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Will climate change impact polar NOx produced by energetic particle precipitation?

Ville Maliniemi[1], Daniel R. Marsh[2,3], Hilde Nesse Tyssøy[1] and Christine Smith–Johnsen[1]

1) Birkeland Centre for Space Science, University of Bergen, Norway

2) National Center for Atmospheric Research, Boulder, CO, USA

3) Faculty of Engineering and Physical Sciences, University of Leeds, UK

ville.maliniemi@uib.no

Energetic Particle Precipitation

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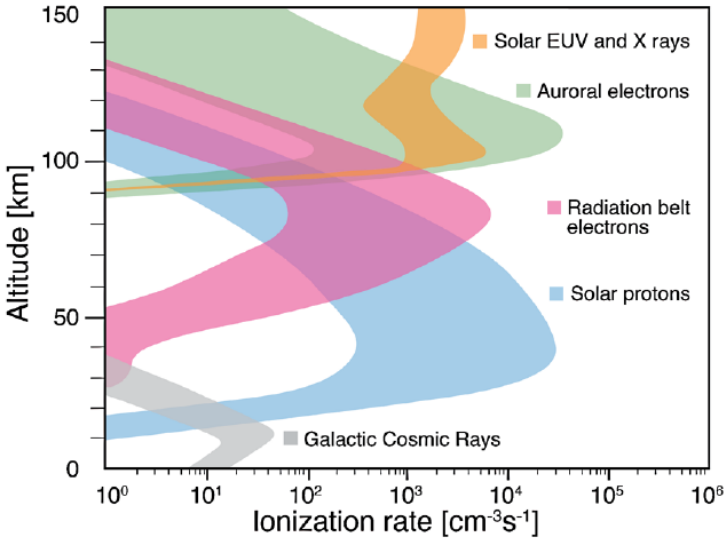
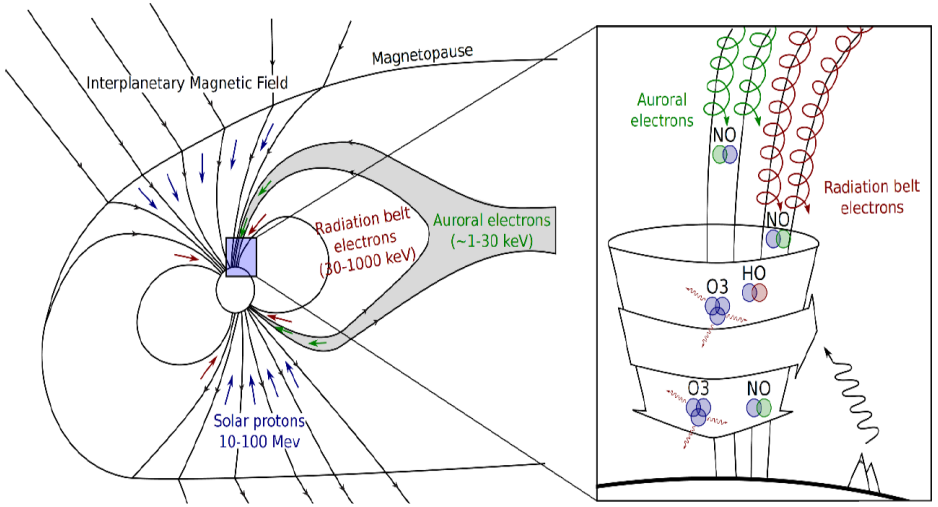
- Solar activity injects energetic particles into the upper (polar) atmosphere, which are guided by the geomagnetic field lines
- Energetic Electron Precipitation (EEP) is constant but variable (related to solar wind speed) source, consisting of auroral electrons (<30 keV) and radiation belt electrons (>30 keV), which ionize thermosphere and upper mesosphere
- Solar Proton Events (SPE) are sporadic events (related to flares) injecting protons (tens of MeVs) that can pentrate over the polar cap down to upper stratosphere



Mironova et al. (2015)



Adapted from Thorne (1975)

Historical Polar NOx

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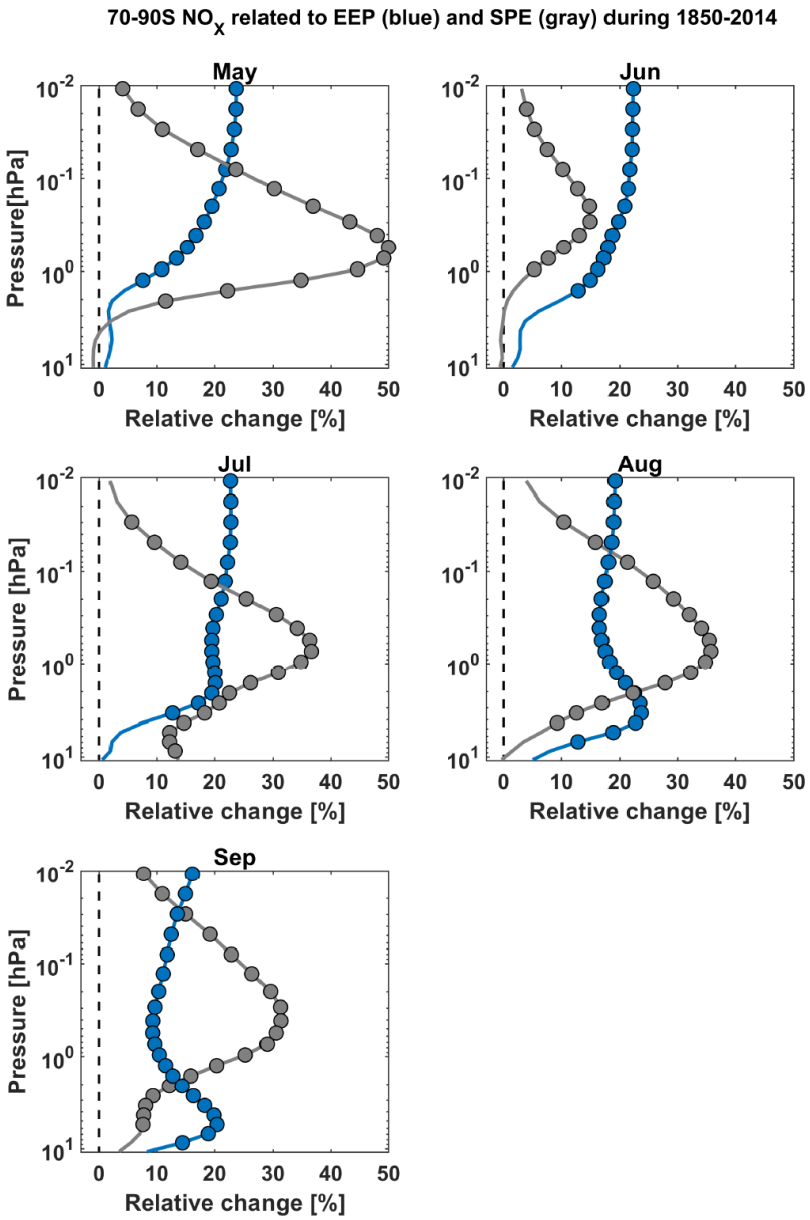
- WACCM6 historical run (DECK, 3 ensemble members) 1850-2014
- Both EEP and SPE are able to produce nitrogen oxides (NOx) in the upper and middle atmosphere
- NOx has a long lifetime in darkness and it is brought down during the winter by the mean meridional circulation

  → EEP indirect effect in the stratosphere
- SPE production altitude fairly constant over the different winter months



Future Polar NOx

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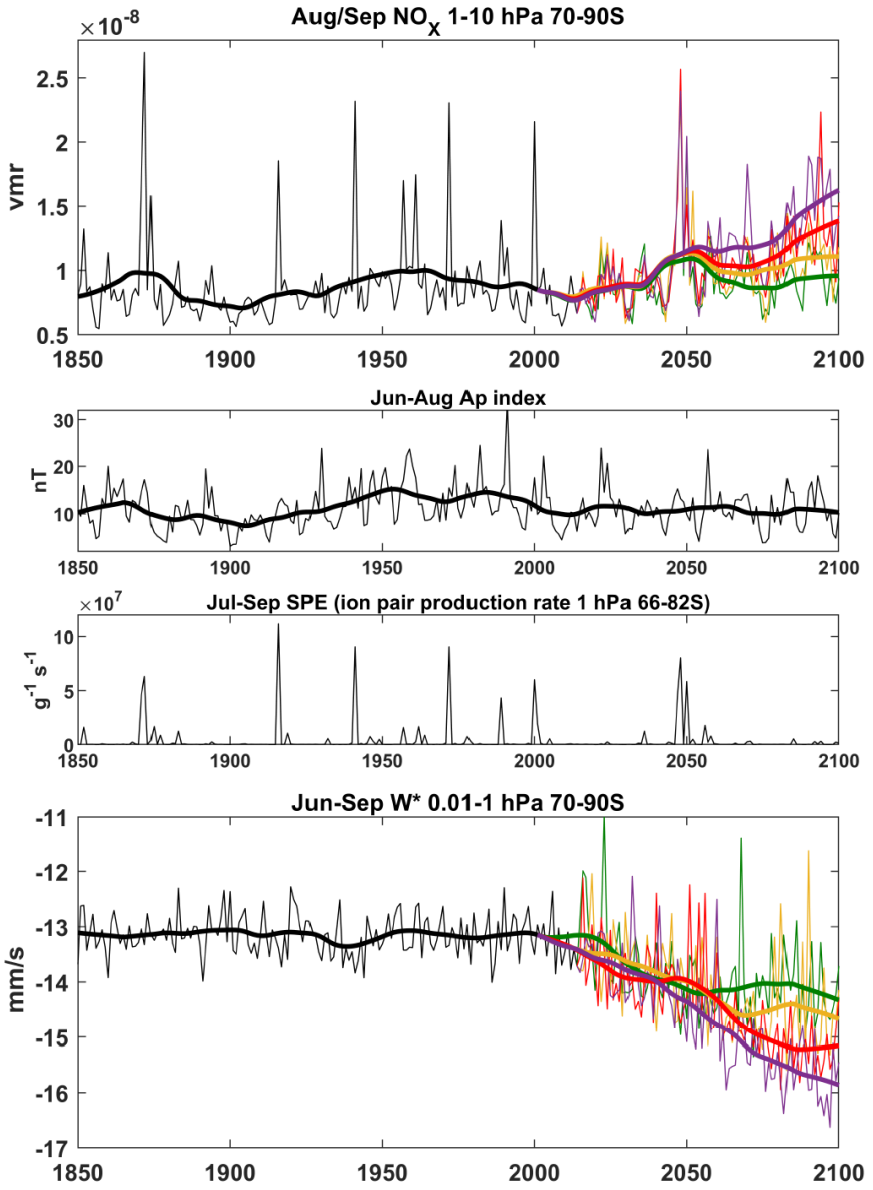
- WACCM6 future scenario runs (CMIP6 ScenarioMIP) 2015-2100
- Vertical descent ($\bar{w}^*$) in the polar mesosphere (mean meridional circulation) is stronger in future scenarios with larger radiative forcing
  - 4 different shared socioeconomic pathways (SSP1, SSP2, SSP3, SSP5)
- Particle forcing scenario same in all model runs



Future Polar NOx

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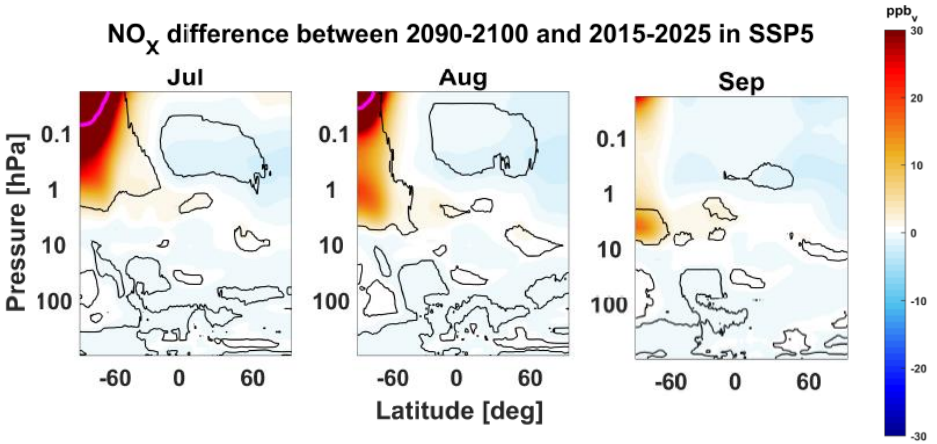
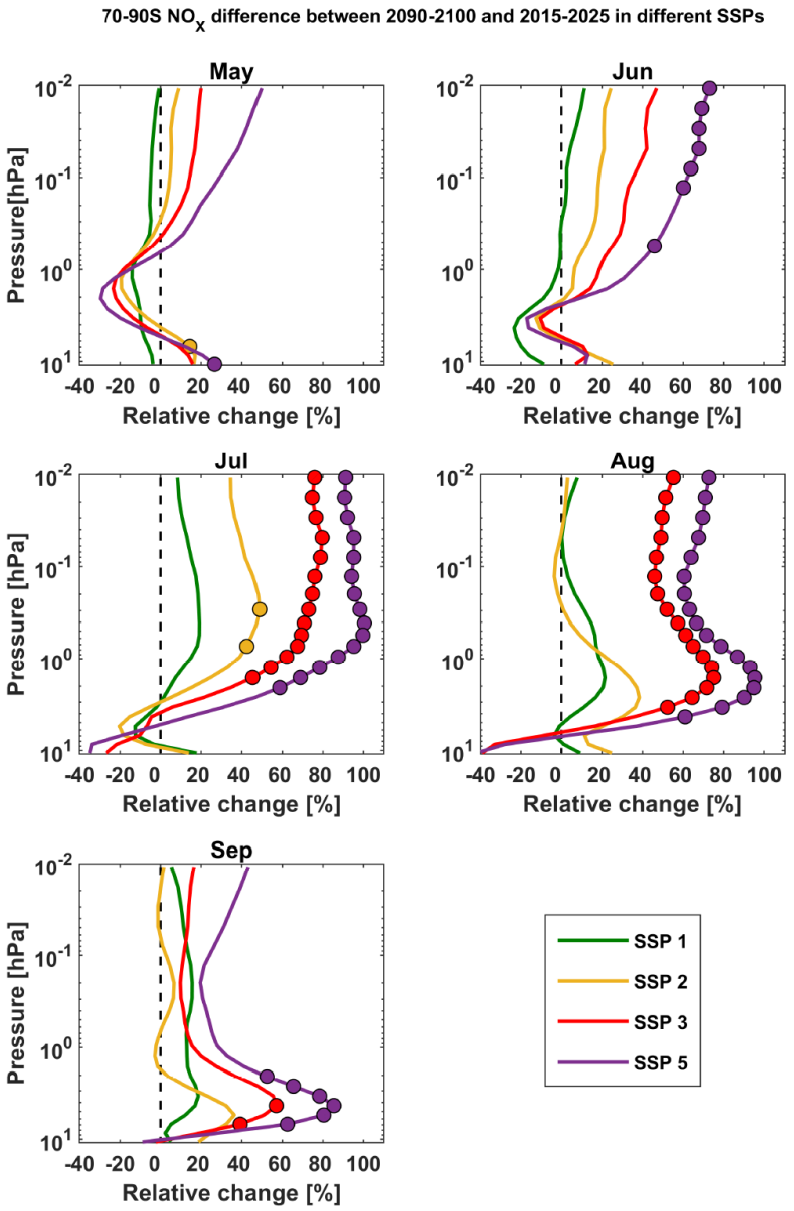
- Up to 100% percent increase in polar NOx by the end of 21st century compared to current times (EEP forcing about the same)
- Vertical distribution of increase is very similar than EEP related distribution

→ More polar stratospheric NOx in the future due to the EEP indirect effect





Conclusions

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- Winter polar NOx below 1 hPa is directly modulated by solar proton events and indirectly by electron precipitation via vertical transport.

- Vertical descent in the polar mesosphere during southern winter is stronger in future scenarios with larger radiative forcing.

- Polar stratospheric NOx increases over the latter part of 21st century, even when particle precipitation is similar to historical levels.

- References:
Maliniemi, V., Marsh, D. R., Tyssøy, H. N., & Smith-Johnsen, C.. (2020). Will climate change impact polar NOx produced by energetic particle precipitation?. *Geophys. Res. Lett.*, 47, e2020GL087041. https://doi.org/10.1029/2020GL087041

- We are hiring a PhD. student to continue work on **Effects of Energetic Electron Precipitation In a Changing Climate (Norwegian Research Council Project). Starting date in August/September 2020, position to be announced soon.**
- **More info:** ville.maliniemi@uib.no