

## Appendix G

The First SEM-2 was launched on the NOAA-15 satellite on May 13, 1998. The TED unit in this SEM-2 was Serial Number 011 and the MEPED unit was Serial Number 010. Archived data from NOAA-15 are available from July 19, 1998 until the present. Both the TED and MEPED instruments on NOAA-15 are operating well, and there have been no technical difficulties.

An error in the archive processing of data from NOAA-15 was detected in late 1999. This error occurred on rare occasions when the sub-satellite geographic latitude location, either in the northern or southern hemisphere, exceeded by a small amount the maximum latitude that would have been determined from the satellite orbital inclination for that day's ephemeris. Under these circumstances, which generally lasted no more than 32 seconds at the very highest latitudes during the NOAA-15 orbit, the archive program miscalculated the pitch angles of the particles detected by the 30° TED, and the 0° and the 90° MEPED instruments. The omnidirectional energy fluxes calculated from the TED data depend upon knowledge of the particle pitch angles and during these short periods of time they will be slightly in error.

The error was corrected for all archive processing beginning on Jan 1, 2000. Prior to the correction being implemented, this error arises whenever the absolute value of the sub-satellite geographic latitude exceeds the value of the supplement of the satellite inclination. For example, if the satellite inclination in the archive record were 98.715°, the pitch angle error would occur whenever the absolute value of the sub-satellite latitude exceeded 81.285°. In these cases the correct pitch angles can be determined to within less than 1° by averaging the correct pitch angles on either side of the incorrect ones.

The second SEM-2 was successfully launched on NOAA-16 on September 21, 2000. This SEM-2 contains TED Serial Number 010 and MEPED Serial Number 011. With one exception, all SEM-2 instruments are operating properly and returning good data.

The sole exception is episodes of anomalous high background rates recorded by the 0° and 30°, TED high-energy proton sensors. This high background appears to be associated with spacecraft charging that accelerates positive ions into the electrostatic analyzers of these two sensors. Because there is a very low residue voltage between the analyzer plates during the background accumulation periods, these low energy ions pass through the analyzer and are counted by the channeltron detector. The periods of anomalous high background from these two sensors occurs when the satellite is in sunlight, not in darkness, strengthening the hypothesis that spacecraft charging is playing a role.

Fortunately, data taken from these two sensor systems during the energy sweep do not exhibit any indication of spurious counts. Both the sensor responses within specific energy bands and the integrated sensor responses, that provide the measure of the directional energy fluxes carried by ions between 1000 and 20,000 eV, are unaffected. The method for correcting sensor responses for penetrating radiation has been modified for NOAA-16 and later satellites so that a background correction is not applied to high-energy auroral ion energy flux values during times of anomalous background.

The third SEM-2 was successfully launched on NOAA-17 on June 24, 2002 and the SEM put into operation on July 12. This SEM-2 contains TED Serial Number 012 and MEPED Serial Number 012.

The NOAA-17 TED experiences the same anomalous high background rates as does the TED on NOAA-16, and for the same reason. The modification for correcting sensor responses that was implemented for the NOAA-16 TED data was used also for processing NOAA-17 data.

Beginning on November 25, 2002 the processing of NOAA SEM data to create the archive output was upgraded to new software. The new software is designed to better handle housekeeping information from these instruments and to provide better data quality control. The structure of the archive data was not affected by this upgrade and the material in this document remains valid.

Further updates added to Appendix G in July, 2006.

Errors in equations 2.3.1 and 2.3.2 of the archive data documentation have been corrected. An error in the unpack2.c routine in Appendix D has also been corrected. The equation numbering in Appendix F has been corrected and made consecutive.

The recipes in Appendix F for converting MEPED omni-directional detector count rates to particle fluxes in physical units were developed assuming that the fields of view of each of those detectors was not shadowed or obscured by the spacecraft or other instruments on the spacecraft and were defined only by the absorbing material in that detector alone. There is evidence that particles entering an omni-directional detector from large angles to the zenith can be shadowed by the dense absorbing material in other omni-directional detectors that are mounted close by. The effect of that additional shielding may account for the P6 omni-directional count rates in the South Atlantic Anomaly typically being some less than the P7 count rates, in spite of being sensitive to protons over a larger energy range.

T. Cayton of the Los Alamos National Laboratory has modeled the response of the SEM-2 omni-directional detectors to energetic electrons. His results show that the P6 omni-directional detector will respond to electrons of energies above

3.0 MeV with an efficiency that for 3.5 MeV electrons is about 10% of the sensitivity to >16 MeV protons. The P7 detector model results show a response to electrons of energies greater than about 6 MeV with a somewhat lower efficiency than the case for the P6 detector. The SEM-2 P8 and P9 detectors show negligible response to relativistic electrons. While significant, the SEM-2 omni-directional detectors have considerably less sensitivity to relativistic energy electrons than the earlier SEM-1 omni-directional detectors because of the very much larger energy loss in the solid-state detector that is required to register an event in the SEM-2 instruments.

The MEPED proton telescope instrument, described in Section 3.1 of the archive data documentation, is also sensitive to energetic electrons above about 800 keV because the magnetic field strength in the broom magnet becomes ineffective at preventing such energetic electrons from reaching the solid-state detector. Recent laboratory measurements indicate that the proton telescope efficiency for counting electrons of 1 MeV is about 30% of the proton counting efficiency. This is equivalent to a geometric factor for electrons >1 MeV of about .003 cm<sup>2</sup> ster.

An MeV energy electron gaining access to the solid-state detectors in the proton telescopes is capable of depositing 30 keV energy in the front detector, passing completely through the front detector and depositing 50 keV energy in the back detector. However, an electron, no matter what its energy, is not capable of depositing 2.5 MeV in the front detector. The signal handling logic shown in Table 3.2.1 of the archive data documentation shows that an MeV electron can produce an event registered in the telescope P6 channel, thus mimicking an event caused by a proton of energy >6.9 MeV. However, no energetic electron can produce an event registered in the telescope P5 channel and has a relatively low probability of registering an event in the telescope P4 channel. A situation where the MEPED proton telescope data displays elevated responses in both the lower energy P1 and P2 channels and the highest energy P6 channel but little or no response in the P5 channel is a very good indication that relativistic electrons are responsible. The alternative interpretation that protons are responsible for that telescope's response would require an physical proton energy spectrum with significant proton fluxes below 800 keV and above 6.9 MeV but no protons with energies between about 2.5 and 6.9 MeV.

This feature in the proton telescope data, together with significant response in the >300 keV electron telescopes can serve as a reliable indication that relativistic electrons may contribute significantly to the responses in the omni-directional P6 and P7 detectors.

As pointed out earlier, the TED ion analyzers can display anomalous background responses when the spacecraft changes several Volts negative. Under conditions of very intense electron fluxes in the auroral zone the spacecraft can become charged to potentials as high as -1000 V for short periods of time. In those instances thermal energy ions local to the spacecraft will be accelerated

into the TED ion analyzers with energies equivalent to the spacecraft potential. The background responses in the TED analyzers remain low during these episodes but the measurement of integrated directional energy fluxes by the TED ion analyzers will be very much increased and will no longer represent a valid measurement of the down-going auroral ion fluxes. It is very rare that the spacecraft charges to the extent that the TED 1000-20000 eV ion analyzers respond to ions that have been accelerated into the instrument and invalid integrated energy flux measurements are confined to the 50-1000 eV ion analyzers.

The archive processing does not identify or flag instances of spacecraft charging from intense auroral electron fluxes that produce erroneous integrated energy flux observations by the two 50-1000 eV TED ion analyzers.

However, those instances can reliably be identified from the data from knowledge of the ion energy band containing the “maximum” energy flux (found in the sixth element of arrays *ted0* and *ted30*) and through a comparison between the measure of the integrated 50-1000 eV ion energy flux (in the second element of arrays *ted0* and *ted30*) the corresponding TED ion sensor response in the “maximum” energy band (contained in the eighth element of arrays *ted0* and *ted30*.) With very rare exceptions, during the auroral charging episodes the energy band containing the “maximum” ion energy flux is in the 50-1000 eV range – energy band number 1 through 8. The “maximum” energy band response should then be multiplied by the product of the *particle energy weight* and *detection efficiency weight* factors found in the Appendix C TED Weighting Factors table for that TED serial number.

The result of this process is the contribution to the integrated ion energy flux value from the TED ion sensor response registered in the “maximum” energy band. If that contribution represents the majority, or all, of the integrated ion energy flux, it indicates that the bulk of the ion flux detected during an energy sweep was concentrated within a narrow energy band, a reliable indication of the spacecraft being charged to a negative potential.

It is recommended that whenever the ion energy flux values appear unusually large, that the above test be applied to the TED ion data to identify whether spacecraft charging has occurred that would invalidate the measurement.

The NOAA-18 satellite was launched in June, 2005 and included at SEM-2. The TED and MEPED serial numbers in the NOAA-18 SEM-2 were both 0013. As was the case in earlier SEM-2 instruments, the TED ion analyzers often exhibited a very high background, thought to be associated with spacecraft charging to a few Volts negative as described above. The NOAA-18 TED also shows indications of spacecraft charging to much larger negative potentials by intense auroral electron fluxes, also described above.

Originally the NOAA-18 TED data was mistakenly processed using sensitivity factors appropriate to the NOAA-17 TED instrument. Those data were reprocessed using what was thought to be the correct sensitivity factors for TED serial number 0013. However, in June 2006, it was further learned that the calibration package used for that reprocessing contained only preliminary information and the definitive calibration information not received until late June 2006. A second reprocessing of data from the NOAA-18 SEM will be required. However, that reprocessing will impact only the data from the TED instrument, not the MEPED. The original NOAA-18 archive data files may be used if only the MEPED data is needed.

A SEM-2 instrument is scheduled to be launched in July, 2006 on board the European METOP-1 satellite. The TED instrument in the METOP SEM-2 package is Serial Number 0014.