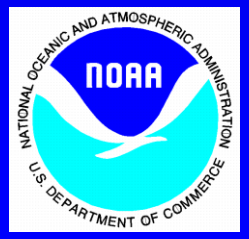
Airborne lidar measurements of horizontal and vertical ozone transport in southern California during CalNex 2010

C. J. Senff, R. J. Alvarez II, R. M. Hardesty, A. O. Langford, R. M. Banta, W. A. Brewer, F. Davies, S. P. Sandberg, R. D. Marchbanks, A. M. Weickmann

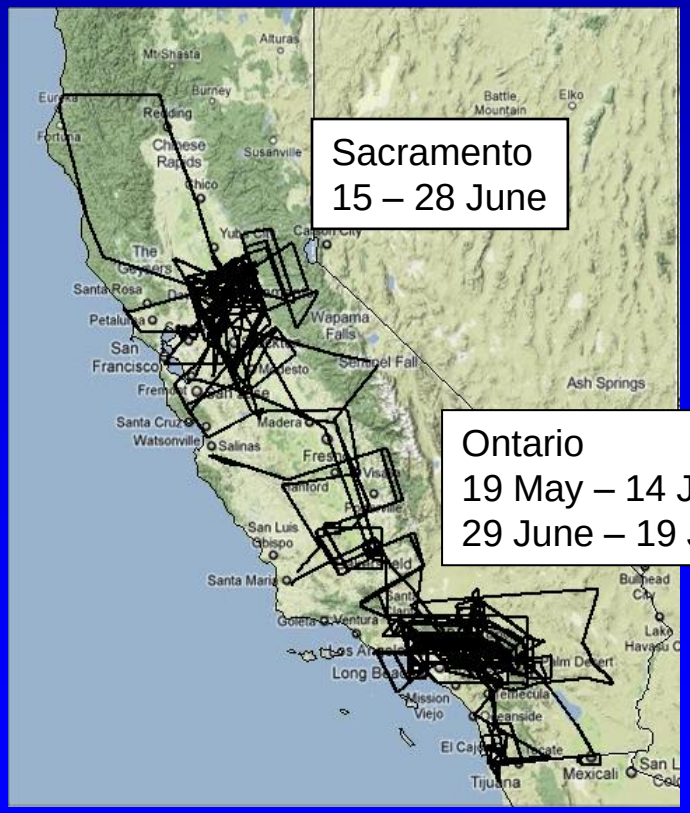


CalNex Data Analysis Workshop

18 May 2011

CalNex 2010 - NOAA Twin Otter

- Optical remote sensing aircraft
- 19 May – 19 July, 2010
- 52 flights, 207 flight hours
- Twin Otter CalNex operating parameters:
  - Speed: ~ 60 m s^{-1}
  - Endurance: up to 4 hours
  - Flight altitude: 500 - 17500 ft MSL

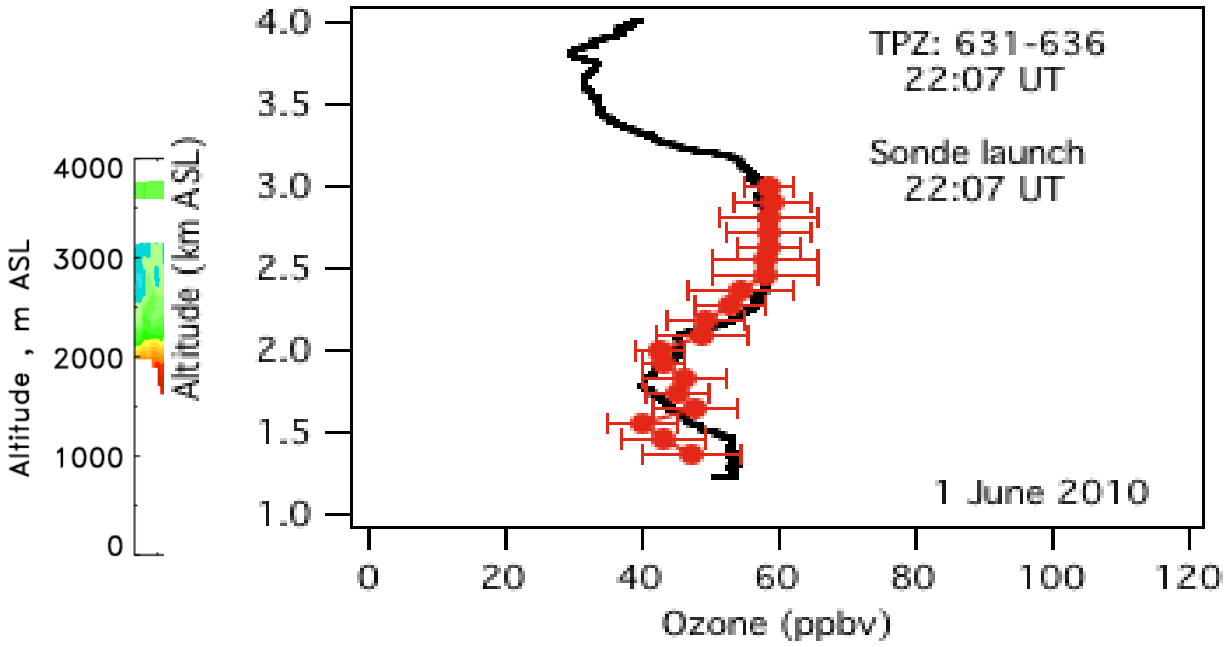


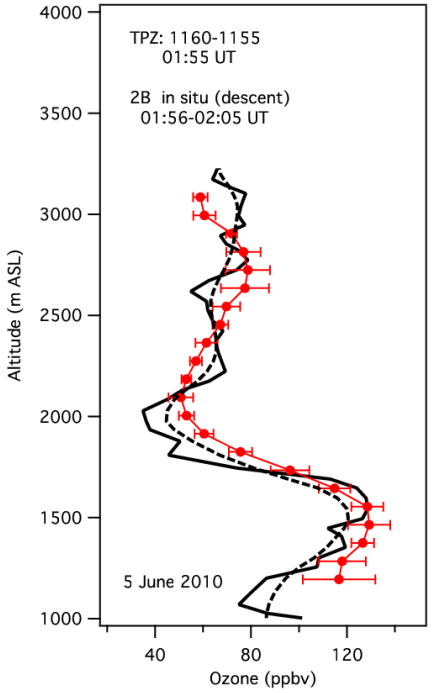
NOAA Twin Otter Instrumentation

- Primary instruments:
  - Downward-looking ozone and aerosol lidar (TOPAZ = Tunable Optical Profiler for Aerosols and oZone)
  - University of Leeds scanning Doppler wind lidar
  - Airborne Multi-Axes Differential Optical Absorption Spectroscopy (AMAX-DOAS) Instrument *(R. Volkamer et al, CU Boulder)*
- Additional instruments:
  - In situ O_3, temperature, pressure
  - Radiometers (surface temp, albedo)

TOPAZ Lidar (19 May – 19 July)

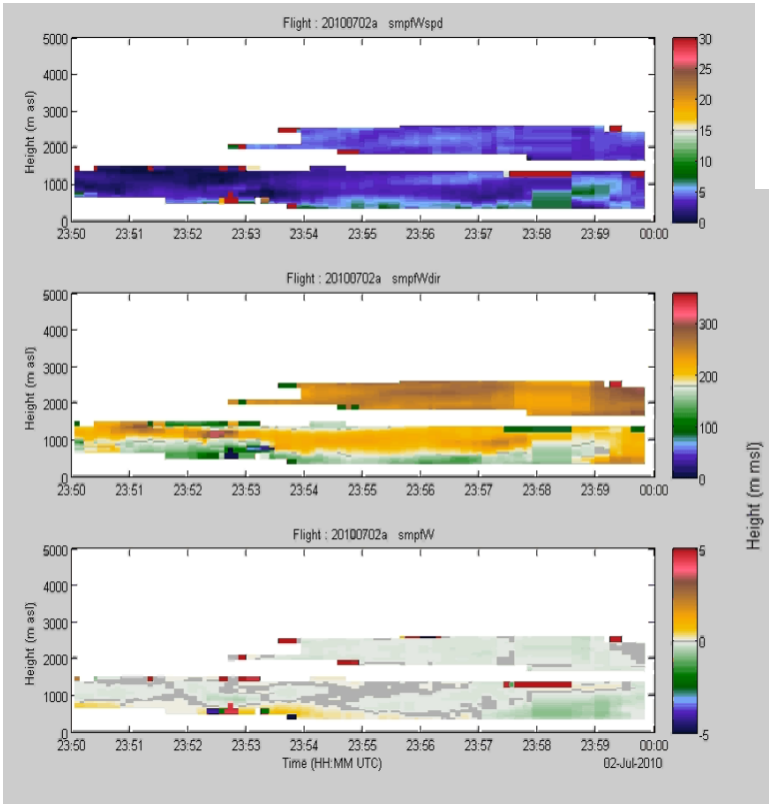
- Ozone & aerosol backscatter profiles
- Min / Max Range: 400 m / 3 – 5 km
- Resolution (O_3): Δx = 600 m, Δz = 90 m

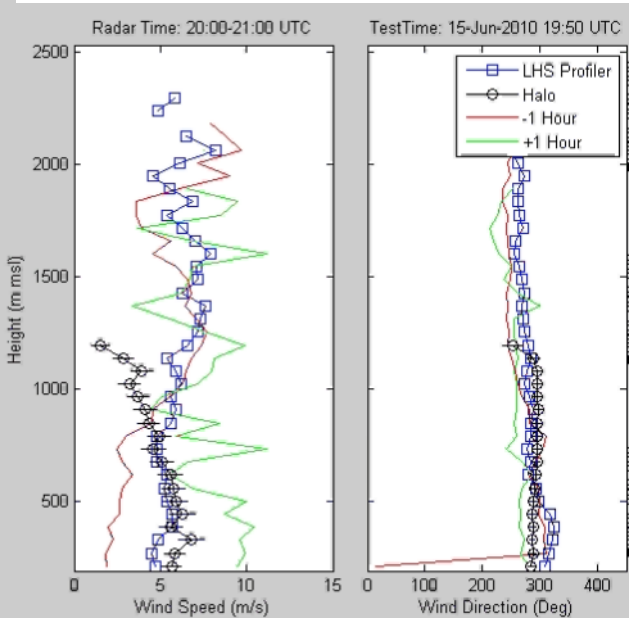


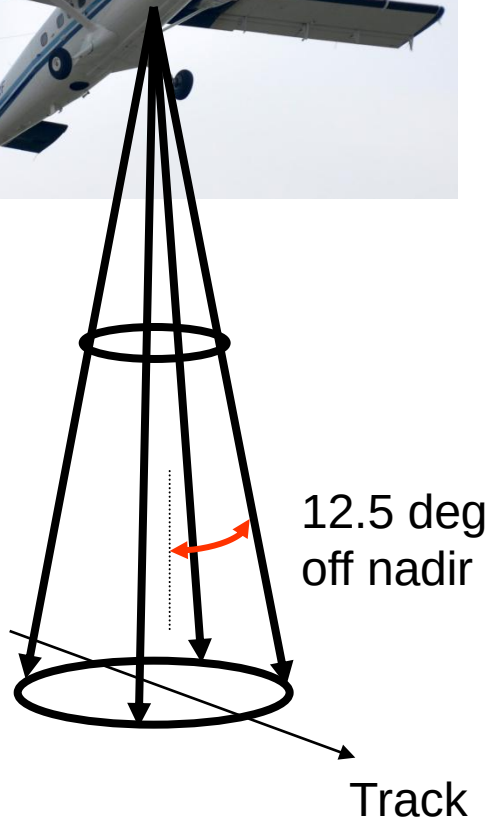


U of Leeds Doppler lidar (7 June – 18 July)

- Horizontal wind speed and direction profiles
- Vertical wind speed profiles
- Min / Max Range: 50 m / up to 3 km
- Resolution: Δx = 500 – 800 m, Δz = 50 m





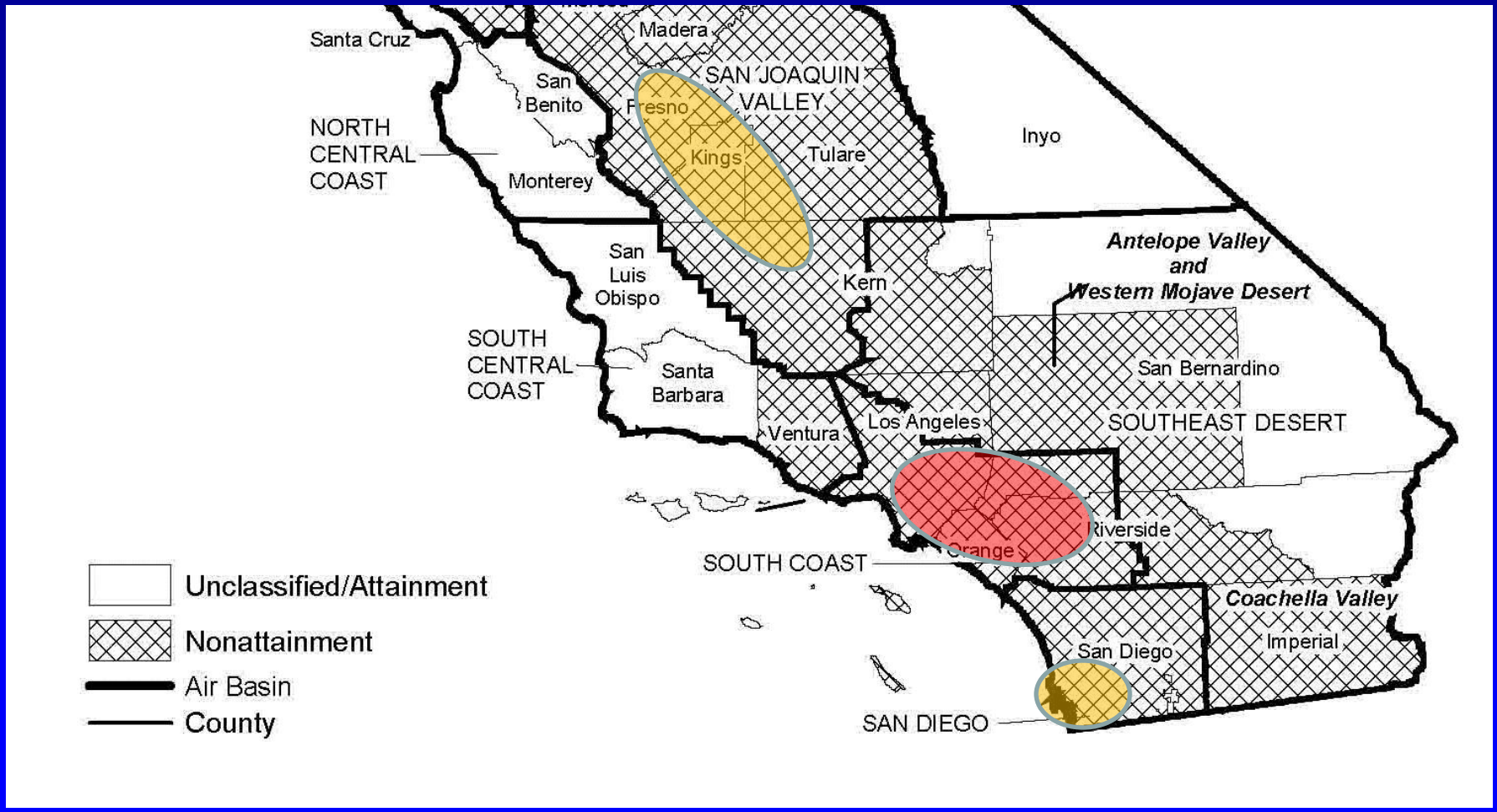


NOAA Twin Otter CalNex Science Objectives

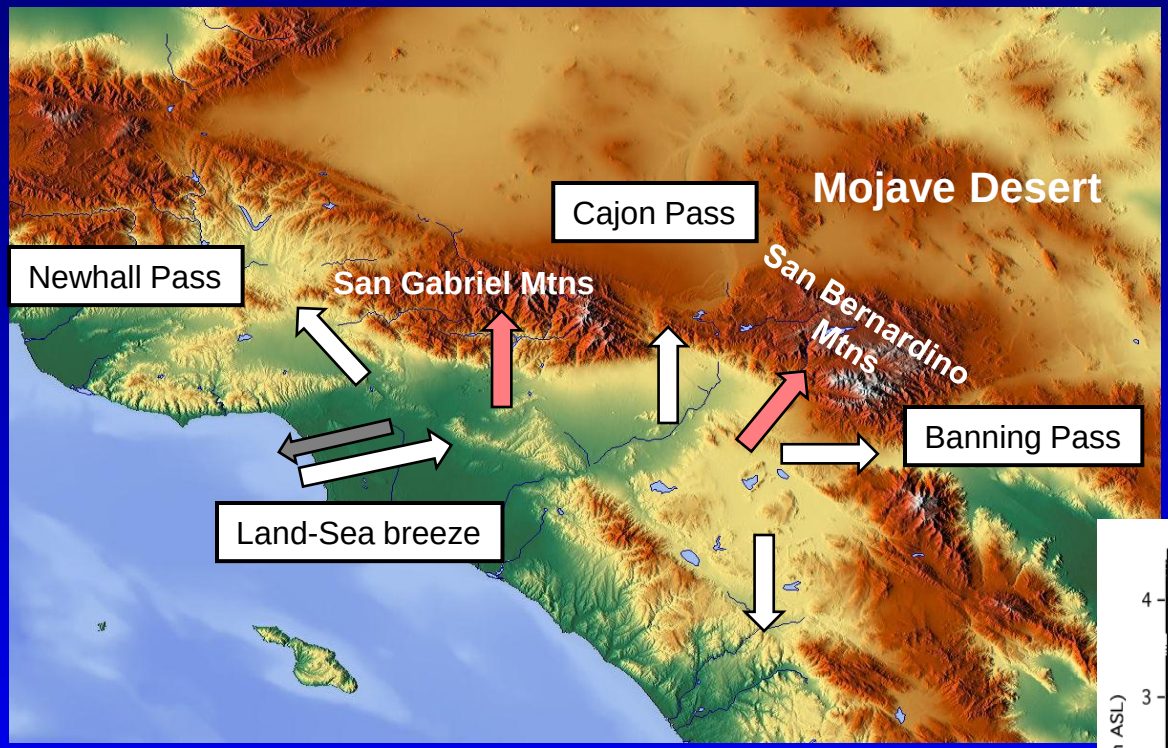
- Distribution of pollutants
  - 3-dimensional distribution of ozone and aerosols over different regions of California
- Horizontal transport
  - Flow of ozone and aerosol between different air basins in California
  - Import and export of ozone into/out of California
- Vertical transport
  - Topographic forcing (Mountain Chimney effect)
  - Boundary layer detrainment
- Ozone layers aloft
  - Stratospheric intrusions (*Andy Langford, talk*)
  - Pollution layers transported from Asia (*Andy Langford, poster*)
- Air Quality model validation
- Synergies between AMAX-DOAS and LIDAR
  - Constrain O_x budget ($O_x = NO_2 + O_3$)

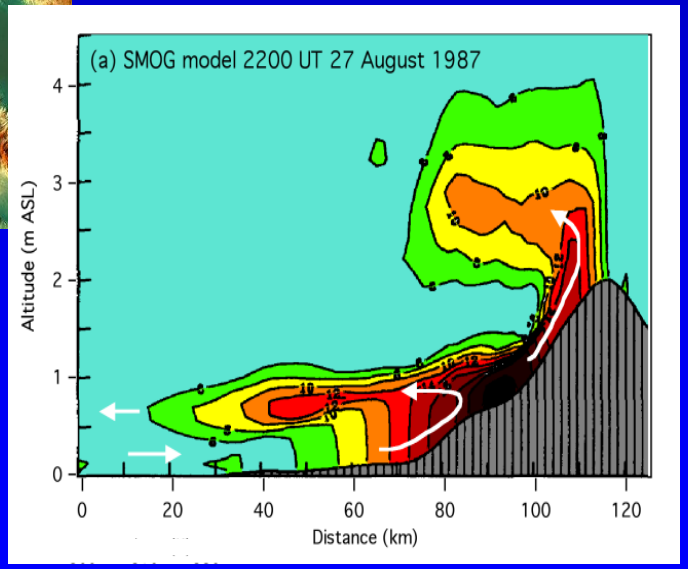
Regional Pollution in Southern California

California Area Designations for 8-hour Ozone NAAQS



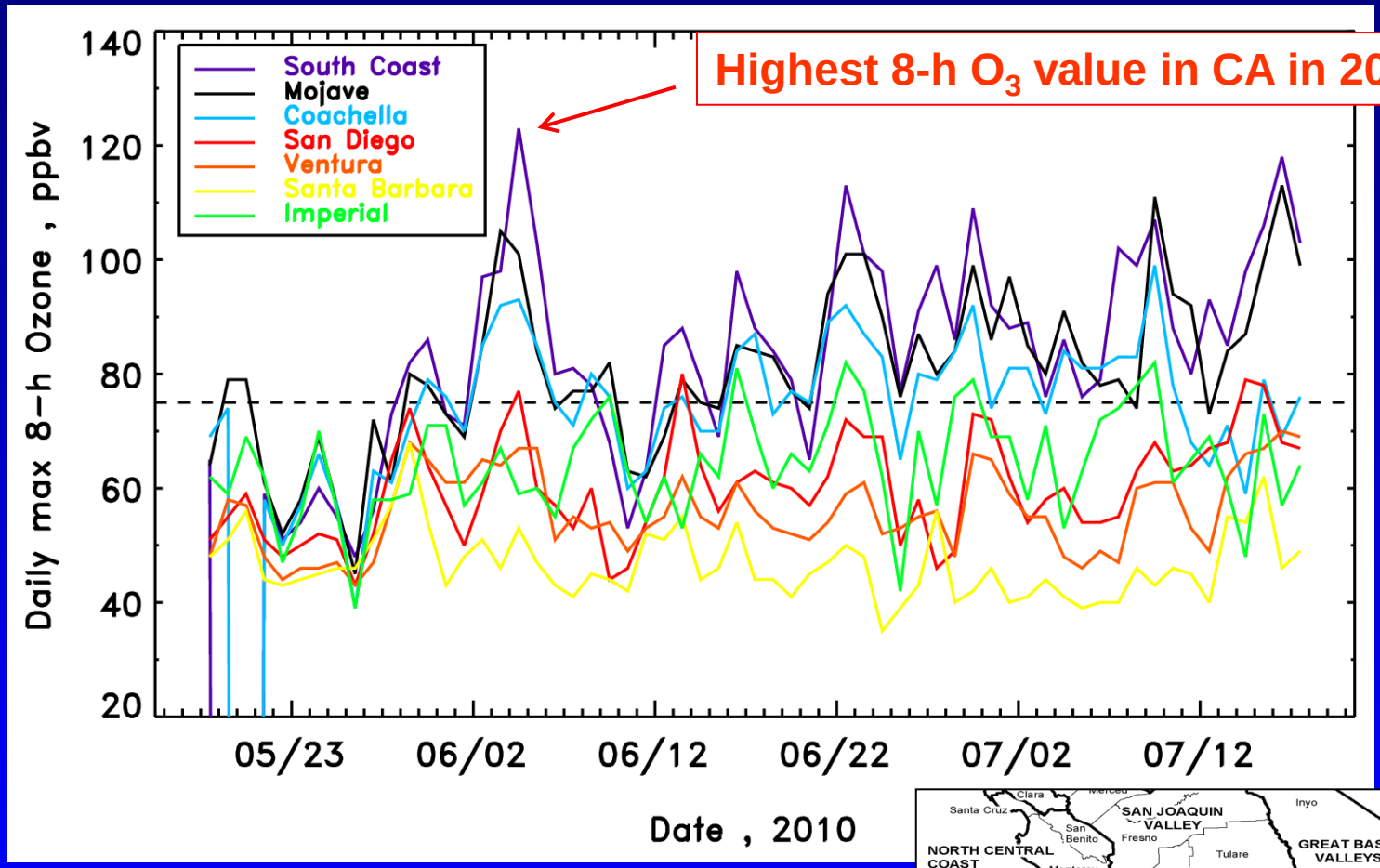
Pollution export pathways from the L A Basin

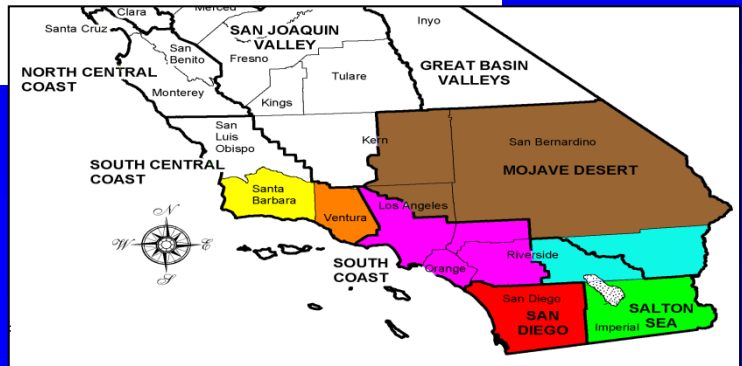




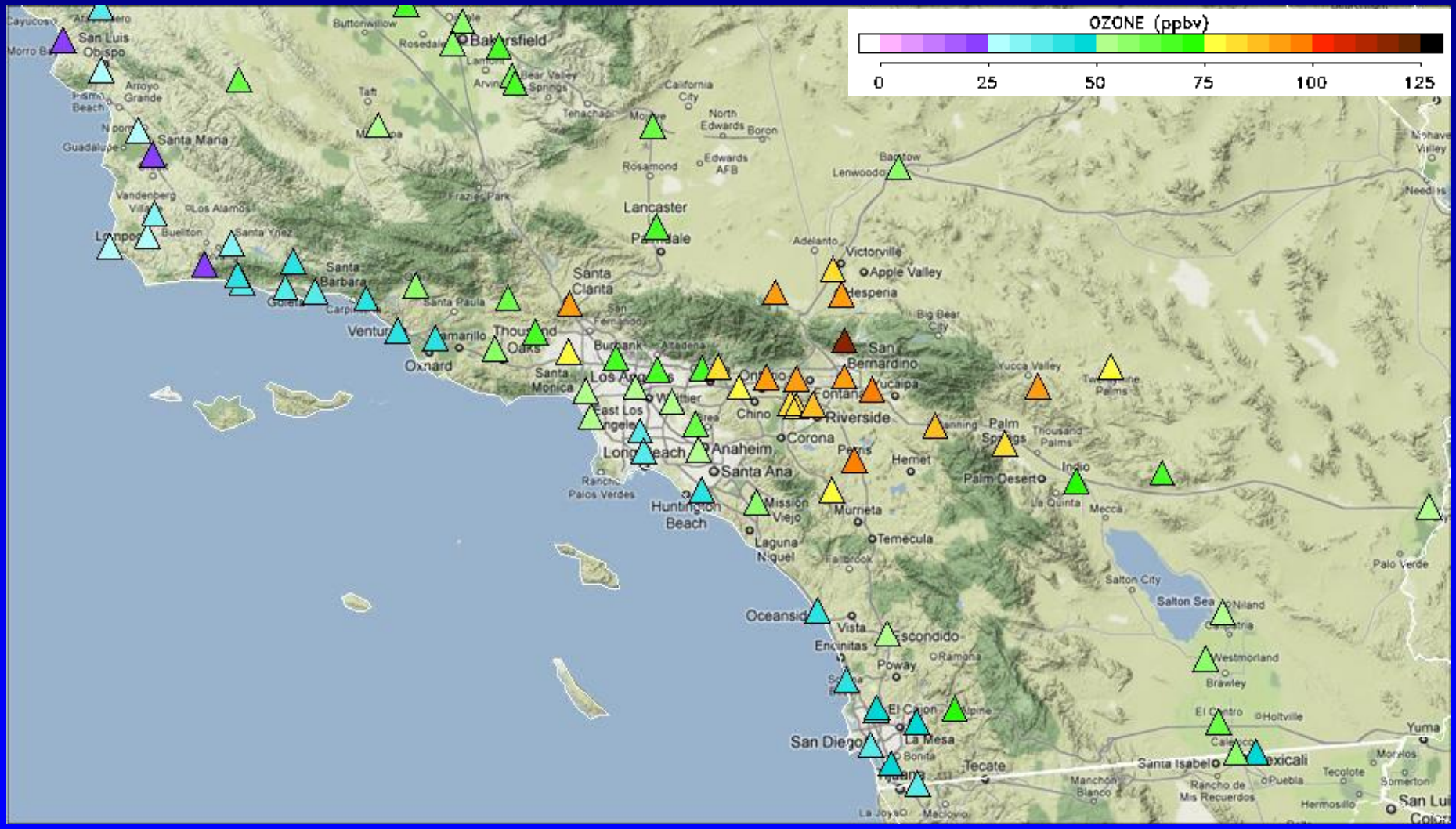
Mountain Chimney Effect

Daily maximum 8-hour surface O_3 concentration
Southern California: May 19 – July 19

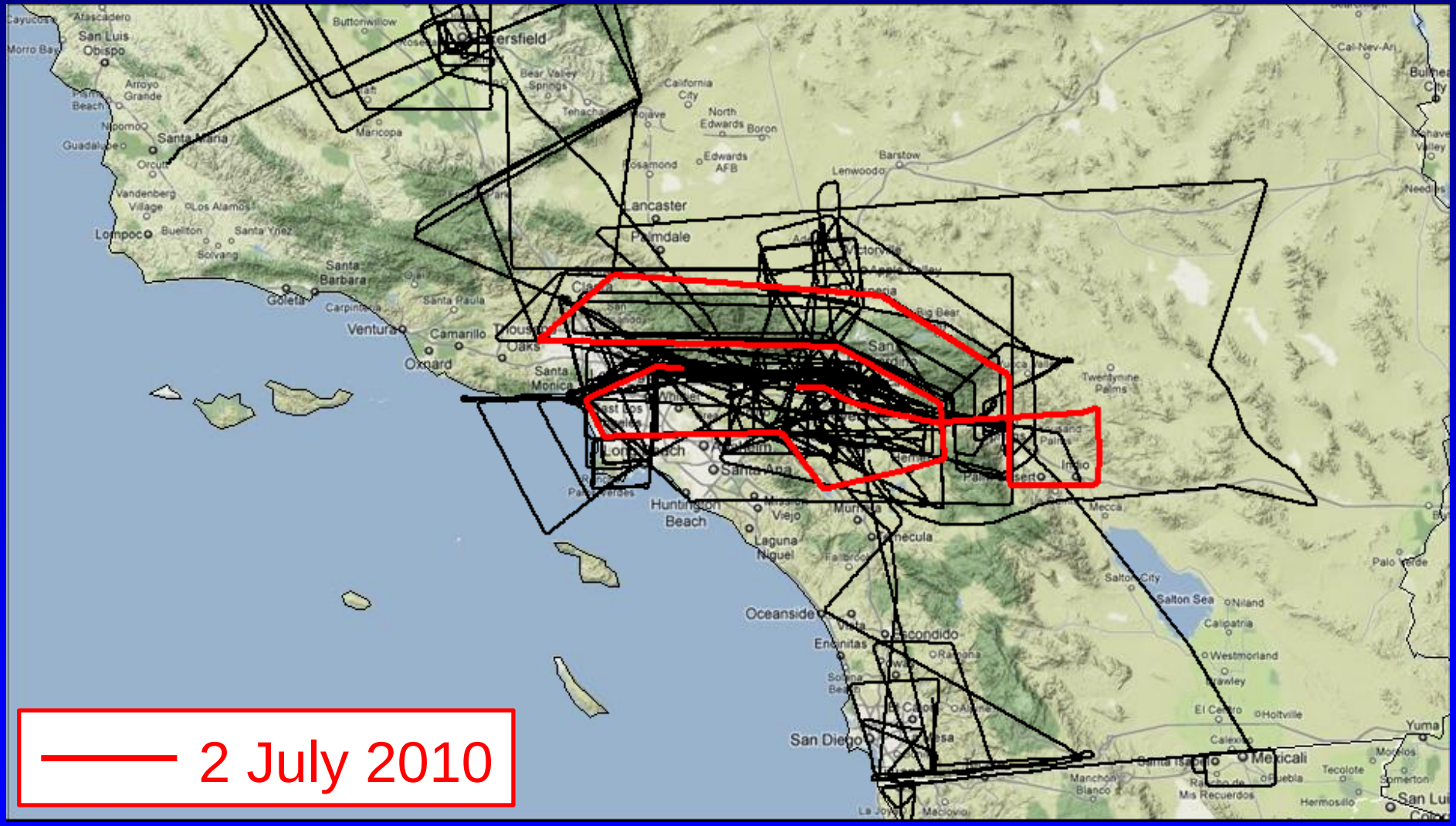




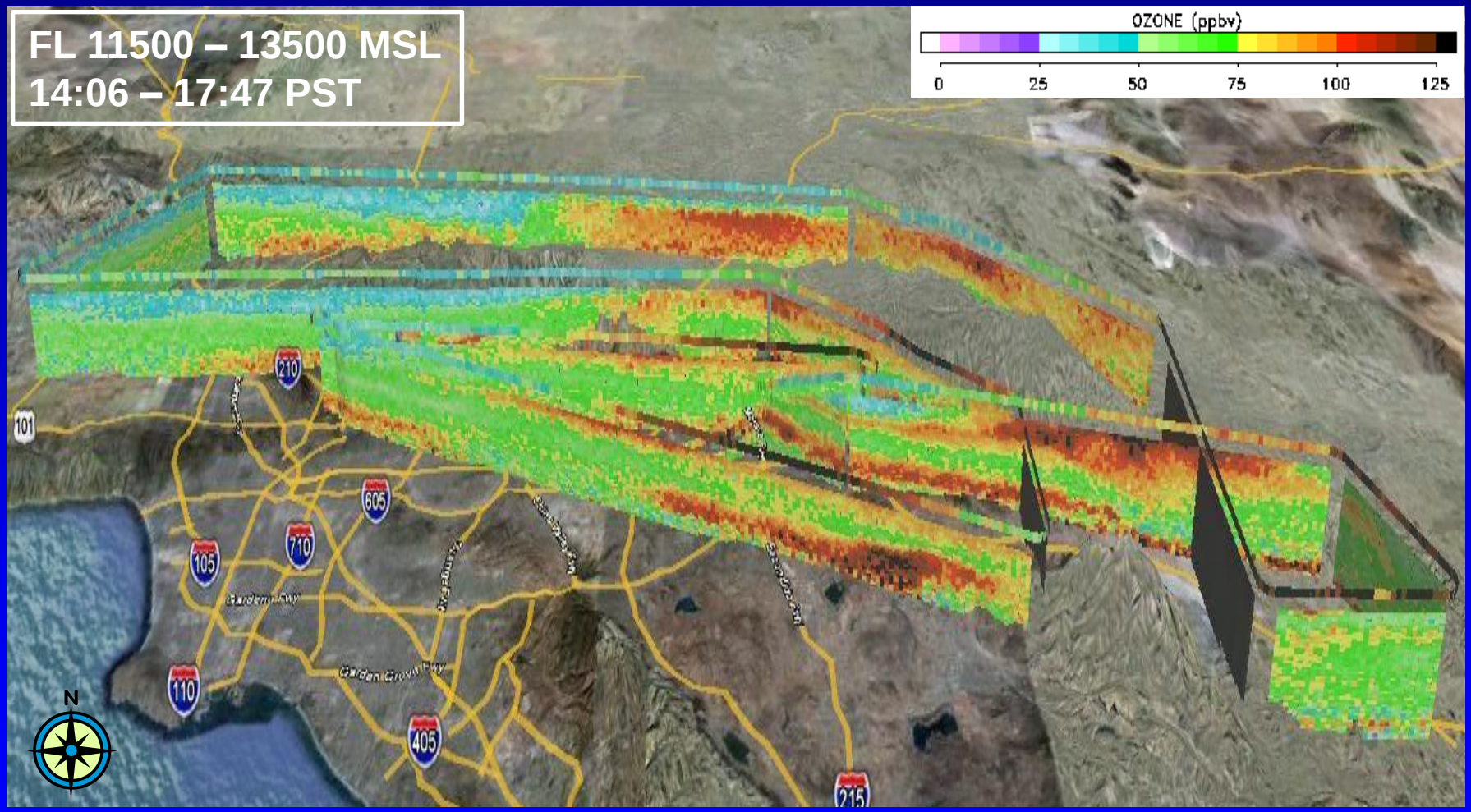
Daily maximum 8-h O_3 concentration averaged for 5 June, 23 June, and 17 July 2010



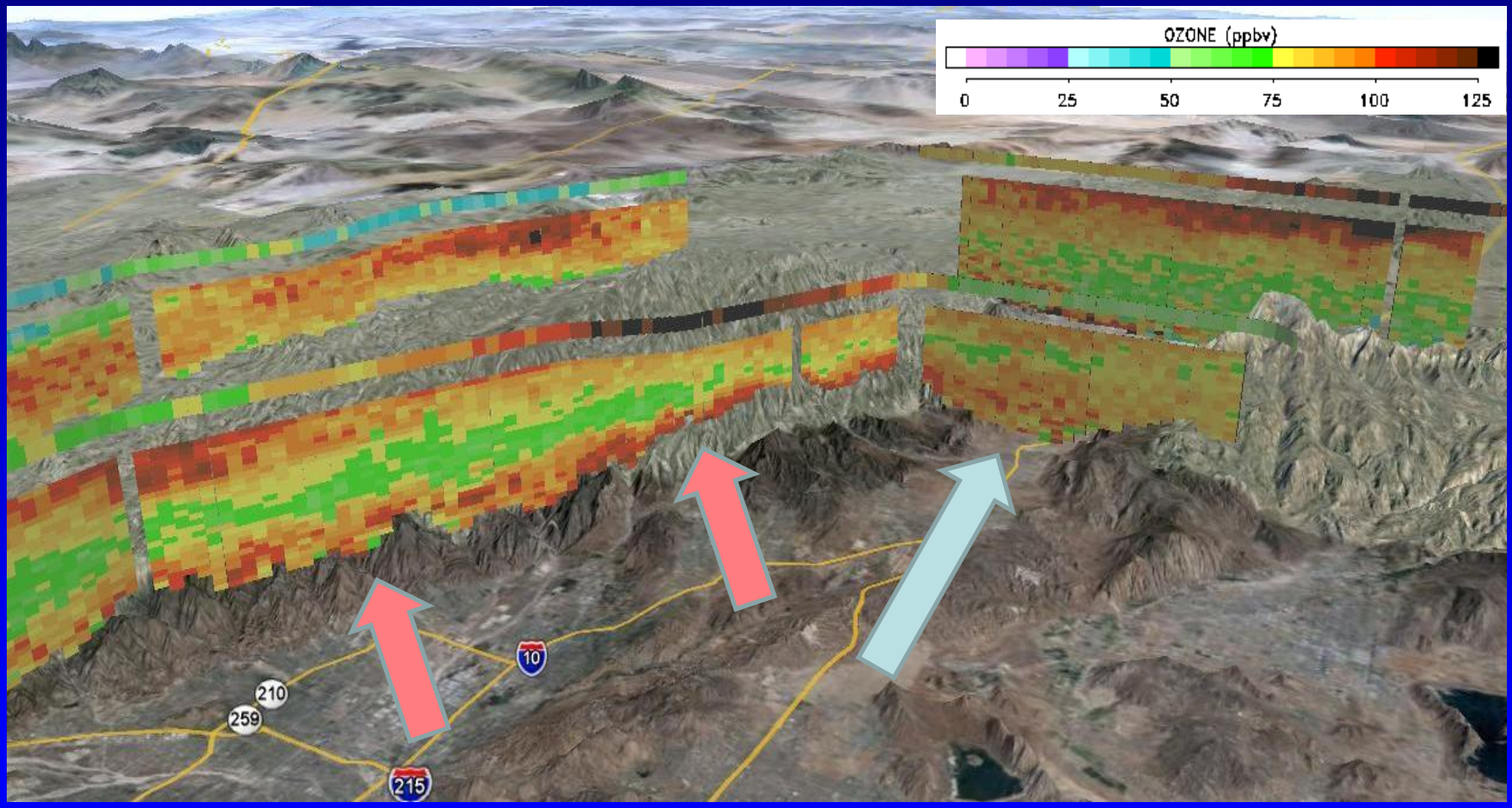
NOAA Twin Otter CalNex flights in Southern California



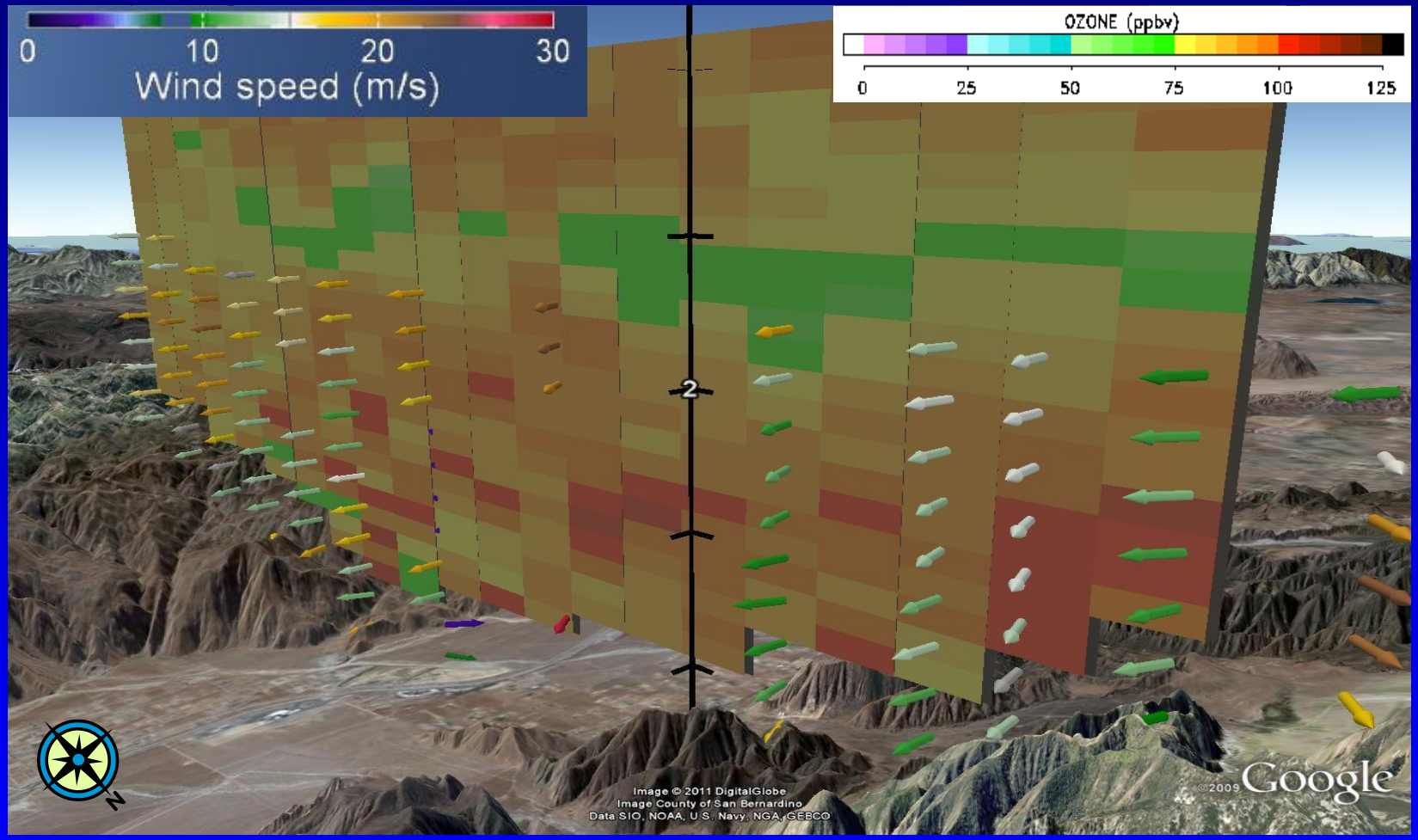
2 July 2010: O_3 distribution over L A Basin and Mojave Desert



2 July 2010: Transport thru Banning Pass and along/over San Gabriel Mtns



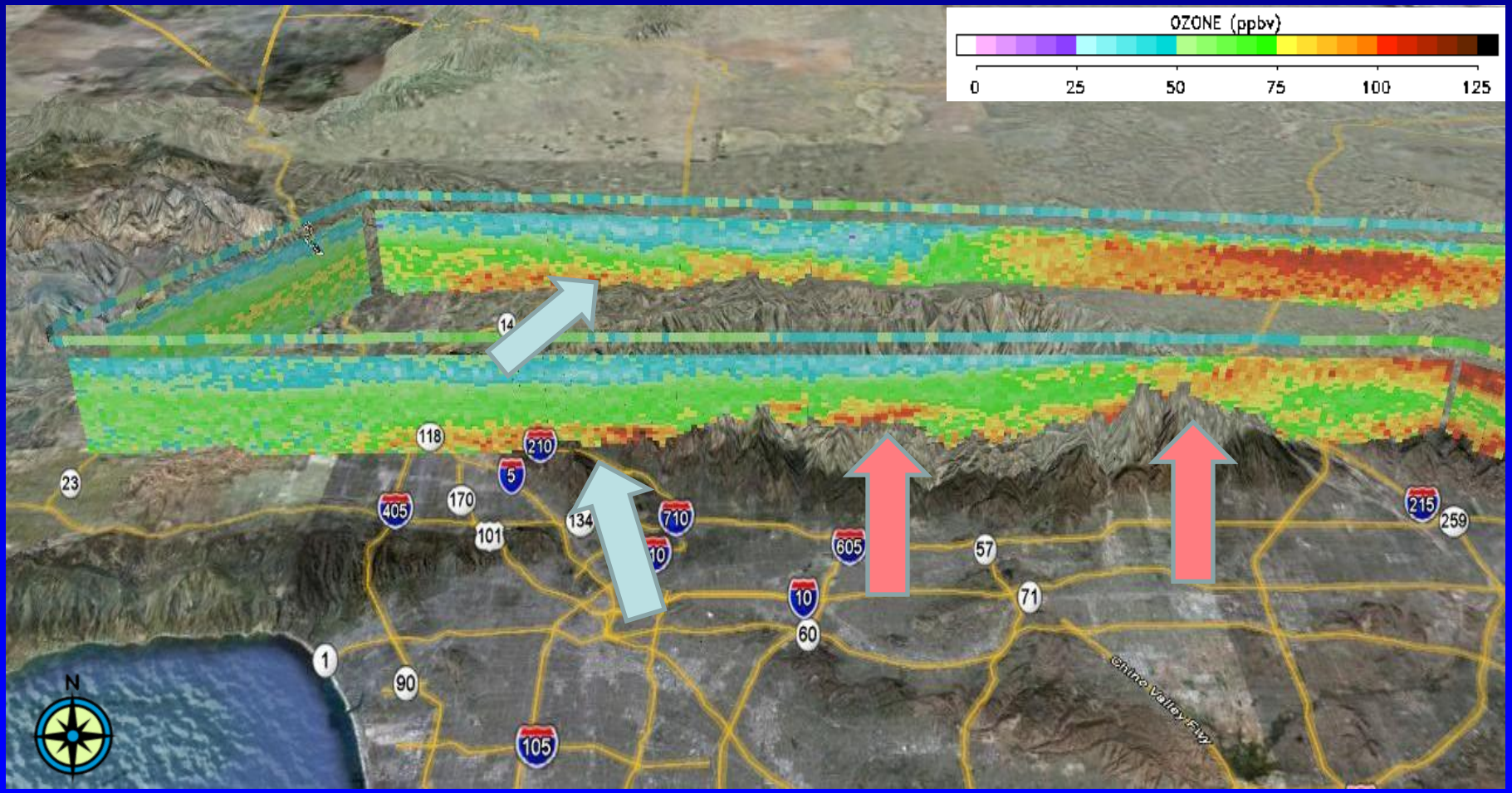
2 July 2010: Transport thru Banning Pass



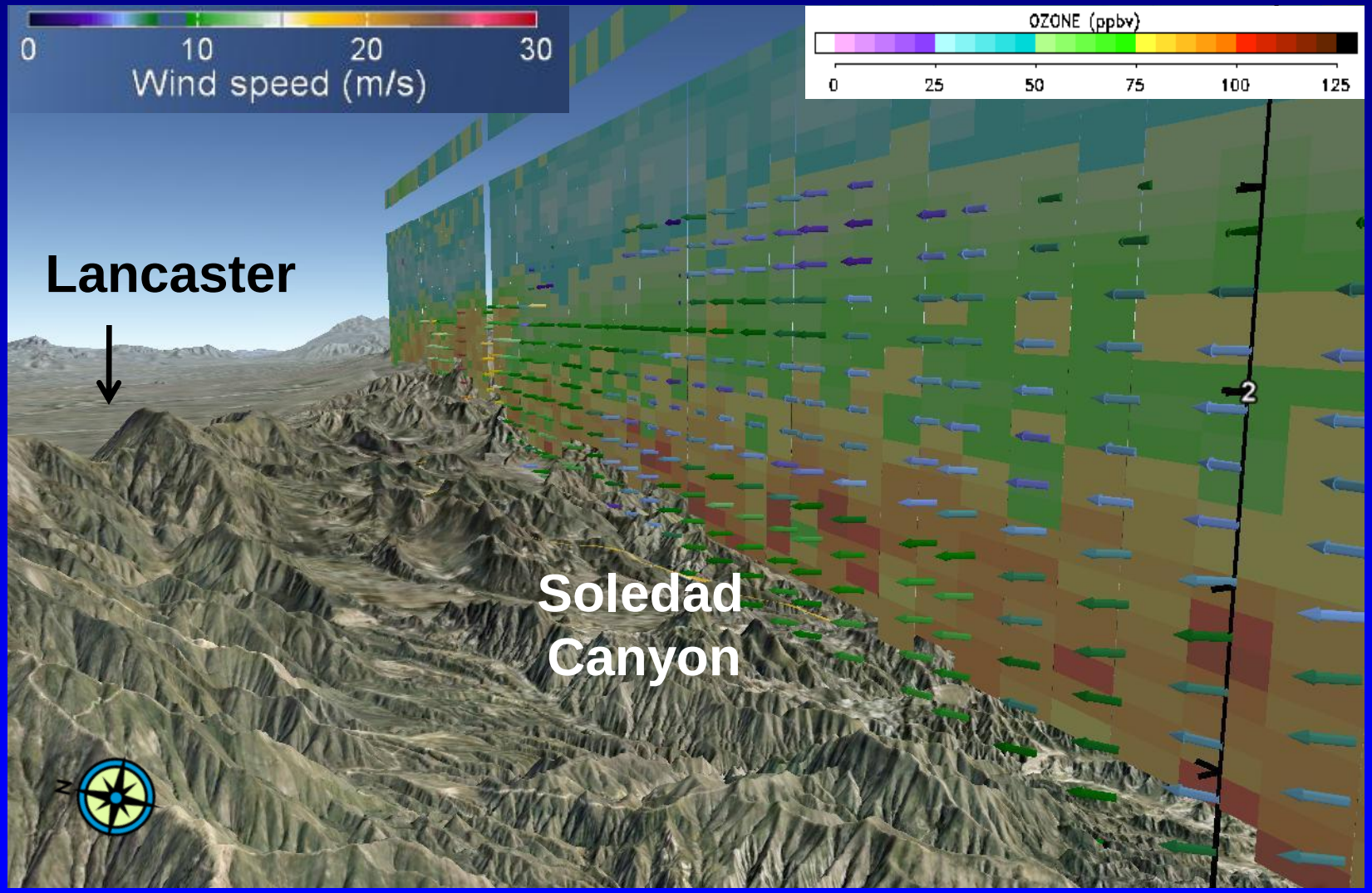
Combination of lidar remote ozone and wind measurements allows to quantify horizontal ozone flux

2 July 2010

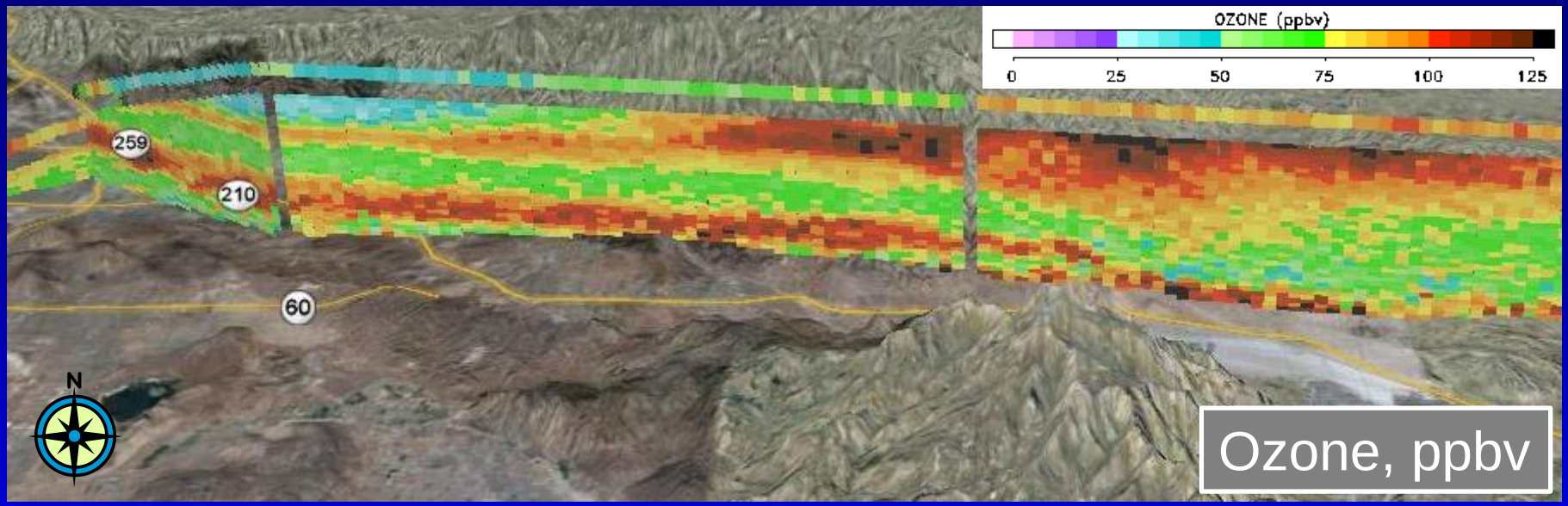
- Upslope transport along/over the San Gabriel Mtns
- Transport into Mojave Desert via Newhall Pass

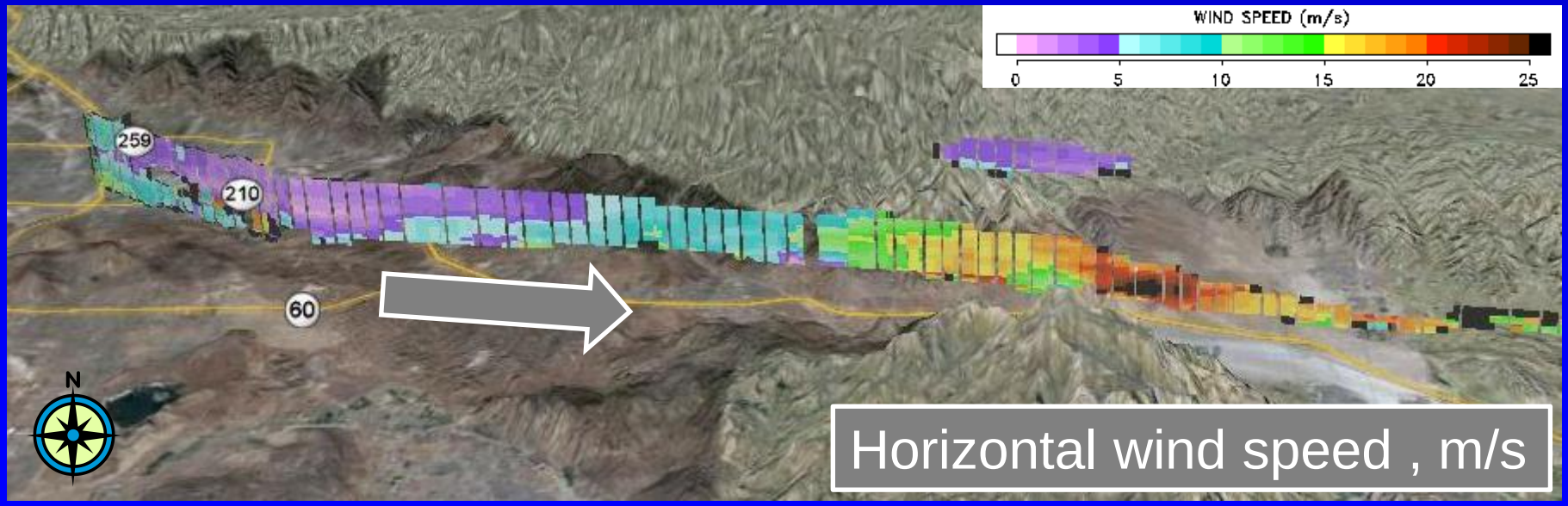


2 July 2010: Transport to Western Mojave Desert via Newhall Pass / Santa Clarita

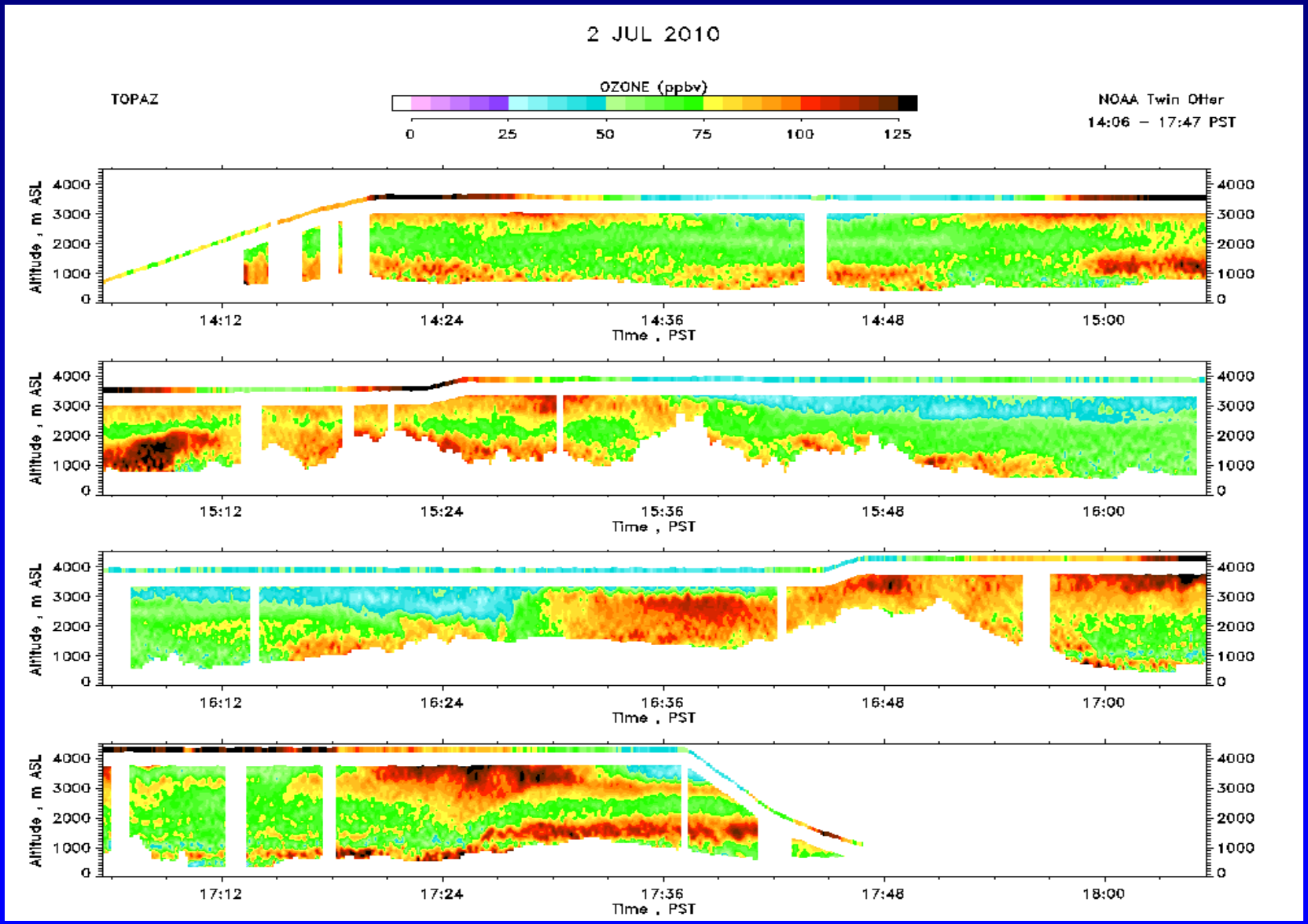


2 July 2010: Transport thru Banning Pass



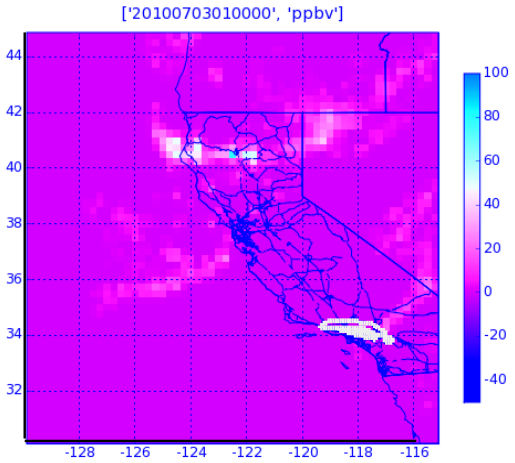


2 July 2010: Orographic Lifting of O_3?

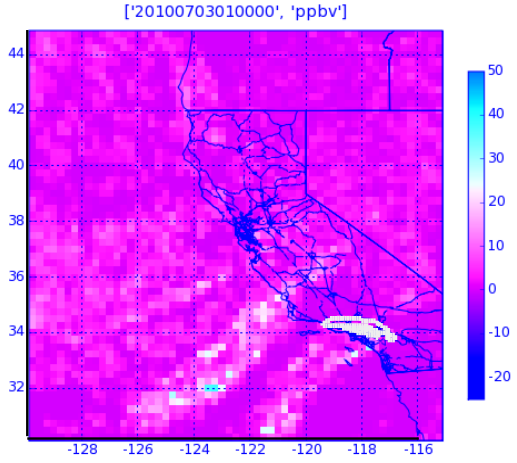


FLEXPART trajectories
01UT 3 July 2010 (3 km MSL)
(Jerome Brioude)

Natural

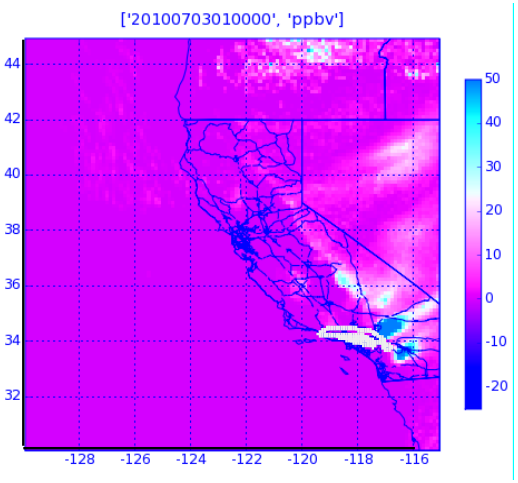


STT (O_3)

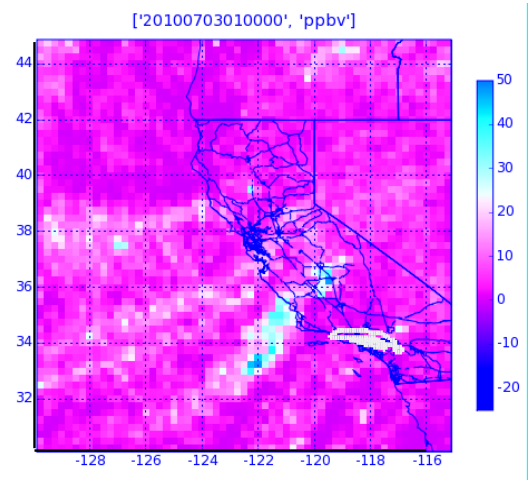


Biomass Burning (CO)

Anthropogenic

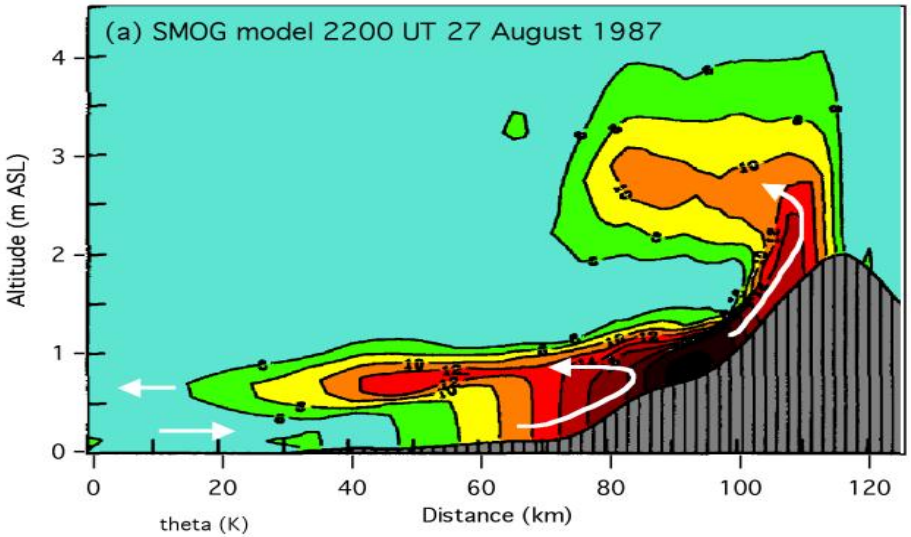


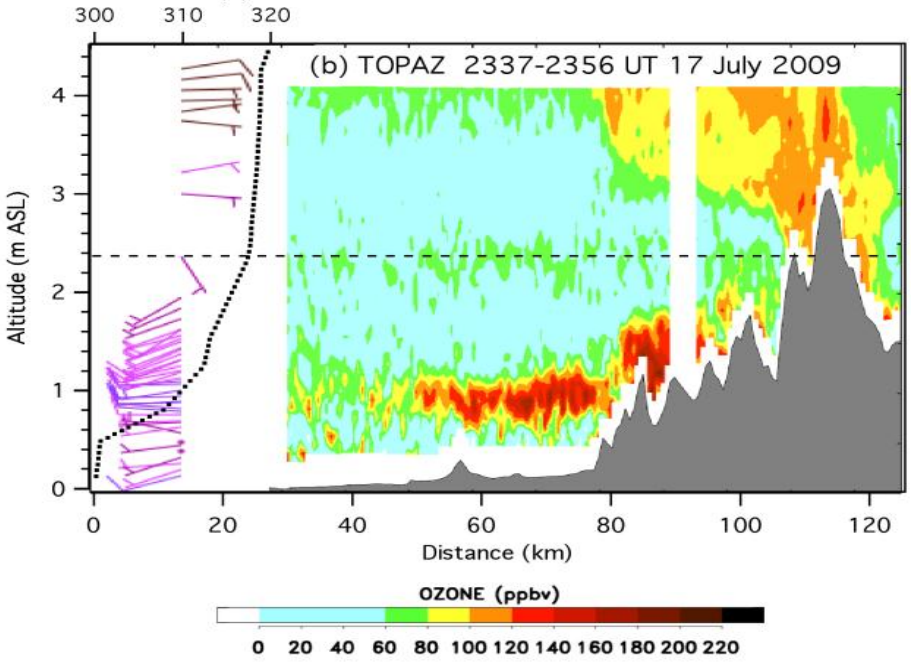
North America (CO)

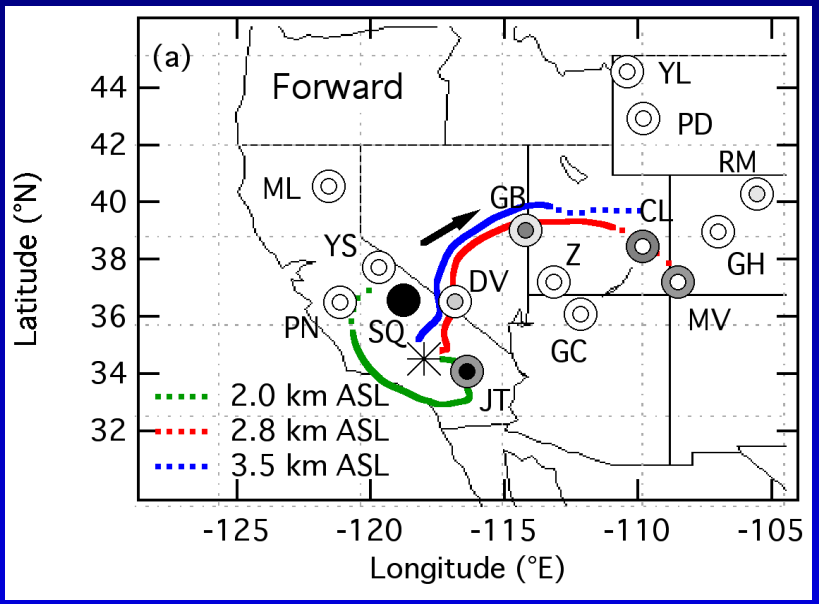


Asia (CO)

Pre-CalNex: 17 July 2009







HYSPLIT forward trajectories

Langford et al, 2010: Long-range transport of ozone from the Los Angeles Basin: A case study, *Geophys. Res. Lett.*, doi:10.1029/2010GL042507.

Summary & Outlook

- Characterized ozone export processes from the L A Basin using airborne lidar and surface ozone data
- Demonstrated capability to remotely measure ozone and horizontal wind speed/direction from an airborne platform

Next steps:

- Retrieve fluxes and quantify ozone transport
- Expand analysis to include other regions in CA

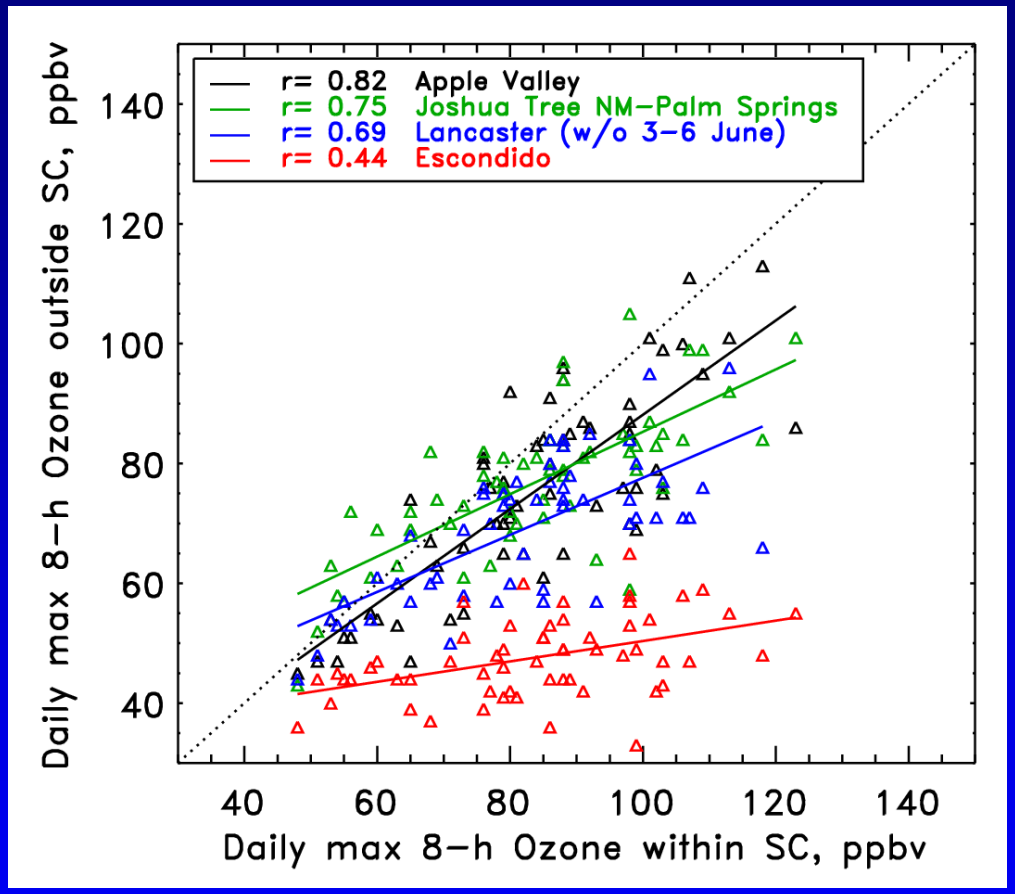
Acknowledgement

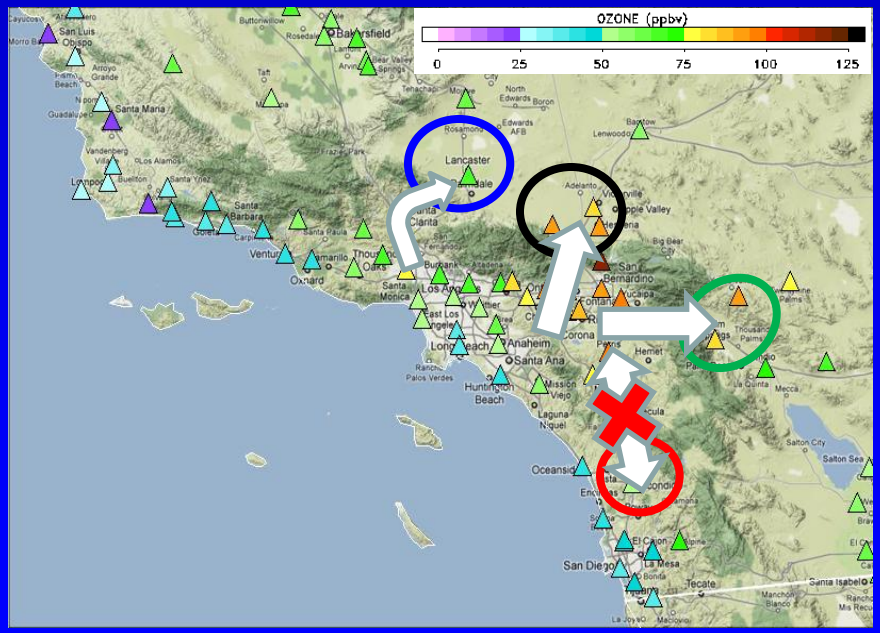
R. J. Alvarez, R. M. Hardesty, A. O. Langford, R. M. Banta, W. A. Brewer, F. Davies, S. P. Sandberg, R. D. Marchbanks, A. M. Weickmann, J. G. George

NOAA Twin Otter flight crews & NOAA Aircraft Operations Center

NOAA Health of the Atmosphere Program

Correlation between daily max. 8-h surface O_3 within and outside of South Coast Air Basin (SC) for 5/19 – 7/19/2010





Correlation between daily max. 8-h surf. O_3 at Mojave and Southern San Joaquin Valley (SSJV) or SC for 5/19 – 7/19/2010