Transport of Air Pollutants in California using WRF - Chem

Pallavi Marrapu [a,b] Gregory R. Carmichael [a,b]

a Department of Chemical and Biochemical Engineering

b Centre for Global and Regional Environmental Research

The University of Iowa, Iowa City , IA 52242, USA.

Email : pallavi-marrapu@uiowa.edu, gcarmich@icaen.uiowa.edu

A fully coupled meteorology-chemistry- aerosol model WRF-Chem is employed to analyze the air quality in California and its impact regional weather and climate. Aim of the study is to estimate species such as Carbon Monoxide (CO), Ozone (O_3), Sulfur Dioxide (SO_2) and Nitrogen Dioxide (NO_2). The model is validated using surface observational data from an intensive filed campaign , Arctic Research of Composition of the Troposphere from aircraft and Satellites in California (ARCTAS-CA) that took place during summer 2008.

The ARCTAS-CA campaign (June15-30,2008) in collaboration with NASA/CARB , aimed at understanding the roles of local summer forest fires, pollution from ships, and contribution from long-distance pollutant sources(such as Asia) on the air quality of California. NASA DC-8 flight 14 , which encircled from Palmdale to San Francisco Bay and back to Palmdale, was selected for this study as it was one of the most representative flights of the campaign in satisfying the ARCTAS -CA objectives.

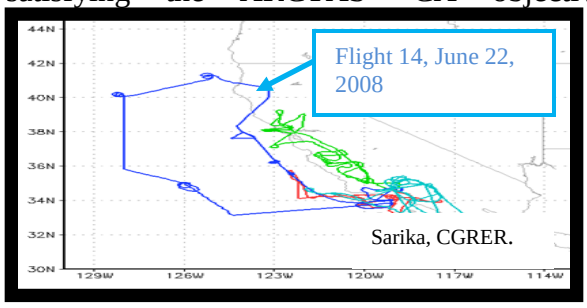

Fig 1.Flight path during ARCTAS period

Model details: WRF-Chem is a state-of-the-science mesoscale meteorology and chemical transport model with multiple dynamical cores. WRF-ARW, a fully compressible and non-hydrostatic model used for the analysis.

Table 1: Model settings for present study

Domain	California
Grid Size	12km X 12km
Grid cell	100 X100
Chemical Mechanism	RADM2 and MADE / SORGAM aerosols
Fossil Fuel Emissions	NEI 2005, USA
Boundary Conditions	RAQMS
Run Period	June 10 - 30,2008

June 2008 saw considerable wild fire activity in California and the fresh plumes were repeatedly sampled by the aircraft. To validate this statement analysis of the WRF-Chem model results were carried out for flight 14, June22, 2008. Species such as CO,O_3,SO_2,NO_2 at surface level (30 m) during day time are analyzed to assess the air quality in California.

The model output is validated along the flight path at different altitudes and time steps. Visualization tool, Grid Analysis and Display System (GrADS) is used in the study.

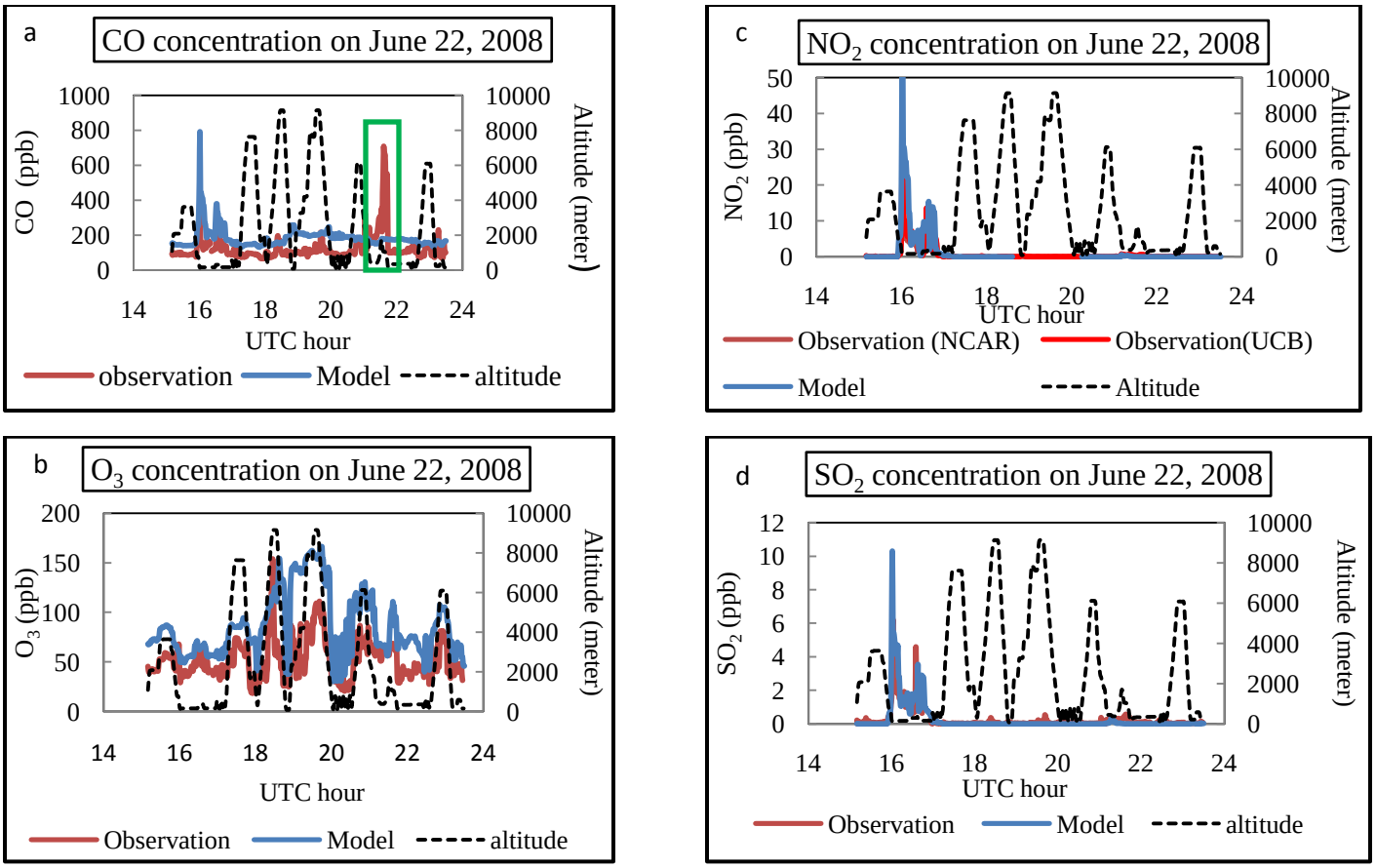

Fig 2. Comparison of modeled and observed pollutant concentrations from NASA ARCTAS DC-8 flight

Fig 2 a-d shows the time series variation of each species along the flight path at different altitudes. Model output of all species follow similar trend variation as of observations data, with higher magnitude. In majority of the case studies it is proved model over predicts, the results also validate the statement. In Fig 2-a CO model output could capture the peak in the first phase of flight but it could not do the same around 21UTC when the flight flew across the wildfire plumes. In the present run wildfires emissions were not included this caused predictions not to capture the peaks. CO is effected by biomass burning and forest fires. Fig 2-b,Ozone captured peaks of the observational data. Ozone is secondary pollutant, formed when primary pollutants participate in complex of ultraviolet - driven photochemical reactions on sunny day. Fig 2- c supports this statement as we could see lower concentrations of Nitrogen Dioxide during the mid day (21 UTC) in summer time. It is expected to have warmer climates in California during period of the model run. All these validate higher concentrations of Ozone. Fuel combustion in stationary sources is the dominant source of sulfur dioxide, reduced levels of SO_2 in California (Fig 2-d) states that the emissions from the stationary sources are low. In past years thermal power plants count is lowered in California this is one of the reason to have low concentrations of SO_2 . SO_2 observes a perfect diurnal variations. The day time concentrations will be low when compared to night time. The flight flew all throughout the day so it capture the diurnal variation.

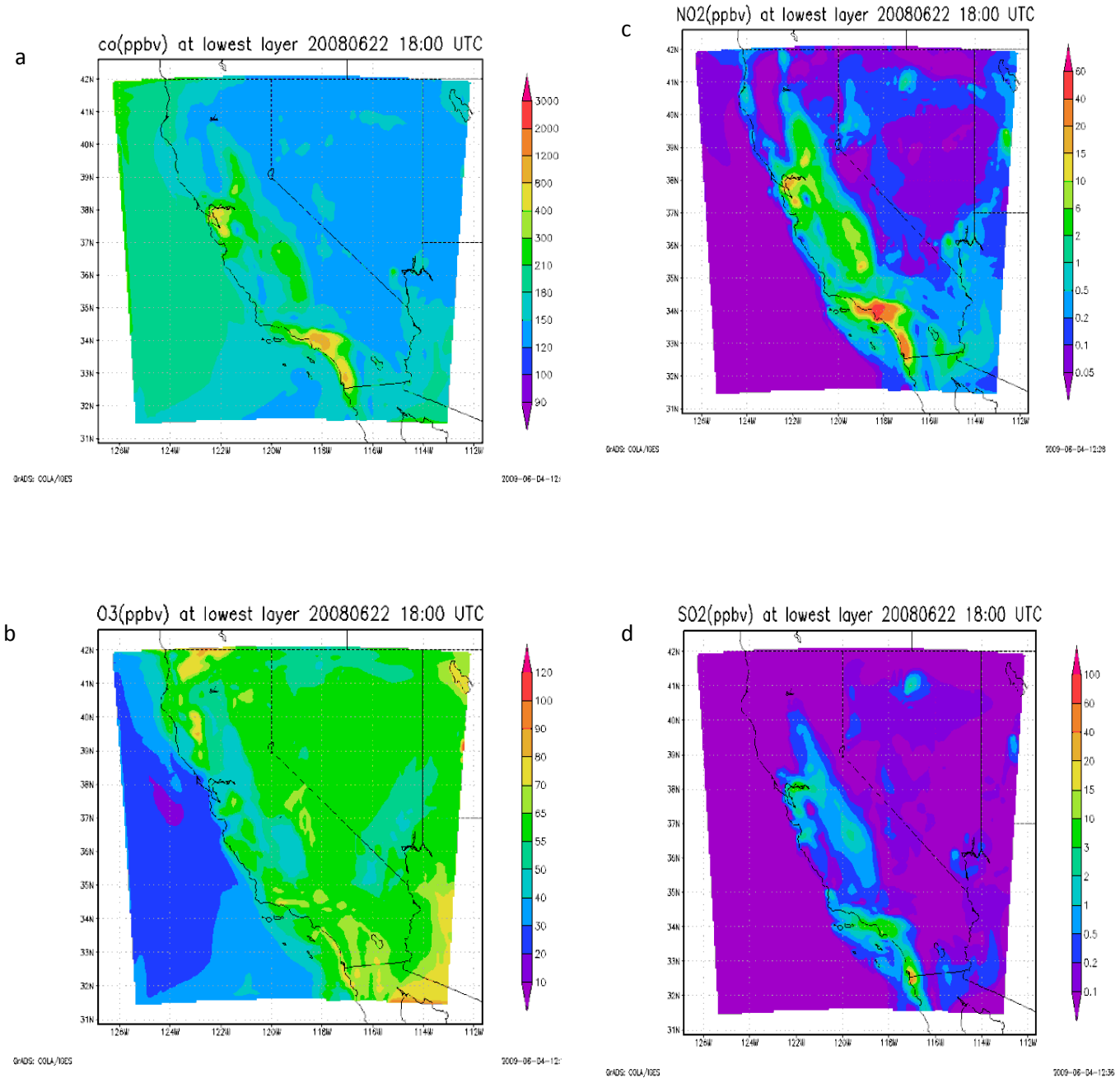

Fig 3 Modeled Surface (30m) over California , June 22,2008 at 10:00 A.M PST

Fig 3 a -d shows the spatial variation of all the species. Fig 3-a, CO show high concentrations in megacity such as Los Angeles. In Fig 3 -b, Ozone (~55 - 70 ppbv) . Higher concentrations of ozone is observed in megacities and many other locations. Summer time has higher O_3 concentrations in California for 100 years, therefore the model results validate this statement. Fig 3 -c , Nitrogen Dioxide has higher levels of concentrations in southern California and San Joaquin valley. High levels in valley region may be due to deposition.

Fig 3-d , Sulfur Dioxide also show similar trend as of NO_2. The major source for these emissions are from power plants in San Diego region.

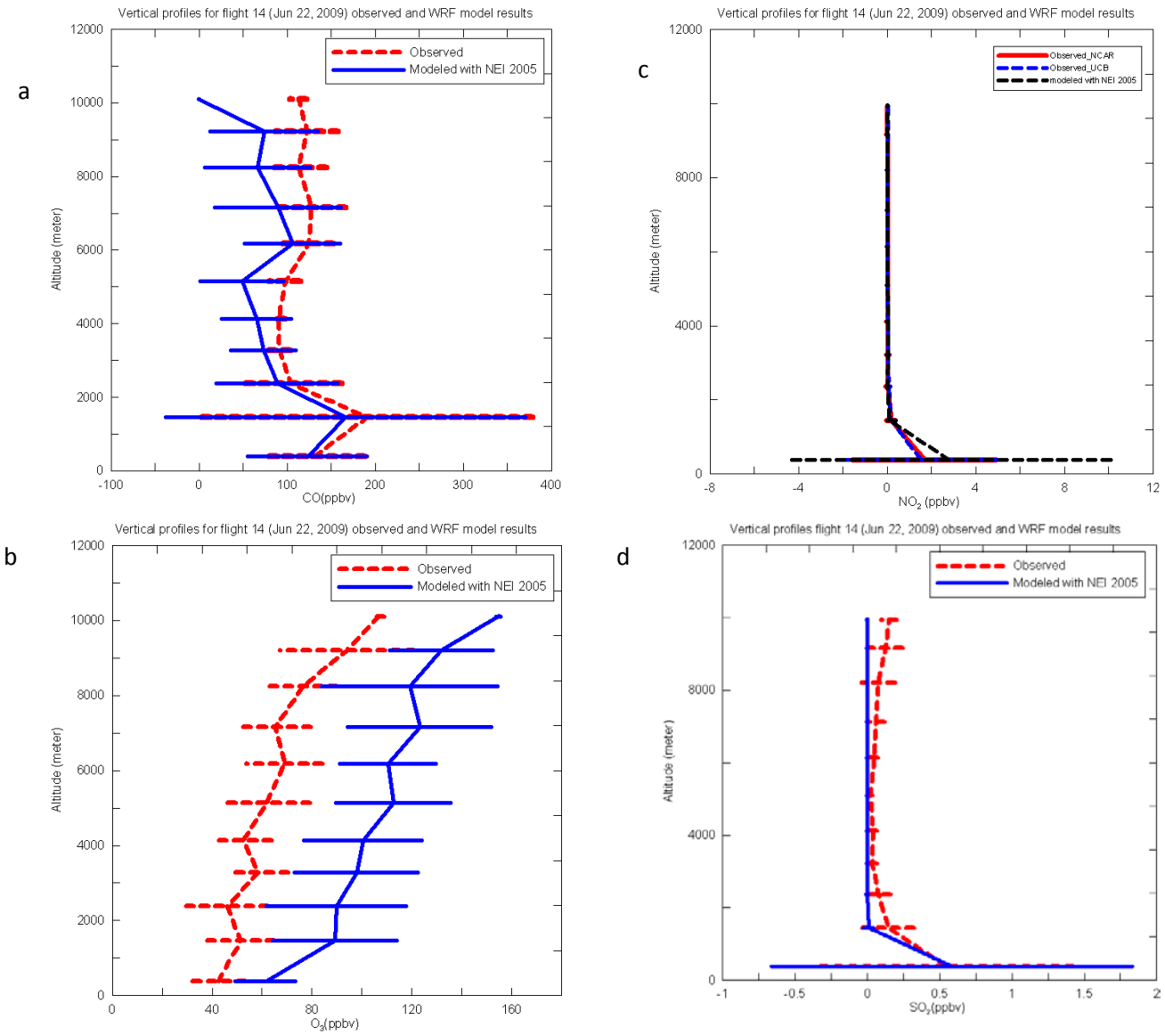

Fig 4. Vertical Profile plots for observed and Modeled data

Fig 4 a -d shows the vertical profiles of the species. The model show biased high levels in ozone and CO , but under predicted NO2 and SO2 especially at lower levels

Conclusion: WRF-Chem predicted higher concentrations and better spatial gradients throughout the region and especially over urban areas. CO, SO_2 are effected by emissions only but Ozone is effected by both emission and chemistry. Summer time has higher concentrations of Ozone in California. Higher levels of pollution ozone at greater altitudes is not primarily by pollutions but due to natural phenomenon.

Reference:

ftp://aftp:.fsl.noaa.gov/divisions/taq/emissions_data.

Grell A. Georg, Peckham E. Steven, Schmitz Rainer, McKeen A.Stuart, Frost Gregory Skamarock, C. William, Eder Brain, “Fully coupled online chemistry within the WRF model”, Atmospheric Environment,39,6957-6975,2005.

http://www.wrf-model.org/index.php.

http://www.cgrer.uiowa.edu/people/carmichael/stem2_desc.html.