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Interactive comment on "Medicane Zorbas: Origin and impact of an uncertain potential vorticity streamer" *by* Raphael Portmann et al.

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Review of "Medicane Zorbas: Origin and impact of an uncertain potential vorticity streamer" by Raphael Portmann, Juan Jesús González-Alemán, Michael Sprenger, and Heini Wernli.

The paper investigates the large-scale dynamics that led to the formation of a tropical-like cyclone over the eastern Mediterranean in late September 2018, which was characterized by high forecast uncertainty in the operational ECMWF ensemble prediction system. A potential vorticity streamer issued from an anticyclonic Rossby wave breaking over eastern Europe was key in the Medicane dynamics. Two clusters of ensemble members with zonal shift of the streamer can be tracked along the Rossby wave guide

back to initial conditions over North America. The evolution of the streamer into an upper-level cut-off low then controls the surface cyclogenesis, the stability and the advection of warm moist air that all support the Medicane formation.

Hybrid cyclones in general and Medicanes in particular are current sources of vivid discussions in atmospheric dynamics and objects of broad interest in the Mediterranean community. Contributions to better understand their dynamics and predictability are thus welcome and the paper presents interesting new material based on sound methods and high-quality figures. However, it suffers two major shortcomings: possible contributions from small-scale dynamics are largely ignored, although they at least partly explain Medicane formation, and the manuscript needs reorganization, as already pointed out by Referee 1. These shortcomings are linked somehow, as the tropical transition of the cyclone is actually assessed at the very end of the paper only. They are described below, as well as (many) specific comments.

The paper thus requires substantial revision before it can be considered for publication in Weather and Climate Dynamics.

General comments

Scales: as stated in the introduction, "the relative role of positive upper-level PV anomalies and air-sea interaction for the intensification of Medicanes is currently debated, as well as the question to which degree they are dynamically similar to tropical cyclones". The paper focuses on the synoptic scale and is based on model forecasts that do not explicitly resolve convection. This is fine but (1) the focus should be explicitly stated, (2) the limitation should be kept in mind throughout the paper and (3) the results should contribute to the current debate.

Organisation: as already pointed by Referee 1, the structure of the paper is unsatisfactory. Please better organize the Sections, make sure important concepts are introduced early in the paper (then stick to the terminology) and methods are described in the appropriate section, and avoid referring to later sections. In particular, show the

warm core structure early in the paper, and comprehensively, based on the analysis for instance; in the present form the reader must wait until the last subsection of the last results section to learn the cyclone actually developed a warm-core structure.

Specific comments

Title: the position and depth of the PV streamer exhibit some uncertainty in the ensemble forecast but the streamer itself is not uncertain; the link between PV streamer and Medicane could be more explicit.

Abstract

l. 3-4 This statement is not clearly supported. l. 5 “uncertain” is not properly used here (see comment on title). l. 7-8 “demonstrated”, “the dominant source”: not necessarily. See comments below. l. 9 Twice “strong(ly)”. l. 12 More details about the two air streams and their key role?

1 Introduction

l. 19-25 All references relate to the North Atlantic, which should either be explicitly stated or extended to other oceanic basins. l. 19-20 ET could also be mentioned here. l. 26-33 It is unclear what is the difference between subtropical, tropical-like and hybrid cyclones, if there is one at all. And do not they by definition undergo tropical transition? l. 29 “air-sea feedback” is not precise enough. l. 32 This “may” result in high damage, as Medicanes often remain over sea. l.35-39 Confusing what “they” and “their” refer to. l. 41-42 Forecast uncertainty and the link with process understanding and ensemble forecasting needs better introduction. l. 42-49 This appears too early and several keywords are not introduced yet (Zorbas, warm core, practical predictability, . . .).

l. 50 The transition should be smoother between 1.1 and 1.2. l. 63 Lamberson et al. studied “extratropical” cyclone Joachim. l. 64-65 The link between the predictability of breaking Rossby waves and Medicanes is far from obvious and need more details; it was extensively explored for a case study in September 2006: Chaboureau, J. , Pantil-

lon, F. , Lambert, D. , Richard, E. and Claud, C. (2012), Tropical transition of a Mediterranean storm by jet crossing. Q.J.R. Meteorol. Soc., 138: 596-611. doi:10.1002/qj.960 Pantillon, F. , Chaboureau, J. , Lac, C. and Mascart, P. (2013), On the role of a Rossby wave train during the extratropical transition of hurricane Helene (2006). Q.J.R. Meteorol. Soc., 139: 370-386. doi:10.1002/qj.1974 Pantillon, F.P., J. Chaboureau, P.J. Mascart, and C. Lac, 2013: Predictability of a Mediterranean Tropical-Like Storm Downstream of the Extratropical Transition of Hurricane Helene (2006). Mon. Wea. Rev., 141, 1943–1962, https://doi.org/10.1175/MWR-D-12-00164.1 l. 67 Who are “they”? l. 67-69 The mentioned studies do not clearly attribute forecast busts to initial uncertainties rather than to the representation of diabatic processes. Both error sources would thus better be described together here. l. 79 Which process?

l. 86 Even if only few case studies exist, there are certainly more than the two cited here. l. 89 Some basic information about the case study are needed here (what, where, when). And where does the name “Zobras” come from? l. 91 Please explicit “short lead times”. l. 94 Which PV streamer? Either detail or remain general; referring to Section 3 does not help. l. 96 “leads” or “led” l. 100-106 Detailing Sections 2, 3, 4, . . . might be required.

2 Operational ECMWF products

l. 110 Why 46 members only? What is the operational short-term forecast? l. 112 Forecast data is actually available at higher frequency. l. 115 What is the reference for computing ACC?

3 Synoptic overview

Figures 1-3 Zooming in on the region of interest would be very helpful to follow the discussion. Large-scale dynamics play an important role but, e.g., the Irish and Red Seas are not relevant. Consider then merging the three figures to avoid jumping from one to the other. l. 135-136 The spiral-like structure is hardly seen. Or do you mean the frontal band? Spiral often refers to a tropical structure. Again, zooming in would

help. l. 139 Fig. 2C l. 140-141 Move to the methods section. l. 144, 146 What are "they"? l. 139-149 Is it convection and/or large-scale ascent? The 600 hPa in 24 h criteria suggests the latter, while lightning suggests the former. The ECMWF model cannot actually resolve convection but you could check whether the precipitation is issued from the convection scheme or not. l. 135-149 There is a general confusion in the paragraph between what was stated by previous studies and what happens here. l. 152 Fig. 3d l. 152 Clarify the precipitation is from model data; using different colors would help distinguishing the -11, 8, 15 and 21 mm (6h) contours on Fig. 1. l. 153 How can you know it is due to conditional instability? l. 156-157 How do you discern a warm seclusion from a warm core? l. 157-160 and 166-167 There is not enough evidence at that point to claim a tropical transition. Relying here on Sec. 6.3 is not a good idea and there is no Fig. 4a. Either show more details or keep for later. l. 162 This would be worth showing!

4 Ensemble clustering according to position of PV streamer

l. 170-172 The sentence presents essential information but needs more support: why 00 UTC 27 Sep? Why 00 UTC 24 Sep? Is it perhaps the combination of valid time and initialization time resulting in largest spread? Can we see this somewhere? "Shown in Fig. 2 six hours earlier" is not too convincing. l. 172-174 Referring to a later Section to motivate the present one is surprising. l. 174-176 Please move technical details to the Methods section. l. 178 Average of 320K and 330K levels or are there additional levels in between? l. 178 Why set PV<2pvu to zero? l. 180 Remind there are 50 members? l. 190-191 Again, referring to a later Section is surprising. l. 192-193 "Decrease" rather than "drop"? Are these values of ACC particularly low? And why not color clusters 2 and 3 in green and red on Fig. 5 as on Fig. 4? l. 198 Errors in the shape of the PV streamer have not been discussed yet, only the zonal shift. l. 199 Which characteristics are relevant? l. 200-204 ACC may not account for the cyclone at all, at least the link is not showed yet. The link with the PV streamer is not obvious either. Consider adding Z500 on one of Figs 1-3.

5 PV streamer scenarios emerge from initial condition uncertainties and baroclinic amplification

l. 205-206 The jet streak has not been mentioned before. Consider either adding the large-scale dynamics leading to the PV streamer in Section 3 or, at least, shortly describing these dynamics here and motivating why they are the focus of the following analysis. l. 209-220 Please move to the Methods. Can you say some words about deltaPV values, e.g., is there a threshold that indicates bi-modal distribution? l. 221-223 While the normalized PV difference is clearly highlighted, PVU and wind contours barely differ between clusters and are not discussed at all. l. 230 The separation between clusters is hardly seen at that point. l. 238-239 Remind Fig. 7d; better "stronger anticyclonic wave breaking" than "westward phase shift and larger amplitude"? l. 242-254 The description of Fig. 7e-h is difficult to follow and Fig. S1 suggests that differences in omega and Z850 are hardly significant in the region of interest. Consider removing altogether. l. 244, 250 Either show or omit potential temperature. l. 255-263 This interpretation is meaningful and consistent with displayed material overall but (1) the formulation partly sounds speculative ("strong QG forcing", "uncertain low-level wave", "exponential growth", "strong vertical coupling") and (2) ensemble members differ not only in their initial conditions but also in their physical parametrisations or any other perturbations implemented by ECMWF to increase ensemble spread.

6 Diverging synoptic development impacts Medicane predictability

l. 268 What is a "Medicane-like" cyclone?

l. 270 The subsection provides a synthetic summary of the dynamics of all clusters, but what is the variability between members within each cluster? l. 275-276 Mention the analysis PV is depicted by the black contour. l. 277 What is meant by "exactly the ones"? l. 278-279 There is no visible difference in PV between clusters in Fig. 8 a, e, i. l. 288 Fig. 2c; slightly different time. l. 288-291 Mention the cyclone in individual members is depicted by dots. l. 295 Differences are substantial but not necessarily

due to latent heat release (only). l. 297-298 Clarify these are mean values. l. 305 Fig. 9d l. 306-306 The smoothing effect due to averaging makes the comparison difficult for precipitation; how do individual members look like? You could e.g. compute PDFs of accumulated or instantaneous precipitation for each member and the analysis. l. 314-316 These arguments are too speculative and are better left to Sec. 6.3.

l. 318 Again, what is a Medicane-like system? l. 318-325 This paragraph is confusing and must be rewritten/streamlined. How do you define a low-level warm core, a warm seclusion and a Medicane-like system, and why do you focus on two air streams? l. 326-327 The analysis tool Lagranto belongs to the methods and is already mentioned above. l. 330 Is the warm core formation shown somewhere? l. 345 “weaker” not “stronger” increase. l. 346 In clusters 1 and 2. l. 347 The Mediterranean Sea is not an ocean. l. 353-356 This would likely better fit at the beginning of the paragraph. l. 363 Closer to the coast but the region remains the eastern Mediterranean. l. 363-371 The discussion is speculative so far, as the cyclone thermodynamics have (still!) not been documented yet. There is also a general confusion between warm core, warm seclusion, warm sector and tropical structure.

l. 377-394 This all belongs to the Methods. What radius is used to compute CPS metrics? l. 394-399 I expect clusters 2/3 to show more favourable low-level/high-level forcing but not necessarily to produce a stronger/weaker Medicane. l. 400 Avoid introducing an additional name (“DWC”), which adds confusion, better stick to the terminology used up to that point. l. 400-402 What about the two other CPS metrics, symmetry and low-level warm core? The upper-level warm core metric might be contaminated by te presence of the PV streamer/cutoff. And what about the cyclone intensity? l. 403-404 But cluster 3 produces stronger upper-level warm cores than cluster 2, which contradicts the other results and interpretation. l. 407-409 The three-day long sustained deep warm core (Fig. 5a) appears unprecedented. Can you provide CPS diagrams for the analysis? l. 412-413 Why? l. 414-416 What about convection?

7 Conclusions

l. 427-418 Again, what is a subtropical cyclone, a tropical-like system or a Medicane? l. 431 More details about this “first case”? l. 432 Which process? l. 435-438 This is not shown here. l. 445-446 How do you know this? l. 446-447 Which process, baroclinic instability? l. 455-457 Ensemble forecasts are computed with different perturbation methods thus the error growth cannot be attributed to initial conditions only here. l. 458-460 . . .and convection and its organisation.

l. 462 As the used data is from ECMWF essentially, it could be stated how to access it.

References

Providing DOIs or URLs for all papers would be helpful.

Figures

Moving all figures to the end of the paper would ease the review. Fig. 5: it is unclear which date relates to which tick mark. Fig. 7 appears before Fig. 6. Fig. 6: consider changing the color scale to [-1,5; 1,5] and plotting coast lines at higher definition. Fig. S1: the title should refer to Fig. 7 not 6.

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