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Reply on RC1

Enrique Pravia-Sarabia et al.

Author comment on "Influence of sea salt aerosols on the development of Mediterranean tropical-like cyclones" by Enrique Pravia-Sarabia et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2020-1312-AC1>, 2021

The present paper uses WRF-CHEM numerical model to consider the role of cloud condensation nuclei, originated mainly from sea salt aerosols (SSA), in three Medicanes. The aim is to assess the effects of an interactive calculation of SSA on the duration and intensity of Medicanes. To this end, simulations have been conducted both considering prescribed aerosols (PA) and interactive aerosol concentrations (IA). The results indicate that IA produces longer-lasting and more intense Medicanes. The paper deals with an issue really worth of investigation, at the forefront of the research in the field. Unfortunately, the paper suffers from many limitations; considering that a considerable amount of work is needed, my recommendation is for rejection, although I encourage the authors to complete and investigate more deeply the simulations.

We will complete the work as suggested. Thank you for your consideration.

MAJOR POINTS:

- **The paper is mainly a model validation exercise, with very limited physics insight; thus, I do not think the paper in the present form fits the topics of ACP;**

The paper is not presented as a model validation exercise, and that was not definitely our intention with this research work. As you have pointed out, as well as we state in the manuscript (paragraph covering lines 269 to 283), no observations are used. Although this limits the scope of the work, the overall ability of the model to reproduce MTLC structures is not evaluated in any part of the presented work. This implies that a sensitivity study is performed in order to determine the role of an SSA interactive production in the MTLC intensification. To our knowledge, this topic has not been previously addressed, and thus, we agree in that it is an issue worth of investigation. However, we do not agree with the lack of physics insight. Although the important role of the SSA in warm-rain production has been widely studied, the explicit feedback mechanism studied in this contribution is worth being carefully taken into account for the rapid intensification stage of a MTLC event. Along with this mechanism, both the

importance of the latent heat release contribution to the core heating, and the microphysical processes are also studied. Please note that this paper was initially conceived as a letter. We admit that the adaptation to an article structure may have not been fully accomplished, but we still think that the results are conclusive and seem to be robust enough for being published, as long as we succeed in accompanying them with a correct interpretation.

- **The analysis of the results is superficial; all figures should be analyzed and commented on more deeply (in particular, Figs. 2 and 3); additional figures should be included to investigate the simulations more comprehensively;**

Thank you for the comment.

- **The role of nudging appears only marginally related to the rest of the paper. The link with the main part (aerosol-cloud interaction) appears very weak. Nudging simulation results confirm what is already known and do not add anything new.**

We did not find any paper addressing the role of nudging in the dynamics of a MTLC. If you do know any references that could be useful for the discussion, it would be really appreciated if you could provide them. Moreover, what is presented in the manuscript is only a part of the complete work, and the results presented with respect to the role of nudging have, to our knowledge, no previous consideration. Specifically, the nudging effect on the differences introduced by the interactive aerosols are the main point here, and is what we have centered the discussion into when it comes to the nudging effect on the development and intensification of a MTLC. As suggested by Referee 2, we will try to further dive into this structure breaking by providing a new figure showing the vertical structure of both no nudging and nudging cases.

- **Also, what emerges from Lines 109-111 is not true: spectral nudging is appropriate to downscale climate simulations in order to obtain finer scale climate fields, but it is not appropriate for individual case studies (as your runs confirm), since the dynamics are not allowed to make the cyclone evolve freely (without constraints) within the domain, affecting negatively the results.**

In lines 109-111, we are echoing the information given in the referenced paper (Miguez-Macho et al., 2004). The discussion involved in the use of nudging for the case study of a MTLC lies in the fact that the initial conditions are critical for its development. In this sense, the selection of the initial time may not be trivial. What we wanted to show is that, for certain initialization times, spectral nudging can be important to ensure a proper "seed" for the medicane appearance. Besides, even with a proper initial conditions, nudging may be beneficial for ensuring a "correct" development of the system. However, what we found conversely is that, although its use may be beneficial in certain cases, the constraining on the medicane development is too strong. Ultimately, the presented results in the response to Referee 2, which will be included in the new manuscript version, are associated to the use of spectral nudging and show the importance of the medicane's vertical structure and the fact that an uneven forcing in the vertical direction, associated to a vertical shear, is critical to the maintenance of its structure.

On another note, we have not really concluded that nudging is not appropriate for our case studies. The use of nudging is important if the main goal of the simulation is to reproduce the real track. However, provided that our aim with this work was to prove that

a physical mechanism as it is the case of the wind-SSA production feedback is of paramount importance for a proper evolution of a medicane, this was conflictive with using the nudging to force the medicane tracks to resemble that of the real storms. In this regard, we decided to center the discussion for this paper in the role of the mentioned feedback in the development of the MTLCs, but not in the "correctness" of their track or intensities, meaning by "correctness" being close to those found in reality. Still, we considered interesting to study the role of nudging in what attains their intensification and maintenance. The role of nudging in the task of achieving more realistic MTLC simulations, along with that of the initial conditions (run-up time), has obviously been omitted provided the difficulty to validate MTLC simulations with observations. However, we will try to address this point with sufficient detail in the new manuscript version. Thank you for the comment.

- **Line 67, 74: I understand (but I am not sure from what is written in the manuscript) that in the WRF-alone approach you are using the double moment microphysics with the single-moment approach (progn = 0, i.e. a constant concentration of an aerosol with a prescribed size). If this is the case, you need to make intermediate runs with: - double moment microphysics fully active but with chemistry switched off, - single moment microphysics and chemistry switched on. In that way, you will take one step at a time, otherwise the comparison is not fair, i.e. you are changing both microphysics and chemistry.**

We are using a double-moments microphysics in both cases. In PA, a prescribed total number concentration (distributed with a lognormal size distribution) of aerosols is used, with double-moments in the distribution of the five hydrometeor types considered. This would correspond to using the double-moments Morrison microphysics (progn=1, mp_physics=10) as described in (Morrison et al 2009). For the IA case, GOCART is used and the concentration of natural aerosols is interactively calculated. Thus, the comparison of both cases seems legitimate since the same microphysics is used for the two. The single-moments simulations are available upon request, but not presented or analyzed in this manuscript. Provided that this case is related to another microphysical solving, this is considered as part of another sensitivity study and not appropriate to be approached here. However, we will revisit our explanation on these details for the sake of clarity. Thank you for pointing that out.

- **Line 84: As discussed in Liu et al. (2012), Veron et al. (2012), Rizza et al. (2021), when intense winds are generated, as in the presence of Medicanes, the range of sea salt size should reach 200 μm , not 20 μm !**

From these papers, it seems like sea spray droplets up to 200 micrometers are produced under intense winds conditions. However, their permanence time in the atmosphere is short provided their large size and subsequently highly probable gravitational deposition. Besides, what we refer to is sea salt aerosols, part of sea spray droplets but not the same. Thus, only sea salt aerosols up to 20 micrometers are usually considered to serve as CCN (see e.g., Andreae and Rosenfeld 2008), and hence the SSA bins considered in the GOCART scheme. Thank you for your comment.

- **The discussion should be less qualitative and more quantitative: e.g., the comments at Lines 186-188 are difficult to identify in Fig. 1; the inclusion of a Table would be helpful, showing for each cyclone the average track length and cyclone intensity for IA and PA runs, for both nudging and no-nudging runs.**

Thank you for your recommendations. We will try to improve these points for the sake of clarity and preciseness.

▪ **Figure 2 and related comment:**

-Line 197: what do you mean with “limiting the intensification potential of the medicane”?

The nudging, as introduced in our simulations, forces the wind (above the PBL) in scales larger than a thousand kilometers to resemble the reanalysis wind field. This is exactly what makes the nudging simulations produce, in general, weaker deep convection and, hence, less robust MTLCs structures, as can be appreciated in Figures S1 to S6.

Apparently, one of the most intense phases of Cornelia (when the cyclone moves toward Sicily; Reale and Atlas, 2001) is reproduced only in the nudging runs;

We will further investigate into this to clarify this fact in the next manuscript version. Thank you for pointing it out.

▪ **to make the analysis more complete, one should add the track of the cyclone as provided by satellite images;**

They have been included in the KDEs plots, as shown in the response to Referee 2. Besides, we will add a short discussion related to them in the new manuscript version. Thank you.

▪ **I do not understand why you do not show all cyclones but you focus only on one case; for example, important differences emerge between no-nudging and nudging experiments for Celeno, but they are not commented on. I think Figure 2 must include all pictures in an 18-panel figure;**

The nudging and run-up time effects are here considered secondary results that should not overshadow the main ones. The fact of having considered only a medicane for the discussion prevented from showing multiple figures for each results, which could end up producing an overextended manuscript. We do think that enough results are presented for the discussion to be valid for the three case studies, since the rest of the cases are presented in the Supplementary material. Still, we will consider your suggestion and try to improve the discussion. Thank you.

▪ **the difference between IA and PA runs is only superficially commented on.**

We suppose Referee makes reference to the introduction and methodology. Thank you for the comment, we will try to improve this point.

MINOR POINTS:

Line 27-28: Note that this is not true for all Medicanes. In some cases, the WISHE mechanism is not so important while the baroclinic development is the driving mechanism even in the mature stage. See Miglietta and Rotunno (2019) and Dafis et al. (2020).

That's right. Provided that the role of the WISHE mechanism is not totally proven to be the main driver in all the MTLC stages, we will try to avoid its use since no explicit discussion about the importance of the surface enthalpy fluxes is addressed in this work. We will also include a short reference to the existence of multiple principal driving mechanisms for MTLC. Thank you for pointing that out.

Line 44: SSA is not defined yet (apart from the abstract);

Thank you.

Line 45: The role of SSA has been partially addressed already in Rizza et al. (2021);

This seems to be an interesting study that we will try to mention in the next manuscript version to account for their results and reinforce our main message: the sea spray production is an important factor for the medicane development and should be interactively calculated. Thank you for discovering this work to us.

Line 94: what do you mean with "with dominant categories recomputed"?

This means that both landuse and soil data are recomputed when running real. When manually modifying these input data, the variable surface_input_source should be set to 3 to ensure the changes persistence. This expression will be substituted in the new manuscript version. Thank you.

Line 96: do you take SST from ERA-Interim as well?

Yes, SST is assimilated from ERA-interim every 6 hours.

Line 99: Why not using ERA-5 as initial and boundary conditions?

To our knowledge, no information is available about the best reanalysis for this type of study, and we wanted to keep ERA5 'unseen' by the model to be consistent with future studies where validation with this finer resolution reanalysis could be useful.

Line 126: what is NRL?

United States Naval Research Laboratory (NRL), it will be included in the new manuscript version.

Line 134: I am confused: you indicate here Rolf as a tropical cyclone, but earlier you mention it is a Medicane. So, what is the right classification?

Rolf was a medicane. We will try to clarify this. Thank you.

Line 141-145: This is not a disagreement, but a normal difference that may occur between observations and reanalysis for a small-scale system.

That's correct. This sentence will be modified. i

Line 157-158: why not evaluating the 4th condition for Celeno???

Although formulated by Hart for tropical cyclones, much of the works that employ the Hart methodology for studying the phase space of MTLC do not consider the 4th condition (see e.g. Picornell et al, 2013). In the tracking algorithm used in this work, the use of the 4th

condition is optional. An interesting discussion around the necessity of imposing this condition associated to the warm core height may turn too extensive and thus is not considered for this work. However, as it was used for Rolf and Cornelia, and not for Celeno, new figures have been produced as a result of removing the 4th condition for the other two medicanes to ensure the consistency of the employed methodology across all the considered cases. These figures will be included in the new manuscript version. Thank you for your comment.

Line 191: additional indications on KDE should be provided.

You are right. We will include a section in the Methodology to briefly define KDE.

Figure 3 caption: "upper half": do you mean farther from the center?

Yes, we will change the way of referring to it.

Line 215: the word "essential" is not appropriate;

Right, thank you.

Line 270-271: As discussed above, at least the track of the cyclone as derived from satellite are available and must be used. Also, some data for Cornelia (Reale and Atlas, 2001), Rolf (Ricchi et al., 2017) and Celeno (Lagouvardos et al., 1997) are available.

We will review these references for the sake of completeness. Thank you.

Line 277-281: the paper does not provide sufficient evidence to support the comments provided here.

Please note that we are not concluding that even if PA simulated medicanes are closer to the "real" ones, we have to use IA. We are concluding that provided the high sensibility that the medicane formation and evolution have on the use of interactive aerosols, it should, at least, be taken into consideration when simulating medicanes. We will still consider to rephrase these lines to provide conclusions in line with the presented results.