WRF-Chem evaluation over the Rocky Mountains forest during BEACHON-RoMBAS 2011

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1. Motivations

- Formation of secondary organic aerosols (SOA) from biogenic sources and their impacts on CCN and climate is poorly understood, in particular in areas influenced by anthropogenic pollutants, which have been suggested to greatly enhance the production of biogenic SOA(1).
- The BEACHON-RoMBAS filed study took place in summer 2011 at the Manitou Forest Observatory (MFO) which is located in a complex mountain terrain at 2300m elevation, and at the forest / urban interface (Figs 1, 2).
- We use WRF-Chem to analyze the circulation patterns that influence the formation and transport of gaseous and aerosol pollutants at the site, and to investigate the sources of organic aerosol that were measured at the site.

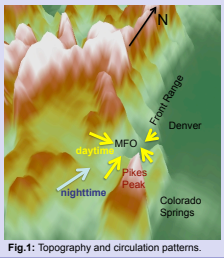

Fig.1: Topography and circulation patterns.

2. Model Setup

- WRF-Chem simulation was performed for 25 July to Aug. 26, 2011 over the U.S. with the following configuration :
  - 2 domains: U.S at 36km, Colorado nested at 4km
  - coarse domain nudged to NARR 32km analysis
  - Morrison double-moment scheme
  - Mellor-Yamada-Janjic PBL parameterization
  - Rapid Radiative Transfer Model for long wave radiation
  - Goddard scheme for short wave radiation
  - SAPRC99 chemistry & MOSAIC aerosols with updated SOA(2,3).
  - Emissions anthropogenic EPA NEI-05; biogenic MEGAN
  - Wet and dry deposition

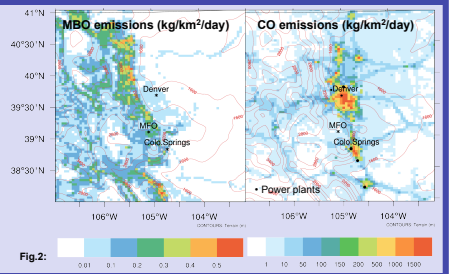

Fig.2:

3. Meteorological conditions during summer 2011

Influence of the North American Monsoon

- 3 active systems with mid-level southeasterly flow bringing moisture and favoring precipitations at MFO (25-28 July; 2-5 Aug.; 26-29 Aug.)

Complex near surface flow

- Daytime winds influenced by the mountain upslope circulation;
- Nighttime southwesterly flow.

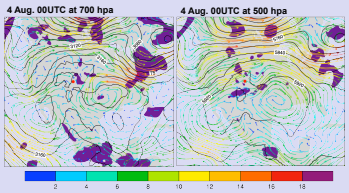

Fig.3: NARR-32km fields: winds, geopotential heights and RH>75% (purple)

- Model bias in predicted near surface RH, nighttime T and wind direction.

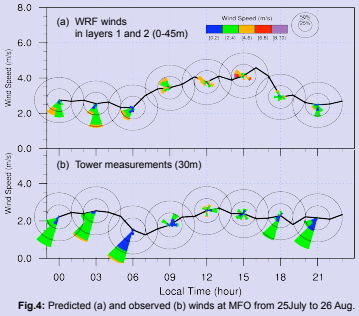

Fig.4: Predicted (a) and observed (b) winds at MFO from 25July to 26 Aug.

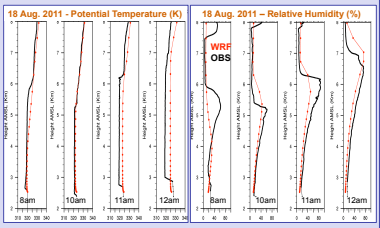

Fig.5: Vertical profiles at MFO for Aug. 18, 2011.

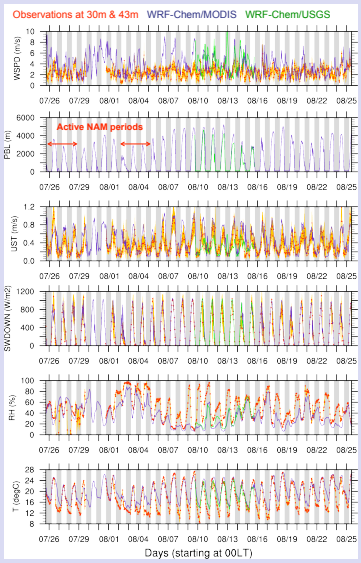

Fig.6: Observed (red) and predicted (purple for MODIS; green for USGS) near surface meteorological fields.

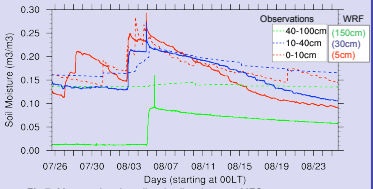

Fig 7: Measured and predicted soil moisture at MFO.

Large difference between MODIS and USGS land cover over Colorado

- Predicted LAI is very different for MODIS, USGS and MEGAN biogenic emissions.

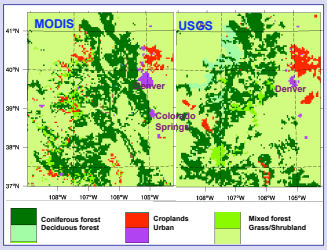

Fig.8: Landuse based on MODIS-2001 and USGS-1992.

4. Transport of anthropogenic pollutants to the site

Flexpart backtrajectories

Observations at MFO suggest (Fig. 9):

- Higher fossil carbon levels 10-30% during 25 July to 1 Aug. (vs. < 10% after 12 Aug.)
- Higher growth rate of newly formed aerosol nucleation clusters (Number Conc. in 4-40nm range).

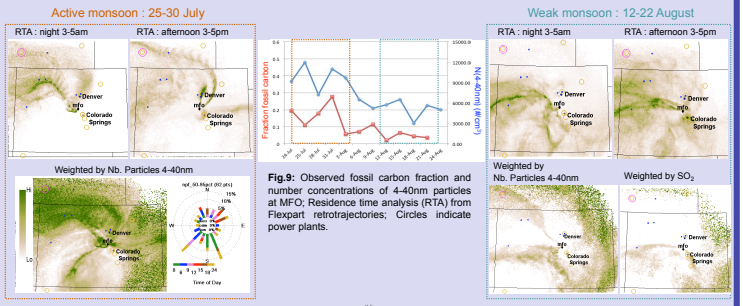

Fig.9: Observed fossil carbon fraction and number concentrations of 4-40nm particles at MFO; Residence time analysis (RTA) from Flexpart retrotrajectories; Circles indicate power plants.

WRF-Chem anthropogenic CO tracers

- Analysis of predicted CO tracer shows frequent transport of front-range pollutants to MFO (Fig. 10).

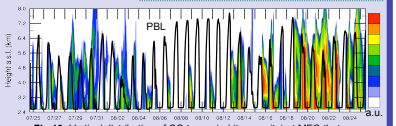

Fig.10: Vertical distribution of CO tracer (arbitrary units) at MFO that was advected from the Front Range (Denver and Colorado Springs).

5. Near-surface concentrations of gaseous and aerosol pollutants at MFO

Reasonable daytime agreement; nighttime CO, ozone and anth. SOA frequently overpredicted:

- titration of O_3 by NO may be too weak, resulting in too low NO_2;
- bias in NO_2 coincides with bias in benzene -> not enough anthropogenic NO at the site
- nighttime PBL (min of 100m) may be too low

Biogenic SOA ~1µg/m³ from OH and ½ µg/m³ from nighttime chemistry

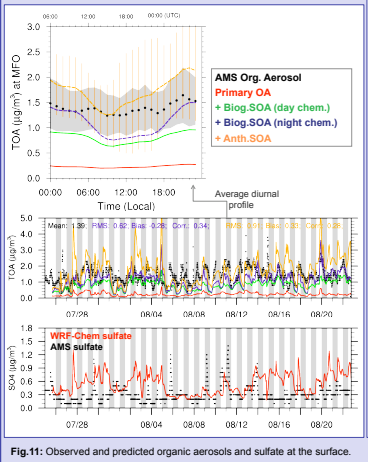

Fig.11: Observed and predicted organic aerosols and sulfate at the surface.

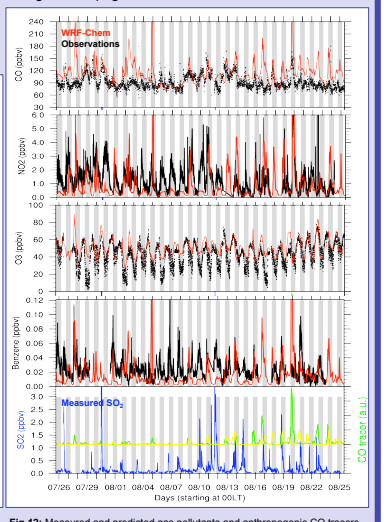

Fig.12: Measured and predicted gas pollutants and anthropogenic CO tracers.

[1] Carlton et al., GRL, 2010.
[2] Hodzic and Jimenez, GMD, 2011.
[3] Hodzic et al., in prep. 2012.

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