



# Observing boundary layer dynamics for urban scale flux measurements

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## Measure trace gas emissions at the urban scale

- Greenhouse gas emissions impact climate – attribution and detectability
  - Oil and gas exploration and production
  - Urban sources
- Pollution emissions impact air quality – local concentrations / process studies

**CSD and our partners** can measure atmospheric concentrations of a wide range of gases from multiple platforms using both in-situ and remote sensing technology.

## Atmospheric dynamics are a piece of the puzzle –

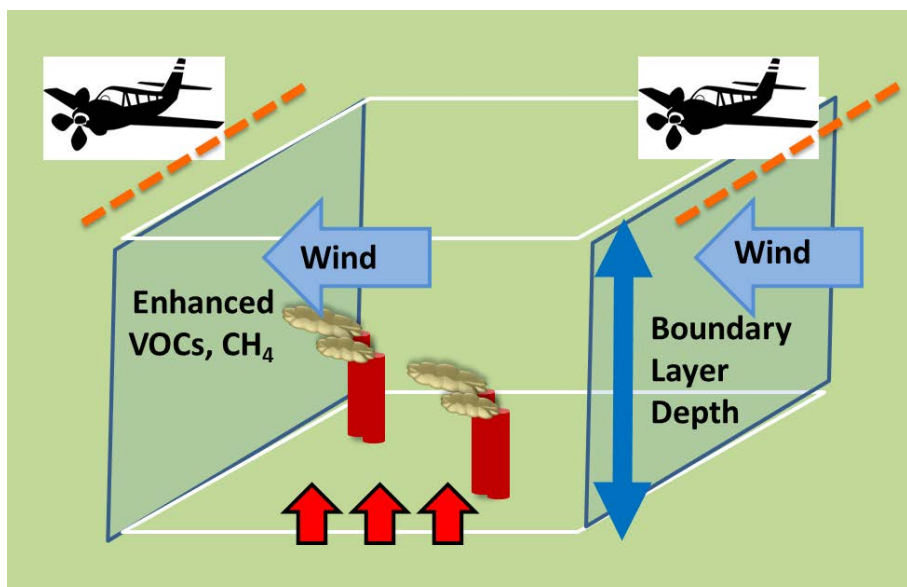
- Concentration -> Emission rates / Flux
- Understanding concentration observations in the context of complex terrain and wind fields (mixing and transport)

## What does CSD bring to the table?

- We use scanning Doppler wind lidars to measure atmospheric dynamics.
- 25+ years of experience in building and deploying systems on a wide range of platforms.

**Need** : Resolve variability in the wind field over larger spatial and temporal scales

# Mass balance approach is used to estimate urban scale flux



## What measurements are required?

Down wind enhancement of trace gas concentrations in planetary boundary layer (PBL)

- Aircraft profiles
- Towers (well mixed boundary layer)

Dynamics :

- Mean wind profile
- Boundary layer depth

$$flux_S = V \cos \theta \int_{-b}^b \Delta X_S \left( \int_{z_{ground}}^{z_{pbl}} n_{air} dz \right) dx$$

Molar flux of species S

Perpendicular wind speed

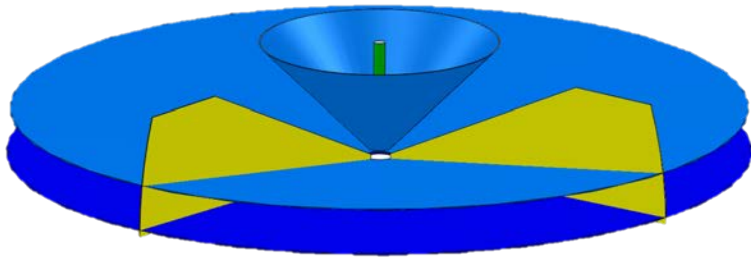
Molar enhancement in PBL

**CSD lidars provide mean wind profiles and estimates of boundary layer depth for the mass balance calculation**

## Additional Information provided from lidar measurements

- Spatial and temporal uniformity of wind field and boundary layer depth
- Time history of the wind speed and direction – trajectories of air mass
- Presence of a residual layer or other dynamic processes such as entrainment

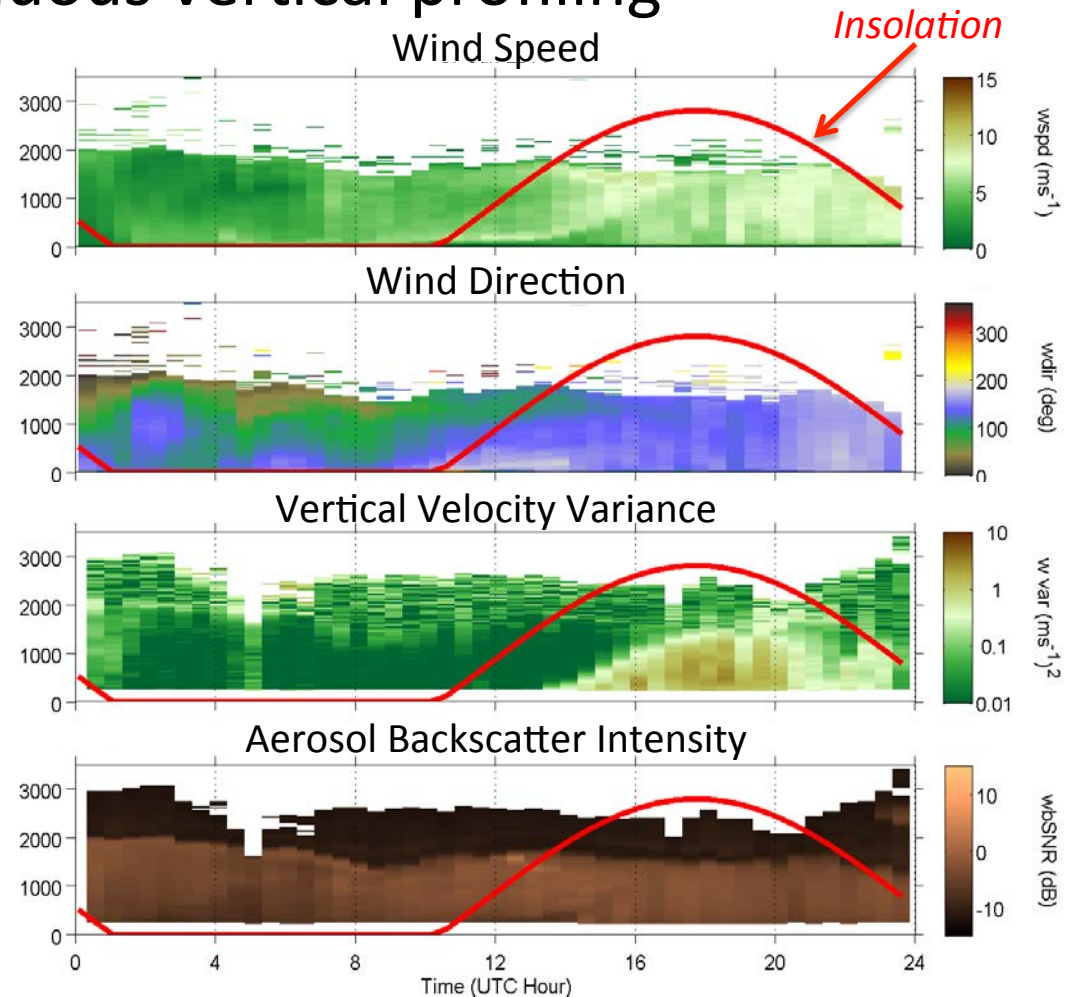
# CSD Lidars provide continuous vertical profiling



Continuous operation with a repeating pattern of azimuth and elevation scans and vertical stares



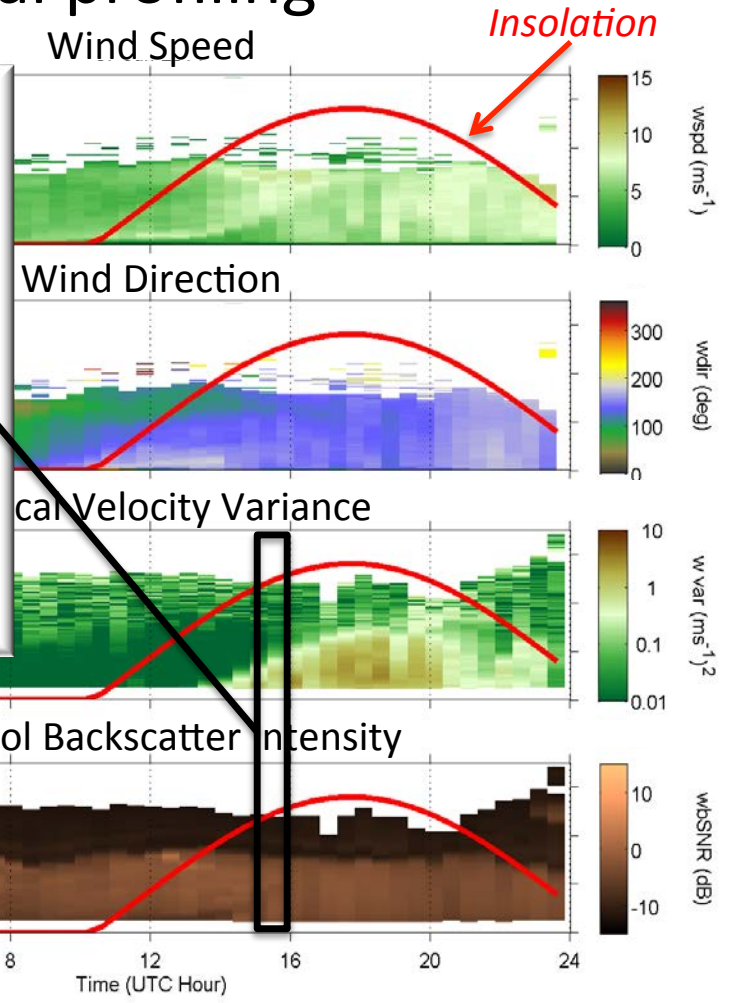
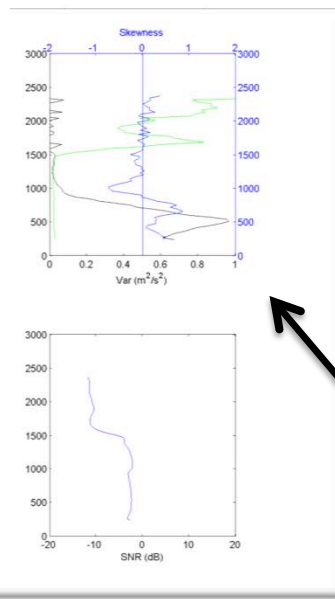
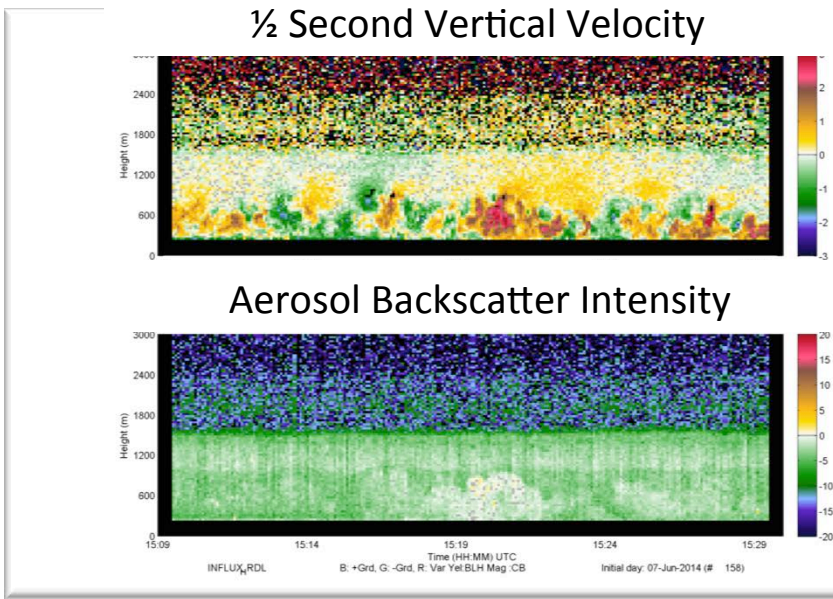
High Resolution Doppler Lidar (HRDL)



**CSD Lidars provide continuous vertical profiles of**

- **wind speed and direction**
- **vertical velocity variance (mixing)**
- **aerosol backscatter intensity**

# CSD Lidars provide continuous vertical profiling



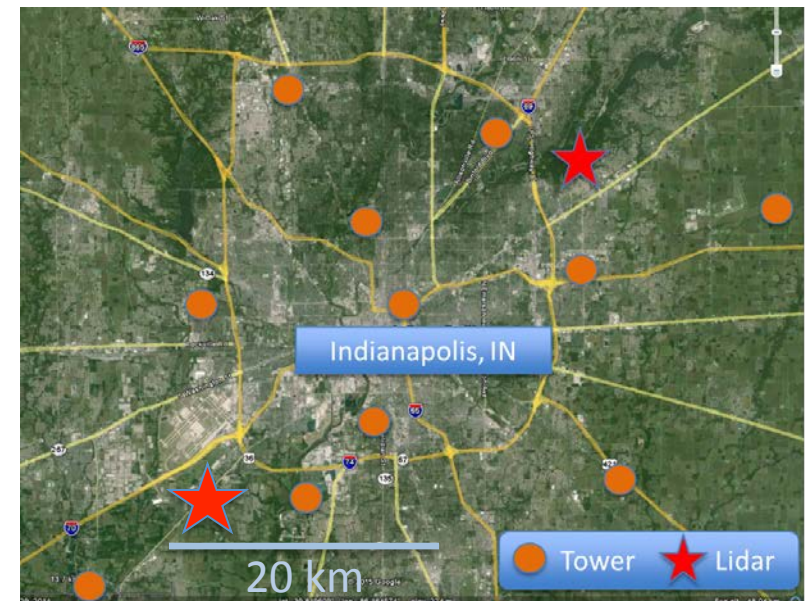
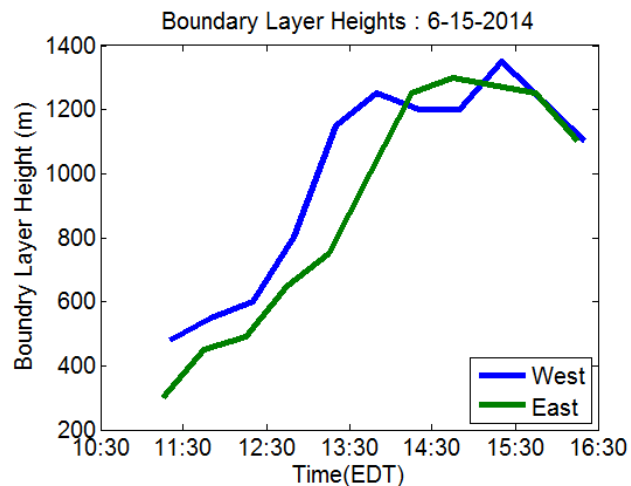
High Resolution Doppler Lidar (HRDL)

Each 30 minute average is comprised of much higher temporal resolution data that can be used to identify dynamic processes and additional features.

# INFLUX - The Indianapolis Flux Experiment

A National Institutes for Standards and Technology led effort

- Develop and evaluate methods for *measurement and modeling* of greenhouse gas fluxes from urban environments.
- Distributed tower measurements and periodic aircraft sampling of greenhouse gases and dynamics.
- Scanning Doppler lidars (one unit : 2 year deployment)
- Partners : NOAA Global Monitoring Division, Penn State

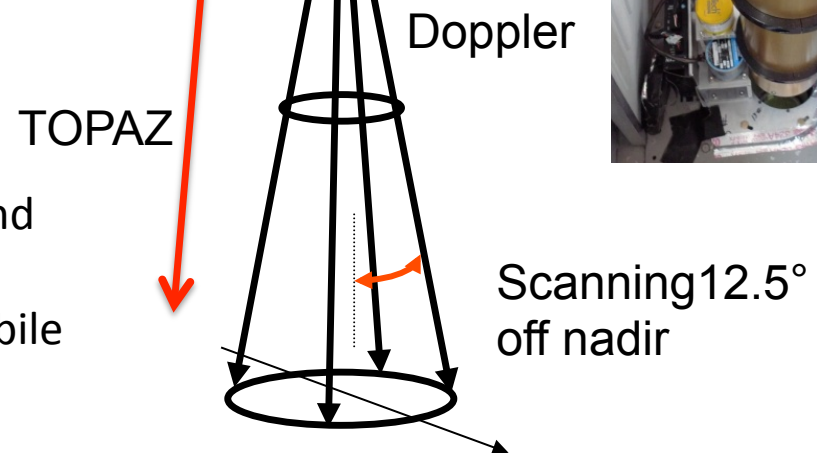
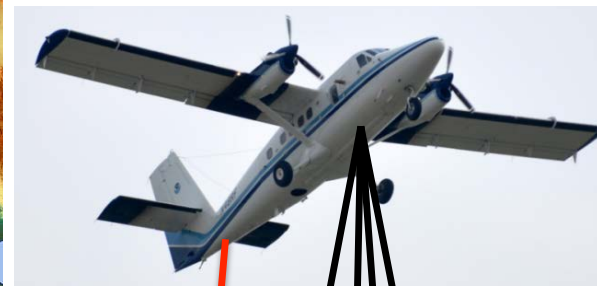
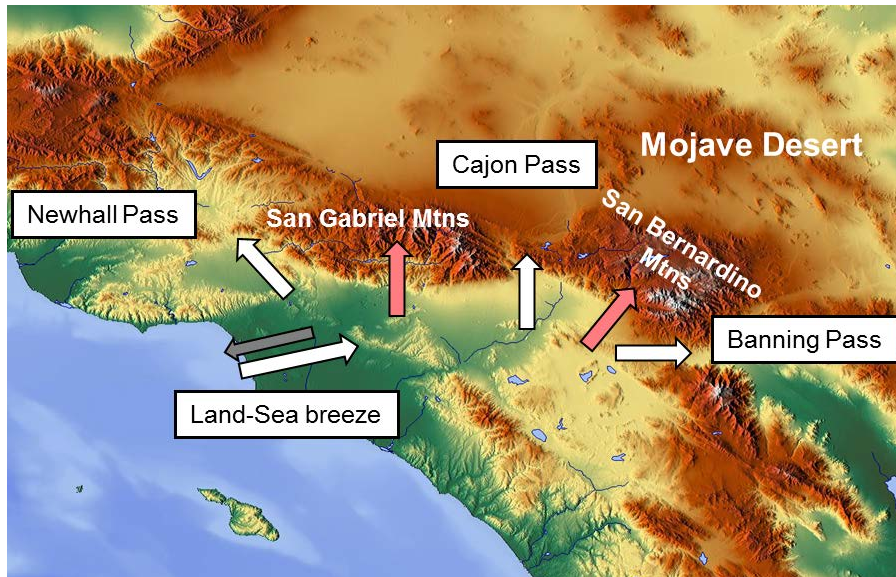


**Spatial / temporal variability of the boundary layer height are important -- even in simple terrain**

# CALNEX : Air quality measurements in the Los Angeles Basin

## Aircraft based Ozone and wind profiles

TOPAZ ozone and Doppler wind lidar on NOAA Twin Otter



- Complex terrain
- Land-sea breeze driving transport in basin and through passes / over mountains
- Required combined observations from a mobile platform

**Simultaneous, range resolved measurements of ozone concentration and dynamics below aircraft**

# View from Northeast



Banning Pass

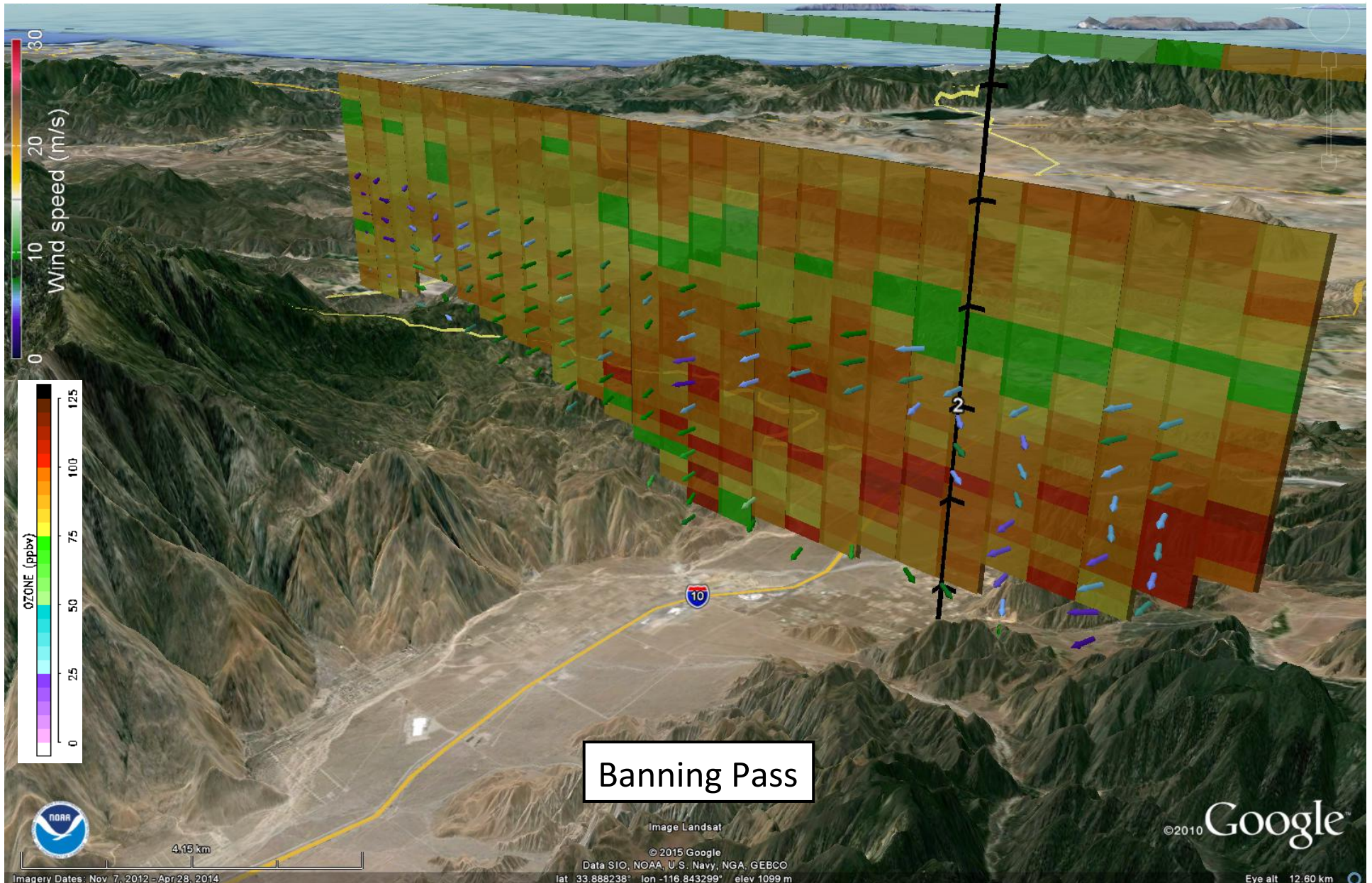
4.15 km  
Imagery Dates: Nov 7, 2012 - Apr 28, 2014

Image Landsat  
© 2015 Google  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
lat 33.888238° lon -116.843299° elev 1099 m

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Eye alt 12.60 km

# Combined Ozone and wind measurements allow calculation of Ozone flux through Banning Pass





## Future work –

- Commercial systems are becoming more available
  - Evaluate performance and utilize when feasible
  - Expensive, less sensitive, inflexible
- Development effort
  - Lower cost / higher sensitivity lidars for spatial arrays
  - High power / operationally flexible systems for mobile platforms

