Assessing the Impact of Initial and Boundary Conditions on WRF Microphysics in Northeast U.S. Winter Cyclones

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Introduction

- Winter cyclones produce a variety of hazards that impact society
- There are still challenges in forecasting precipitation type, precipitation location and amounts
- Most research has focused on WRF microphysics
- How does variability in initial conditions impact the ability to accurately depict precipitation processes and totals?

March 2nd, 2018 Nor'easter in Massachusetts

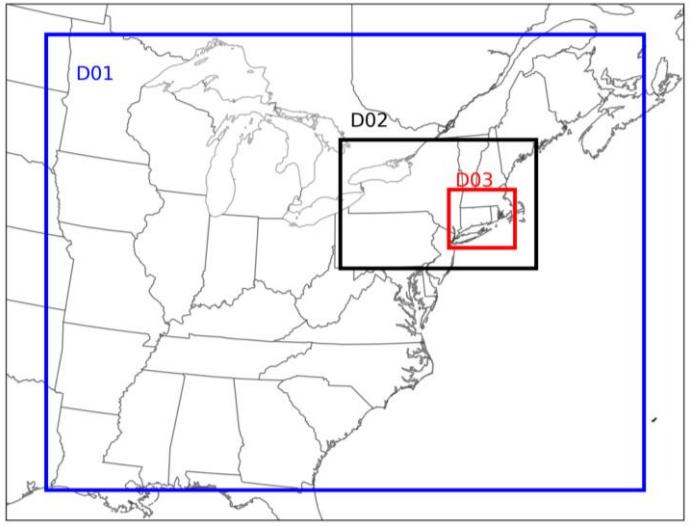
Snowstorms

- NASA GPM Ground Validation and IMPACTS Campaign
  - Overlapping, synergistic observations in 2021-2022 & 2022-2023
- Events Selection
  - Characteristic Nor'easters (Miller A and B)
  - Only snow events based on PARSIVEL^2 at UConn

1. 1/7/2022- Miller A coastal low pressure
2. 1/29-30/2022- Miller A, bomb cyclone, first classified blizzard since 2018
3. 2/13-14/2022- Miller A with stationary front preceding cyclone
4. 2/28/2023- Miller B Great Lakes Cyclone

WRF Simulations

- 60-hour simulations w/ 12 hours spin up
- Simulation window starts 12 hours before the previous synoptic time to precipitation starting at UCONN
- Triple-nested domain with resolution of 12, 4, and 1.33km with two-way feedback
- IC/BC every 6 hours



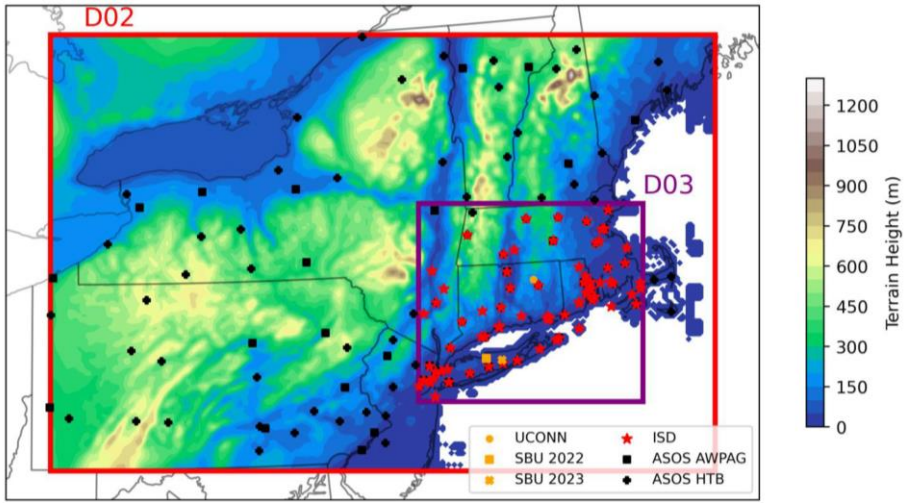
Physics Options	UConn WRF
Microphysics	Thompson
Cumulus (D01 only)	Grell 3-D
Longwave Radiation	RRTM
Shortwave Radiation	Goddard
Boundary Layer	YSU
Land Surface	Unified NOAH
Surface Mayer	MM5

Initial and Boundary Conditions

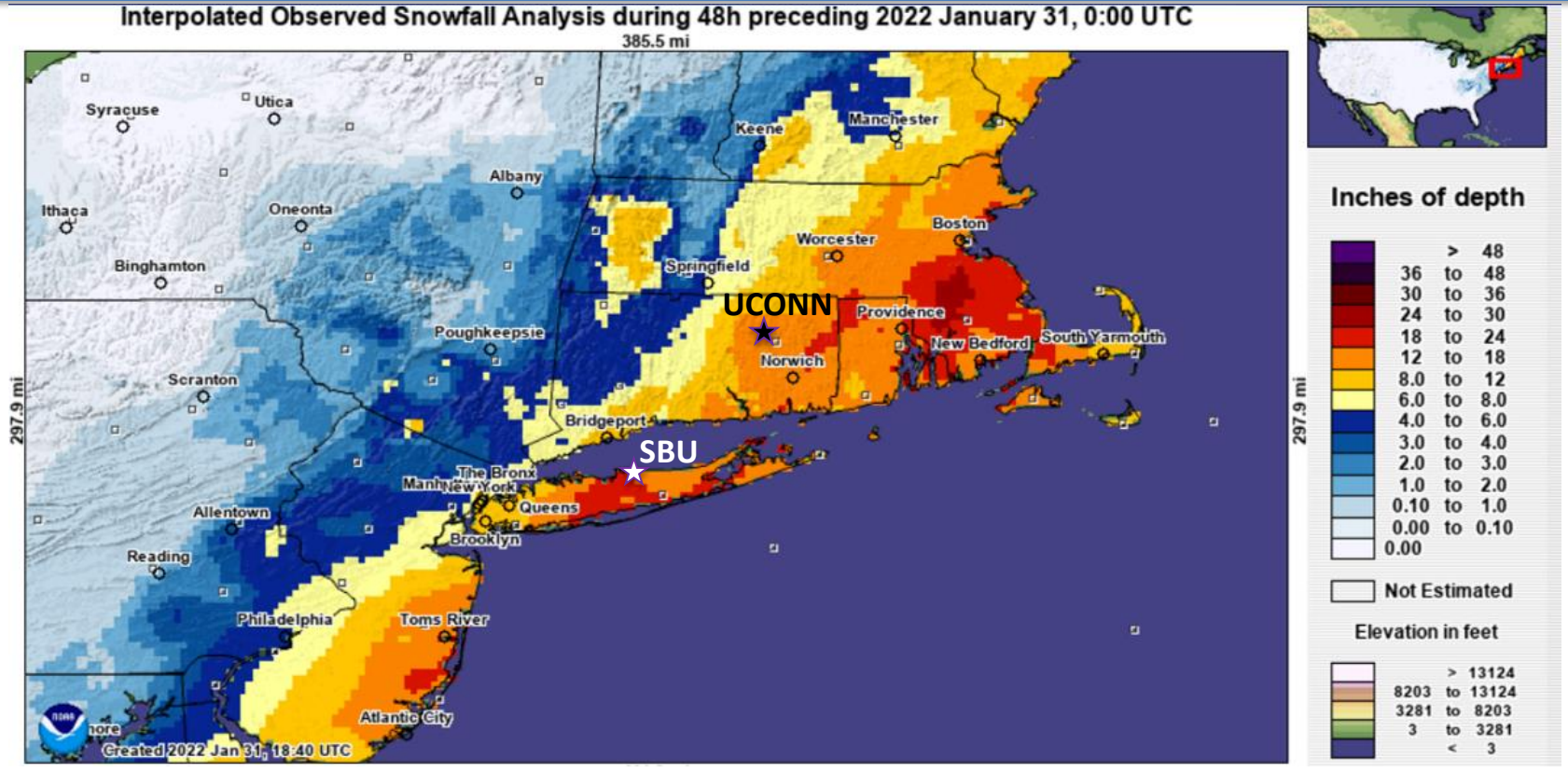
- NCEP-FNL Analysis (WRF-GFS)
  - 6 hourly, 0.25 degree resolution →34 metgrid levels
  - Produced by Global Data Assimilation System which is used for GFS
- NAM Operational Analysis (WRF-NAM)
  - 6 hourly, 12km resolution → 40 metgrid levels
  - Analysis produced by Operational North American Mesoscale Model
- North American Regional Reanalysis (WRF-NARR)
  - 3 hourly, 0.3 degree resolution →30 metgrid levels
  - Produced over North America by Eta Model and regional data assimilation
- ERA-5 Reanalysis (WRF-ERA5)
  - Hourly, 31km resolution →38 metgrid levels
  - Produced by ECMWF's Integrated Forecast System (IFS)

Observational Datasets

- GPM Ground Validation
  - Pluvio Weighing Gauge at UConn (CT)
- IMPACTS
  - Pluvio Weighing Gauge at Stony Brook, NY
- 74 NOAA ISD Stations- D03
- Stage IV Precipitation- D02
- ASOS Precipitation-D02

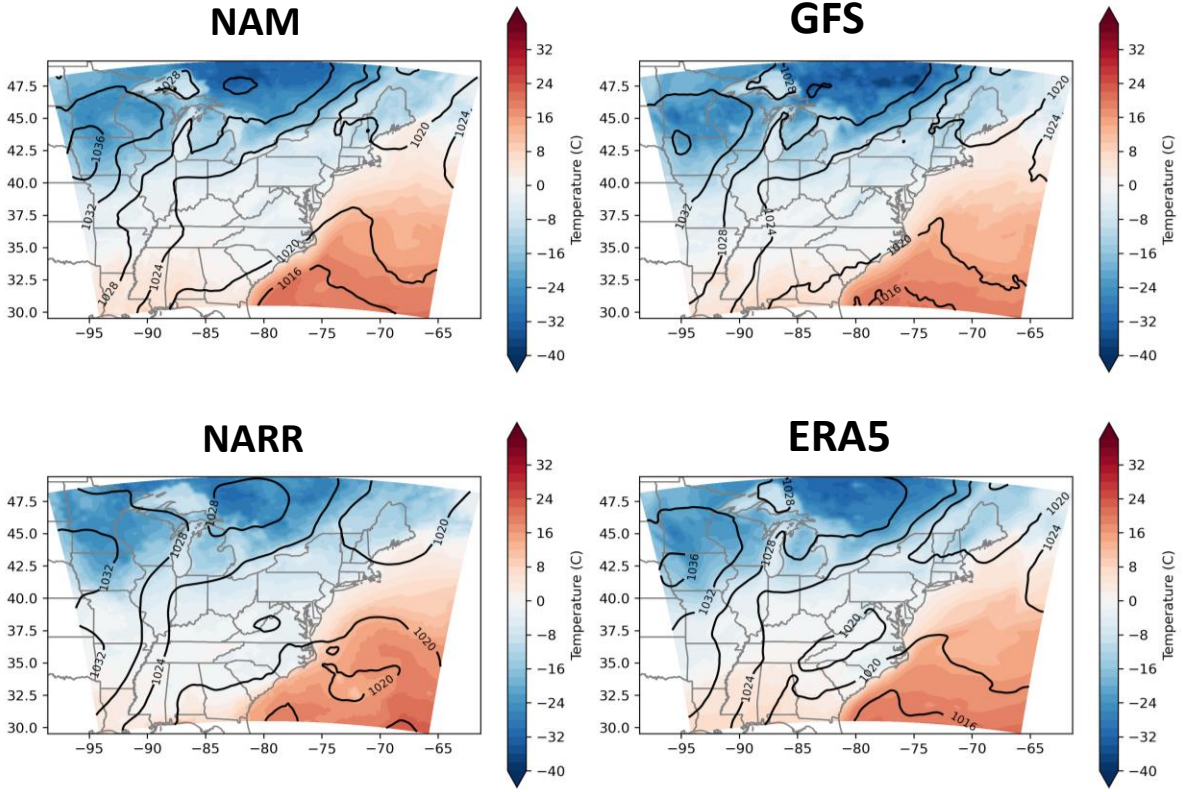


January 28-30, 2022



Source: NWS OKX/ NOHRSC

Initial Conditions - Surface



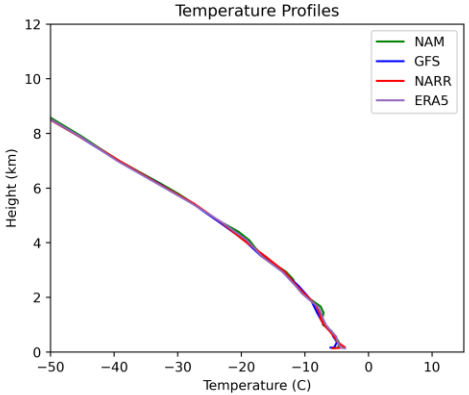
January 28, 2022 @ 12UTC

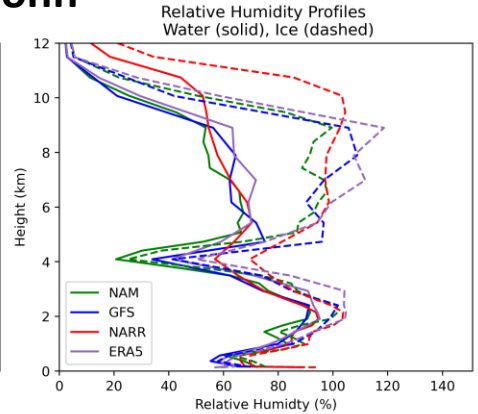
- ✓ Little to no differences across all synoptic levels (SFC, 925, 850, 700, 500)

Initial Conditions (Vertical)

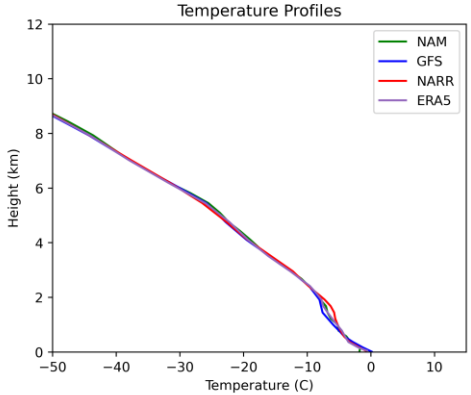
January 28, 2022 @ 12UTC

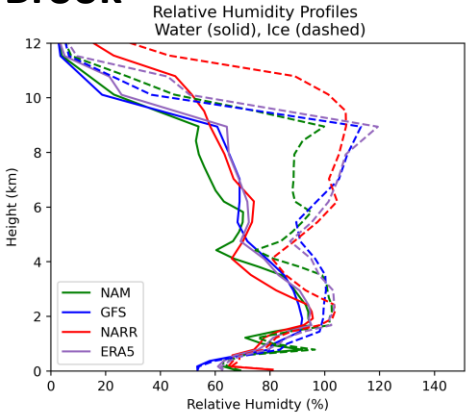
UConn





Stony Brook

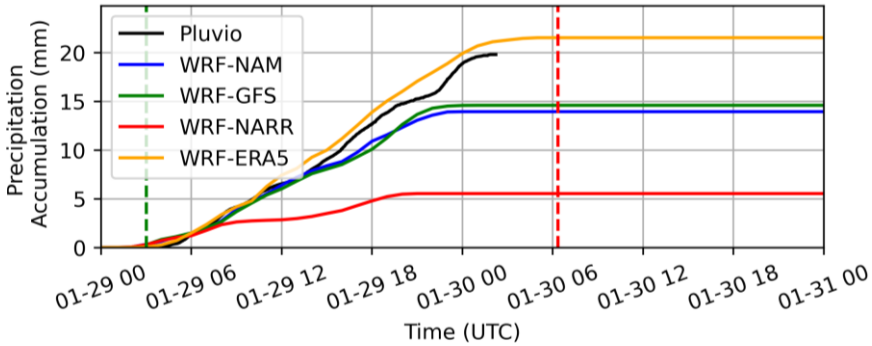




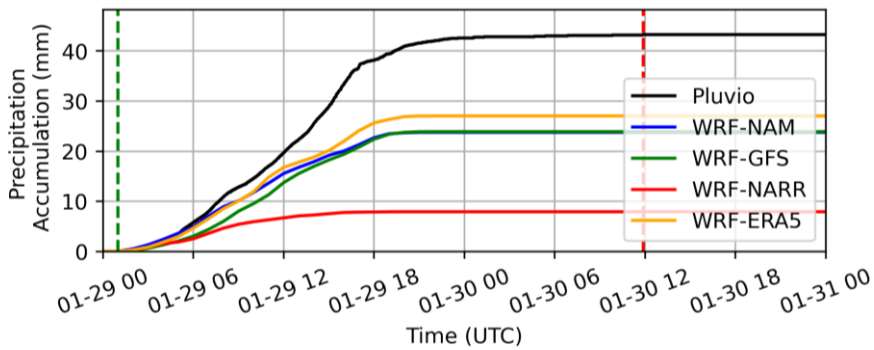
- ✓ Little to no differences in Temperature profiles
- ✓ Significant variability in Relative Humidity profiles

Precipitation

UConn



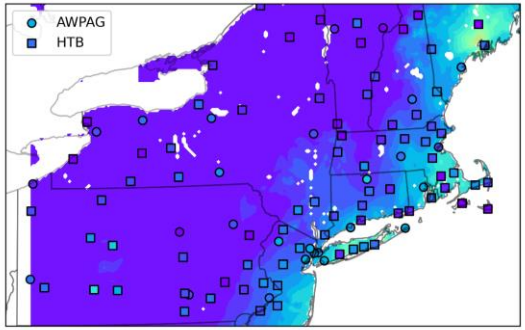
Stony Brook

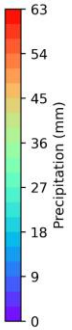


- ✓ WRF-NARR consistently underestimates precipitation
- ✓ The other 3 model configurations follow similar patterns

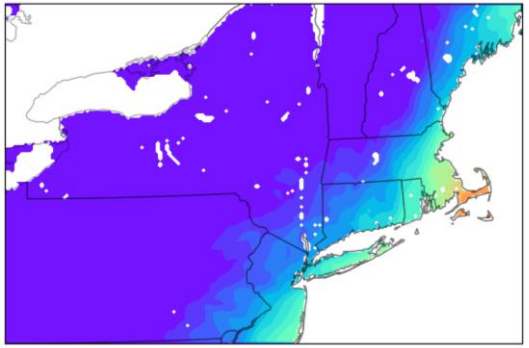
Precipitation

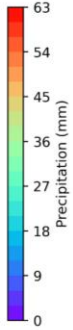
Stage IV & ASOS



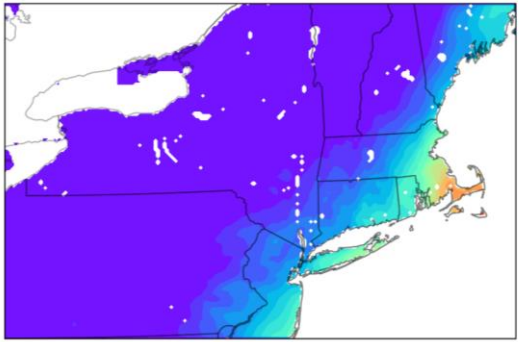


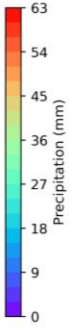
WRF-NAM



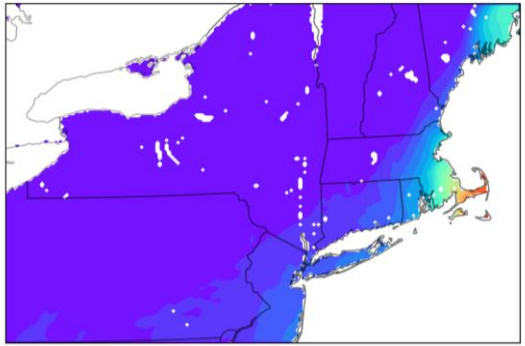


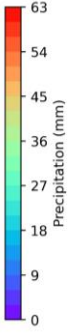
WRF-GFS



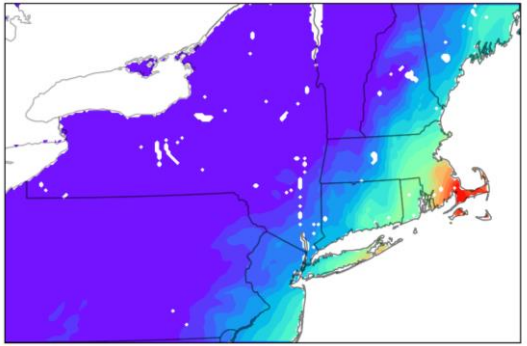


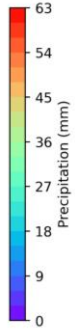
WRF-NARR





WRF-ERA5





✓WRF-NARR: least precipitation

✓WRF-NAM & WRF-GFS: similar precipitation

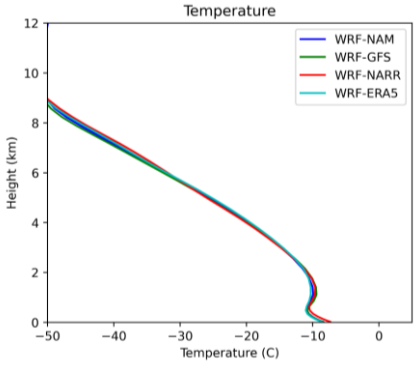
✓WRF-ERA5: most precipitation

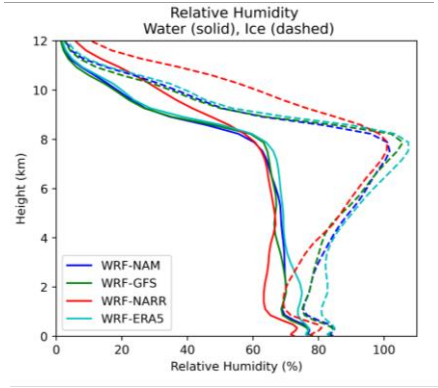
Precipitation Microphysics

Temperature

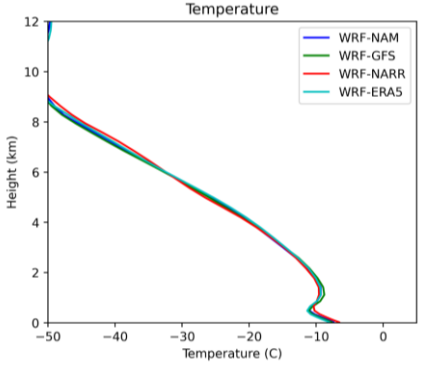
Relative Humidity

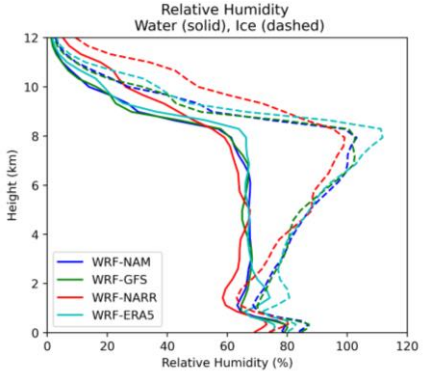
Domain Average



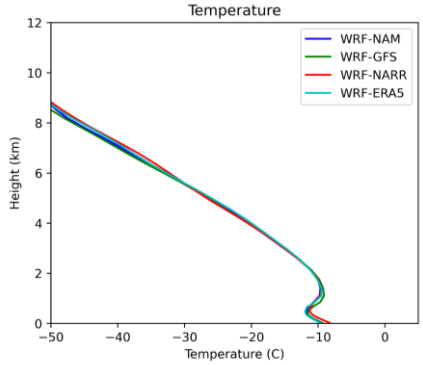


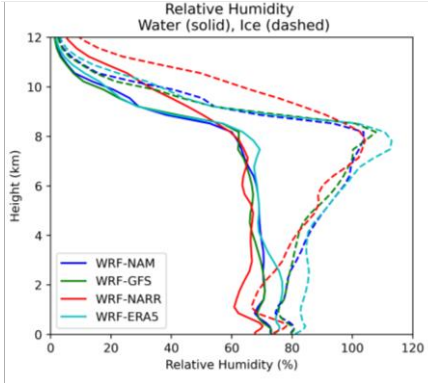
Stony Brook





UConn





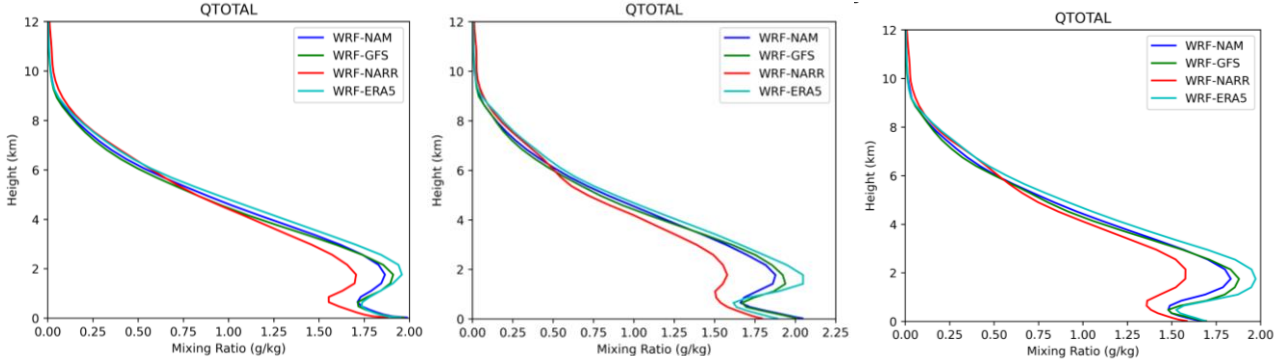
✓Minor variability in Temp profiles

✓Significant variability in RH profiles

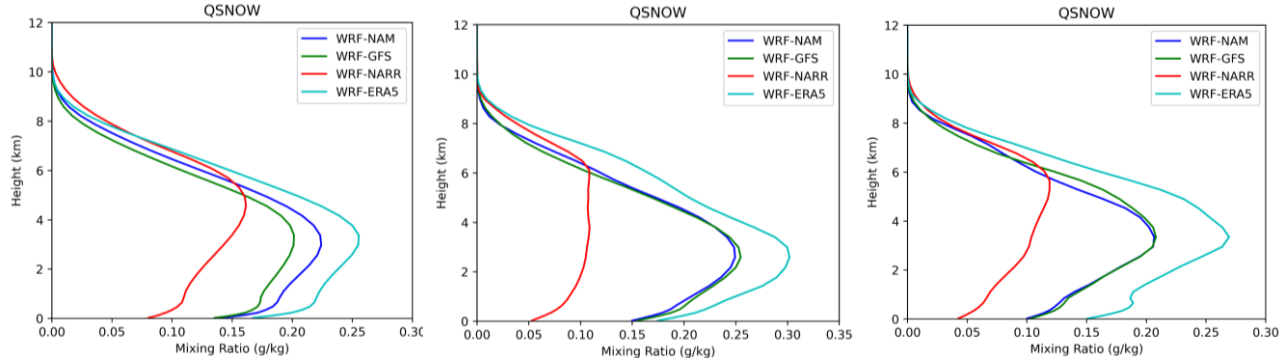
Precipitation Microphysics

Domain Average | **Stony Brook** | **UConn**

Qtotal (g/kg)

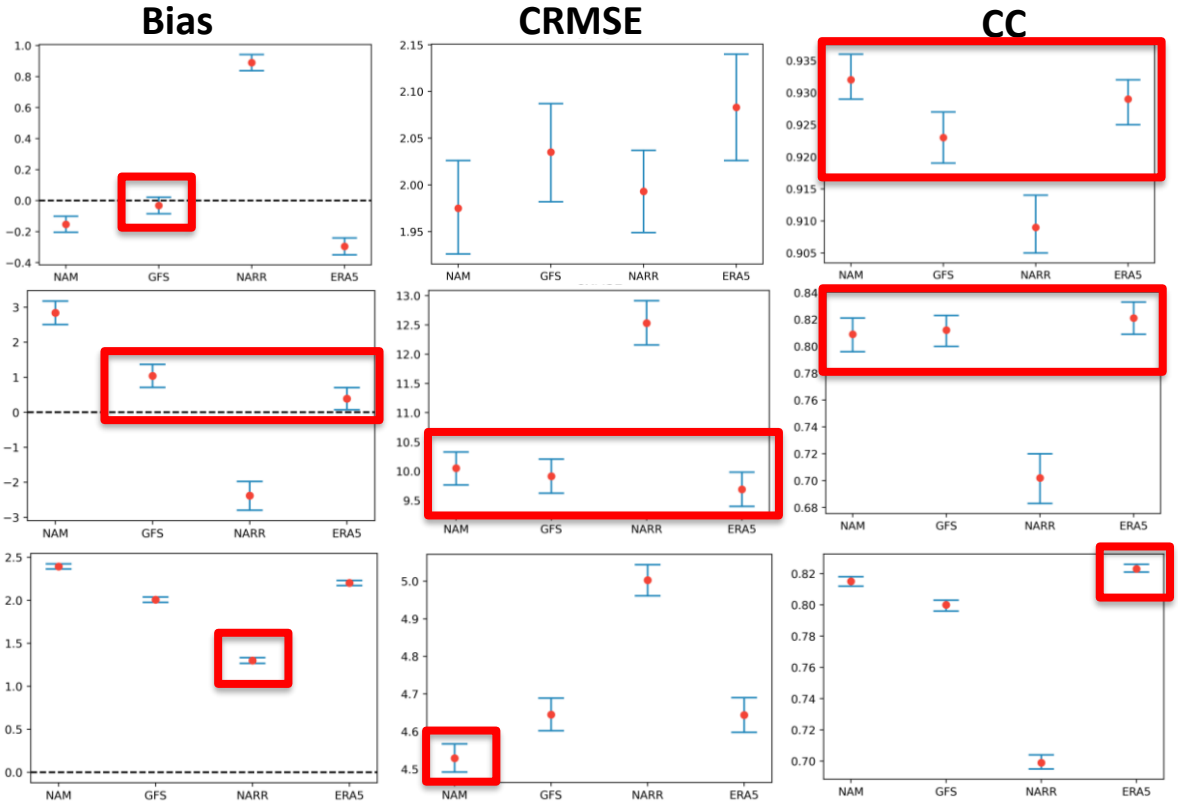


Qsnow (g/kg)



✓Variability in RH connected to microphysics species magnitude

Overall Surface Comparison



Red boxes indicate statistical significance based on 95th percentile Confidence Intervals

Summary

- Simulated four Nor'easters using different initial conditions
- Variability from initial conditions mostly comes from relative humidity profiles rather than synoptic scale differences
- The propagated variability manifests in variations in humidity profiles, precipitation totals and microphysical hydrometeor species
- Future work will focus on using NASA instrumentation and models to enhance understanding of snow microphysics parameterizations

Submitted to Weather and Forecasting

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