Atmos. Meas. Tech. Discuss., 8, C4955–C4964, 2016
www.atmos-meas-tech-discuss.net/8/C4955/2016/

Atmospheric Measurement Techniques Discussions
Open Access

AMTD
8, C4955–C4964, 2016

Interactive Comment

Interactive comment on "Modeling the Zeeman effect in high altitude SSMIS channels for numerical weather prediction profiles: comparing a fast model and a line-by-line model" *by* R. Larsson et al.

R. Larsson et al.

ric.larsson@gmail.com

Received and published: 19 January 2016

We thank the reviewer for the comments and refer to the attached compressed file for plots that have been added. Caption for these are at the end of this text.

This paper presents an interesting comparative study between a fast radiative transfer model (RTTOV) and a reference (line by line) model (ARTS) for the high altitude channels 19-22 of SSMIS. The simulations have been performed using globally distributed numerical weather prediction model profiles from MetOffice. One of the main problems *present in the study is that these atmospheric profiles only reach altitudes up to 10 Pa, and a constant temperature value is extended to lower pressures. Since the higher altitude channels 19 and 20 are not covered by the altitude levels of the numerical weather prediction profiles these two channels are not compared with the sensor measurements. The other two lower altitude channels (21 and 22) are compared between the models and also between models and measurements.*

We agree with this description of the paper. We also share the reviewer's concern that the low top-most altitude of the physically reasonable part of the model profiles impose strong limits on our study. (The justification, as given in the paper, for our extension of the study to cover the two higher altitude channels is that we emulate what the operational behavior would be today at Met Office, and that there are qualitatively important differences between the models for these channels. At least as far as this emulation concerns RTTOV.)

The authors state that the agreements between the forward simulations and the corresponding SSMIS measurements is generally good but there are some discrepancies although there are some discrepancies. They recommend that future iterations of numerical weather prediction software starts using versions of RTTOV from version 10 and onwards for the assimilation of SSMIS channels 21 and 22. Moreover, they suggest that model discrepancies for channel 21 would be likely reduced if the model top levels reached higher altitudes. The necessity of higher numerical weather profiles (with top at 100 km) for modeling the channels 19 and 20 have been also proven. I agree that the study present a reasonable agreement between the two models and also with the sensor measurements for the lower altitude channels. The study also evidences the necessity of work with the RTTOV version which include the Zeeman scheme in order to reduce the uncertainties of the numerical weather prediction profiles at high altitudes. However, I consider that some of the discussion and interpretation of the discrepancies could go a step further. Following I indicate some of the points that should be addressed by the authors:

The authors have found small mean deviations between the two models (RTTOV and ARTS) for the channels 19 and 20 but with an increase in the standard deviations when the three-dimensional magnetic filed is considered in ARTS. The authors state that part of the deviations between the two models could be explained by existing difference in the center of the emission lines for both models. In this sense, it could be clarifying that the authors also show the global distributions of the Tb differences for the ARTS model when the Zeeman effect is and is not considered in the simulation. It could help to identify if some of the patterns observed in these global distributions are due to differences between models or not

The plots described have been prepared and added to the paper. Adding these plots to the paper means that the argumentation elsewhere has also changed to make use of the plots directly We do the following changes to the paper:

- **[Under "Model to model"]** Before comparing RTTOV and ARTS we will discuss Figure 12. The figure shows the model effect of turning the magnetic field on and off in ARTS. By comparing to Figure 2, we see that there is an anti-correlation between magnetic field strength and brightness temperature change for channels 19, 20, and 22. The correlation for channel 21 is instead positive. On a channel-by-channel basis, channel 22 experience minimal Zeeman effect. In the extreme polar regions, the channel is only up to 0.4 K T_b warmer when the Zeeman effect is considered, but most of the rest of the planet experience a Zeeman effect that is less than 0.1 K T_b. Channel 21 experience the absolute strongest Zeeman effect out of all channels of just above 8 K T_b at the strongest sources of magnetic fields. The weaker magnetic field regions only experience around 1 or 2 K T_b. The simulations for channels 19 and 20 change a lot when the Zeeman effect is considered. Channel 20 gets 2 K T_b warmer at strong magnetic sources with the Zeeman effect considered. The same value for channel 19 is higher, at 5 K T_b. Both channels are around 7 K T_b colder at the equator. One interesting feature to note is the angular dependencies of the Zeeman effect near the equator. Es-

AMTD

8, C4955–C4964, 2016

Interactive Comment

pecially clear perhaps above the Atlantic between Brazil and Western Africa, the center of the measurement swaths around the equator are less influenced by the Zeeman effect than the surrounding swath positions.

- **[Under "Channels 21 and 22"]** From Figure 12, the Zeeman effect is up to 8 K T_b at the strong magnetic regions for channel 21 whereas the models compare to within 0.6 K in these regions. This means that the models are still fairly close to one-another in the strong magnetic field regions compared to the size of the Zeeman effect.

The simulations for the channels 19 and 20 evidence very different results when the models are compared with 2D or the 3D magnetic field for the ARTS simulations. The differences are much smaller when RTTOV is compared with ARTS-2D. It would be interesting to check which is the effect of the Zeeman effect only when 2D magnetic field is considered in ARTS and not the full description how it was calculated (right-most column of Table 1). In this way we could evaluate if the Zeeman effect for this configuration (2D) was also significant.

We are unclear on this point. To be clear: you want the same plot as for the previous section but with ARTS-2D, not ARTS-3D, magnetic fields?

There is nothing really new in adding such a figure to the paper. At least not now, after we have added the Zeeman effect on or off for ARTS-3D. The differences between a ARTS-2D to ARTS-3D Zeeman effect plot is per definition the same as the differences between the RTTOV cf. ARTS-3D and the RTTOV cf. ARTS-2D plots. And this difference can be found from the four first global T_b distribution plots.

I consider that the agreement between the models including the Zeeman effect and the measurements has not been sufficiently proven or at least is what I conclude for the current state of the manuscript. Although the agreement between measurements and models are good for channels 22 even better than the results obtained by Han et al.

(2007) it seems that Zeeman effect has not a strong influence over the channel 22. It is evidenced for the ARTS simulations when the effect of the Zeeman effect is assessed for this model (very small mean deviation and standard deviation). Moreover, the channel 21 suffers that the weighting functions are shifted upwards under the presence of strong magnetism field, so it is not possible a correct assessment of this channel with realistic atmospheric profiles only up to 10 Pa. The authors should remark the limitations found in the comparison between models and measurements or argue better their conclusions.

We have changed the text to state more clearly the limitations of our comparison. This in both the conclusion and in the methodological part of the work.

I think it would be clarifying for the reader if the central frequencies of the 19-22 SSMIS channels are specified the first time that the channels are mentioned.

Added this text just under “2. Method”:
These channels are described by Swadeley et al. (2008). Channel 19 has a local oscillator at 63.283248 GHz, with an intermediate frequency of 285.271 MHz, and a 3-db passband width of 1.35 MHz. Channels 20-22 are all on the same local oscillator at 60.792668 GHz, with the same first intermediate frequency of 357.892 MHz. Here the channels start to differ. Channel 20 simply has a 3-db 1.35 MHz wide passband, whereas channel 21 instead has a secondary intermediate frequency of 2.0 MHz applied before placing a 3-db 1.3 MHz wide passband and whereas channel 22 instead has a secondary intermediate frequency of 5.5 MHz applied before placing a 3-db 2.6 MHz wide passband.

It would be very helpful for the readers if the authors include a figure with the channels weighting functions for the SSMIS channels presented in this study.

This has been added as a contour plot for a single orbit for all four channels for two of SSMIS’s pixels. (One is the along-the-orbit pixel, the other is one of the side pixels; together they show how geometry changes weighting functions.) We cannot show the weighting function sets in a clear manner for the dataset that is presented (we are running with a much reduced dataset than the full set of measurements). Still, this plot serves as a qualitative description of what altitudes SSMIS measures. The following text has been added

- **[Under "Spectroscopic considerations"]** Finally, we have prepared weighting functions for one example orbit (the orbit is from 2012-01-01 around 13:30 in the afternoon UTC) and for two measurement pixels (or observational geometries that are relative to the motion of the satellite). These are shown in Figure 5. About each channel, the weighting function of channel 22 is almost constant over the orbit. Observational geometry is not important. Channel 21 is similarly little influenced by observational geometry but in the polar region (reminder: when the magnetic field is stronger) the weighting function is 'smeared' and the channel is influenced by much greater altitudes (though this is influence is not strong). Both channels 19 and 20 weighting functions change with both geographical location and observational geometry. That the observational geometry is important can be seen by the broadened weighting function in the westward-facing pixel as compared with the along-the-track pixel around the first pass at -30° that is not as evident during the second pass (comparing the then eastward-facing pixel to the along-the-track pixel). Again, remember that Figure 5 is for only one example orbit and that the weighting function will be different for other orbits and observational geometries.

- **[Under "Channels 19 and 20"]** We note that a large change over the swath is consistent with the changing weighting functions of channel 19 in Figure 5, which close to the equator can be much broadened by changing the observational geometry.

- **[Under "Channels 21 and 22"]** Since channel 21 weighting functions of Figure 5 is stretched to higher altitudes near the poles, it is possible that some model

AMTD

8, C4955–C4964, 2016

differences have been missed or exaggerated in our study due to our constant temperature profiles at these higher altitudes. That this has had a big impact on our results is deemed unlikely because the largest differences between the models are found across the equator, where channel 21 weighting function is covered by our physical profile.

In addition to these, we change referencing the weighting functions from pointing at Han et al.'s work to our own plots.

Please rewrite the next sentence, it is very confusing in the way that currently is written (Pag. 10193, lines 7-10): "The mean difference between the models should be compared to the size of the Zeeman effect for channel 21 at $T_b = -3.1$ K, which is the largest average Zeeman effect for all of the channels. From this comparison, the mean difference between the models is also small."

This was addressed by referencing Figure 12 by the comment above:

- **[Under "Channels 21 and 22"]** From Figure 12, the Zeeman effect is up to 8 K T_b at the strong magnetic regions for channel 21 whereas the models compare to within 0.6 K in these regions. This means that the models are still fairly close to one-another in the strong magnetic field regions compared to the size of the Zeeman effect.

Some of the discussions about the changes of the global distributions is really hard to follow with the color map. As for example the discussion between models of the channel 21 (page 10192, lines 15-22). I would propose to the discussion in a more quantitative way plotting the deviations for some predetermined latitude and longitude ranges.

The plot has been prepared. This has been referenced in more detail at every time equatorial differences are discussed. (This turns out to be a large change in text.) The following changes have happened to the text:

- **[Under "Channels 19 and 20"]** We draw attention Figure 13, which focuses on equatorial differences in this study. For channel 19, this figure show that the differences between three-dimensional ARTS and RTTOV range over 7 K near the equator, but that the same range for differences between two-dimensional ARTS and RTTOV is only around 1 K.
- **[Under "Channels 19 and 20"]** Also from Figure 13, the equatorial differences between three- and two-dimensional ARTS and RTTOV remain similar. One interesting difference is that while channel 19 has a fairly even equatorial bias when it compares two-dimensional ARTS to RTTOV, this is not the case for channel 20. Instead, the eastern hemisphere experience a positive bias of about .5 to .7 K and the western hemisphere sees close to no biases.
- **[Under "Channels 21 and 22"]** It is also possible to see a systematic 1 K gradient over the swaths near the equator in the comparison of RTTOV and three-dimensional ARTS in Figure 13 for channel 21. This systematic gradient is reduced to a fraction of a Kelvin for differences between two-dimensional ARTS and RTTOV. As for channels 19 and 20, these swath discrepancies should change when SSMIS is scanning northward or southward. Still, since the Zeeman effect is weak for channel 21 at the equator, most model differences there (the average bias of around 1.7 K in Figure 13) are due to other reasons than the Zeeman effect.
- **[Under "Channels 21 and 22"]** As for channel 21, we find from Figure 13 that near the equator there is a larger than average negative bias. For channel 22 it averages at $\Delta T_b \approx -0.75$ K.
- **[Under "Models to measurements"]** Looking at the equator in more details in Figure 13, we cannot determine if ARTS or RTTOV equatorial behavior is best there for channel 21. Both models compare to SSMIS with much larger effects over the swath at the equator than how the models compare to one-another.

AMTD

8, C4955–C4964, 2016

Swath effects are about 3 K large between models and measurements. We remind the reader that these swath effects are 1 K between three-dimensional ARTS and RTTOV. ARTS has in average slightly smaller swath effects — reduced by about 20% judging by differences in the absolute averages of the a-regression coefficient in the linear fit of $y = ax + b$ that is plotted — than RTTOV but there is a large variation in these swath effects.

Please try to avoid using unnecessary abbreviations, especially at the beginning of sentences. It makes reading less fluid. For examples, page 10192, line 11 (E.g., above ....), line 17 (E.g., in the three-dimensional ....).

Removed these. Thanks!

Caption for figure of the name "equatorial_crop.pdf" in plots.zip: Figure 13. The swath dependencies around the equatorial crossings of this study. The first row shows the map of the data. Color-coding is the same in this map as in the other plots where the swath from one orbit has its own colors; black circles are unused because they are more than 5 degrees from the equator (5 degrees was just arbitrarily chosen as the limit). The y-axis label in the other plots overlap with labels in Figures 6 to 11. Plot titles name the channels. Linear regression for brightness temperature differences was performed over longitude and the best-fit line is drawn between plus-minus 20 percent of the longitude range of the data from each orbit. The first two rows of the regression plots are for model comparison and the last row is for comparison between the models and SSMIS measurements.

Caption for figure of the name "fig3p.pdf" in plots.zip: Figure 5. Weighting function for SSMIS from ARTS with three-dimensional magnetic field for one example orbit for channels 19 to 22. Color shows the change in transmissions per kilometer of atmospheric altitude traversed by the radiation. The y-axis is the altitude range and the x-axis shows the latitude of the sensor as a function of time. For both channels, two swath positions are shown. Position #15 points along the orbit of the sensor. Posi-

AMTD

8, C4955–C4964, 2016

Interactive Comment

tion #1 points westward as the sensor travels northward, and it points eastward as the sensor travels southward.

Caption for figure of the name "fig10.pdf" in plots.zip: Figure 12. The Zeeman effect in ARTS for channels 19 and 20. Colors correspond to ARTS without any magnetic field minus ARTS with a three-dimensional magnetic field.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/8/C4955/2016/amtd-8-C4955-2016-supplement.zip

---

Interactive comment on Atmos. Meas. Tech. Discuss., 8, 10179, 2015.