PLASMON: Data Assimilation of the Earth's Plasmasphere

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Abstract

Man and equipment in space are affected by the energetic charged particles in the radiation belts. The degree of exposure is determined by the rate of Relativistic Electron Precipitation (REP), which is driven by wave-particle interactions. The properties of the plasmasphere determine the interaction rate. Current models of the plasmasphere do not encompass all of the structure or physics, and observations are sparse. PLASMON will provide regular measurements of plasmaspheric electron and mass densities across all longitudes and incorporate them into a data assimilative model. The observations and model will also be linked to measurements of REP.

Introduction

Knowing what's going on in the plasmasphere is important for space technology. Satellite observations can provide part of the picture, but are highly localised and centred at a location which is continuously moving in latitude and magnetic local time (MLT). Ground based instruments can make continuous observations and, since they are relatively cheap, can be deployed at a variety of locations. PLASMON is based on ground based observations of Very Low Frequency (VLF) and Ultra Low Frequency (ULF) waves.

Work Packages and Methodology

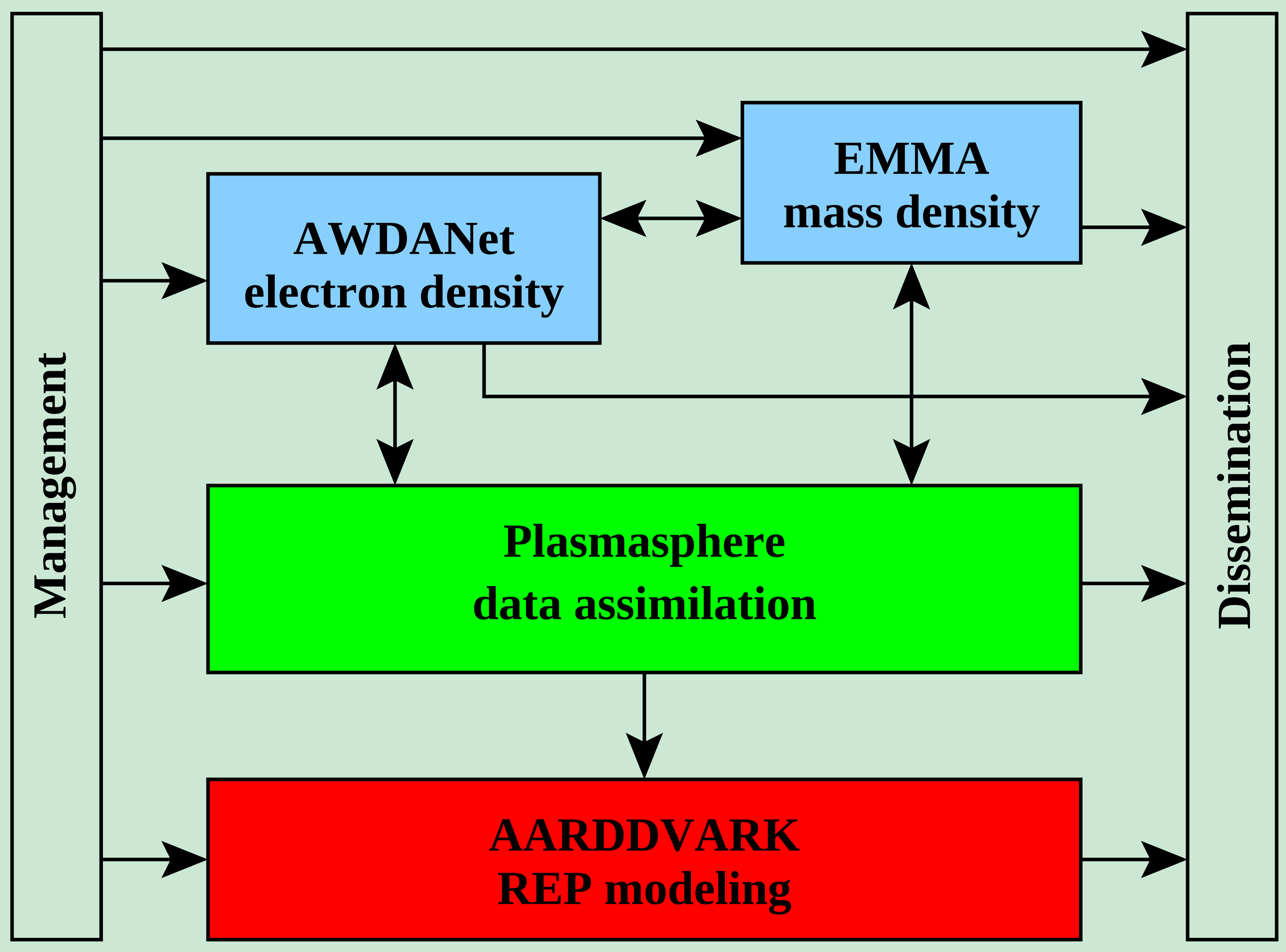

Figure 1: Relationship between Work Packages.

The project is divided into a number of related work packages:

- WP1 Electron density profiles (AWDANet).
- WP2 Plasma mass densities (EMMA); cross-calibration with whistlers.
- WP3 Data assimilative modeling of the Earth's plasmasphere.
- WP4 REP losses (AARDDVARK).
- WP5 Dissemination and exploitation.

AWDANet

An Automated Whistler Detector (AWD) station consists two magnetic loop antennas (Figure 2), VLF data logger and a processing PC. The AWD system identifies whistlers in broadband VLF data. Detailed analysis of these whistlers yields magnetospheric parameters. Traditionally performed by hand in an arduous and error-prone procedure, this analysis has been automated using an extended whistler inversion method [3]. This procedure is, however, computationally expensive and for remote stations where network bandwidth prohibits the transfer of the raw data, analysis will take place on local supercomputers.

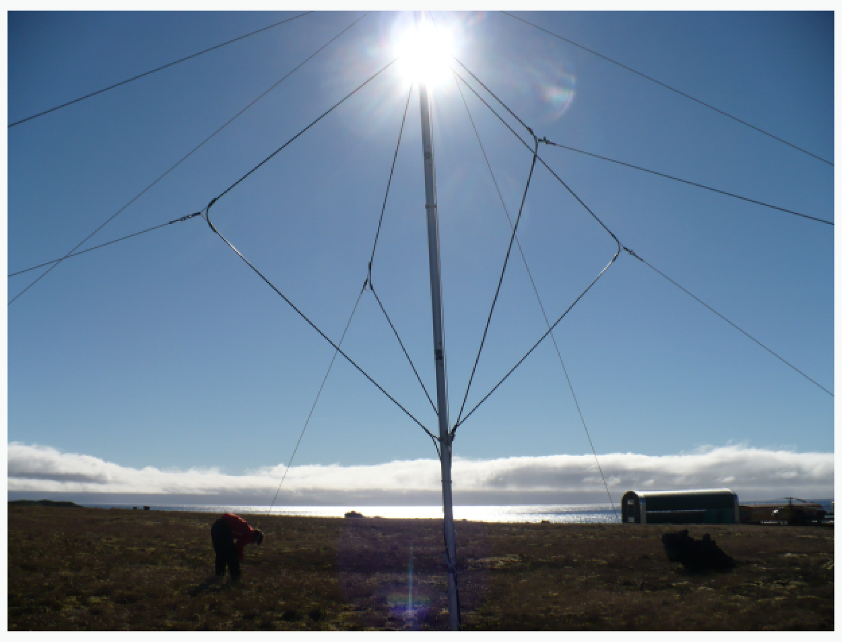

Figure 2: VLF antenna on Marion Island.

A network of stations, AWDANet [4], is distributed across the globe (Figure 1). The AWDANet nodes give reasonable coverage in geomagnetic latitude but coverage in MLT is non-uniform. For statistical analyses this is not problematic but it presents an obstacle to obtaining a snapshot of the plasmasphere. Three additional nodes are planned which will improve MLT coverage.

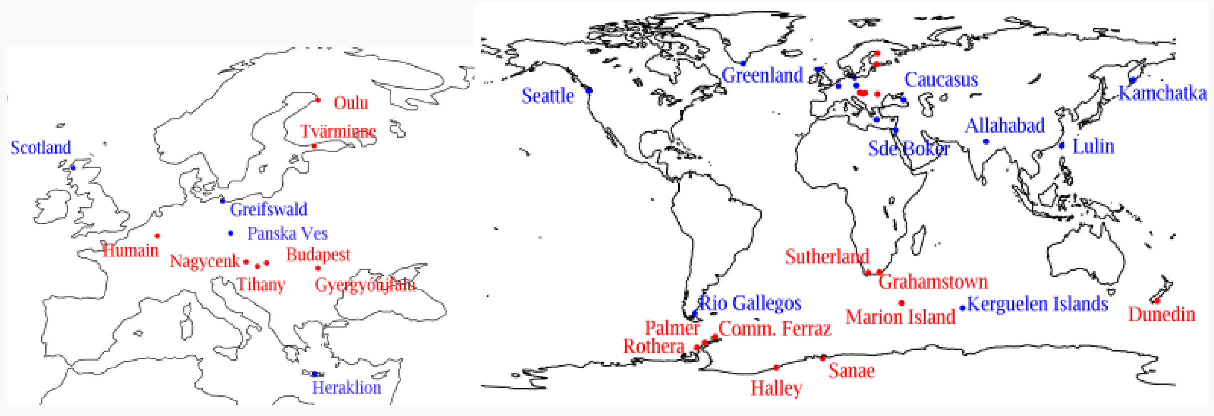

Figure 3: Distribution of existing and planned Automated Whistler Detector and Analyser (AWDA) stations.

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EMMA Network

The quasi-meridional European MagnetoMeter Array (EMMA) will provide Field Line Resonance (FLR) observations of the plasmasphere from $L \sim 1.5$ to the plasmapause and beyond. Each EMMA station consists of a 3-axis magnetometer and a ULF data logger. To obtain the required density of stations will require the installation of several stations at mid-latitudes (two in Namibia and five in Europe). The Earth's rotation will provide coverage in MLT but it will not be possible to map the entire plasmasphere at a given moment.

(a) (b)

Figure 4: Existing and planned EMMA stations.

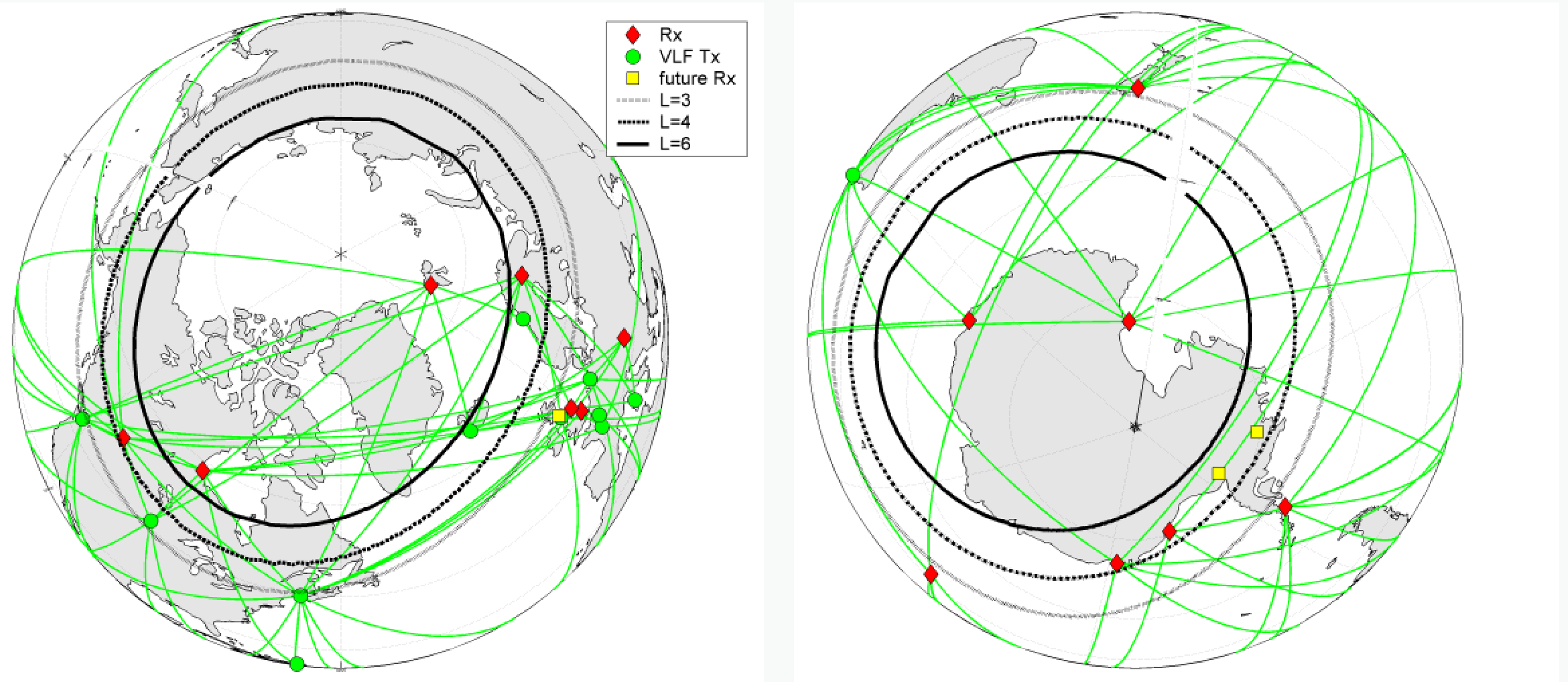
The volume of data produced by each of the EMMA stations is small and will thus be transferred to a central data server for processing. FLRs will be identified by the cross-phase technique [8]. A fully automated FLR identification and inversion procedure is under development which will incorporate realistic geomagnetic and plasmasphere models, and be based on current MHD theory. The inversion will yield equatorial plasma mass densities. A comparison of electron and mass densities will produce the relative abundances of heavy ions.

Assimilation

A plasmaspheric model [6] will be combined with observations via assimilation [2] using particle filtering [5]. The model includes drift due to an external electric field, flow to and from the ionosphere and plasmaspheric saturation. The electric field model, which is the primary driver of plasmaspheric dynamics, will initially be parameterised by the Kp index but more sophisticated fields will be considered later. The magnetic field will be represented by the accurate model of [7]. Model parameters will be adjusted to match densities from whistler and FLR analyses. Satellite measurements will also be integrated into the model and used for validation.

AARDDVARK

The Antarctic-Arctic Radiation-belt Dynamic Deposition VLF Atmospheric Research Konsortium (AARDDVARK) network [1] consists of 10 narrowband VLF receivers monitoring 6 transmitters. In order to improve the coverage in L and MLT three new stations will be installed. The AARDDVARK data will be examined for REP signatures. The propagation conditions along each path will be modelled. The results will be combined with output from the assimilative plasmaspheric model to derive time dependent flux levels and other characteristics for each REP event.



(a) (b)

Figure 5: Receivers, transmitters and propagation paths in the AARDDVARK network.

Acknowledgements

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