Australian Government
Bureau of Meteorology

Satellite Data Assimilation at the Bureau of Meteorology

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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 a combination of **APS3** and **APS2**. The APS3 Systems are summarised in Table 1.

The **APS3 global** model became operational in July 2019. **APS3 city** domains and **TC** model are expected to be operational early 2020. The domains are shown below in Figure 1.

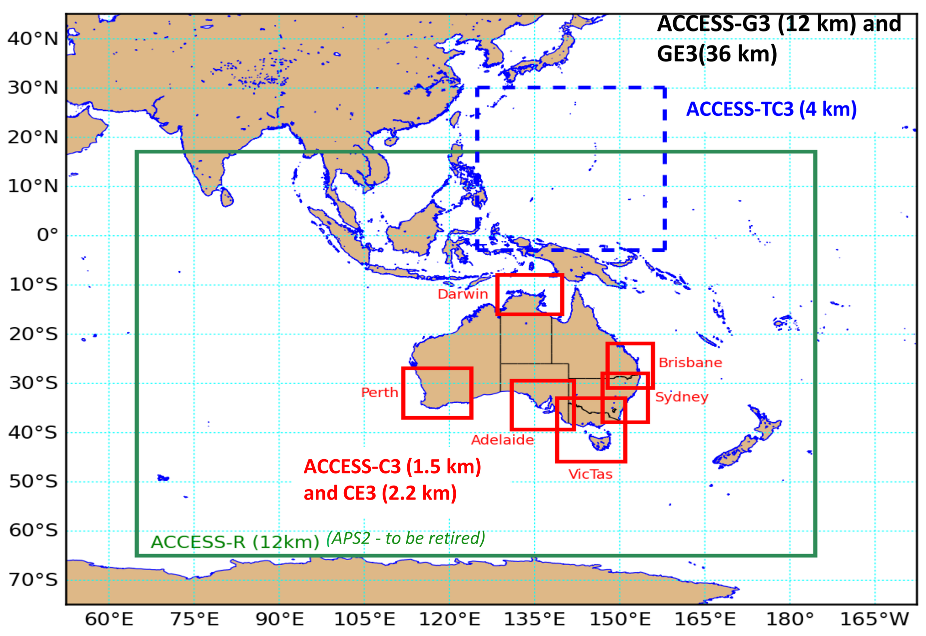

Figure 1: APS3 NWP system domains

	Global (ACCESS-G3 and GE3)	City (ACCESS-C3 and CE3)	Tropical Cyclone (ACCESS-TC3)
Deterministic	N1024 (12 km), L70 00, 06, 12, 18 UTC	1.5 km, L80 6 domains Hourly	4 km, L80, Up to 3 relocatable domains 00, 12 UTC
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
Observations	AHI CSR, AIRS, AMSR-2, ATMS, ATOVS, CrIS, IASI, SSMIS GPSRO, GPS WV AMV, ASCAT, Windsat AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO TC BOGUS	AIRS, ATMS, ATOVS, CrIS, IASI (will include locally-received data) GPS WV AMV, ASCAT AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO Doppler Radar Winds	AIRS, ATMS, ATOVS, CrIS, IASI (will include locally-received data) GPS WV (if in domain) AMV, ASCAT, (ScatSat-1, Windsat) AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO TC BOGUS
Bias Correction	VarBC, with static scan bias correction	Uses VarBC coefficients from G3	Uses VarBC coefficients from G3
SST analysis	GAMSSA[1]	RAMSSA[2]	GAMSSA[1]
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

Table 1: Summary of APS3 NWP systems

* Cycle times and number of domains not yet confirmed

G3 gives substantial forecast benefits over G2,with a 12 hour improvement at 3 days. G2 has a 25 km grid, no ensemble, non-hybrid 4D-Var, and fewer observation sources assimilated.

G3 also improves tropical cyclone forecasts. Mean track errors are reduced by 40-100 km, and central pressure bias by 12-20 hPa, depending on forecast lead time. Figure 2 (below) gives an example of the improvement in track prediction for TC Fani

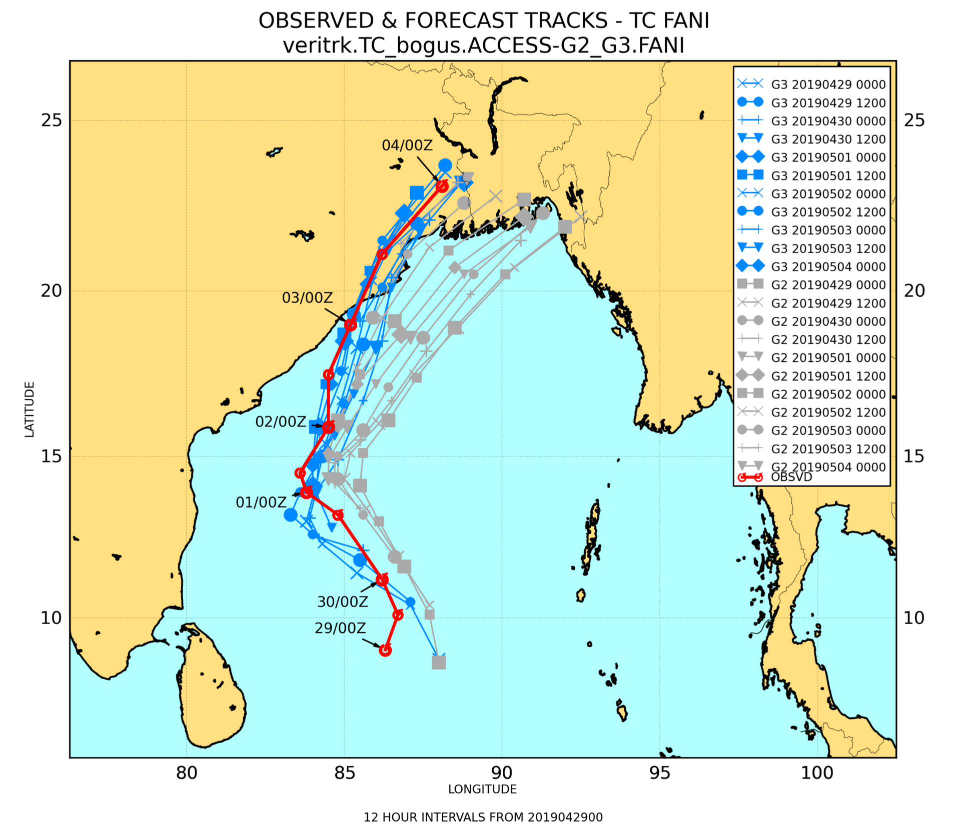

Figure 2: ACCESS-G3 tropical cyclone forecast tracks for TC Fani, compared with ACCESS-G2

Current Satellite Data Assimilation Work

Planned DA Upgrades

ACCESS-G will have a small upgrade by the end of 2019. This will include:

- NOAA-20 ATMS and CrIS
- ScatSat-1
- Metop-C GRAS
- Preparation for Metop-C AMSU/MHS and IASI

Future plans for ACCESS-G include:

- All-sky microwave sounder assimilation
- GMI radiances
- FY-3 Sounder data
- SEVIRI radiances
- Geo-Kompsat 2A radiances
- Polar AMVs from AVHRR and VIIRS, LEO/GEO AMVs
- Locally received ATOVS, IASI, ATMS, CrIS and AIRS
- An increase in DBNet data

Future plans for ACCESS-C include:

- Himawari radiance assimilation
- GeoCloud derived cloud products from Himawari
- Hybrid 4D-Var

We are also preparing a national analysis system (NAS), providing high-resolution hourly analyses across the whole of Australia within half an hour of analysis time.

Our new science

GeoCloud

For ACCESS-C and NAS systems, Himawari radiance data and derived cloud products will be critical, because of the rapid delivery and continuous temporal coverage.

We are planning to assimilate 'GeoCloud' retrievals[1] of cloud height, depth and amount, following the Met Office's method for SEVIRI data, used in the UKV model.

Australia has much more convective cloud than the UK, and the current GeoCloud retrieval is known not to work well in convective situations. The Met Office scheme assigns cloud depth using a UK-climatological function. This results in only thin layers of cloud.

We have developed an innovation to the GeoCloud scheme, which will use a Lifting Condensation Level, calculated using model fields, to provide a depth to each retrieved cloud.

A comparison of the retrieved cloud and the total column moisture analysis increment are shown to the right in Figure 3.

Moisture-affected radiances

As part of the move to all-sky microwave radiance assimilation, the Met Office introduced a new linear moisture incrementing operator[2]. The operator requires regression statistics. We have been calculating local statistics using our city-scale ensemble, CE3, to compare with the global statistics.

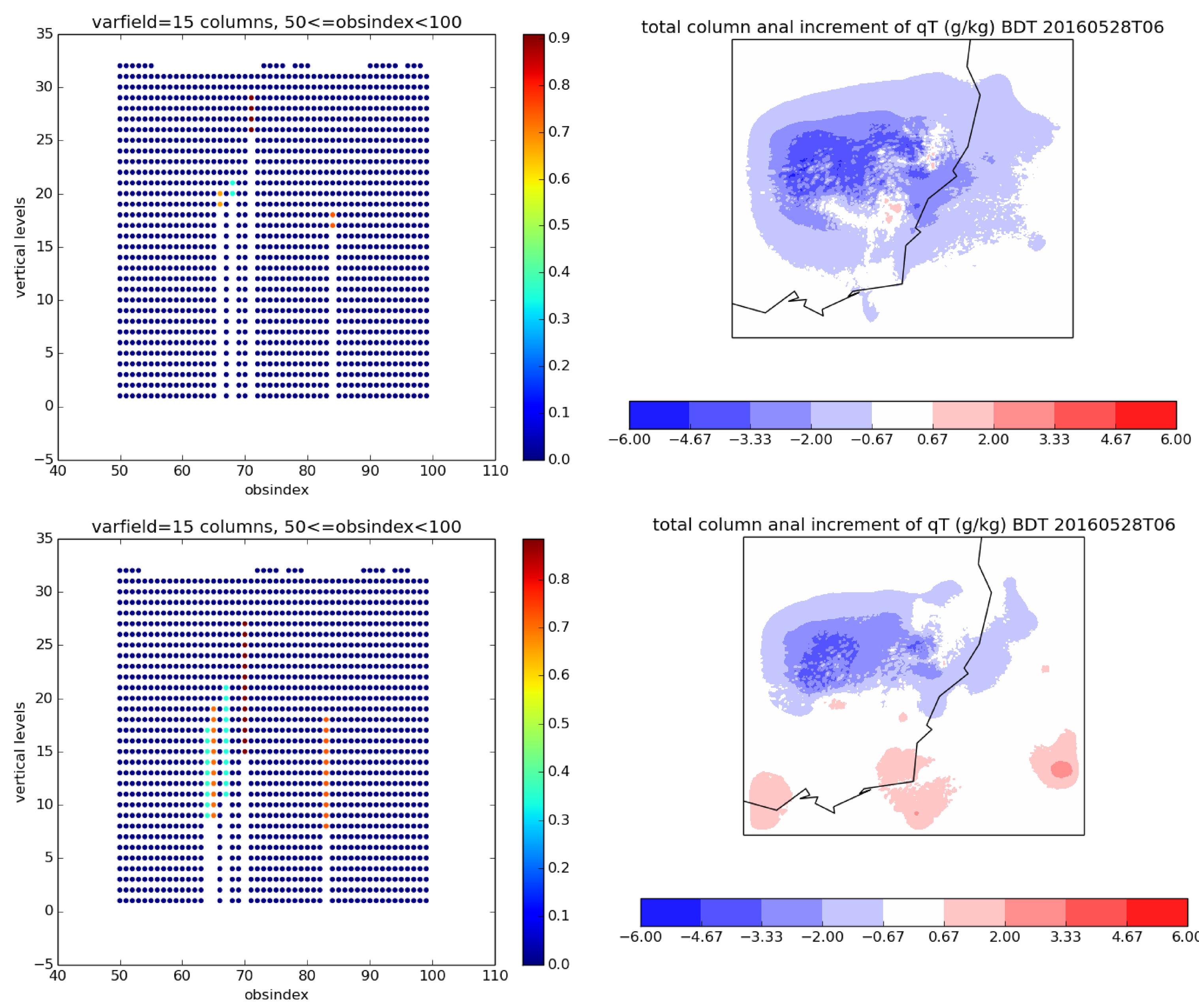

Figure 3: Retrieved cloud columns (left) and total column qT analysis increments (right) derived from Met Office GeoCloud processing (above) and the new Bureau method (below)

Observation Impacts - FSOI

We routinely run the Met Office forecast sensitivity to observation impact (FSOI) scheme[3] for ACCESS-G. FSOI impacts are the reduction in the 24 hour forecast error measured by a moist energy norm. We calculate impacts globally and over the Australian region.

Various aggregations of FSOI data are calculated according to interest within the Bureau, typically to inform observation network assessment and planning. In Figure 4 (below), we show a recent six-month standard aggregation of total FSOI and FSOI per observation, according to observation type, for the global error measure (left two panels) and the Australian error measure (right two panels).

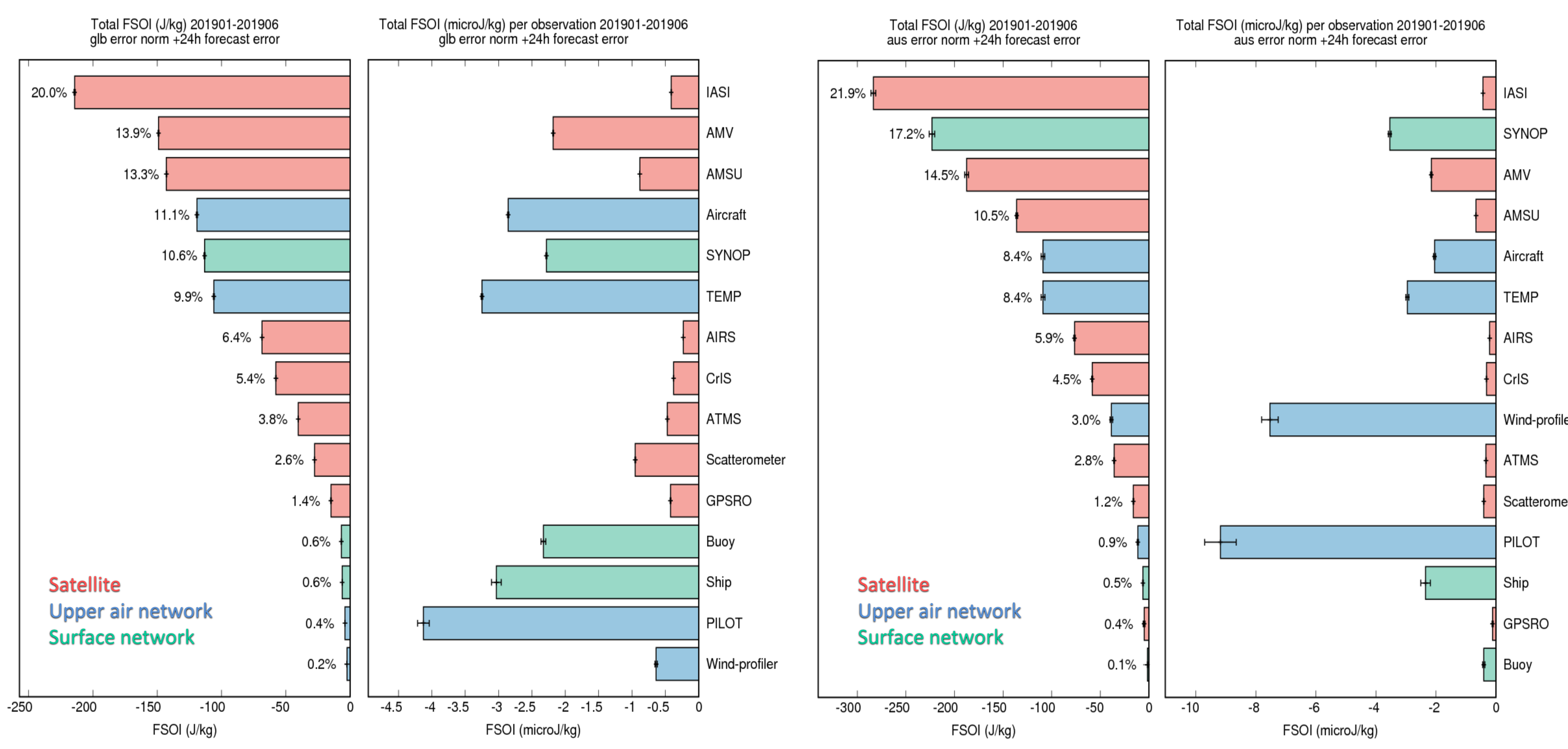

Figure 4: FSOI for each of the major observing instruments/types in ACCESS-G for January to June 2019 (negative values indicate the reduction in forecast error associated with the observation type). For both the global error norm (left) and the Australian region error norm (right) the forecast impact is dominated by the IASI instrument, consistent with the experience of other centres. NB: SYNOP = surface synoptic observations.

FSOI for microwave data in ACCESS-G

Motivated by recent international attention on the impact of radio-frequency interference on NWP, we have looked at the impact of microwave radiances. These provide more than 15% of the total 24 hour forecast impact in ACCESS-G with a distinct yearly cycle visible both globally (Figure 5, below left), also in the Australian region (Figure 6, bottom left). The spatial distribution of microwave FSOI impacts shows that the observations with highest impact on the Australian region forecast error are clustered to the west and north-east of the Australian continent (Figure 7, below right).

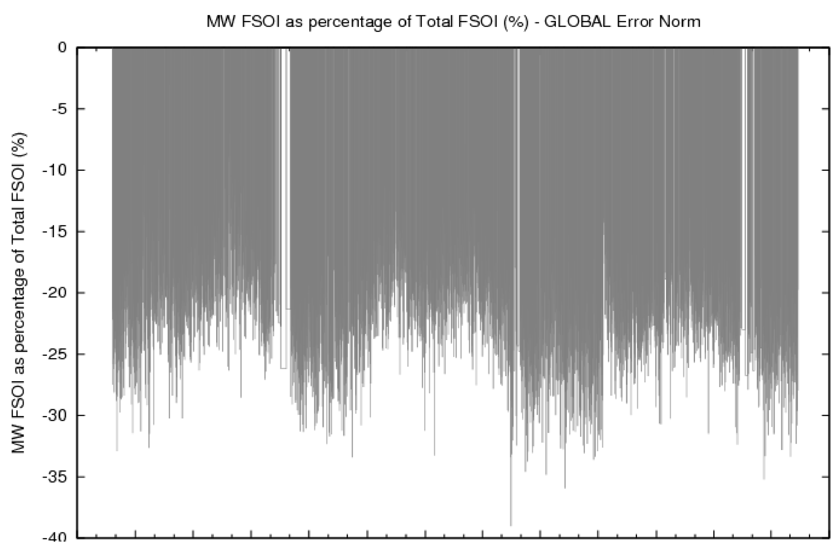

Figure 5: Total microwave (AMSU+MHS+ATMS) 24h FSOI as a percentage of the all-observation FSOI, for the Global error norm. Jul 2015 – Oct 2018. There is a marked mid-year peak.

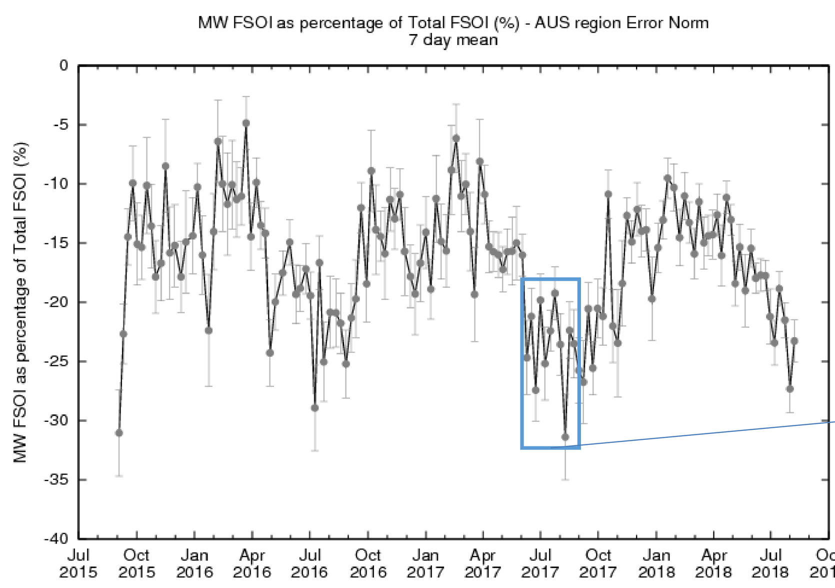

Figure 6: As Fig 5, but for the Australian region error norm. The Jul 2015 – Oct 2018 time series has been averaged over 7 day intervals. The mid-year peak is still apparent.

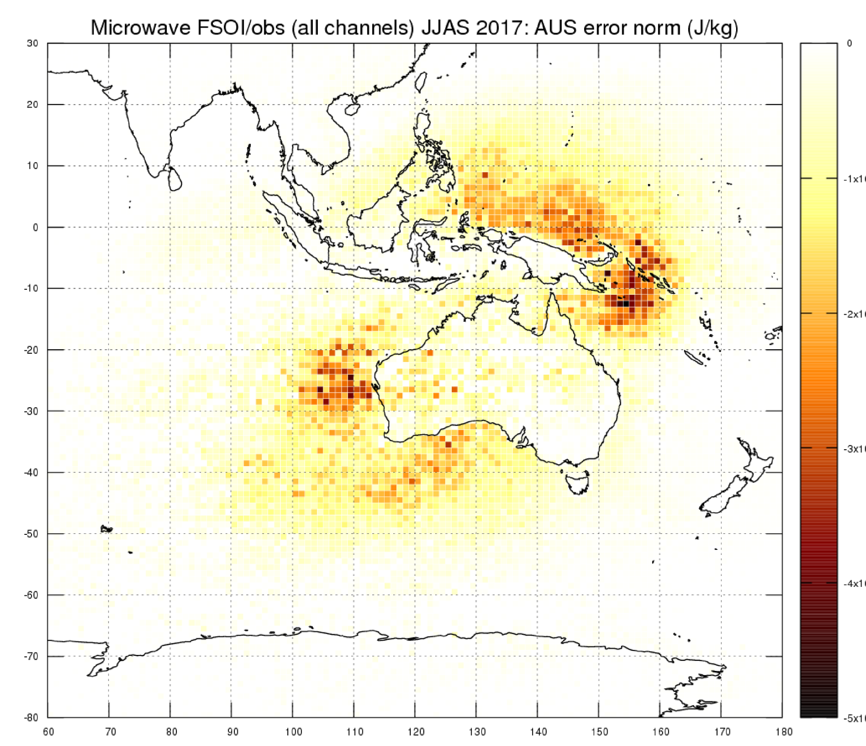

Figure 7: Microwave FSOI per observation (Australian region error norm) plotted at observation locations for the "peak months" June – Sept 2017. FSOI values have been aggregated into 1°x 1° observation location bins.

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] **Francis P., Hocking J.A., Saunders R.. 2008.** Improved diagnosis of lowlevel cloud from MSG SEVIRI for assimilation into Met Office limited area models. In *Proceedings of the 2008 EUMETSAT Meteorological Satellite Conference, Darmstadt*
[2] **Migliorini, S. , Lorenc, A. C. and Bell, W., 2018**: A moisture-incrementing operator for the assimilation of humidity- and cloud-sensitive observations: formulation and preliminary results. *Q.J.R. Meteorol. Soc.*, **144**, 443-457
[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.