The Future of Space Weather Modeling (TBD)

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Outline

What is Space Weather?

Why should we attempt to describe it with physical models?

Recent Accomplishments

The Current Context

Prospects for Future Progress

Some Iconoclastic Recommendations

What is Space Weather?

"Natural processes in space that can affect the near-Earth environment, satellites, and space travel, such as magnetospheric disturbances and solar coronal events."

E.g.:

— Coronal mass ejections and their effects on the magnetosphere

— Variations in solar photon output

— Variations in the near-Earth radiation environment

— Ionospheric disturbances caused by all of the above, and by the internal dynamics of the ionosphere-atmosphere system

— Variations of the upper atmosphere caused by all of the above, and by the internal dynamics of the ionosphere-atmosphere system

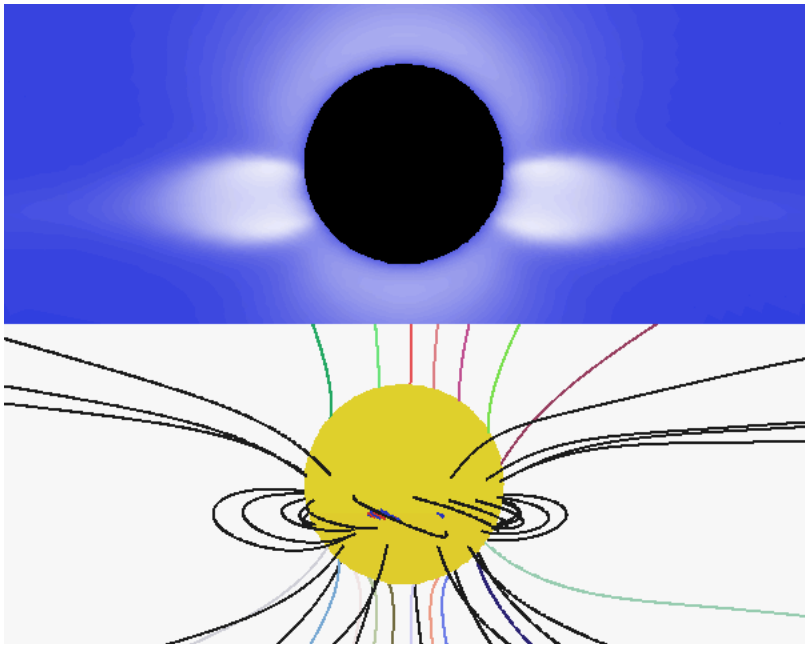
Why should we attempt to describe it with physical models?

— Because prognostic physical description is the traditional test of scientific understanding.

— Because there may be some societal benefit to realistic or probabilistic forecasts of space weather and the space environment.

— Because environmental analysis is a traditional component of exploration.

Recent Accomplishments



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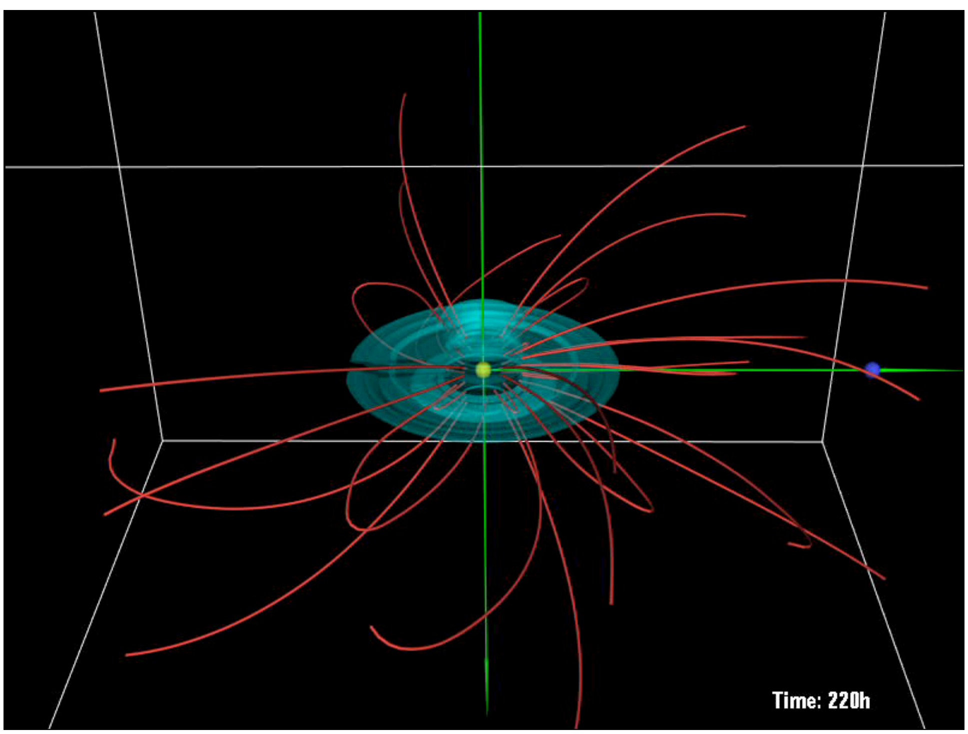

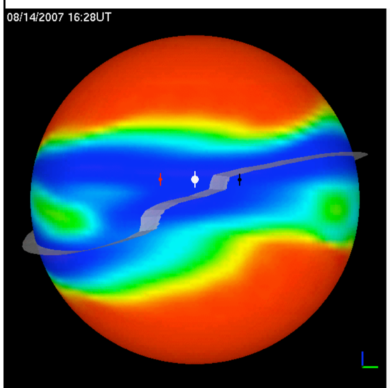
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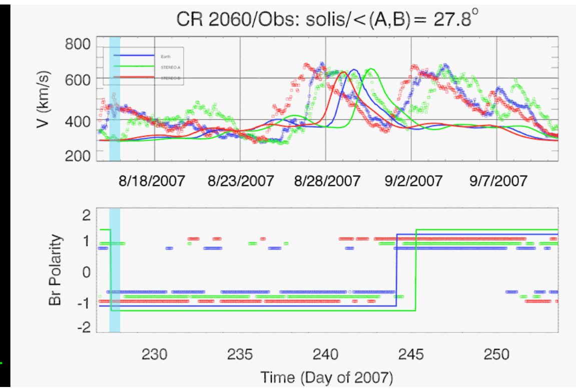
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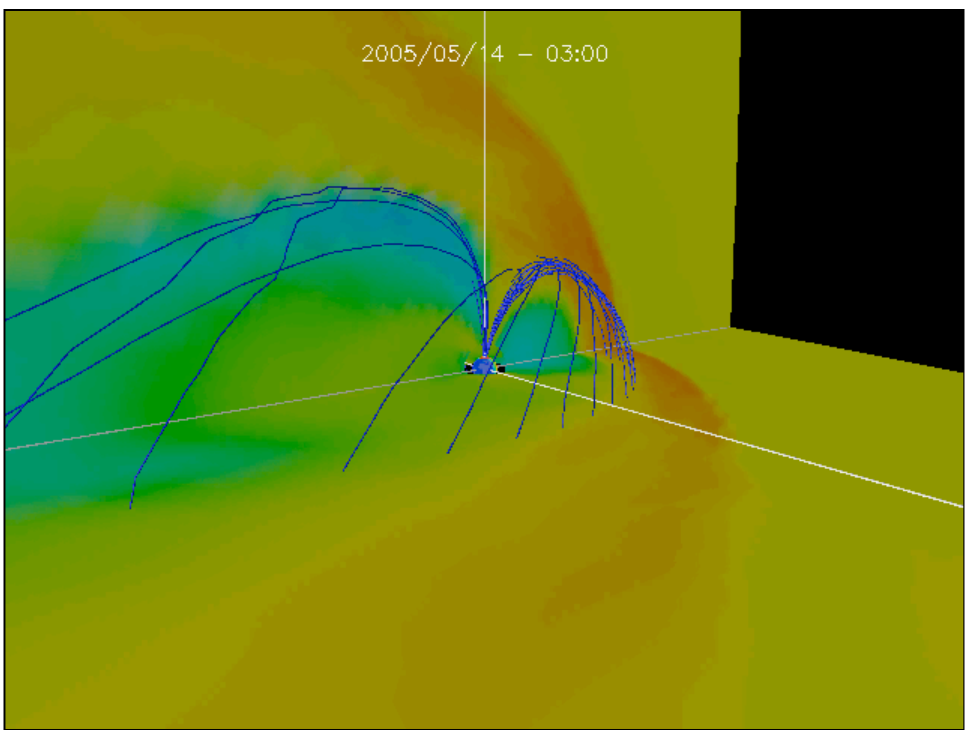
V (km/s)
800
600
400
200
8/18/2007
8/23/2007
8/28/2007
9/2/2007
9/7/2007
Br Polarity
2
1
0
-1
-2
230
235
240
245
250
Time (Day of 2007)

7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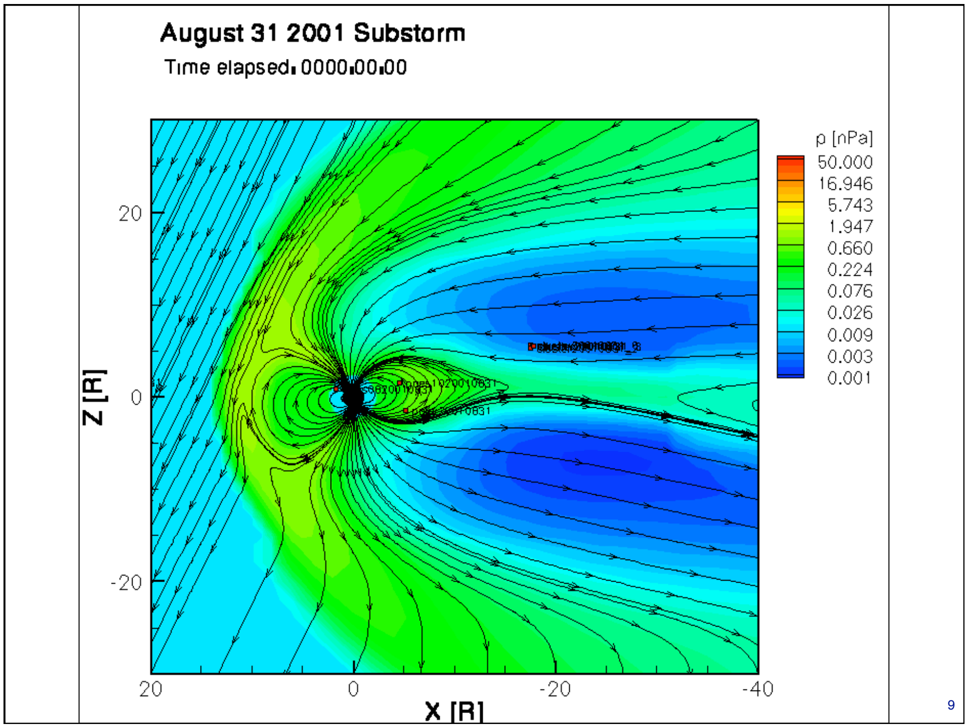
August 31 2001 Substorm
Time elapsed: 0000:00:00
ρ [nPa]
50.000
16.946
5.743
1.947
0.660
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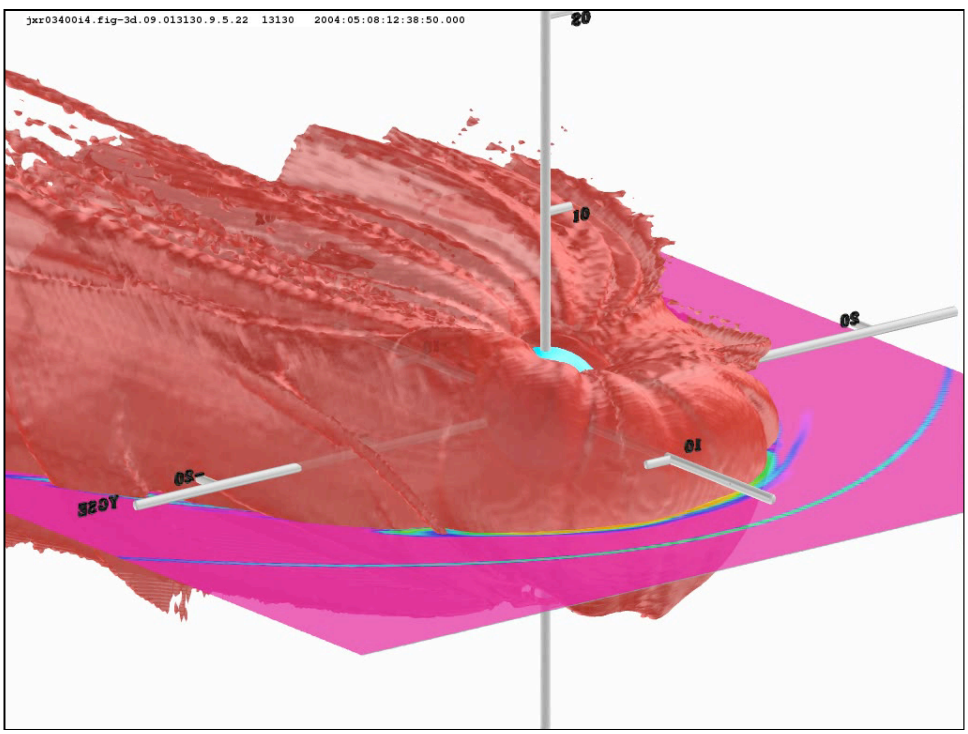
0.076
0.026
0.009
0.003
0.001
Z [R]
X [R]
20
0
-20
-40
9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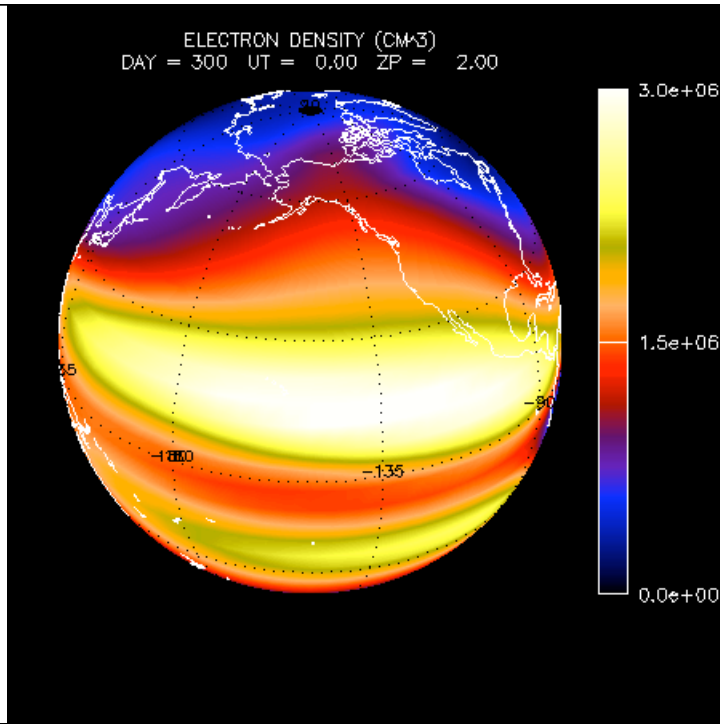
ELECTRON DENSITY (CM^3)
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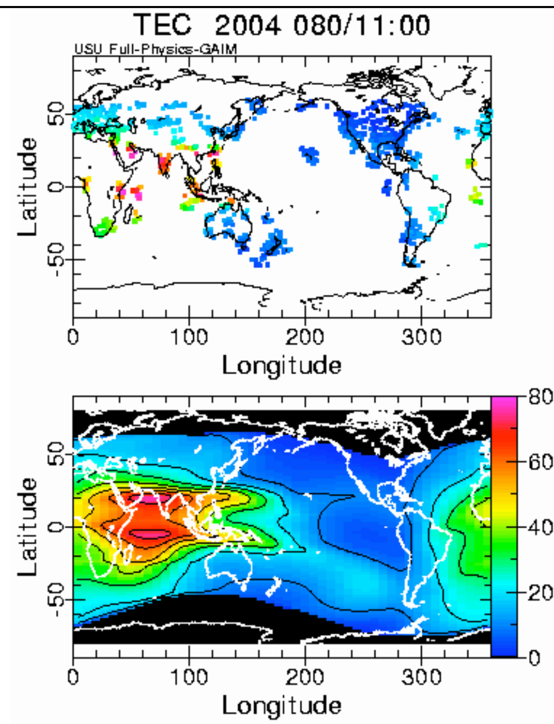
1.5e+06
0.0e+00
-135
-90

11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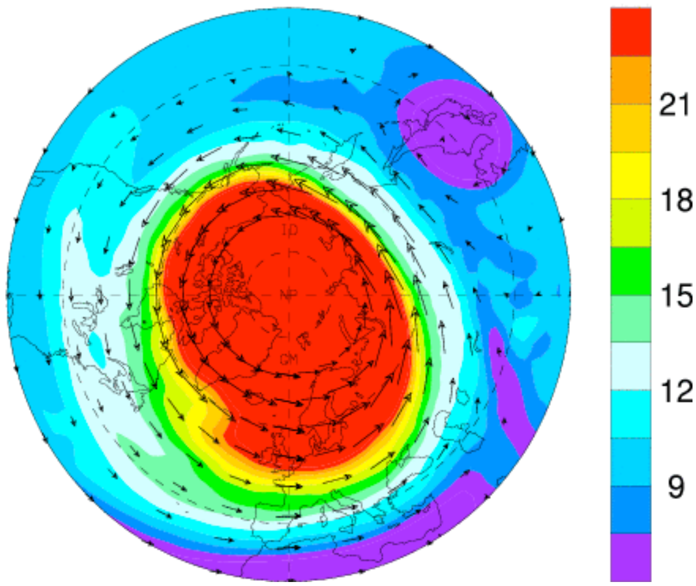
USU Full-Physics-GAIM
Latitude
50
0
-50
0
100
200
300
Longitude
80
60
40
20
0

12

Jan 10 UT00 840K PV North



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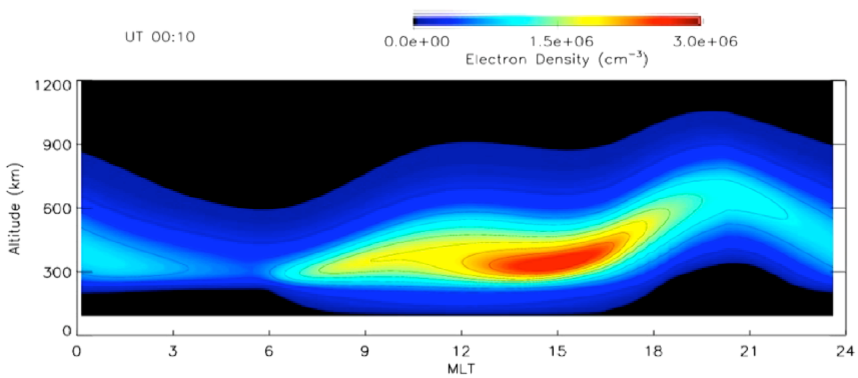

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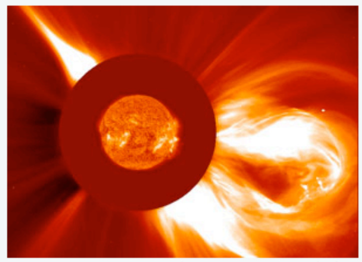
The Current Context

New Space Weather Forecasting Model Going Operational with National Weather Service

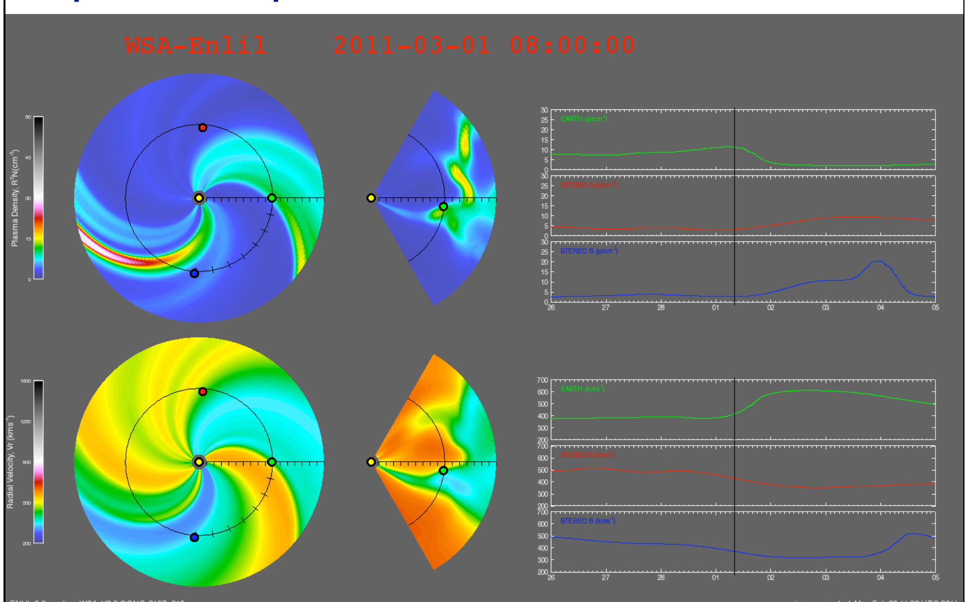
RESEARCH-TO-OPERATIONS TRANSITION OF MODEL THE RESULT OF A PARTNERSHIP BETWEEN THE BU'S CENTER FOR INTEGRATED SPACE WEATHER MODELING AND NOAA'S SPACE WEATHER PREDICTION CENTER

SEATTLE—Through an unprecedented research-operations partnership, the Boston University-based Center for Integrated Space Weather Modeling (CISM) and the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center are transitioning the first large-scale, physics-based space weather prediction model from research into operations. National Weather Service (NWS) scientists affiliated with CISM reported the news today at the annual American Meteorological Society (AMS) meeting in Seattle, Wash. CISM is a National Science Foundation (NSF) Science and Technology Center.



A large coronal mass ejection (CME) observed by the SOHO spacecraft on December 2, 2003, near the end of the last solar maximum. The central image shows the sun imaged in the extreme ultraviolet (EUV, wavelength 30.4 nm) to show the hot outer atmosphere, the corona. The outer image is at the same scale and shows the bright CME in visible light. At this point the CME is much larger than the sun itself, moving away from the sun at a speed of about 600 miles per second. The CME came from the region around the brighter spots on the right hand side of the sun. To scale, the earth is smaller than the white spot caused by a bright star seen just above and to the right of the CME. [Image from NASA]

Operational Implementation of the Enlil Solar Wind Model



The New York Times

The Opinion Pages

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH SPORTS OPINION

I.H.T. OP-ED CONTRIBUTOR

Celestial Storm Warnings

By JOHN P. HOLDREN and JOHN BEDDINGTON
Published: March 10, 2011

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Weather is often in the headlines. But largely unnoticed last month was the weather that forced airlines flying the polar route between the United States and Asia to detour south over Alaska. This unusual routing was a response to a "space weather" event — an enormous ejection of charged gas from the Sun capable of scrambling terrestrial electronic instruments.

Such events can happen at any time but tend to become more severe and more frequent in roughly 11-year cycles. The peak of the current cycle is expected in 2011-12. What's especially significant about this is that the world's reliance on electronic technology — and therefore vulnerability to space weather — has increased substantially since the last peak a decade ago.

From sporadic solar flares to ethereal shimmering aurora, manifestations of severe space weather have the power to adversely affect the integrity of the world's power grids, the accuracy and availability of GPS, the reliability of satellite-delivered telecommunications and the utility of radio and over-the-horizon radar.

The detour of recent flights was due to the potential loss of essential air traffic control radio near the North Pole and was costly and inconvenient; some airlines had to bump passengers to take on added fuel for the re-routing.

Space weather can affect human safety and economies anywhere on our vast wired planet, and blasts of electrically-charged gas traveling from the Sun at up to five million miles an hour can strike with little warning. Their impact could be big — on the order of $2 trillion during the first year in the United States alone, with a recovery period of 4 to 10 years.

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THE WHITE HOUSE
Office of the Press Secretary

FOR IMMEDIATE RELEASE
May 25, 2011

Joint Fact Sheet: U.S.-UK Higher Education, Science, and Innovation Collaboration

Prime Minister Cameron and President Obama agree that science and higher education are the foundation stones of their two nations' 21st century economies and that the UK and U.S. have a responsibility to further their global leadership roles in these essential fields. The U.S. funds approximately one-third of the world's scientific research and the UK is first among G-8 countries in scientific publications and citations as a fraction of GDP. In higher education, the U.S. and UK are home to the world's ten highest ranking universities.

Recognizing the great potential for productive cooperation in these domains, the Prime Minister and President reaffirmed during the State visit their mutual commitment to strong collaboration in science and higher education and agreed to work to increase the number of joint endeavours among individuals in cutting-edge laboratories, universities, scientific societies, think tanks, government agencies to develop human capital and ensure a strong and agile knowledge base. They expressed particular support for cooperation in fields that will create jobs and generate new economic opportunities in both countries while tackling some of the most pressing global challenges facing the world today. The leaders also expressed a determination to maintain research excellence that leads to economic growth and job creation...

The leaders welcomed in particular the growing partnership between the UK Meteorological Office (Met Office) and the U.S. National Oceanic and Atmospheric Administration's (NOAA) National Weather Service, codified with the signing of an historic Memorandum of Agreement in February 2011. This agreement provides for a coordinated U.S.-UK partnership in the delivery of space weather alerts to help provide critical infrastructure protection around the globe. The two governments announced today that they will embark together on an ambitious program to create the world's first combined space weather model capable of forecasting terrestrial weather with great accuracy and also indicating where, when, and for how long space weather effects will persist in our upper atmosphere and whether these anomalies are likely to disrupt and degrade GPS-enabled positioning, navigation, and timing capabilities.

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Unfortunately...

The most deliterious aspects of space weather are the most difficult to forecast on actionable time scales.

E.g.:

— High-energy solar particles (and other energetic particles)

— Rapid variations in solar photon output (flares)

— The strength and direction of the interplanetary magnetic field

— Ionospheric irregularities / plasma bubbles / spread-F / scintillations

"Prediction is hard, especially when it's about the future."

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Prospects for Future Progress

• Models of the heliosphere are primarily constrained by their inner boundary condition — measurements of the coronal magnetic field could greatly improve their ability to describe the interplanetary magnetic field.

• Coupling magnetospheric MHD models to the radiation belts, ring current, and the ionosphere, has demonstrated the power of a systems approach to geospace modeling.

• Great progress has been made in describing ionospheric instabilities and the mechanisms behind the formation of plasma bubbles.

• Comprehensive models of the atmosphere-ionosphere system show the importance of the internal dynamics of the atmosphere to short-term ionospheric variability

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Some Iconoclastic Recommendations

Support modeling and modelers

Recruit students and postdocs into the numerical modeling discipline

Focus on some achievable goals

E.g.:

— Solar wind speed and density forecasting

— Statistical/empirical/assimilation approach to radiation belt forecasting

— Short-term thermosphere-ionosphere forecast based on data assimilation nowcasting, and forward modeling based on upstream IMF measurements

— Nowcasting of the atmospheric radiation environment

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TBD

"...always in motion the future is..."

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