First European Space Weather Week

Space weather - atmospheres, drag, global change - future needs

29 November-3 December 2004
## Timescales of important phenomena

### Weather
- Solar Flares
- CMEs
- Geomagnetic Storms
- Substorms
- Ionospheric Currents and Structure
- Gravity Waves
- Turbulence
- Reconnection
- Radiation Belt Enhancement

### Days-Weeks
- Solar Rotation
- Emerging Flux Features
- Trapped Particles
- Magnetic Clouds
- Geomagnetic Storms
- Radiation Belt Dynamics

### Months-Years
- Solar Cycle
- Solar Dynamo
- Solar Wind Variance
- Cosmic Rays
- Middle Atmosphere
- Composition, Dynamics, Temperature
- SAO & QBO

### Decades-Centuries
- Solar Irradiance Changes
- Earth Surface Temperature
- Ozone Changes
- Galactic Cosmic Rays
- Maunder Minimum
- Climate Change
No single statement of requirement

Effects on Spacecraft & Aircraft
Power Distribution Networks and Pipelines
Oil and mineral Prospecting
Communication Systems
Risks to human health
Space weather influence on climate change
Insuring against space weather effects

26 Service Development Activities - SWENET
User requirement
>95% reliability
Not easy to determine
commercial in confidence

**Timescales**
Weather and Climate
Today, 5 years, 15 years

Why can’t accurate predictions be made?

What do we need to do?
For prediction
Underpinning scientific research
Data provision
Drag

- Long term solar output
- Extreme events
  - $10^{-1}$ TW to 10 TW @ magnetopause; electrojet $10^6$ amps in minutes
  - Prediction/timing
  - Joule and particle heating
    - Electric field distribution
    - Conductivity

![Graph showing solar radio flux and population decrease](image)
Energy inputs - climatology

Solar output as a function of wavelength and time
paleo proxies to extend the time series foE, Be10 etc

Magnetic flux

Climatology 😊
Energy inputs – weather

What do we not know?
Which are “extreme” events as they lift off the Sun?

Research required – high priority

Phenomenology → Integration

The way forward
STEREO, Solar-B, Solar Orbiter and ground-based observations and theory

Timescale – 5+ years
The solar wind

Onset times
IMF orientation
Shock timing

Solar wind fast and slow streams

Helios 1976

Alfvén waves and small-scale structures
Hasegawa, 1991

Stream interaction region

Dynamic processes in interplanetary space

- Wave amplitude steepening ($n \propto r^{-2}$)
- Compression and rarefaction
- Velocity shear
- Nonlinearity by advection ($\propto U^2$)
- Shock formation (co-rotating)

Solar wind stream structure and heliospheric current sheet

Mass up to 10 billion tonnes
Expands at speeds up to 2000 km/s

1997/04/07 15:21 UT
1997/04/07 15:32 UT
Energy deposition – substorms

Critical for drag and GIC

What do we know?

- Timing - for some events but not multiple substorms
- Energy released - dependent upon energy input at the time of the substorm

What do we not know?

- Spatial distribution of energy release
- Rate of energy release
Substorms

What do we not know?

Spatial and temporal distribution of energy release

Research required – high priority

Location - spatial distribution of pressure in the tail
Latitude distribution - ???????
Longitude distribution - ???????
Rate of energy release - ???????

The way forward - Cluster and ground-based observations and theory

Timescale - 5 years
Timescale of operational space weather forecasting

Today
- empirical + assimilation
- neural networks
- prediction filters

5 years
- empirical + more physics

10+ years
- Physics + empirical
A Virtual Radiation Belt Observatory Concept

**Virtual Radiation Belt Observatory**
- Historical Data Base
- Real-Time Data
- Empirical Models / Forecasts
- Physics-Based Models

**Scientific Community**
- Specification
- Climatology
- Case Studies
- Modeling

**User Community**
- Anomaly Resolution
- Model Forecasts
- S/C Design Criteria

**CU / LASP**
- NASA Data
- Models

**NOAA / NGDC**
- Data
- Models

**NOAA / SEC**
- GOES Data
- POES Data
- User Req.

**Aerospace Corp.**
- HEO Data
- AF User Req.

**DoD / AFRL**
- Models
- Data

**LASP / CISM**
- NSF Models
- Assimilation
- Forecast Models

**DOE / LANL**
- GEO Data
- GPS Data
High latitude irregularity operational model

IMF
Oval Location
Conductivity from UV images + EUV model
Model neutral wind
SuperDARN electric field + model
TEC + Scintillation Maps
Equatorial latitude
irregularity operational model
Spatial measurements of electric field
Spatial measurements of neutral wind
TEC + Scintillation Maps

Distribution of observations
Sensitivity of observations

Climatology 😊
Weather ❌

SNR+1 in dB
0.0 9.8 19.6

Local Time (hr)
18 19 20 21 22
Virtual observatory components
Distributed data bases accessed through a single portal

DATA VISUALISATION

FORMAT CONVERSION

DATA ACQUISITION

LOCATION DISCOVERY
Simplified Architecture

Architecture defined in terms of roles
Consumer, Broker and Provider

After R. Linsolas, IAS
**Sun-weather/climate**

**Power:** 4 $10^{26}$ W

2 $10^{17}$ W

**Issue:** Reduce the uncertainties in predictions

**Rationale:** To scope mitigation and adaption strategies more accurately

Links to national and international policy

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British Antarctic Survey
Natural Environment Research Council
Change of Temperature Index Based on Local Linear Trends

(a) 1950 to 1998 Annual Mean
Air Temperature

- Global temperature rise: +0.7 to 2.2°C by 2100.
- Europe: mean +0.5°C.
- Summer +0.7°C.

Predicted sea level rise

Data-sources: IPCC, WMO, UNESCO, etc.

European Environment Agency
Influence of the Sun on the Earth's climate

- Solar irradiance
- Long term changes in solar activity
- Planetary wave reflection
- Aerosols
  - Electric fields
  - Cosmic rays

The global mean radiative forcing of the climate system for the year 2000, relative to 1750

Radiative Forcing (Watts per square metre)

- Halocarbons
- N₂O
- CH₄
- CO₂
- Tropospheric ozone
- Stratospheric ozone
- Black carbon from fossil fuel burning
- Organic carbon from fossil fuel burning
- Biomass burning
- Mineral Dust
- Aviation-induced Contrails Cirrus
- Aerosol indirect effect
- Land-use (albedo) only

High  Med.  Med.  Low  Very Low  Very Low  Very Low  Very Low  Very Low  Very Low  Very Low  Very Low  Very Low

NATURAL ENVIRONMENT RESEARCH COUNCIL
Influence of the Sun on the Earth’s climate

• Solar irradiance
  • Total solar + spectral
• Long term changes in solar activity
  • Paleo data constructions
• Planetary wave reflection
• Aerosols/clouds
  • electric fields
  • cosmic rays
Impacts on dynamic, thermal, chemical and micro-structure of atmosphere

Vertical coupling
Influence of the Sun on the Earth’s climate

**Science Objectives**

Review previous statistics to establish a robust baseline of facts

Quantify the magnitude of the various mechanisms in the troposphere to determine which ones are important

Transferring science results into policy
Influence of the Sun on the Earth’s climate
National and international programmes

ISSI Workshop on Solar Variability and Atmospheric Composition, Temperature and Circulation Variations on Terrestrial Planets Bern, Switzerland, June 6 to 10, 2005

European Solar Terrestrial and Atmospheric Research (E STAR)

Climate And Weather of the Sun-Earth System (CAWSES)

International Living With a Star (ILWS)

The future
Framework 7 2007-2013
Specific programme opportunity
Intergovernmental Panel on Climate Change (IPCC) -2007
# International Year Initiatives

Several global “I*Y” initiatives are under development.

<table>
<thead>
<tr>
<th>I*Y Years</th>
<th>Name</th>
<th>Main Sponsor</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>eGY 2007-2008</td>
<td>Electronic Geophysical Year</td>
<td>IUGG</td>
<td><a href="http://www.egy.org">http://www.egy.org</a></td>
</tr>
<tr>
<td>IPY 2007-2009</td>
<td>International Polar Year</td>
<td>ICSU WMO</td>
<td><a href="http://dels.nas.edu/prb/ipy/">http://dels.nas.edu/prb/ipy/</a></td>
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</tbody>
</table>
The way forward

Comparison with the meteorological community

National and international cooperation over data collection - funded by Governments

Specific forecasts and products produced by business enterprise

Further research funded by Governments
Objective
To bring existing data together to address sets of scientific and operational goals

Need for coordination and investment
(European Digital upper Atmospheric Server, DIAS)

World data centre role in 21st Century + Regional Warning Centres (ISES)
Common approach/feel/analysis tools/standards with a real time element
To get scientific data from various, mostly distributed sources, a scientist may have to:

1. Search through a number of data centres, various institutions, observatories, contact colleagues…

2. Get data via snail-mail, air-mail, e-mail, Web…

3. Then ingest retrieved data into a local database…

4. Process collected data using mostly proprietary codes, run models… and…

5. Finally, do some science

**Increasing requirements**

Interdisciplinary and multi-disciplinary science

Higher resolution - space and time

Assimilation into models
**Key Conclusions**

**Space Weather/Climate**

**User needs**
- generic data collection - government
- individual forecasts for specialist sector

**Next objectives**
- empirical approach with limited physics
- extreme event prediction

**Sun Weather/Climate**

Robust review of existing literature
Focus on quantification

**Maximise forthcoming opportunities**

Integrate Space-Weather and Sun-Weather
Economic **AND** sustainability benefits