Evaluation of visible satellite images from AROME-Austria as preparation for assimilating visible observations

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OmB departures statistics show that the RTTOV operator can simulate the clear-sky visible observations well, except in the alpine region above about 2 km where orographic shadowing is substantial and snow-surface albedo is often misrepresented, and when the solar zenith angle (SZA) exceeds 75°.

1. Context and research questions

The assimilation of visible satellite radiances offers great potential to improve cloud and precipitation initialization in regional NWP models. However, systematic discrepancies between satellite observations and model-based simulations remain a key challenge (a).

Model state - x ➡ Observation operator - H ➡ Simulated H(x) ⟺ Observed Y

(a)

This study evaluates the observation minus background (OmB) departures of the SEVIRI visible 0.6 µm channel to mitigate systematic discrepancies, as a first step toward assimilating all-sky visible observations into AROME-Austria, the operational regional model at the Austrian weather service Geosphere Austria.

We try to answer the following:

1) Which pixels are affected by orographic shadowing in the AROME-Austria domain?

2) Does RTTOV version 13 yield better simulations than RTTOV 12—the current version used by the model?

3) Can we assimilate the visible 0.6 µm channel under all-sky conditions using model-based simulations?

2. Clear-sky comparisons of simulations (RTTOV versions 12&13) and observation SEVIRI 0.6 µm on MSG-3

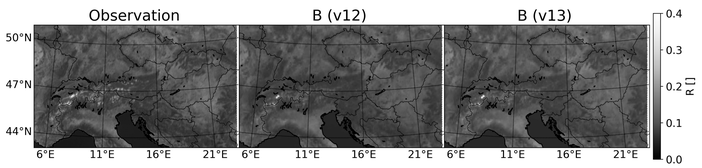
Method to derive clear-sky reflectance (R)

- $R_{\text{clear-sky, target}}(\text{location, time}) = min_{day\ \epsilon D}(R_{\text{all-sky, target}}(\text{location, time, } day))$
- Where target refers to either satellite observations (O) or model background (B) simulations; And D is the test period.

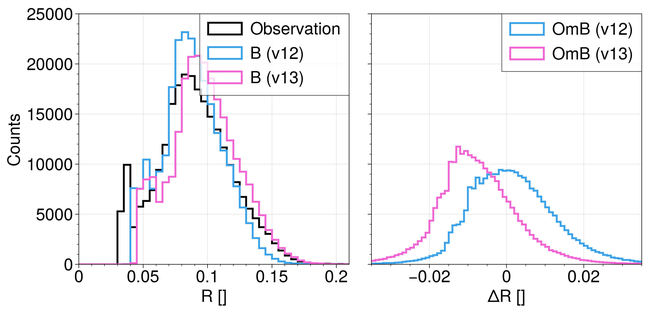
We see that:

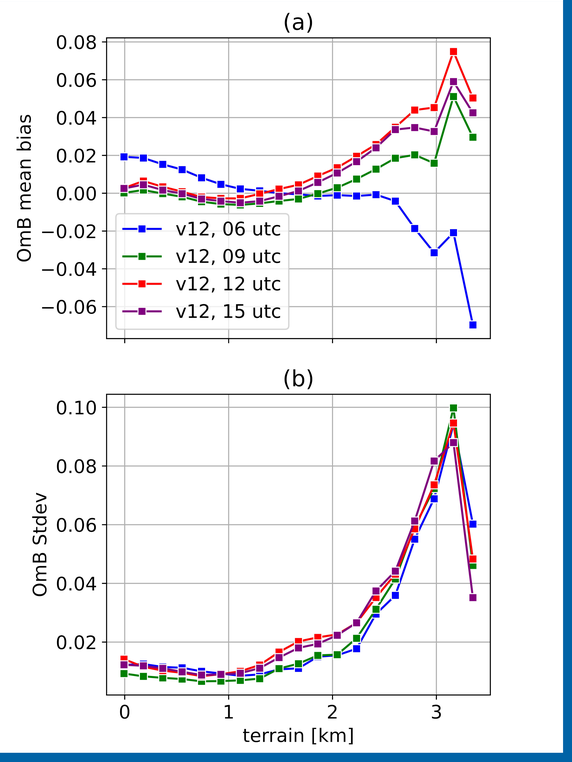
- RTTOV (v13) always produces higher reflectance than (v12).

Clear-sky, 1-31 August 2023 at 12 UTC



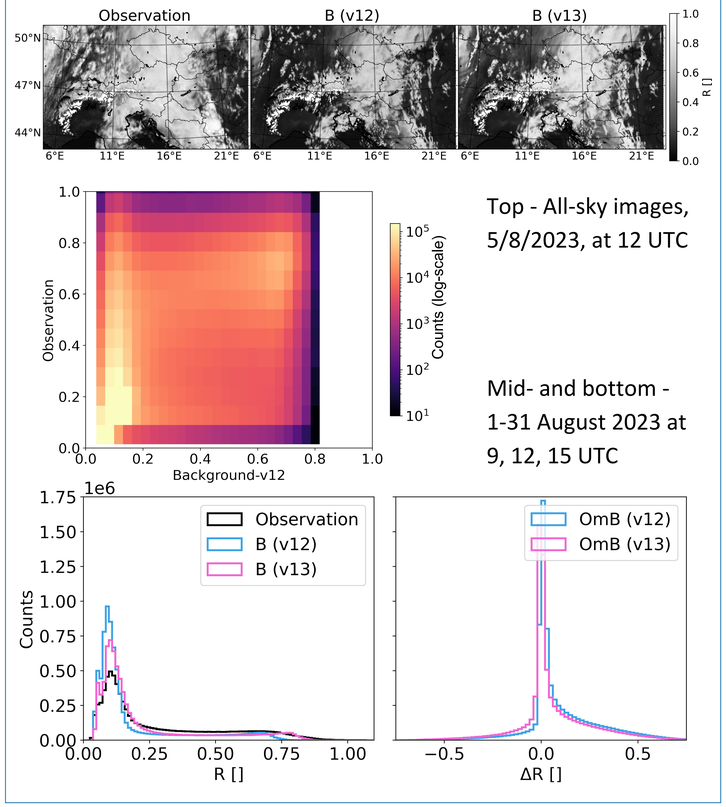
1-31 August 2023 at 9, 12, 15 UTC





3. Evaluation of all-sky deviations

- RTTOV (v13) yields 15.09% reduction in pixels darker than 0.15 and an increase of almost 0.1 for cloudy pixels due to improvements in the multiple Rayleigh scattering scheme (Saunders et al., 2020).
- The OmB departures distributions are non-Gaussian; Using a reflectance-based varying observation error doesn't mitigate this issue. (**Not shown**)
- Superobbing helps reduce extreme OmB for high observed reflectances. (**Not shown**)



Top - All-sky images, 5/8/2023, at 12 UTC

Mid- and bottom - 1-31 August 2023 at 9, 12, 15 UTC

4. Take home messages

- Orographic shadowing and misrepresented snow-surface affect pixels above about 2 km, that are 2.24% of the model domain.
- RTTOV (v13) yields simulations closer to the observations than (v12).
- It's still challenging to assimilate the 0.6 µm visible channel in the AROME-Austria model due to: (1) large discrepancies for mid-range reflectances, and (2) non-Gaussian error distributions, which remain unresolved even with a dynamic error model.

5. References

Saunders, R., Hocking, J., Turner, E., Rayer, P., Rundle, D., Matricardi, M., Geer, A., Lupu, C., Vidot, J., Roquet, P., & Brunel, P. (2020). RTTOV-13 science and validation report (tech. rep. No. NWPSAF-MO-TV-046). EUMETSAT NWP SAF. https : / / nwp - saf .eumetsat.int/site/download/documentation/rtm/docs_rttov13/rttov13_svr.pdf 605