



Australian Government

Bureau of Meteorology

SOME AUSTRALIAN REGION MICROWAVE FORECAST IMPACT RESULTS FOR THE BUREAU OF METEOROLOGY'S GLOBAL NWP SYSTEM

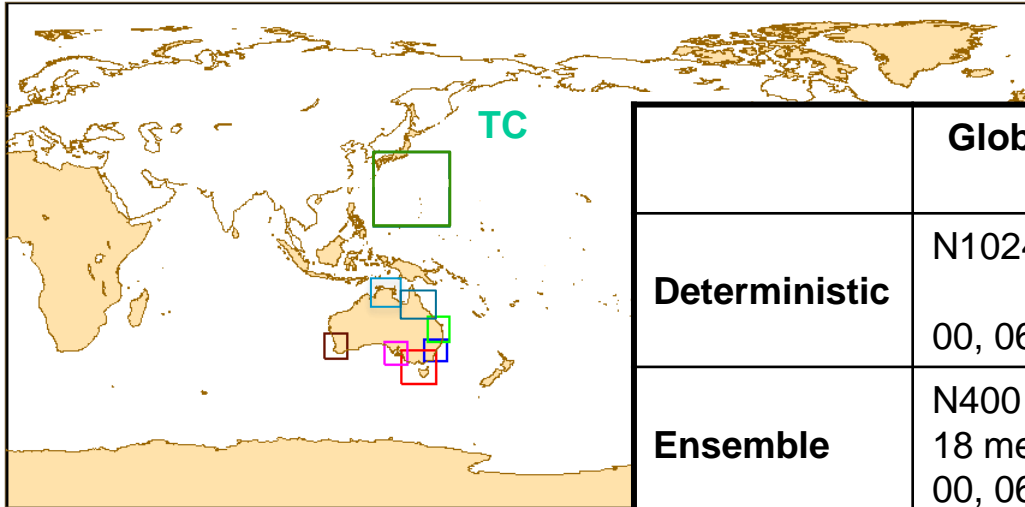
Chris Tingwell, Fiona Smith and Agnes Lane
Bureau of Meteorology, Melbourne, Australia

RFI 2022 14-18 February 2022

Overview

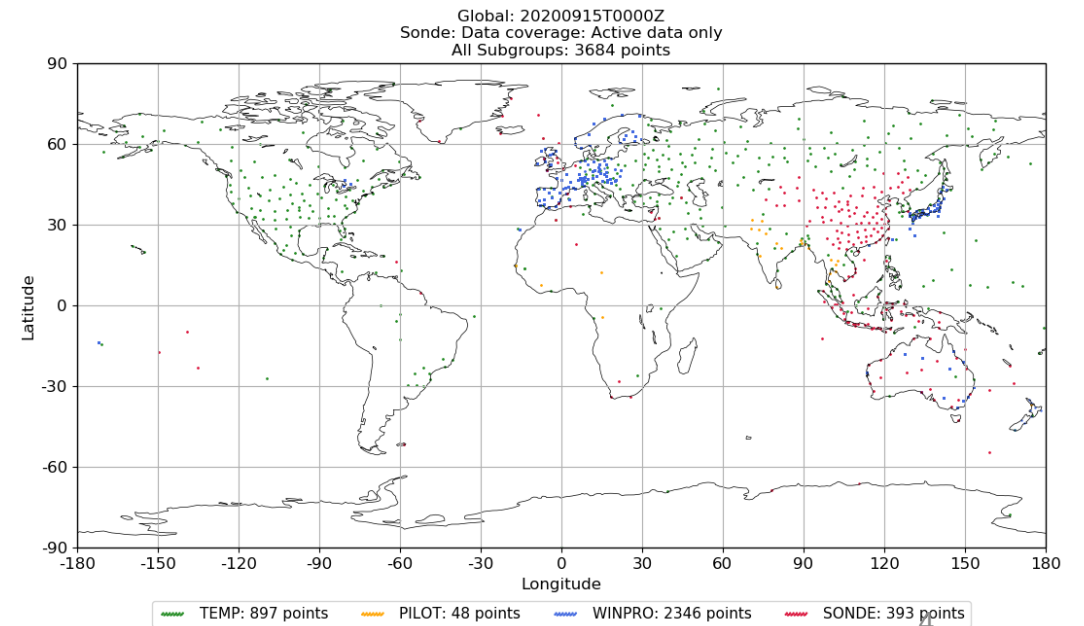
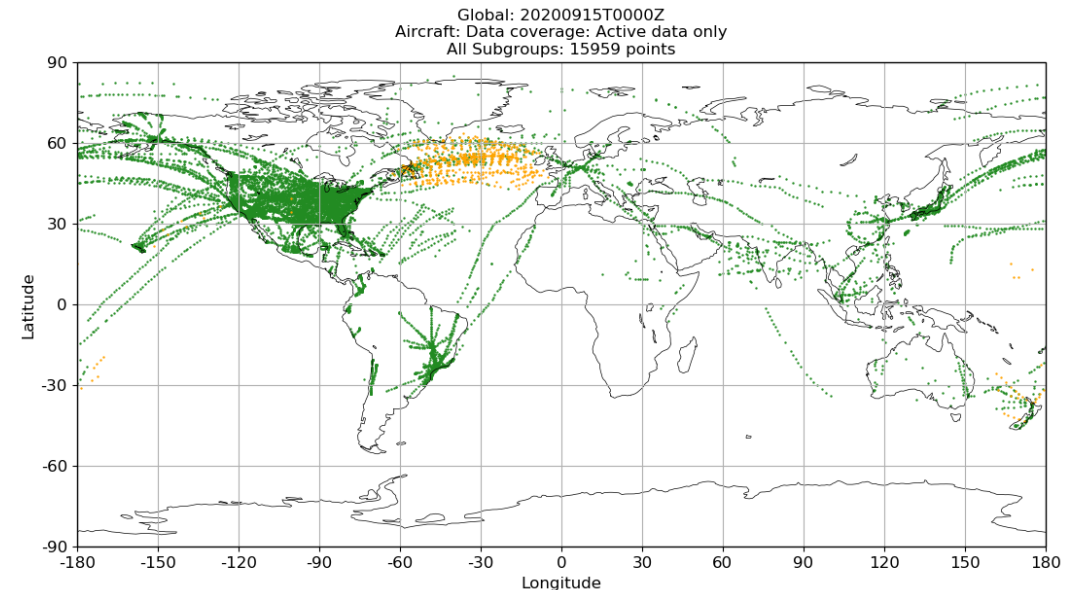
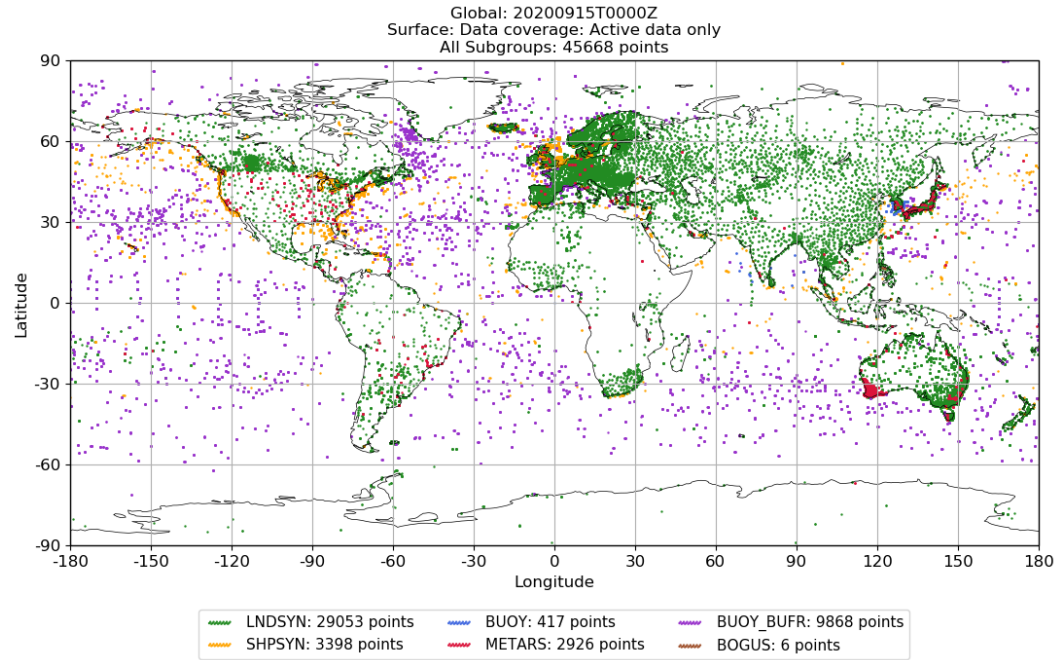
- The Australian Bureau of Meteorology operates a number of numerical weather prediction (NWP) model suites ("ACCESS") based on the UK Met Office Unified Model and associated software. These provide the basis of a large number of Bureau forecast products and services.
- In the Southern Hemisphere, we are particularly reliant on the assimilation of satellite observations to provide accurate initial conditions for our NWP forecasts.
- Assimilation of microwave radiances is a particularly important contributor to forecast accuracy. We'll show some results which highlight the microwave observations which particularly contribute to forecast accuracy in the Australian region.
- Assimilation of microwave radiances will become increasingly important in the next generation of NWP suites. We will outline some of our plans.

Summary of current ACCESS NWP systems

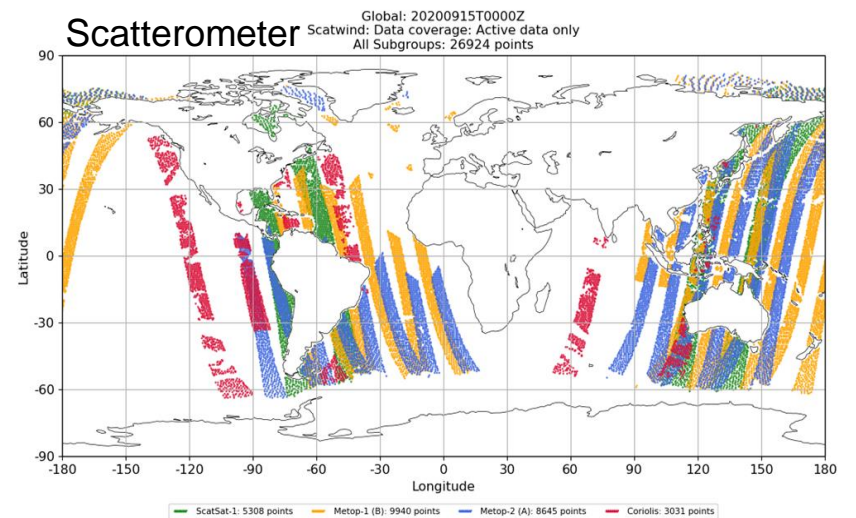
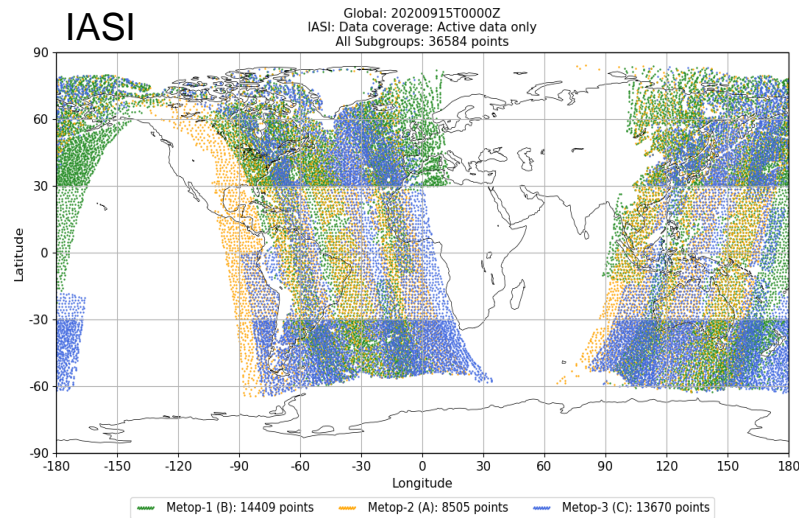
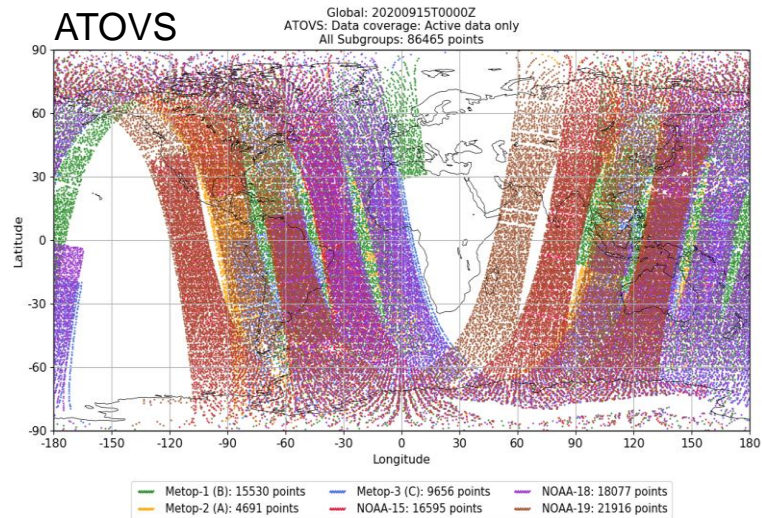
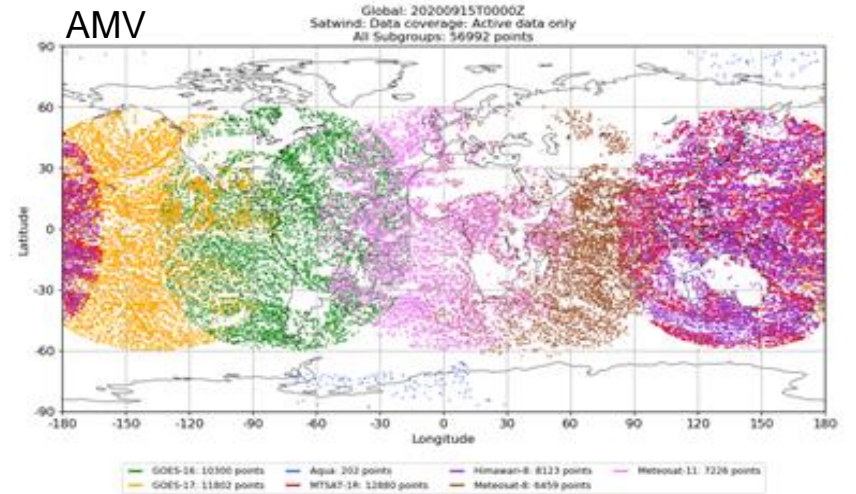
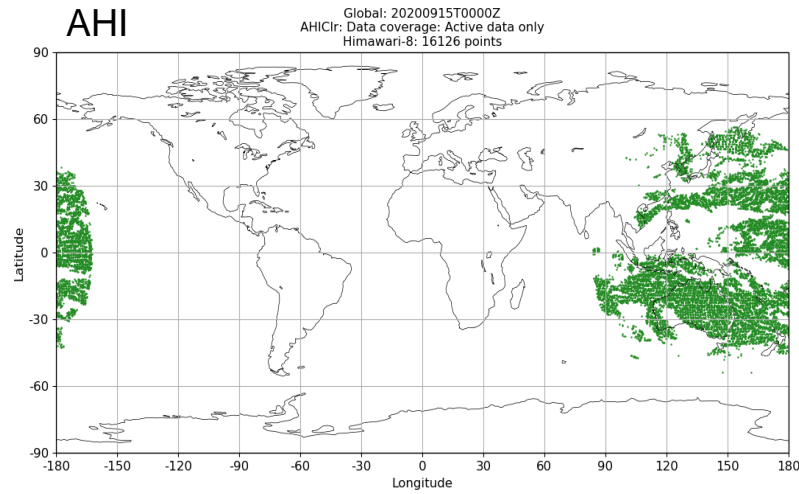
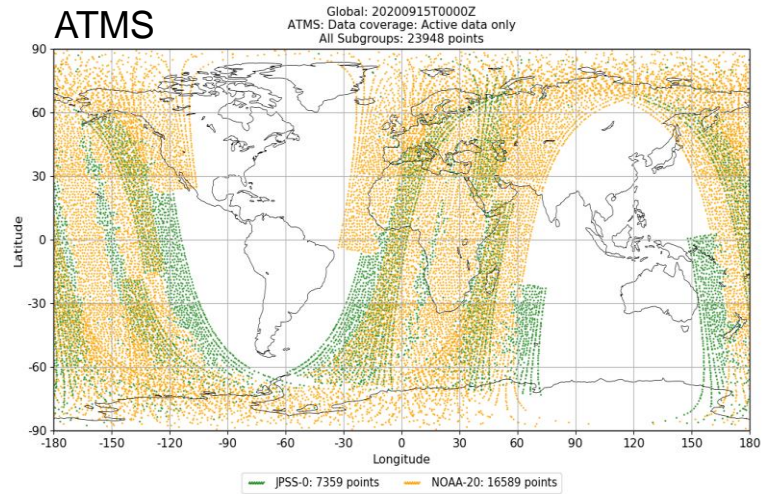


	Global (ACCESS-G and GE)	City (ACCESS-C and CE)	Tropical Cyclone (ACCESS-TC)
Deterministic	N1024 (12 km), L70 00, 06, 12, 18 UTC	1.5 km, L80 6 domains Hourly	4 km, L80, Up to 3 relocatable domains 00, 12 UTC
Ensemble	N400 (36 km), L70 18 members (plus lagging) 00, 06, 12, 18 UTC	2.2 km, L80 12 members (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
Bias Correction	VarBC, with static scan bias correction	Uses VarBC coefficients from G3	Uses VarBC coefficients from G3
SST analysis	GAMSSA	RAMSSA	GAMSSA
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

Observations coverage: Aircraft, Surface and Sonde



Observations coverage: Satellite observations



Recent changes in observation usage – ACCESS-G

	ACCESS-G2	ACCESS-G3 (from July 2019)	ACCESS-G3.1 (status at Feb 2022)
Hyperspectral IR sounder (LEO)	AIRS CrIS – S-NPP IASI – Metop-A, Metop-B	AIRS CrIS – S-NPP IASI – Metop-A, Metop-B	AIRS CrIS – S-NPP, NOAA-20 IASI – Metop-A , Metop-B, Metop-C
IR sounder (GEO)		Himawari AHI CSR	Himawari AHI CSR
Microwave sounders (LEO)	ATMS – S-NPP ATOVS – N18, N19, Metop-A, Metop-B, Metop-C	AMSR-2 ATMS – S-NPP ATOVS – N15 , N18, N19, Metop-A, Metop-B SSMIS	AMSR-2 ATMS – S-NPP, NOAA-20 ATOVS – N15, N18, N19, Metop-A , Metop-B, Metop-C SSMIS
GNSS measurements	GPSRO – COSMIC , TerraSar-X, TanDem-X, Metop-A, B	GPSRO – TerraSar-X, TanDem- X, Metop-A, Metop-B, FY-3C GPS WV	GPSRO – TerraSar-X, TanDem-X, Metop-A , Metop-B, Metop-C , FY-3C,D GPS WV
AMV (mostly GEO)	Himawari, GOES-16, GOES-15 , Meteosat-8, Meteosat-11, MODIS (Aqua)	Himawari, GOES-16, GOES-15 , Meteosat-8, Meteosat-11, MODIS (Aqua)	Himawari, GOES-16, GOES-17 , Meteosat-8, Meteosat-11, MODIS (Aqua)
Scatterometer	ASCAT – Metop-A, B, Windsat	ASCAT – Metop-A, B, Windsat	ASCAT – Metop- A ,B, C from Nov 21 ScatSat-1

Observation usage across all models (satellites in red)

	Global (ACCESS-G3)	City (ACCESS-C3)	Tropical Cyclone (ACCESS-TC3)
Hyperspectral IR sounder (LEO)	AIRS, CrIS, IASI	AIRS, CrIS, IASI	AIRS, CrIS, IASI
IR sounder (GEO)	Himawari AHI CSR		
Microwave sounders (LEO)	AMSR-2, ATMS, ATOVS, SSMIS	ATMS, ATOVS	ATMS, ATOVS
GNSS measurements	GPSRO, GPS WV	GPS WV	GPS WV (if in domain)
AMV (mostly GEO)	Himawari, GOES-16, GOES-17, Meteosat-8, Meteosat-11, MODIS	Himawari	Himawari (Meteosat-8, GOES-17 if in domain)
Scatterometer	ASCAT, ScatSat-1	ASCAT	ASCAT, ScatSat-1
Conventional observations	AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO	AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO	AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO
Radar		Doppler Winds	
Other	TC BOGUS		TC BOGUS

Forecast Sensitivity to Observations Impact (FSOI) in ACCESS-G

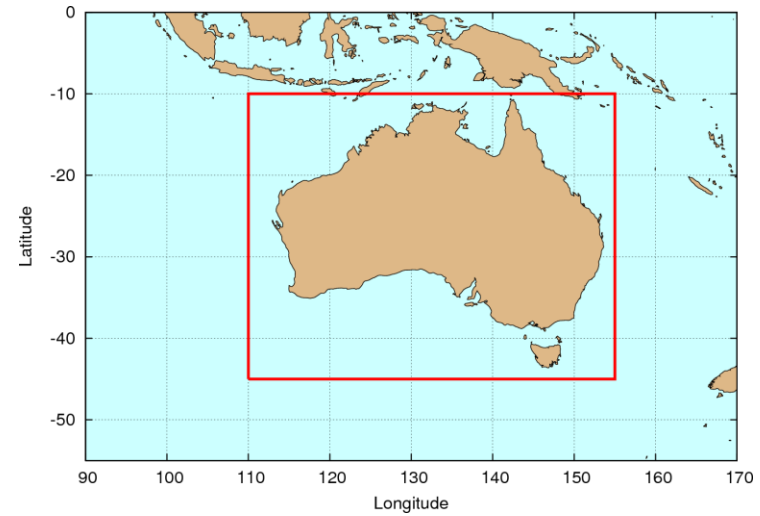
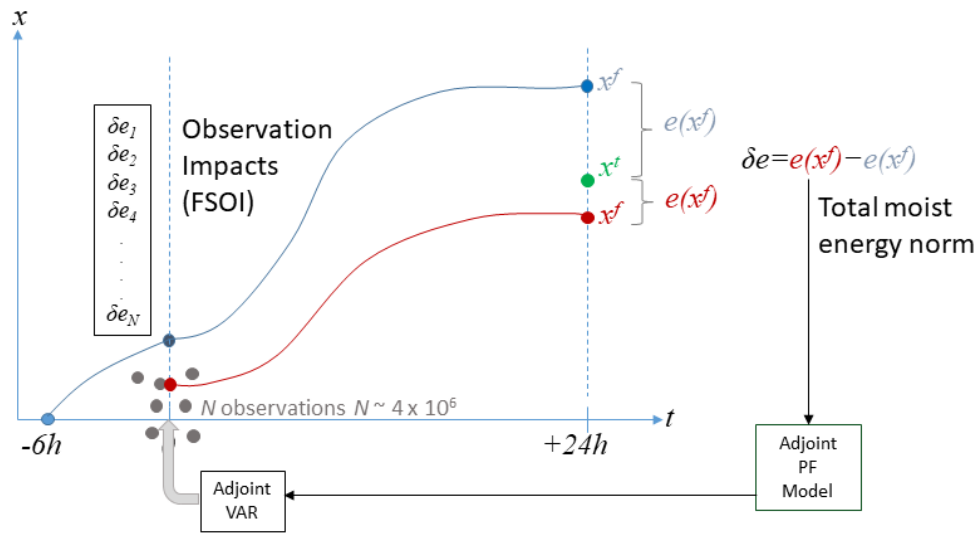
ACCESS-G: global 25 km N512/L70 (OPS/4DVar/UM: equiv. Met Office PS32)

Since September 2015, 24 hour Forecast Sensitivity to Observations impacts have been calculated following each six-hourly ACCESS-G assimilation-forecast cycle.

Met Office FSO suite (Lorenç and Marriott 2014).

Moist energy error norm and sensitivities calculated twice (SFC – 150 hPa):

1) for whole globe and 2) for Australian verification region (below right, in red).



Overall FSO Impact of observations in ACCESS-G

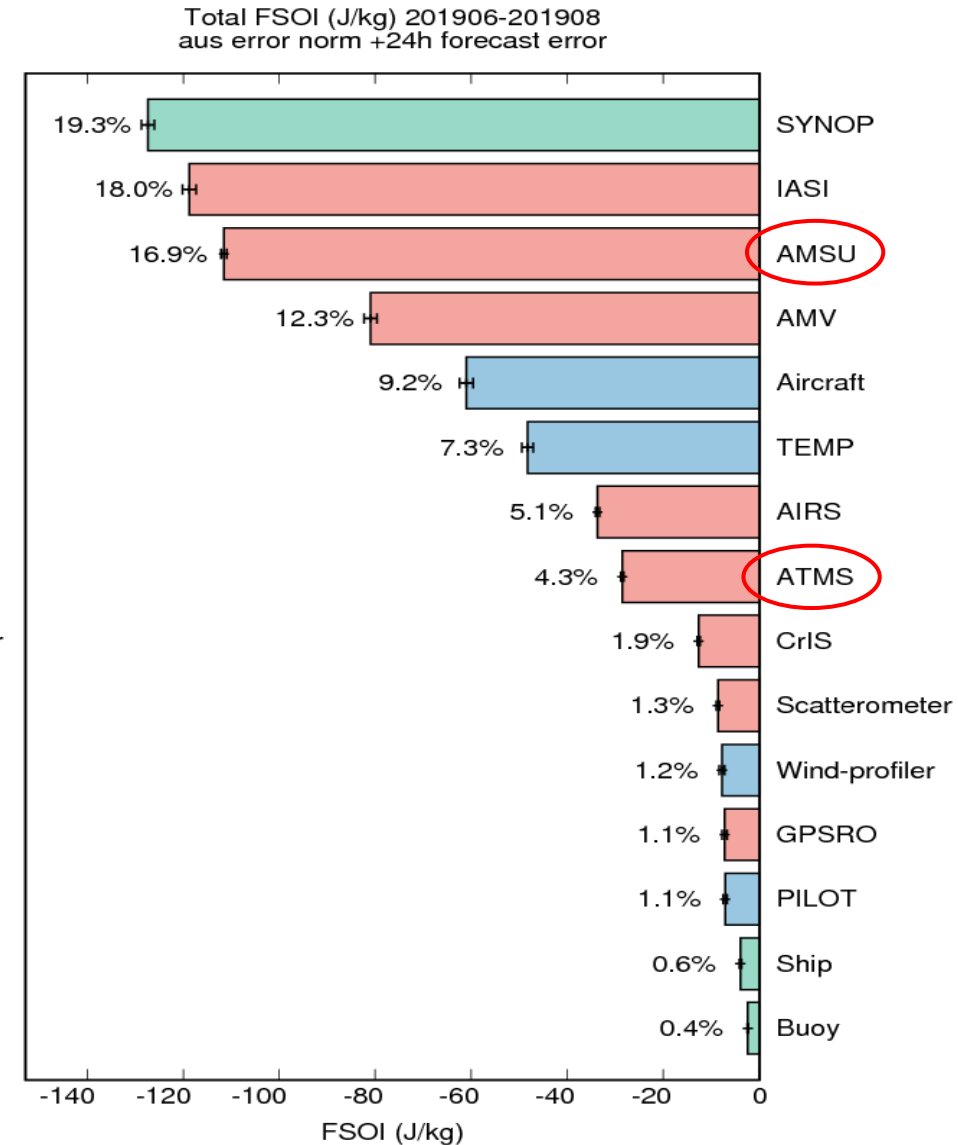
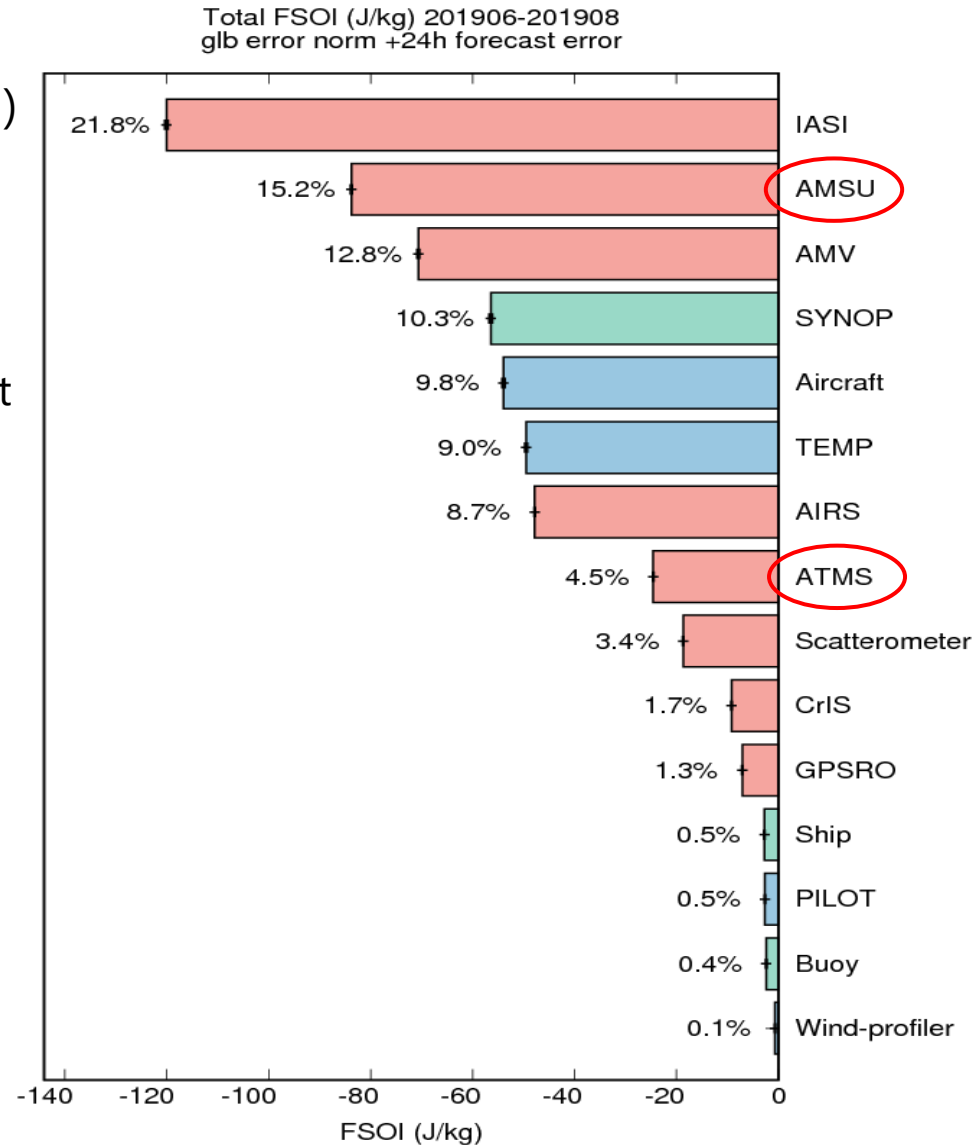
Total Forecast Sensitivity to Observations Impacts (FSOI) in ACCESS-G June - August 2019

Reduction in 24 hour forecast error measured by global moist energy norm (left) and the Australian region norm (right).

Red: space-based observations

Blue: upper air network

Green: surface observations

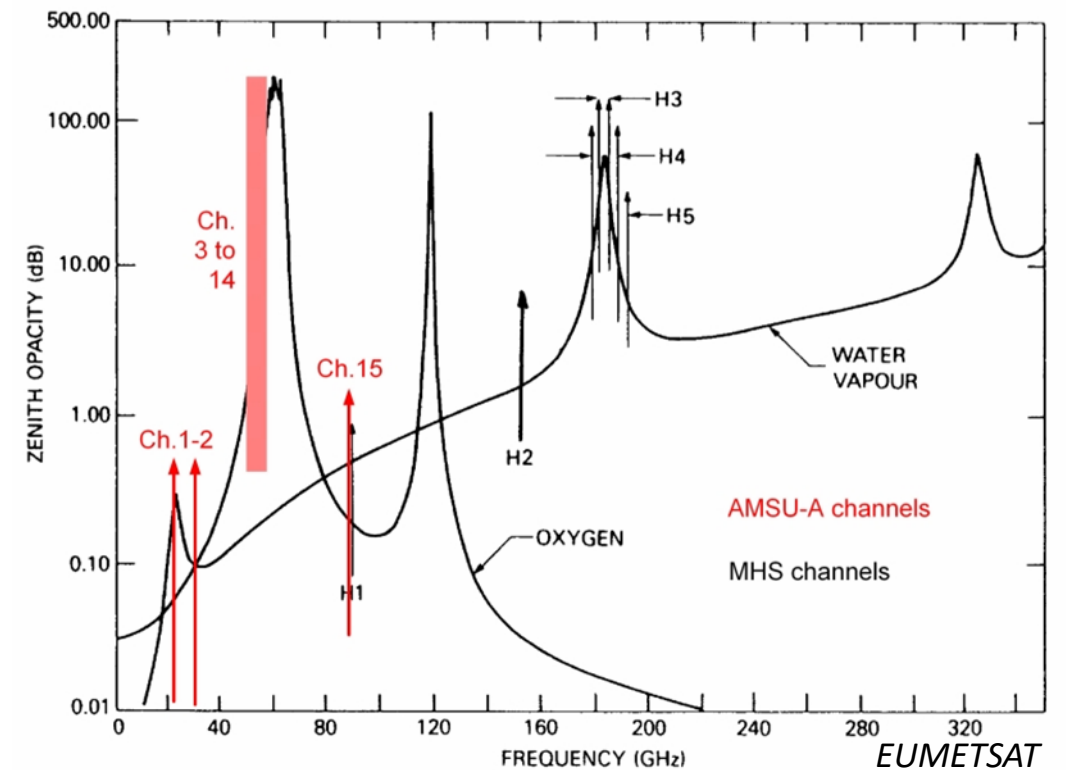


AMSU and ATMS radiances assimilated in ACCESS-G

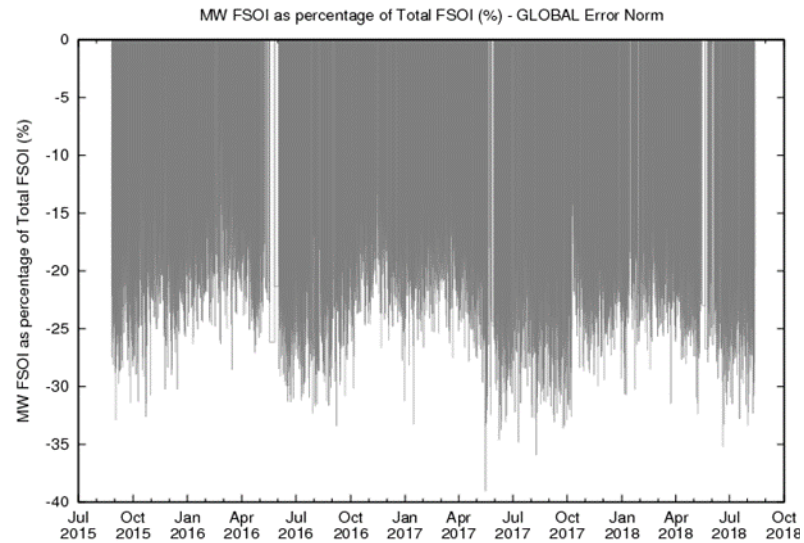
	Channel		Channel
AMSU-A	4	ATMS	6
	5		7
	6		8
	7		9
	8		10
	9		11
	10		12
	11		13
	12		14
	13		15
AMSU-B/ MHS	14	18	
	3	19	
	4	20	
	5	21	
		22	

Temperature channels Humidity channels

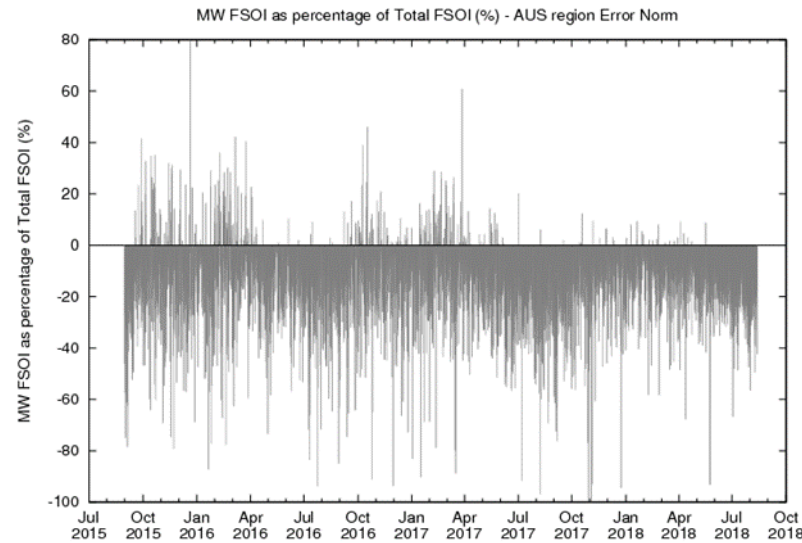
Standard channel selection (as per Met Office) according to cloud/rain tests: only insensitive channels used in the presence of cloud.



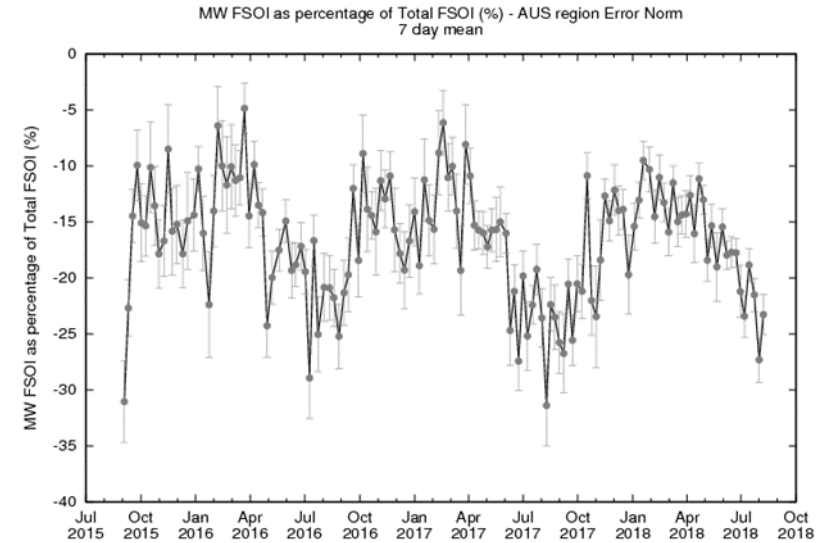
Seasonal, spatial and spectral variation of AMSU/MHS/ATMS impacts in the Australian region



Total microwave (AMSU+MHS+ATMS) 24h FSOI as a percentage of the all-observation FSOI over three years, *for the globally calculated error norm*. There is a marked mid-year peak.

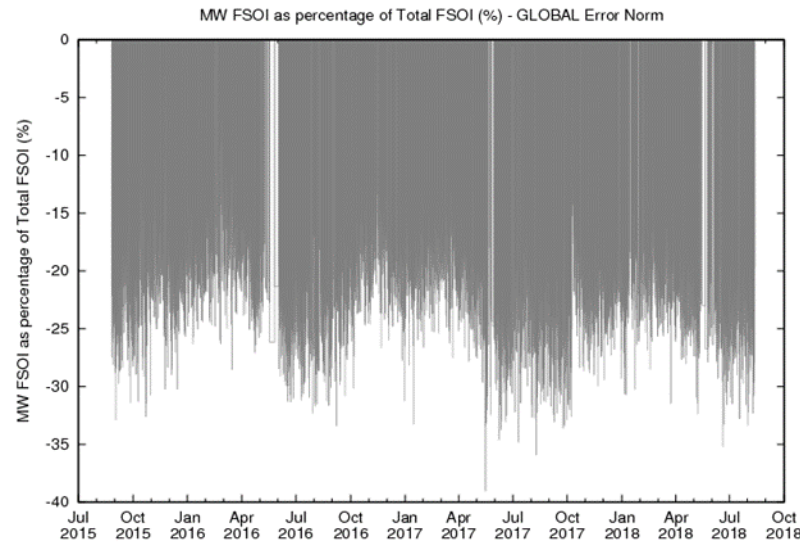


The same, but with the total microwave FSOI calculated from Australian region error norm. The time-series is noisier, but the mid-year peak is still apparent ...

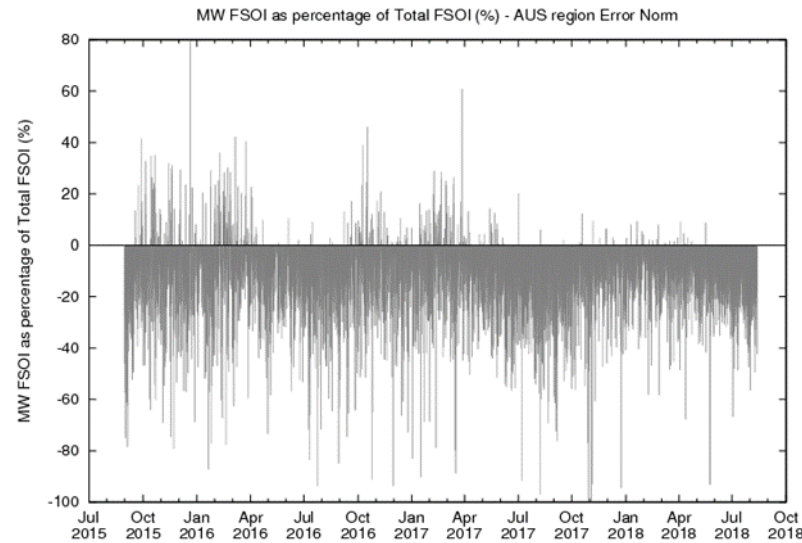


... and becomes more apparent when the Australian region FSOI time series is averaged over 7 day intervals.

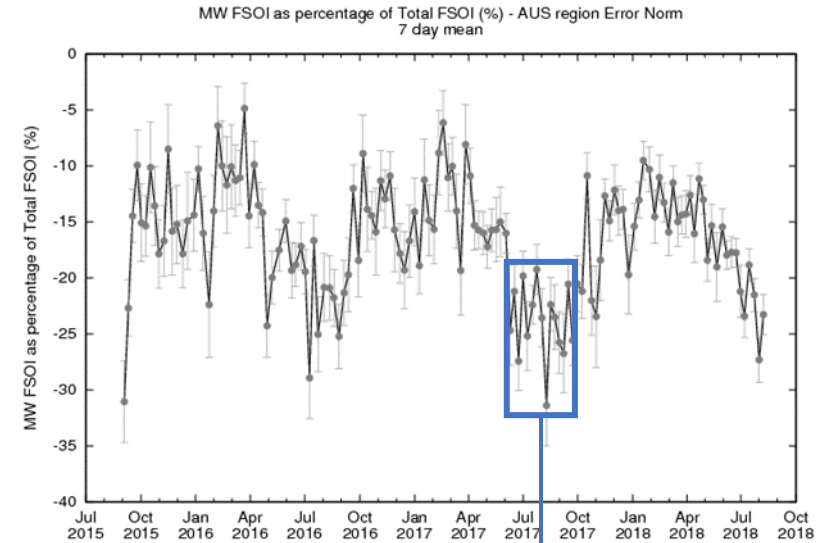
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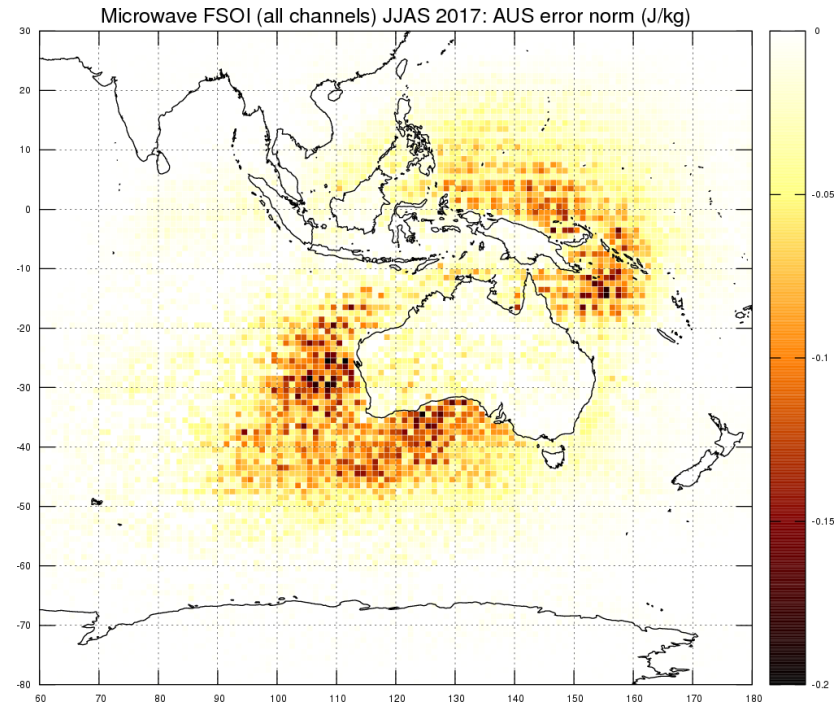
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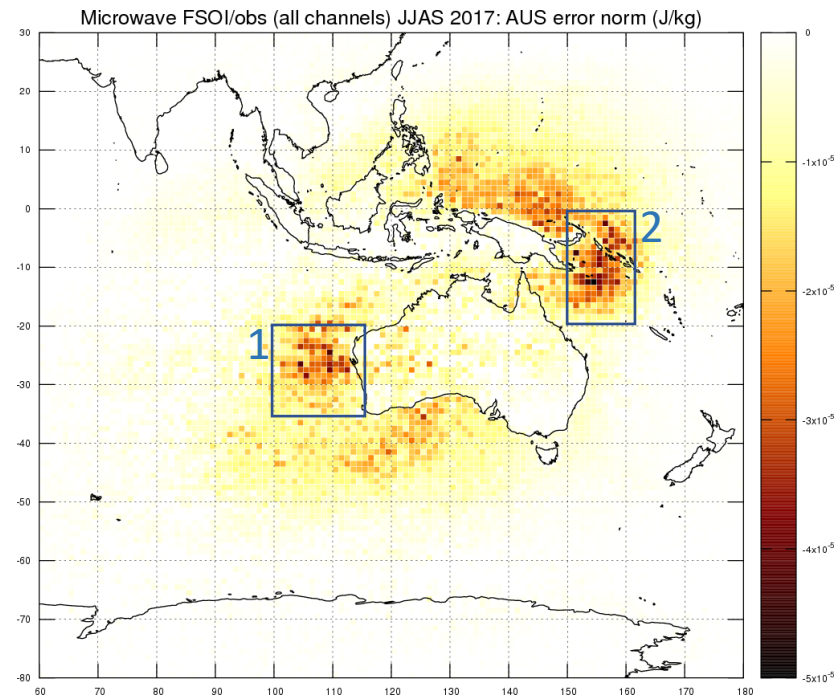
... and becomes more apparent when the Australian region FSOI time series is averaged over 7 day intervals.

Use this period to spatially map microwave FSOI

Seasonal, spatial and spectral variation of AMSU/MHS/ATMS impacts in the Australian region

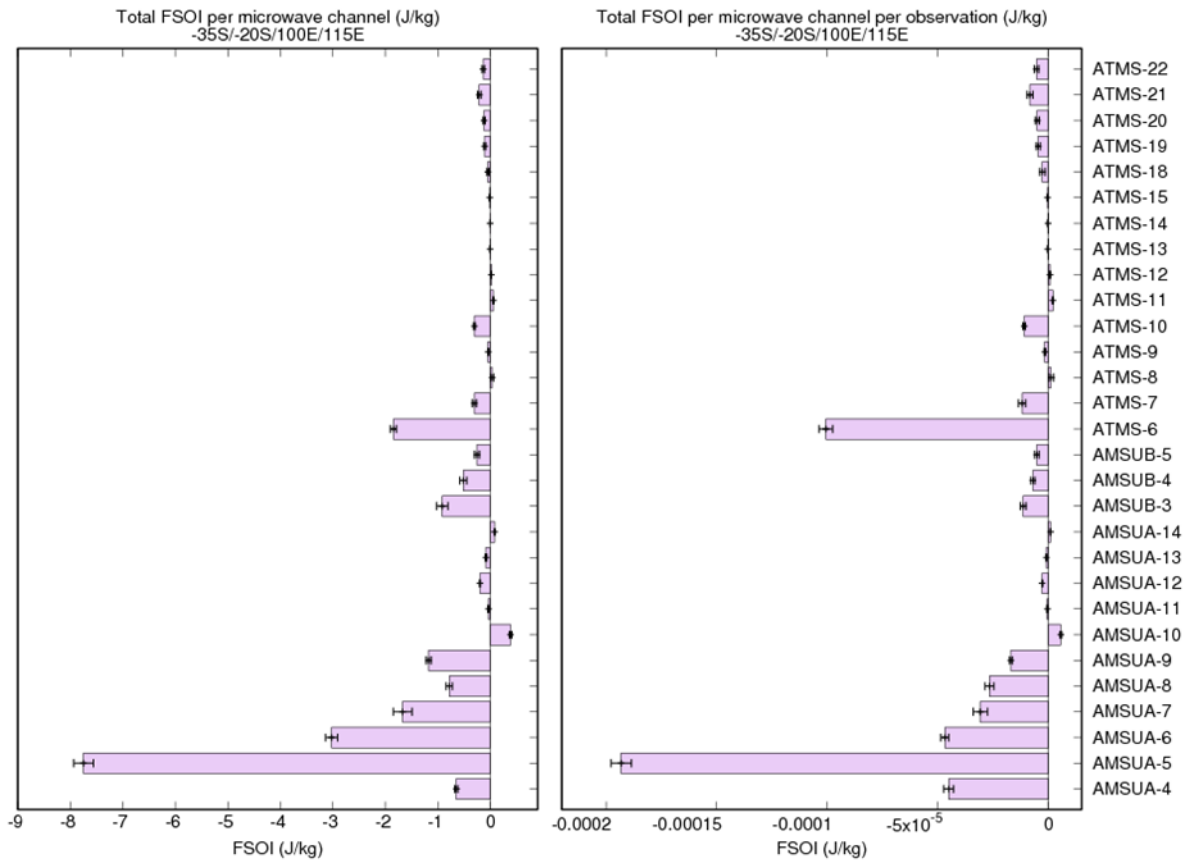


Total microwave FSOI (Australian error norm) plotted at observation locations, for the "peak months" June – Sept 2017. FSOI values have been aggregated into 1°x 1° observation location bins.

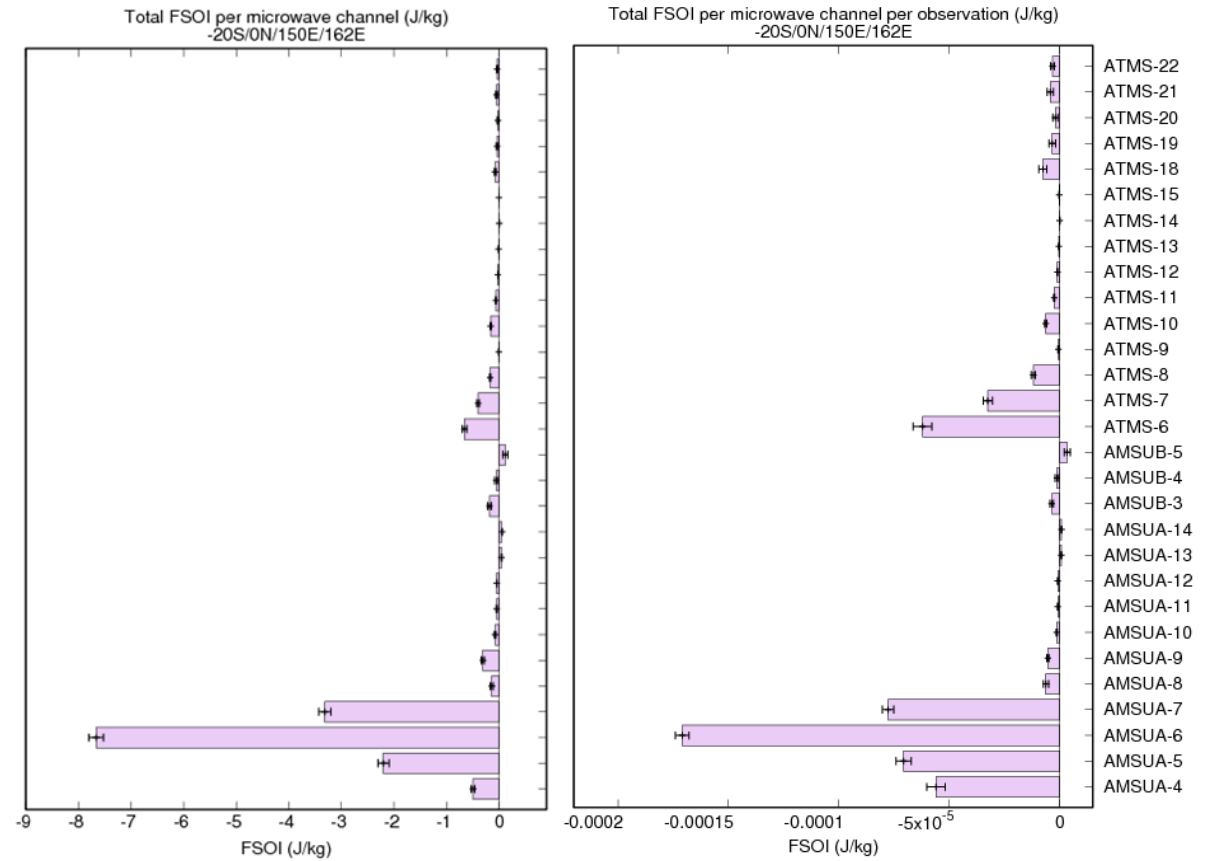


Same, but for microwave FSOI *per observation* – from this we identify two regions where microwave observations seem to be particularly valuable ...

Seasonal, spatial and spectral variation of AMSU/MHS/ATMS impacts in the Australian region

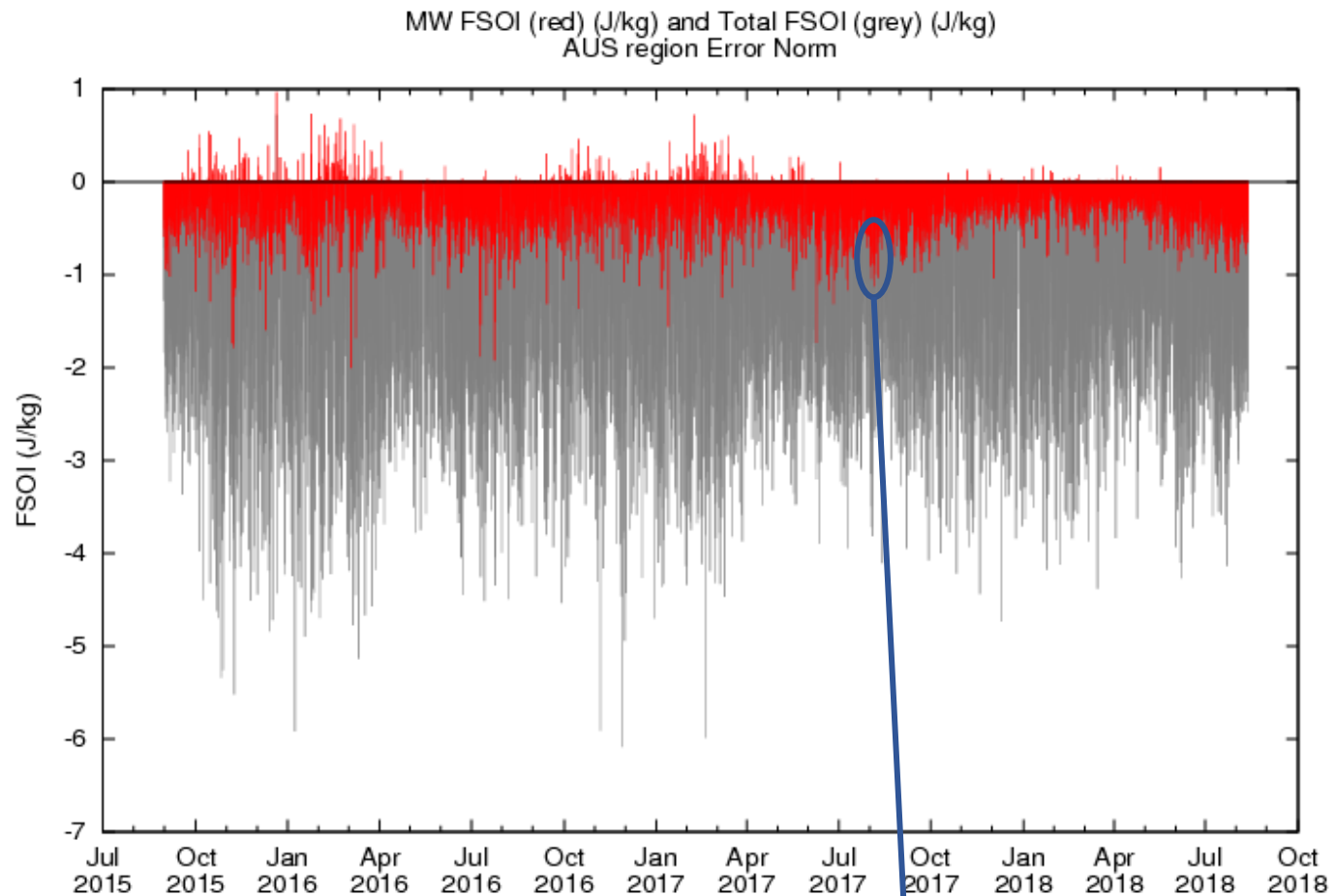


The microwave FSOI per channel (left), and the microwave FSOI per channel *per observation* (right), for observations in **region-1** (Indian ocean, west of Australian mainland). Most impact: from mid-tropospheric temperature channels AMSUA-5 and (equivalent) ATMS-6.



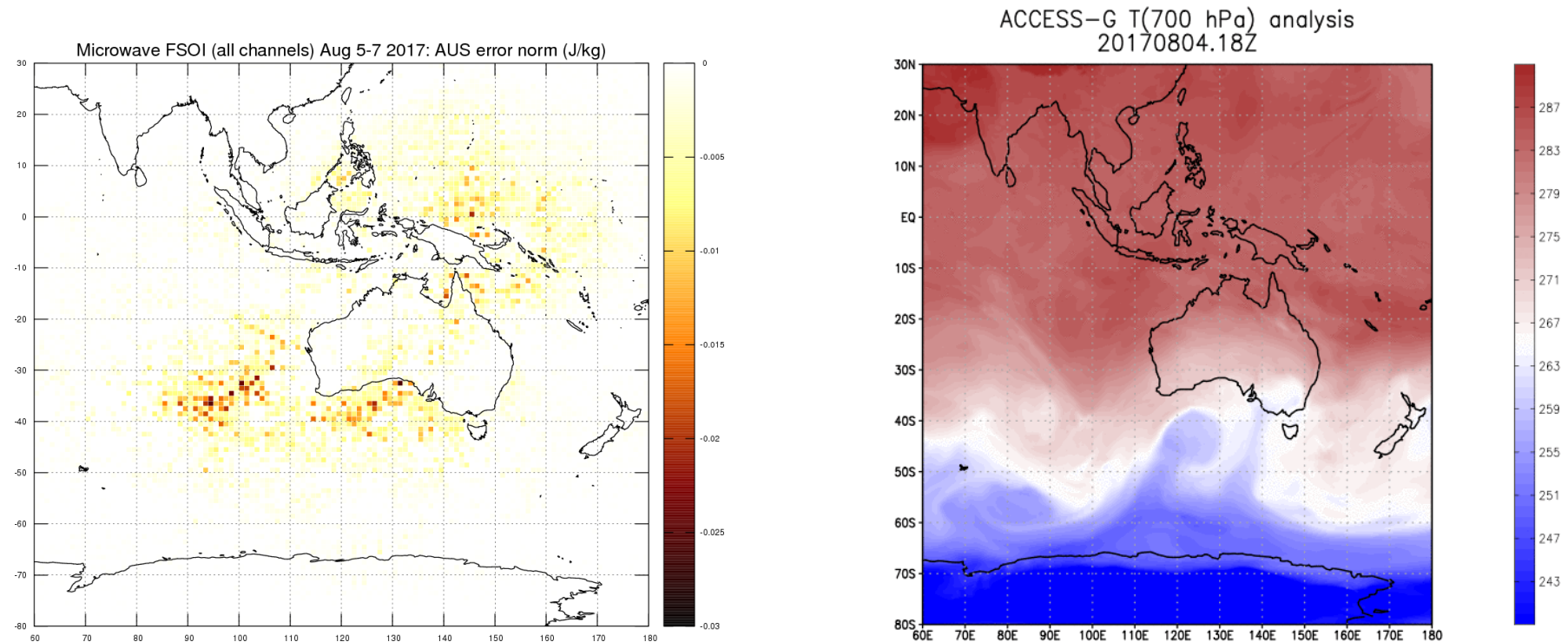
Microwave FSOI per channel (left), and the microwave FSOI per channel *per observation* (right), for observations in **region-2** (Coral/Solomon Seas, north east of Australian mainland). Here we see more impact from the higher peaking AMSUA-6 and ATMS-7 channels.

Seasonal, spatial and spectral variation of AMSU/MHS/ATMS impacts in the Australian region



Time series of microwave FSOI (red) and total FSOI (grey) for the Australian region: we choose a 3 day period in early August 2017 when microwave FSOI peaked ...

Seasonal, spatial and spectral variation of AMSU/MHS/ATMS impacts in the Australian region



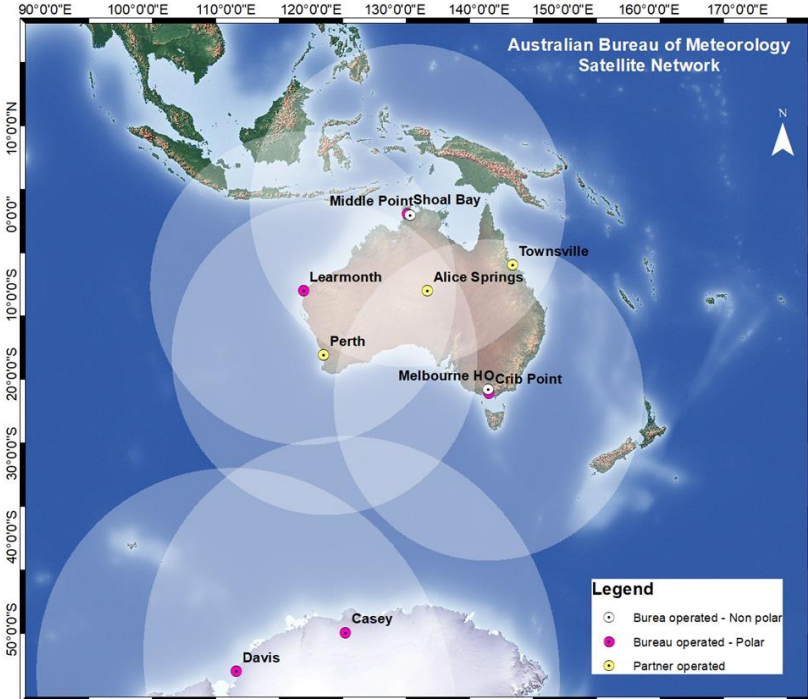
... and map the microwave FSOI values at observation locations for the same period (binned in 1° boxes as before); regions of higher impact match regions of strong mid-tropospheric thermal gradients (see corresponding analyses - right) ... we surmise that microwave observations provide significant impact in the Australian region by helping to define the structure of advancing cold-fronts.

AMSU and ATMS radiances assimilated in ACCESS-C

	Channel		Channel
	AMSU-A		None
7			
8			
9			
10			
11			
12			
14			
15			
18			
19			
AMSU-B/ MHS		3	
	4	21	
	5	22	
Temperature channels		Humidity channels	

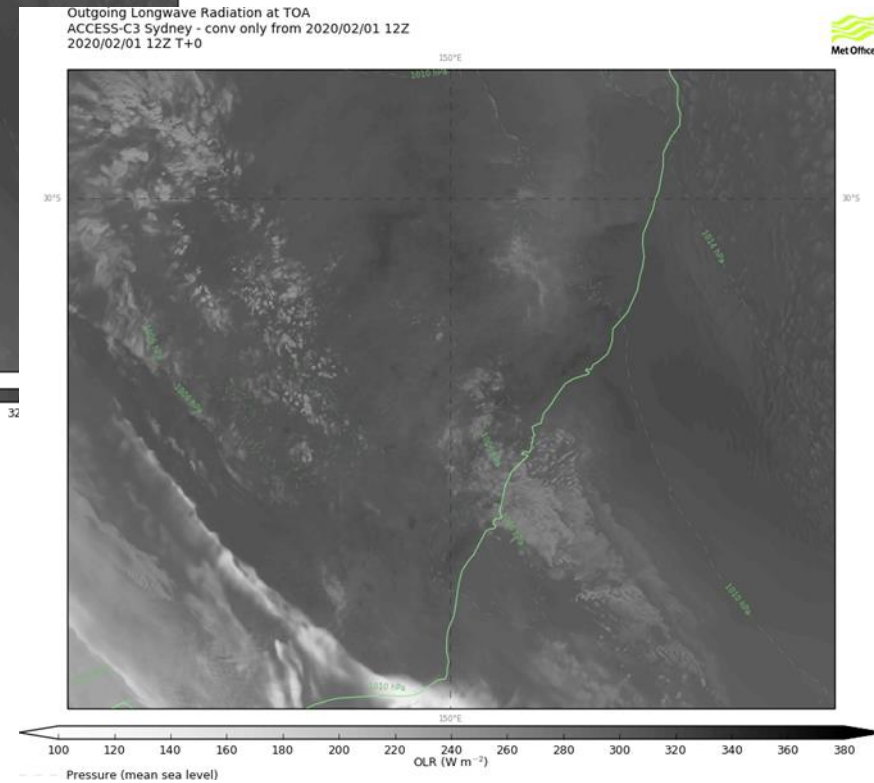
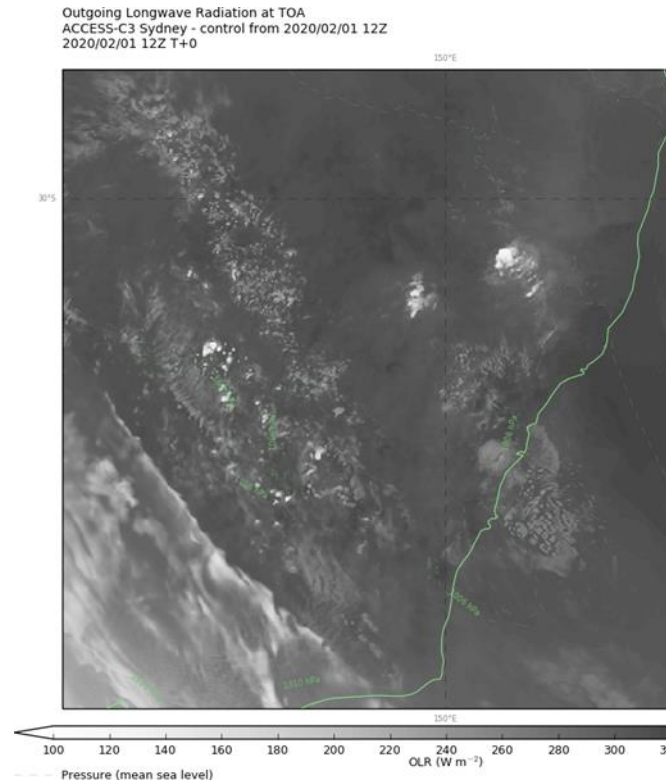
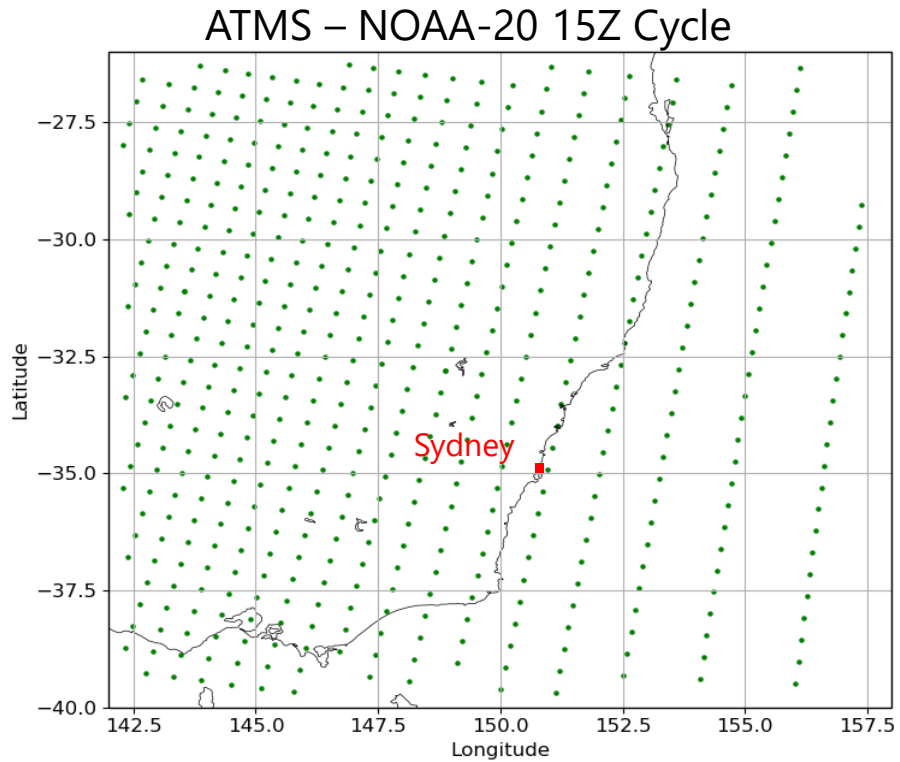
Standard channel selection (as per Met Office) according to cloud/rain tests: only insensitive channels used in the presence of cloud.

Humidity channels are not used over land.



Bureau Direct Reception of LEO sounders for ACCESS-C3: observations from these sites come in quickly enough to use in ACCESS-C3

Impact of remotely-sensed observations in ACCESS-C



	Observation types assimilated
control	"aircraftsondesurface", "airs", "atovs", "atms", "cris", "dopplerradialwinds", "groundgps", "iasi", "satwind", "scat"
denial test	"aircraftsondesurface" only

Current work (implementation expected FY22/23)

- Addition of many new instruments already in space
 - Extra satellite winds: Polar orbiting AMVs, more scatterometers, Aeolus Lidar horizontal line of sight winds
 - Extra GNSS-RO from COSMIC-2 and ground-based GNSS data
- More use of microwave observations over land, and higher resolution sounder observations in ACCESS-C3
- Addition of Met Office scheme for all-sky microwave data assimilation
- Significant expansion of our capacity to assess observation impacts on forecasts
- Use GEO radiances and GeoCloud retrievals in ACCESS-C3 (W.I.P.)

Future work (1)

- Addition of many new instruments already in space
 - Extra GEO radiances
 - Radiances from Chinese and Korean satellites
 - Microwave imagers
 - LEO/GEO AMVs
- Improved tuning of data assimilation for high-resolution models
- Expansion of all-sky assimilation schemes
- Improved treatment of systematic and random errors in observations

Future work and plans (2)

- A significant expansion of our capacity to assess observation impacts on forecast accuracy aiming to:
 - re-establish routine generation of FSO impact data for operational and development ACCESS-G global NWP suites,
 - extend the generation of FSOI data to the ACCESS-C city systems, and
 - establish a capacity to do targeted data-denial/addition experiments.
- Key stakeholders:
 - Bureau observation network planners, and
 - developers of DA systems for future ACCESS NWP suites.
- Supports one of the objectives of the Bureau's decadal Research and Development Plan: *Reliable and trusted forecasts – enhanced assimilation of observations for more accurate predictions.*

Future work and plans (3)

In November 2021 the Australian Space Agency launched the Earth Observations (EO) Roadmap, which articulates Australia's ambitions for EO satellite capabilities. To support the development of the EO Roadmap, the Australian Bureau of Meteorology commissioned a *Pre-Phase A Mission Study** to examine the feasibility of Australian built meteorological sensors.

The Study identified three high priority dedicated satellite missions that would help fulfil the Bureau's future operational needs. One mission is a **hyperspectral microwave sounder** to provide atmospheric temperature and water vapour information for assimilation into numerical weather prediction (NWP) models:

- Chosen because of the high impact of existing microwave sounding data
- SmallSat based
- Explores the feasibility of hyperspectral instrument of ~100 channels - grouped around the 50-60, 118 GHz temperature sensitive bands and the 183GHz moisture sensitive band, and a smaller number of window/hydrometeor detection channels
- Support for short range NWP data assimilation, extreme weather nowcasting. Compliments existing platforms.
- Pathway to operational missions via demonstration or pathfinder missions

*https://www.unsw.adfa.edu.au/sites/default/files/documents/Australian_Bureau_of_Meteorology_Pre-Phase_A_Mission_Study_Report_0.pdf

Concluding remarks

Microwave radiance data are crucial to the Bureau's NWP systems and will become even more so in the future.

Their forecast impact over the Australian region is dominated by observations from two distinct geographical regions. One of these is close to the west coast of Australia and major populations centres, with potential implications for the impact of future RFI sources.

Thank you for your attention.

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