Ground-Based Passive UV-Vis Remote Sensing of Air Quality: Setting the stage for satellite validation and enhanced environmental monitoring for Latin America and the Caribbean

Presentation to the School of Atmospheric Measurements in Latin America and the Caribbean: Atmospheric Particles and Reactive Gases (SAMLAC)

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San Juan, Puerto Rico, November 12, 2018

[1] NASA GSFC (614); [2]Luftblick; [3]GESTAR; [4]JCET; [5]ESSIC; [6]SSAI; [7]Virginia Tech; [8]CCNY; [9]USRA

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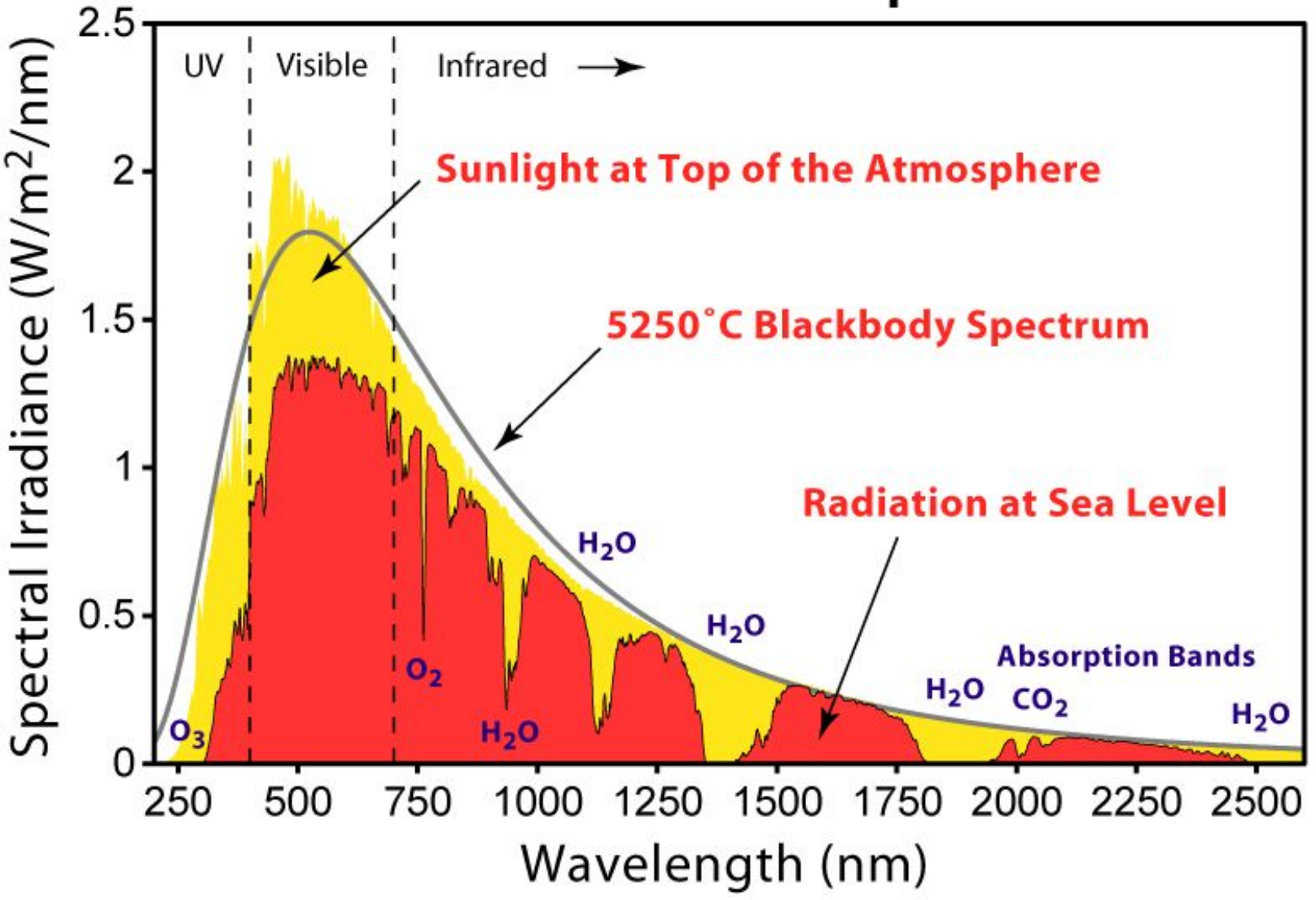
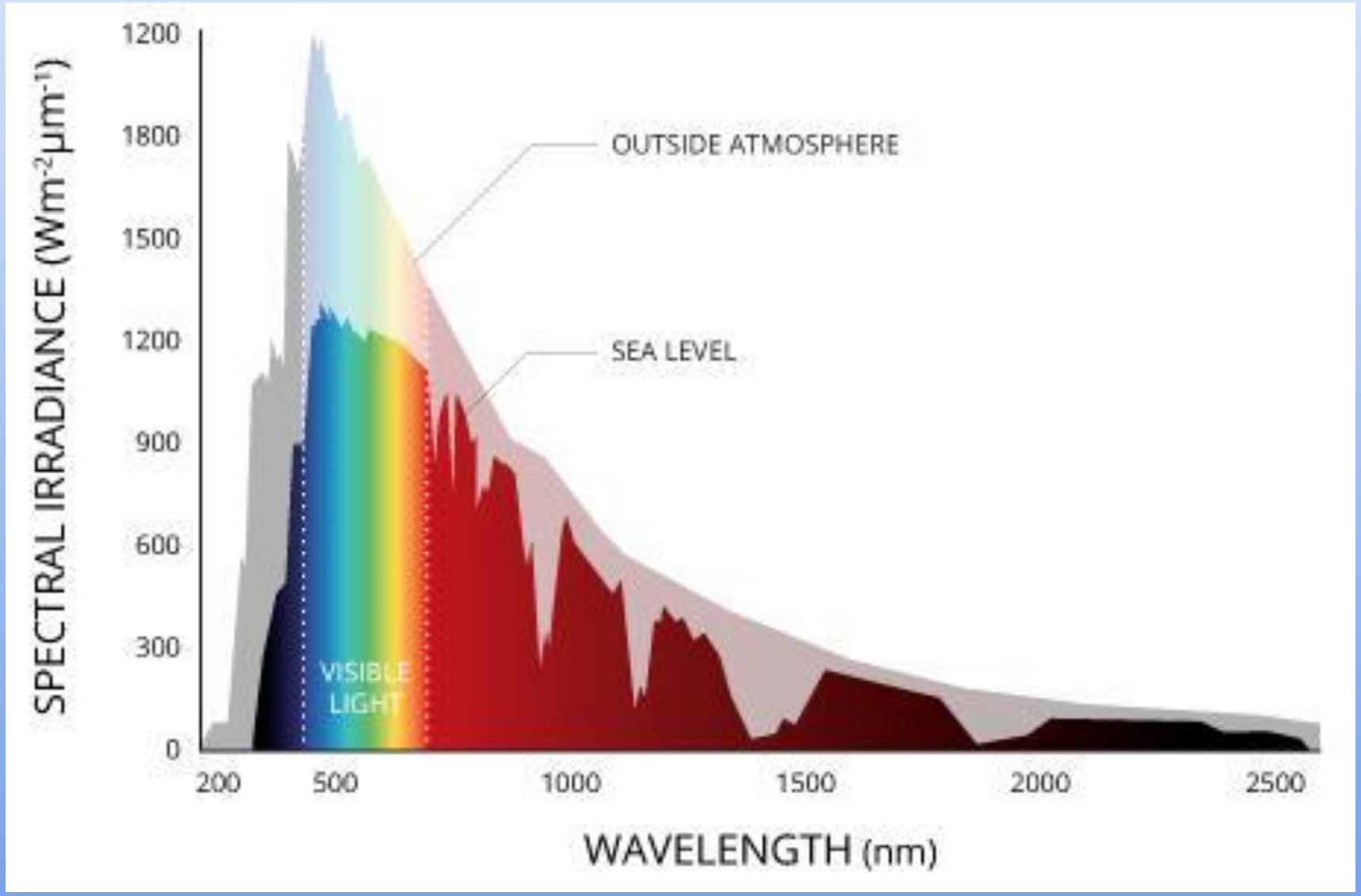
Solar Radiation Spectrum



Figures from commons.wikimedia.org

The solar spectrum in colors...



Figures from commons.wikimedia.org

Passive Ground-Based RS of Trace Gases

Incoming photons from the sun at the top of atmosphere

↓

Photons along the “Slant path” interact with atmosphere & ground

↓

Measured light spectrum of photons making it down to Earth’s surface

↓

Retrievals of total column densities of trace gases of interest give “slant column”

↓

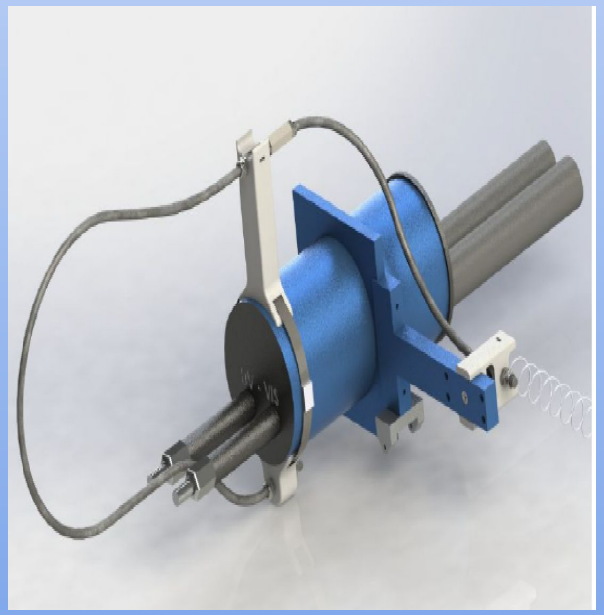
Estimate “Slant path” (or Air mass*) to derive vertical column, profile, or sfc trace gas concentrations

*Air Mass is defined here as the ratio of the slant column densities to the vertical column densities

Origin of the Pandora Spectrometer System

Pandora version
built in 2005

Pandora 2S
(2017)

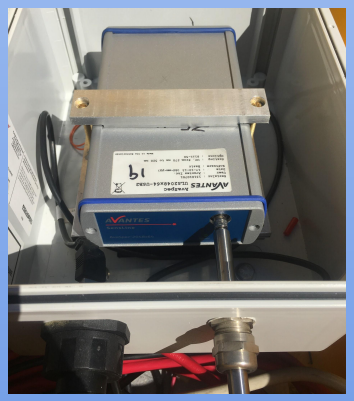


Pandora, Hart Miller Island
Baltimore USA 2018

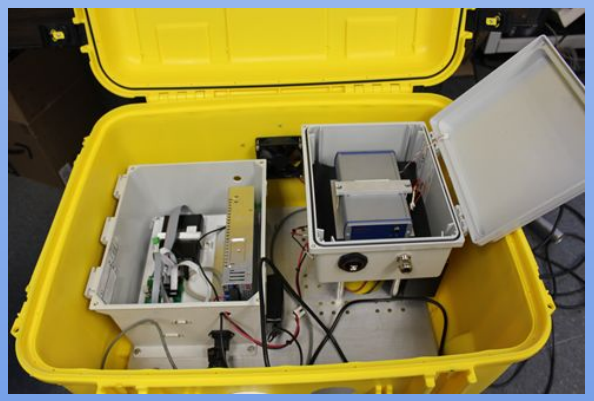
What is the Pandora Spectrometer System?

- Small, ground-based Sun/Sky/Lunar observing spectrometer system initiated in 2005 at NASA Goddard Space Flight Center
  - Pandora 1S: 280 – 530 nm, 0.6 nm
  - Pandora 2S: 280 – 530 nm & 400 – 900 nm, 1 nm
- NRT Standard Products at high frequency (~ 90 secs.)
  - Tot. Column O_3 (+/-15 DU, ~5%); Tot. Column NO_2 (+/-0.05 DU, ~10%)
- Additional non-validated products
  - HCHO - Total column, trop. & near sfc; NO_2, O_3, SO_2 – trop. & near sfc
- Operates autonomously off of line power and wifi; software runs on a small PC found inside the weather resistant container.

Sensor Head



Spectrometer



Pandora Field Box

Boulder, CO

Instrumental Design Influences

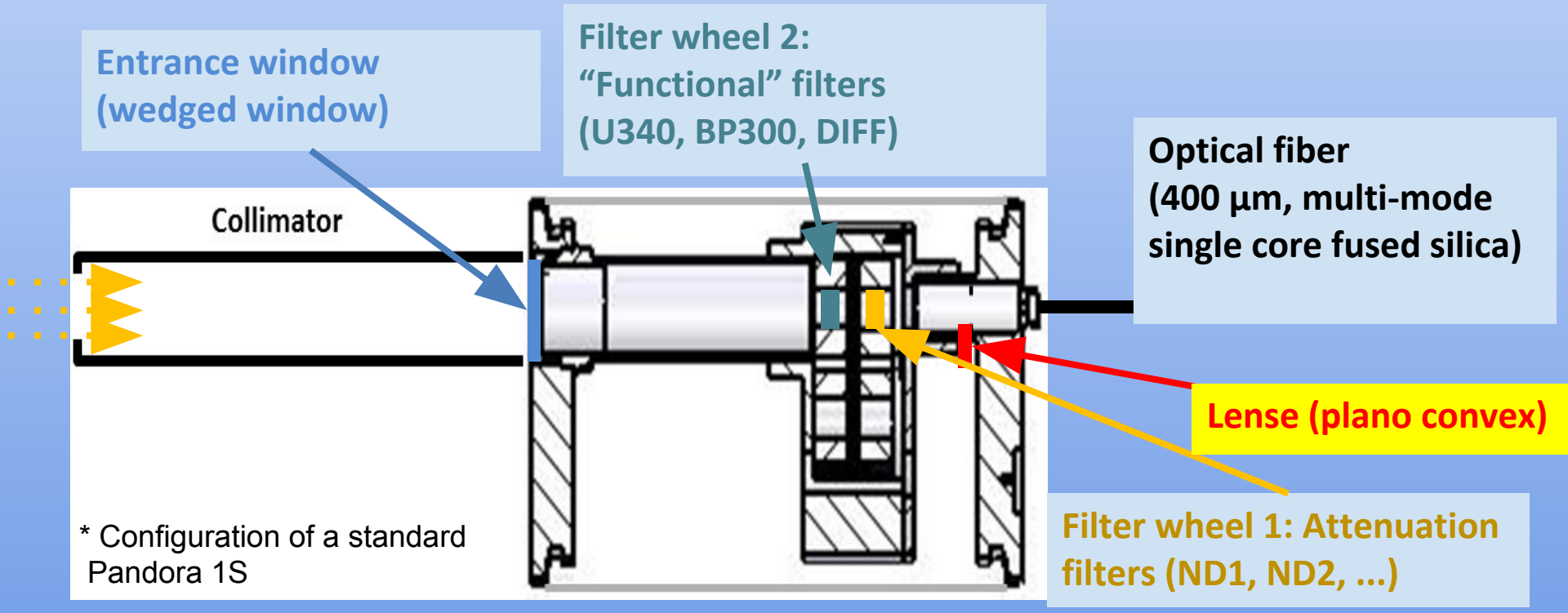
Cimel Sun photometers

Pandora 2S Spectrometer System

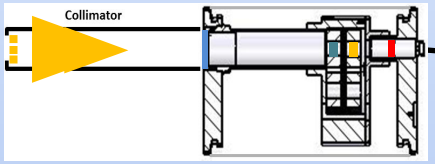
Prede Sun Photometer

Instrument Specifications*

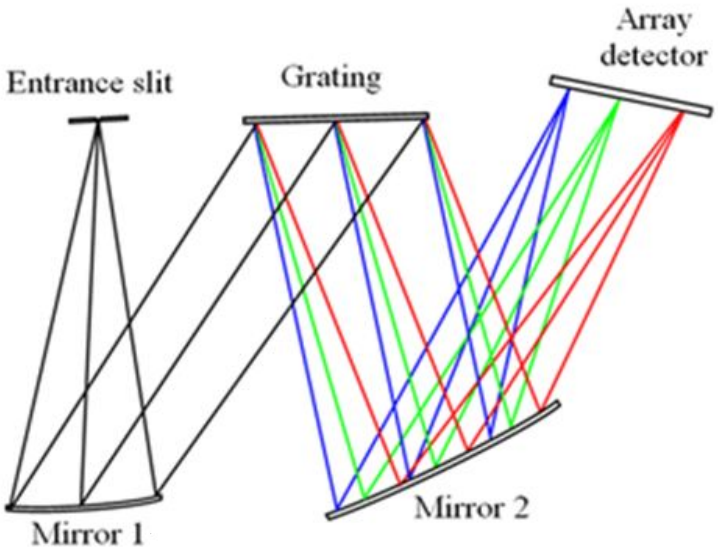
- Elevation (zenith) Range: 0°- 270°
- Azimuth Range: 0°- 370°
- Set Temperature Range: 0°-20°C; calibrated at 15° and 20°C
- Field of View: 1.5°- 2.4°
- Spectral Range: 280 - 530nm
- Spectral Resolution: 0.6nm
- Power: 120/220V AC
- Internet connectivity (Wifi/Wired)

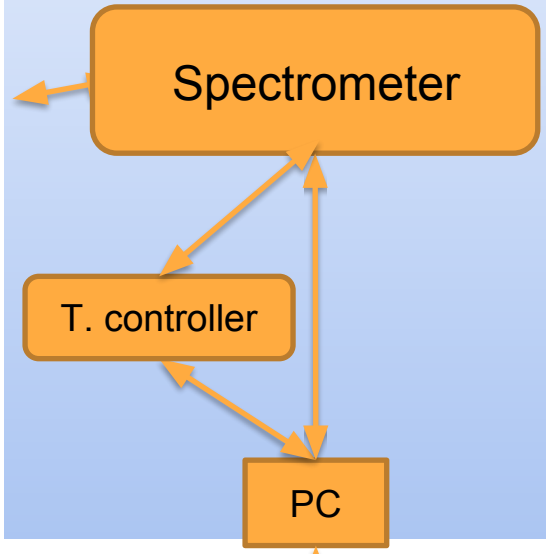


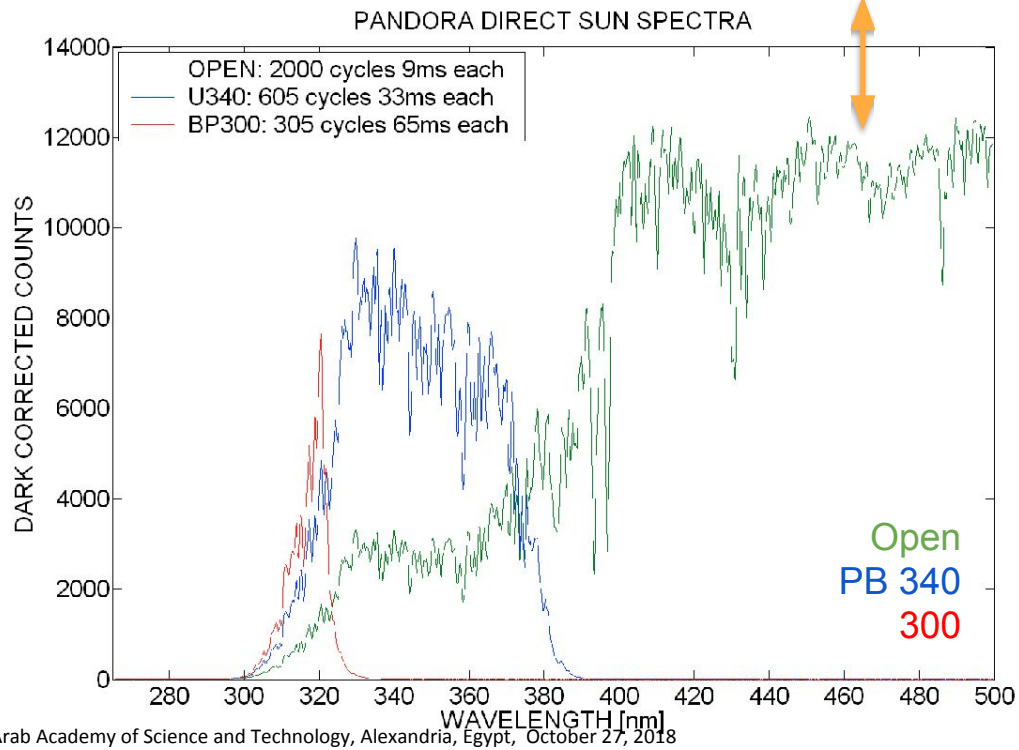
Optical and Processing Configuration



When combined with variable exposure time (2 - 4000 ms), Pandora has a dynamic range of 1 to 10^7, which allows for viewing sun, Moon and sky with the same optics,



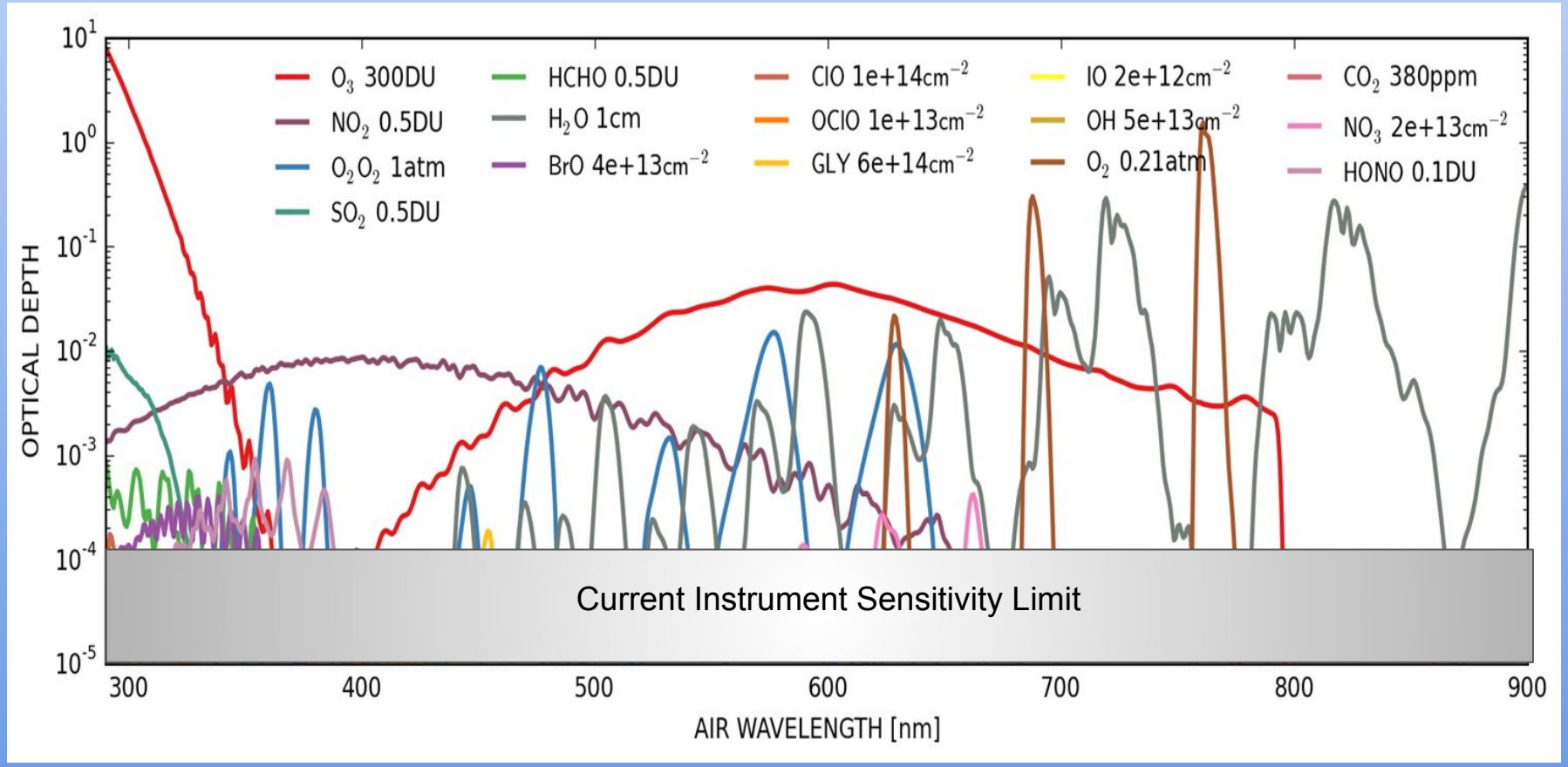




Pandora 1S & 2S Systems

Pandora-1S - 280-530nm

Pandora-2S - 280-530 & 400-900nm



SUN, Moon and Sky observations

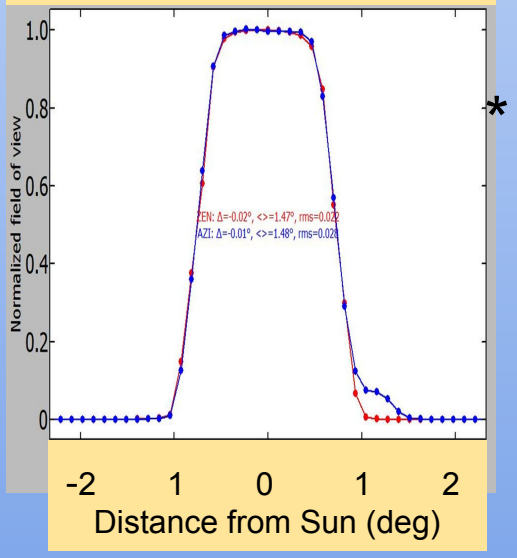
DIRECT SUN
(FOV ~ 2.4 deg)

DIRECT MOON
(FOV ~ 1.5 deg)

SKY SCAN
(FOV ~ 1.5 deg)

Instrument
(FOV ~ 1.5-2.4 deg)

Normalised Field of View
(FOV)



*

Sun gives absolute positioning reference frame → high pointing accuracy ($2\sigma<0.1$ deg)

*Active sun tracking algorithm continuously running during measurements

New Sun Tracking System

- Waterproof Housing
- Elevation (zenith) Range: 0°- 270°
- Azimuth Range: 0°- 370°
- 0.01° Step, Closed Loop
- Improved Communication SW - tracker to PC
- Improved Hardware, Optical Encoder, Temp & Error Monitoring, Real time positioning feedback
- Possibility to add internal heater for extreme cold wx operations
- Higher velocity motion - extremely valuable for moving platforms


Branford, CT


Elkridge, MD


Mauna Loa Observatory

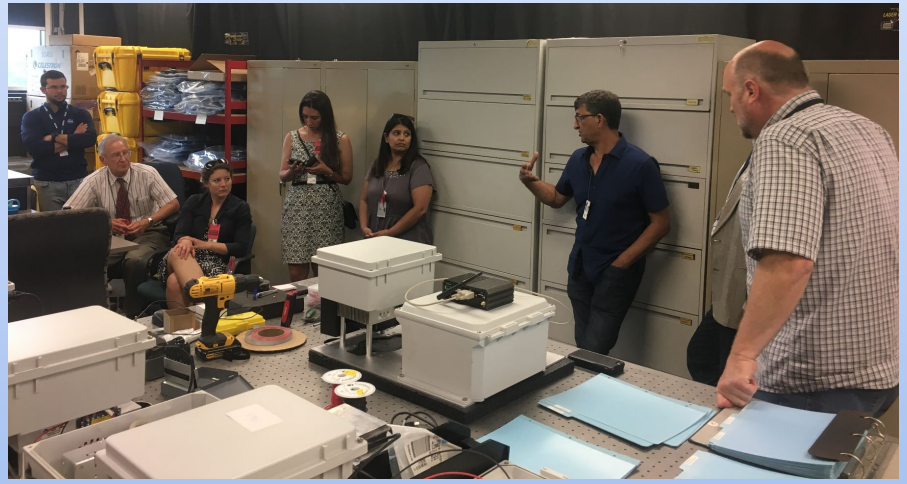
Deployed on Ships/Moving Platforms

Uses a Simple Camera System - both internal and external
with ~15 deg FOV to help the instrument with real time sun tracking

Chesapeake Bay

Gulf of Mexico

Engaging Community Inside & Outside GSFC

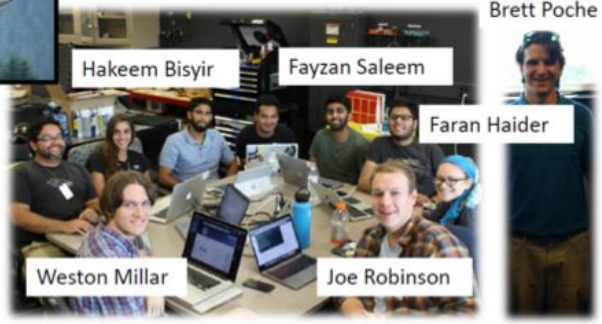


“Growing Our Own Timber”:
Grooming the Next Gen of ES Scientists

Sherpa Student Participation

OWLETS
Ozone Water-Land Environmental Transition Study

6 GSFC summer interns (Swap)



Brett Poche

SERC R/V Student Participation

- 2 CUNY/Columbia Univ. Summer Interns (Mentor: Maria
- 2 NASA/GSFC Summer Interns (Mentor: Bob Swap)
- 1 NASA/GSFC Postdoctoral Researcher (Mentor: Anne Th

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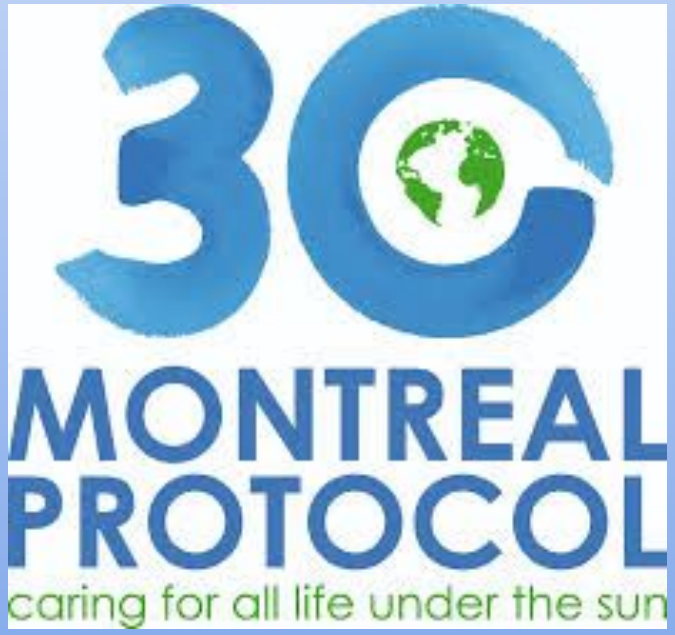
View Opportunity

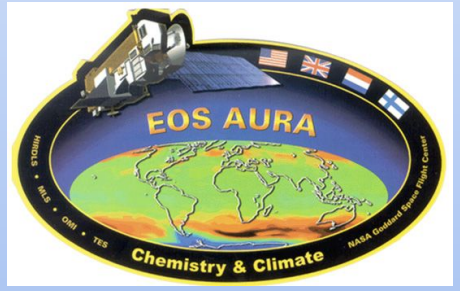
Opportunity Info

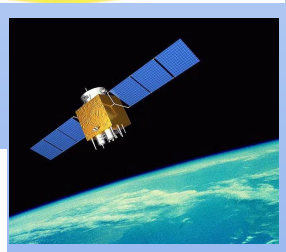
Opportunity Title:	Goddard Groundhogs: Pandora
Opportunity Type:	Internship
Opportunity Description/Objective (specific student assignment):	The NASA GSFC Pandora Proj to be part of the Summer 2018 undergraduate students with the deployment/use of air quality/atr 2) hands on experience with me chemistry and 4) statistics and a ongoing efforts to advance the P and to help support the Pandora number of field campaigns, mos Transition Study-2). Successful System - how it works and the s deploy and monitor the instrume mentored on the Pandora data A with the resultant air quality data ground based campaigns and th
Expected opportunity outcome (i.e. research, final report, poster presentation, etc.):	Successful candidate(s) are exp OWLETS-2 field campaign expe expected, with mentorship, to co as prepare preliminary field data are also expected to contribute
Student's Computer and/or Special Skills:	Familiarity with data analysis an C/C++, Fortran, HTML5 or simil intensive field campaigns/field e interdisciplinary nature highly de highly desirous as is hands on e Experience with ground-based a mindset and comfortability with project management software s webpage software/development Spanish, German, Portuguese,
Comments:	

Why is it important?

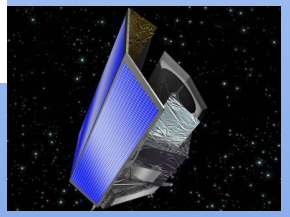
Support of Earth System Science, Satellite Validation/ Verification and Air Quality Monitoring







SENTINEL-4



Recent NASA/ESA/PGN supported Field Campaigns

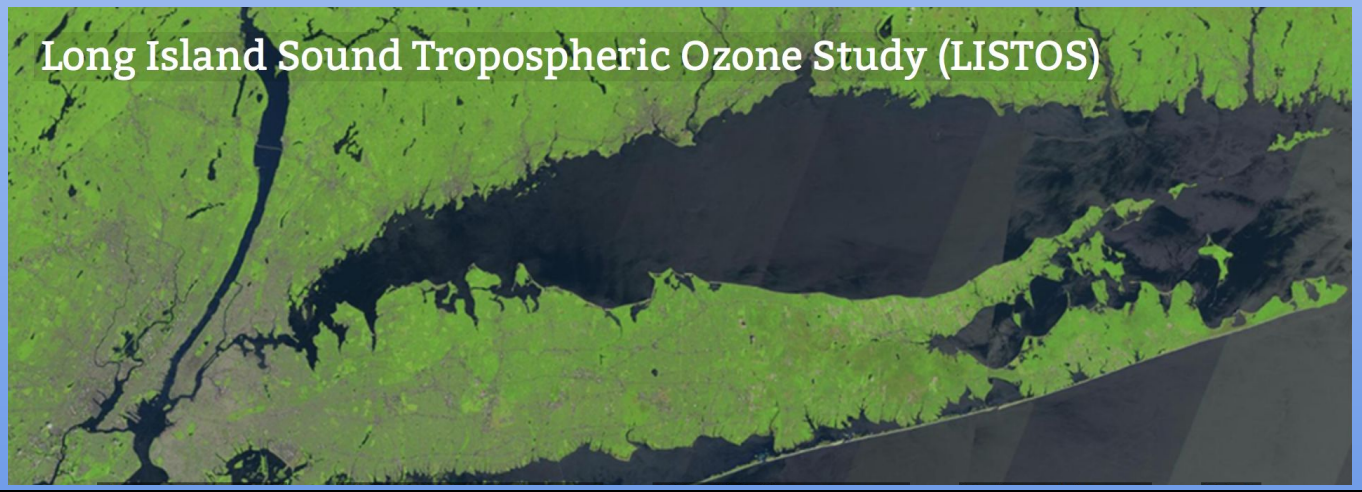
KORUS-AQ
KOREA-UNITED STATES AIR QUALITY STUDY
NIER • NASA

SARP
NASA STUDENT AIRBORNE RESEARCH PROGRAM
NATIONAL SUBORBITAL RESEARCH CENTER

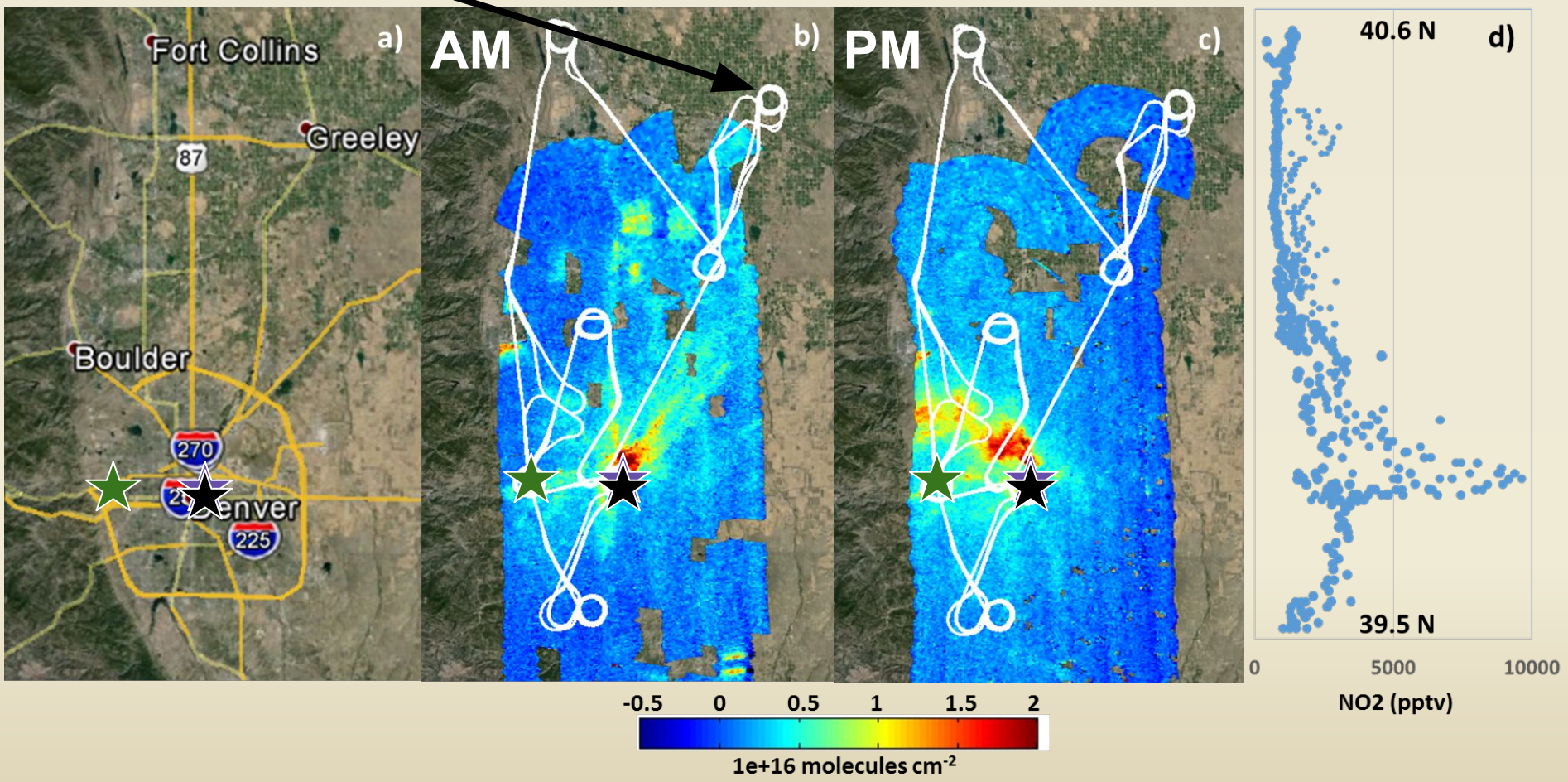
ORACLES
NASA
EVS-2
P-3
ER-2
Namibia and São Tomé

OWLETS
Ozone Water-Land Environmental Transition Study

OWLETS-2
Ozone Water-Land Environmental Transition Study



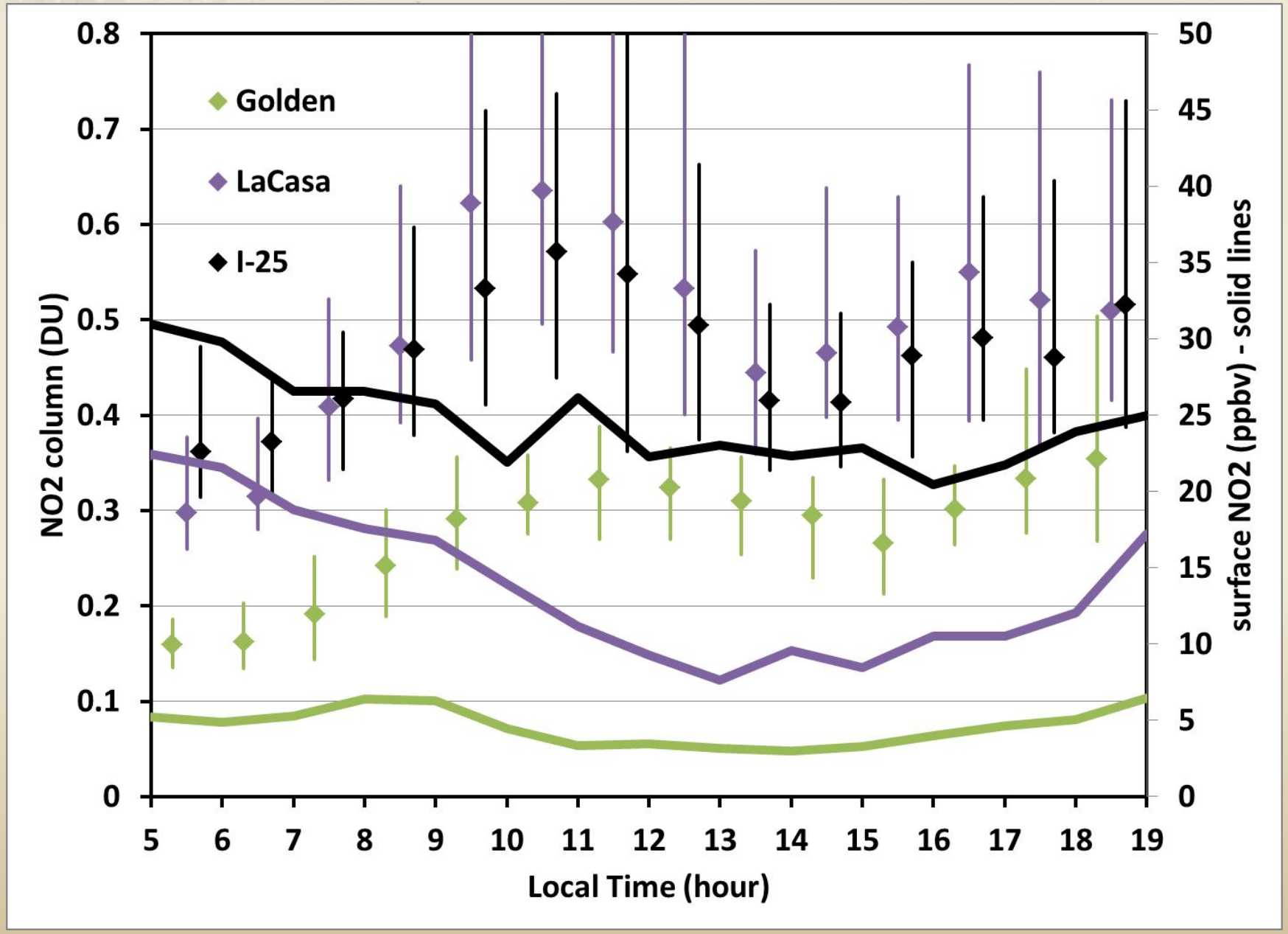
Geo-TASO Observations over the Denver Front-Range Area Summer 2014



The latitudinal distribution of P-3B observations are shown on the right for all flight data averaged over 0.01x 0.01 deg. Symbol sizes increase for data farther to the west in proximity to the foothills of the Front Range.

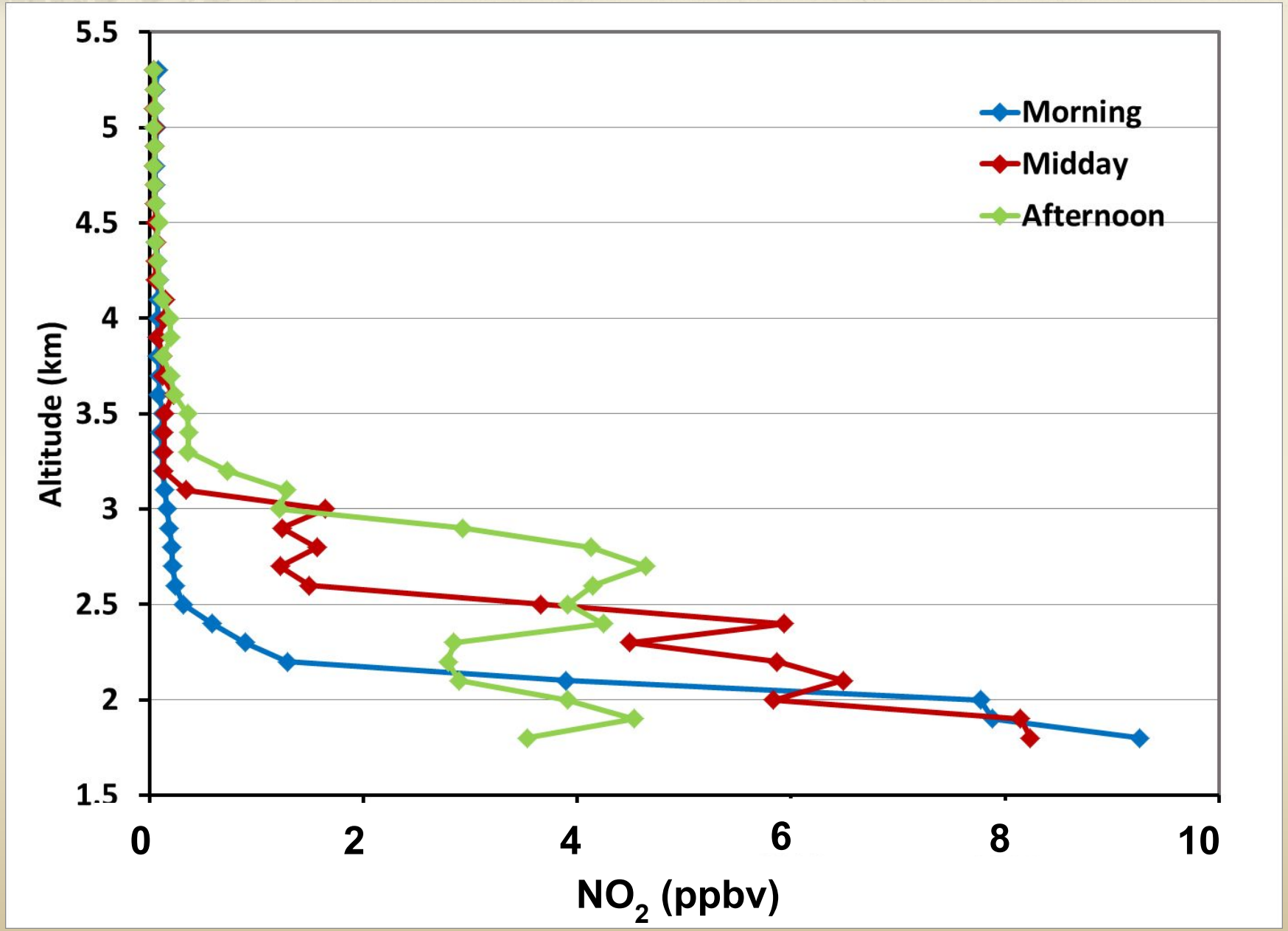
DISCOVER-AQ

Pandora vs Surface- Colorado



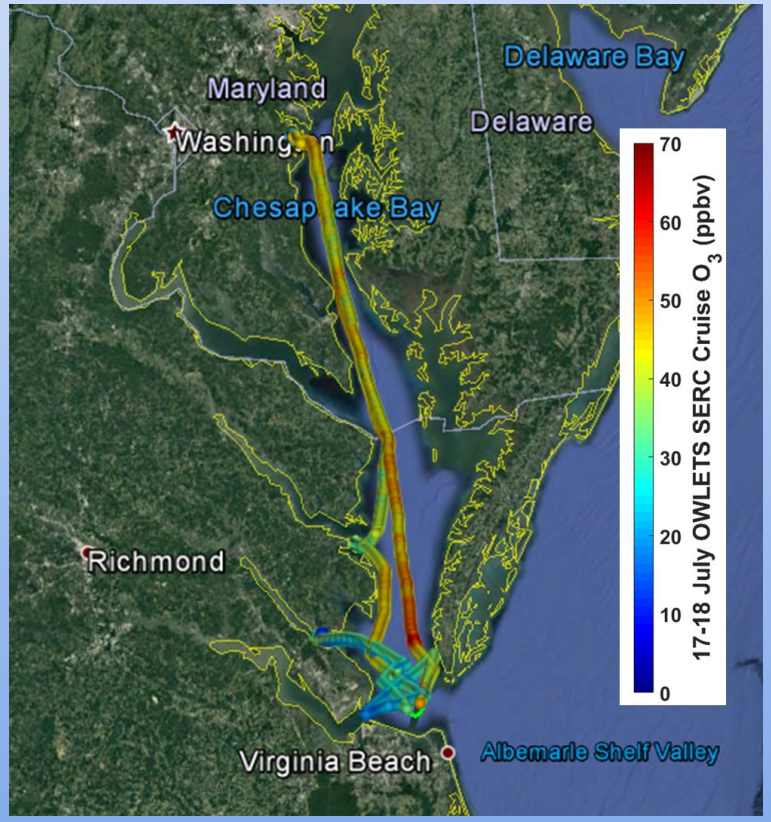
DISCOVER-AQ

LaCasa NO_2 Profiles



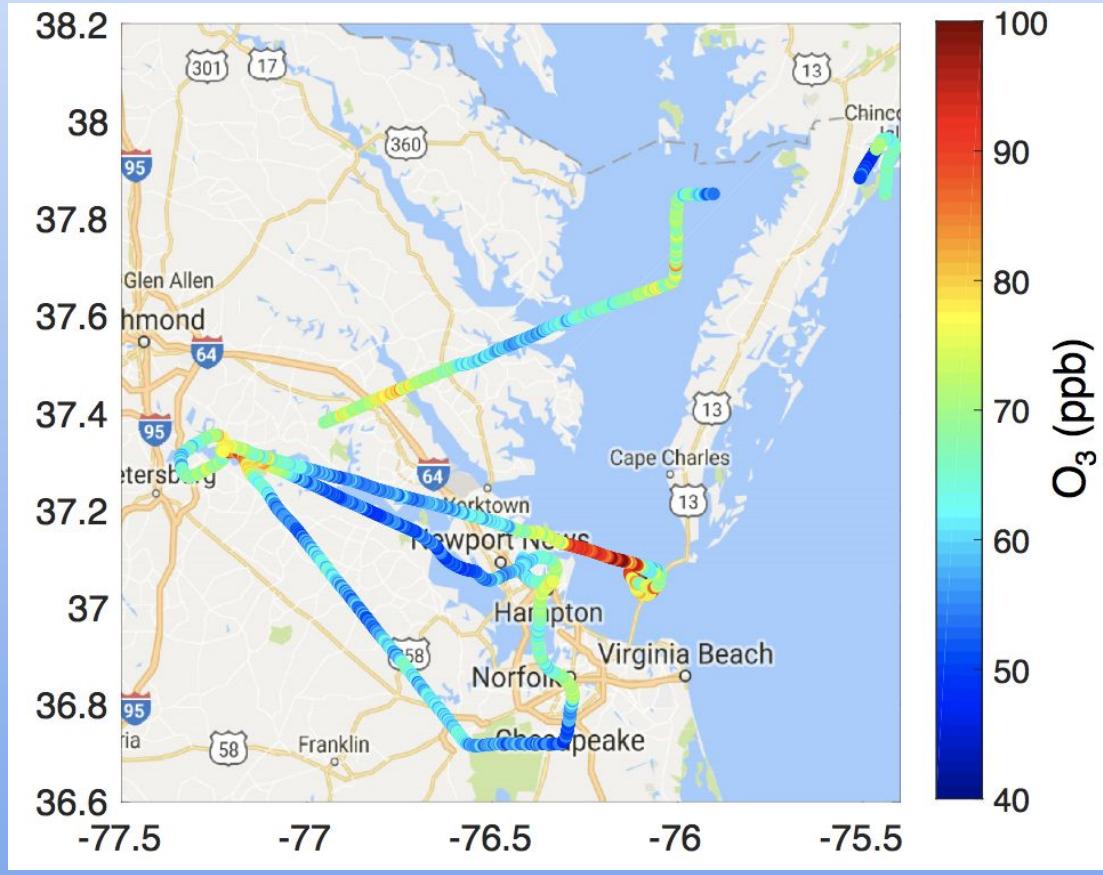
OWLETS Overview

SERC RV



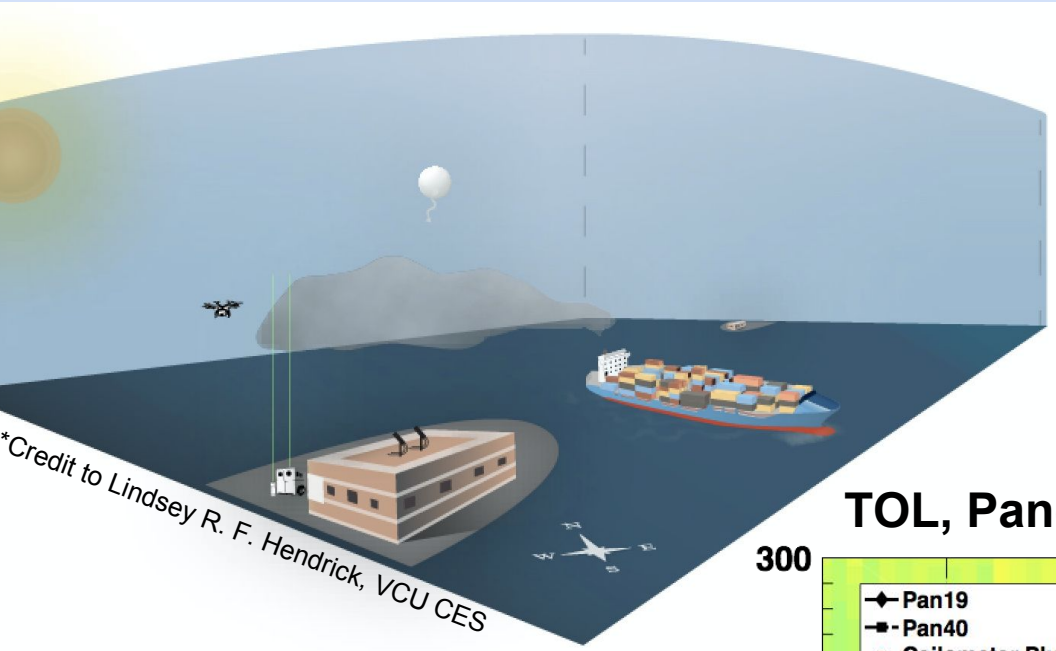
07/17 & 07/18 in-situ Ozone

NASA C-23 Sherpa

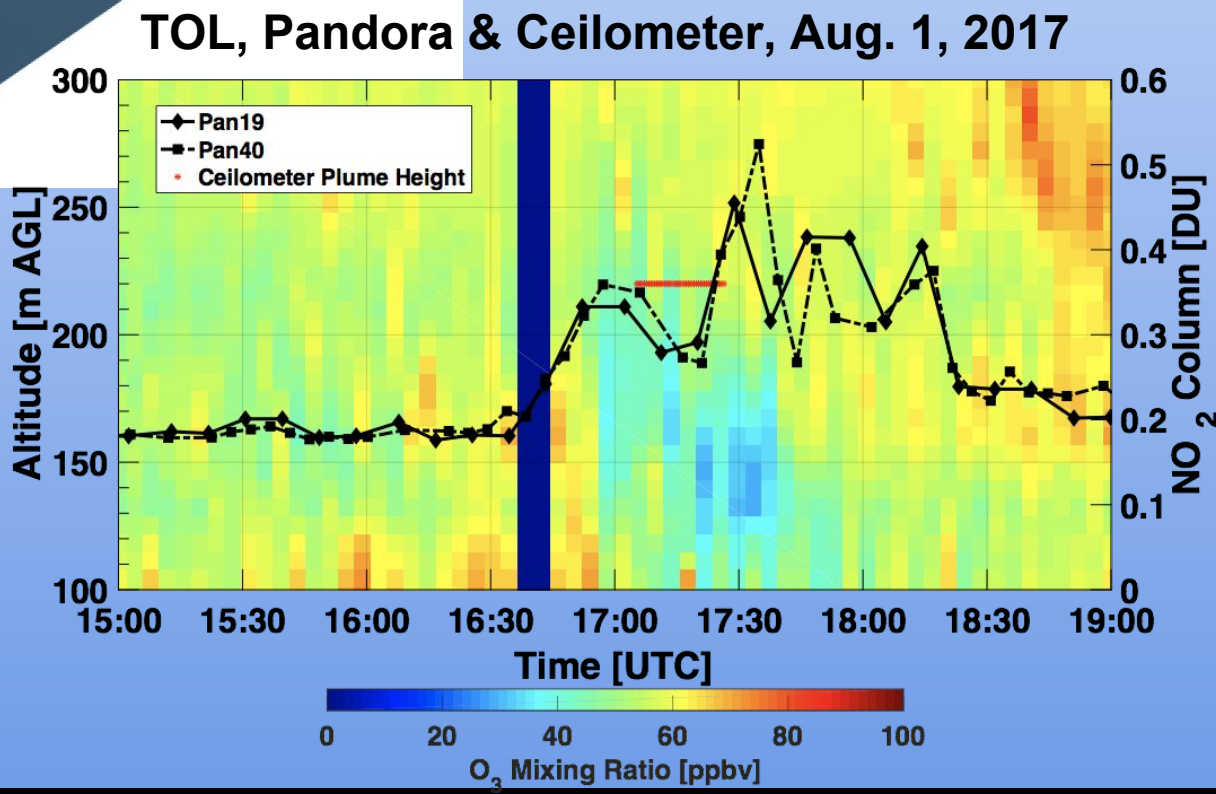


07/20 Ozone (≤ 500 m ASL)

Interconversion/Titration Event



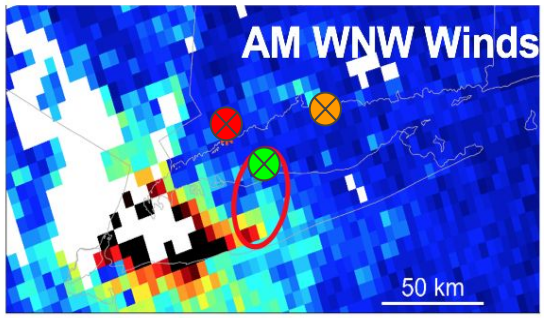
$$NO + O_3 \dashrightarrow NO_2 + O_2$$



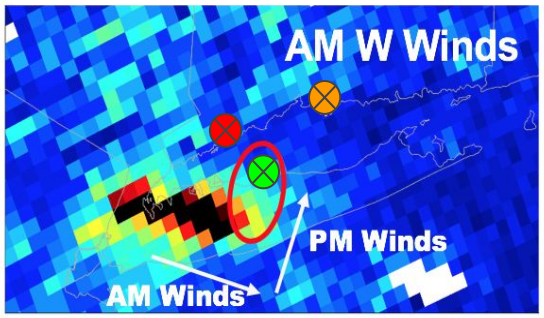
LISTOS - TropOMI and Pandora

Extent of NYC NO2 plume shifts northward over 3-day heatwave, confirming conceptual model of pollutant transport in region

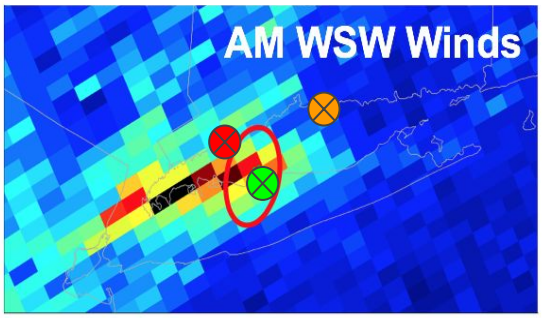
August 27, 2018 1:30pm LT

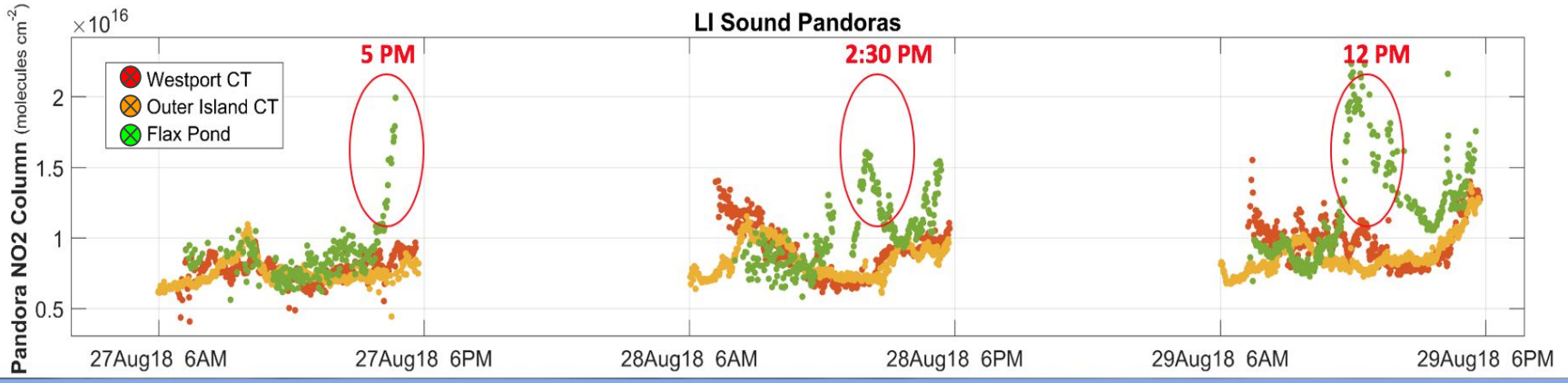


August 28, 2018 1:10pm LT



August 29, 2018 12:50pm LT





*Courtesy of Luke Valin, EPA

- Pandora data is a source of validation data
- Pandora fills in details over time outside of 1PM TropOMI overpass
- TropOMI and Pandora data help to explain observed O_3 distributions

Current and Future AQ/AC Satellite Missions

Mission	Agency	Launch	Instrument(s)	Synergistic Pandora Observations	Orbit
AURA	NASA	2004	OMI	O3, NO2, SO2, HCHO, BrO	LEO
MetOp-A	EUMETSAT	2006	GOME-2	O3, NO2, SO2, HCHO, BrO	LEO
S-NPP	NASA	2011	OMPS	O3, SO2	LEO
MetOp-B	EUMETSAT	2012	GOME-2	O3, NO2, SO2, HCHO, BrO	LEO
DSCOVR	NASA	2015	EPIC	O3, SO2	L1
Sentinel 3A	EUMETSAT	2016	MWR, OLCIS, LSTR	H2O	LEO
Sentinel 5P	ESA	2017	TROPOMI	O3, NO2, SO2, HCHO	LEO
GaoFen-5	CSA	2018	EMI	O3, NO2, SO2, HCHO	LEO
NOAA-20	NOAA	2018	OMPS-N	O3, SO2	LEO
Sentinel 3B	EUMETSAT	2018	MWR, OLCIS, LSTR	H2O	LEO
GEO-KOMPSAT 2	NIER	2019	GEMS	O3, NO2, SO2, HCHO, CHOCHO	GEO
TEMPO	NASA	2020	TEMPO	O3, NO2, SO2, HCHO, CHOCHO	GEO
Sentinel 4	EUMETSAT	2021	UVN	O3, NO2, SO2, HCHO	GEO
Sentinel 5	EUMETSAT	2021	UVNS	O3, NO2, SO2, HCHO	LEO
MAIA	NASA	TBD	MAIA	SO2, NO2 (aerosol precursors)	LEO

From Research/Campaign Mode to Long-Term Monitoring - The Evolution of a Global Network

The Pandonia Global Network (PGN)

- Ground-based network - a joint NASA/ESA collaborative effort modeled in the spirit of other networks (e.g. AERONET)

- From 2017 onwards, focus primarily on systematization of observations

- Objective: to expand and coordinate a global network of standardized, calibrated instruments and systematically process and disseminate the data to the greater global community in support of in-situ and remotely sensed air quality monitoring

Pandonia Global Network (PGN)

NASA Pandora

Responsibilities:

NASA Instrument Builds

Calibration/deployment

Maintenance

Network Operations

Data Mirroring

Managed by: NASA GSFC

Goddard Space Flight Center

Shared Responsibilities

Network Operations

Calibration, QA/QC

Training of Local Operators

Field Campaigns

Science

ESA Pandonia

Responsibilities:

Software Development

Calibration

Network Operations

Central Processing

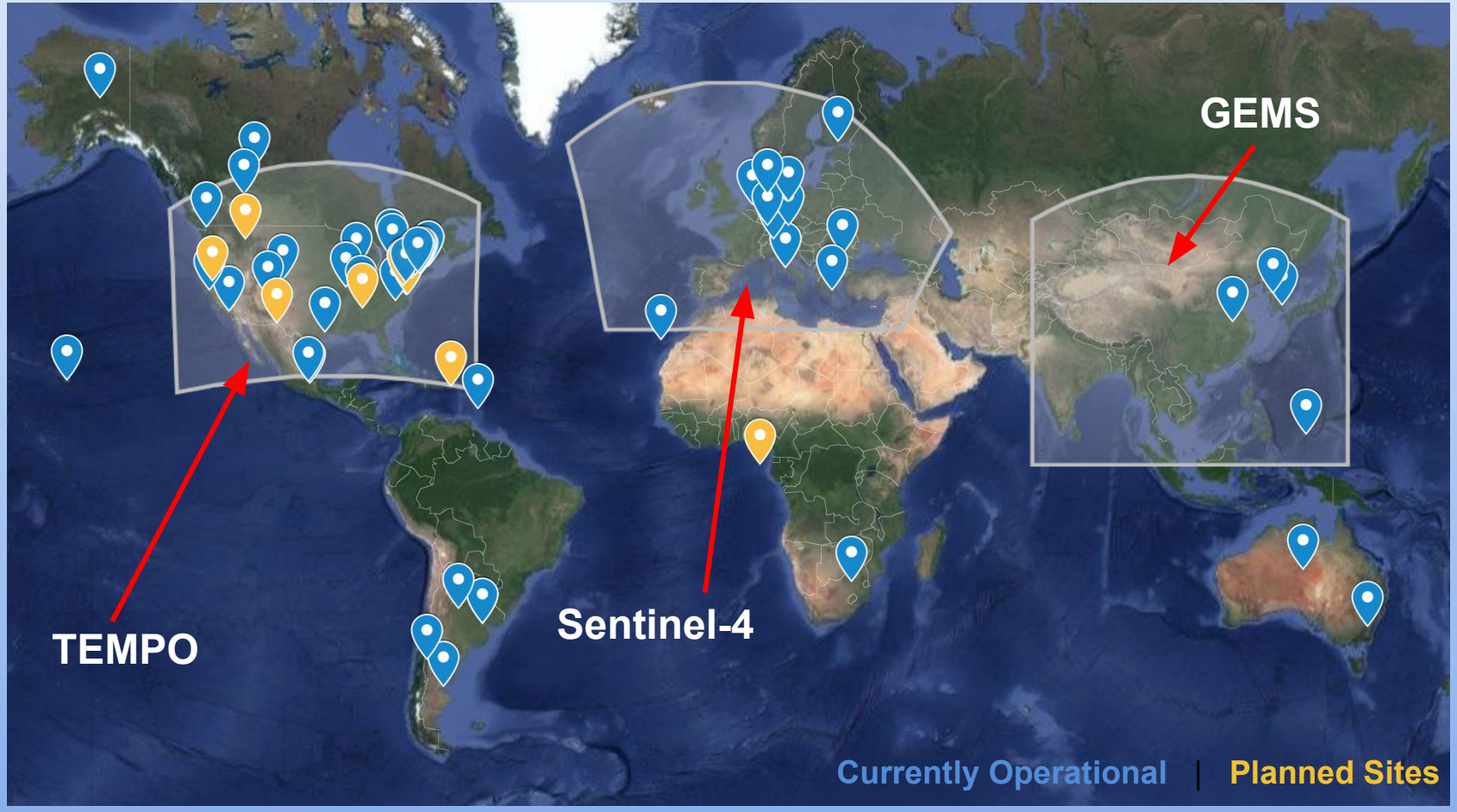
Data Serving

Managed by: Luftblick

LUFTBLICK
EARTH OBSERVATION TECHNOLOGIES

Fall 2018 & beyond

Global Distribution of Pandora's, October 2018



87 Instruments distributed globally with 5 more to be delivered in 2018

- ~51 monitored by NASA GSFC Pandora, ~36 by ESA-Pandonia
- Possibility to provide hourly observations of O_3, NO_2, SO_2, HCHO from GEO is a major advancement for air quality (vs LEO 1x/day)
- By year end min. 50 NASA owned instruments deployed and operational

Thank You

For more information please contact:

robert.j.swap@nasa.gov
nader.abuhassan@nasa.gov