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Atmospheric Measurement Techniques Discussions
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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.

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We would like to thank the reviewer for these comments.

The manuscript is much improved on the original version, the motivation for each part is clear and the separation between what can be learnt from Chs.19-20 and 21-22 much clearer. Thank you.

Thank you.

I have just three minor comments.

1. I did not get a feeling for the significance of the results shown in Fig. 6 which show discrepancies between 3D and 2D magnetic field treatment of up to +/-7K in the tropics. This sounds a lot and makes me wonder if modelling from 2D is in fact useless for these higher channels. A question is how does this compare to variance with respect to climate in observation space at these altitudes / region? If this is less than 7 K then the observation error if processed with a 2D magnetic field is large compared to the climatology error, meaning the information content of the obs even against climatology is small. This would imply to use these data we need to use a 3D field. So its important to get a feel for this. NWP models are pushing higher and the time will come when they beat climatology by some margin. So I would like to understand the relative size of these three errors: climatology, current and potential future NWP, and observation error with 2D and 3D fields. I think such information would further enhance the usefulness of the paper.

That 7 K is a lot is true and a very good point. Being able to provide the suggested information would be great. However, we cannot comment on the usefulness of RTTOV for these higher channels in assimilation schemes in this work. We can inform you that people at Met Office expects to utilize the present version of RTTOV in trial operational settings from this summer. Hopefully, it will be possible to provide the error estimations you suggest by the end of the trial. So, in short, further studies are required to address this concern, but such studies are also expected to take place soon.

2. Related to the above: I did not get a feel for how difficult it would be to use a 3D field in operational processing. The paper simply states its not currently available. It would be useful to have some indication where the issues lie in implementing something similar to the treatment in ARTS in RTTOV, or a fast fit to the ARTS model. Is this feasible? Is it expensive (but noting that observation processing is a small cost now in state of the art data assimilation we can afford more)? Is it technically feasible? What needs to be developed? This would be useful and inspiring information that could

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stimulate such a development.

It should be possible to make RTTOV do 3D Zeeman effect calculations. We do not know how computationally heavy this would be at this point. The problem we see is mostly about returning results to an effective scalar transmission coefficient that RTTOV can use. Equation 2 of the paper describes the return behavior. For now, the magnetic strength and angle is the same in all $\mathbf{T}$s (of Equation 3). Imagine instead that $\mathbf{T}_N$ has a different magnetic strength or angle. This means that for all $i > N+1$, we must re-evaluate $\tau_{x,i}$. So there are quite a bit of extra compute cycles in the preparation phase of the problem if we are to run the full set of simulations required, and if we are not careful, this in itself means we cannot run the required simulations to generate the training set. This is before we have even considered what predictors are required. Do we need just one predictor per magnetic variable per level or do we need one predictor per magnetic variable per level below the highest level experiencing a changed magnetic field? We do not know yet, so the theory requires some development to fit into RTTOV's framework.

What *might* be done in theory is to assume that the angle and strength changes very little over a transfer and that the resulting change in equivalent scalar transmission is also small [both reasonable assumptions]. Thus we can calculate the first order perturbations by

$$\frac{\partial \mathbf{P}_i}{\partial H_j} = \mathbf{T}_n \mathbf{T}_{n-1} \mathbf{T}_{n-2} \cdots \frac{\partial \mathbf{T}_j}{\partial H_j} \cdots \mathbf{T}_i, \quad \frac{\partial \mathbf{P}_i}{\partial \theta_j} = \mathbf{T}_n \mathbf{T}_{n-1} \mathbf{T}_{n-2} \cdots \frac{\partial \mathbf{T}_j}{\partial \theta_j} \cdots \mathbf{T}_i$$

where H_j is the magnetic field strength at some altitude and θ_j is the angle of the magnetic field relative to observational path of the sensor at some altitude. For sufficiently small changes in H_j and θ_j, something like

$$\mathbf{P}'_{i+1} = \mathbf{P}_{i+1} + \sum_{j=i+1}^{n} \frac{\partial \mathbf{P}_{i+1}}{\partial H_j} \Delta H_j + \sum_{j=i+1}^{n} \frac{\partial \mathbf{P}_{i+1}}{\partial \theta_j} \Delta \theta_j, \quad \tau'_{x,i} = \mathbf{P}'_{i+1} \mathbf{P}'^{\dagger}_{i+1} \Big|_x$$

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where ΔH_j and $\Delta\theta_j$ are relatively small should give reasonable numbers and reduce calculation time dramatically for generating the RTTOV training set. It *might* also be possible to create predictors for the perturbations rather than for the transmissions, which would reduce the number of predictors as well. As with the reviewer's previous comment, however, all of this require further study.

We summarize this text to the second paragraph of the conclusion-section, where we state that:

> To update RTTOV for three-dimensional magnetic fields is difficult but it should be possible. The coefficients used in RTTOV are generated from a large set of calculations that fits the effective scalar line-by-line transmission to space (Equation 2) to a predetermined set of predictors. The polarized transmission from a level to space depends on the polarized transmission across all levels closer to the sensor (through the $\mathbf{T}$s of Equation 3). So using a three-dimensional magnetic field with the present set of predictors will not work, since changes at higher altitudes change the effective scalar transmission to space. We have not attempted to extend the present set of predictors to account for perturbations at higher altitudes and further study will be necessary on how to achieve this. Since the magnetic field is fairly slow changing (see Figure 2 for an estimate), a level-by-level set of perturbations might be applied to transmittances on the right in Equation 3, and predictors incorporated into RTTOV to simulate the effect of the perturbations on the left of Equation 2. This would allow the user to perturb a fixed input field, as presently expected by RTTOV, into a field that varies along the radiation path.

3. The authors keep switching between height and pressure as vertical coordinate. I don't know about other readers but I have to go and look up how, say 10 Pa relates to, say, 80km. I don't particularly like that they make me work this hard when reading the paper. Could they choose their preferred vertical coordinate (perhaps height as this is most readily understood by the widest readership) and stick to it?

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We want to keep both coordinates around. Altitude is easier to understand but pressure is more important from a physics point of view since it is not just a coordinate but also influence, e.g., the shape of the line. Whenever altitude or pressure comes up in a paragraph, the first occurrence is now accompanied by its respective partner to help both the flow and understanding of the text.

I would like to take this opportunity to thank the authors for this useful contribution to the literature on this topic.

Thank you once more.

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

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