# Solar and Interplanetary Data from the Advanced Composition Explorer

We describe data plots provided to the NOAA Solar-Geophysical Data Reports by NASA's Advanced Composition Explorer (ACE) mission. From orbit about the L1 Lagrangian point, ~0.01 astronomical units Sunward of the Earth, ACE measures ions and electrons accelerated at the Sun, in interplanetary space, at the edge of the heliosphere, and in the Galaxy. ACE includes six high-resolution spectrometers that measure the elemental, isotopic and ionic charge-state composition of energetic nuclei with energies ranging from ~1 keV/nucleon (solar wind) to ~0.5 GeV/nucleon (cosmic radiation). In addition, three instruments characterize the interplanetary environment by measuring solar wind ions and electrons, the interplanetary magnetic field, and low-energy ions and electrons of solar and interplanetary origin. The ACE mission and spacecraft (launched on August 25th, 1997), each of the nine instruments, and the ACE Science Center (ASC) are described in detail in a special issue of Space Science Reviews (see Stone et al. 1998a and accompanying articles).

This write-up describes the three data plots from ACE that are provided routinely to the Solar Geophysical Data Reports. These plots are intended to be used for identifying time periods when solar and interplanetary events occur, and for characterizing the solar wind parameters and energetic particle intensities associated with a variety of solar and interplanetary phenomena. For more detailed studies, a wide range of additional data products are available to the community through the ASC, NOAA, and the National Space Science Data Center (NSSDC), as described below.

## Interplanetary Magnetic Field and Solar Wind Plasma Plots

The Interplanetary Magnetic Field (IMF) plot shows 1-hour averages of the magnitude of the IMF and its three vector components in the GSE coordinate system. The data plotted are verified Level-2 data from the MAG instrument (see Smith et al. 1998).

The Solar Wind Plasma plot shows the solar wind proton speed, density and temperature. The data plotted are verified Level-2 data from the SWEPAM instrument (McComas et al. 1998). When data from SWEPAM are not available, proton speed data from the SWICS instrument on ACE (Gloeckler et al. 1998) are substituted in red.

The IMF and Solar Wind Plasma plots are intended to be used together – they are especially useful for identifying solar wind variations that include high-speed streams associated with coronal holes and interplanetary transients such as shocks and coronal mass ejections (CMEs). A variety of additional solar wind data products are available through the ACE Science Center (Garrard et al. 1998), NSSDC, and NOAA (see below).

It is well known that the IMF plays a dominant role in triggering and modulating the dynamics of the terrestrial magnetosphere. When the interplanetary magnetic field has a large negative (southward) component, interconnection between the interplanetary and terrestrial magnetic fields is greatly enhanced, with a resulting release of energy. Large transients and/or prolonged periods of southward magnetic fields often result in geomagnetic storms, with associated auroral displays and space weather effects on communications and space hardware.

## Solar and Interplanetary Energetic Particle Plots

The interplanetary intensity of ions and electrons in the MeV energy range and below are highly variable and originate from a number of sources, including solar energetic particle (SEP) events on the Sun, traveling interplanetary shocks, and corotating interaction regions (CIRs). This plot shows ion intensities in three energy ranges and electron intensities in two energy ranges based on data from the EPAM instrument (Gold et al. 1998). Also plotted are higher energy carbon and helium intensities from the SIS instrument (Stone et al. 1998b). The data plotted are all verified Level-2 data.

These energetic particle plots are especially useful for identifying and characterizing SEP events. SEP events are typically categorized into two classes (gradual and impulsive) that reflect the acceleration mechanisms involved. Gradual events result from the acceleration of coronal and interplanetary particles by fast CME-driven shocks, and sometimes extend to energies of hundreds of MeV/nucleon. Because the interplanetary shock can rapidly cross onto field lines in the inner heliosphere that connect to a range of longitudes at 1 AU, gradual events often extend over a wide range of longitudes (e.g., ~120°). Although they derive from a coronal composition, there are frequently large variations in composition, with evidence for several different seed populations of accelerated particles.

Impulsive events, which are associated with impulsive x-ray flares on the Sun, are generally smaller in size and shorter in duration than gradual events. They are typically enriched in $^{3}$He, Fe, and other heavy elements, and are generally observed on field lines that have a nominal connection point within ±20° of the flare site. Not all $^{3}$He-rich events have an impulsive time profile.

During both gradual and impulsive events, large intensity increases can be observed for electrons and ions spanning a wide range in energy. After an initial rise in intensity, in which the higher energy (velocity) particles generally arrive first because of their shorter transit time to AU, the intensity profiles decay exponentially with a time constant frequently greater than 10 hours. Often, there is evidence for multiple injections of particles from the same active region on the Sun.

Other interplanetary particle events can also be identified using these plots. Traveling interplanetary shocks (identifiable using the IMF and Solar Wind plots), often accelerate particles in the sub-MeV energy range, and sometimes to higher energies. Particles accelerated in CIRs usually exhibit broad intensity increases (usually below ~1 MeV/nucleon) lasting several days that re-occur at ~27 day intervals if there is a long-lasting high-speed solar wind stream. The quiet-time intensities of ions with ~10 MeV/nucleon and above include important contributions from anomalous and galactic cosmic rays that vary over the solar cycle.

Energetic particle data from ACE span the energy range from ~40 keV/nucleon to ~200 MeV/nucleon and include a wide range of species. Additional data products available from ACE are described below.

## Data Available to the Scientific Community through the ACE Science Center

There are several types of ACE data available to the community through the ACE Science Center (Garrard et al. 1998), as described in Table 1.

Browse Data, available on the web within 2-3 days, are designed for preliminary monitoring of large-scale particle and field behavior and for identifying interesting time periods. Generated automatically from the telemetry stream using simplified algorithms and available in a variety of time resolutions and coordinate systems, these data are not routinely checked for accuracy and are subject to revision. Although more extensive than the real-time data set discussed below, these data are designed to be used for exploratory purposes, and users are requested to consult with the appropriate instrument investigators about citing them. For serious scientific studies, the ACE science team recommends using the high quality (validated) Level-2 data.

Level-2 data include galactic cosmic ray, anomalous cosmic ray, and solar energetic particle intensities, and solar wind and interplanetary magnetic field parameters as summarized in Table 1. Hourly, daily, and 27-day averages of the data from eight instruments are available. In addition, data with higher time resolution are available from some instruments. In general, there is a period of ~3 months between the generation of data on the spacecraft and delivery of Level-2 data back to the ASC by the instrument teams. Level-2 data are suitable for serious scientific study and may be used in publications. However, to avoid confusion and misunderstanding, it is recommended that users consult with the appropriate ACE team members before publishing work derived from these data.

There are also several miscellaneous contributed data sets available from ACE through the ASC, including solar energetic particle (SEP) velocity and 1/velocity spectrograms, SEP charge vs. time plots, monthly count-rate plots for several species, and daily magnetometer summary plots. All of these data are available from the ASC website: http://www.srl.caltech.edu/ACE/ASC. A subset of ACE Browse and Level-2 data are also available from the CDAWeb site at http://cdaweb.gsfc.nasa.gov, which is provided by the Space Physics Data Facility in close cooperation with the National Space Science Data Center (NSSDC).

## Real-Time Solar Wind Data

Unlike ACE science data that is stored on board and transmitted to NASA’s Deep Space Network once a day, the Real Time Solar Wind (RTSW) data are broadcast continuously from ACE (see Zwickl et al. 1998). The RTSW data consists of measurements of energetic particles, solar wind plasma and magnetic field tracked continuously by NOAA, NASA, USAF and their international partners (CRL in Japan, RAL in England, and ISRO in India). The RTSW data are sent to the NOAA facility in Boulder, Colorado where they are processed using automated routines provided and maintained by the ACE instrument teams. Within 5 minutes of the measurement the data are processed and made available to any user via the web at http://sec.noaa.gov/ace/ACErtsw_home.html. Although not validated, and limited to a few basic solar wind, magnetic field, and energetic particle parameters, real-time data are of interest because they provide current information on solar and interplanetary conditions upstream of the Earth with 30-60 minutes advance notice of potentially geo-effective events. The NOAA/Space Environment Center uses ACE RTSW data to provide short-term alerts and warnings of impending major geomagnetic activity. This same site provides a number of other products based on the ACE observations (e.g., Kp and magnetopause location predictions).

Users of ACE RTSW data provide other real-time predictions including the Dst, AL, AU, and AE geomagnetic indices, magnetopause and magnetosheath locations, polar ionospheric conditions, global ionospheric electrodynamics, and geomagnetic storm and substorm warnings (see a listing and links at http://www.srl.caltech.edu/ACE/ASC/related_sites.html).

## References


Garrard, T.L., J.S. Hammond, A.J. Davis, S.R. Sears, The ACE Science Center, *Space Science Reviews*, **86**, 649, 1998.

Gloeckler, G., P. Bedini, P. Bochsler, L.A. Fisk, J. Geiss, F.M. Ipavich, J. Cani, J. Fischer, R. Kallenbach, J. Miller, O. Tums, R. Winner, Investigation of the Composition of Solar and Interstellar Matter Using Solar Wind and Pickup Ion Measurements with SWICS and SWIMS on the ACE Spacecraft, *Space Science Reviews*, **86**, 495. 1998.

Gold, R.E., S.M. Krimigis, S.E. Hawkins III, D.K. Haggerty, D.A. Lohr, E. Fiore, T.P. Armstrong, G. Holland, L.J. Lanzerotti, Electron, Proton and Alpha Monitor on the Advanced Composition Explorer Spacecraft, *Space Science Reviews,* **86**, 539. 1998.

McComas, D.J., S.J. Blame, P. Barker, W.C. Feldman, J.L. Phillips, P. Riley, J.W. Griffee, Solar Wind Electron Proton Alpha Monitor (SWEPAM) for the Advanced Composition Explorer, Space Science Reviews, **86**, 563, 1998.

Smith, C.W., M.H. Acuna, L.F. Burlaga, J. L'Heureux, N.F. Ness, J. Scheifele, The ACE Magnetic Fields Experiment, *Space Science Reviews,* **86**, 611, 1998.

Stone, E. C., A. M. Frandsen, R. A. Mewaldt, E. R. Christian, D. Margolies, J. F. Ormes, and F. Snow, The Advanced Composition Explorer, *Space Science Reviews*, **86**, 1, 1998a.

Stone, E.C., C.M.S. Cohen, W.R. Cook, A.C. Cummings, B.W. Gauld, B. Kecman, R.A. Leske, R.A. Mewaldt, M.R. Thayer, B.L. Dougherty, R.L. Grumm, B.D. Milliken, R.G. Radocinski, M.E. Wiedenbeck, E.R. Christian, S. Shuman, T.T. von Rosenvinge, The Solar Isotope Spectrometer for the Advanced Composition Explorer, *Space Science Reviews,* **86**, 355, 1998b.

Zwickl, R.D., K. Doggett, S. Sahm, B. Barrett, R. Grubb, T. Detman, V. Raben, C.W. Smith, P. Riley, R. Gold, R.A. Mewaldt, T. Maruyama, The NOAA Real-Time Solar-Wind (RTSW) System Using ACE Data, *Space Science Reviews,* **86**, 633, 1998.

## Table 1: ACE Data Products

| Instrument | Level-2 Data Products | Real Time Solar Wind Products |
|---|---|---|
| SWEPAM - Solar-Wind Electron, Proton, and Alpha-particle Monitor | Solar-wind proton velocity, density, and temperature<br>$^{4}He/H^{+}$ ratio | Solar-wind speed, density and temperature |
| SWICS - Solar Wind Ion CompositionSpectrometer | Bulk thermal ion speeds: $^{3}He^{+2}$, $O^{+6}$, $Mg^{+10}$<br>Element ratios: $He^{+2}/O$, $Ne^{+8}/O$, $Mg^{+10}/O$, $Fe^{+7-12}/O$<br>Charge state ratios: $C^{+5}/C^{+6}$, $O^{+7}/O^{+6}$, $Fe^{+11}/Fe^{+9}$<br>Isotope ratio: $^{3}He^{+2}/^{4}He^{+2}$ | |
| EPAM - Eneregtic Electron and Proton Monitor | Spin-avaraged energetic particle data from 5 telecopes<br>Ions with 0.05 to 5 MeV<br>Electrons with 38 to 312 keV<br>He, CNO, and Fe | Low-energy ion and electron intensities |
| ULEIS - Ultra Low-Energy Ion Spectrometer | Solar/interplanetary particles<br>Seven species in ~10 energy ranges: 0.04 to 4 MeV/nuc<br>$^{3}He/^{4}He$, 0.07 to 7 MeV/nuc | |
| SEPICA - Solar Energetic Particle Ion Composition Experiment | Solar/interplanetary particles<br>Eight species in ~5 energy ranges; ~0.3 to 5 MeV/nuc | |
| SIS - Solar Isotope Spectrometer | Solar particles, anomalous & galactic cosmic rays<br>Nine species with ~6 to >100 MeV/nuc | >10 and >30 MeV proton intensities |
| CRIS - Cosmic Ray Isotope Spectrometer | Galactic cosmic rays<br>24 species in 7 energy ranges; ~60 to >400 MeV/nucleon | |
| MAG - Magnetometer | Interplanetary magnetic field vector<br>Several coordinate systems and time scales | Magnetic field intensity and direction |