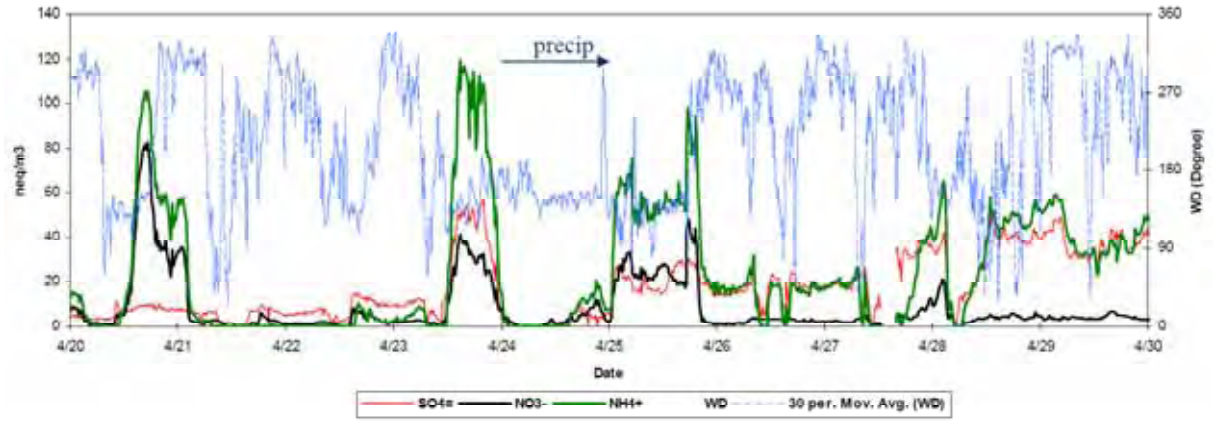
Appendix U

Evaluation of Meteorological Data Grid Resolution
on Airmass Transport Rocky Mountain NP

- The following presentation addresses two questions:
  - How does the simulation of airmass transport to Rocky Mountain NP (ROMO) differ between 36 km and 4 km MM5 wind fields.
  - What implications do these differences have on interpreting source attribution results using 36 km wind fields
- These questions are examined using MM5 wind fields from April 15 through April 30, 2006. This two week period is too short to capture all of the important types of meteorological events influencing air quality at Rocky Mtn. NP, but it does contain the typical westerly transport as well as several upslope events.

ROMO Measured Surface Wind Direction and Particulate Ion Concentrations



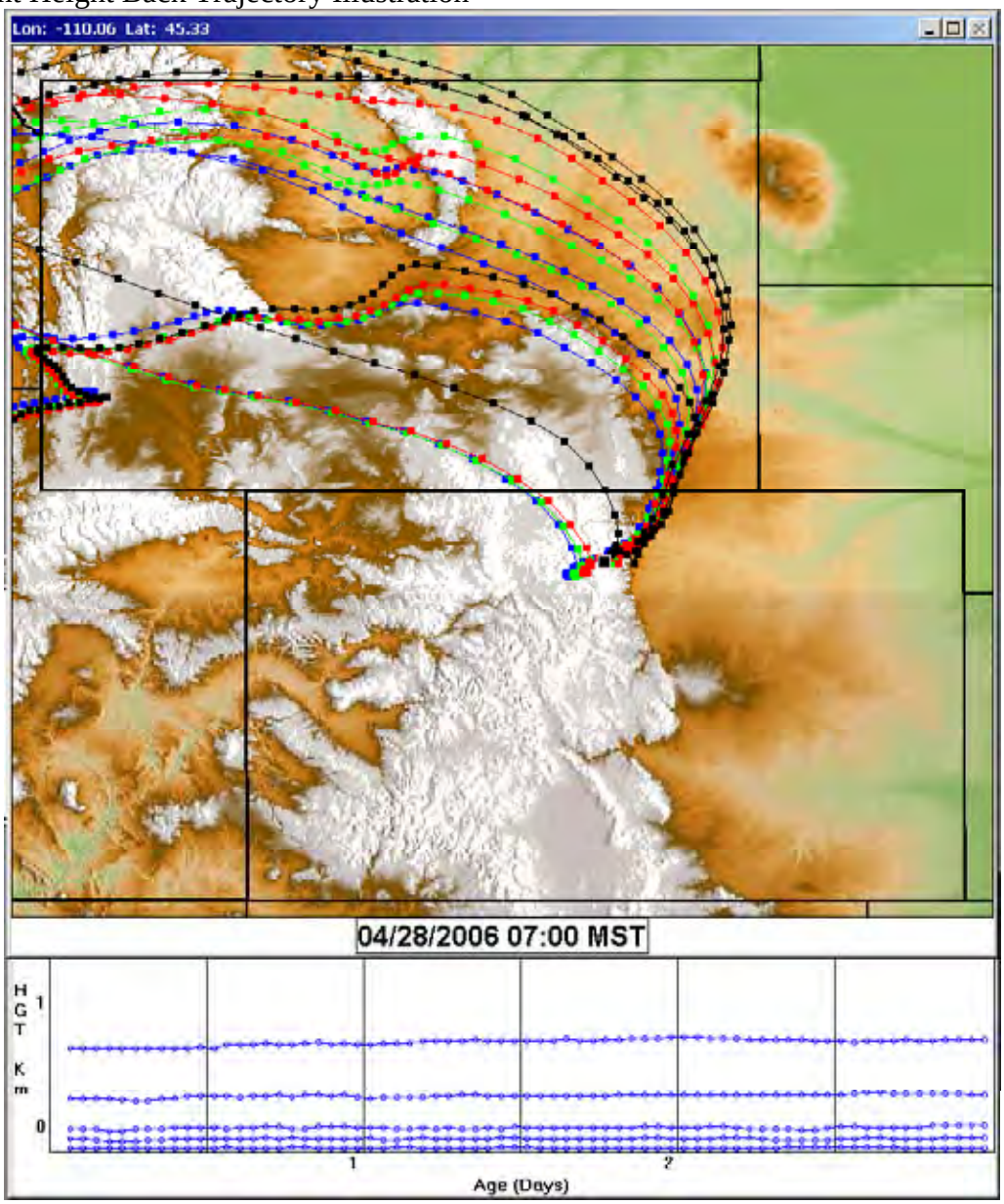
- From April 20-30, 2006 the winds were generally from the west. Three period occurred where the wind direction shifted to the east-southeast; 4/20; 4/23-4/25 and 4/28. This flow was associated with increased nitrate and ammonium concentrations and with the exception of the 4/20 event, increased sulfate. Precipitation at ROMO occurred during the April 25th easterly transport event.

Evaluation of Airmass Transport

- Two airmass transport analyses were conducted. First, back trajectories from the Rocky Mountain IMPROVE monitoring sites, located on the eastern edge of the national park, were calculated separately for the 36 km and 4 km wind fields. The trajectories were calculated for 5 fixed heights above the ground from 10 to 1000 meters. The constant height trajectories allow for the evaluation of the change in transport directions with height above the surface. In order to examine the variation in the back trajectories with the receptor location, the back trajectories were also calculated for receptor sites located 4 km, 8 km, and 20 km east of the Rocky Mountain NP receptor site. The 36 km and 4 km trajectories are compared to identify differences in transport directions.

- The second transport analysis examines the potential for sources located in the Front Range Colorado to impact Rock Mtn NP. This was done by seeding the Front Range with hypothetical sources then calculating the relative impact of the sources on Rocky Mtn NP. Examining only the Front Range sources allows an evaluation of upslope events. This transport simulation was conducted separately for the 36 km and 4 km MM5 wind fields and results compared.

Constant Height Back Trajectory Illustration

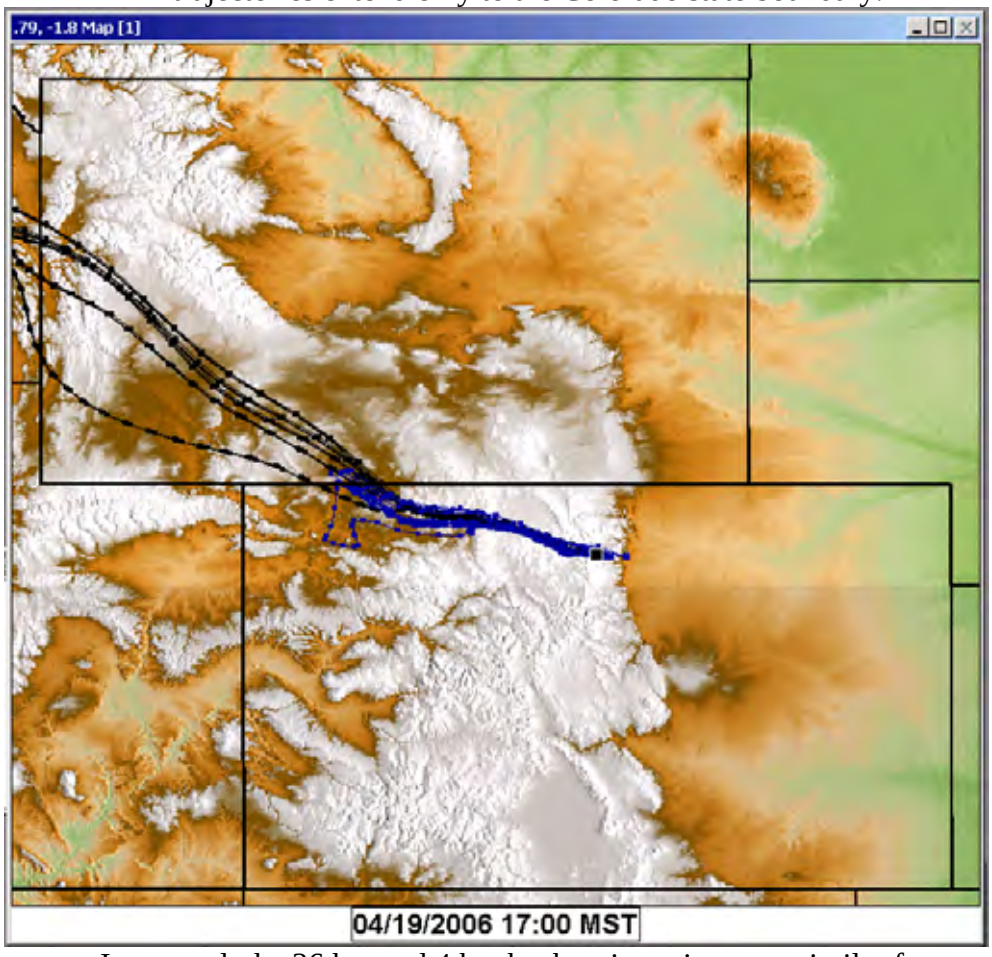


- Three day back trajectories calculated using 36 km wind fields at constant heights from 10 to 1000 m for four receptor sites.
- Blue trajectories are from ROMO, green, red and black trajectories are 4, 8 and 20 km east of ROMO.

- The variation in transport with atmospheric elevation and receptor location east of ROMO is evident on April 18 at 7:00 am. Trajectories released near the ground at all four receptors traverse Southern WY from west to east. The trajectories progressively move northward with increasing elevation at all receptor sites. The trajectories also progressively move northward as the receptor site is moved eastward of ROMO. In all cases the trajectories arrived at the receptors coming from the northeast, similar to that that measured by the ROMO surface winds.

Comparison of Back Trajectories

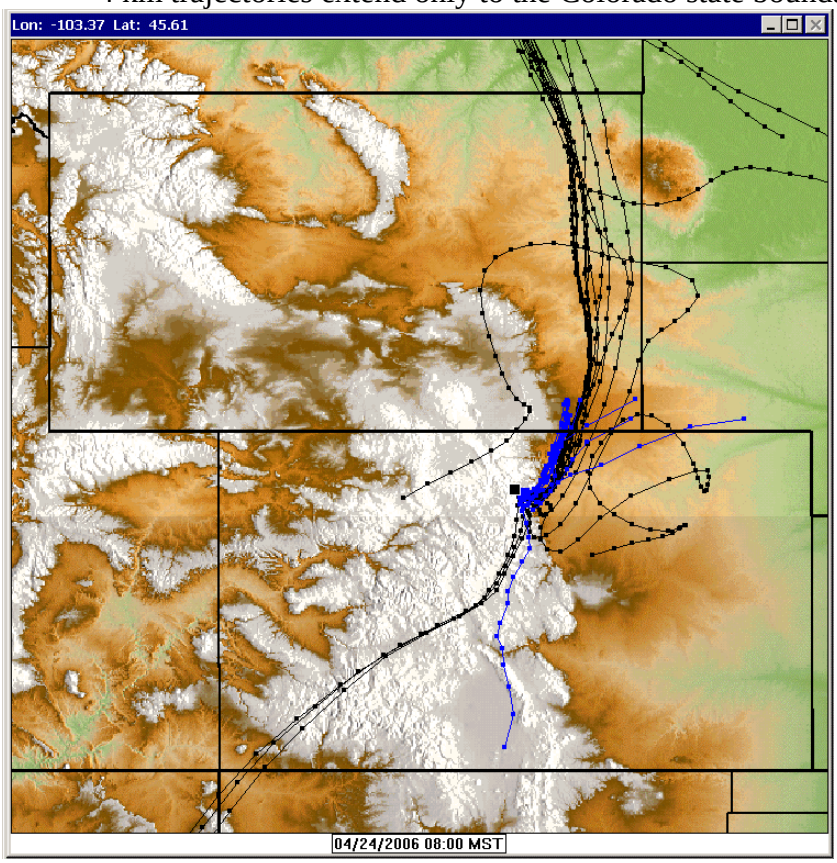
- 36 km trajectories are black, 4 km trajectories are blue
- 4 km trajectories extend only to the Colorado state boundary.



- In general, the 36 km and 4 km back trajectories were similar for transport from the west and north. However, the 4 km trajectories for the easterly most site often showed low level transport from the east while all other trajectories showed westerly transport. This is indicative of a sharp gradient in the low level transport between ROMO and the Front Range. The 36 km winds did have as sharp a gradient.

Comparison of Back Trajectories

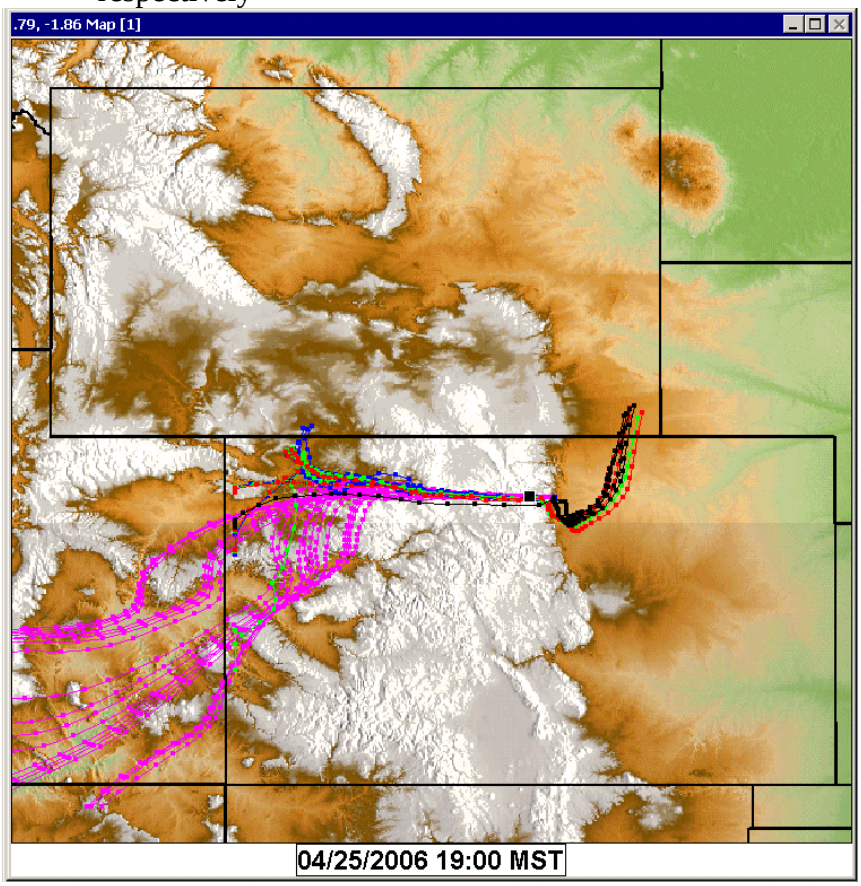
- 36 km trajectories are black, 4 km trajectories are blue
- 4 km trajectories extend only to the Colorado state boundary.



- At times, both the 36km and 4 km trajectories arrived from the east, indicating upslope flow.

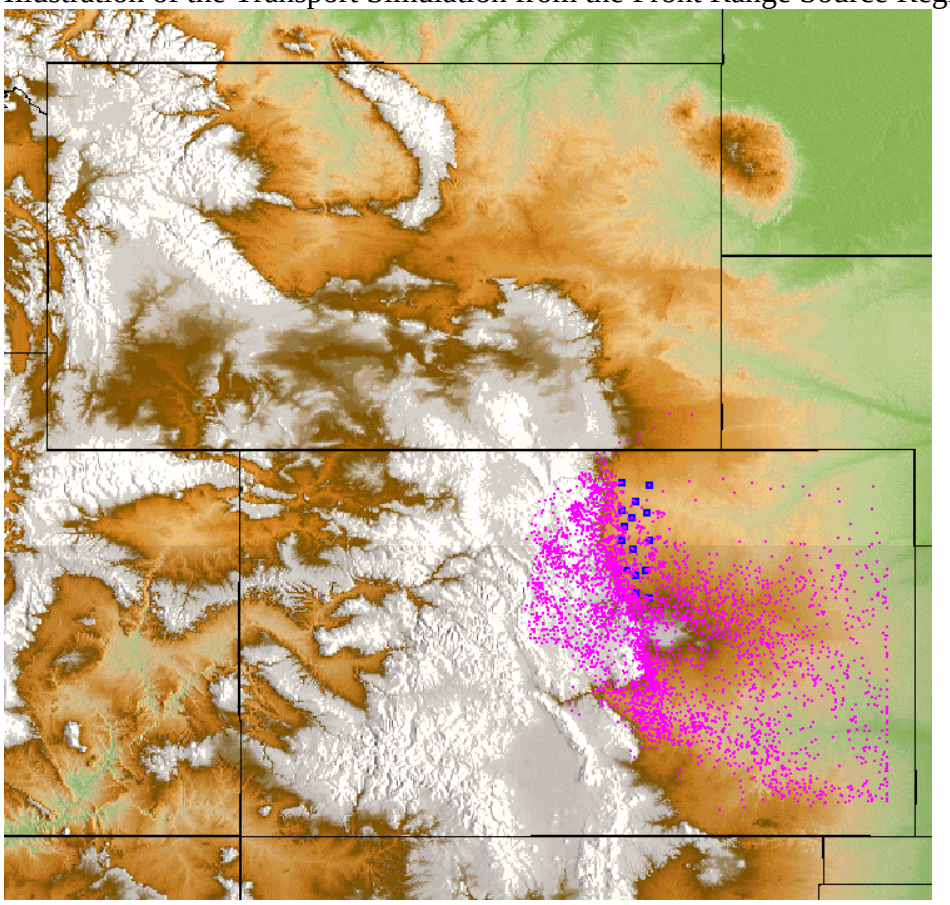
Comparison of Back Trajectories

- 36km trajectories are purple
- 4km trajectories- blue: ROMO, green, red & black, 4, 8 & 20 km E. of ROMO respectively



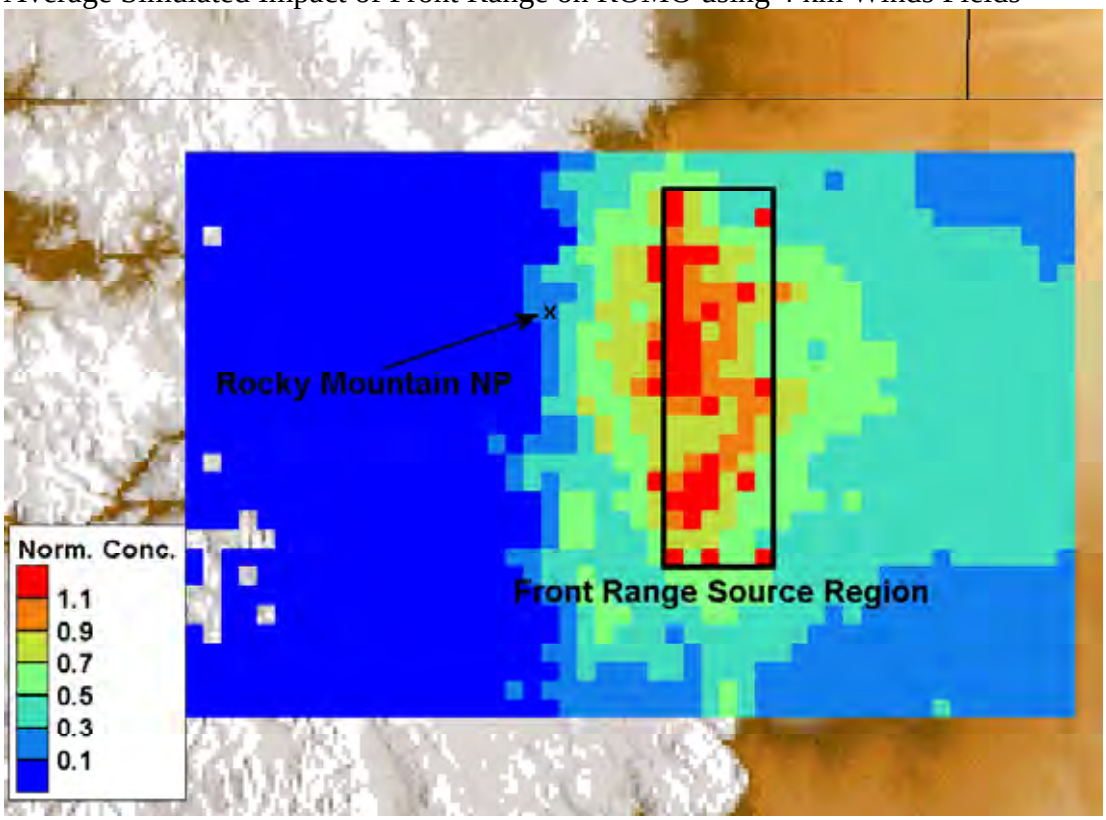
- The 36km and 4 km trajectories could vary considerably under upslope conditions. On April 15, all of the 36 km trajectories arrive from the west while the 4 km trajectories arrive from the east and west.
- Note, the sharp gradient in transport direction for the 4 km trajectories. As the receptor site is moved eastward the more trajectories arrive from the east. There is also an elevation gradient with low level 4 km trajectories coming from the east and higher level trajectories coming from the west.

Illustration of the Transport Simulation from the Front Range Source Region



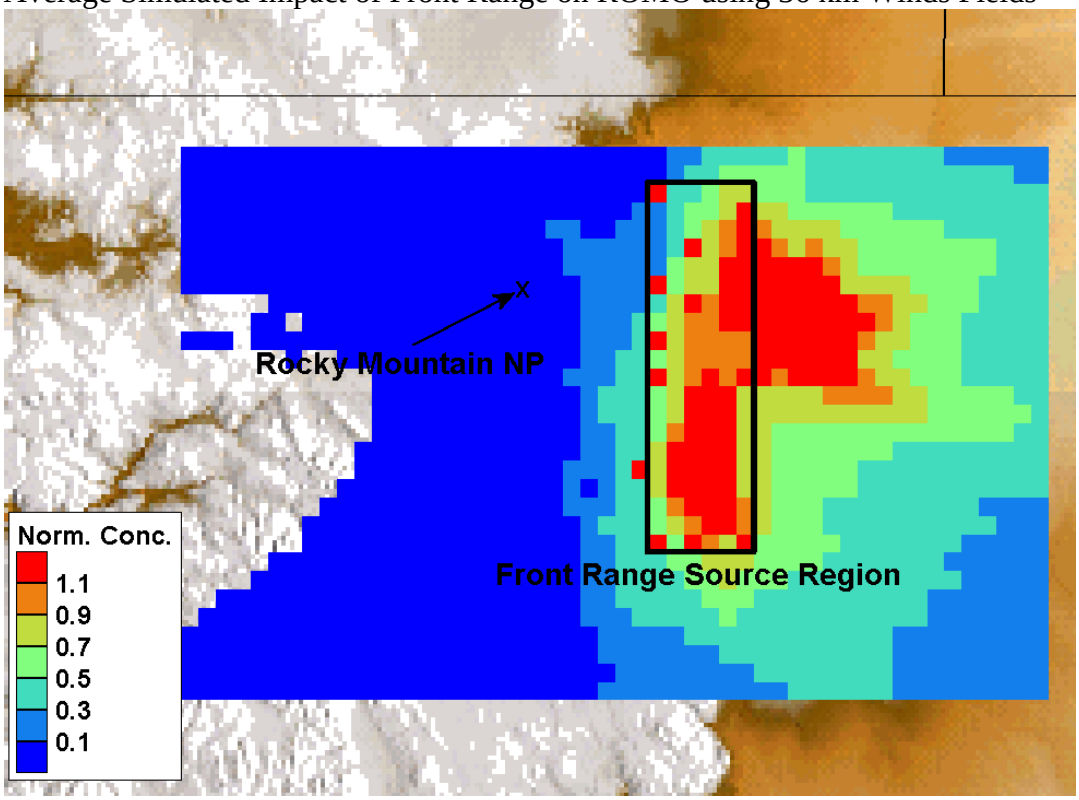
- 17 hypothetical sources from Fort Collins to Colorado Springs were added to the Front Range. Particles were continuously released and tracked for 3 days or until the left the grid.
- The figure shows the location of the particles during an upslope event.

Average Simulated Impact of Front Range on ROMO using 4 km Winds Fields



- At ROMO the average normalized concentrations using the 4 km winds is 0.2.
- West of ROMO the concentrations decrease rapidly to near 0 within a few kilometers.
- East of ROMO there is an increasing gradient and with concentrations doubling to over 0.4 within 10 km.

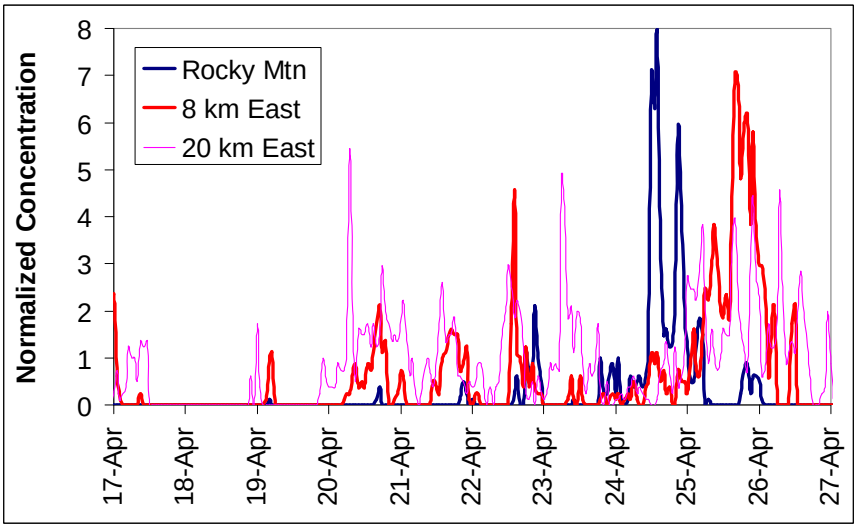
Average Simulated Impact of Front Range on ROMO using 36 km Winds Fields



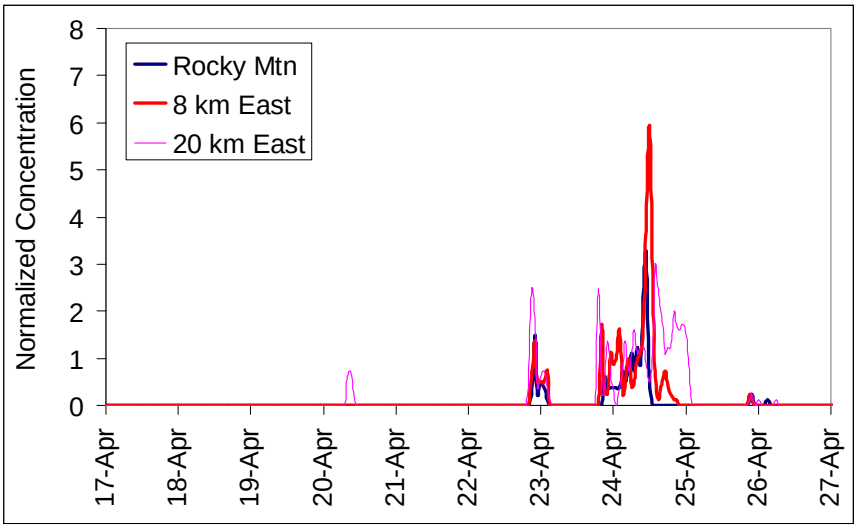
- Using the 36 km wind field the ROMO average normalized concentrations is 0.06 which is a factor of 3.5 smaller than for the 4 km winds.
- The concentrations increase eastward of ROMO, but at a slower rate than for the 4 km wind fields.

Simulated Impact of Front Range Sources on ROMO

4km wind field



36km wind field



- The simulated impact of the Front Range on ROMO occurs more frequently and with higher concentrations using the 4 km winds compared to the 36 km winds. The difference between the two wind fields increases for locations east of ROMO.
- Using the 4 km winds the Front Range impacts the location 8 km east of ROMO 33 % of the time compared to only 11% when the 36 km winds are used.

How does the simulation of airmass transport to ROMO differ between 36 km and 4 km MM5 wind fields?

- The back trajectory analysis and simulation of hypothetical Front Range sources both show that the 4 km wind field produce more easterly upslope flow than the 36 km wind field.
- The eastern edge of the Rocky Mountain NP is a convergence zone for westerly and easterly transport.
  - Virtually no easterly transport occurred for location west of the ROMO IMPROVE site.
  - There was a sharp increasing gradient in the occurrence of easterly transport from ROMO to the Front Range.
- These are preliminary results and conclusions drawn should be used with caution.

What implications do the wind field differences have on interpreting source attribution results using 36 km winds?

- If the wind fields differences for the two week period examined in this analysis are applicable to other time periods, then these results suggest that the 36 km simulation underestimate the contributions from sources east of the ROMO including the Front Range. Since most of the emissions in Colorado occur east of ROMO, this suggests that air quality simulating using 36 km wind fields will underestimate the absolute contributions of Colorado sources to ROMO.
- The impact of underestimating easterly transport to ROMO on the relative contribution of Colorado sources compared to non-Colorado sources is not known.