Earth Observation and Climate Change
"Earth and Atmosphere Monitoring from ISS"

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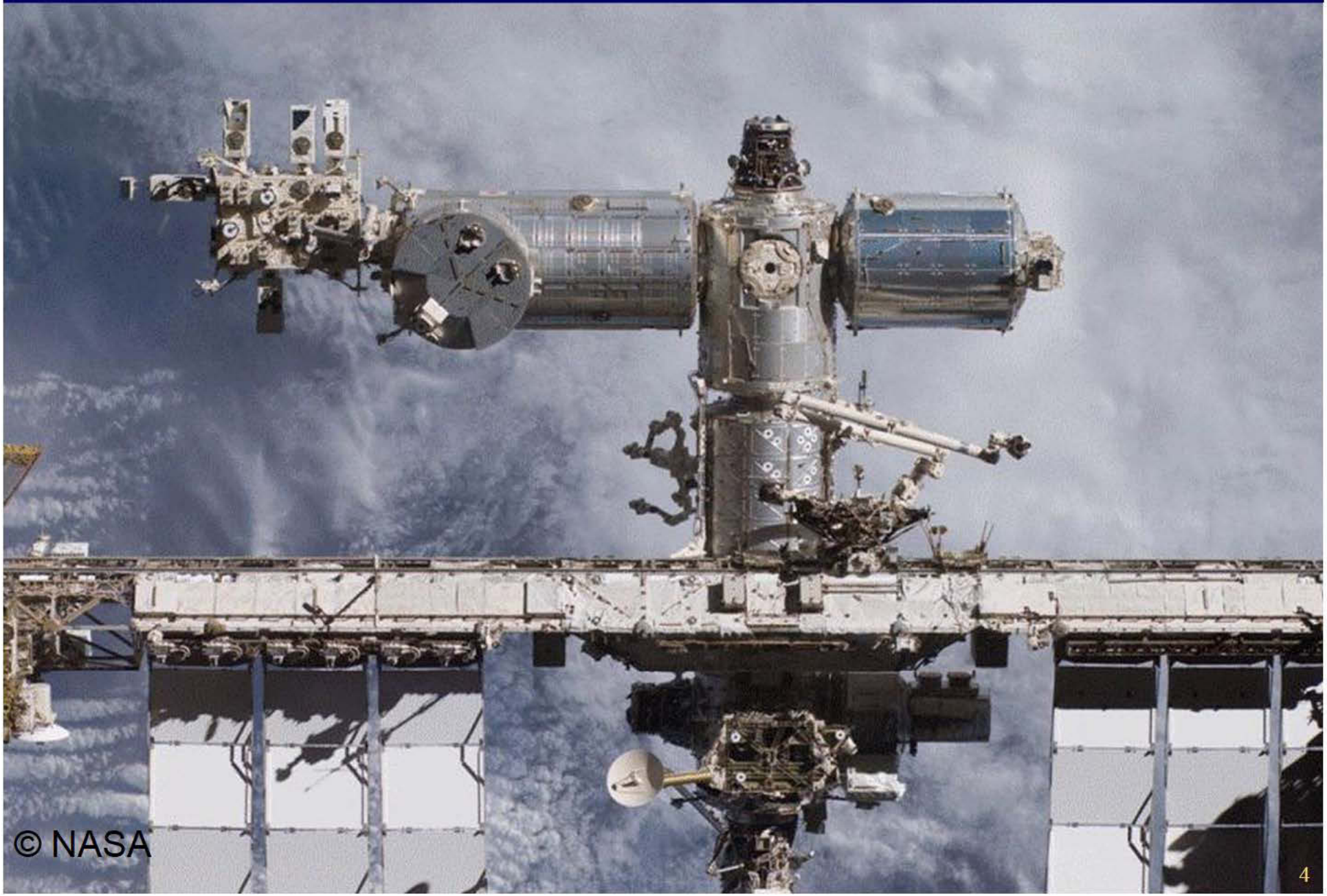
Part 1: ISS as an Observation Platform

Nadir View from ISS



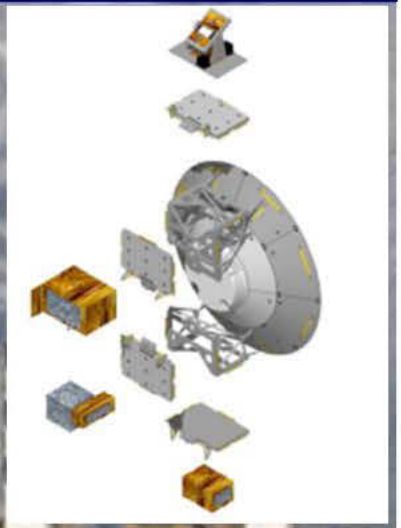
ISS as a space-based Earth Observation platform

- 300-460 km, 51.6° inclination orbit
  - Covers ~85% of earth surface & ~95% population
- Orbit is well adapted to observing diurnal variations
  - ISS passes over approximate 20 minutes earlier each day, permit observations at different times of day over a period of several weeks
- Low altitude benefits active instruments such as Lidars, which can use smaller sensors than higher altitude satellites
- Infrastructure for instrument operation:
  - Power, data downlink, command uplink, active cooling
- Internal and External instrument accommodations
  - Platforms on Truss & exterior of modules including Columbus & JEM/EF
  - Multiple Windows, such as Cupola along with possibility of direct crew intervention

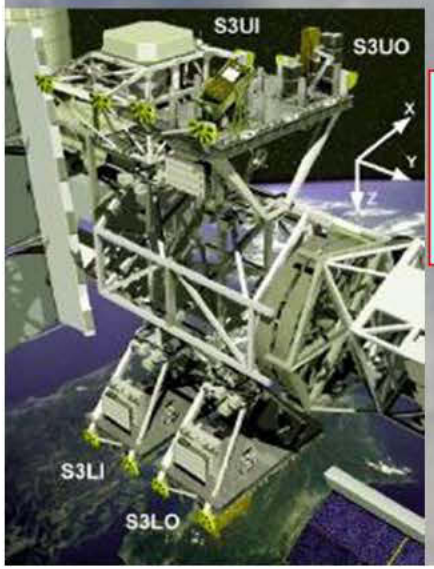
ISS External Instrument Accommodations

JEM
Exposed Facility

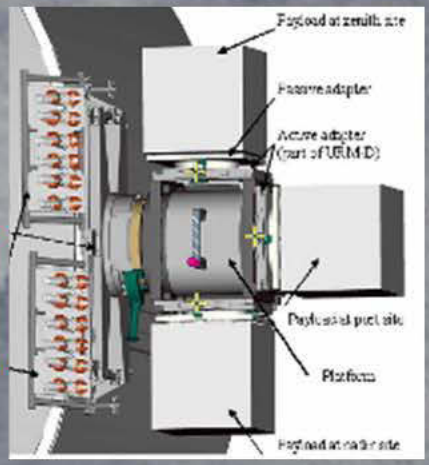
Columbus External
Payloads Facility



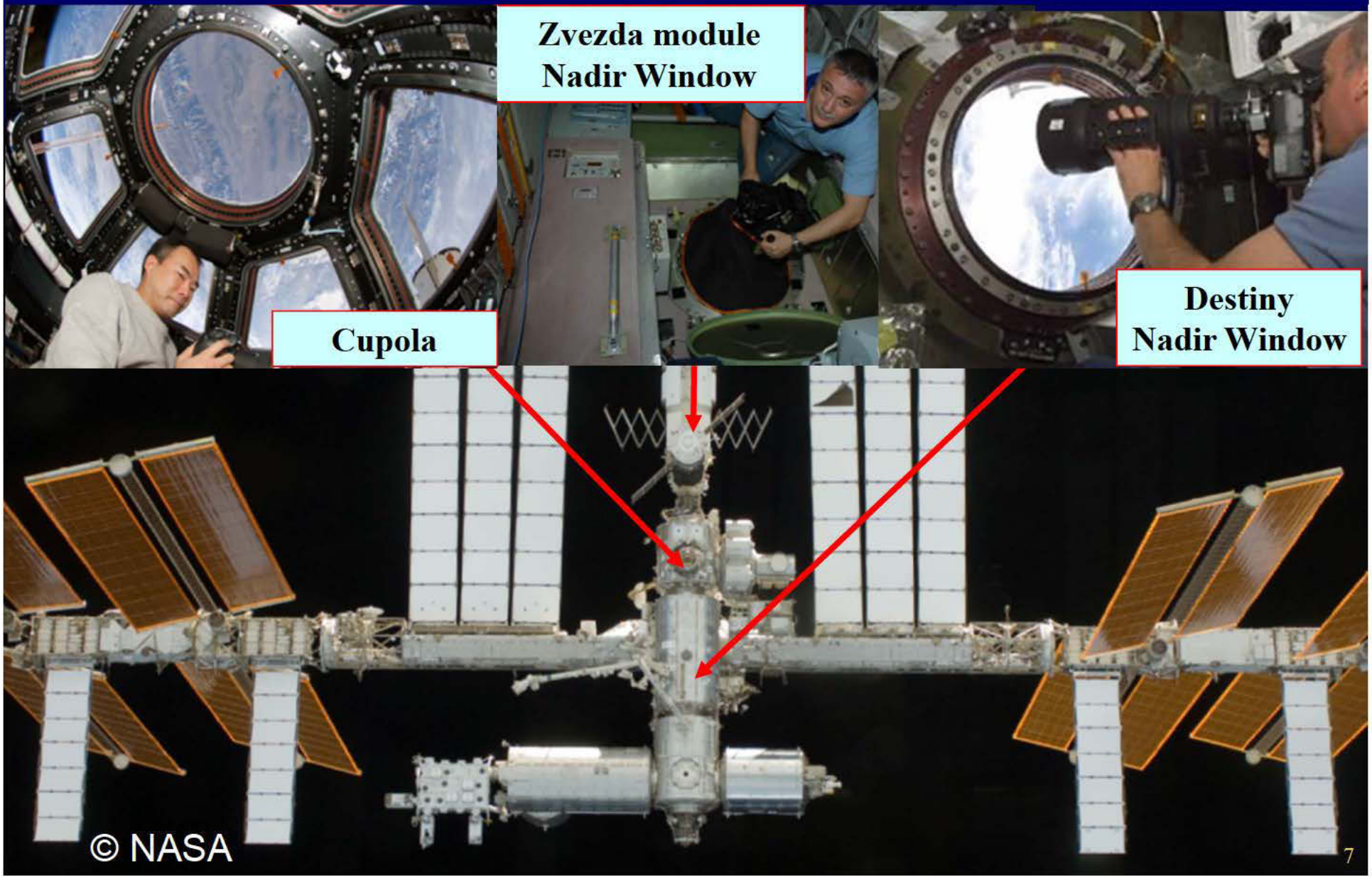
US Truss
(Port & Starboard
attachment sites)



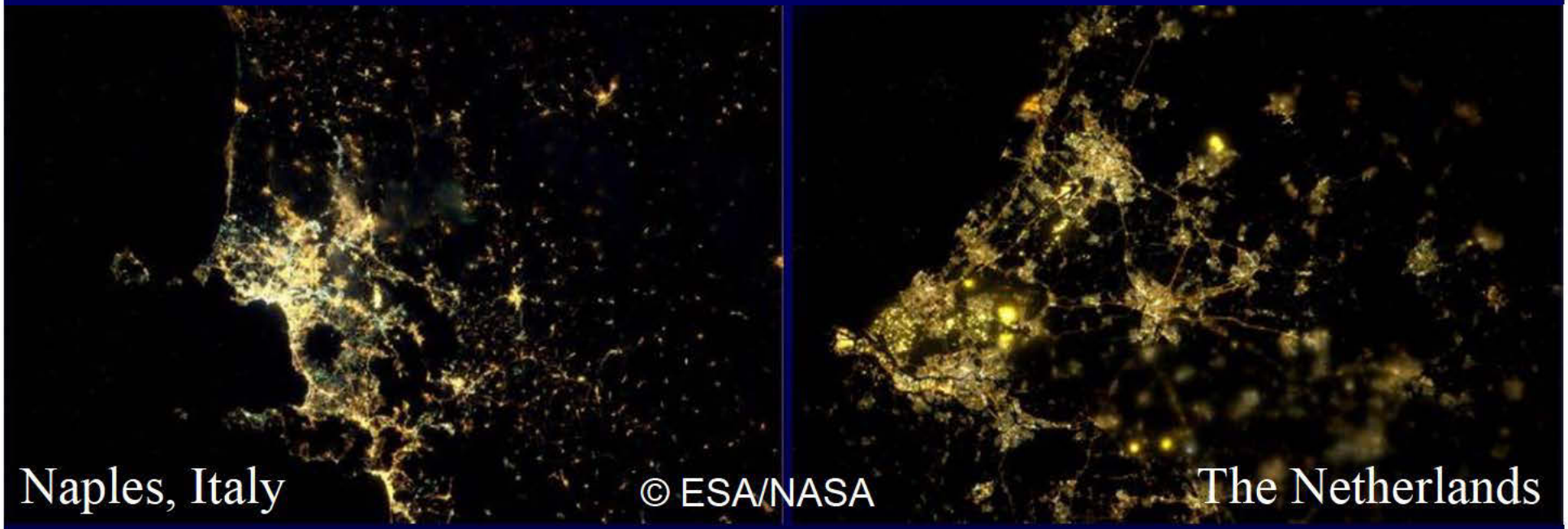
Zvezda
URM



ISS Internal Instrument Accommodations



Tracking cities at night from ISS



Cameras mounted on NightPod track the movement of Earth as it flies under the ISS. Night-time photographs taken by ESA astronaut André Kuipers are less blurred and captured in higher detail.

LEFT: Naples, Italy. The black circle is the volcano Vesuvius.
RIGHT: The Netherlands. The largest cities of the Netherlands are clearly visible: Amsterdam, Utrecht, Rotterdam and The Hague.

Part 2: Science Results of SMILES

Outline of SMILES

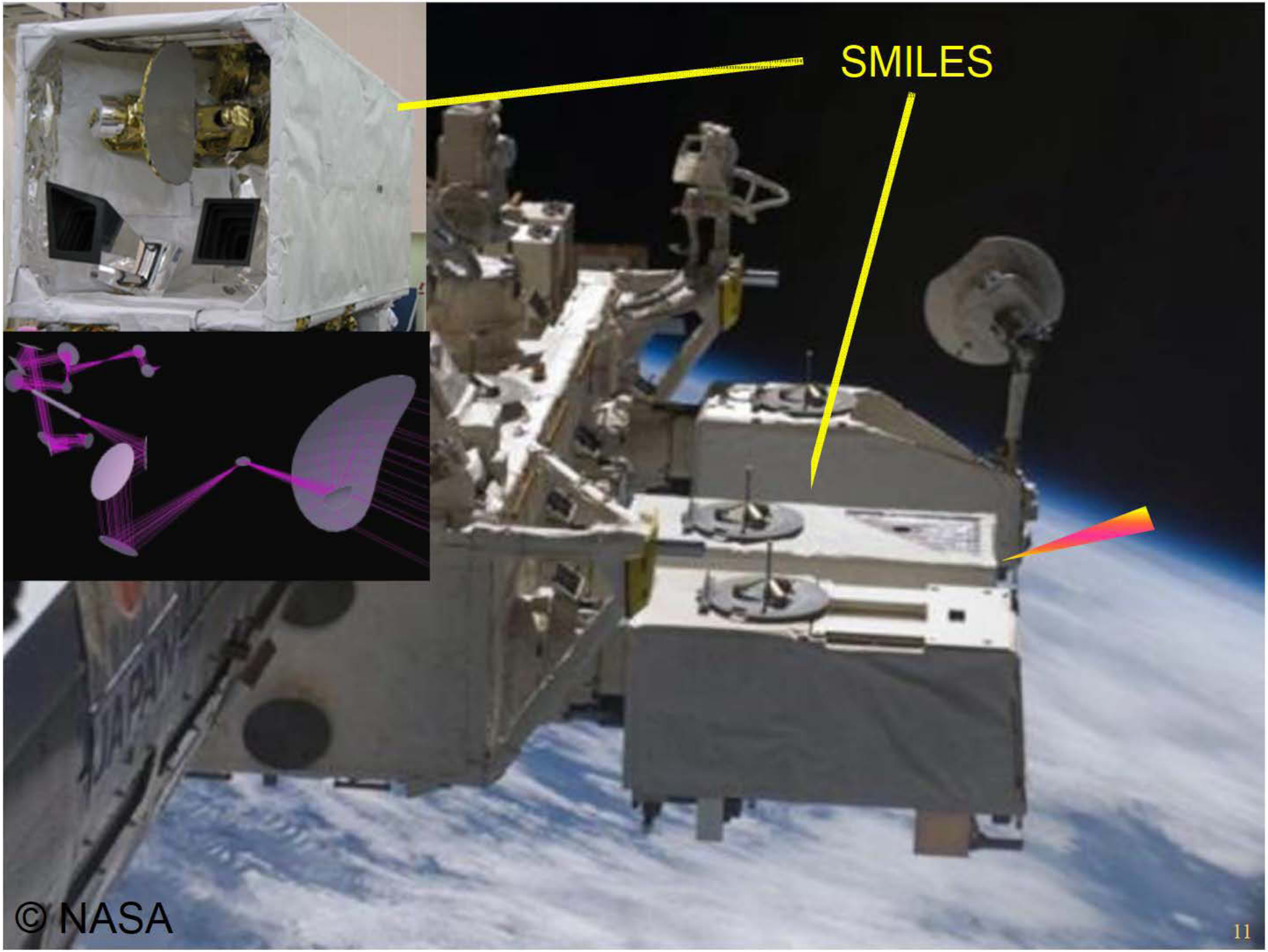
Superconducting Submillimeter-Wave Limb-Emission Sounder

(Mission)

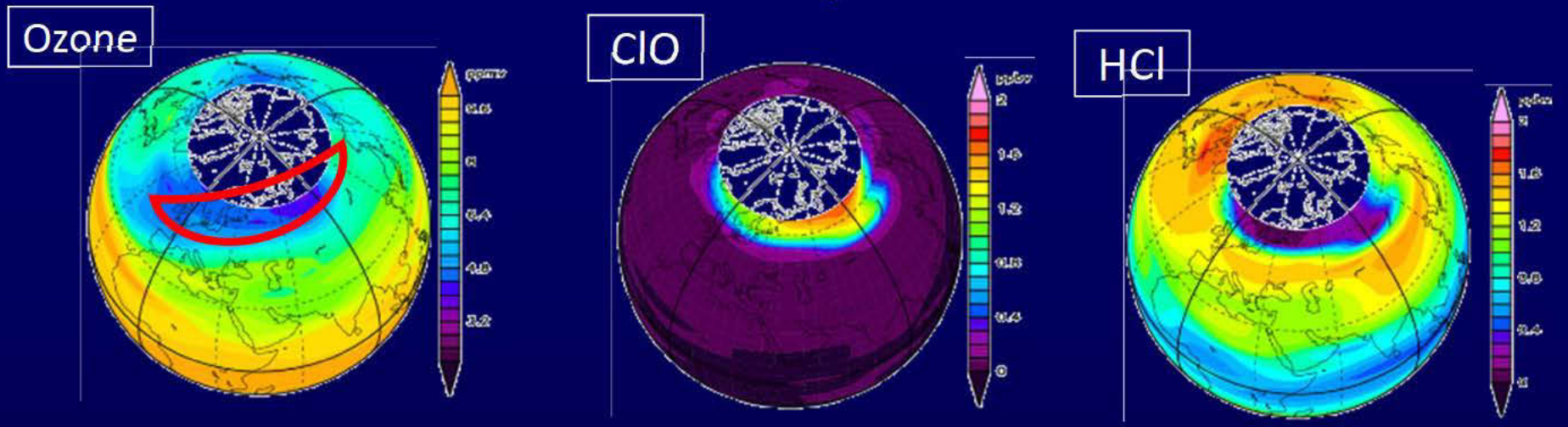
- Monitor global distribution of trace gasses relating to the stratospheric ozone depletion
- Space Demonstration of Submillimeter Sensor Technology based on a Superconductive Mixer and 4-K Mechanical Cooler

(History)

- SMILES was launched to the ISS on Sept. 11, 2009, and attached to a port #3 of EF on Sept. 25.
- SMILES had collected high quality observation data for six months until the instrument encountered trouble, 21 Apr. 2010 .
- These data indicate the excellent performance because the sensitivity is 10 times higher than other space-borne limb sounders.


SMILES
© NASA

Result 1: Ozone Depletion in the NH



$Cl + O_3 \rightarrow ClO + O_2$

$ClO + O \rightarrow Cl + O_2$

23 Jan. 2010

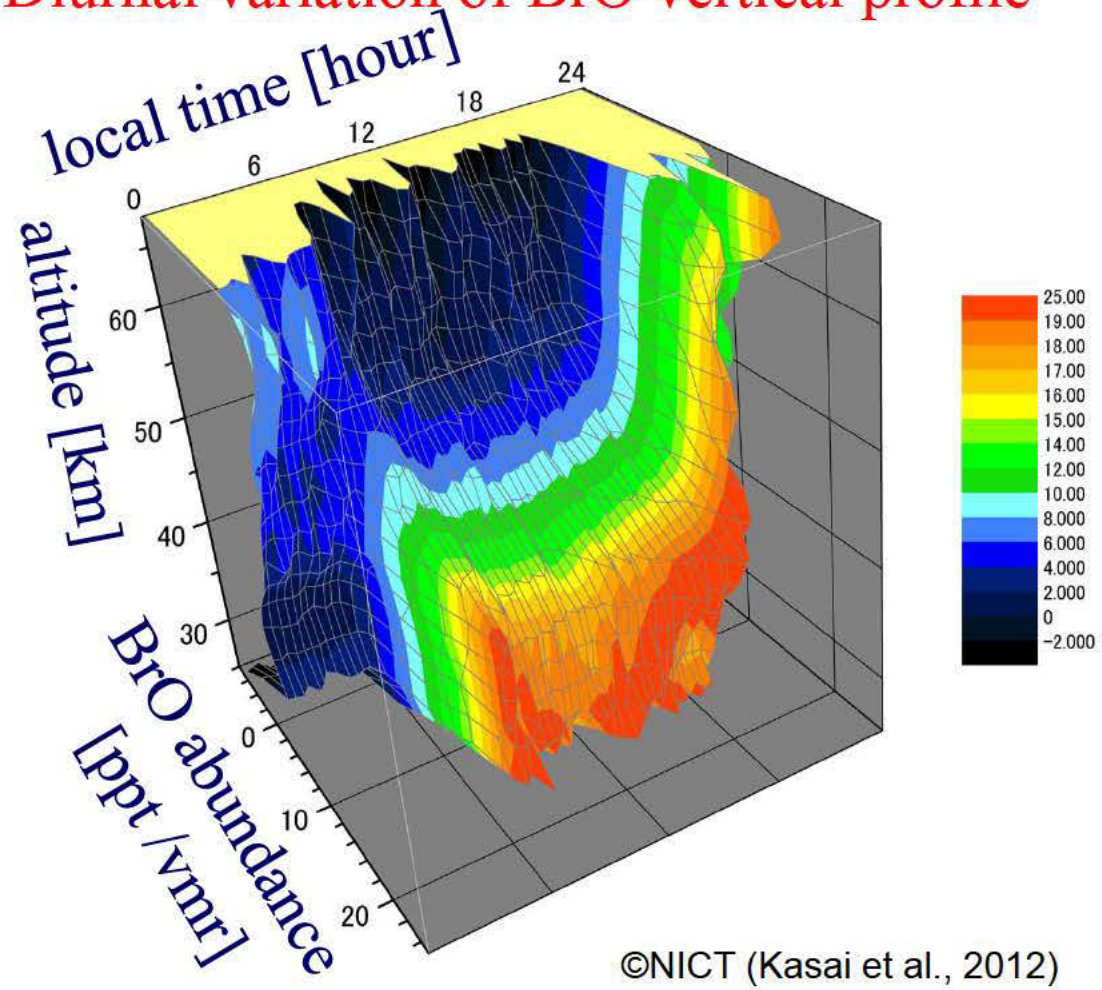
- The data shows that ozone destruction had happened through the same mechanism in the Northern Hemisphere as well as in the Southern Hemisphere.
- When temperature is very low in the polar vortex, HCl has been converted to ClO.
- High ClO abundances cause ozone depletion to continue in the polar region while this condition lasts.

Result 2: Diurnal Variation of BrO

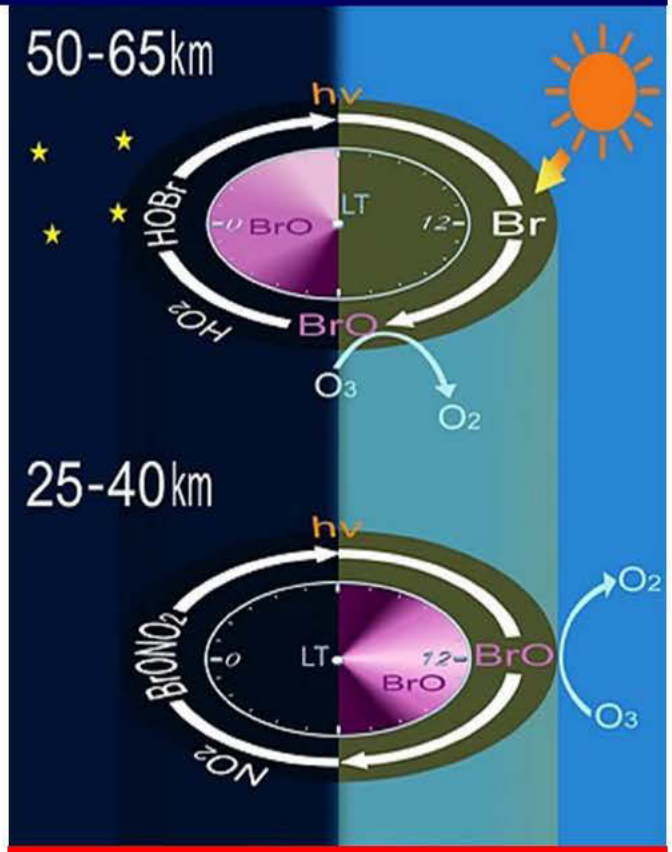
SMILES observed the atmospheric diurnal "behavior" of the BrO, which is a more powerful ozone-destroying radical than ClO.

The abundance of BrO in the atmosphere is only 1/1,000,000,000,000!

Diurnal variation of BrO vertical profile

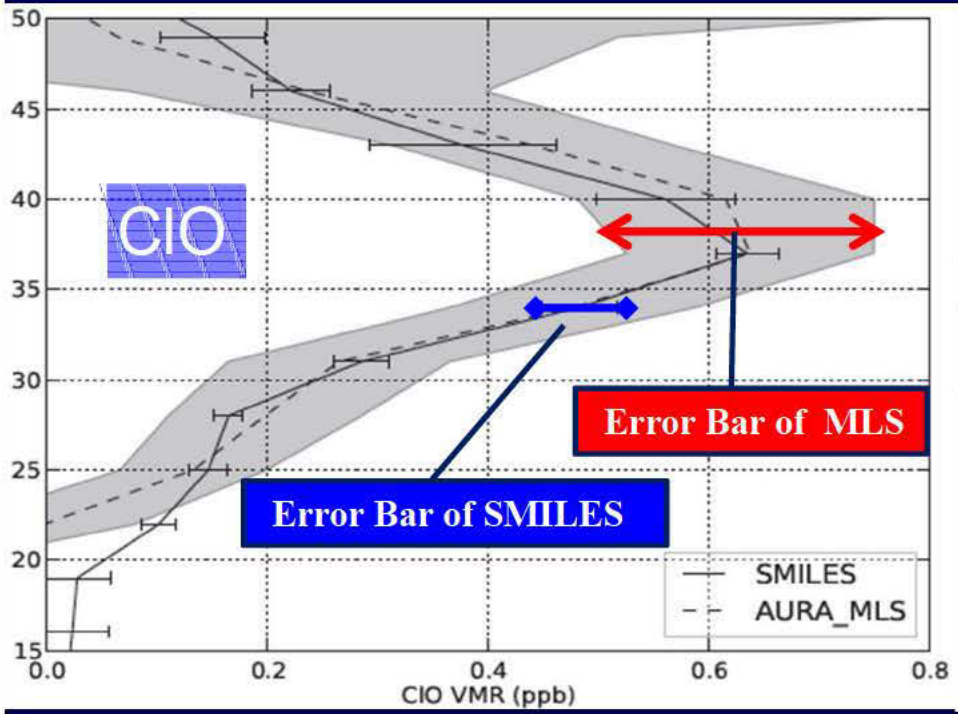


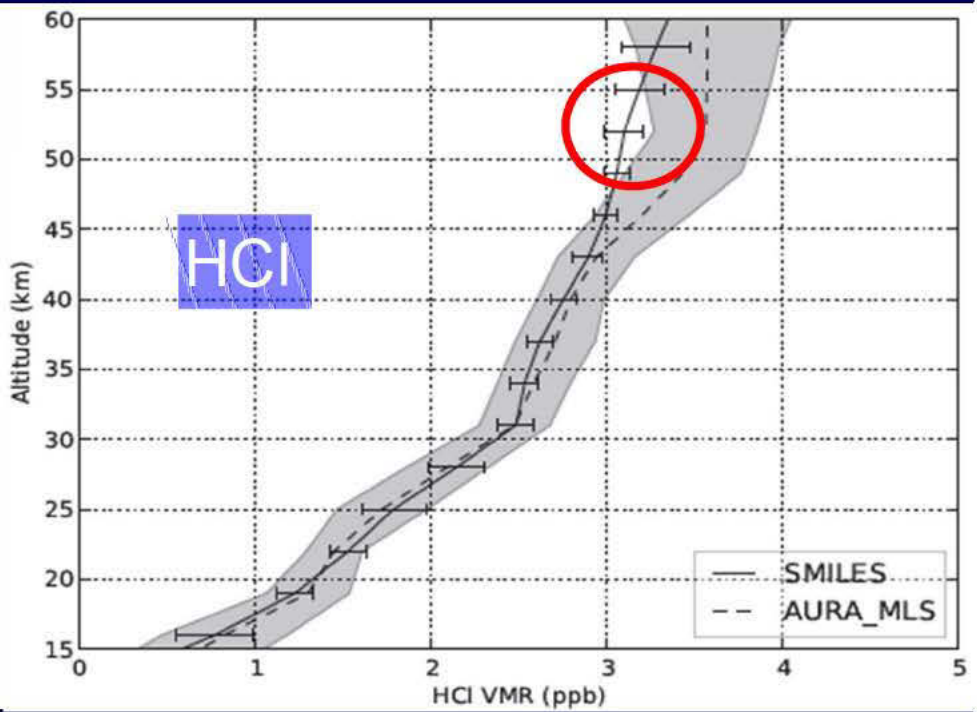
©NICT (Kasai et al., 2012)



Different daily life of BrO in the stratosphere and mesosphere

Result 3 : Back to the Future?



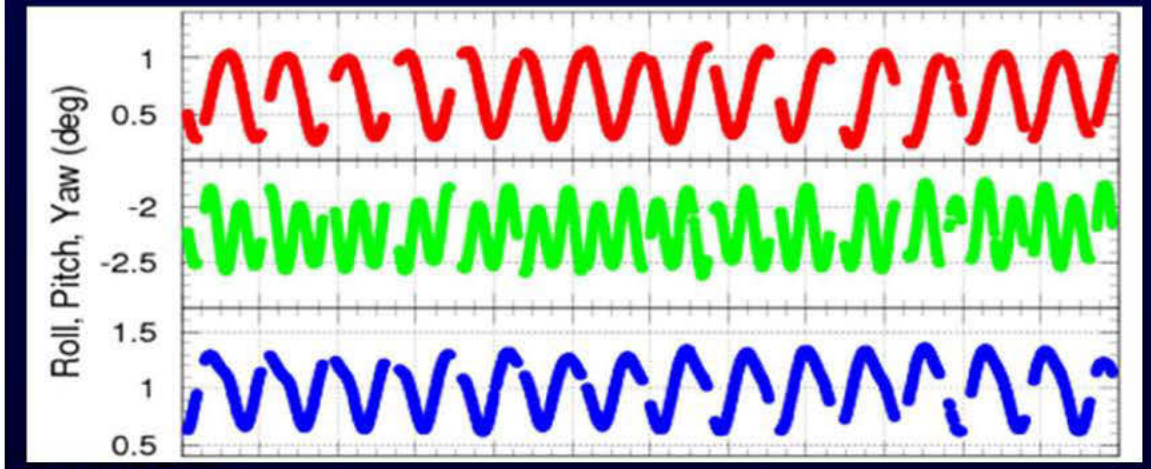


Comparison of AURA/MLS

- Error Bar of SMILES is much less than that of AURA/MLS. AURA/ MLS is still in operation and the data is expected to improve the error bar by finding some relationship between both data.
- SMILES observed at different time of day because of ISS orbit. As a result , SMILES's high-sensitivity observation plays an important role as a cross-calibrator of each sun synchronous satellite which observes at a fixed time of day.
- There is a discrepancy of HCl data around 55km and further analysis is ongoing.

Lessons Learned
-ISS Attitude Variation-

- ISS attitude variation at Standard Mode is approx. 1° periodicity (+/-0.5°) in each axis over one orbit (smooth sinusoidal variation)
- To avoid the variation of ISS attitude for observation, SMILES changes the starting angle of antenna at every scan to compensate for this variation.
- Attitude can be predicted up with accuracy of approx. 0.2° for up to 4 days
- Ground operator forecasts the attitude and uploads correction table.



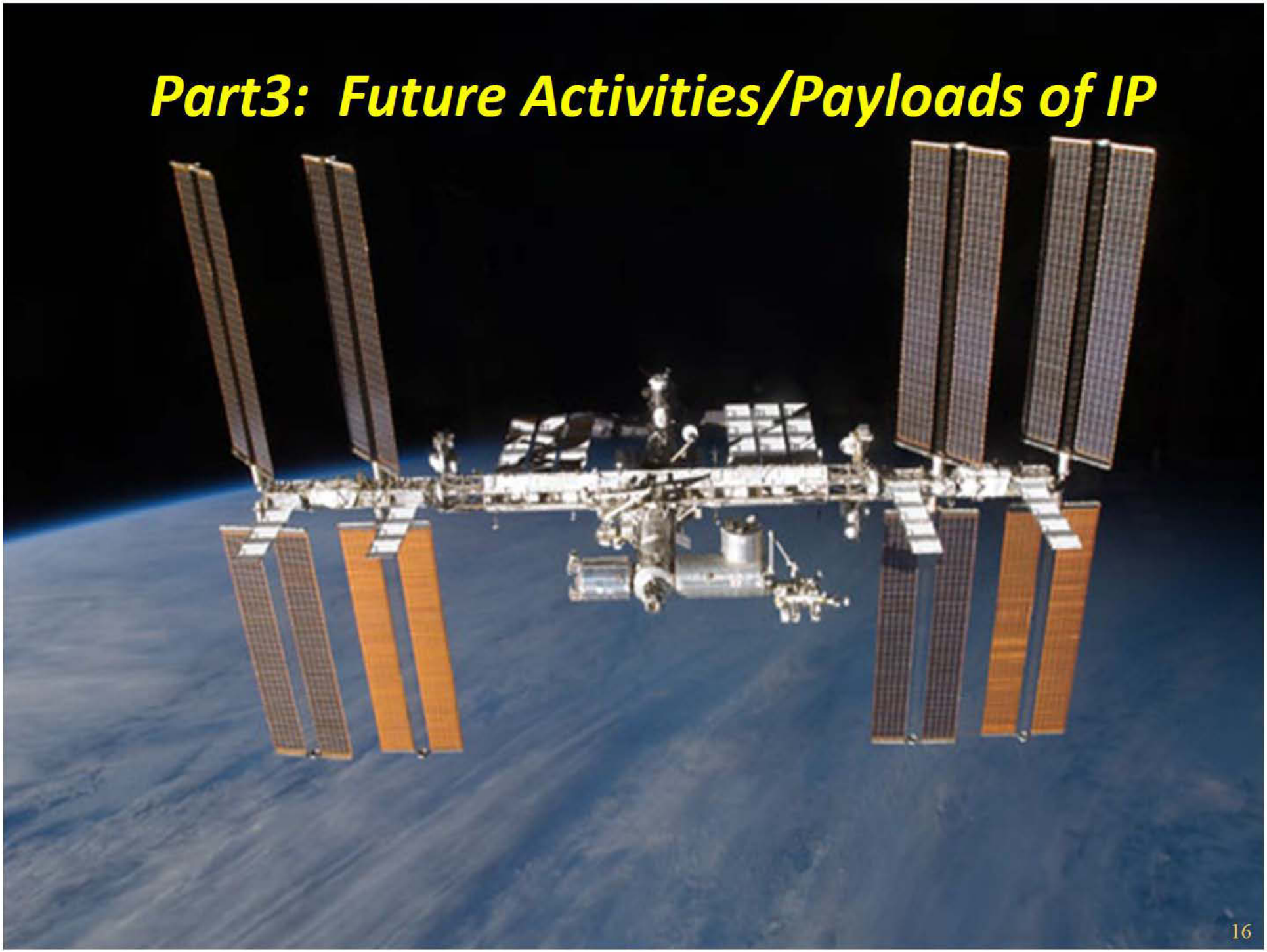
ISS Attitude [deg]

Roll

Pitch

Yaw

Part3: Future Activities/Payloads of IP



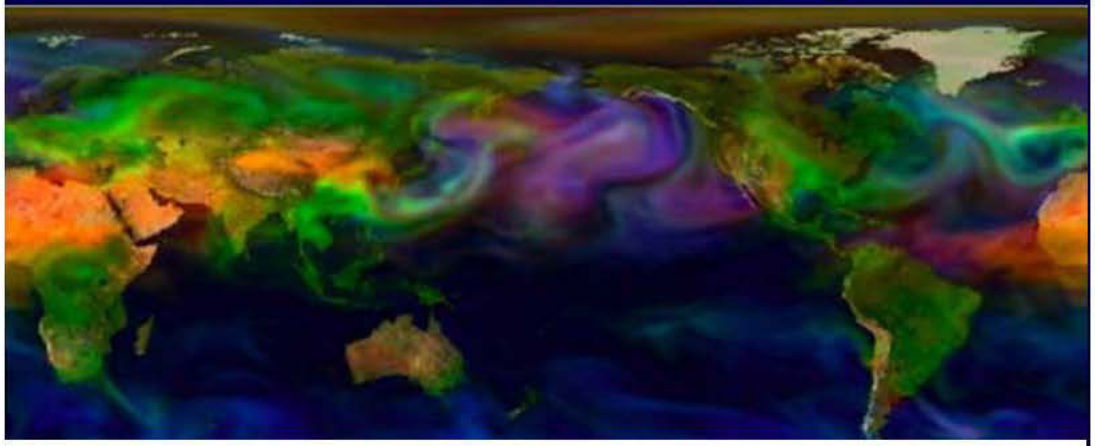
Future Plan of NASA

Cloud Aerosol Transport System (CATS/ISS)

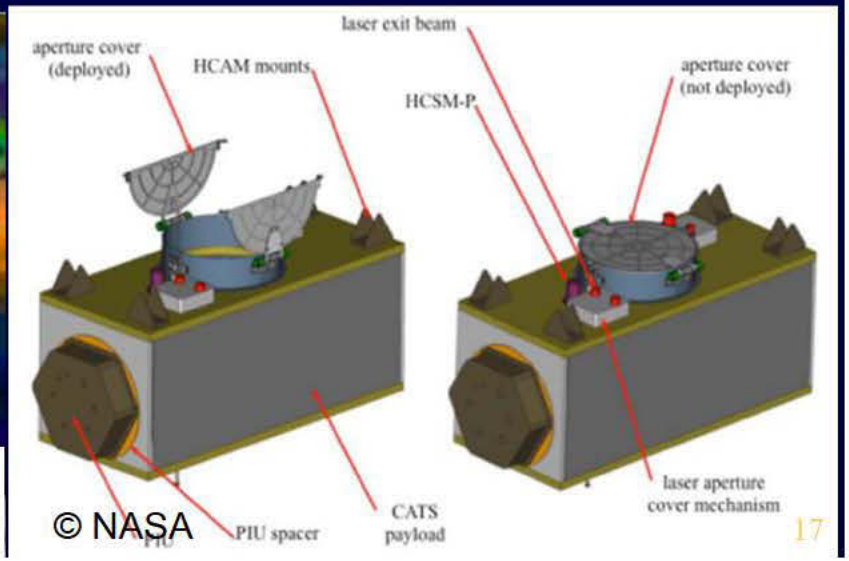
- Cloud Physics LIDAR Instrument which will demonstrate multi-wavelength aerosol and cloud retrievals; planned for launch in 2013
- Enable aerosol transport models by using real-time data downlink from ISS
- ISS orbit is useful for tracking plumes and study of diurnal effects (not possible with A-Train orbit).

SAGE III-ISS

- NASA's Stratospheric Aerosol and Gas Experiment III-ISS (SAGE III-ISS) will measure ozone, water vapor and aerosols in the atmosphere when it is attached to the Truss; planned for launch in 2014 on a SpaceX .



Global Aerosol Distribution Forecast © NASA
Orange = dust; Blue = sea salt; Green = smoke and sulfate



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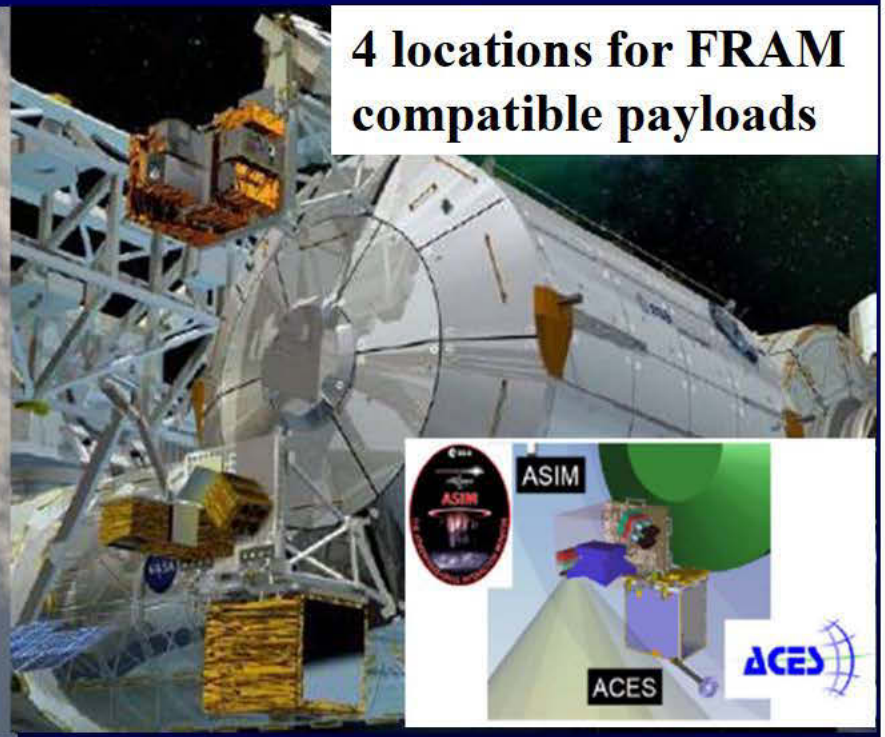
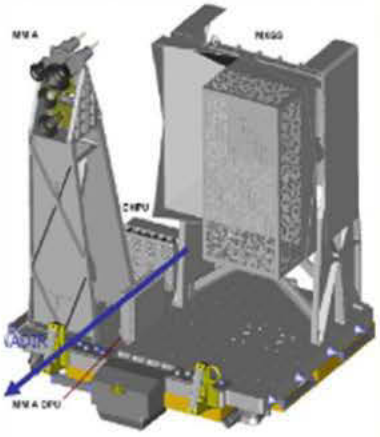
Future Plan of ESA
ASIM: Atmosphere Space Interactions Monitor





CEPF Payloads

- ACES(launch planned in 2013) Atomic clocks –GNSS
- ASIM(launch planned in 2015) -Earth Observation
  - ASIM will study giant electrical discharges (lightning) in the high-altitude atmosphere above thunderstorms and their role in the Earth's climate.

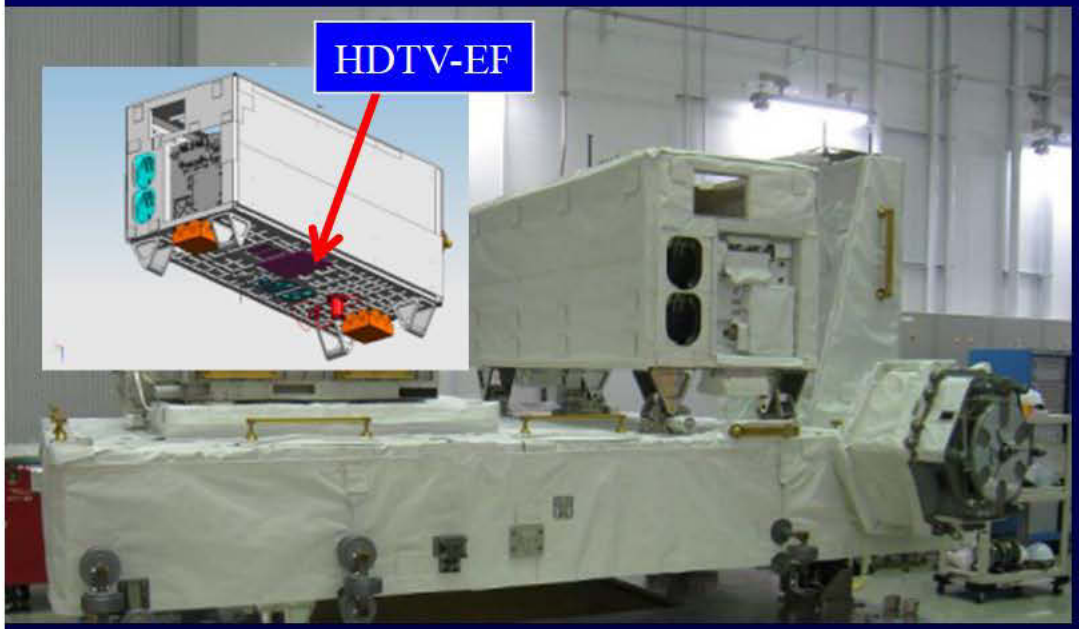
ESA assessment of user interest in use of ISS for Experiments Relevant to Climate Change studies

Interesting Thematic Area's identified in ESA's Call for Ideas (2009)

- GNSS Reflectometry (GNSSR)
- Fluorescence and vegetation measurements
- Vegetation height lidars
- Hyperspectral Imagers
- Atmospheric science
- Other interesting ideas;
  - Thermal IR characterization of small fires
  - Observations of artificial lighting
  - Gravity potential measurements using ACES and ground based atomic clocks

Dedicated Announcement of Opportunity for Experiments released in 2011, evaluation ongoing

Future Plan of JAXA
MCE : Multi-mission Consolidated Equipment



Launch in Jul. 2012

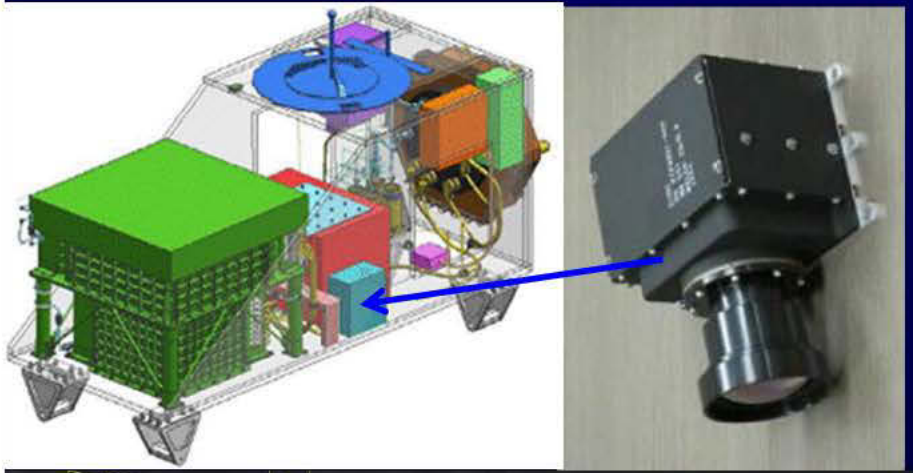
- **High Definition TV Camera System**
- ISS-IMAP: ISS Ionosphere, Mesosphere, upper Atmosphere, and Plasma sphere mapper
- JEM-GLIMS : Global Lightning and Sprite Measurement
- SIMPLE: On-Orbit Demonstration of Space Inflatable Structure
- REXJ: Robot Experiment on JEM

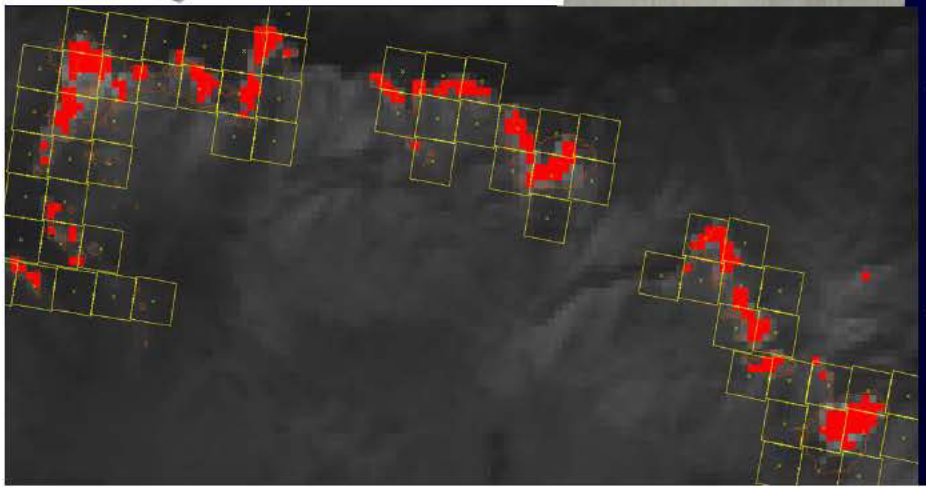
- **Two sets of the High Definition TV camera are installed at the bottom of the Multi-mission Consolidated Equipment system.**
- **The purpose of this mission is to demonstrate the commercial products usage in space and the utilization of the earth image for outreach or education.**

CALET: Calorimetric Electron Telescope

Launch in 2014

To search origin of cosmic ray and dark matter by observing electron and gamma-ray in high energy cosmic ray





Compact InfraRed Camera (CIRC)

- 640x480 Uncooled infrared detector
  The largest format ever used in Earth observations from space
- Small < 18cm x 10cm x 20cm
- light < 3kg
- low power <20W
- Spatial resolution : < 130 m @400 km
- Dynamic range : 180 K - 400 K
- NEdT 0.2 K@300 K
- Other interesting ideas;

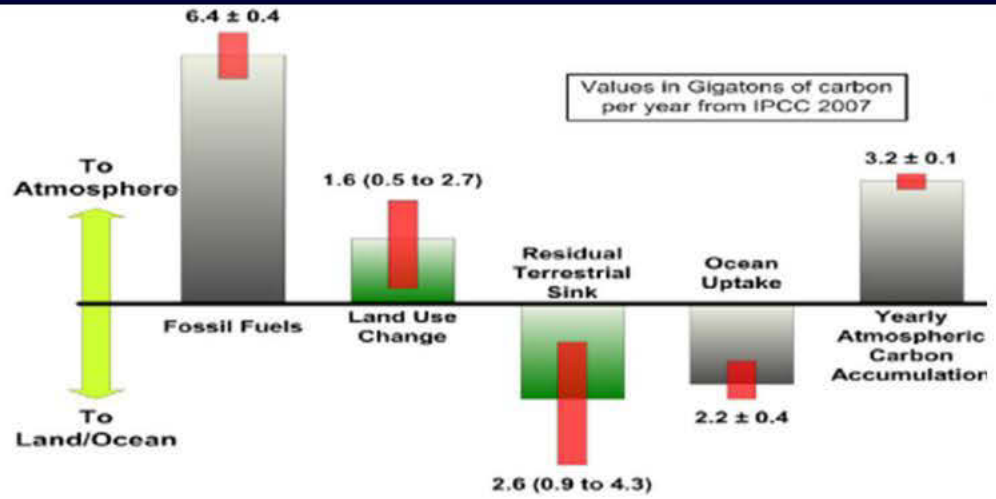
– **Simulation results show that 200m resolution enables us to determine precise location of fire.**

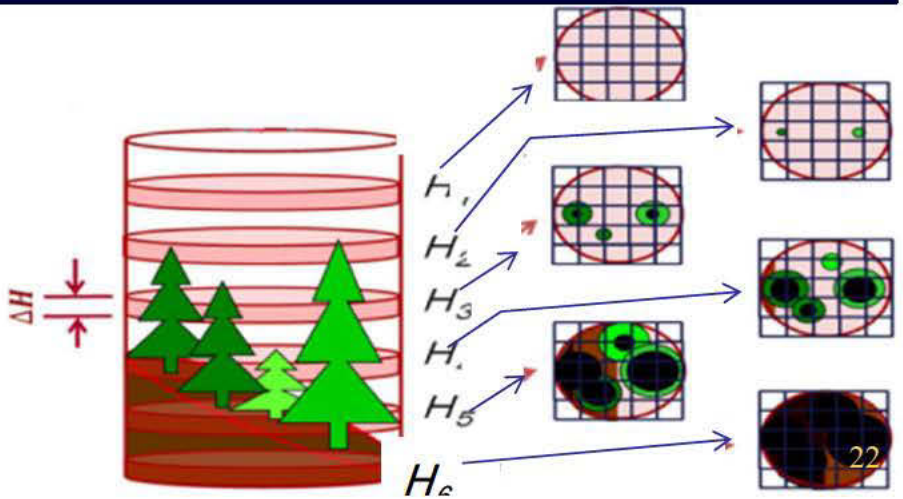
– **CIRC will demonstrate the wildfire detection from ISS**

i-LOVE

iss-jem Lidar for Observation of Vegetation Environment

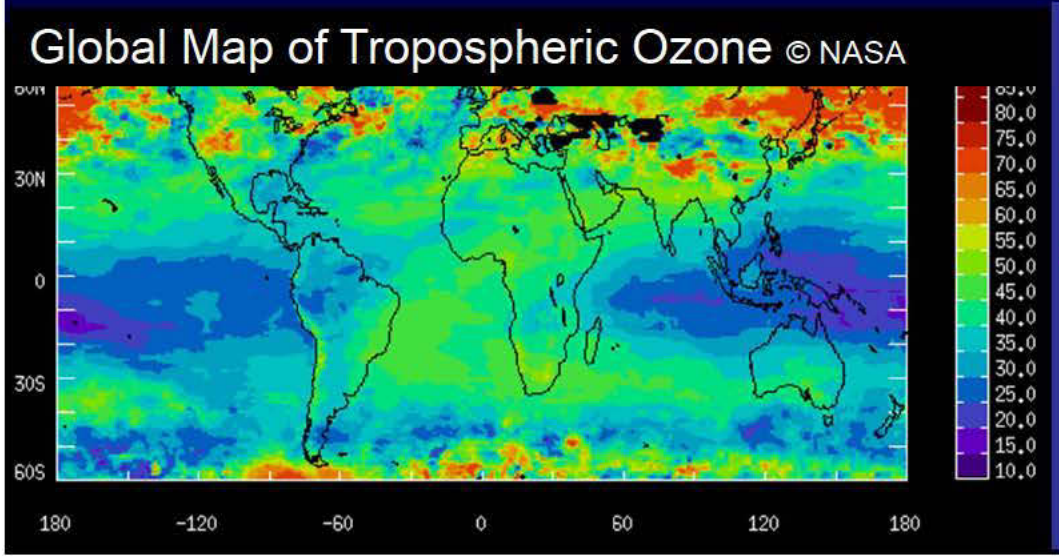
- There is strong evidence that over the last 50 years the terrestrial biosphere (especially, forest) has acted as a net carbon sink. However, the status, dynamics and evolution of the terrestrial biosphere are the least understood and most uncertain elements in the carbon cycle.
- The feature of iLOVE mission is to use an array detector for grasping the slope of the land surface. iLOVE can measure the canopy height more accurately(about 1.0m accuracy) to grasp the forest biomass which is important to figure out the carbon stocks and carbon cycle.
- EF can provide active cooling which is very useful for power consuming lidar system.

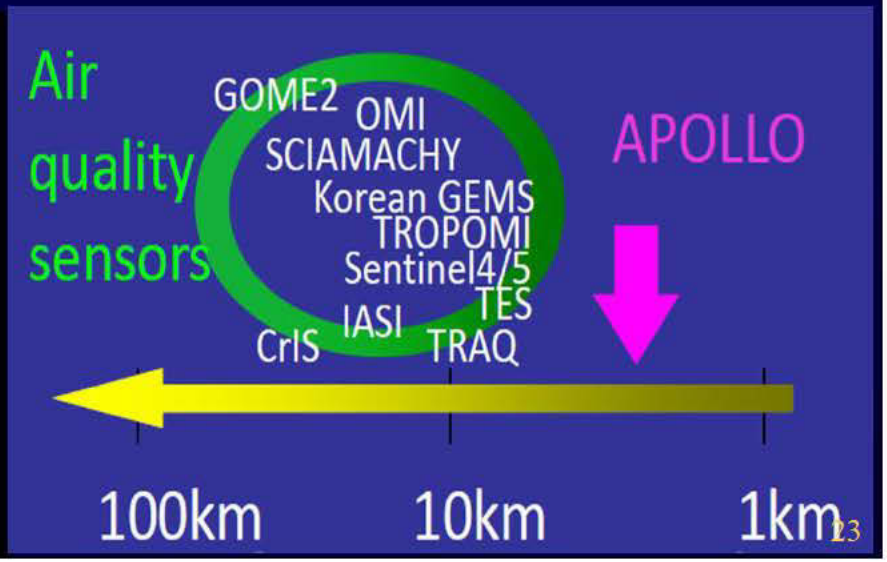




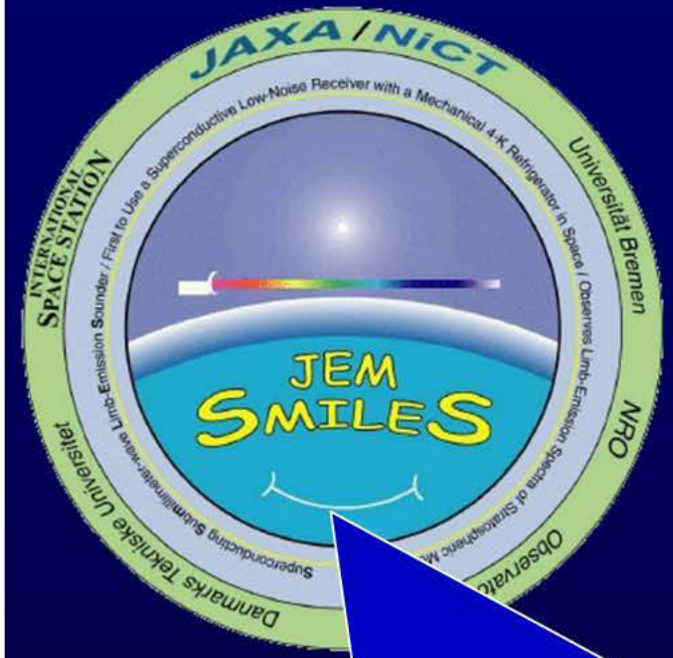
APOLLO: Air POLLution Observing mission

- Ozone in troposphere impacts human health and damages to crops.
- The feature of APOLLO mission is to observe "Ozone and Ozone Precursor in troposphere" by simultaneous observation of a number of sensors (UV/VIS, IR, MW).
- High vertical resolution (～3km) will be fulfilled by "Synergy Retrieval" with the observation at the same spot in the same time.
- High horizontal resolution(～3km) will be fulfilled with the observation from the low orbit of ISS.





Last Word from SMILES



- ISS is an apartment, not an isolated house.
- PL is required to be calm and clean.
- Neighbors are sometimes noisy (EMC, …), and dirty (contamination, …).
- Strict membership test is required. (safety requirement)
- But ISS is a good place for earth observation.

Come on-a my house and enjoy watching our planet earth together!