Utility of Heliophysics Scientific Research Missions for Enabling Space Weather Prediction: NASA Update

Solve fundamental mysteries of Heliophysics
Understand the nature of our home in space
Build the knowledge to forecast space weather throughout the heliosphere

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Lead Scientist, Living with a Star
Heliophysics Division, NASA HQ

17th April 2013

Boulder, CO

Heliophysics Press Highlights

Heliophysics Recent Accomplishments

- NRC Release of Decadal Survey August 15, 2012
- RBSP launch on August 30, 2012. Renamed to "Van Allen Probes" after successful commissioning.
- Explorer full mission & MoO (ITM) selection announcement on 12th April.
- Congressional Testimony on November 28, 2012 to the House Subcommittee on Space and Aeronautics - National Priorities for Solar and Space Physics Research and Applications for Space Weather Prediction - http://science.house.gov/hearing/subcommittee-space-and-aeronautics-national-priorities-solar-and-space-physics-research-and
- Senate Commerce, Science and Transportation Subcommittee on Science and Space Holds Hearing on Assessing Space Threats which included space weather (March 20, 2013).
- Release of NRC Workshop Report: The Effects of Solar Variabili on Earth's Climate -http://www.nap.edu/catalog.php?record_id
- NASA / NSF collaboration on space weather modeling
- Introduction to Heliophysics (science of space weather) in a dedicated session at AMS, 2013.

Excerpts from the Heliophysics Testimony

From acting chair Mr. Palazzo

…..Our hearing today will focus on the incredible work being accomplished by NASA's Heliophysics Division and on the important operational aspect this research has for space weather prediction at NOAA.

NASA has developed and launched a broad network of spacecraft that allow researchers to better understand the Earth-Sun system. Their findings are used daily to help preserve our technological infrastructure by allowing system operators to better react to variations of the Sun. Building our knowledge in this field is essential for maintaining our way of life on Earth as well as for improving the capability of enabling human exploration beyond the protection of Earth's atmosphere and magnetosphere.

Together with a ground-based infrastructure of solar telescopes managed by the National Science Foundation, NASA and NOAA coordinate critical measurements into useable models that predict how space weather will affect our satellites, electric power grid, airline operators, and more…..

From member Ms. Edwards

…..And Mr. Chairman, I'd be remiss if I didn't mention the budgetary challenges for this research and a crunched budget environment, there are significant implications for our society if we don't continue and expand research in this area. We need to protect these R&D investment, our assets, our quality of life, and our economic strength as a nation depend on this research…..

Decadal Survey Research Recommendations

Assumes the Heliophysics budget grows from $650M to $750M by 2024

Recommendations	Science	Cost
Complete the current Program	Support the existing program elements that constitute the Heliophysics Systems Observatory (HSO) and complete missions in development (RBSP, IRIS, MMS, SOC, SPP).	Assumes no cost growth for any of these elements
DRIVE (Diversify, Realize, Integrate, Venture, Educate)	Strengthen observational, theoretical, modeling, and technical advances with additional R&A capabilities: small satellites; MO&DA funding, science centers and grant programs; instrument development	Program rebalance: move up to $40M/yr into Research
Accelerate and expand Heliophysics Explorer Program	Launch every 2-3 years, alternating SMEX & MIDEX with continuous Missions of Opportunity.	Program rebalance: move$70M/yr into Explorers
Restructure STP line as a moderate scale, PI-led flight program. Implement three mid-scale missions.	Mission 1: Understand the interaction of the outer heliosphere with the interstellar medium; includes L1 space weather observations Mission 2: Understand how space weather is driven by lower atmosphere weather. Mission 3: Understand how the magnetosphere-ionosphere-thermosphere system is coupled and responds to solar forcing.	$520M per mission in FY12$; launches in 2021, 2025, 2029
Start another LWS mission by the end of the decade.	Mission 4: Study the ionosphere-thermosphere-mesosphere system in an integrated fashion.	$1B mission, Launch 2024

Notes: 1) Recommendations listed above are top level, each contains a number of sub-elements
2) Recommendations are listed in priority order, pending budget constraints
3) Recommendations are separable by Agency, only NASA Recommendations are listed here

NASA Heliophysics Roadmap: Spring 2013

- **Decadal Survey provides a strategic framework for all of solar and space physics**
  - Advice on the state of the field, the most compelling science challenges, the highest priority science targets for future missions and a recommended strategy to achieve the science goals

- **Roadmap will provide guidance for NASA's tactical implementation responding to the decadal recommendations**
  - Develop a clear science traceability throughout NASA heliophysics programs.
  - Align the science strategy developed by the Decadal with the Heliophysics Program over the next 10 years and extend the strategy out to 2033
  - Develop the technology requirements not just for the coming decade, but for longer term.
  - Follow the 2009 Roadmap paradigm of presenting a science priority with a flexible mission implementation approach consistent with the current (FY13) budget profile

- **Role of NASA Advisory Council Heliophysics Subcommittee (HPS) in Roadmap**
  - Provides direct oversight, dialog, and review of the Roadmap process
  - Delivers the Roadmap to the Science Committee of the NASA Advisory Council

The Effects of Solar Variability on Earth's Climate: A NRC Workshop Report: Research Rationale

- "… no satellite measurements have indicated that solar output and variability have contributed in a significant way to the increase in global mean temperature in the last 50 years. Locally, however, correlations between solar activity and variations in average weather may stand out beyond the global trend; such has been argued to be the case for the El Niño-Southern Oscillation, even in the present day."

- Understanding the significance and magnitude of apparent multi-decade to multi-century Sun-climate couplings is very important. We need to identify the mechanism(s) by which solar magnetic activity (1) drives weak but significant changes in Earth global climate as well as (2) forces measurable impacts in some present-day regional climates (such as the El Niño/La Niña cycle).

- Understanding the impact of solar activity on climate provides climate modelers with a multi-century pre-industrial baseline for comparison with industrial-era changes, and provides solar-heliospheric physicists with multi-century proxies of solar activity in addition to currently available cosmogenic radionuclide measurements.

The Effects of Solar Variability on Earth's Climate: A NRC Workshop Report: Research Needs

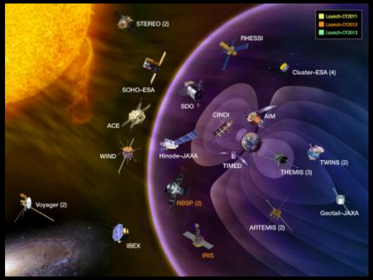
- Understanding of apparently significant long-term Sun-climate couplings and current regional impacts requires
  - improved absolute calibration of the observed total solar irradiance, and
  - establishment of multi-decade records of the solar spectral irradiance, leading to
  - extension of the TSI and SSI components into to pre-instrumentation past by:
    - utilization the solar-stellar connection to expand the knowledgebase for possible solar variability patterns on time scales of years to decades.
    - improved understanding of the various climate proxies to create a uniform global climate history.
    - understanding how to translate empirical proxies of solar activity (such as cosmogenic radionuclides and historically-recorded sunspot numbers) into solar spectral irradiance (via heliospheric modulation of galactic cosmic rays and photospheric flux distributions of spots and faculae).
    - understanding differential impact of distinct parts of the solar spectral irradiance on different parts of the Earth's regional climates and ocean circulation system.
  - With multi-century TSI and SSI data and heliospheric wind and field models in hand, attribution studies can be performed
    - to differentiate between irradiance and cosmic-ray effects, and

Objectives and Programs

Strategic Objective: Understand the sun and its interactions with Earth and the solar system

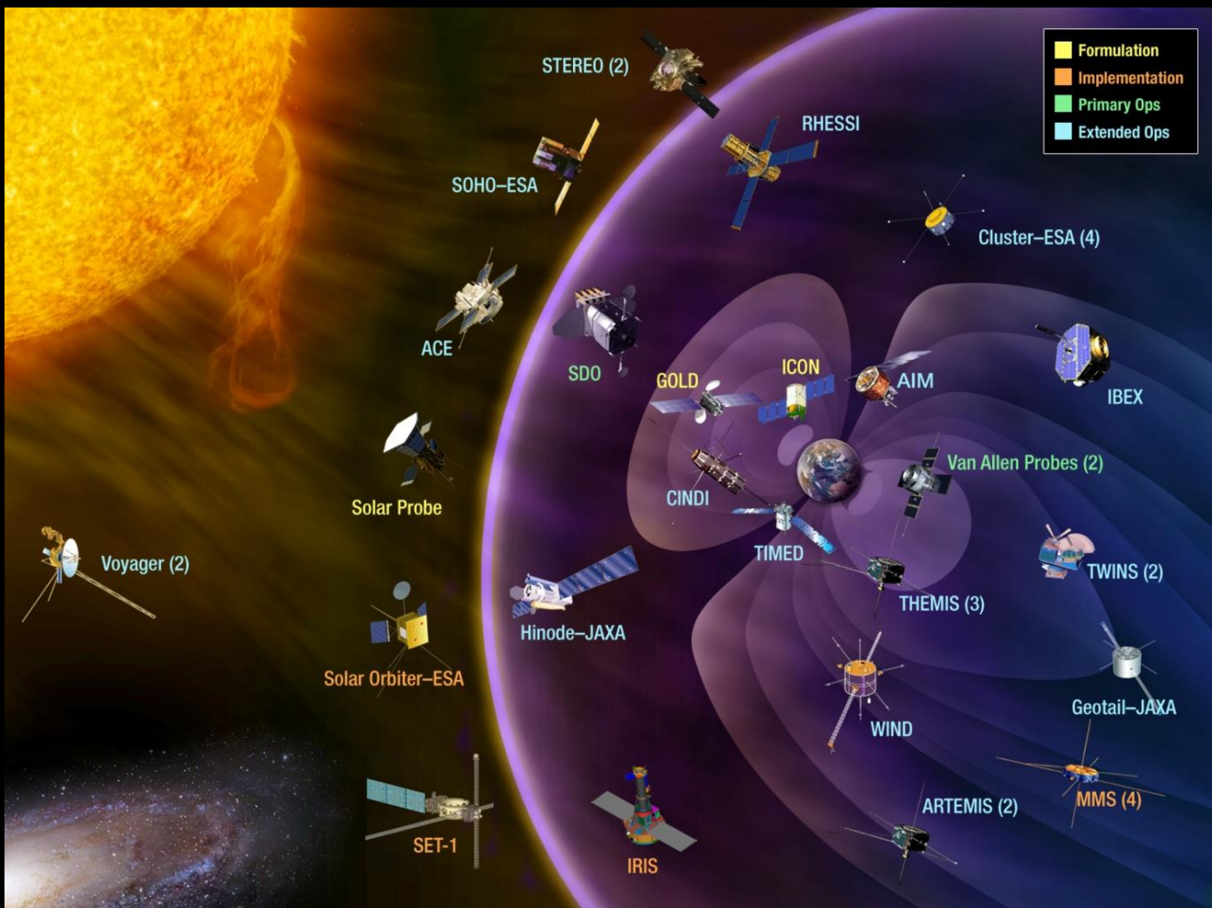
Explore the physical processes in the space environment from the sun to the Earth and throughout the solar system

Advance our understanding of the connections that link the sun, the Earth and planetary space environments, and the outer reaches of our solar system.



Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Heliophysics System Observatory (HSO)



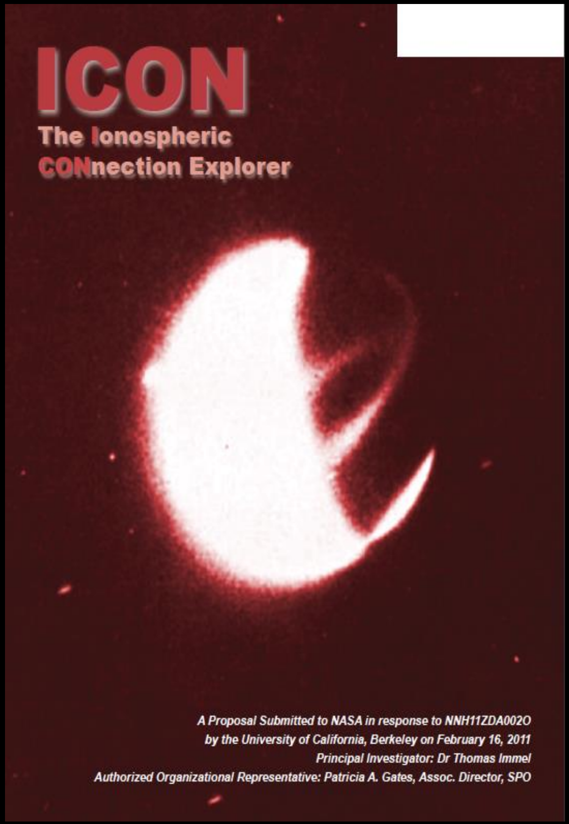
heliospheric, geospace, and planetary spacecraft as a distributed observatory to discover the larger scale and/or coupled processes at work throughout the complex system that makes up our space environment.

HSO consists of 18 operating missions: Voyager, Geotail, Wind, SOHO, ACE, Cluster, TIMED, RHESSI, TWINS, Hinode, STEREO, THEMIS, AIM, CINDI, IBEX, SDO, ARTEMIS, Van Allen Probes

Adding New selections: ICON, GOLD

Ionospheric Connection Explorer

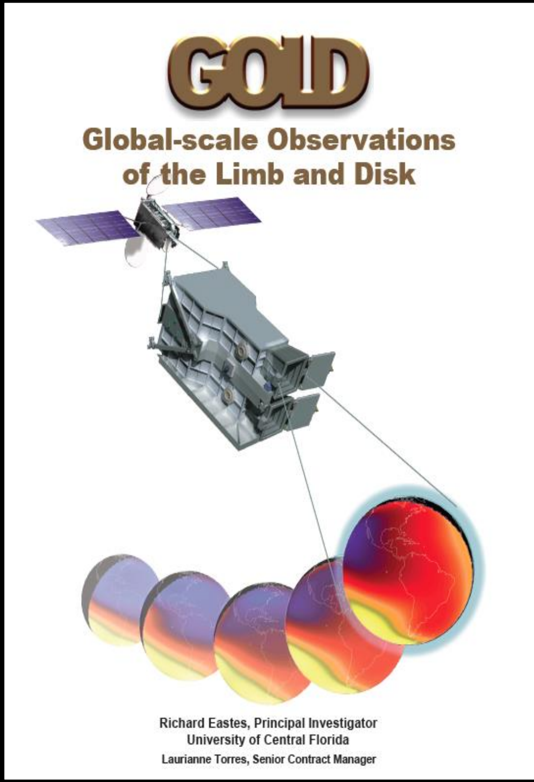
Neutral-Ion Coupling in the Upper Atmosphere



- Ionospheric Connection Explorer (ICON) - Thomas Immel, Principal Investigator (PI), University of California, Berkeley –
- ICON will explore the boundary between Earth and space – the ionosphere – to understand the physical connection between our world and the immediate space environment around us. This region, where ionized plasma and neutral gas collide and react exhibits dramatic variability that affects space-based technological systems like GPS.
- The ionosphere has long been known to respond to “space weather” drivers from the sun, but recent NASA missions have surprised us in showing this variability often occurs in concert with weather on our planet. ICON will compare the impacts of these two drivers as they exert change on the space environment that surrounds us.

ICON is a single s/c traveling eastward and continuously imaging the thermosphere and ionosphere.

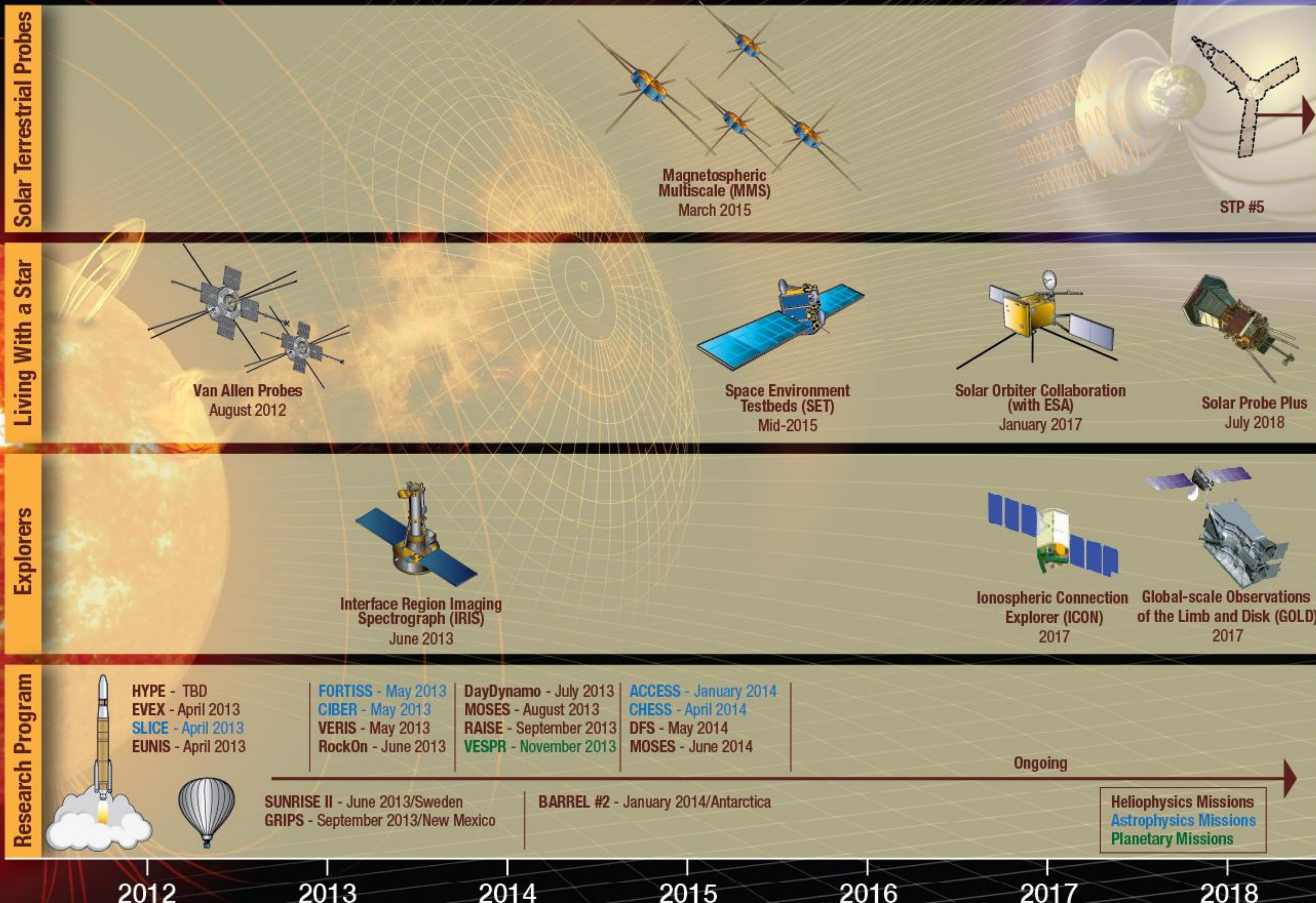
Global-scale Observations of the Limb and Disk (GOLD)



How ionosphere-thermosphere responds to geomagnetic storms, solar radiation, and upward propagating tides

- Global-scale Observations of the Limb and Disk (GOLD) - Richard Eastes (PI), University of Central Florida. This instrument will fly on a commercial communications satellite from SES-GS.
- This Mission of Opportunity would fly an ultraviolet (UV) imaging spectrograph on a geostationary satellite to measure densities and temperatures in Earth's thermosphere and ionosphere. The goal of the investigation is to address an overarching question in heliophysics science: What is the global-scale response of the thermosphere and ionosphere to geomagnetic storms, solar radiation, and forces from the lower atmosphere?
- Measurements from GOLD will be used, in conjunction with sophisticated models of the terrestrial thermosphere and ionosphere, to revolutionize our understanding of the space environment.

Heliophysics Program 2013-2018



NASA Roles In Space Weather Infrastructure

Internal to NASA

Research:
- Living With a Star, Solar Terrestrial Probes, Explorer Flight Programs
- Community Coordinated Modeling Center
- LWS TR&T Program
- Online Integrated Space Weather Analysis System

Operations:
- Tracking and Data Relay Satellite System
- Robotic and Air Fleet
- Nowcast of Atmospheric Ionizing Radiation System (LRC)
- Space Radiation Analysis Group(JSC): Models, EVA, ISS Drag

Engineering:
- Design and Specification
- Models (GSFC/MSFC/JPL)

National

Research:
- GIC Forecast Model
- SEP Forecast Model
- Interplanetary CME model
- NASA/NSF Partnership 4.2 M/year effort of strategic capability to fill gaps and develop end to end space weather models.

Operations:
- Real-time Beacon Data
- SDO and STEREO Near Real-time Data
- Space Weather Theory, Data, Models (available online)

Governance:
- Committee on Space Weather: (NOAA, NASA, NSF, DoD, + 7 others)
- National Space Weather Program Council
- Unified National Space Weather Capability

International

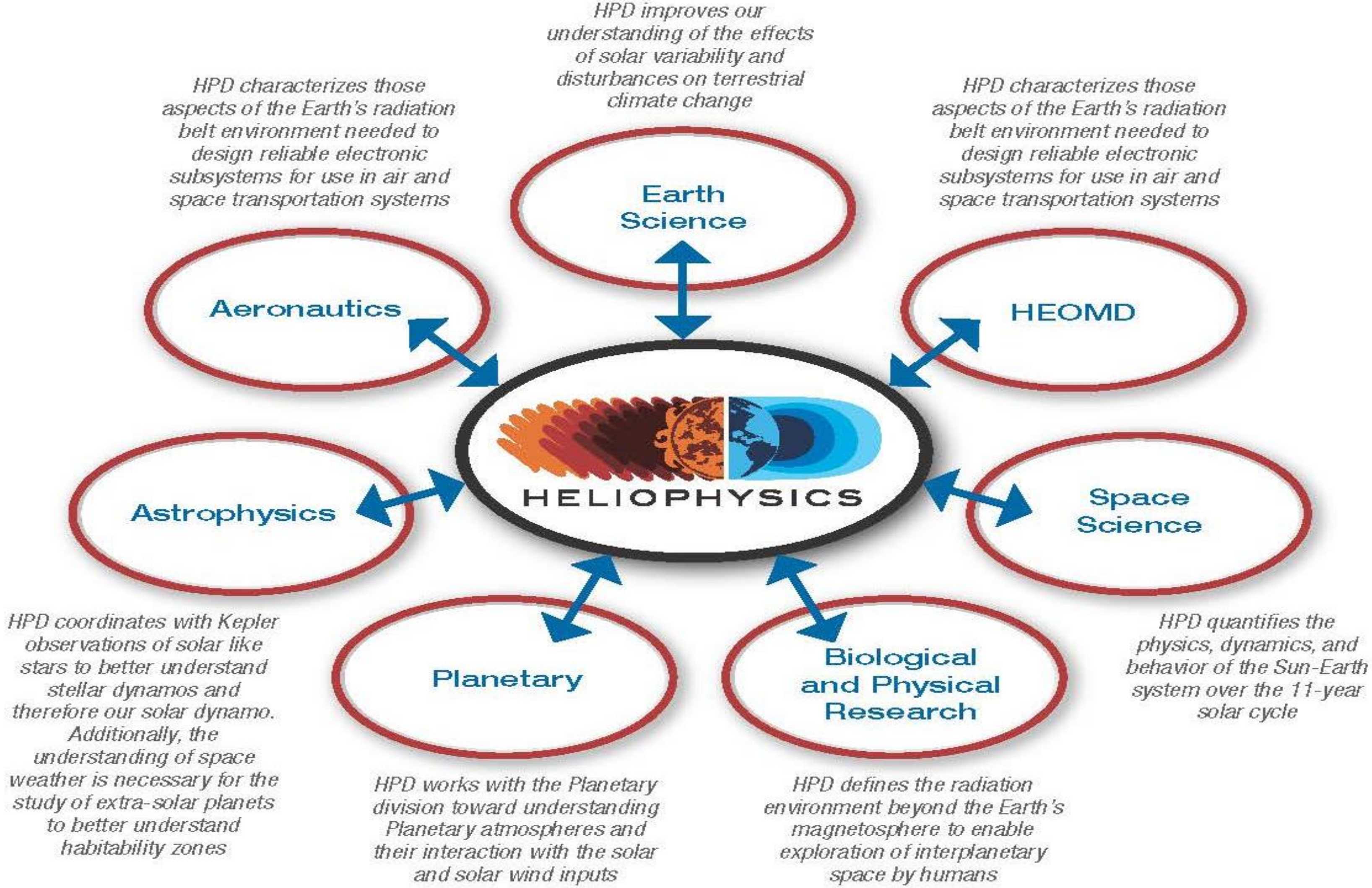
Research:
- International Living With a Star Program
- United Nations / Committee on the Peaceful Uses of Outer Space

Operations:
- International Space Weather Initiative: Instrument Deployment, Data Analysis, and Modeling

Bilateral Agreements:
- Korea and Brazil (anticipated)

Consultation:
- ESA, Sweden, United Kingdom, Germany, and France

Heliophysics Coordination with HEOMD, Earth, Planetary, and Astrophysics



Examples of Heliophysics Coordinated Observations:

- *Astro to Helio – Kepler*
- *HEOMD to Helio – MSL/RAD*
- *Earth to Helio – SORCE, ACRIMSAT*
- *Helio to Earth – TIMED, AIM, SDO/EVE*
- *Helio to Planetary – ARTEMIS*
- *Planetary to Helio – Juno, MAVEN, Messenger, MSL, LADEE, LRO, Cassini*

Jack Eddy Postdoctoral Fellowship Program

Application deadline 11 January 2013

www.vsp.ucar.edu/Heliophysics

- Established 2009 to train the next generation of researchers needed for the emerging field of heliophysics
- 9 postdoctoral fellows were awarded two-year appointments as of December 2012

Nicholas

Maria Spasojevic
Stanford University

Narayan Chapagain

Jonathan Makela
University of Illinois

King-Fai Li

Ka-Kit Tung
University of Washington

Andres Munoz-Jaramillo

Edward DeLuca
Harvard-Smithsonian Center for Astrophysics

Kamen Kozarev

John Raymond
Harvard-Smithsonian Center for Astrophysics

Ksenia Orlova

Yuri Shprits
UCLA

Neel Savani

Angelos Vourlidas
Naval Research Lab

Roger Varney

Stanley Solomon
NCAR HAO

Liang Zhao

Sarah Gibson
NCAR HAO

2013 Jack Eddy Postdoctoral Awards

Stathis Ilonidis
Host Institution: Stanford University, Thomas Duvall

✧ Project: Detection of Solar Active Regions Before They Emerge at the Surface and Improvement of Space Weather Forecasts

Bin Chen
Hosts Institution: New Jersey Institute of Technology, Dale Gary

✧ Project: Coronal Magnetography: an Approach to Understanding Space Weather Drivers - Solar Flares and Coronal Mass Ejections

Antonia Savcheva
Host Institution: Harvard-Smithsonian Center for Atmospherics, Katharine Reeves

✧ Project: Understanding Sigmoid Evolution and Eruption: From Formation to CME Propagation

Thiago Brito
Host Institution: LASP/University of Colorado, Scot Elkington

✧ Project: The effect of drift orbit bifurcations on radiation belt particles in time dependent fields

2013 Summer School
Heliophysics of the Solar System
12-19 July, Boulder, CO

A select group of students and teachers will learn about the exciting science of heliophysics as a broad, coherent discipline that reaches in space from the Earth's troposphere to the depths of the Sun, and in time from the formation of the solar system to the distant future.


HELIOPHYSICS

2013 Summer School

Heliophysics of the Solar Systems

12–19 July 2013 • Boulder, Colorado

Application Deadline: 1 March

Spicules: Jets on the Sun. NASA image.

Special Opportunity for Physics Students & Physics Teachers

Applications are invited for the 2013 Heliophysics Summer School, which will be held in beautiful Boulder, Colorado. We are seeking students and undergraduate level teachers and instructors to join us this coming summer for a unique professional experience. Students and teachers will learn about the exciting science of heliophysics as a broad, coherent discipline that reaches in space from the Earth's troposphere to the depths of the Sun, and in time from the formation of the solar system to the distant future. At the same time, a goal of the Summer School is for the group of instructors to develop materials from Heliophysics that can be applied in their classes.

The Heliophysics Summer School focuses on the physics of space weather events that start at the Sun and influence atmospheres, ionospheres and magnetospheres throughout the solar system. The solar system offers a wide variety of conditions under which the interaction of bodies with a plasma environment can be studied: there are planets with and without large-scale magnetic fields and associated magnetospheres; planetary atmospheres display a variety of thicknesses and compositions; satellites of the giant planets reveal how interactions occur with subsonic and sub-Alfvénic flows whereas the solar wind interacts with supersonic and super-Alfvénic impacts.

Encompassed under a general title of comparative magnetospheres are processes occurring on a range of scales from the solar wind interacting with comets to the interstellar medium interacting with the heliosphere. The school will address not only the physics of all these various environments but will also go into the technologies by which these various environments are being observed. The program is complemented with considerations of the societal impacts of space weather that affects satellites near Earth and elsewhere in the solar system.

The school will be based on lectures, laboratories, and recitations from world experts, and will draw material from the three textbooks Heliophysics I-III, published by Cambridge University Press.

Several teachers along with about 35 students will be selected through a competitive process organized by the UCAR Visiting Scientist Programs. The school lasts for eight days, and each participant receives full travel support for airline tickets, lodging and per diem costs.

Student Application Requirements

- Currently enrolled as a graduate student in any phase of training, or first or second year postdoctoral fellow.
- Major in physics with an emphasis on astrophysics, geophysics, plasma physics, and space physics, or experienced in at least one of these areas.
- Pursuing a career in heliophysics or astrophysics.

Teacher Application Requirements

- At least three years of teaching experience. (Already having a connection with heliophysics is not a requirement.)
- Currently teaching physics (preferably electricity & magnetism), astronomy/planetary science, or Earth sciences at the upper division undergraduate level.
- Willingness to provide feedback to the Summer School faculty and organizers on the comprehensibility and comprehensiveness of the overall set of lectures and supporting materials.

For additional information on this program and instrucions on how to apply, please visit the Heliophysics website at

www.vsp.ucar.edu/Heliophysics

For further information, call (303) 497-8649 or e-mail vspapply@ucar.edu

VSP UCAR Visiting Scientist Programs

The Living With a Star program of the Heliophysics Division in NASA's Science Mission Directorate sponsors the Summer Schools. The University Corporation for Atmospheric Research (UCAR) Visiting Scientist Programs collaborates with NASA in administering the schools. The University Corporation for Atmospheric Research is an EE/AAE who values and encourages diversity in the workplace. Images courtesy of NASA.

School Deans

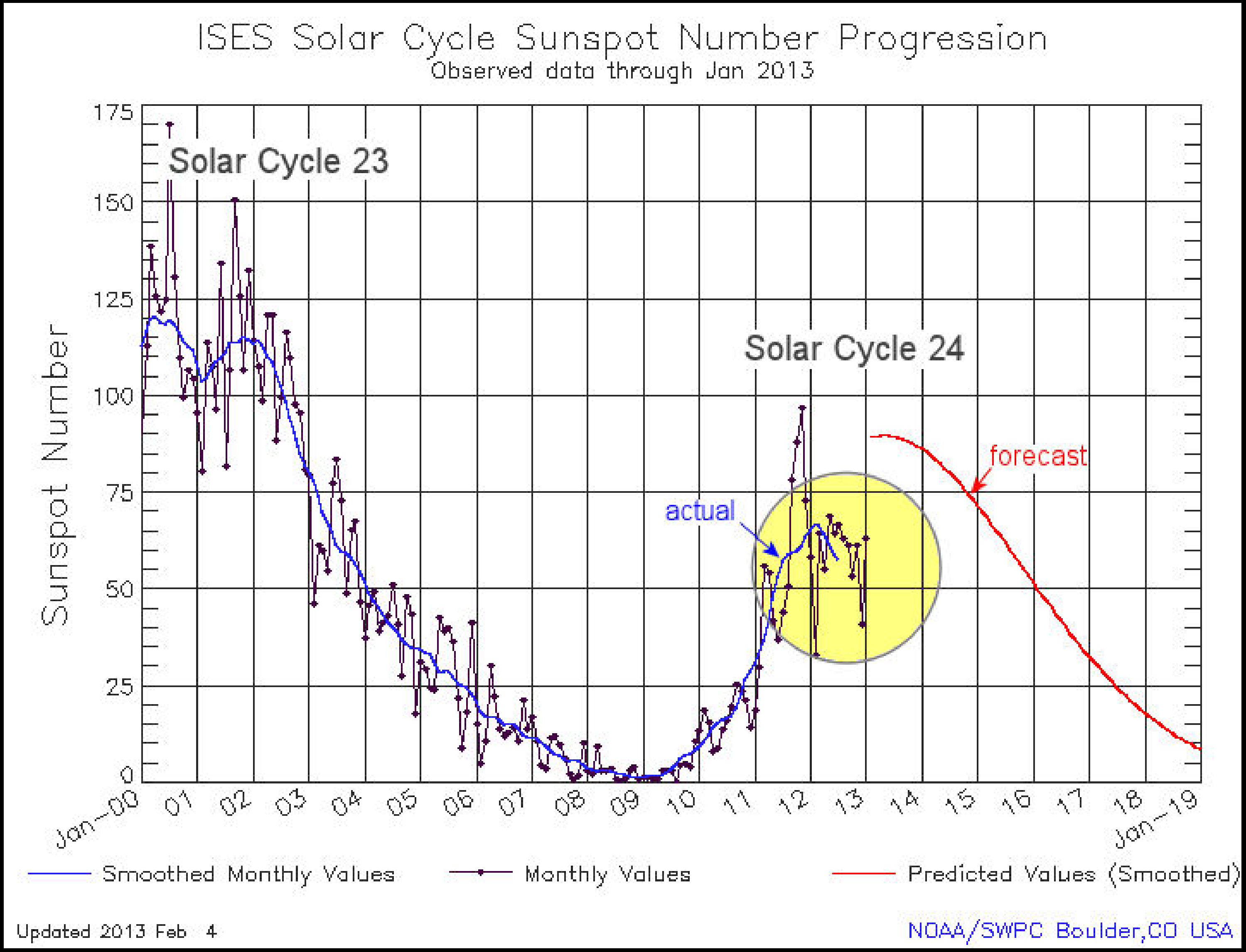
Dr. Karel Schrijver
Lockheed Martin Advanced Technology Center

Prof. Jan Sojka
Utah State University

Frances Bagenal
University of Colorado/LASP/APS

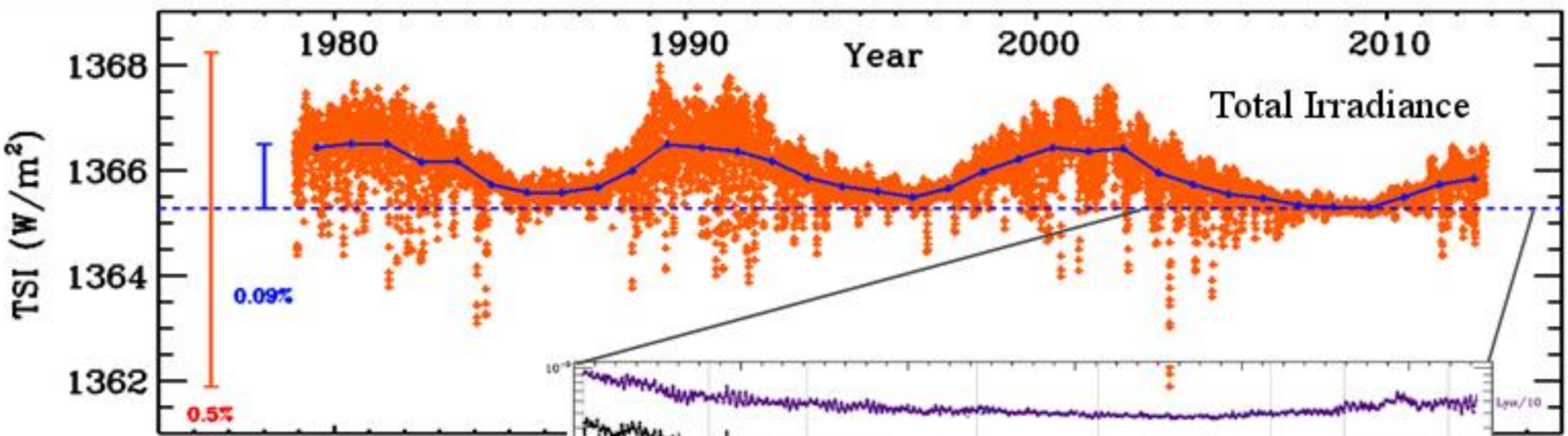
Apply online at www.vsp.ucar.edu/Heliophysics

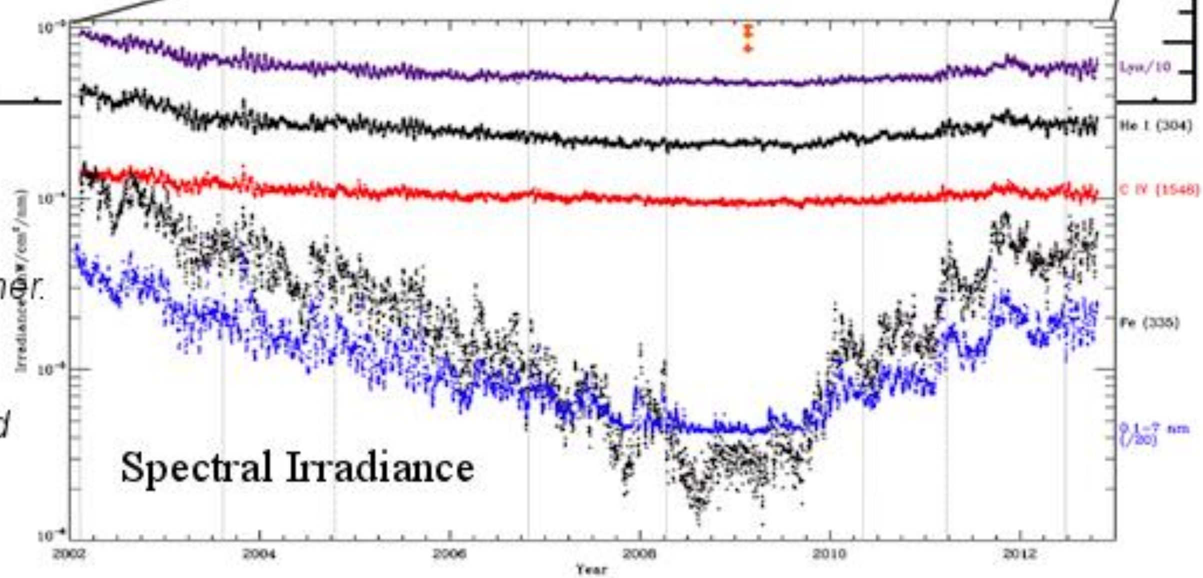
Just When You Thought it was Safe to Predict the Solar Cycle….



Signs of a Weakening Cycle: Total and Spectral Solar Irradiance

Total Solar Irradiance is up only half of its rise in the last three cycles.





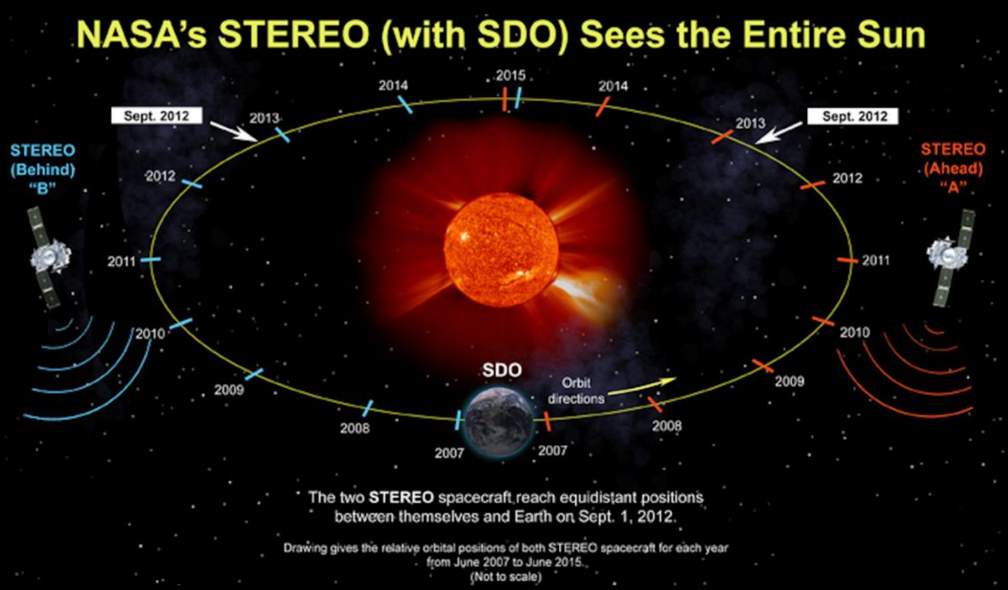
UV, EUV and X-ray spectral irradiances are drivers of space weather.

In Cycle 24, Lyman α is down 30% and He II 304 is down 50% compared to the previous cycle.

The perfect time to surround the sun

The sun is showing itself to be even more intractable and mysterious than experts imagined.

NASA and other space agencies have responded, with impeccable timing, by surrounding the sun with an unprecedented fleet of solar observatories.



First Among Equals: SDO

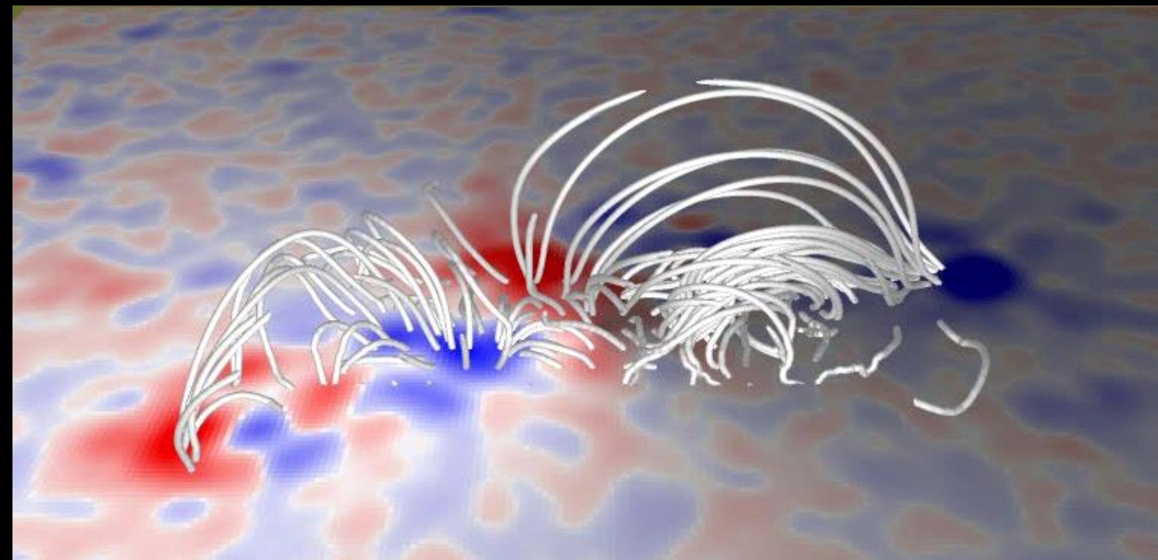
NASA's "Hubble for the Sun"

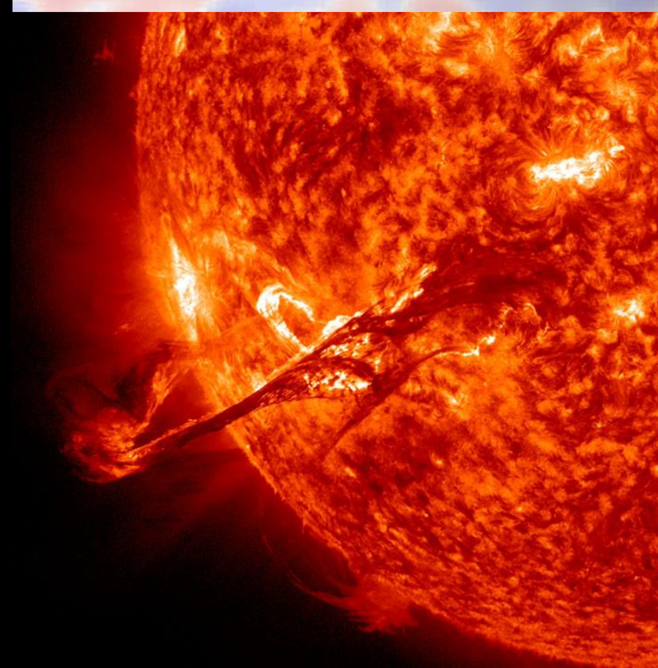
The Solar Dynamics Observatory, launched in 2010, is monitoring solar activity with unprecedented temporal and spectral resolution

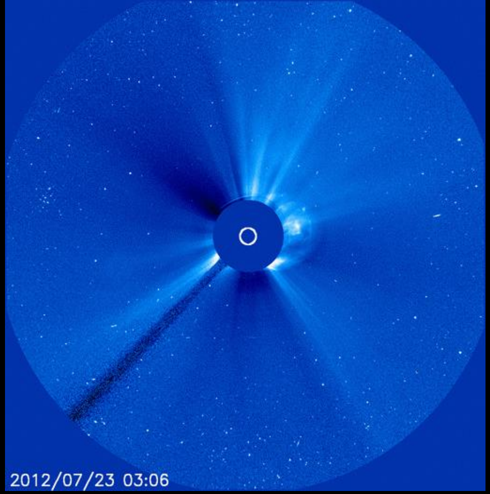
--from the top of the sun's atmosphere, **where the solar wind billows into space** and comets go to die

--to the surface of the sun, **where sunspots form** and solar flares explode,

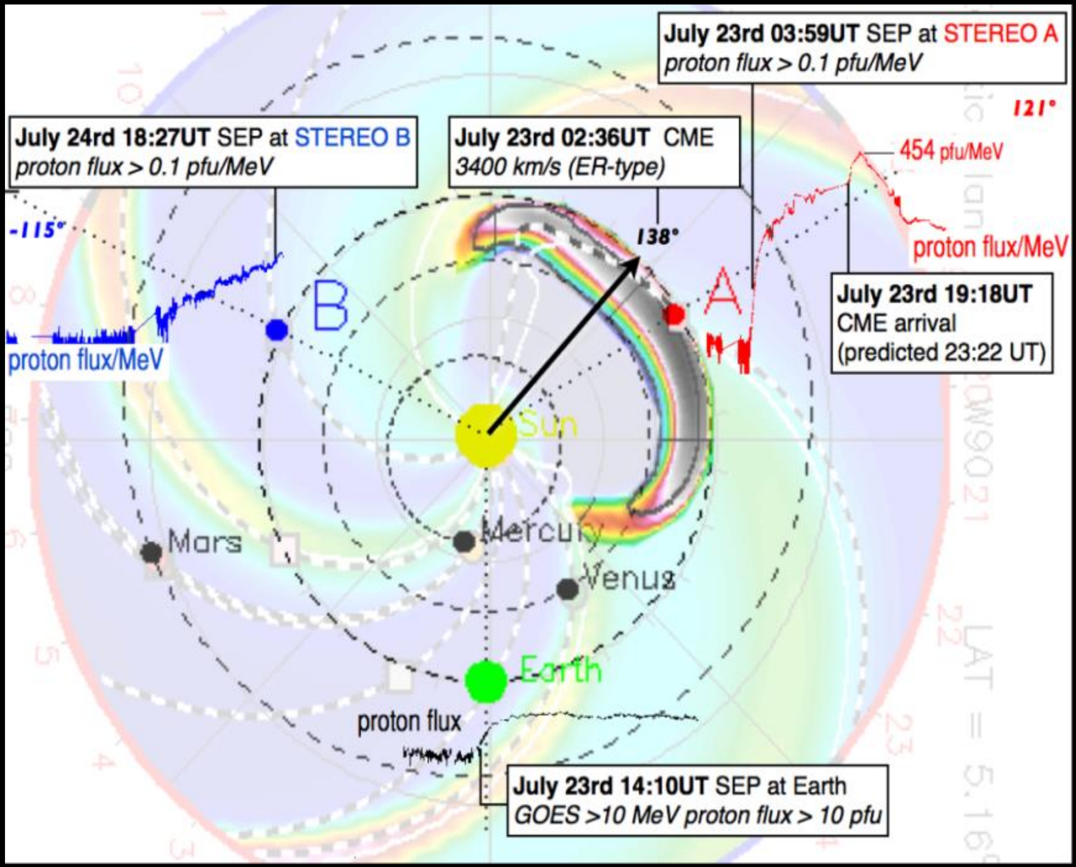
--to the fiery depths of the solar dynamo itself, **where the underlying magnetic fields of the solar cycle** are generated







July 23, 2012, one of the fastest CMEs of the Space Age rocketed away from the western limb of the sun travelling 3500 km/s.



Surrounding the sun has allowed us to detect major storms that otherwise we might have missed.

What would this storm have done to our planet?

STEREO-A was in the line of fire, and the spacecraft was hit by a severe solar radiation storm. It was stronger than any proton event observed since 1976. Without STEREO-A, this major event would have passed unnoticed

As the solar cycle unfolds in an unexpected way, it is important to remember that

Space Weather Swings Between Extreme Effects

Image: Guhathakurta, M. et al, "The Solar Cycle Turned Sideways," Space Weather, Wiley, doi: 10.1002/swe.20039

Solar La Niña
(low sunspot number)

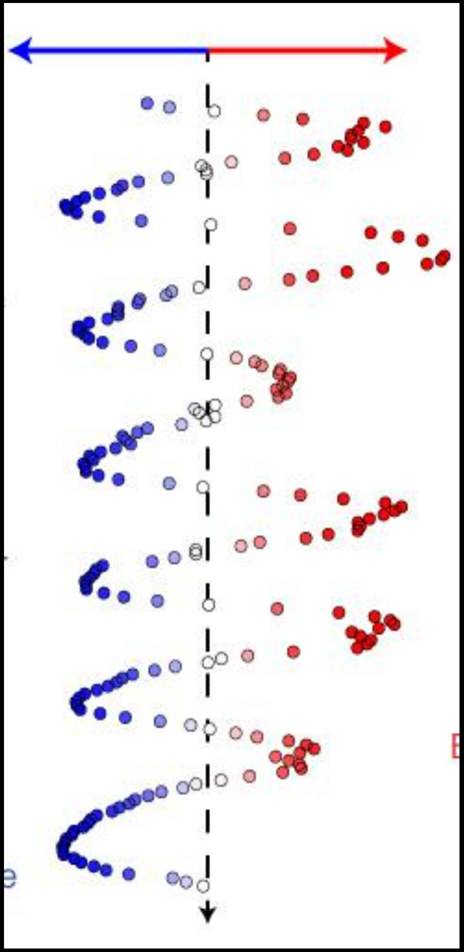
extreme galactic cosmic rays

rapid accumulation of space junk

sharp contraction of the heliosphere

collapse of the upper atmosphere

total solar irradiance changes



Solar El Niño
(high sunspot number)

super solar flares

extreme solar "cosmic rays" (energetic particles)

radio blackouts

extreme geomagnetic storms

melted power grid transformers – power blackouts

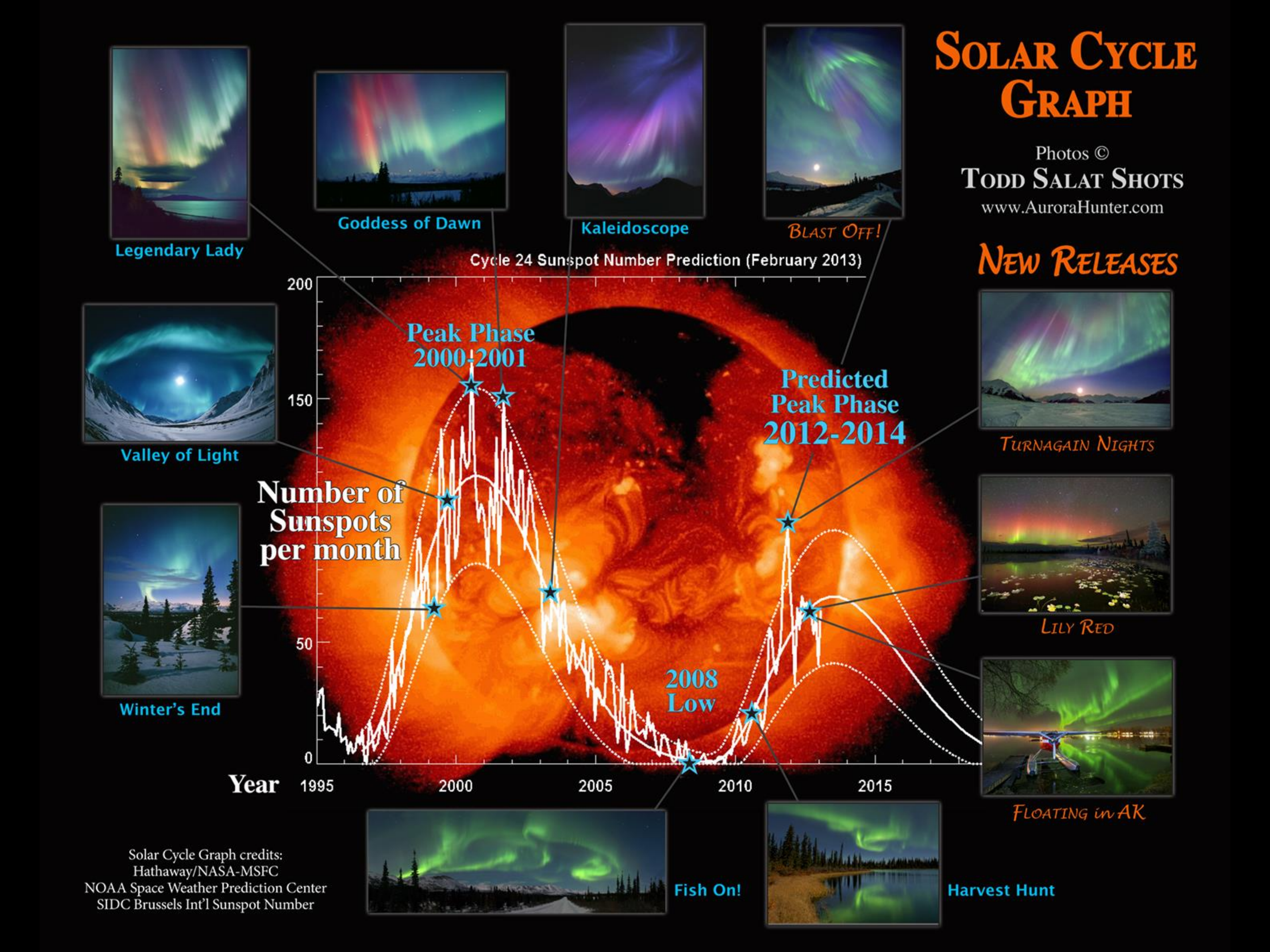
solar wind streams hit Earth

Illustration shows smoothed monthly sunspot counts from the past six solar cycles plotted horizontally instead of vertically. High sunspot numbers are in red and on the right, low sunspot numbers are in blue and on the left. Associated with each high and low sunspot numbers are different space weather impacts experienced at Earth (doi: 10.1002/swe.20039).

If we might be entering into a period of extended low activity, does this mean that we may not have to worry about the sun?

ABSOLUTELY NOT

Heliophysics just got interesting



SOLAR CYCLE GRAPH
Photos ©
TODD SALAT SHOTS
www.AuroraHunter.com
NEW RELEASES
Legendary Lady
Goddess of Dawn
Kaleidoscope
BLAST OFF!
Cycle 24 Sunspot Number Prediction (February 2013)
200
150
50
0
Peak Phase 2000-2001
Predicted Peak Phase 2012-2014
Number of Sunspots per month
2008 Low
Year
1995
2000
2005
2010
2015
Valley of Light
Winter's End
TURNAGAIN NIGHTS
LILY RED
FLOATING in AK
Fish On!
Harvest Hunt
Solar Cycle Graph credits:
Hathaway/NASA-MSFC
NOAA Space Weather Prediction Center
SIDC Brussels Int'l Sunspot Number