Atmos. Meas. Tech. Discuss., 7, C3414–C3422, 2014
www.atmos-meas-tech-discuss.net/7/C3414/2014/

Atmospheric Measurement Techniques Discussions

Interactive comment on "Middle-atmospheric zonal and meridional wind profiles from polar, tropical and mid latitudes with the ground-based microwave Doppler wind radiometer WIRA" *by* R. Rüfenacht et al.

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Received and published: 31 October 2014

Reply to comments from referee #2

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31 October 2014

- blue: referee's comments
- green: author's replies

General Comment:

The paper by Rüfenacht presents an improved set-up and retrieval of the ground-based wind radiometer WIRA. The paper is well written and I only have some minor comments for improvements.

Specific comments:

P7718, l1: Is WIRA an abbreviation? If yes, what is it standing for?
WIRA is an acronym for WInd RAdiometer. To make this clear line 4 on page 7719 was modified from "the wind radiometer WIRA" to "the **WI**nd **RA**diometer WIRA"

P7718, l6: Please add the information what has been changed in the set-up.

This part has been re-written: “A technical upgrade including a new high frequency amplifier and sideband filter has improved the signal to noise ratio by a factor of 2.4. Since this upgrade the full horizontal wind field comprising zonal and meridional wind profiles is continuously measured.”

P7718, l10ff: Please add the locations where the measurements have been performed.
The coordinates of the different measurement sites have been added.

P7718, l26ff: Wind measurements in the stratosphere/mesosphere can also be derived from microwave limb sounding measurements. Please add the reference to the paper by Baron et al., Observation of horizontal winds in the middle-atmosphere between 30°S and 55°N during the northern winter 2009–2010, Atmos.Chem. Phys., 13, 6049–6064, 2013 in the introduction.
Reference added.

P7725, l3: What is the abbreviation ARTS standing for? Please add.
The sentence has been modified to “To allow this, the **A**tmospheric **R**adiative **T**ransfer **S**imulator ARTS...”.

P7725, l26: “....go into this term.....” I would suggest to revise the wording.
This part has been replaced by “... calibration errors are absorbed by this term”.

P7728, l24ff: What is the purpose of the comparison shown in Fig. 8 and 9. This is not clearly stated, e.g. it would be worth to clearly state that you are comparing the performance of the old and new set-up.
In our opinion it is clearly stated that we are comparing the the old double sideband receiver setup with the new single sideband receiver setup by the sentence on page 7727, line 24ff:“The values for the single sideband receiver shown in Fig. 8a are based

on data measured with half of the integration time on the sky compared to Fig. 8b because not only zonal but also the meridional wind was measured at this time.”.

P7729, l15: What does this mean? Which set-up is better? This should be clearly stated. It would be further worth to quantify the improvement.
and
P7729, l18: “.....significantly improved the quality of the data.....”. This becomes not clear from the previous sections. Some more clear statements in this sections would be helpful.
These questions are in our eyes more related to the description of the instrument which is given in Sect. 2. There we state on page 7720 line 28ff: “Noise temperature tests with liquid nitrogen calibrations revealed that the upgrade had reduced the noise temperature from 880K double sideband to 740K single sideband. As the contribution of the image sideband in a double sideband receiver can be regarded as noise, the change in the receiver noise temperature corresponds to a 2.4 times better signal to noise ratio for the upgraded instrument.” We think this is a sufficient quantification of the improvement. Moreover this statement should make clear that the upgraded version of WIRA is significantly more sensitive than the old receiver.

P7729, l21-23: To which set-up are referring? The one sided or double sideband receiver?
To the double sideband receiver. The statement has been clarified by modifying the sentence to “... that with the double sideband receiver more integration time was needed to acquire the data”.

P7729, l21: “....thus meridional wind was not measured...”. Is that a drawback? What does one gain from measuring both zonal and meridional wind? Be more precise.
Wind is a vectorial quantity. Measuring also meridional wind offers the possibility to

get a picture of the full horizontal wind field. This can among others be interesting when studying specific dynamical events. For example the evolution of the wind vector during the 2013 SSW shows a strong meridional component during the zonal wind reversal as stated in the manuscript. Moreover it can be thought of further research projects relating the zonal and meridional wind component and their variations.

P7729, l24ff: Please add during which time periods the measurements were performed (dates, season etc.).
The start and end dates of the different campaigns have been added to the indication of the respective coordinates.

P7730, l26-P7732,l2: Where from did you get the information that a warming had occurred? Add references.
According to ECMWF data and the standard definition given by McInturff 1978. The following footnote has been added on page 7731 at the first mention of a sudden stratospheric warming: "In the present article the classification of sudden stratospheric warmings is made according to the definition by McInturff (1978) based on the temperature and zonal wind data from ECMWF operational analysis."
McInturff, R. M.: Stratospheric warmings: Synoptic, dynamic and general-circulation aspects, Tech. Rep. NASA Reference Publication 1017, Washington DC, 1978.

P7731, 115: "Westward?". The wind changes from west to east during a warming. Eastward winds are prevalent during the summer.
Many thanks for pointing this out! This sentence should indeed read as "... speedup of the eastward circulation" and it has been accordingly adapted in the manuscript. Westward wind at high latitudes is prevalent only during summer and SSW's.

P7731, l19: Doesn't to which part of the atmosphere the wind reversal is confined depend on the strength of the warming?

This can also be a local effect of the vortex shape at the measurement site. To foster such a statement one would need many more SSW events observed locally and/or global data. However, we do not deliver in-depth interpretations of the dynamical features observed as we think this is beyond the scope of the actual paper focussing on the retrieval and the upgraded instrument.

P7731, l23: Where is the discrepancy between model and measurements coming from? Due to measurements uncertainties by WIRA or model uncertainties by ECMWF. You discuss this later, but it should also be discussed here or one should refer to the later coming discussion.
We would like to avoid discussing similar things in distinct parts of the paper. We think that the reference "... (see Sect. 5.2)" on P7731, l23 is sufficient to guide the reader.

P7731: Description/discussion of Fig 13? What information does one gain from the meridional wind?
This question has been answered in the reply to your comment to P7729, l21.

P7732, l6: How accurate is ECMWF in the mesosphere?
and
P7733, l17-18: It is not clear what you try to say here. Do you mean that ECMWF could be inaccurate because there are not enough data available to be assimilated to the model? Problems of the model simulating correctly processes in the stratosphere/troposphere could surely affect the model performance in the mesosphere, but what exactly causes the discrepancies? I am sure that there have been some studies already published performing comparisons in the mesosphere discussing the accuracy of the ECWMF model in the mesosphere which could be helpful for the discussion of your results.
Despite an extended literature search and contact to several people from ECMWF we were not able to get reliable information on the accuracy of ECMWF winds in the

mesosphere.

P7733, l20ff: What is the major improvement? The new set-up or the new retrieval algorithm? This becomes not clear. At same places it sounds like the one way and at other places in the text the other way round.
Retrieval and instrument are two distinct fields of developments and cannot be played off against each other. The technical upgrade allowed us to reduce the measurement noise although we use less integration time for the measurement of zonal wind as we are now also measuring meridional wind. The new retrieval accounts for dependences between the parameters especially also the degree of dependence between the different altitude levels and offers better diagnostics.

P7734, l4: "....displacement events in the polar vortex....." How can the displacement of the vortex be seen in the wind? The SSWs change the wind direction. Isn't the vortex displacement just a cause of the SSW?
This is just a matter of definition. An event is called major SSW if a significant temperature increase poleward of 60° is observed and if the zonal mean zonal wind at 60° reverses. However, the vortex can extend down to some mid latitude stations in a longitude segment without the SSW criterion being satisfied. Under such conditions we locally observe conditions which are very similar to the ones encountered in case of an SSW.

P7734, l10: no input of what? No input of measured data? That does not necessarily mean that the model is not able to reproduce the wind in the mesosphere.
"no input data" has been replaced by "no measured input data". At no point we were stating that ECMWF is wrong. We are not modelers and therefore we are not able to make a statement on the accuracy of the modeled data. We do just provide our data and our knowledge on the ECMWF input variables.

Technical corrections:

P7718.. l23: ".....the the.....", one "the" is obsolete.
Corrected.

P7732, l4: skip "already".
Skipped.

P7732, l5: skip "data".
This sentence seems to be correct in our eyes.

P7733, l18: "mesoshperic" should read "mesospheric".
Corrected.

P7734, l8: "averages of" or "averaged".
Modified to "averages of".

Figures:

Figure 2: What exactly is new compared to the previous set-up of WIRA? Mark this in the figure or name it in the figure caption.
The figure has been adapted in this sense marking each new element by an asterisk.

Figure 6: Add to the figure caption the lowest and highest level that is considered, so that the text reads ".....altitude levels from 32.4-72.4 km.....".
The figure caption has been adapted to "... altitude levels between 72 km (top left panel) and 32 km (bottom right) according to ...". The legend of the different panels is now indicated in pressure levels for consistency with the other plots as suggested by referee #1.

Figure 8 and 9: Add to the caption of the figure what is shown in the left figure and what in the right. It should become clear that you are comparing here the old and new set-up of the instrument.
This information has been added to the figure caption.

Figure 11: Add to the figure caption what the dashed lines are. Add also to the caption what is shown by the red and blue lines.
The horizontal dashed lines were the altitude limits of the trustable altitude range for the worst case (double sideband with 0.2 K noise). The figure has however be adapted just showing data inside the trustable altitude range of WIRA so that these horizontal lines became obsolete (according to a comment from reteree #2). The red and blue lines are described in the legend

Figure 12: Grey lines? I don't see any grey lines. Only the grey areas that mark the data gaps. The larger gaps in figure 12d have been explained, but not the smaller on in figure 12 a,b, c.
The grey lines in the panels showing the WIRA data mark the limits of the trustable altitude range described in Sect. 4.2. The panels showing the ECMWF data do not contain any grey lines as ECMWF data is assumed trustable in the entire altitude range it is provided.