results are positive for APS1 ACCESS-R, with APS1 ACCESS-R having consistently better RMS scores than those of the APS0 systems, though the bias score results are more mixed.

Forecast lead-time (hrs)	Valid time	RMS Error			Bias		
		APS1 R	APS0 R	APS0 A	APS1 R	APS0 R	APS0 A
a) 2m Temperature							
+24	00Z	1.88	2.26	1.97	-0.14	-0.42	0.01
	06Z	2.26	2.72	2.36	-0.09	0.09	0.36
	12Z	2.55	2.78	2.51	1.06	0.84	0.93
	18Z	2.62	2.82	2.55	1.18	0.79	1.02
	avg	2.33	2.64	2.35	0.50	0.32	0.58
+48	00Z	1.97	2.35	2.08	-0.16	-0.50	-0.08
	06Z	2.38	2.79	2.50	-0.17	-0.03	0.30
	12Z	2.63	2.87	2.62	1.05	0.75	0.91
	18Z	2.75	2.98	2.72	1.23	0.81	1.07
	avg	2.43	2.75	2.48	0.49	0.26	0.55
+72	00Z	2.11	2.50	-	-0.17	-0.55	-
	06Z	2.61	3.01	-	-0.27	-0.17	-
	12Z	2.71	2.95	-	1.02	0.68	-
	18Z	2.85	3.11	-	1.22	0.81	-
	avg	2.57	2.89	-	0.45	0.19	-
b) 2m Dew Point							
+24	00Z	2.44	2.66	2.51	0.00	-0.14	-0.15
	06Z	2.81	3.18	2.99	0.10	-0.27	-0.17
	12Z	2.65	2.80	2.66	0.76	0.33	0.35
	18Z	2.59	2.76	2.64	0.84	0.39	0.49
	avg	2.62	2.85	2.70	0.42	0.08	0.13
+48	00Z	2.68	3.02	2.85	-0.20	-0.31	-0.24
	06Z	3.06	3.48	3.26	-0.14	-0.34	-0.20
	12Z	2.81	3.08	2.93	0.56	0.25	0.37
	18Z	2.73	3.06	2.90	0.72	0.36	0.48
	avg	2.82	3.16	2.99	0.23	-0.01	0.10
+72	00Z	2.99	3.25	-	-0.39	-0.35	-
	06Z	3.32	3.74	-	-0.25	-0.36	-
	12Z	2.97	3.30	-	0.48	0.19	-
	18Z	2.97	3.29	-	0.63	0.41	-
	avg	3.06	3.39	-	0.12	-0.03	-
c) 10m Wind Speed							
+24	00Z	1.98	2.10	1.99	-0.21	-0.26	-0.36
	06Z	2.00	2.15	2.04	-0.45	-0.62	-0.56
	12Z	2.06	2.28	2.06	0.30	0.30	0.16
	18Z	2.07	2.27	2.05	0.29	0.31	0.14
	avg	2.03	2.20	2.04	-0.02	-0.07	-0.16
+48	00Z	2.08	2.22	2.13	-0.16	-0.23	-0.34
	06Z	2.08	2.27	2.18	-0.44	-0.62	-0.57
	12Z	2.19	2.40	2.19	0.32	0.28	0.12
	18Z	2.16	2.37	2.16	0.31	0.33	0.16
	avg	2.13	2.32	2.16	0.01	-0.06	-0.16
+72	00Z	2.19	2.38	-	-0.19	-0.29	-
	06Z	2.19	2.42	-	-0.44	-0.71	-
	12Z	2.25	2.46	-	0.32	0.22	-
	18Z	2.24	2.43	-	0.30	0.30	-
	avg	2.22	2.42	-	0.00	-0.12	-

Table 6: RMS error and bias scores of forecast minus metar observational data for a) Screen Temperature (2m Temperature), b) Screen Dew Point (2m Dew Point) and c) 10m Wind Speed. Calculated for the Australian domain, for forecast leadtimes of 24, 48 and 72 hours, and averaged across period 10 March-25 April 2013. Models are APS1 ACCESS-R (APS1 R), APS0 ACCESS-R (APS0 R), and APS0 ACCESS-A (APS0 A). Blue indicates the best score, red indicates the worst score; and green indicates the middle score (should three different scores exist).

Table 6 above lists RMS error and bias scores of forecast versus observational data for screen temperature, screen dew point and 10m wind speed. These scores are calculated across the Australian domain at leadtimes 24, 48 and 72 hours and stratified for the 00Z, 06Z, 12Z and 18Z valid times; along with an average of all four valid times. The RMS results indicate that APS1 ACCESS-R generally has the lowest (best) RMS errors for all data types across almost all valid time and leadtimes - the exceptions being the 12z and 18Z valid time 24hour and 48hour leadtime screen temperature forecasts; and the 18Z valid time 24hour leadtime 10m wind speed forecast for which APS0 ACCESS-A has slightly better results than APS1 ACCESS-R. APS0 ACCESS-R has the worst RMS errors for all valid times, leadtimes and data types. The RMS screen temperature scores (screen dew point and 10m wind speed) are better at 72hour leadtimes for APS1 ACCESS-R compared to the 24hour (48hour) forecasts for APS0 ACCESS-R

The bias score results are more mixed. For the screen temperature APS0 ACCESS-R has better scores than the other models for most valid times and leadtimes although APS1 ACCESS_R (APS0 ACCESS-A) has the best scores for 72hour (24hour and 48hour) leadtimes. Interestingly, the APS1 ACCESS-R screen temperature biases display a diurnal cycle with a daytime negative (cold) bias for 00Z and 06Z but an overnight/early morning positive (warm) bias for 12Z and 18Z.

APS1 ACCESS-R (APS0 ACCESS-R) generally has the best screen dewpoint bias scores for all lead times at 00Z and 06Z (12Z and 18Z) valid times. For all models screen dew point biases are negative (i.e. too dry) or near zero at 00Z and 06Z valid times and positive (i.e. too moist) at the other valid times.

APS1 ACCESS-R has the best 10m wind speed bias scores for all lead times at 00Z and 06Z valid times. For the other valid times at 24hour and 48hour leadtimes APS0 ACCESS-A has the best bias scores. For all models 10m wind speed biases are negative at 00Z and 06Z valid times and positive at the other valid times.

The time series plots of RMS error in Figure 7 below are consistent with the RMS error 48hour leadtime scores in Table 6. APS1 ACCESS-R (red) mostly has lower (better) scores than both of the APS0 systems. APS0 ACCESS-R (green) often has much worse scores for all three data types than the two higher resolution systems. This is particularly evident on those days where all models have high (relatively bad) scores.

The time series plots of bias scores shown in Figure 8 are mainly consistent with the corresponding 48hour leadtime scores in Table 6. A significant diurnal cycle is visible in all plots. APS1 ACCESS-R (red) wind speed bias scores are generally better (smaller magnitude) than the two APS0 systems. The bias scores for screen temperature and dew point are more mixed. APS1 ACCESS-R often has higher magnitude (worse) positive peaks than the APS0 systems, these peaks are generally for the 12Z and 18Z runs. In spite of APS0 ACCESS-R generally having the best screen temperature bias scores in Table 6 there are a number of runs where this model has the highest magnitude negative biases (green) of all the systems.

Timeseries for Access-R/R12/A 48hr forecasts for a number of surface fields showing RMS error across the NMOC Australia domain

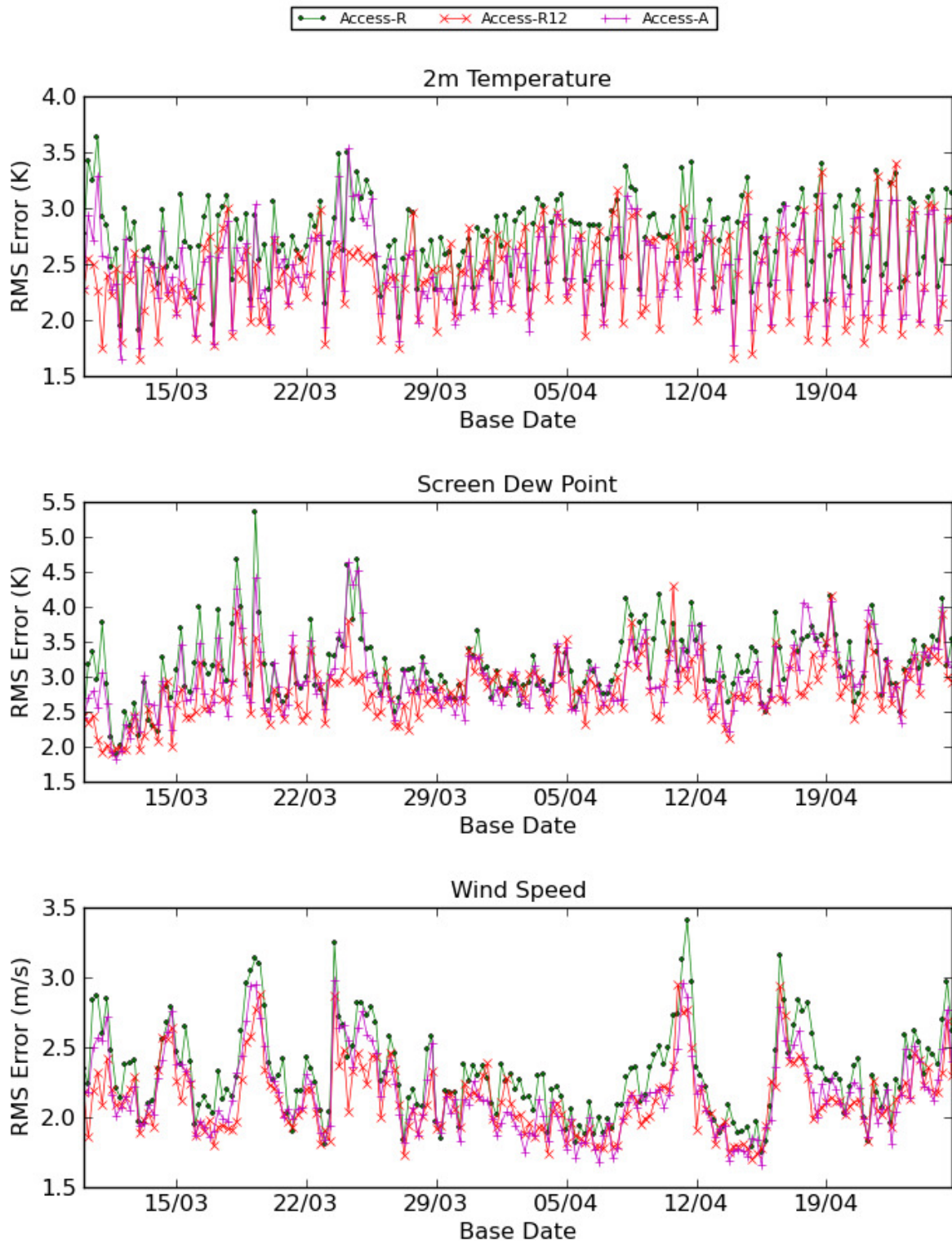


Figure 7: Time series plots of RMS error (forecast minus meter observational data) for screen temperature (2m Temperature), screen dew point and 10m wind speed. Calculated for the Australian domain, forecast leadtimes of 48hours, and averaged across period 10 March-25 April 2013. Systems are APS1 ACCESS-R (Access-R12, red), APS0 ACCESS-R (green) and APS0 ACCESS-A (magenta).

Timeseries for Access-R/R12/A 48hr forecasts for a number of
surface fields showing bias across the NMOC Australia domain

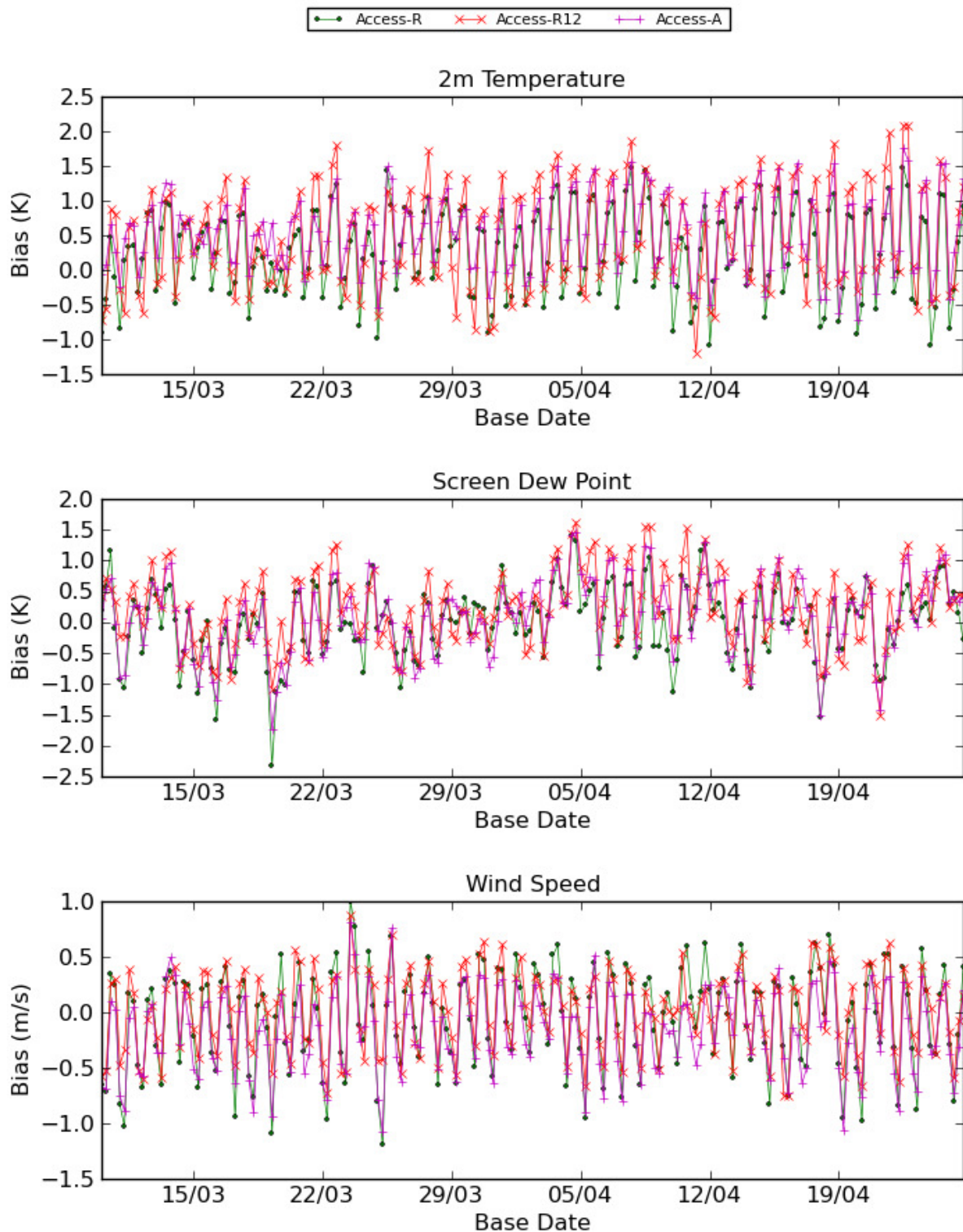


Figure 8: As for Figure 7 but bias rather than RMS error.

3.4 Synoptic Assessment of APS1 ACCESS-R

APS1 ACCESS-R regularly outperforms the lower resolution APS0 ACCESS-R in resolving synoptic features particularly at longer forecast ranges. Figure 9 shows the 72hour MSLP and 3-hourly accumulated precipitation forecasts valid at 12utc 2 Feb 2013 from both these models and the corresponding NMOC MSLP analysis. In this example APS1 ACCESS-R successfully captures the cyclogenesis off the NSW coast, in contrast to APS0 ACCESS-R which only indicates a broad trough over Queensland. APS1 ACCESS-R also successfully predicts the trough line off the Queensland coast as indicted in panel b) by the well resolved line of precipitation. Both models successfully predict the development of a circulation just east of 15°S 170°E. This circulation is just to the east of NMOC analysis but was clearly indicated by the Darwin Regional Specialised Meteorological Centre gradient level analysis (not shown here). The forecast flow over the South Island of New Zealand in APS1 ACCESS-R is much closer to the verifying analysis than the corresponding APS0 ACCESS-R forecast.

In general both the APS0 ACCESS-A and APS1 ACCESS-R systems show similar skill in forecasting the MSLP patterns over the Australian region for the forecast period 00 to 48hours. Figure 10 shows the 48hour MSLP and 3-hourly accumulated precipitation forecasts valid for 12 UTC 18 April 2013 and the corresponding NMOC MSLP analysis. Figure 11 displays the corresponding 10m wind forecasts and the corresponding APS1 ACCESS-R 10m wind analysis. In this example ACCESS-R performed significantly better than ACCESS-A in a number of key synoptic features. The cyclonic curvature and correspondingly tighter gradients in the flow just to the east of Tasmania is well represented in ACCESS-R but not in ACCESS-A (Figure 10 and 11). The cut off low near 35°S 165°E is better resolved in the ACCESS-R forecast compared to ACCESS-A, with the structure and strength of the ACCESS-R 10m wind field being closer to that of the verifying analysis. The strength of the 10m wind field southward of 50°S is better forecast in ACCESS-R compared to ACCESS-A. The structure of the 10m wind field about the trough to the southwest of WA is better resolved in the ACCESS-R forecast than the ACCESS-A forecast. Both models forecast a monsoon low to the southwest of Sumatra.

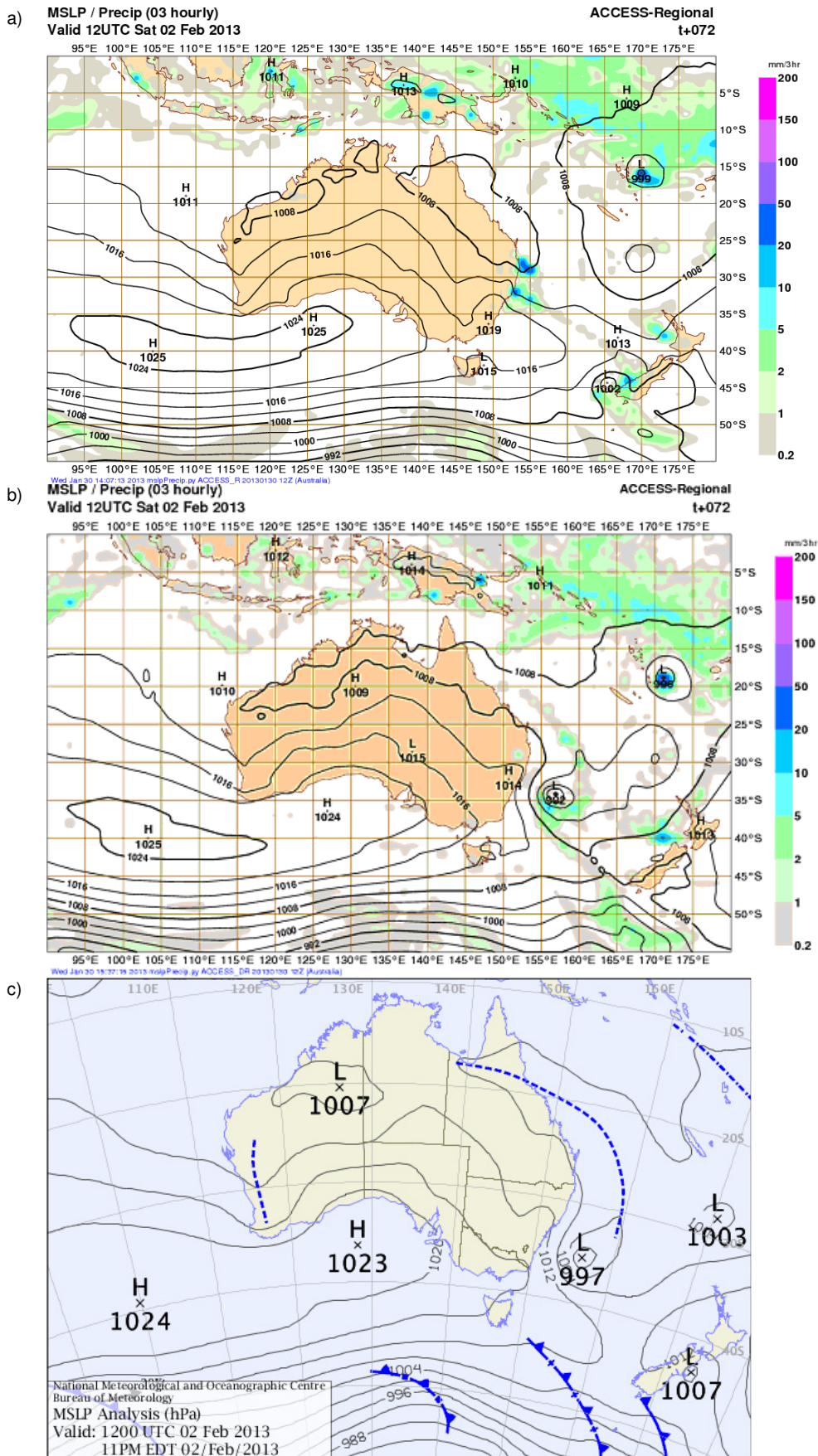


Figure 9: a) APS0 ACCESS-R 72 hour MSLP and 3hr precipitation forecast valid 12utc 2 Feb 2013, b) as for panel a) but for APS1 ACCESS-R NMOC, c) Corresponding NMOC MSLP analysis valid 12utc 2 Feb 2013

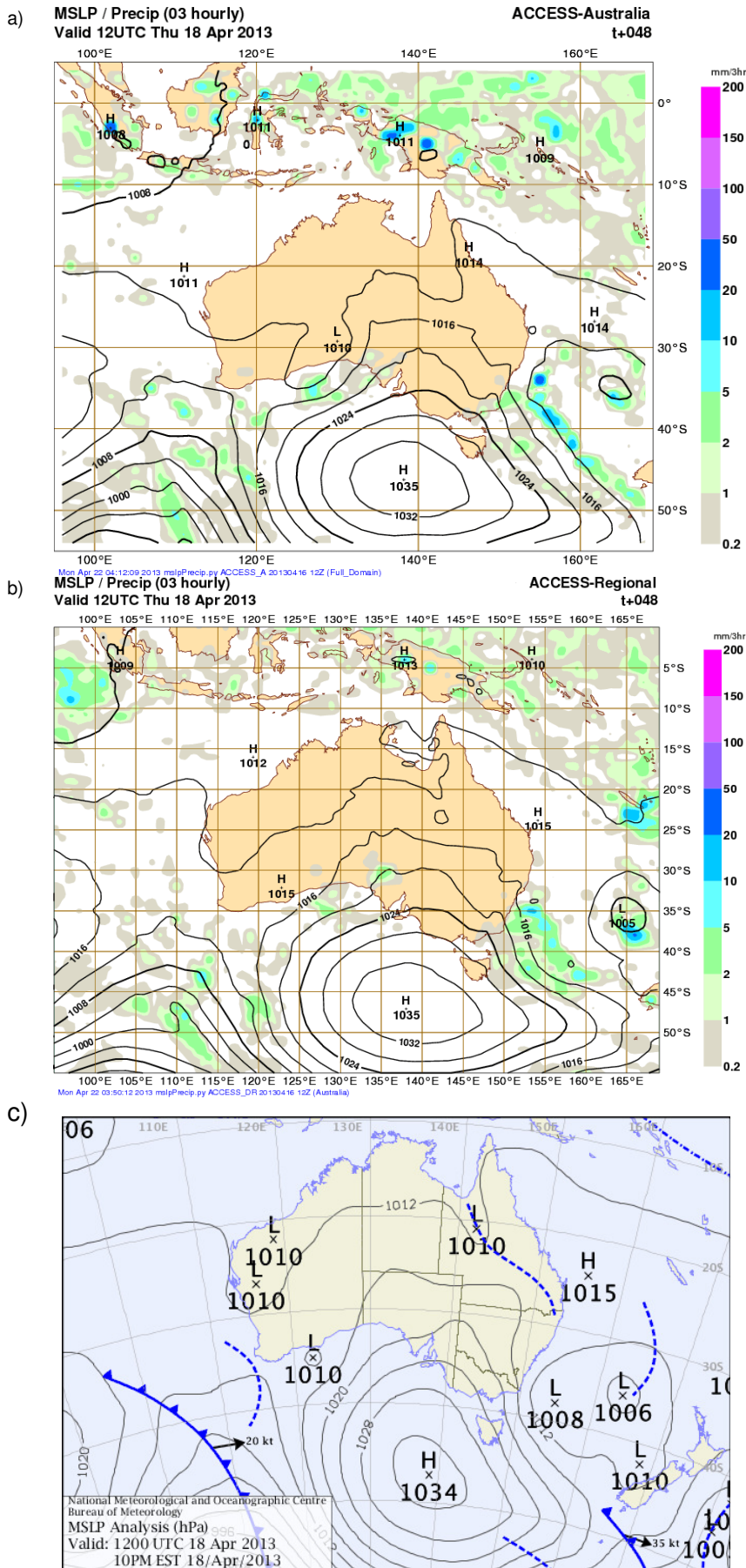


Figure 10: a) APS0 ACCESS-A MSLP & 3hour precipitation at 48hr forecast hour valid 12utc 18 Apr 2013.
b) As for a) but for APS1 ACCESS-R c) Corresponding NMOG MSLP analysis valid 12utc 18 Apr 2013

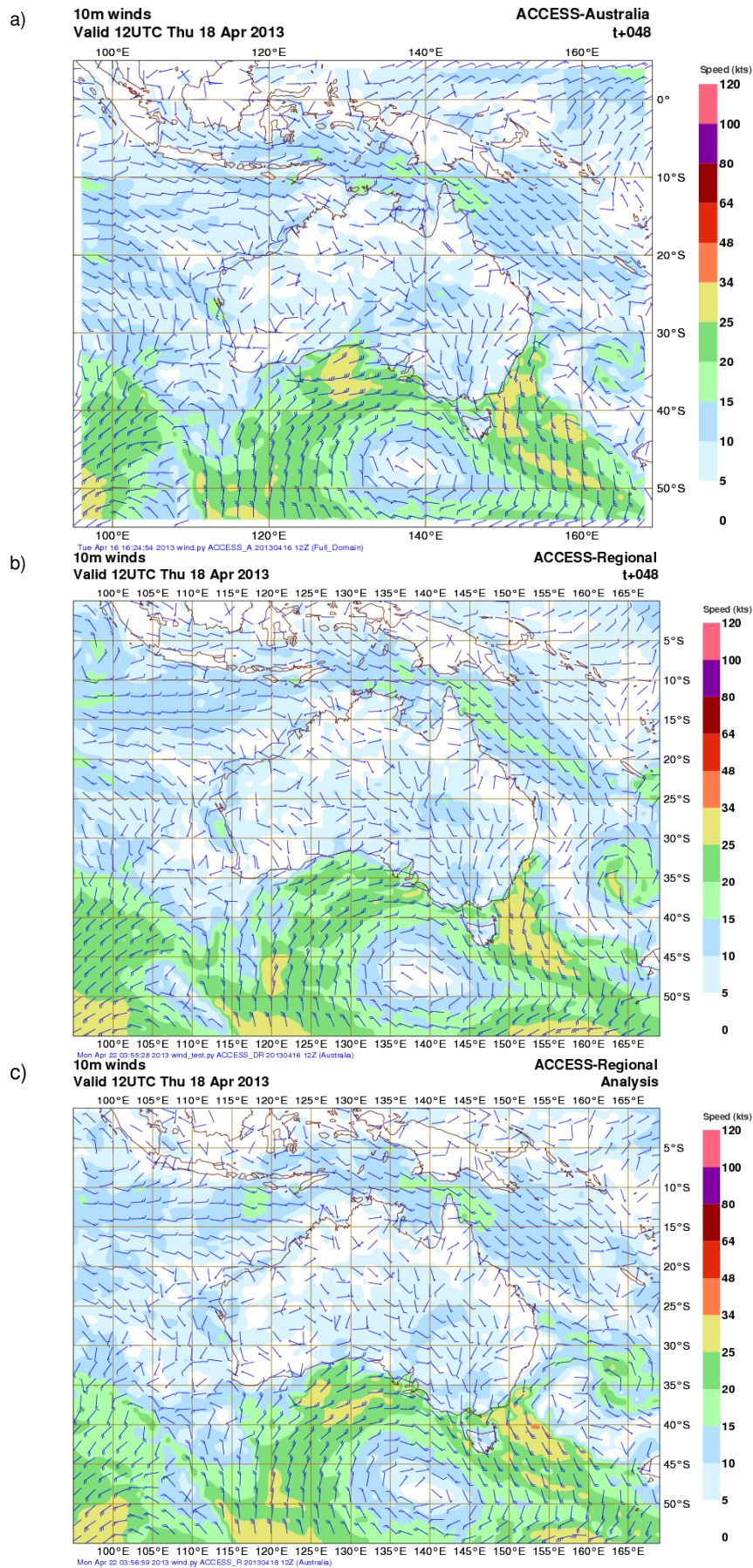


Figure 11: a) APS0 ACCESS-A 10m wind 48hr forecast valid 12utc 18 Apr 2013. b) As for a) but for APS1 ACCESS-R. c) Corresponding APS1 ACCESS-R 10m wind analysis.

4 Model output products

ACCESS model forecast data is written out from the UM in a proprietary UK Met Office format. The raw model files are then converted to GRIB edition1 (GRIB1) binary format before being stored in the Meteorological Archival and Retrieval System (MARS). The GRIB1 files are converted to NetCDF or GRIB2 binary format as required.

The “raw” model-level data is on a horizontally and vertically staggered grid and can be difficult to use without specially designed software. Most users instead choose to use data that has been “de-staggered”, i.e. interpolated to a common grid. Horizontally and vertically de-staggered data with all fields interpolated to the model theta levels (with lower levels at 20m, 53.3m, 100m etc, refer to Table 3 for a full list of model theta levels) are available to users.

For APS1, a tri-linear interpolation technique has been introduced, in contrast to the cubic spline algorithm used for APS0. The linear technique has been shown to produce similar results while requiring significantly less computing resources and also being less prone to “over-shooting” artifacts for fields with sharp gradients.

As mentioned in section 2.1 and described in detail in the appendix of NOB83, the native model vertical levels are “hybrid height” levels which approximate a constant geopotential height above terrain in the low levels, and blend to constant geopotential heights above MSL above approximately 18km.

Details of model field output frequency and the commencement date of the operational MARS historical archive for the APS1 ACCESS-R system are shown in Table 7 below. Unfortunately, capacity limitations with the MARS system has restricted the 1-hourly archive of upper-level fields to the first 24 hours only, reducing to 3-hourly archive frequency beyond that forecast range.

System	Single-level field output frequency	Upper-level field output frequency	MARS archive commencement
ACCESS-R	<p>Prior 00Z 4 Apr 2013: 1-hourly out to +72 hours</p> <p>From 00Z 4 Apr 2013: 1-hourly out to +75 hours</p>	<p>Prior 06Z 31 Jan 2013: 3-hourly out to +72 hours</p> <p>06Z 31Jan to 18Z 3 Apr 2013: 1-hourly out to +24 hours 3-hourly +27 to +72 hours</p> <p>From 00Z 4 Apr 2013: 1-hourly out to +24 hours 3-hourly +27 to +75 hours</p>	00Z 18 Aug 2012

Table 7: Frequency of APS1 ACCESS-R model output and the commencement date of the operational MARS historical archive for this system.

Gridded data

Gridded data from the various ACCESS systems is now distributed internally within the Bureau in GRIB2 format and also made available externally in GRIB2 and NetCDF4 formats for registered users. The switch to using GRIB2 was driven by the need for improved data compression to reduce data transmission costs. The data has been rounded to a moderate degree of precision dependent on the field and then compressed using JPEG2000 or PNG compression algorithms, resulting in a five fold or better reduction in size of a GRIB2 file compared with the equivalent GRIB1 data file. A further advantage of these GRIB2 files is that wherever possible the header information complies with WMO standards, thus facilitating greater compatibility with off-the-shelf data processing and visualisation tools.

Individual data files correspond to collections of data valid at a single forecast time-step and include:

- Single-level fields interpolated to a single uniform (horizontally destaggered) grid
- Multi-level fields interpolated to selected pressure levels on a single uniform (destaggered) grid
- Multi-level fields on the model native “theta” vertical coordinates, interpolated to a single uniform (horizontally destaggered) grid. For convenience, the wind field components have also been interpolated to the model “theta” levels, although the horizontally de-staggered wind fields on the model “rho” vertical levels will also be made available for users who specifically require them.

Multilevel fields on the “raw” model grid (i.e. staggered - horizontally and vertically) will only be made available upon request to advanced users who specifically require such data for precision modelling work.

NOTE: In the past, APS0 output interpolated to sigma levels ($\sigma = P/P_{\text{surface}}$) was made available to facilitate interfacing ACCESS data to legacy downstream systems. However, conversion from the hybrid height levels to sigma levels requires post-processing resources and introduces interpolation errors, so any remaining users of sigma level data are strongly encouraged to convert their applications to use the APS1 hybrid model-level data instead.

The increase in model resolution for APS1 ACCESS-R has resulted in a very large increase in the number of data-points output in the NWP grids compared to APS0 ACCESS-R (11.6-fold for a full-domain single-level). When compared against the equivalent APS0 ACCESS-A gridded products, the increase in domain size makes these files 3.3x bigger. To compensate for this, Australian-region subsets of the gridded products have been produced for registered users who only require data over the Australian region – the domain of this subset is 54.99°S to 4.96°N, 95.03°E to 169.94°E. Unfortunately the new APS1 0.11° model grid does not exactly overlay previous APS0 ACCESS-A 0.11° grid so this sub-domain does not overlap exactly with the ACCESS-A grid but is offset a few kilometers to the southwest – this shift in the model grid has resulted in some changes to the land-sea mask for a few grid points near the coast with some grid points that were previously classed as land in ACCESS-A are now classed as ocean in ACCESS-R and vice versa - this could potentially have a noticeable impact on temperature forecasts for some coastal locations.

Further details of the ACCESS gridded products and product bundles, together with sample data files, a description of the available fields contained within and associated local grib table files will be made available on the Bureau’s website at <http://www.bom.gov.au/nwp/doc/access/NWPData.shtml>

Graphical products

Graphical displays of ACCESS forecast fields are available on the Bureau of Meteorology’s external website at <http://www.bom.gov.au/australia/charts/viewer/>. By default, this page displays a variety of ACCESS-R surface and upper levels fields over the Australian regional domain at 3-hourly intervals out to the +72 hour (i.e. day 3) forecast period, followed by 6-hourly ACCESS-G fields for forecast periods out to day 7. A dropdown menu allows the display of other ACCESS models over a variety of domains. State based sub-domain charts that were previously generated from APS0 ACCESS-A are now generated from ACCESS-R.

5 Future Plans

5.1 Timetable for changes with the ACCESS models

The completion of the APS1 ACCESS upgrade cycle will result in upgrades to ACCESS-C and ACCESS-TC systems followed by the decommissioning of all the remaining APS0 systems.

On 17 April 2012 APS1 ACCESS-R was declared operational. Further APS1-related changes and approximate timetable are as follows:

- 9 May 2012 – APS0 ACCESS-A decommissioned
- 1 August 2013 - APS0 ACCESS-TC tropical cyclone system switched to being nested inside ACCESS-G boundary conditions rather than nesting inside the APS0 ACCESS-T.
- 21 August 2013 – APS0 ACCESS-T decommissioned with all output products being replaced by equivalents sourced from the ACCESS-G model instead.
- August/September 2013 – APS1 ACCESS-C city-based systems declared operational. These will use an increased horizontal grid spacing of 0.036° (previously 0.05°) with the boundaries of the Adelaide, Perth and VicTas ACCESS-C systems expanded slightly in response to requests from forecast users. It is also planned to commence running ACCESS-C every 6 hours with the addition of new 06 & 18UTC forecast runs. (An additional ACCESS-C Darwin domain is currently undergoing testing within CAWCR but any decision on future operational implementation is dependent on satisfactory forecast evaluation.
- August/September 2013 – Final decommissioning of all remaining APS0 systems (ACCESS-G, R & C).

5.2 Other short term developments

Other upcoming developments to be implemented in the next few months include:

- Use of new observational data types, including SSMI/S and WINDSAT scatterometer data. This is awaiting ingestion of these data types into the operational MARS archiving system.
- Porting of all ACCESS NWP systems to a new Oracle supercomputer located at the Derrimut data centre during the 3Q 2013.

5.3 Longer term plans

Longer term developments include (noting that transition to operations depends on resource availability):

- A further resolution increase to N512 (~25 km) for APS2 ACCESS-G.
- Use of latest versions of the UKMO UM/VAR software.
- Introduction of an on-demand model to provide for high-resolution NWP forecasts of high-impact weather.
- In conjunction with SREP (Strategic Radar Enhancement Project) very-high resolution 1.5km, 70 levels city-based models are under development in CAWCR. These will incorporate full data assimilating systems, including assimilation of radar-data in two forms: radar radial winds and latent-heat-nudging from radar-derived precipitation rates. A SREP Sydney domain demonstration system is currently being set up for real-time running and product distribution during 2014.
- An “AGREPS” ACCESS Global and Regional Ensemble Prediction System, which is currently undergoing development and testing in CAWCR.

6 Acronyms

ACCESS	Australian Community Climate and Earth-System Simulator
AIREPS	Aircraft weather report
AIRS	Advanced Infra-Red Sounder
AMDAR	Aircraft Meteorological Data Relay System
AMV	Atmospheric Motion Vector
APS1	Australian Parallel Suite #1
ASCAT	Advanced Scatterometer
ATOVS	Advanced TIROS (Television and Infrared Observational Satellite) Operational Vertical Sounder
CAWCR	Centre for Australian Weather and Climate Research
CSI	Critical Success Index
ESA	European Space Agency
ETS	Equitable Threat Score
FAR	False Alarm Ratio
GFE	Graphical Forecast Editor
GPS-RO	Global Positioning System – Radio Occultation
GRIB	GRIdded Binary
HK	Hanssen & Kuipers Score
HSS	Heidke Skill Score
IASI	Infrared Atmospheric Sounding Interferometer
IDV	Integrated Data Viewer
MARS	Meteorological Archive and Retrieval System
McIDAS	Man computer Interactive Data Access System
MSLP	Mean Sea Level Pressure
NAE	North Atlantic European model
NMOC	National Meteorological and Oceanographic Centre
NWP	Numerical Weather Prediction
POD	Probability of Detection
PS24	(UKMO) Parallel Suite #24
RAMSSA	Regional Australian Multi-Sensor SST (Sea Surface Temperature) Analysis
RARS	Regional ATOVS Retransmission Services
SCS	Suite Control System
SSM/I	Special sensor microwave/imager
SYNOP	Surface synoptic observation
UKMO	United Kingdom Meteorological office
UM	Unified Model
VAR	Variational Assimilation
WMO	World Meteorological Organization

References

- Beggs, H., A. Zhong, G. Warren, O. Alves, G. Brassington and T. Pugh (2011) RAMSSA - An Operational, High-Resolution, Multi-Sensor Sea Surface Temperature Analysis over the Australian Region. *Australian Meteorological and Oceanographic Journal*, 61, 1-22.
- Hilton, F., Atkinson, N., English, S. and Eyre, J., 2009: "Assimilation of IASI at the Met Office and assessment of its impact through observing system experiments", *Q. J. R. Meteorol. Soc.*, **135**, 495-505
- McBride, J. and Ebert, E. 2000: "Verification of Quantitative Precipitation Forecasts from Operational Numerical Weather Prediction Models over Australia", *Weather and Forecasting* **15**, 103-121.
- Mesinger, F. 2008: "Bias Adjusted Precipitation Threat Scores", *Adv. Geosci.*, 16, 137-142
- NMOC Operations Bulletin No. 83, 21 September 2010, "Operational implementation of the ACCESS Numerical Weather Prediction systems" – <http://www.bom.gov.au/australia/charts/bulletins/apob83.pdf>
- NMOC Operations Bulletin No. 93, 22 November 2012, "APS1 upgrade of the ACCESS-G Numerical Weather Prediction system" – <http://www.bom.gov.au/australia/charts/bulletins/apob93.pdf>
- Pavelin, E. G., S. J. English, J. R. Eyre, 2008, "The assimilation of cloud-affected infrared satellite radiances for numerical weather prediction", *Q. J. R. Meteorol. Soc.*, **134**, 737-749
- Puri, K., G. Dietachmayer, P. Steinle, M. Dix, L. Rikus, L. Logan, M. Naughton, C. Tingwell, Y. Xiao, V. Barras, I. Bermous, R. Bowen, L. Deschamps, C. Franklin, J. Fraser, T. Glowacki, B. Harris, J. Lee, T. Le, G. Roff, A. Sulaiman, H. Sims, X. Sun, Z. Sun, H. Zhu, M. Chattopadhyay, C. Engel, 2012: "Implementation of the initial ACCESS Numerical Weather Prediction system", *Aust. Met. Oc. Journal*, submitted
- Rennie M. 2008. The assimilation of GPS radio occultation data into the Met Office global model. [Met R&D Technical Report 510](#) (available via the Met Office website), Met Office, UK.
- Rennie M. 2010. The Impact of GPS Radio Occultation Assimilation at the Met Office. [Q. J. R. Meteorol. Soc. 136: 116-131.](#)
- Walters, D. N., M. J. Best, A. C. Bushell, D. Copsey, J. M. Edwards, P. D. Falloon, C. M. Harris, A. P. Lock, J. C. Manners, C. J. Morcrette, M. J. Roberts, R. A. Stratton, S. Webster, J. M. Wilkinson, M. R. Willett, I. A. Boutle, P. D. Earnshaw, P. G. Hill, C. MacLachlan, G. M. Martin, W. Moufouma-Okia, M. D. Palmer, J. C. Petch, G. G. Rooney, A. A. Scaife, and K. D. Williams, 2011. "The Met Office Unified Model Global Atmosphere 3.0/3.1 and JULES Global Land 3.0/3.1 configurations", *Geosci. Model Dev.*, **4**, 919-941.