Oxygen ion outflow observed at high altitude

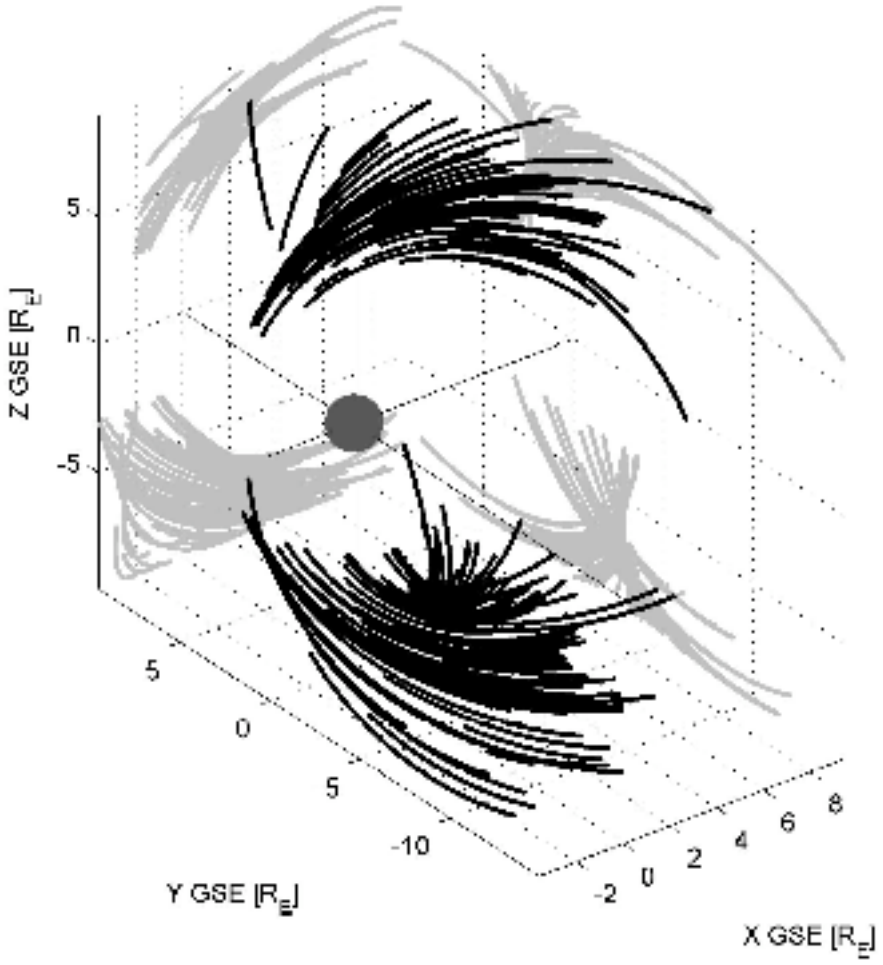
Oxygen ions, centrifugal acceleration and the boundary layer

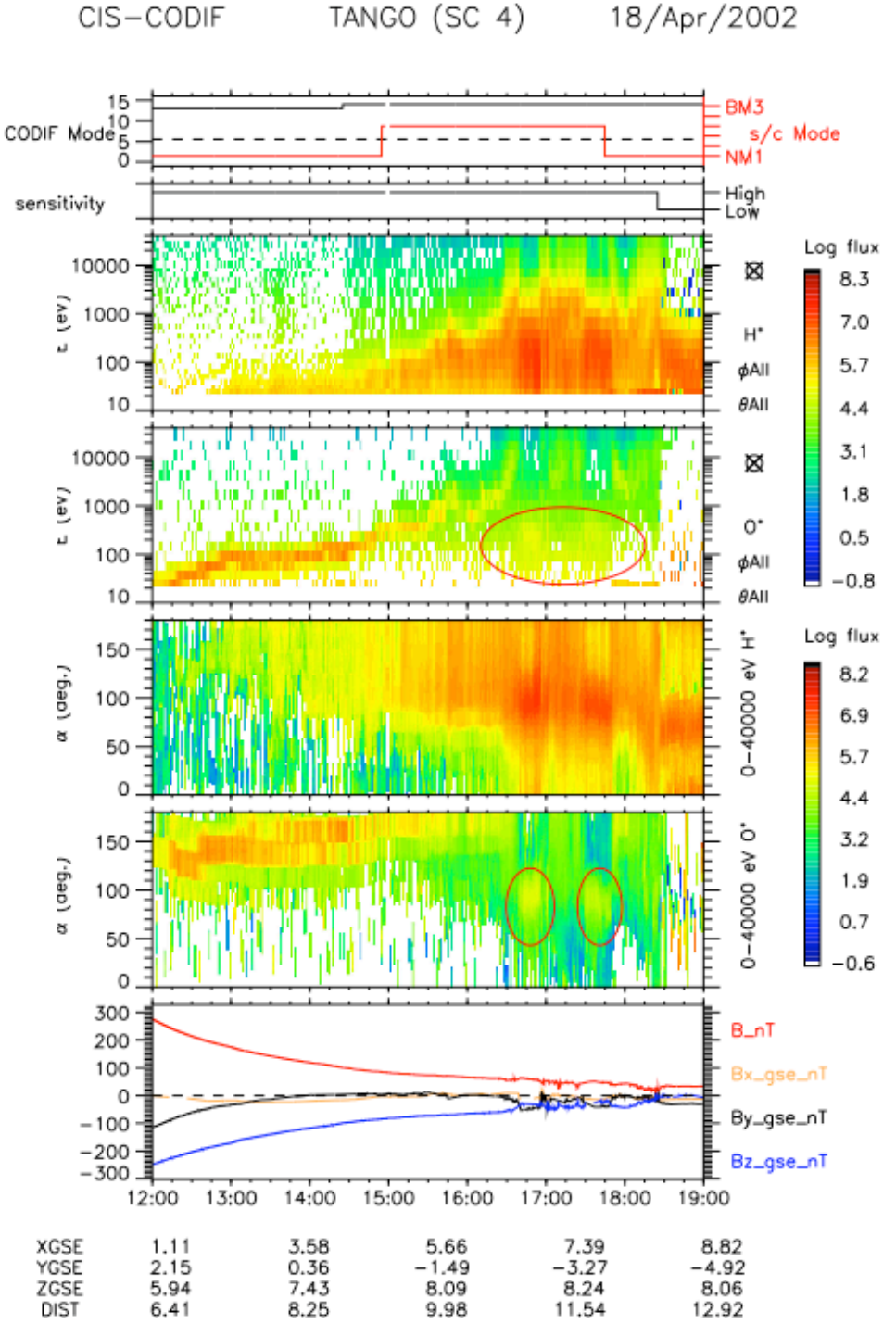
Hans Nilsson, Martin Waara, Octav Marghitu, Sachiko Arvelius, Masatoshi Yamauchi, and the CIS and FGM Teams

Oxygen and boundary layer

- O^+ ions from ionospheric cusp through polar cap to magnetopause
- Loss into magnetosheath?
- Does O^+ affect boundary layer?
- Does centrifugal acceleration affect boundary layer?

Where


Z GSE [R_E]
Y GSE [R_E]
X GSE [R_E]

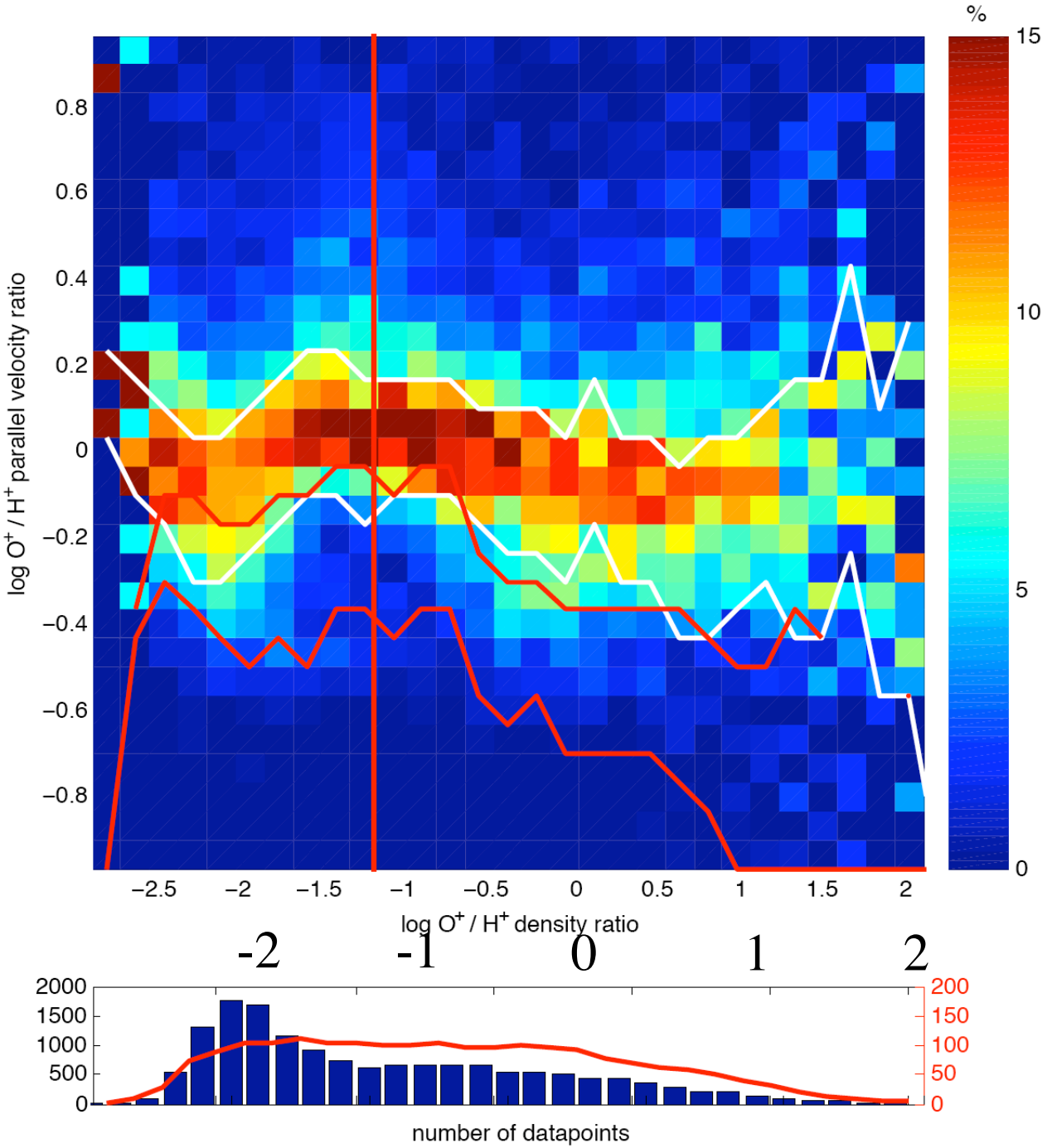

CIS–CODIF TANGO (SC 4) 18/Apr/2002
CODIF Mode
BM3
s/c Mode
NM1
sensitivity
High
Low
Log flux
t (eV)
H+
O+
φAll
θAll
α (deg.)
0–40000 eV H+
0–40000 eV O+
B_nT
Bx_gse_nT
By_gse_nT
Bz_gse_nT
12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00
XGSE 1.11 3.58 5.66 7.39 8.82
YGSE 2.15 0.36 −1.49 −3.27 −4.92
ZGSE 5.94 7.43 8.09 8.24 8.06
DIST 6.41 8.25 9.98 11.54 12.92

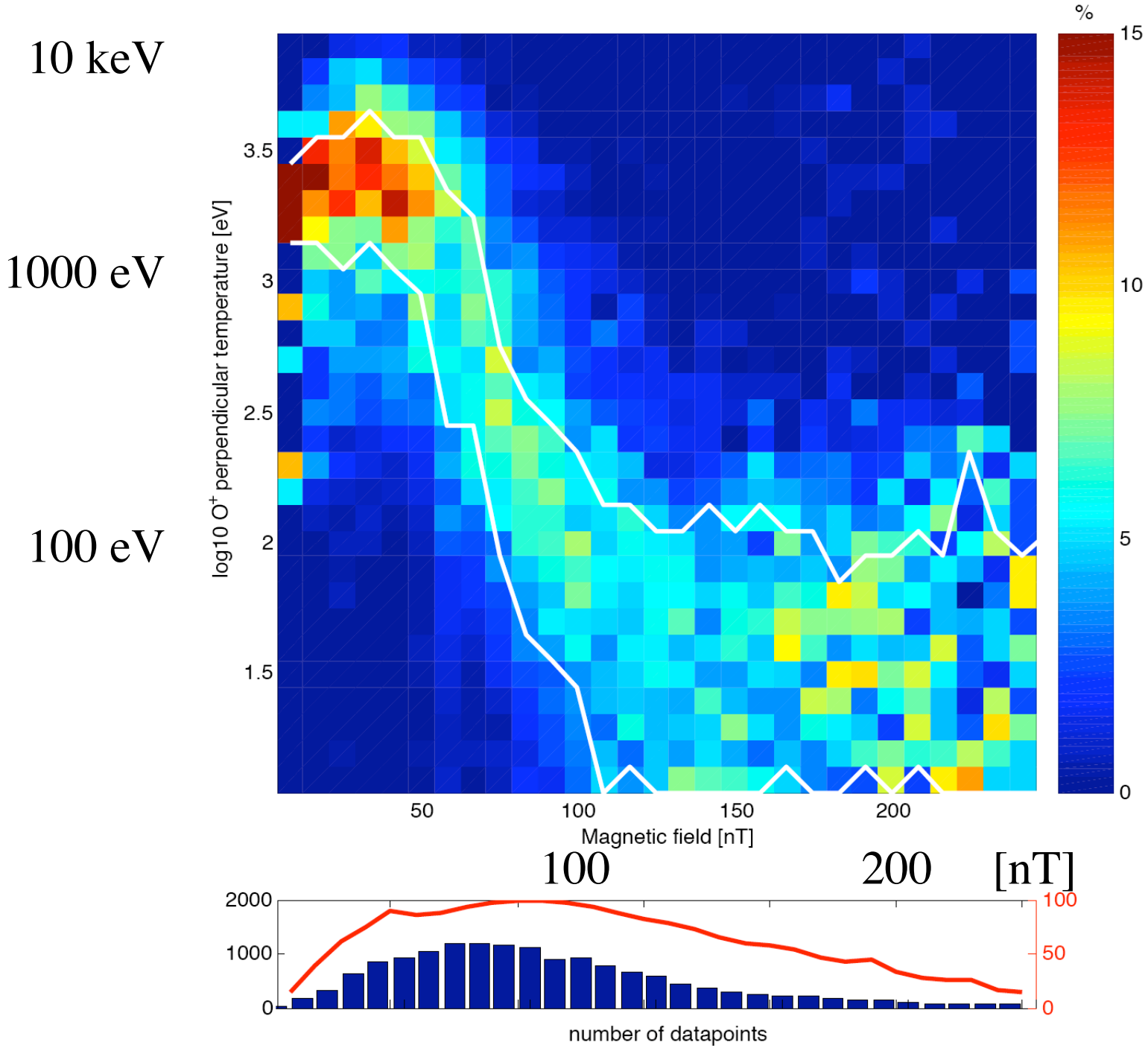
Comparison O^+ and H^+

0

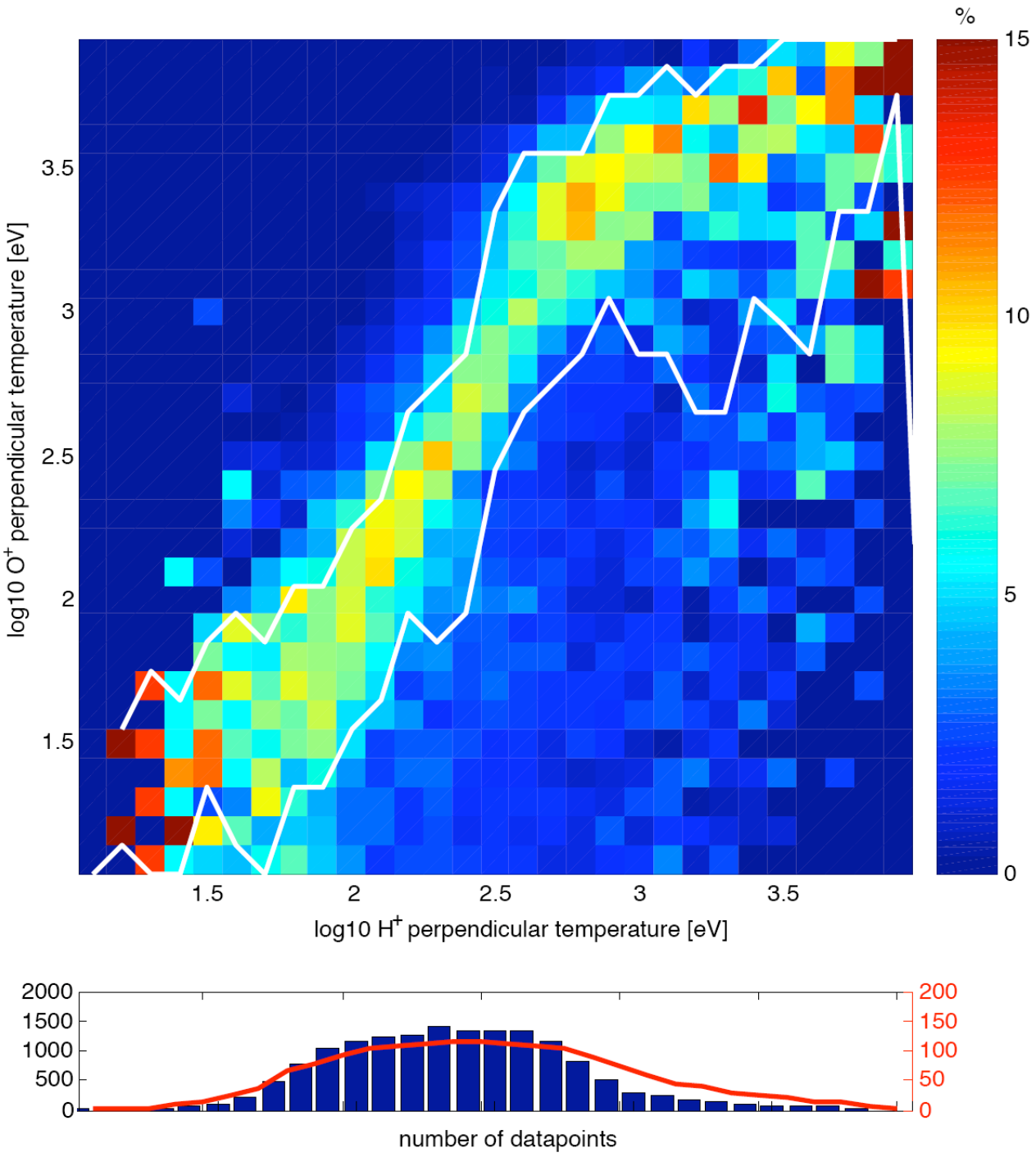
-0.2

-0.4




10 keV
1000 eV
100 eV
%
15
10
5
0
3.5
3
2.5
2
1.5
log10 O+ perpendicular temperature [eV]
50
100
150
200
Magnetic field [nT]
100
200
[nT]
2000
1000
0
100
50
0
number of datapoints

Wave particle interaction where waves heat the heavier ions more efficiently do play a role, but the temperature ratio O^+ over H^+ never reaches 16 so it cannot fully explain the similarity in the bulk parallel velocity



A puzzle with pieces that rather perfectly does not fit

- Altitude extended perpendicular heating to same velocity + mirror force (temperature does increase with altitude but temperature of O^+ only reaches 3 times that of H^+)
- Two-stream interaction (best agreement for full distribution function of H^+ but parallel bulk velocities close to same for large range of relative abundances)
- Parallel acceleration of both H^+ and O^+ through centrifugal acceleration (but different origin and initial energy so why is net result the same?)

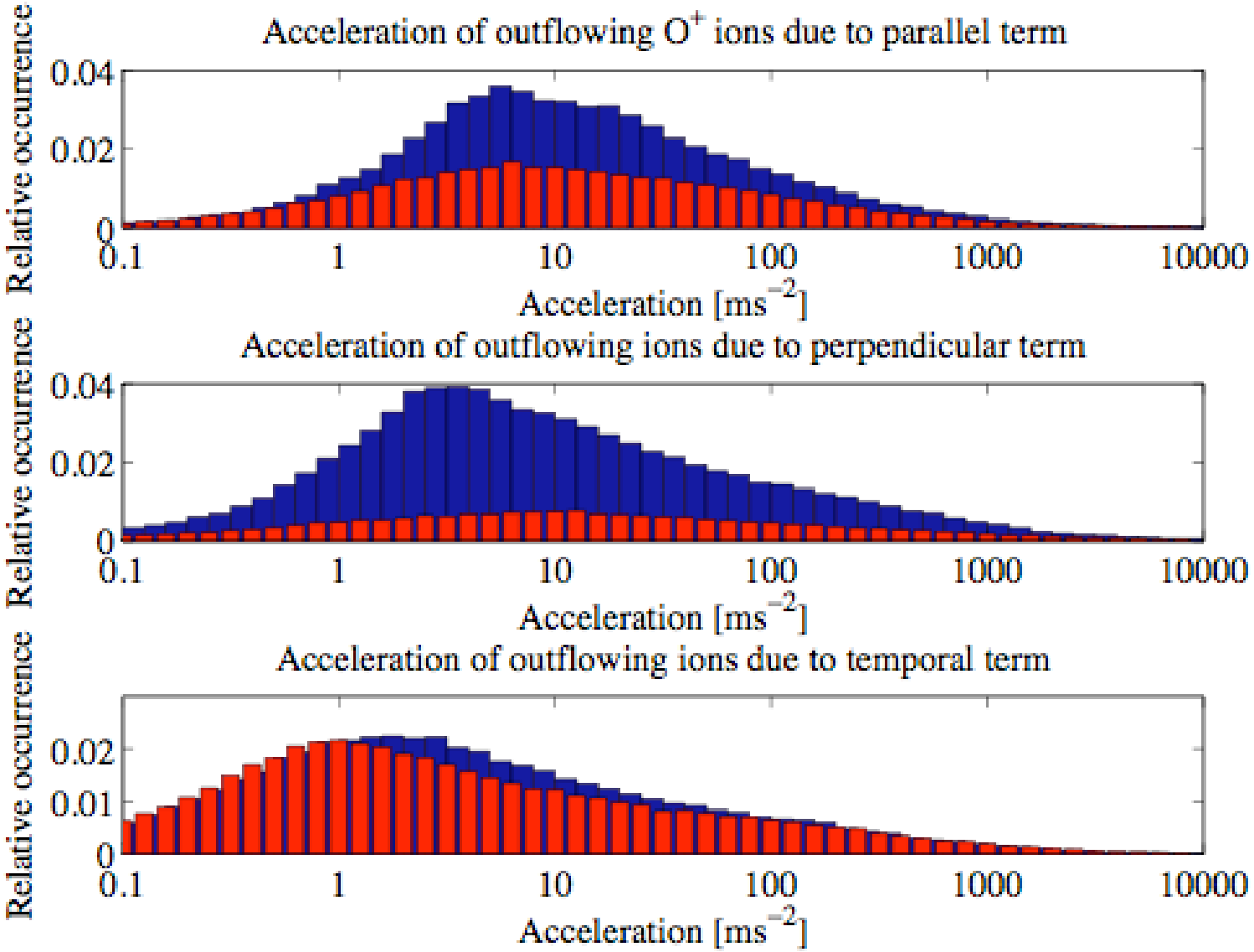
Centrifugal acceleration terms:

With four Cluster spacecraft, magnetometers and ion spectrometers we have all the data we need to estimate all of the terms!

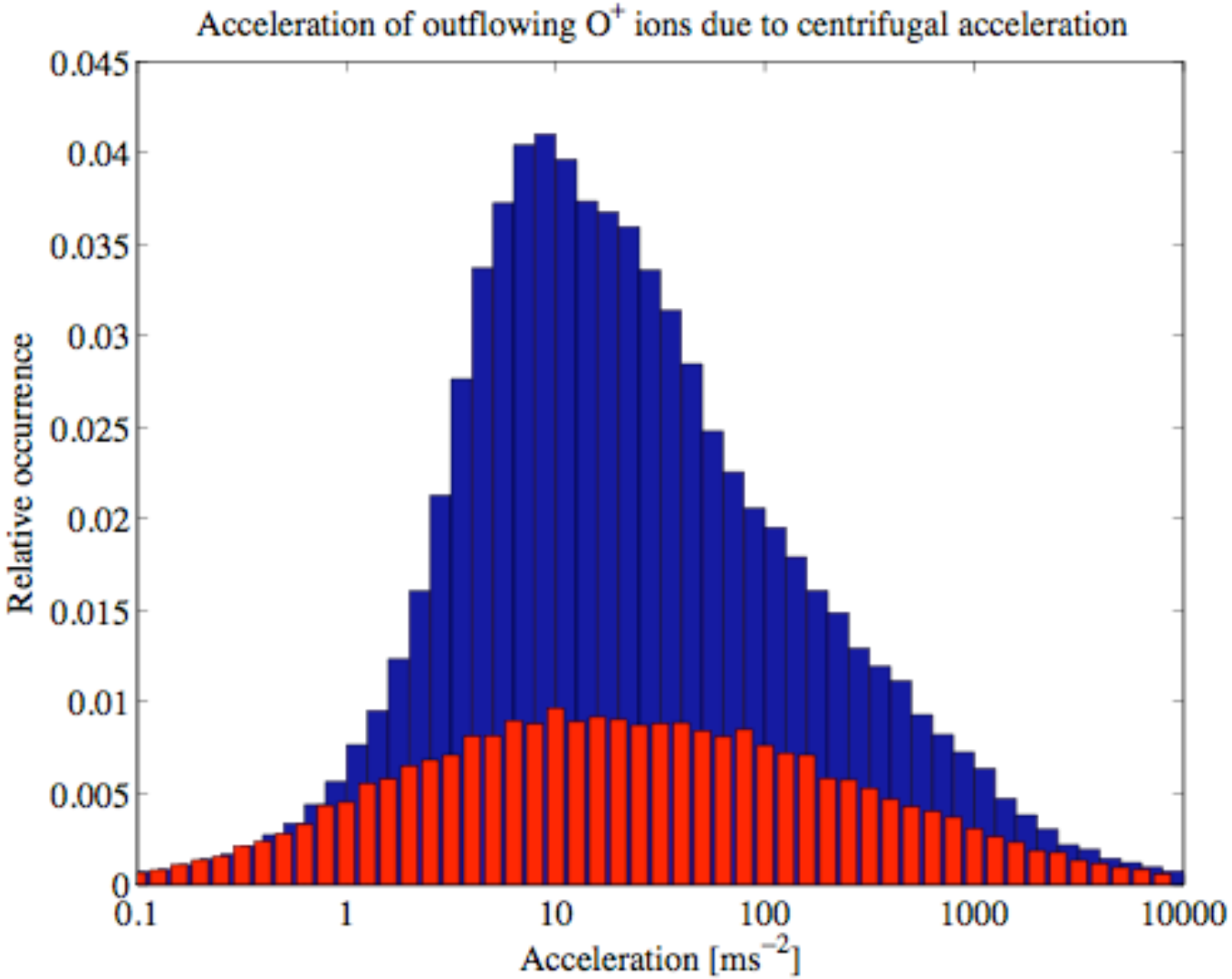
$$V_E \cdot \frac{d\hat{b}}{dt} = V_E \cdot \left(\frac{\partial \hat{b}}{\partial t} + V_{par}\frac{\partial \hat{b}}{\partial s} + (V_E \cdot \nabla)\hat{b}\right)$$

Temporal Term (calculate B change along Sc trajectory, compare with measured data	Parallel Term (B from 4 Cluster sc) +ions	Perpendicular Term (B from 4 Cluster sc + ions

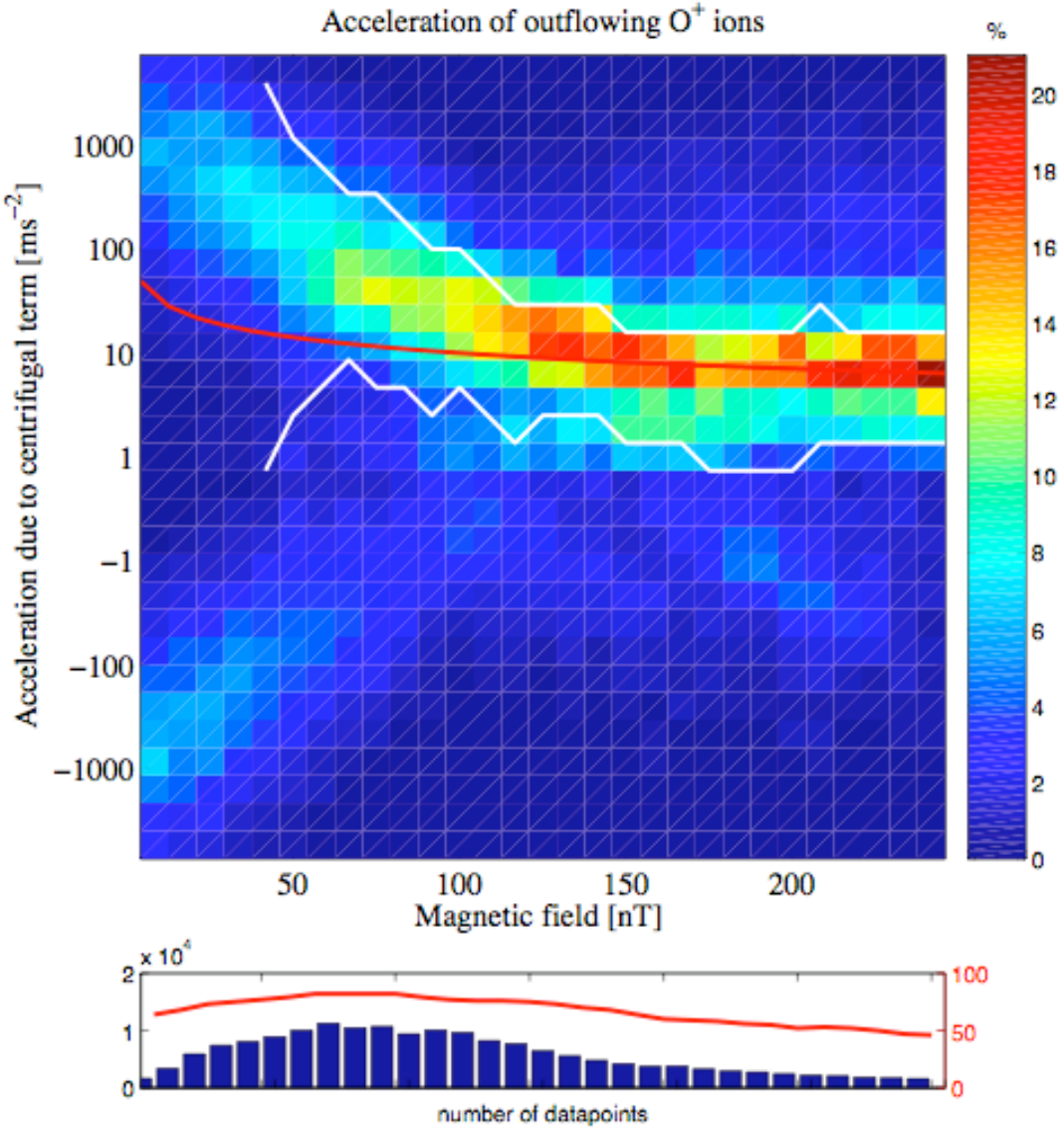
Experimental estimate of terms



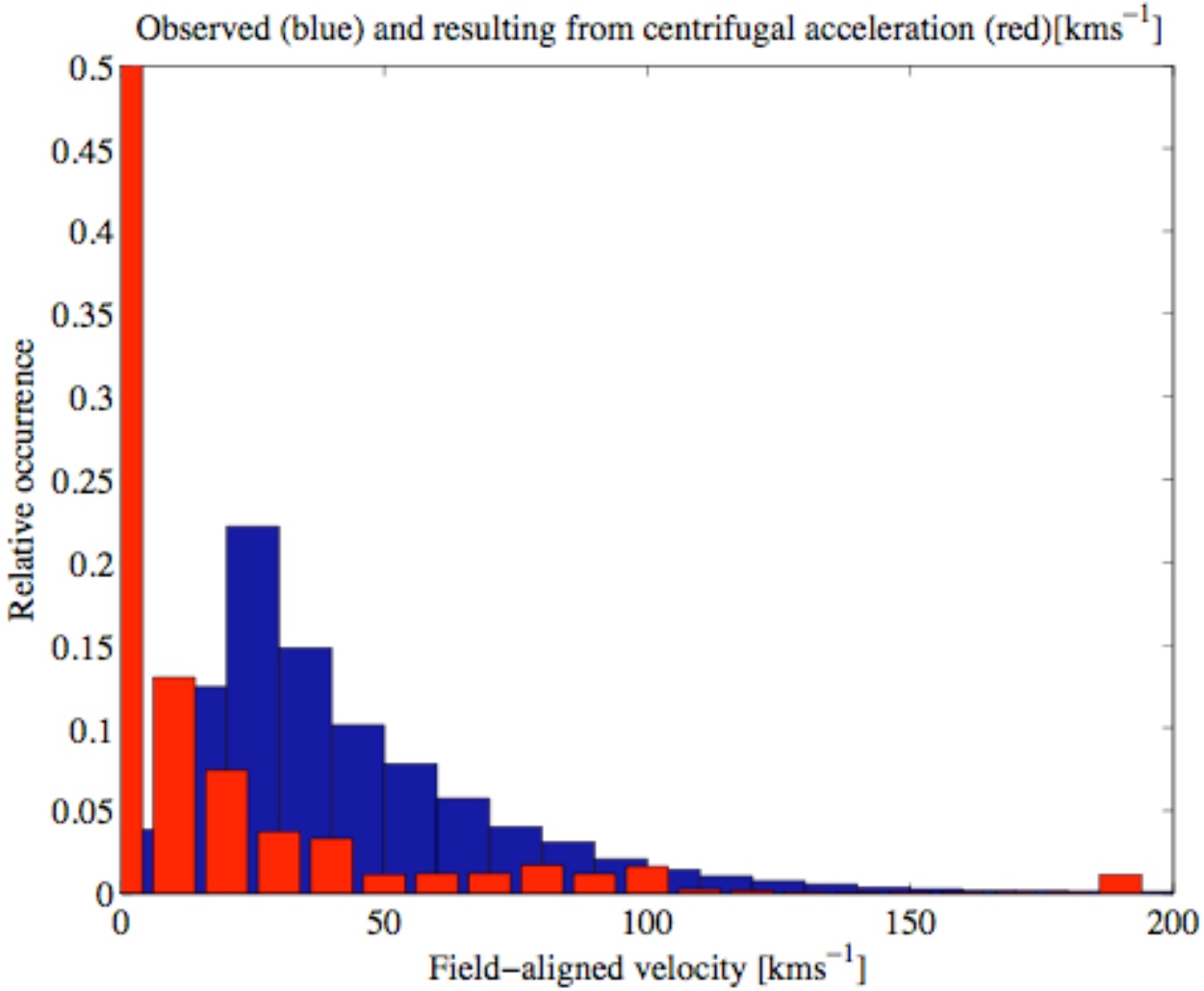
Total energy increase for outflowing O^+ ions



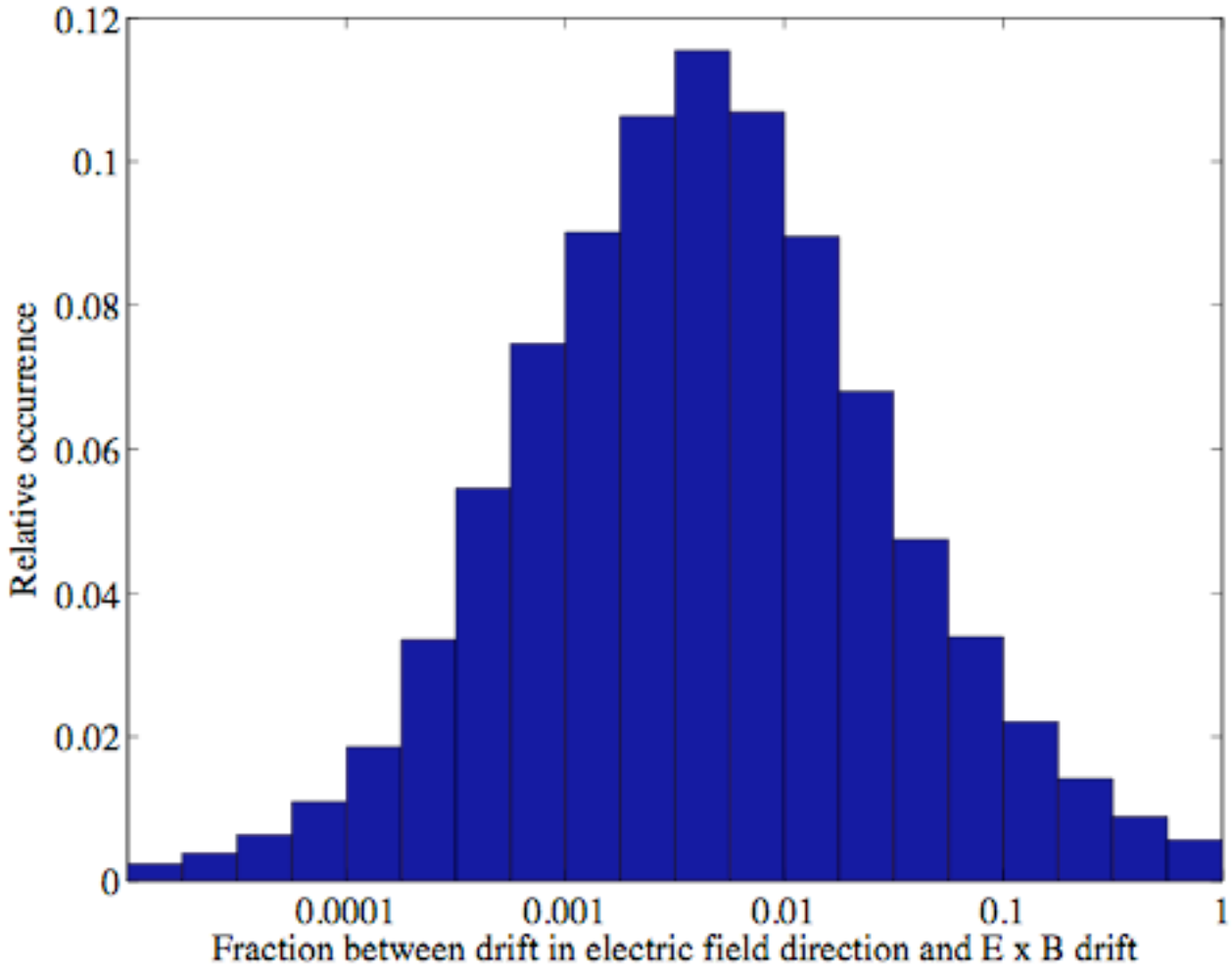
Acceleration as function of B



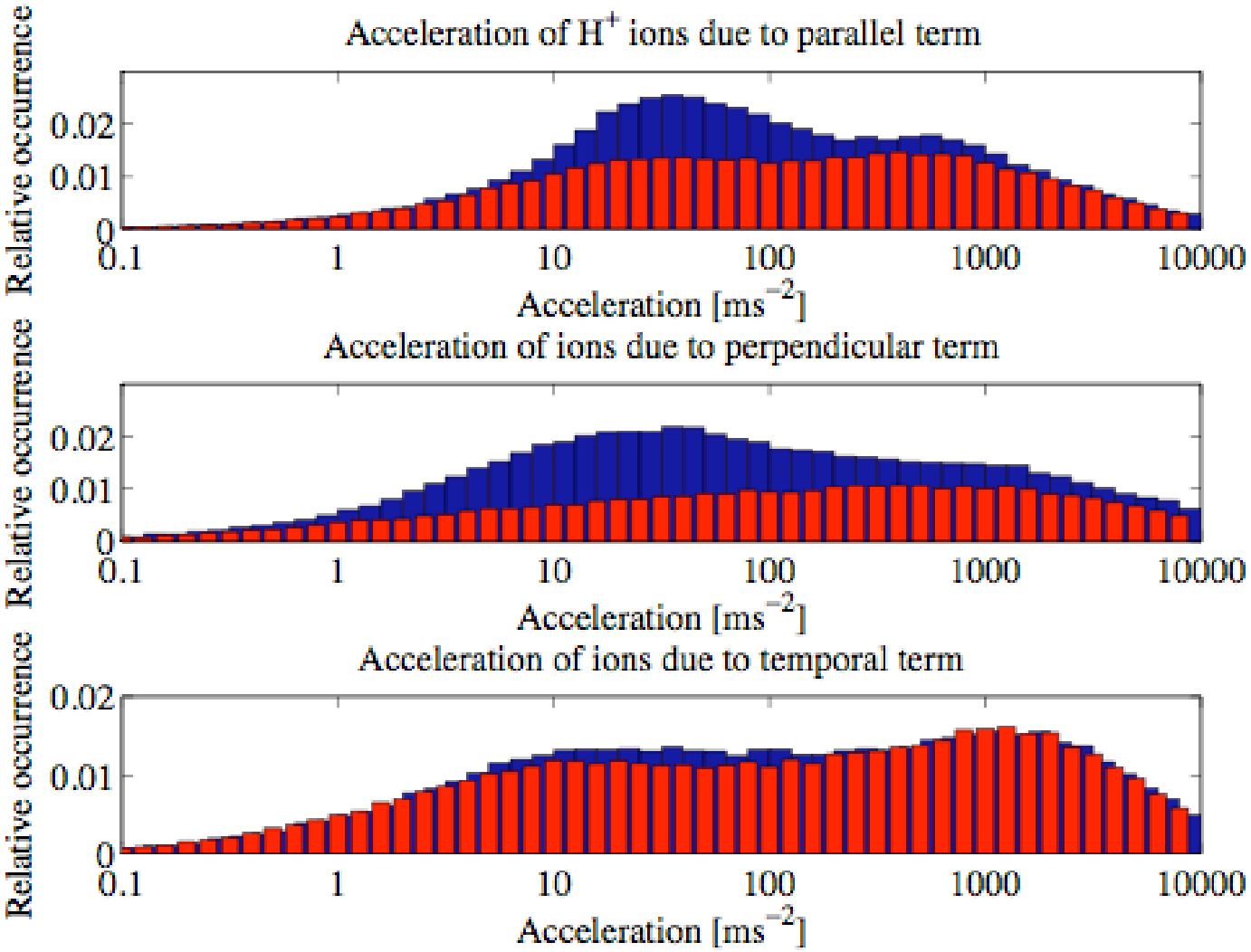
Adding up observed centrifugal acceleration



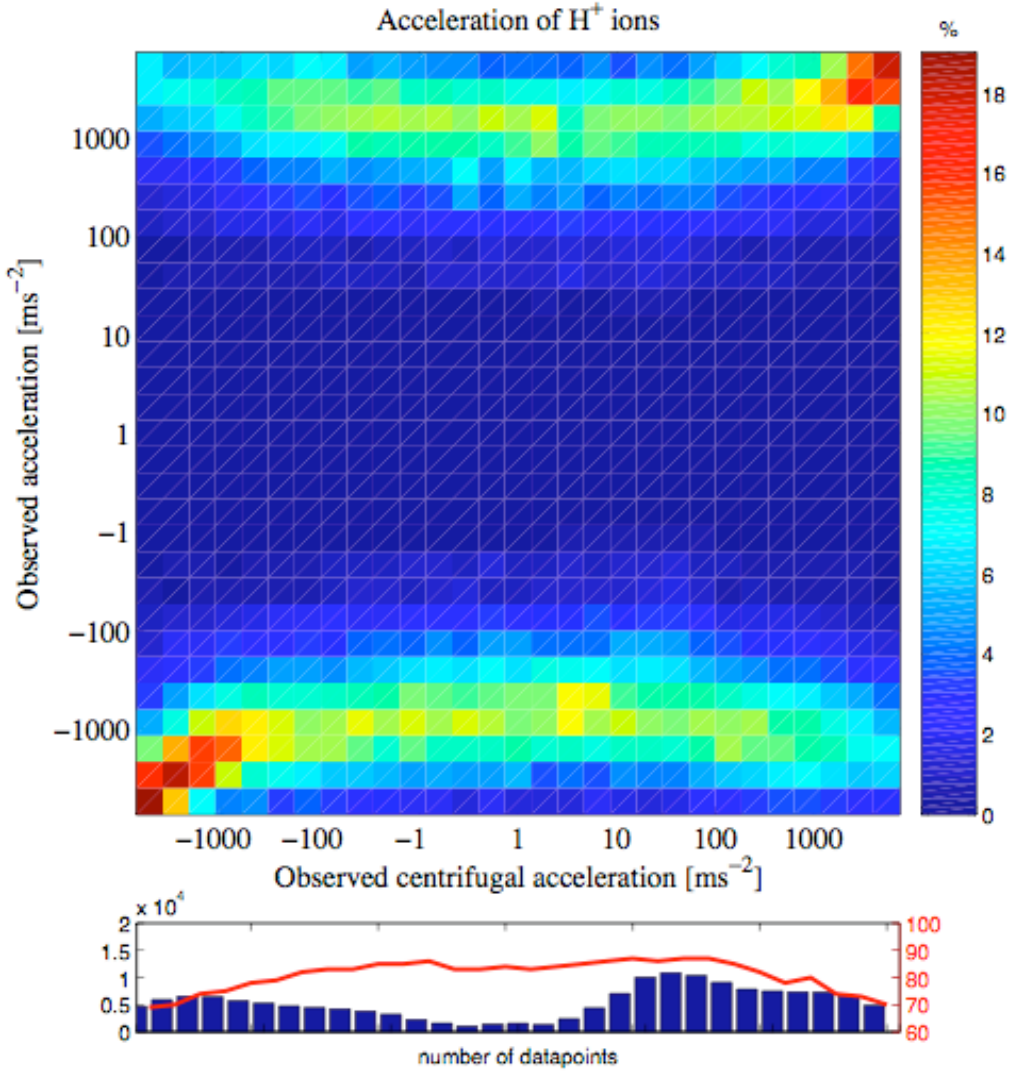
Inertial drift as fraction of E x B drift

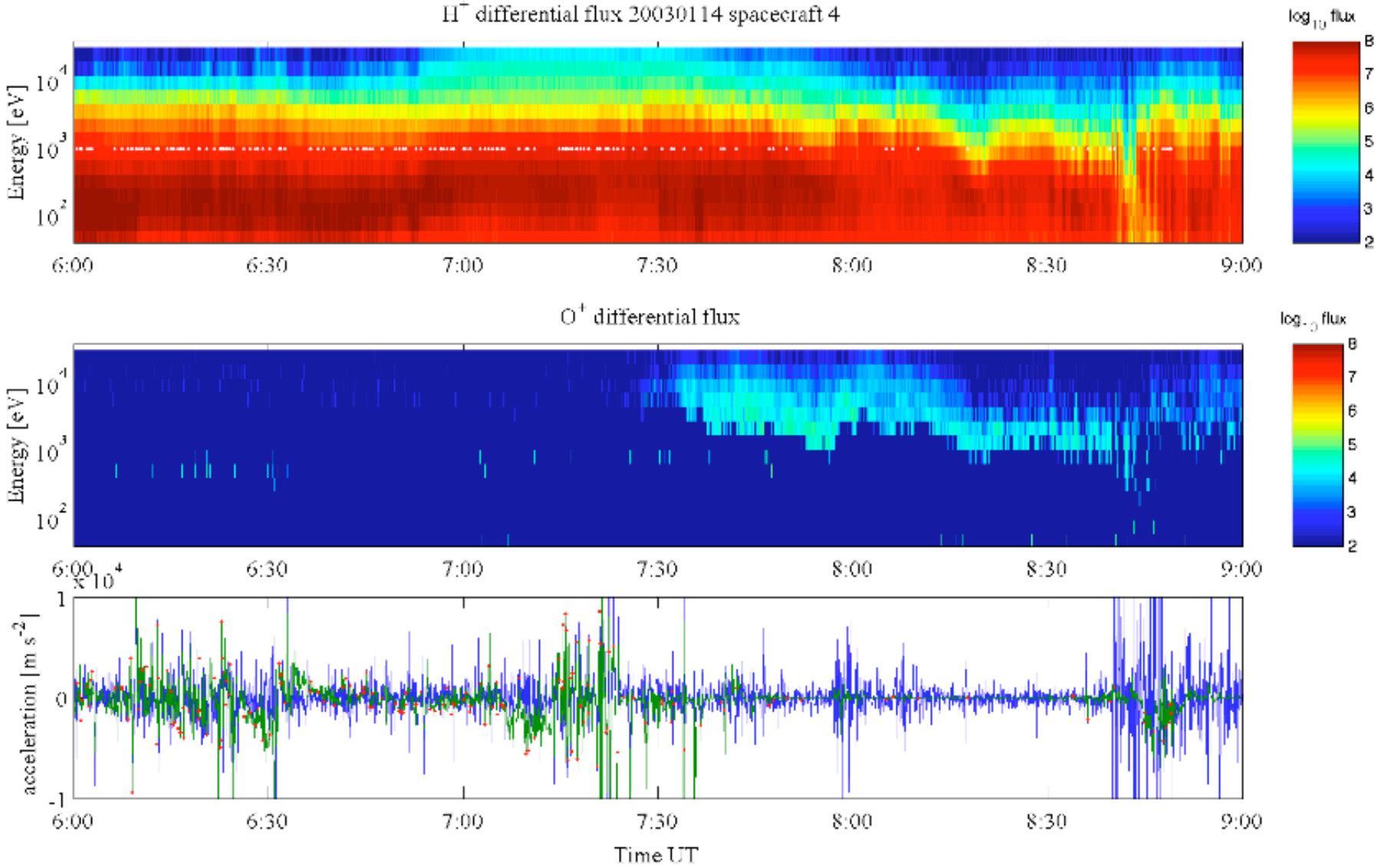


Centrifugal terms for H^+ data



Acceleration from consecutive CIS measurements




H⁻ differential flux 20030114 spacecraft 4
log10 flux
Energy [eV]
10^4
10^3
10^2
8
7
6
5
4
3
2
6:00
6:30
7:00
7:30
8:00
8:30
9:00
O⁺ differential flux
log10 flux
Energy [eV]
x 10^4
acceleration [m s^-2]
1
0
-1
Time UT

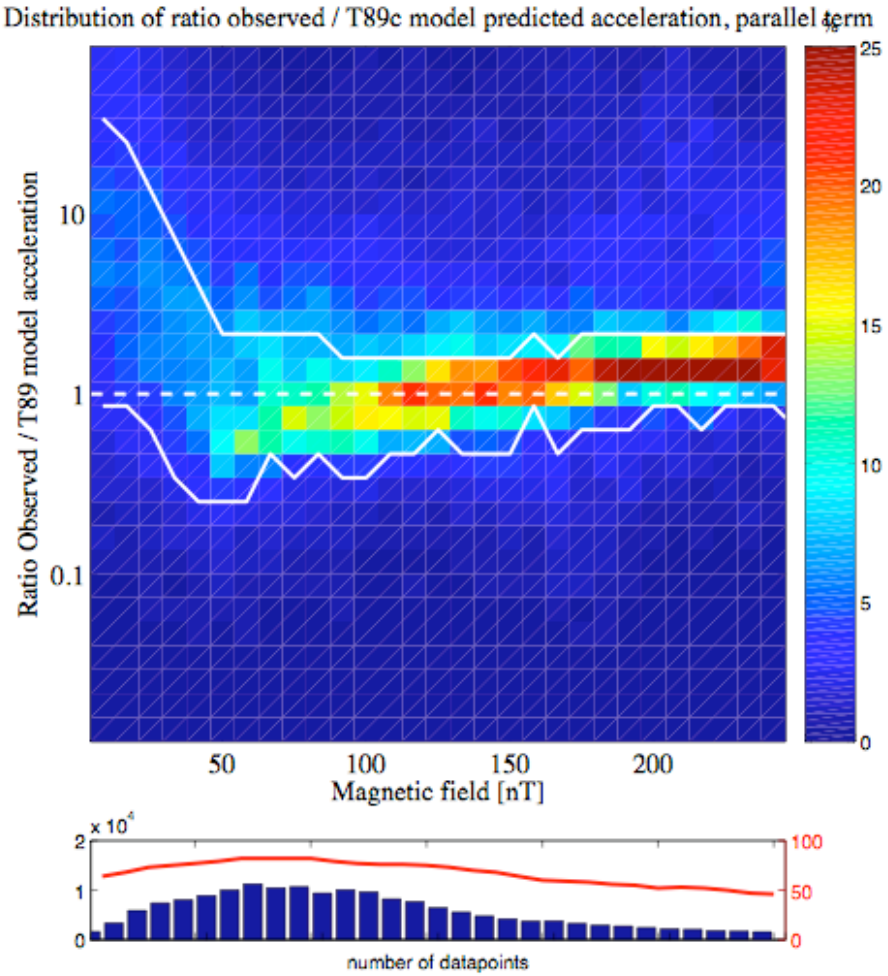
Centrifugal acceleration

- Clearly significant at times
- Can often increase the energy of outflowing O^+ ions with several keV integrated over the flight trajectory
- Affects also H^+ (though the energy increase is much smaller)
- Strongest close to the magnetopause

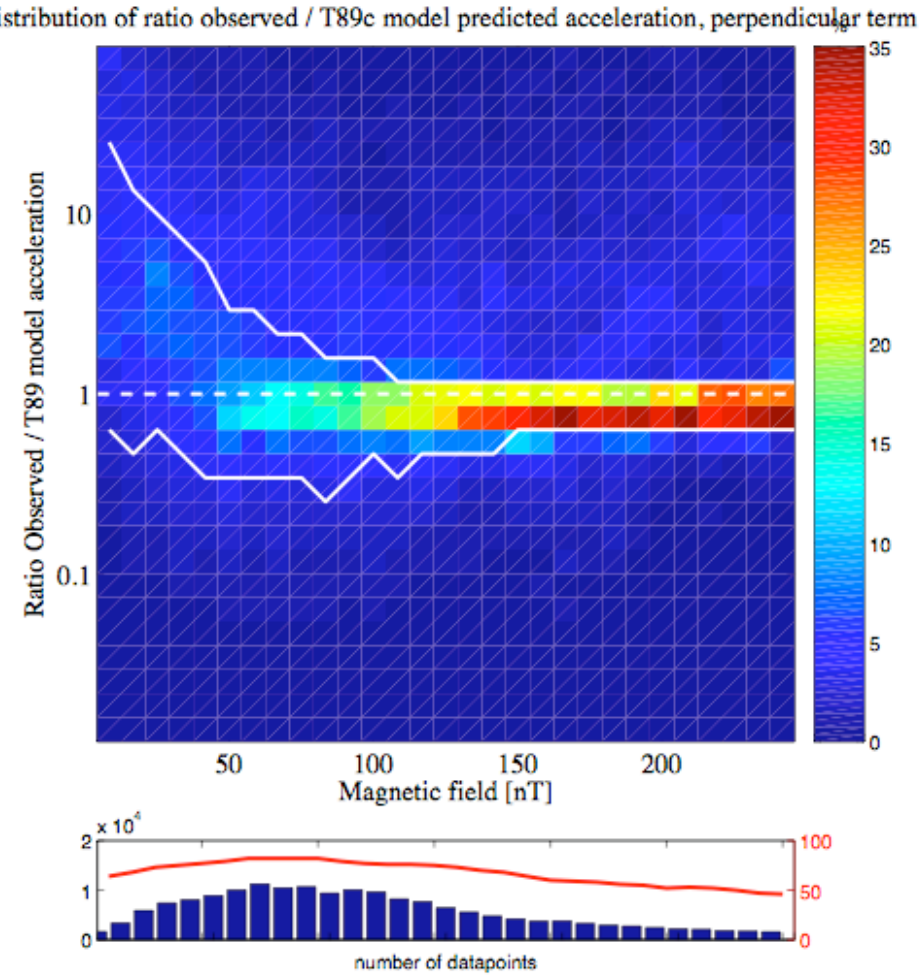
Oxygen ions

- O^+ ions are commonly seen just inside the magnetopause over the polar cap
- May affect the boundary layer
- Careful studies of the location of significant O^+ flow and the boundary layer may help determine how much O^+ is lost from the Earth's magnetosphere

T89, parallel

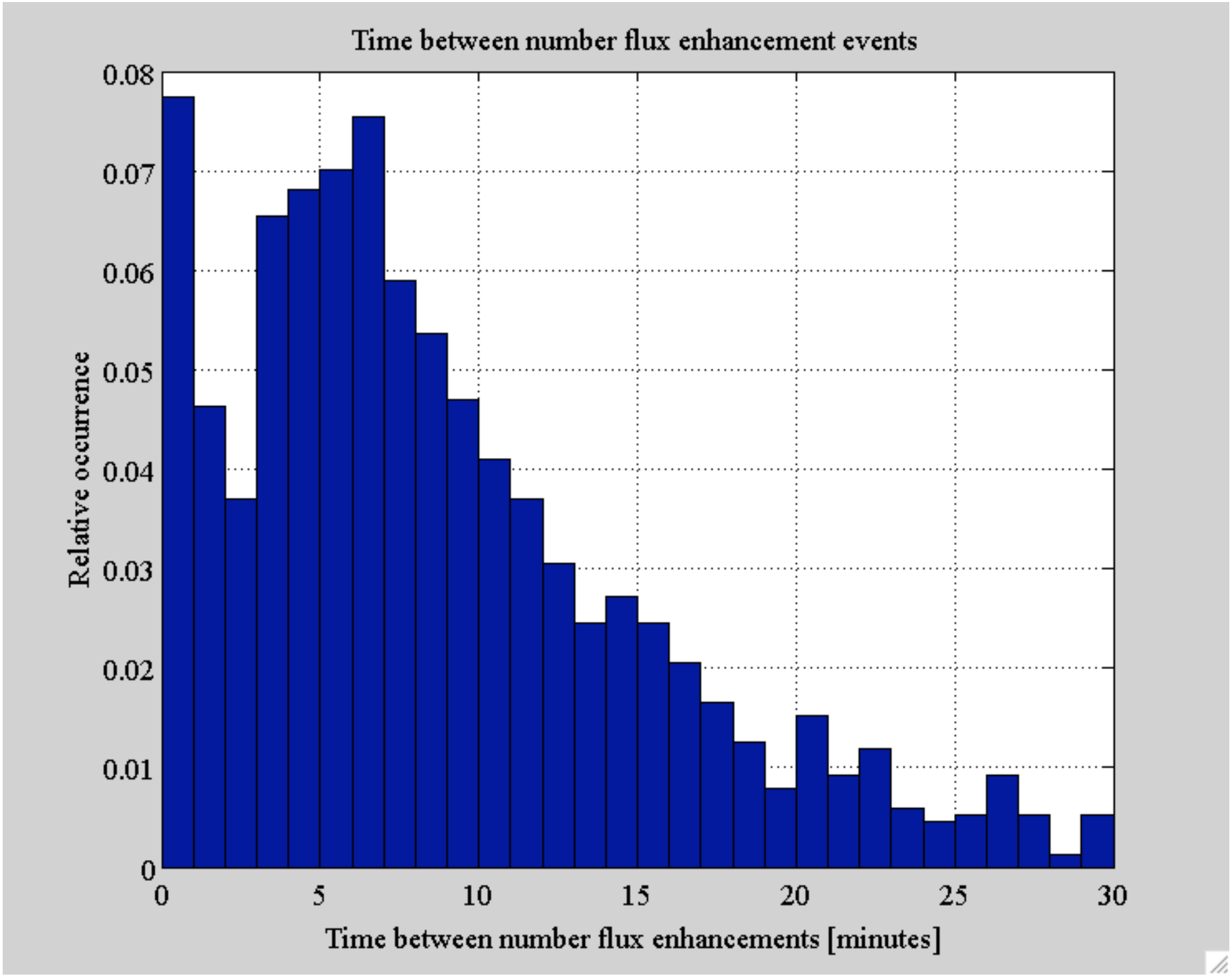


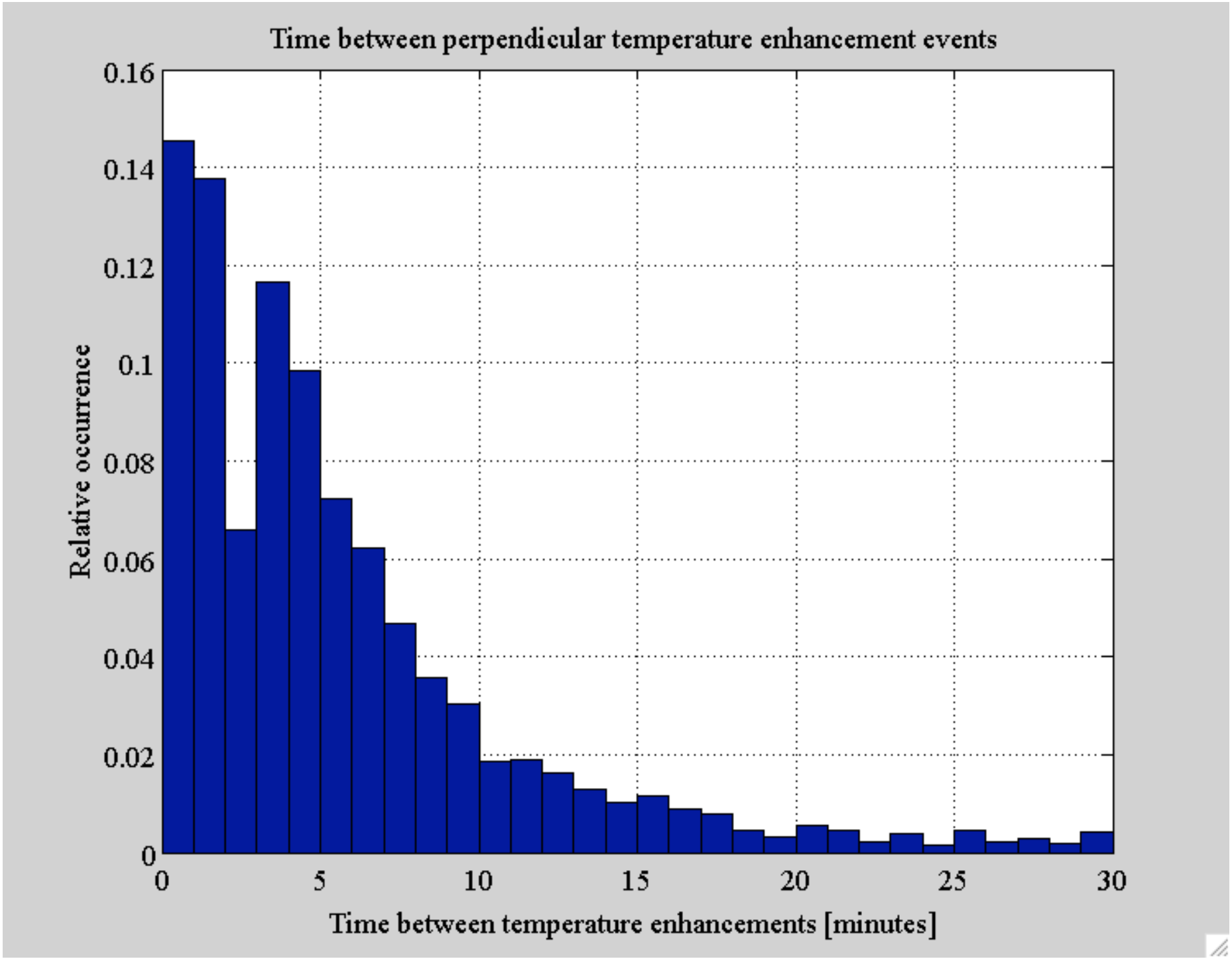
T89, perpendicular



Transient events in O^+ outflow

- Algorithm to detect transient changes in moment values
- Several parameters to adjust, using two consecutive running mean windows
- Will present simple time differences, should really take convection from a source region into account


Time between number flux enhancement events
Relative occurrence
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20
25
30
Time between number flux enhancements [minutes]


Time between perpendicular temperature enhancement events
Relative occurrence
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20
25
30
Time between temperature enhancements [minutes]

Transient events in O^+ outflow

- Typical separation between number flux enhancement events about 6 minutes: FTE? Field-line eigenmodes? Alfvén transit times? (Time subject to change when convection times are included)
- Statistics should be refined before publication, possibly after Kp / SW conditions, location of observations