



Comparing the infrared spectral signature of the climate model ARPEGE-Climat to IASI observations

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MOTIVATION

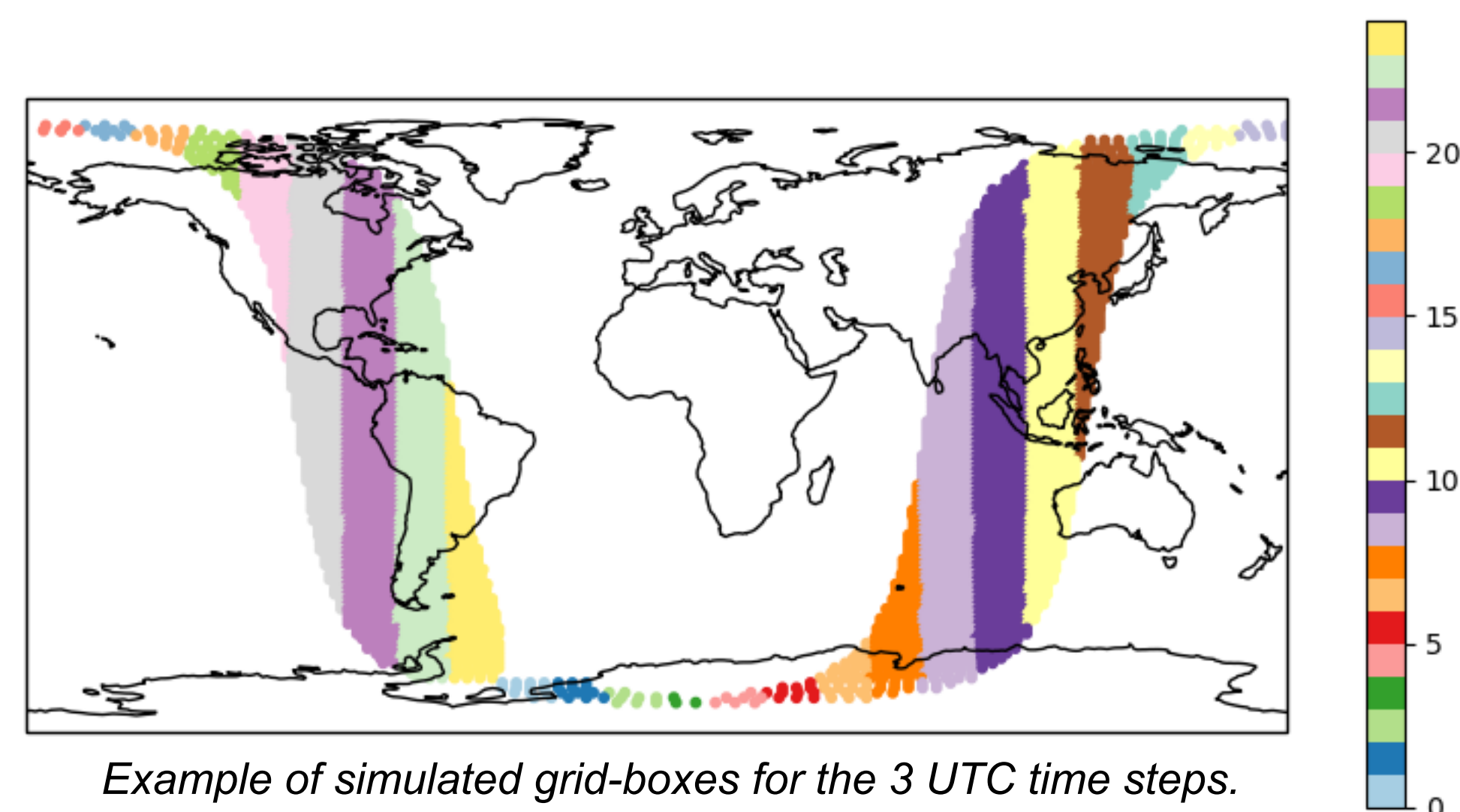
- Climate models are tuned) to match observed broadband radiative fluxes (Hourdin et al., 2017) but apparent matching can hide spectral error compensation (Huang et al., 2007).
- Infrared hyperspectral satellite observations are not much used to evaluate climate models even if they contain valuable information about climate mean state, variability and evolution (Huang et al. 2005 ; Huang et al., 2009; Brindley et al., 2015).
- Here we aim at evaluating the infrared spectral signature of ARPEGE-Climat (Roehrig et al., 2020), the atmospheric component of the CNRM-CM6 climate model developed by CNRM and CERFACS for CMIP6, with respect to IASI observations.

DATA

- Seven years (2008-2014) of 3-hourly ARPEGE-Climat atmospheric profiles from an *amip* simulation (i.e. forced by reconstructed sea surface temperature and sea ice cover, as well as aerosols and GHG concentrations) are used.
- Reprocessed nadir infrared spectra measured by IASI-A (Hilton et al., 2012) under clear-sky conditions are used (in brightness temperature units), covering the same period as the simulation. Cloudy observations are identified using the cloud mask product derived by Whitburn et al., 2021.

COMPARISON STRATEGY

- The radiative transfer model RTTOV (Saunders et al., 2018) is used to simulate IASI nadir spectra from ARPEGE-Climat atmospheric profiles and surface properties.
- The spectra are simulated only for the grid boxes for which IASI local crossing time is less than 1h30 apart, and the cloud fraction at any level is less than 10 %.

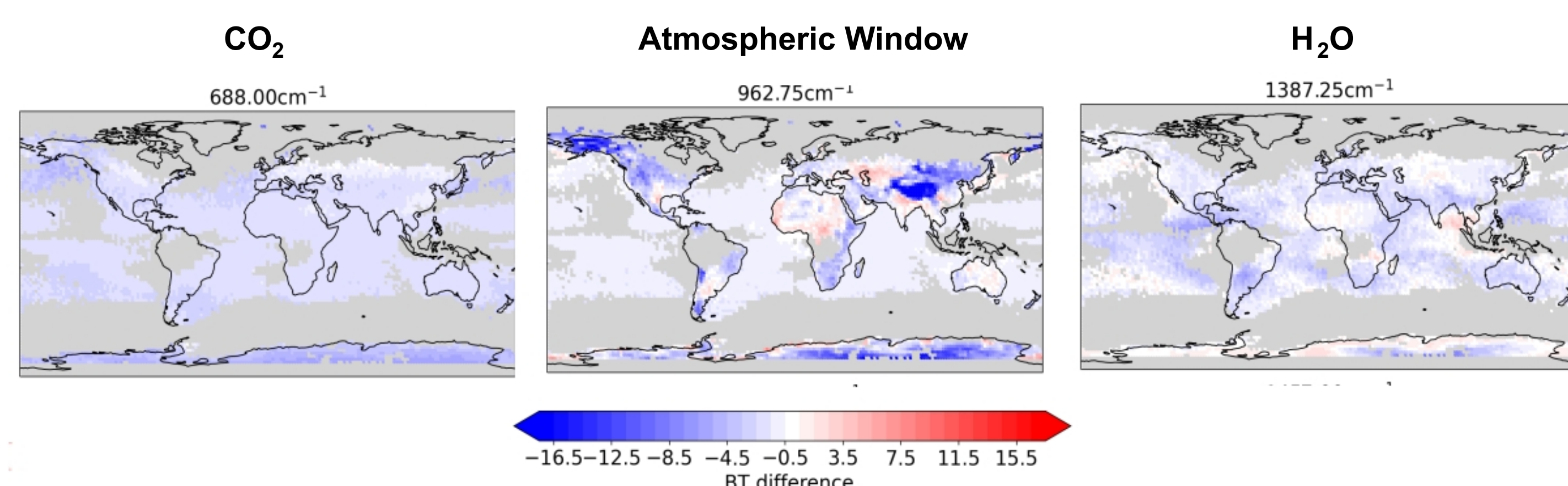


Example of simulated grid-boxes for the 3 UTC time steps.

- Monthly clear-sky climatologies from both IASI observations and simulated spectra are built at the model spatial resolution.
- Grid-boxes containing less than 200 observations or simulations are discarded, as well as wavenumbers > 2300 cm⁻¹ to avoid solar contamination.

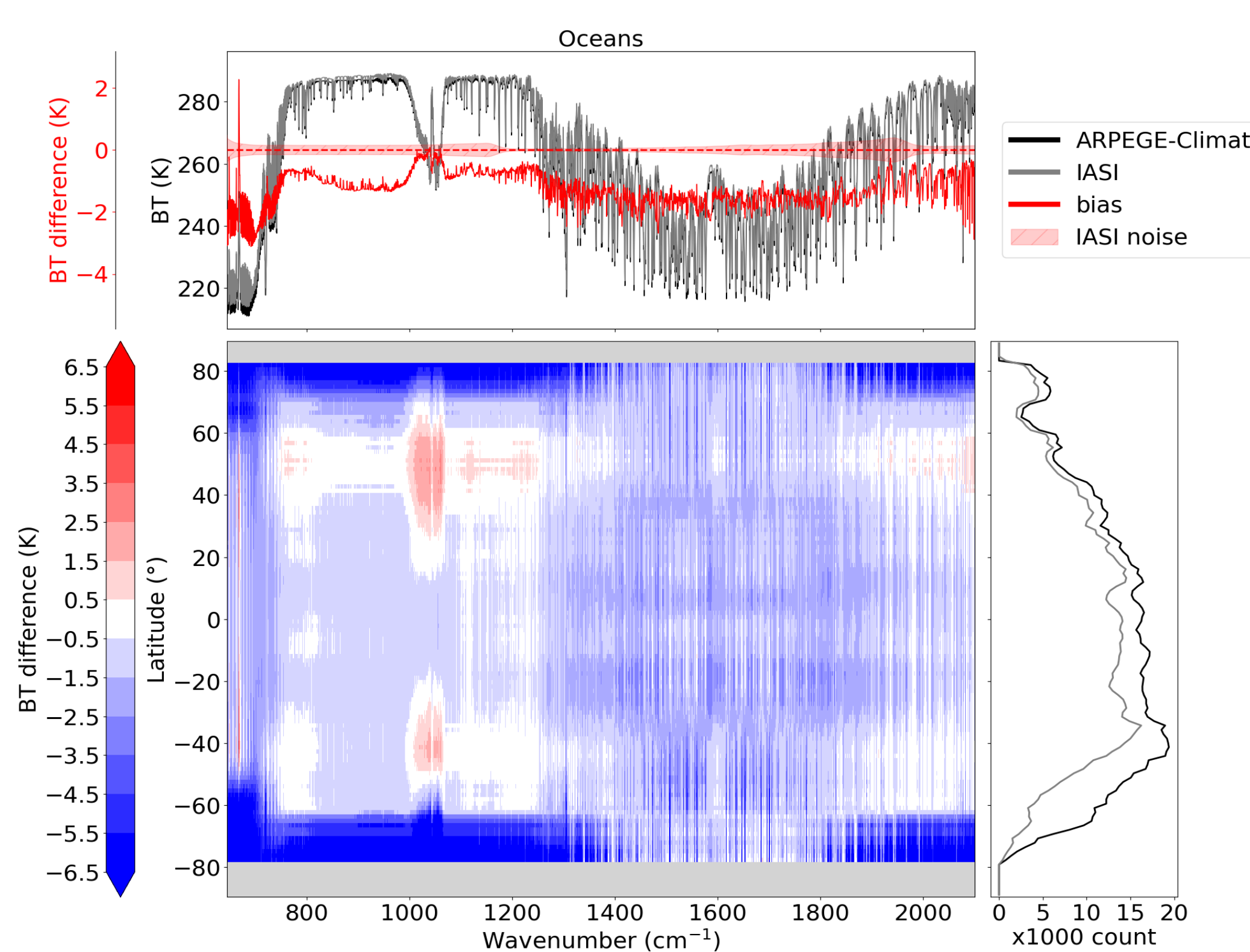
RESULTS

MEAN STATE



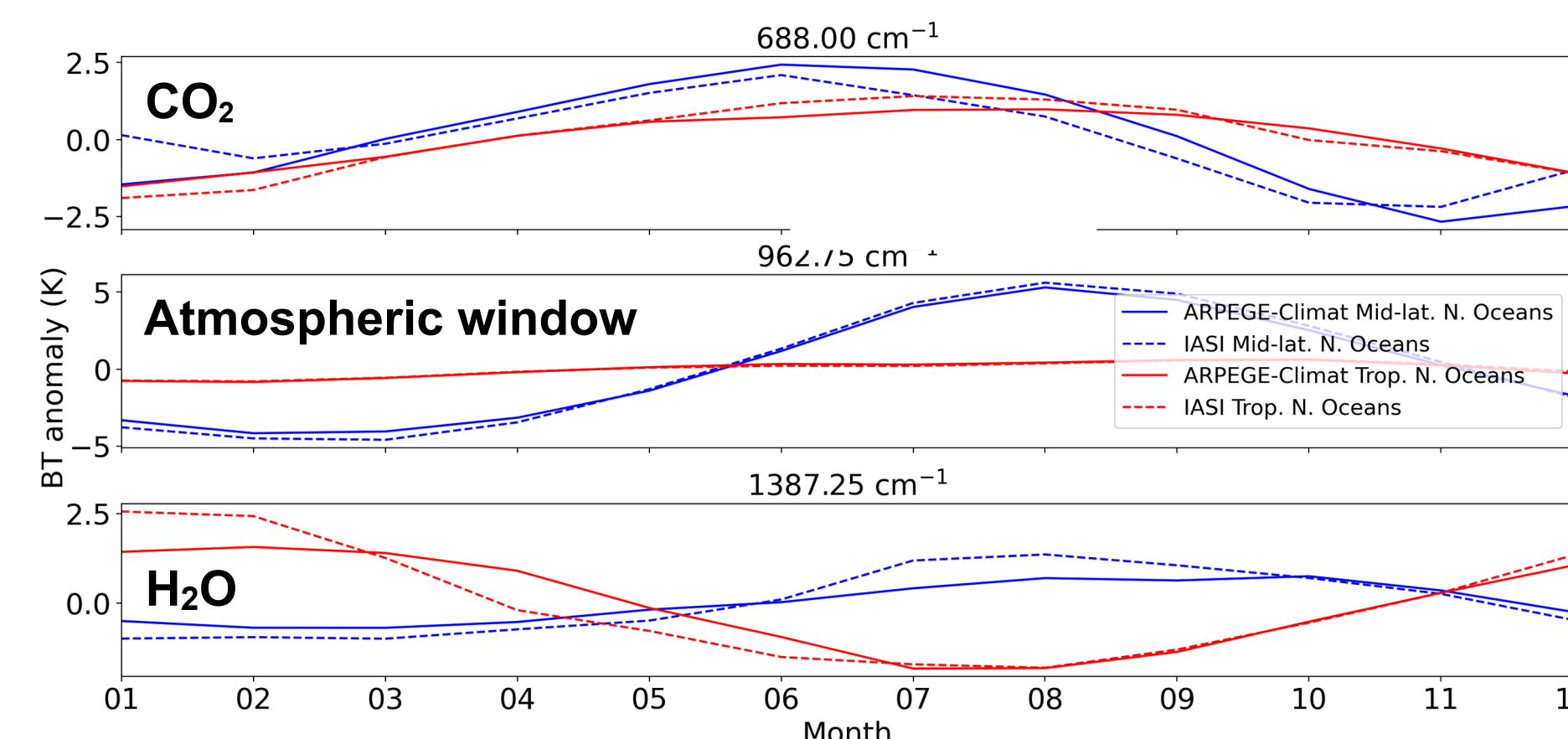
Mean brightness temperature difference (ARPEGE-Climat – IASI) for 3 IASI channels for the DJFM period.

- In the atmospheric window, good agreement between IASI and simulated spectra over oceans (as expected from the *amip* configuration) but significant differences up to 10 K can be seen over continents.
- In the CO₂ and H₂O absorption bands, differences up to 2 K are found (with marked regional patterns for the H₂O band). The overall negative bias is related to an underestimation of atmospheric temperatures in ARPEGE-Climat. A too wet atmosphere can also reinforce this negative bias in the H₂O band by increasing the emission altitude.



Mean brightness temperature difference (ARPEGE-Climat – IASI) averaged over ocean grid-boxes, and latitudinal distribution of the bias. The number of observation/simulation per latitude band is also shown.

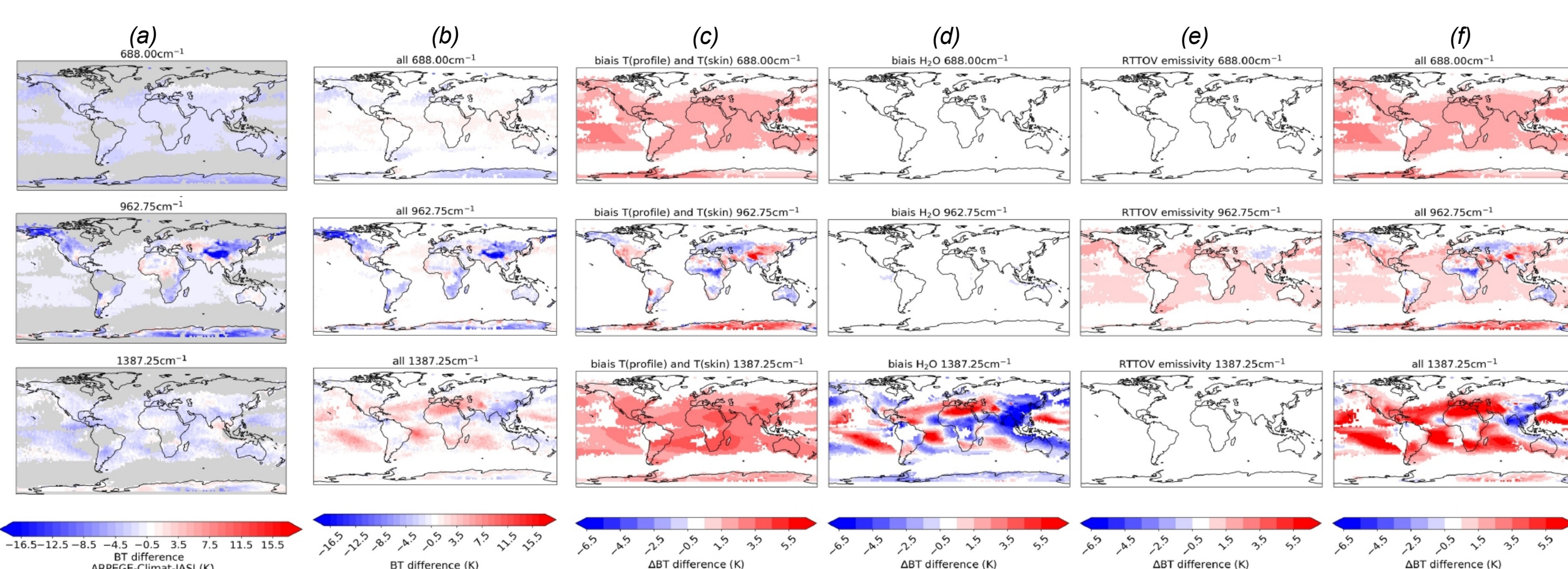
SEASONAL VARIABILITY



Brightness temperature anomaly (annual mean removed to each monthly average) for 3 channels, for ARPEGE-Climat and IASI, averaged over North tropical and mid-latitude ocean grid-boxes.

- Good agreement between IASI and ARPEGE for the climatological annual cycle, especially in the atmospheric window. In absorption bands, the annual cycle of ARPEGE is generally too weak with differences up to 1 K in the most absorbing channels.

INTERPRETATION OF THE DIFFERENCES



Brightness temperature difference over oceans before (a) and after (b) average bias removal. Anomaly changes when temperature (c), water vapor (d) or surface emissivity (e) are individually, or altogether (f) corrected.

- ARPEGE-Climat is debiased by removing the mean annual bias for each grid-box with respect to ERA-5 reanalysis, and IASI spectra for these unbiased profiles are simulated.
- ARPEGE cold bias correction improves the match in the CO₂ channel. In the window channel the bias is largely removed over oceans, due to the use of RTTOV ocean emissivity. Over continents it is only partly reduced, highlighting remaining deficiencies in surface temperature in ERA-5 and/or RTTOV surface emissivity. In the H₂O channel, remaining biases suggest ARPEGE deficiencies in the representation of large scale humidity patterns. The seasonal variability of the bias, not accounted for here, can also contribute to the residual difference, through non-linearities of the simulated spectra.

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CONCLUSIONS AND PERSPECTIVES

- A new methodology is proposed to systematically evaluate climate models against infrared hyperspectral satellite observations. Differences in spectra can be traced to deficiencies of the model, hence provide leads for future improvement. Selection of a few channels already bears much of the information about relevant geophysical variables.
- Future work will focus on extending the analysis to other climate models for model intercomparison purpose, including FORUM and IASI-NG spectra. We will also investigate cloudy conditions.