Implementation of GOES and OMI Total Column Ozone Assimilation within NAM-CMAQ to Improve Operational Air Quality Forecasting Capabilities

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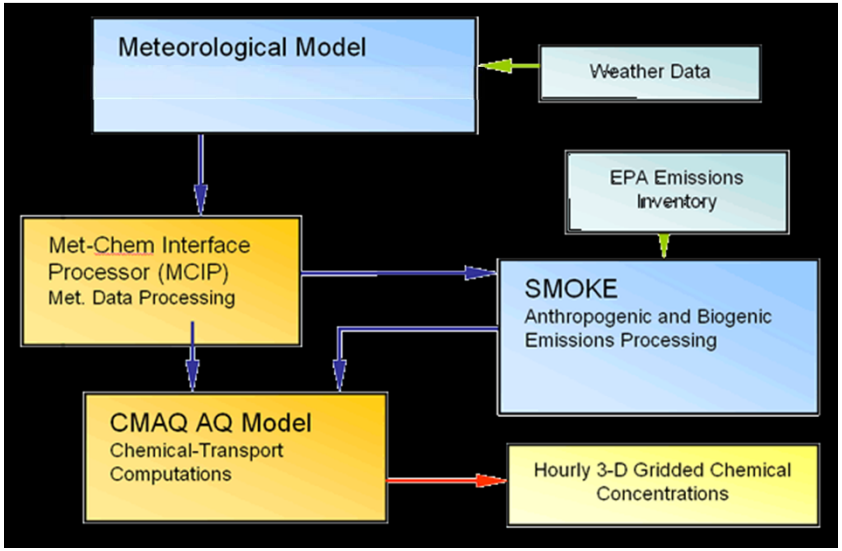
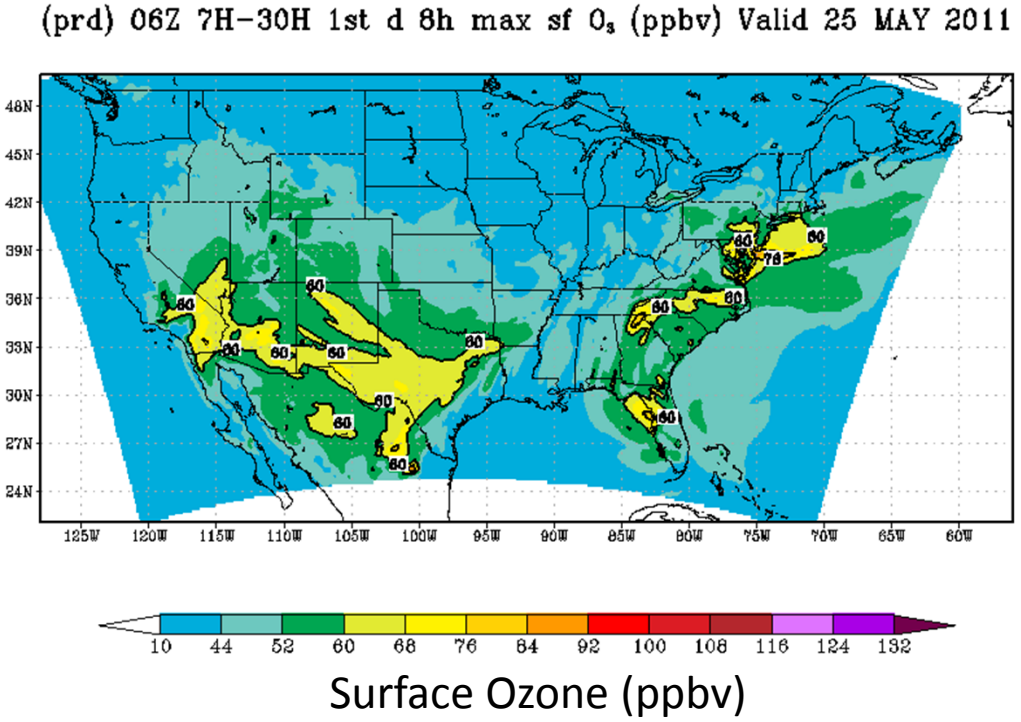
NOAA's National Weather Service

National Air Quality Forecast Capability

weather.gov

Community Multiscale Air Quality (CMAQ)





Surface Ozone (ppbv)

NOAA's NWS and US EPA **National Air Quality Forecasting Capability (NAQFC)** uses CMAQ to provide Air Quality Forecast Guidance to state and local Air Quality Forecasters

http://www.emc.ncep.noaa.gov/mmb/aq/

National Ambient Air Quality Standards [3][4]

	Primary Standard		Secondary Standard	
Criteria Pollutant	**Concentration Limit**	**Averaging Time**	**Concentration Limit**	**Averaging Time**
Carbon monoxide	9 ppmv (10 mg/m^3)	8-hour (1)	None	
	35 ppmv (40 mg/m^3)	1-hour (1)		
Sulfur dioxide	0.03 ppmv (80 µg/m^3)	Annual (arithmetic mean)	0.5 ppmv (1300 µg/m^3)	3-hour (1)
	0.14 ppmv (365 µg/m^3	24-hour (1)		
Nitrogen dioxide	0.053 ppmv (100 µg/m^3)	Annual (arithmetic mean)	Same as primary	
Ozone	0.075 ppmv (150 µg/m^3)	8-hour (2)	Same as primary	
	0.12 ppmv (235 µg/m^3)	1-hour (3)	Same as primary	
Lead	0.15 µg/m^3	Rolling 3-month average	Same as primary	
	1.5 µg/m^3	Quarterly average	Same as primary	
Particulate Matter (PM_{10})	150 µg/m^3	24-hour (4)	Same as primary	
Particulate Matter ($PM_{2.5}$)	15 µg/m^3	Annual (5) (arithmetic mean)	Same as primary	
	35 µg/m^3	24-hour (6)	Same as primary	

(1) Not to be exceeded more than once per year.
(2) The 3-year average of the fourth-highest daily maximum 8-hour average at each monitor within the area over each year must not exceed 0.075 ppmv.
(3a) The expected number of days per calendar year with maximum hourly averages above 0.12 ppm must be equal to or less than 1.
(3b) As of June 15, 2007 , the U.S. EPA revoked the 1-hour ozone standard in all areas except for certain parts of 10 states.
(4) Not to be exceeded more than once per year on average over 3 years.
(5) The 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed 15 µg/m^3.
(6) The 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within the area must not exceed 35.5 µg/m^3.

Primary forecast metric is **75ppbv 8-hour average** Fraction Correct, Threat Score, and Probability of Detection

Based on the **National Ambient Air Quality Standards (NAAQS)** eight hour ozone standard set by EPA in March 2008

National Ambien	
	Primary
Criteria Pollutant	**Concentration Limit**
Carbon monoxide	9 ppmv (10 mg/m^3)
	35 ppmv (40 mg/m^3)
Sulfur dioxide	0.03 ppmv (80 µg/m^3)
	0.14 ppmv (365 µg/m^3
Nitrogen dioxide	0.053 ppmv (100 µg/m^3)
Ozone	0.075 ppmv (150 µg/m^3)
	0.12 ppmv (235 µg/m^3)
Lead	0.15 µg/m^3
	1.5 µg/m^3
Particulate Matter (PM_{10})	150 µg/m^3
Particulate Matter ($PM_{2.5}$)	15 µg/m^3
	35 µg/m^3

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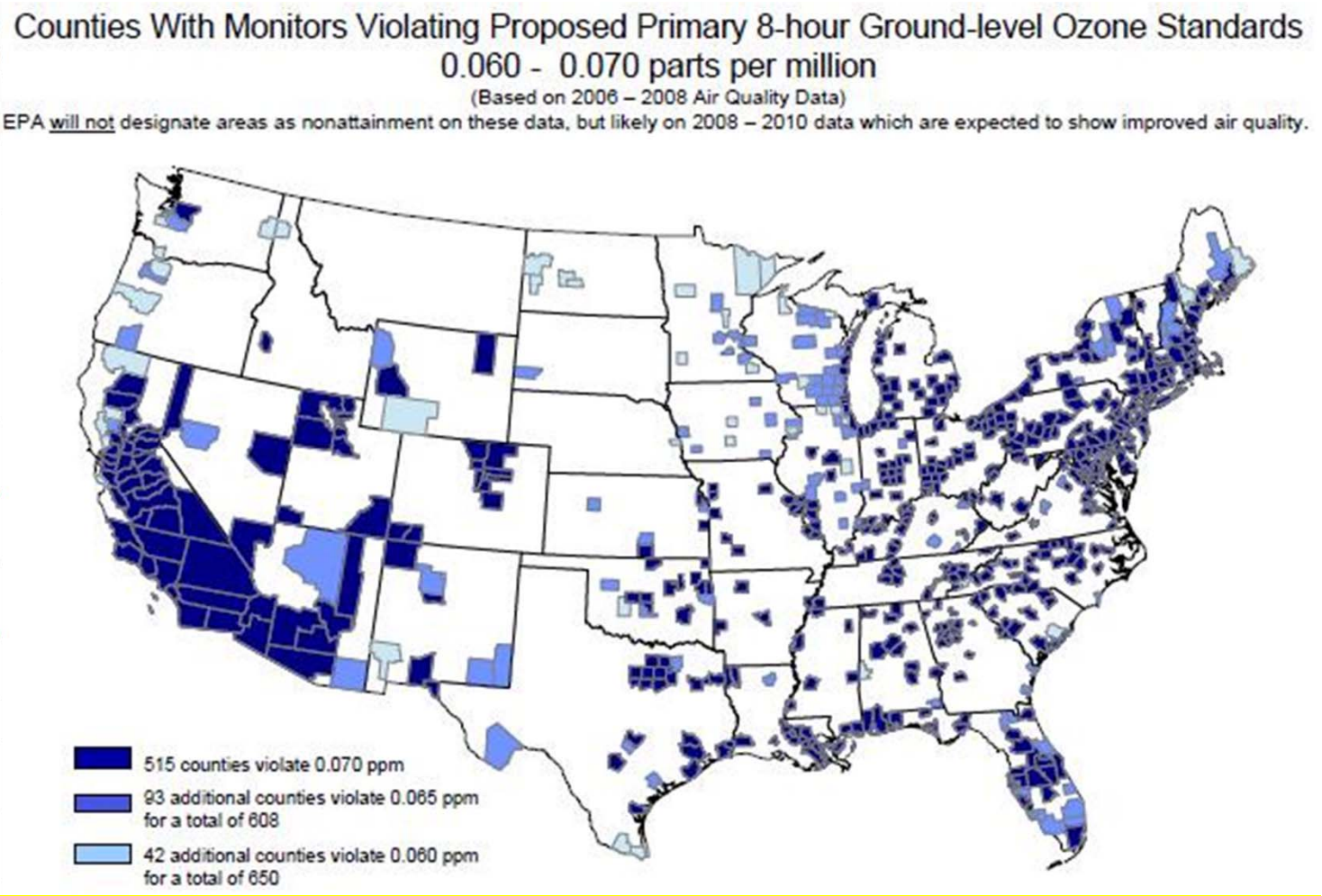
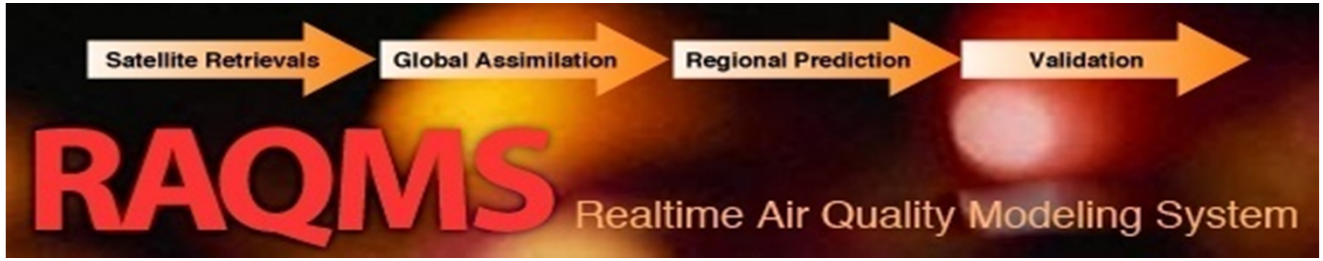


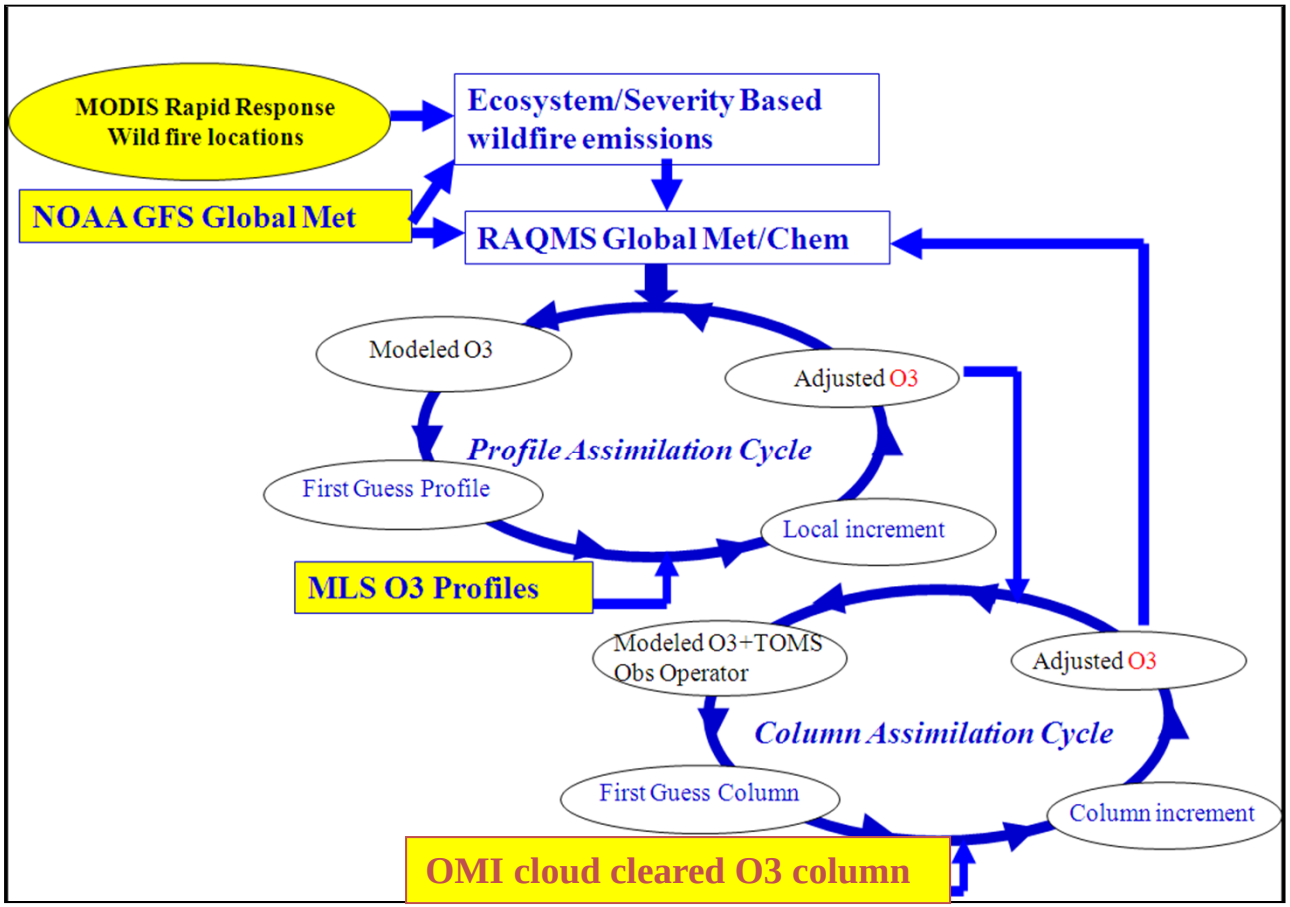
EPA is currently reconsidering 2008 NAAQS

- Range of 60-70 ppb, 4th high daily maximum 8-hr avg.

The proposed level will affect many areas in the west

- Regional transport and **background levels become more significant**
- New areas, including remote sites may be nonattainment

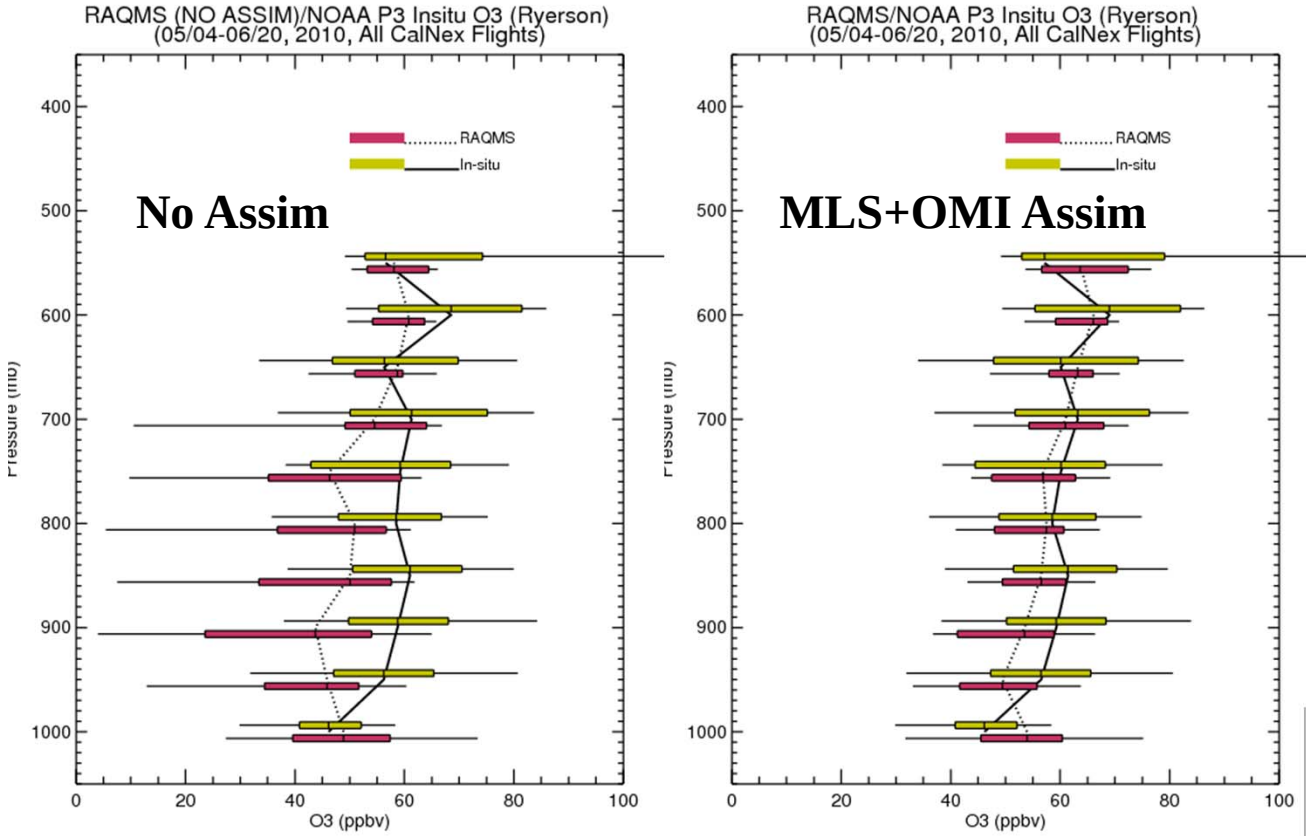




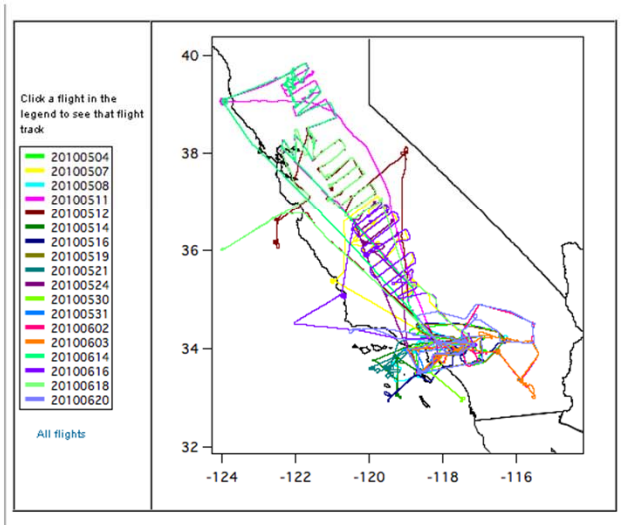
Demonstration of:

- **Real-time assimilation of Microwave Limb Sounder (MLS) stratospheric ozone profiles**
- **Real-time assimilation of Ozone Monitoring Instrument (OMI) total ozone column**
- **Real-time incorporation of Moderate Resolution Imaging Spectroradiometer (MODIS) fire detection**

Comparison with NOAA CalNex Insitu O3 Measurements (Primarily LA Basin/Central Valley)



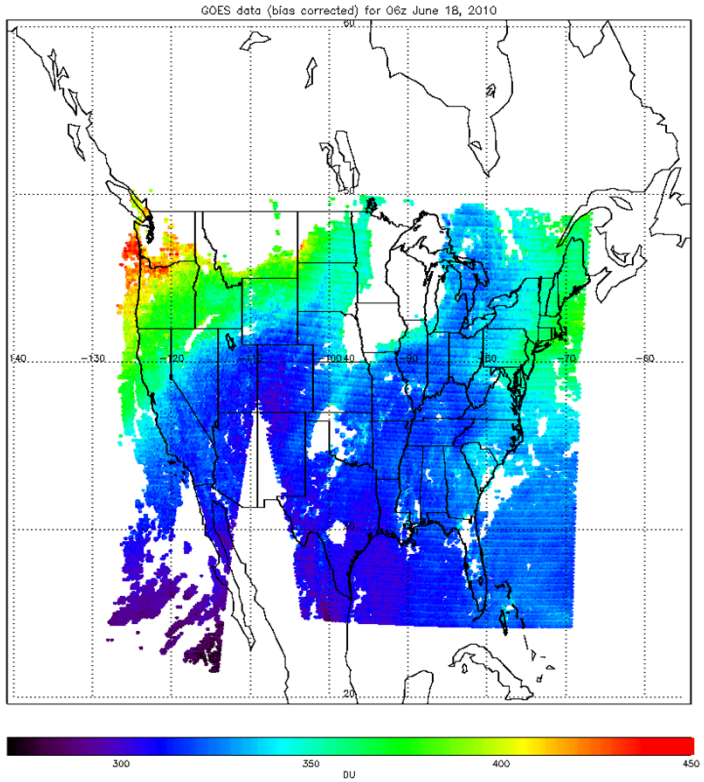
Assimilation of MLS+OMI O3 retrievals results in increased lower-tropospheric O3 (and improved agreement with airborne insitu O3) over Southern California

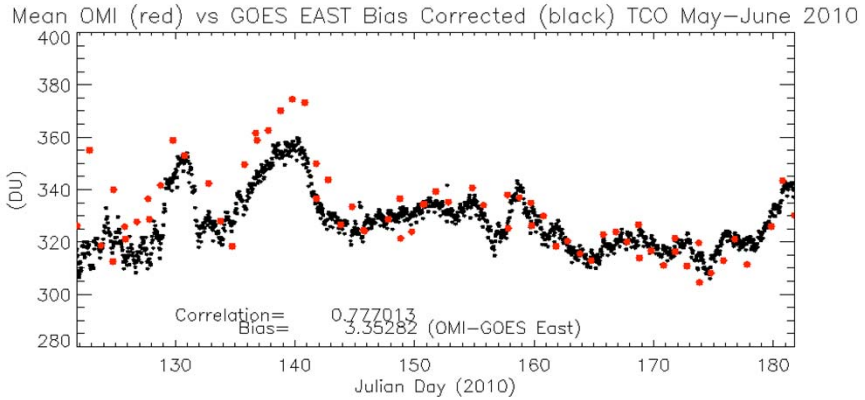


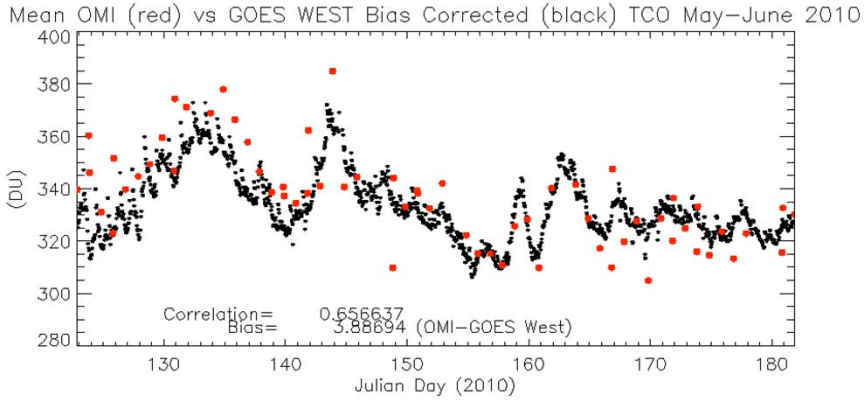
Insitu O3 from Tom Ryerson, NOAA ESRL

Development of GOES Total Column Ozone Assimilation (TCO) Within Operational NAM-CMAQ

We are currently developing capabilities to assimilate GOES Sounder TCO retrievals into the Community Multi-scale Air Quality (CMAQ; http://www.cmaq-model.org/) model using the NCEP Grid-point Statistical Interpolation (GSI) analysis scheme.







CMAQ is driven by meteorological forecasts from the NCEP North American Model (NAM) and used by the NWS to provide air quality forecast guidance.

Point by Point statistics for GOES-13 (East) and GOES-11 (West) Total Column Ozone (TCO) vs OMI for May-June, 2010

- Using only OMI cloud cleared (cloud reflectivity<15) QC (flag<1) data
- Within ½ hour and 0.1degree radius used for coincidence criteria

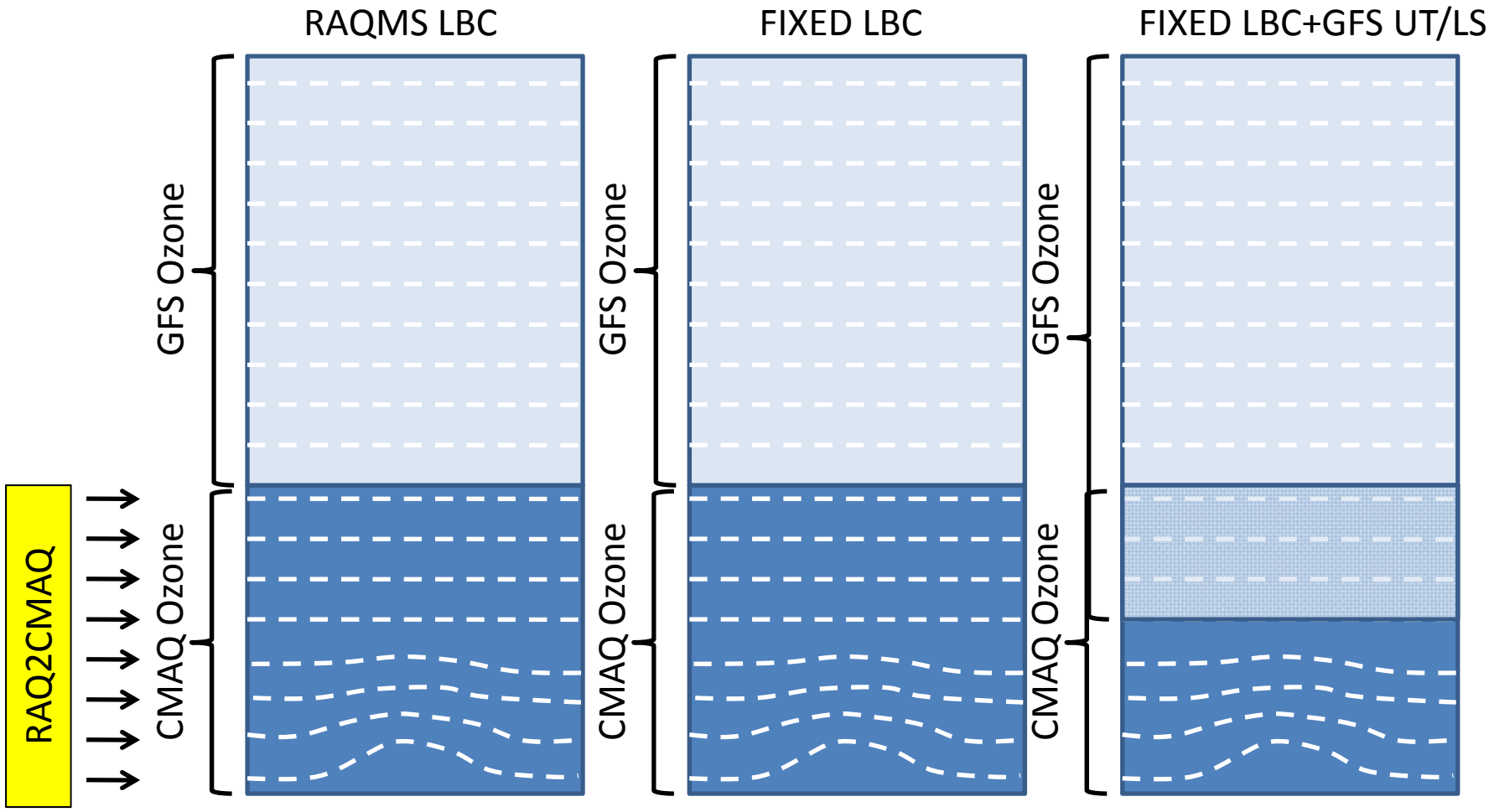
GOES-13	: r=	0.909357	bias=	-4.53328DU	rms= 4.00372%
GOES-11	: r=	0.887193	bias=	9.66413DU	rms= 5.23588%

GOES-13 (bias corrected)	: r=	0.917332	bias=	-0.251311DU	rms= 3.45344%
GOES-11 (bias corrected)	: r=	0.903298	bias=	0.309849DU	rms= 4.29718%

The bias corrected GOES-13 and GOES-11 data is used in the NAM-CMAQ assimilation experiments.

Three NAM-CMAQ/GOES TCO Experiments have been conducted:

- **RAQMS Lateral Boundary Conditions/default background errors**
- **Fixed Lateral Boundary Conditions/default background errors**
- **Fixed Lateral Boundary Conditions+GFS UT/LS/GFS background errors**



GOES TCO cycling experiments conducted from May 20th-June 30th, 2010

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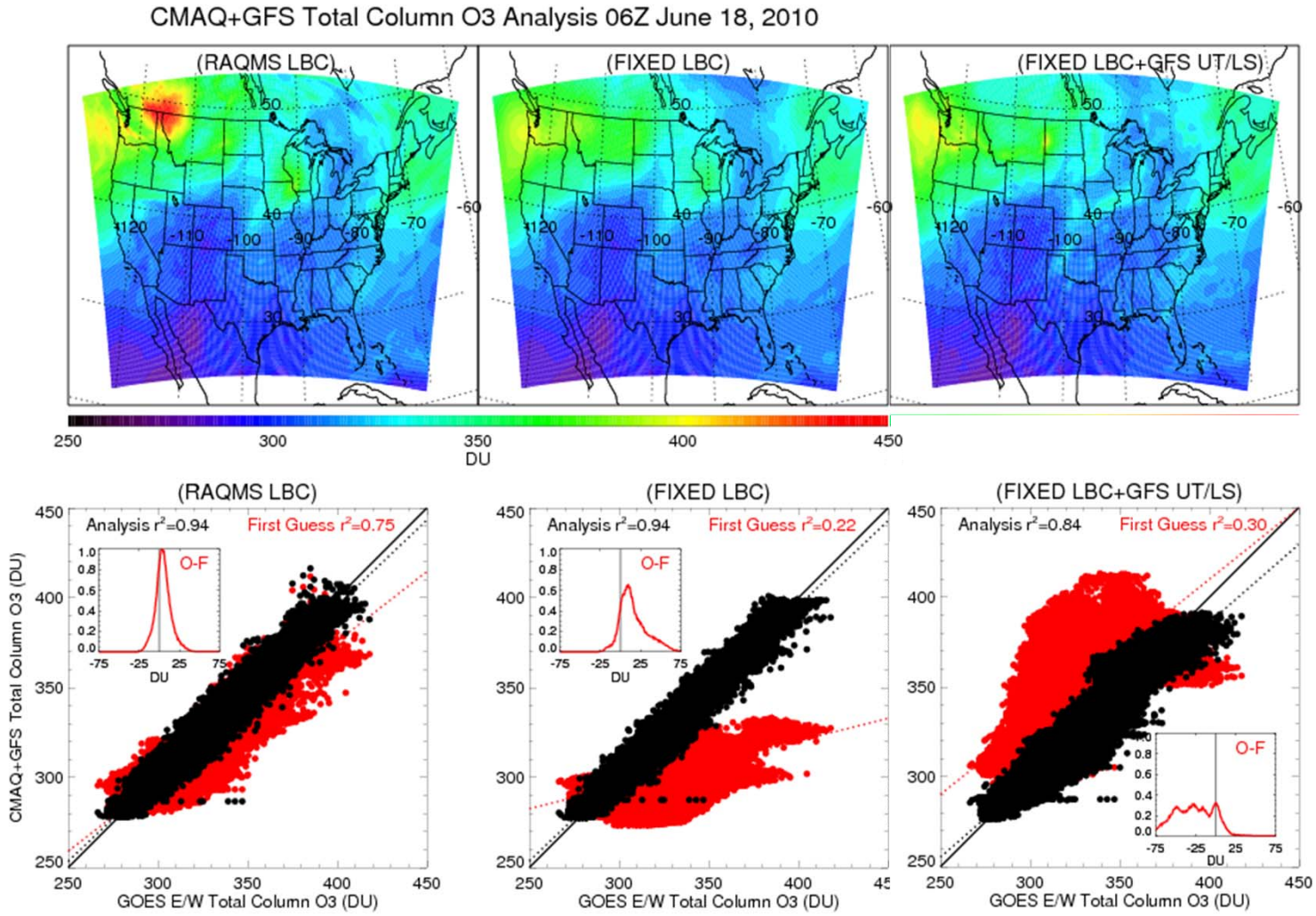
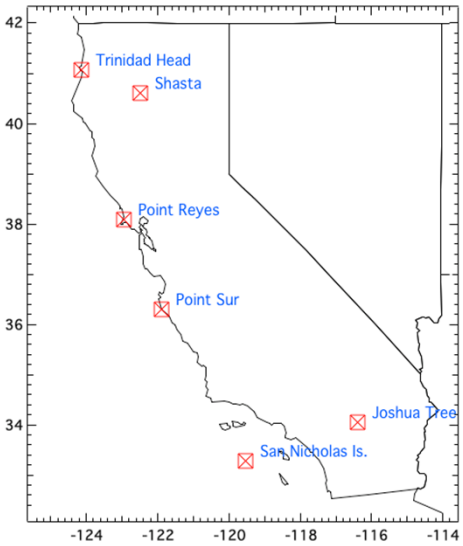


RAQMS LBC result in best O-F

Fixed LBC underestimates TCO, Fixed LBC+GFS UT/LS overestimates TCO

CalNex O_3 sondes – Owen Cooper (NOAA ESRL)

CalNex Ozonesonde

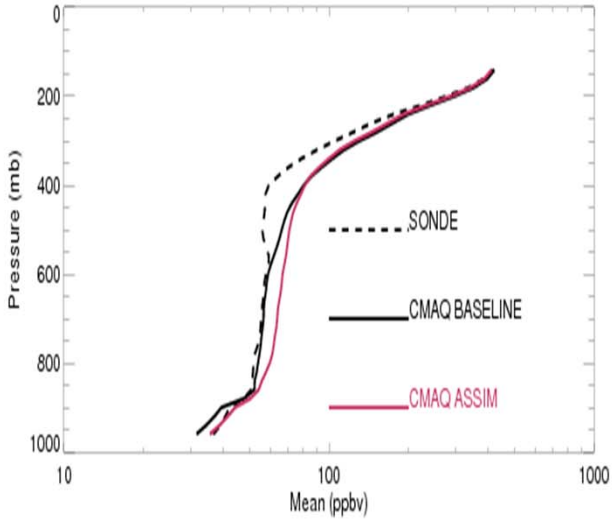


RAQMS LBC and default background errors results in free tropospheric overestimates <u>but good PBL and UT/LS</u>

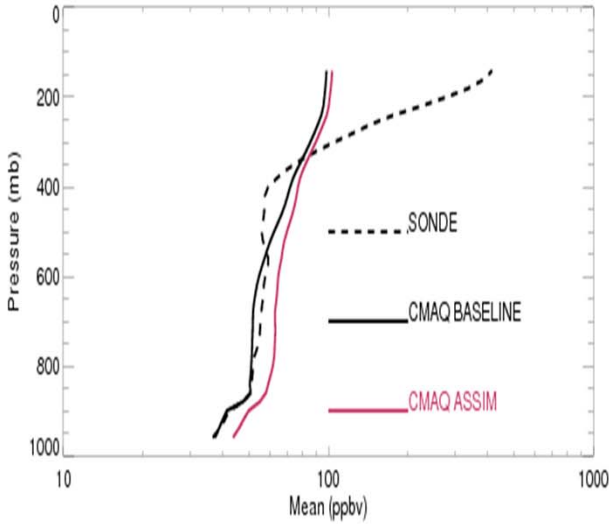
FIXED LBC and default background errors results in free tropospheric and PBL overestimates <u>with UT/LS underestimates</u>

FIXED LBC+GFS UT/LS and GFS background errors results in <u>best agreement</u> with IONS ozonesonde

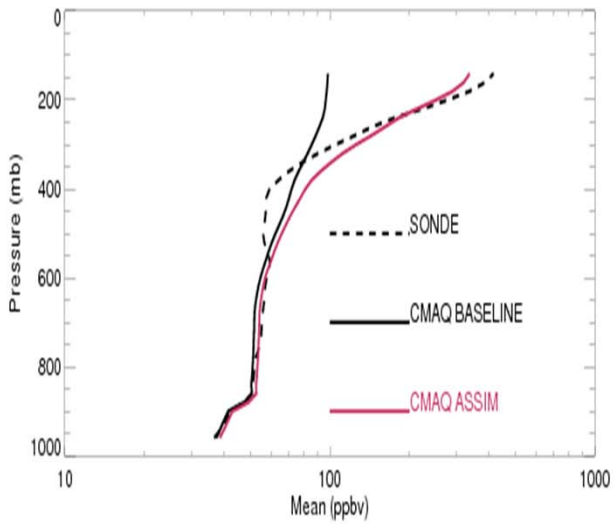
RAQMS LBC
Default Background Errors



FIXED LBC
Default Background Errors



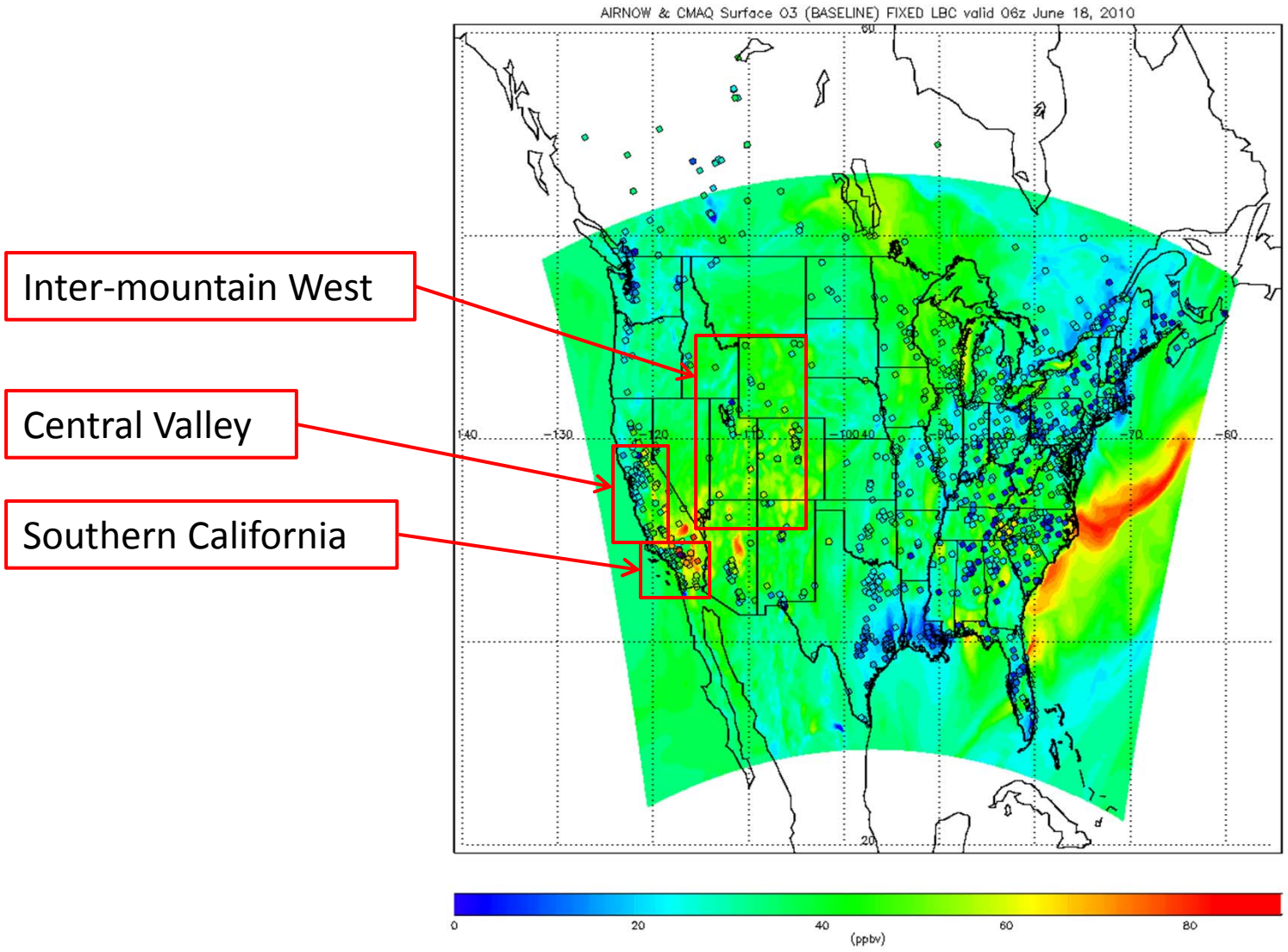
FIXED LBC +GFS UT/LS
GFS Background Errors



NAM-CMAQ CalNex Experimental Runs

- **NO ASSIM (Baseline) Fixed Lateral Boundary Conditions**
- **GOES TCO ASSIM Fixed Lateral Boundary Conditions+GFS UT/LS/GFS background errors**

FIXED LBC 06Z June 18, 2010

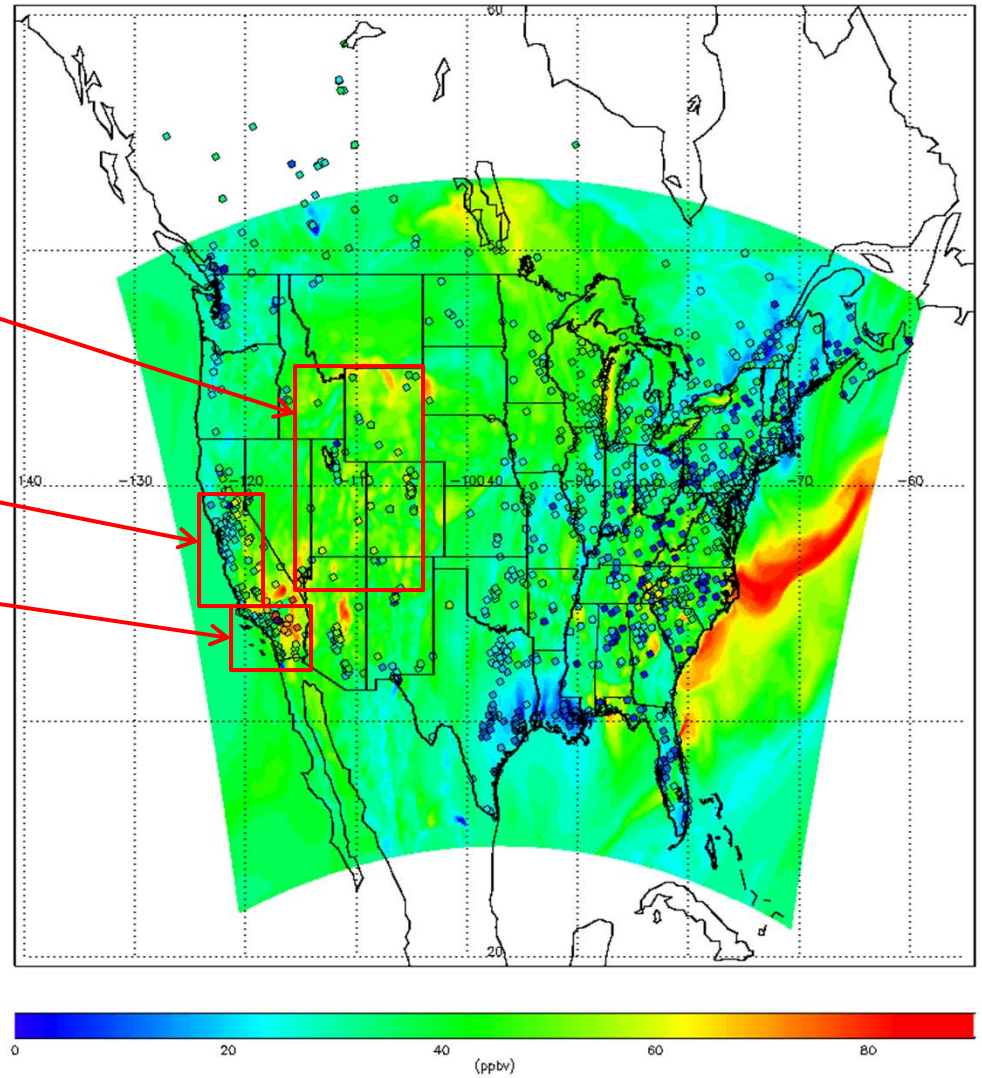


NAM-CMAQ CalNex Experimental Runs

- **NO ASSIM (Baseline) Fixed Lateral Boundary Conditions**
- **GOES TCO ASSIM Fixed Lateral Boundary Conditions+GFS UT/LS/GFS background errors**

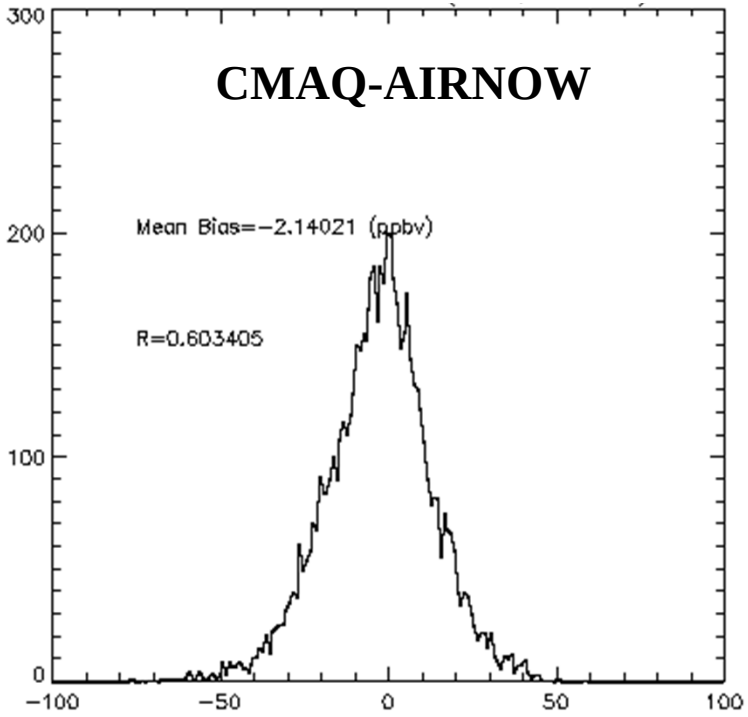
GOES TCO ASSIM results in increased surface ozone over Southern California and Inter-mountain West

ASSIM FIXED LBC +GFS UT/LS GFS Background Errors



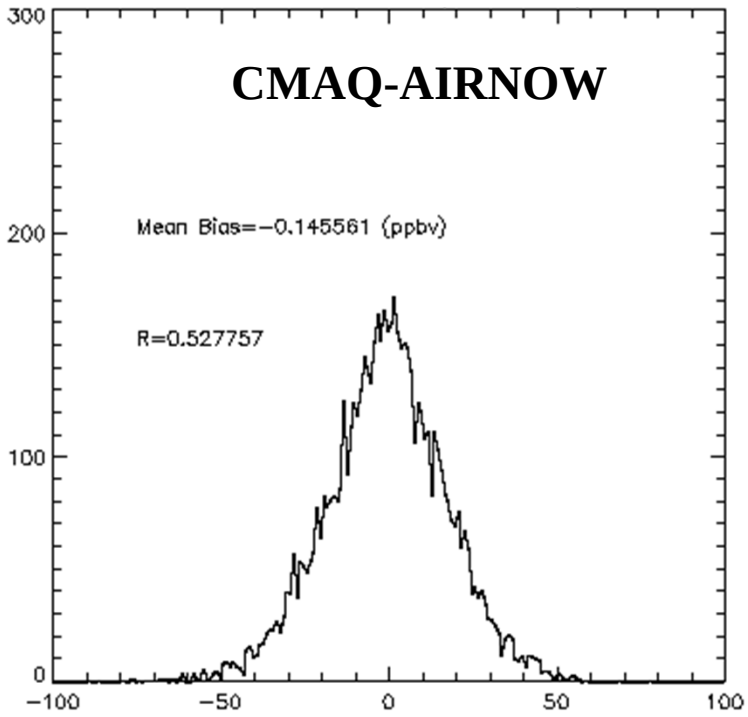
NAM-CMAQ verses AIRNOW May 22-June 30, 2010
Southern California (33N-35N 121W-114W)

NO ASSIM FIXED LBC



Bias = -2.14 ppbv

ASSIM FIXED LBC +GFS UT/LS
GFS Background Errors

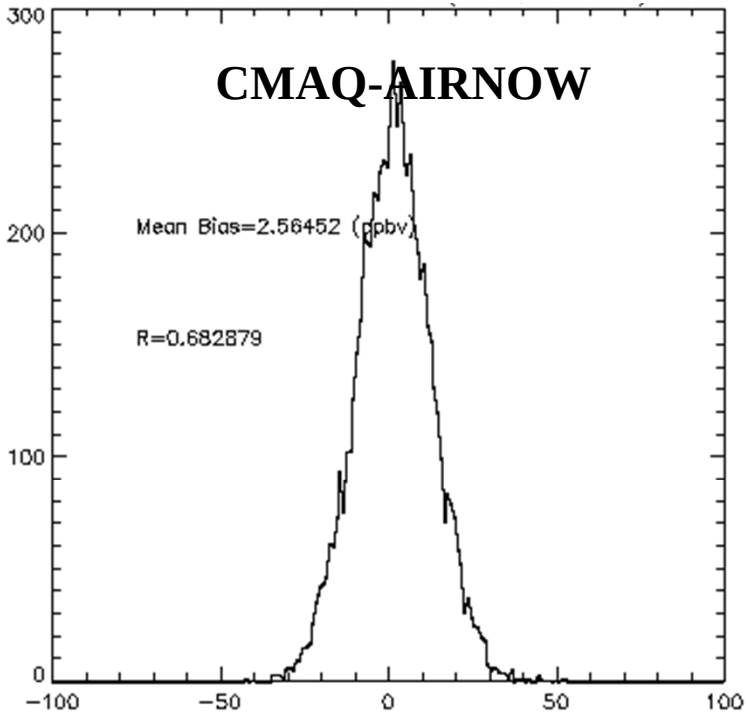


Bias = -0.146 ppbv

GOES TCO ASSIM increases Southern California surface ozone and reduces bias

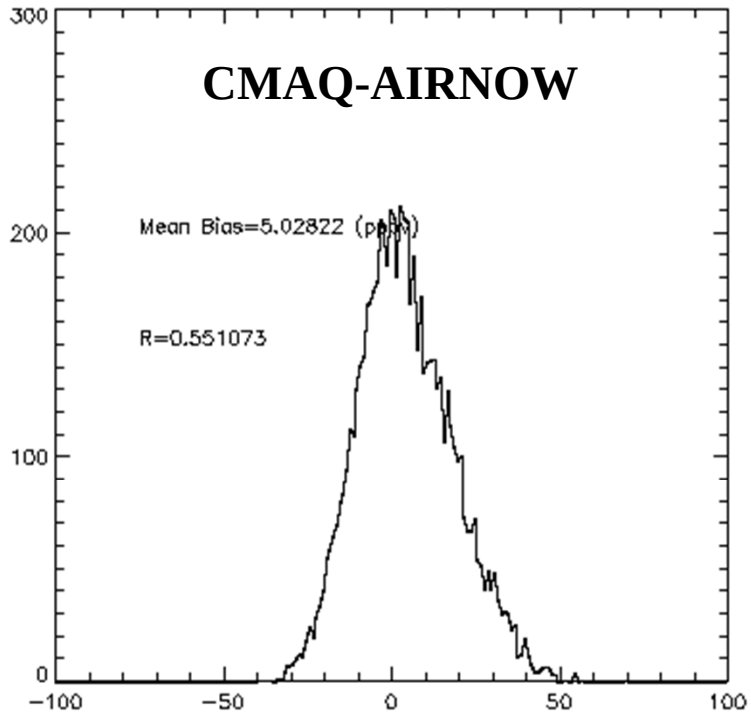
NAM-CMAQ verses AIRNOW May 22-June 30, 2010
Central Valley (35N-39N 124W-118W)

NO ASSIM FIXED LBC



Bias = 2.56 ppbv

ASSIM FIXED LBC +GFS UT/LS
GFS Background Errors

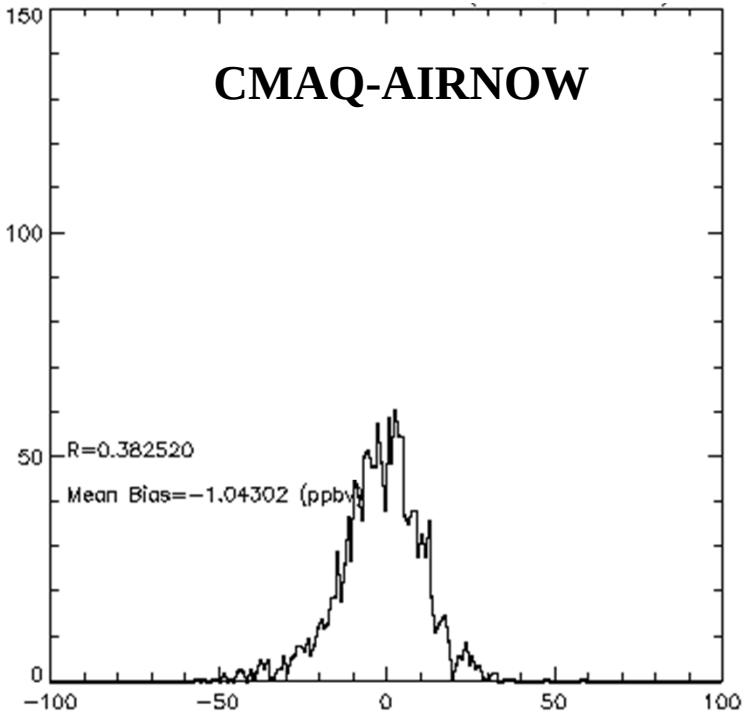


Bias = 5.03 ppbv

GOES TCO ASSIM increases Central Valley surface ozone and increases bias

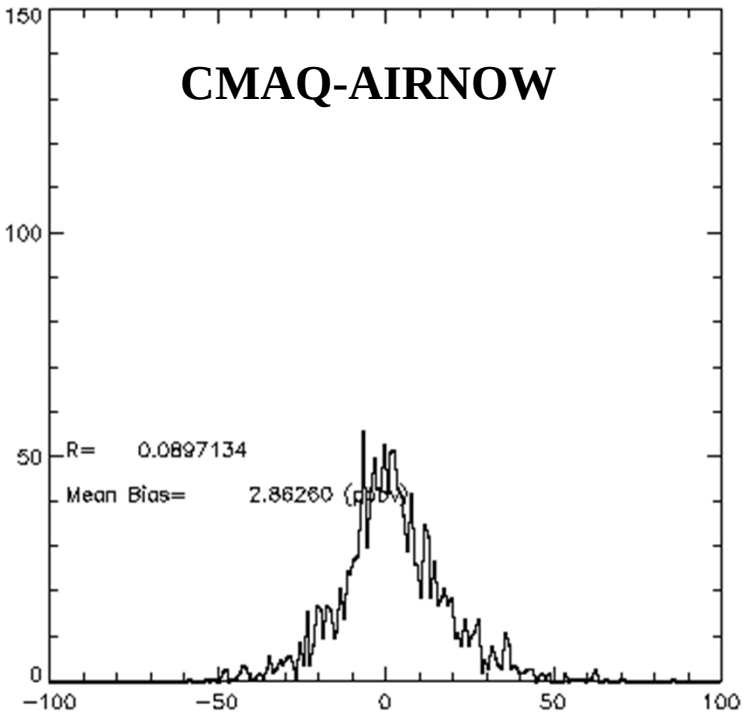
NAM-CMAQ verses AIRNOW May 22-June 30, 2010
Inter-mountain West (35N-45N 115W-105W)

NO ASSIM FIXED LBC



Bias = -1.04 ppbv

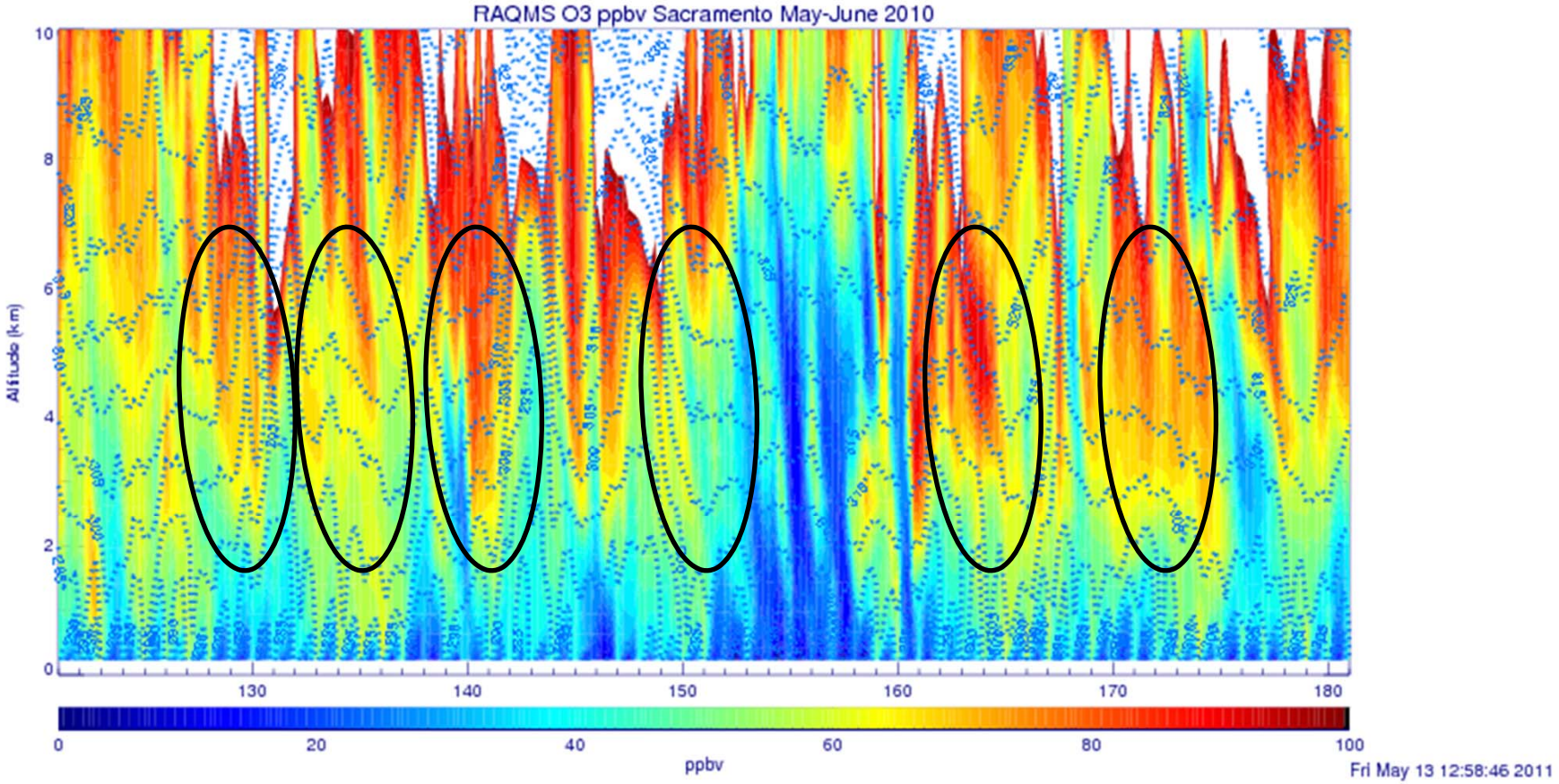
ASSIM FIXED LBC +GFS UT/LS
GFS Background Errors



Bias = 2.86 ppbv

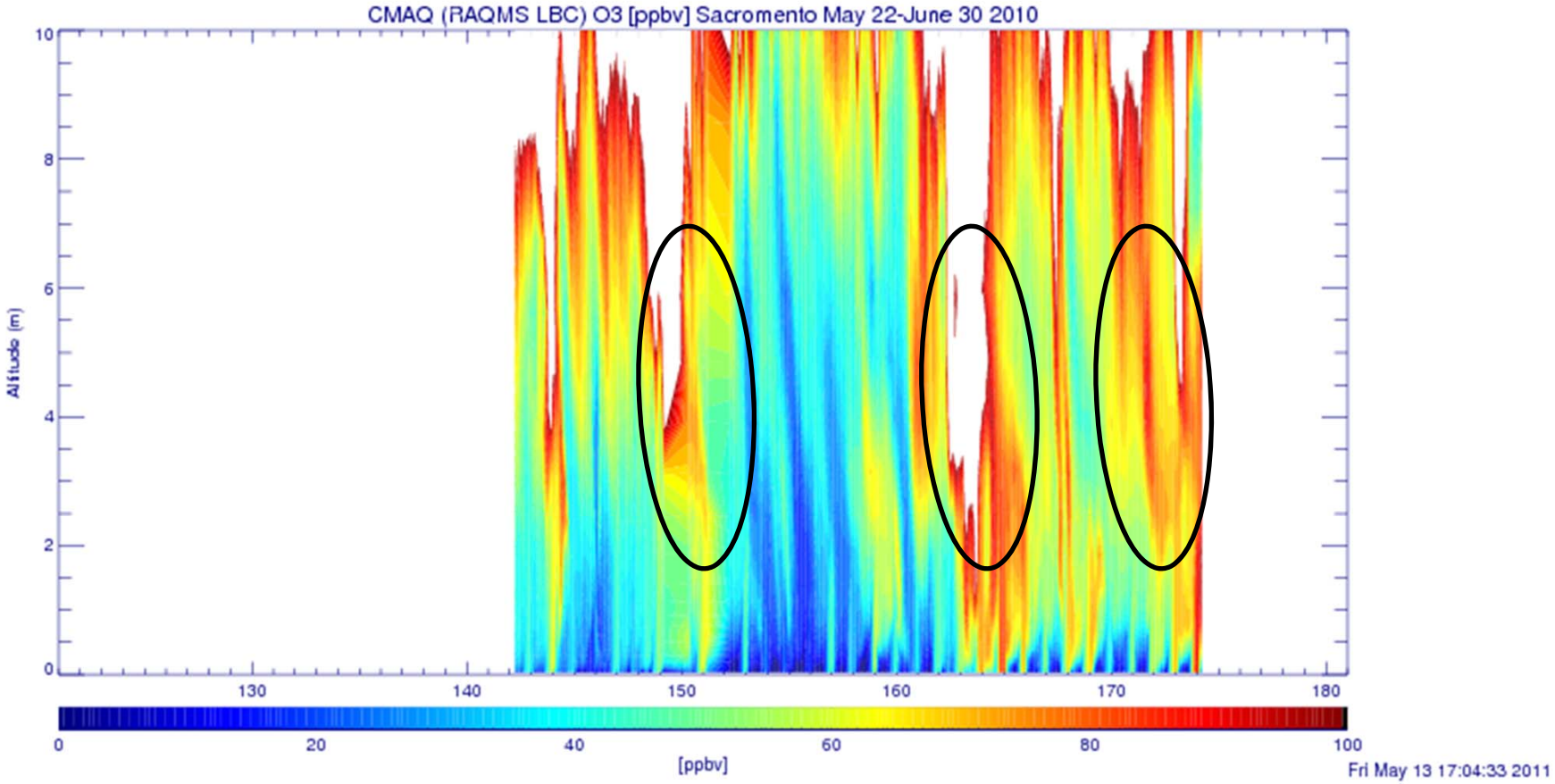
GOES TCO ASSIM increases Inter-mountain surface ozone and increases bias

Sacramento O3 May-June 2010
RAQMS 1x1 Degree Re-analysis



Synoptic scale transport leads to background ozone enhancements in middle and lower troposphere

Sacramento O3 May 22 -June 22 2010
NAM-CMAQ with RAQMS LBC



- **NAM-CMAQ RAQMS LBC experiment shows more descent of high ozone air than RAQMS 1x1 re-analysis which may lead to overestimates in surface ozone**

- **Points to the need for improved vertical resolution in NAM-CMAQ upper troposphere/lower stratosphere**

Conclusions

•GSI GOES Ozone assimilation experiments show that assimilation of GOES Total Column Ozone can lead to improved representation of upper tropospheric and lower stratospheric ozone within NAM-CMAQ

•Coarse vertical resolution within NAM-CMAQ leads to overestimates in decent of high ozone into the lower troposphere and increased biases in surface ozone over the inter-mountain west

•Use of time dependent Lateral Boundary Conditions (RAQMS) leads to the best retention of the GOES TCO information (minimizes O-F)

Directions

•Work with the NOAA Air Resources Lab (ARL) and the National Air Quality Forecasting Capability (NAQFC) team to test impact of improved vertical resolution in NAM-CMAQ

•Add bias corrected GOES TCO into GOES sounder bufr files for real-time parallel testing

•Work with the NASA Air Quality Applied Science Team (AQAST) to test the use of climatological ozone P-L improve the GFS tropospheric distributions and provide time-dependent lateral boundary conditions to NAM-CMAQ