Intercalibration and error characterization of satellite and synergistic sea-surface wind products under tropical cyclone conditions

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In the framework of the ESA OCEAN+EXTREMES MAXSS project, a consistent, inter-calibrated extreme wind data record for satellite scatterometers (ASCAT-A, -B, -C, RapidSCAT, Oceansat-2, ScatSat-1, HY-2A, -2B) and radiometers (AMSR-2, Windsat, SMAP, SMOS) over the period 2010-2020 has been generated, using the Stepped Frequency Microwave Radiometer (SFMR) winds onboard the US National Oceanic and Atmospheric Administration (NOAA) and US Air Force Reserve Command (AFRC) "hurricane hunter" planes as reference for satellite wind data adjustment. Then, the satellite adjusted winds have been blended using the Optical Flow Morphing technique together with the European Centre for Medium-range Weather Forecast (ECMWF) Fifth reanalysis (ERA5) winds, to produce a high spatial and temporal frequency multi-mission (MM) wind product. An important step within the MAXSS study is to characterize the errors of the different MM input wind sources (i.e., scatterometers and radiometers) as well as those of the MM product itself. Note that since the MM product ingests a variety of satellite sensors with different effective spatial resolution and thus different error characteristics over different regions, it is important to fully characterize such errors and understand how these eventually impact the MM product quality.

A very well-established method for error assessment of different wind (and other) data sources is the triple collocation analysis (Stoffelen, 1998). The triple collocation was conceived as a tool for intercalibration and individual error assessment of three different collocated sea-surface wind datasets. The method accounts for different spatial (and/or temporal) representation of the three collocated data sources, allowing for error characterization at the scales of both the medium resolution and the lowest resolution system. The estimation of the so-called representativeness error (i.e., the common true variance resolved by the two higher resolution systems but not by the lowest resolution system, r^2) is a relevant aspect of the triple collocation analysis.

Different methods to estimate r^2, i.e., either based on wind spectra, cumulative spatial variances or intercalibration constraints, have been proposed and used in the literature over the last decade. The spatial variance analysis is used since it is more tolerant to the presence of noise and data gaps due to quality control (e.g., because of rain contamination effects), as expected from these extreme wind datasets. A thorough triple collocation analysis is carried out for the mentioned datasets under tropical cyclone conditions, using different combination of triplets (SFMR-Satellite-ERA5 or SFMR-Satellite-MM) in order to assess consistency as well as uncertainty on the uncertainty estimates.

The estimated wind speed errors (at model scales) show that ASCAT winds contain the lowest errors (standard deviation of about 0.9 m/s) of all the extreme wind datasets. In order to keep extreme wind sampling, some rain contamination is allowed in the Ku-band data (by not using the KNMI_QC flag), which leads to significantly higher errors for Ku-band (ranging from 1.4 m/s to 2.1 m/s) than for C-band scatterometers. The radiometer winds show significantly larger errors than scatterometers, ranging from 2.0 m/s (SMAP) to 2.9 m/s (Windsat), in which the quality of the worst-performing scatterometer (OSCAT) is comparable to that of the best-performing radiometer (SMAP).

Finally, the triple collocation analysis reveals a substantial error reduction of the MM (1.7 m/s) w.r.t. ERA5 (2.6 m/s). However, note that a relatively small sample (i.e., only 1516 collocations) is used to assess the MM errors. This is due to the fact that RSCAT is the only independent satellite dataset (i.e., not used in the MM generation) and the mission only lasted 2 years. As such, it is expected that the MM error estimates are somewhat uncertain. Moreover, the MM has been generated with a suite of ERA5 analyses, rather than ERA5 forecasts, which means that satellite data are used both in the ERA5 analyses (i.e., data assimilation) and in the morphing steps, likely leading to overfitting. Future plans include the generation of a MM product based on ERA5 forecasts in order to properly assess the MM extreme wind random errors.