Earth Syst. Sci. Data Discuss.,
https://doi.org/10.5194/essd-2020-255-AC1, 2021

Interactive comment on "Wind, waves, and surface currents in the Southern Ocean: Observations from the Antarctic Circumnavigation Expedition" *by* Marzieh H. Derkani et al.

Marzieh H. Derkani et al.

marzieh.h.derkani@gmail.com

Received and published: 9 January 2021

Response to Anonymous Reviewer #1

R#1: As suggested by the topic editor, more information could be given in the abstract and conclusion on the questions already addressed by the PIs of these measurements, and those that could be addressed in the future by external users.

AC: Research supported by these data sets as well as future applications have been discussed in the abstract and conclusions.

R#1: A general calendar could be added so that a user can see immediately if data sets exist on their dates of interest.

AC: We thank the reviewer for this suggestion. We have added a general calendar as an additional file (*Available_Measurements_List.txt*) to the data set. This new file provides day and time of available measurements in the format yyyy-mm-dd hh:MM:ss. It is also available via the link below:
https://u.pcloud.link/publink/show?code=XZjMtQXZjzHChPvK1Tyn9WGYLaGhsFWPpN67.

R#1: Also, one information which I could not find is: do you include somewhere in your data sets, the information on the sea-ice cover? (could be interesting if available)

AC: Our observations are limited to open water conditions as measurements in the marginal ice zone were not accurate and thus excluded. We added a comment at the end of Section 3.2 to clarify the exclusion of data in sea ice. Information on sea ice cover is presented in Figure 1 of the manuscript and is retrieved from the Advanced Microwave Scanning Radiometer 2 (AMSR2) database. This database is publicly available at https://seaice.uni-bremen.de/sea-ice-concentration/amsre-amsr2/. We have included the link in the revised version.

R#1: I suggest to add here some references to previous publications on WAMOS –II data sets to let the reader know what are the expected performances or known limitations on other parameters of the data set such as dominant wave direction,dominant frequency, directional spread, surface current.

AC: We thank the reviewer for this suggestion. We have added a brief discussion on the performance of WAMOS-II and relevant references (Hassner et al., 2002; 2007; 2019; Lund et al., 2015b; 2015b) in Section 3.1.

Specific comments

R#1: Section 3.1, line 97: more details should be added on the type of wind sensor, its position on the vessel, the height measurement, the calibration procedure

AC: Details on the wind sensors are extensively discussed in Landwehr et al. (2020), Schmale et al. (2019) and Thurnherr et al. (2020). A brief summary describing the wind sensor has been added in Section 3.1 for completeness.

R#1: Line 120: please give more details on how the shadowing effects and tilting effects are removed. Is it a correction of a filter based on data quality control? How many data sets are eliminated by this procedure?

AC: To minimize imaging effects like shadowing and tilt modulation, the WaMoS-II wave analysis was carried out in areas within a limited range. This approach assumes that these effects are homogeneous and can be compensated by a single Modulation Transfer Function (MTF) as described in Nieto Borge et al. (2004). Note that this is a standard method in WaMoS-II and further details are not disclosed by the manufacturer and thus excluded. A brief discussion on mitigation of tilting and shadowing effects with the MTF (Nieto Borge et al., 2004) is added in Section 3.2.

The internal real time WaMoS-II quality control (iQC) is independent of the applied MTF. The iQC is based on various different individual tests (see Hessner et al., 2019), which evaluate different conditions required for reliable radar-based wave measurements (e.g. sufficient sea clutter information or stable ship motion conditions). Most of the data that were labeled as unreliable were recorded in ice-covered waters with no significant surface waves present or the radar not operating in required short pulse mode. Therefore, data in the marginal ice zone has not been included in the data set. This has been remarked in the revised version of the manuscript.

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Discussion paper

R#1: Line 124 and following: the method for rescaling the wave spectrum deserves more details. Indeed, I could not find details on this rescaling in the Young et al, 1985 publication. Furthermore, other publications on WAMOS, like the one of Nieto Borge et al, 2004 mention that this type of rescaling may not be fully appropriate, as the Transfer Function between image intensity and wave heights depends on the wave number of the ocean waves. Could you comment on that in the manuscript?

AC: We thank the reviewer for this comment. The rescaling that we used is the standard method implemented in the WaMoS-II software. Available details can be found in Nieto Borge et al. (1999) and Nieto Borge et al. (2004). These details are already summarised in the original manuscript (lines 124 and following). Note that additional, more detailed, information about the rescaling is not disclosed by the manufacturer and thus cannot be presented.

The reviewer is right when stating that no information is provided by Young at al. 1985 in this regard. Reference to that paper was included by mistake and the correct citations have been added to the revised version of the manuscript.

The capabilities of the rescaling technique are discussed and demonstrated in Nieto Borge et al. (1999) and Hessner et al. (2002); these two references have been added to the revised version of the manuscript and briefly commented on. We do not find any discussion on the appropriateness of rescaling techniques in Nieto Borge et al. (2004) as mentioned by the reviewer. If we misunderstood the comment, we would appreciate receiving more details in order to better address this concern. Nevertheless, our understanding of the discussion in Nieto Borge et al. (2004) is that the Modulation Transfer Function (MTF) compensates for the nonlinearities related to imaging effects such as tilt modulation and shadowing. As these depend on the view geometry (antenna height and range), WaMoS-II limits the analysis range to an area where the imaging effects are assumed to be homogeneous, allowing application of the MTF method. As the imaging effects also depend on the wavelength, the MTF is a function of wavenumber. While the MTF allows extrapolating the wave spectrum from the image spectrum, the resulting spectral density still requires a calibration to return the correct energy content (the MTF returns the relative energy distribution and not the absolute one). In order to get the absolute values, the spectrum needs to be rescaled, so that the individual frequency and direction bins are related to wave energy. To do so, WaMoS-II uses the rescaling techniques discussed at lines 124 and following. The text has been reworded to clarify the overall process.

R#1: Line 132-133: please give details or references on how the partitions were estimated (method of partitioning, external data used in the partitioning if any - like wind speed and wind direction,...)

AC: The partition of the wave spectrum is performed using the "path of steepest ascent" technique proposed by Hanson Phillips (2001), which is a specific implementation of the inverse catchment scheme introduced by Hasselmann et al. (1996). Different wave systems (i.e. spectral peaks or subcatchments) are determined by associating each spectral grid point to the neighbor with the highest energy level. Grid points corresponding to the same local peak are clustered, and each of these clusters defines a partition (watershed algorithm). The spectral peak that satisfies the condition

$$1.2\frac{U}{c_p}cos(\theta-\psi)>1,$$

where U is the wind speed, c_p is the phase velocity, θ is the wave direction and ψ is the wind direction, is associated with the wind sea. All other systems are swell and are ranked based on their energy contents as primary, secondary and tertiary swell. Details on partitioning and related references have been added to the revised version of the manuscript in Section 3.2.

R#1: Section 3.4: I am surprised that only ship data are used to build reference values of significant wave height Hs. You do not have any possible comparison with buoy data when the ship was in coastal regions? Using ship IMU data as reference to obtain Hs does not seem so trivial as shown for example by Nielsenand Dietz (see e.g. "Estimation of sea-state parameters by the wave buoy analogy with comparisons spectral wave modelsÂż, Ocean Engineering 2020). In the ship to wave spectral transformation, do you take into account the possible non-linearities of the ship response, the effects of ship speed, of direction of waves with respect to the ship heading,....? More details should be added in this section. On the other hand, I must admit that the a posterior validation using satellite significant wave heights, as presented in Fig.7, is convincing.

AC: That is correct, we could not perform a calibration based on buoy data because there were no co-located buoy measurements during ACE. Therefore, the calibration had to rely on the sea state retrieved from ship motion data. The underlying principle for sea state reconstruction is that the ship is a rigid body with six degrees of freedom (three translations: heave, surge, and sway; and three rotations: pitch, roll, and yaw) and moves in response to the incident wave field and restoring forces as a function of its mass, geometry, loading conditions and forward speed among other parameters (Newman, 2018). The relation linking ship motion and energy spectrum of the incident wave field is evaluated by the response amplitude operator ($R(f)$, see Newman, 2018), i.e. a ship-specific function that translates the motion spectrum ($S_{ship}(f)$) into the incident wave spectrum ($S_{wave}(f)$): $R(f)^{-2} = S_{wave}(f)/S_{ship}(f)$.

Motion spectra were evaluated by applying a Fourier Transformation over 5 minute long time series of heave motion. $R(f)$ was calculated by solving the equation of motion with a model based on boundary element methods (Babarit Delhommeau, 2015), taking into account the ship's heading, forward speed and loading conditions; the model is based on a linear approach and thus nonlinearities were excluded. The significant wave height was validated against freely available satellite altimeter data (Ribal Young,

2019) of significant wave height for the entire voyage. The text describing the sea state reconstruction from ship motion has been updated (see Section 3.4). Furthermore, we have added an appendix (Appendix B) in the revised manuscript, where we discuss the accuracy of the reconstructed sea state against satellite altimeter observations. The appendix includes Figure B1, which shows the scatter plot of significant wave height from satellite altimeter versus significant wave height reconstructed from the ship motion. Due to the coarse resolution of satellite data, average values are computed for clusters with spatial resolution of $0.5° \times 0.5°$ and temporal resolution of 3 hours. There is a good agreement overall. The root-mean squared error $(RMSE)$ is $\approx$ 0.4 m, the correlation coefficient (R) is $\approx$ 0.94, and the scatter index (SI) is $\approx$ 0.17. Note that similar error metrics have been obtained by comparing the reconstructed sea state against parameters from ECMWF ERA-5 reanalysis.

R#1: Section 4.1 comments about the statistics on current: You have omitted to mention that the current from satellite altimeters are not surface currents but geostrophic currents.

AC: We thank the reviewer for spotting this error. We used current data from COPERNICUS-GLOBCURRENT - https://marine.copernicus.eu, which combines the total velocity field based on satellite geostrophic surface currents with modelled Ekman currents, which includes wind stress forcing obtained from atmospheric system and drifters data. Information on COPERNICUS-GLOBCURRENT has been added in Section 4.1.

R#1: Section 4.2 lines 204-207: please , indicate how the raw wind measurements were converted into ten meter-height winds (U10), and what is the duration of integration of the raw data.

AC: Wind measurements (20-minutes average) are converted from the measurement height to a 10-metre above sea level wind speed (U_{10}) by assuming a logarithmic profile (see Landwehr at al., 2020). Furthermore, atmospheric boundary layer instability was not considered and thus U_{10} represents the neutral wind speed. Details have been added in Section 3.1.

R#1: Line 223-224: it is strange that the only references that you give to mention the oceanic directional distribution of waves come from wave tank measurements. Could you add some references on field measurements?

AC: References to field measurements by Mitsuyasu et al. (1975), Donelan et al. (1985), Young et al. (1996) and Young et al. (2020) have been added.

R#1: Line 240: here again , mention that the current measurements from WAMOS-II and the climatological currents estimated from altimeter data do not represent exactly the same geophysical quantity.

AC: The reviewer is right. Even though we used a combination of geostrophic surface currents and modelled Ekman currents, WaMoS-II still detects additional components such as inertial oscillations (Treguier and Klein, 1994), which are not represented in the benchmark data set. As inertial oscillations are particularly strong in the Southern Ocean, they represent a notable source of uncertainty. Furthermore, Ekman components remain uncertain in the Southern Ocean due to inaccuracies in estimating wind stress from the atmospheric system, adding more inconsistencies between benchmark and our observations. In the revised version of the manuscript we have commented on the differences between our observations and the benchmark data in Section 4.2.

R#1: Lines 270-273: you could mention that on these examples, SAR does not detect the wind sea, in opposite to WAMOS-II data.

AC: We thank the reviewer for this comment. We have added an additional statement to stress that SAR does not detect wind sea.

Technical corrections

R#1: Figure 5: you could mention in the legend that the circles in dashed light lines (hardly visible) are plotted every15° in latitude

AC: We have edited the figure and added this information in the caption.

R#1: Line 201: "pattern"(instead of "patter")

AC: This typo has been corrected.

R#1: Figure 8 i) the marks for the scales are not visible (circles in wave number or frequency) ii) Also could you add the wind direction on these polar plots?

AC: The figure has been updated accordingly.

References:

Babarit, A. and Delhommeau, G., 2015, September. Theoretical and numerical aspects of the open source BEM solver NEMOH.

Donelan, M.A., Hamilton, J. and Hui, W., 1985. Directional spectra of wind-generated ocean waves. Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences, 315(1534), pp.509-562.

Hanson, J.L. and Phillips, O.M., 2001. Automated analysis of ocean surface directional wave spectra. Journal of atmospheric and oceanic technology, 18(2), pp.277-293.

Hasselmann, S., Brüning, C., Hasselmann, K. and Heimbach, P., 1996. An improved algorithm for the retrieval of ocean wave spectra from synthetic aperture radar image spectra. Journal of Geophysical Research: Oceans, 101(C7), pp.16615-16629.

Hessner, K.G., El Naggar, S., von Appen, W.J. and Strass, V.H., 2019. On the reliability of surface current measurements by X-Band marine radar. Remote Sensing, 11(9), p.1030.

Hessner, K., Reichert, K., Dittmer, J., Borge, J.C.N. and Günther, H., 2002. Evaluation of WaMoS II wave data. In Ocean Wave Measurement and Analysis (2001) (pp. 221-230).

Hessner, K., Nieto-Borge J.C., and Bell P.S., 2007. Nautical Radar Measurements in Europe, Applications of WaMoS II as a Sensor for Sea State, Current and Bathymetry. In: Sensing of the European Seas, Barale, Vittorio; Gade, Martin (Eds.), Springer, p435-446.

Landwehr, S., Thurnherr, I., Cassar, N., Gysel-Beer, M. and Schmale, J., 2020. Using global reanalysis data to quantify and correct airflow distortion bias in shipborne wind speed measurements. Atmospheric Measurement Techniques, 13(6), pp.3487-3506.

Lund, B., Graber, H.C., Hessner, K. and Williams, N.J., 2015a. On shipboard marine X-band radar near-surface current "calibration". Journal of Atmospheric and Oceanic Technology, 32(10), pp.1928-1944.

Lund, B., Graber, H.C., Tamura, H., Collins III, C.O. and Varlamov, S.M., 2015b. A new technique for the retrieval of nearâĂŘsurface vertical current shear from marine XâĂŘband radar images. Journal of Geophysical Research: Oceans, 120(12), pp.8466-8486.

Mitsuyasu, H., Tasai, F., Suhara, T., Mizuno, S., Ohkusu, M., Honda, T. and Rikiishi, K., 1975. Observations of the directional spectrum of ocean WavesUsing a cloverleaf buoy. Journal of Physical Oceanography, 5(4), pp.750-760.

Newman, J.N., 2018. Marine hydrodynamics (p. 448). The MIT press.

Nielsen, U.D. and Dietz, J., 2020. Estimation of sea state parameters by the wave buoy analogy with comparisons to third generation spectral wave models. Ocean Engineering, 216, p.107781.

Schmale, J., Baccarini, A., Thurnherr, I., Henning, S., Efraim, A., Regayre, L., Bolas, C., Hartmann, M., Welti, A., Lehtipalo, K. and Aemisegger, F., 2019. Overview of the Antarctic circumnavigation expedition: Study of preindustrial-like aerosols and their climate effects (ACE-SPACE). Bulletin of the American Meteorological Society, 100(11), pp.2260-2283.

Nieto Borge, J., Hessner, K. and Reichert, K., 1999, July. Estimation of the significant wave height with X-band nautical radars. In Proc. 18th Int. Conf. Offshore Mechanics and Arctic Engineering (OMAE).

Nieto Borge, J., RodrÍguez, G.R., Hessner, K. and González, P.I., 2004. Inversion of marine radar images for surface wave analysis. Journal of Atmospheric and Oceanic Technology, 21(8), pp.1291-1300.

Ribal, A. and Young, I.R., 2019. 33 years of globally calibrated wave height and wind speed data based on altimeter observations. Scientific data, 6(1), pp.1-15.

Thurnherr, I., Kozachek, A., Graf, P., Weng, Y., Bolshiyanov, D., Landwehr, S., Pfahl, S., Schmale, J., Sodemann, H., Steen-Larsen, H.C. and Toffoli, A., 2020. Meridional and vertical variations of the water vapour isotopic composition in the marine boundary layer over the Atlantic and Southern Ocean. Atmospheric Chemistry and Physics, 20(ARTICLE), pp.5811-5835.

Treguier, A.M. and Klein, P., 1994. Instability of wind-forced inertial oscillations. Journal of Fluid Mechanics, 275, pp.323-349.

Young, I.R., Fontaine, E., Liu, Q. and Babanin, A.V., 2020. The Wave Climate of the Southern Ocean. Journal of Physical Oceanography, 50(5), pp.1417-1433.

Young, I.R., Rosenthal, W. and Ziemer, F., 1985. A threeâĂŘdimensional analysis of marine radar images for the determination of ocean wave directionality and surface currents. Journal of Geophysical Research: Oceans, 90(C1), pp.1049-1059.

Young, I.R. and Verhagen, L.A., 1996. The growth of fetch limited waves in water of finite depth. Part 2. Spectral evolution. Coastal Engineering, 29(1-2), pp.79-99.

Interactive comment on Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2020-255, 2020.