GOES-16 SEISS EHIS Level 1b (L1b) Data Release
Provisional Data Quality
July 11, 2018
Read-Me for Data Users

The GOES-R Peer Stakeholder - Product Validation Review (PS-PVR) for Space Environment In-Situ Suite (SEISS) Energetic Heavy Ion Sensor (EHIS) L1b Provisional Maturity was held on July 11, 2018. As a result of this review NOAA has confirmed that the EHIS L1b data are at Provisional Validation Maturity as of July 11, 2018. EHIS observes energetic (>10 MeV/n) ions of solar and galactic origin. In this context, ions heavier than helium are referred to as heavy ions.

The L1b data product consists of 5-minute-cadence differential directional fluxes and associated systematic (instrumental) and statistical errors. Fluxes are produced for hydrogen (H) and helium (He); for the carbon-nitrogen-oxygen (CNO), neon-sulfur (Ne-S), and chlorine-nickel (Cl-Ni) mass groups; and for individual elements between beryllium and copper (Be-Cu) (but see below for a restriction on the beryllium and boron fluxes). EHIS has a single 60^{o} (full cone angle) field-of-view directed radially outward from the Earth (toward the zenith). The energy range is nominally 10-200 MeV/nucleon for hydrogen (protons) and helium (alpha particles), divided into five energy channels. (The actual GOES-16 energy ranges for hydrogen and helium SEPs are 11-239 and 11-165 MeV/n, respectively.) The energy range increases with atomic number (Z) since the stopping power in silicon is the same for all species in each energy channel. Outside of solar energetic particle (SEP) events, EHIS observes galactic cosmic ray (GCR) fluxes.

The H and He fluxes are derived directly from coincidence rates (3-second cadence in the raw Level 0 data), as with SGPS, and can be averaged over longer periods to improve the counting statistics. However, the heavy ion fluxes are derived using a maximum likelihood (ML) fit to a histogram of Z values determined on-orbit (1-minute cadence) using the angle-detecting inclined sensor (ADIS) system incorporated into the EHIS telescope (see Literature). While this ML fit is necessary for meeting requirements in the presence of very sparse heavy ion count rates, it limits the utility of the L1b data in post-processing. From the *Ground Processing Algorithm Document for the GOES-R Space Environment In-Situ Suite (SEISS), Rev. F* (p. 76): "EHIS data is accumulated over 3 second and 1 minute intervals. Data products for longer periods of time must be added together from the raw data and processed as shown below. Taking fluxes from five [or] 1-minute periods (particularly upper limits) and simply averaging them to obtain fluxes for a longer period, is not valid and EHIS reporting requirements will not be met." Moreover, when, in the L1b data, the lower one-sigma statistical error is equal to the mean value, only an upper limit exists (mean plus upper one-sigma statistical error). (In the L1b files, the mean fluxes are contained in the variable 'BeCu5MinuteDifferentialFluxes', and the lower and upper statistical errors are contained in the variable 'BeCu5MinuteDifferentialFluxStatErrorsBounds'.) As a result, derivation of heavy ion fluxes for periods longer than 5 minutes (e.g., SEP event fluences, GCR fluxes averaged over a solar rotation period of 27 days) requires reprocessing from Level 0 raw data. This is a limitation that is independent of the maturity of the product.

Provisional validation means:

- Validation activities are ongoing and the general research community is now encouraged to participate.
- Severe algorithm anomalies are identified and under analysis. Solutions to anomalies are in development and testing.
- Incremental product improvements may still be occurring.

- Product performance has been demonstrated through analysis of a small number of independent SEP measurements obtained from GOES-East (GOES-13) and GOES-West (GOES-15) in 2017.
- Product analysis is sufficient to establish product performance relative to expectations (Performance Baseline).
- Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, and tested.
- Testing has been fully documented.
- Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.

Users of the GOES-16 EHIS L1b data bear responsibility for inspecting the data and understanding the known caveats prior to use. Below is the list of caveats that have been identified and are under analysis. Solutions are in development and testing:

1. No EHIS L1b data processed prior to declaration of Provisional Maturity (e.g., those available from CLASS) should be used, due to a critical error by the ground processing algorithm in reading the on-orbit state of the instrument. For Provisional Maturity, this error has been fixed. NCEI will reprocess and release the early mission data using the Provisional Maturity algorithm and look-up tables.

3. Absolute calibrations are still being refined. In particular, a temperature sensitivity that imparts a significant diurnal variation onto the observed rates still needs to be corrected for.

4. EHIS helium fluxes in the lowest two energy channels (HE1 and HE2) are suppressed when >80 MeV proton fluxes increase substantially above GCR levels. For example, fluxes in the HE1 channel are about a factor of 5 too low in the 10-14 September 2017 SEP event. HE1 and HE2 fluxes from energetic SEP events such as this should not be used.

5. L1b data indicated significant beryllium (Be) and boron (B) fluxes during the 10 September 2017 SEP event. This is not physically realistic; lithium, beryllium and boron ions of solar origin are never observed, being destroyed in the solar interior. It is believed that these counts are due to slow helium nuclei being interpreted as heavy ions. Be and B observations are not a requirement of EHIS. In the future, L1b Be and B fluxes will be replaced with fill values. Do not use.

6. Outside of SEP events, EHIS observes GCR fluxes. Under these conditions, the L1b fluxes are generally too high, since the processing uses geometrical factors and energy bandwidths derived for SEP spectra, in the course of which, derivation of the high-energy response is deemphasized.

7. As described above, time-averaging L1b heavy ion fluxes, particularly those that are upper limits, does not result in improved accuracy and therefore should not be performed.

Literature

Pre-launch SEISS overview:

Dichter, B. K., Galica, G. E., McGarity, J. O., Tsui, S., Golightly, M. J., Lopate, C., Connell, J. J. (2015). Specification, design and calibration of the space weather suite of instruments on the NOAA GOES-R program spacecraft. *IEEE Transactions on Nuclear Science*, *62*(6), 2776–2783.

ADIS:

Connell, J. J., Lopate, C., and McKibben, R. B. (2001). The angle detecting inclined sensors (ADIS) system: measuring particle angles of incidence without position sensing detectors. *Nuclear Instruments and Methods in Physics Research A, 457,* 220-229.

Connell, J. J., Lopate, C., McKibben, R. B., Enman, A. (2007). Accelerator test of an angle detecting inclined sensor (ADIS) prototype with beams of ^{48}Ca and fragments. *Nuclear Instruments and Methods in Physics Research A, 570,* 399-413.

Connell, J. J., Lopate, C., McLaughlin, K. R. (2016). Accelerator test of an improved angle detecting inclined sensor (ADIS) prototype with beams of ^{78}Kr and fragments. *Nuclear Instruments and Methods in Physics Research A, 837,* 11-15.

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NCEI website for GOES-R Space Weather data (will provide daily aggregations of EHIS L1b data):

https://www.ngdc.noaa.gov/stp/satellite/goes-r.html