Satellite Data Assimilation at the Bureau of Meteorology

Fiona Smith, Chris Tingwell, Esteban Abellan Villardon, Monika Krysta, Jin Lee, Susan Rennie
Nahidul Samrat, Andrew Smith, Peter Steinle, Xiaoxi Wu, Yi Xiao

The Bureau of Meteorology

Bureau of Meteorology, GPO Box 1289, Vic. 3001, Australia.

Fiona.smith@bom.gov.au

	Global (ACCESS-G3 and GE3)	Concvective Scale (ACCESS-C3 and CE3)	Tropical Cyclone (ACCESS-TC3)	National Analysis System (NAS)
Deterministic	N1024 (12 km), L70 00, 06, 12, 18 UTC	1.5 km, L80 7 domains Hourly	4 km, L80, Up to 3 relocatable domains 00, 12 UTC	2.2km, L80 Hourly. Short forecasts only.
Ensemble	N400 (36 km), L70 18 members (plus lagging) 00, 06, 12, 18 UTC	2.2 km, L80 12 members (plus lagging) 00, 06, 12, 18 UTC		
Data assimilation	T-3 :T+3 window Hybrid 4D-Var (N144 + N320)	C3: Hourly cycling 4D-Var	T-3:T+2 window 4D-Var	Hourly Cycling 4D-Var, Hourly Quick look 3D-Var, Hourly 3D-Var overfit
Observations	AHI-CSR, AIRS, CrIS, IASI, ATMS, ATOVS, SSMIS AMSR-2 GPSRO Australian GNSS ZTD (WV) AMV, Scatterometer AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO TC BOGUS	AIRS, CrIS, IASI ATMS, ATOVS Australian GNSS ZTD (WV) AMV, ASCAT AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO Doppler Radar Winds	AIRS, CrIS, IASI ATMS, ATOVS Australian GNSS ZTD (WV) AMV, ASCAT AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO TC BOGUS	AIRS, CrIS, IASI ATMS, ATOVS Australian GNSS ZTD (WV) AMV, ASCAT AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO TC BOGUS Doppler Radar Wind AHI Cloud Retrievals
Bias Correction	VarBC, with static scan bias correction	Uses VarBC coefficients from G3	Uses VarBC coefficients from G3	VarBC with static scan bias correction
SST / Sea Ice	GAMSSA[1] / NCEP Ice	RAMSSA[2]	GAMSSA[1]	RAMSSA[2]
Soil moisture analysis	EKF analysis of screen temperature & humidity and ASCAT soil moisture	Uses Soil moisture analysis from G3	Uses Soil moisture analysis from G3	EKF analysis of screen temperature & humidity and ASCAT soil moisture

Table 1: Summary of ACCESS NWP systems
Red highlight indicates observations lost since last ITSC

APS3 NWP Systems

The Bureau's ACCESS NWP systems are based on Met Office UM, OPS, VAR and SURF software. The current operational "Australian Parallel Suite" is **APS3**. The APS3 Systems are summarised in the table to the left.

NAS is a fast, short forecast cycle system, combined with hourly 4D-Var to provide initial conditions for the following cycle. Its products include a quick-look 3D-Var analysis and an overfit 3D-Var analysis, available to forecasters within 30 mins of analysis time. It will be the first system in operations on our new supercomputer.

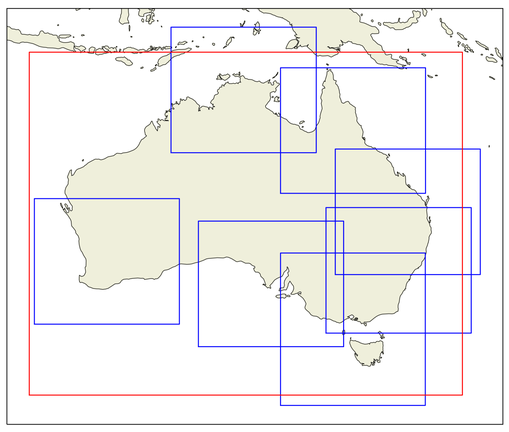


Figure 1: APS3 NWP Australian domains. Blue - ACCESS-C3 models, Red - NAS

The domains of C3 and NAS are shown in Figure 1.

Table 2 provides more details of the satellite observations assimilated at the Bureau as of March 2023. We hope to reinstate AIRS and Himawari radiances in the near future.

Hyperspectral IR sounder (LEO)	AIRS CrIS – S-NPP, NOAA-20 IASI –Metop-B, Metop-C
IR sounder (GEO)	Himawari 9 AHI CSR (not currently available)
Microwave sounders (LEO)	AMSR-2 ATMS – S-NPP, NOAA-20 ATOVS – N15, N18, N19, Metop-B, Metop-C SSMIS – F-17
GNSS measurements	GPSRO – TerraSar-X, TanDem-X, Metop-B, Metop-C, FY-3C Australian Ground-based ZTD (WV)
AMV (mostly GEO)	Himawari, GOES-16, GOES-18, Meteosat-9, Meteosat-11, MODIS (Aqua)
Scatterometer	ASCAT – Metop-B,C

Table 2: Satellite Data Usage in ACCESS models

APS4 NWP Systems

The Bureau's next operational NWP systems (APS4) will be deployed on the Bureau's upgraded HPC (Cray XC-50) system 2023-2024. Table 3 shows a summary of the model to be compared with APS3 above, and details the new satellite data we are adding. This system will also include all-sky microwave radiance assimilation.

At the same time, we are investigating upgrades to the use of AHI radiances and Var-BC for the convective scale models (see poster by Nahidul Samrat).

The APS4 ACCESS-G has already been extensively trialled and is currently running in real time. Verification results show a significant improvement in performance compared to APS3 ACCESS-G (Figures 2 and 3).

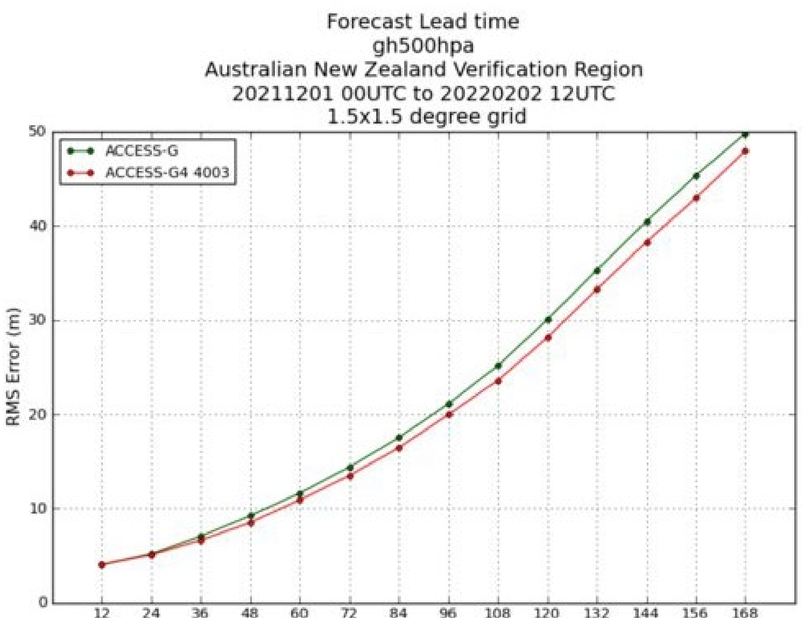
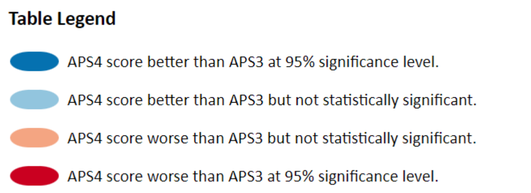


Figure 2: Self-verified RMS Error (m) for 500 hPa geopotential height: APS3 ACCESS-G (green) versus APS4 (red) for the period 2021-12-01 to 2022-02-02 over the WMO Australian and New Zealand Verification region as a function of forecast lead time (hours).



Parameter	Level (hPa)	24	48	72	96	120	144	168
Geopotential Height	250	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	250	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	250	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	250	R	R	R	R	R	R	R
	500	R	R	R	R	R	R	R
	850	R	R	R	R	R	R	R

Figure 3: Verification score cards comparing ACCESS-G APS4 performance to APS3.
Period: 14/01/2021 to 27/02/2022
Domain: WMO Australia + New Zealand
Error metric: RMSE (from self-verification)

	Global (ACCESS-G4 and GE4)
Deterministic	N1024 (12 km), L70 00, 06, 12, 18 UTC
Ensemble	N400 (36 km, with possible upgrade to 25 km in the future), L70 18 members (plus lagging) 00, 06, 12, 18 UTC
Data assimilation	T-3 :T+3 window En4D-EnVar (N144 + N320)
Observations as at March 2023	AHI-CSR (soon - Him 9), AIRS, CrIS (NOAA-20, S-NPP), IASI (Metop-B and -C), ATMS (NOAA-20, S-NPP), ATOVS (NOAA-15, 18, 19, Metop-B and -C), SSMIS (F-17) AMSR-2 GPSRO (TerraSar-X, TanDem-X, Metop-B, Metop-C, FY-3C, COSMIC-2, PAZ, KOMPSAT-5) Australian GNSS ZTD (WV), soon +International ZTD AMV (AHI, GOES-16 and -18, MSG-9 and 11, AVHRR, VIIRS), Scatterometer (Metop-B and -C) AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO TC BOGUS
Bias Correction	VarBC, with static scan bias correction
SST / Sea Ice	GAMSSA[1] or OSTIA SST / OSTIA Ice
Soil moisture analysis	EKF analysis of screen temperature & humidity and ASCAT soil moisture

Table 3: Summary of ACCESS NWP systems
Green highlight indicates observations to be added to APS4

Observations Impact Project

Five year project to uplift the Bureau's capability to assess the impact that global and local observations have in its NWP systems

Aims to:

- Deliver operational FSOI suites [3] for ACCESS-G3 and ACCESS-G4, with
  - processing and visualisation software to generate aggregated FSOI results that are meaningful and useful to all Bureau stakeholders, and
  - routine generation of near real-time web-based FSOI results.
- Provide Bureau observing network planners with routine and customised FSOI results to inform network planning and investment decisions.
- Investigate geographic, seasonal and event-based variations in FSOI.
- Maintain capability and tools to deliver OSE results in response to needs of key customers.
- Possibly deliver FSOI suites for future high resolution ACCESS systems.
- And …

Ensemble Observing System Simulation Experiments: assessing the impact of future observations

- Initially in support of National Space Mission for Earth Observations (NSMEO) (see poster ?)
- Based on ECMWF Ensemble DA approach (Tan et al., 2007 [4])
- Initial two year effort will
  - establish ACCESS Ensemble System suitable for this approach - first example in UM Partnership; high expectation will be suitable (ECMWF 2005 EPS was suitable), and
  - establish suites for NSMEO microwave sounder impact studies.
- Longer term: use capability to assess the impact of new observation types and sources in ACCESS, the impact of network reconfiguration, etc.

References

[1] **Zhong, A. and Beggs, H.,2008**. Analysis and Prediction Operations Bulletin No. 77 - Operational Implementation of Global Australian Multi-Sensor Sea Surface Temperature Analysis http://www.bom.gov.au/australia/charts/bulletins/apob77.pdf

[2] **Beggs, H., Zhong, A., Warren, G., Alves, O., Brassington, G. and Pugh, T.,** 2011. RAMSSA – An Operational, High-Resolution, Multi-Sensor Sea Surface Temperature Analysis over the Australian Region, Aus Met and Oceanographic Journal, 61, 1-22

[3] **Lorenc, A.C. and Marriott, R.T., 2014**: Forecast sensitivity to observations in the Met Office Global numerical weather prediction system, *Q. J. R. Meteor. Soc.* **140**, 209–224.

[4] **Tan, D.G.H., Andersson, E., Fisher, M. and Isaksen, L., 2007**. Observing-system impact assessment using a data assimilation ensemble technique: application to the ADM-Aeolus wind profiling mission, Q.J.R.Meteo.Soc. **133**, 381-390.