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Ionospheric ions in the magnetosphere: Important at large and small scales

M. André
Swedish Institute of Space Physics,
Uppsala, Sweden
mats.andre@irfu.se

S. Toledo-Redondo
University of Murcia, Murcia, Spain

A. W. Yau
University of Calgary, Calgary, Alberta, Canada

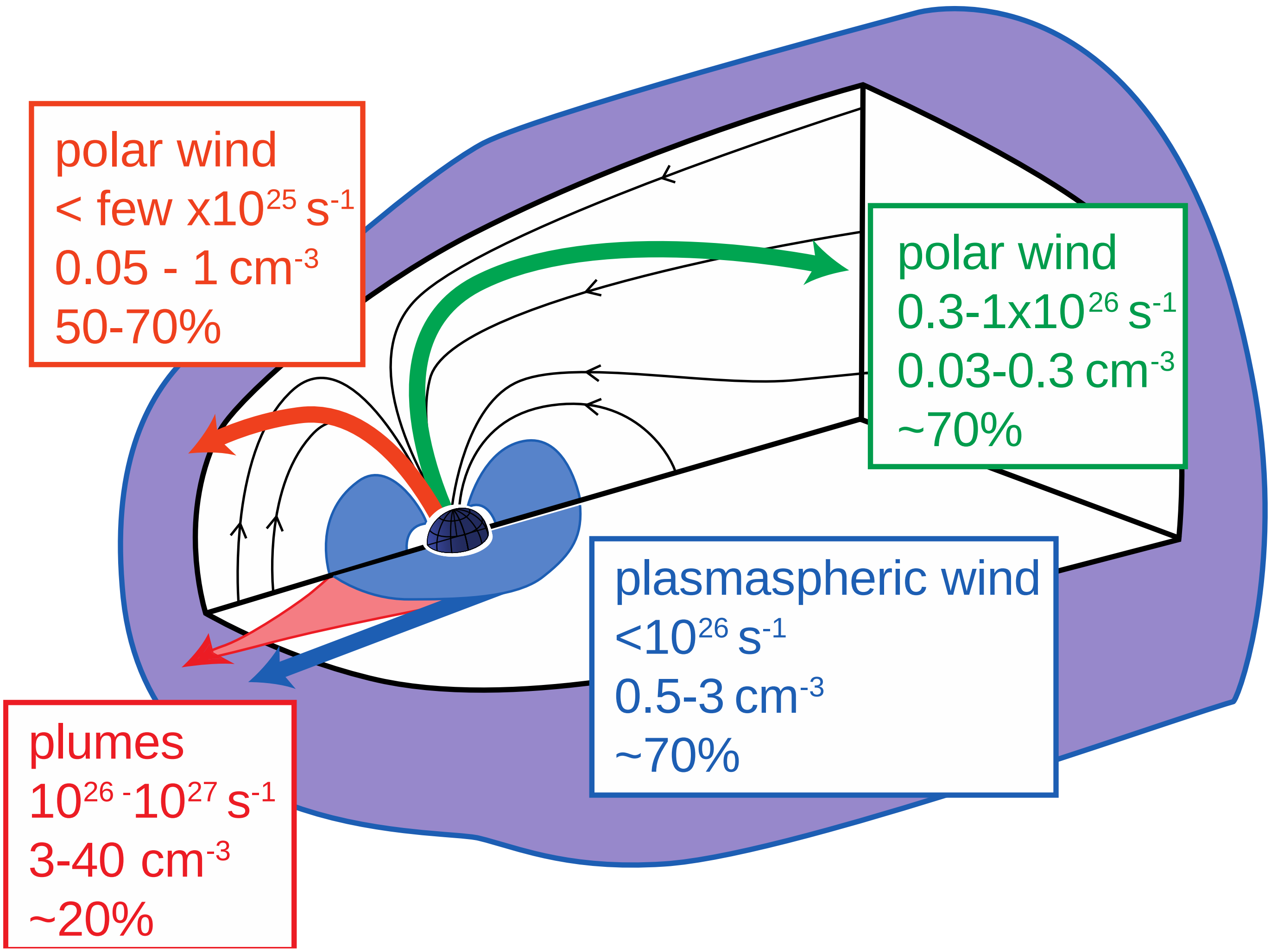
Cold (few eV) ions dominate:

- **Most of the magnetosphere (number density)**
- **Most of the time**
- **Much of the outflow**

These ions:

- **Change the Alfvén velocity**
- **Introduce a new length-scale (gyro radius)**

Large scales: Cold ion outflow



- **Outflow paths**
- **Outflow rates**
- **Typical densities**
- **Fraction of time cold ions dominate**

(Cluster statistics, André and Cully, GRL, 2012)

Large scales: Some statistical studies

High latitude: Cusp/cleft, Polar Cap, Auroral Region

Spacecraft	Nominal energy range (eV)	Altitude (R_E)	Upflow rate (10^{26} ions/s); ion species
Cluster[1]	0 - 60	5 - 20	0.6 - 2.4 (mainly H^+)
Polar/TIDE[2]	<1 - 100	8	1.3 (mainly H^+)
Polar/TIDE[3]	<1 - 450	0.8	1.7 (mainly H^+)
Akebono[4]	<1 - 70	1 - 1.5	0.2 - 2(H^+ and O^+)
DE[5]	10 - 17,000	2.5-3.7	0.2 - 2 (H^+ and O^+)
Polar/TIMAS[6]	15 - 33,000	0.8	0.08 (H^+ and O^+)
Cluster/CODIF[7]	25 - 38,000	10 - 15	0.1 - 2.2 (O^+)

Low latitude: Magnetopause (plumes)

Spacecraft	Nominal energy range (eV)	Outflow rate (10^{26} ions/s)
Cluster[8]	0 - 1000	1 - 10
MPA[9]	1 - 40,000	2
IMAGE[10]	wide range	3.8 - 21

Low latitude: Magnetopause (wind)

Spacecraft	Nominal energy range (eV)	Outflow rate (10^{26} ions/s)
Cluster[8]	0 - 1000	0.1 - 1

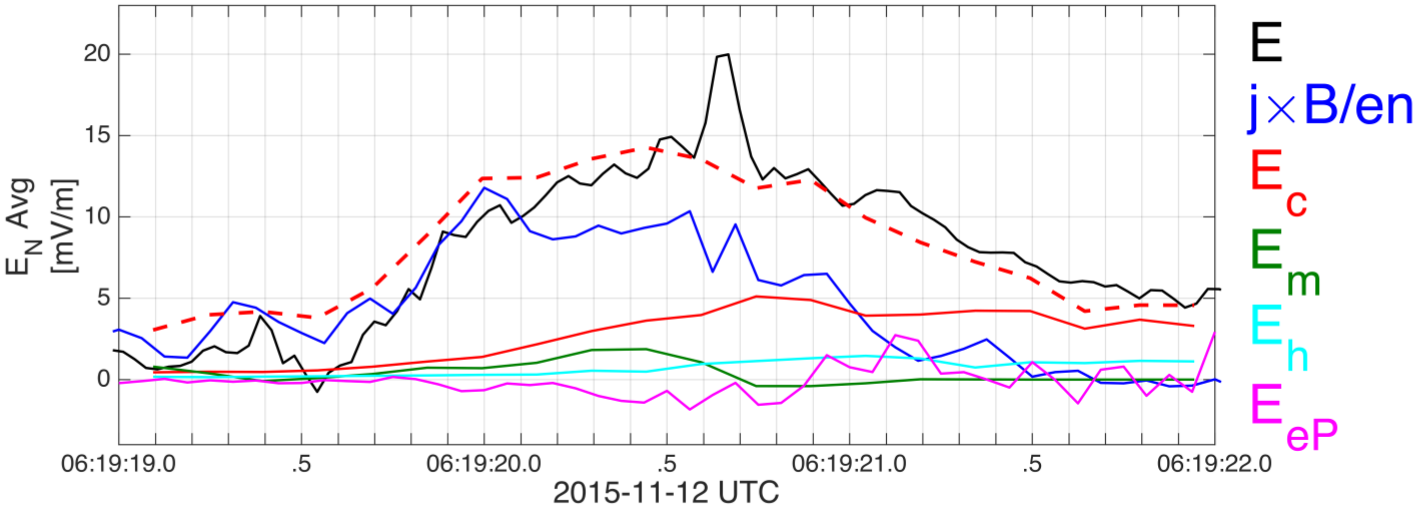
[1] *André et al.* [2015], [2] *Su et al.* [1998], [3] *Huddleston et al.* [2005], [4] *Cully et al.* [2003],
[5] *Yau and André* [1997], [6] *Peterson et al.* [2006, 2008], [7] *Slapak et al.* [2017], [8] *André and Cully* [2012],
[9] Magnetospheric Plasma Analyzers *Borovsky and Denton* [2008], [10] *Spasojevic and Sandel* [2010],

Examples of statistical studies of ion upflow at high latitudes and ion outflow through the magnetopause at low latitudes.

A typical outflow rate is 10^{26} ions/s

(André, Toledo-Redondo and Yau, in press, 2020)

Small scales: Generalized Ohm´s law



(MMS, André et al., GRL, 2016) (200 km)

Magnetopause magnetic reconnection separatrix observed by MMS

E_N is balanced by drifting electrons and cold ions and divergence of the electron pressure tensor

$(1/en)(\mathbf{jxB})$ $(n_c/n)(\mathbf{v_c xB})$ $1/(en)$ div $\mathbf{P_e}$

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