Arctic lightning NO_x emissions estimated from TROPOMI observations

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[3] Vaisala, Inc. [4] Earth Networks Total Lightning Network

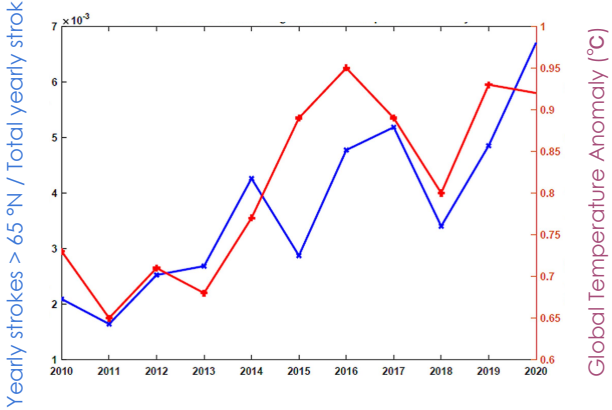
EGU22-8640

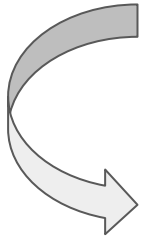
26 May 2022

Arctic Lightning

EGU22-8640

WWLLN strokes above 65 °N
v.s. Global Temperature Anomaly



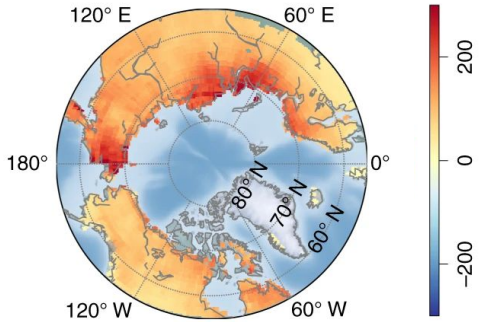


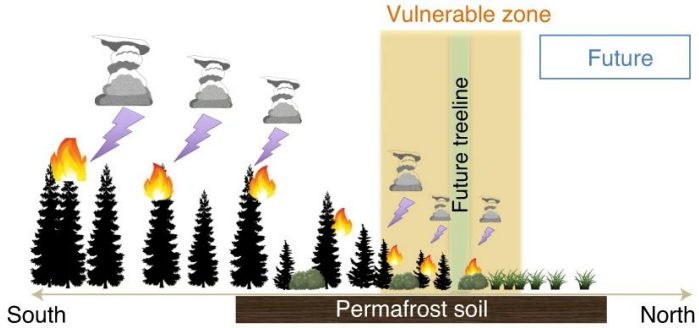
0.5 ℃

2x lightning strokes

Holzworth et al. (2021)

Change in lightning flash rate (%)





RCP8.5 scenario: 3.7 °C global mean temperature rise

Chen et al. (2021)

Datasets for Lightning NO_x Estimation

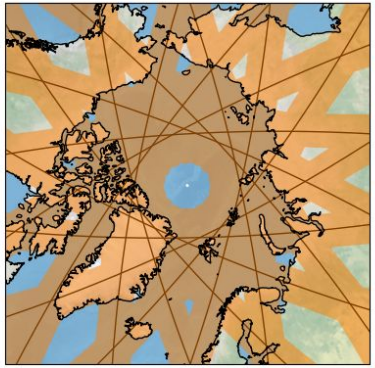
Satellite Observations:

- **TROPOMI** NO_2 L2 product (PAL, V02.03.01)
- **Suomi NPP** fire product

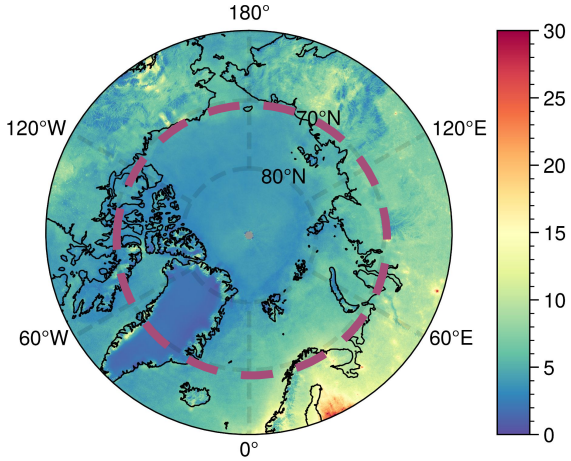
Ground Lightning Data:

- Vaisala **GLD360**

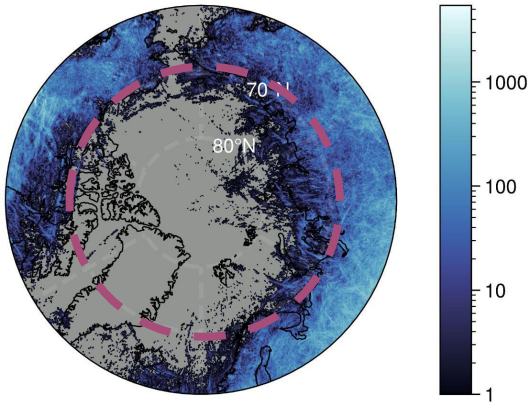
ERA5 Reanalysis Wind Data



NO_2 tropospheric column
(2018-06 ~ 2021-05, μmol m^{-2})



GLD360 strokes
(2019-01 ~ 2021-12)

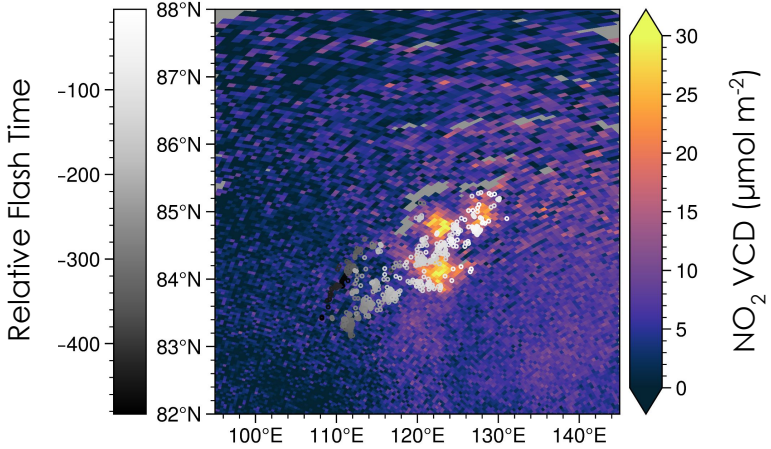


Method

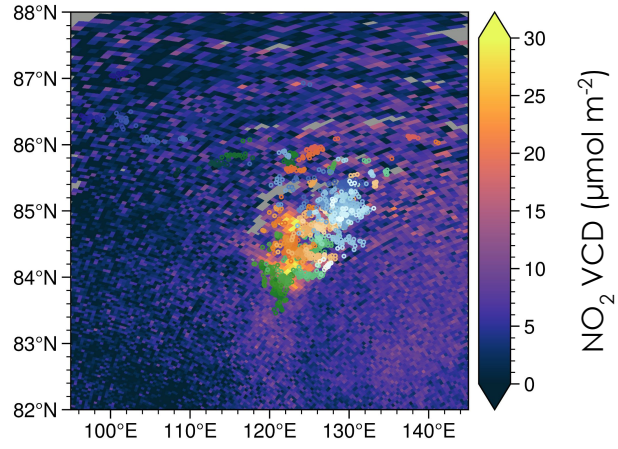
$$LNO_{2_{T2}} = LNO_{2_{T1}} \cdot e^{\frac{-(T_2 - T_1)}{\tau}} + PE \cdot \sum_{i=1}^{m} e^{\frac{-(t_i - T_1)}{\tau}}$$

- LNO_{2T} (mol): Lightning NO_2 at time T (**T2 > T1**)
- **PE** (mol/stroke): Lightning NO_2 production efficiency
- t_i: The datetime when lightning happened
- τ: The lifetime of lightning NO_2 (6 h ~ 12 h, Nault et al. 2017)

Observed lightning



Lightning tracer at **700 hPa**, **500 hPa**, and **300 hPa**



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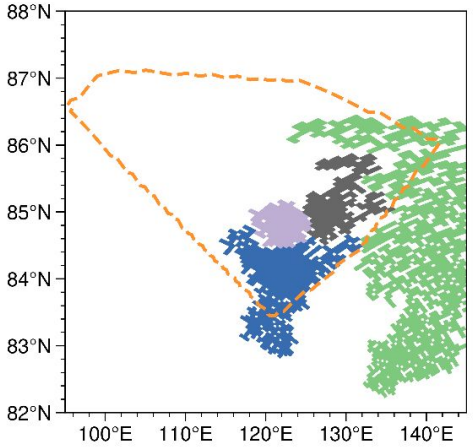
NO_2 segmentation with lightning mask



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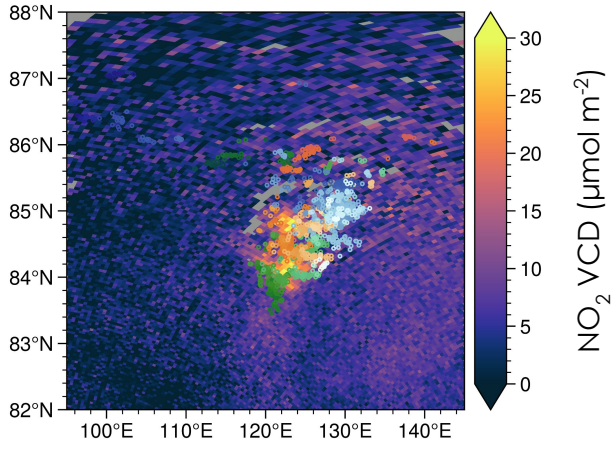

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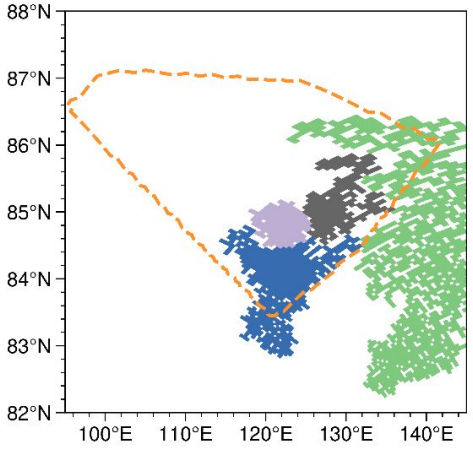
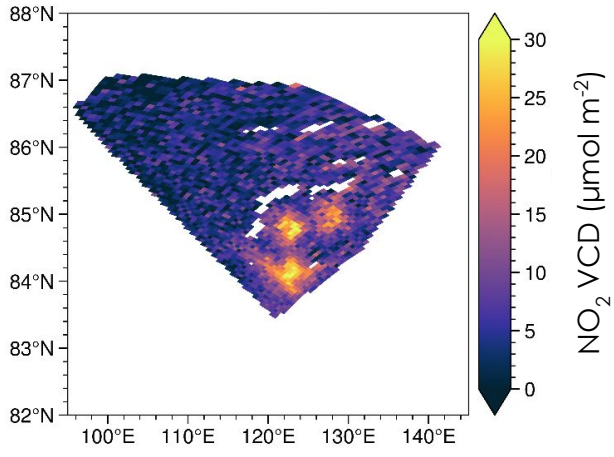


Masked NO_2



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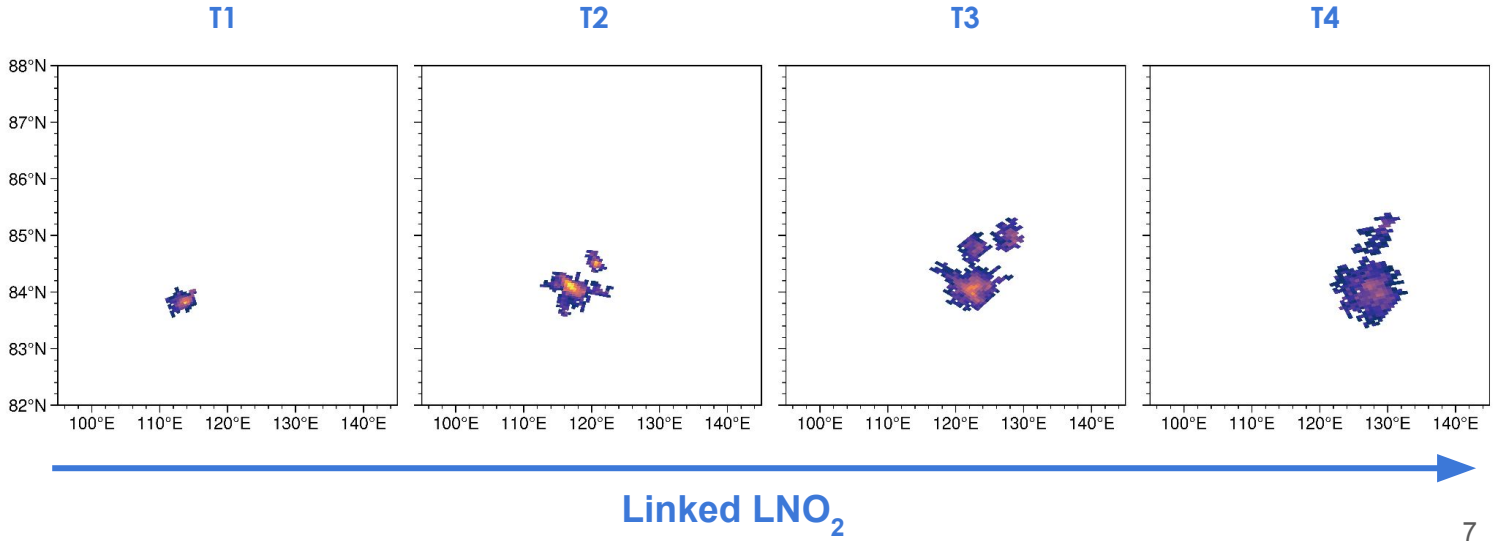
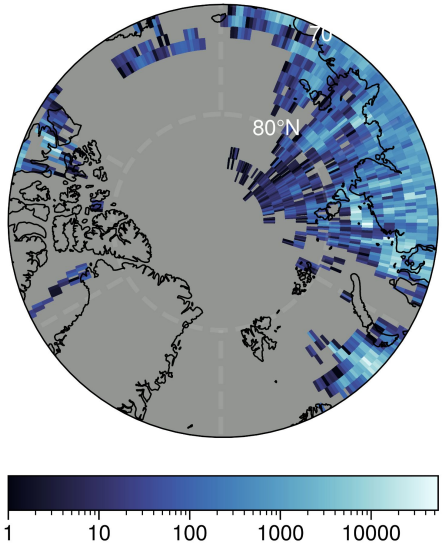
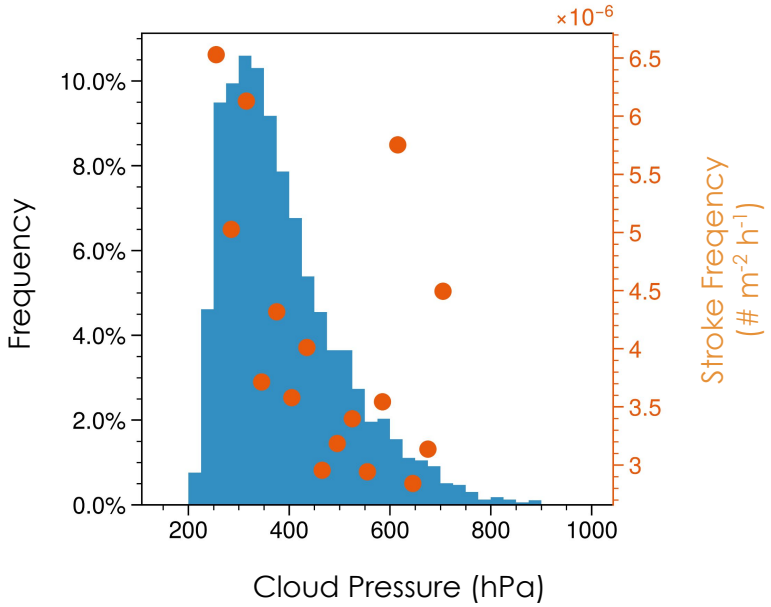


Results

Is the Arctic convection deep?

Tracked strokes



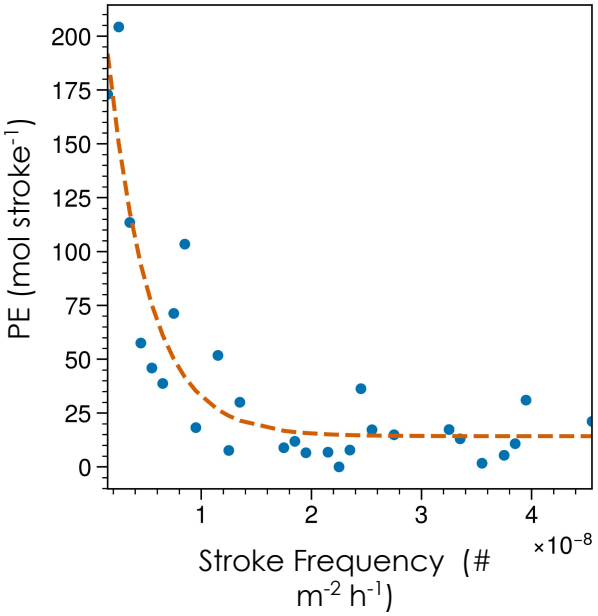


Yes, considering the lower tropopause height than mid-latitude's.

Results

How about the LNO_2 production ?

PE ~ Stroke frequency



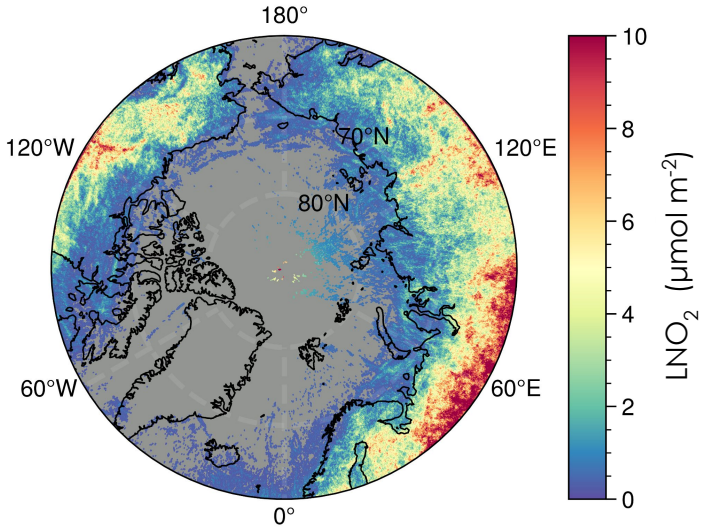
$$LNO_2 = \overline{PE} \cdot N_{stroke}$$

$$LNO_2 = \sum_{i=1}^{m} PE_{freq_i} \cdot N_{stroke_i}$$

Results

How about the LNO_2 production ?

LNO_2 = 215 Mg/year



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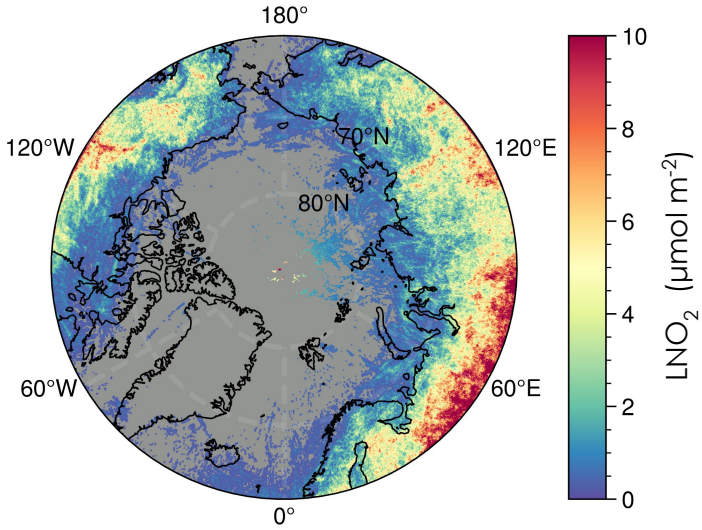

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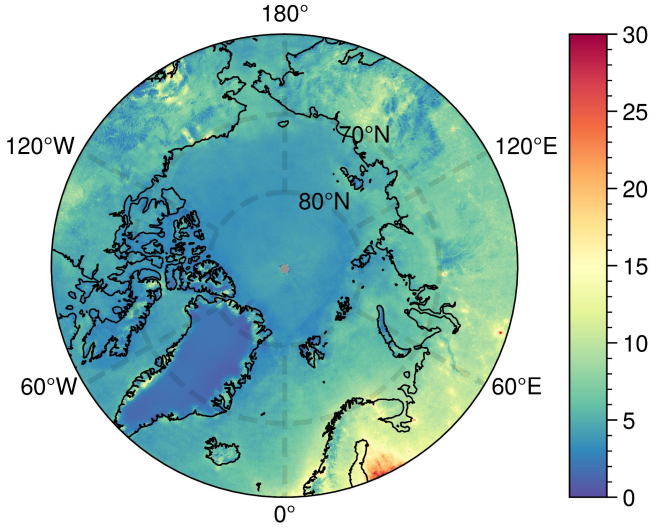


LNO_x = 520 Mg/year

assuming NO_x:NO_2 = 2.4 (Silvern et al. 2018)

Summary

Contact: xinzhang1215@gmail.com

Conclusion

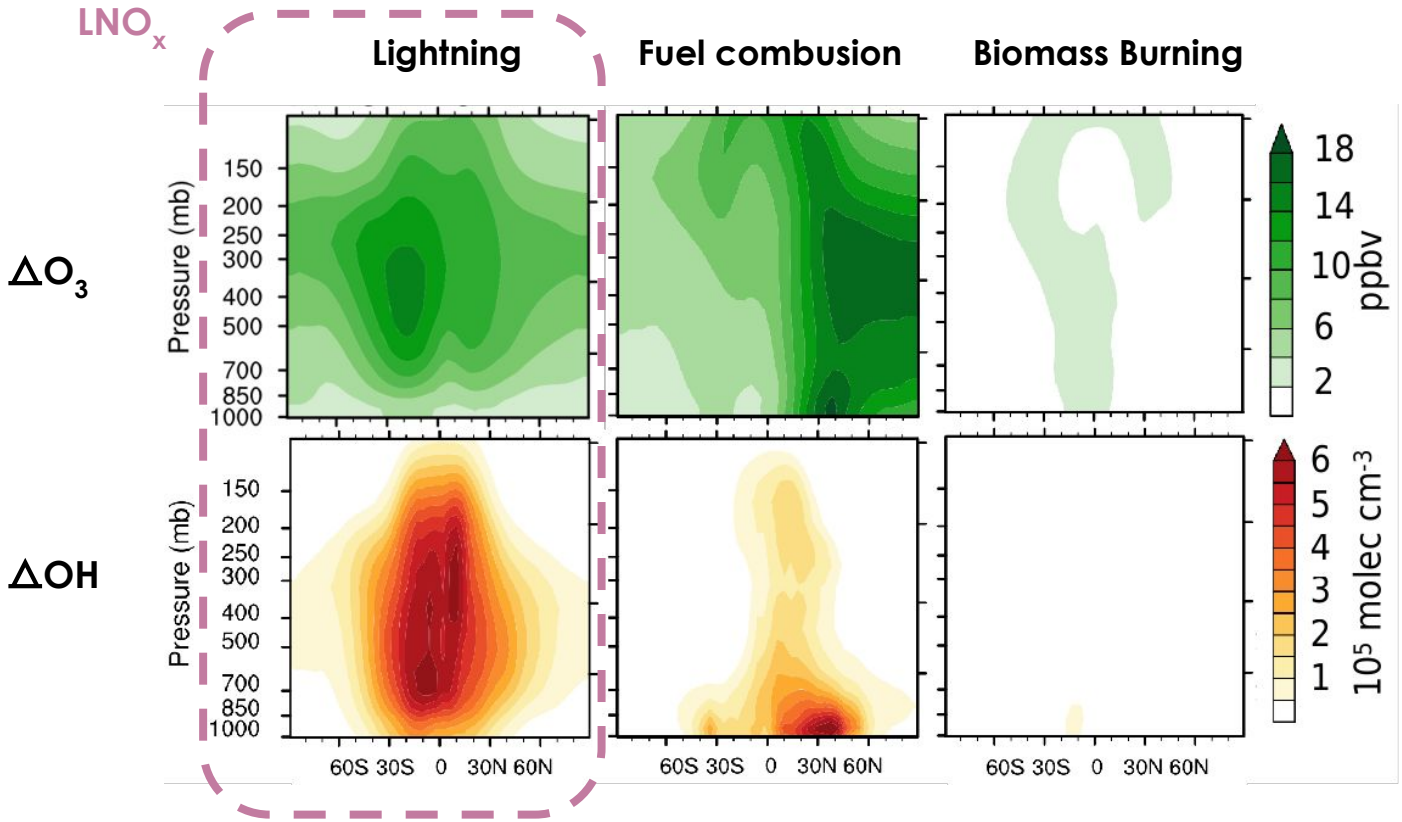
- Deep convection exists in the Arctic.
- The **consecutive observations** can be used to constrain lightning NO_x emission.
- The Arctic lightning NO_x emission is **520 Mg/year**.

Future work

- Detailed evaluations of estimation **uncertainty**.
- **Comparisons** with mid-latitude/tropical LNO_x production efficiency, which needs lighting flash data (clustered strokes).

Extral Slides

Zonal mean abundances of O_3 and OH (1998–2006)



Murray (2016)