Overview of Stratospheric Aerosol and Gas Experiment (SAGE III) on the International Space Station

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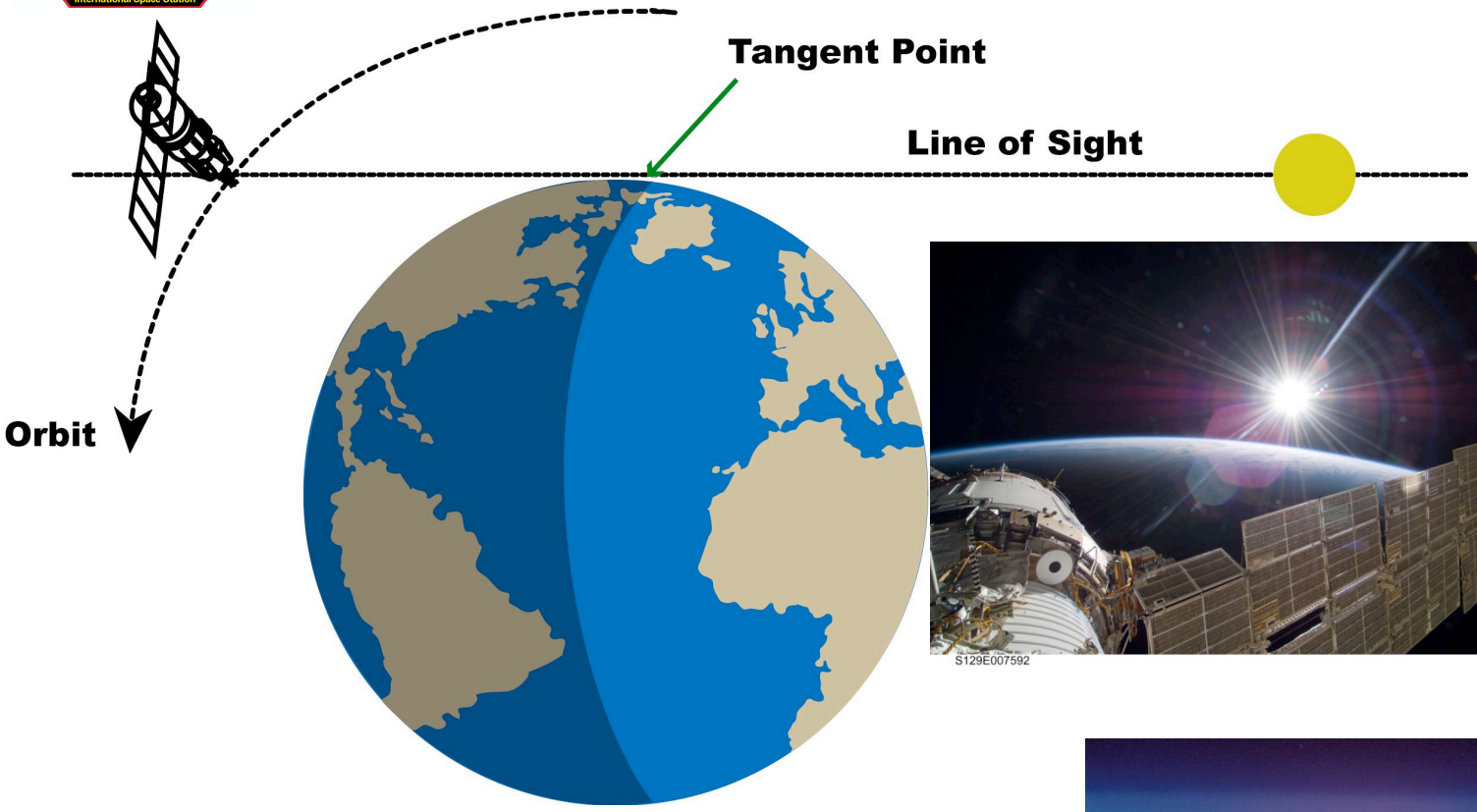
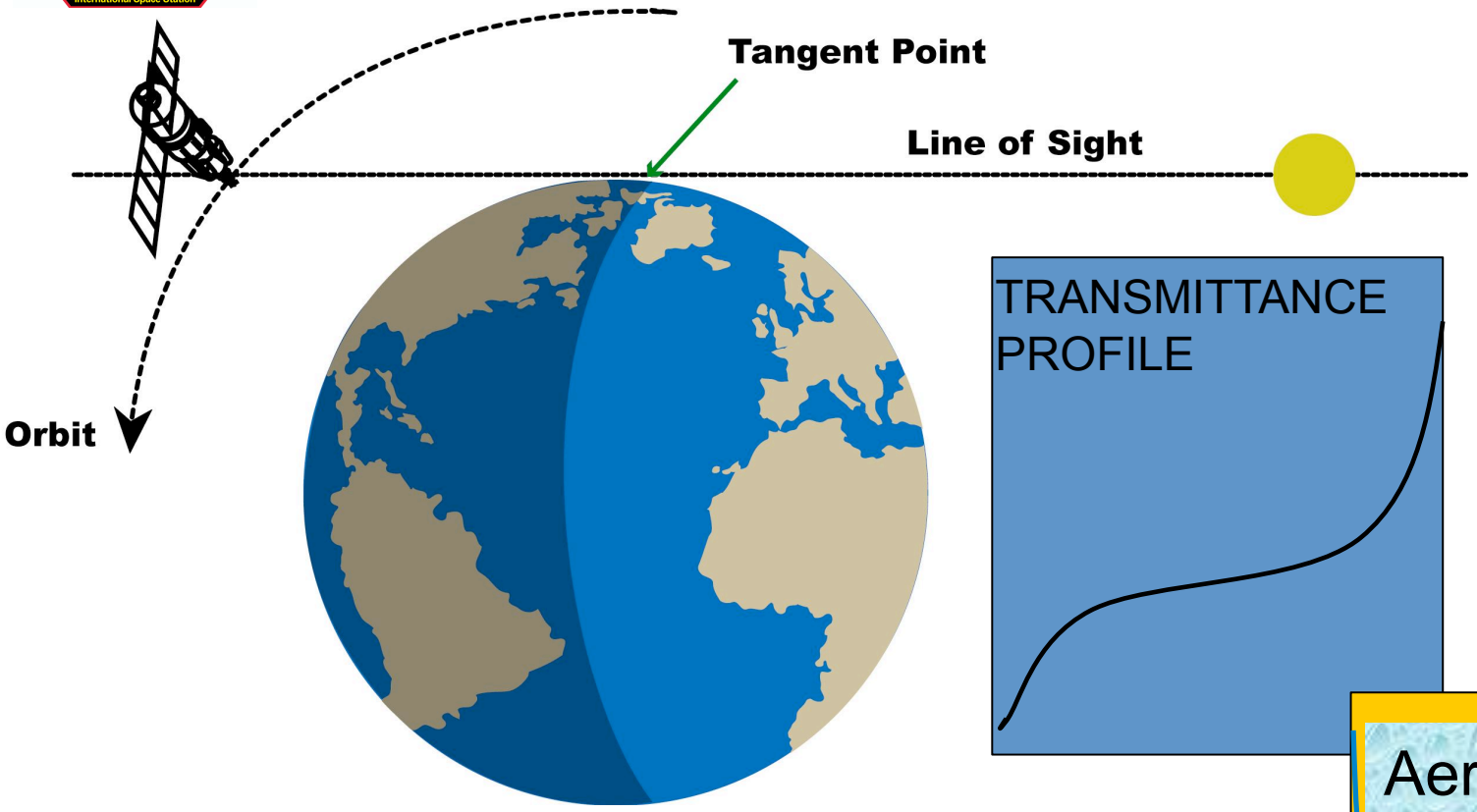
It All Started Back in the Early '70s

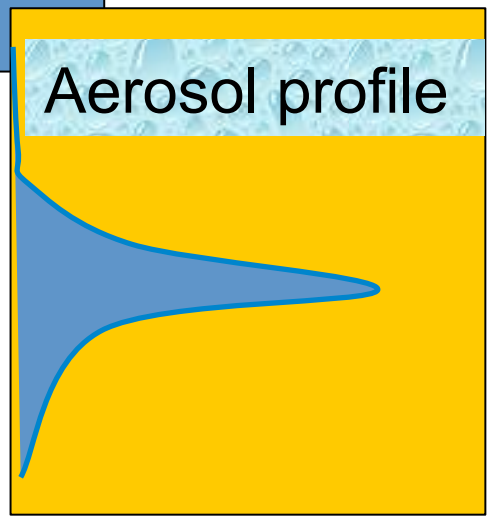
- Stratospheric Aerosol Measurement (SAM) flew on Apollo/Soyuz in 1975.
- Single 1 μm channel solar occultation measurement
- Proof of concept using the entire Sun

Measurement Strategy



Measurement Strategy



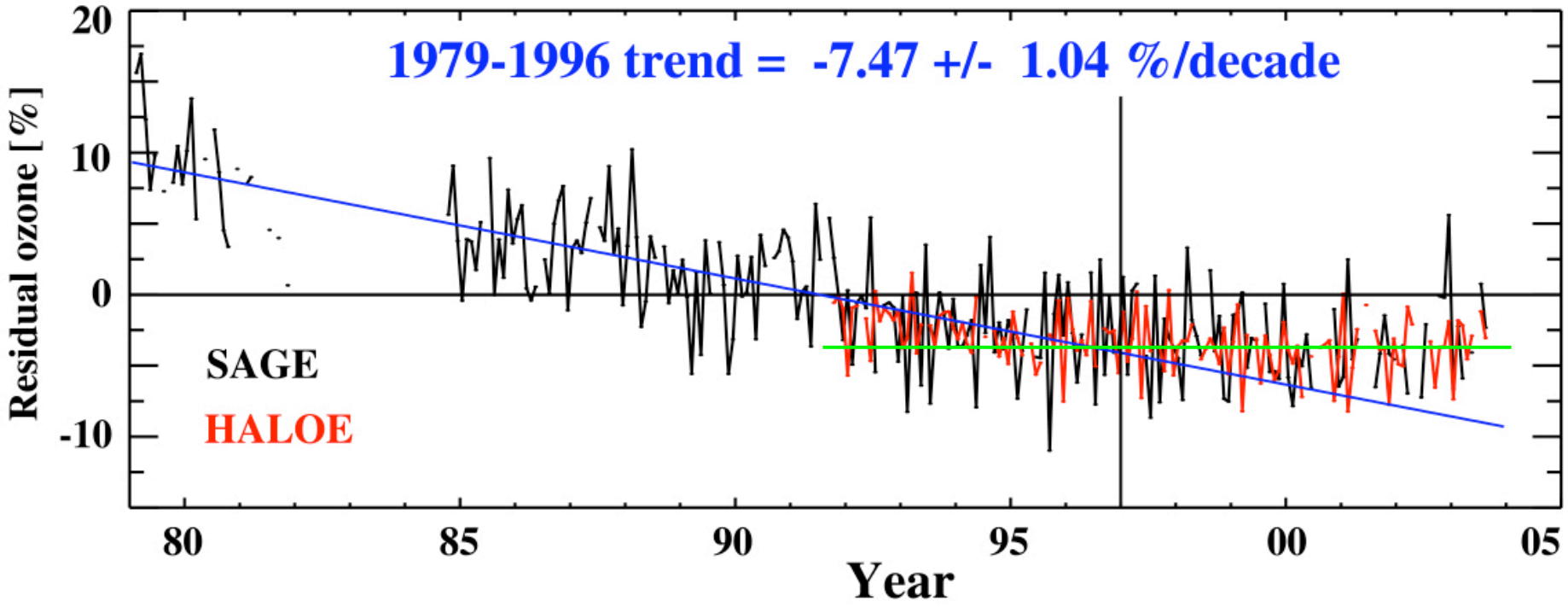


SAGE III LINEAGE

Experiment	Era	Orbit/Platform	Channels	Science Highlight
SAM	1975	Inclined/Apollo-Soyuz	Single channel @ 1 μm	Demonstration
SAM II	1978-1993	Sun-synch / Nimbus 7	Single channel @ 1 μm	Polar Stratospheric Clouds
SAGE I	1979-1981	Inclined/AEM-2	Ozone, Aerosol, NO2	Pre-decline ozone baseline
SAGE II	1984-2005	Inclined/ ERBS	+ Water Vapor	Ozone Trends, Extreme aerosol variability
SAGE III • Meteor • ISS • FOO	2001- 2006 2014-	Sun-synch /Meteor 3M Inclined/ISS	+ O2, NO3, Night-time Ozone, Mesospheric Ozone	Tropospheric measurements, Lunar occultation & Limb scattering

SAGE Science Results

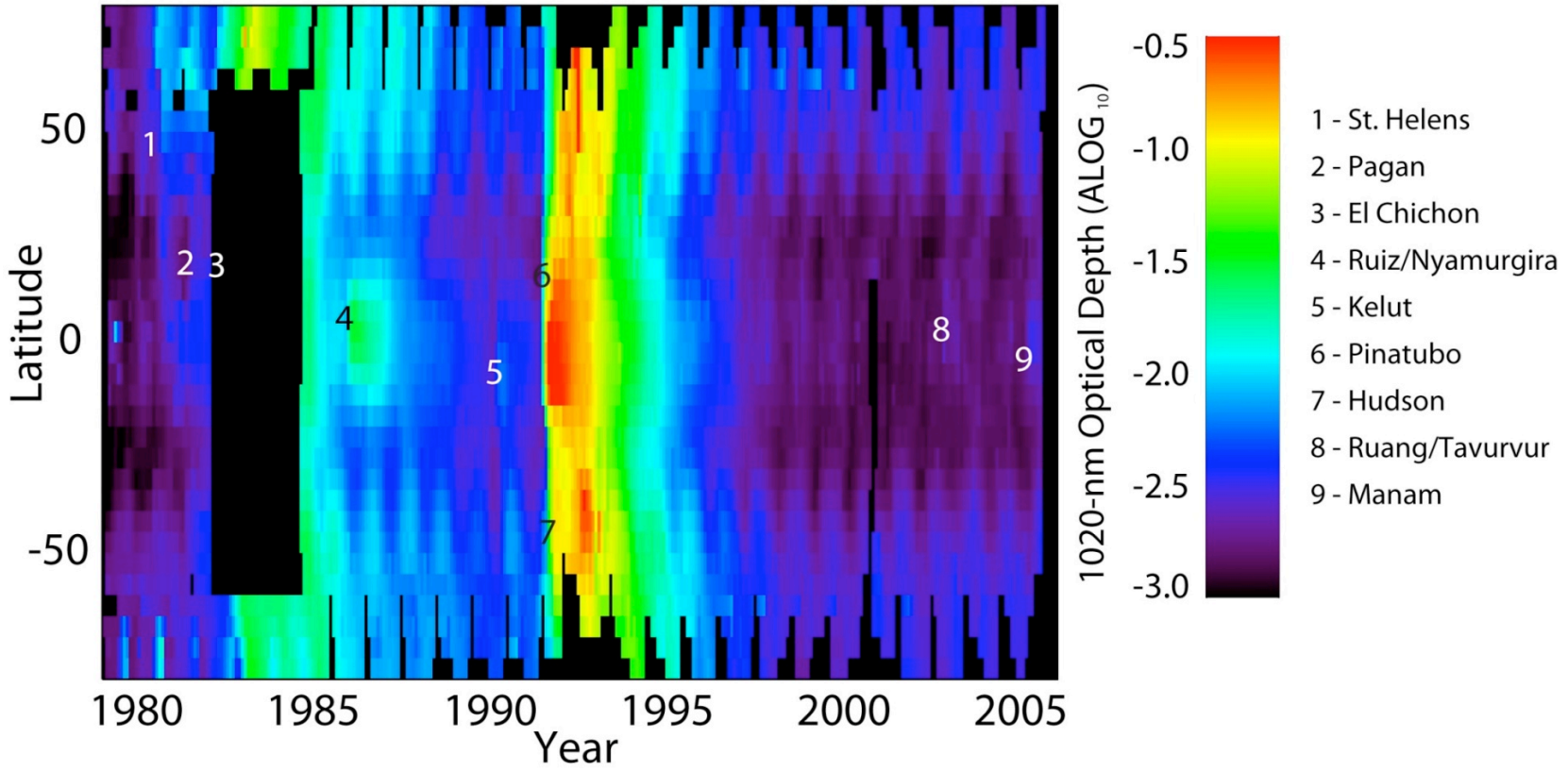
- SAGE produces vertical profiles of aerosols and gases in the stratosphere and upper troposphere
- The multi-decadal SAGE ozone and aerosol data sets have undergone intense scrutiny and have become the international standard for accuracy and stability.
- SAGE ozone data has been used to monitor the effectiveness of the Montreal Protocol



Stratospheric Aerosols

- SAGE aerosol data is recognized as *The Source* necessary for:
  - understanding ozone trends (Montreal Protocol Scientific Assessment Panel)
  - predicting Global Warming (Dr. James Hansen, 2008 AGU Bjerknes Lecture)

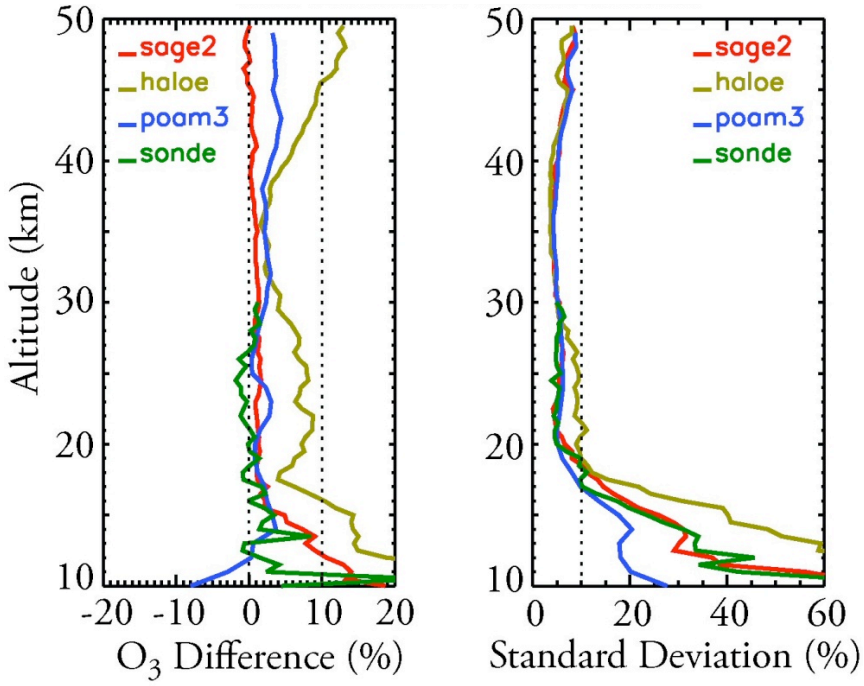
SAGE STRATOSPHERIC AEROSOL



Measurement Consistency

- The high precision, accuracy, and resolution of the SAGE ozone profile measurements is unique.
- Difference between SAGE3 and 'Gold Standard' SAGE2 is virtually a constant, independent of altitude.
- This demonstrated measurement fidelity allows the past ozone record to be linked with the future without loss in trend quality.

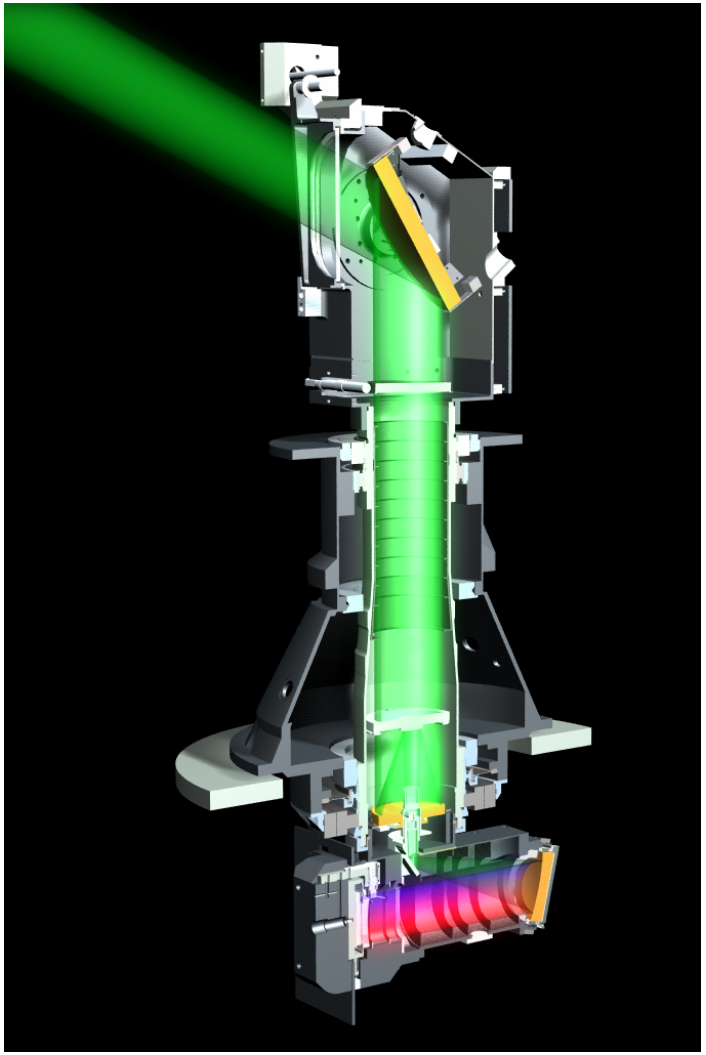
Difference between SAGE3 Ozone and correlative measurements



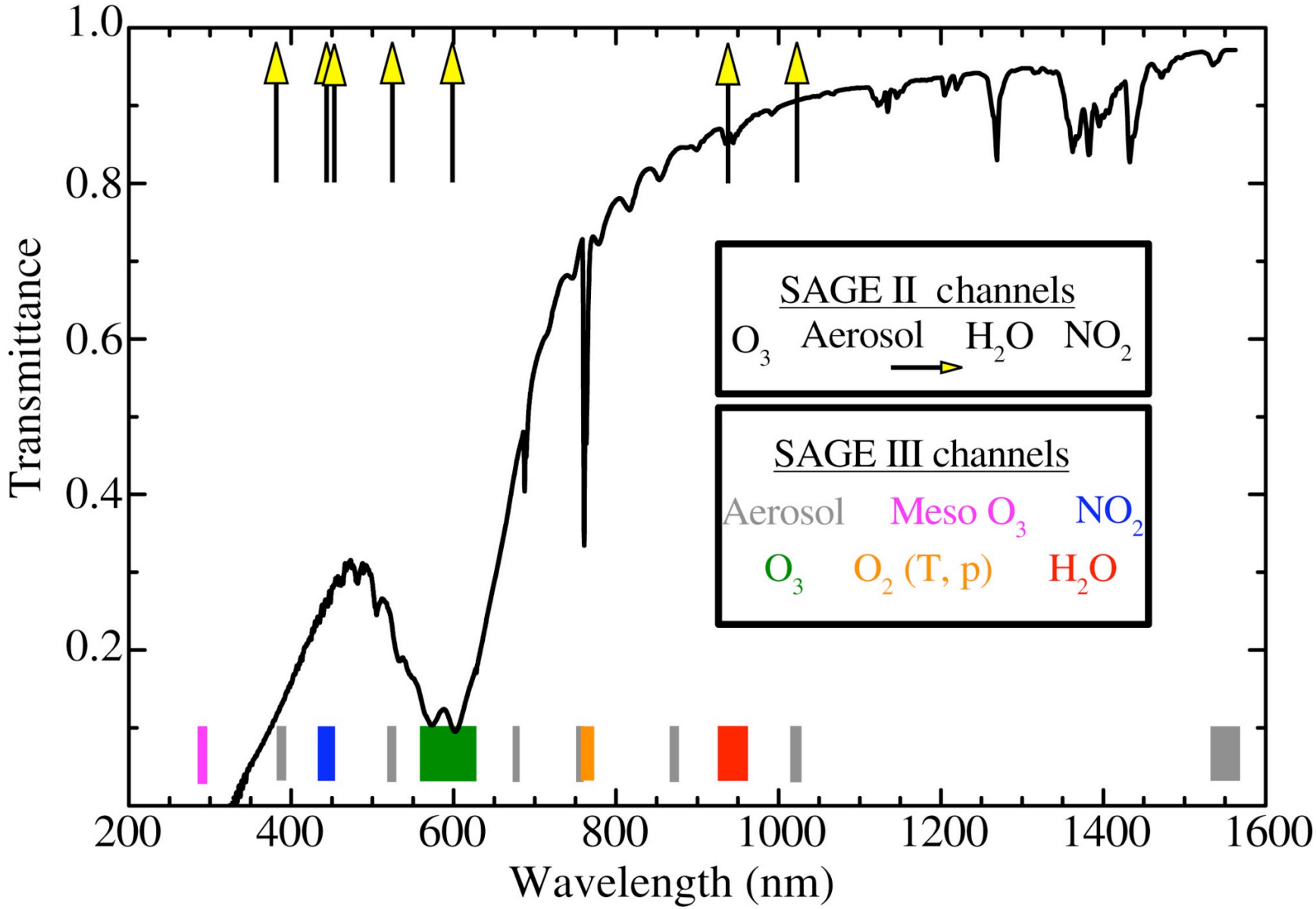
Courtesy of Ray Wang (Georgia Tech)

SAGE III Instrument Features

- UV-VIS-NIR spectrometer
  - Segmented CCD detector
- Multiple modes of operation
  - Solar, lunar, limb scatter
- Surface/cloud top to 50 km, <1 km vertical resolution
- 64 kg, 102 watts, 0.12 Mbps
- 87 channels in solar occultation mode (~1-3-nm resolution between 280 and 1040 nm)

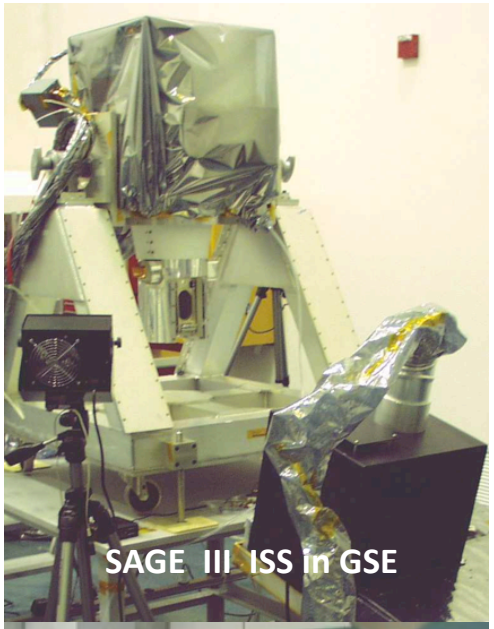


Spectral Sampling

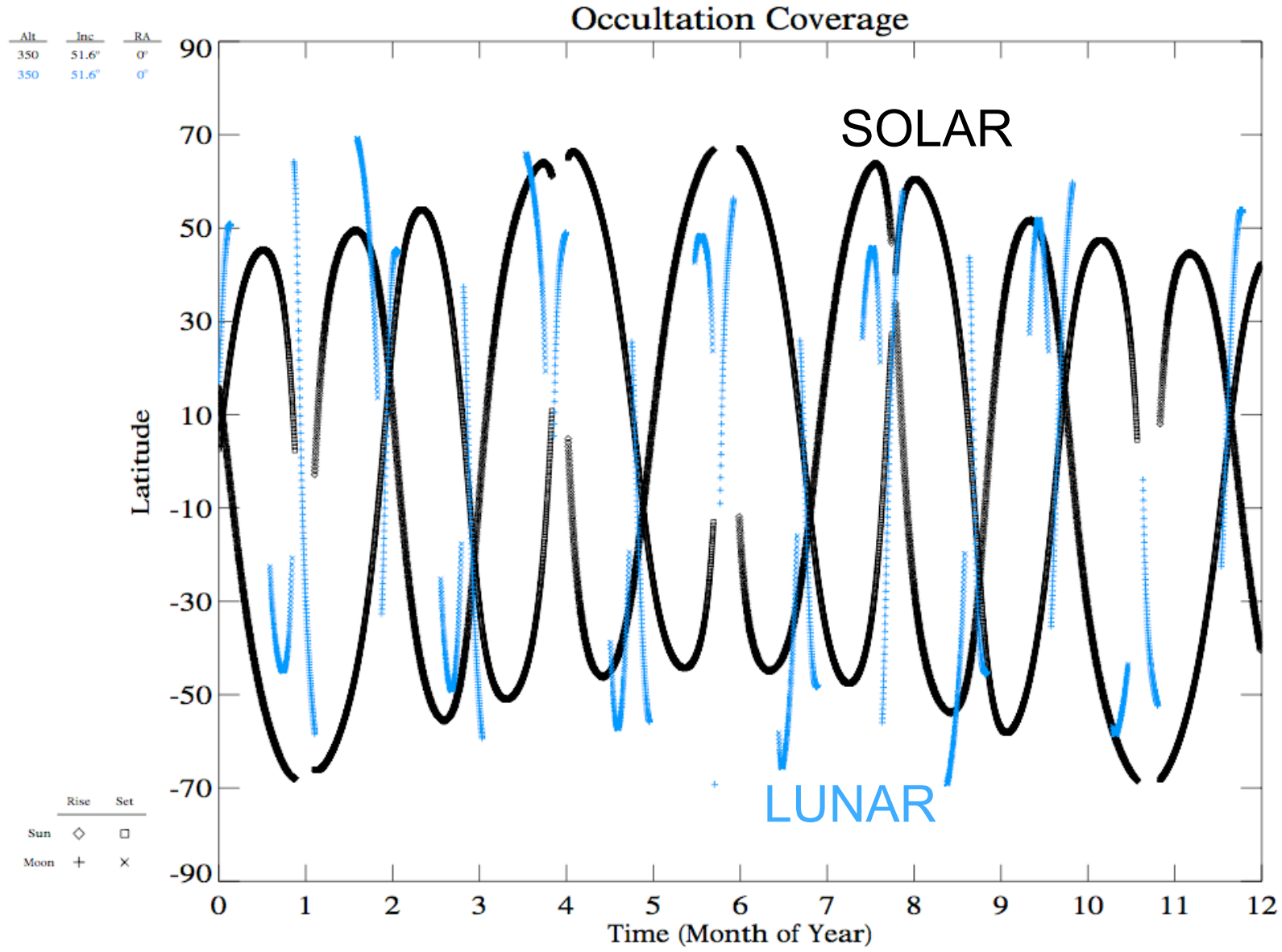


SAGE III on ISS

- ISS Inclined orbit provides excellent measurement coverage
- 2014 launch opportunity
- SAGE III on ISS will extend the SAGE climate record of ozone, aerosols and water vapor, providing scientists with data necessary for:
  - Modeling geophysical variability
  - Understanding how to combine various methods for measuring aerosols
  - Assimilation and Reconstruction of fields of long-lived species
  - Long term climate studies
- Solar and Lunar occultation measurements will be augmented by limb scatter measurements


SAGE III ISS in GSE

SAGE III / ISS


Occultation Coverage
Alt Inc RA
350 51.6° 0°
350 51.6° 0°
SOLAR
LUNAR
Latitude
Time (Month of Year)
90
70
50
30
10
-10
-30
-50
-70
-90
0
1
2
3
4
5
6
7
8
9
10
11
12
Rise Set
Sun
Moon

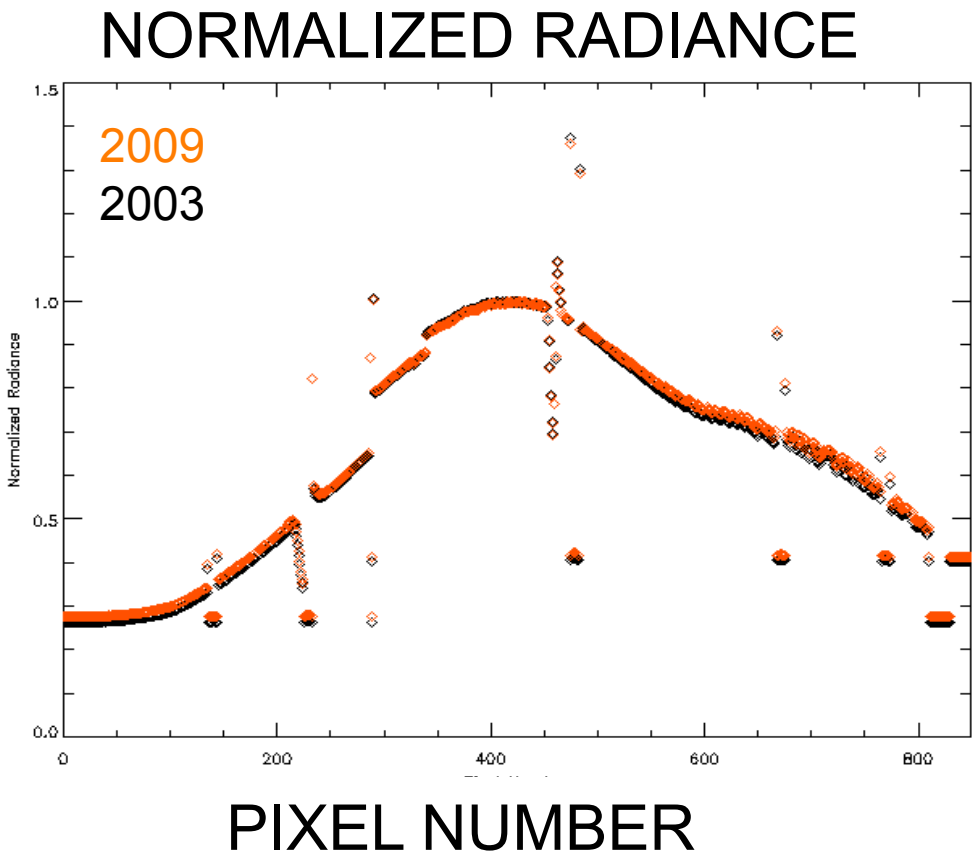
SAGE III/ISS Technical Status

- SAGE III/ISS delivered to LaRC and in storage since 2004
- Instrument assessment, including powered radiometric testing, was performed in 2009 and concluded that instrument is still an excellent flight candidate
- ESA-provided Hexapod pointing platform will be used to compensate for major variations in ISS orientation
- A detailed accommodation study with the ISS program is being performed to determine the best location to mount SAGE III. Mounting location selection criteria include:
  - Clear Measurement Field of View
  - ISS environment including contamination and disturbances

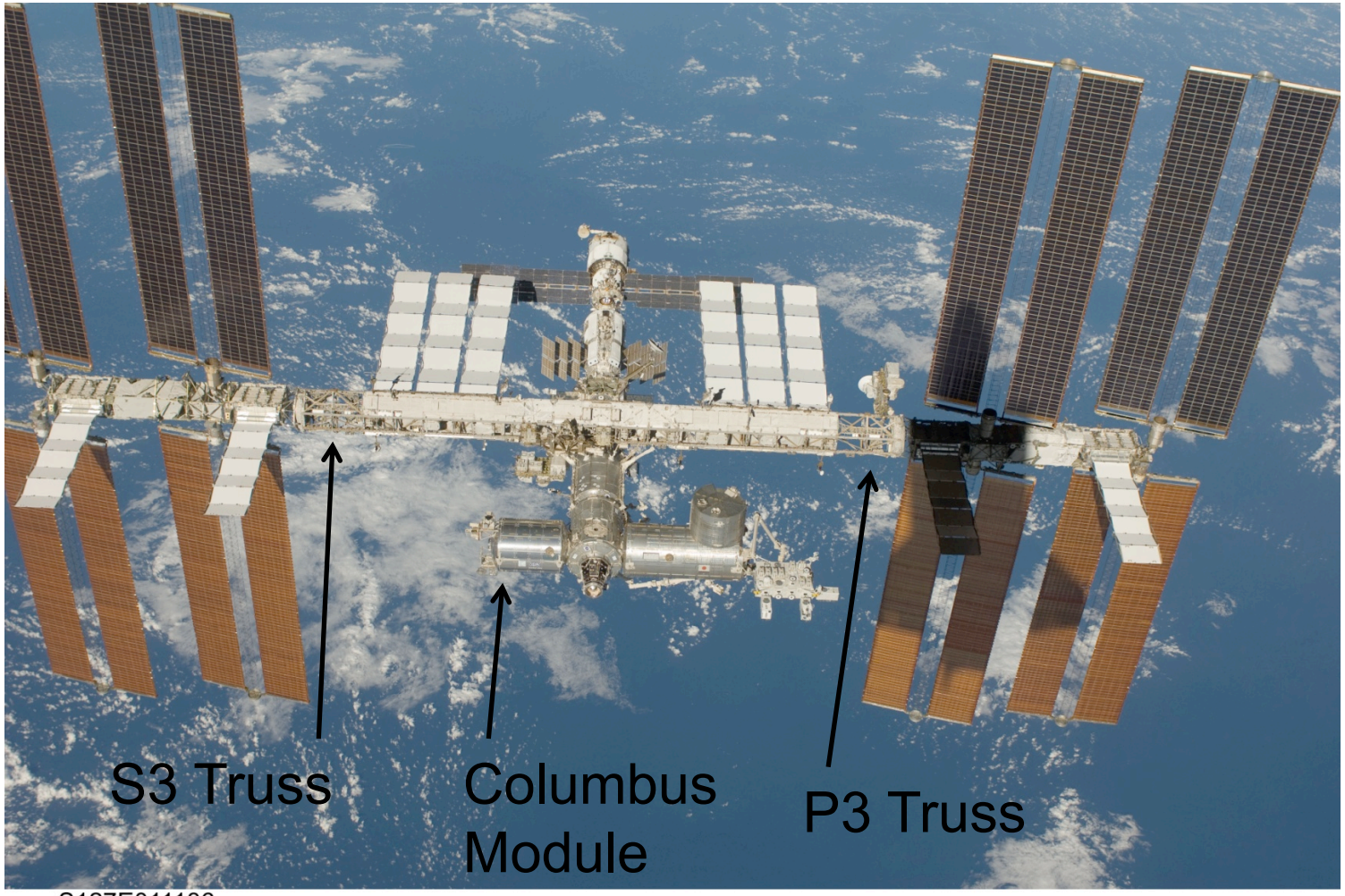
SAGE III/ISS Sensor Performance

After 6 years of storage:

- No obvious anomalies
- Dark Current virtually the same (within ~ 1 count)
- No change in Hot Pixels
- Radiometric Response within specifications



SAGE III/ISS Mounting Candidates



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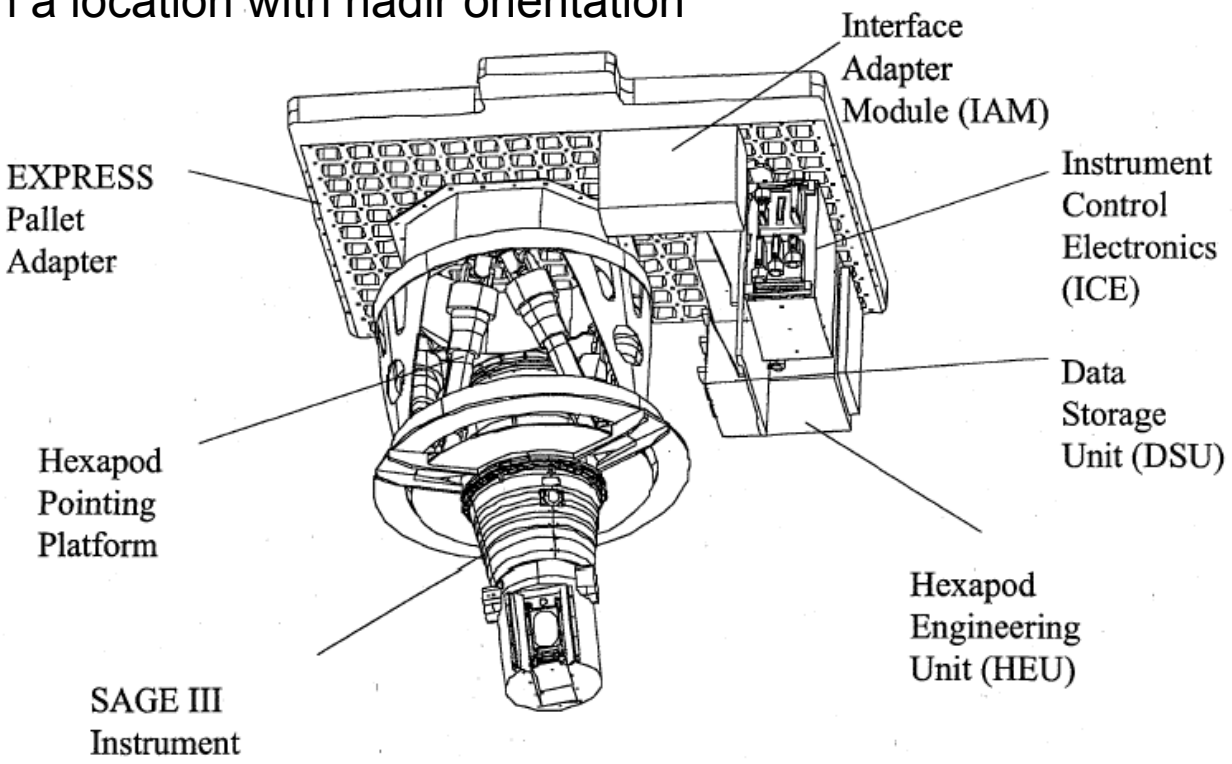
ISS Flight Configuration

- The integrated SAGE III/Hexapod payload will be mounted on an Express Pallet adapter plate.
- The SAGE III / Hexapod payload will be robotically installed on the ISS and mounted in a location with nadir orientation

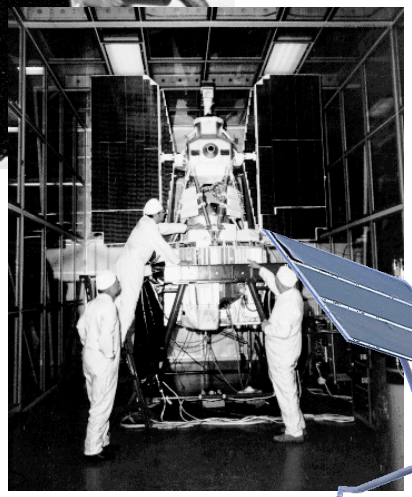


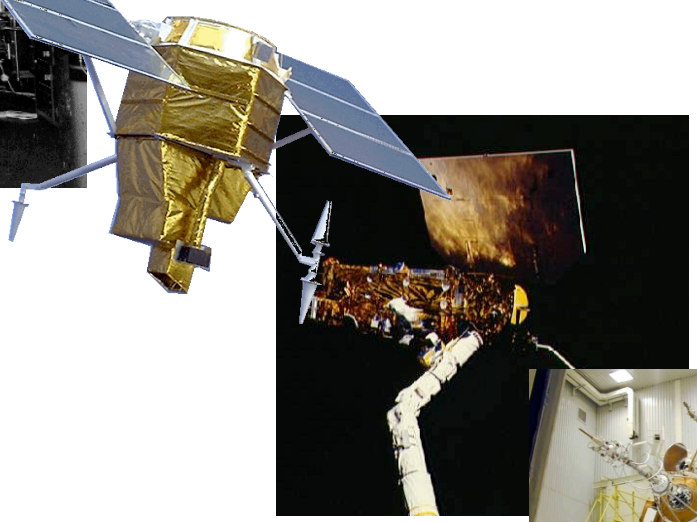
SAGE III and Hexapod on Express Pallet

SAGE III/ISS Summary

- SAGE III/ISS follows in the heritage of the highly successful, long-lived SAGE series
- Continues path of innovation and refinement in atmospheric remote sensing
- Provides information on the state of the global climate, critical for international agreements and scientific understanding of climate change
- Is a well-built and properly handled instrument, so it can continue to be a national and international asset.

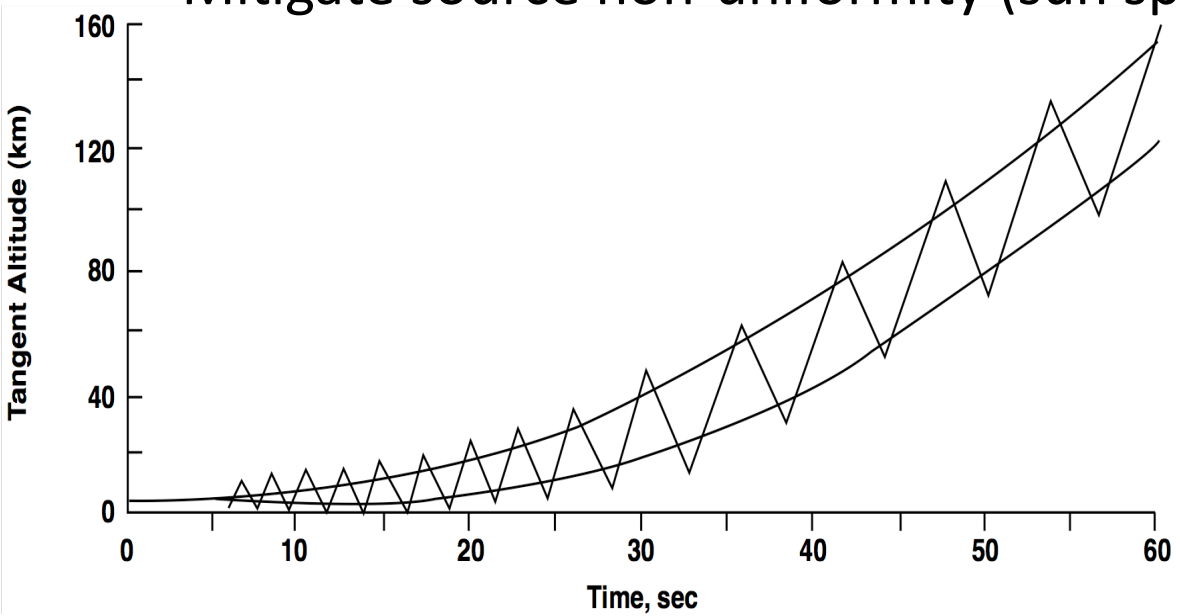
BACKUP SLIDES

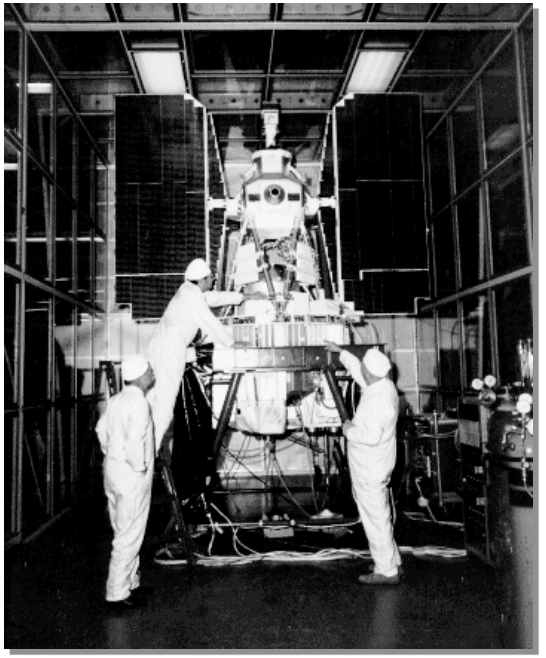




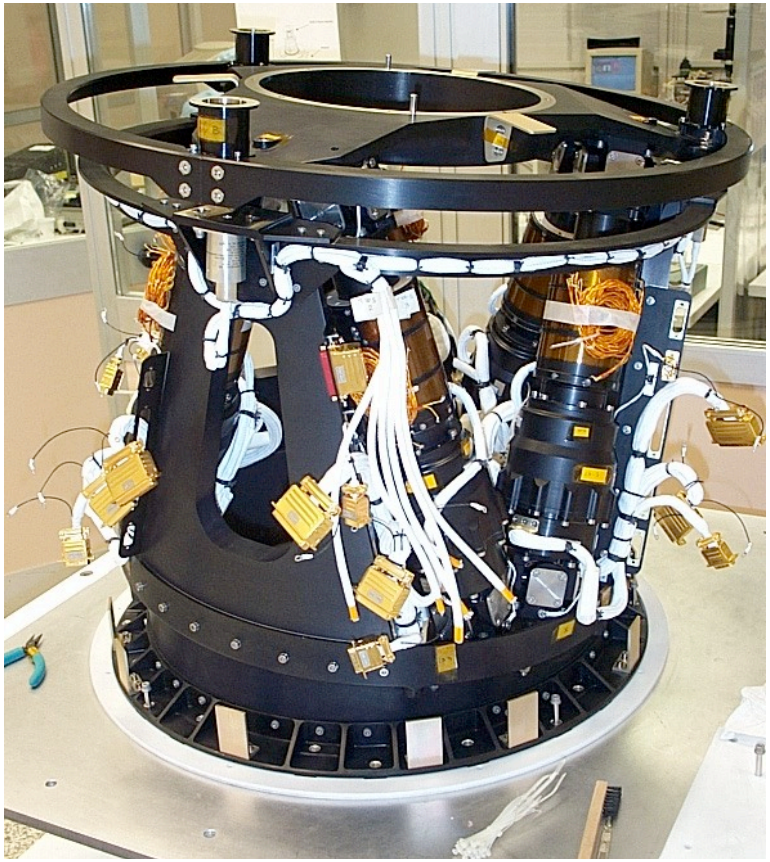
SAM II

- SAM success led to SAM II on Nimbus 7
- Sun synch Orbit provided polar coverage
- Single channel @ 1 μm
- Scanning Field of View
  - Increased vertical resolution ~ 0.5 km
  - Mitigate source non-uniformity (sun spots)





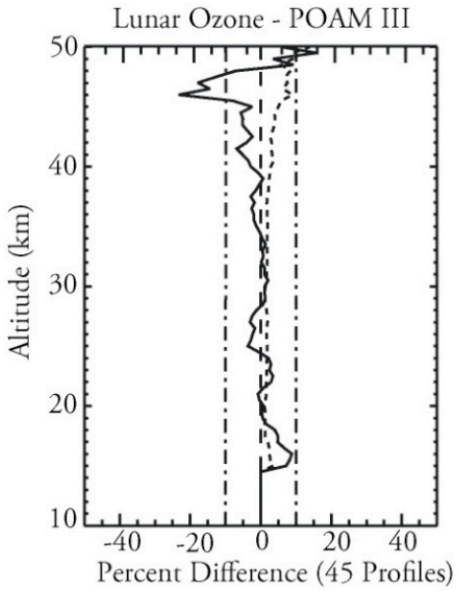
Hexapod Pointing System

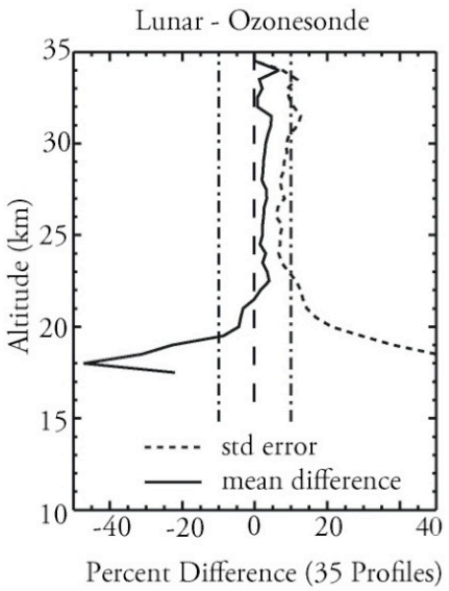


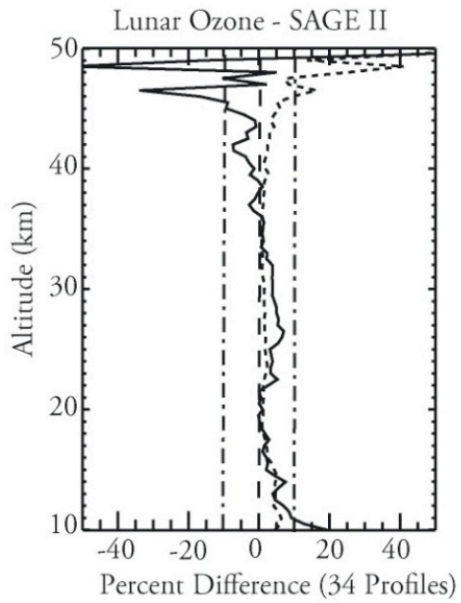
- ISS flight attitude over long-term is a balance of gravity gradient and atmospheric drag forces.
- ESA partnered with NASA to develop Hexapod pointing platform (via Alenia Spazio), providing SAGE III/ISS pointing to within +/- 1 deg to Earth nadir.
- Six linear actuators are extended or retracted to manipulate the orientation of the upper platform.
- Manipulation provides 8° of pitch/roll; SAGE III provides yaw.
- Hexapod is mounted on a 7° (TBC) wedge tilted in the ram direction.

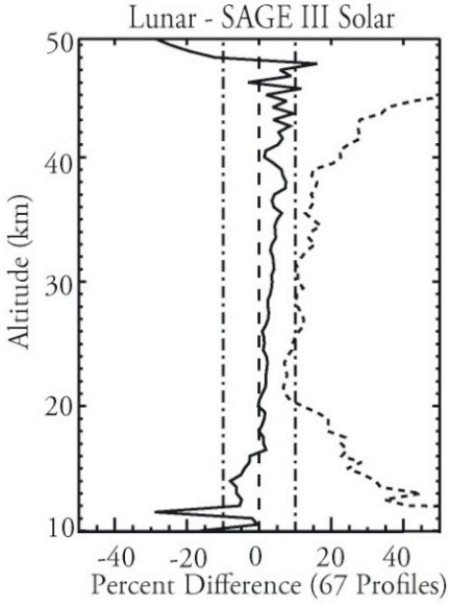
Lunar Occultation

- Lunar occultation adds significantly to spatial sampling
- Excellent O_3 profile
- Adds NO_3 & OClO
- Enables Limb Scatter observations



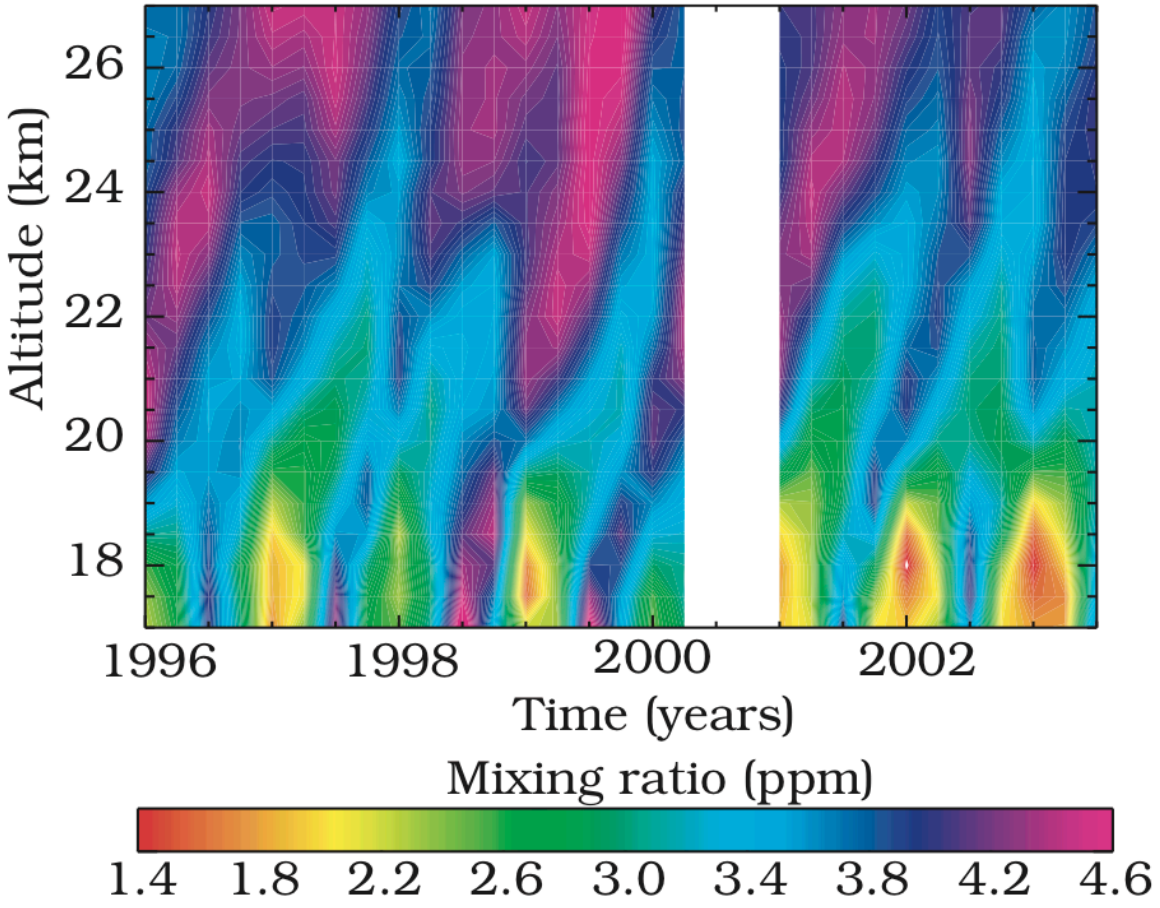


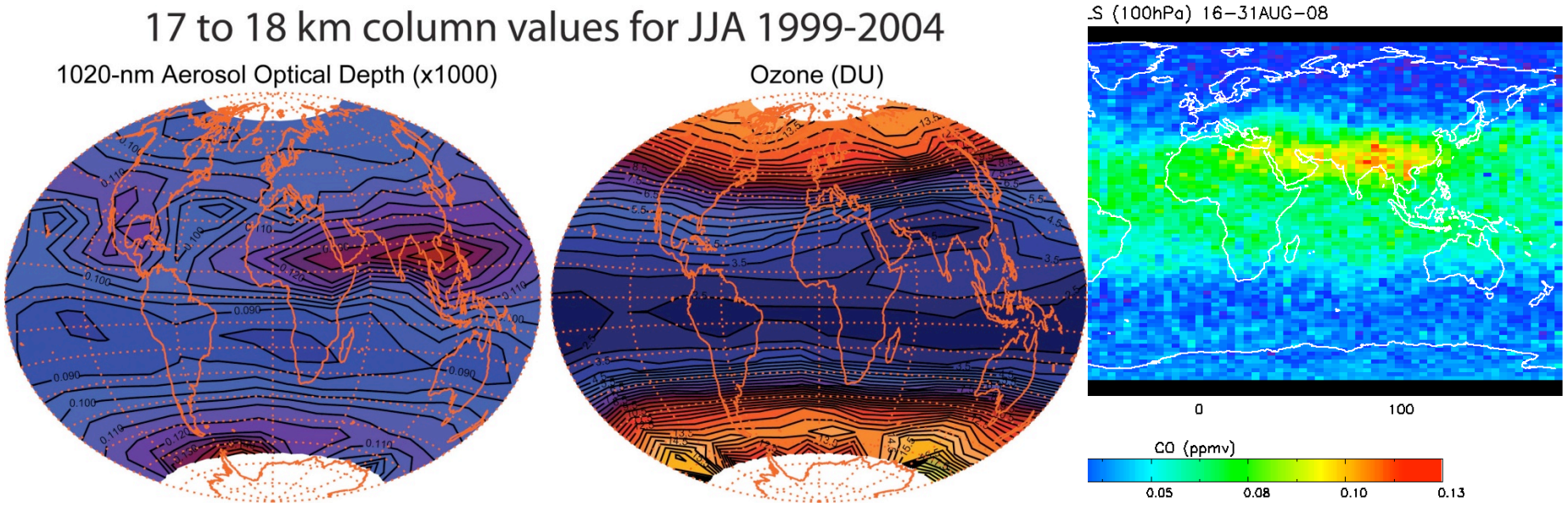




Trace Species

- Water vapor measurements are our current focus
- Long-term data record is unique
- Mostly unmined



Geographic Anomalies

- Important science remains to be discovered in the SAGE measurement record
- Combining data sets provides unique insight
- Tropopause region needs to be fully explored