Lightning Observations from the International Space Station (ISS) for Science Research and Operational Applications


1NASA Marshall Space Flight Center (email: rich.blakeslee@nasa.gov, phone: 256-961-7962), 2University of Alabama in Huntsville, 3Universities Space Research Association (USRA)

Introduction and Overview

Mission

- Fly a space-qualified, flight-spare LIS on ISS to take advantage of unique capabilities provided by the ISS (e.g., high inclination, real time data).
- Integrate LIS as hosted payload on DoD Space Test Program Houston 5 (STP-H5) mission and launch on Space X rocket in January 2016 for a minimum 2 year mission.

Measurement

- NASA, the University of Alabama in Huntsville (UAH) and their partners developed and demonstrated effectiveness and value of space-based lightning observations as a remote sensing tool.
- LIS measures total lightning (amount, rate, radiant energy) during both day and night, with storm scale resolution, millisecond timing, and high, uniform detection efficiency.
- LIS globally detects TOTAL lightning with no land-ocean bias.
- LIS acts like a radar in space: it reveals the heart of the cloud.
- LIS is strongly coupled to severe weather hazards (e.g., tornadoes, hail, wild fires) and can improve forecast models.
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Need and Benefit

- Lightning is quantitatively coupled to both thunderstorm and related geophysical processes, and therefore provides important science inputs across a wide range of disciplines (e.g., weather, climate, atmospheric chemistry, lightning physics).
- ISS LIS (or a LIS as Hugh Christian prefers) will extend TRMM time series observations, expand latitudinal coverage, provide real time data to operational users, and enable cross-sensor calibration.
- LIS acts like a radar in space: it reveals the heart of the cloud.
- LIS is strongly coupled to severe weather hazards (e.g., tornadoes, hail, wild fires) and can improve forecast models.

Science and Applications from LIS Lightning

- Lightning rate is strongly correlated to a quantitative way to thunderstorm processes and responds to updraft velocity and cloud particles (concentration, phase, type, and flux).  
  - LIS acts like a radar in space: it reveals the heart of the cloud.
  - Lightning can improve convective precipitation estimates.
  - Lightning is strongly coupled to severe weather hazards (winds, floods, tornadoes, hail, wild fires) and can improve forecast models.

- Climate: Lightning is an excellent variable for climate monitoring because it is sensitive to small changes in temperature and atmospheric forcing. LIS will:
  - Extend 16 year time series of TRMM LIS, expand to higher latitudes.
  - Monitor the occurrence and changes in extreme storms.
  - Provide much needed cross-sensor calibrations between platforms.

- Chemistry: ISS LIS will help improve estimates of lightning produced NOx for climate and air quality studies.
  - Lightning also impacts ozone, an important greenhouse gas.
  - Lightning most sensitive to ozone in upper troposphere, exactly where lightning is the most important source of NOx.

Other: Complementary ISS LIS observations will help unravel the mechanisms leading to terrestrial gamma-ray flashes (TGFS) and Transient Luminous Events (TLEs).

- LIS is one of thirteen instruments on the STP-H5 payload manifest.
- LIS will be installed on ISS in an Earth viewing (nadir) position.
- Payload built to allow robotic installation on ISS.

Unique Science Contributions from ISS Platform

- Lightning coverage at higher latitude missed by TRMM
  - TRMM LIS missed up to 30% lightning in N. Hemisphere summer
  - Enhance regional and global weather, climate, and chemistry studies
  - Provide CONUS coverage needed for National Climate Assessment.

- Real time lightning using ISS for operational applications
  - Provide real time lightning in data sparse regions, especially oceans (storm warnings, nowcasts, marine aviation and International Space Station (ISS) range lightning system validation, hurricane rapid intensity evaluation).
  - Desired by NASA and strongly endorsed by NOAA partners (partners include: NWS Pacific Region, Joint Typhoon Warning Center, Ocean Prediction Center, Aviation Weather Center, and National Hurricane Center).

- Enable simultaneous / complementary observations with other ISS VI instruments
  - Lightning is strongly endorsed by NOAA and ESA.

- Support cross-sensor calibration and validation activities
  - Inter-calibrate ISS LIS, TRMM LIS, GOES-18 GLM and MTG-IU for improved science and applications (strongly endorsed by ESA and JAXA-GLM).

- Summary

- There exist several core science applications of LIS lightning observations, that range from weather and climate to atmospheric chemistry and lightning physics due to strong quantitative connections that can be made between lightning and other geophysical processes of interest.
- The space-based vantage point, such as provided by ISS LIS, still remains an ideal location to obtain total lightning observations on a global basis.

LIS Launch, Installation and Operation on ISS

- Launch on a Space X rocket with Dragon cargo vehicle in January 2016.
- Robotically installed on an external truss (ELC-1) in position shown.
- Operated for 2 years, but will seek mission extension from NASA.

LIS Performance Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of View (DOV)</td>
<td>89° x 89°</td>
</tr>
<tr>
<td>Pixel DOV (radius)</td>
<td>4 km</td>
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<tr>
<td>Minimum Brightness</td>
<td>773 mV</td>
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<tr>
<td>1σ Noise</td>
<td>172 mV</td>
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<tr>
<td>Dc Leakage Current</td>
<td>1 mA</td>
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<tr>
<td>Dynamic Range</td>
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<tr>
<td>Noise to Signal Ratio</td>
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<tr>
<td>Calibration Accuracy</td>
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<tr>
<td>Time Resolution</td>
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</tr>
</tbody>
</table>

LIS Integration as Hosted Payload on STP-H5

- Real-time lightning observations (lif-time) illustrated strong lightning-storm coupling

LIS Detection

LIS activates lightning during the daytime when most lightning events.