Meeting for Planning the SCAR Action Group Scientific Programme

"GPS for Weather and Space Weather Forecasting (GWSWF)"

Modena, Italy, April 11-12, 2011

GTWITS for Weather and Space Weather Forecasting

UNIMORE UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

SCAR INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

GNSS Tropospheric Water, Ionospheric TEC and Scintillation for Weather and Space Weather Forecasting (GTWITS/WSWF)

Science proposal draft

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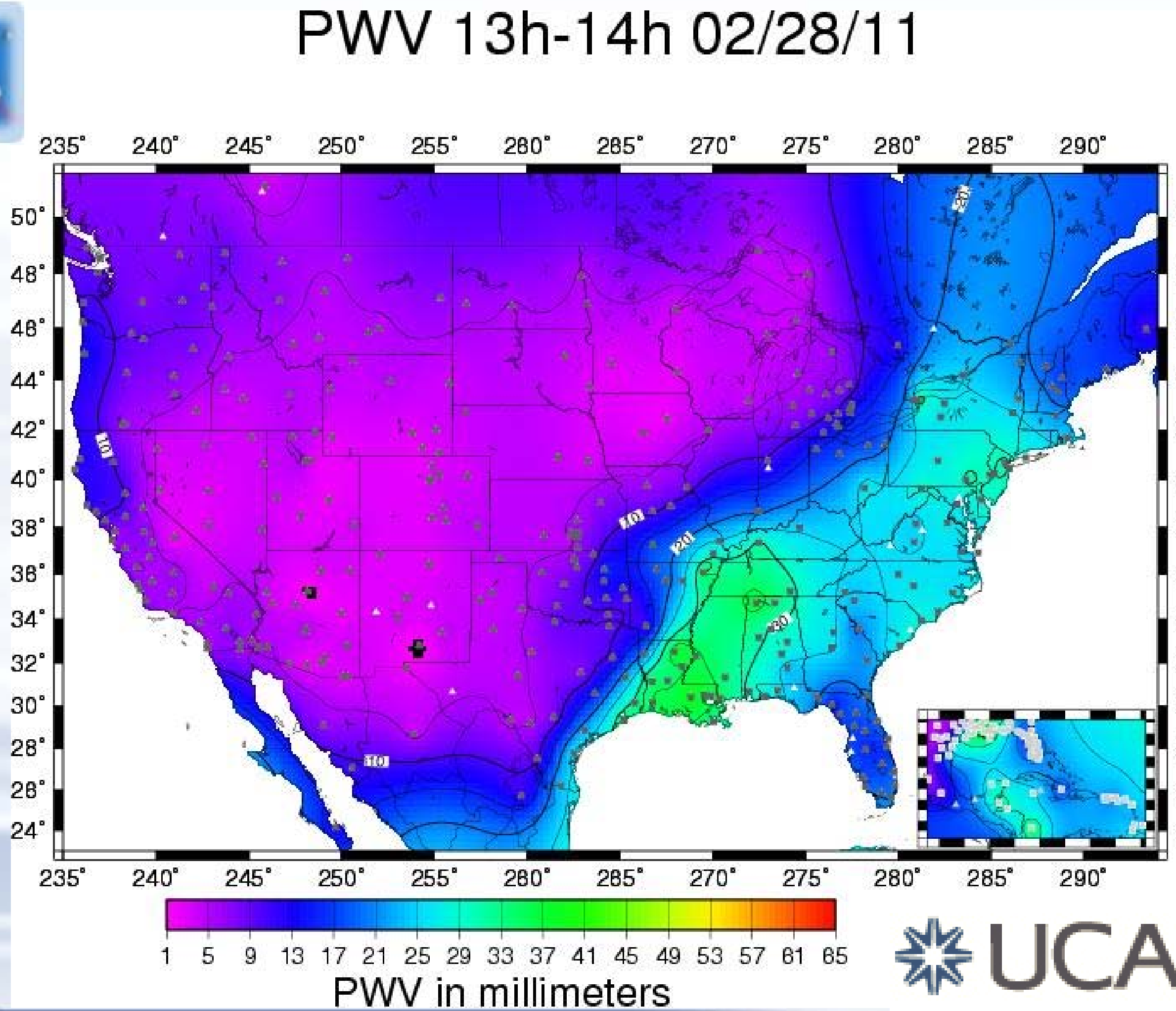
SCIENTIFIC BACKGROUND AND CHALLENGES

- Tropospheric gas concentration causes a delay, which is composed of **hydrostatic and wet delays**, and which influence the GPS/GNSS positioning accuracy.
- **Precipitable water vapor** (PWV) can be retrieved as a valuable input to weather forecast and for atmospheric sensing in remote areas.
- **Ionospheric irregularities** cause rapid fluctuations of radio signal amplitude and phase, called scintillation, that can affect performance of radio communication and navigation systems.
- **Scintillation climatology and mitigation models** to predict and improve the GNSS positioning accuracy in the presence of scintillation need to be developed.
- **Total electron content** (TEC) from L1 and L2 GPS signals provides input to ionospheric models.

GNSS Tropospheric Water, Ionospheric TEC and Scintillation for Weather and Space Weather Forecasting

REAL TIME PRECIPITABLE WATER FROM GPS



SuomiNet Support

http://www.suominet.ucar.edu/map_images/US_PW_CURRENT.jpg

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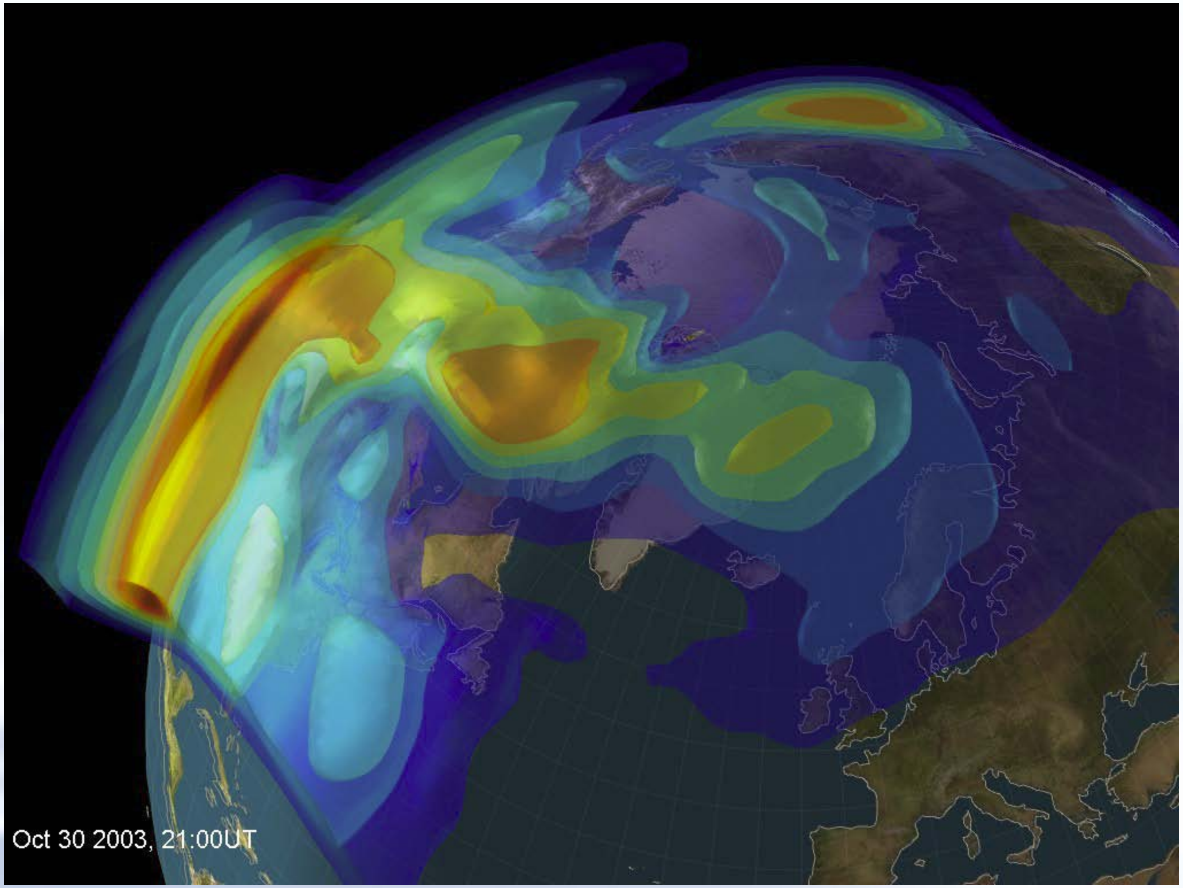
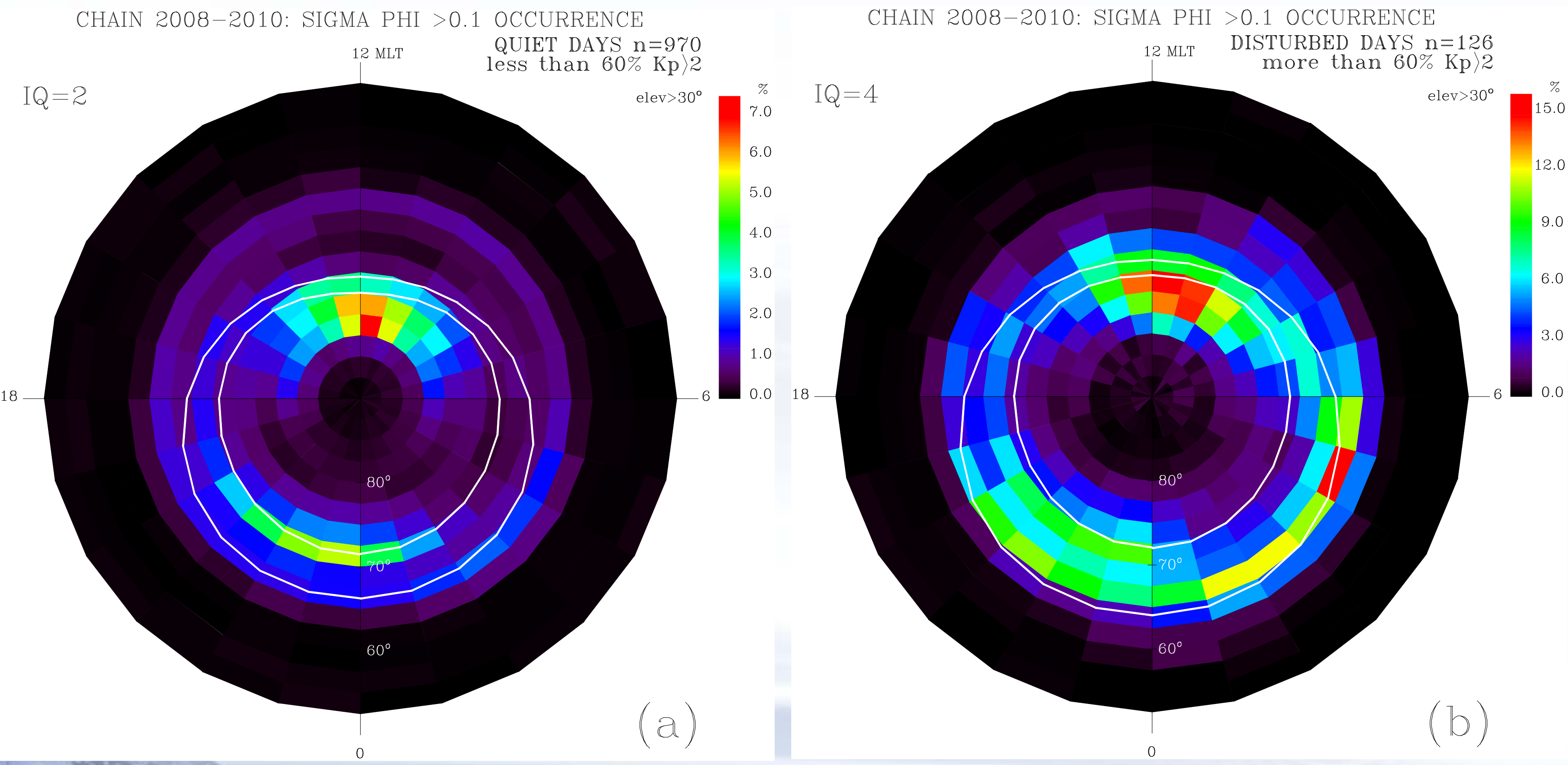
TEC - TOMOGRAPHIC RECONSTRUCTION



4D (3D + time) tomographic inversion algorithm MIDAS (Mitchell & Spencer, 2003, Spencer & Mitchell, 2007) allows to reconstruct plasma density distribution.

Phase scintillation occurrence in 2008-2010 for quiet & moderately disturbed days



OBJECTIVES

- To create and maintain a globally distributed specialized GPS scintillation receiver network.
- To identify and quantify mechanisms that cause scintillation, control interhemispheric differences, asymmetries and commonalities in scintillation occurrence and intensity.
- To develop ionospheric scintillation climatology, tracking and mitigation models to improve prediction capabilities of space weather.
- To retrieve tropospheric PWV for input to weather forecast models and to develop regional PWV climatologies for atmospheric sensing in remote areas.

KEY QUESTIONS

- How does the structure of Earth's ionosphere change qualitatively as well as quantitatively with solar wind conditions and how do these conditions impact TEC variability and scintillation occurrence?

- How do the scintillation-producing irregularities and mechanisms generating them differ in the cusp, auroral oval and at low latitudes?

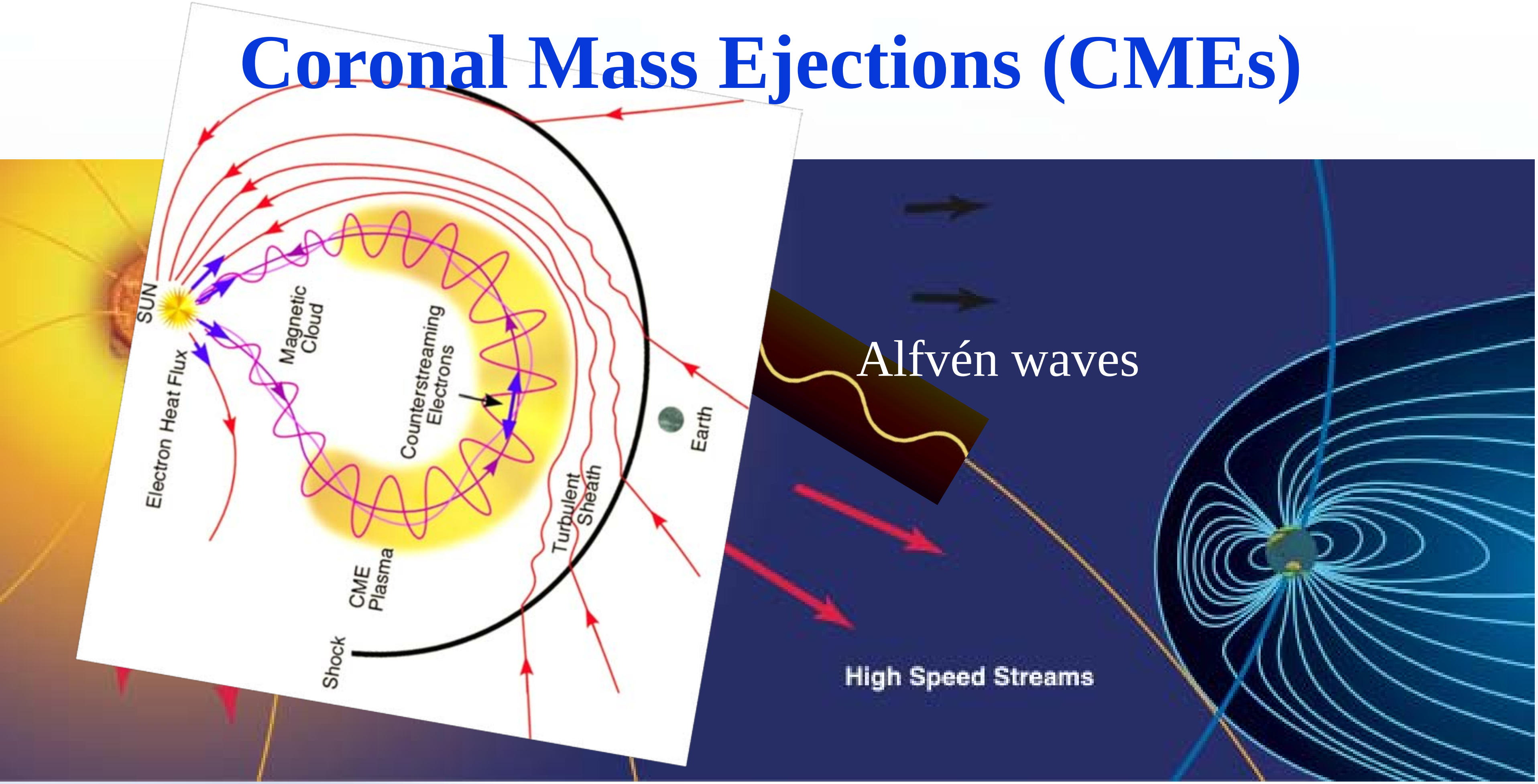
- How to develop scintillation forecasting techniques for high latitude?

- How does the solar illumination control seasonal and diurnal variations of ionospheric scintillation and TEC at high latitudes?

High-Speed Solar Wind Plasma Streams
Corotating Interaction Regions (CIRs)

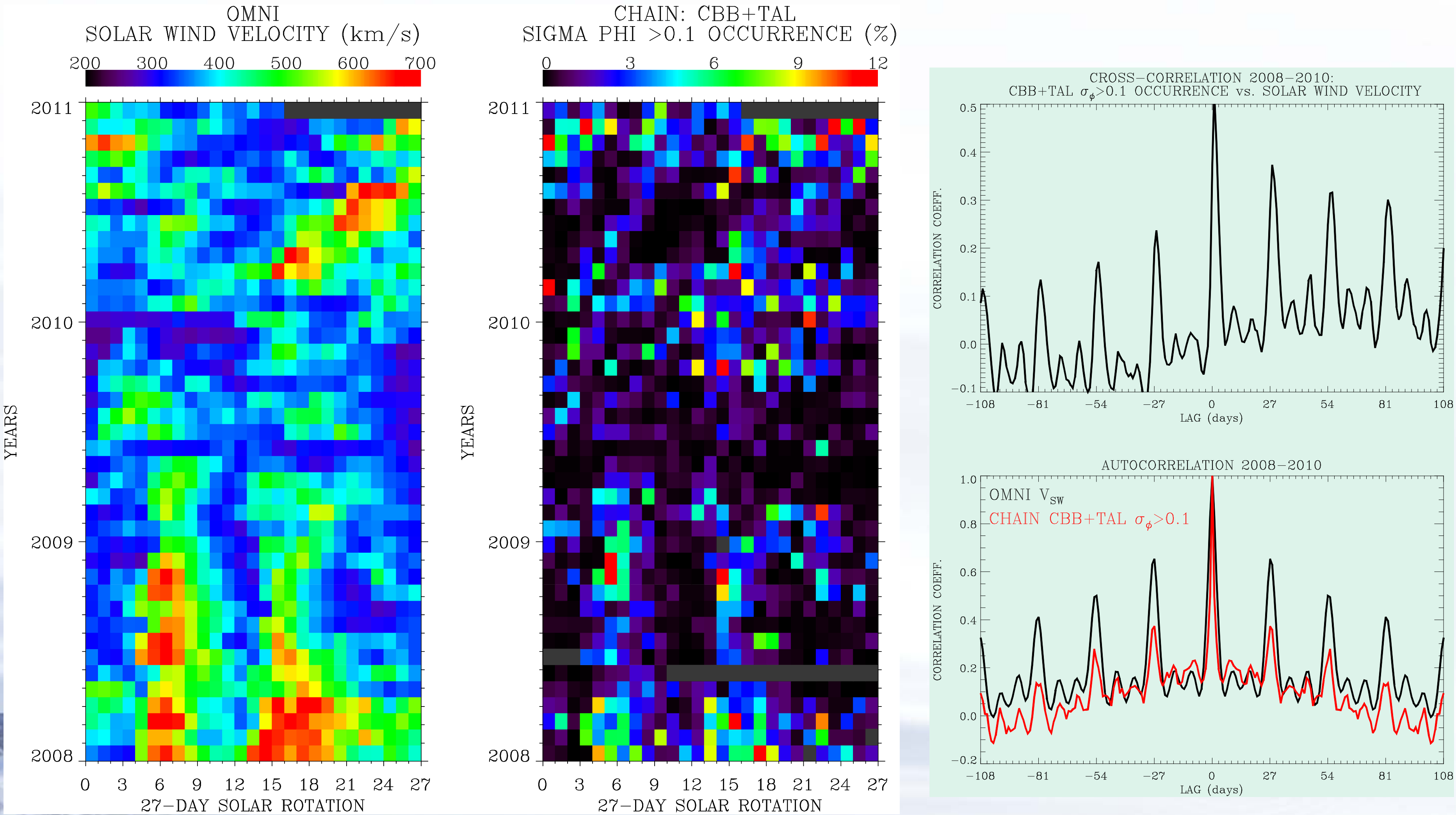
http://www.ava.fmi.fi/~minna/researchseminar/lectures/Eijanluento.pdf

Coronal Mass Ejections (CMEs)



http://www.ava.fmi.fi/~minna/researchseminar/lectures/Eijanluento.pdf

Forecasting phase scintillation at high latitudes?



KEY QUESTIONS cont.

- Are scintillation and TEC affected by mechanical and electrodynamic inputs from the lower atmosphere?

- How accurate are the GPS–based PWV measurements and what is their impact on numerical weather prediction models accuracy?

- What are the short- and long-term variations of PWV in the Arctic and Antarctic regions and what roles do they play in weather and climate?

RATIONALE

- **Ionospheric TEC mapping/imaging.** Aim at realistic 3-D tomographic inversion using the Multi-Instrument Data Analysis System – MIDAS or the Global Assimilative Ionospheric Model – GAIM.
- **Interhemispheric regional differences, asymmetries and commonalities of scintillation occurrence over the Arctic and Antarctic.** Aim at understanding the control mechanisms due to interhemispheric conjugacy, interplanetary or seasonal conditions and the resulting ionospheric structure.
- **Specification and forecasting of scintillation at high latitudes.** Aim at understanding the major solar wind drivers of scintillation including CIRs and CMEs in order to develop appropriate forecasting techniques.

RATIONALE cont.

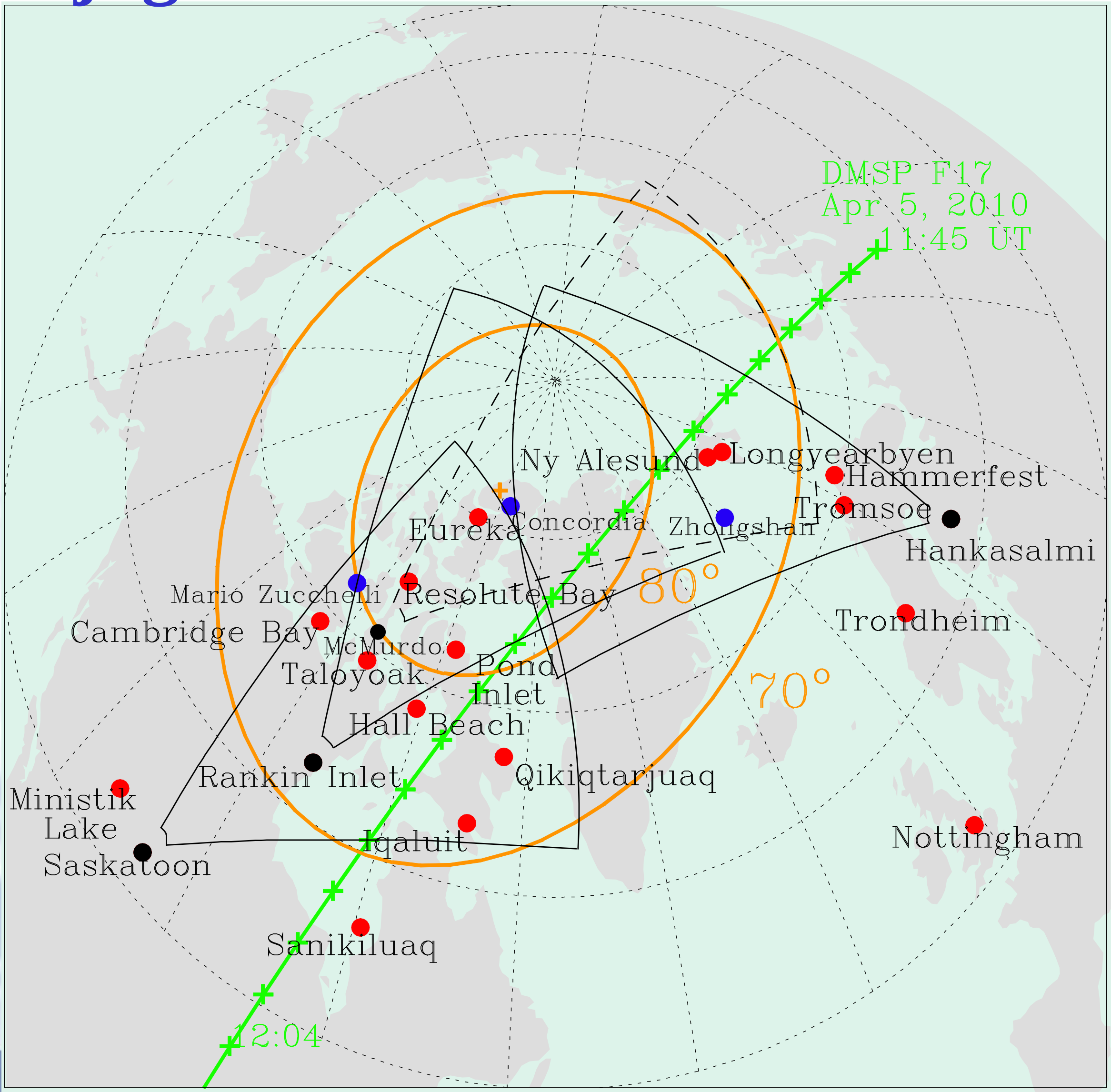
- **Novel countermeasure techniques to mitigate the presence of scintillation and PWV, and to improve GNSS applications like PPP.** Aim at understanding the causes of ionospheric scintillation, applications of appropriate mapping functions and spatial interpolation techniques for input from weather forecast models, in order to develop and use of a scintillation model and tracking error predictor/mitigation model.
- **Atmospheric sensing in remote areas.** Aim at resolving large differences that are found in the seasonal signals, anomalies and variability of PWV between the GPS and reanalysis data in the Southern Hemisphere.
- **Vertical coupling between the lower and upper atmosphere.** Aim at understanding the interaction between the ionosphere and neutral upper/middle/lower atmosphere, and momentum/energy transfer upward or downward.

METHODOLOGY AND IMPLEMENTATION

- Create the GWSWF data portal to facilitate sharing and utilization of the GNSS and geophysical databases. The data portal will be linked to other useful databases for easy access, and encourage the collaboration, data sharing and help in interpretation of the results.

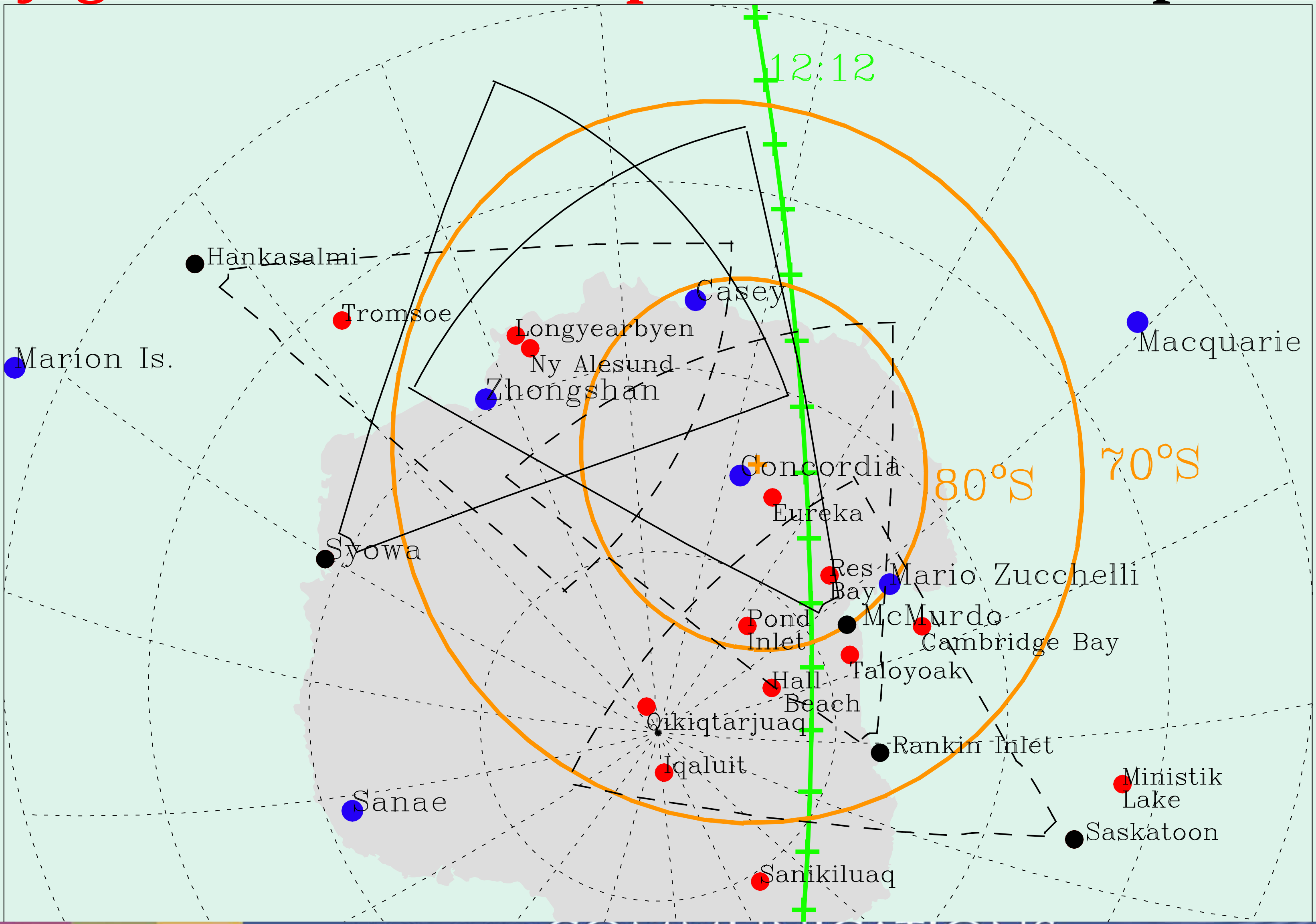
- Merge existing networks of GPS receivers and support instrumentation and identify geographical areas lacking necessary observation. New deployment of needed instrumentation in order to improve climatological studies, forecasting and modeling efforts.

CHAIN + European GISTMs
"Conjugate" GPS receivers in Antarctica



GPS receivers in Antarctica

Conjugate CHAIN + European GISTMs + SuperDARN



METHODOLOGY AND IMPLEMENTATION cont.

- Joint studies on relevant scientific topics, development of models and mitigation techniques will be planned and coordinated. Annual meetings/workshops will provide forum for discussions and focus the community efforts towards the GTWITS/WSWF project goals.
- Identify and form several working groups to focus on areas such as data formats and archiving, common software development and data handling, quantifying the causes of scintillation and the role of solar wind interaction with the Earth’s magnetosphere-ionosphere system, development of scintillation and tropospheric PWV climatologies, scintillation forecasting, and tracking and mitigation models.

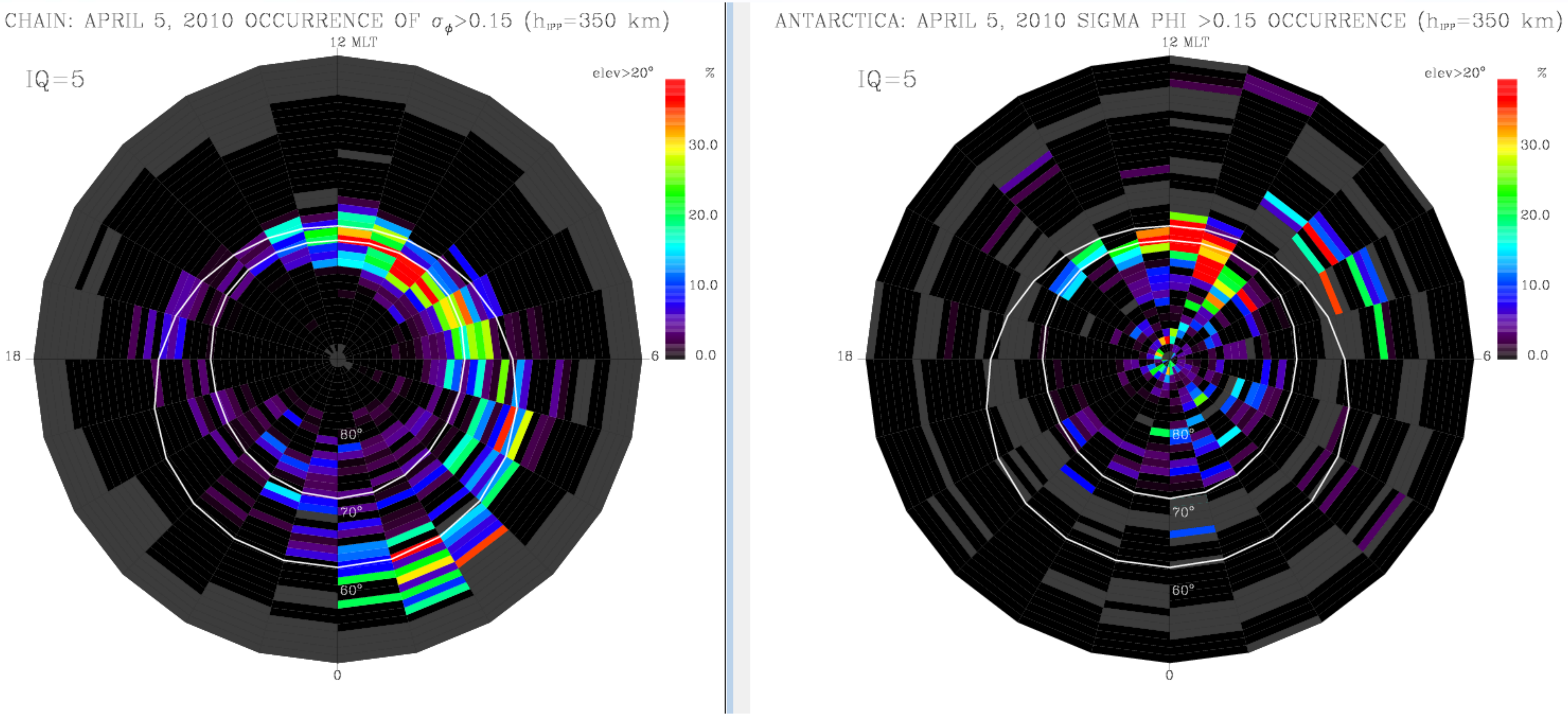
Inter-hemispheric comparison of GPS phase scintillation at high latitudes during the magnetic-cloud-induced geomagnetic storm of April 5-7, 2010

Prikryl, P.[1], Spogli, L.[2], Jayachandran, P. T.[3], Mitchell, C. N.[4], Ning, B.[5], Li, G.[5], Cilliers, P. J.[6], Opperman, B. D. L.[6], Terkildsen, M.[7], Danskin, D. W.[8], Spanswick, E.[9], Donovan, E.[9], Alfonsi, L.[2], De Franceschi, G.[2], Romano, V.[2]

[1]Communications Research Centre Canada
[2]Istituto Nazionale di Geofisica e Vulcanologia
[3]Physics Department, University of New Brunswick
[4]Department of Electronic and Electrical Engineering, University of Bath
[5]Institute of Geology and Geophysics, Chinese Academy of Sciences
[6]Hermanus Magnetic Observatory, Hermanus, South Africa
[7]IPS Radio and Space Services, Bureau of Meteorology, Australia
[8]Space Weather Hazards Geomagnetic Laboratory, Natural Resources
[9]Department of Physics and Astronomy, University of Calgary

Phase scintillation occurrence on April 5, 2010 mapped as a function of magnetic latitude and MLT

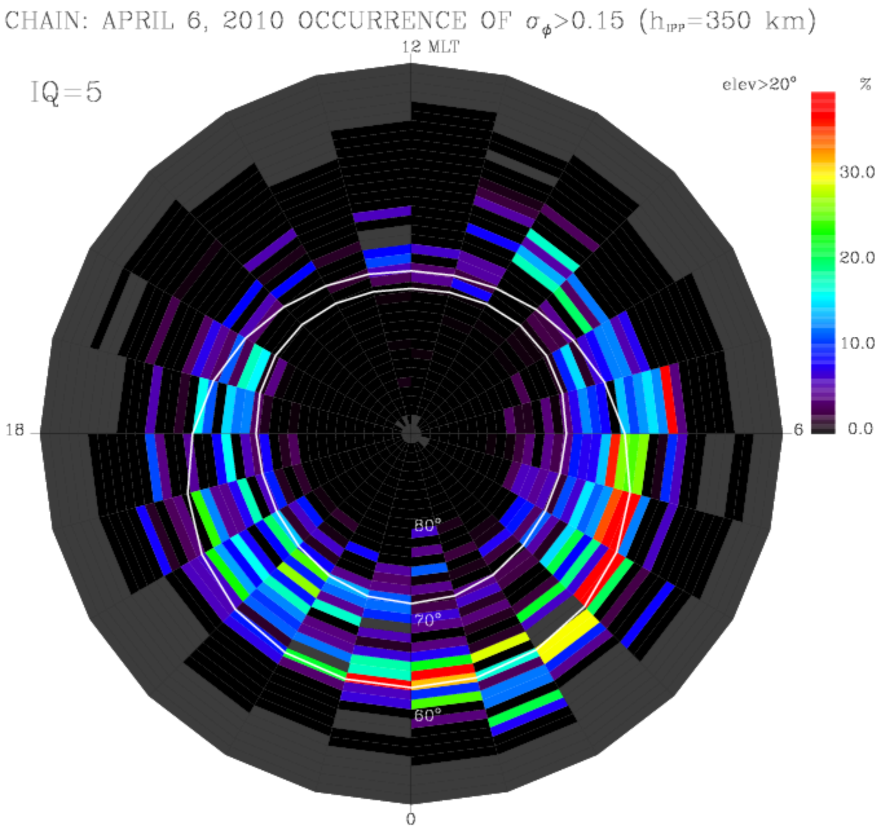
Northern & Southern Hemisphere

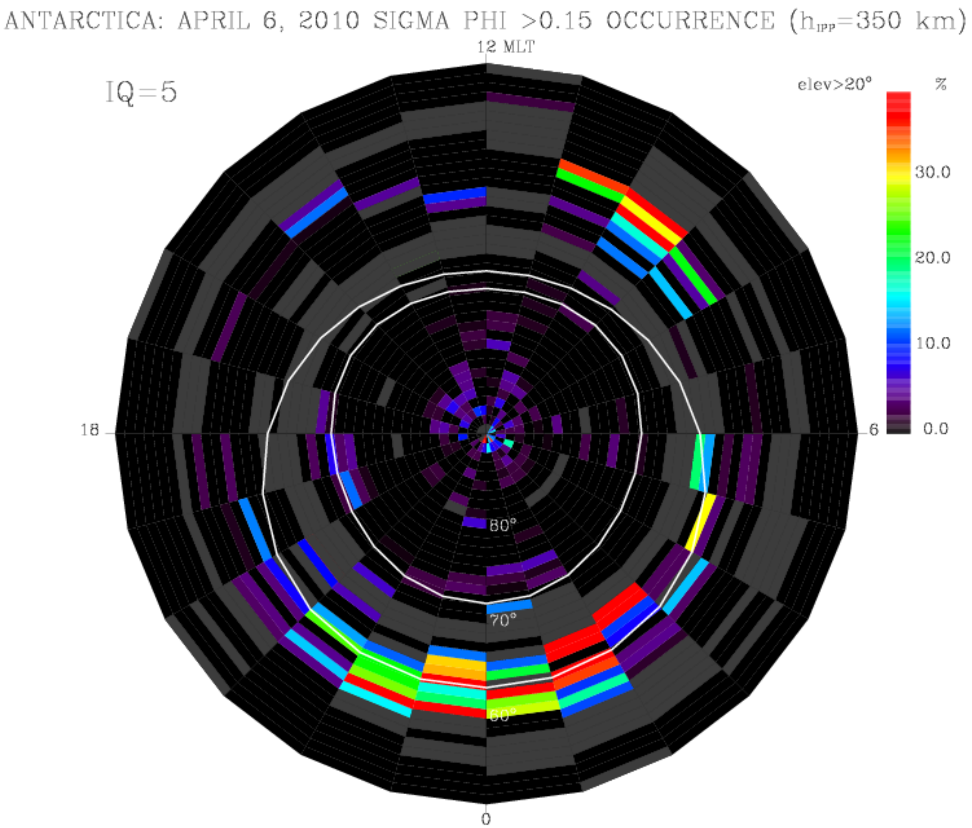


FIRST DAY OF THE STORM

Phase scintillation occurrence on April 6, 2010 mapped as a function of magnetic latitude and MLT

Northern & Southern Hemisphere

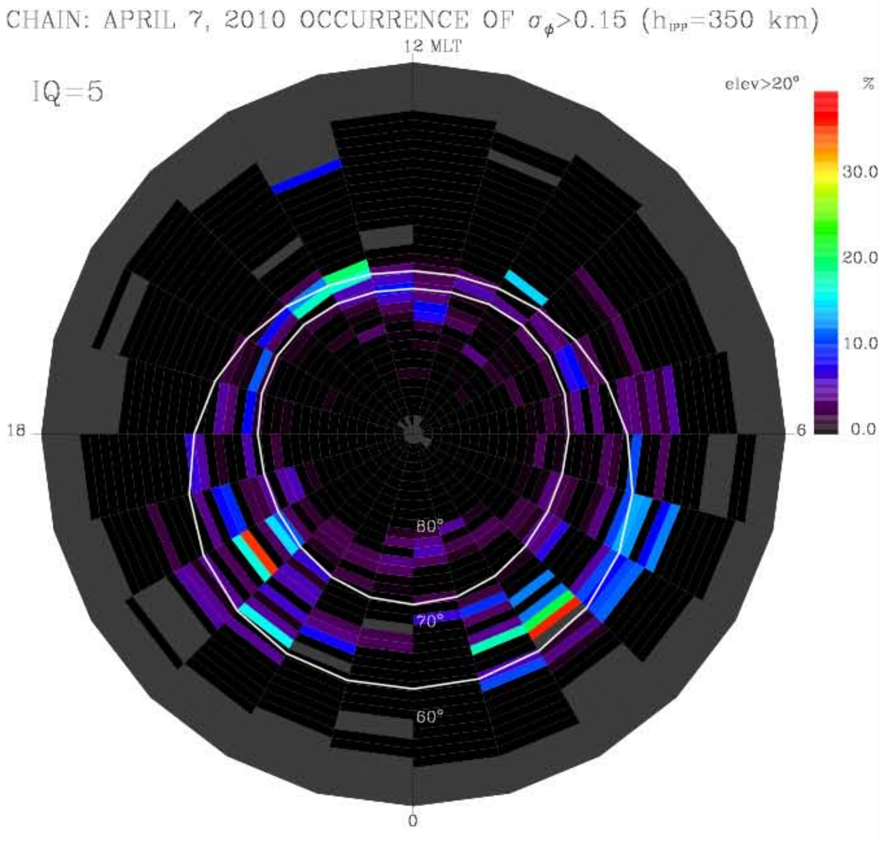


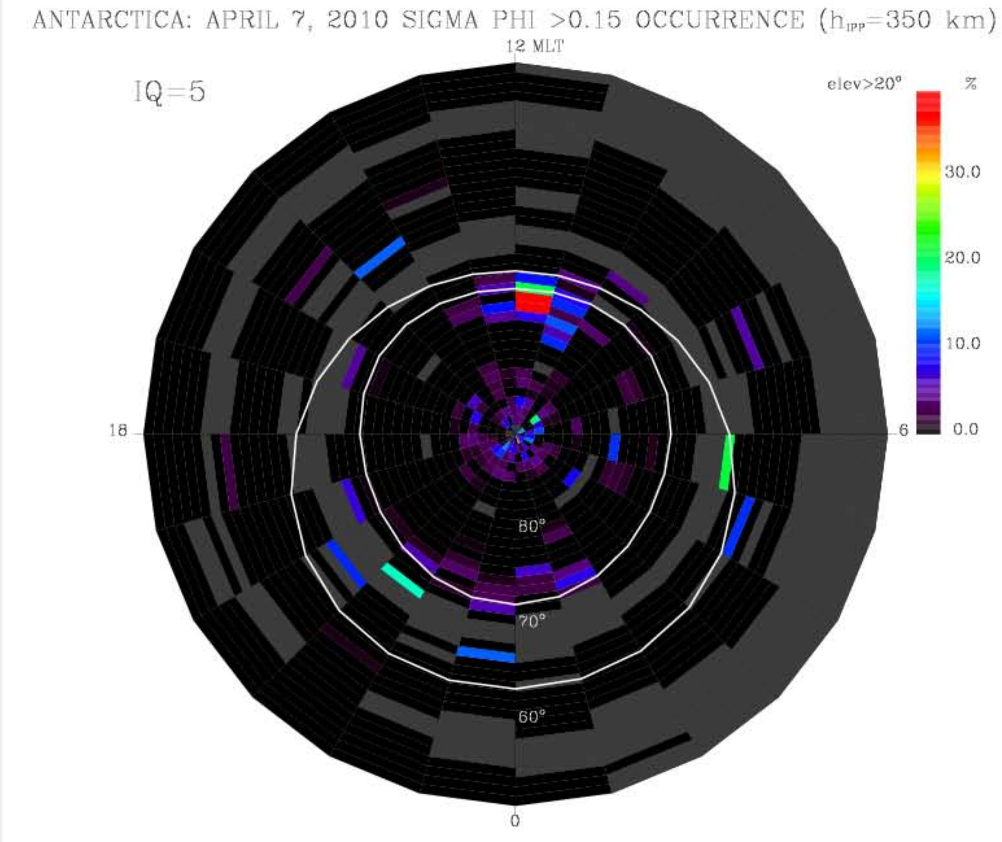


SECOND DAY OF THE STORM

Phase scintillation occurrence on April 7, 2010 mapped as a function of magnetic latitude and MLT

Northern & Southern Hemisphere



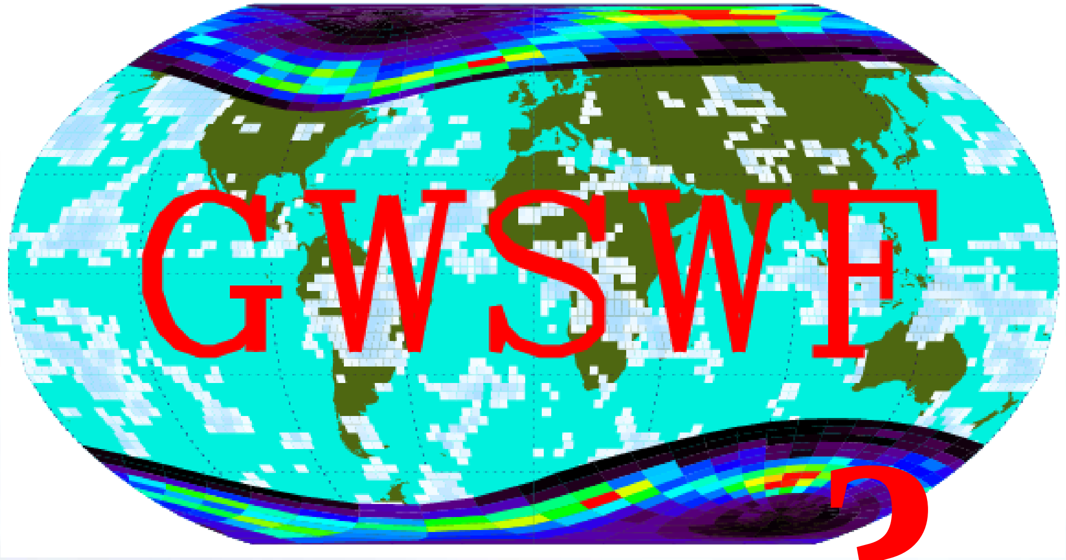


THIRD DAY OF THE STORM

Recovery

Collaboration with SCAR Scientific Research Programmes and/or Standing Groups

- **ICESTAR** (Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research)
- **POLENET** (Polar Earth Observing Network)



GPS for Weather and Space Weather Forecasting

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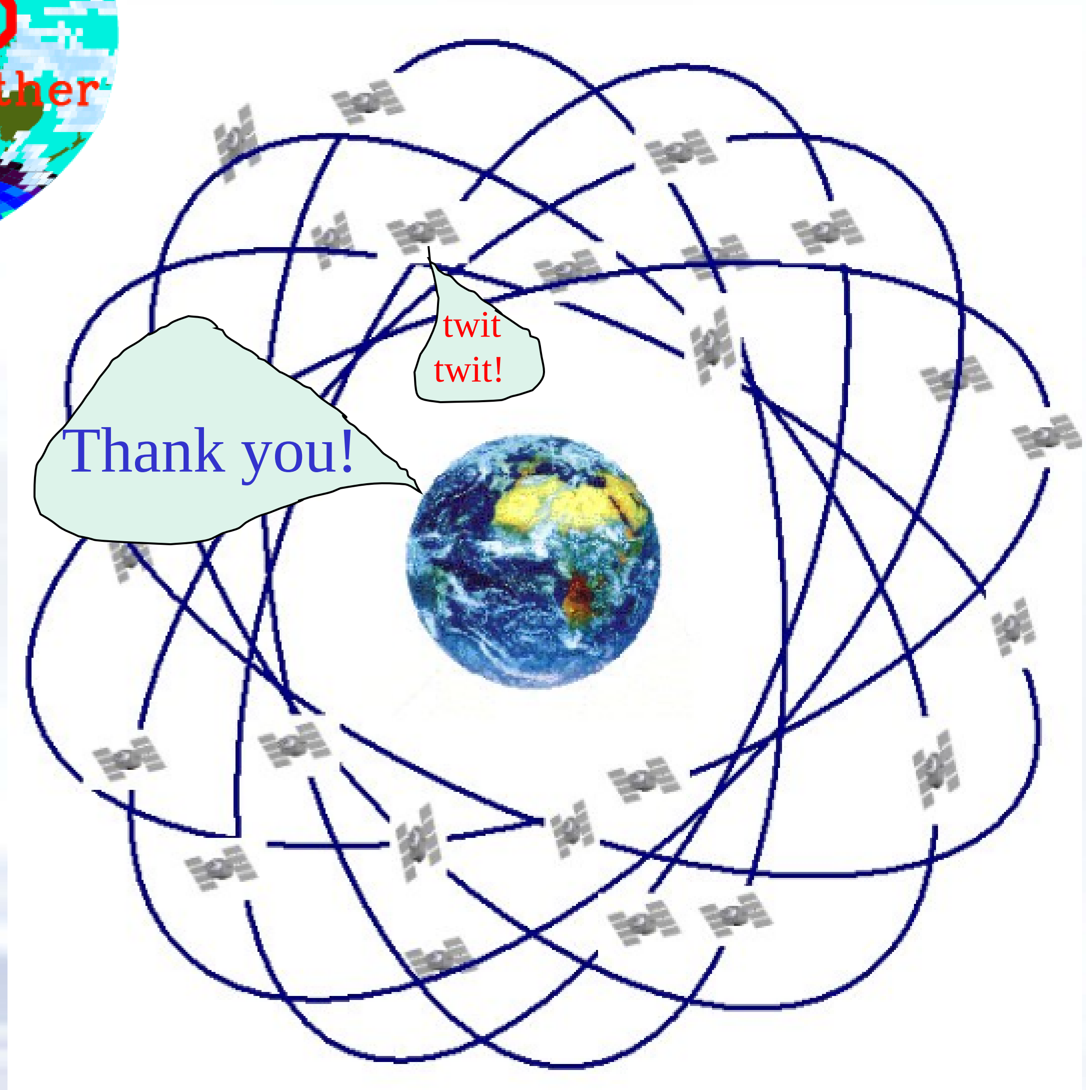
GTWITS

for Weather and Space Weather Forecasting



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