Space Weather and the Space Weather Program @GMU

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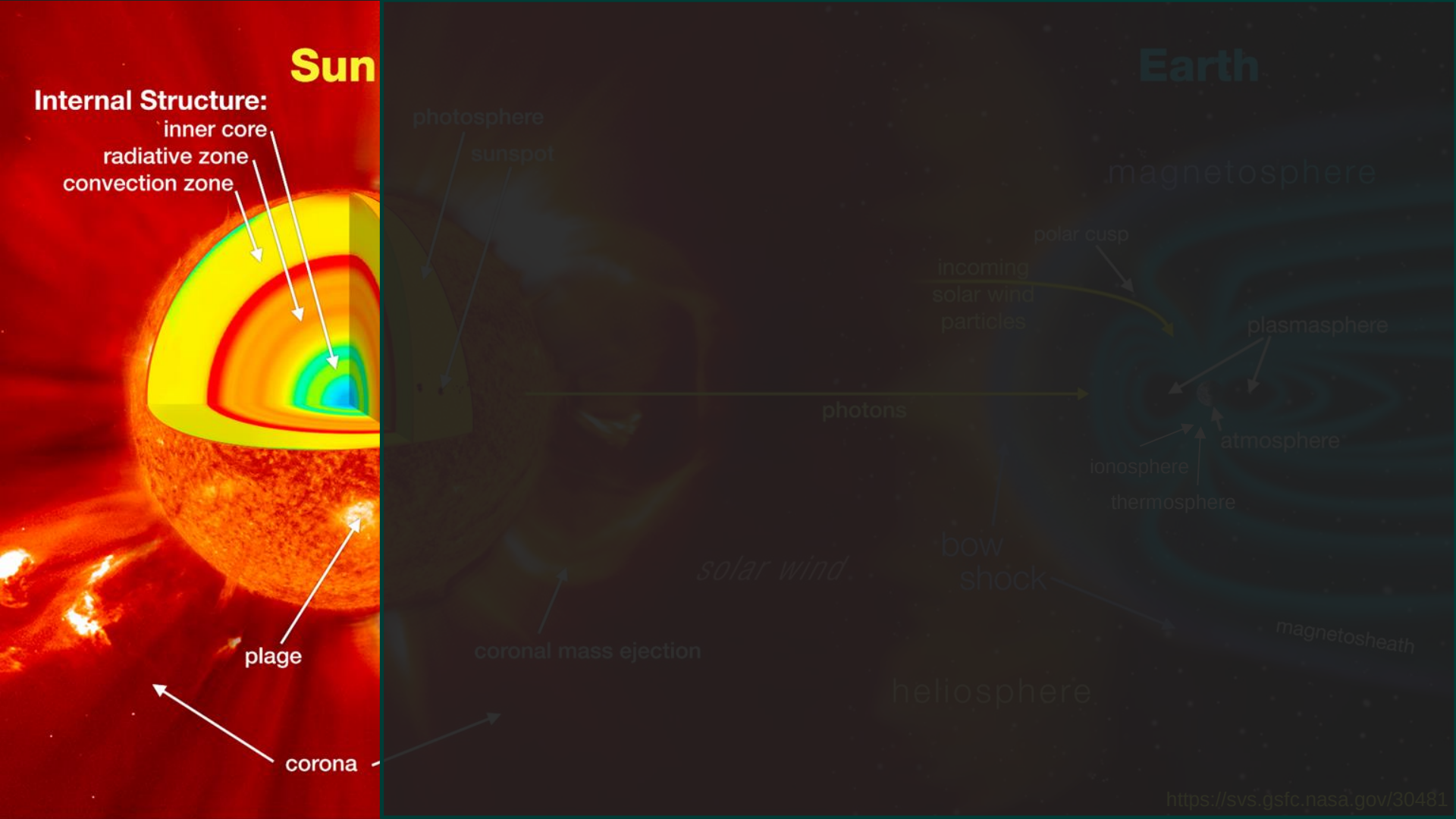
spaceweather.gmu.edu

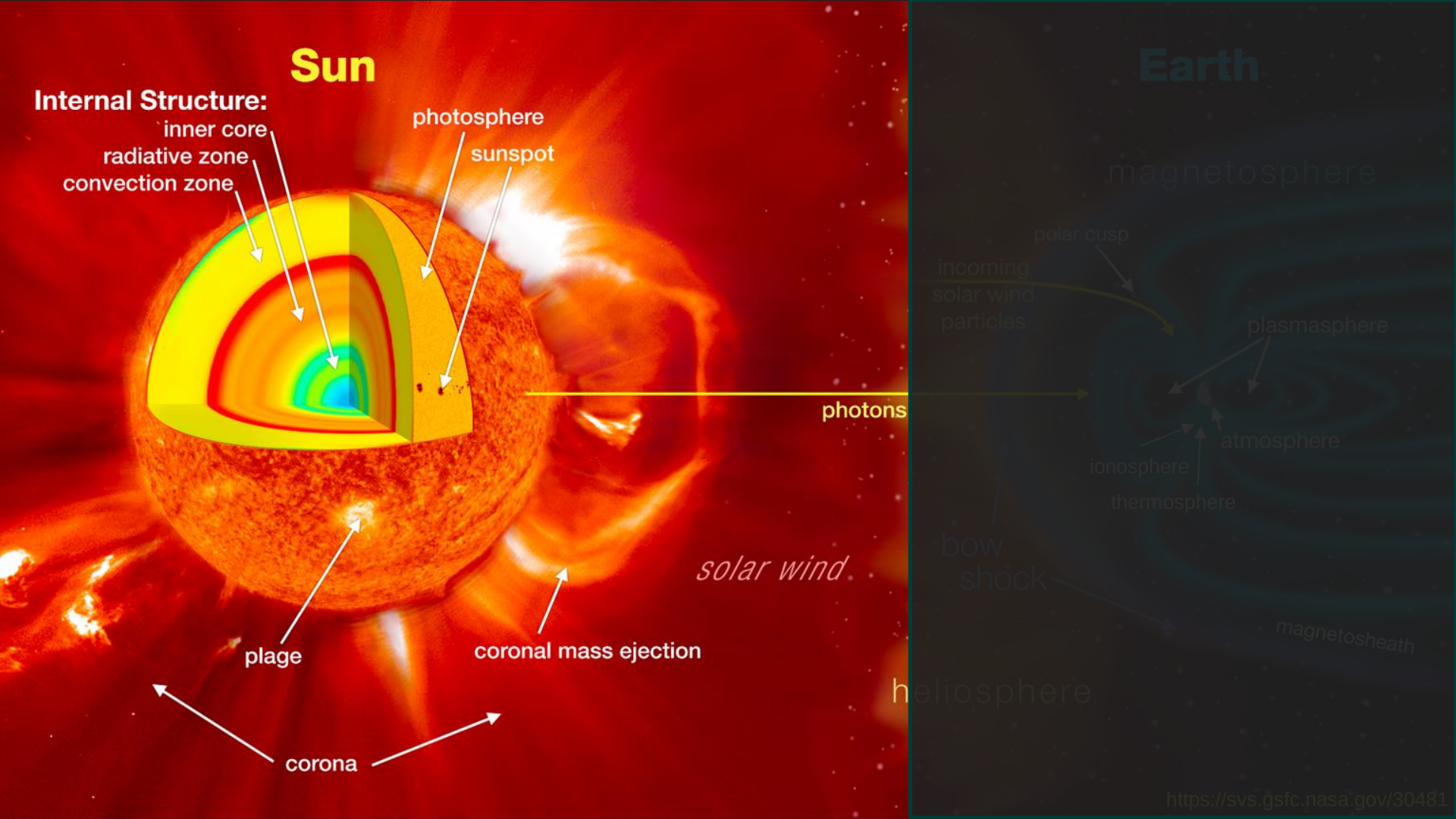
Terrestrial Weather vs. Space Weather

- Terrestrial Weather is primarily driven by the energy of photons from the sun.
- Terrestrial Weather patterns and storms involve the flow of neutral gas in Earth's atmosphere.

- Space Weather is primarily driven by the energy of particles from the sun.
- Space Weather patterns and storms involve the flow of ionized gas (plasma) above Earth's atmosphere and beyond.

Space Weather Systems


Sun
Internal Structure:
inner core
radiative zone
convection zone
plage
corona
photosphere
sunspot
coronal mass ejection
solar wind
heliosphere
Earth
magnetosphere
polar cusp
incoming
solar wind
particles
plasmasphere
photons
atmosphere
ionosphere
thermosphere
bow
shock
magnetosheath
https://svs.gsfc.nasa.gov/30481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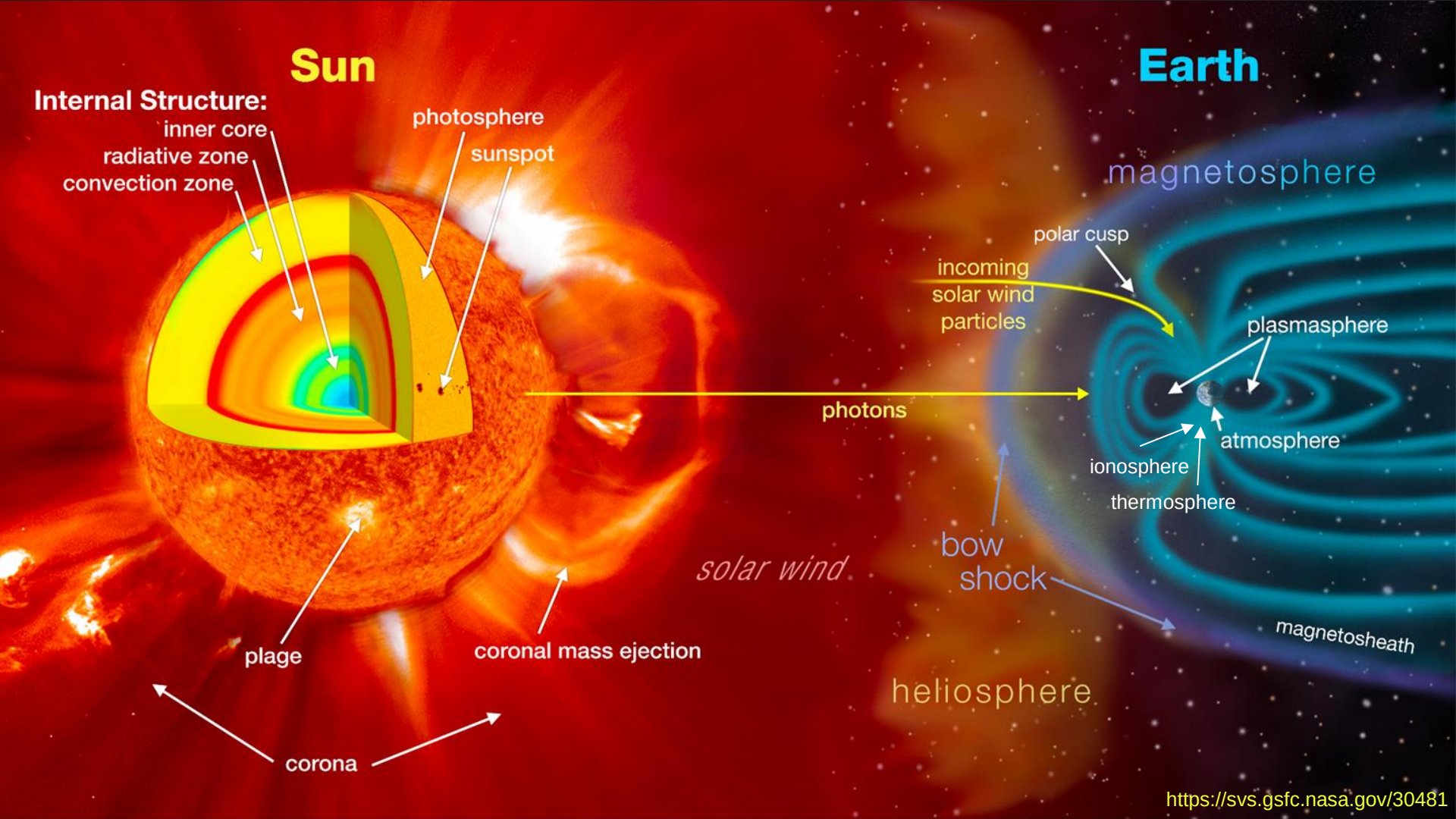
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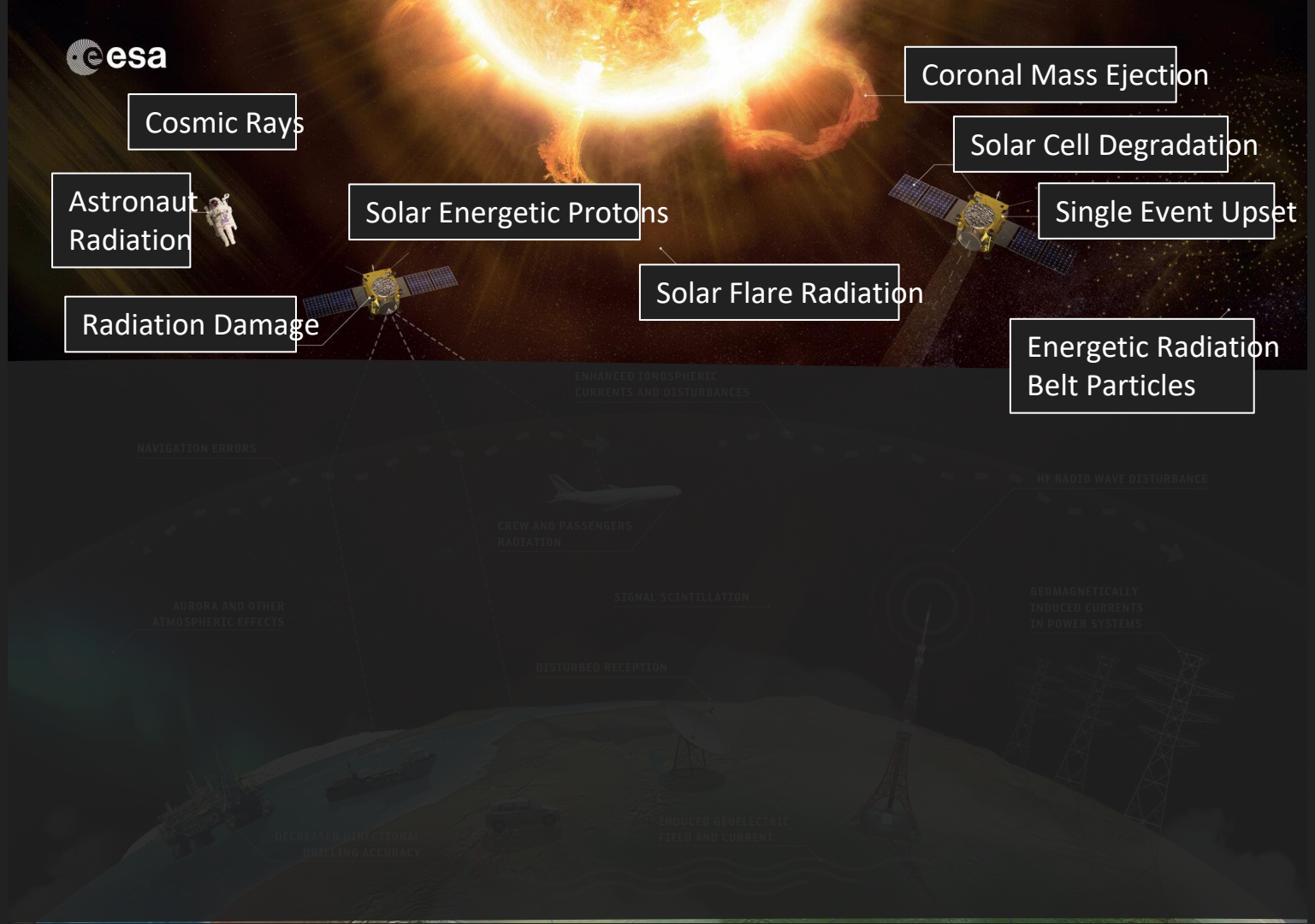
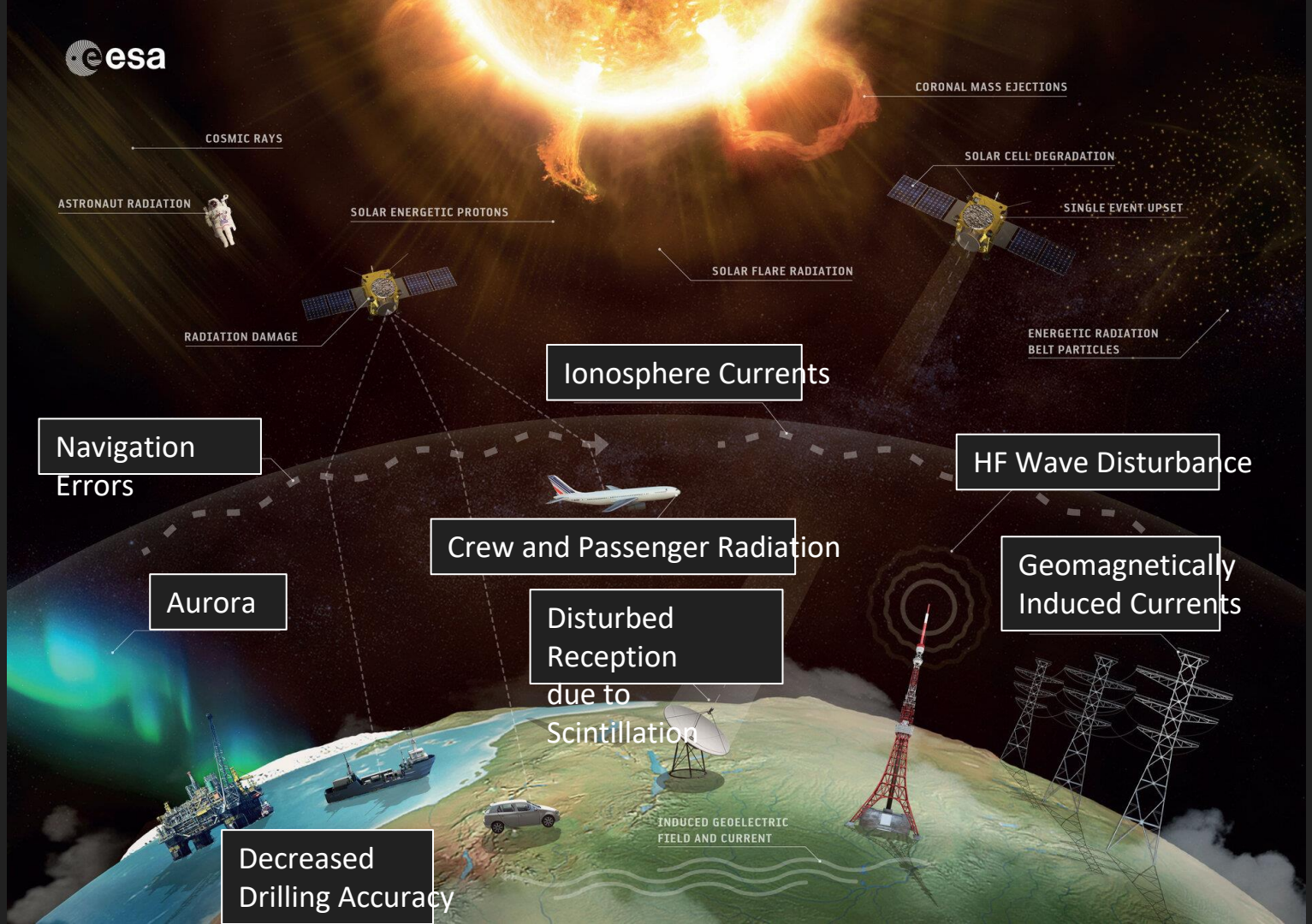
Coronal Mass Ejection


NASA/SDO

Space Weather Effects


esa
Cosmic Rays
Coronal Mass Ejection
Solar Cell Degradation
Astronaut Radiation
Solar Energetic Protons
Single Event Upset
Solar Flare Radiation
Radiation Damage
Energetic Radiation Belt Particles
ENHANCED IONOSPHERIC CURRENTS AND DISTURBANCES
NAVIGATION ERRORS
HF RADIO WAVE DISTURBANCE
CREW AND PASSENGERS RADIATION
AURORA AND OTHER ATMOSPHERIC EFFECTS
SIGNAL SCINTILLATION
GEOMAGNETICALLY INDUCED CURRENTS IN POWER SYSTEMS
DISTURBED RECEPTION
DECREASED DIRECTIONAL DRILLING ACCURACY
INDUCED GEOELECTRIC FIELD AND CURRENT


esa
CORONAL MASS EJECTIONS
COSMIC RAYS
SOLAR CELL DEGRADATION
ASTRONAUT RADIATION
SOLAR ENERGETIC PROTONS
SINGLE EVENT UPSET
SOLAR FLARE RADIATION
RADIATION DAMAGE
ENERGETIC RADIATION BELT PARTICLES
Ionosphere Currents
Navigation Errors
HF Wave Disturbance
Crew and Passenger Radiation
Geomagnetically Induced Currents
Aurora
Disturbed Reception due to Scintillation
INDUCED GEOELECTRIC FIELD AND CURRENT
Decreased Drilling Accuracy

The Space Weather Program @GMU

GMU

- ~ 25,000 undergraduate
- ~ 11,000 graduate
- Total enrollment increase of ~ 20% in past 10 years

Department of Physics and Astronomy (35 tenure line faculty)

- ~ 90 undergraduate
- ~ 20 MS
- ~ 40 PhD

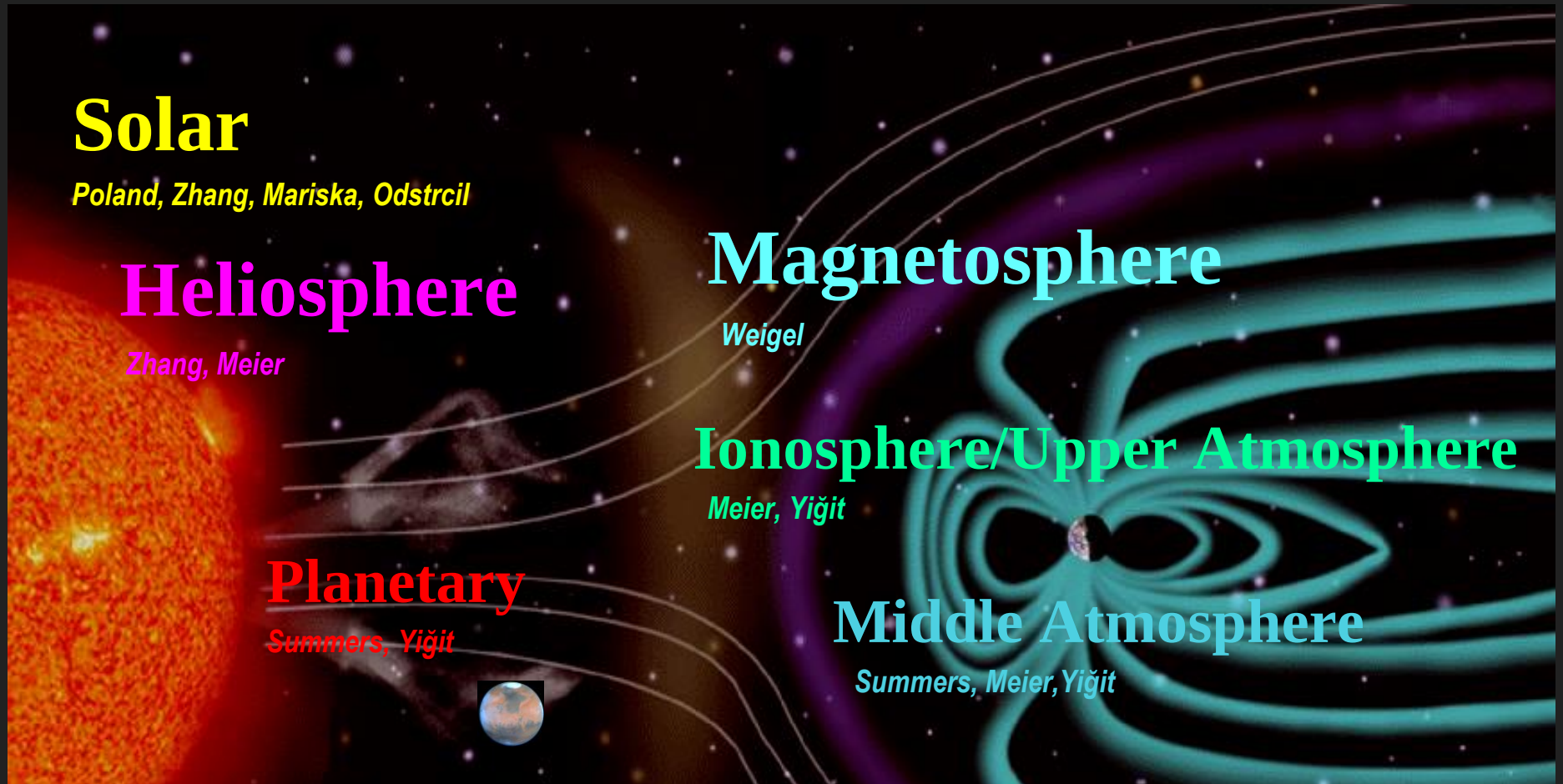
Space Weather Lab (4 tenure line/6 research faculty/1 post-doc)

- 7 Active PhD students
- 18 PhDs since 2004

History

- Space Weather at GMU started in 2003 with addition of Poland, Meier, and Withbroe. Had vision of comprehensive Space Weather Program at GMU
- Proposed tenure line faculty positions in Department of Physics and Astronomy and Department of Computational and Data Sciences
- Three tenure lines started in 2005-2006.
- Have added additional research faculty from NASA and NRL

An Integrated Program



Faculty and Students

Tenure-line:

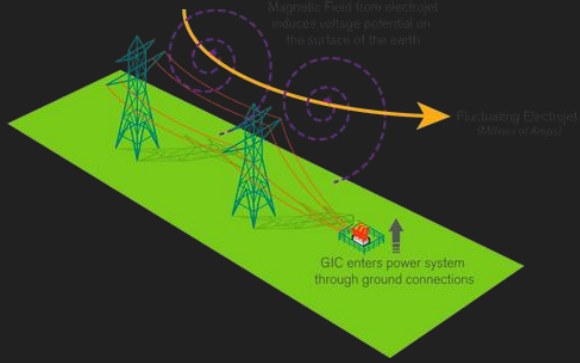
- Jie Zhang - Solar
- Erdal Yiğit – Thermosphere/Ionosphere/Planetary
- Bob Weigel – Magnetosphere
- Mike Summers – Planetary/Upper Atmosphere

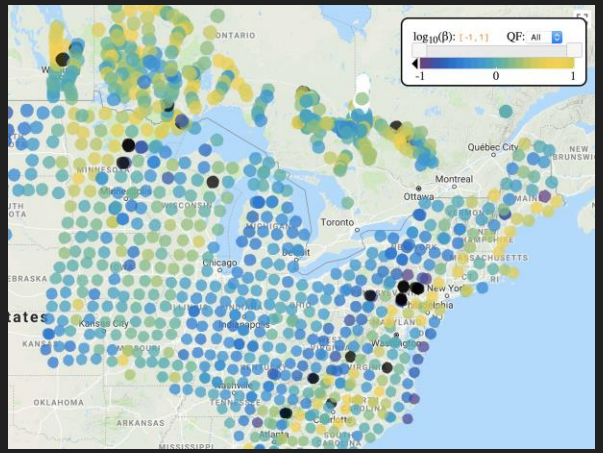
Research Faculty:

- Bob Meier – Ionosphere/Solar
- Art Poland – Solar
- Dieter Bilitza –Thermosphere/Ionosphere
- Dusan Odstrcil – Solar Wind

Weigel - Magnetosphere

- Modeling of geomagnetically induced currents (GICs)
- Prediction of magnetospheric activity using neural networks
- Modeling plasmatrough density variations during geomagnetic storms





Weigel - Magnetosphere

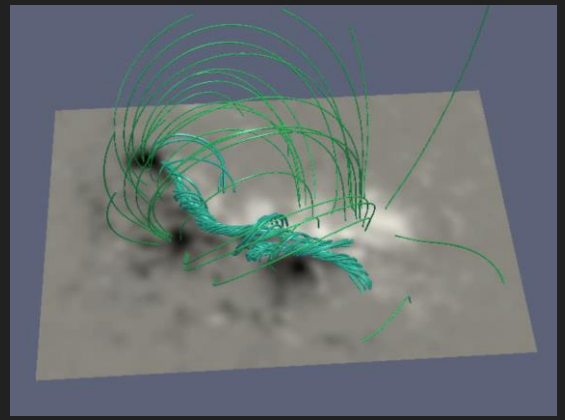
- Modeling Large-Scale Current Systems during Extreme Space Weather Events (with graduate student Dean Thomas and group led by Antti Pulkkinen @ NASA/GSFC)
- Solving MHD equations using Physics Informed Neural Networks (PINNs) (with graduate student Eric Winter)
- Data Mining-Derived Magnetic Field Modeling (with graduate student Grant Stephens)
- Geomagnetically Induced Current and Magnetotelluric Transfer Function Modeling and Prediction (with Antti Pulkkinen and Peter Schuck @ NASA/GSFC)

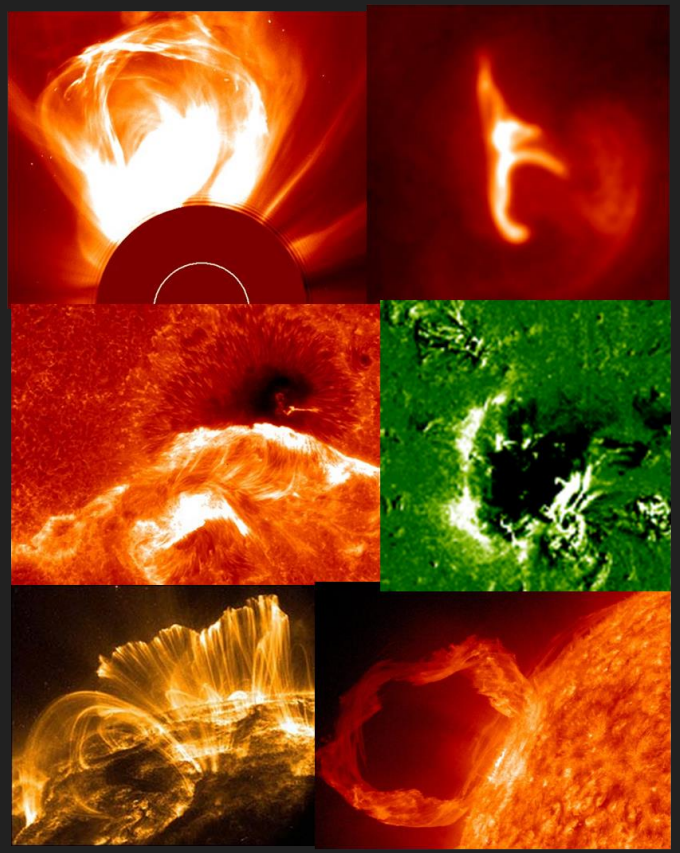
Weigel - Magnetosphere

- Co-Lead on Heliophyiscs API (initiated by Aaron Roberts @ NASA/GSFC)
- Lead on Space Time Coordinate Transform specification (with Brian Thomas, Jin Lian, Bobby Candey, Albert Shih, and Rebecca Ringuette @ NASA/GSFC)
- Contributor to Python in Heliophysics Community (PyHC) software and summer school (NASA sponsored)
- Contributor to COSPAR International Space Weather Action Teams (lead by Masha Kuznetsova @NASA/GSFC)

Zhang – Solar Physics and Space Weather

- Solar Magnetism
- Magnetic Reconnection
- Solar Eruptions: Flares and Coronal Mass Ejections
- Geoeffective Interplanetary Transients
- Space Weather Prediction





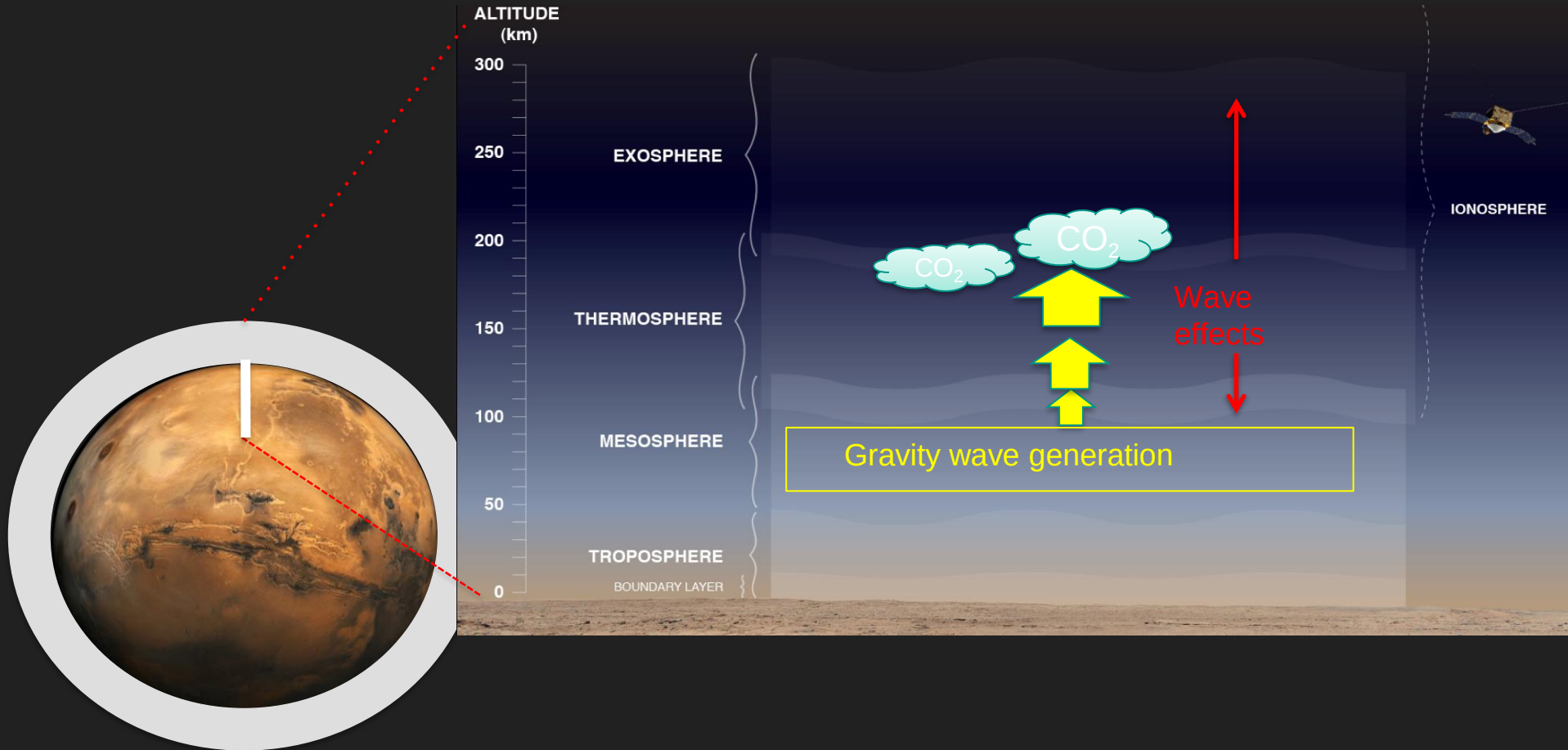
Yiğit – Planetary Atmospheres and Coupling

Science Goal: To quantify the role of atmospheric gravity waves and solar tides and of their interactions in planetary atmospheres.

Methodology:

- General Circulation Modeling
- Satellite data (e.g., MAVEN)

Yiğit – Planetary Gravity Waves and Clouds



Bilitza - IRI

International Reference Ionosphere (IRI)

- One of the principal authors of the IRI model and is working with GMU students and colleagues on improvements of the model.
- IRI describes the density, temperature, and velocity of electrons and ions in Earth's ionosphere based on the large volume of ground and space measurements.
- IRI is widely used for many applications in science, engineering, and education and in 2014 was certified as the ISO standard for the ionosphere
- IRI is a joint project of the Committee on Space Research (COSPAR) and the International Union of Radio Science.

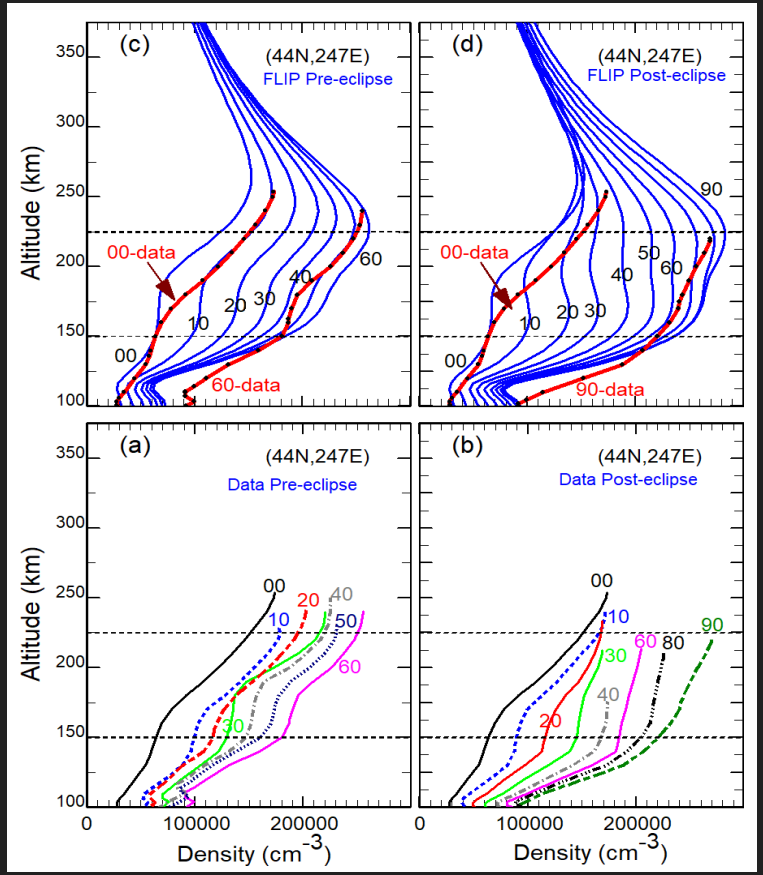
IRI Usage Online and In Journal Articles

Year	JGR	GRL	SW	RS
2009	5.0%	3.6%	0.0%	10.5%
2010	5.6%	4.7%	5.6%	11.8%
2011	7.1%	1.6%	8.1%	14.2%
2012	7.6%	2.7%	4.8%	13.8%
2013	5.1%	1.7%	2.3%	8.2%
2014	6.6%	0.5%	5.7%	10.7%
2015	8.3%	2.3%	1.6%	9.6%
2016	6.8%	0.8%	2.2%	13.2%

Percentage of papers per year that acknowledge usage of the IRI model in the AGU journals.

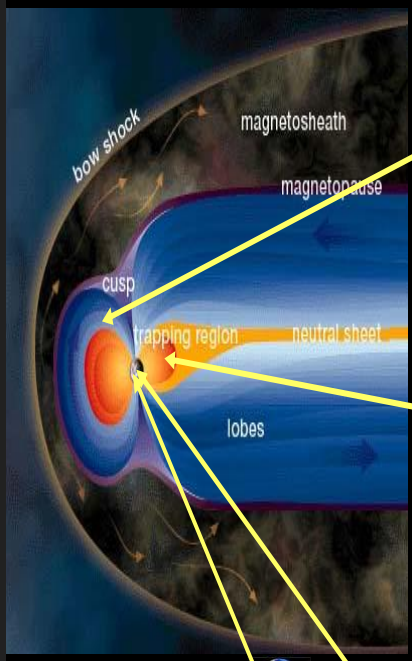
Richards - FLIP

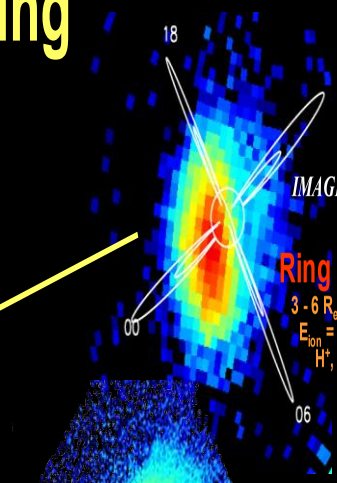
Field line inter-hemispheric plasmasphere model (FLIP)



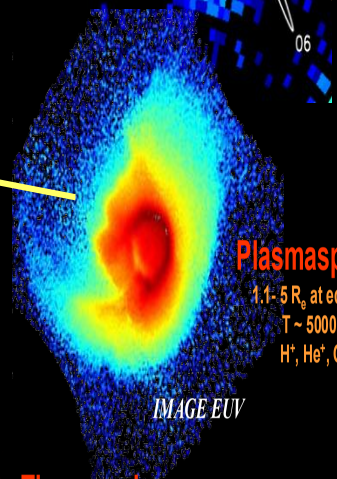
Meier – Geospace Imaging

Geospace Imaging





Ring Current
3 - 6 R_e at equator
E_{ion} = 1-200 keV
H^+, He^+, O^+



Plasmasphere
1.1- 5 R_e at equator
T ~ 5000K
H^+, He^+, O^+

Ionosphere
100-1000 km
T_e = 1-3000 K
O^+, O_2^+, NO^+

Thermosphere
100 – 500 km
T_{500} = 800-1500K
N_2, O_2, O

Education

Regular and Semi-Courses

- Space Plasma Physics
- Space Weather
- Atmospheric Physics
- Planetary Sciences
- Stellar Astrophysics
- Exoplanets

Other (ad-hoc or individualized study)

- Atmosphere/Ionosphere System
- Magnetospheric Physics
- Radiation Belt Physics
- MHD Simulation
- Solar Data Analysis

Aspirations/Challenges

Hardware program

- GMU does not have well-established traditional engineering program
- Difficult to find space on main campus, much space off campus
- This is changing: Landolt Space Mission - https://landolt.gmu.edu/

Industry partnerships

- Develop more formal education program
- Approximately 40% of graduate students are non-traditional – part time students with full-time jobs in related field.

Specialized courses

- Number of students typically not sufficient
- Have cross-listed some graduate courses with undergraduate
- Often send students to summer schools