RAIDS Update

The Remote Atmospheric and Ionospheric Detection System aboard the ISS December 14, 2009

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Figure 1: The gold-blanketed RAIDS experiment can be seen viewing out the open end of the HICO RAIDS Experiment Payload attached to the Japanese Experiment Module Exposed Facility behind Astronaut Mike Foreman during a November 21 spacewalk. (Photo credit: NASA)

RAIDS Begins Science Operations

The Remote Atmospheric and Ionospheric Detection System (RAIDS) successfully completed its month-long commissioning process on October 22 and started its first month of science operations from its vantage point on the International Space Station (ISS). The experiment collected high-quality atmospheric spectra using the EUV spectrograph; MUV, NUV, and NIR spectrometers; and the 630-, 766-, and 777.4-nm photometers. Most of the data were gathered in "Mode 2" as complete spectral scans at a discrete set of altitudes, though the EUV sensor acquired complete spectroscopic limb-scans serendipitously in this mode.

Our collection efficiency for high-quality data was not as high as we had hoped due to the impact of manned spaceflight operations upon ISS attitude. The dockings and departures of supply spacecraft (roughly every two weeks) introduce both transient perturbations and longer-term changes in station pitch, which directly affects RAIDS limb scan pointing control. The HREP star tracker continues to return high-quality information that allows us to determine pointing knowledge for a large fraction of the orbit, excepting times when the Sun or a robotic arm interferes with its field of view. We have been actively adapting our experiment operation plan to improve the data collection efficiency by monitoring space station pitch and adjusting our scan profile on a daily basis, if needed. We have noted a recent improvement in the pitch stability of the ISS over the past few weeks (perhaps due to the lack of any recent additions to the station structure). This stability has encouraged us to extend initial science operations in Mode 2 through the end of December to collect spectra at a full range of local solar times as the orbit precesses and fill any gaps in coverage that were created by station activities.

Science Data Preview

Approximately once per month the RAIDS field-of-regard precesses past the Sun and the experiment is placed in a sun-safe configuration with sensors pointed down to the Earth's disk and powered off for about 3 days. The first sun-safe operation occurred during October 19–22. The science team used this shutdown period as an opportunity to conduct the RAIDS Science Preview after the first few days of science observations were performed. The purposes of this virtual meeting were to evaluate the first science data collected by the sensors and to recommend any changes required for science operations.

The data from all eight sensors were evaluated, and seven of the sensors were found to be meeting our expectations with respect to data quality. The measurements from the scanning spectrometers are particularly good. Unfortunately, the FUV spectrograph was found to be significantly underperforming: after initially encouraging low-gain operational tests, the high-gain sensitivity was found to be quite poor—dramatically degraded since preflight instrument-level calibration. The FUV sensor is currently undergoing troubleshooting to evaluate what appears to be a serious electronic noise issue.

Reviewing Recent Data

The Science Preview served its purpose in helping to plan the first month of science observations. Since then, we have significantly improved our understanding of pointing data that are returned by the HREP star tracker and begun to evaluate geolocation and viewing geometry for the sensor data. This update will focus on a survey of this recent sensor data.

Space Station Attitude

So far the biggest operational challenge has been limited understanding the ISS attitude (especially pitch). The problem is two-fold: non-existent advance knowledge of planned changes to implement effective science data collection, and a slow-developing understanding of the attitude reports from the ISS and the HREP star tracker to interpret the observations.

The first problem reflects the difficulty in obtaining ISS information that includes a flight plan with attitudes specified to the precision required to define RAIDS limb scan activities. Instead, we monitor the ISS attitude daily and react to changes at the next available command window. In addition to a regular oscillation in pitch of roughly ±0.5 degrees over each orbit, every several days or associated with docking maneuvers, the space station pitch suddenly shifts 1-2 degrees. During the most extreme of these events, the ISS spent nearly 10 days with a pitch nearly +15 degrees as the STS-129 mission docked and conducted a variety of activities. This change left RAIDS field of regard entirely on the Earth's disk and requiring many of the sensors to power down.

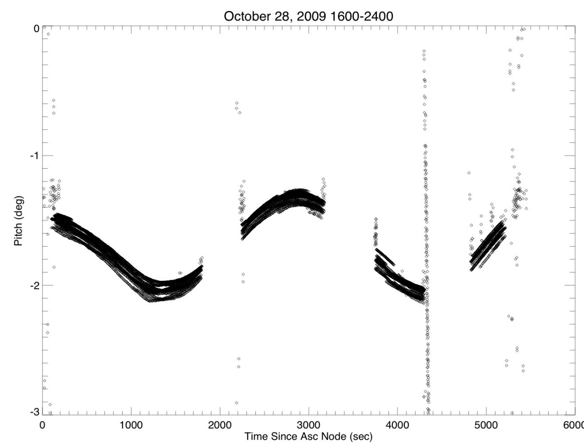

Figure 2: Typical ISS pitch variation for several orbits on October 28 from star tracker attitude.

The other limitation has been the HREP Terma star tracker that was included to provide high-precision (~arcsec) attitude to RAIDS. Unraveling the intricacies of the quaternion analysis proved more challenging than we expected, because the unit reports quaternions in a non-conventional reference frame. In recent weeks we have obtained reliable, accurate pointing information using the HREP Star Tracker. Additionally, the ISS itself broadcasts several sets of quaternions into the health and status data stream recorded at NRL. These can be useful for interpolating between times when the HREP star tracker cannot return valid data. We are currently still working to understand the details of the numerous space station quaternions encoded in telemetry.

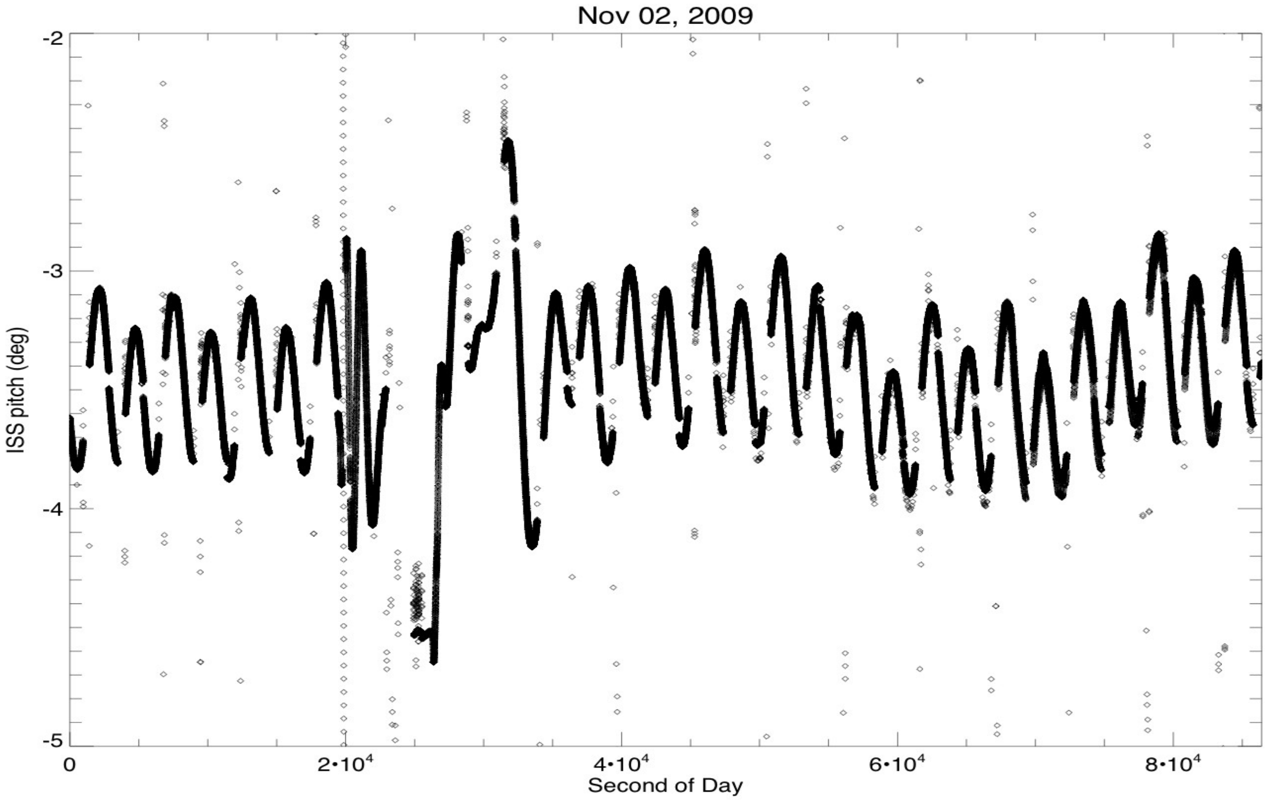

Figure 3: ISS pitch variation over a number of orbits on November 2. The large excursion in the middle isassociated with a docking event. Note that 1 degree corresponds to about 30 km in the RAIDS field-of-view.

Data Availability

We continue to archive the live telemetry stream in real-time on our ground station computer, and these data satisfy our needs for quick-look analysis. Due to TDRSS communication outages these data are typically 60-70% complete. The full data stream is archived at NASA Marshall Spaceflight Center as Near Real Time (NRT) data, and these files must be manually retrieved each weekday. There is usually a delay in obtaining data that accumulates over the weekend due to the large size of the transfer. Automated ftp processes transfer near real time file from NRL to Aerospace as they become available.

The NRL database system has not been fully implemented yet, but soon both HREP health and status and RAIDS science data streams will be automatically ingested and archived. The system at NRL is being mirrored at Aerospace. Until the database system becomes operational, the team has been analyzing and exchanging data using IDL save-sets.

NIR Spectrometer

The RAIDS team has been able to retrieve its first temperature profile from the NIR spectrometer data. This is the most important sensor for the primary science objective of measuring thermospheric temperature. The NIR spectrometer has been running near-continuously since October 8. The grating drive stepper motor for this instruments operates and a sgnigicantly higher temperature (70 C) than the other spectrometers, but remains within the manufacturer's allowed range and shows no problems. The data are high-quality and rae suitable for temperature retrievals.

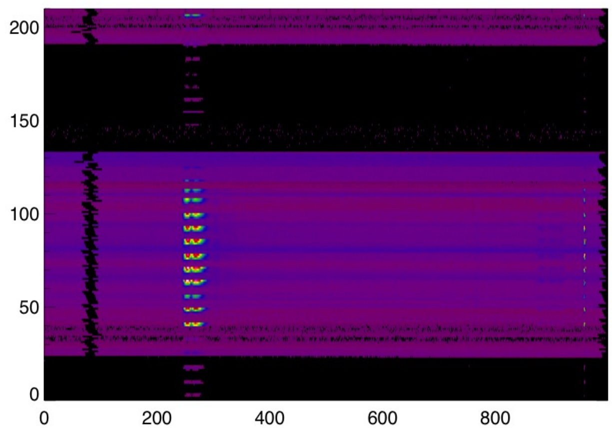

Figure 6: NIR sequence of limb scan spectra for an orbit from Dec 10 shows dayglow and nightglow spectral profiles. Wavelength bin runs horizontally, while spectra are stacked sequentiallly int time vertically.

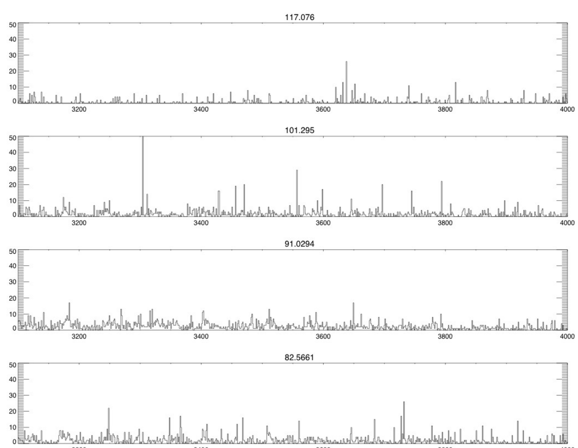

Figure 4: Nightglow NIR spectra from lower altitudes on Dec 10.

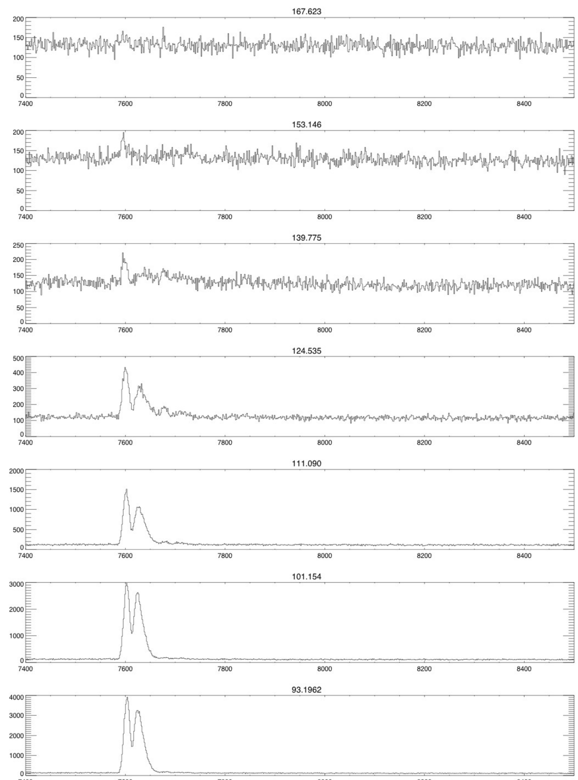

Figure 5: NIR dayglow spectra on Dec 10 at seven discrete altitudes from the midpoint of a dayside pass.

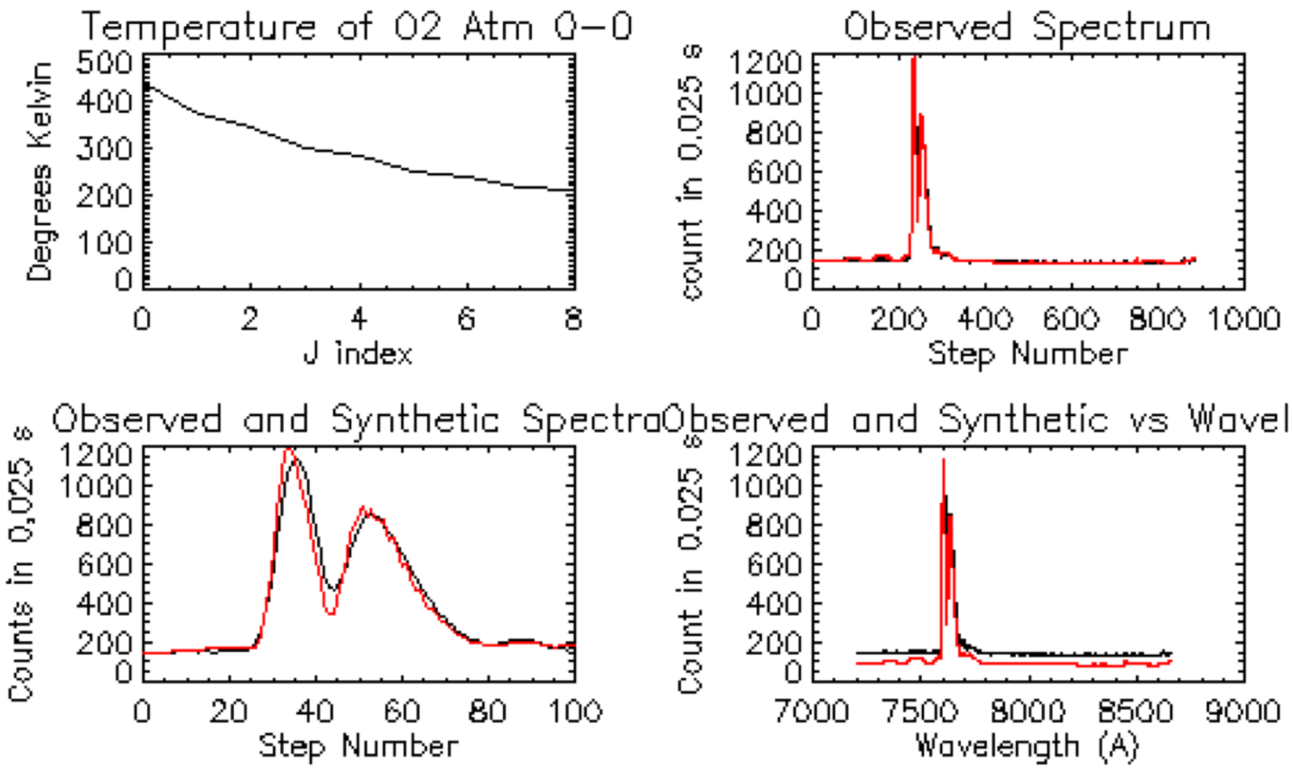

Figure 7: Example of dayside O2 ATM band temperature retrieval (Christensen et al., Fall AGU SA23A-1455).

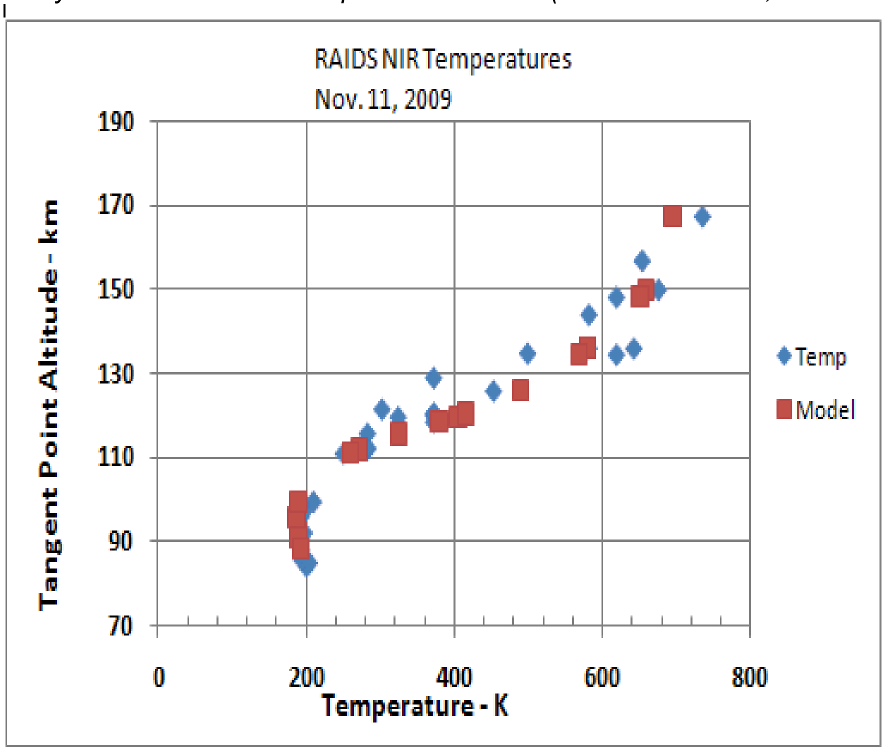

Figure 8: Comparison thermospheric temperature retrieved from O2 and MSIS.

MUV Spectrometer

The MUV spectrometer has collected dayglow and nightglow spectra in Mode 2 for several weeks. At the lower altitudes on the dayside, some Rayleigh-scattered continuum is evident.

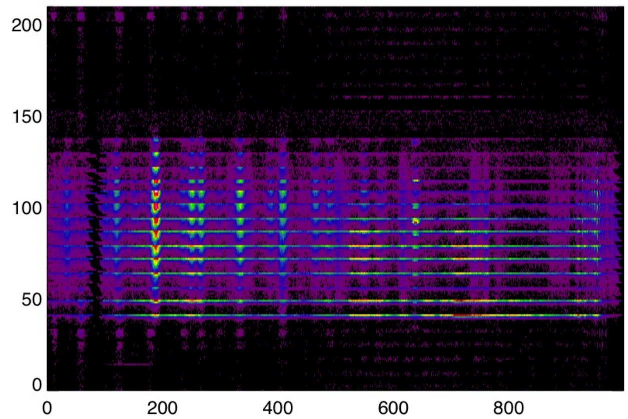

Figure 9: MUV sequence of limb scan spectra for an orbit from Dec 10 shows dayglow and nightglow spectral profiles. Wavelength bin runs horizontally,

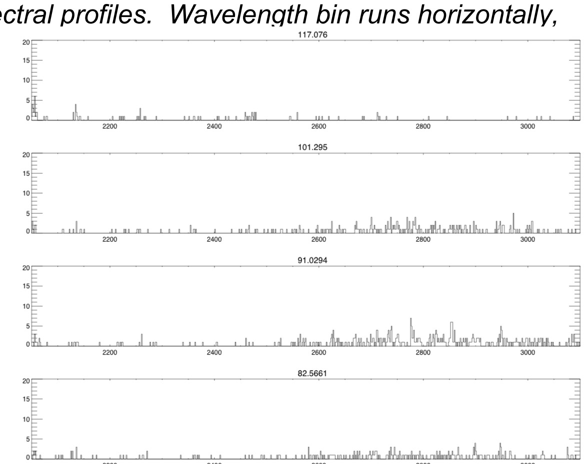

Figure 10: Nightglow MUV spectra from lower altitudes on Dec 10.

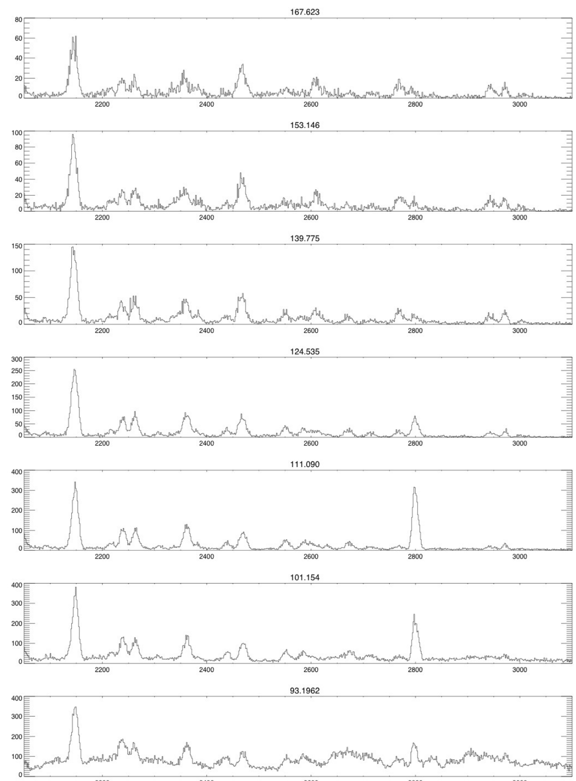

Figure 11: MUV dayglow spectra on Dec 10 at seven discrete altitudes from the midpoint of a dayside pass.

NUV Spectrometer

The NUV spectrometer has been working well. However, this instrument is particularly sensitive to the comings and goings of spacecraft and has a tendency to shut itself down when dockings and undockings occur. The instrument team simply commands the sensor back on at the next command window.

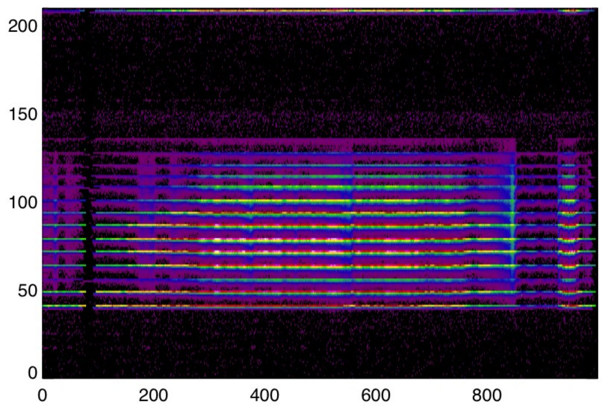

Figure 12: NUV sequence of limb scan spectra for an orbit from Dec 10 shows dayglow and nightglow spectral profiles. Wavelength bin runs horizontally, while spectra are stacked sequentiallly int time vertically.

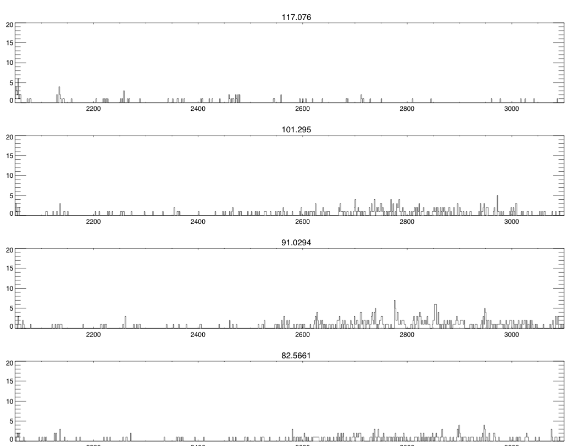

Figure 14: Nightglow NUV spectra from lower altitudes on Dec 10.

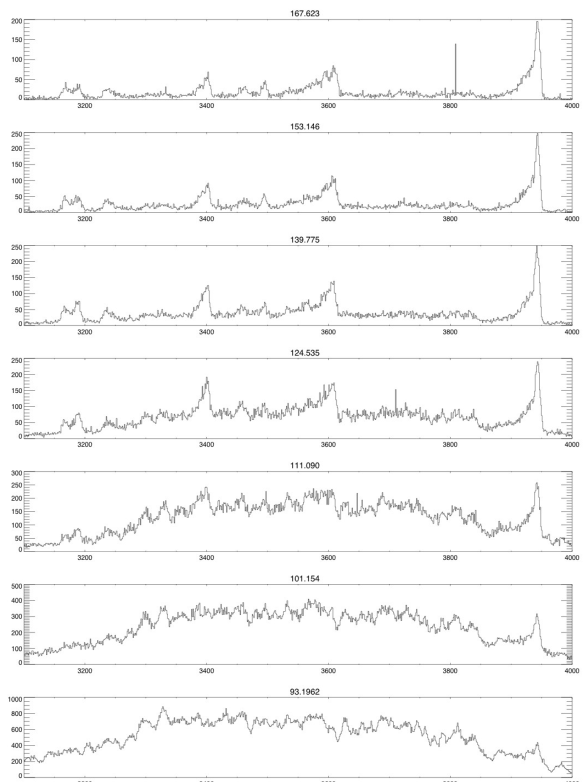

Figure 13: NUV dayglow spectra on Dec 10 at seven discrete altitudes from the midpoint of a dayside pass.

EUV Spectrograph

The EUV spectrograph has measured the OII 61.7 and 83.4 nm emission features on the dayside, as well as the He I 58.4 nm emission line. Although the primary focus early on has been the short wavelength range that obtains these emissions, several days were also completed with the spectrograph at the long wavelength position, obtaining altitude profiles of several prominent features such as OI 98.9, NII 108.5 and 91.6 nm, as well as the OII 83.4 nm emission that is present in both grating positions. These data are the focus of two posters at the fall AGU Meeting.

Concerns about contamination reducing the EUV sensitivity continued to be monitored. After more than two months in orbit, there do not appear to be any dramatic losses in sensitivity. A better quantification of any sensitivity loss over time will be determined as multiple measurements at the same local time are assembled and compared.

Preliminary results show the 83.4 nm intensity is lower than previous measurements, but in line with model expectations for the extended solar minimum conditions. In addition, the ratio of the 83.4 nm to 61.7 nm emission feature is on par with the few previous published measurements. The RAIDS data are the first to show the variation of these relative intensities with altitude.

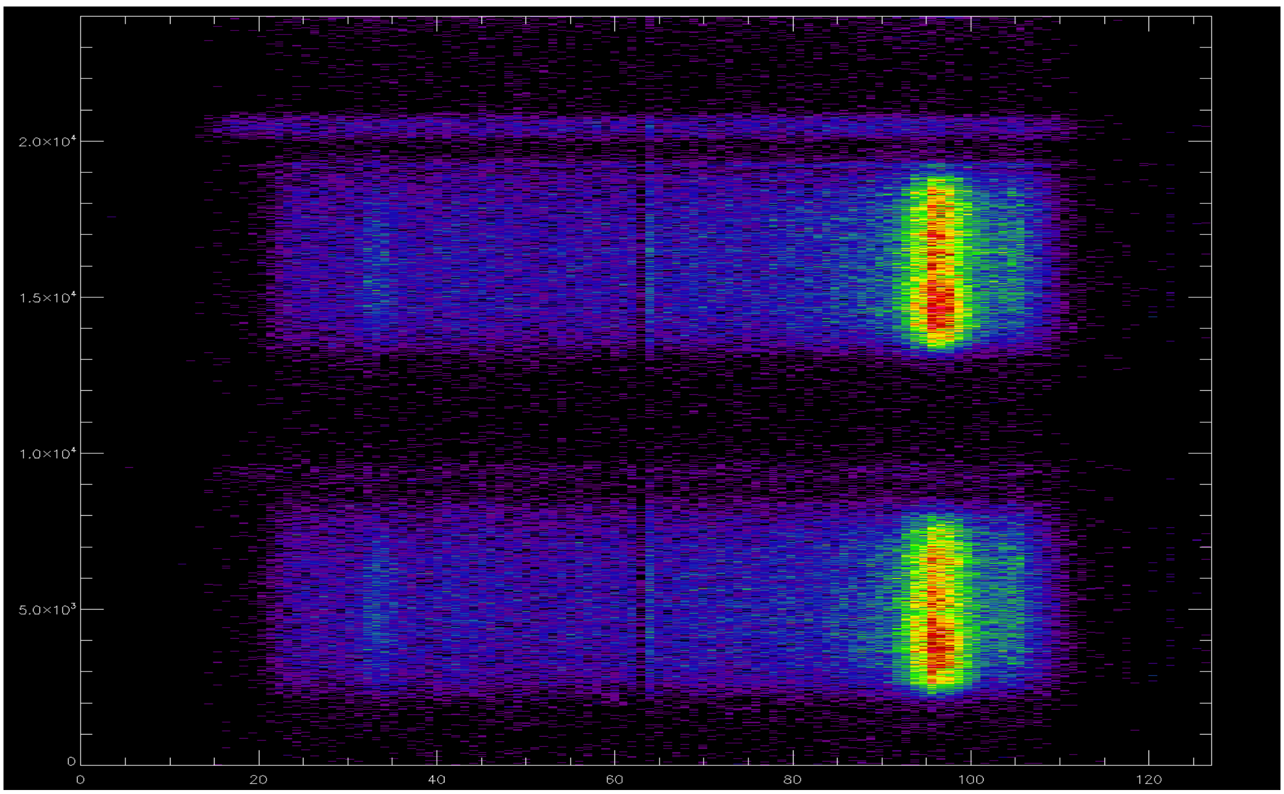

Figure 15: Two orbits of EUV-short spectra, with HeI 58.4 nm to the left and OII 83.4 nm on the right.

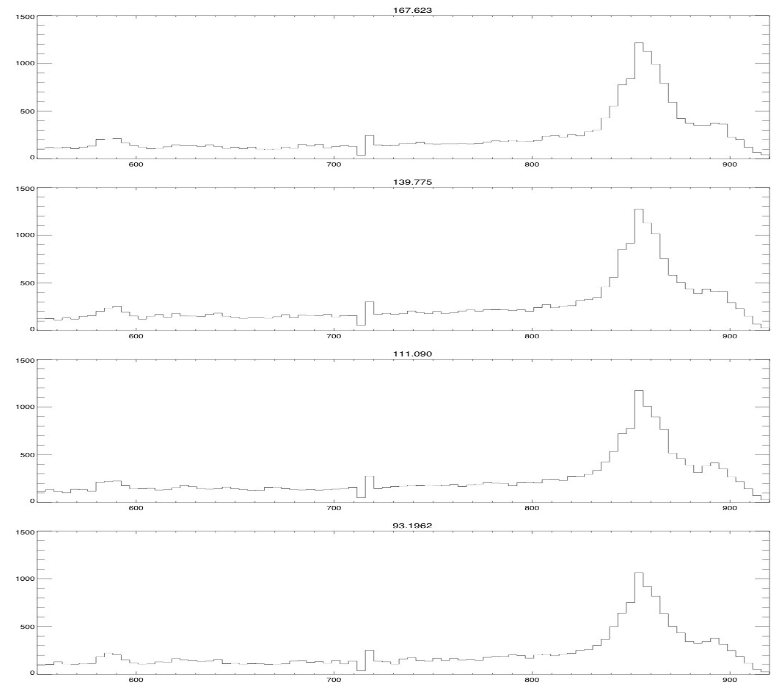

Figure 16: EUV-short spectra at four altitudes on December 10.

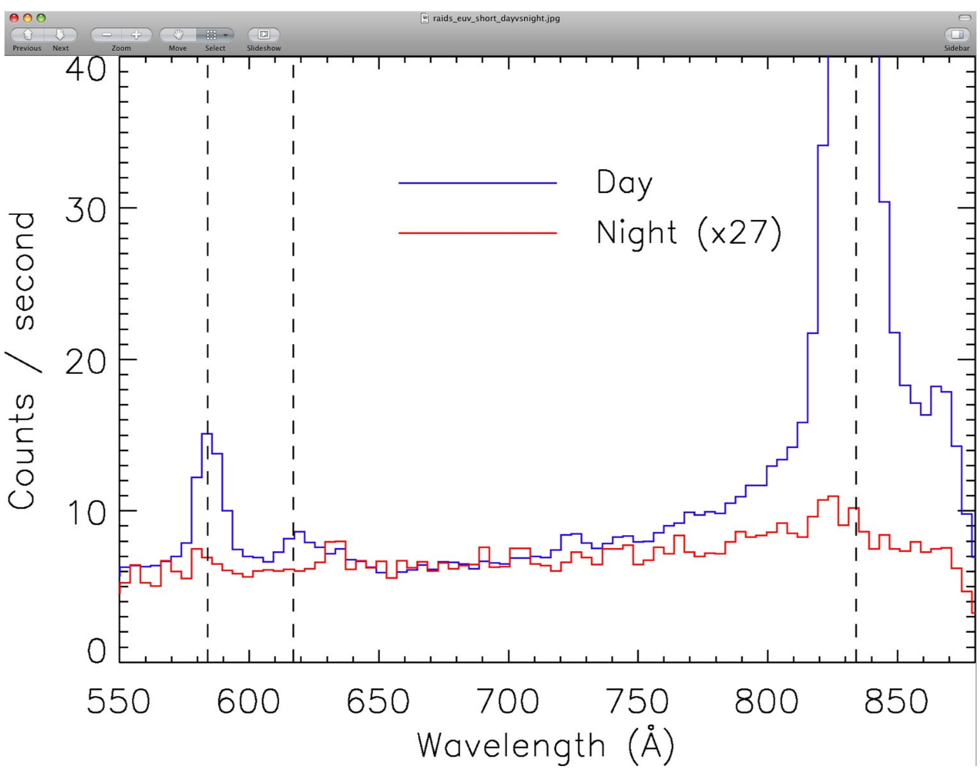

Figure 17: Comparison and dayside and nightside EUV spectra.

6300, 7650, and 7774 Photometers

The photometer data have received the least attention among the RAIDS datasets. Because the photometers are sensitive to the ambient scattered light from space station structures, they register a variable background level as solar illumination of the ISS changes across the dayside. The 0.25-m 6300 and 7774 instruments are most susceptible to the scattered light and glints, and the 7650 somewhat less so. Using a combination of photometers and the NIR spectrograph, subtraction of the scattered light contamination in the photometers may be possible, but probably not easy. On the nightside, the photometers function as expected.

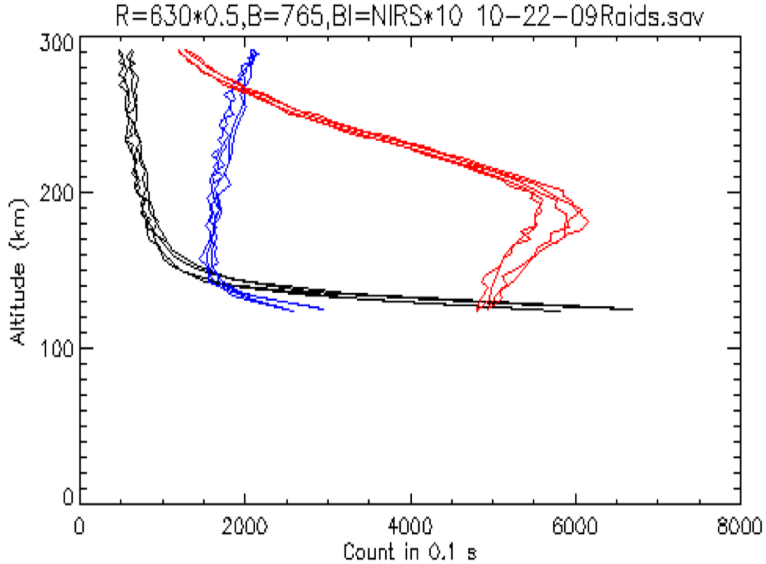

Figure 18: Nightside profiles from all three RAIDS photometers on October 22.

RAIDS Website and Wiki

We have a public website (https://raids.nrl.navy.mil/) with some information of a general nature about RAIDS. On this website is a "Team Member" area with restricted access for the RAIDS Instrument Team and RAIDS Science Team, including a Wiki. The Wiki continues to be a work-in-progress (by nature), but it currently included a substantial amount of RAIDS documentation, presentations, and mission operations information. As you delve into RAIDS analysis, this resource should prove useful to you. Contact Scott Budzien for access.

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