EUMETSAT NWP SAF

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and Water Management

Towards a full exploitation of satellite radiance information using transformed retrievals in HARMONIE-AROME 4D-Var

Erik Dedding [1], Isabel Monteiro [1], Stefano Migliorini [2], Siebren de Haan [1]. Contact: erik.dedding@knmi.nl

With forthcoming satellites expected to add thousands of channels of infrared and microwave sounder data, assimilation of Transformed Retrievals (TRs) can attain equivalent results compared to direct assimilation of radiances, while also offering compression of the information content. A collaborative effort between NWP-SAF (Met Office) and KNMI is initiated to implement TRs into HARMONIE-AROME 4D-Var, corroborating the benefits in a different NWP-system and validating their equivalence. TRs from Infrared Atmospheric Sounding Interferometer (IASI) radiances have been generated using existing software at the Met Office and are assimilated into the local area model HARMONIE-AROME using 4D-Var. Impact on analysis increments from TRs and direct assimilation of radiances are compared using a domain covering the Netherlands.

Transformed retrievals

The dataset generated by **Levens and Migliorini (2024)** with transformed retrievals, computed from atmospheric retrievals of IASI, is used for this study. The TRs, consisting of at most 140 components, are assimilated in the HARMONIE-AROME limited area model with identity observation error correlations through the cost function:

$$J(\mathbf{x}) = \frac{1}{2}\left(\mathbf{x}-\mathbf{x}^{\mathbf{b}}\right)^{\mathrm{T}}\mathbf{B}^{-1}\left(\mathbf{x}-\mathbf{x}^{\mathbf{b}}\right) + \frac{1}{2}\left(\mathbf{y}'_{\mathrm{ret}}-\mathbf{H}'_{\mathrm{ret}}\mathbf{x}\right)^{\mathrm{T}}\left(\mathbf{y}'_{\mathrm{ret}}-\mathbf{H}'_{\mathrm{ret}}\mathbf{x}\right) \quad (1)$$

The information content of the TR-components is characterised through the degree of freedom for signal (DFS). DFS weighting functions are shown for a single observation in figure 1 indicating the sensitivity of TR-components to temperature and humidity in the atmosphere.

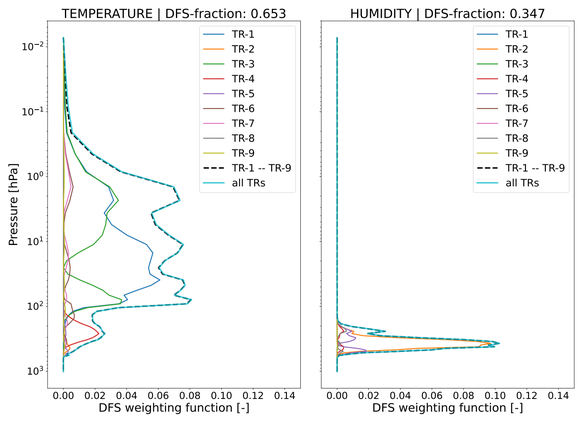

Figure 1: *The degree of freedom signal weighting function is plotted for the (left) temperature and (right) humidity. The first nine TR-components are displayed along with the summed weighting function for the first nine components and all components together.*

Assimilation in HARMONIE-AROME

The HARMONIE-AROME limited area model (LAM) is applied to the Netherlands domain shown in figure 2. A log-linear interpolation from the global model -with a top at around 80km represented by 70 levels- to the LAM -with a top at around 40km represented by 90 levels- has been applied. Consequentially, the top 14 levels in the global model are represented by only a single level in the LAM. The dataset used observations from Metop-B and Metop-C during December 2019. Data is available at around 10 UTC and 22 UTC in the Netherlands domain and are assimilated with 4D-Var.

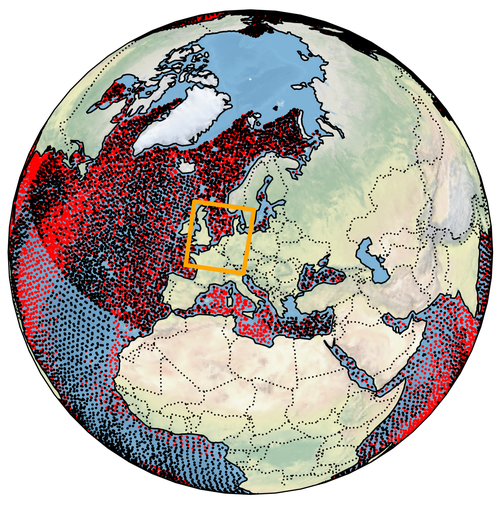

Figure 2: *Map showing the limited area model in orange. Observations from Metop-B and Metop-C are shown in black and red, respectively, for a full day. Note that between 30°S and 30°N, the thinning radius used by the Met Office is larger.*

[1] *Royal Netherlands Meteorological Institute (KNMI), PO Box 201, 3730 AE De Bilt, The Netherlands.* [2] *Met Office, FitzRoy Road, Exeter, Devon, EX1 3PB, United Kingdom.*

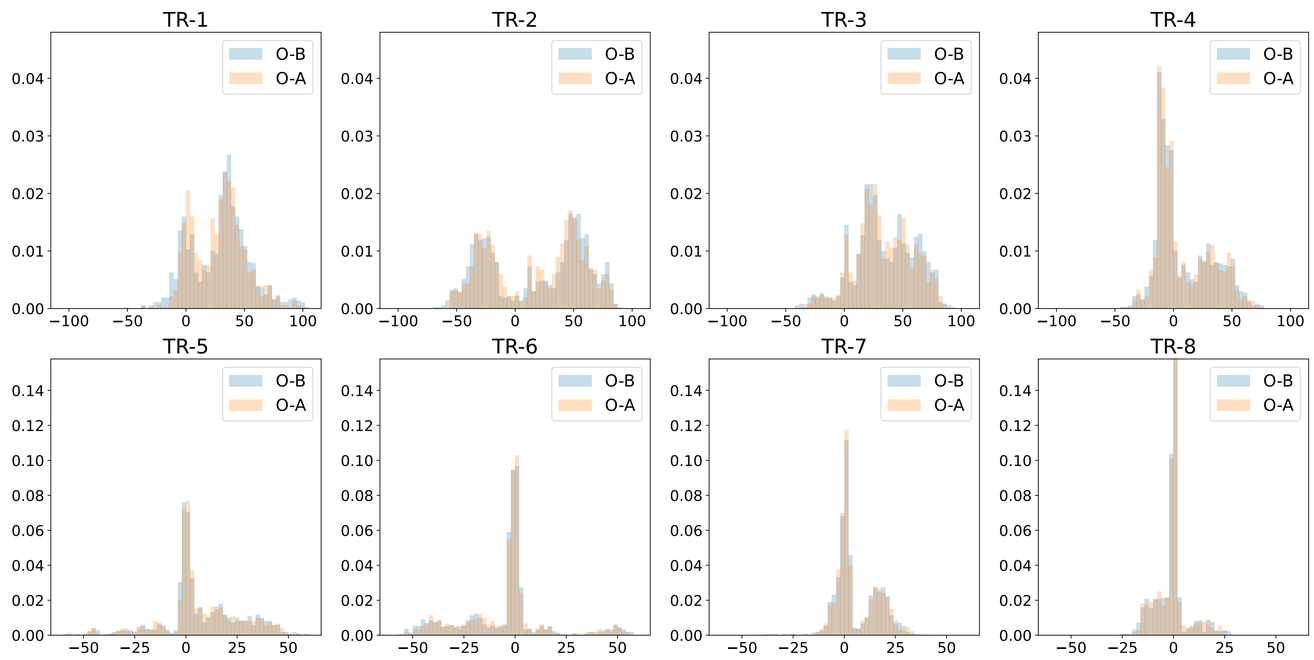

Figure 3: *Histograms showing first guess and analysis departures over approximately four days containing 1059 observations. As this is ongoing work, data has so far been collected during spin-up of the system only.*

Preliminary results

Dual biases

Histograms of the first guess and analysis departures are shown in figure 3. Notwithstanding the spin-up time, there is an indication of a double bias, which may be due to the grouping of TRs from Metop-B and Metop-C.

Transformed retrieval impact

The root mean square increments for two cycles with and without TRs are shown in figure 4. These indicate the effect of TR assimilation over the atmospheric profile, injecting significant temperature and humidity information compared to only conventional observations. Much of the top level signal does not impact the increments as would have been expected from figure 1, likely due to the LAM's lower model top. 2D-field plots of the increments are shown in figures 5 & 6 with observations shown in white.

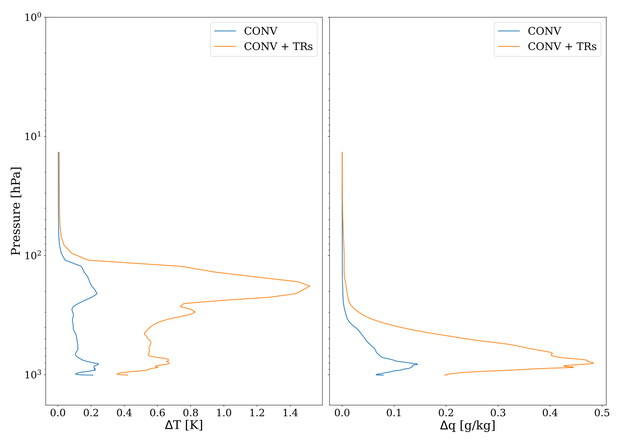

Figure 4: *Root mean squared increments versus pressure of (left) temperature and (right) humidity. The "CONV" graph is of a single cycle from 16-19UTC which only contained conventional observations. The "CONV + TRs" graph uses increments of a cycle six hours earlier from 10-13UTC which contained transformed retrieval and conventional observations.*

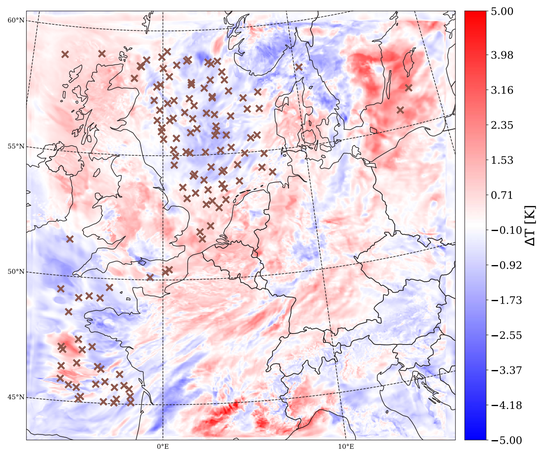

Figure 5: *Analysis increments of temperature (level 65; 880 hPa) for a single cycle with all TR-observations used during assimilation marked by brown crosses.*

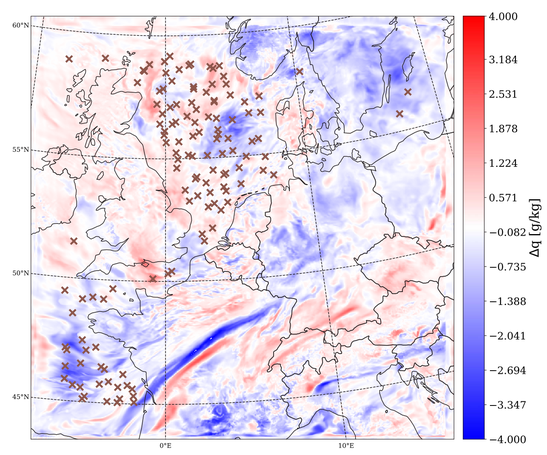

Figure 6: *Analysis increments of humidity (level 65; 880 hPa) for a single cycle with all TR-observations used during assimilation marked by brown crosses.*

Conclusions and next steps

The TRs have been (and are being) assimilated in the HARMONIE-AROME LAM. There are indications of double biases in the TRs, potentially coming from grouping of Metop-B and Metop-C observations. Analysis increments show the injection of additional temperature and humidity information from TRs into the system, though only near the surface due to the LAM's lower model top.

Moving forward, the TRs from Metop-B and Metop-C will be assimilated separately and biases in the HARMONIE-AROME model will be corrected. The TRs will also be grouped so that each group is calculated from the same set of radiance channels, as differences in the choice of used channels can affect the sensitivity to temperature and humidity of given TR-components. Further, a non-identity observation error covariance matrix will be estimated as to partially account for the differing systematic observation error and prior information. Lastly, the system shall be run with a warm spin-up and compared against direct assimilation of radiances.

References

Levens, P.J. & Migliorini, S. (2024) Assimilation of Transformed Retrievals from IASI radiances versus direct assimilation of IASI radiances at the Met Office. *Quarterly Journal of the Royal Meteorological Society*, 150(763), 3601–3622.