Impacts of biomass burning and stratospheric air mass plumes on ozonesonde profiles in the Midwest during SEACIONS summer 2013

Joseph L. Wilkins, PhD

May 17, 2016

St. Louis Area Monitoring Agencies Meeting

Department of Earth and Atmospheric Sciences
Saint Louis University, St. Louis, Missouri 63108

The SEACIONS Mission:

Ozonesonde Network in Support of daily satellite overpasses and aircraft flights

Science Objectives

1. Test Models abilities to simulate biomass burning transport
2. Investigate convective and wave signatures in ozone

http://croc.gsfc.nasa.gov/seacions/

Seac4rs: Studies of Emissions and Atmospheric Composition, Clouds, and Climate Coupling by Regional Surveys.

SEACIONS (SouthEast American Consortium for Intensive Ozonesonde Network Study)

A strategic approach to determining convective impacts on Tropospheric Ozone

31 Ozonesondes were launched from each site during SEACIONS/SEAC^{4}RS

Daily Process

Launch Site:

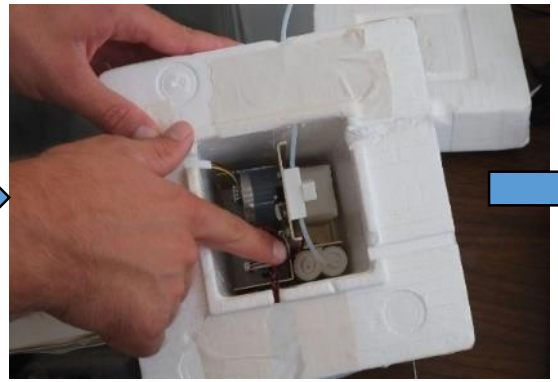
James S. McDonnell Planetarium in Forest Park, St. Louis, MO.

Dr. Jack Fishman Launching an Ozonesonde during the NASA SEACIONS 2013 Campaign

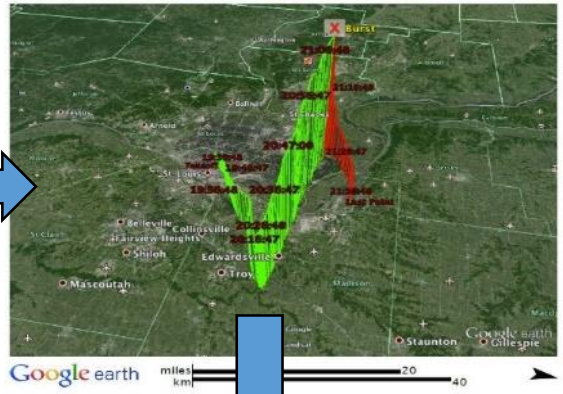
Daily Process

3-5 day Prep-Test the Sonde

0-1 day Prep the Sonde for launch



Check weather & balloon trajectory



Day of launch-Fill balloon & Prepare for launch

Verify O3 reading against local ozone monitor

Checking instrumentation & Final launch preps

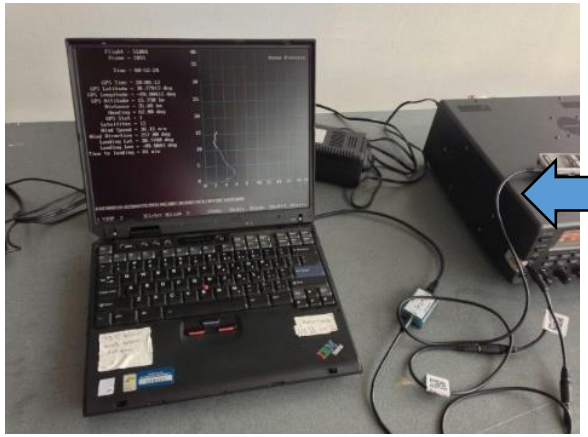


Photo credit: Art Chimes-STL public Radio

SEACIONS In the Press

The St. Louis weather balloon launch program was talked about far and wide

Photo credit: Art Chimes – St. Louis Public Radio

Caption: SLU students Joseph Wilkins, Patrick Walsh, Jackie Ringhausen and Tim Barbeau (standing, from left to right), and Valparaiso Univ. trainers Alex Kotsakis and Mark Spychala (crouching, left to right) stabilize the balloon as it fills with helium.

St. Louis Public Radio, HERE an NOW network,

St. Louis KTVI, news 11 and FOX2

The Kenya Star Newspaper

SEACIONS Outreach Impacts

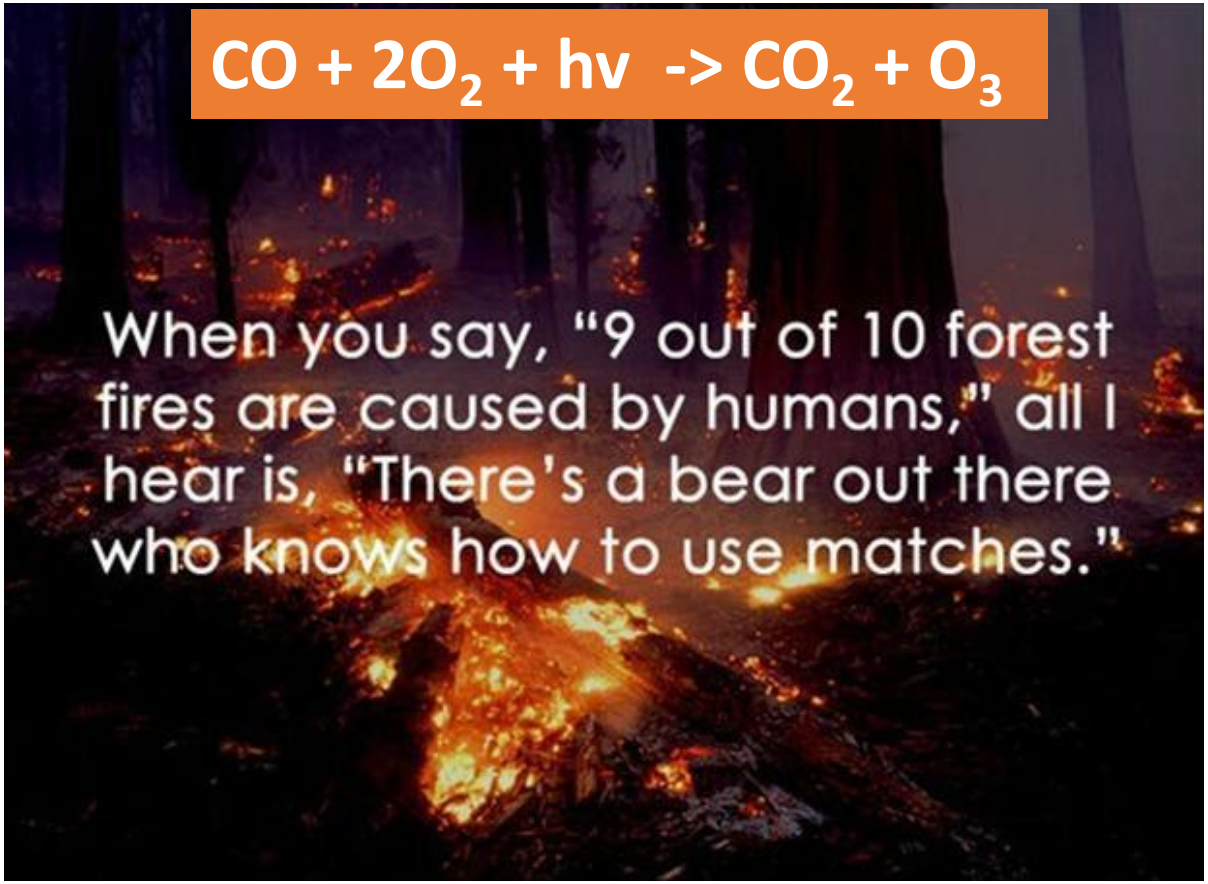
Biomass Burning

Studies estimate that wildfires globally produce approximately 170 Tg of Ozone per year, ~3.5 % of all tropospheric Ozone production.

Why use CO?

Forest fire emission chemistry

Early: NOX, CO, SO4
Late: NOX, CH4, N20



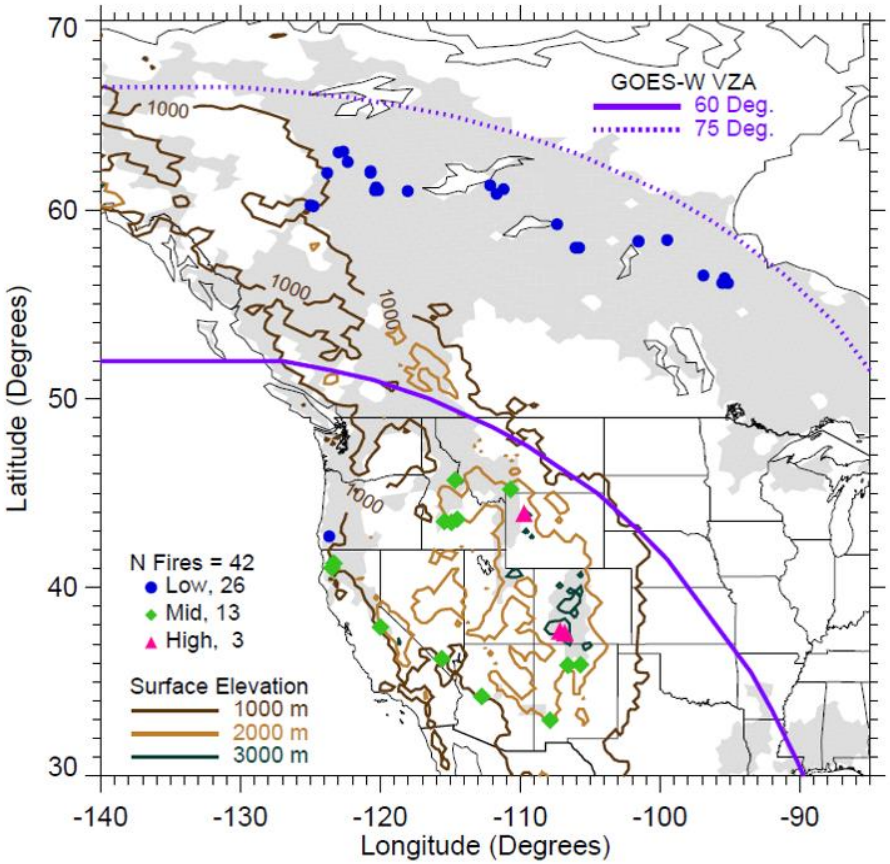
$$CO + 2O_2 + h\nu \rightarrow CO_2 + O_3$$

Climate change
over the past century has increased the frequency and intensity of wildfires leading to more tropospheric production of Ozone

Jaffe, D. A., and N.L. Wigder (2012), AE

Fires can create their own convection

We use a second simulation with the Naval Research Lab new detection algorithm for injection heights



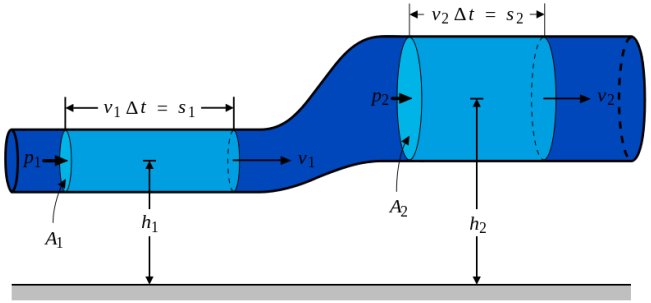
Peterson et al 2013 JGR

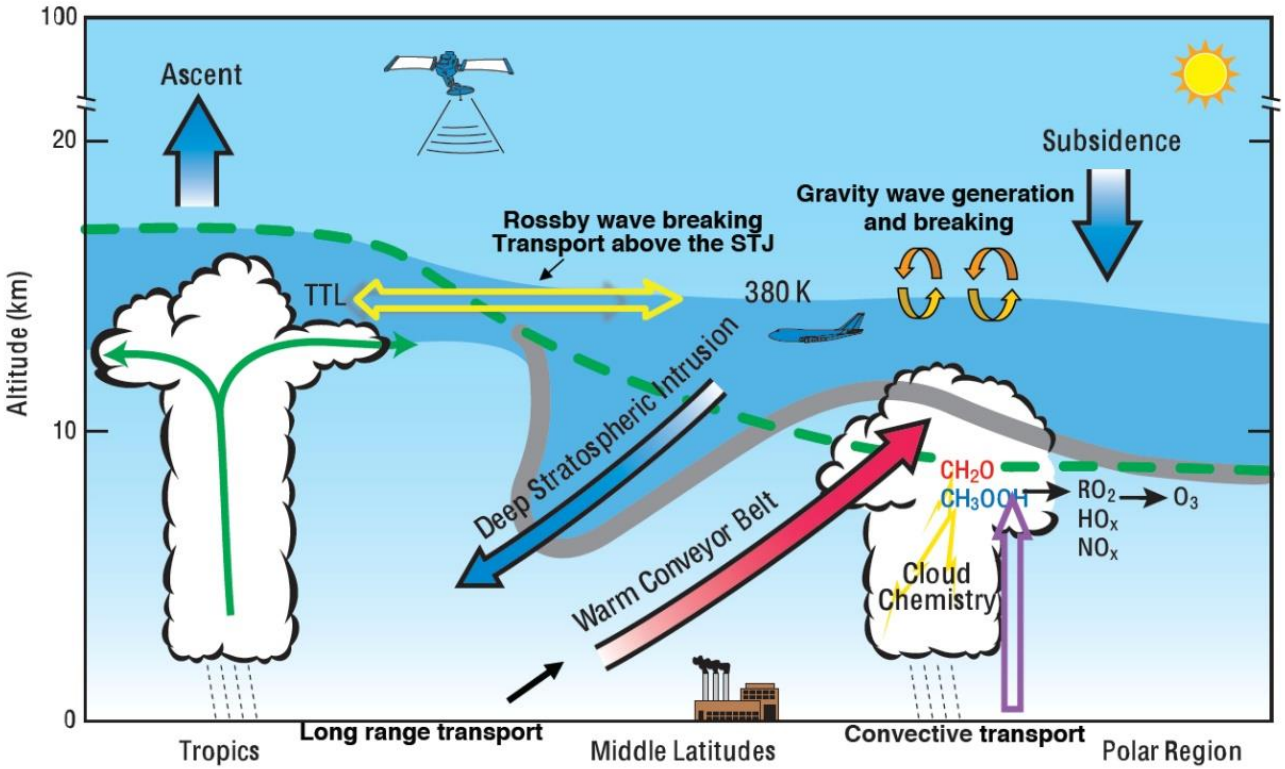
21% of smoke plumes are injected more than 500m above the boundary layer and 8% exceed 2.5 km above ground level

29 PyroCbs during SEACIONS were detected

Stratospheric-Tropospheric Exchange

What comes up must go down





The stratosphere is relatively stable, we know what is in it

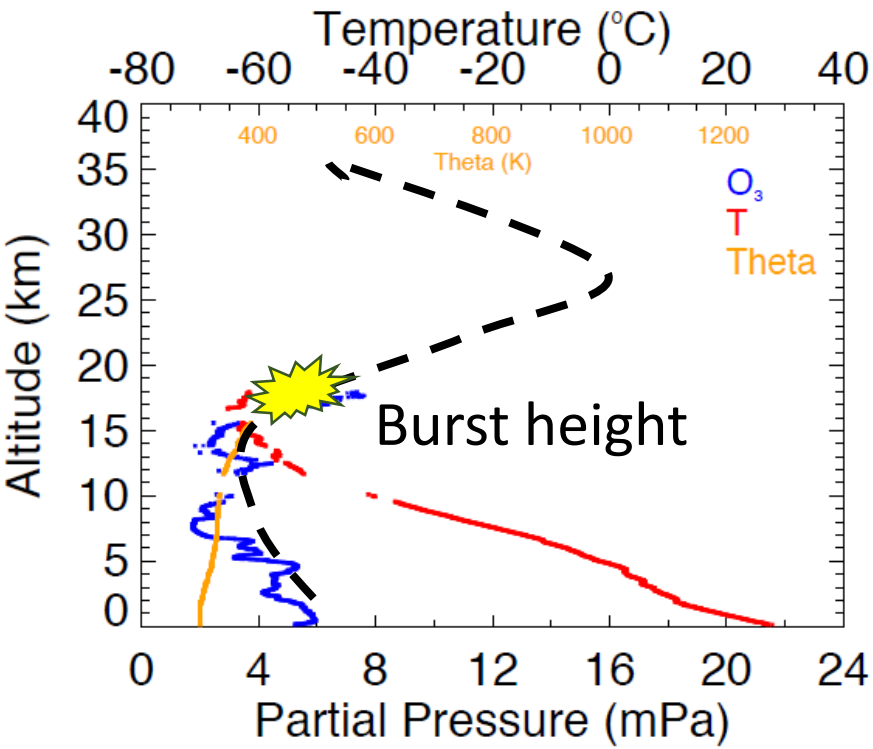
LOW RH
High O3
High Potential Vorticity

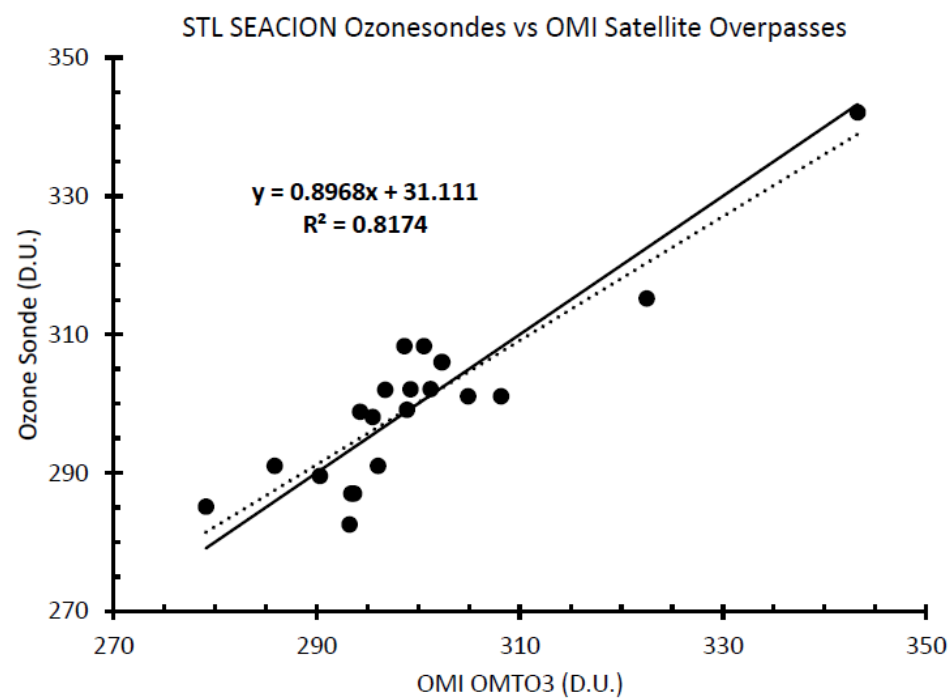
large synoptic systems: Cut off lows, shortwave breakage, high pressure, frontal passages

Using corrected Ozonesondes we can compare to the OMI satellite

Watch for Overcorrection and Shortwaves

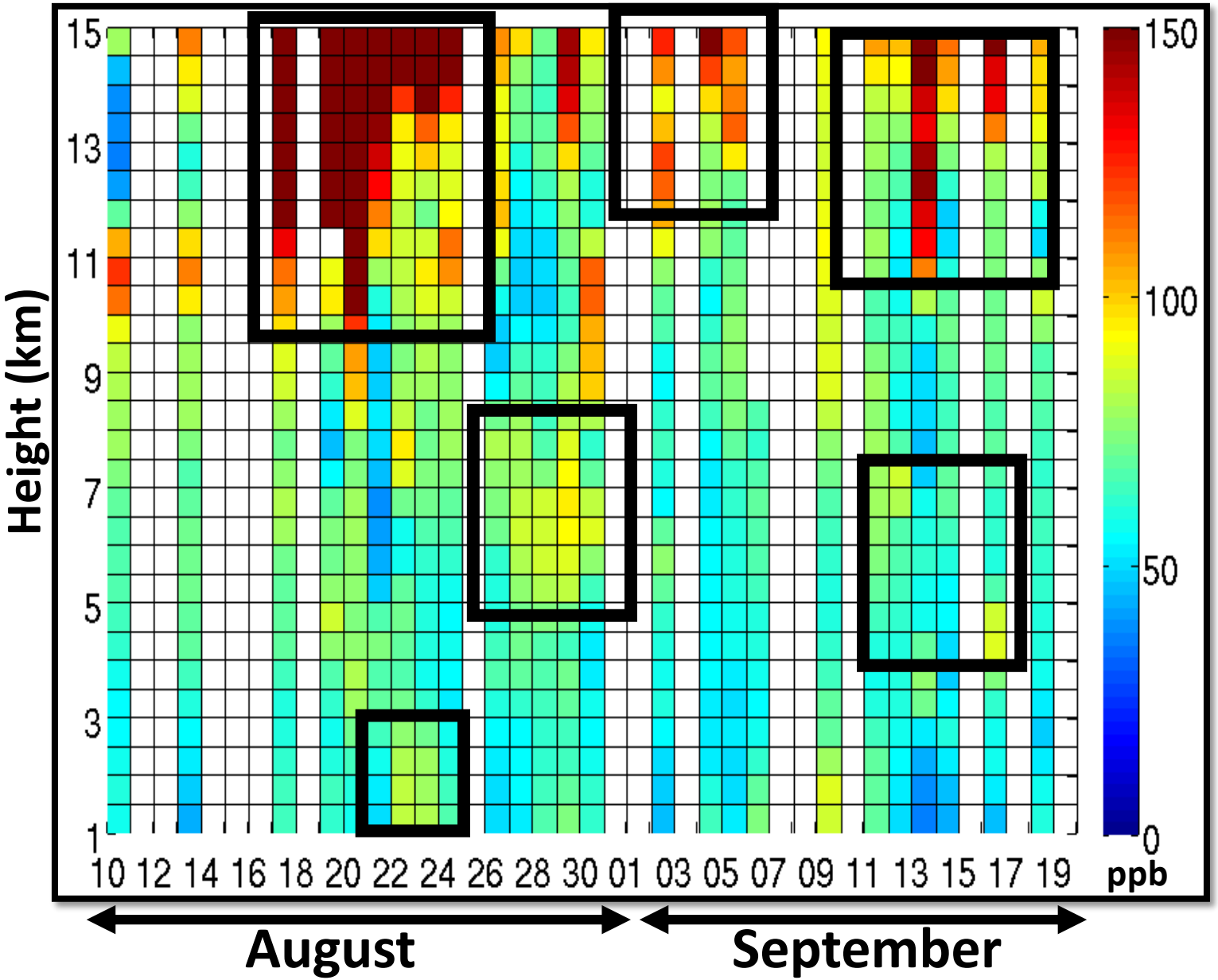
Example: 19 August 2013





With the use of a modified McPeters and Labow (2012) method for 2011 climatology of burst height corrections we improved our ozonesonde to OMI Satellite (Total Column) comparison by 30%

St. Louis Ozonesonde Tropospheric profiles are used to spot enhancements above



ozonesonde profiles are averaged vertically every 500 m

Black boxes indicate O3 rich areas

Identifying the source of the Ozone

Observations

UAH (03 DIAL) LIDAR
OZONE SONDES
OMI OVERPASSES
Air planes DC-8 ER-2

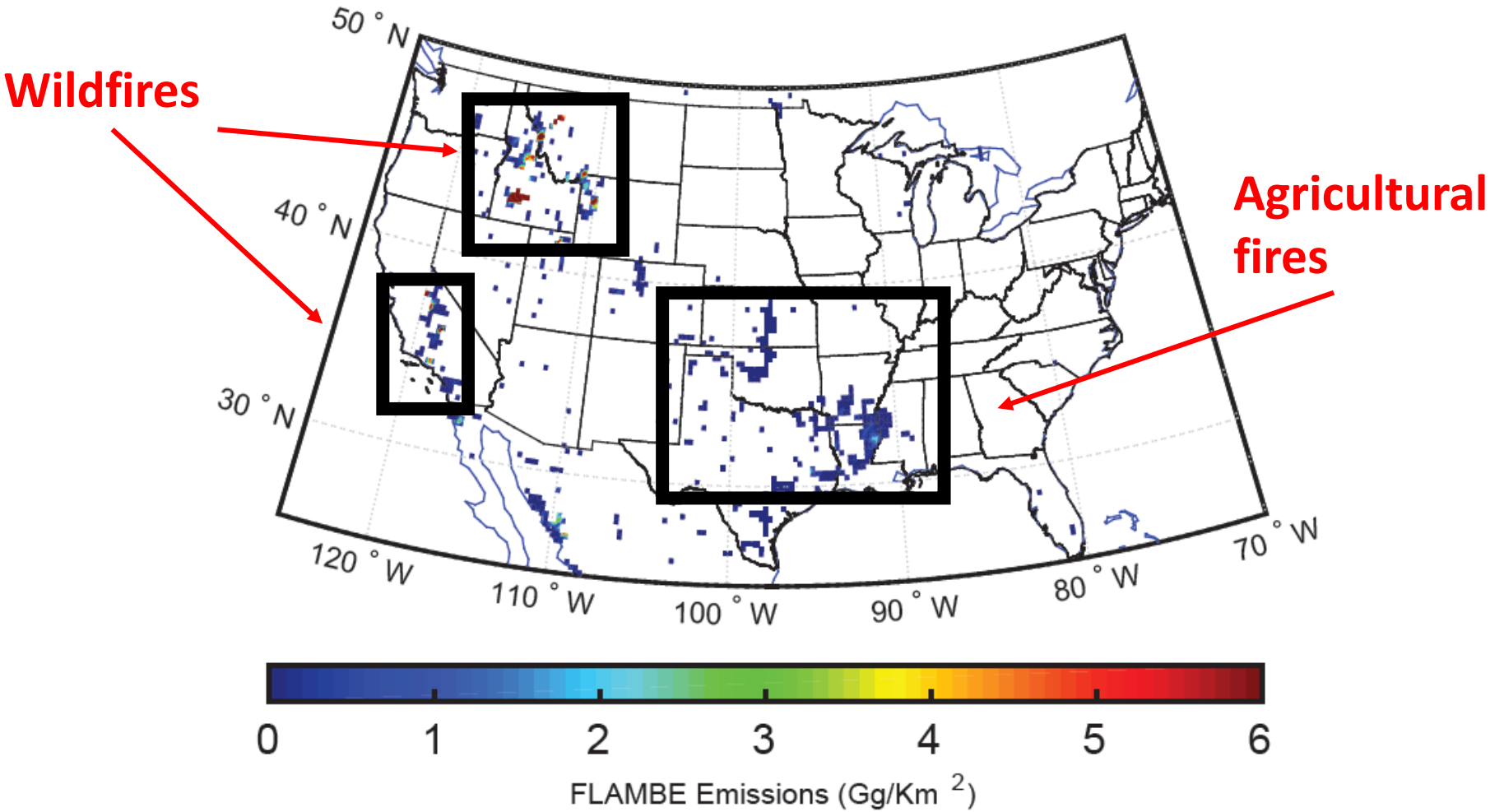
Model

FLEXPART-WRF **CO**
GEOS-5 **PVU**

We focus on model simulations to explain O3 source

How is a CO Plume Simulated

Total smoke emissions mass (1 Gg = 10^9g) from FLAMBE database during 8 Aug to 22 Sept 2013.

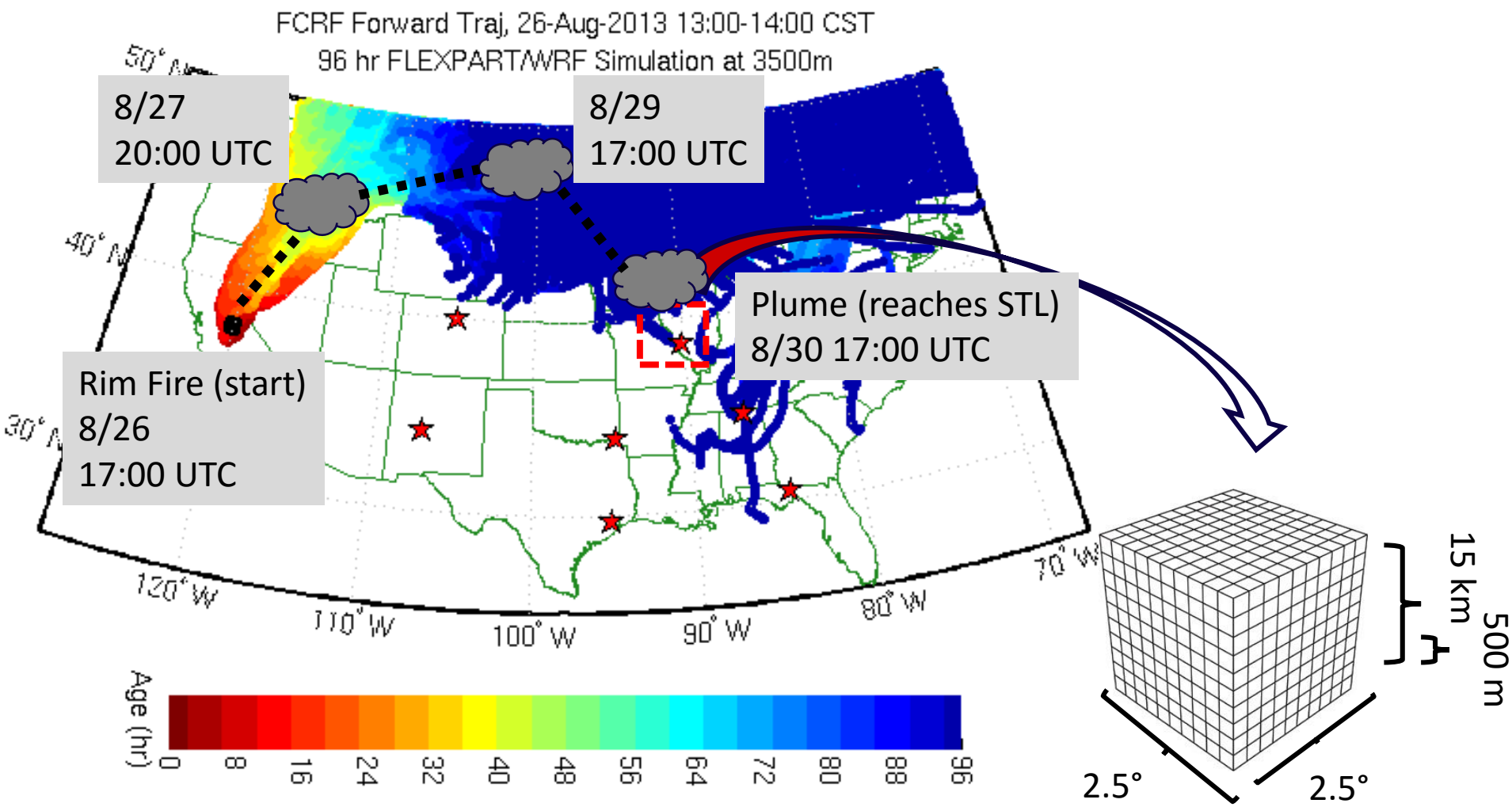


The emissions are gridded per 0.25° cell with a minimum threshold of 2000 kg.

How is a CO Plume Simulated

FLEXPART-WRF hourly CO particles releases from the boundary Layer (0-3.5 km) reaching the STL Area are binned and averaged per cell

FLEXPART-WRF 4 day simulation of CO example



How is a CO Plume Simulated

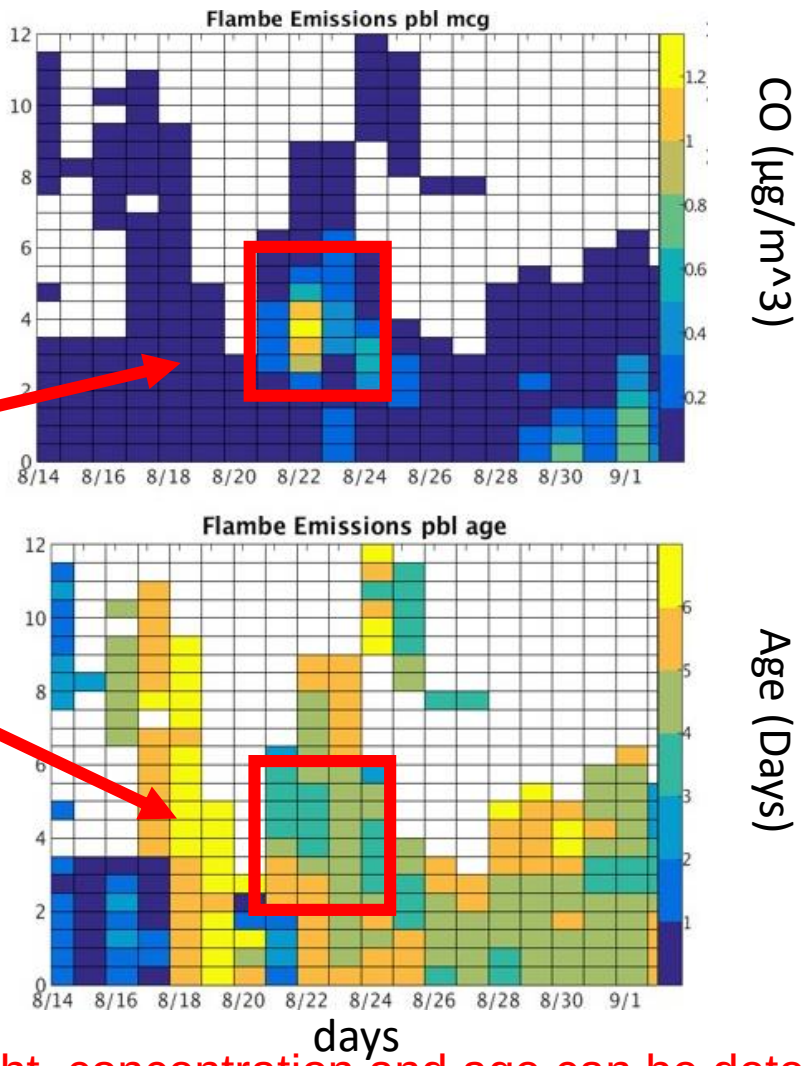
Output from FLEXPART-WRF over St. Louis

21-24 August An area of high CO shows up, let us investigate

Layer with 25 ppb O3 RH < 5% 3-5 km

2.4 ppm CO

4.8 day old

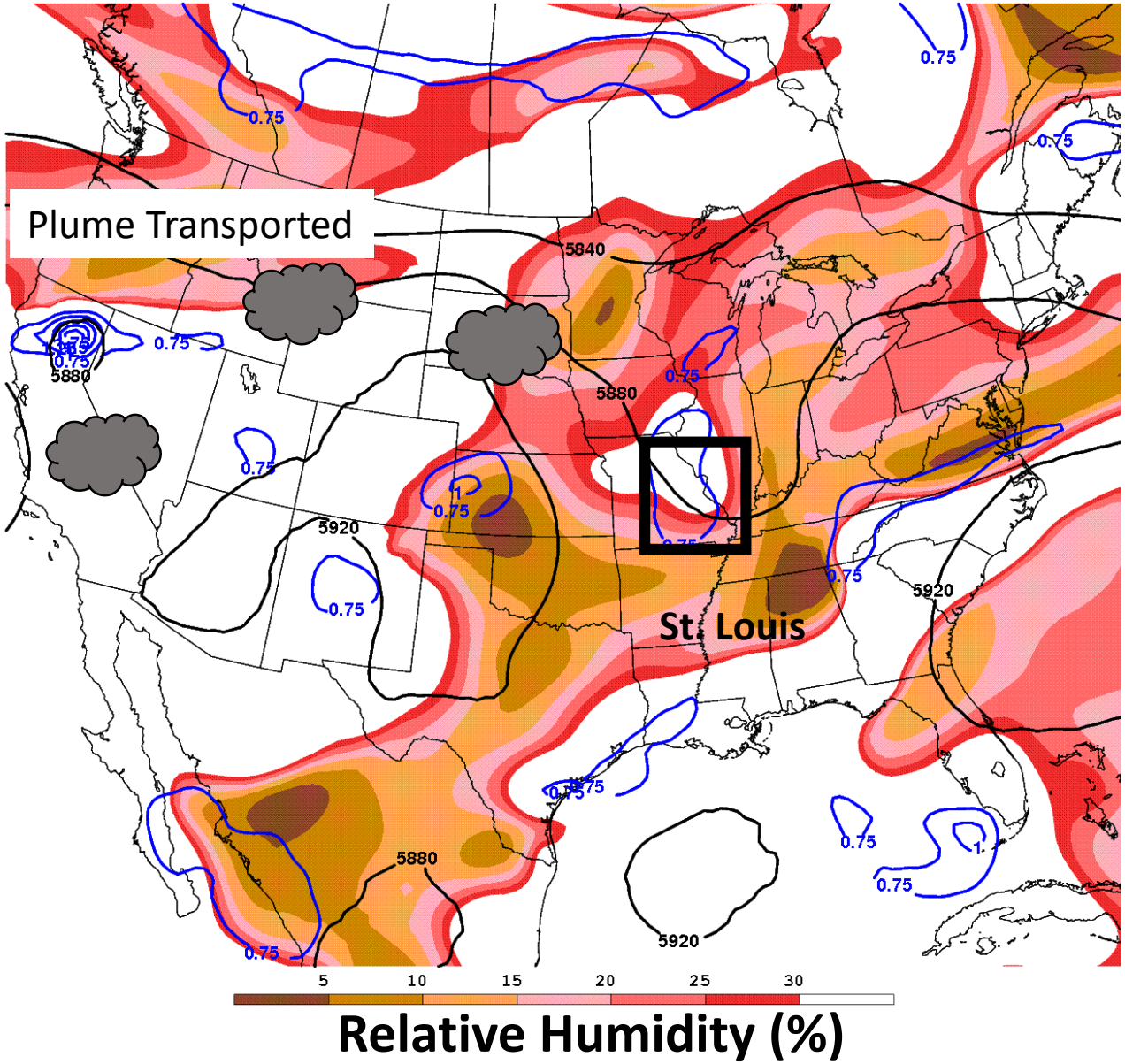


We use 21 august to Investigate Biomass Burning effects over STL

From simulations Plume height, concentration and age can be determined

Meteorology behind Transported CO plume

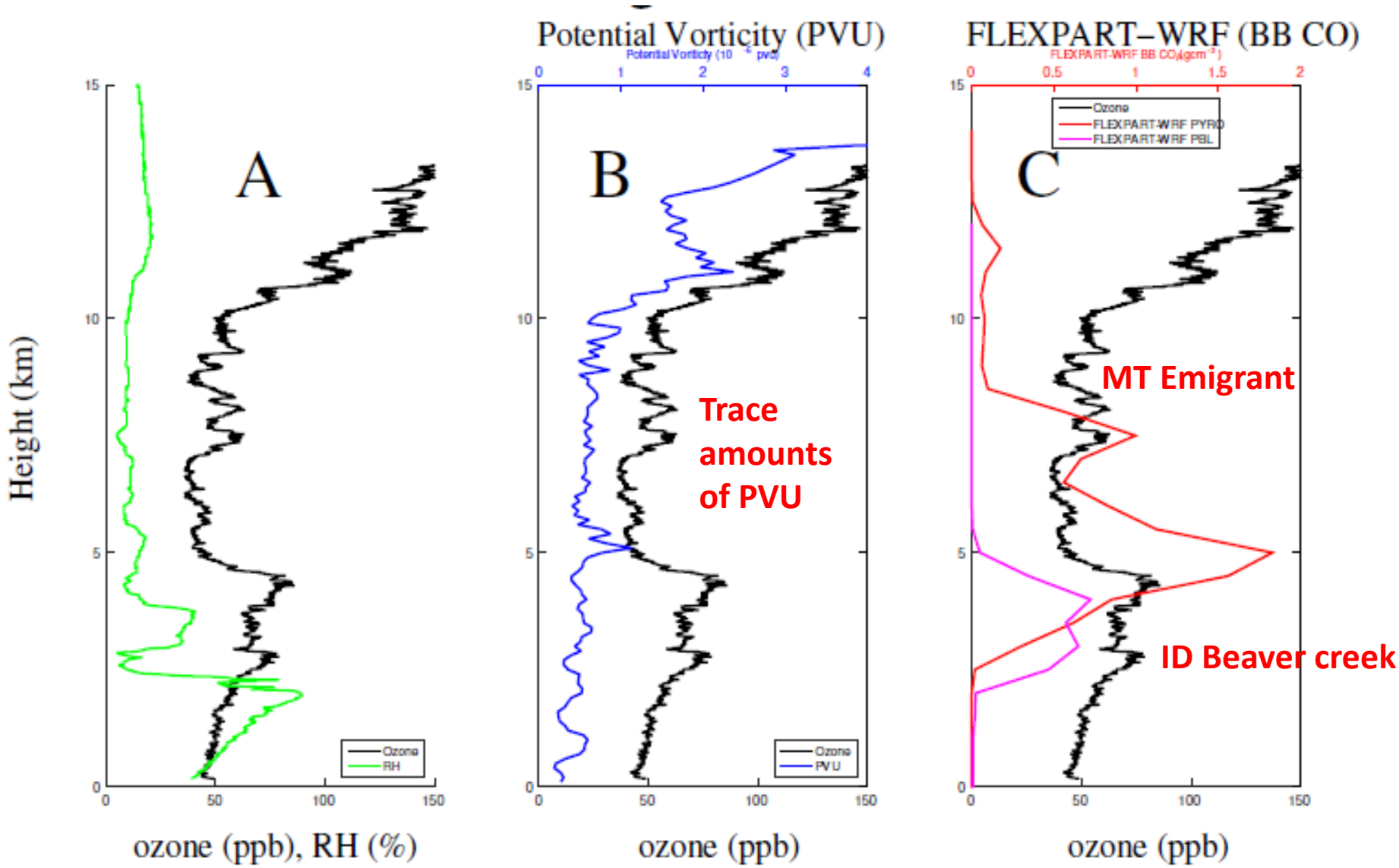
21 Aug 2013 **Cut-off Low → Fire Plume**



Caption: RH<30% (shaded), pressure (black), and Potential Vorticity (blue). 500hPa.

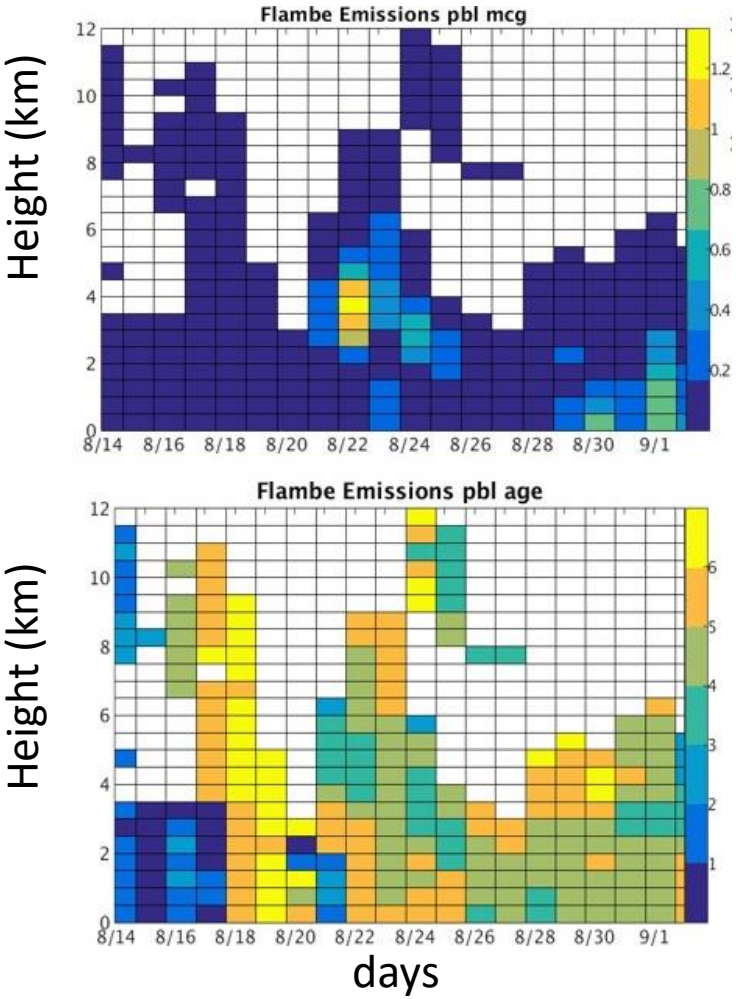
Contours indicate air flowing from out west to the STL location

21 August Test Case: fire transport to STL



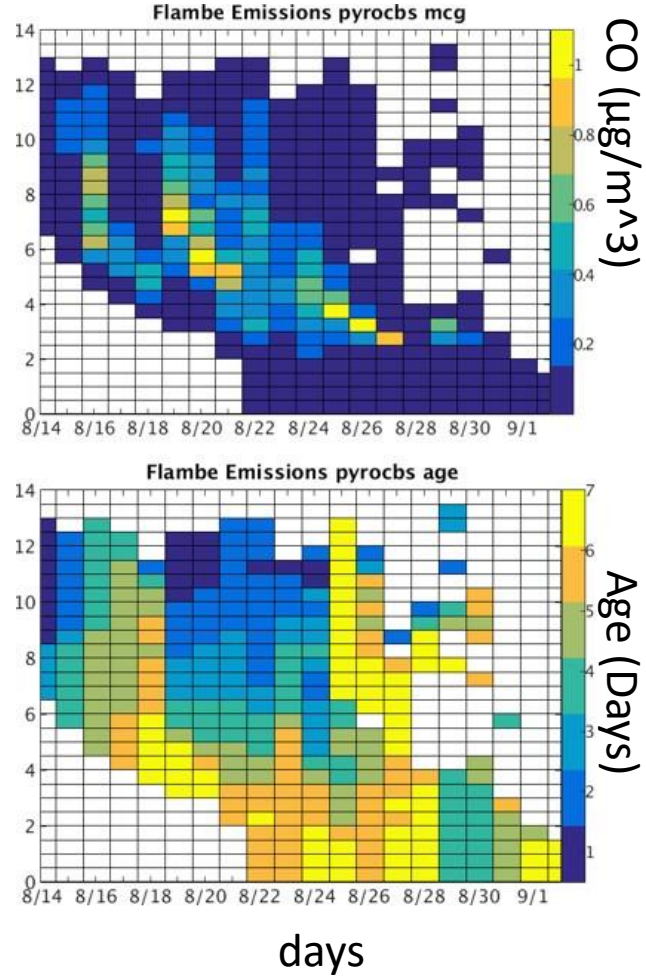
We compare the two simulations

Model limitations due to injection heights. Plumes from PyrCbs >5 km missed



15 days Were effected by Biomass burning

The NRL's Detection algorithm improves our models capabilities

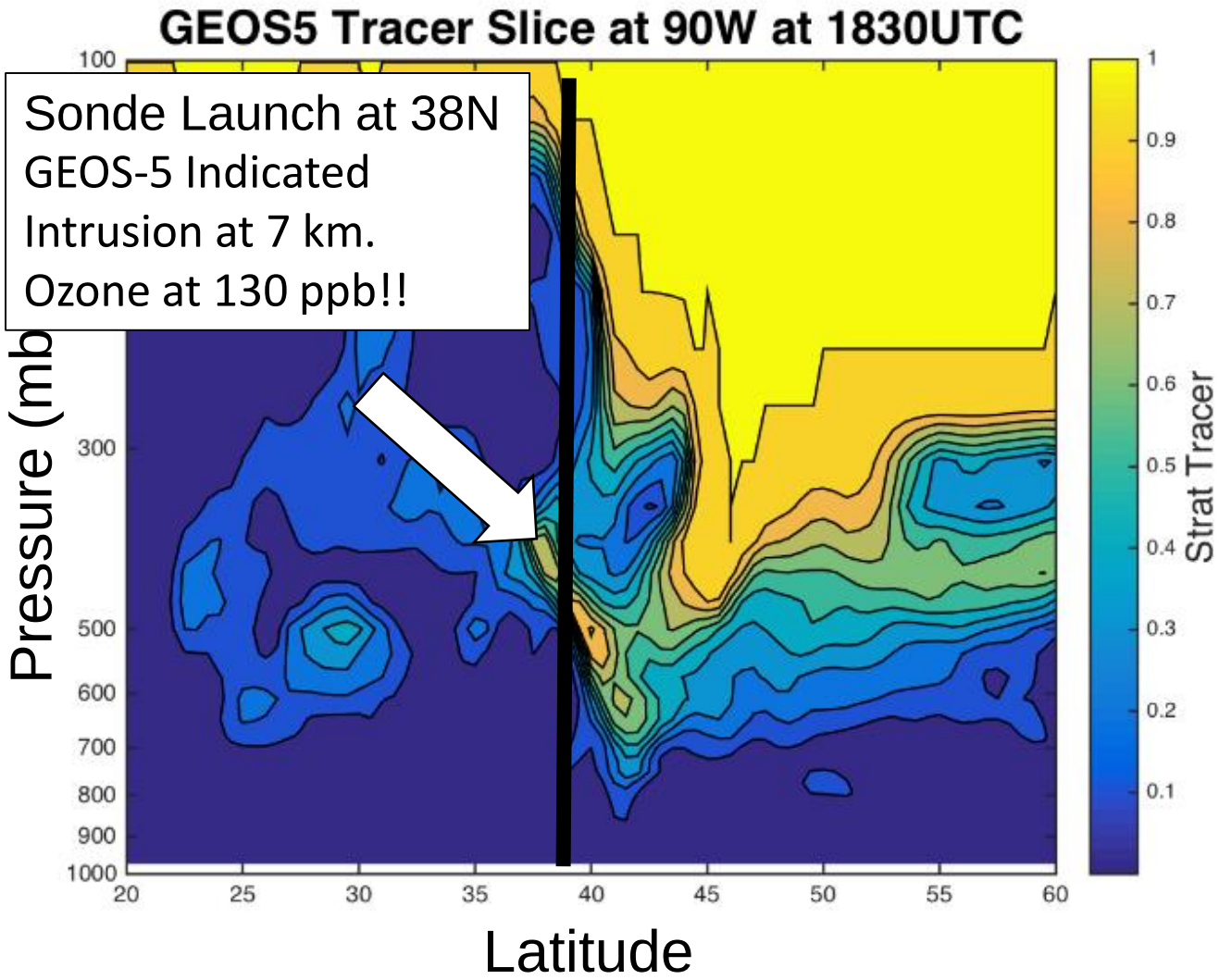


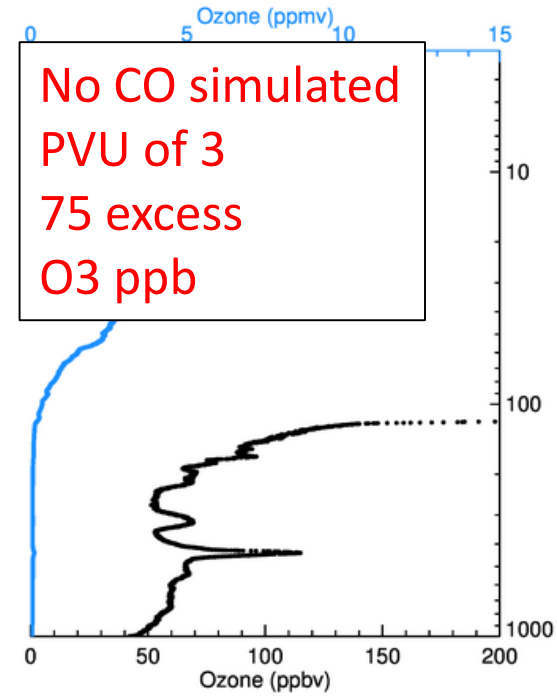
O3 has a positive correlation with age R^2 = 0.33, and concentration R^2 = 0.43

The injection height analysis shows that when fires generate there own convection the emissions that escape the PBL will be missed in a typical model run

Frontal passage increasing ozone indicated in GEOS-5 model

12 September 2013





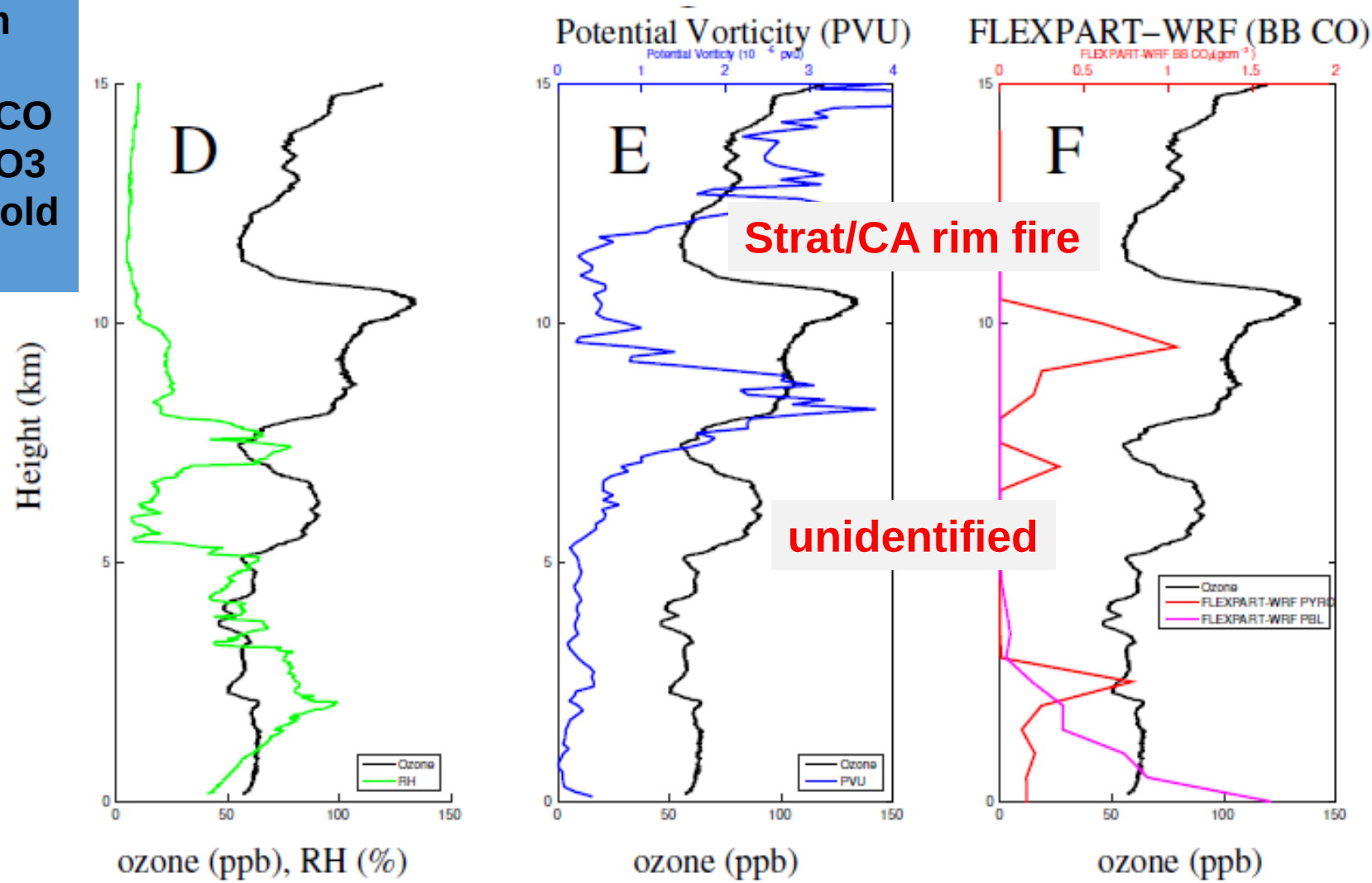
13 days (48%)
Were effected
stratosphere

An intrusion of Stratospheric air (700 hPa) is evident in the model

Can we have Strat Air mix with Biomass Burning?

30 August 2013

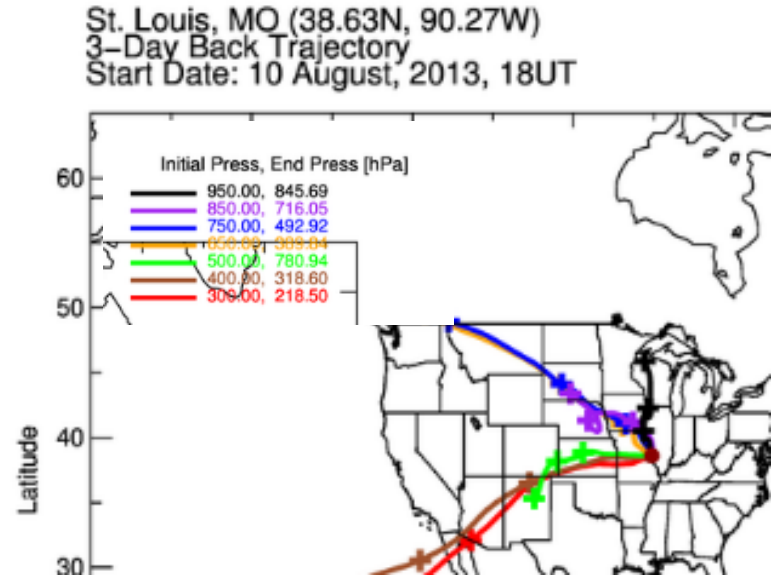
8 – 12 km
3 PVU
6.8 ppm CO
140 ppb O3
5.3 days old
15% RH



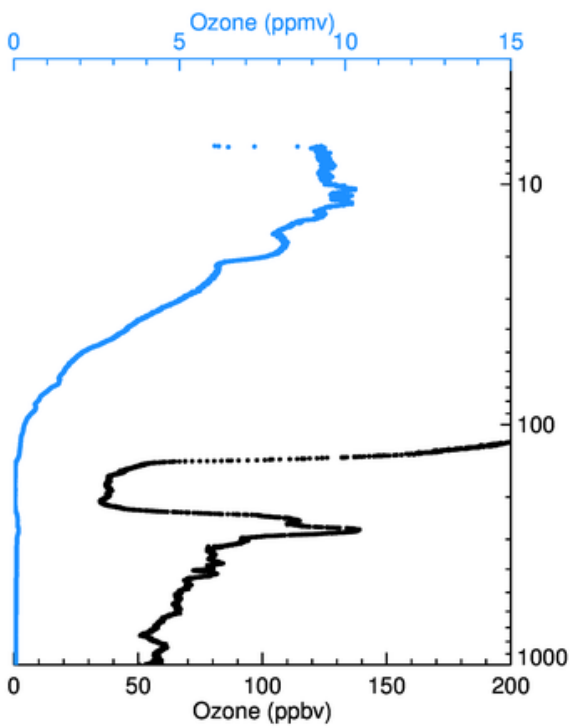
FLEXPART-WRF analysis reveals that 55% of ozonesondes during SEACIONS were effected by biomass burning while 48% were effected by Stratospheric Air Masses.

Multiple sites capture same feature

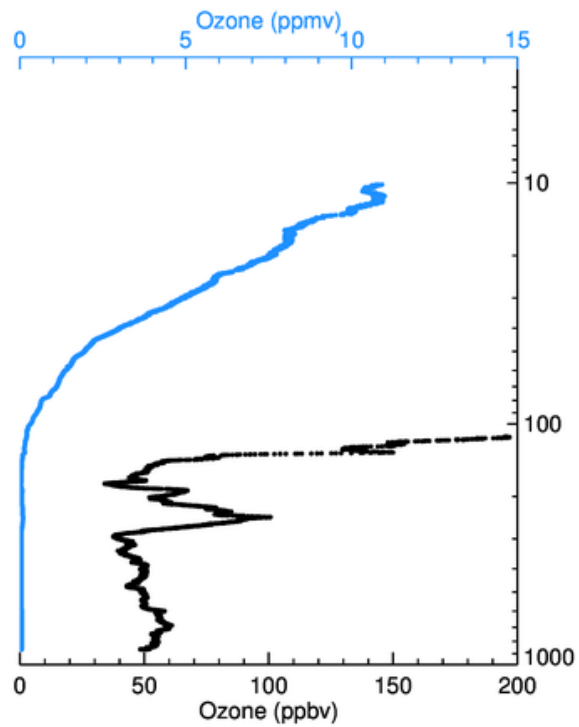
Tropical Cyclone
10 August 2013



St. Louis, MO 19:17 UT



Socorro, NM 19:40 UT



Trajectories indicate air flow at layer 300-500 hPa crossing both

Minschwaner et al. 2015 GRL

Summary

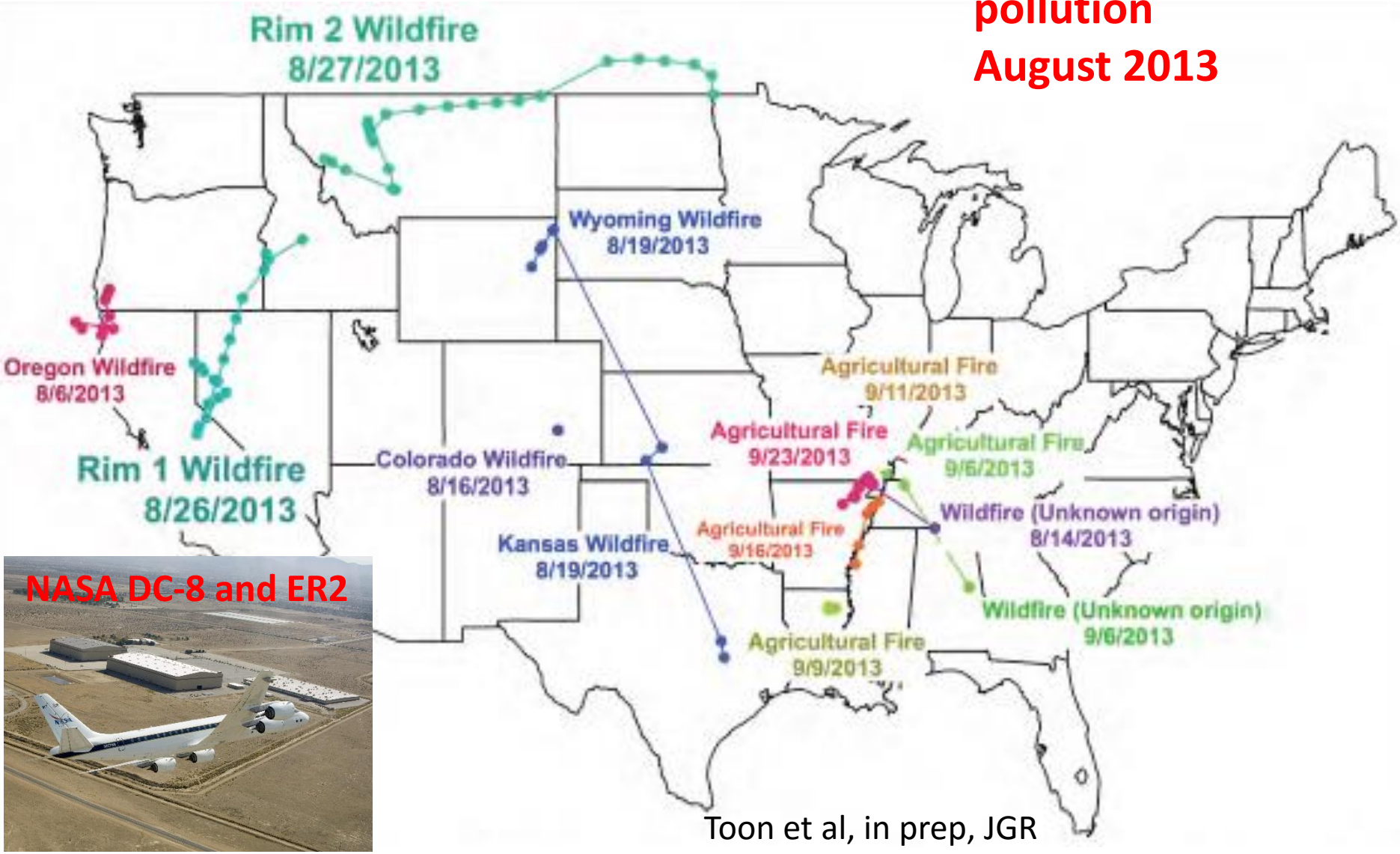
- **Analysis from 27 launches showing enhanced Ozone over STL can be traced back to:**
    - Stratospheric air intrusions on 13 days
    - Biomass Burning on 15 days.
- CO amounts tend to decrease in long range transport but as the plume ages so does the production of Ozone.
- Traditional modeling has difficulties accounting for Hot fire generated convection and vertical transport
- 29 pyroCb detected during SEACIONS time period
- Met features elevating ozone captured at multiple sites.

Thanks To ALL that helped Along the Way

Data available at:
http://croc.gsfc.nasa.gov/seacions/

Fires Sampled During SEAC4RS/SEACIONS

Large amounts of Wildfires pollution August 2013



Toon et al, in prep, JGR

Methods

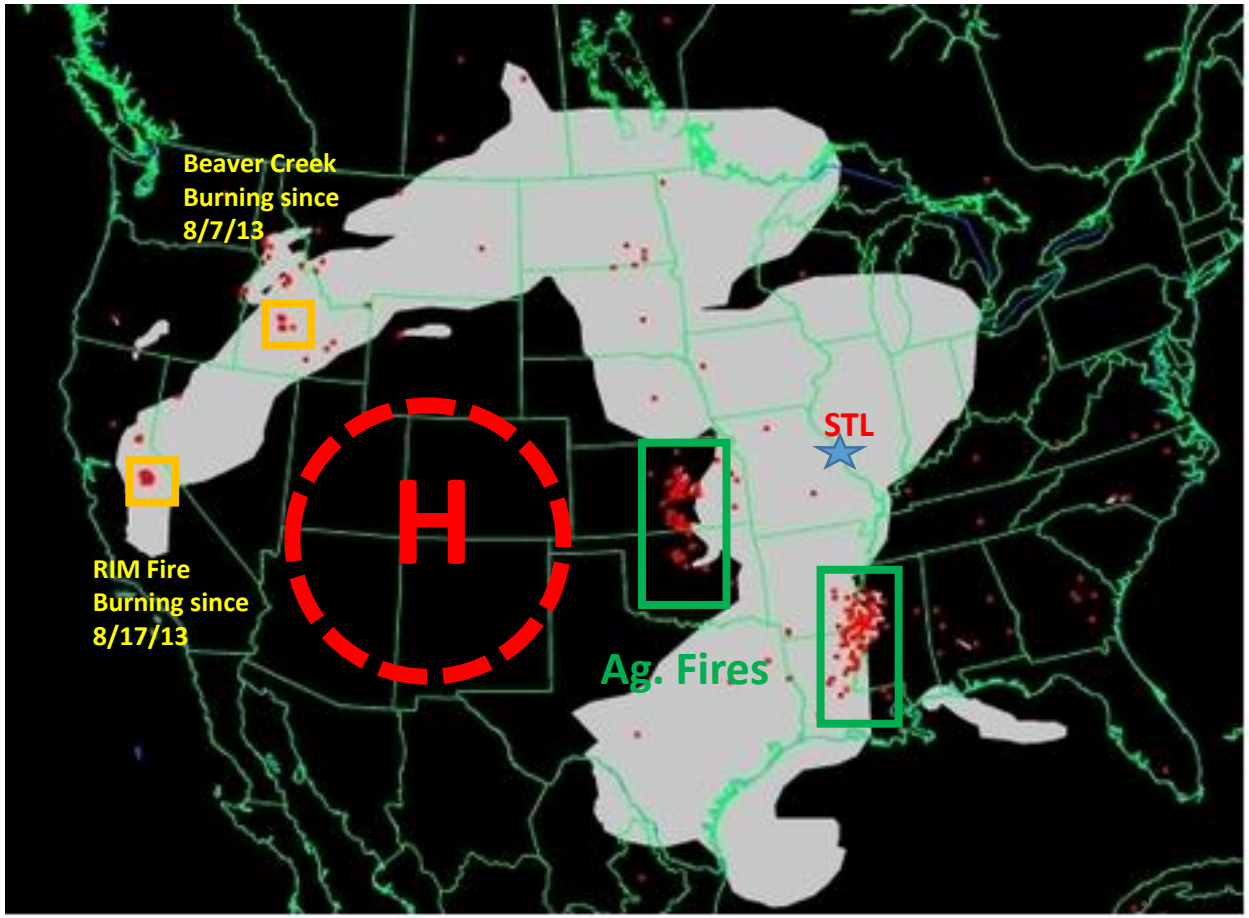
Wait? Where did you say that Ozone came from??

Complex situations

Three potential sources of O_3

1. Pollution from wildfires
2. Previous pollution from agricultural fires
3. Subsidence from a Blocking high

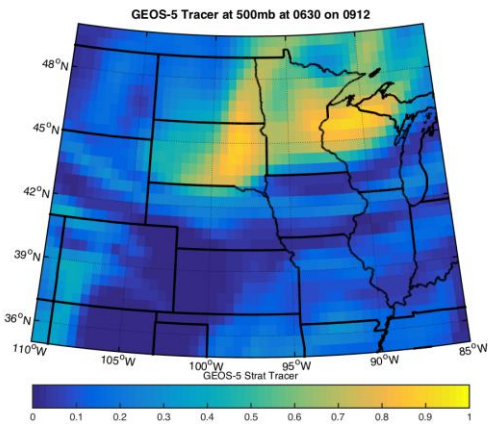
Day of launch Conditions on August 30, 2013 18z (~1pm)



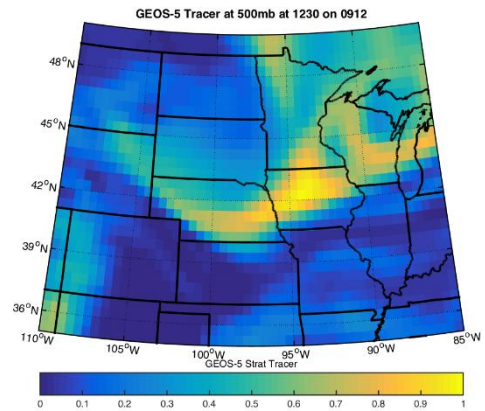
Hazard Mapping System Smoke and fire Product

We use the GEOS-5 model with a stratospheric tracer for Ozone to explain enhancement

9-12-2013 06:30 UTC

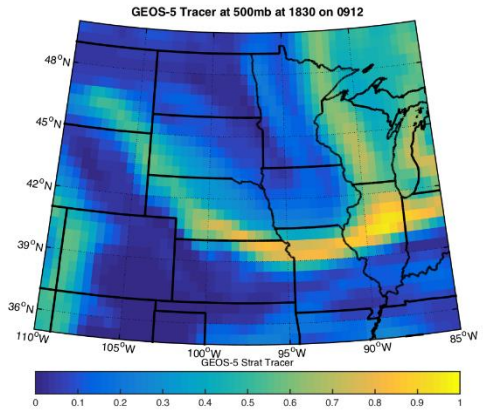


9-12-2013 12:30 UTC

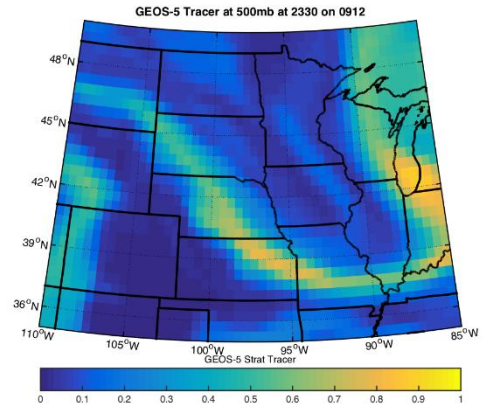


The GEOS-5 strat tracer, is shown, lighter values means greater chance for Strat Ozone

9-12-2013 18:30 UTC



9-12-2013 23:30 UTC



Ozonesonde measurements before, during and after the front passes

We use the GEOS-5 model with a stratospheric tracer for Ozone to characterize enhancement

Start Date UT	End Date UT	Extent	Height hPa	Cause
8/03 03:30	8/04 00:30	shallow	580	Frontal passage
8/07 13:30	8/08 17:30	deep	690	Shortwave
8/10 02:30	8/11 12:30	deep	800	Shortwave
8/12 18:30	8/13 22:30	deep	500-850	Frontal passage
8/14 06:30	8/21 18:30	shallow	600	Cutoff low
8/23 16:30	8/24 01:30	shallow	500	Shortwave
8/28 21:30	8/29 15:30	shallow	480	Shortwave
8/30 08:30	9/03 06:30	shallow	500	Shortwave
9/03 12:30	9/04 18:30	deep	700-1000	Frontal passage
9/06 09:30	9/08 02:30	shallow	600	Shortwave
9/12 16:30	9/13 02:30	deep	800	Frontal passage
9/15 20:30	9/17 20:30	deep	800-1000	Frontal passage
9/22 00:30	9/25 22:30	deep	900	Frontal passage

Stratospheric air intrusions 13 days

NRL's Detection Algorithm PyroCb

Table 2.2: PyroCbs identified using NRLs detection algorithm relevant to SEACIONS 2013.

Fire Name	Event Type	Time (UTC)	Latitude	Longitude
CA_rim	pyroCb	8/19 23:15	37.91	-120.00
CA_rim	pyroCb	8/21 22:41	37.91	-120.00
ID_pony_elk	pyroCb	8/09 22:41	43.50	-115.43
ID_pony_elk	pyroCb	8/10 21:00	43.50	-115.43
ID_pony_elk	pyroCb	8/12 21:00	43.50	-115.43
ID_pony_elk	pyroCb	8/13 23:41	43.50	-115.43
ID_beaver_creek	pyroCb	8/12 23:00	43.62	-114.51
CA_corral_complex	pyroCb	8/22 21:30	41.04	-123.47
OR_big_windy_complex	pyroCb	8/07 22:15	42.71	-123.66
ID_beaver_creek	marginal	8/16 23:41	43.62	-114.51
ID_gold_pan_complex	marginal	8/16 21:41	45.69	-114.66
MT_emigrant	marginal	8/19 22:50	45.20	-110.69
CA_rim	marginal	8/25 17:00	37.91	-120.00

PyroCb…

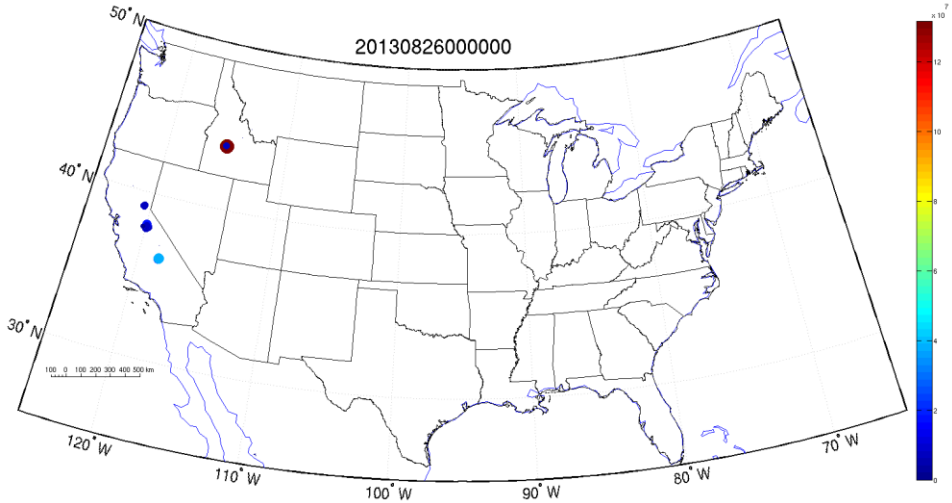
Fires burn so hot that they generate there own convection, which lifts the emissions outside of the boundary layer

Plume	Plume source	Height STL	smoke age	Boundary Layer Sim	PyroCb Sim	Sonde RH	sonde O_3	O_3 excess
Date	location	AGL km	days	CO ppm	CO ppm	%	ppb	ppb
8/21	ID Beaver Creek	2-5.5	4.8	2.4	14	10	65	10
8/21	MT Emigrant	7-9	2.6	0	5.2	5	85	25
8/21	pyroCb/strat mass	11	1.2	0	0.63	20	65	10
8/30	SE-US ag fire	0-2.5	5.1	6.6	0.83	85	65	10
8/30	Unidentified	5-7	6.7	0	0.35	10	100	45
8/30	CA Rim/strat mass	8-12	5.3	0	6.8	15	140	80

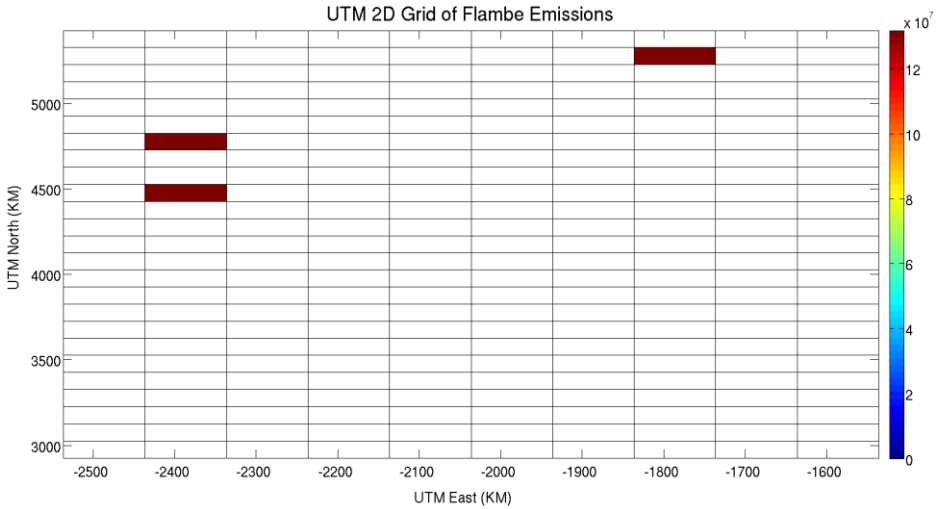
How is a CO Plume Simulated

FLAMBE Emissions are gridded then converted to FLEXPART-WRF CO particles

Raw Hourly FLAMBE emissions



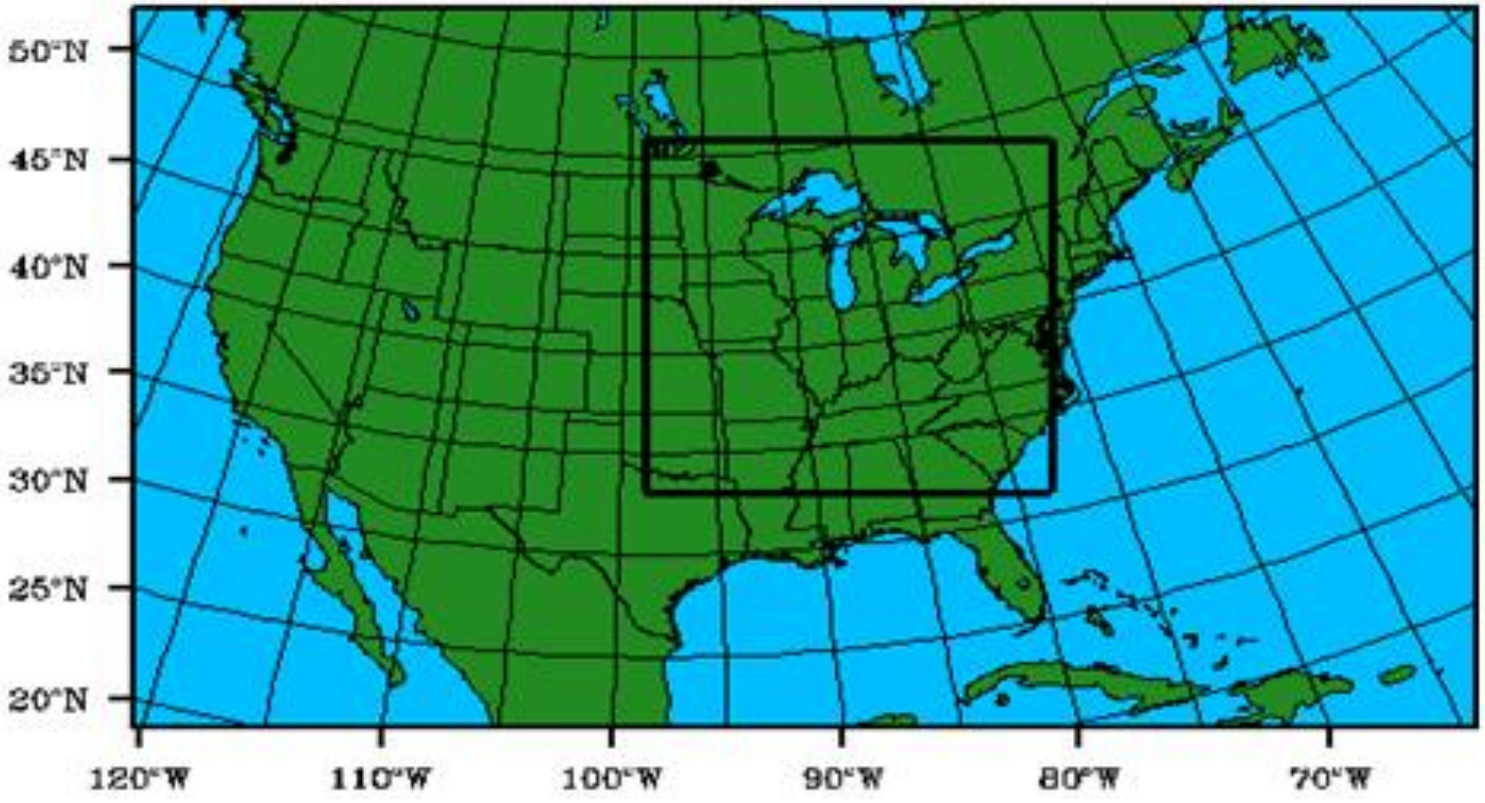
Gridded 0.25° Hourly FLAMBE emissions



Emissions of 500 kg/cell = 1 particle, and for fires <500, particle launch set to 1

How is a CO Plume Simulated

FLEXPART-WRF model domain



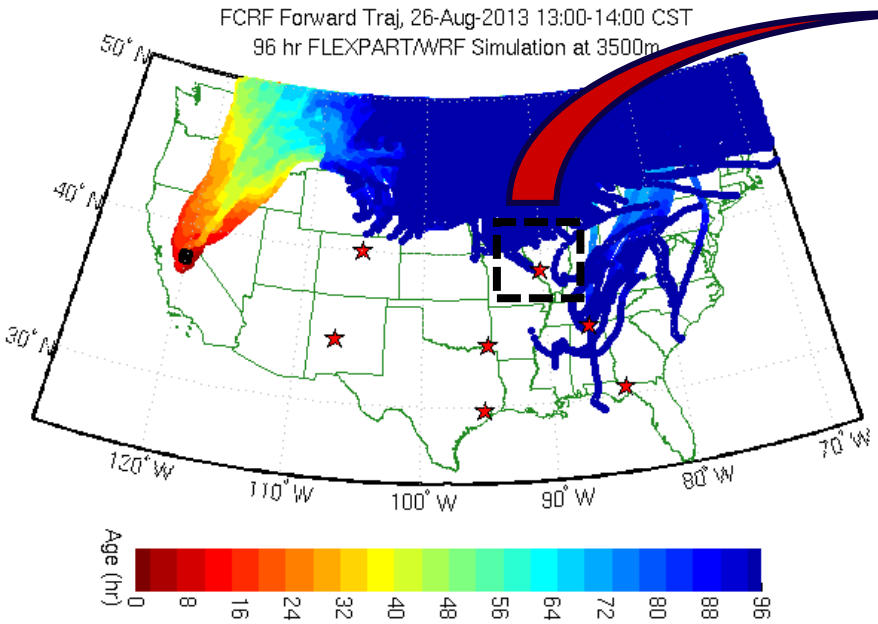
domain; rectangles mark the grids resolution 12km and 4km

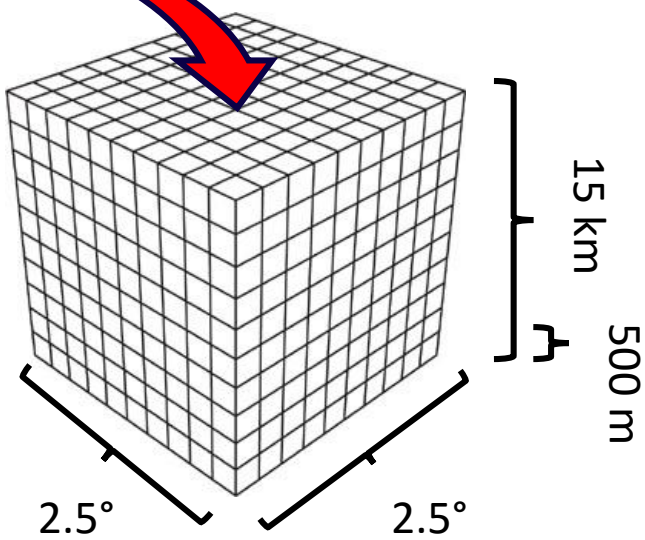
Lagrangian models track transport within a model domain, Determine local concentrations as the number of points within a given volume

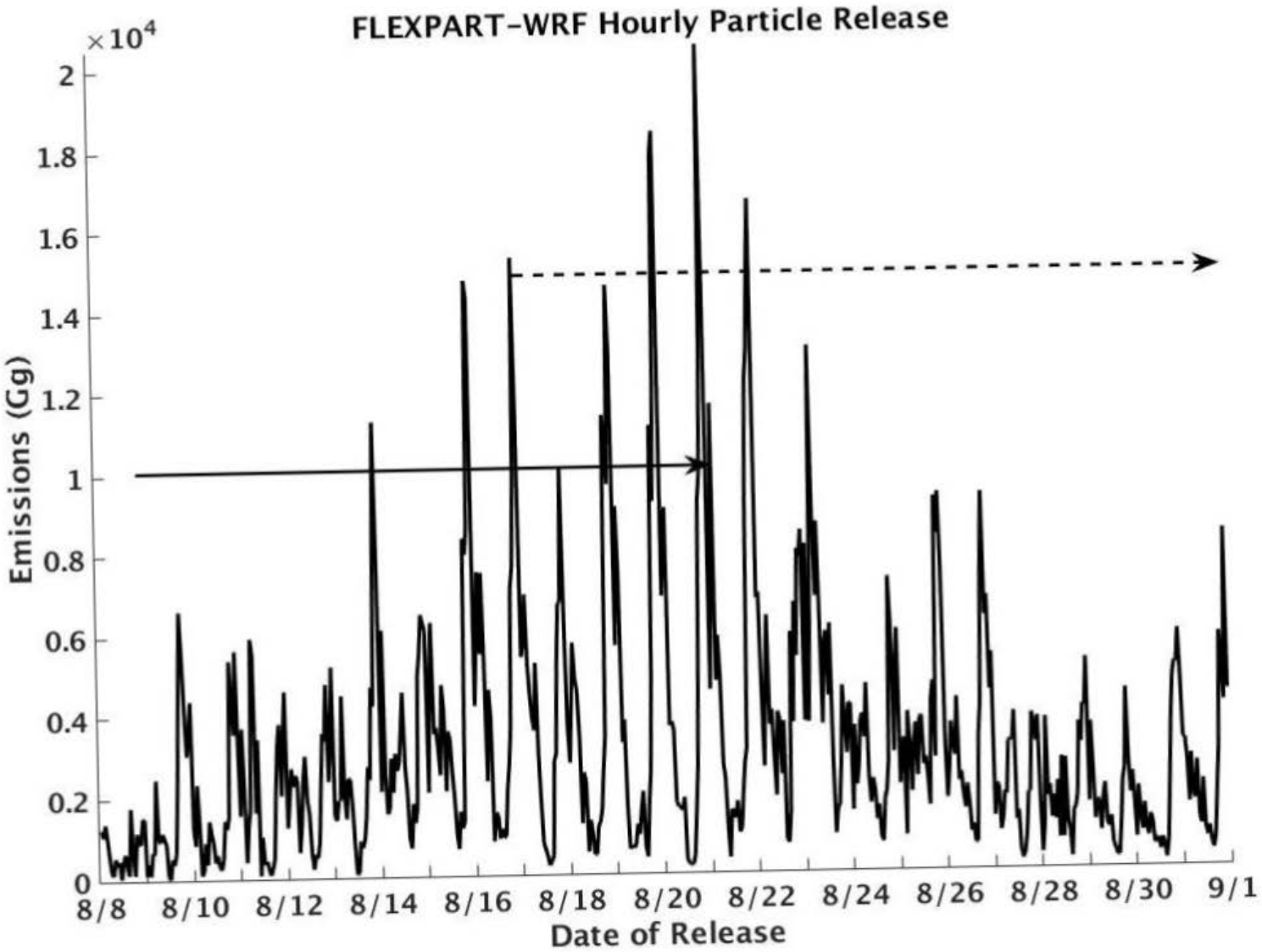
How is a CO Plume Simulated

FLEXPART-WRF hourly CO particles releases from the boundary Layer (0-3.5 km) reaching the STL Area are binned and averaged per cell

Flexpart-wrf 3.1 4 day simulation of co example






FLEXPART-WRF Hourly Particle Release
×10^4
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Emissions (Gg)
8/8
8/10
8/12
8/14
8/16
8/18
8/20
8/22
8/24
8/26
8/28
8/30
9/1
Date of Release