The Impact of a Revised Water Vapour Linewidth at 22GHz on Biases Observed in SSMI Radiances (working paper v1.1)

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It has been shown in previous published work that improved fits between simulated and measured brightness temperatures from zenith viewing groundbased radiometers can be achieved using revised spectroscopic parameters for the 22.235GHz water vapour line included in the HITRAN 1992 compilation compared with earlier data. In particular, a revised linewidth parameter based on measurements by Clough *et al* improves fits in the spectral region around the 22GHz water vapour absorption. The revised linewidth parameter (0.002656 GHz/kPa) represents a change of -5.5 % relative to earlier linewidth data. Estimates of global total column water vapour obtained from a 1D Var analysis of Special Sensor Microwave Imager (SSMI) radiances show bias distributions, relative to model forecast fields at T+6 hours, which are consistent with a spectroscopic error of this kind. In this work we investigate the impact of this modified line parameter on the biases computed from brightness temperatures measured by SSMI at 22.235 GHz. Changes in this parameter have been used to generate new line-by-line simulations which have in turn been used to generate coefficients for a fast radiative transfer model (RTTOV-7) widely used for the assimilation of SSMI radiances at NWP centres. We show that incorporating this new parameter significantly improves the observed brightness temperature biases. Equator to pole bias gradients of 2.35K are reduced to 0.85K.

1 Introduction

In 2004, Liljegren (Ref.1) demonstrated a way to reduce systematic differences between measured and simulated brightness temperatures at frequencies near the centre of the 22 GHz water vapour line. The measurements were obtained using a groundbased zenith viewing radiometer and simulated brightness temperatures were modelled using in co-located radiosonde measurements of temperature and humidity profiles. This was achieved by replacing the older line halfwidth (Ref.2) in the Liebe MPM model (Ref ?) by the value listed in the HITRAN 1992 molecular line database (Ref.3). This corresponded to a change, at 300 K, from 0.00281 GHz/kPa to 0.002656 GHz/kPa.

The Met Office currently uses the same MPM model in computing the transmittances required for generating the co-efficients for the RTTOV fast model (Ref ?) , an important component of the observation operator used for processing satellite radiances in the Met Office assimilation system. Within the Met Office assimilation system estimates of total column water vapour (TCWV) are derived from SSMI observations of brightness temperatures at 19, 22 and 37 GHz using a 1d-Var scheme (Ref ?). Biases in SSMI observations at 22.235 GHz could, in principle, result from errors in the radiative transfer model, instrumental bias or model error. The global distribution of TCWV estimates from SSMI (over ocean) and biases in these estimates are illustrated in Figures 1 - 4. Figures 1 and 2 show the climatology of TCWV derived from SSMI observations for DJF 2003/04 and JJA 2003 respectively. Figures 3 and 4 show the model - observation climatology for the same periods .

The bias of interest in this work is that which appears to track the region of maximum TCWV burden. For TCWV burdens in the range 55 - 65 kg.m^{-2} observed in the tropical West Pacific, for example, biases are typically in the range 2 - 4 kg.m^{-2}, with the observations appearing moist relative to the model. This behaviour is consistent with a radiative transfer error of the type investigated here. For a given linestrength, an erroneously large linewidth will give rise to erroneously low peak centre absorption, which will in turn require a larger TCWV burden to fit a given measured brightness temperature.

The work described here is an attempt to explain one aspect of the complex time dependent SSMI bias climatology using physically based corrections. The same substitution described by Liljegren was tested and the results are briefly reported here.
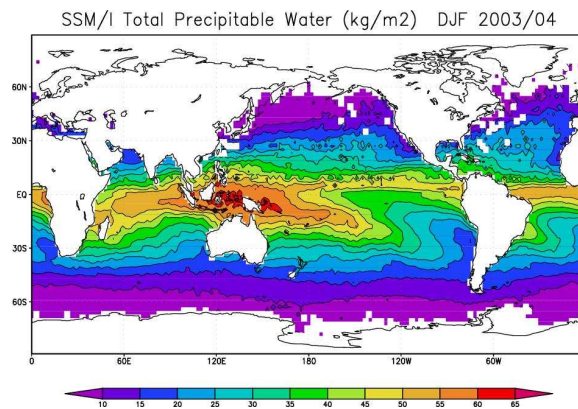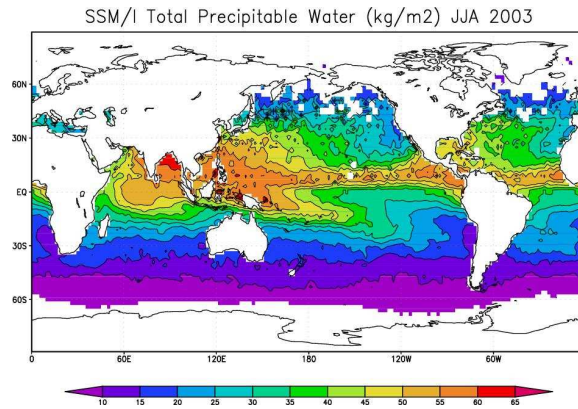
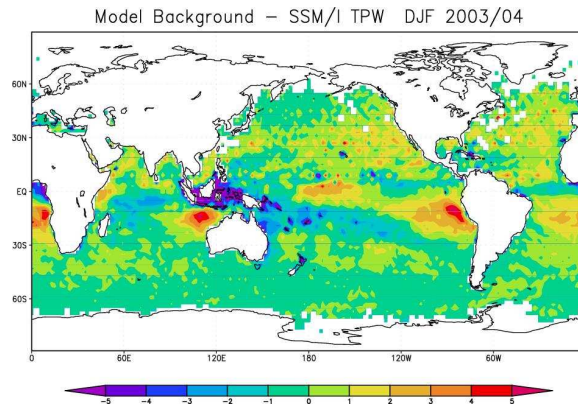

Figure 1: SSMI TCWV DJF 03/04

Figure 2: SSMI TCWV JJA 03

Figure 3: SSMI TCWV Biases DJF 03/04

2 MPM runs

The atmospheric profiles used for the radiative transfer calculations were the diverse TIGR set used to generate operational coefficients for RTTOV-7, having 43 profiles of temperature and water vapour abundance on 43 levels from 1013.25 hPa to 0.1 hPa.

First a control run of the original MPM model was made for channel 1 of the AMSU_A instrument, this being the closest AMSU channel to the line in question. A nadir view was chosen, a surface emissivity of 0.4, and the line parameters were drawn from the original file coef89.inc. From this, note for guidance that the reference profile (i.e. #43) gave brightness temperature of 129.24 K at the top of the atmosphere, though the value will differ from profile to profile.

A new inc-file, identical but for the halfwidth change (one field only), was then supplied, and a new run of the MPM model was then compared with the control. The AMSU channel showed brightness temperature increase of up to 1 K in the moistest profiles. Over the entire set of 43 profiles, the bias resulting from the change was +0.35 K, and the corresonding values for the rmse and the standard deviation were 0.49 K and 0.34 K respectively.

For a channel so close to the line centre, an increase in brightness temperature is to be expected from a reduction in the width (halfwidth at half-maximum) the extra being, in some sense, borrowed from more distant parts of the line
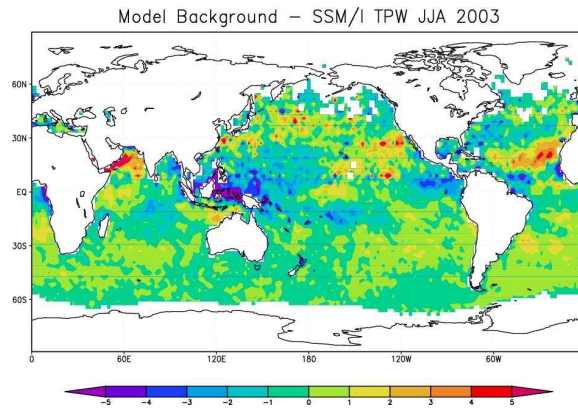
Figure 4: SSMI TCWV Biases JJA 03

given the linestrength is fixed. Since SSM/I channel 3 at 22.235 GHz is even closer to the line centre, it was expected that here too the brightness temperature would increase, and that the effect would be even greater.

3 RTTOV runs

The transmittance calculations were performed for all 5 channels of SSM/I on platform DMSP-15, using 6 viewing angles - from nadir to that with a secant of 2.25. In the linear regression scheme providing SSM/I coefficients for RTTOV-7, these transmittances to space (one for each level of each profile) provide the *predictand* array, and it is set down as the matrix product of a predictor array (drawn for that level of each profile) and a coefficient array (for that level and that instrument channel), this to be determined by the regression.

From the coefficient set based on transmittances with the original halfwidth (the control), RTTOV-7 was run for this SSM/I instrument at nadir viewing angle using a tropical test profile, this to compare with precalculated test output from the RTTOV-7 validation process. The two output files were identical as expected. RTTOV-7 was then rerun using the coefficient file based on the modified halfwidth. In terms of transmittance from surface to space, the original value of 0.7058 was reduced to 0.6935. Within RTTOV, after the transmittance stage, the surface emissivity model Fastem supplied a nadir value of 0.409 for channel 3. The subsequent calculation of nadir radiative transfer to the top of the atmosphere supplied a brightness temperature of 208.72 K in the control, and this was increased by 2.82 K with the modified halfwidth.

Since SSM/I has a conical scan with angle 53.1°, the viewing angle will always be off-nadir. When RTTOV was run with this angle, the control no longer agreed with the test results owing to the longer viewing path and the increased emissivity of 0.574 calculated off-nadir by Fastem. In terms of pure transmittance, the original value of 0.5598 was reduced to 0.5437 with the modified halfwidth, and the control brightness temperature of 252.49 K was increased by 1.92 K.

From the runs of MPM described in section 2, this difference will be dependent on the the total column water vapour burden of the profile used.

4 Impact on SSMI Biases

The impact of the modified line parameters on observed biases in SSMI brightness temperatures was assessed by accumulating statistics of the innovations (*ie* observed minus model background brightness temperatures at 22.235 GHz) over the period 18/02/05 - 08/03/05 from both QU00 and QU12 assimilation cycles. 2.47 million observations were obtained over this period. The background brightness temperatures correspond to the model fields based on T+6 hour forecasts valid at the time and location of the SSMI observation, projected into observation space. As a control run these background brightness temperatures were generated based on the old line parameters and associated RTTOV-7 coefficients.

Figure 5 below shows the results as a contour plot showing the frequency of occurence as a function of both TCWV burden and innovation. Also shown on the plot is the least squares best fit linear regression of the innovations versus the TCWV burden. As can be seen from figure 5 the gradient of the line is reduced significantly for the new line width parameters, from 0.047 to 0.017.

The resulting improvement in the radiance biases are illustated by the considering the equator to pole bias gradient. For the original parameters the bias changes by 2.35 K in going from the pole (TCWV burden of approximately 5 kg.m^{-2}) to equator (TCWV burden of approximately 55 kg.m^{-2}). For the new linewidth parameter this is reduced to 0.85 K.

The slightly increased offset (-3.45 K from -2.80 K) may be due to instrumental biases (incorrect spillover correction) or errors in the modelling of the surface emissivity.
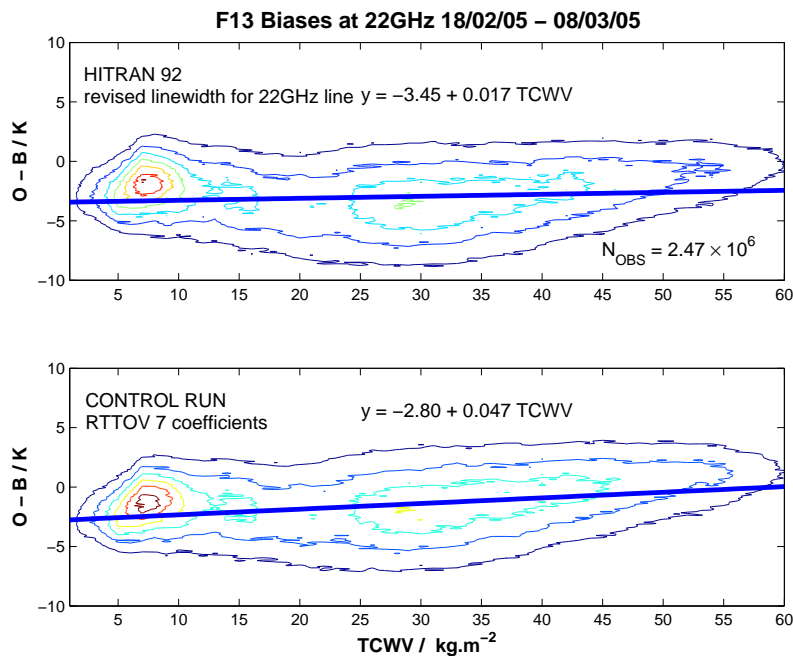

Figure 5: SSMI Biases at 22GHz

5 References

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