Convective-Scale Transport of CO and O_3 During a 5-Day Period over the Southern United States

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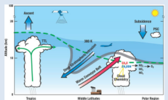
Motivation and Objectives:

Ozone in the UTLS region is important for climate change, for affecting the UV radiation reaching the Earth's surface, and for controlling the production of radicals.

Deep convection alters the composition of the UTLS region. Thus, we want to quantify the transport of CO, O_3, O_3 precursors and tracers to the upper troposphere over the US



Convective transport is simulated better at high resolution where convective systems are explicitly resolved instead of parameterized.

➔Compare high resolution convective transport with parameterized convective transport of chemical constituents and evaluate CO and O_3 results with vertically-resolved TES satellite data

➔Examine the age of the upper tropospheric air since it was transported from the boundary layer

Method:

Simulate the week of August 23-28, 2006 over the southern US and northern Mexico where:

- TES retrievals showed convective signatures with the high vertical resolution nadir view.
- NWS NEXRAD images showed convective activity
- Real-time WRF-Chem simulations showed that WRF simulates the convection
- An upper troposphere anti-cyclone associated with the North American monsoon existed indicating UT air would remain over the southern US – northern Mexico region

→ Simulate at high resolution ($\Delta x = \Delta y = 3$ km) to resolve convective systems explicitly

→ Repeat the simulation using a coarser resolution (12 km) where convective transport is parameterized

Tools:

TES observations: Tropospheric Emission Spectrometer measures spectral IR radiances in limb viewing and nadir mode. Nadir mode gives vertical information for a 5.3 x 8.4 km^2 horizontal footprint.

WRF-chem: Weather Research and Forecasting model coupled with Chemistry simulates meteorology and chemistry together at the cloud to regional scales.

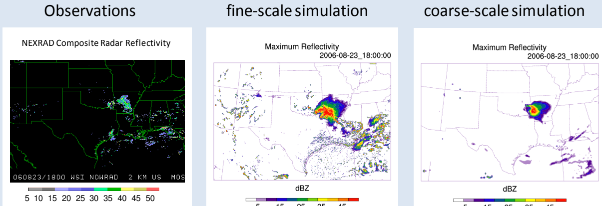
Configuration:

Domain centered at 33N, 98W
Meteorology input from NCEP GFS (global forecast system)
Chemical boundary conditions from MOZART global model results
Transport of scalars, CO and O_3 ; CO emitted from anthropogenic sources
No reactive chemistry

fine-scale simulation	coarse-scale simulation
$\Delta x = \Delta y = 3$ km; 34 vertical levels	$\Delta x = \Delta y = 12$ km ; 34 vertical levels
Thompson microphysics	Thompson microphysics
Mellor-Yamada-Janic PBL	Mellor-Yamada-Janic PBL
No convective parameterization	Grell-Devenyi convective parameterization

Meteorology Results:

Observations — fine-scale simulation — coarse-scale simulation



Both simulations show reflectivity (based on resolved-scale precipitation) of the large convective system over Oklahoma and Arkansas. The coarse resolution simulation does not include convection along Gulf coast or in New Mexico.

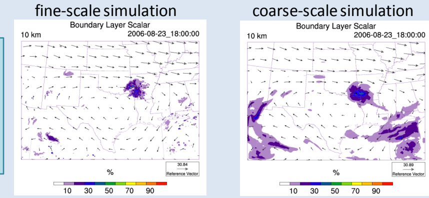
Transport of boundary layer tracer:

Tracer = 100 from surface to PBL height

UT values — fine-scale simulation — coarse-scale simulation

Transport from BL evident through convective system over Oklahoma-Arkansas

Coarse-scale simulation transports more tracer to the upper troposphere

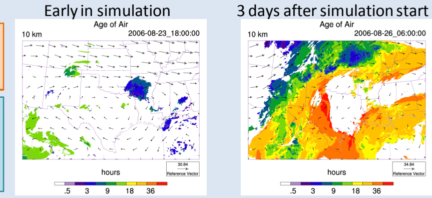


Age of air in UT — Early in simulation — 3 days after simulation start

A second BL tracer decays with a lifetime of one day.
Age of air (hours) = 24 log (T1/T2)

Early in simulation, BL air in UT is young and near recent convection

At later times, the UT air has filled in with aged BL air

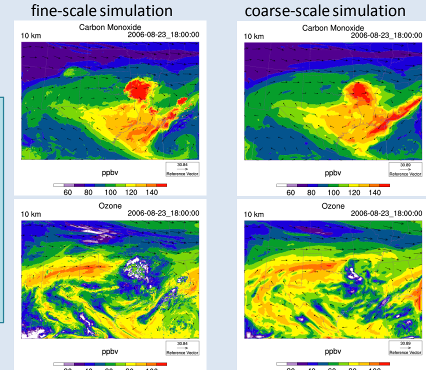


Transport of CO and O_3

UT values — fine-scale simulation — coarse-scale simulation

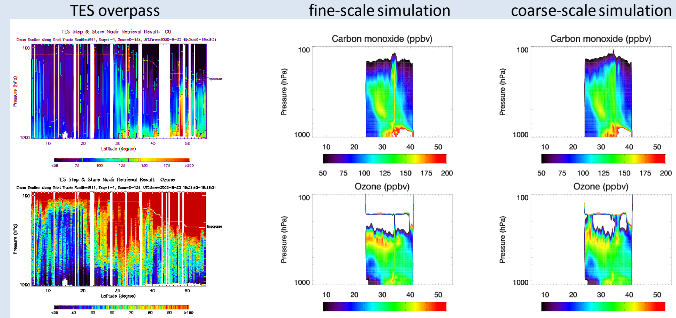
Convective transport is again evident bringing CO-rich and O_3-poor mixing ratios to UT. The convective transport acts to reduce O_3 mixing ratios throughout the UT region.

Coarse-scale simulation transports more CO to UT but less O_3-poor air



Evaluation of CO and O_3 with TES overpass

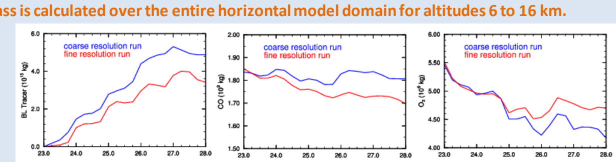
TES overpass — fine-scale simulation — coarse-scale simulation



Without reactive chemistry, the O_3 in the UT is not properly represented, however CO (with a longer chemical lifetime than O_3) is reasonably represented by transport only.

Mass of Species in UT:

Mass is calculated over the entire horizontal model domain for altitudes 6 to 16 km.



Coarse resolution predicts more convective transport than fine resolution simulation.

Conclusions:

WRF-Chem simulated tracers, CO and O_3 for a 5 day period during the North American monsoon. Without chemistry, O_3 in the upper troposphere is reduced by convective transport rather than enhanced as shown by the TES observations.

→Convective transport of ozone precursors and lightning-produced NOx is crucial to UT O_3

The model results show that the UT air does remain in the region which would allow for chemical aging.

Simulations of the period covering the start to finish of the North American monsoon would allow us to quantify the relative contribution of sources to the build-up, maintenance, and decay of the UT O_3 maximum.

Acknowledgments: NCAR is supported by the National Science Foundation. This work is primarily supported by NASA Grant Number NNH07AM47G.