

## Reply to Reviewer#1

by

Koseki, S., Mooney, P. A., Cabos, W., Gaertner, M. A.,  
de la Vara, A., González-Aléman, J.-J.,

We are very grateful to the reviewer for the insightful comments and suggestions. Our responses are coloured **in blue** for the purposes of clarity. Also please note that any corrections/revision corresponding to the reviewer's comments in the revised manuscript are shown in **blue colour**.

Since we have re-performed the simulation with 6 physical ensemble members and all plots have been also re-made. Therefore, we have re-written some descriptions on the figures. Please note that these rewritings are shown in **red colour** in the revised manuscript.

Additionally, following the reviewer#2's comments, we removed most of the descriptions and figures of ERA5 (some of them are transferred to supplemental information).

### General comments:

**This article analyzes the single Mediane Rolf in a regional climate model under present and pseudo global warming conditions of the midst of the 21st century. The relative effects of a warming atmosphere and a warming ocean were analyzed separately, which has not been done before for a Mediane. The approach is indeed very interesting and appealing. However, the study would yield more reliable results by applying the same methodology for a small ensemble of simulations instead of just the current case study with single simulations for present day and future conditions. In the concluding remarks the authors emphasize several times that adding more cases would make the study more robust, and I would strongly agree with this statement. As RCM simulated storm tracks, especially of short-lived and small storms such as Medicanes, tend to be hard to simulate for a climate model, I doubt that another RCM realization with slightly perturbed conditions (e.g. started with a time lag of one day) would yield similar results. This is e.g. the case for Figure 6, which shows the Mediane track for pseudo-global warming of just the ocean or atmosphere; I think these tracks might look different for ensemble simulations. Differing Mediane tracks and storm developments were already shown in e.g. Cavicchia and von Storch (2012) for small ensembles of Mediane simulations when no large-scale constraint was used. The study would largely benefit from including a mini-ensemble of several realizations for Rolf or alternatively from including one or two additional Medicanes (whereby I would think a small ensemble for the same Mediane would provide more robust results) if the results would be similar.**

Thank you so much for the very constructive comment. We agree that the robustness of our results can be improved. Therefore, we have added 20 more simulations. For each PRS, PGW<sub>ALL</sub>, PGW<sub>SST</sub>, PGW<sub>ATMS</sub>, we have added 5 more simulations that use different combinations of physical schemes (3 different microphysical schemes and 2 different PBL schemes) to the original simulations of mediane Rolf. The combinations and abbreviations of the simulations are given in Table 2. That is, PRS/PGWs have 6 ensemble members in the revised results and we performed the same analyses with the ensemble mean.

In principle, the ensemble-mean results of changes in features of the simulated medicane are approximately consistent with the original results (please see all the figures). Therefore, we conclude that our previous discussions and arguments on the climate change impacts on the medicane are the same, but now more robustness.

The addition of these new simulations has led to a substantial text revision in the abstract and especially in Section 2.1. Please see lines 58 and 202-219.

**The advantages of the PWG method and the method itself should be described in more detail; it seems obvious that the effects of a warmer atmosphere or warmer ocean can be examined with it. But please explain why ‘a more direct assessment of impacts of future climate change on an extreme weather event’ can be achieved with it in comparison to directly using GCM scenarios as forcing data for the RCM.**

Agreed. Additional information has been added to the section describing the PGW method and the advantages over that of a single RCM realisation. Please see lines 240-244.

**PGW all is remarkably similar to PBS simulation, there seems to be not much of a climate change effect. Is this statement corresponding to other results in literature? Please put this result better into context of existing articles.**

In terms of SLP minimization, PRS and PGW<sub>ALL</sub> could have very similar results, indicating that the climate change delta has only a minor influence on the medicane. On the other hand, precipitation is enhanced in PGW<sub>ALL</sub> (e.g., Figs. 6 and Fig.10b) due to enhanced latent heat flux and CAPE. In spite of the similar SLP reductions, the SLP deepening (SLP gradient) is relatively stronger in PGW<sub>ALL</sub> than in PRS. Therefore, we have concluded that the medicane would be changed modestly by climate change with greater potential for flooding from the increased precipitation. Actually, a similar suggestion of modest intensification is made by Cavicchia et al. (2014) and González-Aléman et al. (2019). We have cited this paper (please see lines 137-145, 510-511, and 615-618).

These results are in general quite similar in the 6 ensemble simulations presented in the revised. Our results are now therefore more robust.

**The English is generally o.k., but it could be improved for some parts and formulations.**

We re-read the manuscript carefully and improved the English writing where required.

**Due to my concerns with reproducibility of the results for ensemble simulations or other Medicane cases, I suggest major revisions before accepting this article.**

As we state above, we added 5 more ensemble simulations with different combinations of physics schemes. Basically, the new simulations produce results which are similar to the original ones. Therefore, we would think that this revision improved the robustness of our discussions.

**Specific comments:**

**Abstract:** What is missing here is the novelty of the work. This is stated later in the concluding remarks: 'The main novelty of this work is the investigation of the relative roles of the atmosphere and ocean, respectively in the medicane's response to projected global warming.' In section 2.2 the following novelty is stated: 'To our knowledge, the present study is the first investigation to employ the PGW method to a tropical-like cyclone in the Mediterranean Sea.' These novelties should be stated more clearly in the abstract.

Thank you for the suggestions. We added the novelty of this work in the abstract. Please see lines 62-63 and 80-82.

**Line 107:** Do you have a reference for the potential vorticity anomaly statement?

We added Miglietta et al. (2016). Please see line 120-121.

**Line 111:** Which discrepancies? The importance of air-sea interactions does not exclude the former process, does it?

Yes. Here, we explained that air-sea fluxes are important for some medicanes but not all of them. We added "importance of the air-sea interaction". Please see line 127.

**Line 200:** Please state here that PRS stands for present, and not just in the concluding remarks.

Following this suggestion, this has been added. Please see lines 224-225.

**Line 214:** Why were these periods chosen? Why not e.g. WMO standard periods? Please explain.

In the revised version of the manuscript, the following text has been added to address this question: "*These periods were chosen on the basis of data availability for CMIP5 CGCMs and to represent 1.5C global warming in the middle of this century.*" Please see lines 240-241.

**Line 216:** What happens to greenhouse gases and aerosols in the PWG experiments? Were they changed as well or just the variables described? If not, why weren't they changed and what would the effect be if they were changed as well?

In the WRF experiments, we used the same CO<sub>2</sub> and aerosol emissions. The CGCMs computation is driven by such increments of CO<sub>2</sub> and aerosol emission. Their influences are included indirectly through the boundary condition for PGW simulations. Especially, if CO<sub>2</sub> is also increased in the WRF experiments, the additional global warming effect works and the results would be changed. But, this

could overestimate the impacts of global warming due to double-counting of CO<sub>2</sub> effect (indirect and direct).

**Line 245: Please explain all variables of the equation. The equation is numbered (3), but there is no equation (2). Are all equations starting with equation (3) wrongly numbered?**

We added the explanation on the variables. Please see lines 248-255.

**Line 250 and following: Equation (2) is missing**

Added. Please see line 252.

**Line 270: The cyclone tracking method used was not described at all. Please add a subsection the section 2 to describe it in more detail.**

The method of cyclone track is based on minimum sea level pressure. We added this explanation in the revised version of the manuscript. Please see lines 187-189.

**Line 507: Wouldn't one expect a warmer atmosphere to inhibit Medicane formation and warmer SSTs to reinforce it? Warmer SSTs would increase the temperature difference between the surface and cold, higher atmospheric layers and thus lead to a decrease in stability, while a warmer atmosphere would increase stability and thus lead to the very effect that was described.**

As the reviewer comments, such situation could be expected. On the other hand, the warmer atmosphere can contain more water vapour (Clausius-Clapeyron's relation) and the energy available for the medicane development is also potentially increased.

However, as some previous studies and CMIP5 data of climate projection used in this study show, the Mediterranean region tends to be more arid and warmer due to climate change. Our results of  $PGW_{ATMS}$  reflect such conditions for convective inhibition. In addition, as long as we are concerned, there is no study that investigates the relative role of a warmer atmosphere and ocean on the characteristics of a tropical-like storm. This is pointed out as the novelty of this work in the abstract and conclusion sections. Therefore, we still think the discussion is worth of writing and of interest for the paper.

**Line 568: What is 'middle future climate adapting PGW technique'? Please rewrite and explain. I suppose meant is something like applying the PWG method for climate change scenarios according to the middle of the 21st century?**

Agreed. **This text has now been changed to** *“future warming conditions of 1.5°C by applying the PWG method for RCP8.5 according to the middle of the 21st century”*. Please see lines 578-579.

**Line 572: The term 'best track' is to my understanding reserved for a quality-checked product provided by different weather services for (mostly tropical) cyclones which was derived by a multitude of analysis and measurement data**

(such as radar and satellite data), and not just a track derived by some kind of tracking algorithm of reanalysis data. Better term it 'reference track' if that's what was meant.

Thank you for your suggestion. We changed the word to "reference track". The first definition of reference track is given in Section 2. Please see line 187-189.

**Technical corrections:**

**Line 55: assesses instead of assess**

Corrected.

**Line 59: Insert 'an' in front of initial and 'a' in front of tropical**

Inserted.

**Line 112: blank is missing after 'on'**

Corrected.

**Line 125: insert 'to' in front of change**

Added.

**Line 149: southern France**

Corrected.

**Line 185: Tiedtke misspelled**

Corrected.

**Line 229: Include 'by' before approximately**

Added.

**Line 251: Add 'a' in front of deep**

Added.

**Line 255: Insert a blank after 50**

Inserted.

**Line 258: Add 'the' after assess**

Added.

**Line 260: hours**

Corrected.

**Line 262: Add 'that' after low**

Added.

**Line 269: I would rather use 'simulates' instead of 'observes' for ERA5.**

Corrected.

**Line 288: 'still a' instead if 'a still'**

Corrected.

**Line 350: southern France**

Corrected.

**Line 388: Replace 'double' with 'twice'**

Replaced.

**Line 401: small what?**

Added "amount".

**Line 422: Insert box after grid**

Inserted.

**Line 427: through most of the lifecycle**

Corrected.

**Line 437: defined**

Corrected.

**Line 455: What does 'in a moderate value of the space' mean? Please rewrite.**

We rewrote the sentence to “*the maximum value of the deep warm core phase is smaller than those of PRS and other PGWs.*” Please see line 470-471.

**Line 456: Insert ‘, see’ in front of Fig.**

Added.

**Line 459: Delete ‘to’**

Deleted.

**Line 462: smaller**

Corrected.

**Line 466: Delete ‘to’**

Deleted.

**Line 498: ‘a much larger’ instead of ‘much a larger’**

Corrected.

**Line 519: Insert ‘the’ in front of increase**

Inserted.

**Line 577: Insert ‘in’ in front of ERA5.**

Inserted.

**Line 579: impact instead of impacts**

Corrected.

**Line 580: replace ‘march over’ with ‘move into a’**

Replaced.

**Line 595: ‘case studies’ instead of ‘study cases’**

Corrected.

**Line 598: medicanes instead of medicane; delete ‘the’ in front of global**

Corrected.

**Line 611: Insert 'the' in front of medicane**

Inserted.

**Line 613: roles instead of role**

Corrected.

**Figures:**

**Figure 1: Remove comma in front of Rolf Are the years correct or should they read 2036-2065 and 1976-2005?**

Deleted. Regarding the year, that is correct.

**Figure 2: Are the years correct or should they read 2036-2065 and 1976-2005? And what domain is shown here? It is bigger than WRF 2nd domain and smaller than the first one. I would suggest showing results for the 1st domain for a) and b). Please add the information that relative humidity is shown in gray and temperature in black for c).**

For (a) and (b), we replaced with the plots of WRF 1<sup>st</sup> domain. For (c), the vertical profile of temperature and relative humidity at 2011-Nov-05-00UTC has been added for comparison.

**Figure 3: 'ends at' instead of 'is until' Southern France**

Since we changed this figure with 6 ensemble members, the caption has also been modified.

**Figure 5: grid box 'scales' instead of 'labels'**

Corrected. Please note that ERA5 is excluded from this figure following the reviewer#2 comments.

**Figure 7: grid box values within 250 km radius**

Corrected.

**References:**

L. Cavicchia and H. von Storch, "The simulation of medicanes in a high-resolution regional climate model," *Climate Dynamics*, vol. 39, no. 9, pp. 2273–2290, 2012.



Added. Please see lines 153-154.