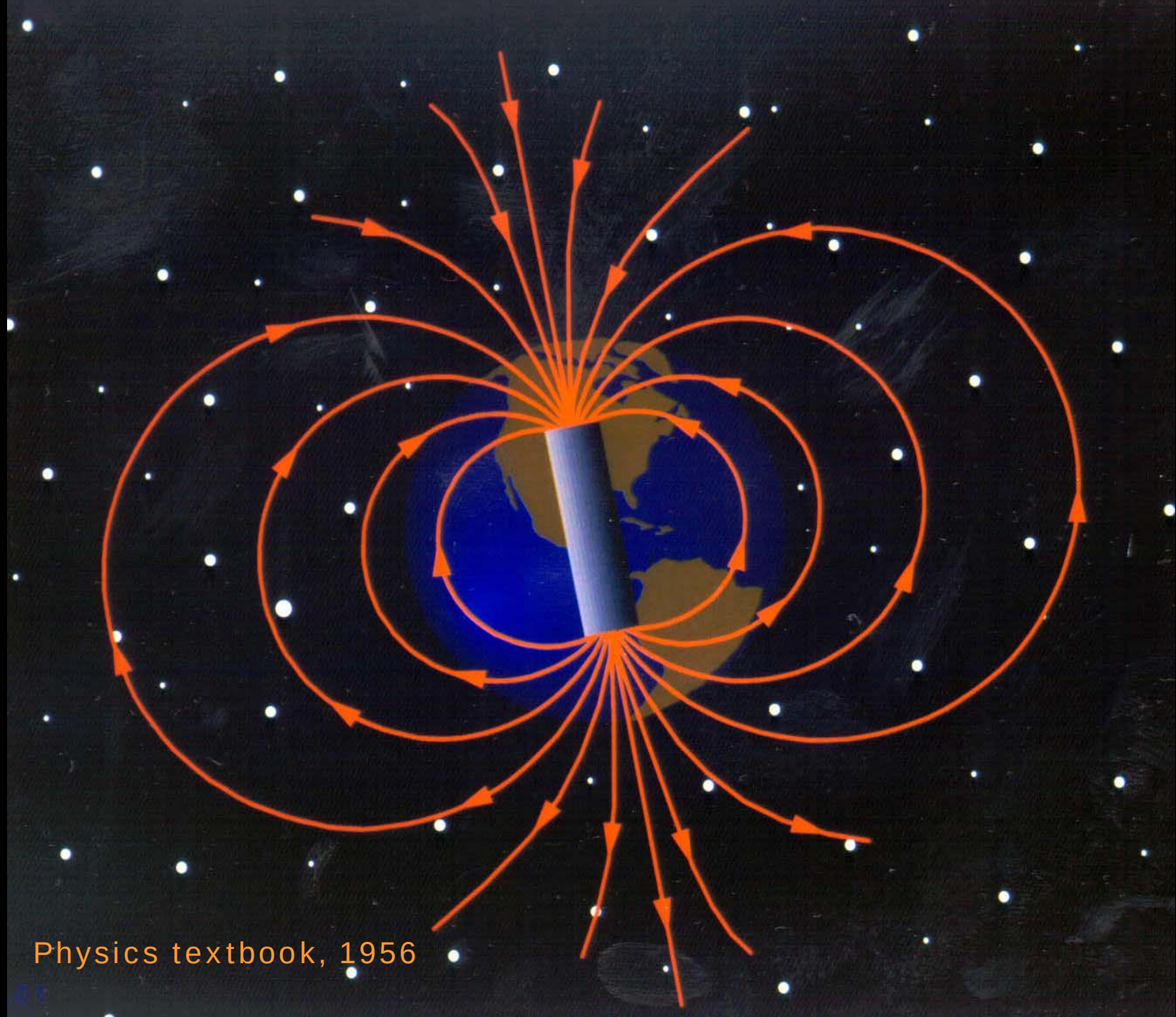
Scientifc Committee on Antarctic Research

Space Weather

Louis J. Lanzerotti

SCAR Lecture, XXXI Antarctic Treaty Consultative Meeting, Kyiv, June 2008


Physics textbook, 1956

Italy Blames Disruption of Comsat NATO Uses on Strong Solar Activity

PETER B. de SELDING, PARIS

The Italian Defense Ministry lost control of its Sicral-1 military telecom

cause we really didn't know what was going on."

In response to *Space News* questions, the Italian joint de-

software modernization on the satellite, which is at the halfway point in its scheduled operating life."

***Space News*, January 15, 2007**

MONDAY, JULY 17, 2000

e Hamilton Spectat

Established 1846

P-ANIK!

High-tech chaos as satellites spin out of control

Plug pulled on phones, TV, radio, papers

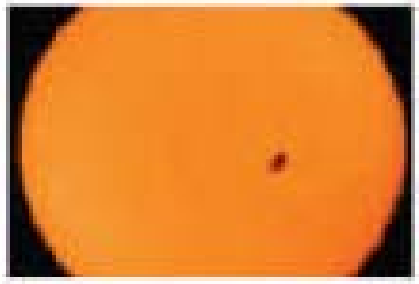
OTTAWA — Telesat Canada was facing some tough questions today as it tries to explain how its two main communication satellites tumbled out of control, interrupting TV, radio, newspaper and telephone signals across the country.

After struggling for more than eight hours to bring the wobbly Anik E-1 under control, Telesat technicians thought they had the problem licked late yesterday.

The were only half right.

Shortly after 9 p.m. EST, as Anik E-1 settled back into position, Telesat's primary broadcasting satellite, Anik E-2, also got a bad case of the shakes.

CBC Newsworld and other national specialty cable channels, including MuchMusic, TSN, Vision and the Weather Channel, were knocked off the air. Partial service, with signals carried by fibre-optic



Space Station Glitch Possibly Caused by Solar Flare

By Tariq Malik

Staff Writer

posted: 15 December 2006

11:49 am ET

Updated at 2:40 p.m. EST

Solar storm ends up just a nuisance

REUTERS

WASHINGTON — A severe geomagnetic storm that hit Earth over the weekend interfered with data from at least one U.S. weather satellite and some power systems, government scientists said yesterday.

Solar Storms Cut Airplane Radio Contact

By Tom Cohen

Associated Press

posted: 04:00 am ET

30 October 2003

A4 Daily Record, Morris County, N.J., Thursday, September 8, 2005

Solar flare may disrupt communications

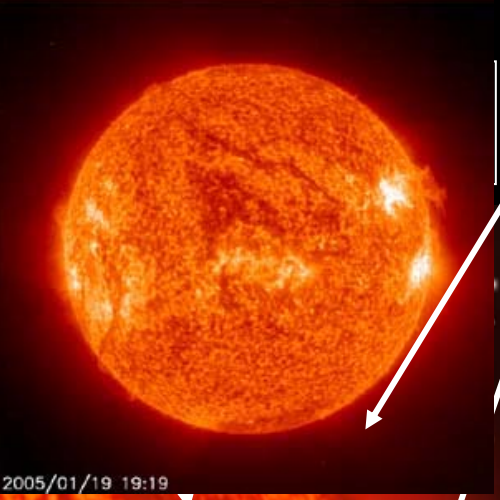
WASHINGTON (AP) — A large solar flare was reported Wednesday and forecasters warned of potential electrical and communications disruptions.

The flare was reported by

THE NEW YORK TIMES, WEDNESDAY, MARCH 8, 1989

Largest Solar Flaring in 5 Years Could Break Up Communications

By WILLIAM K. STEVENS



Solar corona: >1,000,000K

Solar coronal mass ejections

Earth's magnetosphere

k wave

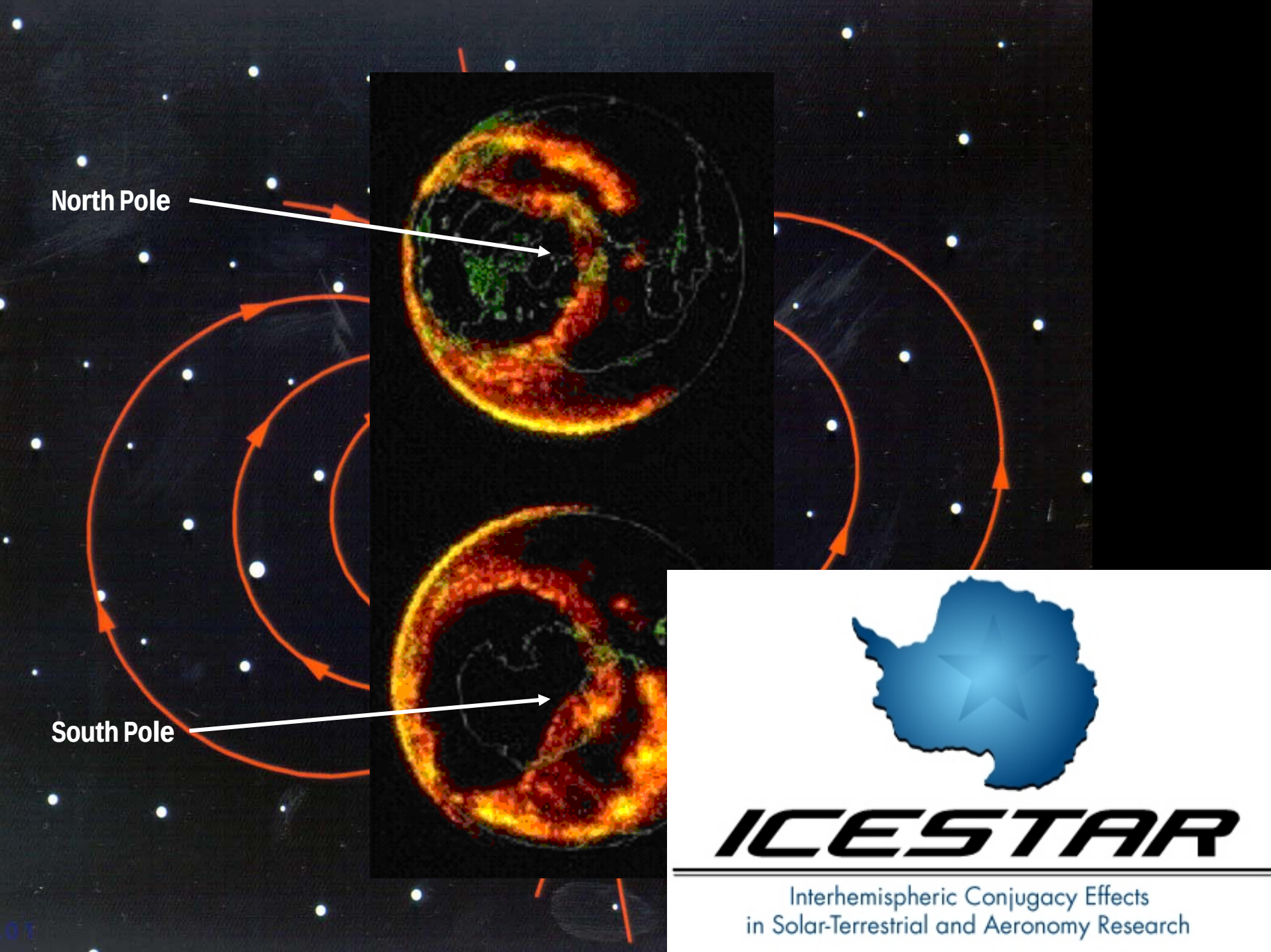
MONDAY, JULY 17, 2000

Solar storm ends up just a nuisance

REUTERS

WASHINGTON — A severe geomagnetic storm that hit Earth over the weekend interfered with data from at least one U.S. weather satellite and some power systems, government scientists said yesterday.

Solar active regions



ICESTAR

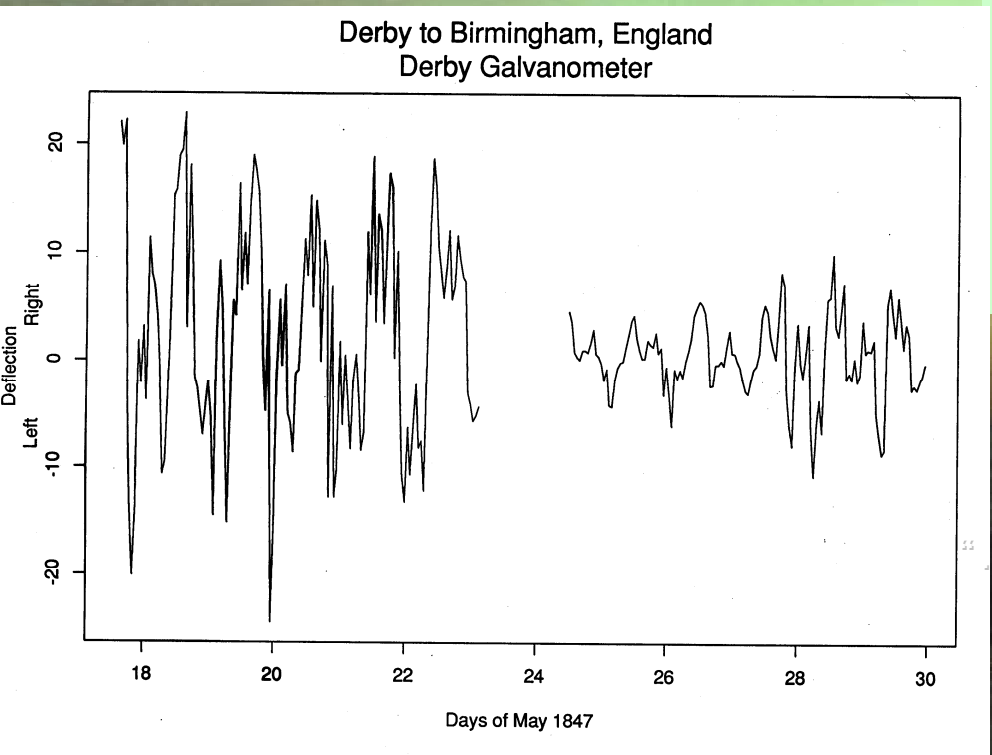
Interhemispheric Conjugacy Effects
in Solar-Terrestrial and Aeronomy Research

Space Weather --

An historical perspective

TELEGRAPH in 1840's

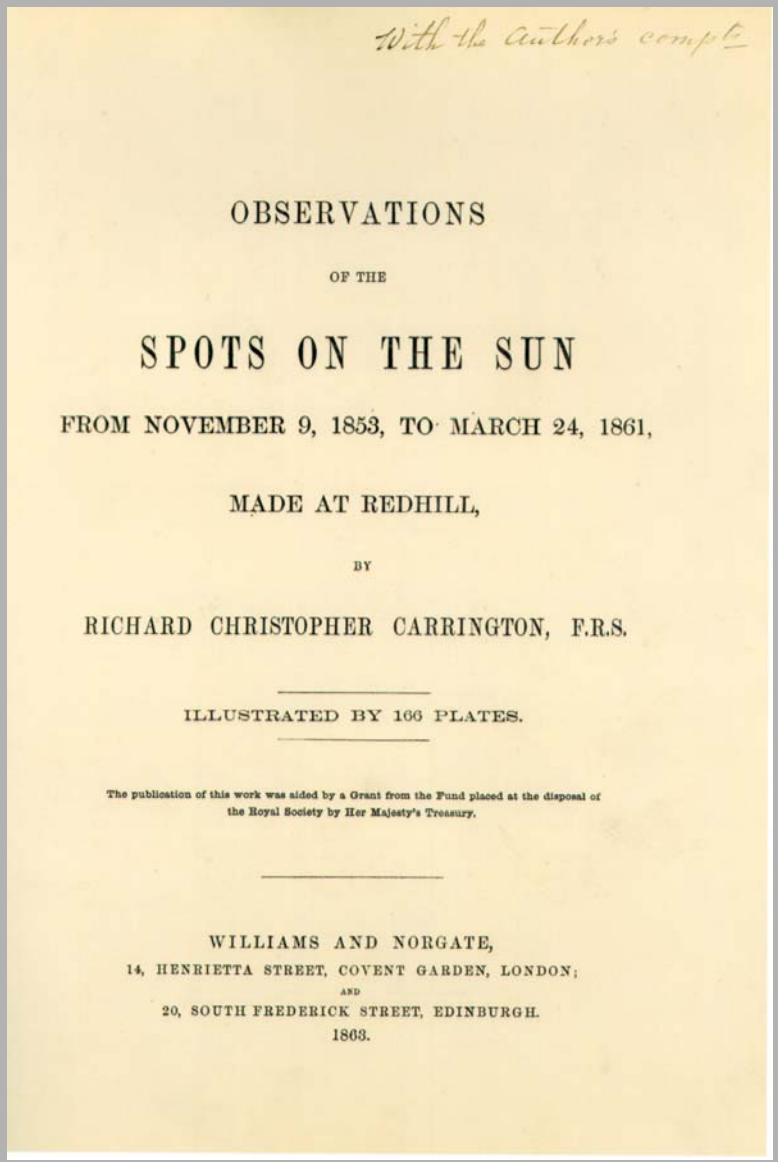
W. H. Barlow, "On spontaneous electrical currents observed in the wires of the electric telegraph", *Phil. Trans. R. Soc.*, 61, 1849:



"The observations described ... were undertaken in consequence of certain *spontaneous deflections* having been noticed in the needles of the electric telegraph on the Midland Railway, the erection of which was carried out under my superintendence as the Company's engineer."

.. in every case which has come under my observation, the telegraph needles have been deflected whenever aurora has been visible"

Discovery of a Solar Flare



With the Author's compts

OBSERVATIONS

OF THE

SPOTS ON THE SUN

FROM NOVEMBER 9, 1853, TO MARCH 24, 1861,

MADE AT REDHILL,

BY

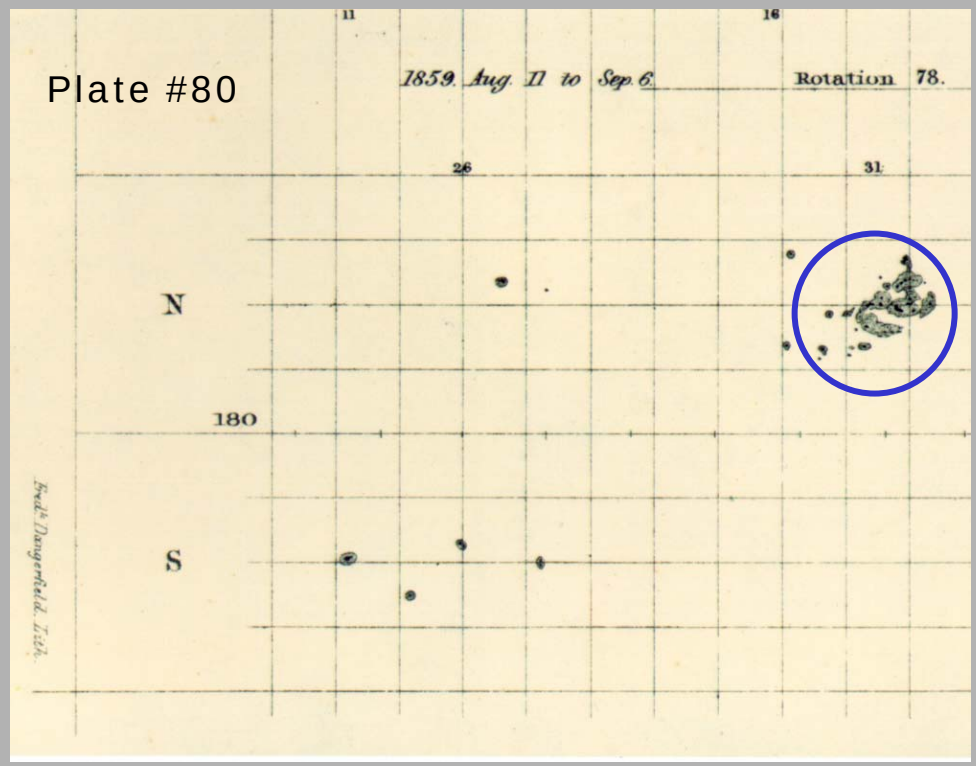
RICHARD CHRISTOPHER CARRINGTON, F.R.S.

ILLUSTRATED BY 166 PLATES.

The publication of this work was aided by a Grant from the Fund placed at the disposal of the Royal Society by Her Majesty's Treasury.

WILLIAMS AND NORGATE,
14, HENRIETTA STREET, COVENT GARDEN, LONDON;
AND
20, SOUTH FREDERICK STREET, EDINBURGH.
1863.

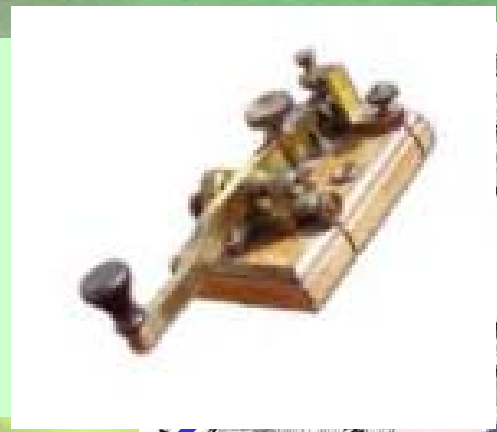
"The observation of this very splendid group on September 1st [1859] has had some notoriety. ... I ... witnessed a singular outbreak of light which lasted about 5 minutes, and moved sensibly over the contour of the spot ...."

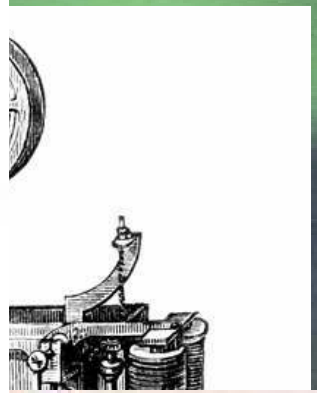


MAGNETIC STORM:

AUGUST 28 to SEPTEMBER 4, 1859

Arching and sparking of telegraph keys and armatures were reported from a wide range of stations, including “eastern U.S., England, Scandinavia, Belgium, France, Switzerland, Prussia, Wurtemburg, Austria, Tuscany, ...”





In Christiania, Norway: “... sparks and
u re
ti es
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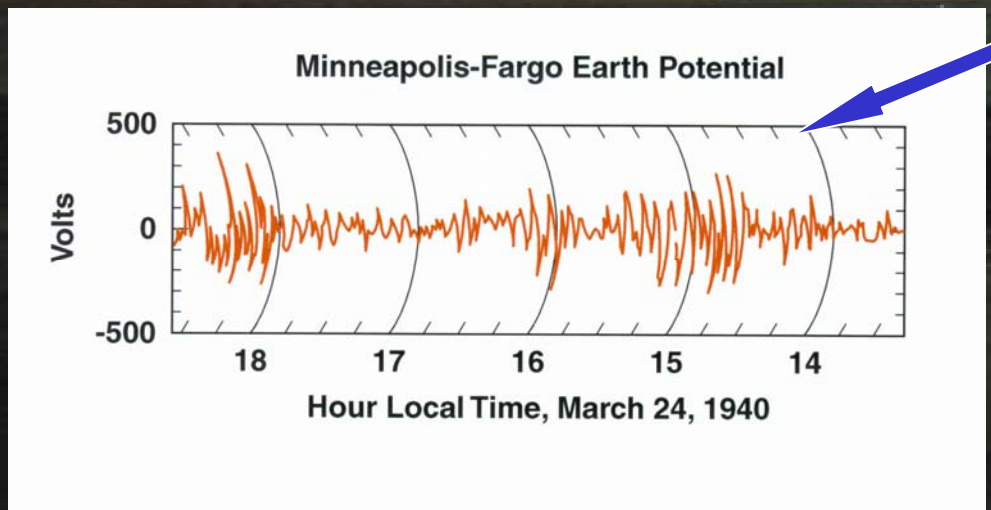
3

F ort September 2d,
1 ied batteries] for
a aurora having subsided, the batteries
w ott, *Am. J. Sci. Arts*, 29, 92, 1860

MAGNETIC STORM:

March 24, 1940

- Numerous Problems (Transformer Tripping; Reactive Power Surges) on Other Systems; e.g.:
  Philadelphia Electric; Public Service NJ; Central Maine; Northern States Power (MN); Eastern MA Electric
- Transformer Tripping, Ontario Hydro Electric Commission
  4 Transformer Banks, Chats Falls, Niagara District (220kV
  6 Transformer Banks, Abatibi System (132 kV)
- Widespread effects on Radio-wave Communications Systems

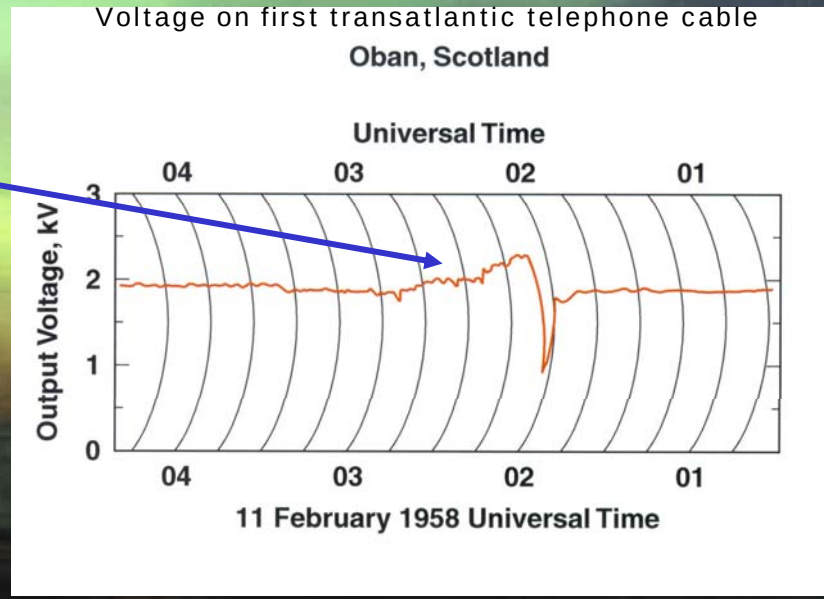


MAGNETIC STORM:

February 10, 1958

"At almost the exact moment when the magnetograph traces leaped and the aurora flared up, huge currents in the earth, induced by the heavenly turbulence, manifested themselves not only in power lines in Canada but in *cables under the north Atlantic*."*

"... Circuit breakers began tripping out in Ontario transformer stations, plunging the Toronto area into a temporary darkness broken only by the strange light of the aurora overhead"*

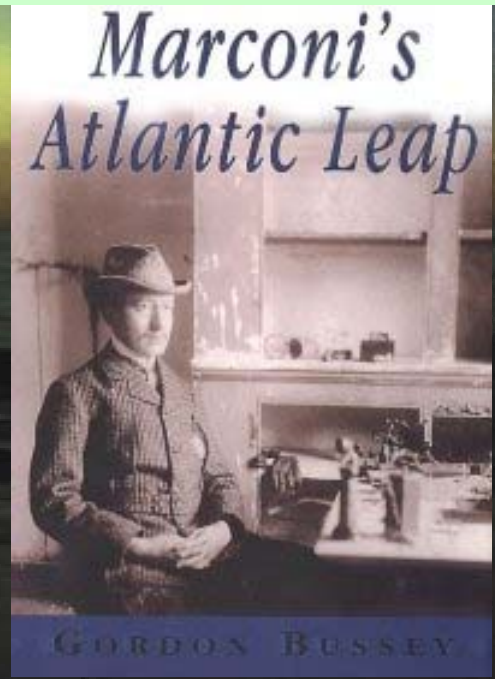


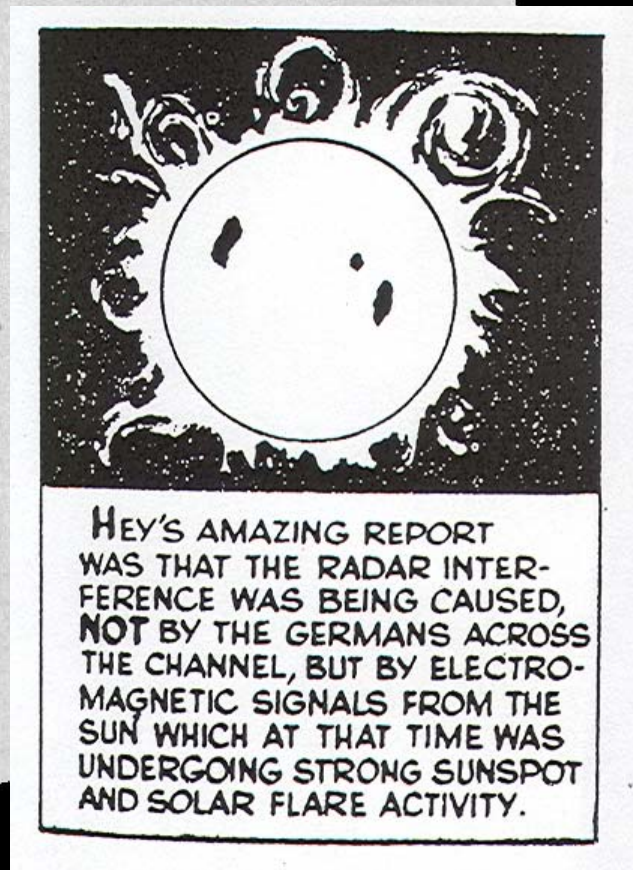
*John Brooks, "A Reporter at Large; The Subtle Storm," *New Yorker*, February 19, 1959

EARLY WIRELESS COMMUNICATIONS

"... times of bad fading practically always coincide with the appearance of large sun-spots and intense aurora-boreali usually accompanied by magnetic storms ...." These are "... the same periods when cables and land lines experience difficulties or are thrown out of action." (G. Marconi, *Radio Communications*, 1928).

Marconi and assistants launching kite-supported aerial, Signal Hill, St. John's, Newfoundland, December 1901. To receive signal from Poldhu, Cornwall






Space Weather --
Contemporary

Utility system effects of space plasmas

IEEE spectrum MARCH 1968

THE NEW YORK TIMES, WEDNESDAY, MARCH 8, 1989

Largest Solar Flaring in 5 Years Could Break Up Communications

By WILLIAM K. STEVENS

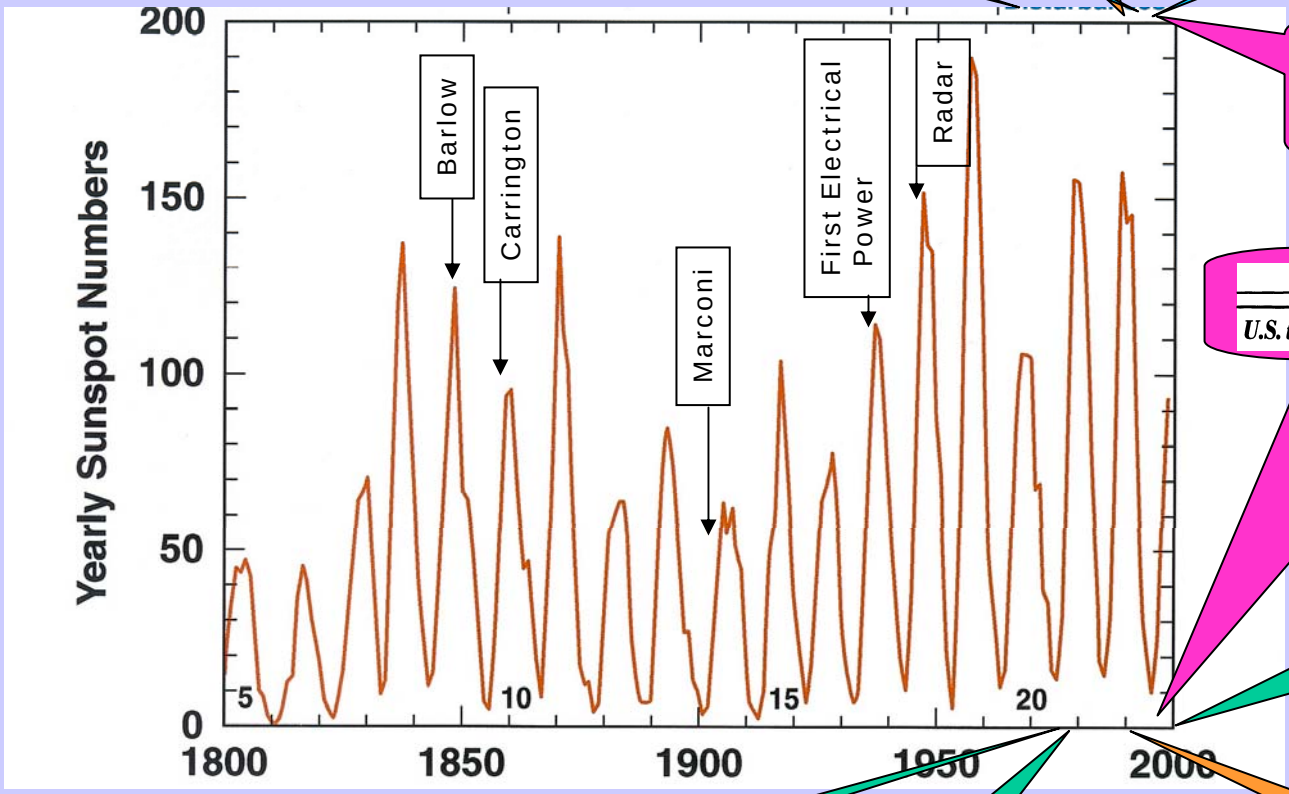
IN BRIEF

Blackout darkens Quebec

MONTREAL — A massive power outage yesterday left more than 3 million people in Quebec without heat and light, crippling Montreal's underground

P-ANIK!

High-tech chaos as satellites spin out of control



AS Daily Record, Morris County, N.J., Sunday, March 7, 1999

Solar storms could disrupt everything under the sun

INTERNATIONAL HERALD TRIBUNE, TUESDAY, MARCH 27, 1990 Page 3

U.S. to Warn Pregnant Women on Airline Radiation Risk

NASA Says Solar Flare Caused Radio Blackouts

WASHINGTON, July 13 (AP) — A strong solar flare early Wednesday

28 NYT, 7/11/76

Scientist Says C.B. Radios Face Sunspot Interference in 1978

Sun Spots Playing Tricks With Radios

Police, Fire Frequencies Cluttered With Messages From Far Off

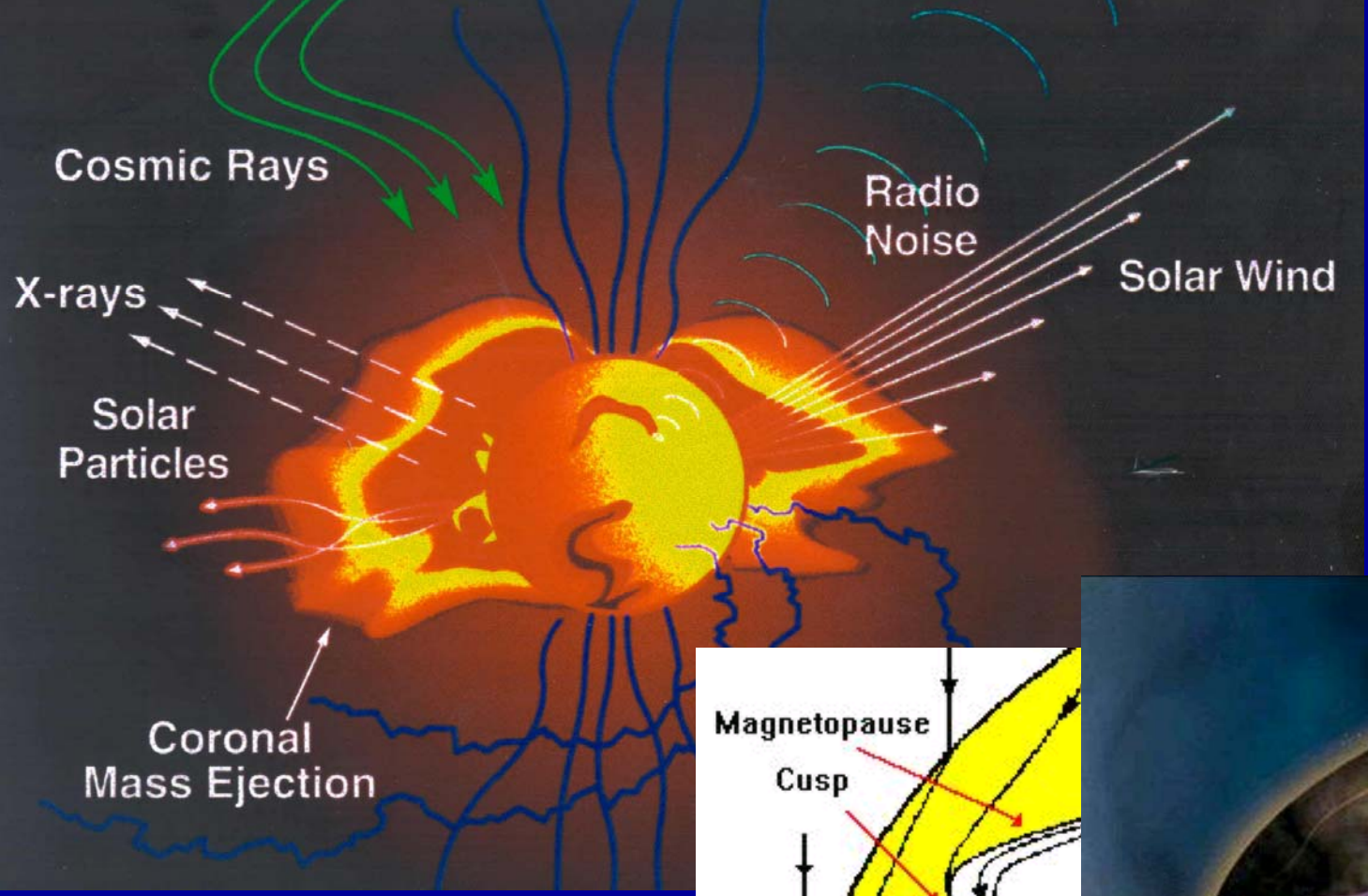
BY STEVE HIMMONS

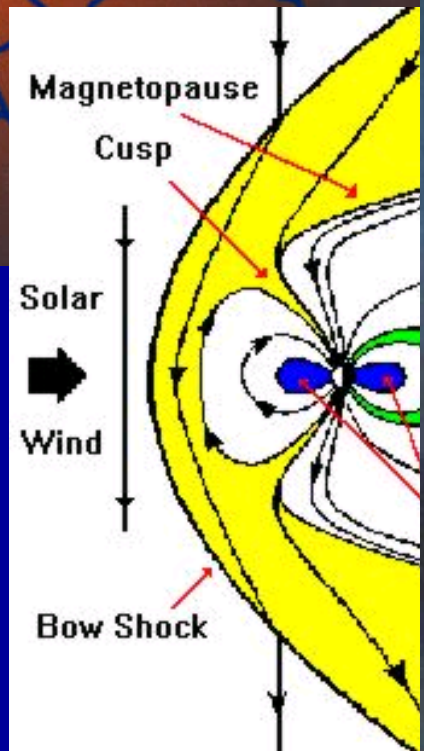
seated in Orange, Calif., while the crash had occurred in Bridgeport, W

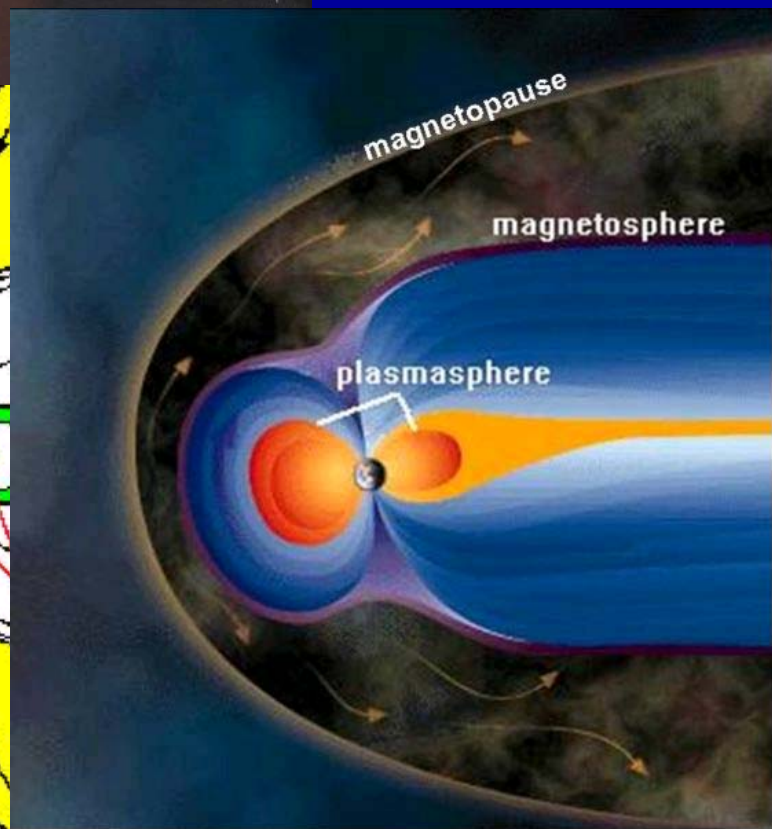
Star-Ledger FINAL EDITION

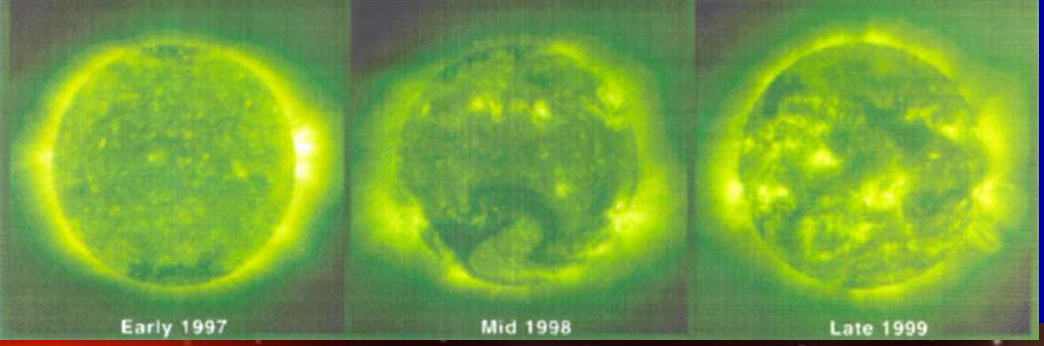
Newark, N.J. Monday, April 9, 1990 Price: 15 cents

Sunspots threatening utilities with blackouts

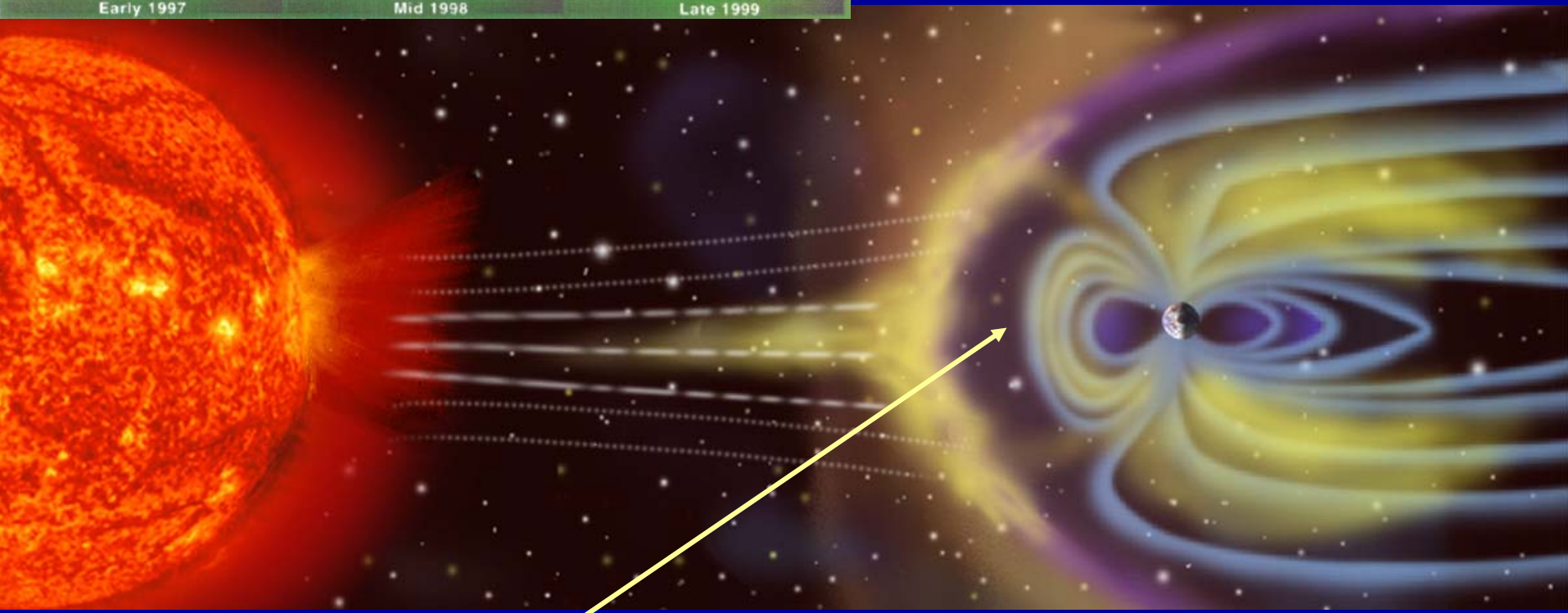

Cosmic Rays
Radio
Noise
Solar Wind
X-rays
Solar
Particles
Coronal
Mass Ejection


Magnetopause
Cusp
Solar
Wind
Bow Shock


magnetopause
magnetosphere
plasmasphere



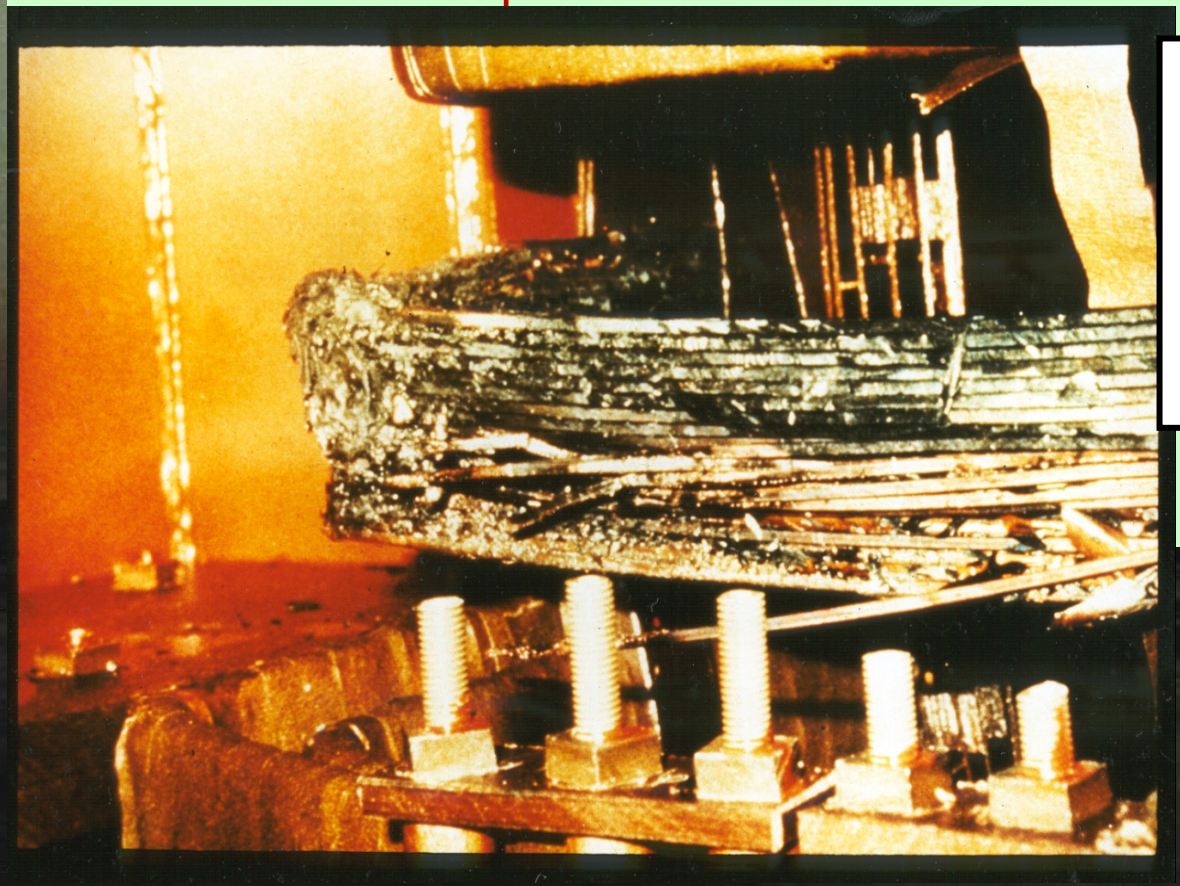
The Sun in ultra violet, solar minimum to near solar maximum (left to right)



Solar wind at Earth: about 10 particles per cubic cm
average velocity about 400km/sec
imbedded magnetic field about 0.0003 Earth's field at surface

Weather in space: Effects on technologies

- IONOSPHERE VARIATIONS
  - Induction of electrical currents in the Earth
    - Power distribution systems
    - Long communication cables: land and sea
    - Pipelines

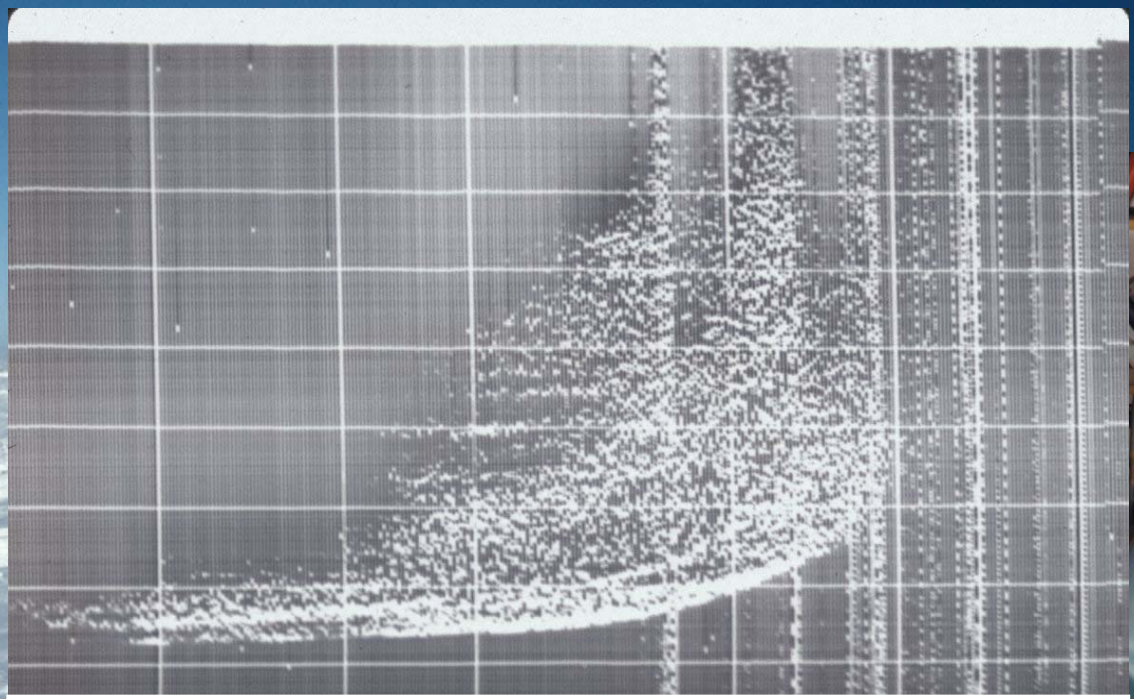


Blown electrical distribution transformer in New Jersey (March 1989 superstorm that caused failure of Quebec power grid in 90 seconds)

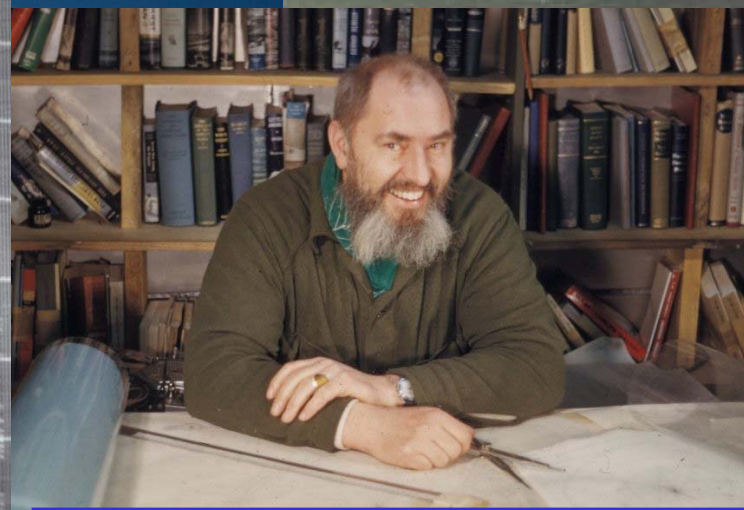
Weather in space: Effects on technologies

- IONOSPHERE VARIATIONS
  - Wireless signal reflection, propagation, attenuation
  - Satellite signals, communications, GPS, etc.: interference, scintillation

Amundsen-Scott IGY South-Pole Station 12 February 1957
(All pictures courtesy of Dr. Robert Benson, IGY South Pole winter over)



IGY South Pole Ionogram: communications research



Dr. Paul Siple
Amundsen-Scott IGY South-Pole Station Leader

Weather in space: Effects on technologies

- IONOSPHERE VARIATIONS

Automatic
Instruments
Using solar a

Automatic Geophysical Observatory
Serviced by LC130 (shown) and Twin Otter aircraft

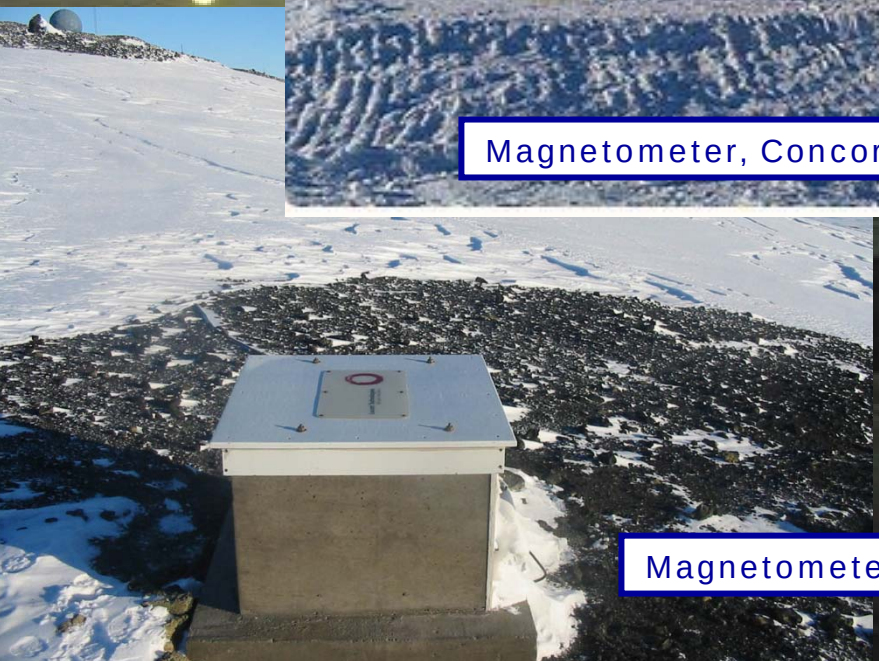
Weather in space: Effects on technologies

- IONOSPHERE VARIATIONS

Magnetometer, Concordia

Magnetometer, Mario Zuchelli

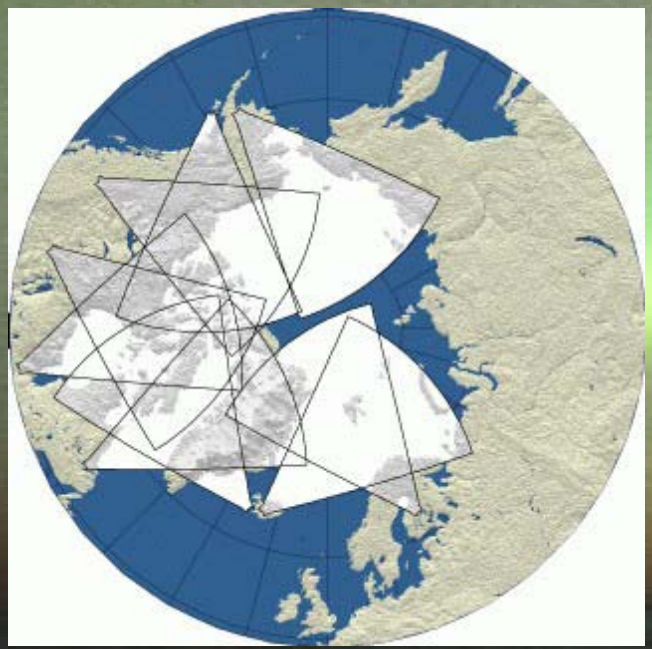
Magnetometer site, 150 km from Davis

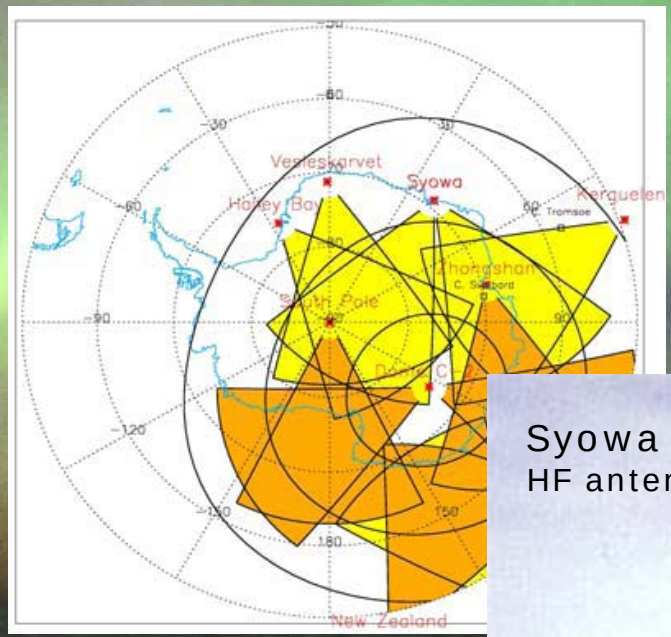


Magnetometer, Arrival Heights

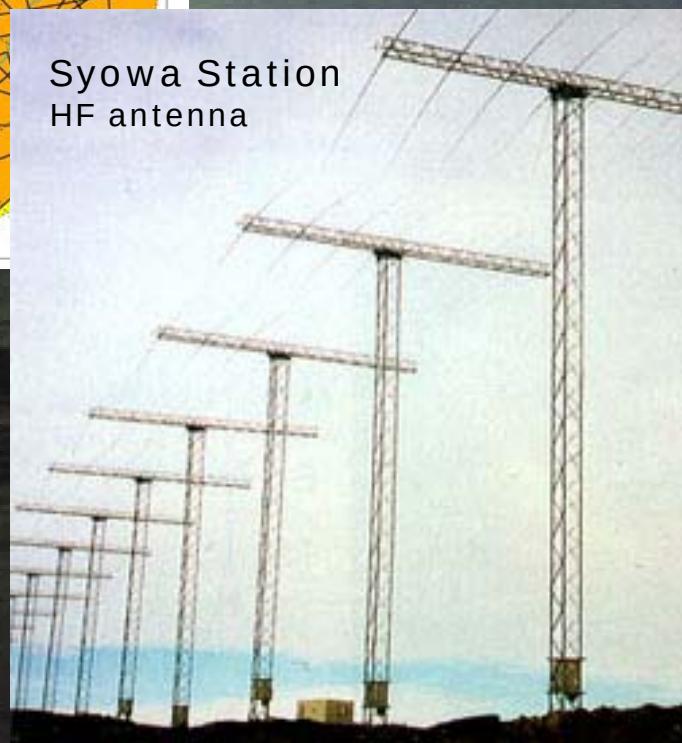
Weather in space: Effects on technologies

- IONOSPHERE VARIATIONS





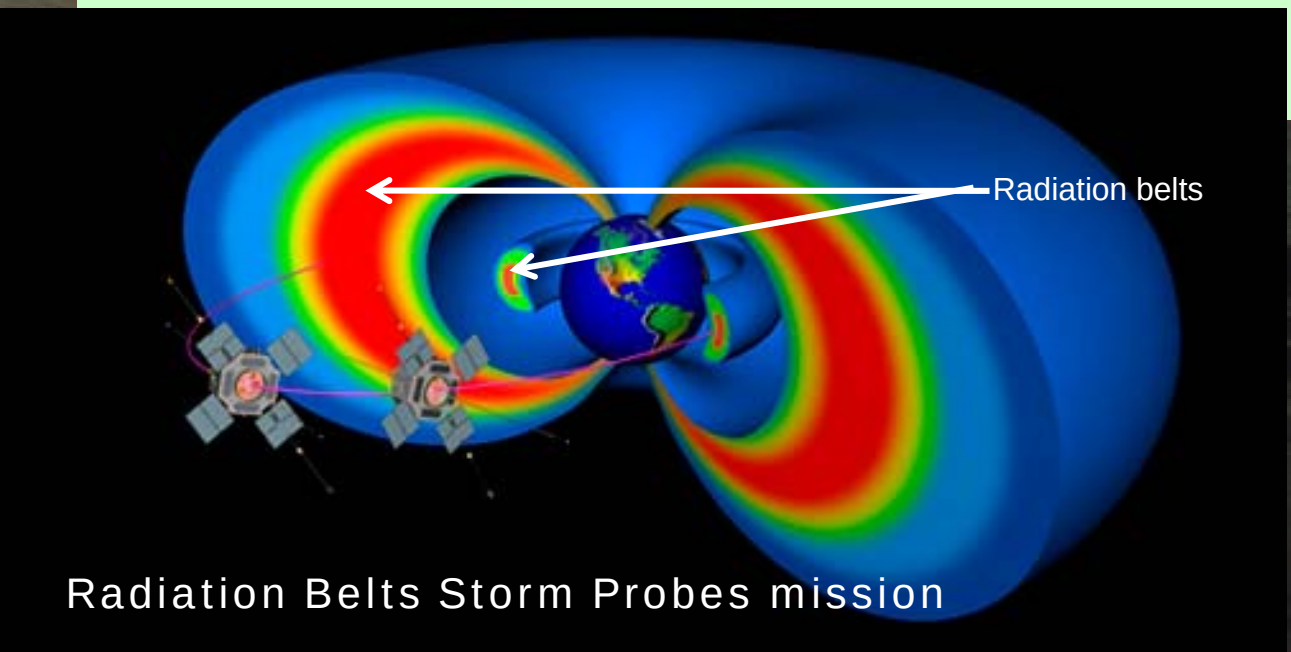
ICESTAR
Interhemispheric Conjugacy Effects
in Solar-Terrestrial and Aeronomy Research



Maps of the Super Dual Auroral Radar Network (SuperDARN) arrays over the Northern (left) and Southern (right) polar regions. The Antarctic map shows fields-of-view for existing and planned radars, which will provide complete coverage of the southern polar region above 60 *degrees* geomagnetic latitude.

Weather in space: Effects on technologies

- SPACE RADIATION
  - Spacecraft solar cell damage
  - Semiconductor device damage and failure
  - Faulty operation of semiconductor devices, space and ground
  - Spacecraft charging: surface and interior materials
  - Astronaut safety
  - Airline passenger safety



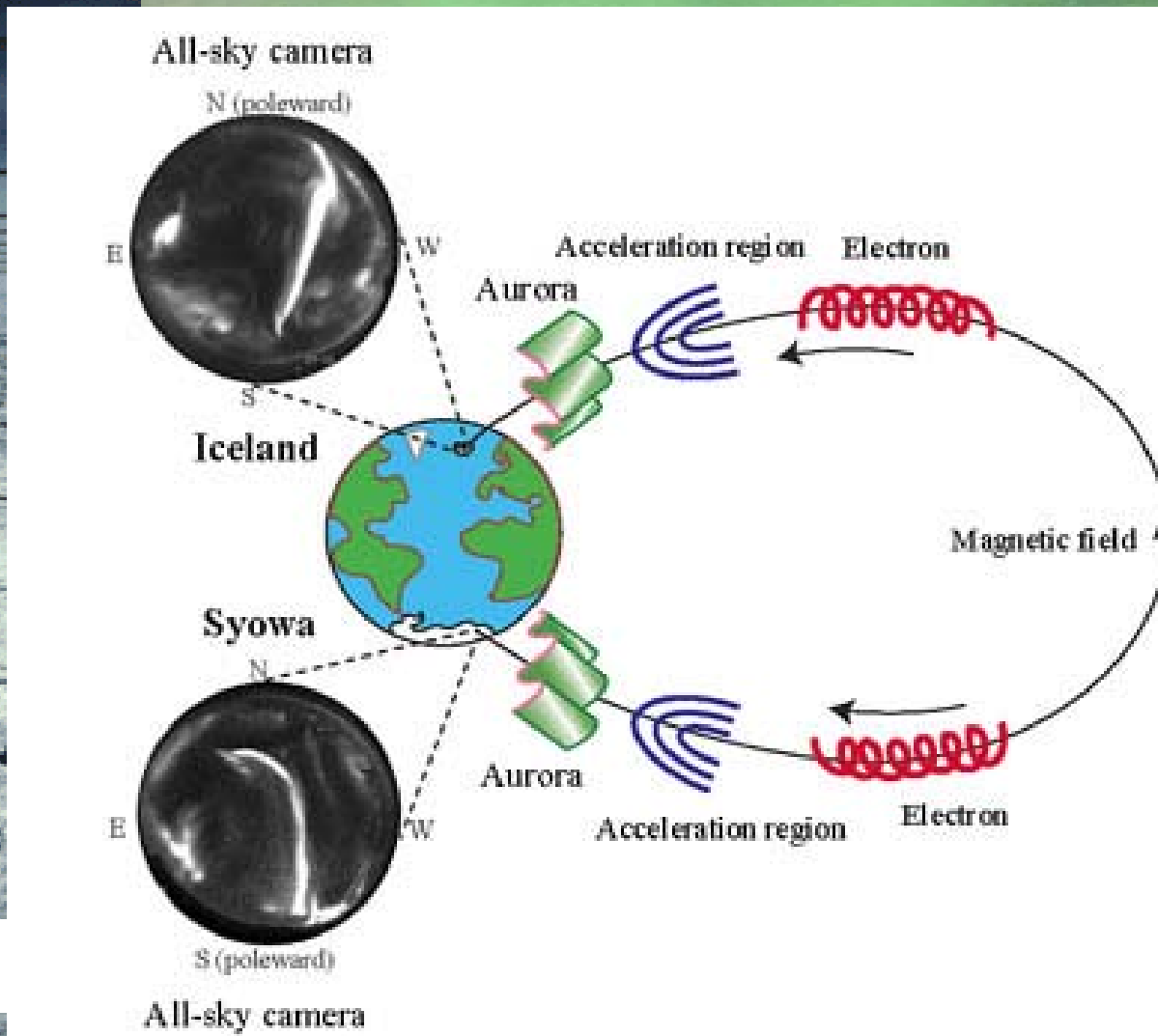
Radiation Belts Storm Probes mission

Weather in space: Effects on technologies

- SPACE RADIATION

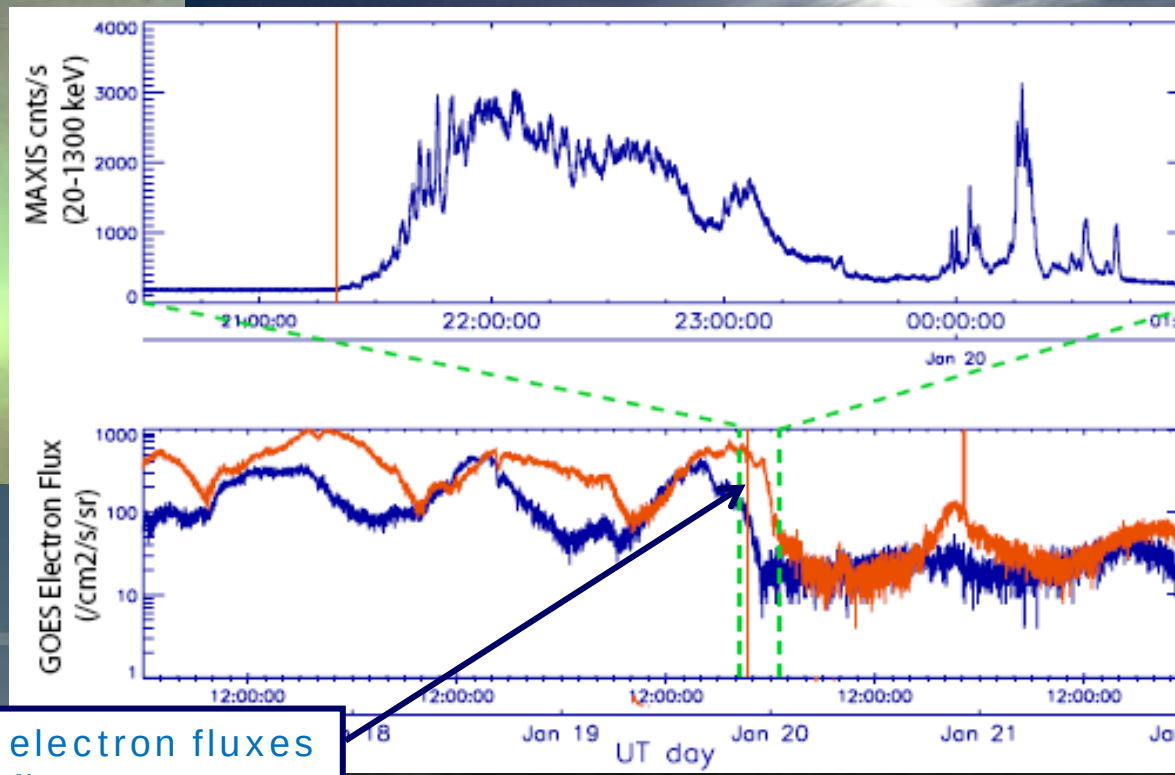
Imaging Riometer in the Antarctic

Measuring loss of radiation belt particles



Weather in space: Effects on technologies

- SPACE RADIATION



Large decrease in geosynchronous electron fluxes at time of large increase of balloon fluxes: Measuring loss of Van Allen belt electrons

Millan et al., 2007

Inflation of MINIS balloon: SANAE IV January 2005

Weather in space: Effects on technologies

SPACE RADIATION

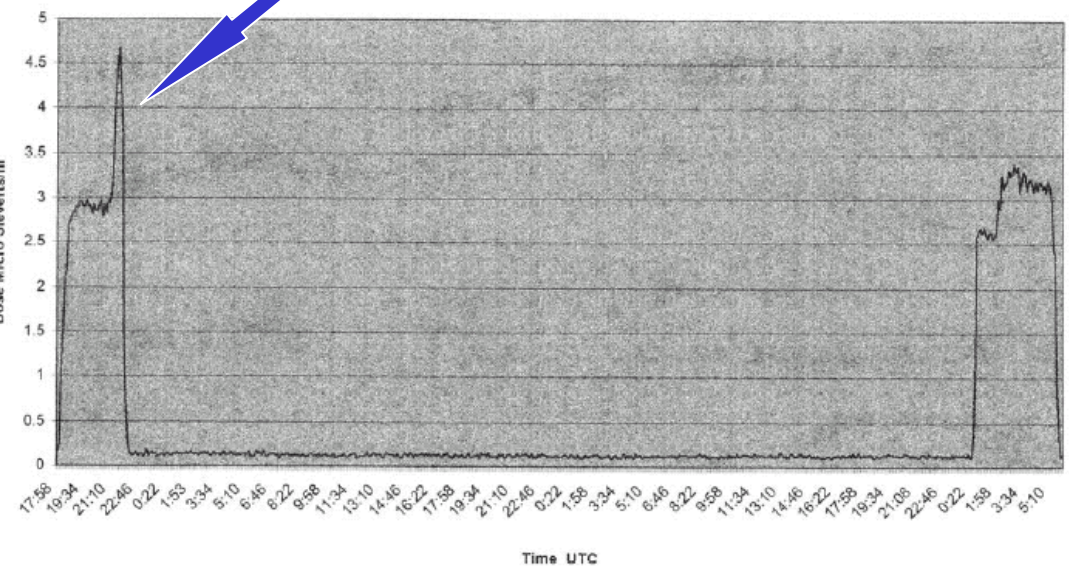
- Astronaut safety
- Airline passenger safety

SPACE WEATHER, VOL. 2, S05002, doi:10.1029/2003SW000058, 2004

Observation of solar particle event on board a commercial flight from Los Angeles to New York on 29 October 2003

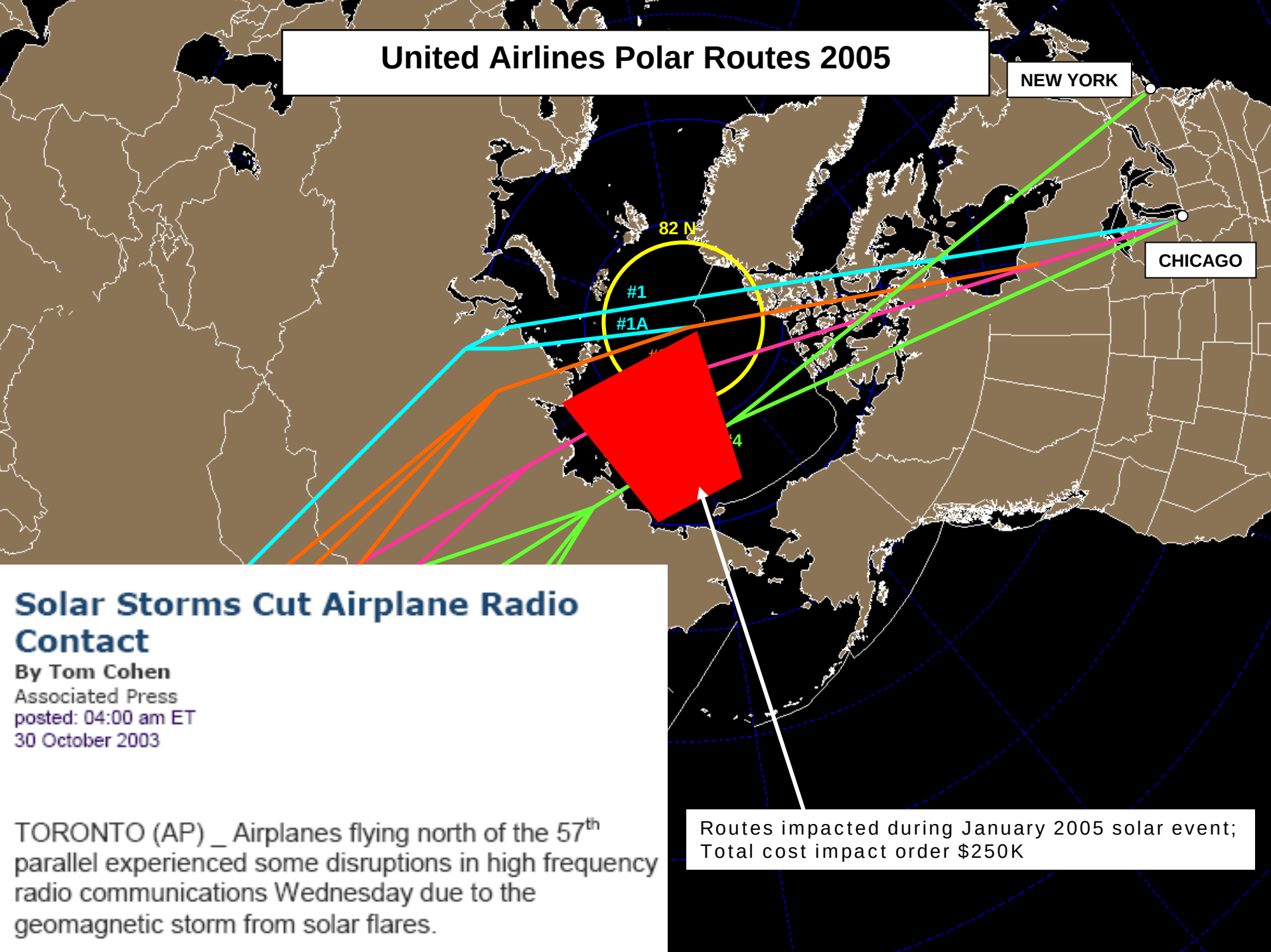
Ian J. Getley
Department of Aviation, University of New South Wales, Sydney, Australia

LAX-JFK 29thOct2003 (37,0[illegible]T, LAST HR 39,000FT) = 12.0 MicroSv. JFK-LAX 1stNov2003(39,000ft most of flt)= 16.0 MicroSv



By MATTHEW L. WALD

United Airlines Polar Routes 2005



Solar Storms Cut Airplane Radio Contact

By Tom Cohen
Associated Press
posted: 04:00 am ET
30 October 2003

TORONTO (AP) _ Airplanes flying north of the 57th parallel experienced some disruptions in high frequency radio communications Wednesday due to the geomagnetic storm from solar flares.

Routes impacted during January 2005 solar event; Total cost impact order $250K

Weather in space: Effects on technologies

- IONOSPHERE VARIATIONS
  - Wireless signal reflection, propagation, attenuation
  - Satellite signals, communications, GPS, etc.: interference, scintillation

Percent U.S. coverage
- Wide Area Augmentation System
Vertical landing approach to 250 ft.

Geomagnetic activity

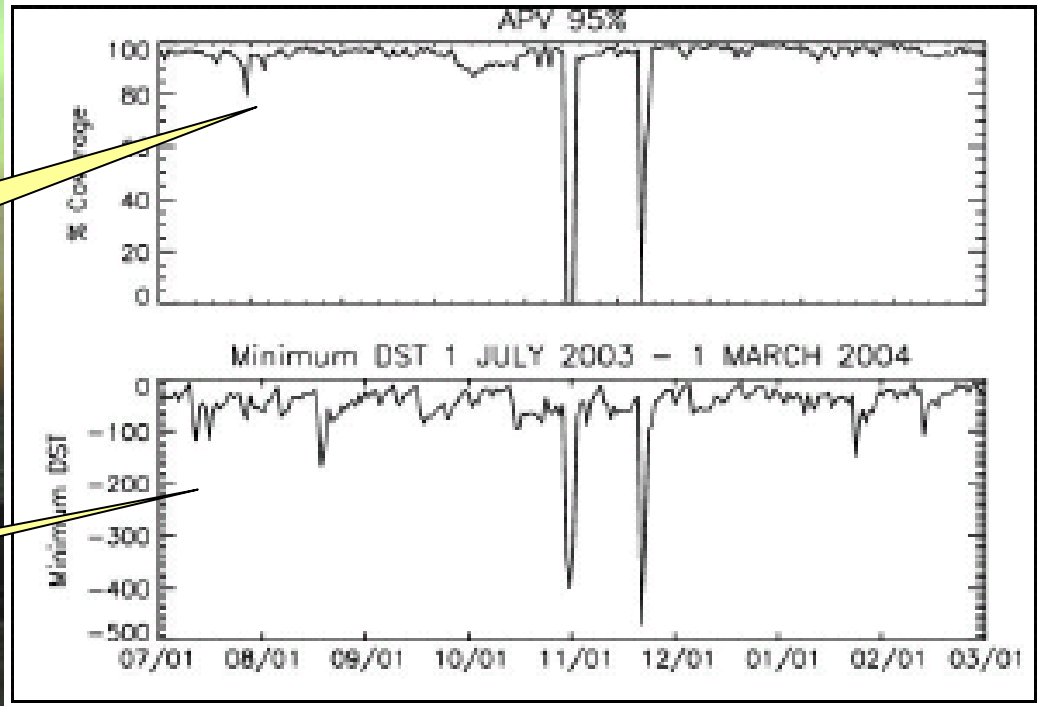
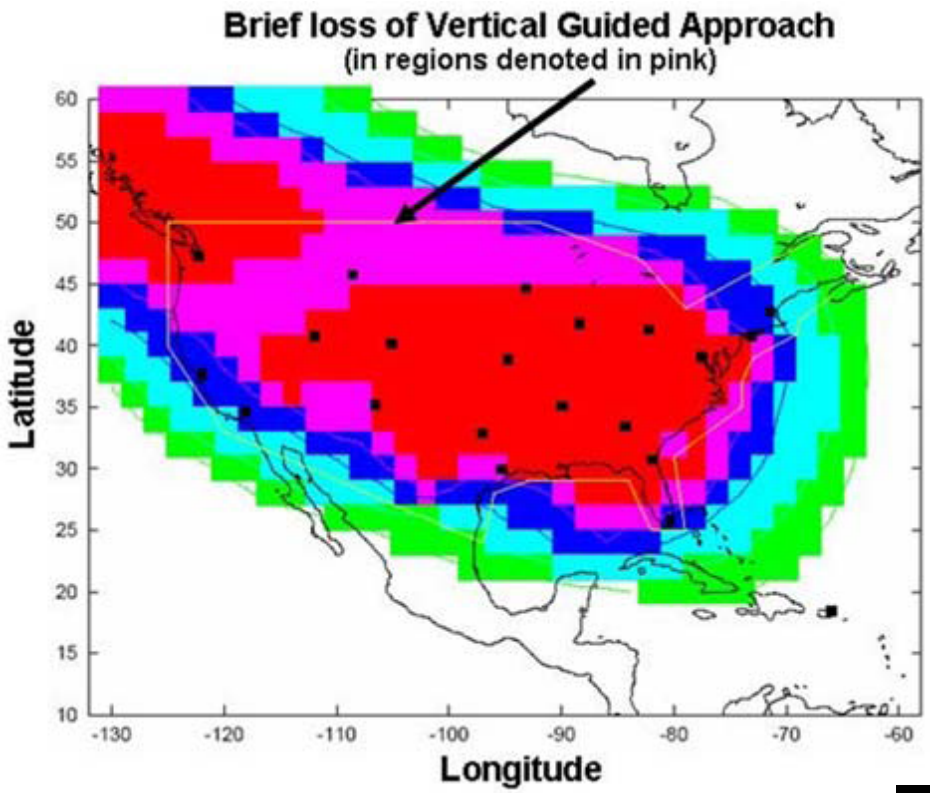


Figure 3-6. WAAS APV response to geomagnetic activity.



The Effect of Intense December 2006 Solar Radio Bursts on GPS Receivers Alessandro P. Cerruti, et al., *Space Weather*, in press. Cornell University

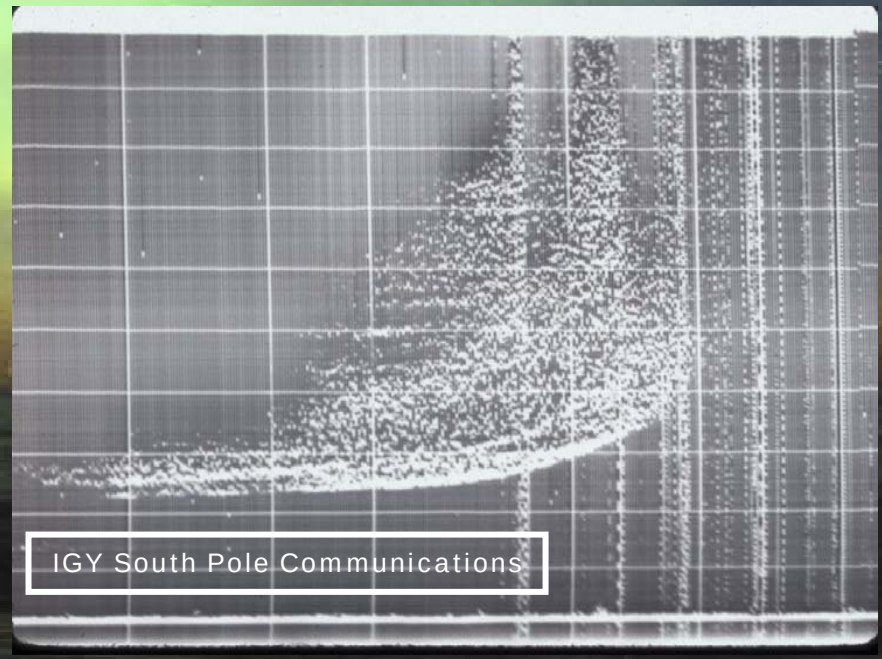
WAAS coverage and availability of the vertical guided approach service on 6 December 2006.

<u>Number of receivers severely impacted by solar radio burst</u>
Yellow: all currently available geodetic quality receivers available through World Wide Web, including from the GPS receivers from the IGS and Continuously Operating Reference System (CORS) networks.
Red: all receivers severely impacted during peak of solar radio burst: 19:30-19:40 UT.

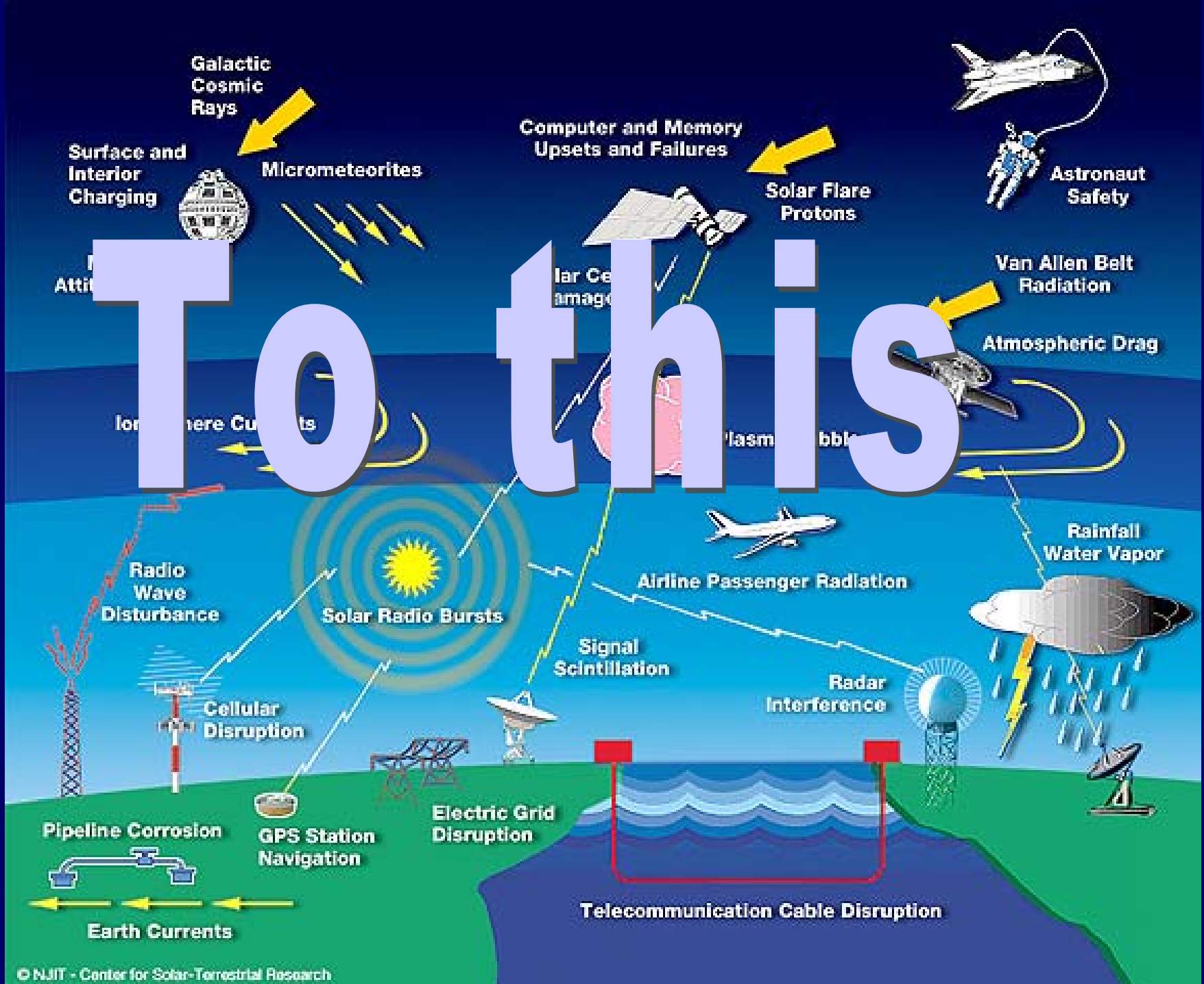
SUMMARY

From this

To this



IGY South Pole Communications


Galactic Cosmic Rays
Surface and Interior Charging
Micrometeorites
Computer and Memory Upsets and Failures
Solar Flare Protons
Astronaut Safety
Van Allen Belt Radiation
Atmospheric Drag
To this
Radio Wave Disturbance
Solar Radio Bursts
Airline Passenger Radiation
Rainfall Water Vapor
Signal Scintillation
Radar Interference
Cellular Disruption
Pipeline Corrosion
GPS Station Navigation
Electric Grid Disruption
Telecommunication Cable Disruption
Earth Currents
© NJIT - Center for Solar-Terrestrial Research

SCAR

ICESTAR

Interhemispheric Conjugacy Effects
in Solar-Terrestrial and Aeronomy Research

SCAR Lecture, XXXI Antarctic Treaty Consultative Meeting, Kyiv, June 2008