Aurora Australis as the Signature of Space Weather: Impacts on Society and Technology

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Atmospheric, Oceanic and Space Sciences
Earth and Space Sciences
MS Boreal Semester @ Sea
Drake Sea 60 Knot winds/45 ft seas/over 40 degree rocking
Before Storm

Had 8 foot drifts and took 6 people over an hour to dig out our Tents when we left. 3 tents destroyed during storm.

Day 1 of 3 day storm
45 knot (52 mph winds)
-30 C temps (-80 windchill)
Aurora and Space Weather

- TWO Points for the “Last” Lecture
  - What is aurora and space weather?
  - How does it impact us?

- This discussion will be an introduction and overview of the solar-terrestrial relationship and its impact on space technology and exploration

- When Doomsday December 21, 2012 happens – look up – you will see aurora ;)
How many of you have seen aurora?

• Occur as ovals in polar regions (in Alaska around 65 degree north; in WAP around 75 degree south)
• Occur 24/7, but only visible at “night/winter”
• Usually 3-6 major displays per day
• Extends down to low latitudes usually once or so per decade
• Evidence of energy from sun transferring energy into the Earth’s space environment

• Reason I got into space physics and work in polar regions
The Dynamics Sun
We live in the Sun’s Dynamic Atmosphere
Storms from the Sun
Coronal Mass Ejections Light Up the Sky

Particles are blasted from the Sun...

Millions of amps surge through our atmosphere...

...And make bright Northern lights
Aurora Borealis over Michigan
October 24, 2011

Photo: Shawn Malone
Captain Cook

- On Feb 17 1773 at 58 degrees south in the Indian Ocean observed aurora.

- His ship’s log
  - “lights were seen in the heavens, similar to those in the northern hemisphere, known by the name of Auroral Borealis:
  - Named them Aurora Australis
You now know what are aurora – Why should you care?

- Not only a ghostly and awesome light show in the polar regions
- It is a signature of space weather

- Space weather storms now have the ability to damage modern space-age technology (communication, navigation and power distribution) and significantly impact civilization
Why should first-world society be interested in Space?

- Do you watch TV?
- Do you listen to radio?
- Do you own a cell phone?
- Have you flown on an airplane?
- Rely on weather forecasts?
- Do you need electricity for your apartment, home, or office?
- All of these activities can be impacted by Space Weather
Space Weather Impacts Society and Technology
Spacecraft Damage/Loss

The New York Times

2 Canadian Space Satellites Are Knocked Out by Storm

OTTAWA, Jan. 22 (Reuters) — An electromagnetic storm knocked out Canada’s two communications satellites Thursday, and one of them may be lost for ever, the operating company, Telesat Canada, said Friday.

Telesat executives said an unusual localized storm caused short-circuits on its Anik E-1 and E-2 satellites, disrupting telephone, television and transmission services.

Developing Service Promises Accurate Space Weather Forecasts in the Future

Scientists, T. Hiebert, K. J. Kiefer, and R. F. Lebourdais, and W. Lottis

Weathering the storm in space

Sun gets blame for zapped Aniks

Telesat still trying to fix $300-million satellite, but chance of revival diminished. Technical storms caused by a dip in the sun's corona.

Image Credit: L. J. Lanzerotti, Bell Laboratories, Lecent Technologies, Inc.
Power Grids

PJM Public Service
Step Up Transformer
Severe internal damage caused by
the space storm of 13 March, 1989.

A large space storm in 1989 caused currents which damaged this transformer and shut off power for six million people for nine hours.

Faraday’s Law at Work
Solar Cycle
Could Space Weather cause an Economic Depression?

• What are the economic impacts of space weather?
• What is the worst case scenario?
• What is the probability of the worst case scenario?
• What could happen?
What is the worst storm in recorded history?

1859 Geomagnetic Storm
- Observed by Carrington (the Sun King)
- Largest fluence of SEP according to ice cores [McCracken et al., 2001]
- Largest ring current development [Tsurutani et al. 2003]
- Aurora Observed in the Tropics

White Light Flare Observation
Solar Proton Events

1859 Event

High-Fluence Proton Events
1855 - 2001

>30 MeV Fluence x 10^9 (pr cm^-2)

Year

1860 1880 1900 1920 1940 1960 1980 2000
Economic Impact of a Severe Space Weather Storm on Power Grid

- Cost to replace transformers
- Cost to economy due to idle workers
- Cost due to disruption of power loss

- >$100-800M/day for a large city
  (Hurricane Katrina impact on New Orleans as an example)
Other large economic events...

San Francisco Earthquake......1906.........$ 500 billion

Hurricane Katrina....................2005...........$ 120 billion

Annual loss from electricity interruptions.......$ 80 billion

North American Power Grid Blackout............$ 30 billion/day
GEO satellite revenue loss....................$ >25 billion

Blackout of East Coast............1965...........$ 10 billion

Mt Lassen Volcanic Eruption...1915...........$ 5 billion

Quebec Blackout....................1989...........$ 2 billion
Latest NASA prediction/observation (odds of Carrington storm about 3% in 2012/2013)
What is Space Weather?

• The energy transfer from Sun to Earth via electromagnetic and particle radiation and a magnetized plasma (solar wind)

• It study has a long history coupled with our understanding of physics and astronomy
  – Google “Moldwin’s Timeline”

• Impacts wide-range of technology from space exploration to modern communication

• Aurora are the signature of energy flow from Sun into the Earth’s space environment

• We must understand to fully utilize space technology and for the future of space exploration
Space weather is an emerging field of space science focused on understanding societal and technological impacts of the solar–terrestrial relationship. The Sun, which has tremendous influence on Earth's space environment, releases vast amounts of energy in the form of electromagnetic and particle radiation that can damage or destroy satellite, navigation, communication, and power distribution systems. This textbook introduces the relationship between the Sun and Earth, and shows how it impacts our technological society.

This is the first undergraduate textbook on space weather aimed at non-science majors, it uses the practical aspects of space weather to introduce space physics and give students an understanding of the Sun–Earth relationship. Definitions of important terms are given throughout the text. Key concepts, supplements, and review questions are given at the end of each chapter to help students understand the materials covered. This textbook is ideal for introductory space physics courses.

Each chapter concludes with:
- a list of key concepts
- supplements exploring the underlying physical principles
- review questions to test readers' understanding

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Mark Moldwin

AN INTRODUCTION TO SPACE WEATHER

Cover illustration (front): an artist's conception showing the Earth inside the atmosphere of our Sun. Space Weather is the emerging field of space science that studies how the dynamic Sun influences the space environment of Earth. Modern society's growing reliance on global communication and satellite technology increases our susceptibility to space weather impacts. (Courtesy NASA/ GSFC/Helophysics Division)

Back: an artist's rendering of the Earth's Van Allen radiation belts. Several future satellite missions will fly multiple spacecraft through this region in order to understand radiation belt structure and dynamics. (Courtesy NASA/Johns Hopkins University Applied Physics Laboratory)
Gilbert and Geomagnetism
Galileo’s Observations
Understanding of Space Weather from 1600 to mid-19th Century

• Earth has a magnetic field and occasionally the field wiggles
• The Sun has sunspots that wax and wane over a 11 year cycle
• Aurora Borealis are curtains of light aligned along the magnetic field, are associated with magnetic wiggles, and occurrence at lower latitudes follow 11-year sunspot cycle
History of Space Weather

September 1, 1859 - Carrington observed a “solar flare” and two days later Magnetic disturbances in London.
“One swallow does not make a summer.”

November 30, 1892 - Royal Society Presidential Address
“It seems as if we may also be forced to conclude that the supposed connexion* between magnetic storms and sunspots is unreal, and that the seeming agreement between periods has been a mere coincidence.” Lord Kelvin (*”old” British spelling)

November, 1905 - Monthly Notices of the Royal Astronomical Society
“The origin of our magnetic disturbances lies in the Sun”
Prof. Maunder

Outstanding Question: What from the Sun Causes Magnetic Storms?