IMPMCT: a dataset of Integrated Multi-source Polar Meso-Cyclone Tracks

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General

The manuscript describes a great data set and a laudable effort to construct such data base of PL and MPC tracks based on ERA5 and satellite data.

However, the characteristics and hence value of the data set is scientifically unclear. For existing similar track data sets, it is investigated how these are matched. It occurs that only a marginal set of points in the data base is characterized in the manuscript by these existing sets. Moreover, these appear the easiest tracks to capture, hence the value of most of the tracks remains unclear.

This is associated with the fact that I miss a critical scientific assessment of the tracks generated. The manuscript appears subjective, rather than rigorous.

There are ways to verify PL and MPC tracks with observations of atmospheric dynamics, in particular wind scatterometers. The use of scatterometers in this manuscript is rather unclear from a dynamic perspective and poor.

In the least, the manuscript should be scientifically clarified and the pros and cons of the methodology better stipulated. In addition, a section on future work appears appropriate as much remains unclear in my interpretation of the manuscript.

Detailed suggestions are provided below.

Detailed suggestions

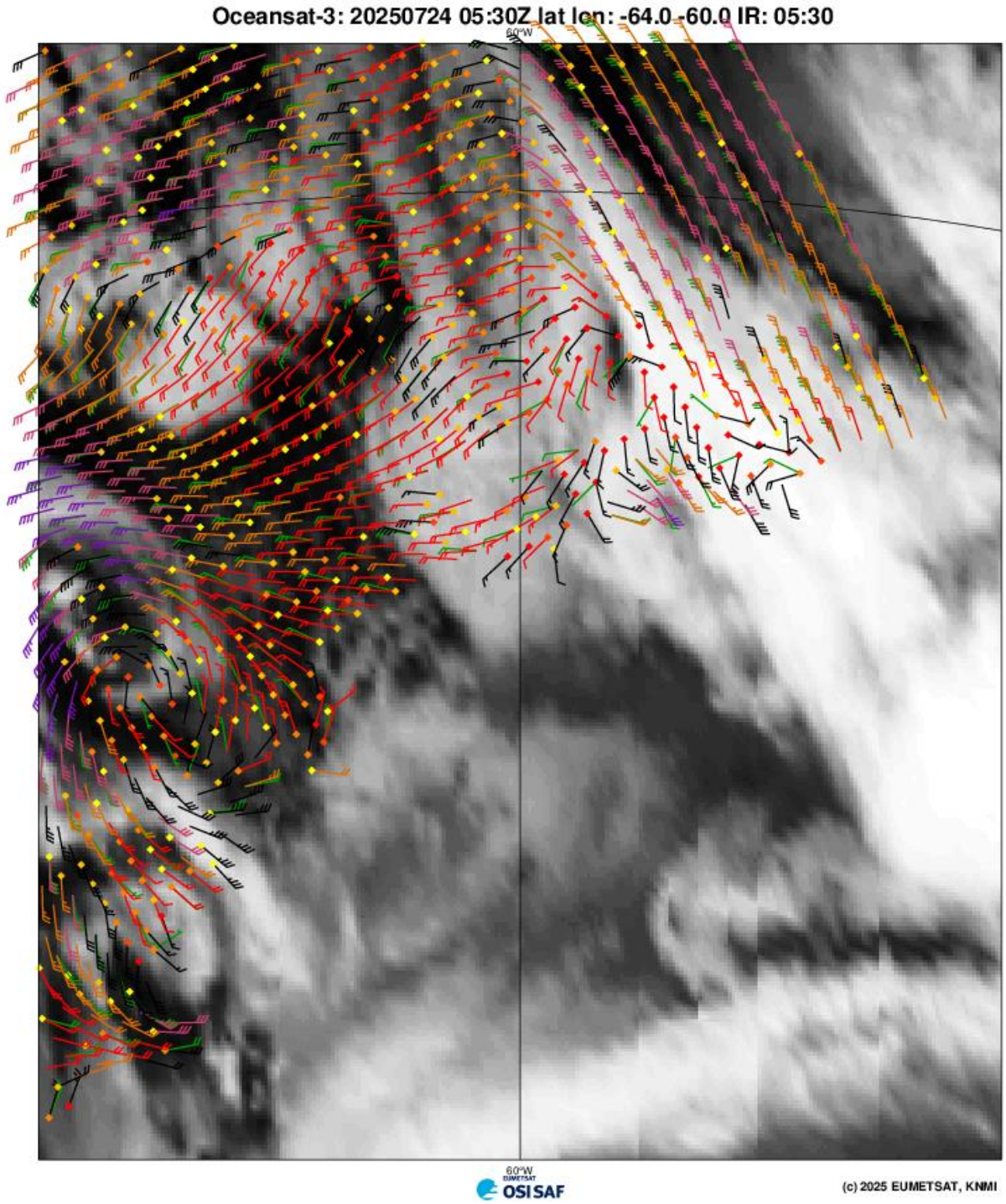
95: These images are not so clear. In a): Could a PMC also be in (8,74), (36,77) or (36,77)? Why not? In b): Could the PL also be in (34,76)? Why not?

96: The ERA5 grid distance is 31 km, hence good dynamical representation will at most be 150 to 300 km following typical dynamical closure procedures. Is that good enough for PL/PMCs?

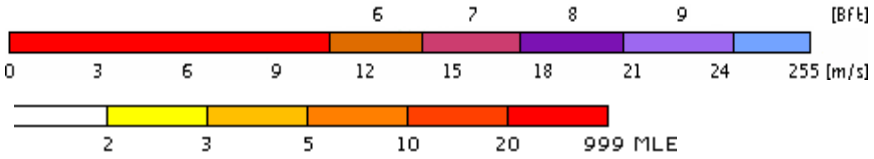
109: Belmonte Rivas and Stoffelen also suggest some other reasons for poor PL/PMC representation in ERA5: lack of transient variability, lack of divergence, lack of resolution; it appears of interest to mention these aspects.

113: Having looked at many collocated IR and scatterometer wind vector fields (e.g., here below), I have some problem with the terminology “cyclonic cloud feature”. Cyclonic cloud features might occur due to closed surface circulation (cyclone definition) indeed, while wind shear conditions may also generate clouds in circles shapes on the mesoscales.

Moreover, a cyclone may also exist in an abundance or lack of clouds in which a cyclone is not recognized in an IR image. In the image below (from today) circular cloud patterns are present on the left hand side, while the streamlines of the vector winds do not coincide with the cloud streaks. On the other hand, a cyclonic wind feature appears on the right side of the plot, but where high clouds cover the wind structure below. This is today's example, while examples of apparent IR cloud mismatch with ocean vector winds occur almost every day on this site, in particular at high latitudes.



From https://scatterometer.knmi.nl/tile_prod/index.php with description:



This picture shows the scatterometer winds (in arrows, flags or all ambiguities), with an infrared satellite image (from METEOSAT, GOES or Himawari) and numerical weather prediction model forecast winds from ECMWF in green arrows or flags. These model winds are valid at the time of observation. A wind flag is represented by barbs and solid pennants, a full barb representing a wind speed of 5 m/s, a half barb representing a wind speed of 2.5 m/s, and a pennant representing a wind speed of 25 m/s. A calm indicator circle is plotted if the wind speed is less than 0.5 m/s. The scatterometer winds are coloured according to the Beaufort scale, winds up to 5 Bft. (10.7 m/s) are in red, winds as of 6 Bft. are coloured as shown in the legend below the picture. A black arrow or flag indicates that the KNMI QC flag is set, such winds are likely to be unreliable but they may provide extra information to experienced users.

The ambiguity plots show up to 4 wind solutions that are input to ambiguity removal. The winds are shown as arrows without head, i.e., they point to the direction where the wind is blowing to. For the ambiguity plots a different wind speed colour scale is used. Infrared imagery and model winds are not shown in these plots. The winds having the KNMI QC flag set are coloured according to the colour scale but they are indicated with a black dot.

The exact data acquisition time is plotted in red next to the satellite swath.

The coloured dots give the value of the Maximum Likelihood Estimator (MLE) which indicates how well an observation fits to the Geophysical Model Function. High MLE values usually indicate high spatial wind variability or rain presence in the Wind Vector Cell.

170: remove “resolution”; Skamarock (2004) defines effective resolution as 5-10 times the grid distance of an atmospheric circulation model, due to the necessary dynamical closure for numerical stability of the model.

172: Note that in particular the initiation of PMCs and PLs in ERA5 is brought by wind scatterometers as can be observed in time sequences at https://scatterometer.knmi.nl/tile_prod/index.php. Hence ERA5 PMCs/PLs may be biased to the availability of the satellite data used, which could be problematic in time series analyses of PMCs/PLs. As readers may not be generally aware of this dependency, it is better to state it.

173: with a spatial resolution -> on a spatial grid

182: To refer to scatterometer accuracy, one may use Vogelzang and Stoffelen (2022).

192: ASCAT-A, -B and -C have been operational since 2007.

197: with stable spatiotemporal resolution -> exploiting the evolving global observing system ; I.e., not necessarily of stable spatiotemporal resolution effectively, since depending on the initialization of small scales by observations, when available.

208: Scatterometers measure the surface wind vector field and hence curl and divergence. See, e.g., Belmonte Rivas and Stoffelen (2019). King et al. (2022) found that tropical divergence as measured by scatterometers is closely related to moist convection. Similarly, one would expect that cyclonic disturbances are very well depicted in curl and divergence. These are furthermore available at https://data.marine.copernicus.eu/product/WIND_GLO_PHY_L4_MY_012_006/description. It also provides hourly corrected ERA5 wind variables for reference.

Why not put them in the database? They provide a stable reference over time as each instrument product does not change over time.

232: The vorticity field appears noisy as I understand the text. Nevertheless, no observations exist to initialize 4D dynamical structures well on scales below 100 km over the ocean, hence 60-km filtering may not be too problematic. The noise may be due to the fact that you use analyses, rather than more consistent dynamical model fields, i.e., background (first guess) ERA5 data as in Belmonte Rivas and Stoffelen (2019) for example. Reanalyses fields are affected by the observations being assimilated, using spatial structure functions, which are posed as stream function and velocity potential “blobs”, defined based on forecast ensemble statistics. These increments may not treat vorticity fields well and produce noise. Another reason may be in interpolation of the vorticity fields, but where no details are provided.

314: All steps appear rather ad hoc, but together they define a vortex isolation and data procedure. Moreover, it appears as a community procedure, as others elaborated similar procedures. Does the procedure work similarly well for other reanalyses, mesoscale models or the operational ECMWF analysis? To me, it appears tuned to the characteristics of your input ERA5 fields. Perhaps mention that other meteorological model fields may require further tuning of the vortex detection procedure.

316: established -> constructed

318: Terrain-induced flows are normally tied to the terrain and not to the wind, hence presumably they’d typically not produce vortex tracks according to your criteria?

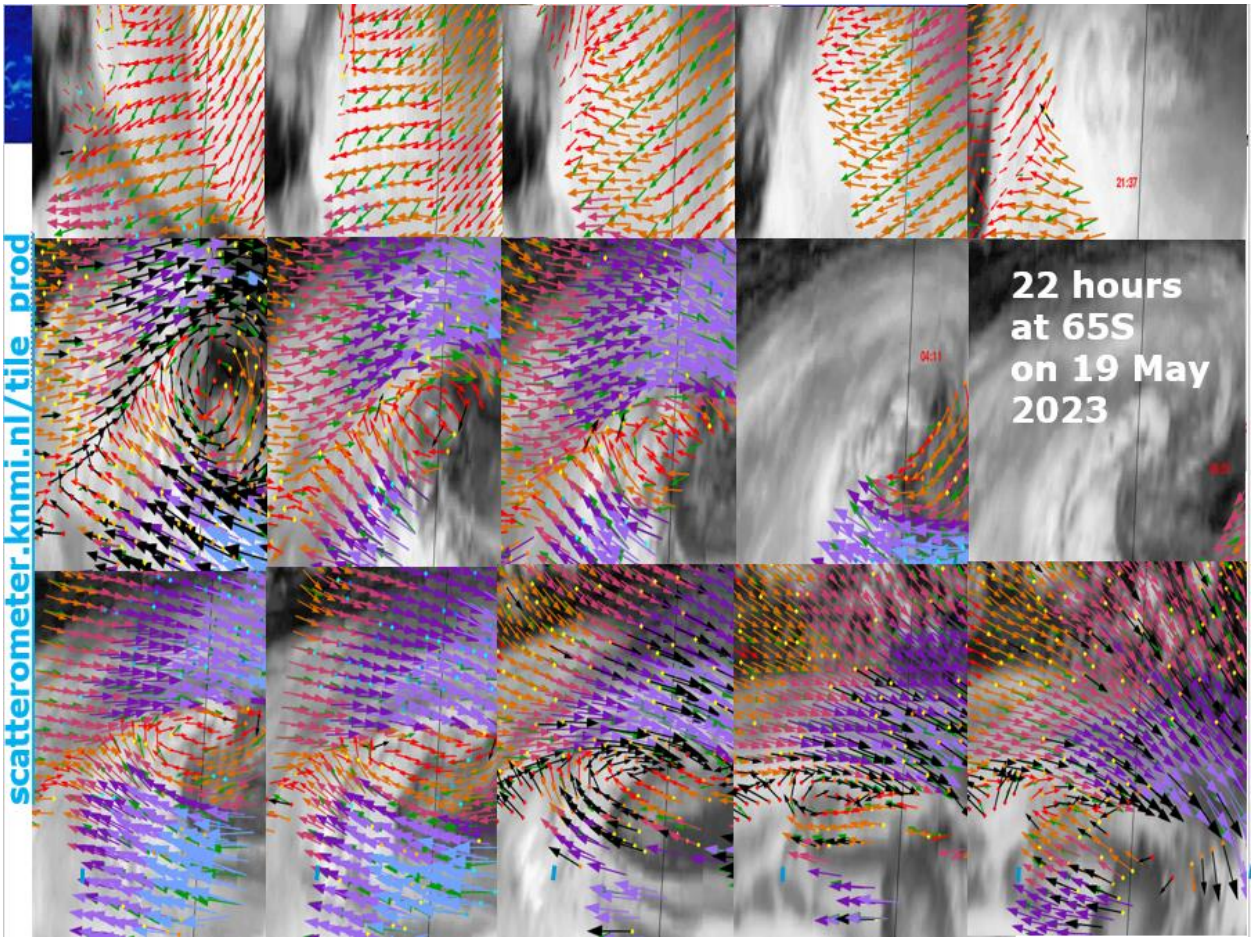
320: established -> comparison ; recall that AVHRR are not a direct measurement of PMC, cf. comment 113.

455: The concept of environmental wind speed is not clear. What is its use? The 10m wind vector around a moving vortex is rather variable, depending on steering flow and vortex strengths. The baroclinic nature of these high-latitude vortices makes their surface appearance usually asymmetrical. I can understand you'd like to capture this, but this is not clear from the text. Please clarify what relevant dynamical characteristics can be extracted. Fig. 11b appears a vortex interacting with land and hence surface winds are distorted?

458: To first order, the destructive force goes with the third power of the wind speed, irrespective of it is generated by the environmental flow, vortex contribution or related to local convection, all count. In open sea, the waves, build by the wind, are of course very important as well, as the dimensions of the structures at sea may resonate with long and forceful waves.

470: The scatterometer section is rather poor as scatterometers, in particular ASCAT, reveal detailed dynamical PL characteristics. Wind vectors fields reveal the exact surface position, structure and divergence and curl and with high coverage. See also comment 208. Unfortunately, not much has been published on active satellite surface winds and PLs, while Furevik et al. (2015) provide some overview.

476: "measurable wind patterns"? My experience in scatterometry for PL/MPC is that tracking is very well feasible and measurable. I copy below a slide I show in nowcasting training using https://scatterometer.knmi.nl/tile_prod/index.php . For a description, see the figure above. Several things to note here: 1) Many scatterometer acquisitions exist over a day to verify both model dynamics (green arrows) and IR images (grey-scale). 2) IR clouds follow the dynamics seen at the surface, i.e., the dynamics produce clouds in upward motion and dissolve clouds in downward motion, i.e., the clouds follow the winds. 3) Initially, a through appears in the scatterometer winds below a cloud shield, where the green arrows are not informed by it initially. As scatterometer winds are assimilated at ECMWF the disturbance appears in the model data over the day. As mentioned earlier, L3 and L4 products are produced with scatterometer information, model information, incl. ERA5, and fields of spatial derivatives. These appear more ideal to "measure" model and, after collocation, AVHRR characteristics in PL/MPC than the rather unfavorable diagnostics presented here.



475: You find many tracks that are not in AVHRR. Following the comment above, this could well be because the vortical structure is not well expressed in the clouds. Observed dynamics at the surface may prove a better way to verify these vortices. A problem here is that scatterometer winds are only consulted after a imperfect AVHRR filter, rather than before this filter. This can be done by exploiting collocated model and scatterometer data and their spatial gradients, which are available. When only one scatterometer is available (up to 2007), then track cannot be well verified, but every occasion a vortex appears in a scatterometer swath verification may be done. That would results in hits and misses of ERA5 vortices, which verify your product more substantially in my view.

486: 3 hours implies three points, right? 50% in these cases implies only 2 of 3 points and 80% 3 of 3 points and 4 of 5 hits for longer tracks for example. It is clear that adding more lenient vortex criteria will improve apparent skill as the Stoll data set is fixed. It does not necessarily imply better performance though as Stoll. How much false tracks/points do you add?

493: demonstrates? Clearly, wind variability is high in cold air outbreaks near the surface and upper air interaction more fierce. Allowing more noise in ERA5 vorticity or more lenient

vortex criteria will reveal more tracks, but are they reliable? If some of them appear in the proximity of observed tracks, it appears insufficient to demonstrate capability. How many unverified tracks are produced (false alarms)? Could these accidentally be added to the hit list? In that case skill is not enhanced, but rather PL/MPC noise is added.

495: So, ERA5 finds about 10 times more PLs/MPCs than the most extensive observational data set (Rojo). Is this noise? Looking at your AVHRR score, noise appears indeed manifest; 57,688 ERA5 vortex tracks, only 1,184 or 1 in 50 are confirmed. This may be related to the fact that AVHRR is a rather indirect measure of vortical activity, while you appear to appreciate the skills of AVHRR. What are the >90% misses in your data set? As these amounts appear rather overwhelming, it appears very relevant to understand their characteristics if these are used for geophysical analyses or trend analyses. The difference with Stoll's 3179 tracks from the same ERA5 is also rather overwhelming. What are the differences? I further understand less than 700 (only about 1%) remain for further comparison. I'm concerned what the other 99% represent?

507: demonstrate that such discrepancies are not errors -> characterize such discrepancies ; they are errors as ERA5 uniquely represents PLs/MPCs.

509: stable -> negligible

512: remove "stable"; the choice of this word is a bit concerning, does it imply that you favor a smooth representation of disturbances? Spatial smoothing is applied, but it can obviously kill PLs/MPCs, which is a negative effect. If Stoll uses data from ERA5 that is less interpolated, it may in fact be a good thing that it represents more variability? Please elaborate in your manuscript.

532: Please indicate in the figure legend what percentage of the most favorable (matched) cases it represent. The non-matched cases are less detectable and probably have much less favorable verification.

541: "Despite" or "Due to"? Less favorable cases may not match well?

544: "reasonable"; you allow a 120 km separation and then one gets separations with a SDD of about 120 km, which implies little skill. Do you reason for little skill? Presumably, further work is needed to explain the lack of skill? Better explain to the users what further work would be appropriate in this discussion.

559: How do you know what these cases are? They have not been verified, at least not in the manuscript. Could they not be numerical artefacts? Are they associated with real features or are these ERA5 simulated features?

565: Is the point not how reliable ERA5 is to represent PLs and PMCs? One could test that using the cases where verification is available and determine and not yet used in ERA5 (by data assimilation). Therefore, testing ERA5 background states, winds are independent of any new observations, one could establish the capability of ERA5 to predict PLs and MPCs. Only after this, ERA5 can be used with confidence for associated geophysical studies in my view. Would you agree?

580: As explained above, observations directly associated with PL/MPC dynamics may be further exploited to characterize these systems and the fidelity of reanalyses to represent them.

Additional references:

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