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The Canadian Enhanced Polar Outflow Probe (e-POP) mission in ILWS

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Abstract

The Enhanced Polar Outflow Probe (e-POP) small satellite mission will be Canada's first mission contribution to the International Living with a Star (ILWS) initiative. The e-POP project comprises three important and interconnected components: a small-satellite component to investigate atmospheric and plasma flows and related wave-particle interaction processes in the topside ionosphere, a coordinated ground-based and a theoretical assimilation component. Its scientific objectives are to quantify the micro-scale characteristics of plasma outflow and related micro- and meso-scale plasma processes in the polar ionosphere, explore the occurrence morphology of neutral escape in the upper atmosphere, and study the effects of auroral currents on plasma outflow and those of plasma microstructures on radio propagation. The escape of plasma from the polar ionosphere – its acceleration and subsequent transport towards the magnetosphere – is one of the most important processes in the Ionosphere–Thermosphere–Magnetosphere system. The e-POP science payload will carry a suite of 8 science instruments (experiments), including imaging plasma and neutral particle sensors, magnetometers, radio wave receivers, dual-frequency GPS receivers, CCD cameras, and a beacon transmitter. The imaging plasma sensors will measure particle distributions and the magnetometers will measure field-aligned currents on the time scale of 10-ms and spatial scale of $\sim$100 m. The neutral mass and velocity spectrometer will measure the density and velocity of major atmospheric species. The CCD cameras will perform auroral imaging on the time scale of 100-ms. The radio wave and GPS receivers will perform near real-time imaging studies of the ionosphere, in conjunction with ground-based radars, as will the beacon transmitter, in conjunction with ground receiving stations. The e-POP payload is scheduled for launch in 2007 as part of the Canadian CASSIOPE multi-purpose small satellite, and will be placed in a low-altitude, elliptical polar orbit (80° inclination, 325 km perigee, and 1500 km apogee). It will utilize the Ka band telemetry downlink on the companion communications technology demonstration payload onboard, to transmit the large volume (up to 15 gigabytes/day) of high-resolution science data to ground at a maximum telemetry rate exceeding 300 megabits/s.

Keywords: Outflow; Radio propogation; Small satellites; Magnetosphere–ionosphere interactions; Ionosphere–thermosphere

1. Introduction

In this paper, we describe the scientific objectives and planned investigations of the Canadian Enhanced Polar Outflow Probe (e-POP) small satellite mission, in the context of the International Living with a Star (ILWS) program.

The e-POP will be Canada's first mission contribution to the ILWS initiative. It will be a part of the multi-purpose Canadian CASSIOPE small satellite mission, which will also carry a companion CASCADE™ communications technology demonstration payload

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developed by MacDonald Dettwiler and Associates (MDA) in Canada. The e-POP project comprises three important and interconnected components: a small-satellite component to investigate atmospheric and plasma flows and related wave-particle interaction processes in the topside ionosphere, a coordinated ground-based and a theoretical assimilation component. Its scientific objectives are to quantify the micro-scale characteristics of plasma outflow and related micro- and meso-scale plasma processes in the polar ionosphere, explore the occurrence morphology of neutral escape in the upper atmosphere, and study the effects of auroral currents on plasma outflow and those of plasma microstructures on radio propagation.

In Section 2, we discuss the scientific motivation behind the e-POP mission and outline the scientific questions to be addressed. In Section 3, we present the concept of the mission, including its orbit characteristics and investigation approach. In Section 4, we describe the science instruments on e-POP, and planned measurements to address the scientific questions discussed in Section 2. In Section 5, we discuss the scientific connection of the e-POP mission to ILWS.

2. Science motivation

2.1. Ion outflows

The polar ionosphere is the crossroads of the ionosphere–thermosphere–magnetosphere (I–T–M) system that constitutes the near-Earth space. It is directly coupled to the magnetosphere in mass and energy on the one hand, via polar ion outflows, auroral particle precipitation, and mapping of magnetospheric electric fields, and to the upper atmosphere and thermosphere in mass and momentum on the other hand, via charge–exchange, photo-ionization, and Joule heating (Yau and Andre, 1997).

The escape of plasma from the polar ionosphere – its acceleration and subsequent transport towards the magnetosphere – is one of the most important processes in the I–T–M system. This is because ion outflow from the auroral and polar ionosphere plays a very important role in magnetosphere–ionosphere coupling: it provides a significant source of plasma for the inner magnetosphere and the plasma sheet (Chappell et al., 1987, 2000), and is believed to influence the onset of magnetic reconnection on both the dayside and the nightside (Winglee, 1998, 2004).

As demonstrated in multi-fluid MHD simulation (Winglee, 2004), heavy ion outflow plays a significant role in controlling the global dynamics of the magnetosphere and the transport of solar wind energy and momentum in the magnetosphere, by limiting (reducing) the cross-polar cap potential, acting as a substantial energy sink in the auroral region, and mass-loading the magnetotail; the mass-loading is believed to influence the reconnection rate and structure and the occurrence of substorms.

Fig. 1 identifies the important populations of ion outflow, including the polar wind, auroral bulk upflow, upwelling ions, and ion conics, which will be the focus of plasma outflow investigations in e-POP. A number of recent studies of ion acceleration and outflow, including that of Peterson et al. (2001) on the seasonal variation of upflowing ion flux observed on POLAR and that of Abe et al. (2004) on solar-cycle variation of polar wind acceleration observed on Akebono, point to the importance of polar wind and auroral bulk upflow as a source of cold plasma for energetic ions at higher altitudes. They also underscore the scarcity of low-energy ion outflow observations below 3000-km altitude relative to those at higher altitudes, and the need for such observations at high resolution to complement the considerable body of recent observations from Freja (Andre et al., 1998) and FAST (Strangeway et al., 2000, 2005), which are focused on higher ion energies.

On FAST, Strangeway et al. (2005) identified the important roles of the Poynting flux and precipitating soft electrons in controlling auroral ionospheric ion acceleration, and interpreted their observations in terms of electromagnetic energy transmission (via the Poynting flux) from the magnetosphere along auroral field lines and dissipation in the auroral acceleration region. The intimate connection between ion outflow and Poynting flux motivates our attention to the topside ionosphere, where the Poynting flux is converted to heat

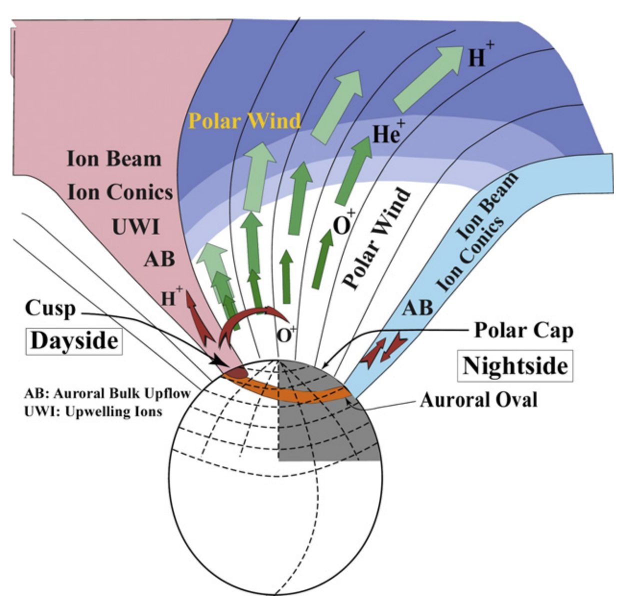

Fig. 1. Schematic depiction of important ion outflow populations in the polar ionosphere, including the polar wind, auroral bulk upflow, upwelling ions, and ion conics, which will be the focus of plasma outflow investigations in e-POP.