National Aeronautics and Space Administration

FY23 Strategic Initiatives Research and Technology Development (SRTD)

Ozone and Trace Gases

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Strategic Focus Area: Earth System Explorer – Science Definition and Technology Maturation | **Initiative Leader:** Sabrina M Feldman

Objectives

Our overall objective is to mature concepts that JPL could submit to future calls of the "Earth System Explorer" (ESE) program in the "Ozone and Trace Gas" category. Specific objectives for FY23 include:

1. Further characterizing approaches to quantifying tropospheric hydroxyl (OH, the "atmospheric detergent" that cannot be directly measured from space) through measurements of other related species and atmospheric chemistry modeling.
2. Developing radiative transfer and measurement retrieval calculations to quantify how much additional information on ozone in the lowermost troposphere (the bottom ~2 km of the atmosphere) can be obtained by adding a polarimetric capability to the long-established ultraviolet imaging spectroscopy technique.
3. Developing multiple point designs for a polarimetric UV imaging spectrometer that could make the measurements in Objective 2.
4. Developing a ground-based ultraviolet polarimetric instrument to be deployed at JPL's Table Mountain Facility to validate the calculations in Objective 2 and inform future spaceborne instrument designs.
5. Defining multiple mission point designs and determining their suitability to the ESE program (mass, power, cost, etc.).

Approach and results

Objective 1: Used the "MOMO-Chem" chemical data assimilation system to identify CO, PAN, and C_2H_6 as the most valuable species to observe for constraining tropospheric OH abundances (Figure 1).

Objective 2: Used the "VLIDORT" radiative transfer model and established retrieval calculations to quantify additional information on ozone that can be obtained with polarization information (in a ground-based viewing geometry for now – will extend to spaceborne next year).

Objective 3: Developed four point-designs for a spaceborne ultraviolet spectro-polarimetric imager. One design employs photo-elastic modulators (as for MAIA), a second uses a rotating polarizing wheel, while the third limits polarimetric information to specific spectral windows with the majority of the observed band measured with a single polarization only. The fourth, and potentially most compact, approach employs a "metagrating", which enables simultaneous separation by both wavelength and polarization – this is being developed in a recently selected NASA ACT project (Brian Drouin PI), building on prior work at longer wavelengths.

Objective 4: We have developed a ground-based "Multi-angle Polarimetric Spectrometer" MAPS at the JPL Table Mountain Facility (Figure 3) to prototype the UV polarimetric measurements. All the critical components have been verified and integrated, except for the mechanical shutter, which proved to be unsatisfactory. A replacement is on order.

Objective 5: JPL "A-Team" study evaluated four mission point designs each with a thermal infrared imaging spectrometer and a polarimetric UV imaging spectrometer. The study considered all combinations of "large" and "small" versions of both instruments. All four combinations were estimated to fit within the anticipated ESE cost cap, though, the "large/large" combination had less cost margin than desired for this level of concept/study maturity.

Background

- Anthropogenic influences on atmospheric composition are the main drivers of global environmental change and have major impacts on human and ecosystem health.
- A major challenge in Earth System Science is to improve predictive capability for atmospheric composition on the timescales associated with climate forcings and feedbacks and those required for air quality forecasts.
- Atmospheric composition is affected by many processes, including surface emissions and deposition, horizontal and vertical transport, photochemistry, interactions with aerosols and clouds, impacts of lightning and solar/cosmic particles, transport between the various atmospheric layers, and transport/mixing and chemical processing within those layers.
- All these processes take place in different domains (boundary layer, free troposphere, upper troposphere, stratosphere), and no single measurement technique is capable of probing them all.

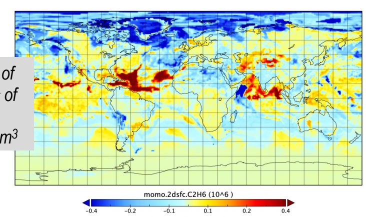

Figure 1: *The relative contribution of ethane (C_2H_6) to local abundances of OH at 700 hPa (~3 km altitude) on July 1, 2014. Units are molecule/cm^3*

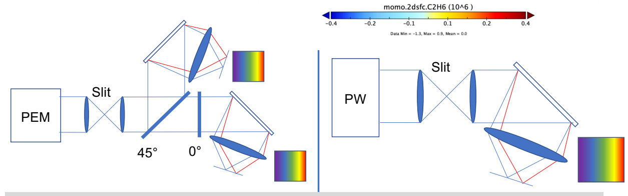

Figure 2: *Two of four possible optical designs for an imaging UV spectro-polarimeter. Left: a photoelastic modulator (PEM)-based approach (as used for MAIA). This has the advantage of making simultaneous observations of all polarizations but requires two separate focal plane arrays (FPAs) giving two sets of spectra. Right: An approach using a rotating polarizing wheel (PW). This employs common detectors for all polarization states but gives time-delayed polarization information and requires a faster FPA.*

Figure 3: *Initial test configuration for MAPS instrument at the JPL Table Mountain Facility. Left to right: optics for polarized sky scattering and lunar measurements; EKO pointing system; optics for direct sun measurements.*

Significance and benefits to JPL

- The work lays the groundwork for future JPL-led or JPL-participating Earth System Explorer (ESE) proposals.
- It cements JPL's strong role in OTG-related observations by developing concepts for next-generation sounders that fill identified gaps in established knowledge and the expected observations from the Program of Record (PoR).
- Concepts developed may also be suitable for proposal to other opportunities, including the Earth Venture program.

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