NASA SBIR 2019 Phase I Solicitation

S1.08 Suborbital Instruments and Sensor Systems for Earth Science Measurements

Lead Center: LaRC

Participating Center(s): ARC, GSFC, JPL, LaRC

Technology Area: TA8 Science Instruments, Observatories & Sensor Systems

In-situ sensors & sensor systems targeting trace gas measurements

Earth science measurements from space are considerably enhanced by observations from generally far-less costly suborbital instruments and sensor systems. These instruments and sensors support NASA's ESD science, calibration/validation and environmental monitoring activities by providing ancillary data for satellite calibration and validation; algorithm development/refinement; and finer-scale process studies. Accordingly, instrument and sensor systems are sought that include air quality, greenhouse gases, flux measurements, advancement of methods for assessing air mass photochemical age or for differentiating emissions sources (for example, real-time, fast response isotopic carbon measurements) and atmospheric composition. In-situ sensor systems (airborne, land and water-based) can comprise stand-alone instrument and data packages; instrument systems. This subtopic solicits instrument systems configured for ground-based/mobile surface deployments, as well as for integration on NASA's Airborne Science aircraft fleet or commercial providers, UAS, or balloons. An important goal is to create sustainable measurement capabilities to support NASA's Earth science objectives – most notably support of its Earth Venture programs especially validation and verification of LEO and GEO AQ/AC satellites through involvement with NASA's intensive targeted field campaigns and or its ground-based networks. Instrument prototypes as a deliverable in Phase II proposals and/or field demonstrations are 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.

Desired passive sensors/instruments, in-situ/airborne sensors or mated platform/sensors include:

- Small, turn-key trace gas measurement sensors with 1-10 Hz time response that are suitable for autonomous aircraft and/or UAV deployment and capable of detecting:
  - NOx, NOy, CH_2O, O_3, benzene, toluene at < 5 % uncertainty
  - CO, CH_4, OCS and N_2O at < 1% uncertainty
  - CO_2 at < 0.05% uncertainty,

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

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

- 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 of 2-5 um and/or 8-12 um bands with low return light cone divergence (<2°).
- Low-volume (<0.1 L) multi-pass cell spectrometer subsystems that advance NASA extractive trace gas measurements. Operational at wavelengths 2-5 um or greater with pathlengths of 50+ meters.
- Aircraft static air temperature sensor measurement to better than 0.1° C accuracy under upper troposphere / lower stratosphere conditions.
- Miniaturized passive sensor systems that observe both trace gases *and* aerosols at a similar price point but beyond the capabilities of both the Pandora spectrometer (http://sciglob.com) and Cimel sun photometer (https://www.cimel.fr) systems are sought. System should be stand-alone, user-friendly, autonomous/remotely operated instruments actively tracking the Sun and Moon (with a pointing precision of at least if not better than 0.1^o) and capable of making sky/surface observations on the scale of tens of seconds from both stable (e.g., roofs/towers) and mobile platforms (e.g., ship and or vehicle) while having integrated real-time preliminary data processing for trace gases and aerosols. Systems must be capable of providing high-resolution UV-VIS-NIR solar/lunar/clear sky spectra that can be used to determine atmospheric abundance of O_3, NO_2, HCHO, SO_2, BrO, HONO, CHOCHO, H_2O_v and aerosols. TG observations require a S/N ratio of better than 2500:1 whereas aerosol observations require an accuracy of at least 3%. Proposed systems must maintain an absolute calibration while deployed.

Desired ocean color sensors/instruments include:

- In-situ instruments to measure in-situ and lab-based absorption, backscatter and beam attenuation in the ocean, extending the current commercial capability beyond what is available today (410-750 nm) and obtaining measurements that extend into the UV and Near-IR regions of the spectrum.
- In-situ instruments to measure ocean Volume Scattering Function (VSF) and backscatter, extending the current capacity of few specific wavelengths to a hyperspectral capability extending from the UV to NIR with high angular ($<10^o$) resolution.
- Instrumentation with improved methods and measurement platform for upwelling radiances just below the water surface (Lu(0-)), extending spectrally from the UV to NIR.
- Instrumentation for in-situ measurements of polarization IOPs (Mueller Matrix: S11, S12 and S22) spanning from UV<->NIR, with high angular resolution ($<=10^o$) of scattering components.

The S1.08 subtopic is and remains highly relevant to NASA SMD and Earth Science research programs, in particular, the Earth Science Atmospheric Composition and Climate focus areas. In-situ sensors and, specifically trace gas sensors, inform directed Airborne Science field campaigns led by these programs and provide important validation of airborne and ground-based remote sensors (e.g., GCAS, 4STAR, AERONET, and Pandoras) as well as the current and next generation of satellite-based sensors (e.g., OCO, TEMPO). The solicited measurements are highly relevant to past and future NASA airborne campaigns (e.g., FIREX-AQ, CAMP2EX, KORUS-AQ, DISCOVER-AQ). Given the on-going and continuing need for such airborne science missions, it is expected that the sensors and sensor systems developed under this subtopic would directly benefit these missions and those expected in the coming decade.

Other programs relevant to NASA are ESD Tropospheric Composition Program and ESD Radiation Sciences Program.

Instruments developed for this subtopic would provide synergistic trace gas and aerosol observations that would contribute to the validation and or verification of the following satellites (both U.S. and international):

- Active Satellites:
  - AURA NASA LEO.
  - MetOp-A EUMETSAT LEO.
  - S-NPP NASA LEO.
  - MetOp-B EUMETSAT LEO.
  - DSCOVR NASA L1.
  - Sentinel 3A EUMETSAT LEO.
  - Sentinel 5P ESA LEO.

    - GaoFen-5 CSA LEO.
    - NOAA-20 NOAA LEO.
    - Sentinel 3B EUMETSAT LEO.

- To be launched:

    - GEO-KOMPSAT 2 NIER GEO.
    - TEMPO NASA GEO.
    - Sentinel 4 EUMETSAT GEO.
    - Sentinel 5 EUMETSAT LEO.
    - MAIA NASA LEO.

The need horizon of the subtopic sensors and sensors systems is BOTH near (<5 years) and mid-term (5-10 years). The expected Technology Readiness Level (TRL) range at completion of the project is 4-7.

References:

Relevant current and past field campaign websites include:

- KORUS-AQ: https://espo.nasa.gov/korus-aq
- DISCOVER-AQ: https://discover-aq.larc.nasa.gov/
- CAMP2Ex: https://espo.nasa.gov/camp2ex/content/CAMP2Ex
- FIREX-AQ: https://espo.nasa.gov/firex-aq/content/FIREX-AQ, https://www.esrl.noaa.gov/csd/projects/firex/science.html
- AToM: https://espo.nasa.gov/home/atom