To: Janet Green
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Re: General update

I have finished the clean up and verification of NOAA-15, NOAA-16, NOAA-17, NOAA-18 and MetOp-02 SEM-2 data from 2007 and have some updated performance information and figures that may be of interest.

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SEM-2 performance on the operating satellites during 2007.

General Comments:

While it has been pointed out in the past, it is worth re-emphasizing the fact that the proton telescope instruments in SEM-2 are sensitive to electrons of energies greater than about 800 keV. This is because the sweeping magnetic field in the proton telescope apertures is not effective in suppressing very energetic electrons from reaching the detector and very energetic electrons are capable of depositing >30 keV energy in the front solid-state detector and >60 keV in the back detector, thus triggering an event in the 0P6 or 90P6 channels and mimicking an event from a >6.3 MeV proton. That same electron is, however, incapable of depositing enough energy in the front solid-state detector produce an event in either the P4 or P5 (800-2500 keV and 2500 to 6300 keV) proton telescope channels. Thus instances when the proton telescope detectors display significant count rates (roughly greater than 10 counts per second) in either the 0P6 or 90P6 channels but essentially zero responses in the corresponding P4 and P5 energy channels are very likely instances of relativistic electron contamination. The alternative explanation would be an unphysical proton energy spectrum with significant fluxes >6.3 MeV energy but no protons of lower energy. The contractor estimates that the efficiency for detecting >800 keV electrons in the proton telescope detector systems is about 30% of the efficiency for detecting protons of similar energies (assuming minimal radiation damage to the detectors.) Further confirmation that relativistic electrons are playing a role in the proton telescope responses may be obtained from examining the coincident response of the omni-directional P6 detector that can respond to electrons of energies greater than about 3 MeV.

The electron telescope detectors in SEM-2 can show spurious responses in the >30 keV and >100 keV energy channels when the telescopes encounter large fluxes of auroral electrons having energies well below the nominal 30 keV detector threshold. This is due to pulse pile-up that occurs when a number of lower-energy electrons deposit energy in the solid-state detector within a time interval short compared to the charge sensitive amplifier integration time (about 80 ns) for collecting charge from the detector to identify an event. While it is difficult to unambiguously identify when such pulse pile-up occurs,

care should be taken in interpreting data from the SEM-2 solid-state electron telescopes when intense auroral energy electron fluxes are present.

The POES and MetOp spacecraft can, on occasion, charge to a negative potential relative to the local plasma when the spacecraft surface is bombarded by intense fluxes of >10 keV auroral electrons. This usually occurs when the satellite is in darkness when encountering the intense electron fluxes. Whenever the spacecraft charges negative, positive ions from the local thermal plasma are accelerated into the TED ion detectors and give rise to a large spurious response, almost always confined to the low-energy ion detectors in the TED (indicating that the satellite charges to potentials of less than 1 kV.) This spurious response can be identified because, in this circumstance, the low energy TED ion data shows that the sensor counts accumulated during the 50 eV to 1000 eV energy sweep were essentially entirely confined to a single energy channel of the eight (the energy associated with that channel is an indication of the spacecraft potential.) Care should be taken in interpreting low-energy ion data from the TED instrument in situations where the satellite is in darkness and the energy fluxes of auroral electrons exceeds some 25 ergs cm^{-2} sec^{-1}.

Over time radiation damage to the front solid-state detector in the MEPED proton telescopes can significantly change the effective threshold energies for protons. This is because radiation damage to the detector decreases the mobility of free charge produced by the passage of the proton in the detector so that an ever-decreasing fraction of that free charge is collected during the integration time of the charge sensitive amplifier. The change in effective energy thresholds with time is estimated by comparing proton telescope responses from an existing instrument with those from a newly launched instrument when data were taken at nearly the same location (in L-value and longitude) and time (within one-minute.) The results of those comparisons are given below for each satellite.

In contrast to damage to the detectors in the proton telescopes, the solid-state detectors in the MEPED electron telescopes (which are protected from low energy ions by a nickel foil) appear to suffer little or no radiation damage and little or no change in the effective energy threshold for detecting electrons based upon the inter-satellite comparisons.

Finally, it should be pointed out that the satellite orbit numbers that are in the daily archive files are calculated in the course of routine processing and can be in error. Orbit numbers should not be used as a proxy for ordering data, for example in time.

NOAA-15

The electron and proton solid-state detector telescopes on NOAA-15 continue to operate nominally. Detector noise and all electronic threshold levels remain the same since instrument turn-on in July 1998.

The NOAA-15 SEM-2 has been in orbit for nearly 10 years and radiation damage to the solid-state detectors in the MEPED proton telescopes has produced large changes in the effective proton energy thresholds.

Comparisons between instrument responses on NOAA-15 and NOAA-16 shortly after the launch of NOAA-16 in late 2000 indicate that the nominal 30 keV energy thresholds in the NOAA-15 instrument had increased by that time to about 40 keV in the 90-degree telescope and to about 35-40 keV in the 0-degree telescope.

Comparisons between instrument responses on NOAA-15 and NOAA-17 shortly after the launch of NOAA-17 in late 2002 indicate that the nominal 30 keV energy thresholds in the NOAA-15 instrument had increased by that time to between 45 keV and 50 keV in the 90-degree telescope and to about 40 keV in the 0-degree telescope.

Comparisons between instrument responses on NOAA-15 and NOAA-18 shortly after the launch of NOAA-18 in mid 2005 indicate that the nominal 30 keV energy thresholds in the NOAA-15 instrument had increased by that time to about 70 keV in the 90-degree telescope and to about 55 keV in the 0-degree telescope.

Finally comparisons between instrument responses on NOAA-15 and MetOp-02 in early 2007 shortly after the launch of the European MetOp-02 satellite indicate that the nominal 30 keV energy thresholds in the NOAA-15 instrument had increased by that time to about 80 keV in the 90-degree telescope and to about 60 keV in the 0-degree telescope.

Increases in the nominal energy channel thresholds at 80 keV, 240 keV, etc undoubtedly increased by similar factors over the same time intervals.

Care should be taken in working with data from the MEPED proton telescopes on NOAA-15 after about late 2001, especially where converting the sensor count rate data to physical fluxes within a specified energy band.

The four omni-directional proton detectors also continue to operate nominally. The electronic thresholds remain at the same levels as at launch and there is no evidence of noise on the part of the solid-state detectors.

The TED in the SEM-2 on NOAA-15 continues to operate nominally. The electron gains on all eight channeltron detectors in the TED instrument were checked for the in-flight calibration on December 25, 2007 and all are at satisfactory levels.

NOAA-16

The electron and proton solid-state detector telescopes on NOAA-16 continue to operate nominally. Detector noise and all electronic threshold levels have essentially been unchanged since instrument turn-on in late 2000

The NOAA-16 MEPED instrument has been in orbit for 7 years and radiation damage to the solid-state detectors in the MEPED proton telescopes has produced large changes in the effective proton energy thresholds. Comparisons between the NOAA-16 instrument and the instruments on NOAA-17, NOAA-18, and MetOp-02 shortly after the launch of those satellites yielded the following estimates of the changes in the NOAA-16 proton telescope 30 keV energy thresholds.

Comparisons between instrument responses on NOAA-16 and NOAA-17 shortly after the launch of NOAA-17 in late 2002 indicate that the nominal 30 keV energy thresholds in the NOAA-16 instrument had increased by that time to about 45 keV in the 90-degree telescope and to about 40 keV in the 0-degree telescope.

Comparisons between instrument responses on NOAA-16 and NOAA-18 shortly after the launch of NOAA-18 in mid 2005 indicate that the nominal 30 keV energy thresholds in the NOAA-16 instrument had increased by that time to about 50 keV in the 90-degree telescope and also to about 50 keV in the 0-degree telescope.

Finally comparisons between instrument responses on NOAA-16 and MetOp-02 in early 2007 shortly after the launch of the European MetOp-02 satellite indicate that the nominal 30 keV energy thresholds in the NOAA-16 instrument had increased by that time to about 60-65 keV in the 90-degree telescope and to perhaps as much as 80 keV in the 0-degree telescope.

The four omni-directional proton detectors also continue to operate nominally. The electronic thresholds remain at the same levels as at launch and there is no evidence of noise on the part of the solid-state detectors.

Based upon in-flight calibrations taken during 2007 the gains for several of the channeltron particle detectors in the NOAA-16 TED instrument are inadequate for proper operation. Specifically, the channeltrons in the 0-degree, 50-1000 eV electron analyzer and both the 0-degree and 30-degree, 1000-20000 eV ion analyzers have gains far too low to provide creditable data. The gains in both the 0-degree and 30-degree, 1000-20000 eV electron analyzers are marginal. The bias voltages for all the TED channeltrons are very near to the maximum voltage available from the power supply. It is intended to increase all bias voltage levels to the maximum available in the hope of increasing the quality of the TED observations. However, TED data, from NOAA-16 during 2007, especially the data from the 1000-20000 eV ion analyzers, should be treated with caution.

NOAA-17

The electron and proton solid-state detector telescopes on NOAA-17 continue to operate nominally. Detector noise and all electronic threshold levels remain unchanged since instrument turn-on in July 2002.

The NOAA-17 MEPED instrument has been in orbit for 5 1/2 years and radiation damage to the solid-state detectors in the MEPED proton telescopes has likely become significant and produced changes in the effective proton energy thresholds. Comparisons between the NOAA-17 instrument and the instruments on NOAA-18, and MetOp-02 shortly after the launch of those satellites yielded the following estimates of the changes in the NOAA-17 proton telescope 30 keV energy thresholds.

Comparisons between instrument responses on NOAA-17 and NOAA-18 shortly after the launch of NOAA-18 in mid 2005 indicate that the nominal 30 keV energy thresholds in the NOAA-16 instrument had increased by that time to about 50 keV in the 90-degree telescope and to about 40 keV in the 0-degree telescope.

Comparisons between instrument responses on NOAA-17 and MetOp-02 in early 2007 shortly after the launch of the European MetOp-02 satellite indicate that the nominal 30 keV energy thresholds in the NOAA-16 90-degree proton telescope instrument had remained near the 50 keV level that was estimated in 2005 while the nominal 30 keV energy threshold had increased to between 40 and 50 keV in the 0-degree telescope.

The four omni-directional proton detectors in the NOAA-17 SEM continue to operate nominally. The electronic thresholds remain at the same levels as at launch and there is no evidence of noise on the part of the solid-state detectors.

The TED in the SEM-2 on NOAA-17 continues to operate nominally. The electron gains on all eight channeltron detectors in the TED instrument were checked for the in-flight calibration on December 27, 2007 and all are at satisfactory levels.

NOAA-18

The electron and proton solid-state detector telescopes on NOAA-18 continue to operate nominally. Detector noise and all electronic threshold levels remain unchanged since instrument turn-on in June 2005.

No particularly high quality conjunctions between NOAA-18 and MetOp-02 (close encounters in space and time with large proton telescope count rates) were exposed during the year after the SEM-2 on MetOp-02 was turned on in December 2006. Thus comparisons between responses in the NOAA-18 proton telescope and those in the freshly launched MetOp telescope to expose degradation in the NOAA-18 instrument are not especially good. Based upon the marginal quality comparisons that were made, radiation damage to the front solid-state detector in both the 90-degree and 0-degree proton telescopes over the course of 2.5 to 3 years may have increased the threshold energy for detecting protons from the nominal 30 keV to about 40 keV.

The four omni-directional proton detectors in the NOAA-18 SEM continue to operate nominally. The electronic thresholds remain at the same levels as at launch and there is no evidence of noise on the part of the solid-state detectors.

The TED in the NOAA-18 SEM-2 continues to operate normally. Based on the in-flight calibration on December 25, 2007 the gain of the channel multiplier in the 0-degree, 1000-20000 eV analyzer is inadequate and an increase in the bias voltage has been requested. Proton data obtained from the high-energy, 0-degree TED analyzer during 2007 likely underestimates the energy fluxes of protons over this energy range.

MetOp-02

This satellite, operated by EUMETSAT, was launched in October 2006 and carried a SEM-2 package identical to those on the NOAA satellites. The SEM-2 was turned on in early December 2006 and data has been received and processed since then.

The noise in all the MetOp-02 telescope (proton and electron) solid-state detectors is at satisfactory low levels. The electronic thresholds for particle energy discrimination are at their nominal values and have not changed since instrument turn-on. Of course, no inter-satellite comparisons to estimate radiation damage are possible.

The four omni-directional proton detectors in the MetOp-02 SEM are operating nominally. The electronic thresholds are stable at their nominal values and there is no evidence of noise on the part of the solid-state detectors.

The TED in the MetOp SEM-2 package is functioning normally in all respects. Based on analysis of an in-flight calibration done on January 1, 2008 the electron gains of all channeltron particle detectors are adequate although the channeltron servicing the 0-degree, 50-1000 eV analyzer is becoming marginal. Should the gain of that multiplier continue to degrade, an increase in bias voltage would be requested.

Summary of SEM data recovery during 2007

During 2007 the Space Weather Prediction Center was blessed with 5 operating polar satellites carrying a Space Environment Monitor. The following summarizes the data recovery from each of these instruments.

NOAA-15 had the potential of acquiring 10402 passes over the polar region during 2007. Of that potential, 10329 passes showed up in the database (73 passes missing). This is a data recovery of 99.3%, and one cannot expect much better. Of the 10347 polar passes that were obtained, 10276 had sufficient data to estimate the hemispheric power input, and auroral activity level, a recovery rate of 99.5%.

NOAA-16 had the potential of acquiring 10303 polar passes during 2007, and of those 10158 passes were logged into the database. This is a recovery rate of 98.6%. Of the 10158 valid polar passes in the database, 10076 had sufficient data to estimate the hemispheric power input, a success rate of 99.2%.

Of the potential of acquiring 10388 NOAA-17 polar passes during 2007, 10330 were logged into the database, a recovery rate of 99.4%. Of the 10330 valid polar passes in the database, 10279 had sufficient data to estimate the hemispheric power input and auroral activity level, a success rate of 99.5%.

NOAA-18 had the potential of acquiring 10297 passes over the polar region during 2007 and of those 10219 passes were logged into the data base, a recovery of 99.2%. Of the 10219 passes in the data base, 10161 had sufficient data to estimate the hemispheric power input and auroral activity level, a success rate of 99.4%

The SEM on MetOp-02 had the potential of acquiring 10371 passes over the polar region during 2007 and of those 9799 passes were logged into the data base, a recovery of 94.5%. Of the 9799 passes in the data base, 9580 had sufficient data to estimate the hemispheric power input and auroral activity level, a success rate of 97.8%. The marginally lower success rates for MetOp-02 compared to the NOAA data are likely due to the need to develop new procedures to handle data originating from Europe as MetOp is operated by the EUMETSAT.

In summary, about 50,000 estimates of hemispheric power were obtained during 2007.