Annual report 2022 for Flagship Pilot Study

Assessing the Use of Regional Models in a Storyline Framework for Understanding Climate Hazards

Progress over the past year

We summarize progress amongst the various storylines in HyperFACETS.

For windstorms, we have focused on building a small ensemble of WRF simulations at 3km resolution of three key windstorm events in the US Northeast. These events are selected based on Letson et al. (2021) and are selected to represent cyclones with different tracks and translational speeds. The ensemble members have been assessed for fidelity and then the 'optimal' configuration has been used to perform thermodynamic global warming (TGW) experiments to examine how the storylines respond to enhanced temperature and moisture availability. A key issue that has been explored in these simulations is finding appropriate perturbations to apply to skin temperatures and SST, air temperature and specific humidity profiles. A presentation of the simulations and associated stakeholder implications was given at the 2022 workshop; Use of Storylines from Regional Simulation for Climate Hazards and Stakeholder Engagement, an abstract describing the work has also been submitted to the AGU Fall meeting 2022.

The character and statistics of flash droughts were examined across the conterminous US using Tempest Extremes (TE), software that uses object-based techniques to identify and track 3-D space-time objects. This software was applied to dynamically downscaled historical reconstructions from ERA-I and as well as future dynamically downscaled GCM outputs. Gutowski et al. (2021) found that an increasing frequency of flash drought will plague America's agricultural heartland throughout the 21st century. These results were presented at the 2021 AGU Fall meeting. Xue and Ullrich (2021a) developed a set of widely applicable metrics for quantifying the model skill in simulating drought across the US. They applied this metric set to statistically downscaled and dynamically downscaled GCMs, as well as native GCMs to identify the drivers of model bias. Finally, Xue an Ullrich (2021b), who examined the 1960s northeastern US drought, found that the wet season will wetten while the dry season will get drier should the same drought occur in the future by use of the pseudo-global warming technique (PGW; only temperature, seas-surface temperature, and specific humidity modified), thus impacting water availability. In the PGW technique, a dynamically downscaled reanalysis is used to approximate the present-day weather and climate, while the future period is simulated by imposing GCM-computed climatological deltas (e.g., temperature, specific humidity, etc.) on the native reanalysis signal, after which downscaling is performed to simulate the future period.

For the flooding storyline examined, tests making use of the PGW approach for simulating future climate were again conducted by Xue et al. (2022) across the northeastern US to address the following questions of downscaling technique: At what spatial scale should climate perturbations be applied? Among the different meteorological variables available, which should be perturbed? And will PGW projections vary significantly under different experiment designs? Among other findings, the authors noted that PGW experiments with perturbations from temperature or the combination of temperature and wind at the gridpoint scale are both recommended, depending on the research target. Fisel et al (2021) used TE to quantify the changing likelihood of flooding across the Missouri River Basin, as this software was used on dynamically downscaled reanalysis and future climate scenarios.

For the atmospheric river storyline, we have been exploring the implications of bias correction of the mean state in dynamical downscaling. Specifically, we have dynamically downscaled an ensemble of 18 CMIP6 GCMs: 9 with a mean-state bias correction applied before downscaling, and another 9 that are the same as the first, except no bias correction was applied, across the western US. Generally, directly downscaled precipitation is too wet across the region due to mean-state biases in winds and temperature that are inherited from the GCM. Upon removal of these biases, the RCM results are much more like observations. We are also finding that bias correction of the mean state has implications for dynamically downscaled future trends.

We have also fine-tuned RCMs and regionally refined models (CESM) to tackle research questions surrounding mesoscale convective systems and hurricanes.

List of each workshop/activity/talk/interview held during the year

2022: Use of Storylines from Regional Simulation for Climate Hazards and Stakeholder Engagement. A workshop convened under the auspices of CORDEX – North America. Virtual workshop hosted by Ouranos, Montréal, PQ, Canada, Conveners: Melissa Bukovsky, William Gutowski, Linda Mearns, Dominique Paquin and Sara Pryor, April 2022. [Up to 78 attended] https://www.ouranos.ca/en/storylines_simulation/

2022: Oral presentation at 2022 WCR Ultra-high-resolution modeling workshop (NCAR). Nearly [~100 attendees] https://www.mmm.ucar.edu/events/workshops/wcrp

2022: Connecting Climate Information with Users' Needs: Storylines from Object-Oriented Analysis. *Sustainability Research and Innovation Congress*

2022, Future Earth, virtual presentation (about 50 attending), June 2022.

2021: Heavy precipitation events influencing Missouri river flooding in contemporary and scenario climate. *Fall Meeting – American Geophysical Union*, New Orleans, LA, and online, December 2021.

2021: Gutowski, W., Object-oriented analyses of precipitation and drought for stakeholder storylines. *HyperFACETS Project Spotlight Session*, virtual presentation, July 2021.

2021: McGinnis, S., Mearns, L., Building a climate service for North America based on the NA-CORDEX data archive. Climate Services 22, 100233. https://doi.org/10.1016/j.cliser.2021.100233

2022: Gutowski, W. J., and O. F. McCauley, 2022: *Projected Changes in Extreme River Flow in the Upper Mississippi River Basin,* part of a panel: *Examining Climate Problems through Research* (With R. Viadero, M. Aluvalasit, and G. Villarini). *Upper Mississippi River Conference – Changing Climage – Evolving River*, Moline, Illinois, October. [invited]

2022: Gutowski, W .J.,: *Current status on downscaling and climate services – IPOC, Australia, Asia, South America, Africa, USA, Europé, the Arctic.* (Virtual panelist with M. Thatcher, C. Lennard, M. L. Bettolli, D. Jacob, K. Dairaku and D. Chen). *Consolidating CORDEX (ConCord) Conference,* Oslo, Norway and online, October. [invited]

2022. Gutowski, W. J.,: Connecting Climate Information with Users' Needs: Storylines from Object-Oriented Analysis. *Sustainability Research and Innovation Congress 2022,* Future Earth, virtual presentation (about 50 attending). [invited]

2022. Brighenti, T., P. Gassman, W. Gutowski, and J. Thompson, 2022: Evaluation of bias correction methods for current and future RCM projections in hydrological regional applications. *General Assembly*, European Geophysical Union, Vienna, Austria, May.

2022. Gutowski, W., B. Fisel, A. Ellingworth, S. Garbers, C. Todesco and L. Shenk, 2021: Object Tracking of Extreme Events: Storylines Linked to Stakeholder Concerns. *DOE RGMA Climate Extremes Monthly Meeting*, virtual presentation.

2022. Environmental/Water Resources Engineering Graduate Seminar, Iowa State University: "Decision-Relevant Hydroclimate Change in the Upper Midwest"

2022. Gutowski, W., LAS Dean's Distinguished Lecture, Iowa State University: "Climate Change in Iowa: How We Got Here, How We Can Choose a Better Future Together" [https://events.las.iastate.edu/2021/12/08/las-deans-lecture/]

2022. Gutowski, W., Department of Earth, Atmosphere and Environment, Northern Illinois University: “The Ongoing Need for High-Resolution Regional Climate Models: Process Understanding and Stakeholder Information” Virtual seminar.

2022. Gutowski, W., Interview regarding IPCC AR6 WGIII report shortly after its release: Dave Downey (WOI TV)

2022. Gutowski, W., Interview about climate change in Iowa: Chris Gloninger (KCCI-8 TV)

2022. Gutowski, W., Interview about recent drought and heavy rainfalls: Neel Dhanesha (*Vox Media Network*; https://www.vox.com/science-and-health/23297362/kentucky-flood-lake-mead-california-arizona-drought.

2022. Gutowski, W., Guest speaker for brief presentation: “Inequities Caused by Climate Change” at *Listen to the Voice of Creation*, an ecumenical prayer service. St. Cecelia Catholic Church, Ames, Iowa.

2021. Gutowski, W., Object Tracking of Extreme Events: Storylines Linked to Stakeholder Concerns. *DOE RGMA Climate Extremes Monthly Meeting*, virtual presentation, March 2022.

2021. Gutowski, W., Flash droughts impacting agriculture in contemporary and future scenario climates. *Fall Meeting – American Geophysical Union*, New Orleans, LA, and online, December 2021.

2022. Ullrich, P., UC Davis Department of Land, Air and Water Resources Seminar, A Retrospective and Prospective Examination of the 1960s U.S. Northeast Drought, Davis, USA, there is no website for it, we presented our work where we used the PGW method to simulate the potential risks of returned 1960s drought over Northeast US.

2021. Ullrich, P. AGU 2021, A Retrospective and Prospective Examination of the 1960s U.S. Northeast Drought, New Orleans, USA, https://www.agu.org/Fall-Meeting-2021, we presented our work where we used the PGW method to simulate the potential risks of returned 1960s drought over Northeast US.

2022. Ullrich, P. CoM Workshop, A Retrospective and Prospective Examination of the 1960s U.S. Northeast Drought, it’s held online, there is no website for it, we presented our work where we used the PGW method to simulate the potential risks of returned 1960s drought over Northeast US.

2022. Ullrich, P. EGU 2022, A Retrospective and Prospective Examination of the 1960s U.S. Northeast Drought, Vienna, Austria, https://www.egu22.eu/ , we presented our

work where we used the PGW method to simulate the potential risks of returned 1960s drought over Northeast US.

Relevant publikations over the past year

2022. Reed et al., Metrics as tools for bridging climate science and applications, https://wires.onlinelibrary.wiley.com/doi/abs/10.1002/wcc.799?casa_token=qMIzvsWJwo4A

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2022. Xue and Ullrich, Sensitivity of the PGW method under flood conditions: a case study from the NE US, https://egusphere.copernicus.org/preprints/2022/egusphere-2022-482/

2022. Xue and Ullrich, A Comprehensive Intermediate-Term Drought Evaluation System and Evaluation of Climate Data Products over the Conterminous United States, https://journals.ametsoc.org/view/journals/hydr/22/9/JHM-D-20-0314.1.xml

2022. Xue and Ullrich, A Retrospective and Prospective Examination of the 1960s U.S. Northeast Drought, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020EF001930

Project activities for the next year

New storylines addressed within a dynamical downscaling framework in FY2023 for the new iteration of HyperFACETS. These storylines include:

1. Integrated hydroclimate of California
2. Wildfire in the western US
3. Megadrought in the Upper Colorado
4. Compounding effects from Tropical Cyclones
5. Worst-case hurricane tracks
6. Freezing rain and icing
7. North American Derechos and convective winds
8. Urban flooding in the Northeast Corridor
9. Winter windstorms

Additional updates

NA CORDEX data now on Amazon S3 (2021). https://doi.org/10.1002/essoar.10510535.1

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