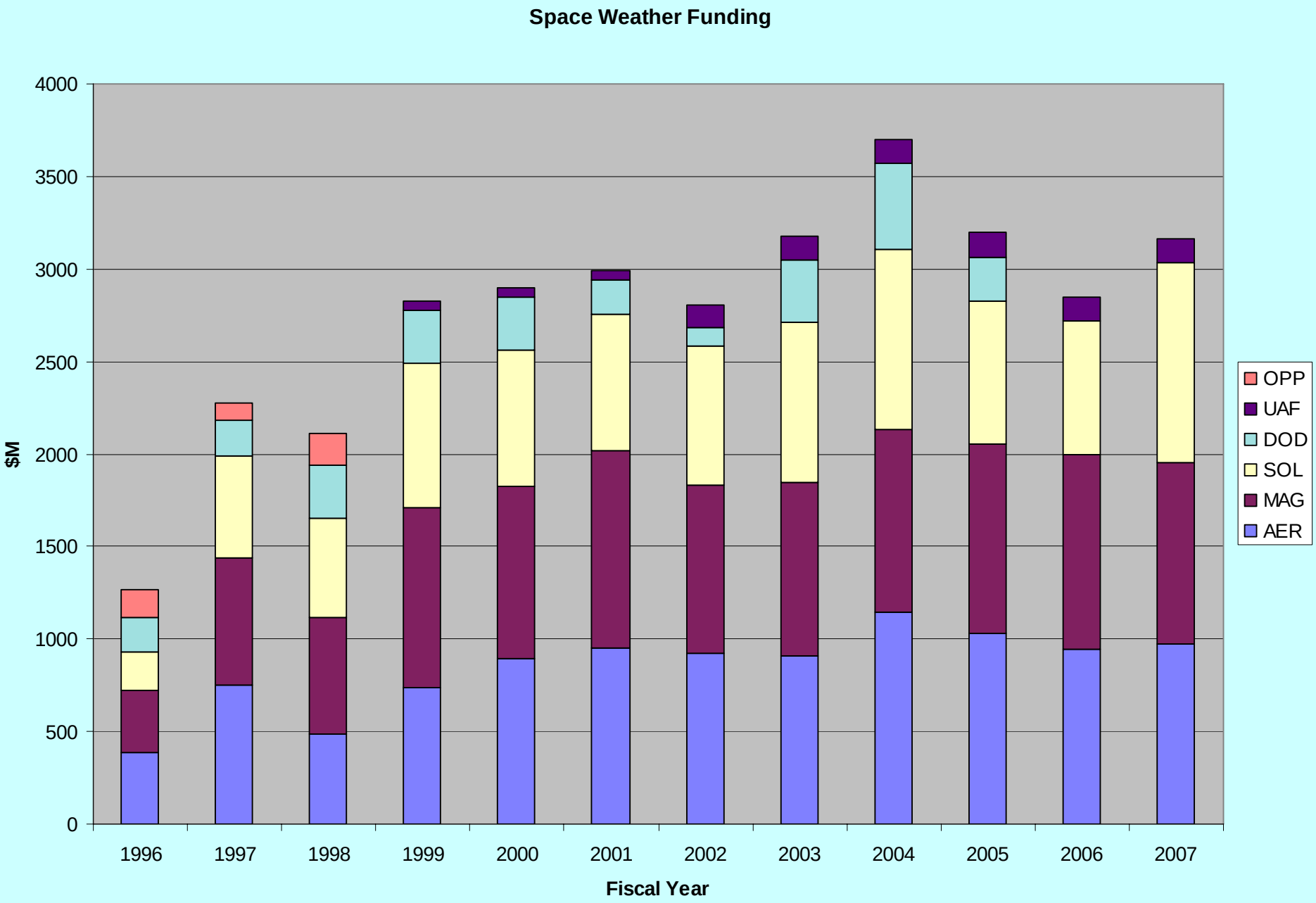
NSF Space Weather Research

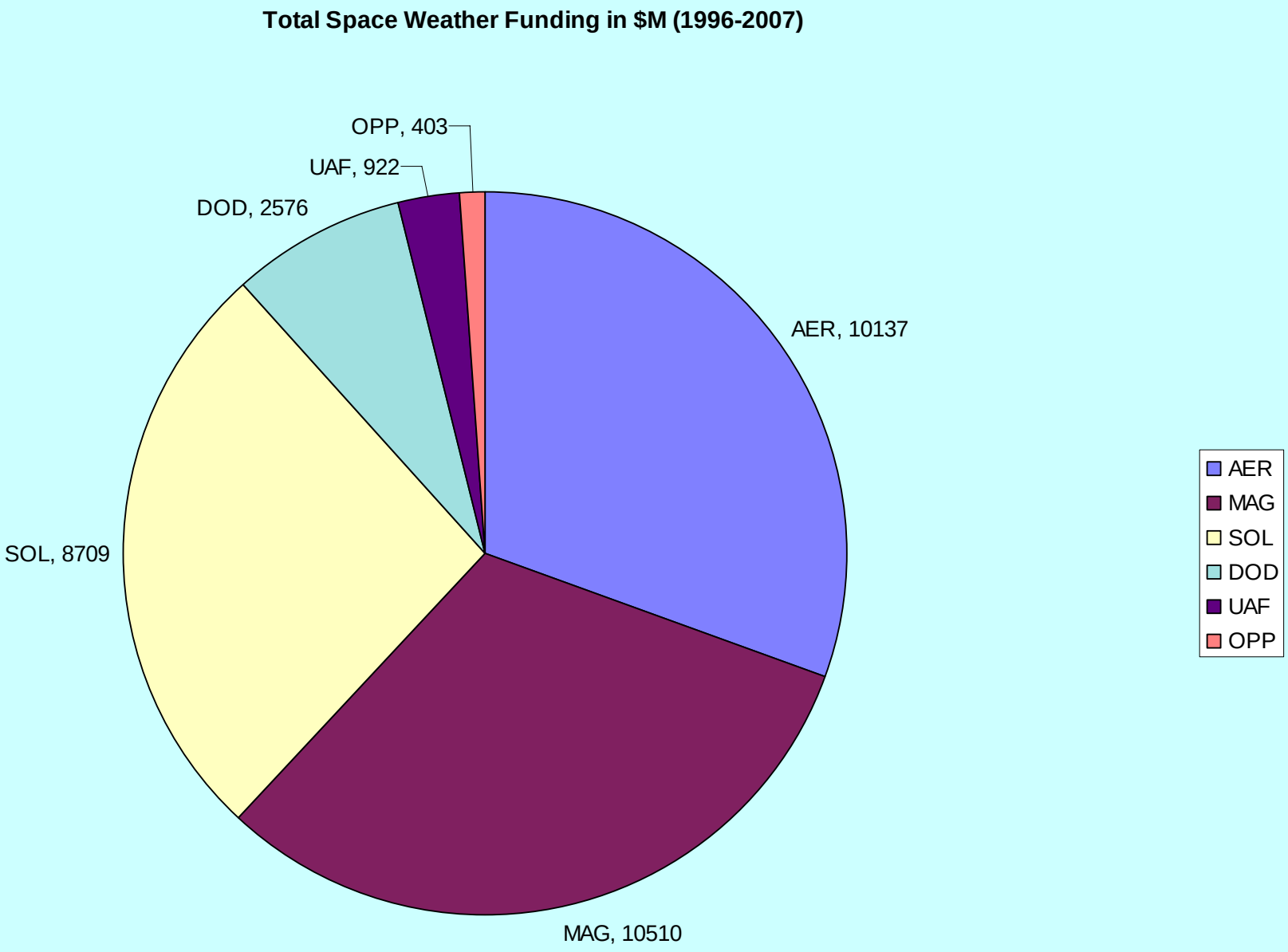
Bob Robinson

Upper Atmosphere Research Section

Outline

- NSF's Space Weather proposal competition
- Relevance to aviation and spaceflight
- A few examples of funded space weather research
- Conclusions and a prediction about research trends in space weather


Space Weather Funding
4000
3500
3000
2500
2000
1500
1000
500
0
$M
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Fiscal Year
OPP
UAF
DOD
SOL
MAG
AER


Total Space Weather Funding in $M (1996-2007)
OPP, 403
UAF, 922
DOD, 2576
AER, 10137
SOL, 8709
MAG, 10510
AER
MAG
SOL
DOD
UAF
OPP

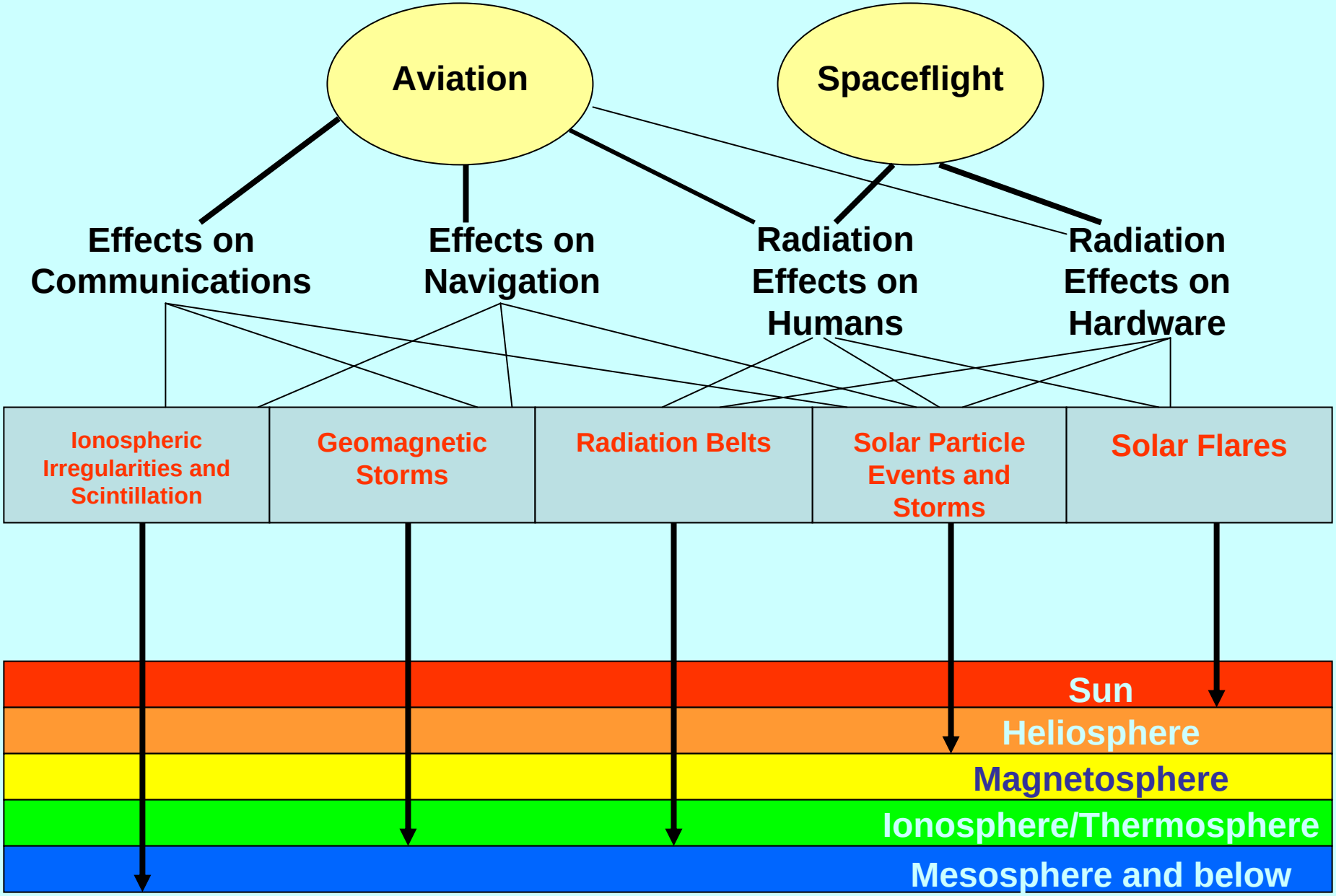
NSF Space Weather Proposal Solicitation Research Priorities

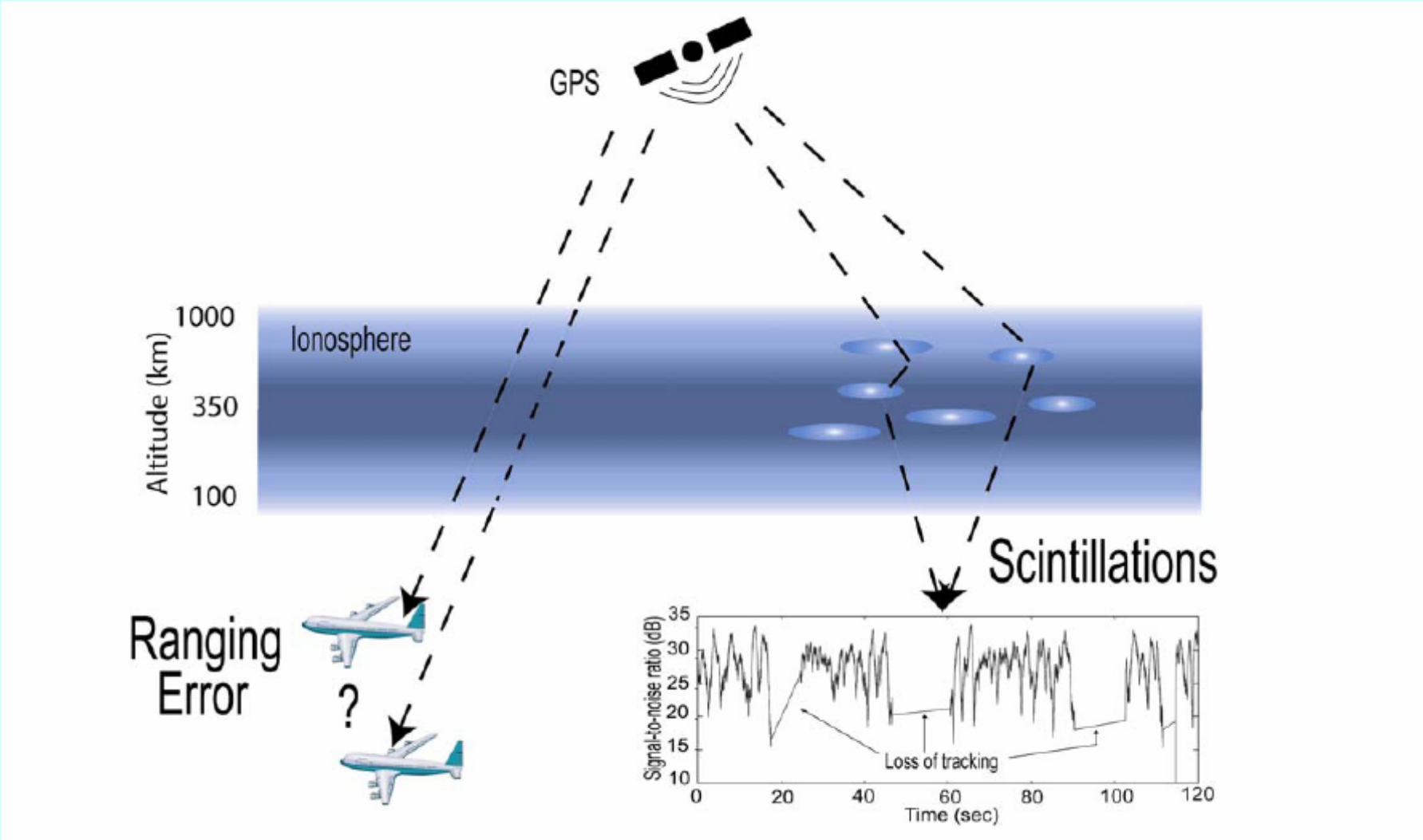
1996	1997	1999	2000	2001-Present
Understanding and prediction of processes affecting solar activity, such as coronal mass ejections and solar flares	Understanding and prediction of processes affecting solar activity, such as coronal mass ejections and solar flares	Understanding and prediction of processes affecting solar activity, such as coronal mass ejections and solar flares	Understanding and prediction of processes affecting solar activity, such as coronal mass ejections and solar flares	Understanding and prediction of processes affecting solar activity, such as coronal mass ejections and solar flares
Coupling between the solar wind and the magnetosphere	Coupling between the solar wind and the magnetosphere	Coupling between the solar wind and the magnetosphere	Coupling between the solar wind and the magnetosphere and between the magnetosphere and ionosphere	Coupling between the solar wind and the magnetosphere and between the magnetosphere and ionosphere
The origin and energization of magnetospheric plasma	The origin and energization of magnetospheric plasma	The origin and energization of magnetospheric plasma	The origin and energization of magnetospheric plasma	The origin and energization of magnetospheric plasma
The triggering and temporal evolution of substorms and storms	The triggering and temporal evolution of substorms and storms	The triggering and temporal evolution of substorms and storms	The triggering and temporal evolution of substorms and storms	The triggering and temporal evolution of substorms and storms
The evolution of ionospheric irregularities and scintillations	Improved global ionospheric specification and forecast and the evolution of ionospheric irregularities, including the onset of low latitude ionospheric irregularities	Improved global ionospheric specification and forecast and the evolution of ionospheric irregularities, including the onset of low latitude ionospheric irregularities, with particular emphasis on those processes affecting communication and navigation systems	Improved global ionospheric specification and forecast and the evolution of ionospheric irregularities, including the onset of low latitude ionospheric irregularities, with particular emphasis on those processes affecting communication and navigation systems	Improved global ionospheric specification and forecast and the evolution of ionospheric irregularities, including the onset of low latitude ionospheric irregularities, with particular emphasis on those processes affecting communication and navigation systems
Thermospheric dynamics and its coupling to the ionosphere	Improved specification of thermospheric dynamics and neutral densities	Improved specification of thermospheric dynamics and neutral densities	Improved specification of thermospheric dynamics and neutral densities	Improved specification of thermospheric dynamics and neutral densities
		Validation and enhancement of ionospheric and magnetospheric models, including data assimilation techniques, to improve operational forecasting and specification capabilities	Validation and enhancement of ionospheric and magnetospheric models, including data assimilation techniques, to improve operational forecasting and specification capabilities	Validation and enhancement of space weather models to improve specification and prediction capabilities, with emphasis on the application of data assimilation techniques
			Modelers who wish to implement and run codes at the Community Coordinated Modeling Center (CCMC) in order to accomplish any of the above objectives may include these activities in their proposals.	Modelers who wish to implement and run codes at the Community Coordinated Modeling Center (CCMC) in order to accomplish any of the above objectives may include these activities in their proposals.
				Advanced remote sensing instrumentation for improved detection and/or understanding of key space weather phenomena.

Categories of Space Weather Awards

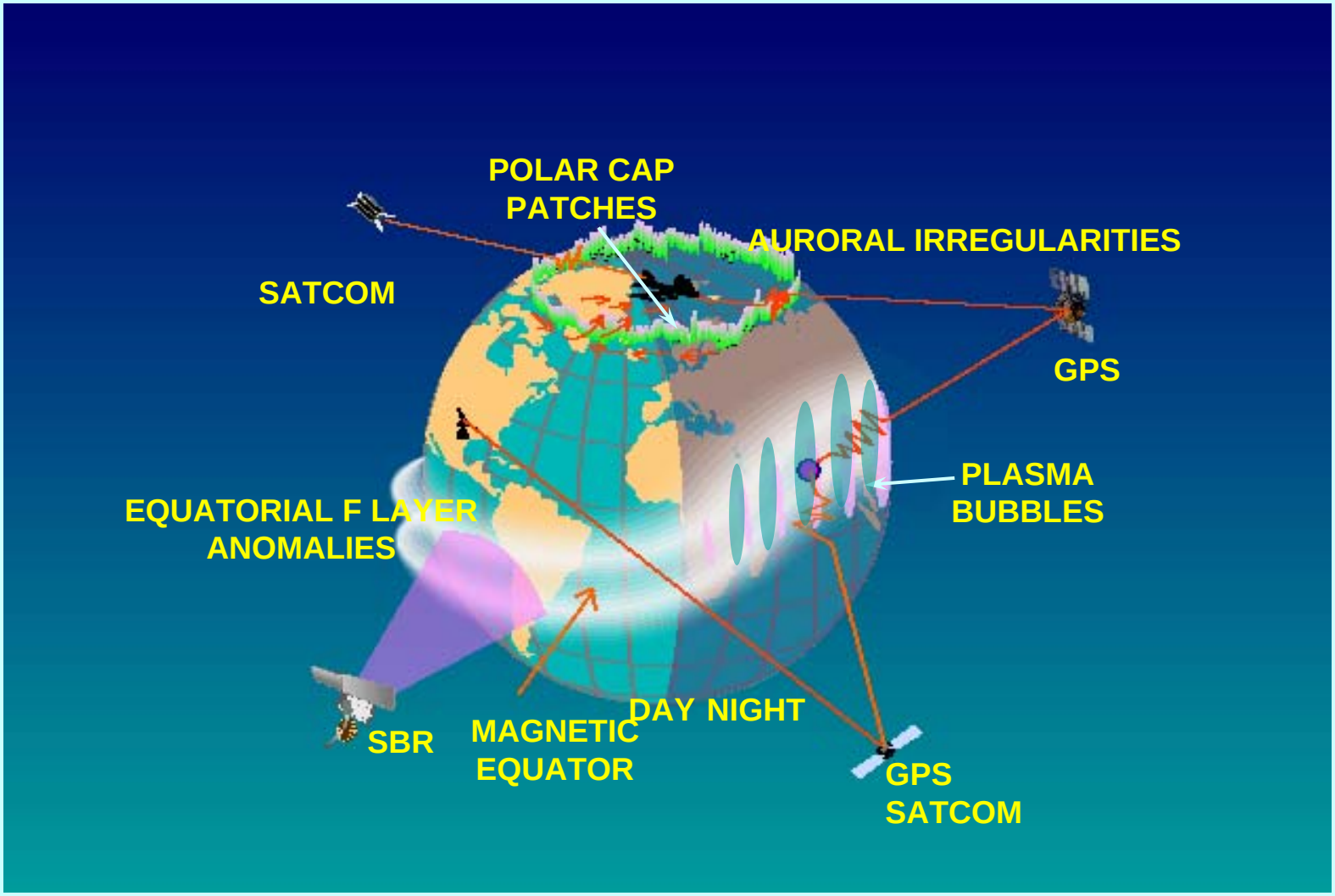
- Space weather model development
- Space weather model validation (comparison with data, intercomparison of models)
- Observational campaigns and event studies
- Development of neural nets and other space weather prediction schemes
- Instrument development, deployment, and operation
- Other awards—for example, education, space weather policy development, economic impact studies, workshops, Space Weather Journal, Community Coordinated Modeling Center

The Science of Space Weather Impacts on Aviation and Space Flight

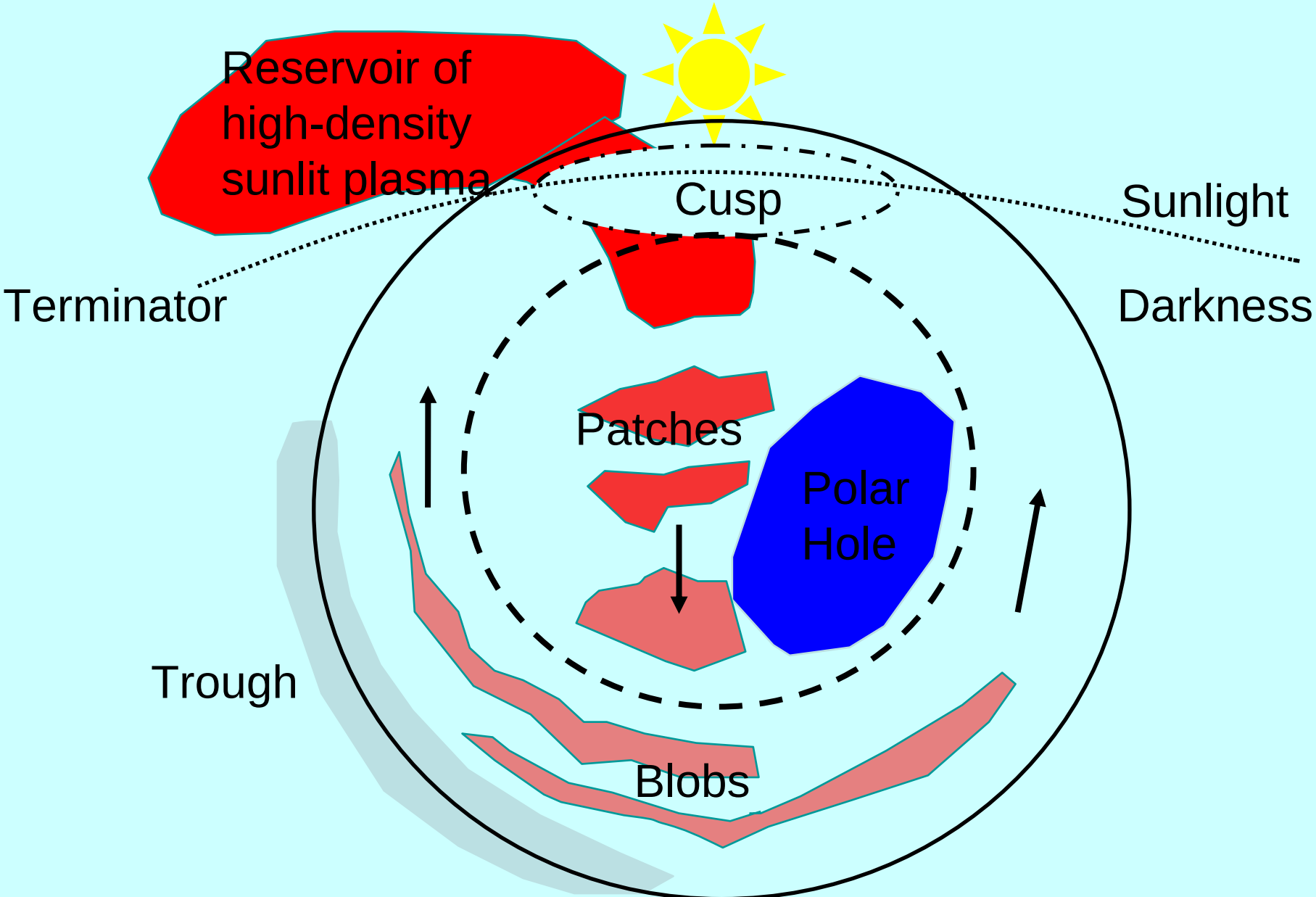



GPS
Ionosphere
Altitude (km)
1000
350
100
Scintillations
Ranging Error
?
Signal-to-noise ratio (dB)
35
30
25
20
15
10
Loss of tracking
0
20
40
60
80
100
120
Time (sec)

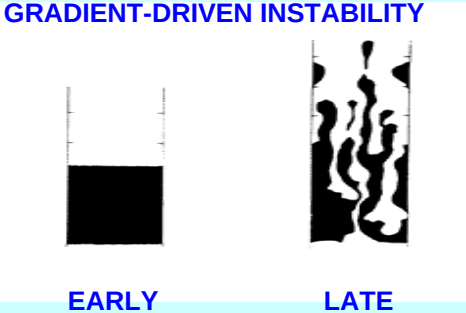
Disturbed Ionospheric Regions and Systems Affected by Scintillation

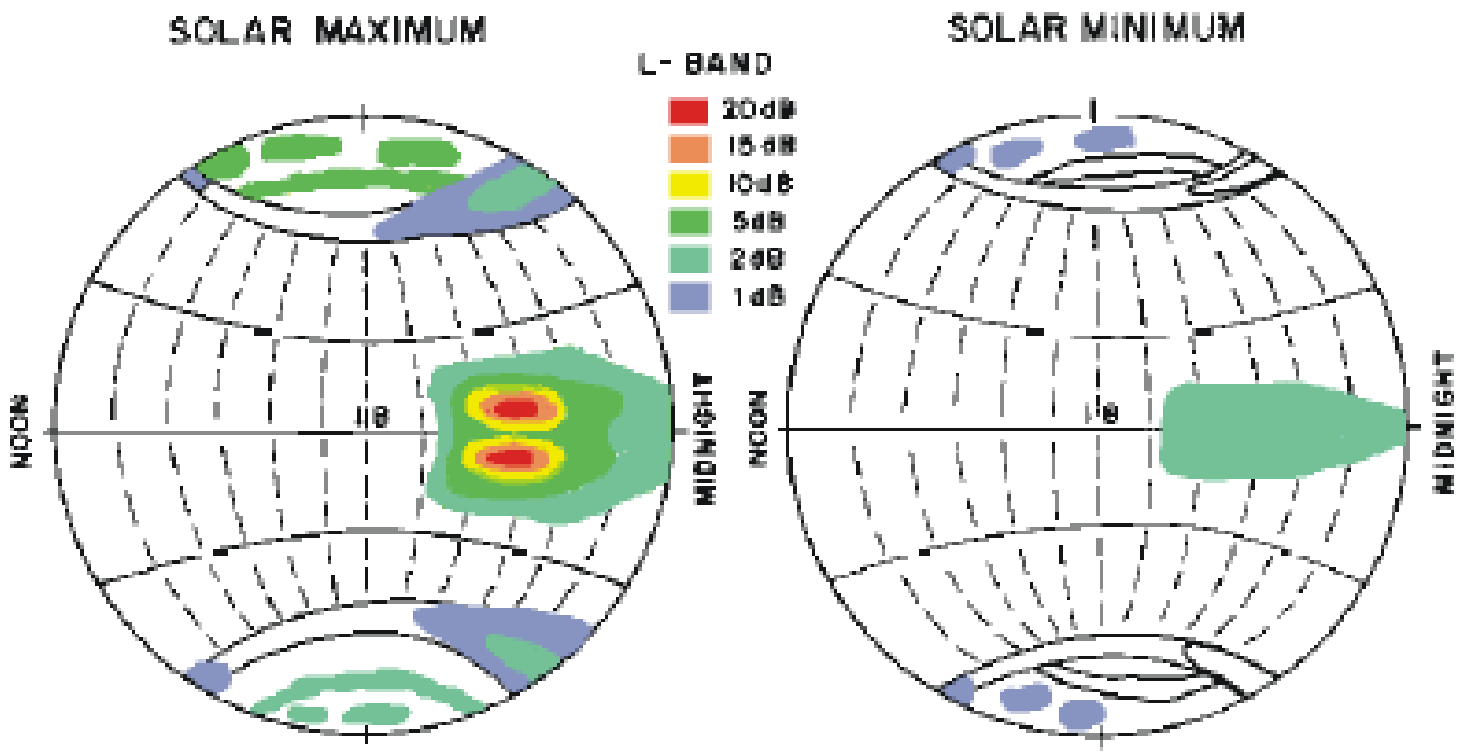


Polar Ionosphere Density Regimes
(Winter, Bz < 0)

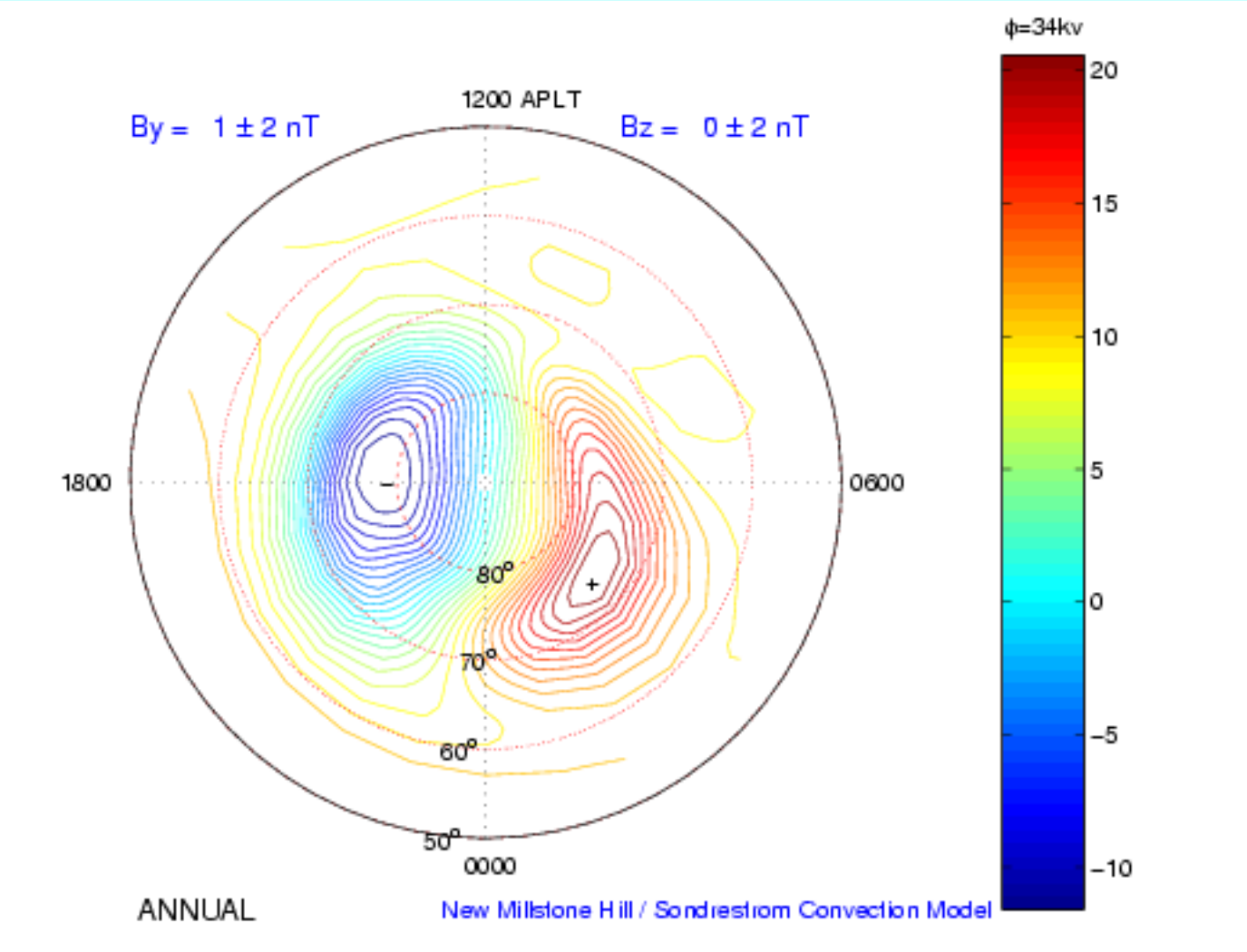


POLAR CAP F-REGION STRUCTURES

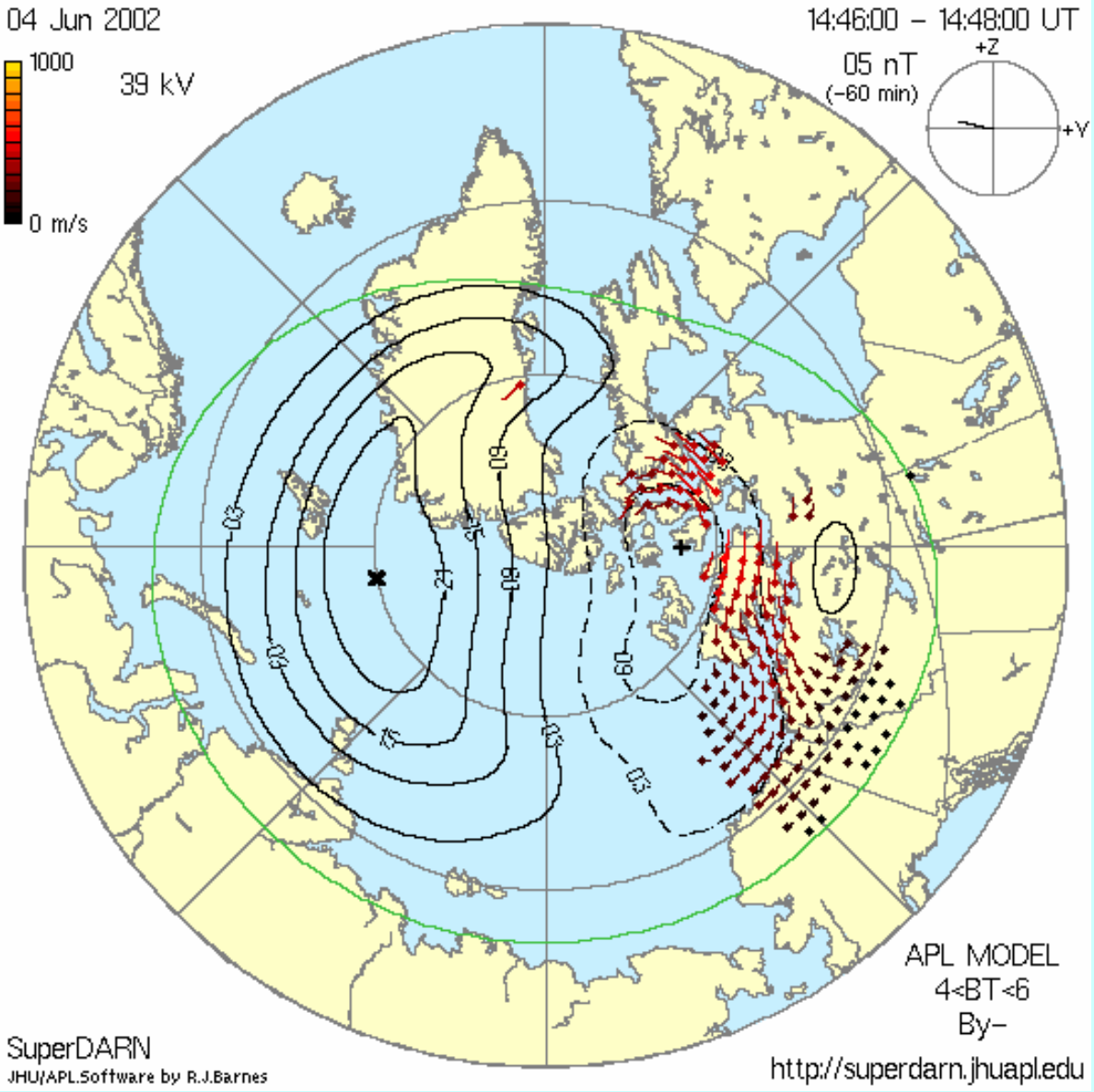
IMF B_Z NORTHWARD	IMF B_Z SOUTHWARD
SUN-ALIGNED ARCS DAWN/DUSK DRIFT	POLAR CAP PATCHES ANTI-SUNWARD DRIFT
SHEAR-DRIVEN INSTABILITY EARLY LATE	GRADIENT-DRIVEN INSTABILITY  EARLY LATE


SOLAR MAXIMUM
L- BAND
20dB
15dB
10dB
5dB
2dB
1dB
NOON
MIDNIGHT
SOLAR MINIMUM
NOON
MIDNIGHT

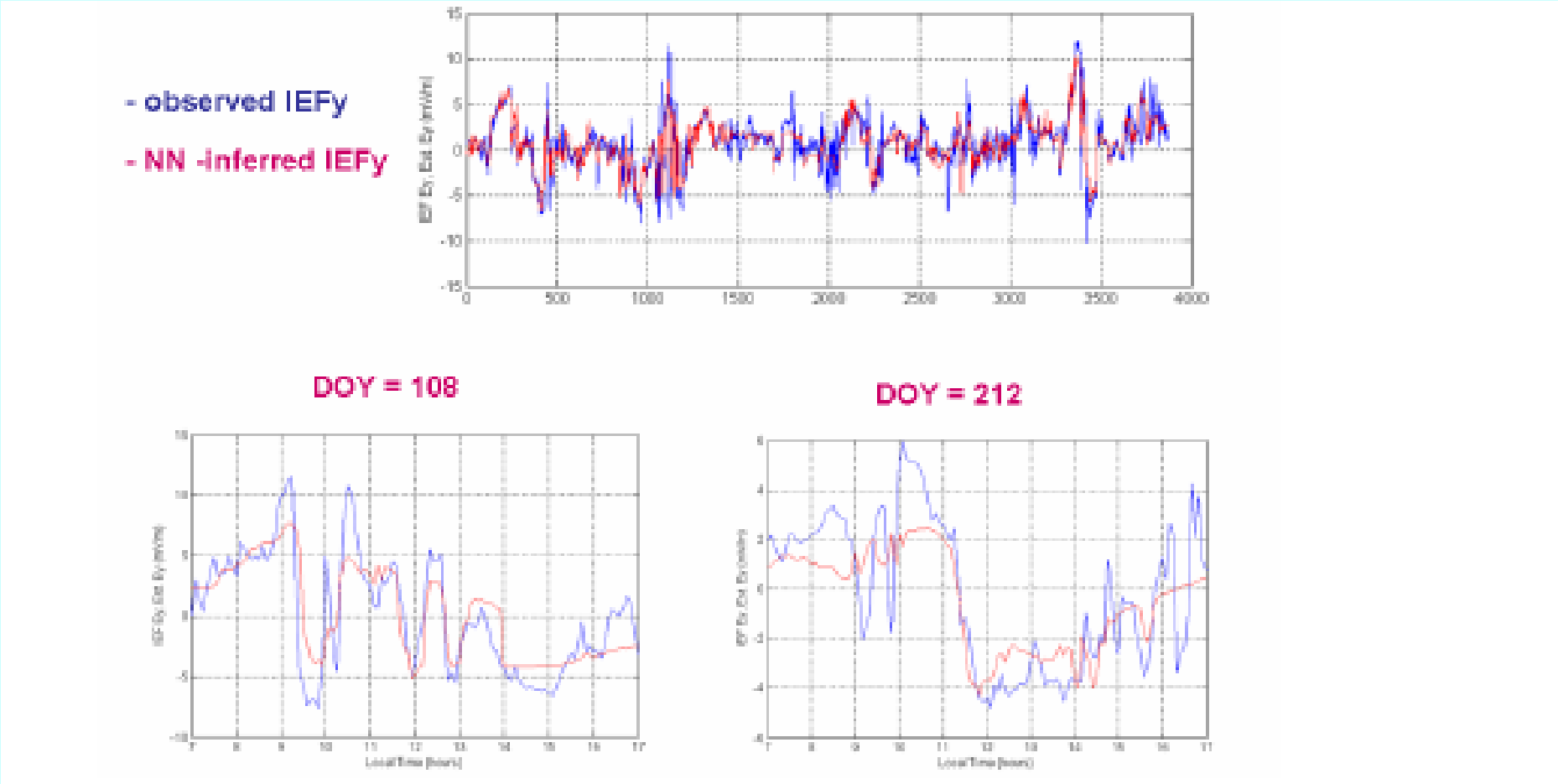
ISR Convection Model



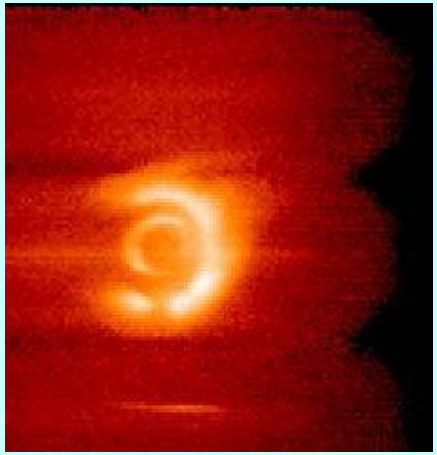
Real-time Determination of High Latitude Convection using the SuperDARN Radars



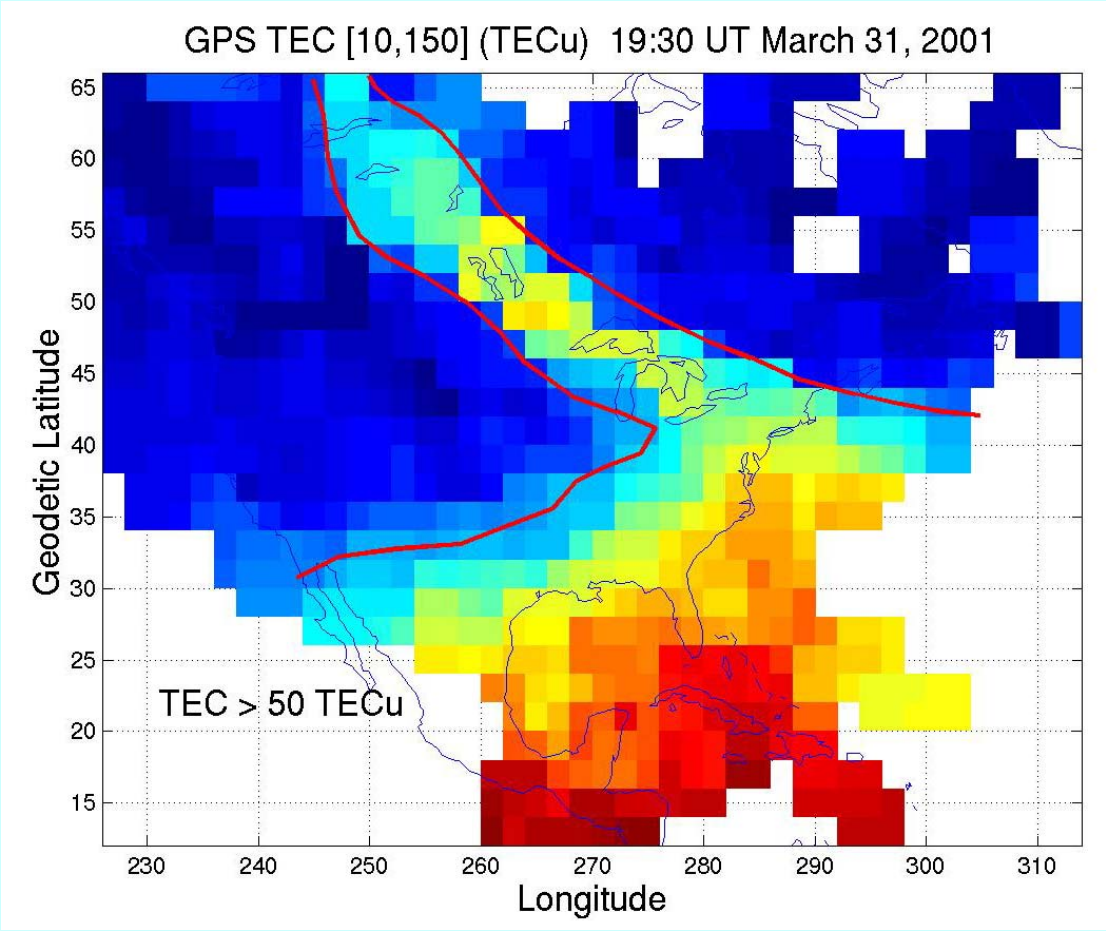
Relationship Between Interplanetary Electric Field and Vertical Plasma Drift at the Magnetic Equator

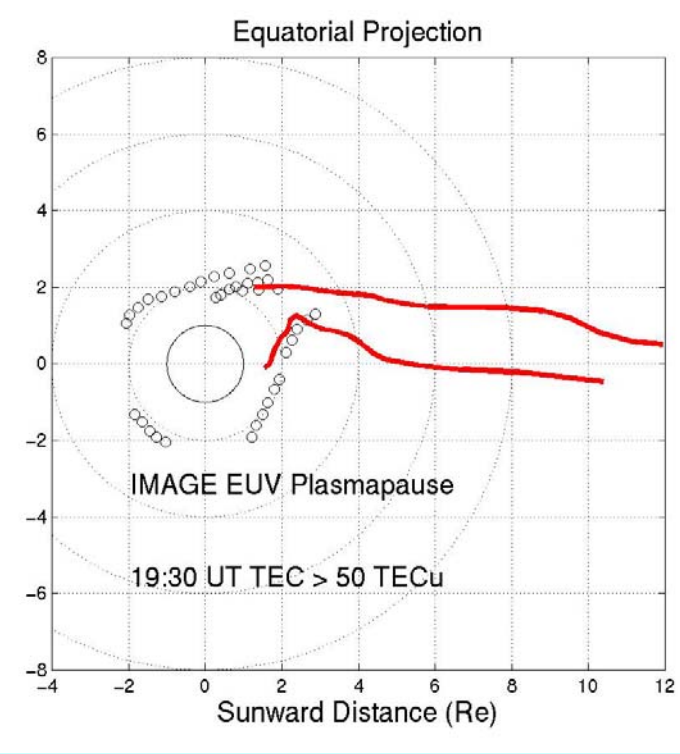


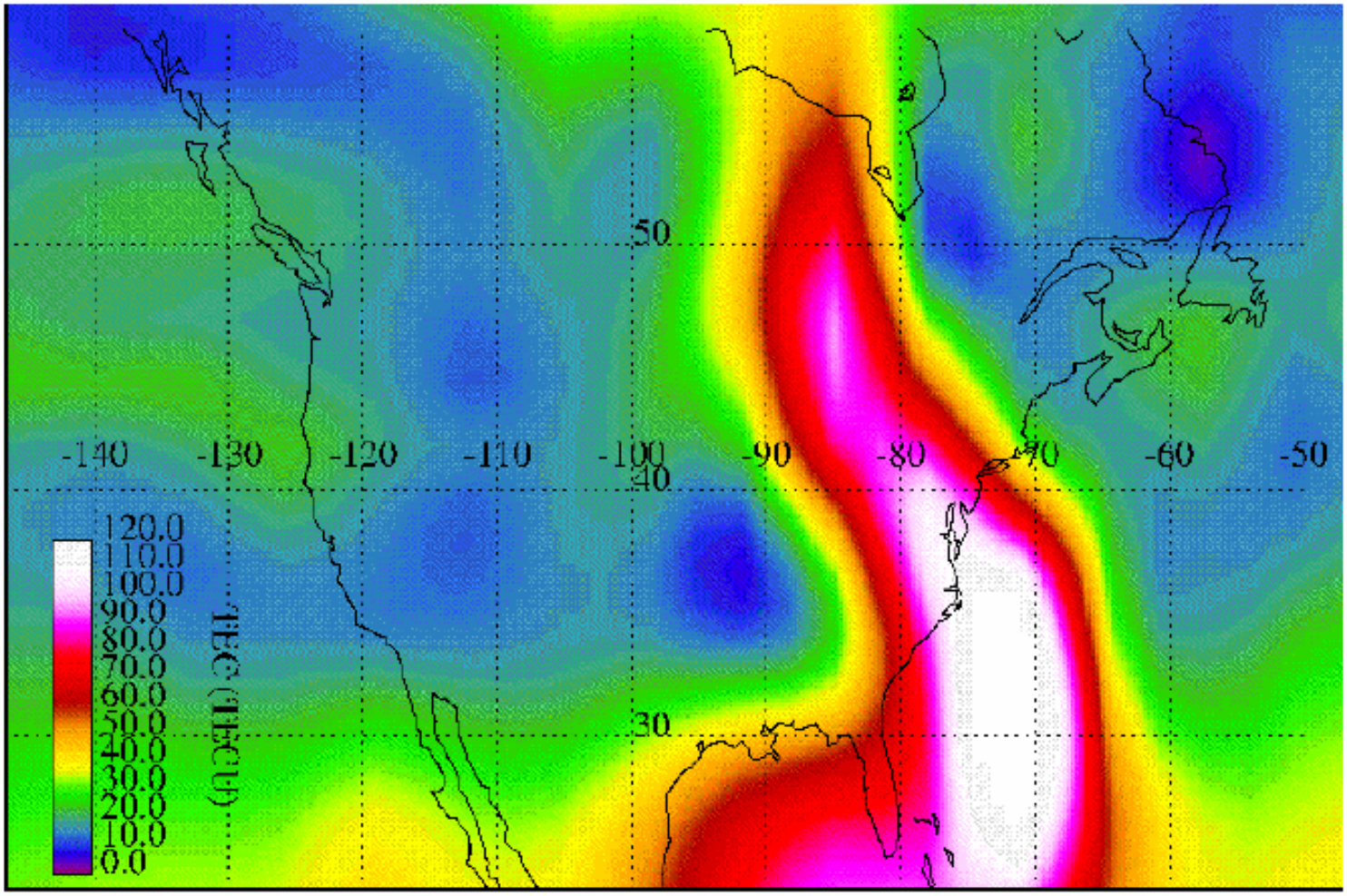
Ground and Space-Based Observations of the Perturbed Plasmasphere



IMAGE

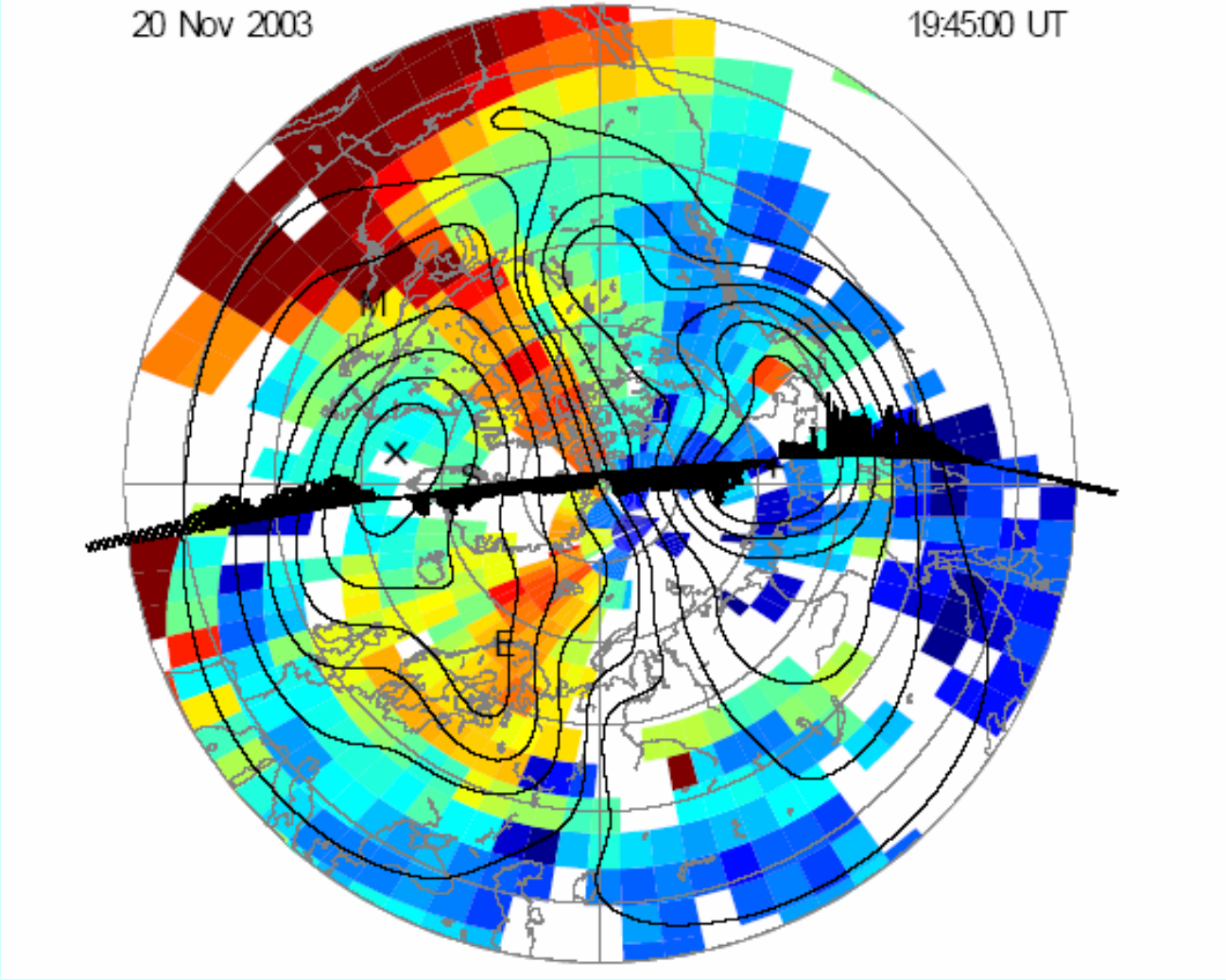


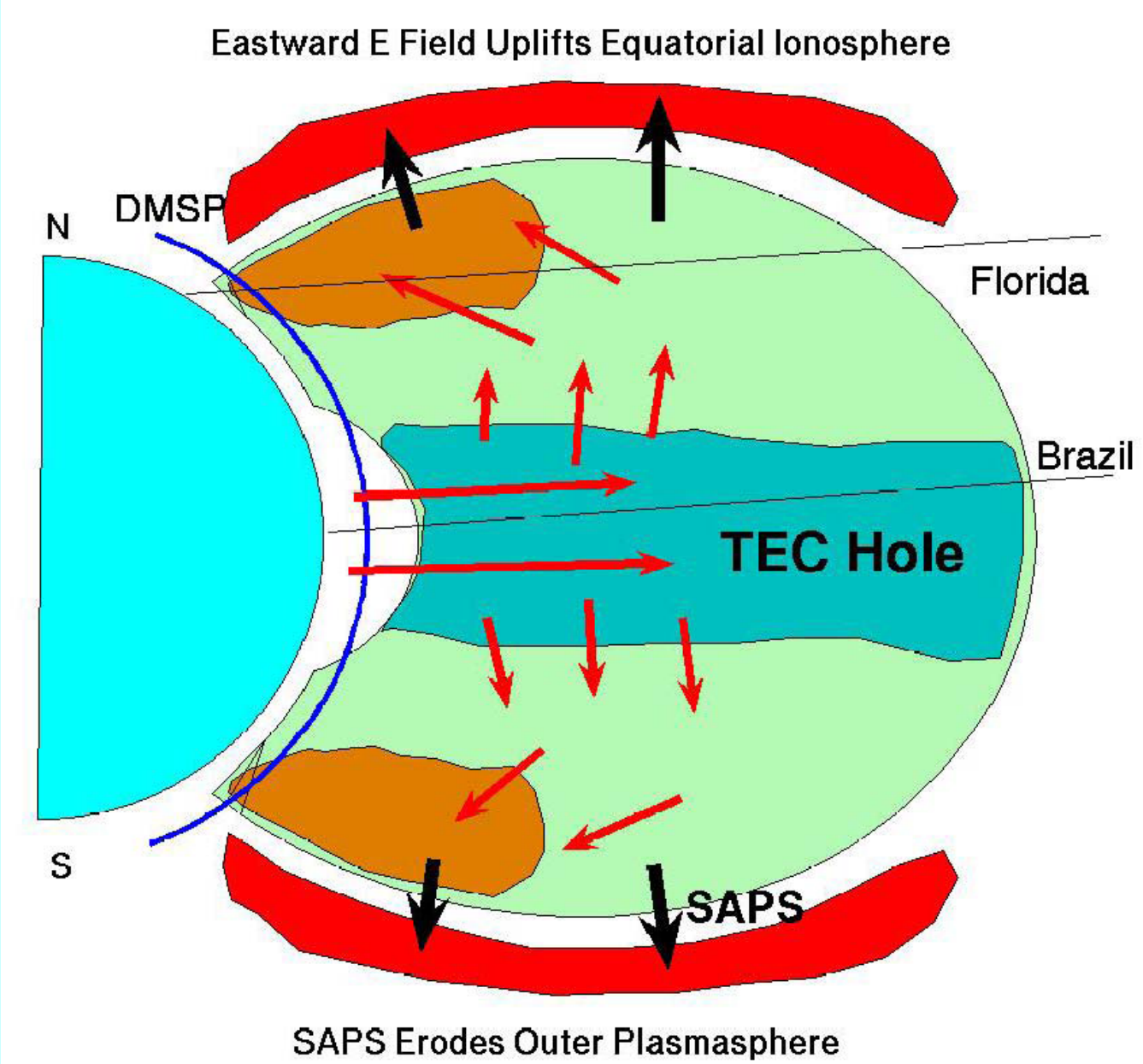



-140
-130
-120
-110
-100
-90
-80
-70
-60
-50
50
40
30
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
TEC (TECU)

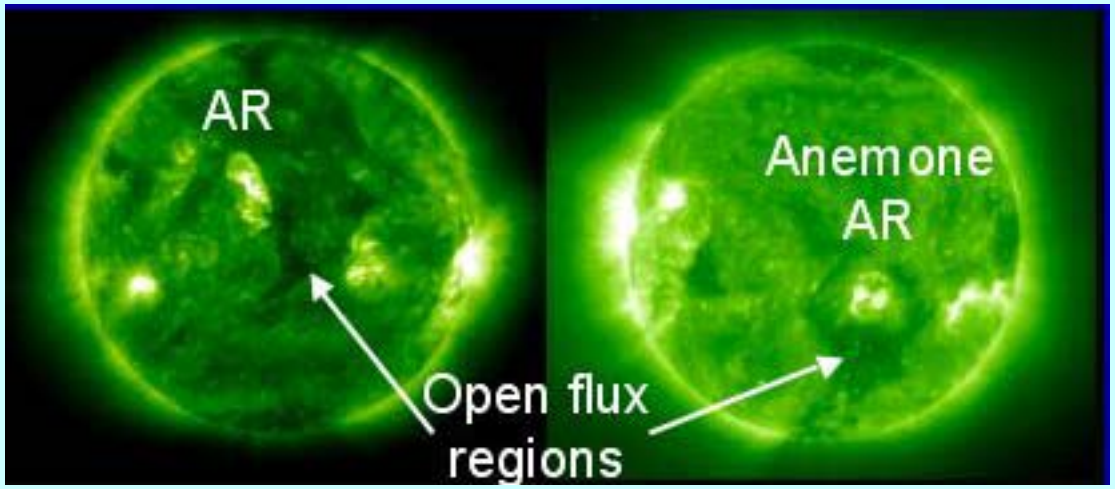
Millstone Hill Research on

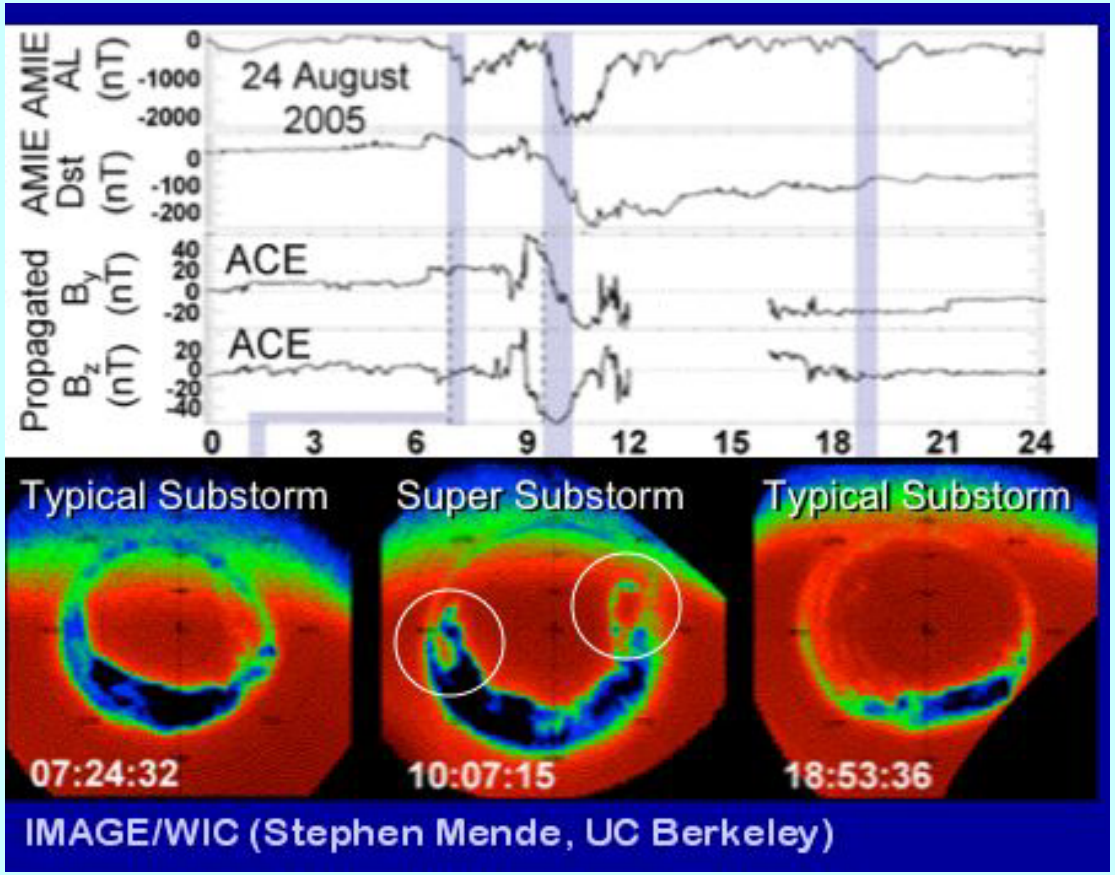
Storm-Enhanced Density Plumes




Eastward E Field Uplifts Equatorial Ionosphere
N
DMSP
Florida
Brazil
TEC Hole
S
SAPS
SAPS Erodes Outer Plasmasphere

The Space Weather System



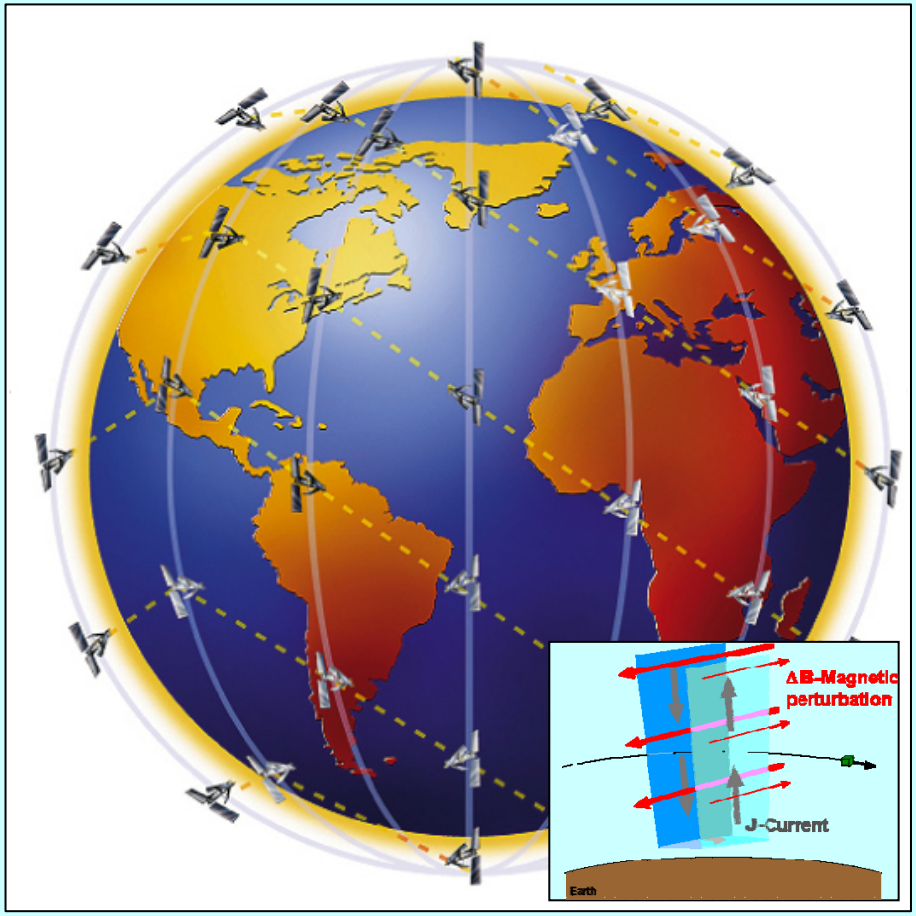


Ionospheric features uniquely linked to solar active regions

Active regions that give rise to distinctive features in the auroral ionosphere

AMPERE: Active Magnetosphere and Planetary Electrodynamics Response Experiment

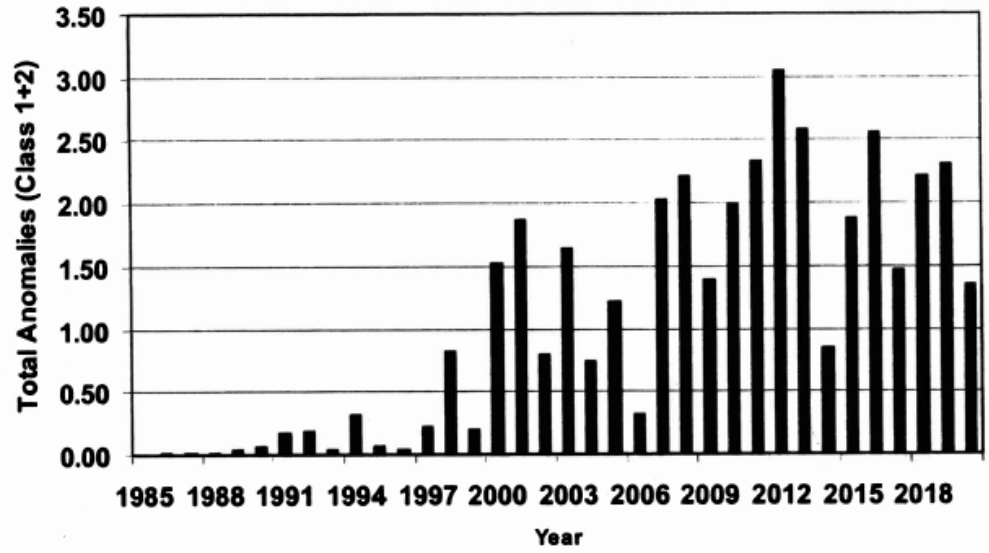
An NSF-funded project to use magnetometers on the Iridium constellation of satellites to obtain a global instantaneous determination of the large-scale ionospheric current system.

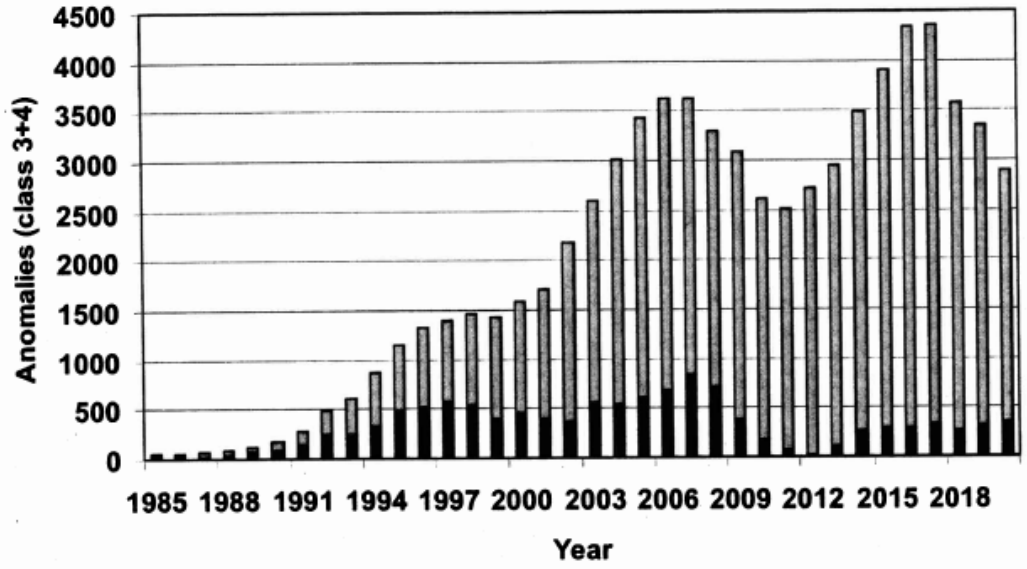


Coverage: 6 planes, polar orbits

Cadence: 11 satellites/plane, 9 min revisit time

Sensors: magnetometers on all satellites



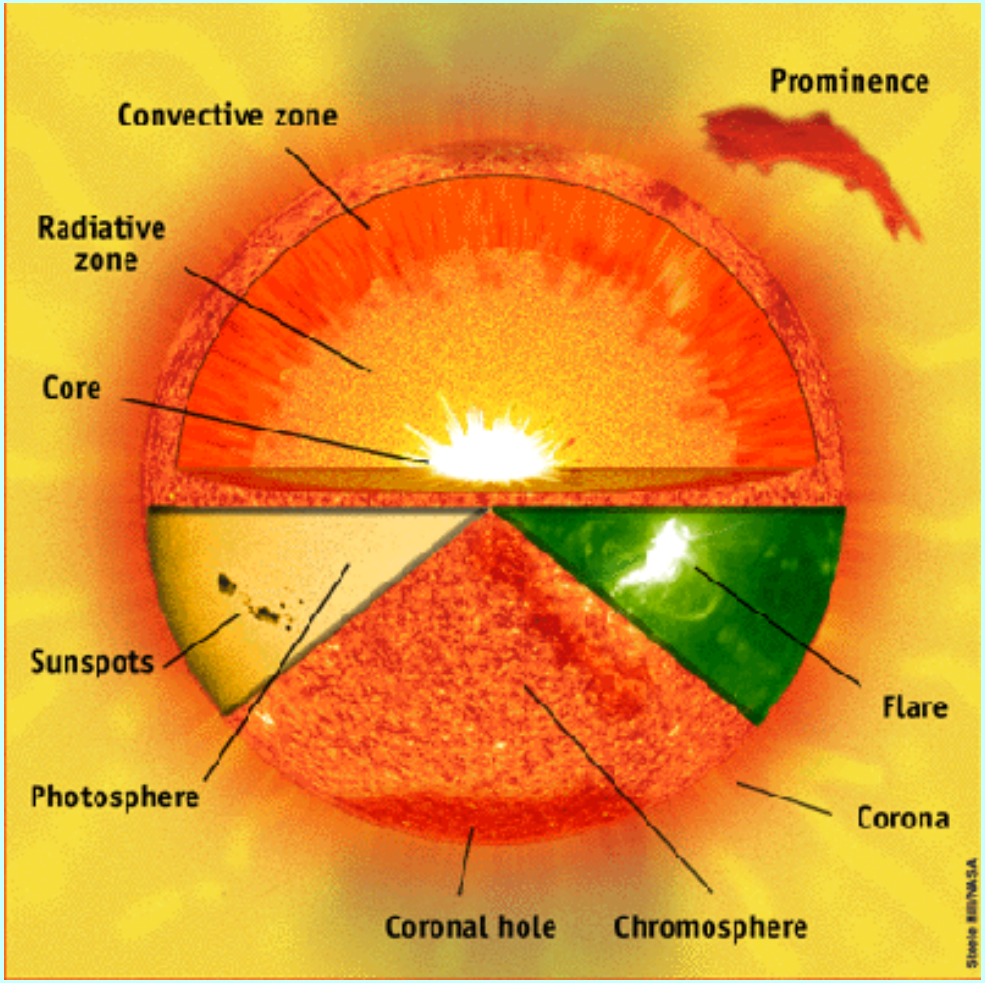


Statistical Study of Impacts on GEO Satellite Systems by Sten Oldenwald, Catholic University

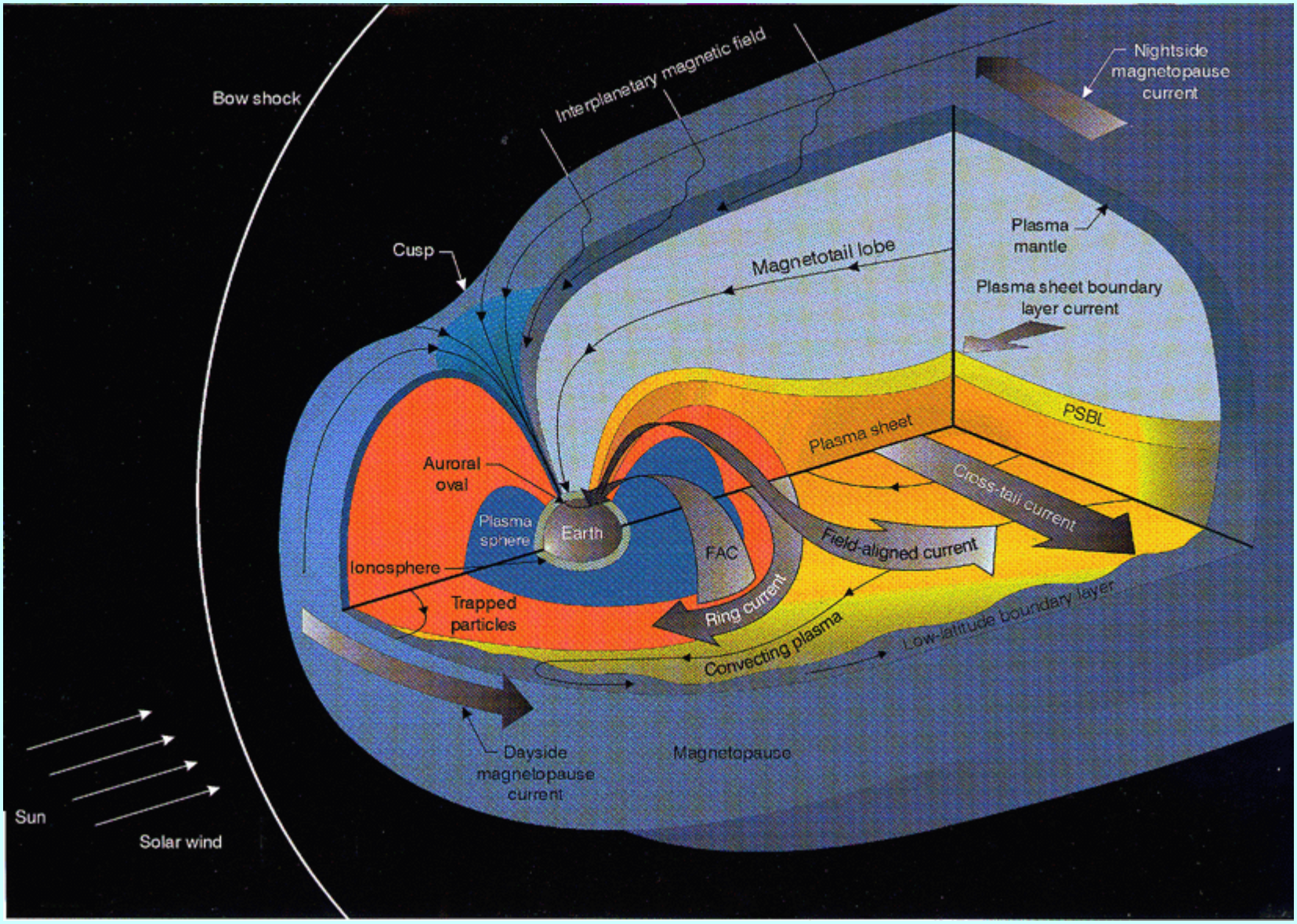
Anomaly Classes:

1) **Mission Failure**
2) **Mission Interruption**
3) **Mission Performance Decrease**
4) **Inconsequential**

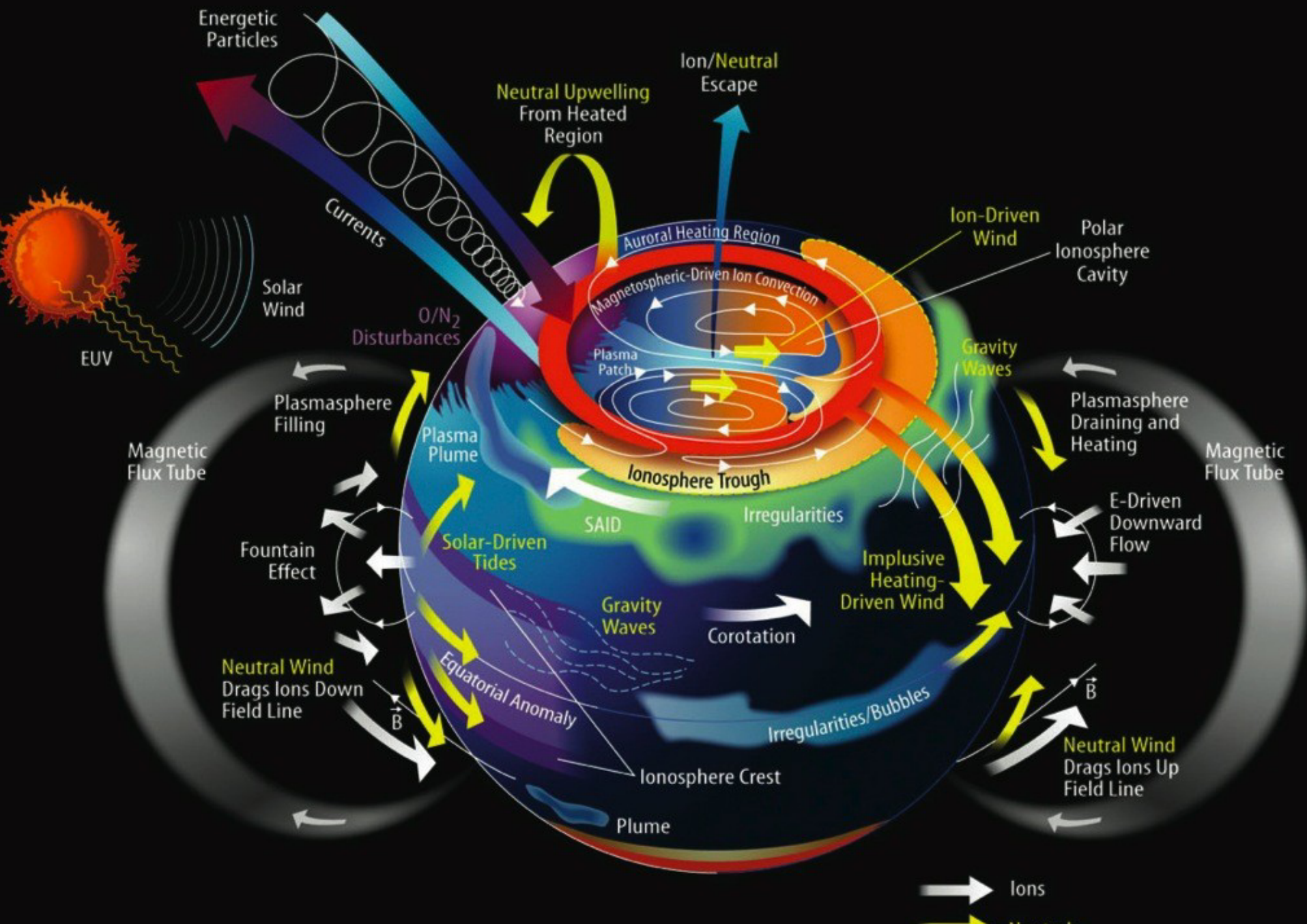
The Sun


Prominence
Convective zone
Radiative zone
Core
Sunspots
Photosphere
Flare
Corona
Coronal hole
Chromosphere

The Magnetosphere



The Ionosphere/Thermosphere/Mesosphere

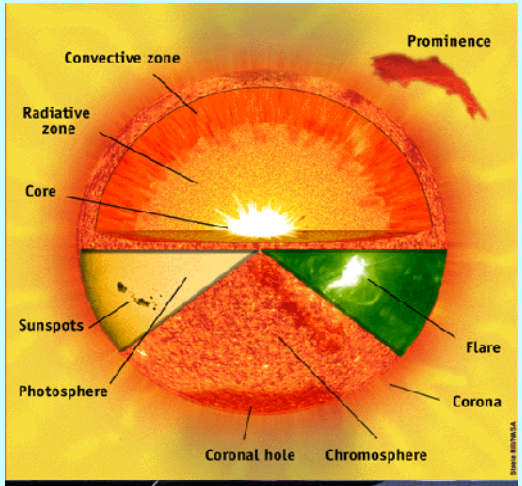


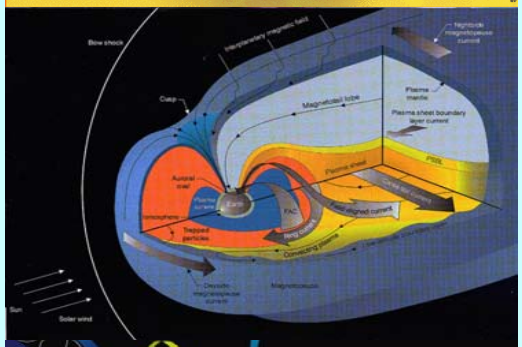
Questions about the human body:
Questions about the space weather system:

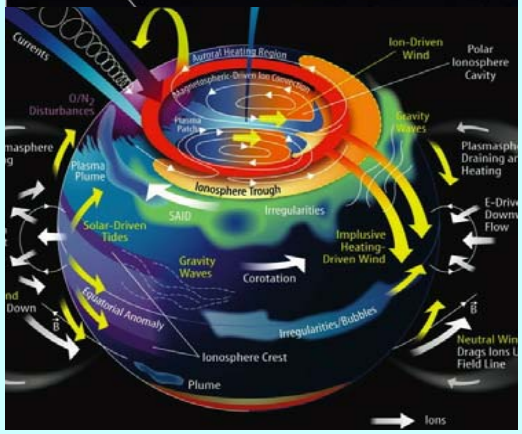
- **What are the regulatory circuits within the body that serve to process the external stresses imposed by the environment?**

- **How do positive and negative feedback processes act to maintain stability in the body in spite of these often variable external influences?**

- **What is the energy deposition distribution in penetrating epithelial tissues?**







Geoscience Systems

- **Dynamical (Seismic, ocean waves, atmospheric circulation, tidal actions, solar wind, helioseismology)**
- **Radiative (photosphere, airglow, aurora, dayglow, daylight)**
- **Chemical (Sun to Earth exchange of matter)**
- **Electromagnetic (Solar interior, corona, solar wind, magnetosphere, ionosphere, atmosphere, Earth's core)**
- **Hydrologic (Earth, Oceans, Atmosphere)**
- **Biological (Earth, Oceans)**

Conclusions and a Prediction about Space Weather Research of the Future

- **Space weather effects on aviation and spaceflight can best be understood through a systems approach to space weather research**
- **The domains of space weather are chemically, dynamically, radiativedly, electrically, and magnetically linked**
- **Future breakthroughs and discoveries in space weather will involve the identification of unanticipated linkages among processes that are seemingly disconnected spatially, temporally, and phenomenologically.**