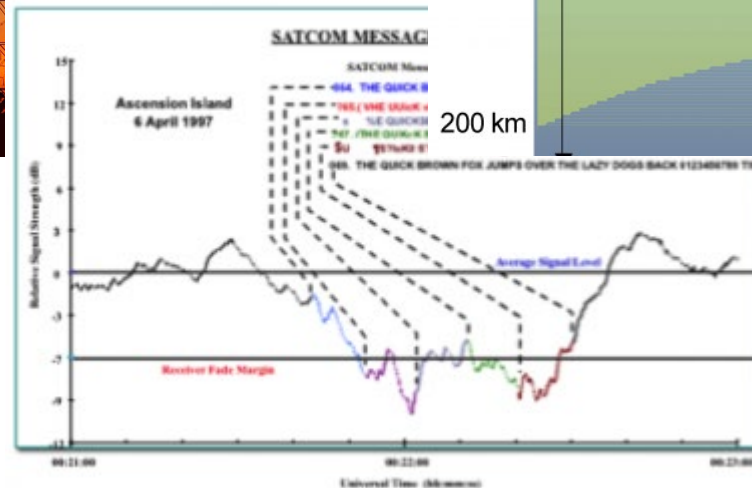
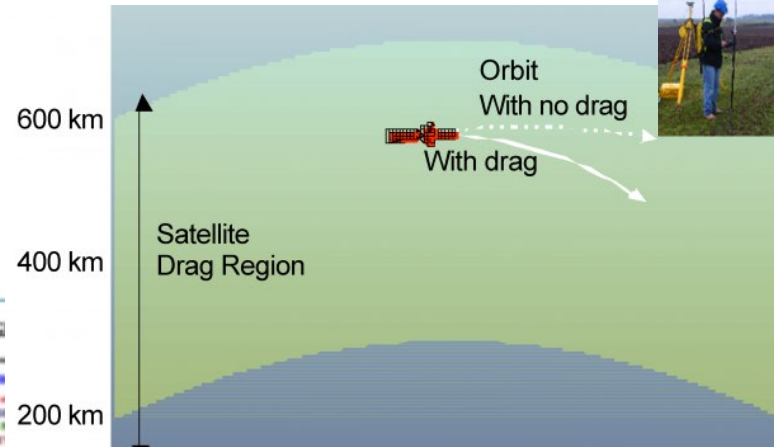


Solar Synoptic Observations from the Moon

Alexei A. Pevtsov

National Security through Space Weather Prediction

- Impact on our civilization's technological systems (power transmission, satellite operation (atmospheric drag), radio and satellite communications, global positioning, transportation, agriculture, human space flight)



Images: NOAA/SWPC
<https://www.swpc.noaa.gov/impacts>

Space Weather Impacts

May 2024 solar storm cost \$500 million in damages to farmers, new study reveals

News By Tereza Pultarova published June 22, 2025

GPS receivers were off by up to 230 feet during the worst solar storm in 20 years.

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SpaceX says a geomagnetic storm just doomed 40 Starlink internet satellites

News By Tariq Malik published February 8, 2022

The satellites launched on Feb. 3, only to be hit by the storm a day later.

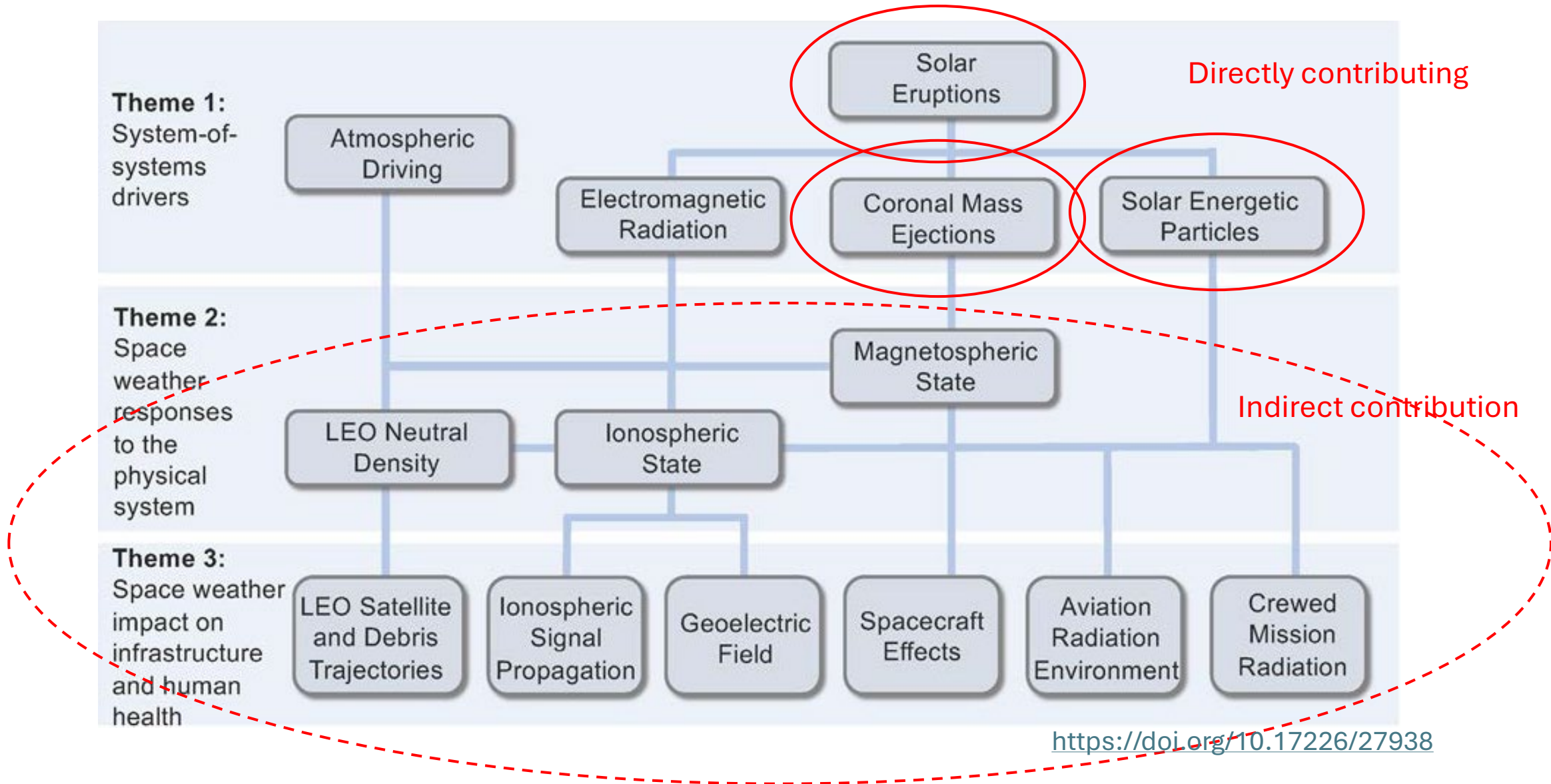
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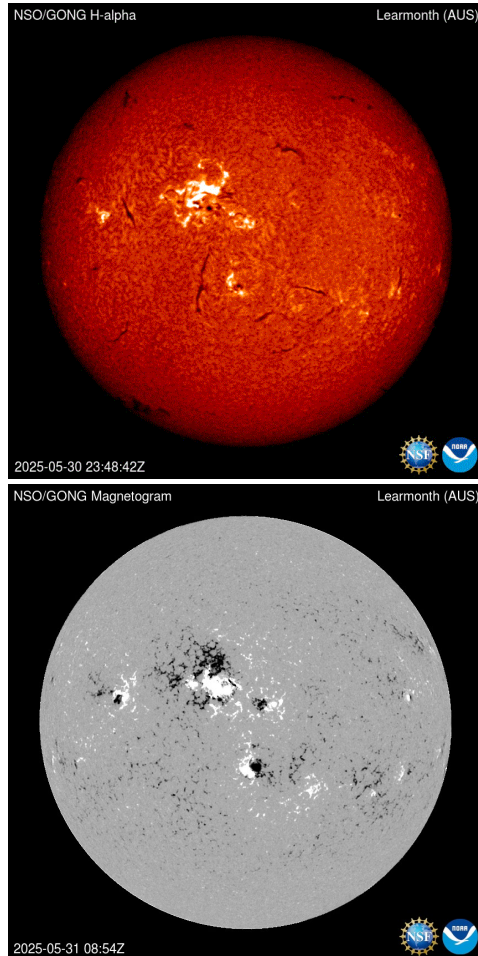
Slide courtesy C. Keller

Heliophysics Decadal: space weather research themes

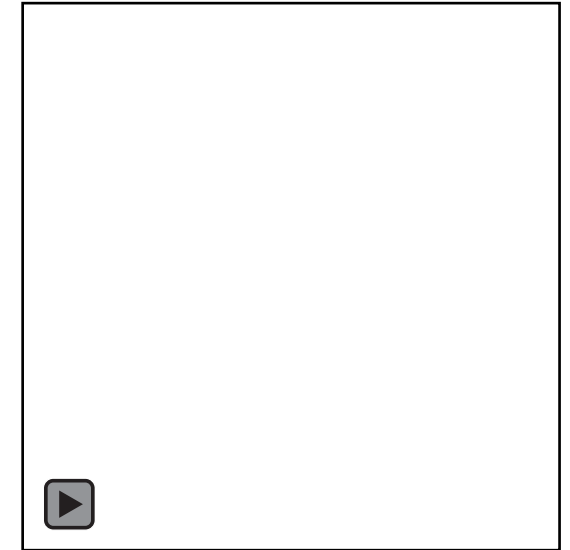


Solar Flares and CMEs

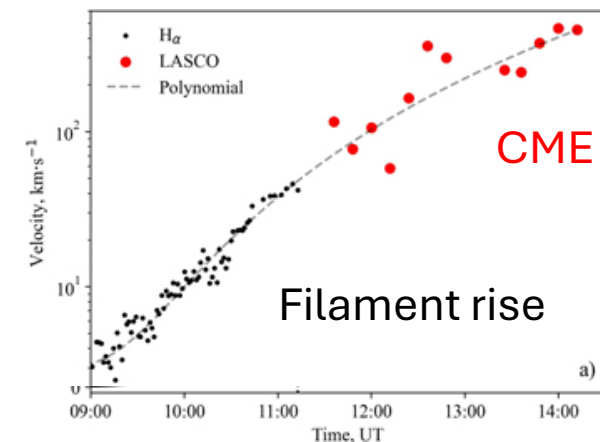
- Understanding and predicting onset of flares and coronal mass ejections (CME)



Filament
eruption
followed
by CME



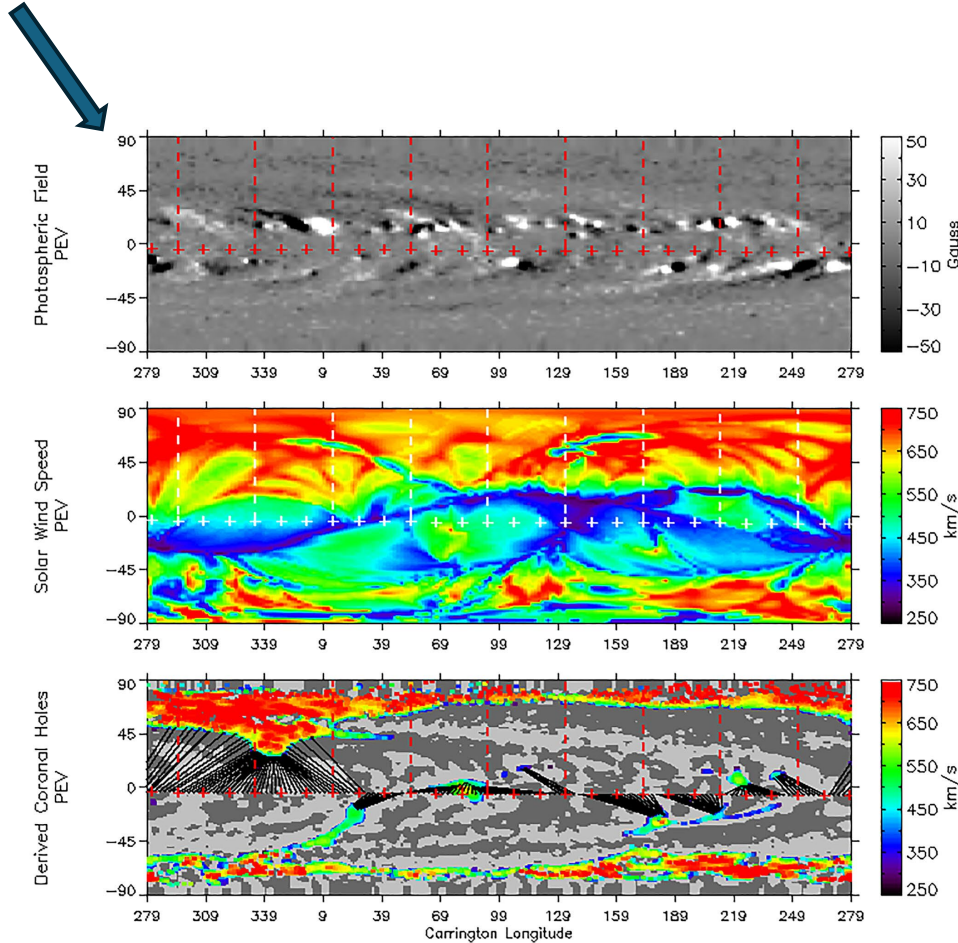
- Full disk, high cadence observations
- Maps of magnetic field, narrow-band and coronal/EUV imaging are required
- Magnetic field data are used for identifying magnetic topology of SEP source regions



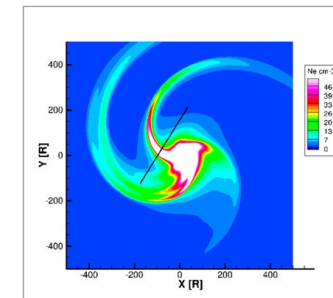
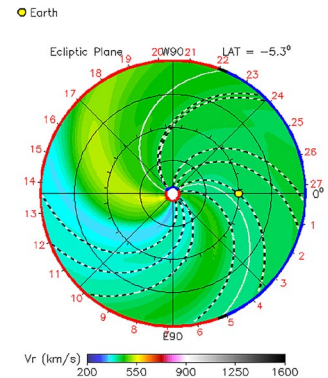
Berezin et al (2023)

Solar Wind Modeling

- **Maps of magnetic field are required for modeling:** Wang-Sheeley-Arge (WSA-Enlil) model - LOS; Alfvén wave solar model (AWSoM) – vector magnetic fields (Un. of Michigan)
- NOAA/SWPC uses GONG synoptic maps updated at 1-hour cadence
- Air Force Data Assimilative Photospheric Flux Transport (ADAPT) Model provides improved representation of solar magnetic fields
- Far-side imaging may provide additional improvements

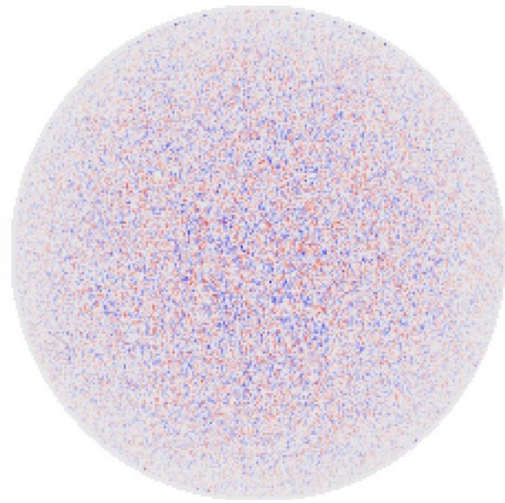


Pevtsov et al, 2020, <https://doi.org/10.1029/2020SW002448>

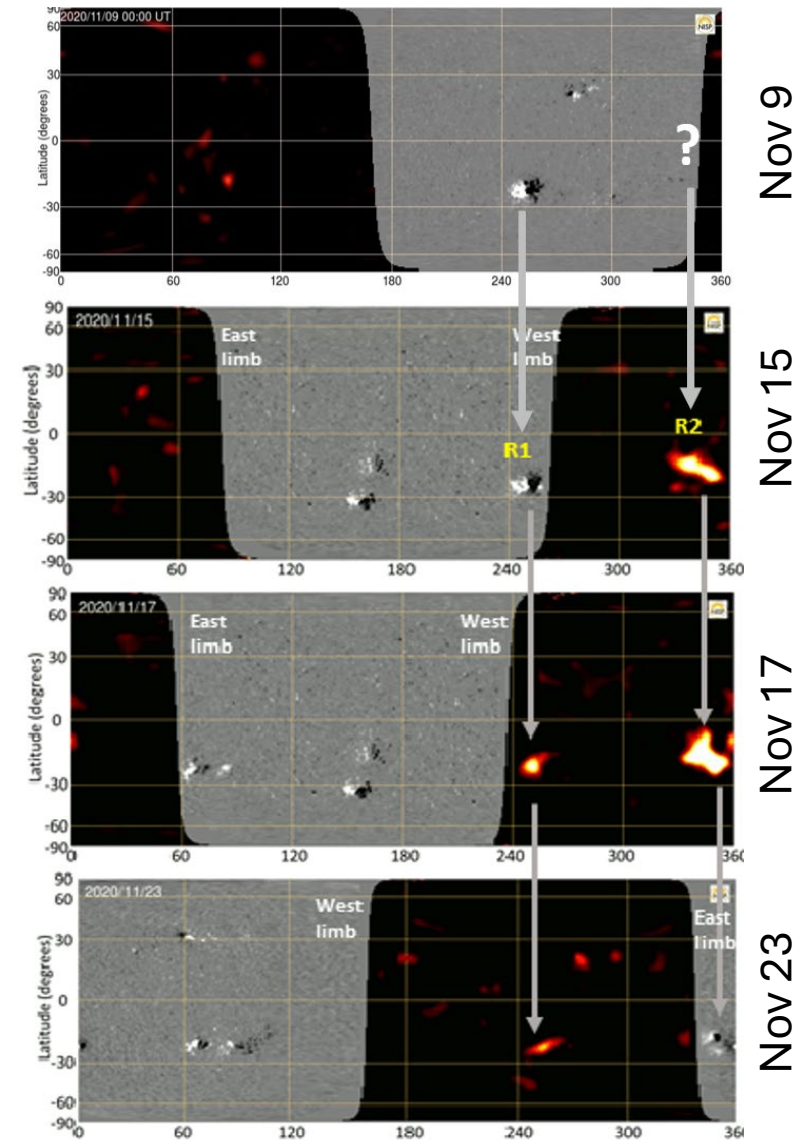
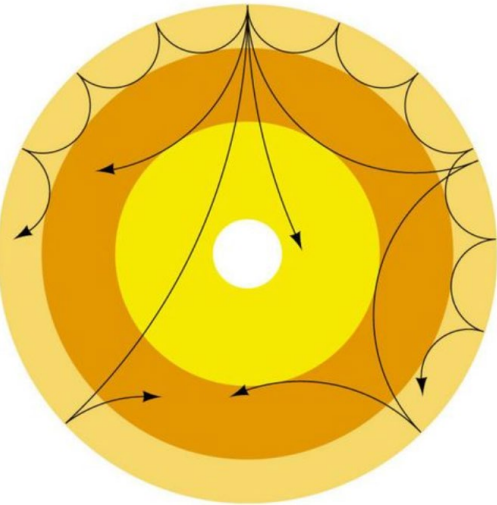


Jensen et al (2023),
<https://doi.org/10.3389/fspas.2023.1064069>

Solar Far Side Imaging gives 14-Day Warnings



There are several thousands wave sources inside the Sun that go off each second. As the waves move into the Sun, they get refracted (bent out) back to the surface due to increasing sound speed in deeper layers. When the waves encounter an active region, they change their phase, which is identified as possible active region on far side of the Sun.



Courtesy K. Jain (NSO)

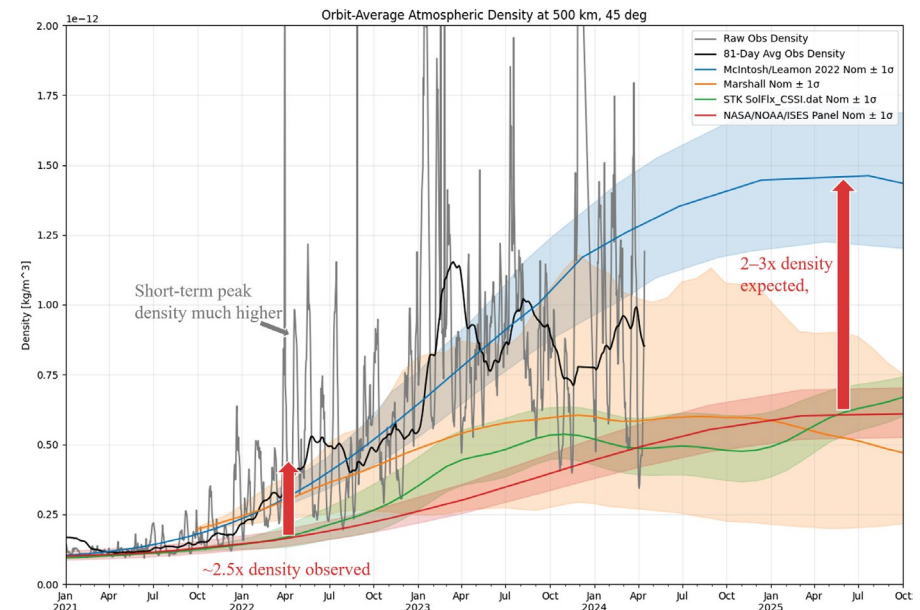
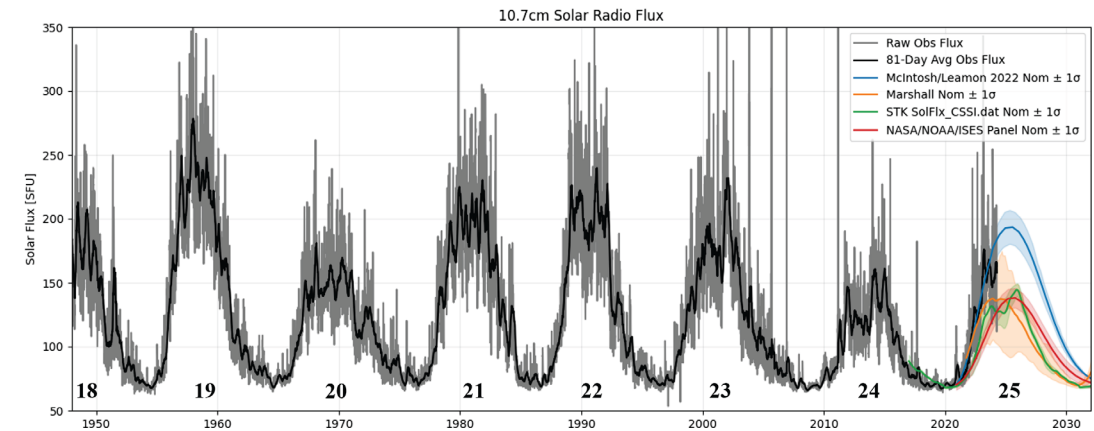
Greyscale: Frontside Magnetogram
Dark Background: Farside Seismic Map

Understanding and predicting solar cycle

Synoptic observations of magnetic field and far-side imaging are critical for prediction of UV flux for modeling atmospheric drag.

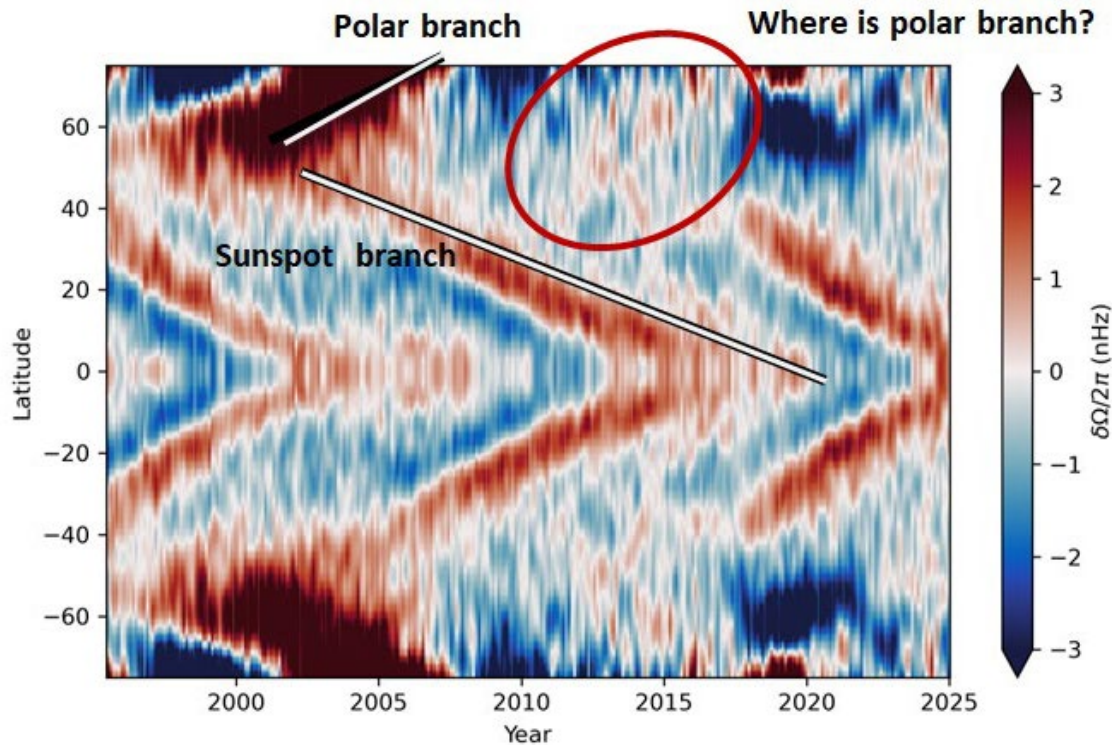
Much better cycle predictions are needed (e.g., In April of 2022, Capella Space discovered that their Whitney satellites were deorbiting faster than NOAA SWPC's consensus solar cycle model predicted.

Capella revised their satellite lifetime estimates and found that they expected to lose six out of seven operational satellites by the end of the year (Shambaugh, 2024).



Predicting solar cycles

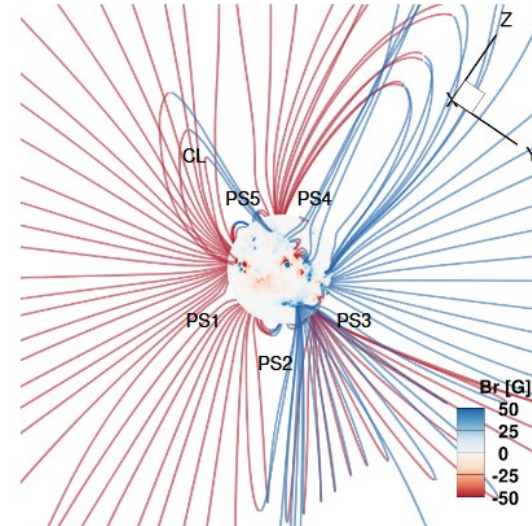
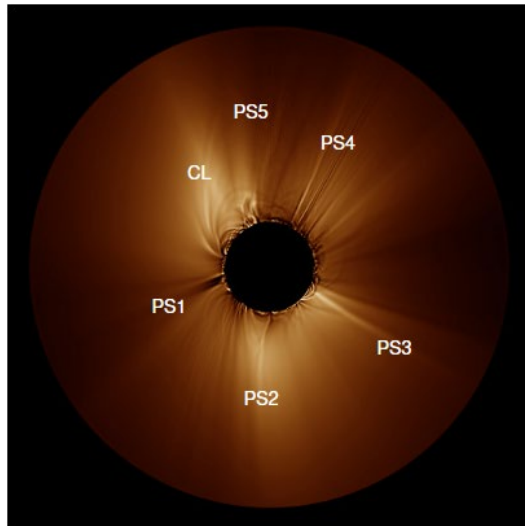
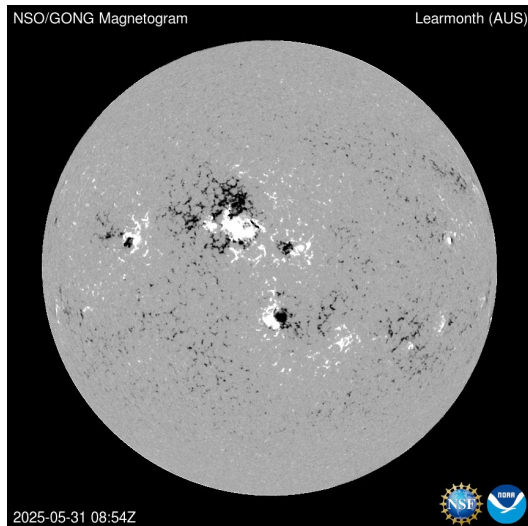
- Successful prediction of long-term activity/solar cycles requires synoptic observations



Requires helioseismology at 60 sec cadence and continuous observations over solar magnetic cycle (22+ years): Rotation-rate residuals as a function of latitude and time, from inversions of GONG data. The white lines mark approximate location of sunspot and polar branches in cycle 24. The sunspot branch re-appears after 2018 heralding cycle 25. A polar branch for cycle 25 appears to be missing. Background image is courtesy R. Howe

What observations are required

- Vector/line-of-sight magnetic field maps (10 minutes cadence)
- Doppler velocities (Helioseismology: 60 second cadence/ $>80\%$ duty cycle)
- Narrow/broad band Imaging (visible and EUV/X-ray)
- Coronagraphic observations



Liu et al (2025), DOI: [10.48550/arXiv.2503.10974](https://doi.org/10.48550/arXiv.2503.10974)

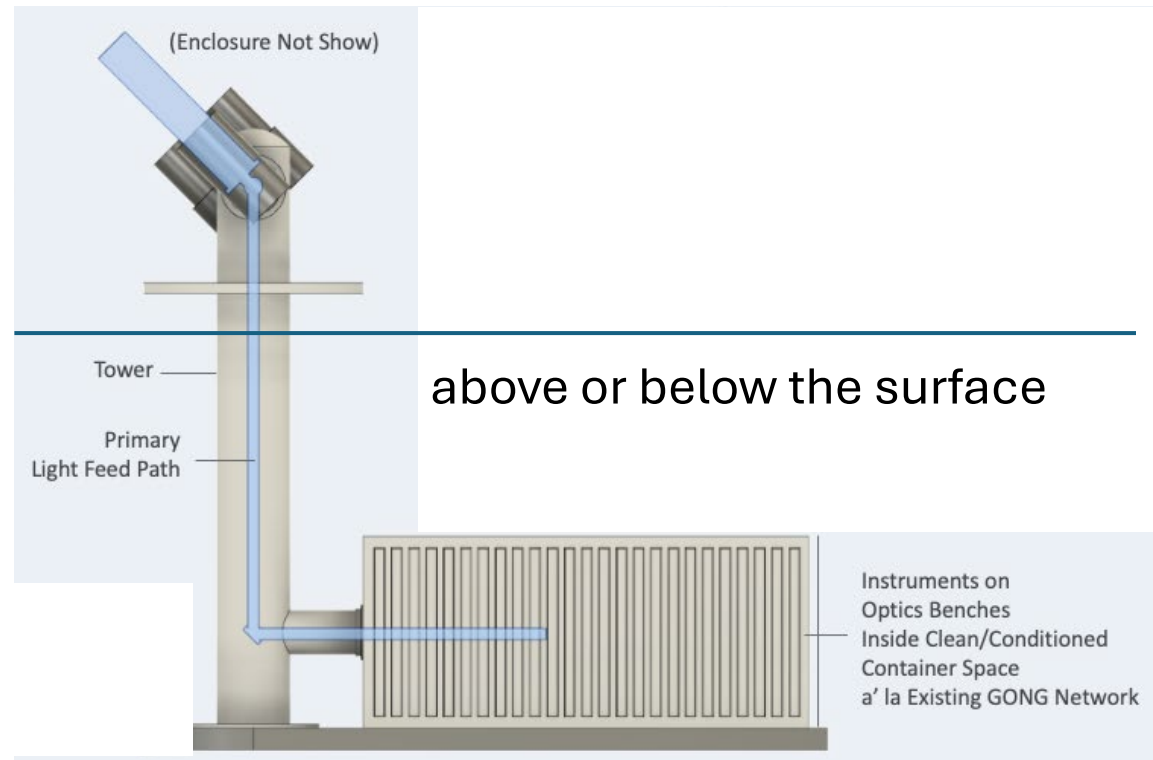


Advantages

- 3 stations in equatorial region will provide a 100% duty cycle
- Stable instrument environment (could be underground if necessary), stable telescope mount with tracking for a moderate size instruments, ability for repairs and future upgrades, large amount of data could be stored on site, processed, and operationally transmitted to Earth, redundancy for site failures
- Simultaneous observations in visible and EUV/X-ray
- Small vantage point difference from Earth

3-site network

- 3 fully robotic stations in the equatorial region
- Fully evacuated 50 cm aperture main telescope (visible); a coronagraph as separate instrument
- Small tower (lunar dust levitation height ~ 2 m, doi:10.1029/2010JA015286)
- Instruments could be located underground or above the surface



Courtesy M. Warner

Credits

- NASA's Scientific Visualization Studio

Visualizer	Ernie Wright (USRA) 
Scientist	Jacob Bleacher (NASA/GSFC)
Technical support	Laurence Schuler (ADNET Systems, Inc.)
	Ian Jones (ADNET Systems, Inc.)

- Dr. C. Keller
- Dr. R. Howe
- Dr. K. Jain
- Mr. M. Warner