Observations of Mesoscale and Microscale Space Weather Processes on the Canadian CASSIOPE Enhanced Polar Outflow Probe (e-POP)

Andrew W. Yau¹, H. Gordon James²

¹University of Calgary, Canada
²Communications Research Centre, Canada
CASSIOPE

**e-POP** Science Payload: to study space storms – plasma outflows, radio propagation, aurora, and ionosphere non-uniformities

**Small-Sat Bus**: Generic, low-cost satellite bus to address needs of future Canadian small-satellite missions

**Cascade** Technology Payload: to demonstrate high bandwidth store-and-forward data delivery
Outline

1. e-POP Science Targets
   Physics of space weather effects in ionosphere-thermosphere

2. Meso-/Micro-scale Space Weather Processes
   Existing Observations

3. e-POP Instruments & Measurements

4. Planned e-POP Studies of Space Weather Processes

5. Conclusions
**e-POP Science Targets**

*Physics of space weather effects is overarching theme.*

- Ion acceleration and outflow
  
  Meso-scale outflow; micro-scale wave particle interaction

- Ionospheric irregularities and scintillations
  
  3D irregularities; GPS occultation

- Effects on radio wave propagation
  
  Trans-ionospheric radio wave propagation

- Thermospheric expansion
  
  Thermosphere heating, composition changes, and escape

- Aurora
  
  Small-scale auroral and auroral current structures
2. Meso-scale and micro-scale space weather processes

Existing Observations
Thermal and Suprathermal Ion Outflows

**Observations (Cully et al. 2003)**

- Suprathermal (>10 eV) >16000 km (DE-1)
- Suprathermal (>15 eV) < 9000 km (Polar)
- Thermal (<20 eV) < 9000 km; (Akebono)

**Physical Significance**

- Outflow rate increases >10-fold at high Kp
- Significant H⁺ acceleration above 9000 km
- Significant O⁺ acceleration below 9000 km
- Large-scale depletion of ionosphere!?
- Space weather effects?
**Ion Heating and Lower Hybrid Solitary Structure**

**Observations**

10- to 100-m ion heating and lower hybrid solitary structures

Transversely accelerated ions

- Heated ions at several eV
- 63±25 m width

LHSS signatures

- Density depletion ~15%; ~10 ms
- Associated w/ TAI and/or BB VLF

**Physical Significance**

Large field and acceleration at small scale

Affect larger-scale space weather effects?

---

Ion distributions at 980 km (Burchill et al., 2004)

“Spikelet” electric fields at ~600 km (LaBelle et al. 1986)
Small-scale Auroral Structures

Observations

Auroral spatial scales:

10-100 km (bands),

to 0.1-1 km (curtains)

Auroral curls

Scale ~ 4 km; ~2 s

Anti-clockwise rotation; 10 km/s

Physical Significance

Are small (sub-km) structures important?
Thermospheric Response to Magnetic Storms

**Observations**

Thermosphere expansion (temperature and density increase) in magnetic storms

Equatorial propagation of expansion

More localized response to substorms

**Physical Significance**

Large neutral wind; composition change

Anomalous orbit decay in polar LEO

From CHAMP at 410 km (Sutton et al. 2005)
3. e-POP Instruments and Measurements
e-POP Mission Approach

**In-situ, small-scale** plasma, waves, fields at highest resolution

Radio wave propagation: **ionospheric irregularities in 3D**

**Fast imaging** of **meso-scale** auroral morphology

**Polar orbit** in key transition region (325 $\pm$ 1500 km; 80 $\pm$ inclination)

**3-axis stabilized** S/C for imaging and high-resolution measurements

**Large data capacity** (TB storage, $>$10GB/day, $>$300 Mbps downlink)
<table>
<thead>
<tr>
<th>Science Instrument</th>
<th>Principal Investigator</th>
</tr>
</thead>
</table>
| IRM      Imaging ion mass spectrometer | Dr. Peter Amerl  
University of Calgary                                    |
| SEI      Suprathermal electron imager     | Dr. David Knudsen  
University of Calgary                                    |
| NMS      Neutral mass/velocity spectrometer | Dr. Hajime Hayakawa  
JAXA/ISAS, Japan                                           |
| FAI      Fast auroral imager            | Drs. Sandy Murphree and Leroy Cogger  
University of Calgary                                    |
| RRI      Radio receiver instrument      | Dr. Gordon James  
Communications Research Centre                              |
| MGF      Magnetic field instrument      | Dr. Donald Wallis  
Magnametrics and University of Calgary                       |
| GAP      GPS attitude/profiling experiment | Dr. Richard Langley  
University of New Brunswick                                   |
| CER      Coherent EM radio tomography   | Dr. Paul Bernhardt  
Naval Research Laboratory, USA                                 |
e-POP Plasma Outflow Instruments:

will measures ions, electrons, and neutrals at up to 10-ms resolution.

Space storm results in electrical current and plasma outflow in the ionosphere.

IRM, SEI, NMS, MGF will measure ions, electrons, neutrals, and electrical currents.
4. Planned e-POP Studies of Space Weather Processes
Examples of Planned e-POP Studies

- Detailed dynamical characteristics of polar wind; Role of escaping atmospheric photoelectrons
- Exosphere neutral outflows: Role of polar wind, charge exchange, and other acceleration processes
- Micro-scale ion heating/energization characteristics: Connections between aurora, ion energization and upflow
- Wave particle interaction associated with ion energization: detailed wave propagation characteristics
- Plasma instabilities: creation of F-region density structure, growth and saturation of instabilities, constraints on flow
Planned e-POP Observations and Studies

- In-situ Observations*
  - Plasma, Neutral, Magnetic Field
  - Radio (Electric Field)
  - Optical (IR and visible) imaging
  - Radio occultation (GPS, beacon)
- Coordinated ground observations*
  - Radio: SuperDARN, CADI etc
  - Others: CGSM, …
  - Active Experiment: HAARP etc
- Data assimilation and modeling*
  - Kinetic, MHD, …

* Collaborative opportunities being pursued
E-POP Science Team & Participating Organizations

Communications Research Centre: HG James, P Prikryl
Royal Military College: JM Noel
U. Alberta: R Rankin, C Watt
U. Athabasca: M Connors
U. Calgary: P Amerl, L Cogger, E Donovan, D Knudsen, JS Murphree, T Trondsen, D Wallis, A Yau
U. New Brunswick: A Hamza, PT Jayachandran, D Kim, R Langley
U. Saskatchewan: G Hussey, S Koustov, G Sofko, JP St Maurice
U. Victoria: R Horita
U. Western Ontario: L Kagan, J MacDougall
York U: J Laframboise, J McMahon
JAXA/ISAS, Japan: T Abe, H Hayakawa, K Tsuruda
NRL, USA: P Bernhardt, C Siefring
UNH, USA: M Lessard