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Invited perspectives: Thunderstorm Intensification from Mountains to Plains.

Recommendation: Accept pending major revisions

This article is a discussion about a potential field campaign designed to examine severe weather in the mountainous regions within Europe. Thorough motivation is provided and a real need for the campaign is evident. Many different topics are identified as potential foci of the campaign and of interest to the participating European partner institutions. In fact, essentially every potential severe weather hazard is included, with the only real discriminator the need for the hazard to occur near a mountain. I don't envy the authors their job of needing to synthesize dozens of competing interests into a single article. Unfortunately, that is exactly what the lead investigators of this campaign will need to do to make it successful. The number of research topics included is too large to be addressed by just one campaign, unless the budget is much larger than I'm used to for campaigns (if so, great!). But by trying to address everything, you'll have a big chance of not addressing anything.

I understand that the funding decisions are still very much unknown, and the sources of the funding will dictate (at least in part?) what research topics will be highlighted. However, I highly recommend the following:

1. A lead investigative team needs to be established. It might need to be expanded as additional funding sources are added, but there should be a core team from the start.
2. A process needs to be established to identify what research topics will be focused on. Will the lead team decide unilaterally? Will each contributing institution get to make their own decisions? Perhaps there will be a rotation, with focus on, say, hail storms during one period and severe winds the next period.
3. It reads like the campaign will be a mix of extended instrumentation deployment coupled with more targeted observing periods. How will these more targeted period be decided upon? Who will be in charge of each one? (While obviously they will want input from everyone, this could easily turn into "too many cooks spoil the soup".)
4. How will data sharing be handled? Will one organization host everything, or will there just be agreements that the data will be available (and to whom)? What guidelines will be provided for how available the data must be? Who will decide those guidelines?

The article needs describe how points 1-4 above will be addressed. If they can't be addressed completely yet (e.g., #3 might depend on who participates), explain how it will be addressed and when. I have a few more targeted comments about this same subject.

- Lines 220- 251 (Section 2.4): This section describes at least 3 different connective modes (supercell, non-supercell pulse storms, MCSs) and 3 hazards (hail, flooding, and downbursts). Each of these represent full lines of research in their own right. It will be difficult to avoid each group trying to optimize observations for their interests at the expense of others. As just one example, observational strategies for the 3 hazards listed above are quite different. Hail needs radar scanning maximized in mid-levels with a focus on high resolution dual pol data. Downbursts need it maximized in low-levels; with the range brought in so velocities aren't aliased.
- Lines 331-339: The wide-ranging research problems described in this short paragraph (including aerosol impacts on convection! A whole line of research mired in controversy over whether it even exists!) cannot be solved with the 3 new observation types listed. Drones cannot provide in situ microphysical observations within a storm (unless

European laws are significantly different than US ones, which of course could be a possibility.) Vertically pointing radars, while helpful, require the thunderstorm to traverse directly overhead, so the sample size will unfortunately be small. While I don't doubt that a targeted set of remote sensing and in situ observations, using existing observation technologies, coupled with carefully structured planned DA and modeling experiments could provide improvement in NWP convective microphysical processes, nothing like that is suggested/described herein. It would need its own dedicated campaign/research effort.

- Figure 5: It seems like almost all of the research topics could fit under both scales and all methods. Can you offer some explanation about why topics are placed under one method/scale and not another? I understand you are still working out the priorities of the project, but even identifying topics that are *not* to be included would be helpful here. (E.g., data assimilation is mentioned back in Section 2, but doesn't show up Section 3 – is it being saved for later?)

In addition, I have the following major comments:

- Lines 19 - 27: I would not necessarily conclude from Fig. 1 that the largest hail is concentrated near peaks in terrain. Obviously, the southern Alps is a hot spot, but beyond that reports seem fairly scattered. I don't doubt what you say is the case, but I'd recommend including plots of other datasets, like those you mention on lines 23-24, to support your claim, particularly given your main science question in Line 28. Population biases also need to be accounted for. Further, unless you also want to include global hail data in your intro, I'd change that science question to "why are storms in the vicinity of European mountain ranges more severe"?
- Lines 163- 165: How will the operations plan handle the mobility challenges that happen near orography? What about forecasting challenges?
- Lines 197- 198: The impact of dust (or even CCN) on convection or CI is still uncertain. I would provide more background information to support this specific idea as a hypothesis.
- Lines 200-201: Do we have sufficient aerosol measurements (particularly aloft) to make them worth assimilating?
- Lines 273-282: Great points and ideas! However, I'd like to see more explanation about how they will be carried out as they are hard goals to achieve. Are there specific plans to partner with identified educational groups? What about partnerships with the news media (or other typical disseminations of warning information)? What about the forecasters issuing the warnings themselves, are they comfortable incorporating guidance about recommended safety measures/behavior into their warnings? What additional information might they need to provide more tailored recommendations?
- Lines 340-392: This section has a great description of the many complex problems that can prevent climate models from capturing all the complexities of trends in severe weather. However, one point not explicitly mentioned is the difficulty in translating environmental convective parameters into knowledge of severe weather. Even convection-allowing models that correctly predict the development of thunderstorms still struggle with translating that information into the severe convective hazard itself. I remind the authors that no existing study or method has successfully shown positive skill in forecasting the occurrence of 50 mm hail, for example, and many studies, in fact, have shown no skill at all or even negative skill (e.g., Gange et al. 2017; Adams-Selin et al. 2019, 2023; Gensini et al. 2021). The field campaign plans and increased spatial/temporal observations mentioned in Lines 388-392 may very well uncover new environmental condition - storm dynamics relationships that can improve the situation.

However, it is also highly possible that small, storm-scale processes may be the differentiator between a storm that produces a severe hazard and one that does not; processes that cannot be identified solely by the surrounding environment (e.g., Adams-Selin 2024). If that is the case, it will mean predicting these hazards, and estimating trends in their occurrence solely from relatively coarse environmental fields, may not be possible. I caution the authors to allow for that result.

- Lines 509-512: Yes, I absolutely agree that data sharing will be one of the key outcomes of this effort. It will be so important, in fact, that I'd like to see more detail here explaining my point #4 above.

Minor comments:

- Line 26: What makes these population centers highly vulnerable?
- Line 34: Based on Fig. 2, it seems like the survey pre-assumed the severe storms would be near mountains? Again, not a problem as long as that assertion is better motivated up in the intro.
- Lines 53-57: What about LIFT and Swabian MOSES?
- Lines 90-91: If you included a lightning rate climatology in section 1, being able to reference the spatial differences between it and OTs and/or hail reports would be a good supporting statement here.
- Line 104: These perturbations would be over a deeper layer than just the boundary layer, right? Boundary layer perturbations alone won't produce the modifications you mention.
- Line 109: "could not be"→ "have not been"
- Line 128-129: Re: upslope few on the leeward side. I agree with the statement, but perhaps include a clarifying phrase about how the upslope flow is opposite to the typical prevailing winds (otherwise, of course, it wouldn't be the leeward side.)
- Lines: 162- 163: Expand upon the results in Feldmann et al. (2023) instead of relying upon Fig. 1.
- Line 210: I'd reference the section where outreach and education efforts will be discussed further.
- Lines 221-223: While I agree with your statement here, how frequent are these different types of storms? How difficult will they be to sample, and climatologically, how likely are they?
- Lines 258-259: Are tornado surveys planned as part of TIM?
- Lines 270-272: While comparison of collections of scanned and dissected hailstones between different continents, elevations, etc. are indeed important, they can still only represent a very small percentage of possible hail instances produced by a given storm. Additional observational methods need to be included that will capture larger spatial and temporal areas of the hailswath: e.g., drone survey, time-dependent disdrometer information, a targeted (mobile, if possible) hailpad network.
- Lines 321: Some comparison of the spatial and temporal resolution of currently assimilated observations to the planned TIM observations would be helpful here. Right now the reader doesn't have a good way to assess how impactful these new observations might be. Over how large an area are they planned?

- Lines 326-330: While I agree that more observations are always helpful, my feeling is that determining the location and quantity of such observations to allow for potential improvement of model calibration is not a simple thing. I'd like to see more information from past studies explaining why and how these observations will be configured. Again, one suspects that this goal is worthy of a research project all on its own.
- Lines 407-409: ESA's new EarthCARE satellite, and the upcoming planned NASA INCUS mission, would both be good satellite datasets to incorporate.
- Lines 410-422: The described research topics, particularly validation of LI data via ground-based LMAs, will require deployment of a reasonably sized ground network for a not-insignificant amount of time, particularly if measurements of such precision will be made that can be linked to storm microphysics. Will enough of a network be able to be established that these science questions can reasonably be answered?
- Lines 428, 432: What is the horizontal and vertical resolution of these new profiling instrument datasets? How much of an impact will these resolutions have on the planned science?
- Lines 442-444: Will these new commercial microwave link networks be established near the campaign location(s) of interest? Where do they monitor? What kind of observations are needed for validation/DA studies?
- Lines 448: What type of airspace regulations re: drones are there in the field campaign location(s) of interest? Will the regulations allow measurements to any reasonable depth? (Drones not being able to fly within thunderstorms due to airspace regulations has been a big frustration of mine.)
- Lines 470-474: Do you have plans for how you will prioritize placement of radars? For example, will filling in gaps in coverage, or establishing the best dual-Doppler coverage be more important? How will those priorities be decided?
- Lines 494-495: This sentence encompasses ~5 different lines of research in just the first half of the question!
- Line 500: Observations most important to NWP models and forecasting…. For what purpose? Convection, orography, other?
- Line 501: What is meant by high resolution? (Rough order of magnitude)
- Lines 523, 530: What instrumentation will the mobile teams consist of? How will their focus be determined, both overall and IOP-by-IOP? What types of convection will be prioritized?
- Lines 527-528: Will research topics, in addition to instrumentation, also be based on individual funding?
- Lines 532: What kind of climatologies do the ESWD severe report database agree with?
- Line 549: How will the numerical modeling experiments be designed and coordinated among groups?
- Line 563: Educating through public outreach and introducing students to convective research are great goals, but no details are provided on activities to achieve those goals.