Quantifying Energy Circulation in Space Plasma: QuESpace project

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INTRODUCTION

The QuESpace project aims to quantify energy circulation in space plasmas. Scientifically, energy transfer is a fundamental plasma physical problem having many applications in a variety of plasma environments ranging from coronal heating on the Sun to electric heating in the ionosphere. Technologically, understanding the plasma and energy transport properties is a step toward predictions of the space environment needed for spacecraft design and operations. The space physics community lacks an accurate and self-consistent numerical model capable of describing the global plasma system in particular in the inner magnetosphere, where major magnetic storms can cause serious damage to space-borne technology. The project has two goals:

1. Novel integration of observations from ESA's four-spacecraft Cluster mission with simulation results to gain quantitative understanding of global energy transport properties in the near-Earth space; and
2. Development of a new self-consistent global plasma simulation that describes multi-component and multi-temperature plasmas to resolve non-MHD processes that currently cannot be self-consistently described by the existing global plasma simulations.

The new simulation methods are now feasible due to the increased computational capabilities. Our existing simulation environment and unique analysis methods have brought exciting new results on magnetospheric energy circulation. Seven years after launch, the Cluster database is now large enough to quantitatively assess these effects. The QuESpace team has a long record in observational research of global energetics and a world-leading role in developing global magnetospheric computer simulations.

THE QUESPACE PROJECT

WORK PACKAGE 1

Quantitative analyses of our global magnetohydrodynamic (MHD) simulations have recently produced results that agree with earlier observational studies [1], but also suggest new phenomena that have not been reported before: The maximal energy transfer is observed to occur during southward interplanetary magnetic field; however, we also discovered a "hysteresis" effect, where energy transfer seems to depend on earlier enhanced activity [2]. The MHD simulations also suggest that the electromagnetic energy focussing controls both temporal and spatial features of the energy transfer, and that reconnection depends on the solar wind dynamic pressure [3].

In Work package 1 we combine simulation results with the data gathered by the *Cluster* mission launched by the European Space Agency.

WORK PACKAGE 2

Global MHD simulations have been successful in describing systems where the important spatial scales are larger than ion gyro radii and the plasma has a well defined temperature. The weakness of global MHD simulations is their inability to model the multi-temperature, multicomponent plasmas in the inner magnetosphere, where most of space-borne technology, including communication and navigation systems reside. Two possibilities exist to overcome the problem: 1) To couple the MHD simulation to a code modelling the inner magnetosphere [4], or 2) to develop a self-consistent global simulation based on another plasma description. The first, still somewhat limited, attempts for hybrid simulations are being made for the Earth [5].

Coupling different codes carries a risk that the effects of the coupling scheme dominates over the improved physics. On the other hand, hybrid codes are noisy due to the limited number of ions that can be launched in the simulation. In Work package 2 we will develop a Vlasov-hybrid simulation, where electrons are fluid and ions are Vlasov-fluid modelled by distribution functions. With such a simulation, we will be able to describe multiple ion populations without noise and in scales unreachable by MHD. With the Vlasov-hybrid simulation, we will address energy transport and reconnection dynamics, but will also expand to other effects related to the instability and wave modes that the simulation can resolve.

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References

[1] M. Palmroth, T. I. Pulkkinen, P. Janhunen, and C.-C. Wu,, "Stormtime energy transfer in global MHD simulation",*J. Geophys Res.,* vol. 108(A1), 1048, doi:101029/2002JA009446, 2003.

[2] M. Palmroth, P. Janhunen, and T. I. Pulkkinen, "Hysteresis in solar wind power input to the magnetosphere", *Geophys. Res. Lett.*, vol. 33, L03107, doi:10.1029/2005GL025188, 2006a.

[3] M. Palmroth, T. V. Laitinen, and T. I. Pulkkinen, "Magnetopause energy and mass transfer: Results from a global MHD simulation", *Ann. Geophys.*, vol. 24, pp. 3467-3480, 2006b.

[4] C.-L. Huang, H. E. Spence, J. G. Lyon, F. R. Toffoletto, H. J. Singer, and S. Sazykin, "Storm-time configuration of the inner magnetosphere: Lyon-Fedder-Mobarry MHD code, Tsyganenko model, and GOES observations", *J. Geophys. Res.,* vol. 111, A11S16, doi:10.1029/2006JA011626, 2006.

[5] N. Omidi, and D. G. Sibeck, "Flux transfer events in the cusp", *Geophys. Res. Lett.*, vol. 34, L04106, doi:10.1029/2006GL028698, 2007.