



The Influence of Turbulence Parameterizations on the 2 March 2018 Snowstorm

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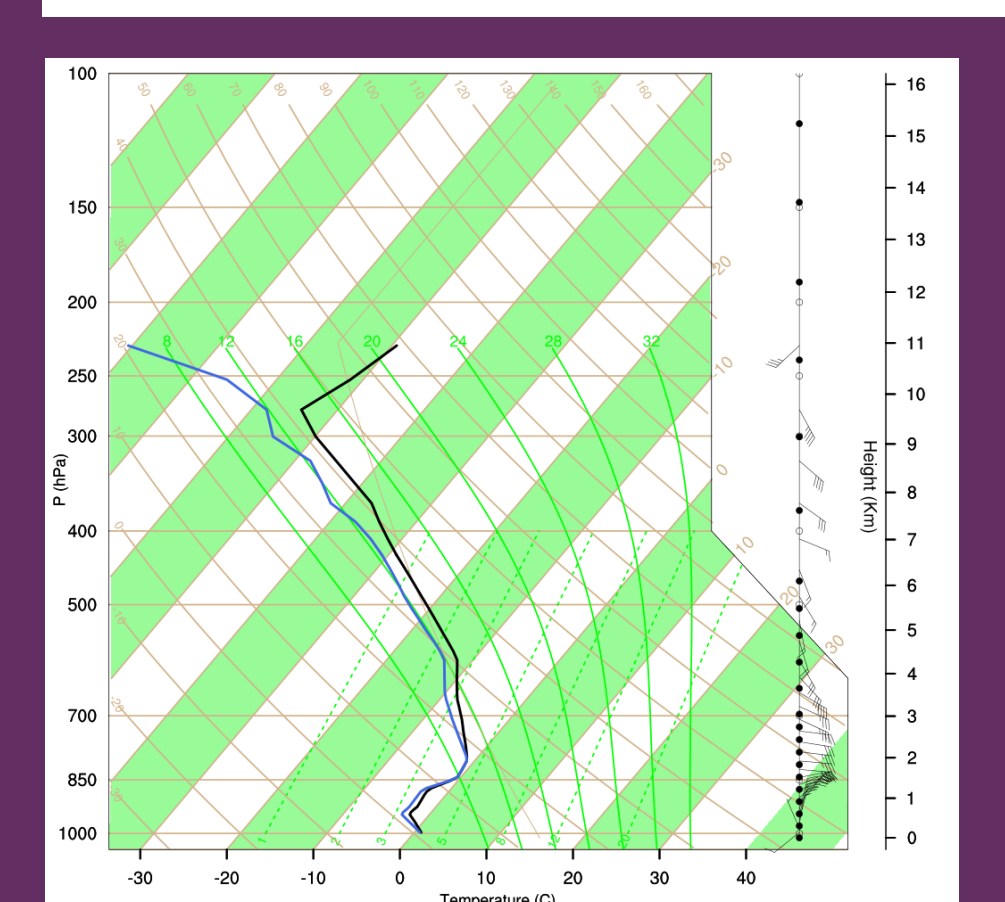
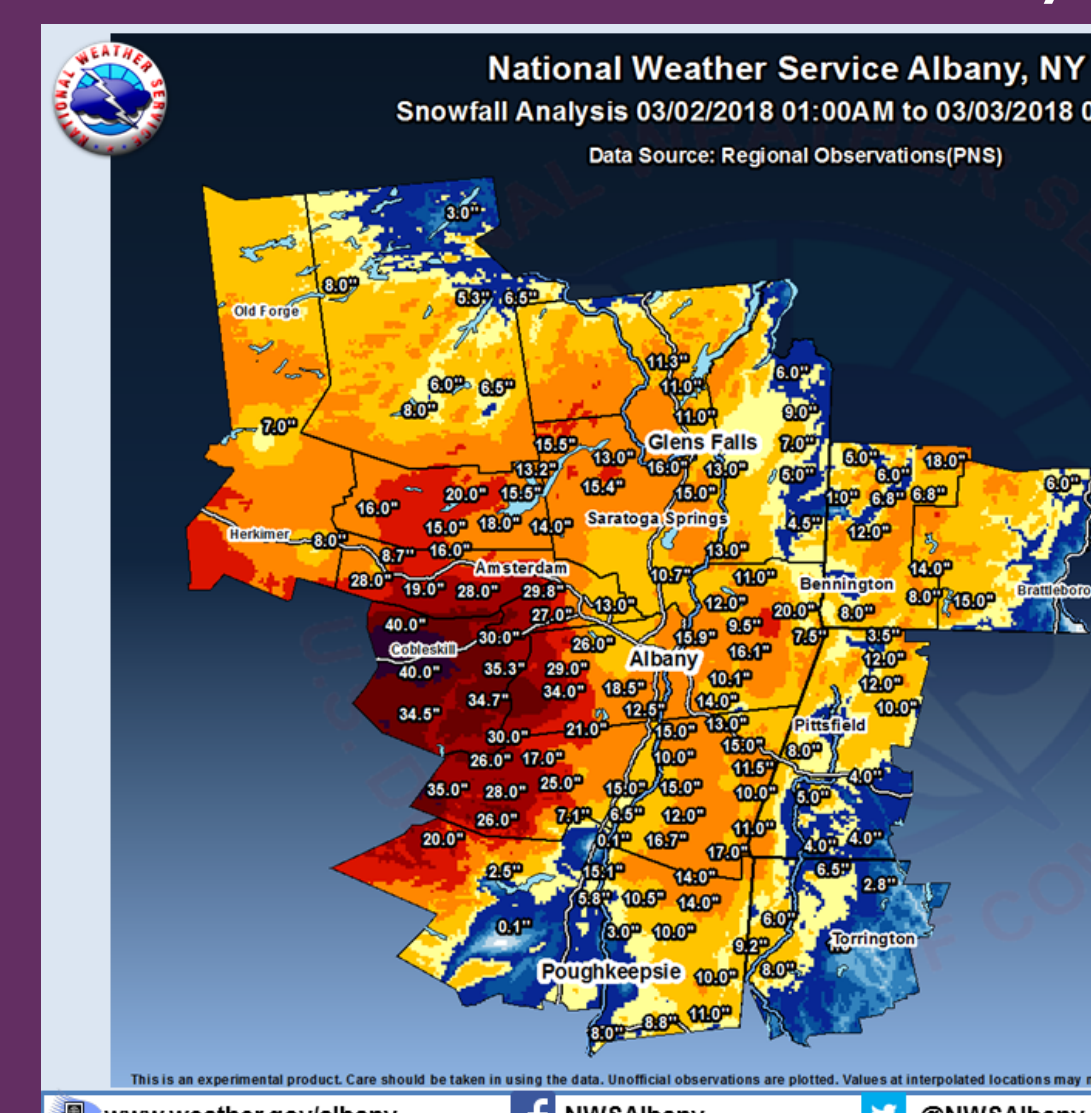
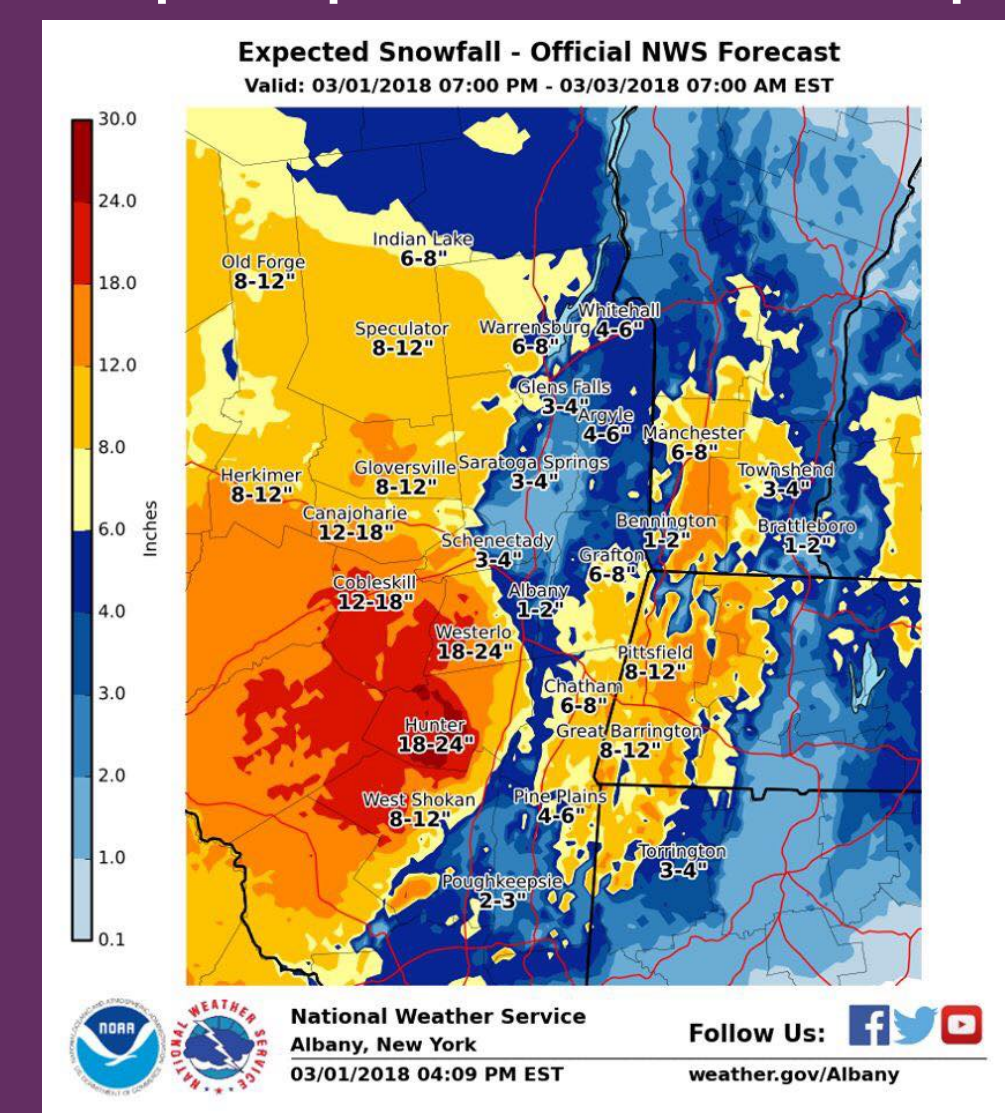
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Research Questions

- Why was this event so difficult to forecast?
- How sensitive is the forecast to PBL scheme selection?
- What biases, if any, exist between PBL schemes in this storm environment?

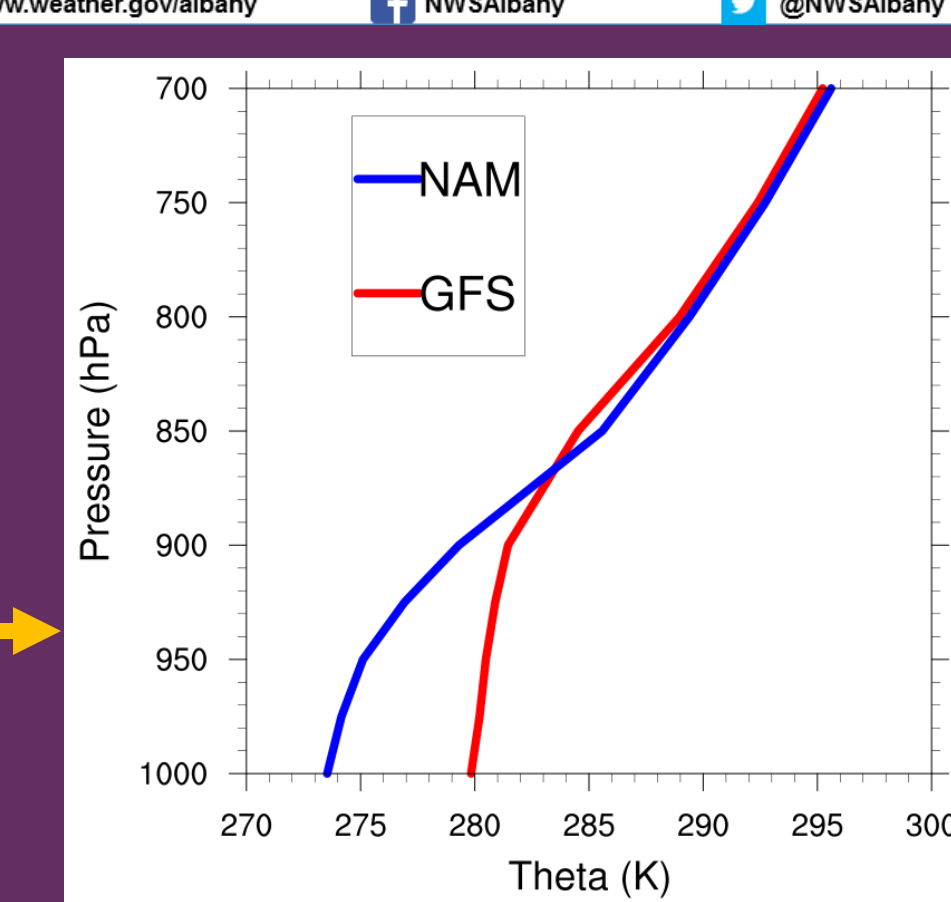
Event Background

- Extratropical cyclone bringing predominantly snow and some mixed precipitation to NY Capital Region with marked forecast uncertainty



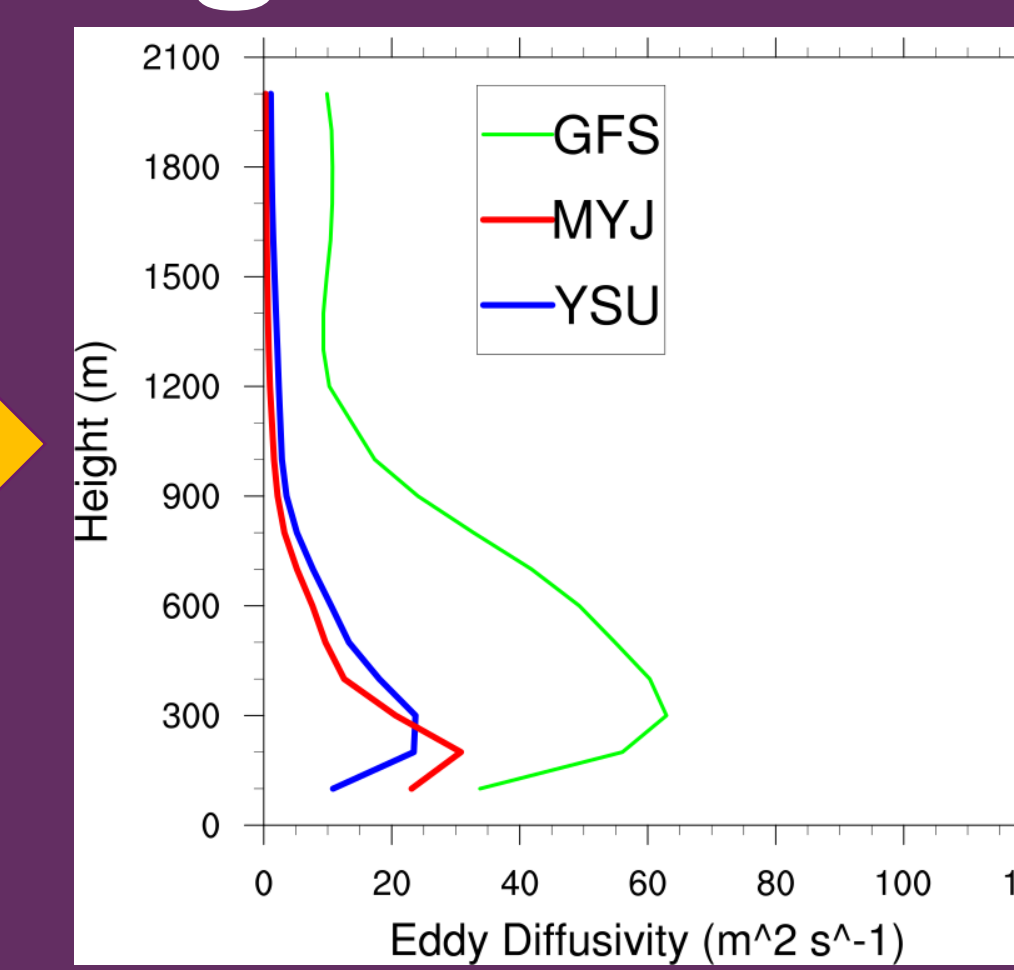
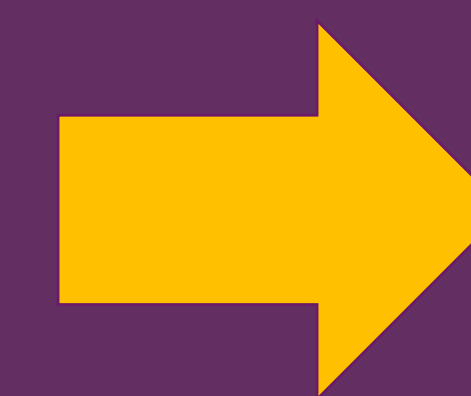
Observed 1200 UTC 2 March sounding at ALY.

24-h forecast temperature profiles valid 1200 UTC 2 March for ALY.



Main Finding:

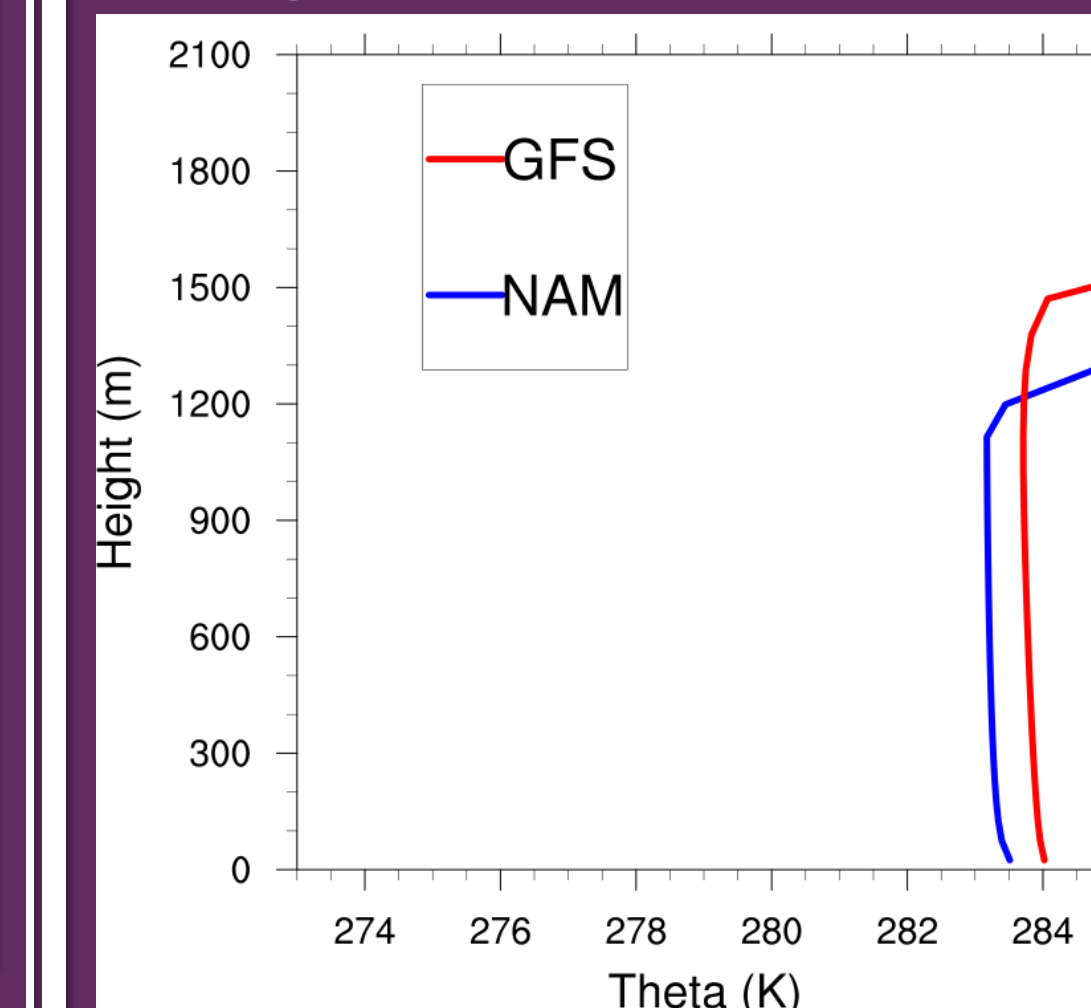
GFS PBL scheme **mixes more aggressively** than other PBL schemes during 2 March snowstorm



Domain-averaged eddy diffusivity for GFS, MYJ, and YSU WRF simulations valid 1400 UTC 2 March 2018.

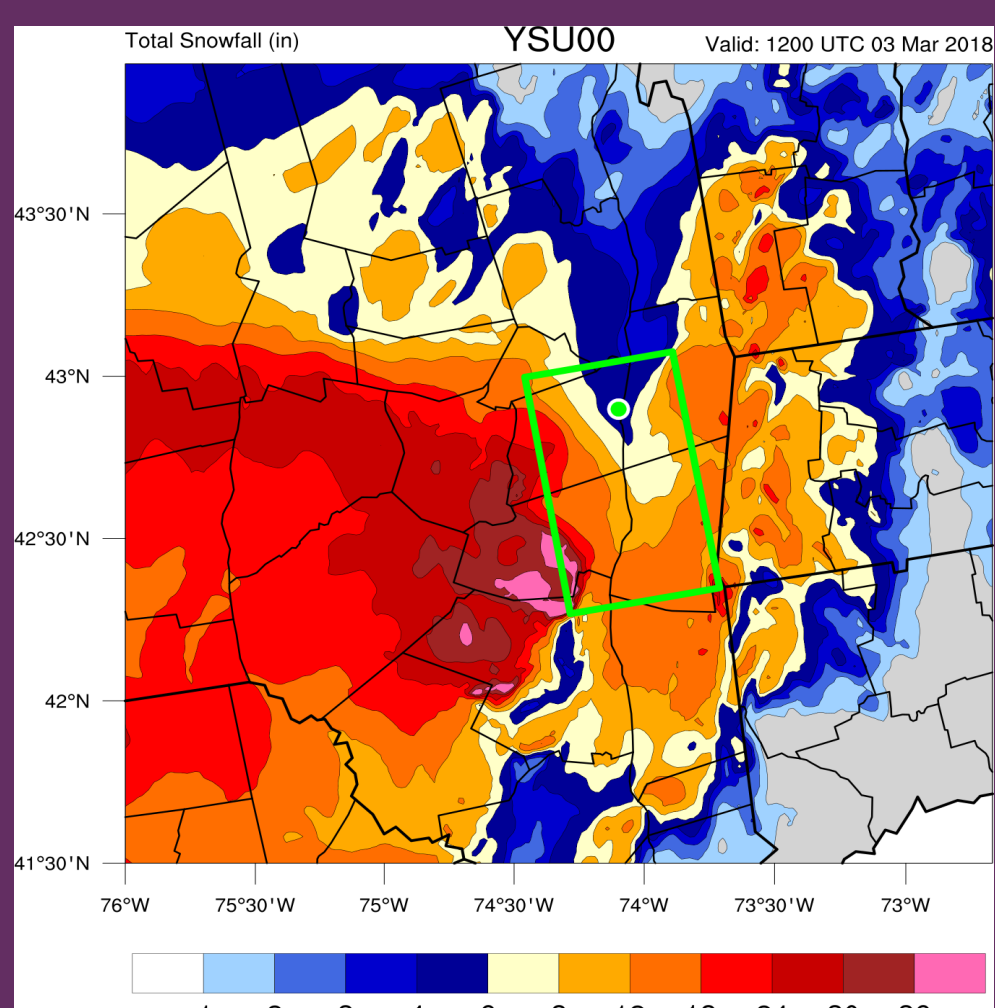
SCM and YSU Comparison

Single Column Simulations



2100 UTC (9 hour run)

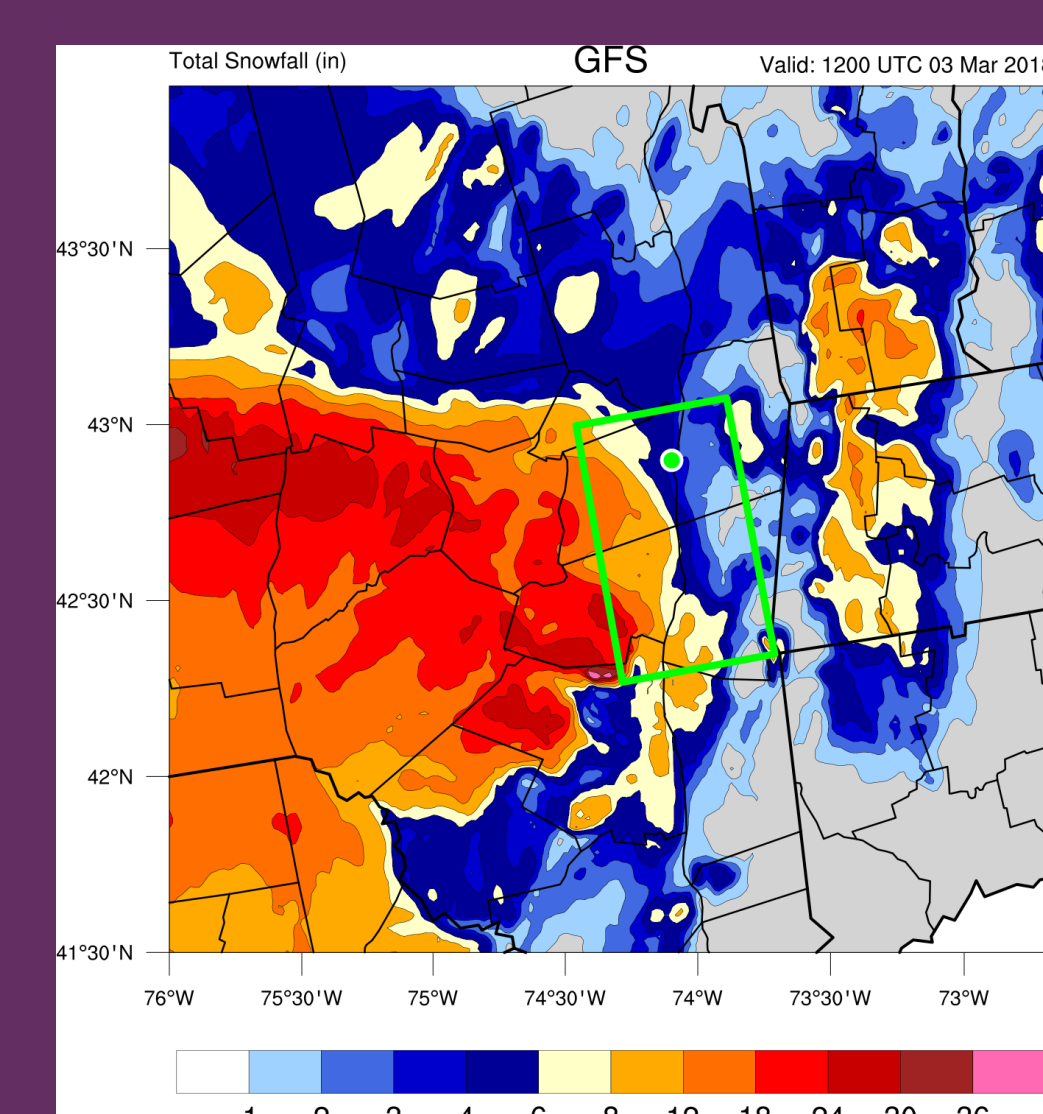
YSU Snowfall



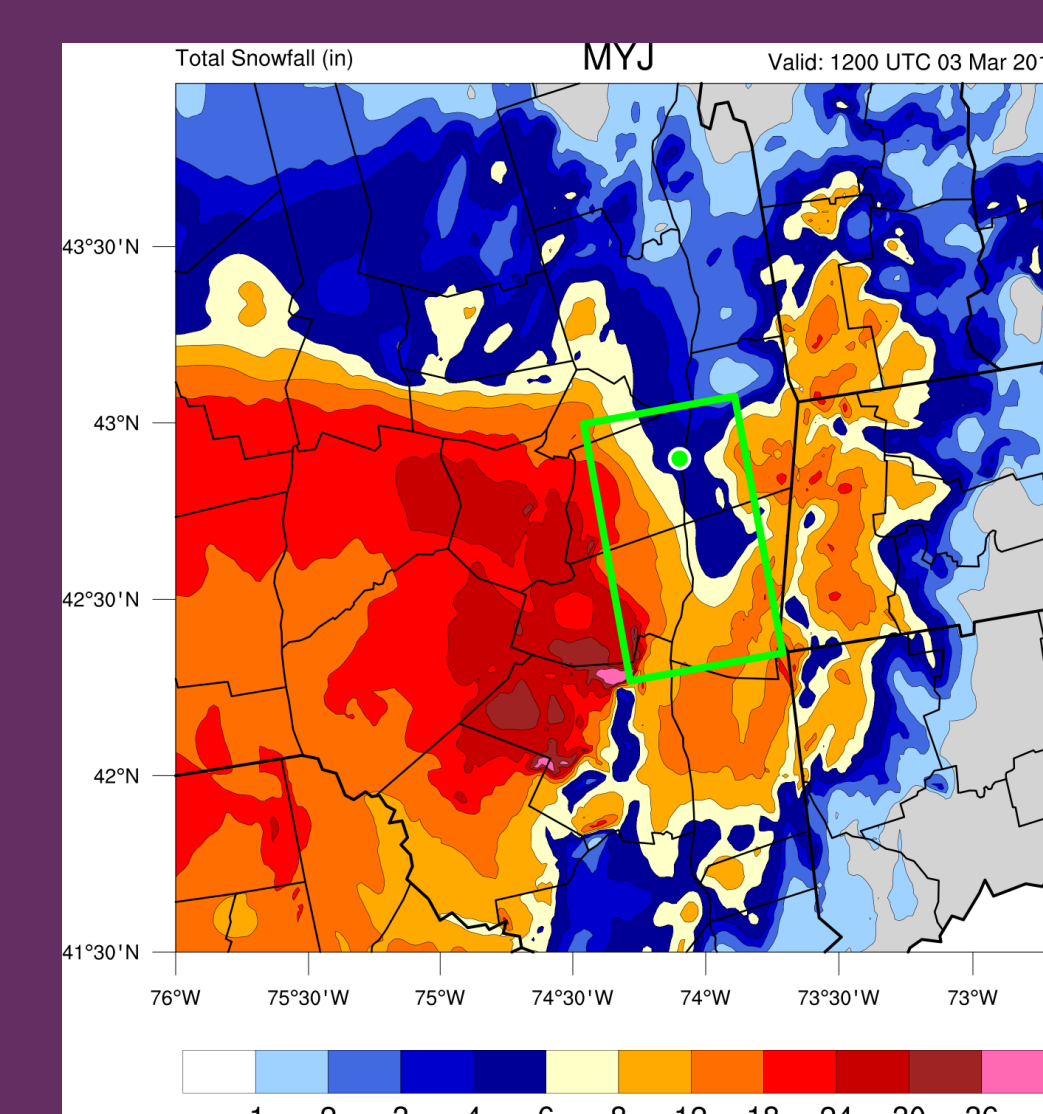
Single Column Model using 1200 UTC 2 March ALY sounding as initial conditions valid 2100 UTC (9-hour runtime). Microphysics is disabled and radiative forcing is set for 2 March 2018.

Precipitation Differences

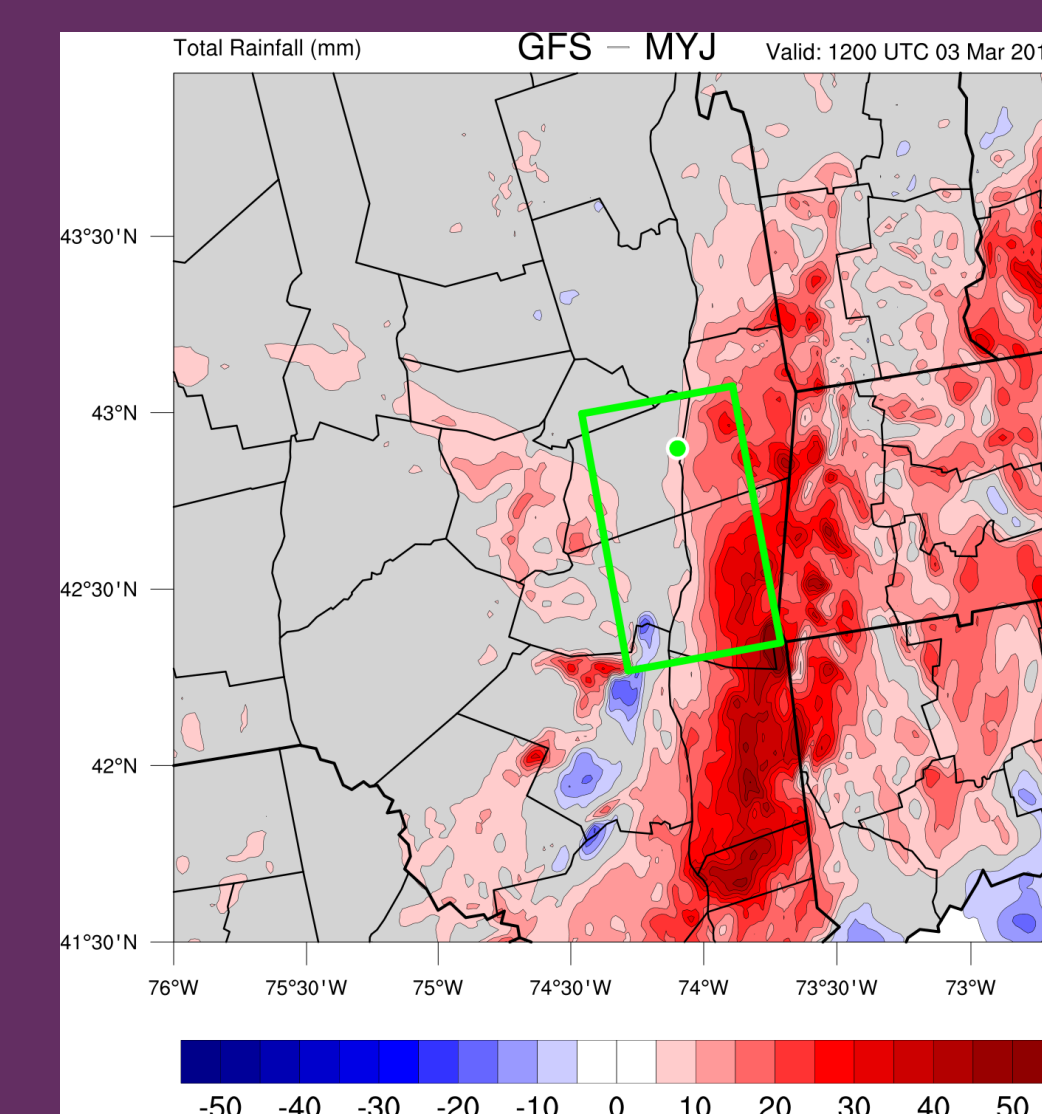
GFS Snowfall



MYJ Snowfall

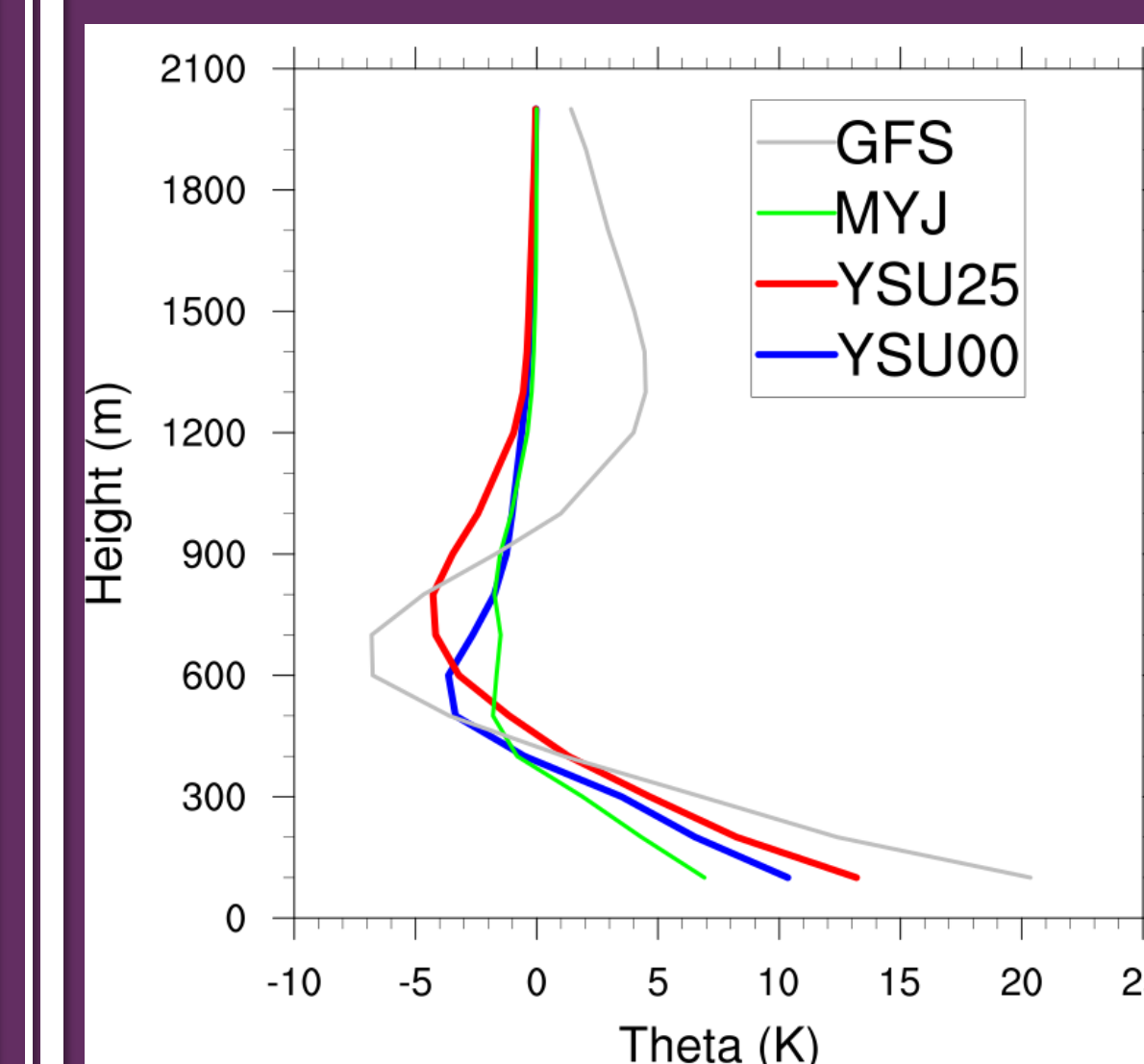


Rainfall Difference



- GFS has less snow along and on the eastern slopes of the Hudson river valley
- Difference is attributable to enhanced rainfall in the GFS simulation
- What caused the enhanced rainfall production in the GFS? ↓

Accumulated PBL Theta



Accumulated PBL potential temperature for GFS (grey), MYJ (green), YSU with bulk critical Richardson number (BCR) set to 0.25 to enhance mixing (red), and default YSU (blue) valid 1400 UTC 2 March. Accumulation begins at 0600 UTC 2 March (8-h accumulation time).

- The GFS scheme produces a taller, warmer PBL than the NAM (MYJ scheme) when using identical incoming radiative fluxes for 2 March.
- YSU, a K-profile PBL scheme similar to GFS, produces a snowfall field and thermal profile similar to that of MYJ.
- Turning up mixing in the YSU (by modifying the BCR to 0.25) fails to replicate the mixing and warmth exhibited by the GFS

Experiment Design

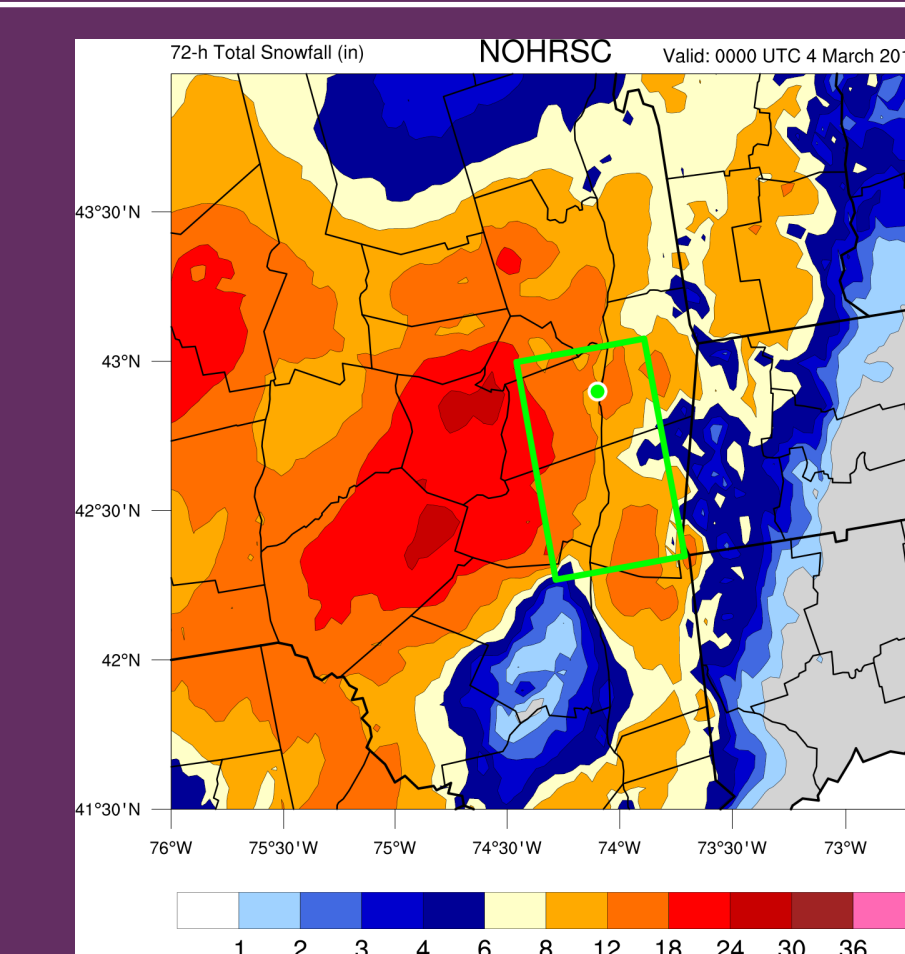
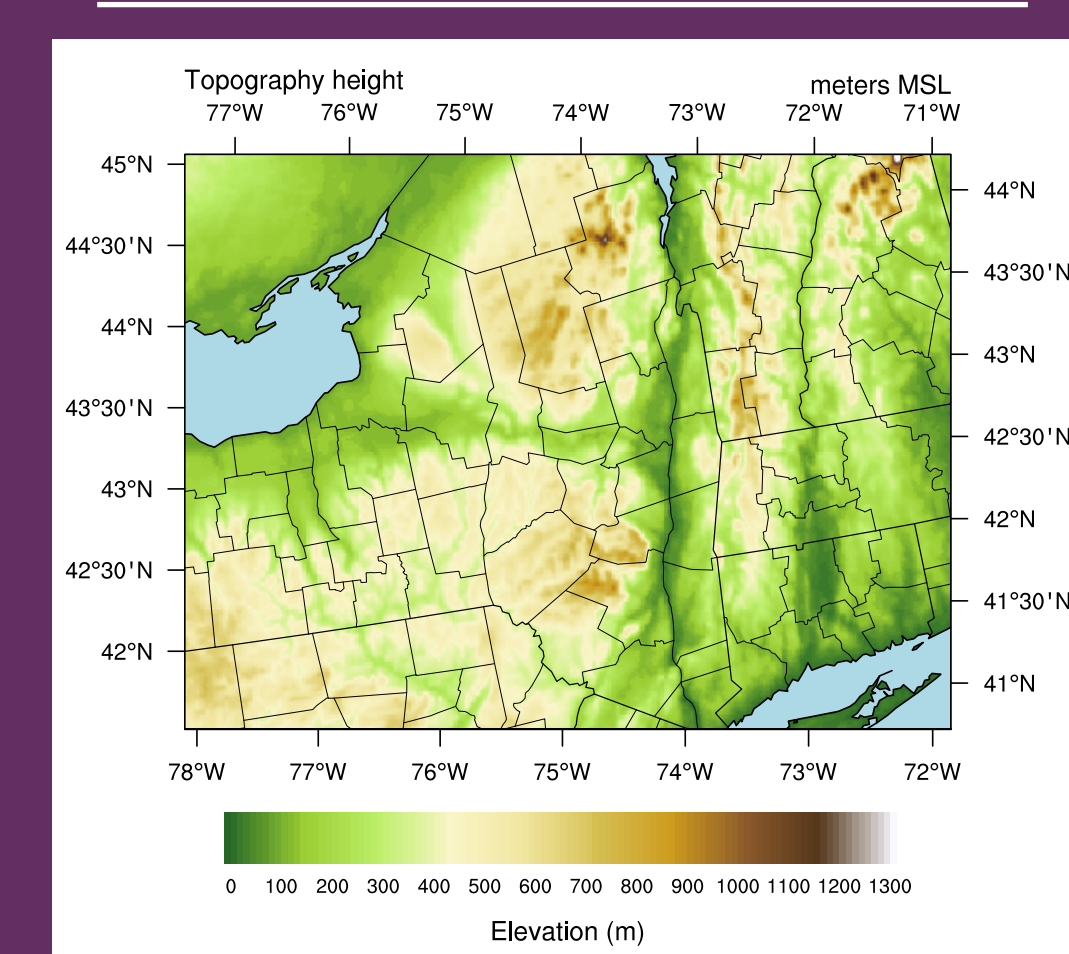
- Simulate the 2 March 2018 snowstorm using GFS and NAM (MYJ) PBL schemes using a "fair judge" model (WRF-ARW)
- Deduce whether PBL scheme differences are a contributing factor for PBL temperature differences by tracking PBL tendencies

Model Setup

- WRF-ARW simulation using ERA5 for initial and boundary conditions
- 1.33-km inner domain using physics similar to the HRRR (except PBL)
- 1200 UTC 1 March – 1200 UTC 3 March 2018 (72-h runtime)

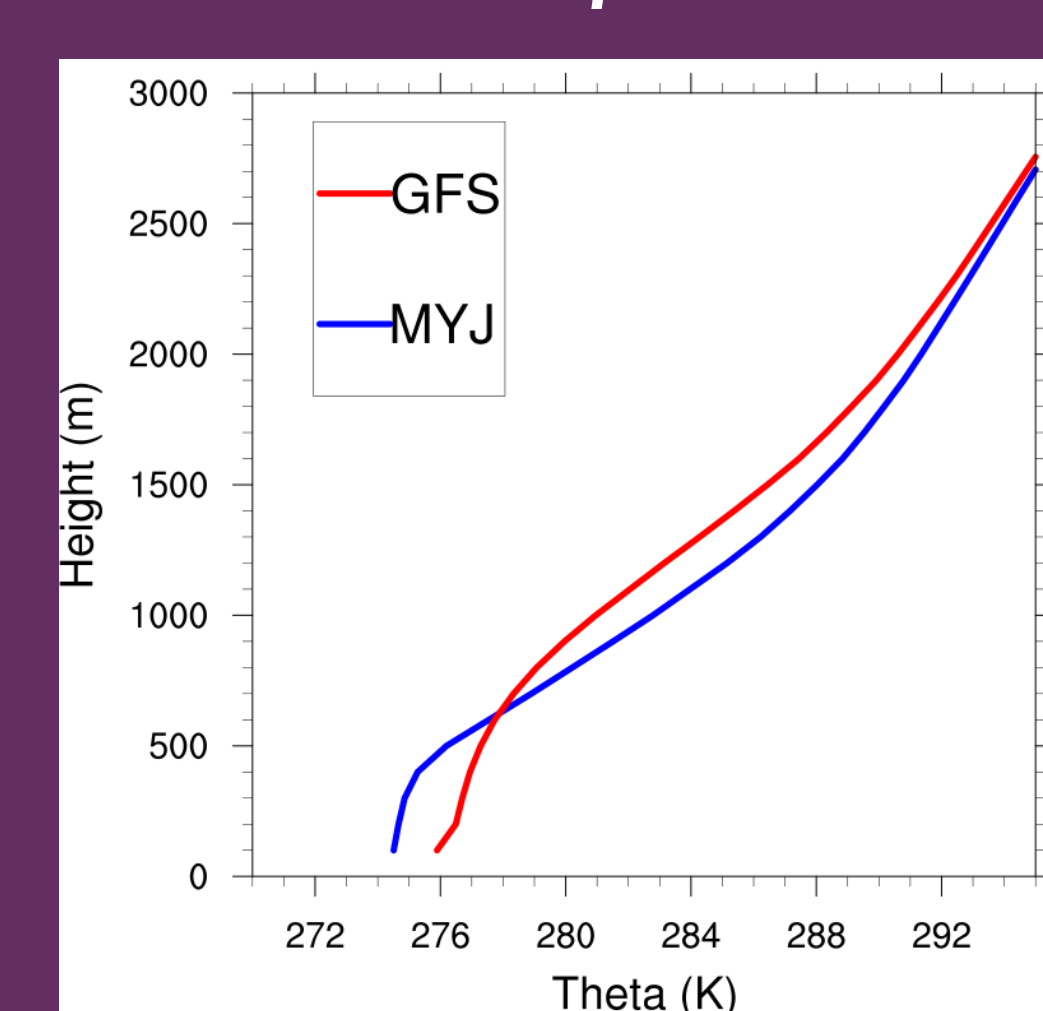
Inner Model Domain

Event Observed Snowfall

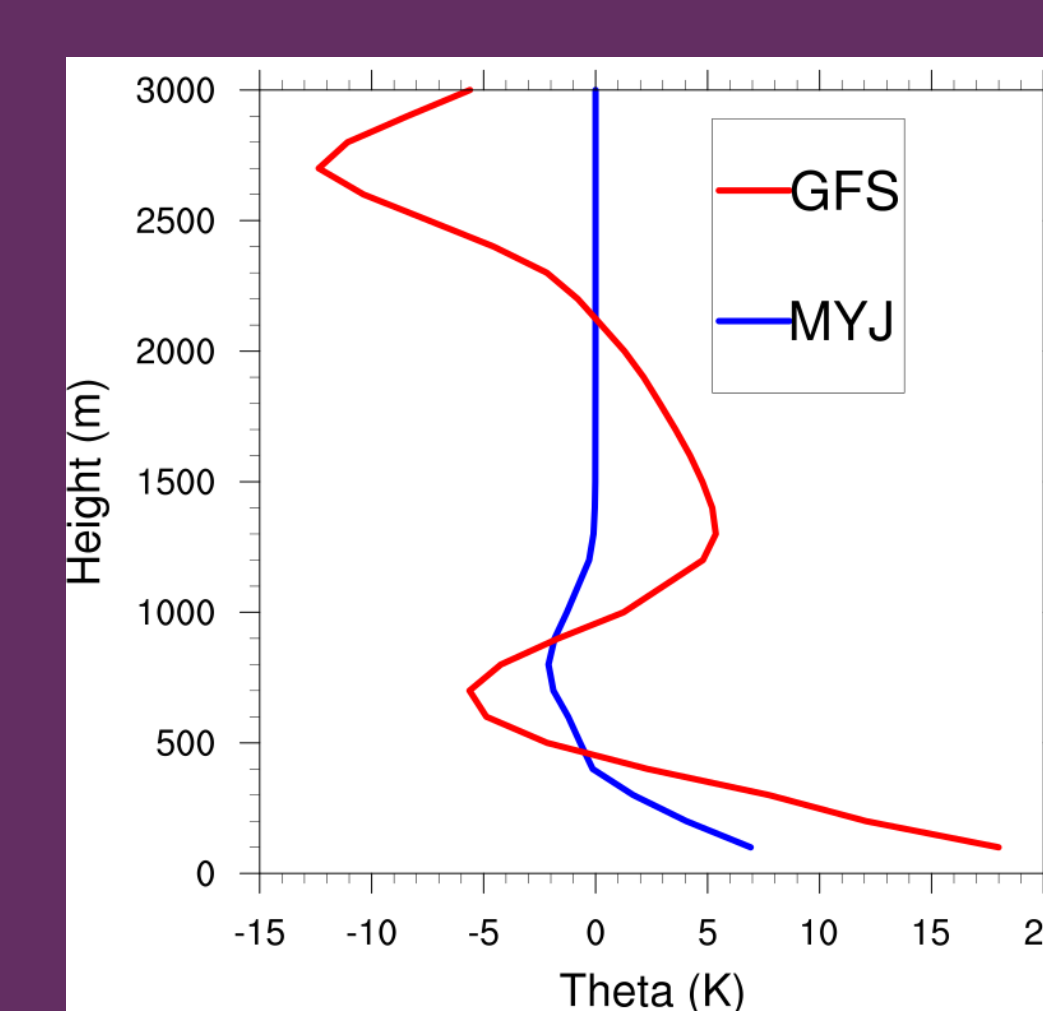


Boundary Layer Temperature Analysis (1400 UTC 2 March)

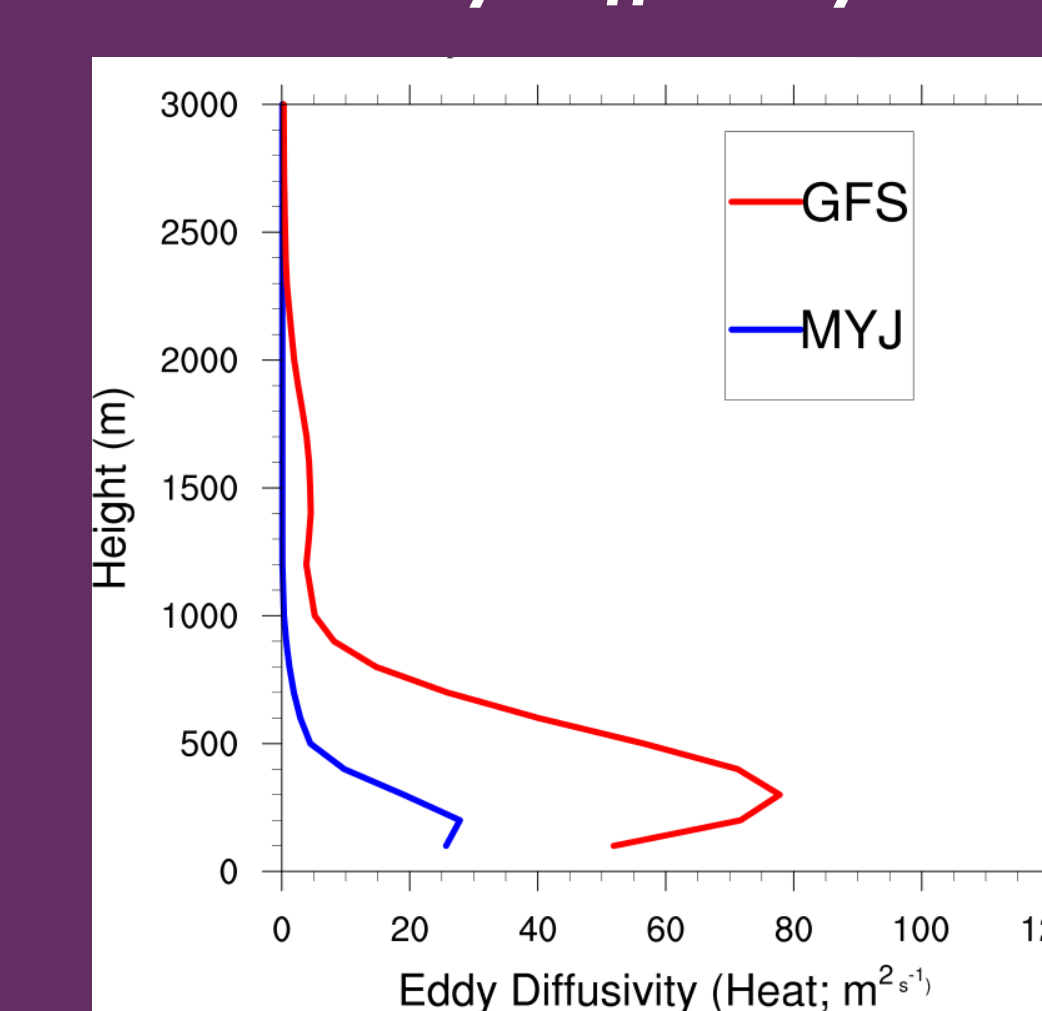
PBL Temperature



Accumulated PBL Theta



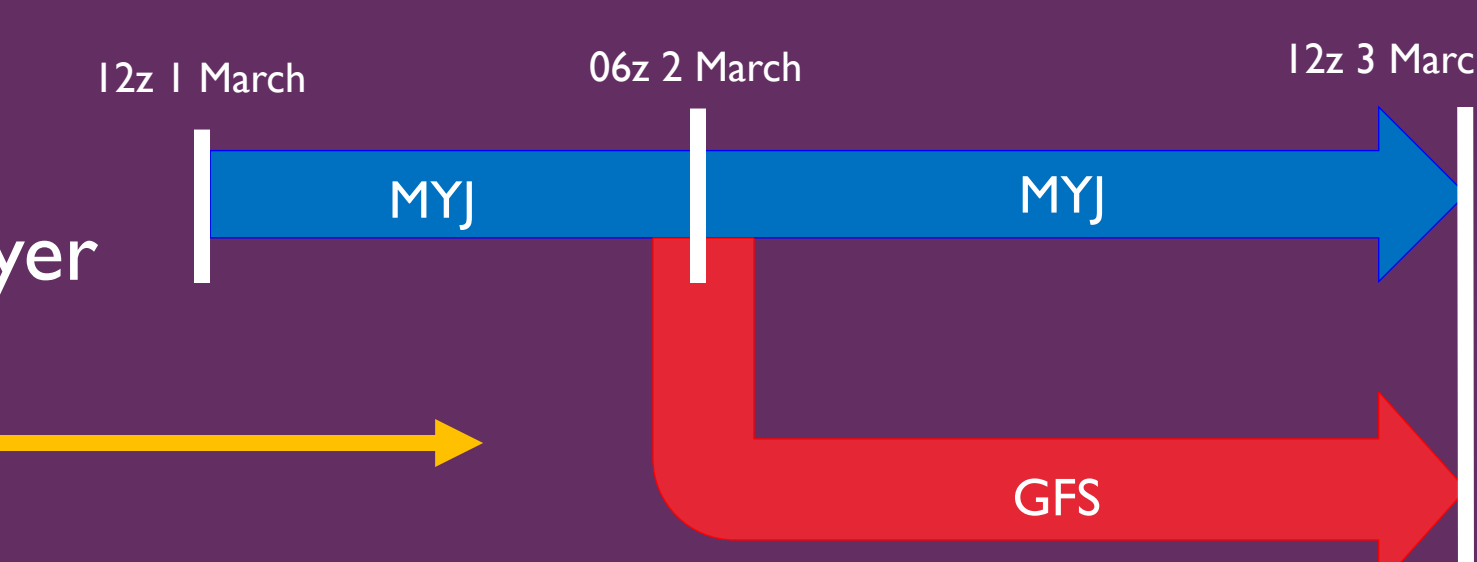
Eddy Diffusivity



$$ACPBL_{\theta} = \overline{ThTEND}_{PBL} * timestep$$

(a) Potential temperature, (b) accumulated PBL potential temperature, and eddy diffusivity averaged over green boxed domain valid 1400 UTC 2 March. Accumulated PBL potential temperature initialized at 0600 UTC 2 March.

- GFS simulation is warmer in the lower boundary layer
- Attributable to warming tendency via the PBL scheme
- Changes to GFS profile happen quickly



Conclusions and Caveats

- During the 2 March snowstorm, the GFS PBL scheme supports less snowfall than the MYJ scheme through enhanced warming/mixing of the lower atmosphere
- Microphysics also plays a role in forecast uncertainty for this event (see Yanna Chen's work)
- Surface layer schemes differ between GFS and MYJ, complicating the results (GFS surface layer produces slightly stronger upward heat fluxes than MYJ surface layer)
- GFS PBL scheme varies between 4 separate regimes, depending on near-surface stability (Han et al. 2016) (GFS generally remained within the moderately stable and moderately unstable regimes during the bulk of event)

References:

- Han, J., M.L. Witek, J. Teixeira, R. Sun, H. Pan, J.K. Fletcher, and C.S. Bretherton, 2016: Implementation in the NCEP GFS of a Hybrid Eddy-Diffusivity Mass-Flux (EDMF) Boundary Layer Parameterization with Dissipative Heating and Modified Stable Boundary Layer Mixing. *Wea. Forecasting*, 31, 341–352.

Acknowledgements

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