Intercalibration of C-band scatterometer records using cone metrics

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Abstract

With an eye on the generation of a consistent long-term climate record of ocean winds, soil moisture and sea ice extents across the C-band scatterometer missions, a new calibration tool termed cone metrics has been developed. This contribution describes the new method and its application as intercalibration tool in the context of the reprocessing activities for ERS and ASCAT. Cone metrics succeeds at characterizing the temporal stability of the C-band scatterometers down to an accuracy of 0.01-0.02 dB, and establishes the linear and nonlinear corrections necessary to homogenize the ASCAT and ERS C-band records down to 0.05 dB.

1. Cone metrics

Long-term climate records of proven homogeneity are fundamental to study climate change and variability. While the homogenization of the C-band and Ku-band scatterometer records remains a challenge due to their different radar physics, the homogenization of the C-band record formed by ASCAT and ERS scatterometer data is already obtainable.

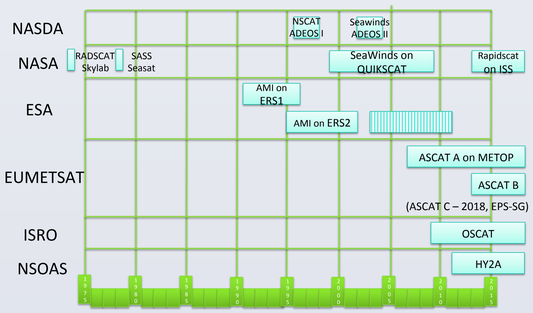

Figure 1 – Chronology of satellite scatterometers

NWP ocean calibration (NOC) is currently the standard method for scatterometer wind calibration, though it has its limitations, most notably an inability to deal with sensor nonlinearities and a dependence on the stability of the NWP winds used as reference. In response to these needs, a new method termed cone metrics has been developed [1]. The new method is based on monitoring changes in the mean distribution of ocean backscatter measurements, also known as "the wind cone", taking as absolute reference the wind cone formed by the ASCAT-A instrument over 2013. The cone metrics approach is self-referential and guarantees that the wind cone (i.e. the empirical law that relates surface winds to backscatter) does not change with time.

2. The wind cone

The wind cone is defined by the surface of maximum density of ocean backscatter points. It conforms to a double-folded conical surface in the space of ASCAT or ERS measurements.

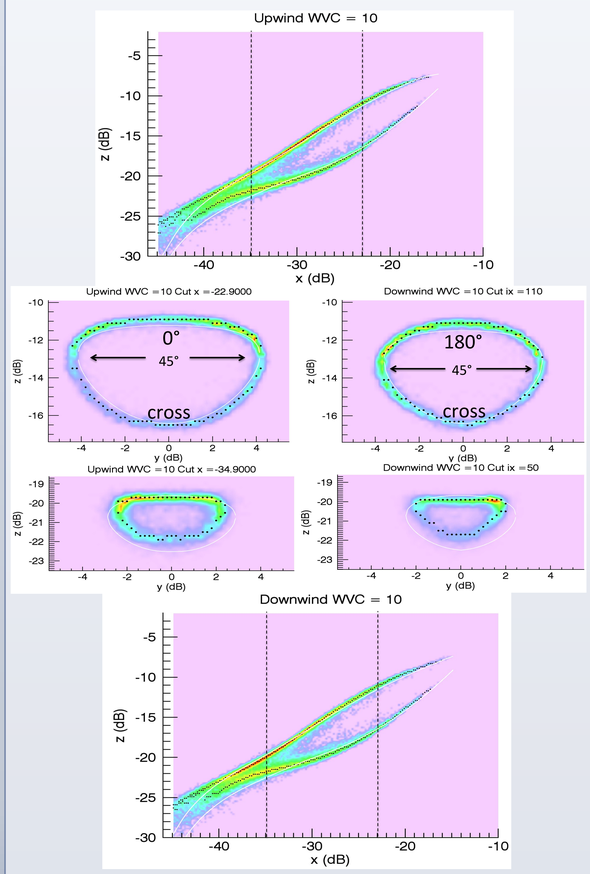

Figure 2 – Reference ASCAT-A 2013 wind cone

The relative linear offset between two datasets is determined by finding the cone shifts that minimize the RMS difference of the wind cone surfaces. After finding the optimal cone shifts, the presence of structure in residuals reveals changes in the wind cone shape that are constitutive of beam non-linearity.

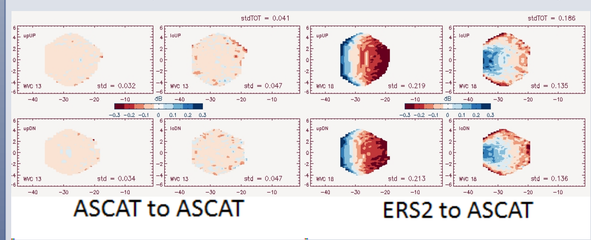

Figure 3 – Optimal residuals to the reference ASCAT-A 2013 wind cone: from an ASCAT cone (left) and an ERS cone (right)

3. Nonlinear corrections to ERS

Aligning the ERS-1 and ERS-2 records to the ASCAT reference cone is made difficult by the presence of systematic structures in the wind cone residuals. The nonlinearity in ERS is removed after subtraction of a combination of noise floor corrections (NFC) in the fore, mid and aft beams of the form:

$$NFC(\sigma^0_{dB}) = \alpha \cdot 10^{-(\sigma^0_{dB} - N_{dB})/\beta}$$

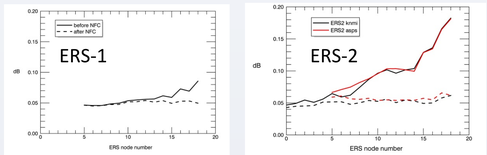

Figure 4 – Optimal residuals to the reference ASCAT-A 2013 wind cone before (continuous) and after (dashed) nonlinear corrections

4. Expected GMF improvements

Cone metrics may also be used to evaluate the agreement between the observed ocean backscatter distributions and the geophysical model functions used for wind retrieval.

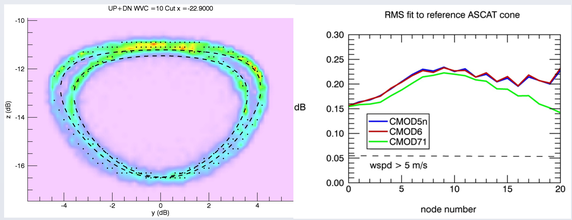

Figure 5 – CMOD71 versus the reference ASCAT-A 2013 wind cone

5. Expected backscatter stability

Cone metrics succeeds in bringing the ERS and ASCAT wind cones in line with the ASCAT-A 2013 calibration reference to within 0.05 dB, well in compliance with the GCOS stability requirement of 0.1 dB (~0.1 m/s) per decade for the provision of a climate data record of ocean surface wind speeds.

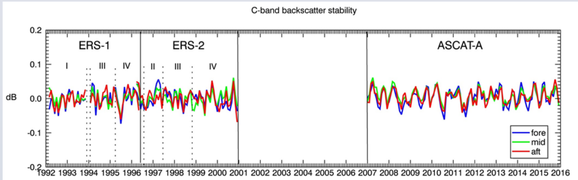

Figure 6 – Temporal stability of the C-band backscatter record after cone metrics corrections

Residual seasonal and diurnal (ascending/descending) beam offset variabilities are observed, which correlate positively with the global eddy wind energy (i.e. wind variability usually associated with unstable boundary layer conditions).

5. Reprocessed ERS/ASCAT winds

The ASCAT and ERS data records have been reprocessed at KNMI after the introduction of two major upgrades: 1) nonlinear corrections to ERS data, and 2) a new GMF (CMOD71). The linear beam offsets have been obtained via NWP ocean calibration (NOC).

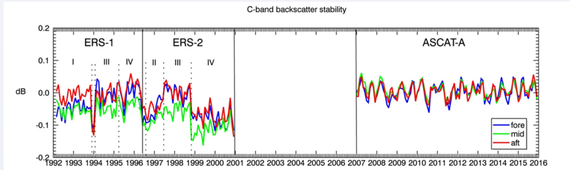

Figure 7 – Temporal stability of the latest ERS/ASCAT reprocessed backscatter record

Although the impact of the latest upgrades is clearly felt in terms of improved MLE and buoy triple collocation scores, the NOC corrections for the ERS period are not optimal according to cone metrics.

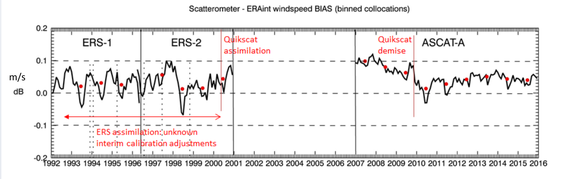

Figure 8 – Temporal stability of the total wind speed differences to ERA-interim

ERA interim is not a stable reference because of the evolution of assimilated observation systems (e.g. Quikscat, ERS) and the somewhat opaque bias correction schemes used for ERS.

6. Understanding biases to ERA

So perhaps it is time to start inquiring into the ERA reference.

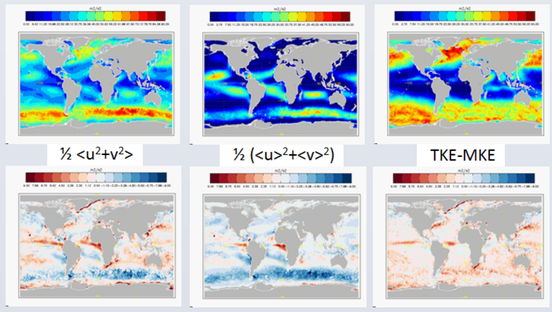

Figure 9 – Total, mean and eddy wind kinetic energies according to ASCAT-A 2012 (top) along with differences to collocated ERA-interim (bottom)

References

[1] Belmonte Rivas, M. Stoffelen, A., Verspeek, J., Verhoef, A., Neyt, X., Anderson, C., *Cone metrics: a new tool for the intercomparison of scatterometer records, IEEE JSTARS, doi: 10.1109/JSTARS.2017.2647842, 2017.*

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