Cold Ion Escape from Mars - Observations by Mars Express and MAVEN

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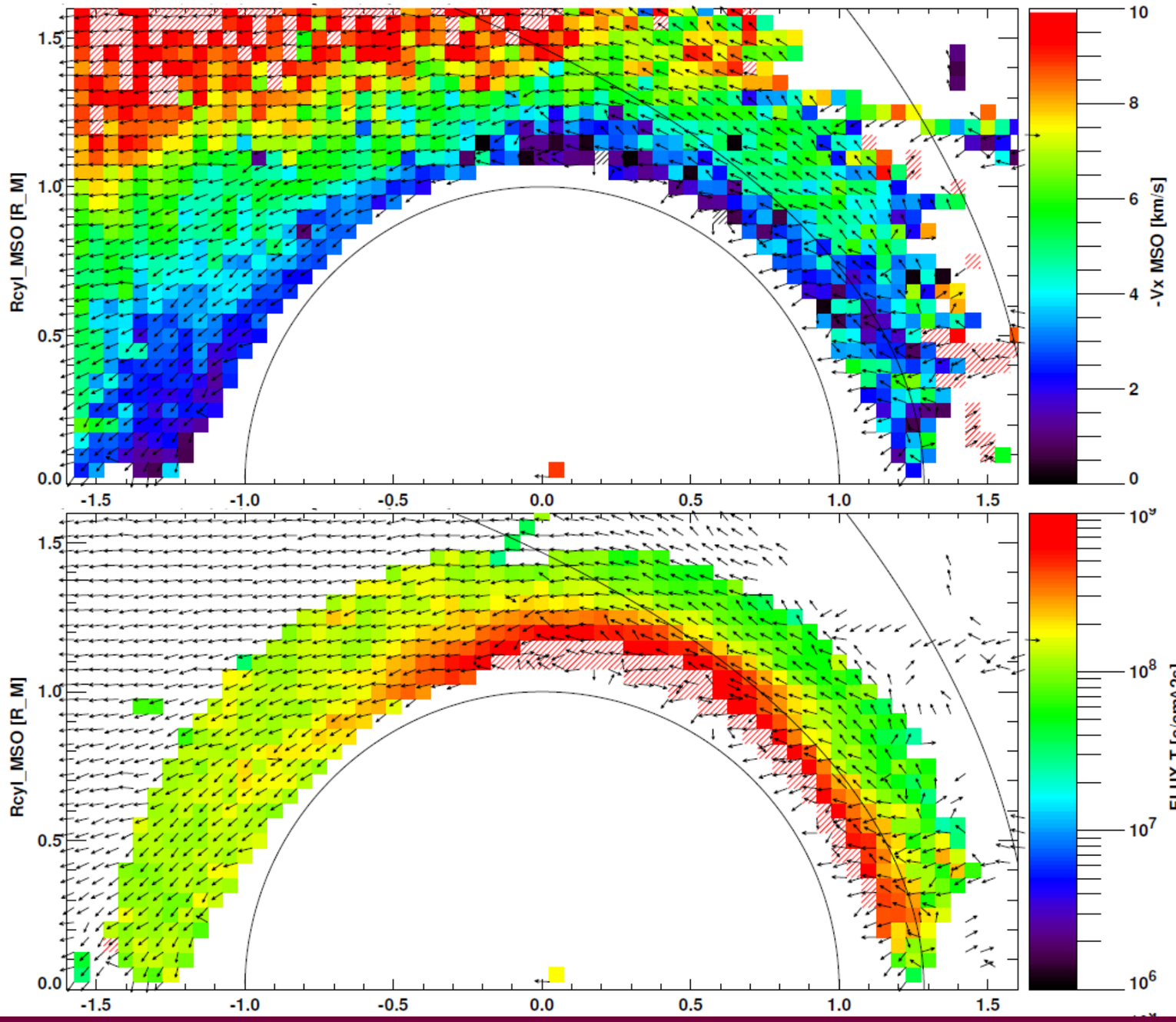
Heavy Ion Velocities and Fluxes

Mars Express 2007 - 2014



Top: Mean MSO X velocity (-Vx [km/s]) derived from the mean MEX Aspera IMAEXTRA velocity distributions (VD) with spacecraft velocity and potential correction observed between 1 May 2007 and 1 June 2014, arrows indicate cylindrical projection of the full velocity vector.

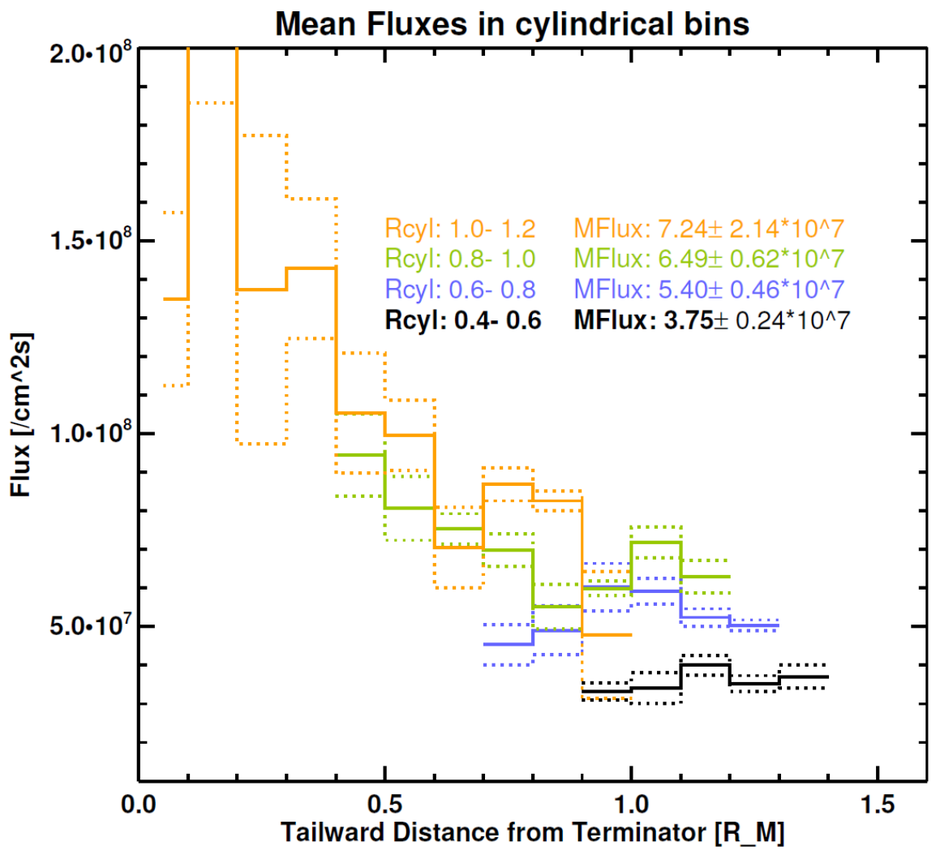
Bottom: Total flux calculated from the total velocity derived from IMAEXTA VD multiplied by the mean MARSIS local density observed over the same period in the same spatial bins, scaled in /cm2s. The vertical component of vectors shows the deviation from the cylindrical symmetry axis.

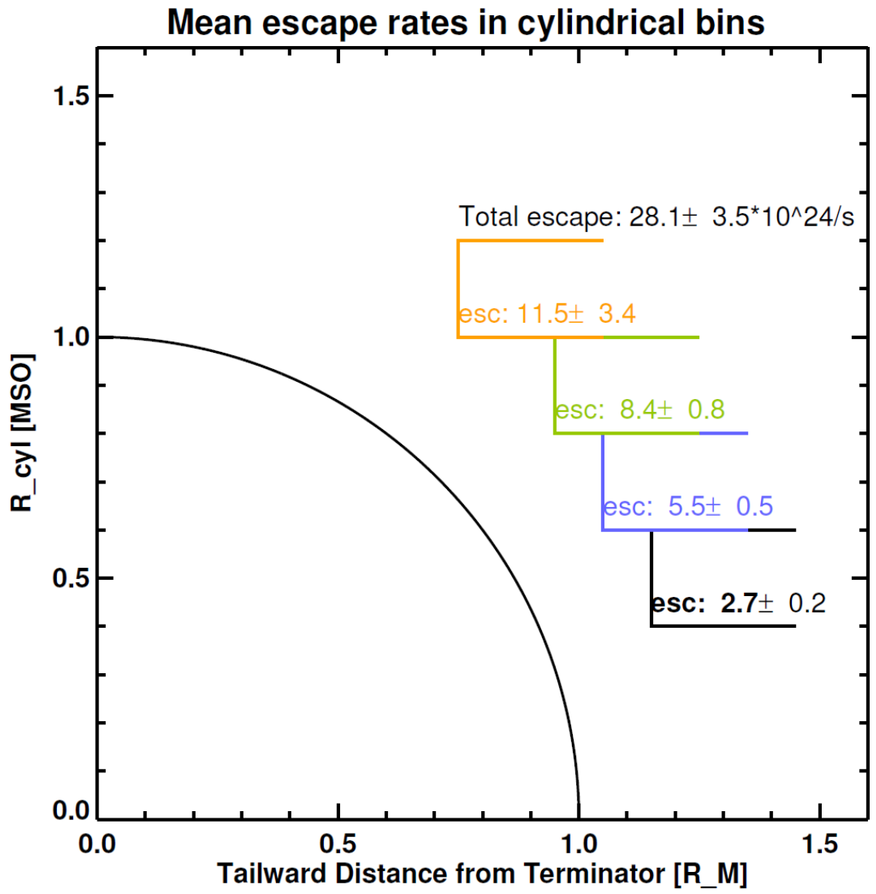
From Fränz et al., PlanSpaceSci, 119, 92, 2015

We here used the mean ion velocities observed by the spectrometer and derived fluxes using the plasma density observed by MARSIS: Tailside fluxes are about $10^8/cm^2s$.

Median cold heavy ion flux from Mars Express

from all orbits in between 05/2007 and 06/2014
where both IMA and MARSIS data are available



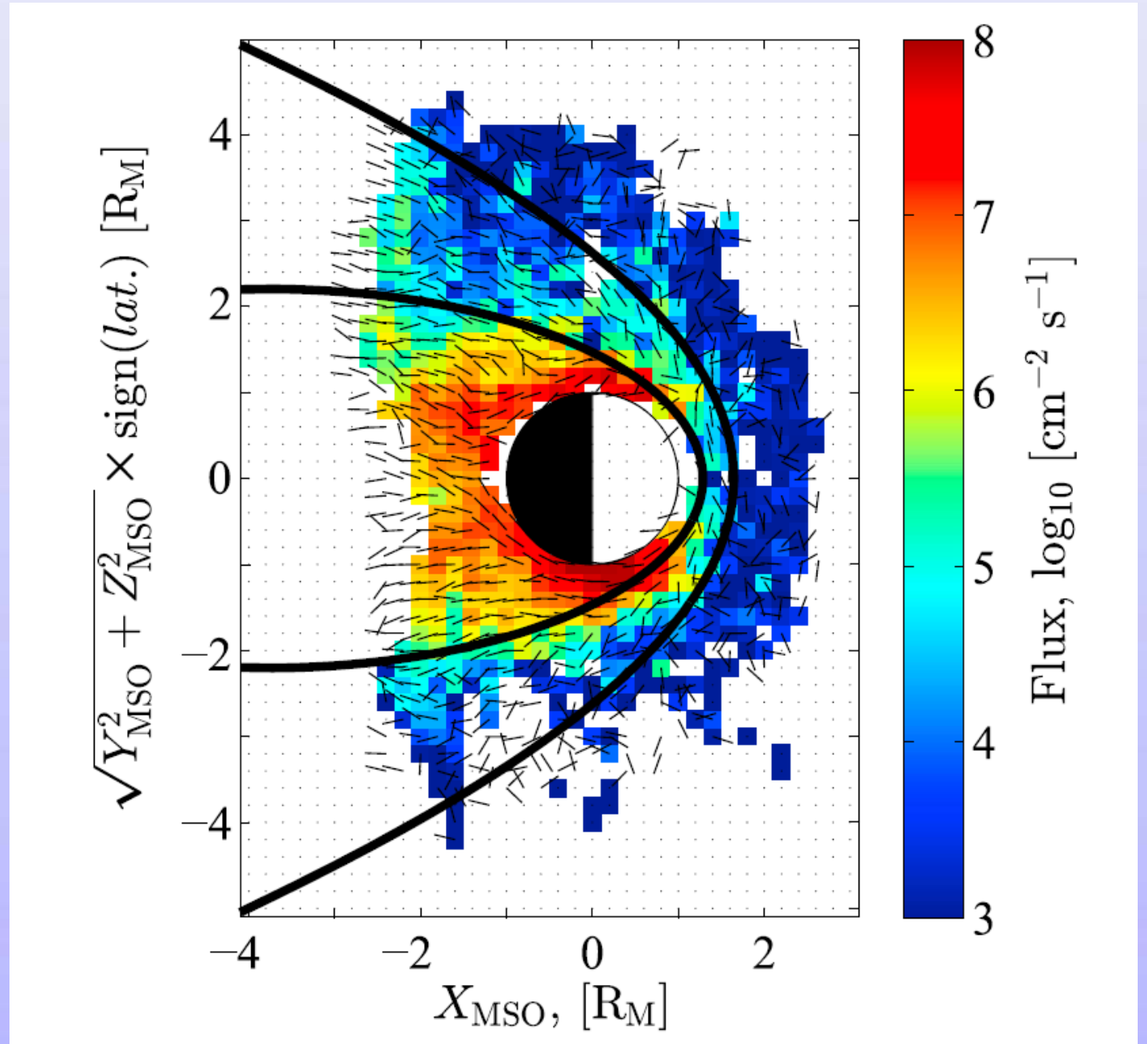


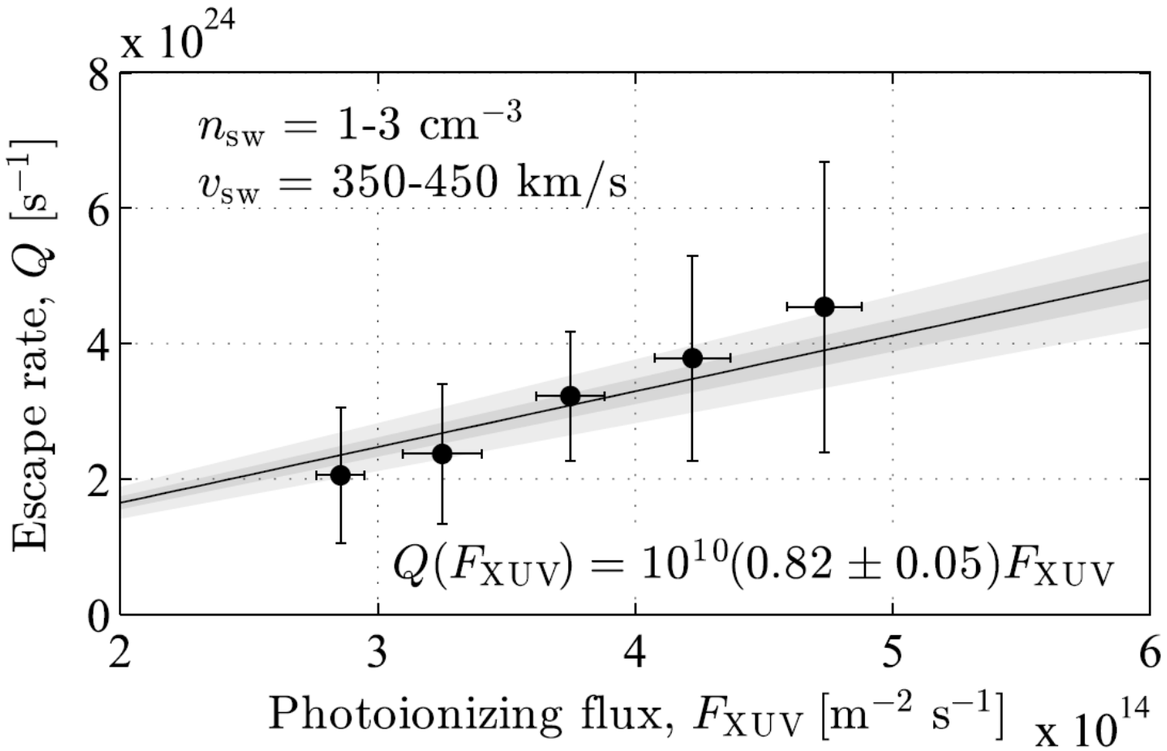
Tailward flux becomes constant beyond 0.5 R_M tailward distance and main flux is between 0.9 and 1.3 R_M cylindrical distance from tail axis resulting in a total escape rate of 2.8 10^{25}/s.

From Fränz et al., PlanSpaceSci, 119, 92, 2015

Mars Express Other Recent Results on Escape Rates

Ramstad et al. (GRL,2016) determine a mean ion escape rate of 2.5×10^{24}/s from MEX IMA alone with minor dependence on crustal field location.

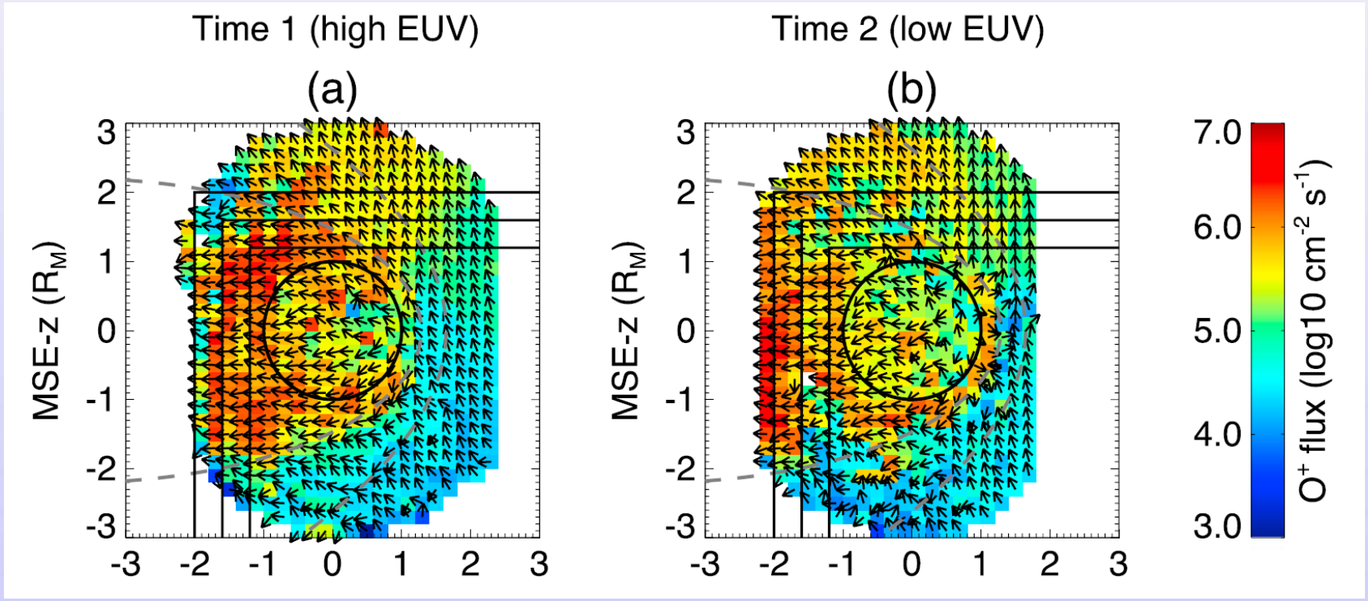




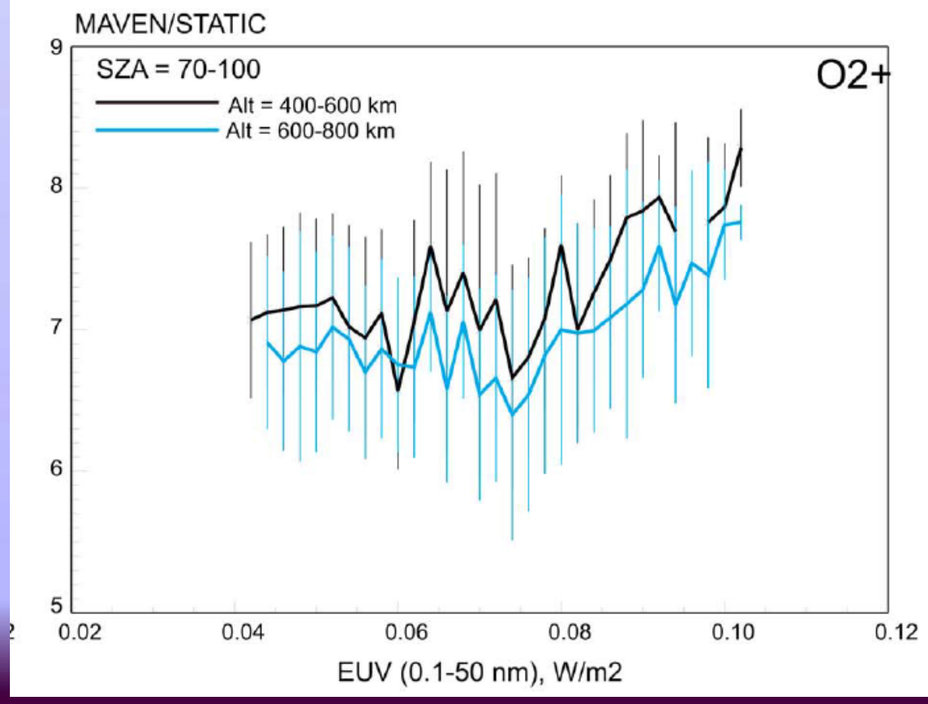
Ramstad et al. (JGR,2017) determine a linear dependence of the ion escape rate on solar EUV flux.

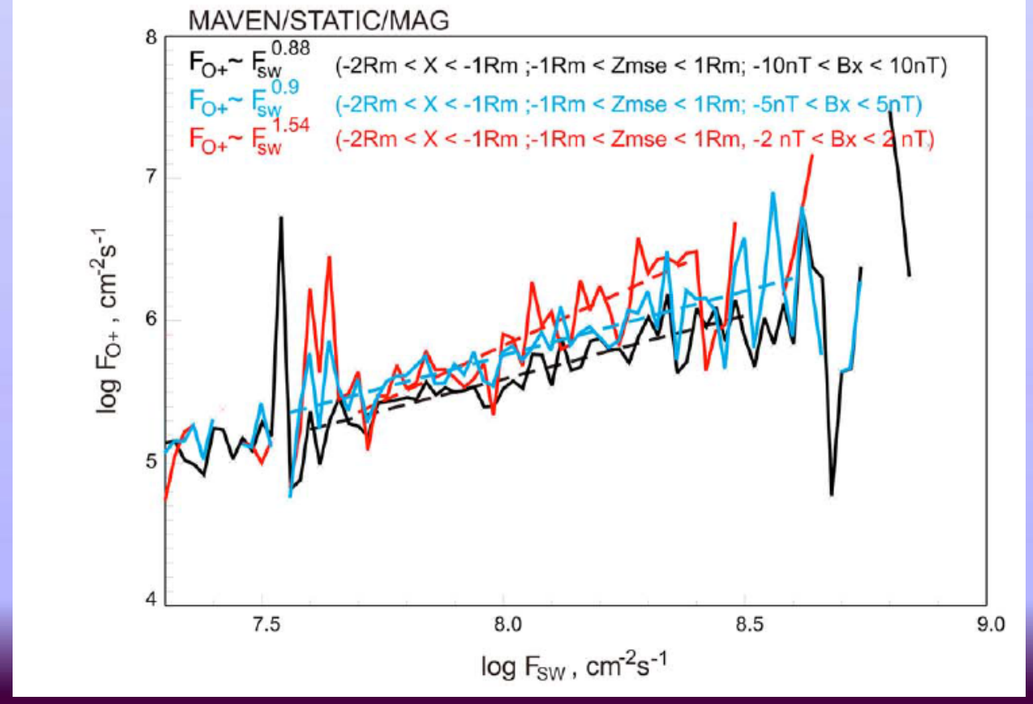
No correction for low energy observation efficiency.

MAVEN Recent Results on Ion Escape Rates



Dong et al. (JGR,2017) determine a mean O+ escape rate of 1.7-2.6x10^{24}/s through the tail depending on solar UV from MAVEN STATIC using only ‘d0’ data above 6eV.

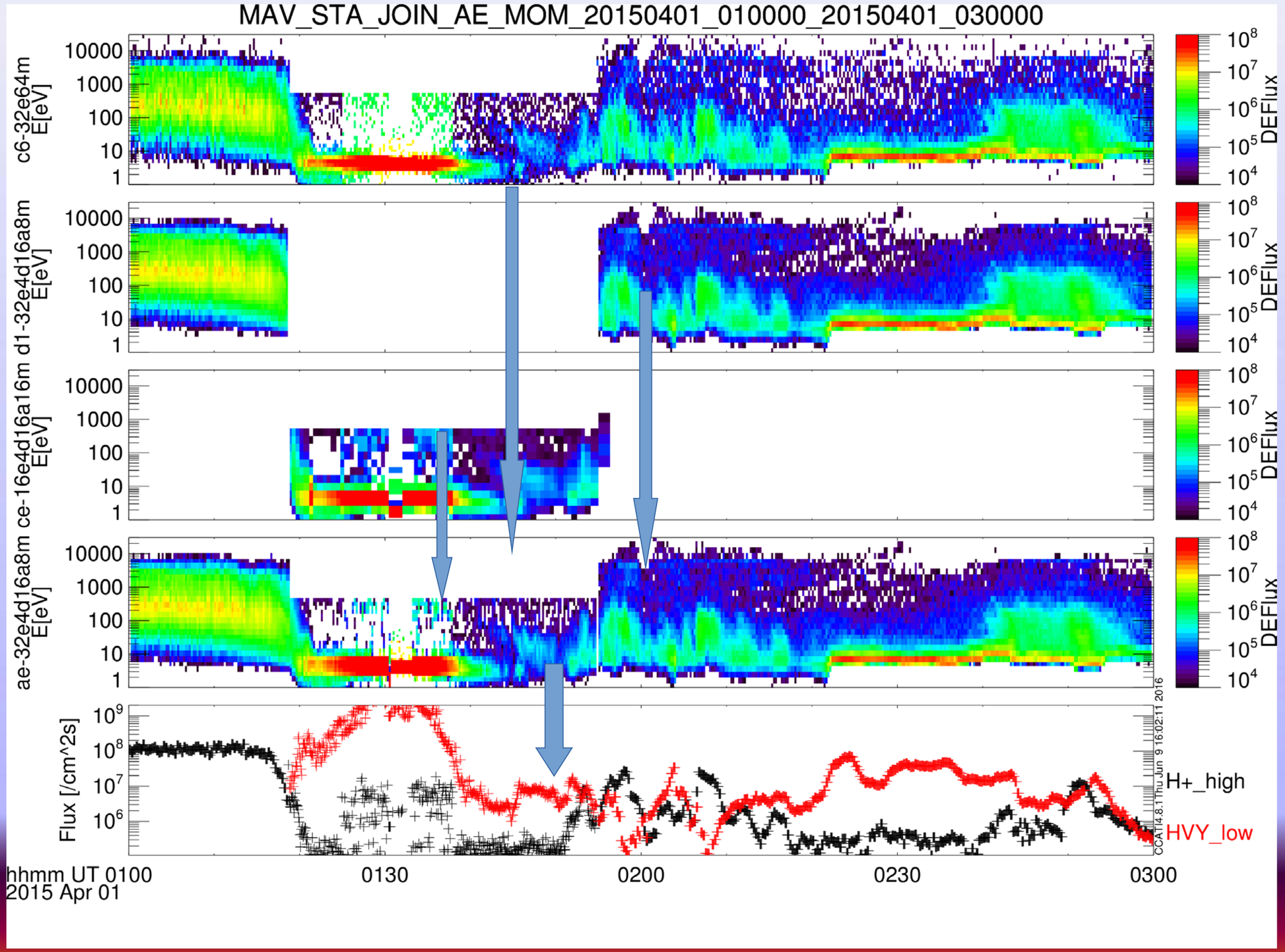




Dubinin et al. (JGR,2017a, left) determine cross terminator fluxes of O+ and O2+ of more than 10^8/cm^2s for high EUV with maximum escape rates of 1.7x10^{25}/s. Escape flux through the plasma sheet (JGR, 2017b, right) depends more on SW dynamic pressure and is minor.

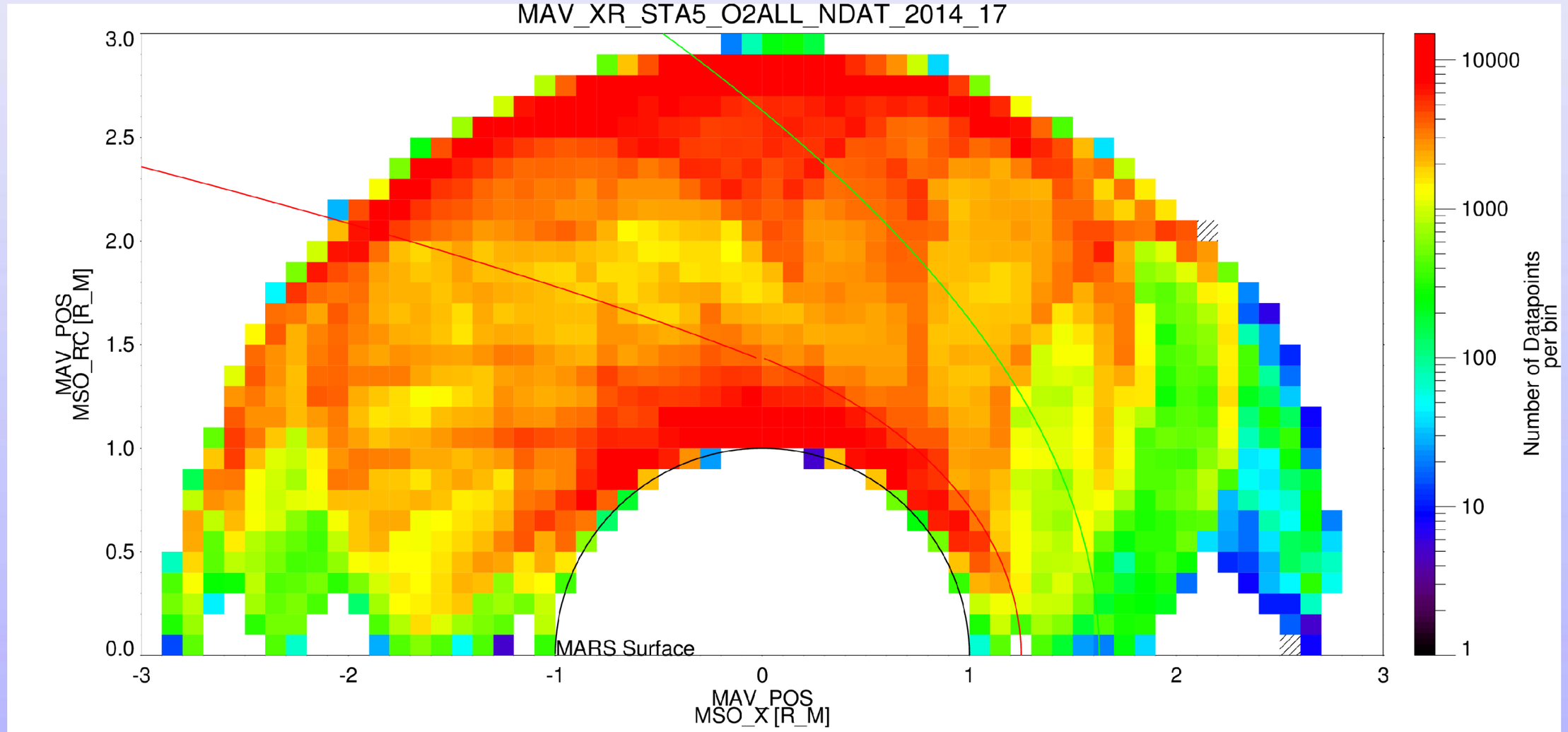
STATIC data processing at MPS

1. Join products
   c0,cf,d1,ce,d0,cd,cc,ca
   into an interpolated
product with resolution
   32e,8m,4d,16a at 4s.
2. Store this product
   as hourly CDF-files.
3. Determine moments
   from joined products for
   H+,O+,O2+
3. Store moments as
   CDF-files
5. Calculate flux-vectors
   from moments.



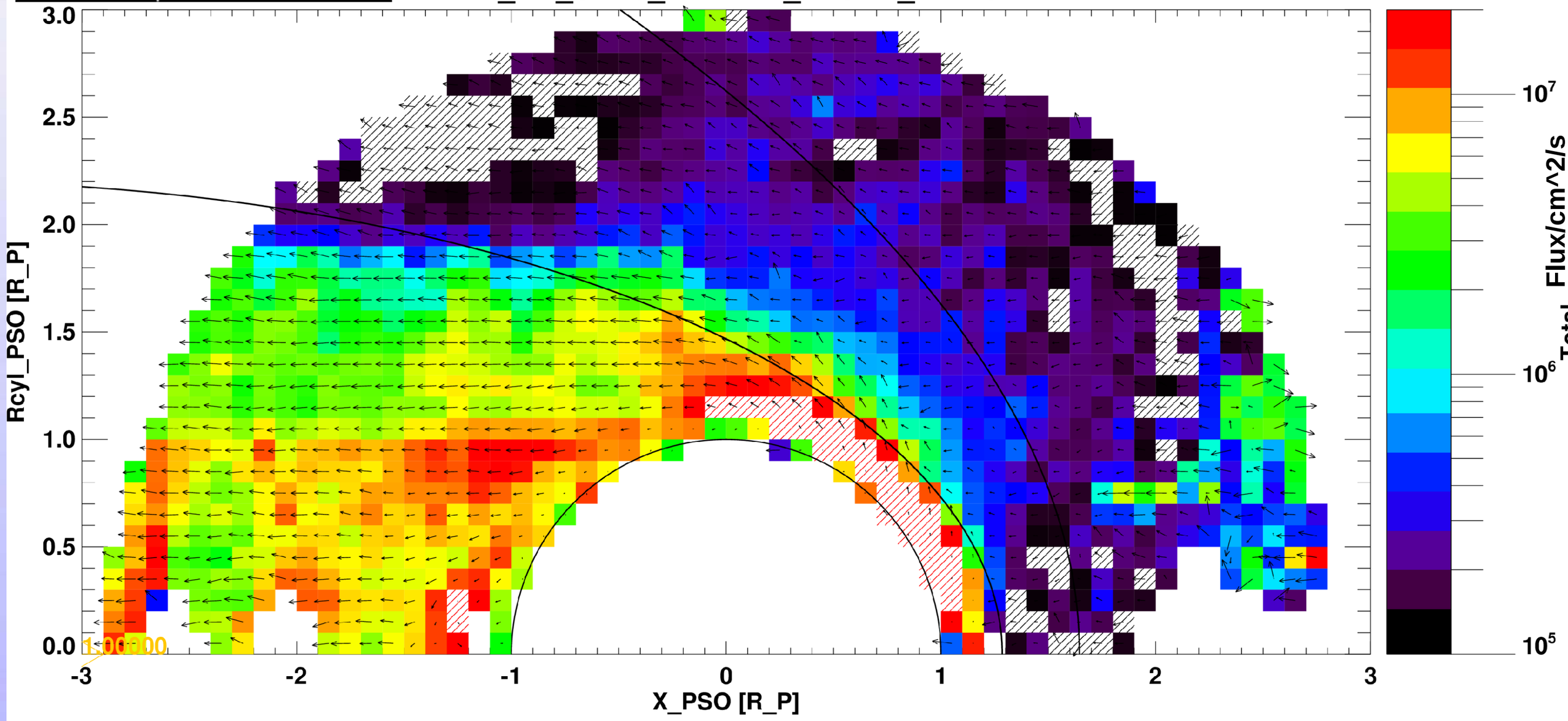
Joined products and moment CDF-files can be made available on request!

Statistical Coverage Maven Static
01 Dec 2014 to 15 Aug 2017



< Tail **Sun >**

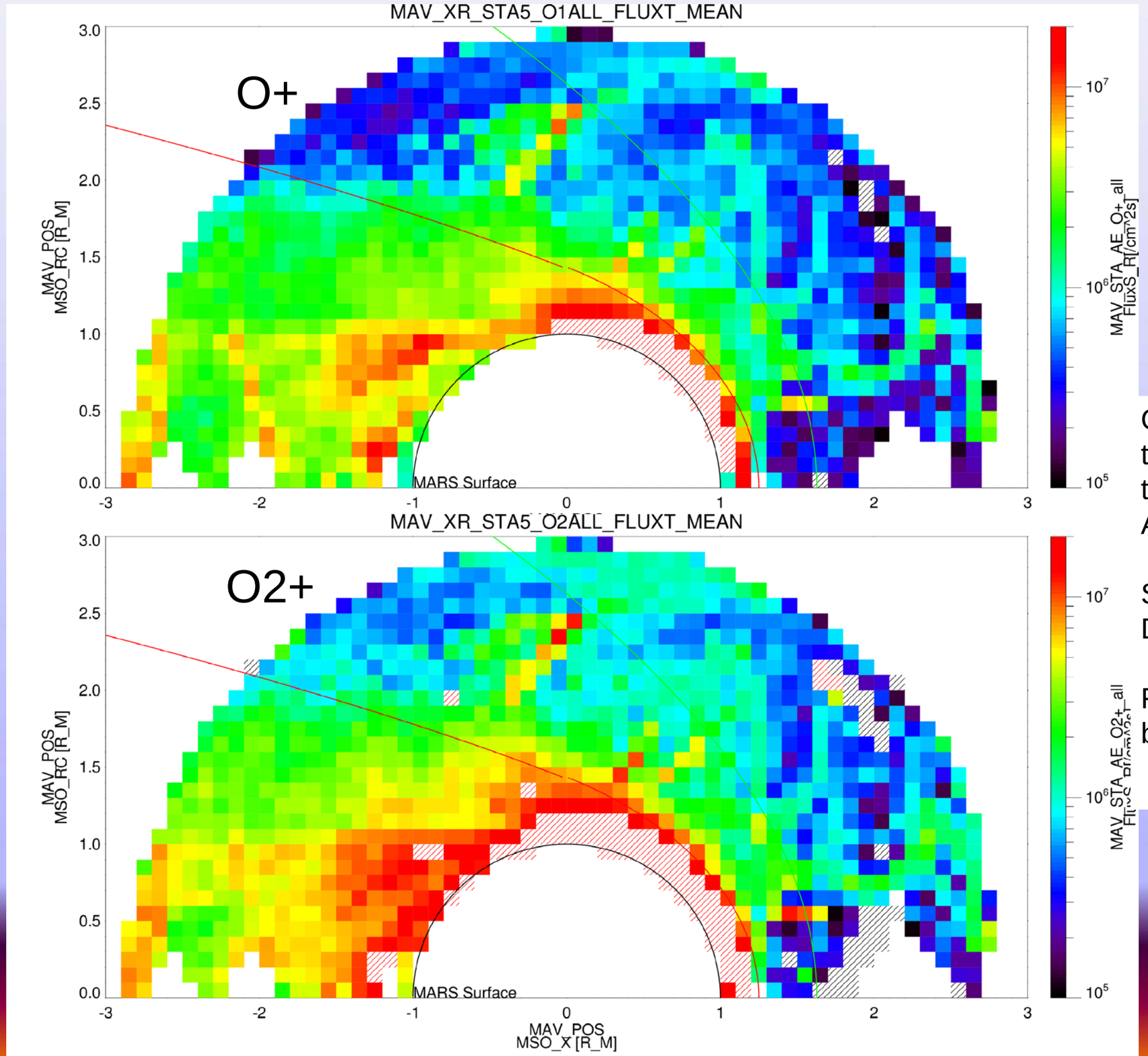
Mars Atmosphere and Volatile Evolution Mission



Median total flux and flux vector direction of heavy ions (O+ & O2+) observed by MAVEN STATIC between 01 Dec 2014 and 15 Aug 2017, scaled in /cm^{2}s. The vertical component of vectors shows the deviation from the cylindrical symmetry axis. (corrected for SC potential and SC velocity)

Is the tailward ion flux dominated by O+ or O2+?

Mean flux of O+ and O2+ ions
Dec 2014 to Aug 2017



O2+ is dominating the tailward flux up to 2.5 R_M downtail.

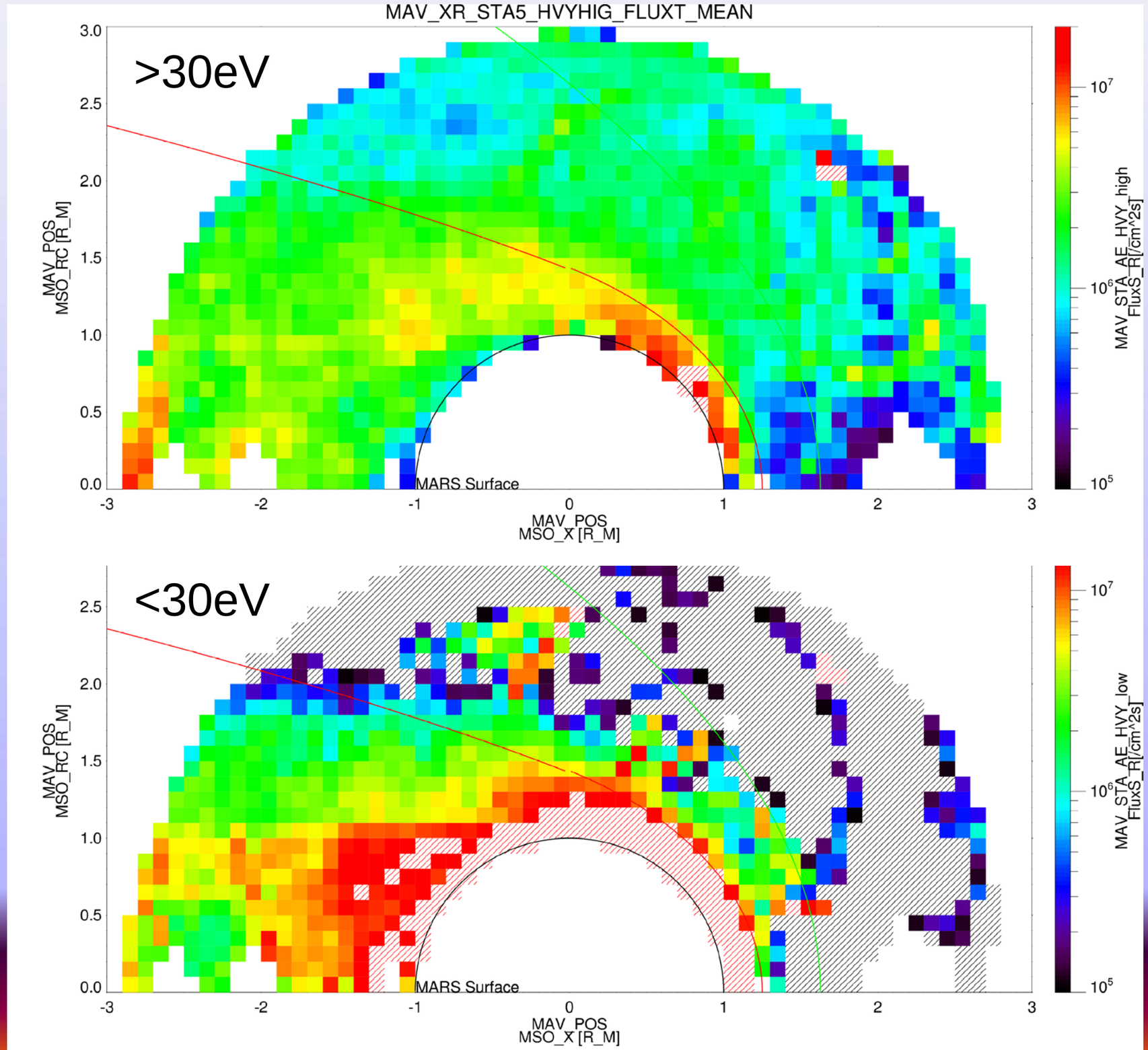
At 3 R_M O+/O2+~1.0

See also:
Dubinin et al.,JGR, 2017

For CO2+ see poster 9 by Lukas Maes.

Is the tailward ion flux dominated by low or high energy ions?

Mean flux of heavy ions
Dec 2014 to Aug 2017

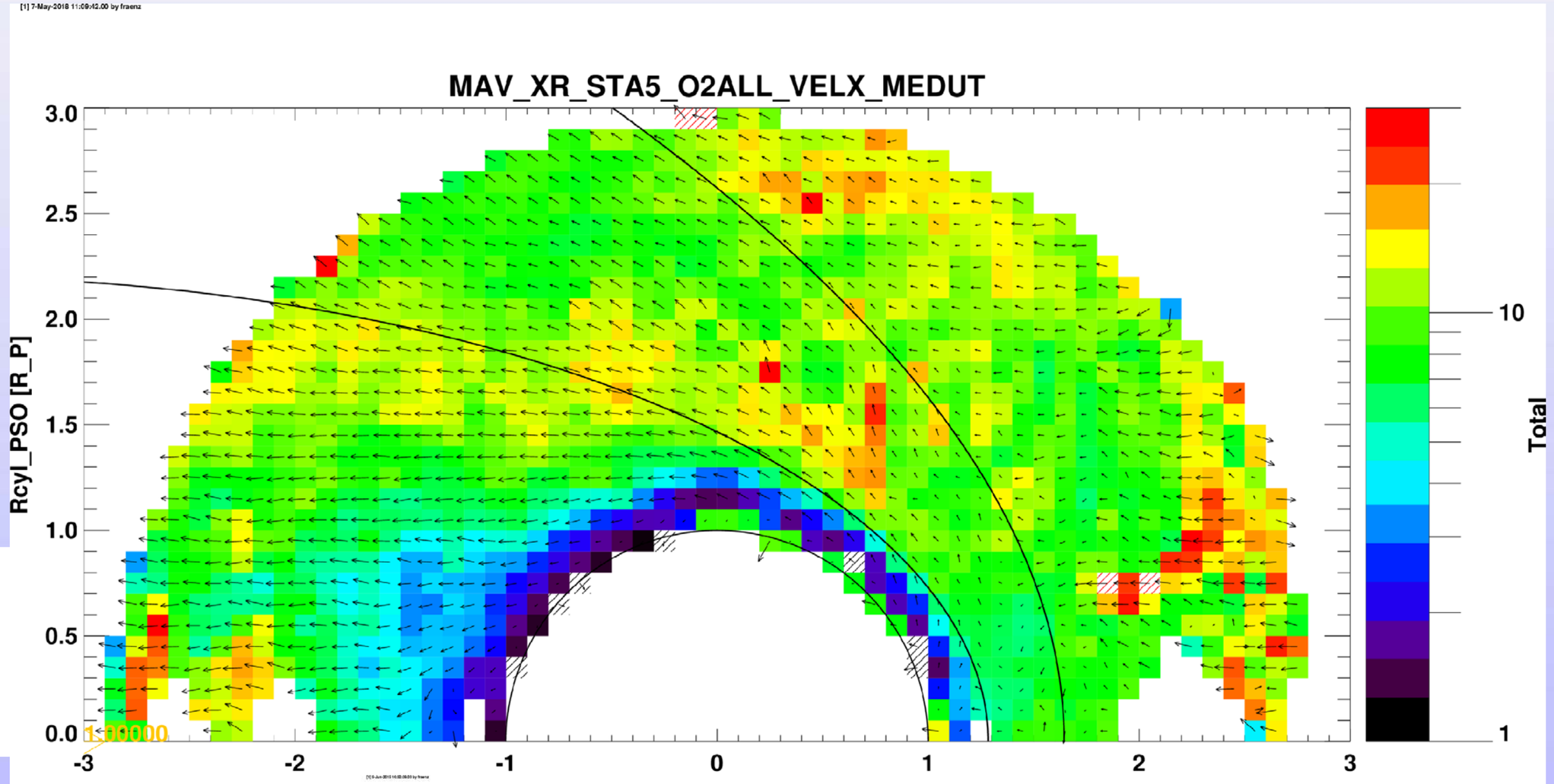


Low energy ions are dominating the tailward flux up to 2.0 R_M downtail, than energy starts to increase.

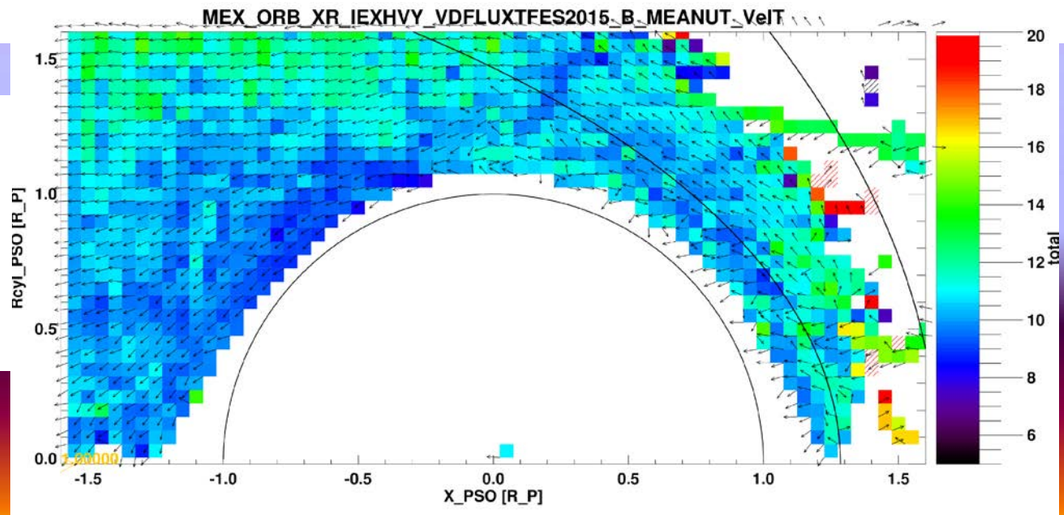
See also:
Dubinin et al., JGR, 2017

How is this reflected in ion velocities?

Maven O2 median velocity
01 Dec 2014 to 15 Aug 2017



Median tailward velocities increase from about 5km/s at 1.5 RM to 15 km/s at 2.5RM.



Respective map by MEX Aspera (2007-2014) shows velocities Of 9-11km/s at 1.5RM.

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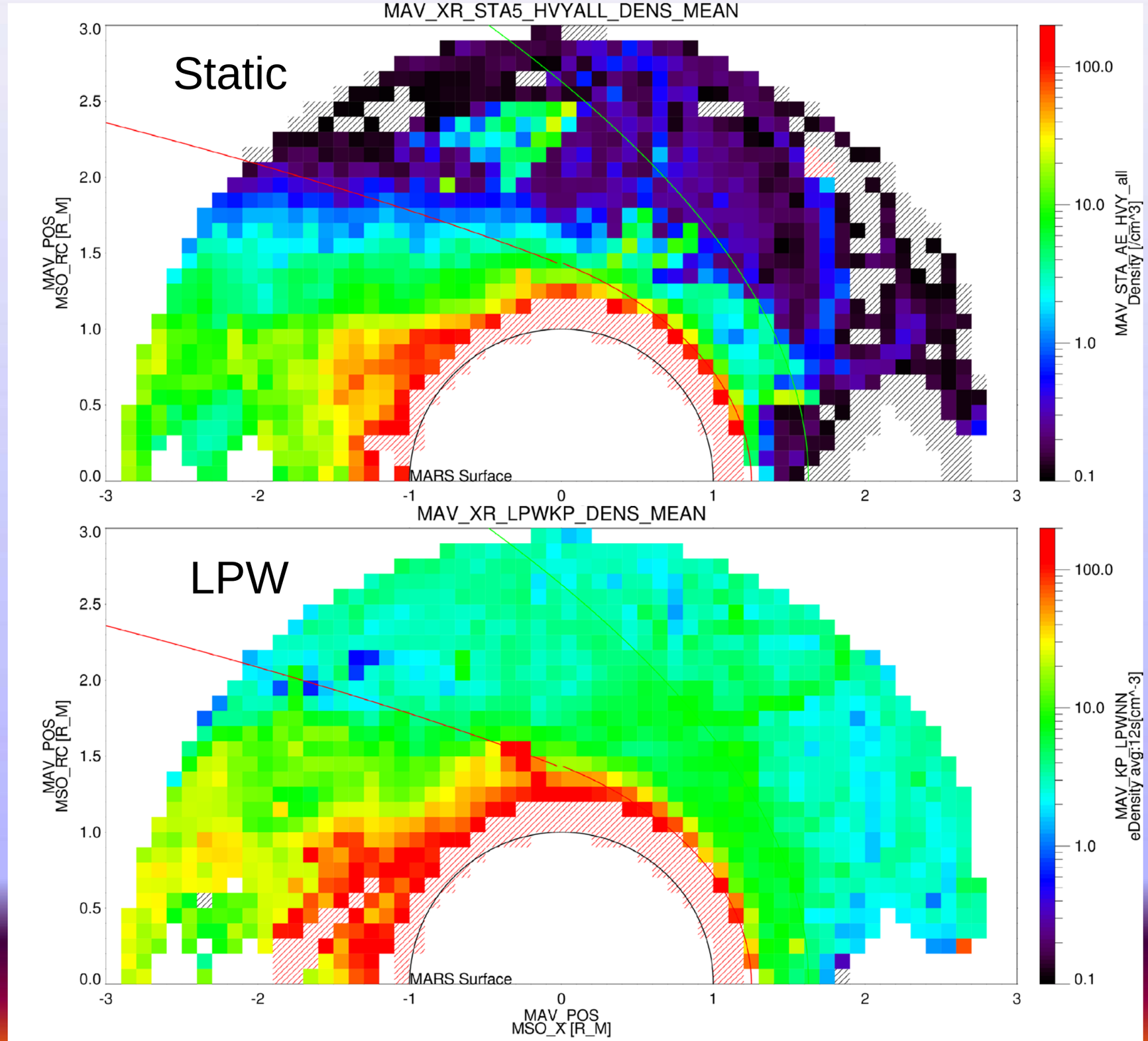
Do we need to correct the Static fluxes using the electron density measured by the Langmuir probe (LPW)?

Mean density of heavy ions and electrons
Dec 2014 to Aug 2017



In the tail mean electron densities (LPW) are about 2 times higher than heavy ion densities.
Some correction to the fluxes may be needed. (H+ not taken into account).

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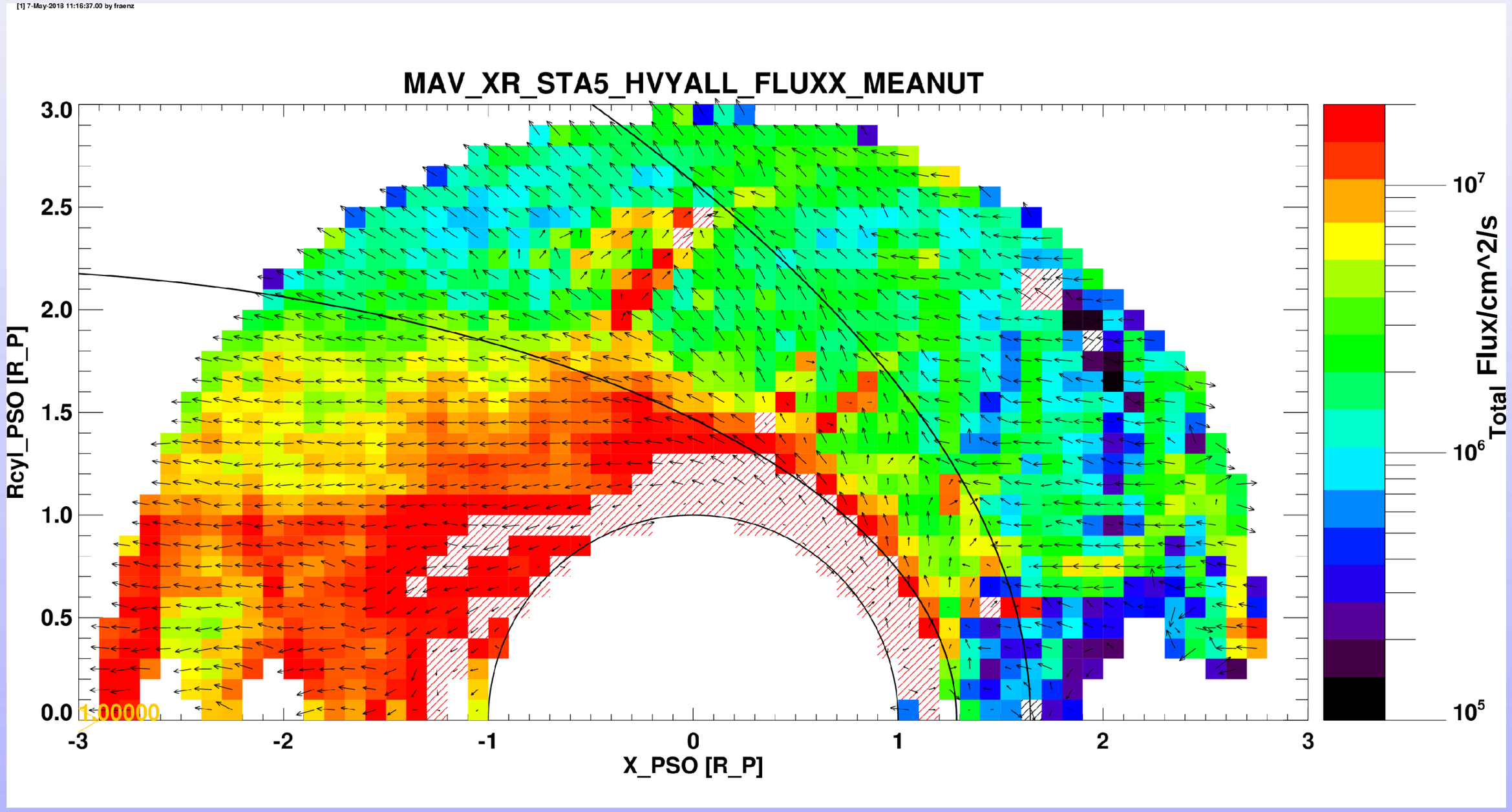
What is the mean total heavy ion escape rate through the Martian tail?

Mean Heavy Ion Fluxes observed by MAVEN STATIC
Dec 2014 to Aug 2017



Mean total flux and flux vector direction of heavy ions (O+ & O2+) observed by MAVEN STATIC between 01 Dec 2014 and 15 Aug 2017, scaled in /cm^{2}s. The vertical component of vectors shows the deviation from the cylindrical symmetry axis. (corrected for SC potential and SC velocity)

Cold Ion Escape from the Martian Ionosphere
Conclusions from Mars Express – MAVEN comparison

- Observations by MAVEN STATIC show tailward heavy ion fluxes of about $1.5 \times 10^7/cm^2s$ over the whole tailside cross-section (2014-2017).

- This flux is about 3 times higher than observed by MEX IMA alone (2007-2014).

- When MEX IMA velocities are corrected for SC potential and velocity and determined by mean velocity distribution and then multiplied by MARSIS electron densities mean fluxes increase by factor 10 (about $6 \times 10^7/cm^2s$).

- The flux observations by MAVEN STATIC should not depend very much on SC potential, but the variations observed indicate that the potential may move part of the distribution out of the STATIC energy range.

- If we take the MAVEN STATIC heavy ion fluxes uncorrected but including the cold ion part we get a mean escape rate of heavy ions of about 7.8×10^{24} ions/s from Mars between 1 Dec 2014 and 15 Aug 2017 over a radius of 1.2 R_M.

- About half of this escape is O2+ ions.

- An earlier estimate from STATIC data by Brain et al. (GRL,2015) using a slightly different method gave a minimum escape rate of 3.0×10^{24} ions/s.

- Cross-calibration with LPW may result in a correction by factor 2 but will not reach the value of 2.8×10^{25} ions/s estimated from MEX IMA/MARSIS for the period 2007-2014.

Acknowledgements:
We express our thanks to the Mars Express teams at IRF, Kiruna and Uppsala, Sweden, IRAP, Toulouse, France and Univ. of Iowa, USA for continuous support and providing the MEX data. We thank the whole MAVEN team and especially Jim McFadden for providing calibrated data within a very short time.