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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Updates of radiance forward modelling in the global DWD system

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This poster presents recent updates in the implementation and use of RTTOV in the DWD system.
It is well known that some satellite instruments used in NWP are affected by trace gases and that RTTOV offers the option to supply individual trace gas profiles. We implemented the use of realistic, actual O_3 profiles in the DWD system. For this purpose we use ECMWF O3 analyses and forecast fields interpolated to the observation positions. The use of these profiles for IASI has a striking positive impact. Experiments with more realistic CO_2 profiles are ongoing.

With the release of RTTOV-13 a new version of optical depth predictors was made available. Results of tests and experiments with these new RTTOV-13 predictors in the DWD assimilation system are presented. We started to use these predictors operationally in January 2023.
During the testing of the new predictors we faced some problems with the convergence of the assimilation algorithm. These problems are explained and a workaround is presented. The root of this problem is not unique to RTTOV-13 predictors.

1. Current O_3 in RTTOV

At the ITSC-22 in Saint-Sauveur several results were presented, that demonstrated the crucial impact of accurate O_3 onto radiance forward modeling and radiance impact in NWP systems. Since O_3 is not a prognostic variable in the DWD system, we decided to use operational ECMWF O_3 forecasts and analyses. We implemented options to read trace gas forecast/analysis fields from various external sources and to interpolate these to the radiance observation positions. It is either possible to use current trace gas fields or a seasonally varying climatology. Fig. 1 shows obs-fg statistics for IASI with current O_3 fields from ECMWF.

Impact of current O3 onto IASI

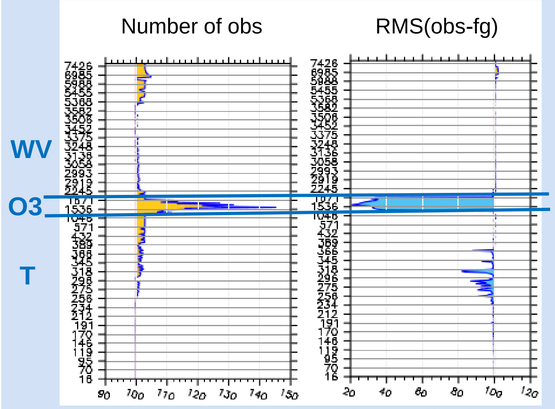

*Figure 1a: Impact of current O3 onto **all** IASI channels used in the NWP system.*

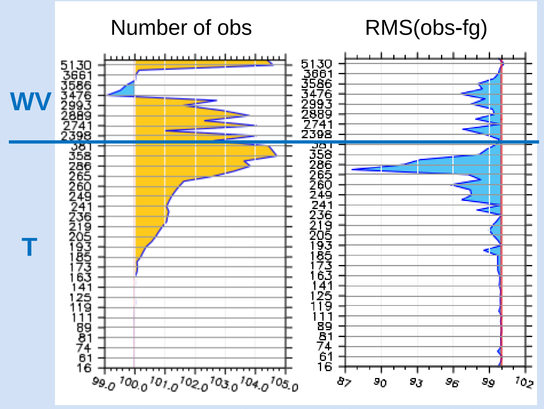

*Figure 1b: Impact of current O3 onto **assimilated** IASI channels.*

Statistics are based on 6 weeks of assimilation. In both figures the left plot is the relative change in the number of observations that passed all quality control checks – in particular the first guess check, i.e. yellow colours are good. The right plot(s) are the relative change in rms(obs-fg), i.e. blue colours are good.

The massive improvement in the O_3 band (which is not assimilated) in Fig. 1a is not surprising and should be considered as a technical test. However, Fig. 1b shows also a drastic positive impact for some assimilated channels: 12% decrease in rms(o-f) with an increase of 3% in data numbers for some low peaking channels in the T-band is striking compared to most other NWP system updates. A very positive impact is also present in obs-fg statistics of other observation systems like radiosondes (not shown).
Also the impact onto forecast verification scores shown in Fig. 2 is distinctly positive. This update was made operational at 11th May 2022.
We also ran experiments with CO_2 climatologies from CAMS. However, the results are currently mixed and further work is required.

Impact of current O_3 for IASI onto forecast verification

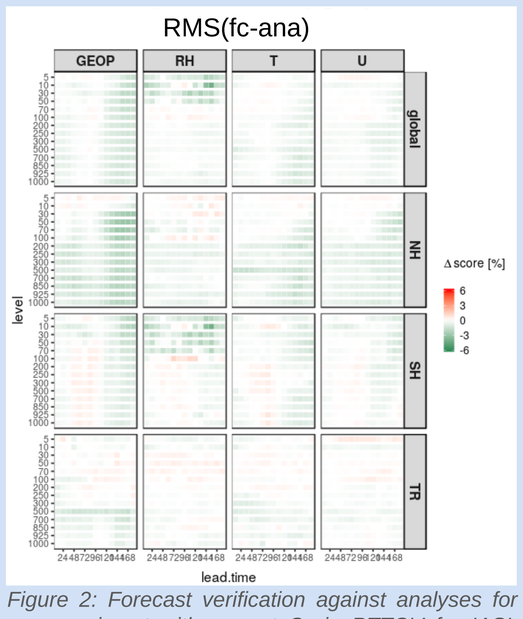

Figure 2: Forecast verification against analyses for an experiment with current O_3 in RTTOV for IASI. Displayed are relative differences of rms(fc-ana) between experiment and control run, i.e. negative/positive values (green/red) indicate improved/degraded forecasts. Results are based on a 3-month summer period in 2021.

2. RTTOV13

RTTOV13 was released in November 2020. It includes new gas optical depth coefficients based on updated spectroscopy and new optical depth predictors (see e.g. Hocking et al 2021). DWD implementation works started in autumn 2020, with RTTOV13 becoming operational in March 2022 and the new coefficients in January 2023. The delay between RTTOV13 release and operational use at DWD was due to convergence issues as our minimization is iterated to full convergence. We have to apply a so-called ”optical depth smoothing“ within RTTOV, which is sketched in Fig. 3:

Optical depth clipping in RTTOV (and workaround)

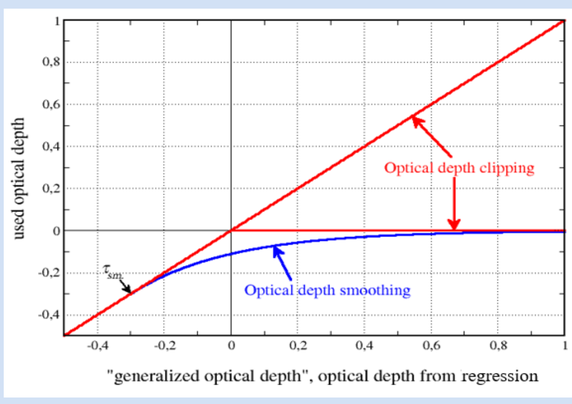

Figure 3: Sketch of the optical depth clipping in RTTOV (red) and of the DWD workaround, that replaces the clipping with a smooth transition towards zero (blue). Please note that physically meaningful optical depths are negative in this sketch. The x-axis is the optical depth resulting from the regression, which might become positive. The y-axis is the effectively used optical depth. The optical depth smoothing threshold τ_{sm} has to be tuned for each layer and each channel. This is necessary for all channels with significant water vapor sensitivity.
This is crucial for systems with many outer loops, that try to converge. For typical 4dvar systems with few outer loops the optical depth clipping is not a problem.

- Optical depths with the wrong sign are set to zero within RTTOV (optical depth clipping, red in fig. 3)
- This results in edges in the cost function that is minimized by the assimilation algorithm. These edges prevent the minimization algorithm from converging.
- Solution: replace the clipping with a smooth transition (blue in fig.3)
- The parameters τ_{sm} for this „optical depth smoothing“ had to be retuned for RTTOV13, which is extremely time-consuming.

Please note, that this problem is not new in RTTOV13. However, in RTTOV13.1 the optical depth clipping is additionally applied to the optical depth contribution of each individual gas. This problem cannot be reasonably tackled with our ”optical depth smoothing“ approach. Thus, we removed the optical depth clipping for individual gas contributions. In RTTOV 13.2 a switch for this additional clipping was implemented.
The switch to RTTOV13 has a neutral impact onto forecast verification scores and obs-fg statistics. There are some small positive hints (e.g. consistency of the system, smaller obs. biases). However, it is not clear whether this can be attributed to RTTOV13 itself or the accompanying spinup of new appropriate bias corrections.

3. Conclusions

- Current O_3 in RTTOV for IASI significantly improves forecast scores.
- The update to RTTOV13 has a neutral impact. It was connected with major convergence issues in the DWD EnVar system.

- James Hocking, Jérôme Vidot, Pascal Brunel, Pascale Roquet, Bruna Silveira, Emma Turner and Christina Lupu: A new gas absorption optical depth parameterization for RTTOV version 13, Geosci. Model Dev., 14, 2899-2915, 2021, https://doi.org/10.5194/gmd-14-2899-2021

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