Nested Simulation of a Winter Storm in the Southern Plains

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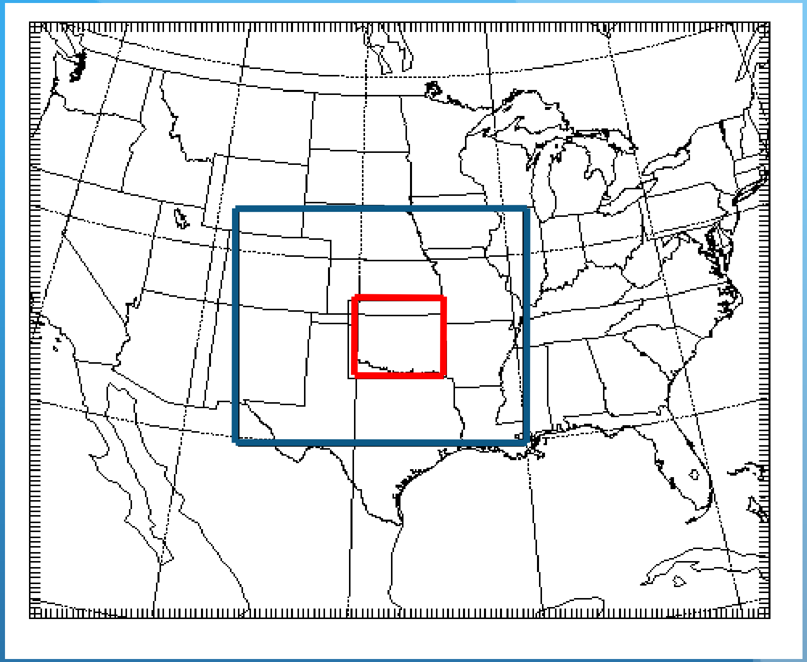
Case Study: January 3rd-5th 2005 Winter Storm:

- Strong theta-e advection at low and mid levels ahead of an upper level trough produced elevated convection and locally heavy precipitation north of a surface front that fell as rain, freezing rain followed by a transition to snow.
- Unlike some winter storms, this event was observed by the SGP cloud radar and so has a larger range of useful in situ observations.
- The intention of this project is to examine a range of case studies to elucidate detail on mesoscale and microphysical processes. For now however, We examine how the model simulation compares to observations over a range of parameters.

Model Setup

•Large outer domain to capture synoptic scale features.
•Horizontal grid of Parent domain is 30km, outer nest 10km and inner nest 3.3km.
• 50 vertical levels

• Nesting is 2-way, allowing feedback between the higher resolution domains and the parent domain



• <u>WRF Physics Configuration:</u>
•_WSM6 Microphysics
• Kain-Fritsch convective scheme for parent domain and outer nest
• YSU PBL, Noah LSM
• RRTM longwave and Dudhia shortwave radiation.

<u>Simulation Duration</u>

•_2 simulations- 12Z 3rd to 12Z 4th (1) and 12Z 4th to 0Z 7th (2).

•_We consider case 2 which encompasses most of the event

Model Setup

Observational and Grid Nudging

- Nudging four dimensional data assimilation (FDDA) options are available in WRF-ARW and are used to reduce model error by improving initial and boundary conditions.

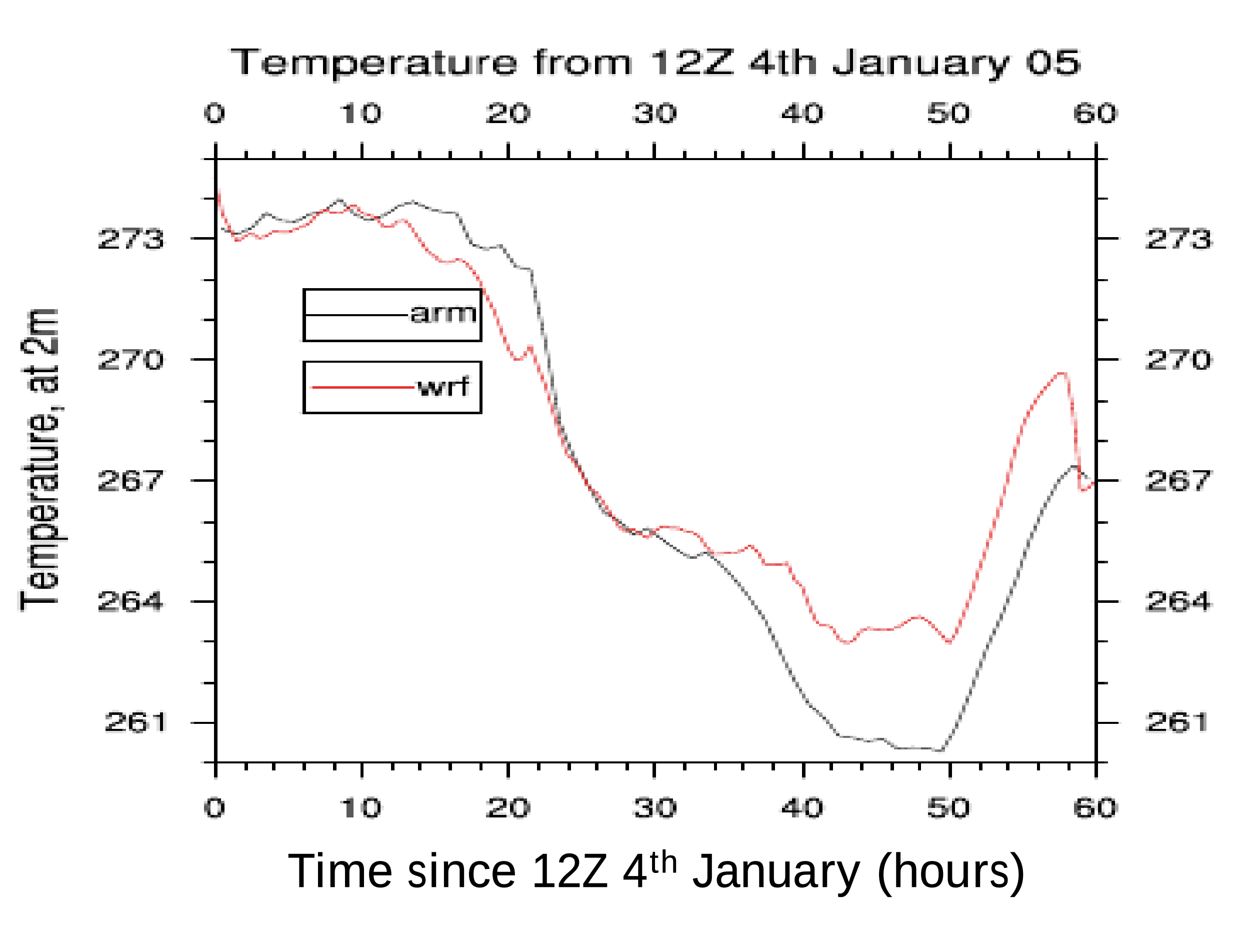
- Nudging is applied only for the parent domain during the first 12 hours of simulation

  - Analysis Nudging: Simulation nudged toward the input data (NAM AWIP at 40 km resolution and 3 hour intervals). This technique is applied for winds, temperature and moisture fields above the boundary layer.

  - Observational nudging: Applied above the surface using Radiosonde data from NCAR (6 hour intervals). This type of nudging has been shown to improve simulation of upper level wind fields.

Results: Atmospheric State

Surface Temperature:

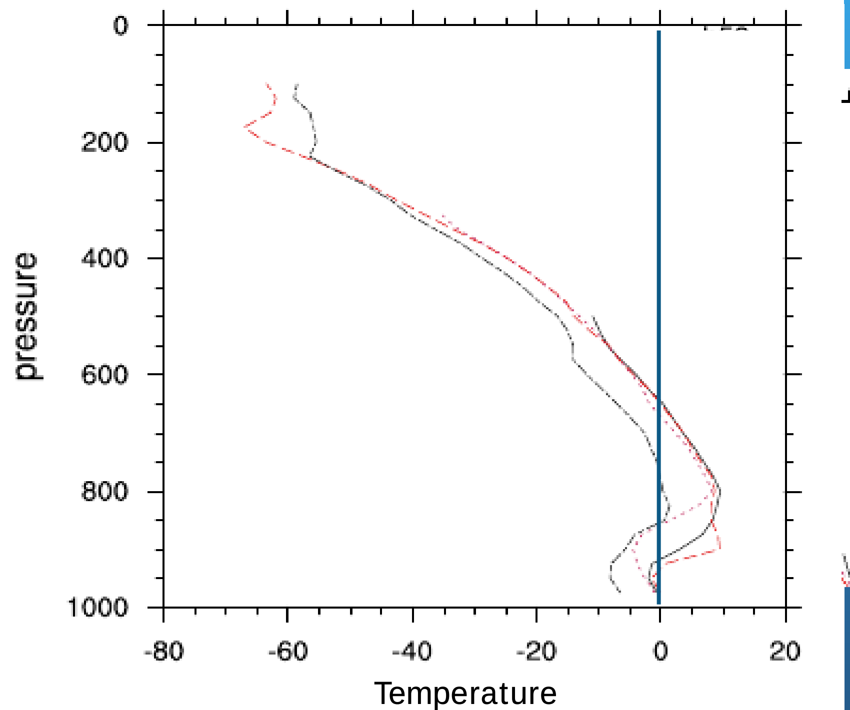


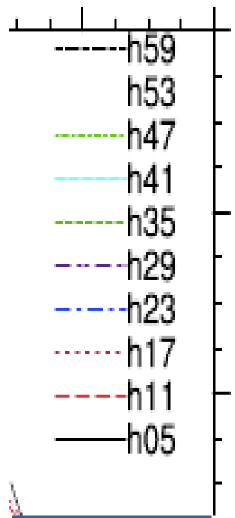
- Model is able to capture rapid temperature drop associated with deepening Arctic airmass and strong surface cold air advection.

Results: Atmospheric State

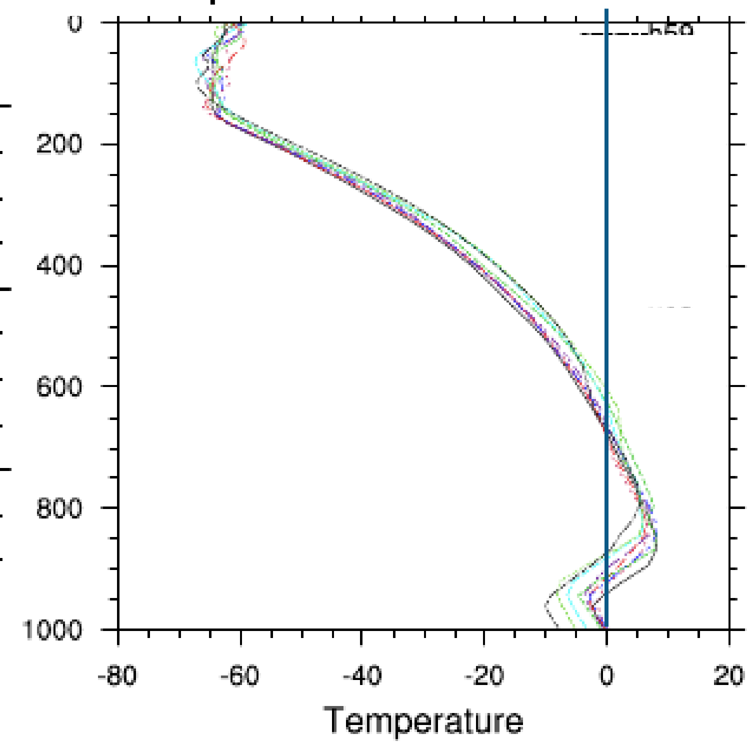
Vertical Temperature Profile: Temporal Evolution

ARM Temperature from 12Z 4th Jan





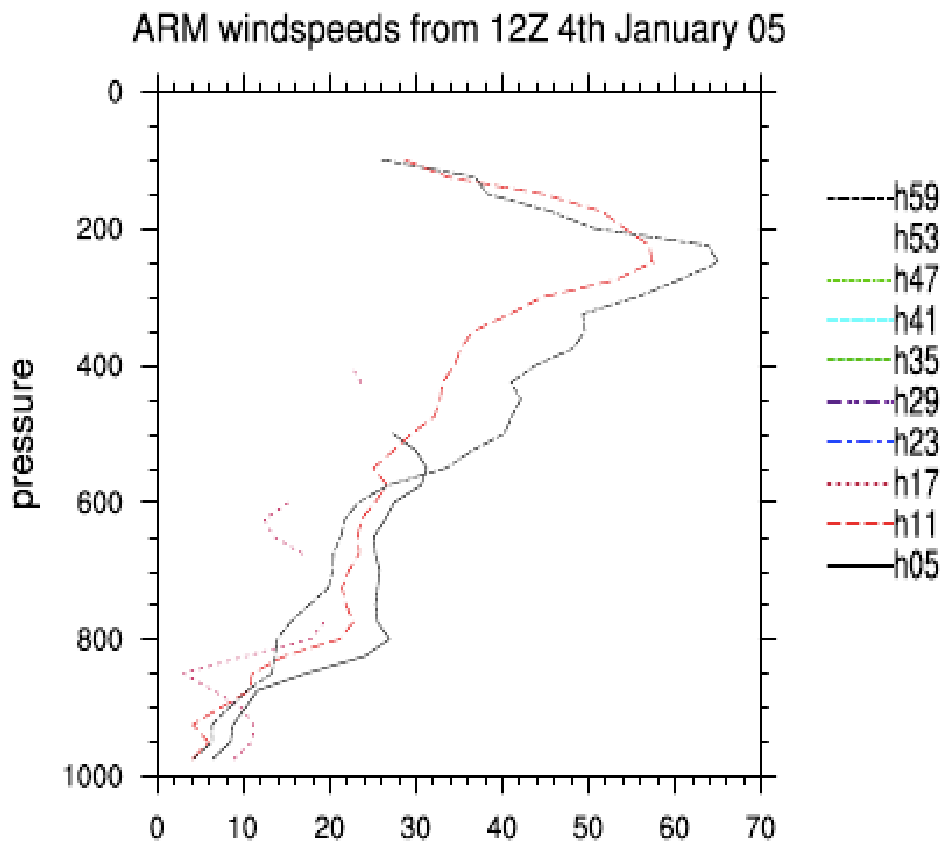
WRF Temperature from 12Z 4th Jan

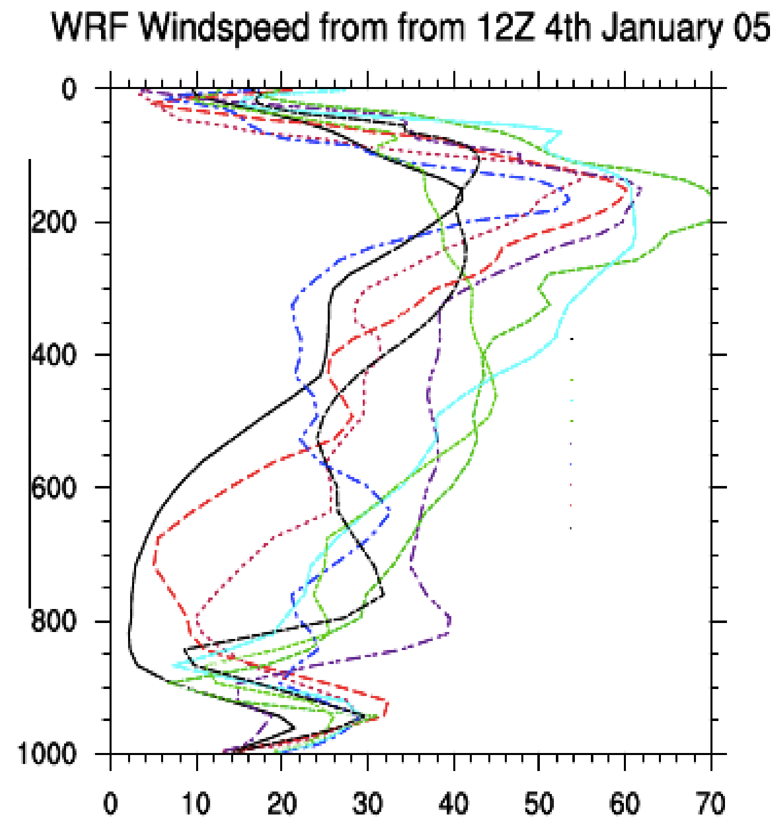


- WRF captures frontal inversion and its magnitude well, especially in the first several hours
- Later in the simulation the profile is typically warmer than the observations with lower lapse rates

Results: Atmospheric State

<u>Vertical Profile of Wind speed</u>

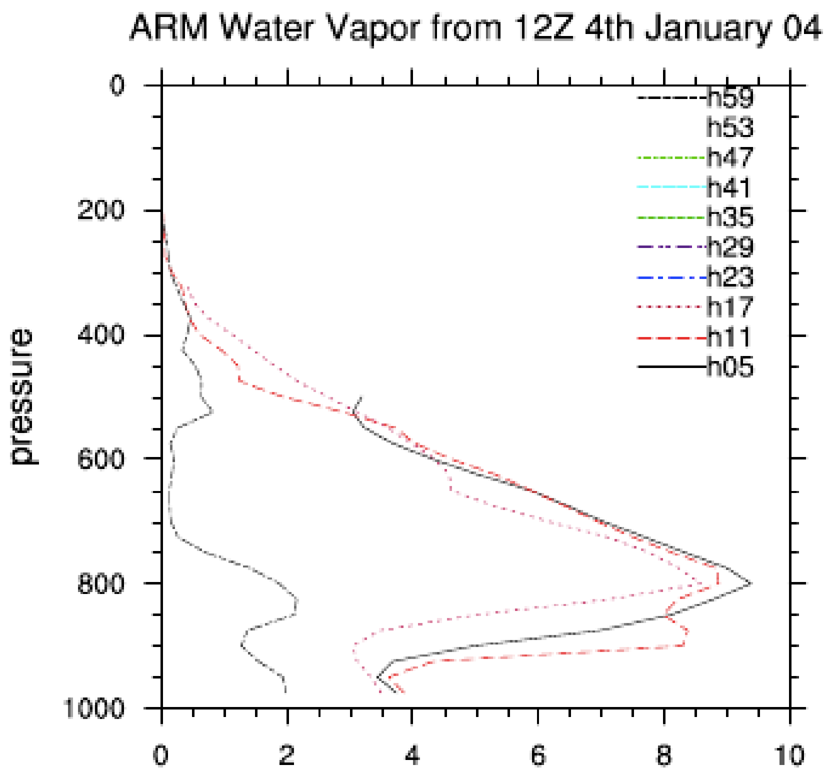


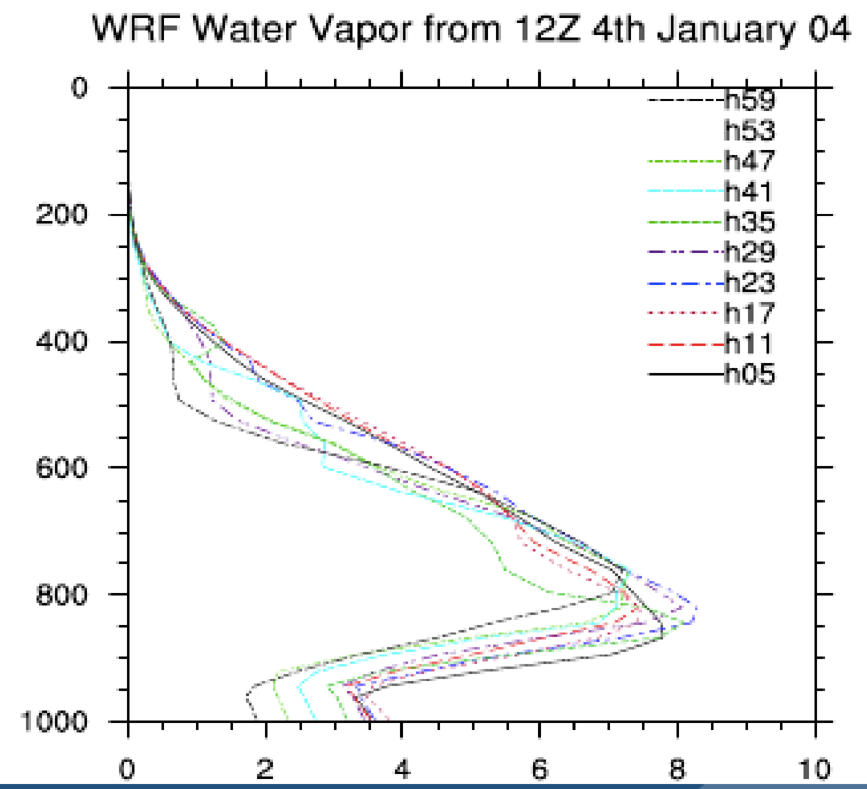


- Clear underestimation of wind speed for the early stages of the simulation and particularly between 800-600hpa.

Results: Atmospheric State

Vertical Profile of Water Content (g/kg)

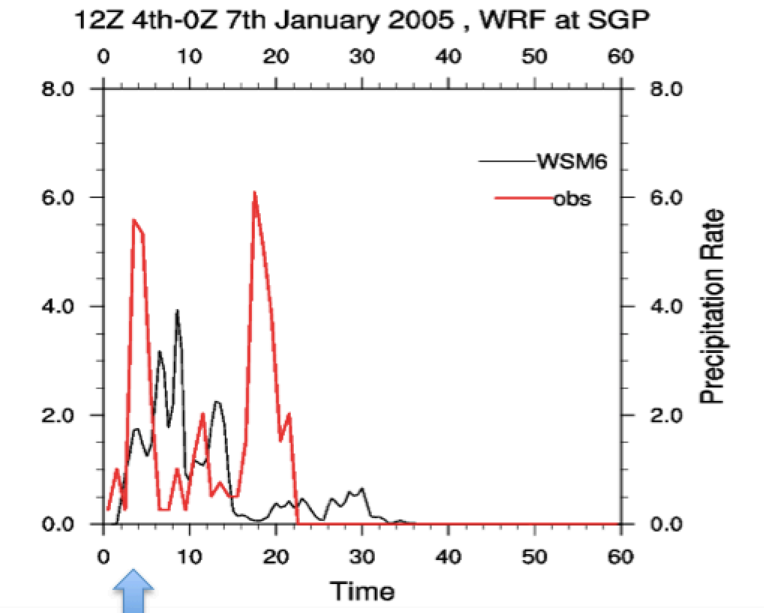


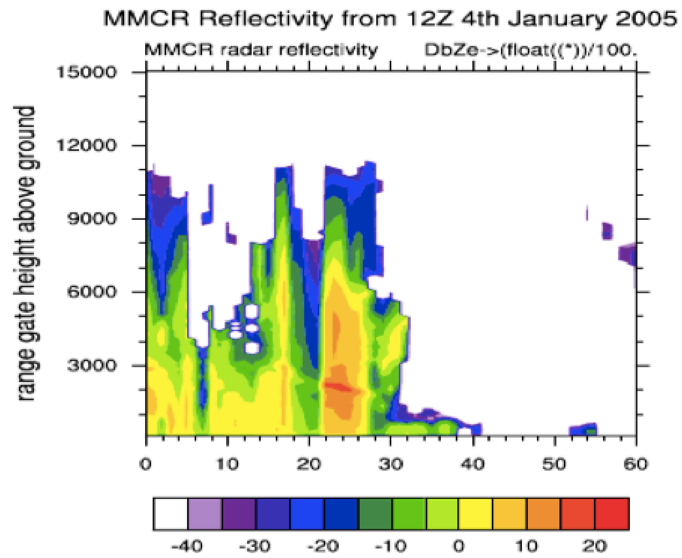


- Good agreement between observed and simulated water vapor profiles in the first part of the simulation.
- Near the end of the simulation period, WRF overestimates midlevel moisture.

Results: Precipitation

Precipitation Rate





Period of best model-observational agreement

WRF missed second period of Heavy rainfall near 08Z 5th

- Precipitation rate in mm/hr

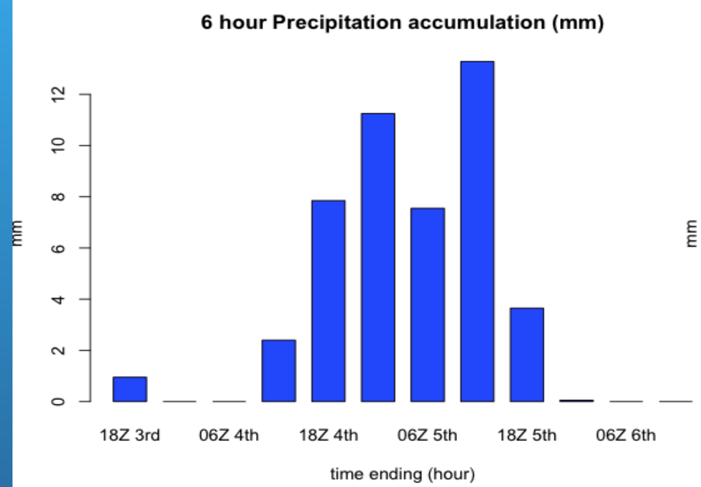
Results: Precipitation

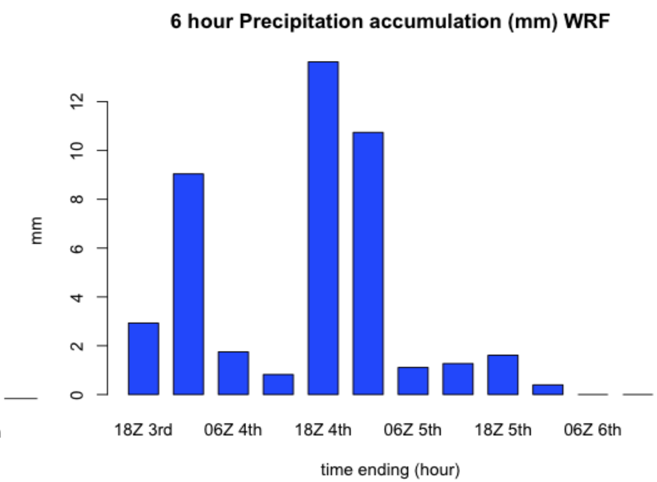
Obs

Temporal Evolution

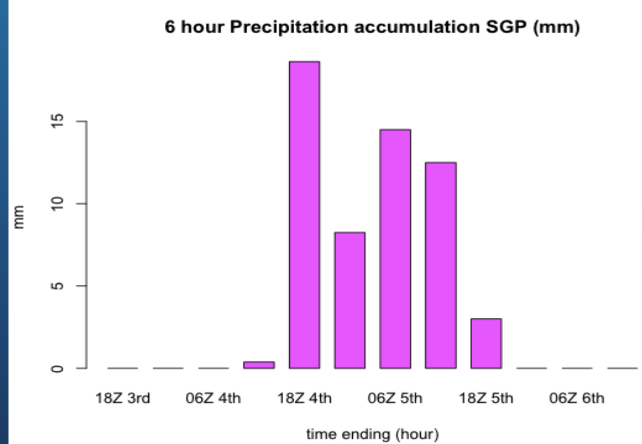
WRF

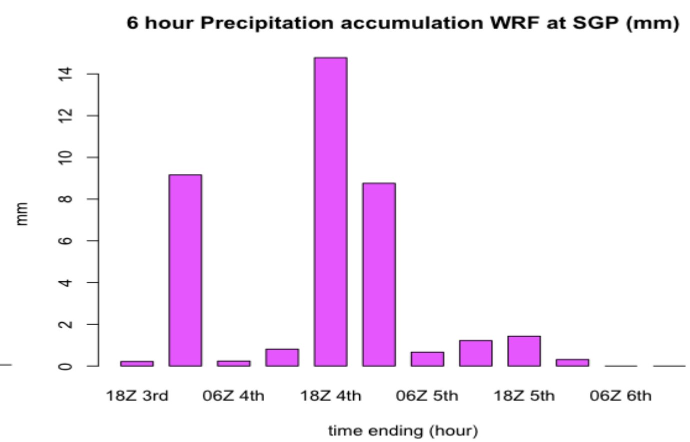
As a spatial average (36.2-37.7 N, 96-98.6 W): Observations from NCEP-stage IV



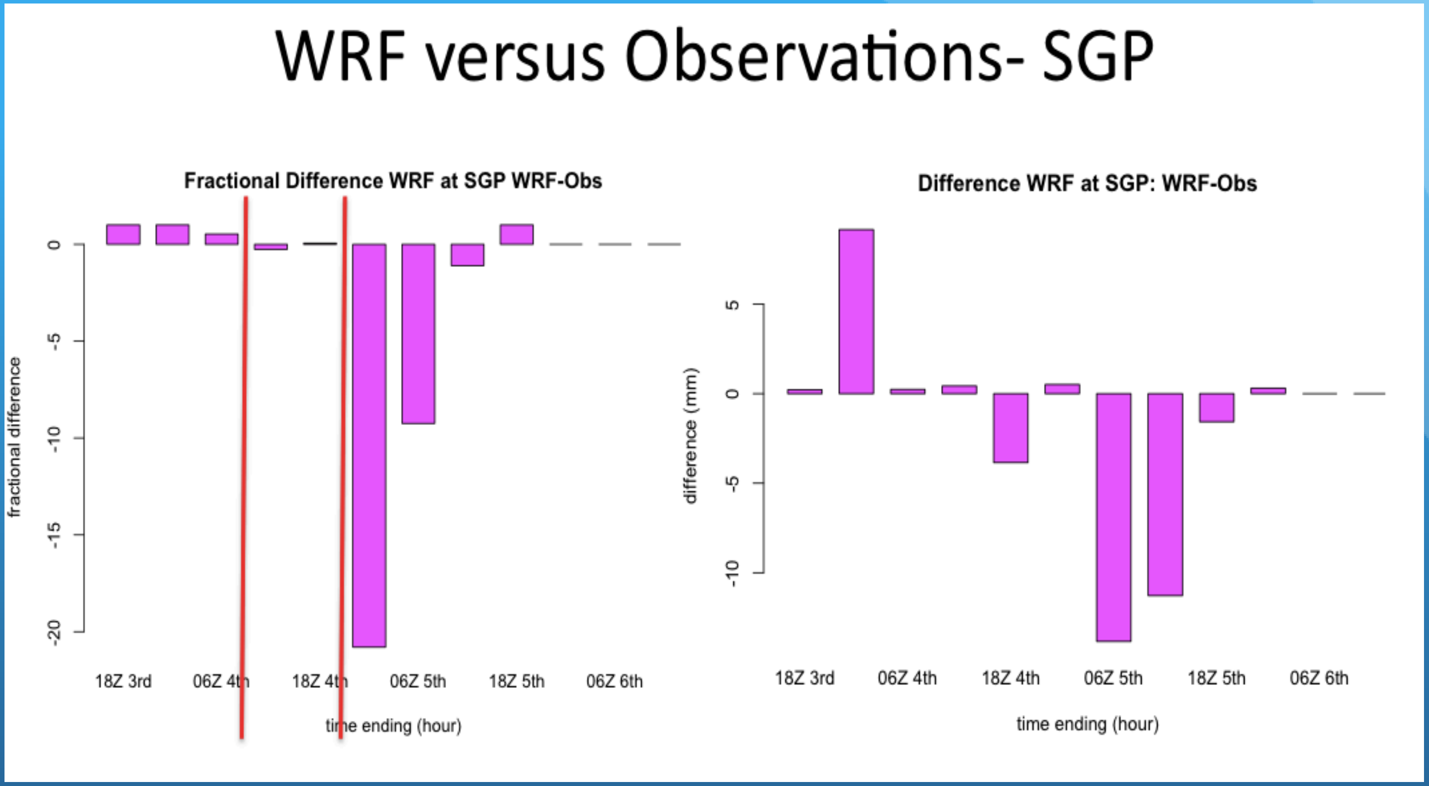


At the SGP Site. Observations from NCEP Stage IV





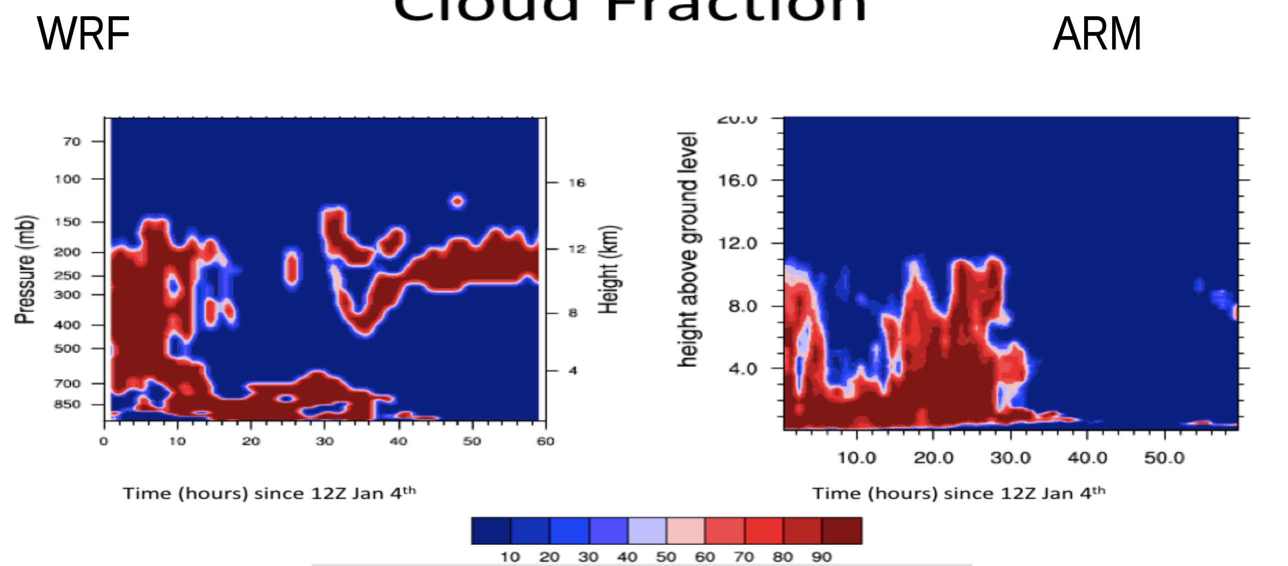
Results: Precipitation



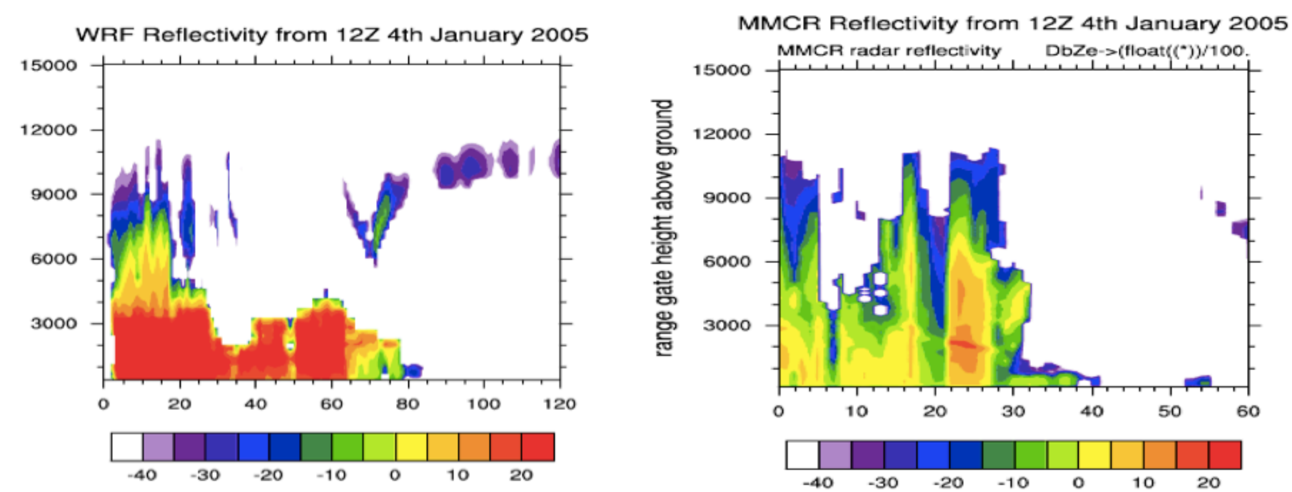
- WRF captures the precipitation event between 12Z 4th and 0Z 5th relatively well but misses the precipitation event between 4Z and 12Z on the 5th. Overall evolution of the precipitation event is quite different in the model compared to observations.

Results: Cloud Properties

Cloud Fraction

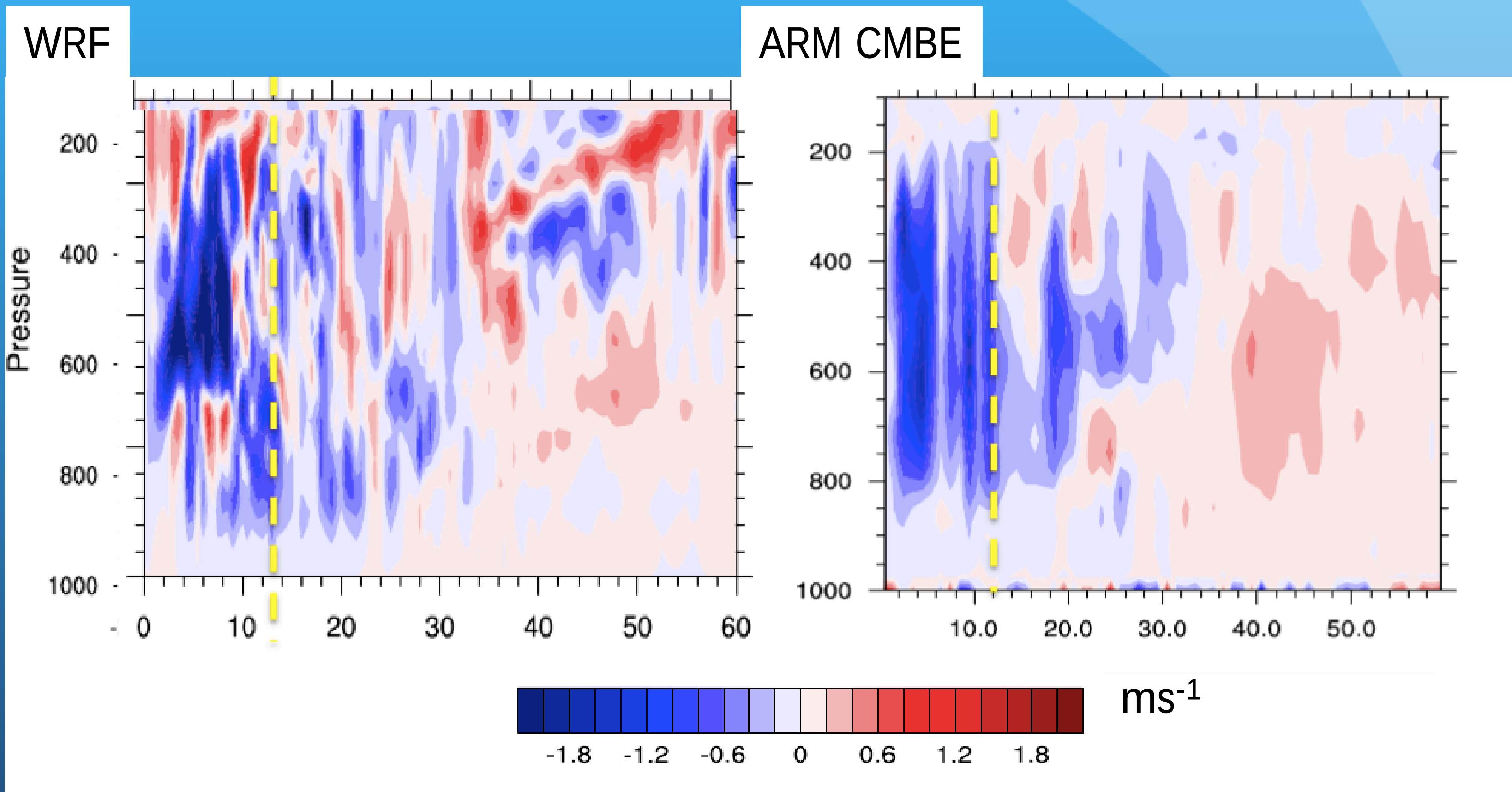


WRF MMCR Simulated cloud radar reflectivity versus MMCR Observations (Mace dataset)



Results: Cloud Properties

Model vs Observed Vertical Velocities from 12Z January 4th



Ascending motion denoted by negative vertical velocity

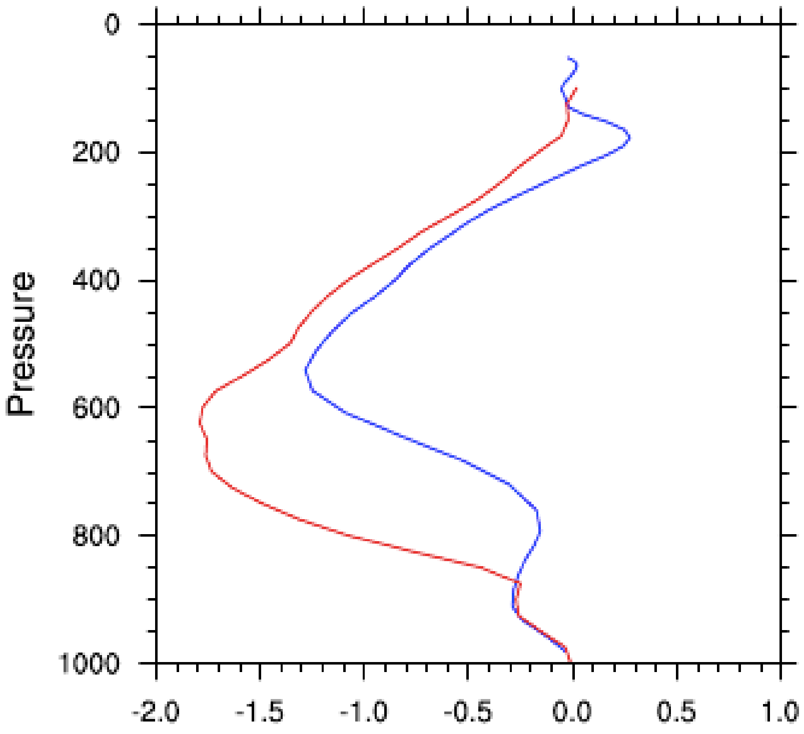
Results: Cloud Properties

Vertical Velocity Profiles

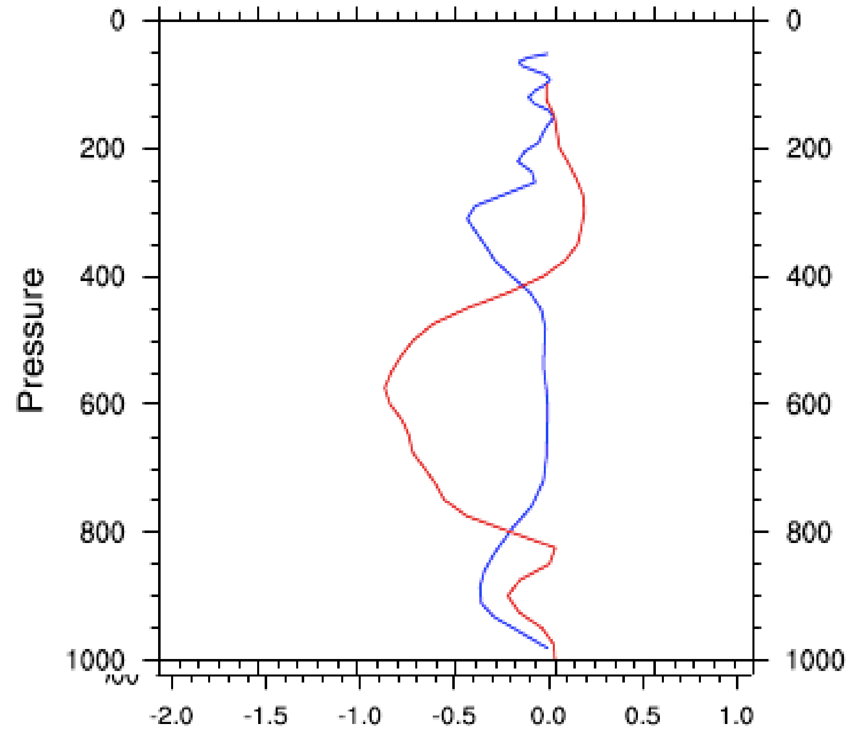
ARM CMBE

WRF

12Z 4th to 0Z 5th Jan 2005 (rain event 1)

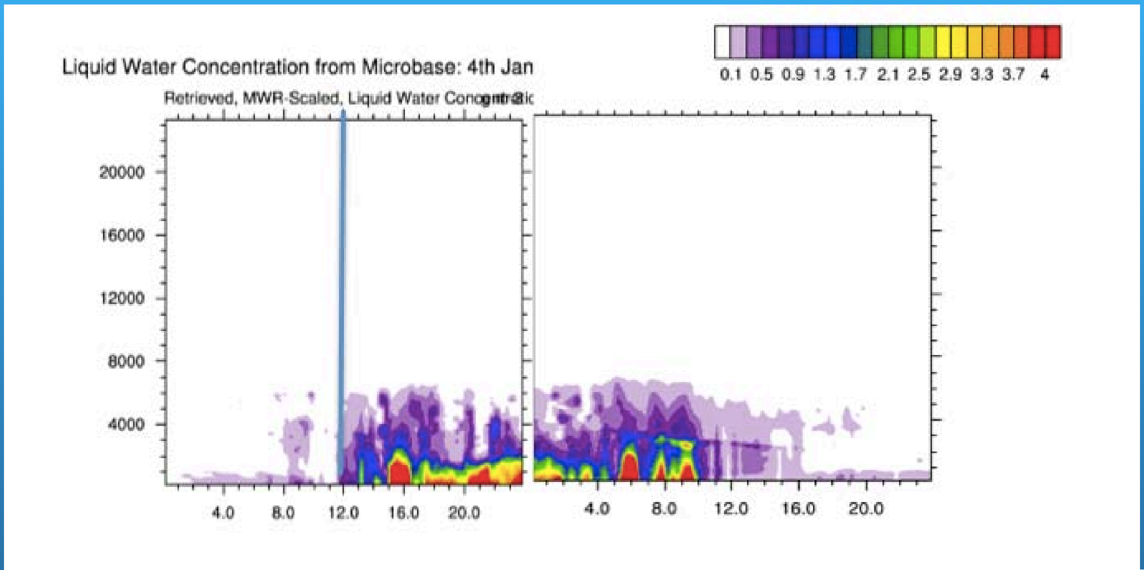


04Z-14Z 5th Jan 2005 (rain event 2)

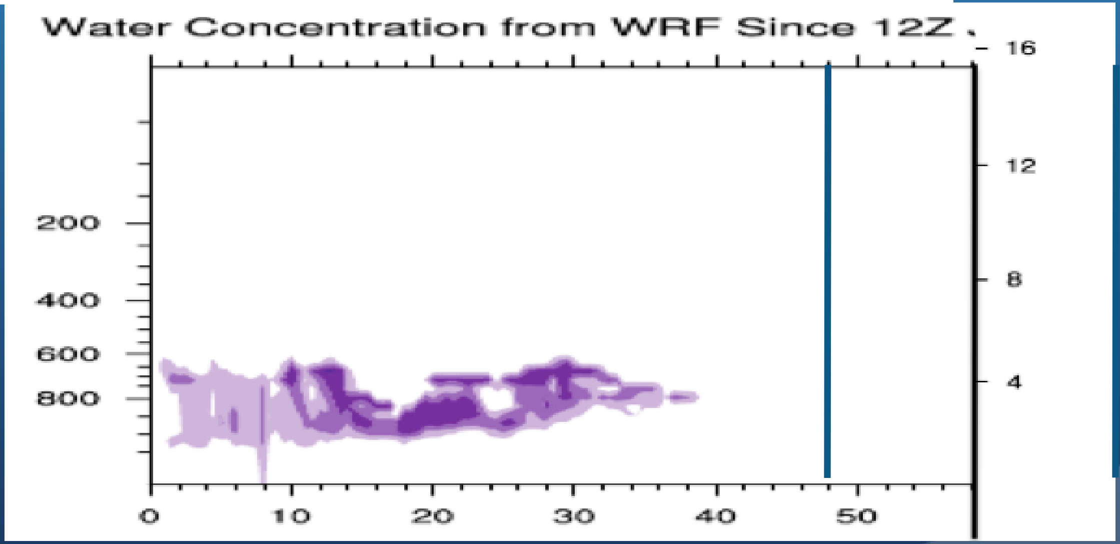


Results: Cloud Properties

Model vs Observed Liquid water profiles



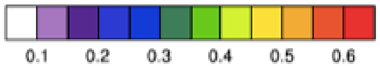
Microbase



WRF

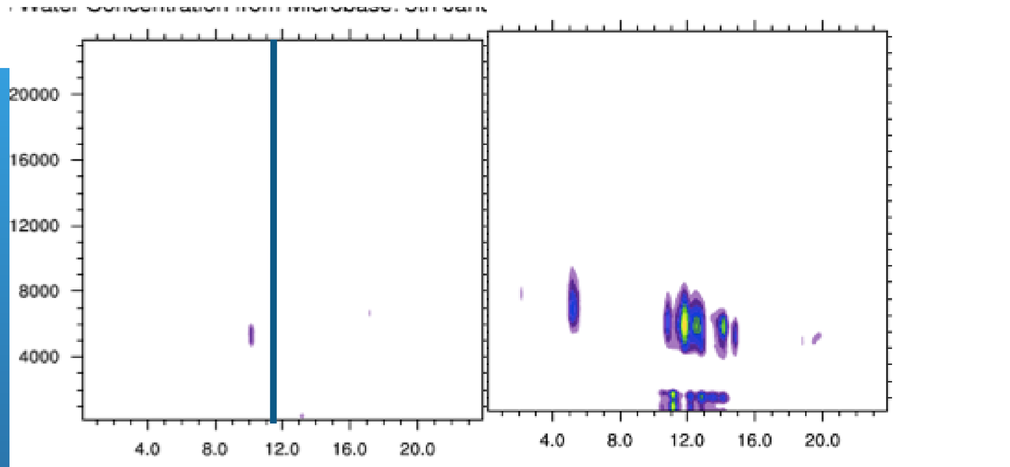
Results: Cloud Properties

Model vs Observed Ice water profiles

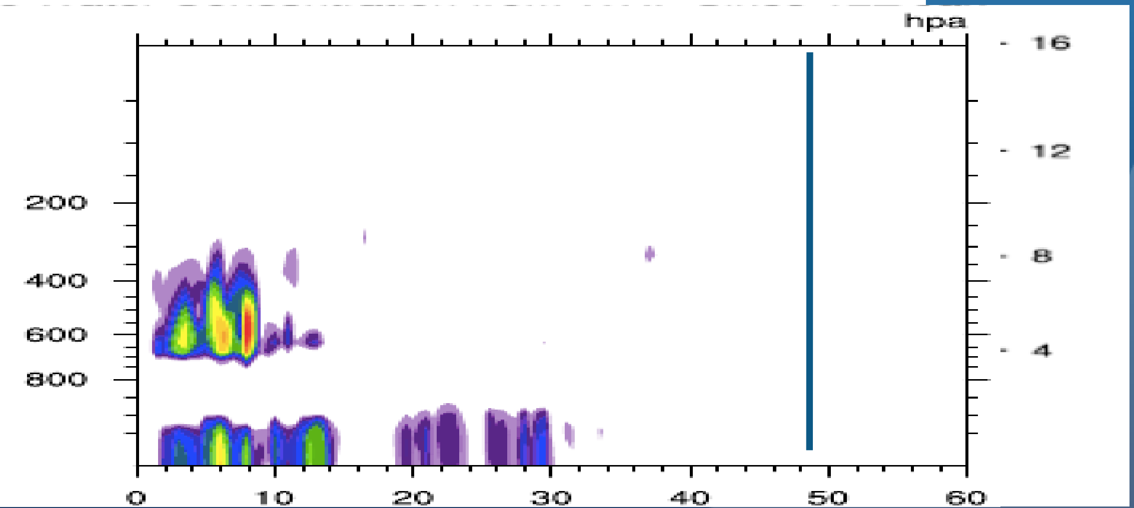


Ice Water Concentration from 12Z 4th January

Microbase



WRF



Conclusions

- This study examined model-observation consistency across a range of variables for a winter weather event
- WRF captures some elements of the event very well, including temperature and moisture profiles and cloud cover and precipitation, particularly in the first 12 hours of the simulation when FDDA was applied.
- WRF shows some discrepancies with observations in cloud composition and microphysics, surface precipitation phase and the evolution of the precipitation event.
- Despite FDDA, upper level winds show large errors, although surface winds are more consistent with observations. This may be a consequence of initial and boundary conditions. In addition, errors in cloud evolution may also arise from the initial and boundary forcing.

Further Work

- Examine accuracy of input data and the effectiveness of FDDA across a range of timescales.
- Reexamine the case with different microphysics schemes and PBL schemes, both of which can exert large influences of simulated cloud properties.
- Quantitative evaluation of the model simulation
- Examine relationship between cloud microphysics variables, precipitation phase and larger scale environment for a range of similar winter systems with varied intensity (e.g. drizzle events up to heavy convective events).

Acknowledgements: