Increase of Nitric Acid in the Lower Mesosphere During Solar Proton Events

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The Team

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Solar proton event (SPE)

Earth’s magnetic field directs charged particles into polar regions
EPP affects both ionosphere and middle atmosphere
Atmospheric effects of EPP

energetic particles precipitate into atmosphere

\[ \text{N}_2 + \text{O}_2 + \text{O}^+ + \text{NO}_x + \text{HO}_3^+ (\text{H}_2\text{O})_n \]

Ozone connects to temperature and dynamics
Production of nitric acid by ion chemistry

Ionisation of atmospheric gases

Production of negative ions

Production of water cluster ions

Production of OH

Production of HNO₂

Production of H

Production of HNO₃
SIC model – Ion and neutral chemistry

Neutral Atmosphere MSISE-90

Solar radiation 10 - 4225 Å

Diffusion parameters: molecular/eddy

Forcing: GCR protons, electrons, X-rays, TLE

Sodankylä Ion and Neutral Chemistry: a 1-D model

- Altitude range: 20 - 150 km
- Typical time resolution: 5 min
- About 400 photochemical reactions
- Unknowns: 65 ions, 15 minor neutrals
- Solver: time-dependent or steady-state

Ionization and dissociation rates

Electron density
Positive and negative ion composition
Odd oxygen, hydrogen, and nitrogen concentrations
Influence of polar vortex
HNO$_3$ (ppbv) at 45 km, Oct–Dec 2003

FinROSE chemistry-transport model
Nitric acid: comparisons

Modeling: Sodankylä Ion and Neutral Chemistry

– Uses MLS temperatures, neutral density, and water vapor.
– Dynamical effects cannot be considered.
– All produced HNO₃ remains, the model gives an upper limit estimate.
– Revised reaction rate coefficients for ionic HNO₃ production.

Observations: data version 2.2x, SZA > 100°

– Useful range up to 3.2 hPa (≈40 km) in normal conditions, but can extended into mesosphere when high amounts are observed.
– Mesospheric data have not been validated.
– Altitude resolution is worse than in the model, so model results have been converted to same resolution using averaging kernels.
– Comparison is made with the highest amount of HNO₃ observed after the peak of SPE forcing, assuming that it is least affected by dynamics/photodissociation.
Observations: increase of nitric acid at 50 – 60 km
Solar proton event of January 2005
Comparison at selected altitudes
Solar proton event of January 2005

0.316 hPa (55 km)

- SIC revised
- SIC old
- MLS daily mean

0.022 hPa (73 km)

- SIC revised
- SIC old
- MLS daily mean

Mixing ratio (ppbv)
Comparison: before, during, and after SPE
Solar proton event of January 2005
Comparison: before, during, and after SPE
Solar proton event of December 2006
Summary

- MLS/Aura observations show substantial increases of lower mesospheric HNO$_3$ during solar proton events.

- Ion and neutral chemistry modeling is in agreement with the largest mixing ratios observed.

- Comparisons with MLS data led to significant improvements in modeling.

- Quantitative understanding the SPE-related production of HNO$_3$ is challenging because of the dynamics.