On the use of Planck-weighted transmittances in RTTOV

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Several fast radiative transfer models including RTTOV assume that the Planck function does not depend on wave number when integrating over the width of a satellite filter function. This approximation is less valid for wide spectral bands, like the MSG SEVIRI 3.8 micron channel. In the operational weather centres, that error is partly corrected downstream in a bias-correction scheme.

This paper presents an alternative approach, where the model regression predicts convolved transmittances that are weighted by the Planck function. The method is applied to RTTOV in the operational weather centres, that error is partly corrected downstream in a bias-correction scheme.

Results are presented comparing the performance of the model to reference line-by-line computations. This paper presents an alternative approach, where the model regression predicts convolved transmittances that are weighted by the Planck function. The method is applied to RTTOV in the operational weather centres, that error is partly corrected downstream in a bias-correction scheme.

The transmittances are obtained by the convolution of the line-by-line transmittances by the instrument spectral response function. The transmittances resulting from the basic convolution are called Ordinary transmittances while the alternative approach taking into account the variation of the Planck function are called Planck Weighted transmittances.

In clear non scattering atmosphere and black body surface, the polychromatic radiative transfer equation is

\[ R = \int \phi(b, T) \tau \left( \int \phi(b, T') \frac{1}{T'} dB \right) dB + \int \phi(b, T) \tau(b, T') dB \]

Where

\[ \tau = \frac{1}{T} \left\{ \int \phi(b, T') \frac{1}{T'} dB \right\} \]

The Fast model approximation replaces the transmittance and the Planck functions with the polychromatic radiative transfer equation:

\[ R = \int \phi(b, T) \frac{1}{T} \left\{ \int \phi(b, T') \frac{1}{T'} dB \right\} dB + \int \phi(b, T) \tau(b, T') dB \]

Ordinary and PW transmittances for a basic case

Consider a single atmospheric layer in which the Planck function is linear with the wave numbers and a spectral instrument response function of 1 over the bandwidth. The distribution of the absorption by water vapour and mixed gases is different in the two cases. The left case reproduce somehow the SEVIRI 3.8 micron channel. The line by line total radiance is computed. kCarta output is reduced by averaging on 0.25cm⁻¹ intervals.

Line-by-line total radiance is 1/8. The fast model approximation with the Planck weighted transmittances is giving the right result but the Ordinary transmittances fail. This is the typical case where PW can improve the fast model.

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Validation

Two sets of RTTOV-7 coefficients are produced, one with the ordinary transmittances (referred as ORD) and the other with PW transmittances. There is no difference in the fast model code, only the nature of the data inside the input coefficient files is different. For the PW we have 2 possibilities concerning the radiance-temperature conversion, according to the selection of band correction (referred as PWBC) or not (referred as PW), keeping the same central wave number.

The validation of PW transmittances is performed by comparing the line-by-line kCarta results with RTTOV-7. The fast model is run over the same set of profiles and for the same viewing and surface conditions. The profile dataset is the same as the one used for the creation of the fast model transmittances, it is a “dependent” test.

Below are presented the results for MSG-1 SEVIRI channel of RTTOV-7 minus kCarta brightness temperatures. The bias in channel 3.8м (1.35K channel number 1) where bias is larger than 0.10K. For all channels PW transmittances do a good job resulting in bias always less than 0.06K and standard deviation less than 0.03K.

The bias values for channels 13, 15 and 16 are now below 0.04K with standard deviation less than 0.03K.

Same test as for SEVIRI is performed for NOAA-17 HIRS. The ordinary transmittances give a good agreement with kCarta for most channels, bias is less than 0.05K, standard deviation is less than 0.01K except for channels 13, 15 and 16 (4.57, 4.47, 4.45 μm) where bias is larger than 0.05K. For all channels PW transmittances do a good job resulting in bias always less than 0.04K and standard deviation less than 0.02K (except channel 13). Especially the bias values for channels 13, 15 and 16 are now below 0.04K with standard deviation less than 0.03K.

In the current experiment, for nadir case:

- 3.8м of MSG-1 SEVIRI instrument is a very wide channel partly covering the CO2 absorption band and the 3.7μ window, the Planck function varies a lot inside this wavelength range. The RTTOV simulation of this channel shows large bias when compared with other models (RFM, MODTRAN, Synsatrad...). The PW transmittances are reducing the bias and standard deviation to a reasonable value.

Channel 8 (13.4μm) is degraded by 0.4K, same order was observed by Turner (October 2002 ORD=-0.27 PW=-0.78 at nadir, =0.5K difference), this indicates spectral overlap between the absorbing groups.

The PW standard deviation is highly reduced for channels 1 to 3.

Brightness temperature difference for RTTOV – kCarta for all profiles and all secant angles as a function of the BTs. Only the most improved channels are shown (13, 15, 16 and 17). Results obtained from ordinary transmittances are plotted on left and Planck weighted on right.

Independent test

Chris Merchant (University of Edinburgh) and Pierre Le Borgne (MétéoFrance) compare brightness temperatures simulated for SEVIRI on MSG for channels 3.8, 8.7, 11 and 12 μm (id 1, 4 6 and 7). The radiative transfer models are RTTOV7 MODTRAN (v3.5 and v4.0) RAD7 and RFM (v4.20). The profile dataset is made of 58 ocean profiles extracted from the ECMWF 60 levels reduced profiles (60L_SDr) and converted to RTTOV 43 pressure levels. RTTOV7 is run with/without coefficients derived from Planck weighted transmittances. Results below confirm the current experiment, for nadir case:

<table>
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<th>Model</th>
<th>3.8</th>
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</table>

Models - RFM difference for nadir case for some MSG-1 SEVIRI channels.

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