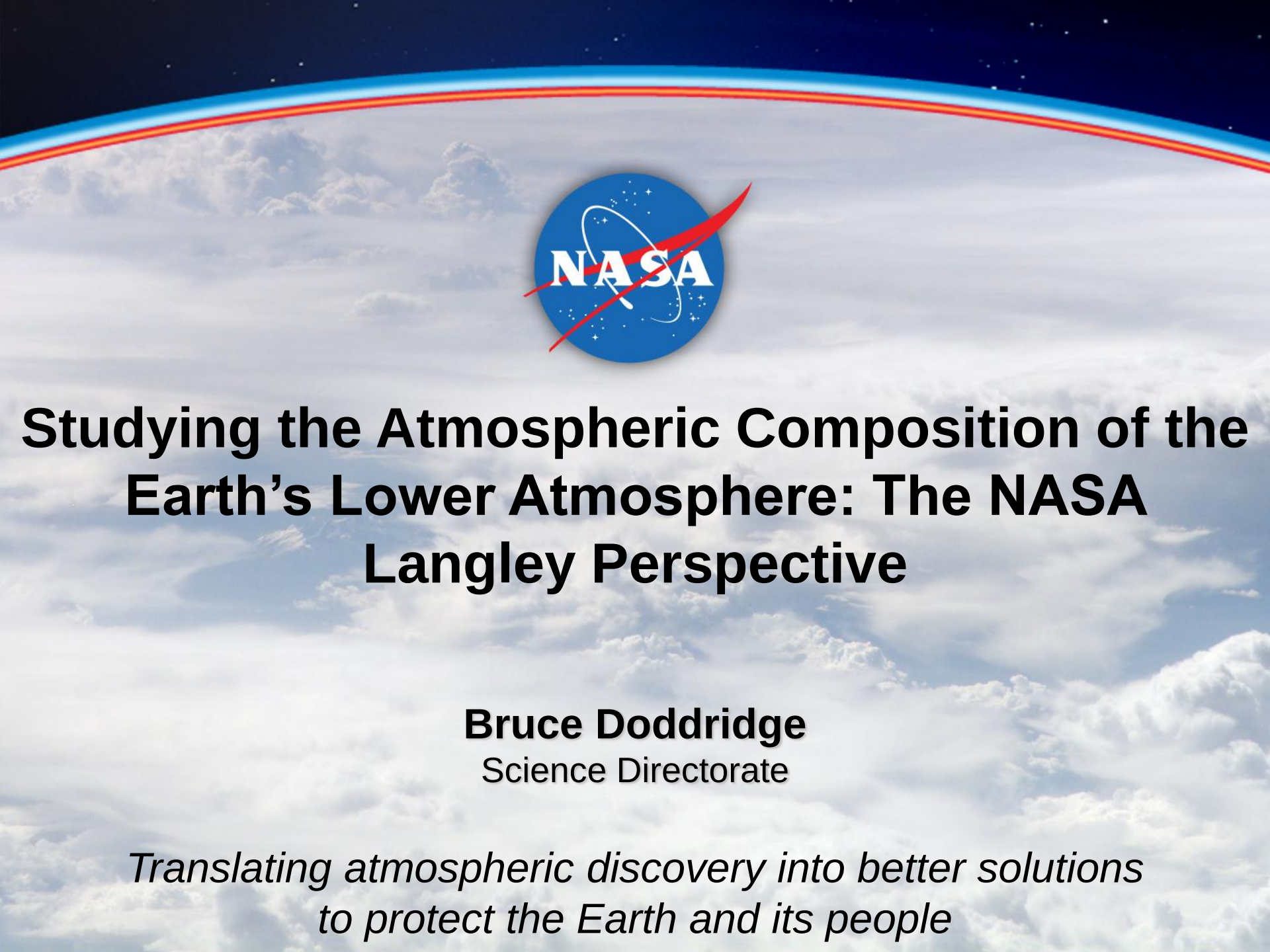


Studying the Atmospheric Composition of the Earth's Lower Atmosphere: The NASA Langley Perspective

Bruce Doddridge
Science Directorate

Translating atmospheric discovery into better solutions to protect the Earth and its people

Outline

- Brief Overview of the Science Directorate (SD)
- Selected Atmospheric Composition Projects
  - DISCOVER-AQ
  - CAPABLE
  - TEMPO
  - SAGE III on ISS
- Research Opportunities in Science and Engineering

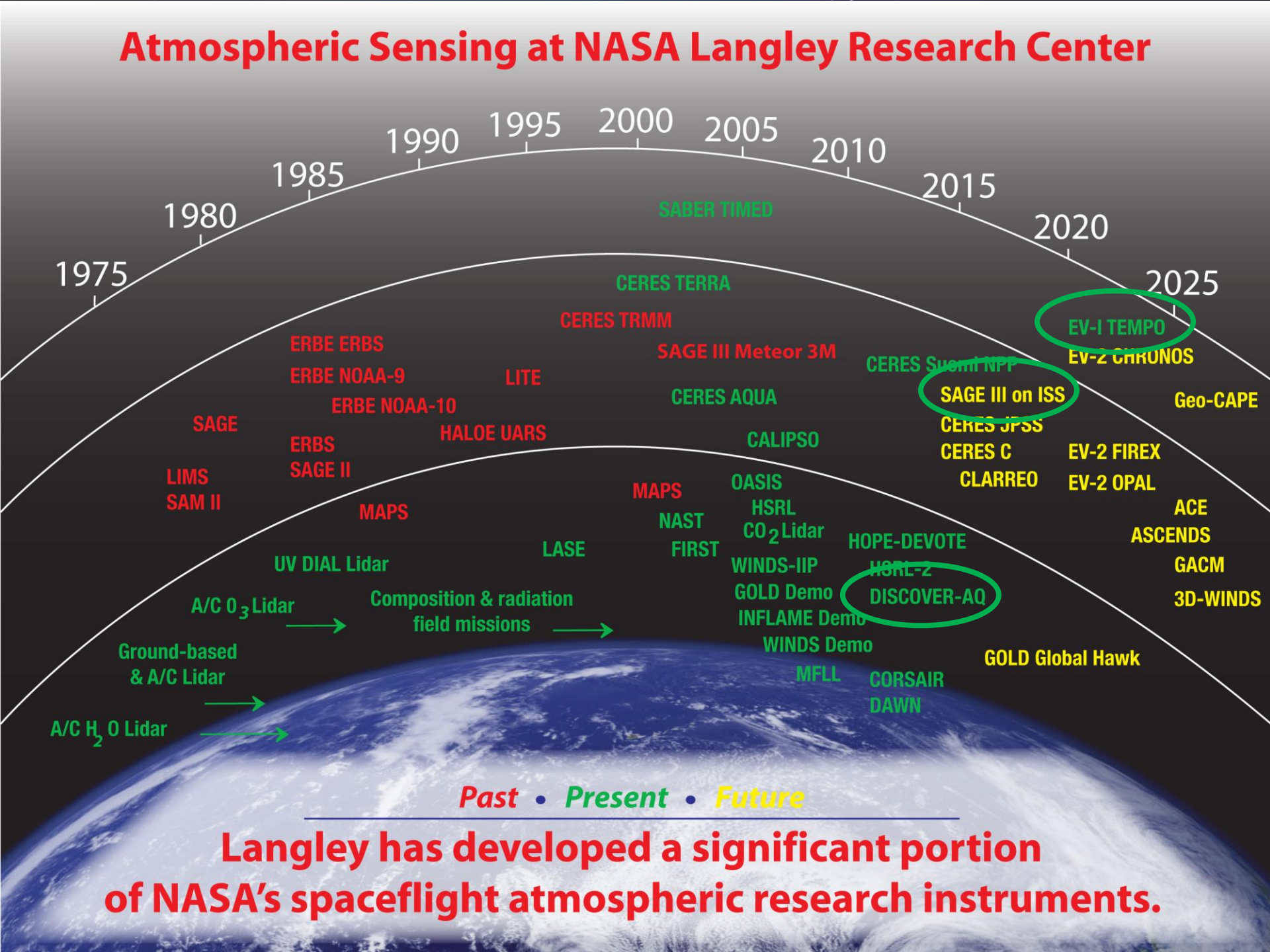
The Science Directorate At NASA Langley

Major Research Areas:

- Earth's Energy Balance and Climate Science
- Atmospheric Composition
- New Technologies
- Applied Science

Through our research, we strive to unlock the secrets of Earth's atmosphere for the greater good, a safer planet, and a better tomorrow

Atmospheric Sensing at NASA Langley Research Center



Past • *Present* • *Future*

Langley has developed a significant portion of NASA's spaceflight atmospheric research instruments.



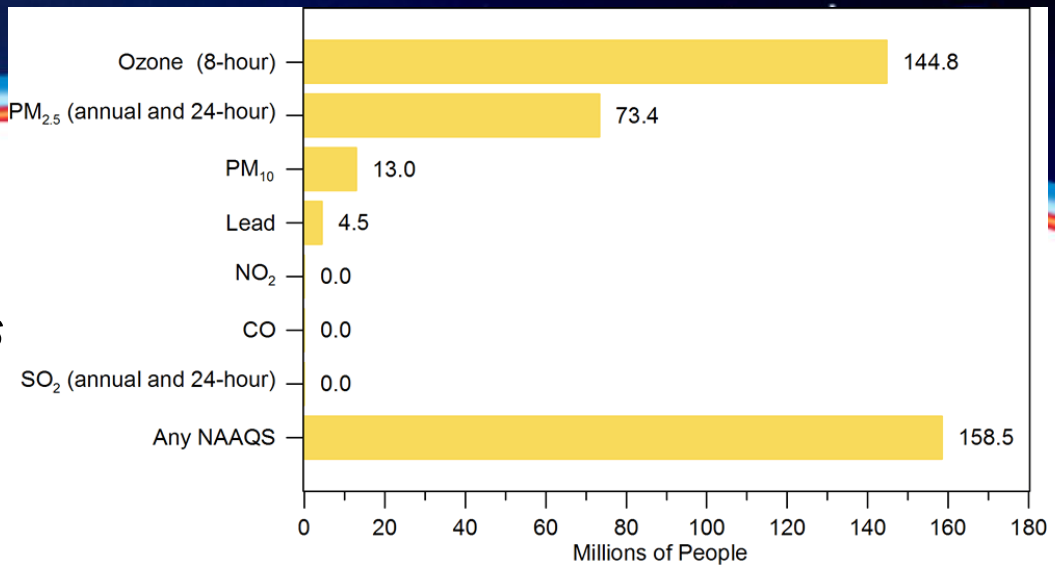
DISCOVER-AQ

Improving the View of Air Quality from Space

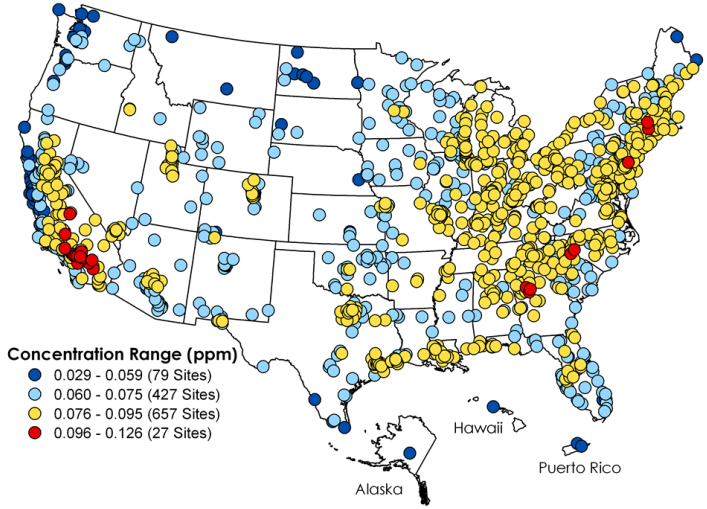




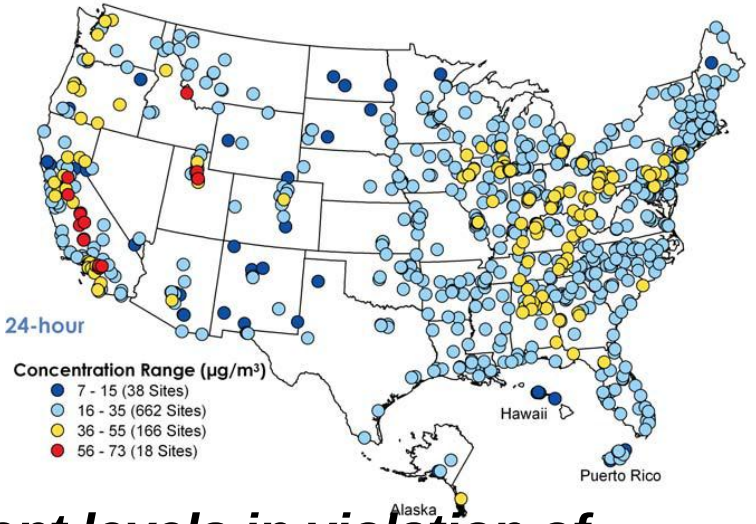
National Ambient Air Quality Standards (NAAQS): Violations are primarily related to ozone and fine particulate matter.



Ozone concentrations in ppm, 2007
(fourth highest daily max 8-hour concentration).



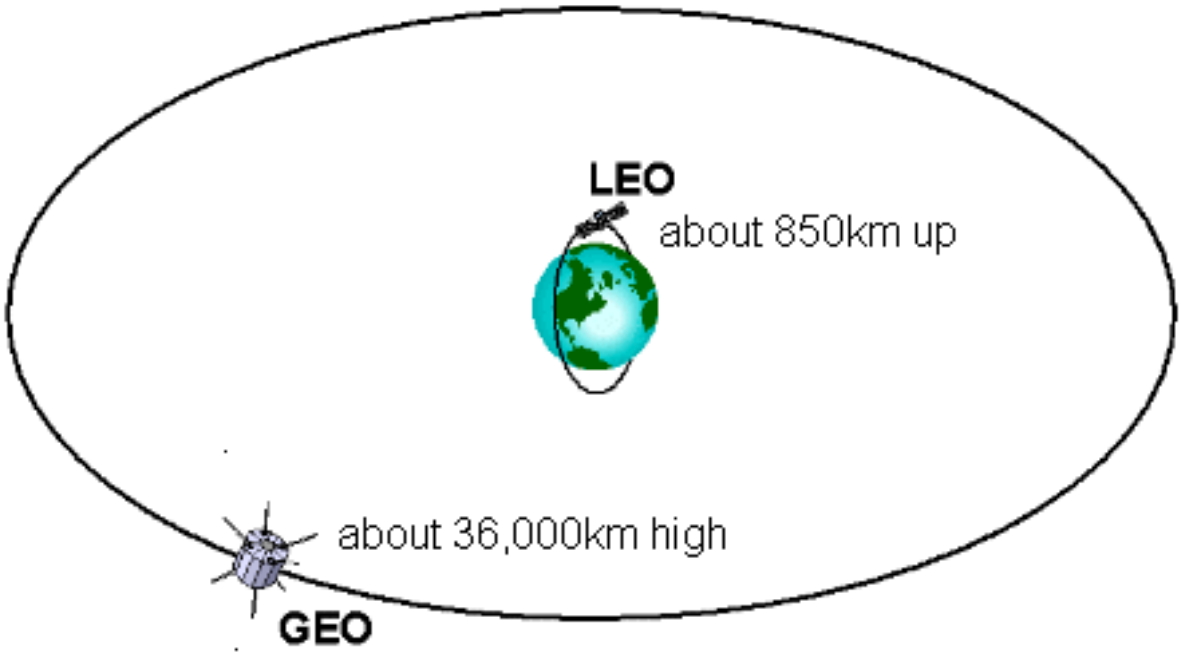
24-hour PM2.5 concentrations in µg/m3, 2007
(98th percentile 24-hour concentration)



**** Yellow and Red symbols represent levels in violation of NAAQS***

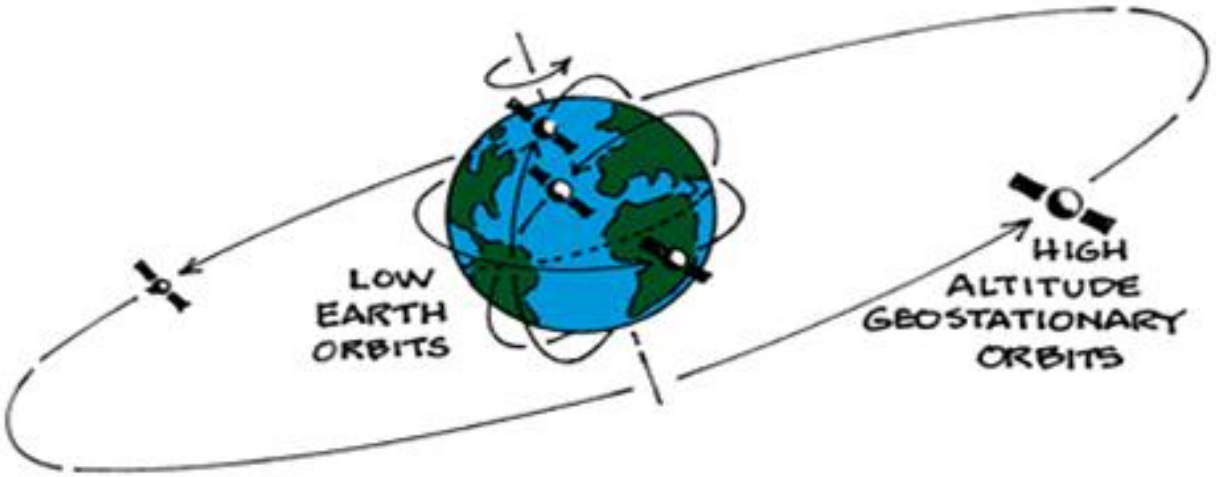
Taken from National Air Quality-Status and Trends through 2007 (http://www.epa.gov/airtrends/2008/)

Satellite Orbits used for Earth Observations.



<u>Low Earth Orbit (LEO)</u>
Global Coverage
Brief viewing time
Relatively Close

<u>Geostationary (GEO)</u>
Hemispheric coverage
Continuous view
Far Away



The Problem

Near-surface pollution is one of the most challenging problems for Earth observations from space…

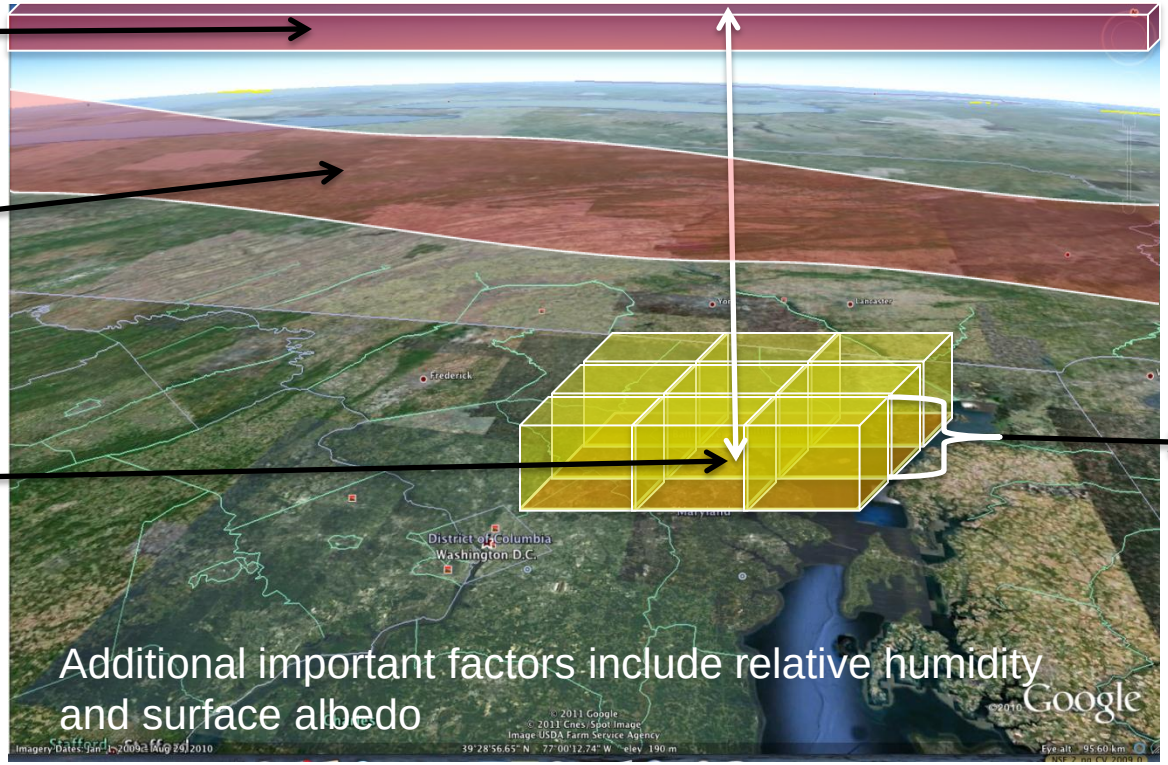
Near-surface information must be inferred from column-integrated quantities obtained by passive remote sensing from downward-looking satellite instruments.

Some constituents have large relative concentrations in the stratosphere and/or free troposphere (e.g., O_3 and NO_2) making it difficult to distinguish the near-surface contribution to the total column.

Stratospheric Burden

Long-range transport of pollution aloft

From space, the size of the measurement pixel matters (as does grid size for models)



Boundary layer depth influences the volume over which surface pollution is mixed

It also matters how well the pollution is mixed

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 current and future 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



Deployments and key collaborators

Maryland, July 2011 (EPA, MDE, UMd, UMBC, Howard U.)
California, January 2013 (EPA, CARB, UC-Davis&Irvine)
Texas, September 2013 (EPA, TCEQ, U. of Houston)
Colorado, Summer 2014 (EPA, NSF, NOAA, CDPHE)

Deployment Strategy

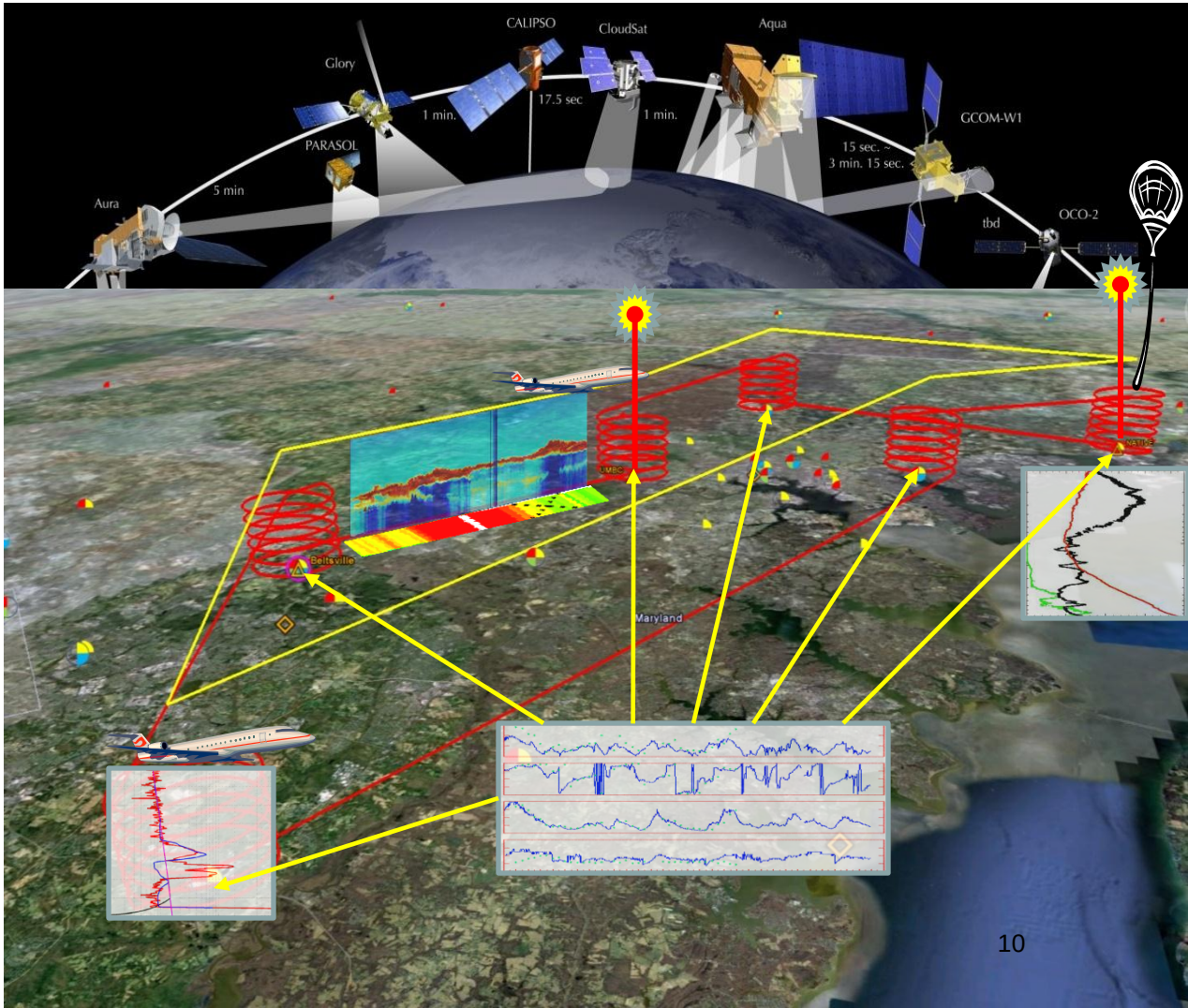
Systematic and concurrent observation of column-integrated, surface, and vertically-resolved distributions of aerosols and trace gases relevant to air quality as they evolve throughout the day.

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
Ozonesondes
Aerosol lidar observations



DISCOVER-AQ California

Ten science flights documented the details of two successive PM2.5 episodes in the San Joaquin Valley

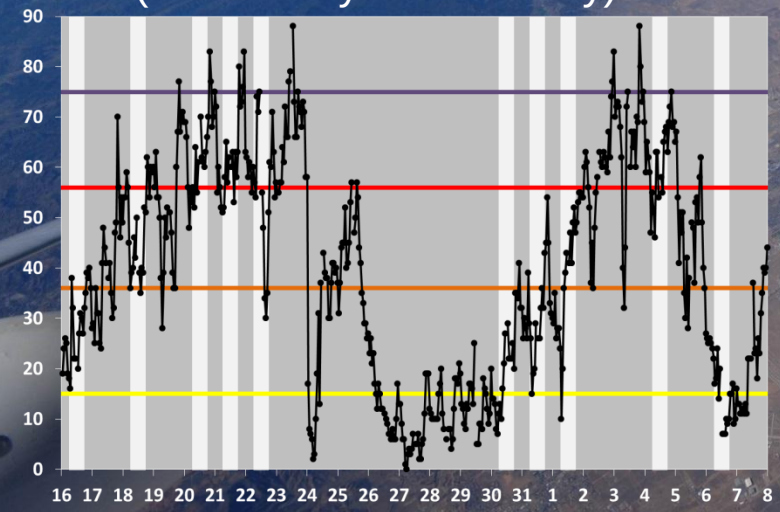
HSRL-2 on the King Air Maps the Spatial Distribution of Aerosol between ground monitors across the valley

Fresno

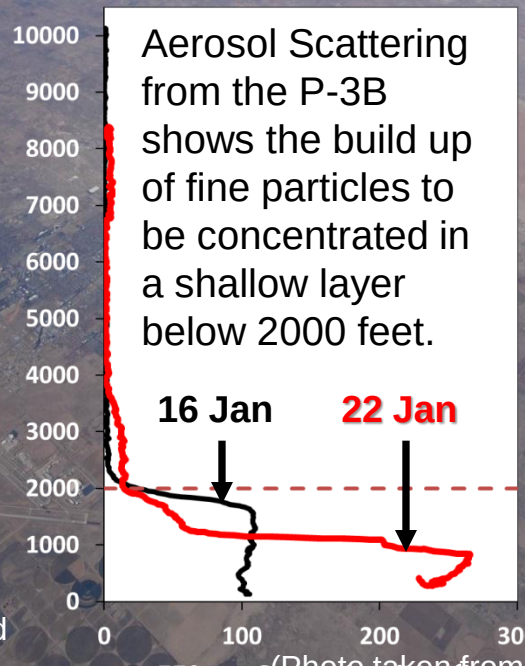
Bakersfield



Bakersfield PM2.5
(16 January - 7 February)



*Orange line (36 ug/m^3) is the 24hr average threshold for violating National Ambient Air Quality Standards

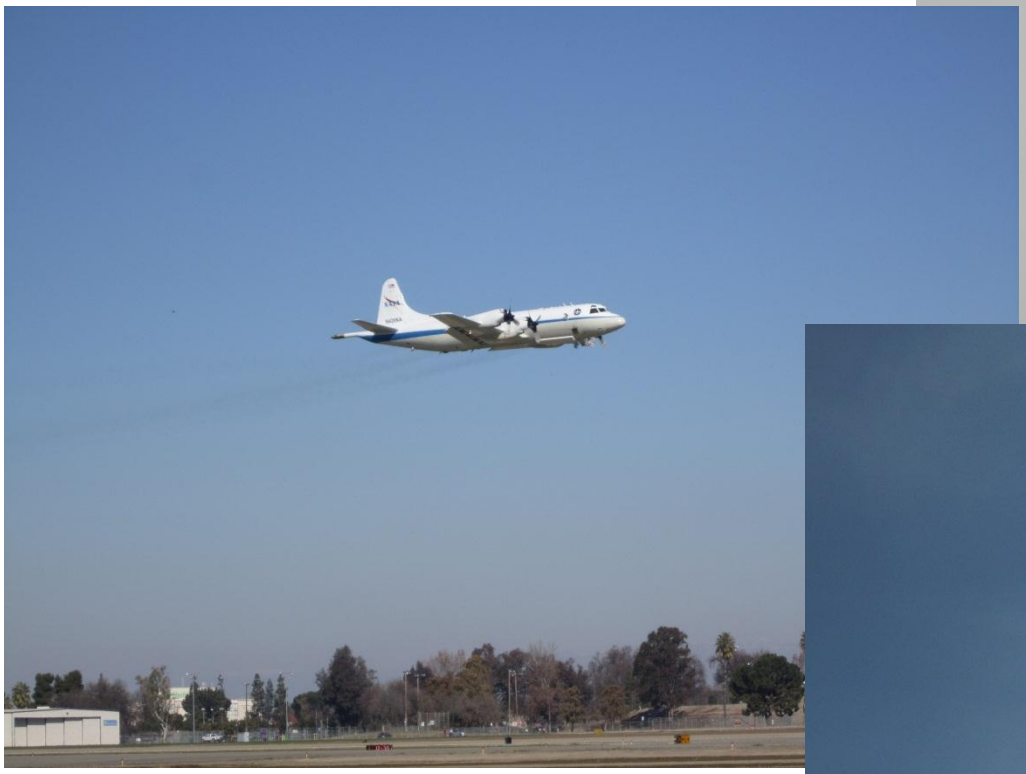


(Photo taken from ER-2 during PODEX flight on 20 January)

DISCOVER-AQ

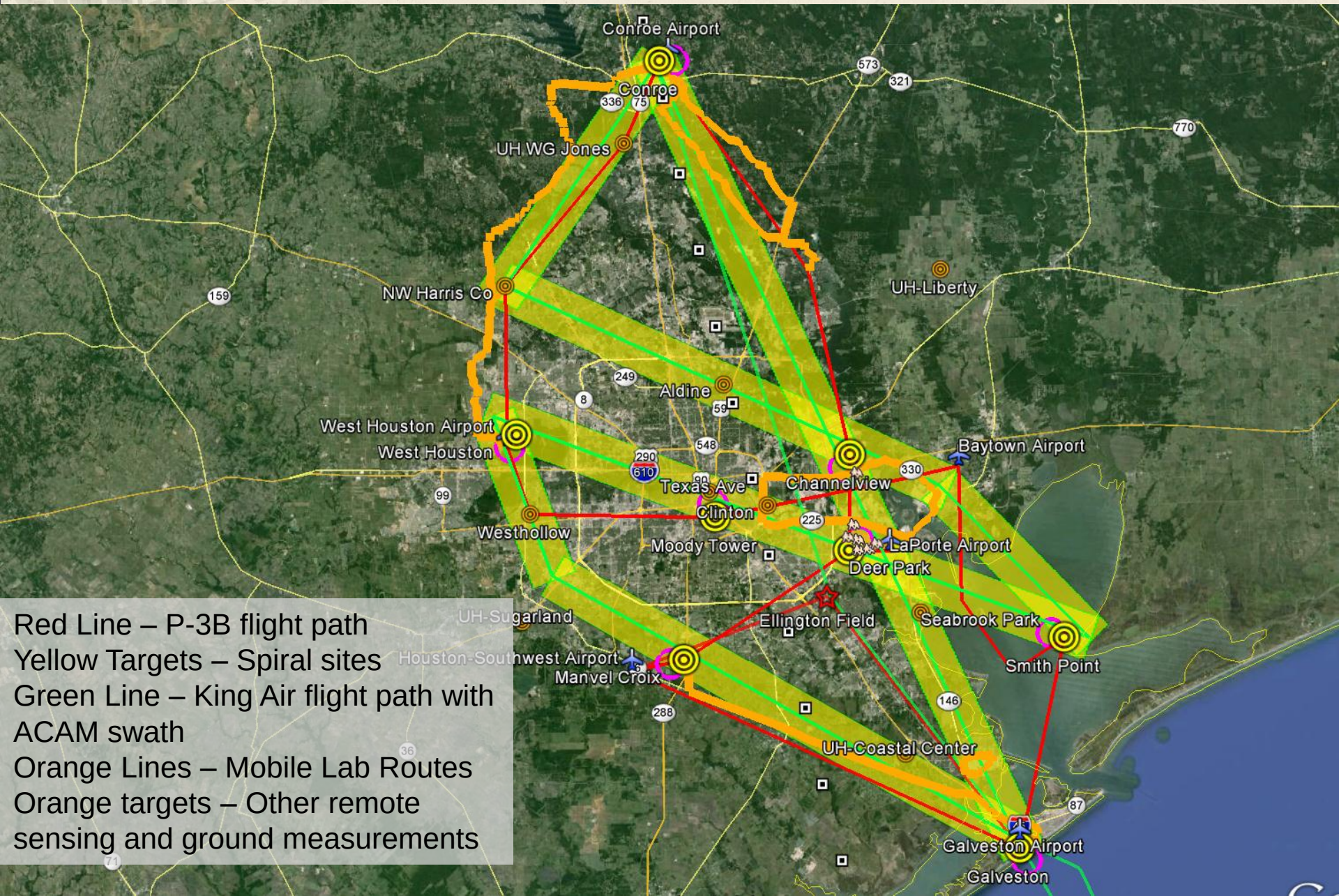
P-3B in action







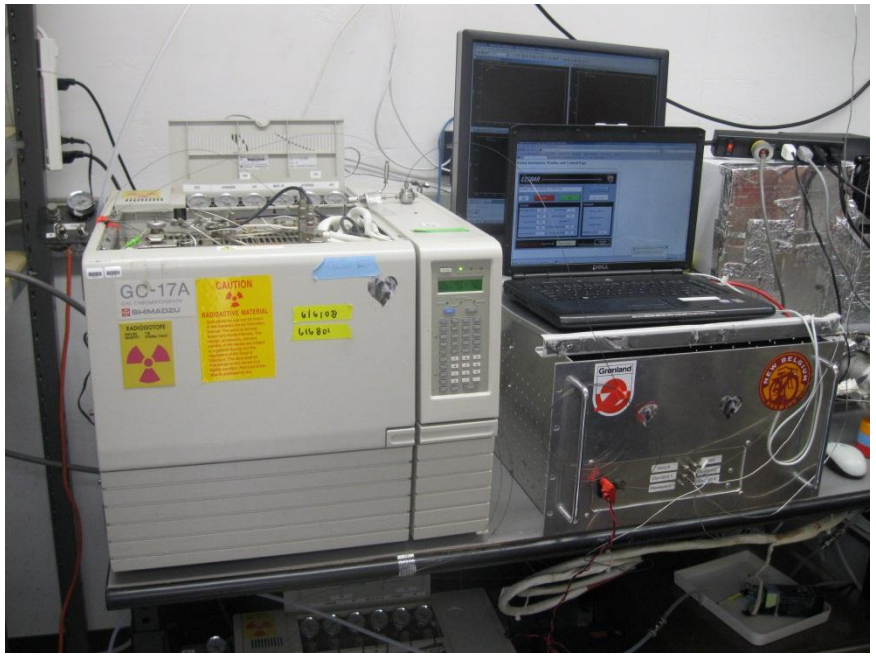
Observing Strategy for Houston



Red Line – P-3B flight path
Yellow Targets – Spiral sites
Green Line – King Air flight path with ACAM swath
Orange Lines – Mobile Lab Routes
Orange targets – Other remote sensing and ground measurements

Appalachian State Instruments at Moody Tower to monitor Formaldehyde and VOCs







Dr. Barkley Sive

Information and Data Management



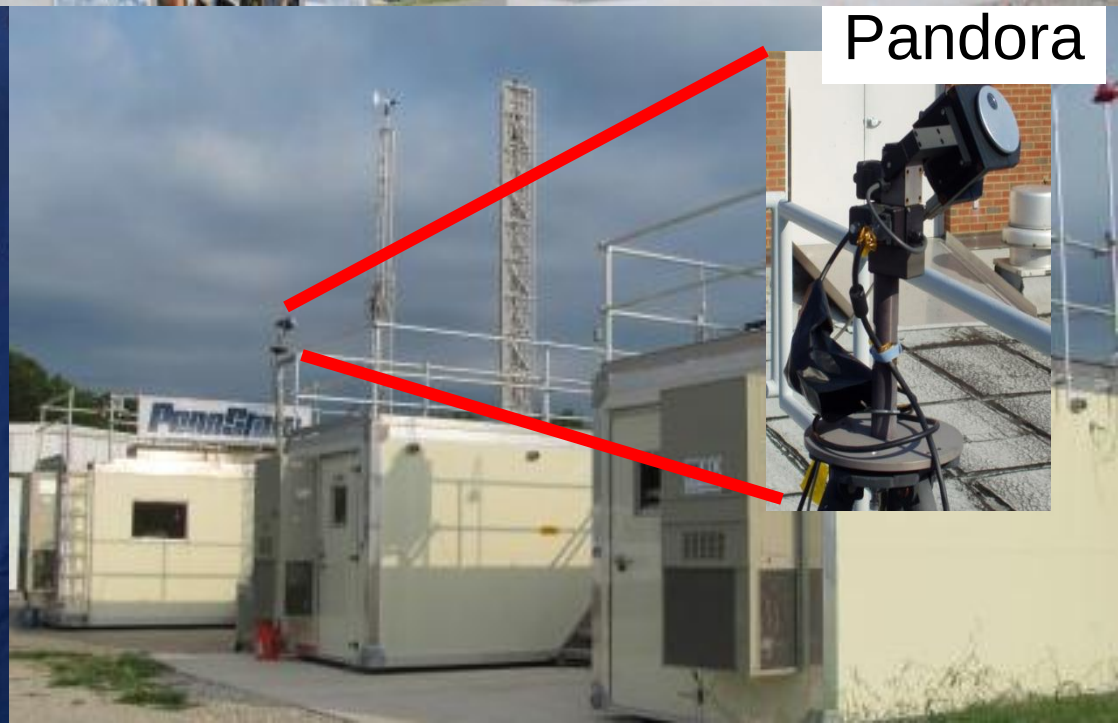
https://discover-aq.larc.nasa.gov/



http://www-air.larc.nasa.gov/missions/discover-aq/discover-aq.html



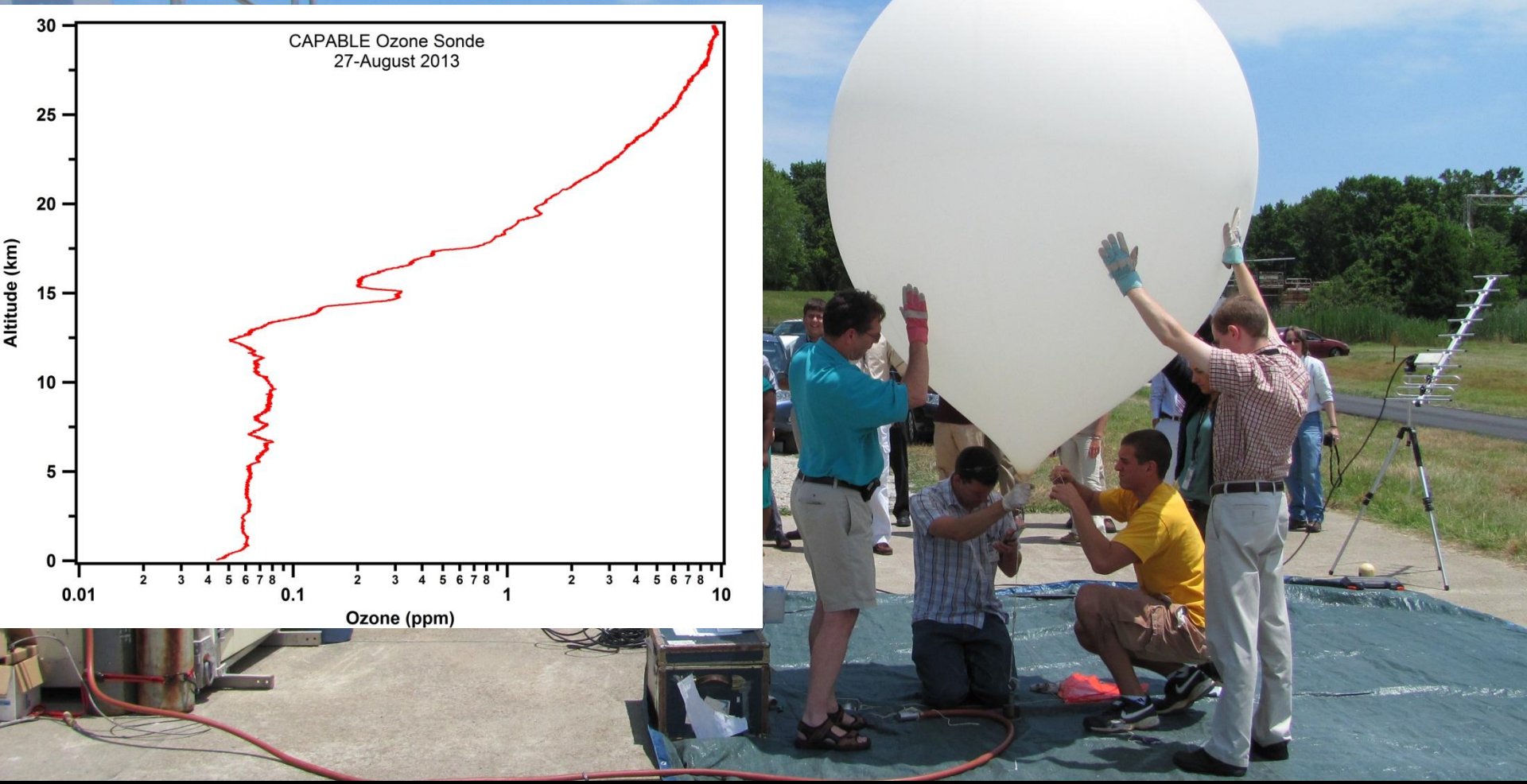




- Collocated with Virginia Department of Environmental Quality station at the NASA Langley Research Center, Hampton VA
- Collocated with U.S. EPA photolytic NO_2 instrument

http://capable.larc.nasa.gov/

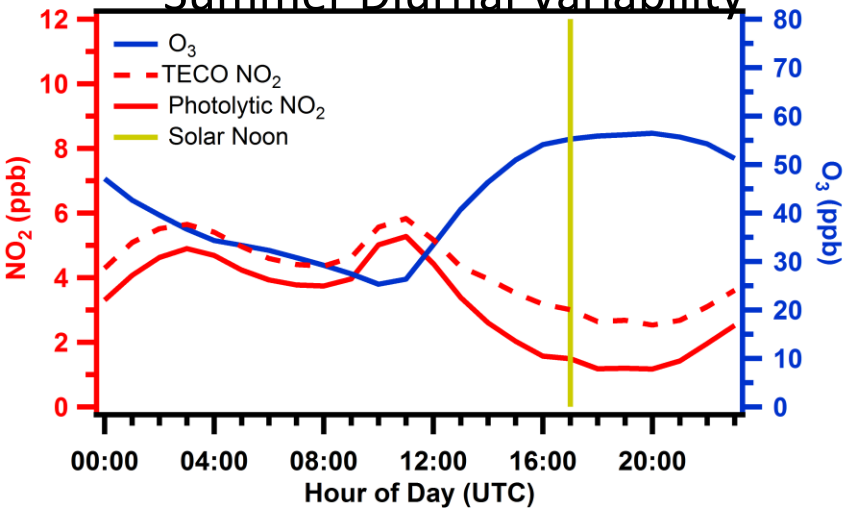
National Aeronautics and Space Administration



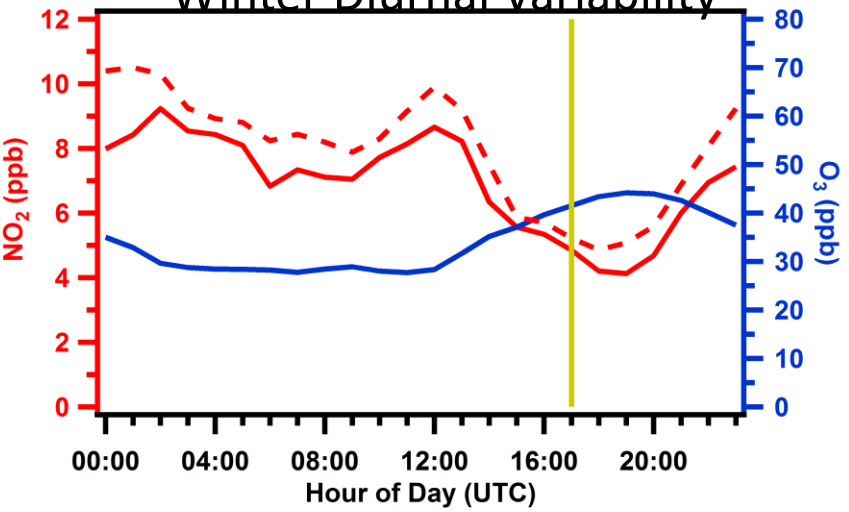
http://capable.larc.nasa.gov/

Meteorology Interacting with Chemistry

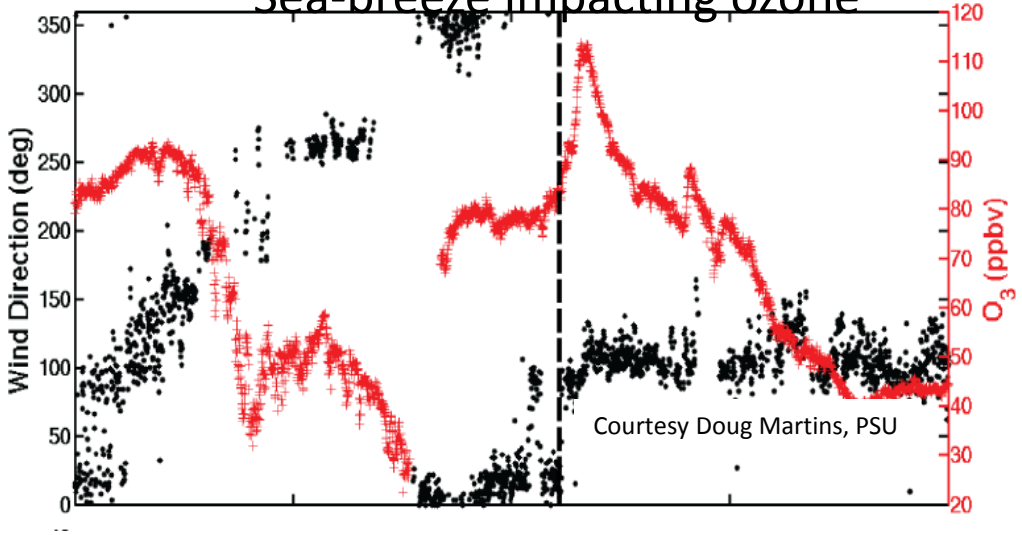
Summer Diurnal Variability



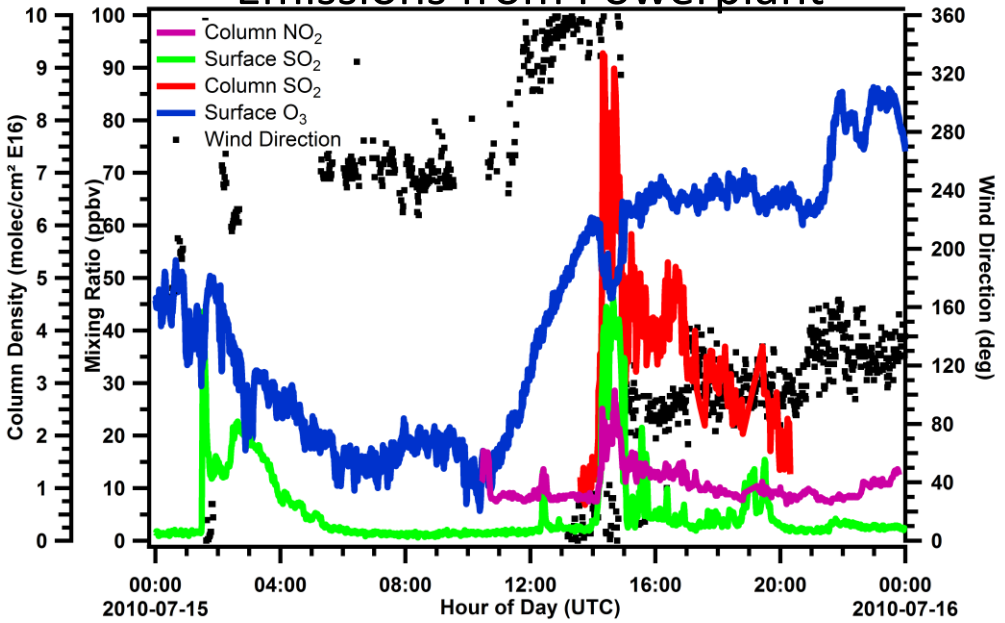
Winter Diurnal Variability



Sea-breeze impacting ozone

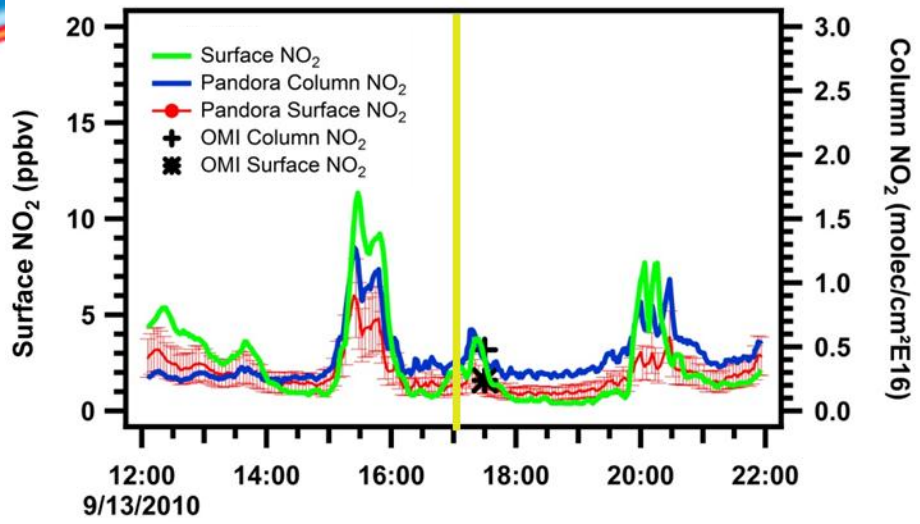


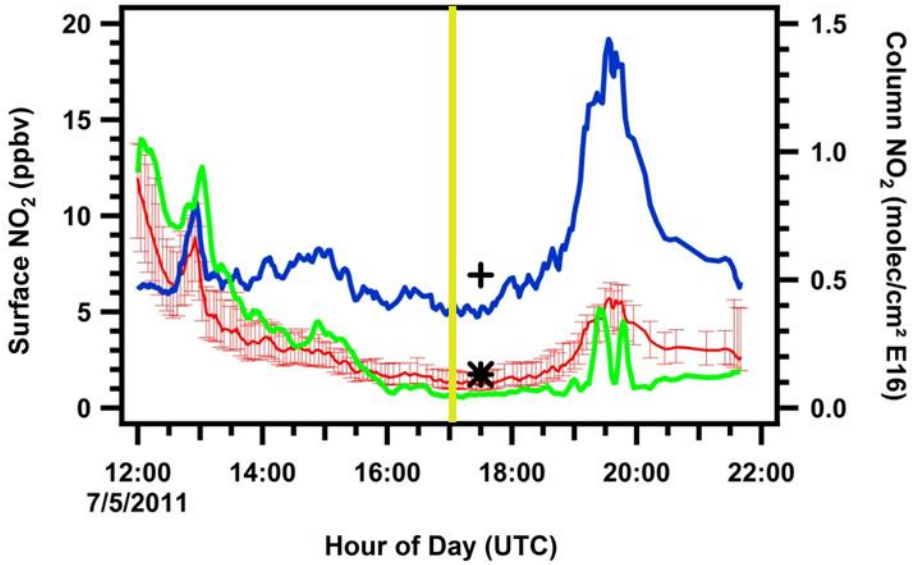
Emissions from Powerplant

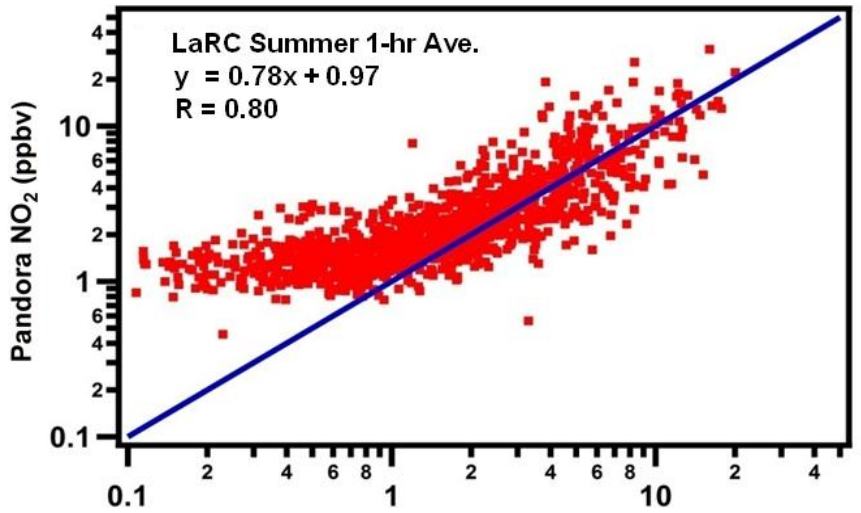


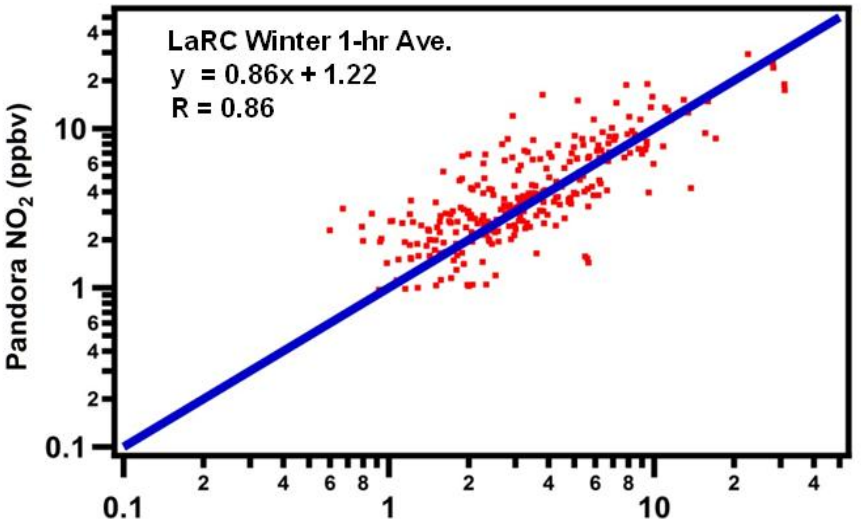
http://capable.larc.nasa.gov/

Detecting Surface Pollution from the Column









http://capable.larc.nasa.gov/

Hourly Atmospheric Pollution From Geostationary Earth Orbit

PI: Kelly Chance, Smithsonian Astrophysical Observatory
Instrument Development: Ball Aerospace
Project Management: NASA LaRC
Other Institutions: NASA GSFC, NOAA, EPA, NCAR, Harvard, UC Berkeley, St. Louis U, U Alabama Huntsville, U Nebraska
International collaboration: Korea, Europe, Canada

Selected Nov. 2012 as NASA'sfirst Earth Venture Instrument

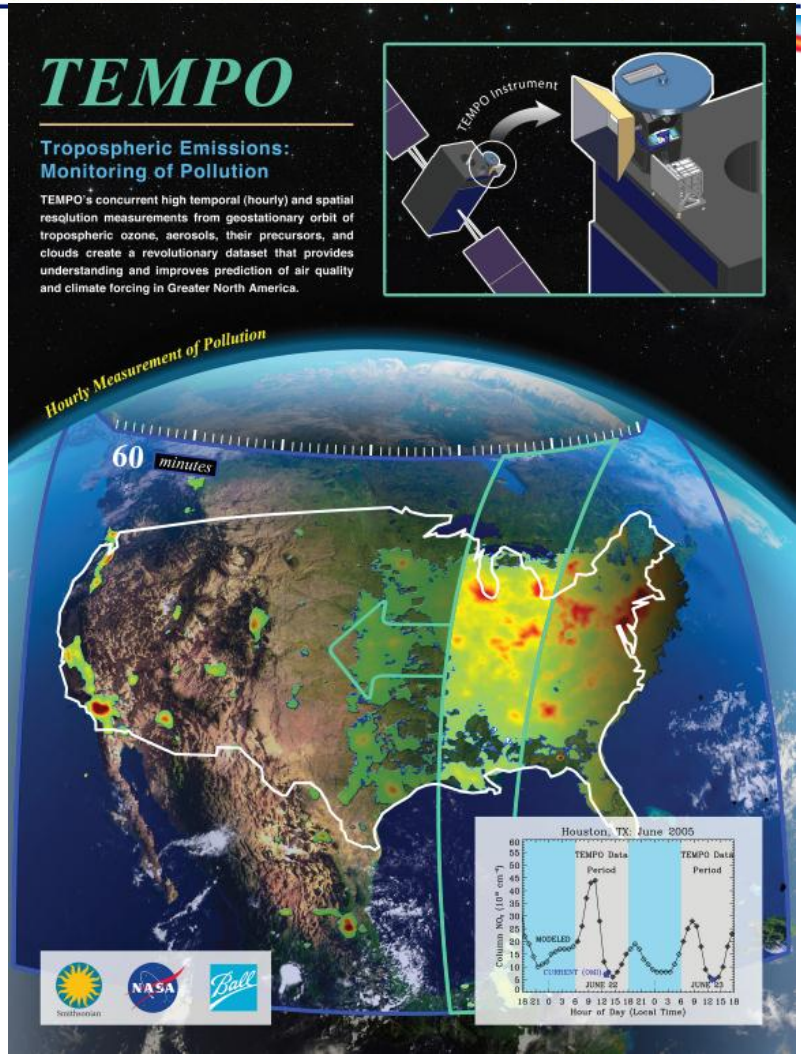
- Instrument delivery September 2017
- NASA will arrange hosting on commercial geostationary communications satellite with launch expected 2019-2023

Provides hourly daylight observations to capture rapidly varying emissions & chemistry important for air quality

- UV/visible grating spectrometer to measure key elements in tropospheric ozone and aerosol pollution
- Exploits extensive measurement heritage from LEO missions
- Distinguishes boundary layer from free tropospheric & stratospheric ozone

Aligned with Earth Science Decadal Survey recommendations

- Makes many of the GEO-CAPE atmosphere measurements
- Responds to the phased implementation recommendation of GEO-CAPE mission design team

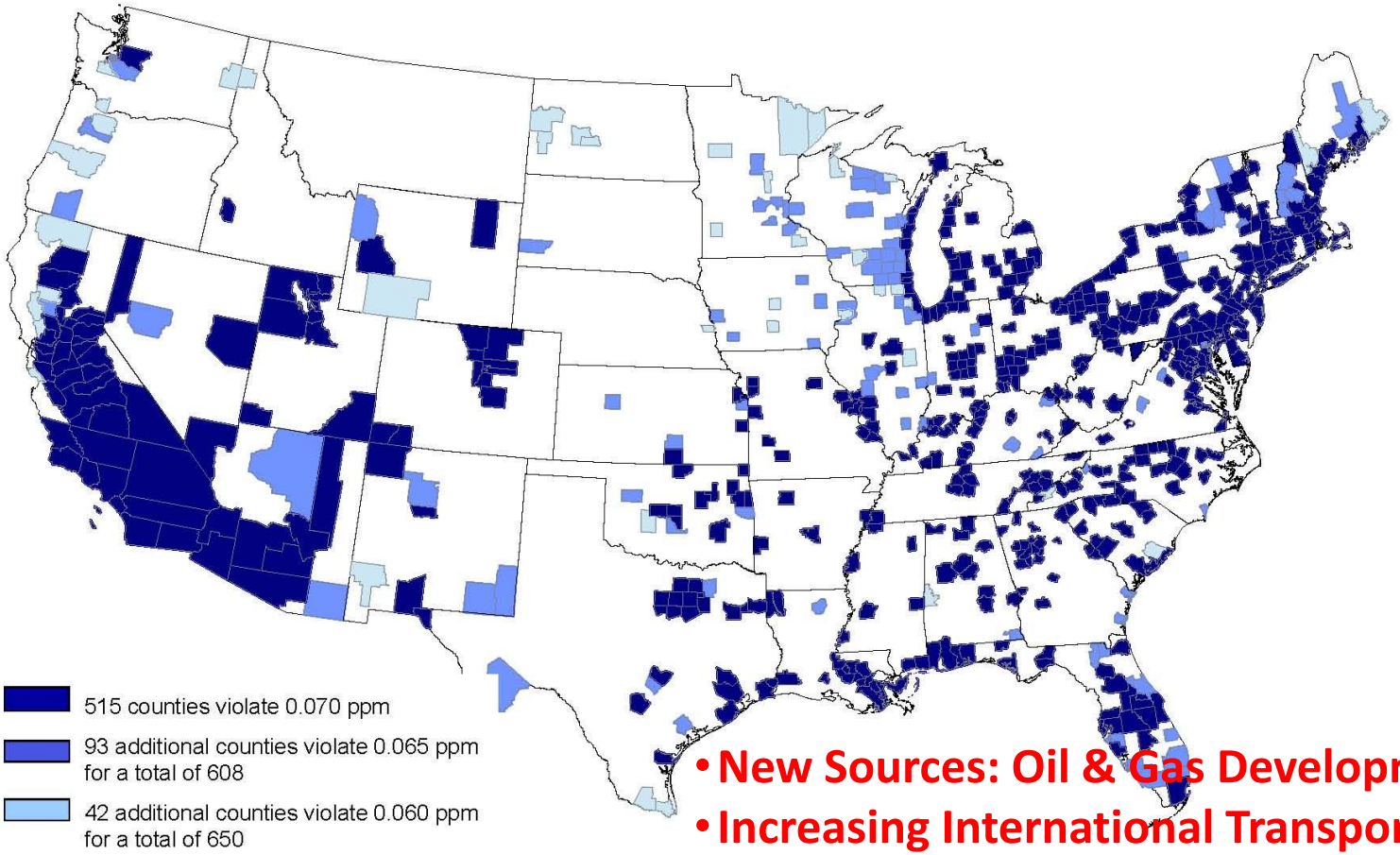


North American component of an international constellation for air quality observations

Counties With Monitors Violating Primary 8-hour Ground-level Ozone Standards
0.060 - 0.070 parts per million

(Based on 2006 – 2008 Air Quality Data)

EPA will not designate areas as nonattainment on these data, but likely on 2008 – 2010 data which are expected to show improved air quality.



- **New Sources: Oil & Gas Development**
- **Increasing International Transport**
- **Impact of Climate Change**

Notes:

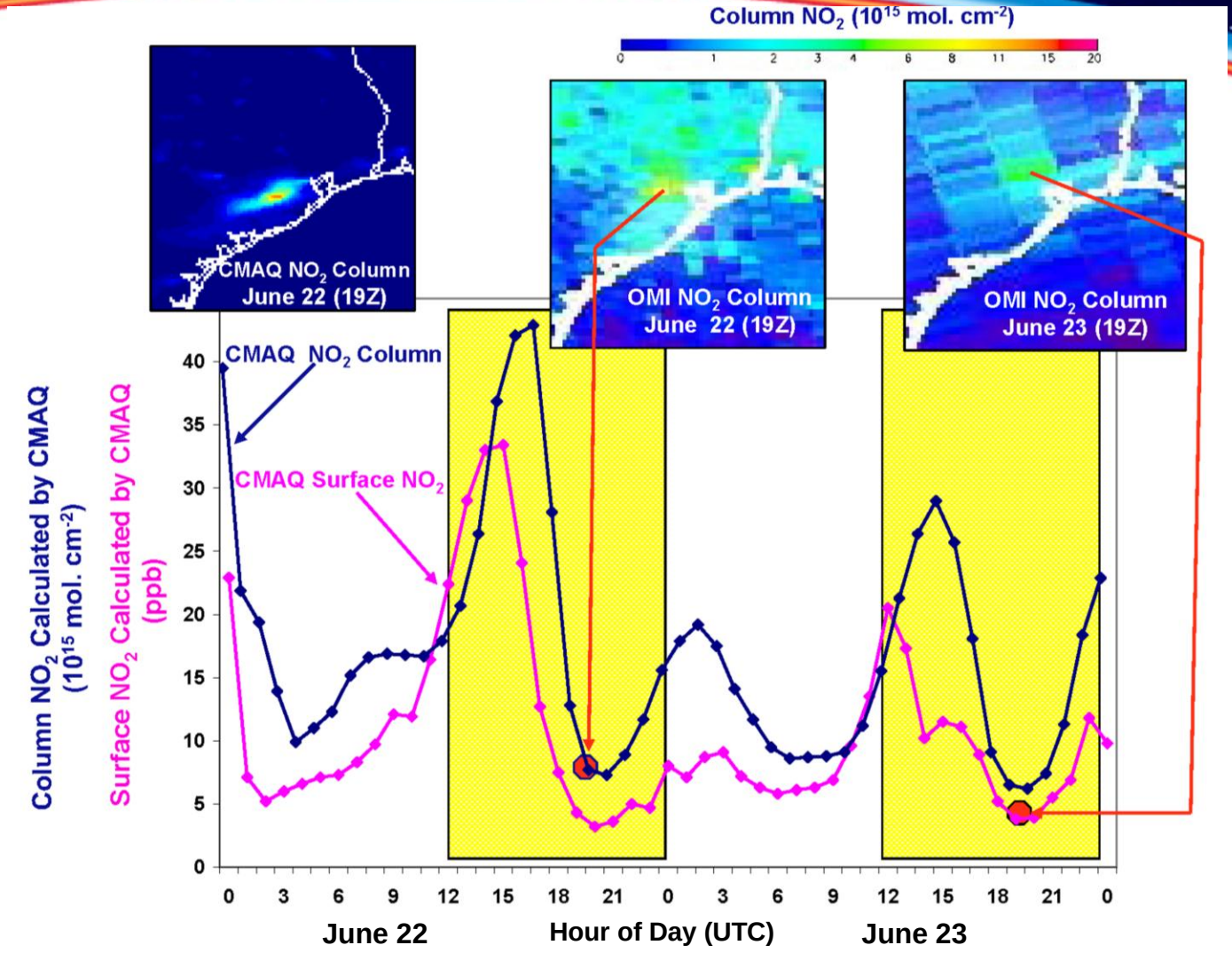
1. No monitored counties outside the continental U.S. violate.
2. EPA is proposing to determine compliance with a revised primary ozone standard by rounding the 3-year average to three decimal places.

Cite: http://www.epa.gov/air/ozonepollution/actions.html

Why Geostationary? High temporal and spatial resolution

OMI accurately detects column NO_2 - once per day and with varying horizontal resolution

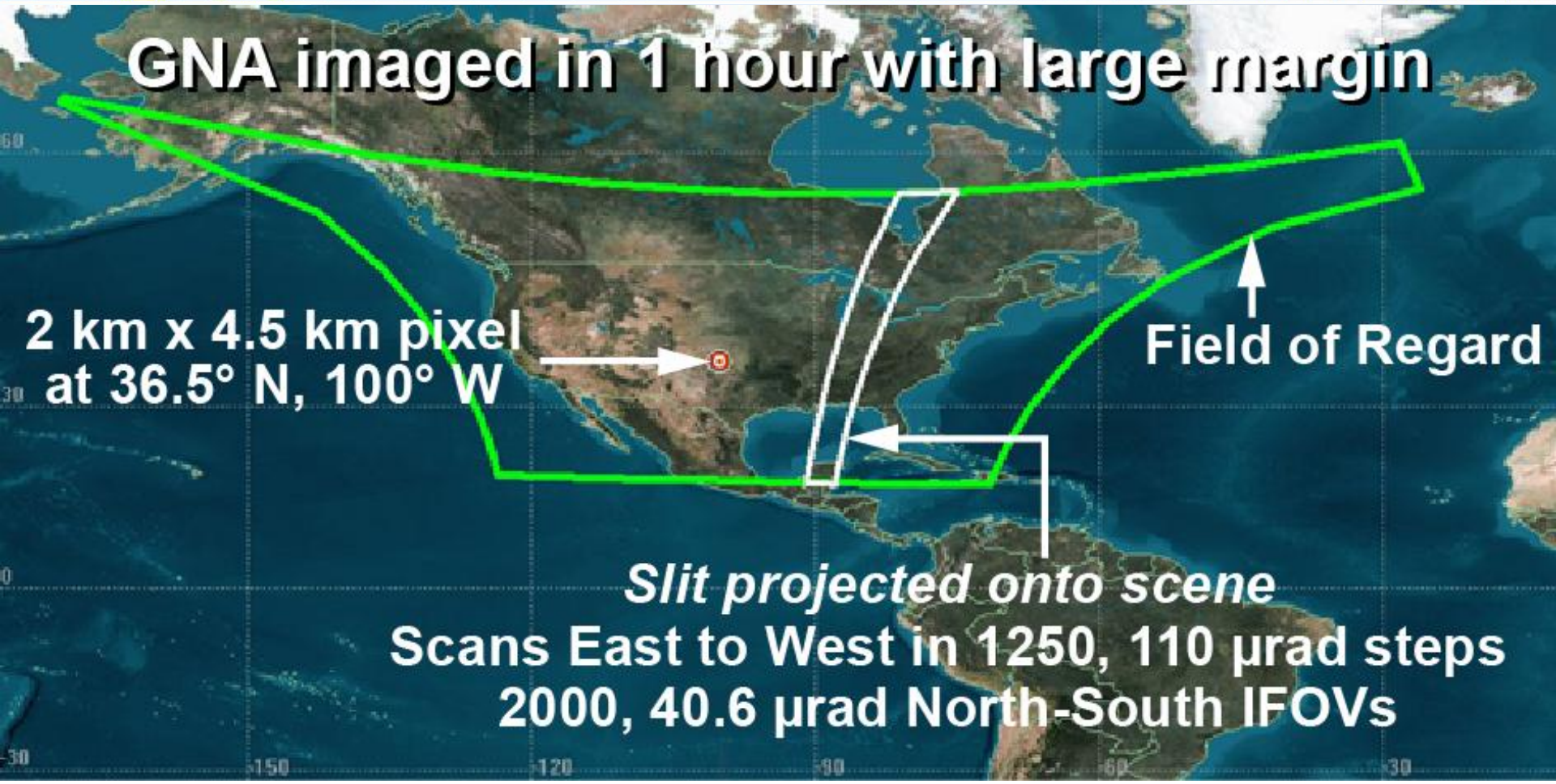
Hourly NO_2 surface concentration and integrated column calculated by CMAQ air quality model: Houston, TX, June 22-23, 2005



- LEO observations provide limited information on rapidly varying emissions, chemistry, & transport

GEO will provide observations at temporal and spatial scales highly relevant to air quality processes

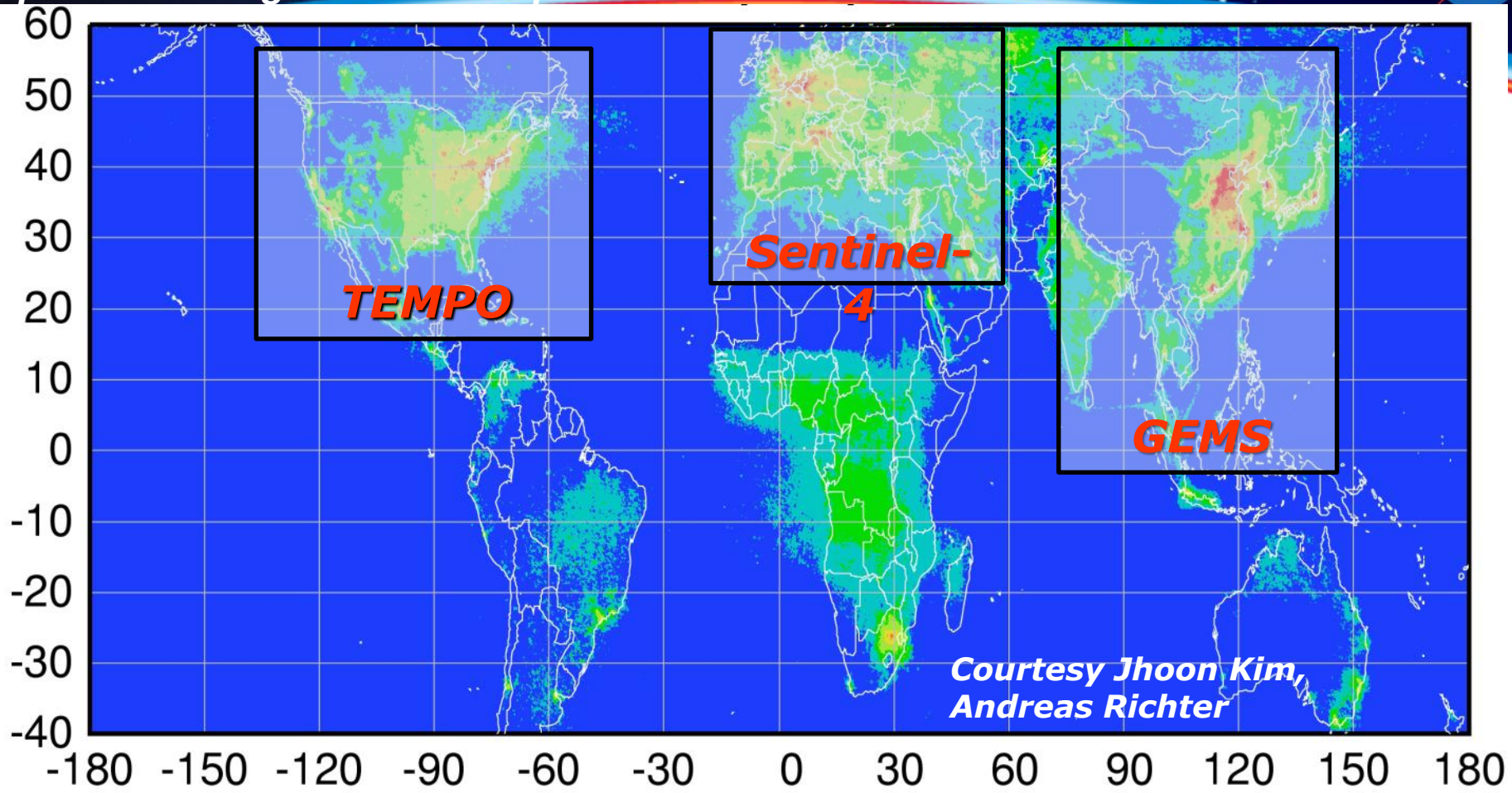
TEMPO footprint, ground sample distance and field of regard



- *Each 2 km × 4.5 km pixel is a 2K element spectrum from 290-750 nm*
- *GEO platform selected by NASA for viewing Greater North America*

Geostationary pollution monitoring

Spatial coverage of funded spectrometers 2018-2020



Policy-relevant science and environmental services enabled by common observations

- Improved emissions, at common confidence levels, over industrialized Northern Hemisphere
- Improved air quality forecasts and assimilation systems
- Improved assessment, e.g., observations to support United Nations Convention on Long Range Transboundary Air Pollution

National Aeronautics and Space Administration

Stratospheric Aerosol and Gas Experiment

SAGE III on ISS

An Earth Science Mission on the International Space Station



NASA Langley Research Center

Introduction

SAGE III on International Space Station (ISS) is the fifth in a series of instruments developed for monitoring ozone, aerosols and gaseous constituents in the stratosphere and upper troposphere

SAGE III will be one of the first continuous Earth-observing instruments on the ISS

SAGE uses the occultation technique to take measurements using the sun or moon as a source

The orbital path of ISS helps maximize the scientific value of SAGE III observations

SAGE III on ISS is led by NASA Langley Research Center with many partners:

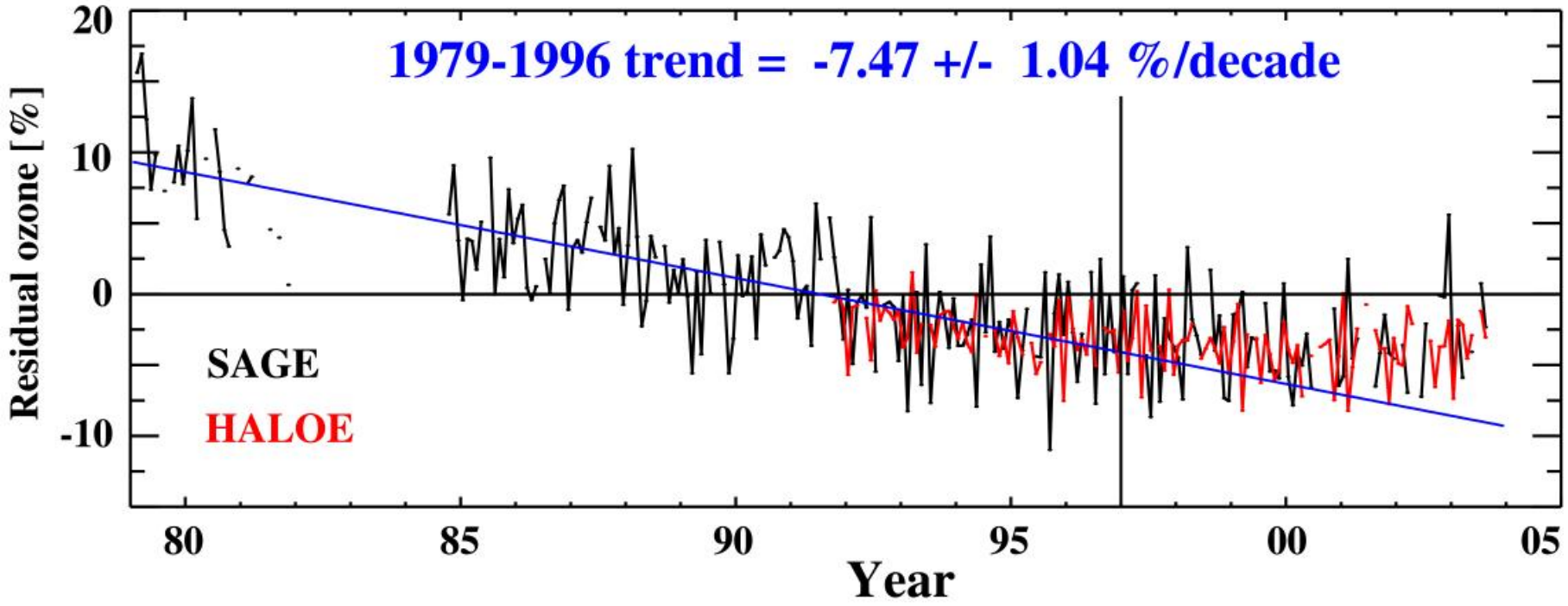
- NASA Johnson Space Center
- NASA Marshall Space Flight Center
- Ball Aerospace and Technology Corp
- European Space Agency
- Thales Alenia Space-Italia



SAGE Science Results – Over 30 Years

SAGE produces vertical profiles of aerosols and gases in the stratosphere and upper troposphere

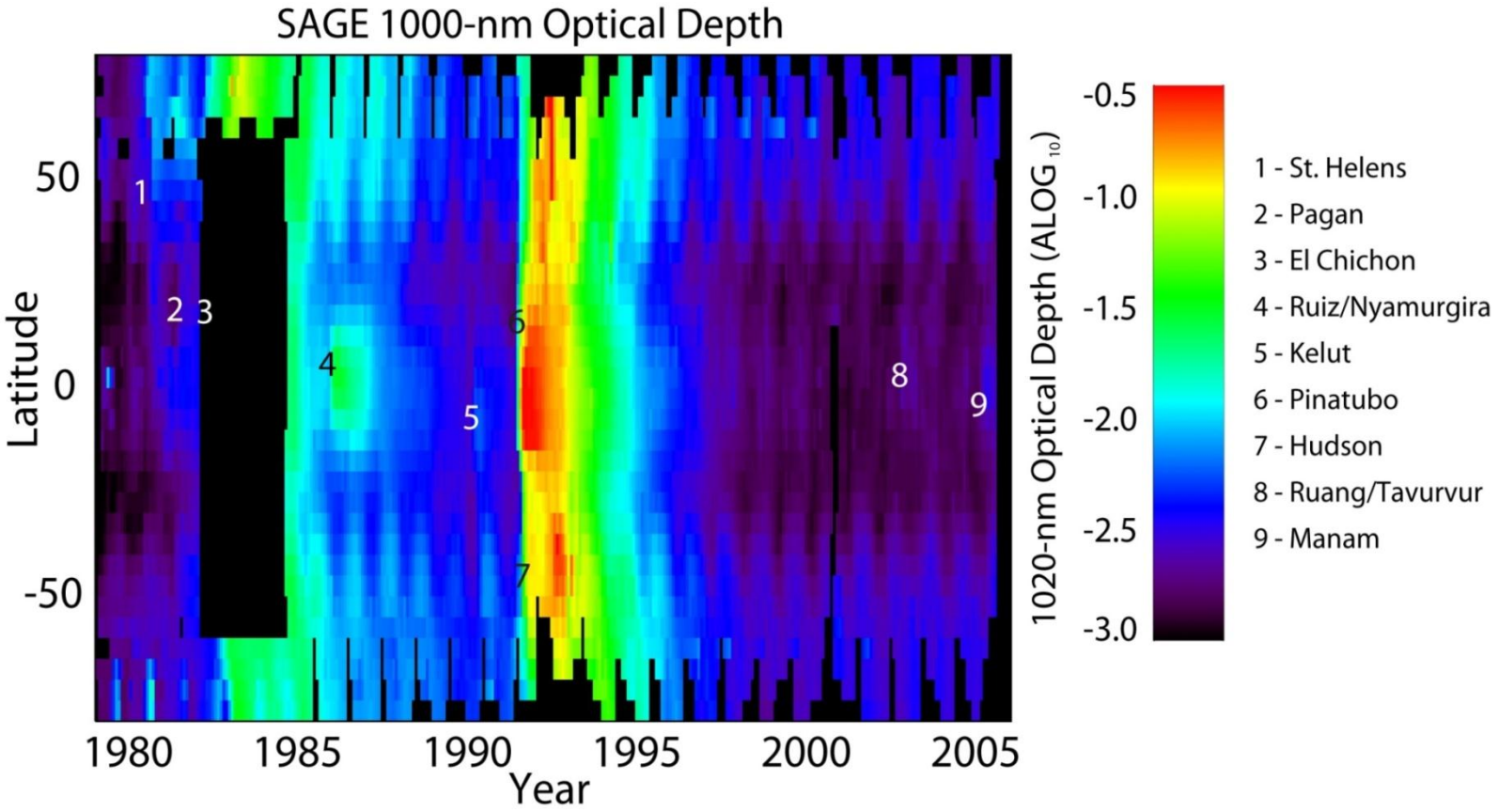
The multi-decadal SAGE ozone and aerosol data sets have undergone intense scrutiny and are the international standard for accuracy and stability.



Stratospheric Aerosols

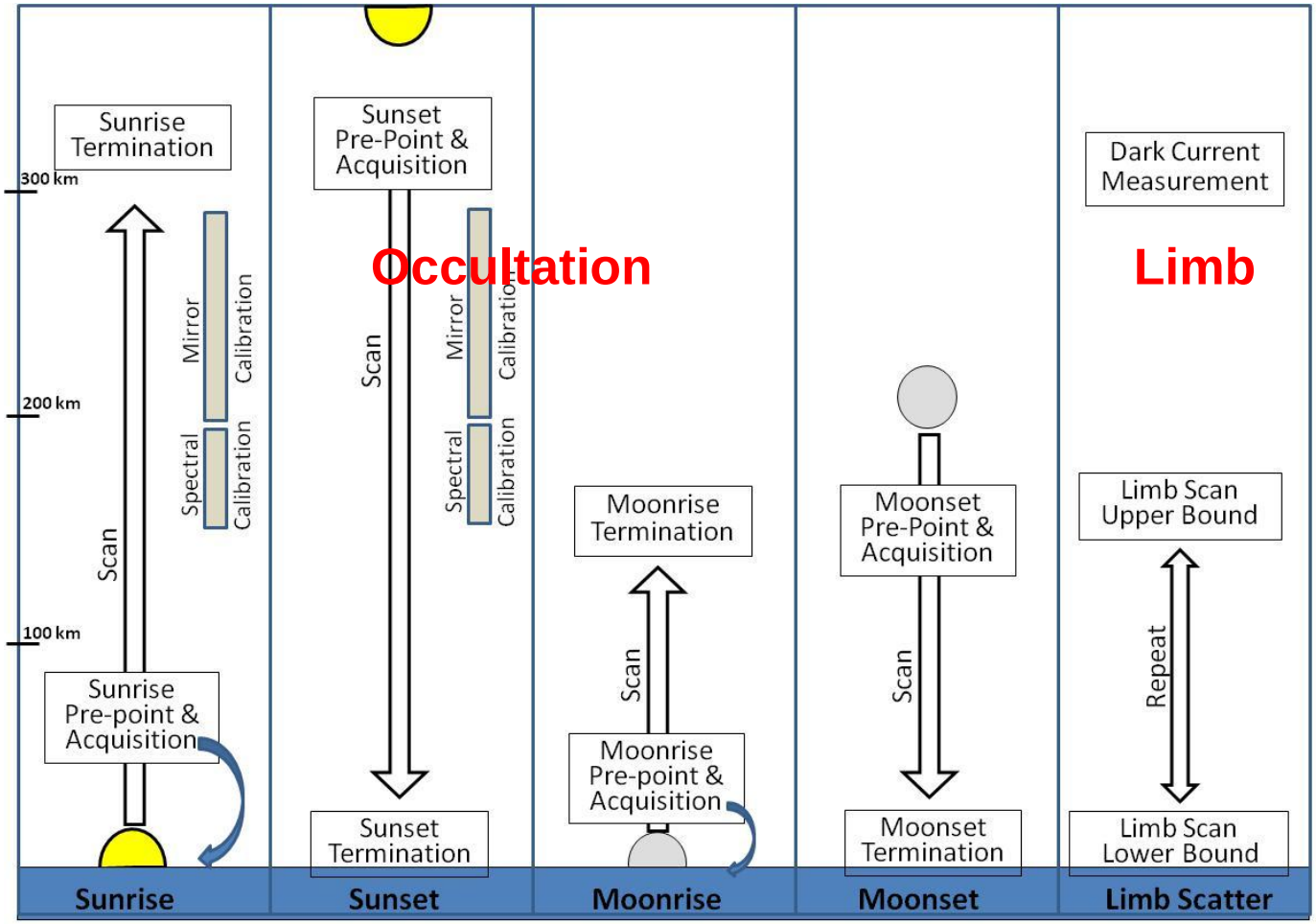
SAGE aerosol data is recognized as *the source* necessary for:

- Understanding O_3 trends (Montreal Protocol Scientific Assessment Panel)
- Predicting global climate change (Hansen, 2008 AGU Bjerknes lecture)



SAGE III Science Measurements

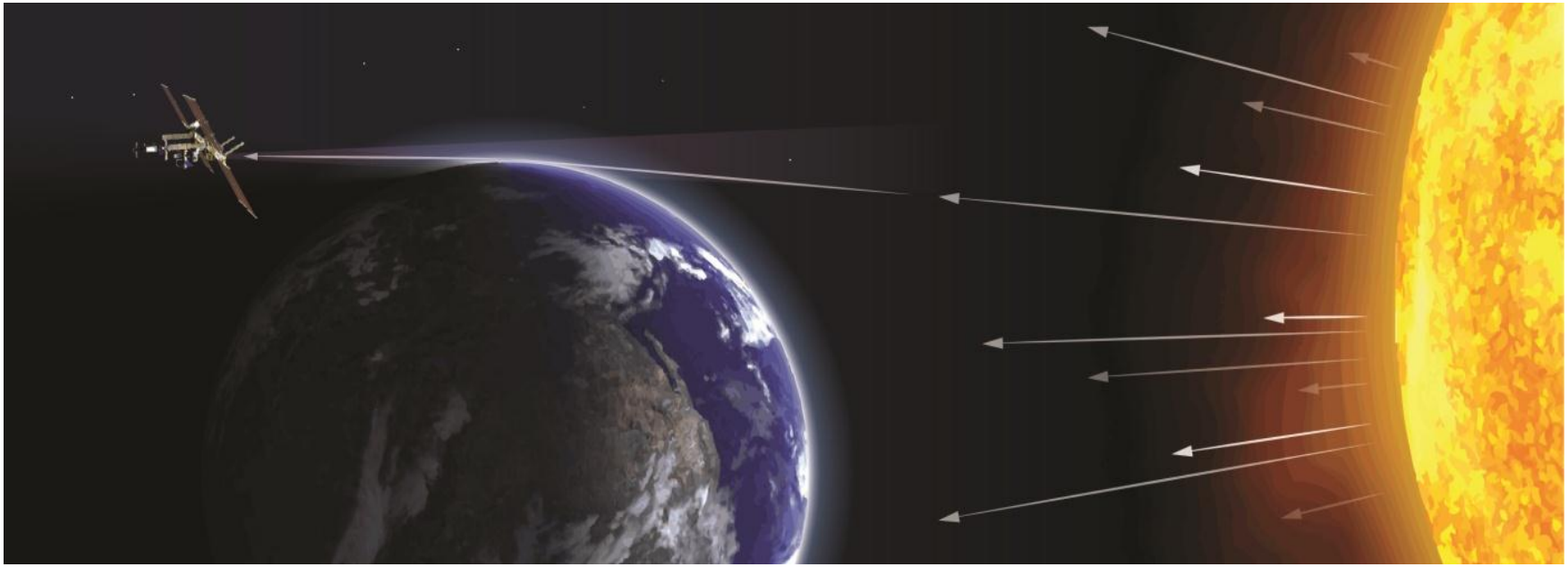
SAGE III on ISS makes three types of science data measurements



Occultation Observations

Solar energy, attenuated by the Earth's atmosphere, is monitored in nine wavelength bands centered at 290, 385, 440, 525, 600, 760, 940, 1020, and 1550 nm

The reflected light from the moon provides a radiant source for making measurements of key nighttime atmospheric constituents such as nitrogen trioxide and chlorine dioxide

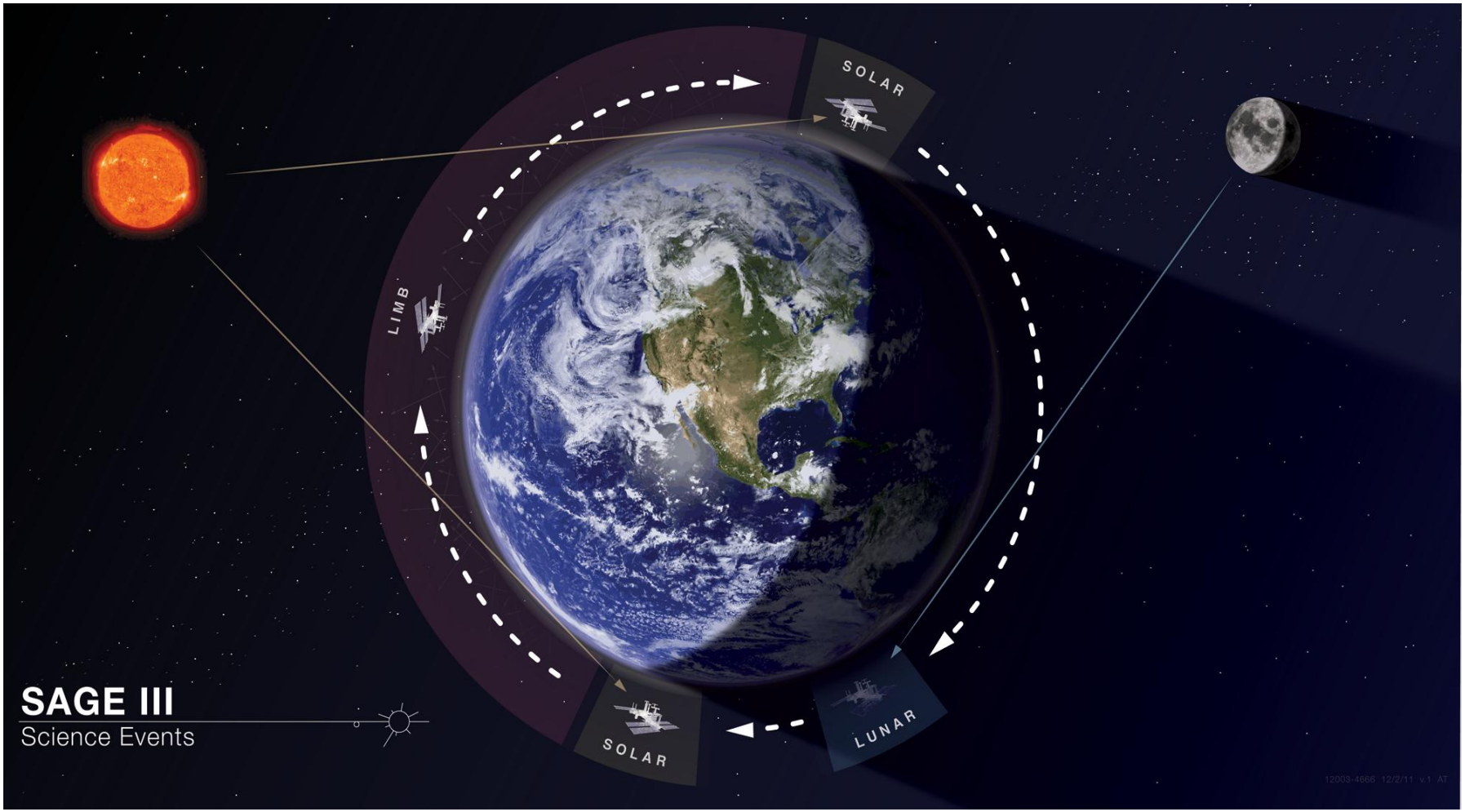


Limb Scatter Observations

Limb Scatter (LS) observations measure the sunlight as it is scattered by atmospheric gases and particulates (aerosols and clouds) as well as by the Earth's surface



Typical Orbit



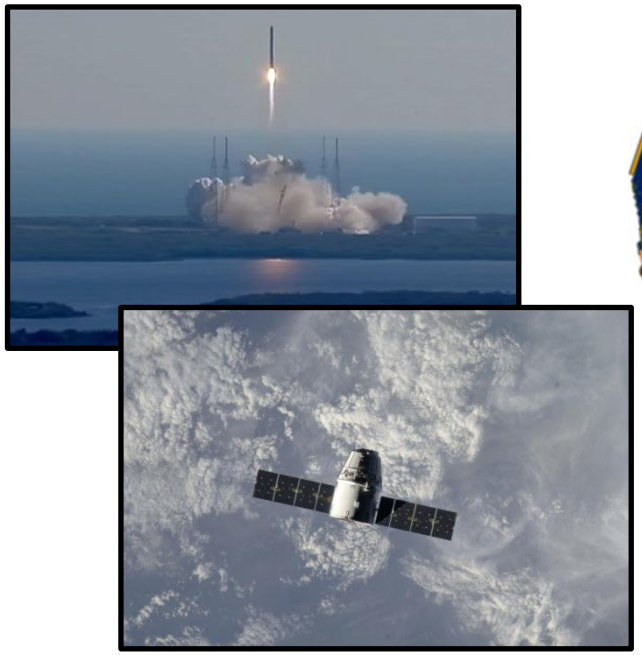
Launch Configuration

Falcon 9

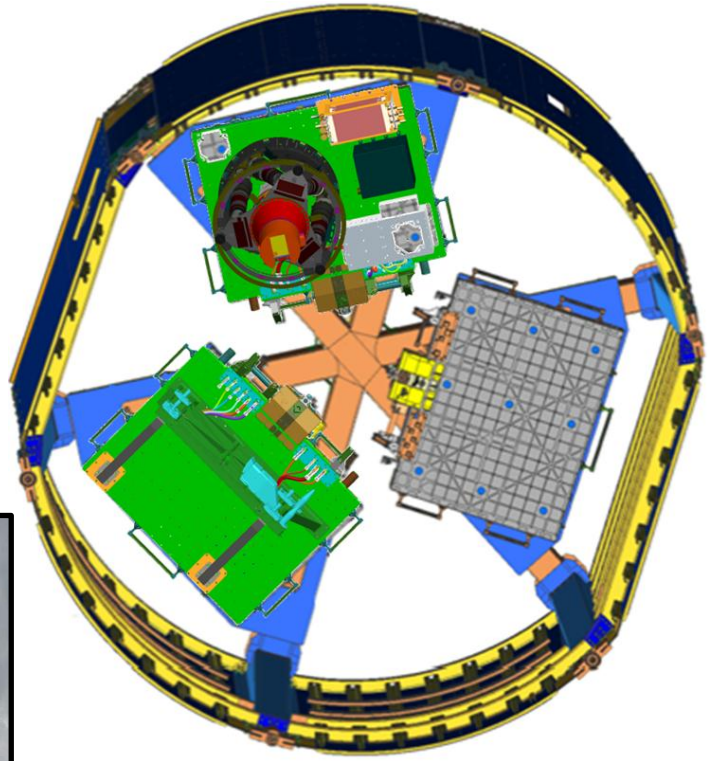




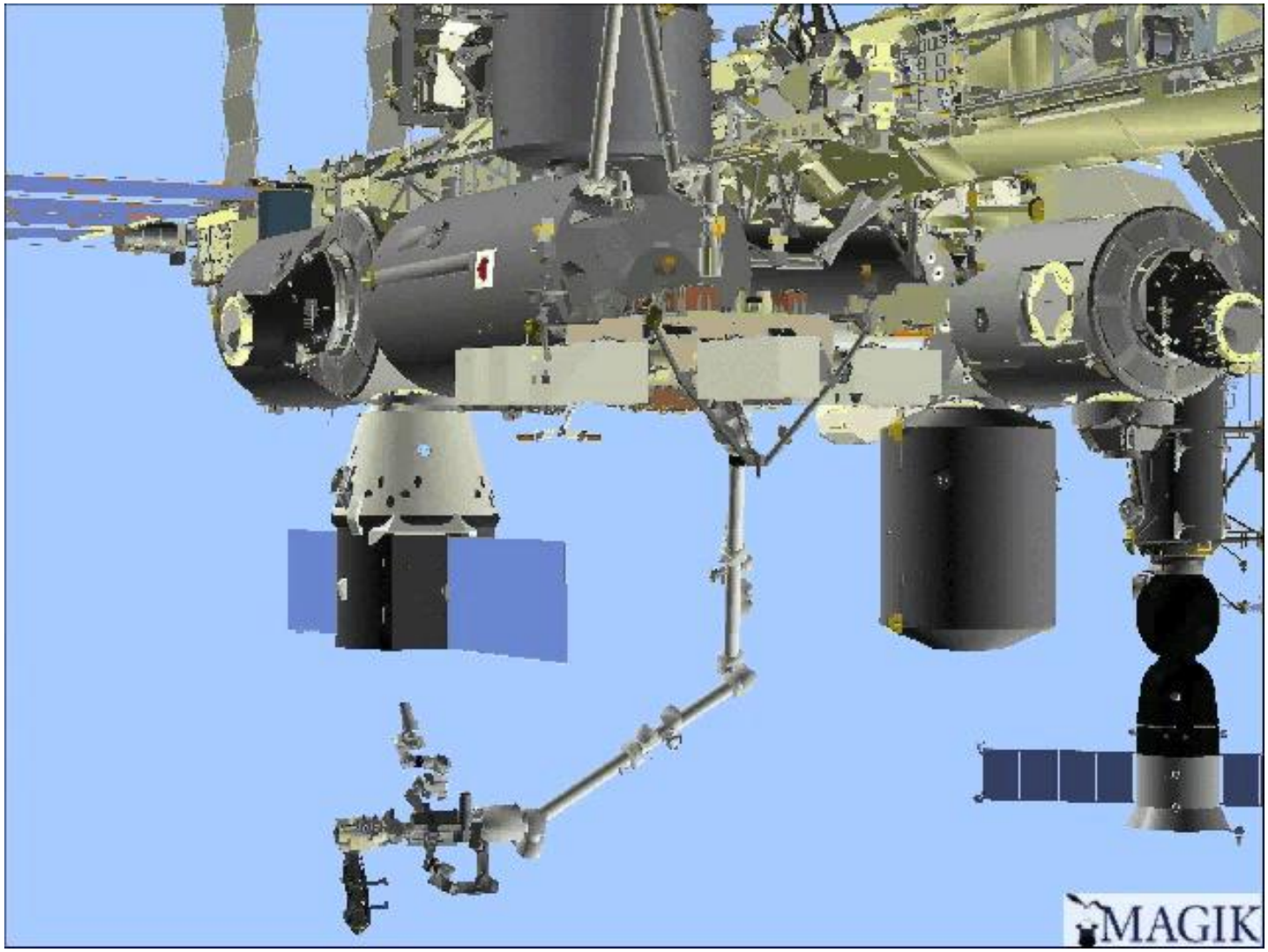
Integration Hangar



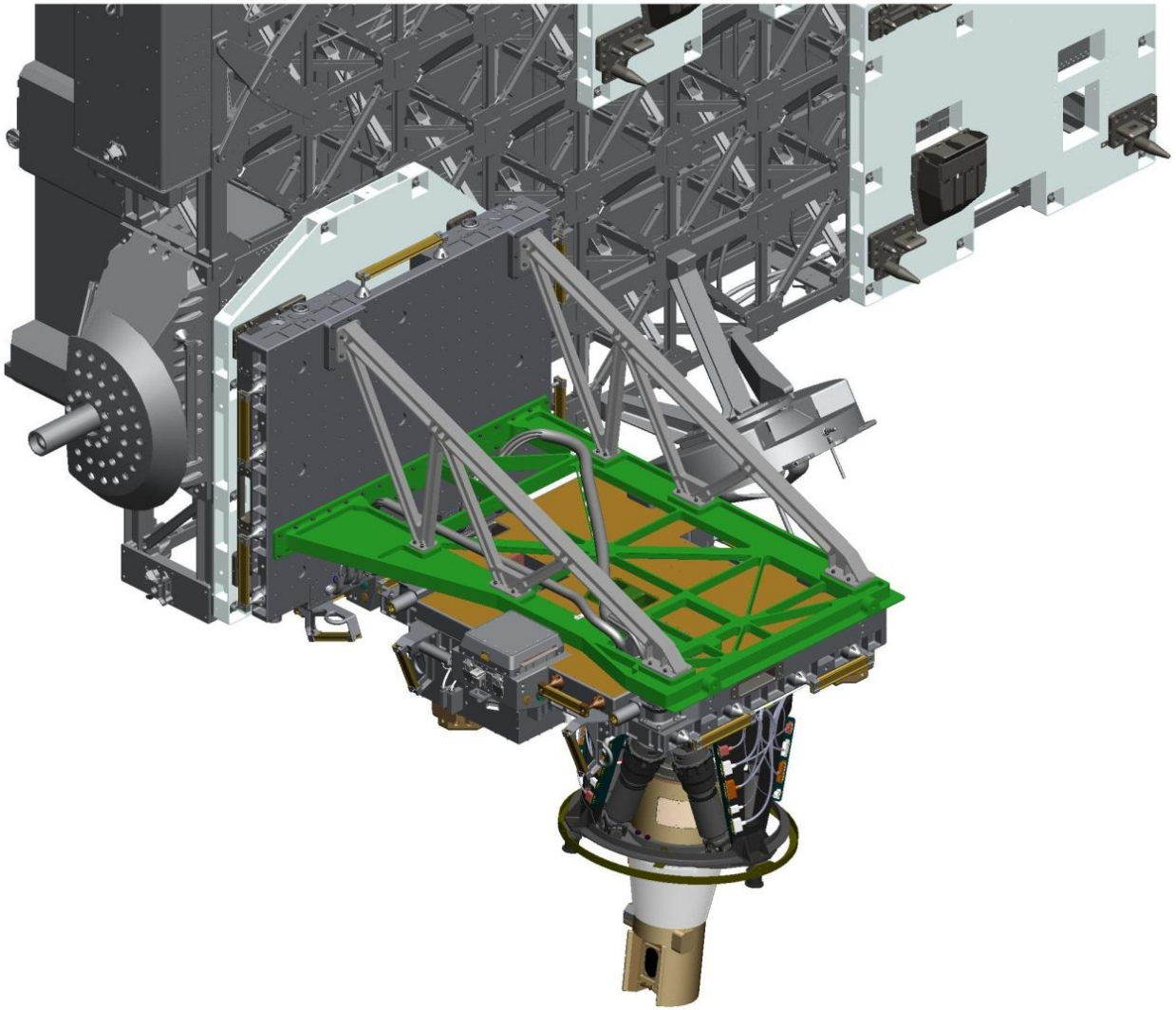
Dragon Unpressurized Cargo Module



SAGE III Installation

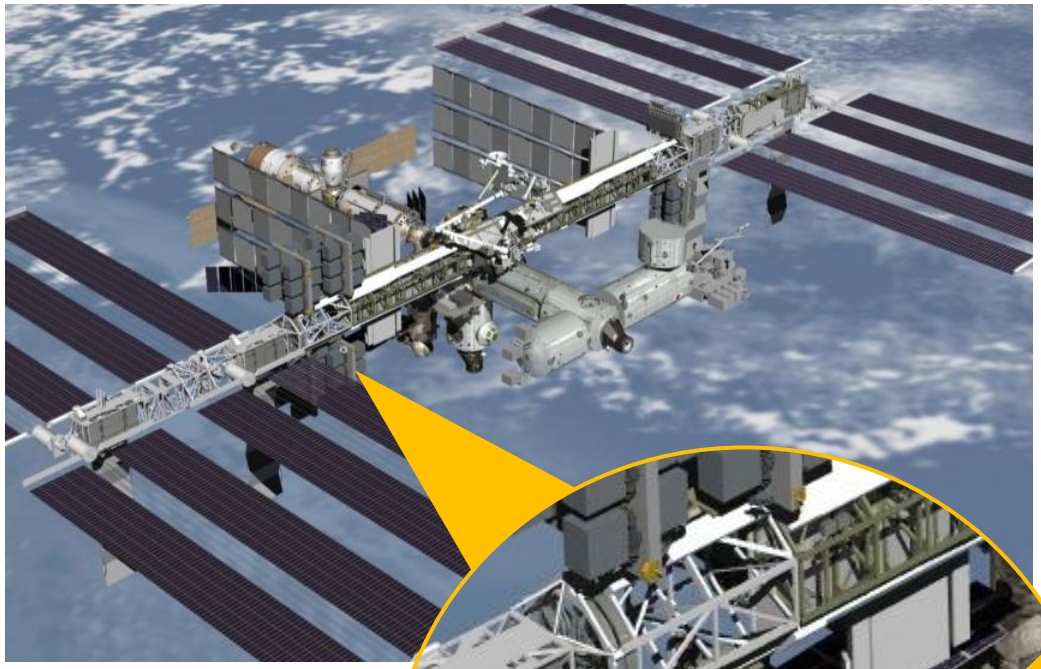


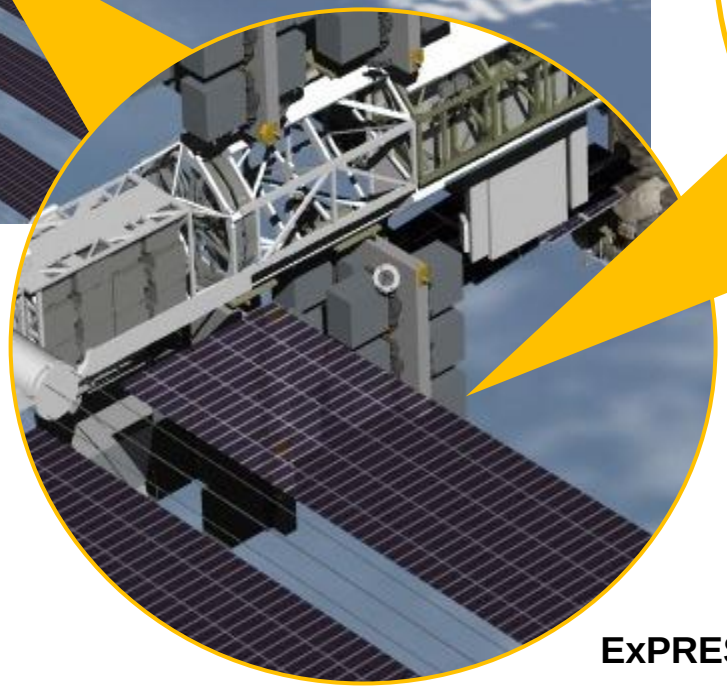
SAGE III On-Orbit Configuration

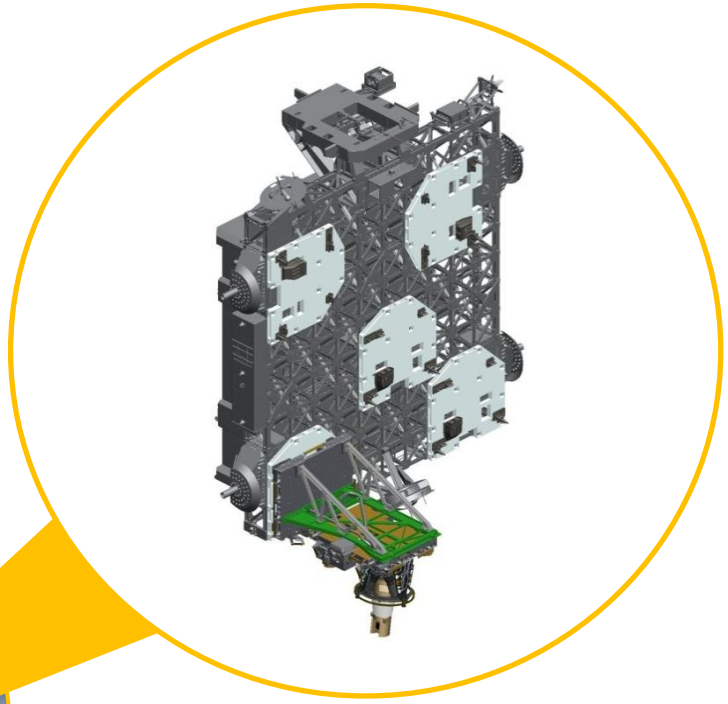


ISS Location

S3 Truss Payload Attachment System-4 Site (PAS-4)



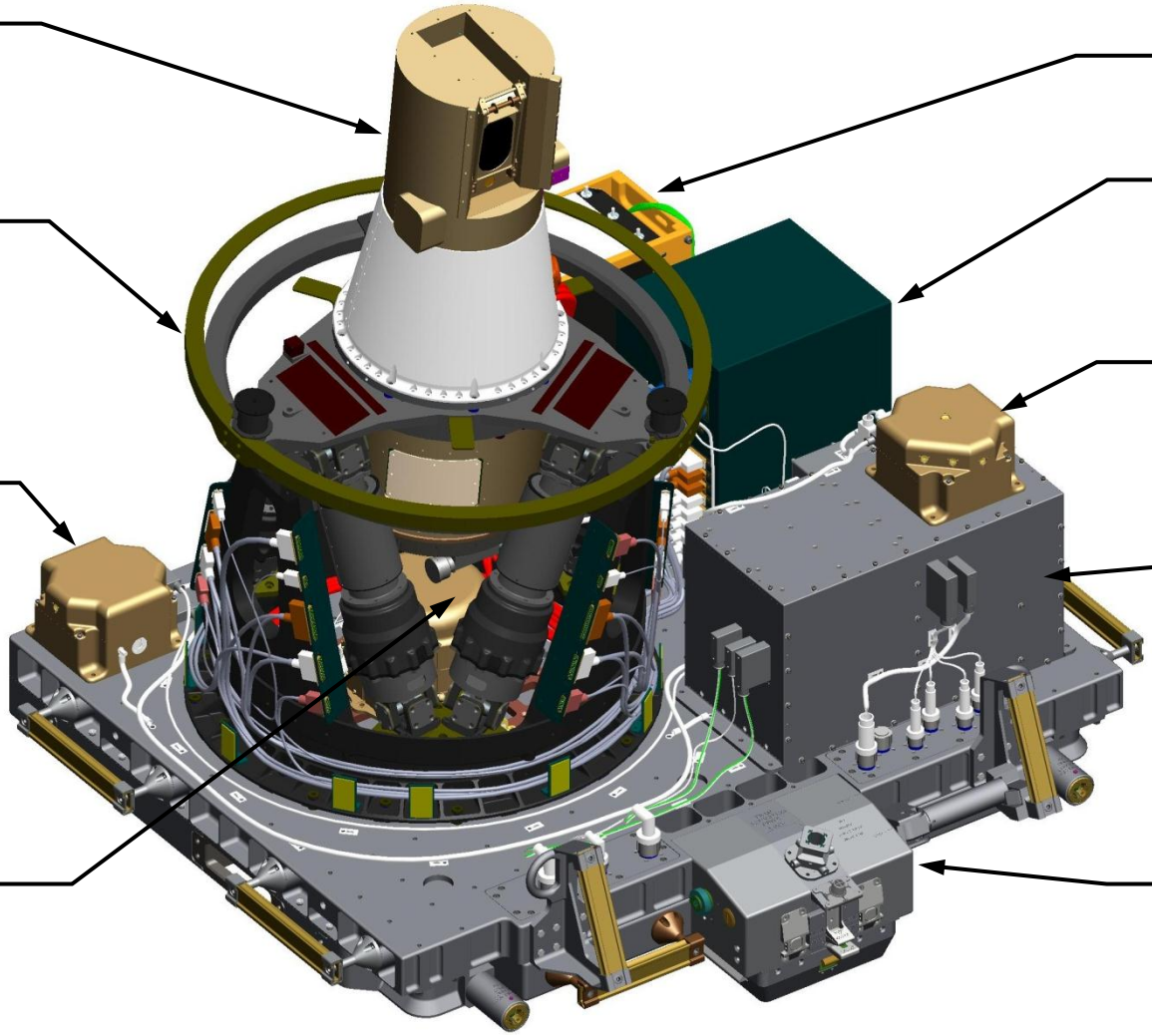




Passive FRAM Adapter Plate Site 3 (PFAP-3)

ExPRESS Logistics Carrier-4 (ELC-4)

Instrument Payload



Sensor Assembly (SA)
LaRC/BATC

Hexapod Mechanical Assembly (HMA)
ESA

Contamination Monitoring Package (CMP)
LaRC

Disturbance Monitoring Package (DMP)
LaRC/Honeywell

Instrument Control Electronics (ICE)
LaRC

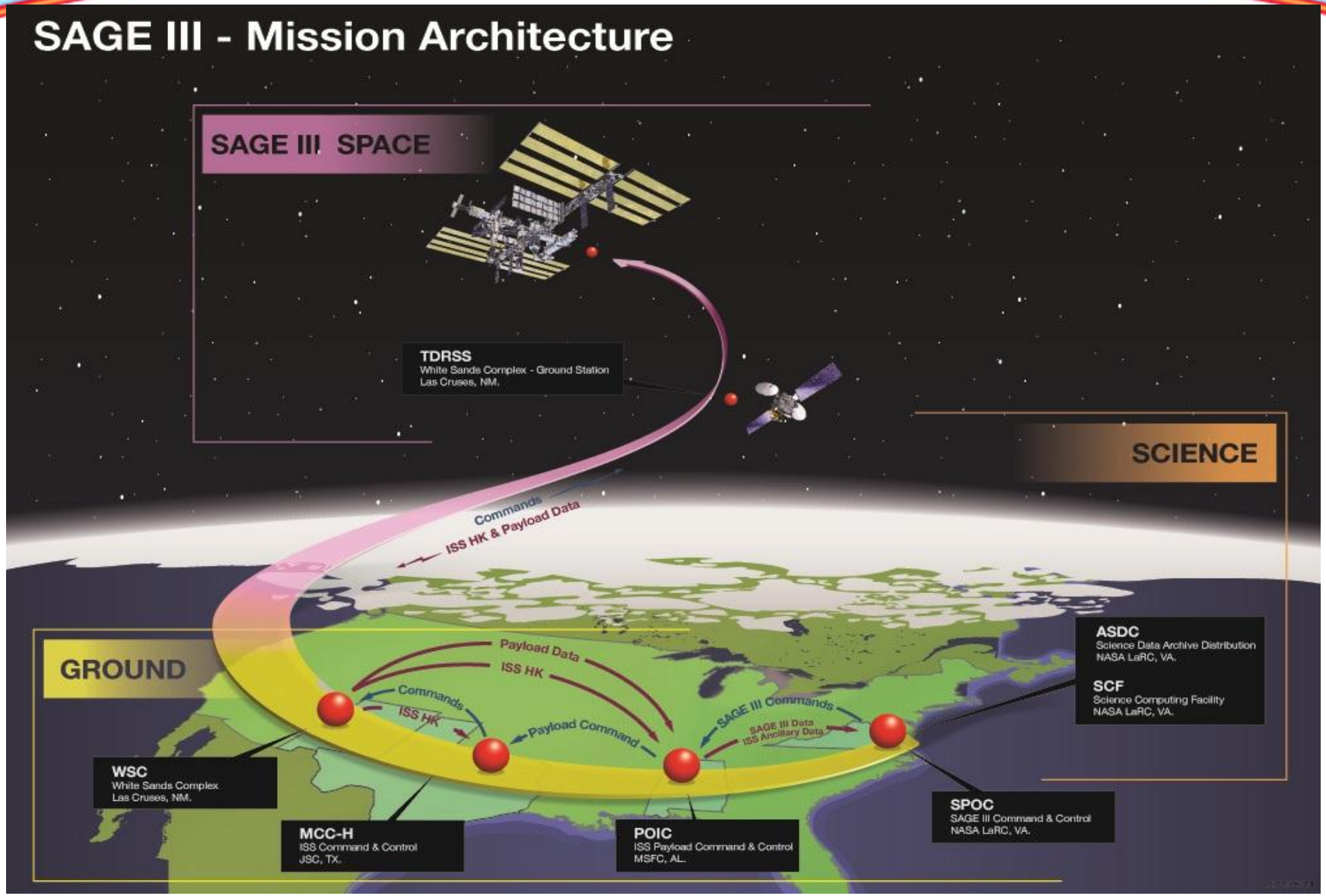
Hexapod Electronics Unit (HEU)
ESA

Contamination Monitoring Package (CMP)
LaRC

Interface Adapter Module (IAM)
LaRC

ExPRESS Payload Adapter (ExPA)
JSC/ISSP

Mission Architecture



Operations – Routine Ops

SAGE III operations will be highly autonomous

- Lights out operations/nominal staffing 8x5, except when required to support ISS operations (vehicle rendezvous, etc.) or anomalies

Commanding will be done once a week

Telemetry will be stored on the onboard recorder, the stored data will be downlinked once a day

Health and Status telemetry streamed nearly continuously to the SPOC

Payload status and telemetry processing will be checked twice a day, seven days a week





The DEVELOP National Program

http://develop.larc.nasa.gov

DEVELOP Locations

NASA Center Locations

- *Ames Research Center*
- *Goddard Space Flight Center*
- *Jet Propulsion Laboratory*
- *Langley Research Center*
- *Marshall Space Flight Center*
- *Stennis Space Center*

Regional Locations

- *Great Lakes & St. Lawrence Cities Initiative*
- *Mobile County Health Department*
- *Wise County Circuit Court Clerk's Office*
- *USGS Fort Collins Science Center*

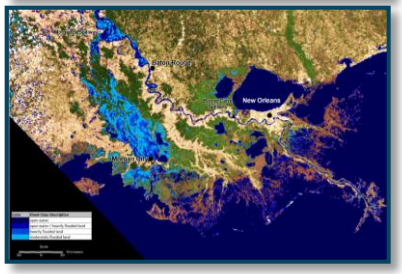
Leveraged Academic Locations

- *St. Louis University*
- *Monterrey Tech, Mexico*
- *IRI, Columbia University*
- *University of Georgia (NEW!)*















DEVELOP Website

http://develop.larc.nasa.gov

Science and Engineering Work in SD

Major satellite missions

Research & Analysis (including field experiments)

Work is funded by competitive research proposals to NASA Science Mission Directorate; we partner/collaborate with scientists and engineers at LaRC, other NASA centers & federal labs, university researchers worldwide, and private sector

Collaborative and career opportunities (civil servant, contractor, fellows) in:

- Scientific Leadership
- Engineering
- Instrument Development
- Mission Planning and Operations
- Algorithm Development and Implementation
- Data Processing, Validation, and Analysis
- Field missions
- Atmospheric modeling



Contractor Support to Science and Engineering Directorates for Instrument Design

SSAI is often interested in the following skill sets:

- Electrical Engineers
  - EE's cover the whole gamut, so that central skill is very desirable ... and includes both digital and analog design and construction.
- Optical/Electro-optical/Opto-mechanical Engineers
- Laser Scientists/Engineers
- Systems Engineers
- Software Engineers
- Power, Aerospace & "pure" Mechanical Engineers (Occasionally)

Thanks for listening !

NASA Langley Science Directorate Areas of Expertise

Radiation and Climate

- investigation of the Earth's energy balance to enable prediction of global climate change; Develop climate data records

Stratospheric Chemistry

- studies of middle atmospheric chemistry and dynamics to improve understanding and prediction of climate variability and trends

Tropospheric Chemistry

- to improve understanding and enable prediction of air quality and climate change on multiple scales

Remote Sensing (Active and Passive)

- develop new technologies, instruments, and algorithms to measure earth-reflected and emitted radiation, cloud and aerosol properties, and derive useful parameters to improve understanding of climate

Cloud and Aerosol Physics

- to improve understanding of aerosol and cloud effects on radiative transfer and improve understanding of cloud-climate feedback

Weather and Climate

- to improve understanding of weather and climate, and model development to enable better prediction of hazards and events

Space Weather and Planetary Atmospheres

- to understand effects of intense solar radiation on communications, aviation and human health, and to enable better prediction of hazards and events
- chemistry and dynamics of atmospheres on other planets