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The GOES-16 Energetic Heavy Ion Instrument Proton and Helium Fluxes for Space Weather Applications

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ABSTRACT

The Energetic Heavy Ion Sensor (EHIS) was built by the University of New Hampshire, subcontracted to Assurance Technology Corporation, as part of the Space Environmental In-Situ Suite (SEISS) on the new GOES-16 satellite, in geostationary Earth orbit. The EHIS measures energetic ions in space over the range 10-200 MeV for protons, and energy ranges for heavy ions corresponding to the same stopping range. Though an operational satellite instrument, EHIS will supply high quality data for scientific studies. For the GOES Level 1-B and Level 2 data products, protons and helium are distinguished in the EHIS using discriminator trigger logic. Measurements are provided in five energy bands. The instrumental cadence of these rates is 3 seconds. However, the primary Level 1-B proton and helium data products are 1-minute and 5-minute averages. The data latency is 1 minute, so data products can be used for real-time predictions, as well as general science studies. Protons and helium, comprising approximately ~99% of all energetic ions in space are of great importance for Space Weather predictions. We discuss the preliminary EHIS proton and helium data results and their application to Space Weather.

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EHIS Theory of Operation for proton and helium measurements

The EHIS instrument has two modes for determining particle counts. For heavy ions, where the count rate is low and particle energy depositions are proportionally close, on-board calculations of the element charges are tabulated on 1-minute time scales through the use of some involved software calculations (see Poster SH31B-2728).

For protons and helium, where the particle energy deposits are well separated, the counts are determined solely through a series of discriminator triggers, set to differentiate both particle species and energy range.

Absolute fluxes are calculated by dividing the counts by the geometrical factor (cm^2-ster), energy band width (MeV/nuc) and collection time (sec). Corrections for instrument dead time are applied to generate the final absolute fluxes.

EHIS in the Space Weather Suite on GOES-16

The Space Environmental In-Situ Suite (SEISS) on GOES-16 is a set of three instruments designed to monitor the electron, proton and heavy ion fluxes in geostationary orbit.

The Energetic Heavy Ion Sensor (EHIS) is an addition to previous GOES space weather suites. The new instrument EHIS has as its primary purpose to monitor the absolute flux of heavy ions, helium through nickel, in the near-Earth environment. EHIS has the additional capability to measure energetic protons.

In the energy range 10-200 MeV/nucleon for protons and helium, EHIS can be used to monitor and predict the mid-range energies for Solar particle events. These particles, comprising approximately 99% of all Solar energetic particles and have the same ranging capability. At comparable energies, protons and helium will penetrate farther into materials than any heavier ions, thus pose the greatest risk to the interior of space craft (e.g. rockets, satellites, or the space station). Thus, these particles need to be monitored for possible adverse afffects (e.g. SEUs, or cell damage) to even the most protected systems in space.

Absolute Fluxes and Spectra

The EHIS 8-hour averaged absolute fluxes for protons (upper) and helium (middle) since 10 March 2017 are shown to the right. These fluxes are reported in 5 energy bands, with nominal energies listed.

Note that, in absence any of Solar energetic particles, the fluxes remain relatively constant, as expected from GCR on short time scales.

In the lower right figure, the proton and helium spectra for a single 8-hour period are shown – both using the same scaling.

To the far lower-right, the helium spectra is reproduced, and compared to the required operating range for the EHIS instrument, as defined by the GOES-R PORD.

Note the scale change to accommodate the higher flux requirements.

When GCR levels are being recorded, longer time averaging is needed to reach statistics at the 10% level, but EHIS still accurately measure the fluxes. The helium flux shows GCRs and ACRs (at lower energies).

At 09:10 UTC on Wednesday 6 September 2017 there was an X2.2 flare, followed by a X9.3 flare three hours later at 12:02 UTC. Both were from the same active region, which was at Solar E40, so were poorly connected to Earth. A large transient event, associated with these flares and following CMEs, was observed at Earth starting on 10 September 2017 at 12:15 UTC. The main portion of this SPE continued for 5 days through 09:25UTC on 15 September 2017, though the lowest energy protons remained elevated in intensity through 14:24 on 19 September.

Proton data for this event are shown below. At high flux levels 1-minute data can be used with good statistical validity. The 1-minute fluxes are shown below right and the spectrum at the peak of the the event is shown below left.

The 1-minute data allows for fine structure during the particle event to be monitored. Note that even with the 1-minute average data, the statistical errors are about 2%. Special processing can be used to calculate proton and helium fluxes at a 3-second cadence. Also, at the peak of this event EHIS was recording about 30 heavy ion events per minute.