Evaluation of RTTOV-11 in IFS

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Introduction

The latest development of the radiative transfer code RTTOV v11.1 (see *Saunders et. al*, 2013) has been evaluated for use in the operational assimilation system at ECMWF.

- Assimilation experiments shows neutral forecast impact when RTTOV v11.1 was used instead of RTTOV v10.2.
- The run time and billing units appear to be reduced or equivalent when compared with RTTOV-10 experiment.
- RTTOV v11.1 is ready for operational implementation in the IFS cycle 40R2.

Here we evaluate an optional update to RTTOV v11.1 which provide new interpolation options and a new set of coefficient files that includes 54 levels with better-spaced vertical level structure and revised spectroscopy for all infrared sensors based on LBLRTM v12.2.

Alternative interpolation options in the RTTOV-11

Interp_mode	User--> Coef. level	Coef. -->User level
1	**Rochon**	**Rochon in optical depths**
2	Log-linear	Log-linear on optical depth
3	**Rochon**	**Log-linear on optical depths**
4	Rochon	Rochon on weighting functions
5	**Rochon**	**Log-linear on weighting functions**

Table 1 Interpolation modes available in the RTTOV-11.

The RTTOV interpolator (*Rochon et al*, 2007) provide sensitivity to all model levels, but can results in oscillations in temperature Jacobians when the number of input levels significantly exceeds the number of coefficient levels. Spiky Jacobians are undesirable, because if not smoothed by **B** they could cause noisy and unphysical temperature increments.

The alternative interpolation options (*Hocking & Rundle*, 2013) aims to eliminate the oscillations in temperature Jacobians that results when the Rochon interpolator is used to interpolate the optical depths from coefficient to user levels in NWP models. Table 1 shows all interpolation modes available in the RTTOV-11. Instead of interpolating the optical depths directly, the new attempts evaluated here include log-linear interpolation (mode 3) or weighting function interpolation (mode 5).

Temperature Jacobians for individual AMSU-A/MetOp-A channels

The effect of the new interpolation modes 3 and 5 has been tested in the ECMWF system in one single cycle experiments assimilating only one single AMSU-A channel at the time. The temperature Jacobian can be recovered from the adjoint gradient in this case because only one channel is being used. To get the Jacobian from the adjoint requires dividing the adjoint in physical temperature by the adjoint in brightness temperature.

The largest differences in temperature Jacobians between different interpolation modes occur in channels with the sharpest peaks in their weighting functions.

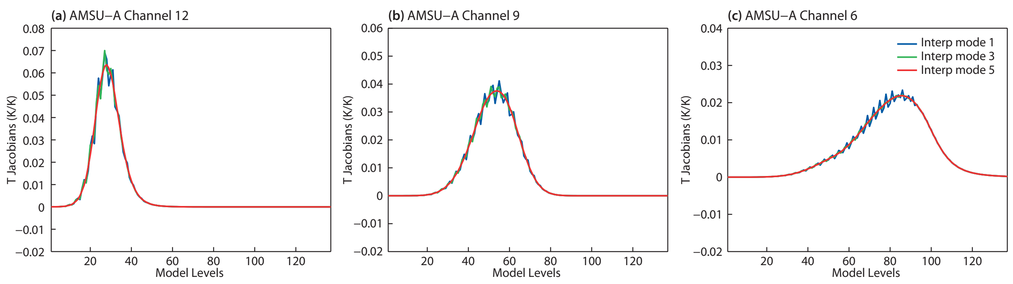

Figure 1 AMSU-A temperature Jacobians for channels: a) 12, b) 9 and c) 6 for 44 levels coefficients using the default Rochon interpolation (blue), the new interpolation mode 3 (green) and the new interpolation mode 5 (red).

Comparisons of the Jacobians for each AMSU-A channels show that mode 5 results in very smooth Jacobians, while mode 3 does not appear to offer much benefit over the Rochon interpolator.

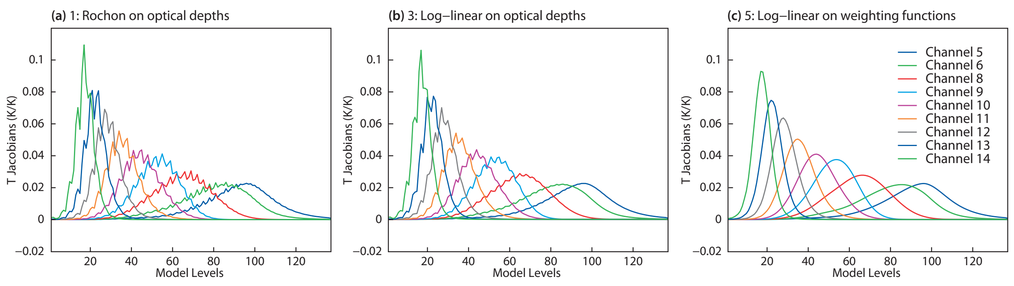

Figure 2 AMSU-A temperature Jacobians for channels 5-14 for 44 levels coefficients using: a) the default Rochon interpolation, b) the new interpolation mode 3, c) the new interpolation mode 5 as implemented in RTTOV-11.

Evaluation of new interpolation options in the IFS

To further compare the new interpolation options in the IFS, assimilation experiments were run with RTTOV-11 and interpolation modes 3 and 5 in the 40R1 version of the ECMWF system at T511 resolution (~40km) over 3.5 months in July – October 2013:

- **Control**: the same as the operational 4D-VAR system at ECMWF, except that RTTOV v11.1 with the default Rochon interpolator is used instead of RTTOV v10.2.
- **RTTOV-11 Interp. Mode 3**: As control, but RTTOV-11 with log-linear interpolation on optical depths (mode 3).
- **RTTOV-11 Interp. Mode 5**: As control, but RTTOV-11 with log-linear interpolation on weighting functions (mode 5).

All experiments use coefficient files as in ECMWF operations.

Standard deviation of background departures for ATMS and MHS were reduced, indicating better quality of the short-range forecast:

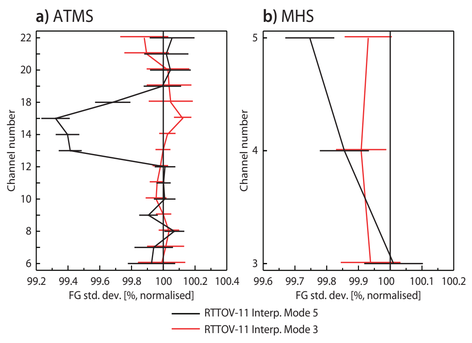

Figure 3 Normalised difference in the standard deviation of background departures between each of the experiments and the control for a) ATMS and b) MHS. Values are for used data averaged globally for the period 19 August – 19 October 2013. Values are normalised to the control so that a shift left indicates a reduction. The horizontal bars indicate 95% confidence interval.

Results of the experiments with the new interpolation modes 3 and 5 indicated a generally neutral impact on globally averaged forecast scores:

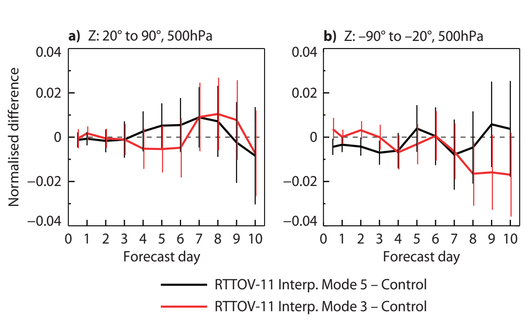

Figure 4 Normalised differences in the root mean squared forecast error of the 500hPa geopotential averaged over a) Northern Hemisphere extra-tropics and b) the Southern Hemisphere extra-tropics. Values are shown as a function of forecast range (days) and the vertical bars indicate 95% confidence interval. Each experiment has been verified against the own analysis, with a total of 104 -123 cases.

New set of radiometer coefficient files

RTTOV-11 was released with a new set of coefficient files that includes 54 levels with better-spaced vertical level structure and revised spectroscopy for all infrared sensors based on LBLRTM v12.2.

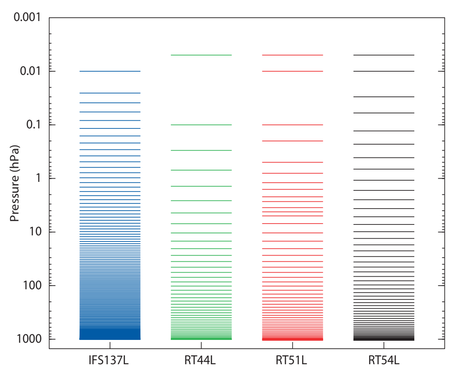

Figure 5 IFS 137 model levels for a standard surface pressure (blue) and the 44 (green), 51 (red) and 54 (black) RTTOV fixed pressure levels.

Initial assimilation experiments using the upgraded coefficient files in ECMWF system shows that the changes primarily alter bias characteristics of the assimilated radiances and results in a major shock to the system in terms of biases and VarBC spinup issues.

- **New Control**: RTTOV-11 with interpolation mode 5 and old coefficients files.
- **New RT54L**: As control, but with the new set of coefficient files (54 levels and revised spectroscopy for IR sensors).

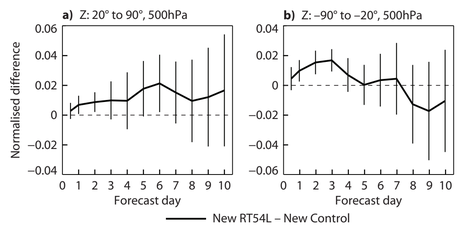

Figure 6 As Fig. 4 but for New RT54L experiment verified against the own analysis, with a total of 42–61 cases (19 September – 19 October 2013).

Conclusions

	Stage	Results	Outcome
1	Move from RTTOV-10 to RTTOV-11 (Scientifically neutral)	Neutral	Already in CY40R2
2	Improved vertical interpolation	Neutral	Ready for CY40R3
3	New coefficient files	Negative*	Needs more work

*This may be due to VarBC not spinning up yet

References

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