Scope Title

Sensors and Sensor Systems Targeting Trace Gases

Scope Description

Earth science measurements from space are considerably enhanced by observations from generally much less costly suborbital instruments and sensor systems. These instruments and sensors support NASA’s Earth Science Division science, calibration/validation and environmental monitoring activities by providing ancillary data for satellite calibration and validation; algorithm development/refinement; and finer-scale process studies. NASA seeks measurement capabilities that support current satellite and model validation, advancement of surface-based remote-sensing networks, and targeted Airborne Science Program and ship-based field campaign activities as discussed in the ROSES solicitation. Data from such sensors also inform process studies to improve our scientific understanding of the Earth system. In-situ sensor systems (air-, land-, and water-based) can comprise stand-alone instrument and data packages; instrument systems configured for integration on ship-based (or alternate surface-based platform) and in-water deployments, NASA’s Airborne Science aircraft fleet or commercial providers, uncrewed aircraft systems (UAS), balloons, and ground networks; or end-to-end solutions providing needed data products from mated sensor and airborne/surface/subsurface platforms. An important goal is to create sustainable measurement capabilities to support NASA’s Earth Science objectives, with infusion of new technologies and systems into current/future NASA research programs. Instrument prototypes as a deliverable in Phase II proposals and/or field demonstrations are highly encouraged.

Complete instrument systems are generally desired, including features such as remote/unattended operation and data acquisition, and minimum size, weight, and power consumption. All proposals must summarize the current state of the art and demonstrate how the proposed sensor or sensor system represents a significant improvement over the state of the art.

Specific desired sensors or subsystems include:

- Small, lightweight, turn-key trace in situ gas measurement sensors with 1 to 10 Hz time response that are suitable for small aircraft, UAV, or balloon deployment and capable of detecting:
- NO$_x$, NO$_2$, CH$_2$O, O$_3$, benzene, toluene at <5% uncertainty.
- CO, CH$_4$, OCS, N$_2$O at <1% uncertainty.
- SO$_2$ at <100 parts per trillion by volume (pptv) uncertainty.

where these uncertainties apply to measurements made on airborne platforms under flight conditions (variable ambient pressure and temperature).

- Small, turn-key spectrometer-based Sun photometer sensors capable of detecting NO$_x$, CH$_2$O, and O$_3$, at <5% uncertainty. These sensors must be capable of long-term measurements to support NASA ground networks. Improved performance Sun and sky viewing spectrometer subsystems that increase measurement accuracy and stability and simplify instrument calibration of Sun photometers may be considered. Potential improvements are wavelength stability (<100 pm/°C) and reduced stray light (<10$^{-4}$).

- Real-time, 0.1 to 1 Hz gas-phase radioisotopic (especially radiocarbon) measurements suitable for distinguishing emissions sources and for deployment on aircraft or UAVs.

- Airborne-capable bulk or film retroreflector subsystems that advance NASA open-path trace-gas measurements (similar to the widely used NASA LaRC Diode Laser Hygrometer). Operational at wavelengths between 2 and 12 µm, or some subset of wavelengths within that range, with low return light cone divergence (<2°).

- Low-volume (<0.1 L) multipass cell spectrometer subsystems that advance NASA extractive trace-gas measurements. Operational at wavelengths 2 to 5 µm or greater with pathlengths of 50+ meters.

- Aircraft static-air-temperature sensor measurements to better than 0.1 °C accuracy under upper troposphere-lower stratosphere conditions.

- In situ spectrometer instruments for measuring atmospheric trace gases (ozone, NO$_2$, IO) from fixed platforms, ships, and small autonomous surface vessels. The instrument requirements are: Low-power operation modes; portability; autonomous operation: active, fast, and precise pointing for targeting Sun or Moon while gathering data; absolute radiometric calibration conservation, user-friendly field tools for the validation of the optical characterization of the system such as radiometric and spectral calibration and field of view (FOV); very low straylight and low electrical noise with capability to monitor and account for the electrical noise; wide dynamic range with capabilities of measuring low and high light intensities with the same optics (Sun, Moon, sky, and reflective surfaces); broad UV-vis-IR (ultraviolet-visible-infrared) spectral range with 0.6 nm spectral resolution for trace gases; capability of operating on fixed and moving ocean platforms; and auxiliary environmental sensors (site temperature, humidity, and pressure).

- Innovative, high-value sensors directly targeting a stated NASA need (including aerosols, clouds, and ocean) may also be considered. Proposals responding to this specific bullet are strongly encouraged to identify at least one relevant NASA subject matter expert.

**Expected TRL or TRL Range at completion of the Project**

4 to 7

**Primary Technology Taxonomy**

**Level 1**

TX 08 Sensors and Instruments

**Level 2**
Desired Deliverables of Phase I and Phase II

- Prototype
- Hardware
- Software

Desired Deliverables Description

The ideal Phase I proposal would demonstrate a clear idea of the problem to be solved, potential solutions to this problem, and an appreciation for potential risks or stumbling blocks that might jeopardize the success of the Phase I and II projects. The ideal Phase I effort would then address and hopefully overcome any major challenges to (1) demonstrate feasibility of the proposed solution and (2) clear the way for the Phase II effort. These accomplishments would be detailed in the Phase I final report and serve as the foundation for a Phase II proposal.

The ideal Phase II effort would build, characterize, and deliver a prototype instrument to NASA including necessary hardware and operating software. The prototype would be fully functional, but the packaging may be more utilitarian (i.e., less polished) than a commercial model.

State of the Art and Critical Gaps

The subtopic is and remains highly relevant to NASA Science Mission Directorate (SMD) and Earth Science research programs, in particular the Earth Science Atmospheric Composition, Climate Variability & Change, and Carbon Cycle and Ecosystems focus areas. Suborbital in situ and remote sensors inform NASA ground, ship, and airborne science campaigns led by these programs and provide important validation of the current and next generation of satellite-based sensors (e.g., PACE, OCO-2, TEMPO, GLIMR, SBG, A-CCP; see links in References). The solicited measurements will be highly relevant to current and future NASA campaigns with objectives and observing strategies similar to past campaigns (e.g., ACTIVATE, NAAMES, EXPORTS, CAMP2EX, FIREX-AQ, KORUS-AQ, and DISCOVER-AQ; see links in References).

Relevance / Science Traceability

The subtopic is and remains highly relevant to NASA SMD and Earth Science research programs, in particular the Earth Science Atmospheric Composition, Weather and Atmospheric Dynamics, Climate Variability & Change, Carbon Cycle and Ecosystems, and Earth Surface and Interior focus areas. In situ and ground-based sensors inform NASA ship and airborne science campaigns led by these programs and provide important validation of the current and next generation of satellite-based sensors (e.g., PACE, OCO-2, TEMPO, GLIMR, SBG, A-CCP; see links in References). The solicited measurements will be highly relevant future NASA campaigns with objectives and observing strategies similar to past campaigns (e.g., NAAMES, EXPORTS, CAMP2EX, FIREX-AQ, KORUS-AQ, DISCOVER-AQ; see links in References). The need horizon of the subtopic sensors and sensors systems is both near-term (<5 yr) and midterm (5 to 10 yr).

Relevant Programs and Program Officers include:

- NASA ESD Ocean Biology and Biogeochemistry Program (Laura Lorenzoni, HQ Program Manager).
- NASA ESD Tropospheric Composition Program (Barry Lefer, HQ Program Manager).
References

Relevant current and past satellite missions and field campaigns include:

- Decadal Survey Recommended ACCP Mission (now named Atmos) focusing on aerosols, clouds, convection, and precipitation: https://science.nasa.gov/earth-science/decadal-surveys
- TEMPO Satellite Mission focusing on geostationary observations of air quality over North America: http://tempo.si.edu/overview.html
- CAMP2Ex airborne field campaign focusing on tropical meteorology and aerosol science: https://espo.nasa.gov/camp2ex
- FIREX-AQ airborne and ground-based field campaign targeting wildfire and agricultural burning emissions in the United States: https://www.esrl.noaa.gov/csd/projects/firex-aq/
- GLIMR Satellite Mission focusing on geostationary observations of coastal waters and ocean productivity, land-to-sea carbon fluxes, and harmful algal blooms along the U.S. coast and other regions of interest off South America and the Caribbean Sea: https://www.nasa.gov/press-release/nasa-targets-coastal-ecosystems-with-new-space-sensor
- KORUS-AQ airborne and ground-based field campaign focusing on pollution and air quality in the vicinity of the Korean Peninsula: https://espo.nasa.gov/korus-ag/content/KORUS-AQ
- DISCOVER-AQ airborne and ground-based campaign targeting pollution and air quality in four areas of the United States: https://discover-ag.larc.nasa.gov/
- NAAMES Earth Venture Suborbital field campaign targeting the North Atlantic phytoplankton bloom cycle and impacts on atmospheric aerosols, trace gases, and clouds: https://naames.larc.nasa.gov
- ATom airborne field campaign mapping the global distribution of aerosols and trace gases from pole to pole: https://espo.nasa.gov/atom/content/ATom
- PACE Satellite Mission, scheduled to launch in 2022, that focuses on observations of ocean biology, aerosols, and clouds: https://pace.gsfc.nasa.gov/
- EXPORTS field campaign targeting the export and fate of upper ocean net primary production using satellite observations and surface-based measurements: https://oceanexports.org
- Decadal Survey Planetary Boundary Layer (PBL) Incubation Study: https://science.nasa.gov/earth-science/decadal-pbl
- Decadal Survey Surface Topography and Vegetation (STV) Incubation Study: https://science.nasa.gov/earth-science/decadal-stv