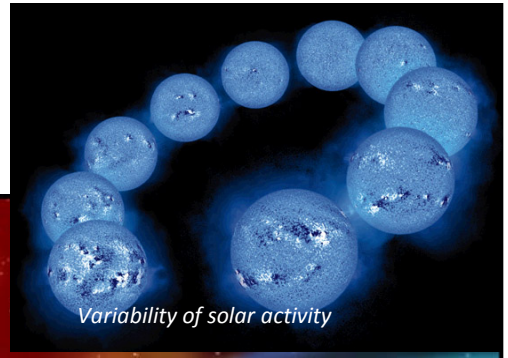
Variability of the Sun and Its Terrestrial Impact
VarSITI

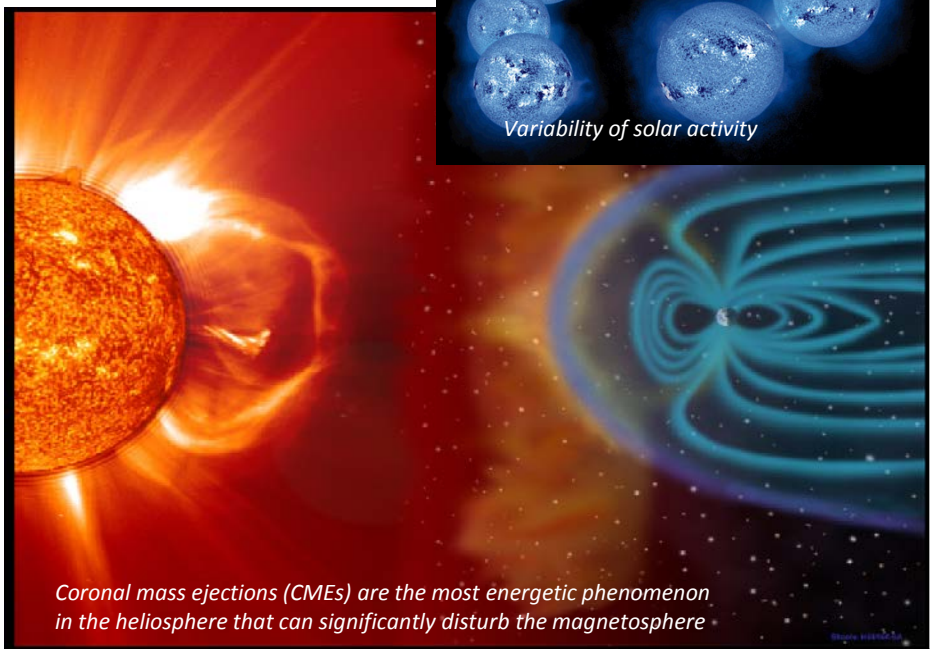
SCOSTEP is an ICSU Interdisciplinary Body tasked with the responsibility to organize long-term scientific programs in solar terrestrial physics and *Variability of the Sun and Its Terrestrial Impact (VarSITI)* is that program for the period 2014 – 2018. VarSITI was defined based on a community effort in the form of a forum organized by the International Space Science Institute (ISSI) in Bern in May 2013. The VarSITI program will strive for international collaboration in data analysis, modeling, and theory to understand how the solar variability affects Earth. The VarSITI program will have four scientific elements that address solar-terrestrial problems keeping the current low solar activity as the common thread:

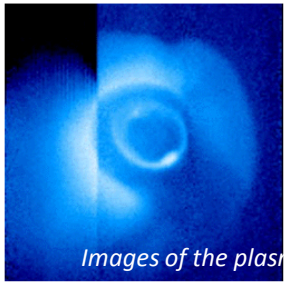
1) **SEE (Solar evolution and Extrema)**
2) **ISEST (International Study of Earth-affecting Solar Transients/MiniMax24)**
3) **SPeCIMEN (Specification and Prediction of the Coupled Inner-Magnetospheric Environment), and**
4) **ROSMIC (Role Of the Sun and the Middle atmosphere/ thermosphere/ionosphere In Climate).**

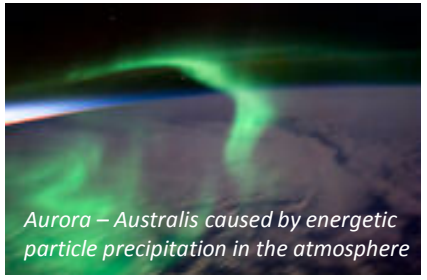
VarSITI Co-Chairs:

Prof. Katya Georgieva, Bulgaria
Prof. Kazuo Shiokawa, Japan


Variability of solar activity


Coronal mass ejections (CMEs) are the most energetic phenomenon in the heliosphere that can significantly disturb the magnetosphere


Images of the plasmasphere


Aurora – Australis caused by energetic particle precipitation in the atmosphere

Solar Evolution and Extrema (SEE)

Are we at the verge of a new grand minimum ?

Project Co-Leaders:

Prof. Petrus C Martens, Montana State University, USA
Prof. Dibyendu Nandi, Indian Institute of Science Education and Research, Kolkata, India
Prof. Vladimir N. Obridko, IZMIRAN, Moscow, Russia

Goals & Objectives:

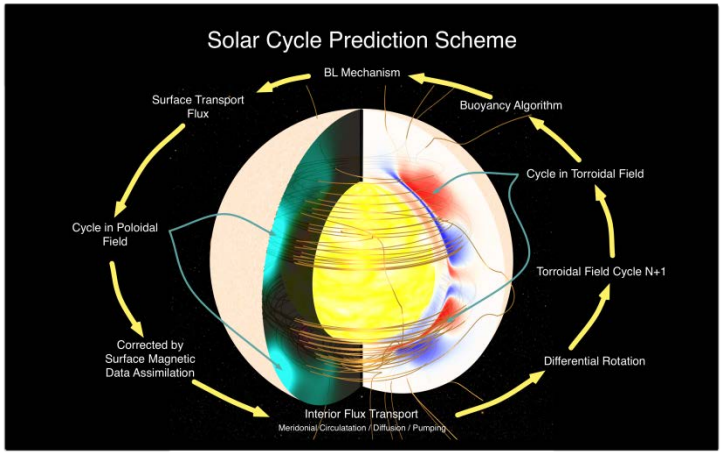
1) Reproduce magnetic activity as observed in the Sunspot record, including grand minima and extended minima in dynamo simulations,
2) Amalgamate the best current models and observations for solar spectral and wind output over the Earth's history,
3) Determine the size and expected frequency of extreme solar events.

Science Questions:

1) Are we at the verge of a new grand minimum? If not, what is the expectation for cycle 25?
2) Does our current best understanding of the evolution of solar irradiance and mass loss resolve the "Faint Young Sun" problem? What are the alternative solutions?
3) What is the largest solar eruption/flare possible? What is the expectation for periods with absence of activity?

Anticipated Outcome:

1) Dynamo Models for the near future or for an upcoming grand minimum,
2) A timeline of solar activity -- spectral radiation, wind - from the Earth's formation up to the present,
3) A frequency distribution and likelihood prediction of extreme events.



International Study of Earth-affecting Solar Transients/MiniMax24 (ISEST)

Can we predict the impact of solar transients on space weather?

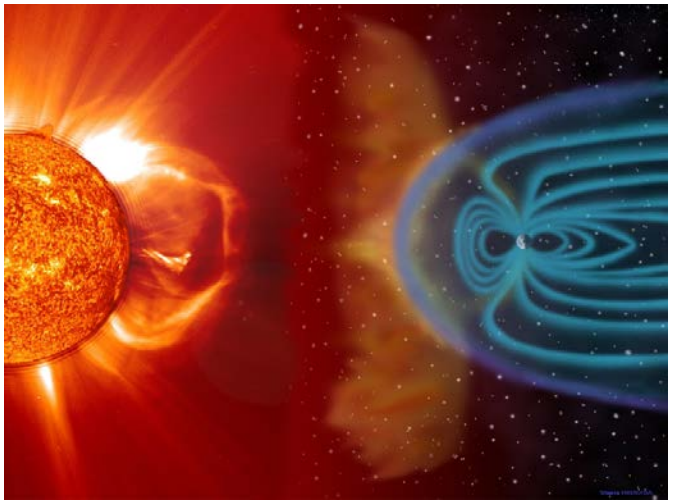
Project Co-Leaders:

Prof. Jie Zhang, George Mason University, USA
Prof. Manuela Temmer, University of Graz, Austria
Dr. Nat Gopalswamy, USA

Goals & Objectives: Understand the origin, propagation and evolution of solar transients through the space between the Sun and the Earth, and develop the prediction capability of space weather.

1) Carry out campaign study to integrate theory, simulations and observations in order to get a complete view and understand of the chain of cause-effect activities from the Sun to the Earth.
2) Use observations to Identify all Earth-affecting flares, CMEs, SEPs and CIRs during the STEREO era and their solar sources.
3) Use theoretical studies and numerical simulations to understand the structure, evolution and dynamics of CMEs and the global context of transient events.
4) Carry out campaign study to integrate theory, simulations and observations in order to get a complete view of the chain of cause-effect activities from the Sun to the Earth.

Science Questions: How do coronal mass ejections (CMEs) and corotating interaction regions (CIRs) propagate and evolve, drive shocks and accelerate energetic particles in the heliosphere?



Data/theory/modeling: Establish a database of Earth-affecting solar transient events including CMEs, CIRs, flares, and energetic particle events based on remote sensing and in-situ observations from an array of spacecraft, run observation campaigns such as MiniMax24, develop empirical, theoretical, and numerical models of CME propagation and prediction, validate models using observations.

Anticipated outcome: A comprehensive database of Earth-affecting solar transients will be created, and space weather prediction capability will be significantly improved. A significant improvement of space weather prediction to forecast the arrival time and expected intensity of solar transients.

Specification and Prediction of the Coupled Inner-Magnetospheric Environment (SPeCIMEN)

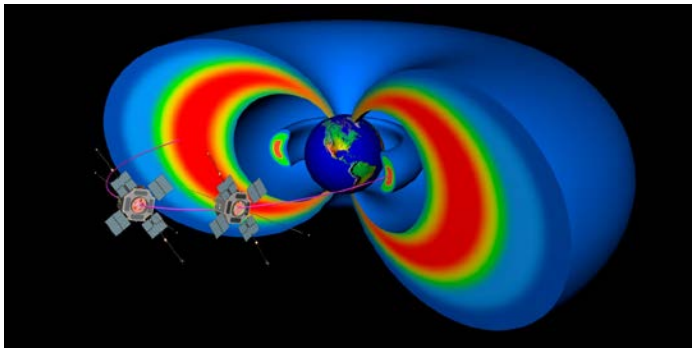
What is the physics behind radiation belt electron flux dynamics to enable the development of predictive models?

Project Co-Leaders:

Dr. Jacob Bortnik, University of California, Los Angeles USA

Prof. Craig J. Rodger, University of Otago, New Zealand

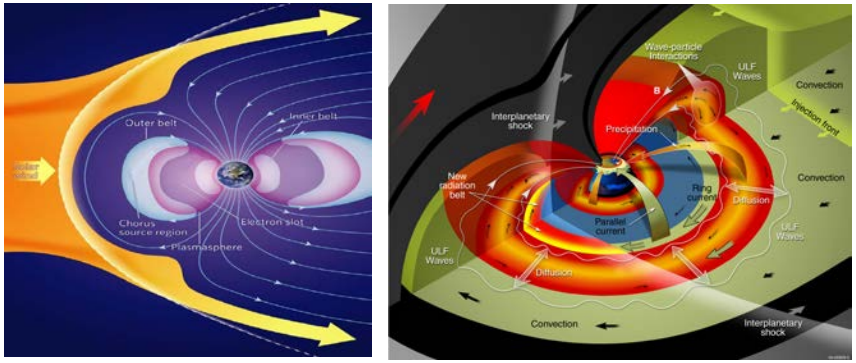
Goals & Objectives: The quantitative prediction and specification of the Earth's inner magnetospheric environment based on Sun/solar wind driving inputs.



The SPeCIMEN project is particularly timely given the recent launch of NASA's Van Allen Probes, the most recent mission to investigate the physical processes that control the dynamical behaviour of the Earth's radiation belts, eponymously named after its discovered, Prof. James Van Allen. During the 5-year VarSITI programme multiple additional satellites are expected to be launched, providing a constellation of spacecraft focused on the inner magnetosphere.

Science Questions:

Can the state of the Earth's inner magnetosphere be specified and predicted to high accuracy, based on inputs from the Sun and solar wind?



A schematic of the inner magnetosphere, showing the high velocity solar wind impinging upon the Earth's magnetic field (yellow, left), compressing it, and flowing around the boundary forming the magnetopause. Closer to the Earth are pictured regions of high energy electrons in two distinct zones of radiation (inner belt, outer belt, and slot region separating them), the cool, high-density plasma region known as the plasmasphere, and a region dominated by an electromagnetic wave known as chorus. The formation of the radiation belts is an active area of research which is intimately coupled with the dynamics of the solar wind, plasmasphere, and chorus region.

Anticipated Outcome: A series of coupled, related models that quantitatively predict the dynamical evolution of the inner magnetospheric state (radiation belts, ring current, cold plasma distribution, plasmasheet, convection electric field, and so on).

Role Of the Sun and the Middle atmosphere/thermosphere/ionosphere In Climate (ROSMIC)

What influence does Solar Forcing have on Climate and Weather?

Project Co-Leaders:

Prof. Dr. Franz-Josef Lübken, Leibniz Institute of Atmospheric Physics, Germany

Dr. Annika Seppälä, Finnish Meteorological Institute, Finland

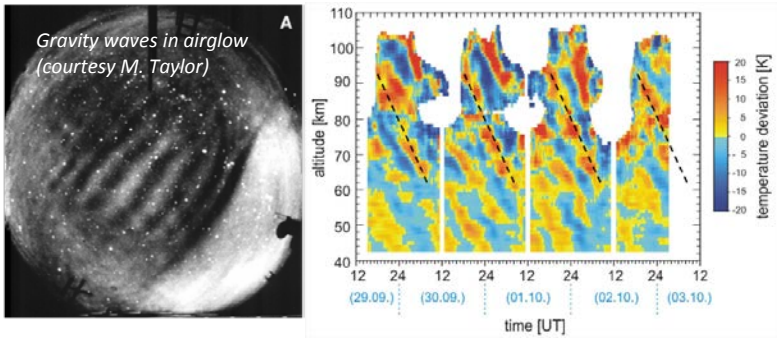
Prof. William E. Ward, University of New Brunswick, Canada

Goals & Objectives: To understand the impact of the Sun on the terrestrial middle atmosphere/lower thermosphere/ ionosphere (MALTI) and Earth's climate and its importance relative to anthropogenic forcing over various time scales from minutes to centuries.

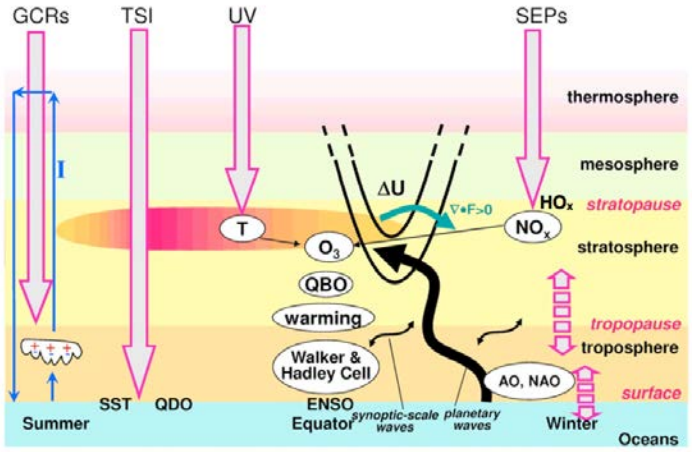
Science Questions:

1) What is impact of solar forcing of the entire atmosphere? What is the relative importance of solar irradiance versus energetic particles?
2) How is the solar signal transferred from the thermosphere to the troposphere?
3) How does coupling within the terrestrial atmosphere function (e.g. gravity waves and turbulence).
4) What is the impact of anthropogenic activities on the Middle Atmosphere, Lower Thermosphere, Ionosphere (MALTI)?
5) What are the characteristics of reconstructions and predictions of TSI and SSI?
6) What are the implications of trends in the ionosphere/ thermosphere for technical systems such as satellites.

Anticipated Outcome: The development of a better understanding of the impact of solar activity on the entire atmosphere, relative to anthropogenic forcing and natural long term variability.



Gravity waves in temperature (Courtesy of IAP, Kühlungsborn)



Mechanisms of Solar Influence (after Gray et al, 2010).