Dear Editor,

We are submitting the revised version of the paper entitled (the title is slightly changed):

"Assimilating WIVERN wind pseudo-observations in WRF model: an application to the outstanding case of the Medicane Ianos"

The paper has been revised according to the reviewers comments. The reviewers are warmly acknowledged for their careful work. Changes to the paper were major, with the addition of new numerical experiments. According to the reviewers' comments:

A new section entitled: "3.4 Numerical experiments for different initialisation times" was added. Figure 2, 4 and 16 are new, while the old figures 3 and 12 were removed. The other figures were redrawn or modified according to the reviewers' comments. Finally the paper was put in a more general context and the usefulness for NWP users/developer is highlighted both in the introduction and in the conclusions.

In addition we made the following changes:

Correction and Justification of Model Configuration:

An oversight regarding the simulation start date (from 2022 to 2020) was corrected. The choice of spatial resolution and short spin-up time was justified through comparisons with previous studies.

Addition of Details on WIVERN Observations:

A new section was created dedicated to WIVERN pseudo-observations, including a figure showing wind pseudo-observations (only modules as WIVERN samples the component of the wind along the direction of the antenna) at different vertical levels, a comparison with radiosonde data for error evaluation, and clarifications on the absence of vertical thinning and the minimum assimilation levels.

New Experiments for Early Phases of the Medicane:

Experiments were added in which WIVERN observations were assimilated before the full development of the Medicane (September 15 and 16), highlighting a significant improvement in trajectory and intensity forecasts, thereby increasing the operational relevance of the study.

Clarity in Data Assimilation Methodology:

The distinction between the use of En3DVar (ensemble 3DVar) for the main experiments and the classical 3DVar approach for a sensitivity experiment was clarified, specifying the origin and computation of the background error covariance matrix.

Recognised Limitations and Future Perspectives:

It is emphasised that the results are based on a single case study and that additional cases are needed to generalise the conclusions. It is also noted that WIVERN data are useful even when the performance of the reference model is poor.

Improvements in Presentation and Clarity:

Changes were made to improve terminological consistency, figure organisation, the addition of schematic diagrams to illustrate the experimental setup, and the inclusion of standard data assimilation diagnostics to assess system quality.

Responses to Minor and Stylistic Comments:

Editorial corrections were made, bibliographic references were added, clarifications were provided regarding model configurations and observation interpretation, along with improvements in graphical presentation and terminology used in the text.

ANSWERS TO REVIEWER 1

Review of **"Assimilating WIVERN winds in WRF model: an application to the outstanding case of the Medicane Ianos"** by Stefano Federico et al.
The wind velocity radar nephoscope (WIVERN) represents a pioneering spaceborne mission that aims to deliver in-cloud horizontal wind observations with fine vertical resolution. This paper explores the impact of assimilating WIVERN derived Doppler wind observations into the WRF model for the high-impact case study of medicane Ianos. Results indicated that assimilating WIVERN observations leads to a positive impact on the prediction of the medicane trajectory, reducing trajectory forecast error by 43%. It is also shown that the assimilation of such observations will improve prediction of precipitation and surface winds. This study is innovative, interesting and well-written and I found these results of interest for the scientific community, addressing the value of next-generation wind observations in regional numerical weather prediction. However, there are several aspects that require significant clarification or improvement before the manuscript can be considered for publication. For this reason, I recommend **major revision** before it can be accepted for publication in *Weather and Climate Dynamics*.

First, we acknowledge the reviewer for the careful and insightful review of the paper. We have corrected the paper according to the reviewer comments. Hereafter, you'll find the detailed answers.

Major Comments:

1. In L113-114, it is mentioned that the CTRL ensemble is initialized at 12 UTC on 16 September 2022 using the ECMWF-EPS data. First, this appears to be a typo, the correct data should be "16 September 2020", corresponding to the Medicane Ianos case. Second, it should be added information about the approximated horizontal grid resolution of the ECMWF-EPS data used for initialization, to consider the significant resolution mismatch between the coarser ECMWF-EPS fields and the 4 km grid resolution of the WRF model used in this study. More importantly, the current setup does not seem to adequately address model spin-up problem. Since the WRF model is run on a single, relatively small domain at convection-permitting resolution, the atmospheric fields initialized from a much coarser ensemble forecast would require a proper spin-up period to develop balanced mesoscale structures. However, the model begins data assimilation just three hours after initialization. This short spin-up time is likely insufficient for the model to reach a dynamically and thermodynamically consistent state at 4 km resolution, which may degrade the quality of the assimilation and forecast performance. I recommend that the authors reconsider the model spin-up strategy, either by lengthening the spin-up period or by conducting a sensitivity test to justify the chosen approach.

   Yes 2022 is a typo. It was corrected. Considering the point of the resolution mismatch between ECMWF-EPS (36 km) and our simulations (4 km) we searched for a compromise between the quality of the model simulations and the computing time. We followed a heuristic approach, and we were guided by the comparison of our results with those reported in Pantillon et al (2024) and in previous studies conducted with WRF for Ianos (Comellas Prat et al., 2021; this study was coauthored by some of the authors of this paper). The evolution of the trajectories of the Medicane Ianos simulated by our ensemble are compatible with those reported in the cited studies and we used this as proof of a reasonable setting of the model. In addition, among different physical parameterizations that we used with the WRF model for the simulation of the Medicane Ianos (Comellas Prat et al., 2021), the one selected for this paper was the best one, even if the differences among the configurations of the WRF model considered in Comellas Prat et al. (2021) were not large.

Considering the point of assimilating WIVERN just after 3h, we agree that this could cause imbalances in the model for the WIV_{3h} simulations. Nevertheless, the simulations assimilating WIVERN every 3h smoothly converge towards the reference trajectory and, likely, unbalances are eventually mitigated by the frequent DA.

To consider this point we performed an experiment randomly choosing 20 members of the ensemble and repeating the experiment WIV_{3h} but starting the assimilation after 12 h of integration time, i.e. at 00 UTC on 17 September, to account for the spin-up problem. The result for the trajectories is shown below:

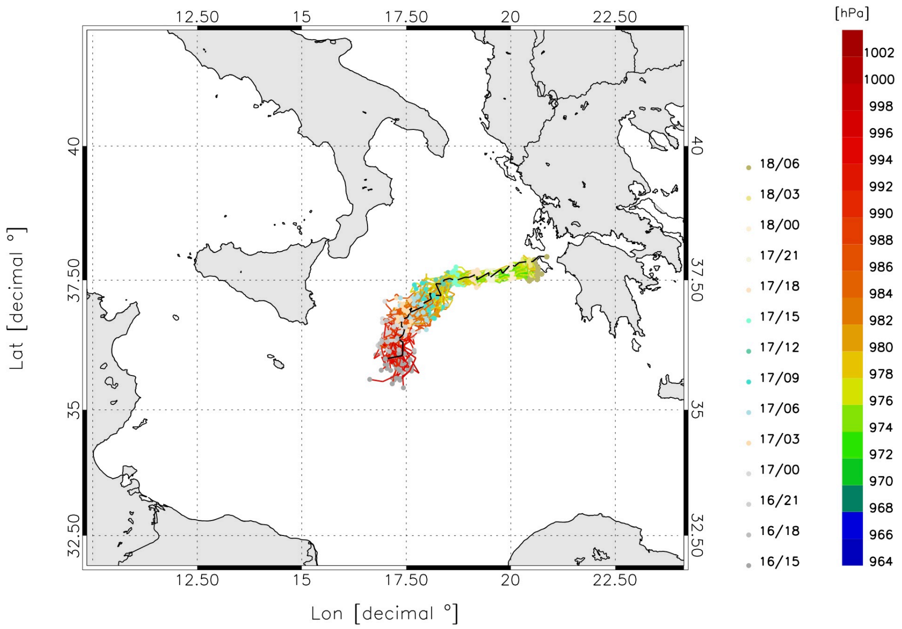

Figure 1: Trajectory followed by the WRF ensemble when WIVERN DA is applied every 3 h starting from 00 UTC on 17 September. The black trajectory is the reference member 42.

As shown in Figure 1, the trajectories again focus on the representative member 42 and the experiment is in line with the results presented in the paper for WIV_{3h}. Of course, the focusing occurs later, as we initiated the DA later. Considering the results of Figure 1, we maintained the results of the experiment WIV_{3h}; however, we agree with the comment of the reviewer, and we added a paragraph in Section "3.1 Impact on trajectory, surface pressure and winds forecast" to discuss it. We wrote:

"It is important to note that the current setup of WIV_{3h} has a very short spin-up time (3h). Since the WRF model is run on a single, relatively small domain at convection-permitting resolution, the atmospheric fields initialized from the coarser ensemble forecast could produce imbalances in the WRF forecast, lowering its quality. While a longer spin-up time will be adopted in future studies, we did a sensitivity experiment to evaluate the impact of the short spin-up time for the W IV3h experiment. We chose randomly 20 members of the ensemble, and we assimilated the WIVERN winds starting from 00 UTC on 17 September allowing for a 12h spin-up time. Results for the 20 members are similar to those of Figure 5, in the sense that the trajectories of the ensemble strictly follow the trajectory of member 42 after 12h from the first DA time. So, for the specific case study and settings of this paper, the short spin-up time used by WIV_{3h} does not impact the quality of the results.

2. Given that the focus of this study is on the assimilation of WIVERN wind derived observations, the lack of a clear and dedicated figure showing the structure of these observations at multiple vertical levels is a significant omission. Please, add a figure that visualizes the WIVERN wind fields (i.e., direction and speed) at different pressure levels or heights. This would greatly enhance the reader's understanding of the observational coverage and characteristics. Indeed, adding a new section in the manuscript focus on the WIVERN data itself, would be very beneficial for the manuscript. It would benefit from a more-in-depth discussion of the WIVERN data itself. For instance, how do the WIVERN winds compare with conventional wind observations, such as from radiosondes? Some sort of consistency check or statistical comparison would help assess data reliability. Also, it should be specified which vertical levels of WIVERN observations are assimilated or if there are any thinning or level selection applied. What is the lowest vertical level at which WIVERN observations are available? Understanding the vertical range of WIVERN is important, especially when discussing its impact on near-surface variables such as wind and precipitation.

   Thank you for noticing this point. We have reorganized and developed the content about the WIVERN observations. In the revised version of the paper there is a new section, entitled "2.4 WIVERN pseudo-observations" where we reported the material. In particular, we added a new figure showing the WIVERN wind observations along the LoS at three different vertical levels, we added the comparison of WIVERN error for the Ianos scene at 12 UTC on 17 September with radio-sounding error used by WRFDA package and we clarified better how the error of the winds along the LoS is computed. Is it important to clarify that the winds along the LoS component do not have a straightforward physical meaning as it is a combination of the zonal and meridional wind components through the sine and cosine of azimuth, which rotates at 12 rpm, and of the sine of the angle between the antenna and the vertical direction (41°). This is clearly shown by the values of the wind along the LoS that largely vary depending on the position.
   Of course, the direction of the winds along the LoS is that where the antenna is pointing (again rotates at 12 rpm and makes an angle with the vertical direction of 41°). Considering the error of WIVERN observations it was already fully developed in the paper, and we just put the same material with some clarification in the same section "2.4 WIVERN pseudo-observations".
   Finally, no data thinning was applied in the vertical direction, and we start to assimilate from 1 km height above the sea and starting from 2 km height above the land to consider the ground clutter. This has been clarified.

3. A major concern with the current study is the design of the WIVERN24h assimilation experiment, which only assimilates WIVERN wind observations at 12 UTC on 17 September, when the medicane is already fully developed, followed by a 24 h free

forecast until 12 UTC on 18 September. From a predictability and forecasting perspective, this approach raises questions about the broader relevance of the findings. Since the cyclone structure is already well stablished at the time of assimilation, the potential for WIVERN winds to meaningfully influence the genesis or early intensification phase is not tested. As such, the experiment does not provide insight into whether WIVERN observations can enhance forecast skill in the more critical lead-up phase, when predictability in inherently lower and guidance is more valuable for early warning. I strongly recommend that the authors design an additional experiment where WIVERN observations are assimilated prior to cyclone development, such as during the early stages on 15 September. This would allow the authors to assess whether WIVERN winds improve the characterization of the pre- convective environment, and whether that leads to improved prediction of the cyclone's formation, track, or intensity. Such an experiment would greatly increase the impact and relevance of the study by demonstrating the added value of WIVERN observations in a more operationally realistic forecasting context.

As stated into the paper, the time for data assimilation was chosen when the storm was well formed to fulfill these two requirements: a) we are able to have at least one member that simulates well the real Ianos trajectory ; b) the storm is enough far from the landfall to ensure at least few hour of alerting time. We think that the refinement of the forecast for the trajectory is important as it gives the opportunity to take actions more effectively during the landfall phase.
However, to consider the point raised by both reviewers, we added 3 experiments to the paper. In these experiments, the CTRL ensemble starts at 12 UTC on 15 September 2020, and the methodology is the same as that presented for the ensemble starting at 12 UTC on 16 September 2020. The member that generates pseudo-observations is the number 32 and pseudo-observations are assimilated once: in one experiment at 12 UTC on 16 September (i.e. after 24 h from the ensemble initial time); in another experiment at 00 UTC on 16 September (i.e. after 12 h from the ensemble initial time). In this phase, the storm is also well developed even if it is farther from landfall compared to the forecast starting on the following day.
The results show a notable impact of WIVERN winds data assimilation on the WRF forecast. Figure 16 of the revised version of the paper shows the trajectories followed by the members of the CTRL ensemble (panel a), the trajectories followed by the simulation assimilating WIVERN wind pseudo-observations at 12 UTC on 16 September (Panel b; experiment W IV_{24h16}), and the trajectories followed by the simulation assimilating WIVERN wind pseudo-observations at 00 UTC on 16 September (panel c; experiment W IV_{12h}.).

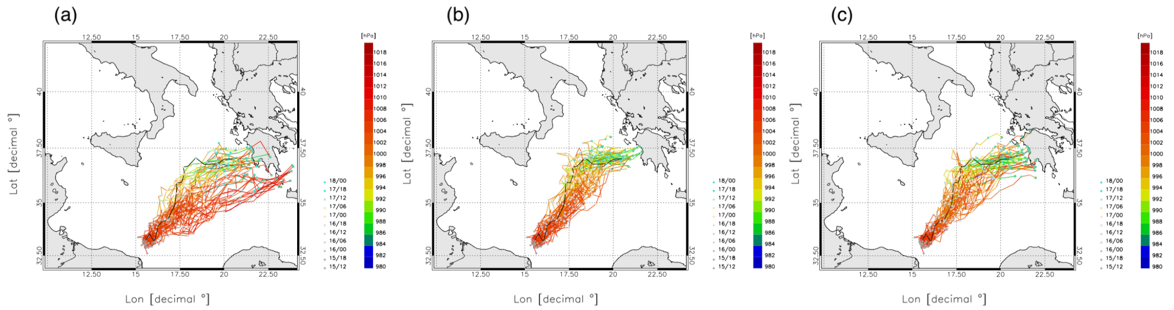

Figure 16: Trajectories of the Medicane Ianos for the experiment starting at 12 UTC on 15 September; a) CTRL ensemble; b) W IV$_{24h16}$; c) W IV$_{12h}$. In b) the assimilation is done at 12 UTC on 16 September; in c) the assimilation is done at 00 UTC on 16 September. The trajectory in black is that of reference member 32.

Looking to the results of Figure 16 panel a) there are two main points to highlight: a) the spread of the trajectory is much larger than that of the CTRL ensemble forecast starting at 12 UTC on 16 September (Figure 3 of the revised version of the paper); b) Many trajectories go south of Greece and towards the Aegean Sea and, for these trajectories, the surface pressure remains greater than 1000 hPa. These two points show the lower predictability of the Medicane Ianos on 15 September compared to 16 September; more specifically, from Figure 16 panel a) the spread of the trajectories remains wide to take precise actions, and it is not clear if the storm would deepen.

Both uncertainties are solved by the assimilation of WIVERN pseudo-observations in the W IV$_{24h16}$ forecast. The trajectories of this ensemble are all going towards the western Peloponnese and the storm is deepening. The trajectories of the W IV$_{12h}$ are shown in Figure 16 panel c). All trajectories, with just one exception, approach the western and southern Peloponnese; again, most of these trajectories show a clear deepening of the cyclone improving the forecast of the CT RL ensemble.

The results of these experiments are discussed in the new subsection: “**3. 4 Numerical experiments for different initialization times”.**

Following the above results, we tried to repeat the method for the ensemble starting at 12 UTC on 14 September. However, we couldn't find a good member to generate pseudo-observations as almost all members have trajectories remaining close to the northern African coasts in our experiment. For this reason, we do not show the results of this experiment. At the same time, we believe that the experiment starting at 12 UTC on 15 October clearly shows the potential of WIVERN for forecast improvement.

4. To improve clarity and reader understanding of the experimental set-up, add a schematic diagram or timeline that illustrates the configuration and sequencing of the different simulations performed in this study (CTRL, WIVERN24h, WIVERN3h). Include initialization times, assimilation windows, duration of the free forecasts, timing of observation ingestion, among others. Such a visual aid would be particularly helpful in understanding how the experiments differ in terms of when and how WIVERN observations are assimilated, and it would complement the textual descriptions in the methodology section.
Ok. We have added this schematic diagram (Figure 2 in the revised paper) and referred to it when necessary.

5. Another aspect that needs to be improved from this study is related to the lack of standard data assimilation diagnostics in the performance of the WIVERN3h cycling DA experiment. Typically, in cycling DA, it is standard practice to include observation-space diagnostics to evaluate how the DA system is performing. These diagnostics often include: i) root-mean-square innovation, ii) total spread, iii) mean innovations and iv) consistency ratio, which compare the ensemble spread against the observation error (see Dowell et al., 2004; Yussouf et al., 2013 or Jones et al., 2016). These diagnostics not only help in understanding whether the system is behaving as expected but also provide confidence and robustness to the DA system. In particular, the "sawtooth" plots (e.g., Fig. 2 in Jones et al., 2016) are useful for showing the temporal evolution of these quantities across assimilation cycles, helping to assess whether the ensemble has sufficient spread and whether the assimilation is consistent with the assumed error statistics. I strongly encourage the authors to include these diagnostics to demonstrate that the assimilation of WIVERN winds is working properly and to validate the underlying assumptions of the ensemble DA framework.

   Thank you for the comment. We have introduced this analysis at the start of Section "3.1 Impact on trajectory, surface pressure and winds forecast". Specifically, we considered the observation diagnostics in the form of mean innovation (bias), root-mean-square innovation (RMSI) and the total number of data assimilated for each assimilation cycle. We followed Jones et al., (2016), who is cited in the revised version.

5. A key omission in the current manuscript is the lack of discussion regarding observation error characterization, which is essential in any data assimilation study. Specifically, the study does not clarify i) what observation error variance was assigned to the WIVERN-derived wind observations, ii) whether this error was estimated, assumed or tuned and, iii) if the same error was applied uniformly across vertical levels or observation types. Given that WIVERN represents a novel observing system, it is particularly important to justify the error assumptions used in the assimilation process. This includes specifying the source of the observation error (e.g., instrument noise, representativeness errors), and how it was implemented in the assimilation system.

The discussion about the observation error computation was already fully included in the paper, however, considering the comment above, the material was reorganized and discussed more in detail in the section "2.4 WIVERN pseudo-observations". The observation error variance is given by Eqn. 8 and depends on the reflectivity (SNR ratio, through equation 7 and other equations in section "2.4 WIVERN pseudo-observations"). The matrix **R** is diagonal with each element given by Eqn. 8. The error is estimated from the scene of the member 42. Stated in other terms, the WIVERN simulator computes the reflectivity from the hydrometeors simulated by member 42 at 12 UTC on 17 September and estimates the error associated with the observations through the equations 7 and 8 (and others in section "2.1 WIVERN pseudo-observations").

These details have been clarified better in the revised version of the paper. In addition, we compared the WIVERN LoS error with radio-sounding error and model error in the new section

6. There is a significant ambiguity in the Methodology section (L103-105) regarding the type of data assimilation approach employed. The manuscript states that a 3DVar is used, yet it also notes that the background error covariance matrix is computed from the CTRL ensemble, which is inconsistent with traditional 3DVar frameworks that typically rely on climatological, static covariance estimates. Are the authors using a pure 3DVar approach with a static covariance matrix or is this a form of ensemble-based 3DVar (En3DVar) or a hybrid 3DVar-ensemble method? If an ensemble is being used to estimate flow-dependent covariance, this must be explicitly stated and clearly explained. The choice of DA techniques is crucial to interpreting the system's ability to adjust to observational input, especially with novel data like WIVERN. Additionally, further clarification is needed regarding the NMC method (used in traditional 3DVar) mentioned for estimating background errors. What period or set of simulations was used to generate the perturbations for the NMC covariance matrix? Was any covariance inflation used? These details are essential for understanding the structure and realism of the background error covariance, which strongly affects how observations influence the analysis.
   We are sorry for not being clear about the terminology. In the paper there are several experiments presented. The experiments WIV_{24h}, WIV_{3h}, WIV_{12h} and WIV_{24h16} use the En3DVar approach. In our setting of the En3DVar, the background error matrix is entirely determined by the ensemble. In the experiment NMC the background error matrix is static, and it is computed for the month of September 2020 (Lines 316-323). In the two experiments CTRL there is no data assimilation. We apologize for the confusion, and we have corrected this point in the revised version of the paper. We added several references, in the Introduction, to the En3DVar method.

7. Results and conclusions drawn in this study are based solely on a single case study. While the results are promising and the case is certainly relevant, relying on one event significantly limits the generalizability and statistical robustness of the findings. medicanes are highly variable in structure, environment, and predictability, and it remains unclear whether the demonstrated benefits of WIVERN wind assimilation would hold across other cases with different dynamical regimes or forecast challenges. In this sense, a larger number of cases is necessary to draw robust conclusions. In addition, it would be very interesting to know how useful are the WIVERN observations when the baseline model performance (CTRL) is poor?

   Ok. We will clarify better this limitation in the conclusion section. Of course, a much larger number of case studies is required to better define the usefulness/limitation of the WIVERN winds data assimilation (this is already clearly stated in the paper). Considering the point of exploring how useful are the WIVERN observations when the CTRL performance is poor there are two points to consider: a) we added an experiment starting at 12 UTC on 15 September 2020 with two different DA at 00 UTC and 12 UTC on 16 September, respectively. For these experiments the performance of CTRL is poorer compared to the experiment starting at 12 UTC on 16 September and already presented in the original version of the paper. The good impact of WIVERN DA on this forecast should clarify better the point ; b) the performance of the member 10 of the ensemble initialized on 16 September, widely discussed in the paper, was poor and the impact of WIVERN winds pseudo-observations on the simulation of this member 10 was large (Figure 12 in the revised version of the paper). As stated in the paper there are members for which the improvement is large and members for which the improvement is low but, on average, a notable and positive impact of WIVERN DA is expected for this type of storm.

We clarified better the limitations of the study in the conclusion section. "While the performance of WIVERN DA for the Ianos case study is promising, further research is needed. First, we considered only one case study and no general conclusions can be derived on the performance of the WIVERN DA at the regional scale. This is valid not only considering other storm types, as extra-tropical cyclones in the Mediterranean, but also Medicanes, as they are highly variable in structure, environment, and predictability, and it remains unclear whether the demonstrated benefits of WIVERN wind assimilation would hold across other cases with different dynamical regimes or forecast challenges. Second, we assimilated WIVERN data only, neglecting the global observing system, which is, however, considered indirectly from the ECMWF initialisation. This could result in an overestimation of the WIVERN impact on the forecast of the Medicane Ianos. Studies are in progress considering this point, and preliminary results show an important impact of WIVERN winds DA compared to other data sources. So, respect to this point, WIVERN plays a major role. Third we assumed that the storm is well sampled and that the Medicane is nearly at the center of the satellite swath. Considering the above limitations of this study, the results shown in this paper could represent an upper limit of what expected from the DA of WIVERN winds at the regional scale and further studies are needed to precisely quantify this point."

Jones, T. A., Knopfmeier, K., Wheatley, D., Creager, G., Minnis, P., & Palikonda, R. (2016). Storm-scale data assimilation and ensemble forecasting with the NSSL experimental Warn-on-Forecast system. Part II:

Combined radar and satellite data experiments. Weather and Forecasting, 31(1), 297-327.

Minor comments:
Thank for the careful review of these minor comments. We have considered all the points and correct the paper accordingly.

The following are some suggestions that could help to improve the quality of the manuscript:
Introduction Section:

1) L25: "... *The purpose of data assimilation is ...*" => "*The purpose of data assimilation (DA,* **add references***) is ...*"

ok. We added the book of Kalnay (second edition) as the reference at this point. Other references to DA have been added later in the introduction.

2) L31: "... *using a Doppler Wind Lidar*." => Please add references.

Illingworth, A. J., and Coauthors, 2015: The EarthCARE Satellite: The Next Step Forward in Global Measurements of Clouds, Aerosols, Precipitation, and Radiation. *Bull. Amer. Meteor. Soc.*, 96, 1311–1332, https://doi.org/10.1175/BAMS-D-12-00227.1.

3) L36: "*The Wind Velocity Radar Nephoscope (WIVERN) Illingworth et al. (2018); …*" => Add parenthesis before references => "*The Wind Velocity Radar Nephoscope (WIVERN)* **(***Illingworth et al. (2018); …*"
Done.

4) L45: It is introduced for the first time the acronym (DA). Remove from here (see my previous comment 1) above).

Done.

5) L45-46: It is stated that an ensemble-based data assimilation framework is used in this study. This is very confusing because later it is stated that a 3DVar, which is based on static climatological background error covariance matrix, is used. This is inconsistent. Please, clarify this point and be more specific about the DA methodology used in this study.

Ok. We clarified the context. We use both En3DVar and classical 3DVar, the latter only for one sensitivity experiment.

6) L58: Please, be more specific on the dates and hours in which medicane Ianos took place.

Ok. 15-21 September 2020. Clarified.

7) L75: After introducing acronym 3DVar, please add some references. Again, note that in L46 it was mentioned the use of ensemble-based DA method. However, here it is mentioned the use of the standard 3DVar, which is NOT an ensemble- based DA technique. Please, clarify this point carefully.
This point is now clarified in the Introduction. We adopt the En3DVar method to preserve the simplicity of the 3DVar and computing a background error matrix which is aware of the "error of the day".

Data and Methods Section [**Section 2.1**]:

8) L79: "*WRF model 4.1 with …*" => "*WRF model **V**4.1**,** with …*"
Ok.

9) L79: I suggest removing (WE) and (SN).
Done.

10) L80: Why the authors use such a reduced number of vertical levels (55)?. Add information about how vertical levels are distributed through the atmosphere (e.g., denser vertical levels near surface, …).

The number of vertical levels is the result of a compromise between the quality of the simulations and computing power. The number is adequate for the simulation of the storm, as shown by the comparison of the results of our paper with other simulations of the Medicane Ianos (both with different WRF settings and with different models). In addition, a similar configuration was successfully used in Comellas Prat et al. (2021, this paper was co-authored by some authors of this paper). We added a sentence to clarify the point.

11)L80: "*The model horizontal resolution is …*" => "*The model horizontal **grid** resolution is …*"

Thanks. Done.

12) L80-81: Remove "*in both WE and SN directions*"

Thanks. Done.

13) L82: Remove "*with the SW and NE corners …, respectively.*"

Thanks. Done.

14) L82: I suggest your 1st figure in the paper to be your numerical domain.

Thanks for the suggestion. We modified Figure 1 to include both the model domain (panel a) and the WIVERN track for the Medicane Ianos as panel b).

15) L82-85: Add a justification about the choice of these parameterizations used in this study. What are the main reasons the authors use this configuration?

Added. In a comparative study of the performance of the WRF model in simulating the Medicane Ianos, the WRF configuration of this paper performed better, even if no substantial differences were found compared to other settings.

16) L86: Again, at this point it is confusing why it is used the EPS if you are going to use 3DVar, which only requires a deterministic field.

The ECMWF-EPS was used to initialize the different members of the ensemble and to compute the background error matrix. This is now clarified.

17) L87: Are you using "analysis" or "forecasts" from the ECMWF-EPS? Please, add this clarification. Also, add further information about spatial resolution of the fields provided by the ECMWF.

As stated into the paper: "Initial and boundary conditions (IC/BC) are taken from the European Centre for Medium-range Weather Forecast – Ensemble Prediction System (ECMWF-EPS) of the Integrated Forecasting System (IFS) analysis/forecast cycle issued at 12:00 UTC on 15 or 16 September 2020, depending on the numerical experiment considered. " This means that we use the analysis at the initial time (12 UTC on 15 or 16 September, depending on the experiment) and then the forecast. We are not sure if this needs further clarification. Please let us know if we need to improve this point. We added the information about the resolution of the ECMWF-EPS (36 km).

18) L89: A direct downscaling from global model to a single domain at 4 km is used here. Why do the authors not make use of a nested approach?

As explained, this setting was a good compromise between the computing resources and the quality of the forecast. We didn't add a specific comment here as it was already stated few lines above.

Data and Methods Section [**Section 2.2**]:

19) L92: Be consistent with the notation. In the previous section, it was used 12:00 UTC, instead of 12 UTC.

Thanks for noticing. In the revised version, we use 12 UTC consistently throughout the paper.

20) L93: "*data assimilation cycles are considered*" => "*data assimilation* **experiments/simulations** *are considered*"

Ok.

21) L94: What do you mean by "*a longer repetition cycle*"? Please, clarify.

Clarified. We state: "Although WIVERN would have sampled Ianos less frequently, this 3h experiment is used to assess the effectiveness of WIVERN wind data assimilation under idealized conditions, assuming the satellite operates in a constellation formation."

22) L98: "*In the 24h cycle*" => "*In the* **24-hourly** *cycle*"

Changed.

23) L98: Why do the single assimilation is performed at 12 UTC? Which was the state of Ianos at this time (initiation phase, fully developed, decaying, …)? Please add this information.

Fully developed. Added.

24) L99: What do you mean by "*WIVERN overpasses a mature storm system*"? It is not clear to me. Please, improve this sentence.

Thank you for noticing the point. We deleted the sentence as it didn't add much to the discussion.

25) L103: Add more references to the 3DVar system. Again, this is not an ensemble- based system. If you are referring to an ensemble-based 3DVar, please specify.

Ok. We added references to the En3DVar approach in the introduction.

26)L104: "*background error matrix*" => "*background error* **covariance** *matrix*". Replace along entire manuscript.

Ok. Thanks.

27) L104: Typo: "form" => "**from**"

Ok. Thanks.

28)L105: Why the background error covariance matrix is computed at 12 UTC? Provide justification.

We justified it.

29) Equation 2: According with the notation, XNens should be replaced by X**b,**Nens

Ok. Corrected.

30) L113-114: The model should spin-up first using 6-12 hours. Direct downscaling from global resolution to 4 km without considering spin-up time will lead to imbalance physical fields.

For the WIV_{24h} experiments this is not an issue. For the WIV_{3h} this is an important point. However, as clarified in the major point 1 above, a simulation, similar to WIV_{3h}, but starting to assimilate data after 12h produced qualitatively the same results of the WIV_{3h} simulation. We added a paragraph in the subsection "3.1 Impact on trajectory, surface pressure and winds forecast" to discuss the importance of this point.

31) L117: What do you mean by "*simulator*"? Do you mean "forward observation operator"? Please clarify.
Ok. We use "forward observation operator". The radar community prefers the term "simulator".

32) L114: The assimilation of WIVERN observations in this study is performed in stratiform areas, where no convection is present. What do you obtained if you assimilate observations where vertical velocity W is not negligible?
Ok. This is a good point. It is important to highlight that WIVERN will not provide observations in deep convective (W comparable with U and V) zones as the radar signal is strongly attenuated in these zones. In addition, we are considering observations averaged over a cube of 5 by 5 km^2 and 500 m tick in the vertical. It is not so frequent to have W velocity comparable to horizontal velocities on these volumes. Finally, there could be occasions where/when W is not negligible (we believe this is marginal) compared to U and V. The quality of the results obtained in the paper shows that this is not not a serious issue.
We clarified the point in the paper stating: "Stratiform areas are simply identified by the presence of a radar echo above a minimum threshold (−15dBz), as the attenuation of the radar signal in deep convective areas prevents the return of the echo from these areas (see below). In addition, for the setting of the WIVERN simulator used in this paper, we are considering observations averaged over volumes of 5 by 5 km^2 in the horizontal and 500 m thickness in the vertical direction, and it is not common to have W velocities comparable to U and V velocities on these large volumes. Finally, there could be occurrences where/when we assimilated the WIVERN winds in volumes where/when W is not negligible compared to U and V, nevertheless we assumed W negligible.". Please note that the content about WIVERN pseudo-observations was moved in the new section "2.4 WIVERN pseudo-observations".

33) L127: Is this assumption, right? How do you know that the medicane is well sampled by WIVERN? A two-panel figure comparing the model wind field of the medicane (left) and the observed wind field from WIVERN (right) at different vertical levels and times is missing in the manuscript and should be added.
Ok. Thanks for noticing the point. As stated, we added a new section in the paper named: "2.4 WIVERN pseudo-observations" where we showed this figure. However, we considered only the 12 UTC on 17 September time. The track of member 42 is shown in Figure 1 panel b. The track shows approximately the center of the Medicane, which has a small tilting in the vertical direction, so it is (approximately) the center of the storm at all levels. As you can see in most of the pseudo scenes generated by the WIVERN simulator, the storm center is well inside the WIVERN track. In addition, we put only the WIVERN pseudo-observations, without the model output, to have a smaller figure. If further requested, we will add the model output to the figure.

Data and Methods Section [**Section 2.3**]:
34) L138: "*The red line in 2*" => "*The red line in* **Figure** *2*"

Ok. Done.

35) Figure 2: Remove title and add this information in the caption of the figure. Labels in x- and y- are not consistent with notation used in Fig.1. Please, use same notation.

Ok. Done. Note that the trajectory of member 42 is now in black. This change was made to account for the corrections of the reviewer#2. Also, from the suggestion of reviewer #2 we removed Figure 3 (original version numeration), because unnecessary. The information about the pressure of member 42 is recovered in Figure 7 (old version, Figure 8 new version).

36)Figure 3: a) Remove title of figure. Add blank space between AVG and parenthesis in y-label; b) Use same x- and y-labels as the rest of figures. Could you make larger the trajectory points. They are too small.
This figure was removed.

Results Section:
37) L197: “*has a very important impact*”. Subjective comment. Please, rephrase.
Rephrased.

38) Figure 4: Remove titles. Add blank space between Height and [cm] in y-labels.
Done.

39)Figure 5: Remove title and add this information to the caption of the figure. Consistent x- and y-labels with the rest of figures.
Done.

40) Figure 6: Use same y-axis limits for both panels. Use black colour to x- and y- labels.
Done.

41) Figure 8: Use black colour to x- and y-labels.
Done.

42) Figure 9: To small figure. Add units to panel d). Modify x- and y-labels according to the rest of figures. Use same notation.
Done.

Results Section [**Section 3.1**]:

43) Figure 10: Remove panel titles. Modify x- and y-labels according to the rest of figures. Use same notation for latitude and longitude. Add units to colorbar.
Done.

44) L289-290: What was the observed precipitation? It seems you are assessing the performance of your simulations without comparing with the observations. If not, please rephrase sentence to clarify this point.
Yes, as we are assimilating pseudo-observations from member 42, we want to simulate what predicted by member 42. This is clarified in the revised version of the paper. We wrote:

"It is important to note that, as we assimilated WIVERN winds pseudo-observations derived from member 42, this member becomes our truth, and comparison is done against its output, and no real observations are considered in this section."

45) L295: Add reference to Table 2, where the RMSE is shown.
Following the comments of the second reviewer, the discussion about the surface winds forecast in Kefalonia has been shortened and the Table 2 has been removed.

46) L303: Table 2 or Table 3? Table 3 is not mentioned in the text.
Same as above.

47) Figure 11: Adjust the colorbar height to match the figure panels. Remove decimal places from colorbar labels.
Done.

Conclusions Section:
48) L347: "*a constellation of many (4)*". This sentence is unclear. Please clarify what the "*(4)*" stands for.
Four WIVERN satellites. We wrote "a constellation of four satellites".

Appendix A Section:
49) L391: Should **Bx** and **By** been replaced by **Ux** and **Uy**, respectively?
No, they are **Bx** and **By.** The background error matrices in x and y are correlation matrices, while **Ux** and **Uy** are obtained through eigenvalue-eigenvector decomposition.

50) Equation A5: Should n, *U* and *H* been written in bold notation?
Corrected.

ANSWERS TO REVIEWER 2

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 confused 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 have put the paper in a wider and more general context and highlighted the benefits to a broader community (both in the Introduction and in the Conclusions).

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 have motivated better the specific case selected and why a Medicane in the introduction. Medicane are Important as they 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. In addition, we studied Ianos in another paper (Comellas Prat et al., 2021) and we have a good setting of the WRF model for this case.

The role of WIVERN observations for these storms, as well as for other storms, is expected to be very important as WIVERN will observe 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, AMV, 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.

However, we cannot quantify the impact of WIVERN for a cyclone. This is clearly stated in the conclusion of the paper, and also for Medicanes as we examined just one case and Medicanes are different among each other.

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 143-144. The comment on the agreement between the member 42 surface pressure and the observation in Palliki has been anticipated to give to it more relevance. 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 has been clarified in Section "3.2 Impacts on the precipitation and surface winds forecasts".

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?

   Thank you for rising this question. It is important to note that the En3DVar used in this paper neglects the cross correlation among the variables and only zonal and meridional wind components are changed by the DA. Nevertheless, the impact of assimilating in cloud winds is transferred to the mass field, through the WRF model physics. After changing the dynamical field through WIVERN DA, the WRF model adjusts the other parameters to the new dynamical field, following the physical equations and parameterizations of the model. For example, the cyclostrophic balance changes the surface pressure according to the winds assimilated. Once the storm circulation has been modified by DA (look for example at the member 10 of the ensemble), the thermodynamic characteristics change accordingly through the model physics. This has been better clarified into the paper in Section 3.1 where we wrote:

"Importantly, the En3DVar implementation of this paper neglects cross correlation among variables and only zonal and meridional wind components are adjusted by the DA. Nevertheless, the other atmospheric variables are adjusted by the model physics. For example, the cyclostrophic equilibrium is important for Medicanes and, once velocities are adjusted by DA, the pressure field is adapted to the adjusted winds. These changes propagates to other variables through the model physics and, in general, the model follows a different trajectory in the phase space after DA."

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 we missed some points. Some suggestions come from the specific comments below. We have revised carefully the paper to avoid 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 changed the title in: "Assimilating WIVERN wind pseudo-observations in WRF model: an application to the outstanding case of the Medicane Ianos"

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 adapt the content of the lines, nevertheless we think that it is appropriate to introduce these characteristics already at the abstract level, also because this puts the paper in a more general context. The mission will be launched as the next Earth Explorer 11.

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 added details.

l. 36 missing (

Thanks.

l. 37 What is Earth Explorer 11?

Ok. We explained better what is EE11. In addition, we use the term selected as WIVERN, in last summer, was selected to be launched as EE1. We added a short description taken from the ESA web page on Earth Explorers and we added a link to this page.

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 are very important, and, considering the 800 km swath, WIVERN will fill the gap between synoptic scale and mesoscale. We commented on this. We wrote: "From the numbers above, WIVERN will make a bridge between the synoptic scale and the mesoscale thanks to the wide swath and the high spatial resolution. In addition, WIVERN can play a synergistic role with Aeolus as the latter samples the winds in clear sky, while WIVERN will sample in-cloud winds."

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 added the citation in the paper) considered the problem for the global model ARPEGE. We have clarified the point stating that it is the first study focusing on this specific task.

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

We tried to make this passage smoother and to motivate the choice of the Mediterranean better.

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 rephrased the sentence.

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 our paper.

l. 85 Is a cumulus parametrization activated?

No, it is assumed that the convection is explicitly resolved at 4 km. Now it is stated into the paper.

l. 94 during 24 or 48h?

During 48. Thanks.

l. 105 what about the 3h cycle?

The same as for the 24h cycle. 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?

At this point of the paper, what is necessary is to specify that the pseudo-observations are generated from scenes well sampled by WIVERN (the conical scan at 12 UTC on 17 September). We removed the time label because it is unnecessary. Of course, the time label is relevant for the WIV_{24h} simulation, and this was clarified in section 3 where we wrote: ". 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."

Of course, there is an 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, storms not sampled at all by WIVERN, and storm partially observed by WIVERN (for example storms not at the center of the swath and short-lived). However, WIVERN will give a good sample for many storms during its lifetime (7 years or more) and, for these storms, a significant impact is expected. This paper does an investigation in this direction (i.e. what happen for a storm well sampled?).

l. 131 repetition of l. 127

Thanks. We deleted it from line 127.

l. 133 CTRL using the above terminology

Thanks. We used 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. We rephrased the sentences to clarify the point.

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

Ok. We computed the spread. We wrote: " This is confirmed by the spread of the ensemble, which steadily increases from 23.2 km at 00 UTC on 17 September to 60.4 km at 06 UTC on 18 September."

l. 138 Figure 2

Thanks.

l. 139 From Flaounas et al. 2023?

Added.

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

We rephrased the sentence to be clearer.

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

Yes thanks. This was anticipated to Section "2.2 Methodology".

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

Ok. We added $\bar{D}$ 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 relevant discussion.

l. 166–170 largely repeats Section 2.2

Removed.

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

Ok. We added 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?

This is the horizontally averaged model error and it 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), Appendix B, has been added. Also, the Appendix A was modified to better fit this comment.

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

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

l. 195 Start with Section 3.1?

Thanks. We introduced Section 3.1.

l. 200 which is which island on the map?

Ok. Figure 5 has been updated to show the names of the islands.

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

Corrected.

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 slightly rephrased the sentence.

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

Ok. It is now expressed explicitly.

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 rephrased according to the comment.

l. 211 see comment on l. 129

See the answer above. Here we added 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

Thank you for the suggestion. We added the member 42 on Fig.2 and we removed the Figure 3 as not necessary anymore.

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. We deleted the lines from 219 to 222 as, to explain the point clearly, we need to introduce new material. In addition the part it is not mandatory for the following discussion.

l. 221–222 how changes propagate is obscure

The sentence was deleted.

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)

Thank you. Corrected.

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 shortened the discussion.

l. 257 in the lower troposphere

Added.

l. 259 well represented compared to what?

To the background. Added.

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 of both components of zonal and meridional winds. Considering the fact that WIVERN pseudo-observations are a combination of zonal and meridional wind components, it seems interesting to show the impact of WIVERN winds DA on both zonal and meridional wind components. In addition, the state vector of WIVERN DA is made by the zonal and meridional wind components, so it seems adequate to show the impact of WIVERN DA on these wind components. The cross section helps to understand the vertical depth of the analysis increments. We tried to explain better into the text.

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

Thank you for noticing the point. Even though there is attenuation of the W band radar signal and there is a decrease of pseudo-observations in the lower troposphere, the number of pseudo-observations is enough to produce substantial increments in the lower troposphere. Added it into the text.

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. This is now clarified.

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

It is closer to member 42. Again, member 42 is not the truth, but as we assimilated pseudo-observations derived from its scene, it becomes the truth. We wrote: " Figure 11 shows that the assimilation of WIVERN winds changes the evolution of the storm not only for the trajectory but also for the physical characteristics, providing a representation of the Medicane Ianos closer to member 42. It is important to note that, as we assimilated WIVERN winds pseudo-observations derived from member 42, this member becomes our truth and being closer to it is equivalent to have an improvement of the forecast"

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 decided to shorten the discussion substantially and referring to the version of this paper published in the discussion.

l. 285 overplotting the cyclone track would make it clearer

Done.

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

ok.

l. 293 "better": as above

Removed.

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)

As stated above, following this comment we shortened the discussion on surface winds in Kefalonia and we referred to the version of the paper published 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 taking into account for the error of the day. In the revised version of the paper, the description of the Ens3DVar and classical 3DVar approaches are better put into the context. We rephrased the sentences to clarify the point.

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?

Ok. A similar comment was raised by the reviewer #1. Here we report the same answer.

As stated into the paper, the time for data assimilation was chosen when the storm was well formed to fulfill these two requirements: a) we are able to have at least one member that simulates well the real Ianos trajectory ; b) the storm enough far from the landfall to ensure at least few hour of alerting time. We think that the refinement of the forecast for the trajectory is important as it gives the opportunity to take actions more effectively during the landfall phase.

However, to consider the point raised by both reviewers, we added 2 experiments to the paper. In both experiments, the ensemble starts at 12 UTC on 15 September 2020, and the methodology is the same as that presented for the ensemble starting at 12 UTC on 16 September 2020. The member that generates pseudo-observations is the number 32 and pseudo-observations are assimilated once: in the first experiment at 12 UTC on 16 September (i.e. after 24 h from the ensemble initial time); in the second experiment at 00 UTC on 16 September (i.e. after 12 h from the ensemble initial time). In this phase, the storm is also well developed even if it is farther from landfall compared to the forecast starting the following day.

The results show a notable impact of WIVERN winds data assimilation in WRF. Figure 2 shows the trajectories followed by member of the CTRL ensemble (panel a), by the simulation assimilating WIVERN wind pseudo-observations at 12 UTC on 16 September (Panel b; experiment W IV_{24h16}) and by the simulation assimilating WIVERN wind pseudo-observations at 00 UTC on 16 September (panel c; experiment W IV_{12h}.).

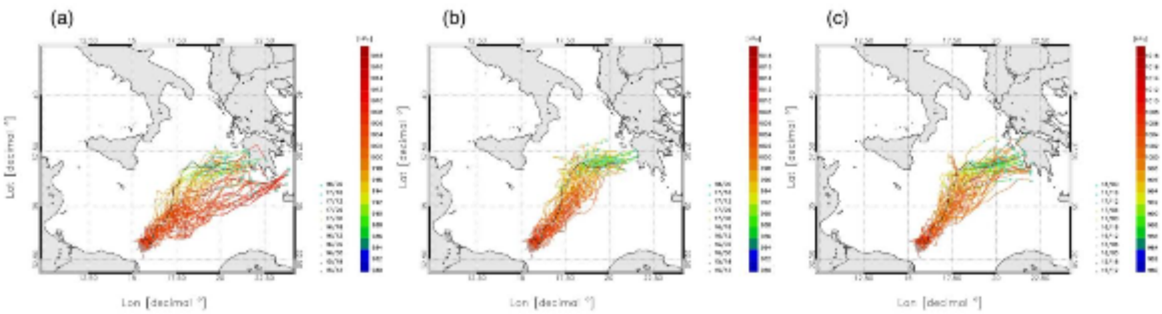

Figure 2: Trajectories of the Medicane Ianos for the experiment starting at 12 UTC on 15 September; a) CTRL ensemble; b) W IV_{24h16}; c) W IV_{12h}. In b) the assimilation is done at 12 UTC on 16 September; in c) the assimilation is done at 00 UTC on 16 September. The trajectory in black is that of reference member 32.

Looking to the results of Figure 2 panel a) there are two main points to highlight: a) the spread of the trajectory is much larger than that of the CTRL ensemble forecast starting at 12 UTC on 16 September (Figure 2 of the paper); b) Many trajectories go south of Greece and towards the Aegean Sea and, for these trajectories, the surface pressure remains greater than 1000 hPa. These two points shows the lower predictability of the Medicane Ianos on 15 September compared to 16 September; more specifically, from Figure 2 panel a) the spread of the trajectories remains wide to take precise actions, and it is not clear if the storm would deepen.

Both uncertainties are solved by the assimilation of WIVERN pseudo-observations in the W IV_{24h16} forecast. The trajectories of this ensemble are all going towards the western Peloponnese and the storm is deepening. The trajectories of the W IV_{12h} are shown in Figure 15 panel c). All trajectories, with just one exception, approach the western and southern Peloponnese; again, most of these trajectories show a clear deepening of the cyclone improving the forecast of the CT RL ensemble.

It is also noted that the forecasts of W IV24h16 and W IV12h are not very different, even if the W IV24h16 forecast follows more closely the trajectory of the representative member 32.

The results of these experiments are discussed in the new subsection: “**3. 5 Numerical experiments for different initialization times**”.

Following the above results, we tried to repeat the method for the ensemble starting at 12 UTC on 14 September. However, we couldn't find a good member to generate pseudo-observations as almost all members have trajectories remaining close to the African coasts in our experiment. For this reason, we do not show the result of this experiment. At the same time, we believe that the experiment starting at 12 UTC on 15 October clearly shows the potential of WIVERN for forecast improvement.

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 added this information in the figure caption.