Space Weather Prediction Center Mission and Introduction

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National Centers for Environmental Prediction
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Center Overview

An introduction to Space Weather

- ***What is it?***
- ***Where does it come from?***
- ***What does it do?***

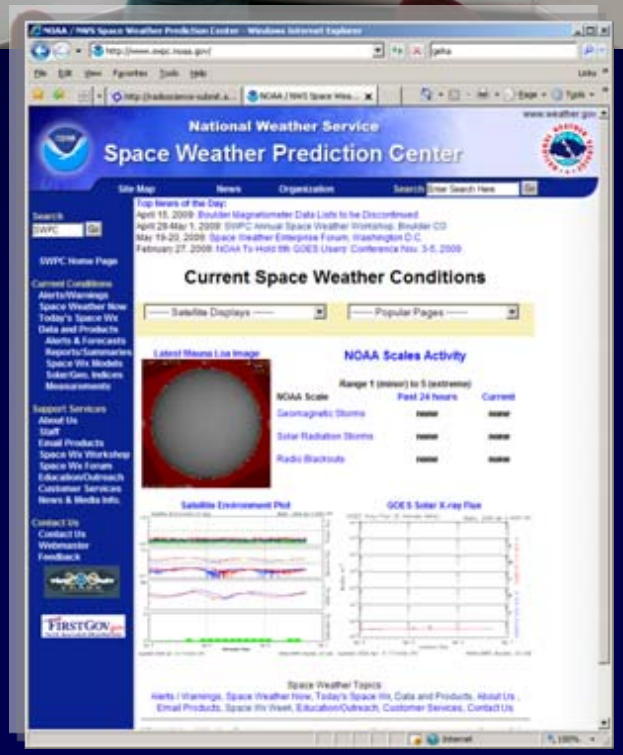
Aviation Weather Community Forum

Aviation Weather Center

April 15, 2009

Space Weather Prediction Center

- 49 FTE's
- FY '09 Budget $6.3M
- World Warning Center of International Space Environment Service



Core Mission

To provide space weather products and services that meet the evolving needs of the nation.

Office of the Director

Partnerships
Planning

Manage

Policy

Stakeholders

Space Weather Services Branch

Assess

Survey
Analyze
Evaluate
Recommend

Transition

Design
Fabricate
Test
Install

Provide

Deliver
Forecast
Validate
Verify

Administrative & Technical Support Branch

Finance

Administration

Support

IT Support
Facilities

Plan

Strategic Direction Team

Execute

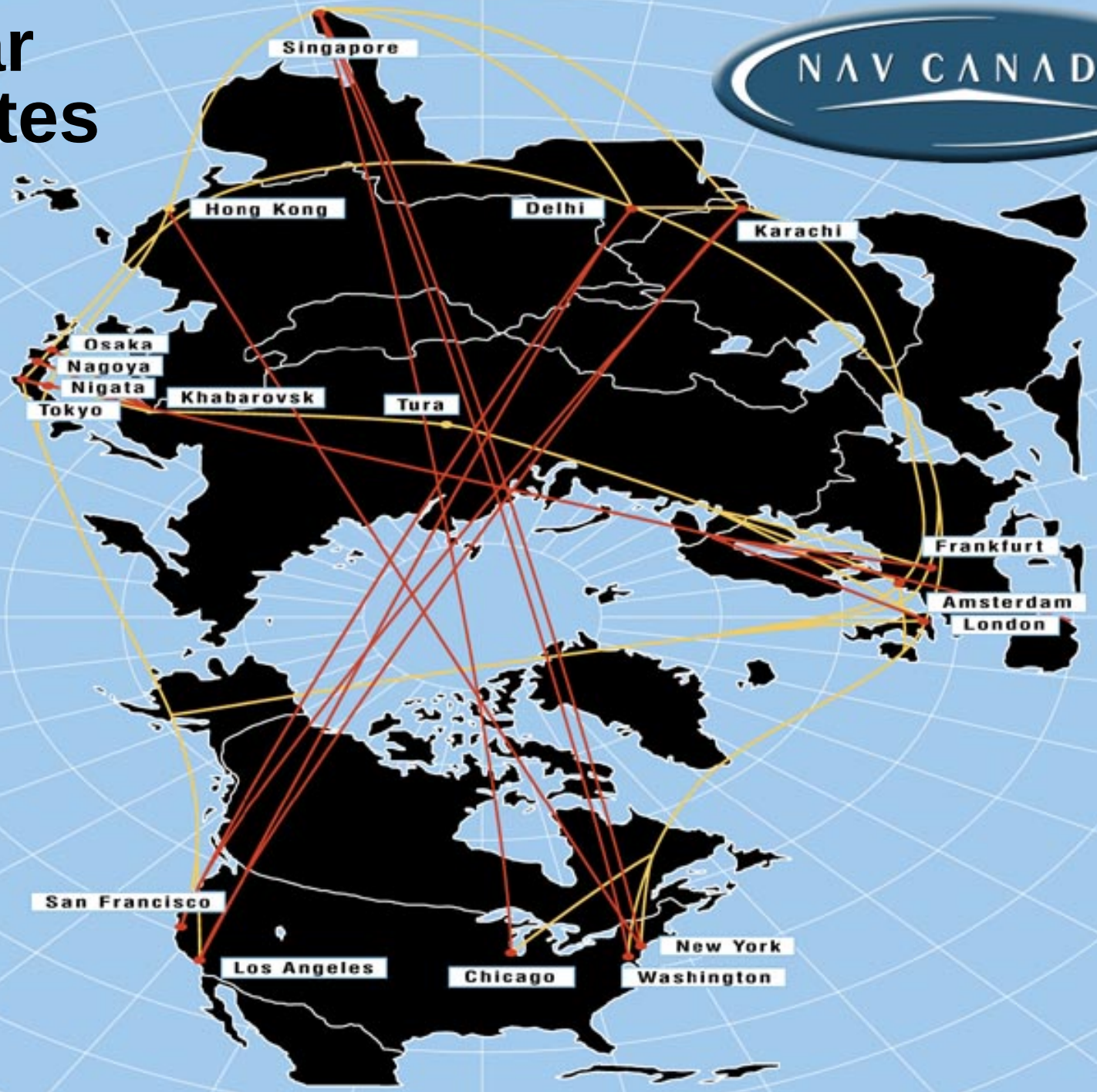
Project Management Team

Air Transport of the Future

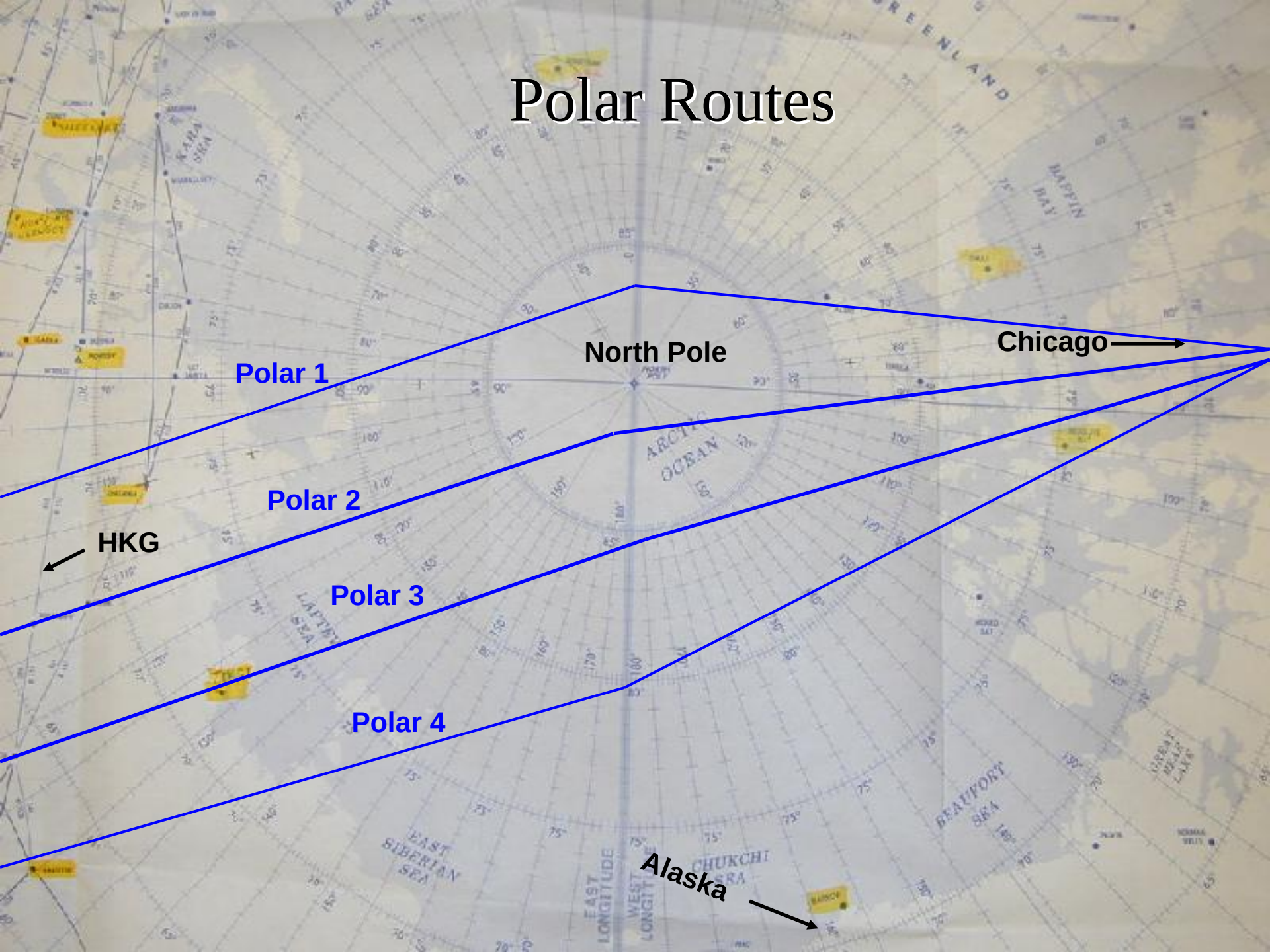
- *More Efficiency*
- *More Capacity*
- *More Profitable*

Discussions are underway between the U.S. and E.C. to develop a global framework for future air traffic management.

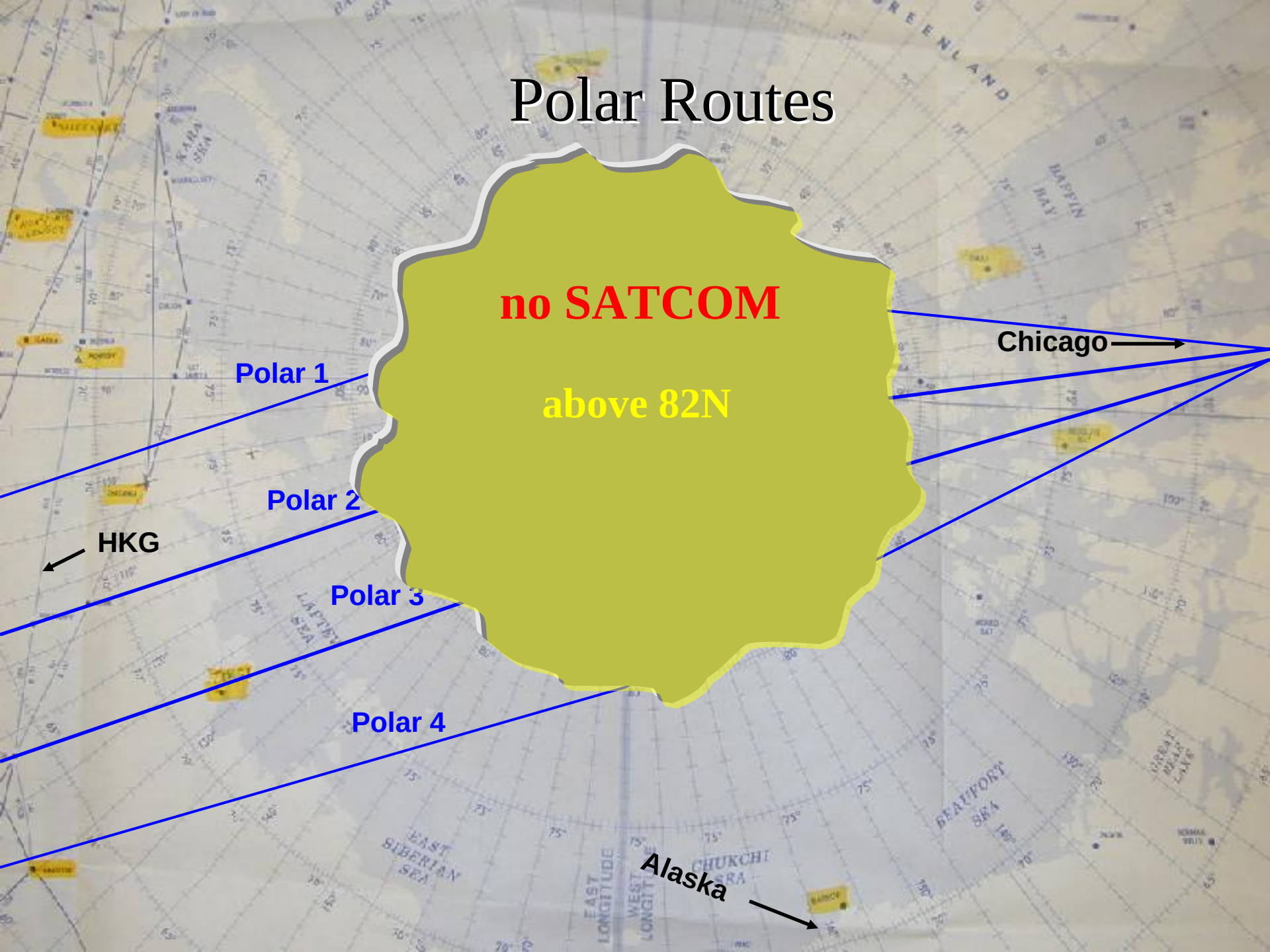
Polar Routes



Polar Routes



Polar Routes



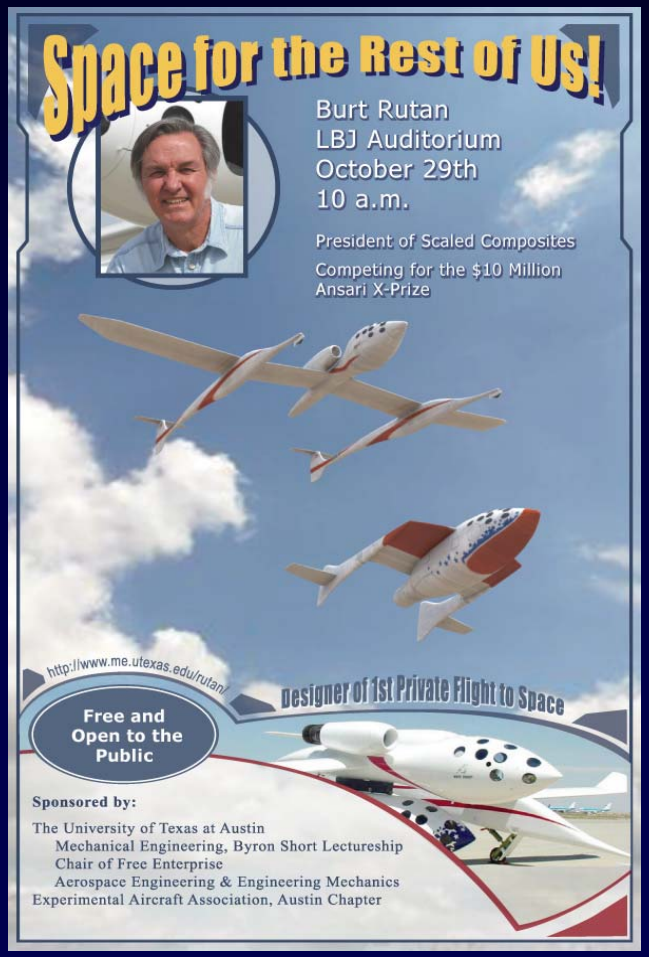
Predicted Polar Route Capacity

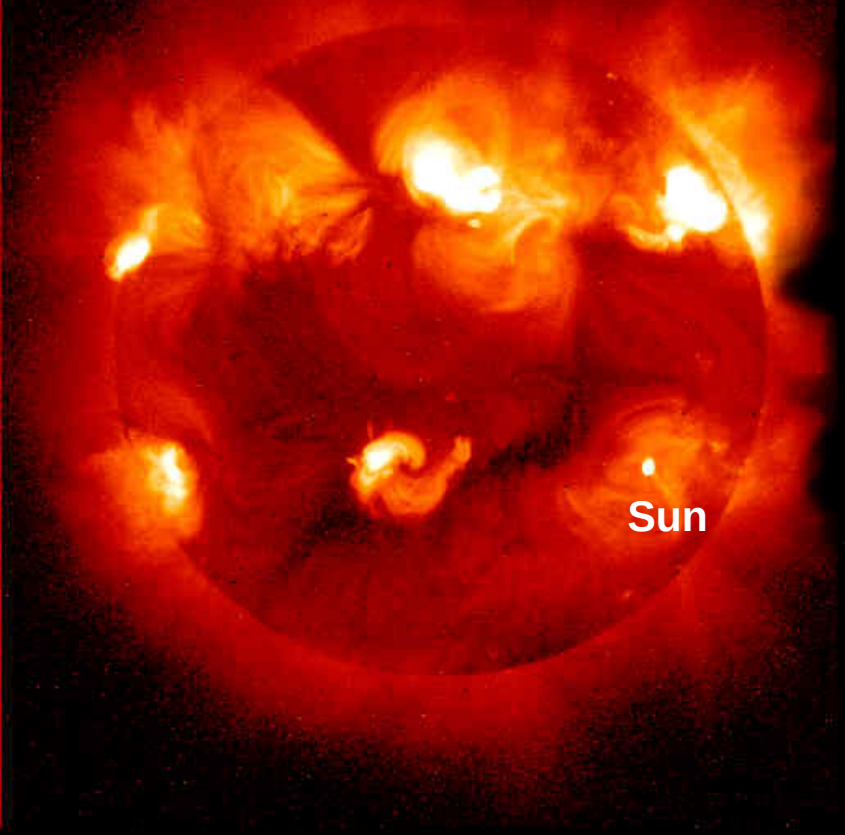
	2005	2009	2014	2019
Capacity	228,000	384,000	972,000	1,768,000
Growth Rate		13.9%	20.4%	12.7%

Source: *Transport Canada Assumptions Report 2005-2019, September 2005, p. 60*

The Dawn of a New Era – Commercial Human Space Flight

American space tourist Dennis Tito gives a thumbs-up prior to boarding the Soyuz TM-32 rocket at the Baikonur cosmodrome in Kazakstan in this April 28, 2001 file photo.

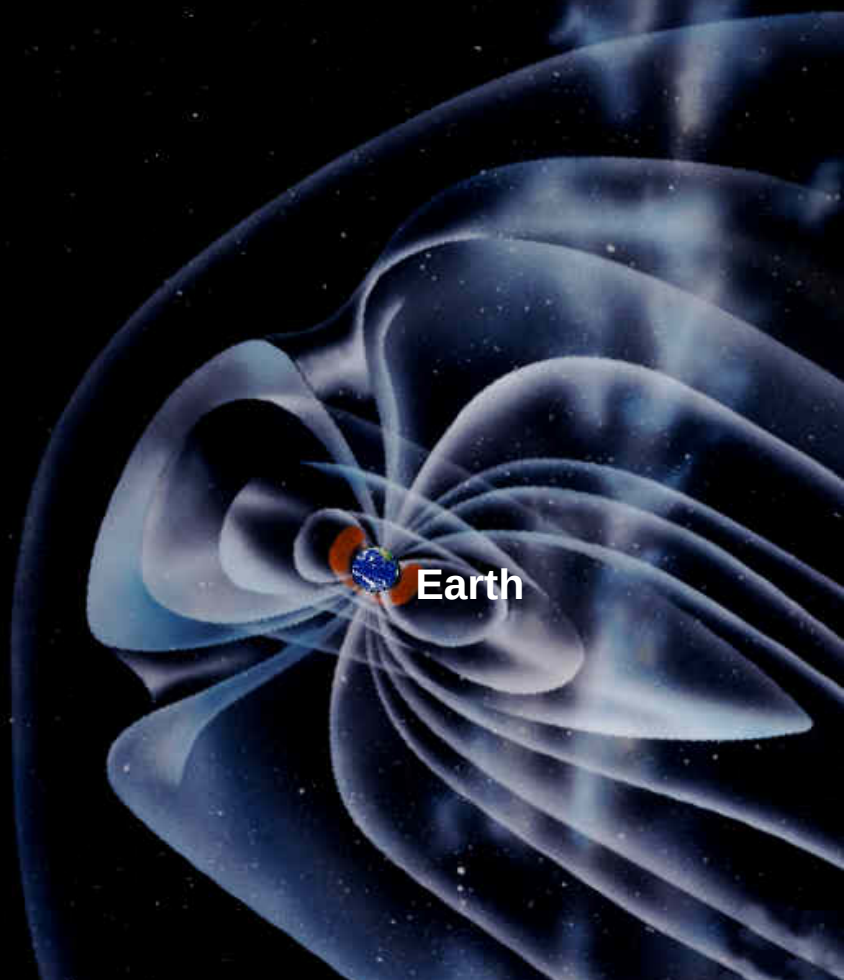




Space Weather:

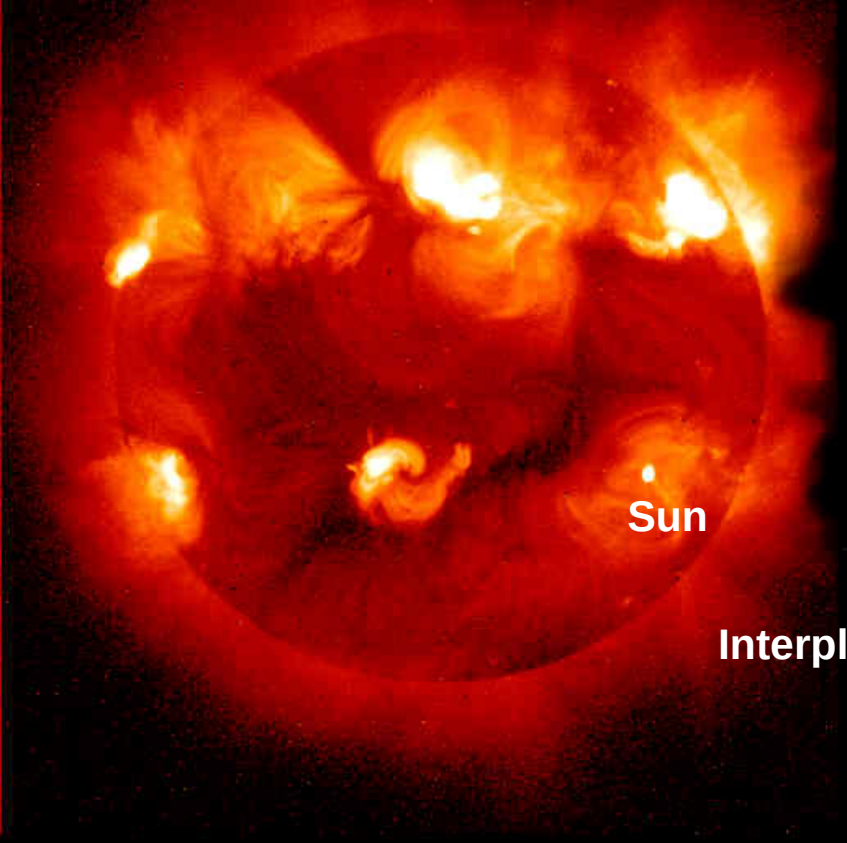
What is it?

Space Weather refers to changes in the space environment near Earth



Sun:

- Energy released in the form of…
  - Light
  - Particles (electrons and protons)
  - Magnetic Field
- Activity Cycles
  - 11 years
  - 22 years
  - 88 years
  - 208 years



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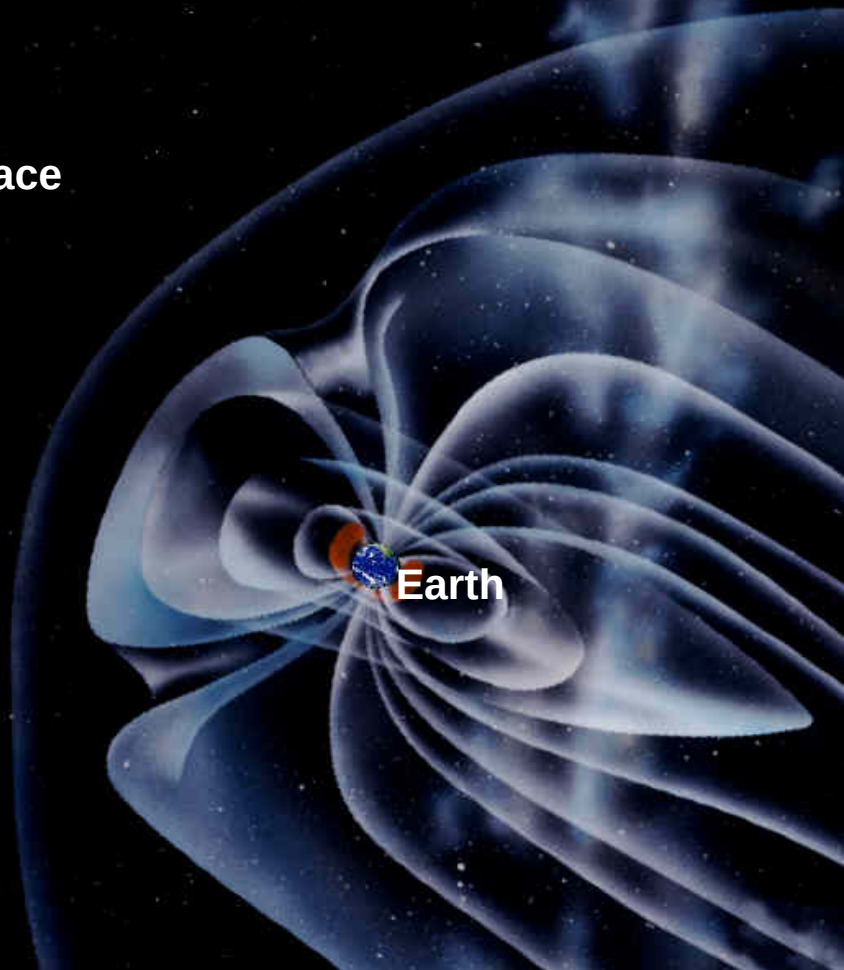
Interplanetary Space



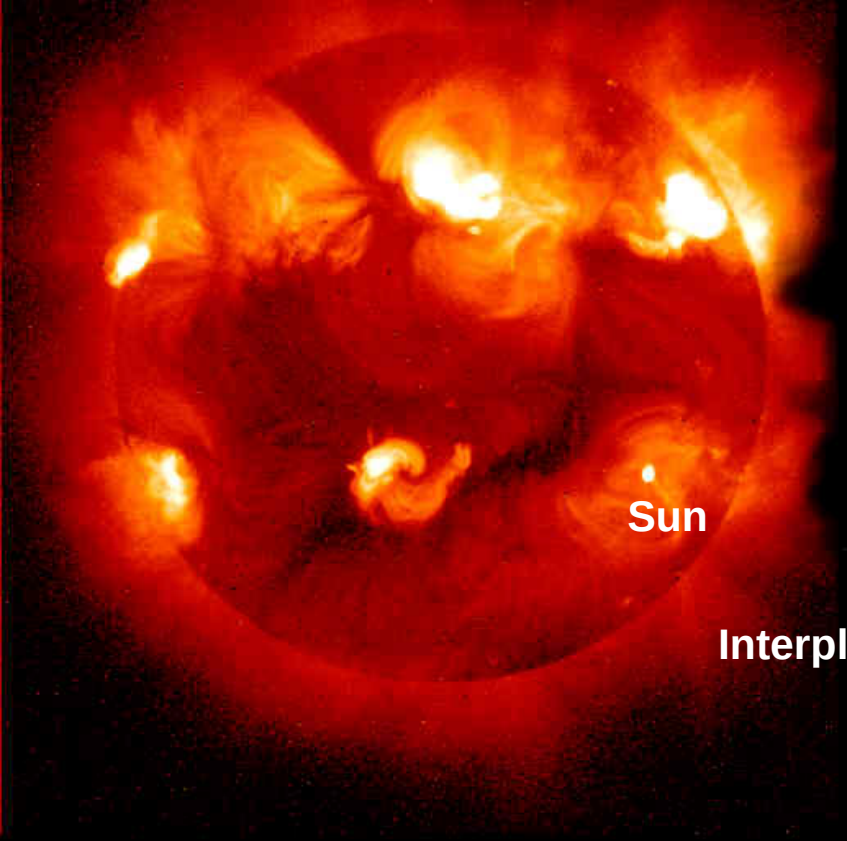
Interplanetary Space:

- Not quite a vacuum
- Solar Wind
  - Electrons and protons
  - Magnetic field
- Disturbances from the Sun make waves in the solar wind

Space Weather:

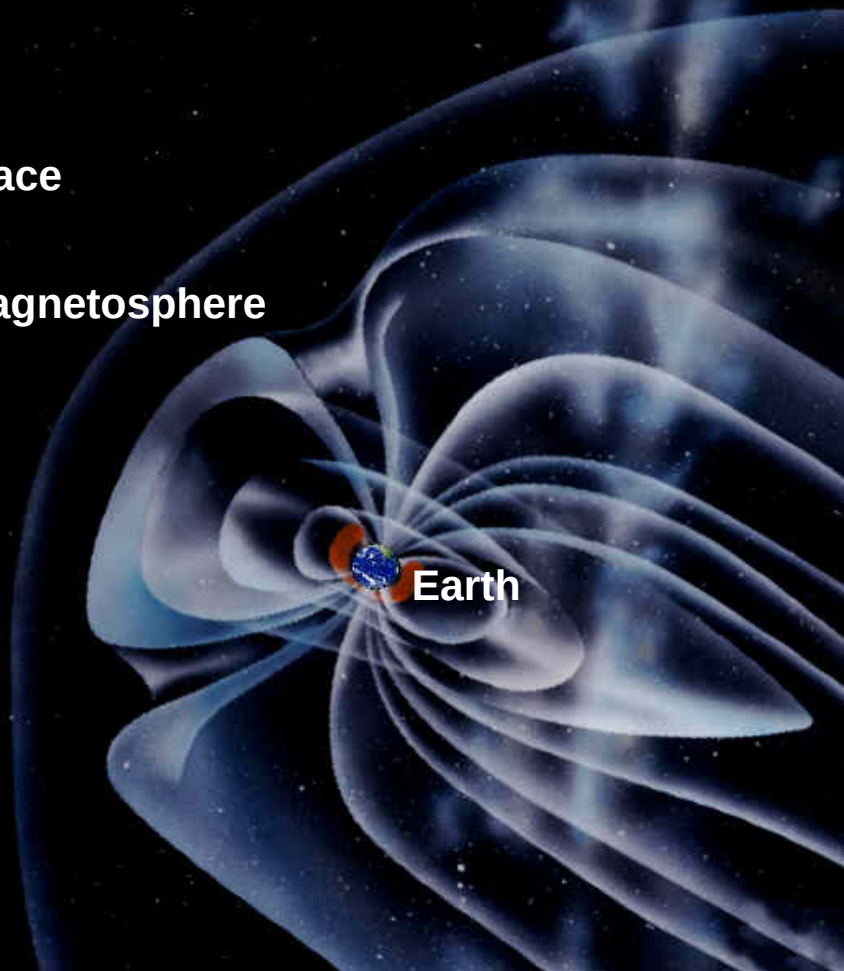
What is it?

Space Weather refers to changes in the space environment near Earth



Interplanetary Space

Magnetosphere



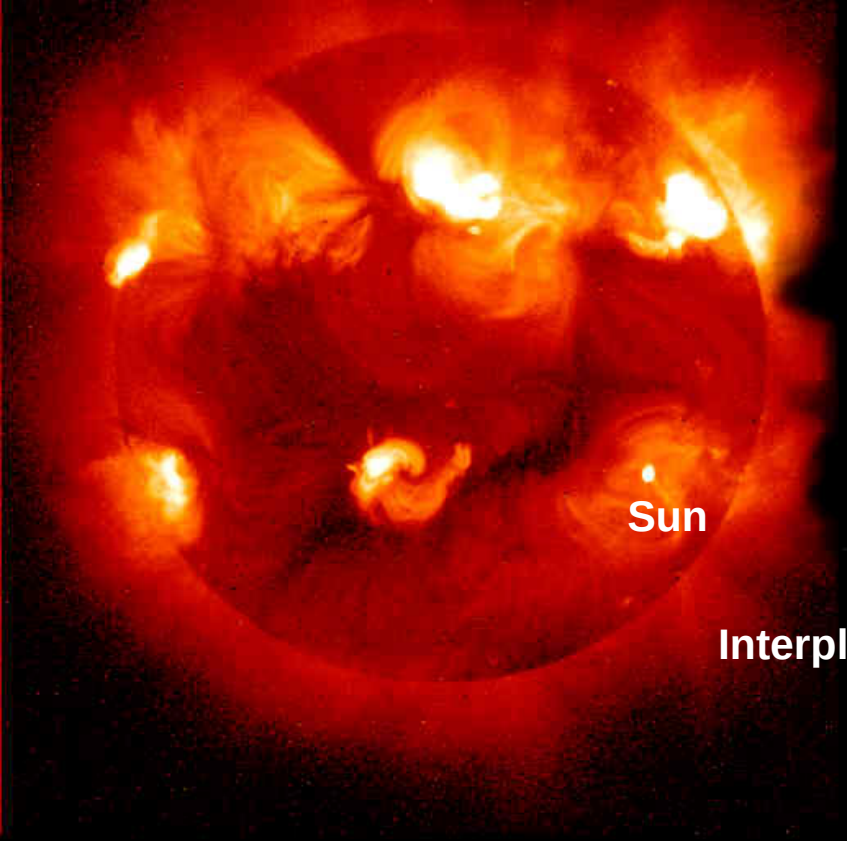
Magnetosphere:

- Created by Earth's magnetic field
- Deformed by the Solar Wind
  - Not Quite a Vacuum
    - Particles (electrons and protons) trapped on magnetic field lines

Space Weather:

What is it?

Space Weather refers to changes in the space environment near Earth



Ionosphere:

- Layer of electrons at the top of the atmosphere (100 – 400 km up)
- Formed when extreme ultraviolet light from the Sun hits Earth's Atmosphere
- Critical in the reflection and transmission of radio waves

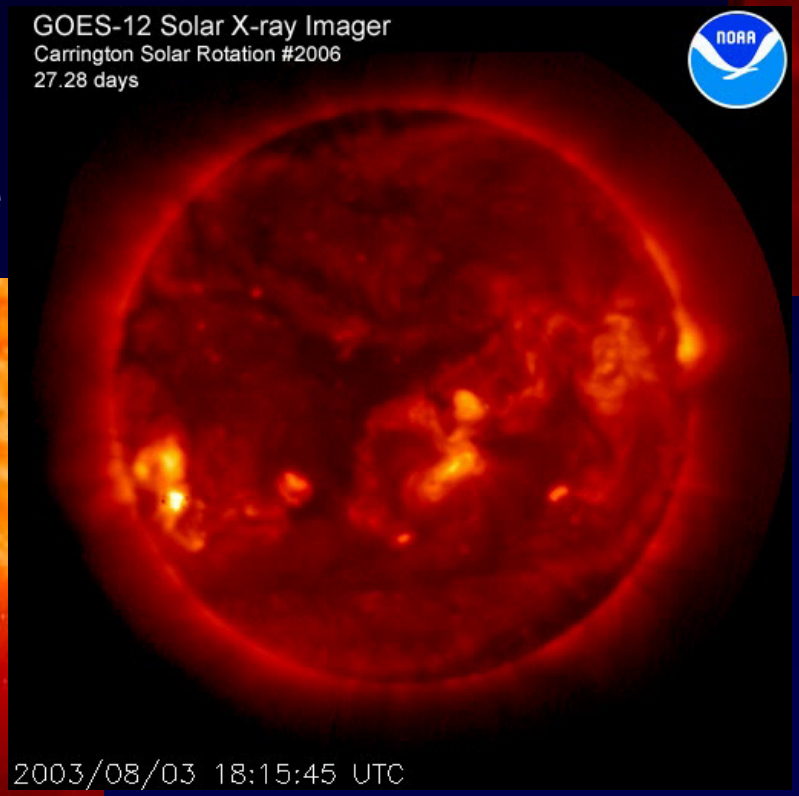
Other Space Weather Terms

- **Solar Storm:** A disturbance in the interplanetary space.
- **Geomagnetic Storm:** The disturbance in the Near-Earth environment that can upset technological systems and create Aurora.
- **Solar Wind**: The outward flow of electrons, protons, and magnetic field.
- **Solar Flare:** A small-scale eruption on the Sun that emits light (UV and x-rays) and particles (electrons and protons).
- **CME (Coronal Mass Ejection):** A disturbance in the solar wind caused by a large-scale eruption on the Sun.
- **Energetic Particles:** Electrons and protons that have been accelerated to high speeds.

The Sun
Solar Flares

- Rotates every 27 days
- Has an 11-year cycle of activity

The Sun in X-rays
From GOES 12



A Solar Flare

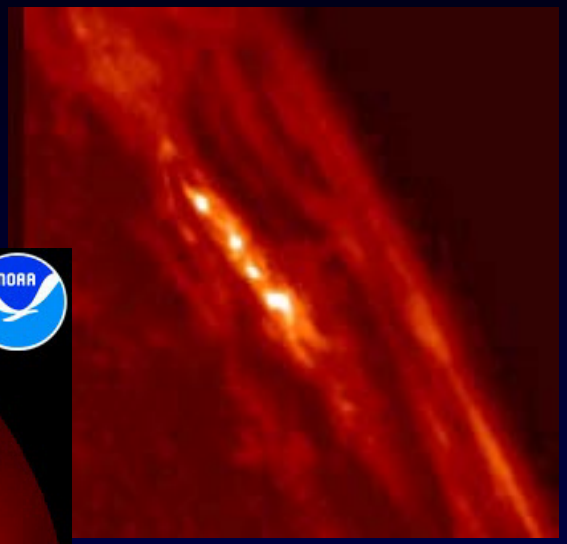


Image from NASA TRACE Satellite

An Erupting Prominence

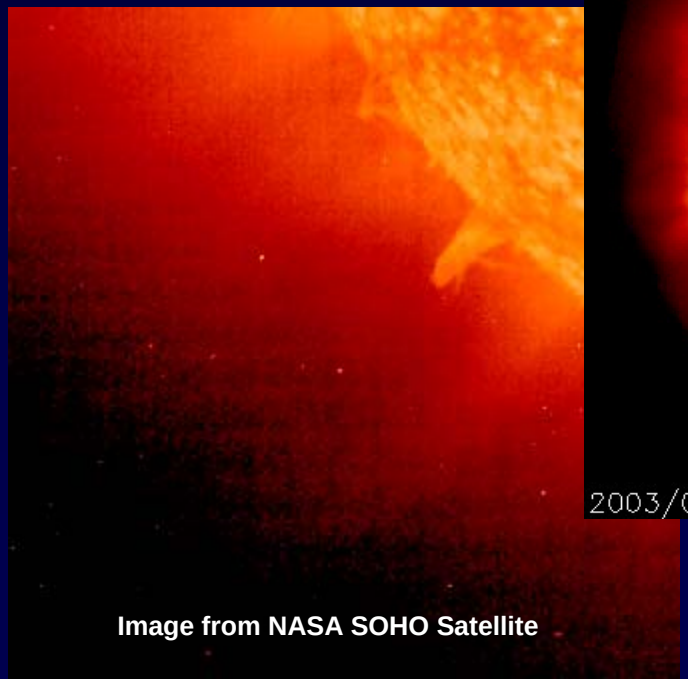
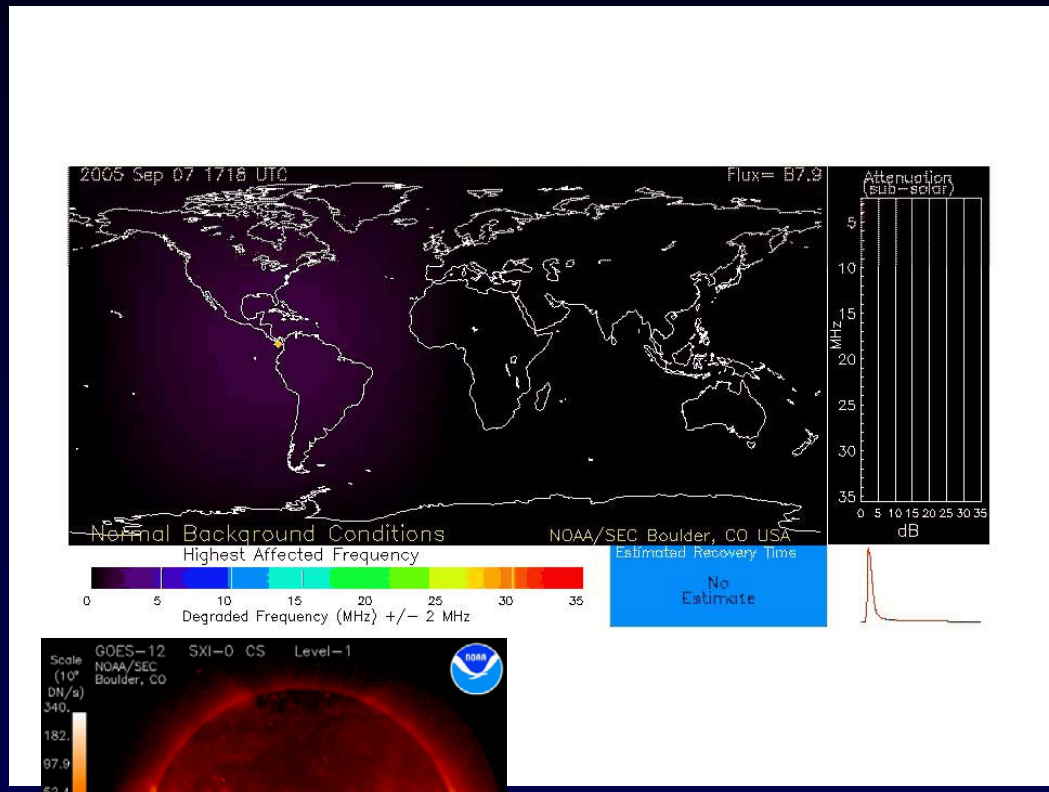
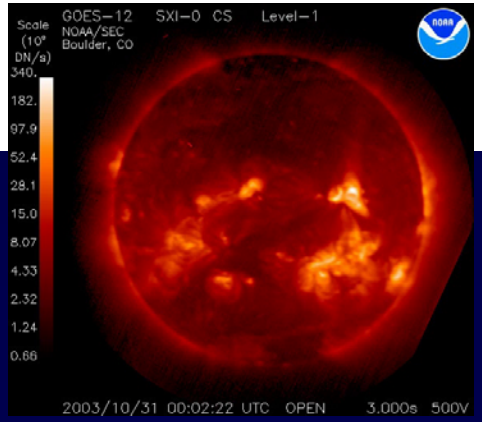


Image from NASA SOHO Satellite

Radio Blackouts

- Dayside of Earth
- Speed of light
- Affects aviation, maritime users, communications





CMEs in Interplanetary Space

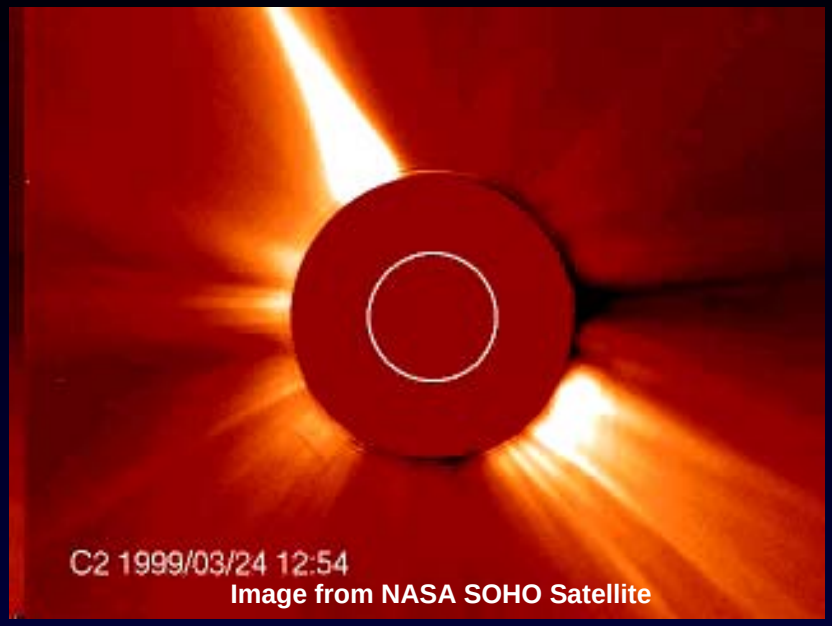


Image from NASA SOHO Satellite

- CMEs send out
  - Magnetic field and plasma
  - Energetic particles
  - Sometimes associated with flares

The CME disturbances propagate away from the Sun but their paths are modified by the background solar wind and the Sun's magnetic field

- Some of these disturbances reach Earth

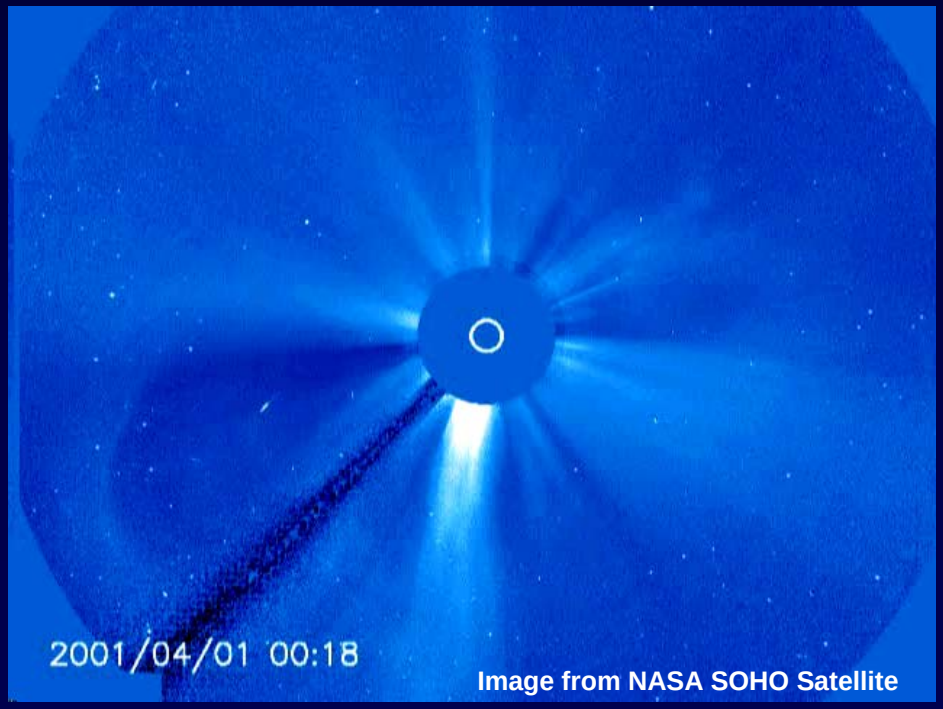


Image from NASA SOHO Satellite

Sun to Earth

- An animation of a space weather event as it starts at the Sun and passes Earth
  - Solar Flare
    - Light
    - Particles
  - CME
  - Magnetosphere
    - Deflects the solar wind
    - Responds to the disturbance
    - Accelerates particles
  - Ionosphere
    - Accelerated particles collide with the atmosphere producing the Aurora

NASA Animation

Geomagnetic Storms

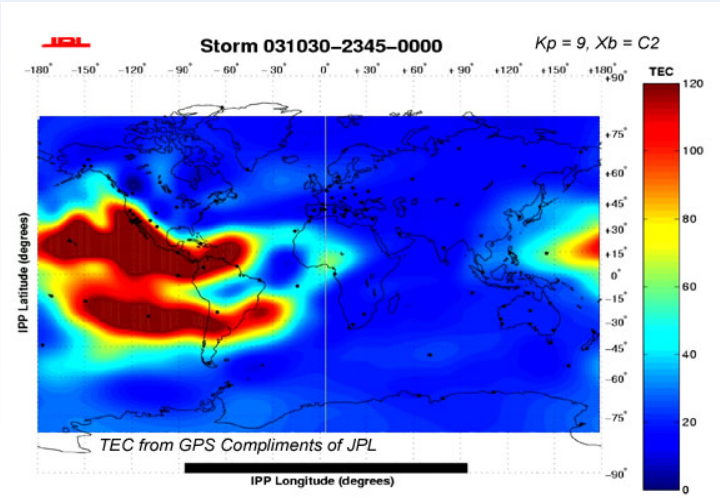
- Global
- Dynamic
- Affects power grids, aviation, satellites, geophysical surveys

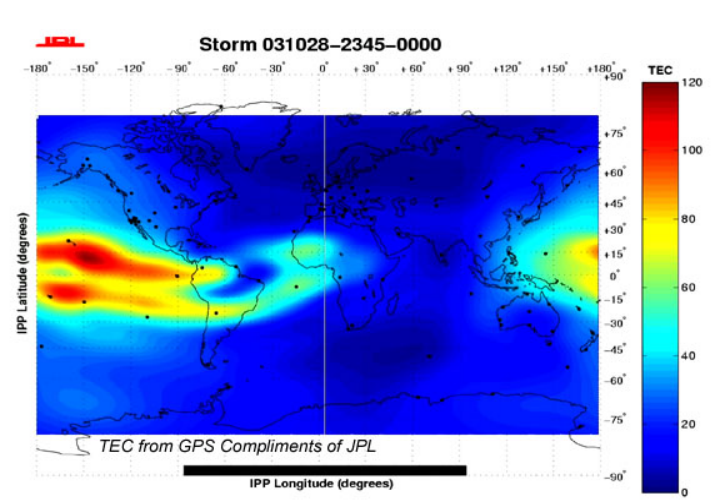
Movie courtesy of NASA

Navigation Systems

FAA's Wide-Area Augmentation Systems (WAAS)

The WAAS system was seriously impacted during the Halloween Storms. For a 15-hour period on October 29 and an11-hour interval on October 30, the ionosphere was so disturbed that the vertical error limit, as defined by the FAA's Lateral Navigation Vertical Navigation (LNAV/VNAV) to be no more that 50 meters, was exceeded. That translated into commercial aircraft being unable to use the WAAS for precision approaches.



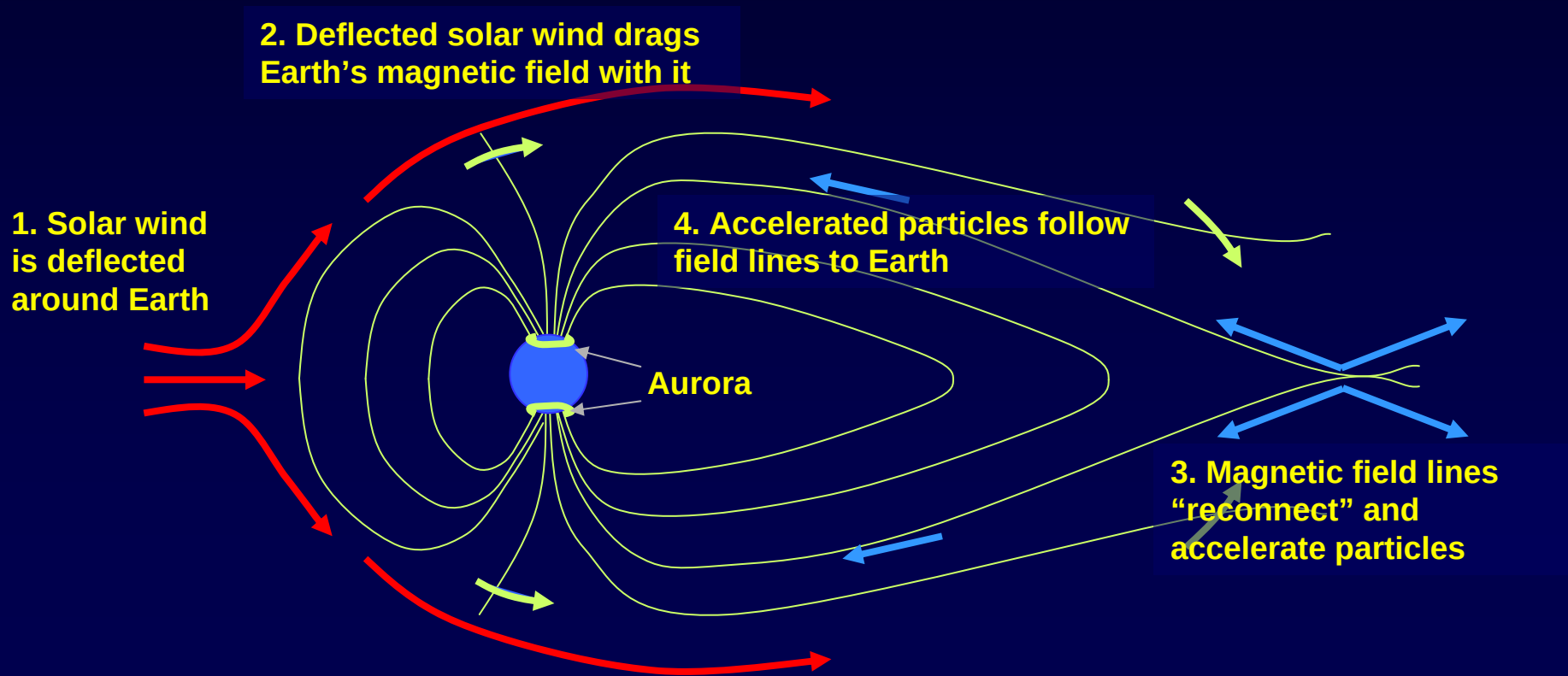


Magnetosphere

What happens when a CME hits Earth?

1. **Solar wind is deflected around Earth**
2. **Deflected solar wind drags Earth's magnetic field with it**
3. **Magnetic field lines "reconnect" and accelerate particles**
4. **Accelerated particles follow field lines to Earth**

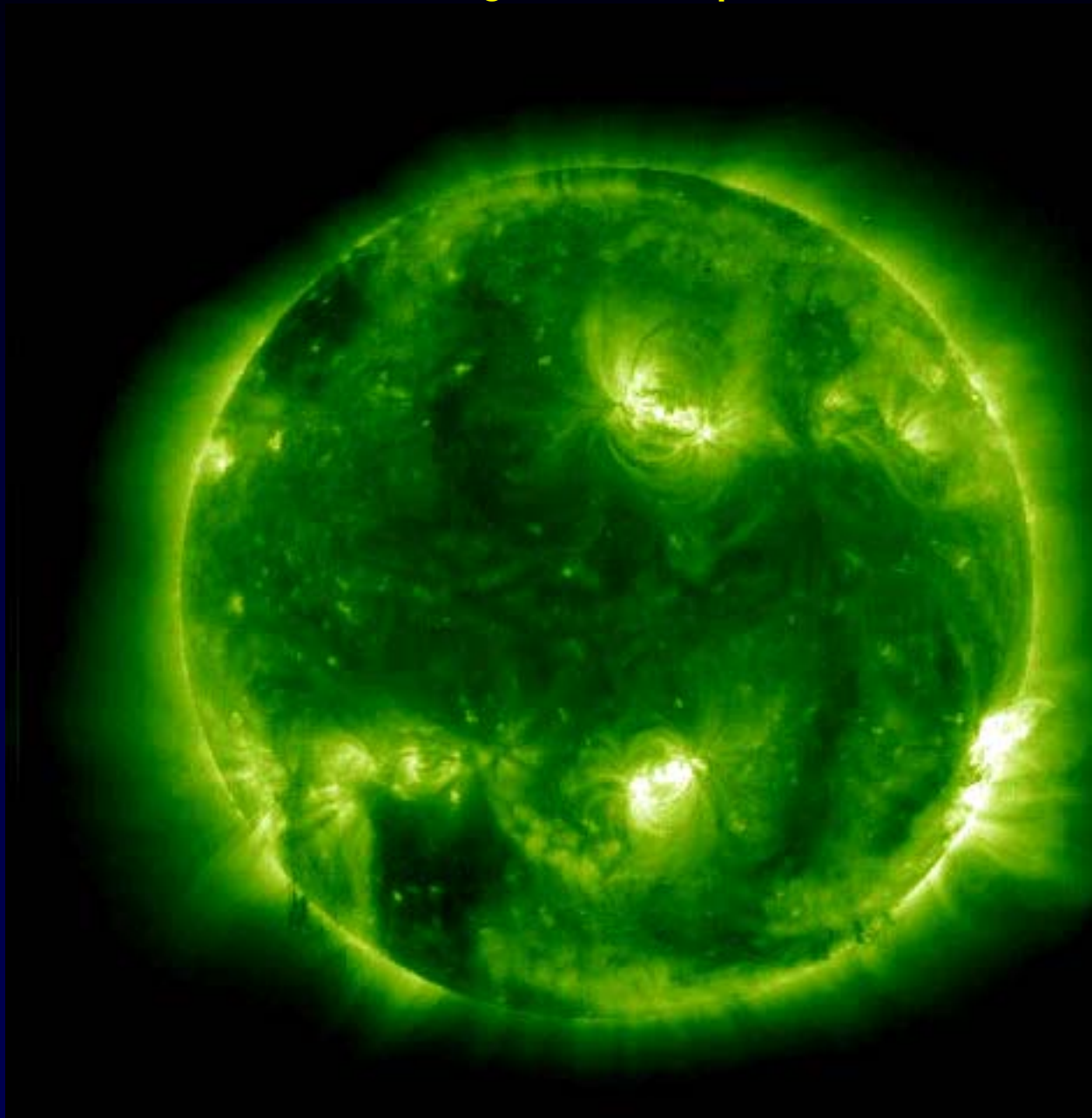
Aurora is produced when particles hit Earth's atmosphere



Space Weather Storms

Timing and Consequences

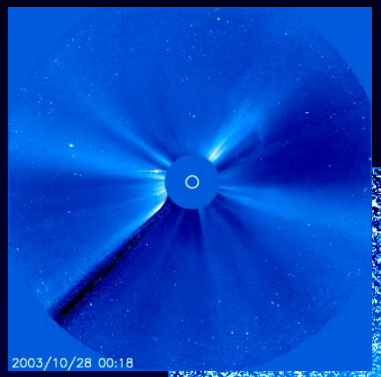
- A Flare and/or CME erupt on the Sun
- 8 Minutes later: First blast of EUV and X-Ray light increases the ionospheric density
  - Radio transmissions are lost
- 30 to 1000 minutes later: Energetic Particles arrive
  - Astronauts are at risk
  - Satellites are at risk
  - Polar flights are at risk
- 1 to 4 Days later: CME passes and energizes the magnetosphere and ionosphere
  - Electric Power is affected
  - Navigation Systems are affected
  - Radio Communications are affected

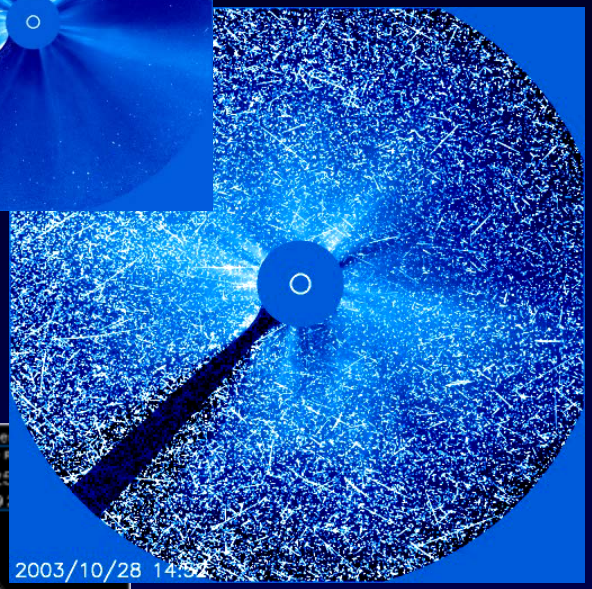


Movie from NASA SOHO Satellite

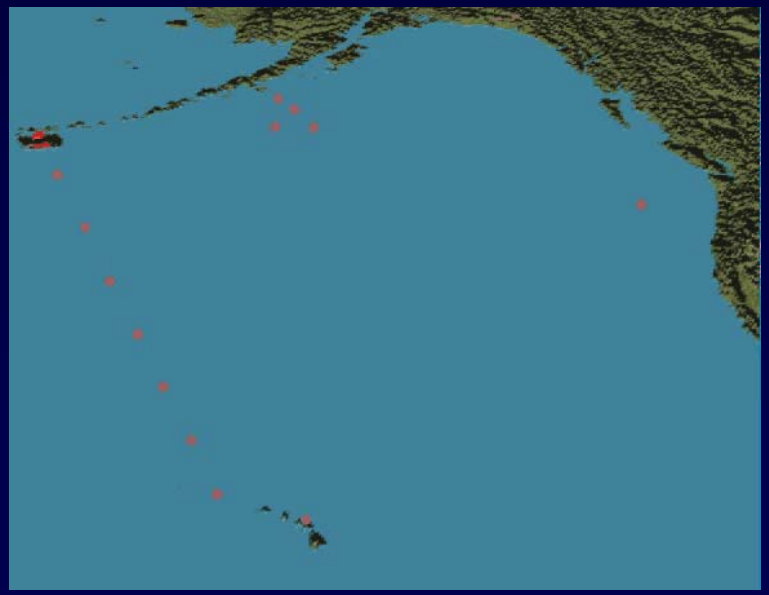
Solar Radiation Storms

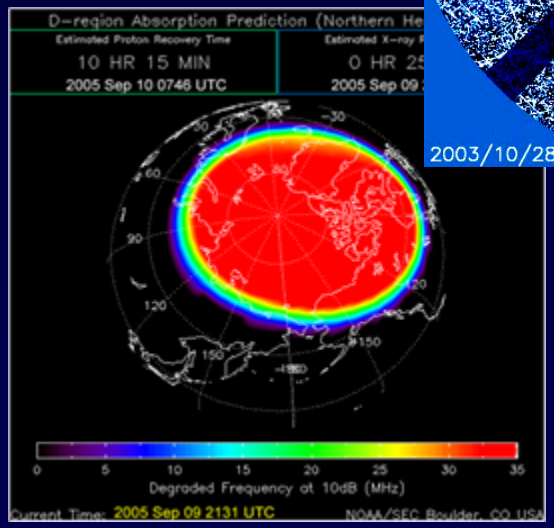
- Larger than global
- Threatening
- Affects satellites, aviation, manned spaceflight



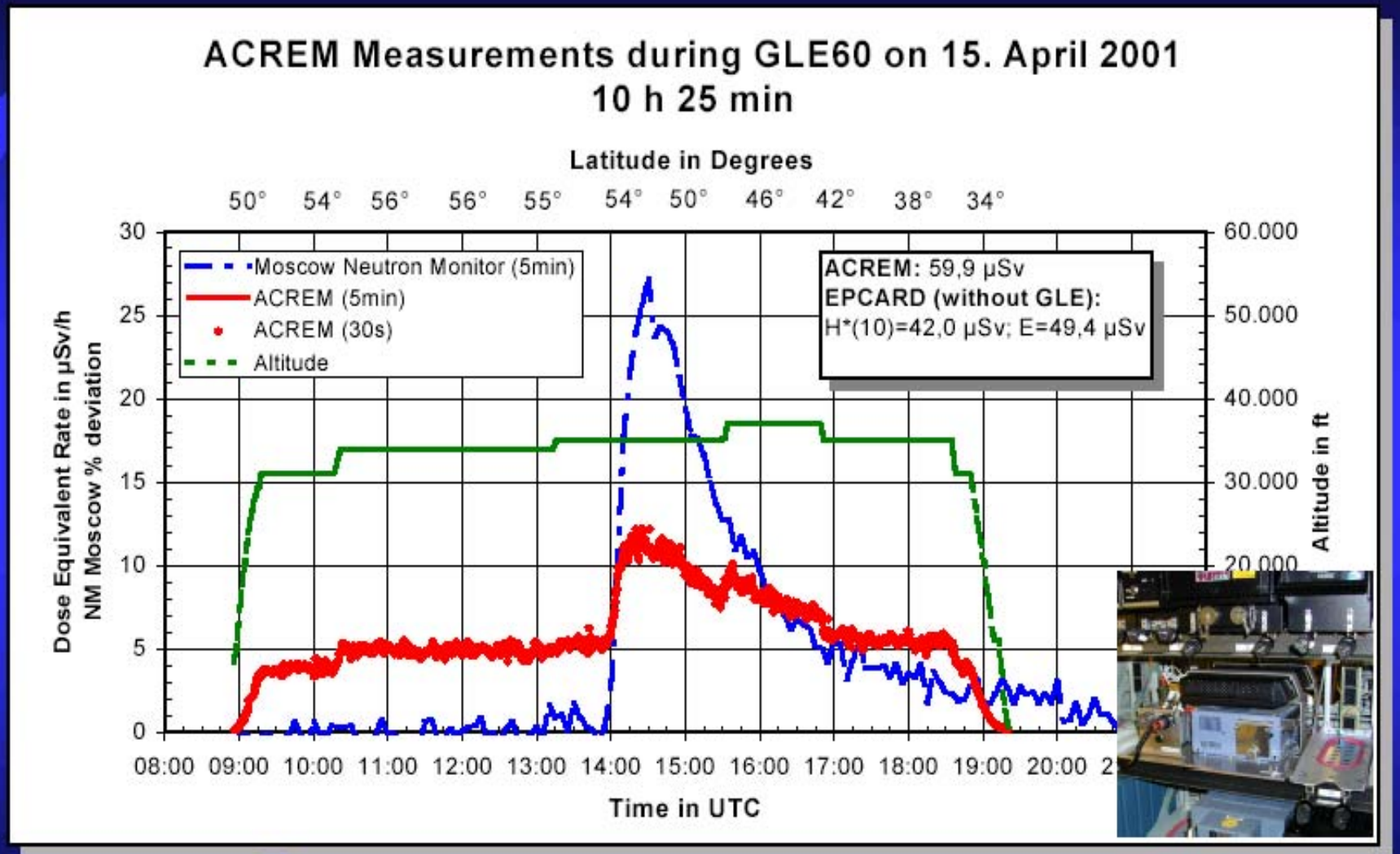


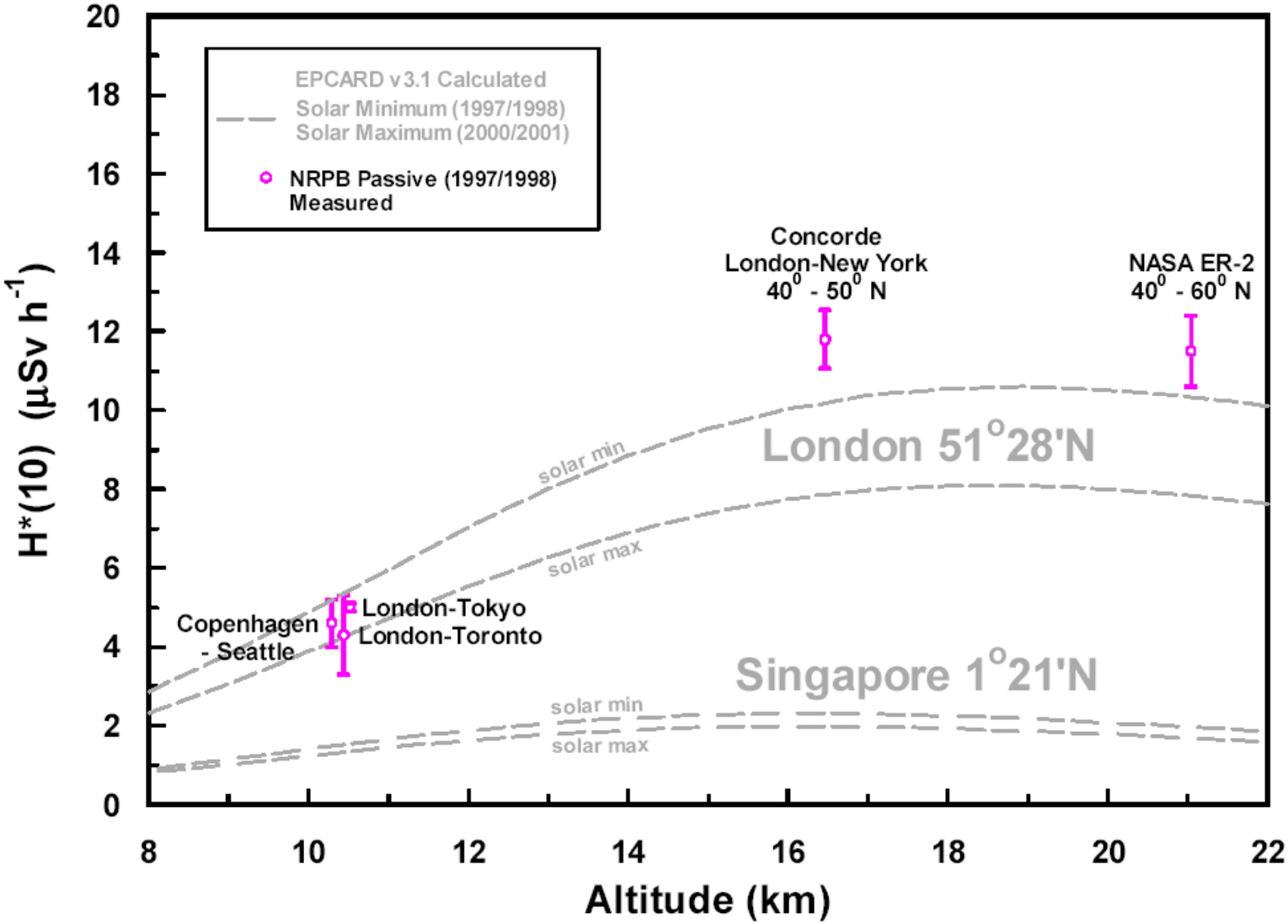
Courtesy of NASA



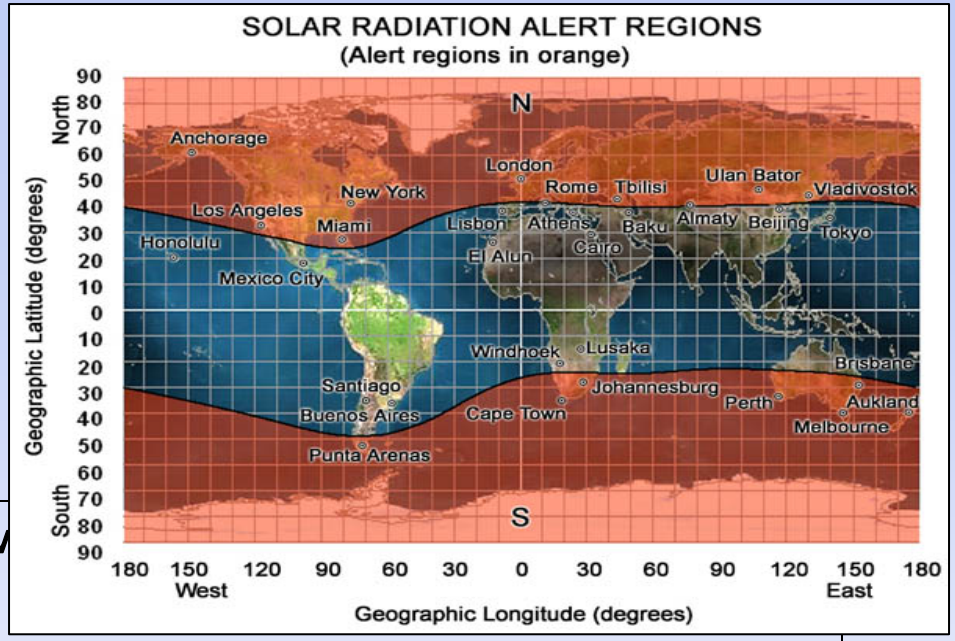


FRA to DFW flight




EPCARD v3.1 Calculated
Solar Minimum (1997/1998)
Solar Maximum (2000/2001)
NRPB Passive (1997/1998)
Measured
Concorde
London-New York
40° - 50° N
NASA ER-2
40° - 60° N
London 51°28'N
solar min
solar max
Copenhagen
- Seattle
London-Tokyo
London-Toronto
Singapore 1°21'N
solar min
solar max
H*(10) (µSv h-1)
Altitude (km)
0
2
4
6
8
10
12
14
16
18
20
8
10
12
14
16
18
20
22

Federal Aviation Administration (FAA) Radiation Alert



ALERT: Solar Radiation Alert at Flight Altitu
Conditions Began: 2003 Oct 28 2113 UTC

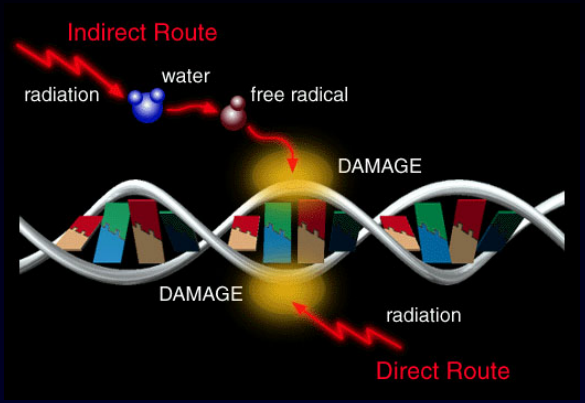
Comment:
Satellite measurements indicate unusually high levels of ionizing radiation, coming from the sun. This may lead to excessive radiation doses to air travelers at Corrected Geomagnetic (CGM) Latitudes above 35 degrees north, or south.

Avoiding excessive radiation exposure during pregnancy is particularly important.

Reducing flight altitude may significantly reduce flight doses. Available data indicates that lowering flight altitude from 40,000 feet to 36,000 feet should result in about a 30 percent reduction in dose rate. A lowering of latitude may also reduce flight doses but the degree is uncertain. Any change in flight plan should be preceded by appropriate clearance.

Energetic Particles Effects

Radiation Hazard



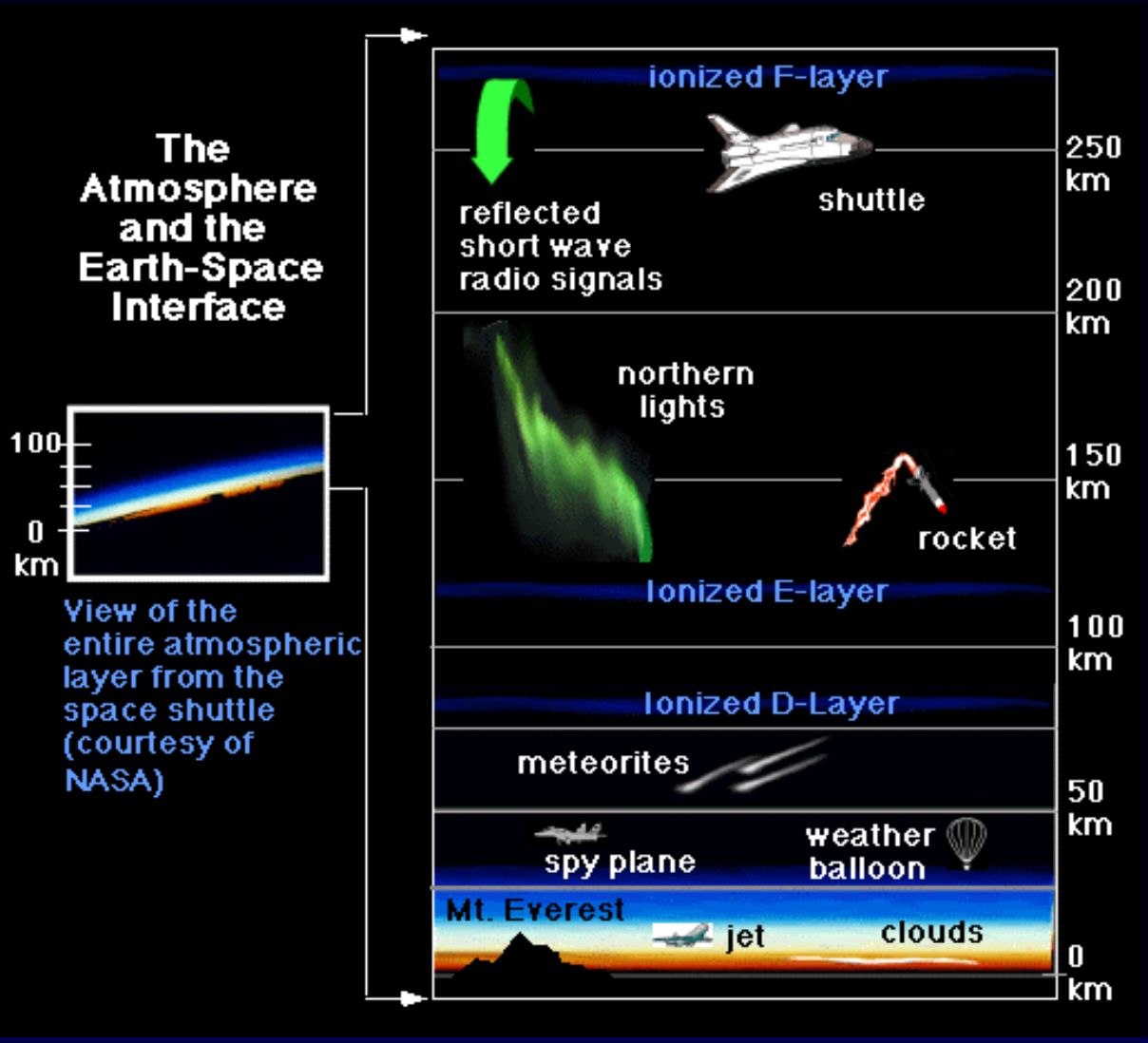
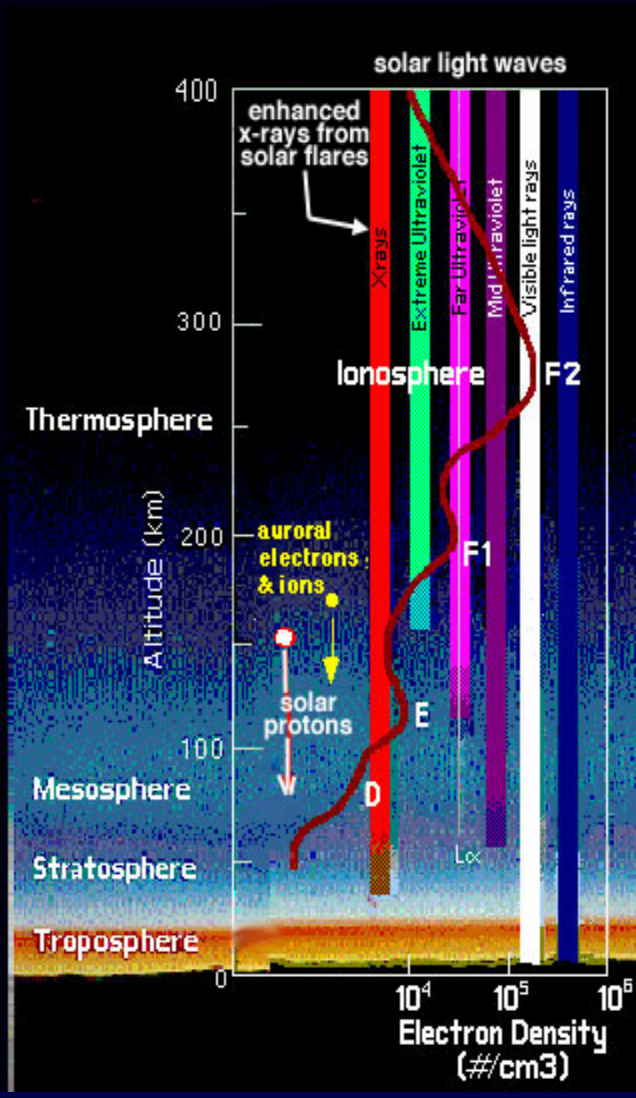
Health Hazards from Energetic Particles

- **Humans in space**
  - **Space Shuttle, International Space Station, missions to Mars**
- **Crew/Passengers in high-flying jets**
  - **Concorde carried radiation detectors**
  - **Passengers may receive radiation doses equivalent to 10 - 100 chest X rays.**

NASA Video Clip

Summary

- Space Weather Storms come in three categories
- Each category arrives at a different speed
- Each category affects different users and technologies

	Bursts of X-ray and EUV radiation	Energetic Particles (electrons and protons)	CMEs that produce Geomagnetic Storms
Arrival Time	8 minutes	15 min. to 24 hrs.	1 to 4 days
Systems Affected	Radio Comm. Satellite Drag	Satellites Astronauts Airlines	Power Companies Radio Comm. Navigation Aurora

The Thermosphere and Ionosphere