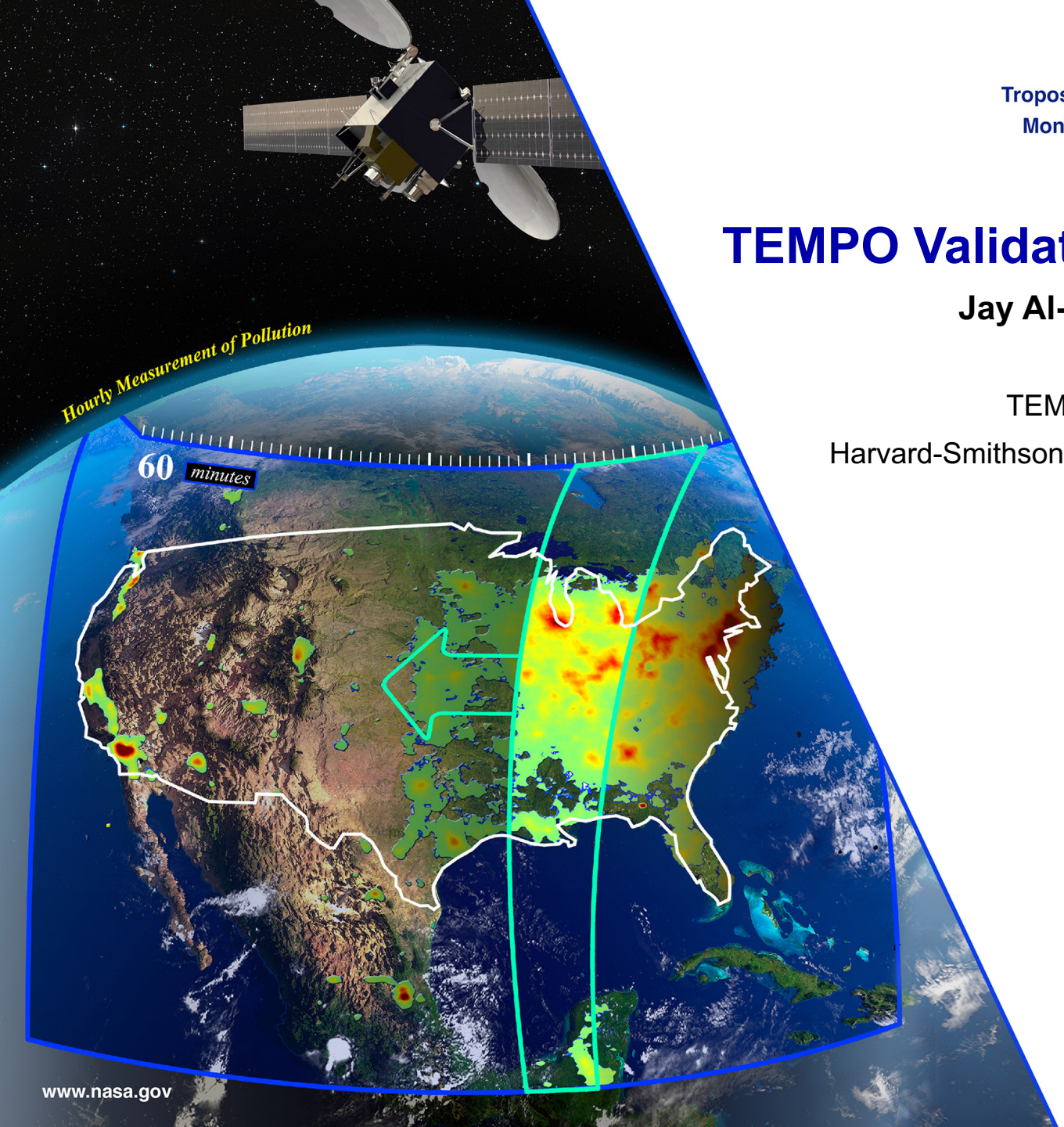


Tropospheric Emissions:
Monitoring of Pollution

TEMPO

TEMPO Validation by Aircraft

Jay Al-Saadi & Jim Crawford

May 31 – June 1, 2017

TEMPO Science Team Meeting

Harvard-Smithsonian Center for Astrophysics

Cambridge, MA

Smithsonian

NASA

www.nasa.gov

DISCOVER-AQ

Deployment Strategy

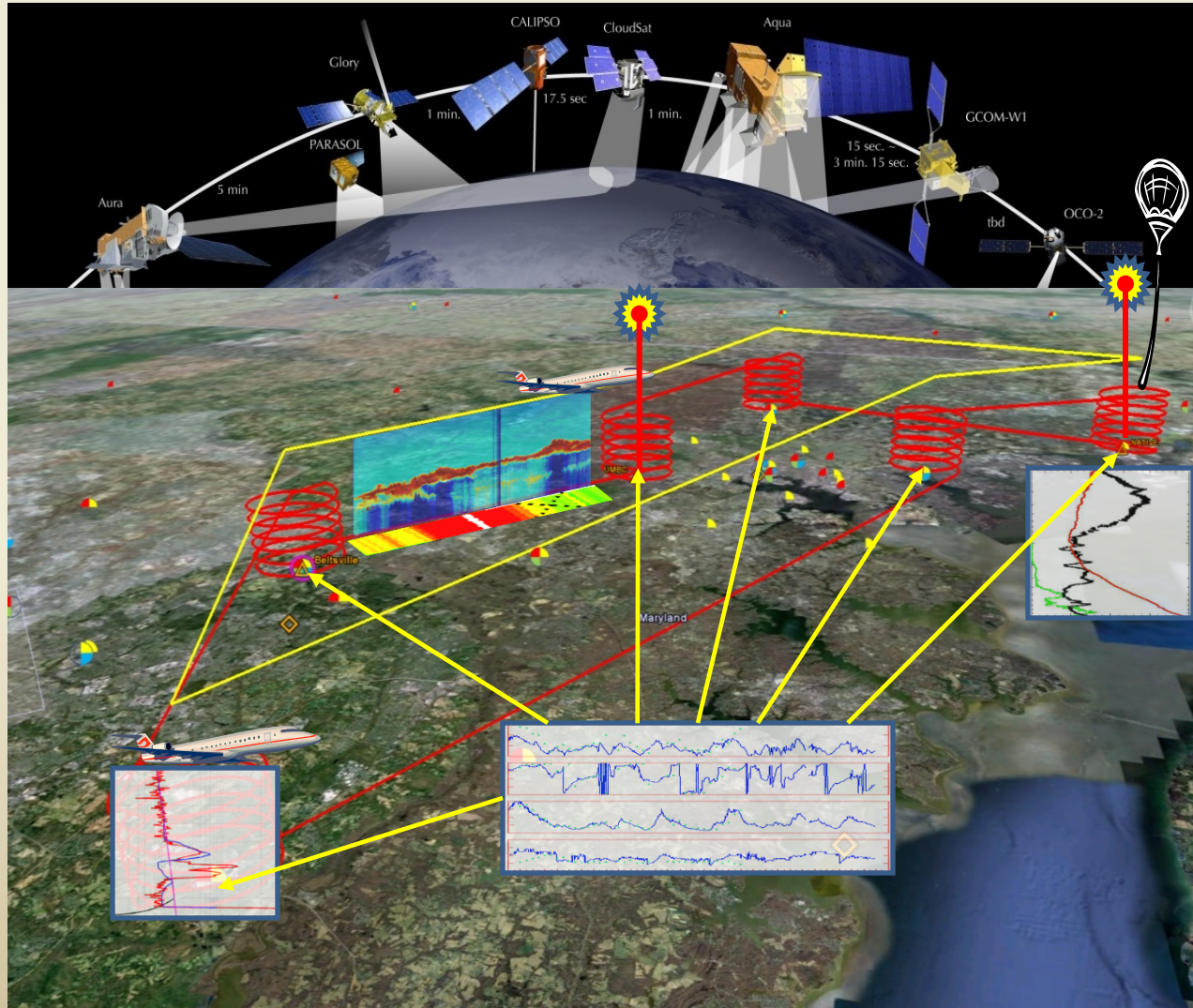
Systematic and concurrent observation of column-integrated, surface, and vertically-resolved distributions of aerosols and trace gases relevant to air quality as they evolve throughout the day.

Three major observational components:

<u>NASA King Air (Remote sensing)</u>
Continuous mapping of aerosols with HSRL and trace gas columns with ACAM

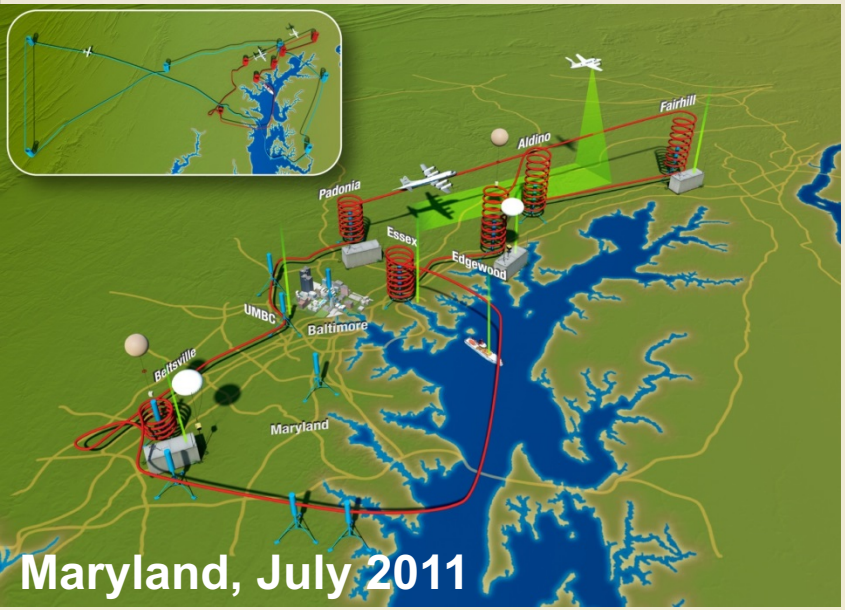
<u>NASA P-3B (in situ meas.)</u>
In situ profiling of aerosols and trace gases over surface measurement sites

<u>Ground sites</u>
In situ trace gases and aerosols
Remote sensing of trace gas and aerosol columns (Pandora and Aeronet)
Ozonesondes
Lidar observations of aerosol (and ozone)

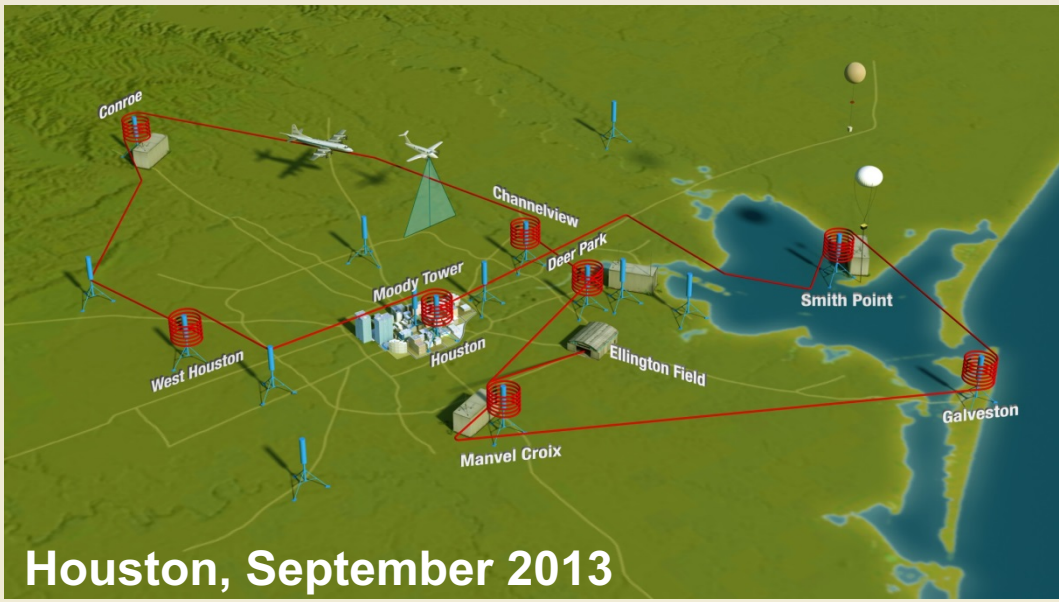


DISCOVER-AQ

Deployment Locations



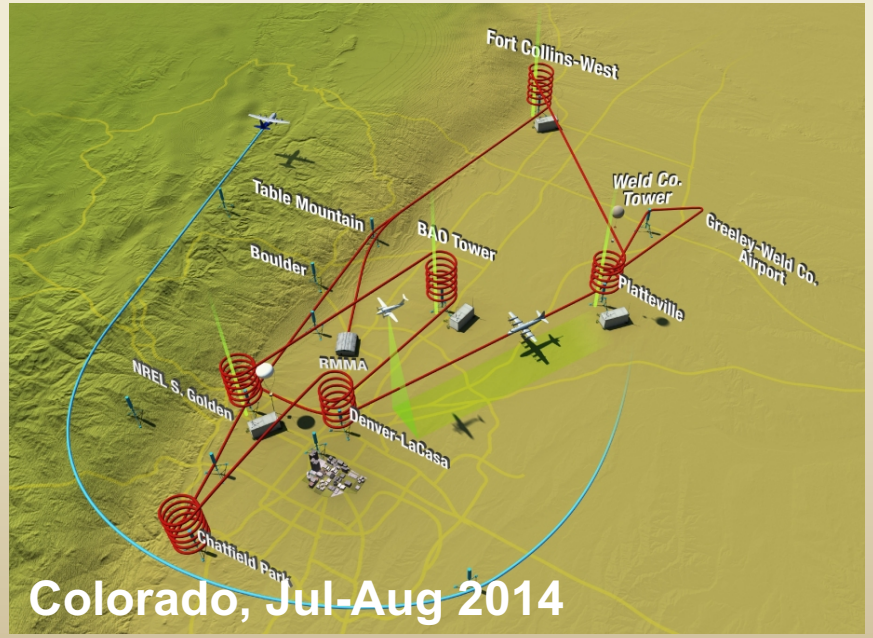
Maryland, July 2011



Houston, September 2013

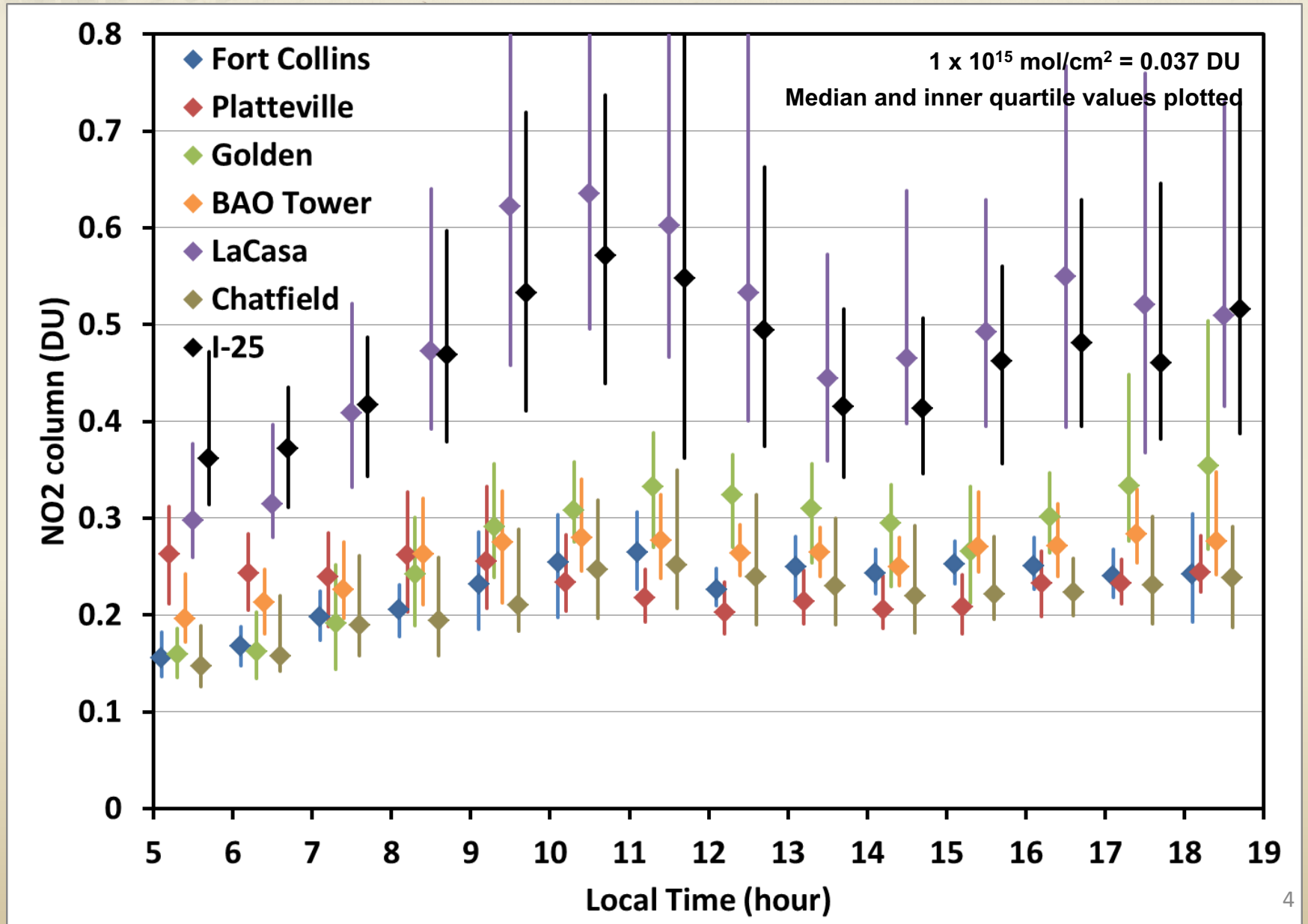


California, Jan-Feb 2013



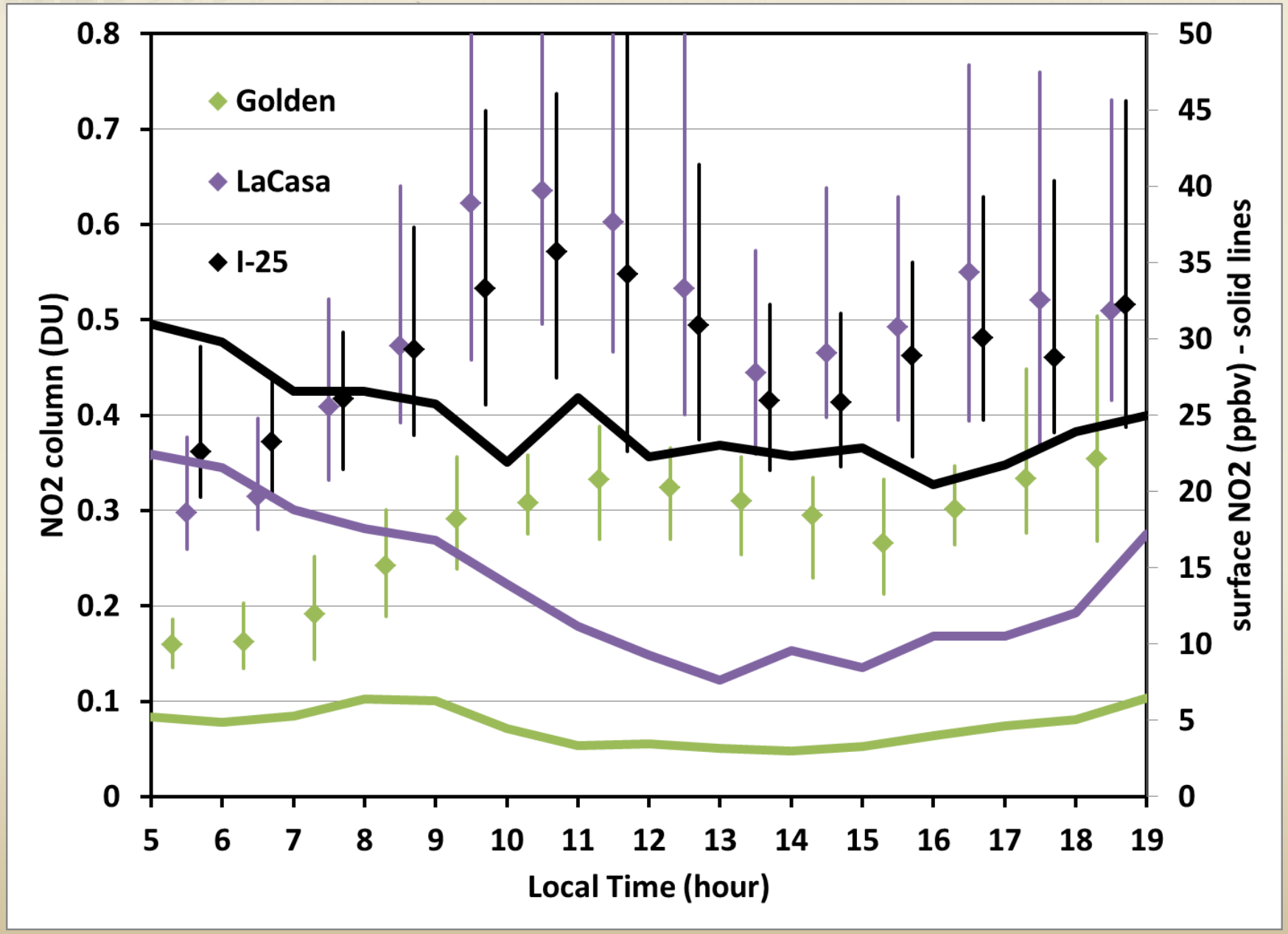
Colorado, Jul-Aug 2014

Pandora Statistics-Colorado



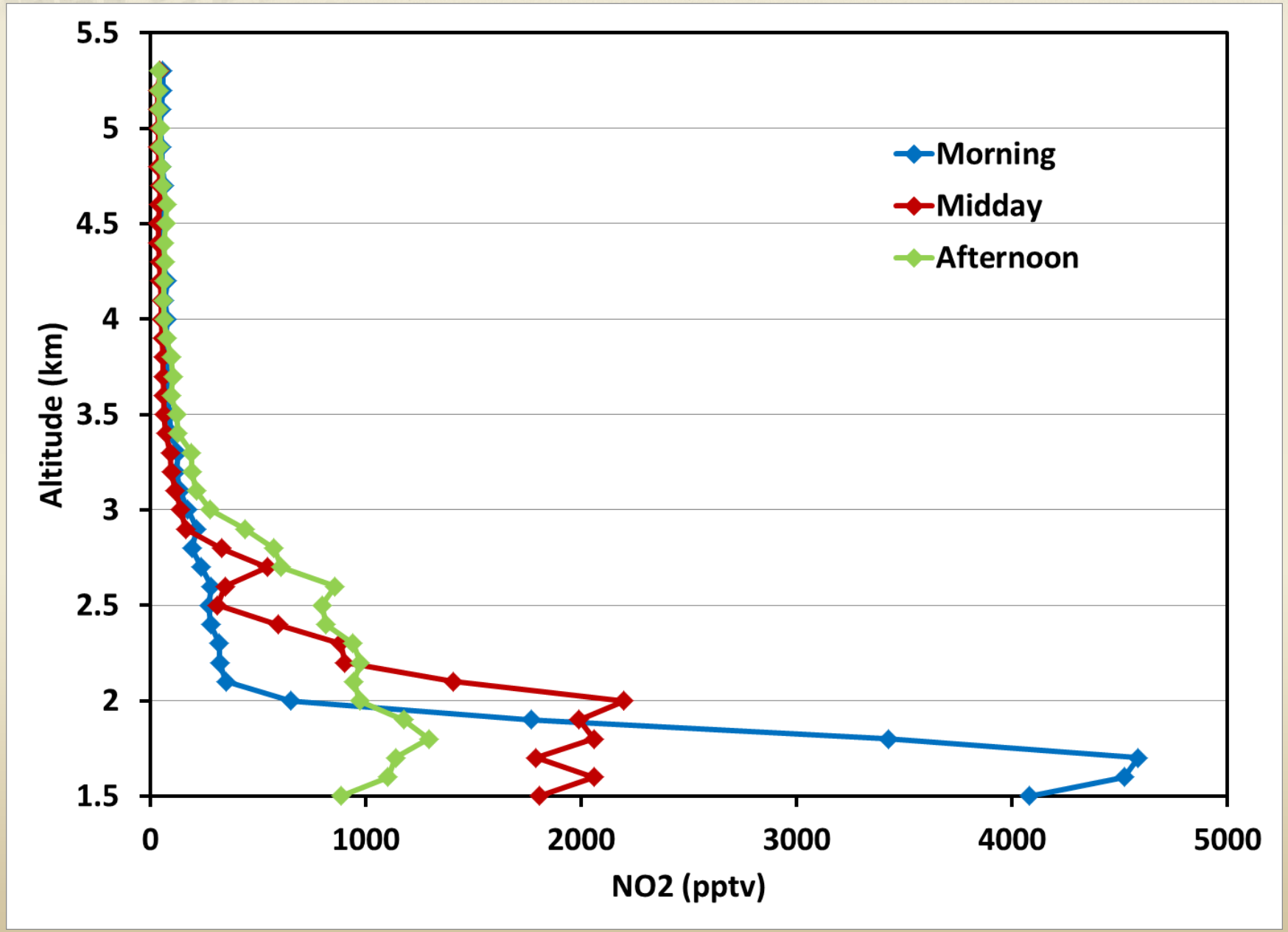
DISCOVER-AQ

Pandora vs Surface-Colorado



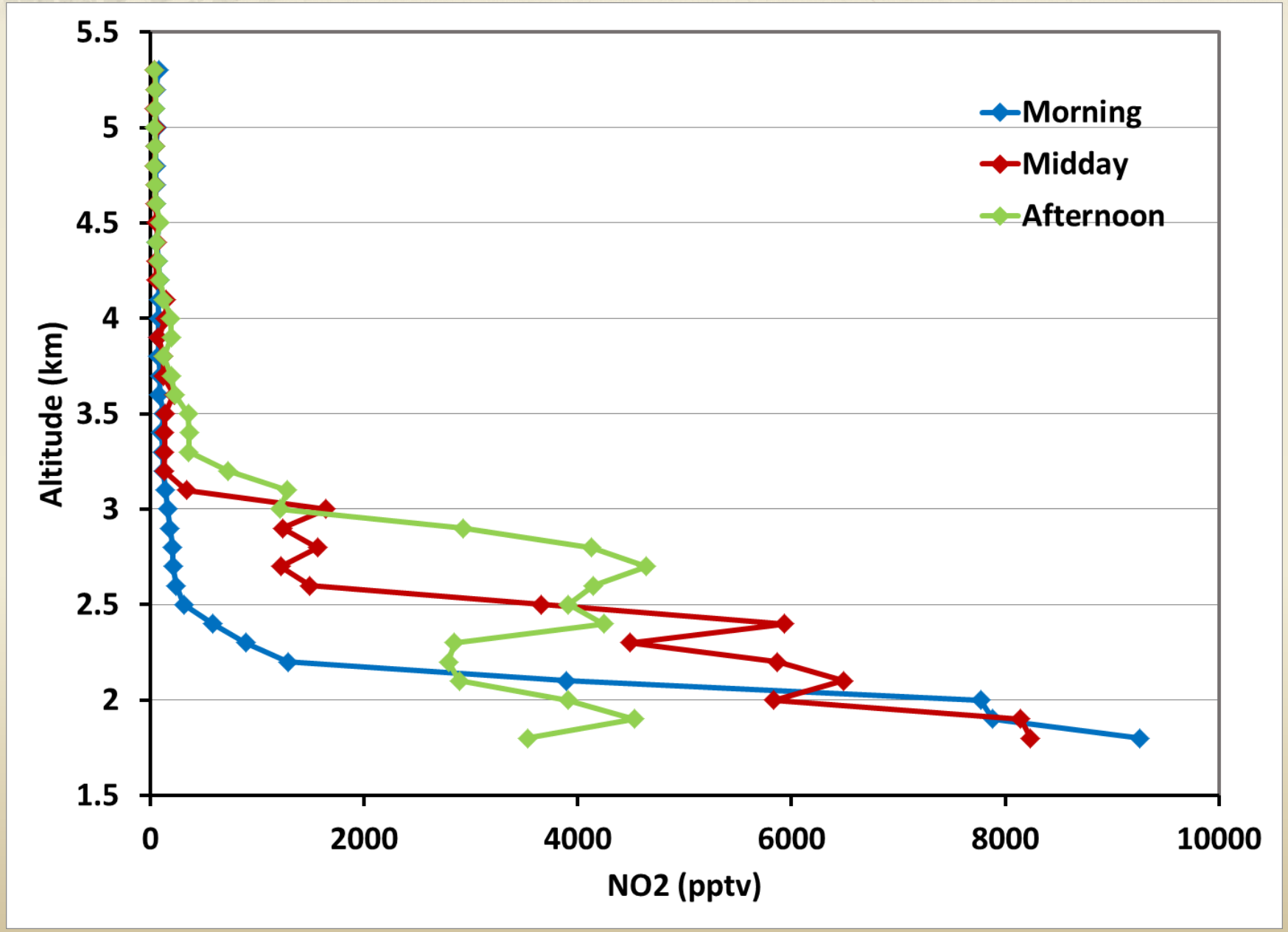
DISCOVER-AQ

Golden NO_2 Profiles



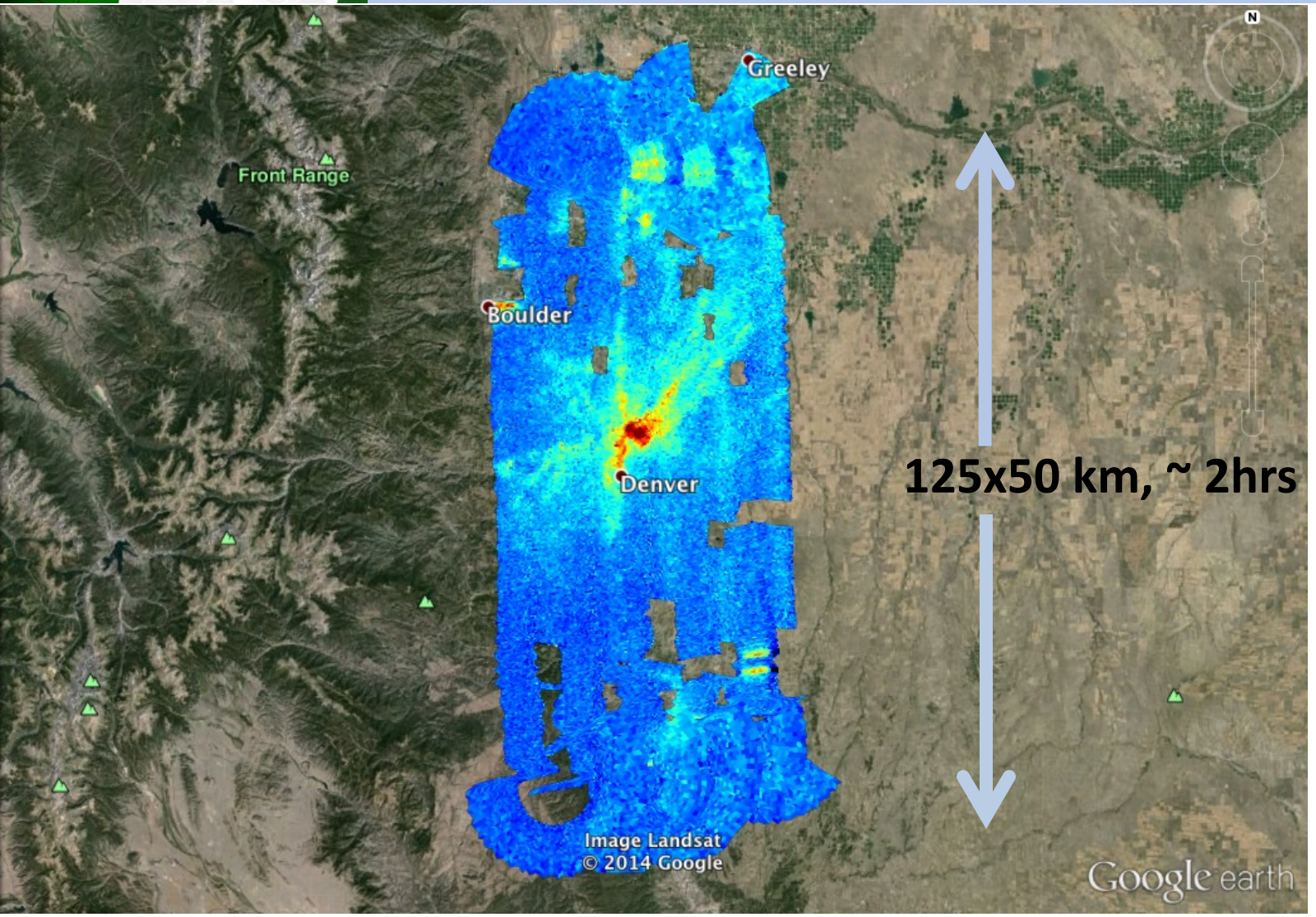
DISCOVER-AQ

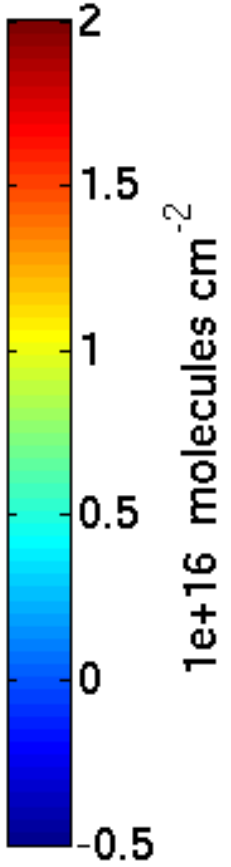
LaCasa NO_2 Profiles



GeoTASO NO_2 Slant Column, 02 August 2014

Morning





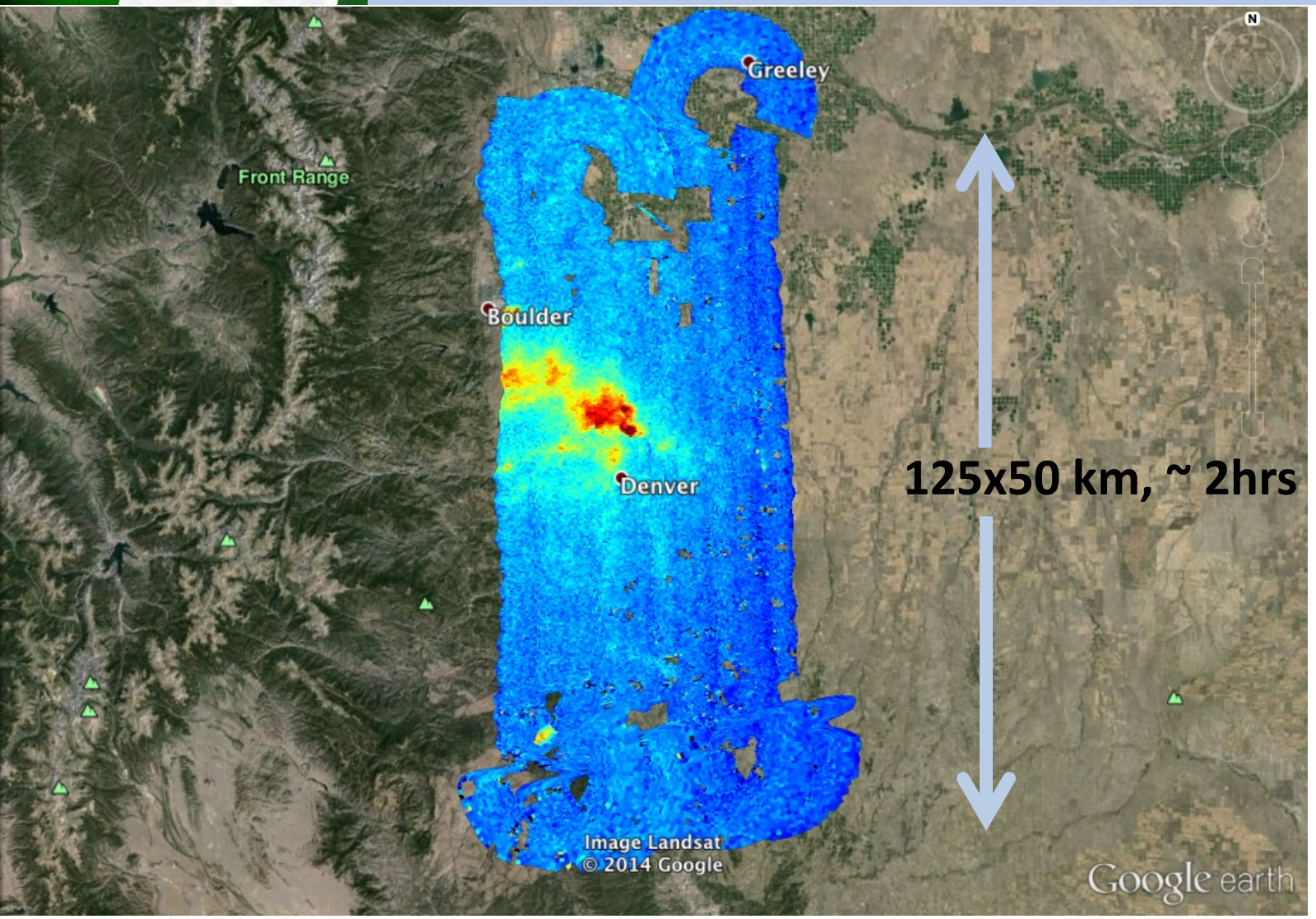
Co-added to approx. 500m x 450m

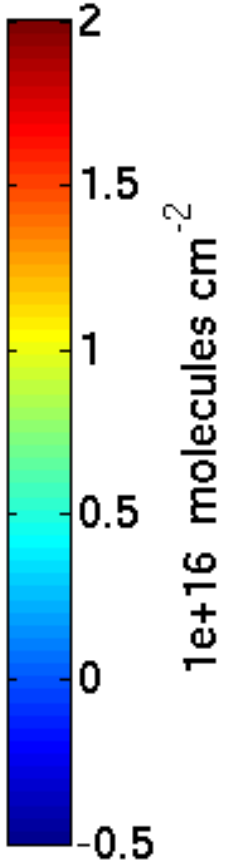
Morning vs. Afternoon

From Caroline Nowlan, SAO
Preliminary data

GeoTASO NO_2 Slant Column, 02 August 2014

Afternoon





Co-added to approx. 500m x 450m

Morning vs. Afternoon

From Caroline Nowlan, SAO
Preliminary data

KORUS-AQ





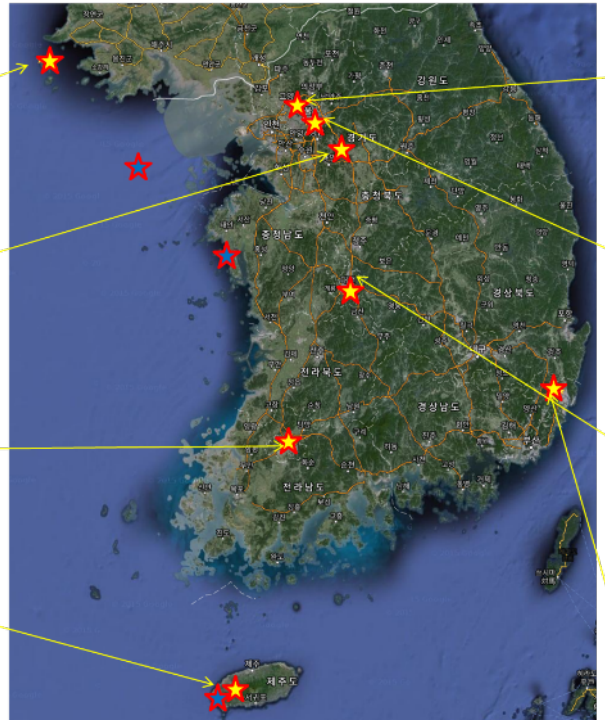










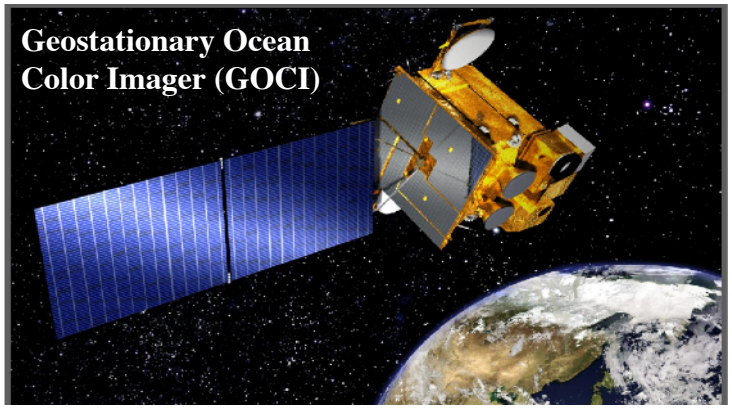








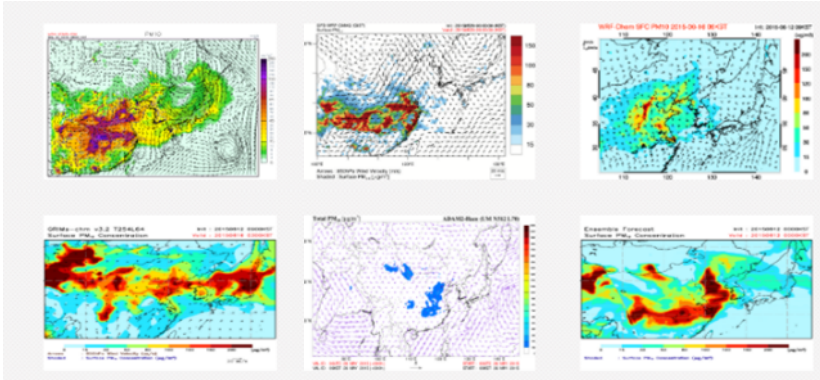


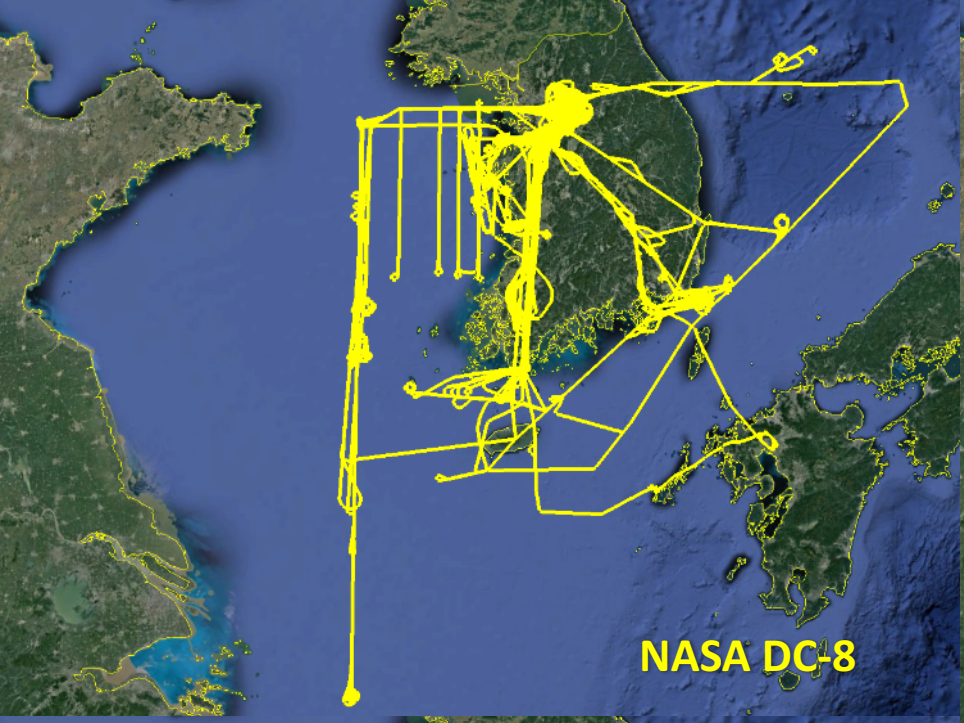


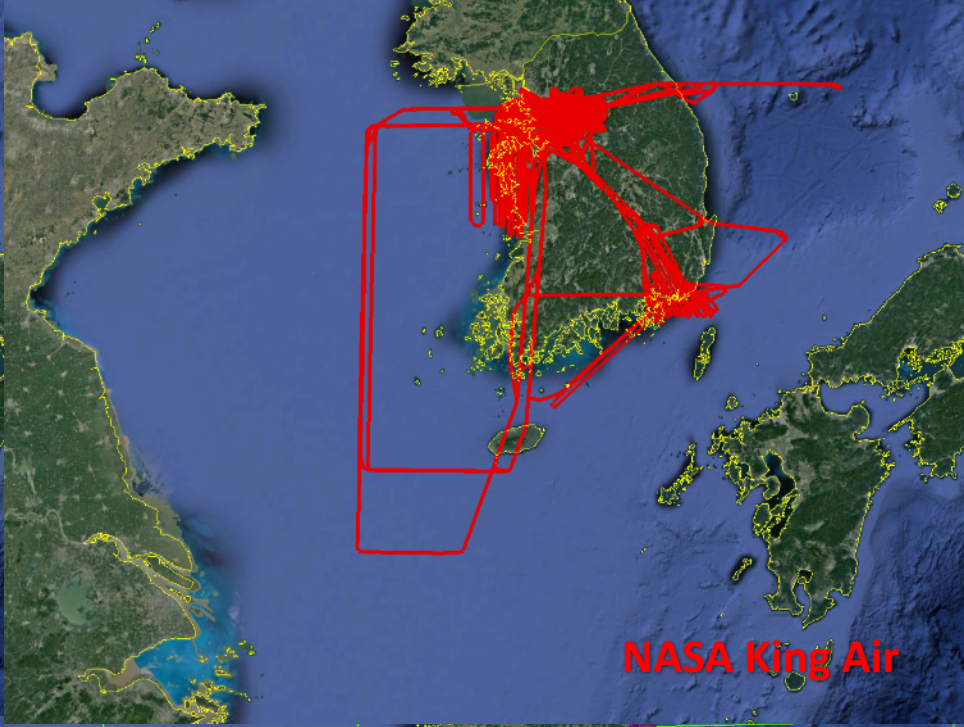


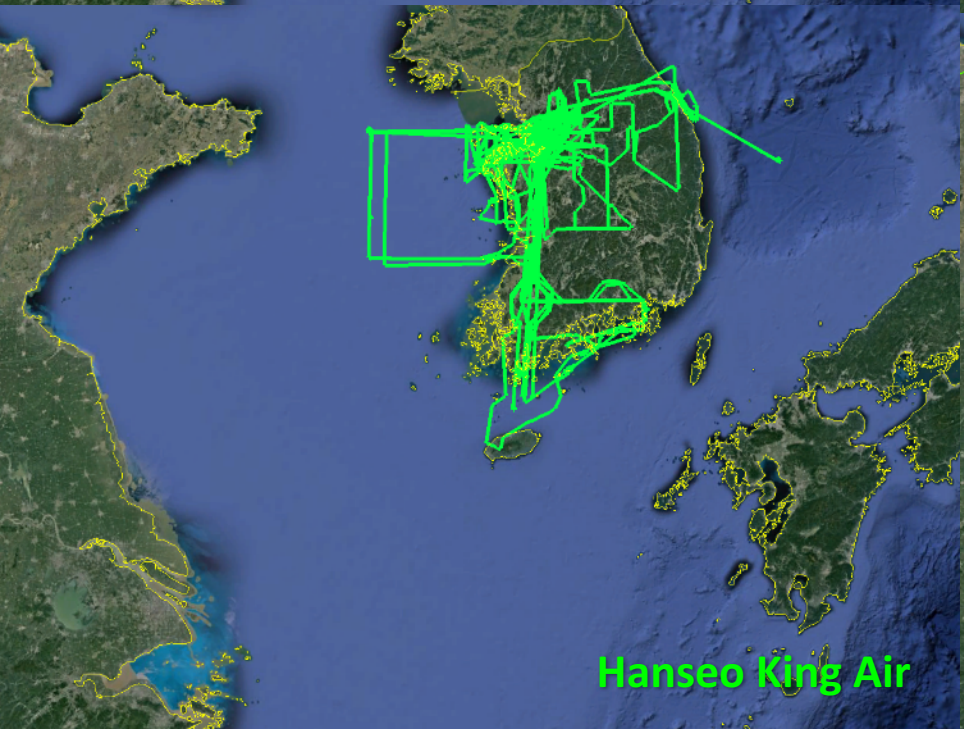


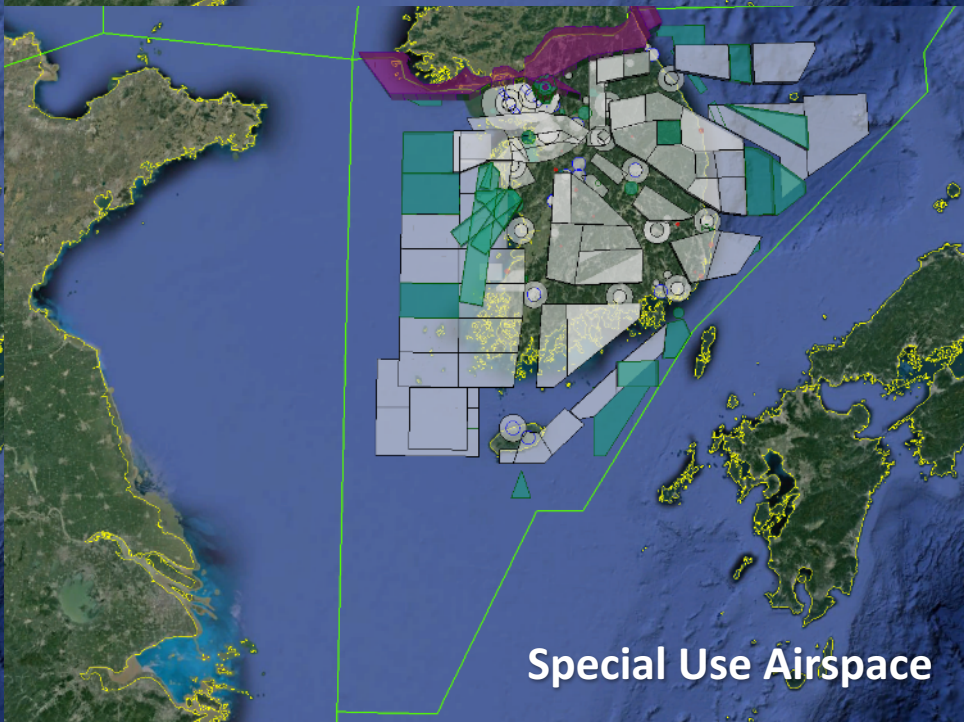
Korean and US Air Quality Model Forecasts




NASA DC-8

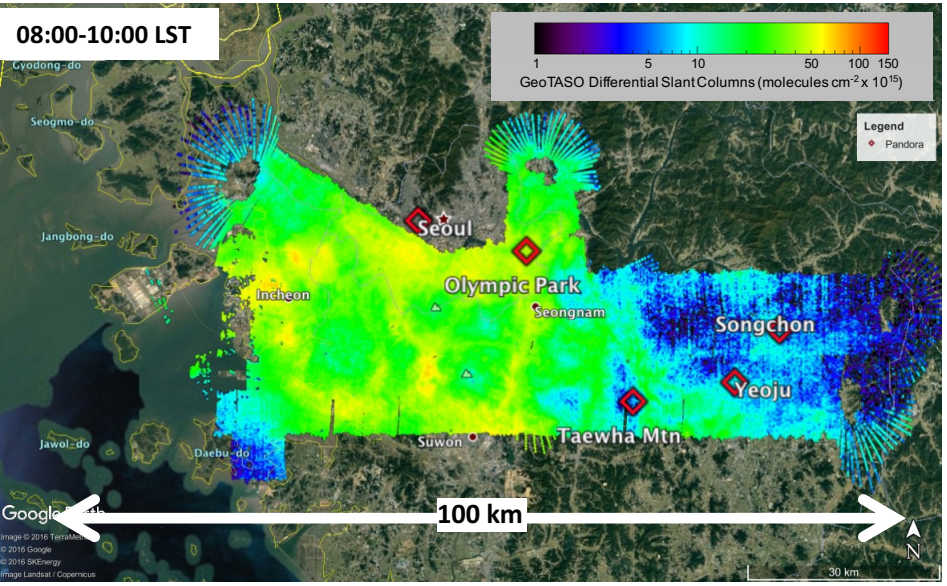

NASA King Air

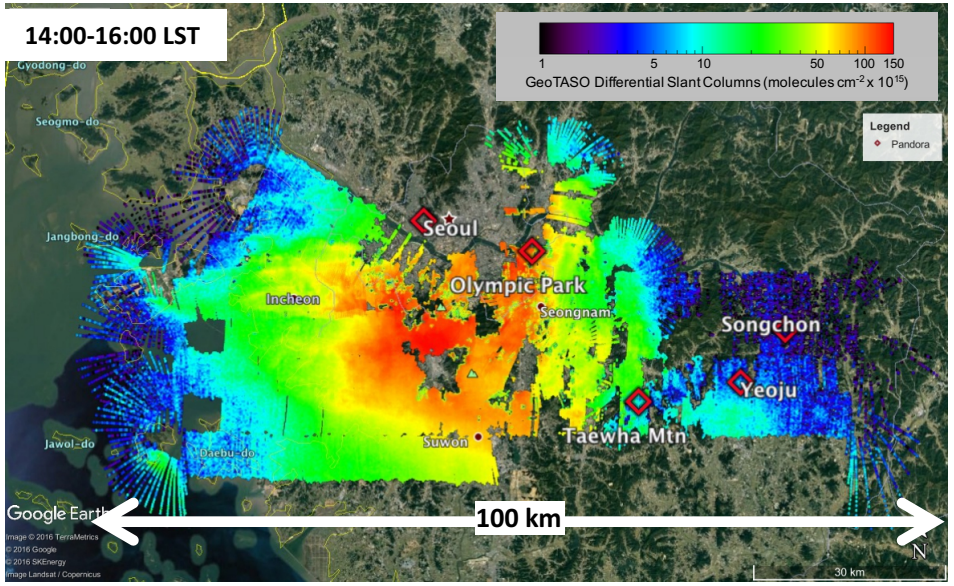

Hanseo King Air

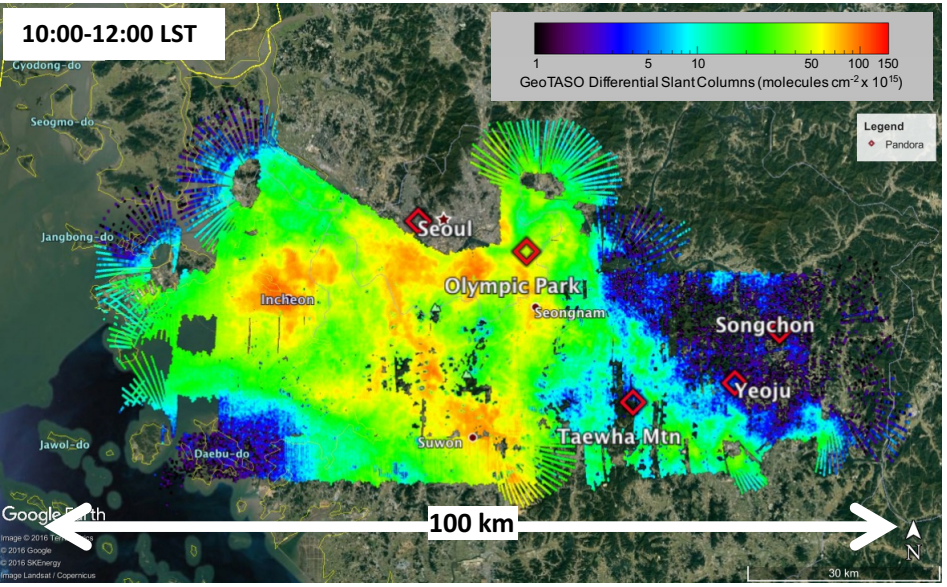

Special Use Airspace

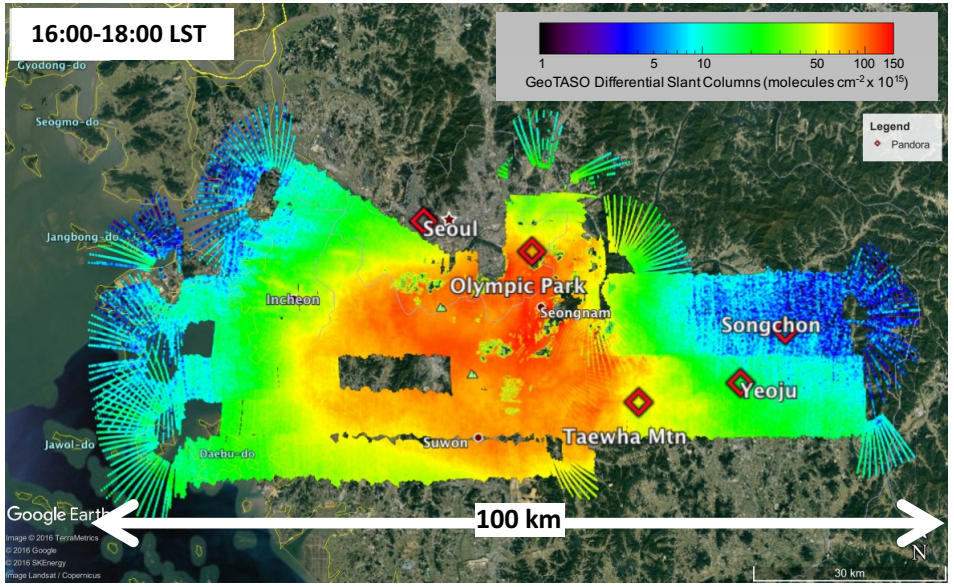
GeoTASO Quick-look differential slant column NO_2 – Seoul, Korea, 2016/06/09

Images courtesy Laura Judd/NASA LaRC and Scott Janz/NASA GSFC







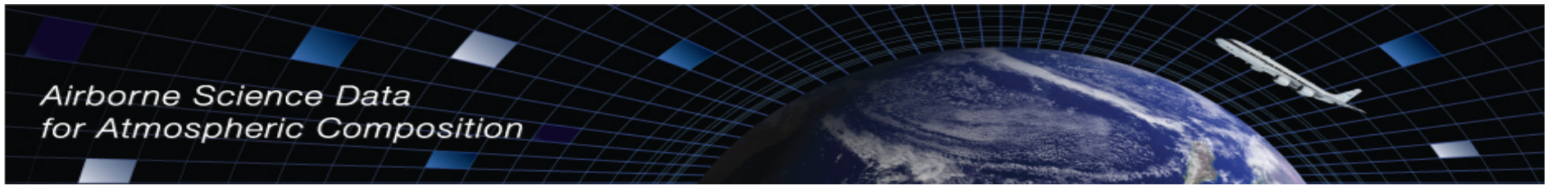


Data retrieved at approx. 250m x 250m horizontal resolution

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

https://www-air.larc.nasa.gov/missions/lmos/index.html

+ HOME | + MISSIONS | + DATA | + TOOLS | + ABOUT US



LMOS – Lake Michigan Ozone Study 2017

Data Archive: LMOS 2017 ArcView

Relevant Data / Links

Quicklook Reports :
View / Upload Images & Data --
Aircraft, Ground, Mobile, etc.

File Sharing [private] :
Forecasts, etc.

Forecast Products . . .
Meteorology Links . . .

AirNow

ICARTT Data Format Document

Data Upload Tools

Steps for submitting data to the Archive

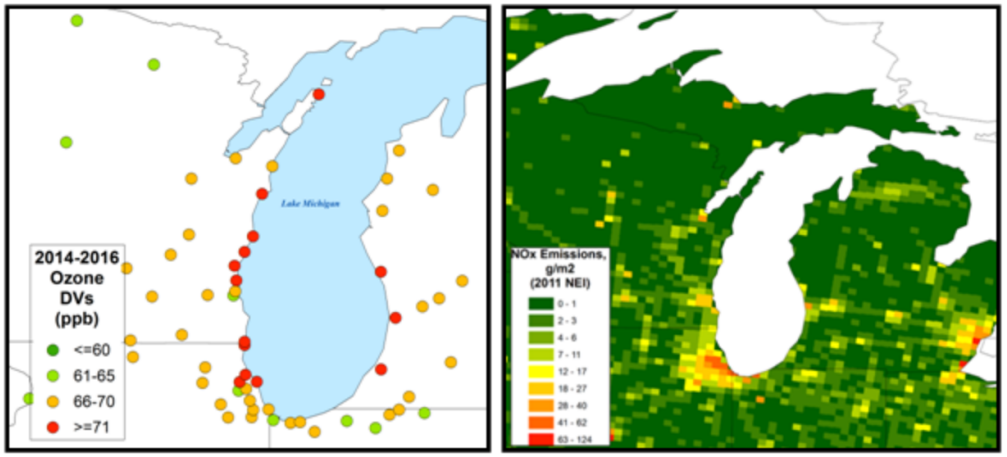
- Data Submittal / Scanning ICARTT File Scanning Submittal FSc
  - » Help FScan
- Register PI datalDs

Useful Tools

Download HDFView -- visual tool for

Mission Overview:

Elevated spring and summertime ozone levels remain an air quality challenge along the coast of Lake Michigan, with a number of monitors exceeding the 2015 National Ambient Air Quality Standards (NAAQS) for ozone. Production of ozone over Lake Michigan combined with onshore daytime "lake breeze" airflow is thought to increase ozone concentrations preferentially at locations within a few kilometers of the shore. This observed lake-shore ozone gradient motivated the Lake Michigan Ozone Study (LMOS) 2017 during May and June 2017.



Ozone Design Values (DVs) for 2014-2016 in ppb (left) and NEI 2011 NOx area emissions in g/m2 (right). DVs greater than or equal to 71ppbv (red) exceed the 2015 NAAQS for ozone and are primarily found around the shore of Lake Michigan in this region.

LMOS Measurement Suite

UW SSEC SPARC Trailer (HALO Wind Lidar, AERI T/Q profiles, HSRL aerosol extinction, CIMEL aerosol optical depth)

EPA Pandora (Column NO_2, O_3, CH_2O), *in situ* (O_3, NOx, CH_2O)

NOAA Ship (EPA Pandora, ceilometer, *in situ* O_3 and NO_2

EPA Geospatial Measurement of Air Pollution (GMAP) mobile van (O_3)

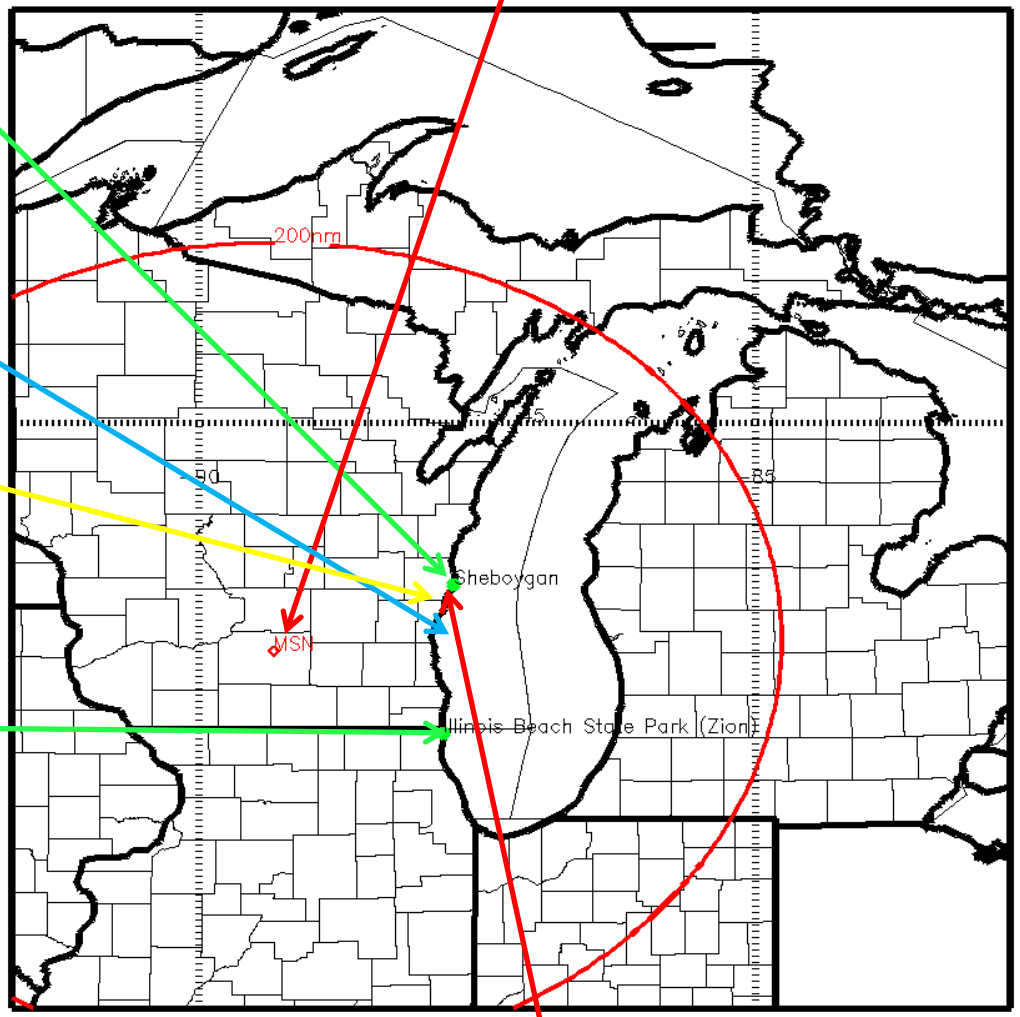
UNI Microwave Radiometer T/Q profiles, SoDAR winds

EPA Pandora (Column NO_2, O_3)

In situ super site (UW-Madison/ UofM NOy/VOC, U-Iowa Aerosol)

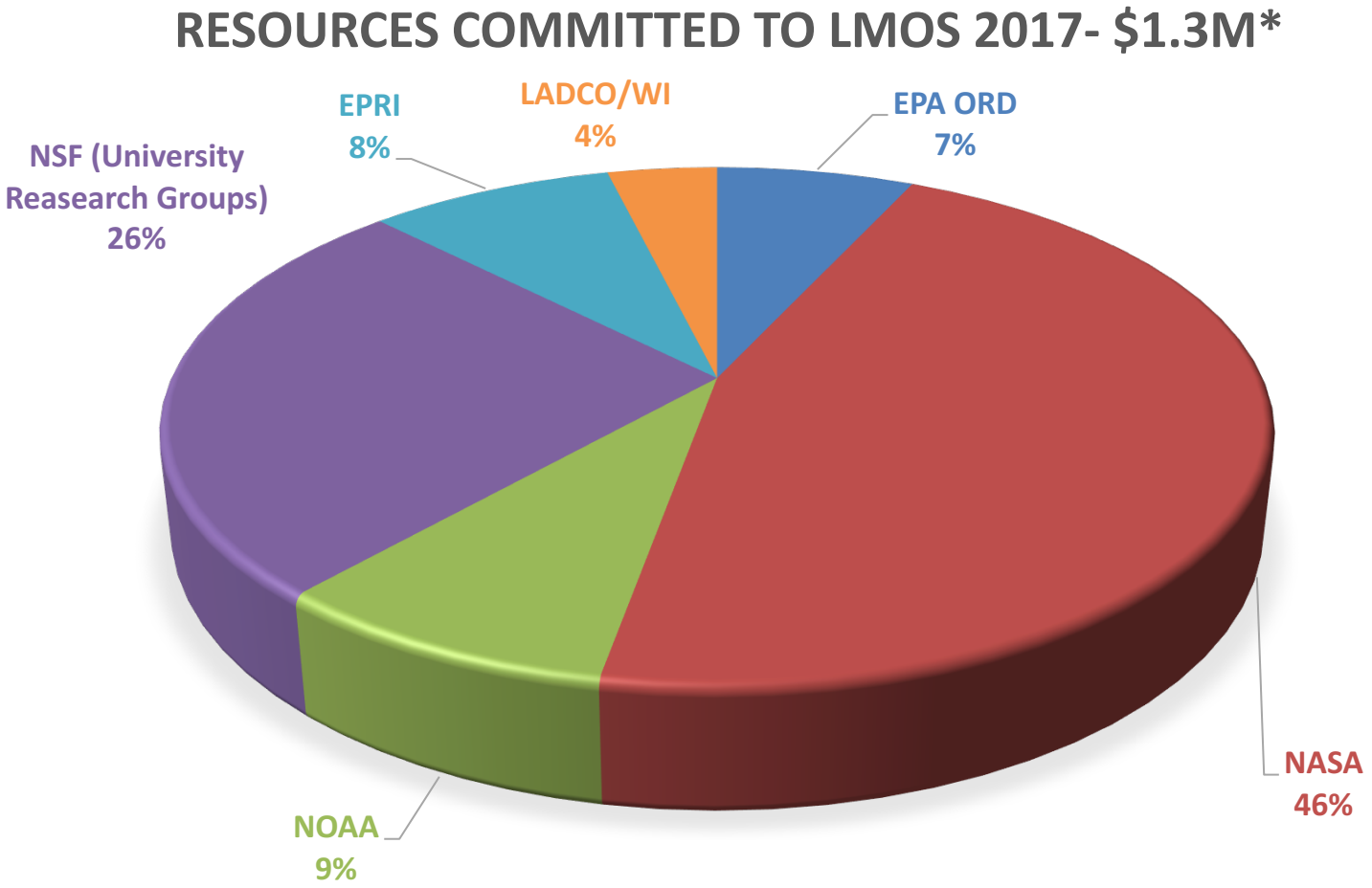
White Paper: http://www.ladco.org/

NASA airborne column NO_2, CH_2O, O_3, aerosols (GeoTASO Airborne UV-VIS Spectrometer, AirHARP Polarimeter)



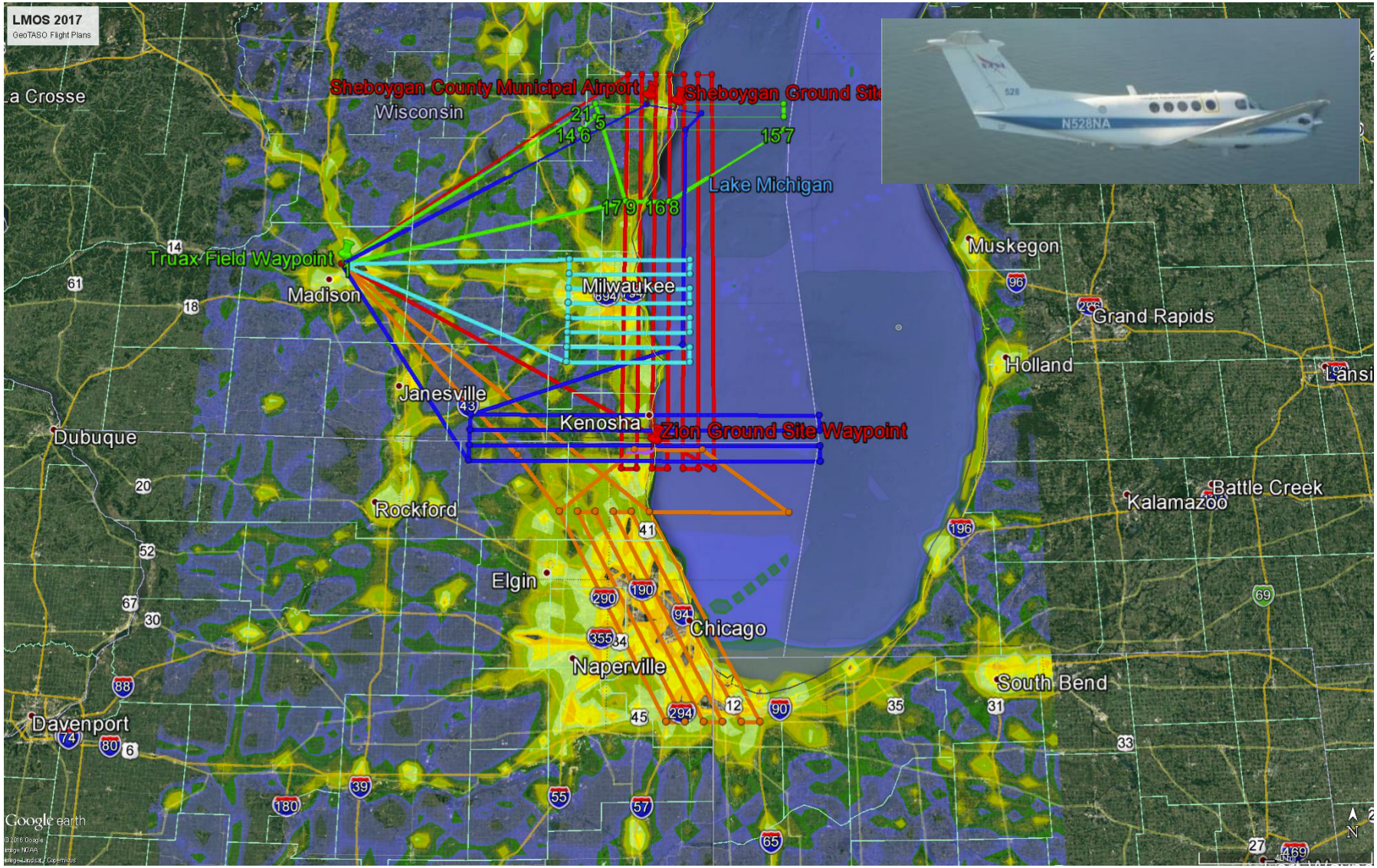
Scientific Aviation/EPRI *in situ* O_3, NO_2, T, q, wind

Leveraged Resources

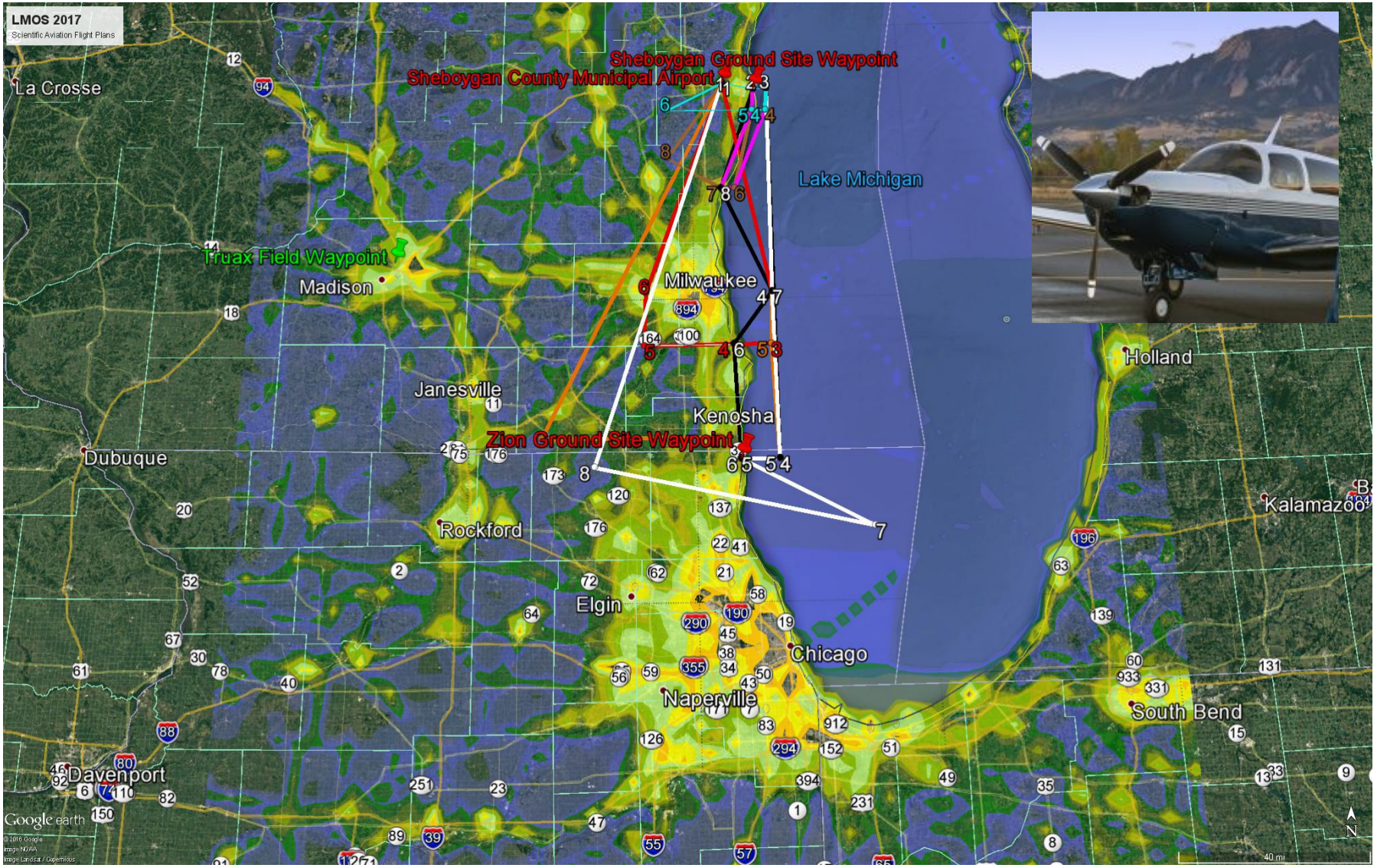


*Does not include FTE or travel cost from participating Federal Agencies.

All Planned LMOS 2017 NASA GeoTASO Flights with NEI 2011 NOx emissions



All Planned LMOS 2017 Scientific Aviation Flights with NEI 2011 NOx emissions



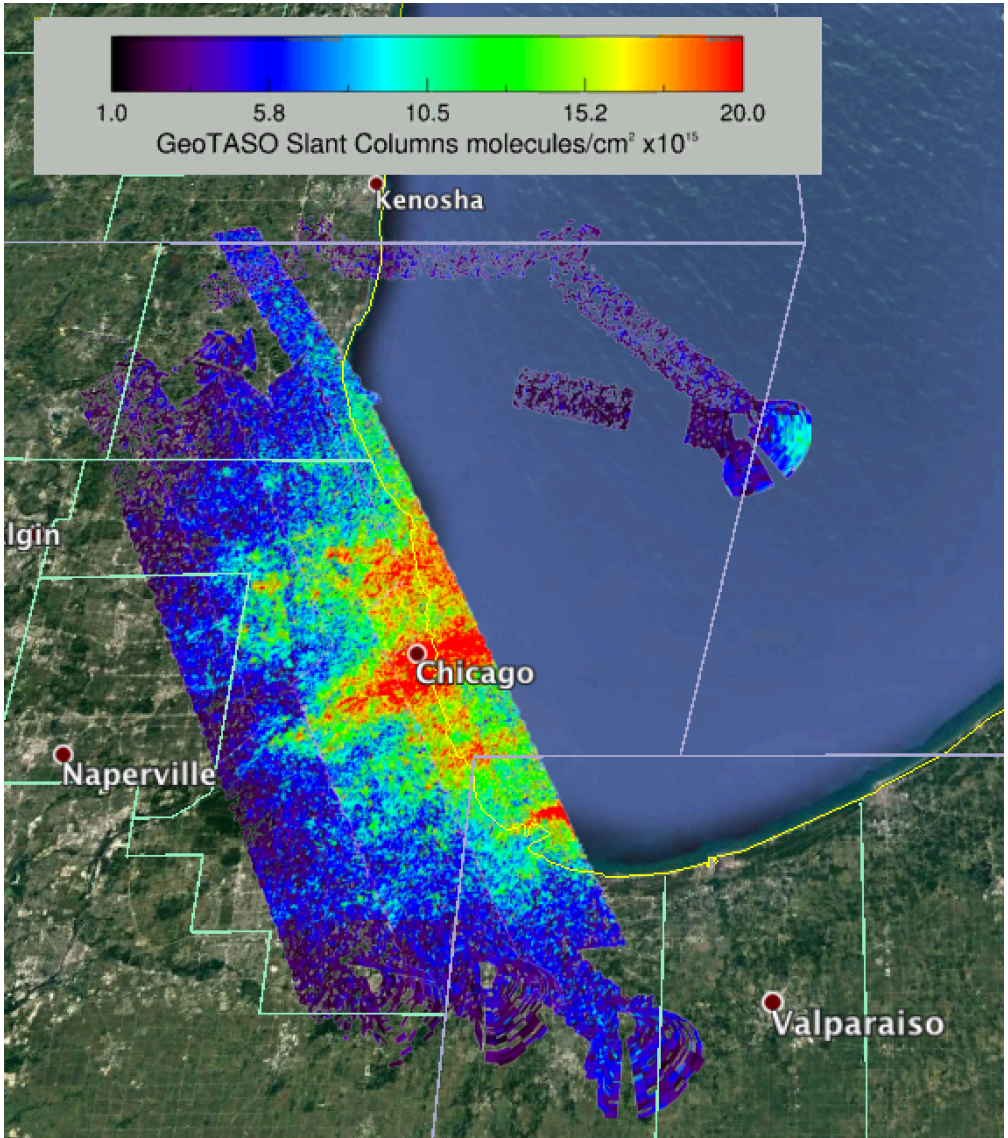
Air quality & Ocean color from space
GEO-CAPE

5/22/17 Quick-look GeoTASO NO_2 Differential Slant Columns

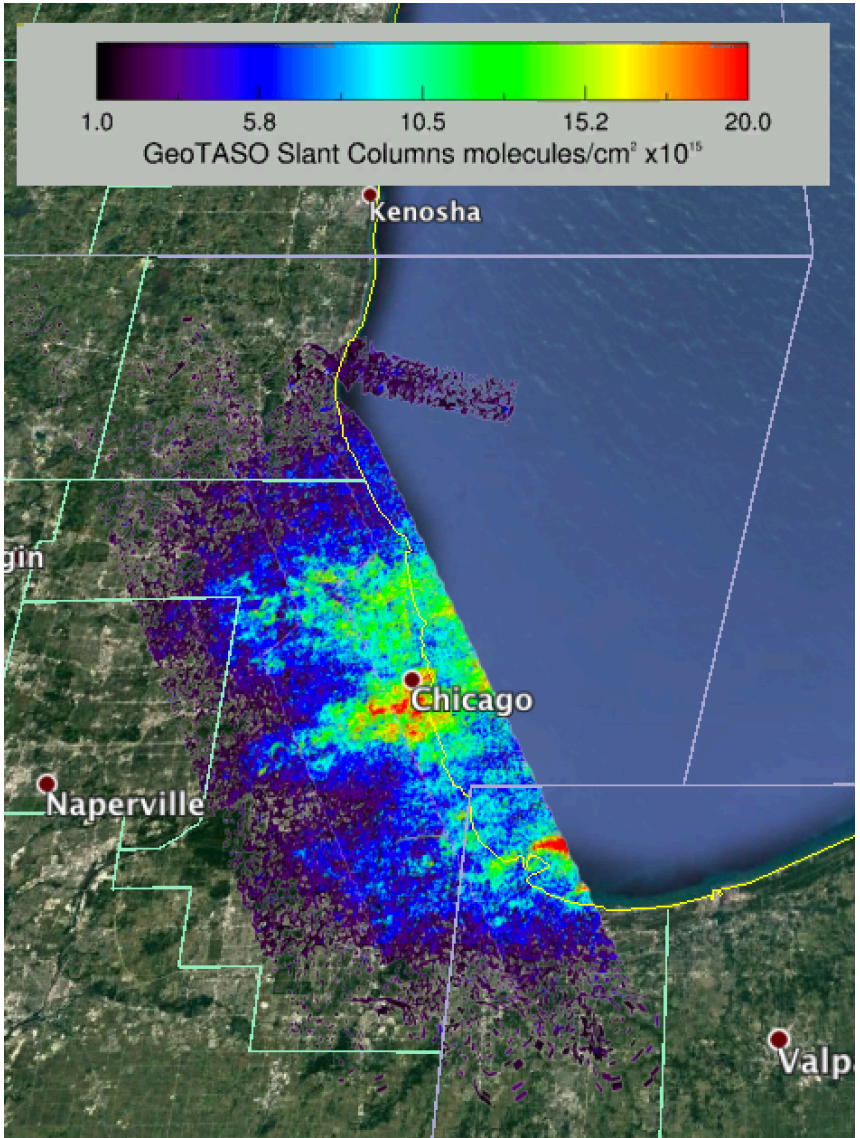
(courtesy Laura Judd, Scott Janz, Matt Kowalewski)

NASA

12.5-14.5Z (7:30-9:30 AM CDT)



14.5-16.5Z (9:30-11:30 AM CDT)



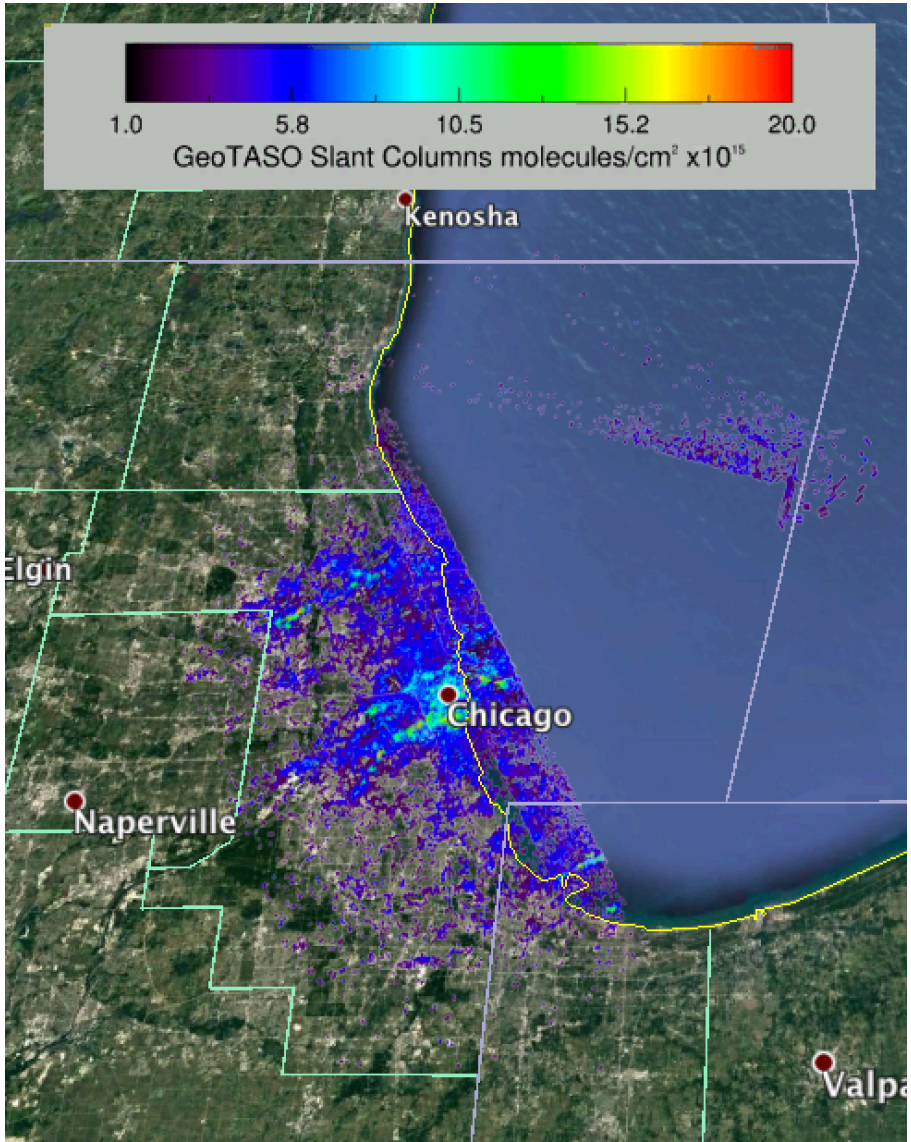
Air quality & Ocean color from space
GEO-CAPE

5/22/17 Quick-look GeoTASO NO_2 Differential Slant Columns

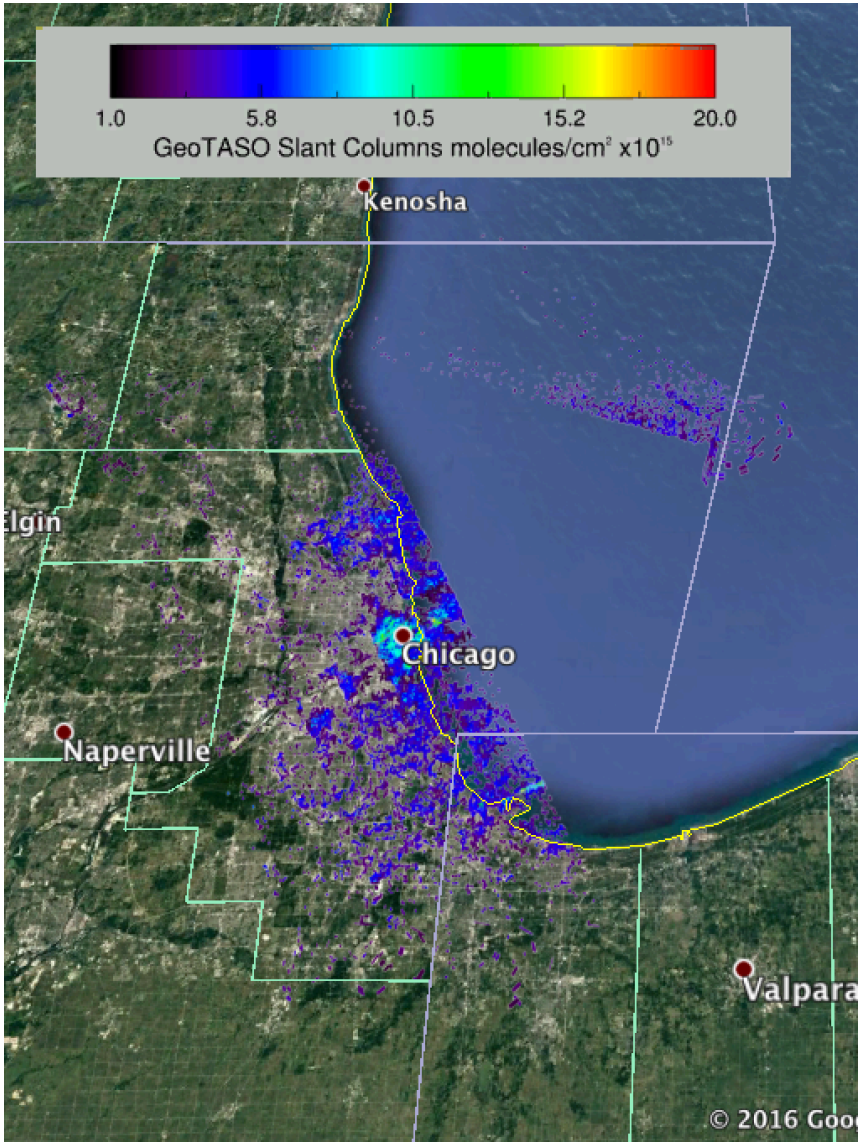
(courtesy Laura Judd, Scott Janz, Matt Kowalewski)

NASA

17.5-20Z (12:30 PM-3:00 PM CDT)

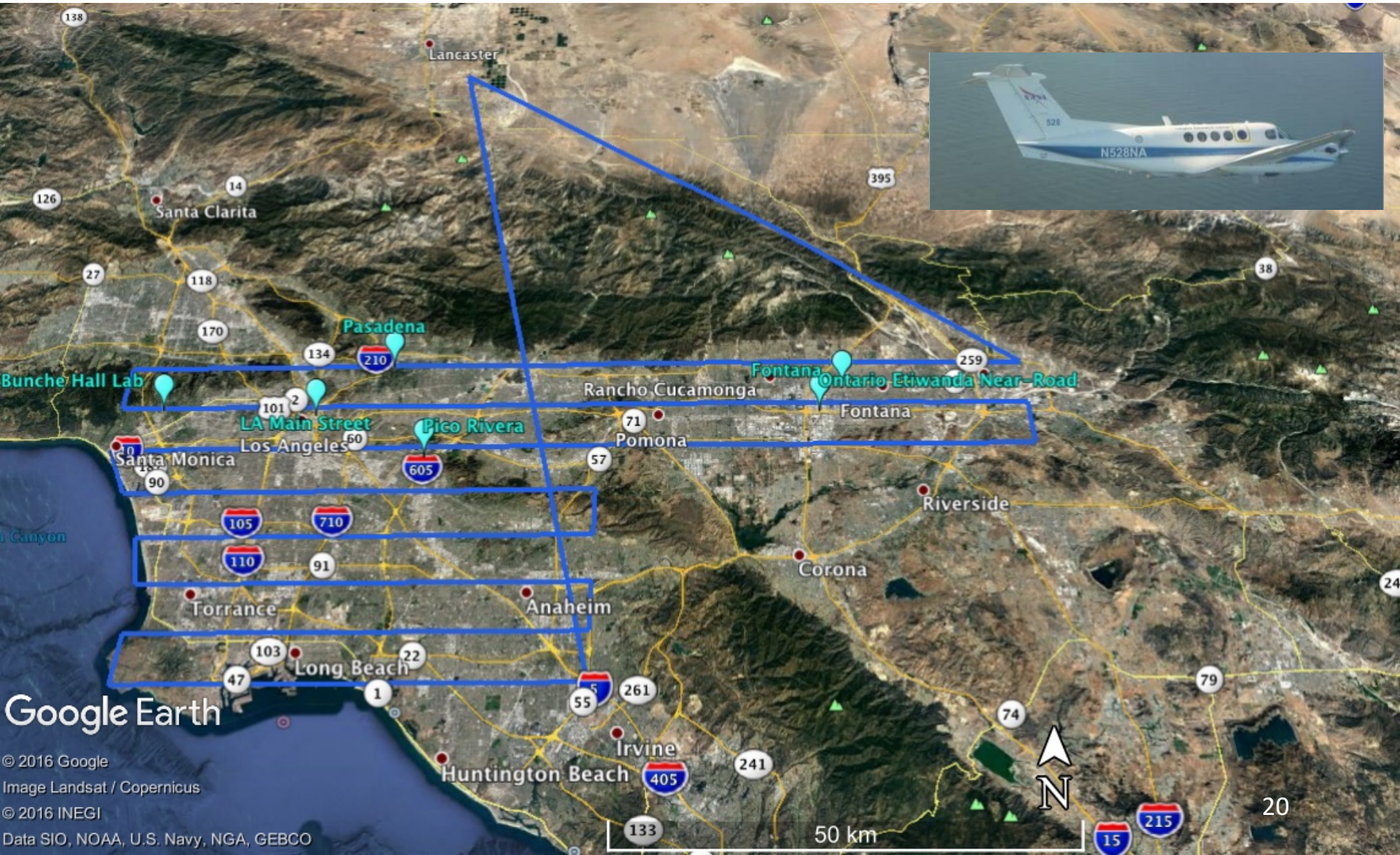


19.5-21.5Z (2:30-4:30 PM CDT)



Planned mapping of LA Basin in June 2017 as part of SARP

- Plan to repeat this sampling pattern 3 times in 1 day for 2 consecutive days
- Blue pins show SC AQMD sites with 1-minute NO_2 and planned Pandora spectrometers



Summary

1. DISCOVER-AQ and KORUS-AQ have collected datasets 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. (Also true of O_3 and CH_2O tropospheric columns.)

4. Airborne column mapping observations are key to understanding spatial representativeness of TEMPO and ground measurements.

5. Accurately accounting for these details is important not only for TEMPO validation but also essential for the science and applications of TEMPO.

How do we sustain these airborne activities?

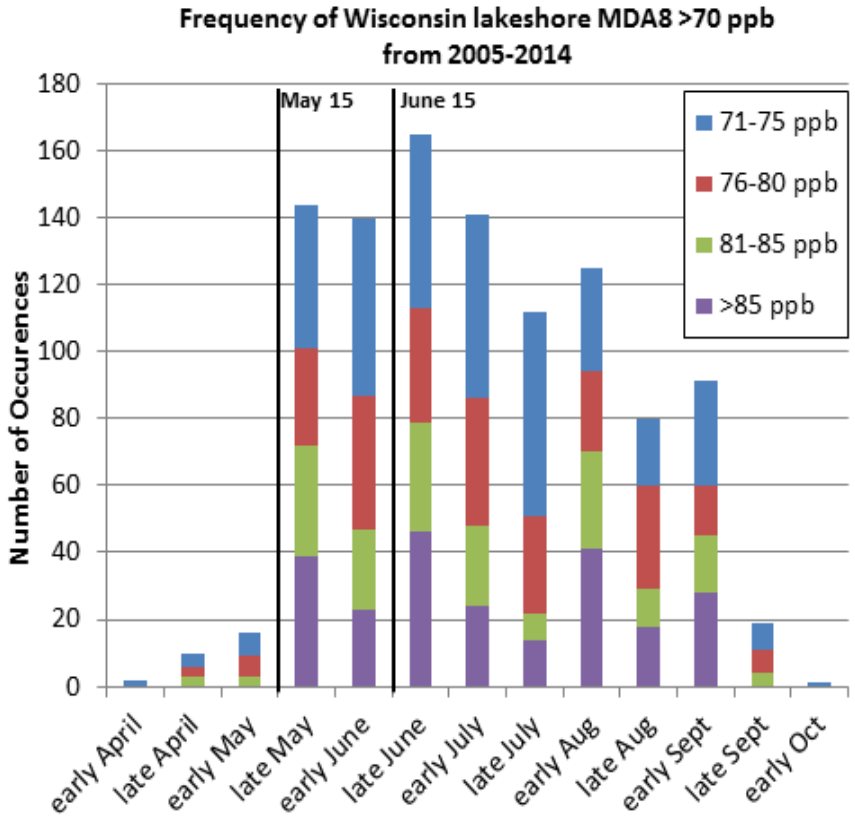
- **Build advocacy: field campaign concepts typically start as grass-roots efforts leading to development of white papers and nucleation**
- **Partner, partner, partner. With any and all stakeholders. International, federal, state, local, non-profit, private, ...**
  - **Partnering was crucial to all the examples shown in this talk**
  - **Studies related to TEMPO observations are a logical priority for various science, monitoring, and forecasting programs, especially post-launch**
  - **Consider TEMPO funding to seed future campaigns**
- **Develop flexible campaign options, from comprehensive (e.g. DISCOVER-AQ, KORUS-AQ, est. $5M-$6M per campaign per year) to very focused (e.g. LMOS, SARP, est. $1M-2M per campaign)**
- **Pursue all funding options, including proposal opportunities; don't rely on directed funding**

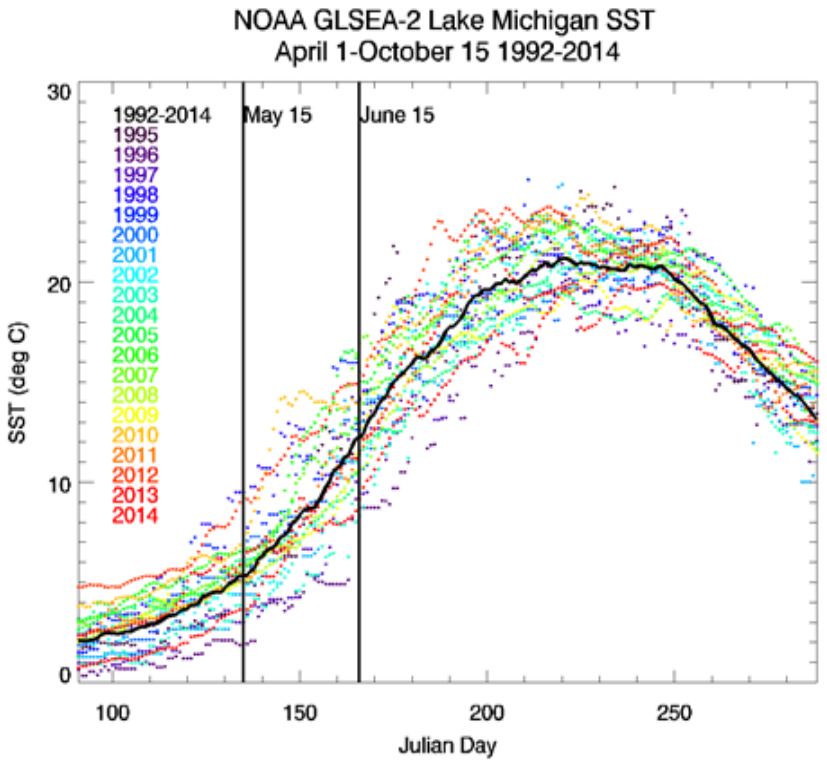
Fusion of TEMPO data with airborne and ground based measurements and models will be critical for bringing an integrated AQ observing system for North America into reality

BACKUP SLIDES

Lake Michigan Ozone Study (LMOS) 2017

Campaign Study Period May 22- June 22, 2017





Primary science objectives focusing on characterizing the recirculation, aging, and mixing of the Chicago and Milwaukee urban plumes as they move over Lake Michigan and their impact on surface ozone.

White Paper: http://www.ladco.org/

Flight #	Flight Name	Objective	Duration	Frequency
SA1/GT1	Sheboygan to Zion	Zion to Sheboygan coastal survey with onshore and offshore profiling	GT: 1507km SA: 182nm (5hrs)	2 flights GT/SA once a day One early in the mission One during ozone event
SA2/GT2	Chicago (two GT circuits)	Chicago emissions with background and offshore profiling	GT: 1580 km SA: 248nm (5.4hrs)	4 flights (Two days, weekday and weekend), SA once a day GT twice a day
SA3/GT3c	Sheboygan inland (three GT circuits)	Sheboygan survey with background, onshore and offshore profiling	GT:1306km SA: 47nm (3.6hrs)	4 (3) flights (2 days) SA twice a day GT twice a day
SA5/GT3c	Sheboygan coastal (three GT circuits)	Sheboygan/Port Washington survey with onshore and offshore profiling	GT: 1306km SA: 64nm (4.3hrs)	4 (3) flights (2 days) SA twice a day GT twice a day
SA6/GT5	Zion (two GT circuits)	Zion survey with background, onshore and offshore profiling	GT: 1583km SA: 215nm (5.3hrs)	8 (6) flights (4 days) SA twice a day GT twice a day
SA7/GT4	Milwaukee (three GT circuits)	Milwaukee emissions with background and offshore profiling	GT: 1552km SA: 139nm (4.8hrs)	2 flights (1 day, diurnal sampling weekday) Non forecast ozone day SA twice a day GT twice a day

Notes:

- Currently have 24 GT flights, budget for 22, need to balance Zion (8) and Sheboygan (4+4) at 6&8 or 8&6
- Currently have 22 SA flights
- SA Flights total 83.2 flight hours, have confirmed that flights longer than 4 hours can be flown twice per day