Evolution of the International Space Station (ISS) To Support Climate Science

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The ISS As A Remote Sensing Platform

The International Space Station (ISS) is unique within this paradigm from several perspectives with the most significant being the presence of a human crew, a low-orbit altitude of approximately 400 km (approximately 249 miles) above sea level, and an inclined equatorial orbital (51.6° N – 51.6°S) that provides for variable fields of view (nadir to oblique) and diurnal imaging opportunities over 90% of the inhabited earth surface (Stefanov et al, 2019). The ISS also provides a variety of internal and external mounting locations, and common data transfer and power interfaces, for automated remote-sensing systems that have contributed to its development as a key platform for climate science.

Evolution of Earth Observation Capability

The evolution of the ISS to its current climate science-focused instrument configuration has taken place over the past nearly 24 years of crew-occupied operation (beginning November 2, 2000). The following discussion will focus on US Operating Segment sensors; for an overview of the history of Russian earth remote sensing including ISS, see Vedeshin and Shapovalov (2022). Initially, the only remote sensing system was the Crew Earth Observations Facility consisting of handheld visible wavelength film camera (digital after 2004) images of the Earth taken by crew through Station windows including the high optical quality US Laboratory window and Cupola. Increased crew complement, improved sophistication of commercial-off-the-shelf cameras, and recent implementation of automated georeferencing solutions have maintained the relevance of handheld crew earth imagery for climate science.

Sensor	Operational Period	ISS Location	Type/Focus
Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES)	2009-2014	JEM-EF	Atmospheric sounder/ozone processes
Hyperspectral Imager for the Coastal Oceans (HICO)	2009-2014	JEM-EF	VNIR Hyperspectral/coastal oceanic processes
ISS Agricultural Camera (ISSAC)	2011-2013	WORF	VNIR Multispectral/agricultural monitoring and disaster response
ISS RapidSCAT	2014-2016	Columbus Module	Scatterometer/sea surface winds
ISS SERVIR Environmental Research and Visualization System (ISERV)	2012-2015	WORF	Visible camera, telescope, with ground command pointing/Land use-land cover change and disaster response
Cloud-Aerosol Transport System (CATS)	2015-2017	JEM-EF	LiDAR/atmospheric profiles of aerosols and clouds

Table 1. Selected historical ISS remote sensing systems. VNIR - visible/near infrared; LiDAR - Light Detection and Ranging; JEM-EF - Japan Experimental Module Exposed Facility; WORF – Window Observational Research Facility.

A succession of both internal and external sensor systems of increasing sophistication began in 2009, some of which are described in Table 1. Additional details can be found in Stefanov et al (2019). While not intentionally tied to climate science as a primary objective, these systems demonstrated the advantages of the ISS for remote sensing to relevant communities (and funding sources) while also developing technical solutions (e.g. isolation mounts) to undesirable aspects such as vibrations from crew activities and structural flexure.

The Climate Science Sensor Suite

The current array of Earth remote sensing instruments on the ISS presents a unique capability for complementary data collection for climate science (Fig. 1) that leverages the advantages of a large, crewed orbital platform. This serendipitously developed suite of multispectral, hyperspectral, LiDAR, and microwave sensors provides an opportunity for coordinated investigation of earth system response to increasing global temperature and improvement of global climate change models. The importance of this capability is recognized by NASA and the International Partners by the extension (confirmed or in consideration) of the sensor missions to planned ISS end-of-life (currently 2030). The value of the capability may likewise inform ongoing development and planned use of commercial Low Earth Orbit stations (e.g. Axiom, Orbital Reef, and others) past the current ISS operational horizon.

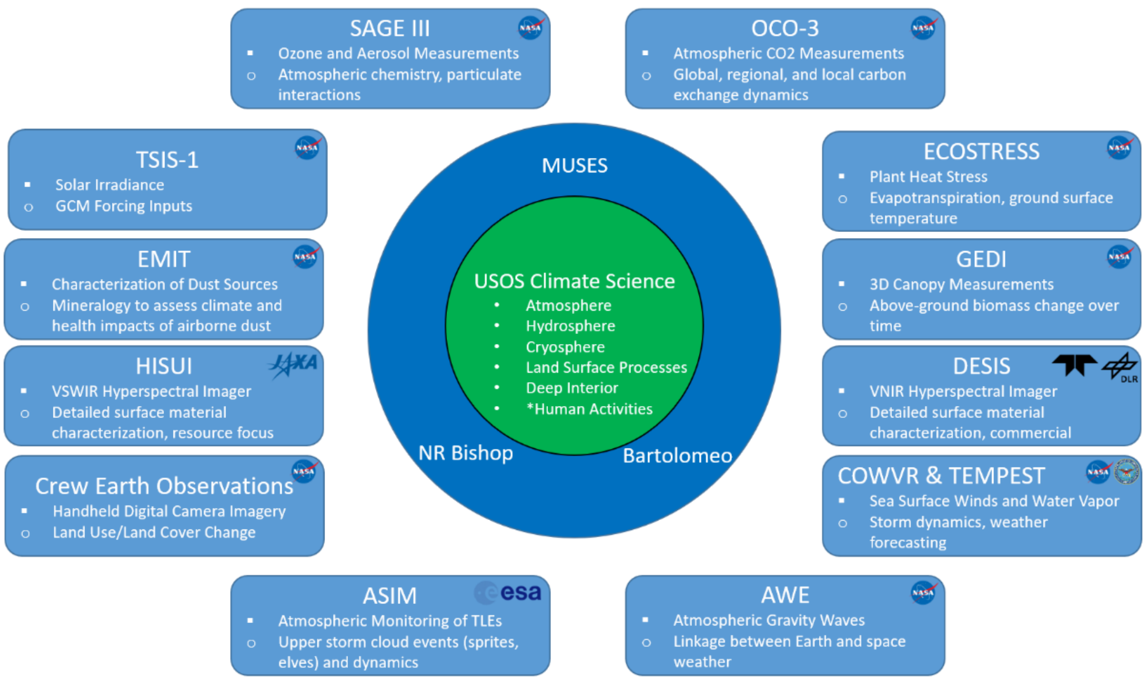

Figure 1. Climate Science Sensor Suite on ISS. ASIM – Atmosphere Space Interactions Monitor; AWE-Atmospheric Waves Experiment; COWVR - Compact Ocean Wind Vector Radiometer; DESIS - DLR Earth Sensing Imaging Spectrometer; ECOSTRESS - ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station; EMIT - Earth Surface Mineral Dust Source Investigation; GEDI - Global Ecosystem Dynamics Investigation; HISUI - Hyperspectral Imager Suite; MUSES - Multi-User System for Earth Sensing; NR – Nanoracks; OCO- Orbiting Carbon Observatory; SAGE – Stratospheric Aerosol and Gas Experiment; TEMPEST - Temporal Experiment for Storms and Tropical Systems; TSIS - Total and Spectral Solar Irradiance Sensor. MUSES, Bishop, and Bartolomeo are external sensor mounting points.

References

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Vedeshin, L.A., Shapovalov, D.A. (2022) The First Scientific and Technical Experiments in Space Earth Sciences (On the 60th Anniversary of Satellite Images of the Earth from Manned Spacecraft). Izv. Atmos. Ocean. Phys. 58, 1689–1692. https://doi.org/10.1134/S0001433822120258