The Impact of the Geocorona on the Lifetime of Ring Current Ions

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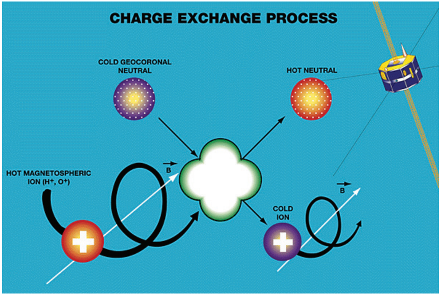
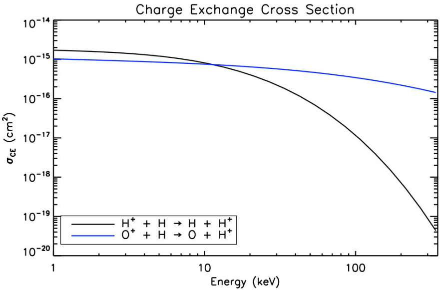
Loss of ring current ion through charge exchange

Long-term ring current decay following a magnetic storm is mainly due to charge exchange collisions of ring current ions with geocoronal neutral atoms forming energetic neutral atoms (ENAs) that leave the ring current system on ballistic trajectories.

The probability of charge exchange with neutral atoms from the exosphere depends strongly on the energy of the incident ion and the charge exchange cross sections → different ion species have different lifetimes in the ring current.





Geocoronal Hydrogen Models

Rairden et al. [1986]

- Spherically symmetric isothermal *Chamberlain* [1963] model of the exospheric hydrogen density.
- Density distribution fitted to the DE1 observation from 1981 to 1985.

Hodges [1994]

$n_H(r, \theta, \phi) =$
$$N(r)\sqrt{4\pi} \sum_{l=0}^{3} \sum_{m=0}^{l} \left(A_{lm} cos(m\phi) + B_{lm} sin(m\phi)\right) Y_{lm}(\theta)$$

- Includes local time dependence.
- Time dependence is implicit (A_{lm} and B_{lm} derived for both equinox and solstice and 4 different F10.7).

Ostgaard et al. [2003]

$n_H(r, \theta, \phi) =$
$$C(t)\left[n_1(\phi) exp\left(-\frac{r}{\alpha_1(\phi)}\right) + n_2(\phi) exp\left(-\frac{r}{\alpha_2(\phi)}\right)\right]$$

- Based on GEO IMAGE data. Valid past $R > 3.5 R_E$.
- r is in R_E, $n_1, n_2, \alpha_1, \alpha_2$ are tabulated.

Bailey and Gruntman [2011]

$n_H(r, \theta, \phi) =$
$$N\sqrt{4\pi} \sum_{l=0}^{2} \sum_{m=0}^{l} \left(A_{lm} cos(m\phi) + B_{lm} sin(m\phi)\right) Y_{lm}(\theta)$$

where,
$N(r) = p \cdot r^k$
$A_{lm}(r) = a_{lm} + b_{lm} \cdot r$
$B_{lm}(r) = c_{lm} + d_{lm} \cdot r$

- Based on LAD TWINS observation.
- a_{lm}, b_{lm}, c_{lm}, d_{lm}, p, k are tabulated for June 11, 2008.

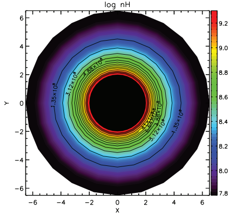
Zoennchen et al. [2011]

$n_H(r, \theta, \phi) =$
$$N\sqrt{4\pi} \sum_{l=0}^{2} \sum_{m=0}^{l} \left(A_{lm} cos(m\phi) + \cancel{B_{lm} sin(m\phi)}\right) Y_{lm}(\theta)$$

- Also based on LAD TWINS observation.
- All parameters are tabulated for 4 time periods between June–September 2008.

Distribution of neutral H density in the equatorial plane

Rairden et al. [1986]



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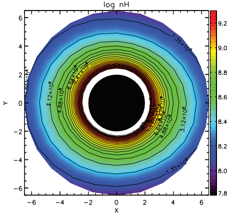

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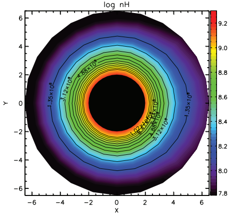

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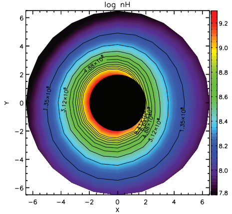
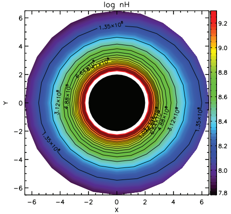


Vast differences in magnitude and topology between the neutral H densities predicted by different models (*Ilie et al.* [2013]).

Zoennchen et al. [2011]



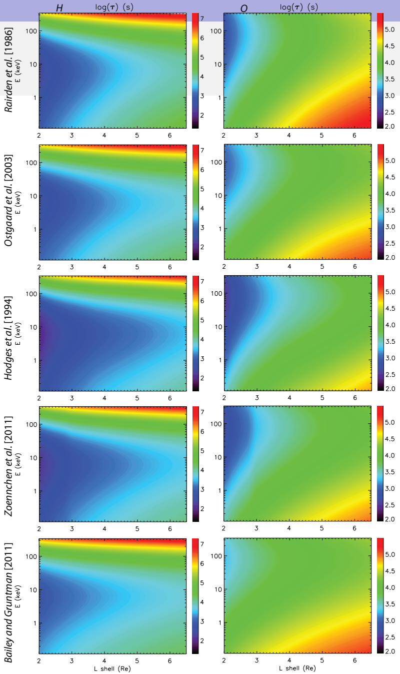
Lifetimes of Ring Current Ions

The ion lifetime is increasing with radial distance (due to the exponential decrease in geocoronal hydrogen density) and increasing with energy (more energetic particles have lower cross sections).

Both H^+ and O^+ lifetimes are highly dependent on the n_H distribution in the near Earth region.

For lower energy particles, different models of the geocorona produce ion lifetimes that differ from each other by up to a factor of 10 → the distribution of the neutral hydrogen density alone is an important factor in determining the decay time of the ring current.

The ion lifetimes change with local time and pitch angle as well (not show here).



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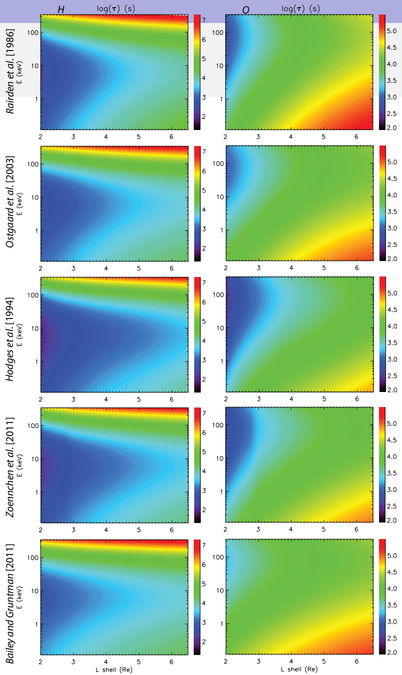

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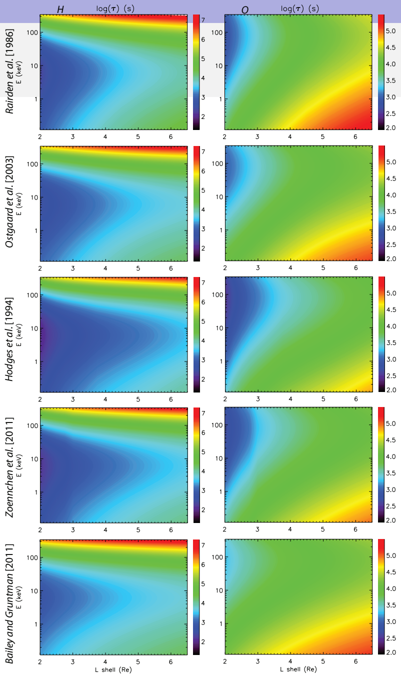

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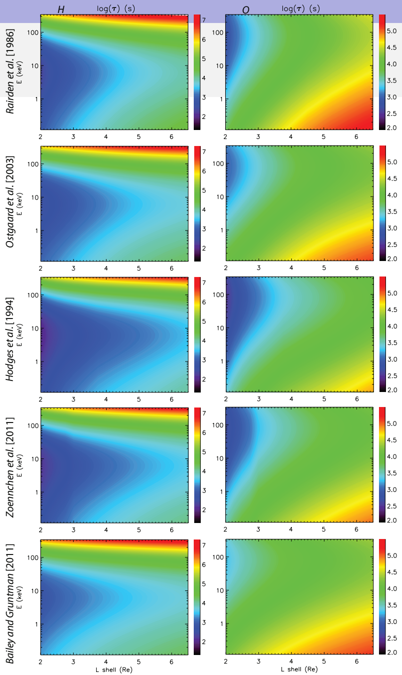
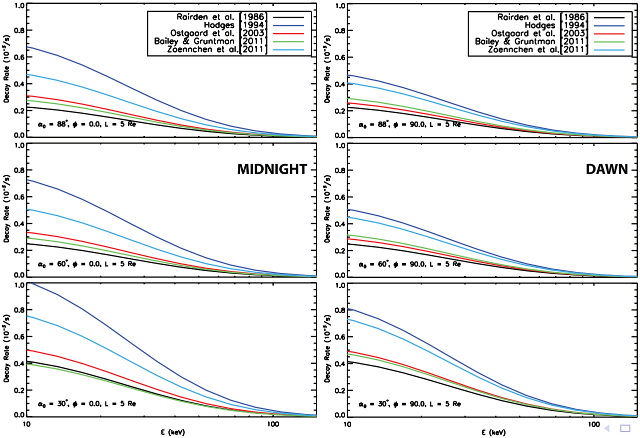


Charge exchange decay rate of H^+ with energy

The decay rate $\left\langle \left(\frac{\partial Q}{\partial t}\right)_{CE} \right\rangle = -\sigma_{CE\,i}\sqrt{\frac{2E}{m_i}}\langle n_H \rangle Q$ is governed by an interplay between the σ_{CE} and n_H.



For high energy H^+ ($\geq 100\ keV$) all geocoronal hydrogen distributions predict very similar decay rates, while at lower energies they are significantly different.

The decay rate shows asymmetry with MLT and pitch angle.

For particles that bounce farther along the field line, the hydrogen distribution models produce different decay rates.

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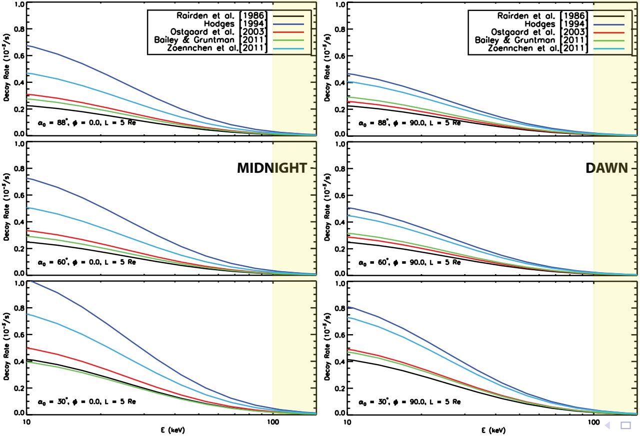

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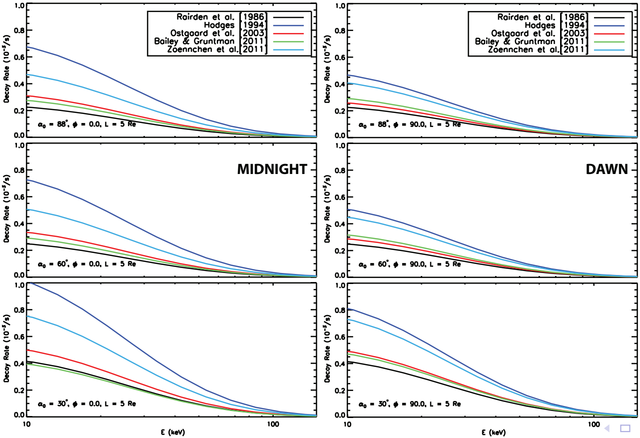

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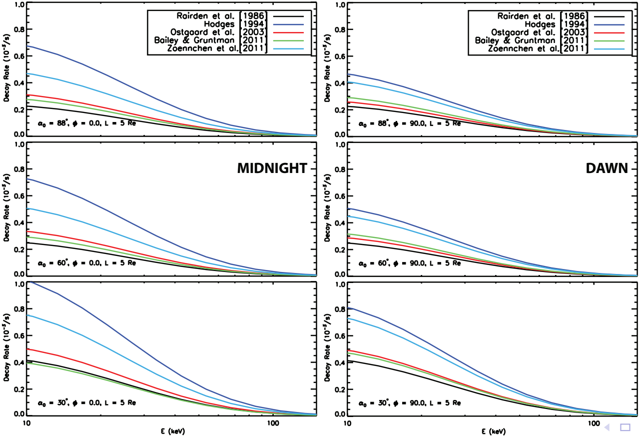

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Charge exchange decay rate of O^+ with energy

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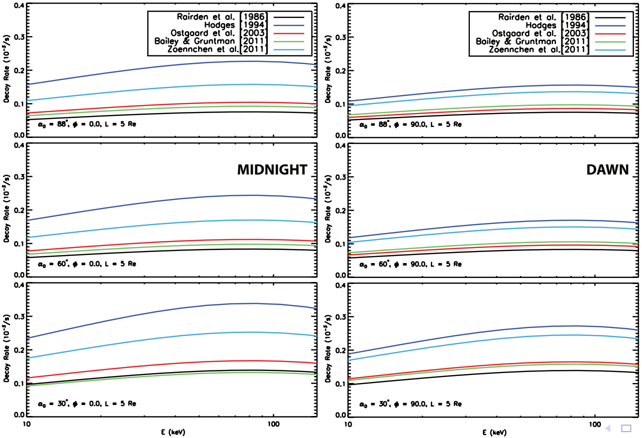

Little variation with energy at all MLTs.

The decay rate is strongly dependent on the local time variations within each of the geocoronal models.

This suggests that variations in the oxygen decay rate (hence ENA fluxes) are largely governed by the geocoronal hydrogen rather than energy.

Charge exchange decay rate of H^+ with L-shell

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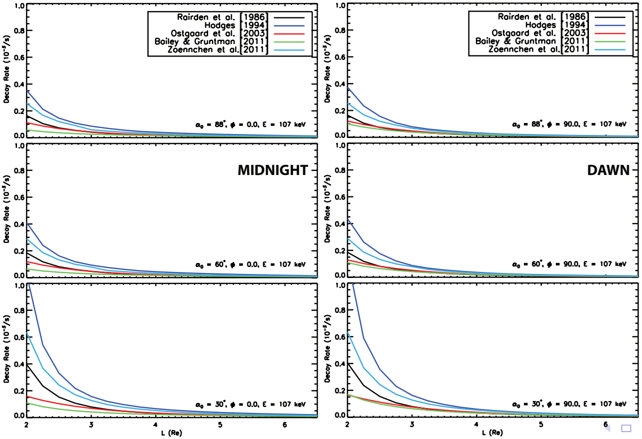

At a given energy the decay rate as a function of radial distance from the Earth changes significantly (up to $\sim 75\%$) depending on the geocoronal hydrogen density model, at both dawn and midnight.

The spread of decay rates predicted by the geocoronal models is largest below $4\ Re$.

Charge exchange decay rate of O^+ with L-shell

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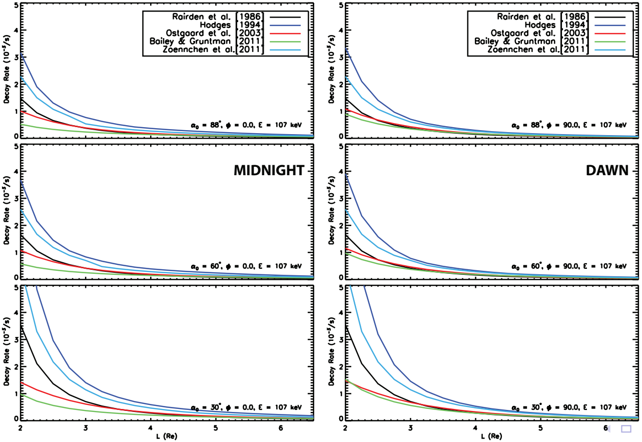

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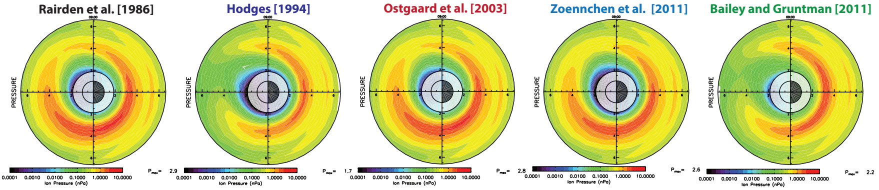
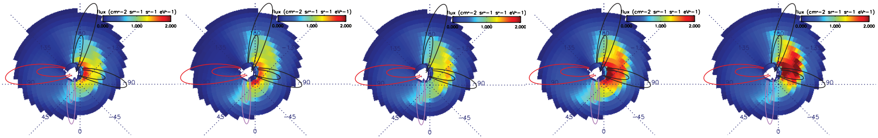
HEIDI Hot Ions Pressure



Synthetic ENA Images



Summary and Conclusions

Neutral hydrogen distribution controls the loss of H^+ below $100\ keV$ and O^+ for all energies.

The distribution of geocoronal H can alter the ring current topology and increase its asymmetry.

Due to their symmetrical distributions and lower densities, it is possible that previous models for H-density distribution used for ring current modeling led to an overestimation of the total ring current energy.

Synthetic ENA images are very sensitive to the geocoronal H density distribution and the location and intensity of the peak ENA enhancements are controlled by the distribution of neutrals.