MagEIS Level 2&3 Data Caveats: Data Release 03 ("rel03")

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Major updates between rel02 and rel03:

A. Background corrections on the electron channels (item #8 below).
B. Revised HIGHe energy channels and efficiencies (item #7 below).
C. New variables and deleted variables (item #9 below).
D. Proton noise masking (item #6 below).
E. RED/YELLOW/GREEN data quality flags (item #10 below).
F. Revised counting statistics error variables (item #11 below).
G. Thermal oscillation in HIGHe data (item #12 below).
H. Detector failure on HIGHe-A (item #13 below).

Level 2 (L2) Data

The public level 2 (L2) MagEIS data files combine data from three of the four MagEIS units on a given spacecraft: LOW, M75, and HIGH. These three units all point 75 degrees with respect to the spacecraft spin-plane, biased in the anti-sunward direction. The fourth unit, M35, points 35 degrees with respect to the spacecraft spin-plane and data from this unit are not included in the combined level 2 data files. There are no angular resolved electron data in the public L2 files – only spin-averaged fluxes ("FESA"). The proton data contains both a spin-averaged ("FPSA") and angular-resolved ("FPDU") flux product. The angular resolved proton data is a function of spin-phase angle (aka "sector angle," 0-360 degrees), not pitch-angle (the level 3 MagEIS data files contain the pitch-angle resolved electron and proton fluxes).

Level 3 (L3) Data

The L2 to L3 conversion converts sector angle (e.g. spin-phase angle) to pitch-angle. The public level 3 (L3) MagEIS data files combine data from three of the four MagEIS units on a given spacecraft: LOW, M75, and HIGH (see above). The angular resolved flux variables are called "FEDU" (electron) and "FPDU" (proton). These variables are binned into a fixed number of pitch-angle bins. The L3 data files also contain unbinned pitch-angle data (FEDU_Unbinned_*/FPDU_Unbinned_*), where the instantaneous sector angle is converted to pitch-angle. Full-spin flux data variables are also available (*_0to360). Omnidirectional data products ("FEDO" (electron) and "FPDO" (proton)) are not included in this data release but will be in a future data release.

Level 2&3 data files from each individual unit, which contain the spin-angle/pitch-angle resolved data, can be made available upon request. Each of the six LOW/MED MagEIS units contains 9 electron detectors ("pixels"), from which the different energy channels are obtained. The HIGH units house both an electron spectrometer and a proton telescope. The HIGH unit electron spectrometers contain 4 electron pixels, from which 7 energy channels are obtained. The primary data products from the HIGH unit proton telescopes produce 20 data channels from a singe detector. Deadtime corrections have been performed on all of the electron and proton flux measurements in this release. These are the known issues and caveats with the L2&L3 data files in this release:

1. Noise in Pixels 0 and 1: Pixel 0 and pixel 1 on the 6 LOW/MED units (LOW-A,B; M35-A,B; M75-A,B) are known to be noisy and do not produce valid data. This is also leads to a ~15 minute period oscillation in the fluxes from these two pixels, due to the thermal control system, which is purely an instrumental artifact. All data from pixel 0 and pixel 1 should be set to fill in the L2&L3 data files – if you encounter what you believe to be noisy data from pixel0 and pixel1, please contact the MagEIS team at the above email address.

2. Major Changes in HIGHe Logic: Extensive cross-calibration work by the MagEIS and REPT teams led to a major reconfiguration of onboard logic in these units. For the MagEIS HIGHe data (~900-4000 keV energy range), these changes occurred between 2013/07/03 and 2013/09/26 (specific dates listed below). Data acquired prior to the reconfiguration (pre-July 2013) should be used only for qualitative purposes. We emphasize that extensive tuning was done during this time interval and that any step-function like changes in flux during this time are likely instrumental (non-physical) effects:

    - 2013/07/03: HIGHe-A, HIGHe-B (threshold changes).
    - 2013/07/18: HIGHe-A, HIGHe-B (threshold changes).
    - 2013/07/25: HIGHe-B only (threshold changes).

- 2013/07/26: HIGHe-A only (threshold changes).
- 2013/08/03: HIGHe-A, HIGH-B (threshold changes).
- 2013/08/14: HIGHe-A only (threshold changes).
- 2013/08/14: HIGHe-A (coincidence window changed from 10 microseconds to 5 microseconds).
- 2013/08/21: HIGHe-A (threshold changes).
- 2013/09/26: HIGHe-A (threshold changes).

A second round of tunings was performed in late May and early June of 2014. There may be data gaps between 2014/05/23 and 2014/06/05.

3. Light Contamination in the HIGHp: When the proton telescopes see the sunlit Earth, it saturates the detectors and the fluxes drop to zero. This typically occurs near perigee and only over part of a spin. The angular-resolved data (FPDU) can be examined to look for this feature. The L3 FPDU data contains a masking array to remove these light-contaminated portions of the orbit but this effect is not accounted for in the L2 FPDU data.

4. Detector Bias: For a few reasons throughout the mission, some MagEIS spectrometers were operated in the "Bias Off" configuration for varying periods of time, which corresponds to a low-bias state. **When the bias is off, the data are not set to fill values, as the data can still be used for qualitative purposes.** The bias state is contained in a variable called BIAS_MODE (see item #9 below).

5. Time-varying Sectoring and Energy Channels: MagEIS energy channels in the L2&L3 files are time-varying, as new look-up-tables (LUTs) can be uploaded to the instruments to optimize the detector performance. In addition, the number of sectors per-spin can be set via ground command and has changed often throughout the mission. The user should be aware of these two features, especially when considering long time-intervals (e.g. months) of data at a time. For example, if array index 7 corresponds to the 180 keV energy channel on a given day, there is no guarantee that this same array index corresponds to 180 keV channel on a later date (the same holds true for the sector-angle/pitch-angle array index). Such LUT and sectoring changes were much more frequent during the early portions of the missions. Changes in sectoring have occurred periodically throughout the mission, while there have not been any changes in the energy channels since March 2013. Changes in the energy channels occurred on the following dates:

   - 2012/09/19 (MagEIS-A and MagEIS-B electrons).
   - 2012/09/29 (MagEIS-A and MagEIS-B protons).
   - 2012/10/04 (MagEIS-A and MagEIS-B electrons).
   - 2012/10/17 (MagEIS-B electrons).
   - 2012/10/24 (MagEIS-B electrons).
   - 2013/02/24 (MagEIS-A and MagEIS-B electrons).
   - 2013/03/31 (MagEIS-A and MagEIS-B electrons; MagEIS-A protons).

6. Noise in Low Energy Proton Channels: The HIGHp proton telescope has noise in the lowest energy channels on both spacecraft. This issue was discovered between data releases rel02 and rel03 but appears in all of the data releases, beginning around 2013/03/17. At that time, a low level of noise is observed in proton channels 00, 01 and 02 (roughly 60, 70, and 80 keV) and this noise increases over time. The noise first appeared in channel 00, then moved into channel 01, and subsequently into channel 02 as time progressed from 2013/03/17. By October 2014, it has moved into the first six (00-05) proton channels. It is believed that the noise is due to radiation damage (ion implant) on the surface of the detector. It has spread into the higher channels as the mission has progressed. **Proton data in the lowest channels (<150 keV) should only be used qualitatively after March 2013.** The MagEIS team has determined that the low energy proton data cannot be used even qualitatively after October 2014. Thus, the first 6 proton channels (~60-140 keV) are set to fill after 2014/10/15.

7. New Bow-tie Energy Channel Definitions and Efficiency Factors: As part of the on-going MagEIS/REPT cross-calibration efforts, the MagEIS team has completed a physics-based simulation of the HIGH electron spectrometer using GEANT4. This has resulted in a revised set of energy channels centroids, energy

channel widths and efficiency factors for the HIGHe data. Thus, both the flux levels and the energy channel locations have changed for the MagEIS HIGHe data. The changes are not insignificant and greatly improve the agreement between the MagEIS and REPT electron measurements in the energy overlap region (2-4 MeV). These calculations are being documented; please consult the MagEIS team if you have immediate concerns and questions.

8. Background Contamination: Electron measurements from the MagEIS suite have been corrected for background in this data release. Electron data in the previous releases (rel01 and rel02) were NOT corrected for background contamination. Background results from several sources, both external and internal. Penetrating radiation that reaches the focal planes of the instruments will cause an "event" in the electronics system. The penetrating radiation includes galactic cosmic rays, energetic solar particles, inner zone protons, and bremsstrahlung from the interaction of energetic electrons with the spacecraft. Internal background results from electron backscatter from the silicon focal plane and other scattering events within the magnetic spectrometer itself. The level of instrumental background depends strongly upon several factors, including the intensity of the energetic particles in the radiation belts at a given time, and the location of the Van Allen probes within the radiation belts. A good rule-of-thumb is that above about 900 keV, electron data in the inner proton belt is highly suspect and likely entirely contaminated by high energy protons. However, background influences all of the MagEIS data at various locations along the orbit. In particular, bremsstrahlung appears to be a major source of background contamination in the LOW/MED units, at energies ~30-500 keV, in regions of space where >1 MeV electrons are present. Note that the MagEIS HIGH unit proton telescopes are a single parameter measurement and cannot be corrected for background. **It is important to remember the complexity of background removal and that the MagEIS data can never be blindly used.** Please consult *Claudepierre et al, JGR [2015] doi: TBD* before you use background corrected MagEIS data and contact the MagEIS team if you have questions or concerns about these data. The background corrected variables are described below in item #9.

9. New and Deleted Variables: There are a number of new variables in the rel03 data files, mostly pertaining to the new background corrected electron data:

   - ***FESA_CORR***: background corrected electron flux (spin-averaged).
   - ***FEDU_CORR***: background corrected electron flux (sector/pitch-angle resolved).
   - ***FESA_CORR_ERROR:*** Percent error in the background corrected electron data (spin-averaged). See item #11.
   - ***FEDU_CORR_ERROR:*** Percent error in the background corrected electron data (sector/pitch-angle resolved). See item #11.
   - ***FESA_ERROR:*** Percent error in the uncorrected electron data (spin-averaged). See item #11.
   - ***FEDU_ERROR:*** Percent error in the uncorrected electron data (sector/pitch-angle resolved). See item #11.
   - ***FPSA_ERROR:*** Percent error in the proton data (spin-averaged). See item #11.
   - ***FPDU_ERROR:*** Percent error in the proton data (sector/pitch-angle resolved). See item #11.
   - ***FESA_Quality:*** 3-value quality flag (spin-averaged electrons): 0=green, 1=yellow, 2=red. See item #10.
   - ***FPSA_Quality:*** 3-value quality flag (spin-averaged protons): 0=green, 1=yellow, 2=red. See item #10.
   - ***FEDU_Quality:*** 3-value quality flag (sector/pitch-angle resolved electrons): 0=green, 1=yellow, 2=red. See item #10.
   - ***FPDU_Quality:*** 3-value quality flag (sector/pitch-angle resolved protons): 0=green, 1=yellow, 2=red. See item #10.
   - ***BIAS_MODE:*** Flag to indicate whether or not the electron detectors are in the normal-bias or low-bias state (0=low bias; 1=normal bias). In the low-bias state, the electron fluxes should only be used qualitatively, and with caution.
   - ***INSTRUMENT_MODE:*** Flag to indicate mode of the MagEIS instruments (0=maintenance; 1=science; 2=high rate). Only the LOW and MED (~20-1000 keV) can go into high rate mode. The HIGH unit (~850-4000 keV), can only be in maintenance or science mode. The most common reason why background corrections cannot be done (e.g. FESA_CORR, FEDU_CORR are fill) is when

the LOW and/or MED units are in high-rate mode.

- ***COINCIDENCE_MODE:*** Flag to indicate whether or not the electron coincidence is enabled 0=disabled; 1=enabled). This variable is only defined for the HIGH unit (850-4000 keV), as this is the only MagEIS unit with coincidence. In the disabled coincidence state, the fluxes should only be used qualitatively, and with caution.

In addition to the new variables, there are a number of variables that appeared in the rel02 files, but have been removed in the rel03 data files, to reduce the file sizes. This was done because a number of spin-averaged variables were redundant with their FEDU_*/FPDU_* counterparts. For example, FESA_Energy was an identical copy of FEDU_Energy. Thus, FESA_Energy has been removed from the file and FEDU_Energy can be used instead. All of these variables were removed for similar considerations: {*FESA_Energy, FESA_Energy_Widths, FESA_LABL_1, FESA_Energy_DELTA_plus, FESA_Energy_DELTA_minus, FPSA_Energy, FPSA_Energy_Widths, FPSA_LABL_1, FPSA_Energy_DELTA_minus, FPSA_Energy_DELTA_plus*}.

In addition, the FEDU variable has been removed from the combined L2 data file. This variable is always fill, as code has never been developed to combine sectored data from three different MagEIS units. Thus, it has been removed to avoid confusion. Sectored electron data (FEDU) can of course be found in the combined L3 data file, which is organized by pitch-angle (not spin-phase angle). Once data are organized by pitch-angle, it is much more straightforward to combine data from 3 different units. Finally, the SQRT_COUNTS variables have been removed in favor of percent error variables (see item #11).

10. Data Quality Flags: The L2 files contain a RED/YELLOW/GREEN data quality flags that the user should consult when undertaking any study using MagEIS data. The L3 files do not contain a data quality flag in this release. However, the L2 data quality flags can be used as a guide. These variables are called FESA_Quality* for the spin-averaged electron data; FPSA_Quality* for the spin-averaged proton data; and FPDU_Quality for the sectored-resolved proton data. There are three possible values:

    0) GREEN: There are no known issues with the data.
    1) *YELLOW: Data should be used with caution.* Examples include: background corrections could not be performed** (electrons only); low counts, large backgrounds (electrons only), or both; detector coincidence was disabled (HIGHe only); deadtime correction was not performed.
    2) *RED: Data is highly suspect and should be used with extreme care*. Examples include: very low counts, very large backgrounds (electrons only), or both; detector bias was disabled (i.e. in the low-bias state); large deadtimes (>40%); noisy channels.

    *The spin-averaged RED/YELLOW/GREEN quality flag (e.g. FESA_Quality) takes the most frequently occurring value of the sectored RED/YELLOW/GREEN quality flag (e.g. FEDU_Quality) in a given spin. For example, if there are 4 sectors/spin, and FEDU_Quality = [0,0,1,2] in that spin, the FESA_Quality = 0 for that spin.

    **Sometimes background corrections cannot be performed (e.g. the unit was in high rate mode – see section 5 in *Claudepierre et al., JGR [2015] doi:TBD).*

11. Error Due to Counting Statistics: When the count rates are low there is of course a significant statistical uncertainty in the MagEIS measurements. There is a variable included in the L2&L3 files (FESA_ERROR/FEDU_ERROR for electrons; FPSA_ERROR/FPDU_ERROR for protons) that can be used to quantify this error. Note that this variable is a replacement for the SQRT_COUNTS variable that appeared in rel02 but has been removed from rel03. The only difference between the rel03 FXXX_ERROR variables and the rel02 SQRT_COUNTS variables is the equation used to compute the percent error. The rel02 variable computes the percent error as:

    $$\% \text{ error} = 100 * [1/\text{sqrt}(C)]$$

    where C is the counts accumulated over the integration time. The rel03 variable uses a slightly different formula (see *Claudepierre et al., JGR [2015] doi:TBD)*:

% error = 100 * [sqrt(1+C)/C].

Thus, the one count level in the rel02 variable corresponds to 100% error, while the one count level in the rel03 variable corresponds to 141% error. **These percent error variables are computed from the uncorrected data and, for the electron data, they should not be confused with the percent error variables for the background corrected data (FESA_CORR_ERROR/FEDU_CORR_ERROR), which also include error terms due to background contamination (see *Claudepierre et al., JGR [2015] doi:TBD).***

12. Thermal Oscillation in HIGHe Data: The MagEIS-HIGHe data is sensitive to temperature, with the yoke temperature maintained by an active thermal control system. When the yoke temperature gets too low, the count rates dropout and are not valid. The reason for this is not fully understood. It appears to affect only some HIGHe pixels (likely related to the individual pixel threshold settings). There have been two long time intervals where the temperature periodically dipped below the nominal range, resulting in brief (~5 minute) flux dropouts at the thermal control period (~60 minutes). These data are set to fill during these time intervals but can be made available upon request: HIGHe-B, pixel 03 (~3.2 and 4.0 MeV channels) from 2014/05/29-2014/09/18; HIGHe-A pixel 01 (~1.2 and 1.5 MeV channels) from 2014/08/06-2014/11/07.

13. Detector Failure on HIGHe-A: At ~1125 UTC on 2013/10/02, pixel 00 failed on HIGHe-A. Post-failure analysis revealed a slow buildup of noise that occurred over ~6 months preceding the failure. The root cause has yet to be determined. This failure results in the loss of the ~1 MeV channel from HIGHe-A after this time. This channel is redundant with the highest energy channel on the MED units, thus the impact is minimal.

Abbreviations

LOW: the MagEIS low energy electron (~20-200 keV) spectrometers (e.g. LOW-A and LOW-B)
MED: the MagEIS medium energy electron (~200-1000 keV) spectrometers (e.g. M35-A, M35-B, M75-A and M75-B).
HIGH: the MagEIS high units (e.g. HIGH-A and HIGH-B). Each unit contains both an electron spectrometer and a proton telescope.
HIGHe: the MagEIS high energy electron (~1000-4000 keV) spectrometers.
HIGHp: the MagEIS proton telescope (~60-1000 keV).
FESA/FPSA: spin-averaged, differential electron/proton flux.
FEDU/FPDU: unidirectional, differential electron/proton flux. These data are resolved by spacecraft spin-angle (e.g. "sector angle", ranging from 0-360 degrees) in the L2 data files (protons only – see above), and resolved by pitch-angle in the L3 data files (electrons and protons).
FEDO/FPDO: omnidirectional, differential electron/proton flux.