Project Details

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Project Title:
Analyzing the Web of Correlations and Time Lags between the Solar Wind and the Inner Magnetosphere: Systems Science with CCA

PI Name: Joseph Borovsky
PI Email: jborovsky@spacescience.org
Affiliation: Space Science Institute
Project Member(s):
- Consolini, Giuseppe ; Collaborator; Self
- Ostgaard, Nikolai ; Collaborator; Birkeland Centre for Space Science, University of Bergen, Norway
- Denton, Michael H; Co-I/Science PI; Space Science Institute

Summary:
The overarching objective of this LWS Investigation is to use a systems-science approach to increase understanding of the connections, time lags, feedback loops, and hysteresis in the reaction of the inner-magnetosphere system to the solar wind. The mathematical technique of canonical correlation analysis (CCA) will be used to simultaneously analyze a global data set (millions of points) comprised of multiple measures of the solar wind and multiple measures of the inner magnetosphere. Specific objectives are (1) To determine and assess the dominant correlations and time lags between the multiple variables of the solar wind and the multiple measures of the inner magnetosphere, (2) To determine the important hysteresis terms in the reaction of the inner magnetosphere to driving by the solar wind, (3) To identify correlations with known physical processes and to highlight unexplained correlations, (4) To exploit CCA methods to gain information about causality and information flow in the web of correlations, and (5) To interact with the VarSITI SPeCIMEN community to attain its goals.

Canonical correlation analysis is an ideal tool when causes and effects cannot be described or measured by a single variable, which is the case for the solar wind driving the highly coupled inner magnetosphere. CCA has a demonstrated ability to uncover patterns in the reaction of the magnetosphere-ionosphere system to the solar wind. In this NASA LWS Investigation, CCA will be applied to the inner magnetosphere driven by the solar wind. A multiyear , "Grand Inner-Magnetosphere Data Set , will be assembled from multiple time-dependent variables measuring the plasmasphere, the plasma cloak, the ion plasma sheet (ring current), the electron plasma sheet, substorm-injected electrons, the electron radiation belt, the ion radiation belt, ULF amplitudes, magnetospheric convection, magnetic-field morphology, particle anisotropies, plus other measures that become available from the SPeCIMEN community. The solar wind data set will be the multiyear OMNI2 data plus a new solar-source categorization of the solar wind.

CCA techniques have been developed to identify and quantify hysteresis in the reaction of the Earth to the solar wind and to identify feedback processes. Techniques will be developed in this Investigation to study time lags and the flow of information between the solar wind and the inner magnetosphere. CCA methodologies will be exploited that can provide information about which correlations are causal and which are spurious.

This proposed investigation directly supports Key Science Goal 2 of the Decadal Survey: , "Determine the dynamics and coupling of Earth , " s magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs , . This investigation supports the NASA Heliophysics Division Science Goal 2 , "Advance our understanding of the connections that link the Sun, the Earth and planetary space environments, and the outer reaches of our solar system , . This proposed Investigation supports the NASA Strategic Subgoal 2.2 , "Understand the Sun and its interactions with Earth and the solar system , from the 2011 NASA Strategic Plan and it directly supports the Heliophysics Science Question , "How do the Earth and planetary systems respond? , . This Investigation supports the LWS Program Objective , "Understand solar variability and its effects on the space and Earth environments with an ultimate goal of a reliable predictive capability of solar variability and response , . This investigation uses a systems science approach to directly address the VarSITI SPeCIMEN overarching question , "How does the inner magnetosphere respond as a coupled system to Sun/solar-wind driving? , and this investigation will help to achieve the SPeCIMEN stated anticipated outcome , "A better understanding of the physical processes leading to a series of coupled, related models that quantitatively predict the dynamical evolution of the inner magnetospheric state. ,

Publication References:

Summary: no summary

Reference: Borovsky, Joseph E.; Cayton, Thomas E.; Denton, Michael H.; Belian, Richard D.; Christensen, Roderick A.; Ingraham, J. Charles; (2016), The proton and electron radiation belts at geosynchronous orbit: Statistics and behavior during high-speed stream-driven storms, Journal of Geophysical Research: Space Physics, Volume 121, Issue 6, pp. 5449-5488, doi: 10.1002/2016JA022520

Summary: no summary

Reference: Podesta, John J.; Borovsky, Joseph E.; (2016), Relationship between the durations of jumps in solar wind time series and the frequency of the spectral break, Journal of Geophysical Research: Space Physics, Volume 121, Issue 3, pp. 1817-1838, doi: 10.1002/2015JA021987

Summary: no summary

Reference: Borovsky, Joseph E.; Denton, Michael H.; (2016), Compressional perturbations of the dayside magnetosphere during high-speed-stream-driven geomagnetic storms, Journal of Geophysical Research: Space Physics, Volume 121, Issue 5, pp. 4569-4589, doi: 10.1002/2015JA022136

Summary: no summary

Reference: Borovsky, Joseph E.; (2016), The plasma structure of coronal hole solar wind: Origins and evolution, Journal of Geophysical Research: Space Physics, Volume 121, Issue 6, pp. 5055-5087, doi: 10.1002/2016JA022686

Summary: no summary

Reference: Borovsky, Joseph E.; Denton, Michael H.; (2016), The trailing edges of high-speed streams at 1 AU, Journal of Geophysical Research: Space Physics, Volume 121, Issue 7, pp. 6107-6140, doi: 10.1002/2016JA022863

Summary: no summary

Reference: Denton, M. H.; Borovsky, J. E.; (2017), The response of the inner magnetosphere to the trailing edges of high-speed solar-wind streams, Journal of Geophysical Research: Space Physics, Volume 122, Issue 1, pp. 501-516, doi: 10.1002/2016JA023592

Summary: no summary

Reference: Borovsky, Joseph E.; Yakymenko, Kateryna; (2017), Substorm occurrence rates, substorm recurrence times, and solar wind structure, Journal of Geophysical Research: Space Physics, Volume 122, Issue 3, pp. 2973-2998, doi: 10.1002/2016JA023625