Model evaluation of aerosol wet scavenging in deep convective clouds based on observations collected during the DC3 campaign

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ASR working group meeting – CAPI breakout
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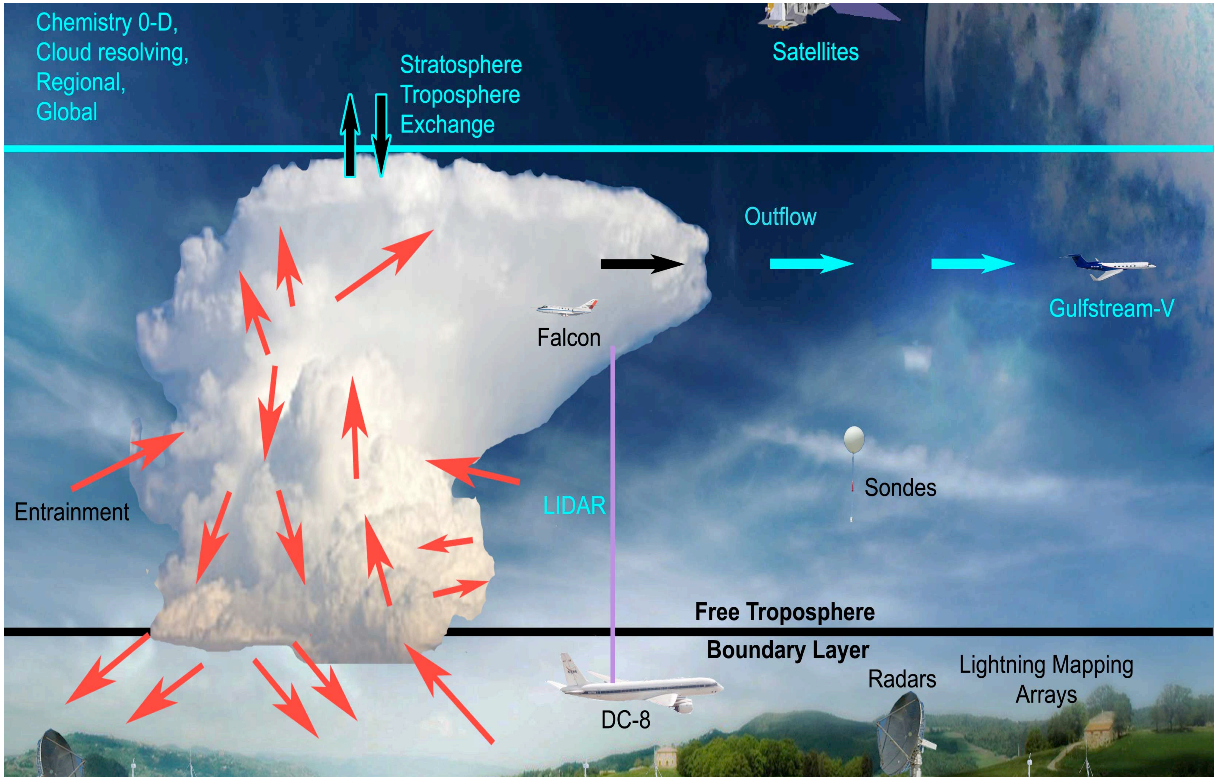
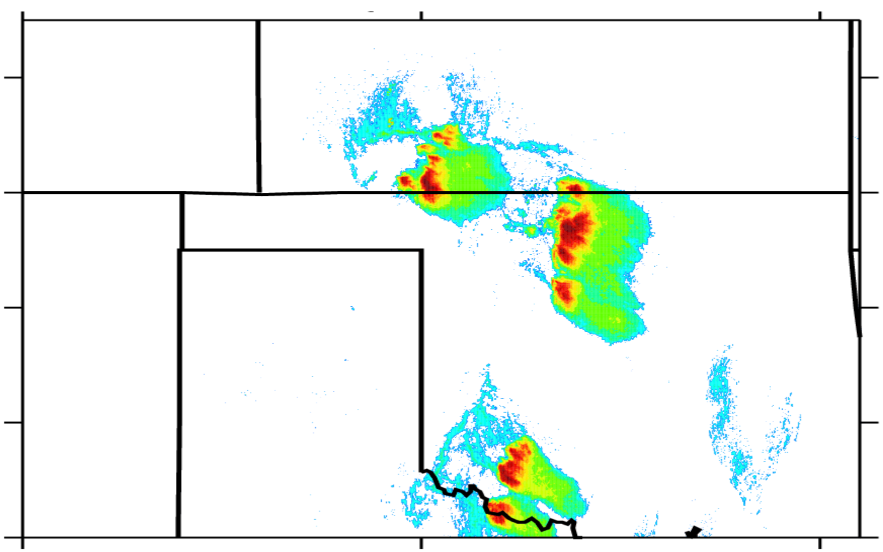


- Storms greatly influence the vertical distribution of aerosols through transport and wet scavenging
- Model representation of wet scavenging is a major uncertainty in simulating the vertical distribution of aerosols

Introduction

- The effect of wet scavenging on ambient aerosols in deep mid-latitude continental convective clouds
  - a severe storm case over Oklahoma on May 29, 2012 during the Deep Convective Clouds and Chemistry (DC3) field campaign.



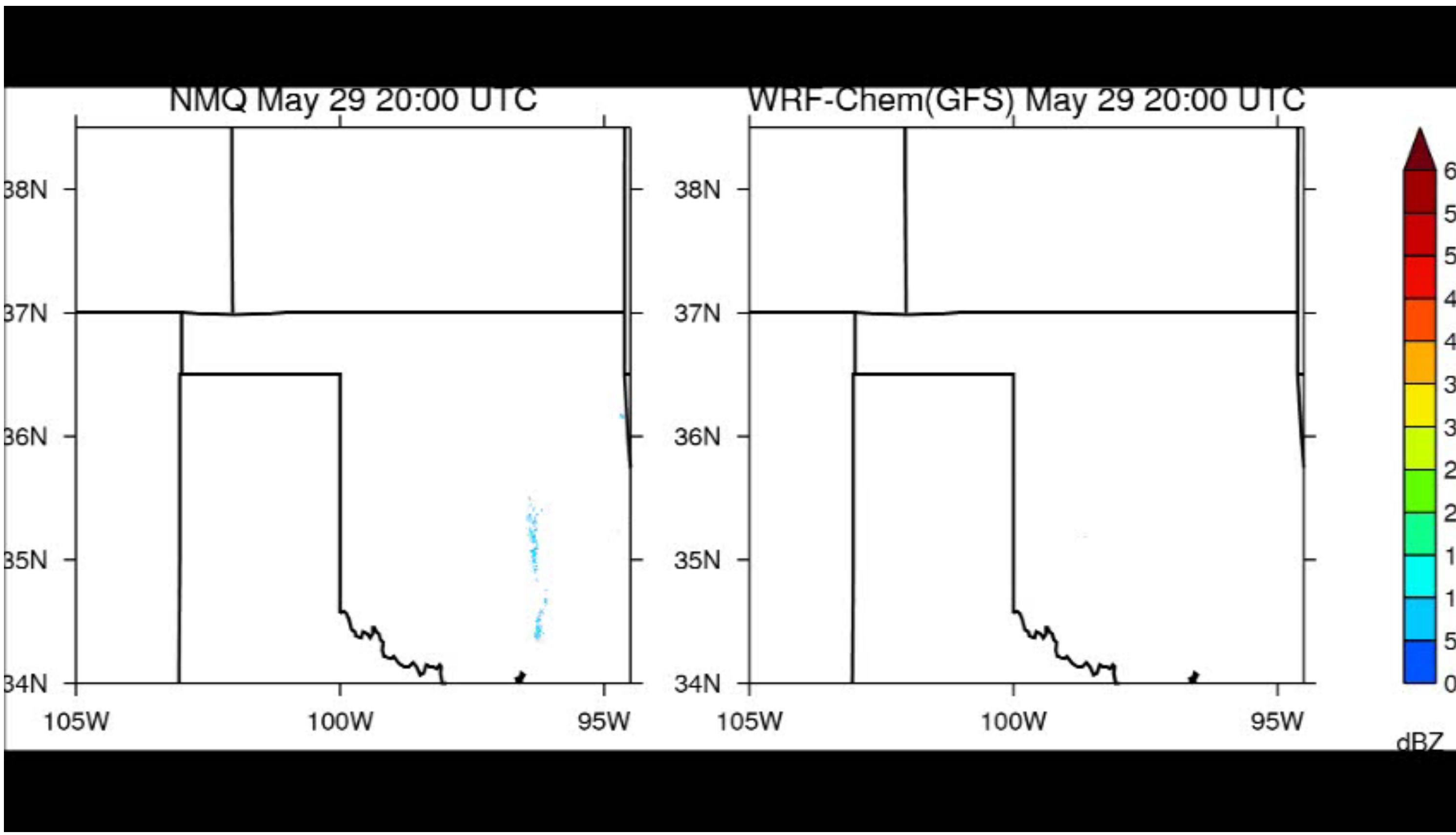
Observed column maximum reflectivity on May 29 23:00 UTC

WRF-Chem configuration

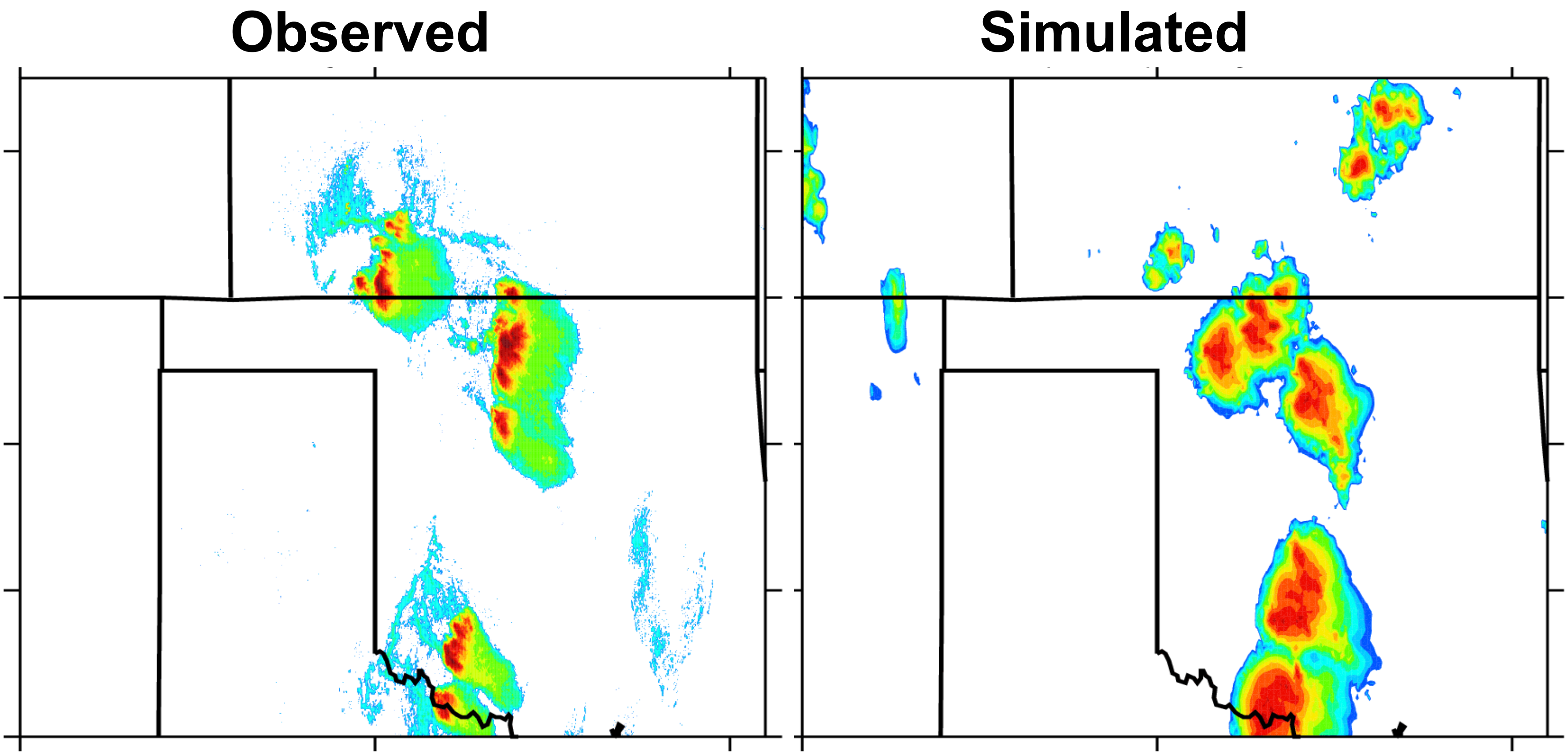
- The Model for Simulating Aerosol Interactions and Chemistry (**MOSAIC**) with a 8-bin sectional approach.
- An advanced volatility basis set (**VBS**) treatment of secondary organic aerosol formation
- The VBS is coupled to **SAPRC-99** gas-phase chemistry mechanism to model gas-particle partitioning and multiple generations of gas-phase oxidation of organic vapors.
- Meteorology is nudged with **GFS** data until six hours before the storm. The gas and aerosols observed before the storm initiation were used as initial (six hours before initiation time) and boundary conditions.

Column maximum reflectivity

Observed **Simulated**



Column maximum reflectivity on May 29 23:00 UTC



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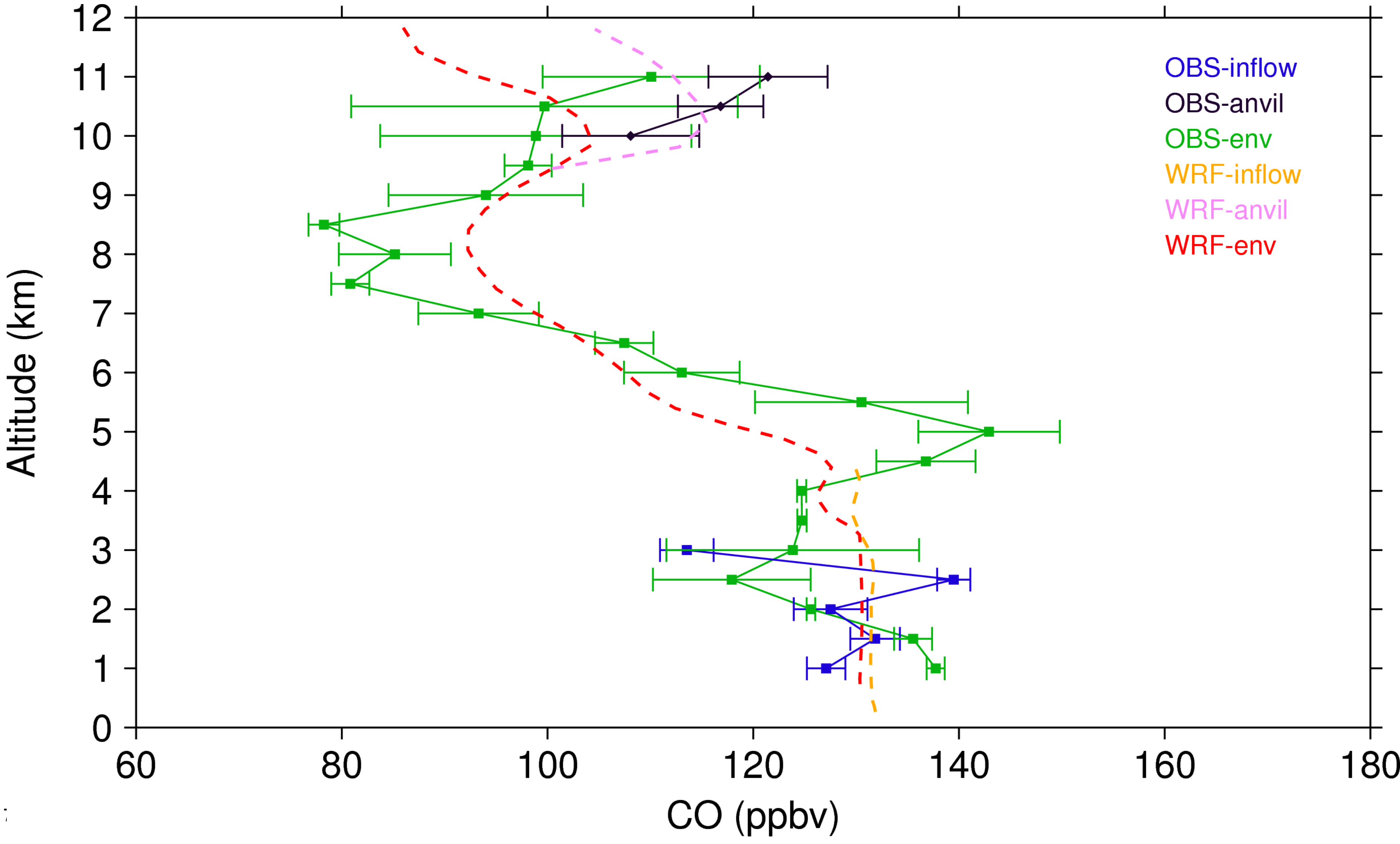
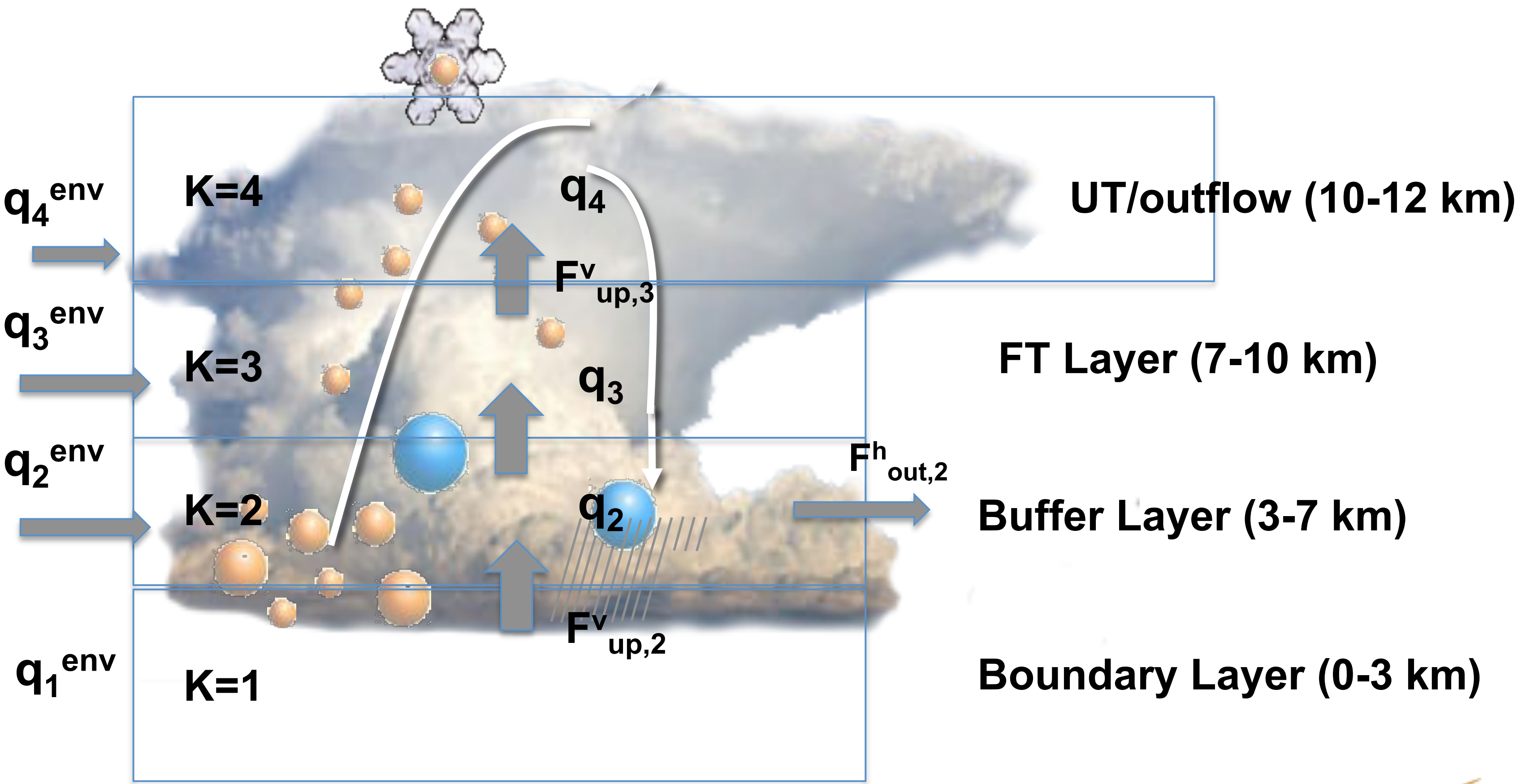
Trace gases

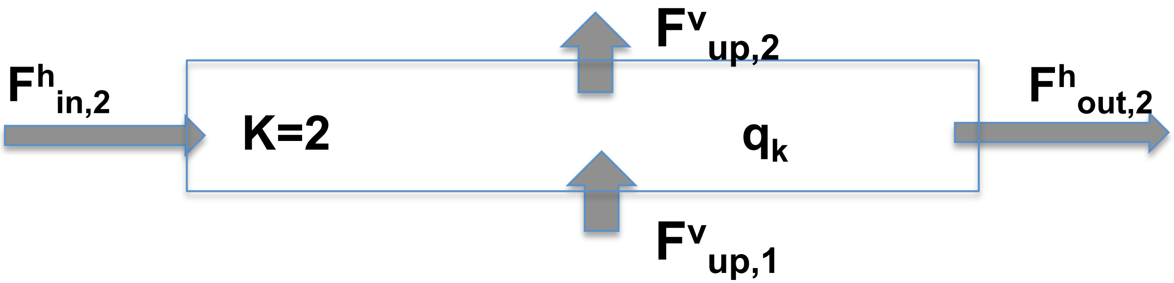


Altitude (km)
CO (ppbv)
OBS-inflow
OBS-anvil
OBS-env
WRF-inflow
WRF-anvil
WRF-env
0
1
2
3
4
5
6
7
8
9
10
11
12
60
80
100
120
140
160
180

Transport budget framework



Transport budget framework



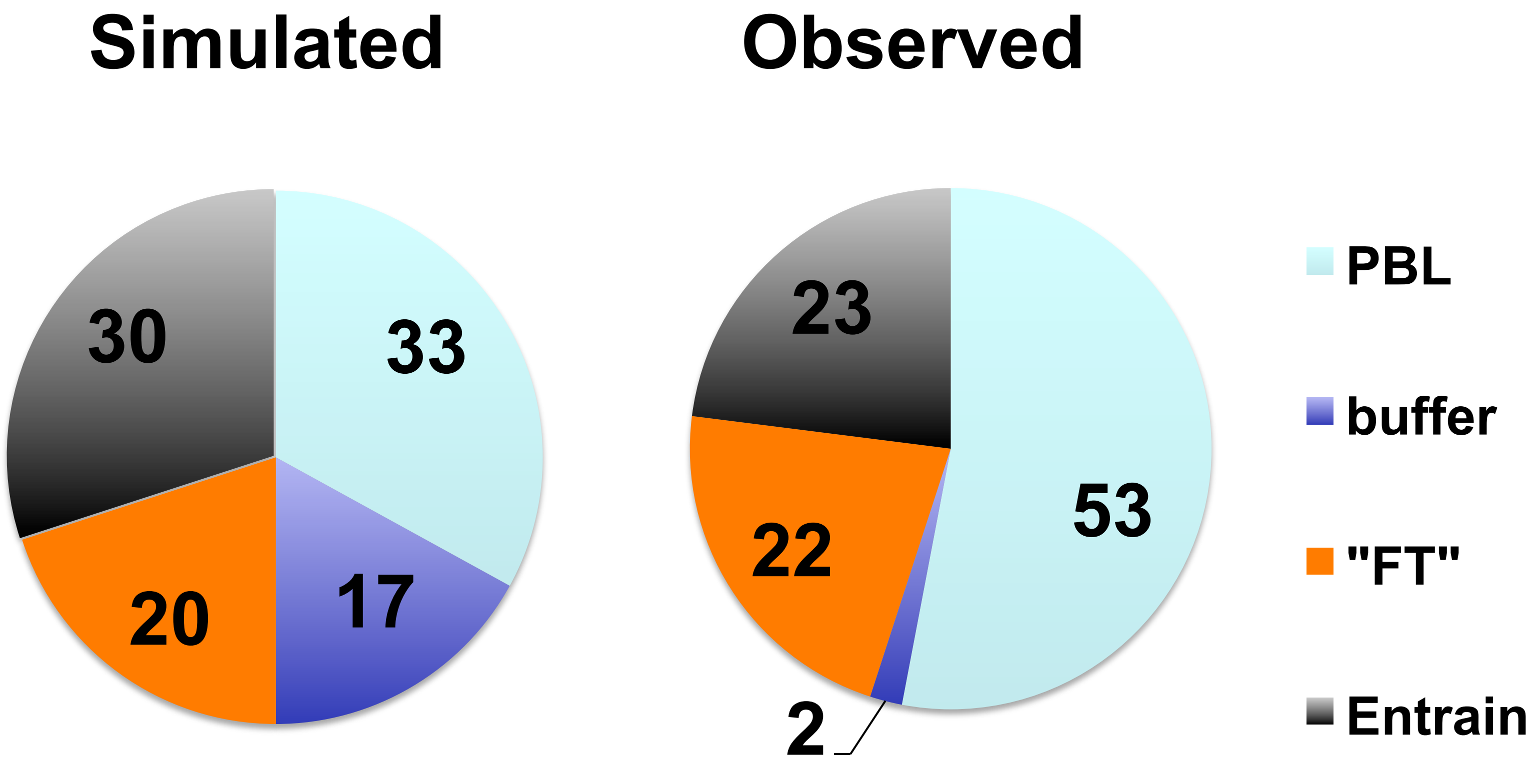
$$F^h_{in,k} + F^v_{up,k} = F^h_{out,k} + F^v_{up,\ k+1}$$

$$q^{env}_{in,k} * F^h_{in,k} + q_{k-1} * F^v_{up,k} = q_k \left(F^h_{out,k} + F^v_{up,\ k+1}\right)$$

$$\beta_k = \frac{F^h_{in,k}}{F^h_{out,k} + F^v_{up,k+1}}$$

$$q_4 = \underline{\beta_4} * q^{env}_{in,4} + \underline{(1-\beta_4)*\beta_3} * q^{env}_{in,3} + \underline{(1-\beta_4)*(1-\beta_3)*\beta_2} * q^{env}_{in,2} + \underline{(1-\beta_4)*(1-\beta_3)*(1-\beta_2)} * q^{env}_{in,1}$$

Transport feature



Wet scavenging estimate

$$q_4 = \underline{\beta_4} * q_{in,4}^{env} + \underline{(1-\beta_4)*\beta_3} * q_{in,3}^{env} + \underline{(1-\beta_4)*(1-\beta_3)*\beta_2} * q_{in,2}^{env} + \underline{(1-\beta_4)*(1-\beta_3)*(1-\beta_2)} * q_{in,1}^{env}$$

Using the know β_k values, the aerosol concentrations at the anvil (q_4) can be calculated using the equation above, which assumes "inert behavior" of aerosols.

Wet scavenging efficiency:

$$\xi = 1 - \frac{q_{anvil}(derived)}{q_{anvil}(observed)}$$

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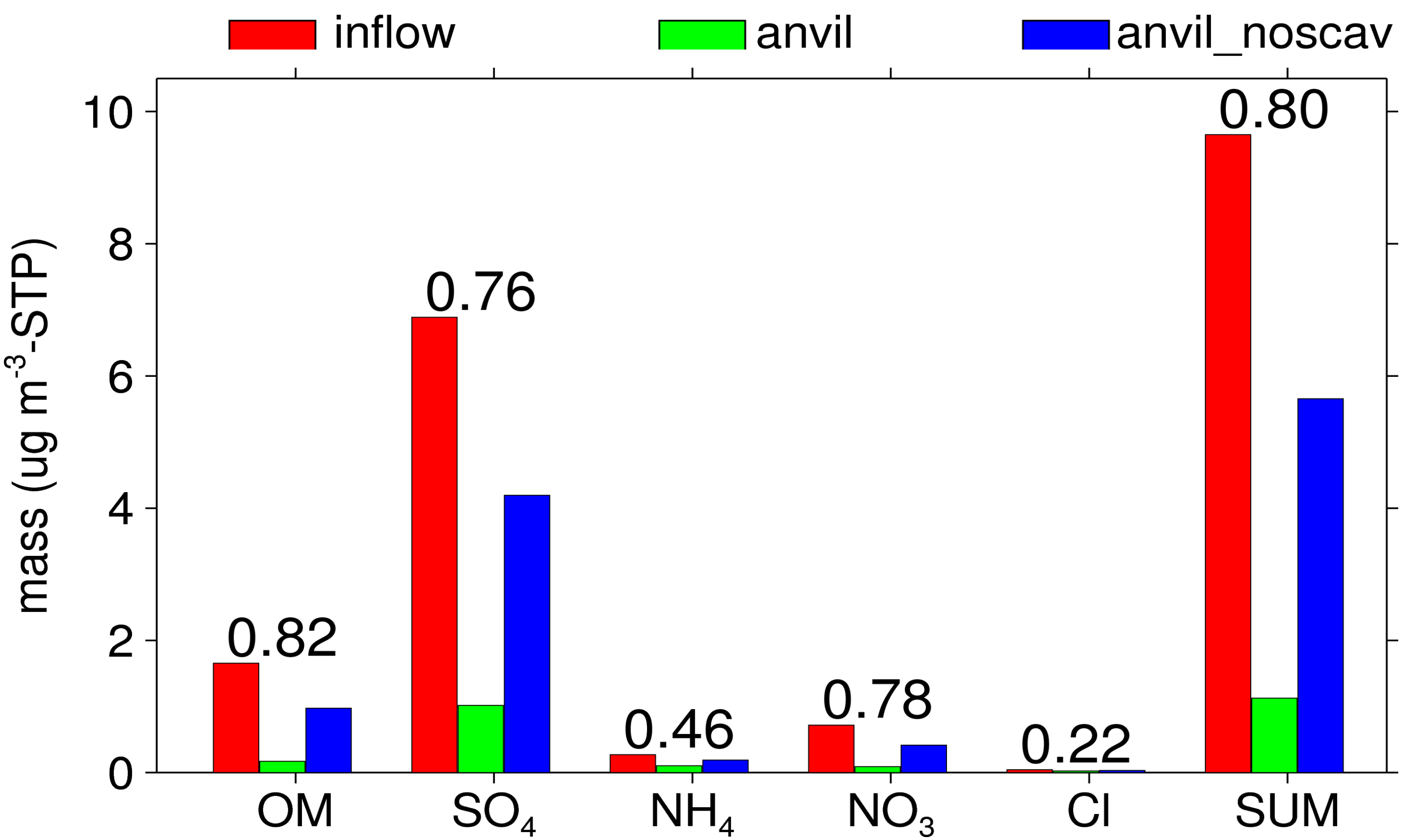
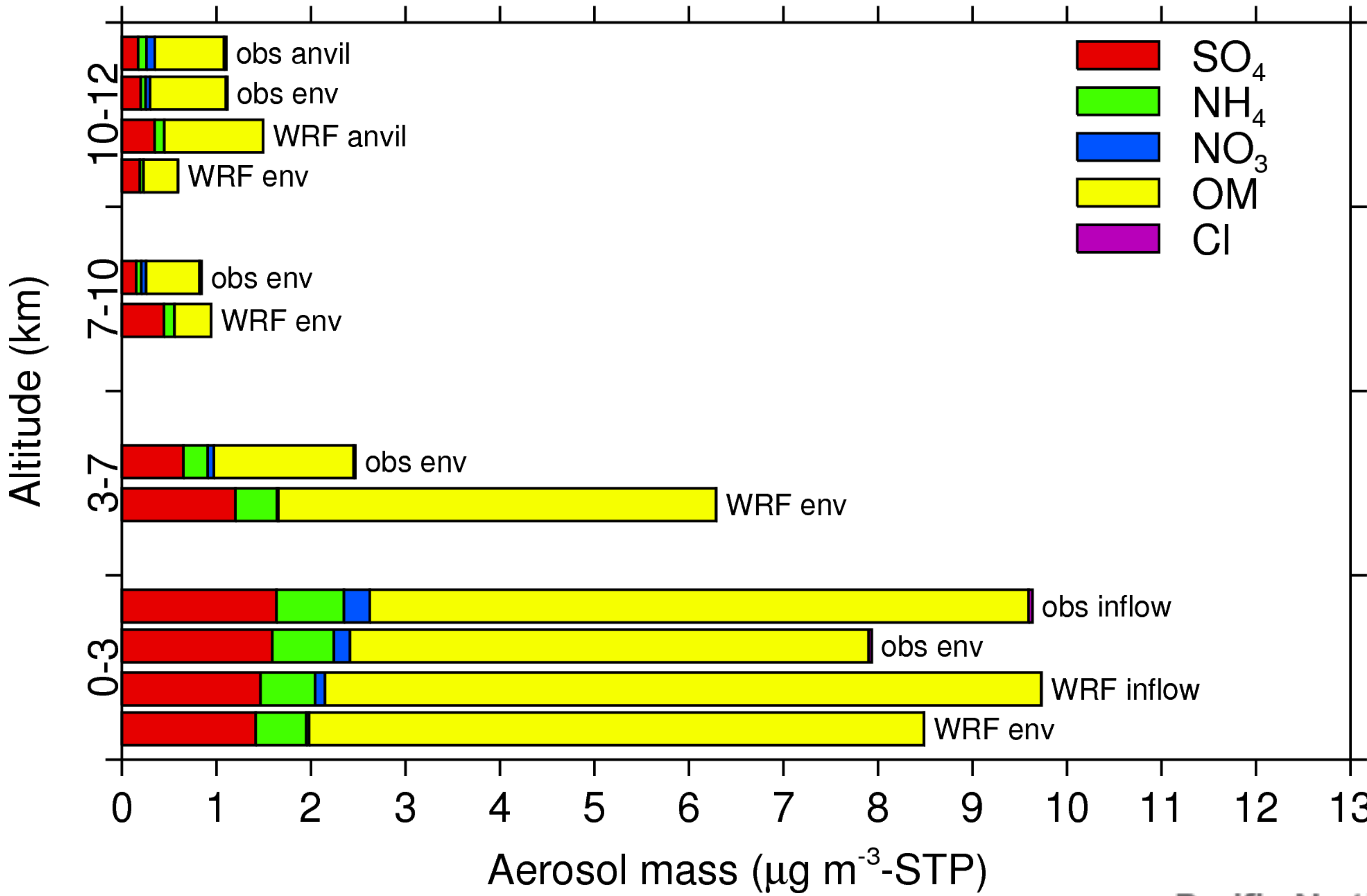
Observed aerosol concentrations at the inflow and anvil and the estimated wet scavenging efficiencies



Comparisons of AMS observed and simulated Dp <1μm aerosol mass



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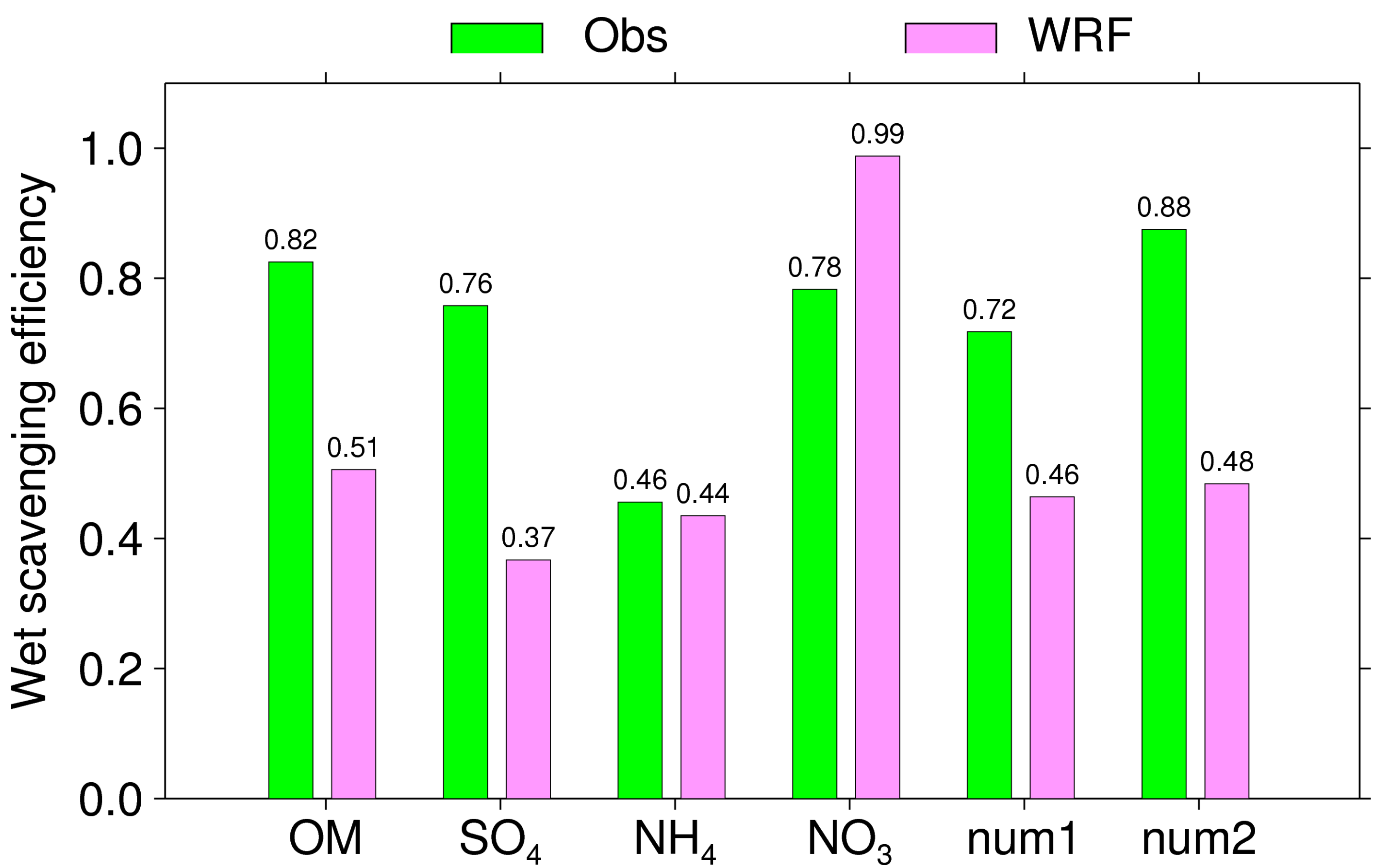
Wet scavenging efficiency



Masses: Dp <1µm.
Num1 and num2: Dp = .03-.15 and .15-2.5 µm

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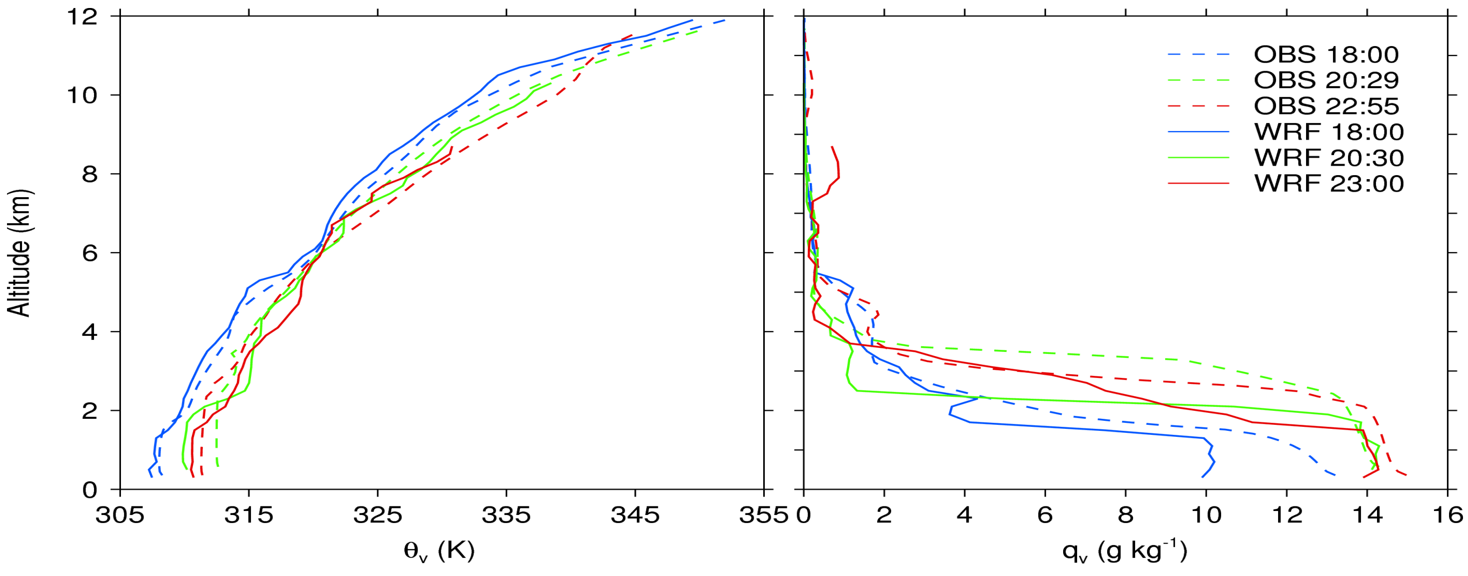
Summary

- A new budget analysis approach estimates that 50%, 2%, and 23% of the "inert" gas in the anvil came from PBL, buffer layer, and entrained in the UT, respectively. Model simulates similar inert gas enhancement in the anvil as observed but with a larger contribution from buffer layer (17%) and a smaller contribution from PBL (30%).
- High scavenging efficiencies (~80%) for aerosol number (Dp<2.5μm) and mass (Dp<1μm) are obtained from the observations. There is little chemical selectivity to wet scavenging, and slightly higher scavenging efficiency is found for larger particle sizes (0.15-2.5μm versus 0.03-0.15 μm). The scavenging efficiency is comparable between aerosol mass and number.
- The model underestimates the wet scavenging efficiency, in general, which is quite likely due to neglect of secondary activation above cloud base, which will be implemented.
- It is challenging to estimate transport and wet removal for a convective storm due partly to the uncertainties and limitations in the measurement data (e.g., no wet deposition) and the analysis approach.
- On-going and future work also includes adding new treatment of ice-borne aerosol to improve the representation of aerosol wet scavenging, and evaluate the sensitivity of aerosol wet scavenging to different microphysical schemes.

Humidity and temperature profiles



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