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# Comparison of Modeled and Observed Effects of Radiation Belt Electron Precipitation on Mesospheric Hydroxyl and Ozone

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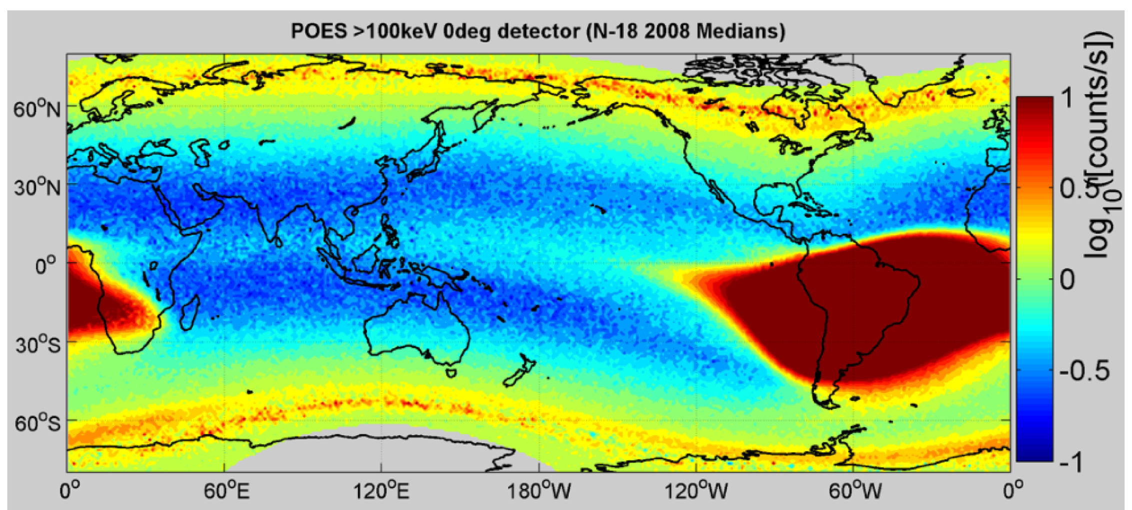
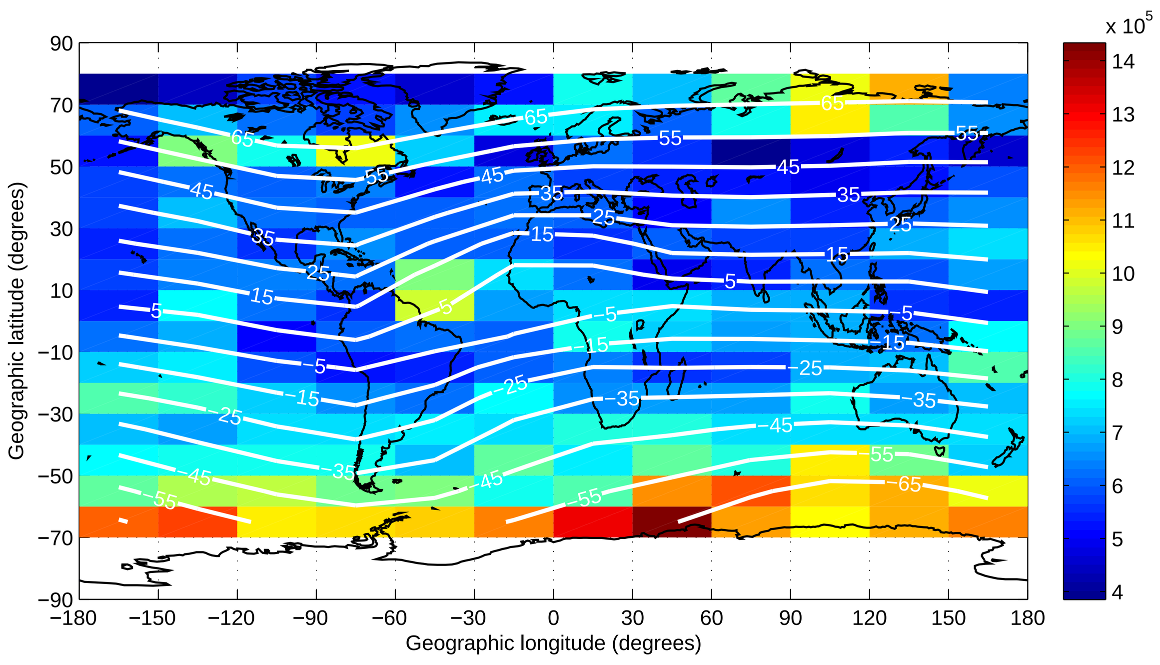
**ABSTRACT.** Energetic electron precipitation (EEP) is driven by solar activity and affects the polar middle atmosphere. EEP produces odd nitrogen ($NO_x$ = N + NO + $NO_2$) and odd hydrogen ($HO_x$ = H + OH + $HO_2$) through impact ionization, dissociation, and ion chemistry. $HO_x$ and $NO_x$ catalytically destroy ozone which could lead to EEP-driven changes in UV absorption and dynamics. However, it is not clear if the current satellite-based electron flux observations can be used to accurately describe EEP in atmospheric models. Here we use the Sodankylä Ion and Neutral Chemistry (SIC) model to reproduce the changes in OH and ozone observed by the Microwave Limb Sounder (MLS/Aura) during four strong EEP events. The daily mean electron energy-flux spectrum, needed for ionization rate calculations, is determined by combining the Medium Energy Proton and Electron Detector (MEPED/POES) fluxes and spectral form from the IDP high-energy electron detector on board the DEMETER satellite.

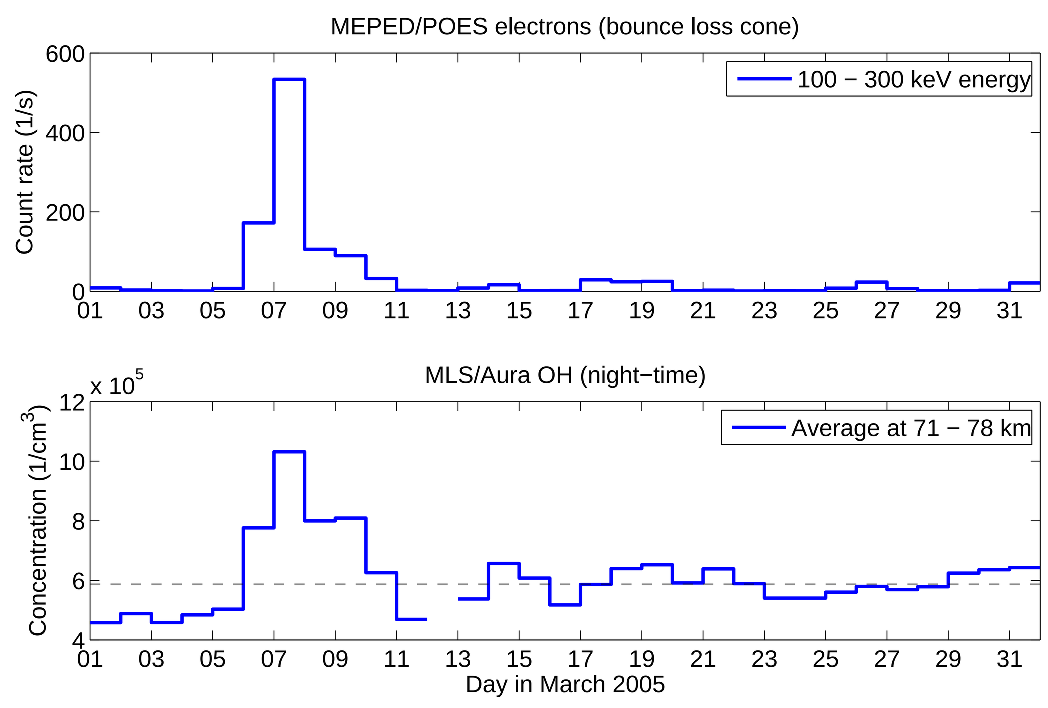
## DATA CORRELATION




**Above:** Yearly median map of electron count rates, measure by the MEPED/POES instrument.

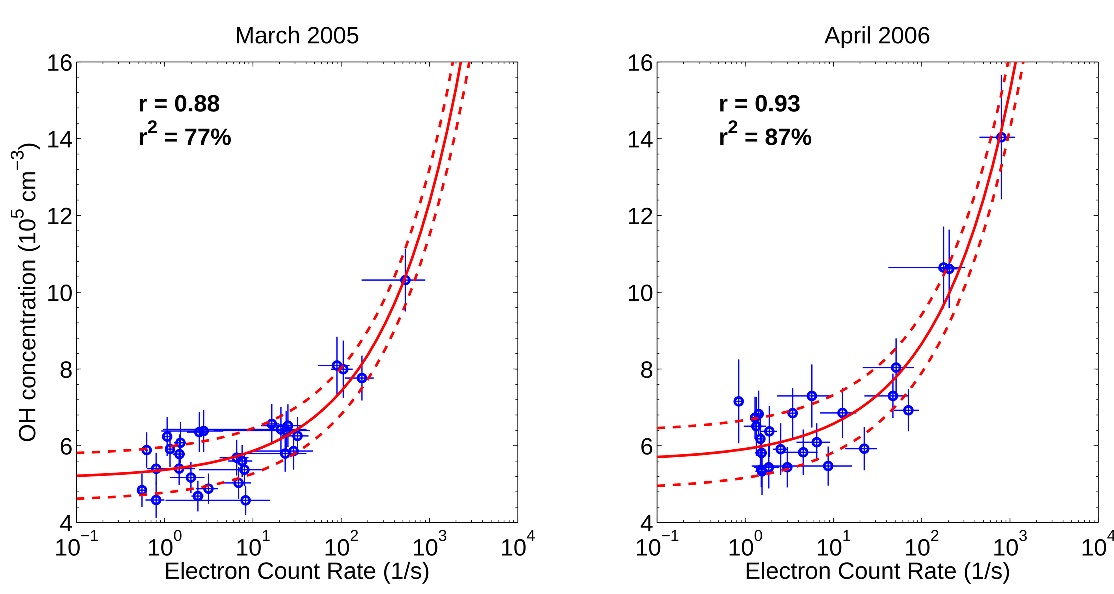
**Below:** Mean nighttime OH at 71–78 km measured by MLS/Aura, March 5–10, 2005. Units $cm^{-3}$. Magnetic latitudes are marked with white lines.



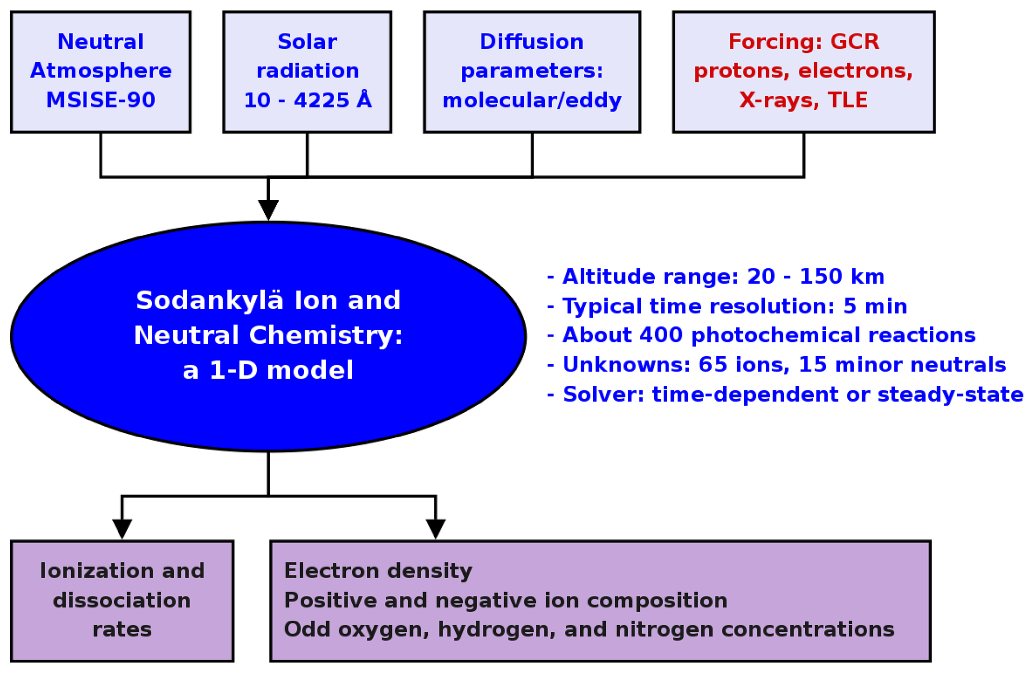




**Above:** Daily mean electron count rates and OH concentrations in March 2005. Magnetic latitudes 55–65°.

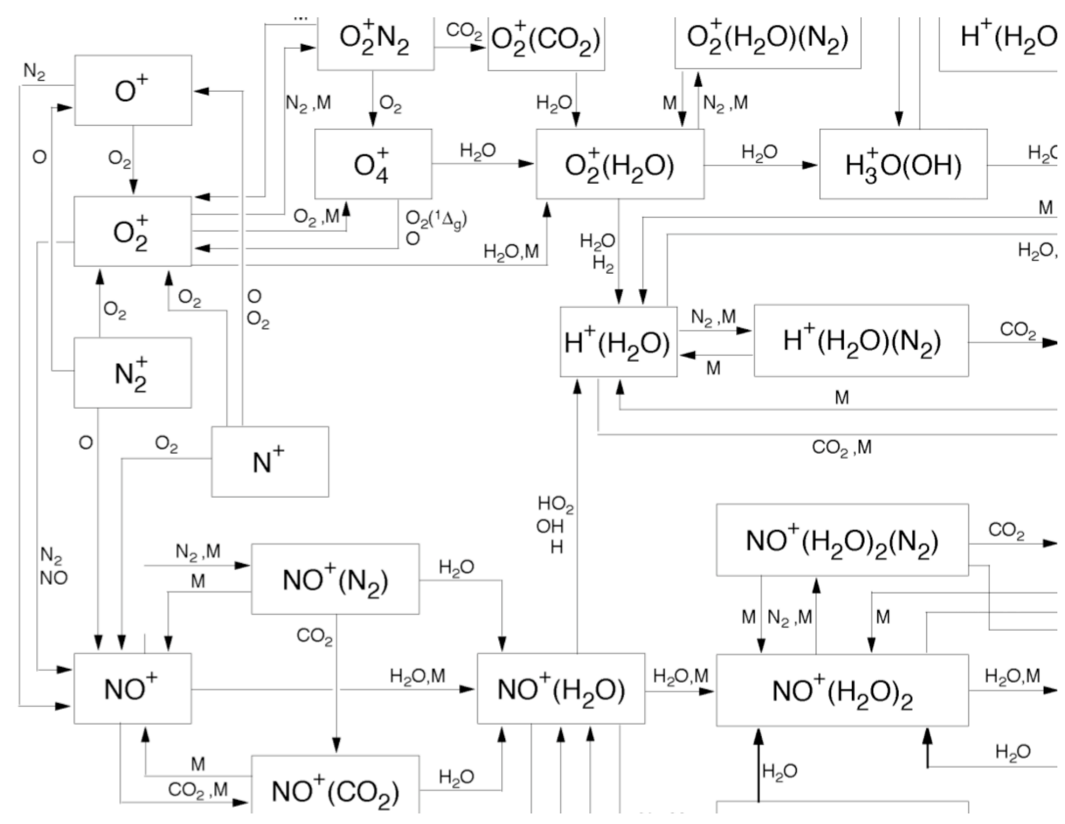
**Below:** OH concentration vs. electron count rate, daily averages. r = correlation coefficient. Red lines indicate a fit and its estimated uncertainty.




## THE SIC MODEL

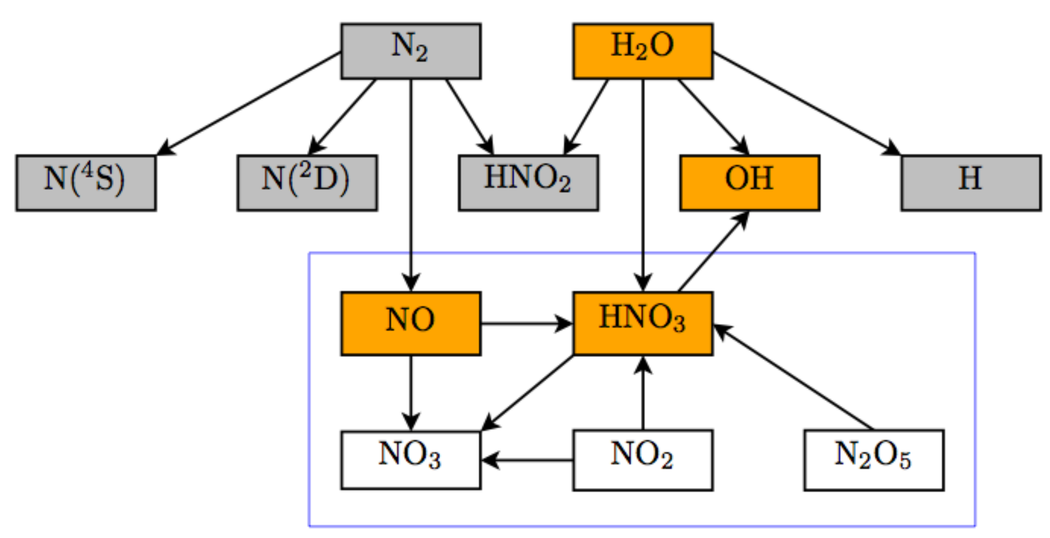



**Above:** SIC model input/output diagram.
**Below:** part of the SIC positive ion scheme, and an examples of reaction pathways leading to $HO_x$ production.

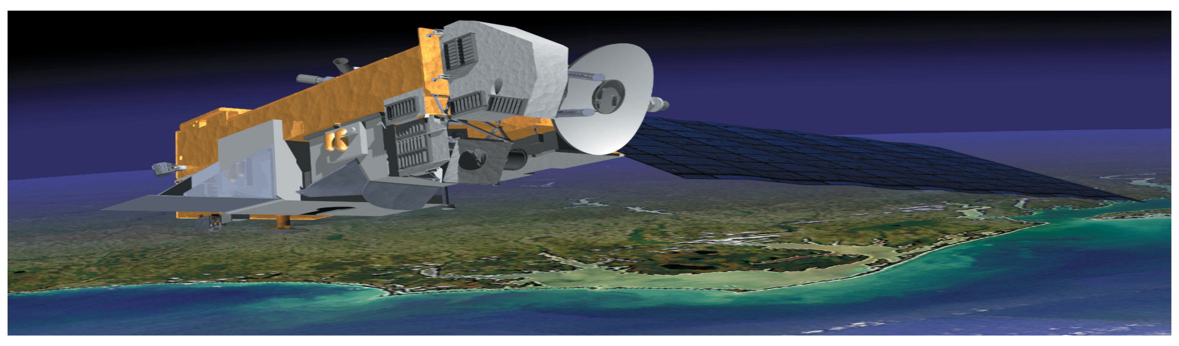


$$N_2 + p^+(E) \rightarrow N_2^+ + e^- + p^+(E - \Delta E)$$
$$N_2^+ + O_2 \rightarrow O_2^+ + N_2$$
$$O_2^+ + O_2 + M \rightarrow O_4^+ + M$$
$$O_4^+ + H_2O \rightarrow O_2^+(H_2O) + O_2$$
$$\ldots$$
$$H_3O^+(OH)H_2O + H_2O \rightarrow H^+(H_2O)_3 + \mathbf{OH}$$
$$H^+(H_2O)_3 + H_2O + M \rightarrow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

**Below:** A diagram of hydrogen and nitrogen conversions due to EEP and subsequent ionic reactions. The species in the gray boxes are affected by positive ion chemistry, while $NO_y$ redistribution by negative ion chemistry affects the species inside the blue box. NO, $HNO_3$, and $H_2O$ are directly affected by both positive and negative ion chemistry.

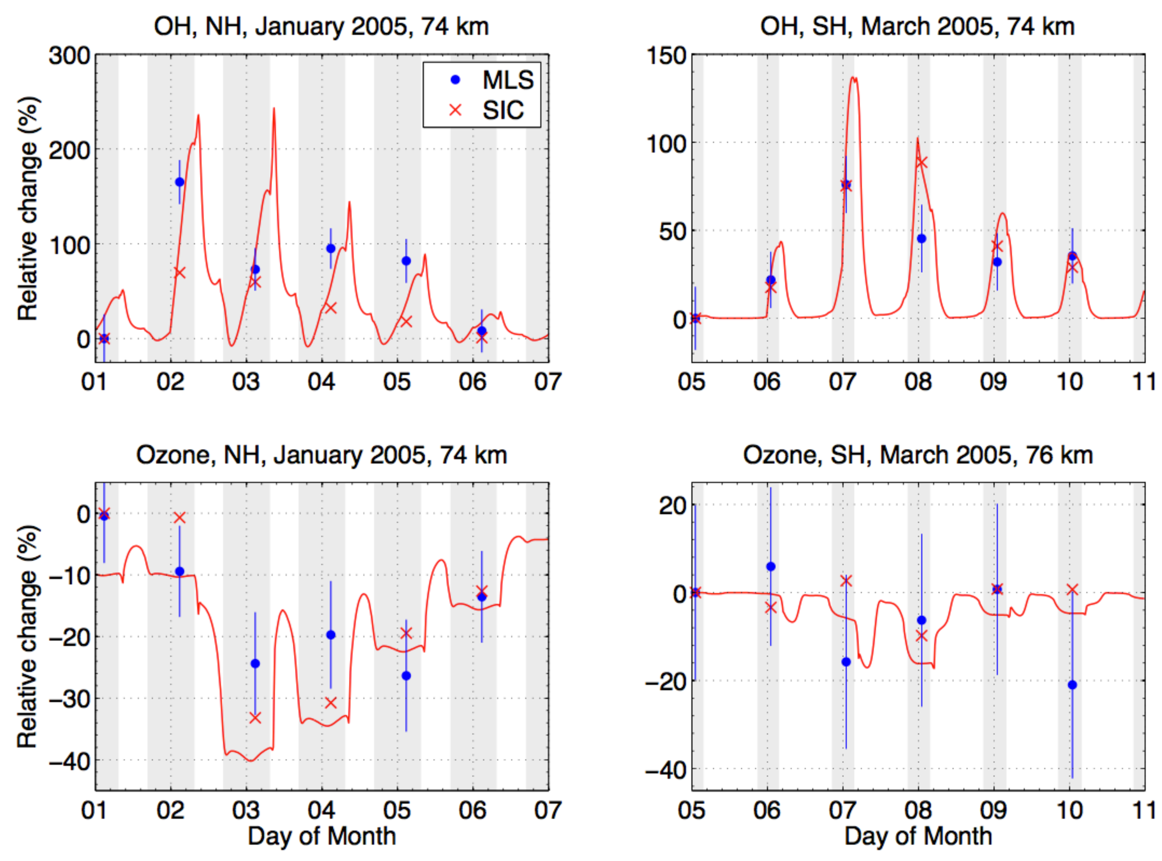


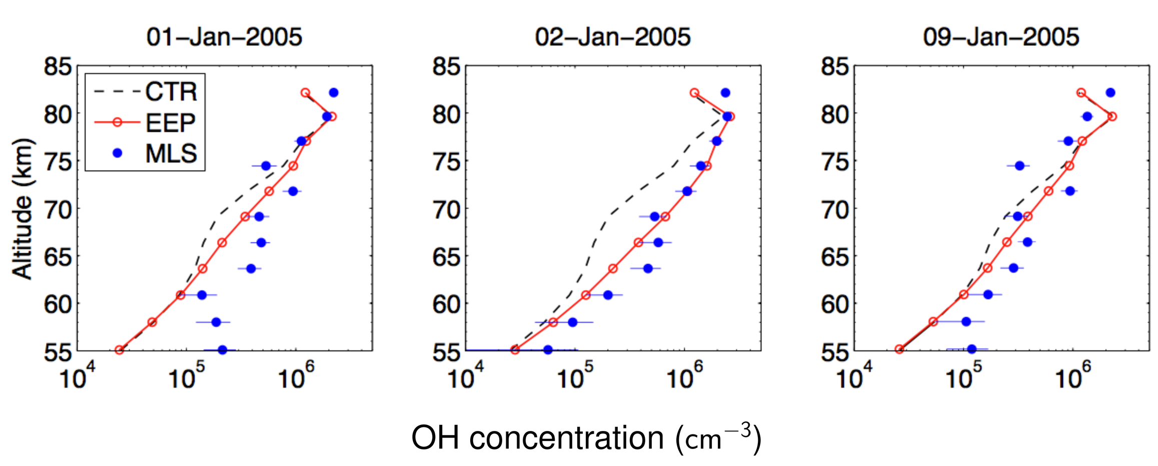

## MODEL-SATELLITE COMPARISON



**Above:** Aura satellite on orbit with Microwave Limb Sounder (MLS) on board.

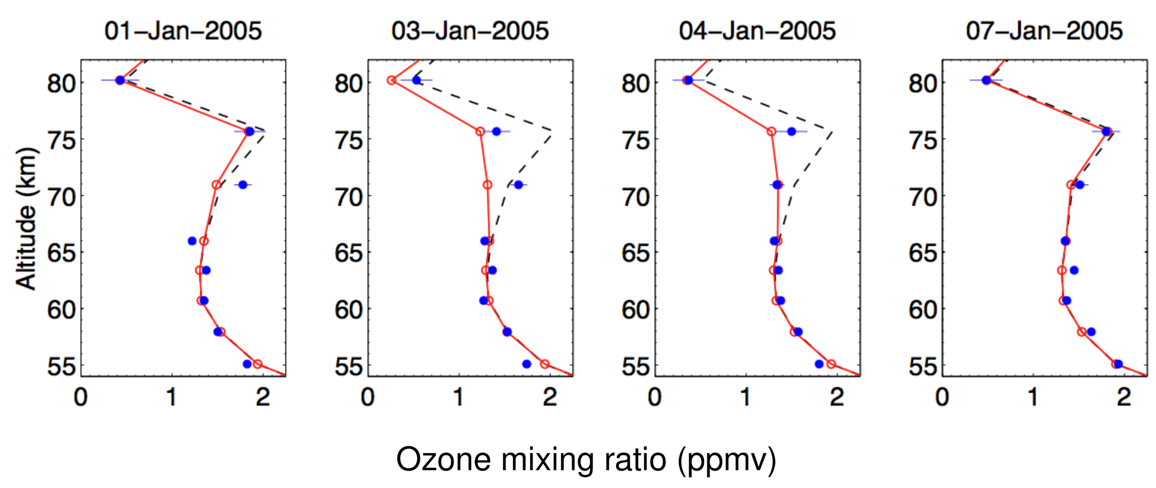
**Below:** Comparison between modeled and observed EEP-caused relative change of OH and ozone. Red line: SIC data showing 100 × (EEP/CTR - 1), where EEP and CTR are gas concentrations from the electron and control runs, respectively. Red X marks: Same as Red Line, except that CTR is replaced by 1st-day result from the EEP run, and shown only at the LST of MLS observations. Blue circles: MLS data showing the change with respect to the observations on the day before EEP peak. Gray shading marks the local nighttime.




**Above:** Comparison of NH modeled and observed nighttime OH concentrations before (left), during (middle), and after (right) the peak EEP day. Black, red, and blue colors mark data from SIC CTR run, SIC EEP run, and MLS observations, respectively.

**Below:** Comparison of modeled and observed nighttime ozone mixing ratios. Black, red, and blue colors mark data from SIC CTR run, SIC EEP run, and MLS observations, respectively.




**CONCLUSIONS.** In general SIC, using the satellite-based electron fluxes, is able to reproduce the observed day-to-day variability of OH and ozone. In the lower mesosphere, the model tends to underestimate the OH concentration, possibly because of uncertainties in the electron spectra for energies >300 keV. The model predicts OH increases at 60–80 km, reaching several hundred percent at 70–80 km during peak EEP forcing. Increases in OH are followed by ozone depletion, up to several tens of percent. The magnitude of modeled changes is similar to those observed by MLS, and comparable to effects of individual solar proton events. Our results suggest that the combined satellite observations of electrons can be used to model the EEP effects above 70 km during geomagnetic storms, without a need for significant adjustments. However, for EEP energies >300 keV impacting altitudes <70 km, correction factors may be required.