Review

Dynamics, predictability, impacts, and climate change considerations of the catastrophic Mediterranean Storm Daniel (2023)

Flaounas et al.

This manuscript contains a comprehensive analysis of Storm Daniel, choosing not to focus on one single aspect of its lifecycle, dynamics, impacts, drivers or climate change contextualisation but rather to include all those angles. I think this is what the authors mean with the term "holistic". While it is certainly needed a certain degree of effort to go through and understand the results from all the different analyses, in my opinion the authors do a very good job in presenting them in a single article that is successful in highlighting the importance of events like Daniel and describing "how they work".

I think that this manuscript could become a very worthwhile contribution to WCD and I don't have any major issues with it being accepted following revision. As I don't think the overall structure needs fundamental changes, I went into some level of detail with the line-by-line comments. There are quite a few of them (sorry!) but most should be quick and easy to address. I have also a few general comments, that in my opinion are more important. You can find them below. The last of those comments is on the section discussing the attribution to climate change. I understand that my tone there could possibly sound critical and dismissive and I would like to stress that that is not the case. I would be very happy to see the section retained in the manuscript but I think that there are some issues that need addressing. Should you find anything in my comments that is not clear, please feel free to contact me.

General Comments:

It is confirmed in the author contributions section that the manuscript was written by several of the authors and it does indeed give an impression of being a little "fragmented". My suggestion to improve readability would be that one of the authors could go through it and try to harmonise the writing style, choice of words and sentence structure, to improve its readability (see the line-by-line comments).

Abstract: I hope this comment doesn't sound too subjective, but I think that this abstract is quite complex and long-winded. There are many points in which the novelty and importance of this study are highlighted, but their effectiveness is hindered by some sentences being too long, convoluted and not direct enough. Could you make it neater and sharper? See also some specific comments in the "Line-by-line comments" section.

Conclusions: I did not spend the same amount of time on them as I did on the abstract, so I would just recommend that as you improve the abstract you also amend the conclusions accordingly.

Attribution to climate change:
- I have some questions on the methodology used and on describing Daniel as hitting / making landfall over Greece, see in particular comments on Line 580 and 625.
- Coming to the conclusions that can be drawn from the section, it is stated that "Mediterranean depressions like Daniel hitting Greece and Libya show lower MSLP and higher precipitation in the present climate than in the past" and from this it is concluded that "[w]e thus interpret Daniel as an event whose characteristics can be ascribed to human-driven climate change". I understand the argument on heavier precipitation in a warmer climate (although it will have to be expanded without assuming that all readers are familiar with Clausius-Clapeyron and related implications) but no explanation is provided here on the changes in MSLP. As it stands, those conclusions look fairly weakly justified and not adding much to this particular study. For example, the "heavier precipitation in a warmer climate" link could have just been made by looking at the anomalously high SSTs during the event. Could you please make the case as to what the added value of this section is and why is it worth including?

Line-by-line comments:

Line 38: It would be nice if you could remove this "probably" as you will agree that it doesn't sound great in an article abstract. I appreciate that you won't have access to every weather report that has ever been produced in the region but, assuming some prior research (that you have likely already done), you could replace "probably" with "to our knowledge" or similar, or remove it altogether and add "in recent times" or similar (while also removing "ever").

Line 39-45: I like the creativity in the choice of words, but using simpler and shorter sentences could make it easier for the reader to understand what the aims, perspectives and strategies of this study are.

Line 46: "Our results ... cyclone". This is a bit vague. Are you referring to its structure, its intensity or other properties? Are Medicanes included in this "any other intense Mediterranean cyclone" terminology?

Line 50: "The predictability of ~~the~~ cyclone formation was rather low even ~~in~~ at relatively short lead times...".

Lines 52-53: "Our analysis of impacts shows that numerical weather prediction models are capable to capture the extreme character of ...".

Line 58: "while ~~in~~ at its maturity".

Line 61: Another petty comment (sorry…), but the "event" is Daniel, not its impacts.

Lines 83-84: "Daniel was an intense cyclone, preceded by Rossby wave breaking over the Atlantic and the consequent intrusion of an upper-level trough": do you know if any weather report by national agencies was published showing this evolution? It would be nice to see this wave-breaking somewhere.

Line 146: "Can ~~Are~~ numerical weather prediction models adequately ~~for the prediction~~ simulate climate extremes?"

Lines 192-195: Could you explain why "two-dimensional objects of extreme precipitation" are defined using 99th percentile values of precipitation **and wind**?

Lines 206: "Greece and Libya boxes"

Lines 216-217: I would say "we identified moisture sources in Daniel and in the 100 most extreme daily precipitation events"

Line 219: "Precipitate" or just condensate, given that the criterion only considers specific humidity?

Line 220: "All subsequent moisture uptakes or losses weight a moisture uptake". Could you rewrite this? I don't think I'm understanding what it means. Also, could you clarify what you mean by "weighted" in the following sentence?

Lines 240-242: "To account for the seasonal cycle in surface pressure and temperature data, we remove the average pressure and temperature values for the corresponding calendar days at each grid point and each day". I assume to do this you take advantage of the MSWX ensemble forecasts to increase sample size, given that there are only 22 years in each dataset. Could you give more information on this? For example, how many realisations do you use? At what lead time? ….

Lines 272-274: Could you motivate the choice of considering the role of ENSO, PDO and AMO (all having different frequency) among the many modes of natural variability? Also, as these indices are just diagnostic, what value do they add to the analogue analysis? In other words, does it matter if two cyclones with the same MSLP pattern occur during different phases of ENSO?

Figure 1: There seems to be something wrong with the track. If red dots are shown every 6 hours, then a few are missing between 6 Sep 18Z and 8 Sep 18Z and too many are shown between 11 Sep 00Z and 11 Sep 12Z. Also, the location 11 Sep 00Z red dot is not consistent with that of the black dot in Fig 2b.

Figure 1,caption: It should be "Storm Daniel" and not "Daniel storm" (please correct it here and elsewhere in the manuscript).

Lines 287-288: Are there any articles or reports showing the omega-blocking pattern and anticyclonic wave breaking that you could cite here?

Lines 303-304: Any reference for the NOAAN rainfall observations?

Fig 2: It is difficult to see what the max rainfall values are in both panels and to agree that they are "underestimated by about 50% in the ECMWF analysis" (lines 305-306) as all values above 200mm are purple. I'm sure you'll have already tried many different colour scales and intervals, so one possible alternative solution could be adding a small marker at the location of peak rainfall and annotating the value next to it.

Fig 3: In the caption, should "total moisture uptake" be replaced by "maximum moisture uptake", or am I getting this wrong? This comment is related to those regarding lines 219 and 220 (see above) as I have to admit that the methodology here is not totally clear to me. More generally, whilst I understand the need to show a large domain and thus for the Mediterranean region to be rather small, could you make the panels wider (and try playing with projections and domain edges, coastline and state boundary colours or adding zoomed-in boxes) to facilitate identifying locations in them? At the moment is not very easy to see where "the Aegean and Black Seas" (line 313) are, for example.

Line 315: "concomitant to the upper-level PV streamer". The wind barbs are at 850hPa while the PV streamer is at 300hPa. Why is it relevant that they share location and orientation?

Lines 320-324: Moisture sources for Storm Daniel are "partly in contrast" with the climatology, but also "somewhat overlap" with it. Could you please rewrite these sentences, as the above claims seem to be in conflict with each other?

Fig 4: Please replace "1993-2023" with "Jan 1993 – Aug 2023" in the two panels and in the first line of the caption.

Line 333: Replace "signify" with "indicate"?

Line 344: I don' t think "events" is correct here. Please rephrase.

Line 348: "in the central Mediterranean ~~has been~~ was anomalously high, ~~by~~ roughly 2 K ~~respect to~~ above the average"

Lines 362-364: "While weaker than earlier, the wrap-up of the upper-level PV streamer around the cyclone centre was proposed to be responsible for its intensification just before the cyclone made landfall". Do you see any resemblance with the "low-PV bubble" dynamics highlighted in WCD - The impact of preceding convection on the development of Medicane Ianos and the sensitivity to sea surface temperature ? I am

not suggesting you should cite this work (of which as you know I am coauthor), it's just curiosity.

Lines 354-356: Is it possible to see these features anywhere (papers/reports/publications)?

Line 388: "(~~Weather~~ World Meteorological Organisation, 2023)"

Lines 400-401: "Eventually, after landfall, Daniel dissipated fast over the Sahara Desert when it reached Egypt on 11 September 2023." Is this sentence relevant here? Also, without adding any more context, could it not be at least partially in contrast with the inland intensification described in Hewson et al. (2024) (included in your references) and your earlier discussion on the importance of the upper-level setting for the intensification near landfall? Please consider removing or clarifying it.

Lines 425-426: "at the initial stage of Daniel, it is the timely prediction of cyclogenesis that would primarily provide useful information to civil protection". If, as you say, "most precipitation was produced in areas remote to the cyclone centre" and caused by moist flow impacting from NE, wouldn't it be that moist flow the key ingredient to be predicted rather than the actual presence of a fairly weak developing cyclone downstream? Can you elaborate on this? (here or in the section that is most suited to this discussion)

Lines 433-434: "numerical weather prediction models" (here and elsewhere).

Lines 452-454: "the direct relationship between the Rossby wave breaking over the Atlantic Ocean and the accurate prediction of Mediterranean cyclogenesis." From what you show, I would say that the direct relationship is between the upper-level PV streamer and the surface cyclogenesis (although the link between the streamer and wave breaking, not shown in this work, can certainly be mentioned and placed in the context of recent literature as currently done at the end of this paragraph).

Figure 7: In my view panels b,d,f,h should refer to 11 Sep 00z, to be consistent with Figs 2,8,9.

Lines 461-462; "while two members of the EPS do not even predict cyclogenesis (not shown)." Or is it shown anywhere?

Line 474: Is it 10 Sep or 11 Sep here? See comment on the date and time issues in Fig 1.

Line 482: "MSLP spread does not have a clear pattern"

Lines 484-486: It would be nice if you could add a discussion here on the agreement between EPS members on the PV streamer for 11 Sep, as it does not seem to be higher than that for 5 Sep. This would be particularly interesting as you previously highlighted its relevance for Daniel's intensification at this stage.

Figure 9: I suggest reconsidering the order of the figures, as (unless I'm missing something)Fig. 10 is mentioned before Fig.9 in the text.

Figure 9, caption: "Percentage of overlapping precipitation objects"

Figure 10: "(b) As in (a) but as a time series for tracks of cyclone Daniel."

Line 522: Shouldn't it be three days, given what you've just said on the limited agreement in Fig 9a and considerable increase in Fig9b? (by the way, I think you mean Fig 9c there)

Lines 528-529: "This suggests that the EPS members have been more consistent in the production of extreme precipitation even if cyclone centres presented a comparably greater spread." This is consistent with my comment on lines 425-426, on the moist flow towards Thessaly being the key ingredient for the prediction of the floods rather than the actual cyclogenesis further downstream.

Lines 539-540: What does "pretty corrected" mean?

Figure 11: Is it time that is indicated on the x-axis? Please specify it (including the interval between ticks). Also, could you add (a),(b),(c) ... next to each panel?

Figure 11, caption: "Wandi Derna River" (here and in the text, line 551).

Lines 551-555: The discharge predictability for Wadi Derna River is generally lower than for Pinios (particularly on the 1st, 2nd and 4th rows from the top). Can you elaborate on this?

Line 580: I wouldn't use the expression "landfall over Greece" (here and later in this paragraph) given that the cyclogenesis is SW of Greece and then Daniel moves further away from it. Starting from this trivial comment, there is a more fundamental question that I would like to see discussed. If I understand well the methodology (apologies if this is not the case), the ClimaMeter framework uses single-time surface pressure patterns. This means that a cyclone going in the opposite direction to Daniel (e.g., eventually making landfall over Greece rather than moving away from it) would be considered a suitable analogue provided it has, for at least one time, a pressure pattern similar to Daniel's. This example cyclone could be associated with impacts throughout its evolution that are completely different from those associated with Daniel. I know that ClimaMeter has already been peer-reviewed and I'm not questioning its merits, but I would like to at least see a brief discussion of how the issue presented above can be considered acceptable, in particular in this study. Also, could this issue be avoided, if only partially, by selecting a substantially larger domain (and thus forcing a much larger region to have similar circulation?)

Line 583: I would remind the reader here that 15 analogues for each period are considered in the analysis.

Line 590: "persistence of all the cyclones".

Figure 12, caption: Is "concerning" the correct word in "color-filled areas indicate significant anomalies concerning the bootstrap procedure"?

Lines 592-593: "Figs 12q-s show no significant changes between the two periods (present and past climate)." If significance is evaluated using the test presented at line 595, then I would move its description before this sentence.

Lines 593-594: "We can… present periods". There must be a word missing here. Possibly "that" or "which" after "Q"?

Line 611: Is the period under analysis 10 Sep as written here or 10/11 Sep as in the caption of Figure 13?

Line 614: No description of T2m changes?

Lines 604-606 and 619-621: Sources of variability "may" have influenced the event. Written in this way it sounds like we don't know anything more about it that we didn't before the analysis. Could you rewrite it less vaguely and highlight what the result is?

Line 625: Daniel does not "hit" Greece (although some of the analogues may, see above). I think this choice of words is misleading.