Australian Government
Bureau of Meteorology

Status report: satellite data assimilation at the Bureau of Meteorology

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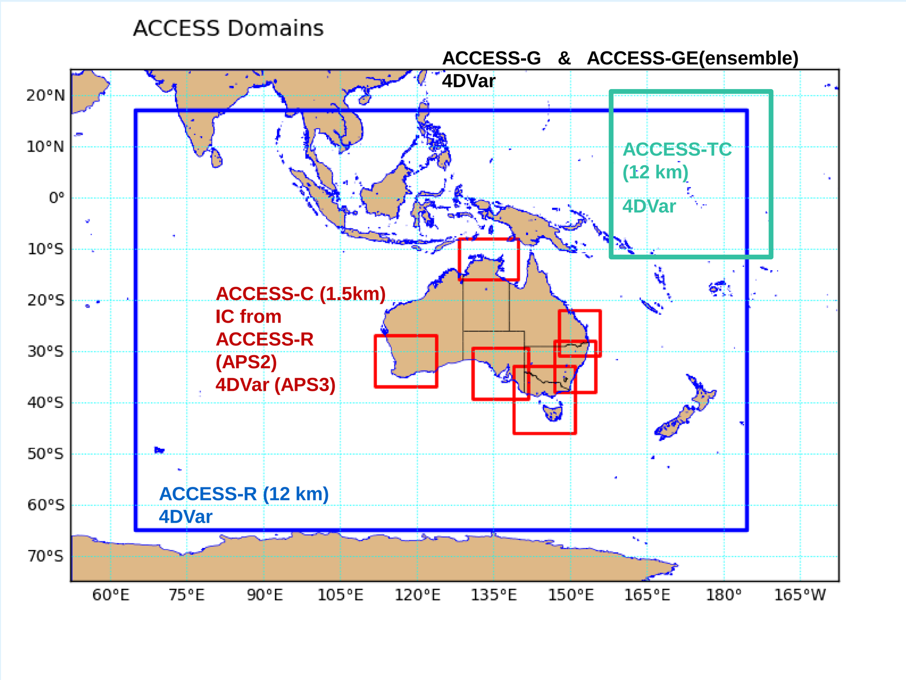
The Bureau's ACCESS NWP systems are based on Met Office UM, OPS, VAR and SURF software (Puri et al. 2013). The current operational "Australian Parallel Suite" is **APS2**. **APS3** is due to become operational in 2018.



Upgrade of ACCESS Limited Area Systems

ACCESS-C Introduction of 4DVar DA (1h rapid update cycle)

ACCESS-R; DA as per ACCESS-G
ACCESS-TC: as per ACCESS-R.

Summary of differences between the APS2 and APS3 ACCESS-G Global NWP systems

	APS2	APS3
Horizontal resolution (lat x lon)	769 x 1024 (nominal 25 km grid), L70	1536 x 2048 (nominal 12 km grid), L70
Data assimilation	6-hourly for base-times 00, 06, 12 , 18 UTC 4DVAR (N108 + N216)	Same **Hybrid** 4DVAR (N108 + N216)
Observational data used (6hr window)	AIRS, ATOVS, ASCAT, AMV, IASI, GPSRO, CrIS, ATMS, SYNOP, SHIP, BUOY, AMDARS, AIREPS, TEMP, PILOT, WINPRO	as for APS2, plus AMSR-2*, SAPHIR*, MWHS-2*, GEO CSRs, WindSAT, SSMIS *TBC
Soil moisture analysis	SURF nudges soil moisture field via screen-level analysis. Once every 6 hours	EKF analysis of screen temperature & humidity and ASCAT soil moisture

The next ACCESS operational system (**APS3**) is due to be implemented in 2018. This will include:

- Resolution increases.
- Increased use of satellite data.
- Ensemble hybrid-VAR covariances.
- VarBC replacing static radiance bias corrections.

Introduction of 4D-Var DA in high resolution (1.5 km) ACCESS-C systems featuring:

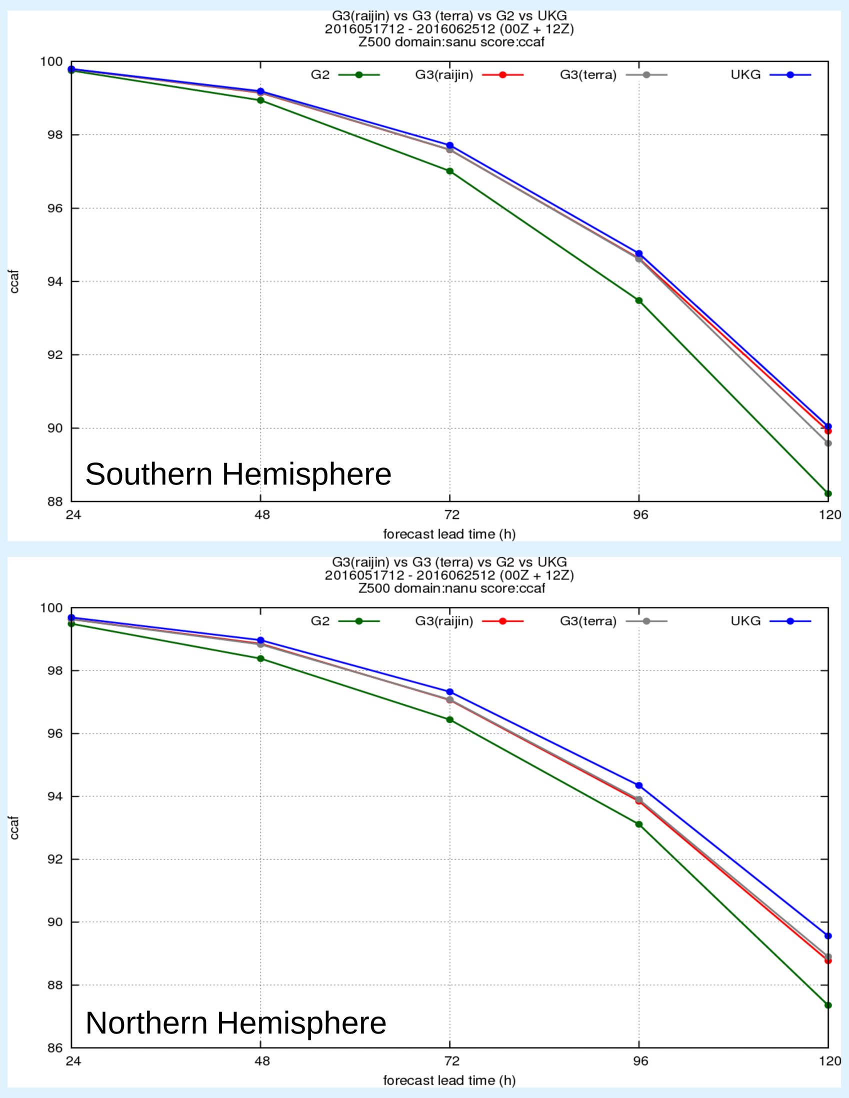
- Hourly rapid update cycles (RUC)
- Assimilation of:
  - radiance and cloud properties derived from the Himawari-8 AHI,
  - locally received and processed POES radiances,
  - GNSS ZTD,
  - radar winds plus latent heat nudging.

Verification of APS3 trial system

Standard measures of forecast skill have been used to assess the likely impact of the **APS2 → APS3** upgrade.

Two low resolution (N320) trials of prototype APS3 ACCESS-G systems have been run for May – June 2016: these assimilated only the same observation types available to the operational APS2 system.

At right: 500 hPa geopotential height Anomaly Correlations for operational **APS2** (green), trial **APS3** (red and grey) ACCESS-G and the then operational **Met Office global** system (blue) in the Southern Hemisphere (top) and Northern Hemisphere (bottom).



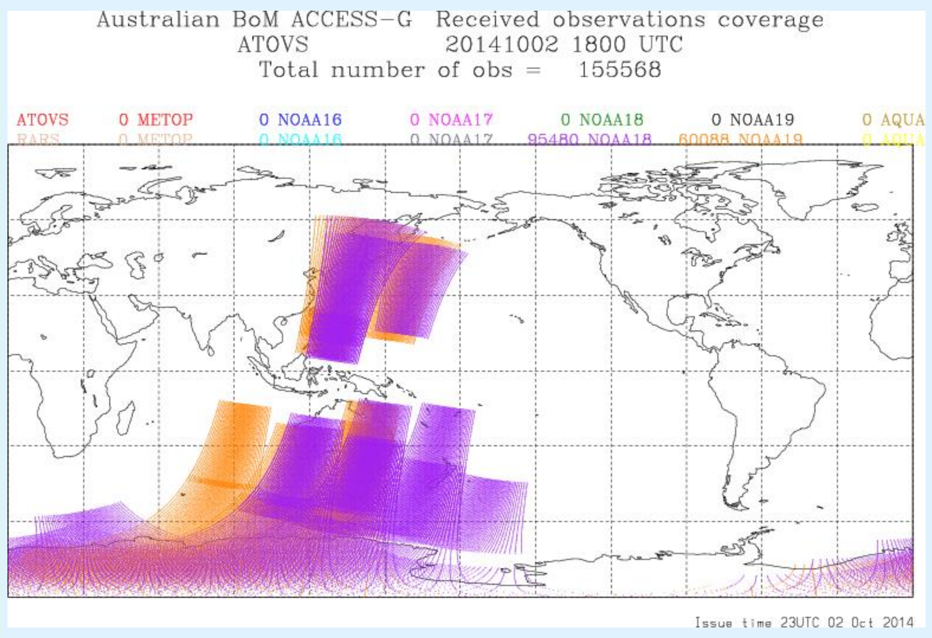
There's a marked improvement over the operational forecast skill in the Southern Hemisphere, and a more modest but still significant improvement in the Northern Hemisphere.

We expect to see additional forecast skill gains for full resolution (N1024) trials and with the addition of new satellite observation sources.

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.

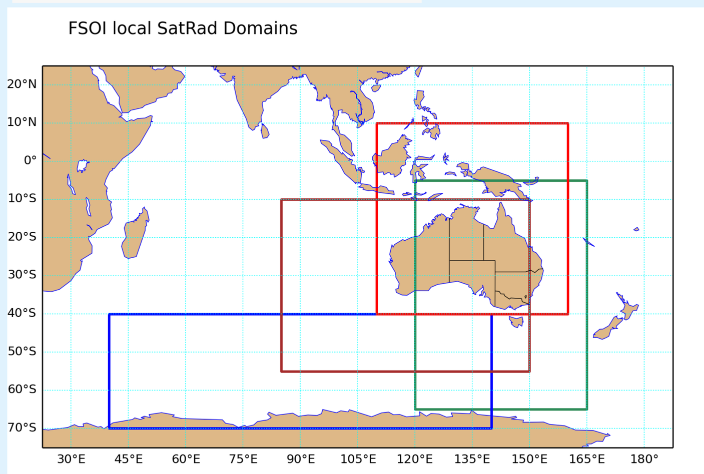
Low latency satellite data will be crucial for upcoming APS3 city-scale systems.

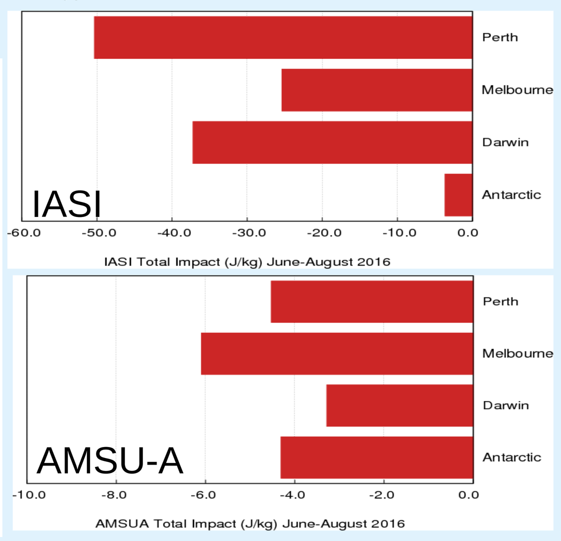


FSOI proxies for locally received and processed POES radiance observations: which receiving stations matter most ?

Australian-region error-norm FSOI impacts for sounder data were sorted into latitude/longitude regions which approximate the reception footprint of each local receiving ground station (Melbourne, Darwin, Perth and Antarctic coastal stations). Impacts from these localised observations are assumed to be a proxy for individual station receiving-station impact in RUC city scale NWP systems and a mooted Australia-wide RUC system which would depend heavily on low-latency locally received and processed radiance data. The relative ranking of each station depends on the observation type:

Station	lon1	lon2	lat1	lat2
Antarctica (Davis and Casey combined)	40	140	-70	-40
Darwin	110	160	-40	+10
Melbourne (Crib Point)	120	165	-65	-5
Perth	85	150	-55	-10

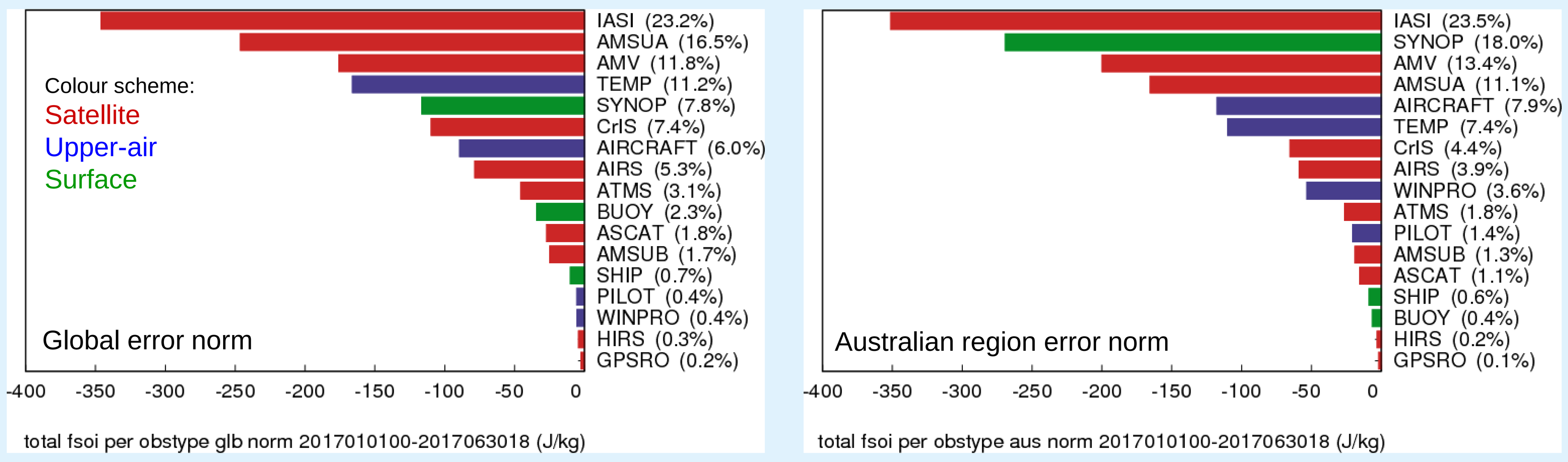




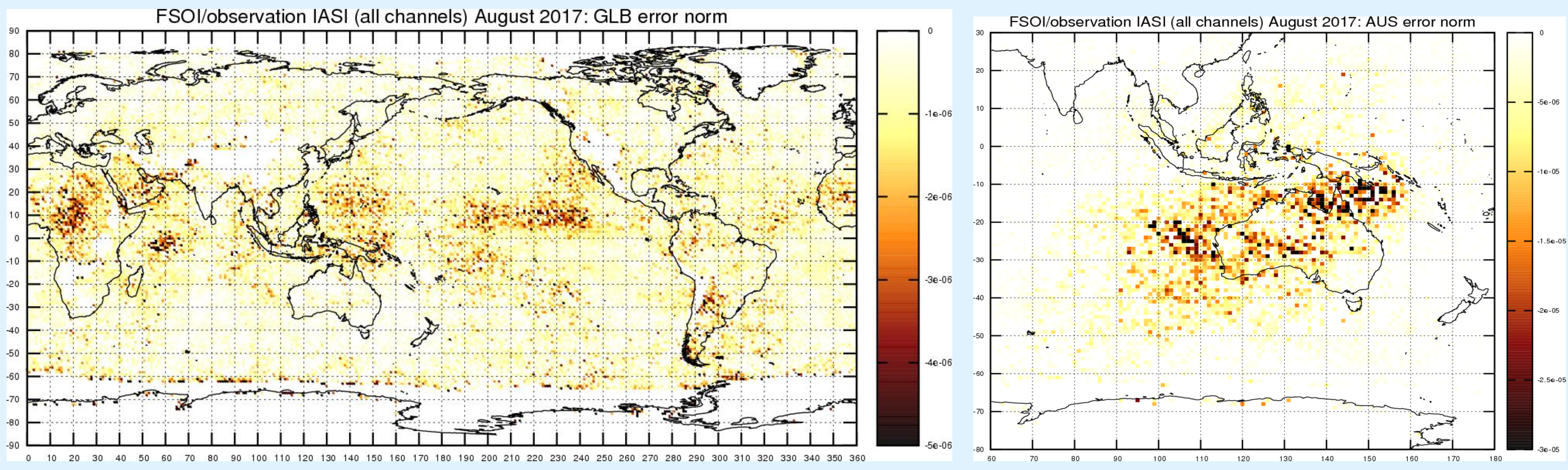
Forecast Sensitivity to Observations (FSO)

We have implemented the adjoint-based method of calculating forecast sensitivity to observations (FSO) developed as part of the Met Office VAR system (Lorenc and Marriott 2014) . This runs routinely in conjunction with the operational APS2 ACCESS-G system. A moist energy norm is used to measure the reduction of the 24 hour forecast error which is then projected onto the assimilated observations via the adjoints of a perturbation forecast model and VAR. The resultant FSO impact (FSOI) values can then be aggregated according to instrument type, observation location etc. The moist energy error norm is calculated twice: globally, and restricted to the Australian verification domain, producing two sets of FSOIs.

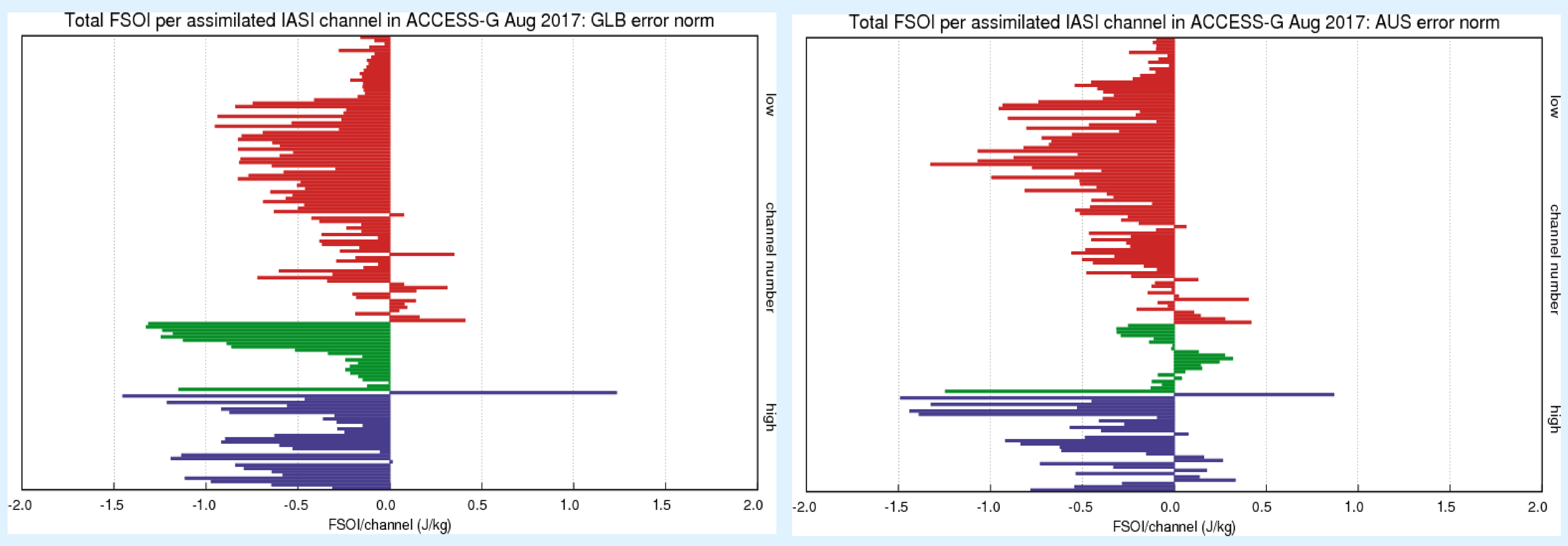
The technique has attracted interest and support within the Bureau as a valuable source of information and guidance for surface and upper-air network assessment and planning. We are also exploring its potential to assess and possibly guide any extensions to our use of satellite observations in ACCESS.



Total FSOI for each of the major observing instruments/types in ACCESS-G for January to June 2017 (negative values indicate the *reduction* in forecast error associated with the observation type). For both the global error norm (left) and the Australian region error norm (right) the forecast impact is dominated by the IASI instrument, consistent with the experience of other centres. NB: SYNOP = surface synoptic observations.



FSOI/observation for all assimilated **IASI** channels for August 2017: for the global error norm (left) and the Australian-region error norm (right). Darker colours represent greater reductions in forecast error. The reduction in 24 h **global** forecast error due to IASI is dominated by observations over the tropics. IASI observations which reduce the Australian region error are localised to the vicinity of the Australian continent, but with several regions dominating: of particular interest is the region to the west of the continent and to the north east over the Coral Sea. Further work will explore whether this localisation is driven by particular events.



Total FSOI per assimilated IASI channel for the global error norm (left) and the Australian-region error norm (right) in August 2017. Temperature sounding channels are red, window/O_3 green and moisture-sensitive channels blue. Temperature-sounding channels contribute a proportionally larger impact in the Australian region than globally.

References

K. Puri, 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 and C. Engel. Implementation of the initial ACCESS numerical weather prediction system, 2013, *Aust. Meteor. and Ocean. J.*, **63**, 265–284.

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

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. J.*, **64**, 283-288.

Some 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 (Le Marshall et al 2014.) We aim to investigate the impact of extra moisture-sensitive hyperspectral channels in ACCESS.

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