Responses to Anonymous Referee #2's comments on the manuscript tc-2013-199

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The manuscript presents a data set of polar gridded L-band radiometer and scatterometer observations from Aquarius and salinity retrievals. It fills a gap as until now these observations have been much more difficult to access. Thus, the contribution opens the door for more investigations of the geophysical content of Aquarius observations of sea ice, land ice and open ocean. Example observations of all these surface types are presented.

In order to facilitate the data use, also sea ice concentrations from NCEP GSF GDAS are given. The latter data set should be characterized in more detail, especially its differences to microwave based brightness temperatures which might be more familiar for the remote sensing community.

Some of the figures should be improved (see details below). In Figure 4 of time series of Tbs, also the surface temperature shold be given in order to substatiate the discussion.

I suggest to accept the paper after minor revisions.

We thank the reviewer for these relevant comments and suggestions. They were useful in producing a refined description of the Aquarius weekly-polar-gridded products, and an improved description of the Aquarius observations and retrievals over the polar regions. Following reviewer 1's suggestion, we now present our study in two papers. This allows us to include additional text and material, especially more physical explanations when describing the observations, as recommended by the two reviewers. The papers are named as follows:

- Weekly-gridded Aquarius L-band radiometer/scatterometer observations and salinity retrievals over the polar regions, part I: Product description
- Weekly-gridded Aquarius L-band radiometer/scatterometer observations and salinity retrievals over the polar regions, part II: Initial product analysis

A minor reorganization of our text was done in order to allow a publication in two parts. A new abstract, introduction, and conclusion were written. In this response document, we address every comment and present the corresponding improvements made in the manuscripts.

The calculation of ice fraction in the Aquarius footprint requires to integrate sea ice concentration field over the sensor's field of view and to weight the data by the antenna gain patterns. These are not straight forward calculations, and they require the use of an Aquarius simulator. Therefore, comparing the sea ice concentration estimates used in the processing of Aquarius Level 2 data sets with other sea ice concentration products represents a dedicated study.

We improved every figure for which the reviewer requested improvements. For example, now maps contain observations for every two months in 2013 with larger font for the latitude and longitude values. The time series of air temperature measurements were added for two locations in Greenland (South Dome and Summit). We also added on the brightness temperature time series the standard deviation values.

Abstract

Line 14: give also physical resolution, in addition to grid cell size

We added:

The largest 3-dB footprint dimensions are 97 km x 156 km and 74 km x 122 km (along x across track) for the radiometer and scatterometer, respectively.

Text

Page 5923 Line 15/16: SMAP launch currently scheduled early 2016. Check again when revising.

As of 02/25/14, according to the NASA webpages and members of the SMAP Science Team, SMAP launch is still planned for late 2014 (specifically November 5, 2014). Our statement is left unchanged. If the reviewer has an official and public source, we can reconsider our statement.

P 5924 L 9 Aquarius has three L-band radiometers for three incidence angles, each providing...

Corrected as suggested.

L 13 '..using the same feed horns as the radiometers, and thus coincident with the radiometer's observations': This is not possible as radiometer and scatterometer observe at different times. On p 5926 L8 stated more plausible: observing at the same incidence angle.

We added specific details about the sensors to explain why the radiometer and scatterometer observations can be considered coincident:

For all practical purposes the radiometer and scatterometer measurements are considered coincident. The data used to produce the weekly-gridded products are from the Level 2 product, which consists of 1.44-s observation samples. These blocks are composed of twelve 120-ms subsamples, during which the radiometers and scatterometer measure alternatively over 10~ms samples. During this time sample, the footprint moves only a few meters on the ground (an infinitesimal fraction of the footprint size) and environmental parameters are considered constant.

P5929 L 8: weekly polar gridded products: give reason why not producing daily products: coverage? Variability of geophysical quantities of interest?

We added:

According to the orbit and sensor characteristics, the temporal resolution of the product was set to one week, corresponding to the time of revisit. Since the Aquarius' sensors are in a push-broom alignment, a weekly-gridded product provides the largest spatial coverage.

P 5926 L 4-7: Third Stokes also measured, but assumed null at surface: Put this assumption into the context of WindSat observations of 3rd Stokes over land (Narvekar etal. 2007), land ice (Narvekar et al. 2010) and sea ice (Narvekar et al. 2011): Over periodic structures it may take up to few K.

We added:

The third Stokes parameter (U) is also measured. At L-band, U emitted by the ocean surface is small, and the assumption of U=0 is used in the Aquarius Level 2 processing to retrieve properties of the Faraday rotation in the ionosphere (Yueh, 2000), and properties of the antenna cross-polarization coupling (Le Vine et al., 2011; Kim et al., 2011). As shown by Yueh et al. (2013), there could be a sizeable variation of U over the oceans for large wind speeds, but a study of the ice-covered surfaces is still to be carried out. Analysis of U at higher frequencies with WindSat (e.g. 10.7 or 37 GHz) have shown that over the Antarctic ice sheet there is a small dependency on the azimuth angle (Narvekar et al., 2010). Over sea ice, WindSat U observations were low expect during the melt season, and in the marginal ice zone (Narvekar et al., 2011).

Yueh, S.H.; Wenqing Tang; Fore, A.G.; Neumann, G.; Hayashi, A.; Freedman, A.; Chaubell, J.; Lagerloef, G.S.E., "L-Band Passive and Active Microwave Geophysical Model Functions of Ocean Surface Winds and Applications to Aquarius Retrieval," *Geoscience and Remote Sensing, IEEE Transactions on* , vol.51, no.9, pp.4619,4632, Sept. 2013, doi: 10.1109/TGRS.2013.2266915

Parag S. Narvekar, Georg Heygster, Thomas J. Jackson, Rajat Bindlish, Giovanni Macelloni, Justus Notholt: Passive Polarimetric Microwave Signatures Observed Over Antarctica. IEEE T. Geoscience and Remote Sensing 48(3-1): 1059-1075 (2010)

Parag S. Narvekar, Georg Heygster, Rasmus Tonboe, Thomas J. Jackson: Analysis of WindSat Third and Fourth Stokes Components Over Arctic Sea Ice. IEEE T. Geoscience and Remote Sensing 49(5): 1627-1636 (2011)

L10 night side of the sun-synchronous orbit: mention equator crossing time.
We added line 9:
During the ascending pass, Aquarius crosses the equatorial node at 6 pm.

P5927 L 24 'in SH, L-band RFI are rare': can you quantify this?
We added a map of RFI occurrences over Antarctica in 2013. We also added the following text:
In the high latitudes of the Southern Hemisphere L-band RFI occurrences are rare ***(~30 instances in 2013), and contamination was never repeated in a given grid cell (Figure 2).***

P5928 L6 NCEP GSF GDAS sea ice product: which resolution of the model is used here?
The new text is:
Sea ice concentration estimates are ***obtained from the analysis by NOAA's Marine Modeling and Analysis Branch (http://polar.ncep.noaa.gov/seaice/Analyses.shtml), available daily at a spatial resolution of 1/12º , and*** *distributed by the US National Centers for Environmental Prediction (NCEP) as the Global Forecast System (GFS) Global Data Assimilation System (GDAS) sea ice product.*

L15 'L2B product calibrated against forward RTM': give reference. Which surface types used for calibration?
We reorganized the paragraph so that the reference now appear right after line 15, and added the surface type used for calibration:
Level 2 TB product is computed after empirical calibration of the measured antenna temperatures against a forward radiative transfer model ***over ocean surfaces Le Vine et al. (2011)***. ***More details about the Level 2 processing can be found in Wentz and Le Vine (2012); Le Vine et al. (2012) and Piepmeier et al. (2013). Briefly,*** *the antenna temperatures are corrected for […].*

P5929 L 18: In addition, the distinction per beam...
"***In addition,*** " added as suggested.

L 20: Mention that for each week, in total nine TB maps are given.
We added: ***For each week and hemisphere, eighteen TB maps are produced and distributed (one for each of the three radiometers, each of the two polarizations, and each of the three orbit combinations).***

L 24: Also for NRCS, each beam and each orbit...
We added: ***For each week and hemisphere, eighteen NRCS maps are produced and distributed (one for each of the three beams, each of the three polarizations, and each of the two orbit combinations).***

P 5930 L 22 interpolation: in space or in time? If in space: bilinear?
The weekly-averaged values are interpolated in space. We added:
*In these situations, a **Delaunay triangulation with linear interpolation was applied to** the weekly-gridded values **to spatially interpolate TB and NRCS** in grid cells without observations during the cycle.*

P5931 L 9: Data volume per week?
We added the requested information in the description of each product:
For TB and SSS: ***The data volume for all incidence angles, per week and per hemisphere, is ~5.5 MB.***
For NRCS: ***The data volume for all incidence angles, per week and per hemisphere, is ~1.1 MB.***
For SSS3b: ***The data volume for all incidence angles, per week and per hemisphere, is ~0.7 MB.***

P5932 L1 ICEF_STD_SCA: inconsistent naming convention. In all other products, '_STD' is at end of name string. Reason? Make it consistent?
In the future reprocessing, the variables will be renamed as follows: ICEF_RAD, ICEF_RAD_STD, ICEF_SCA, ICEF_SCA_STD. Names were modified accordingly in the revised manuscripts.

L 14 ... e.g. liquid water content...
As suggested, we added: *liquid water **content***

P5934 L 2: 'almost similar': 'similar' or 'almost equal'
We deleted almost.

L 7-9: mark the two places of the time series Figure 4 in Figure 2 and Fig. 5.
The localization of the two places were added on the maps.

L 10 'temperature profile': do you mean temperature time series of temperature vertical profile?
The revised sentence is:
*[...] the time series of TB [...] show that there is no annual cycle related to **seasonal** variations in the snow temperature profile**.***

L 11 'impacted by snow melt': show this by adding surface temperature to time series Fig 4.
Now, this figure contains two subfigures (one for observations at South Dome, and the other for observations at Summit). Each subfigure includes two panels, one with TB observations and the other with hourly air temperature measurements from the South Dome weather station, which is part of the Greenland Climate Network: GC-Net (Steffen et al., 1996). We added page 5934, line 10:
*However, observations in summer are impacted by snow melt. Observations in the South Dome area show a sudden increase of TB. **Hourly air temperature measurements at the nearby weather station (63.149ºN, 44.817ºW), part of the Greenland Climate Network (GC-net; Steffen et al., 1996), were above the melting point during that week (during 3 consecutive days for 12h). Thus, the sudden increase of TB is associated with the presence of liquid water in the snow cover. TBs remain high as long as measured air temperatures exceed 0ºC, maintaining the presence of liquid water. Later in the summer, TB decrease as liquid water content decreases (freezes)**. This is a typical TB evolution at microwave frequencies when snow is melting.*

Figure 4 also shows the TB observations at Summit during the summer 2012, and the time series of hourly air temperature measurements recorded by the Summit GC-net weather station (72.579ºN, 38.505ºW).

Steffen, Koni, Jason E. Box, and Waleed Abdalati. 1996. “Greenland Climate Network: GC-Net”, in Colbeck, S. C. Ed. CRREL 96-27 Special Report on Glaciers, Ice Sheets and Volcanoes, trib. to M. Meier, pp. 98-103.

L 14 ‘later in the summer when snow grain size and density increase’: where from known? In this form this is speculation. Give physical reason and reference.
These elements were deleted. The revised sentence is available in our previous response.

P 5935 L 11 ‘eastern part of the continent’: does not make sense for Antarctica. Do you mean East Antarctica?
Yes, we now use East Antarctica though out the manuscript.

Fig. 5:
- Mark all places mentioned in text in one of the sub-figures: Vostok, Mary Byrd, Amery, Larsen C.
- lat/lon numbers too small to read.
We added the location names on one map.
Every hemispheric map was updated to enlarge the font of the lat/lon numbers.

P 5939 L 27: the correlation between A and D orbits will also be interesting for HH and VH polarizations, as well as the correlation between the polarizations. It seems that VV and HH are quite similar, but VH is different.
We added the following text and three tables with the various correlation coefficients:
The linear correlation coefficient between NRCS ***co-polarized (VV and HH)*** *observations of the ascending and descending orbits for this first week of July, 2013 is* ***weak (0.51 – 0.61; Table 1*** (similarly Table R2.1)***). NRCS observations at the cross-polarization VH have a stronger correlation coefficient between the two orbit types (0.81 – 0.88; Table 1). These values*** *illustrate the importance of distinguishing the ascending and descending orbits when analyzing the NRCS observations,* ***regardless of the polarizations.*** **For a given orbit type, the correlation between the polarizations is the strongest between VV and HH, and increases as the incidence angles increases (from 0.991 at 29.2*** ***º*** ***to 0.998 at 46.3º).** See Table R2.2.

Table R2.1 Linear correlation coefficients of the weekly-gridded NRCS observations made during the ascending and descending orbits over the AIS during the first week of July 2013 (cycle 98).

	Beam 1	Beam 2	Beam 3
VV	0.519	0.608	0.526
VH	0.813	0.868	0.884
HH	0.510	0.625	0.569

Table R2.2 Linear correlation coefficients of the weekly-gridded NRCS observations at different polarization for a given orbit type over the AIS during the first week of July 2013 (cycle 98).

			Ascending		
			VV	VH	HH
Ascending	Beam 1	VV		0.904	0.997
		VH			0.913
		HH			
	Beam 2	VV		0.918	0.995
		VH			0.932
		HH			
	Beam 3	VV		0.878	0.991
		VH			0.908
		HH			

			Descending		
			VV	VH	HH
Descending	Beam 1	VV		0.888	0.998
		VH			0.880
		HH			
	Beam 2	VV		0.917	0.995
		VH			0.933
		HH			
	Beam 3	VV		0.908	0.993
		VH			0.930
		HH			

P 5941 L 22: Aquarius observations -> L-band observations
Modified.

P 5942 L11-12 'SSS in the polar regions varies seasonally...': sentence currently unrelated to manuscript and Fig. 17 and 18: can this be seen in the figures? How strong is the expected effect (ref?)? How will the data set of this manuscript be helpful in this context?
We discuss in the text the fact that it is currently very challenging to detect seasonal signals due to hydrological cycle in the polar regions because of the inaccuracies still present. This is something that will need to be improved on, and that will be included in future iterations of the product. We moved the following modified sentence sentence to the next paragraph, as an introduction:
SSS in the polar regions ***is expected to vary*** *seasonally as ice freezes up (leaving saltier water in the ocean) and melts (adding fresh water in the ocean).*

L 27 six continuous pixels: in time or space?
We added:
Where less than six contiguous grid cells do not have ***weekly-averaged values****, a* ***Delaunay triangulation with linear interpolation was*** *applied* ***to spatially interpolate Aquarius data****.*

P 5943 L 13 'These products enhance the use..': are intended to enhance, or intended to facilitate.
We replaced it by ***intend to facilitate***.

L 16 impacted the L-band TB: increased 'with implications for surface mass balance monitoring': surface does not have a mass. Do you mean surface characteristics and mass balance monitoring?
Yes, we meant surface characteristics and mass balance monitoring. We modified the sentence.

L 17 shows -> show
Corrected.

L 18 0.3 – 0.4 dB

These values correspond to the ice fraction (unitless) values. We rephrased the sentence to avoid any ambiguities:

NRCS values over Antarctic sea ice shows a transition ("bright NRCS ring") from the packed sea ice to lower ICEF ***with values of*** *0.3–0.4.*

Figure 3: select lighter blue tone for easier distinguishing

The histograms were updated with a lighter blue color.

F4: show also surface temperature of both places of that year. Which year shown?

As mentioned above, we have added physical temperature data.

We now mention the year on the x-axis.

F6 select lighter blue tone for easier distinguishing

Similarly to figure 3, the histograms were updated with a lighter blue color.

F9, F10: lat/lon unreadable

Every map with a too small font for the lat/lon values was updated.