



Beyond the Flare: An SWF-AAS Briefing on Space Weather

*NASA's effort to characterize,
understand and predict space
weather events*

Lika Guhathakurta
Heliophysics Division
Science Mission Directorate

November 20, 2014



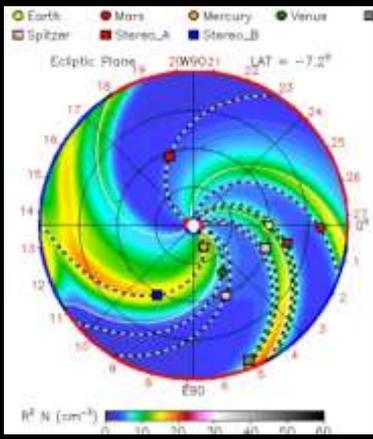


What is Heliophysics

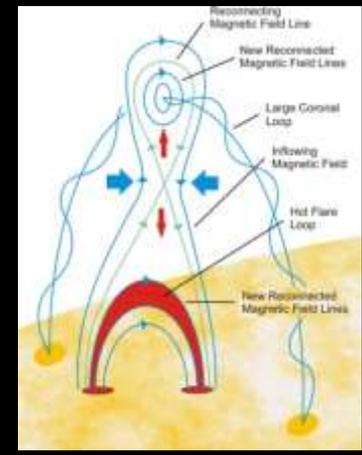
Heliophysics is an environmental science:
a unique hybrid between meteorology and astrophysics

It has an applied branch
space weather

And a pure branch
fundamental physical process



Propagation models of solar disturbances out to 2 AU



Magnetic reconnection

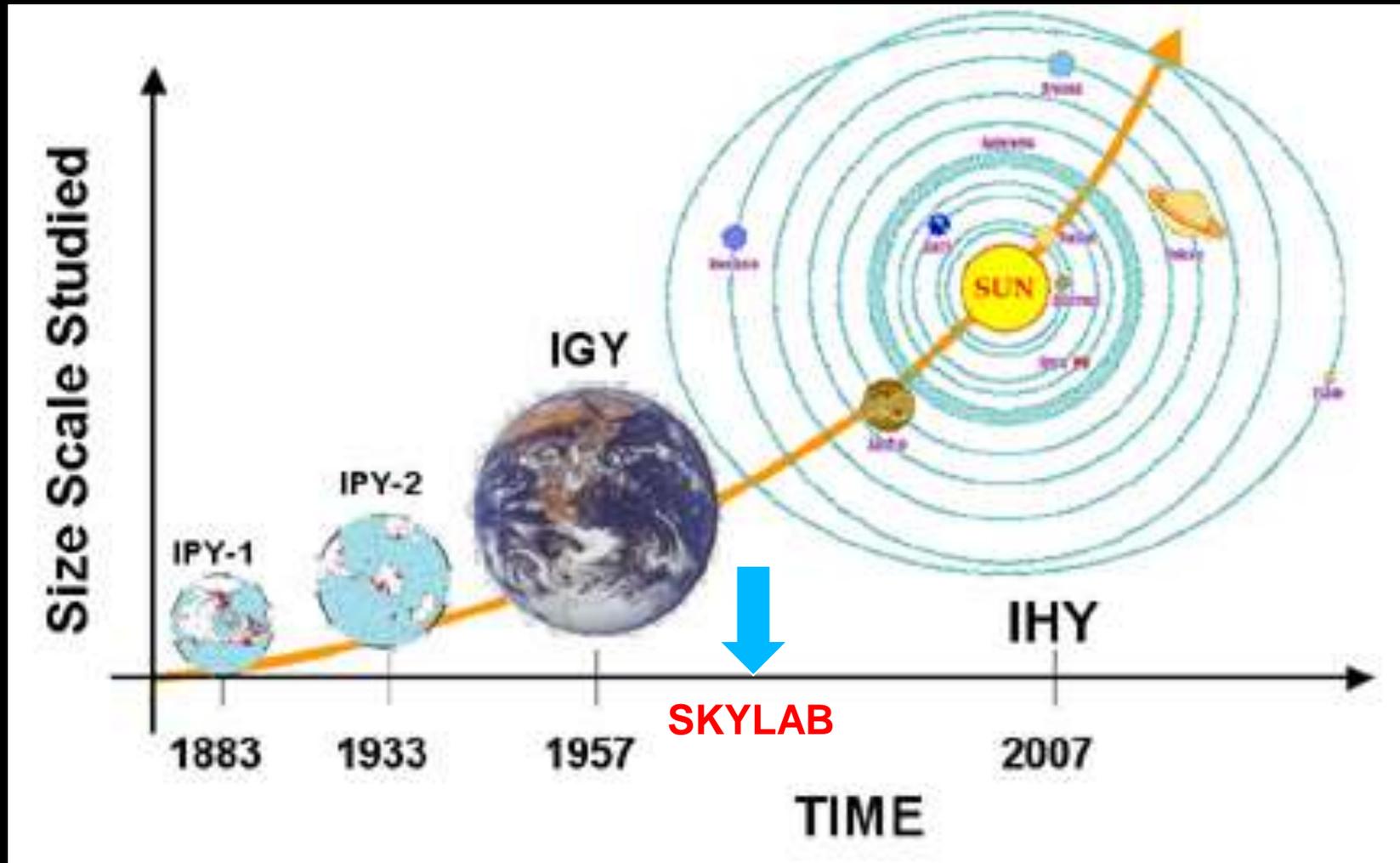
National Space Weather Program 1995

Living With a Star 2000

International Heliospherical Year 2007

Applications
directed science
Add comparative
coordinated by
NASA community
studies

Evolution of System Studies



Heliophysical: A broadening of the concept "geophysical," extending the connections from the Earth to the Sun & interplanetary space.

SUN

EARTH



HELIOPHYSICS

convection zone
radiative zone
core

particles and magnetic fields

photons

bow shock

solar wind

heliosphere

surface atmosphere

ionosphere
plasmasphere

magnetosphere

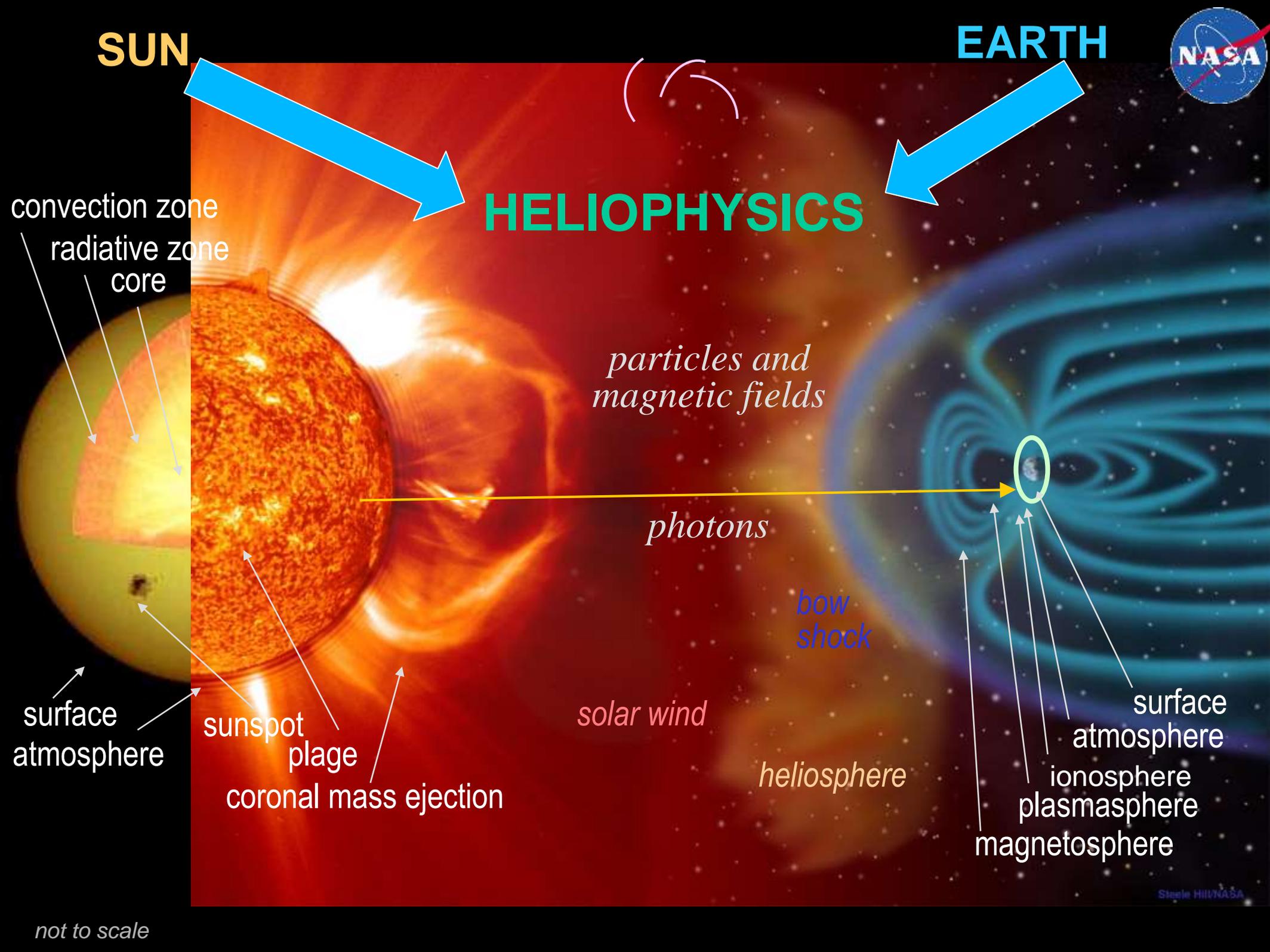
surface atmosphere

sunspot
plage

coronal mass ejection

not to scale

Steele Hill/NASA



Sun-Earth System Science: Growth from a “consuming” science to a “producing” science for the benefit of humankind



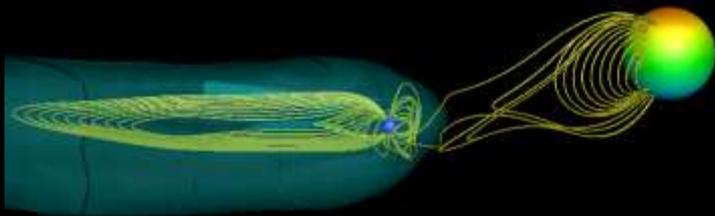
Space Weather is no longer the domain of Earth only!

Space Weather is now Interplanetary!!

Space Weather just became Exopla

Extreme Space Weather

T=00:00



SkyLab Heliophysics GAME CHANGERS



The Corona is hot and controlled by magnetic fields

→ X-Ray and EUV Variability at Earth (**NOAA R-Scale**)

High-Speed Solar Wind originates from coronal holes

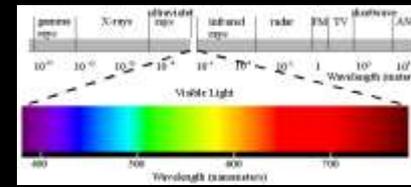
→ Solar Particles Impact Earth (**NOAA S-Scale**)

Mass from the corona is ejected into interplanetary space

→ Solar catastrophic events can impact Earth's magnetosphere (**NOAA G-Scale**)

Terrestrial Space Weather

Electro-magnetic Radiation



Ultra Violet and X-ray Radiation

8 minutes



Satellite drag; radio blackouts

R-Scale

Matter

Charged Particle Radiations

10-30 minutes

S-Scale



Radiation: astronaut health, aviation & satellite function

NOAA Space Weather Scales

Blame it on *B* (*magnetic field*)

Matter

Magnetic Fields

Magnetized Blobs of Solar Material

18-96 hours

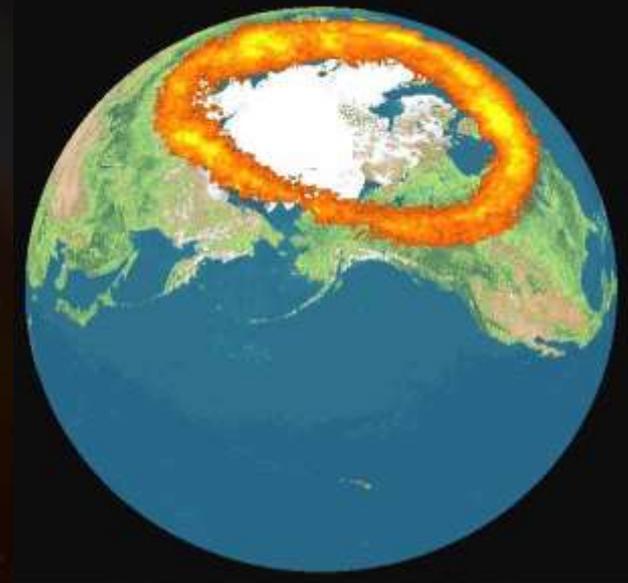
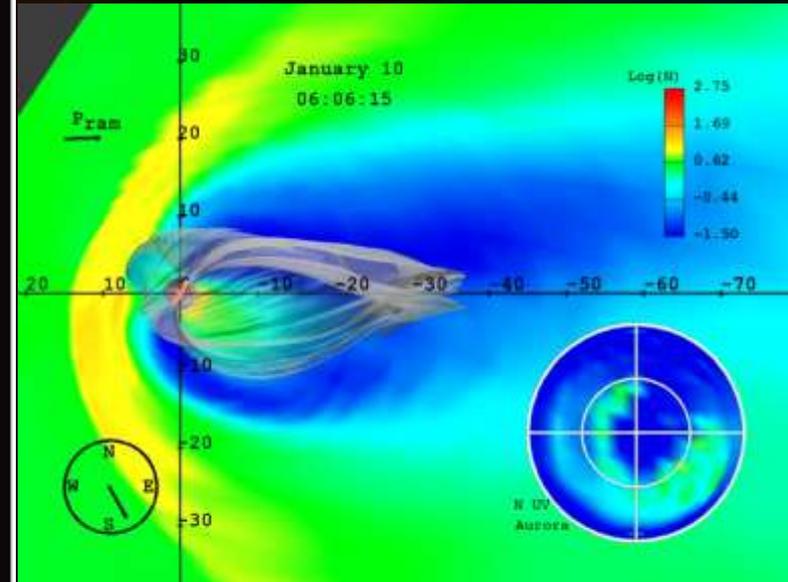
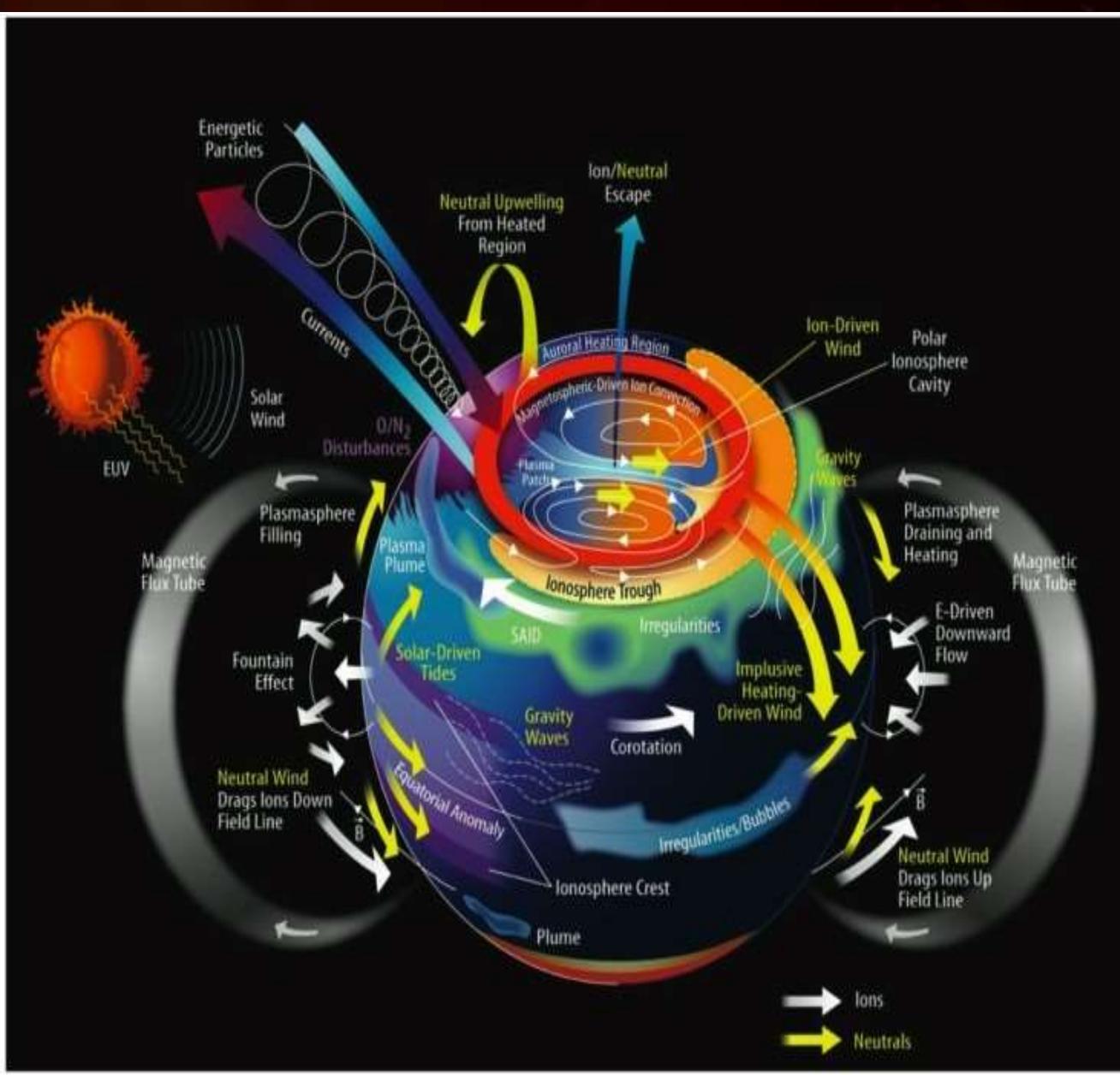
G-Scale

Aurora; geomagnetic storms & radio disturbances



Space Weather's Terrestrial Influence

(an example)

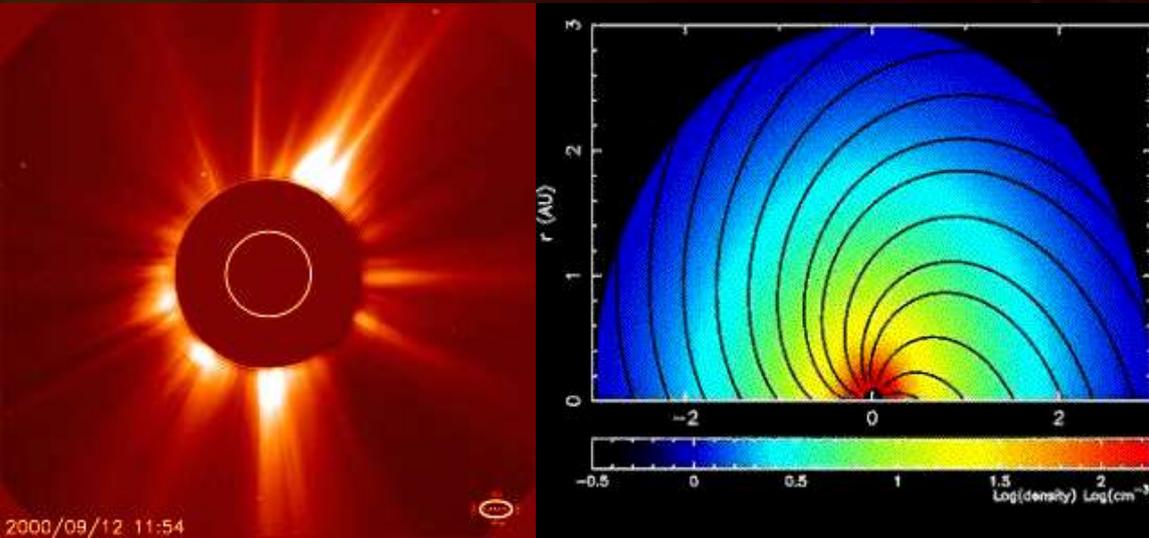



Space weather interacts with Earth's B-Field and can dramatically affect the Earth

Forecasting Space weather

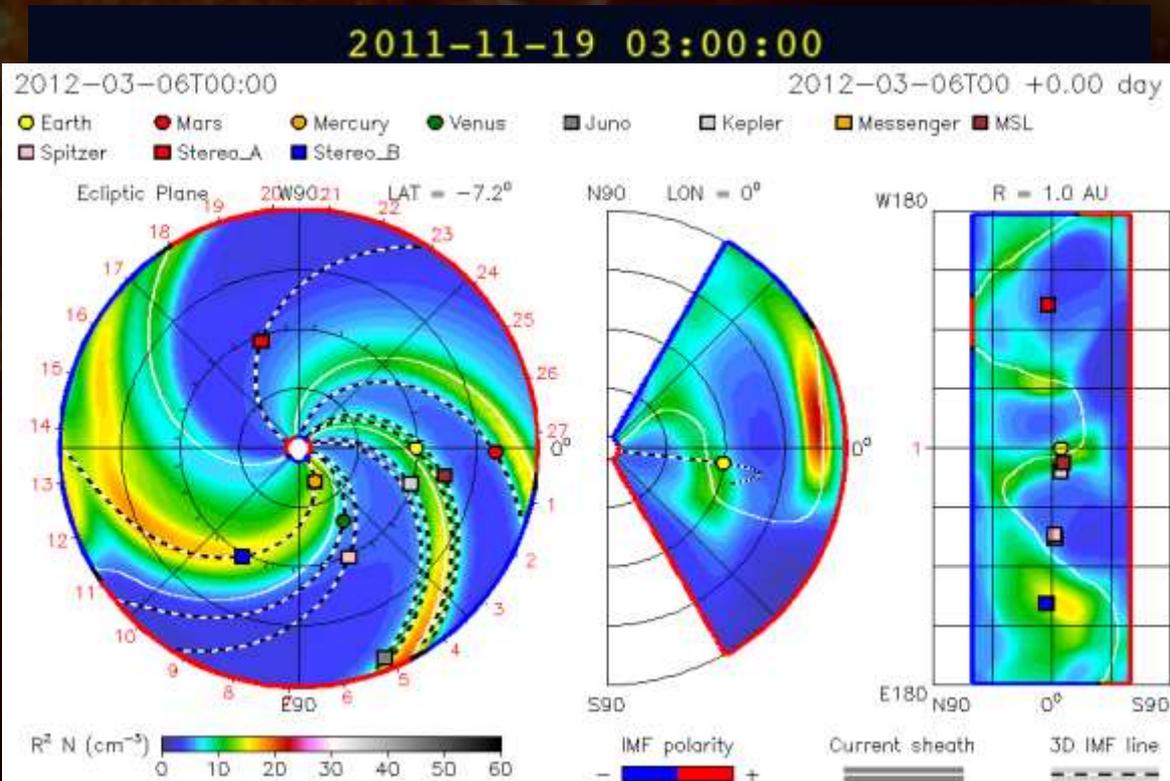


- Semi-empirical near-Sun module that approximates the outflow at the base of the solar wind
- Sophisticated 3-D magnetohydrodynamic numerical model that simulates the resulting flow evolution out to Earth.

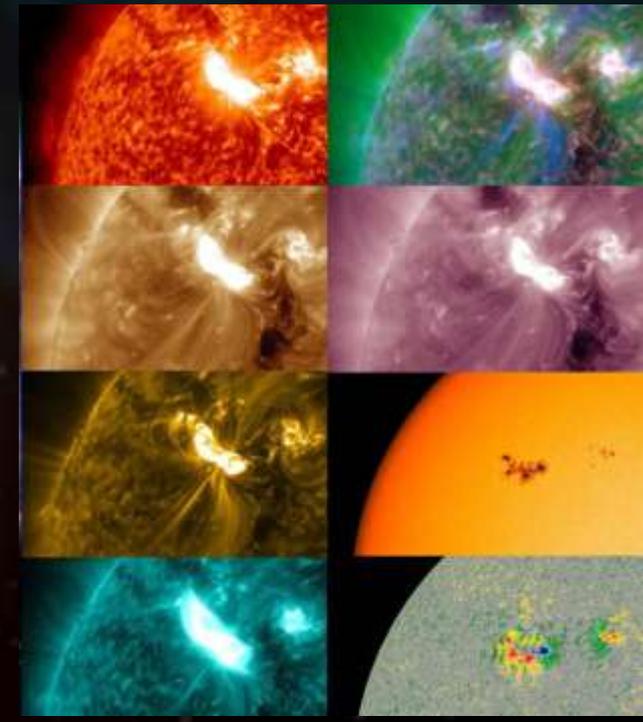


Courtesy: Dr. G. Zank UAH-CSPAR

AR1429 unleashed a powerful X5-class solar flare on 7 March 2012, commencing the "St. Patrick Day storms" of 2012. The blast also propelled a massive coronal mass ejection (CME) toward Earth. NASA's Solar Dynamics Observatory recorded the flare at multiple extreme ultraviolet wavelengths



3D CME model run from CCMC/iSWA shows how the CME would propagate through the inner solar system.

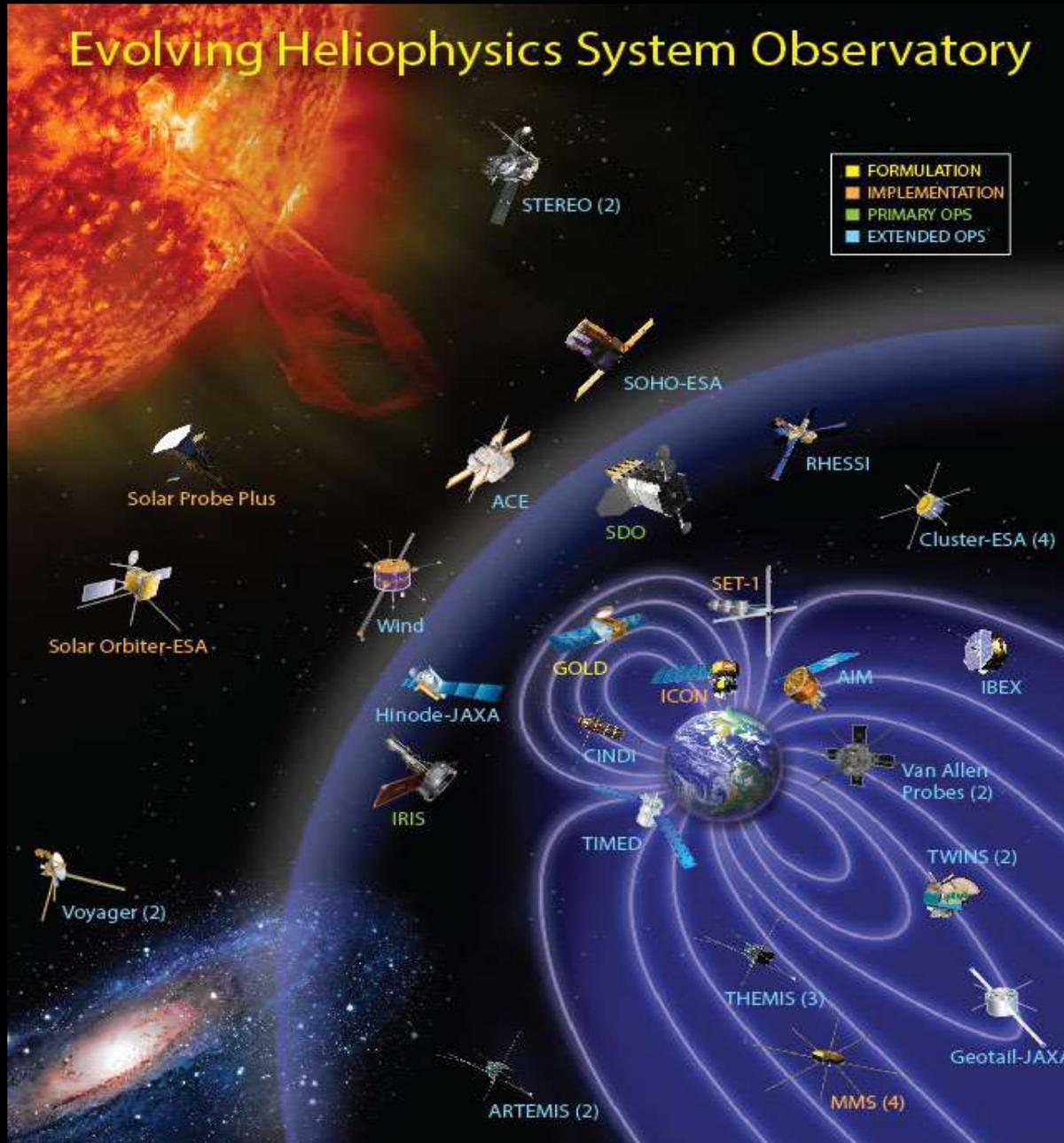


Heliophysics System Observatory



A coordinated and complementary fleet of spacecraft to understand the Sun and its interactions with Earth and the solar system

Evolving Heliophysics System Observatory



Heliophysics has 18 operating missions (on 29 spacecraft): Voyager, Geotail, Wind, **SOHO ACE** Cluster, TIMED, RHESSI, TWINS, Hinode, **STEREO** THEMIS/ARTEMIS, AIM, CINDI, IBEX, **SDO** Van Allen Probes IRIS

(Missions in red contribute to operational Space Weather.)

6 missions are in various phases of development: SET, MMS, SOC, SPP, ICON, and GOLD

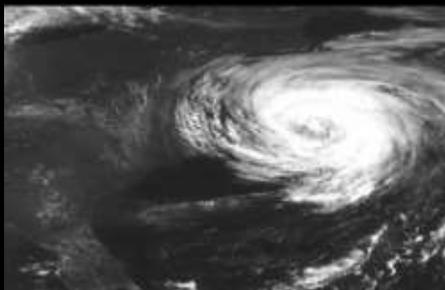
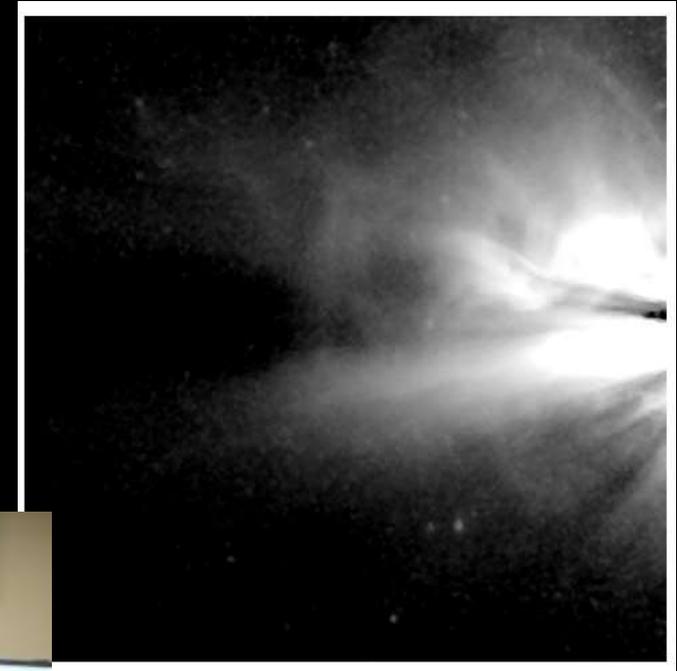
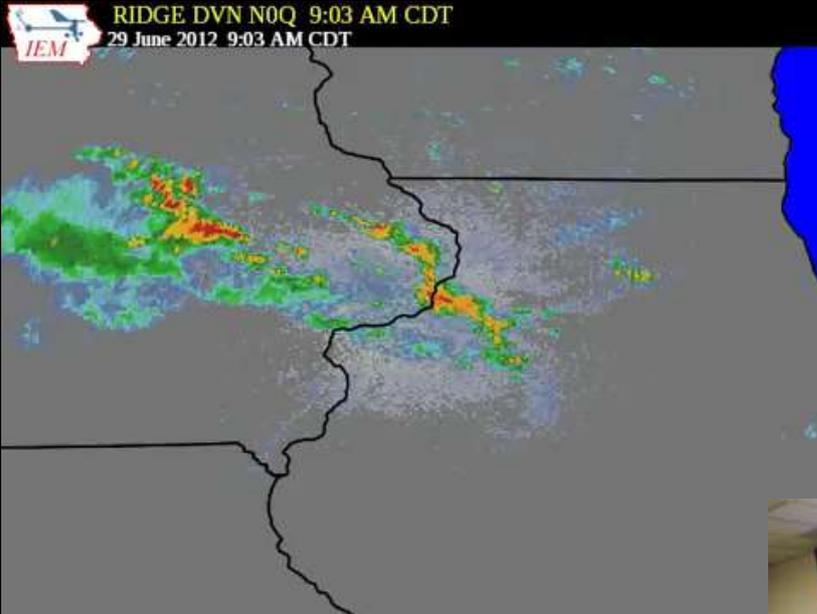
Heliophysics is an environmental science

– a hybrid between meteorology and astrophysics



Weather in the mid-west today is
Washington's weather tomorrow.

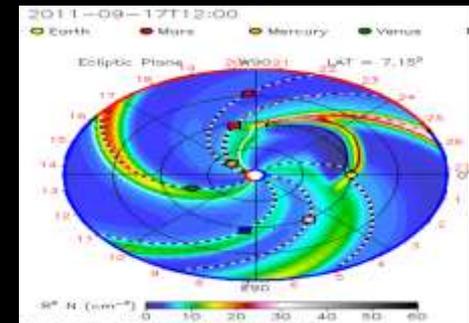
Weather on the sun today is space
weather in low-Earth orbit later this
week



meteorology



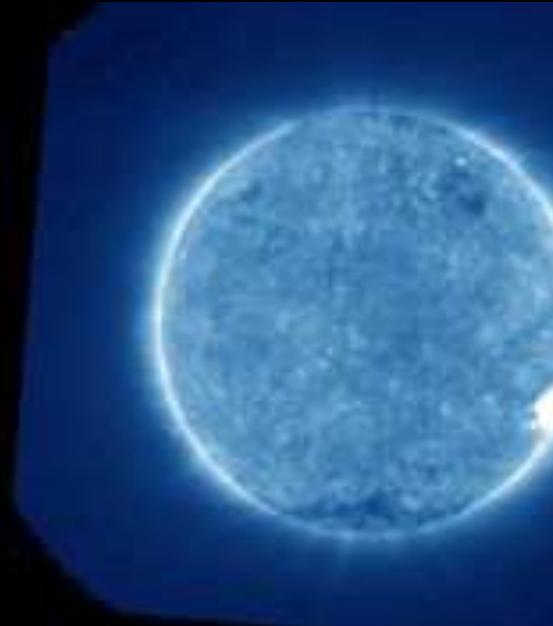
At NOAA's SWPC, forecaster Dave Marshall sits at the crossroads.



astrophysics

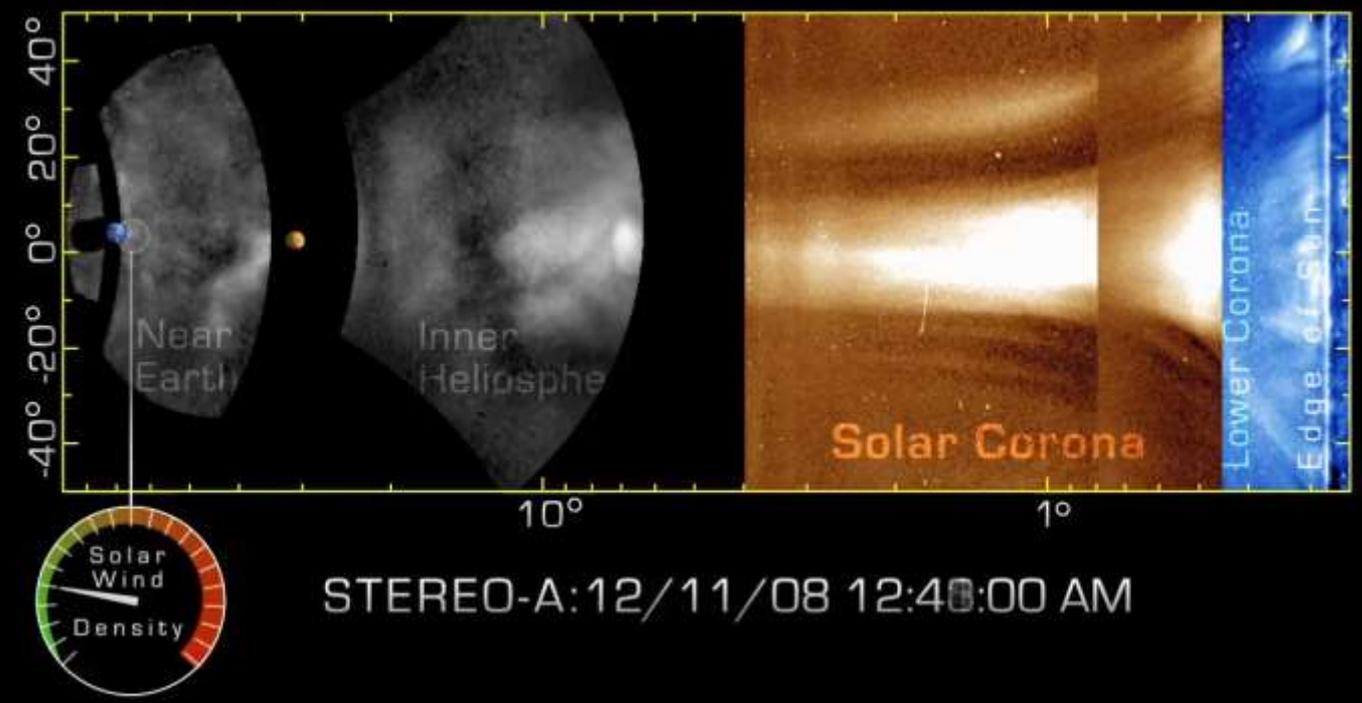


The next frontier in space weather forecasting involves the uninterrupted tracking of storm clouds from the sun to the planets.



NASA's STEREO spacecraft and new data processing techniques have succeeded in tracking space weather events from their origin in the Sun's ultra hot corona to impact with the Earth's magnetosphere

STEREO includes 5 telescopes that monitor the sky at large angles from the Sun



Heliophysics Text Books & Summer School Eddy Postdoctoral Fellowship



Spontaneous Generation Of structures and Transients

- * Flux ropes-filaments
- * Current Sheets
- * Cellular Structures
- * Turbulence
- * Waves & Emissions

Creation and Annihilation of Magnetic Fields

- * Dynamos
- * Diffusion
- * Dissipation
- * Reconnection

Generation of Penetrating Radiation

- * GCRs
- * SCRs
- * ACRs
- * Radiation Belts

Heliophysics

A universal science

Magnetic Coupling

- * Non-Local (Non-Contact)
- * Flow-object
- * Cross-Scale (Hierarchical)
- * Dusty Plasmas



Explosive Energy Conversions

- * Solar (Stellar) Flares
- * CMEs
- * Substorms
- * Bursty Bulk Flows

Coupling Sun, Heliosphere, Galactic Environment, and Planetary Climate

- * Dynamos in stars and planets
- * Radiative and electromagnetic couplings

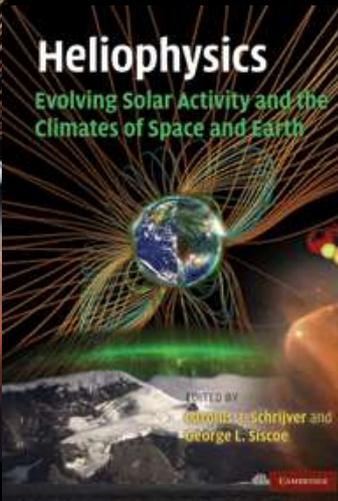
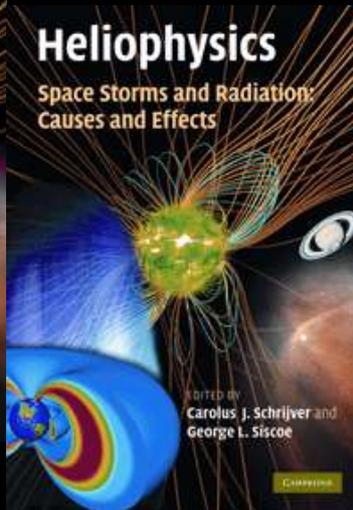
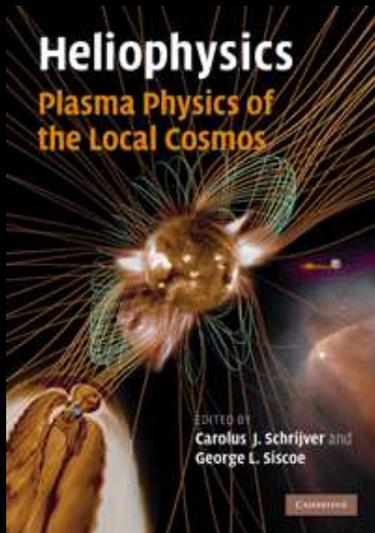


Since 2007-2014, we have had:

- Total Students ~250
- International Students ~120
- PhD Level ~220
- Masters Level ~30

Jack Eddy Postdoctoral Fellowship 2010-2014, 17 appointments

To train the next generation of researchers needed in the emerging field of heliophysics, in honor of the pioneering interdisciplinary researcher, Jack Eddy.



"Space Weather Impacts: They Happen All the Time"



SOLAR CYCLE GRAPH

Photos ©
TODD SALAT SHOTS
www.AuroraHunter.com

NEW RELEASES



TURNAGAIN NIGHTS



LILY RED



FLOATING in AK



Goddess of Dawn

Kaleidoscope

BLAST OFF!



Legendary Lady



Valley of Light



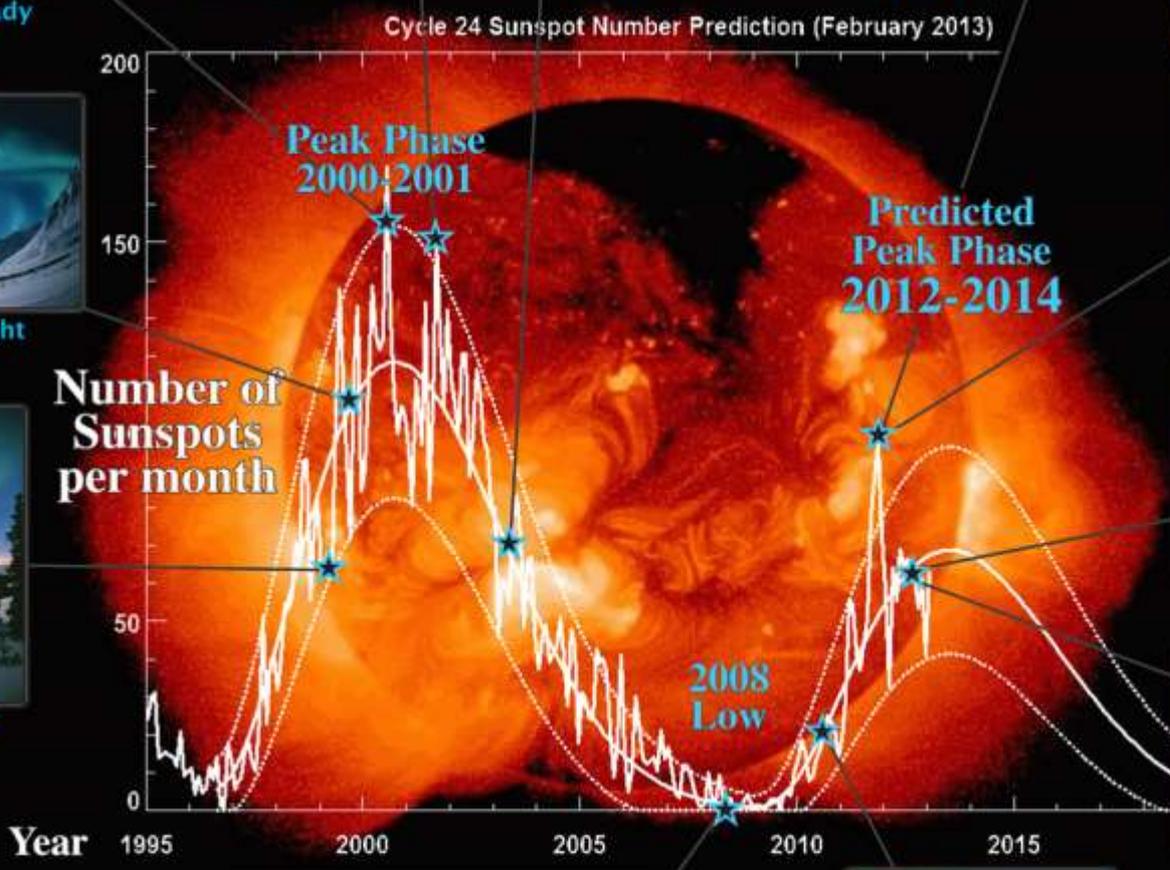
Winter's End



Fish On!



Harvest Hunt



Solar Cycle Graph credits:
 Hathaway/NASA-MSFC
 NOAA Space Weather Prediction Center
 SIDC Brussels Int'l Sunspot Number