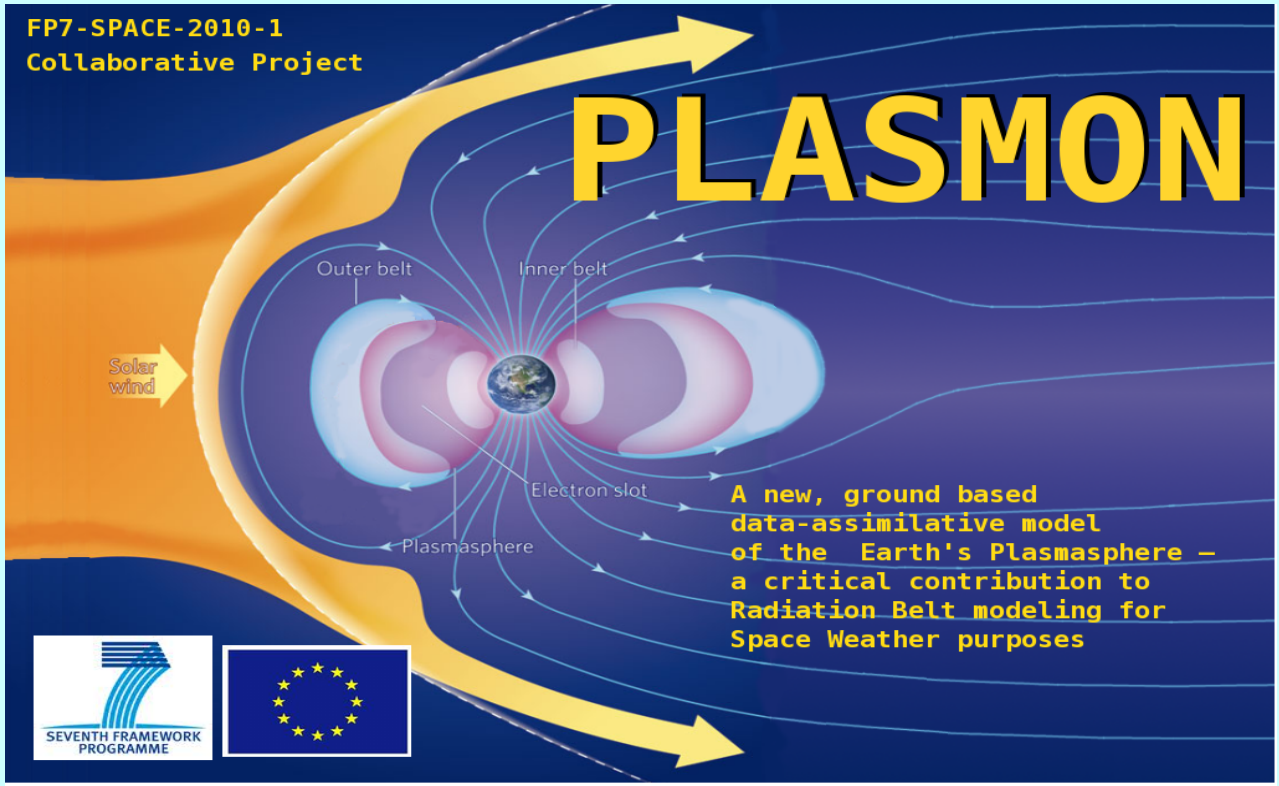


Global Ground Based VLF and ULF Networks for Modeling the Plasmasphere and Space Weather Events - PLASMON

Lichtenberger, J. 1, M. Clilverd2, M. Vellante3, J. Manninen4, C. Rodger5, A. Collier6, A. Jorgensen7, J. Reda8, R. Holzwoth9, Reiner Friedel10, and ***B. Heilig11***

(1) Eötvös University, HU, (2) British Antarctic Survey, UK, (3) University of L'Aquila, IT, (4) University of Oulu, FI, (5) University of Otago, NZ, (6) South African Space Agency, SA, (7) New Mexico Institute of Mining and Technology, US, (8) Institute of Geophysics, PL, (9) University of Washington. US, (10) Los Alamos National Laboratory, US, (11) Eötvös Loránd Geophysical Institute, HU

8th European Space Weather Week

PLASMON

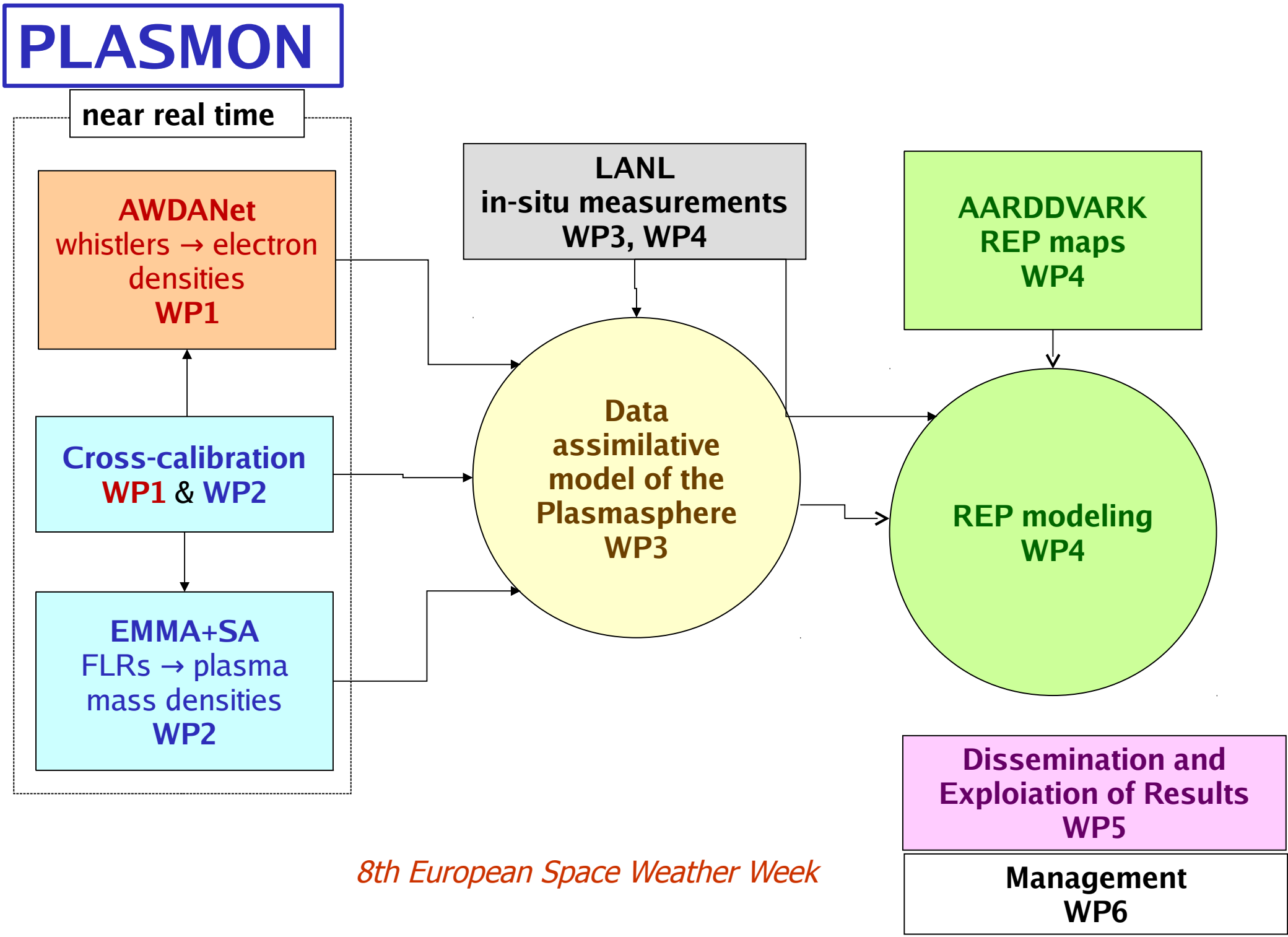
Objectives

The security of space assets are affected by the high-energy charged particle environment in the **radiation belts**. During geomagnetic storms the time during which space assets are in danger is determined by the loss mechanisms, particularly by **relativistic electron precipitation (REP)**. The primary mechanism for this precipitation is the interaction of several wave modes with resonant electrons which leads to scattering into the atmospheric loss cone. The nature of the wave activity and the interactions between the waves and radiation belt **particles** are strongly governed by the properties of the **plasmasphere**.

PLASMON aims

- at near real time monitoring **plasmaspheric electron** and **mass densities** and hence the changing composition of the plasmasphere
- to develop a **data assimilative model of the plasmasphere**
- to monitor the occurrence and properties of **REP**, tying the time-resolved loss of relativistic electrons to the dynamic plasmasphere observations.

PLASMON



8th European Space Weather Week

PLASMON

Participants

Participant		Country
Eötvös University	János Lichtenberger	Hungary
British Antarctic Survey	Mark Clilverd	UK
Eötvös Loránd Geophysical Institute	Balázs Heilig	Hungary
University of L'Aquila	Massimo Vellante	Italy
Sodankyla Geophysical Observatory	Jyrki Manninen	Finland
University of Otago	Craig Rodger	New Zealand
Hermanus Magnetic Observatory	Andrew Collier	South Africa
New Mexico Institute of Mining and Technology	Anders Jorgensen	USA
Institute of Geophysics, Polish Academy of Sciences	Jan Reda	Poland
University of Washington	Robert Holzworth	USA
Los Alamos National Laboratory	Reiner Friedel	USA

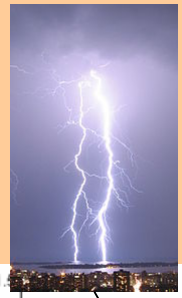
5 European countries + USA (3), New-Zealand, South-Africa

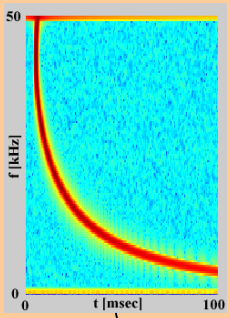
PI: J. Lichtenberger (Hungary)

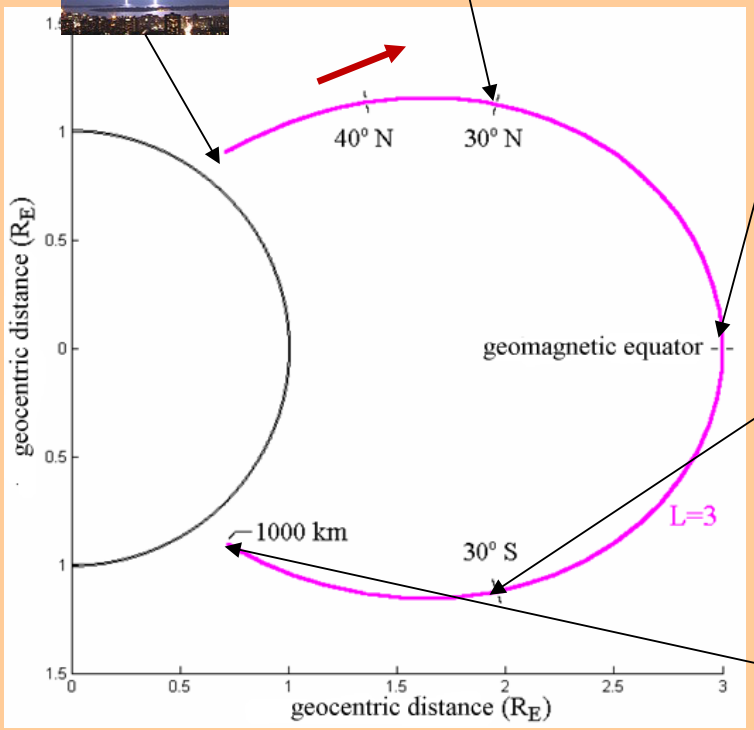
WP1

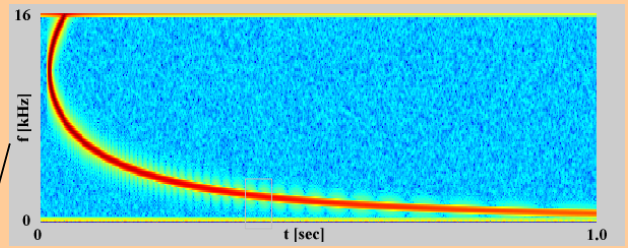
VLF whistlers

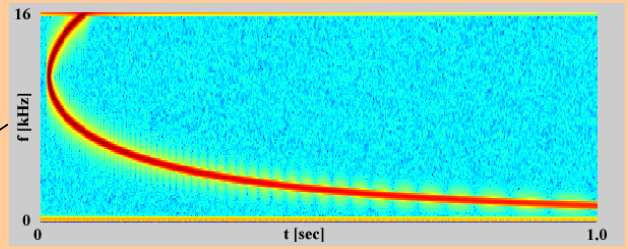
WP leader
J. Lichtenberger

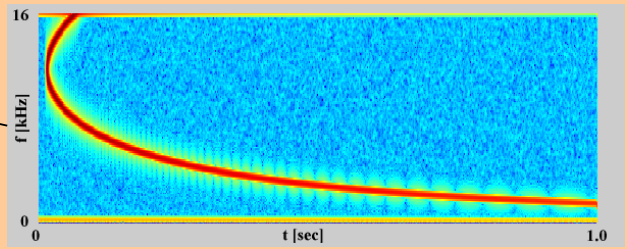












- **lightning > whistlers**
  short, broad band impulse (UWB)

- from the **nose frequency** and **dispersion:**

  - **Equatorial e- density**
  - **L-value**

WP1

AWDA

WP leader
J. Lichtenberger

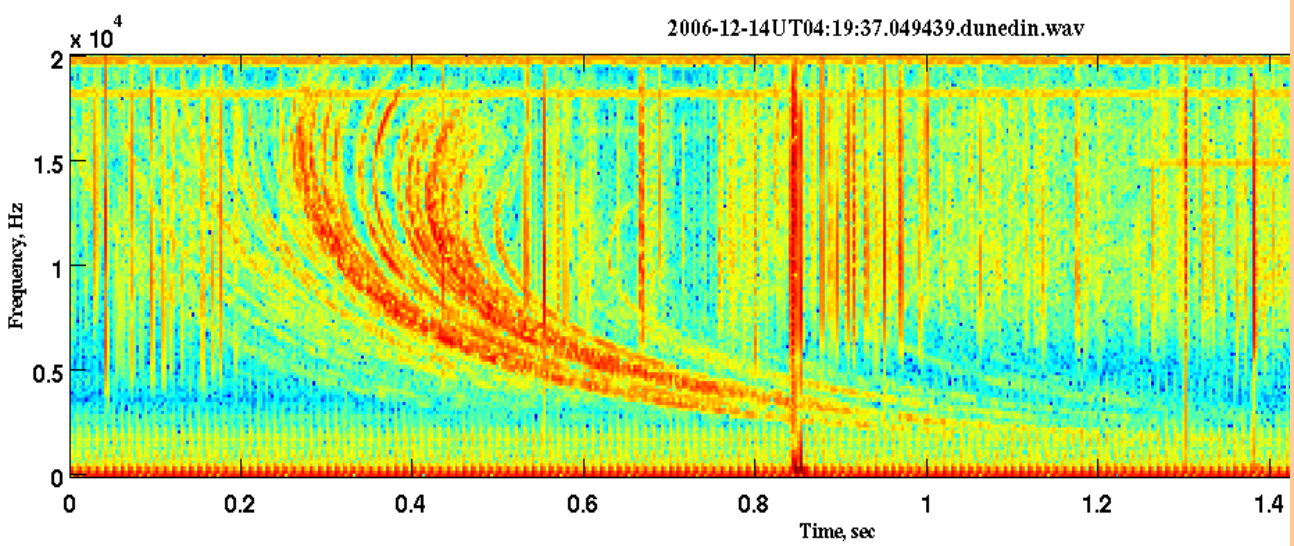
Automatic Whistler Detector and Analyser:

Lichtenberger et al. 2008, JGR; Lichtenberger et al. 2010, JGR

New inversion method:

Lichtenberger 2009, JGR

yields e- density as a function of L-shell



Whistler group recorded at Dunedin, New Zealand

Exact full-wave solution of Maxwell's equations in inhomogeneous, moving media (Ferencz 2011, Radio Sci.)

WP1

DANet - Europe

existing stations

planned stations

planned in PLASMON

nta szöveg szerkesztése

sodik szint

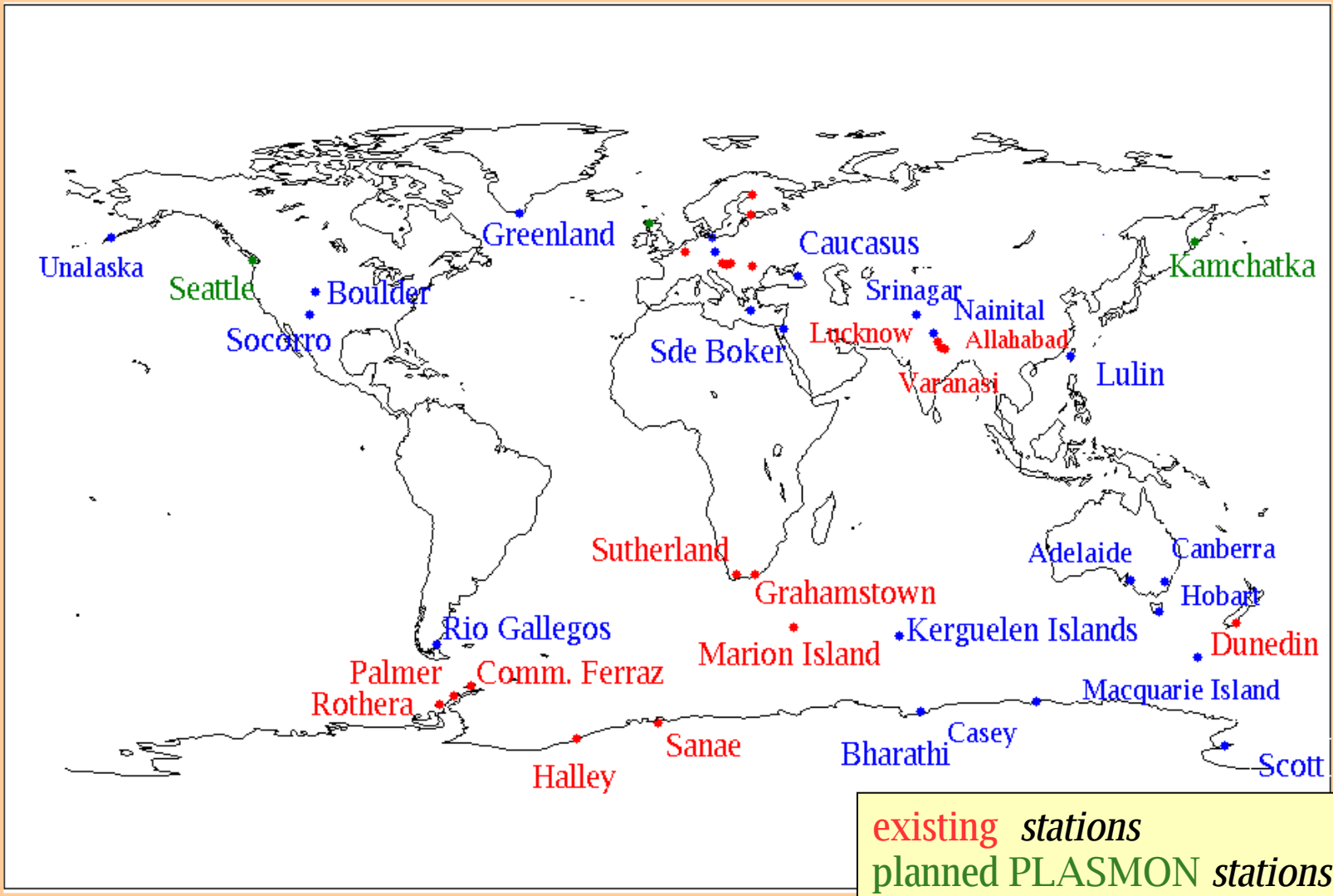
madik szint

yedik szint

lik szint

WP1

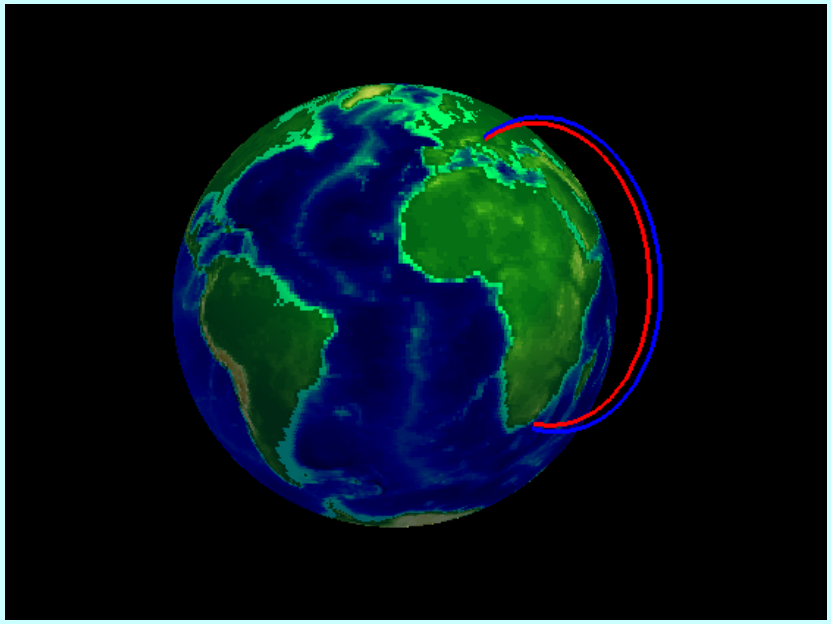
DANet - World

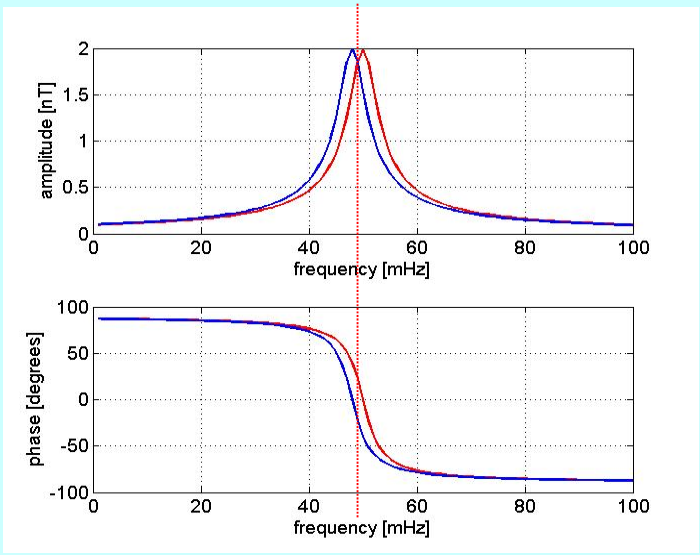


existing *stations*
planned PLASMON *stations*
planned *stations*

WP2 ULF Field Line Resonances

WP leader
M. Vellante





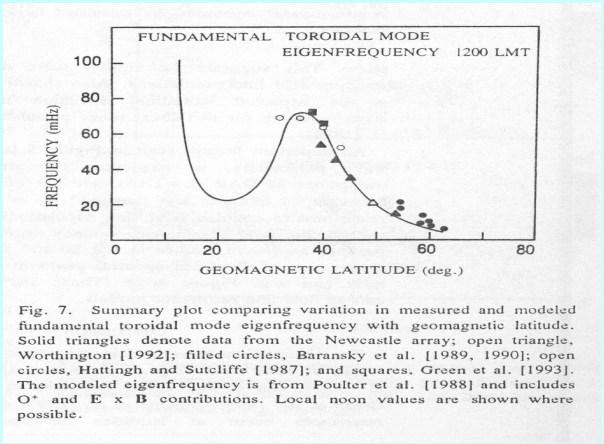
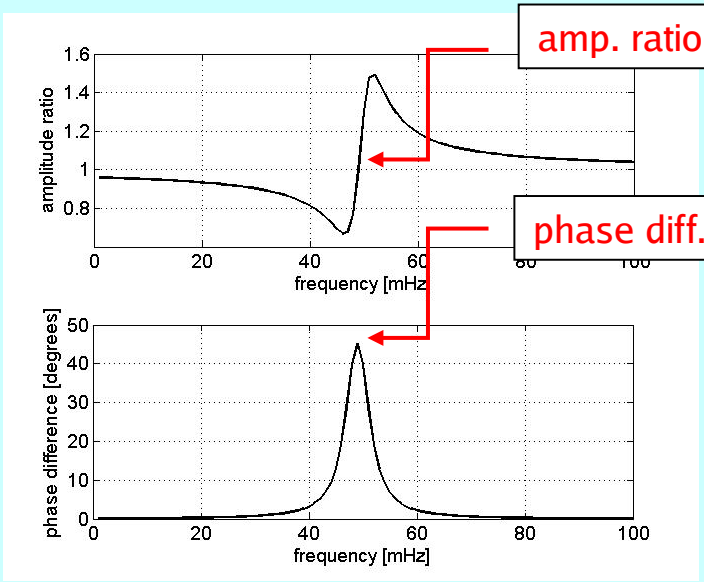


Fig. 7. Summary plot comparing variation in measured and modeled fundamental toroidal mode eigenfrequency with geomagnetic latitude. Solid triangles denote data from the Newcastle array; open triangle, Worthington [1992]; filled circles, Baransky et al. [1989, 1990]; open circles, Hattingh and Sutcliffe [1987]; and squares, Green et al. [1993]. The modeled eigenfrequency is from Poulter et al. [1988] and includes O^+ and E x B contributions. Local noon values are shown where possible.



WP2

FLRID routine

WP leader
M. Vellante

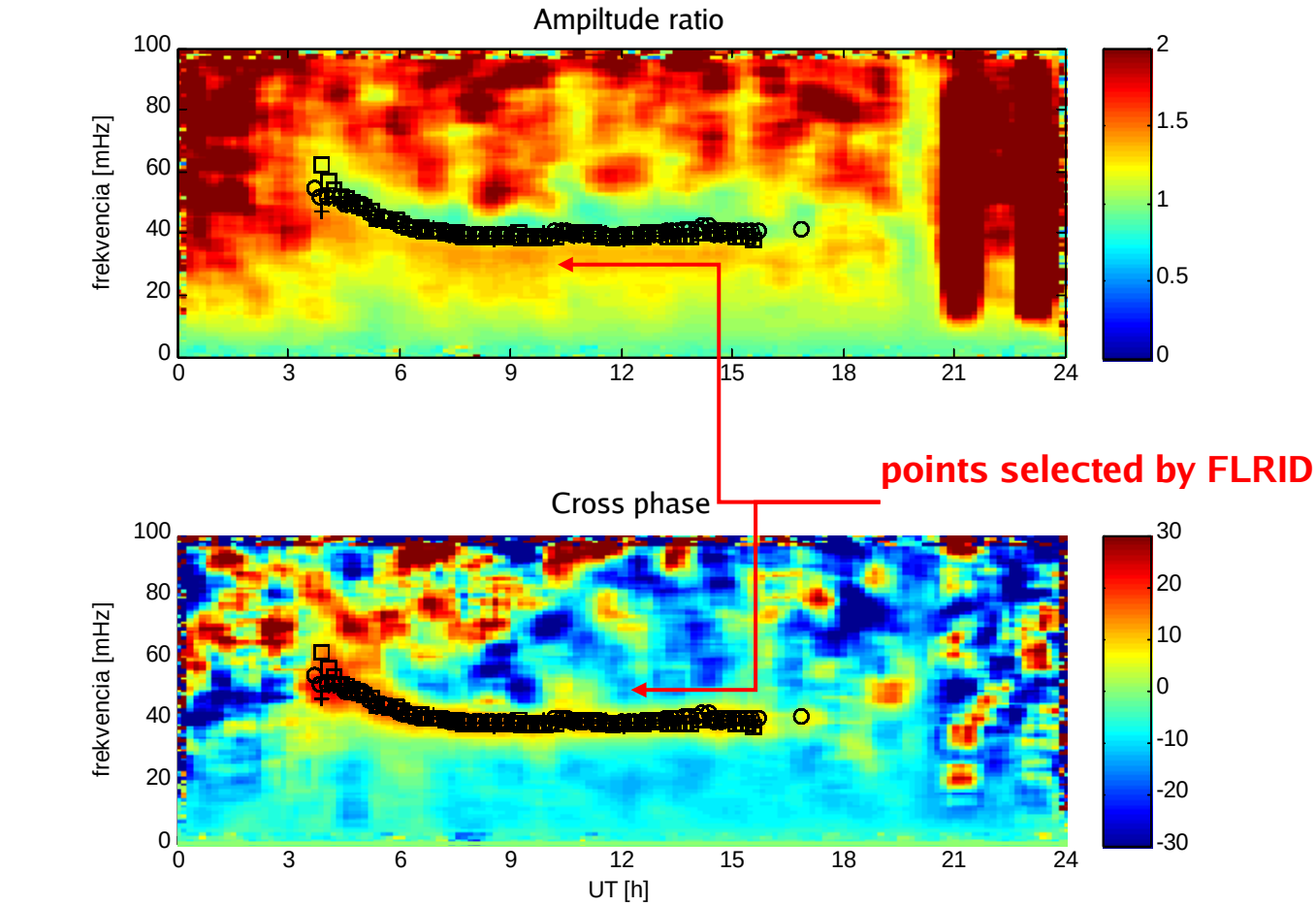
ULF records

FLRID
Amplitude and Phase Gradient Method (APGM)

Waters et al. 1991, JGR
Berube at al. 2003, JGR

FLRINV
numerical solutios of Singers, 1981

plasma mass densities

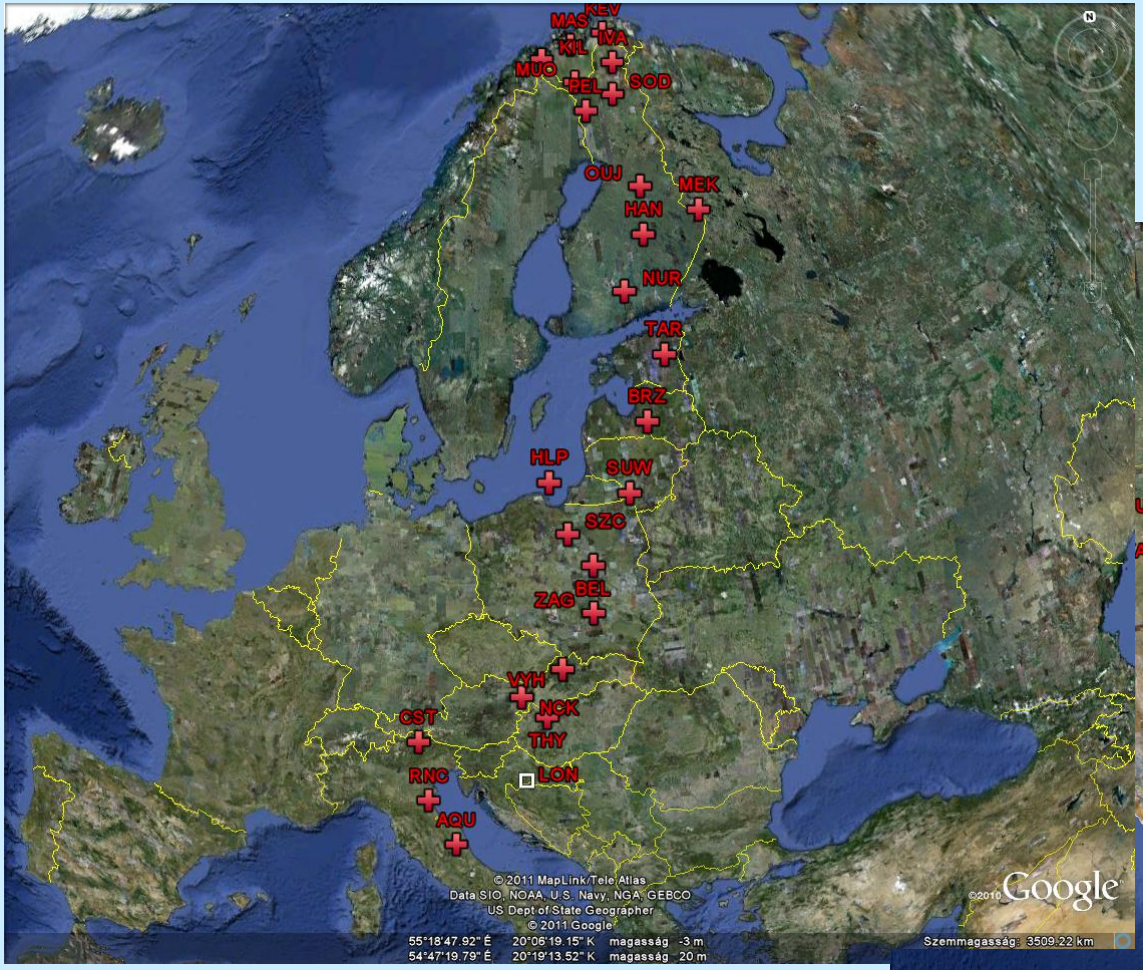


Daily spectrogram

WP2

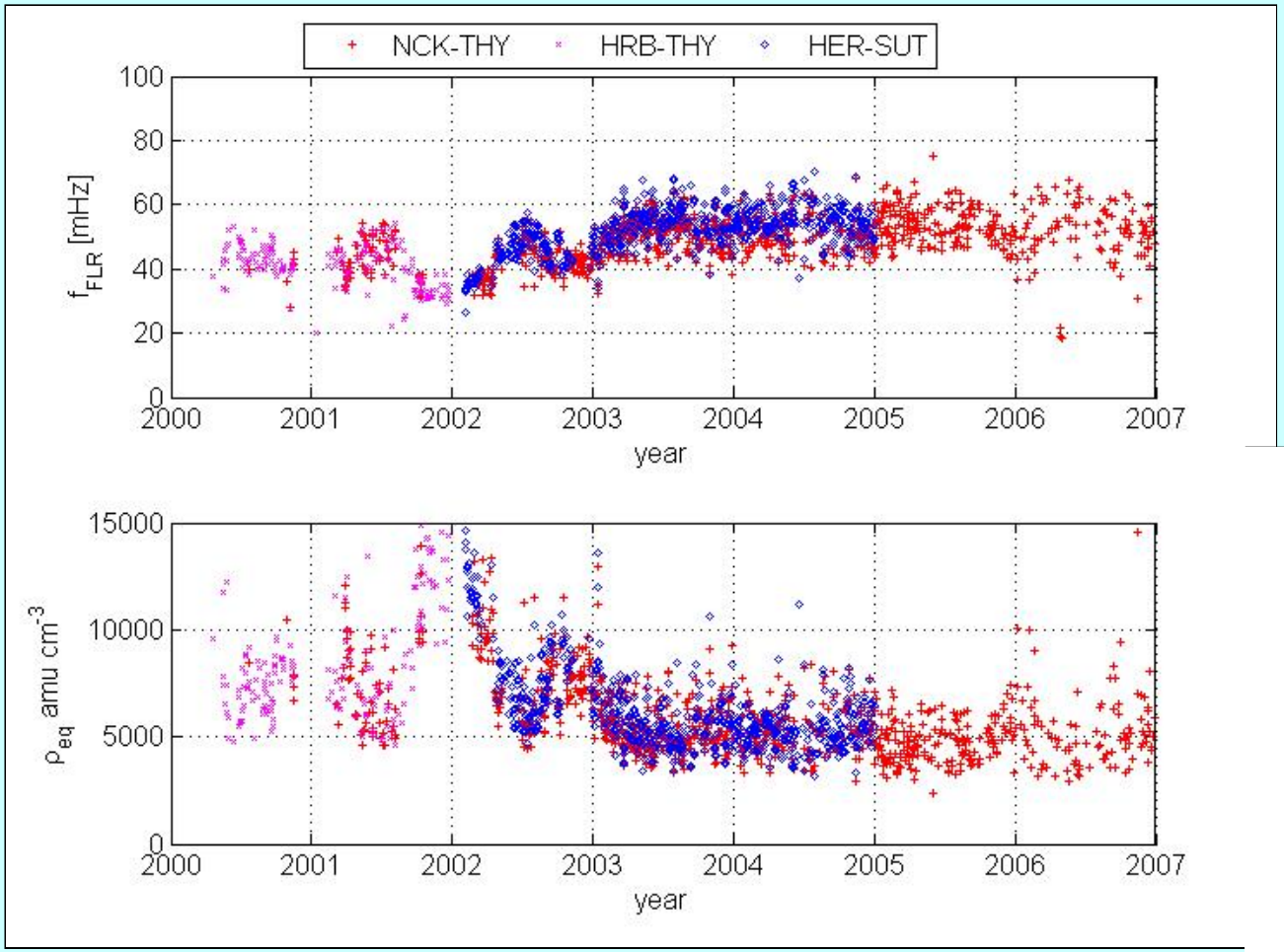
EMMA + SA network

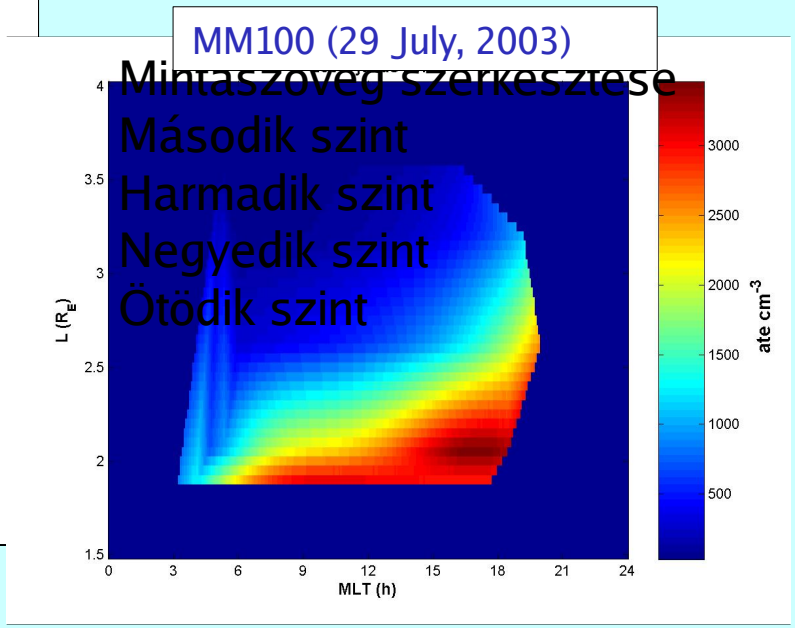
European quasi-Meridional Magnetometer Array



SANSA Magnetometer Network

WP2 Seasonal and solar cycle variation of plasma mass density at L = 1.85

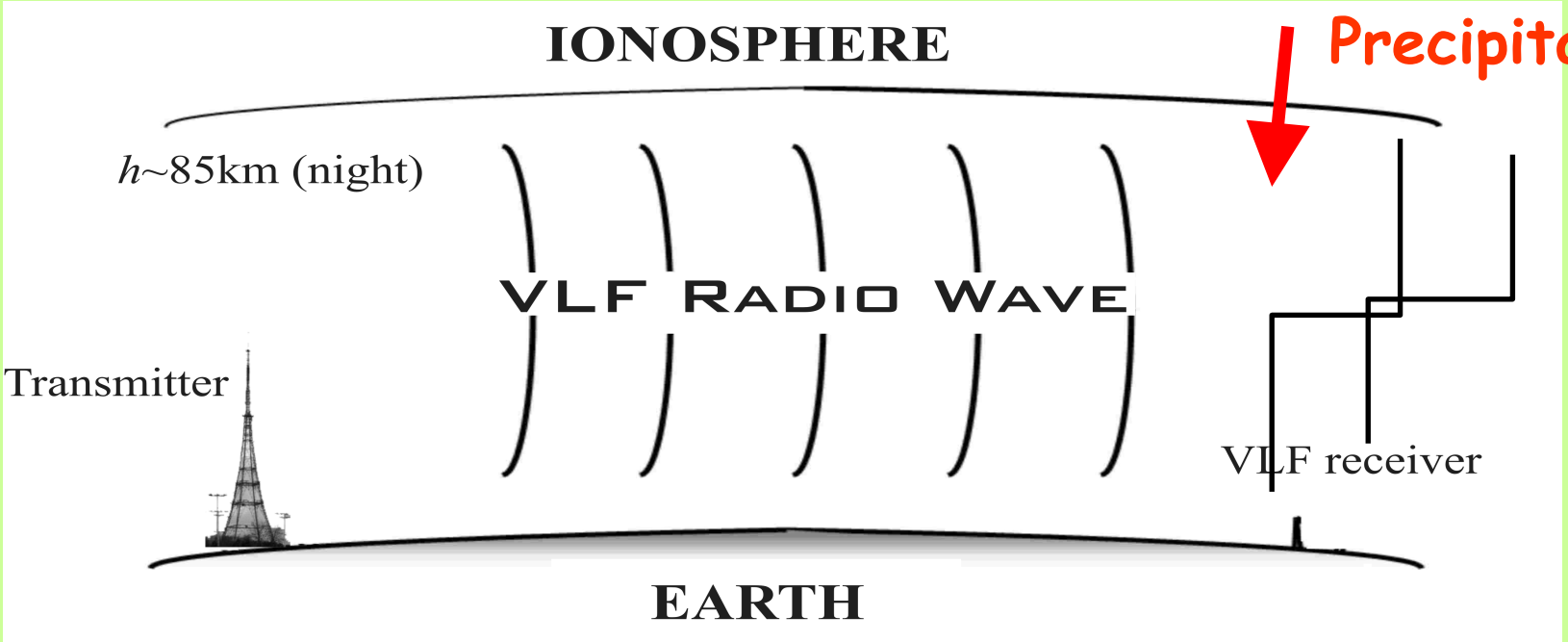




WP4

AARDDVARK

WP leader
M. Clilverd



Ionosphere is used as a precipitation detector: Subionospheric Radio Wave Propagation

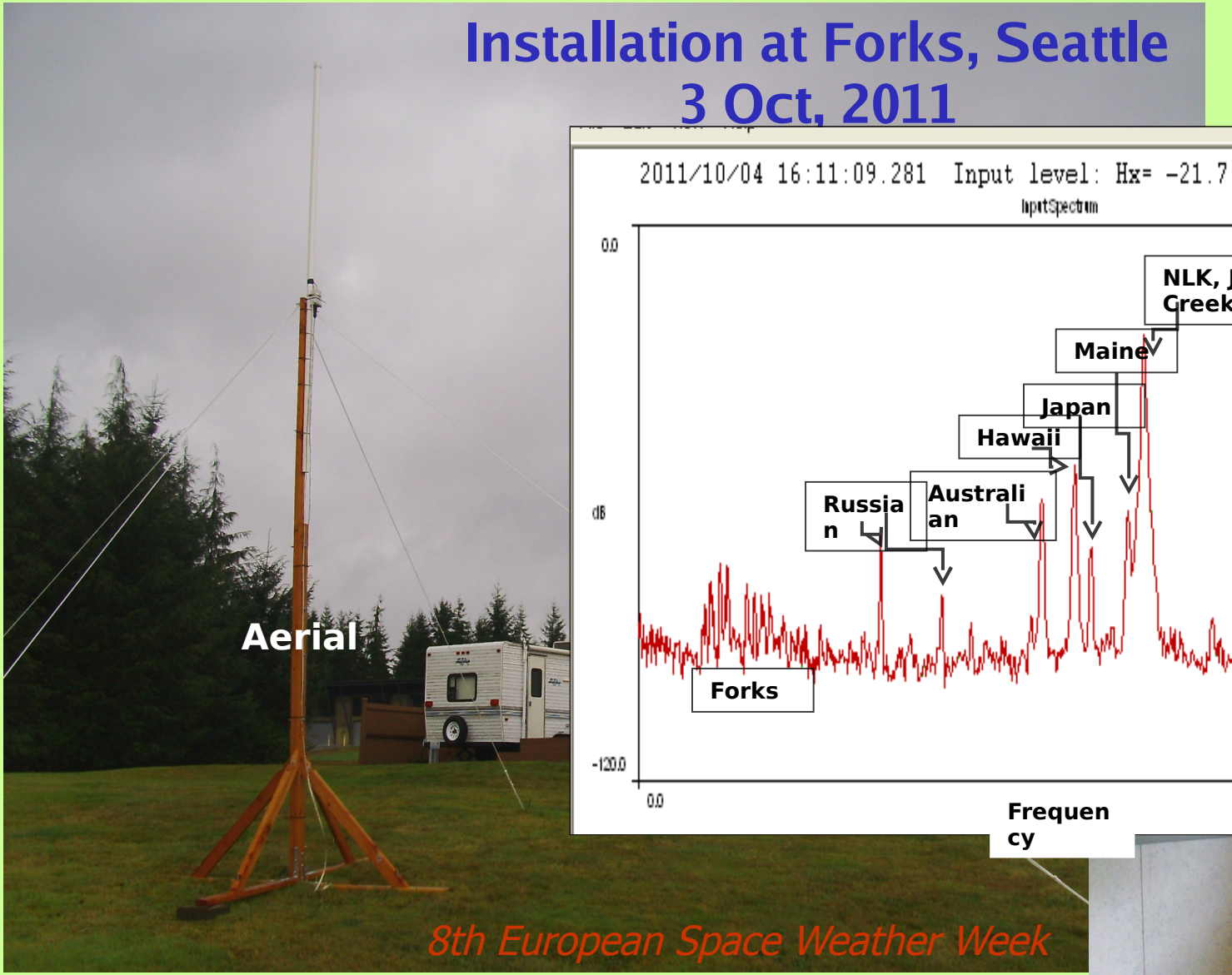
Radio transmissions at VLF largely trapped between the conducting ground (or sea) and the lower part of the ionosphere (70-90 km), forming the Earth-ionosphere waveguide.

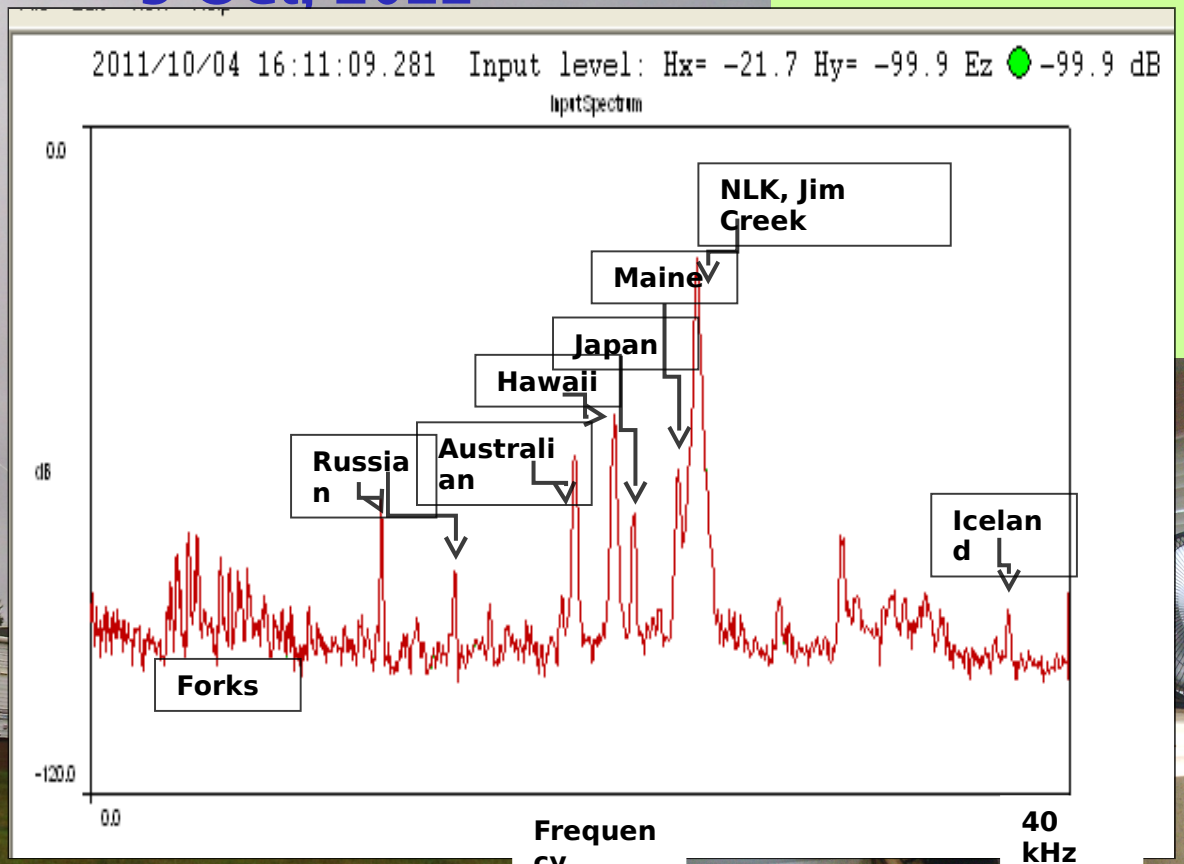
Changes in the ionosphere cause changes in the received signal. There is very low attenuation in this frequency range, such that transmissions can propagate for many 1000km's - long range sensing of the upper atmosphere!

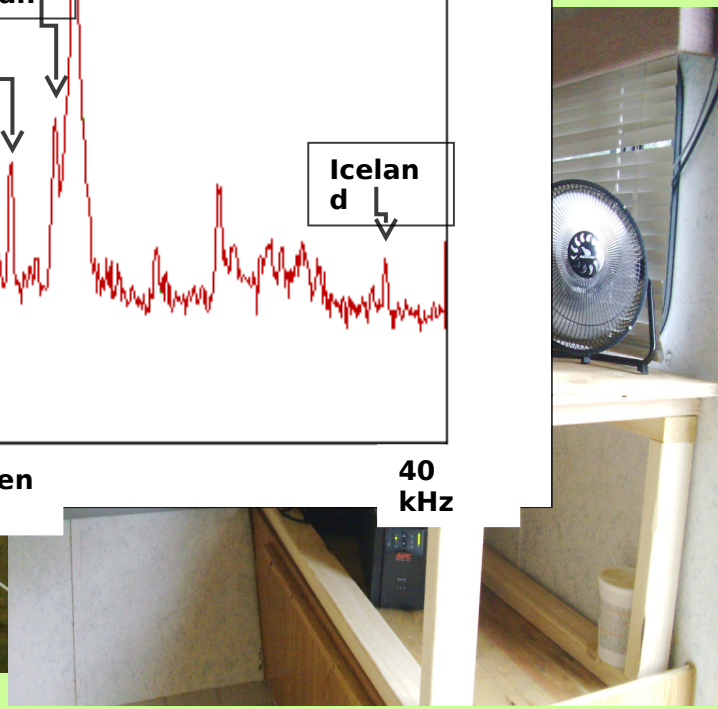
WP4

What does a Forks AARDDVARK look like?

Installation at Forks, Seattle 3 Oct, 2011

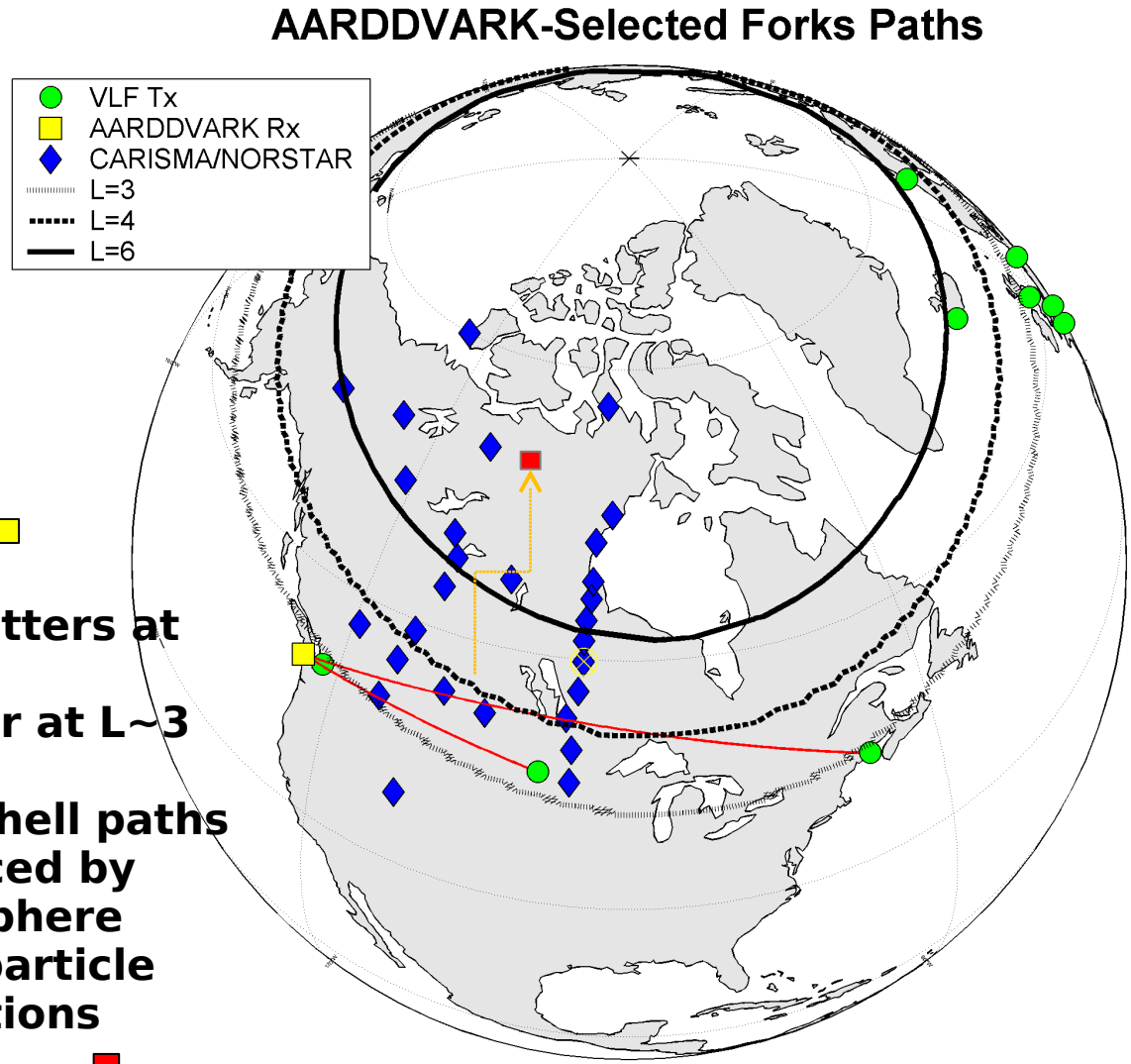






WP4

What does a Forks AARDDVARK measure?



Forks

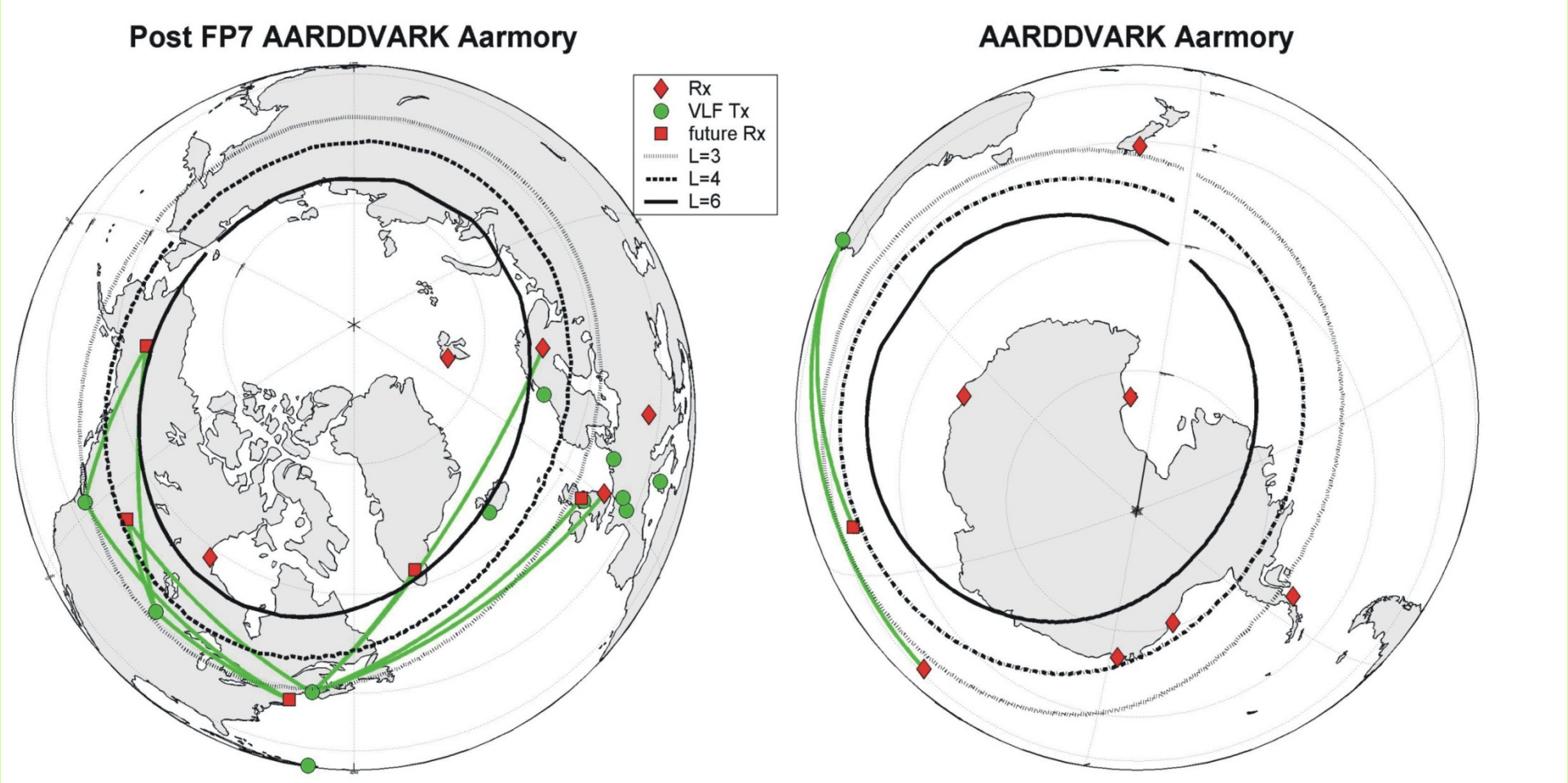
Transmitters at L~3
Receiver at L~3

Low L-shell paths influenced by plasmaphere wave –particle interactions

(Good combination with Churchill)

WP4

AARDDVARK – extended network



WP3

Plasmasphere model: DGCPM

WP leader
A. Jorgensen

Main objective:

to produce **plasma density maps** for **WP4**

DGCPM Dynamic Global Core Plasma Model (Ober 1997)

Dayside refilling -- nightside depletion

Conservation

Convective transport

FLIP Field Line Interhemispheric Plasma Model (Richards et al., 1997)

E-field model Primary driver of dynamics

Gallagher et al. (1995)

Sojka-model with shielding (Sojka et al. 1986)

AMIE-output

WP3

DGCPM

Advantages:

Very fast to run. 30 days in 15 minutes.

Two-dimensional: small memory

Simple parametrization:

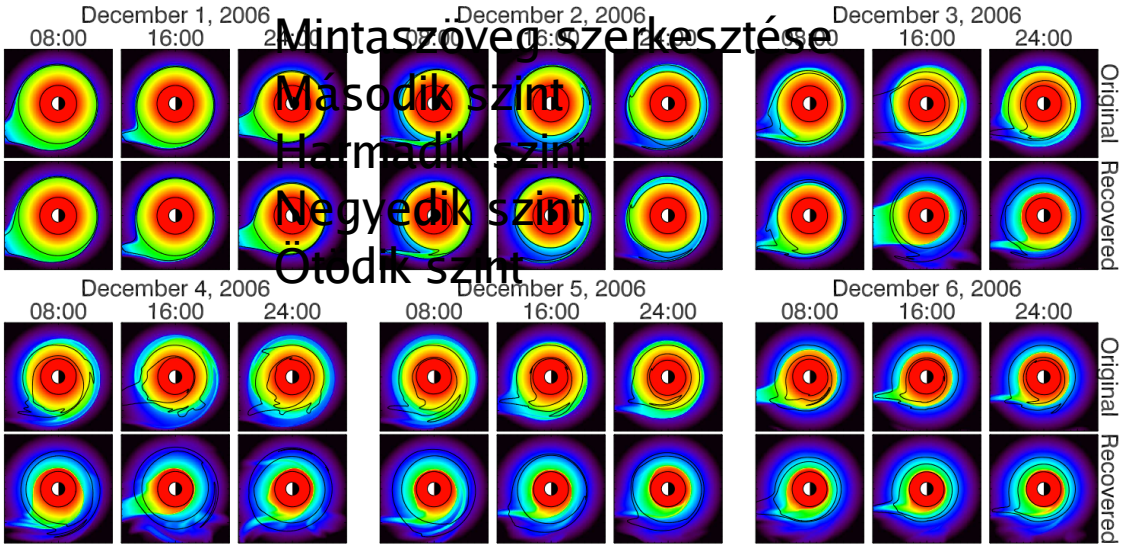
Ionospheric sources and sinks.

E field on a grid defined in magnetic coordinates.

Disadvantages:

No ionosphere – GPS TEC data cannot be used.

Two-dimensional: no field-line distribution



(Jorgensen 2010)

Mintaszöveg szerkesztése

Második szint

Harmadik szint

Negyedik szint

Ötödik szint

WP3 Data assimilation

WP leader
A. Jorgensen

Data:

- **WP1** **AWDANet**
- **WP2** **EMMA** + McMac, CARISMA, MEASURE, SAMBA
- **WP4** **AARDDVARK**
- + **in-situ LANL satellite data (point measurement)**

Data assimilation schemes:

Develop a data assimilation scheme which applies a **Kalman filter** or **particle filter** to the DGCPM and assimilates in-situ and remotely sensed density measurements.

- Ensebmle Kalman filter
- Ensemble Kalman Smoother
- Particle filter

Implementation:

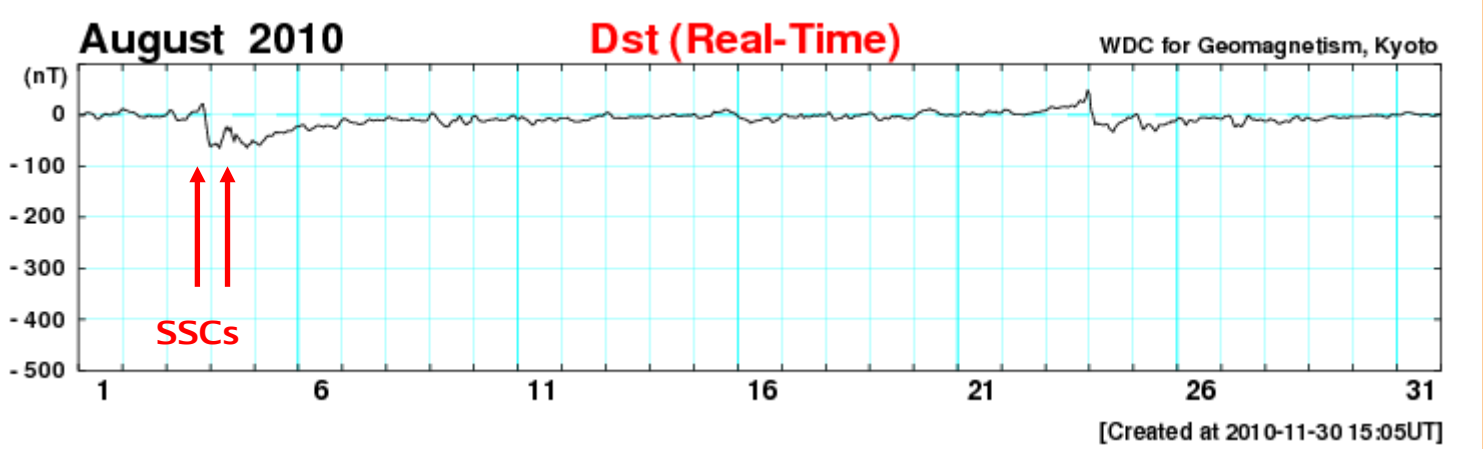
- C++ and CUDA on GPGPUs
- Translation from Fortran to CUDA C

WP1

Testing the AWA algorithm

a case study: double SSC on 3-4 Aug 2010

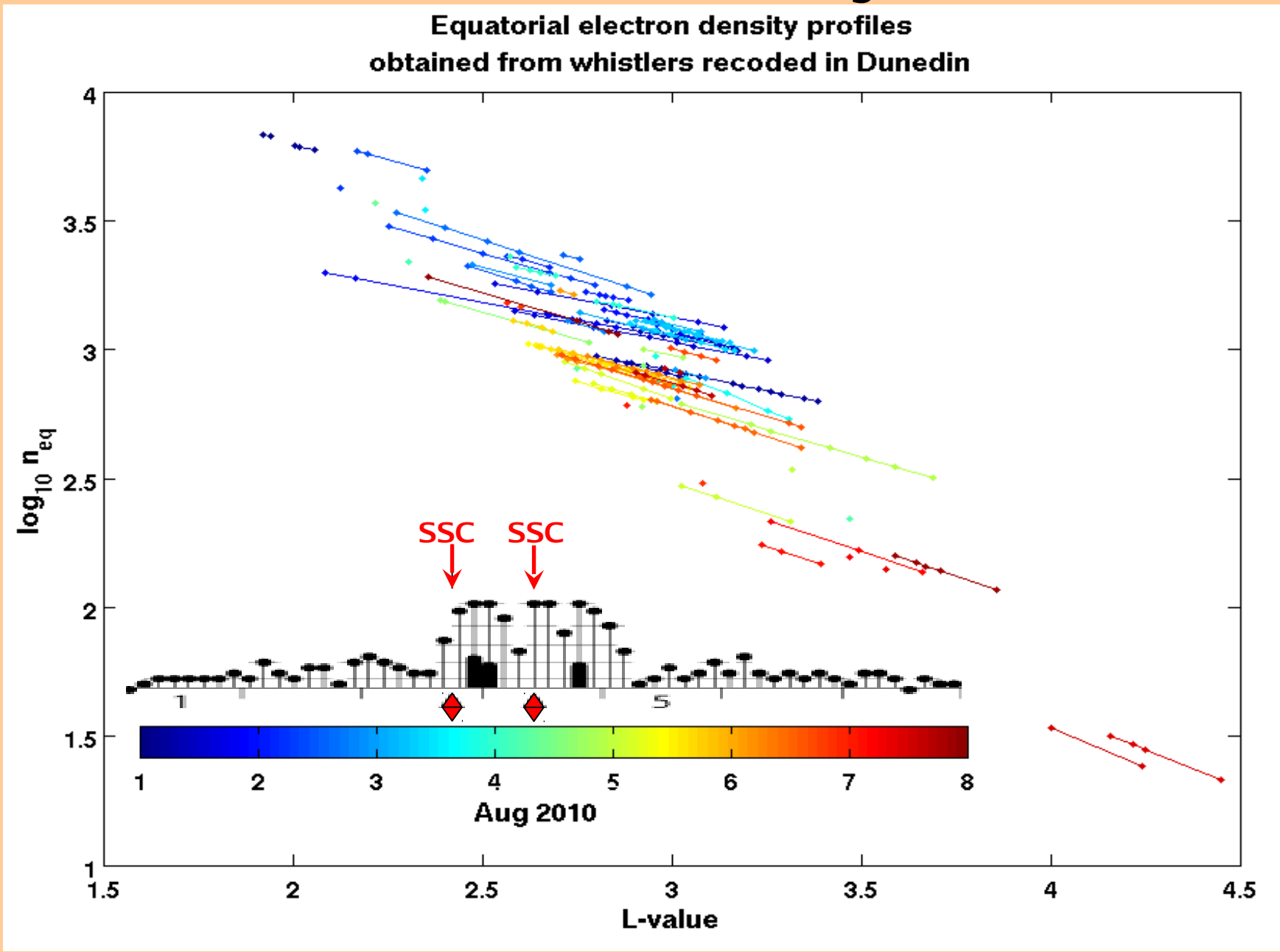
- 82 events between 1-8 August 2010 processed
- Whistlers recorded in Dunedin (New Zealand)



WP1

Case study

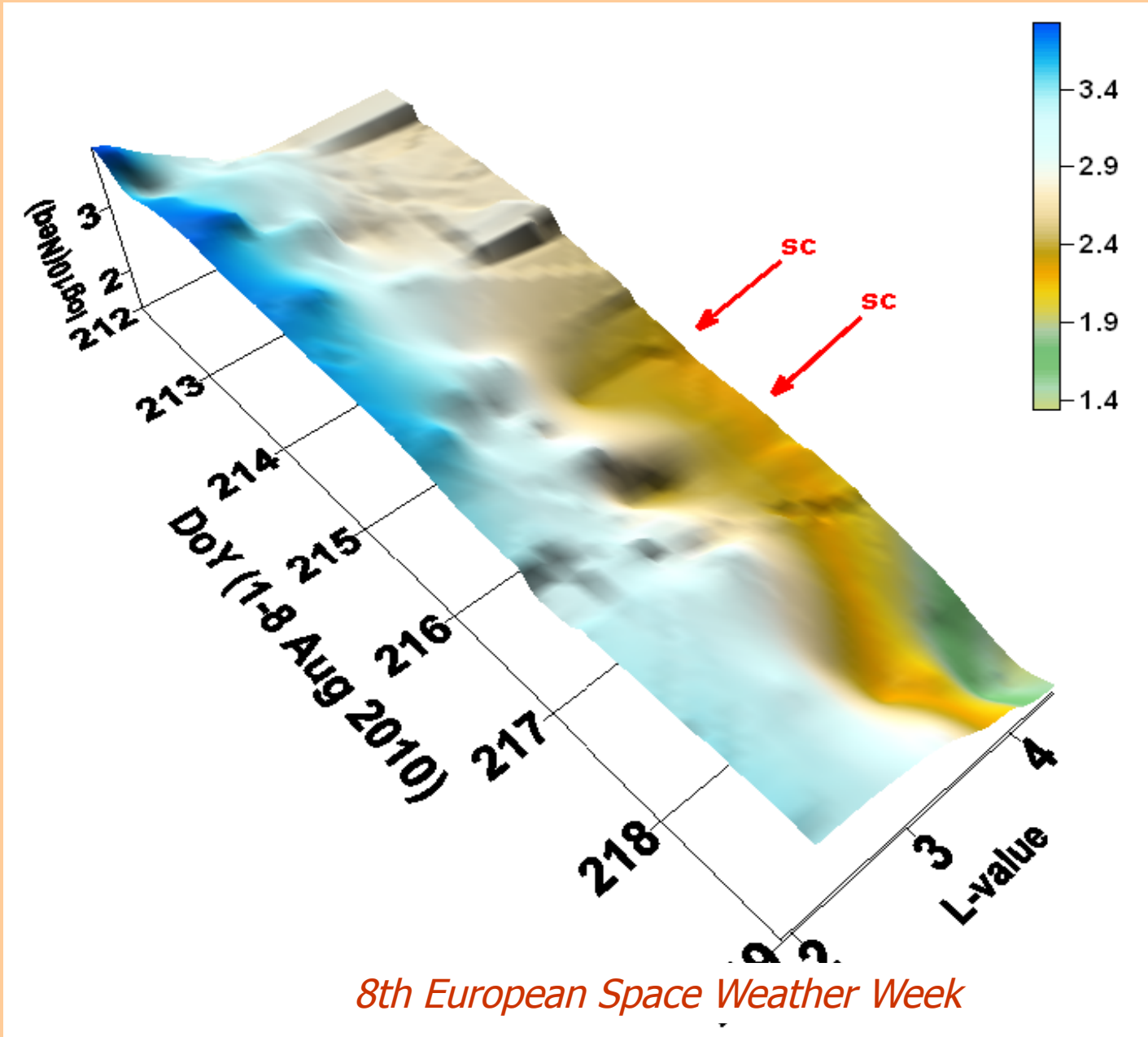
double SSC on 3-4 Aug 2010



WP1

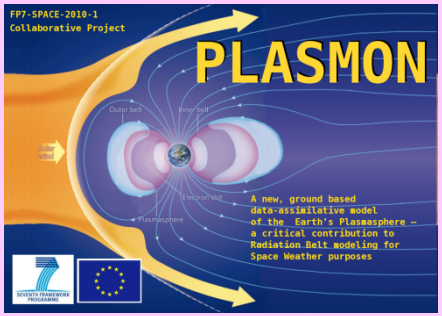
Case study

double SSC on 3-4 Aug 2010



WP5

Dissemination and exploitation of the results

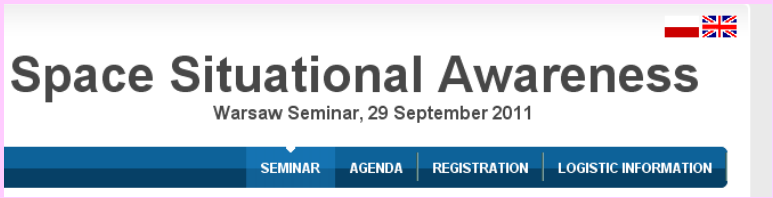


Results achieved:

Conference presentations, **16 PLASMON conference presentations** to date
PLUS **4 seminars/popular talks**

A vital part of disseminating scientific results comes through presentations at scientific workshops, meetings and conferences. This becomes more important as the publication and uptake process can be very slow.

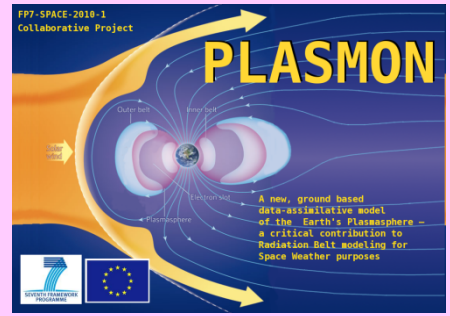
We aim to produce 30 such presentations - coordination will be undertaken to ensure that this includes a wide range of different international meetings (URSI, IAGA, EGU, AGU and also at topical meetings such as VERSIM and HEPPA).



8th European Space Weather Week

WP5

Dissemination and exploitation of the results



Results achieved:

PLASMON website is operational – please visit ***http://plasmon.elte.hu***

The web page contains **general information** about the project and will include **summaries of the results** obtained in different phases of the project.

At the end of the project, **selected data** will also be published for the scientific community through this website.

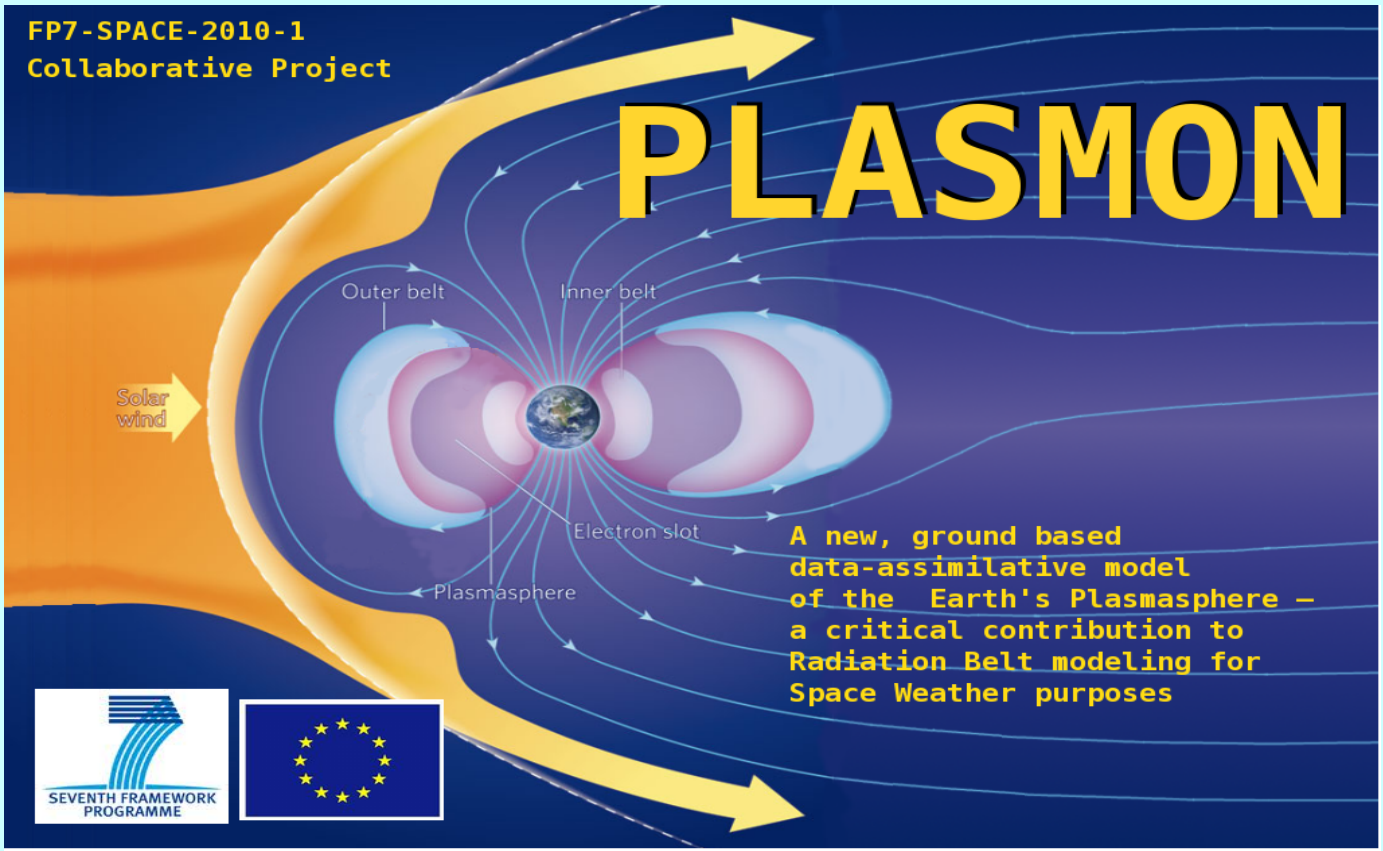
Eötvös university

University of L'Aquila

Eötvös Loránd Geophysical Institute

FP7-SPACE-2010-1
Collaborative Project

PLASMON



University of Whasington

University of Otago

Institute of Geophysics, PAS

Thank you for the attention

Please visit http://plasmon.elte.hu

The research leading to these results has received funding from the European Union Seventh Framework Programme [FP7/2007-2013] under grant agreement n°263218

Workpackages and methology

WP1: Automatic retrieval of equatorial electron densities and density profiles by Automatic Whistler Detector and Analyzer Network (AWDANet)

WP2: Retrieval of equatorial plasma mass densities by European quasi-Meridional Magnetometer Array (EMMA) magnetometer arrays and cross-calibration of whistler and Field Line Resonance method

WP3: Data assimilative modeling of the Earth's plasmasphere

WP4: Modeling REP losses from the radiation belts using the Antarctic-Arctic Radiation-belt (Dynamic) Deposition – VLF Atmospheric Research Konsortia (AARDDVARK) network

WP5: Dissemination and Exploiation of Results