National Aeronautics and
Space Administration

Science Mission Directorate

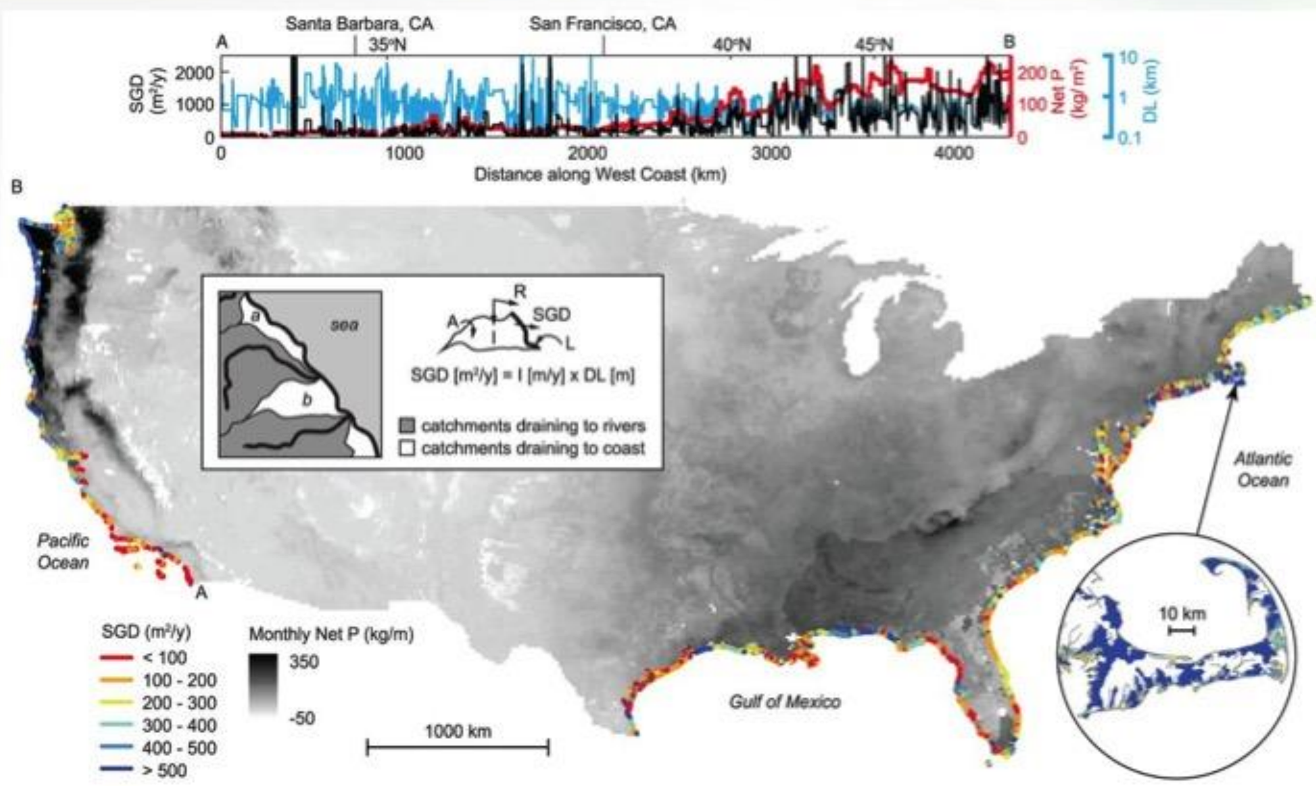
Weekly Highlights

August 12, 2016

Continental Patterns of Submarine Groundwater Discharge Reveal Coastal Vulnerabilities

Sawyer, A. H., David, C. H., & Famiglietti, J. S. | Science | August 2016 | doi: 10.1126/science.aag1058

Researchers from NASA -JPL and the Ohio State University introduced the first-ever high-resolution map of underground flows that connect fresh groundwater beneath the contiguous United States and seawater in the surrounding oceans. The study presented spatially resolved estimates of fresh (land-derived) submarine groundwater discharge (SGD) based on a simple water budget analysis, state-of-the-art continental-scale hydrography, and climate datasets. Estimates of recharge were obtained from the second phase of NASA's North American Land Data Assimilation System (NLDAS2). Climate controls regional patterns in fresh SGD, while coastal drainage geometry imparts strong local variability. Because the recharge zones that contribute fresh SGD are densely populated, the quality and quantity of fresh SGD is vulnerable to anthropogenic disturbance. The study unveiled hot spots for contaminant discharge to marine waters and saltwater intrusion into coastal aquifers.



Submarine groundwater discharge (SGD) influences global geochemical cycles and coastal water quality by delivering chemical compounds and dissolved ions from land to sea. SGD patterns also influence ocean temperature and alkalinity, which are key controls on marine ecological and biogeochemical processes. Unlike rivers, SGD is broadly distributed and relatively difficult to measure, especially at continental scales.

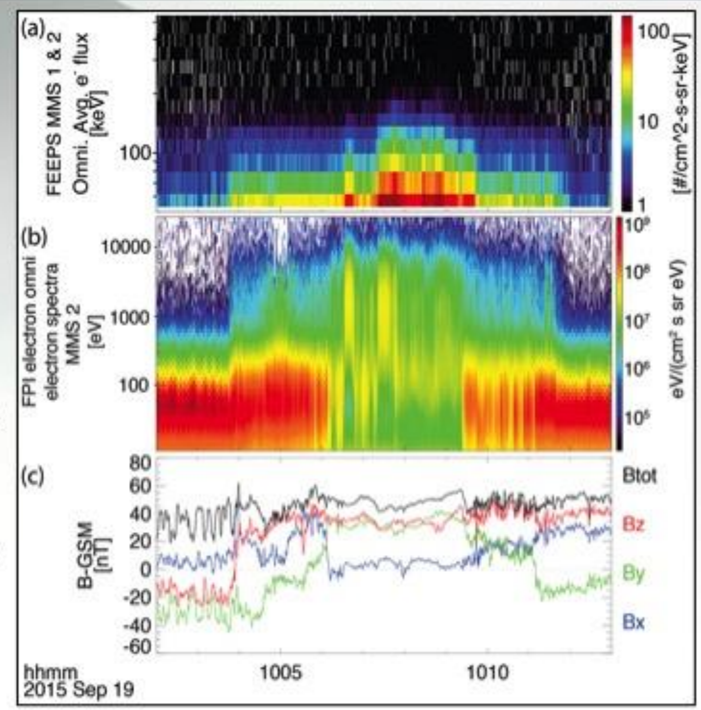
Left: Map of fresh SGD rates along the contiguous United States coast. **(top)** On the West Coast, fresh SGD increases from south to north with net precipitation (Net P), while drainage length (DL) remains consistent; **(bottom)** the shape of recharge zones (map inset) dictates local variability. Blue areas indicate greater flow than red areas.

NASA Heliophysics MMS Mission Sheds New Light on the Science of Magnetic Reconnection

Jaynes, A. N., et al. (2016). ENERGETIC ELECTRON ACCELERATION OBSERVED BY MMS IN THE VICINITY OF AN X-LINE CROSSING. Geophys. Res. Lett., 43. doi:10.1002/2016GL069206.

The NASA Heliophysics Magnetospheric Multiscale (MMS) mission continues to provide important science data, helping us unlock more of the mysteries around magnetic reconnection close to home. Magnetic reconnection is a ubiquitous process that occurs in plasmas all over the universe. Although plasma is rare here on Earth, it's found in 99% of the visible universe making it an important focus of study for space research. Learning more about magnetic reconnection, and in particular electron acceleration, will help us better understand how magnetic and electric energy travel through our magnetosphere and affect important resources we rely on everyday like our power grids, our communications infrastructure, and GPS systems.

A recent Geophysical Research Letters paper published in July discusses new MMS observations of high-energy (>100 keV) electron acceleration seen in an area of Earth's magnetosphere called the magnetopause. The magnetopause is the boundary between Earth's magnetic field and the magnetic fields of the interplanetary space around Earth. Electron acceleration is known to occur in the magnetotail region of the magnetosphere, but we have not yet seen it to these levels at the magnetopause. Onboard sensors captured the electrons being energized, as well as the simultaneous appearance of a type of plasma wave called chorus thought to play a fundamental role in accelerating electrons. Although these waves are known to interact with and energize lower-energy (<50 keV) electrons in the inner magnetosphere, we haven't yet seen this happen at the magnetopause.



This is data from 19 September 2016 from the MMS Fly's Eye Energetic Particle Spectrometer (FEEPS), Fast Plasma Investigation (FPI), and fluxgate magnetometers (FGM) instruments. The image above is an overview of the electron dynamics and magnetic field in the magnetopause during the event; the omni-averaged FEEPs energy spectrogram covering ~44 keV to 500 keV is shown in (a), the FPI electron energy spectrogram covering 10 ev to 30 keV is shown in (b) and the FGM magnetic field in GSM coordinates in is (c).

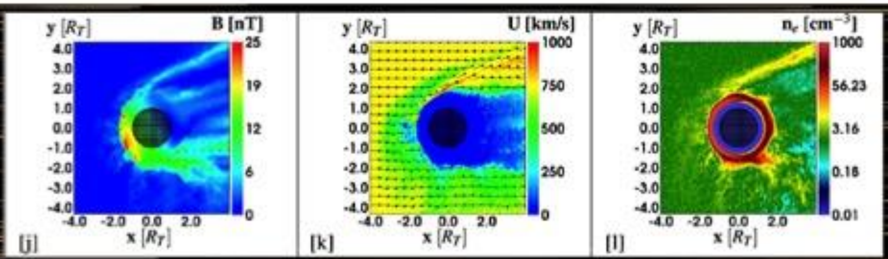
The paper proposes a possible explanation, drawing on a theory for lower-energy electron acceleration in the magnetotail. The first step occurs in the diffusion region of magnetic reconnection– an area where electron acceleration is known to occur. The second step is theorized to happen in the magnetic reconnection exhaust region. Based on these new observations, the researchers believe that magnetic reconnection plays a key and unique role in energizing high-energy particles we see in the inner magnetosphere. The result has implications for the occurrence and production rate of energetic electrons throughout near-Earth space under a wide variety of plasma conditions.

These new observations give us important clues into the relationship between electron acceleration and reconnection but we have much more to explore. The capabilities aboard MMS can provide us with opportunities to learn more about important characteristics such as current sheet thickness – something related to magnetic reconnection processes. And, because the spacecraft were launched in highly elliptical orbit formations designed to gather *in situ* plasma, electric and magnetic field measurements, the comprehensive, high-resolution data obtained can help us better understand plasma waves, such as the plasma chorus waves discussed above. We anticipate more exciting fundamental new plasma research findings and high impact results from the exquisite MMS data going forward.

Titan as a Natural Space Weather Station

On rare occasions, Titan's orbit takes it outside of Saturn's fluctuating magnetic environment, and on December 1, 2013, after 9 years in the Saturn system, Cassini observed Titan immersed in the supersonic solar wind.

- The observed interaction showed that Titan's interaction is similar to other unmagnetized planets, such as Mercury and Venus. However Titan's magnetosphere showed a more complex structure which was attributed partly to Titan's richer atmospheric chemistry.
- Modeling of the plasma environment around Titan indicated that the large-scale observed features could be described as a steady state interaction between the moon's ionosphere and the high-pressure solar wind flow.
- However, one of the more interesting observations was that Titan's ionosphere "remembered" its immersion in the solar wind in the form of "fossilized" magnetic fields. These fields are trapped in the ionosphere between 1000-1800km, and Cassini found that these preserved evidence of variations in space weather for nearly an hour after the moon crossed into the solar environment.
- The changes detected in Titan's ionosphere allowed scientists to reconstruct the solar wind at Saturn's distance, and this second-hand space weather report, courtesy of Titan, provides the first such measurement so far away from the sun. It is also the last opportunity for such a measurement, as the orbital dynamics in the remaining mission lifetime does not bring the Cassini spacecraft past Titan under these conditions again.



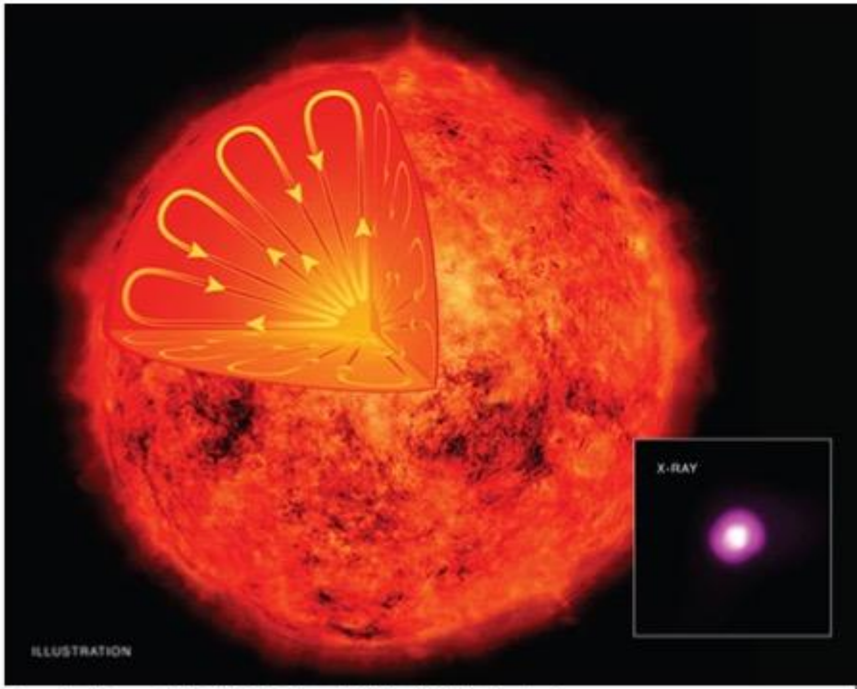
Plasma quantities of a model run in the gyroplane. Magnetic field magnitude (j), plasma bulk velocity (k), and electron number density (l). Arrows denote the projection of the respective vector field on the cutting plane.

Feyerabend, et al., *GRL* 2016 & Bertucci, et al., *GRL*, 2015.

Astronomers Gain New Insight into Magnetic Field of Sun and its Kin

A paper describing these results appeared in the July 28, 2016 issue of the journal Nature.

- Magnetic fields on the Sun and stars like it are responsible for much of their behavior, including the generation of powerful storms that can produce spectacular auroras on Earth, damage electrical power systems, knock out communications satellites, and affect astronauts in space. New research relying on data from NASA's Chandra X-ray Observatory is helping astronomers better understand how these magnetic fields are produced.
- By comparing the X-ray emission, an excellent indicator of a star's magnetic field strength, between low-mass stars and the Sun, a pair of astronomers was able to find an important clue about how stellar magnetic fields are generated.
- The Sun and stars with approximately the same mass have a divided internal structure with an inner radiation zone (energy moves outward) and an outer convection zone (the energy circulates). Stars with significantly lower masses, however, do not have such a differentiated structure. Instead, the process of convection is dominant throughout the star, which is depicted in the artist's illustration in the main panel of the graphic.
- The researchers in this latest study looked at four low-mass stars - two with Chandra and two with archival data from the ROSAT satellite - and found their X-ray emission was similar to that of stars like the Sun. (The inset in the graphic shows Chandra's data of one of these low-mass stars, GJ 3253).
- This result was surprising because many scientists think the boundary between the radiation and convection zones in the Sun and Sun-like stars contributes to the strength of its magnetic field. If stars without such a boundary have relatively powerful magnetic fields, then this theory may need to be re-examined.



Credit: X-ray: NASA/CXC/Keele Univ/N.Wright et al; Illustration: NASA/CXC/M.Weiss

Northwest Earth & Space Sciences Pipeline

- Northwest Earth & Space Sciences Pipeline (NASA Science education award) supported summer camps serving underserved and underrepresented populations in Washington, Montana, and Oregon
- While summer camps in urban areas are nothing new, having NASA-sponsored camps in rural areas has a major impact to these populations

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