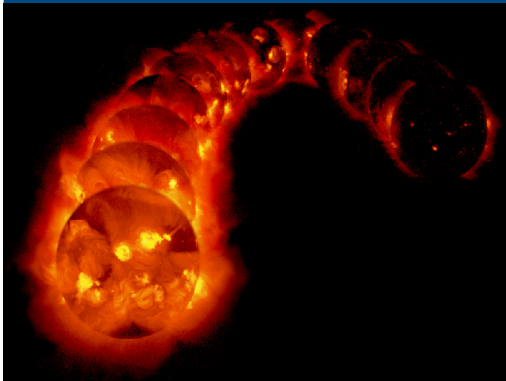




The Los Alamos Laboratory: Space Weather Research and Data

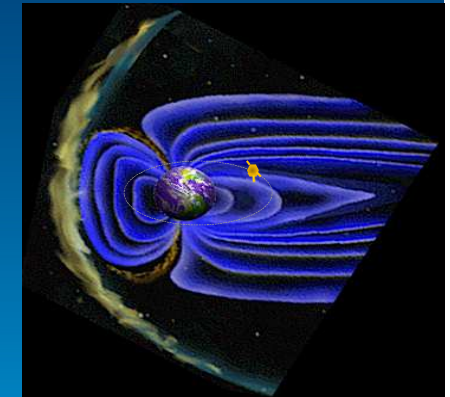
R. Friedel, - Center for Earth and Space Science

M. G. Henderson, S. K. Morley, V. K. Jordanova, G. S. Cunningham, J. R. Woodroffe, T. Brito, B. A. Larsen, G. D. Reeves, R. M. Kippen, J. P. Sullivan – ISR-1



Los Alamos National Laboratory

ces.lanl.gov
www.lanl.gov

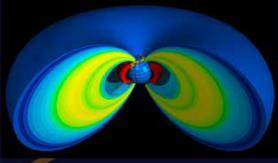


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Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

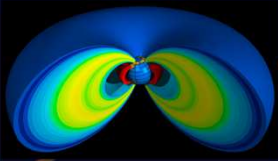




Agenda



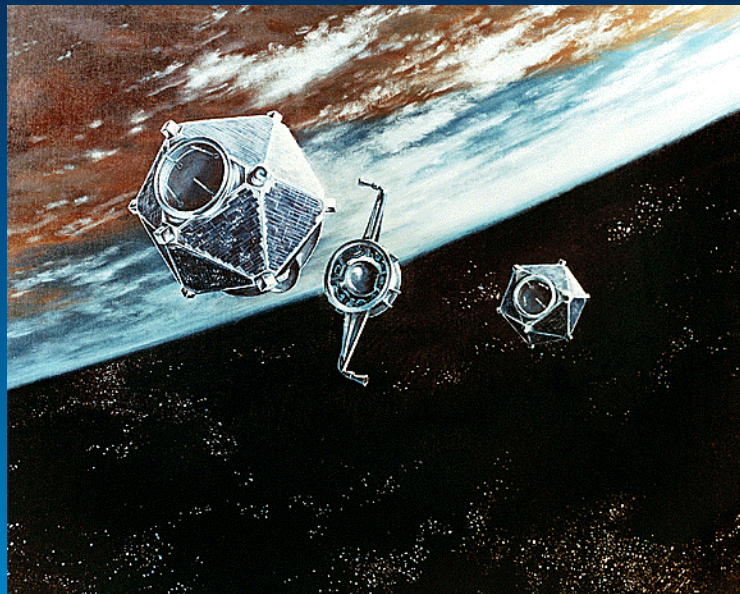
- Why is LANL in Space?
- LANL Data
 - US National Space Weather Plan
 - LANL GPS Data
 - LANL GEO Data
 - Other Missions
- LANL Space Weather Modeling
- Pearl Harbor in Space



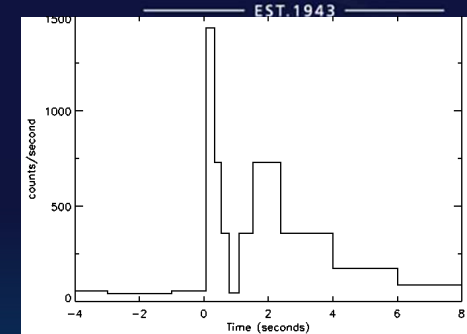
Why is LANL / DOE in Space?



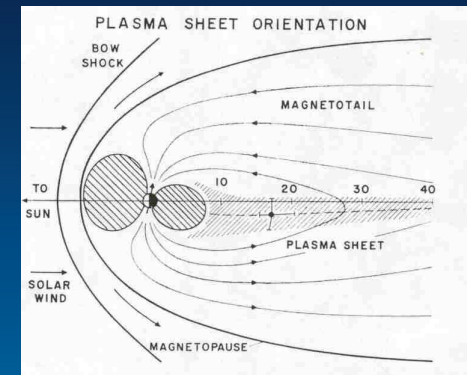
The Vela Program, 1963-1984: Monitoring the 1963 Limited Nuclear Test Ban Treaty



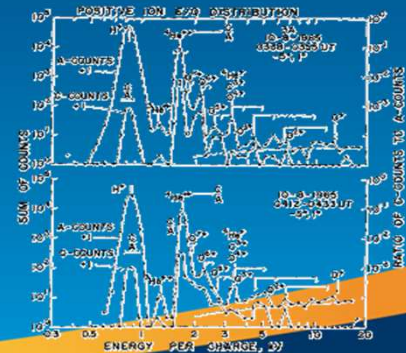
- **Discovery of Gamma Ray Bursts** (*Klebesadel et al., 1973*)

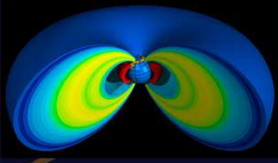


- **Discovery of the Earth's Plasma Sheet** (*Bame et al., 1967*)



- **Discovery of Heavy Ions & High Charge States in the Solar Wind** (*Bame et al., 1968*)



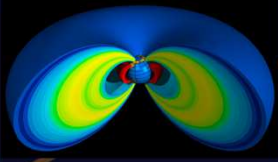


LANL Data and the US National Space Weather Plan

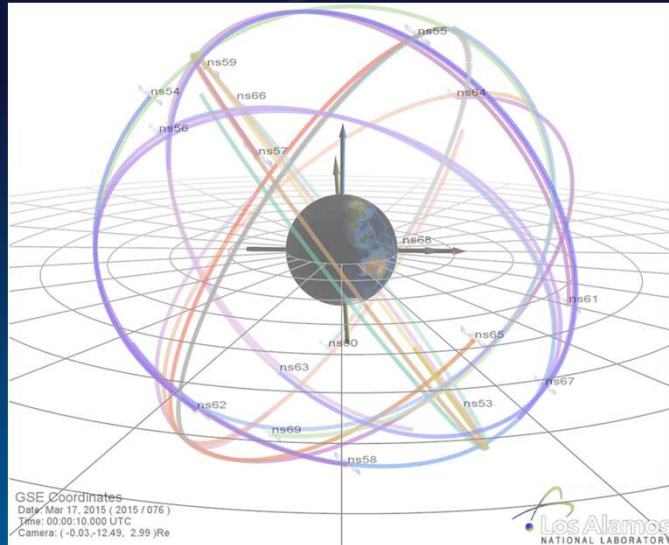


The October 2016 Executive Order “Coordinating Efforts to Prepare the Nation for Space Weather Events” mandated:

“Within 120 days of the date of this order, the Secretaries of Defense and Commerce **shall make historical data from the GPS constellation and other U.S. Government satellites publicly available**...to enhance model validation and improvements in space weather forecasting and situational awareness.”



LANL GPS Energetic Particle Data

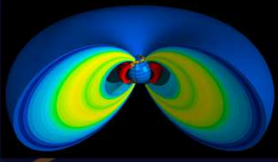


Energetic particle detectors have been flown on the GPS constellation for more than two decades; by February 2016 there were 23 GPS satellites equipped with energetic particle instrumentation.

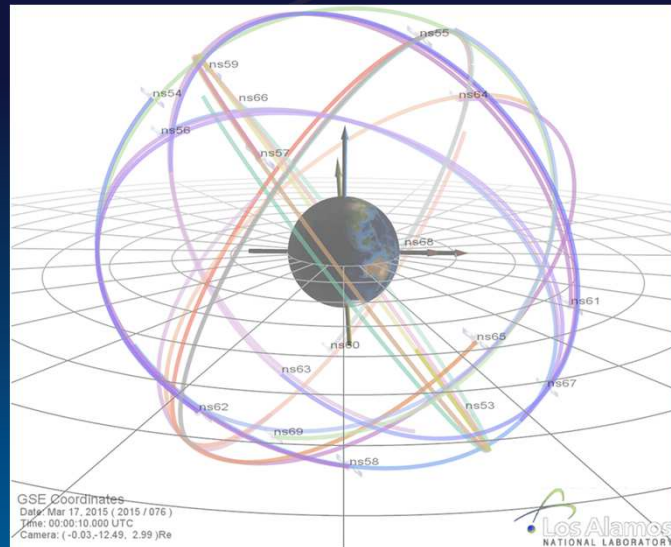
The Combined X-ray Dosimeter (CXD), is flown on 21 GPS satellites and covers

100/200 keV – 10 MeV electrons
5/9 MeV – 60 MeV protons

The Global Positioning System (GPS) satellites are distributed across six orbital planes and follow near-circular orbits, with a 12 hour period, at an altitude of approximately 20200 km. The six orbital planes are distributed around the Earth and are nominally inclined at 55 degrees.



LANL GPS Energetic Particle Data



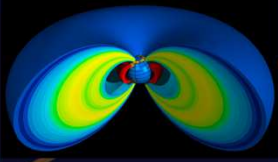
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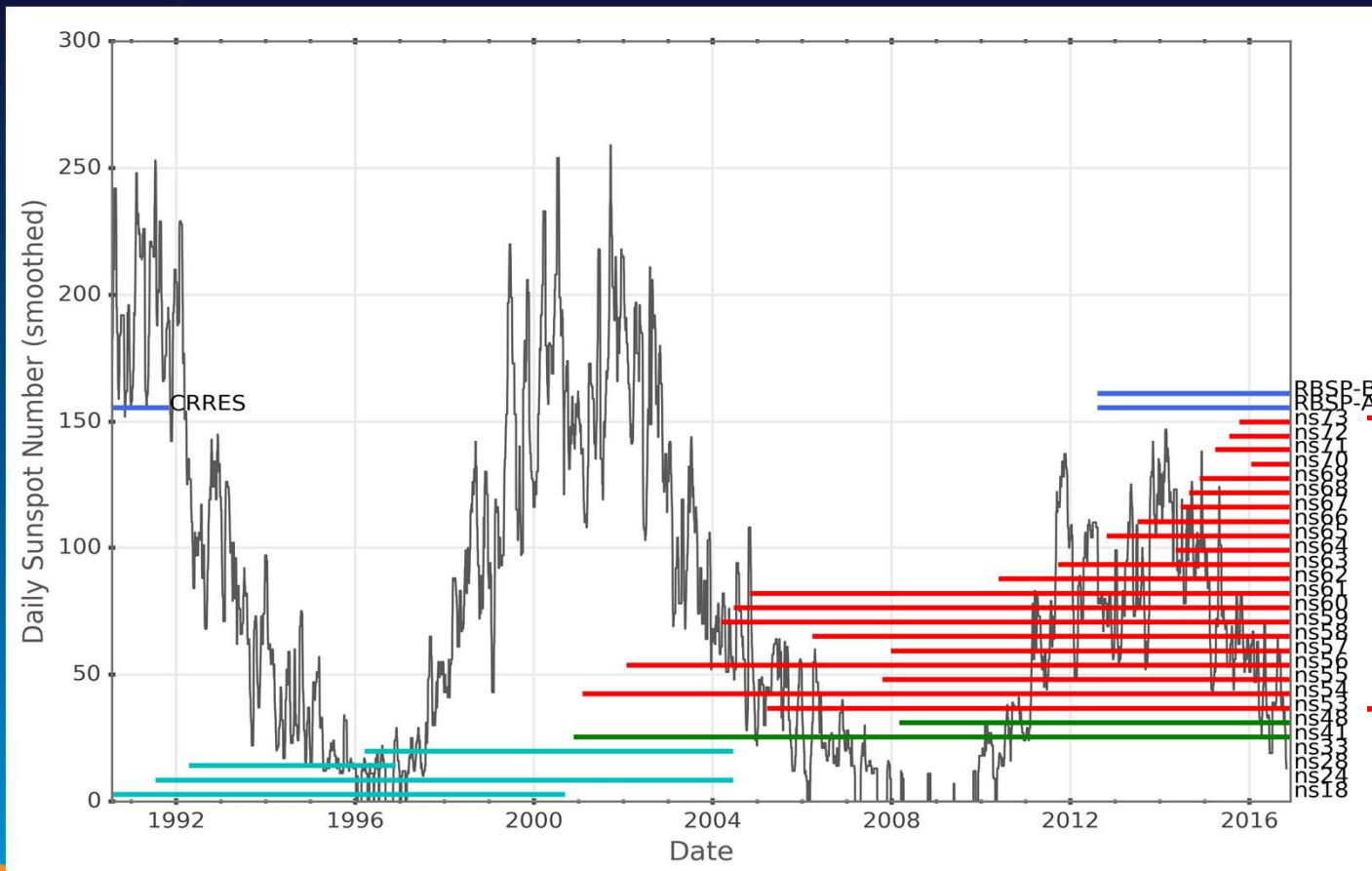
Sixteen years (2000-2016) of energetic particle data from Los Alamos instruments on GPS have been released to the public and is now available via the data.gov website.

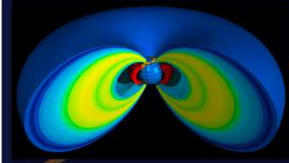


The next space weather data revolution

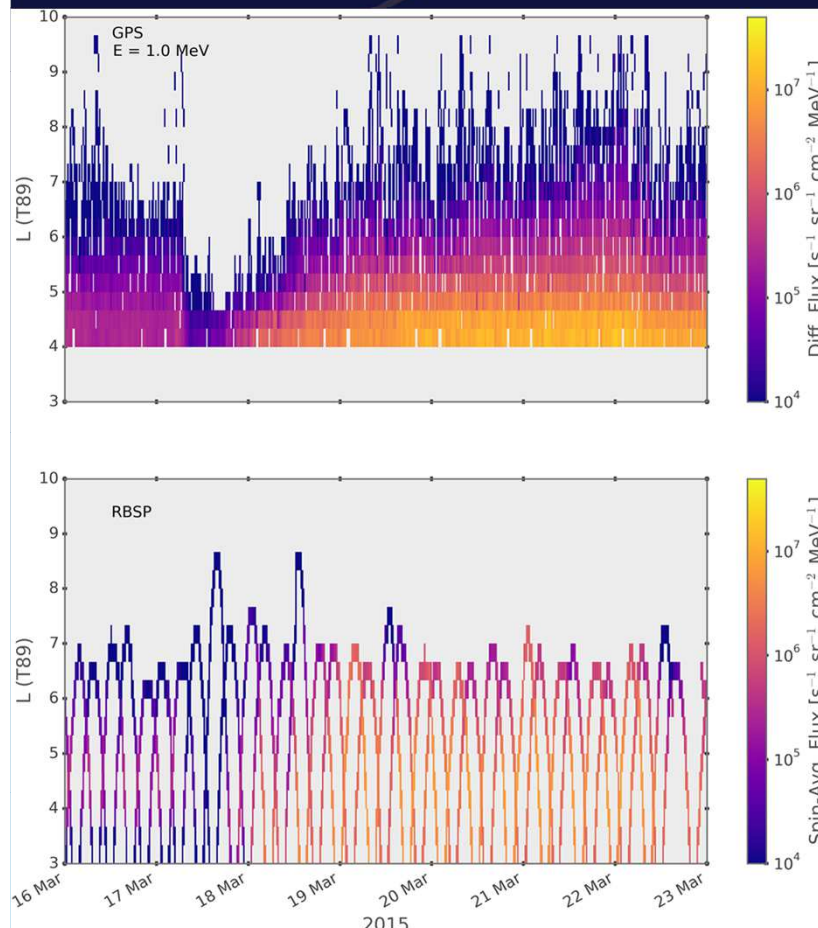


23 satellites: More than 141 satellite-years of data!





GPS Data is Science Quality Data



LANL GPS CXD data is highly consistent across instruments and can be combined to provide unprecedented temporal and spatial coverage in the $L > 4$ region:

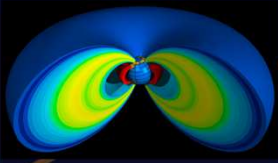
0.2 L spatial by 15 min time Resolution!

LANL GPS data has recently been cross-calibrated against electron data from the NASA Van Allen Probes mission, demonstrating its utility for scientific research and radiation environment specification.

Energetic particle data from the global positioning system constellation

SK Morley, JP Sullivan, MR Carver, RM Kippen, RHW Friedel, GD Reeves, MG Henderson, Space Weather 15 (2), 283-289, 2017

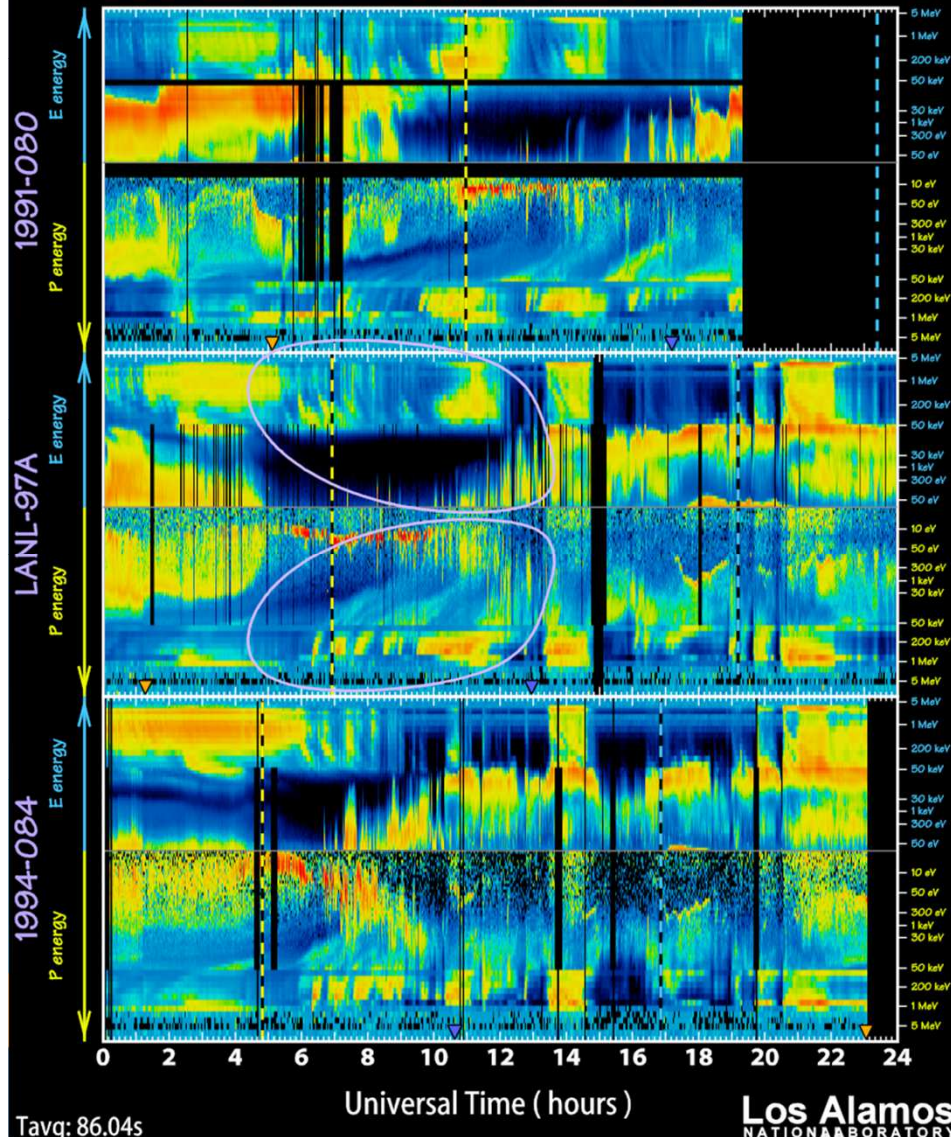




LANL GEO Energetic Particle Data



November 9, 1998 (1998313)



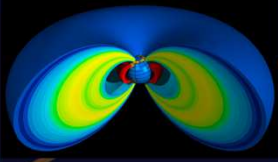
Historical data from MPA, SOPA and ESP instruments on the LANL/GEO spacecraft:

- MPA - plasma instrument (few eV-40keV)
- SOPA - Energetic particles (50keV - 6MeV)
- ESP - Energetic particles (700keV-26MeV)

Fluxes from all 3 instruments and full moments from MPA (densities, temps, velocities, B-Field direction, S/C potential, etc.)

From: 1989-2016, 27 years of Data, 135+ Satellite years. More than 2 solar cycles!





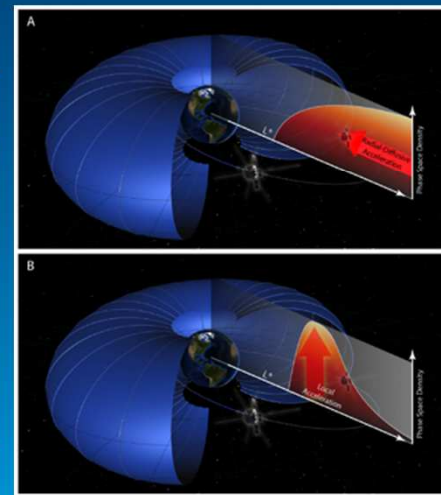
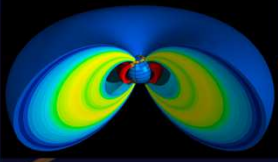
LANL GEO

Energetic Particle Data

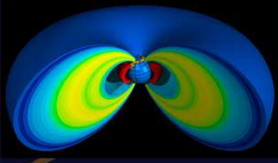


- LANL Geo Data had originally been made available by Geoff Reeves, and are currently publicly available through the end of 2007.
- LANL Data was also released as part of the International Solar-Terrestrial Physics (ISTP) Science Initiative started in the 1990's through the mid-2000's.
- Data has been widely used by scientific community: Google Scholar list 8000+ publications referring to to LANL Geo data.
- New data plots are available for the Van Allen probe era at:
https://rbsp-ect.lanl.gov/data_pub/LANL-GEO/pngs/LANL-GEO-RBSP_electron_survey.html
- Public release of all data to the end of 2016 is underway.

Other Missions



Los Alamos National Laboratory has been involved in >400 instruments on >60 satellites.

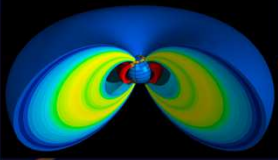


LANL Space Weather Modeling



LANL's Laboratory Directed Research and Development Program has or is supporting large Magnetospheric Modeling efforts – three year projects at a level of ~\$1.2 to 1.6M per year:

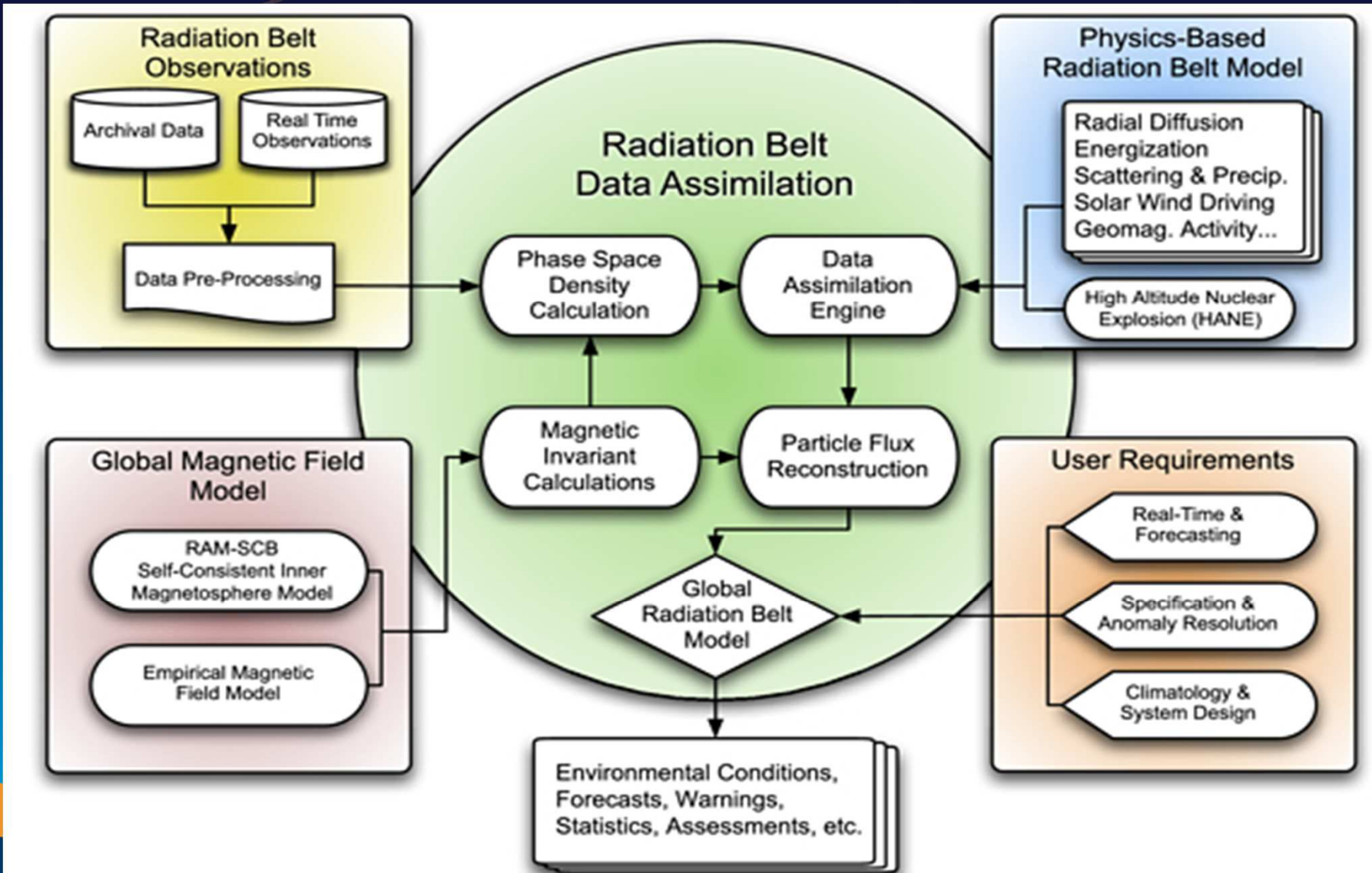
- **DREAM** (Sept 2006 – Sept 2009) PI Geoff Reeves
The Dynamic Radiation Environment Assimilation Model
- **SHIELDS** (Sept 2014 – Sept 2017) PI Vania Jordanova
Space Hazards Induced near Earth by Large, Dynamic Storms
[covered by presentation in Space Weather Modeling 2 Session,
10:55, Thursday 3 August]
- **Carrington GIC** (Sept 2016 – Sept 2019) PI Mike Henderson
Impacts of Extreme Space Weather Events on Power Grid
Infrastructure

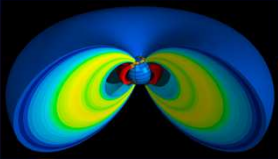


DREAM:



Dynamic Radiation Environment Assimilation Model

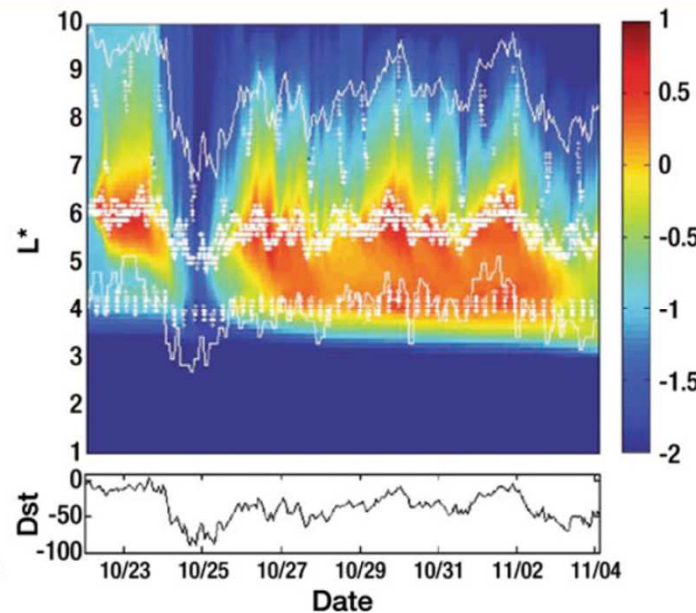
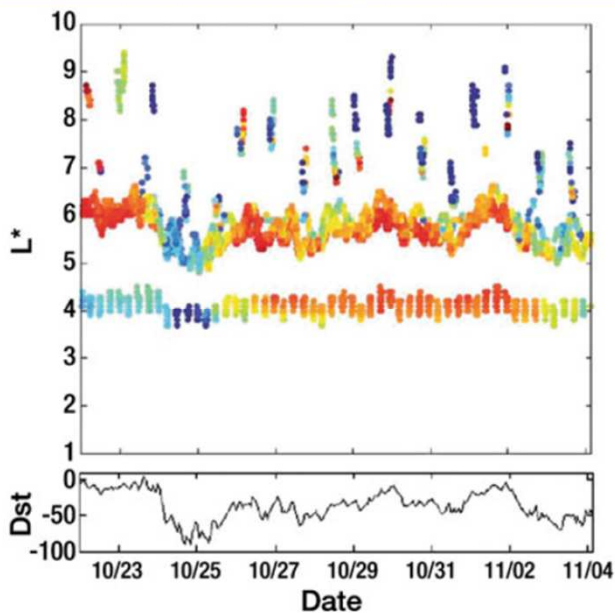




DREAM:

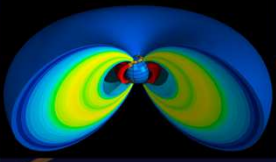


Dynamic Radiation Environment Assimilation Model



DREAM/1D data assimilation code is currently running in an operational mode at the Korean Space Weather Center and will soon be running at NOAA/SWPC.

A 1D radial diffusion code for modeling the high-energy "killer electron" population within the Earth's Van Allen radiation belts. It is fundamentally designed to be run in a data-assimilative mode in which sparse observations (of phase space density) are routinely integrated with model solutions via an Ensemble Kalman Filtering (EnKF) approach. A 3D version of DREAM has also been developed, but does not yet utilize data assimilation.



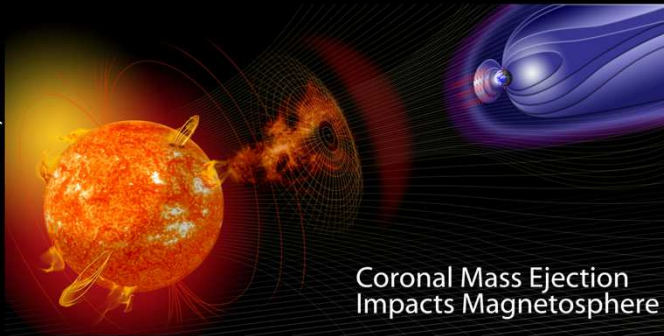
Carrington GIC

Impacts of Extreme Space Weather Events on Power Grid Infrastructure



New project that builds in SHIELDS Infrastructure

Model Development
GMD Inputs:
Tasks: 1, 2

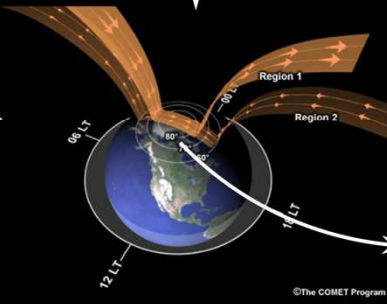


Coronal Mass Ejection
Impacts Magnetosphere



EMP-E3

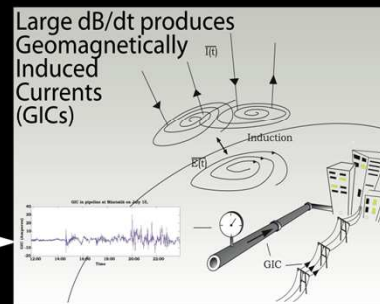
Propagation of
GMD to Ground:
Tasks: 3, 4



©The COMET Program

3D
Ground
Conductivity

FDTD
EM Solver

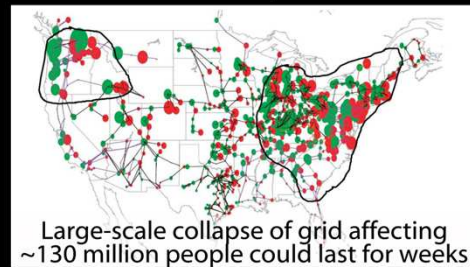


Large dB/dt produces
Geomagnetically
Induced
Currents
(GICs)

Power Grid Impacts
and Mitigation:
Tasks: 5, 6



Permanent damage to transformers

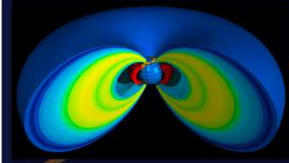


Large-scale collapse of grid affecting
~130 million people could last for weeks

EMP-3: Tie in to LANL mission

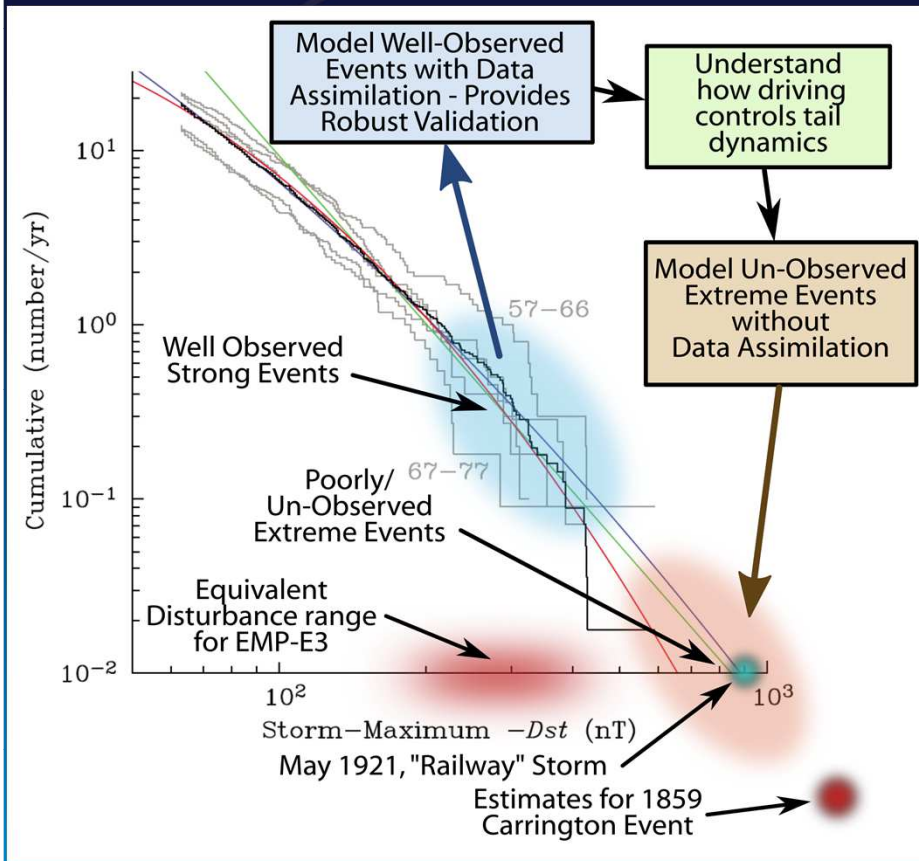
Late-time (E3) high-altitude electromagnetic pulse (HEMP) produced by nuclear explosions above an altitude of ~30 km.

Conversion of the B-fields into electric fields in the Earth is the mechanism for coupling to the high voltage power grid.

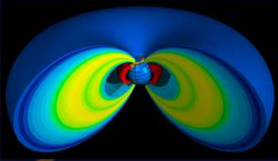


Carrington GIC

Impacts of Extreme Space Weather Events on Power Grid Infrastructure

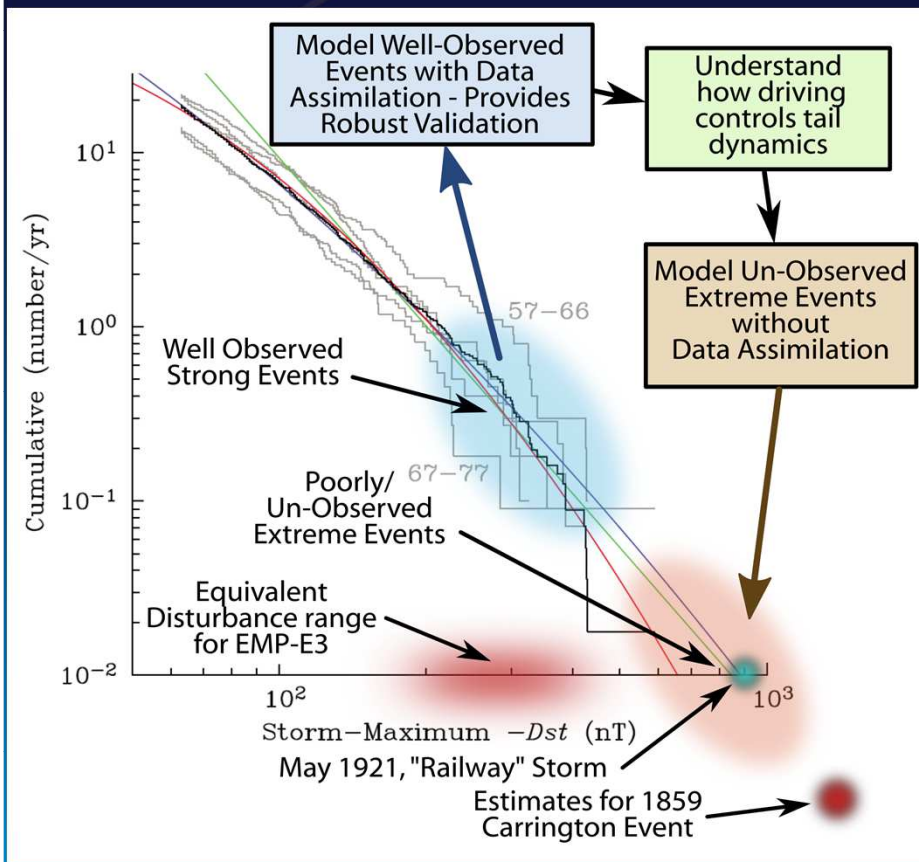


This newly funded project at LANL will assess impacts of extreme space weather events on ground-based power grid infrastructure via physics-based modeling of Carrington-class geomagnetic storm events.



Carrington GIC

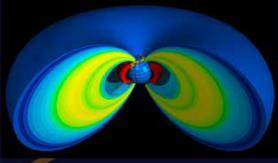
Impacts of Extreme Space Weather Events on Power Grid Infrastructure



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Related upcoming research:
 Is Carrington a 100 year storm? How extreme can storms really get?
 Basic idea: You can observe our sun for 100 years or 100 suns for one year

← Actual 100 year event?

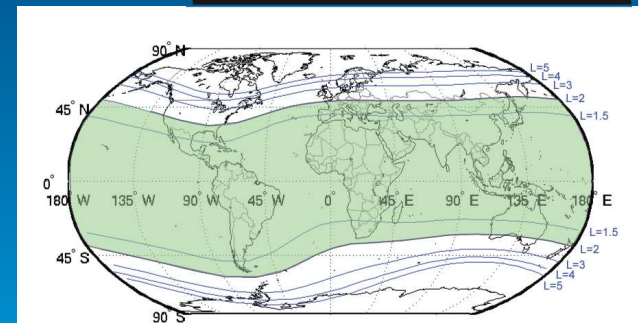
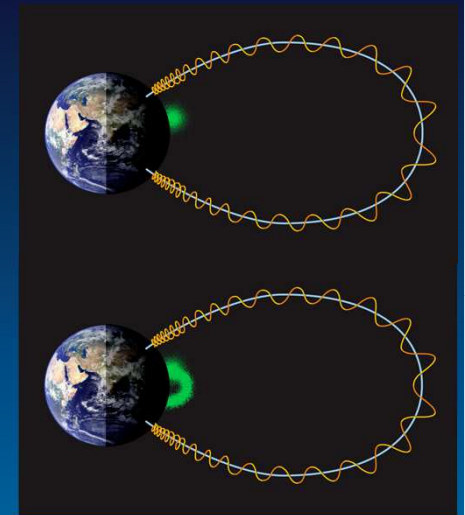


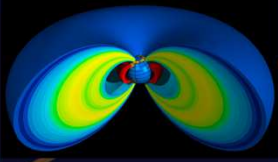
Pearl Harbor in Space: Laying the Scientific Foundation for Radiation Belt Remediation



The Sun is not the only possible source of Extreme Space Weather!

- An exoatmospheric nuclear explosion such as the Starfish Prime test creates a very intense radiation environment for satellites.
- Prompt effects include X-rays, Gamma-rays, neutrons, and EMP.
- Beta-decay of debris ions creates a belt of MeV electrons trapped in the Earth's magnetic field.
- The HANE electron belt can be many orders of magnitude more intense than the natural belts. Very few satellites are hardened to those levels.
- Below L=2 (~45° latitude) these intense radiation levels last for many years.

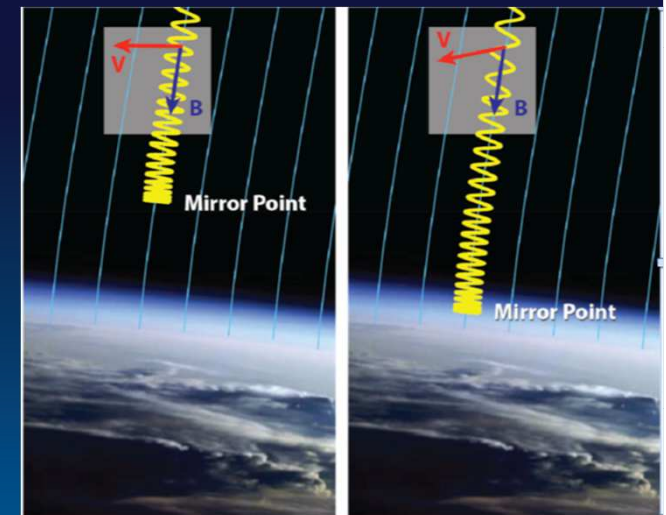




Pearl Harbor in Space: Laying the Scientific Foundation for Radiation Belt Remediation



- LANL's radiation belt models have been used to evaluate the evolution of HANE belts (DREAM)
- LANL has performed evaluation studies for several proposed remediation strategies
- LANL is part of the upcoming Air Force DSX mission (deployed VLF Antenna in space)
- Active R&D program for new space technologies for VLF wave generation using modulated electron accelerators
- Development includes a proposed rocket experiment to raise TLR of the accelerator and planning of the CONNEX NASA Midex mission



Natural Remediation occurs through wave (VLF) particle interactions leading to electron precipitation: How do we harness this process?