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Odd Hydrogen Partitioning in the Mesosphere during Solar Proton Events

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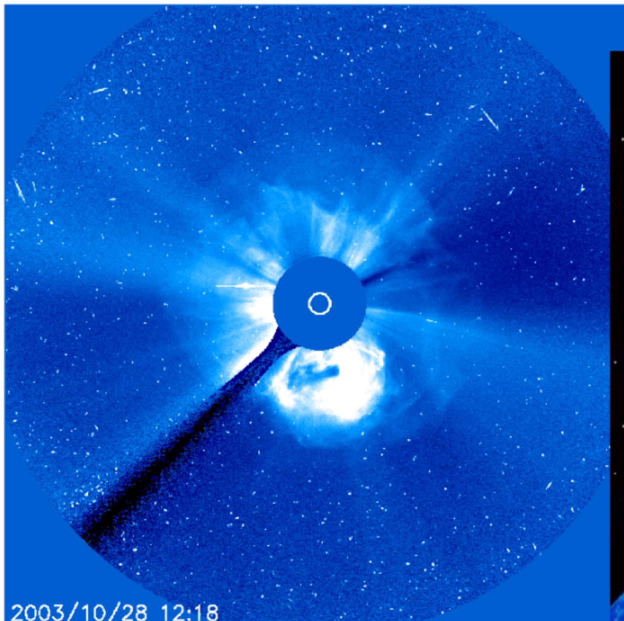
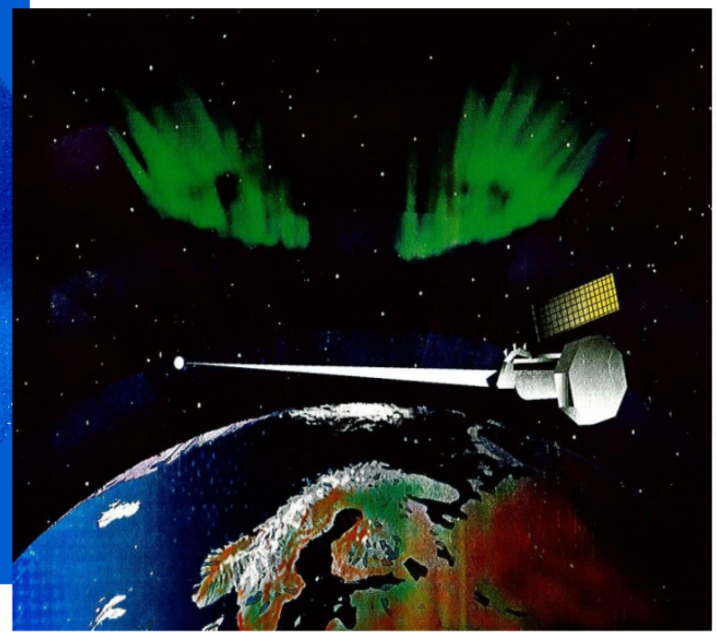
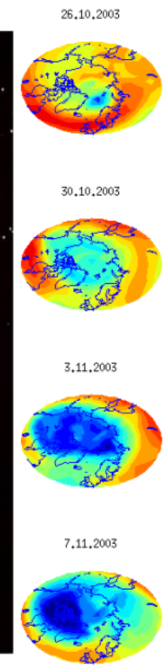
Energetic particle precipitation (EPP)



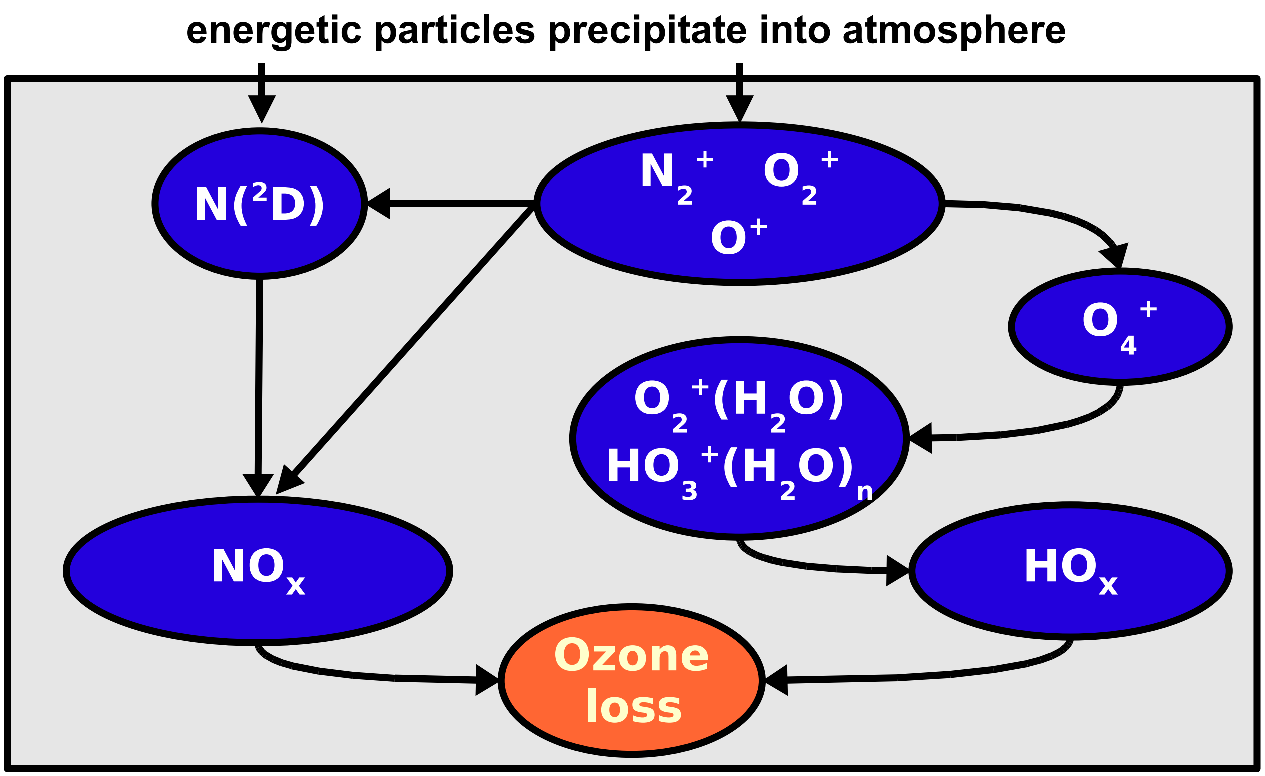




Earth's magnetic field directs charged particles into polar regions

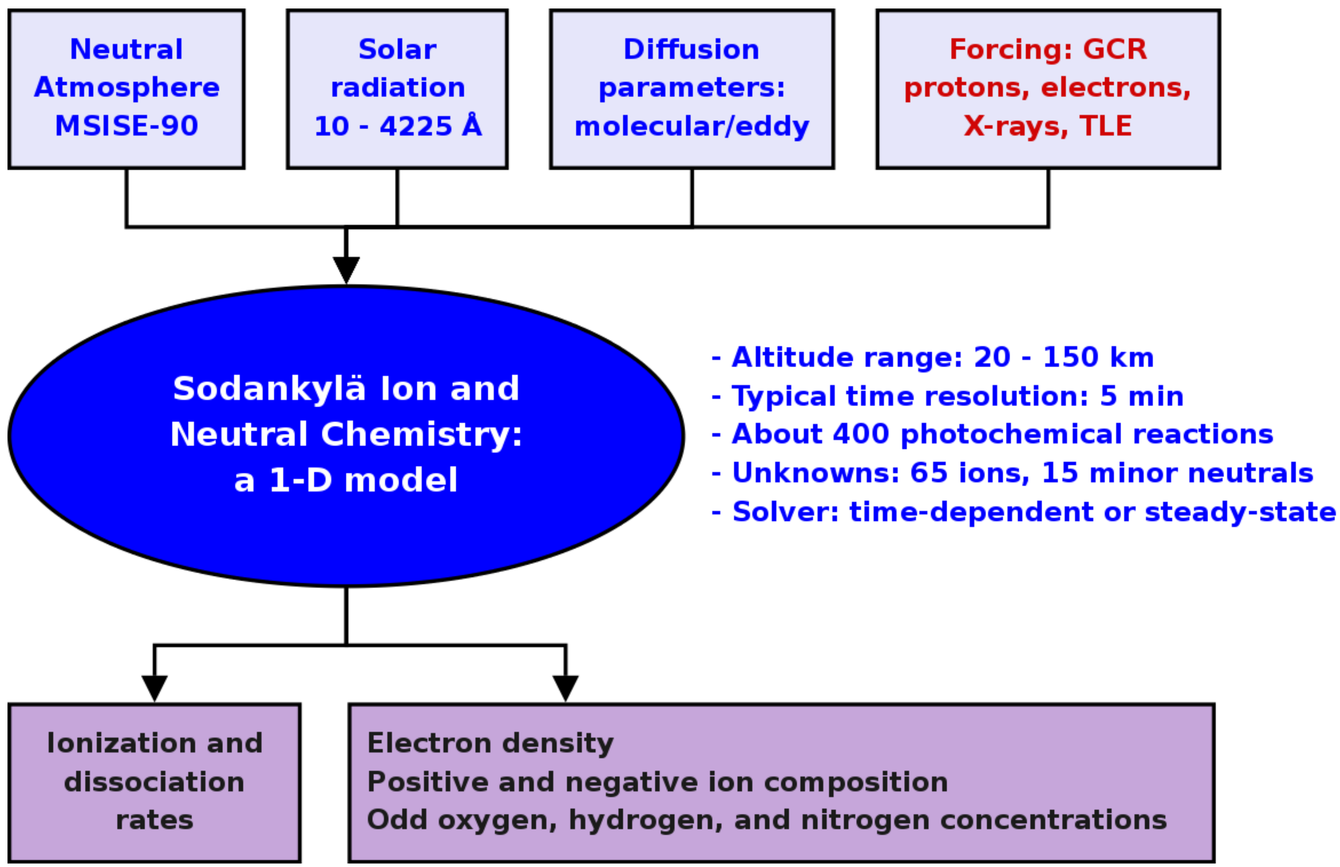
EPP affects both ionosphere and middle atmosphere

Effects of energetic particle precipitation (EPP)



Ozone connects to temperature and dynamics

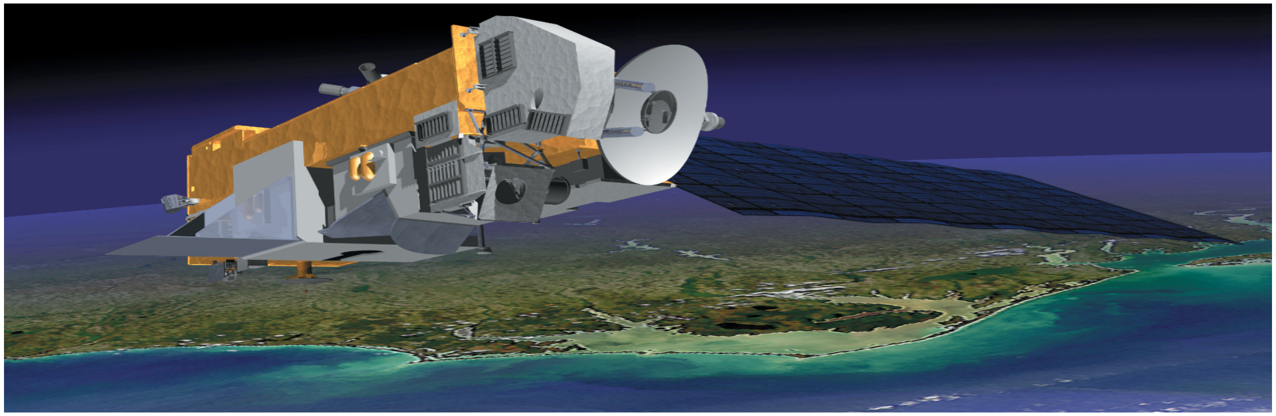
Sodankylä Ion and Neutral Chemistry (SIC)



SIC: example of HO_x production paths

$$
\begin{aligned}
N_2 + p^+(E) &\rightarrow N_2^+ + e^- + p^+(E - \Delta E)\\
N_2^+ + O_2 &\rightarrow O_2^+ + N_2\\
O_2^+ + O_2 + M &\rightarrow O_4^+ + M\\
O_4^+ + H_2O &\rightarrow O_2^+(H_2O) + O_2\\
\ldots & \\
O_2^+(H_2O)_2 + H_2O &\rightarrow H_3O^+(OH)H_2O + O_2\\
H_3O^+(OH)H_2O + H_2O &\rightarrow H^+(H_2O)_3 + \mathbf{OH}\\
H^+(H_2O)_3 + H_2O + M &\rightarrow H^+(H_2O)_4 + M\\
H^+(H_2O)_4 + e^- &\rightarrow \mathbf{H} + 4H_2O\\
--- & \quad ---\\
\mathbf{Net}: H_2O &\rightarrow OH + H
\end{aligned}
$$

MLS/Aura observations



- Microwave Limb Sounder, measures emissions at mm and sub-mm wavelengths
- Launched in July 2004 into a near-polar orbit, observations cover latitudes between 82°S – 82°N, day and night
- Can be used to monitor temperature and more than 15 trace gases, including O_3, OH, and HNO_3
- First satellite instrument providing continuous observations of mesospheric OH and HO_2

Odd hydrogen: comparisons

Modeling: Sodankylä Ion and Neutral Chemistry

- Uses MLS temperatures, neutral density, and water vapor.
- Latitudes >60°N, solar proton events of January 2005 and December 2006.

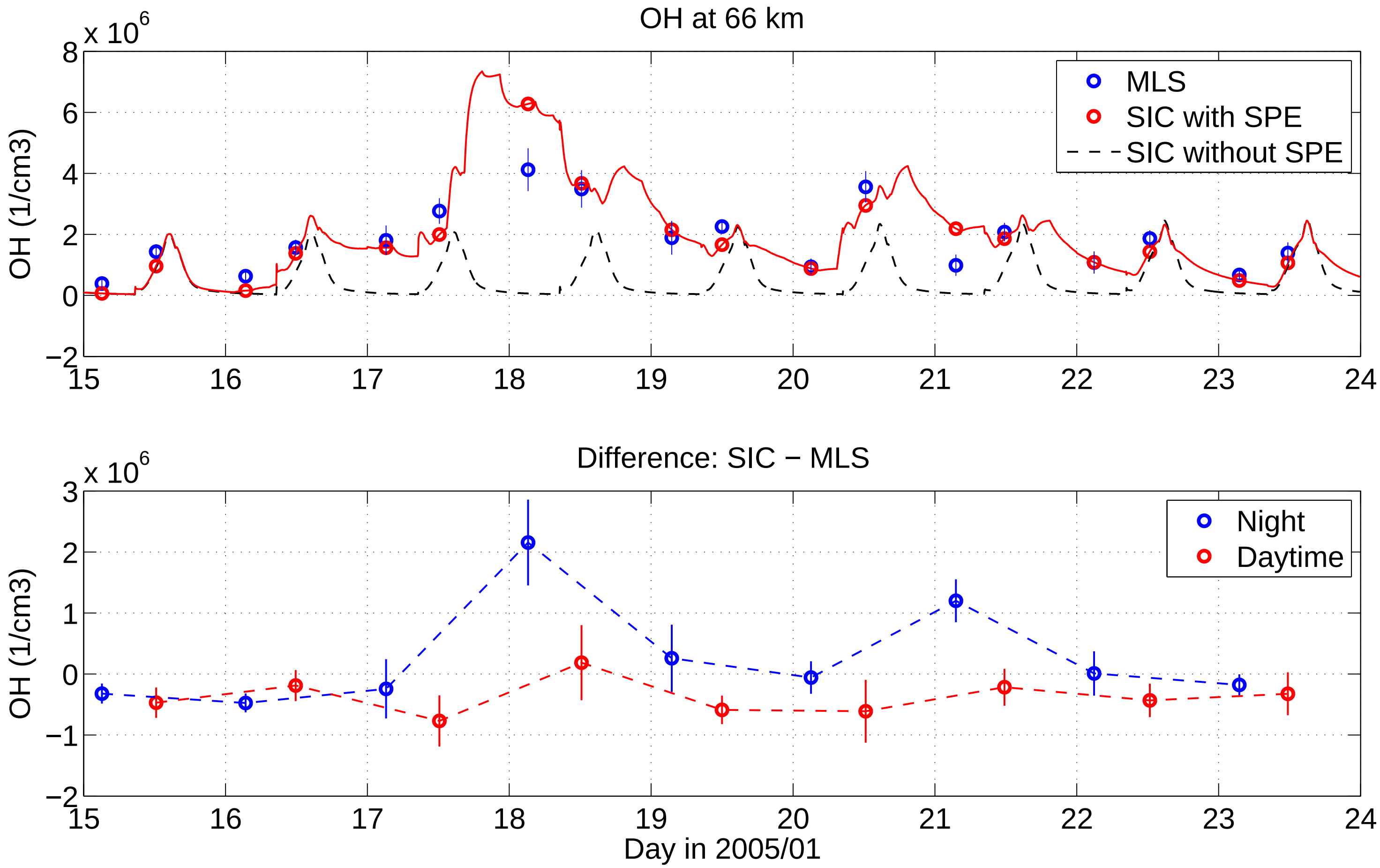
OH observations: data version 3.30

- Useful range up to 0.0032 hPa (≈90 km).
- Mesospheric data have been validated by Pickett et al., JGR, 2008.
- Data are averaged at 65–75°N, for day and night separately.

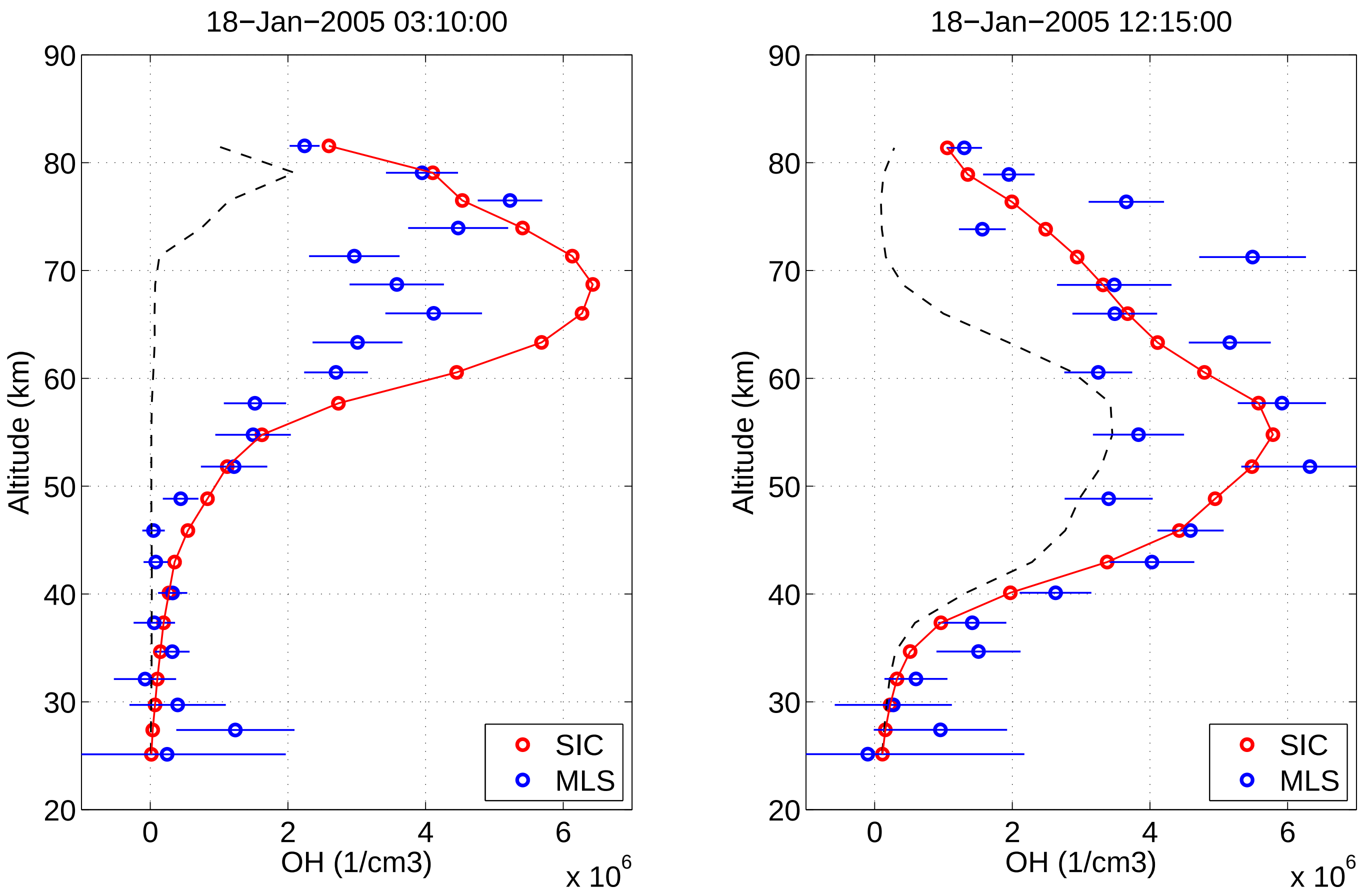
HO_2 observations: data version 3.30

- Useful range up to 0.046 hPa (≈70 km).
- "Noisy" product, requires significant averaging.

SIC vs. MLS: hydroxyl, January 2005

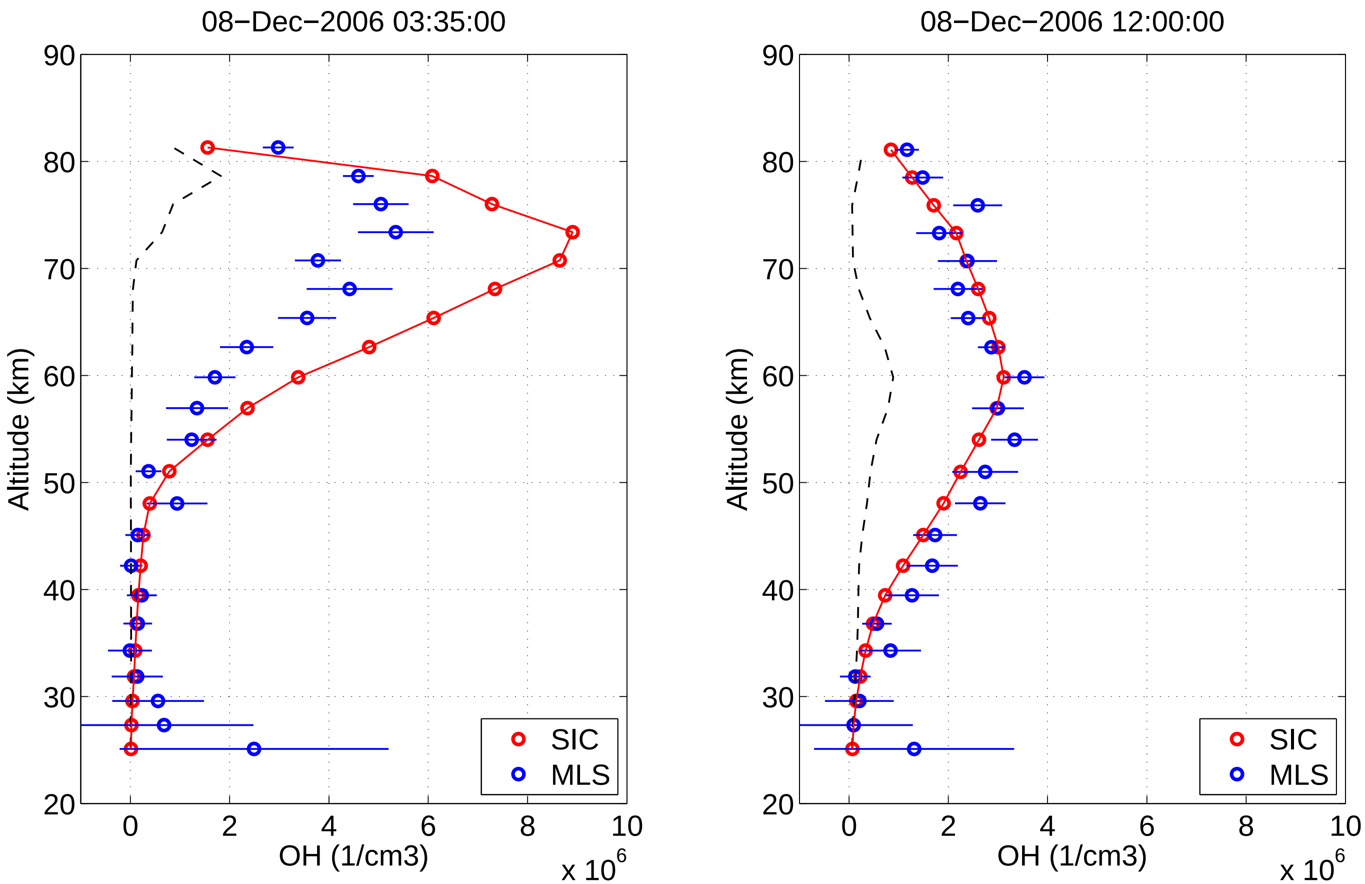


SIC vs. MLS: hydroxyl, January 2005



Night-time: differences up to 100% at 60–75m.

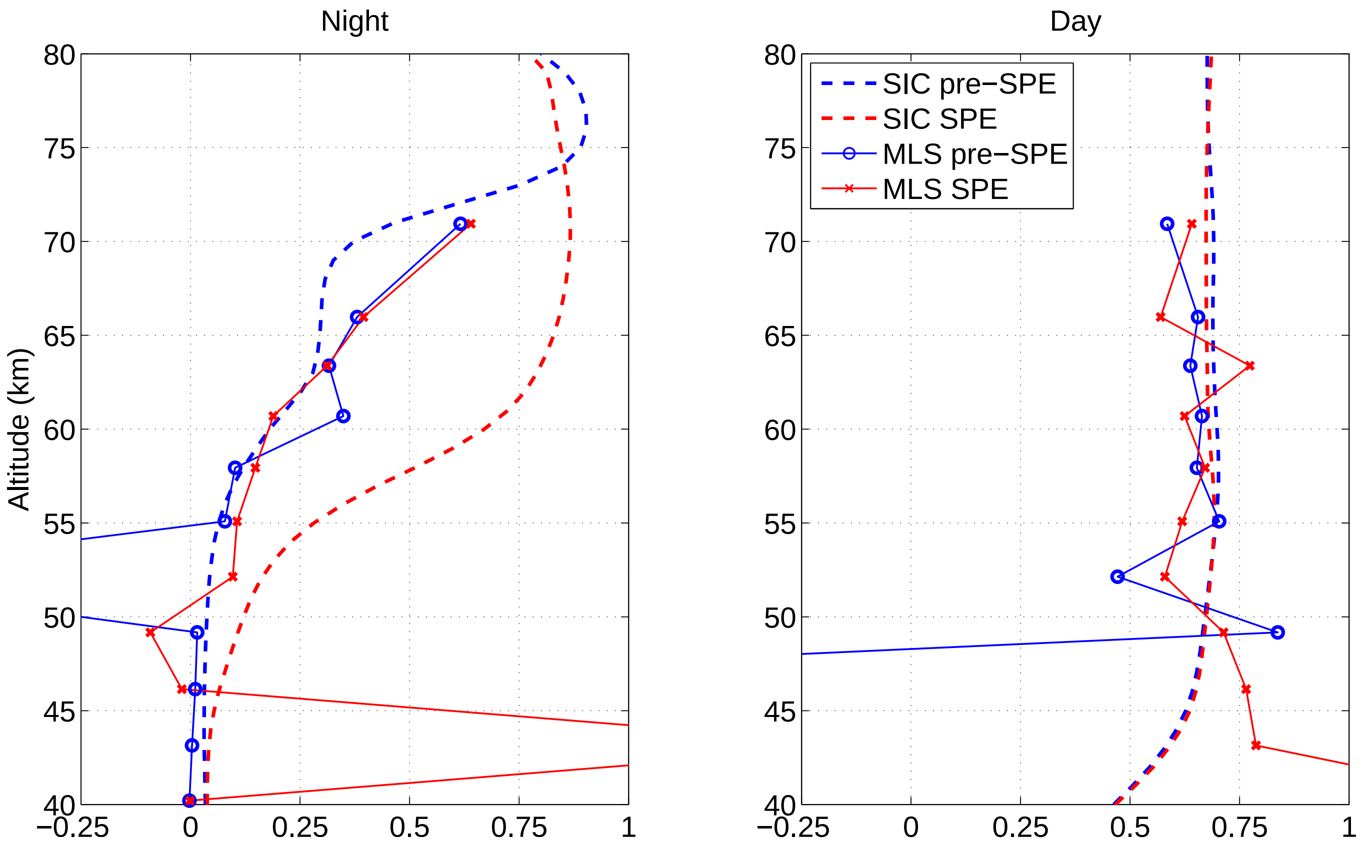
SIC vs. MLS: hydoxyl, December 2006



Difference is not caused by H_2O, T, or ionization rate.

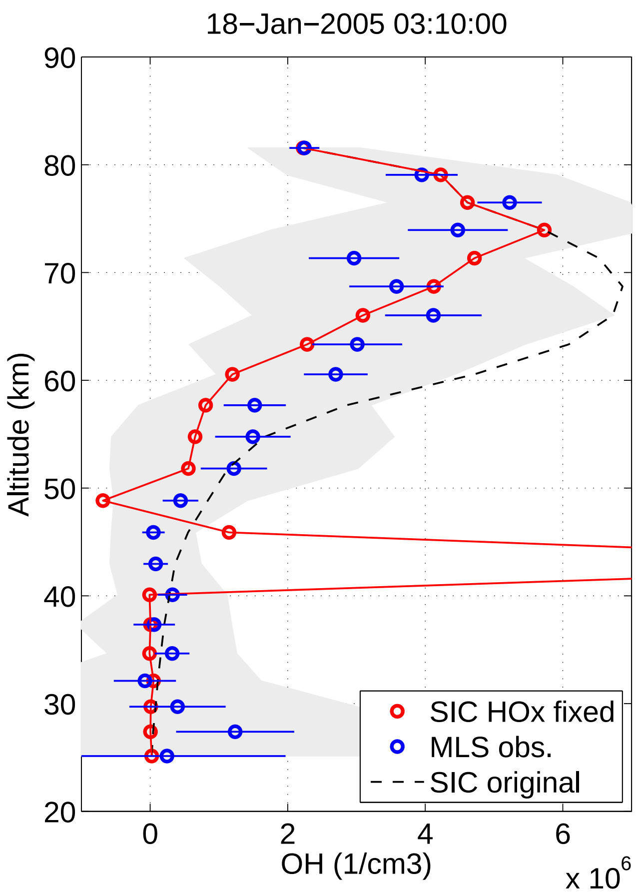
SIC vs. MLS: odd hydrogen partitioning

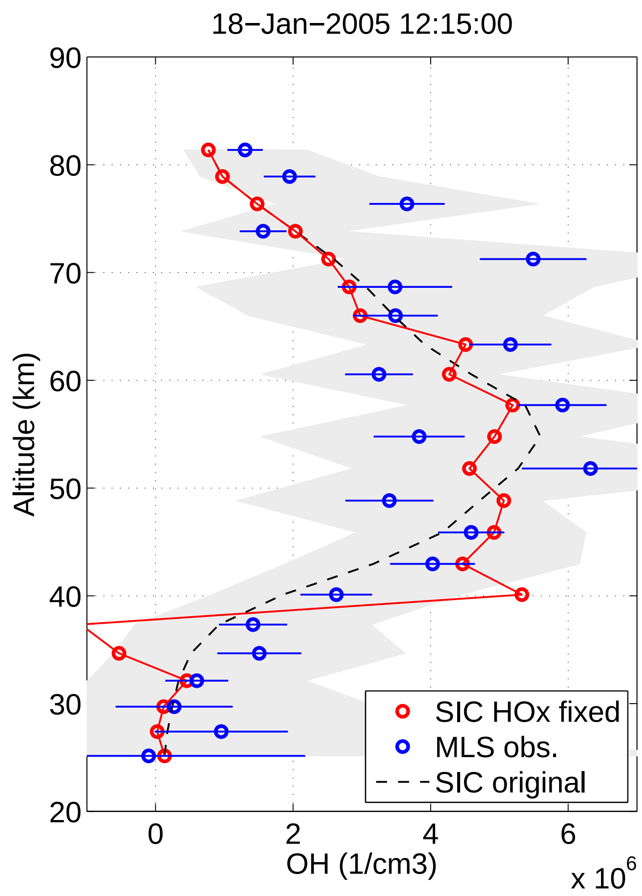
OH / (OH + HO_2), January 2005



Because of HO_2, MLS data are 30/8-day averages.

SIC vs. MLS: corrected partitioning

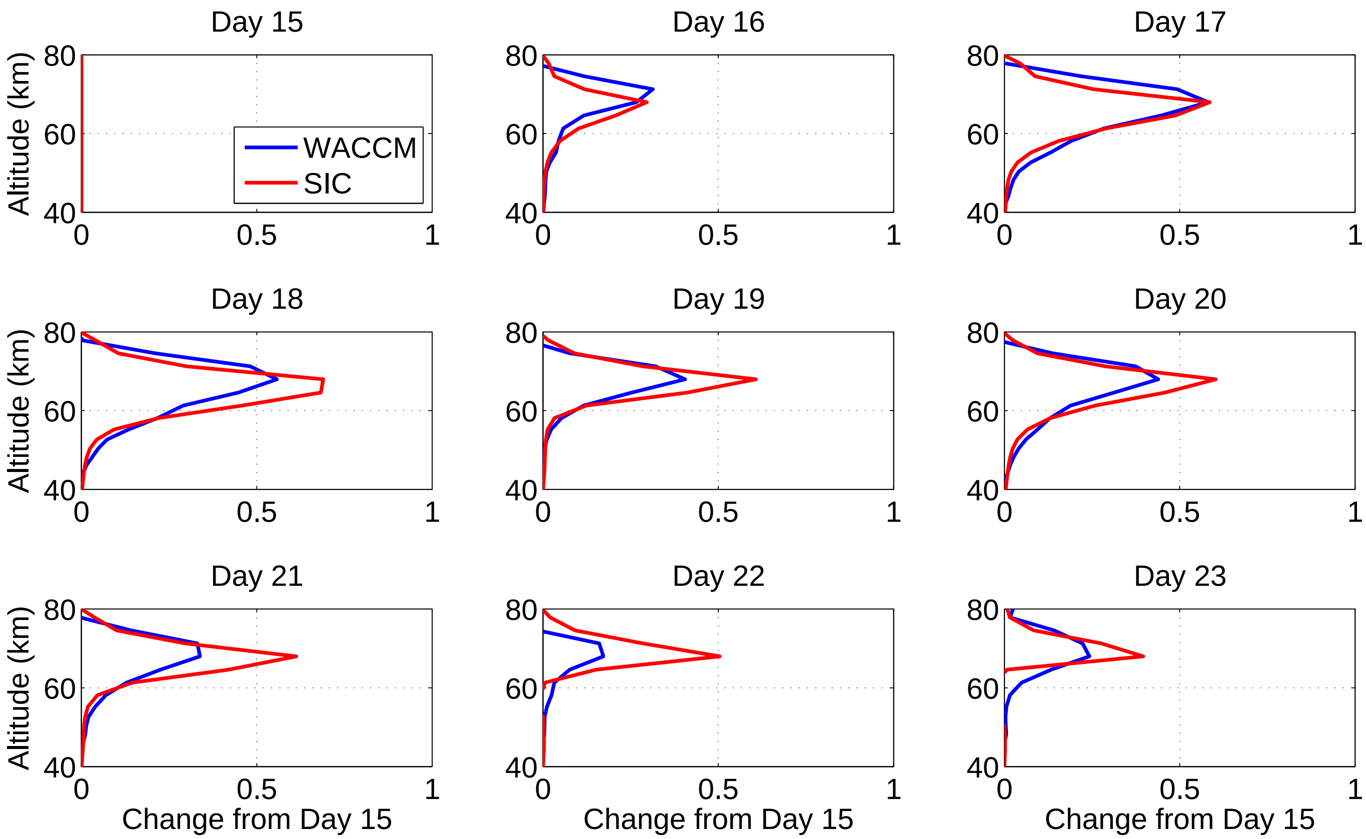




SIC model predicts the total HO_x correctly.

SIC vs. WACCM: odd hydrogen partitioning

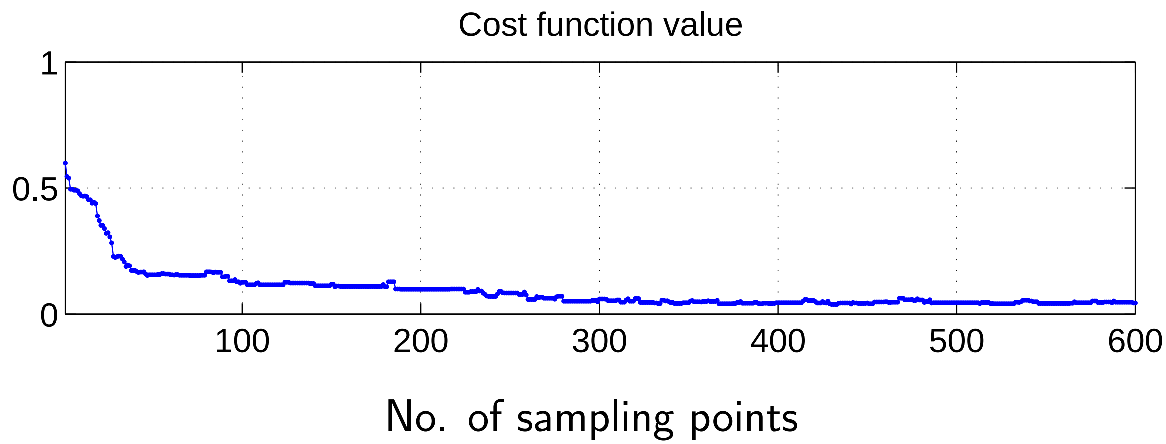
OH / (OH + HO_2), January 2005, 85N



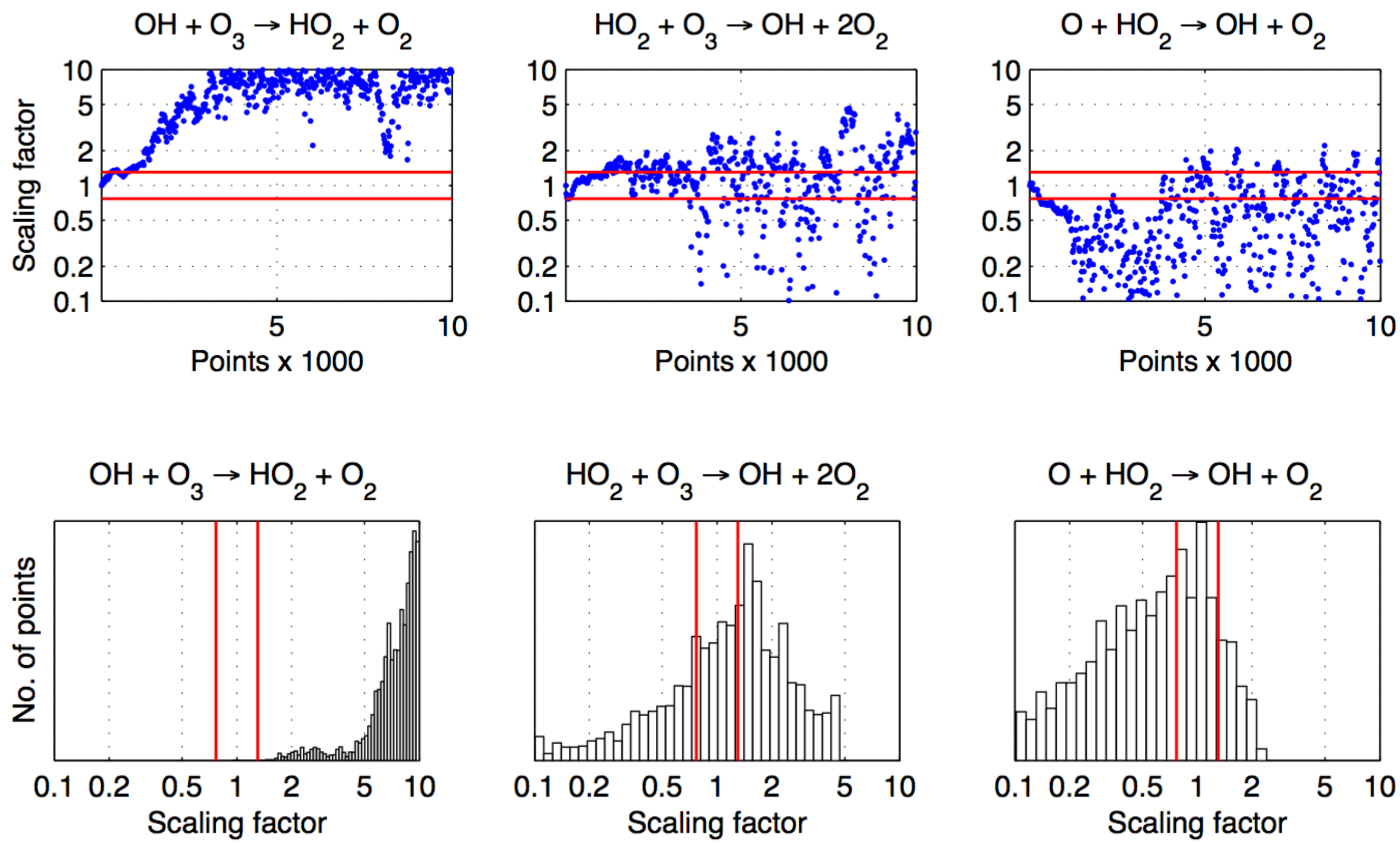
Agreement: partitioning changes after SPE onset.

MCMC: reaction rate coefficients

- Neutral chemistry is dominant in HO_x partitioning.
- Considering 12 reactions important to mesospheric HO_x.
- Markov Chain Monte Carlo sampling of rate coefficient combinations.
- 10,000 samples, for each a SIC model calculation.
- Cost function is the SIC-MLS HO_x partitioning difference.
- Aim is to find the distribution of rate coefficients minimizing the cost function.



SIC: MCMC reaction rate coefficient sampling



Observed HO_x partitioning requires too large changes for some coefficients.

Summary: SPEs and hydroxyl

- MLS/Aura observations show substantial increases of mesospheric and upper stratosphere OH during solar proton events.

- Ion-neutral chemistry modelling can produce a behaviour similar to that observed.

- However, the are clear and significant nighttime differences, ∼100%, in the absolute OH amounts at 60–75 km when proton fluxes are largest.

- Reason for the differences is HO_x partitioning, the model is predicting the total HO_x correctly.

- Preliminary MCMC sampling results in a distribution of rate coefficients, but some of these are outside their current uncertainty estimates.