Asymmetries in ion outflow from the Earth's polar cap regions

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with inputs from
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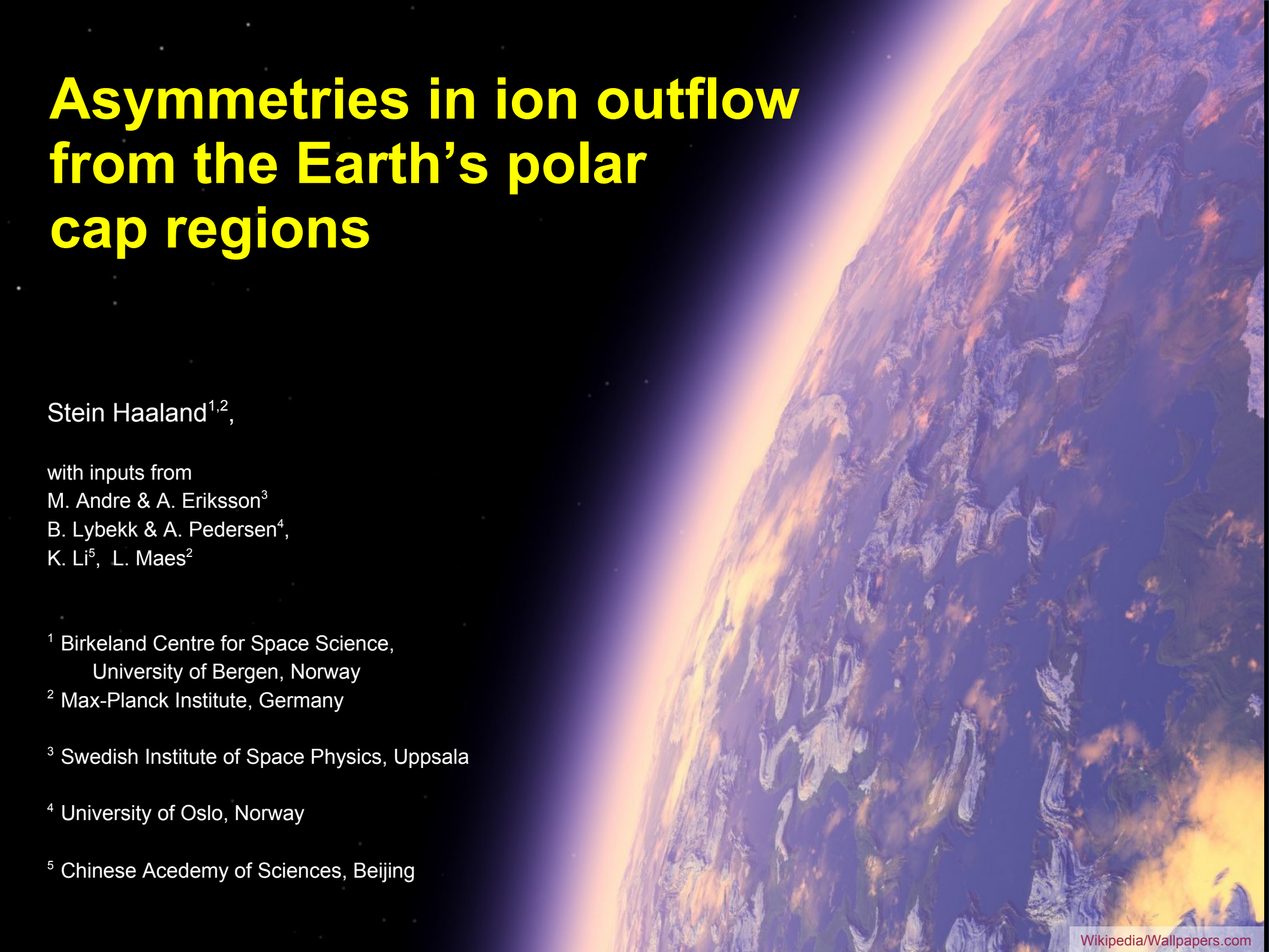
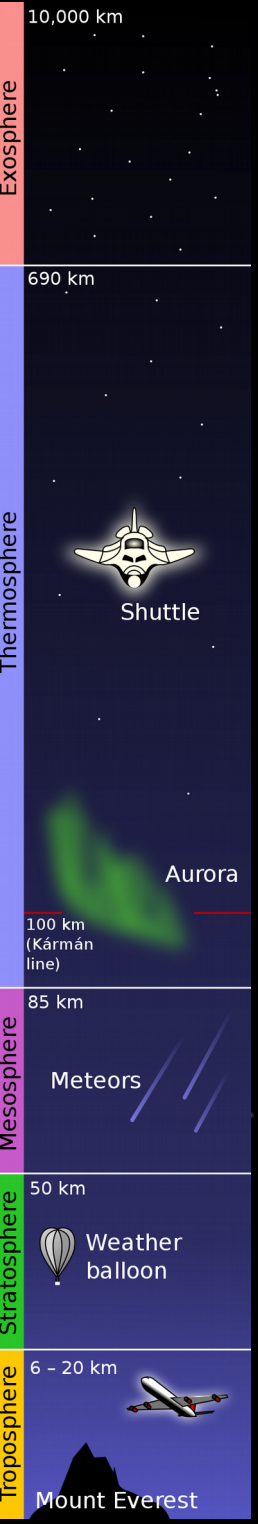


Earth:

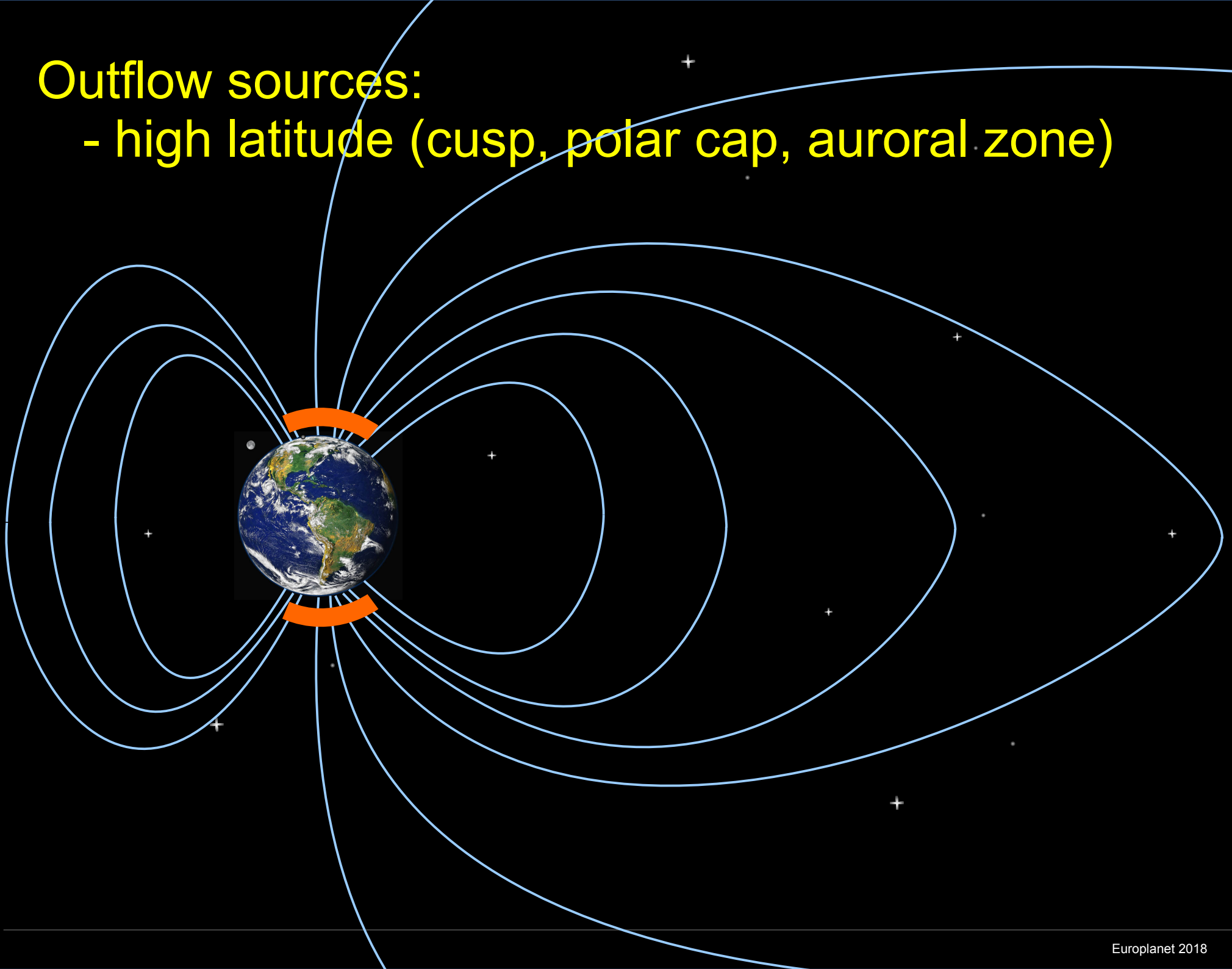
* Composition N, O, H

* Ionization mainly from EUV

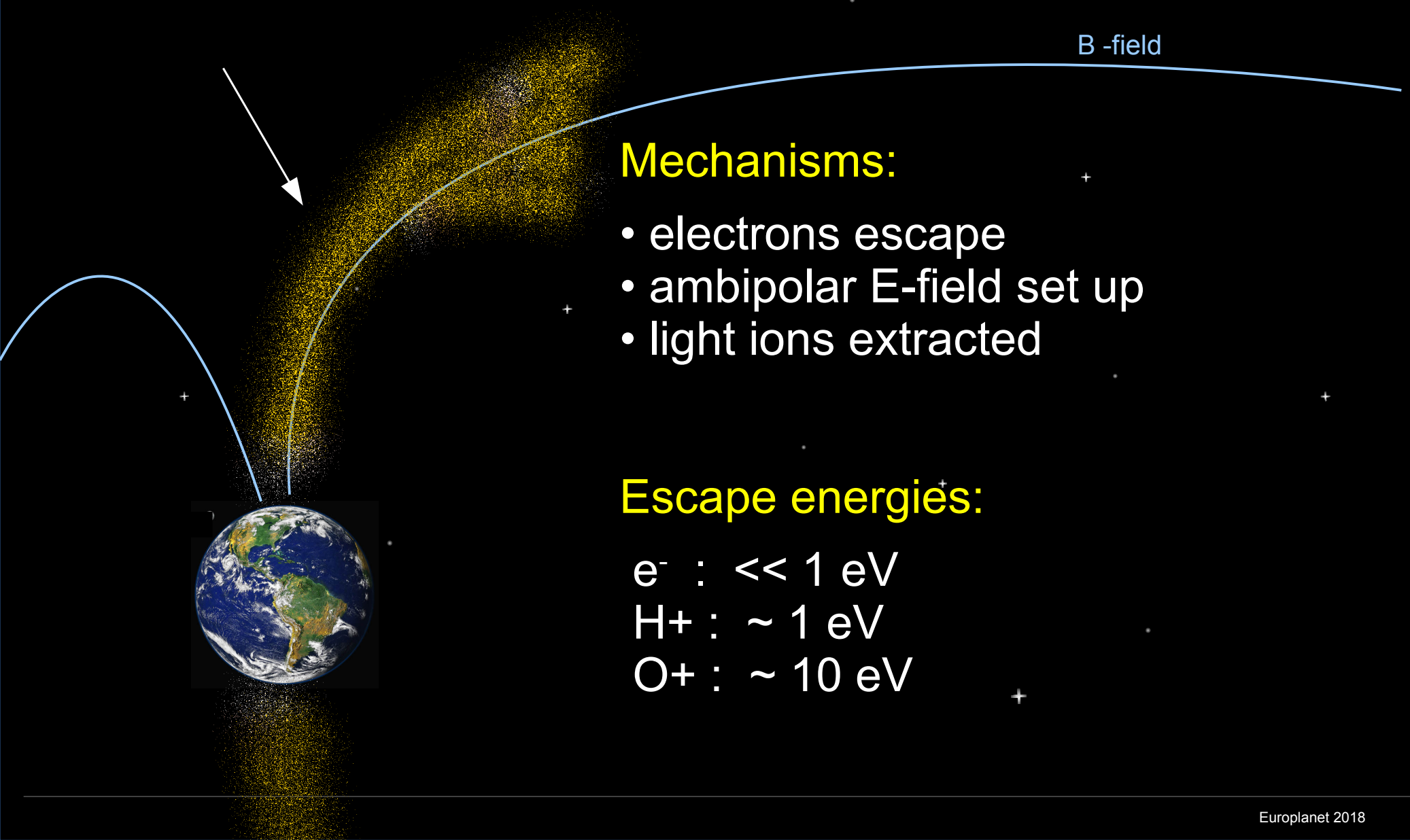


Outflow sources:

- high latitude (cusp, polar cap, auroral zone)



Mechanisms, polar wind escape



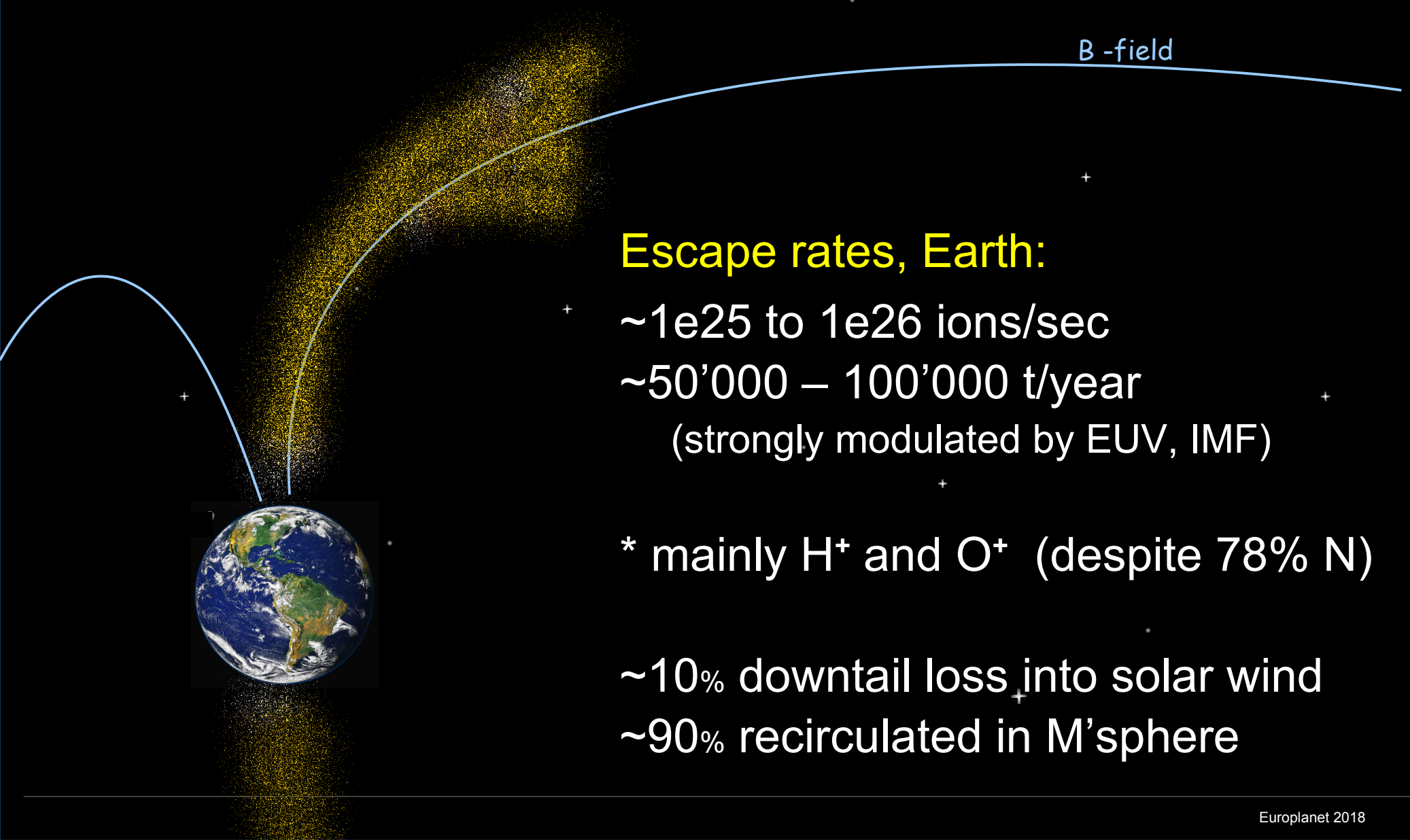
Mechanisms:

- electrons escape
- ambipolar E-field set up
- light ions extracted

Escape energies:

e^- : << 1 eV
H+ : ~ 1 eV
O+ : ~ 10 eV

Ion outflow from polar cap regions



Escape rates, Earth:

~1e25 to 1e26 ions/sec

~50’000 – 100’000 t/year

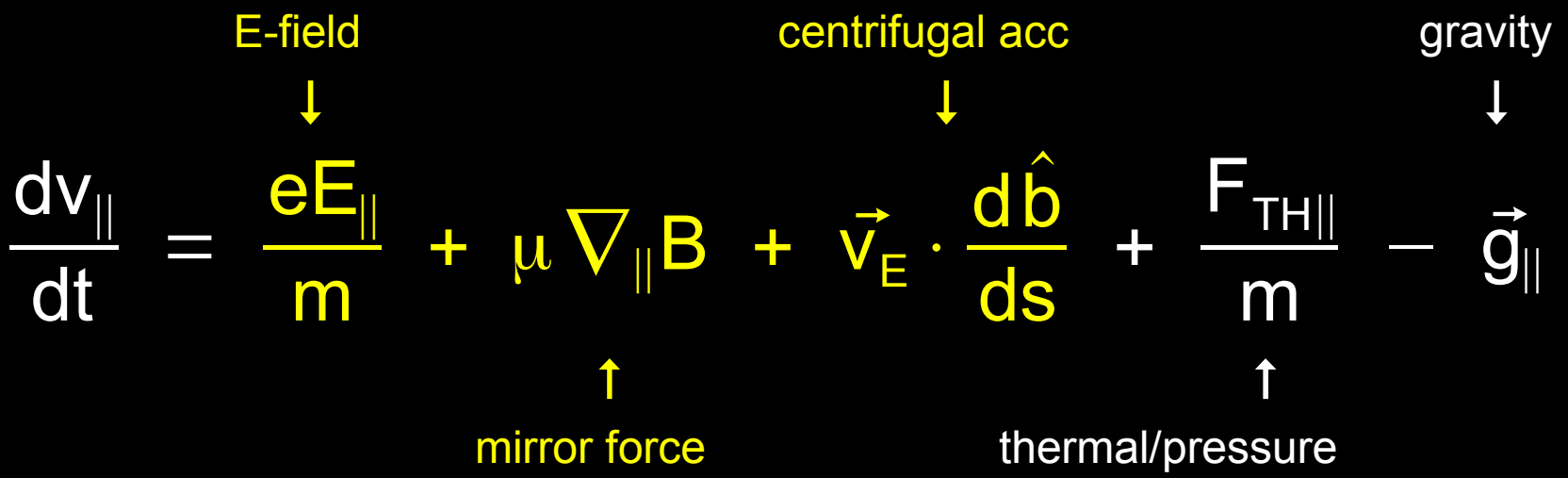
(strongly modulated by EUV, IMF)

* mainly H^+ and O^+ (despite 78% N)

~10% downtail loss into solar wind

~90% recirculated in M’sphere

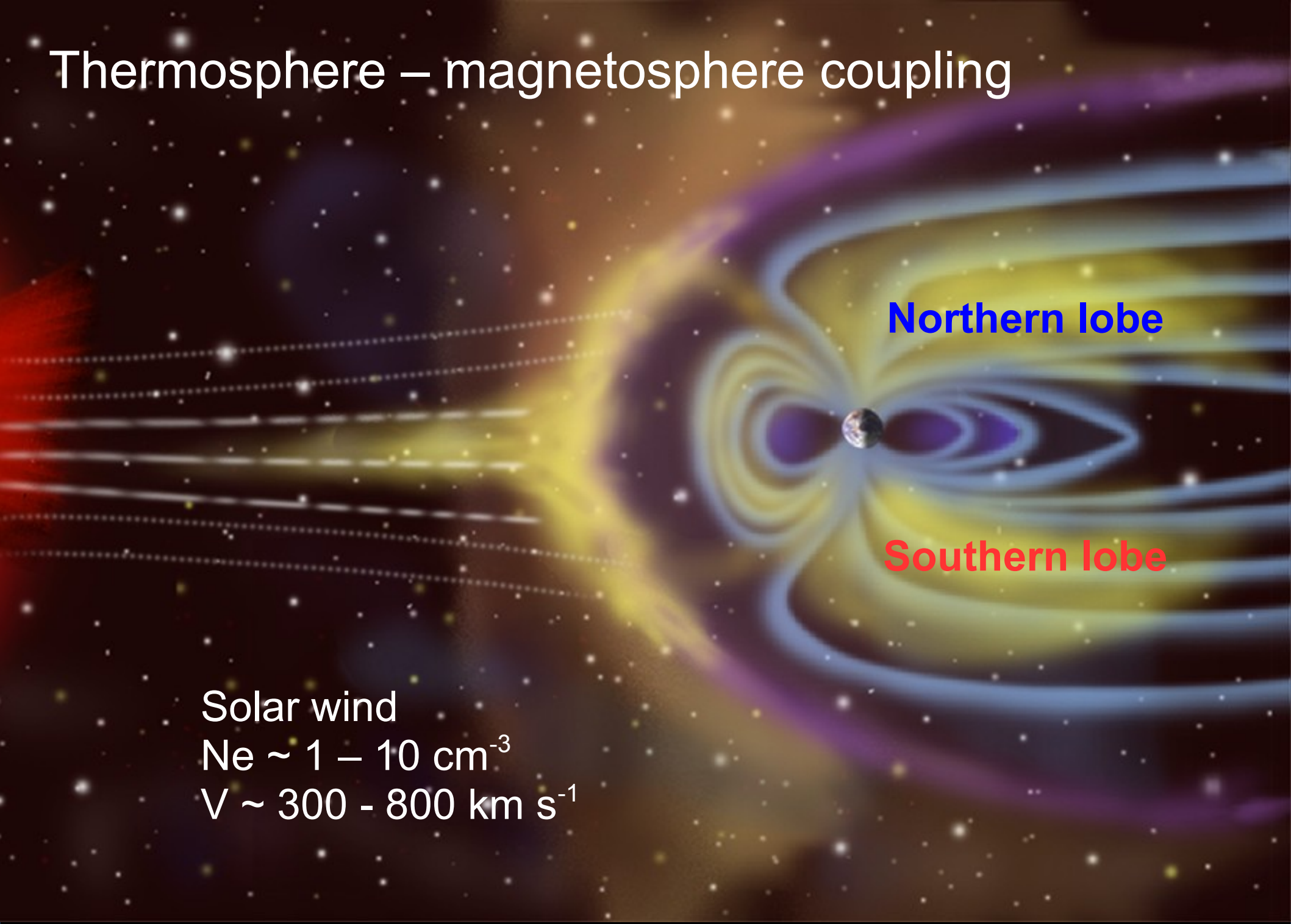
Transport and forces



Field aligned acceleration of cold ions are primarily governed by :

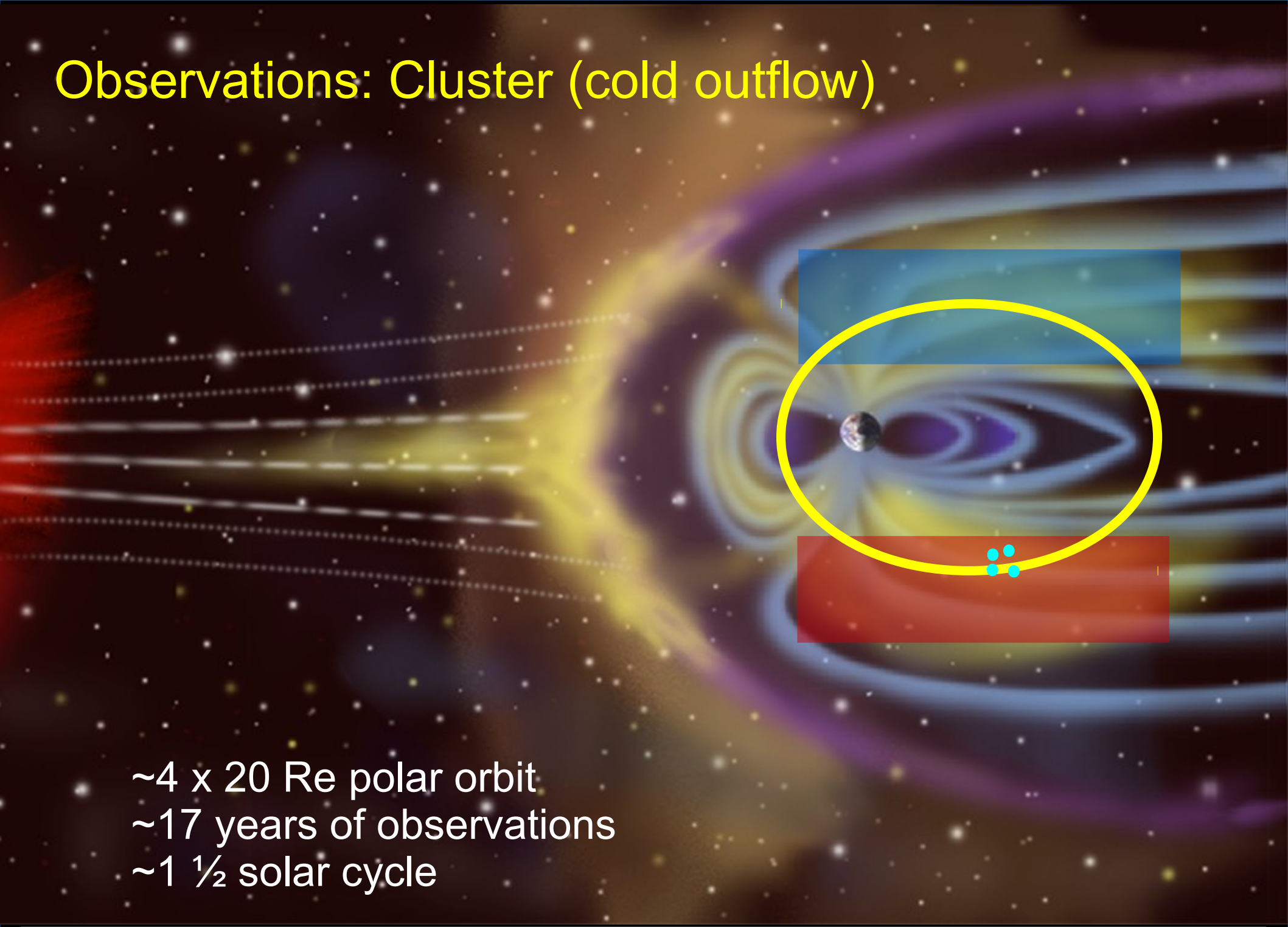
* Gravity (low altitudes)
* Mirror force (low altitude)
* Centrifugal force (intermediate altitudes)
* Electric fields (relevant at low altitudes otherwise $E_{\parallel} \sim 0$)

Thermosphere – magnetosphere coupling



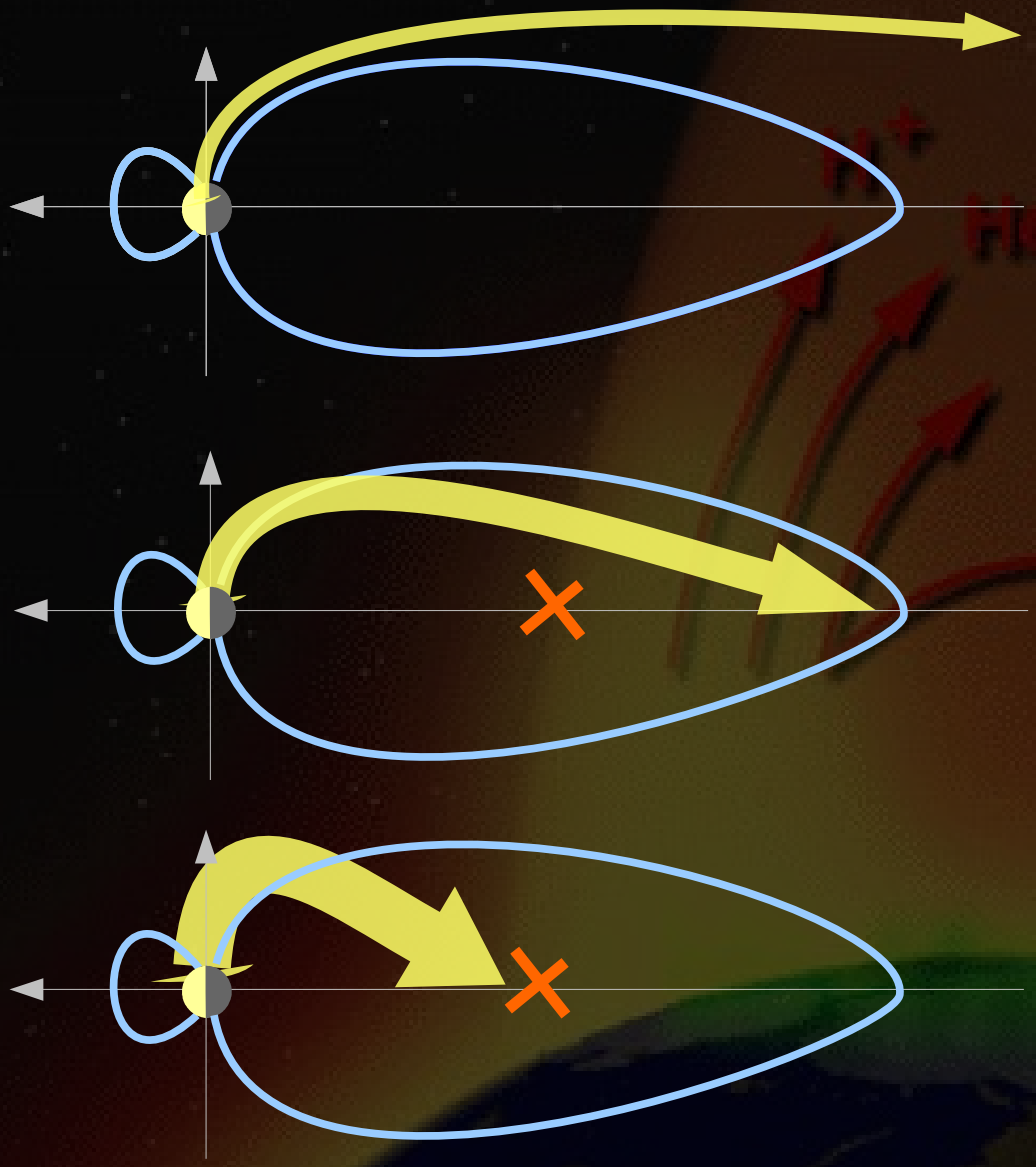
Solar wind
Ne ~ 1 – 10 cm^{-3}
V ~ 300 - 800 km s^{-1}

Observations: Cluster (cold outflow)



~4 x 20 Re polar orbit
~17 years of observations
~1 ½ solar cycle

Polar cap / cusp outflow : supply to plasma sheet



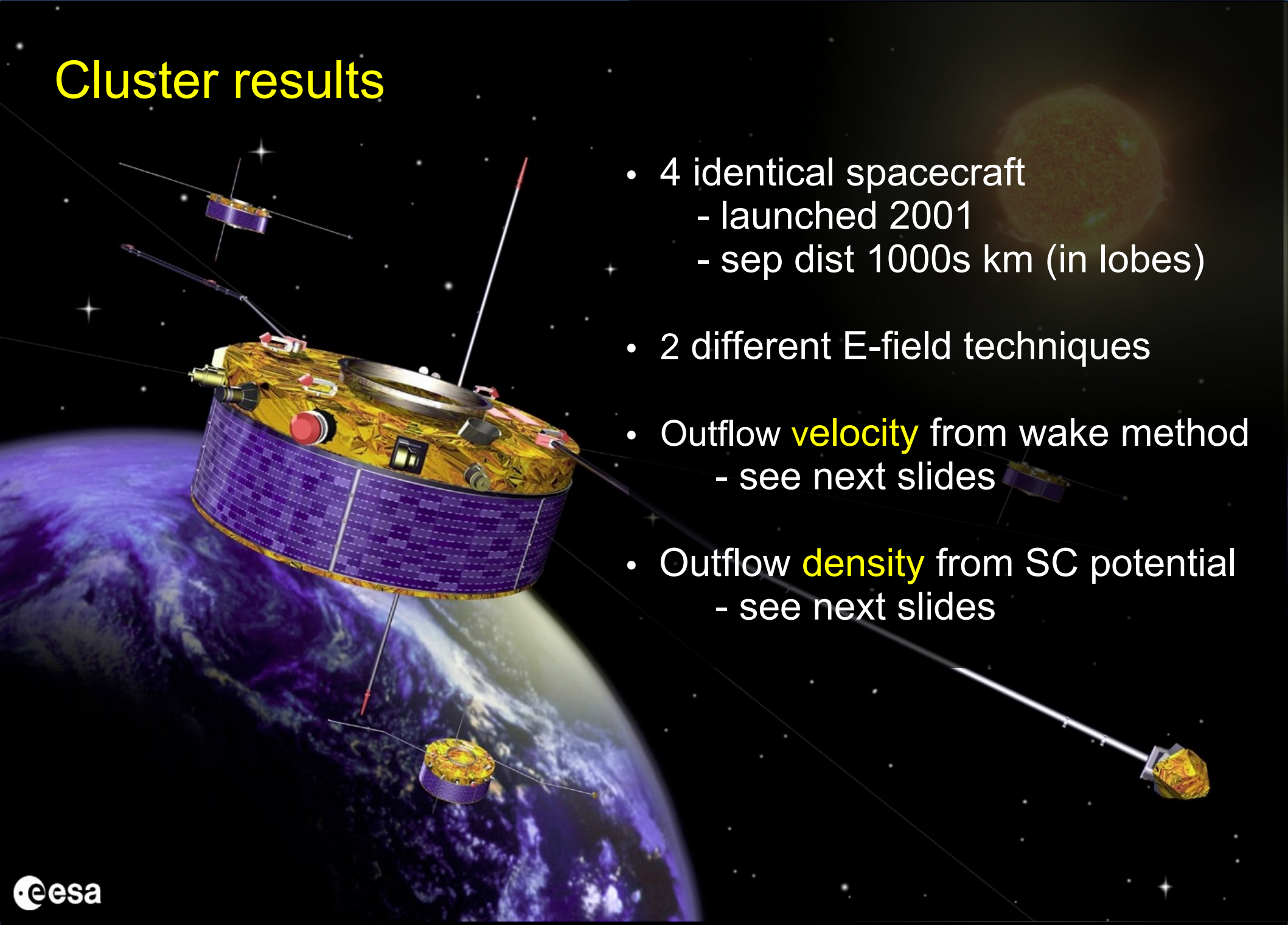
Quiet conditions, stagnant convection
- direct loss downtail

Intermediate geoactivity
– 80-90 % circulation
- supply far downtail

Disturbed conditions, strong convection
- little downtail loss
- supply close to Earth

Haaland et al, 2014, 2017

Cluster results

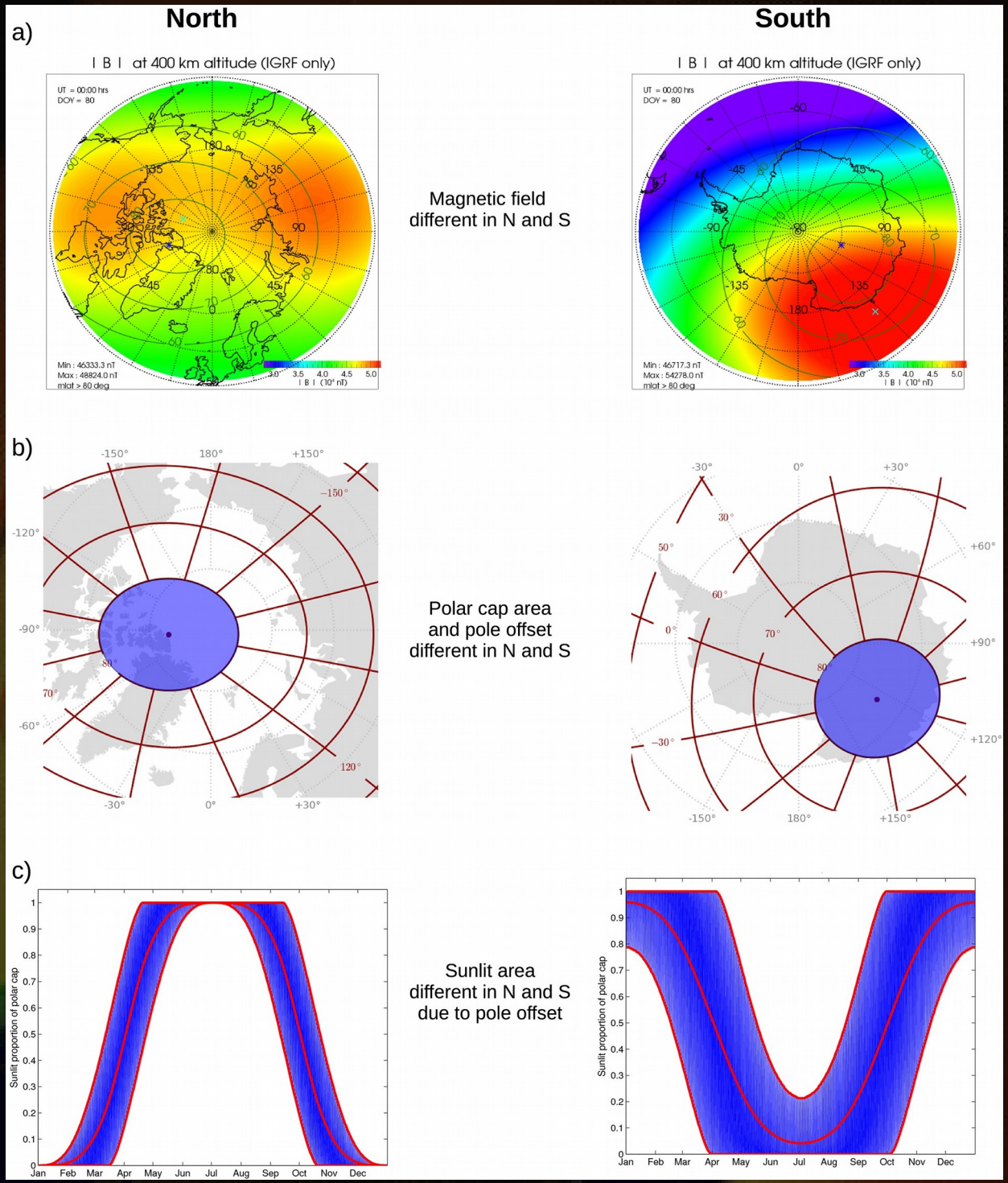


- 4 identical spacecraft
  - launched 2001
  - sep dist 1000s km (in lobes)
- 2 different E-field techniques
- Outflow velocity from wake method
  - see next slides
- Outflow density from SC potential
  - see next slides

esa

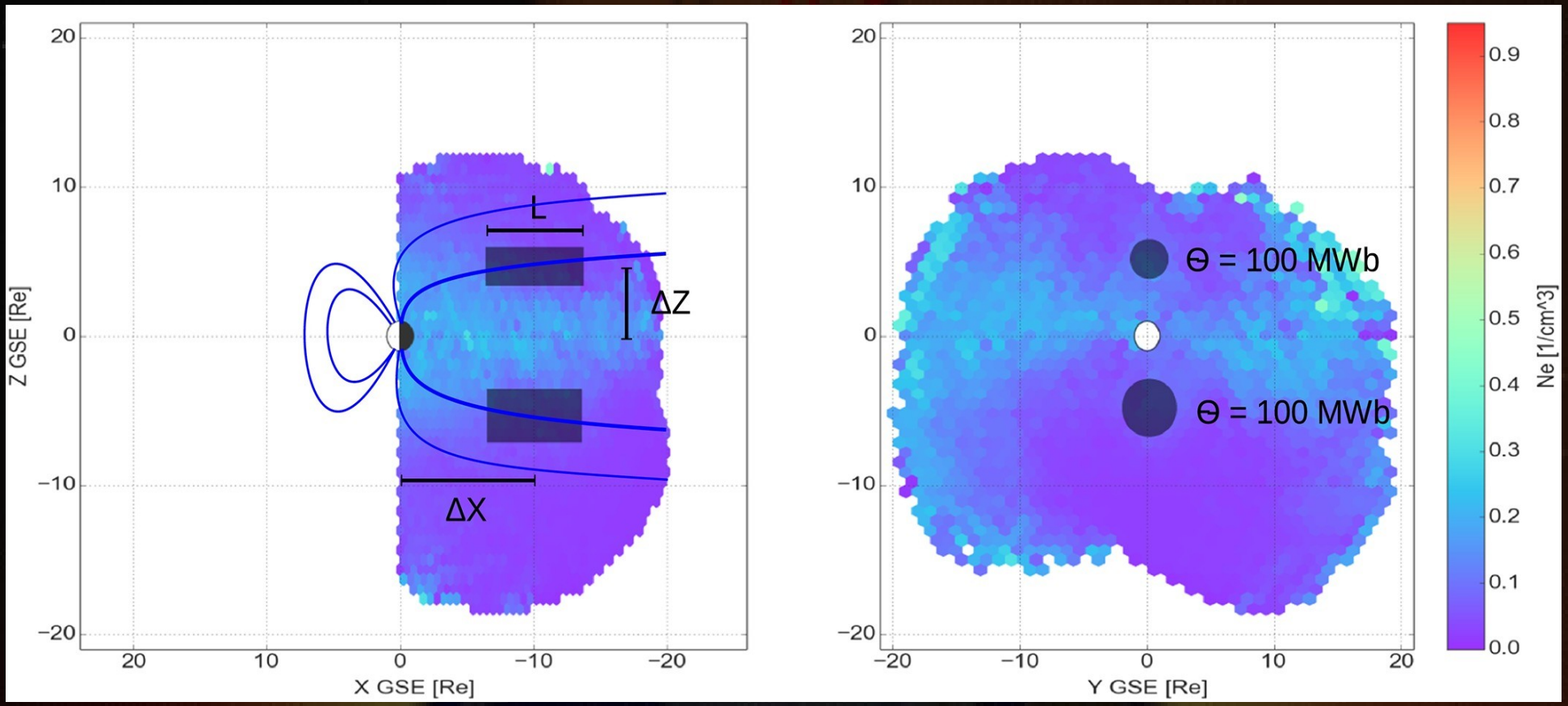
North – south asymmetries ?

- B-field different
- dipole offset
- polar cap area
- effective illumination



North – south asymmetries

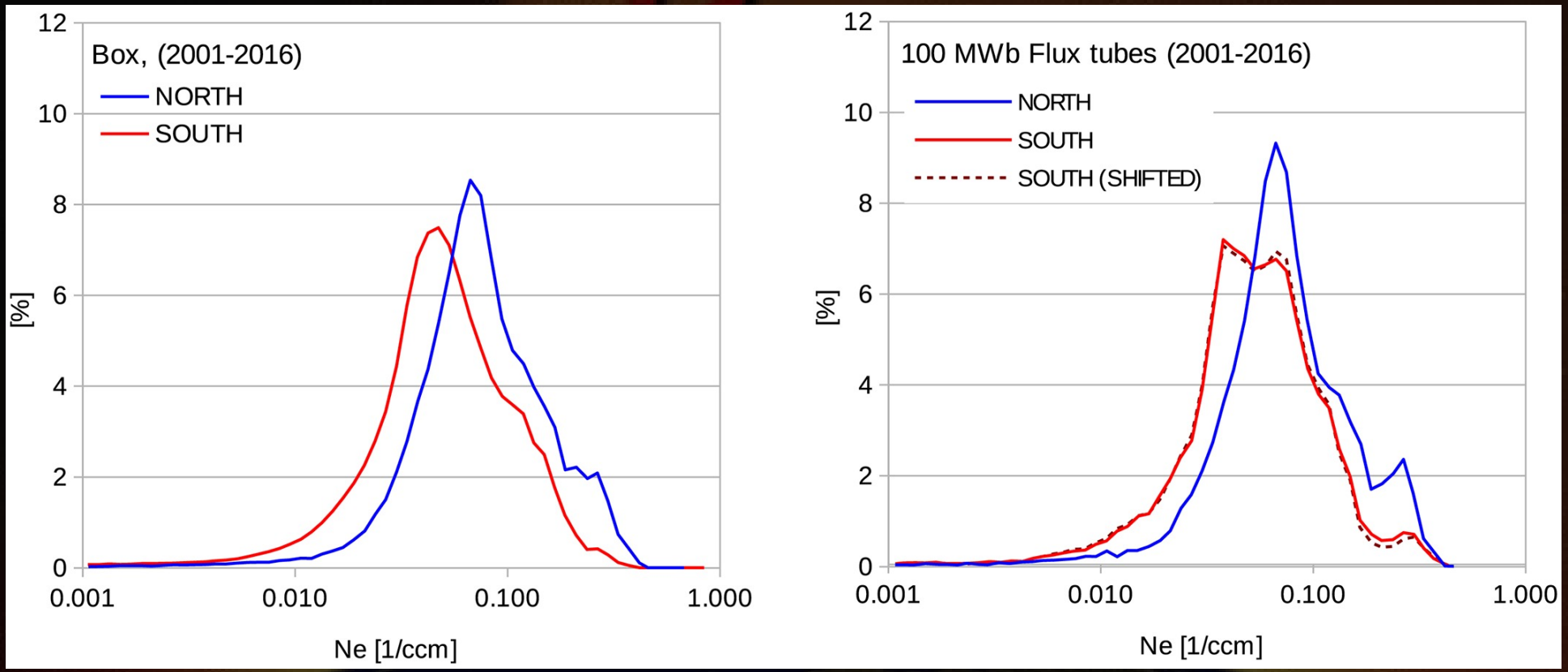
Cluster lobe densities 2001-2016 :



Haaland et al, 2017

North – south asymmetries

Cluster lobe densities 2001-2016 :
Higher outflow from Northern hemisphere



Haaland et al, 2017

Cluster around September equinox :

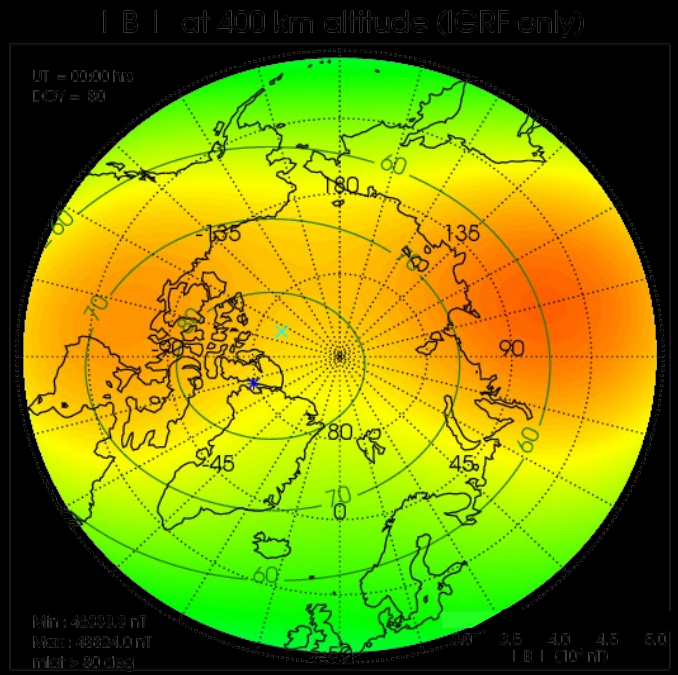
- Plasma density higher in the northern lobe

- Why ?

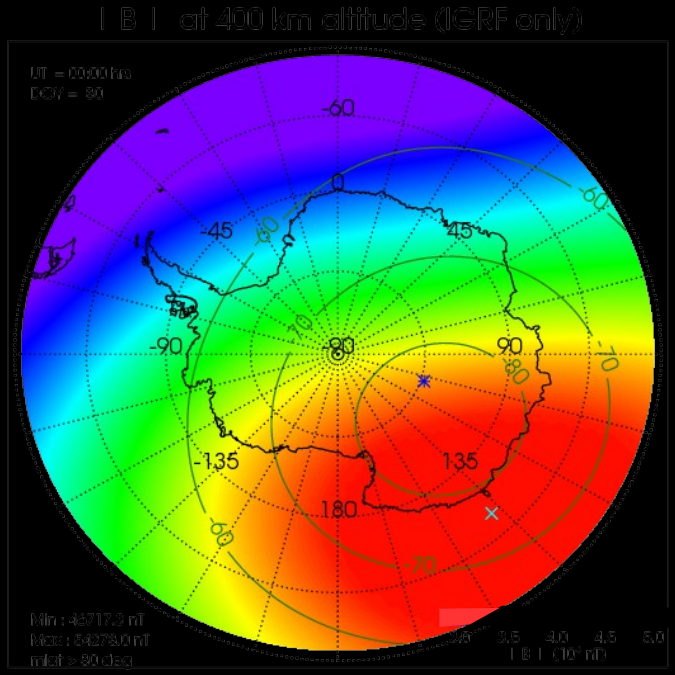
- difference in outflow ?

1) Geomagnetic field different

North



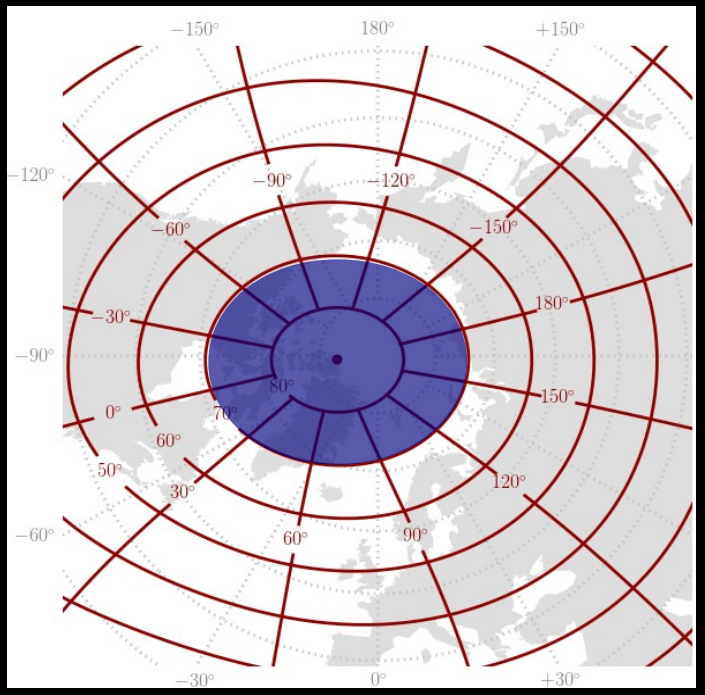
South



After Foerster et al, 2012

2) Source area different

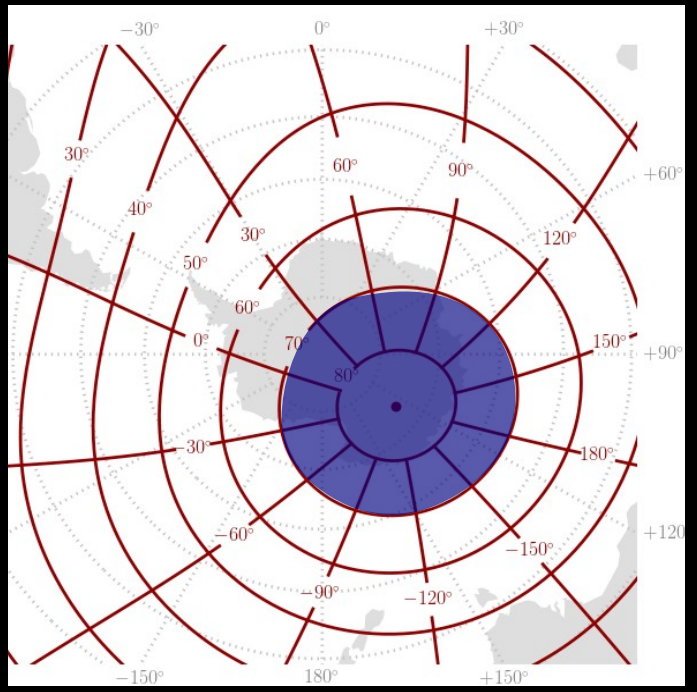
North



Area A = Θ/<B>

Different in
N and S

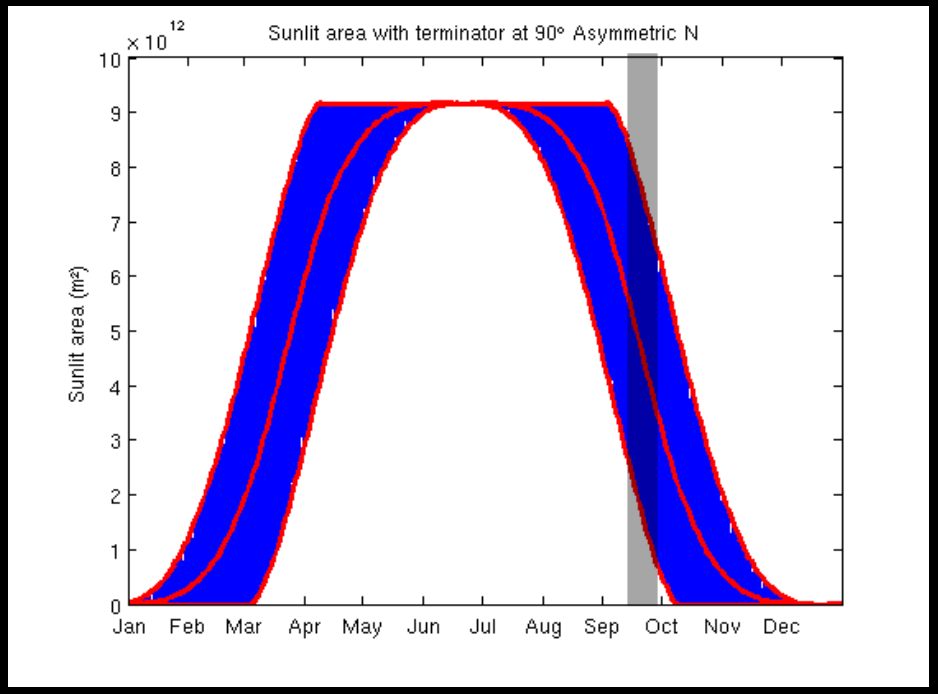
South



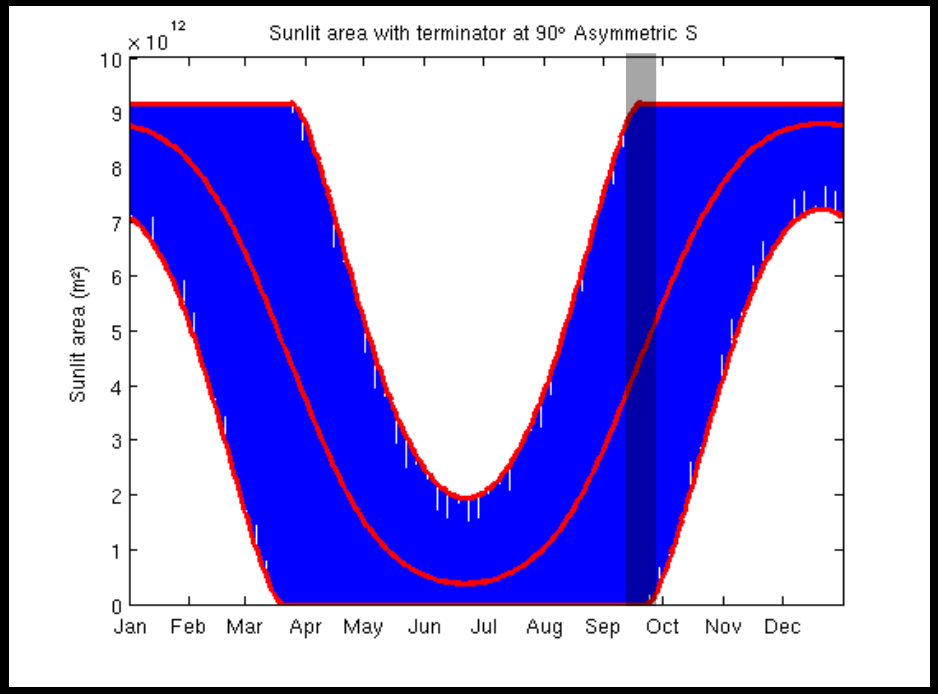
Laundal et al, 2016

3) Differences in solar illumination

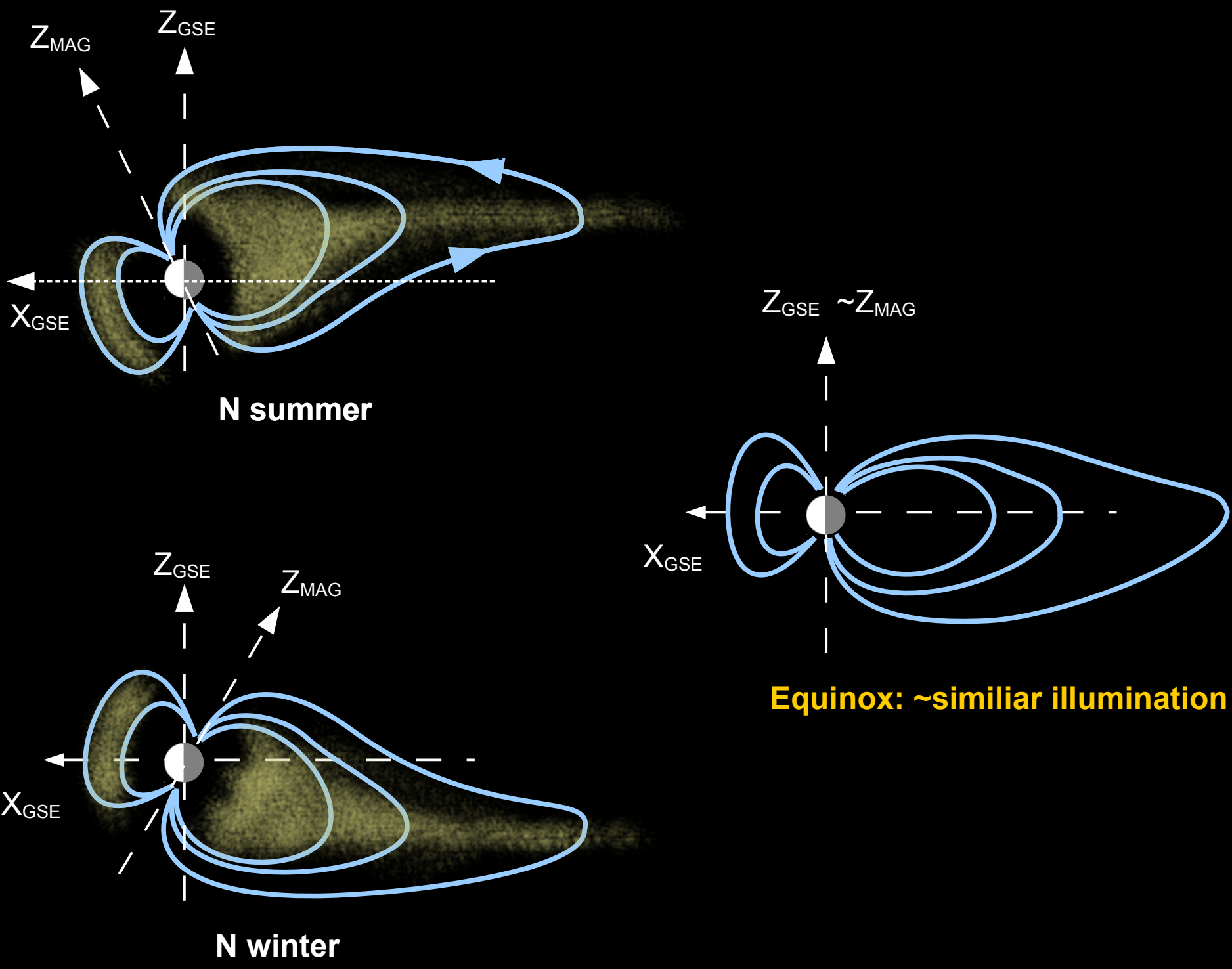
North



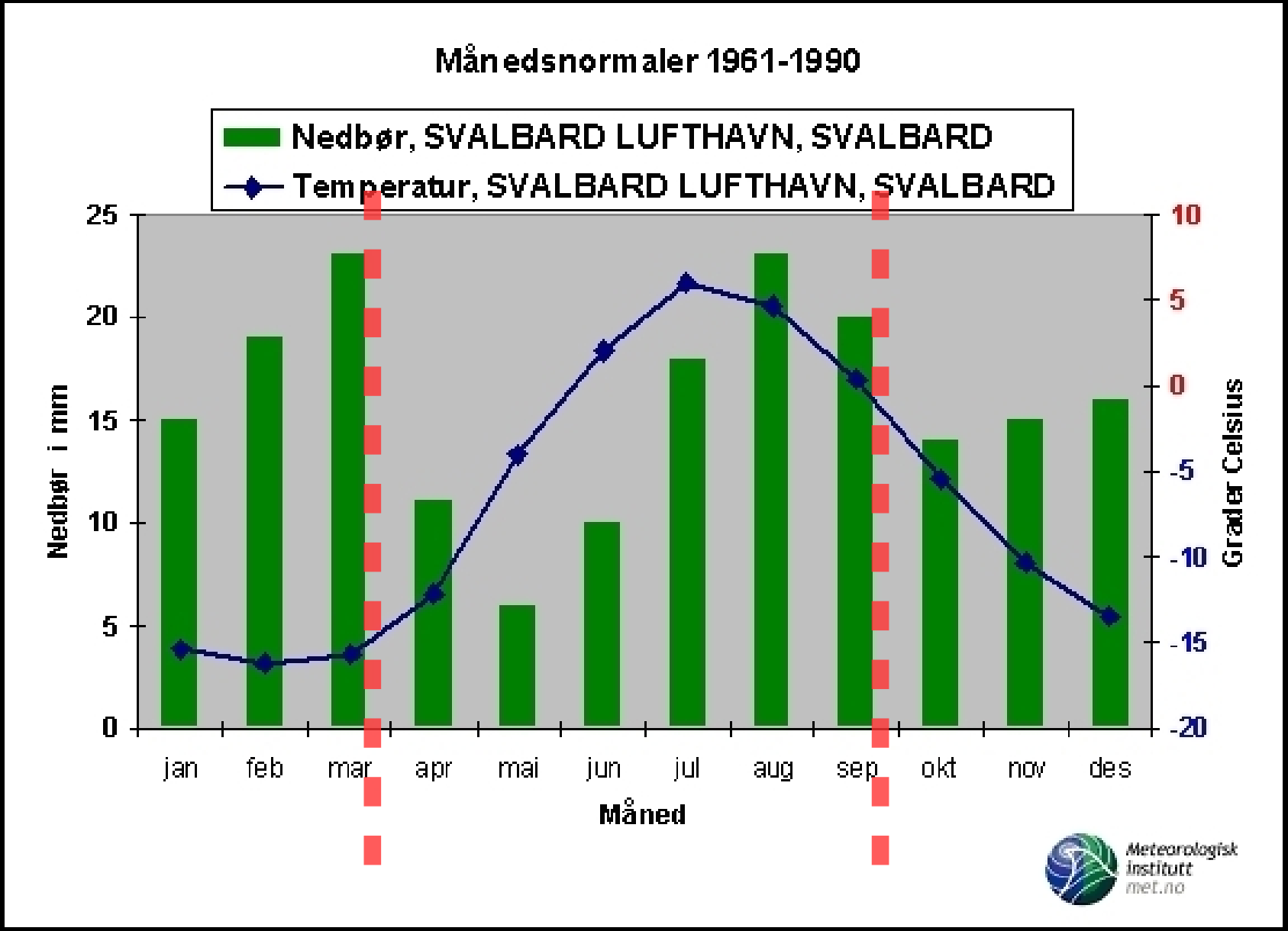
South



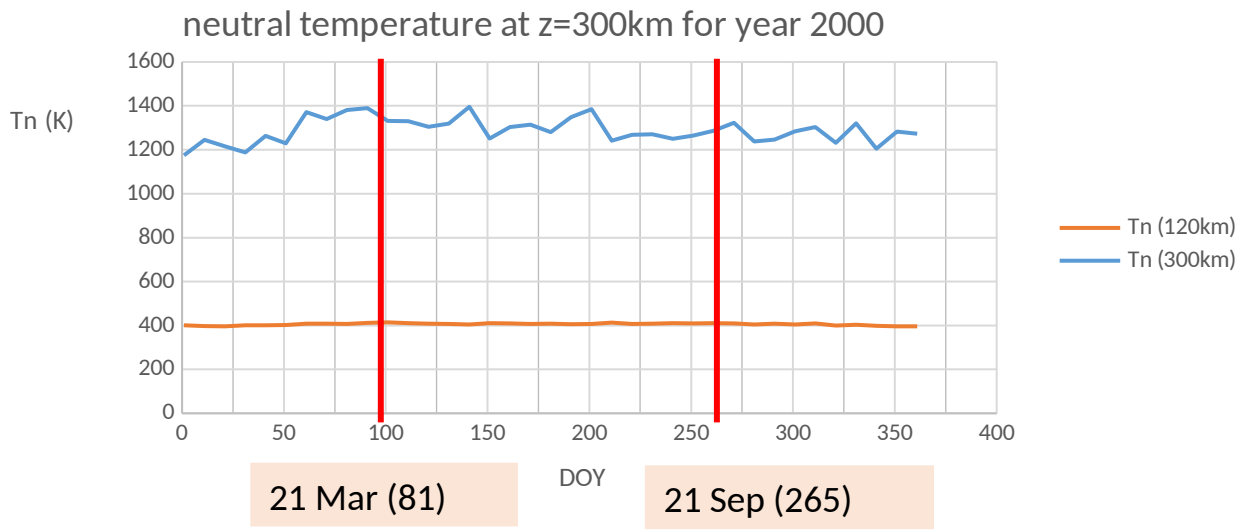
Maes et al, 2017

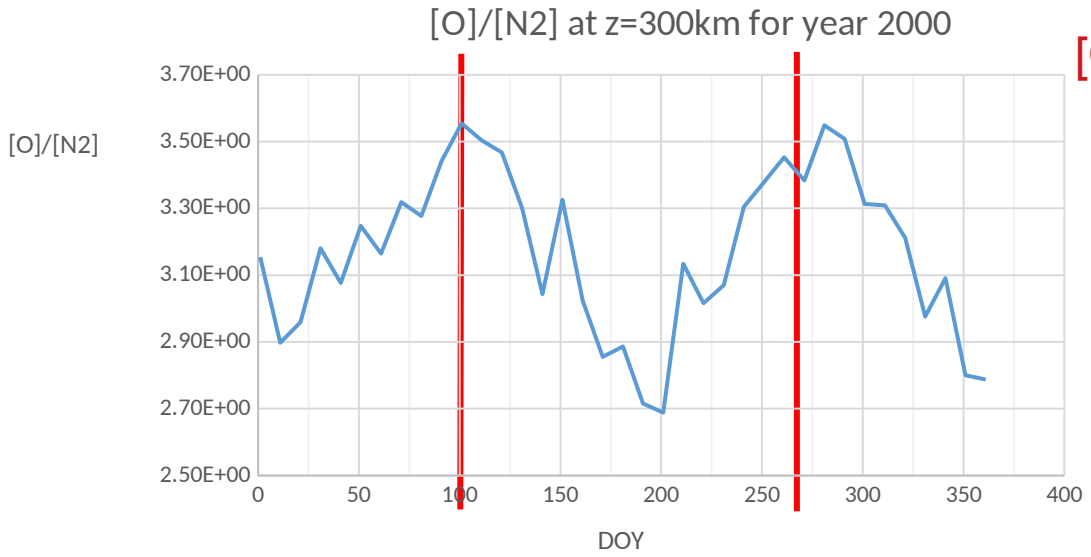

Z_{MAG}
Z_{GSE}
X_{GSE}
N summer
Z_{GSE} ~Z_{MAG}
X_{GSE}
Equinox: ~similiar illumination
Z_{GSE}
Z_{MAG}
X_{GSE}
N winter

4) Properties of the thermosphere/ionosphere ?



MSIS E90 model (run for year 2000; 10 day resolution)





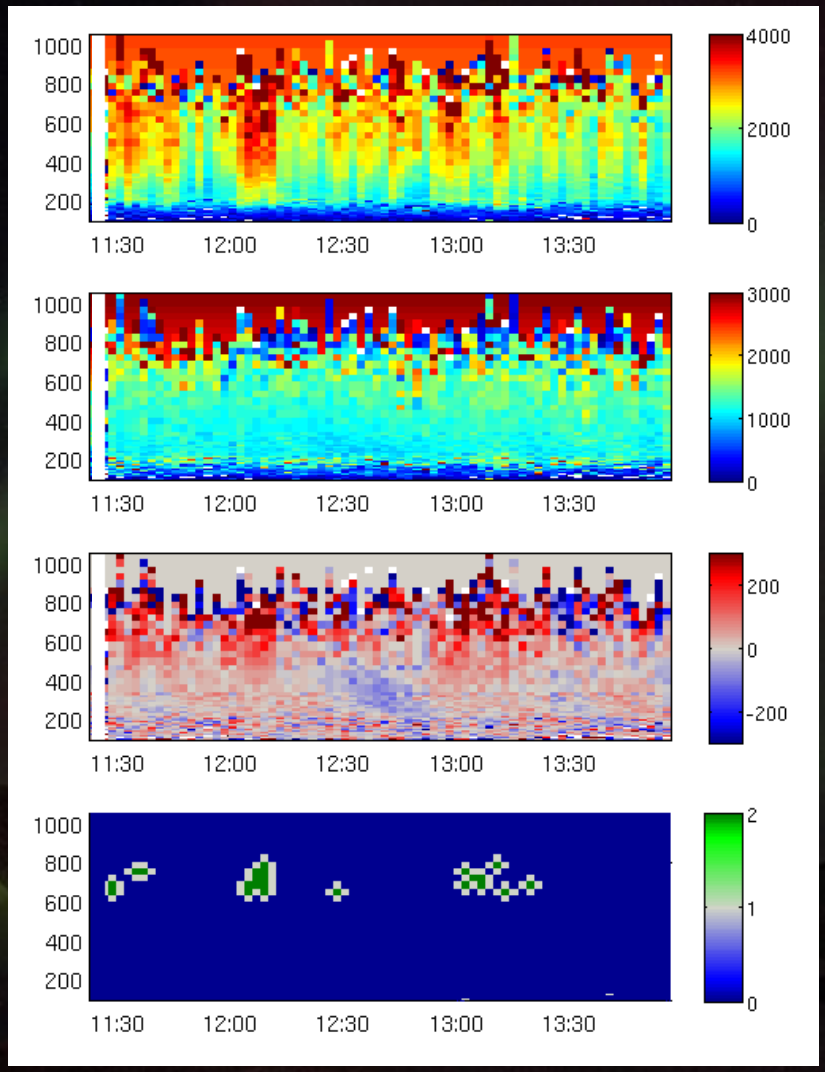
[O]/[N2] = proxy for Ne

A. Aruliah (private communication)

Work in progress: EISCAT Svalbard seasonal variations

Photo : N. Gulbrandsen

EISCAT – profiles of Te, Ti, Ne, Vi

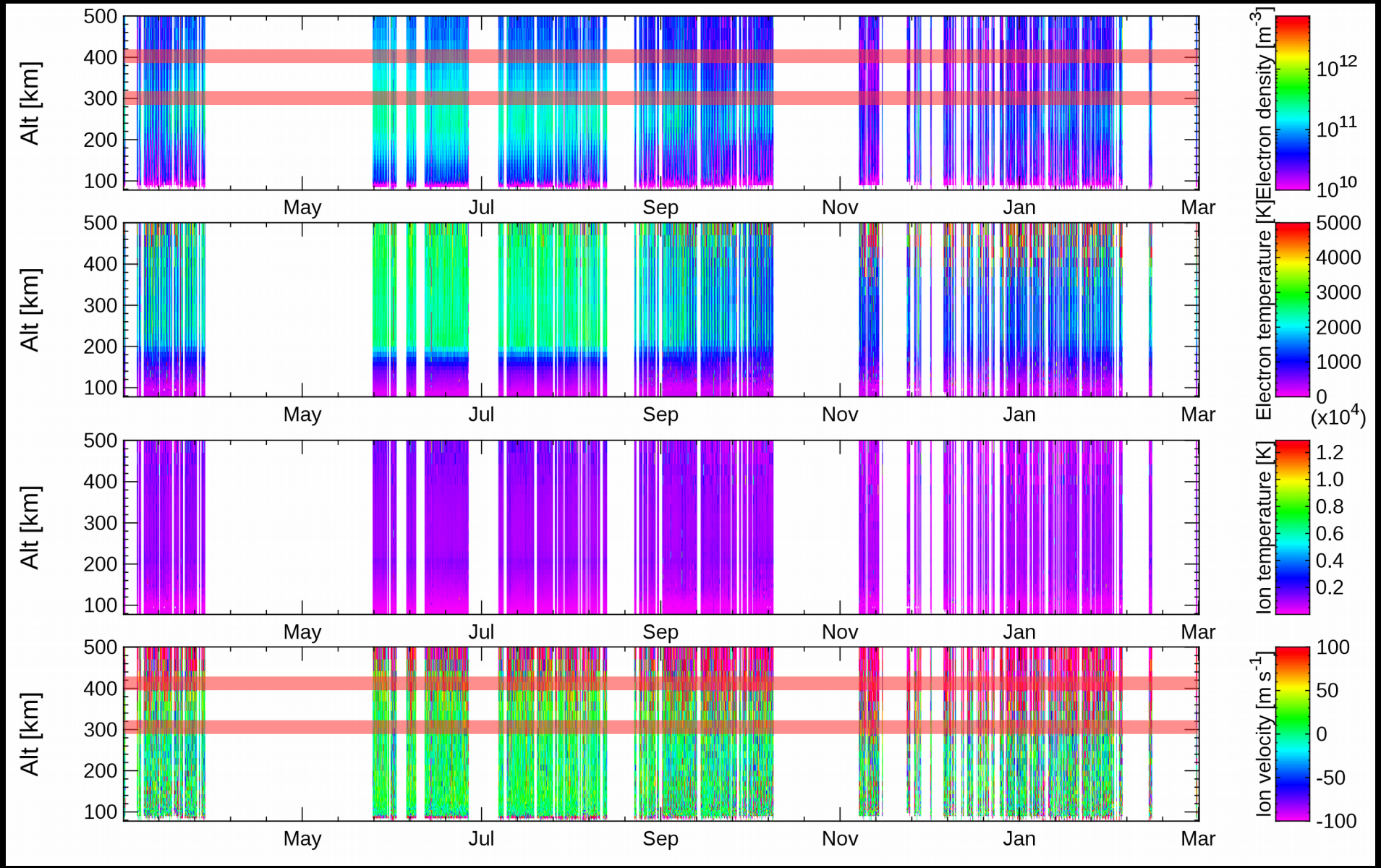


EISCAT Svalbard, 2015

Cons :

- Max ~1500 km
- **UP**flow, not **OUT**flow
- ….

EISCAT – measurements available 1996-2018



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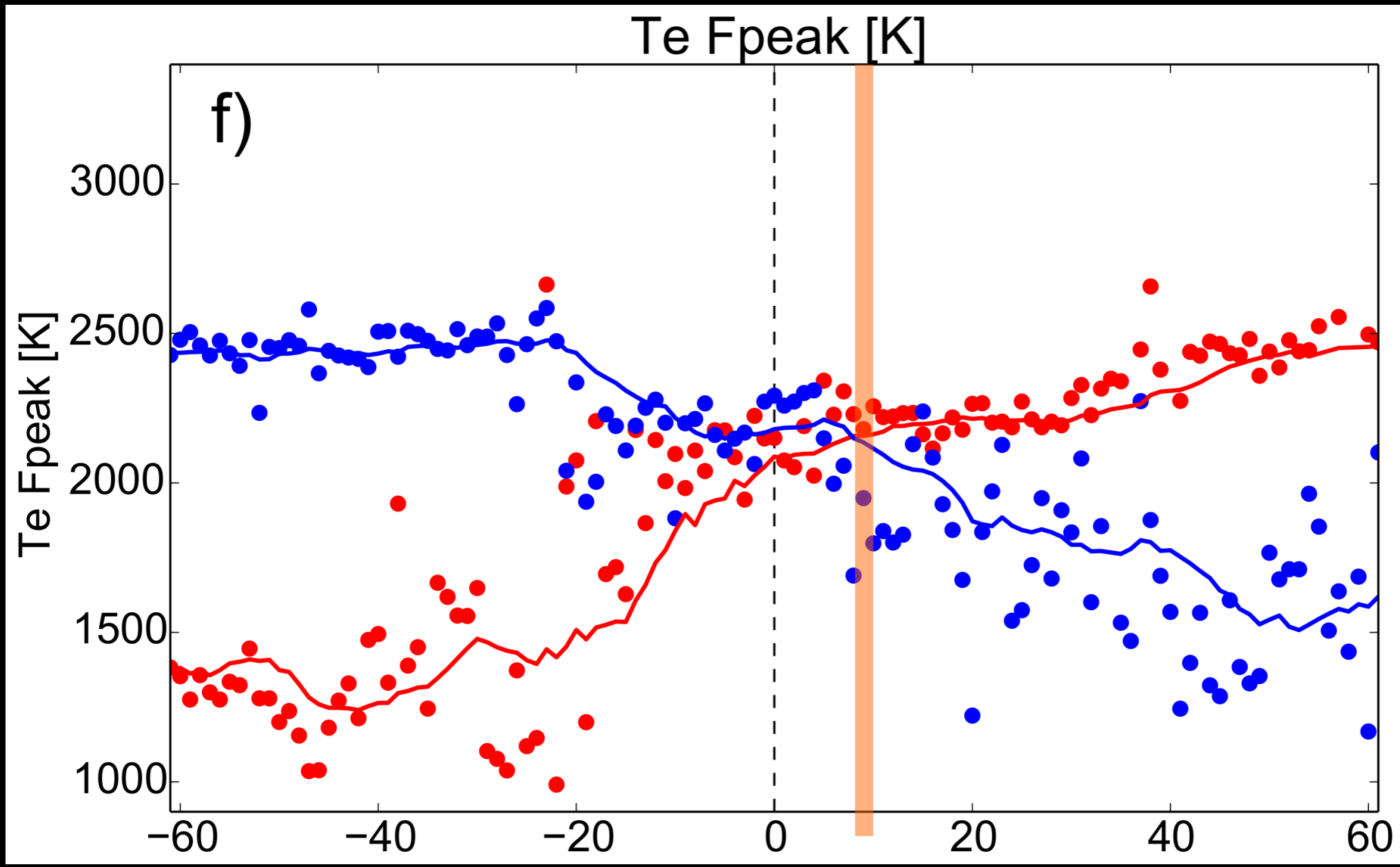

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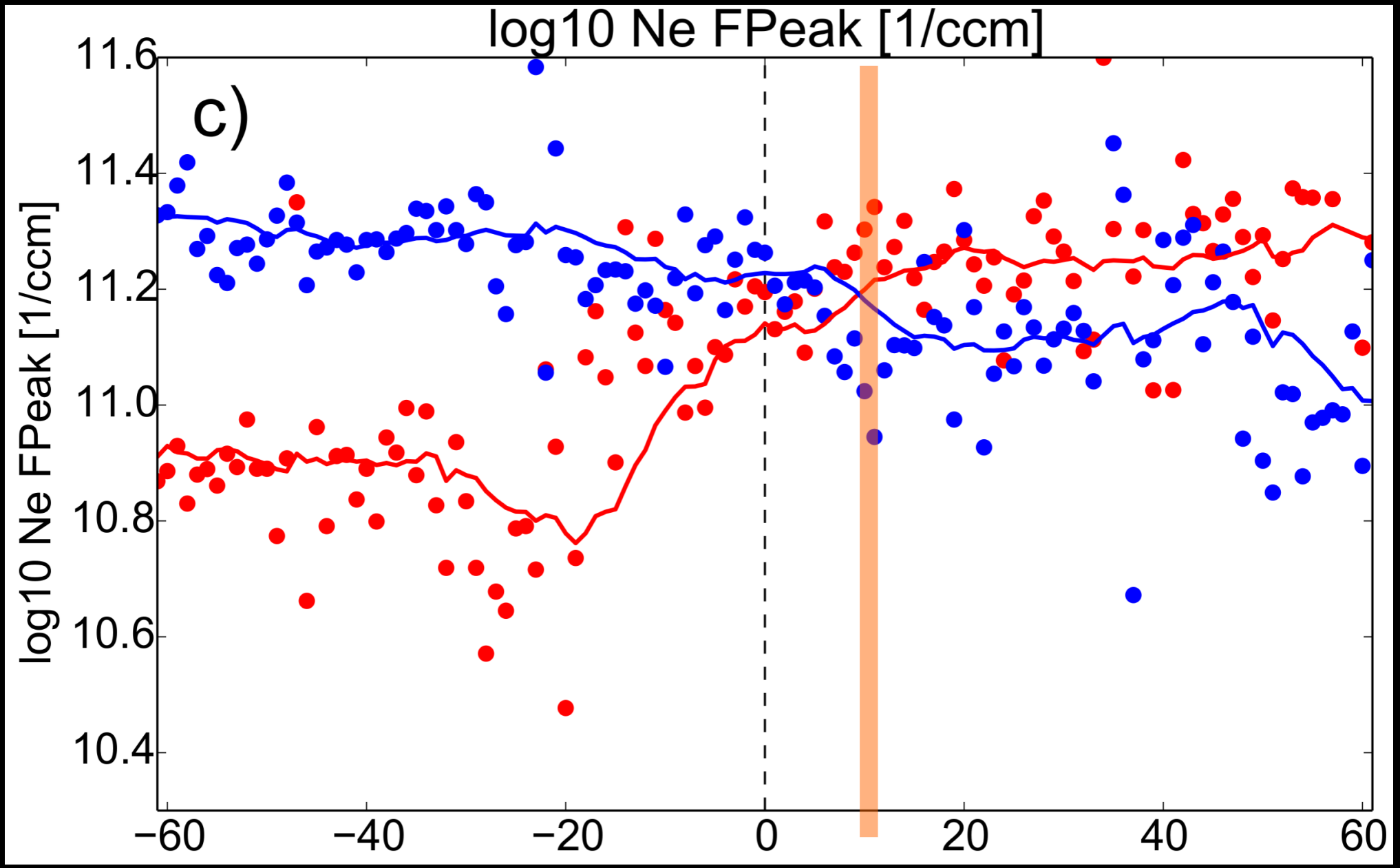

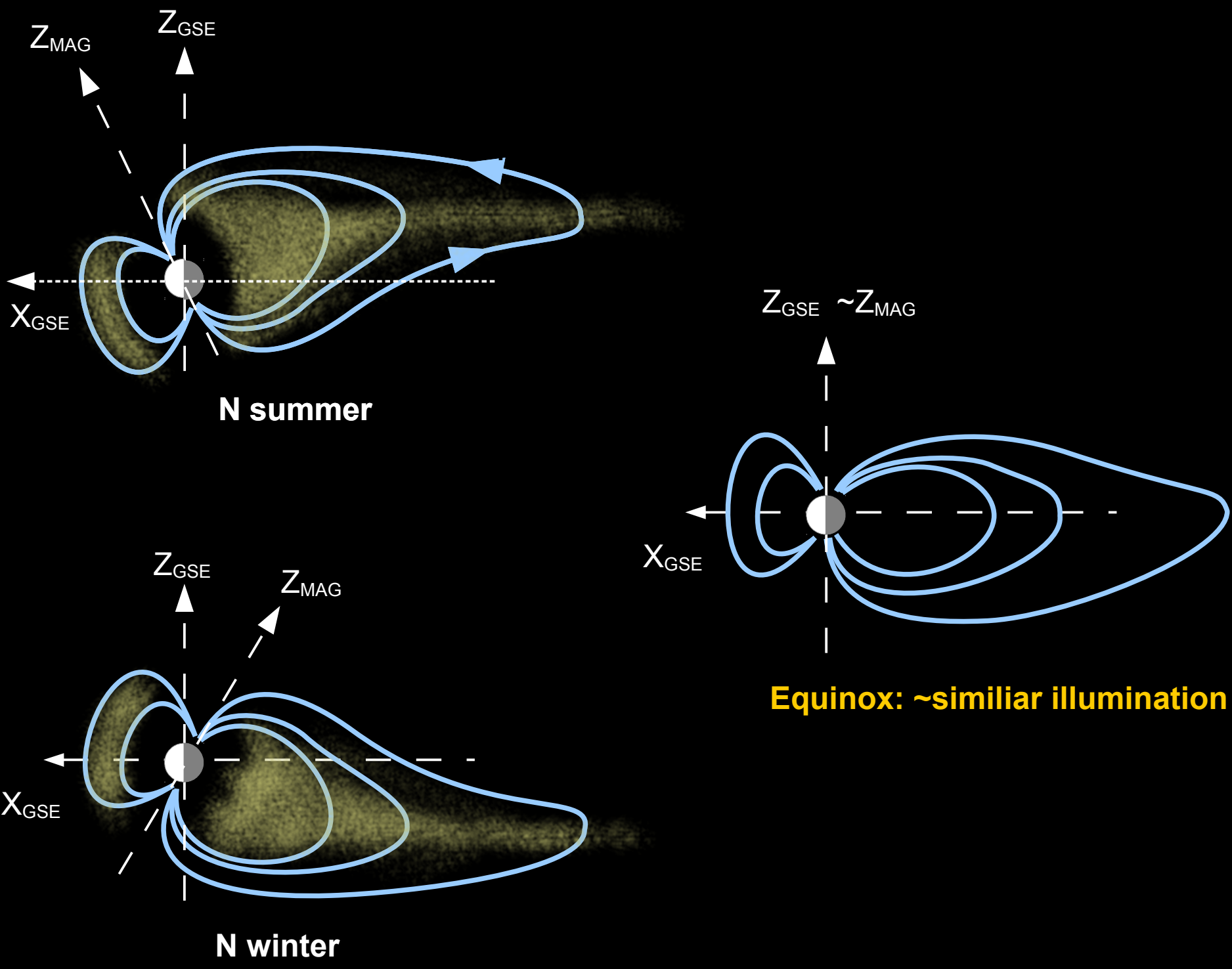
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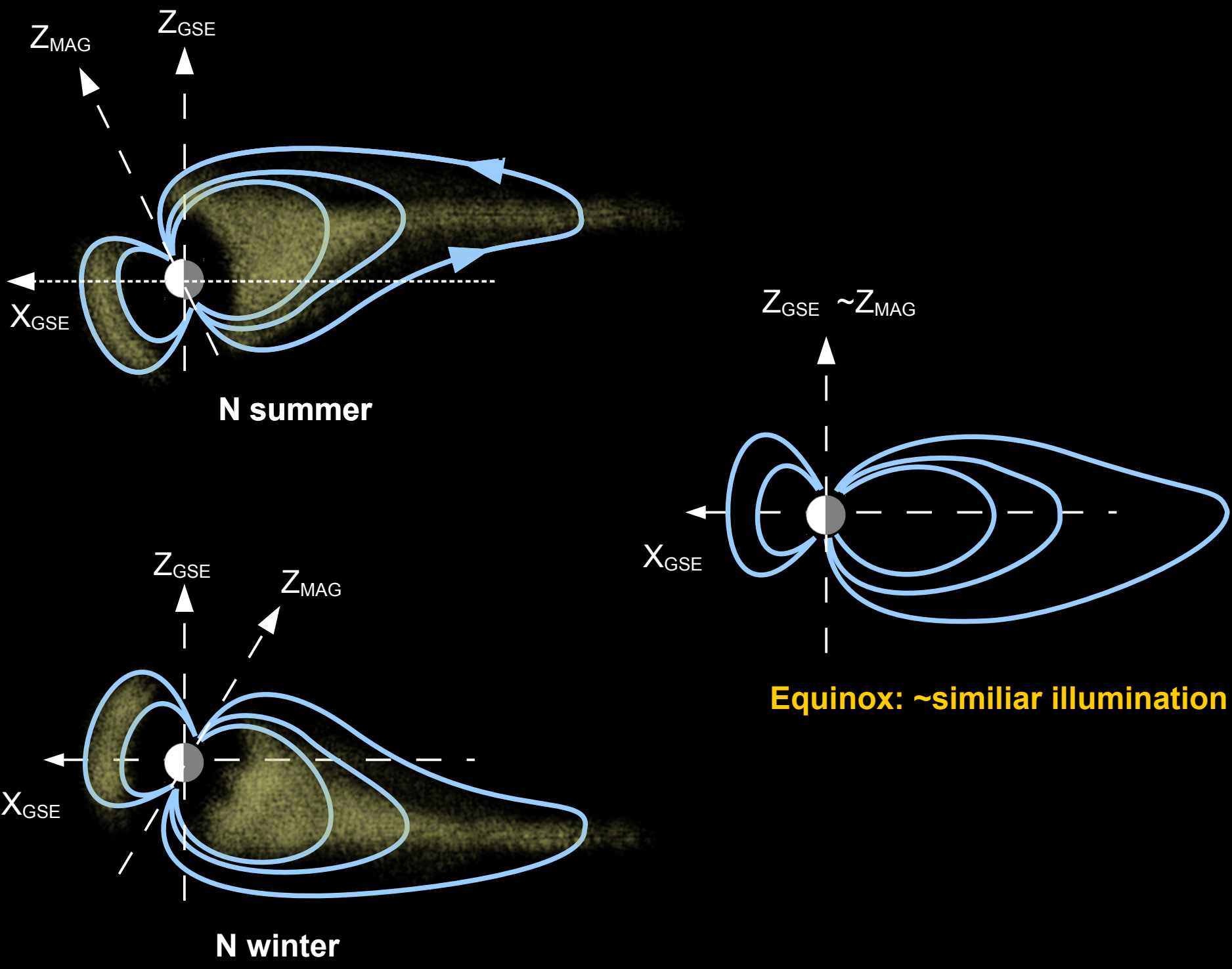
Z_{MAG}
X_{GSE}
N winter

Summary

Significant NS asymmetry in lobe density around equinox
- NH densities higher
- Indicate differences in outflow from N and S

Explanations
- Geomagnetic field different
- Effective source area different
- Solar illumination (Solar zenith angle)

Equinox is not equinox in terms of thermospheric properties
- time lag 4-6 weeks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