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Atmospheric Measurement Techniques Discussions

Interactive comment on "Comparison of total water vapour content in the Arctic derived from GPS, AIRS, MODIS and SCIAMACHY" *by* Dunya Alraddawi et al.

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The authors would like to thank the anonymous referee for his/her valuable perspectives and suggestions; we are pleased to discuss the suggestions and answer the questions.

Suggestions

Suggestion 1: I think you should mention the temporal period of study in the abstract.

AC answer: We can add the temporal period of study, but we didn't mention it as it is different for the three sensors. However, a sentence in the abstract is modified

to be (P1 L23) "The comparisons between GPS and satellite data are carried out for three reference Arctic observation sites (Sodankyla, Ny-Alesund and Thule) where long homogeneous GPS time series of more than a decade (2001-2014) are available".

Suggestion 2: A figure showing time series of cloud cover could be clarifying.

AC answer: in the manuscript, we have presented the annual cycle in order to highlight the different seasonality of cloud cover at the three stations (fig. 6). The inter-annual variability is also examined and presented when necessary, station by station (fig. 7, 8, 9). We did not include the monthly time series of cloud cover because it is not easy to see the correlation between cloud cover variations and TCWV biases which are better highlighted in Fig 7, 8, and 9.

Suggestion 3: Section 2.1 should explain the meaning of "f (lambda, h)".

AC answer: In the section 2.1, it is mentioned that ïĄň and H are the latitude and altitude of the station. We completed the sentence with "f (ïĄň, h) accounts for the geographical variation of the mean acceleration due to gravity (Davis et al., 1985)."

Suggestion 4: Why do you use only cloud cover from AIRS? This way it is only measured at AIRS passes, and this could influence your results. This should at least be discussed in the paper, or changed to use reanalysis cloud cover or cloud cover from the same satellite (AIRS cloud cover with AIRS TCWV; MODIS cloud cover with MODIS TCWV). Notice for instance that SCIAMACHY removes data with AMF < 0.8 where most cloud scenes are screened out, so it is quite difficult that SCIAMACHY product is affected by cloud cover (except for sampling effects).

AC answer: The given AIRS cloud cover has to be interpreted as a typical average value only. It is clear that different sensors with different sampling and different retrieval methods have different sensitivity to cloudiness. Cloud cover fraction by AIRS is used as AIRS has the longest overpasses among the three sensors at the three stations (see table1). So it covers (even partially) the other sensors overpasses. This is mentioned

more clearly in P6-L36: “AIRS cloud fraction is used for this study as AIRS has longest overpasses (Table.1), which include (partially) both other sensors passing hours over the studied stations.”

Suggestion 5: Section 3.1: You could compare with other regions of the world to see if the positive bias in MODIS is something typical of cold regions or it also happens in other regions. See for example Iberian Peninsula references [1], [2]

AC answer: Thank you for providing these references. However, the GPS products are not the same, MODIS spatial sampling is different (L2, L3), and the climate and environmental conditions are too different to compare the results. Actually, our results meet for MODIS all the yearlong at Sodankyla, except winter. Nevertheless, MODIS nearly underestimates GPS all the year at both higher latitudes sites.

Suggestion 6: In several occasions in the results section, you mention possible problems with albedo, specially at Sodankyla. Could you get albedo information (from the satellite products, or from reanalysis) in order to check whether your hypothesis are valid or not?

AC answer: Actually, the albedo hypothesis doesn’t concern mainly a direct relationship between the biases and the albedo values, in a similar way to the study of the clouds effect. However, we think that the biases here are linked with misestimating the surface albedo, and that includes underestimating/overestimating. In consequence, a classic approach that correlates simply the albedo and the biases is not expected to usefully help the interpretation.

Suggestion 7: I think you should provide a "theoretical" explanation of the effect that cloud cover should have on the satellite measurements, based on their respective retrieval method. If, for example, clouds are expect to introduce just noise, then you should repeat your calculations of biases vs cloud cover correlations using absolute biases (mean absolute error for example, or the bias without sign). Then you might find more correlations.

AC answer: Generally, clouds shield parts of the atmosphere (placed under the clouds) to the instrument, so that the observed radiance is only a part of the real one. On the other hand, depending on wavelengths, multiple scattering inside the clouds may even increase the observed radiance. This is handled / corrected by the different retrieval methods in a different way, which may cause both under -or over- estimation of the retrieved TCVW. For example, the air mass correction in the SCIAMACHY data includes a correction for the part of the atmosphere below the cloud, but this relies on some assumptions (e.g. about profile shapes) which might lead to under -or over- correction. In general, clouds are expected to have a systematic effect on the retrieval results (not only noise). This effect is different for the different data sets, which we describe in the manuscript.

Suggestion 9: Page 10, line 31, you mention a correlation that is positive but not significant. I think that if it is not significant, it should not be mentioned. If it is not significant it could be either positive or negative, we cannot say anything about it, no matter that the estimate is positive.

AC answer: Accepted. This sentence has been deleted

QUESTIONS

Question 1: Section 2.1: Is there a reason for you to use 0.75_x0.75_ horizontal resolution? I think Era-Interim products can be downloaded with more resolution (up to 0.125_x0.125_).

AC answer: The ERA-Interim products are archived at IPSL data center at a resolution of 0.75x0.75 degree which is recommended by ECMWF as it is very close to the actual model grid resolution (T255).

Question 2: Section 2.2: Authors say the product is from Terra platform. Why is not any MODIS Aqua data used?

AC answer: Aqua observations of TCWV suffer from many gaps due to interruptions

and downtimes that prevent authors from using it.

Question 3: Last paragraph of page 6: it should be more deeply explained. I understand that this is number of cloudy measurements divided by the number of measurements, but what is the limit to consider a cloudy measurement? CF>0? CF>0.05?

AC answer: Effective cloud fraction meet the condition CF> 0.01, this information was added in P6 L 37 “cloudy measurements are considered for CF>0.01”

Question 4: Section 3.3, Page 8, line 36, wet bias in drier periods and dry bias in moister periods was observed for several satellite instruments in [3], and associated to different spatial resolution (GNSS is local while satellite measurements cover an area of several km). Do you think it could be explained by that reason?

AC answer: The authors don’t think that the explanation is that simple, as there were many exceptions to this remark, see section 3.

Question 5: From your analysis from Section 4, it does not seem to me that clouds are the only reason behind the satellite TCWV biases. Sure there is some influence, but in the majority of cases the correlations are not significant. So there is probably another factor responsible for the biases.

AC answer: That’s right, clouds have an influence but this effect couldn’t be responsible for all the biases, and we refer to this remark in our conclusions.

Question 6: Page 10, line 35, you say "inversely linear". Do you mean linear with negative slope?

AC answer: Yes. The sentence has been clarified.

TECHNICAL CORRECTIONS:

AC answer: All accepted.

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