Notes - Extremes and Impacts Breakout

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What interactions across spatial and temporal scales drive extreme and impactful events, and how can we leverage understanding of such interactions be leveraged to better comprehend, quantify, and predict extreme and impactful events?

**can we be sure to include extremes beyond precipitation. E.g. extreme wind speeds across scales. -Yes!

Compound, sequential and multi-variate extremes (eg rain on snow events)

Current Challenges and Research in RGMA to Highlight

Challenges related to implementation of GEV for model evaluation & dare we say 'extrapolation'?
I wonder if we should also think about mixed climates and emerging sources of extremes (e.g. polar lows in regions currently not impacted by them) in the future climate that do not occur within the contemporary climate? And specifically the ability of different ESM & RCM to capture those? - i.e. the continuing need for RCMs?
Do improvements in model resolution, and better representation of events (like TCs, ARs). Need Error Budgets?

Maybe we should call out compound events (co-occurence of extremes) - e.g. wind storms with freezing rain?
Also a need to increasingly focus on joint probabilities of extremes - e.g. maybe something like derechos or MCS where heavy rain and high wind gusts occur?
Acknowledging the imperfection of assuming Poisson processes I think using it to examine serial clustering of extreme events is very interesting both in a geophysical process level and impacts. We're doing that for wind storms.

Did the concept of 'tipping points' lose traction?

Research Gaps and Future Directions

Michael Wehner: Drought - complex interdisciplinary problem that RGMA scientists could connect over - eg Naresh Devineni - crop soil moisture database - could use root level moisture (as opposed to 10 cm soil moisture that comes from models)
Abby Swann - current project - uncertainty on plant side propagation into drought

Renu - do we have enough data to validate soil moisture? Who does that? Michael Wehner
SMAP - instrument failed - Naresh says NDVI is in some other datasets (>30 y)
Forrest Hoffman - RUBISCO - a few people working on synthesizing soil moisture datasets from various measurement and surrogate data sets; need longer dataset than is available
Abby - we'll probably need to infer water stress from indirect measurements (ie not of soil moisture)
Naresh paper: https://www.sciencedirect.com/science/article/pii/S0022169416000020 crop water stress

Emanuele Di Lorenzo - "One aspect that would need more focus in the case of heatwaves and droughts is understanding their phenomenology across the land/ocean boundary as they impact both marine and terrestrial ecosystems (and their services). Most studies focus on these dynamics a bit in isolation. " - more holistic understand across spheres
Mike Wehner - CA drought, Manu - AK peninsula drought - also Bering Sea impacts like fisheries / coastal ecosystem
Antonietta Capotondi - also temperature changes related to changes in winds

Sara Pryor - wind / compound events (eg high winds + extreme precip)

- Wind is multi-scale atmospheric hazard - derecho scale / TCs / large-scale wind storms
- Wind is important both for impacts and also as a fundamental dynamical variable

Mike points out - resolution matters for wind. Orographic?

- Sara - last 30% gust magnitude needs more than geophysical variables. Machine learning?

Yufei Zou - subscale processes need model development to capture extreme events
Sara Pryor qu. for Mike Wehner - is cyclone tracking better in CMIP6? Mike says no he doesn't trust coarse res models - Colin Zarzycki says TCs are perhaps problematic for TCs, but there's convergence for ETCs. Differences are within the storm-scale wind field and precip details

Sara Pryor - dynamical downscaling with WRF from GCMs - RCM can't correct for location bias - for statistical downscaling (especially MPI) - **members are so different that they don't tell a consistent story (wind storms + damage from ETCs)**

Colin - hierarchy of utility - depends on application where your best bang for your buck is (eg bulk stats)

Richard Grotjahn - As for research gaps: Getting back to question Michael raised: what are the human impacts on blocking? I'd expand that to impacts on circulations. The example I cited was for California, summer, heat waves. Climatology is a block there in that season, so, maybe not much room to change. There may well be human impacts, especially in winter on circulations. LSMP analysis provides a context to look into this targeting extremes specifically.

- What about the work on waviness - Francis+Vavrus / Barnes (~2013) - Mann?
- Wehner - SOM work - weather patterns

Short Term (3- 5 years) Research Goals

Long Term (10 years) Research Goals

Session 1 Zoom Chat Notes:

From S.C. Pryor to Everyone: (1:51 PM)
Qu to Micheal - so what has to change to actually make meaningful improvement for skill? Or does this just mean that convection permitting RCM are the game in town right now? OR as you say does everything point at the importance of statistical 'right-scaling'?
From Michael Wehner to Everyone: (1:54 PM)
Sara. I think this is the question at hand. Convection permitting is my favorite solution. But it needs to be demonstrated. Also, since we know that storm properties are more realistic at high resolution, perhaps we gain confidence even if these metrics do not show improvement.
From Richard Grotjahn to Everyone: (1:54 PM)
This reminds me of the problem with topography, smoothed topog missing the ridge tops, so elevations too low to properly block flow. Random thought: Could there be an approach like 'envelope topography' applied to extremes?
From Paul Ullrich to Everyone: (1:55 PM)
I think somebody should try using ML to build functional translators between pointwise observations and associated gridded data
From Michael Wehner to Everyone: (1:56 PM)
Paul. That is surprising coming from you! I feel better about using what we know from EV statistical theory.
From Paul Ullrich to Everyone: (1:57 PM)
Michael: I was about to add an addendum that I don't think it'd be substantially better than Mark's approach. But it might allow us to see if there's something the EV statistical theory is "missing"
From S.C. Pryor to Everyone: (1:57 PM)
GEV is only as good as the degree to which the assumptions are met! :-)
From R. Saravanan to Everyone: (1:59 PM)
To Risser: Since extremes are by definition large perturbations, is nonlinearity an issue when trying to partition the causes of extremes between different modes of variability?
From Mark Risser to Everyone: (2:00 PM)
Hi Ram-
From Mark Risser to Everyone: (2:02 PM)
(Oops, hit enter too soon.) That's an excellent question. We use linearity as a "first order" approximation, since trying ro simultaneously estimate a large number of nonlinear relationships can be problematic for a limited data record (i.e., there's a degrees of freedom question)
From Mark Risser to Everyone: (2:02 PM)
I think we should definitely think about exploring nonlinearity as future work. I know there's at leas tone paper out there about ENSO's nonlinear effects
From Paul Ullrich to Everyone: (2:02 PM)
Ankur: Have you assessed sensitivity of the training to subsetting the ARTMIP algorithms?
From S.C. Pryor to Everyone: (2:02 PM)
Ankur- Did you test is CNN out-perform simply approaches - maybe something as simple at logistic regression?
From R. Saravanan to Everyone: (2:04 PM)

We (Patricola et al.) found that interference between Atlantic Meridional Mode and ENSO could affect TCs. Similar interference between modes could be important for extreme decomposition, in a nonlinear fashion

From Michael Wehner to Everyone: (2:05 PM)

At Sara's request, I put links to my papers on the slack channel

From Michael Wehner to Everyone: (2:06 PM)

Sara/Paul/Mark. GEV is clearly lacking for extreme precipitation. It does not permit a bounded long tailed distribution, which extreme precipitation is. It does however work well for extreme temperature as it is short tailed.

From Michael Wehner to Everyone: (2:08 PM)

Regarding non-linearity in Mark's covariate work, it is likely higher order and hard to detect. AIC would of some use, albeit limited.

From Paul Ullrich to Everyone: (2:09 PM)

Michael/Mark/Sara: It'd be interesting to incorporate David Neelin's work on the cut-off scale for precipitation intensity, which may be more appropriate for the tail.

From Michael Wehner to Everyone: (2:10 PM)

Also, the big conclusion of Mark's work is that the influence of ENSO alone is smaller than expected. Rather, the large effect previously found is really from a set of the covariates.

From Ankur Mahesh to Everyone: (2:10 PM)

@S.C. Pryor: In this task, we aim to label each grid cell as AR/ not-AR. CNNs are better suited for this grid-cell level identification; there are specific architectures (called semantic segmentation architectures) that perform this task efficiently and for large datasets. Other ML algorithms, such as logistic regression, are more naturally suited for classification, in which the entire image gets a label, but there is not pixel-level identification. For due diligence, we did compare CNNs to other algorithms, and we found that CNNs do outperform them, and it is easier to train them on large datasets. Thanks for the question!

From Ankur Mahesh to Everyone: (2:12 PM)

@Paul Ulrich: That's a great suggestion. We have not done that yet, but one of our next steps is to train one neural network on relative threshold ARTMIP algorithms and one on absolute threshold algorithms. Then, we can compare their performance. Did you have any other subsets in mind?

From Michael Wehner to Everyone: (2:12 PM)

Sara, I have also been thinking along those lines as to how to exploit David's work. I am not sure that GEV can accommodate a boundary condition. One key question is what GEV assumption does precipitation violate. It is not clear to me.

From Paul Ullrich to Everyone: (2:13 PM)

@Ankur: I would remove each of the ARTMIP algorithms and train on 13/14. Then quantify which algorithms produce the greatest shift in performance.

From Ankur Mahesh to Everyone: (2:14 PM)

@Paul: That would be a very informative test! Thank you!

From Christine Shields to Everyone: (2:24 PM)

@Ankur and @Paul — There are a number of additional globals you could potentially include! Check out the CDG for the current list…https://www.earthsystemgrid.org/dataset/ucar.cgd.ccsm4.artmip.tier1.html

From Paul Ullrich to Everyone: (2:26 PM)
@Chris - great idea. That also makes me wonder if ML could be used to “group” ARTMIP algorithms by behavior
From Christine Shields to Everyone: (2:26 PM)
@Paul as in flavors? I like this idea!
From Ankur Mahesh to Everyone: (2:27 PM)
@Christine: Thank you for sending this! Yes, absolutely; there are more algorithms here than were originally used.
From Paul Ullrich to Everyone: (2:27 PM)
@Chris yes. Something a bit more quantitative than the current distinction between absolute/relative or permissive/strict
From Christine Shields to Everyone: (2:28 PM)
@Paul yes, as Travis has been suggesting — there is a need for process driven constraints. Will mention it in the ARTMIP overview tomorrow as a current gap.
From Paul Ullrich to Everyone: (2:28 PM)
One could probably build a contingency table P(algo 1 detects AR | algo 2 detects AR), then use principal feature analysis
@Michael: Is there a ‘truthful’ upper bound for precipitation? GEV is heavy-tailed but we need to observe large number of samples to reach asymptotic level. Since we only observe finite number of precipitation measurements, the assumption of unboundedness does seem to be violated. We can control the shape to reduce the heavy tail.
From Michael Wehner to Everyone: (2:34 PM)
Likun, yes, there is a literature on “Probable Maximum Precipitation”. Dave Easterling has papers on this.
From Richard Grotjahn to Everyone: (2:34 PM)
Maybe the metrics could be improved by including those with individual events instead of some kind of longer period average, like annual max, or similar
From Michael Wehner to Everyone: (2:35 PM)
Richard, exactly!

Session 2 Zoom Chat Notes:

From Michael Wehner to Everyone: (2:39 PM)
Probable max precip paper by Kunkel et al. based on available moisture and convergence arguments https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/grl.50334
From COLIN ZARZYCKI to Everyone: (2:41 PM)
also, just to follow up on michael/Kevin’s thread re: precipitation, it is worth noting that (at least in CESM and E3SM) precipitation in mature cyclones is dominated by the resolved large-scale microphysics, lending some credence to Michael’s thoughts on available moisture
From LikunZhang to Everyone: (2:41 PM)
@Michael: thanks for the link!
From COLIN ZARZYCKI to Everyone: (2:42 PM)
a fruitful question might be evaluating storm size and structure, which could impact the partitioning between integrated precipitation flux and the areal rates.

From Michael Wehner to Everyone: (2:43 PM)
Colin: Re: size and structure/ Exactly!
From Zhe Feng to Everyone: (2:48 PM)
I agree with Colin's comment on the importance of looking at storm feature size and structure, and Michael's point on metrics should be resolution dependent. Our paper on MCS tracking for mesoscale resolution GCMs show that MCS precipitation feature characteristics need to be adjusted for different resolutions: https://doi.org/10.1175/JCLI-D-20-0136.1
From Michael Wehner to Everyone: (2:50 PM)
Zhe, can we make any sensible MCS statements with 25km models (Full disclosure, I have a lot of such data in climate change scenarios).
From Zhe Feng to Everyone: (2:53 PM)
Michael, I think so. The MCS tracking method we developed for 12, 25, 50km resolutions can reproduce 4km radar-based MCS tracking statistics, as we show in the paper. But when we applied that to the MPAS-CAM model with 25, 50km grid spacing, we find the model significantly underestimate frequency of MCS in spring, and much worse in summer
From William Collins to Everyone: (2:55 PM)
This begs the question of whether the underestimate is due to state error, or to parameterization/structural error. Do high-resolution reanalyses do a better job of reproducing the radar data? If so, this would point a finger at state error
From Zhe Feng to Everyone: (2:58 PM)
Bill, we find the biases come from both state error and physics error. The model can simulate different types of MCS favorable large-scale patterns, but the frequency is underestimated due to lower moisture and weaker meridional wind at low-levels. When the model can simulate similar large-scale environments, the precipitation response is a lot weaker in many situations due to the ZM convection scheme
From S.C. Pryor to Everyone: (2:59 PM)
Back to Bill I think ERA5 assimilates RADAR so… harder to evaluate - since its not indepndent
From Christine Shields to Everyone: (3:00 PM)
@Alan or @Michael, can you remind me what the HAPPI simulations are? (Resolution, etc)?
From Michael Wehner to Everyone: (3:00 PM)
Christine. 25km fvCAM5.1
From William Collins to Everyone: (3:00 PM)
Thanks Zhe Feng and Sara
From Zhe Feng to Everyone: (3:00 PM)
We are currently looking at if ERA5 has sufficient representation of MCS-like features, but preliminary analysis seem to suggest ERA5 precipitation is quite a bit weaker than radar-observed at equivalent resolution, and MCS-like features are significantly less from our tracking
From Michael Wehner to Everyone: (3:01 PM)
Sara, I thought only the NARR assimilated precipitation directly. I could be wrong.
From Christine Shields to Everyone: (3:01 PM)
Thanks Michael — same model as the ARTMIP C20C+ then?
From julie caron to Everyone: (3:02 PM)

zhe feng, i'm finding the same thing you are with ERA5 MCSs using tempest extremes
From Zhe Feng to Everyone: (3:02 PM)
ERA5 claims they assimilate observed precipitation, but it's not clear what source they use, or where, how
From Michael Wehner to Everyone: (3:03 PM)
Zhe. I would expect it to be station data as the radar set is only CONUS. But need to find out. Christine. Same model. Different version. CESM1.2.2 vs CESM1.0.3. Differences in climatology are small but detectible
From Christine Shields to Everyone: (3:05 PM)
Michael, yes, ok, I am familiar with those different version. Thanks.
From S.C. Pryor to Everyone: (3:07 PM)
ERA5 documentation actually states after 2009 they assimilate RADAR
From Michael Wehner to Everyone: (3:09 PM)
Sara, Thanks!!
From julie caron to Everyone: (3:09 PM)
yes, thank you!
From S.C. Pryor to Everyone: (3:09 PM)
Can we move beyond precipitation to other extremes? (Please)
From Michael Wehner to Everyone: (3:10 PM)
Sara, I am curious about winds. Can you elaborate?
From Me to Everyone: (3:10 PM)
More non-precipitation extremes are in the next session after the break.
From S.C. Pryor to Everyone: (3:12 PM)
OK I shall look forward to it :-)
From Michael Wehner to Everyone: (3:15 PM)
This paper by Paul O'Gorman is relevant to the present discussion
https://pog.mit.edu/src/precip_extremes_idealized_2009.pdf
From Angeline Pendergrass to Everyone: (3:20 PM)
Thanks Mike!
From Michael Wehner to Everyone: (3:25 PM)
Derecho
From Michael Wehner to Everyone: (3:28 PM)
Paul, good point.
The words in coastal were "Compound, sequential and multi-variate"

Session 3 Zoom Chat Notes:

From Emanuele Di Lorenzo (he/him) to Everyone: (4:41 PM)
One aspect that would need more focus in the case of heatwaves and droughts is understanding their phenomenology across the land/ocean boundary as they impact both marine and terrestrial ecosystems (and their services). Most studies focus on these dynamics a bit in isolation.
From Naresh Devineni to Everyone: (4:43 PM)
https://www.sciencedirect.com/science/article/pii/S0022169416000020

From Emanuele Di Lorenzo (he/him) to Everyone: (4:50 PM)
Atnonietta is a much better speaker! Well said
From Richard Grotjahn to Everyone: (4:52 PM)
As for research gaps: Getting back to question Michael raised: what are the human impacts on blocking? I'd expand that to impacts on circulations. The example I cited was for California, summer, heat waves. Climatology is a block there in that season, so, maybe not much room to change. There may well be human impacts, especially in winter on circulations. LSMP analysis provides a context to look into this targeting extremes specifically.
From Michael Wehner to Everyone: (5:01 PM)
Colin, do we even know how many ETCs there are in the real world? In addition to tracker uncertainty, reanalysis uncertainty is high.
From Emanuele Di Lorenzo (he/him) to Everyone: (5:01 PM)
Thank you for the discussion and talks. Going back to Project Overview in the plenary.
From COLIN ZARZYCKI to Everyone: (5:02 PM)
@michael - not really. there is a hand curated dataset put together by some researchers in Europe, but ETCs lack a well defined heuristic definition unlike TCs
From Christine Shields to Everyone: (5:02 PM)
I'll just add to the XTC and resolution conversation in that the frequency of these storms may be entirely dependent on the tracker. ARTMIP Tier 2 looking at different reanalysis products hints that the shape of the distribution may be significantly affected by resolution.
From COLIN ZARZYCKI to Everyone: (5:02 PM)
it is quite similar to ARs in that regard
(good timing for Christine to comment there!)