

Central California Ozone Study (CCOS) Improvement of Air Quality Model Aloft Performance

Final Presentation 05-2CCOS

**Neil Wheeler, Ken Craig, and Steve Reid
Sonoma Technology, Inc.
Petaluma, CA**

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CCOS Technical Committee
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Overview

- Introduction
- Analyses
- Summary and Conclusions
- Recommendations



Background

- Progress towards attaining the NAAQS
- Model Performance Issues
- Episodes
 - July 8-15, 1999 – Limited data aloft
 - July 29 - August 2, 2000 – High ozone aloft ✓
 - September 16-21, 2000 – Normal ozone aloft
- Roles
 - MM5 Meteorological Modeling – NOAA
 - Meteorological and Air Quality Modeling - ARB
 - Air Quality Model Improvement – STI



Performance Hypotheses (1 of 2)

1. Emission inventories are biased low
2. Wildfires are not adequately represented
3. Boundary concentrations are inaccurately specified
 - Lack of data
 - Transport from Asia
 - Transport from Southern California
 - Tropopause folding events (stratospheric ozone intrusion)
4. Grid resolution is insufficient
5. Meteorological models are unable to capture stagnant air conditions caused by terrain blocking of the flow



Performance Hypotheses (2 of 2)

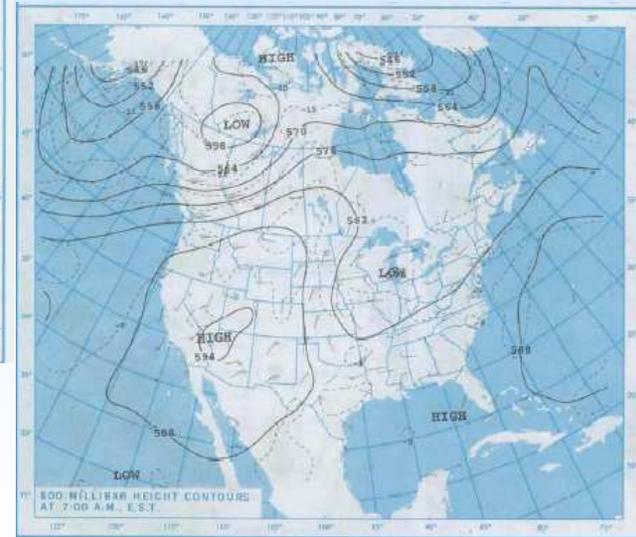
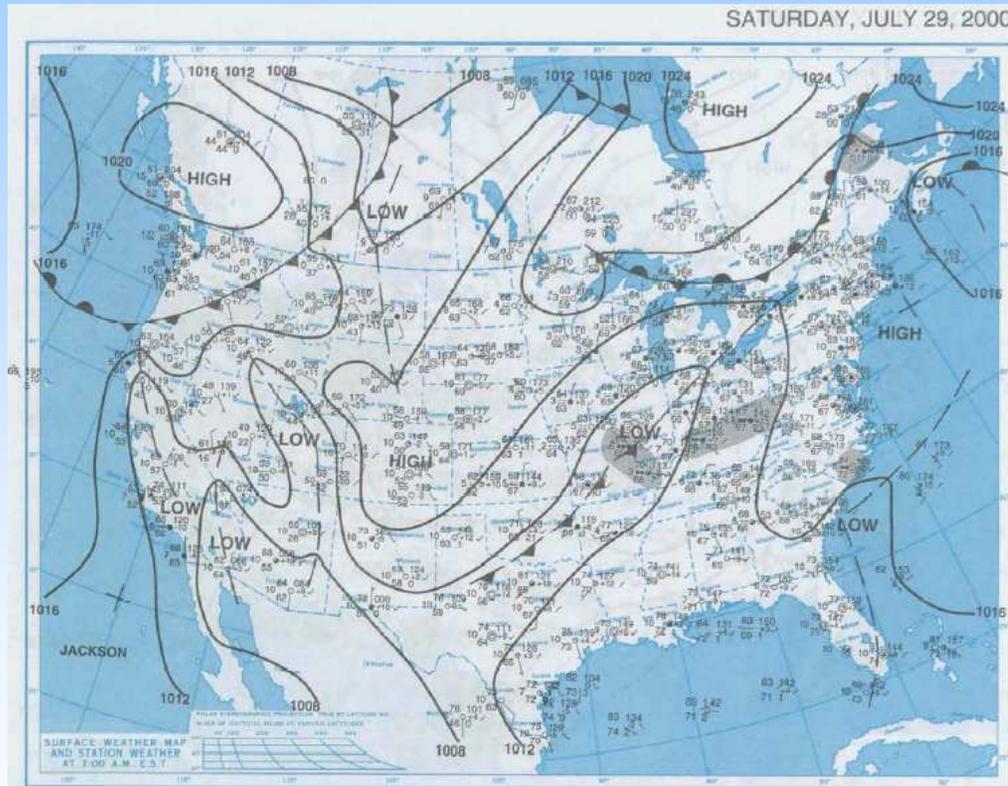
6. Vertical mixing of pollutants in the planetary boundary layer is overestimated resulting in relatively clean air aloft being mixed downward
7. Mixing of high ozone surface air to the interior of the convective boundary layer is inadequate.
8. Recirculation of upslope flow from the Sierra Nevada Mountains and Coastal Range over the Central Valley are inadequately represented.
9. Chemical mechanisms underestimate ozone production efficiency at low precursor concentrations
10. Dispersion in areas of significant and steep terrain in central California is treated inadequately.
11. Photolysis rates at higher elevations are treated inadequately



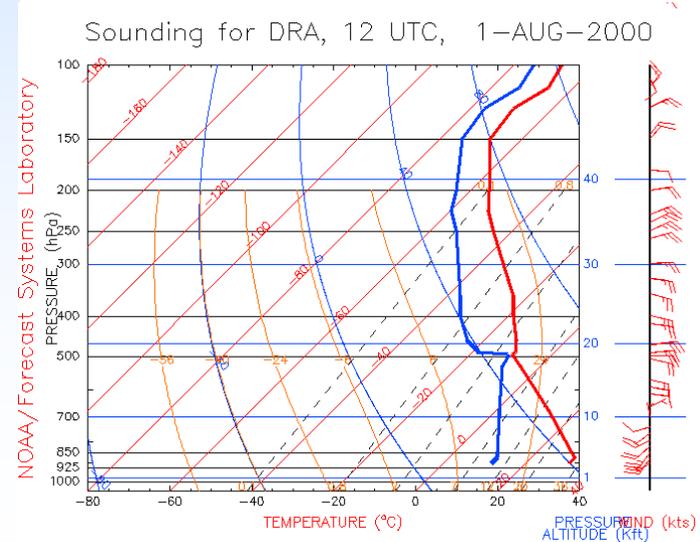
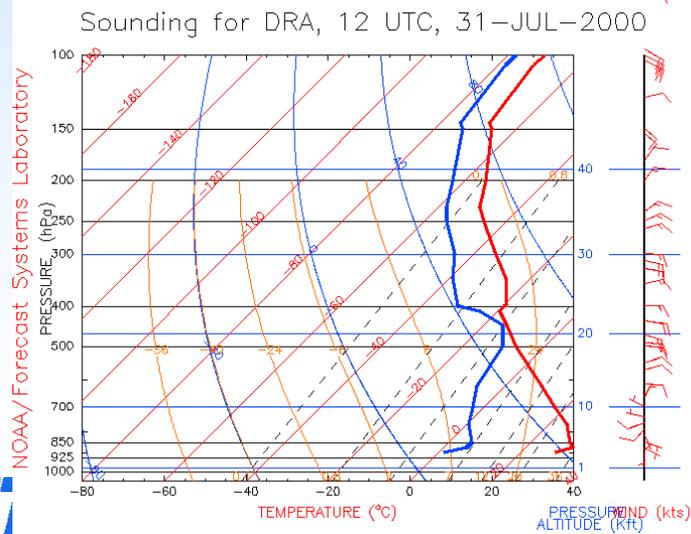
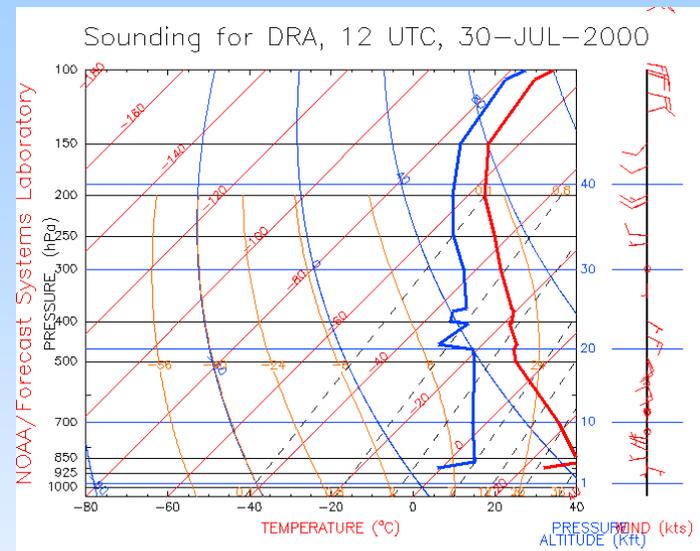
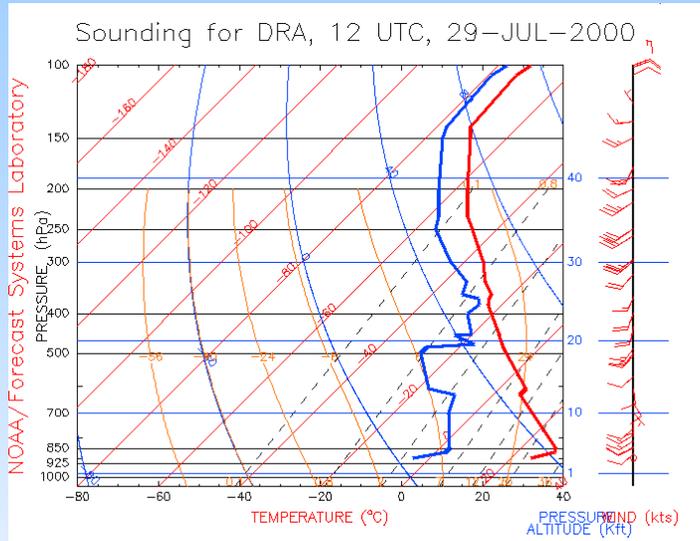
Improvement Process

- Characterization
- Evaluation
- Identification of model performance issues
- Diagnosis of the possible causes
- Correction
- Reevaluation

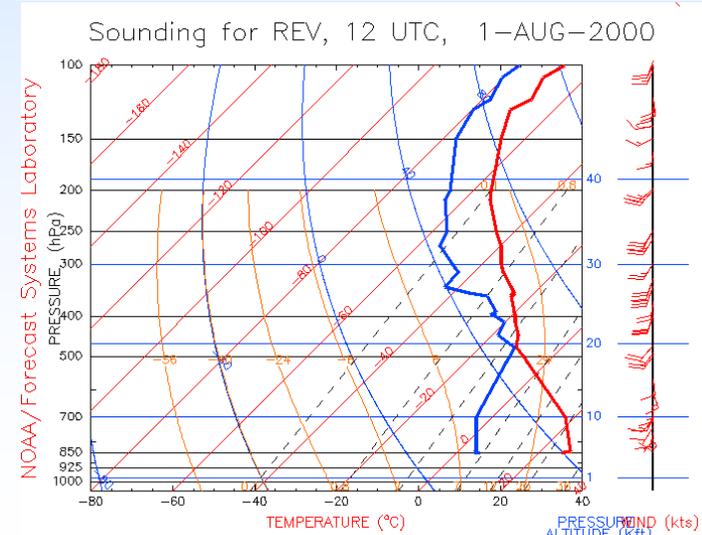
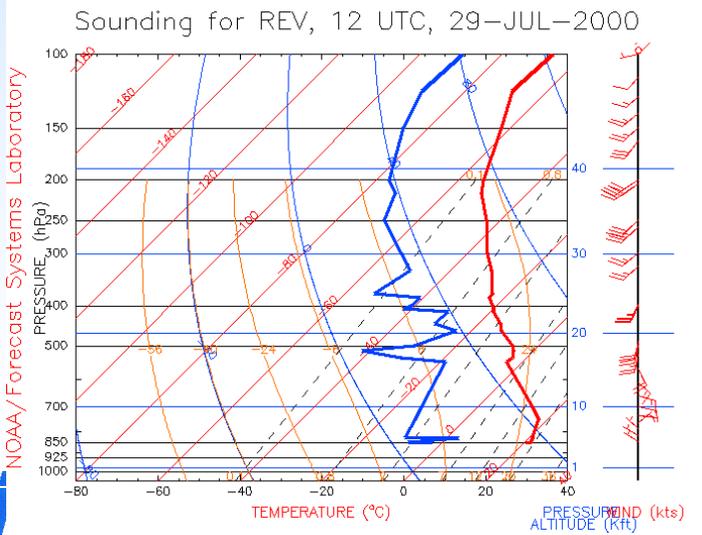
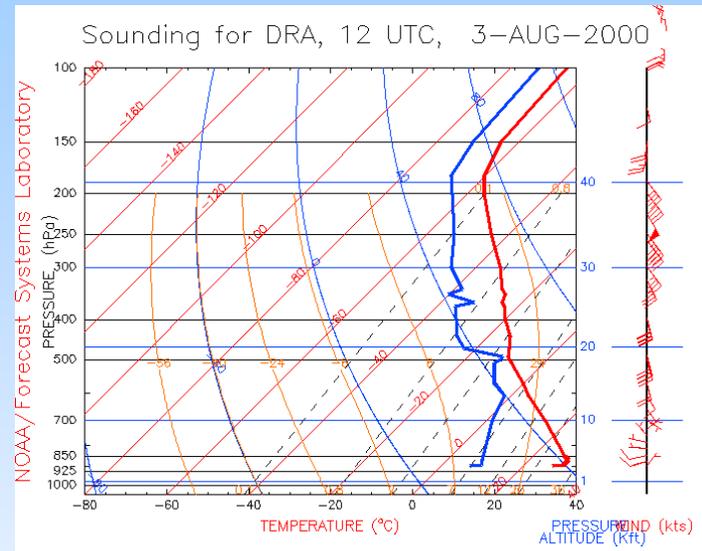
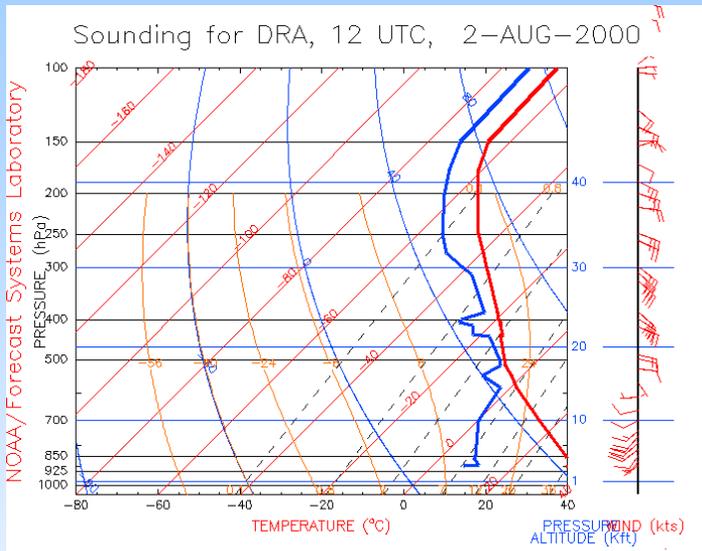
Daily Weather Maps



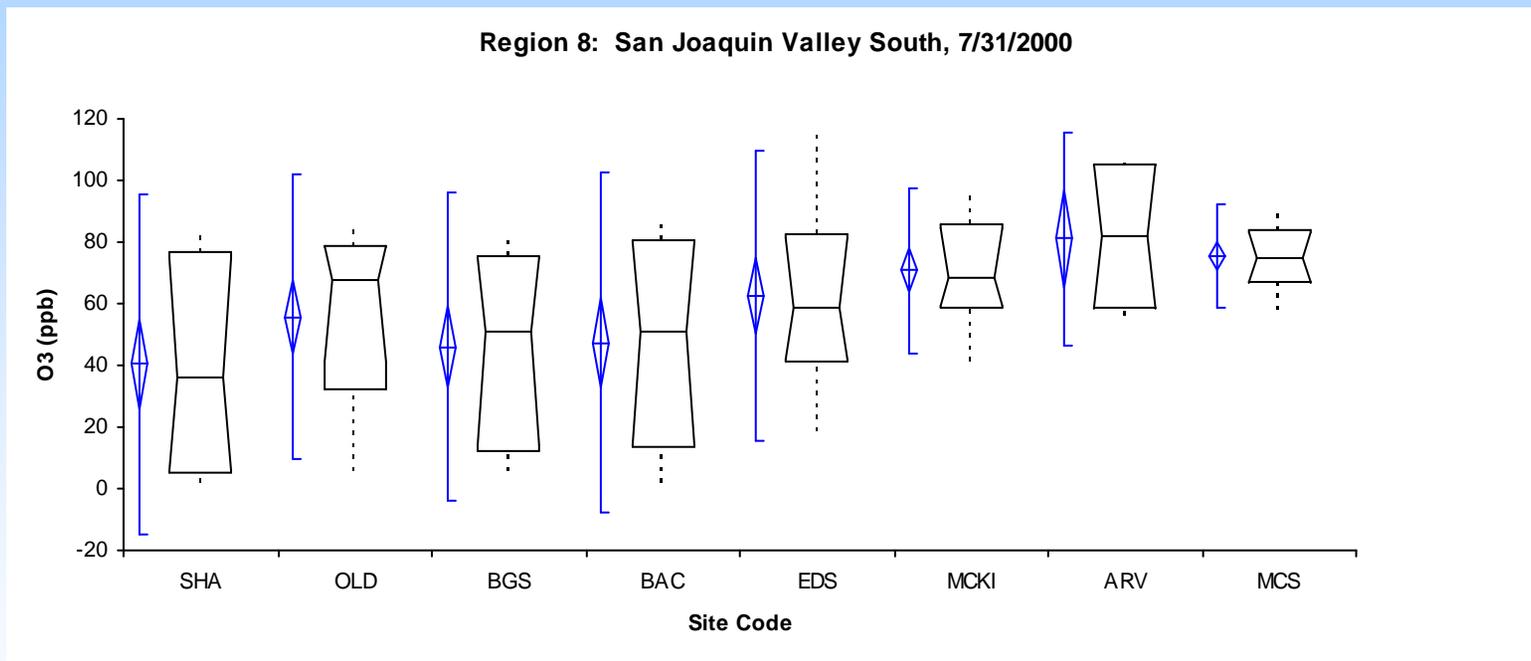
Meteorological Soundings (1 of 2)



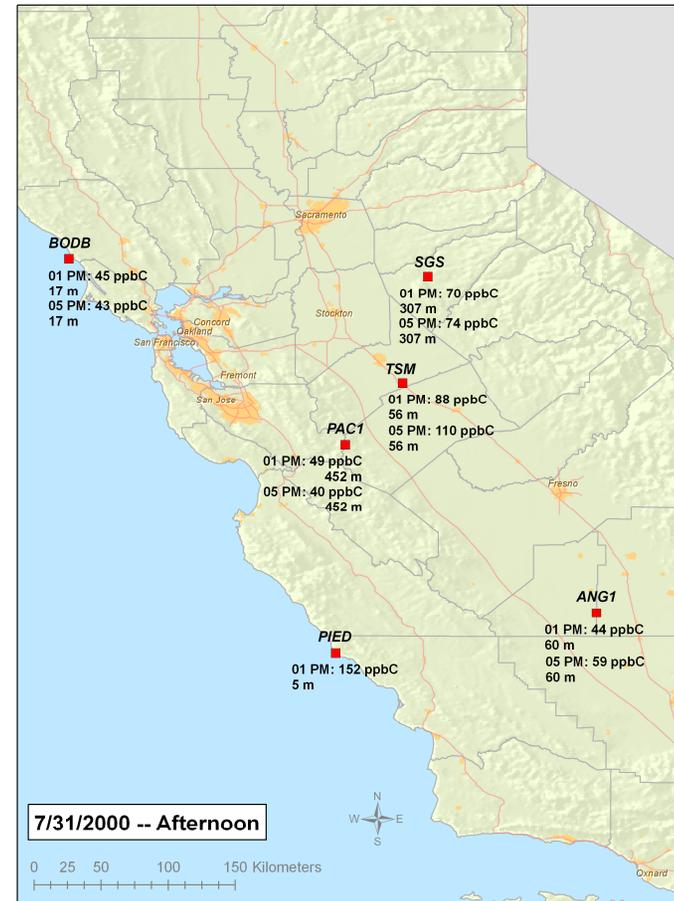
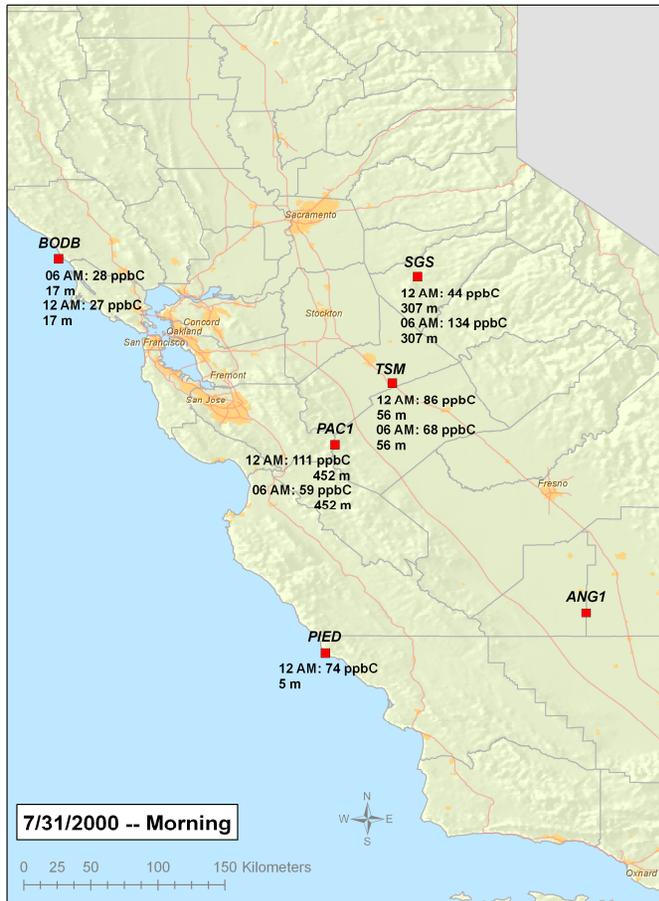
Meteorological Soundings (2 of 2)



Descriptive Statistics



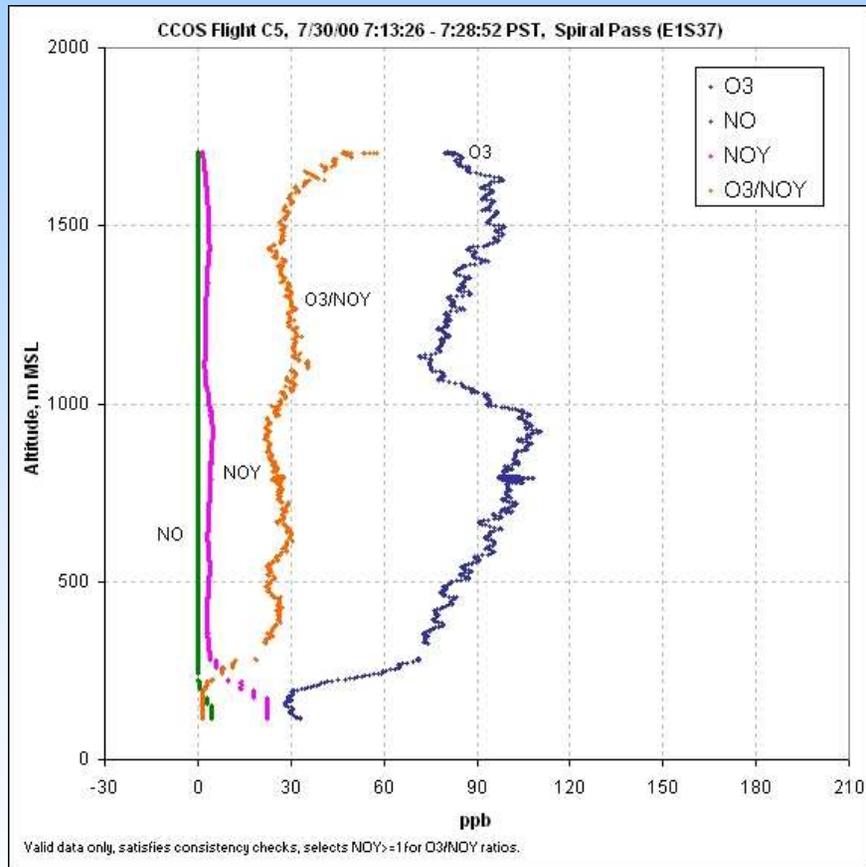
Surface NMHC Plots



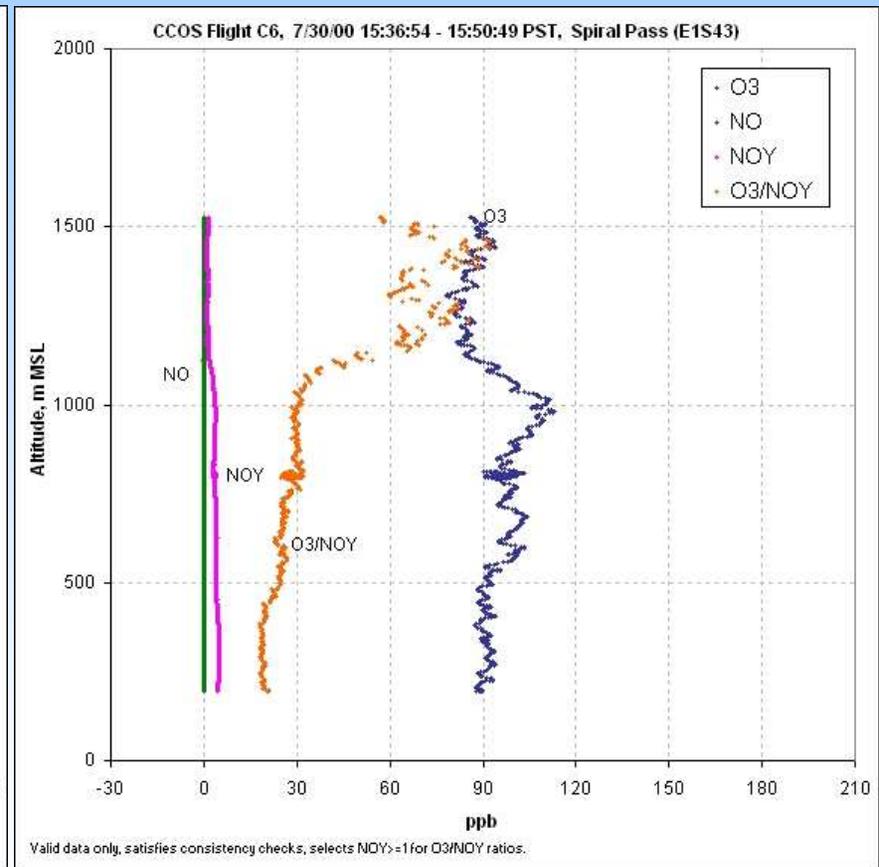
Structure of Air Quality Aloft

- Aircraft Spirals
- Aircraft Traverses
- Ozonesondes
- Hydrocarbons

Aircraft Spirals

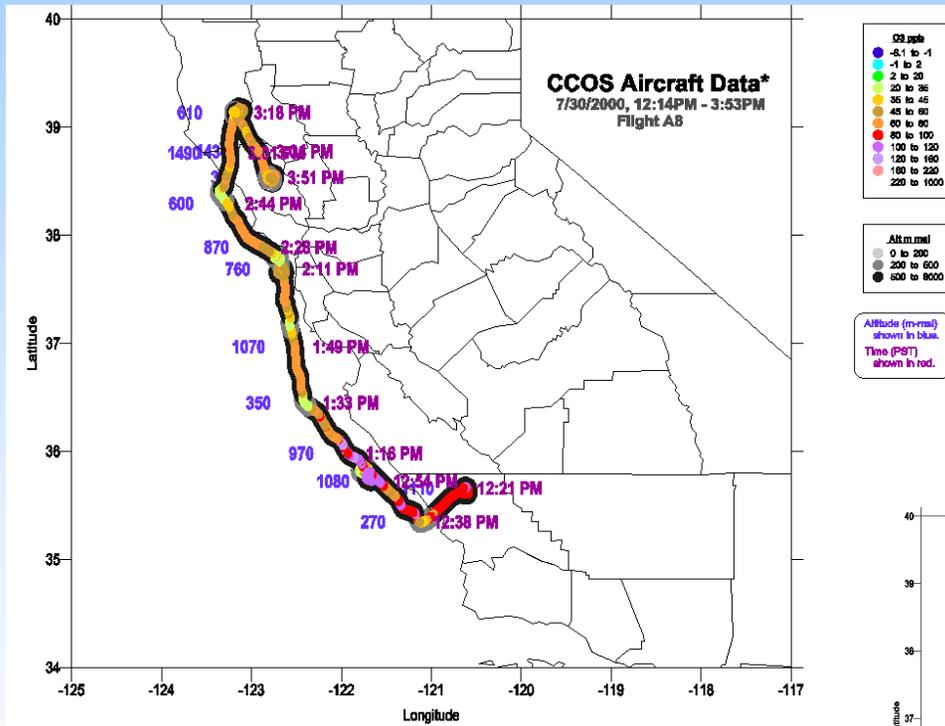


37.0N 120.1W

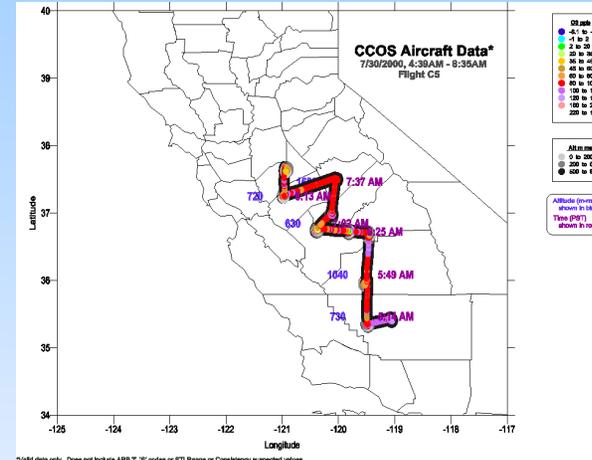


35.9N 19.5W

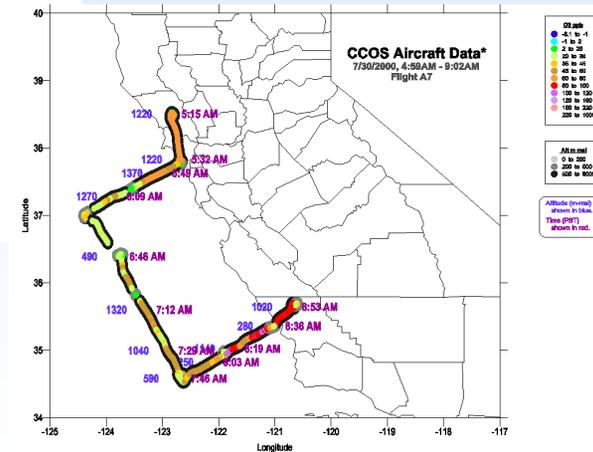
Aircraft Traverses



*Valid data only. Does not include ARB 'T', 'S' codes or STI Range or Consistency suspected values.

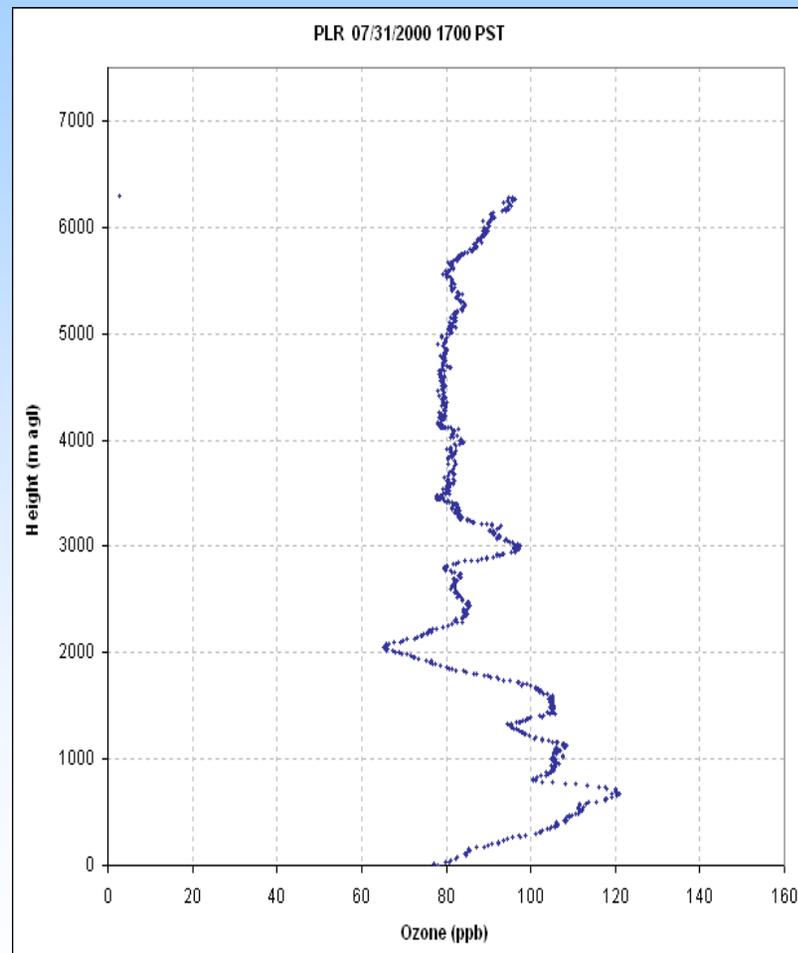
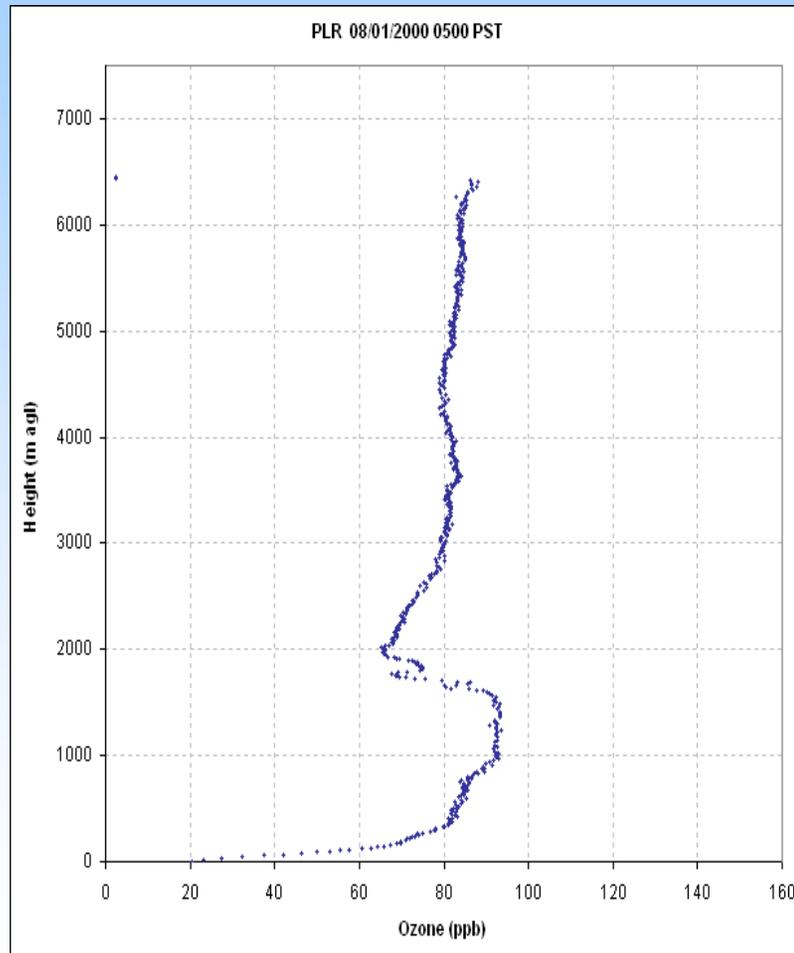


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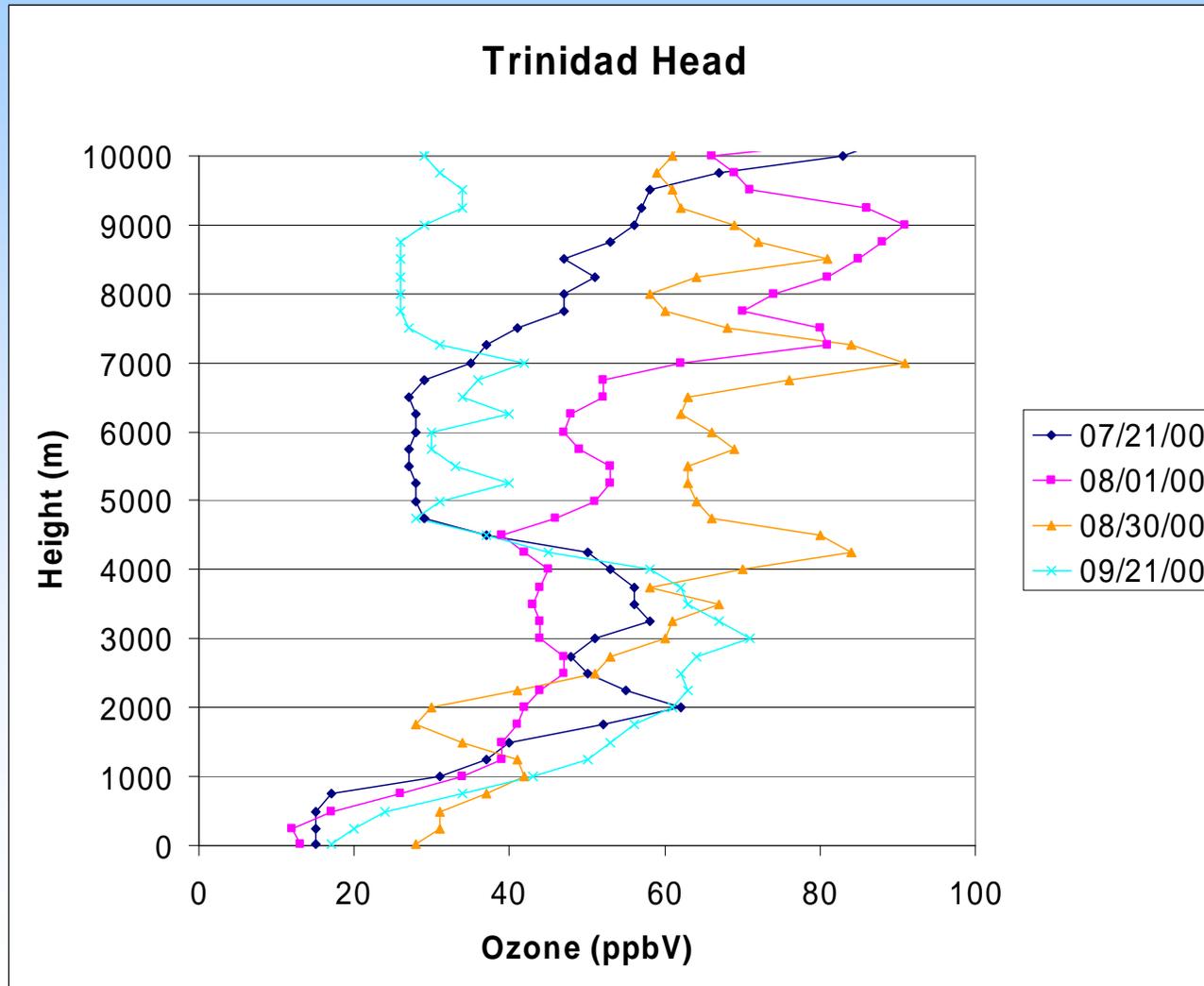


*Valid data only. Does not include ARB 'T', 'S' codes or STI Range or Consistency suspected values.

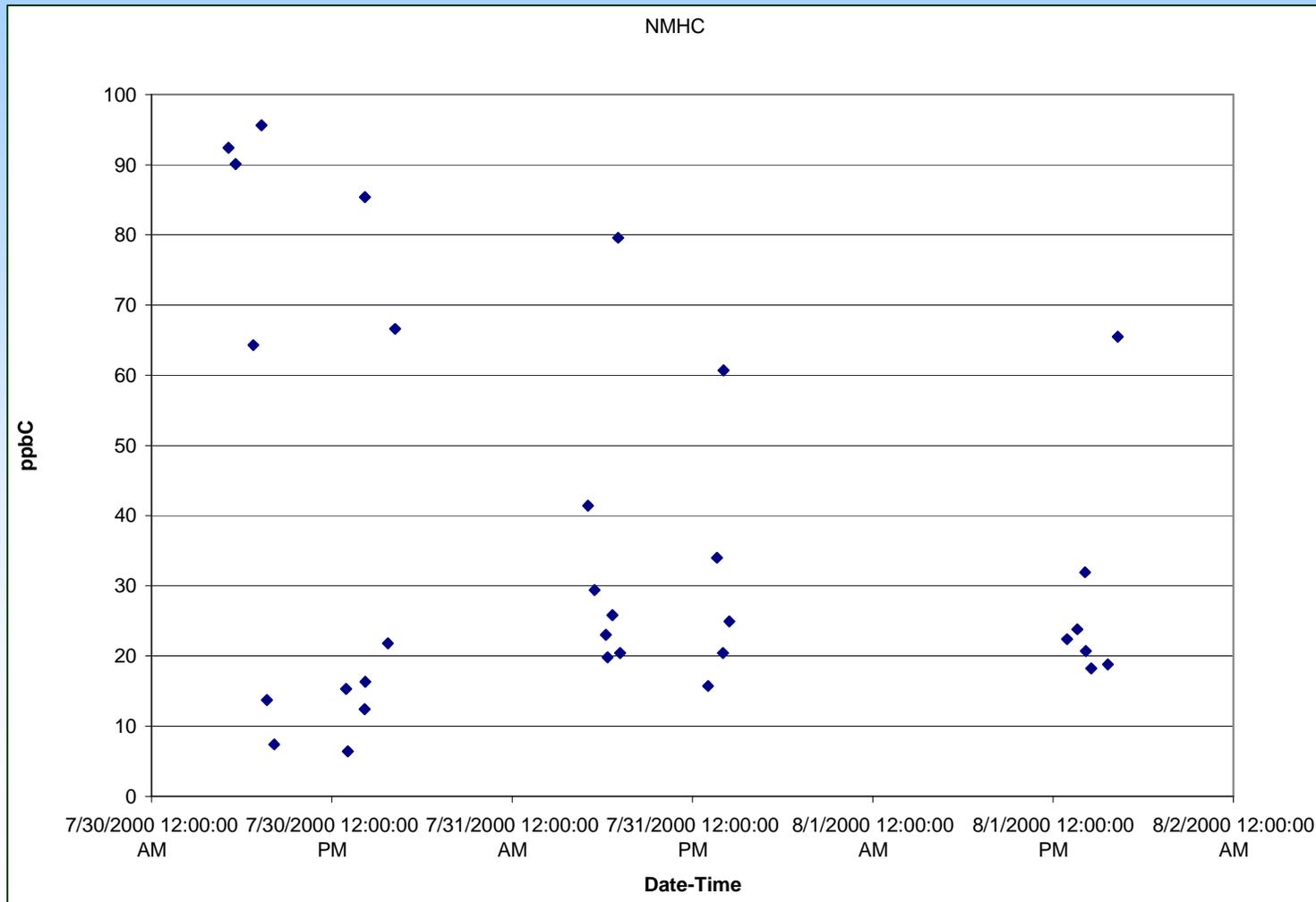
Ozonesondes (1 of 2)



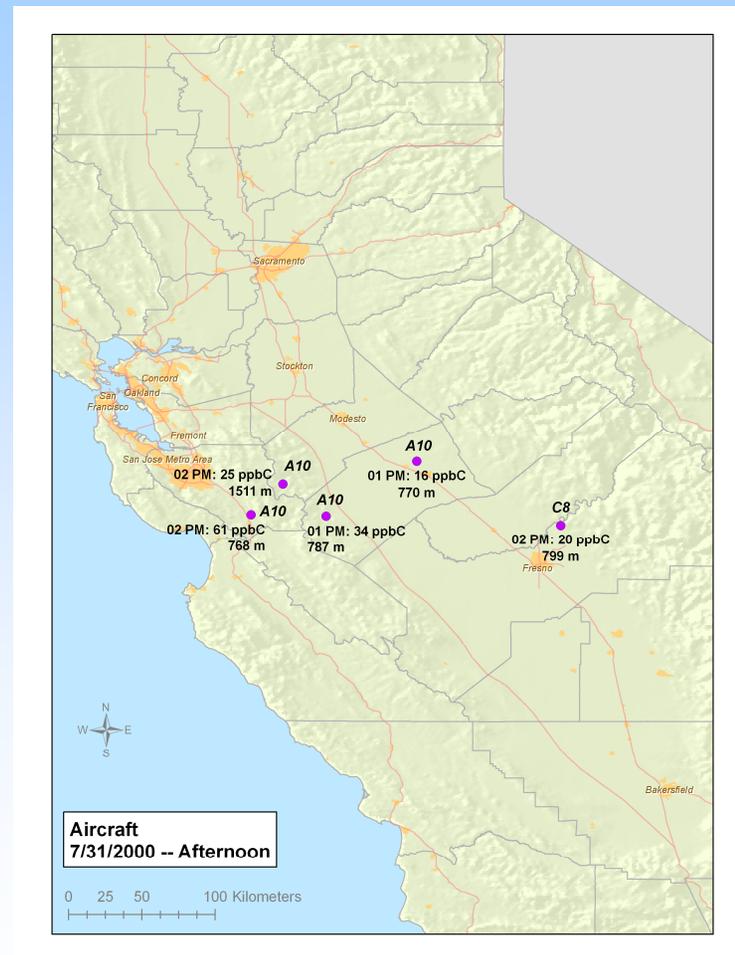
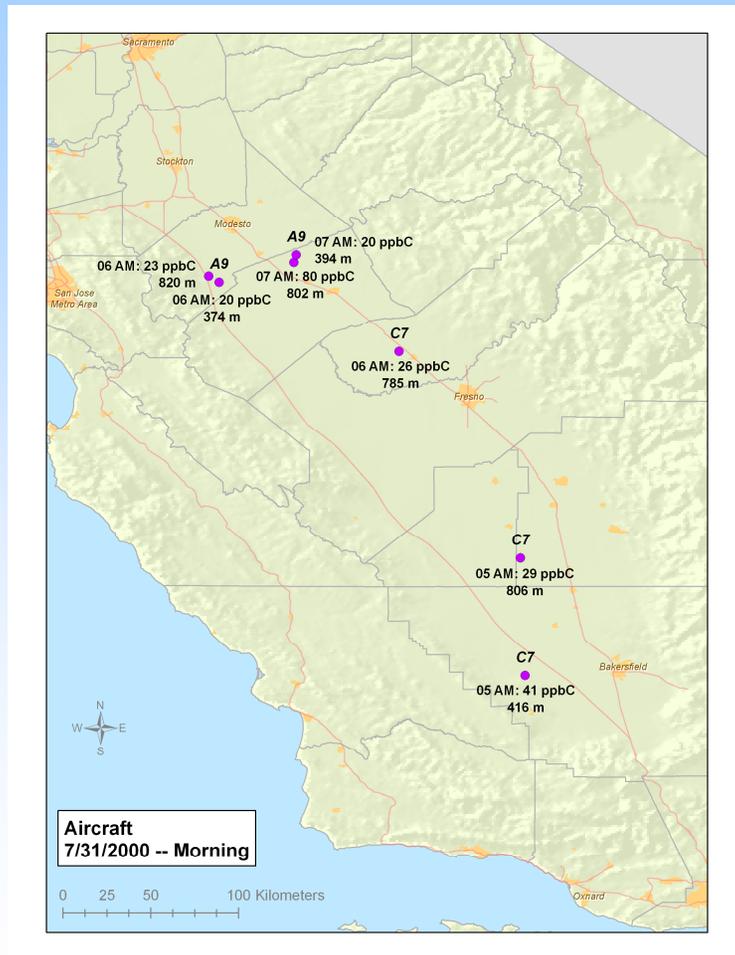
Ozonesondes (2 of 2)



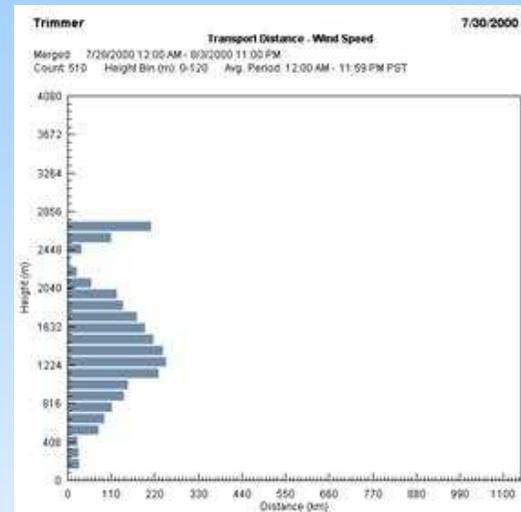
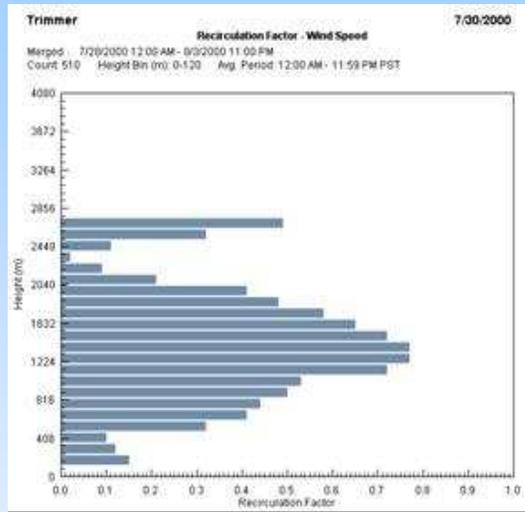
Hydrocarbons Aloft



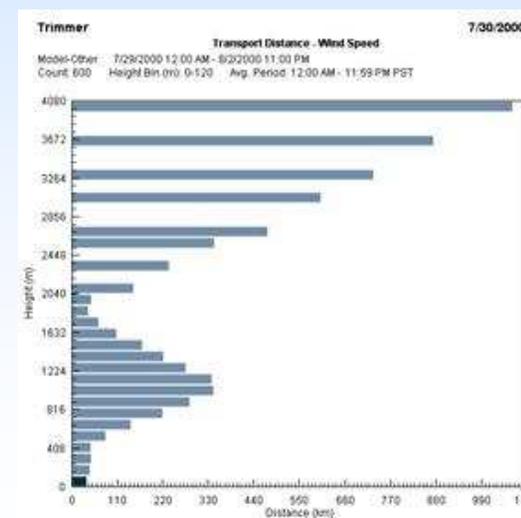
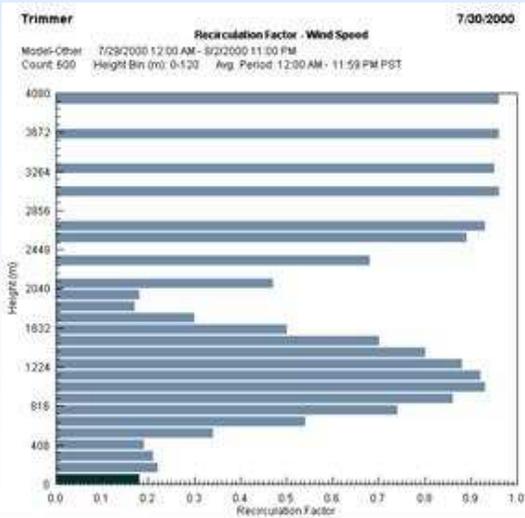
Aloft HMHC Plots



Transport Statistics



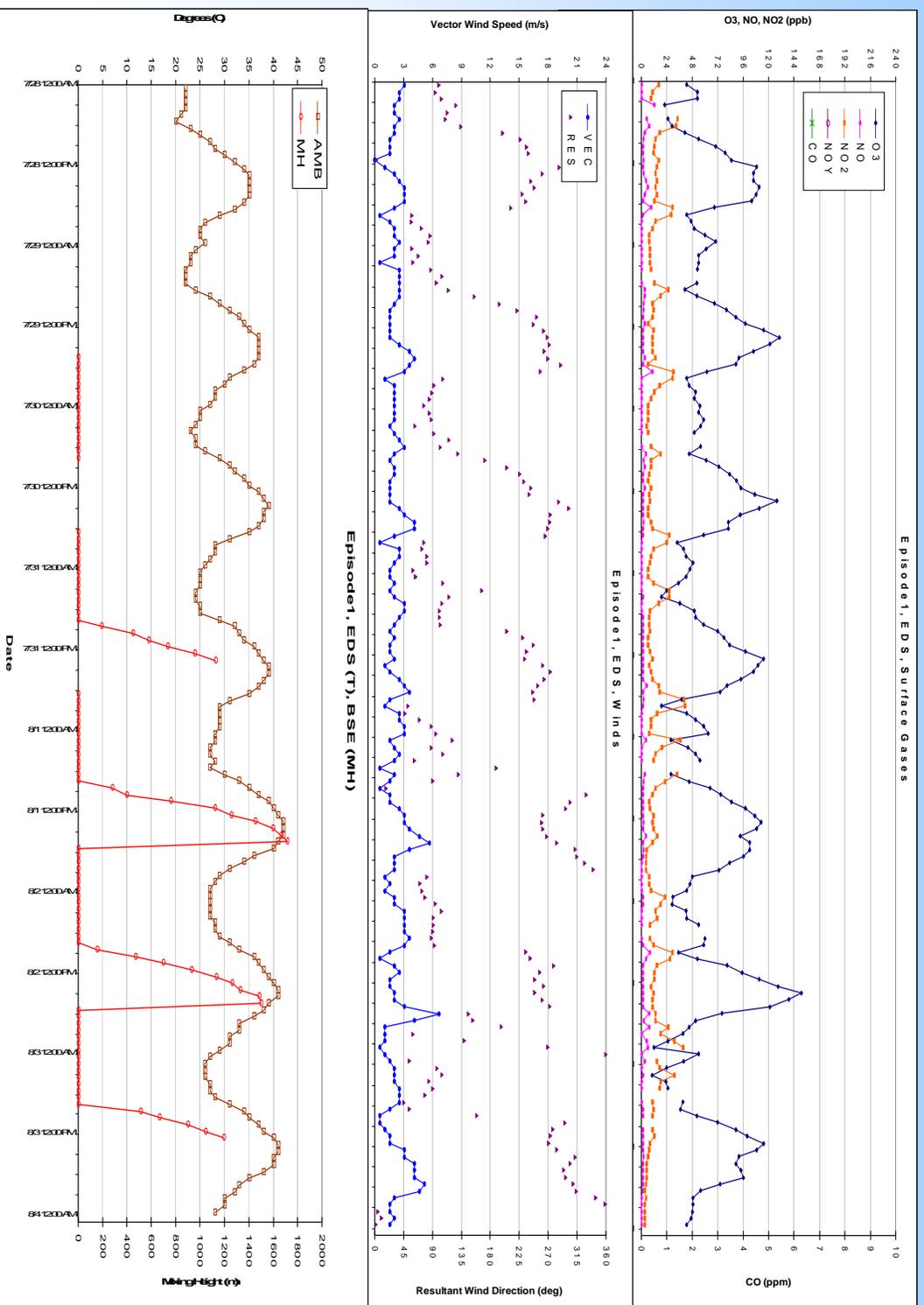
RWP



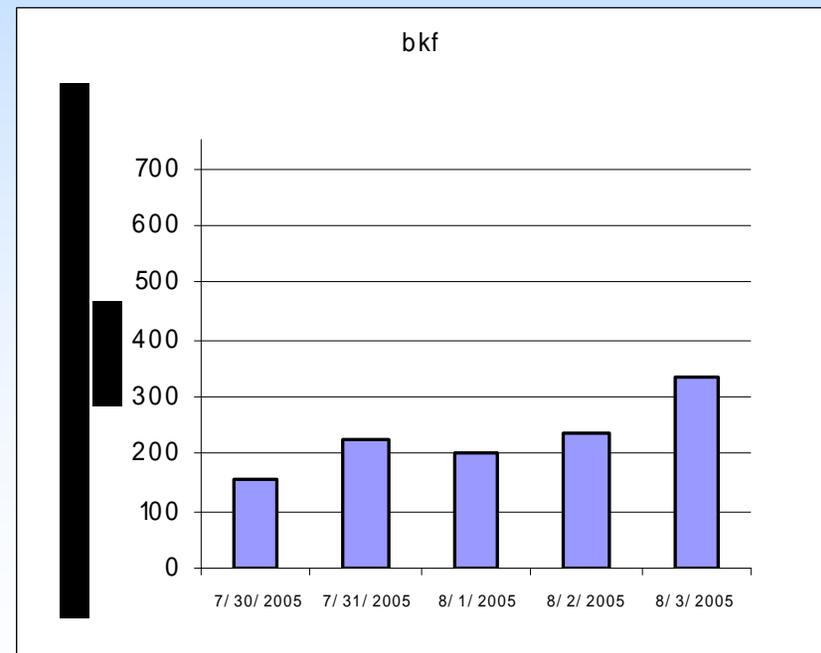
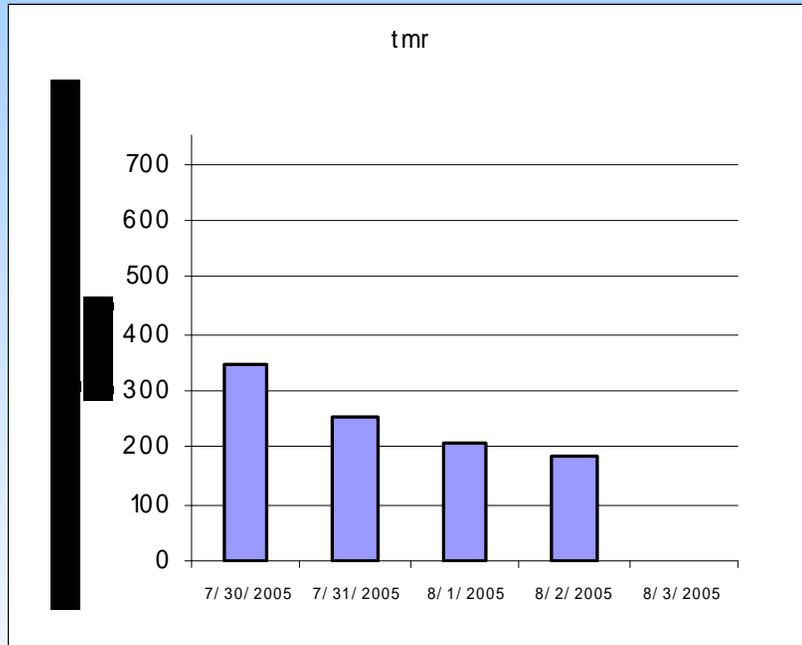
MM5



Time Series Plots

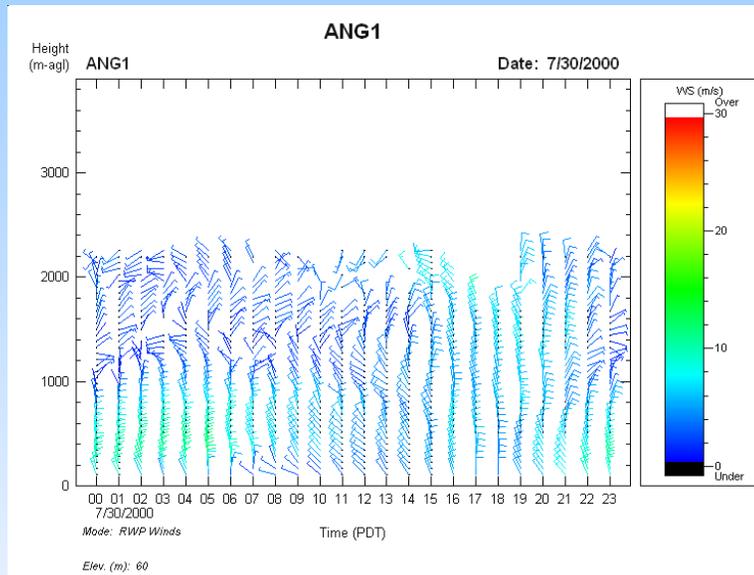


Mixing Depth Growth

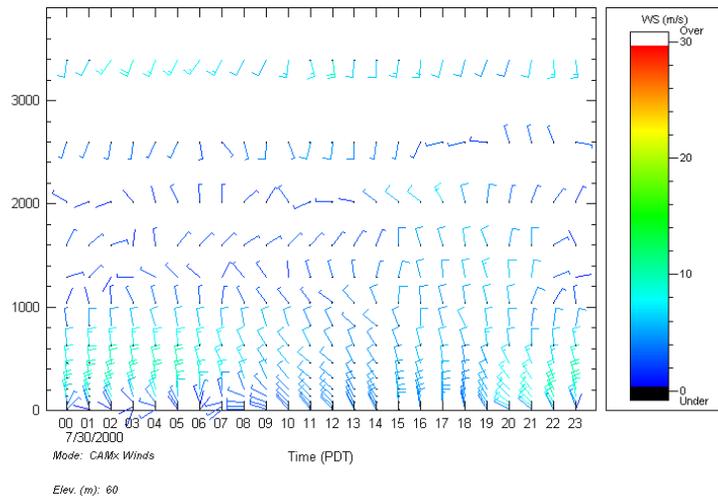


Vertical Wind Profiles

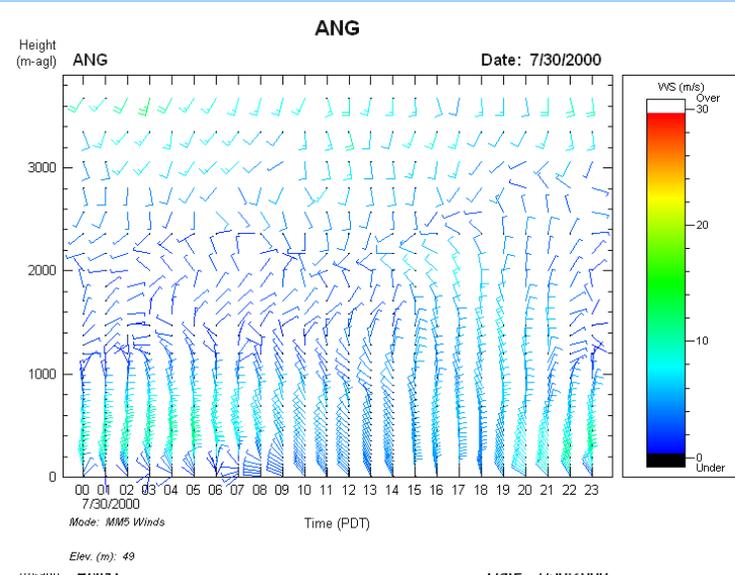
RWP



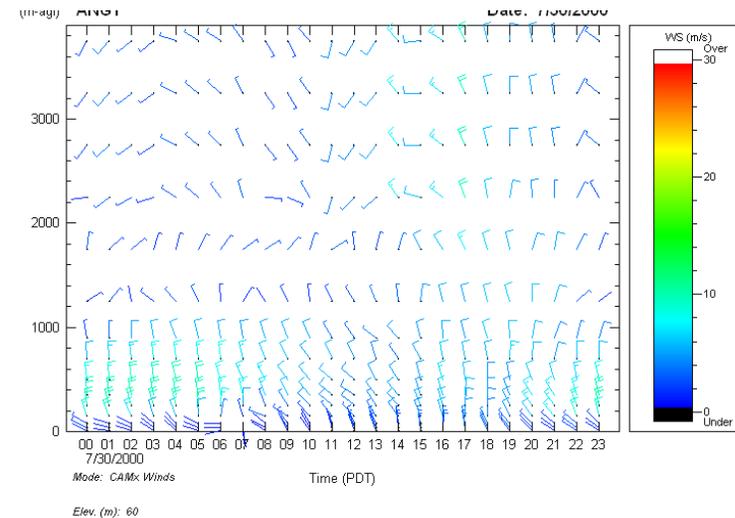
TC



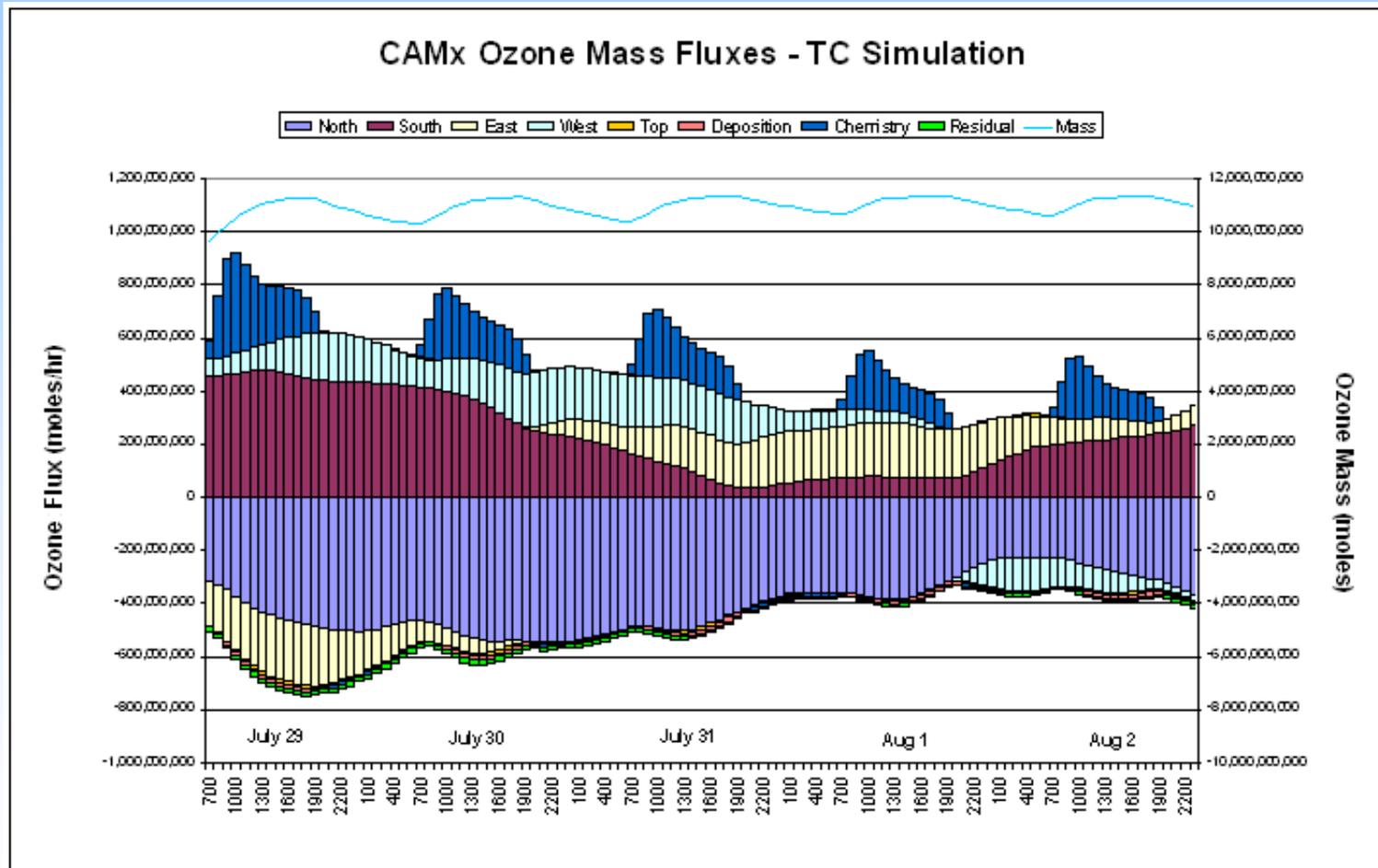
MM5



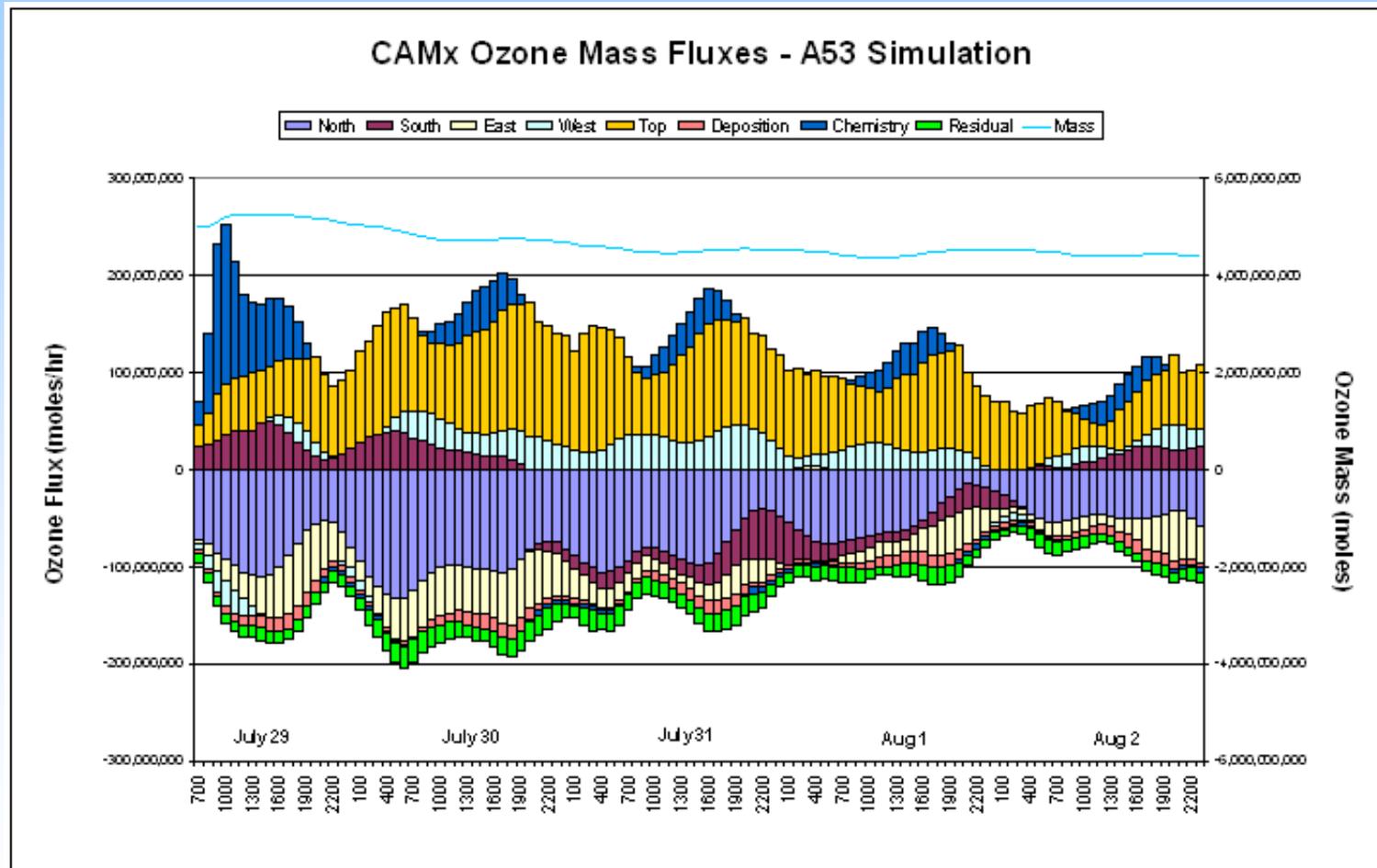
A53



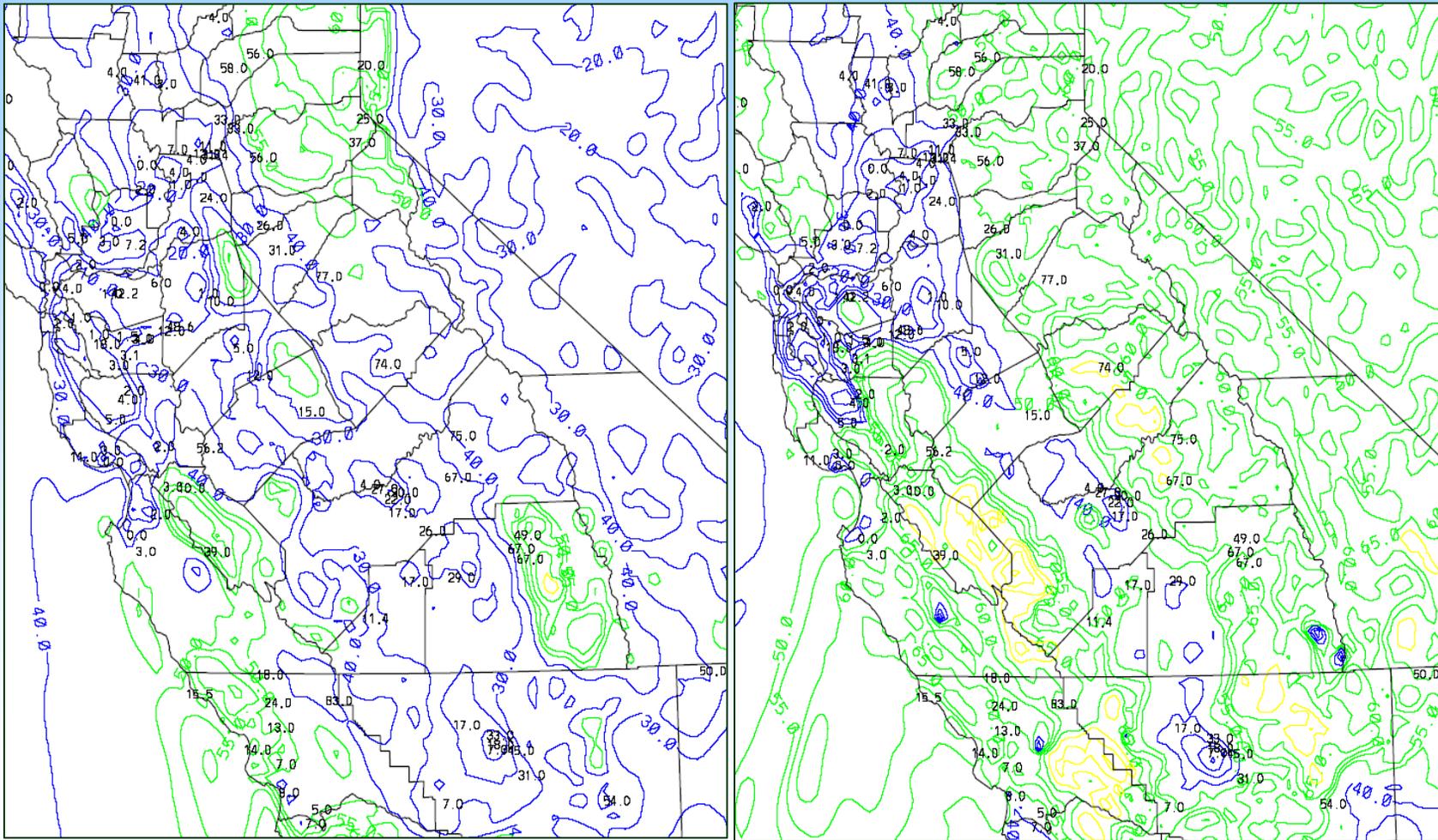
Mass Flux Analysis – TC MM5



Mass Flux Analysis – Hybrid



Morning Ozone Predictions



A53

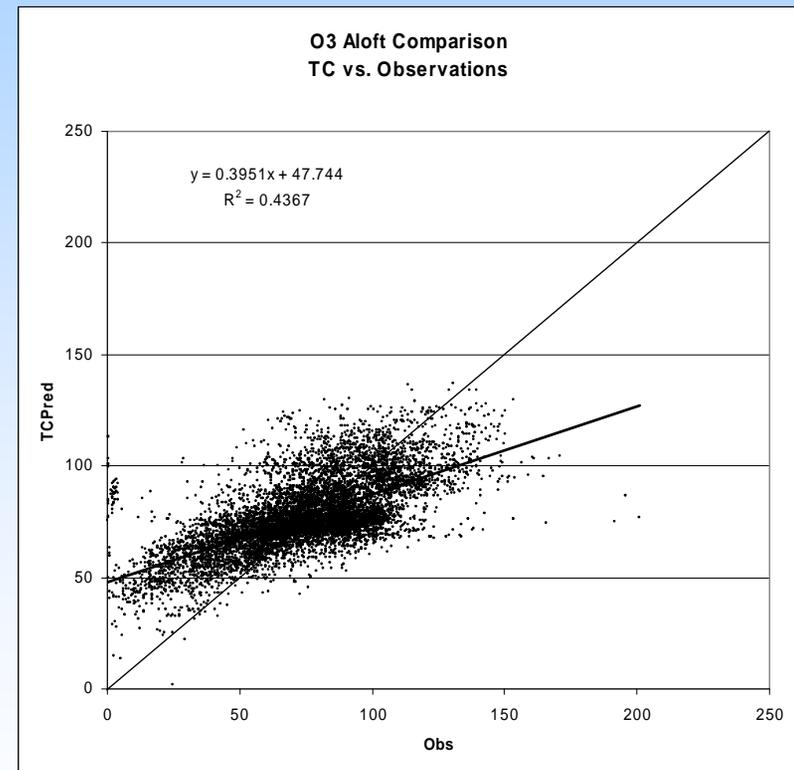
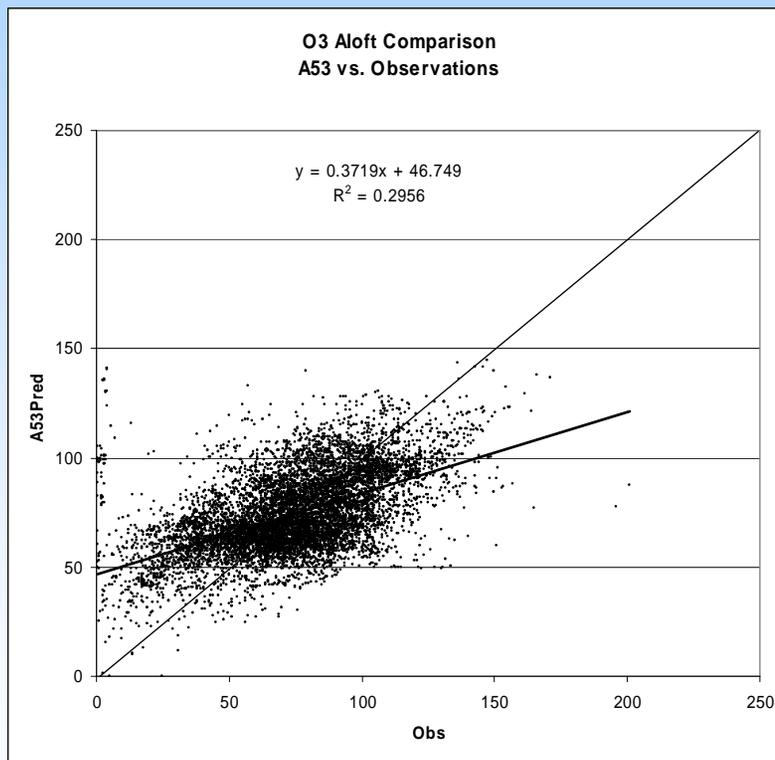
TC

0700 PDT August 1

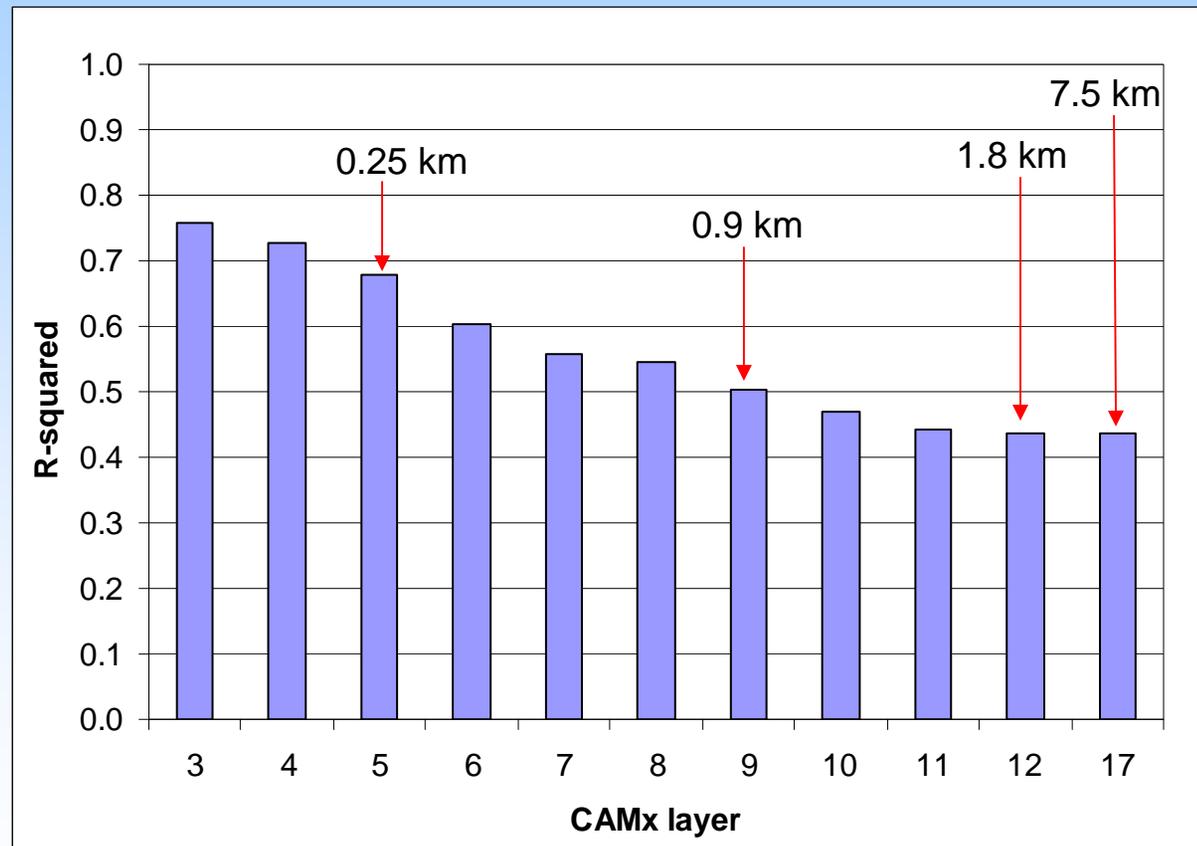


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Model Performance Aloft



Ozone Correlation by Level



Meteorological Modeling Issues

- MM5
- CALMET-MM5 Hybrid
- Mapping to CAMx vertical structure
- Evaluation of winds above 2-km
- Mechanical mixing at night

Improvements

- Meteorology (MM5)
- Vertical Structure
- Nighttime Mixing
- Photolysis Rates
- Wildfire Emissions
- Anthropogenic and Biogenic Emissions
- Emphasis on July-August 2000 Episode

Evaluation Process

- Aloft Model Performance for Ozone
 - Hourly Averages for Grid Cells
 - Scatter Plots
 - Correlation
- Inert Tracer Simulations for Meteorology Changes
- Vis5D Animations of Ozone & Inert Tracers
- Difference Plots
- Ground Level Model Performance



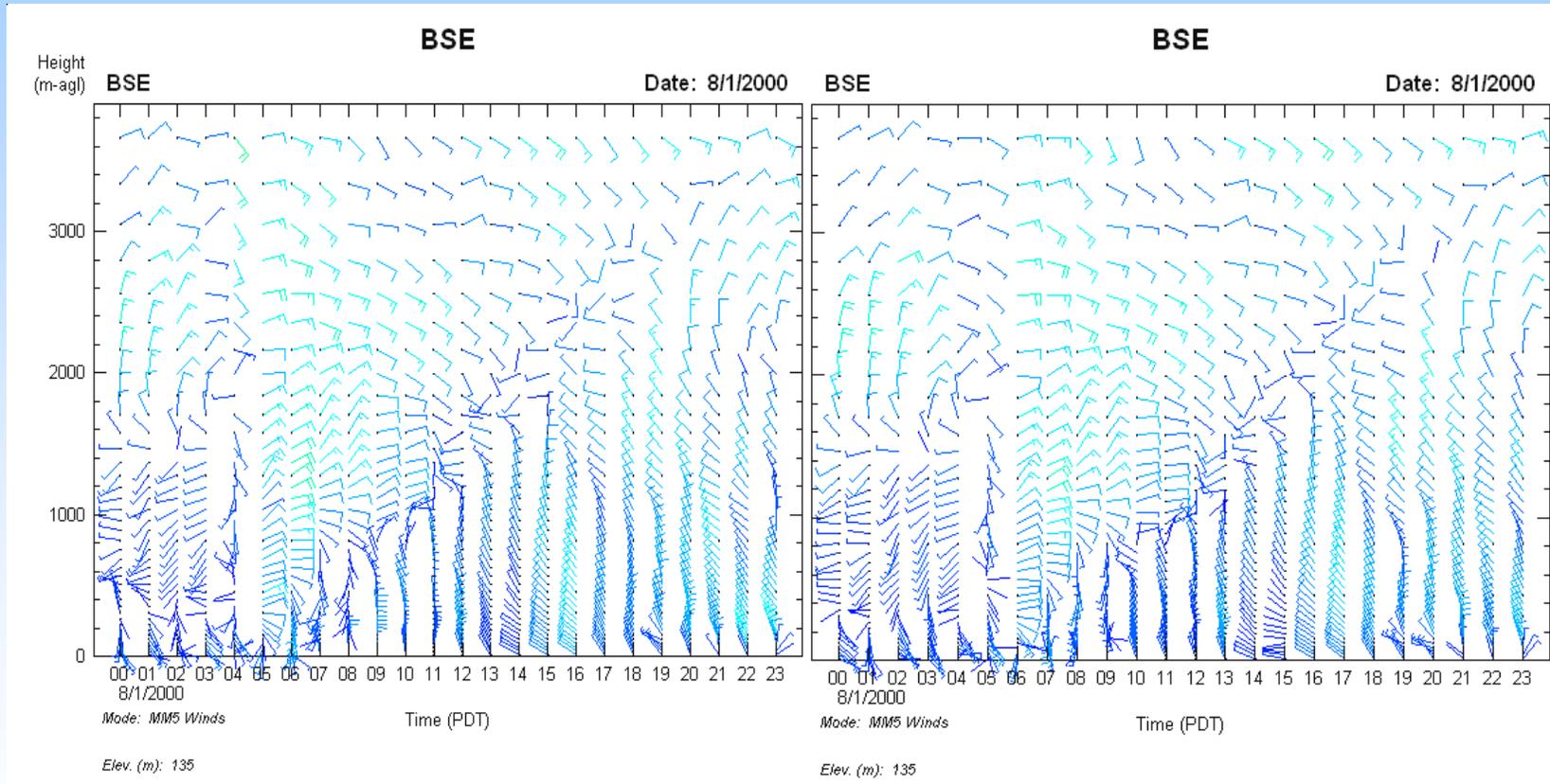
Results

- Meteorology (MM5)
- Vertical Structure
- Nighttime Mixing
- Photolysis Rates
- Wildfire Emissions (partial)
- Emission Inventory Improvements (incomplete)

Meteorology

- NOAA's "Best" Simulation
 - Not our requested simulation
 - No hourly average output
 - Interpolated observation FDDA
- Results
 - Not much change in performance or flow structure
 - Vertically interpolated observation nudging did not obscure or significantly weaken return flows

Winds



Original

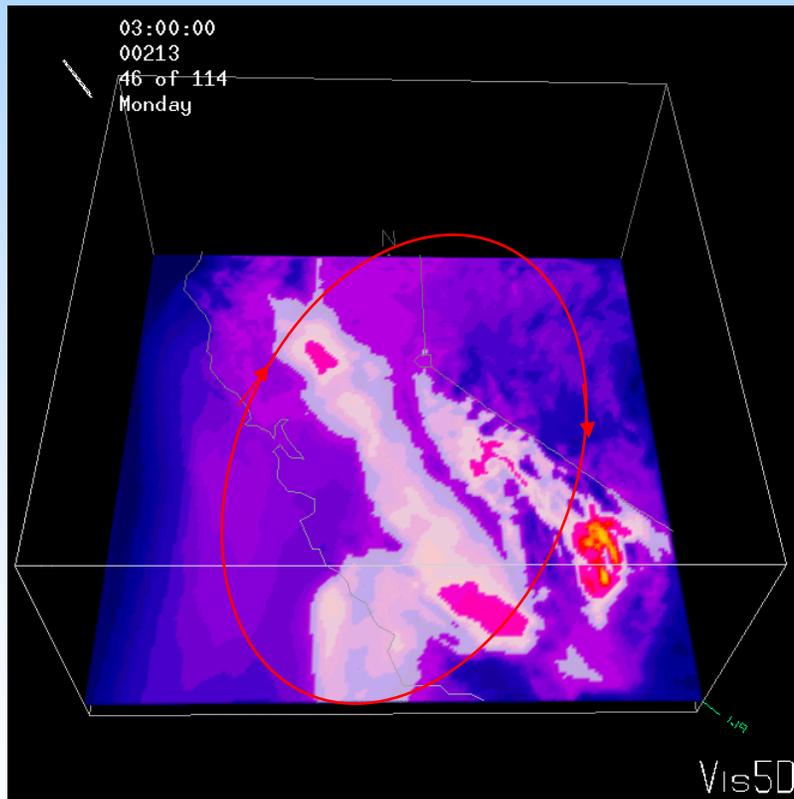
New

Vertical Structure

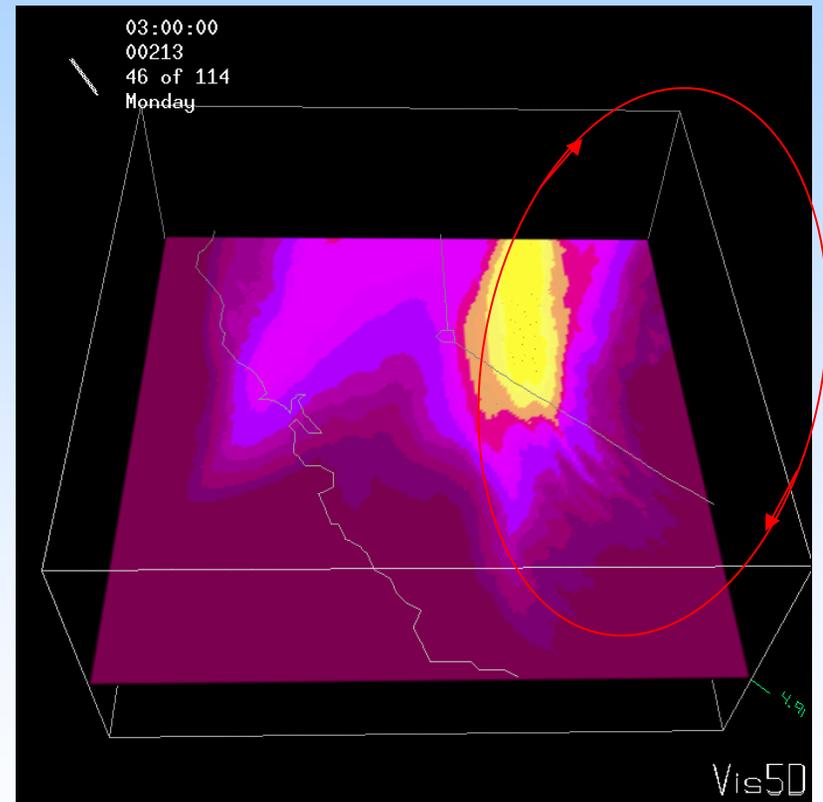
- CAMx and MM5 layers matched in first 2 km
- 38 Layers
- Results
 - Better vertical resolution of winds in CAMx
 - Little change in net circulation
- Transport through boundaries aloft

Ozone Transport Through Boundaries

Monday, July 31, 2000



1.3 km



5.0 km

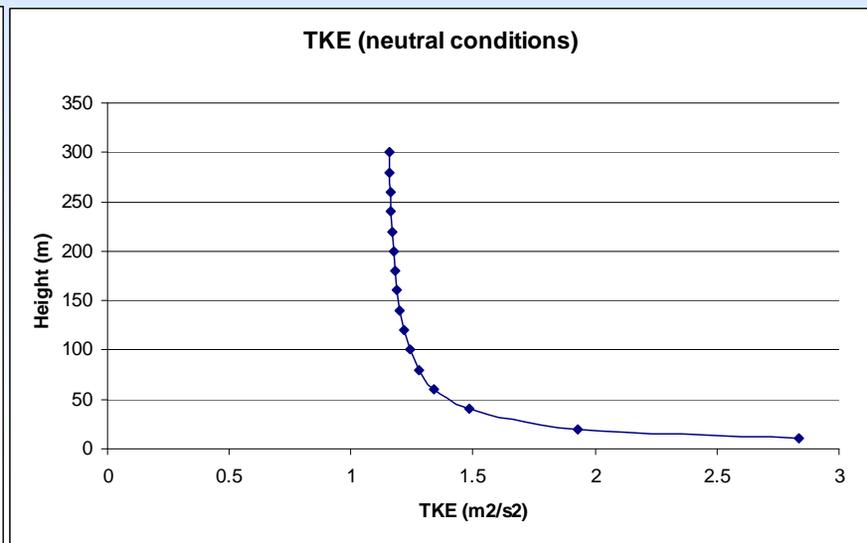
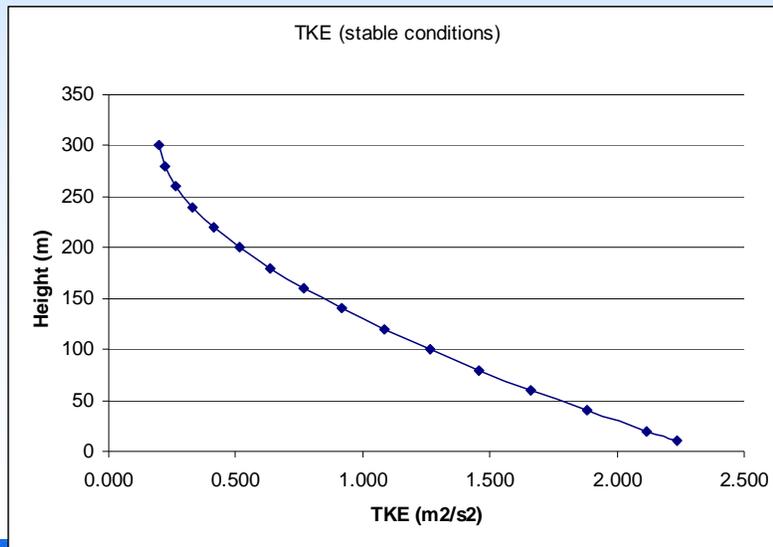
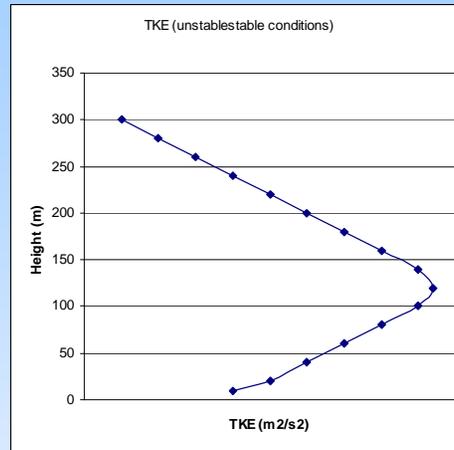
Nighttime Mixing Issues

- Surface roughness and friction velocity
- Fire emissions
- Recirculation

Nighttime Mixing

- Mechanical Mixing Model
 - Neutral and stable: van Ulden and Holtslag (1985)
- TKE profiles
 - Near neutral : Zhang et al. (1996)
 - Stable: Lenschow et al. (1988)

TKE Profiles



Alternate Photolysis Rates

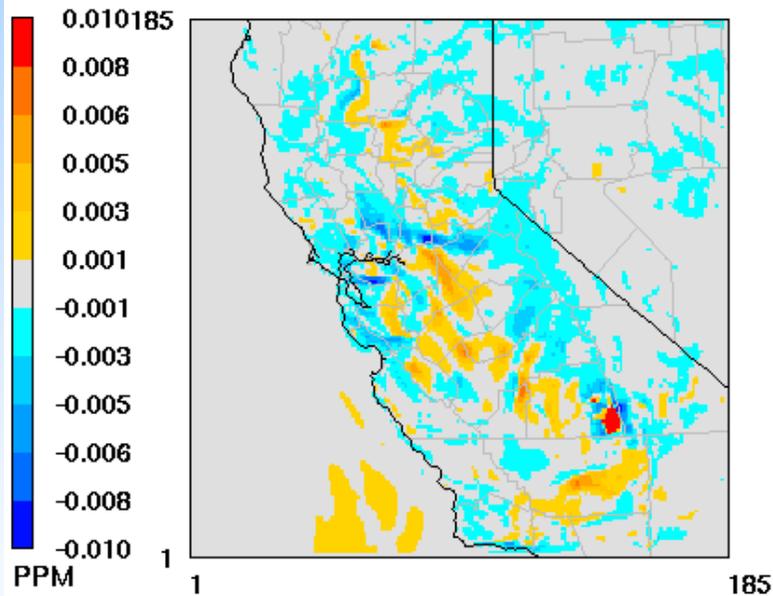
- Modified CAMx 4.31 to read in terrain elevations and calculate layer heights above mean sea level (MSL)
- April 2006 release of TUV 4.01 allows levels to be specified
- Pseudo-spherical two-stream delta-Eddington scheme
- Increased number of photolysis levels in CAMx from 11 to 27



Spatial Differences – New Photolysis

Layer 1 Ozone Difference

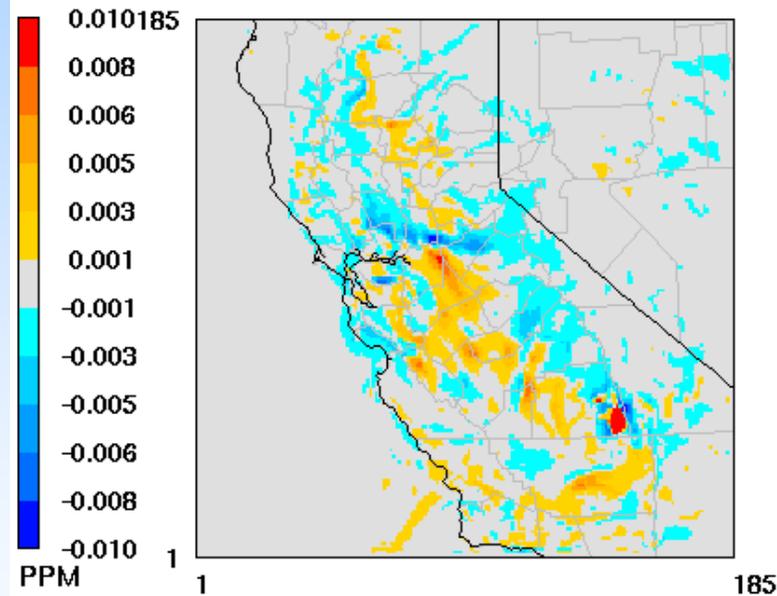
(newphot - photorig)



July 31, 2000 16:00:00
Min= -0.011 at (148,52), Max= 0.077 at (145,48)

Layer 6 Ozone Difference

(newphot - photorig)



July 31, 2000 16:00:00
Min= -0.011 at (148,52), Max= 0.079 at (145,48)

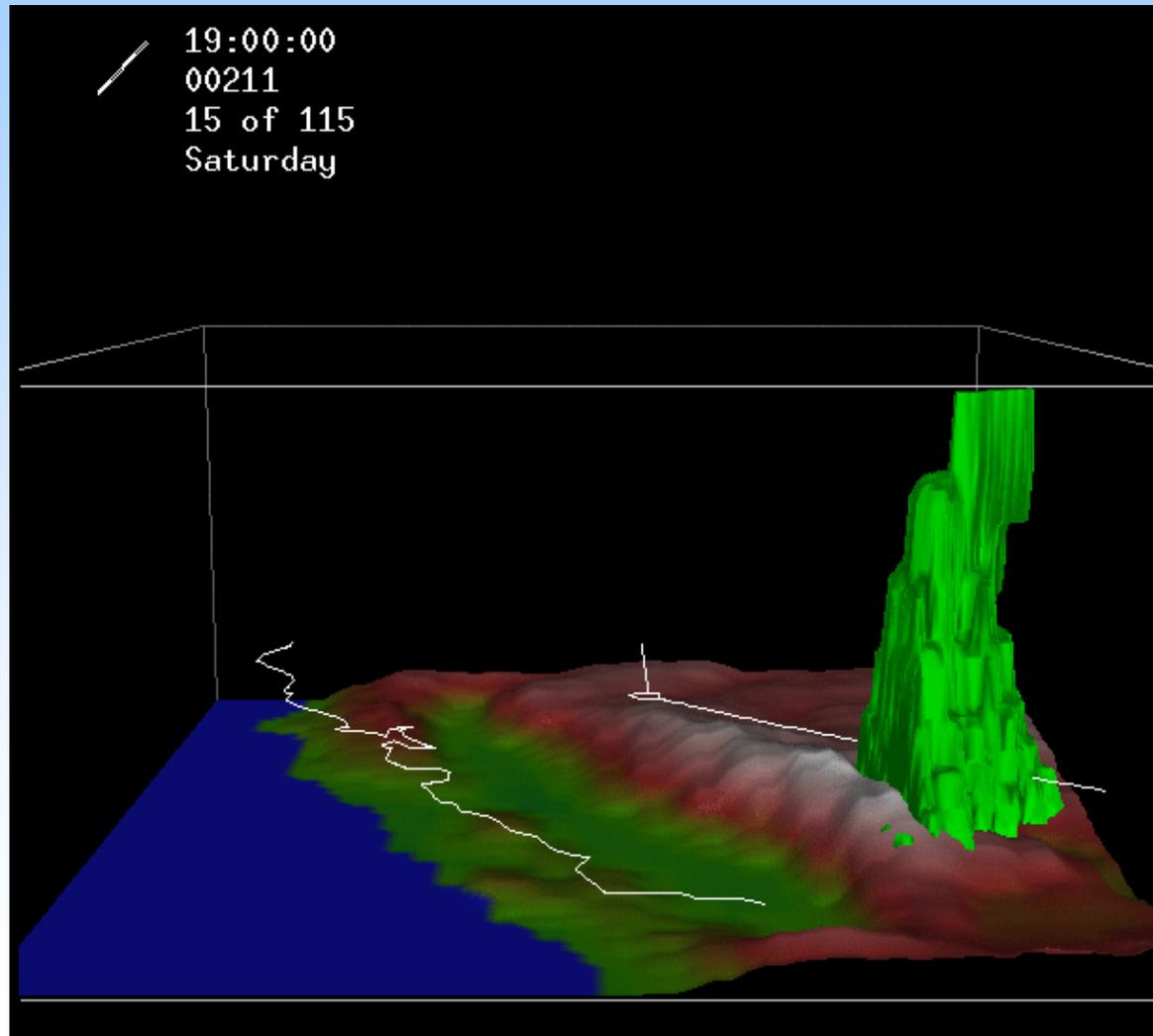
Case photorig: Photolysis rates used in TC simulation

Case newphot: Terrain-corrected photolysis rates

Wildfire Emissions

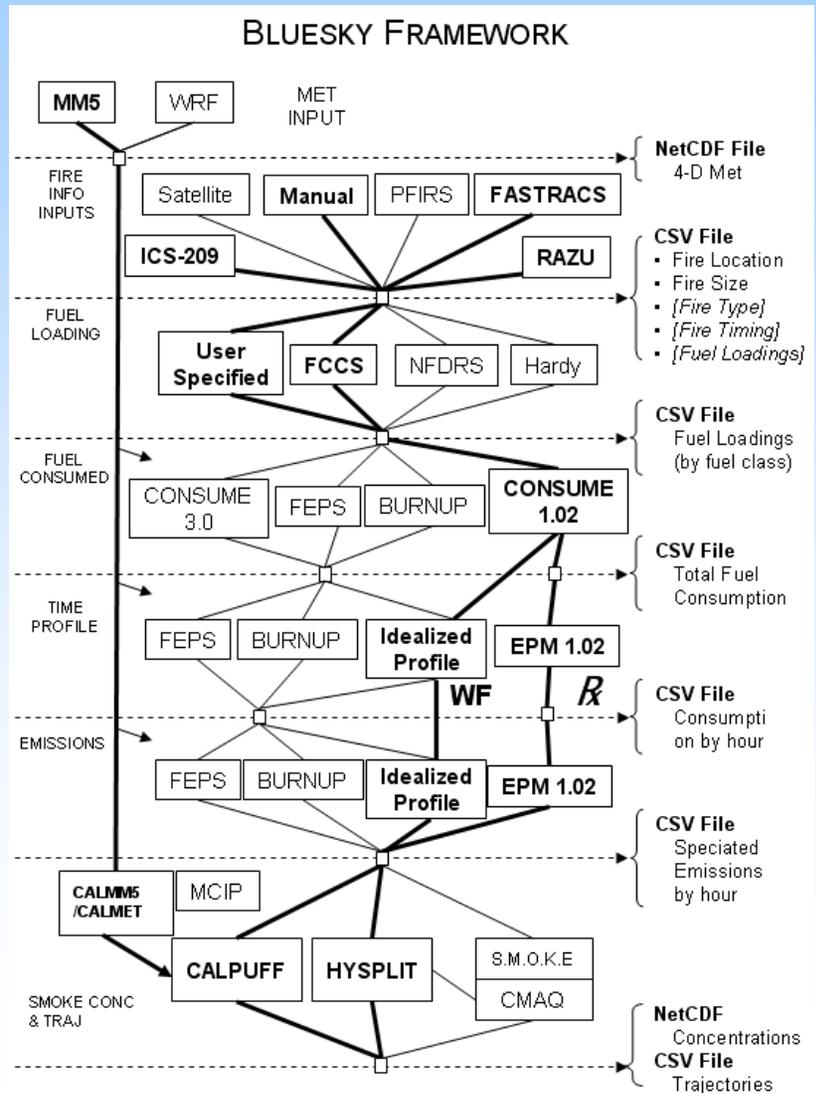
- Stack parameters and plume rise
 - Plume rise:
2 km (intended) vs. > 10 km calculated in CAMx
 - Default stack parameters: $T=295$ °K and $V=4$ m/s
- Smoldering emissions
 - Fire effects models
 - Dominate VOC emissions from fires
 - Diurnal variations
 - Post burn smoldering
 - Issues with establishing defensible profiles

Wild Fire Tracers



Wild Fire Emissions Research

- JFSP Matrix
- JFSP FT-CSA
- USFS-FERA FCCS
- NASA Vertical Analysis
- JFSP SEMIP



EI Improvements

- Acquired draft improved EI for Emissions Reconciliation Project
- Initial review indicated the changes were not large enough, based on past sensitivity studies, to warrant a separate simulation
- Emissions Reconciliation Project indicated additional investigation warranted

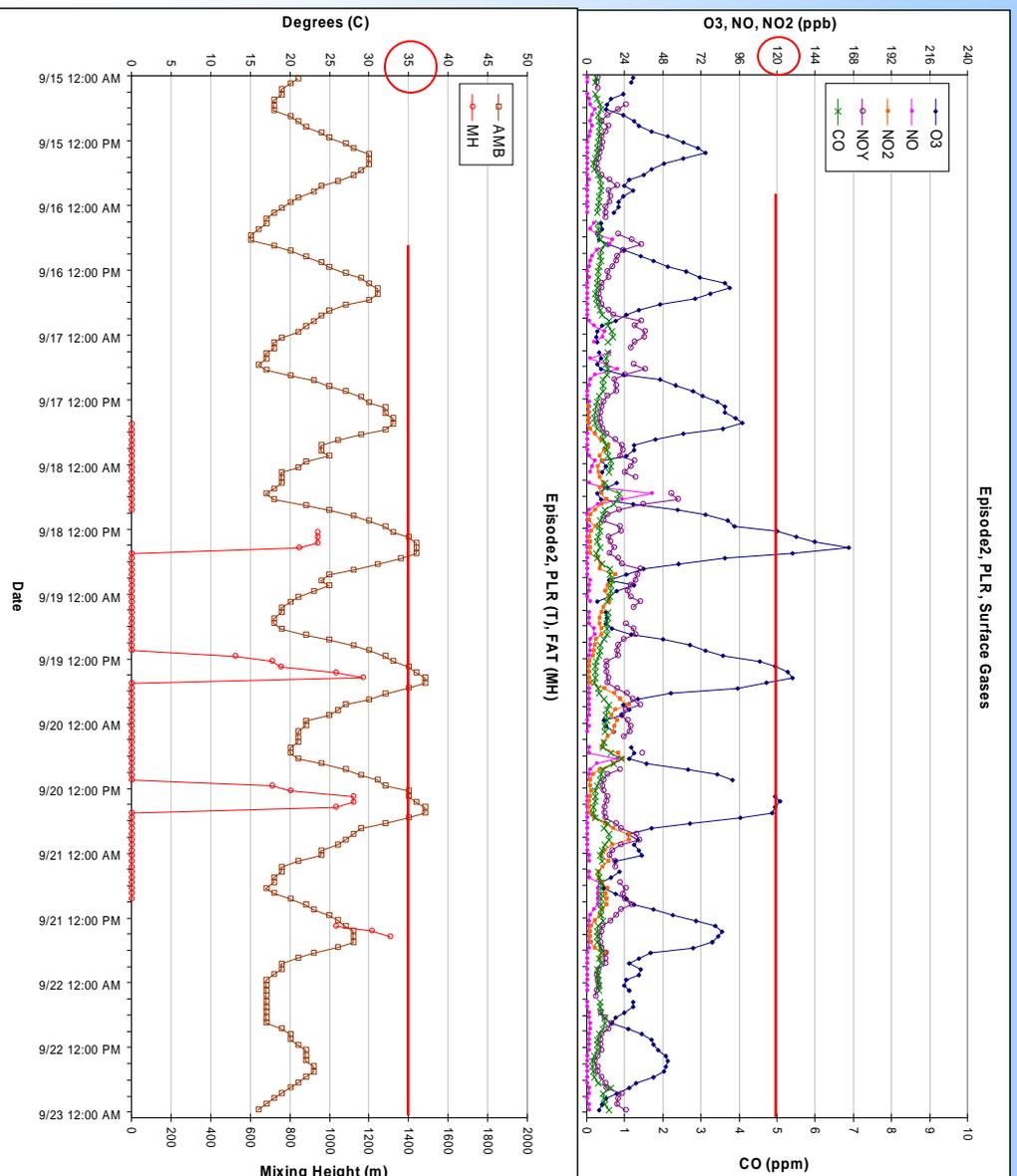
Modeling Domain

- CAMx Simulations
 - Ozone mass flux analyses
 - Transported ozone and tracers through southern and western boundaries
- SJVAQS 1990
- Animations

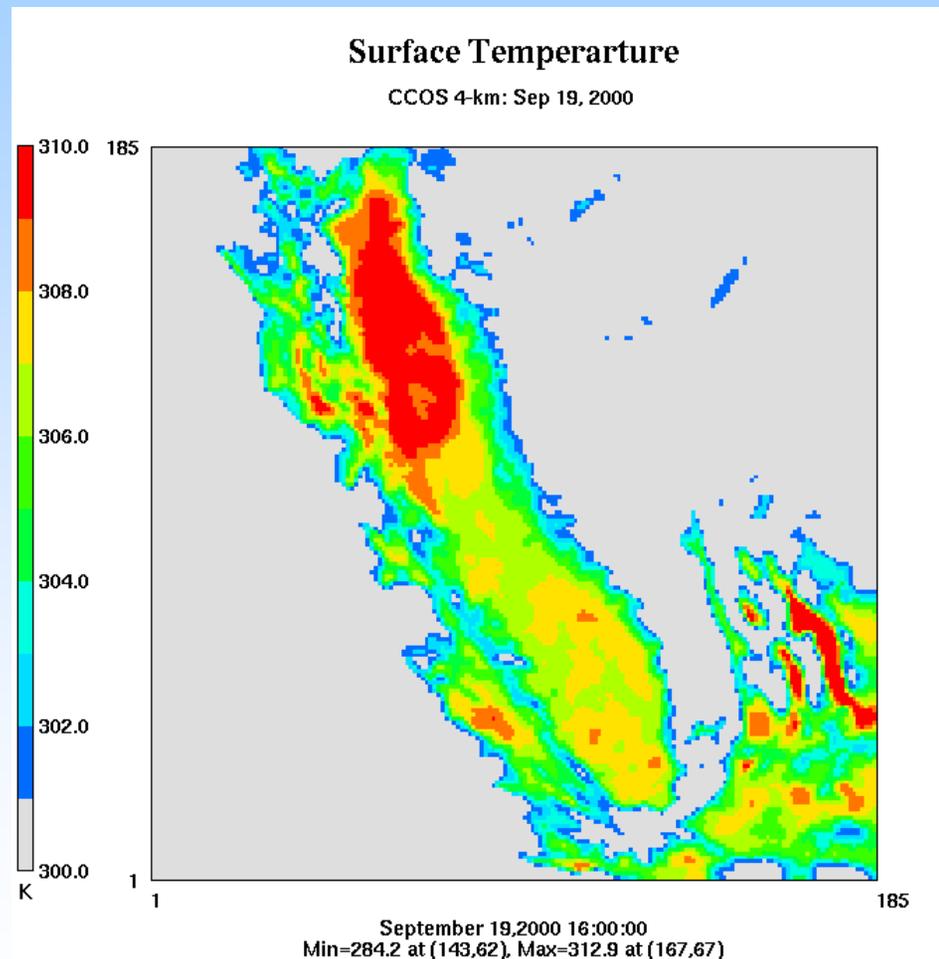
September 2000 Episode

- MM5 temperature bias
- No new MM5 simulations
- Biogenic emissions in southern SJV
- Underestimation of TNMOC:NOX emission ratios in southern SJV

High Ozone Day Temperatures



Maximum Predicted Temperatures



Summary

- Air Quality Aloft
- Transport Processes
- Production Processes
- Fires
- Emissions
- Meteorological Model Biases
- Modeling Domain

Hypothesis Evaluation (1 of 2)

1. Emission inventories are biased low ✓
2. Wildfires are not adequately represented ✓
3. Boundary concentrations are inaccurately specified ✓
 - Lack of data ✓
 - Transport from Asia X
 - Transport from southern California ✓
 - Tropopause folding events (stratospheric ozone intrusion) X
4. Grid resolution is insufficient ±
5. Meteorological models are unable to capture stagnant air conditions caused by terrain blocking of the flow X

Hypothesis Evaluation (2 of 2)

6. Vertical mixing of pollutants in the planetary boundary layer is overestimated resulting in relatively clean air aloft being mixed downward **X**
7. Mixing of high ozone surface air to the interior of the convective boundary layer is inadequate **X**
8. Recirculation of upslope flow from the Sierra Nevada Mountains and Coastal Range over the Central Valley are inadequately represented **±**
9. Chemical mechanisms underestimate ozone production efficiency at low precursor concentrations **±**
10. Dispersion in areas of significant and steep terrain in central California is treated inadequately **±**
11. Photolysis rates at higher elevations are treated inadequately **±**



Recommendations

- Implement new emission inventory
- Nest CCOS domain within a larger regional 12-km domain
- Continue to monitor research on fire emission in the Fire Sciences community