Review: “Assimilating WIVERN winds in WRF model: an application to the outstanding case of the Medicane Ianos” by Stefano Federico, Rosa Claudia Torcasio, Claudio Transerici, Mario Montopoli, Cinzia Cambiotti, Francesco Manconi, Alessandro Battaglia, and Maryam Pourshamsi

The paper simulates the expected improvement from assimilating line of sight Doppler winds from the future WIVERN mission for a medicane case study. Pseudo observations are produced by a selected member in an ensemble of 4 km WRF simulations downscaled from the ECMWF EPS. The cyclone track is found to improve in an ensemble with 3h or 24h data assimilation cycles compared to a control ensemble. The pressure, wind and precipitation are also impacted and the difference is reduced with respect to the selected member. The benefits of data assimilation are weakly affected by an increase in observational error estimate but clearly limited when using a generic instead of a cyclone specific background error.

The paper is generally interesting and presents new opportunities for the prediction of medicanes. However, it tends to be too specific and miss a broad general context, while lacking depth in the interpretation of results. In other words, how should the paper benefit to a broader community? Also, the text tends to be confusing by lacking consistency and repeating concepts and results. For these reasons, the paper needs major revisions before it can be considered for publication. General and specific comments are given below to help improve the paper quality.

We acknowledge the reviewer for the careful review of the paper and for the useful comments about this paper. We will try to put the paper in a wider and more general context and highlight the benefits to a broader community. We will answer shortly to this discussion and then we will update the paper according to the comments/suggestions in the review phase.

General comments

1. From the abstract and introduction, a general scientific context is missing to motivate the specific case study using specific data in a specific model configuration: what are current limitations, what will be new or different with WIVERN, what impact is expected for a cyclone, why a medicane? The scientific context should also be discussed in the conclusions, which currently lack references to previous studies

Ok. We will motivate better the specific case selected. Of course, Medicane are destructive storms and improving their prediction is of practical importance. Ianos was selected for two main reasons: a) it is among the most intense Medicanes to date; b) it was already well studied in the bibliography and comparison with other studies are possible.

The role of WIVERN observations for these storms, as well as for other storms, is expected to be very important as WIVERN will observe in cloud winds globally and at high spatial

resolution. This is the main novelty of WIVERN. Of course, there are other instruments that observe in clouds winds as sondes, AMS, aircrafts, but their spatial resolution in not comparable with WIVERN. WIVERN, with its 800 km swath, will sample from the synoptic scale to the mesoscale in a single passage.

2. There is a contradiction between the first validation of track only due to the absence of reference intensity, then validation of wind and precipitation as well but with respect to member 42 that is best in terms of track only; either include observations to assess other variables, or clarify throughout the paper what is actually achieved by data assimilation.

   The member 42 has the best agreement with the a-posteriori estimated trajectory. It is also important to stress that member 42 has a good representation of the timing when Ianos approached the Kefalonia and Zakynthos islands and that the surface pressure of member 42 is well in agreement with the observation in Palliki, as also noticed by the reviewer at the specific comment l143-144. After determining that the member 42 gives a reasonable representation of Ianos, it becomes our truth because we assimilated pseudo-observations derived from member 42 into the other members. As member 42 is our truth, the performance of the WIVERN DA on the other members is quantified by comparing these members (after DA) with member 42. This will be stated more clearly in the revised paper.

3. The interpretation of the results is somehow blurred: how does assimilating winds impact other variables relevant to the cyclone (e.g. clouds and thermodynamics) but also the steering wind of the cyclone environment to ultimately improve tracks?

   We showed that the impact of assimilating in cloud winds is transferred to the mass field, thanks to the WRF model. This has an impact on the precipitation and wind forecast, as shown in the paper. According to the comment above, we will try to extend this analysis.

4. Repetitions in the methods and inconsistent use of definitions (acronyms and symbols) throughout the paper make the read difficult

   We tried to be consistent with the use of symbols and definitions, but likely we missed some points. Some suggestions come from the specific comments below. We will review carefully the paper avoiding repetitions and inconsistent use of acronyms and symbols.

Specific comments

In the title is it not explicit that WIVERN has not been launched yet and pseudo observations are assimilated here

Ok. We will use the words ” wind pseudo-observations” in place of ”winds”.

l. 4–10 This sounds like an advertisement for WIVERN and does not seem too relevant here

In these lines we state the uniqueness of WIVERN observations. We will reduce the content of the lines, nevertheless we think that it is appropriate to introduce these characteristics already at the abstract level.

l. 17 improves: reduces

Ok thanks.

l. 24 largely depends (but not only)

Ok thanks.

l. 28–29 This sentence is way too narrow in the broad context of data assimilation: wind at which levels? Forecasts at which scales? In which region, context, etc.? What about other observations?

Ok. We agree with this comment. We will add these details.

l. 36 missing (

Thanks.

l. 37 What is Earth Explorer 11?

Earth Explorer 11" (EE-11) is not a satellite that's already in orbit, but rather the name for ESA's upcoming 11th Earth Explorer mission, to be selected and developed as part of the European Space Agency's Living Planet Programme of Earth observation missions.

Earth explorer missions are proposed by the scientific community, continue to demonstrate how breakthrough technology can deliver an astounding range of scientific findings about our planet. The first mission was launched in 2009. Aeolus and EarthCare are among the EE missions.

l. 40–42 Some comments are expected for these numbers: e.g. what can be learned from such resolution compared to previous instruments such as Aeolus described above?

Of course, the high resolution and the three-dimensionality of the WIVERN observations a are very important and, considering the 800 km swath, WIVERN will fill the gap between synoptic scale and mesoscale. We will comment on this.

l. 43–44 Why? It is the first study dedicated to this specific task but what about previous studies using WIVERN or WRF (E)DA for Mediterranean storms or elsewhere?

This is simply the first study on the assimilation of WIVERN data in limited area models. Another study (Sasso et al., 2025, we will cite it) considered the problem for the global model ARPEGE. We will clarify this context.

Sasso, N., Borderies, M., Chambon, P., Berre, L., Girardot, N., Moll, P., et al. (2025) Impact of WIVERN Wind Observations on ARPEGE Numerical Weather Prediction Model Forecasts

Using an Ensemble of Data Assimilation Method. *Quarterly Journal of the Royal Meteorological Society*, e4991. Available from: https://doi.org/10.1002/qj.4991

l. 47 Here the introduction jumps from isolated and mostly technical sentences to more structured paragraphs about Mediterranean cyclones

Yes, this is to put Ianos Medicane in the context of Mediterranean cyclones. We will try to make the passage smoother, nevertheless we think that it is necessary to introduce the Mediterranean cyclones.

l. 55 missing)

Thanks.

l. 57 Why Ianos?

Ianos was chosen for two main reasons: a) it was among the most intense Medicanes; b) it is well studied. We will rephrase the sentence to consider this comment.

l. 65 Any insights about WRF from this paper?

Yes, the results of Pantillon et al. (2024) study suggest that the WRF simulation of the Ianos' trajectory were to the south of the a-posteriori estimated trajectory, as in out paper.

l. 85 Is a cumulus parametrization activated?

No, it is assumed that the convection is explicitly resolved at 4 km.

l. 94 during 24 or 48h?

During 48. Thanks.

l. 105 what about the 3h cycle?

The same as for the 24h cycle. This will be clarified.

l. 118 it is not well emphasized that the pseudo observations are given by the best member

Thanks for this comment. We will clarify it better.

l. 129 how is the scan defined for a virtual case study? Why noon rather than midnight local time?

Of course, there are infinite number of possible combinations of sampling, and we don't know at which time WIVERN will pass over the area considered in this paper. There will be storms well sampled by WIVERN, storm not sampled at all by WIVERN and storm partially observed by WIVERN (for example storm not at the center of the swath and short-lived). However, WIVERN will give a good sample for many storms during its lifetime (5 years or more) and, for these storms, a significant impact is expected, as confirmed by the results of this paper. The motivation for choosing the 12 UTC on 17 September is that: a) the storm is well formed, so we can generate a good pseudo-scene; b) the landfall is enough far (18 h before the landfall)

and the forecast can be of practical importance; c) the spread of the ensemble is in line with that of Pantillon et al. (2024).

l. 131 repetition of l. 127

Thanks. We will delete from line 127.

l. 133 CTRL using the above terminology

Thanks. We will use CTRL.

l. 135 why are there three segments between two dots?

The model output is saved every 1h and segments are every 1h. The dots are every 3h to indicate reference time. This will be clarified.

l. 137 This is not obvious from Figure 2; compute the spread?

Ok. We will report the spread.

l. 138 Figure 2

Thanks.

l. 139 From Flaounas et al. 2023?

We will add this reference.

l. 142 Why does the use of ERA5 explain the discrepancy?

We will rephrase the sentence. While ERA5 agrees well with satellite observations on the cyclone track, the ERA5 reanalysis indicates MSLP values up to 10 hPa shallower than the IFS analysis during the period of maximum intensity. However, ERA5 and IFS have a huge different horizontal resolution and this likely plays a role.

l. 143–144 This sounds like an important motivation for using the track only and should be clarified earlier

Yes thanks. This will also help to answer to general comment

l. 154–155 is this definition (6) of $\bar{D}$?

Ok. We will add $\bar{D}$ In parentheses to be clearer.

l. 161 what should be learned from Figure 3a? It is not commented apart from the two extremes

We agree. This figure will be removed maintaining the discussion.

l. 166–170 largely repeats Section 2.2

We agree. It will be deleted.

l. 171 some details on the WIVERN simulator are needed to understand this result

Ok. We will add some details on the WIVERN simulator.

l. 173 remove “which”

ok.

l. 185 should be “corrected observation error sigma^2_cLOS”

Right, thanks.

l. 188 how is the model error computed?

The model error is given by the square root of the diagonal elements of the vertical component of the background error matrix. A reference to Federico et al. (2013) will be added.

l. 193 clarify why 5 km (to match the sampling of WIVERN)

Yes, the settings of the simulator shown in lines 181-182 produces winds at 5 km horizontal resolution. This is one of the products provided by WIVERN.

l. 195 Start with Section 3.1?

Yes. We will introduce Section 3.1.

l. 200 which is which island on the map?

Ok. This will be clarified in Figure 5 (to be updated).

l. 200 distance $\bar{D}$?

Yes. We will say it explicitly.

l. 202 I do not get the point: the cyclone track is not directly related to the model winds, so why would only the cyclone intensity be the result of a propagation through model physics?

We apologize for not being clear. We wanted to stress that changes in the winds propagate to other parameters. We will rephrase or delete.

l. 204 compare panels b) WIV3h and a) CTRL?

Ok. We will express it more clearly.

l. 206 where is member 42 in Fig. 6b? Closer to member 42 does not necessarily means improves, as there is no reference for intensity (l. 143–144)

We will rephrase according to the comment.

l. 211 see comment on l. 129

See the answer above. Here we add that, being Ianos a long-lasting storm (few days), for sure it would have been sampled in the period 16-18 September.

l. 215 plotting member 42 in black on Fig. 2 with the other CTRL ensemble members (instead of Figure 3b) would make it easier to compare with Figs. 5 and 7 for the other experiments

Ok. We will add the member 42 in black in Fig.2, even if the trajectory of Flaounas et al. (2023) will likely be masked. We will see the output and decide the action. We would like to maintain Figure 3b to show the clear superposition between the member 42 and the best estimated a-posteriori trajectory.

l. 215–216 syntax

Thanks.

l. 216 clarify Figure 2 shows CTRL (in the text and figure caption)

Ok.

l. 219–221 This is hard to see without a time evolution of MSLP as in Fig. 6

We agree. Likely the comment will be deleted as, otherwise, we need to introduce a new figure.

l. 221–222 how changes propagate is obscure

After modifying the initial dynamic field of the WRF model through DA, the evolution of the model in the phase space changes. There is not a simple connection between what changed in the dynamic field and what obtained in the mass field. We will rephrase or delete.

l. 226 and WIV3h

Thanks.

l. 228 for WIV3h: 100 ($\bar{D}$ CTRL − $\bar{D}$ exp) / $\bar{D}$ CTRL = 76% (not 64% as in Table 1)

Sorry for the error.

l. 233 Fig 8a

ok.

l. 234 discussed below

ok.

l. 233–241 rather than discussing individual members, the member-to-member variability could be summarized by the standard deviation around the mean distance error $\bar{D}$ for each ensemble in Table 1

OK. We will shorten the discussion, nevertheless it is important to say that there is a certain variability.

l. 257 in the lower troposphere

Ok. This will be added.

l. 259 well represented compared to what?

Yes, member 42.

l. 264 why discuss the zonal wind here (vertical cross section) vs. meridional wind in the other panels (horizontal cross sections)? It is very confusing and very hard to interpret

The idea here, was to show the impact of the WIVERN DA in the analysis.

l. 265–266 how does it relate to the number of observations in Fig. 4a?

Of course there is relation with the number of observations, but it is not easy to disentangle the different contribution of first guess error.

l. 271 Why show this specific forecast time? Discussing different forecast times may help better understand how the data assimilation impacts the forecast

This specific forecast time was chosen to show that the impact of WIVERN DA is long-lasting. We assimilated 18 h before the time shown in Figure 10

l. 280 how do you know it is more realistic? (see comment on l. 206)

Close to member 42. Again, member 42 is not the truth but we assimilate pseudo-observations derived from its scene and so it becomes the truth.

l. 283 surface winds have just been discussed

The sentence refers to the surface winds in Kefalonia. We will correct it. However, considering also the comment in l.296-308 we are also evaluating to delete the analysis of surface winds in Kefalonia.

l. 285 overplotting the cyclone track would make it clearer

ok.

l. 289 clarify it is underestimated compared to member 42 (no obs here)

ok.

l. 293 “better”: as above

ok.

l. 294 with respect to

ok.

l. 296–308 in the absence of obs, discussing the wind at a specific point does not look relevant: the local “error” in intensity and direction is due to the shift in cyclone track mainly, which is largely discussed already, rather than to the simulated cyclone intensity (that is higher in CTRL)

The main idea, here, was to show that the shift in the wind pattern can produce, locally, a large difference for Medicanes as they have sustained and strong winds, as noticed by the

reviewer. Considering the fact that observations are missing and that the comparison is not meaningful, it is import to stress that we assimilate winds from member 42 that becomes our truth (in real cases we assimilate observations and compare with observations). So, comparing again member 42 seems reasonable. Stated in other terms, the shift of the storm is a consequence of WIVERN winds DA and seems relevant for the case. We will clarify this in the discussion.

l. 324 please stick to the terminology defined above for the trajectory errors

Ok. Thanks for noticing the point.

l. 328 “very similar”: how much is it for WIV24h?

We will add this information (34.4 km).

l. 331 what should be learned from the bias and MAE shown on Fig. 14?

The information about the MAE is redundant. We will remove it.

l. 337–341 this suggests that the NMC choice of background error matrix is not meaningful here

We would not say that NMC is not meaningful as there is a reduction of the trajectory errors compared to the CTRL experiment. Of course, it is sub-optimal compared to the background error matrix computed from the error of the day.

l. 362 Pantillon et al. (and other authors) discuss earlier initializations, while here (12 UTC on 16 September 2020) the track error is rather moderate; what would be the improvement of WIVERN data assimilation one or two days earlier?

We will try another initialization time (12 UTC on 15 September) as requested by the reviewer. Nevertheless, we cannot guarantee that the approach used in this paper could be applied for that date.

Table 1 Err(km) should be distance $\bar{D}$

Ok.

Table 2 clarify it is w.r.t. member 42

Ok.

Table 3 is not referred to in the text

Ok. We will insert the reference in the appropriate place.

Figure 1 The symbols cannot be read: please zoom in

Ok.

Figures 2, 3b, 5, 7, 9a-c Zooming in would greatly help here as well

ok.

Figure 4b using the same notations as in the text would be helpful (see equations 7–8)

Ok, we believe the reviewer refers to Figure 3b.

Figure 6 what is the background ensemble? = control ensemble CTRL?

Yes, thanks for noticing the point.

Figure 8 what do diamonds and square represent?

We will add this information in the figure caption.