Preparation for Sputtering on Titan

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Hybrid simulations on Titan

- Based on S. A. Ledvina et al., Earth Planets Space 64, 207-230, 2012 → Three Saturn local time (SLT) studies.
- Ambient O^+ flow with density of 0.2 cm^{-3} and 120 km/s.
- Southward magnetic field = 5 nT.
- Comparison studies from S.A. Ledvina and I. Sillanpaa in future.

Ledvina model

- Cold O^+ beams.
- Include a complex ion-neutral chemical network (12 neutral profiles & 7 major exospheric ion species).

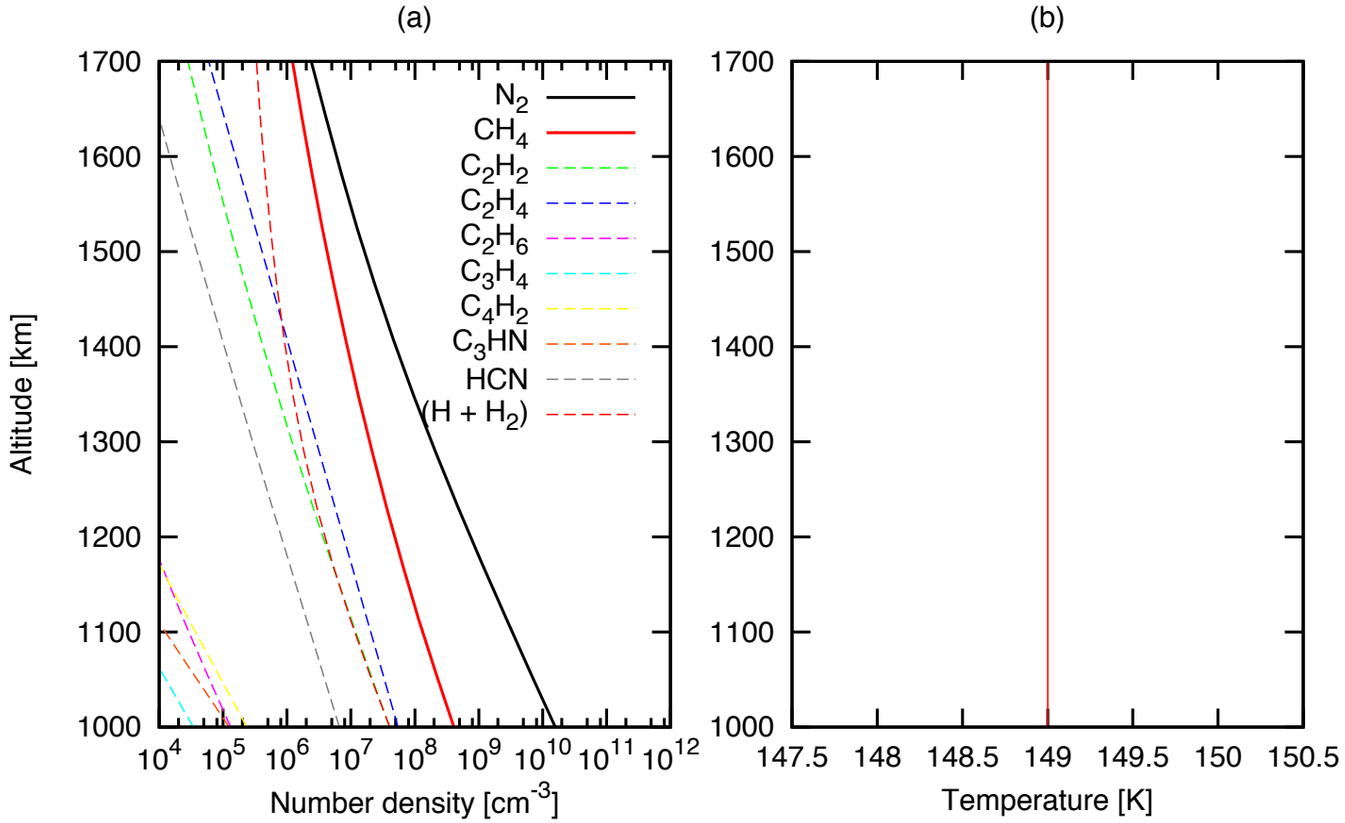
Table 1. The generic ion species used in the model, the actual ion species they represent, their assigned mass and the mass range of the actual ions represented.

Name	Components	Mass (amu)	Mass range
L^+	H^+, H_2^+, H_3^+	2	1–3
M^+	CH_5^+, N^+, CH_4^+, CH_3^+, CH_2^+, CH^+, C^+	14	12–17
$H1^+$	$C_2H_5^+$	29	29
$H2^+$	$CHNH^+$	28	28
MHC^+	C_3H^+, $C_3H_2^+$, $C_3H_3^+$, $C_3H_4^+$, $C_3H_5^+$, $C_4H_3^+$, $C_4H_5^+$	44	37–53
HHC^+	$C_5H_3^+$, $C_5H_5^+$, $C_5H_7^+$, $C_5H_9^+$, $C_6H_5^+$, $C_6H_7^+$, $C_7H_5^+$	70	68–89
HNI^+	$C_3H_2N^+$, $C_5H_5N^+$, C_3HN^+	74	51–79

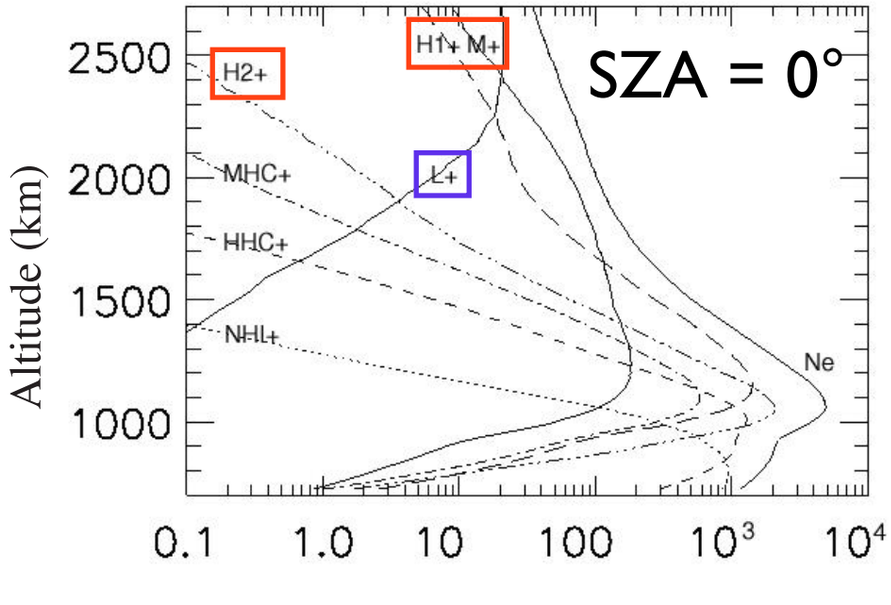
Ledvina et al., 2012

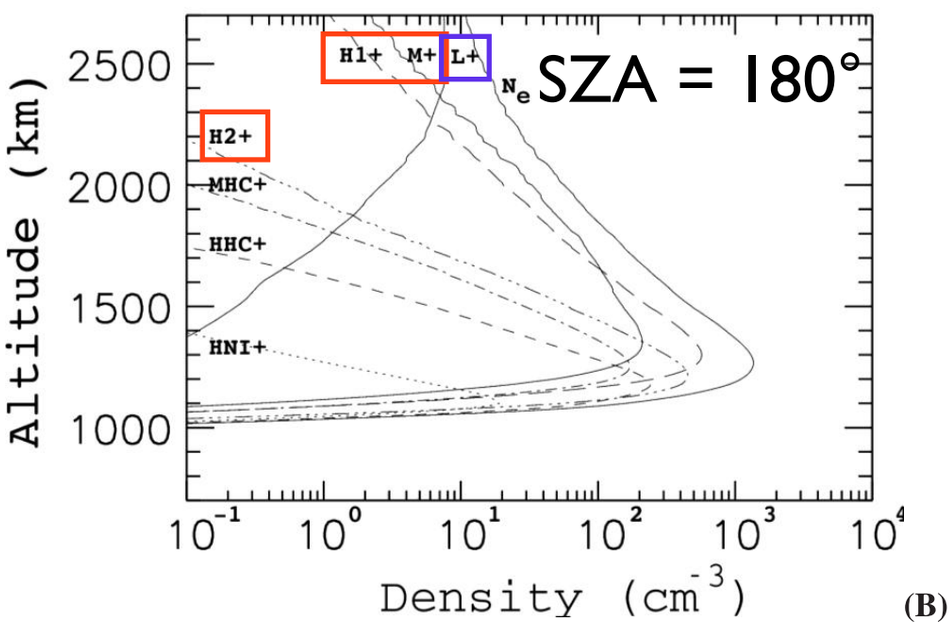
Atmosphere and ionosphere

N_2 & CH_4 are major species in upper atmosphere ↓



L^+, M^+, $H1^+$ dominate in upper ionosphere →



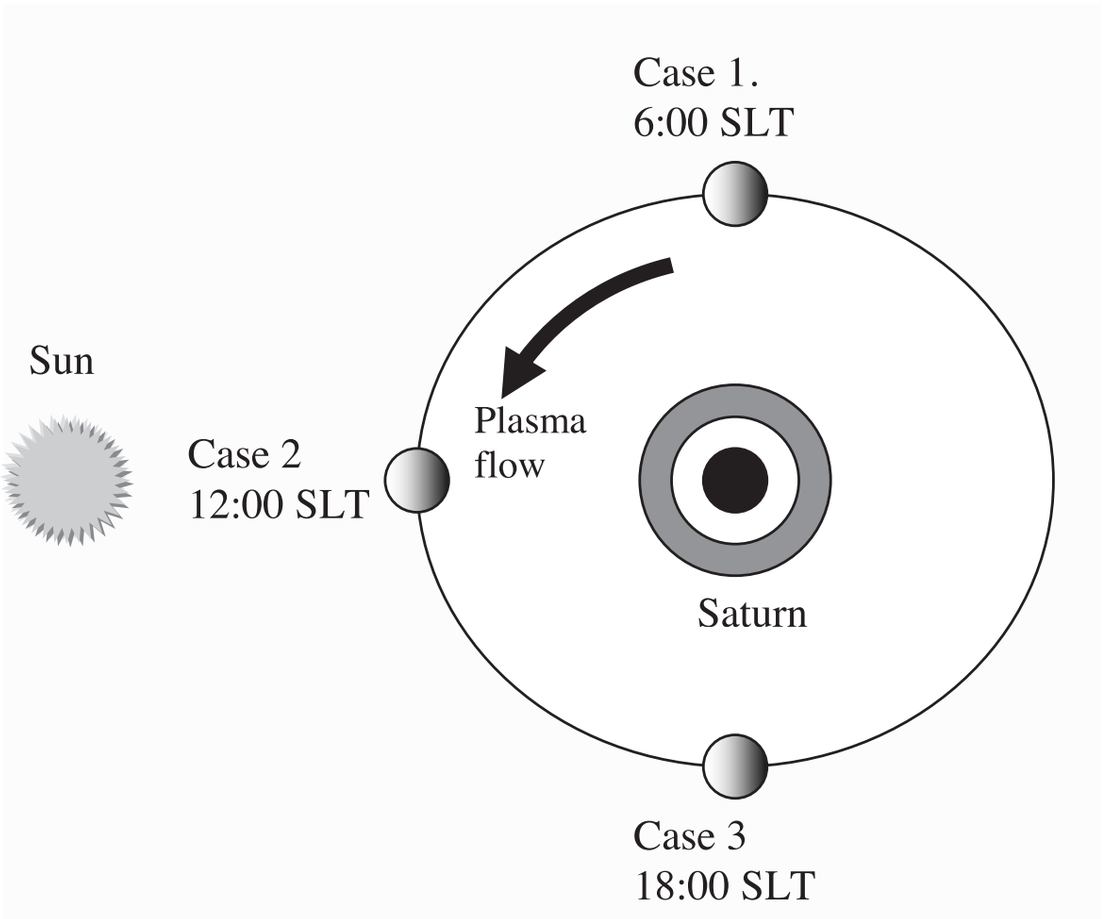


Ledvina et al., 2012

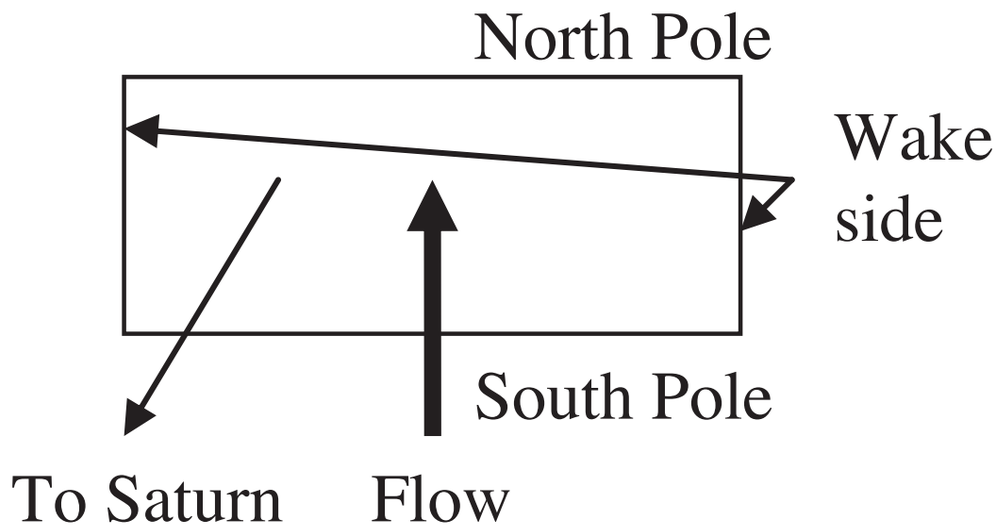
6:00 SLT case

Case 1

Gathering downward ions as incident fluxes.
Altitude: 1400 ± 50 km (too low... Gathering 1600-1800 km in future.)



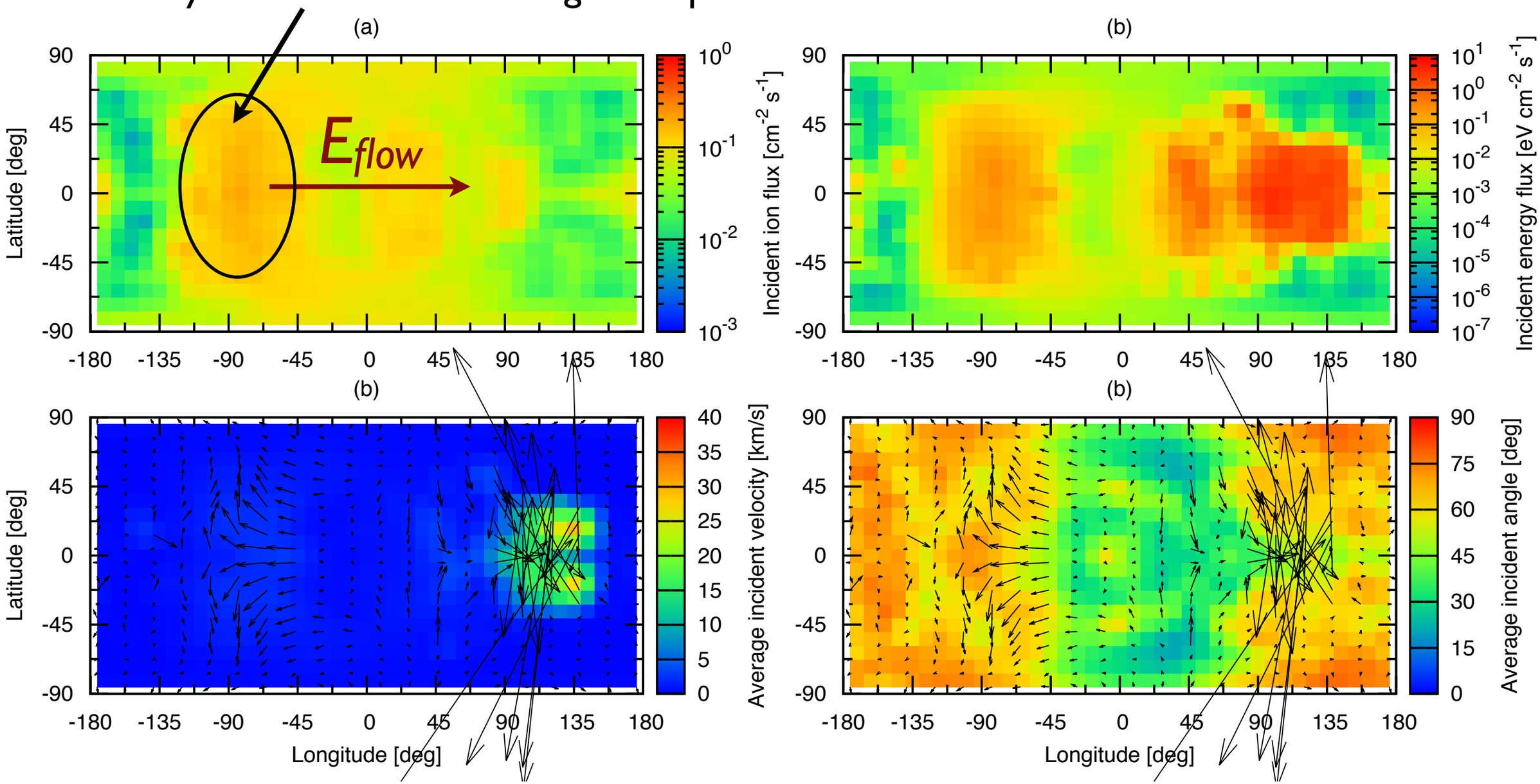
Projected View



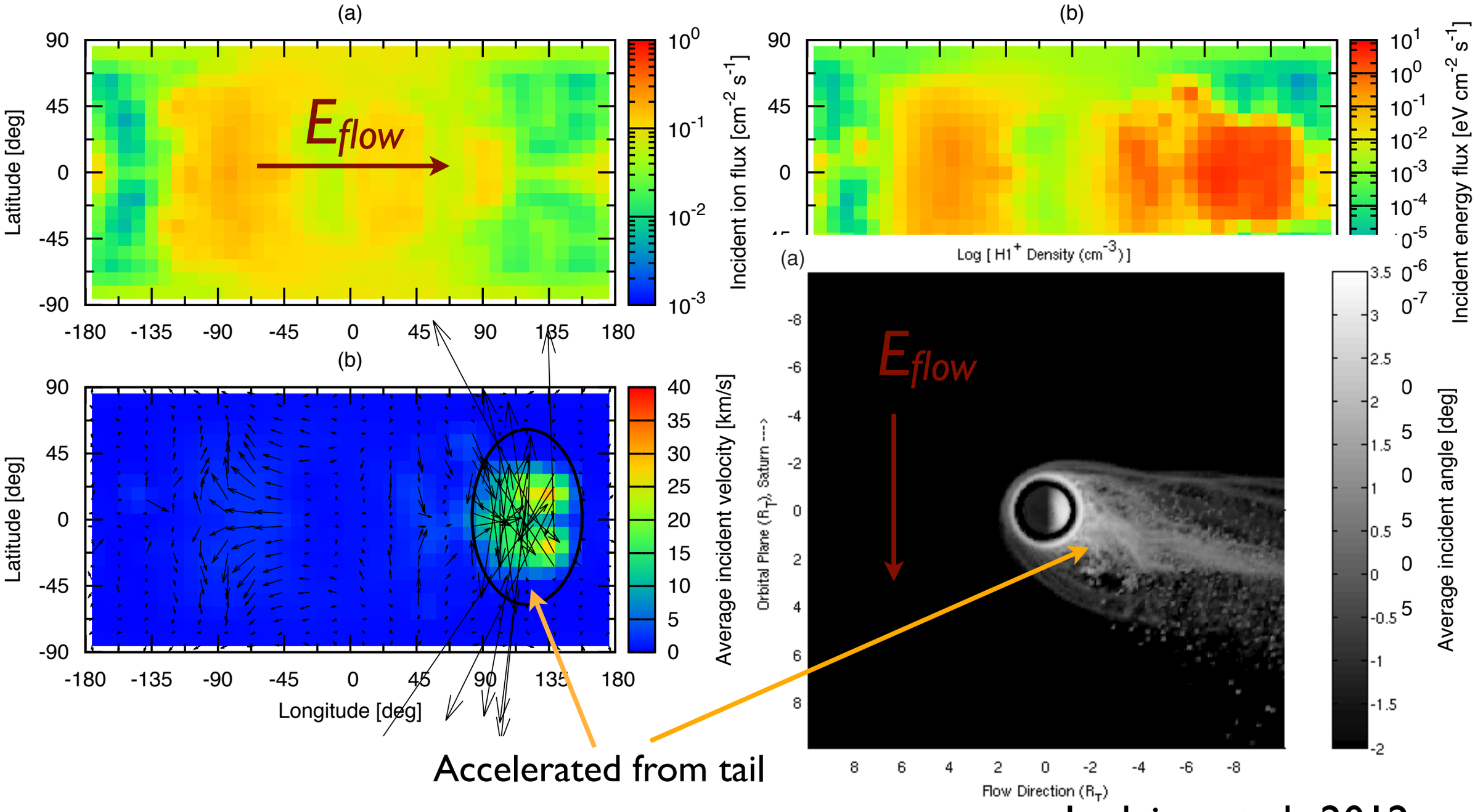
Ledvina et al., 2012

Exospheric ions (N^+, CH_4^+...) I

Accelerated by E field to Saturn facing hemisphere



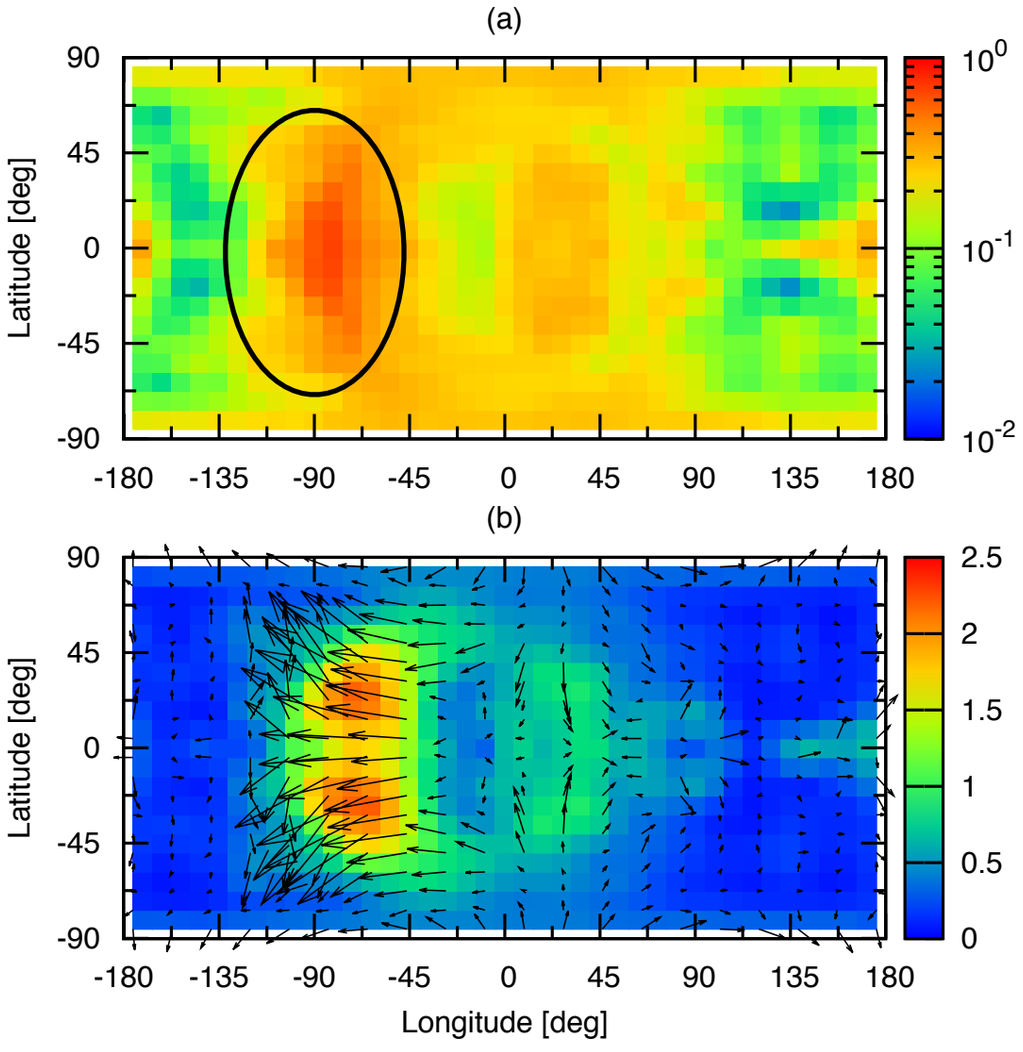
Exospheric ions (N^+, CH_4^+...) II



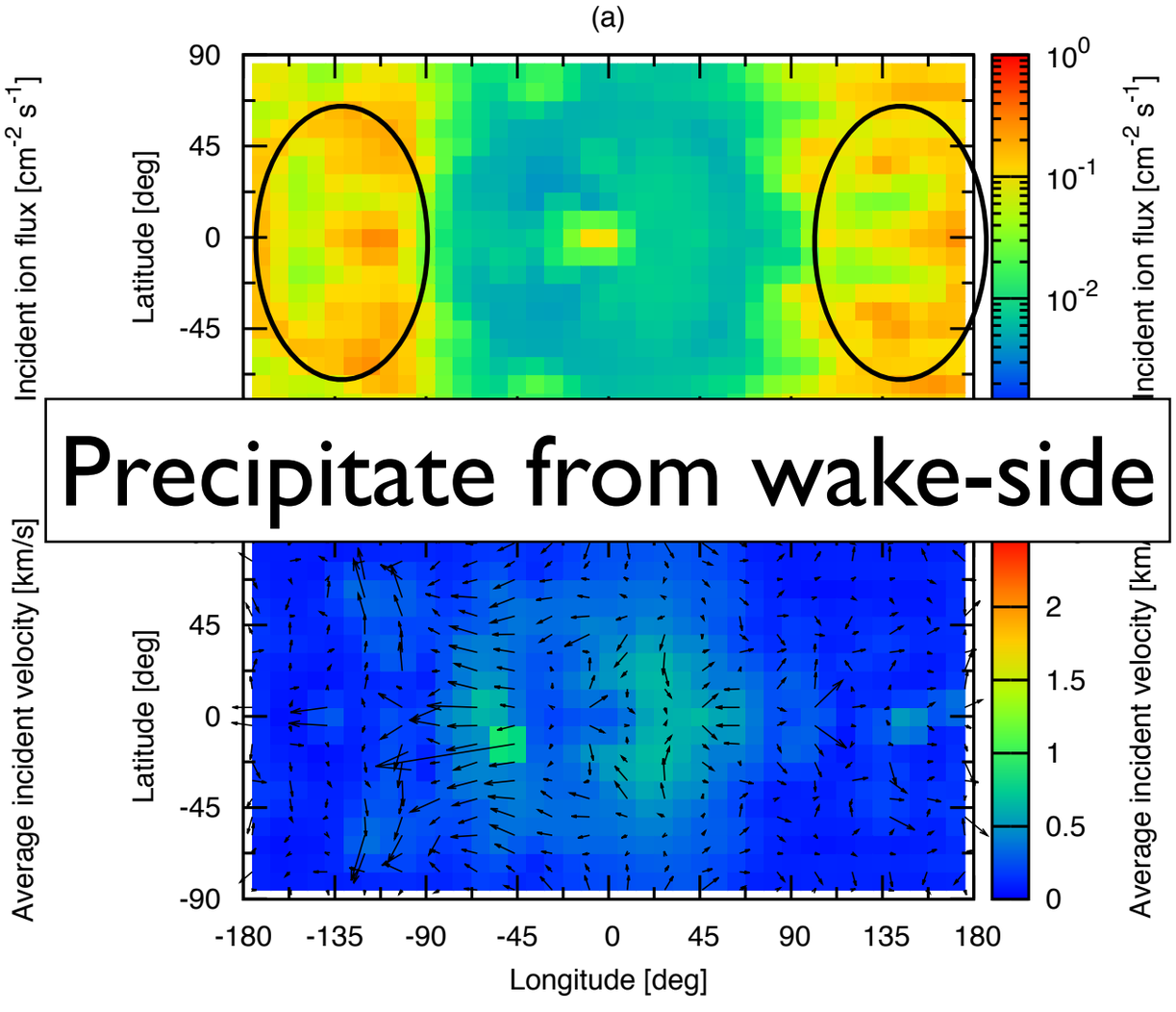
Ledvina et al., 2012

Exospheric ions ($C_2H_5^+$ & $CHNH^+$)

$C_2H_5^+$



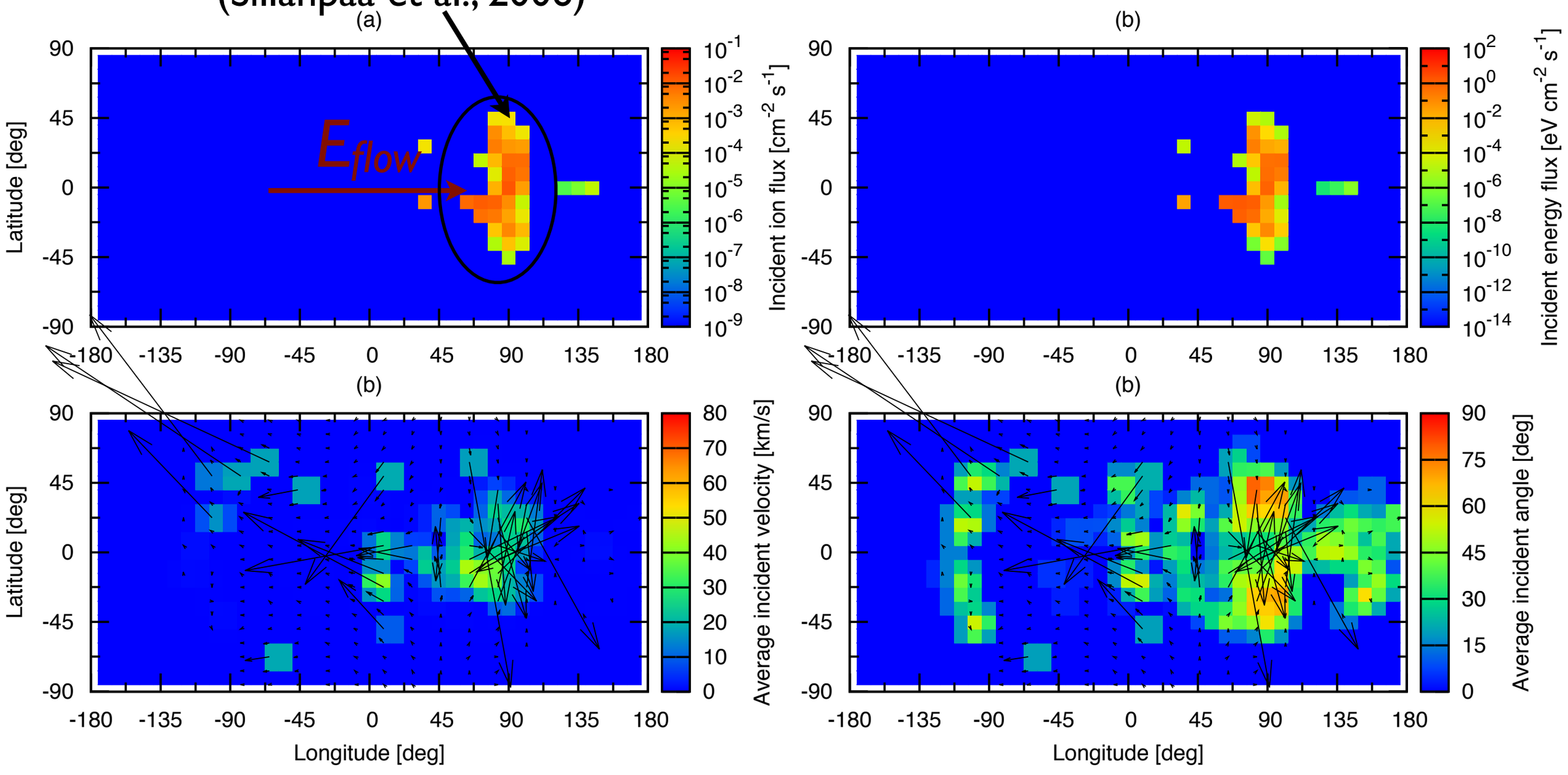
$CHNH^+$



Although molecular weight is similar, the altitude distribution of ions are different (see page 4).

Ambient O^+

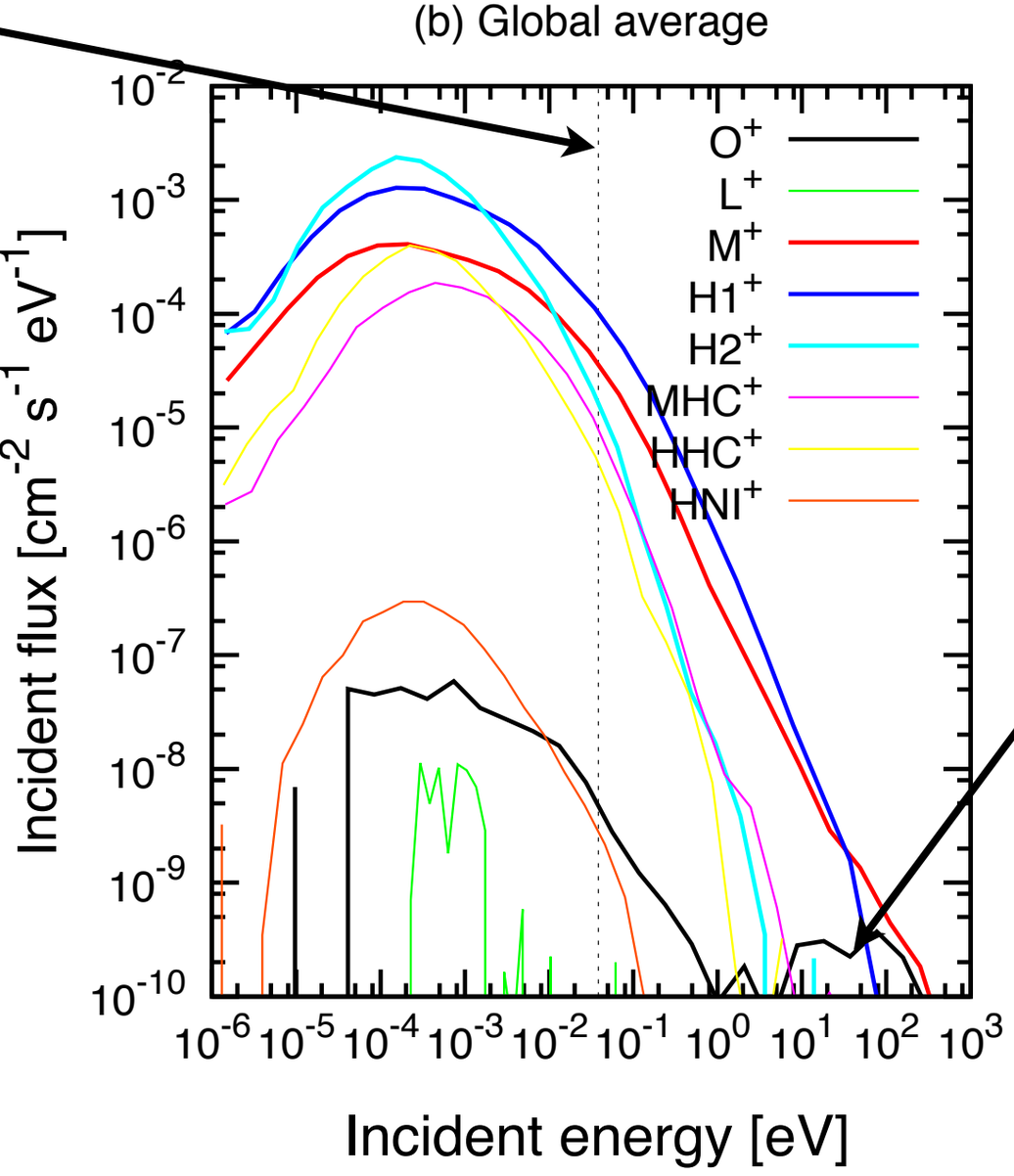
Momentum conservation with exospheric ion flows
(Sillanpaa et al., 2006)



Incident fluxes expect to be larger at higher altitudes.

Energy spectra

0.1 E_{escp}(O)



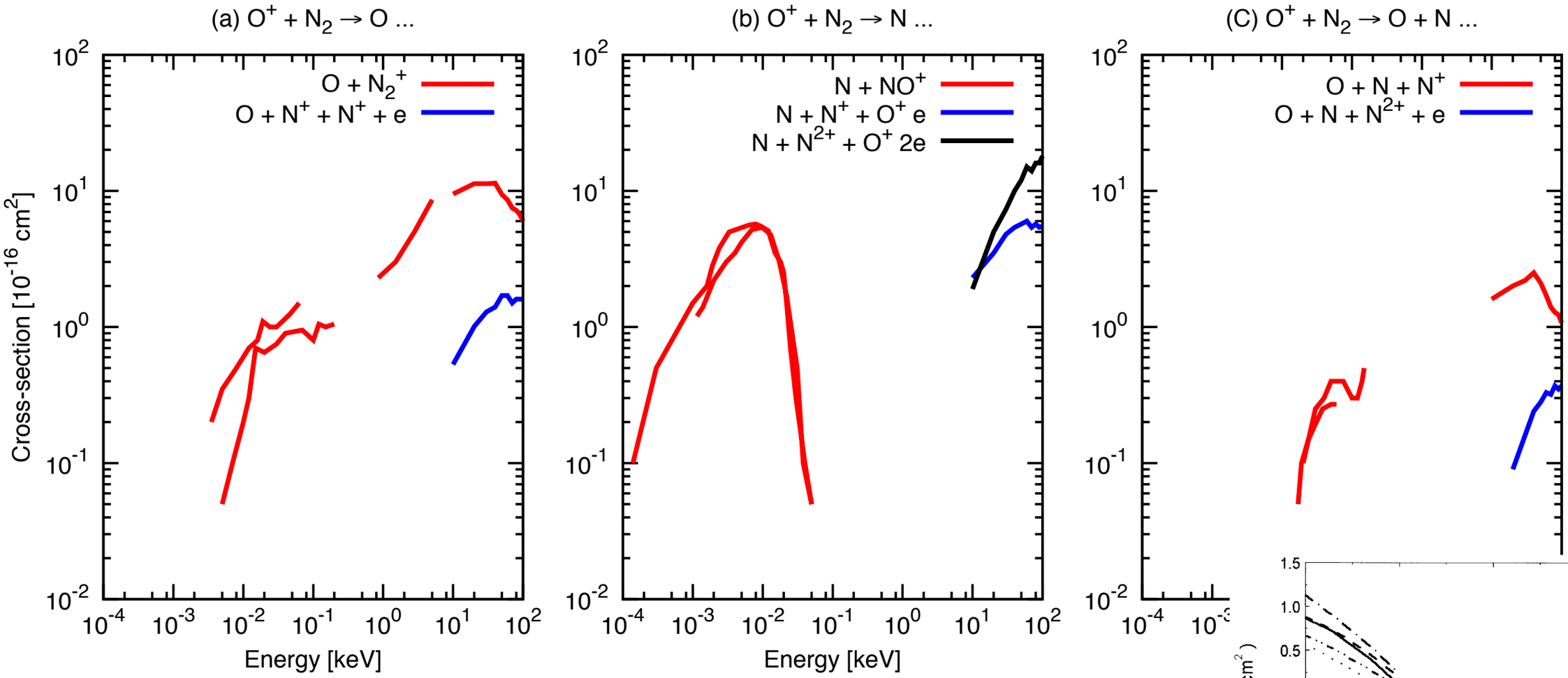
Larger energy from ambient flow

Note: expect larger flux when gathering particles at higher altitudes!

Sputtering model ...

- Atmosphere: N_2 (and CH_4?)
- Incident ions: Ambient O^+, and exospheric $N^+(CH_4^+)$, $C_2H_5^+$, $CHNH^+$ (particularly interested species in Ledvina model); exospheric CH_4^+, N_2^+ (in Sillanpaa mode)
- Modify Mars model to Titan: (Are these assumptions reasonable?)
  - Modify potentials from Johnson et al. (PSS 50, 123-128, 2002) for O, N, N_2 + N_2 → will underestimate N_2 dissociation rate without considering three-body potential (Tully and Johnson, Journal of Chemical physics 117, 6556-6561, 2002)
  - Treat CH_4^+ as N^+, and $C_2H_5^+$, $CHNH^+$ as N_2^+ ??
  - Charge exchange rate before reaching exobase (see next page). Is the charge of a molecule important ?

Charge exchange for O^+



If energies of O^+ > 100 eV, charge exchange dominate. (Cross-sections and references provided by Wendy Tseng)

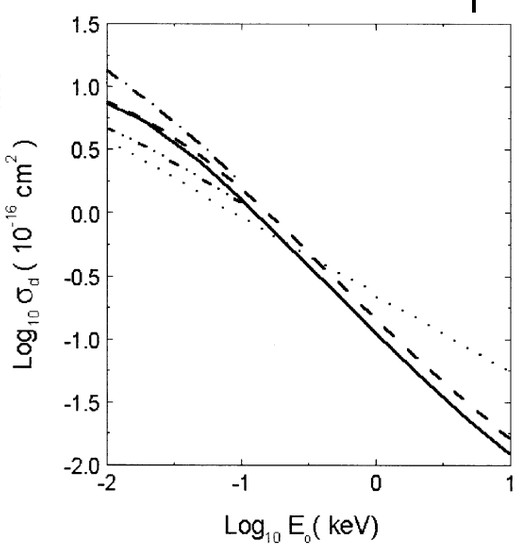


Fig. 3. Diffusion (momentum transfer) cross section, σ_d, calculated using the pair potentials in Table 2. $O + O_2$ (solid line), $O_2 + O_2$ (dash–dot), $N + N_2$ (dotted), and $N_2 + N_2$ (dash–dot–dot). $O + O_2$ (dashed line) using $S_n/[\gamma E_o/2]$ as discussed in the text.