Spring 2020 HamSCI Workshop
Mar 20-21, 2020
The University of Scranton
Scranton, PA

Using Amateur Radio to Validate Model-Based Properties of Earth's Protective Shield

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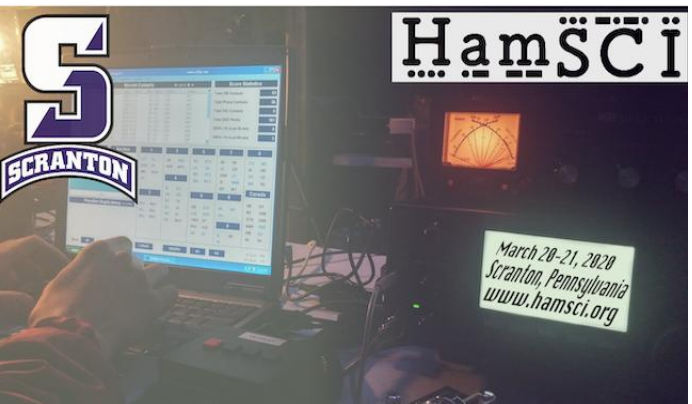


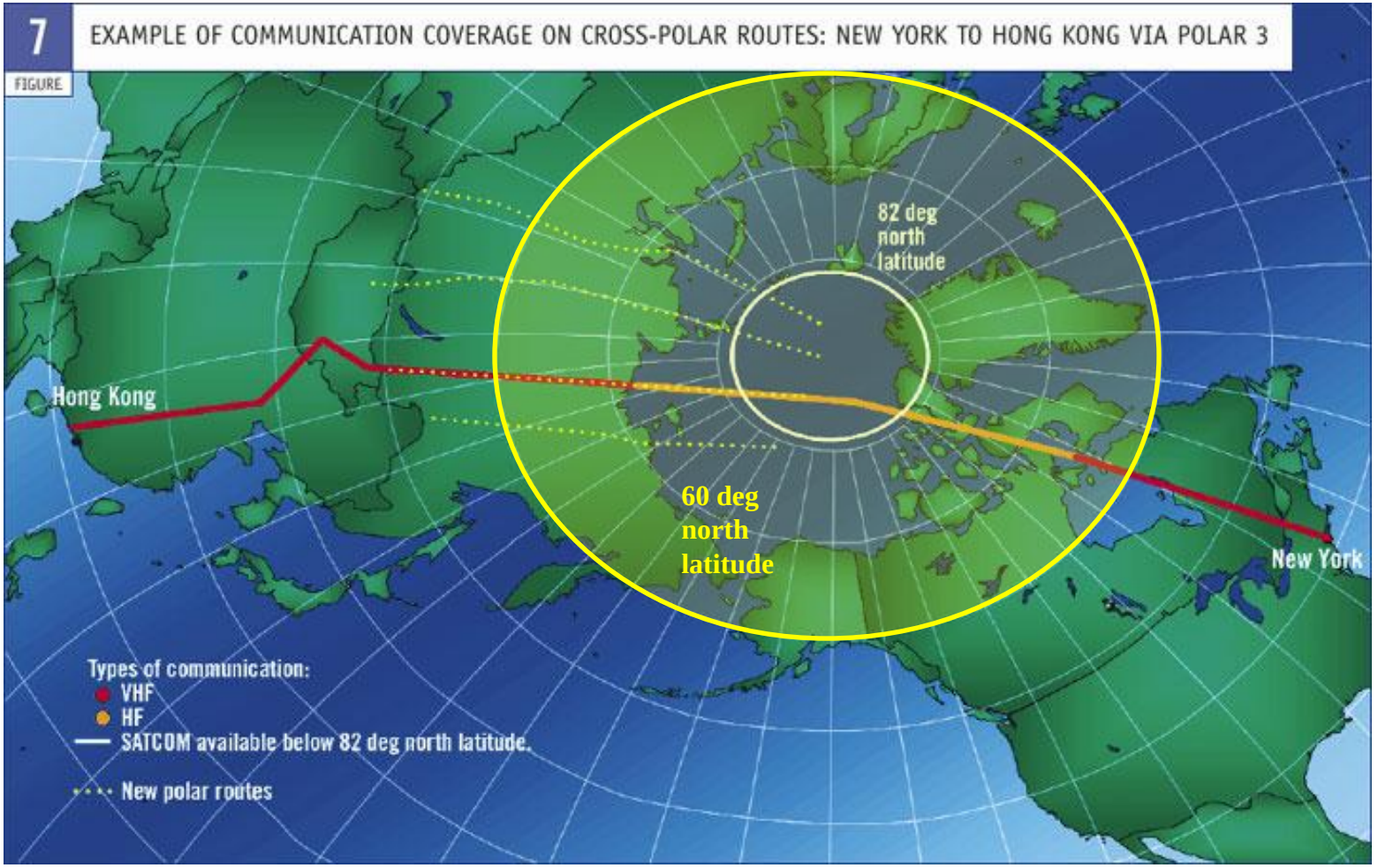
UtahStateUniversity
DEPARTMENT OF PHYSICS

Introduction

Current Research Focus

- Polar Cap Absorption Events
    - Energetic Proton Transport
    - D-Region
    - HF Absorption

Introduction



Average cost for diverting a flight between North America and Asia about $100,000

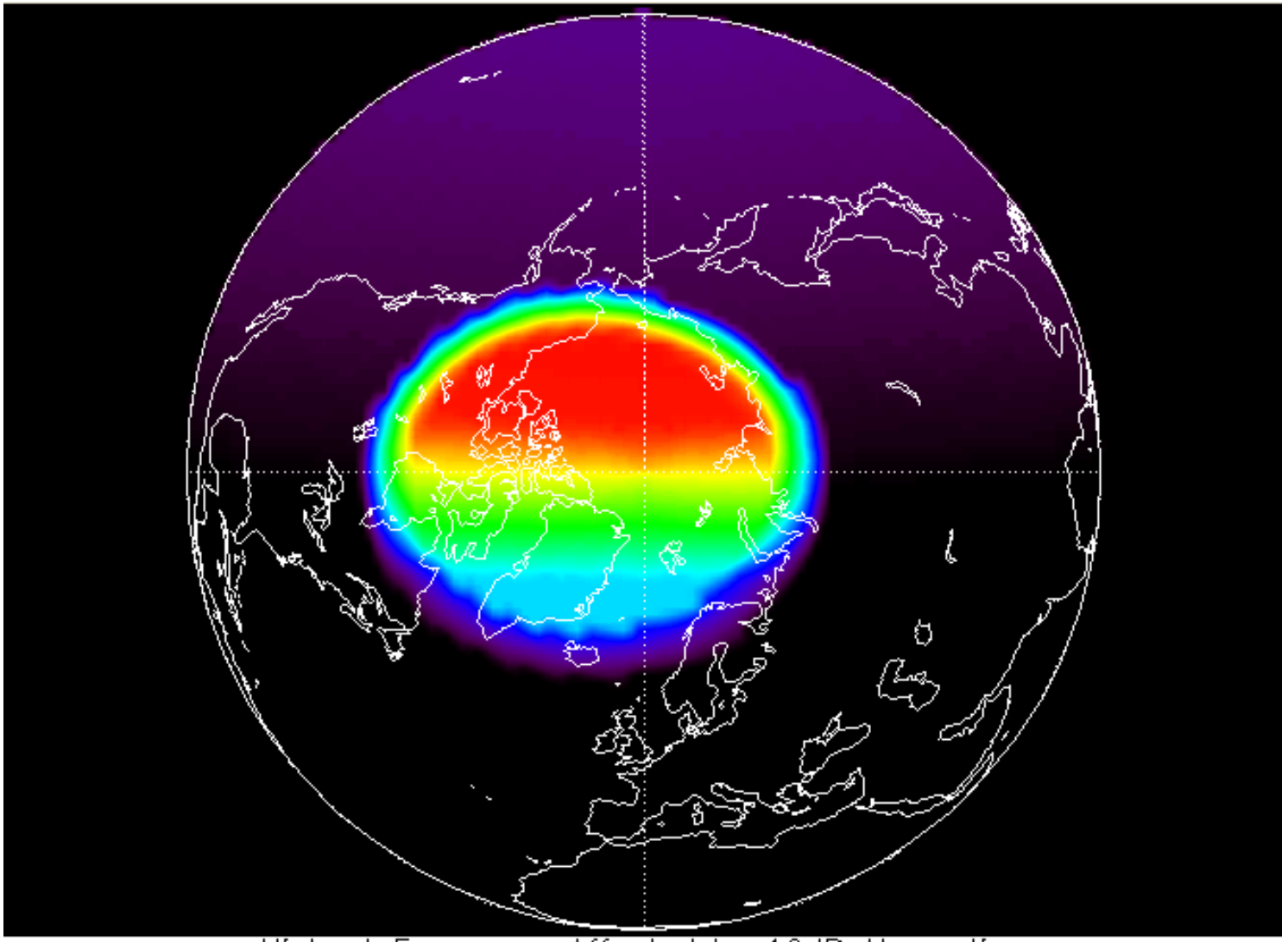
Fiori & Danskin (2016)

As of 2007 about 7000 transpolar flights per year

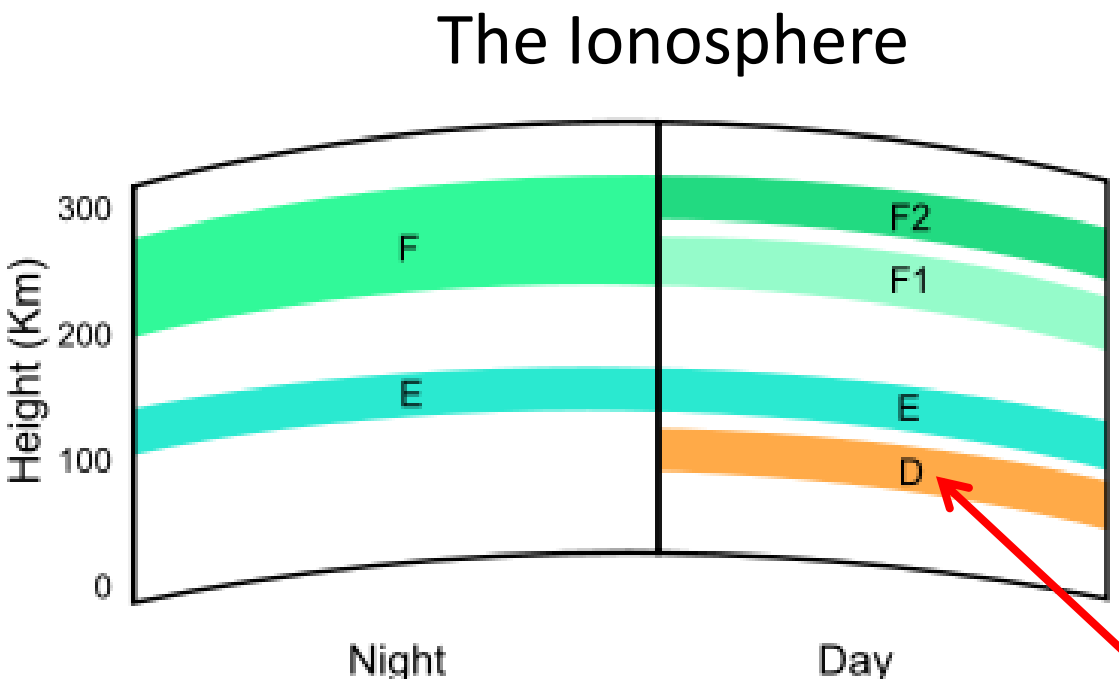
Sauer & Wilkinson (2008)

http://www.boeing.com/commercial/aeromagazine/aero_16/polar_story.html

Introduction



Polar Cap Absorption Events (PCA)



The D-Region

- ***Altitude about 50-100 km***
- ***Primarily Absorbs HF radio waves (3-30 MHz)***
- ***Usually exists only during daylight***

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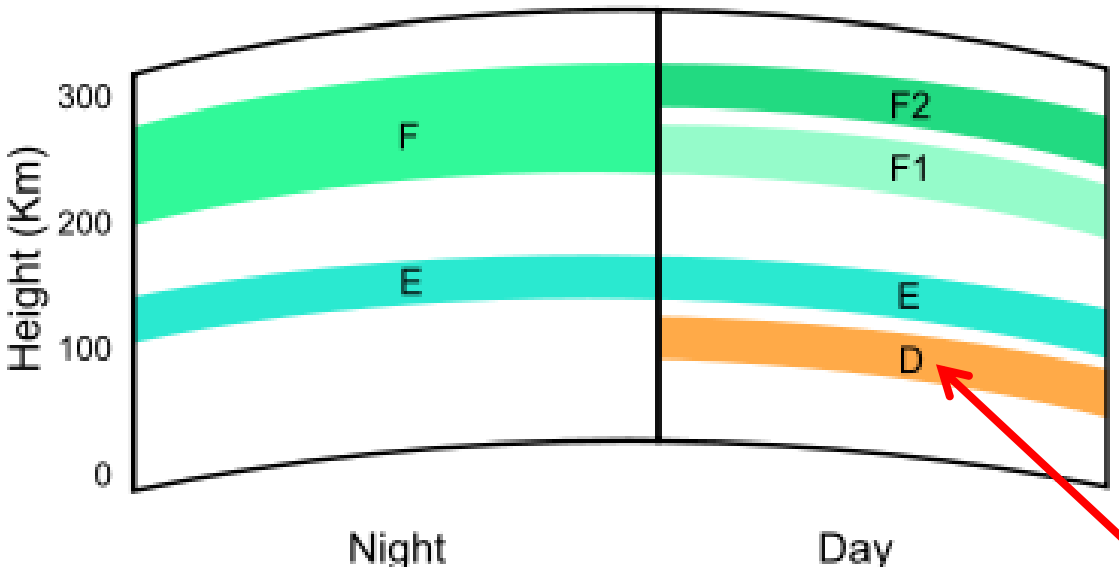

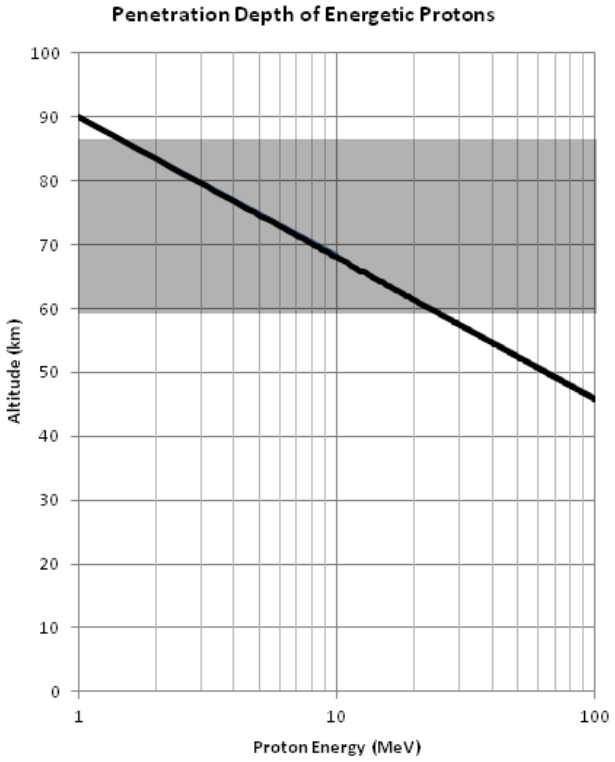

The D-Region

- Altitude about 50-100 *km*
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- ***Enhanced ionization from solar protons during PCA events***
- ***1-20 MeV protons most responsible for PCA events***

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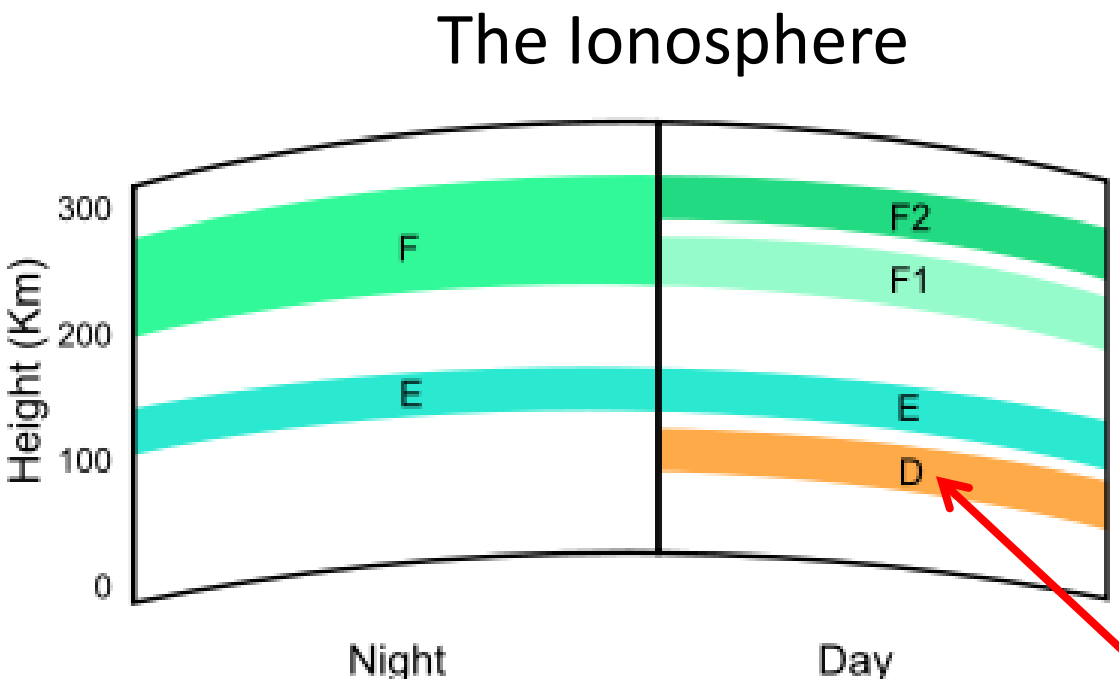

- **Can solar protons reach any location?**

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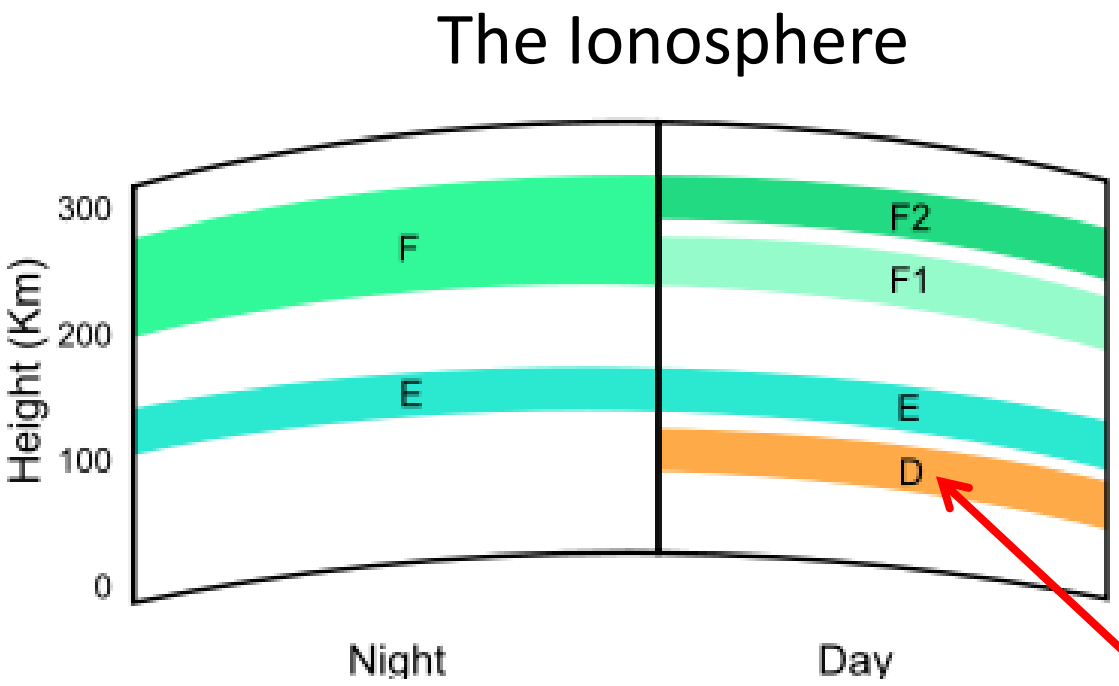

- **Can solar protons reach any location?**
- **How do we study solar protons?**

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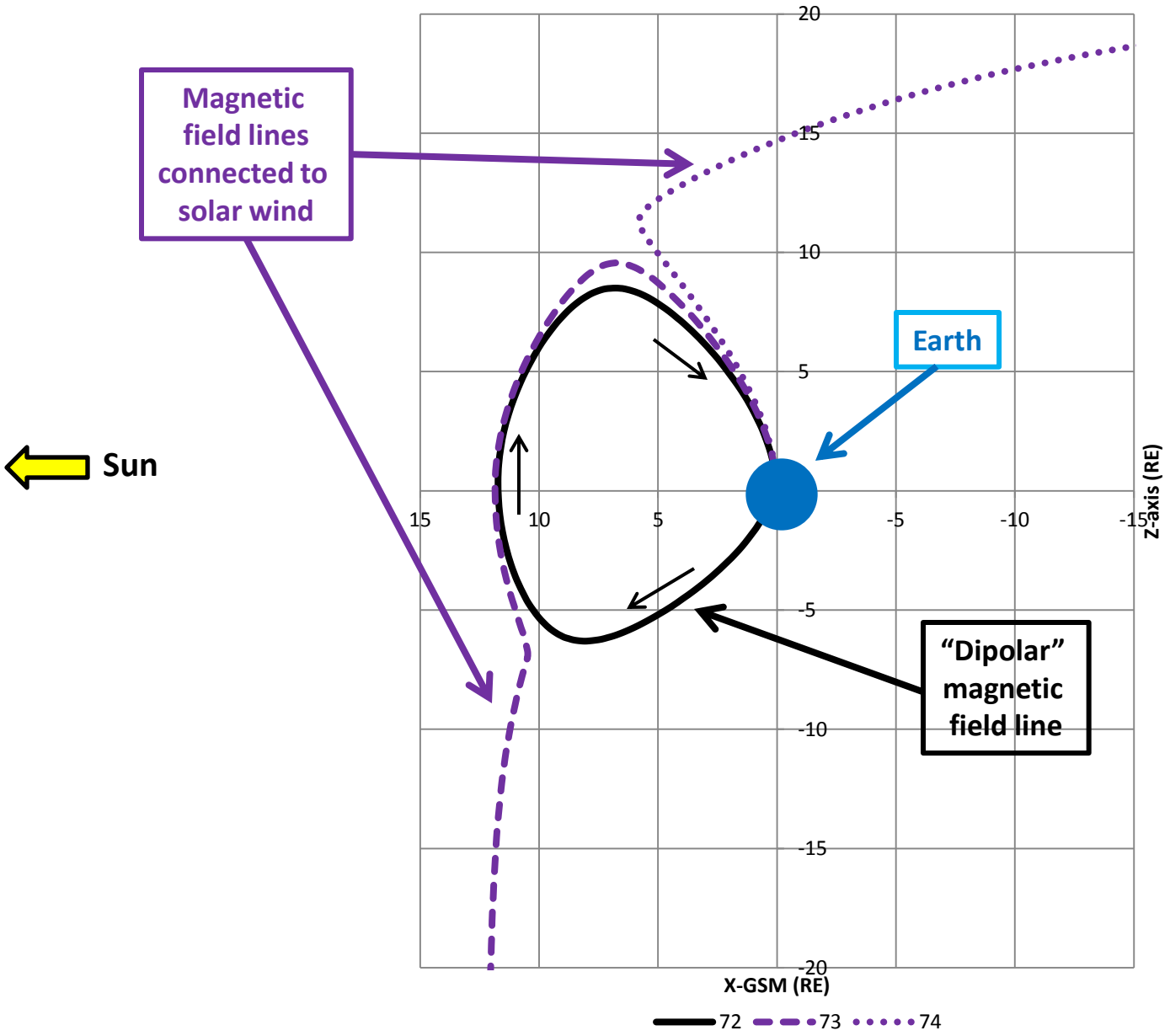
Our Tracing Model

Tsyganenko Geomagnetic Field Model

- Semi-empirical best-fit representations of geomagnetic field
- Based on large number of satellite observations
- Outputs include:
    - Field line tracing
    - Geomagnetic field vector at selected point
- Internal Field – International Geomagnetic Reference Field (IGRF)
- External Field – 1996 Version of Tsyganenko Model (T96)

https://ccmc.gsfc.nasa.gov/models/modelinfo.php?model=Tsyganenko%20Magnetic%20Field

How Do We Study Solar Protons?



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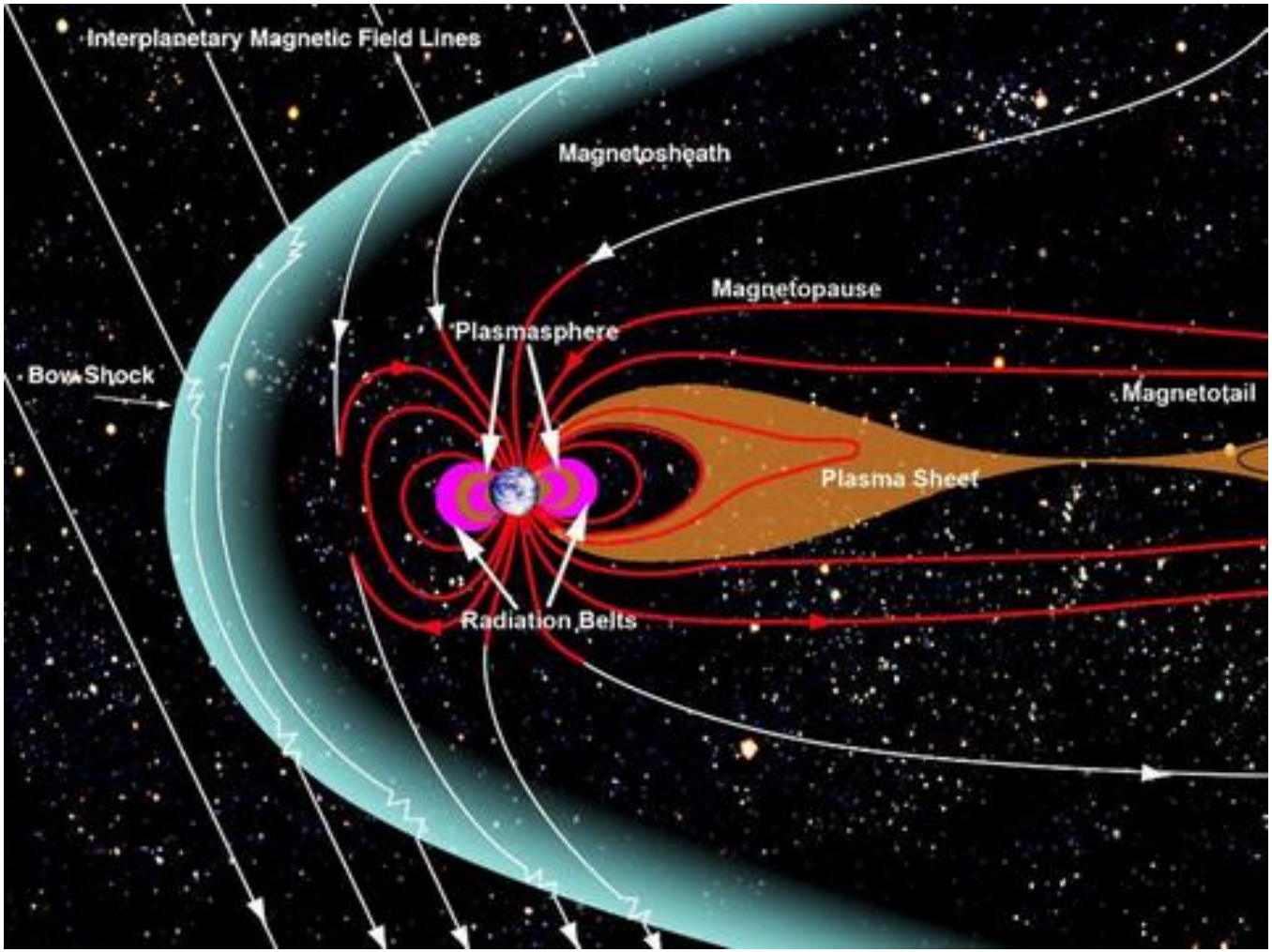


⇦ Sun

Open field lines connect Earth's upper atmosphere with Solar Wind

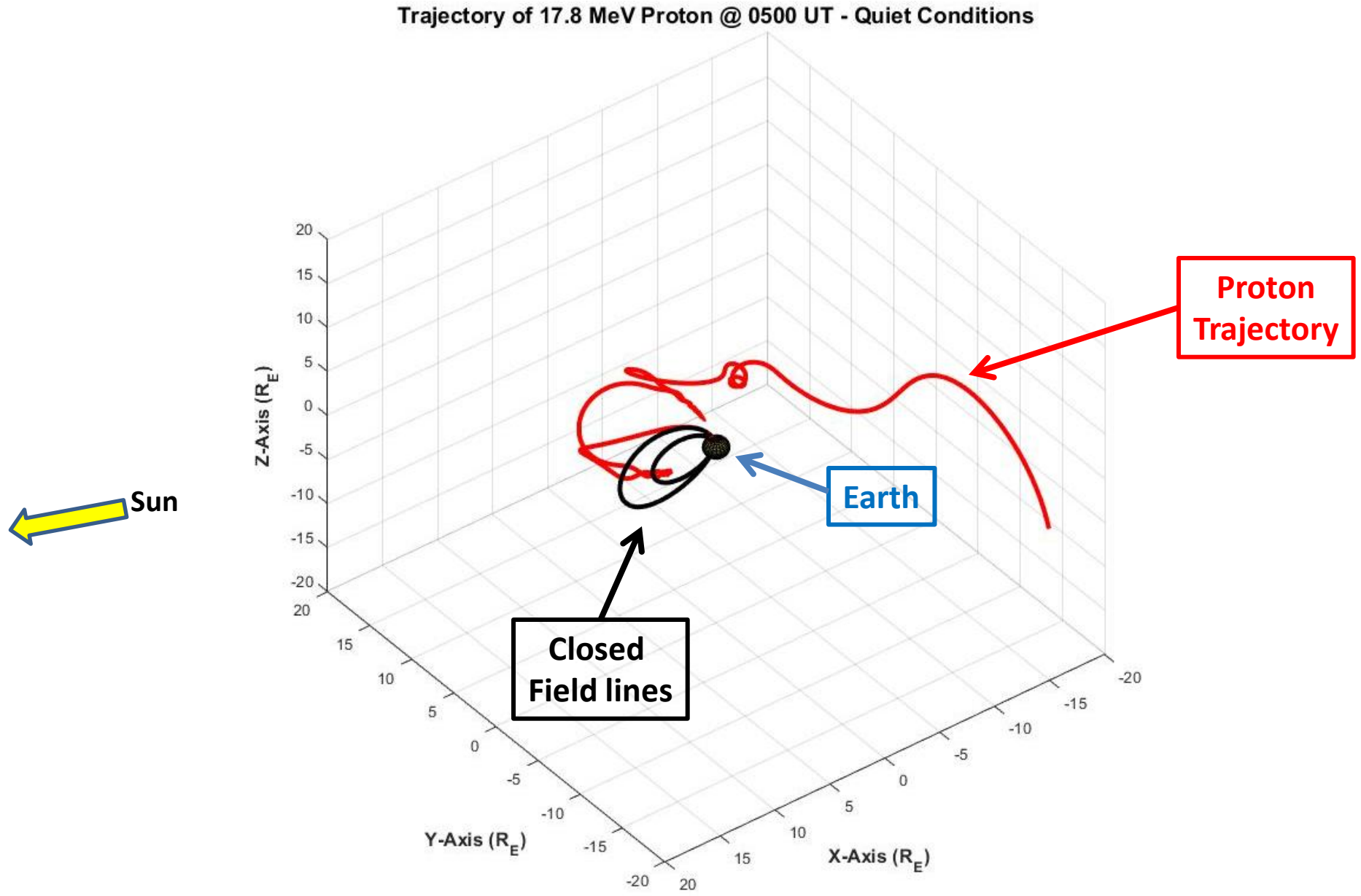
Image courtesy of: http://www.q-mag.org/old-african-huts-reassure-us-about-the-geomagnetic-field.html

Can Solar Protons Reach Any Location?

Proton Energy Cutoff Latitude

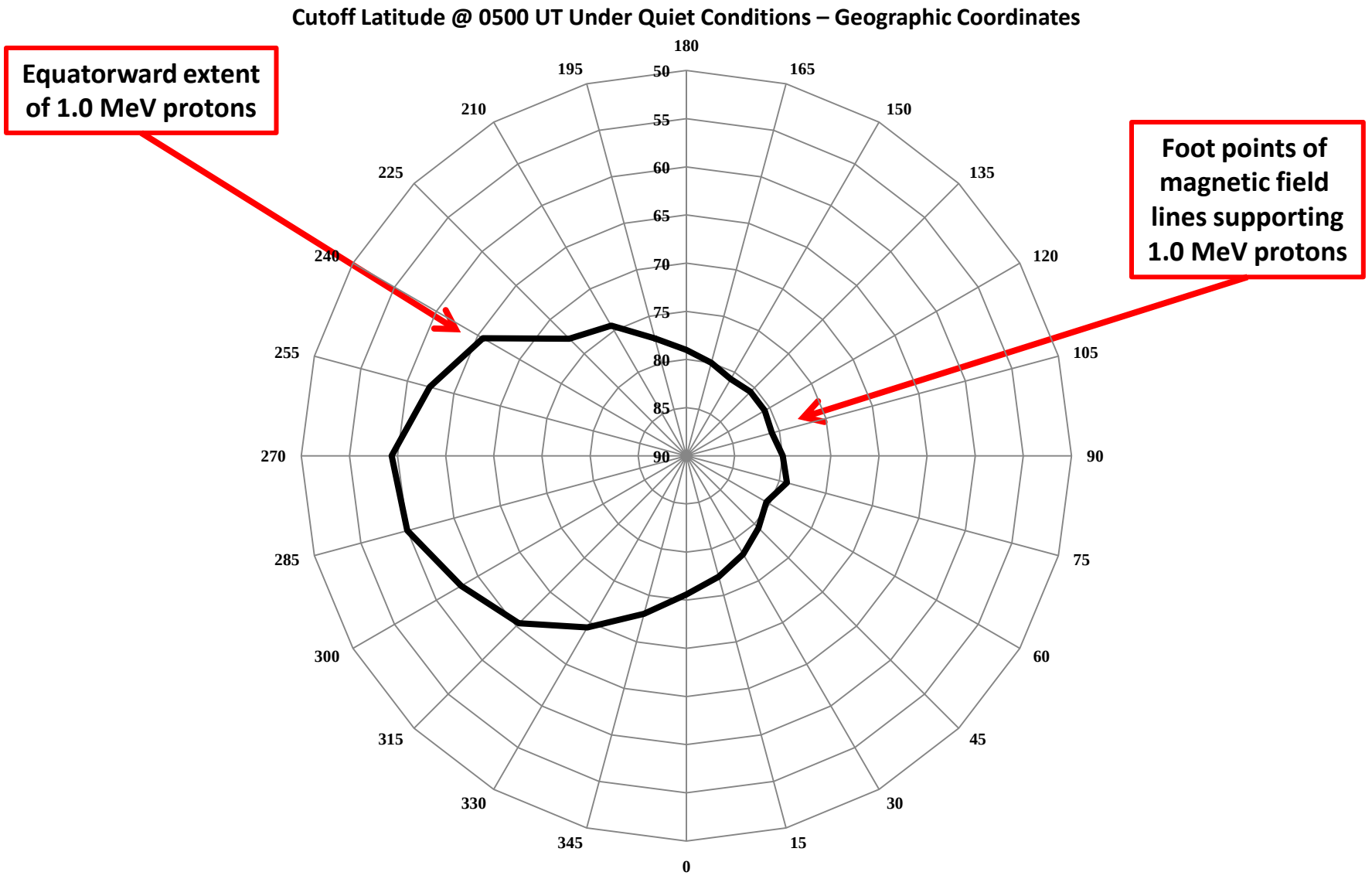
- ***Lowest latitude to which a solar proton can penetrate***
- Variable depending on
    - ***Proton Energy***
    - ***Local Time***
    - ***Geomagnetic storm conditions***
    - ***Universal Time***

Proton Energy Cutoff Latitude



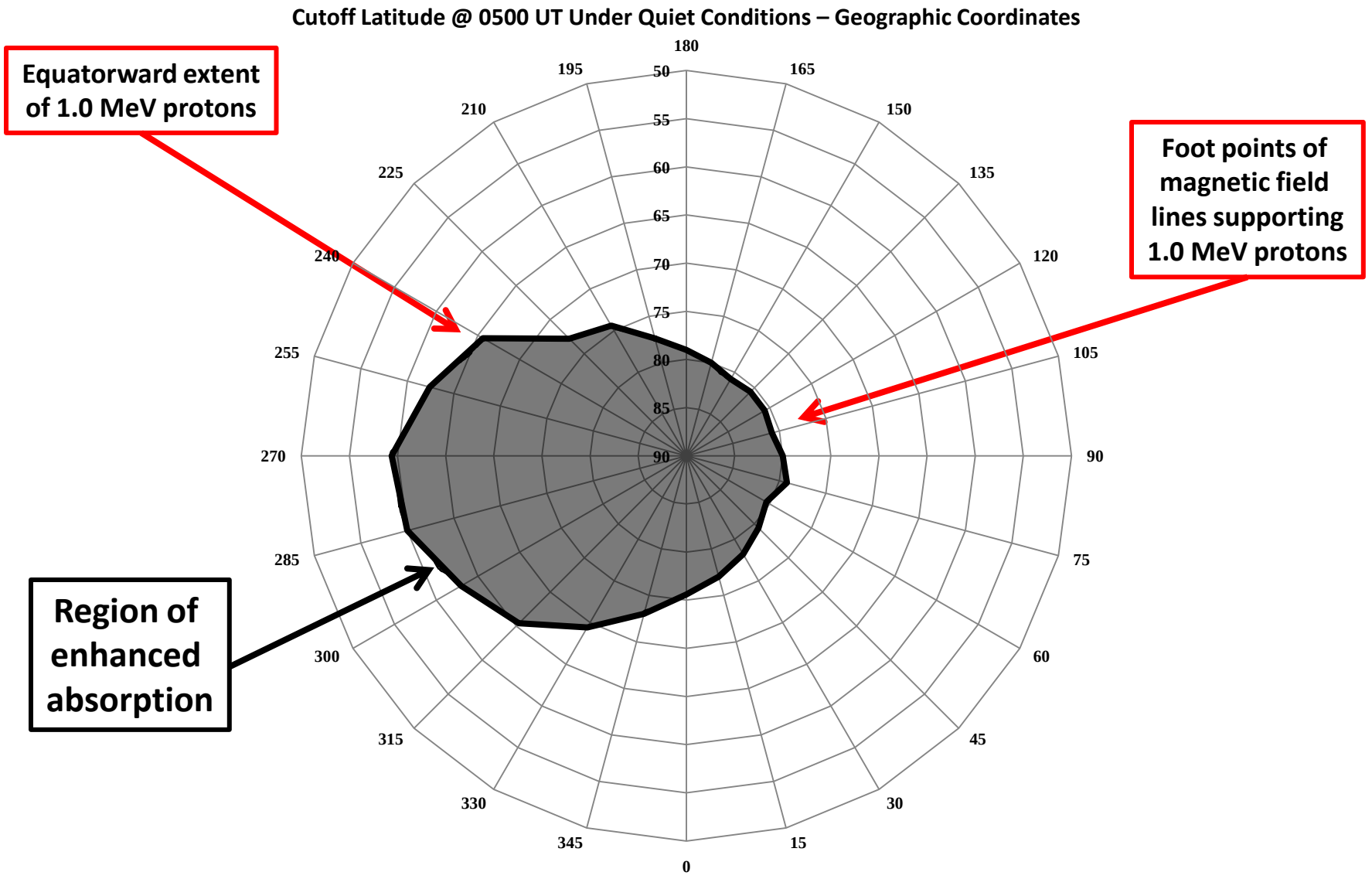
Example of Allowed Trajectory

Equatorward Extent of Polar Cap Absorption



Cutoff latitude variation due to proton energy and Local Time

Equatorward Extent of Polar Cap Absorption



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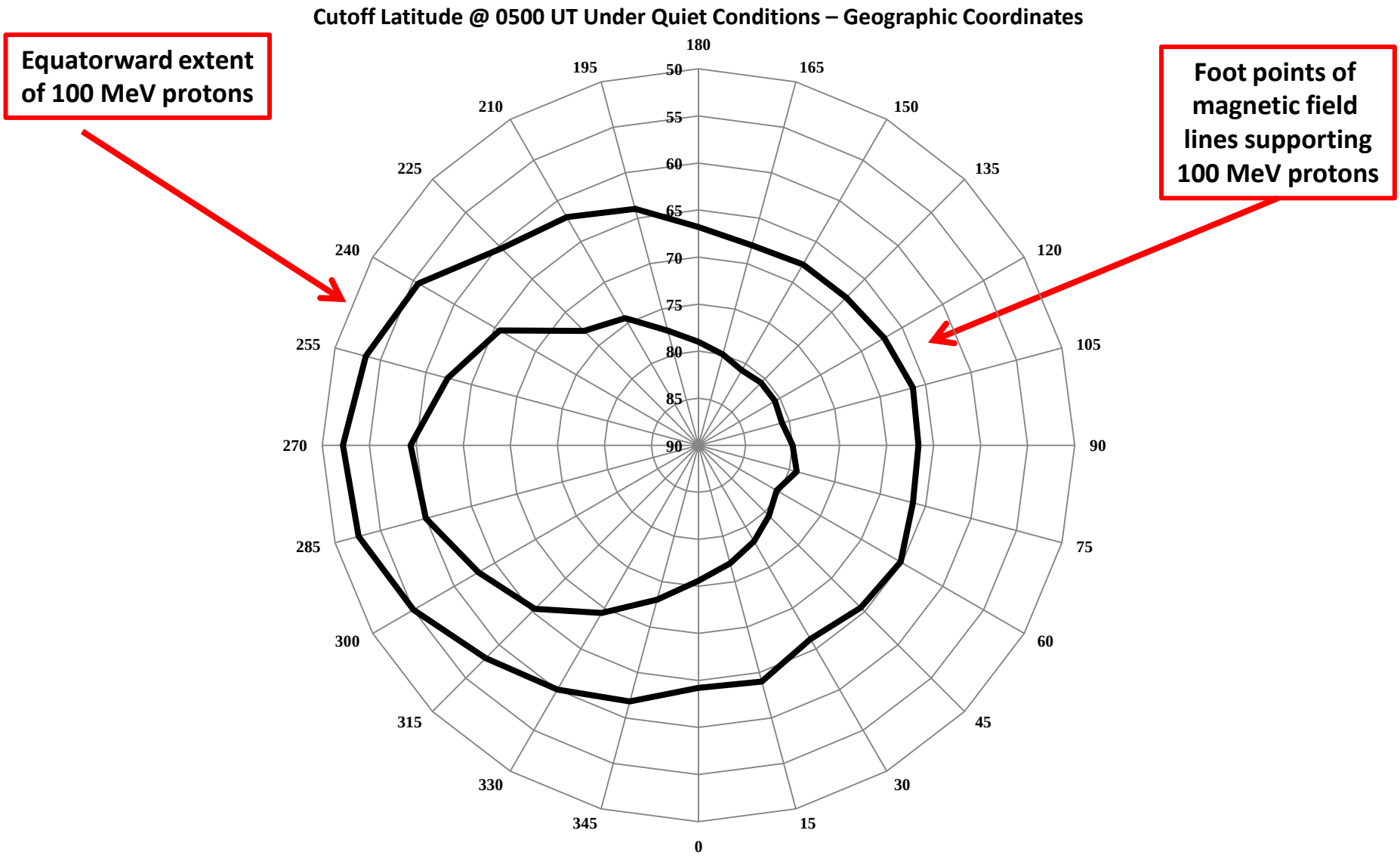
Proton Energy Cutoff Latitude



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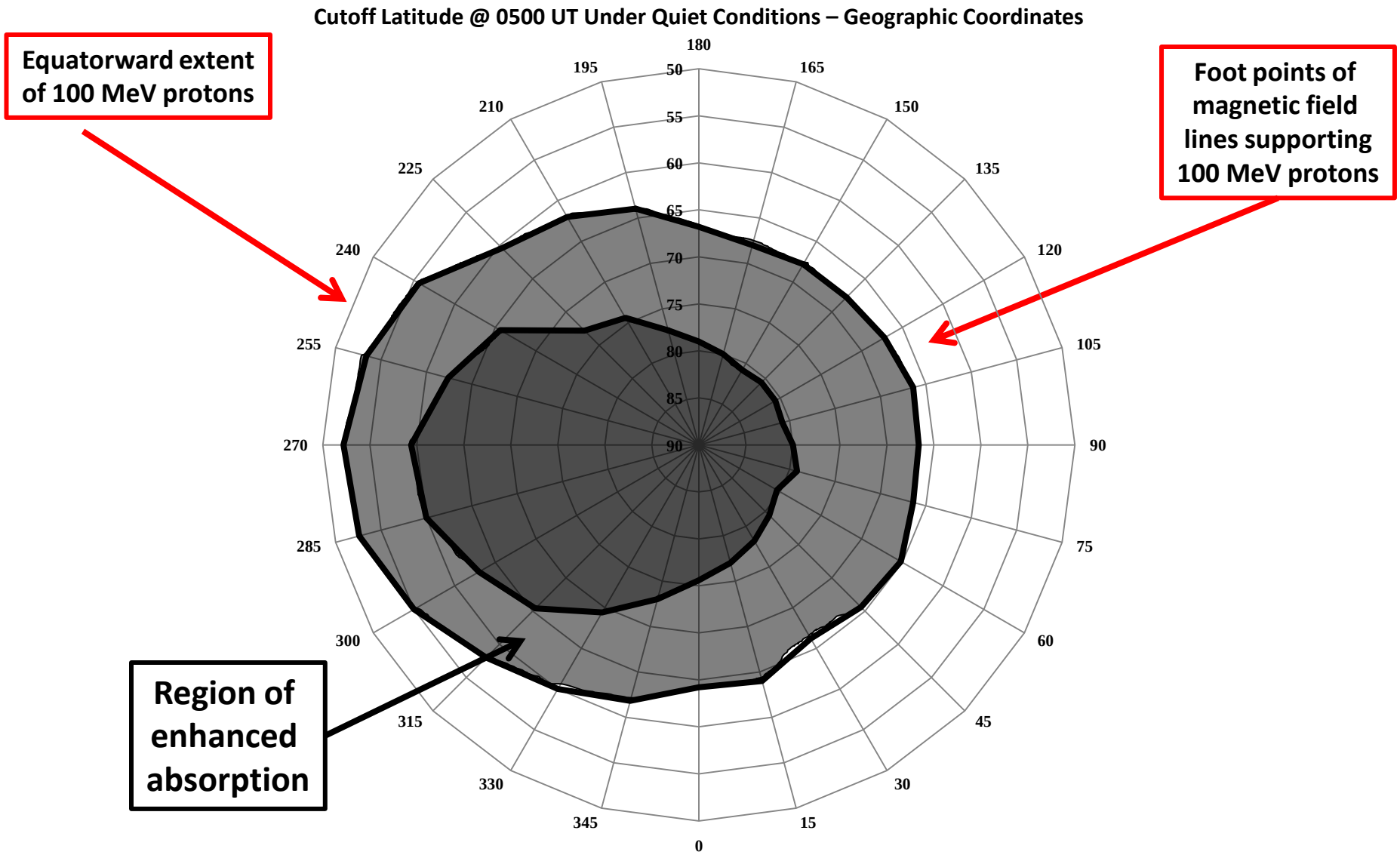


Cutoff latitude variation due to proton energy and Local Time

Proton Energy Cutoff Latitude
The Penumbra

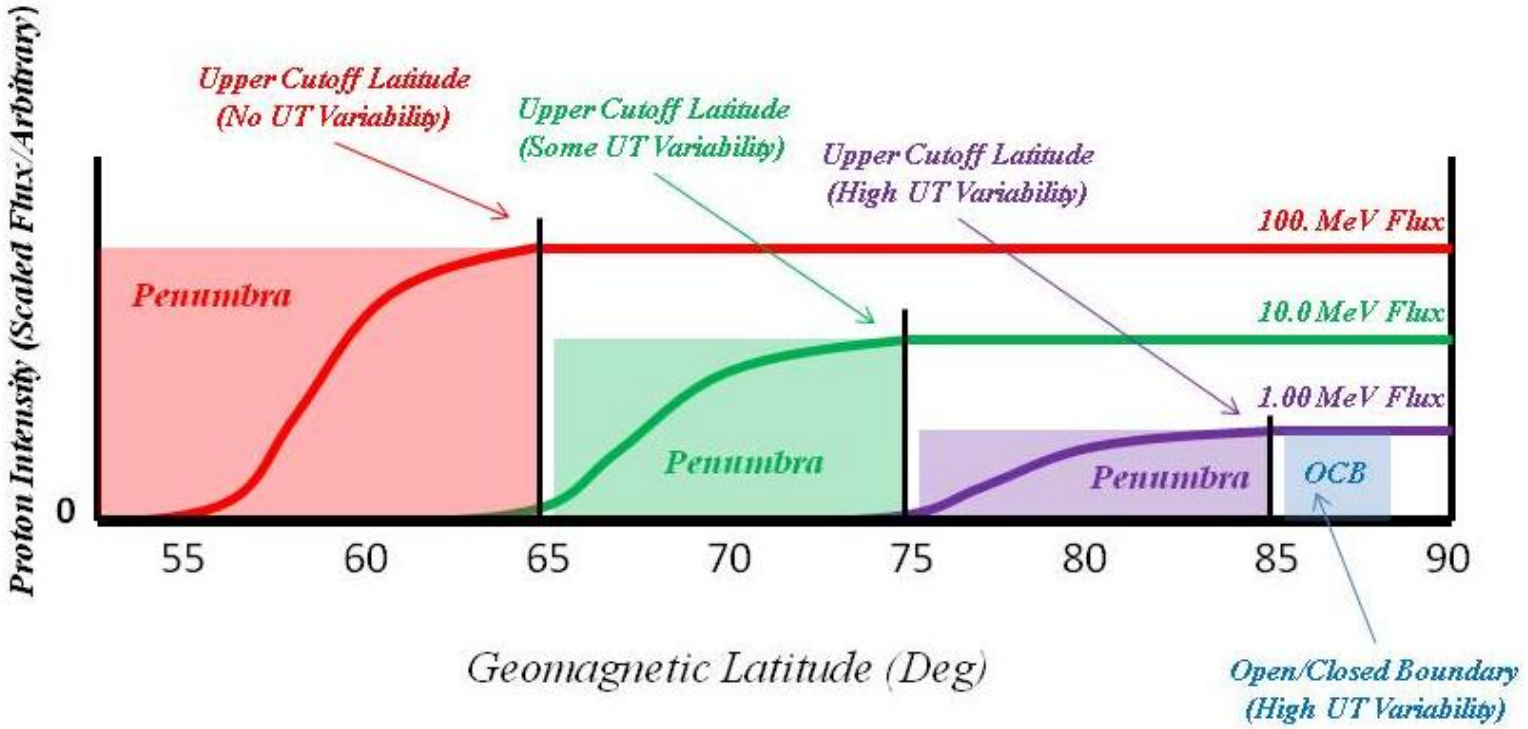
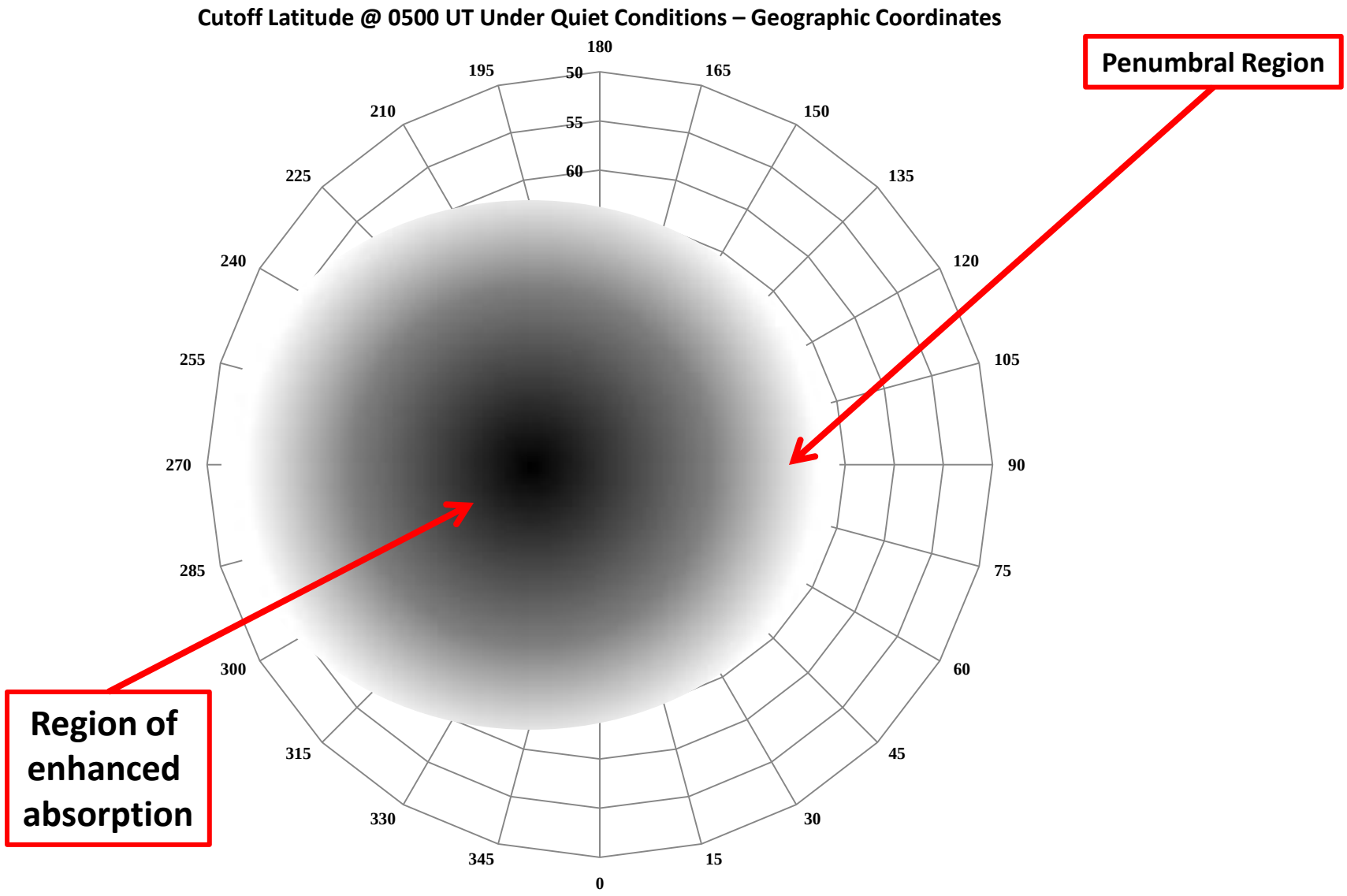


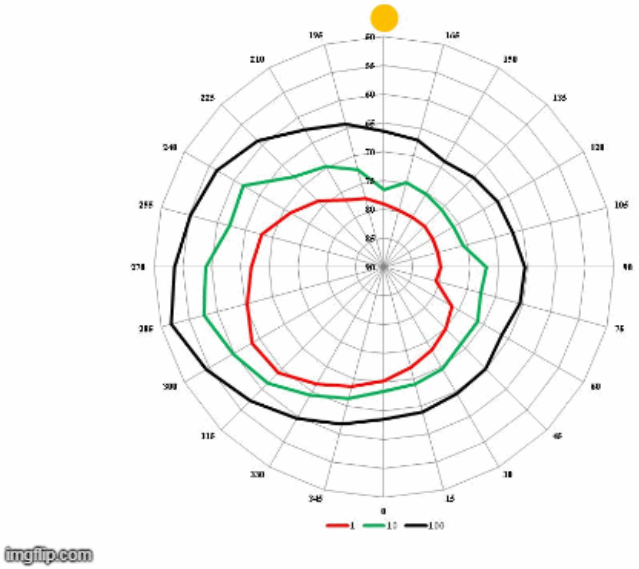
Illustration Only Not Drawn to Scale

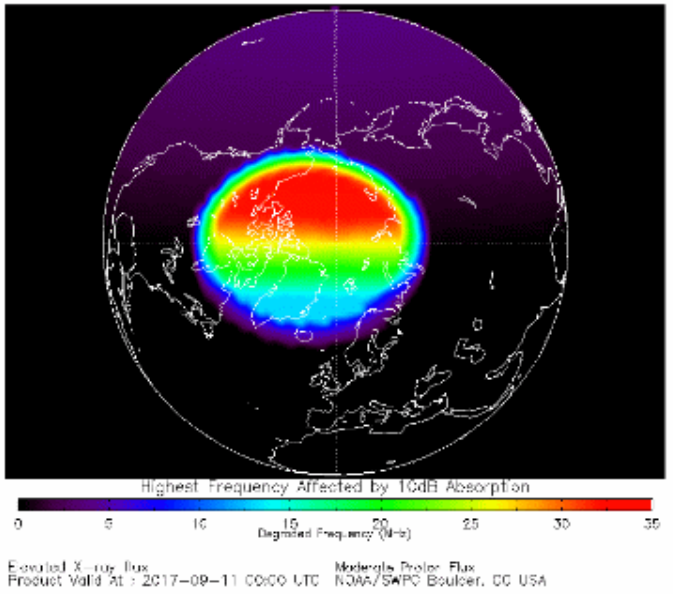
Proton Energy Cutoff Latitude



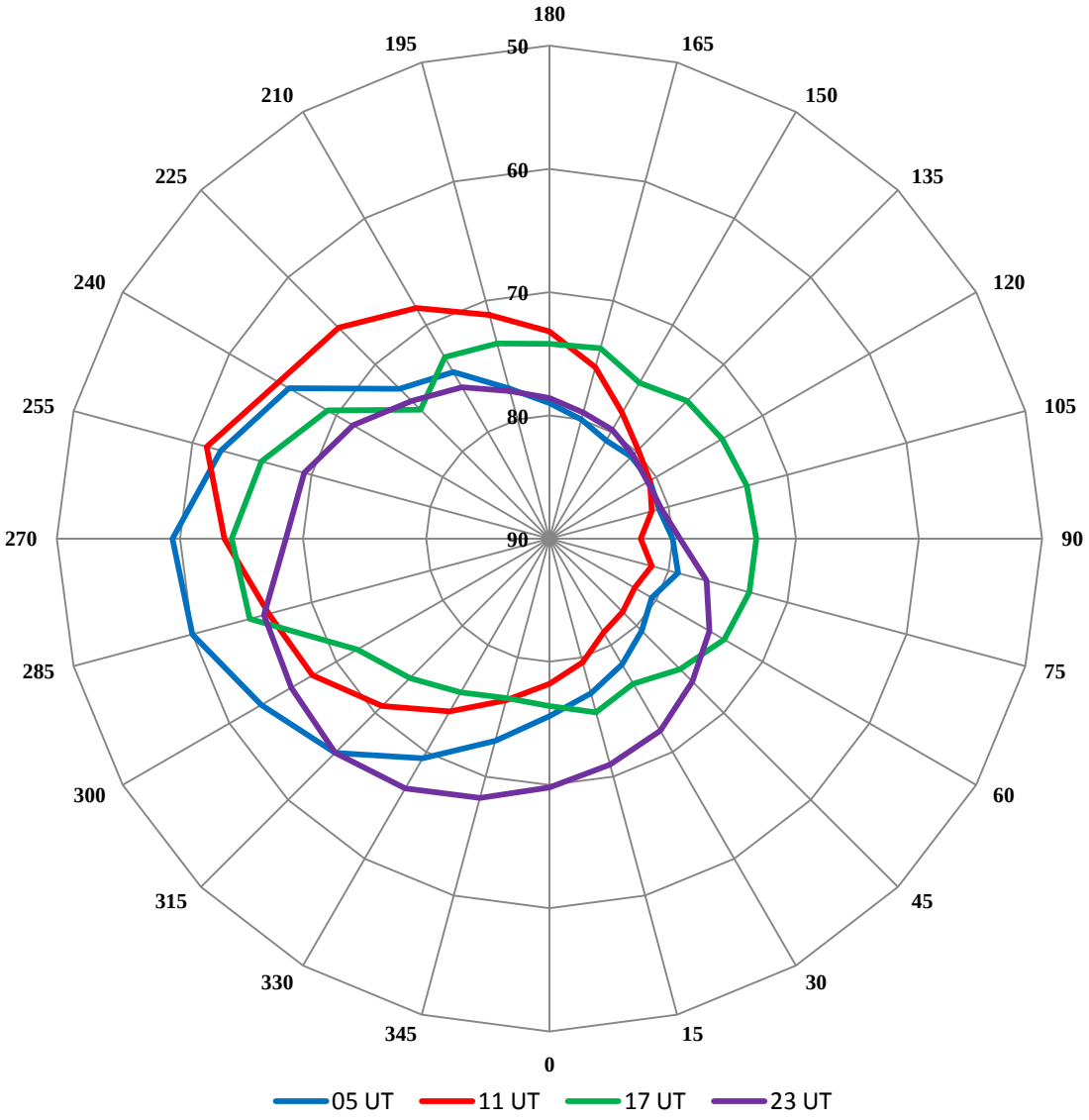
Cutoff latitude variation showing penumbral effect

Proton Energy Cutoff Latitude

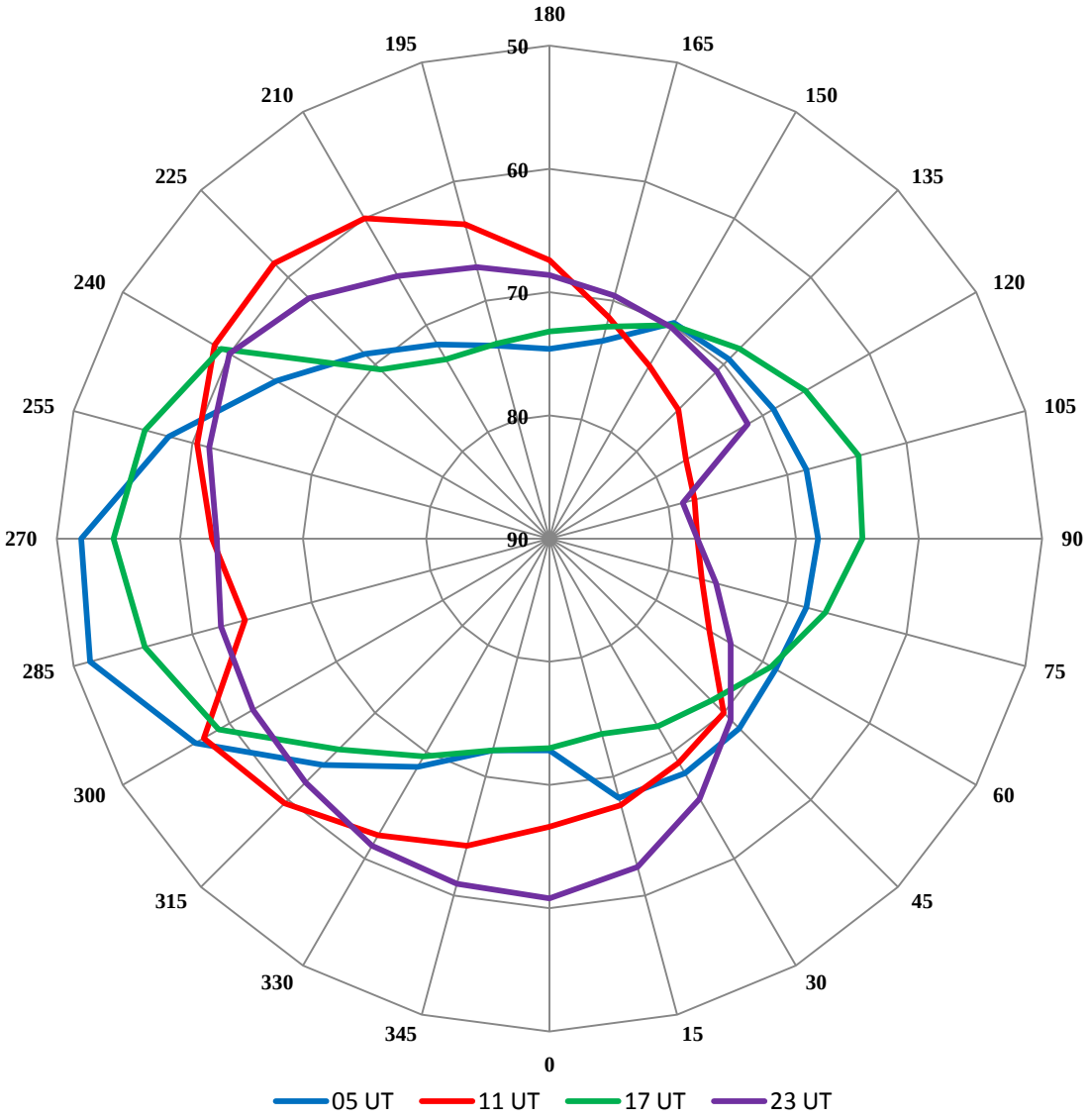




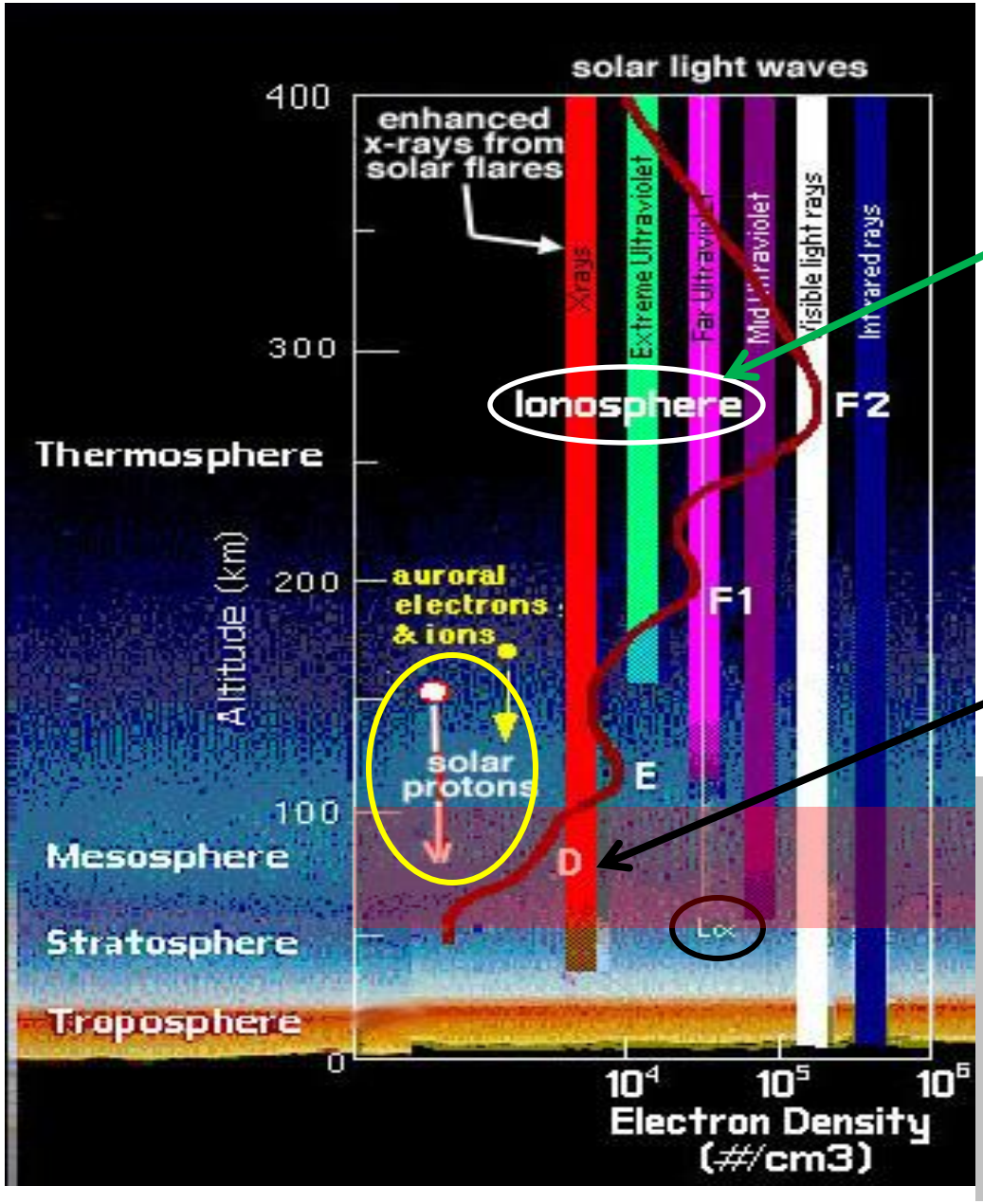
Proton Energy Cutoff Latitude
Quiet Conditions – 1 MeV Proton



Proton Energy Cutoff Latitude
Severe Conditions – 1 MeV Proton



HF Absorption – Normal Conditions



Photons collide with neutral atoms and molecules creating ionosphere (free electrons)

Photons penetrate to different depths

D-Region

$$Absorption \propto \frac{N \cdot \nu}{f^2}$$

$N \equiv$ *Electron density*

$\nu \equiv$ *Collision frequency*

$f \equiv$ *Radio wave frequency*

Why Is This Important…

High Frequency radio wave propagation is important…

- Commercial and Military Aviators
    - Over 7000 transpolar commercial flight per year
- RADAR Installations
- Anyone using transpolar HF radio wave propagation

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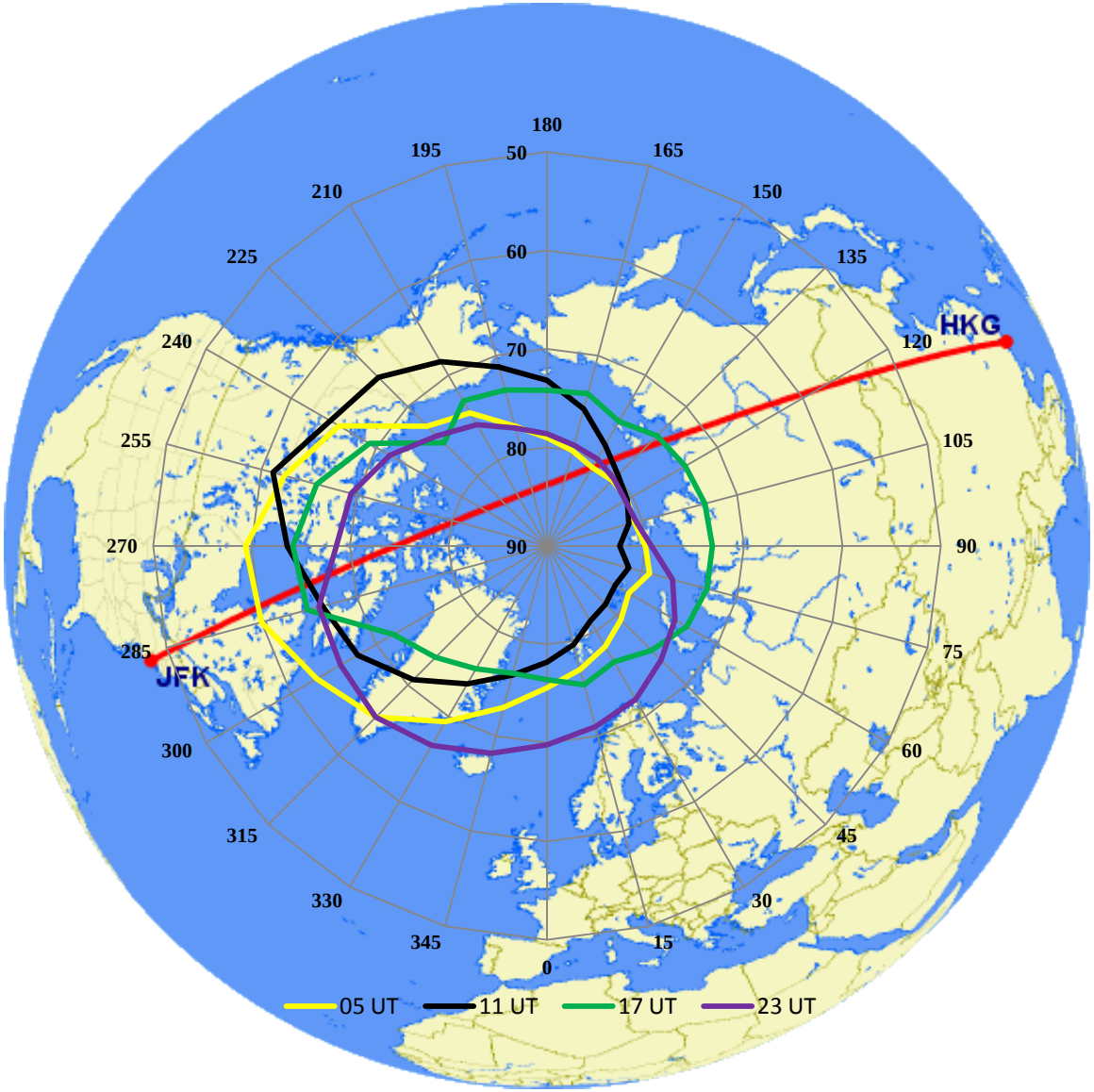
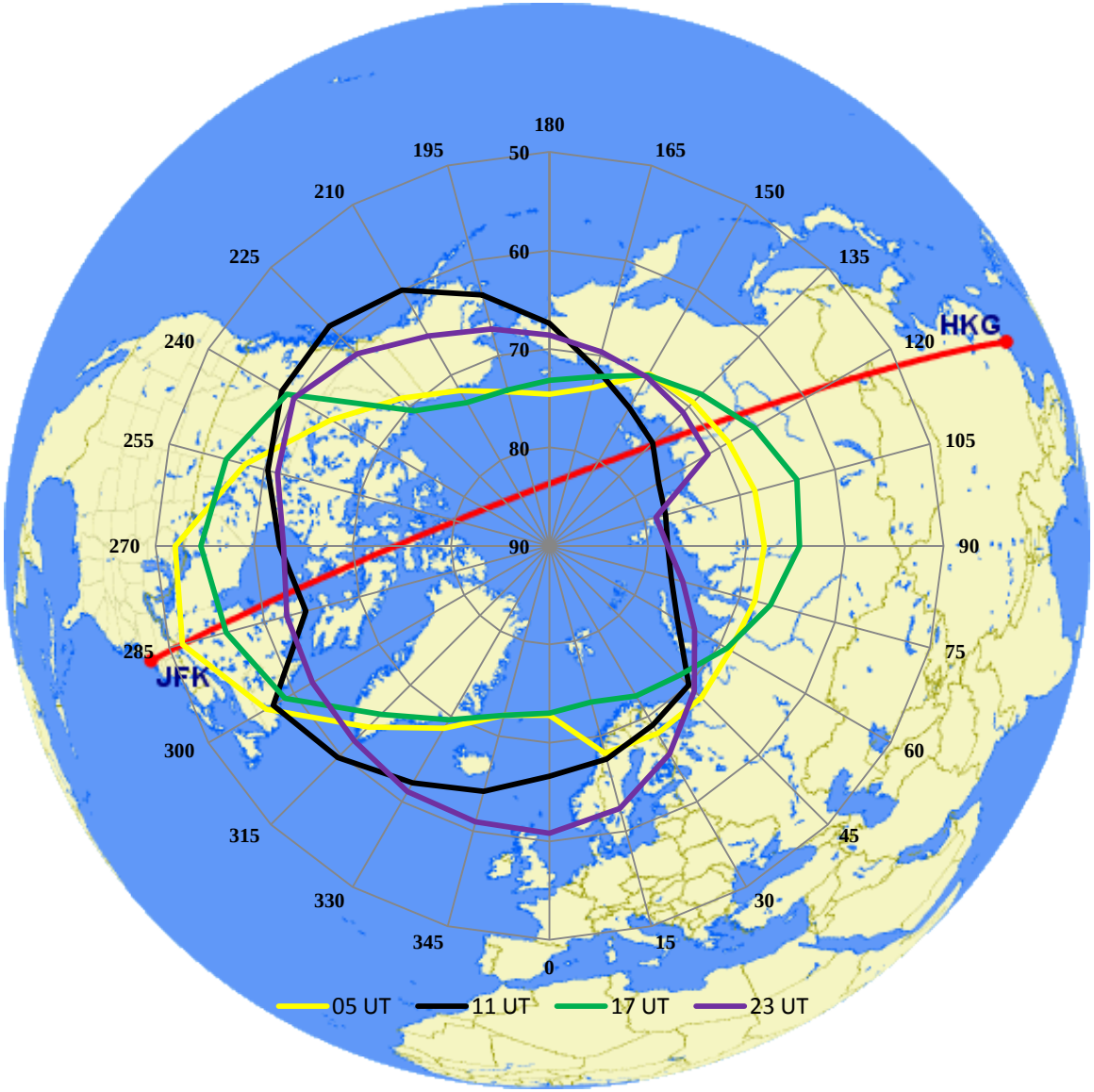


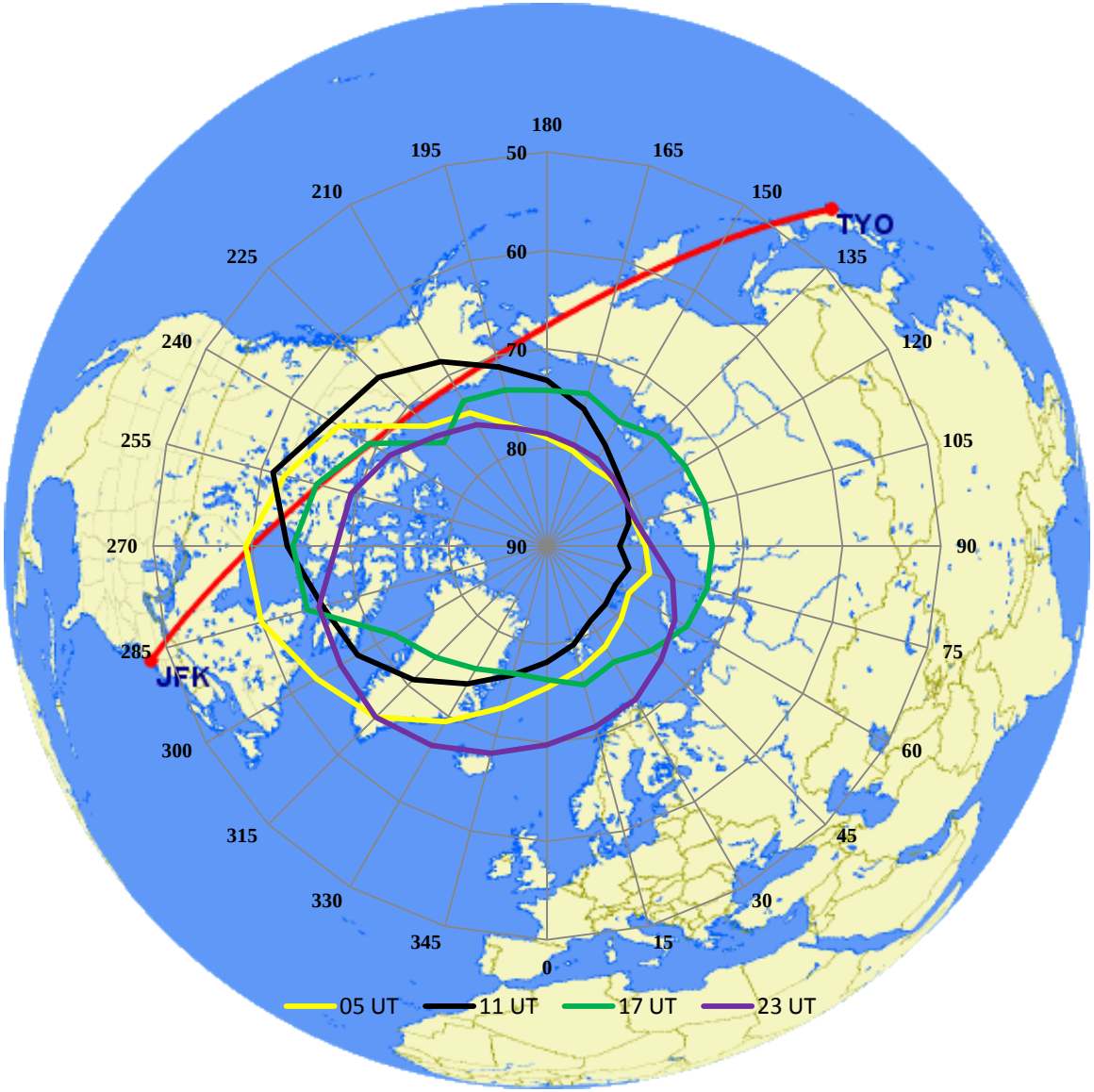
1 MeV Proton Cutoff Boundary, Quiet Conditions

Why Is This Important…



1 MeV Proton Cutoff Boundary, Severe Conditions

Amateur Radio Involvement…



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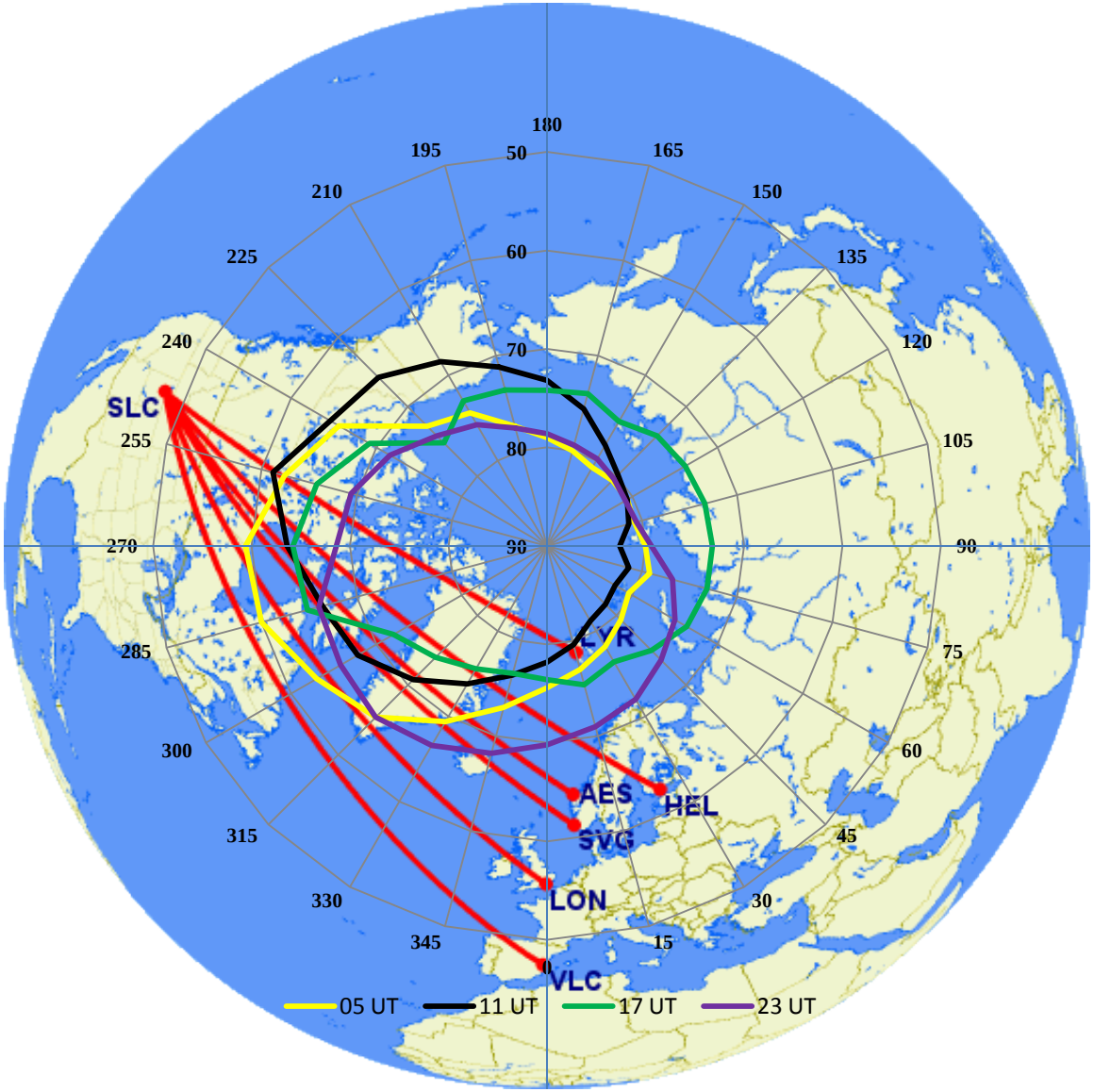

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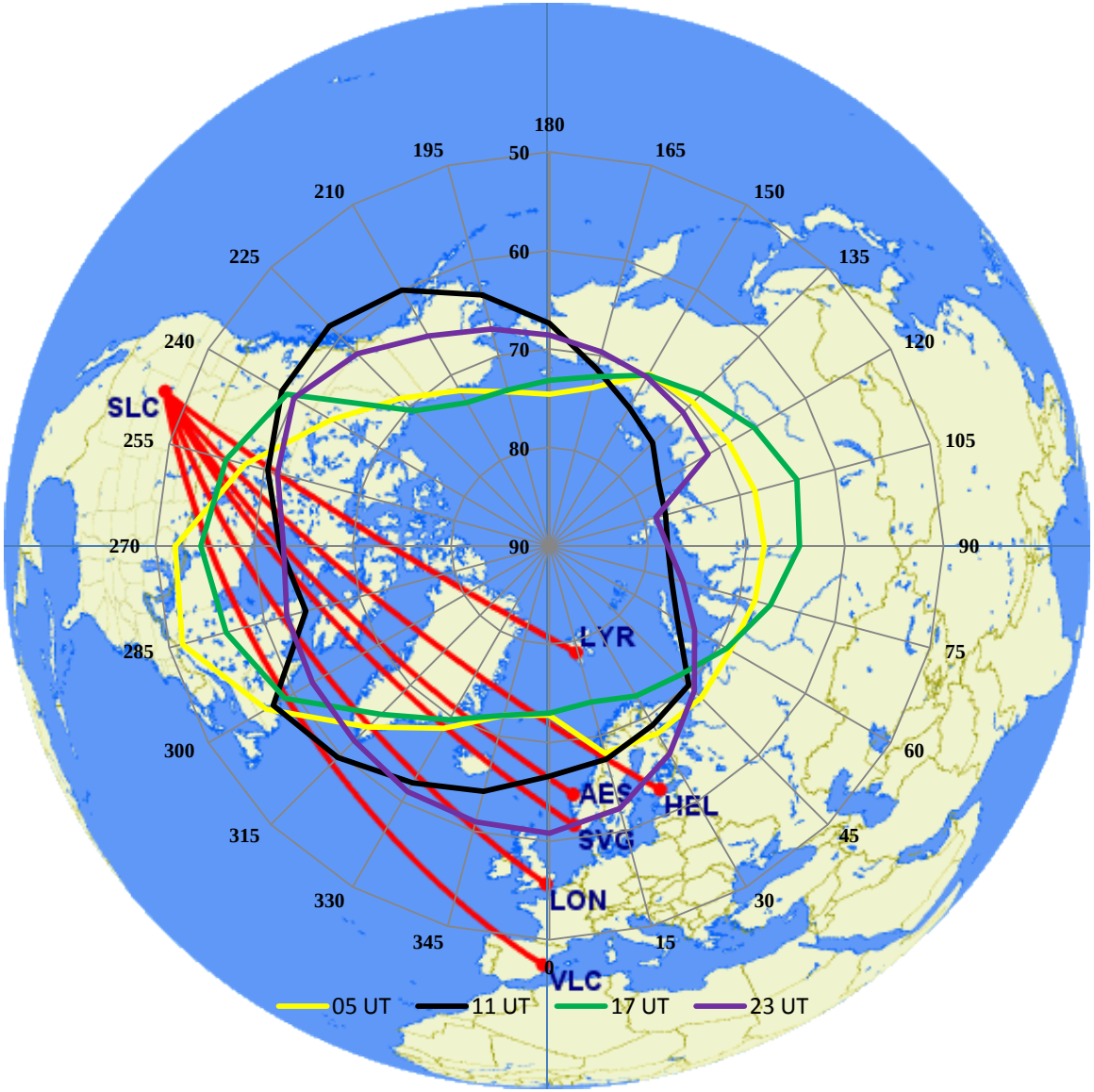

1 MeV Proton Cutoff Boundary, Severe Conditions

Summary

- **Modeled Cutoff Latitude Shows Diurnal Variation aka "UT Effect"**

- **UT Effect an important consideration:**
  - **Transiting Polar Regions**
  - **Modeling D-region characteristics**
  - **HF absorption**

- **Amateur Radio Could Help Demonstrate UT Effect**

- **Enhanced Understanding/Improvement of PCA Effects**

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