Identification and Prediction of Cold-Air Damming in the Northeast United States: A Comparison of Numerical Models in 2022-2023

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Background:

- Cold-air damming (CAD) occurs when cold air does not have the energy to overcome mountains and settles at the base, creating a cold dome (Bailey et al., 2003)
- CAD typically forms on the eastern side of the Appalachian Mountains and is noted by a "U" shaped pressure ridge on weather maps (Bell et al., 1988)
- Warm air from the Atlantic Ocean is advected inland creating a temperature gradient and an inversion over the cold dome (Bell et al., 1988)
- CAD occurs during all seasons, with winter having longer and stronger events than other seasons (Bailey et al., 2003)
- Unfortunately, there is not a lot of recent research on CAD
  - Even less data on CAD in the Northeast United States

CAD and models:

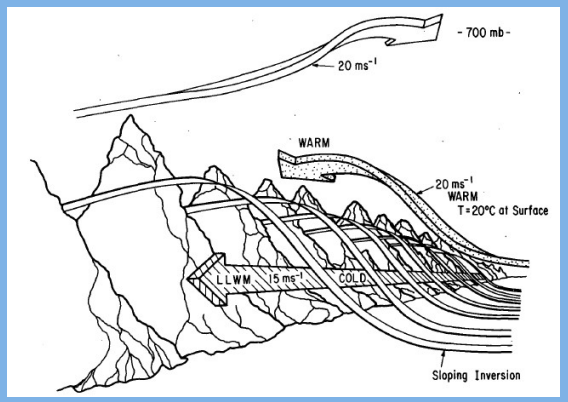
- Usually, models have not handled cold-air damming (CAD) very well with most models tending to erode CAD early.
- In 1995, the Eta model failed to capture the cold pool completely and had errors up to 10℃ (Rogers et al., 1995)
  - A year later, newer updates helped the Eta capture more of the CAD events (Rogers et al., 1996)
- In 2014, the NAM (previously the Eta) was compared to the RUC, and the capture of CAD was improved (Rowley, 2014)
  - RUC captured the spread of CAD better, and the NAM did better at predicting surface winds and the connected costal front
- In 2017, the HRRR had a mean temperature bias of less than 2℃ during CAD events with freezing rain (Ikeda et al., 2017)

Model Parameters:

- A model's coordinate system is important in determining its ability to predict CAD
  - Since the lower 2 vertical layers of the model are tied to topography, a sigma coordinate system may produce better predictions (Forbes et al., 1987)
- Models need at least 3 layers of the vertical resolution below 800mb to resolve CAD regimes (Stauffer et al., 1987)
- The height as well as the roughness of terrain is essential for CAD development in models
  - Any reduction to the terrain roughness reduces friction making it easier for models to overcome the blocking (Xu et al.,1995)
- Planetary Boundary Layer schemes are a bigger factor in modeling CAD than microphysical schemes (Simms, 2017)

Scientific Question:

During winter 2022 and 2023, which forecasting model (the HRRR, GFS, or NAM) was able to correctly initialize and detect the existence of cold air damming events as well as predict the correct cold dome temperature intensity in the Northeast?



Bell, G. D., and L. F. Bosart, 1988: Appalachian Cold-Air Damming. *Mon. Wea. Rev.,* **116**, 137-161

Identifying CAD:

Hourly observational METARs collected from October 2022 to March 2023

- KCON- Concord, NH
- KGFL- Glens Falls, NY
- CYSC- Sherbrooke, Quebec Canada
- KPVD- Providence, RI

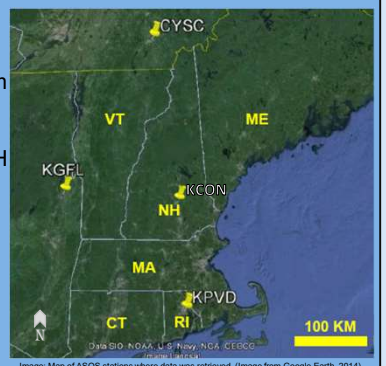


Image: Map of ASOS stations where data was retrieved. (Image from Google Earth, 2014)

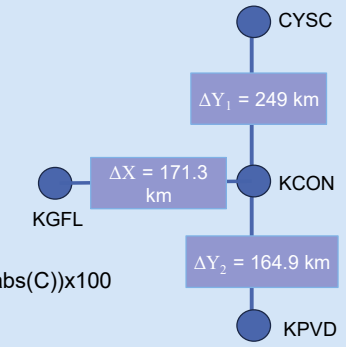
Methodology:

- Determined the dates and times where CAD took place by using the CADINX mathematics laid out by Miller (2014) and Strickland (2016)

$$A = \frac{\theta_v^{CYSC} - \theta_v^{KCON}}{\Delta Y_1}$$

$$B = \frac{\theta_v^{KPVD} - \theta_v^{KCON}}{\Delta Y_2}$$

$$C = \frac{\theta_v^{KGFL} - \theta_v^{KCON}}{\Delta X}$$



CADINX= mean(abs(A),abs(B),abs(C))x100

Parameters:

Units = ℃/100 km

All values must be positive to indicate occurrence of CAD

- Comparison of the dates and times that have strong and middle values to model data
  - Examined the HRRR, GFS, and NAM models
  - Observed lead times for 12, 24, and 36 hours
  - Variables of interest: Onset, dissipation, and temperature Intensities of CAD events

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Full list of references for this project ->