High latitude space weather effects from an Incoherent Scatter Radar (ISR) point of view

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What is Space Weather?

“The conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and endanger human life or health.”
Impact of Space Weather on Human Activities

- Satellites
- Power grids
- Humans in space
- Radios

June 2008
InSAR interferometry through a variable ionosphere
InSAR imaging

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InSAR Imaging

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In order to nowcast and forecast space weather in our near Earth environment we need:

– Reliable and sufficient observations of plasma processes on all scales over extended time periods.
– Accurate theories on what is linking the processes together.
– Robust models.
– Lots of computing power.
Where does Incoherent Scatter Radars fit into this?

- High quality range resolved geophysical data.
- Measurements (almost) independent of weather, seasons and space weather conditions.
- Extended time series of high resolution data for small scale dynamics to long term trends.
Variability on a several day scale

Note day-to-day variability in $N_e$

Precipitation effects

Ion heating events (Note $T_i$ is almost independent of $h$ at $h > 130$ km in events)

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“Sufficient measurements” - Location of the high latitude ISRs
What is all this about?

~1° beam width (a few km)
QuickTime™ and a decompressor are needed to see this picture.
International Polar Year Support

- EISCAT Svalbard Radar and PFISR are operating 24 hours per day in support of the IPY.
- Low duty-cycle, single beam mode at PFISR (some augmentation).
- Longest ever IS ionospheric dataset.
- Supposed to emphasize “quiet time variability” - coupling from below.

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Spring, Summer, Autumn, Winter

EISCAT Svalbard Radar IPY data
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A challenge to modelers:
The Future of Space Science: Coordinated Measurements

- **Long term climate and weather (Long Time Scales)**
  - International Polar Year (IPY)

- **Ionosphere-Magnetosphere coupling (Large Spatial Scales)**
  - Energy transfer to the ionosphere and atmosphere
  - Substorm triggering, etc.

- **Plasma structuring (Small Spatial and Short Time Scales)**
  - Auroral physics
  - Instabilities
  - Sporadic layers

- **Atmosphere-Ionosphere coupling (All Scales)**
  - Gravity waves, tides, forcing from below
  - Mesospheric phenomena
Combined velocities

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MI Coupling - Motion of the Plasma Sheet

Equatorward moving region of enhanced flows with enhanced plasma sheet convection - SAPS

Lyons et al. [2008]

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Joule 2 and PFISR

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Imaging the aurora with PFISR

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Courtesy of Thomas Butler

Ne 09:15:05 -- 09:15:19
90 degrees out of phase

Vadas and Nicolls (2007)

Variation of vertical wavelength with altitude tells us where the waves are dissipating (depositing energy) and also about the background neutral atmosphere - for the first time.

Source studies
atmosphere

Unambiguous winds/waves in lower atmosphere

Meridional

Zonal

Vertical
Coordinated THEMIS observations will be critical for identifying MI coupling issues like flow bursts, substorm initiations, etc.

Extensive THEMIS ground network
Summary

• In order to predict space weather we have to be able to describe the current state ("nowcasting").
• IS radars are very important contributors in providing high quality ionospheric data on a variety of scales.
• Space weather effects are truly global - as must our approach to understand it be.