# Quantifying the Transport of Air into Mesoscale Convective System Updrafts

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## Introduction

An MCS (Mesoscale Convective System) is defined as a thunderstorm with a continuous precipitation region at least 100 kilometers in the horizontal direction (AMS Glossary).

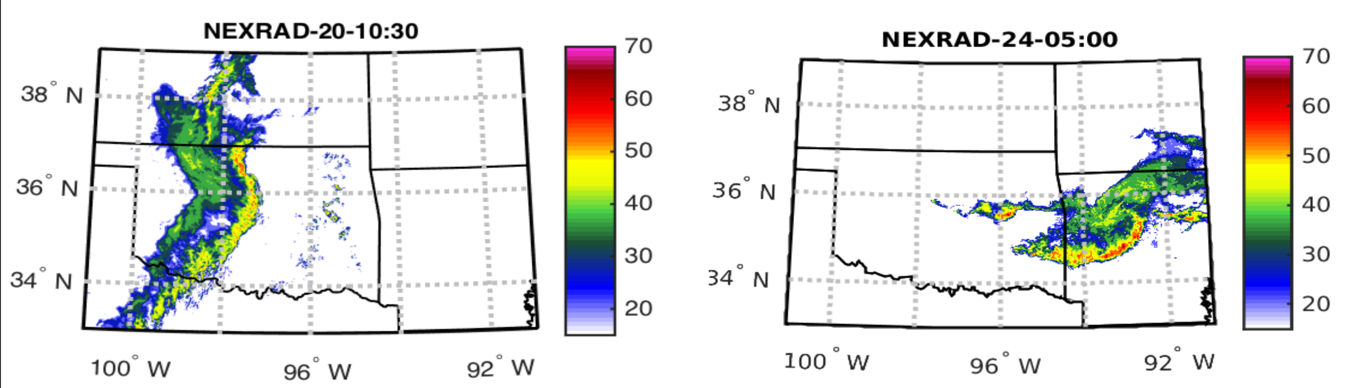
Air has distinct characteristics at different levels throughout the atmosphere. It's known that air near the surface enters into MCS updrafts, but what about air from the mid-levels? The characteristics of air in these layers, such as the dryness of the layer or the aerosol content, could impact the MCS microphysics and dynamics.

Scientific Question: **How much mid-level air is getting into MCS updrafts?**

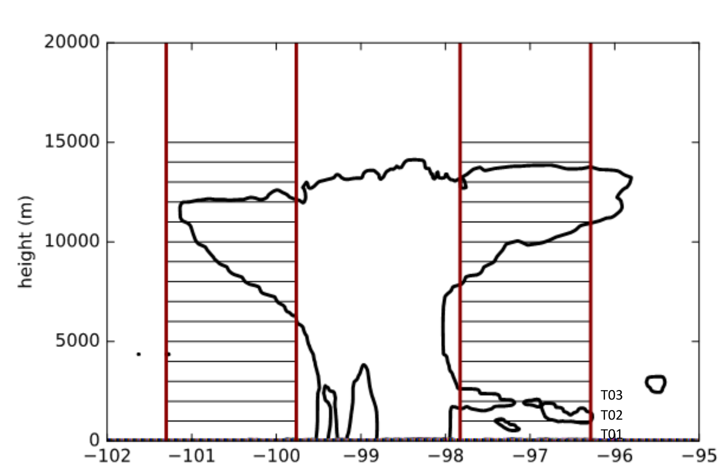
## Methods

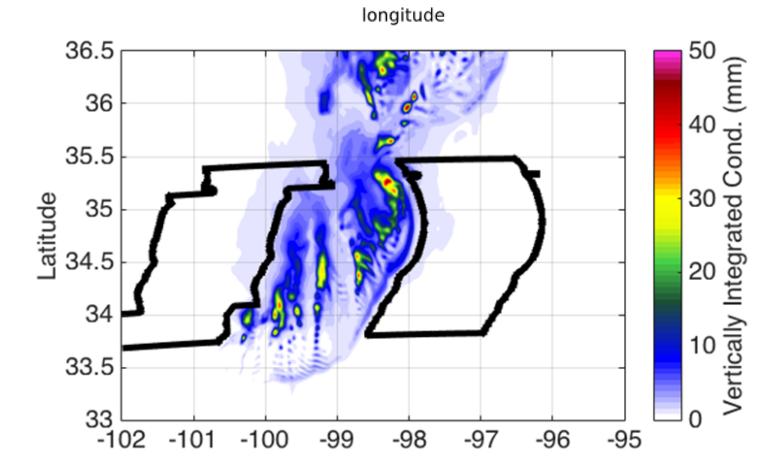
The Regional Atmospheric Modeling System (RAMS)[1] was used to simulate two cases from the Mid-latitude Continental Convective Cloud Experiment (MC3E)[2,3]: May 20, 2011 and May 23-24, 2011.

*Figure 1. NEXRAD radar reflectivity (dBZ) at 2.5 km above ground for (left) 20 May at 10:30 UTC and (right) 24 May at 05:00 UTC*




The RAMS simulations utilized are described in Marinescu et al. (2016). They used 1.2 km horizontal grid spacing and vertical grid spacing of 75 m near the surface, stretched to 500 m near 4 km above ground level. For the study here, these simulations were restarted during the MCS mature stages and run for 2 hours. Tracers were placed in front and behind the MCS at multiple altitudes to study air transport within MCSs.





### Tracer Initialization

There were 16 tracer heights, each 1km in the vertical, and 150 km x 150 km in the horizontal (Figures 2 and 3). Each layer was populated with the same total number of tracers.

*Figure 2. (top). Cross section of the 20 May case at 09:00 UTC showing the location of the tracer initialization. Each section is 1km thick and 150 km x 150 km in the horizontal. Total condensate is contoured in black.*

*Figure 3. (bottom). Plan view of the 20 May at 09:00 UTC with vertically integrated condensate contoured and the tracer locations outlined in black.*

## Results: Low vs. Mid-level Tracers

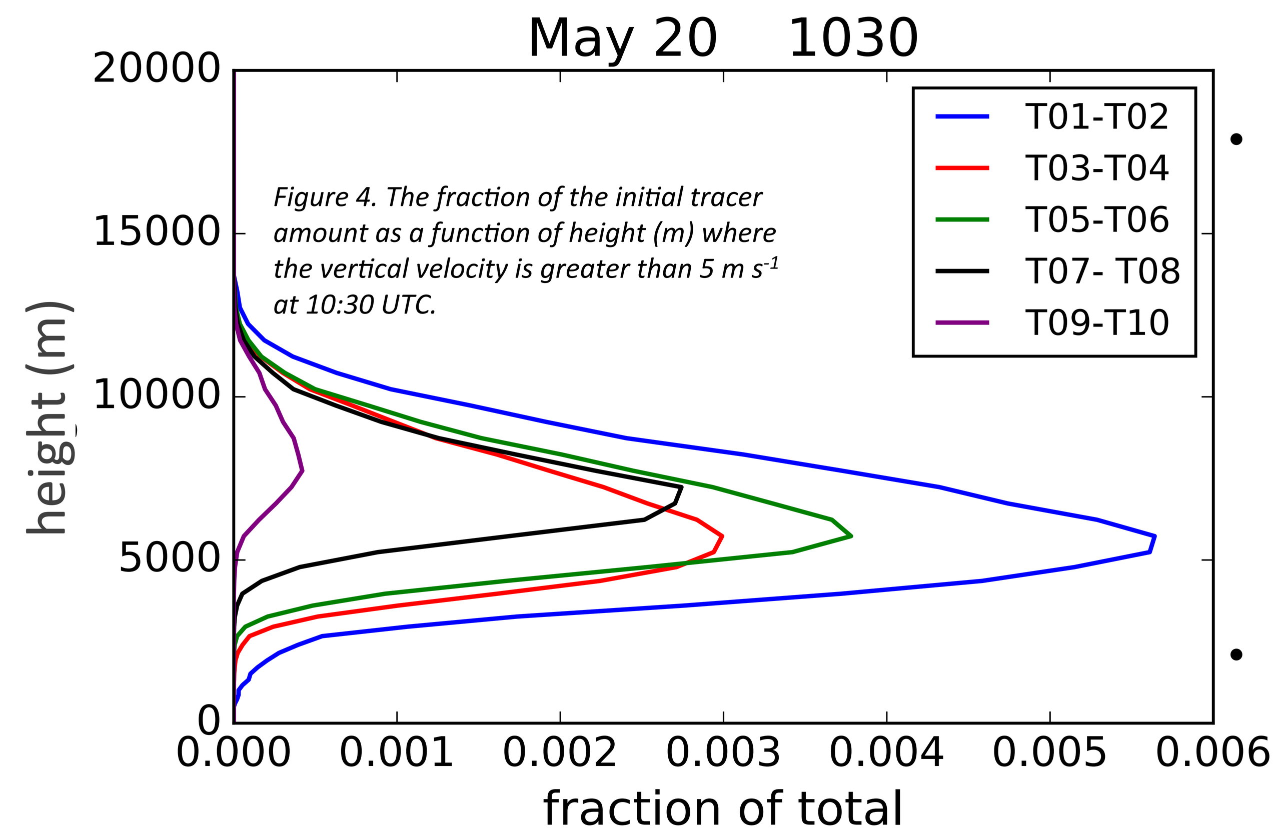



*Figure 4. The fraction of the initial tracer amount as a function of height (m) where the vertical velocity is greater than 5 m s$^{-1}$ at 10:30 UTC.*

- The total quantities of the tracers within the updraft show that 6% of air from the low-levels (T01-T02) and 3% of air from the mid-levels (T05-T06) are contained within the MCS updrafts (w>5 m s$^{-1}$) after 1.5 hours.
- Results from the 24 May case as well as other times show similar results.

- To see how many tracers were entering into the upper regions of the storm the total quantities of tracers between 7 and 8 kilometers were evaluated. It was discovered that in this region there were 1.5 times more low-level tracers than mid-level tracers (Figure 5). This is consistent with our findings when looking at the tracer quantities for al heights.

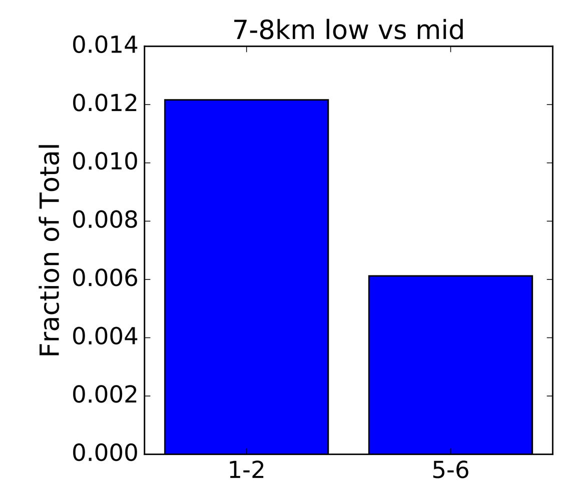



*Figure 5. Bar graph comparison of T01-T02 and T05-T06 between 7 and 8 kilometers on 20 May at 10:30 UTC.*

### Cross sections

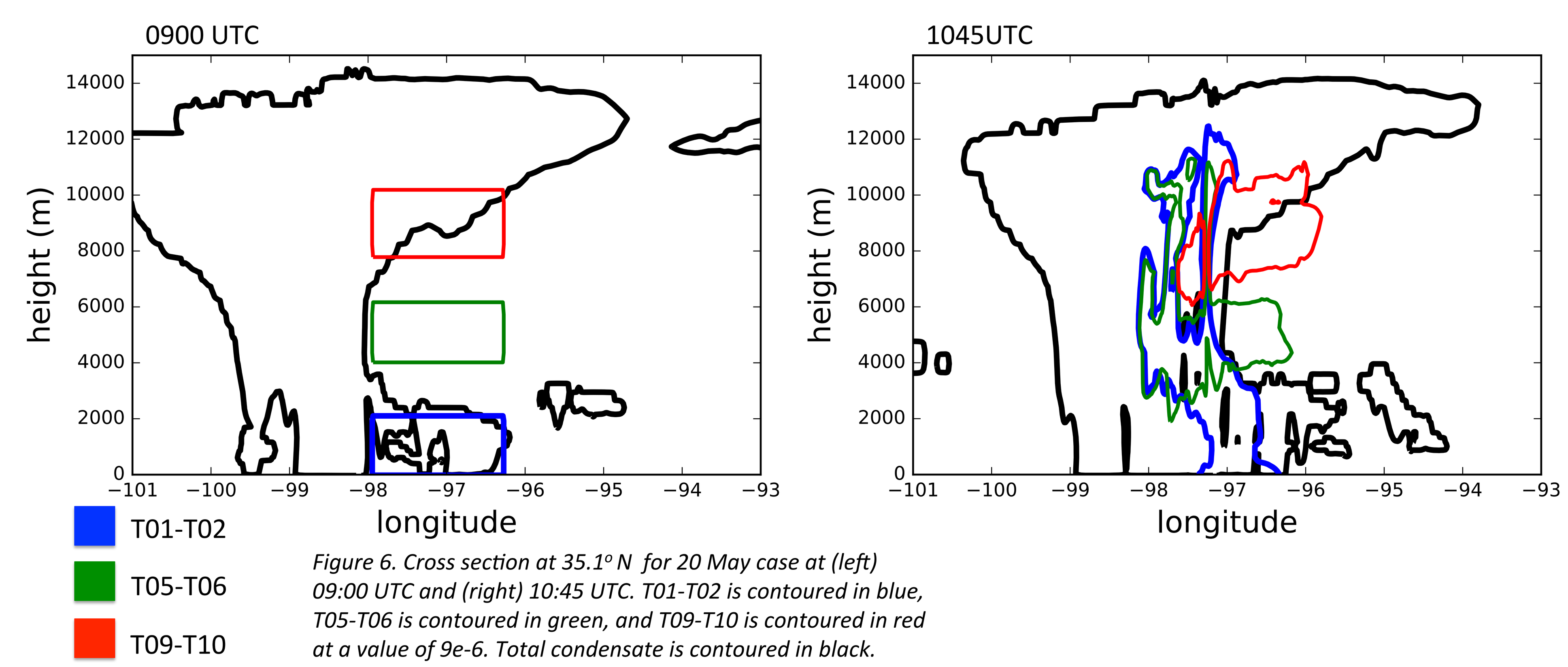



*Figure 6. Cross section at 35.1° N for 20 May case at (left) 09:00 UTC and (right) 10:45 UTC. T01-T02 is contoured in blue, T05-T06 is contoured in green, and T09-T10 is contoured in red at a value of 9e-6. Total condensate is contoured in black.*

## Conclusions

- As expected, more low-level air is within MCS updrafts (6% compared to 3%). This also shows, however that mid-level tracers are present within MCS updrafts in amounts that could have impacts on the microphysics and dynamics of the system.
- Updraft strength and width of the updraft region may impact the amount of mid-level tracers getting into MCS updrafts.

## Future Work

- Analyze tracers placed behind the MCS
- Compare tracers to CCN concentration to determine how many aerosols get activated and where inactivated aerosols end up.

## Results: Case Comparison

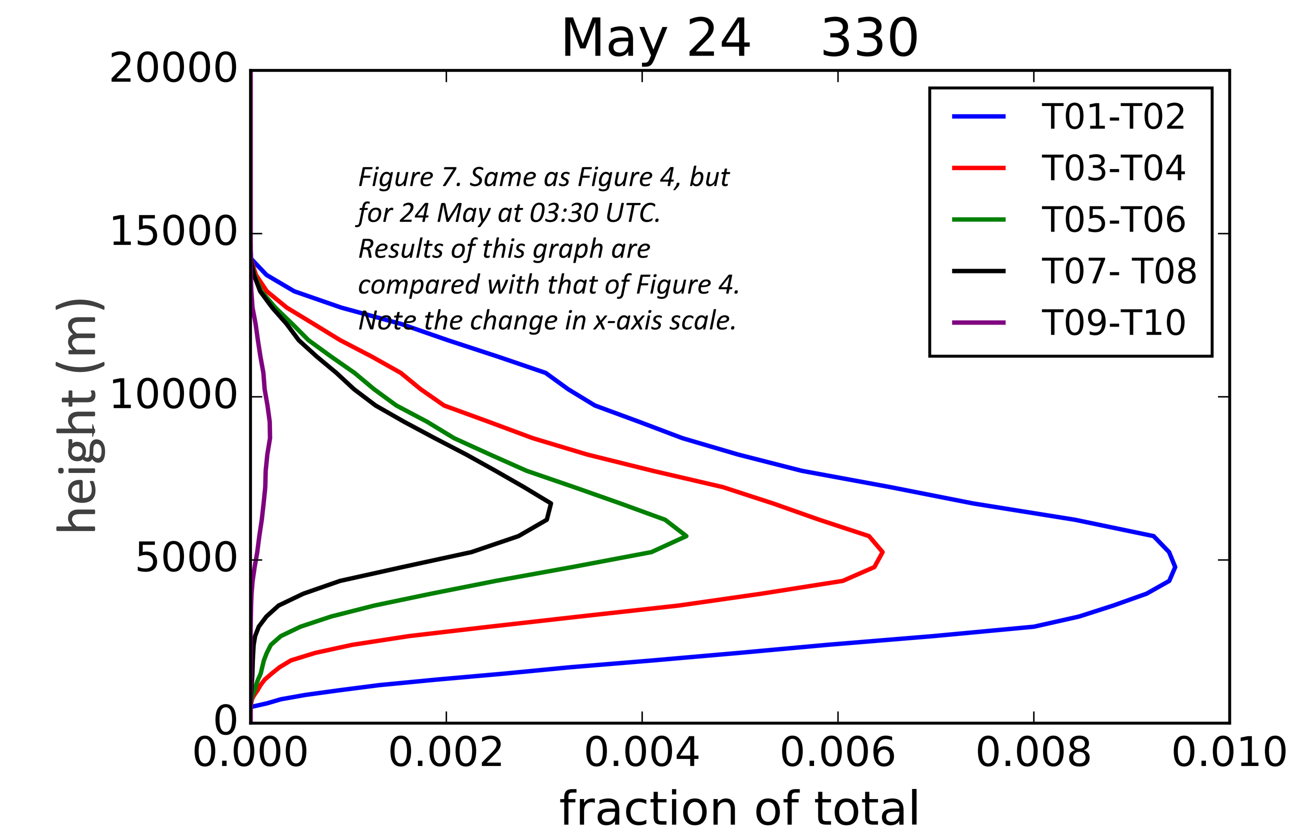



*Figure 7. Same as Figure 4, but for 24 May at 03:30 UTC. Results of this graph are compared with that of Figure 4. Note the change in x-axis scale.*

1) Greater amounts of tracers are observed in the 24 May case.
2) The difference between low-level and mid-level tracers is smaller in the 20 May case i.e. mid-level air provides a larger fraction of the air within updrafts in the 20 May case compared to the 24 May case.

Both of these observations are thought to be partly due to the stronger updrafts as well as the larger updraft region in the 24 May case which has significantly more updrafts than 20 May case (Figure 8). The greater amount of tracers observed within the convective line in the 24 May case were also partly due to the northern advection of tracers by winds in the 20 May case which meant that these tracers did not become entrained into the updraft.

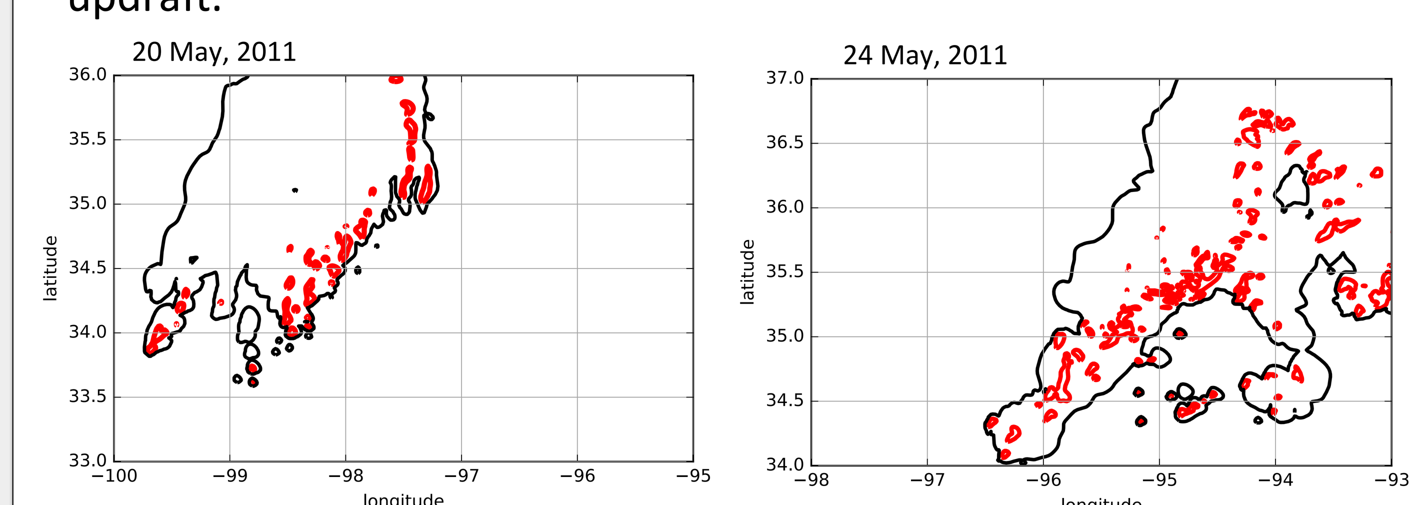



*Figure 8. Plan view plots for (left) 20 May case at 10:30 UTC and (right) 24 May case at 03:30 UTC with vertical velocity greater than 5 m s$^{-1}$ contoured in red. Total condensate is contoured in black.*

## Acknowledgements

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## References

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