README: POES Radiation Belt Indices

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The POES belt indices are calculated from measurements by the SEM-2 MEPED instrument. They were originally developed by the late Dr. Dave Evans of the NOAA Space Weather Prediction Center (SWPC). NCEI has been producing belt indices since 2013 from SEM-2 MEPED data from the NOAA-15, -16, -18, and -19, and Metop-A, B and C satellites. They are recorded in yearly ASCII files for each satellite. NCEI has made this product available to the public.

As of January 1, 2023, belt indices were only being produced from three SEM-2 MEPEDs: NOAA-15 (N15), NOAA-18 (N18), and NOAA-19 (N19). The NOAA-16 and Metop-A (M02) belt indices ceased when those satellites stopped operating, respectively, in June 2014 and November 2021. In 2023, upon user request, NCEI extended the calculation of the belt indices to include Metop-B (M01) and -C (M03).

The count rates are read from the 'raw' NetCDF files and the L values are read from the 'full' files. For each day, the total count rates over each radiation belt region (inner, slot, outer, and total) are calculated for each MEPED energy/angle channel. These total count rates are normalized to the corresponding medians of the daily totals determined from approximately the first year of mission data. These are the daily belt indices.

There are 37 L bins from 1.0 – 10.0 in 0.25L increments. The inner zone, the slot region and the outer zone correspond to the regions with an L-value less than 2.0, L-value from 2.0 to 2.5, and L-value greater than 2.5, respectively. The total belt index is determined from all 37 bins.

An example of the use of the belt indices is in a human-in-the-loop decision tool for preliminary assessment of the relevance of the space environment to a satellite anomaly (O'Brien et al., 2020). In this decision tool:

- Index 5 (>300 keV electrons, 90 degree telescope) is used in a flow chart for internal charging.
- Index 17 (>6.9 keV protons, 90 degree telescope) is used in a flow chart for event total dose.
- Index 19 (>35 MeV protons, omnidirectional) is used in a flow chart for single event effects.

Data coverage:

NOAA-15: January 1, 2013 - present
NOAA-16: January 1, 2013 - June 4, 2014
NOAA-18: January 1, 2013 - present
NOAA-19: January 1, 2013 - present
Metop-A: January 1, 2013 - November 15, 2021
Metop-B: January 25, 2023 - present
Metop-C: January 25, 2023 - present

Format:

The bi_sat_YYYY.txt files contain the following data, delimited by one or more spaces. (A belt index value of -1.0000 signifies that the particle count rate for that data channel was insignificant, i.e. less than 10 per second.)

Day of month
Month number (1-12)
Year (4 digits)
Sensor number
Total Belt Index
Inner Belt Index
Slot Belt Index
Outer Belt Index

****
SEM-2 Sensor Numbers
****
0 >30 keV Electrons (0 deg detector)
1 >30 keV Electrons (90 deg detector)
2 >100 keV Electrons (0 deg detector)
3 >100 keV Electrons (90 deg detector)
4 >300 keV Electrons (0 deg detector)
5 >300 keV Electrons (90 deg detector)
6 30-80 keV Protons (0 deg detector)
7 30-80 keV Protons (90 deg detector)
8 80-250 keV Protons (0 deg detector)
9 80-250 keV Protons (90 deg detector)
10 250-250 keV Protons (0 deg detector)
11 250-250 keV Protons (90 deg detector)
12 800-2500 keV Protons (0 deg detector)
13 800-2500 keV Protons (90 deg detector)
14 2500-6900 keV Protons (0 deg detector)
15 2500-6900 keV Protons (90 deg detector)
16 >6.9 MeV Protons (0 deg detector)
17 >6.9 MeV Protons (90 deg detector)
18 16-70 MeV Protons (Omnidirectional)
19 35-70 MeV Protons (Omnidirectional)
20 70-235 MeV Protons (Omnidirectional)
21 140-275 MeV Protons (Omnidirectional)

Example: file header and first day's worth of belt indices for 1 January 2024:

```
:Data_list: bi_M03_2024.txt
```

```
:Created: 22-Mar-2024 04:05:04
#Please send comments and suggestions to Rob Redmon
(sem.poes@noaa.gov)
#
#
#Note:Sensor numbers are described in the README

#Source: NOAA POES/MetOp (metop03)
#Units: none

#Format: White-space-delimited text:

#Day of month
#Month number (1-12)
#Year (4 digits)
#Sensor number (0..21, 90-deg and Omnidirectional sensors only)
#Total Belt Index
#Inner Belt Index
#Slot Belt Index
#Outer Belt Index

 1  1 2024  0     1.4447     0.5620     1.1667     4.6357
 1  1 2024  1     1.5254     1.4313     1.5287     1.5450
 1  1 2024  2     0.8184     0.6836     1.0247     5.5289
 1  1 2024  3     1.1168     1.5247     1.9328     0.8076
 1  1 2024  4     0.8689     0.8434     0.8204     2.2707
 1  1 2024  5     0.7259     1.1054     2.5176     0.4569
 1  1 2024  6     1.8902     0.9926     1.2902     1.9040
 1  1 2024  7     1.5421     0.9186     1.8209     1.5472
 1  1 2024  8     1.6737     0.9678     0.7916     1.9234
 1  1 2024  9     0.7953     0.9870     1.4385     0.7756
 1  1 2024 10     1.0140     0.9041     0.7603     3.5863
 1  1 2024 11     0.6548     0.9288     0.4944     0.3684
 1  1 2024 12     1.1858     0.8978     0.8444    21.0240
 1  1 2024 13     0.9197     0.9094     0.5643     1.0793
 1  1 2024 14     1.0779     0.9004     0.8182     9.7448
 1  1 2024 15     0.9476     0.8815     0.5202     2.4273
 1  1 2024 16     0.9489     0.9667     0.8491     0.6782
 1  1 2024 17     0.9195     0.9527     0.7664     0.8940
 1  1 2024 18     0.4377     0.4394     0.3870     0.2755
 1  1 2024 19     0.4524     0.4538     0.4098     0.2555
 1  1 2024 20     0.2270     0.2280     0.1947     0.1280
 1  1 2024 21     0.2264     0.2287     0.1920     0.1384
```

Caveats

1. The belt indices are not cross-calibrated amongst the multiple source satellites.
2. The belt indices calculated from the MEPED omnidirectional channels P6-P9 are low by a factor of 2 or 4 from the true normalized medians because the software divides the daily total count rates by 'first year' medians of daily total counts. Conceptually, the algorithm should be normalizing counts by counts. While all the channels have 1-s accumulation periods, P6 and P7 have 2-s cadences, and P8 and P9 have 4-s cadences. This means that the count rates for these channels numerically are a factor of 2 or 4, respectively, lower than the counts. After this error was discovered in 2023, NCEI decided to continue to be 'incorrect and consistent' with this normalization, in order not to affect existing uses of the indices.
3. There appears to be some leakage into the belt indices of artificially injected signals during in-flight calibrations (IFCs). The IFC flag used to mask the data is not always long enough. This causes weekly spikes in daily values and affects the normalized medians. For example, such spikes appear in the 800-2500 keV and 2500-6900 keV inner belt and total indices (numbers 12-15, see above). This happens on different days for different satellites. NCEI recommends that users evaluate the time series of belt indices they wish to use and ask NCEI about signatures they are unsure about.
4. The lower-energy proton telescope channels are known to degrade with time (Sandanger et al., 2015, and references therein). Since the indices are calculated by normalizing each day to the first year, the belt indices calculated from these channels are also expected to degrade with time.

References

T. P. O'Brien, A. J. Boyd, T. B. Guild, and J. E. Mazur (2020), A Human-in-the-Loop Decision Tool for Preliminary Assessment of the Relevance of the Space Environment to a Satellite Anomaly—Update with REACH and MEO, Aerospace Report No. TOR-2020-00349.

Sandanger MI, Ødegaard LKG, Nesse Tyssøy H, Stadsnes J, Søraas F, Oksavik K, Aarsnes K. (2015). In-flight calibration of NOAA POES proton detectors—Derivation of the MEPED correction factors. J Geophys Res Space Phys 120: 9578–9593. https://doi.org/10.1002/2015JA021388.