Monitoring, Analyzing and Assessing Radiation Belt Loss and Energization

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Abstract

We present the concept, objectives and expected impact of the MAARBLE (Monitoring, Analyzing and Assessing Radiation Belt Loss and Energization) project, which is being implemented by a consortium of seven institutions (five European, one Canadian and one US) with support from the European Community's Seventh Framework Programme. The MAARBLE project employs multi-spacecraft monitoring of the geospace environment, complemented by ground-based monitoring, in order to analyze and assess the physical mechanisms leading to radiation belt particle energization and loss. Particular attention is paid to the role of ULF/VLF waves.

Objectives

The main objectives of MAARBLE are:

1. To create a database of ULF and VLF waves in the radiation belts that is complementary to other FP7 projects, to be disseminated to the scientific community

2. To develop a statistical model of radiation belts relevant wave activity

3. To elaborate on specific aspects of wave-particle interactions, which are of strong relevance to radiation belt dynamics

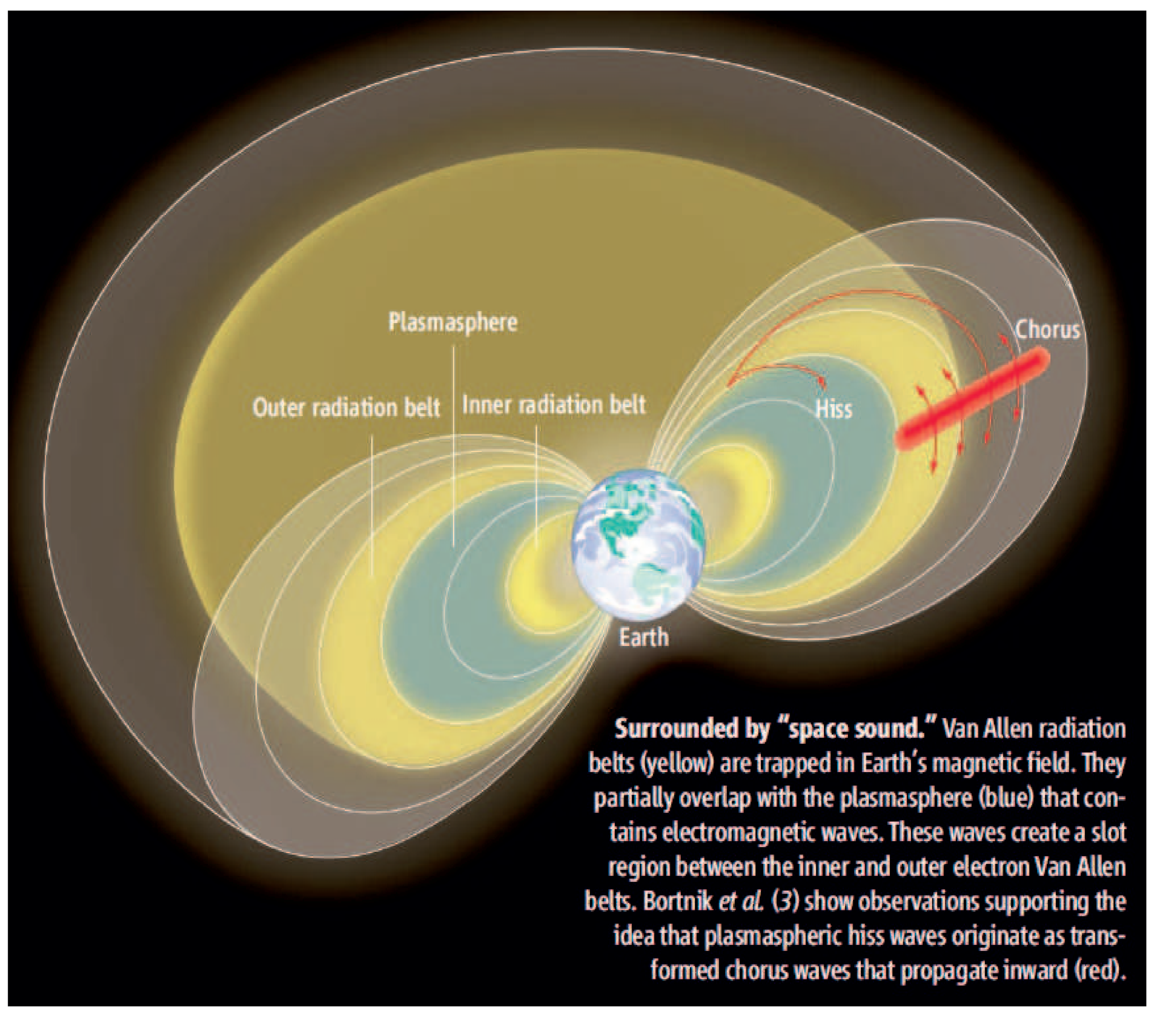
4. To use data assimilation techniques to guide 'the best' estimate of the state of a complex system such as the electron radiation belts

Concept

MAARBLE aims at a deeper understanding of the relationships between ULF and VLF waves and radiation belt dynamics through the development of a statistical model of waves and the incorporation of particle measurements into data assimilation tools. The project foresees the efficient exploitation of data from a number of European space missions (Cluster, INTEGRAL, XMM-Newton, PROBA-1, CHAMP), in combination with data from US space missions (THEMIS, GOES, POES, SAMPEX, Polar) and ground-based magnetometer data (European IMAGE array and Canadian CARISMA array), with a focus on the scientific problem of radiation belt energization and loss.

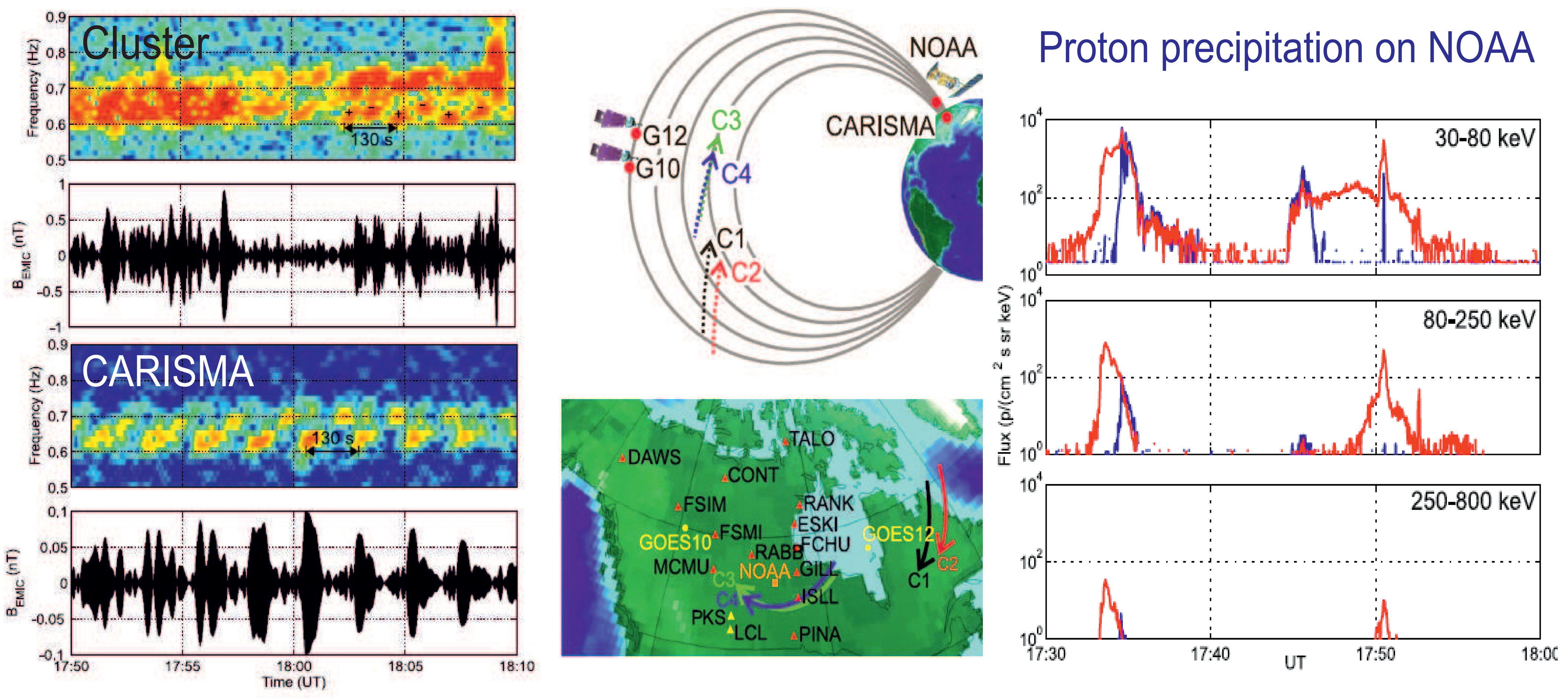
Expected impact

Radiation belt variability is of outstanding scientific interest and has direct impacts on spacecraft and on humans in space. Most satellites operate in regions where they can be exposed to intense fluxes of extremely energetic radiation belt particles. In addition, the orbit of the International Space Station is such that the exposure of astronauts to relativistic radiation belt electrons is a serious concern. Consequently, understanding the radiation belt environment has important practical applications in the areas of spacecraft operations, spacecraft-system design, mission planning and astronaut safety. Therefore MAARBLE will bear results beneficial to both robotic space exploration and manned spaceflight. Furthermore, it will support and complement other ongoing European space programmes, such as the FP7-Space SPACECAST project and the ESA Space Situational Awareness Programme (SSA). Moreover, MAARBLE will contribute to the goals of the European Space Policy through its impact on robotic and human space exploration.



A sketch of the Earth's radiation belts [see Santolik, O., & J. Chum, Science, 324, 2009]

EMIC-related loss of energetic particles



Cluster, CARISMA magnetometer and NOAA POES observations of EMIC waves and related precipitation [see Usanova et al., JGR, 115, 2010]

WP2 Particle Data Assimilation

Objectives

The objective of this work package is to use data assimilation techniques to guide 'the best' estimate of the state of a complex system such as the electron radiation belts. It will then take advantage of physical model for the radiation belts (global to the system but never perfect due to modelling uncertainties) to overcome some of the problems associated with the paucity of measurements arising from limited spatial and energy coverage.

It will give clues to the important questions:

1. Can we improve the knowledge of the global dynamics of the radiation belts using data assimilation techniques?

2. How many data sets do we need and along which orbit type particle measurements should be available to ensure a reasonably good estimate of the true state?

WP3 Wave Database & Map

Objectives

- Creation of an extended database of ULF and VLF waves in the radiation belts, covering both wave power and more advanced wave parameters such as propagation information
- Creation of a data distribution system through which other researchers can access this database
- Development of a statistical model of wave activity which includes carefully selected wave parameters (e.g. propagation information) as well as wave power
- Development of a statistical model for bursts of high-amplitude EMIC and whistler-mode waves, including the spatial extent of the bursts and selected wave parameters such as propagation information

WP4 Synergy of Particle and Wave Observations

Objectives

- To develop, run and assess physics-based ULF wave driven energy dependence radial diffusion model to establish importance of the contribution of ULF wave transport to radiation belt dynamics.
- To discover the role of coherent ULF wave transport in outer radiation belt electron dynamics.
- To discover the L-shell and azimuthal width of EMIC and VLF wave elements in the magnetosphere, hence contributing to an assessment of their role in radiation belt electron loss.
- To observationally assess the role of EMIC and VLF waves in driving outer zone relativistic electron and energetic ion precipitation into the atmosphere.
- To assess the relative importance of the plasmasheet source distributions, new injections, particle convection and magnetospheric compressions on VLF and EMIC wave excitation and their impact on MeV electrons in the radiation belt.
- To determine the pitch angle and energy diffusion coefficients for electromagnetic ion cyclotron waves, whistler mode hiss and chorus for use in data assimilation.
- To determine electron loss timescales for use with radial diffusion models.

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