GOES-16 SEISS EHIS Level 1b (L1b) Data Release
Full Data Quality
January 19, 2022
Read-Me for Data Users

The Peer Stakeholder - Product Validation Review (PS-PVR) for the GOES-16 Space Environment In-Situ Suite (SEISS) Energetic Heavy Ion Sensor (EHIS) L1b Provisional Maturity was held on January 19, 2022. As a result of this review, NOAA has confirmed that the EHIS L1b data are at Full Validation Maturity as of January 19, 2022.

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 (sum of five 1-minute cadence histograms) 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.

Full validation maturity, by definition, means:

- Validation, quality assurance, and anomaly resolution activities are ongoing;
- Incremental product improvements may still be occurring;
- Users are engaged and user feedback is assessed;
- Product performance for all products is defined and documented over a wide range of representative conditions via ongoing ground-truth and validation efforts;
- Products are operationally optimized, as necessary, considering mission parameters of cost, schedule, and technical competence as compared to user expectations;
- All known product anomalies are documented and shared with the user community;
- Product is operational.

Users of the GOES-16 EHIS L1b data bear responsibility for inspecting the data and understanding the known caveats prior to use. Current understanding of GOES-16 EHIS performance is limited to a few moderate-sized SEP events from early September 2017. In particular, understanding of heavy ion performance is based solely on the event whose onset was on 10 September 2017 (GLE 72). 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. This error was fixed for Provisional Maturity. NCEI will reprocess and release the early mission data using the a later-maturity algorithm and look-up tables.

3. Absolute calibrations are still being refined. For example, a temperature sensitivity that imparts a significant diurnal variation onto the observed proton (hydrogen) fluxes still needs to be corrected for.

4. EHIS helium fluxes are inaccurately low when >80 MeV proton fluxes increase substantially above GCR levels. For example, fluxes in the HE1 channel are about a factor of 7 too low in the 10-14 September 2017 SEP event compared to GOES-16/SGPS, GOES 13-15/EPS, and ACE/SIS measurements, which are approximately in agreement. At this time, helium fluxes from EHIS should not be used. Despite extensive work, the root cause of this problem has not been determined. NOAA recommends that the SGPS alpha particle (helium) fluxes be used instead of the EHIS helium channels. SGPS produces helium fluxes over a wider energy range and in more energy channels than EHIS.

5. EHIS hydrogen fluxes are inaccurate compared to GOES 13 and 15 proton measurements. During 11-15 September 2017, SEP fluxes in the H1 channel were about a factor of 3-5 too low, and fluxes in the H5 channel were a factor of 2-3 too high. The root cause of this problem has not been determined. NOAA recommends that the SGPS proton fluxes be used instead of the EHIS hydrogen channels. SGPS produces proton fluxes over a wider energy range and in more energy channels than EHIS. (Proton fluxes are not a requirement of EHIS.)

6. 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 counted as heavy ions. Be and B observations are not a requirement of EHIS. L1b Be and B fluxes are replaced with fill values. Do not use.
7. Outside of SEP events, EHIS observes GCR fluxes. Under these conditions, the L1b fluxes are not accurate, since the processing uses geometrical factors and energy bandwidths derived for SEP spectra. Steep SEP spectra emphasize the lower-energy ends of the energy response functions while flatter GCR spectra more strongly emphasize the higher-energy ends of the energy response functions.
8. 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.

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NCEI website for GOES-R Space Weather data (provides daily aggregations of EHIS L1b data): https://www.ngdc.noaa.gov/stp/satellite/goes-r.html