Report on Use of Recommended L4 Product

Dear Prof. Stoffelen

We are pleased to report on our use of the L4 product (WIND_GLO_PHY_L4_MY_012_006) you recommended. We successfully downloaded the hourly 10m wind field products, including vorticity and wind component variables, for November to April from 2000 to 2006. This data (hereafter referred to as CMEMS) was used to match all ERA5 and IMPMCT track points for the validation of surface cyclonic circulations. The methods for identifying surface vorticity centers and constructing tracks were identical to those used for the 850 hPa vorticity tracks described in the main text. To ensure the robustness of the matching results, three different parameter combinations were tested, and the corresponding matching results are presented in Table 1.

1) Experiment a: R_{smth}(uniform smoothing radius) = 60 km, ζ_{max0} = 0.8×10^{-4} s^{-1}, ζ_{min0} = 0.5×10^{-4} s^{-1}, γ = 0.15
2) Experiment b: R_{smth} = 45 km, ζ_{max0} = 0.8×10^{-4} s^{-1}, ζ_{min0} = 0.5×10^{-4} s^{-1}, γ = 0.15
3) Experiment c: R_{smth}= 45 km, ζ_{max0} = 1×10^{-4} s^{-1}, ζ_{min0} = 0.5×10^{-4} s^{-1}, γ = 0.25

Matching between 850 hPa and surface vortices was determined based on their actual geographical distance. For vorticity centers at the same time step, a match was identified if the distance was less than 100 km. For a track pair, the tracks were considered matched if the proportion of matched points exceeded 80% of the overlapping time period of both tracks, provided the overlap duration exceeded half the lifetime of at least one of the tracks.

Table 1: Matching results between 850 hPa vorticity tracks and surface features for different parameter combinations.

Experiment	Points	Tracks (>3hr)	Points matched fraction(%)		Tracks matched fraction(%)		Mean wind speed bias (m/s)
			ERA5	IMPMCT	ERA5	IMPMCT	QuickScat-CMEMS
a	378627	22750	46.1	77.4	33.0	88.0	5.2
b	520103	31589	51.6	79.8	36.6	88.5	5.4
c	388577	23652	43.1	74.0	32.1	86.0	5.4

As shown in Table 1, among the 12,030 ERA5 tracks and 200 IMPMCT tracks from 2000–2006, up to 88.5% of IMPMCT tracks and 79.8% of IMPMCT points were matched with surface vorticity. This proportion significantly exceeds the match rate for all ERA5 tracks during this period (36.6%). These results demonstrate that surface vorticity serves as an effective method for tracking and validating Polar Mesoscale Cyclones (PMCs). In other words, the dataset we previously provided, which primarily references cloud charts, has been demonstrated to be representative.

However, if the maximum wind speed within the surface vortex area is taken as the core wind speed of the PMC points, the results show a significant low bias (approximately ~5 m/s, as shown in Table 1) compared to near-real-time wind speeds measured by QuikScat ($n \approx 200$). Below, we present five matched cases (Figure 1-5) showing surface vorticity and the corresponding 850 hPa vorticity tracks from IMPMCT, along with comparisons of the associated ERA5 10m wind fields, CMEMS bias-corrected ERA5 10m wind fields, and QuikScat 10m wind fields. We find that compared to the near-real-time wind fields, the hourly averaged wind fields do not always adequately represent the explosively strong surface winds associated with the cyclones. While it is difficult to definitively conclude whether this discrepancy arises from an overestimation by QuikScat or an underestimation by the CMEMS corrected product, the wind difference fields (e.g. Figs. d of 1-5) often appear to align more closely with cloud features. This indicates a better correspondence between real-time wind fields and cloud imagery.

Although the WIND_GLO_PHY_L4_MY_012_006 product provides consistent, hourly, and bias-corrected ERA5 wind data that would greatly enhance the wind speed information within the IMPMCT dataset, integrating these corrected winds would require additional research to fully interpret the associated discrepancies. Moreover, incorporating derived dynamic features such as vorticity and divergence would introduce further complexity due to the inherent challenges in validating such parameters.

We sincerely acknowledge the value of this product and have carefully considered its inclusion. However, after thorough evaluation, we concluded that it would be more appropriate to address these challenges in a separate, dedicated study rather than incorporating the product into the current dataset. We highlight in the discussion section of our paper both the limitations in wind data resolution and the potential of this product for future applications such as cyclone validation. We believe it holds particular promise for supporting dynamic investigations in subsequent research:

"The dataset does not explicitly distinguish between PMCs and PLs due to the time-sparse wind speed data, particularly when the cyclone's wind speed at a given time step falls below the 15 m s^{-1} threshold. In such cases, it is difficult to determine whether the cyclone is a PMC or merely in a weaker phase of a PL. **A more reliable validation method may be provided by the hourly bias-corrected sea surface wind product from the E.U. Copernicus Marine Service Information (https://doi.org/10.48670/moi-00185). This product systematically corrects ECMWF ERA5 model fields using scatterometer observations to reduce persistent biases and includes uncertainty estimates.**"

Three CMEMS track-datasets are stored at: https://github.com/thebluewind/IMPMCT. We sincerely appreciate your valuable comments and suggestions, particularly the recommendation of this product. It will be the dataset of choice for our subsequent statistical work investigating the development mechanisms of PMCs and PLs.

Sincerely,

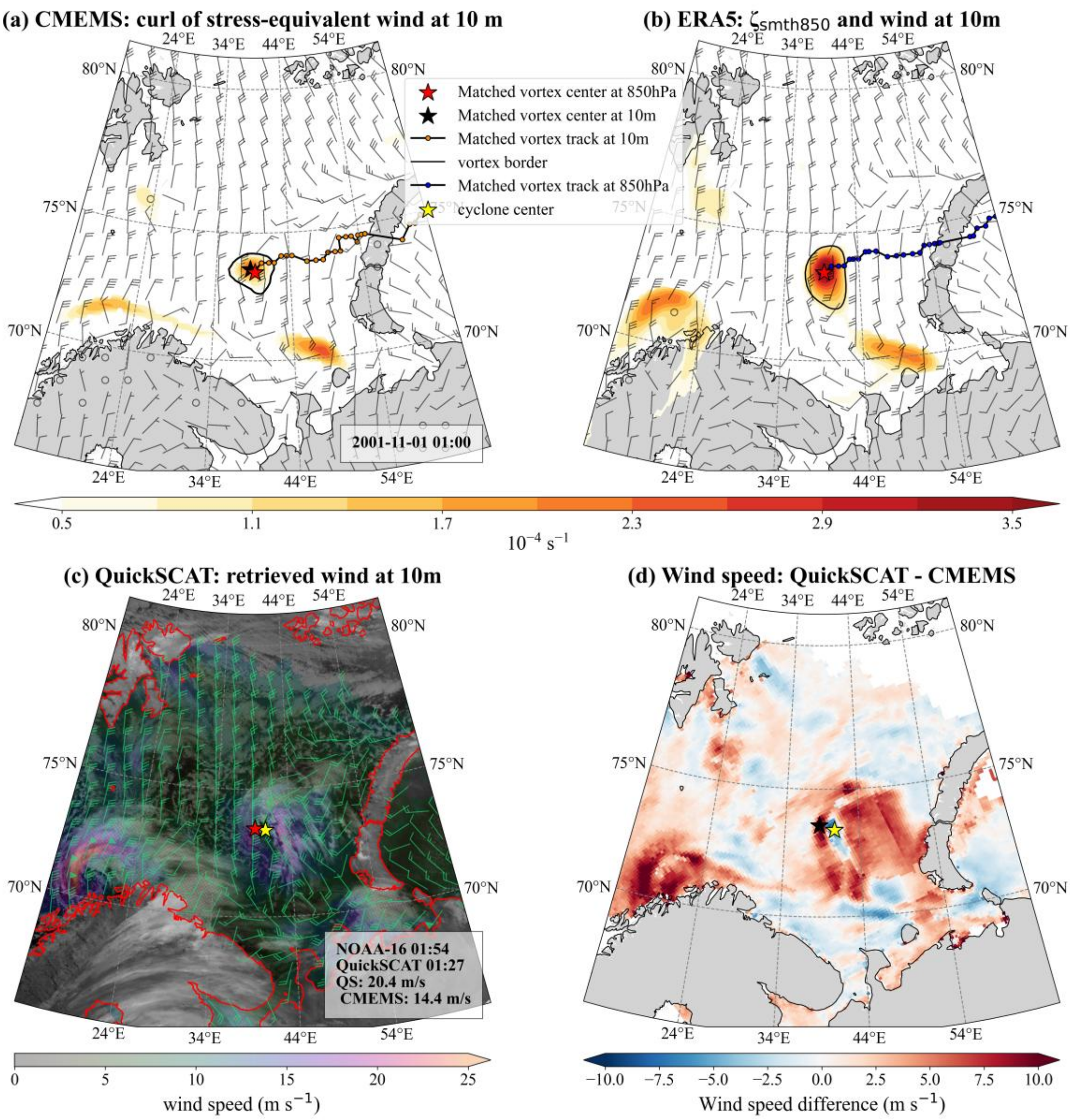

Figure 1: Vorticity matching results. (a) 10m vorticity and wind fields from the WIND_GLO_PHY_L4_MY_012_006 product. (b) 850 hPa vorticity and 10m wind fields from ERA5 hourly data. (c) Brightness temperature image from AVHRR channel 4 and 10m wind field data from QuickSCAT. (d) Wind speed difference: (c) minus (a). Black and red stars represent matched 10m and 850 hPa vorticity points, respectively. Orange and blue dotted lines represent matched 10m and 850 hPa vorticity tracks. The legend in (c) shows the AVHRR and QuickSCAT scan times, as well as the cyclone (vortex) core maximum wind speeds retrieved from QuickSCAT and CMEMS wind fields.

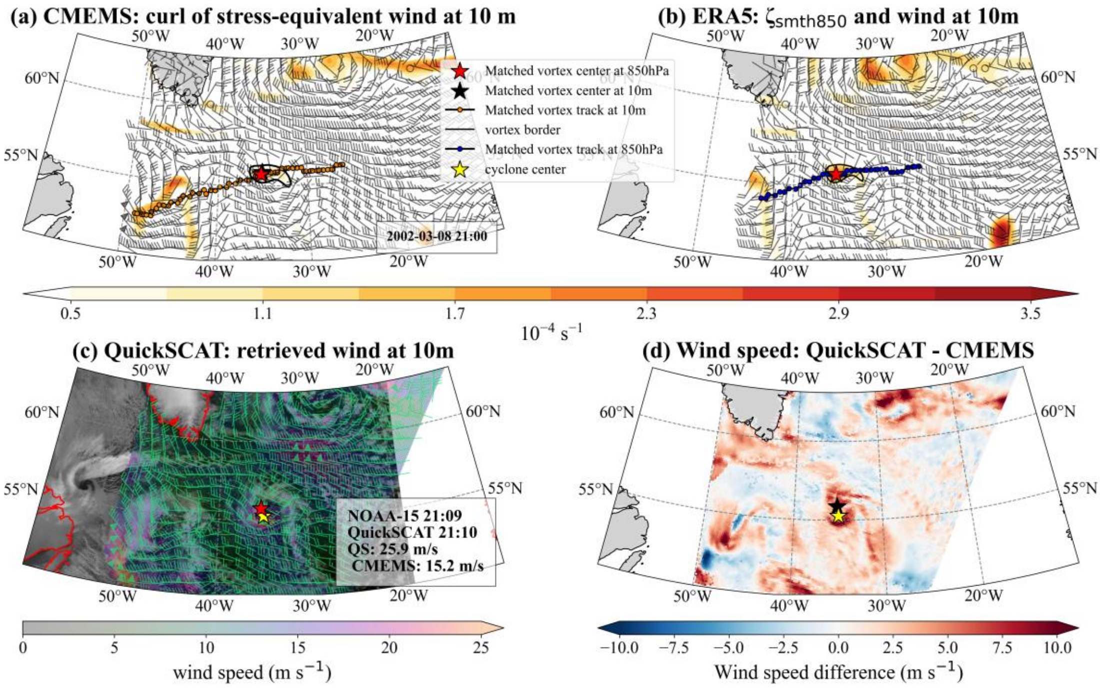

Figure 2: Same as Figure 1

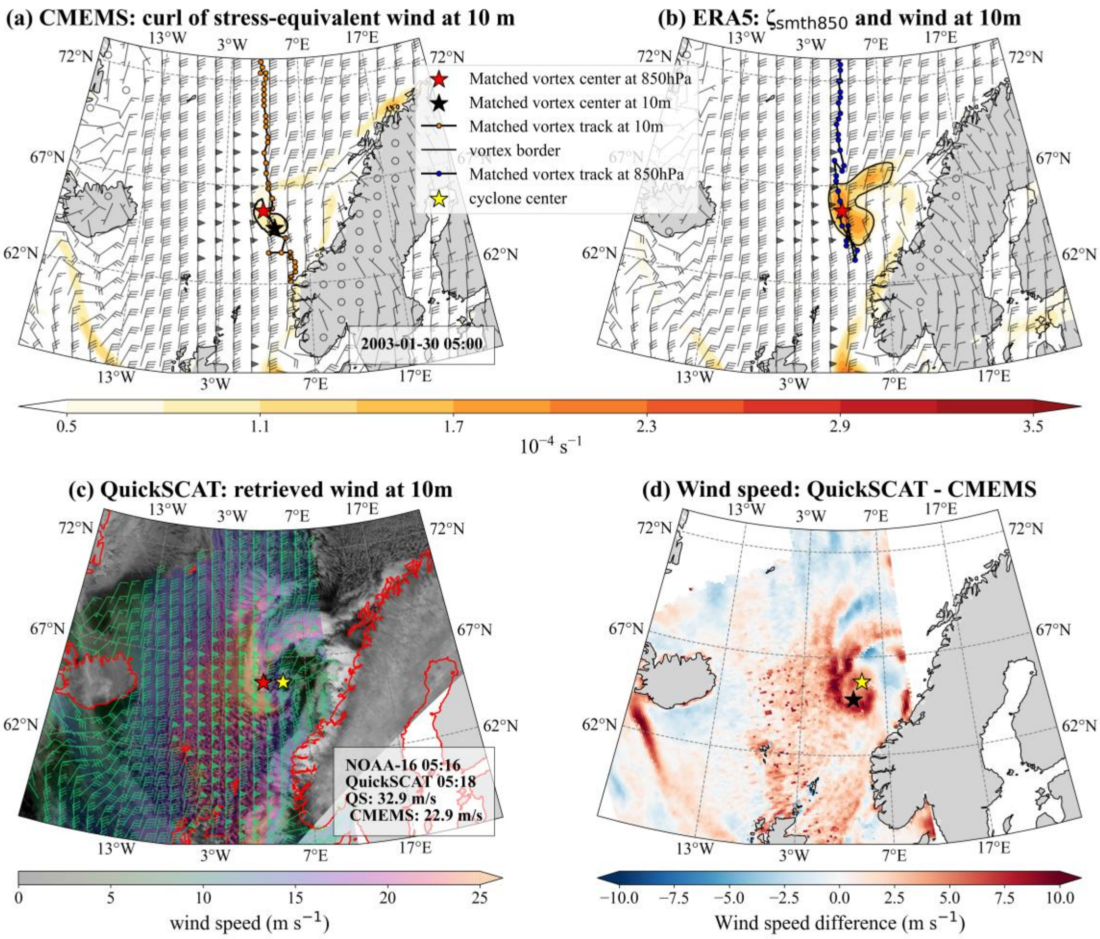

Figure 3 : Same as Figure 1

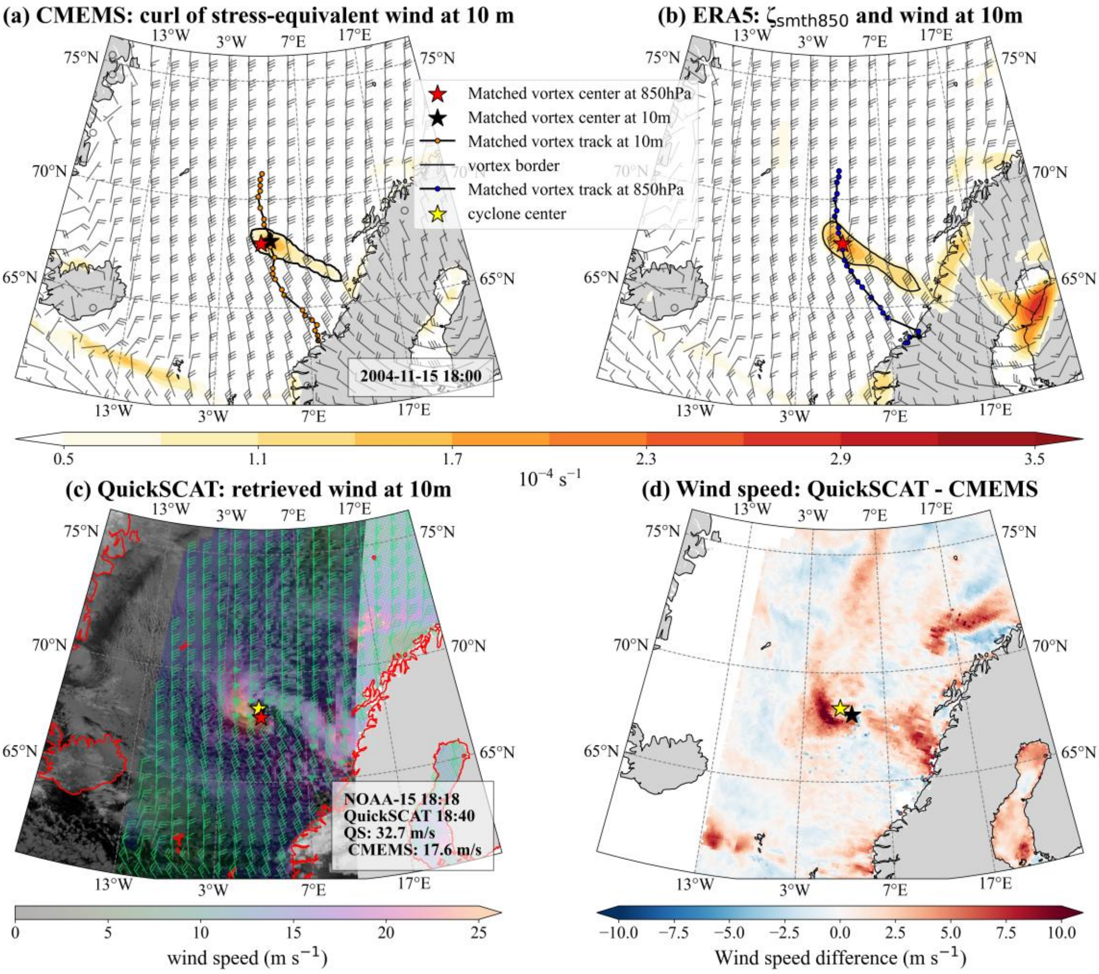

Figure 4 : Same as Figure 1

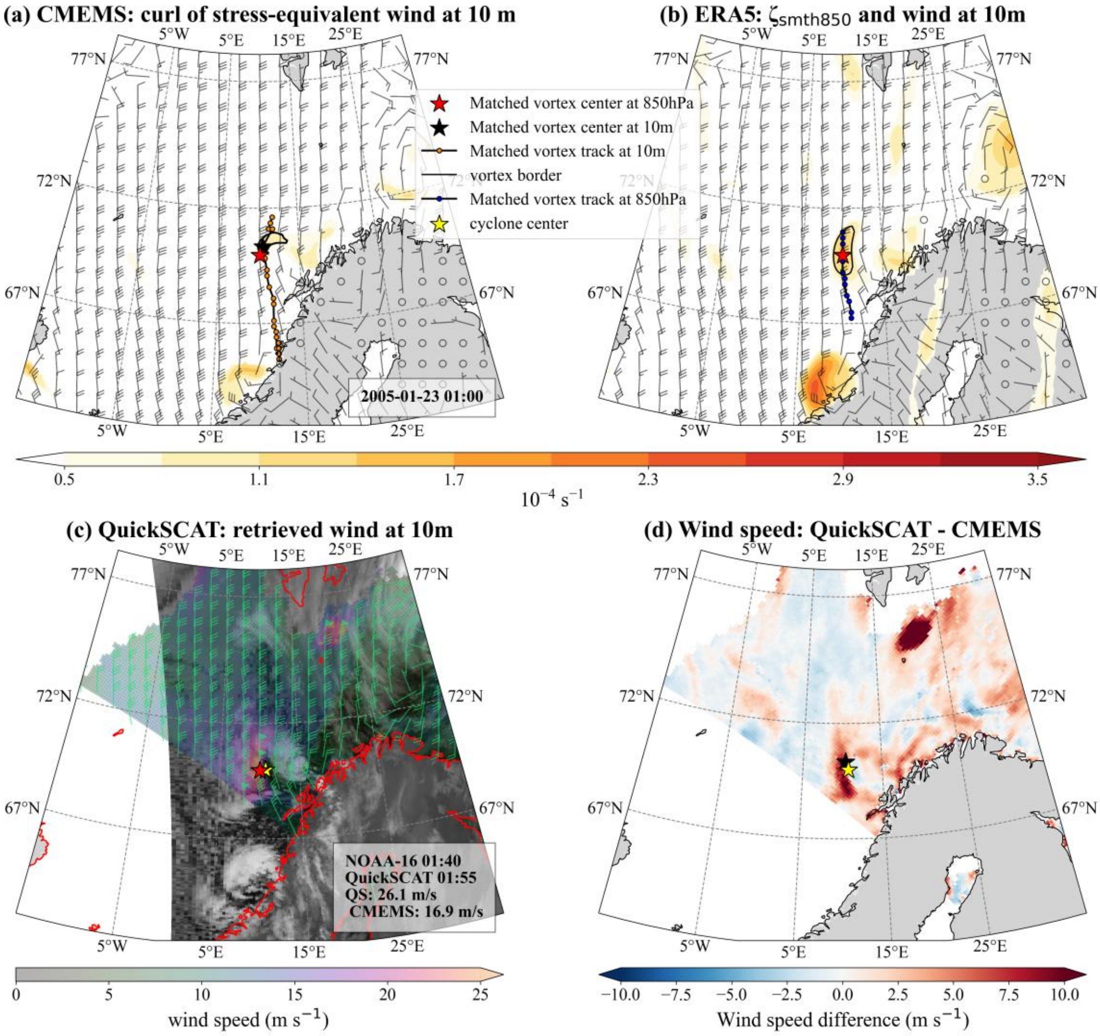

Figure 5 : Same as Figure 1