Did stratospheric variability drive the extreme cold air outbreak in the United States in February 2021?

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The February 2021 cold air outbreak over North America



Figure from Bollinger et al. (2022)

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The February 2021 cold air outbreak over North America

Study: Warmer Arctic led to killer cold in Texas, much of US

By SETH BORENSTEIN September 2, 2021



- Cold air outbreaks: more likely after a sudden stratospheric warming, but *most* likely when the polar vortex is stretched [Kretschmer et al. 2018]
- Early February 2021: polar vortex was stretched over Atlantic, reflected planetary waves back down toward troposphere
- Argued to have invigorated trough, intensified cold air outbreak; connects extreme weather to Arctic amplification [Cohen et al. 2021]

Image/title from the Associated Press.



Initial condition scrambling



- CESM2(WACCM6) 21-member real time + "scrambled" forecasts
- Direct hypothesis testing: leverage the forecast model to unveil hidden physics in the system that can't be deduced from observations or standard forecasts; align experimental scope at process level

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Cold air outbreak forecasts

- Average -5.5C over all of North America, coldest event in MERRA2
- Forecasts of -3 to -3.5C, some members match verification
- Scrambling stratospheric initial conditions: no impact on forecast, still extreme cold
- Scrambling tropospheric initial conditions: extreme warmth

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Wave reflection in the middle stratosphere



- Wave activity traveling up from Eurasia was reflected down toward North America for 2 weeks preceding the cold air outbreak (*a*,*b*)
 - Tapers more rapidly in forecasts (*c*,*d*)
- No wave reflection in forecast with scrambled stratospheric initial conditions (e, f)

If there's no wave reflection...how is the surface forecast unchanged?

Midlatitude wave dynamics

- Streamlines of wave activity show reflected wave activity never reaches trough (*a*,*b*)
- Instead, wave activity acting to deepen trough propagates along tropopause (*a*,*b*)
- Scrambling stratospheric initial conditions has no impact on surface temperature forecast, because the mechanism is not wave reflection off a stretched vortex

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Summary

- Vortex stretching and wave reflection did not appear to play a role in the February 2021 cold air outbreak
 - Supported by initial condition scrambling (mechanism denial) experiments
 - Also supported by MERRA2 wave activity flux streamlines, derived from properly scaled wave activity flux vectors (scaling described in Jucker 2021)
 - Streamlines constrain interpretation
- Initial condition scrambling experiments are a decisive attribution tool
 - Leverages the forecast model to unveil hidden physics the world that would occur without the mechanism/process in question

Davis, N. A., Richter, J. H., Glanville, A. A., Edwards, J., and LaJoie, E. (2022). Limited surface impacts of the January 2021 sudden stratospheric warming. Nature Communications, 13, 1136.

