The Stratospheric Aerosol & Gas Experiment III (SAGE III) on the International Space Station (ISS): Mission Overview and Validation Description

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Abstract

The Stratospheric Aerosol and Gas Experiment III (SAGE III) is the fifth in a series of occultation instruments developed by NASA Langley Research Center (LaRC), used to develop measurement techniques to monitor aerosol, ozone, water vapor and other gaseous constituents in the stratosphere and troposphere. The multi-decadal SAGE ozone and aerosol data sets have undergone intense scrutiny, and are the international standard for accuracy and stability. SAGE III on the International Space Station (ISS) will provide scientific measurements of five of the nine critical constituents identified in the U.S. National Plan for Stratospheric Monitoring including aerosol, ozone (O_3), nitrogen dioxide (NO_2), air density using O_2, and water vapor (H_2O). The SAGE III payload is scheduled to be installed on the ISS in 2016, collecting 16 sunrise and 16 sunset occultation measurements per day in an orbit inclination and period similar to the SAGE II orbital tracks.
Along with solar occultation events, SAGE III will perform lunar occultations between the first and third quarters of each lunar month providing a radiant source for retrieval of key nighttime atmospheric constituents such as nitrogen trioxide (NO_3) and chlorine dioxide (OClO). SAGE III will also perform limb scattering measurements allowing for retrievals of atmospheric gases and particulates (aerosol and cloud) using the scattered sunlight from the Earth's atmosphere.
LaRC will manage the validation and calibration campaign during the first 3 years of SAGE III operations. The validation and calibration campaign will consists of aerosol backscatter, water vapor, and ozone sondes launched during local day and night times in both the northern and southern hemispheres during SAGE III Instrument/ISS orbital overpasses of the local sonde launch sites. Monthly planned solar/lunar occultation and limb scatter events will be available on the SAGE III Validation Planning web-page accessible from the SAGE III web-site http://sage.nasa.gov/ for use by our validation partners as a planning tool for correlative measurements.

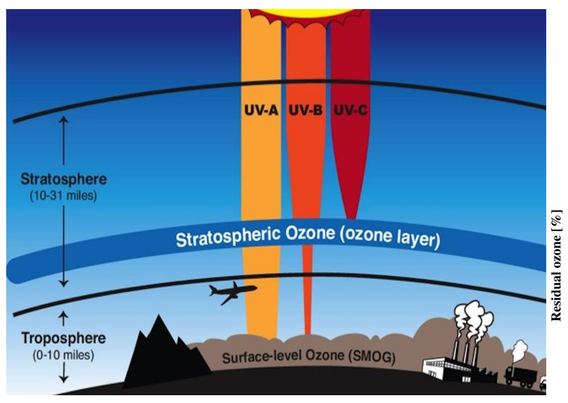
Ozone and Aerosol Measurements

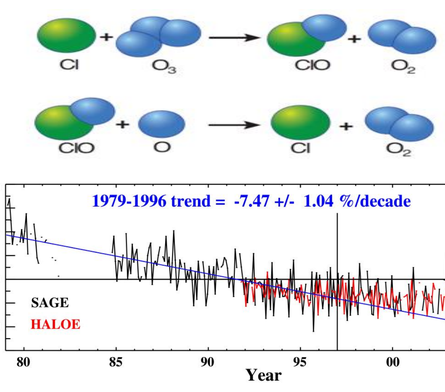
Though ozone represents only a tiny fraction of the atmosphere it is crucial for life on Earth. Without stratospheric ozone the Earth is exposed to more of the Sun's UV radiation which can cause reduced crop yield, cancer and cataracts. Ozone is created and destroyed naturally by sunlight but in the 1970s scientists discovered human-made cholorfluorocarbons (CFCs) were also destroying ozone. As a result of scientists and policy makers working together the Montreal Protocol was signed in 1987 limiting the production of CFCs.

Congress mandated that NASA monitor stratospheric ozone with SAGE III being pick as one of several instruments to perform this task. The goal of these measurements is to determine if the trend in residual stratospheric ozone is recovering from the recorded lows of the late 1990s/ early 2000.

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 are the international standard for accuracy and stability. SAGE scientific measurements provide the basis for five of the nine critical constituents identified in the U.S. National Plan for Stratospheric Monitoring including profiles of aerosols, ozone (O_3), nitrogen dioxide (NO_2), water vapor (H_2O), and air density using O_2.

SAGE aerosol data is recognized as *the source* necessary for understanding O_3 trends (Montreal Protocol Scientific Assessment Panel) and Predicting global warming (Hansen, 2008 AGU Bjerknes lecture).



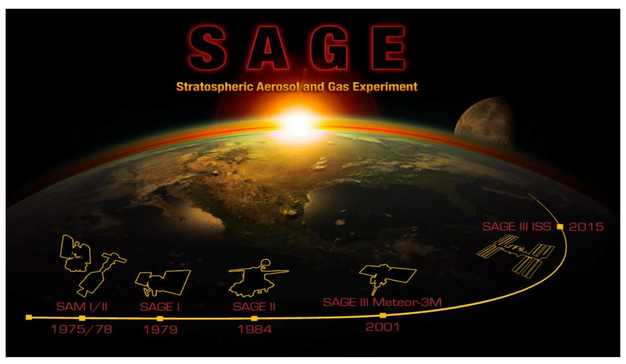


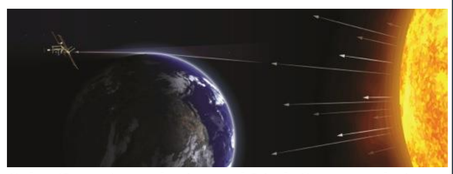
SAGE History

SAGE III on International Space Station (ISS) is the fifth in a series of instruments developed for monitoring ozone, aerosols and gaseous constituents in the stratosphere and upper troposphere. SAGE III will be one of the first continuous Earth-observing instruments on the ISS. SAGE uses the occultation technique to take measurements using the sun or moon as a source. The orbital path of ISS helps maximize the scientific value of SAGE III observations.

SAGE III on ISS is led by NASA Langley Research Center with many partners:

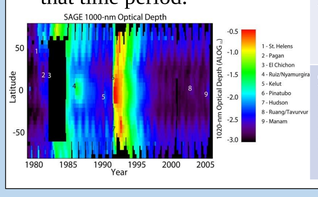
NASA Johnson Space Center, NASA Marshall Space Flight Center, Ball Aerospace and Technology Corp, European Space Agency, Thales Alenia Space-Italia





Solar (Lunar) occultation and Limb Scatter techniques

The SAGE II 20 year record of aerosol, ozone, and water vapor has been the standard for these measurements in both accuracy and stability. The aerosol record documented all the major volcanic eruption during that time period.



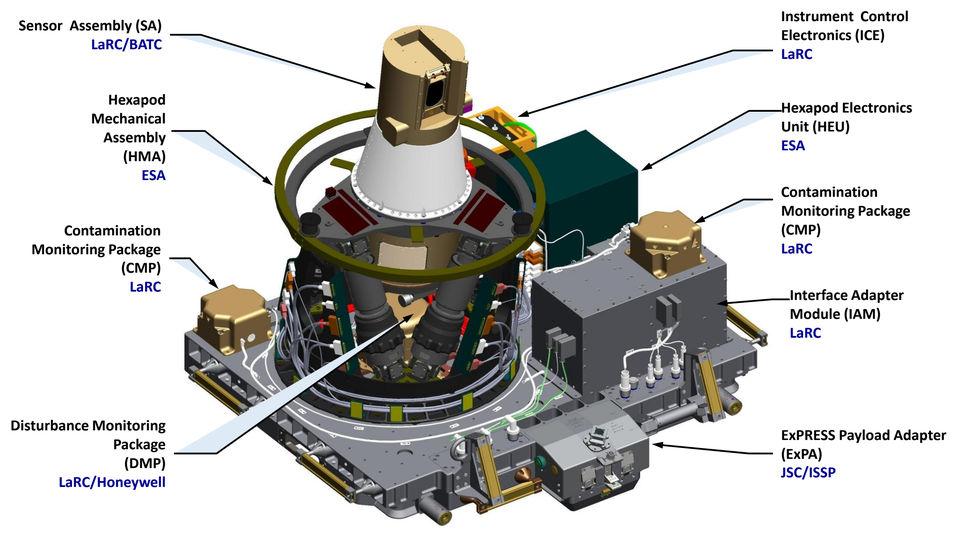
Experiment	Era	Orbit/Platform	Channels	Science Highlight
SAM	1975	Inclined/Apollo-Soyuz	Single channel @ 840 nm	Demonstration
SAM II	1978-1993	Sun-synch / Nimbus 7	Single channel @ 1 µm	Polar Stratospheric Clouds
SAGE I	1979-1981	Inclined/AEM-2	Ozone, Aerosol, NO_2	Pre-decline ozone baseline
SAGE II	1984-2005	Inclined/ ERBS	+ Water Vapor	Ozone Trends, Extreme aerosol variability
SAGE III ➢ Meteor ➢ ISS ➢ FOO	2001- 2006 2015-	Sun-synch /Meteor 3M Inclined/ISS	+ O_2; Night-time: Ozone, NO_2, NO_3; Mesospheric Ozone	Tropospheric measurements, Lunar occultation & Limb scattering

References

SAGE III on ISS Instrument Description

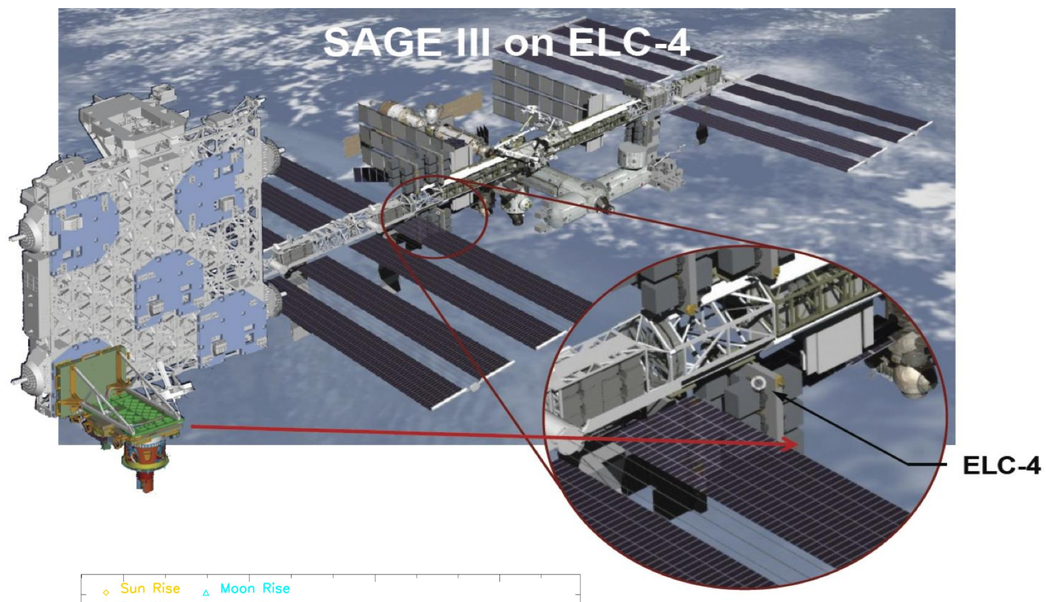
SAGE III on ISS instrument payload includes a Sensor Assembly (SA) which houses the telescope, optics and detector, an Instrument Controller Electronics (ICE) box that controls the sensor assembly operation, a Hexapod Mechanical Assembly (HMA) along with its control electronics housed in the Hexapod Electronics Unit (HEU) designed to orient the SA in a nadir viewing position compensating for changes in the ISS orientation, two Contamination Monitoring Packages (CMP) that will be used to determine contamination in the environment that may harm the optical window and mirrors, a Disturbance Monitoring Package (DMP) to provide information for flagging data sets if location information for science event profiles are compromised by disturbances to the platform, and the Interface Adaptor Module (IAM) which provides the command and control between the SAGE III Instrument payload and the ISS.

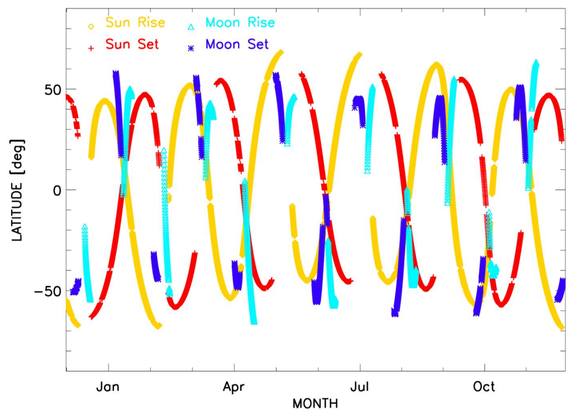
The SAGE III Instrument Payload is attached to a JSC supplied ExPress Payload Adaptor (ExPA) which will be robotically attached to a Langley Research Center built Nadir Viewing Platform (NVP) which orients the SAGE III Sensor Assembly in a relative nadir position to the earth. The NVP will be attached to the ELC-4 location on the ISS.



ISS as a science platform

SAGE III on ISS is currently scheduled to be launched to the ISS on November 16, 2016 using the SPACE X 10 launch vehicle. The SAGE Instrument Payload will be robotically installed on the ExPress Logistic Carrier 4 (ELC-4) within 2 weeks of launch with SAGE III science event collection commencing shortly after installation on ELC-4.





ISS orbit provides solar and lunar occultation coverage from between +/- 70 degrees in latitude. The ISS platform location allows the SAGE III instrument to collect 70% of the possible solar occultation measurements with seasonal coverage over most of the mid-latitudes and equator.
ISS operational constraints (docking and undocking of vehicles, etc…) will minimally affect SAGE III science data collections.

SAGE III Science Data Product Validation

Continuous validation over the lifetime of the mission is essential for assessing the stability of the SAGE III datasets. SAGE III on ISS has a validation planning website to facilitate the involvement of institutes doing regular soundings of ozone, water vapor and aerosol (e.g. NDAAC network) to coordinate coincident measurements between SAGE III science measurement overpasses and ground in-situ measurements. Predicted ephemeris of SAGE III occultation events and limb scatter events will be distributed to institutes to enables better co-incidence comparisons between ground based and satellite measurements.

The calibration and validation of the SAGE III science products will rely on the NDACC sites for routine correlative measurements. Additional validation of NO_2 science products will be performed using Pandora LIDAR measurements from locations in New Zealand and the USA. Balloon launched sonde packages consisting of frost-point measurements for H_2O validation, ozone and aerosol measurements for O_3 and aerosol validation respectively will be performed from two sites in the northern and southern mid-latitudes.