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Odd hydrogen response thresholds for indication of solar proton and electron impact in the mesosphere and stratosphere

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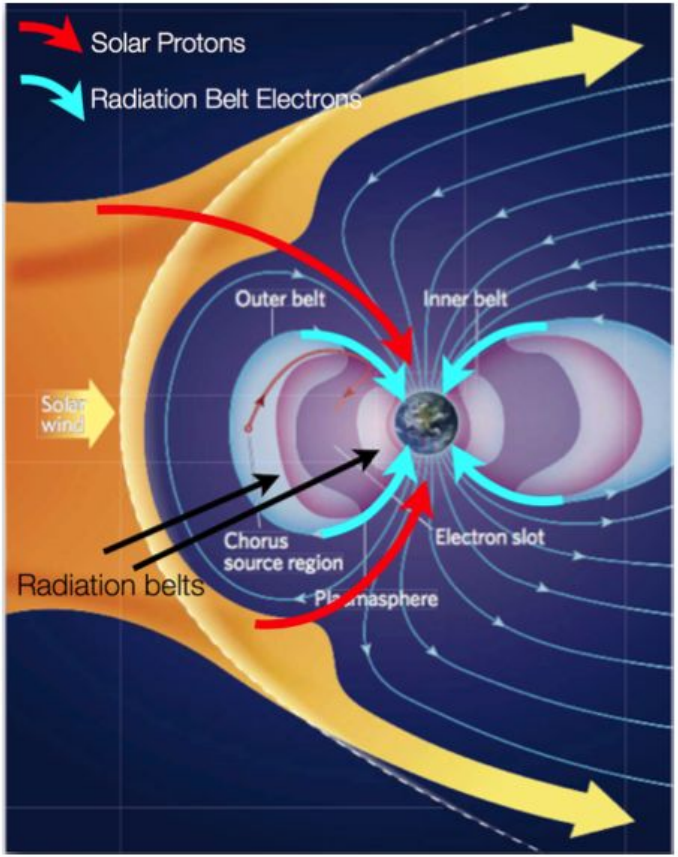
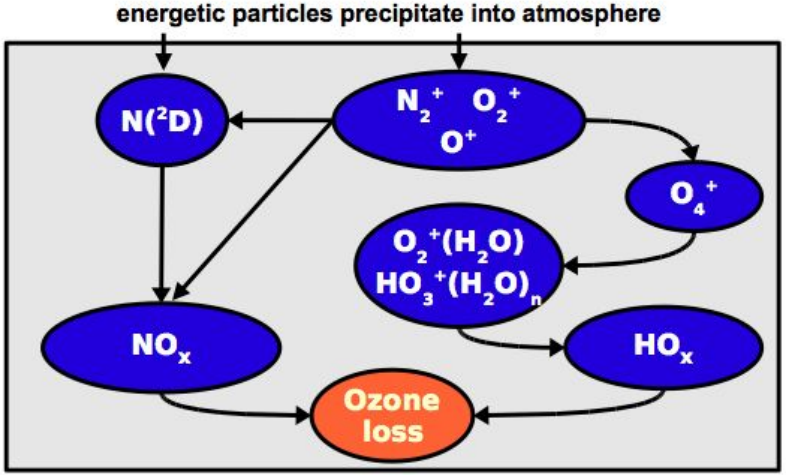
Energetic particle precipitation (EPP) - Atmospheric effects



The concept: particles ionize middle atmosphere, leading to an ozone response.



Mesospheric odd hydrogen: indicator of EPP

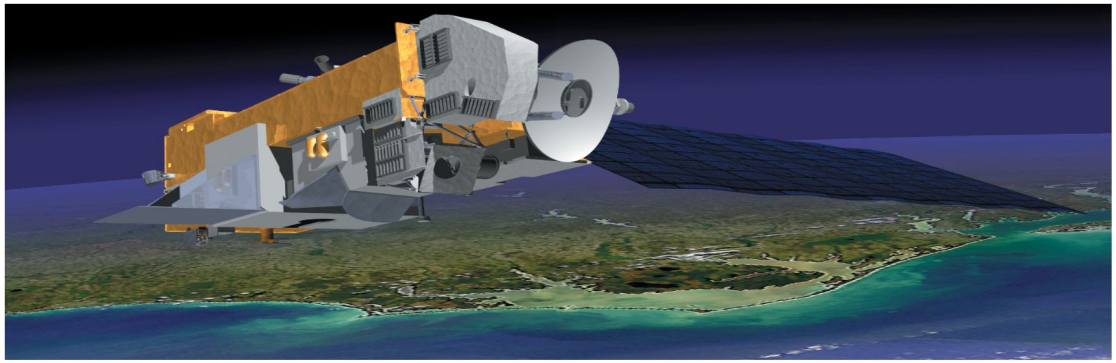
- nighttime HO_x ($= H + OH + HO_2$) concentration is relatively low.
  $\Longrightarrow$ It can be enhanced by moderate EPP forcing.

- HO_x has a relatively short chemical lifetime (hours) below $\approx$ 80 km.
  $\Longrightarrow$ Returns quickly to normal values after EPP forcing stops.

Odd hydrogen follows closely increases and decreases of EPP forcing

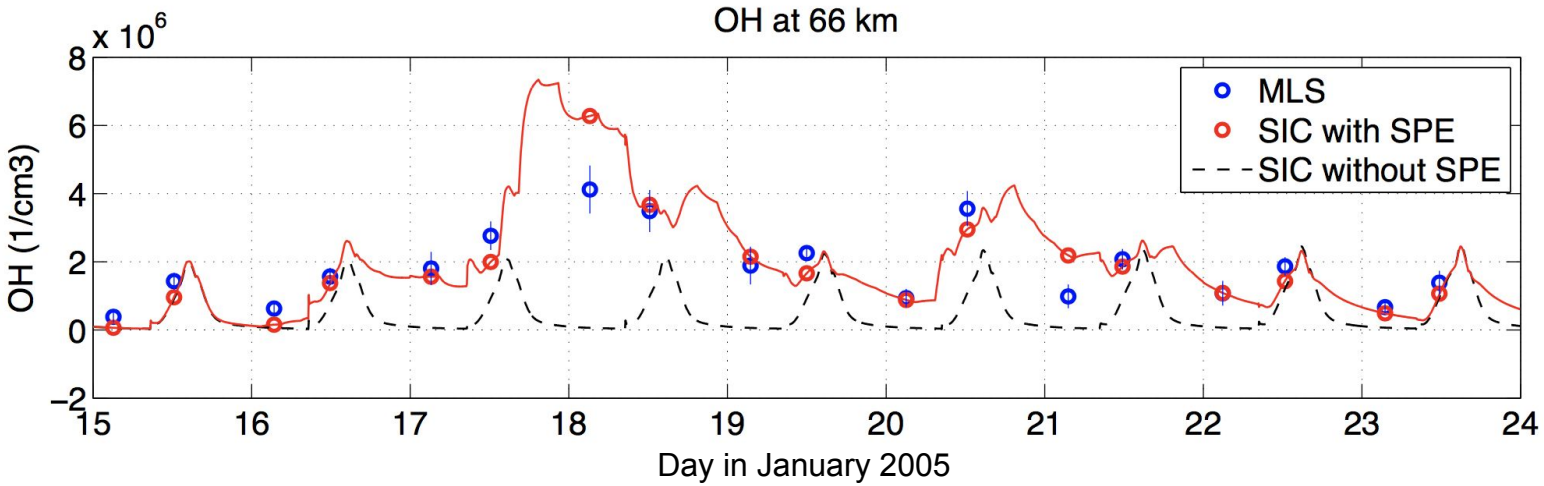
- In the case of major solar proton events, HO_x increases are relatively easy to detect due to the large fluxes and polar cap coverage of the forcing.

MLS/Aura observations

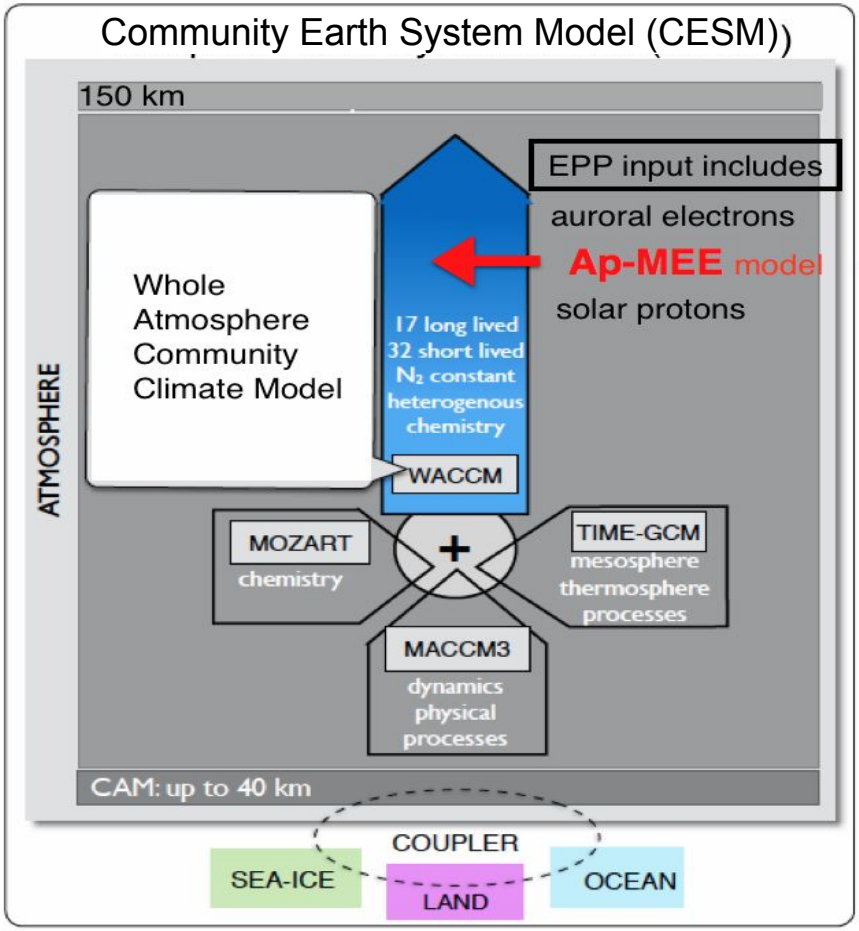


- Microwave Limb Sounder, measures emissions at mm and sub-mm wavelengths
- Launched in July 2004 into a near-polar orbit, observations cover latitudes between 82°S – 82°N, day and night
- Can be used to monitor temperature and more than 15 trace gases, including O_3, OH, and HNO_3
- First satellite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

SPE impact: model vs. observations at 70°N



SIC = Sodankylä Ion and Neutral Chemistry Model (1-D)



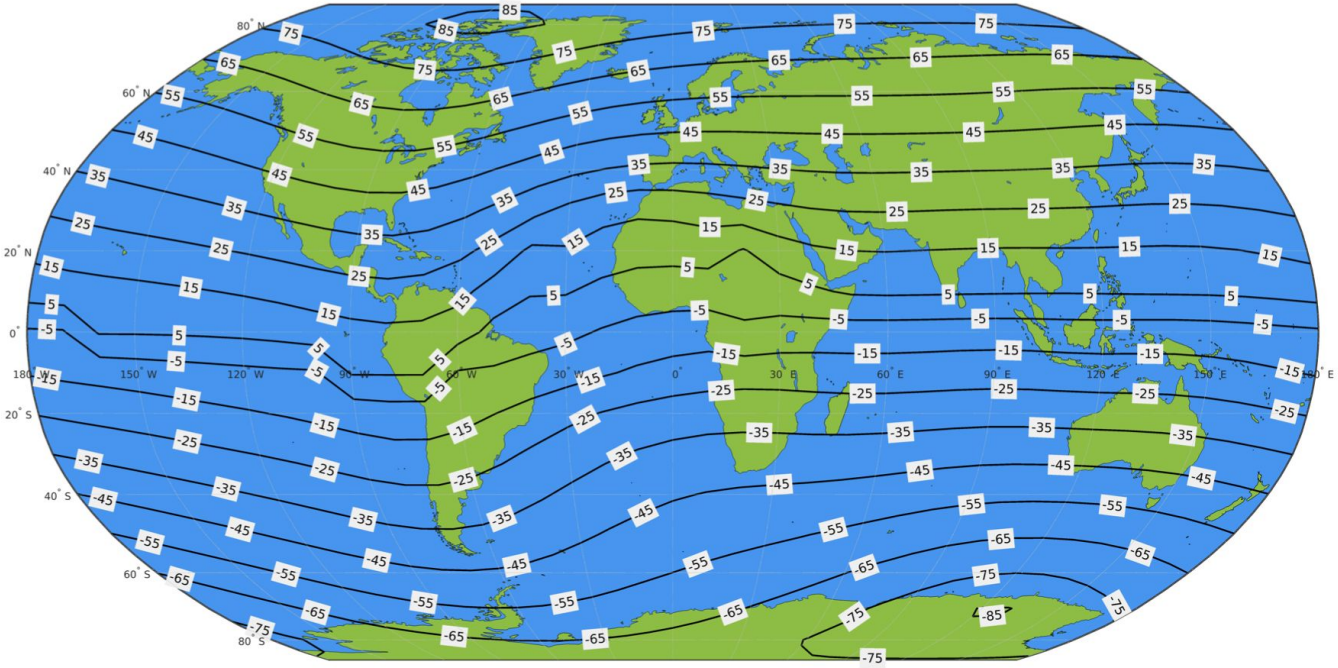
CESM / WACCM model

Whole Atmosphere Community Climate Model (WACCM)

- Global, 3-D chemistry-climate model
- Range of altitude 0 - 140 km
- Fully interactive chemistry, radiation, and dynamics
- Horizontal resolution is 1.9° latitude by 2.5° longitude.
- Vertical resolution: 1-2 km below stratopause, 3.5 km above
- The chemical time step is 30 minutes.
- Ionization sources include
  - EUV and soft X-ray photons,
  - photoelectron impact
  - SPE, GCR, MEE, Kp aurora
  - D-region ion chemistry (WACCM-D)

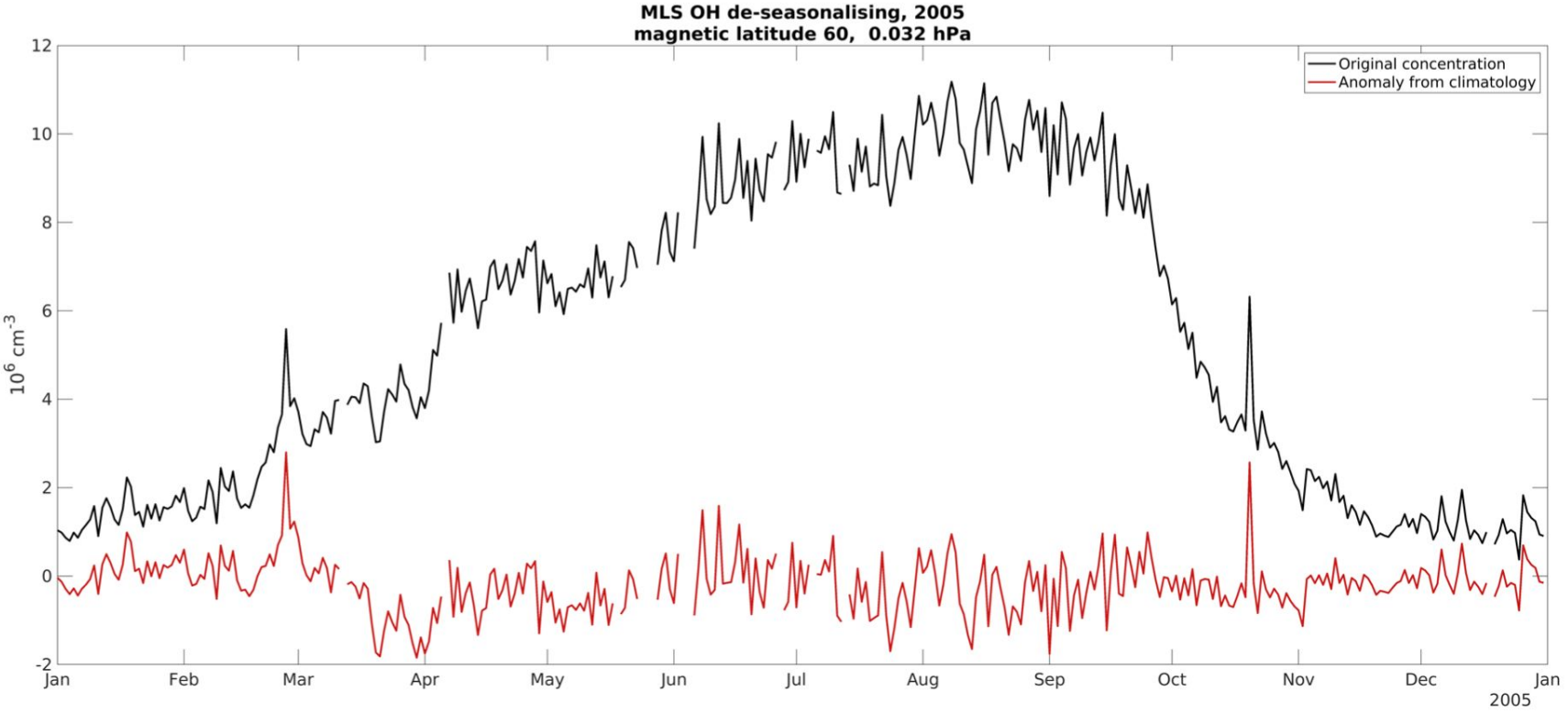
- **In this study:** we run SD-WACCM-D, i.e. with MERRA specified dynamics.

MLS OH data binned into magnetic latitudes

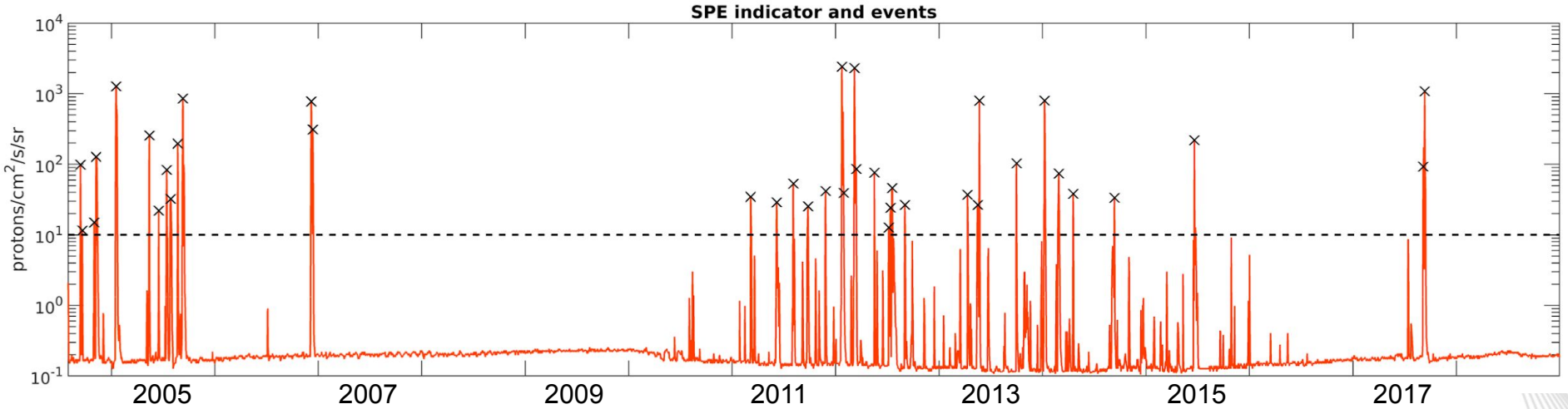


Altitude-Adjusted Corrected Geomagnetic Coordinates (for a definition, see e.g. Shepherd, 2014)

Daily climatology removed from OH data

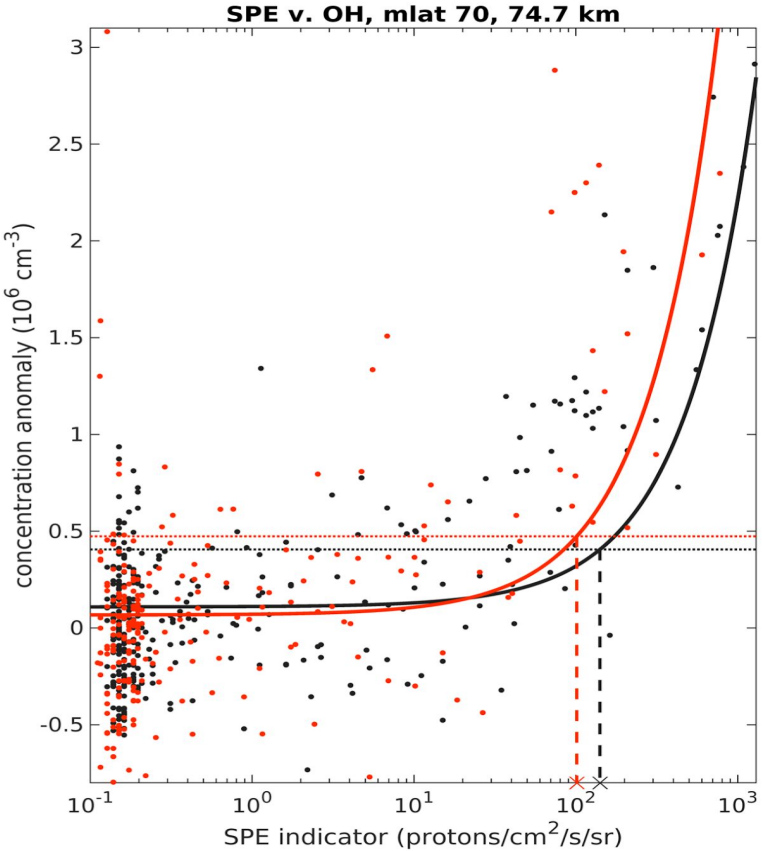


SPEs of the MLS/Aura era



SPE indicator = daily average >10 MeV flux from GOES observations.

Threshold detection method: example

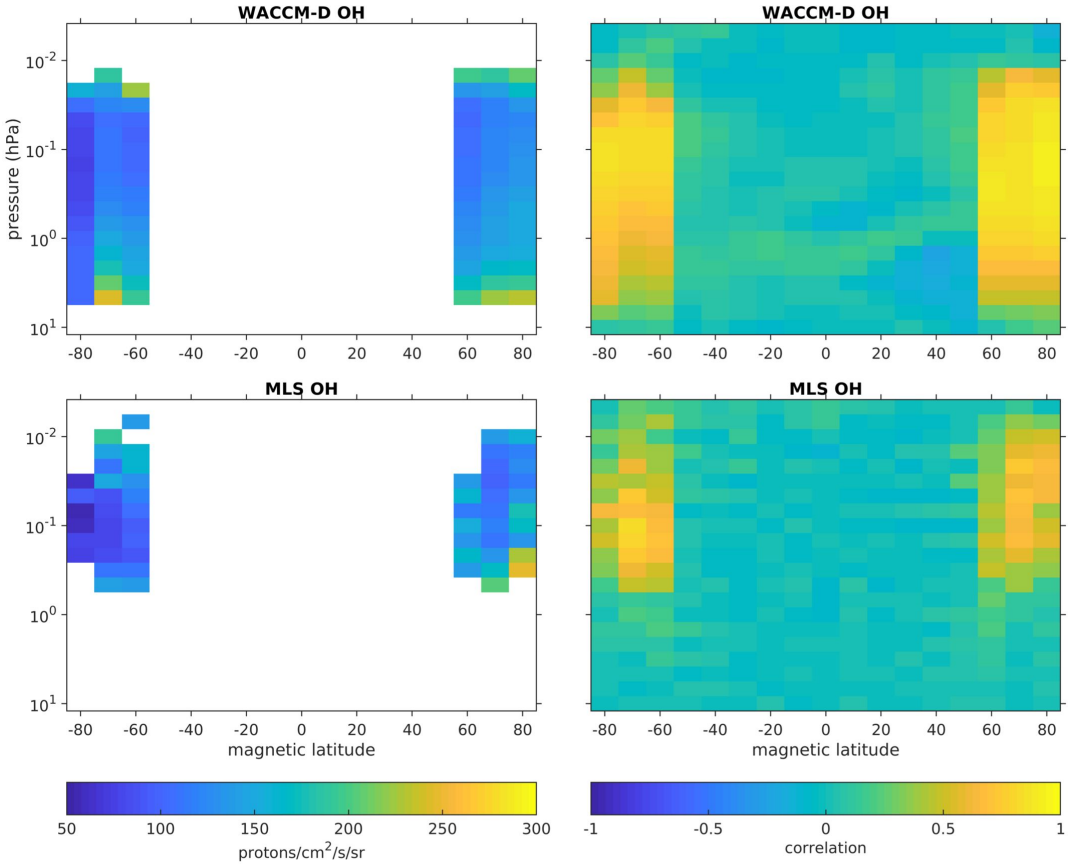


Connection between
- SPE indicator
- OH amount

Shown for
- WACCM-D (black)
- MLS OH (red)

Solid lines = linear fit
dashed lines = OH median + 0.5 x STD

Detection thresholds: nighttime



Latitudes:

- 55° - 85° geomagnetic.

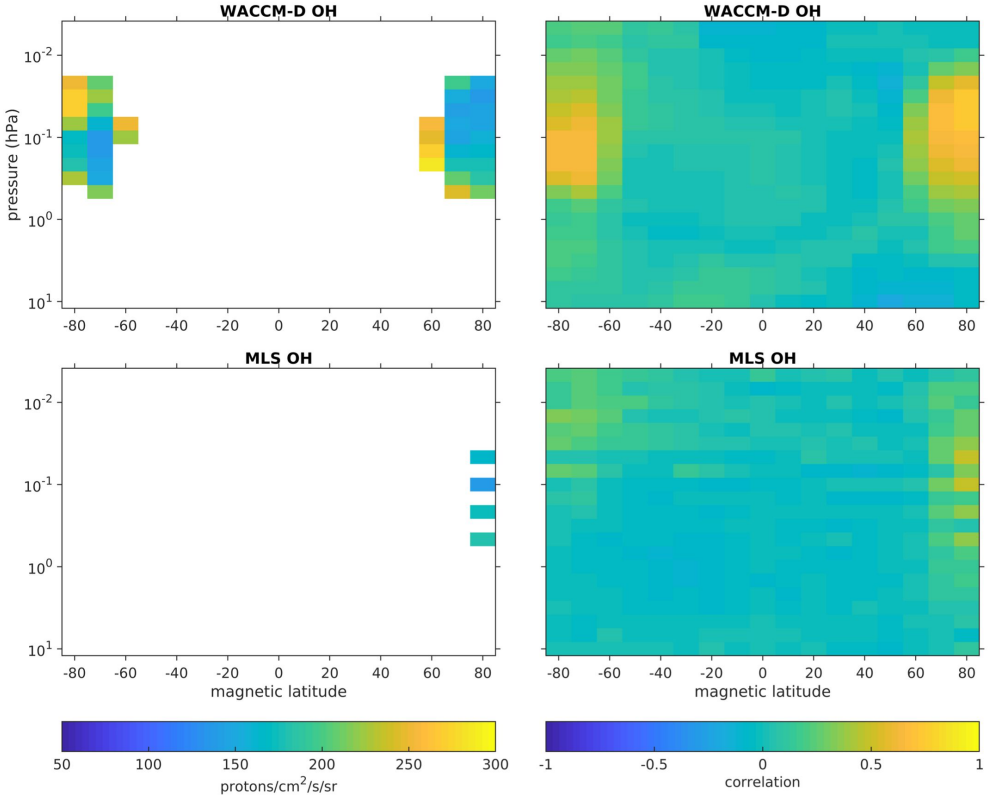
Altitudes:

- 35 - 80 km (WACCM-D)
- 50 - 85 km (MLS)

Thresholds:

- 50 - 175 protons/cm2/s/sr

Detection thresholds: daytime



Latitudes:

- 55° - 85° geomagnetic (WACCM-D)
- only 75° - 85° in NH

Altitudes:

- 50 - 75 km (WACCM-D)
- 50 - 70 km (MLS)

Thresholds:

- 130 - 300 protons/cm2/s/sr

The end