The MTG-IRS Level 2 Processor: Assimilation in regional scale NWP

Stephen Tjemkes, P. Antonelli, S. de Haan, & R. Stuhlmann

Contact:stephen.tjemkes@eumetsat.int

Background

For the generation of level 2 products from MTG-IRS observations a processor is needed. The high level processing functionality are documented in an ATBD. The processor generates level 2 products for different operational applications. One of these potential application is the assimilation of level 2 information in a regional scale weather prediction model.

Problem

Direct assimilation is not desirable because of error propagation. The MTG-IRS level 2 processor will rely on ECMWF background information and hence the level 2 products will have. Therefore normally level 1 information is assimilated. However level 1 assimilation has its own limitations especially for regional scale systems, which is the one of the target user groups for geostationary observations. A method has been developed by [Migliorini, 2012], in which he shows that assimilation of level 1 data and level 2 products can be equivalent under certain conditions. This method is explored here in two case studies to demonstrate the relative merits of this method. One study is using the WRF model over Hawaii (consortium lead by P. Antonelli) and the other is using HARMONIE (Study team at KNMI, lead by S. de Haan) over Europe. These two studies are complementary, as they consider two different regions with different surface conditions (sea and land) and also different number of alternative observations (e.g. radiosonde / GPS / AMDAR).

Scaled Projected State

The projection of the L2 products for data assimilation is based on a SVD of the scaled jacobian matrix ($\hat{\mathbf{S}}_s = \mathbf{S}_o^{-1/2}\hat{\mathbf{K}}\mathbf{S}_a^{1/2} = \mathbf{U}\mathbf{\Lambda}\mathbf{V}^T$). Using this it can be shown that the retrieved state is linear combination of true state and the background information [Grieco et al., 2007, e.g.]:

$$\hat{\mathbf{x}} = \hat{\mathbf{\Lambda}}^T\left(\hat{\mathbf{\Lambda}}\hat{\mathbf{\Lambda}}^T + \mathbf{I}\right)^{-1}\hat{\mathbf{\Lambda}}\mathbf{x} + \left(\hat{\mathbf{\Lambda}}\hat{\mathbf{\Lambda}}^T + \mathbf{I}\right)^{-1}\mathbf{x}_b + \hat{\mathbf{\Lambda}}^T\left(\hat{\mathbf{\Lambda}}\hat{\mathbf{\Lambda}}^T + \mathbf{I}\right)^{-1}\epsilon'. \quad (1)$$

If only the eigenvectors with eigenvalue > 1, the contribution to the retrieved state $\hat{\mathbf{x}}$ can be minimized. This is used to generate a scaled projected state, which together with an observation operator is being provided to data assimilation applications. The projected observations $\mathbf{y}'_{ret}$ can be defined as :

$$\mathbf{y}'_{ret} = \left(\hat{\mathbf{\Lambda}}\hat{\mathbf{\Lambda}}^T + \mathbf{I}\right)\hat{\mathbf{\Lambda}}^{-T}\hat{\mathbf{V}}^{-1}\mathbf{S}_a^{-1/2}\mathbf{y}_{ret}. \quad (2)$$

And a linear relation between the projected observation ($\mathbf{y}'_{ret}$) and the true state $\mathbf{x}$ follows from this. The operator to project the true state onto the observation is named by Migliorini [2012] $\mathbf{H}'_{ret}$ and is given by:

$$\mathbf{H}'_{ret} = \hat{\mathbf{\Lambda}}\hat{\mathbf{V}}^T\mathbf{S}_a^{-1/2}. \quad (3)$$

The scaled projected state distributed to the users consists of two elements as indicated above, namely the state which is referred to as y'_{ret} and the observation operator referred to as H'_{ret}. Though the state is relatively small, the observation operator can be large. Note that for the method not all state vector elements needs to be consider. Only those elements which are part of the assimilation system are considered (e.g. T(p), q(p)).

Current status and next steps

Currently the study concentrate on the response of the system after assimilation of a single scaled projected state (see next blocks). Results seems to be very positive. For the next steps a more complete assimilation experiment is foreseen where all observations collected over the three week period are used. It will also be interesting to see when additional observations (e.g. radiosonde or GPS) are assimilated at the same time. Note that here concentrate on results of KNMI study, results by the second team are very similar.

Domain and retrieval method

The data has been generated from IASI observations using the MTG-IRS L2VDP. The Product Generation module embedded in the L2VDP is a basic 1DVAR routine based on the Optimal Estimation theory described by Rodgers [2000]. The state vector consists of $\mathbf{x} = (\mathbf{T}, \log(\mathbf{q}), \log(\mathbf{O_3}), T_s, logit(\epsilon))^T$. Background information is extracted from the ECMWF deterministic model for the state and from the ensemble system for the associated covariances [Hólm and Kral, 2012]. This information is currently available on 137 hybrid sigma coordinates but only twice per day. The radiative transfer code adopted is the Optimal Spectral Sampling described by Moncet et al. [2008]. The minimization is a standard Marquardt-Levenberg minimization, and convergence criterion is based on state, if change in state is smaller than uncertainty of the state, the iterative process is stopped.

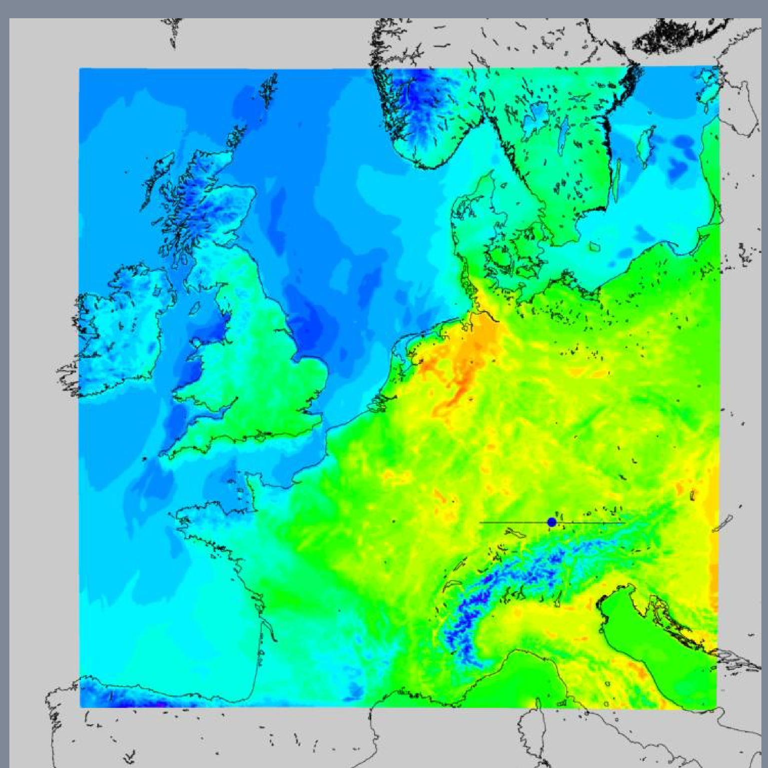
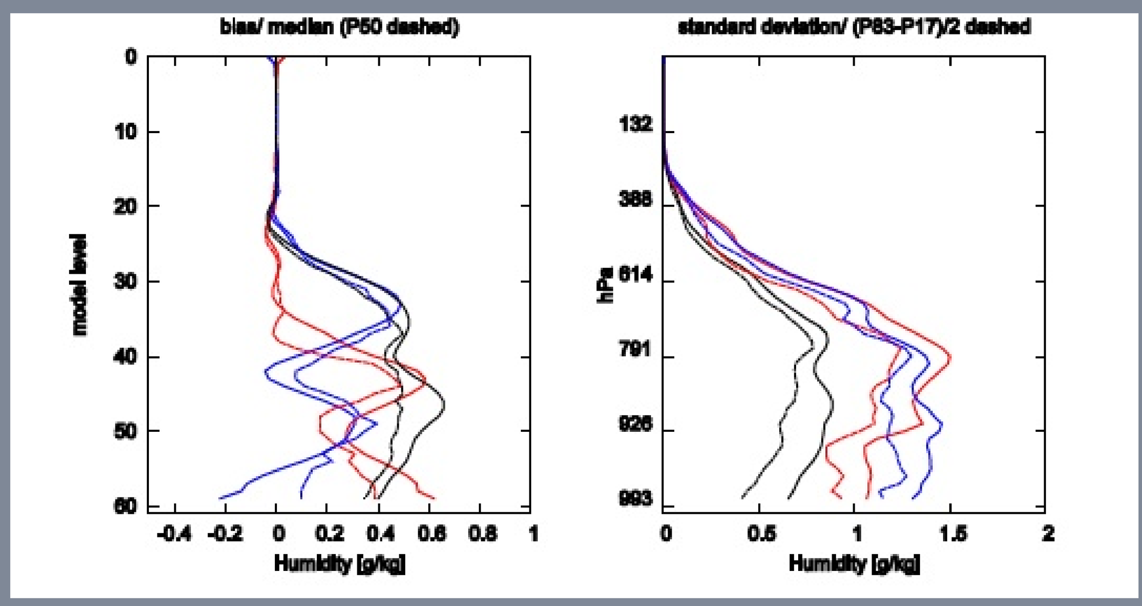


Fig. 1: Harmonie Domain

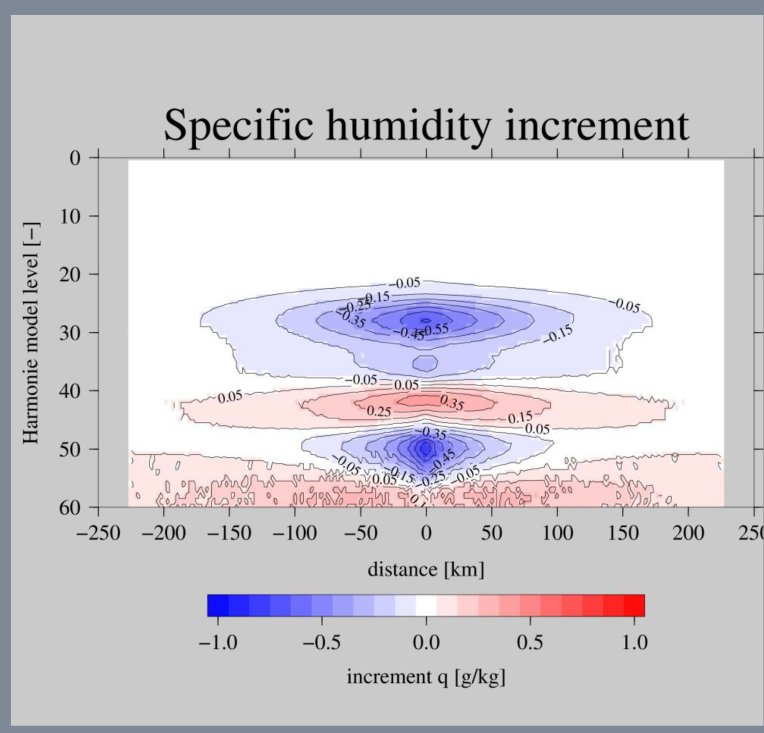
Step 1: Validation

Prior to the assimilation experiment the accuracy of the level 2 products (so prior to transformation) in comparison to the HARMONIE results. An example is shown here where retrieved moisture is compared to harmonie (blue) also shown is retrieved moisture compared to ecmwf (black) and ecmwf compared to harmonie (red), shown are bias (left) and rms (right). Although some bias between Harmonie and the retrievals have been found, the accuracy is considered good enough to start the assimilation experiment.



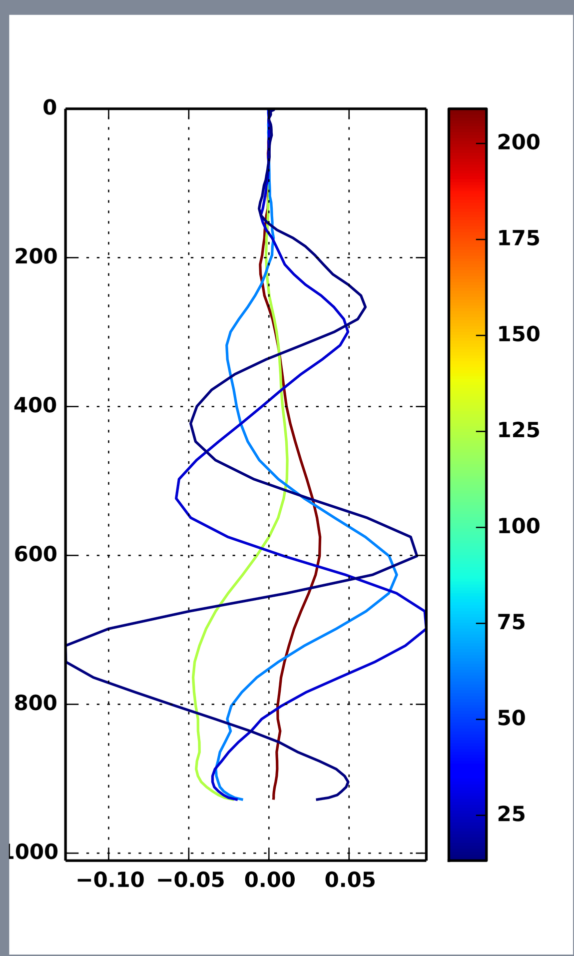
Step 2: Single Profile assimilation

The second step towards assimilation of the entire dataset is the assimilation of a single level 2 product derived from IASI observations. The location of the IASI FOV used for this is located by the dot in figure 1. Shown is a cross section of the moisture increment after assimilation of a single state vector consisting of temperature and humidity profile. Shown is that the increments have a horizontal extend of 200 km. This will be compared to the increments after assimilation of the collocated radiosonde.



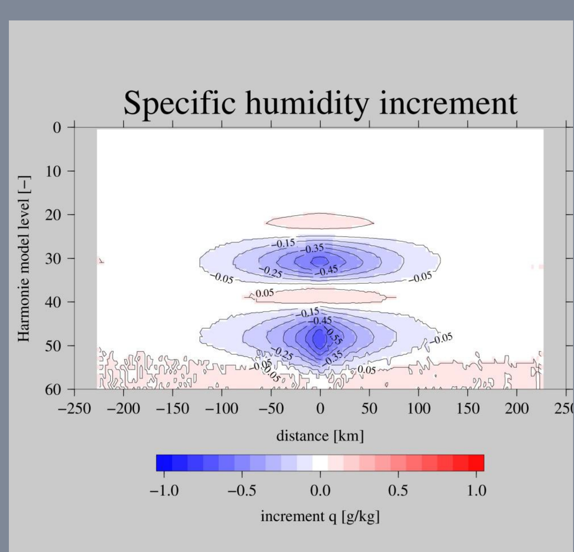
Step 3: Scaled Projected State

It is important to realize that the scaled projected state does not need to be generated from the full state vector. Only those elements of the state vector are used which can be assimilated by the system. This means that we extract the T(p) and q(p) elements from $\hat{\mathbf{x}}$ and project that into the new space using the transformation described above. Of interest is to see where the information contained in the scaled projected state originates from. This is shown in the figure where the first eigenvectors of the projection are shown. This shows that the information is extracted from the lower levels of the troposphere which is a desired feature.



Step 4: Scaled Projected State assimilation

Finally a single scaled projected state is assimilated. Shown is the q-increment after assimilation of a single projected state. Shown is a similar structure as above, but the amplitude is smaller. Also it appears that the horizontal extend of the increments is smaller. A clear response of the system near the surface is visible, which is a desired feature as a key mission objective of MTG-IRS is to monitor the low level moisture.



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