
# *Challenges and opportunities for remote sensing of air quality: Insights from DISCOVER-AQ*

**Jim Crawford[1], Ken Pickering[2], Lok Lamsal[2], Bruce Anderson[1], Andreas Beyersdorf[1], Gao Chen[1], Richard Clark[3], Ron Cohen[4], Glenn Diskin[1], Rich Ferrare[1], Alan Fried[5], Brent Holben[2], Jay Herman[6], Ray Hoff[6], Chris Hostetler[1], Scott Janz[2] , Mary Kleb[1], Jim Szykman[7], Anne Thompson[2], Andy Weinheimer[8], Armin Wisthaler[9], Melissa Yang[1]**

**[1] NASA Langley Research Center, [2] NASA Goddard Space Flight Center, [3] Millersville University, [4] University of California-Berkeley, [5] University of Colorado-Boulder, [6] University of Maryland-Baltimore County, [7] Environmental Protection Agency, [8] National Center for Atmospheric Research, [9] University of Innsbruck**

***http://discover-aq.larc.nasa.gov/***

# Thanks to Partners

*Maryland Department of the Environment (MDE)*
*San Joaquin Valley Air Pollution Control District (SJV APCD)*
*California Air Resource Board (CARB)*
*Bay Area Air Quality Management District (BAAQMD)*
*Texas Commission on Environmental Quality (TCEQ)*
*Colorado Department of Public Health and Environment (CDPHE)*

*Environmental Protection Agency, Office of Res. and Dev.*
*National Center for Atmospheric Research*
*National Science Foundation*
*National Oceanic and Atmospheric Administration*
*National Park Service*

*University of Maryland, College Park; Howard University*
*University of California, Davis; University of California, Irvine*
*University of Houston; Rice University; University of Texas;*
*Baylor University; Princeton*
*University of Colorado-Boulder; Colorado State University*

# Investigation Overview

***Deriving Information on Surface Conditions from Column and VERtically Resolved Observations Relevant to Air Quality***

***A NASA Earth Venture campaign intended to improve the interpretation of satellite observations to diagnose near-surface conditions relating to air quality***

***Objectives:***

***1. Relate column observations to surface conditions for aerosols and key trace gases $O_3$, $NO_2$, and $CH_2O$***

***2. Characterize differences in diurnal variation of surface and column observations for key trace gases and aerosols***

***3. Examine horizontal scales of variability affecting satellites and model calculations***

# Deployment Strategy

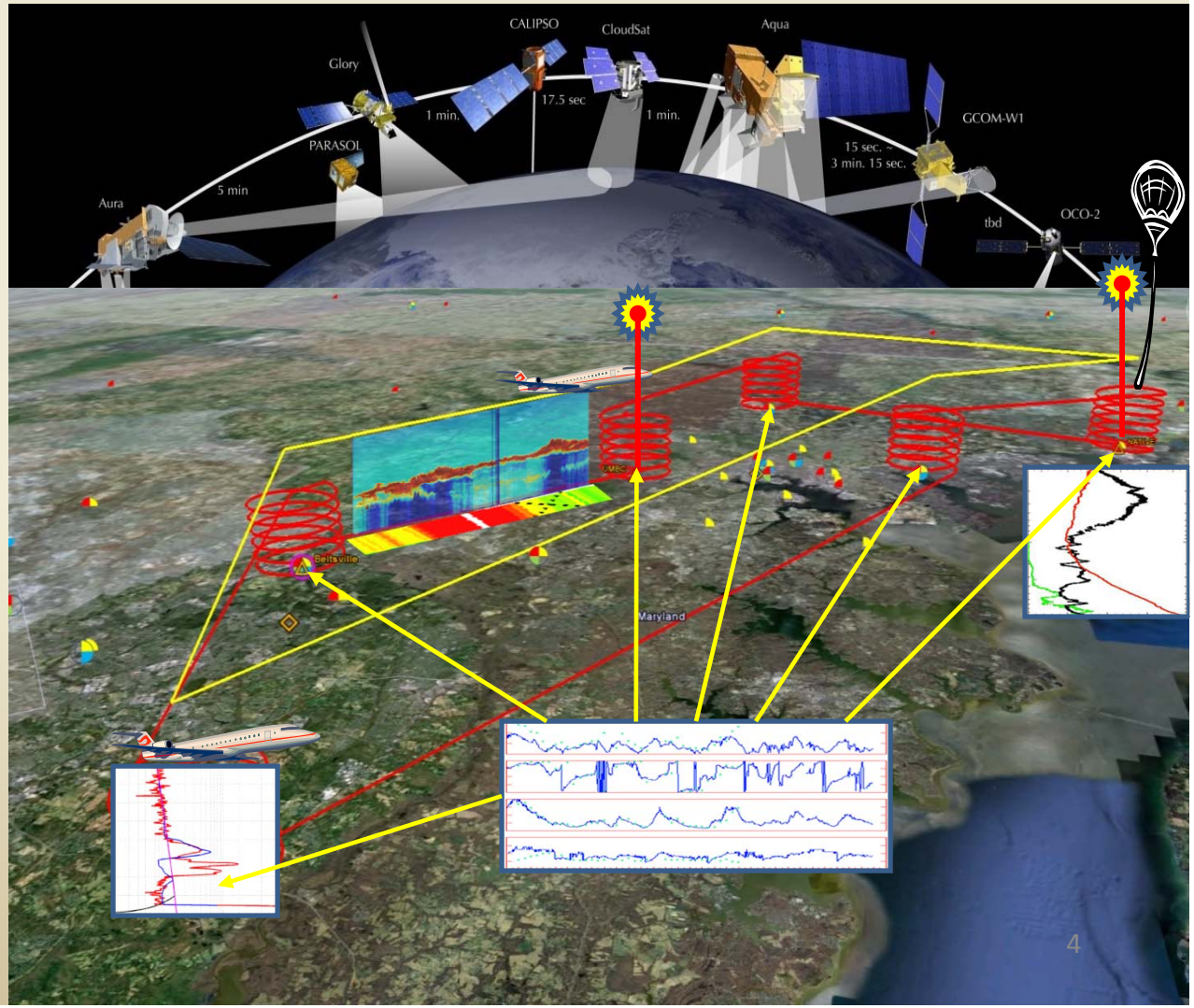
***Systematic and concurrent observation of column-integrated, surface, and vertically-resolved distributions of aerosols and trace gases relevant to air quality as they evolve throughout the day.***

***Three major observational components:***

***<u>NASA UC-12 (Remote sensing)</u>***
***Continuous mapping of aerosols with HSRL and trace gas columns with ACAM***

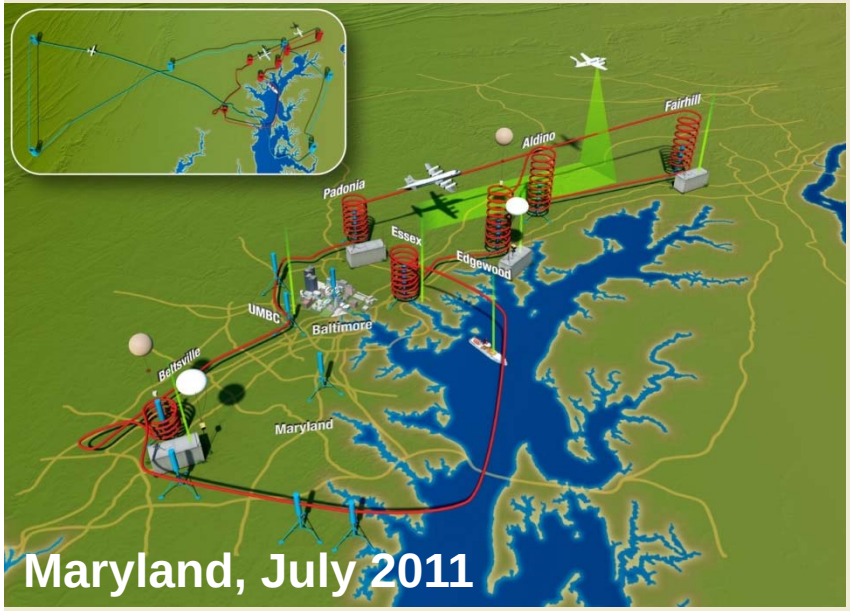
***<u>NASA P-3B (in situ meas.)</u>***
***In situ profiling of aerosols and trace gases over surface measurement sites***

***<u>Ground sites</u>***
***In situ trace gases and aerosols***
***Remote sensing of trace gas and aerosol columns***
***Ozonesondes***
***Aerosol lidar observations***

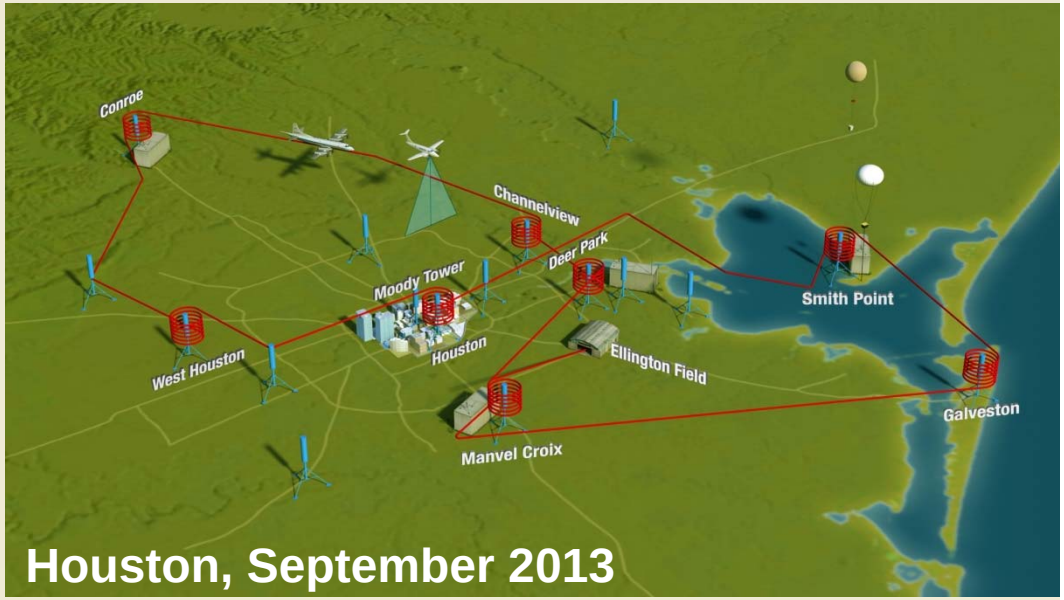


DISCOVER-AQ

# Deployment Locations

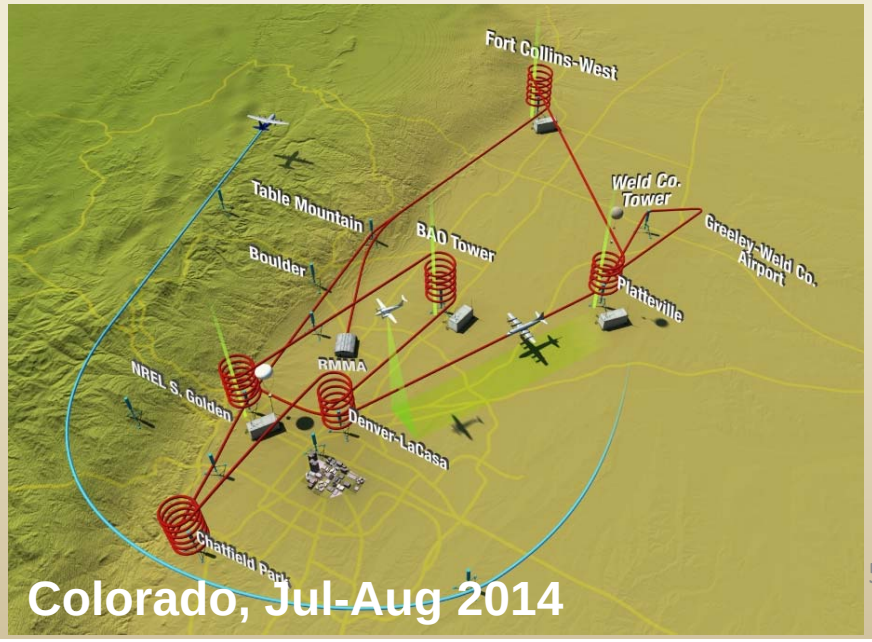


Maryland, July 2011



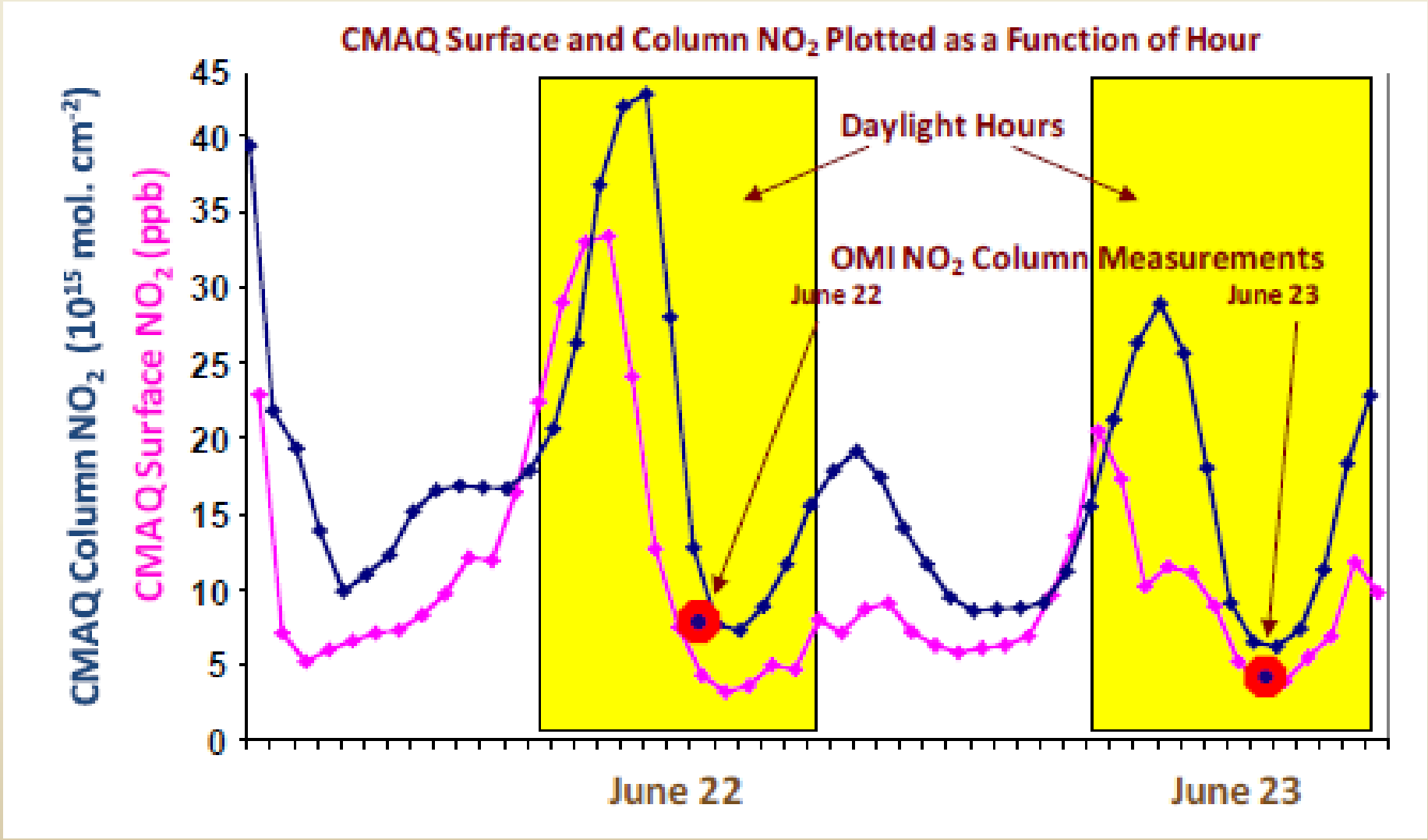
Houston, September 2013

California, Jan-Feb 2013



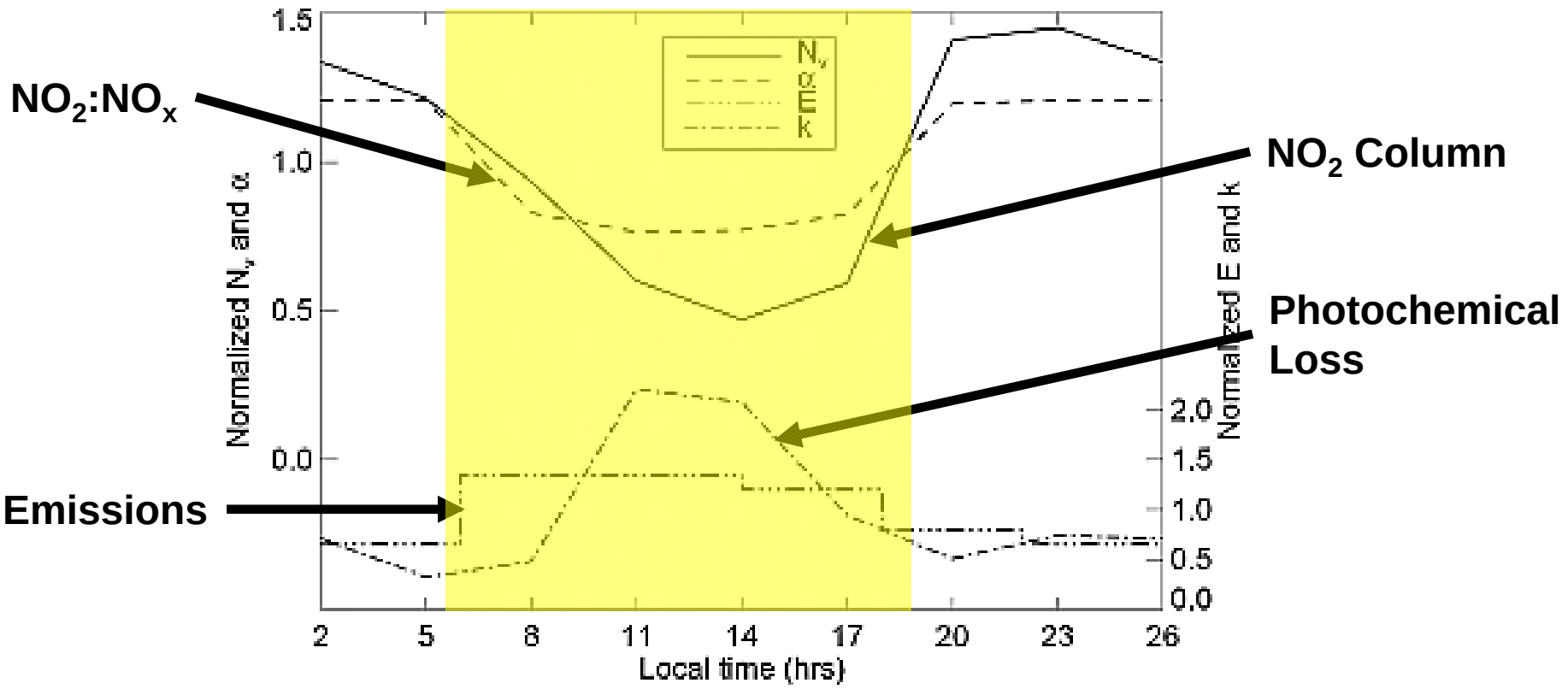
Colorado, Jul-Aug 2014

# Predicted $NO_2$ Column Behavior



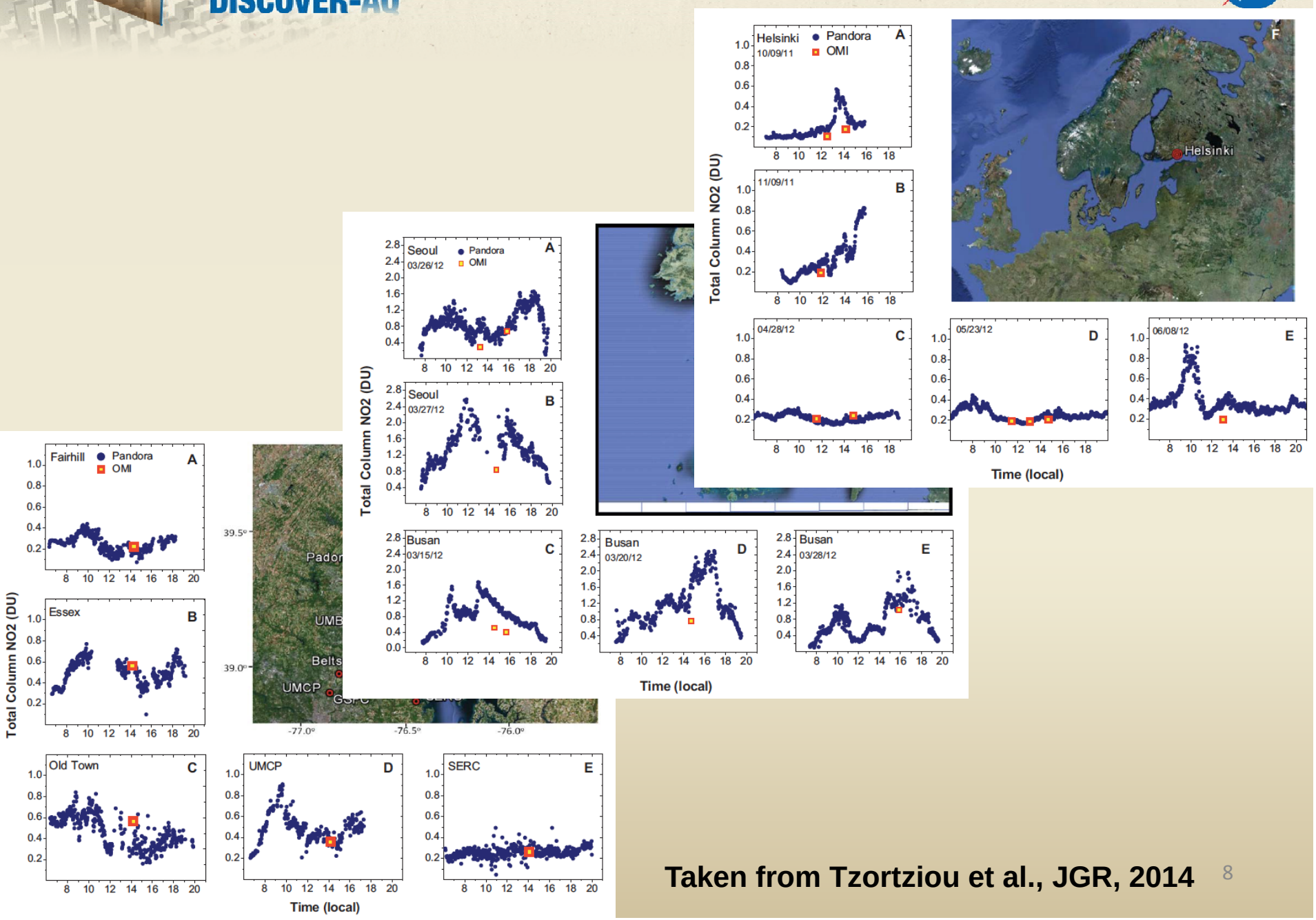

**Taken from Fishman et al., BAMS, 2008**

# Predicted $NO_2$ Column Behavior



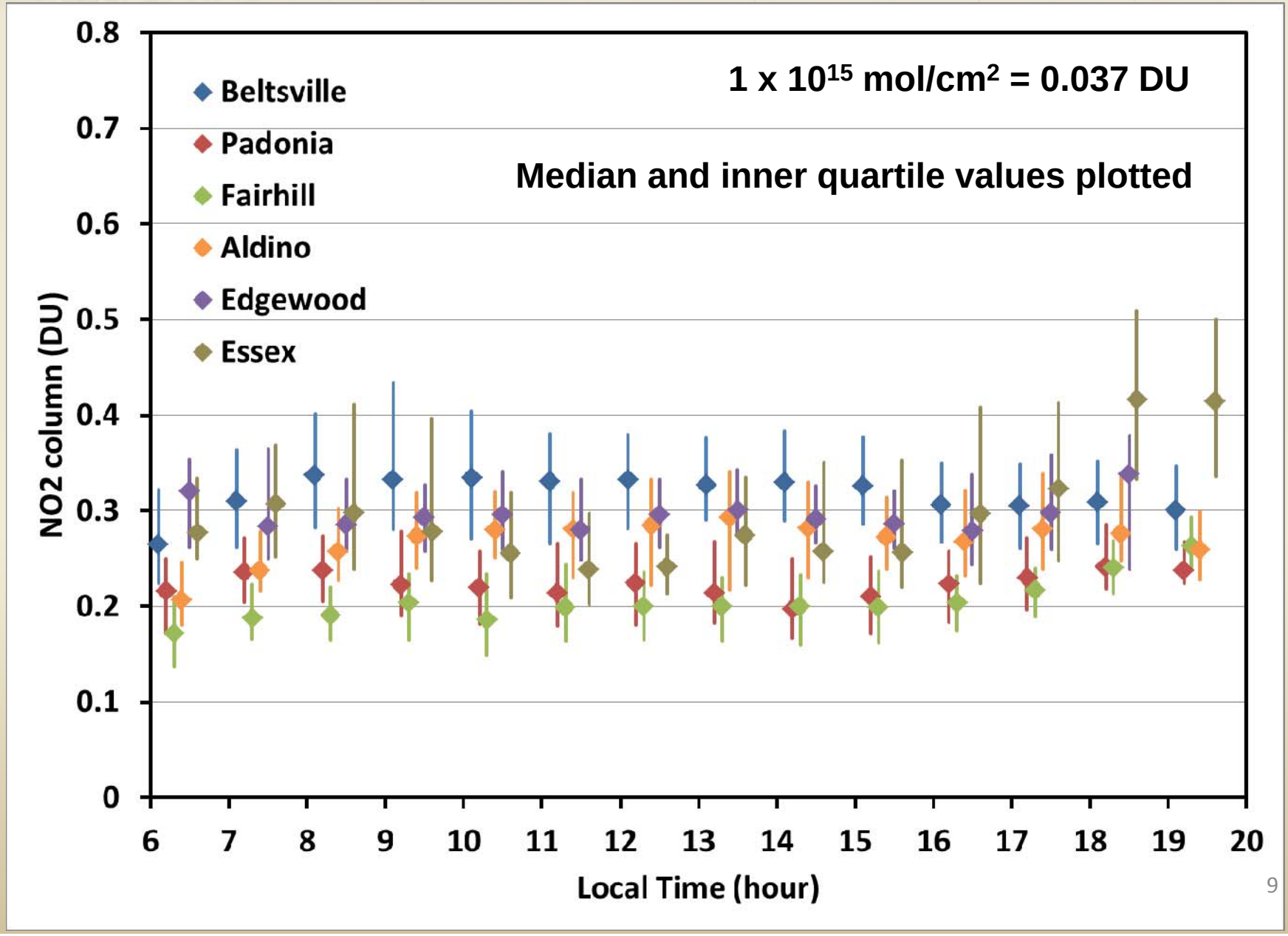

Taken from Boersma et al., JGR, 2008

# Observed $NO_2$ Column Behavior



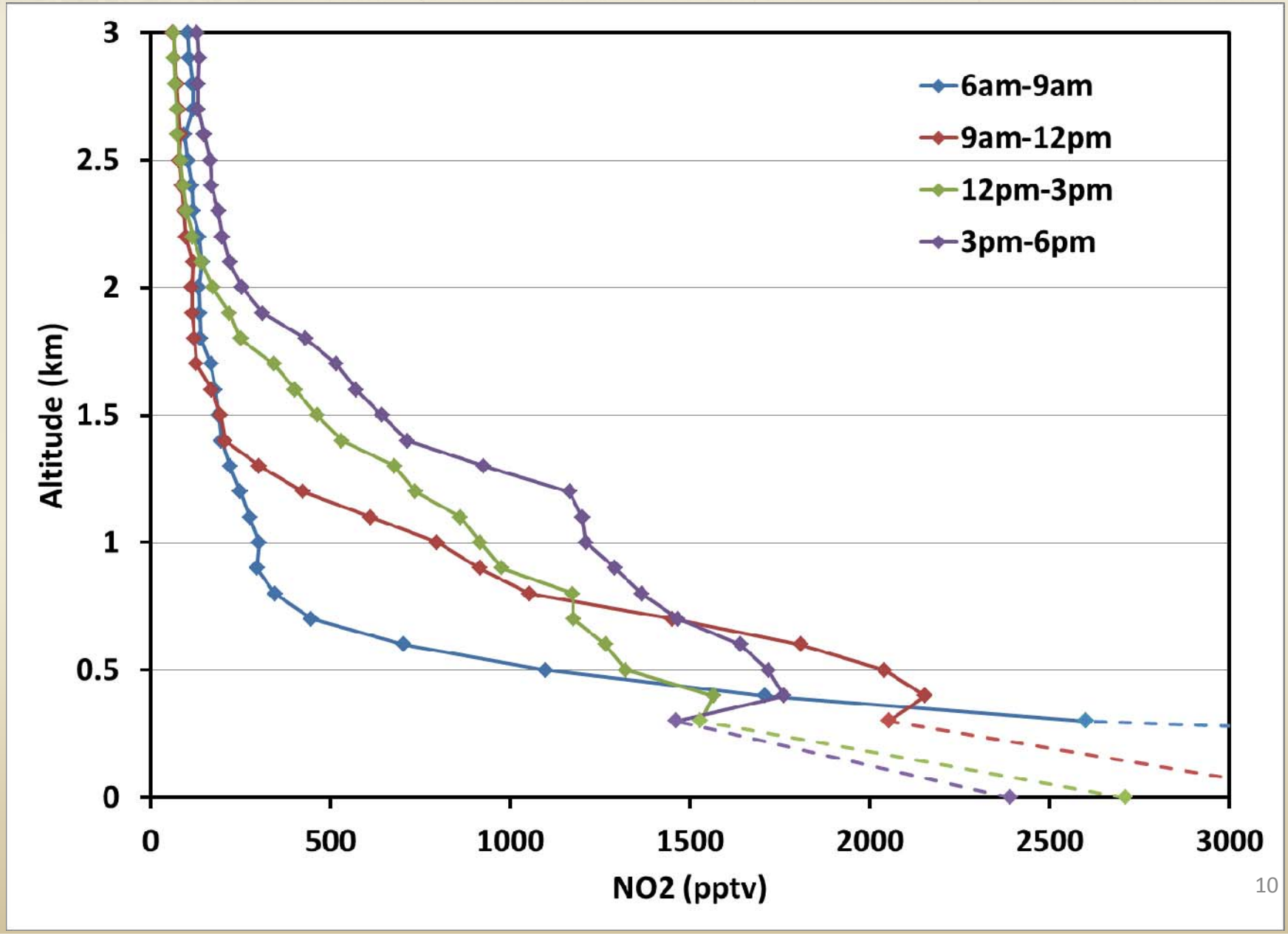

**Taken from Tzortziou et al., JGR, 2014**

# Pandora Statistics-Maryland

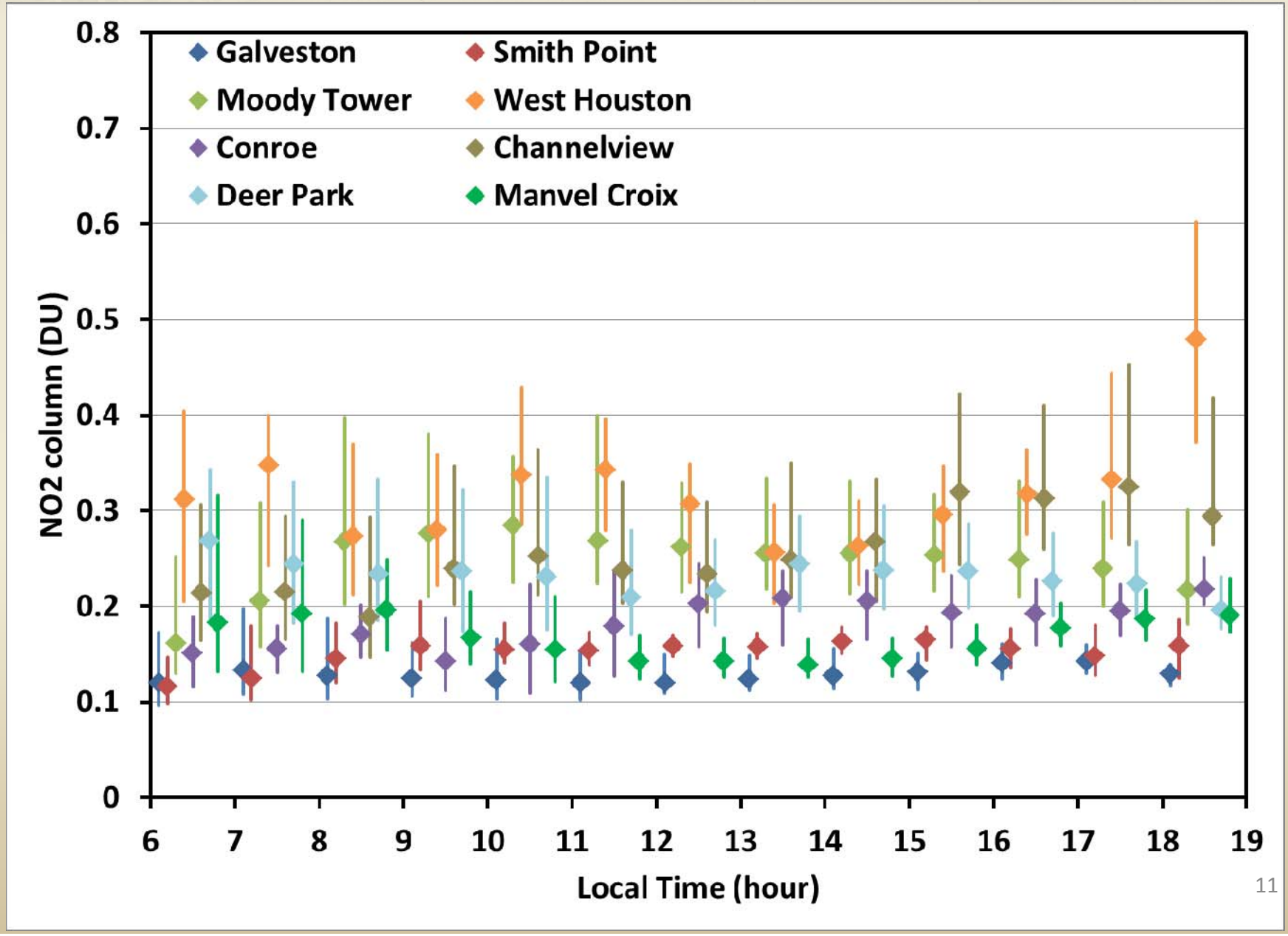


DISCOVER-AQ

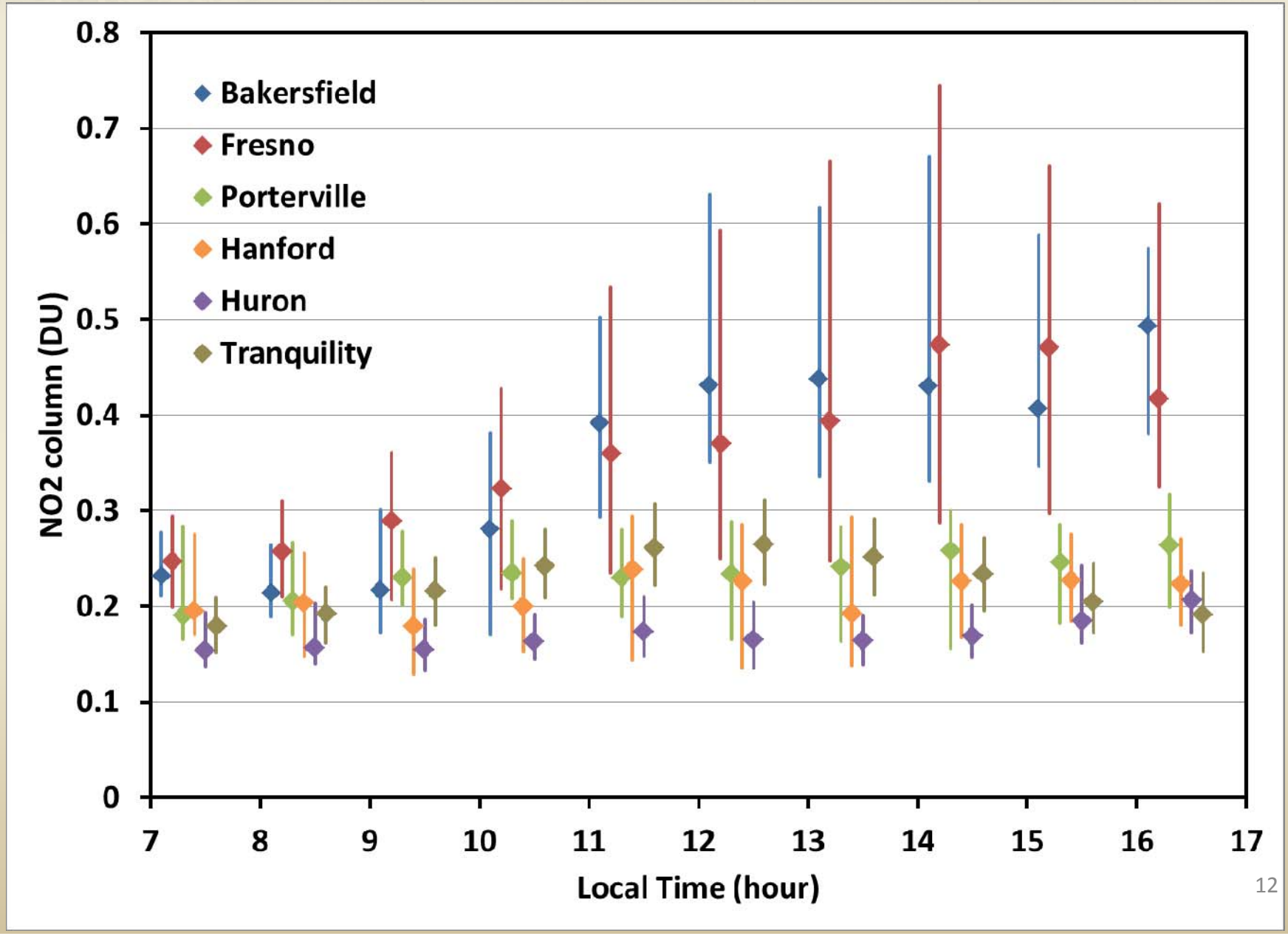
# P-3B Average Profiles-Maryland



# Pandora Statistics-Houston

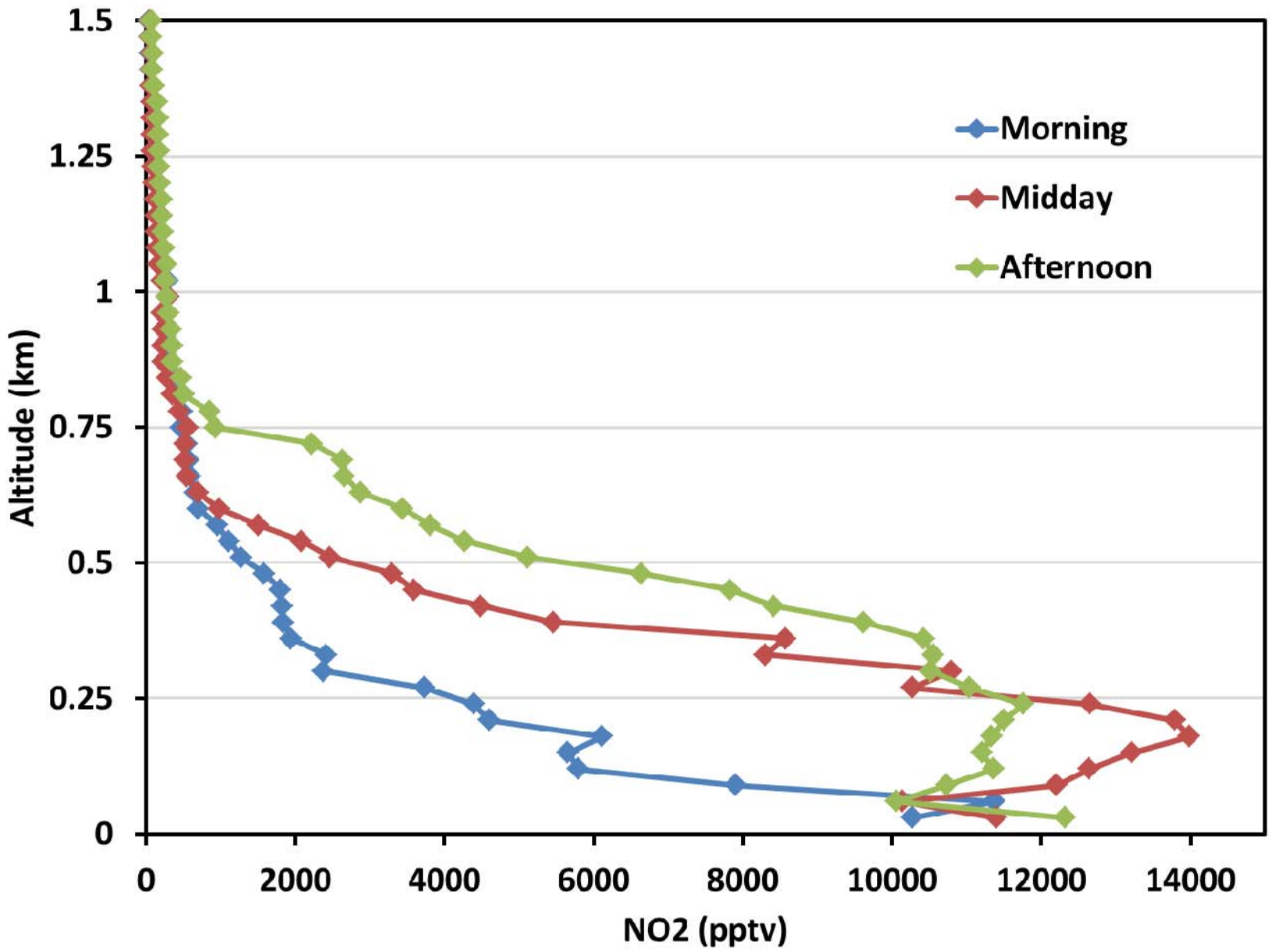


# Pandora Statistics-California



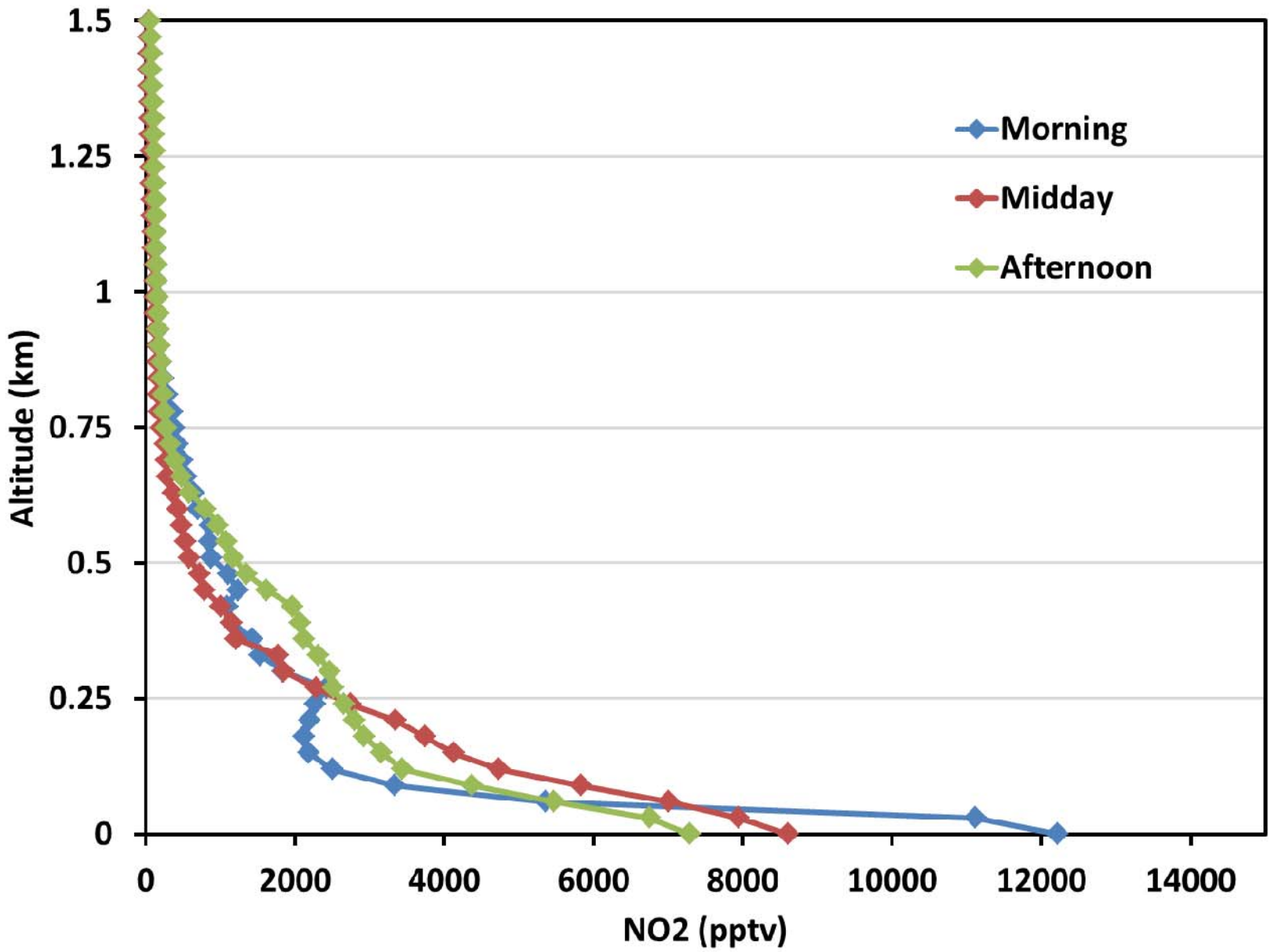
# P-3B Profile Statistics-California

## *Urban sites: Bakersfield+Fresno*



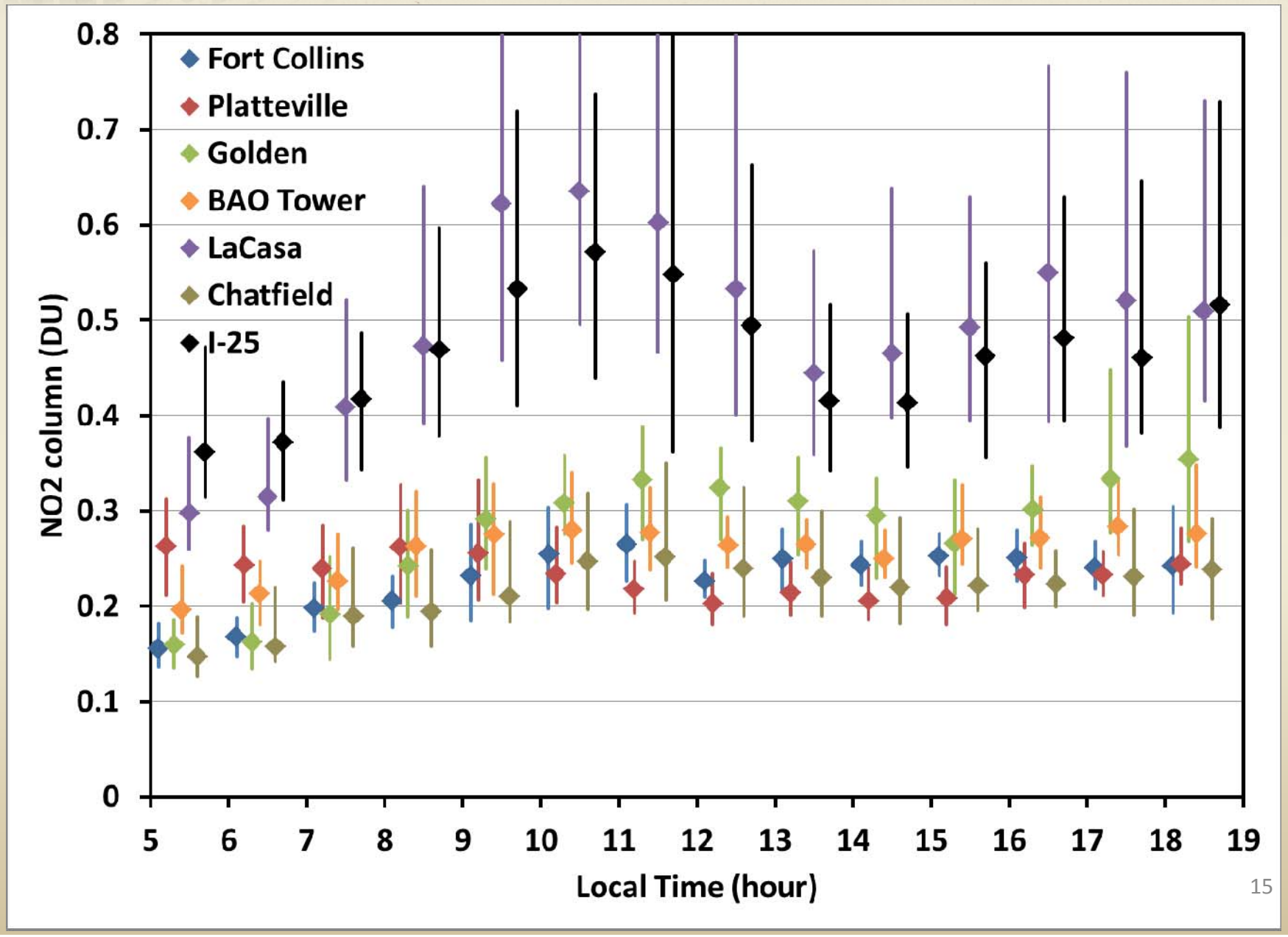
# P-3B Profile Statistics-California

## Sub-Urban sites

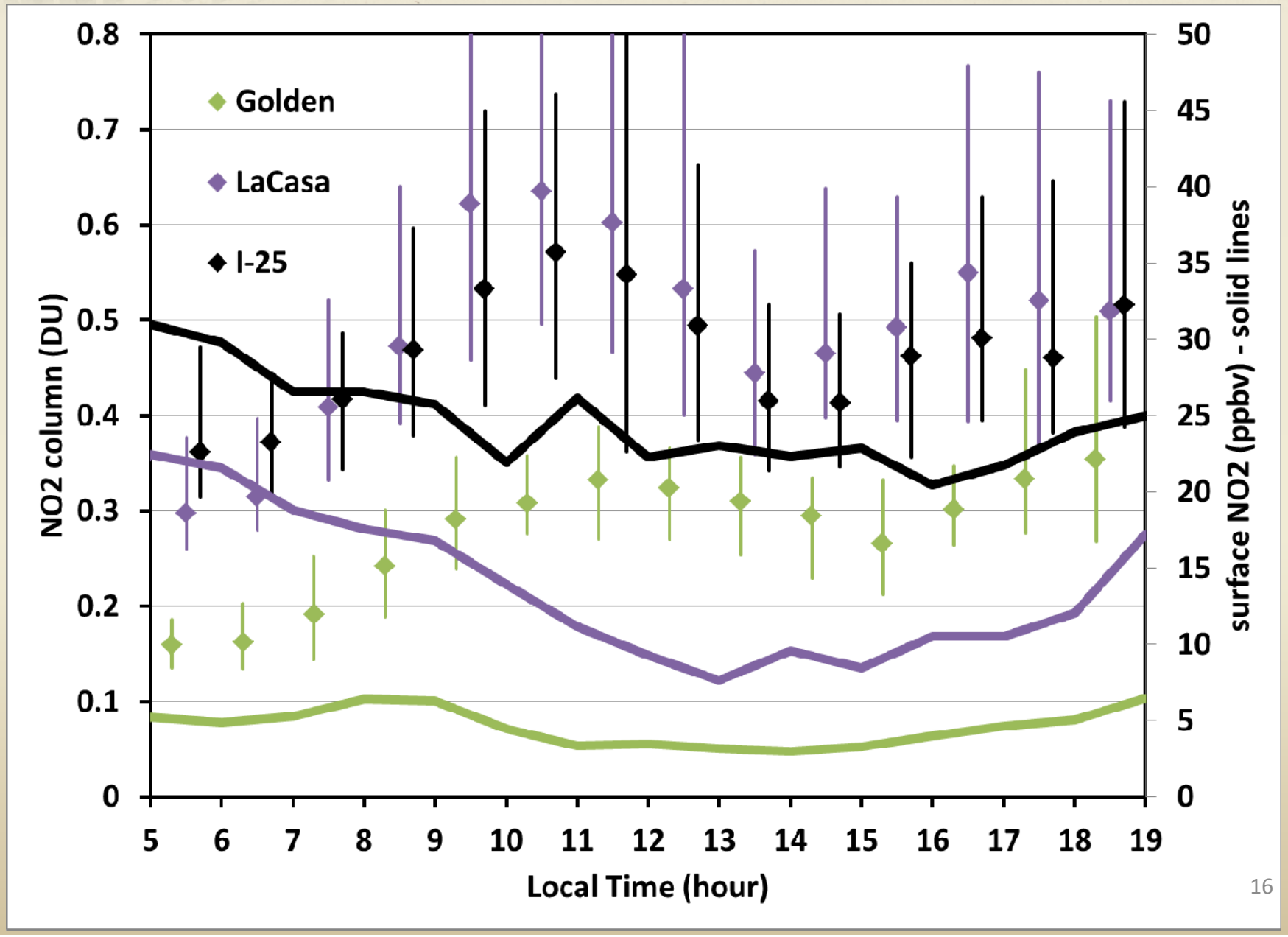


DISCOVER-AQ

# Pandora Statistics-Colorado



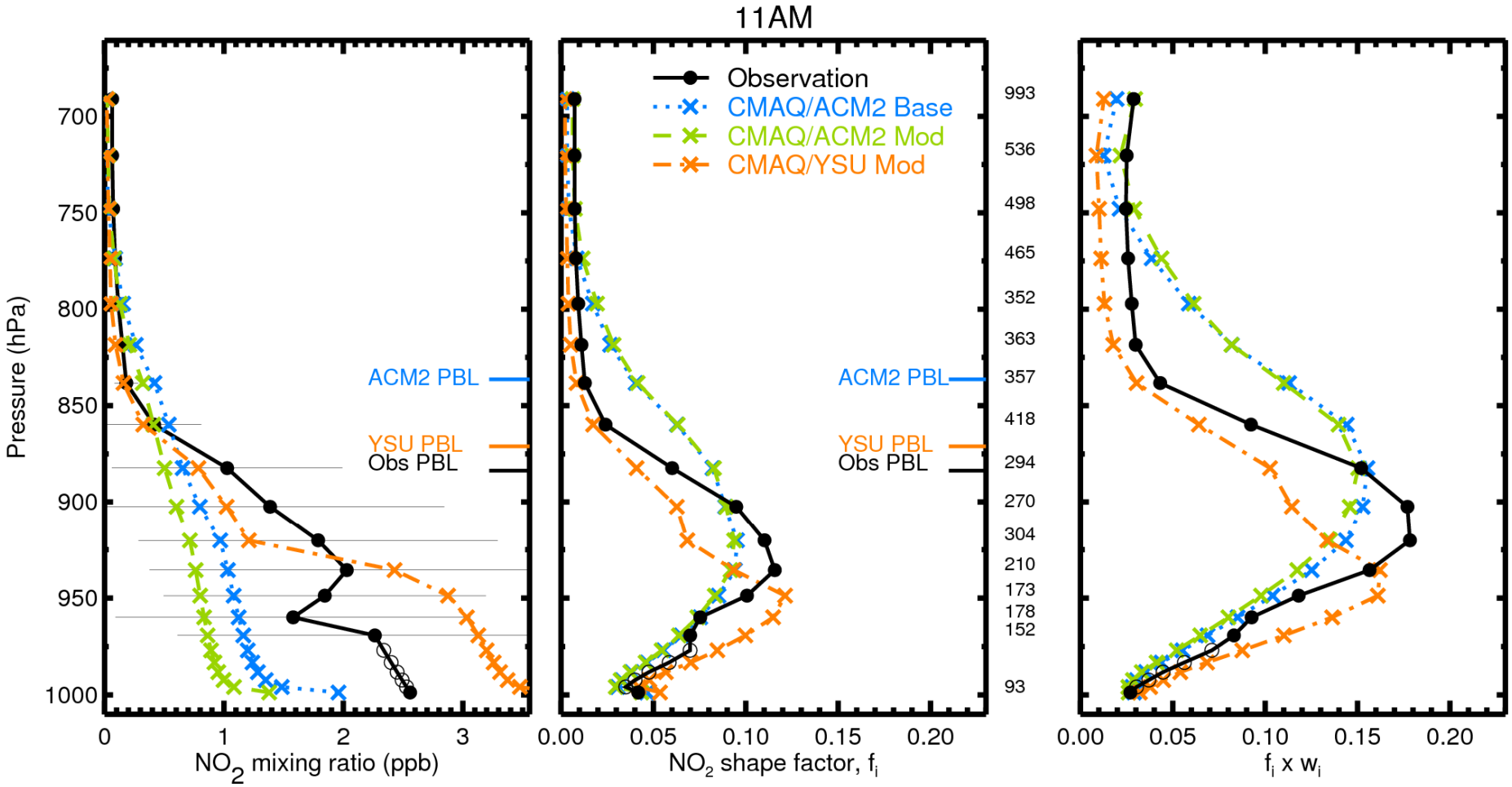
# Pandora vs Surface-Colorado



# Remote Sensing Column Air Mass Factor Sensitivity: Observations and Methods

- **Location:** Padonia, Maryland
- **Observation period**: 3-4 spirals for 14 days in July 2011 (Hours covered 6 AM – 5 PM, local time)
- **$NO_2$ observations:**
  - Aircraft (P3B) measurements (200 m - ~4 km) NCAR data (accuracy better than10%)
  - Surface measurements by photolytic converter instrument (accuracy better than 10%)
  - Spatial resolution comparable between model (4x4km) and spiral (radius ~4km)
- **Observed PBL heights** : Estimation based on temperature, water vapor, $O_3$ mixing ratios, and RH (Donald Lenschow)
- **Methods**:
  - Model and surface measurements sampled for the days and time of aircraft measurements
  - Spiral data sampled at model vertical grids

# Comparison of $NO_2$ profiles and shape factors




Filled circles: observed grid average

Open circles: linear interpolation in log space

Error bars: standard deviation

$$f_i = \frac{\Omega_i}{\sum \Omega_i}$$

**$f_i$ → $NO_2$ shape factors**

**$\Omega_i$ → partial column**

**$w_i$ → scattering weights (VLIDORT)**

$$AMF = \int_{surface}^{h} w_i \times f_i$$

**AMF (Observation) = 1.94**

**AMF (Base) = 2.16**

**AMF (ACM2 Mod) = 2.3**

**AMF (YSU Mod) = 1.8**

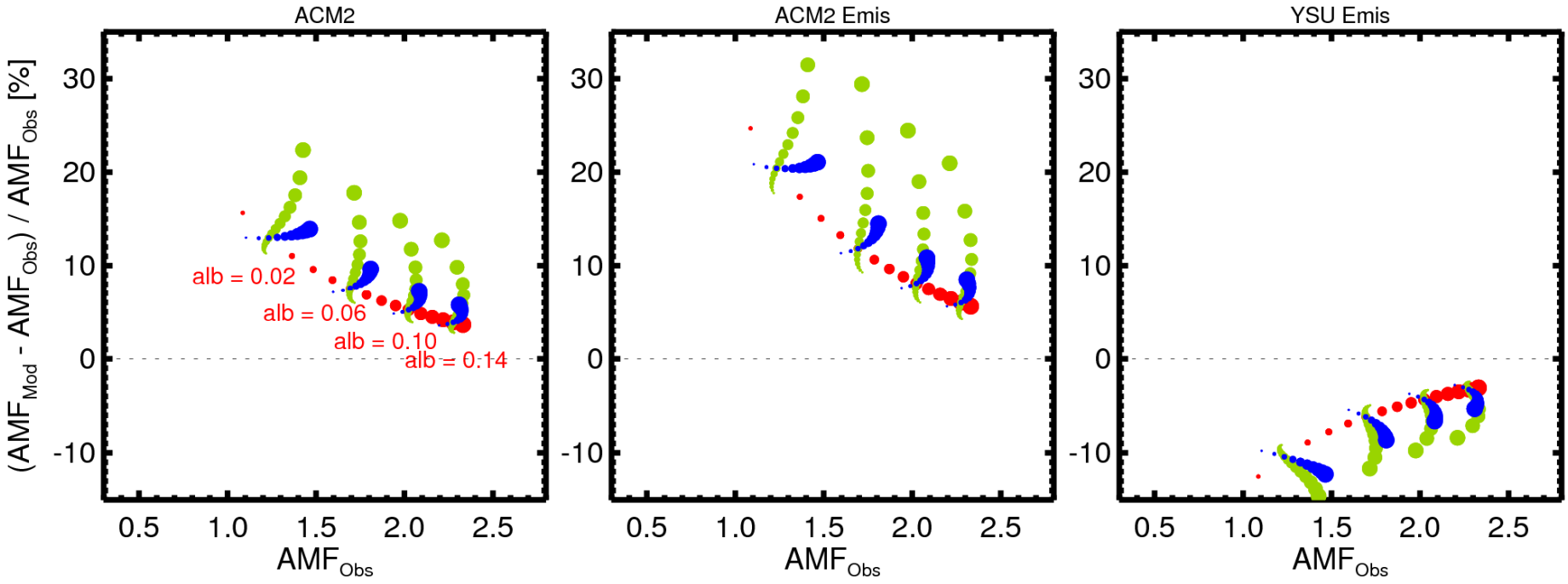
# Errors in AMFs/retrievals from a-priori $NO_2$ profiles

$$AMF = \int_{surface}^{8\,km} w_i \times f_i$$

$w_i$ → scattering weights

$f_i$ → $NO_2$ shape factors

- AMF calculated for ACAM (air-borne spectrometer located at ~8km) but is also relevant for tropospheric $NO_2$ column retrievals

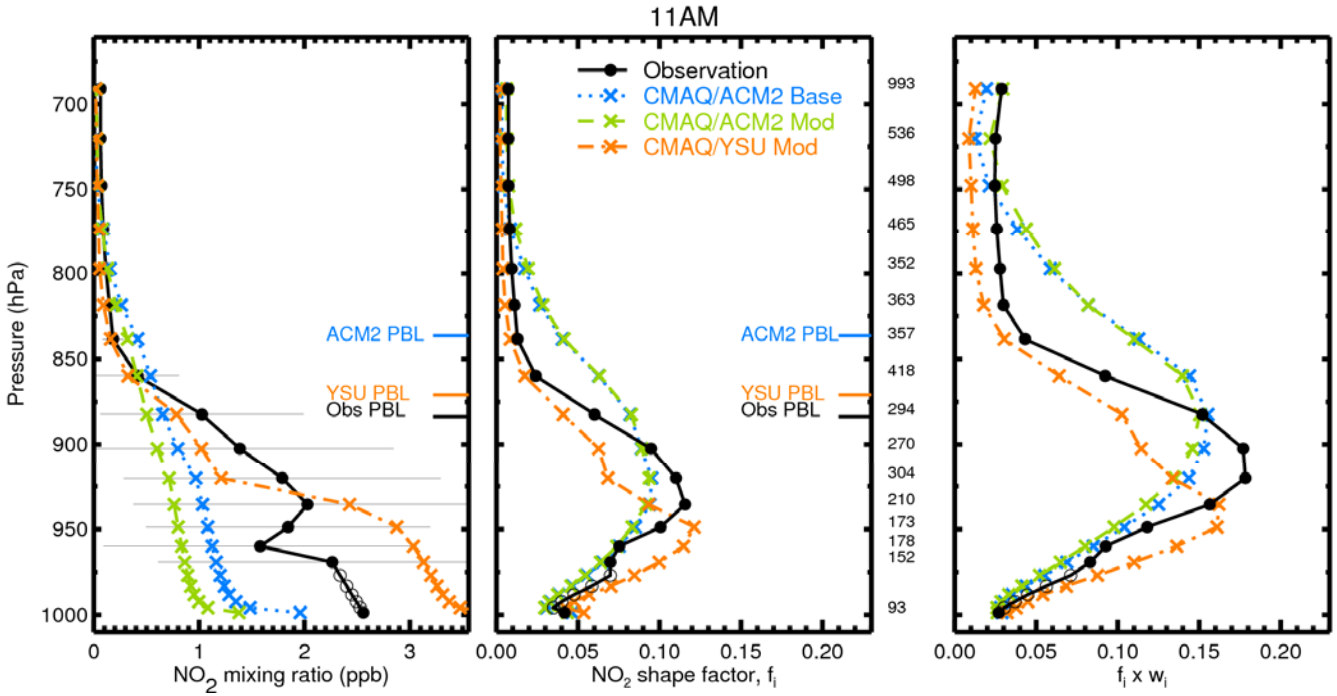



Surface reflectivities: 0.1 to 0.14 at 0.01 steps

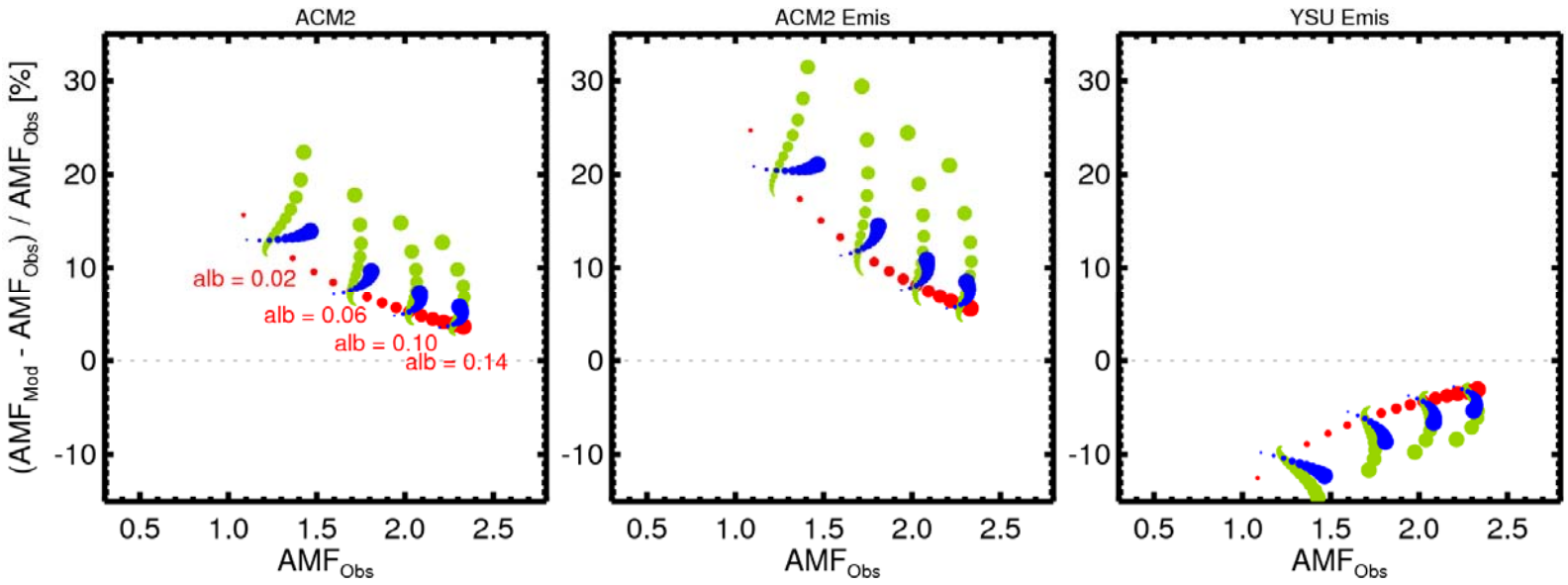
Solar zenith angles: 10° to 80° at 10° steps

Aerosol optical depths: 0.1 to 0.9 at 0.1 steps

# $NO_2$ profiles and AMFs (11 AM)




**AMF (Observation) = 1.94**
**AMF (Base) = 2.16**
**AMF (ACM2 Mod) = 2.3**
**AMF (YSU Mod) = 1.8**



# Summary

***1. DISCOVER-AQ has collected a dataset of unprecedented detail on the diurnal trends in air quality as it is discerned from in situ and remote sensing methods.***

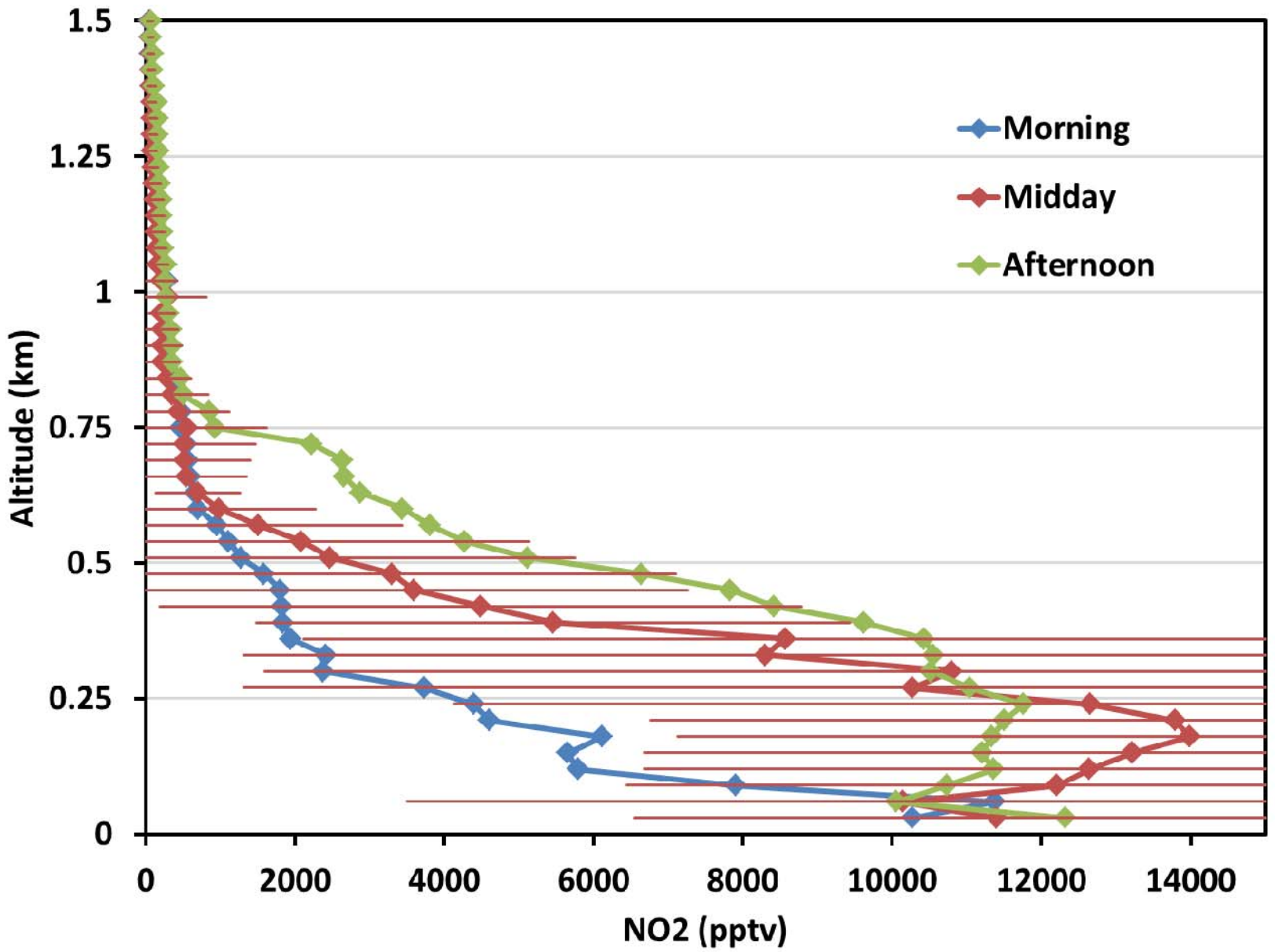
***2. $NO_2$ columns exhibit both unexpected and diverse diurnal trends that are consistent with vertically resolved profiles.***

***3. $NO_2$ tropospheric column retrievals are highly sensitive to diurnal variation in a-priori profile shapes.***

# Backups

# P-3B Profile Statistics-California

## *Urban sites: Bakersfield+Fresno*



| CMAQ model: Three simulations | | | |
|---|---|---|---|
| **Horizontal resolution** | 4 km x 4 km | | |
| **Vertical levels** | 45 (surface-100 hPa) | | |
| **Domain** | Washington-Baltimore | | |
| **Chemical mechanism** | CB05 | | |
| **Aerosols** | AE5 | | |
| **Dry deposition** | M3DRY | | |
| **Vertical diffusion** | ACM2 | | |
| **Chemical and initial boundary condition** | RAQMS; 12 km x 12 km | | |
| **Biogenic emissions** | Calculated within CMAQ with BEIS | | |
| **Biomass burning emissions** | FINNv1 | | |
| **Lightning emissions** | Calculated within CMAQ | | |
| **Anthropogenic emissions** | NEI-2005 projected to 2012 | | |
| | **1. ACM2 Base** | **2. ACM2 Mod** | **3. YSU Mod** |
| **PBL scheme** | ACM2 | ACM2 | YSU |
| **Mobile emissions** | Standard | Reduced 50% | Reduced 50% |
| **Alkyl nitrate photolysis** | Standard | 10 times faster | 10 times faster |

- Two PBL schemes selected based on the study by Clare Flynn
- Emissions and photolysis rate changed based on Anderson et al., 2014 and Canty et al., 2014