Impact Assessment of Himawari-8 AHI radiance assimilation in the ACCESS-C model

The Bureau of Meteorology

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1 Introduction

- Clear-sky AHI radiances are currently assimilated in the Bureau's operational global Numerical Weather Prediction (NWP) system, but they are not used directly in the Bureau's limited area models (LAMs). These observations are high resolution with a rapid scan frequency. They can provide valuable information for the forecasting of quickly developing convective weather in hourly-cycling LAMs.
- This study examines the impact of assimilating full spatial resolution AHI in the Bureau's ACCESS-C LAMs.
- In addition, independent radiance bias-correction for ACCESS-C is tested in this study. We assessed the impact of applying VarBC (Variational Bias Correction) to ACCESS-C, compared with the current operational bias correction coefficients that come from the ACCESS-G global model. (These are labelled VarBC_C and VarBC_G respectively)

2 System Configuration and Methods

The Bureau's ACCESS NWP systems are based on the Met Office model.

- Global: ACCESS-G [6-hour cycle, 4 times per day]
- LAM: ACCESS-C [1-hour cycle, 24 times per day, over 7 regional domains]
- Study Area: Sydney domain, shown in blue in Figure 1 [1-2].

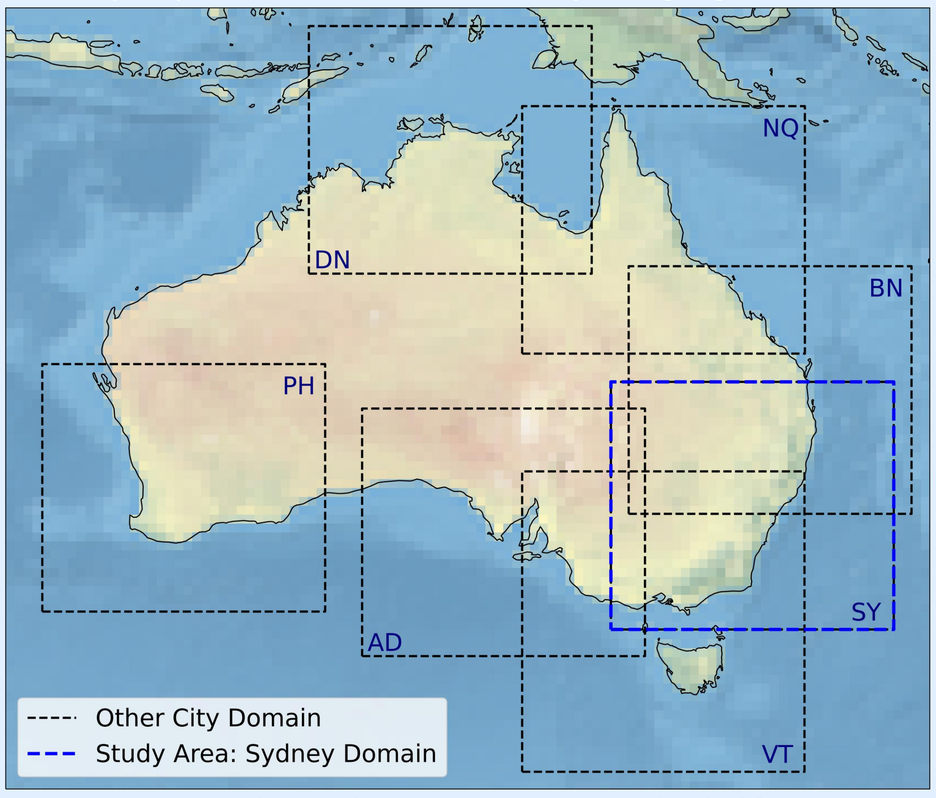

Figure 1: The Bureau ACCESS-C system domains [1].

Experiment details:

Experiment	Details
Control	All observations (conventional, radar, satellite) currently used operationally [1]
AHICSR_G	Control + AHICSR (clear-sky radiances) + VarBC_G
AHICSR_C	Control + AHICSR + VarBC_C
AHIASR_G	Control + AHICSR + AHIASR (all-sky radiances) + VarBC_G
AHIASR_C	Control + AHICSR + AHIASR + VarBC_C
Trial Period	1st Feb – 15th April 2020
DA System	4D-VAR [1]

3 AHI assimilation in ACCESS-C (Sydney)

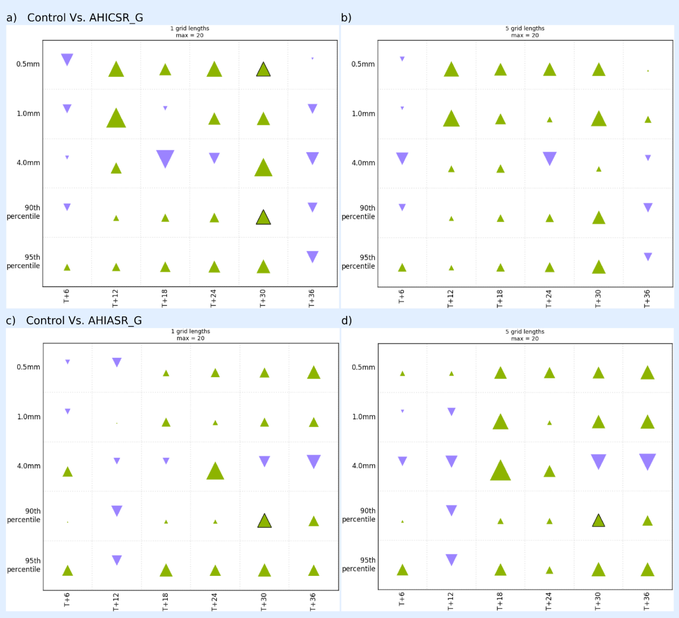

Figure 2: ΔFSS Hinton diagrams for 1-hr precipitation accumulation.

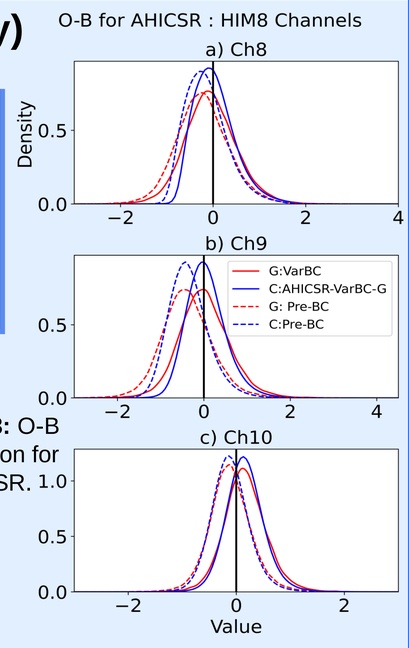

Figure 3: O-B distribution for AHICSR.

Verification Metrics:

- Improvements and degradations in ΔFSS are represented by green and purple triangles. The FSS indicated mixed impacts for adding AHI to ACCESS-C (Figure -2).
- Mean O-B reduced to near zero in most cases with VarBC_G. However, Ch10 looks positively biased after correction.

4 AHI with independent VarBC in LAM

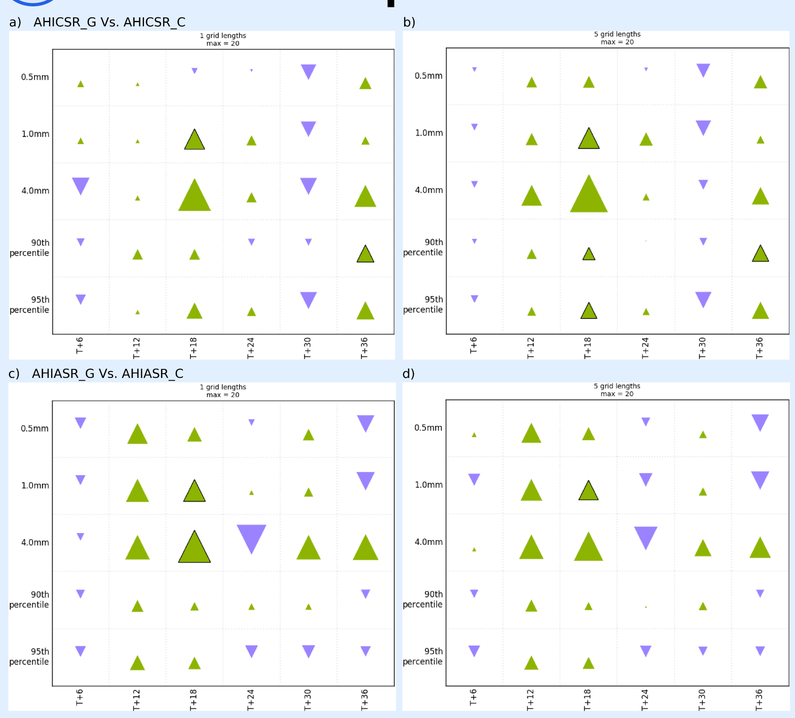

Figure 4: ΔFSS Hinton diagrams for 1-hr precipitation accumulation with VarBC-LAM.

- The ΔFSS in Figure 4 improves when applying independent VarBC.
- Significant improvement occurs at the T+12 forecast cycle for the AHIASR case.
- No significant change applying independent VarBC to other radiances (not shown).
- O-B distributions of AHICSR and AHIASR water vapour channels [ch8-ch10] are similar (Figure 5) with both schemes.

- Noticeable improvement in ch10 fit after independent VarBC, showing a smaller positive bias.

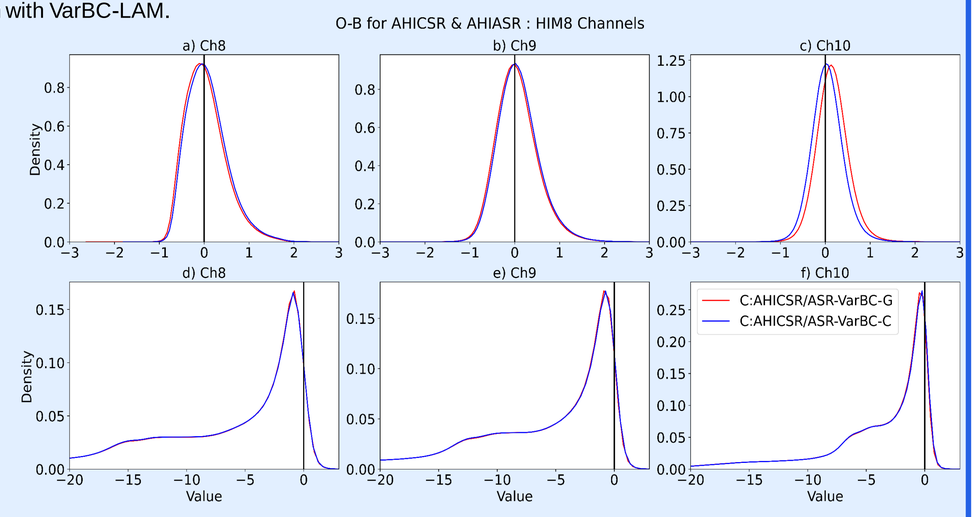

Figure 5: O-B distribution for AHICSR(a-c) and AHIASR (d-f) after VarBC_C

How well does VarBC in ACCESS-C work?

Channel	AHICSR Mean O-B		AHICSR U-Stat	AHIASR Mean O-B	
	AHICSR-G	AHICSR-C	AHICSR-G Vs. AHICSR-C	AHICSR-G	AHICSR-C
5	0.147	0.147	0.95	-6.98	-6.79
7	-0.068	-0.060	0.97	-7.51	-7.30
8	-0.044	-0.027	0.98	-7.50	-7.29
9	0.114	0.118	0.98	-6.47	-6.30
10	0.273	0.229	0.88	-3.46	-3.35

- For most channels, there is little significant difference in statistics for the trials, which suggests applying VarBC does not lead to a degradation in the model fit. However, there is a significant improvement for channel 10 observation bias in AHICSR.
- AHIASR biases are universally improved but by a relatively small amount compared to their large magnitude

Further O-B examination for AHIASR:

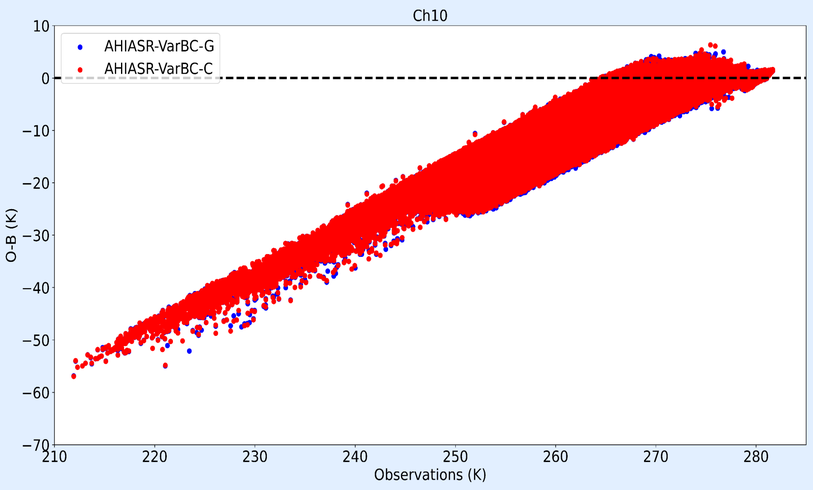

Figure 6: O-B plot over observations for Ch10 AHIASR.

- In Figure 6, Ch10 for AHIASR shows a negative skewed distribution and bias with both VarBC_G and VarBC_C; this result is consistent with the study in [3] for the global model. The bias in this case comes from the model representation of cloud, particularly ice cloud, or multilayer cloud. This bias is too large for assimilation of AHIASR Ch10.

5 Summary and future work

- Assimilation of AHICSR and AHIASR in ACCESS-C can give a small positive impact
- Independent bias correction is beneficial for AHICSR and AHIASR. The impact for other radiances (overall neutral) in ACCESS-C is described in more detail in [2].
- There is substantial negative bias for most channels in AHIASR. This is because model cloud properties are inconsistent with observations. For this reason, only the highest peaking temperature channel (Ch2) is assimilated.
- A hybrid VarBC scheme (active for AHI radiance data but not others) may give the best outcome.
- Optimal density of AHI observation use is being tested and analysed.

Plain Language Summary:

Satellite data are essential for NWP operation and account for more than 70% of the impact of data assimilation on forecast skill. Using more high-resolution, high-frequency satellite data can deliver further improvement at both global and regional scales. In this study we add high-resolution Himawari-8 satellite data to Bureau regional models and assess their impact on the forecast. Further, we investigate the use of a self-determining bias correction scheme with these models to account for biases in the observations that restrict their use. The real-time bias correction approach is used for the global system, but there are still open questions regarding its use in the regional system. Overall, our investigations exhibited a small positive forecast impact from the addition of Himawari radiances together with regional bias correction.

Acknowledgements and References:

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[1] Rennie, S., Cooper, S., Steinle, P., Dietachmayer, G., Krysta, M., Franklin, C., Bridge, C., Marshall, M., Xiao, Y. and Sgarbossa, D., 2022. ACCESS-C: Australian Convective-Scale NWP with Hourly 4D-Var Data Assimilation. Weather and Forecasting.

[2] Samrat, N.H., Smith, F., Lee, J., Smith, A., 2022, Testing variational bias correction of satellite radiance data in the ACCESS-C: Australian Convective-Scale NWP system, Sensors

[3] Okamoto, K., Hayashi, M., Hashino, T., Nakagawa, M. and Okuyama, A., 2021. Examination of all-sky infrared radiance simulation of Himawari-8 for global data assimilation and model verification. Quarterly Journal of the Royal Meteorological Society, 147(740), pp.3611-3627.