# Evaluating Spectral Biases in IASI and FORUM Clear-Sky Simulations using RTTOV

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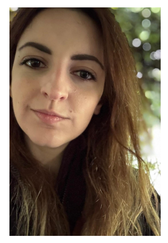


## PhD Objectives

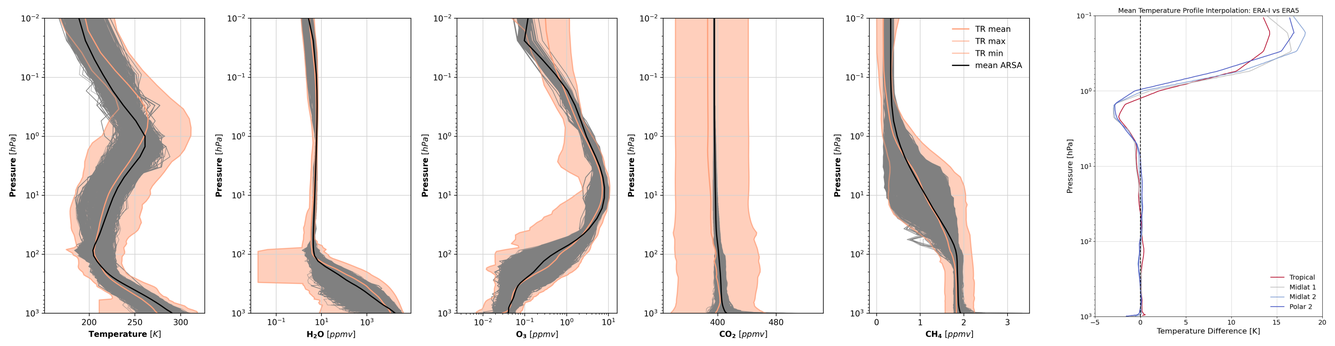
- Characterize simulation biases and attribute differences to spectroscopy, atmospheric profiles or parametrization
  - * Comparison with other RT models to assess various spectroscopic databases (HITRAN, GEISA)
- Interpret spectral level sensitivity using Jacobians for few selected channels
- Examine the modelling in RTTOV
  - * Look into the parametrization of OD and coefficients generation process
- Implications of spectroscopy in Data Assimilation
  - * Inversion Algorithm 1D Var for Temperature and Water Vapor profiles
  - * Test different sets of coefficients in Data Assimilation Experiments

## Radiative Transfer Models

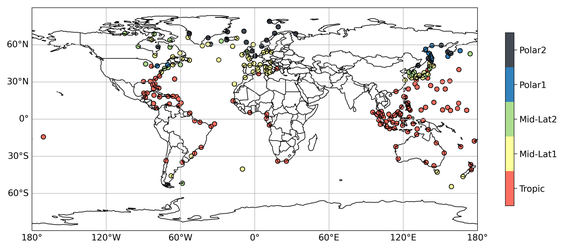
| | **RTTOV v13** | **LBLRTM v12.8** |
|---|---|---|
| **Model type** | Fast Band model† | Line-By-Line |
| **Spectral Range** | UV to Submillimeter | $[0 - 30000]\ cm^{-1}$ |
| **# Molecules** | 28 (7 variables) | 43 |
| **Spectroscopic DB** | HITRAN 2012 | HITRAN 2012 |
| **Water Vapor** | MT CKD (3.2) | MT CKD (3.2) |
| **Jacobians** | ✓ | ✓ |
| **Main Purpose** | Data Assimilation in NWPs | Reference Simulations |

† Parametric model of convoluted transmittances (#120 instruments)

## Database of atmospheric profiles colocated with IASI observations: ARSA v2




- **Radiosounding:** $P(z)$, $T(z)$, $H_2O(z)$ interpolated on ERA-5 grid (note the warm bias introduced by ERA-5 around 1-2 hPa)
- **ERA-5:** $O_3(z)$, $T_{surf}$
- **CAMS:** $CO_2(z)$, $CH_4(z)$
- **Conditions:** Night (avoid non-LTE effect) / Ocean / Clear-sky
- **19706 IASI** observations (Fourier Transform Spectrometer) colocated with 43 levels profiles
- Dataset spans all four seasons of **2017** and profiles are sorted per airmass class (TIGR2000 classification)




## Intercomparison RTTOV vs LBLRTM vs IASI observations

The figures on the bottom left shows IASI observations vs simulated spectra from RTTOV and LBLRTM.
Potential sources of bias may come from the spectroscopic database, numerical scheme of the RT model, transmittance parametrization (in case of RTTOV), or the atmospheric profiles.

**$1^{st}$ band [645-1210 $cm^{-1}$]**

⇝ 667 $cm^{-1}$ ($CO_2$ bending mode): affected by temperature biases in ERA-5 (see figure in the top right panel)

⇝ 700-750 $cm^{-1}$: likely related to $CO_2$ concentration profiles errors

⇝ 1010-1080 $cm^{-1}$: $O_3$ spectroscopy and ERA-5 ozone profiles

**$2^{nd}$ band [1210-2000 $cm^{-1}$]**

⇝ 1305 $cm^{-1}$: associated with $CH_4$ concentration profiles

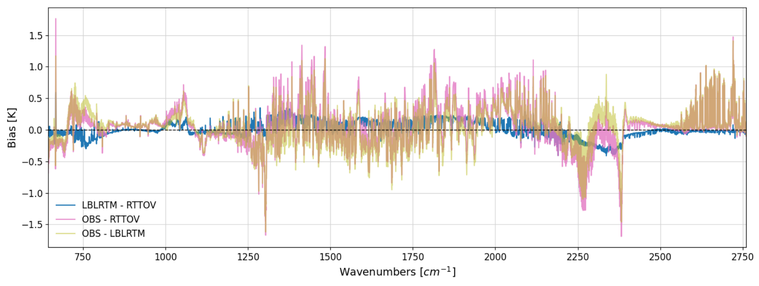
⇝ Broad bias: Due to $H_2O$ continuum absorption and ERA-5 overestimation of water vapour

**$3^{rd}$ band [2000-2760 $cm^{-1}$]**

⇝ 2080–2200 $cm^{-1}$: CO spectroscopy and concentration profiles errors

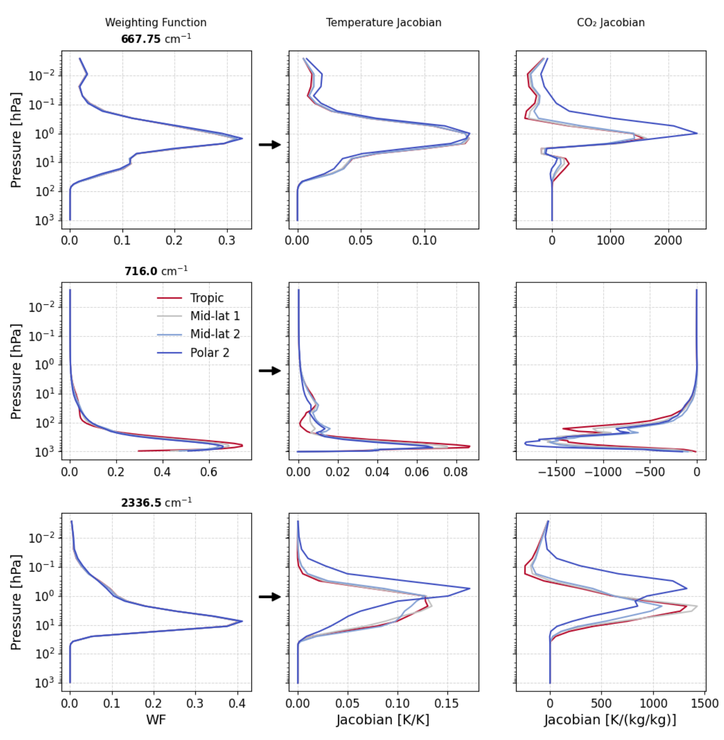
⇝ 2230–2390 $cm^{-1}$ & 2200 $cm^{-1}$: influenced by $CO_2$ and $N_2O$ features

⇝ 2590–2760 $cm^{-1}$: HDO spectroscopy likely responsible




The central figure provides a deeper look into bias sources using Jacobians and weighting functions from three **$CO_2$ IASI channels: 667.75 $cm^{-1}$, 716 $cm^{-1}$ and 2336.5 $cm^{-1}$**.

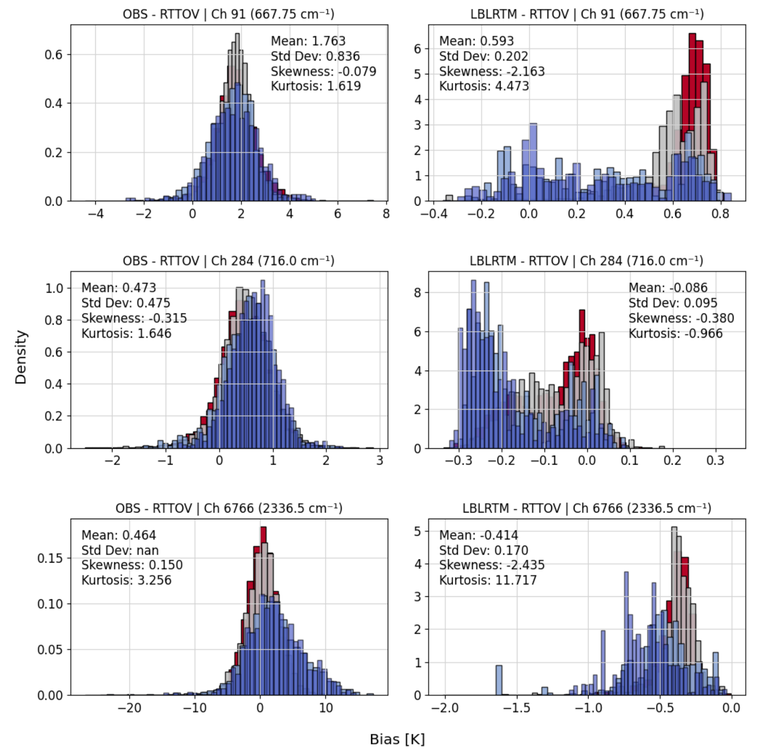
- Weighting functions determine the atmospheric level contributing most to the observed radiance
- Jacobians are computed to study the level sensitivity of radiances to temperature and gas concentration




The last figure compares **bias distribution** between observations and RTTOV and the reference model (LBLRTM) and RTTOV.

The LBLRTM–RTTOV results highlight total model bias and isolates RTTOV's parametrization and modelling error.

**While observation biases tend to follow mostly a Gaussian distribution, model-to-model differences vary significantly across spectral regions and atmospheric conditions.**




## Intercomparison RTTOV vs LBLRTM: FORUM

The bottom figure illustrates the radiance bias between RTTOV and LBLRTM simulations across the FORUM spectrum, evaluated against the **NESR (Noise-Equivalent Spectral Radiance)** goal. Regions where the bias exceeds the NESR indicate potential limitations in RTTOV's spectroscopic modelling or radiative transfer assumptions, particularly in the far-infrared.

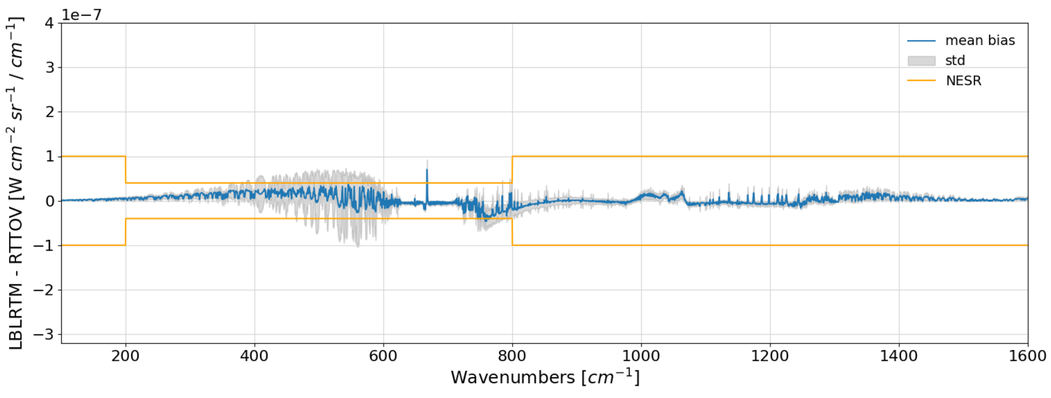
On the top-right the same bias in BT is shown profile by profile (IREMIS emissivity model), while the bottom-right figure displays the values obtained using a constant emissivity of 0.98.

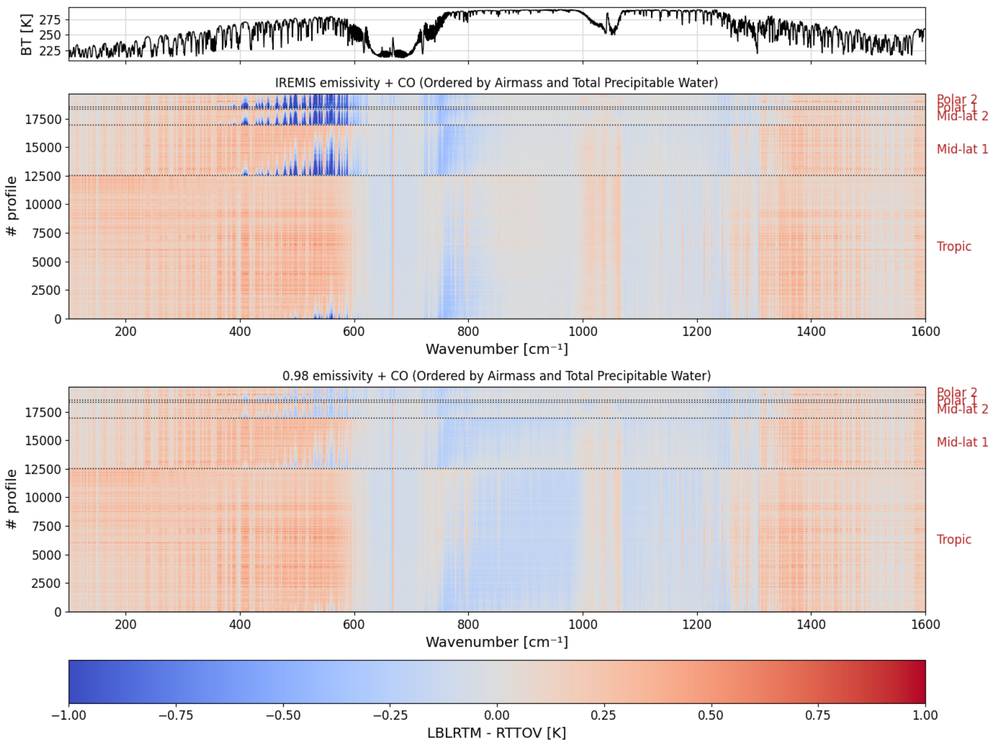
⇝ RTTOV tends to be colder in absorption bands and warmer in the windows, indicating an **overestimation of gas absorption**

⇝ When $\epsilon = 0.98$ the RT model considers less atmospheric contribution ($R = 1 - \epsilon$)

⇒ RTTOV BT are warmer in the atmospheric window (800-1000 $cm^{-1}$) due to less absorption from water vapour

⇒ The decrease of the bias the close FIR (400-600 $cm^{-1}$) for profiles with low TPW suggests a smaller **RTTOV error for reflected radiation** $(1 - \epsilon)$.




## Next Steps and Outlook

- Analyse the coefficient generation process and its role in the absorption features of main gases
- Strengthen the link between spectroscopic uncertainty and RTTOV modelling performance
- Improve RTTOV's FIR simulation capability
- Generate new coefficient sets based on updated spectroscopic data (e.g. HITRAN 2020)

## Contact information

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