National Aeronautics and
Space Administration

Science Mission Directorate

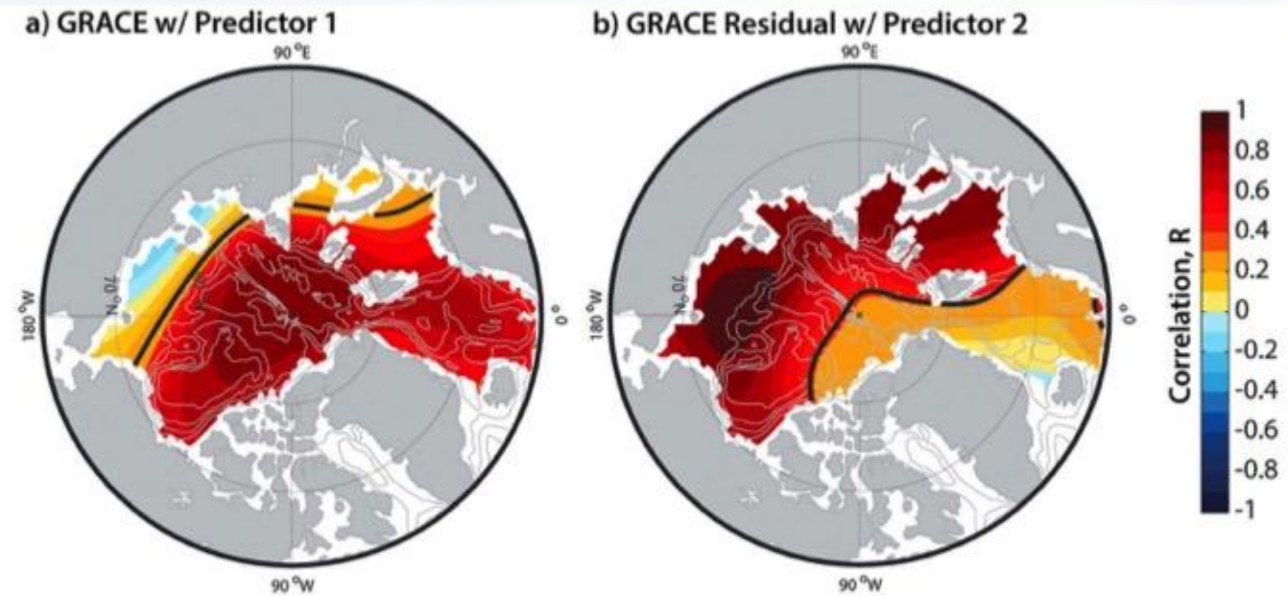
Weekly Highlights

October 21, 2016

Proxy Representation of Arctic Ocean Bottom Pressure Variability: Bridging Gaps in GRACE Observations

Peralta-Ferriz, C., Morison, J. H., & Wallace, J. M. | Geophysical Research Letters| October 2016 | doi:10.1002/2016GL070137

NASA funded scientists used time-varying ocean bottom pressure (OBP) measurements from NASA's Gravity Recovery and Climate Experiment (GRACE), a 9 year (2005-2015) in situ OBP record at the North Pole, and wind products from the NCEP/ NCAR reanalysis, to perform a linear regression analysis and identify primary predictor time series. The methodology enabled the study team to create a proxy representation of the Arctic time-varying OBP that explains the largest fraction of the observed Arctic OBP variability. After cross validation, two predictors, the North Pole OBP record and the wind-OBP coupling from maximum covariance analysis (MCA), were found to explain 50% of the total variance of the Arctic OBP. The study provides a means for bridging existing short gaps in GRACE measurements and potentially longer future gaps that may result if, for instance, GRACE and its follow-on mission do not overlap. Furthermore, despite the long-term scale limitations, the technique may be applicable to bridge gaps in GRACE observations in other oceanic regions.

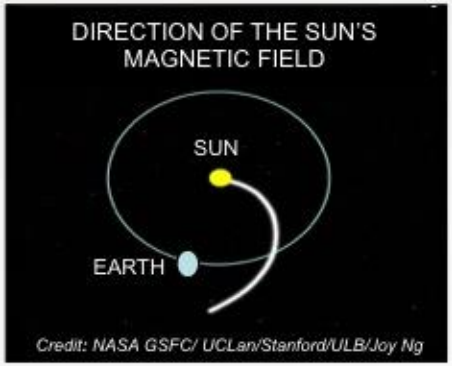


Above: Correlation maps of (a) GRACE OBP and North Pole OBP record (predictor 1) and (b) GRACE OBP minus what is correlated with predictor 1 (residual 1) and the wind OBP coupling through MCA (predictor 2).The black lines delimit the correlations that are significant above 95% confidence level.

Since 2002, the Gravity Recovery and Climate Experiment (GRACE) has contributed to understanding the Arctic environment by providing measurements of changes in mass distribution. Using Arctic ocean bottom pressure (OBP) observations from GRACE (2002 to 2011), scientists identified three primary modes of Arctic OBP variability that together explain about 80% of the total variance of the nonseasonal Arctic OBP. These modes are linked to patterns of the ocean circulation and are primarily forced by winds. Mass change in the Arctic Ocean is linked to effects of circulation variability as the Arctic system changes.

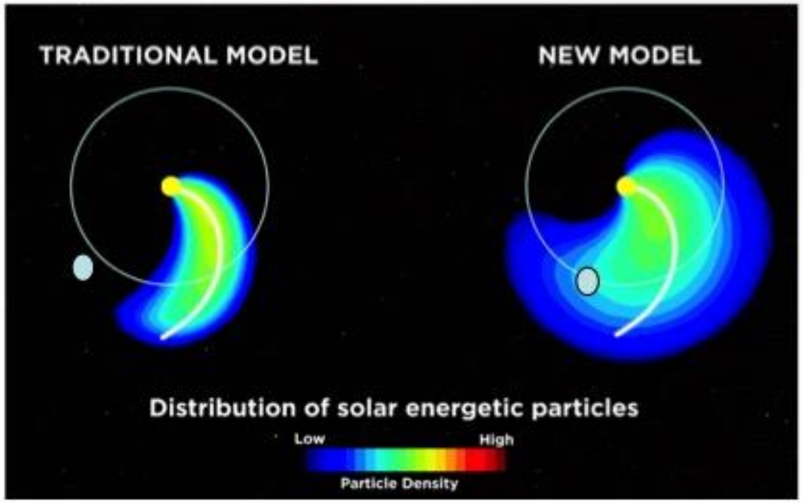
Wayward Field Lines Challenge Solar Physics Radiation Models

Laitinen, T.; Kopp, A.; Effenberger, F.; Dalla, S.; Marsh, M. S. (2016) SOLAR ENERGETIC PARTICLE ACCESS TO DISTANT LONGITUDES THROUGH TURBULENT FIELD-LINE MEANDERING. Astronomy & Astrophysics, Volume 591, id.A18, 9 pp. 10.1051/0004-6361/201527801



Solar energetic particles (SEPs) are a category of cosmic rays originating from the sun. They can be harmful to astronauts and can cause problems with operating spacecraft. An international team of scientists, funded in part by the NASA Heliophysics Supporting Research Program, recently authored a paper investigating the propagation of SEPs from the sun to Earth orbit. Scientists tend to distinguish SEP events as coming from either a localized solar flare source or from a much wider coronal mass ejection source. The authors of this study, in order to distinguish between these two possibilities for SEP origination, used the twin NASA/Heliophysics STEREO spacecraft and the ESA/NASA SOHO mission, which were widely distributed along Earth orbit. The data collected was then used as input for two particle propagation models. The observations showed that for many SEP events particles spread out so much that they covered much of Earth orbit. This begged the question as to what mechanism could send the particles so far in longitude away from the source location?

One of the propagation models seems to answer this question. It shows how particles could effectively spread out far away from the source longitude, independent even of the type of event they originate from. Previous models assumed the particles mainly follow the magnetic field lines on their way from the sun to Earth, leading to slowly spreading out in longitude over time. Note that the average field line follows a simple, spiral-shaped path as a consequence of the sun's rotation. The new model, however, takes into consideration that magnetic field lines can wander – a result of near-sun turbulence in the solar wind. The figure shows a comparison of the old, narrow spread of particles (left) and much wider spread of SEPs (right) that in this scenario would reach Earth. **The difference is critical to understand, as it would form a basis for being able to predict whether Earth's space environment is in the path of a radiation storm.**



These images compare the two models for particle distribution. The white line represents a magnetic field line, the general path that the SEPs follow, and the colors show the distribution of particles within just three hours after an SEP event. The line starts at an SEP event at the sun, and leads the particles in a spiral away from the sun. The updated model, on the right, depicts a static field line, but as the SEPs travel farther in space, turbulent solar material causes wandering field lines. In turn, wandering field lines cause the particles to spread much more efficiently than the traditional model, on the left, predicted.

Understanding the nature of SEP propagation and transport in the solar wind helps scientists as they continue to investigate the origins of high-energy SEPs. This study is summarized in a paper published in *Astronomy and Astrophysics* on June 6, 2016.

A Surprisingly Young Region in Saturn's Rings

Chunks of solid ice in the middle of Saturn's A ring suggest an unexpectedly young ring region.

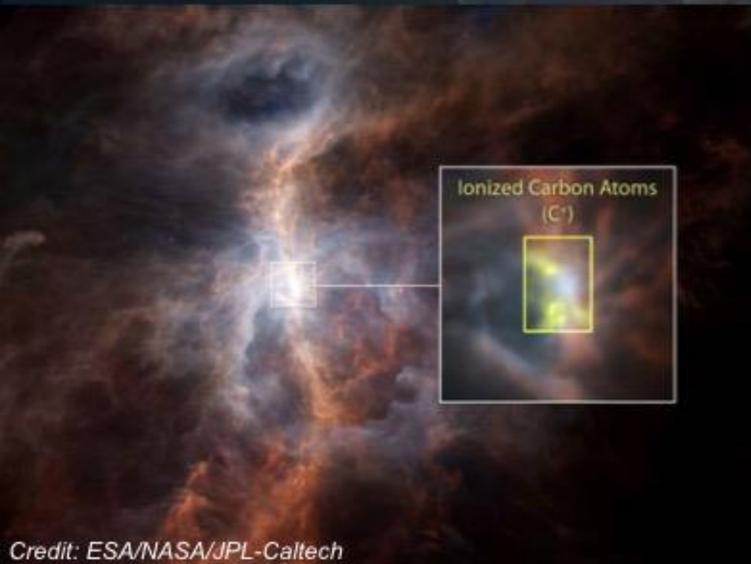
- Recent results from Cassini's infrared spectrometer found that particles in one section of Saturn's rings are much denser than the normal ring particles elsewhere.
- After equinox, when the sun shines edge-on to Saturn's rings, one section of the A-ring did not cool down as much as expected, providing a unique window into the interior of the ring particles.
- Perhaps a tiny moon broke apart only 100 million years ago and its solid, icy fragments are slowly spreading through the rings.

Saturn's rings may therefore be a mix of young and old material, providing clues to their formation and evolution.

Above: Model of Saturn's rings showing both small and large particles.
Below: Estimated location in A ring of denser particles.

Morishima, et al., Icarus, 279, 2-19, 2016. doi:j.icarus.2015.06.025

Building Blocks of Life's Building Blocks Come From Starlight



The dusty side of the Sword of Orion is illuminated in this IR image from ESA's Hershel Space Observatory. Within the inset image, the emission from ionized carbon atoms (C+) is overlaid in yellow.

- Life exists in a myriad of wondrous forms, but if you break any organism down to its most basic parts, it's all the same stuff: carbon atoms connected to hydrogen, oxygen, nitrogen and other elements. But how these fundamental substances are created in space has been a longstanding mystery.
- Now, astronomers better understand how molecules form that are necessary for building other chemicals essential for life. Thanks to data from ESA's Herschel Space Observatory, with mission-enabling technology from NASA, scientists have found that ultraviolet light from stars plays a key role in creating these molecules.
- Scientists studied the ingredients of carbon chemistry in the Orion Nebula, the closest star-forming region to Earth that forms massive stars. They mapped the amount, temperature and motions of the carbon-hydrogen molecule (CH), the carbon-hydrogen positive ion (CH+) and their parent: the carbon ion (C+).
- On Earth, the sun is the driving source of almost all the life on Earth. Scientists have now learned that starlight drives the formation of chemicals that are precursors to chemicals that we need to make life.
- In the early 1940s, CH and CH+ were two of the first three molecules ever discovered in interstellar space. In examining molecular clouds -- assemblies of gas and dust -- in Orion with Herschel, scientists were surprised to find that CH+ is emitting rather than absorbing light, meaning it is warmer than the background gas. The CH+ molecule needs a lot of energy to form and is extremely reactive, so it gets destroyed when it interacts with the background hydrogen in the cloud. Its warm temperature and high abundance are quite mysterious.
- Why is there so much CH+ in molecular clouds such as the Orion Nebula? Many studies have tried to answer this question, but their observations were limited because few background stars were available for studying. Herschel probes an area of the electromagnetic spectrum -- the far infrared, associated with cold objects -- that no other space telescope has reached before, so it could take into account the entire Orion Nebula instead of individual stars within.
- One of the leading theories about the origins of basic hydrocarbons has been that they formed in "shocks," events that create a lot of turbulence, such as exploding supernovae or young stars spitting out material. Areas of molecular clouds that have a lot of turbulence generally create shocks. Shock waves cause vibrations in material they encounter. Those vibrations can knock electrons off atoms, making them ions, which are more likely to combine. But the new study found no correlation between these shocks and CH+ in the Orion Nebula.
- Herschel data show that these CH+ molecules were more likely created by the ultraviolet emission of very young stars in the Orion Nebula, which emit ultraviolet light. When a molecule absorbs a photon of light, it becomes "excited" and has more energy to react with other particles. In the case of a hydrogen molecule, the hydrogen molecule vibrates, rotates faster or both when hit by an ultraviolet photon. It has long been known that the Orion Nebula has a lot of hydrogen gas. When ultraviolet light from large stars heats up the surrounding hydrogen molecules, this creates prime conditions for forming hydrocarbons. As the interstellar hydrogen gets warmer, carbon ions that originally formed in stars begin to react with the molecular hydrogen, creating CH+. Eventually the CH+ captures an electron to form the neutral CH molecule.
- Scientists combined Herschel data with models of molecular formation and found that ultraviolet light is the best explanation for how hydrocarbons form in the Orion Nebula.

2017 Destinations for Girl Scouts Selected: Total Solar Eclipse and Astronomy Camp

Total Eclipse of the Heartland: Trip to the St. Louis Science Center, Challenger Learning Center, and Zoo in St. Louis, MO and then total eclipse viewing in Carbondale IL! August 18-21, 2017

The Great Eclipse Adventure: STEM immersion at University of Missouri, Columbia with women professors and students, plus total eclipse observing at a regional Girl Scout camp! August 19-21, 2017

Eyes to the Sky — A Once in a Lifetime Destination: A total solar eclipse weekend in the Blue Ridge Mountains of South Carolina! Visit science center, observatory, and observe the eclipse from a Girl Scout Camp on the centerline! August 19-22, 2017

Astronomy Camp—University of Arizona: An adventure in scientific exploration at mountaintop telescopes at the Catalina Observatories atop scenic Mt. Lemmon in southern Arizona. Girls explore the sky both day and night, creating their own observations and images. June 30, 2017-July 4, 2017

Girl Scout Destinations are the ultimate adventure for individual girls ages 11 and older! Girls make friends from all over the country as they travel with Girl Scouts from different states and pack their bags full of inspiring, life-changing experiences. Current Girl Scouts, or any interested girl can contact her local Girl Scout Council to apply! **http://forgirls.girlscouts.org/travel/take-a-trip/destinations/**