U.S. Environmental Protection Agency participation in DISCOVER-AQ Augmentation of Surface NO_2 Monitors

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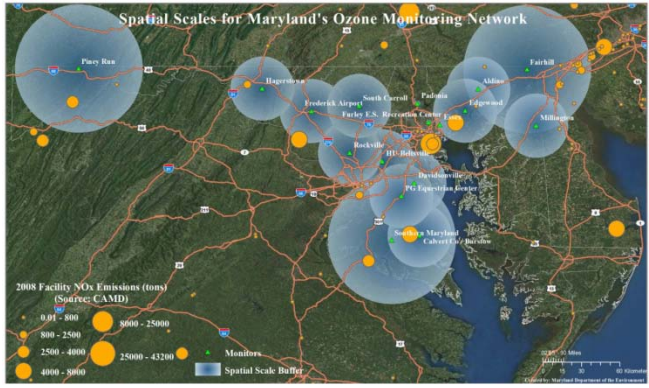


DISCOVER-AQ Science Team Meeting
October 5-7, 2010
National Institute for Aerospace
Hampton, VA

Motivation

- EPA's research directions are N focused, now more than ever
- The Laboratory always interested in advancing remote sensing methods to meet our information needs
- Air Quality modeling a EPA needs better emission estimates

Methods

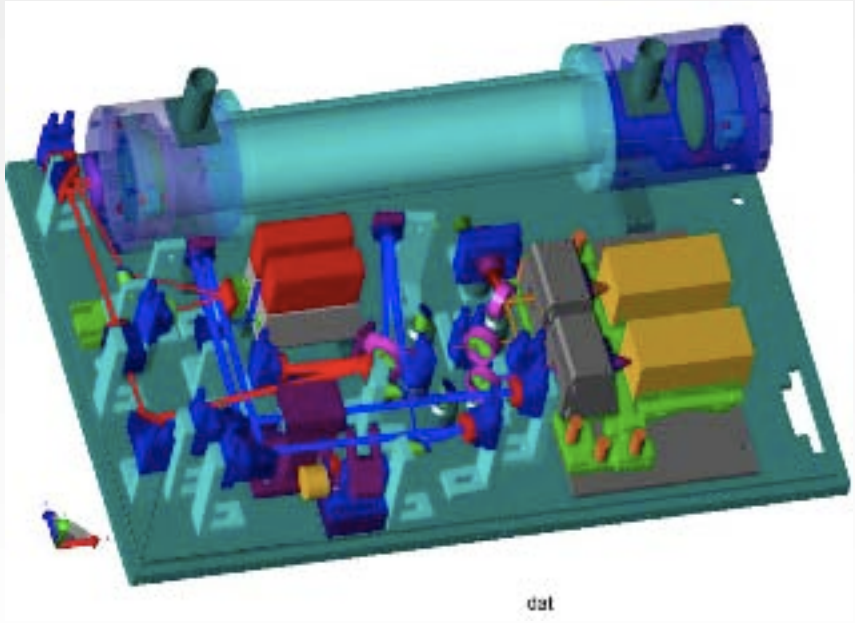
- Discussion of:
  - Trace gas spectrometer (QCL based system)
  - Mobile NO_2 Observatory
  - Fixed NO_2 Monitors
  - Proposed data collection
  - Overview of NASA Cessna 206 w/ EPA instruments for ocean color

Trace Gas Spectrometer

- Based on quantum cascade laser technologies
- Dual laser system uses single 200 m pathlength cell. Atmospheric sampling at a pressure of 30-60 Torr
- Compact, rugged, and operates at room temperatures
- Continuous wave laser operates at 6.25 μm or 1600 cm^{-1} .
  - Limit of Detection (2 σ): 30 ppt at 1 sec, 5 ppt at 100 sec average time. Precision: < 10 ppt $Hz^{-1/2}$
- combined with a 500 liter/minute oil-less scroll vacuum pump provides a time response (1/e) of less than 0.3 seconds
- System being built by Aerodyne Research Inc (ARI), Billerica MA

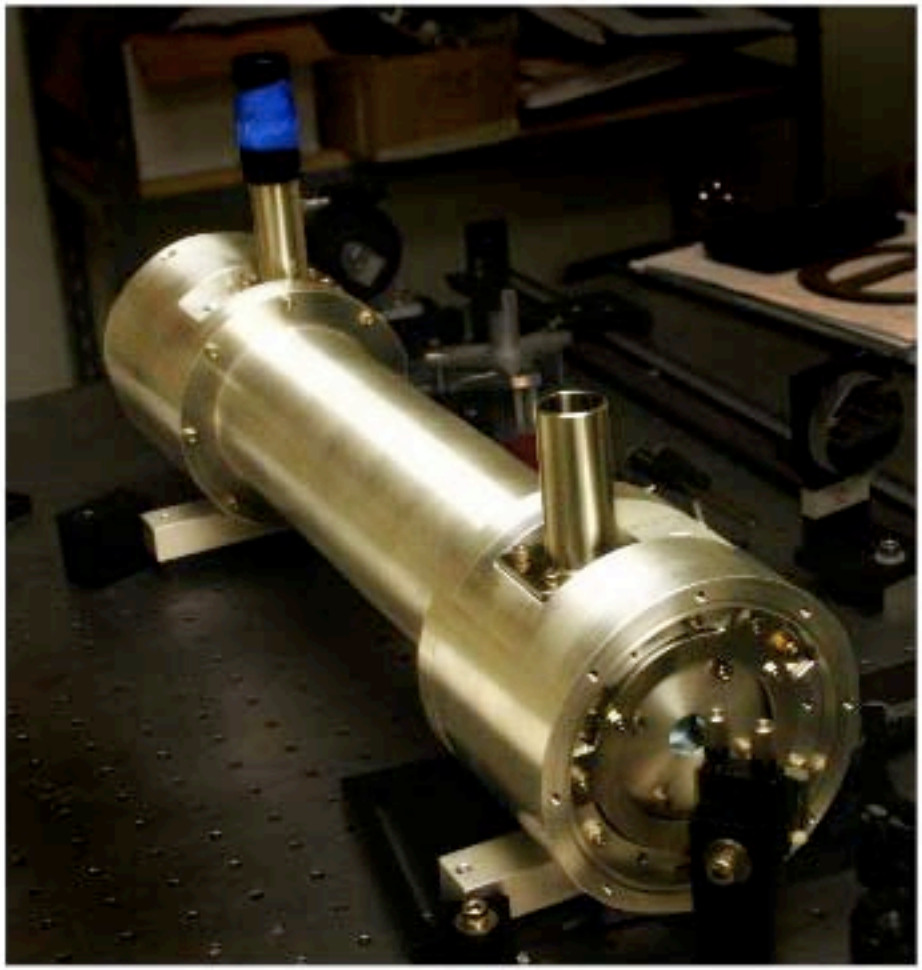
Aerodyne CW-RT QCL Spectrometer

Dual QCL instrument



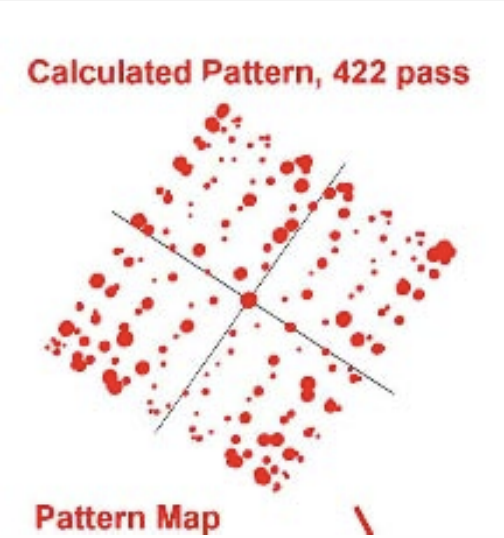
Compact 200 m astigmatic cell

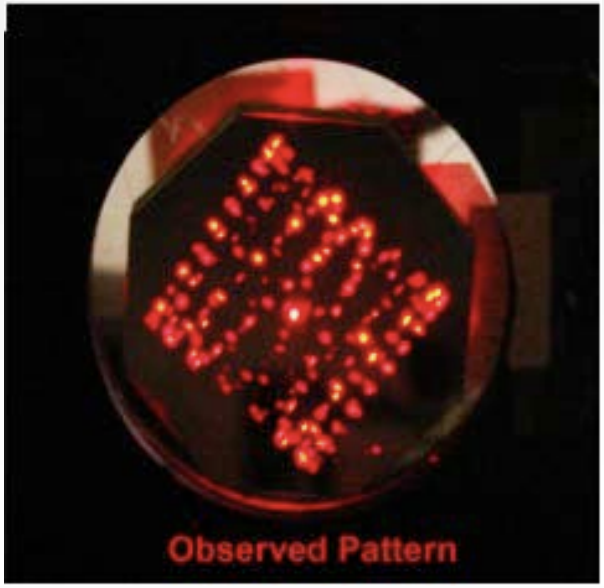
Path Length:	200.16 m
Base Length:	0.474 m
Passes:	422
Mirror Diameter:	78 mm
Volume:	2.16 liter
Overall Length:	0.584 m



Astigmatic Multipass Cells

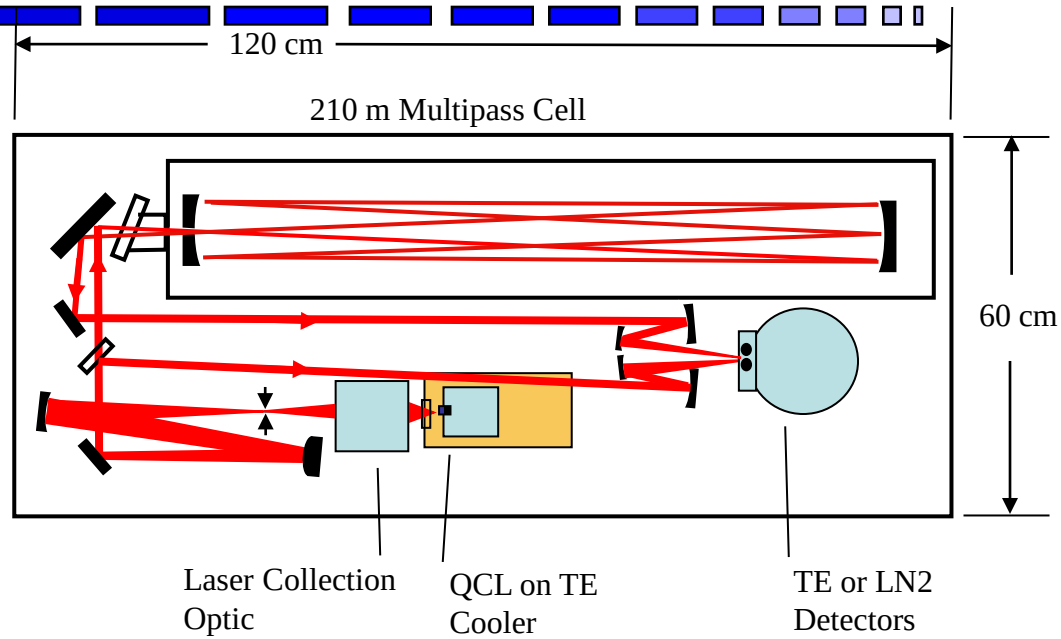
- Astigmatic mirrors in an off-axis resonator produce mirror filling recirculation patterns with high pass number (>400), in low volumes (e.g. 200 m in 2.16 Liter), with controllable pass number.



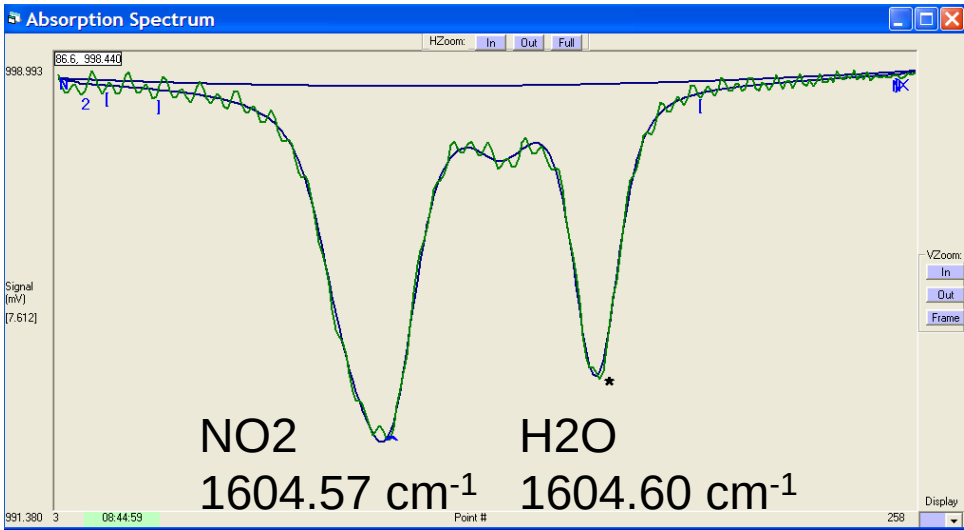


OPTICAL SYSTEM FOR HIGH SENSTIVITY DETECTION USING CWRT QCLs

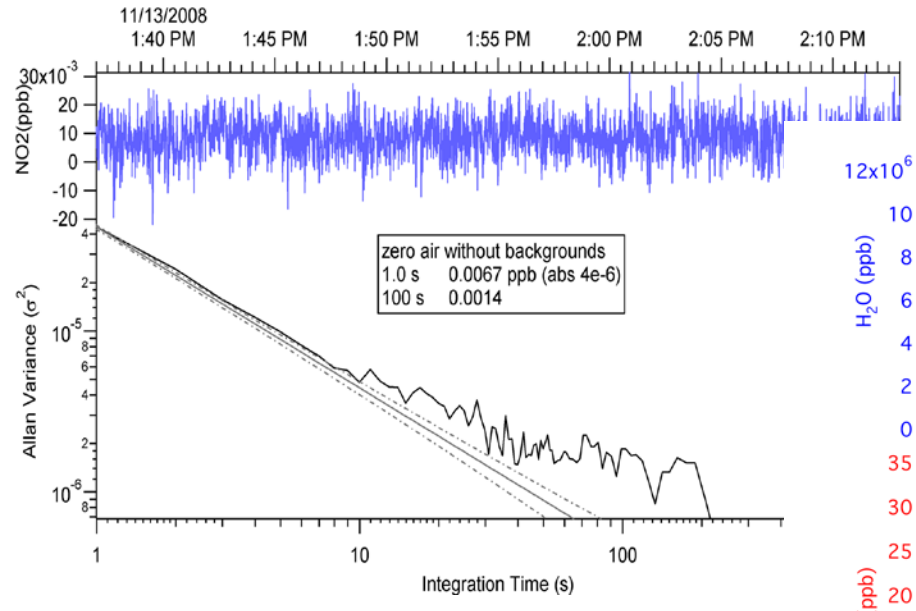
- 210 m Sample path
- Normalization path
- Reference path for line-lock
- Direct absorption
- Sweep integration
  - Sweep rate 3 kHz
  - Digitization rate 1 MHz
- ILX-Lightwave Driver
- Thermal stabilization of optics

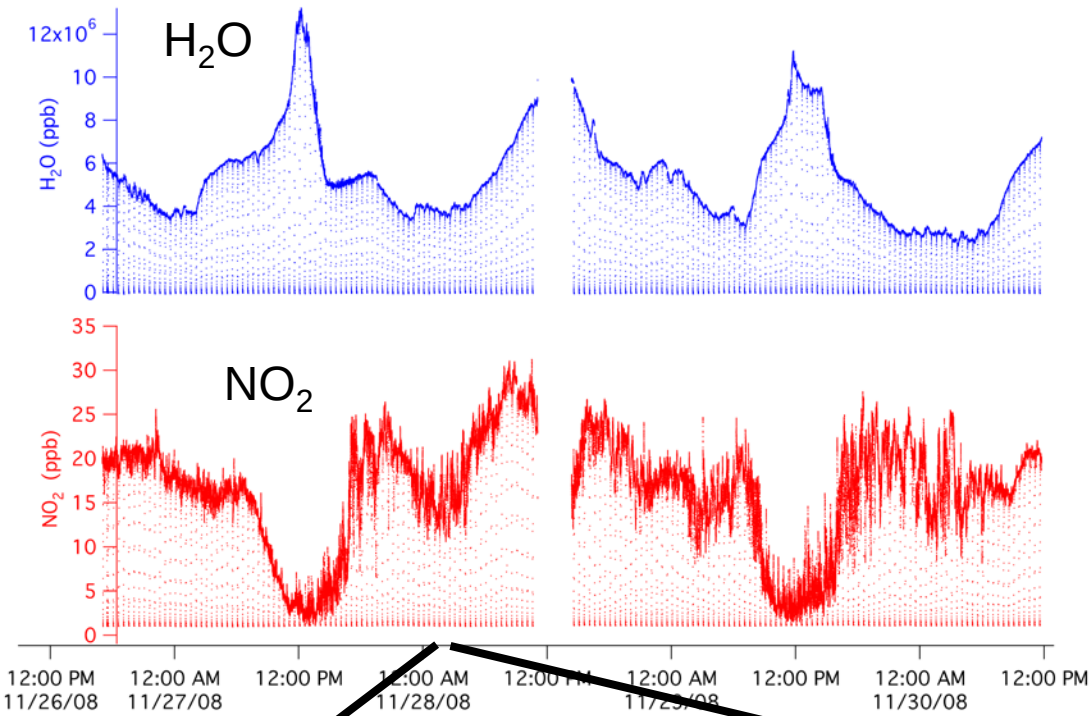


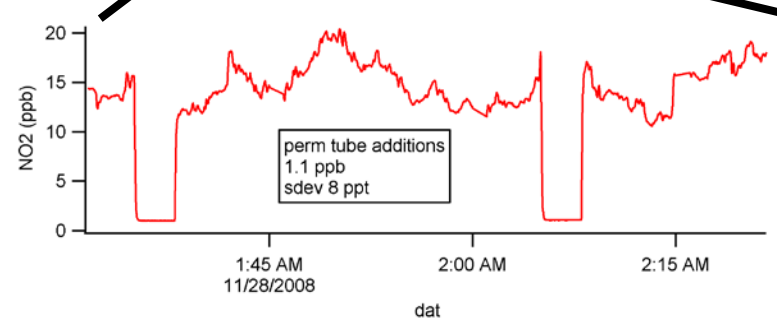
NO_2 10 ppb
Pressure 35 Torr
abs peak 5×10^{-3}



NITROGEN DIOXIDE with CW-RT QCL 1604 cm^{-1}



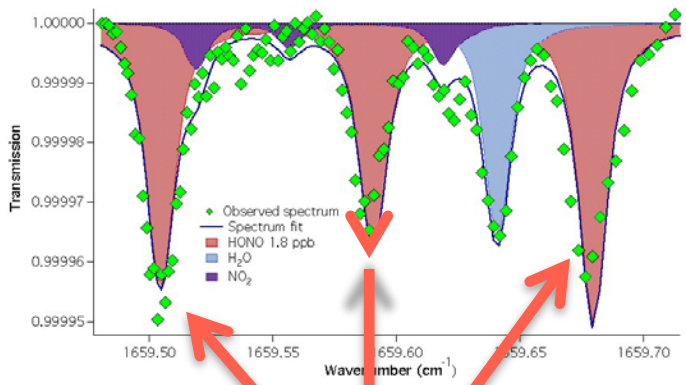




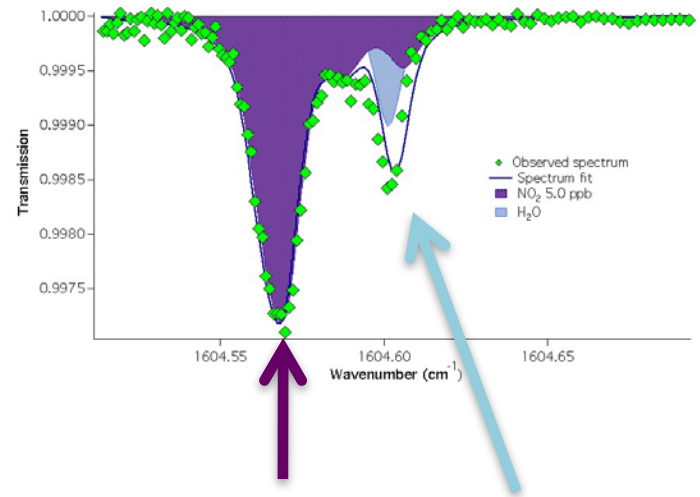
NO_2 precision
7 ppt in 1 s (abs $4x10^{-6}$)
1.4 ppt in 100 s
abs $8x10^{-7}$ (210 m, 35 Torr)
abs/cm $4x10^{-11}$ cm^{-1}
$2x10^{6}$ molecules cm^{-3}

Zahniser et al. SPIE 7222 (2009)

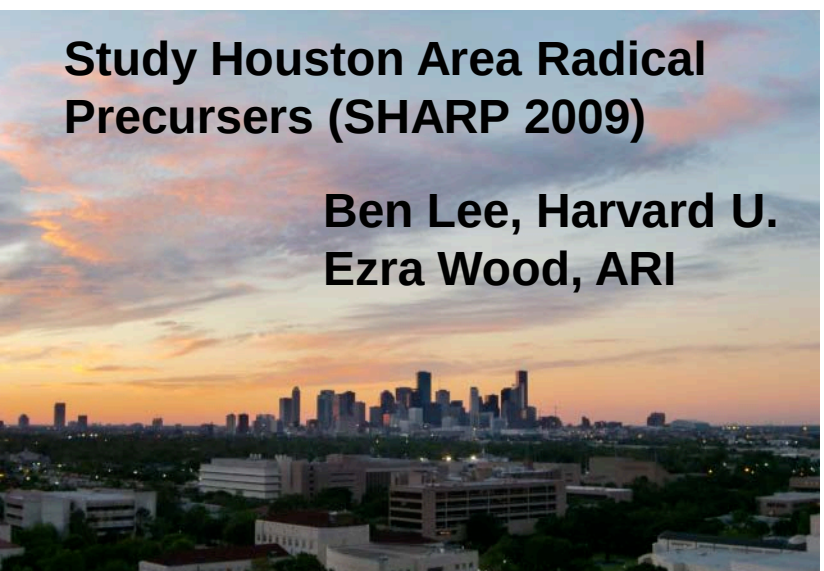
NITROUS ACID (HONO) and NO_2 with CW-RT QCLs



HONO



NO_2 H_2O



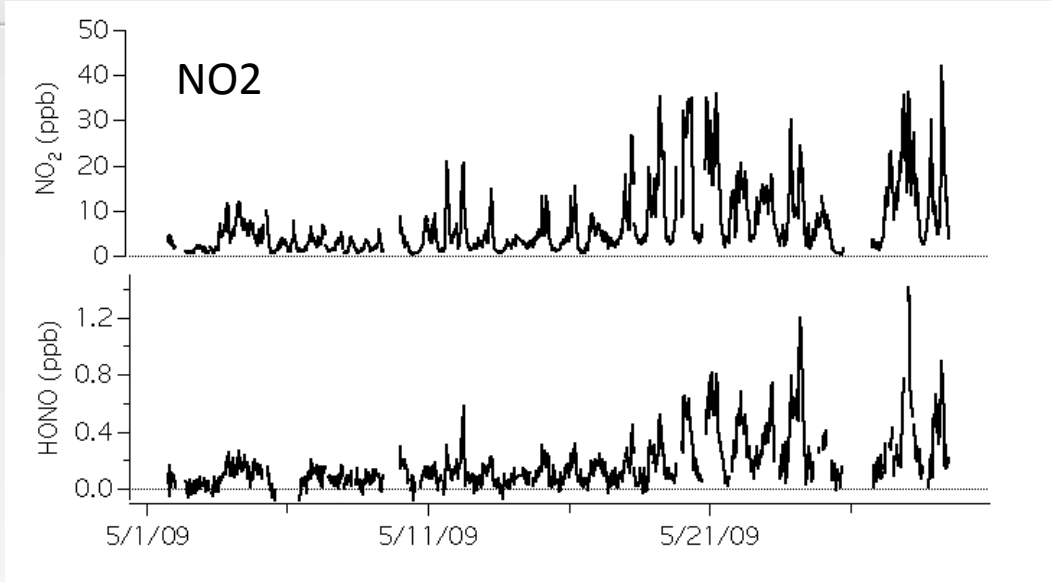
Detection precision (S/N = 1) in 1 s

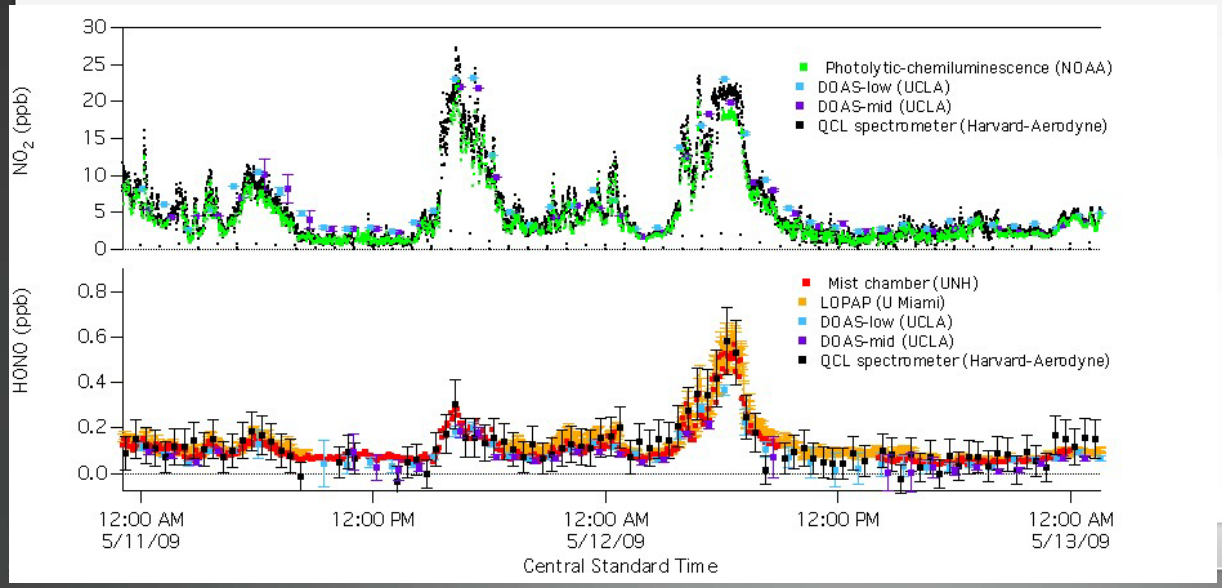
HONO = 120 ppt

NO_2 = 12 ppt

Study of Houston Atmospheric Radical Precursor

April-May '09 - Houston, TX





- Good agreement between different techniques;
- Inter-comparison study by S. Thomas [manuscript in prep].

Mobile NO_2 Observatory

- Towed configuration
  - QCL system mounted in trailer. Towed by SUV
    - Large battery system in trailer runs QCL system. 12 hr run time
  - Operator resides in vehicle
    - Aerodyne system can start up and run autonomously if desired
    - Operator can network to QCL computer wirelessly using VPN connection
    - Data stored on QCL computer
    - GPS will log position

PSN

2010 Chemistry and Physics Atmospheric Boundary Layer Experiment CAPABLE summer intensive (21 June – 6 August 2010)

NASA Langley Research Center: Pandora – NO_2 Column Density; Leosphere Wind Lidar (derived boundary layer height); Sondes – temperature, pressure, H_2O vapor, wind speed, wind direction

VA DEQ: *in situ* CO, NO, NO_2 (molybdenum converter), NOx, O_3, SO_2, $PM_{2.5}$, PM_{10}

EPA: NO_2 (photolytic converter)

Pennsylvania State University: NATIVE – CO, NO, NOy, O_3, SO_2, temperature, pressure, wind speed, wind direction, UV spectra, Jno_2, NO_2 (estimated from NO, O_3, and Jno_2 values); Sondes – O_3, temperature, pressure, relative humidity

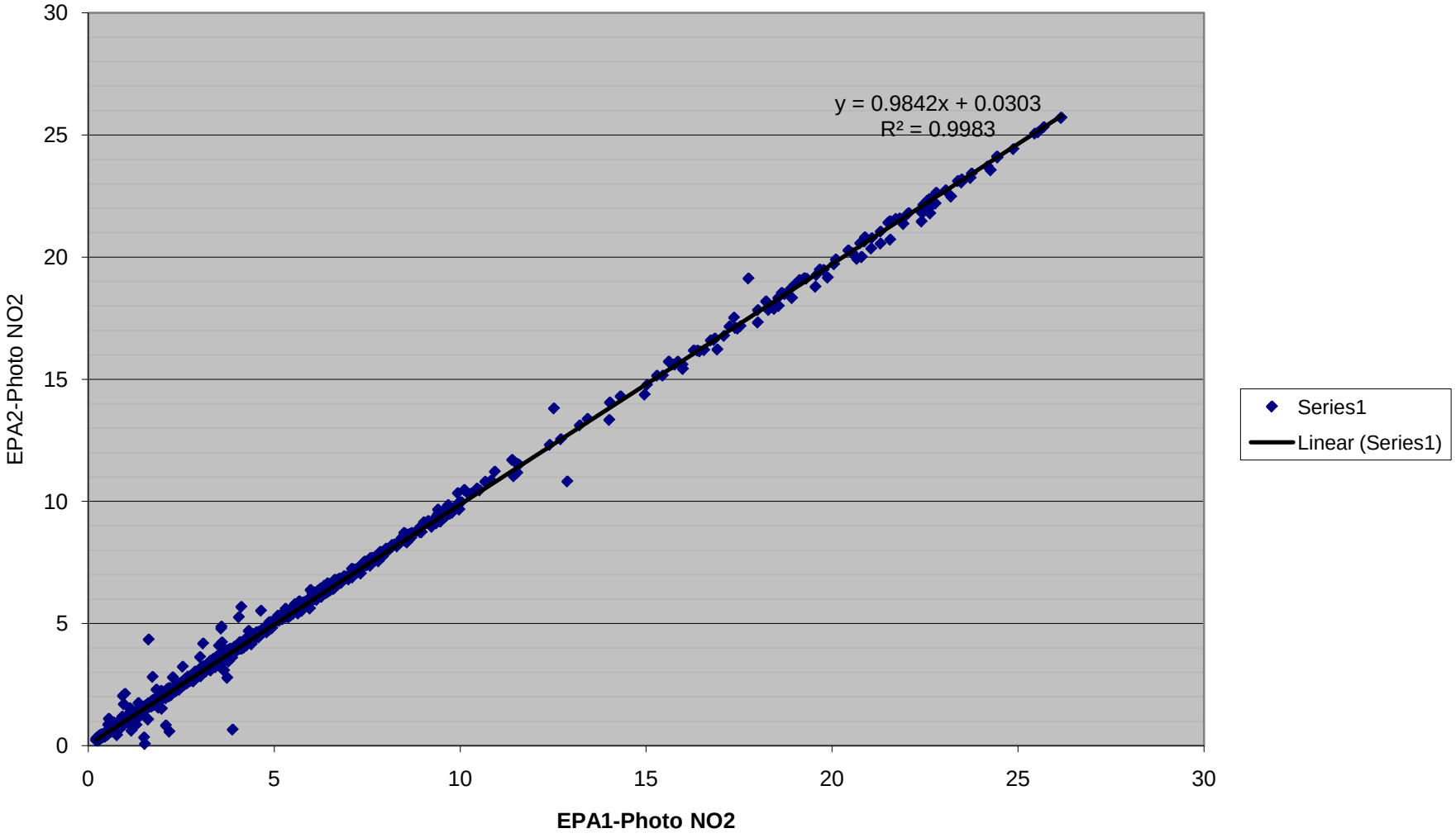
Hampton University: ASSIST (Atmospheric Sounder Spectrometer for Infrared Spectral Technology) – Downwelling atmospheric radiance to profile temperature and moisture (derived boundary layer height); inter-comparison with LaRC NAST-I

NATIVE, CAPABLE and VA DEQ

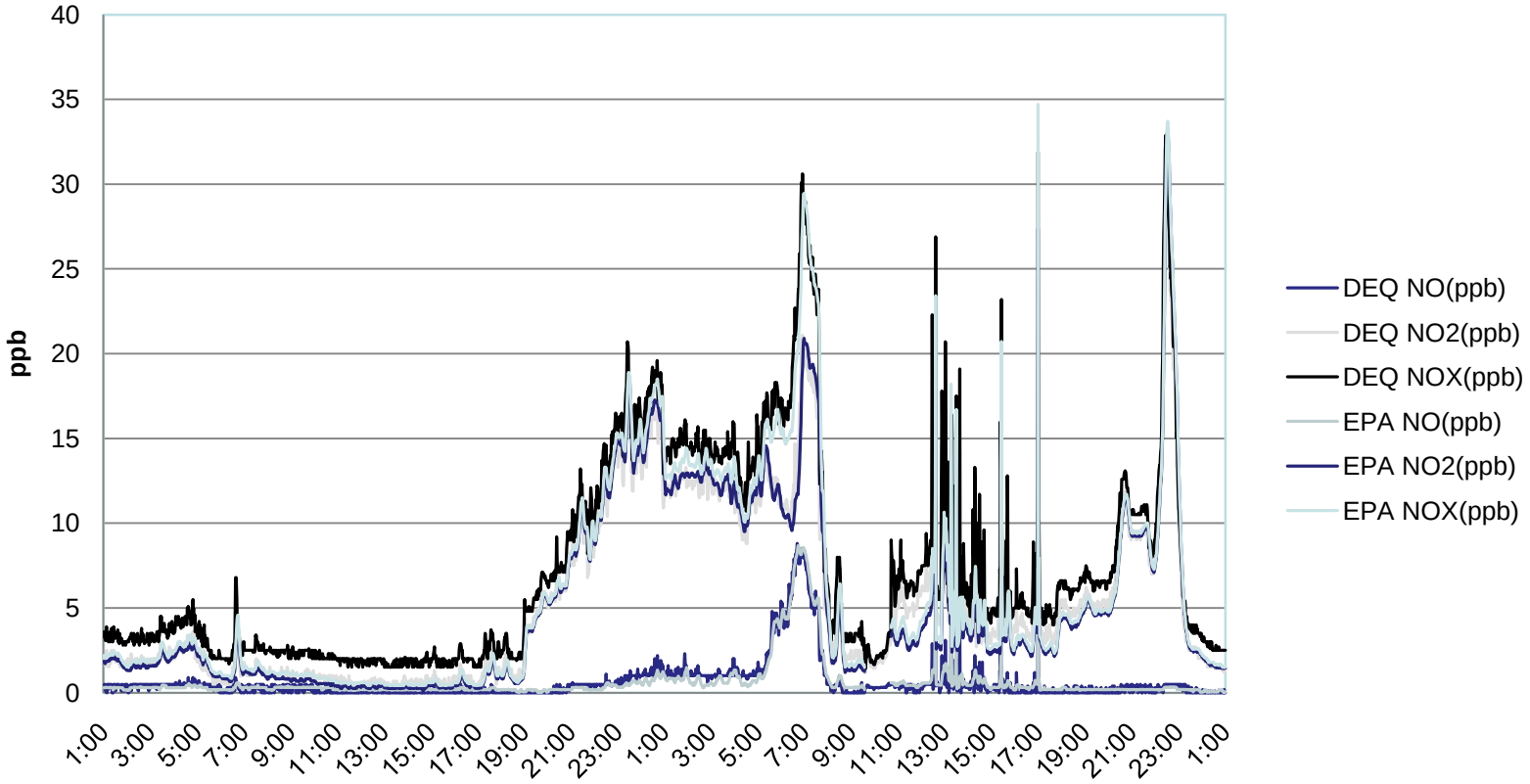
Leosphere, ASSIST and NAST-I

Source: M. Pippin, CAPABLE-PI

Comparison of EPA Photolytic NO2 Instruments
Burden Creek Site, RTP, NC
5 min. avg.

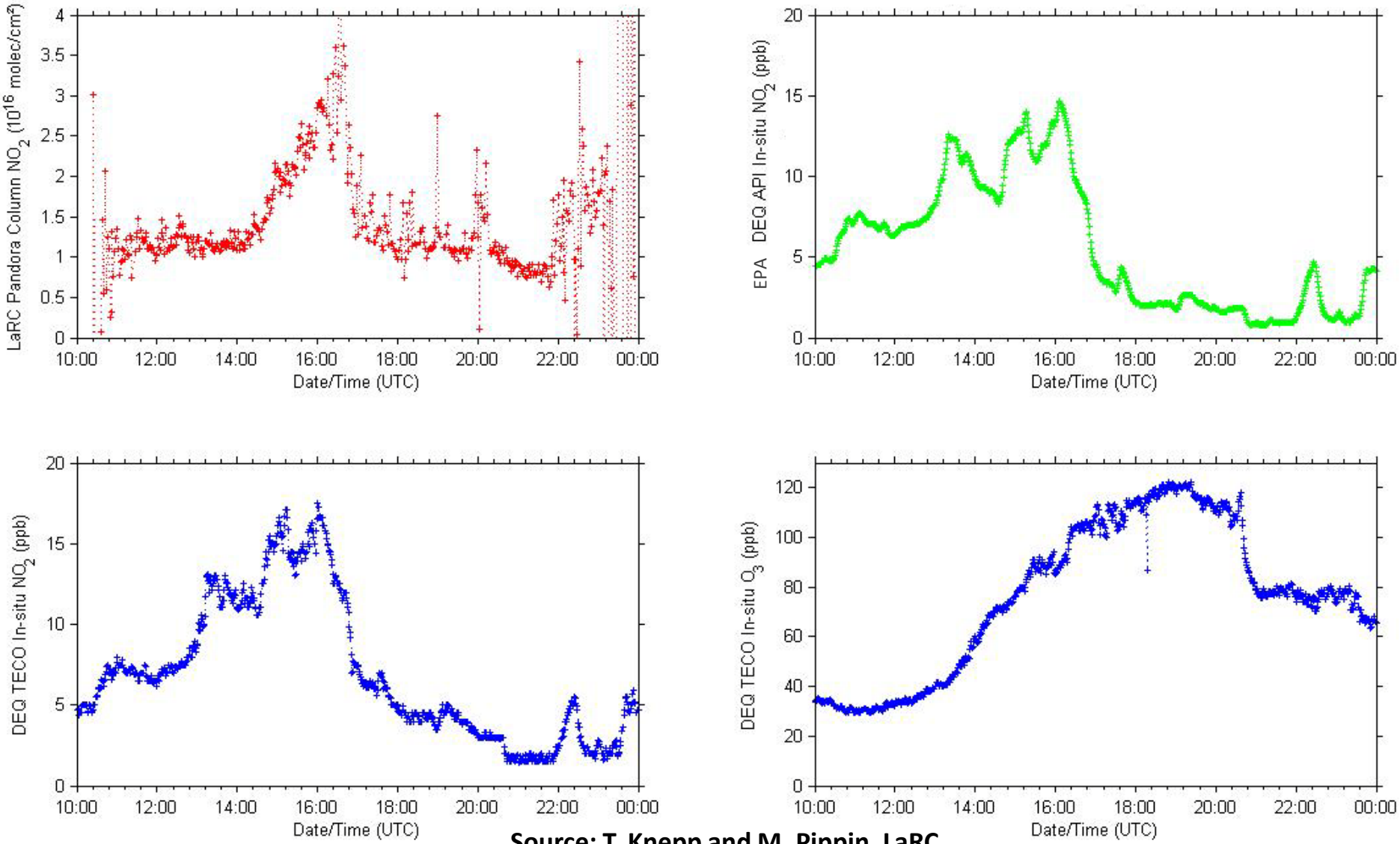


26-27 Jul 2010 (EST)
DEQ Thermo (Moly) NOx vs. EPA API (Photolytic) NOx
NASA Langley Station - Hampton, VA



Summer 2010 CAPABLE Site Preliminary Data
Good Agreement - NO2 Column and In-situ Times Series

11 Aug 2010 LaRC Pandora NO_2, EPA (API) NO_2, DEQ (TECO) NO_2 and O_3

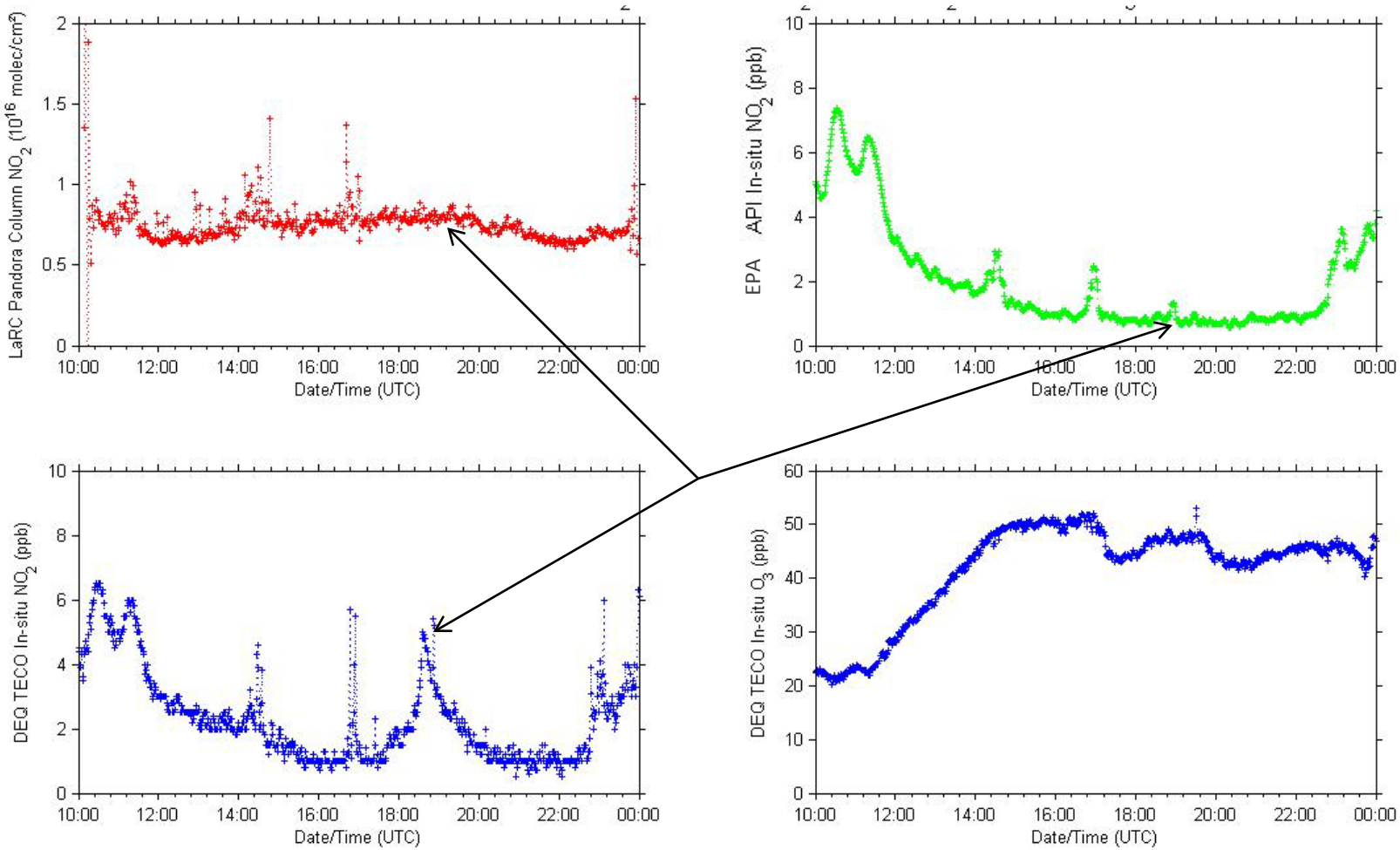


Source: T. Knepp and M. Pippin, LaRC

Summer 2010 CAPABLE Preliminary Data

Potential Conversion of NOy compounds by TECO instrument

24 Jul 2010 LaRC Pandora NO_2, EPA (API) NO_2, DEQ (TECO) NO_2 and O_3

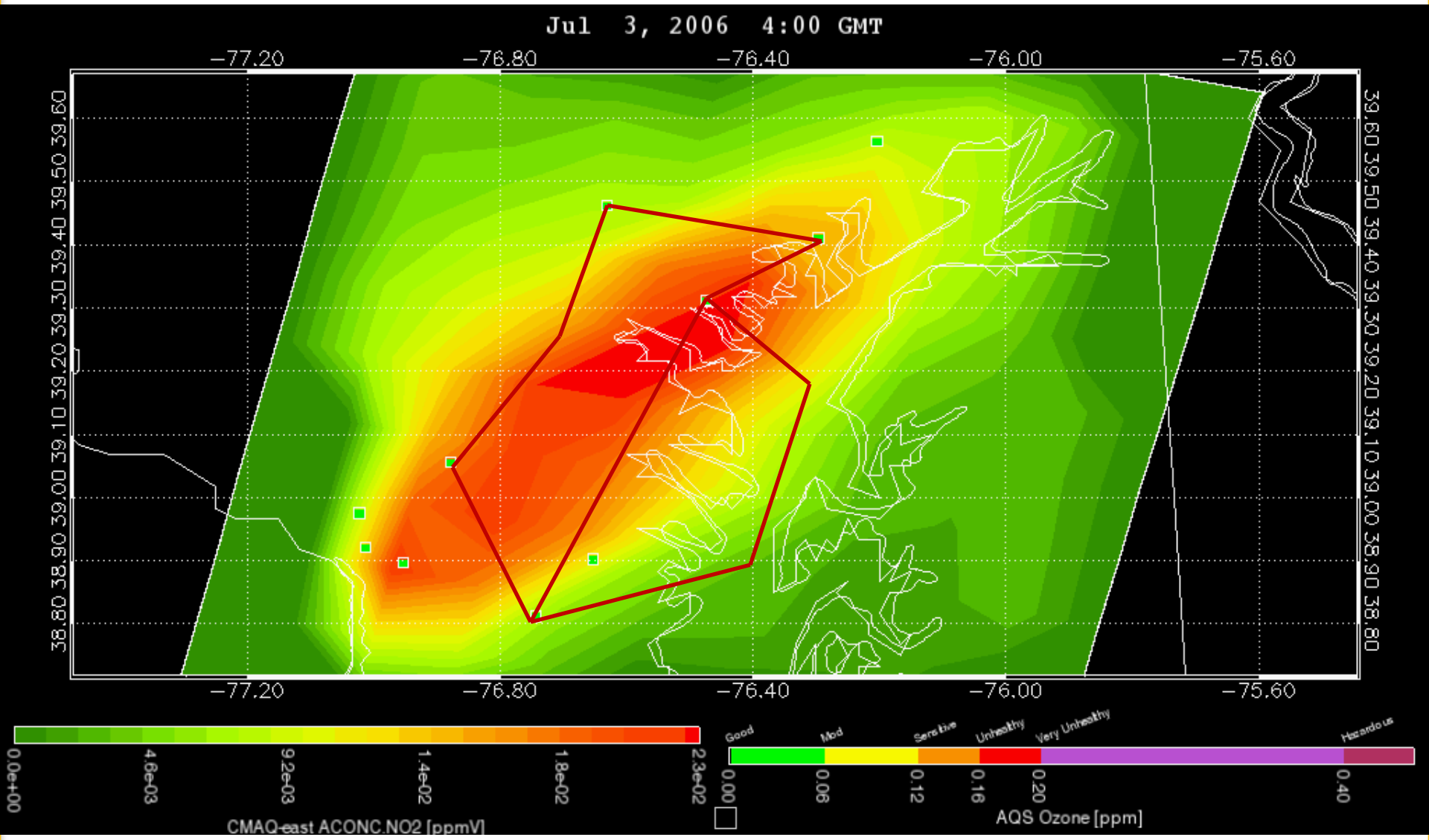


Source: T. Knepp and M. Pippin, LaRC

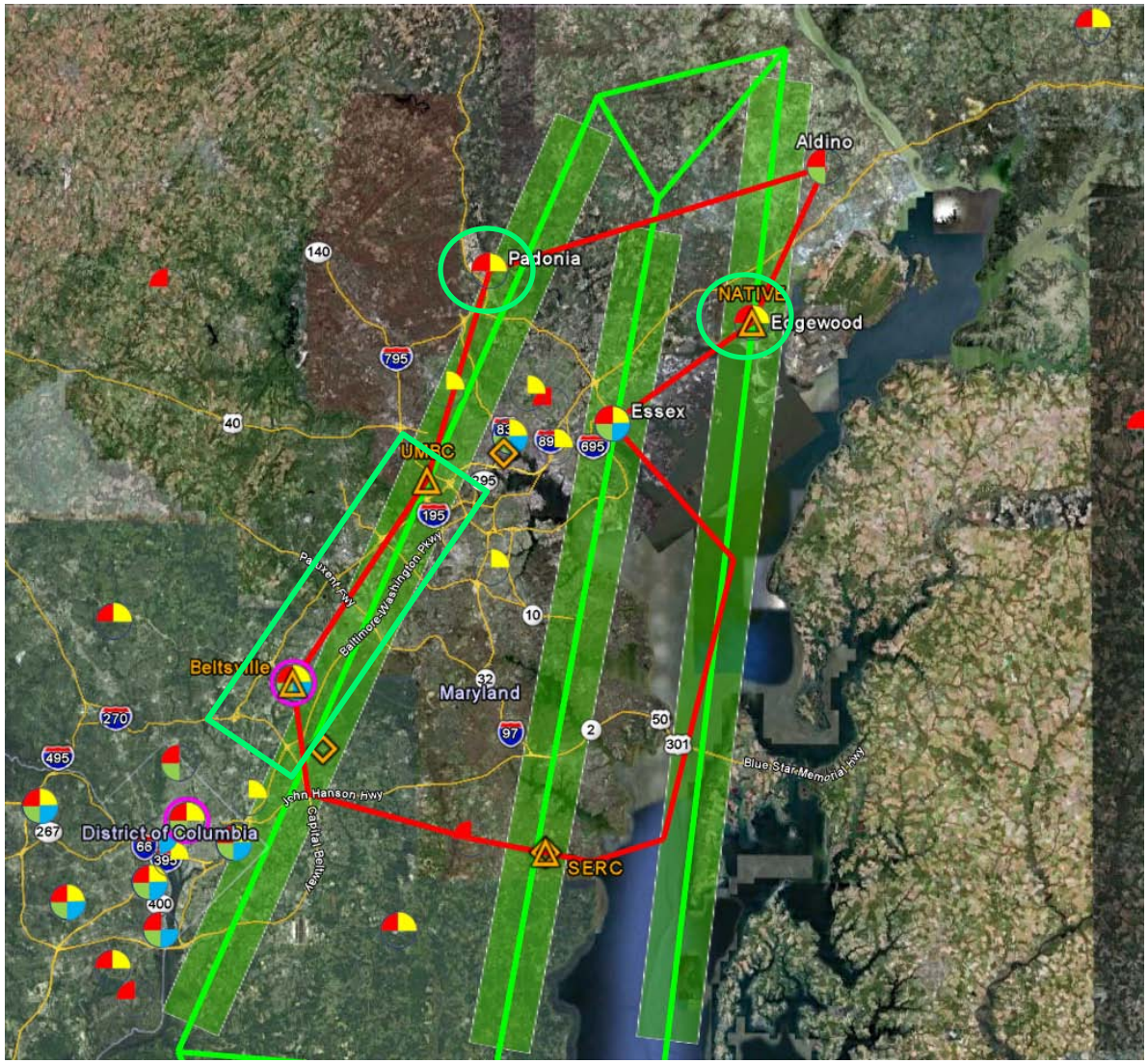
Data Collection (proposed)

- Drive the study area during times required. Sampling continuously.
- Possibility exists for intercomparision with other monitors

2 July 2006 hourly NO_2 surface Concentrations
Internal EPA CMAQ run w/ initial DISCOVER AQ flight track



DISCOVER-AQ Proposed Flight Track
Additional NO_2 Instruments



-Potential location for EPA NO_2 photolytic monitors at fixed sites

-Potential area to be covered by mobile EPA NO_2 QC Laser system.

NASA Cessna 206
with EPA sensors for derived Chl

- Hyperspectral Ocean Color Radiometers

-one irradiance (Es) sensor

-two radiance (Lt & Li) sensors

- Specifications:

-Spectral range: 350 nm to 800nm

-Spectral resolution 10nm

-FOV 3°

- Infrared radiation pyrometer – measures SST

- EMVIS hyperspectral imager
- Vis-NIR spectral range: 400-1000 nm
- 240 bands at 2nm resolution
    - Data useful for atmospheric modeling using MODTRAN

NASA Cessna 206 w/ EPA sensors
Flight Considerations

- Straight and level flight pattern
- Flight altitude 1000 to 2000 ft AGL
- Constant airspeed 100-120knots
- Winds < 20 knots
- Cloud cover <= 50%
- Visibility >= 3 miles

United States Environmental Protection Agency

Disclaimer

Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.