The Bureau of Meteorology

Observation Impacts in ACCESS-C Models

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1. Introduction

The quality of the forecasts from the Bureau's convection-permitting ACCESS-C models is dependent on the use of observations. The impact comes

- directly from assimilation into the ACCESS-C model hourly, providing the most accurate initial conditions for forecasts, and
- indirectly via assimilation into the global model ACCESS-G, which provides lateral boundary conditions (LBCs).

We examined the impact of satellite observations in ACCESS-C via observing system data denial experiments (DDEs) in the Sydney and Darwin domains.
We also looked at the impacts of observations on global model forecast skill over the Australian region, giving a guide to which observations are most influential to the quality of the LBCs.

2. ACCESS-C Experiment Setup

- ACCESS-C runs over 7 domains. We tested the impact of satellite observations in the **Darwin** domain and the **Sydney** domain (**Fig 1**) from 25/11/21 to 30/01/22.
- We tested *removing*
  - satellite radiance observations from CrIS, IASI, ATMS and ATOVS;
  - all satellite observations: radiances, Atmospheric Motion Vectors (AMVs), scatterometer surface winds and Ground-based GNSS ZTD;
  - just GNSS ZTD (Darwin only).
- We also tested *adding* AHI radiances
- We compared these experiments to a baseline containing the observations listed in **Table 1**.

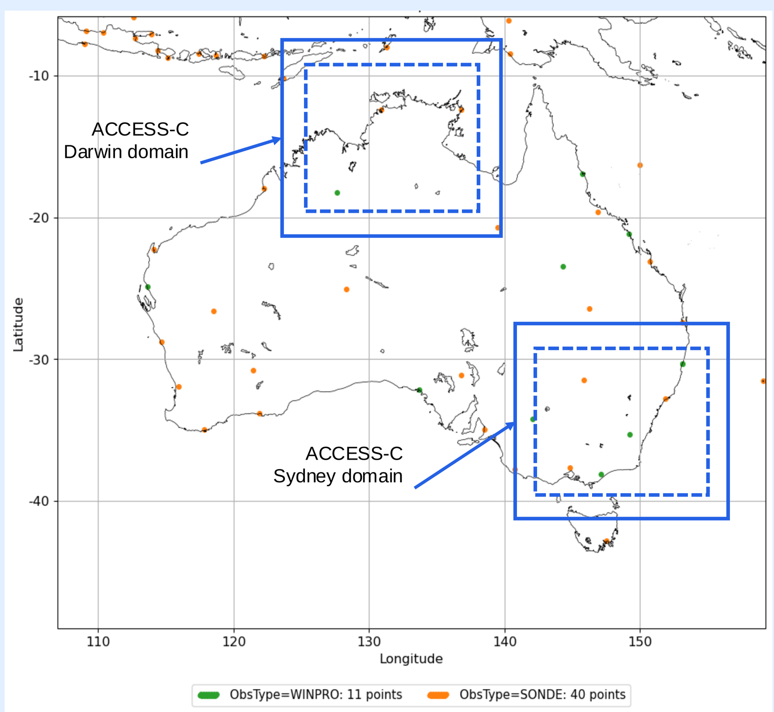


Figure 1: ACCESS-C domains in this study

ACCESS-C
Infrared radiances: AHI (soon), CrIS, IASI
Microwave radiances: ATMS, ATOVS
GNSS ZTD
Satellite wind obs: AMV, ASCAT
AIREPS, AMDAR, BUOY, METAR, PILOT, SHIP, SYNOP, TEMP, WINPRO
Doppler Radar Winds

Table 1: Observation usage in ACCESS-C. Satellite data sources are listed in red.

4. Global Model Experiment Setup

- Global observation impacts were tested via data denial experiments using the Met Office Global model, similar to ACCESS-G for a period 15/12/22 to 15/03/23
- The control run used all available observations. Each class of data listed in **Table 2** was then removed in a DDE and impact evaluated
- The impact was measured over the Australian region (roughly similar to Fig 1).
- **Fig 11** shows the proportions of observations used each day in the Met Office global model.

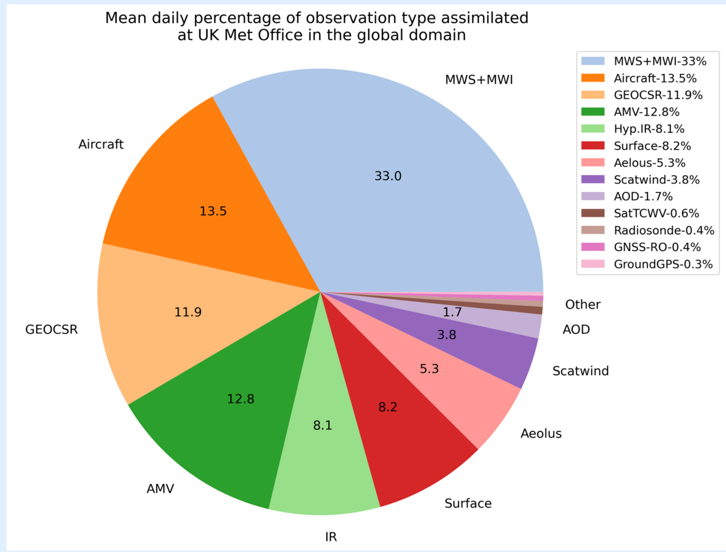


Figure 11: Percentage of each class of observation used each day in the Met Office global model.

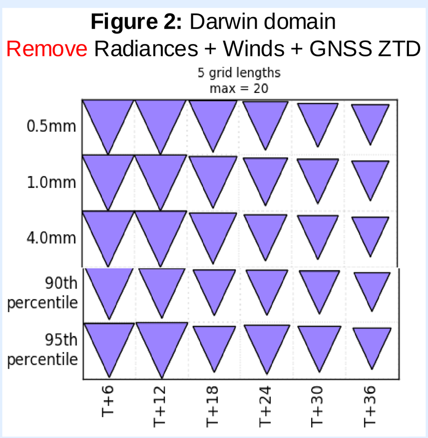
ACCESS-G
MW: microwave sounders and imagers
IR: hyperspectral infrared sounders
AMV: Atmospheric Motion Vector winds
GNSS-RO: GNSS Radio Occultation
Aircraft: aircraft including MODE-S
SCATT: scatterometer surface winds
Sonde
GroundGPS: GNSS ZTD
Synoptic-ocean
Synoptic-land
Additional to Met Office Global
GEOCSR: geostationary clear sky radiances (AHI soon in ACCESS-G)
Aeolus: wind profiles.
AOD : Aerosol Optical Depth
SatTCWV: satellite-derived total column water vapor
MWIM: microwave imagers alone (AMSR-2 used in ACCESS-G)
MODE-S: aircraft wind and temperature

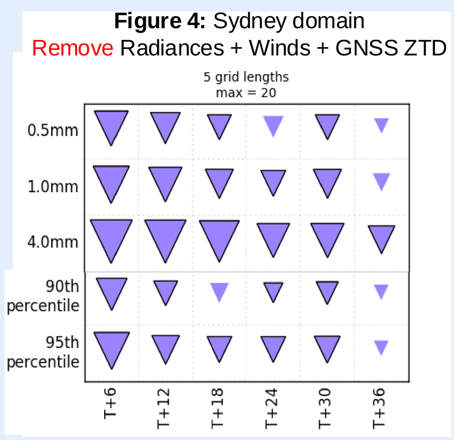
Table 2: Observation usage in ACCESS-G and additional observations used in the Met Office Global Model but not in ACCESS-G. Satellite data sources are listed in red.

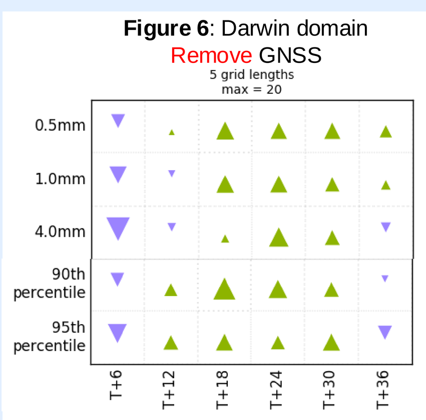
3. ACCESS-C Impact Results

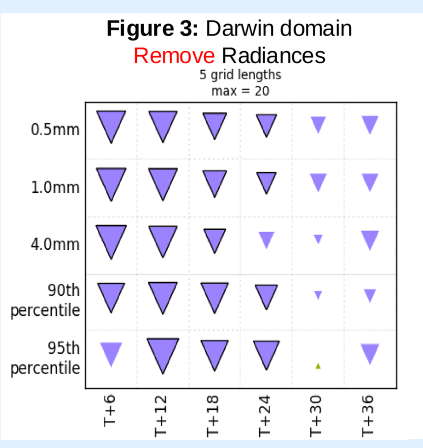
Fractions Skill Score for Precipitation:

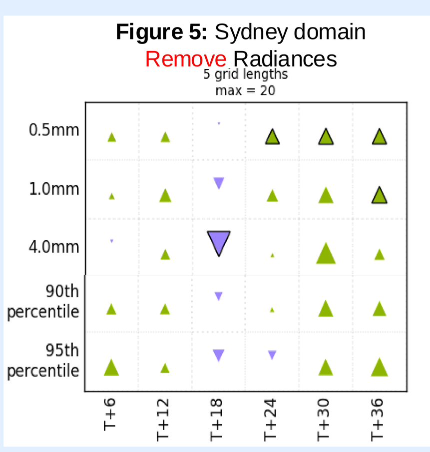
- **Satellite data** has a positive impact on precipitation accumulation Fractions Skill Score (FSS) at all forecast ranges for both Darwin (**Fig 2**) and Sydney (**Fig 3**).
- **Satellite radiance** observations formed a big part of this impact in the Darwin domain (**Fig 4**), while their impact in the Sydney domain was neutral to slightly negative for the trial period (**Fig 5**) showing the influence of weather and climate.
- **GNSS ZTD** observations had a fairly neutral impact in Darwin (**Fig 6**). Taken with Figures 2 and 4, this implies that satellite wind observations also have strong positive impact.
- **AHI** observations have a clear positive impact in Darwin (**Fig 7**).

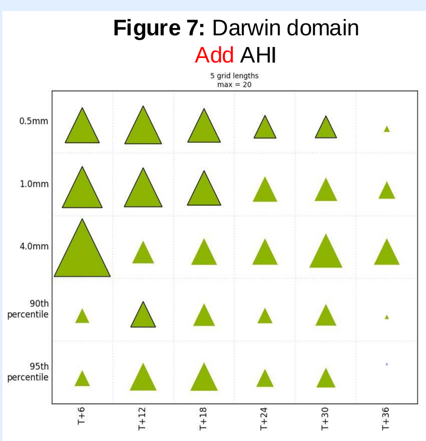












Figures 2 to 7: Δ Fractions skill score (FSS) for 6 hr precipitation accumulation on a neighbourhood size of 5 (~7.5 km)

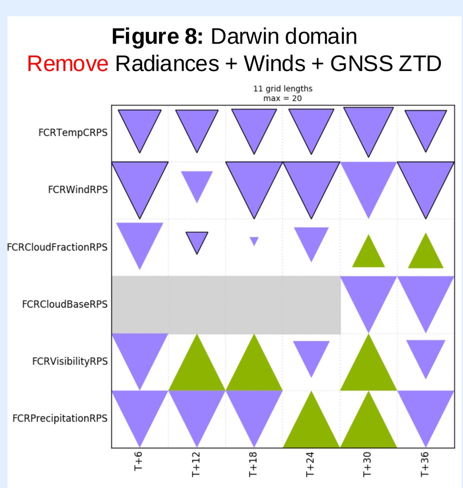
Figures 2 to 6 are for observation removal: A downward pointing blue arrow means the observations have positive impact.

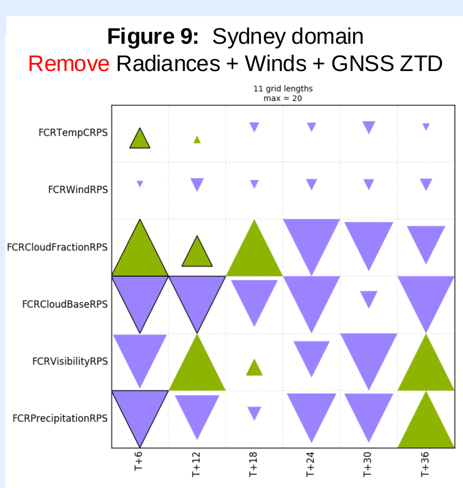
Figure 7 is for observation addition. An upward pointing green arrow means the observations have positive impact.

A bigger triangle means a bigger impact, and a bold border means the result is statistically significant

Continuous Ranked Probability Skill Score for Surface Weather:

- Impacts of removing satellite observations are mixed in both Darwin (**Fig 8**) and Sydney (**Fig 9**) but the pattern is rather different, with positive impacts on Temperature and Wind in Darwin, positive impacts on Cloud Base Height and Precipitation in Sydney. There is negative impact at short range for Cloud Fraction in Sydney
- Results are similarly variable for removing radiances and GNSS ZTD (not shown).

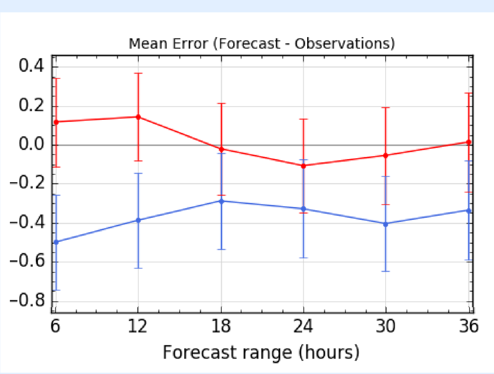




Figures 8 and 9 (left): CRPS for Surface Weather

A bigger triangle means a bigger impact, and a bold border means the result is statistically significant. Downwards blue arrows mean the observations have positive impact

Figure 10 (below): Mean error in Surface (1.5m) Relative Humidity. Red = Control, Blue = Remove GNSS ZTD



Surface Verification

- GNSS ZTD reduces the biases in surface field forecasts at all forecast ranges for relative humidity (**Fig 10**), temperature, mean sea level pressure and wind.

Upper Air Verification

- There are few radiosondes (especially in Darwin), so verification is not very reliable.
- There is an indication that radiances generally reduce RMSE and bias for temperature and humidity at all forecast ranges out to T+36 for the Sydney domain

5. Global Model Australian Region Impact Results

Average Root Mean Square Error Reduction

- We compared the RMSE of different forecast fields (PMSL, temperature, wind, geopotential height) at different forecast ranges against observations or analyses
- Here, we summarise the change in RMSE for observation denial experiments vs control, verified with ECMWF analyses
- The change in RMSE for variables and forecast ranges is averaged together to give one overall score.

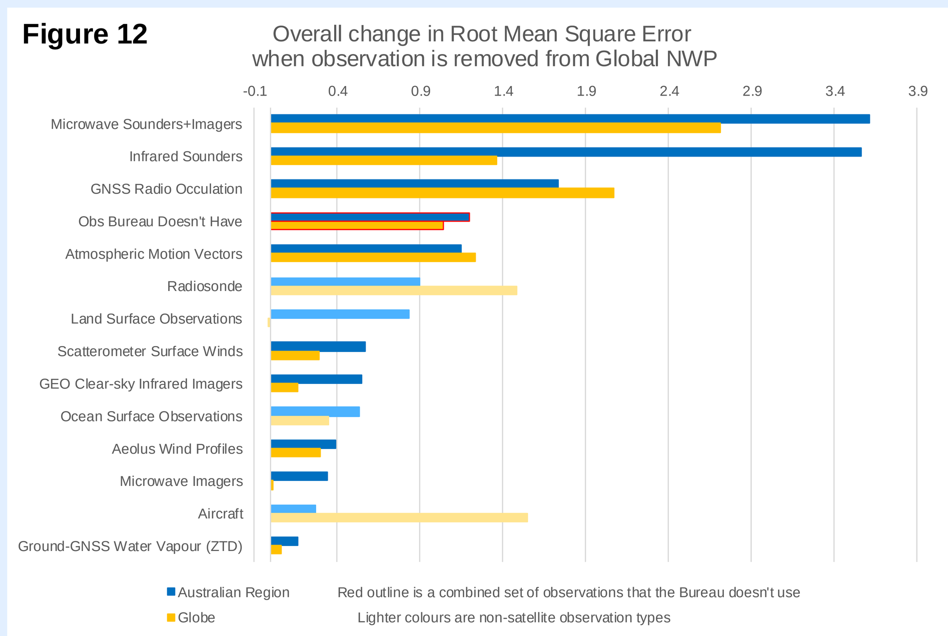


Figure 12: Average change in RMSE. Yellow bars show the average score across the whole globe, and blue bars are the score over the Australian region. Darker bars indicate satellite observations, lighter are non-satellite. The bars outlined in red are a bundle of observations that ACCESS-G does not yet assimilate.

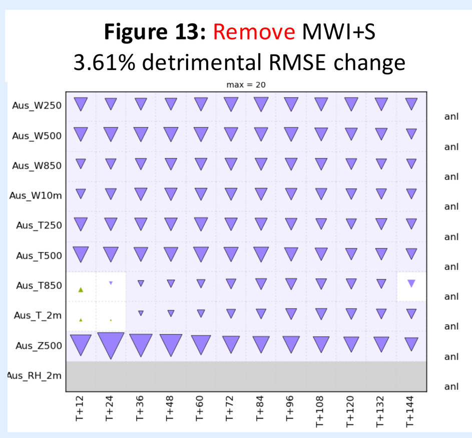


Figure 13: RMSE Scorecard for MW Sounders. Shows the change in RMSE for each variable and lead time from removing microwave sounder and imager observations.

Downward pointing purple arrows indicate that the observations have positive impact on forecast skill. Purple shading behind indicates a statistically significant result.

- The results for the Australian region are compared against those for the whole globe in **Fig 12**.
- **The most impactful observations** over Australia are microwave (MW) and infrared (IR) sounders, followed by GNSS-RO.
- **Fig 13** shows the scorecard for microwave sounders: the impact is **positive across all variables**
- Microwave instruments, infrared sounders and land surface observations have **more impact over the Australian region** than over the globe as a whole.
- Conversely, GNSS-RO, Sonde and Aircraft have more impact globally than over Australia.
- Observations missing in ACCESS-G account for as much impact as AMVs or Sondes, our 4th and 5th most impactful observation types.

How much forecast lead time can observations give us?

- Depends on the observation type and variable
- **Fig 14** considers the error in forecasts of 850 hPa temperature
- The error of a T+24 forecast without IR hyperspectral sounders is about the same as the error of the T+36 forecast from the control.
- This means that we lose 12 hours of forecast skill if we don't assimilate IR sounders

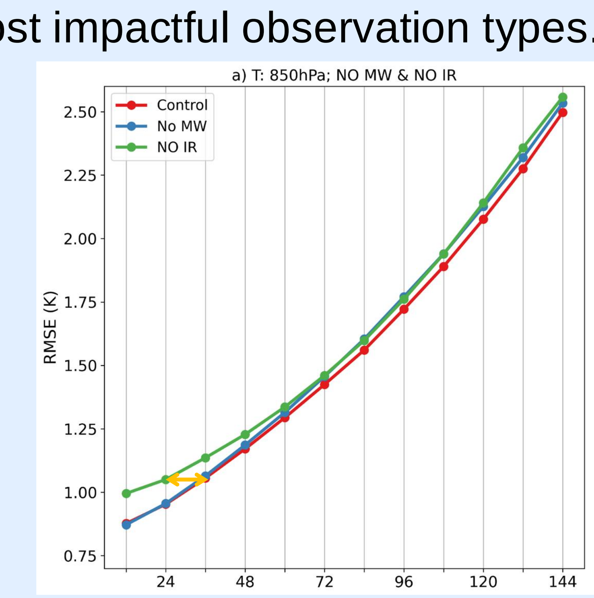


Figure 14: RMSE for Australian region 850hPa Temperature for MW and IR denials vs Control, verified against ECMWF analyses

5. Conclusions

- Satellite observations have a large direct impact on forecast skill in ACCESS-C that is seasonally and/or climatically variant, and is different in the two domains.
- In the global model, satellite observations have a larger impact on forecast skill for the Australian region than for the globe as a whole. Sounders and GNSS-RO are the most impactful.
- We should investigate the magnitude of the indirect impact of observations in ACCESS-G on the forecast skill of our high-resolution models.