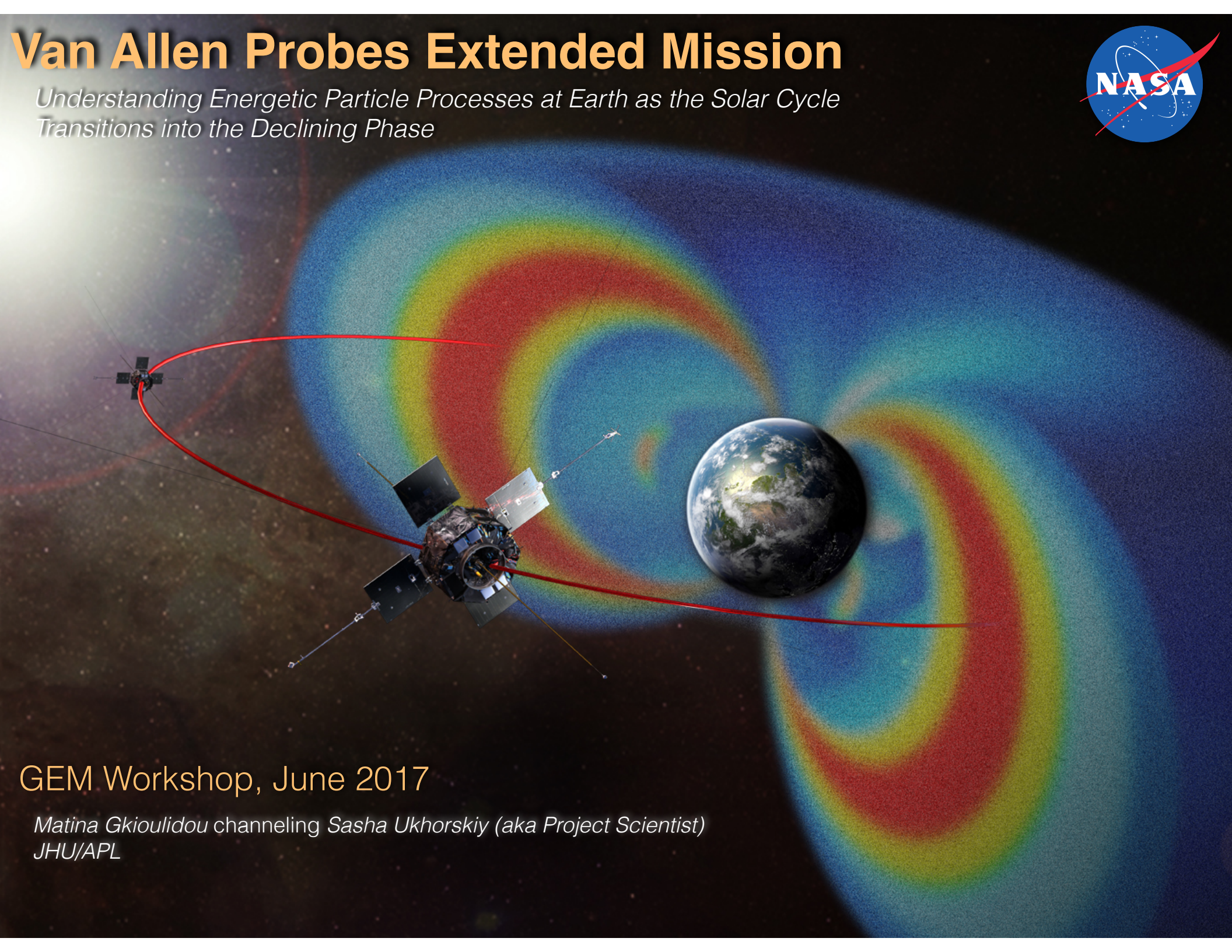
Van Allen Probes Extended Mission

Understanding Energetic Particle Processes at Earth as the Solar Cycle Transitions into the Declining Phase



GEM Workshop, June 2017

Matina Gkioulidou channeling *Sasha Ukhorskiy (aka Project Scientist)*
JHU/APL

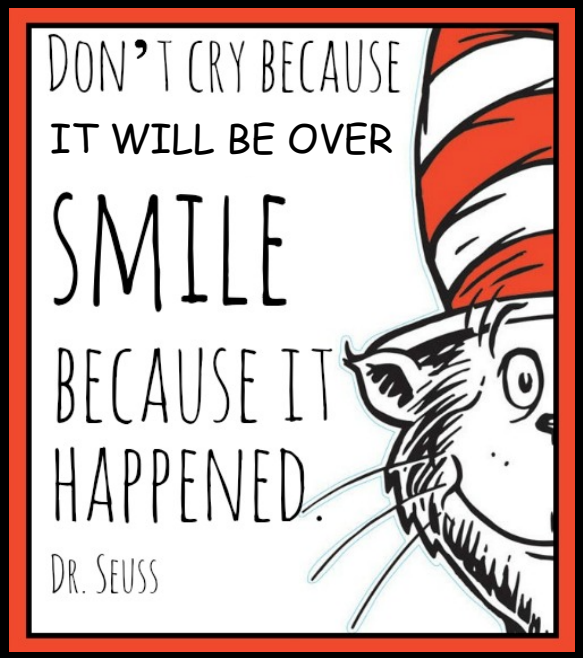
Van Allen Probes Mission

Launch
August 30, 2012

Bridge Phase
November 1, 2014

Extended Mission
November 1, 2015

End of SC ops
~April, 2019

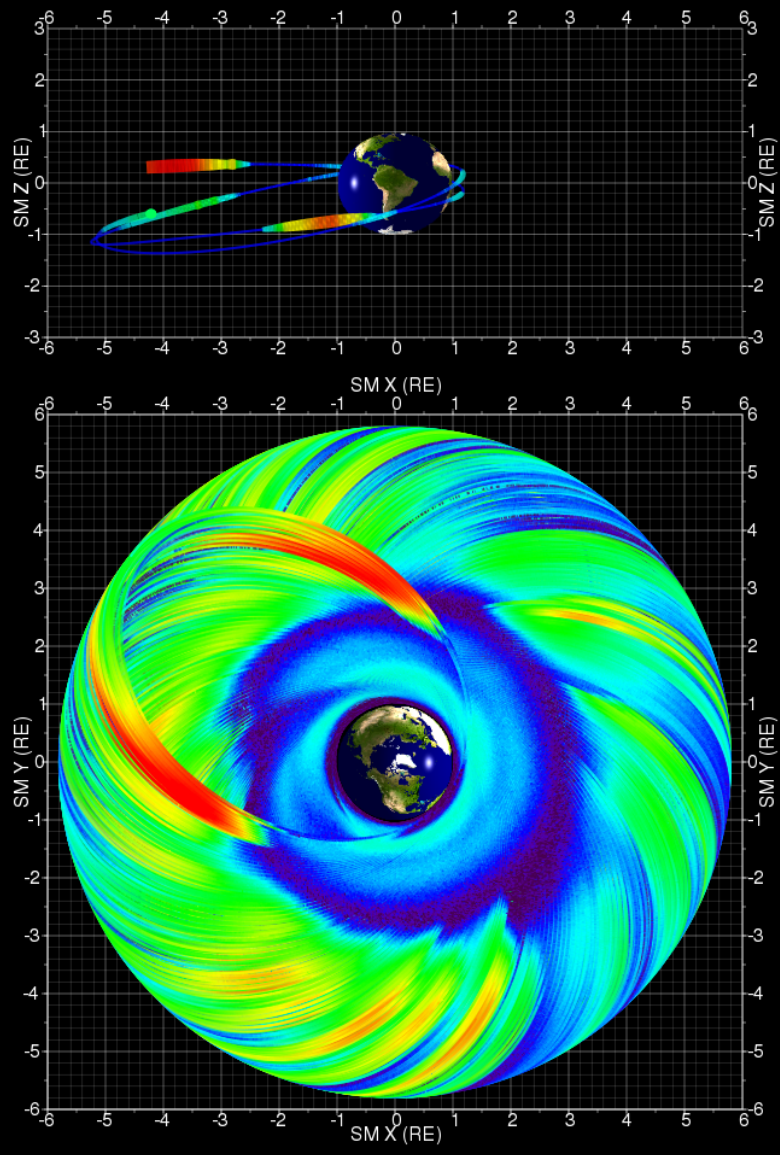


Mission Configuration and Science Investigation

Near-equatorial orbit (10°)
- direct measurements of the acceleration region

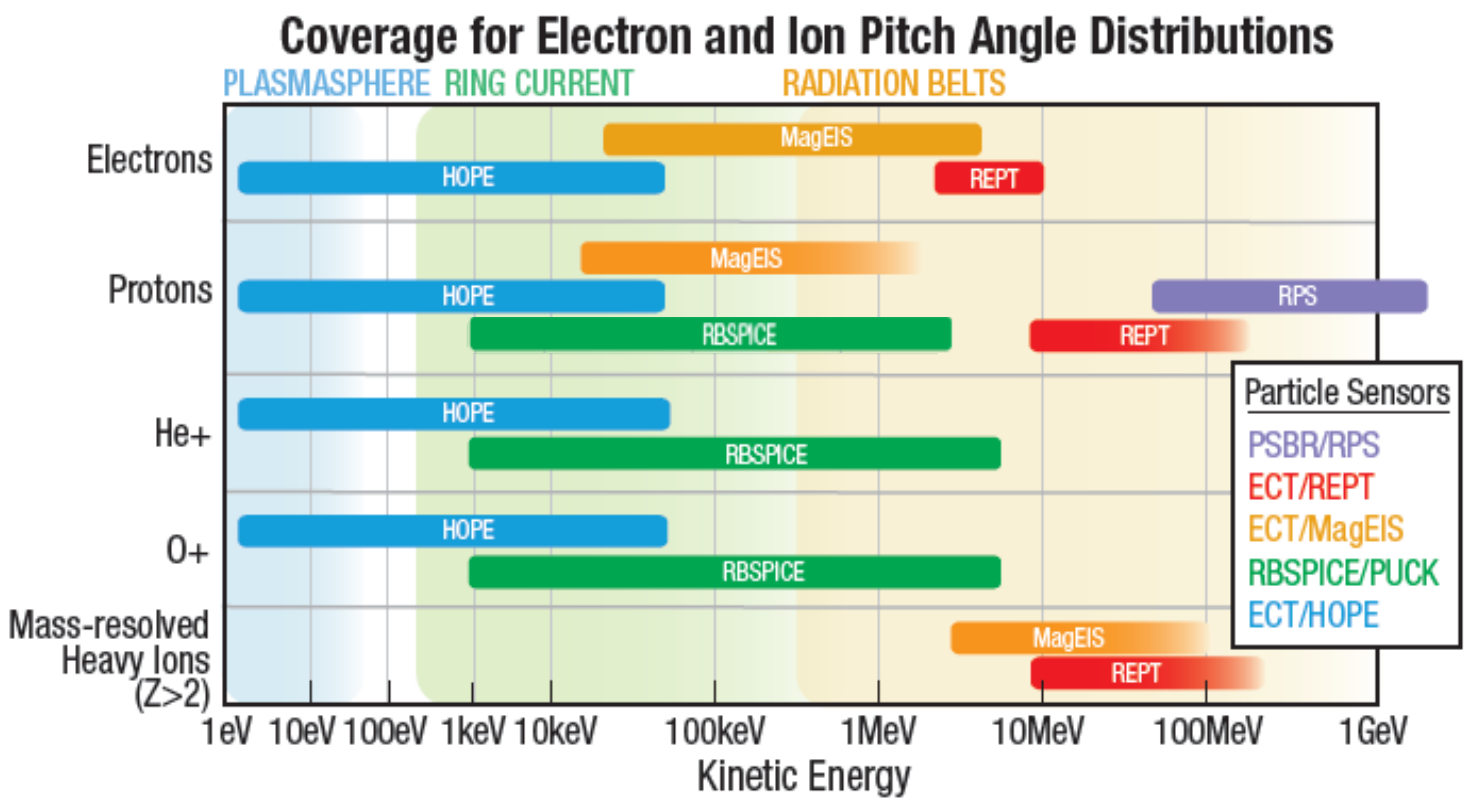
Two identical spacecraft with variable separation
- separation of temporal and spatial effects
- sampling different scales/mechanisms

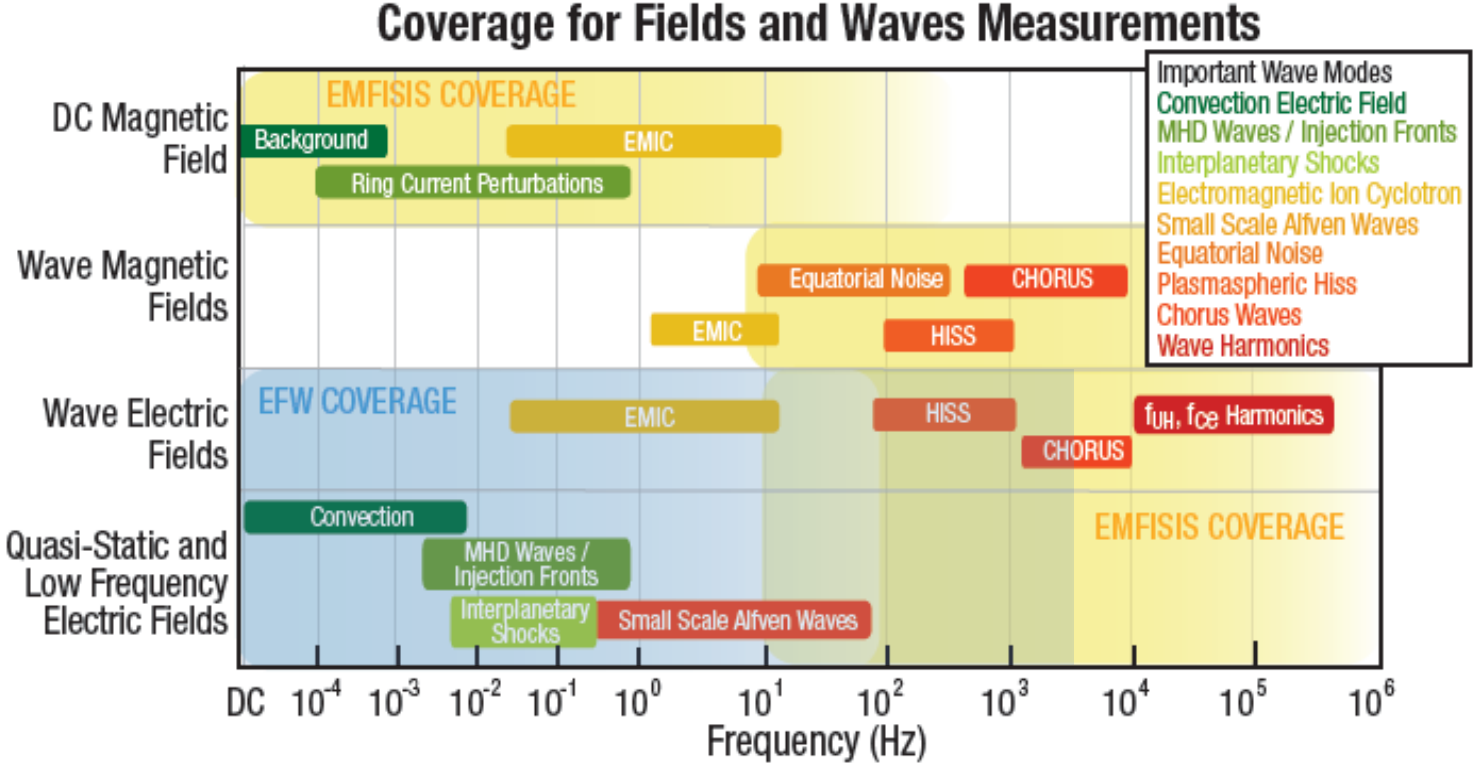
Complete MLT coverage
- spans different physical mechanisms/interaction regions



Van Allen Probes Instrument Investigations

Instruments	Science Teams
Energetic Particle, Composition and Thermal Plasma Suite (ECT), including: Helium, Oxygen, Proton, and Electron spectrometer (HOPE) Magnetic Electron Ion Spectrometer (MagEIS) Relativistic Electron-Proton Telescope (REPT)	**Harlan Spence**, PI, University of New Hampshire **Key Partners:** LANL, SwRI, Aerospace Corp., LASP Herbert Funsten, LANL J. Bernard Blake, Aerospace Corp. Daniel Baker, University of Colorado LASP
Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS)	**Dr. Craig Kletzing**, PI, University of Iowa **Key Partners:** NASA/GSFC, University of New Hampshire
Electric Field and Waves Instrument (EFW)	**John Wygant**, PI, University of Minnesota **Key Partners:** University of California, Berkeley; LASP
Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE)	**Louis Lanzerotti**, PI, New Jersey Institute of Technology **Key Partners:** JHU/APL, Fundamental Technologies
Relativistic Proton Spectrometer (RPS)	**Joseph Mazur**, PI, Aerospace Corp.
Balloon Array for RBSP Relativistic Electron Losses (BARREL)	**Robyn Millan**, PI, Dartmouth College





Instrument Performance

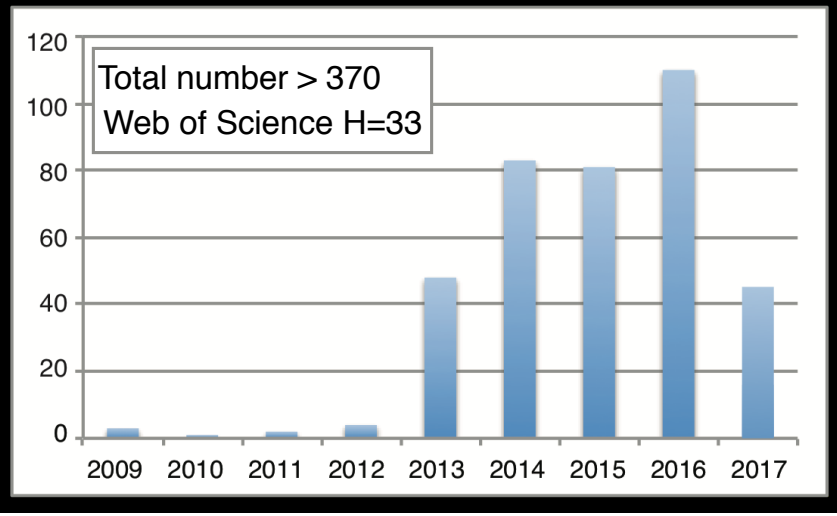
All instruments are healthy and returning quality data.

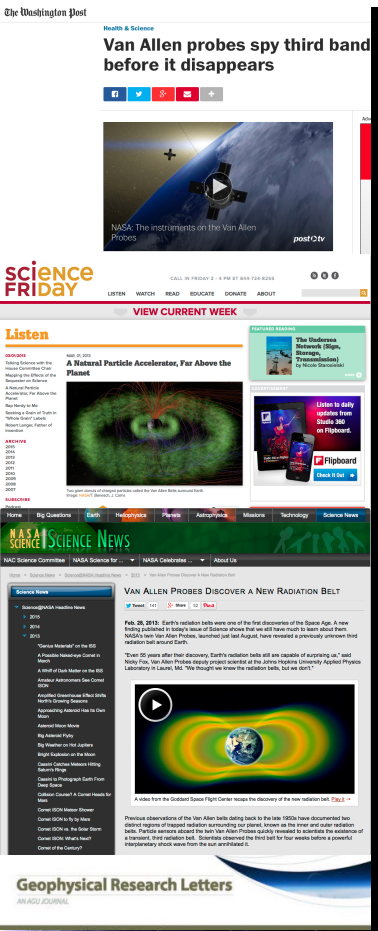
Overlapping energy/ frequency ranges provide excellent basis for cross-calibration.

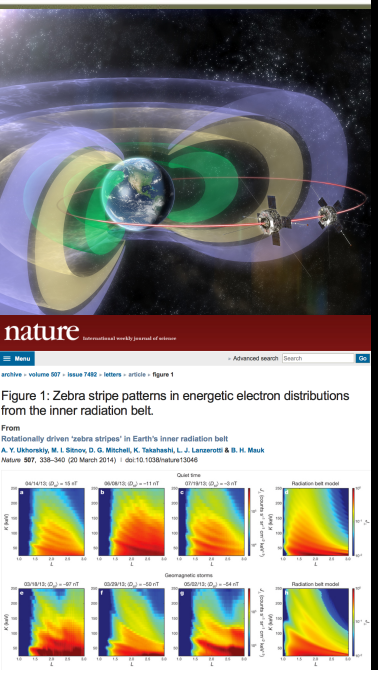
Scientific Success of Van Allen Probes

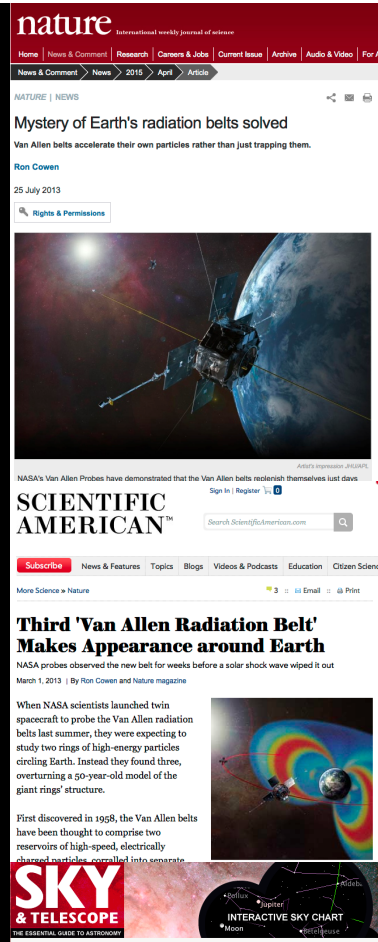
- More than 370 publications. Approximately 4000 citations
- More than 50% of publications are lead by authors not directly funded by Van Allen Probes
- H-index of 33 (Web of Science)
- High-profile results include: *Nature* (6 pub.), *Science* (2 pub.), *Nature Publishing Group* (5 pub.), *Physical Review Letters* (2 pub.)
- Special Issue of *Space Science Reviewers* (Volume 179, 2013)
- Special Issue of *Geophysical Research Letters* (26 pub.)
- 2 Special Issues of *Journal of Geophysical Research* (>60 pub.)
- Steady stream of press releases with new results featured on NASA and JHU/APL websites
- International press interest, popular science radio shows and magazine articles

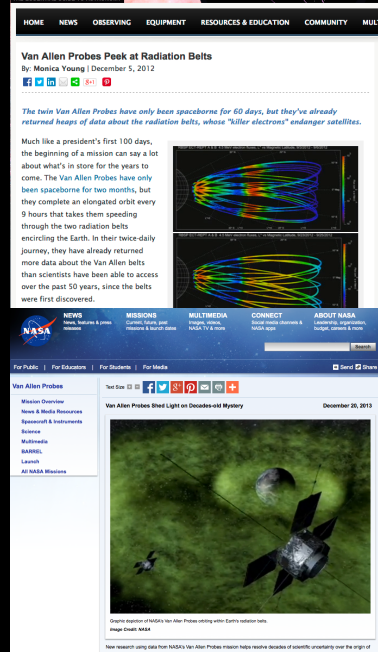
Steady rise of publications and citations







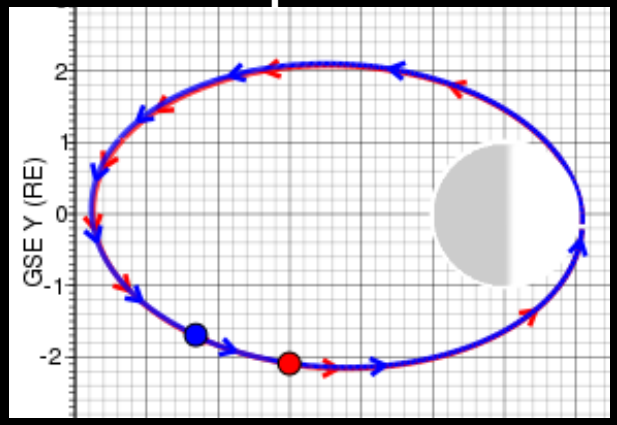




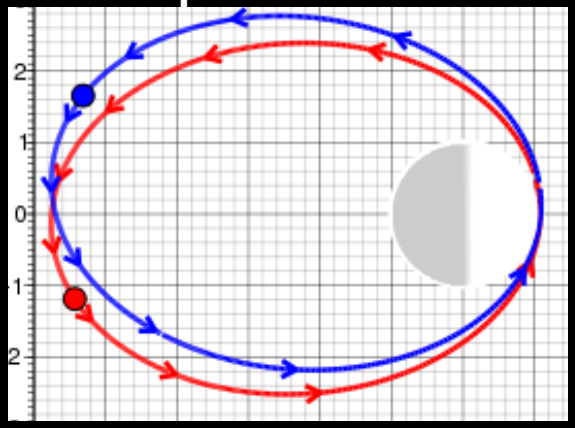
What the future holds: Extended Mission II (next 2+ yr)

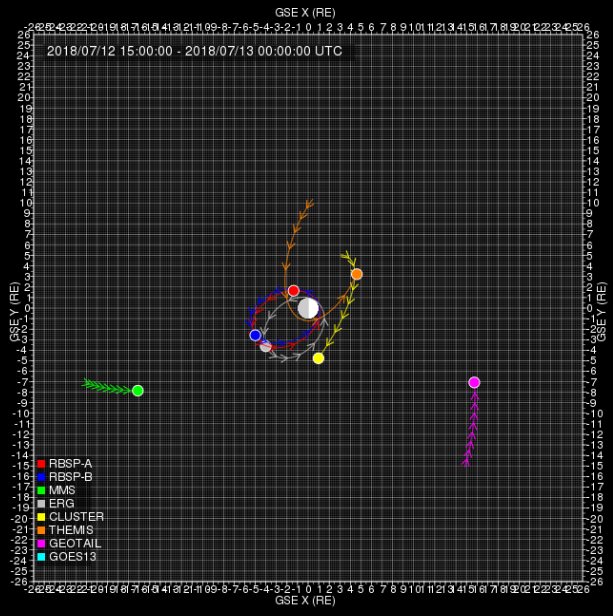
- **New orbit:** Apogee adjustment maneuver on 9 October 2015: Probe A decreased by 75 km, Probe A increased by 75 km. It approximately doubled the cadence of lapping events (from 67 days to 36 days). By the Extended Mission 2 it will also substantially increase the sampling are at ΔL=1.5-2.0.

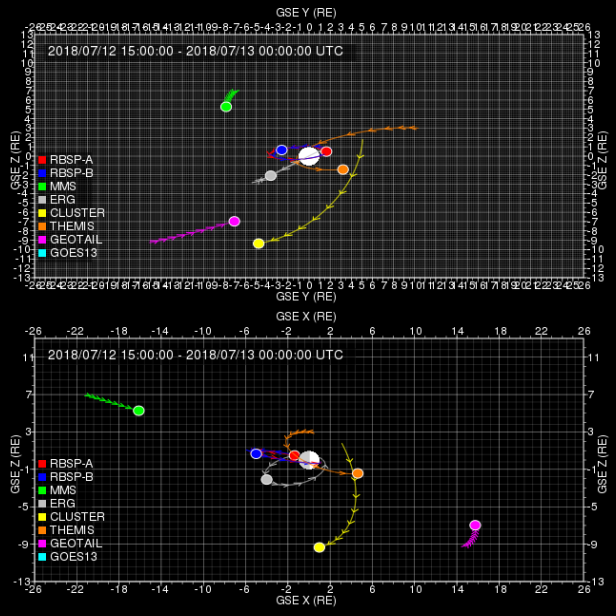
April 2013



September 2018

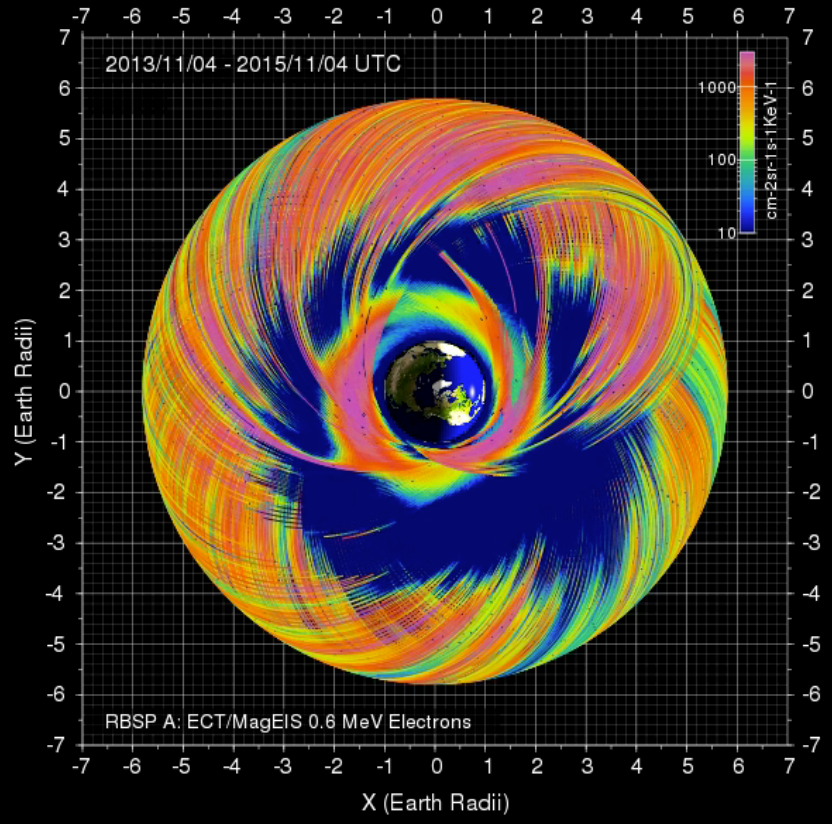






Comprehensive Dynamics-Configuration Sampling - Systems Understanding & Predictability

5 yr, 2x+ full MLT coverage, >75 geomagnetic storms



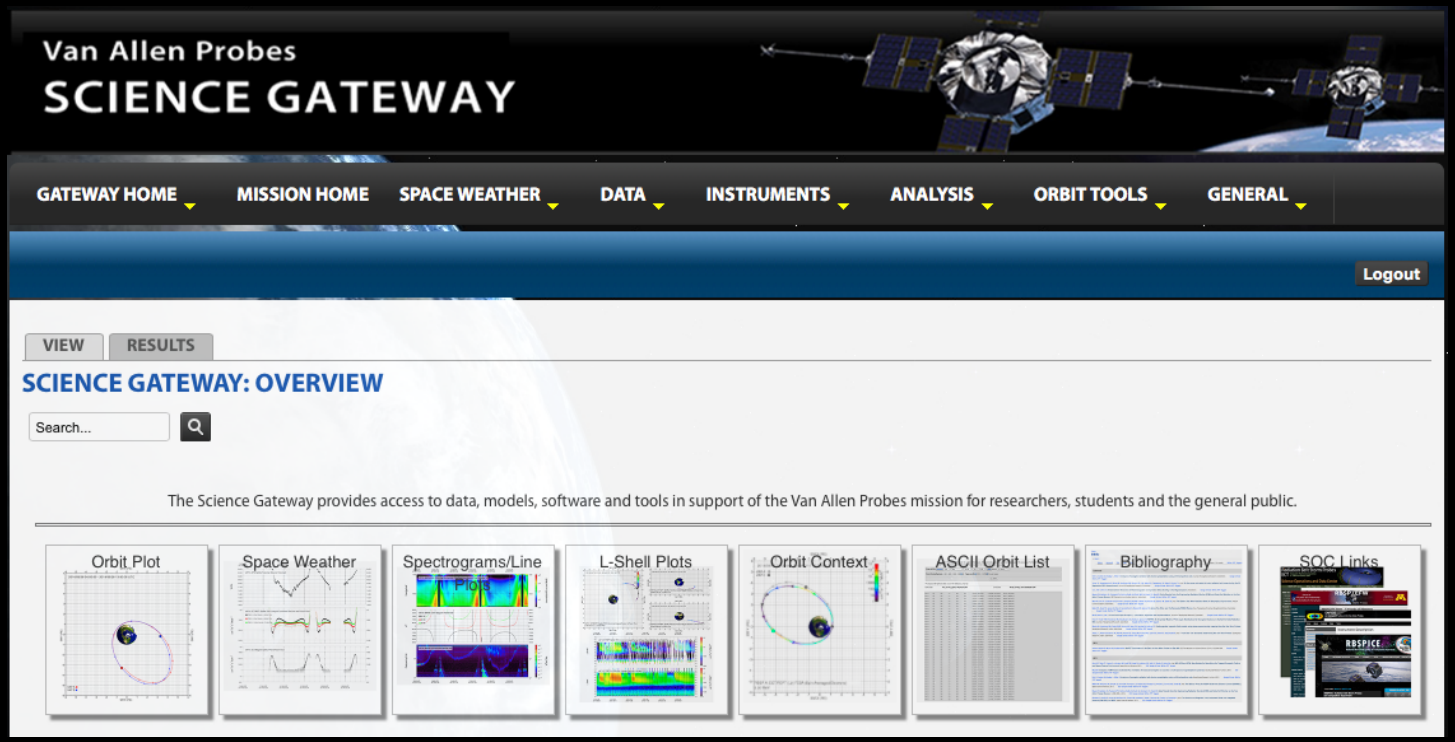
Over past ~5 years the Van Allen Probes lines of apsides made 2 full circles around Earth providing comprehensive measurements of the inner magnetosphere over more than 75 geomagnetic storms. This unprecedented dynamics-configuration sampling enabled: (1) major development of key empirical models; (2) unveiling the solar wind drivers of the inner magnetosphere activity critical for the development of predictive models.

Give me a lever long enough and a fulcrum on which to place it, and I shall move the world.

–Archimedes

Science Gateway

http://rbspgway.jhuapl.edu

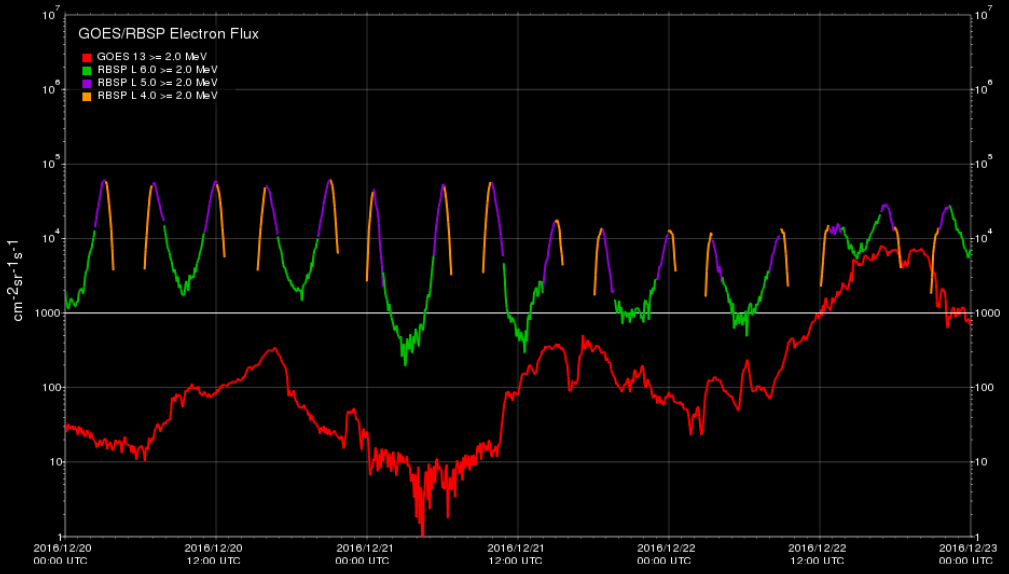


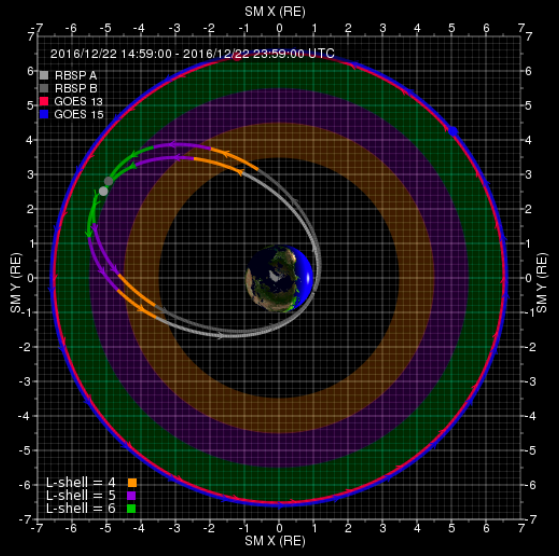
- Interactive plotting of all high-level data products from all instrument teams
- Digital data download (CDF)
- Latest (TS07D) magnetic field model, magnetic ephemeris, and adiabatic invariants
- SpWx data
- Multi-mission orbit tools
- Bibliography

Real Time SpWx Data from Radiation Belts

Predict the response of the radiation belts to solar storms to protect space assets in the near-Earth space

http://www.swpc.noaa.gov/products/van-allen-probes-radiation-belt-plots





Van Allen Probes near-real-time data products are re-broadcasted by NOAA SWPC

- All instruments continuously broadcast a subset of their science data in real time
- Van Allen Probes partners with three foreign institutions who operate ground stations that receive the broadcast:
  - Korea Astronomy and Space Science Institute (KASI)
  - Institute of Atmospheric Physics, Czech Republic
  - National Commission for Space Activities (CONAE), Argentina
  - National Institute of Space Research (INPE), Brazil
- The data are collected and processed at APL and then disseminated via Science Gateway tools

http://rbspgway.jhuapl.edu/analysis_models

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Home » ANALYSIS

ANALYSIS: Relevant Models of Interest

CCMC	The CCMC hosts a variety of models covering the entire domain from the solar corona to the Earth's upper atmosphere. CCMC works with model developers to make their models available to a wide research community through runs on request as well as instant runs.
DREAM	The Dynamic Radiation Environment Assimilation Model (DREAM) is a Space Weather model developed at Los Alamos National Laboratory to understand and to predict hazards from the natural space environment and artificial radiation belts produced by high altitude nuclear explosions (HANE) such as Starfish.
AE-8/AP-8	CCMC Services available for AE-8/AP-8 RADBELT. A software package that includes (1) an improved and updated version of the old MODEL program (MODEL87), (2) an interactive driver program (RADBELT), (3) the electron AE-8 and proton AP-8 flux maps for solar maximum and minimum, and (4) the interpolation subroutines. RADBELT and MODEL87 compute omnidirectional, integral, or differential (in energy) fluxes of electrons and protons trapped in Earth's radiation for specified energy, L-value, and B/Bo range (B/Bo is magnetic field strength normalized to the equatorial value). The fluxes are obtained by an interpolation procedure from the AE-8 and AP-8 trapped particle flux maps. The RADBELT program allows the user to specify input parameters and options online and generates flux tables that can be stored for later use.
SIZM	Inner Zone Model. A radiation belt proton, antiproton, and secondary model.
Tsyganenko Geomagnetic Field Model and GEOPACK libraries	The Tsyganenko models are semi-empirical best-fit representations for the magnetic field, based on a large number of satellite observations. The models include the contributions from major external magnetospheric sources: ring current, magnetotail current system, magnetopause currents, and large-scale system of field-aligned currents. The Tsyganenko model suite also includes GEOPACK library with 20 FORTRAN subroutines. Provides instantaneous calculation of external and internal geomagnetic fields along a field line and at a specified point based on T96 and Geopack08.
Empirical Geomagnetic Field Models	The Tsyganenko and Sitnov empirical models of geomagnetic field (e.g. TS07D) provides a relativistic high-resolution description of the magnetic field evolution in the inner magnetosphere during geomagnetic storms as a function of the solar wind and geomagnetic input parameters. Model applications include the magnetic mapping and correlation of spacecraft observations, computation of the adiabatic invariants of particle motion in the belts, the analysis of particle transport and losses from the belts, global visualization of storm-time magnetospheric-ionospheric current systems including computations of the inductive electric field induced by their storm-time reconfigurations. Given the increased spatial resolution of TS07D, custom fits of the model coefficients are needed for each time interval, which are then stored in ascii files, which must be loaded to evaluate it. The non-linear parameters are fit at hourly resolution and are then interpolated and used to fit the linear coefficients at 5 min cadence. These ascii files can be downloaded here. Additionally, the model also requires a set of static coefficients which are used in evaluation of the magnetopause shielding fields, and must be loaded prior to model evaluation and are available here. A sample FORTRAN program is available here. The program demonstrates how to configure both the static and the dynamic inputs to the TS07D model as well as model evaluation for the external magnetic field vectors. Additionally, the program demonstrates how to obtain the internal magnetic field vectors using the Geopack implementation of the IGRF model. In order to speed up computation time, the TS07D's modeled external magnetic field vectors have been precomputed on a uniform gridded cube, and written out to a binary VTK file (.vti), these cube files are available here. A sample FORTRAN program that demonstrates how to read the cube files and evaluate and interpolate the magnetic field vectors is included here. The magnetic vector potential is a useful quantity in computing the inductive electric field and is also used for computation of the third-invariant, however, is a computationally expensive quantity to evaluate. Similarly, in order to speed up computation time, the TS07D's modeled external magnetic vector potential field vectors have been precomputed on a uniform gridded cube that are available here. The Van Allen Probes' magnetic ephemeris (L*) from the TS07D model has been computed and the files are available here. TS07D Magnetic Field Model Data Products Users Guide can be found here.
Empirical Models of Ionospheric Electrostatic Potential	Empirical models of ionospheric electrostatic potential combined with geomagnetic field models provide global maps of the electrostatic field across the inner magnetosphere for the analysis of storm-time convection and the buildup of the ring current and the radiation belt seed population.
AF-GEOSPACE	A user-friendly graphics-intensive software program bringing together many of the space environment models, applications and visualization products developed by the Air Force Research Laboratory and others in the space weather community.

That's all folks