Australian Government
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Recent upgrades to the Bureau of Meteorology ACCESS NWP system

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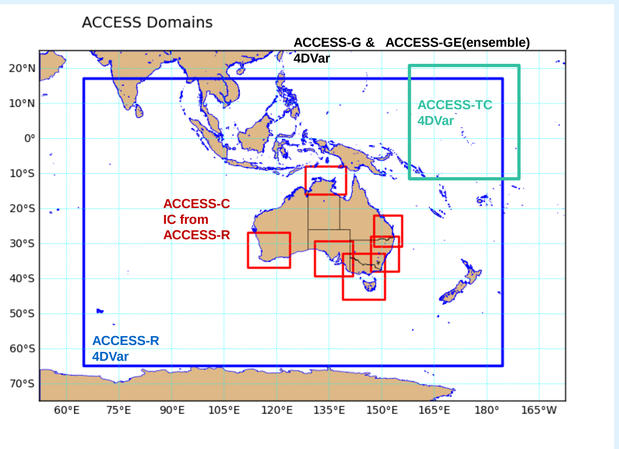
The Bureau's ACCESS NWP systems are based on Met Office UM, OPS, VAR and SURF software. We are currently upgrading ACCESS from the current operational "Australian Parallel Suite" **APS1** to **APS2**.



Upgrade of ACCESS Limited Area Systems

ACCESS-R: UM7.5 → UM8.4; DA as per ACCESS-G
ACCESS-C: UM7.6 → UM8.2; Grid spacing 4km → 1.5 km
ACCESS-TC: as per ACCESS-R

Summary of differences between the APS1 and APS2 ACCESS-G Global NWP systems

	APS1	APS2
UM horizontal resolution (lat x lon)	481 x 640 (0.3750° x 0.5625°)	769 x 1024 (0.234375° x 0.351562°)
Analysis horizontal resolution (lat x lon)	217 x 288 (0.8333° x 1.25°)	163 x 216 (1.11111° x 1.66667°) 325 x 432 (0.555556° x 0.833333°)
Vertical resolution	L70, top level at approximately 80km (~0.009 hPa)	Same
Frequency of data assimilation	6-hourly for basetimes 00, 06, 12 and 18 UTC	Same
4DVar	Single loop N144	Double loop N108 + N216; updated moisture control variable
Observational data used (6hr window)	AIRS, ATOVS, ASCAT, AMV, IASI, GPSRO, SYNOP, SHIP, BUOY, AMDARS, AIREPS, TEMP, PILOT	as for APS1, plus CrIS and ATMS, ATOVS and IASI from MetOp-B (not used in APS1), MTSAT CSRs
Sea surface temperature analysis	GAMSSA Daily global 0.25° SST analysis	Same
Sea ice analysis	NCEP 1/12° sea ice analysis	Same
Soil moisture analysis	SURF nudges soil moisture field via screen-level analysis. Once every 6 hours	Same
Snow amount	Warm running from previous model first guess	Same
Internal model time step	12 minutes (120 time steps per day)	10 minutes (144 time steps per day)
Analysis time step	30 minutes	40 minutes (N108) 20 minutes (N216)
Software suite details	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) v18.3	Suite Control System (SCS) v18.2 Unified Model (UM) v8.2 4DVAR analysis System (VAR) v29.1 Observation Processing System (OPS) v30.0 Surface Fields Processing (SURF) v18.5

APS2 and comparable Met Office systems

System	PS32	APS2 ACCESS-G
UM	8.2	8.2
UM Horz. Grid	1024x769	1024x769
UM Vertical	L70 (~80km)	L70 (~80km)
OPS	29.2.2	30.0.0
VAR	29.2.1	29.1.0
SURF	19.2.3	18.5.1

The Met Office Parallel Suite whose global system most closely matches APS2 ACCESS-G is PS32. PS32 and ACCESS-G2 match in their use of UM version 8.2; differences in other systems are summarized above.

Observation types assimilated in PS32 but not in APS2 ACCESS-G: dust aerosol optical depths (AOD) from MODIS/Aqua, ground-based GPS Total Zenith Delay data, WindSAT scatterometer winds, BOGUS winds and US METAR observations.

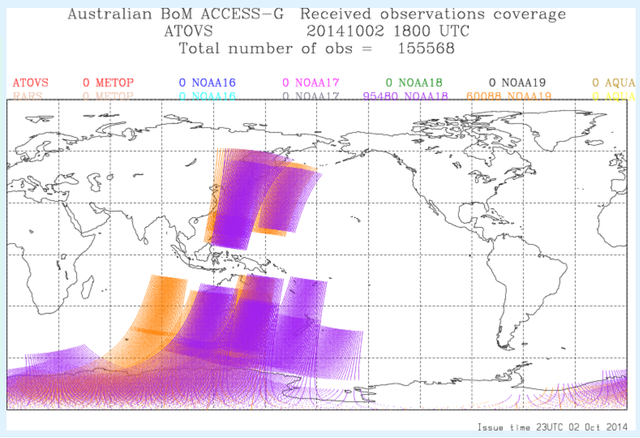
A significant difference is in the Met Office's use of hybrid-VAR assimilation in which information from the global MOGREPS system is used to modify the climatological background error covariances used in 4dVAR, to provide an estimate of "errors of the day": it will not be used in ACCESS until APS3 because it requires a co-running operational ensemble prediction system.

SAT thinning distances (km)

Instrument	APS1	APS2 extra-tropics	APS2 tropics
ATOVS	154	125	154
AIRS	154	125	154
IASI	154	125	154
Scatwind	92	80	80

Locally received & processed + AP-RARS ATOVS data

Low latency locally received and processed ATOVS data are important for ACCESS-R, which runs with a short data cut-off to meet forecast schedules, and, in combination with data from the Asia Pacific Regional ATOVS Retransmission Service, adds robustness to the ACCESS DA system in the event of communications interruptions.

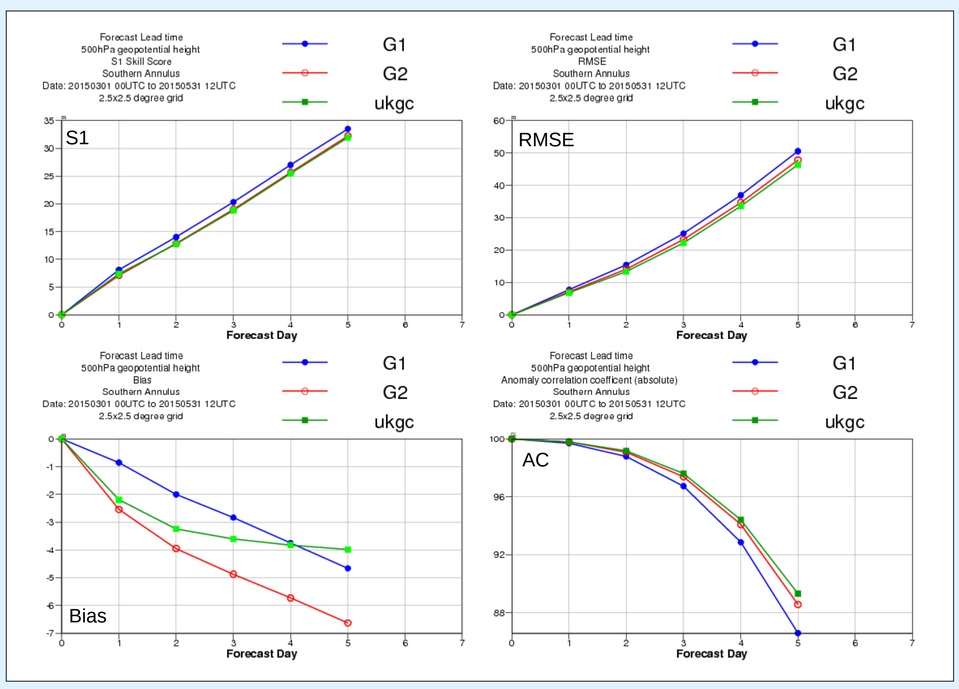


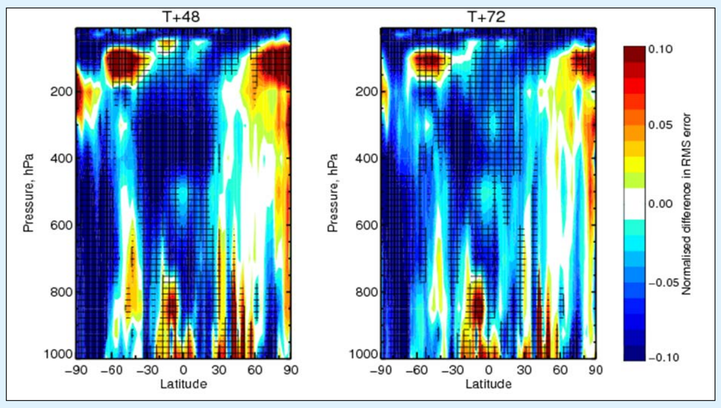
Verification

Standard measures of forecast skill have been used to assess the impact of the APS1 → APS2 upgrade.

There has been a marked improvement in forecast skill in the Southern Hemisphere, and a more modest improvement in the Northern Hemisphere.

The plots below compare the 500 hPa geopotential height forecast skill of APS1 and APS2 ACCESS-G and the concurrently operational Met Office global NWP system in the Southern Hemisphere (20°S to 60°S).





Spatial distribution of forecast skill

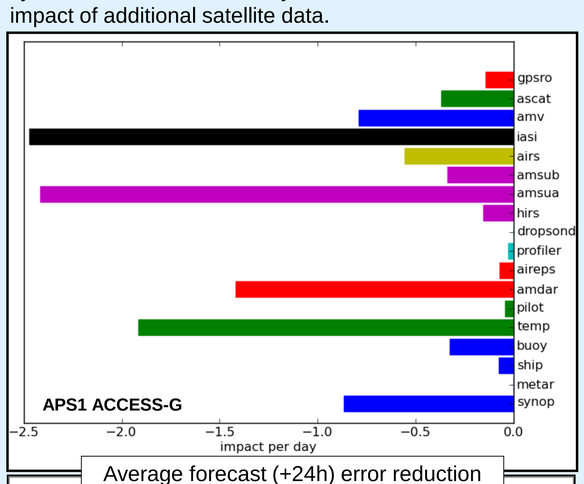
Zonally averaged normalised change in the RMS of temperature forecast error between APS2 and APS1 for forecast day 2 and day 3. Verification is against ECMWF analysis and score Dec 2014 to Feb 2015. Negative values (light and dark blue areas) show reduced RMS forecast errors; cross-hatched areas indicate a statistically significant change with 95% confidence level. There is a marked reduction in APS2 RMSE.

Domain	Parameter	Level (hPa)	24	48	72	96	120	144	168
Australia	Geopotential Height	200	R	R	R	R	R	R	R
		500	R	R	R	R	R	R	R
		850	R	R	R	R	R	R	R
	Mean Sea-Level Pressure	0	R	R	R	R	R	R	R
	Temperature	200	R	R	R	R	R	R	R
		500	R	R	R	R	R	R	R
		850	R	R	R	R	R	R	R
	Wind U-Component	200	R	R	R	R	R	R	R
		500	R	R	R	R	R	R	R
		850	R	R	R	R	R	R	R
	Wind V-Component	200	R	R	R	R	R	R	R
		500	R	R	R	R	R	R	R
		850	R	R	R	R	R	R	R

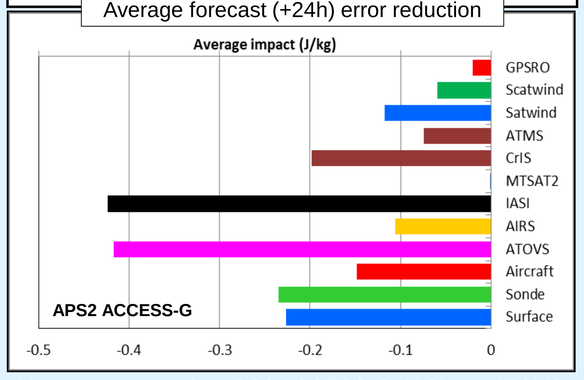
Scorecard visualization compares verification scores from APS1 and APS2 ACCESS-G, for various variables, lead-times, sub-domains and levels. Shown here are the RMSE comparisons for the Australian region. Dark green: APS2 score better than APS1 with >95% confidence; pale green: better, but < 95% confidence; pale red: worse, but with < 95% confidence.

Forecast Sensitivity to Observations (FSO)

We have implemented the adjoint-based method of calculating FSO developed as part of the Met Office VAR system. This will run routinely and be used to assess the impact of additional satellite data.



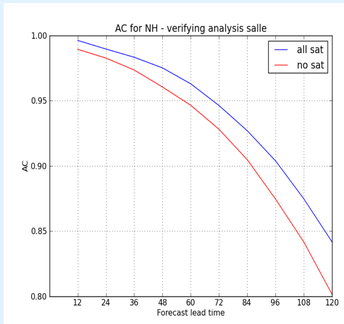
Average forecast (+24h) error reduction



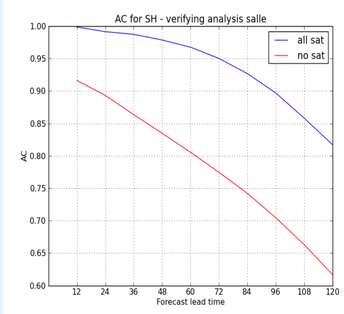
Very early results for APS2 ACCESS-G: IASI and ATOVS continue to produce the most significant forecast error reduction. CrIS and ATMS (new to APS2) are also significant

Impact of Satellite data assimilation on Southern Hemisphere ACCESS-G forecast skill.

- Southern Hemisphere sparseness of in-situ observations means that NWP forecast skill is highly dependent on satellite observations
- Withholding satellite observations degrades forecast skill by ~3.5 days in the Southern Hemisphere, but only ½ day in the Northern Hemisphere.



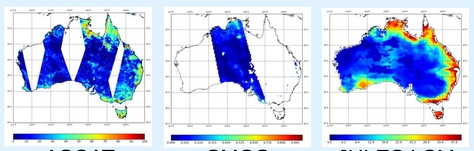
Anomaly correlations of mean sea-level pressure for the control run (blue) and the data-denial run (red) as a function of forecast lead times. The control analyses were used as verifying analyses. The verification scores were calculated for the Northern Hemisphere.



Same as above, but for the Southern Hemisphere

Impact of Satellite Observations on Southern Hemisphere Forecasts from Operational ACCESS-G NWP Model
J. Lee, J. Le Marshall, C. Tingwell, B. Roux, CAWCR Research Letters Issue 10, August 2013

Land Data Assimilation System



- Extended Kalman Filter
- Offline soil moisture analyses at 5 km horiz. resolution.
- Initialise high resolution regional NWP systems.
- Used for fire danger warnings.
- Used in research mode, in operational use ~2016.
- Built around the JULES land surface model (LSM).
- Observation types and status:

Observation Type	Platform	Status
2 m Temperature	Screen-level	Yes (Research)
2 m Humidity	Screen-level	Yes (Research)
Soil Moisture	ASCAT	Yes (Research)
Soil Moisture	SMOS	No (Planned)
Land Surface Temperature	Himawari-8	No (Mid-term)
NDVI/LAI	MODIS etc.	No (Long-term)

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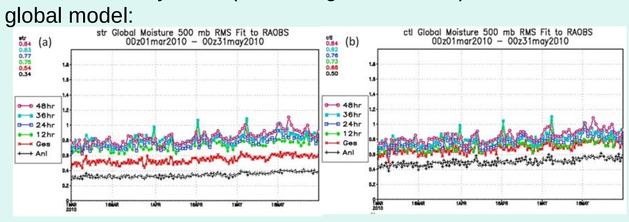
Future Work: improving moisture analyses using hyperspectral IR radiances

Additional hyperspectral channels (AIRS and IASI) have been shown to considerably improve the analysis and short term forecast humidity fields (verified against sondes) in the NCEP global model:



Time series of specific humidity RMS Difference (RMSD) statistics with respect to rawinsonde data during March, April and and May 2010 for the (a) Water Vapor Experiment and (b) Control . The various colors are for the analysis, 6(Ges)- , 12- , 24- , 36- and 48-hour forecasts. Note the considerable specific humidity RMSD improvement to the analysis and 6-hour forecasts for the water vapour experiment (a). (John Le Marshall, James A. Jung, Jin Lee, Chris Barnet and Eric S. Maddy. 2014. Improving Tropospheric and Stratospheric Moisture Analysis with Hyperspectral Infrared Radiances, 2014, . *Aust. Meteor. and Ocean. Jnl.*, **64**, 283-288.)

We aim to investigate the impact of extra moisture-sensitive hyperspectral channels in ACCESS

Future Work: ACCESS upgrades

Work has begun on the next ACCESS upgrade (APS3) which will be implemented on the Bureau's newly acquired Cray XC40 system. This will include further resolution increases and extended use of satellite data. The implementation of an operational ensemble prediction system (ACCESS-GE) in APS2 onwards, will also facilitate the use of ensemble hybrid-VAR covariances in ACCESS 4DVar.

Very significantly, APS3 will see the introduction of 4DVar data assimilation in the Bureau's high resolution city based ACCESS-C systems. This will be implemented as hourly rapid update cycles (RUC) in ACCESS-C: a key data source for these systems will be radiance and cloud property data derived from Himawari-8 IR imagery. The implementation of city-based RUC DA in ACCESS is seen as a key component of the Bureau's prioritisation of short-range significant weather forecasting.

Acknowledgements

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