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Satellite radiance assimilation at the Bureau of Meteorology

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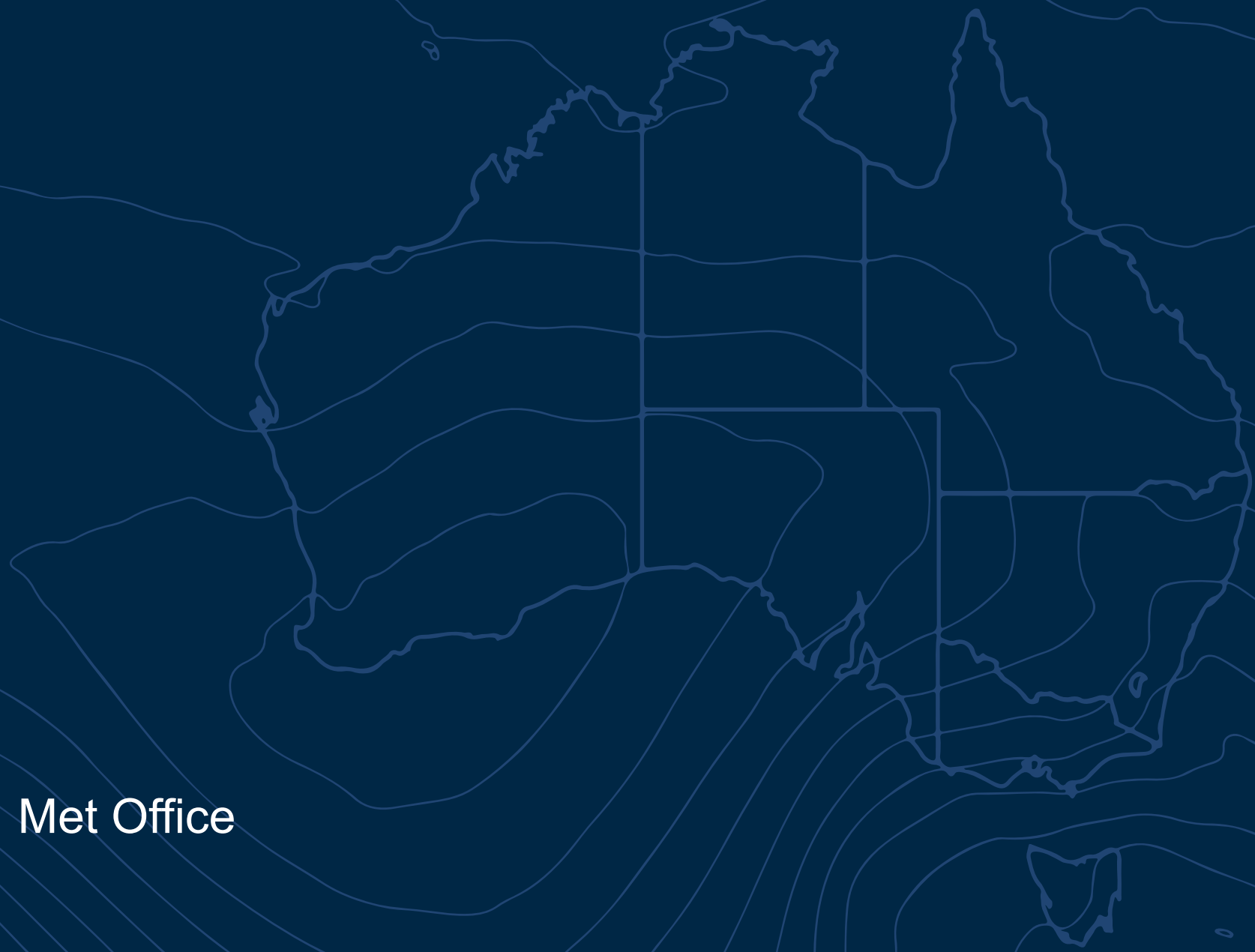
Thank you to our collaborators



Jin Lee,
Jim Fraser,
David Howard,
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Susan Rennie,
Andrew Smith,
Peter Steinle,
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Acknowledgement: Met Office

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Overview

- Since the last ITSC,
  - our ACCESS-G global NWP system had a mid-term upgrade which included the addition of new radiance data sources, hourly background files and new background error covariances, delivering a significant increase in forecast skill,
  - our latest ACCESS-C convection-allowing NWP suites (now including hourly 4D-Var assimilation cycles) became operational, and
  - work is now well advanced on the development of a National Analysis System which features multi-pass hourly 4D-Var + 3D-Var assimilation cycles, and includes radiance data assimilation.
- Future work towards the next ACCESS upgrades includes extending our use of radiance data and the addition of new data sources.

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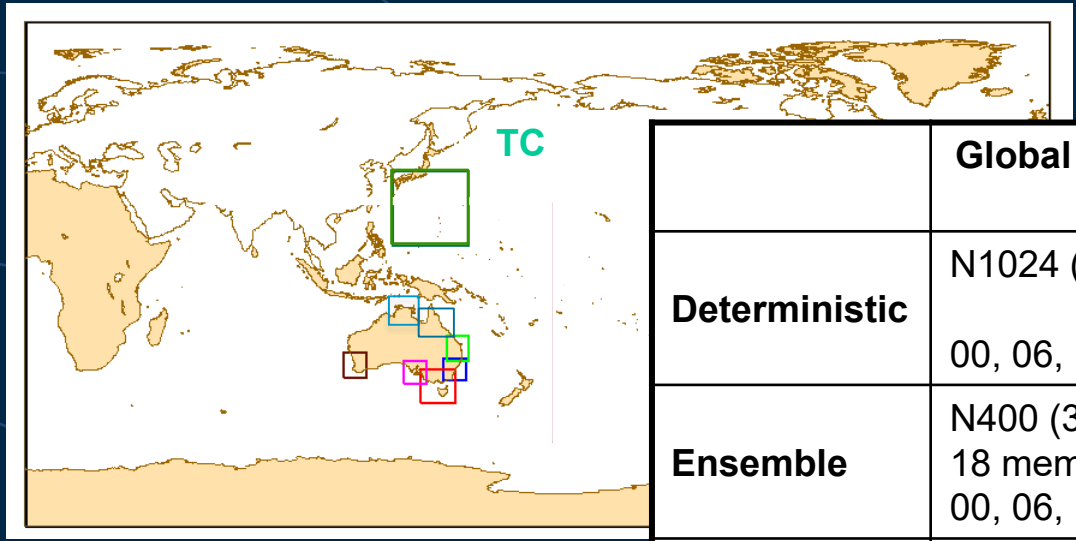
Summary of ACCESS APS3 systems



	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
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

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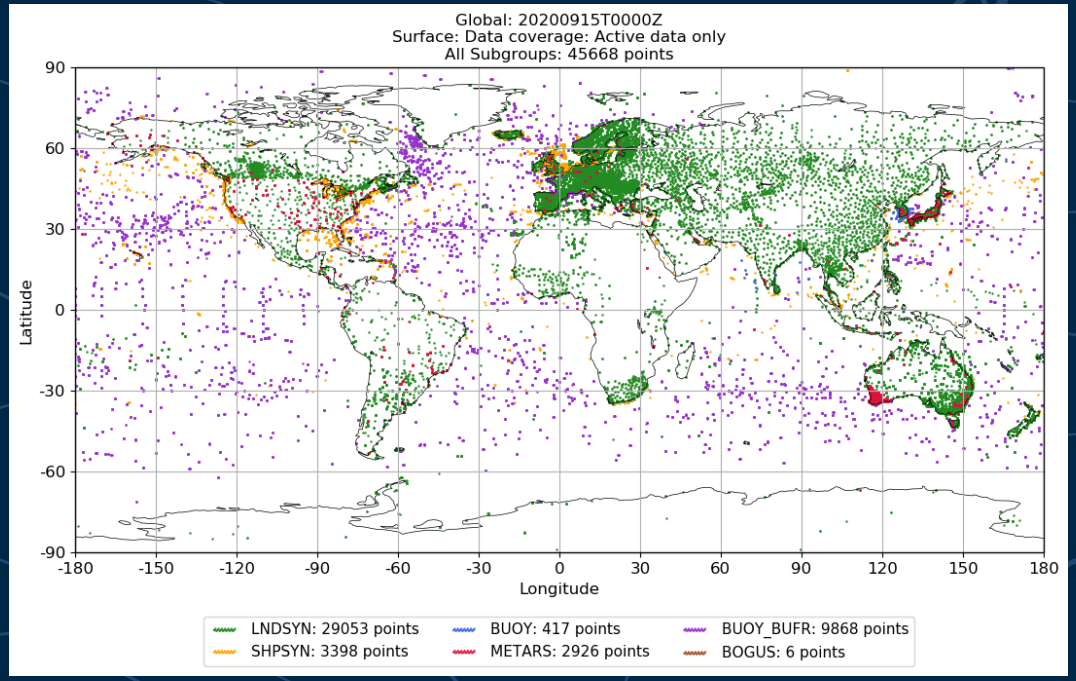
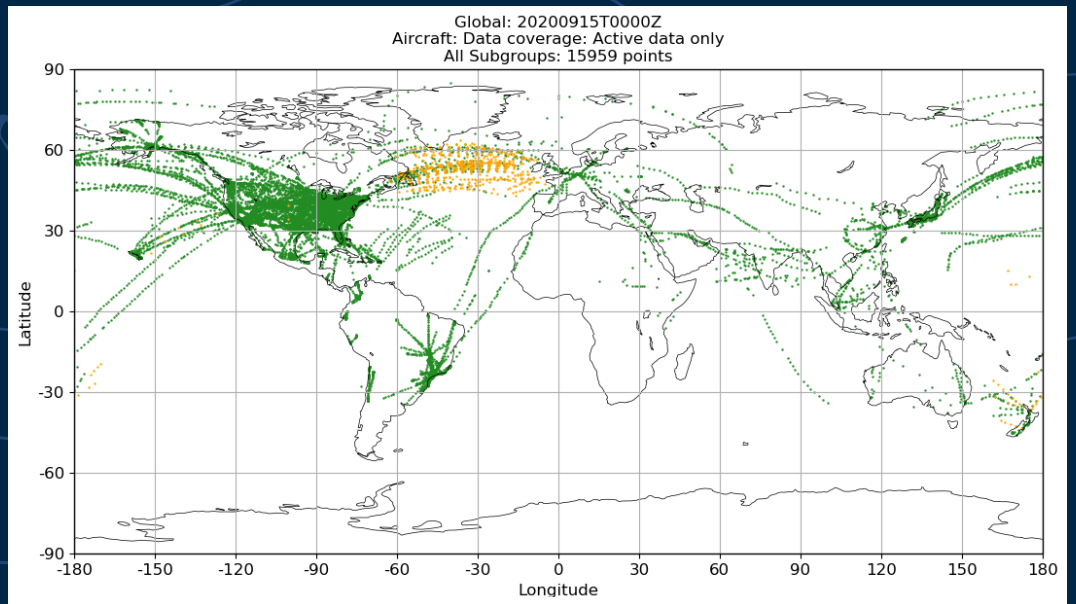
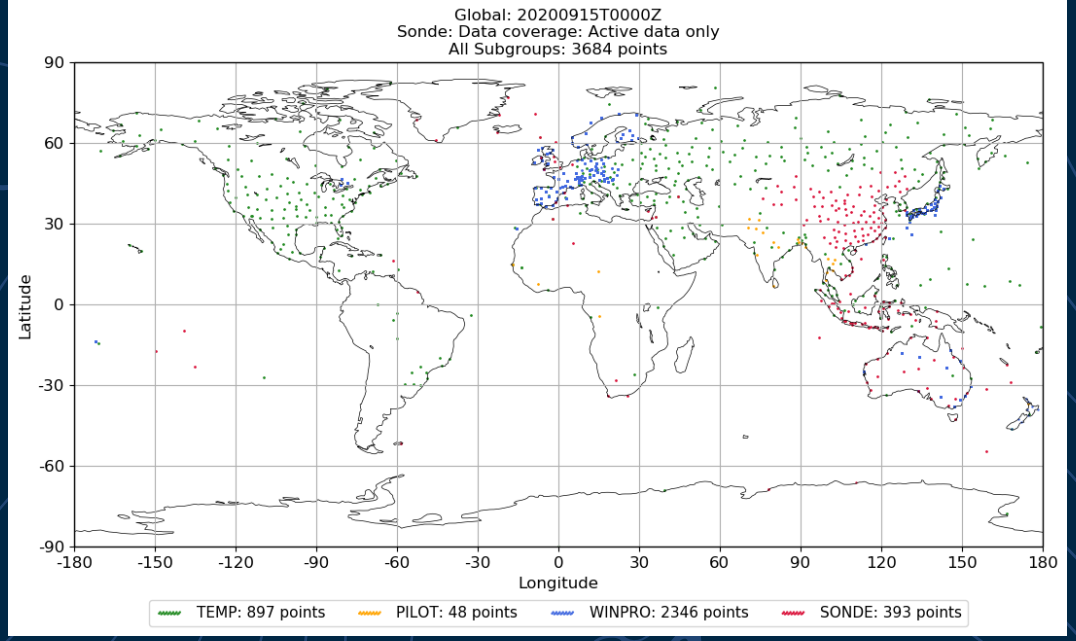
Observations coverage: Aircraft, Surface and Sonde







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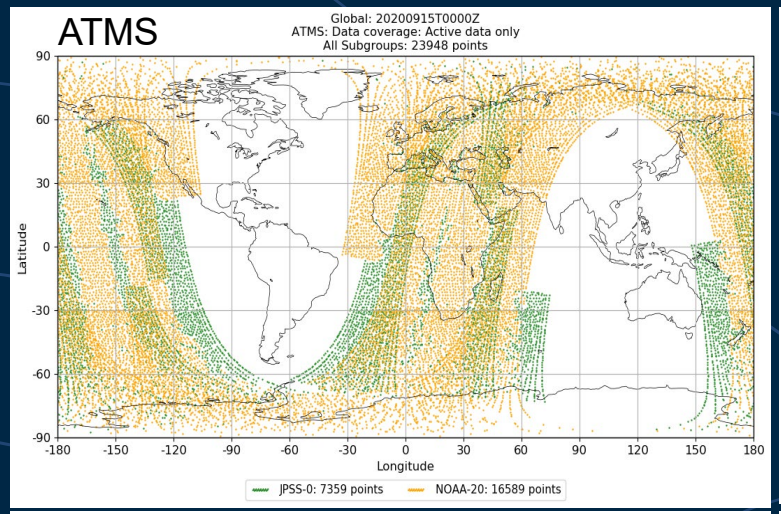
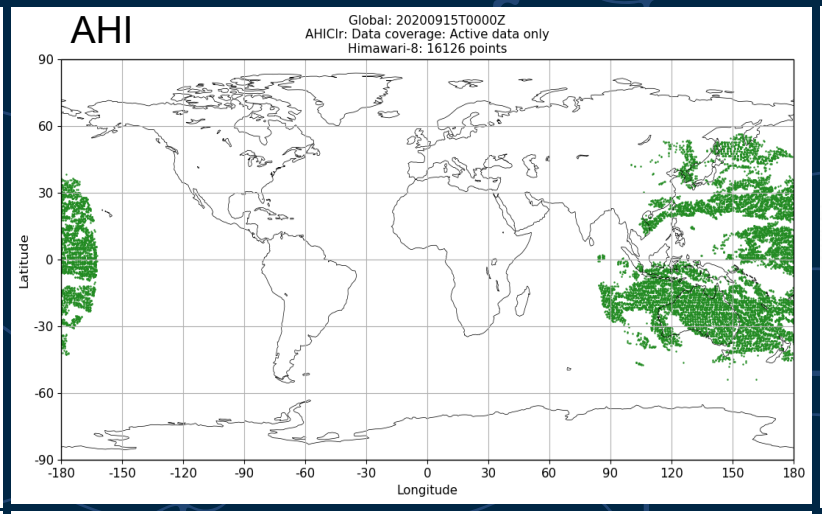
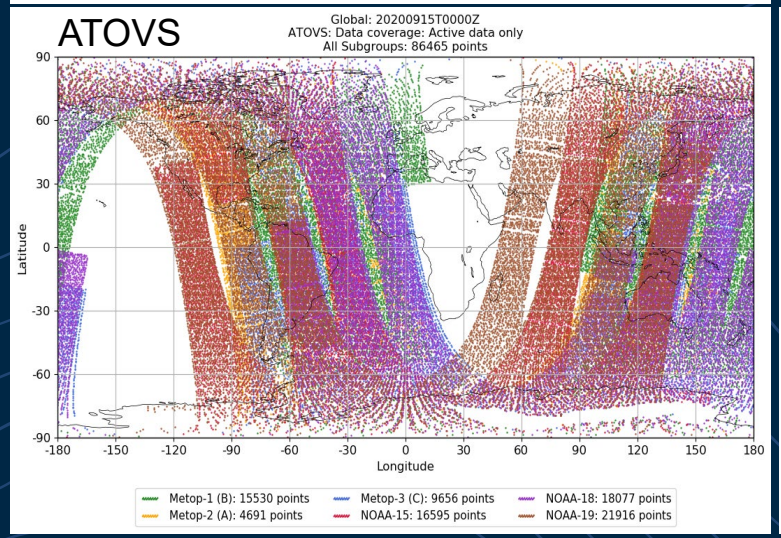
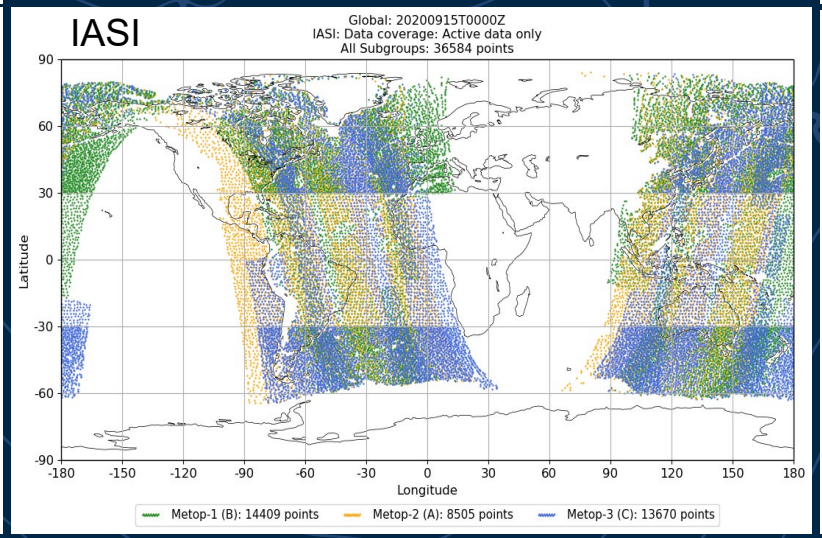
Observations coverage: Satellite observations

Radiances

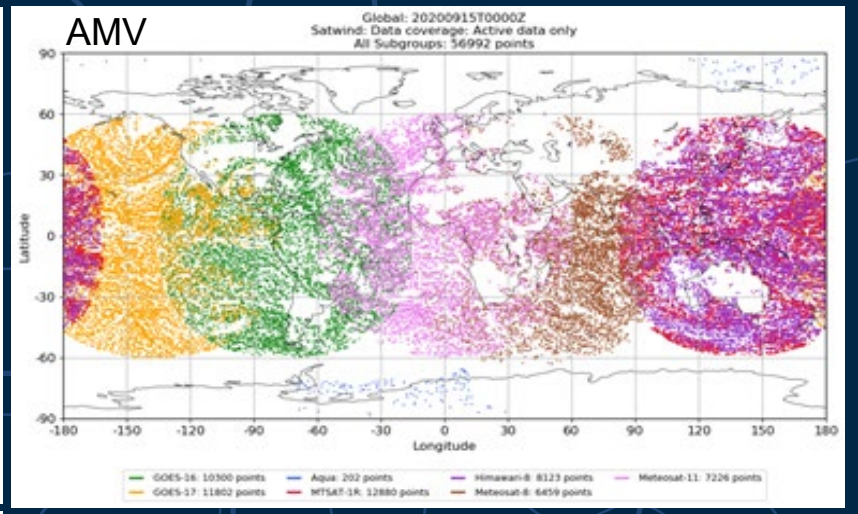


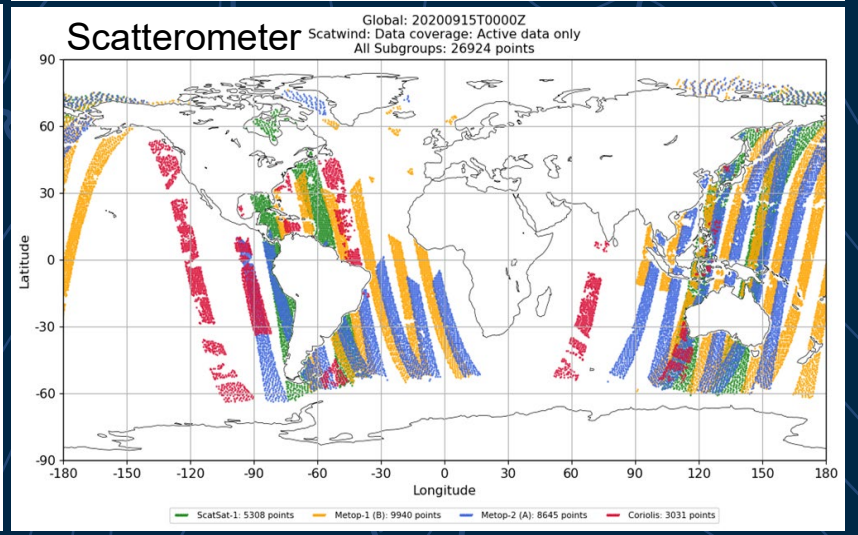






Winds





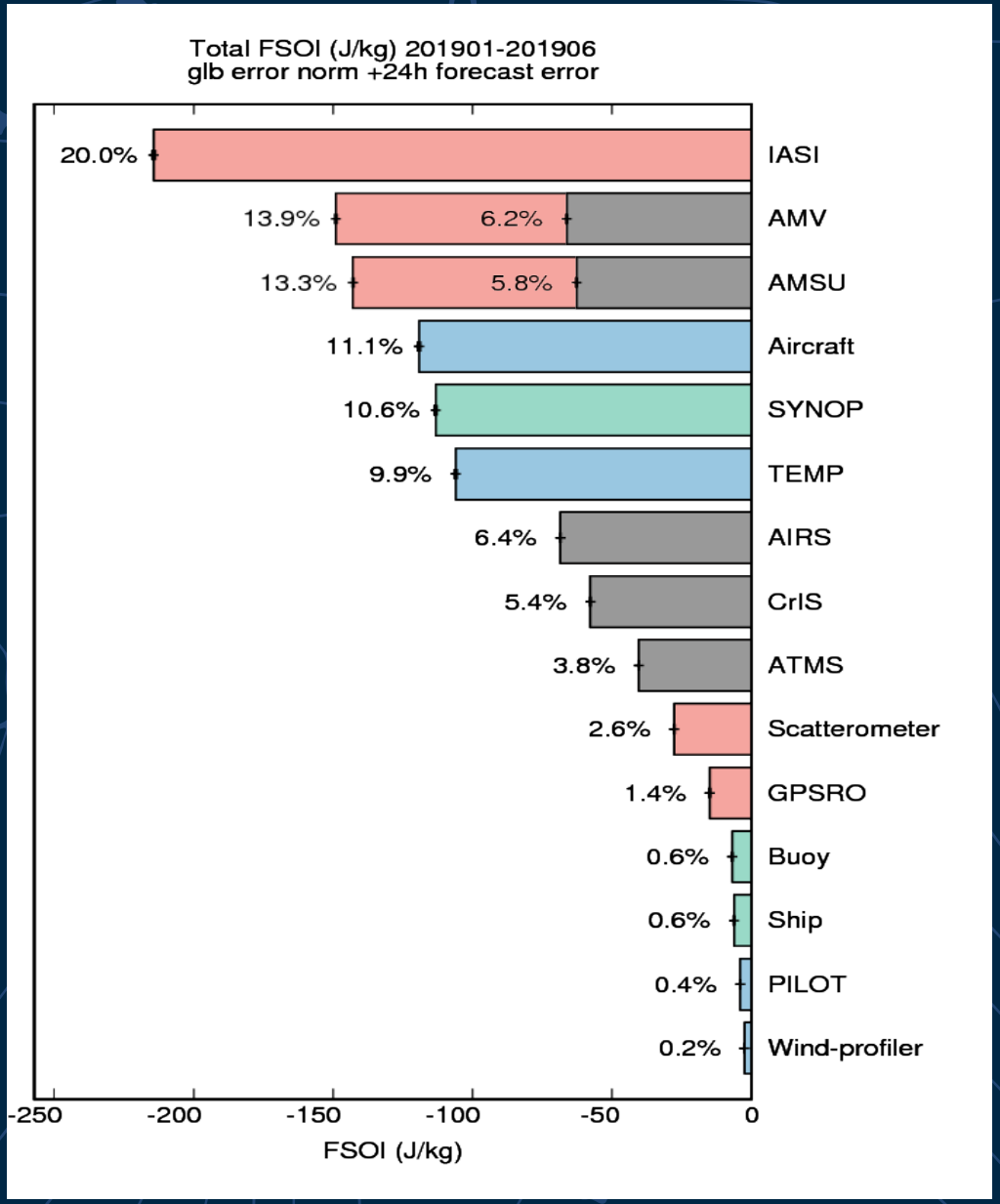
Impact of observations in ACCESS-G

Total Forecast Sensitivity to Observations Impacts (FSOI) in ACCESS-G2 January – June 2019

Reduction in 24 hour forecast error measured by global moist energy norm.

Red: space-based observations
Blue: upper air network
Green: surface observations

(contributions from NOAA/NASA satellite platforms)



Recent changes in observation usage – ACCESS-G3

	ACCESS-G2	ACCESS-G3 (from July 2019)	ACCESS-G3.1 (from June 2020)
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	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, 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, ScatSat-1

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G3.1 trial Scorecard

Australia

Anomaly Correlation and S1 Skill Score on left

Bias and RMSE on right

Statistically significant values in colour:
+ve Blue
-ve Red

Australia

Parameter	Level (hPa)	24	48	72	96	120	144	168
Geopotential Height	100	A S	A S	A S	A S	A S	A S	A S
	250	A S	A S	A S	A S	A S	A S	A S
	500	A S	A S	A S	A S	A S	A S	A S
	850	A S	A S	A S	A S	A S	A S	A S
Mean Sea-Level Pressure	0	A S	A S	A S	A S	A S	A S	A S
Temperature	100	A S	A S	A S	A S	A S	A S	A S
	250	A S	A S	A S	A S	A S	A S	A S
	500	A S	A S	A S	A S	A S	A S	A S
	850	A S	A S	A S	A S	A S	A S	A S
Wind U-Component	100	A S	A S	A S	A S	A S	A S	A S
	250	A S	A S	A S	A S	A S	A S	A S
	500	A S	A S	A S	A S	A S	A S	A S
	850	A S	A S	A S	A S	A S	A S	A S
Wind V-Component	100	A S	A S	A S	A S	A S	A S	A S
	250	A S	A S	A S	A S	A S	A S	A S
	500	A S	A S	A S	A S	A S	A S	A S
	850	A S	A S	A S	A S	A S	A S	A S

Australia

Parameter	Level (hPa)	24	48	72	96	120	144	168
Geopotential Height	100	B R	B R	B R	B R	B R	B R	B R
	250	B R	B R	B R	B R	B R	B R	B R
	500	B R	B R	B R	B R	B R	B R	B R
	850	B R	B R	B R	B R	B R	B R	B R
Mean Sea-Level Pressure	0	B R	B R	B R	B R	B R	B R	B R
Temperature	100	B R	B R	B R	B R	B R	B R	B R
	250	B R	B R	B R	B R	B R	B R	B R
	500	B R	B R	B R	B R	B R	B R	B R
	850	B R	B R	B R	B R	B R	B R	B R
Wind U-Component	100	B R	B R	B R	B R	B R	B R	B R
	250	B R	B R	B R	B R	B R	B R	B R
	500	B R	B R	B R	B R	B R	B R	B R
	850	B R	B R	B R	B R	B R	B R	B R
Wind V-Component	100	B R	B R	B R	B R	B R	B R	B R
	250	B R	B R	B R	B R	B R	B R	B R
	500	B R	B R	B R	B R	B R	B R	B R
	850	B R	B R	B R	B R	B R	B R	B R

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G3.1 trial Scorecard

Tropics

Anomaly Correlation and S1 Skill Score on left

Bias and RMSE on right

Statistically significant values in colour:
+ve Blue
-ve Red

Tropics

Parameter	Level (hPa)	24	48	72	96	120	144	168
Geopotential Height	100	A S	A S	A S	A S	A S	A S	A S
	250	A S	A S	A S	A S	A S	A S	A S
	500	A S	A S	A S	A S	A S	A S	A S
	850	A S	A S	A S	A S	A S	A S	A S
Mean Sea-Level Pressure	0	A S	A S	A S	A S	A S	A S	A S
Temperature	100	A S	A S	A S	A S	A S	A S	A S
	250	A S	A S	A S	A S	A S	A S	A S
	500	A S	A S	A S	A S	A S	A S	A S
	850	A S	A S	A S	A S	A S	A S	A S
Wind U-Component	100	A S	A S	A S	A S	A S	A S	A S
	250	A S	A S	A S	A S	A S	A S	A S
	500	A S	A S	A S	A S	A S	A S	A S
	850	A S	A S	A S	A S	A S	A S	A S
Wind V-Component	100	A S	A S	A S	A S	A S	A S	A S
	250	A S	A S	A S	A S	A S	A S	A S
	500	A S	A S	A S	A S	A S	A S	A S
	850	A S	A S	A S	A S	A S	A S	A S

Tropics

Parameter	Level (hPa)	24	48	72	96	120	144	168
Geopotential Height	100	B R	B R	B R	B R	B R	B R	B R
	250	B R	B R	B R	B R	B R	B R	B R
	500	B R	B R	B R	B R	B R	B R	B R
	850	B R	B R	B R	B R	B R	B R	B R
Mean Sea-Level Pressure	0	B R	B R	B R	B R	B R	B R	B R
Temperature	100	B R	B R	B R	B R	B R	B R	B R
	250	B R	B R	B R	B R	B R	B R	B R
	500	B R	B R	B R	B R	B R	B R	B R
	850	B R	B R	B R	B R	B R	B R	B R
Wind U-Component	100	B R	B R	B R	B R	B R	B R	B R
	250	B R	B R	B R	B R	B R	B R	B R
	500	B R	B R	B R	B R	B R	B R	B R
	850	B R	B R	B R	B R	B R	B R	B R
Wind V-Component	100	B R	B R	B R	B R	B R	B R	B R
	250	B R	B R	B R	B R	B R	B R	B R
	500	B R	B R	B R	B R	B R	B R	B R
	850	B R	B R	B R	B R	B R	B R	B R

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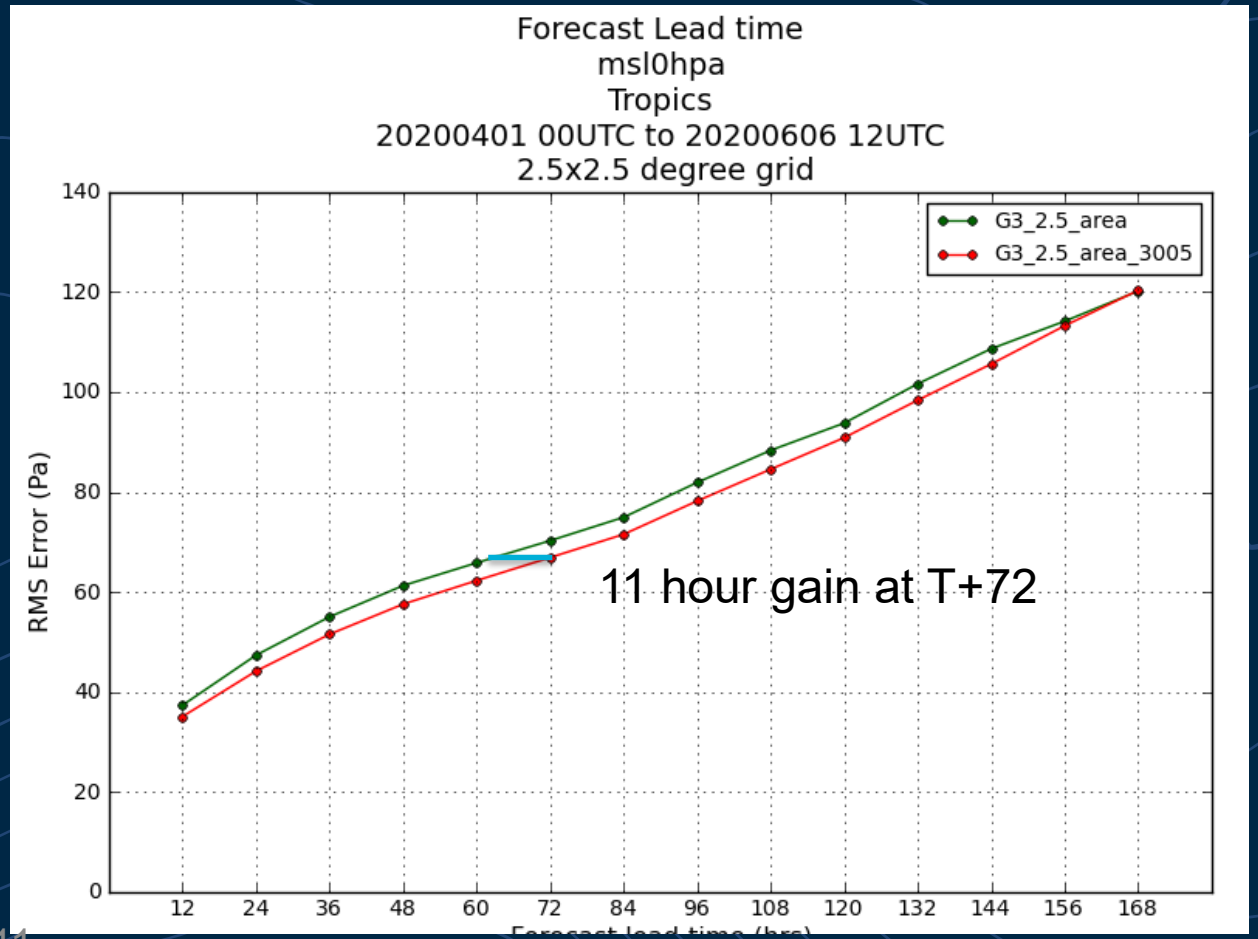
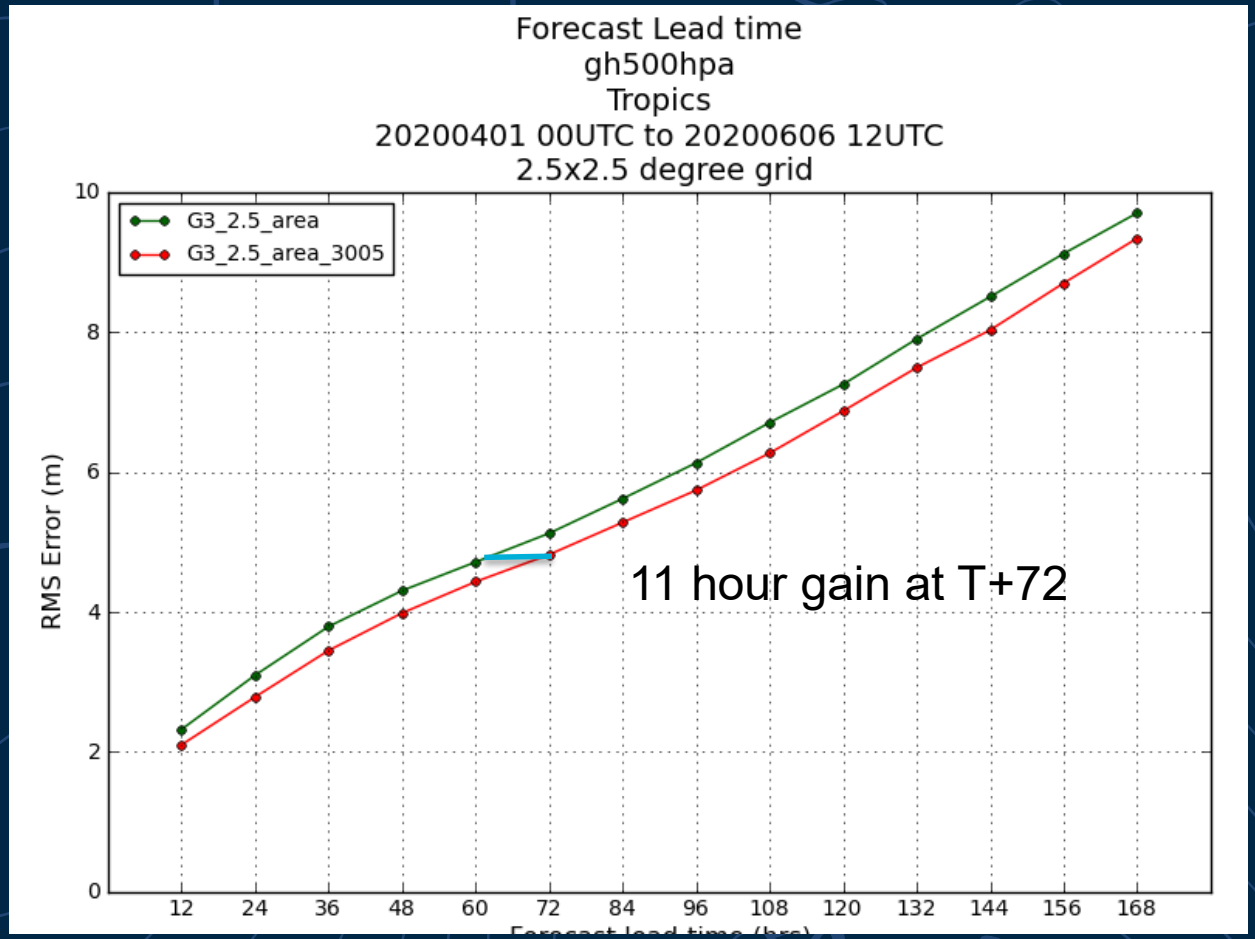
Tropics – change in RMSE for G3.1 vs G3

PMSL **G3** **G3.1** Z500





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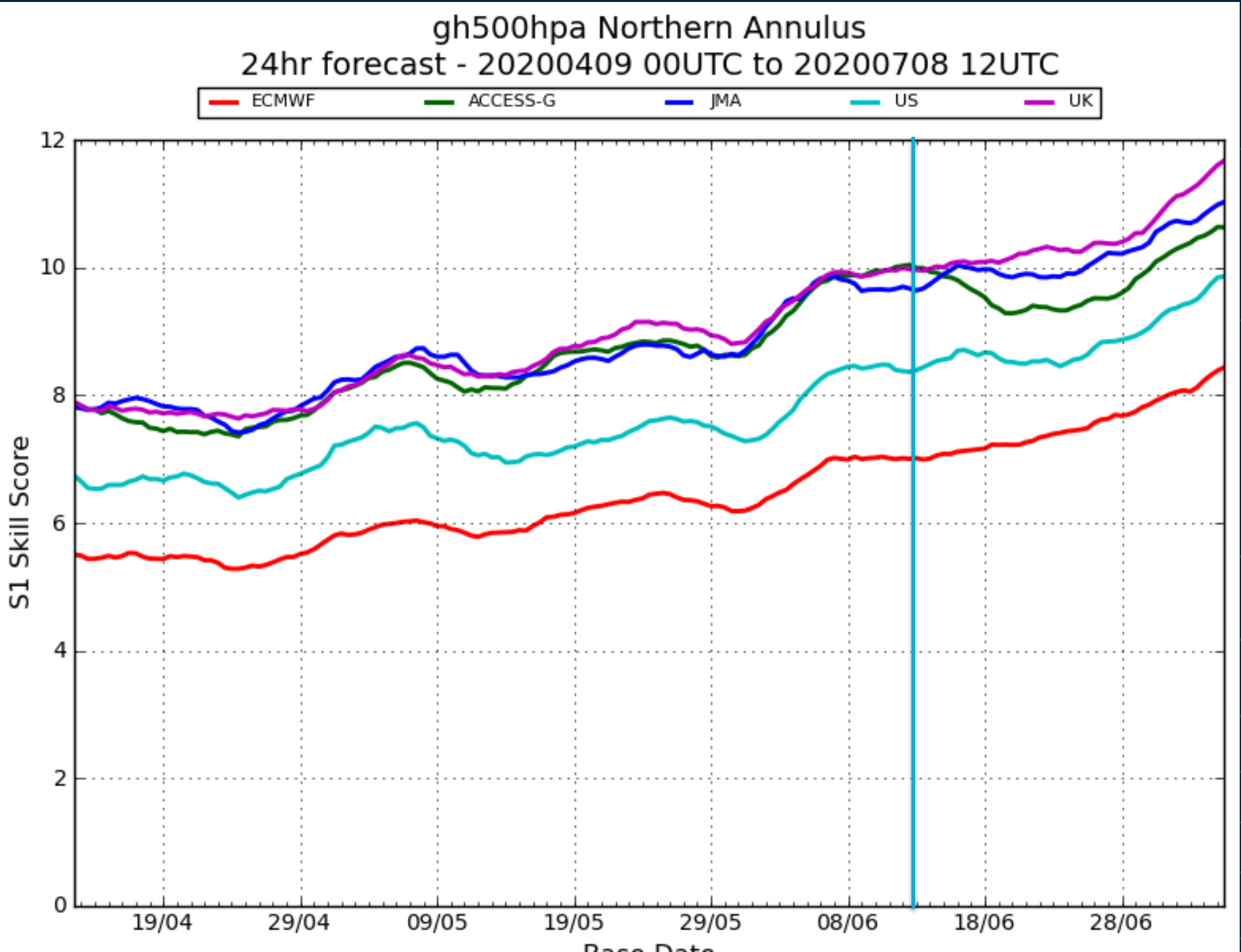
+24h S1 skill score 500 hPa geopotential hgt for Northern Hemisphere, pre/post ACCESS-G3.1 upgrade (vertical line).



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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

Bureau Direct Reception of LEO sounders for ACCESS-C3

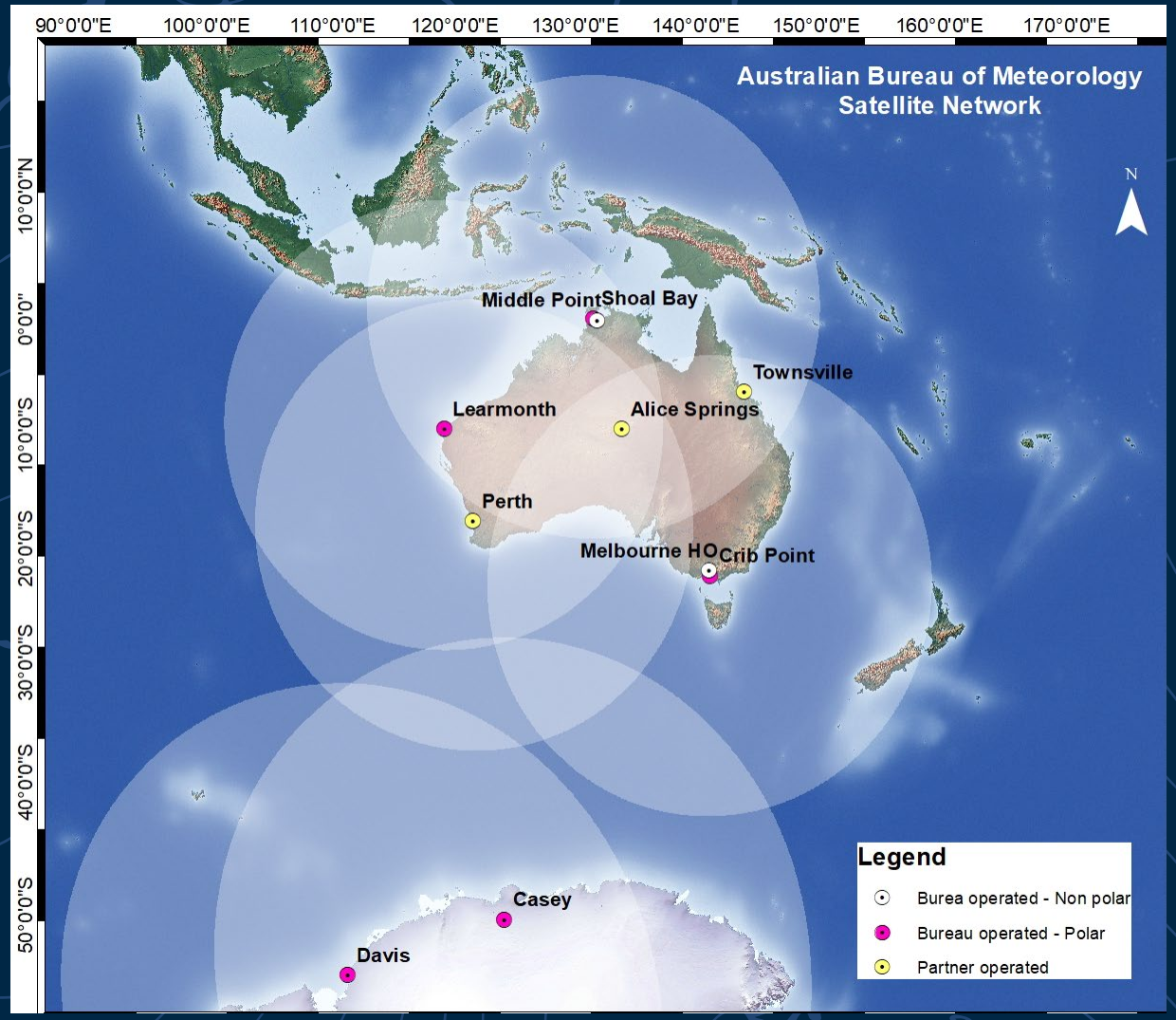
The Bureau operates three mainland receiving stations and two in Antarctica

- Shoal Bay, Learmonth, Crib Point
- Casey, Davis

Three additional reception sites are operated by partner agencies

- Perth, Alice Springs, Townsville

Observations from these sites come in much more quickly, allowing us to use sounder data in ACCESS-C3



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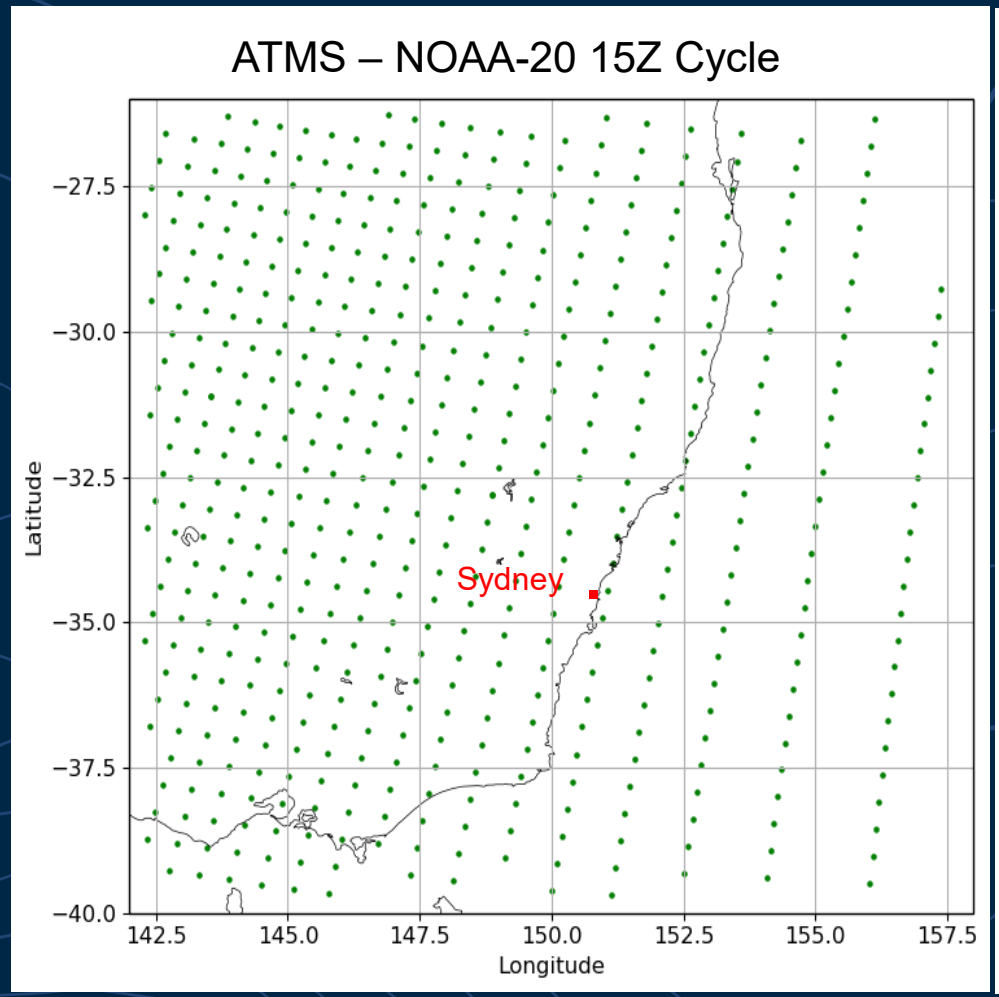
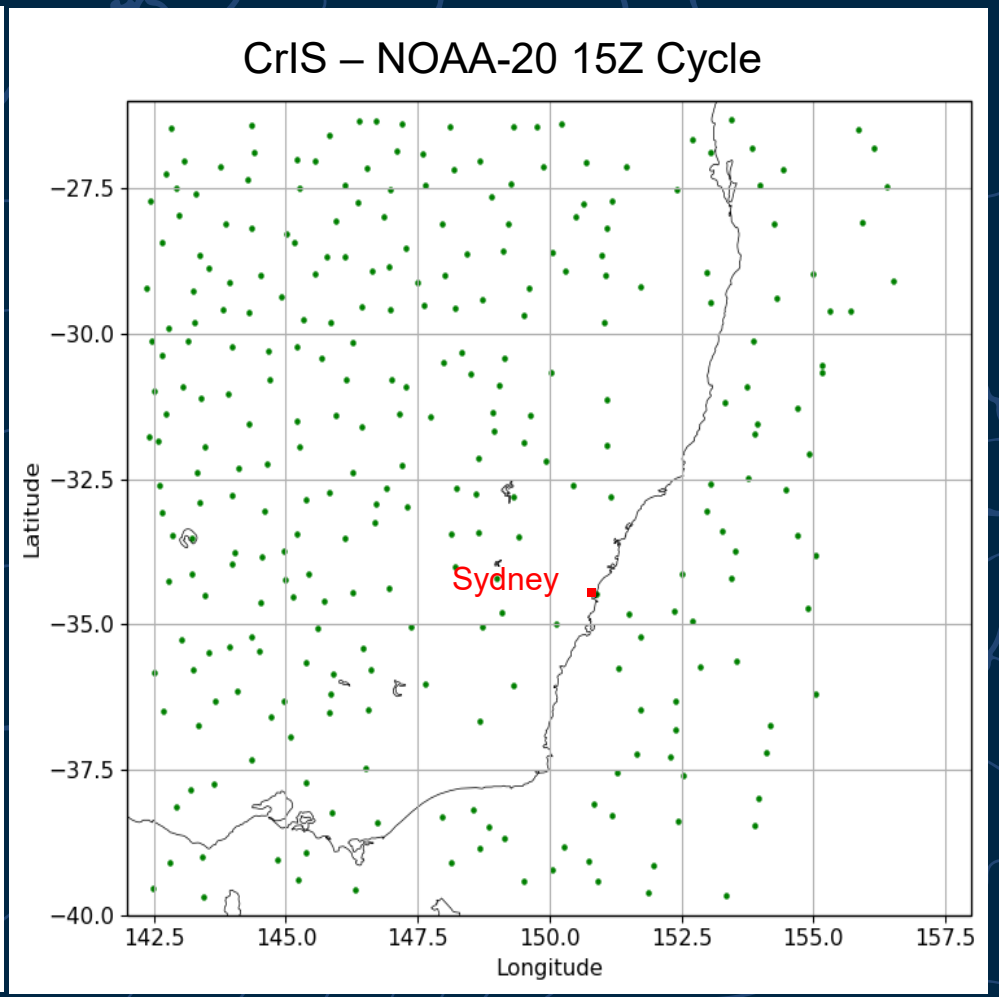
S-NPP and NOAA-20 data in C3 Sydney model





Impact of satellite observations in ACCESS-C3 (1)

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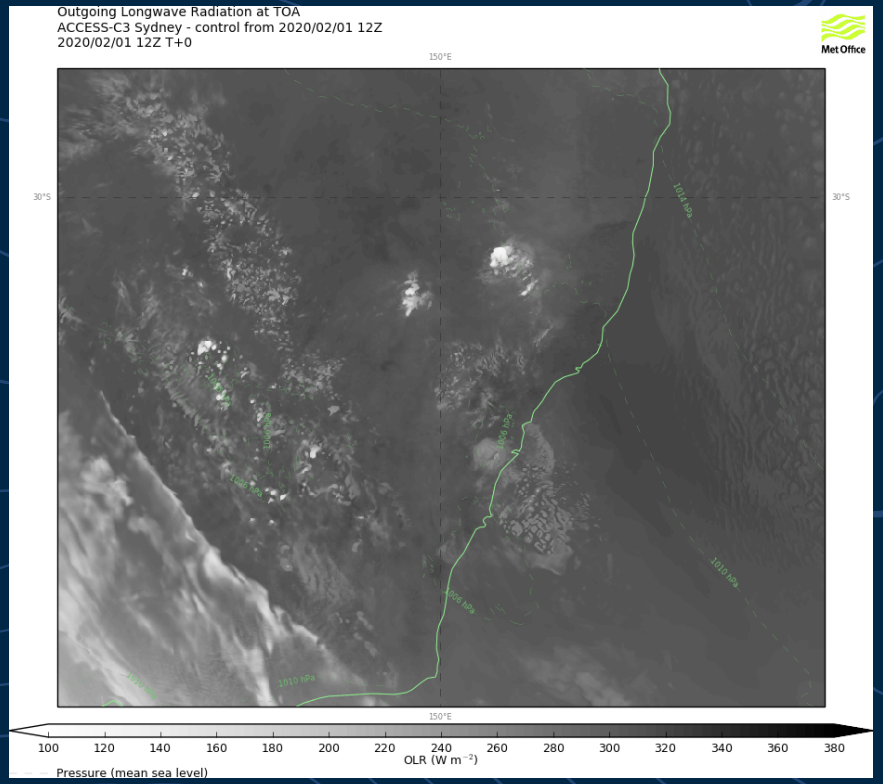
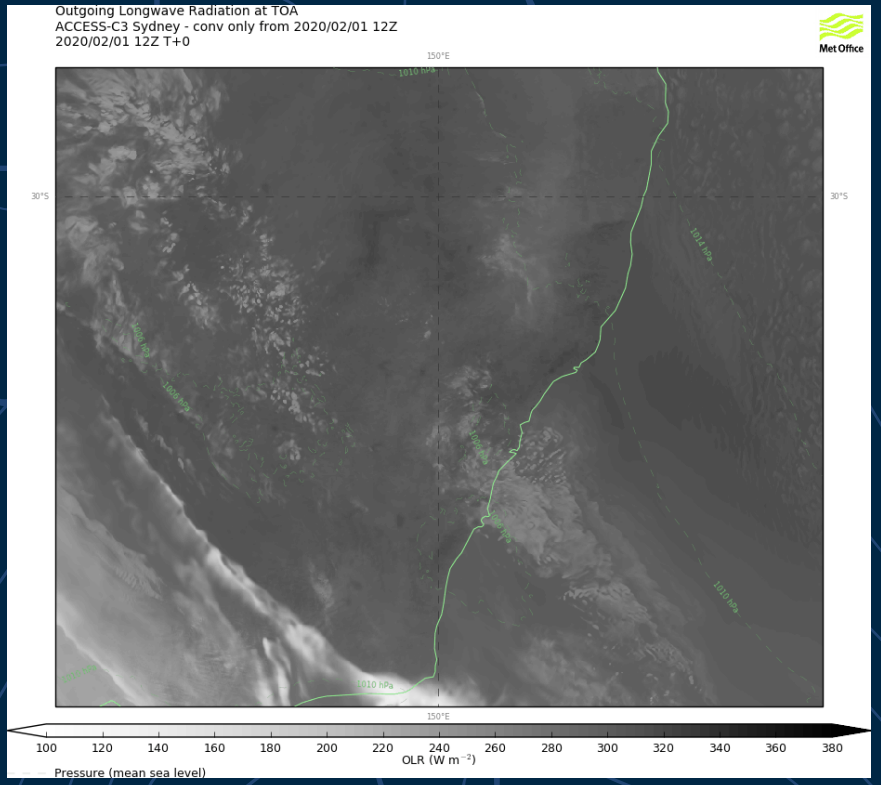
	Observation types assimilated
control	"aircraftsondesurface", "airs", "atovs", "atms", "cris", "dopplerradialwinds", "groundgps", "iasi", "satwind", "scat"
denial test	"aircraftsondesurface" only



All observations

Outgoing LW radiation at TOA



Conventional only

Impact of satellite observations in ACCESS-C3 (2)

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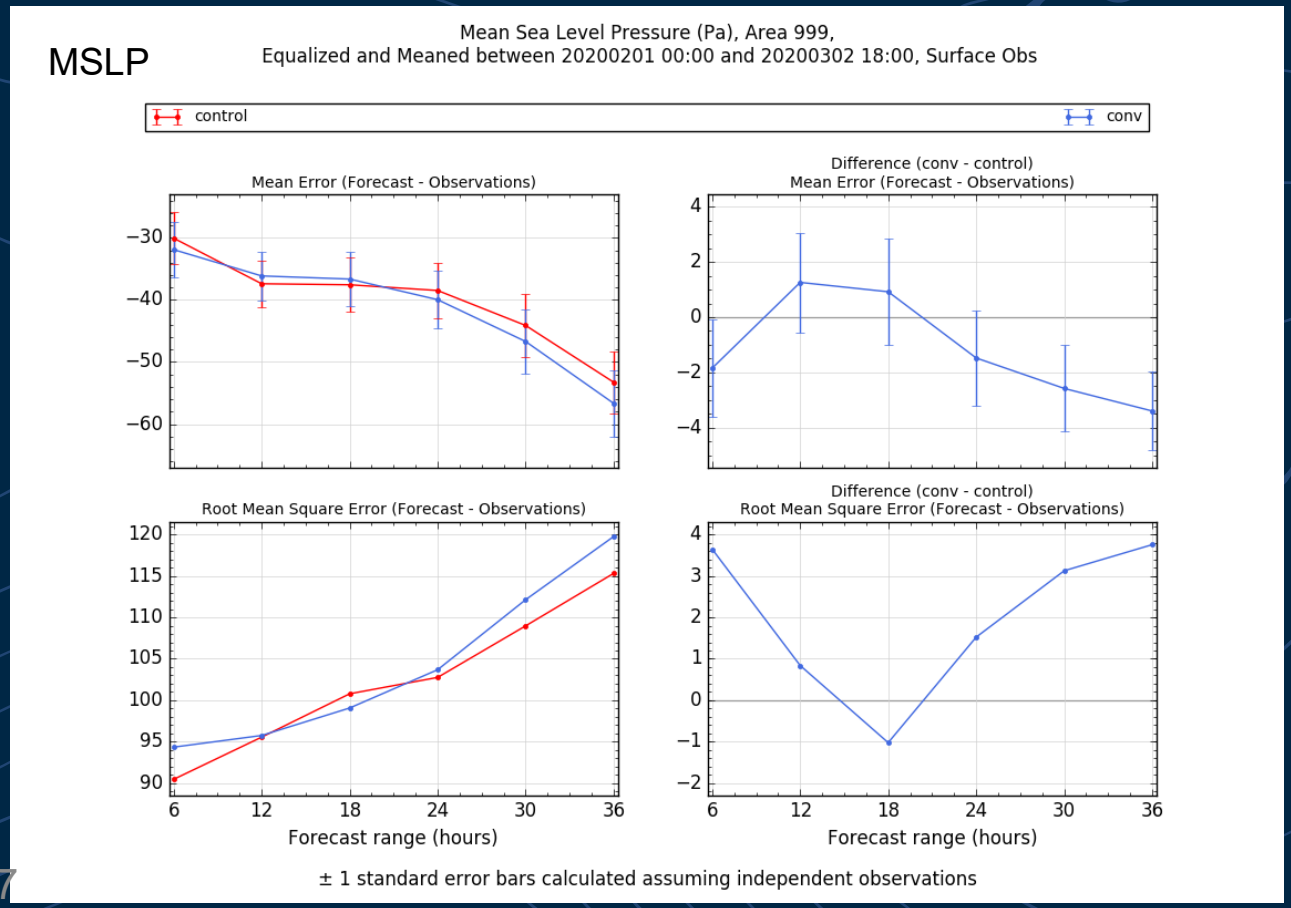
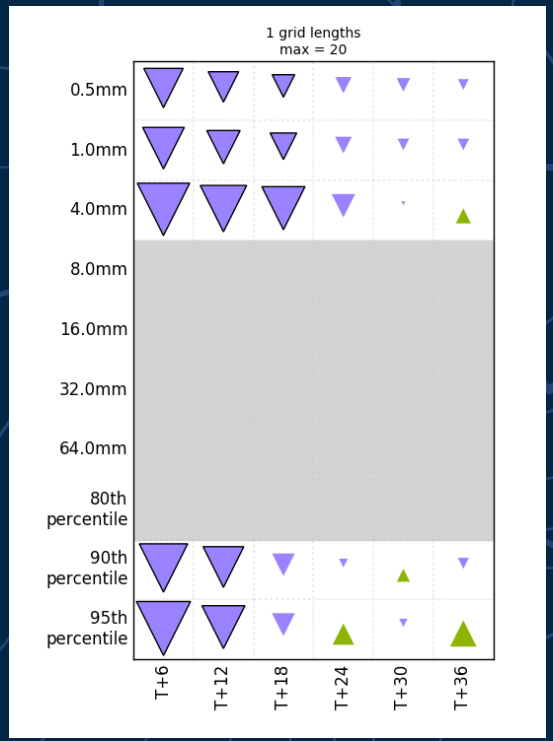
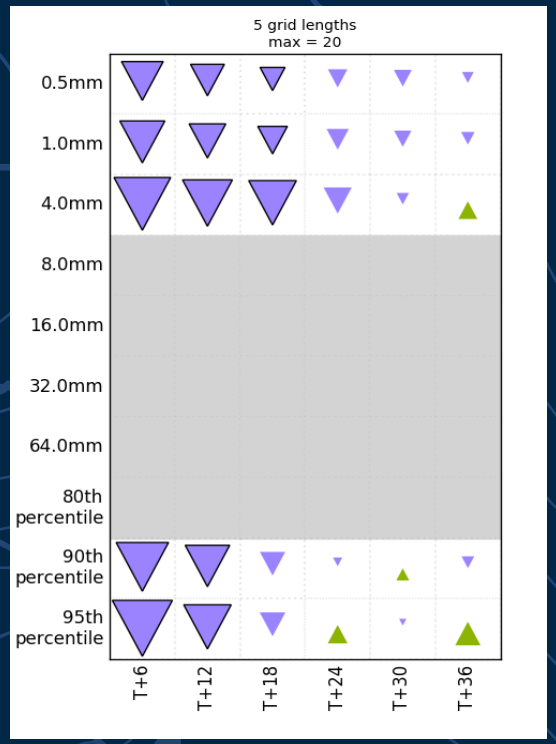
Conclude: significant positive impact on ACCESS-C3 forecast skill from satellite observations as measured by a number of skill metrics.

MSLP

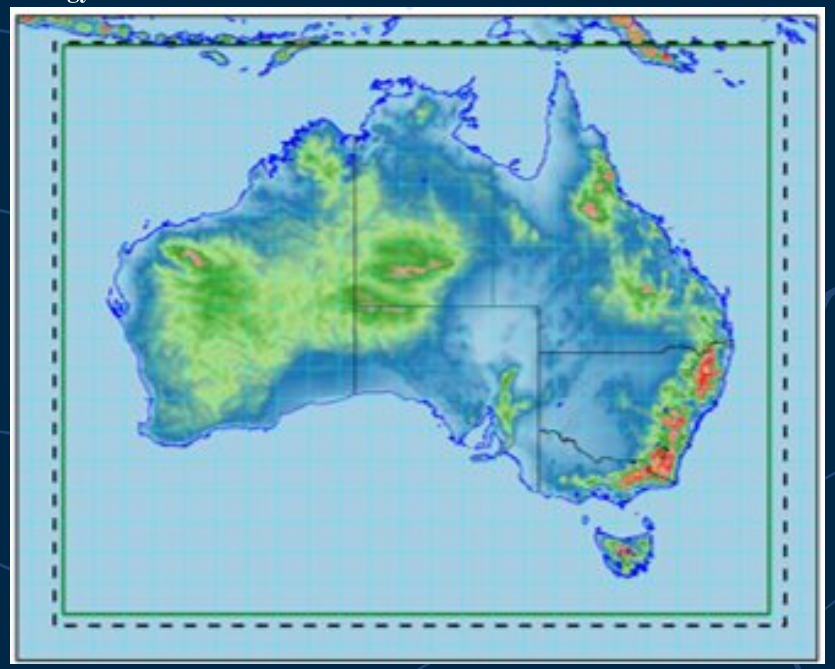


% diff FSS Conv. vs All-obs 6h accum. precip.





National Analysis System (NAS) – due in 2022



Domain covers Australia

- size 2400 x 1920 x L90
- ~ 2.2 km

Based on ACCESS-C

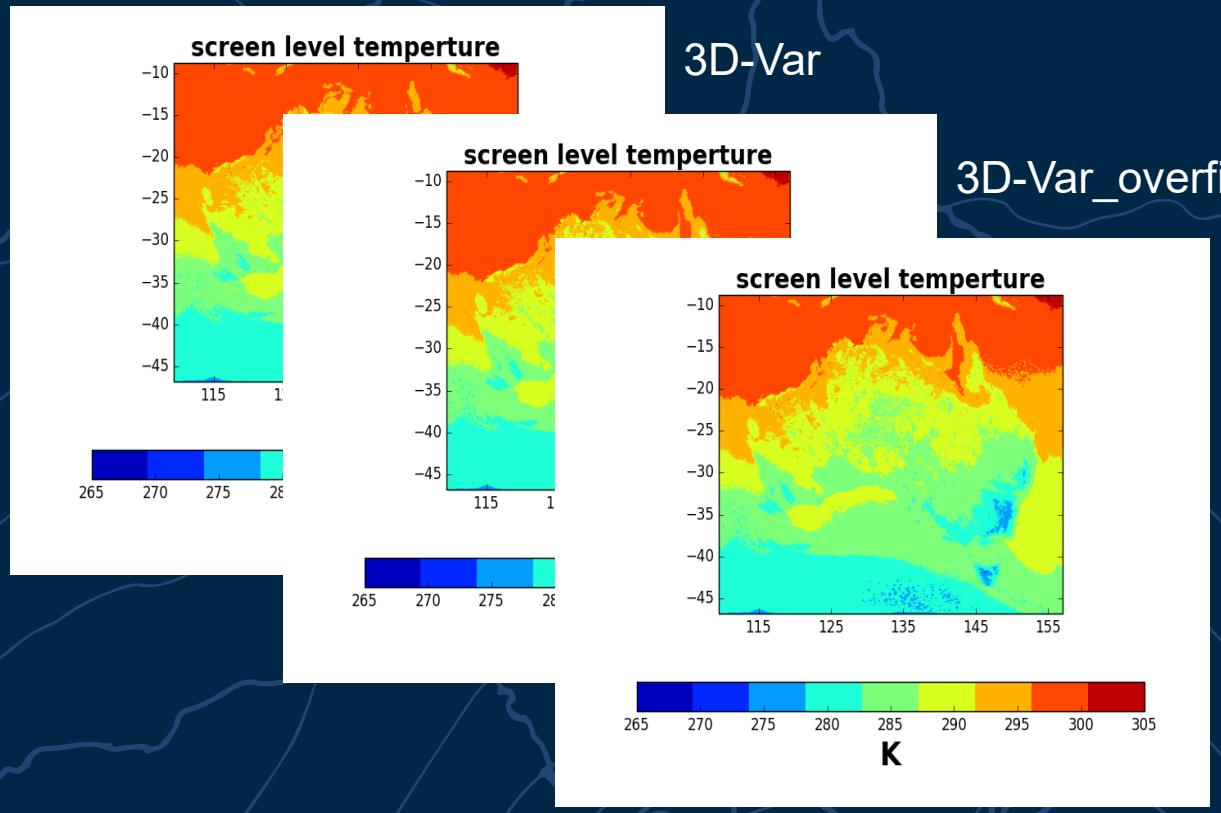
Produces analyses reflecting the current meteorological situation over Australia

Increases forecaster situational awareness

4D-Var

3D-Var

3D-Var_overfit



- Hourly RUC analyses (3 types)
  - 4D-Var (including satellite radiances)
  - 3D-Var
  - 3D-Var overweighting observations

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Future work

- Addition of many new instruments already in space
  - Extra GEO radiances
  - Radiances from Chinese and Korean satellites
  - (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.)

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Thank You

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