Objectives

**Objective 1:** Obtain direct solar/lunar measurements of NO$_3$ and NO$_2$ from Table Mountain Facility in support of SAGE III/ISS validation.

**Objective 2:** Analyze comparisons with coincident SAGE III/ISS measurements and work with the algorithm and science teams to interpret the comparisons and incorporate improvements into retrieval algorithms.

**Objective 3:** Utilize in-situ measurements of NO$_3$ and N$_2$O$_5$ and chemical modeling to separate stratospheric and tropospheric partial columns.

<table>
<thead>
<tr>
<th>Co-Investigators</th>
<th>Role</th>
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<tbody>
<tr>
<td>Thomas J. Pongetti, JPL</td>
<td>Data Acquisition/Analysis</td>
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<td>Steven S. Brown, NOAA</td>
<td>In-situ measurements</td>
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Two pathways to HNO₃ formation:
- Daytime (through OH + NO₂ + M reaction)
- Nighttime (through N₂O₅ + sulfate aerosol reaction, NO₃-mediated)
Ground-Based Measurements
Direct Solar and Lunar Spectroscopy
at JPL Table Mountain Facility
Schematic of the instrument light path. (a) Light is collected by the primary of the heliostat (tracker) then through an off-axis telescope which also serves as a fine guider for the pointing system. (b) The light is directed through a condensing lens, shutter, order-sorting filter, and then into the spectrometer where it is dispersed and recorded by a CCD camera.
Correcting for Trace Gas Absorption in the NO₂ Reference Spectrum

- A reference spectrum is acquired near zenith to obtain a background solar spectrum.
- The reference spectrum contains absorption(s) from the molecule(s) of interest.
- A Langley Plot is constructed to determine the slant column density in the reference spectrum.


**Fig. 9.1.** Sketch of direct light observation geometries. In first approximation, the light path through a trace gas layer varies with $1 / \cos \vartheta$ ($\vartheta =$ zenith angle of celestial body observed)
Modified Langley Extrapolation

- X-axis is transformed from $AMF_i$ to $AMF_i \times VCo(AMF)$ where the function $VCo(AMF)$ is derived from the model’s a priori time-dependence of NO$_2$
- This transformation results in the correct value of the reference column abundance as determined from the y-intercept
• NO₂ reference column using modified Langley method
• Overall agreement is excellent; First continuous night/day record
• MUGS cannot measure at the exact time of sunrise or sunset due to obstructions
• October 27 daytime data show influence of a polluted air mass
24 Hour Back-Trajectories Reaching TMF at 1500

LA basin

TMF
MUGS Comparisons with SAGE-III/ISS
• Exact coincidences between SAGE-III and TMF are exceedingly rare
• We consider coincidences within a global zonal belt ± 5° latitude from TMF (34.4 °N)
• SAGE occultations at other longitudes are converted to TMF local time
Typical SAGE-III Sunrise NO$_2$ Profiles (zonal average)
Typical SAGE-III Lunar NO$_2$ Profiles (zonal average)
Typical SAGE-III Lunar NO$_3$ Profiles (zonal average)
Example SAGE-MUGS NO₂ Comparison: January

MUGS stratospheric partial column is derived from lowest 20th percentile.
SAGE-MUGS NO$_2$ Correlation (Solar)

- Scatter plot between monthly averages of SAGE-III columns (z>15 km) and MUGS total columns (± 2 hours from sunset or sunrise, 20$^{th}$ percentile)
SAGE-MUGS NO₂ Correlation (Lunar)

Note: Lunar NO₂ is a research product – not formally released
SAGE-MUGS NO$_3$ Comparison: February

February NO$_3$

TMF-MUGS
- Black circle: Single measurement
- Grey circle: Hourly 20th percentile

SAGE-III
- Green circle: Lunar daily average
SAGE-MUGS NO$_3$ Correlation (Lunar)
Take-Home Points

• Ground-based TMF direct sun/moon total column measurements provide very good comparisons with SAGE-III/ISS stratospheric partial columns because:
  o High altitude (2.3 km) and remote location of TMF minimize PBL pollution contributions to the total column
  o Sorting methods are available to identify measurements (NO₂, NO₃) that contain significant tropospheric contributions.
  o 1-D model provides the nominal tropospheric partial column contributions

• *Preliminary* comparisons between MUGS and SAGE show good correlations for NO₂. NO₃ agrees well in winter/spring, less well in summer/fall

• *Future work* will focus on extending the ground-based climatologies, using the 1-D model for diurnal corrections, working with algorithm team on lunar NO₂ product including cross sections.