7'th CCMC workshop - 2014
Annapolis

DTU CCMC/SWRC collaboration: Space Weather Forecast

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DTU Space

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DTU - Space Weather

Linking expertise in 4 important areas:

1. Interplanetary disturbances - magnetosphere coupling (Section of Astrophysics)

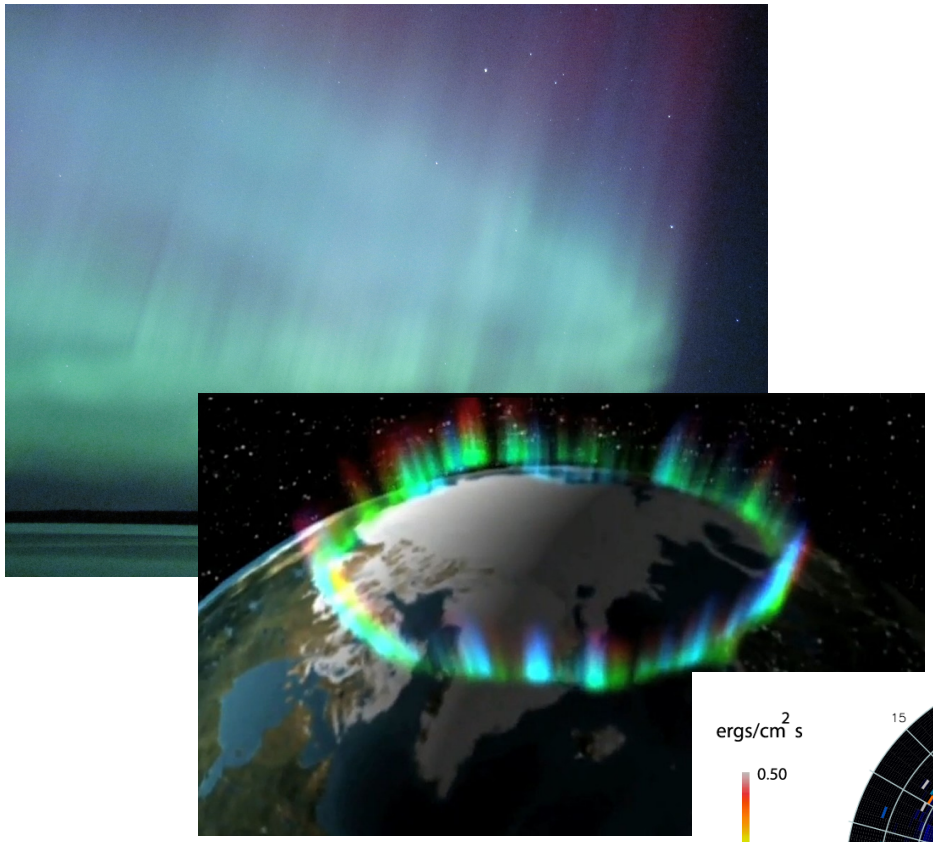
2. The ionosphere - communication and navigation (Section of Geodesy)

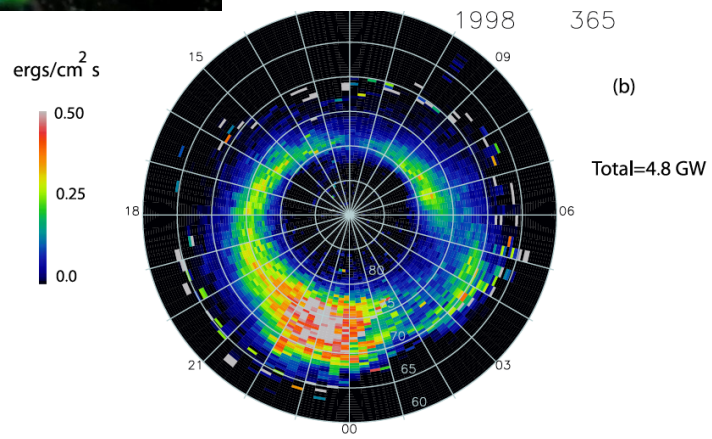
3. The Earth's magntic field and geomagnetic activity (Section of Geomagnetism)

4. Space instrumentation (Section of Measurement and Instrumentation)

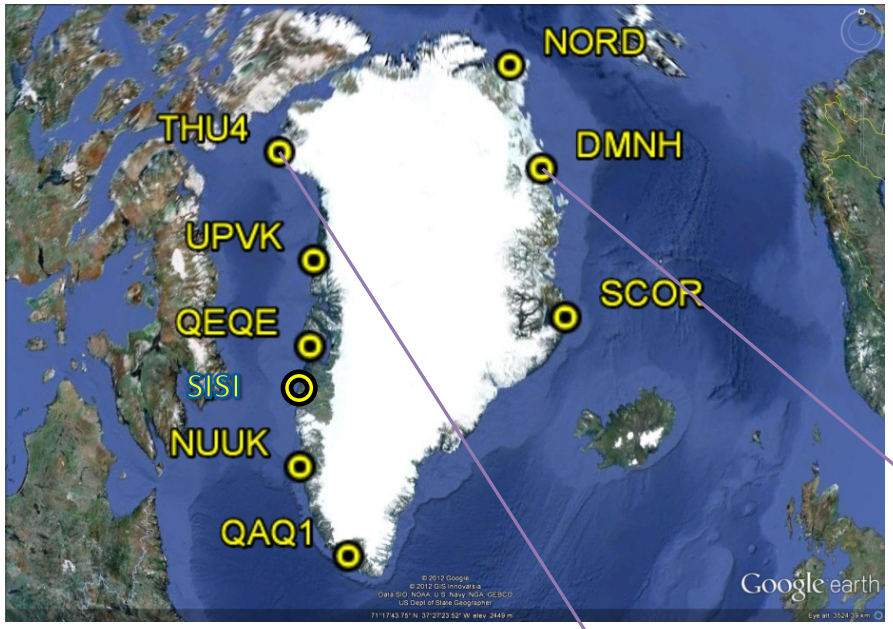
DTU – Space weather

Polar region experience





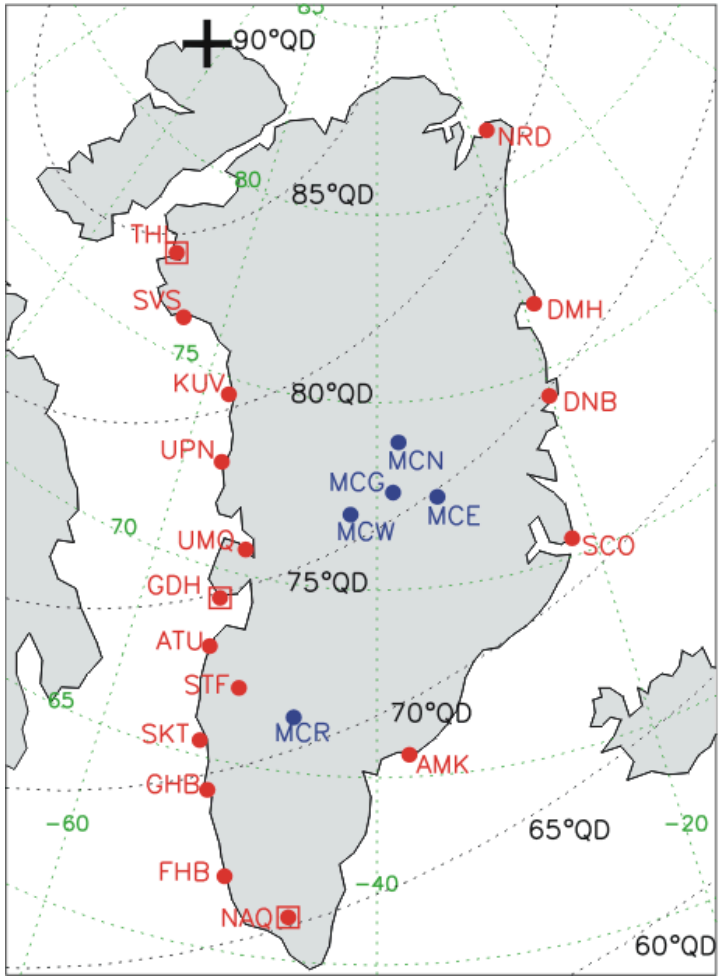
Greenland GPS/GNSS Reference Stations



Number	Station	ID Number	Latitude [deg]	Longitude [deg]	Ellipsoidal Height [m]
1	Thule	THU4	76,5371	-68,8259	36,49
2	Upernavik	UPVK	72,7883	-56,1280	164,80
3	Godhavn	QEQE	69,2526	-53,5223	48,71
4	Nuuk	NUUK	64,1835	-51,7312	109,47
5	Julianehåb	QAQ1	60,7152	-46,0478	110,46
6	Scoresbysund	SCOR	70,4853	-21,9503	128,50
7	Danmarkshavn	DMNH	76,7711	-18,6557	55,49
8	Station Nord	NORD	81,6001	-16,6554	69,36
9	Sisimiut	SISI	66,9343	-53,6729	62,50

IGS standards implemented at all stations

DTU Space ground magnetometers: special focus on Greenland



- 12 West Coast magnetometer stations along constant geomagnetic longitude
- Longitudinal coverage from polar cap to auroral oval
- Monitoring electric current systems in the Arctic ionosphere and magnetosphere
- Monitoring geomagnetic variations that drive ground induced currents, affect directional drilling.
- East Coast magnetometer stations

When developing the arctic

- There are severe challenges
  - Challenging nature
  - Accuracy of maps
  - Remoteness of the region
  - Communication
  - Weather

  ……. and …….

  - Space Weather…

Vision:
DTU - Space Weather

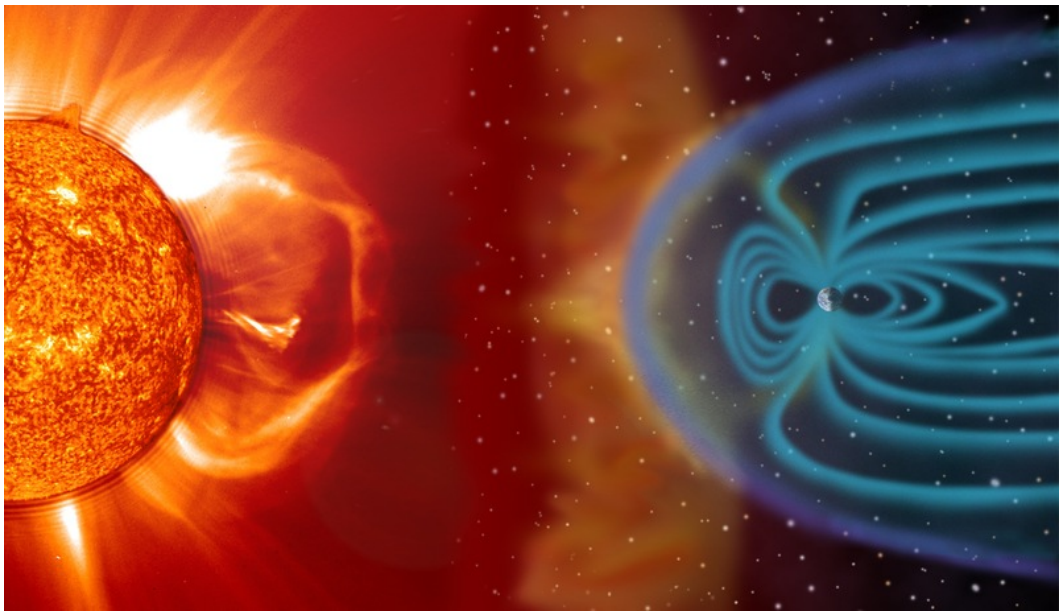
Observations from ground and satellites

Forecast
Experimental and educational forecast activities

Monitoring
Derivation of space weather relevant parameters

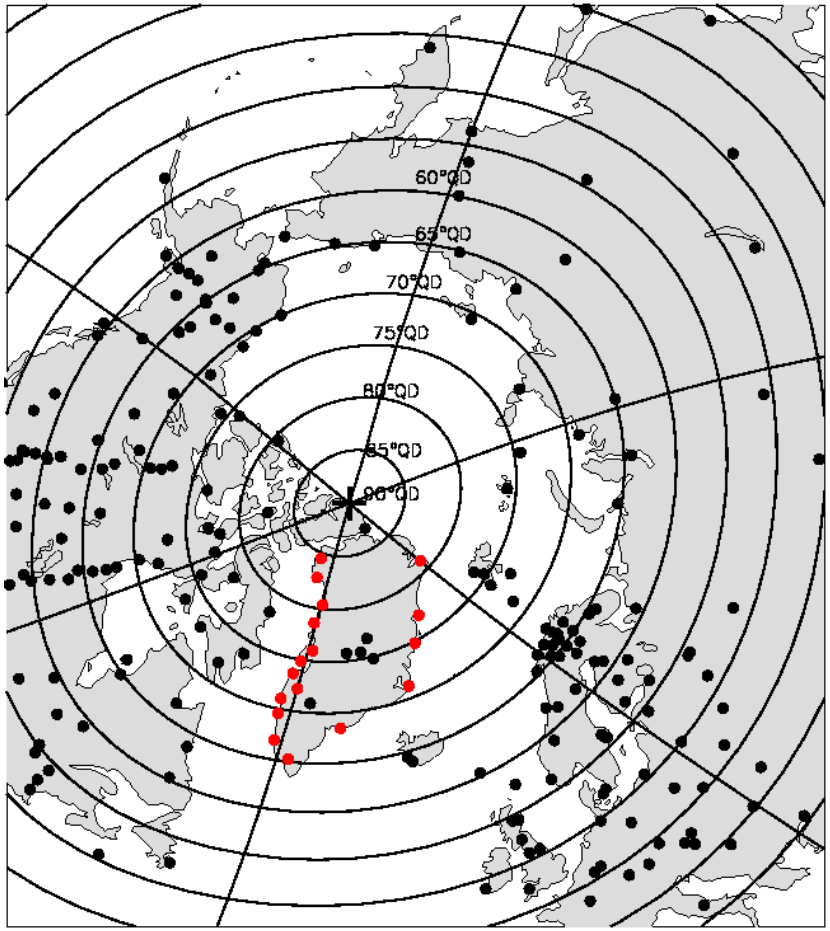
Dissemination in user-friendly representations to users and the public in Denmark and Greenland

Most space weather events are **global** phenomena



Space Weather Forecast is a GLOBAL CHALLENGE which should be addressed through INTERNATIONAL COLLABORATION

Europe and North America



Magnetometer stations

Closing the gap in scientific and operational space weather infrastructure between North America and Europe in near real time.

DTU - Space Weather
Experimental and Educational Forecast Service

- Experimental:
  - The main goal is to improve current space weather forecasting

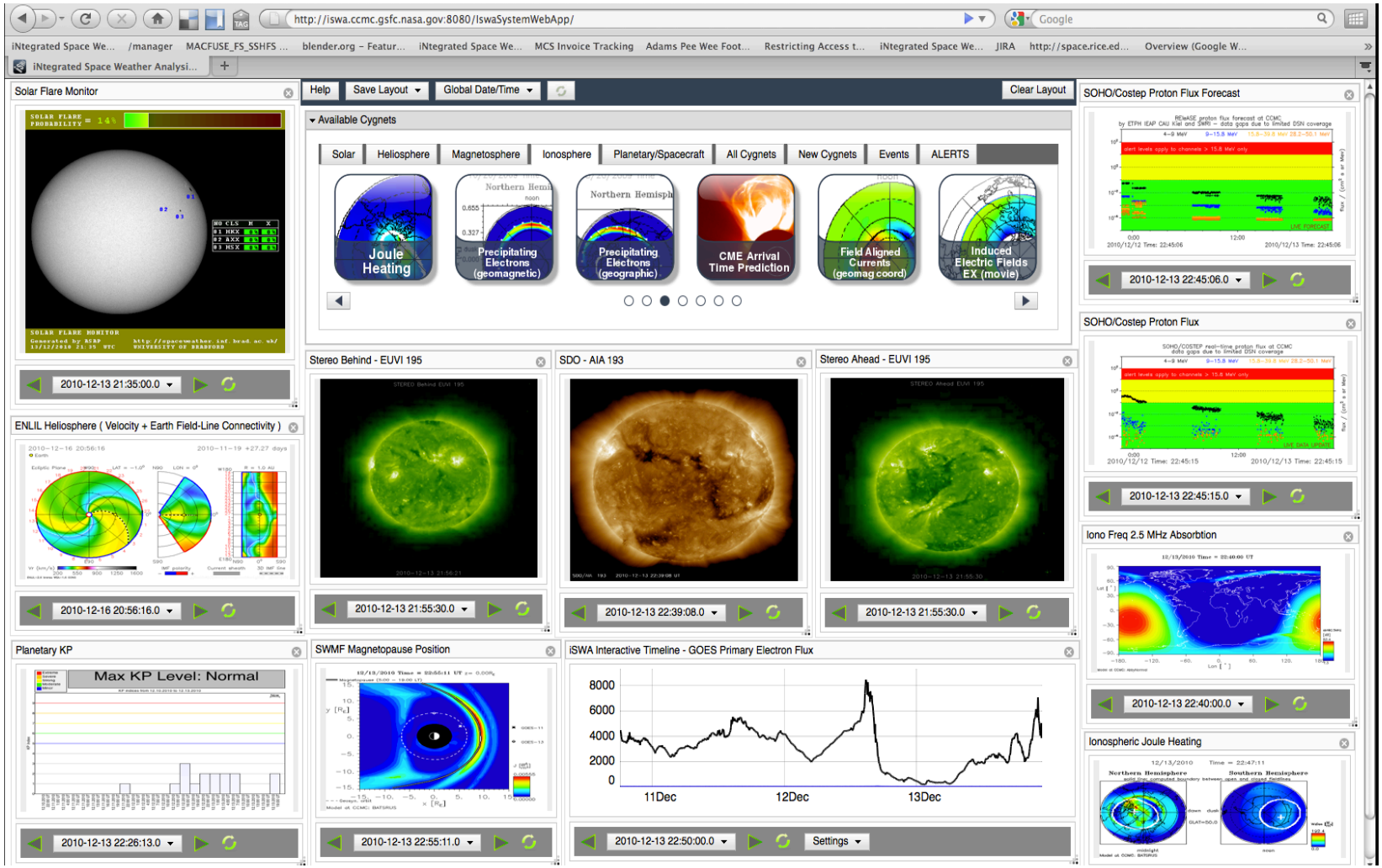
- Educational:
  - Education is an integrated part of the activity

DTU – CCMC/SWRC Collaboration: Daily forecast

First training as forecasters:

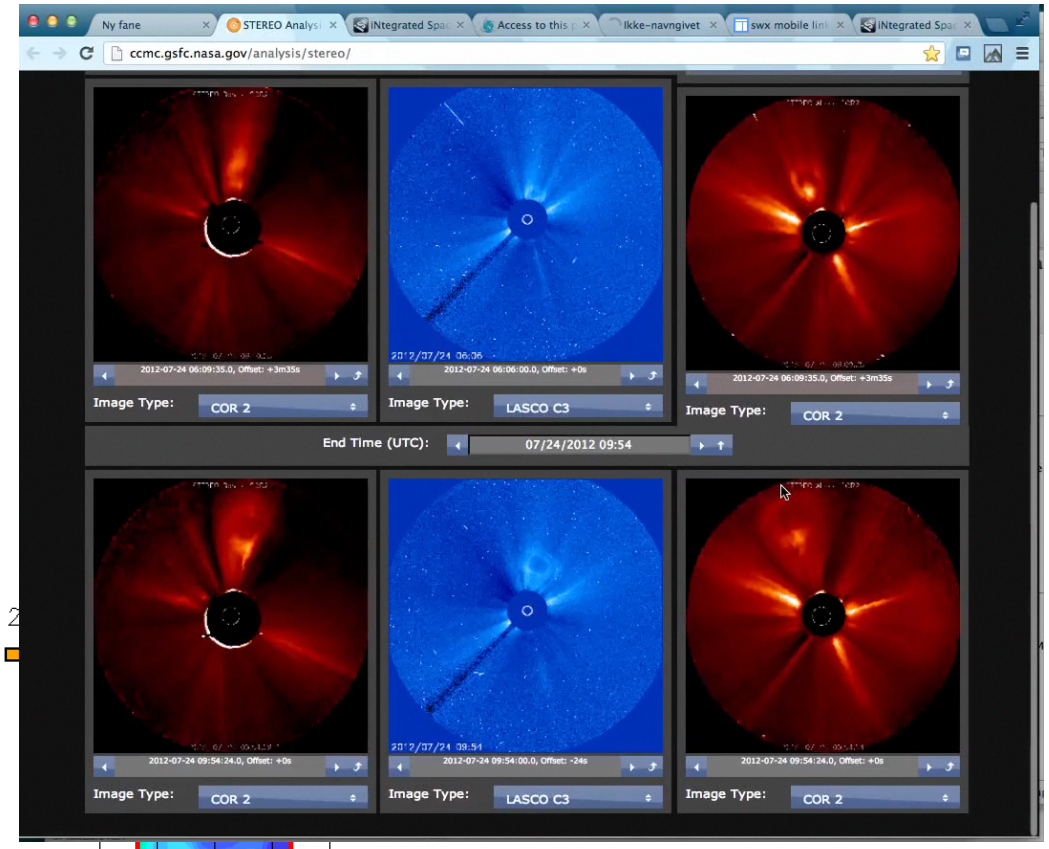
- What to look for?
- Which models to use?
- How to derive input parameters for models and launch model runs?
- Procedures for alerts: Events, thresholds
- How to create daily/weekly reports

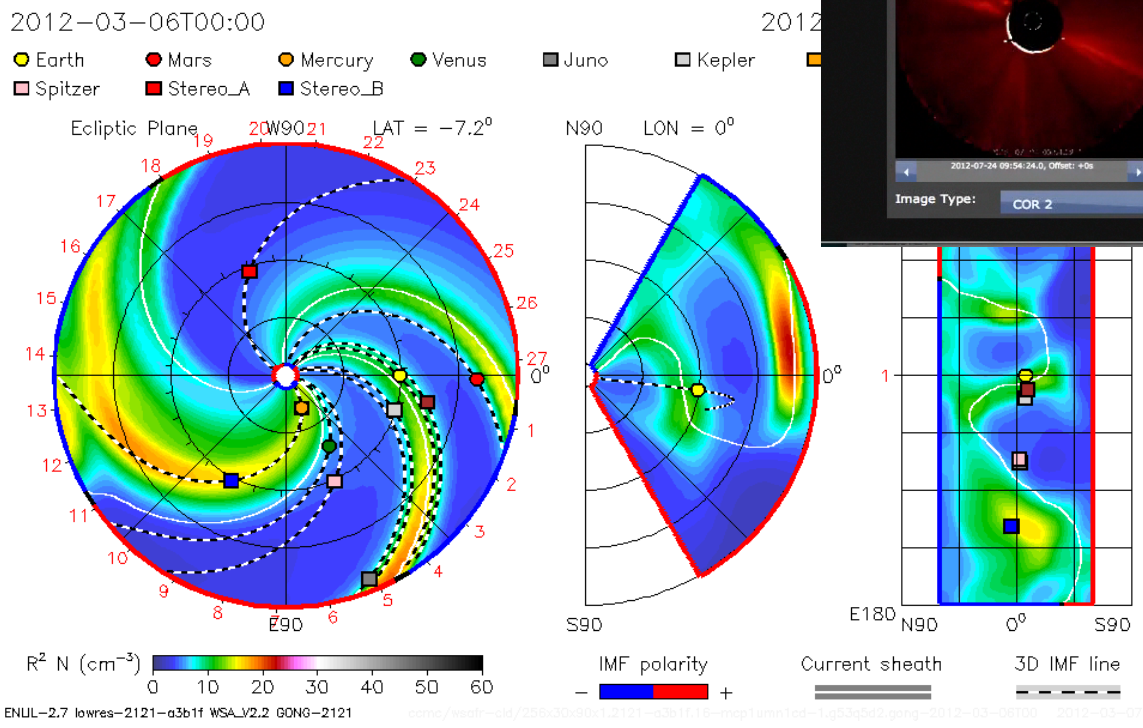
iSWA - Integrated Space Weather Application



Forecasting CME arrival and impact

StereoCat-tool





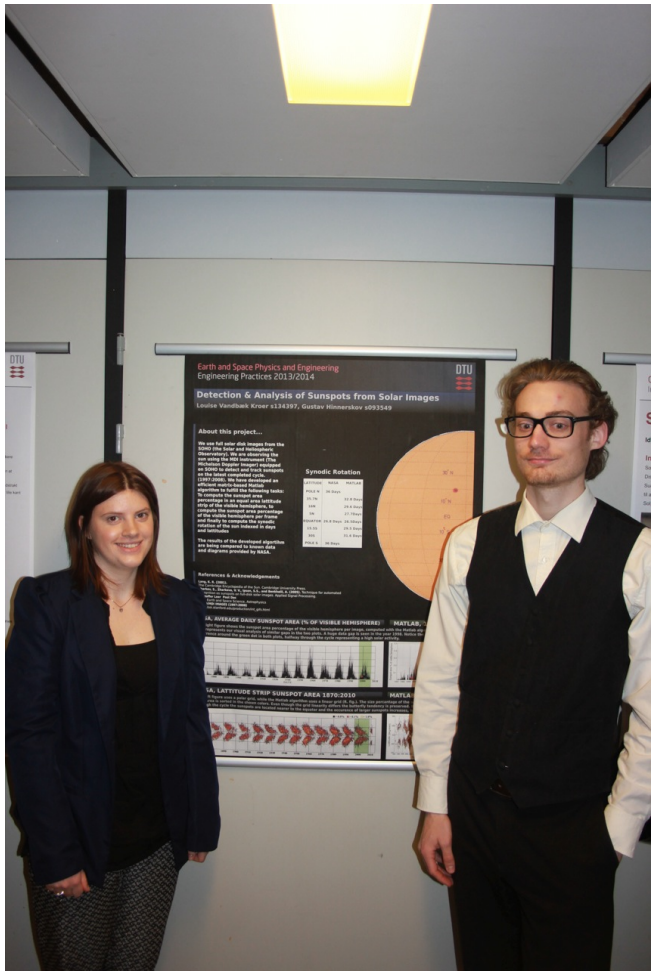
ENLIL

Weekly international tag-up, Thursday 15.00 UTC

Educational forecast

DTU education:
"Earth and Space Science and technology"

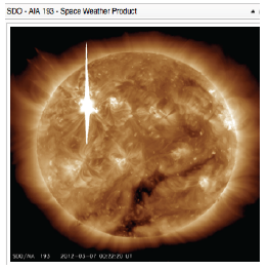
- Regular Courses:
  - Students are trained in forecast methods
  - Students participate in international tag-up
- Students engage in project to develop new forecast and monitoring methods



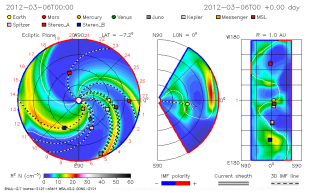
Experimental forecast service

You are in a good position to improve forecasting when you:

- Keep track of which observations (often science driven) are available in near-real time and with which time-delay (and adapt the methods)



- Keep track of new models developments and tools, their strengths and limitation



- Think in terms of user needs (preferably one step ahead).

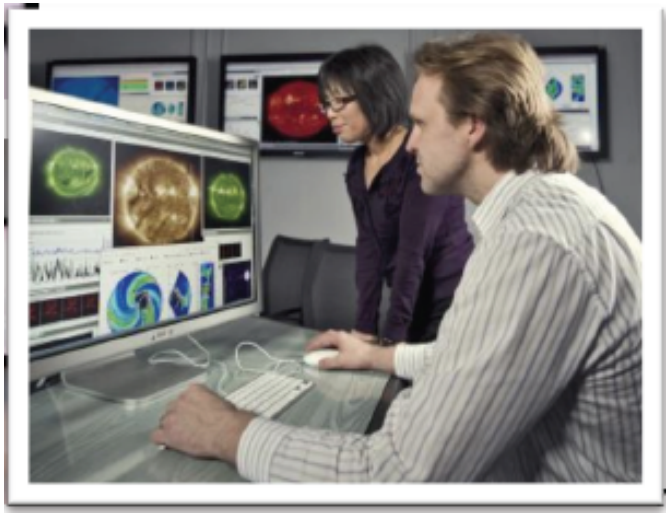
The obvious way to achieve this is to engage as forecaster!

DTU – CCMC/SWRC collaboration

- Daily forecasts based on world top methods
- Daily logs and Database of space weather events
- Easy access to real-time data and model output
- Weekly international “tag-ups” (telecons)
- Student participation

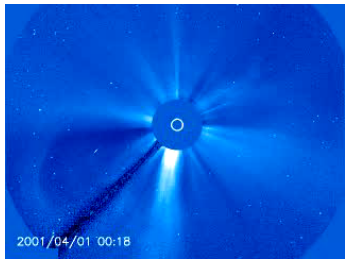
PERSPECTIVE:

24/7 Space Weather forecast through international collaboration



Space Weather is an international challenge!

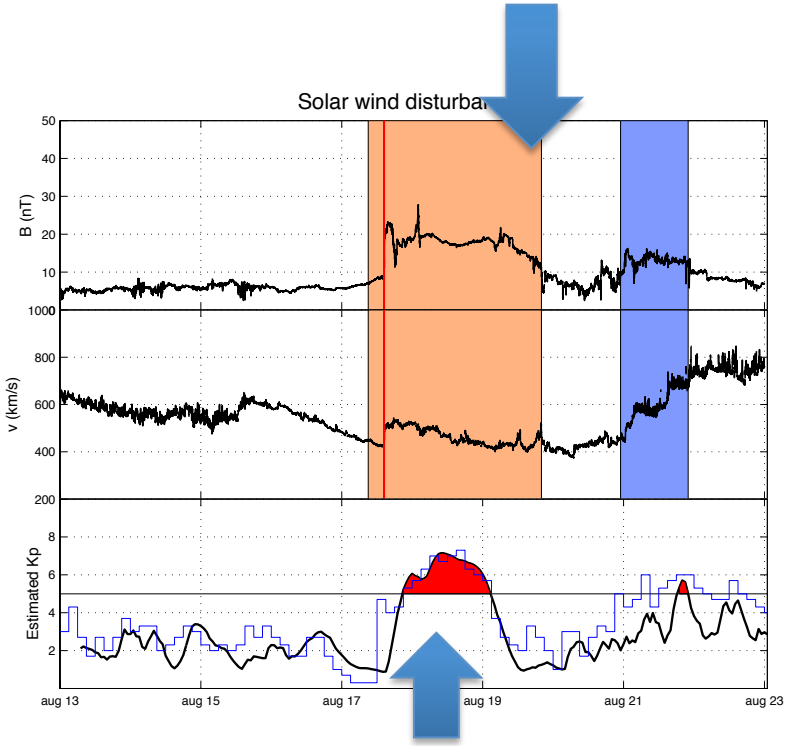
SSA Heliospheric Expert Service Centre: - Space weather forecast



DTU Space Weather:

- Automatic detection of solar wind disturbances
- Geomagnetic storm forecast
- Focus on polar electrojets

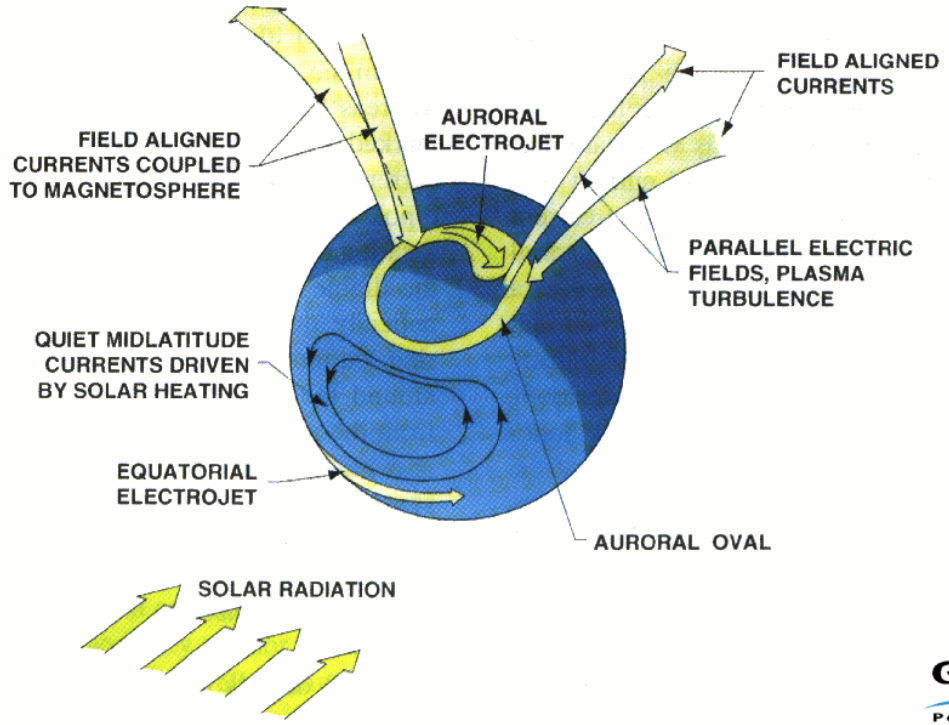
Solar wind disturbance

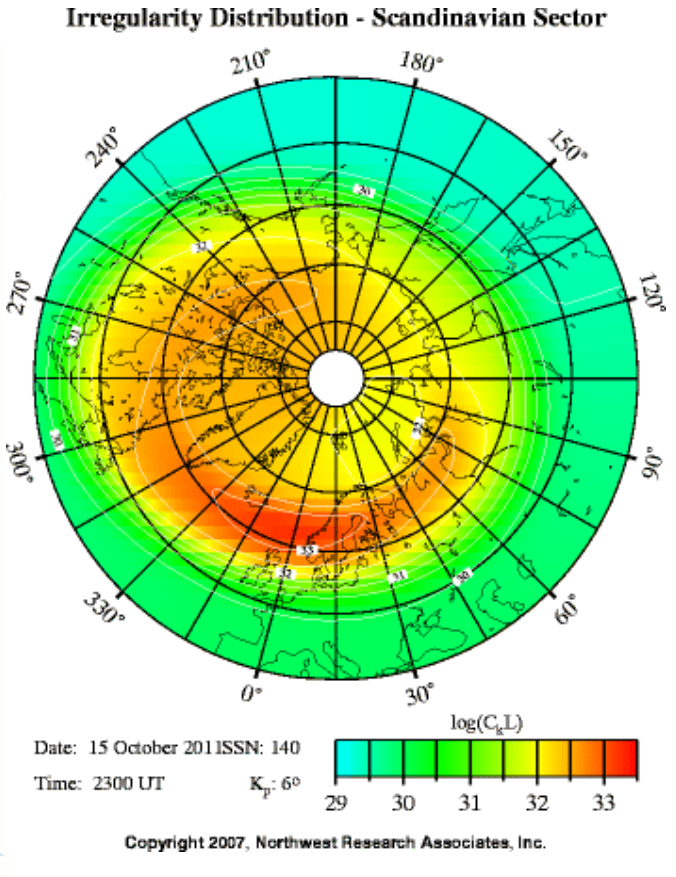


Geomagnetic storm forecast

Effects in the Arctic

- Impulsive currents are generated in the auroral oval of the ionosphere
- Small scale perturbations of the ionosphere densities (scintillations)
  - Affecting communications and GNSS applications
- Perturbing the magnetic field:
  - Affecting e.g. oil exploration

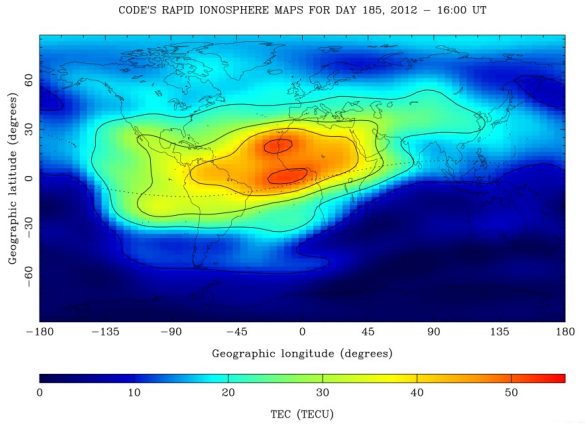




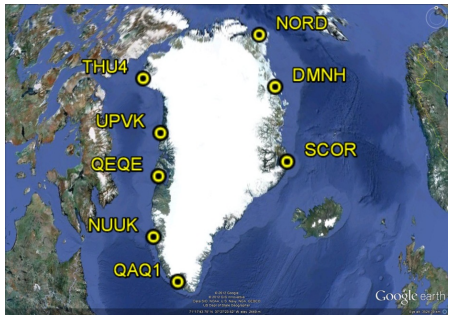
SSA Ionospheric Expert Service Centre: - Ionospheric monitoring and modelling

Monitoring:

- Each station: Slant-TEC, VTEC, S_4, σ_{rms}
- The Greenland sector: TEC (lat, lon, time)
- **Products:**

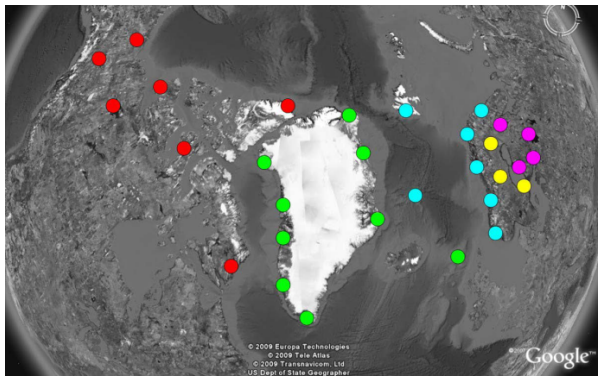


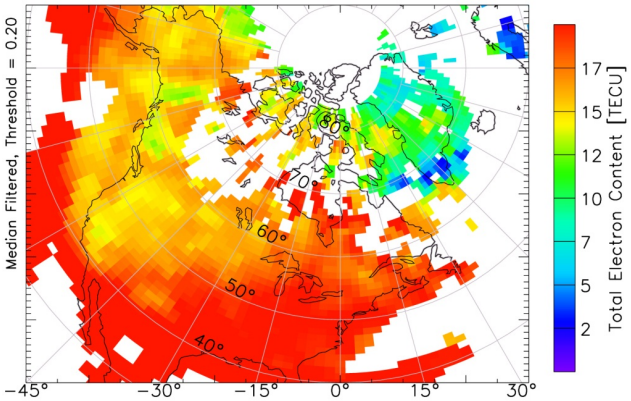
- Each station: f_oE, f_oF2, f_{max}, H_E, H_{F2}, cycle slips
- Tomographic data: Global Ionosphere Maps (GIM) of TEC and N_e, Auroral Oval (Feldstein), Scintillations (1-25 Hz), $\Delta TEC_{Obs-Model}$ (lat, long, time)
- Baseline-variations (Nuuk and Sisimiut) for general RTK-users
- Arctic GIM, PIM, NTCM-GL modelling
- Arctic scintillation and propagation modelling (WBMOD, GISM, and FSM)



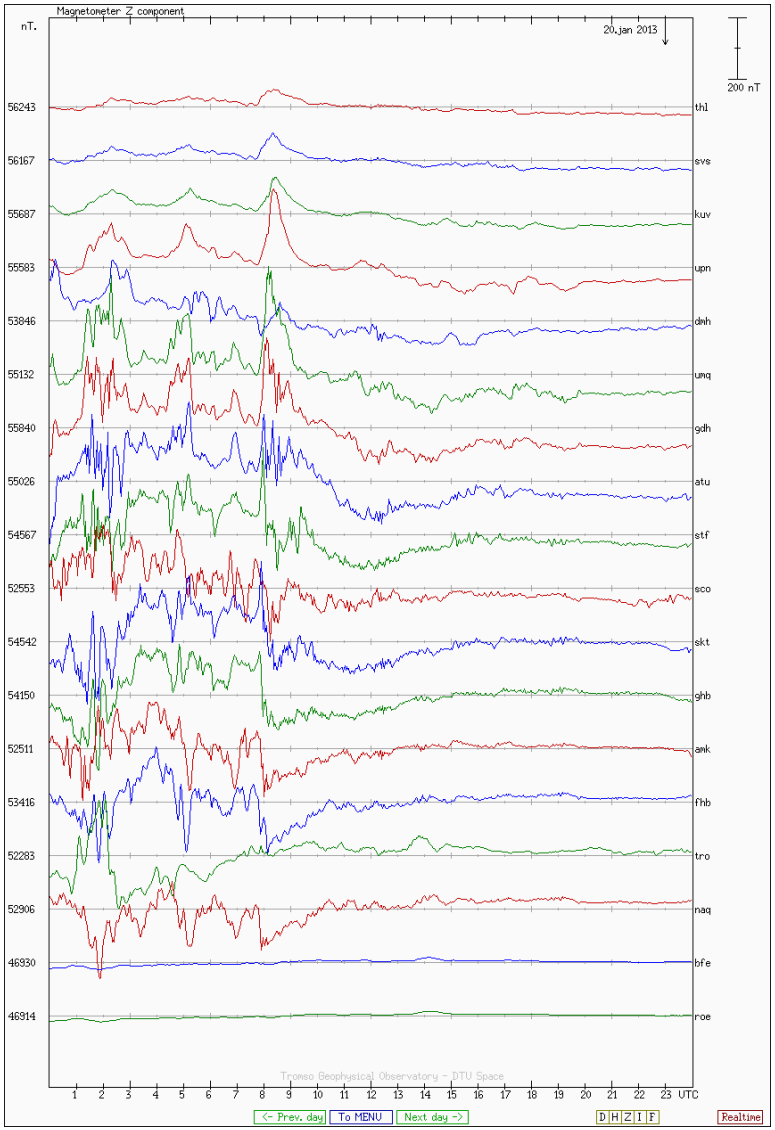
Possible users in Arctic

- Air traffic in Greenland – availability of local airport HF-communication
- Ship traffic and routing (fleet of fishing ships)
- Oil- and gas industry prospecting (primarily west of Greenland)
- Infrastructure tasks for local communities
- Danish Coastguard and Navy (ship monitoring and 'Search & Rescue' activities)





SSA Geomagnetic Expert Service Centre: - Geomagnetic activity monitoring



Magnetometers in Norway and **Denmark**

- Near-real time federated service in ESA SSA.
- polar electrojet, GIC, directional drilling

Magnetometers in **Greenland**

- polar electrojet, GIC, directional drilling

Polar Cap Index

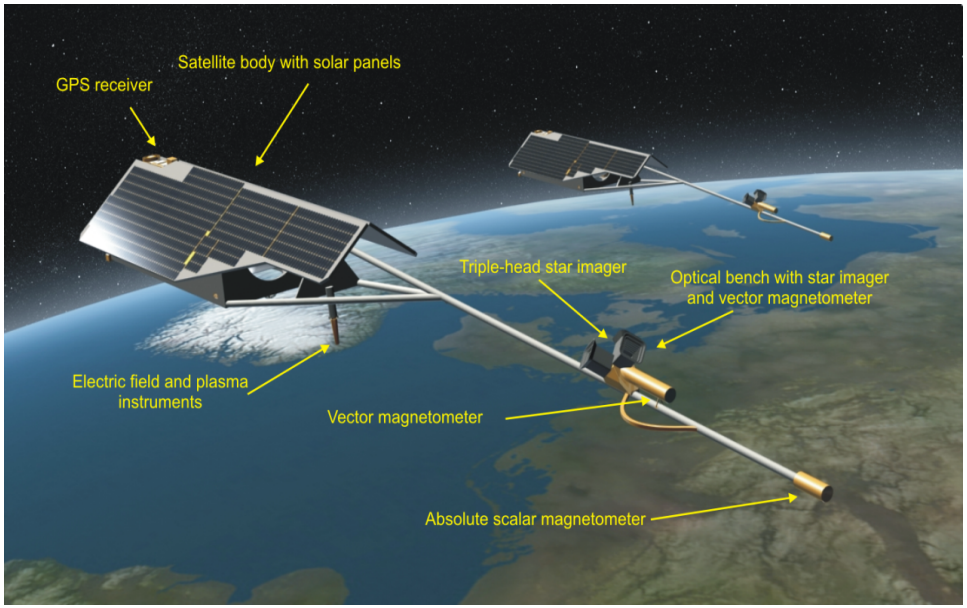
- Single station index (Qaanaaq/Greenland)
- Proxy for energy input from solar wind / merging electric field
- Ground based solar wind indicator

NRT: near real time.

Swarm Satellite Constellation and Data products for Space Weather application

DTU leads the ESA-funded *Swarm* Level 2 Processing System *SCARF*

- six European institutes and two US partners
- six processing chains processing Swarm Level 1b data
- product delivery to ESA for distribution to the scientific community



Level 1b data: Validated time series of:

- High-precision magnetic field (1Hz, 50Hz)
- Electron and ion density and temperature, ion drift velocity, electric field (2Hz)
- Pre-processed accelerometer data (1Hz)

Level 2 data with Space-Weather relevance:

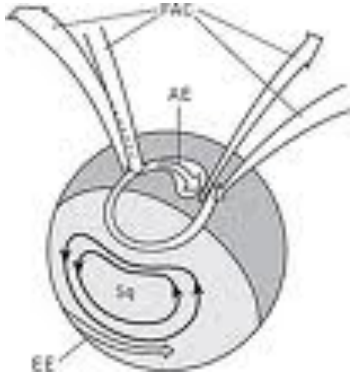
- Advanced models of the Earth's magnetic field
- Radial and field-aligned currents
- Equatorial "bubble" index
- Dayside equatorial eastward electric field
- Slant Total Electron Content
- Thermospheric density and winds
- Magnetic signal of magnetospheric currents (Dst-like)

Swarm provides timely and accurate geomagnetic reference field that can be used in ESA SSA.

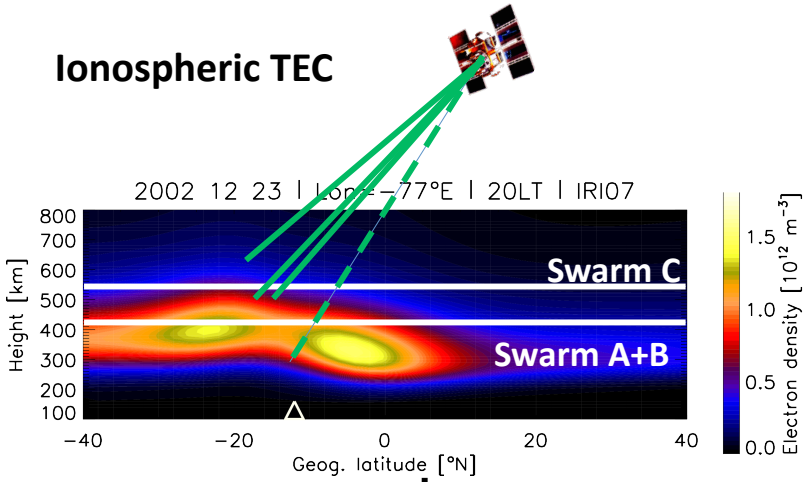
Possible Swarm Products

Realtime versions can be developed

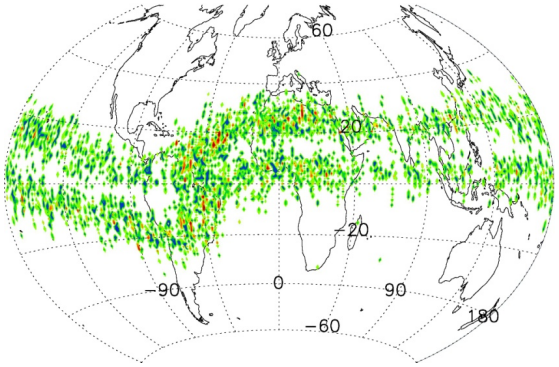
Monitoring electrojets



Ionospheric TEC



Equatorial bubble index



Monitoring Ionospheric irregularities