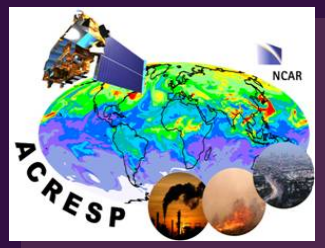
Gabriele Pfister
National Center for Atmospheric Research
Boulder, CO



Analysis of ARCTAS-Carb Using WRF-Chem and MOZART

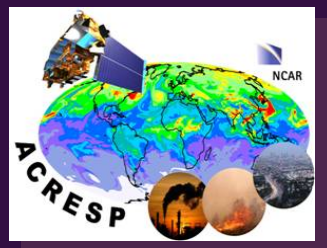
ARCTAS California Workshop, 30 June 2009

Acknowledgements:
Louisa Emmons, Christine Wiedinmyer, Stacy Walters, David Edwards (NCAR)

ARCTAS Science Team

EPA for surface monitoring data
Satellite Teams for data
NSF and NASA for funding

and many others...



Analysis of ARCTAS-Carb Using WRF-Chem and MOZART

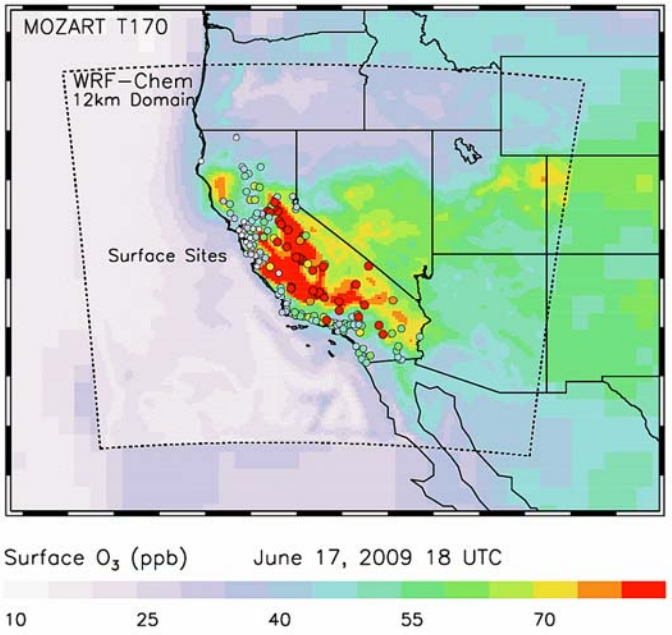
ARCTAS California Workshop, 30 June 2009

Primary Research Questions

- What are the characteristics of AQ in California. How well do we understand and model it and what datasets are needed for evaluation?
- How do fires impact AQ in urban and remote areas?
- How does the inflow of pollution impact AQ in California?

Primary Research Questions

- What are the characteristics of AQ in California. How well do we understand and model it and what datasets are needed for evaluation?
- How do fires impact AQ in urban and remote areas?
- How does the inflow of pollution impact AQ in California?



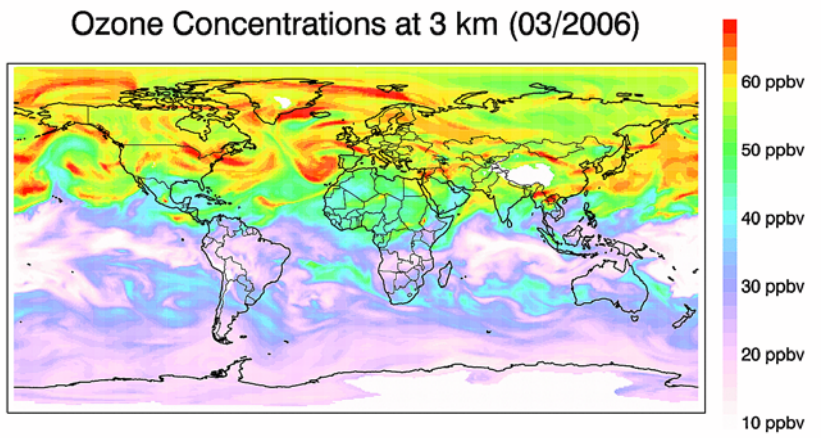
- **Global MOZART Model**
- **Regional WRF-Chem Model**

- **Aircraft Data from ARCTAS-Carb**
- **Surface Monitoring (EPA)**
- **Satellite Data (OMI NO2 and HCHO, MODIS AOD, IASI,…)**

Model Description – MOZART-4

Model for OZone and Related Chemical Tracers V4

- Global chemistry transport model for tropospheric studies
- Driven by standard meteorological fields
- Constrained to climatologies in stratosphere
- Online calculation of photolysis (FTUV),
  dry deposition (Wesely),
  biogenic emissions (MEGAN)
- MOZART-4 Chemical Mechanism
  85 gas species
  12 bulk aerosol compounds*
  39 photolysis reactions
  157 gas phase reactions

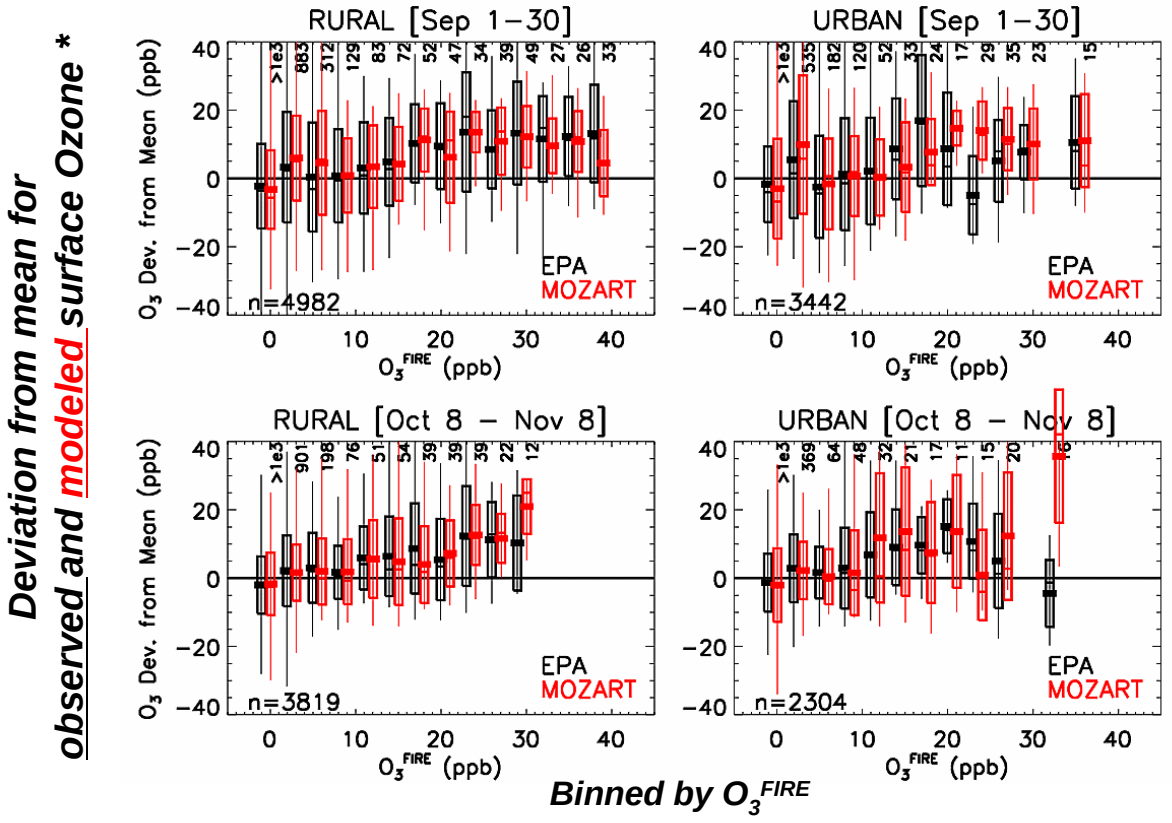


- XNO_X Tagging Scheme: Tracking O_3 produced from a specific NO_x source

* Sulfate, black and organic carbon, SOA, ammonium nitrate, sea salt, dust

Previous Work - California Fires in Fall 2007

✓ Analyzing surface observations of O_3 using MOZART (@T85) with O_3^{FIRE}



Rural Sites: Mean observed (modeled) enhancement for

O_3^{FIRE} > 20 ppb	12 ± 14 ppb	(10 ± 10 ppb)	September
	10 ± 13 ppb	(12 ± 9 ppb)	October

Pfister et al., GRL, 2008

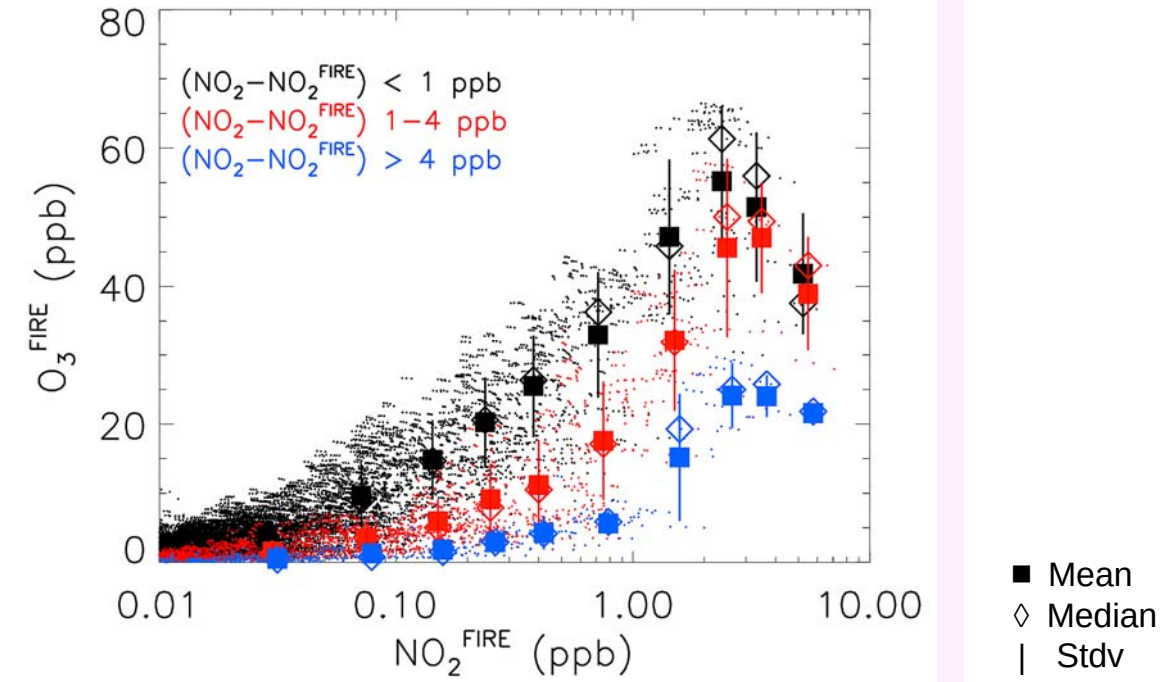
* 8-hour afternoon concentrations

Previous Work - California Fires in Fall 2007

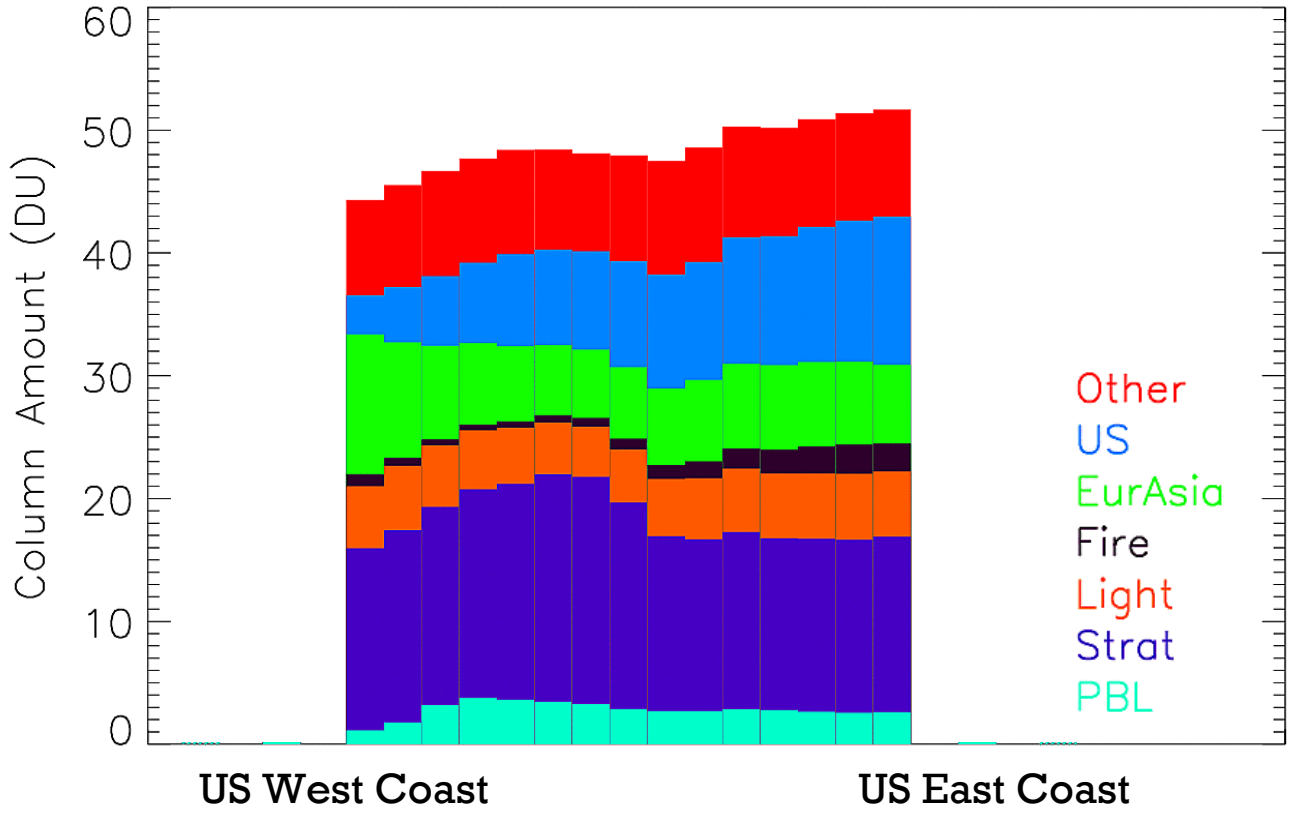
Hypothesis:

Adding additional NO_x in a less polluted environment causes a larger ozone increase compared to a NO_x and VOC richer environment

NO_2^{FIRE} and O_3^{FIRE} Relationship for different NO_x regimes



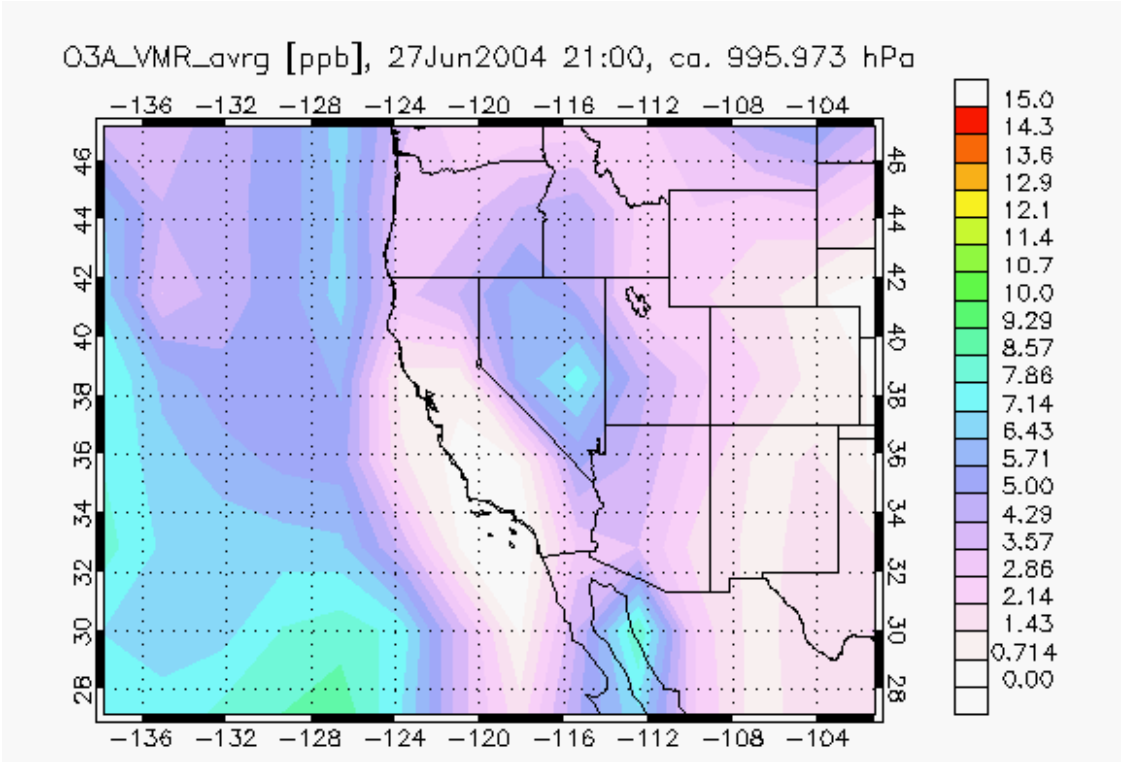
Previous Work – O_3 Budget over US in Summer 2004



Source Contributions to Tropospheric O_3 across the Contiguous US
July-August 2004 (MOZART @ T85)

Pfister et al., JGR, 2008

Previous Work – O_3 Budget over US in Summer 2004



Surface Ozone from NO_x Sources in Europe & Asia
July-August 2004 (MOZART @ T85)

Pfister et al., JGR, 2008

ARCTAS-Carb – Summer 2008

Preliminary

Model Description – WRF-Chem

Weather Research and Forecast (WRF) Model with Chemistry

- Online and offline simulation of chemistry and aerosols from cloud to regional scales
- Selection of different chemistry (e.g. RADM, CBMZ) and aerosol schemes (e.g. MADE/SORGAM, GOCART, MOZAIC)

WRF-Chem/MOZCART

- MOZART-4 Chemistry scheme included in WRF-Chem V3.0 through KPP and linked to GOCART aerosols
- Update photolysis and deposition processes to MOZART parameterization

➔ **Ensure chemical compatibility, support consistent analysis across spatial scales, and enable use of common data assimilation capabilities.**

Model Description – WRF-Chem

Weather Research and Forecast (WRF) Model with Chemistry

- Online and offline simulation of chemistry and aerosols from cloud to regional scales
- Selection of different chemistry (e.g. RADM, CBMZ) and aerosol schemes (e.g. MADE/SORGAM, GOCART, MOZAIC)

WRF-Chem/MOZCART

- MOZART-4 Chemistry scheme included in WRF-Chem V3.0 through KPP and linked to GOCART aerosols
- Update photolysis and deposition processes to MOZART parameterization

➔ **Ensure chemical compatibility, support consistent analysis across spatial scales, and enable use of common data assimilation capabilities.**

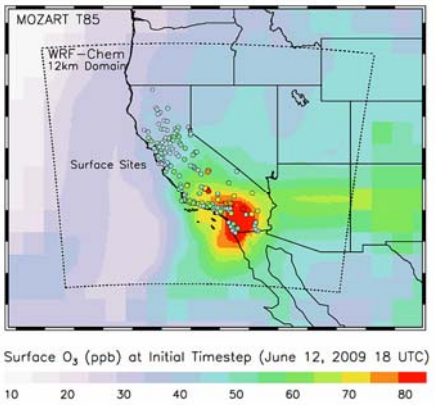
Under Work

Update to V3.1; MEGAN and fire plumerise modules; MOZART XNO_x scheme

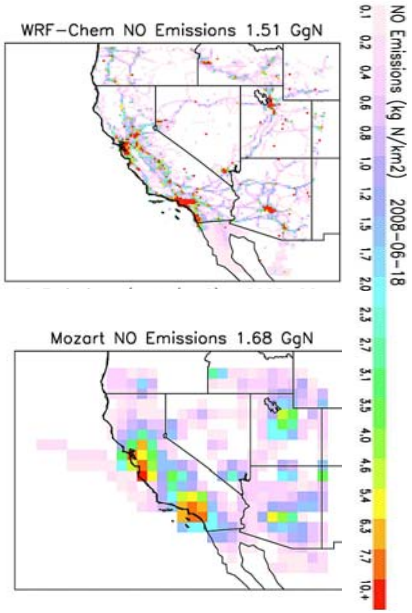
Model Simulations

Simulation Period: June 12-30, 2008

MOZART (@T85) provides initial and boundary conditions for WRF-Chem/MOZCART



	WRF-Chem/MOZCART	MOZART-4
Resolution	12x12 km^2, 1 domain	T170 (~0.7°x0.7°)
Anthr. Emissions	EPA NEI -2005 * Hourly	Daily
Fire Emissions Injection Height Diurnal Cycle	C. Wiedinmyer (NCAR) Surface-1.5 km WRAP daily profile	Surface none
Biogenic Emis.	Guenther	MEGAN V2.1, soil NO_x
Met. Fields	NAM (IC,BC, grid nudging)	NCEP/GFS
Vertical Levels	51 (up to 65 hPa)	42 (up to 2 hPa)

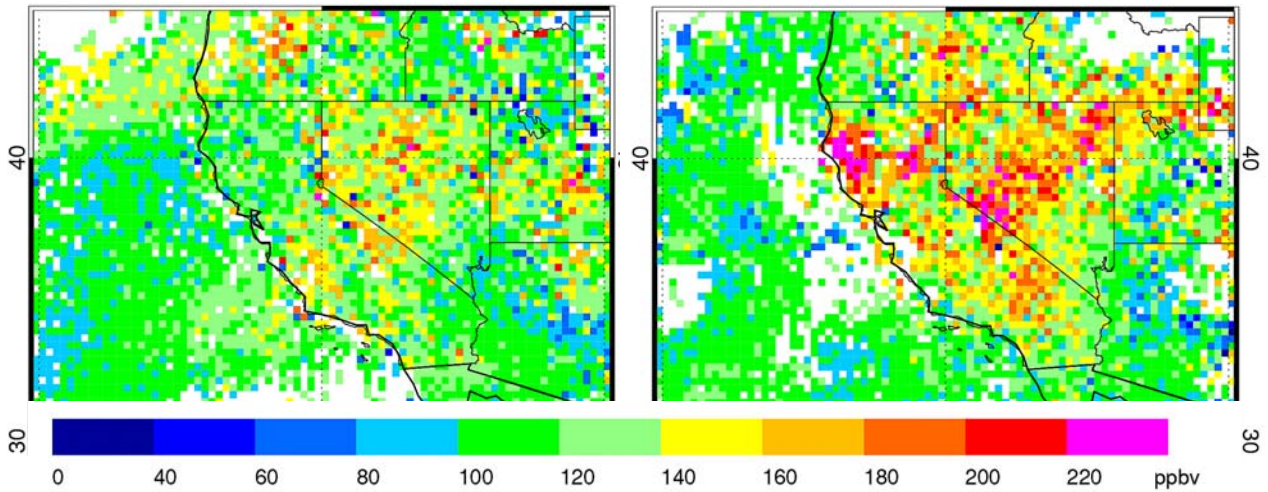


* provided by Stu McKeen (NOAA)

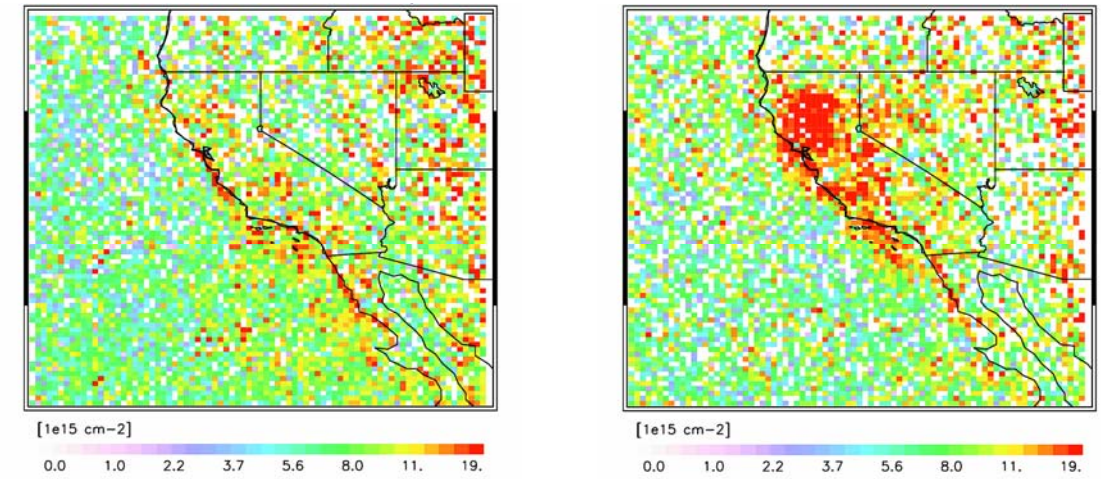
Fires in CA in Summer 2008

June 16-19, 2008

June 23-26, 2008



MOPITT CO @ 700 hPa



OMI HCHO Column

Fire Emission Inventory

Model for North American Fire Emissions

(Wiedinmyer et al., *Atmospheric Environment,* 2006)

Continental-scale fire emissions model

- 1 km^2 spatial resolution
- Predicts emissions of: CO, PM, NO_x, NH_3, SO_2, VOC, CH_4, CO_2
- More recently: Hg, HCN
- Updated to Version 2.0 (paper in preparation)
  - reprocessed fire counts
  - updated emission factors

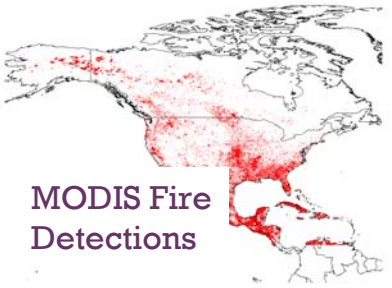
Fire Emission Inventory

Model for North American Fire Emissions

(Wiedinmyer et al., *Atmospheric Environment,* 2006)

Continental-scale fire emissions model

- 1 km^2 spatial resolution
- Predicts emissions of: CO, PM, NO_x, NH_3, SO_2, VOC, CH_4, CO_2
- More recently: Hg, HCN
- Updated to Version 2.0 (paper in preparation)
  - reprocessed fire counts
  - updated emission factors



MODIS Fire Detections

$$Emissions_i = f(A(x,t), B(x,t), E_{fi})$$

A(x,t): Area burned

B(x,t): Biomass burned (biomass burned/area)

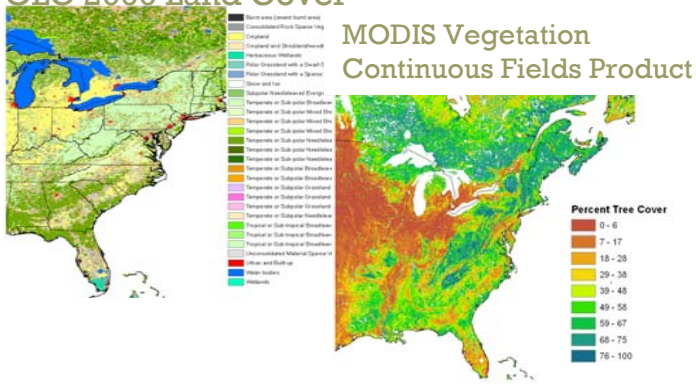
- type of vegetation (ecology)
- fuel characteristics:
- amounts of woody biomass, leaf biomass, litter, …
- fuel condition
- moisture content

E_{fi}: Emission factor (mass $emission_i$ /biomass burned)

- fuel characteristics
- fuel condition

GLC 2000 Land Cover

MODIS Vegetation Continuous Fields Product



Fire Emission Inventory

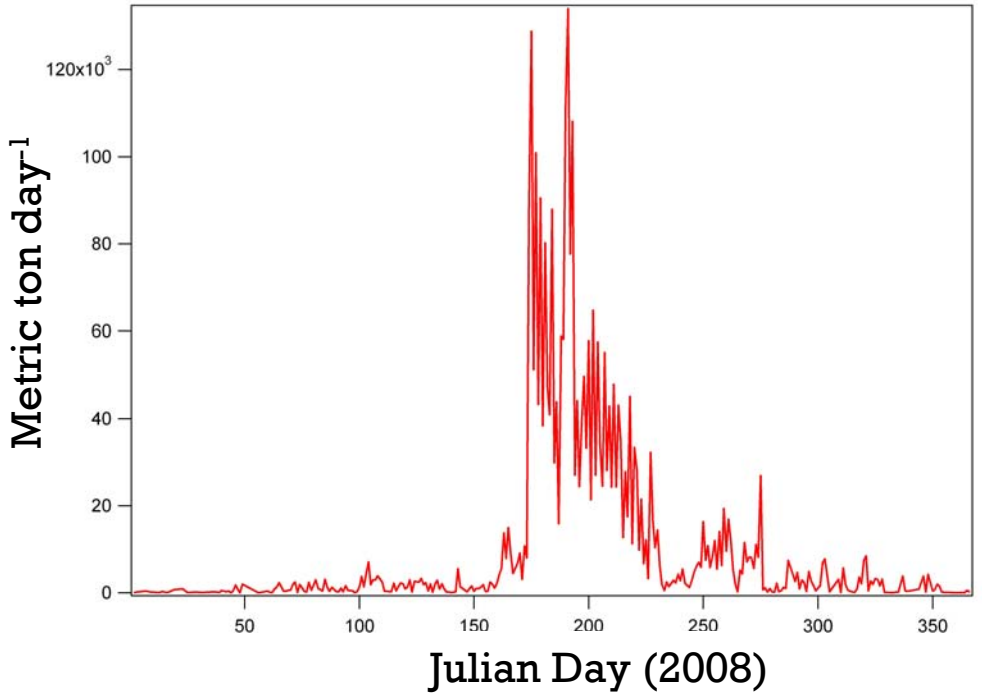
Model for North American Fire Emissions

(Wiedinmyer et al., *Atmospheric Environment,* 2006)

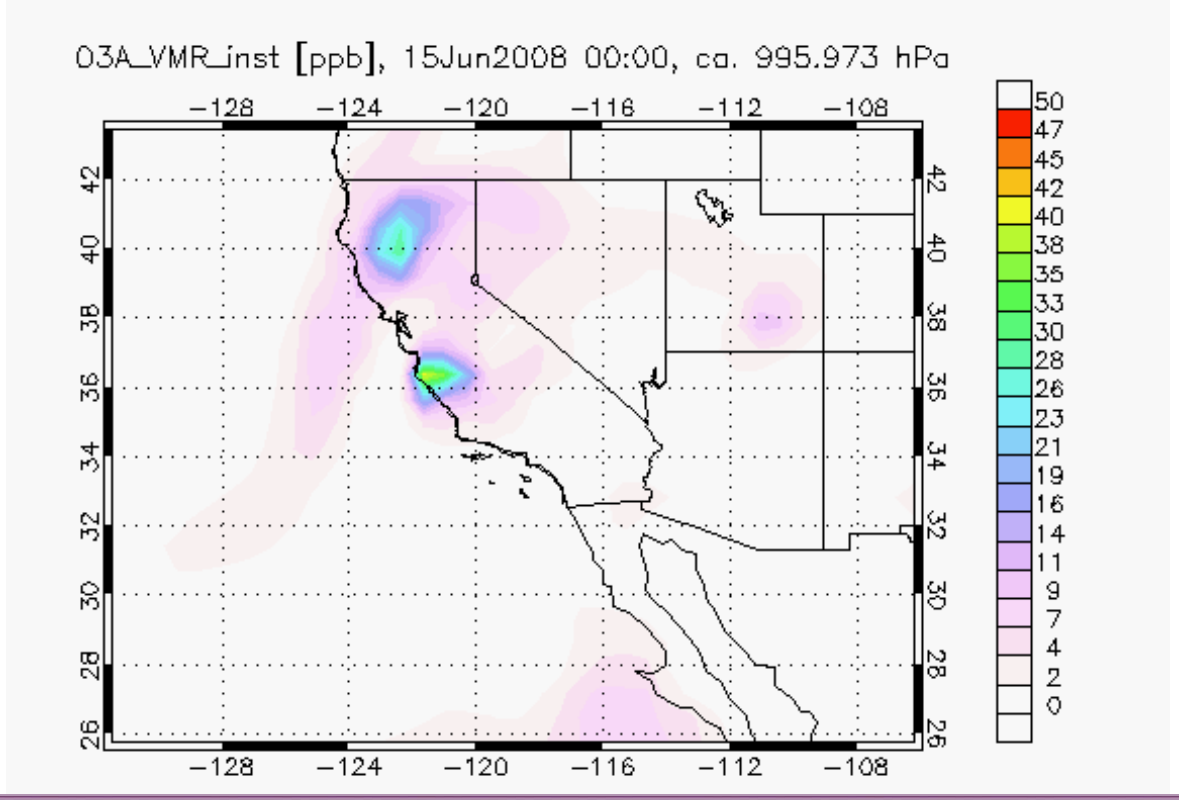
Continental-scale fire emissions model

- 1 km^2 spatial resolution
- Predicts emissions of: CO, PM, NO_x, NH_3, SO_2, VOC, CH_4, CO_2
- More recently: Hg, HCN

Daily CO Emissions for California



MOZART O_3 Fire Tracer



Surface Ozone from Fires in Contiguous US
(15 June – 7 July 2008, MOZART @ T170)

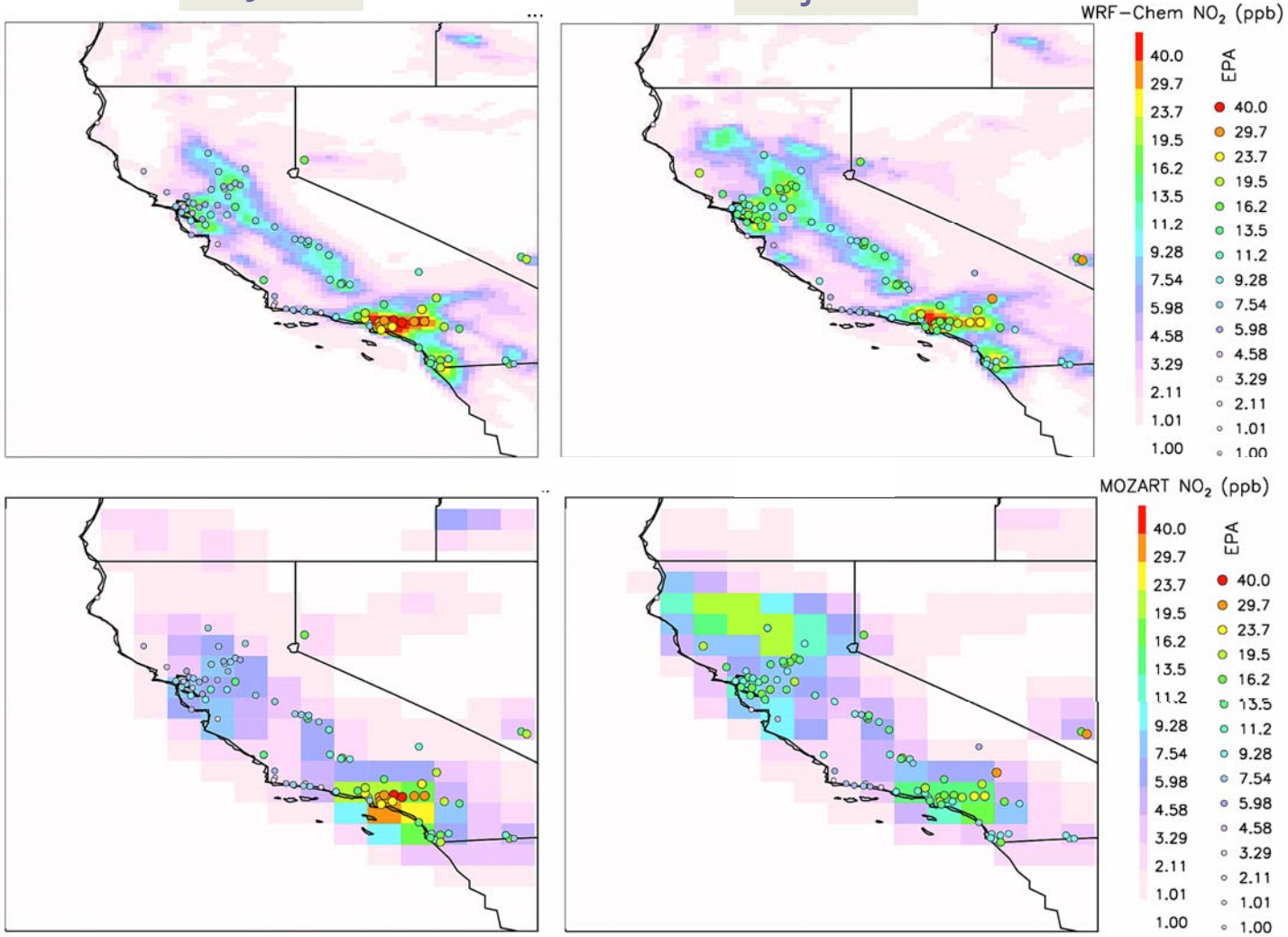
Evaluation with EPA Surface NO_2

16 June

28 June

WRF-Chem/ MOZCART

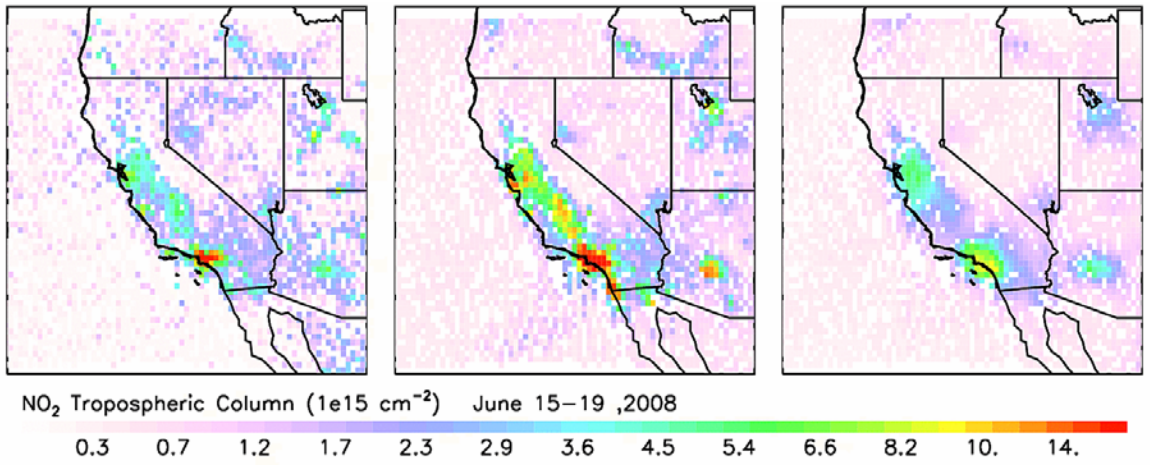
MOZART



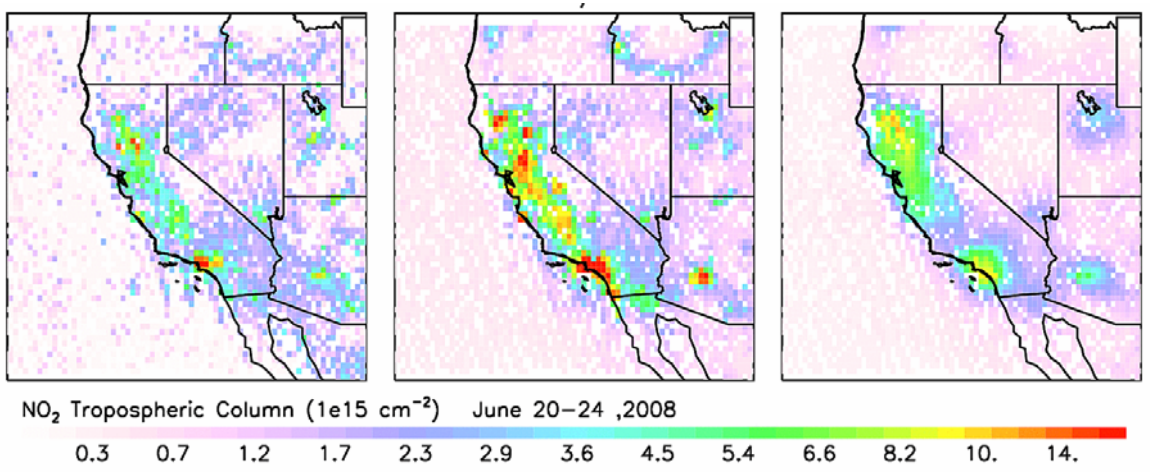
Average for Local Afternoon

Evaluation with OMI NO_2

OMI | WRF-Chem/MOZCART | MOZART



June 15-19, 2008



June 20-24, 2008

Preliminary No exact match of model time with AURA overpass time

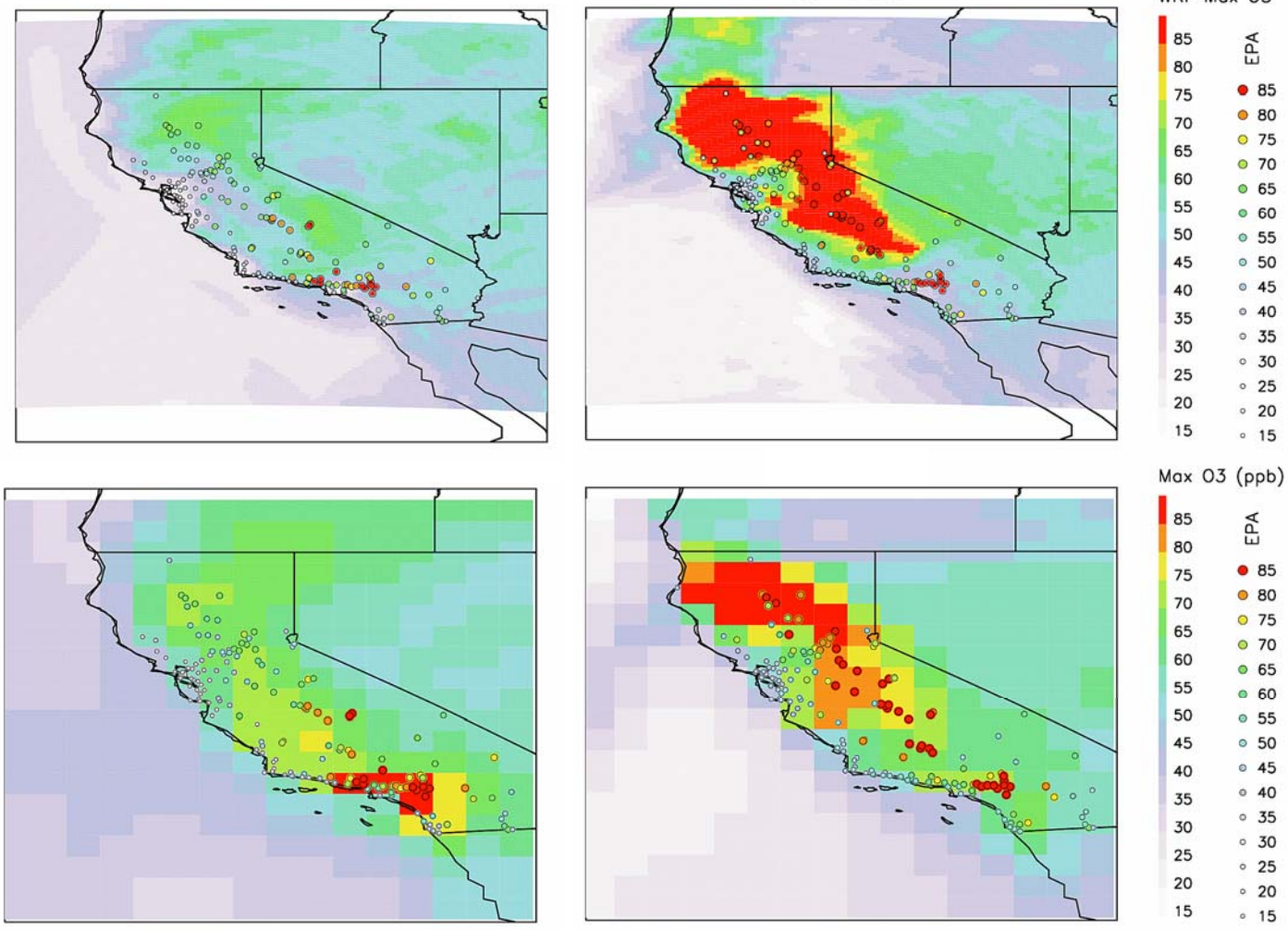
Evaluating Surface O_3 – EPA Monitoring Sites

16 June

28 June

WRF-Chem/ MOZCART

MOZART



Daily 8-hour Maximum

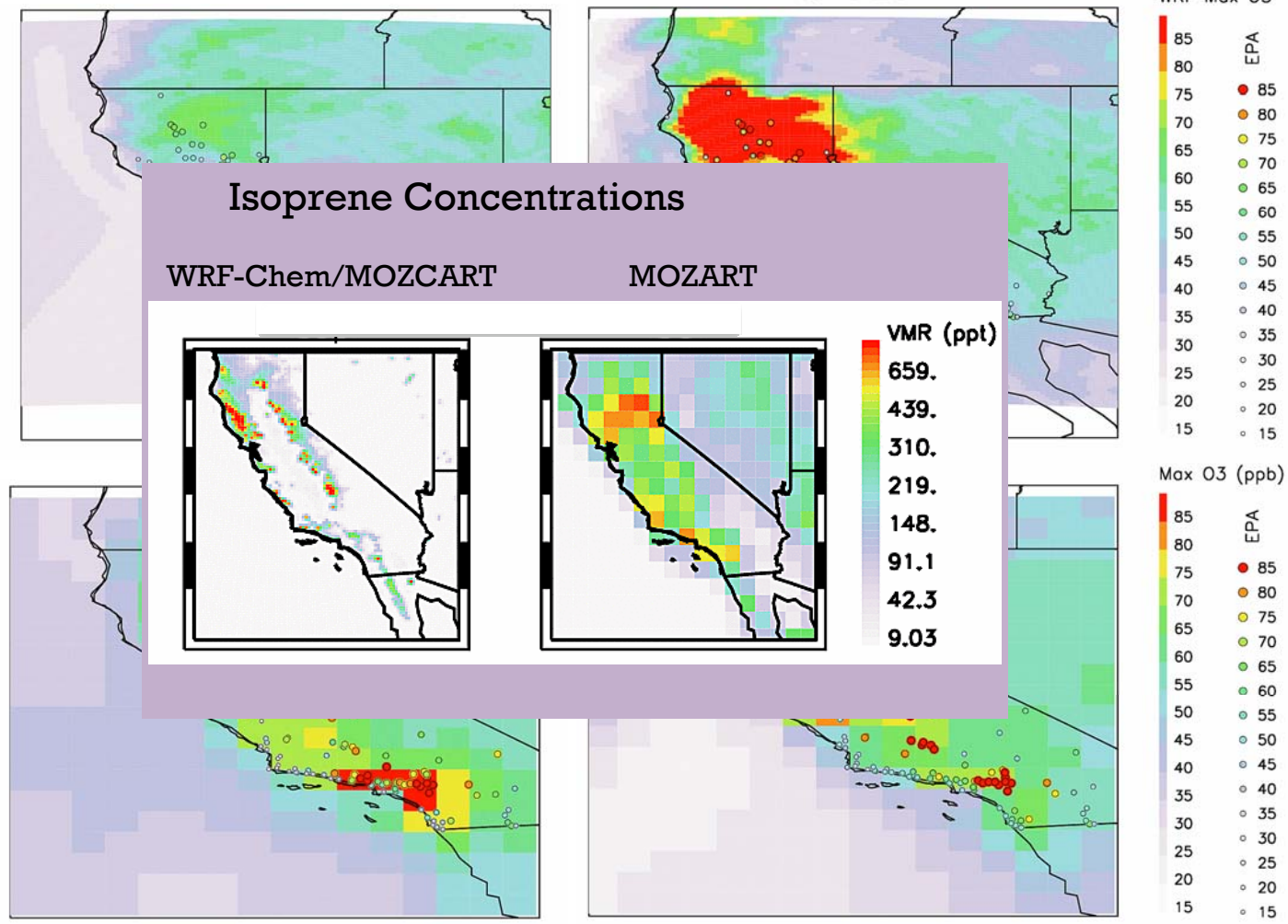
Evaluating Surface O_3 – EPA Monitoring Sites

16 June

28 June

WRF-Chem/ MOZCART

MOZART

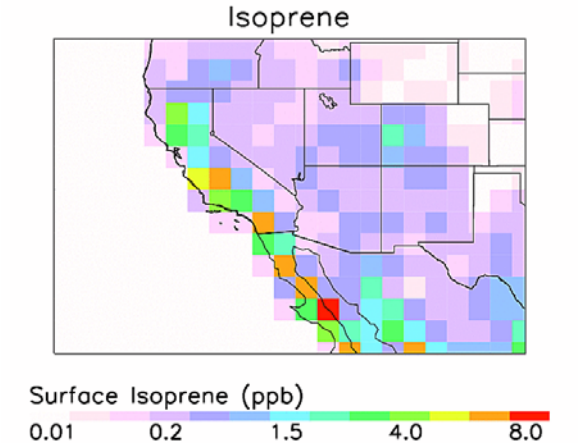


Isoprene Concentrations

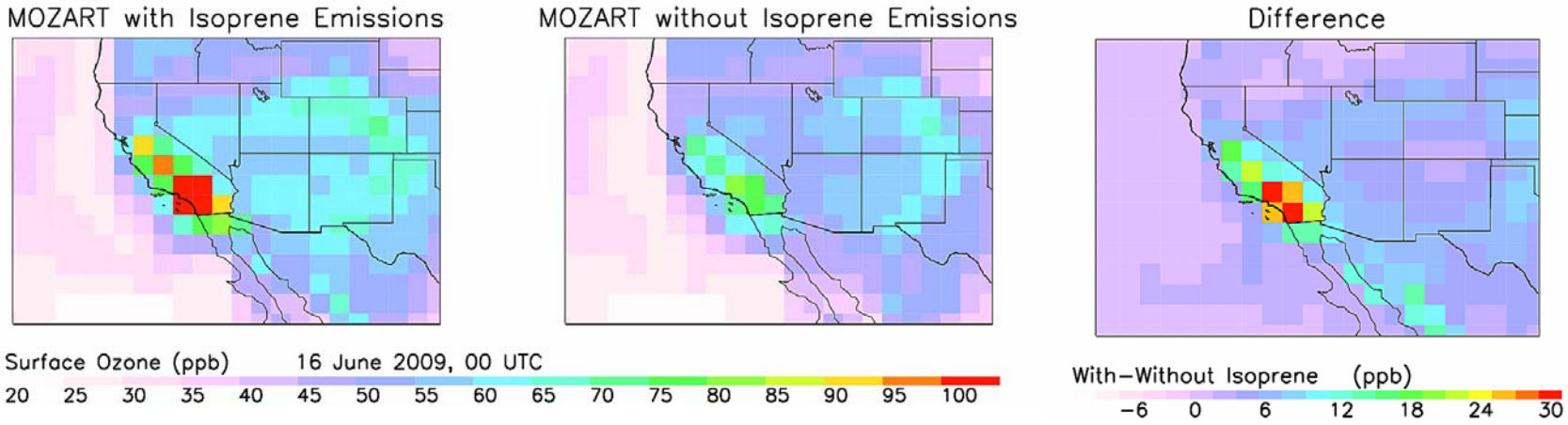
WRF-Chem/MOZCART MOZART

Daily 8-hour Maximum

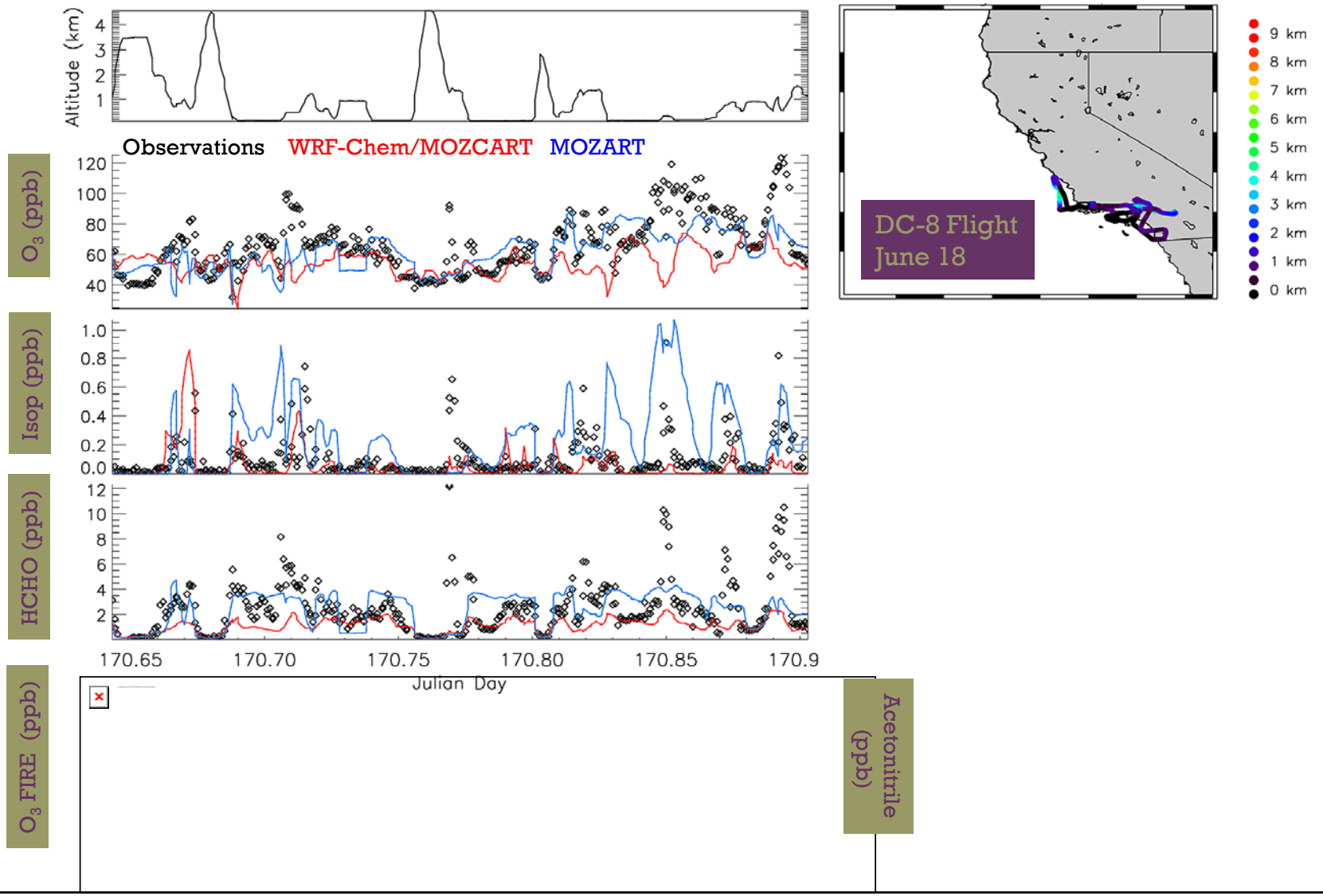
Impacts of isoprene emissions on Surface O_3



Comparing Surface O_3 from MOZART (@T85) with and without isoprene emissions



Impacts of isoprene - DC-8 Aircraft Data

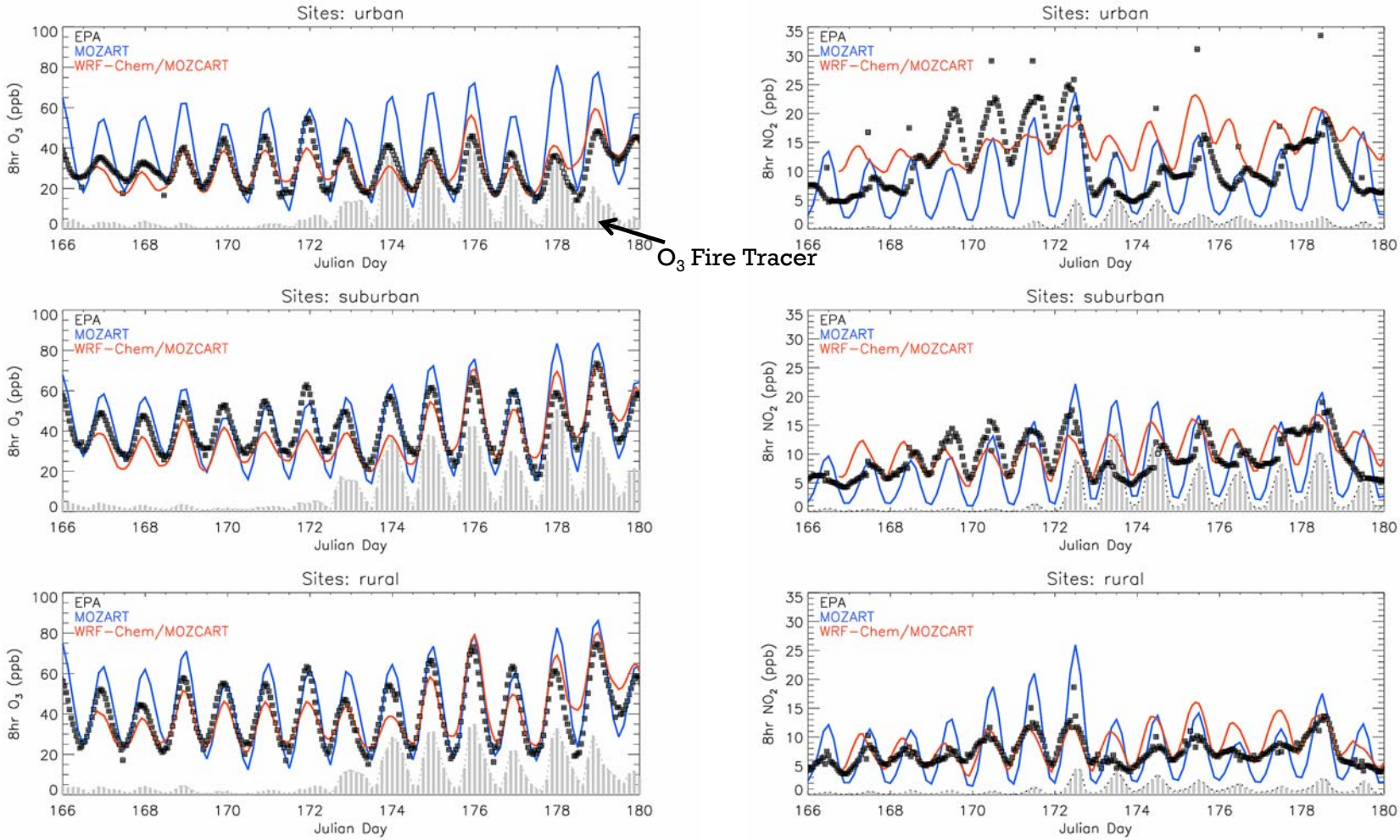


Surface NO_2 and O_3 – absolute VMR

Surface 8-hour O_3

Northern California

Surface 8-hour NO_2

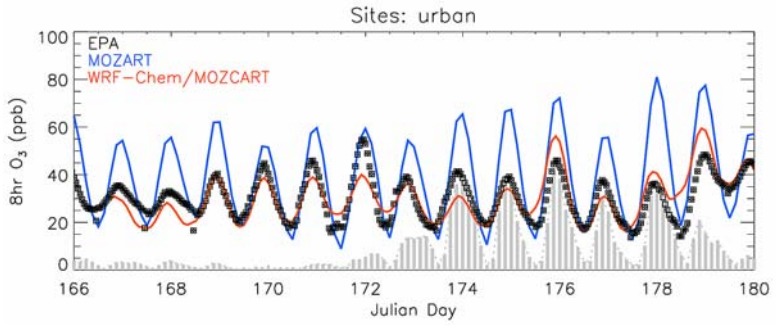


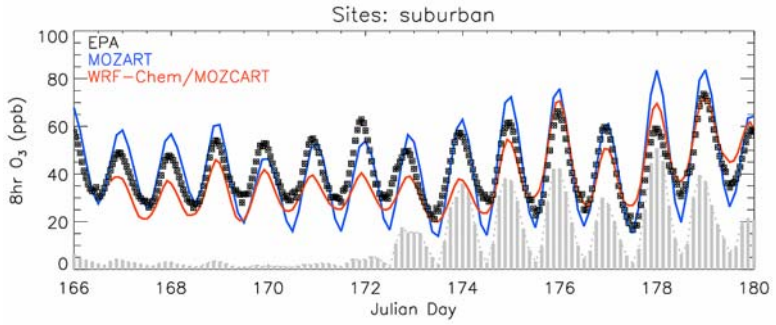
Surface O_3 – Absolute & Deviation from Mean

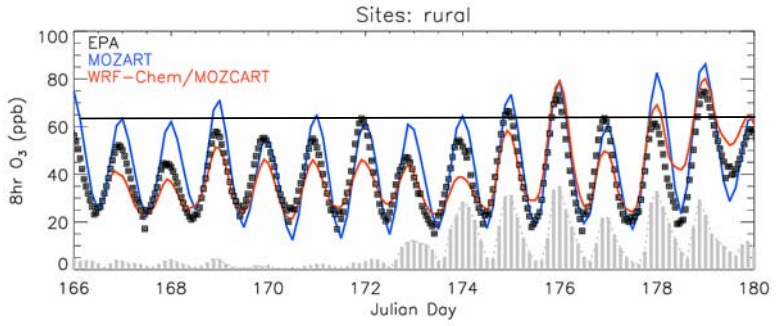
Surface 8-hour O_3

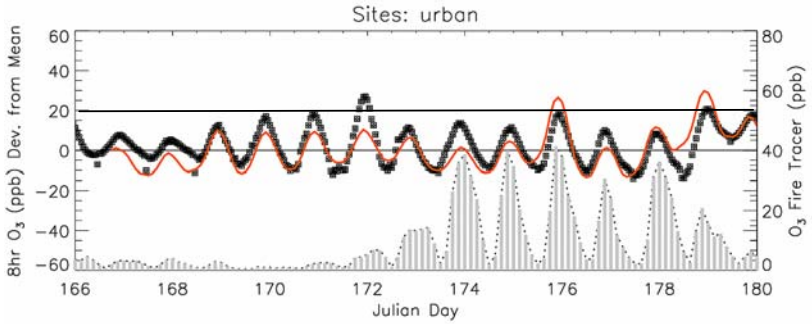
Northern California

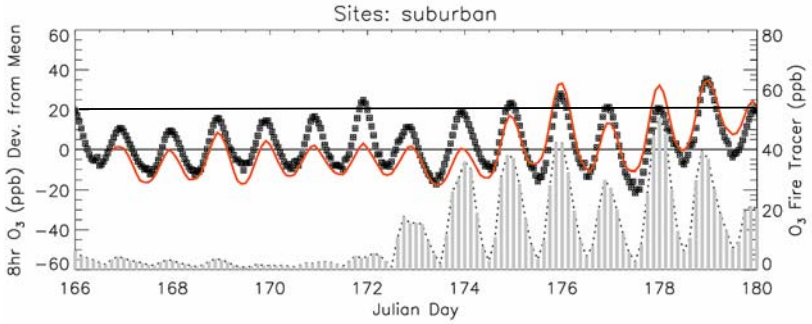
Deviation from Mean

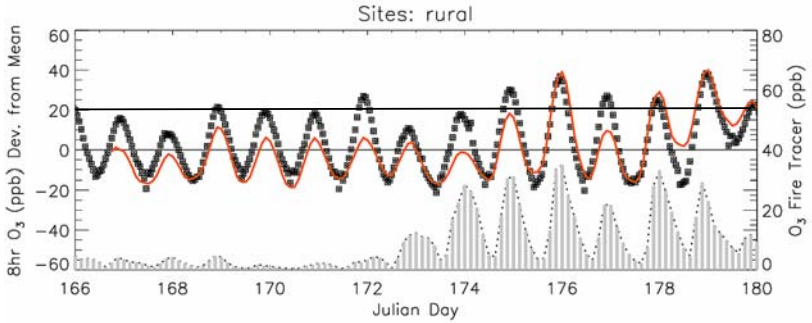












Summary

- Analysis of ARCTAS-Carb will integrate in-situ data (ground & aircraft), satellite data and the WRF-Chem and MOZART models. Observations will be essential in model evaluation and models will play a significant role in data interpretation.

- Large impact of biogenic emissions over the study region – careful evaluation of biogenic emission schemes needed

- Intense wildfires during ARCTAS-Carb. Combination of datasets and models will help to evaluate emission inventories, emission factors, injection height, etc.

- Research goal is to understand the spatial and temporal characteristics of the different factors that impact air pollution over California (pollution inflow, local sources, fires and biogenic emissions).

Summary

- Analysis of ARCTAS-Carb will integrate in-situ data (ground & aircraft), satellite data and the WRF-Chem and MOZART models. Observations will be essential in model evaluation and models will play a significant role in data interpretation.

- Large impact of biogenic emissions over the study region – careful evaluation of biogenic emission schemes needed

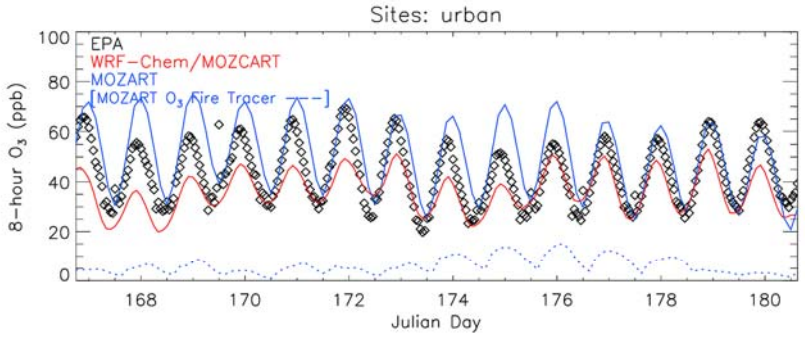
- Intense wildfires during ARCTAS-Carb. Combination of datasets and models will help to evaluate emission inventories, emission factors, injection height, etc.

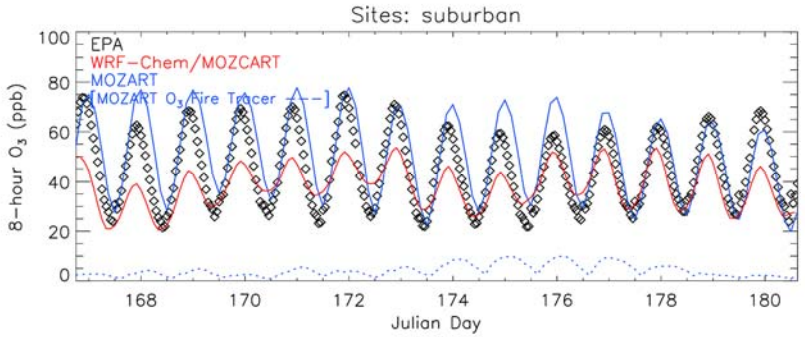
- Research goal is to understand the spatial and temporal characteristics of the different factors that impact air pollution over California (pollution inflow, local sources, fires and biogenic emissions).

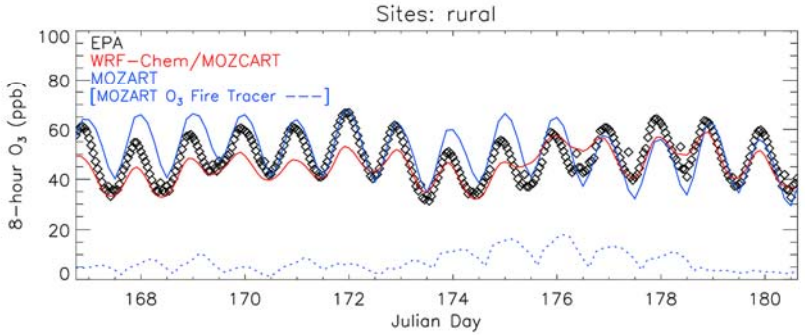
Thanks

Additional Slides

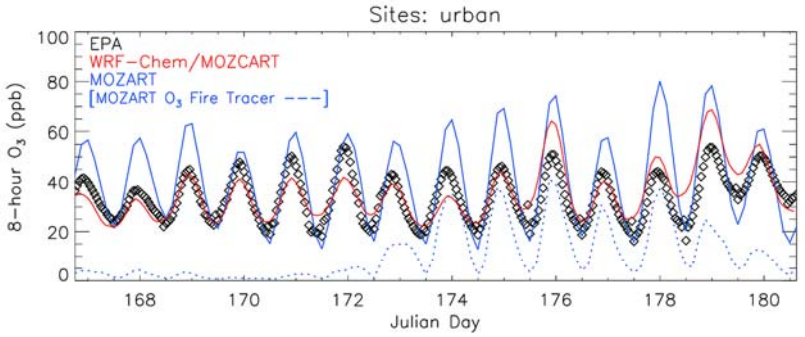
Evaluating Surface O_3 – EPA Monitoring Sites

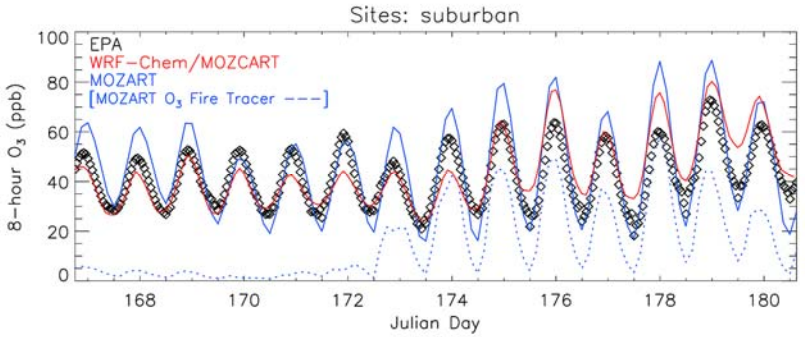


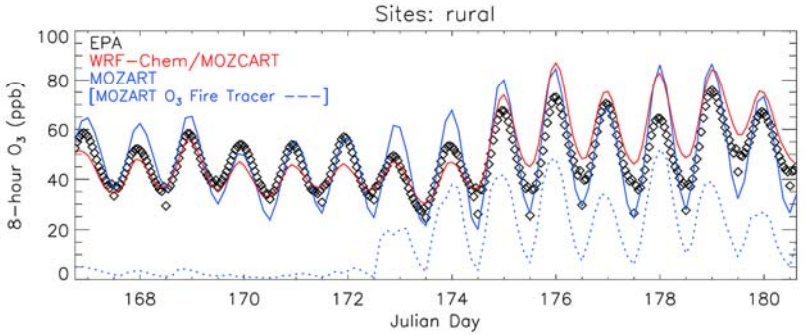




Southern CA (< 36N)

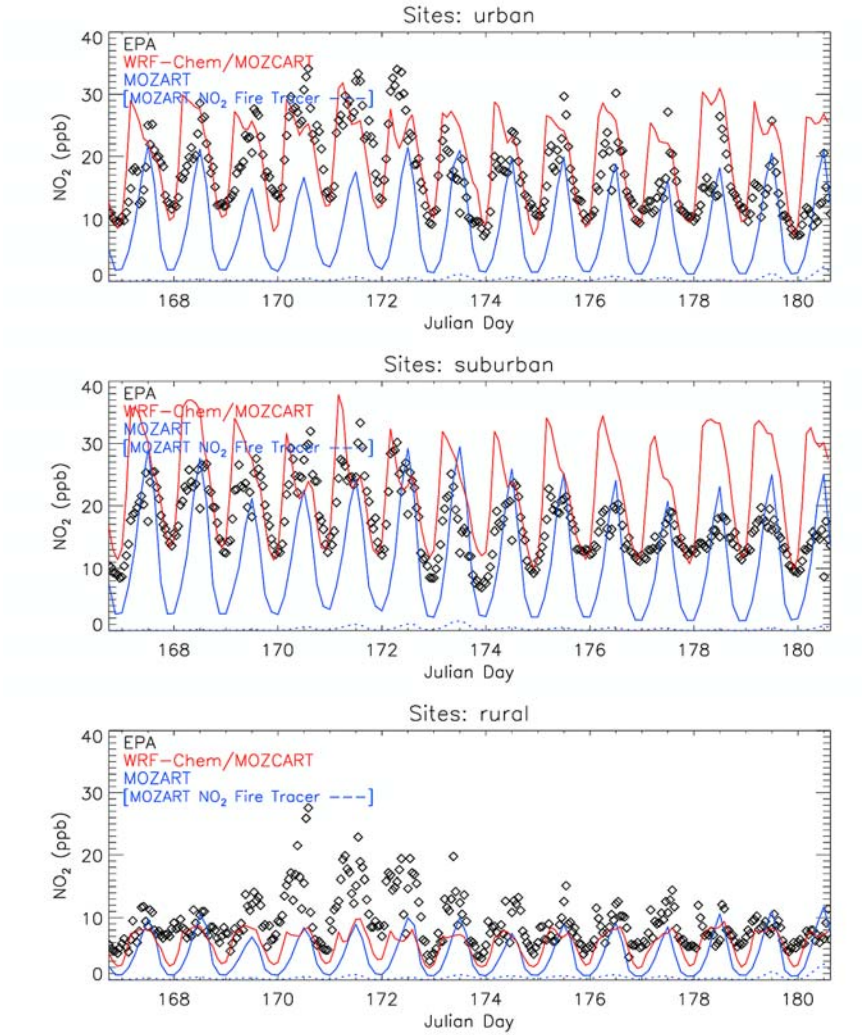




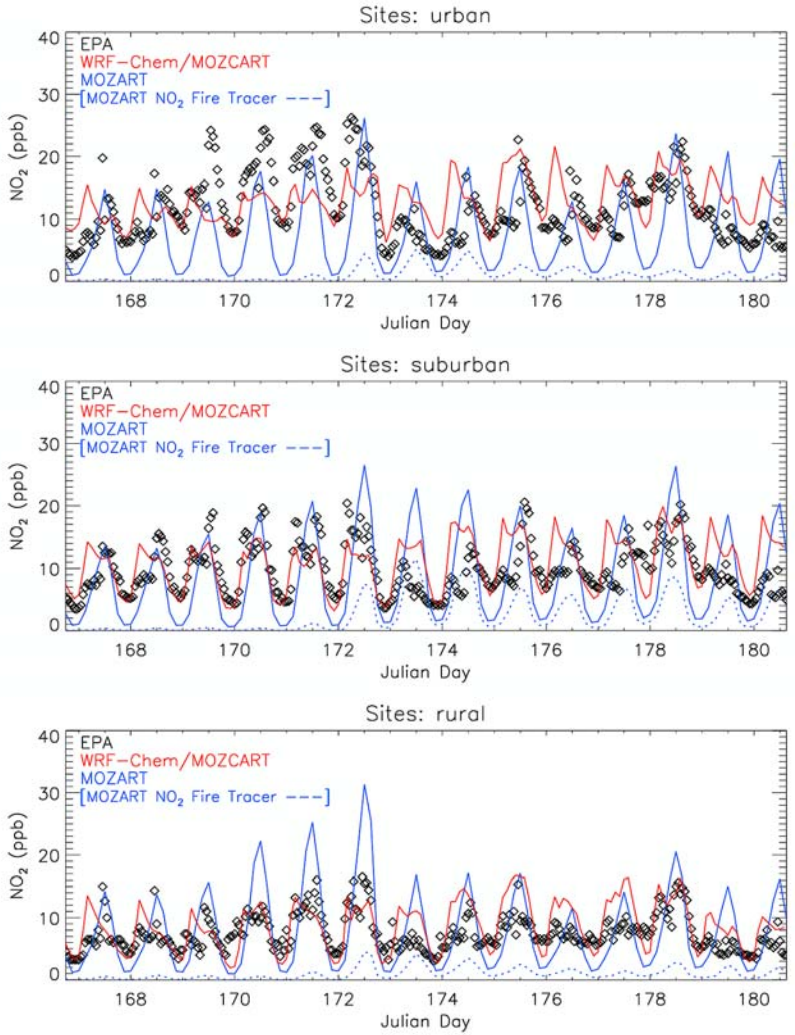


Northern CA (> 37N)

Evaluation with EPA Surface NO_2



Southern CA (< 36N)



Northern CA (> 37N)