The ocean we want: inclusive and transformative ocean science.
Pelegrí J.L., Gili J.M., Martínez de Albéniz M.V. (eds.). 2022. Institut de Ciències del Mar, CSIC, Barcelona.

5.5. Too extreme, or not too extreme, that is the question

Marcos Portabella, Federica Polverari, Wenming Lin, Ad Stoffelen, Albert S. Rabaneda, Joe Sapp, Paul Chang, Zorana Jelenak, Giuseppe Grieco, Ana Trindade, Eugenia Makarova, Federico Cossu

How strong does the wind blow in extreme weather conditions?

This proves to be a question that is difficult to answer, but has far-reaching consequences for satellite meteorology, weather forecasting, oceanography, climate and hurricane advisories. Hurricanes are among the deadliest of the existing natural disasters, moreover causing formidable economic losses (Bevere *et al.* 2020). Accurate, short- and medium-range forecasting of their intensity and track (among others) are therefore essential to mitigate human and economic losses. In the longer range, it is also important to understand whether extreme weather conditions are becoming more extreme in a changing climate, stirring deeper waters in the ocean and hence affecting climate system dynamics. Unfortunately, tropical circulation conditions, such as *El Niño* and the Madden Julian Oscillation, are associated with large year-to-year variability in extreme wind speed distribution and their link to climate change is poorly understood, limiting our ability to determine whether the hurricane climatology is actually changing or not.

Since hurricanes are sparsely sampled, satellite instruments are in principle very useful to monitor their spatial and temporal distribution, and intensity with respect to climate change. However, to do so the stability over time in quality and quantity of satellite measurements (sampling) needs to be guaranteed. Furthermore, climate analysis requires the longest possible satellite records, but these are only useful when accurate satellite instrument inter-calibration is achieved, especially at high and extreme wind speeds (Verhoef *et al.* 2017).

To properly assess and calibrate the current and future satellite-derived extreme winds, including those from the C-band scatterometers, building a consolidated high and extreme wind reference dataset is crucial. So far, two independent *in situ* wind references have been widely used for wind calibration purposes: moored buoys and GPS drop-wind-sondes (dropsondes). A new approach has recently been presented by Polverari *et al.* (2021) to assess the consistency between these two *in-situ* datasets, for which coincident data acquisitions are rather sparse. To overcome such limitation, wind speed measurements from the Advanced Scatterometer (ASCAT) onboard Metop satellite series at 12.5 km grid resolution are used as common reference between the two *in-situ* datasets. As such, coincident measurements (collocations) from ASCAT and moored buoys are compared to coincident measurements from ASCAT and the Stepped-Frequency Microwave Radiometer (SFMR) onboard the NOAA "hurricane hunters", over the period 2009–2018. Note that, while ASCAT winds have been calibrated with buoy data, SFMR winds have been calibrated with dropsonde data.

ASCAT and buoy winds are, as expected, in good agreement up to 25 m/s, showing though a somewhat enhanced scatter between 15 and 25 m/s (not shown). The ASCAT/SFMR anal-

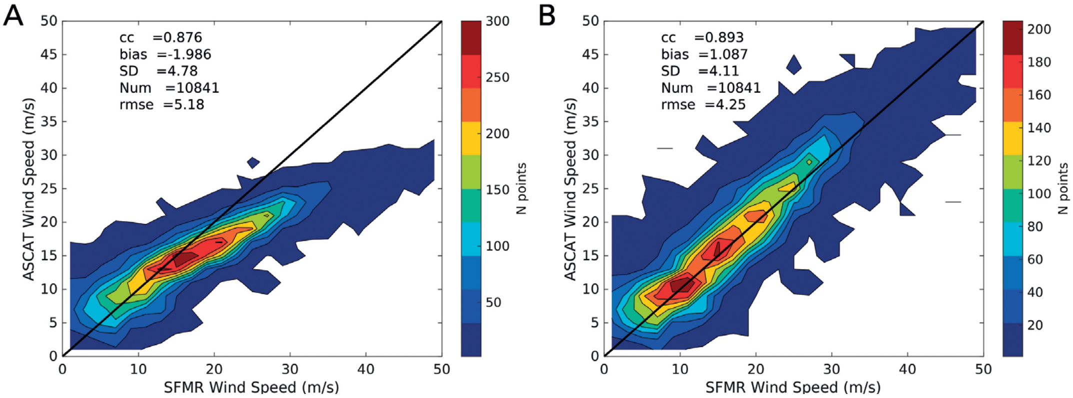

Figure 1. Two-dimensional histograms of ASCAT (onboard Metop-A and -B) and collocated SFMR wind speeds averaged over a distance of 12.5 km along track (a). In (b), ASCAT winds have been rescaled using dropsondes, i.e., using the following conversion $V'(ASCAT)=0.0095x^2+1.52x-7.6$, with $x=V(ASCAT)$, above 12 m/s. The statistical parameters can be found in the legend, i.e., correlation coefficient (cc), bias, standard deviation (SD), number of points (Num), root mean square error (rmse).

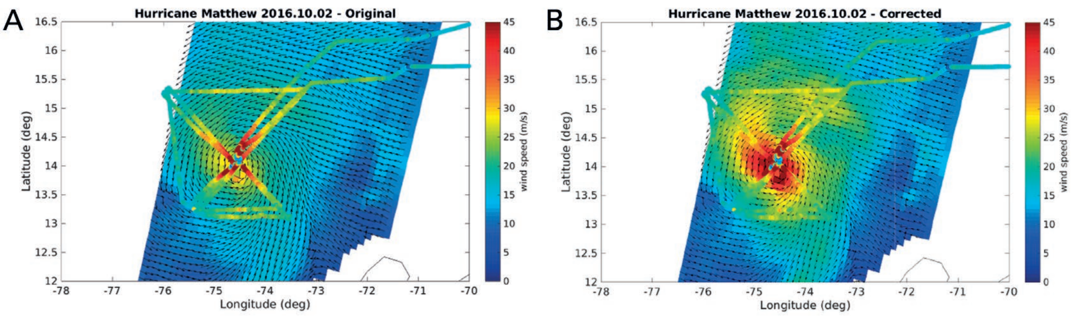

Figure 2. SFMR wind speeds (colored lines), together with (original) ASCAT buoy-scale wind speeds (A) and (corrected) ASCAT dropsonde-scale wind speeds, for a hurricane Matthew overpass.

ysis reveals an ASCAT wind underestimation for winds above 15 m/s (see Figure 1A). SFMR measurements are averaged along-track to represent winds of similar spatial resolution to that of ASCAT winds. Both SFMR (thus dropsonde) and buoy winds appear to be highly correlated (about 0.9 in both cases) with ASCAT at the high wind regime, however, they show a very different wind speed scaling. A suitable dropsonde-scale based re-calibration of ASCAT winds using averaged SFMR winds as reference can be achieved for winds up to 50 m/s (see Figure 1B) (Polverari *et al.* 2021). However, buoy and dropsonde wind scales are very different at high and extreme wind conditions. For example, while the ASCAT buoy-scale produces a 25 m/s wind (light green areas in Figure 2A), the ASCAT dropsonde-scale produces roughly a 37 m/s wind (light red areas in Figure 2B), and such differences increase exponentially with wind speed.

As such, the question is what wind source should be trusted at high and extreme wind conditions: moored buoys or dropsondes?

The best controlled resource for *in-situ* ocean wind speed calibration is the moored buoy for low, moderate and high winds. This is the main reason why the ASCAT and the global Numerical Weather Prediction models like ECMWF follow the moored buoy scale. They are validated by masts to be unbiased up to 25 m/s (within ~10%) (Stoffelen *et al.* 2020). Although buoys show lower dispersion than dropsondes at 20 m/s, there is room for further uncertainty assessment and attribution. The dropsondes in turn can fail in reporting the winds at the surface and, even when they do, the measured surface winds can be compromised by surface waves and wind gust effects. Therefore, the 10-m surface winds are usually estimated by layer-averaged winds and a correction based on the logarithmic profile is then applied to get to the surface (Uhlhorn *et al.* 2007). The main sources of uncertainty in this case are the atmospheric drag producing a strong deceleration of the dropsonde near the surface, and the accuracy of the position computation (including height) by the embedded GPS chip which has not (yet) been investigated and may cause further bias in the deceleration estimation. In other words, can the mentioned bias be responsible for the inconsistencies between dropsonde and buoy high and extreme winds?

At this stage, conclusions cannot be drawn on which high-wind reference is favorable for satellite wind calibration/validation at high and extreme wind conditions or how to consolidate both references. Further investigations are needed to better understand the sources of such differences. As per request, the so-called ASCAT dropsonde-scale winds (Figure 2B) are made available to the operational extreme wind community, which uses SFMR wind scaling (as calibrated by dropsondes) as reference for tropical cyclone characterization, monitoring, and tracking. The same approach is being used in the framework of the European Space Agency (ESA) project MAXSS to intercalibrate all other scatterometer and radiometer high and extreme wind speeds. But the question whether winds are too extreme (dropsonde-scale) or not too extreme (buoy-scale) remains for the time being.

References

Bevere L., Fan I., Holzheu T. 2020. Swiss Re Institute estimates USD 83 billion global insured catastrophe losses in 2020, the fifth-costliest on record. Accessed on June 9 2021. https://www.swissre.com/media/news-releases/nr-20201215-sigma-full-year-2020-preliminary-natcat-loss-estimates.html.

Polverari F., Portabella M., Lin W., *et al.* 2021. On High and Extreme Wind Calibration Using ASCAT. IEEE Trans Geosci Remote Sens "in press".

Stoffelen A., Mouche A., Polverari F., *et al.* 2020. C-band High and Extreme-Force Speeds (CHEFS). EUMETSAT Technical report. 74 pp. Accessed on June 9 2021. https://www-cdn.eumetsat.int/files/2020-06/pdf_ss_chefs_final_rep.pdf

Uhlhorn E., Black P., Franklin J., *et al.* 2007. Hurricane Surface Wind Measurements from an Operational Stepped Frequency Microwave Radiometer. Mon Weather Rev 135: 3070–3085.

Verhoef A., Vogelzang J., Verspeek J., Stoffelen A. 2017. Long-Term Scatterometer Wind Climate Data Records. IEEE J Sel Top Appl Earth Obs Remote Sens 10: 2186–2194.

DOI: https://doi.org/10.20350/digitalCSIC/14106