Evaluation of the radiative transfer model RTTOV-12 at ECMWF

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1. Introduction

This study summarises the evaluation of the very latest release of the radiative transfer model RTTOV-12 (*Saunders et al., 2017; Hocking et al., 2017*) for use in the assimilation system at ECMWF. The evaluation is performed through comparisons of radiative transfer simulations with RTTOV-11 and through an analysis of departure characteristics against observations. The impact on forecasts is also investigated through a series of assimilation experiments.

RTTOV v12.1 with updated microwave (MW) surface emissivity models and new NWP-SAF MW coefficients have been included in cycle 45r1 of the IFS configuration. The features of RTTOV-12, in terms of direct relevance to the operational use at ECMWF include:

- A major review of the microwave (MW) line-by-line code AMSUTRAN.
- The use of FASTEM-6 surface emissivity model over ocean for all microwave sensors and an updated TELSEM2 atlas over land, which includes emissivities for snow and sea-ice.
- A new set of MW coefficient files which better describe the half width of the 183 GHz water vapour line and its temperature dependency and with updated values for the oxygen line parameters. An initialisation bug was also corrected in the line-by-line code that affect sensors that have channels influenced by the 184 GHz ozone line.
- IFS specific changes: no more γ-correction for optical depths for AMSU-A channels 5-8 on NOAA-15, NOAA-18 and Aqua (*Lupu et al.,* 2016);
- No infrared (IR) coefficients upgrade in Cy45r1, except format update; retain sea surface emissivity model ISEM and UWiremis land emissivity atlas;

2. RTTOV-12 assessment in the ECMWF's IFS

Assimilation experiments were run in the Cy43r3 version of the ECMWF system at $T_{CO}399$ resolution (~55 km) over 8 months period (June to September 2016 and November 2016 to February 2017):

- **Control**: ECMWF data assimilation and forecasting model with all operational observations and using RTTOV-11 and the IFS operational IR and MW coefficient files (*Lupu et al.,* 2015).

- **RTTOV-12**: Same system configuration, except that RTTOV-11 has been replaced by RTTOV-12 with updated MW surface emissivity models and the operational MW coefficient files have been replaced with the new RTTOV-12 files.

Statistics of observation departures from NWP model estimates

Standard deviation of background departures were reduced for many observations indicating improved first-guess fit to humidity sensitive observations (*e.g., MHS, GMI, SAPHIR, AMSR2*) and to temperature sensitive channels (*e.g., ATMS chs.6-9, AMSU-A chs. 5-8*) and to conventional observations (*e.g., GPS-RO*). Slightly degraded fit to *ATMS chs.10-15* and to *SSMIS* imager chs.

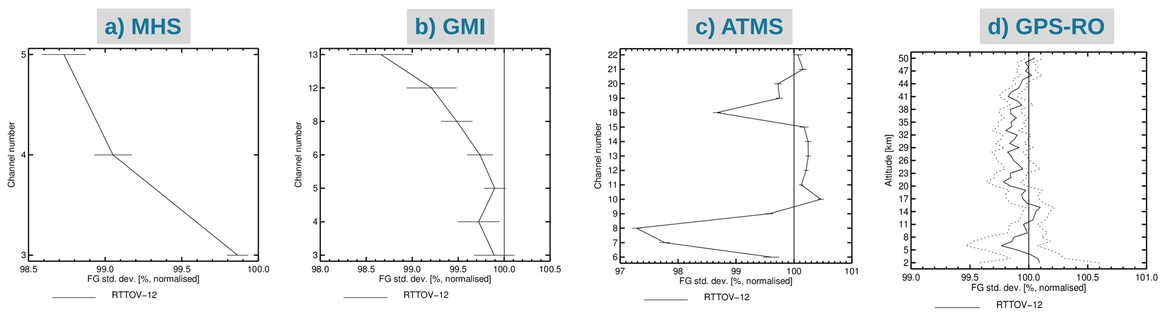

***Figure 1**: Normalised difference in the standard deviation of background departures between RTTOV-12 experiment and the Control for a) MHS on four satellites, b) GMI, c) ATMS and d) GPS-RO. Values are for used data averaged globally for 6 month period (July to September 2016 and December 2016 to February 2017). Values are normalised to the control so that a shift left indicates a reduction. The horizontal bars indicate 95% confidence interval.*

Forecast impact: Results of the RTTOV-12 with updated microwave coefficients files provide generally neutral to positive forecast impact.

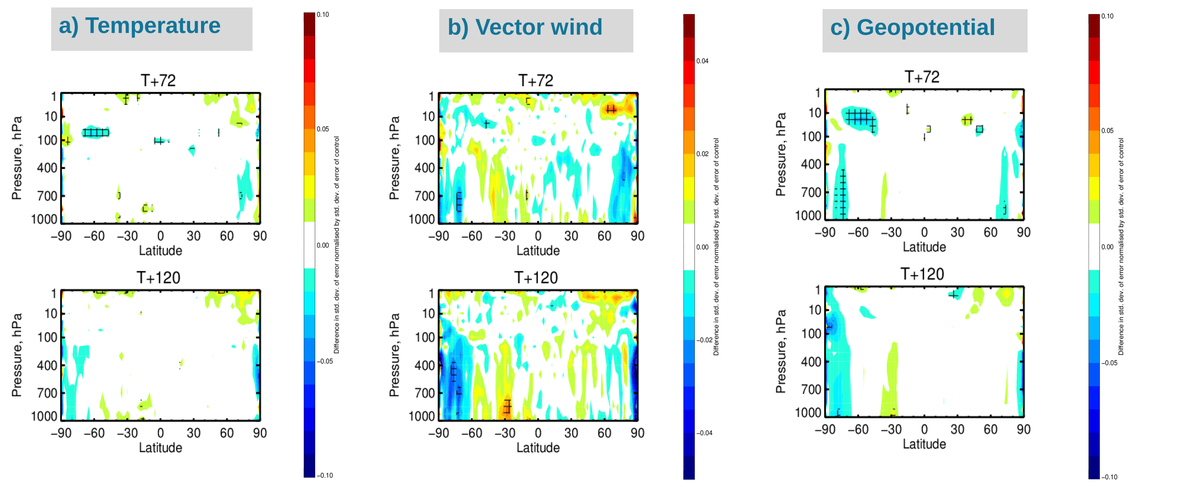

***Figure 2**: Normalised difference in the standard deviation of the forecast error in the: a) temperature, b) vector wind and c) geopotential at day 3 (top) and day 5 (bottom) between the RTTOV-12 and Control experiments. Each experiment has been verified against its own analysis, and negative numbers indicate a reduction in the forecast errors from using RTTOV-12 with* updated MW surface emissivity models and MW coefficient databases*. Hatching indicate statistical significance at the 95 % level. Results for the two seasons considered here have been combined.*

3. Impact of updating IR coefficient files

A third experiment has been carried out, **RTTOV-12 IR**, with the same configuration as RTTOV-12 run, but using NWP-SAF infrared coefficients updated with the latest spectroscopy from LBLRTM (v12.2).

IASI statistics with different spectroscopy and line-by-line models

First-guess (FG) departures statistics before VarBC based on spatially and temporally coincident IASI clear-sky radiances (aerosol- and cloud-free) are used to evaluate the accuracy of the computations and the quality of the spectroscopic databases on which the RTTOV coefficients are based. The standard deviations of FG-departures increase in the RTTOV-12 IR run in the temperature sounding band between 710 cm^{-1} and 730 cm^{-1} and in the ozone sounding band (1000 cm^{-1} to 1080 cm^{-1}).

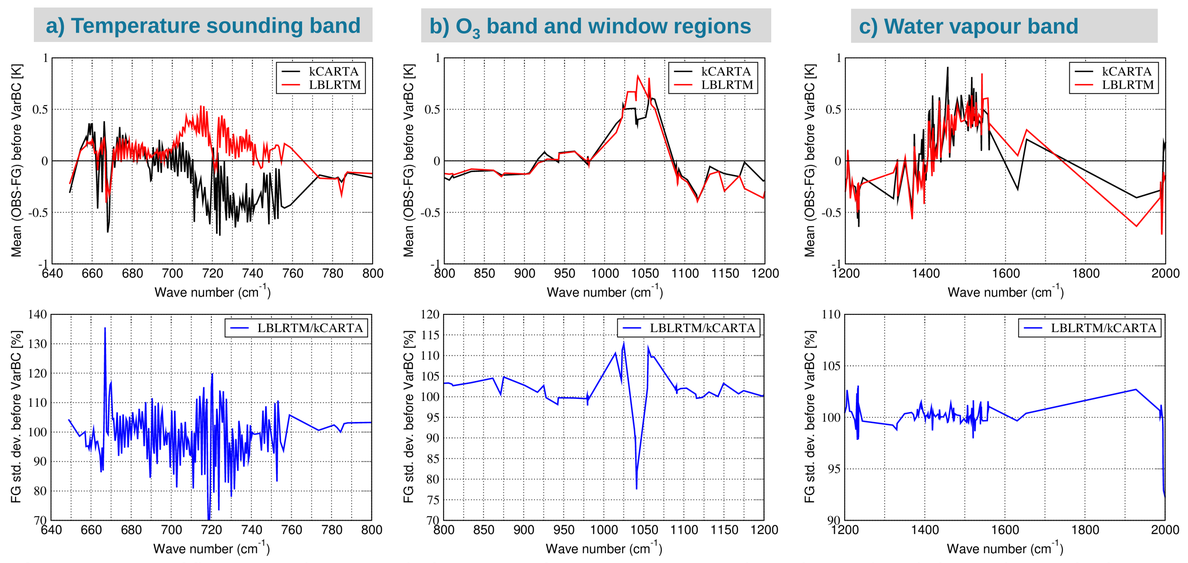

***Figure 3**: Mean of first-guess departures before VarBC for IASI on MetOp-A (420 chs., top) and change in standard deviation of first-guess departures against the control experiment (bottom). Results are shown for three spectral regions (640-800 cm^{-1}, 800-1200 cm^{-1} and 1200-2200 cm^{-1}) for the Control run based on the kCARTA model and for the RTTOV-12 IR run based on LBLRTM v12.2 model. Changes in IASI files also include updated concentrations of CO_2 in the mixed gas transmissions and a different training set of diverse atmospheric profiles.*

Impact on first-guess departures and forecast impact

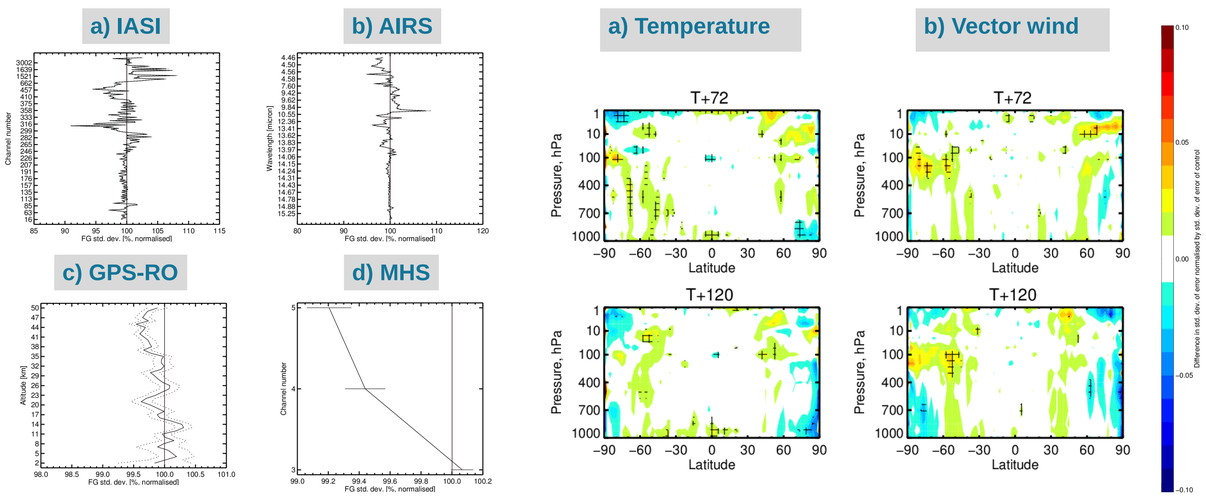

***Figure 4**: As Figure 1. Results of the RTTOV-12 IR run show improved first-guess fits to MW humidity sensitive obs., degraded fit to IASI mid-tropospheric chs. and ozone sensitive chs. (also AIRS) and degraded fit to GPS-RO below 14 km (~150 hPa);*

***Figure 5**: As Figure 2 a)-b). Results of the RTTOV-12 IR with updated coefficients databases show a detrimental impact in forecast scores of temperature and wind.*

References

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4. Summary

- RTTOV-12 with updated MW surface emissivity models and MW coefficient files has been included in cycle 45r1 of the IFS configuration for operational implementation in early 2018. Experiments showed a decreased standard deviation of background departures for many observation types. Forecast scores were neutral overall.

- The new coefficient databases for the infrared sensors, also available with RTTOV-12, has not been included yet for operational implementation in the IFS pending investigation of some unexplained discrepancies in the simulation of ozone sensitive channels and of mid-tropospheric CO_2 channels affected by line mixing effects.

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