# Understanding and Projecting Extreme Winter Weather Events: A Sensitivity Study of the 2021 Texas Winter Storm

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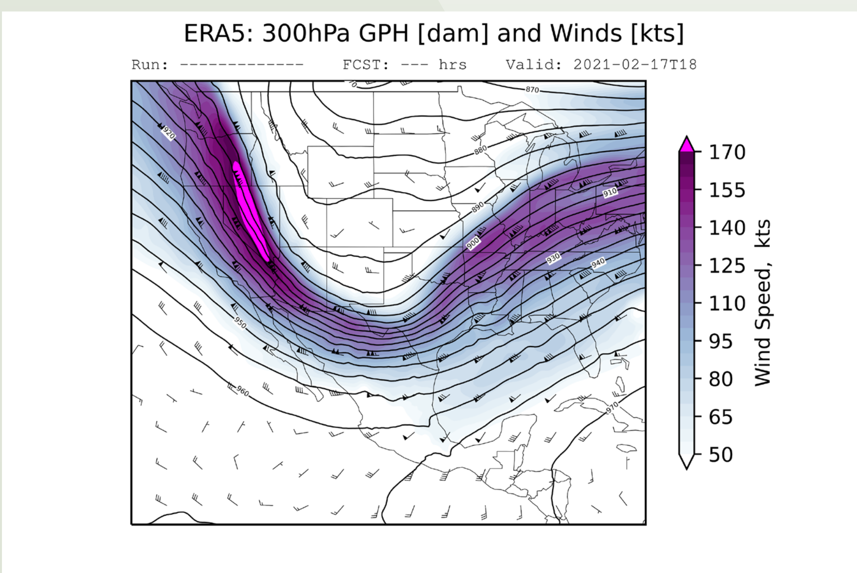
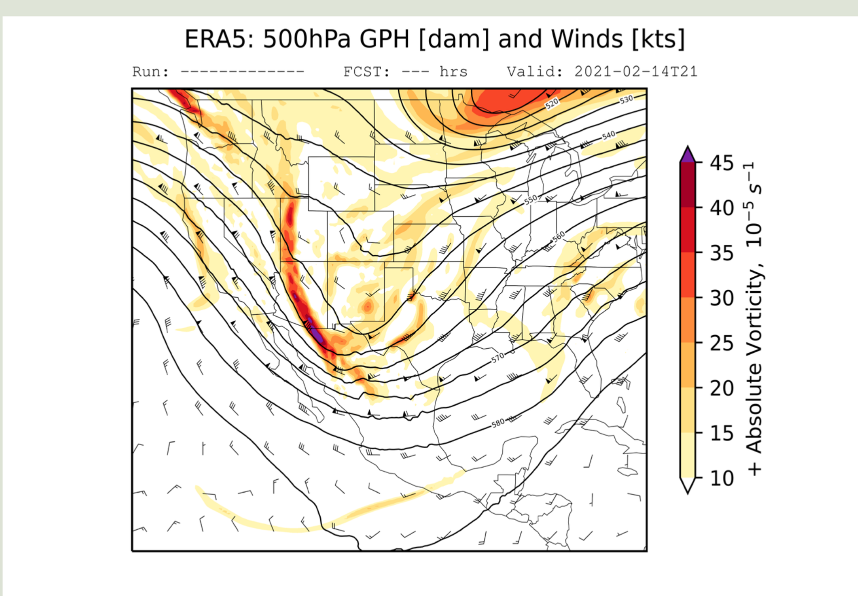
## Abstract

The Texas Winter Storm was an unprecedented and historical eight-day period of winter weather that occurred between 10 February 2021 and 18 February 2021 across South-Central Texas. Originating from the February 13 - 17, 2021 North American winter storm, extreme temperatures and record winter precipitation crippled the Texas economy, causing power outages, road closures, and other societal impacts across the state. It is consequently an interest to the predictability, capture and frequency of such an extreme weather event. Using the Climate-Weather Research and Forecasting (CWRF) model, we will initialize the study by comparing the CWRF to the WCRP Coupled Model Intercomparison Project (CMIP) for two distinct modeling groups (projects) (MG), investigating trends in their model structural and forcing differences. We will then analyze CWRF data output on the potential of similar timescale, future extreme events through investigating modular temperature, geopotential height, specific humidity and precipitation threshold projections for a 50-year run.

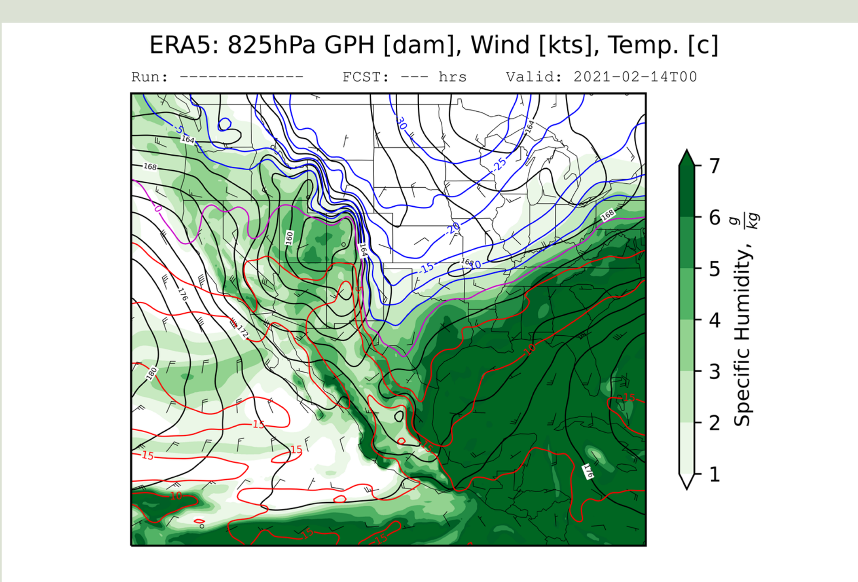
## Key Features of Texas Winter Storm




This storm features an extremely high amplitude pattern in the jet stream, illustrating significant potential for cyclogenesis.



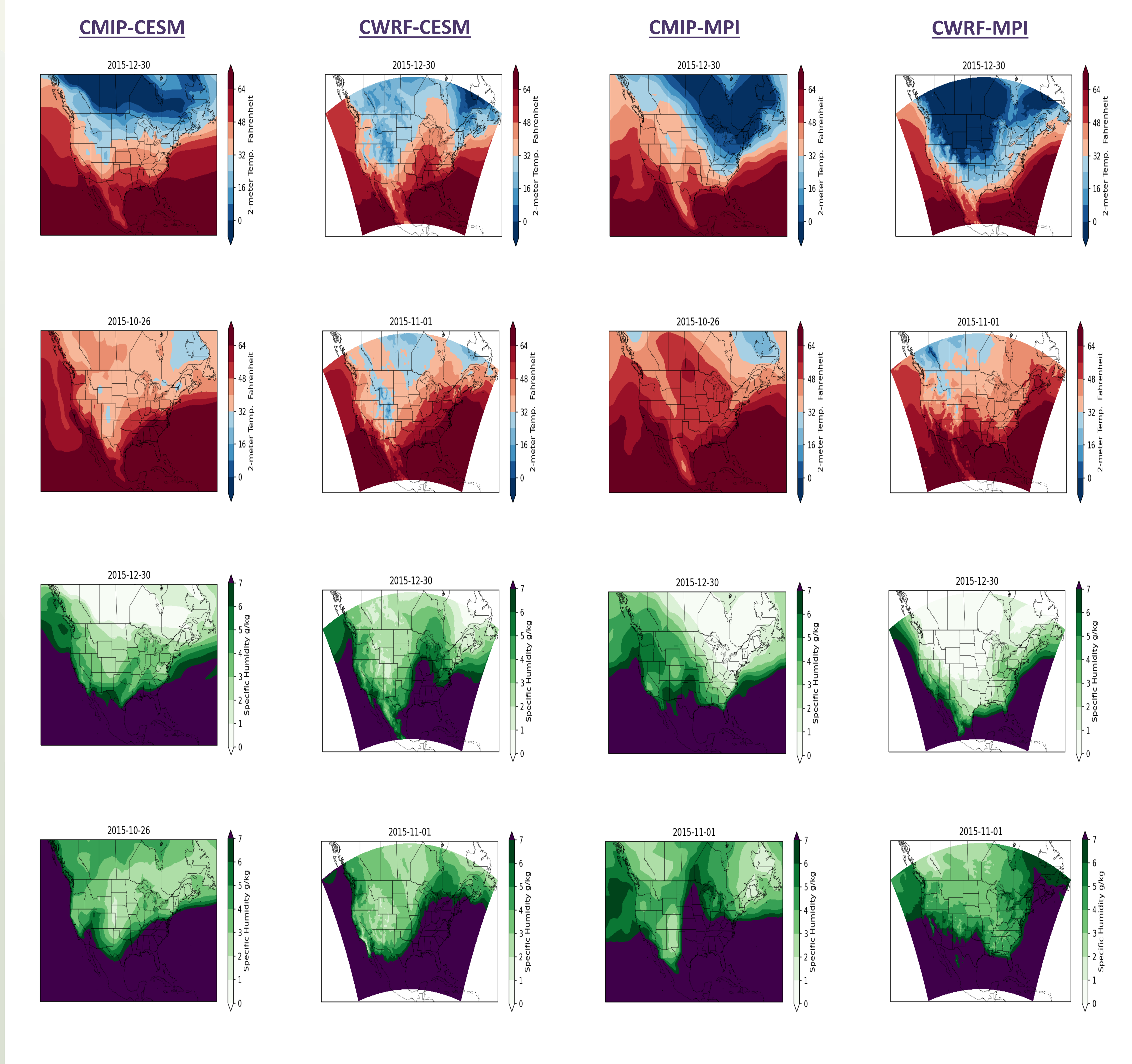

The 500 hPa isobaric surface shows significant height falls and positive vorticity advection for the Texas Region, illustrating cold air advection as well as lifting in the mid-troposphere, respectively.




This feature shows significant moist advection from the Gulf of Mexico, co-located with sufficiently cool temperatures aloft for wintry precipitation.

## CWRF MG Distributions for GRIB plotted against CMIP MG Distributions for Comparisons

Illustrations of commonly used field variables are plotted (i.e. temperature, specific humidity, precipitation and geopotential height). CWRF was nested within the global Community Earth System Model (CESM) and the Max Planck Institute for Meteorology Earth System Model (MPI), our two MG profiles. Our data sets did not include identical pressure level increments, resulting in a 25 hPa-variance between the wind speed/direction and vorticity plots. Fortunately, however, the data sets do overlap at exactly 828 hPa, resulting in a 'perfect' representation of error for that isobaric level. We are focusing more on the potential frequency of these models capturing an equivalent event to the Texas Winter Storm, rather than a replication of the event during that time. Models were initialized and driven using identical boundary conditions across the MG profiles.

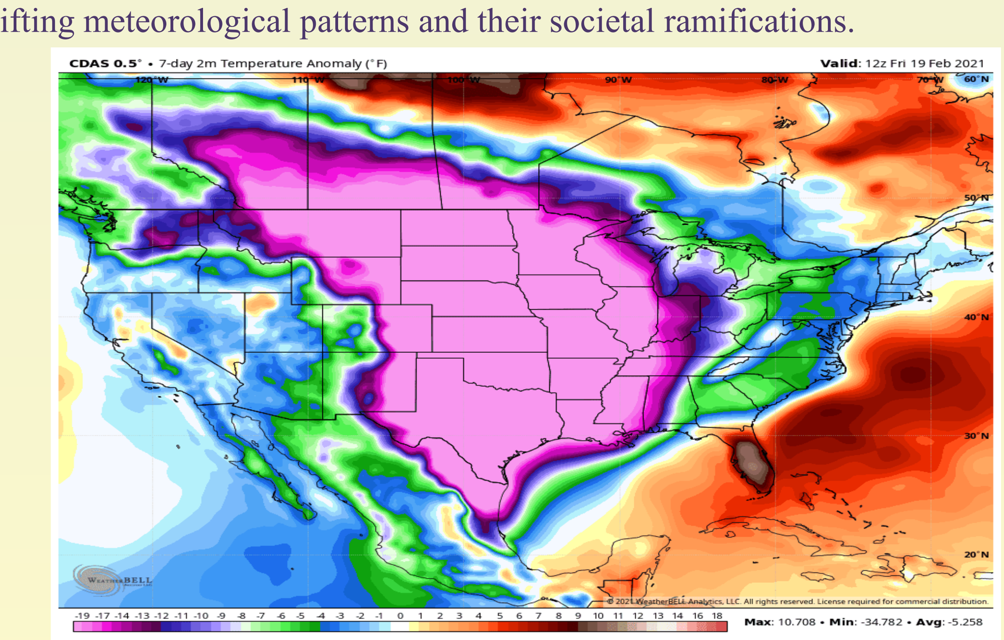


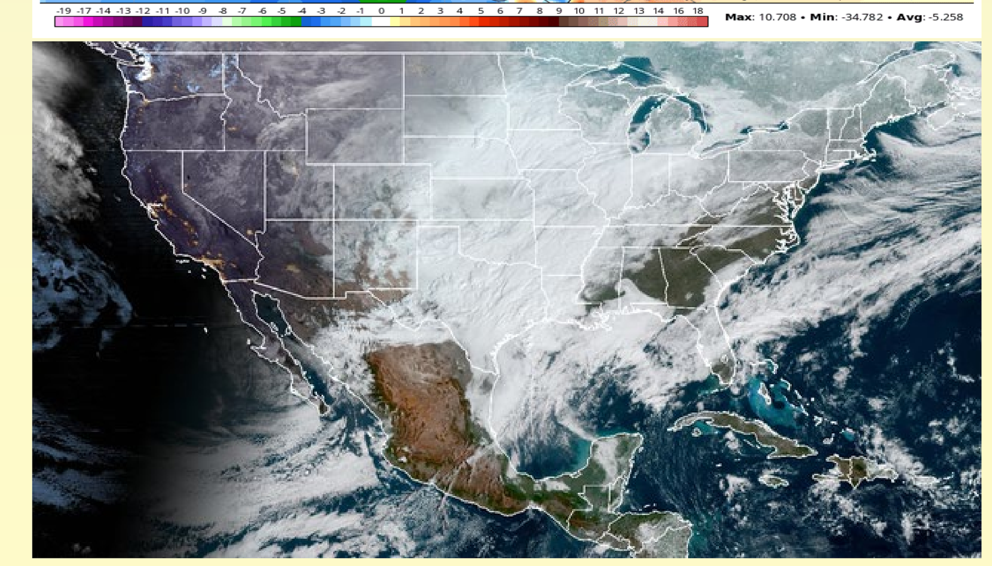

## Results

Upon initial analysis, CWRF adeptly resolves terrain effects, portraying mountains and valleys with enhanced temperature variations. Notably, it excels in delineating the Great Lakes' influence on temperature, showcasing superior handling of sensible heat flux compared to raw CMIP. While both models exhibit an uptick in latent heat flux near the lakes, CWRF uniquely captures a substantial sensible heat flux, providing a more nuanced perspective. In assessing the Appalachian and Rocky Mountains, CWRF reveals distinct notches of cool air and clearly defining ridgelines, a contrast to CMIP's generalized temperature patterns. CWRF also resolves the temperature contrasts in the California and Nevada mountain ranges, where CMIP maintains temperatures above freezing (even in winter months).

## Conclusion

- CWRF's high spatial resolution dynamically captures complex terrain effects, delineating mountains and valleys with thermally distinct signatures.
- The model's prowess is evident in detailing the impact of the Great Lakes on 2-meter temperature, showcasing an advanced treatment of sensible heat flux, a feature notably superior to the raw CMIP.
- In the topography of the Appalachians and Rockies, CWRF excels, providing heightened precision by intricately delineating ridgelines, a granularity absent in the generalized representation of CMIP.
- Significantly, the model aptly represents climate change impacts on the California-Nevada water supply mountain range, portraying prolonged periods above freezing. This stands in stark contrast to CMIP's proclivity for maintaining temperatures above freezing, underlining the imminent threat to California's water supply.
- CWRF's nuanced portrayal positions it as a pivotal tool for forecasting the nuanced impacts of extreme weather events and climate change on intricate terrains and hydrological resources.
- While anticipating the 50-year output, this study underscores CWRF's potential mechanisms for discerning climate-scale extreme events. Its intricate resolution offers a robust foundation for addressing the evolving challenges posed by shifting meteorological patterns and their societal ramifications.



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