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Interactive comment on "A process-based anatomy of Mediterranean cyclones: From baroclinic lows to tropical-like systems" *by* Emmanouil Flaounas et al.

Anonymous Referee #3

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This study presents an in-depth and thorough analysis of Mediterranean cyclones from a potential vorticity (PV) perspective. The authors use a very rigorous approach by computing an on-line PV budget in the Weather, Research, and Forecasting (WRF) model, along the lines of Stoelinga (1996). The study presents a large number and variety of cases derived from an ERA5 climatology, and simulated with WRF to collect PV information associated with various physical processes (including physics parameterizations). Then, PV inversion was used to quantify the contributions of different physical processes to the cyclone's circulation. Results demonstrate the varying contributions of different processes, including "Medicane" systems that are shown to rely heavily, but not always exclusively on diabatic processes. The conclusions and interpretations in

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this study are strongly supported by rigorous analysis and clear graphics. In sum, I review many papers, and this is one of the stronger papers I've reviewed recently. I enjoyed reading it.

However, there are ways that the study could be strengthened and clarified, though I view these suggestions as minor revisions.

In terms of the WCD review criteria, I would rate the Scientific significance as "good" (see main suggestion #1 below), Scientific quality as "excellent", and Presentation quality is good to excellent.

Main suggestions: 1) While the goal and focus of the study is on Mediterranean cyclones, the results seem disconnected from other studies that have used PV-based methods to quantify cyclone dynamics in different geographical regions. I was surprised that even some of the PV-based cyclone classification studies that include the second author were not cited, for example (e.g. Gray and Dacre 2006). Also, none of Ahmadi-Givi et al (2004), Deveson et al. (2002), Plant et al. (2003) were cited. Placing your Mediterranean results within the context of existing literature using similar methods in different would strength your conclusion sections, where you allude to such connections. This would elevate the scientific significance of your study.

2) The process you call "momentum forcing" is unclear, and possibly incomplete. What, exactly, is this process? Can you please explain this more clearly, perhaps with a schematic? Also, you selected a convective parameterization scheme that doesn't adjust momentum (Kain-Fritsch), and so convective momentum adjustment is missing in your model runs. Perhaps the slack is picked up by the turbulence parameterization? It would be interesting to see if there would be differences in the online PV budget if you used one of the WRF schemes that also adjusts momentum (e.g., Zhang-McFarlane, Arakawa-Schubert, Tiedtke. . .)

3) There are some other classic Alpine lee cyclone studies of Mediterranean cyclones that are not cited, for example, especially Bleck and Mattocks (1984), who used a

PV-based approach to study this phenomenon:

Bleck, R., & Mattocks, C. (1984). A preliminary analysis of the role of potential vorticity in Alpine lee cyclogenesis. Beiträge zur Physik der Atmosphäre, 57(3), 357-368.

Minor corrections and suggestions: Line 40: “Topographic PV streamers” comes to my mind, but they are “banners” here. Are the terms used here consistent with previous literature? E.g., Aebischer and Schär (1998).

Line 49: Suggest adding modifier “Mediterranean” before “cyclones”

Line 67: It may be a minor, semantic point, but I would disagree that convection affects all cyclones, unless you are including slantwise convection perhaps. Upright convection is often, but not always present. Some cyclones, such as “heat lows” in the Southwestern US, can be accompanied by clear skies, albeit perhaps with dry convection during daytime hours. Some lee cyclones may be devoid of convection though.

Lines 110-112: I am curious how you implemented the on-line PV code with the WRF hybrid coordinate. The PV tendency equations would then have to vary with the vertical coordinate. This must have been very difficult, technically, and I am impressed. I would love to work with this module, as would many others I’m sure – is the code available to share?

Lines 113-115: Again, somewhat minor, but I would not recommend simulating tropical-like systems with a 5-class microphysics scheme. Without hail or graupel, snow is unrealistically lofted in strong, convectively forced systems with updraft speeds greater than a m/s or so.

Section 2.2, around line 170: Citation of some prior work may be useful here, such as the Schubert et al. 2004 paper: Schubert, W.H., Hausman, S.A., Garcia, M., Ooyama, K.V. and Kuo, H.C., 2001. Potential vorticity in a moist atmosphere. Journal of the atmospheric sciences, 58(21), pp.3148-3157.

Line 183: Check spelling on Stoelinga

Line 189: The 3-day time average is quite a lot shorter than Davis' 7-day average. No need to re-do anything, but what are the implications? My thought is that some upper-level PV contributions are lost, as the anomaly computed as a deviation from a 3-day average will be weaker for large, strong, persistent upper troughs.

Figure 1: Note typo in caption "smean ea"

Line 240: The position of cold-frontal, lower-tropospheric cyclonic PV maxima will vary from case to case, and so in a composite, there will be a large degree of cancellation (e.g., the type of feature highlighted by Lackmann 2002): Lackmann, G.M., 2002. Cold-frontal potential vorticity maxima, the low-level jet, and moisture transport in extratropical cyclones. Monthly Weather Review, 130(1), pp.59-74. This is also mentioned and discussed near lines 325-327.

Line 265: At some point, it seems that diurnal changes in PBL depth, and the fact that PV $\sim$ 0 in the PBL should be mentioned or discussed. Or perhaps better near line 360.

Line 285: I wonder if there is any seasonality to the varying contributions?

Line 458: Capitalize Gulf

Line 484: Is it Fig. 16c that should be referenced?

Line 506: Can references be provided to support this sentence?

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