

GEOS-Chem Modeling of Intercontinental Transport of Global Tropospheric Ozone to East Asia

Jane Liu^{1,2}, Ye, Zhu¹, Han Han¹, Bingliang Zhuang¹, Tijian Wang¹, Yue Wu¹, and Yichen Li¹
¹School of Atmospheric Sciences, Nanjing University, Nanjing, China, ²University of Toronto, Toronto, Ontario, Canada

1. Introduction

- Ozone is an important trace gas in the troposphere as a major pollutant and greenhouse gas. Because of ozone lifetime of days to weeks, intercontinental transport of ozone is possible.
- In this study, transport of ozone from the global troposphere to East Asia (EA) is investigated through analysis of a 20-year simulation (1987-2006) from a chemical transport model (GEOS-Chem) and forward trajectories.
- The objective is to better understand the underlying mechanisms responsible for the seasonal and interannual variations of imported ozone over East Asia.

2. Methodology

- GEOS-Chem model: driven by assimilated meteorological observations from NASA Goddard Earth Observing System (GEOS-4). Using tag ozone simulations, imported ozone over East Asia can be tracked back to various source regions. Set up: 1986-2006 (GEOS-4), 4°x5°, 30 layers.
- HYSPLIT Forward Trajectory model: driven by reanalysis meteorological data from National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) (not shown in this poster, see Han et al. 2018 and Zhu et al. 2017 for more information)
- Using climatic indices to explore connections between some of the indices and interannual variation of imported ozone in East Asia.

3. Influence of North American (NA) O₃ on East Asia

- NA ozone increases with latitude at all the pressure levels over East Asia. South of 30°N in East Asia, NA ozone influence is small (Fig. 1)
- North of 30°N in East Asia, NA ozone peaks in the middle and upper troposphere in spring and fall in East Asia north of 30°N (Fig. 1).
- The fractional contribution is at a maximum in the fall in the free troposphere (not shown).

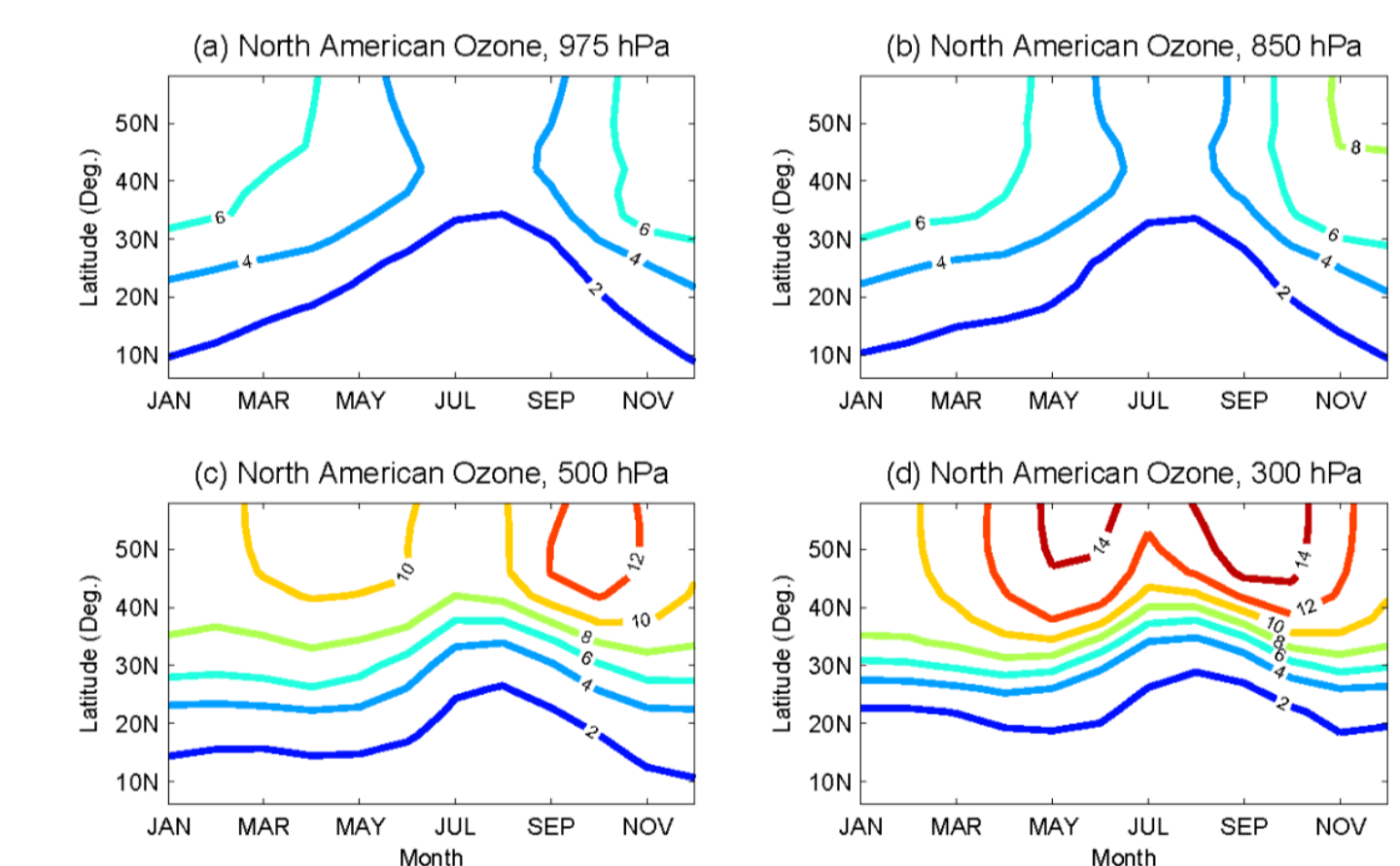


Fig. 1. GEOS-Chem simulated North American ozone (in ppbv) over East Asia, varying with season and latitude at (a) 975, (b) 850, (c) 500, and (d) 300 hPa. At each latitude, the monthly mean ozone concentrations are averaged over 60-150°E for 20-years (1986-2006).

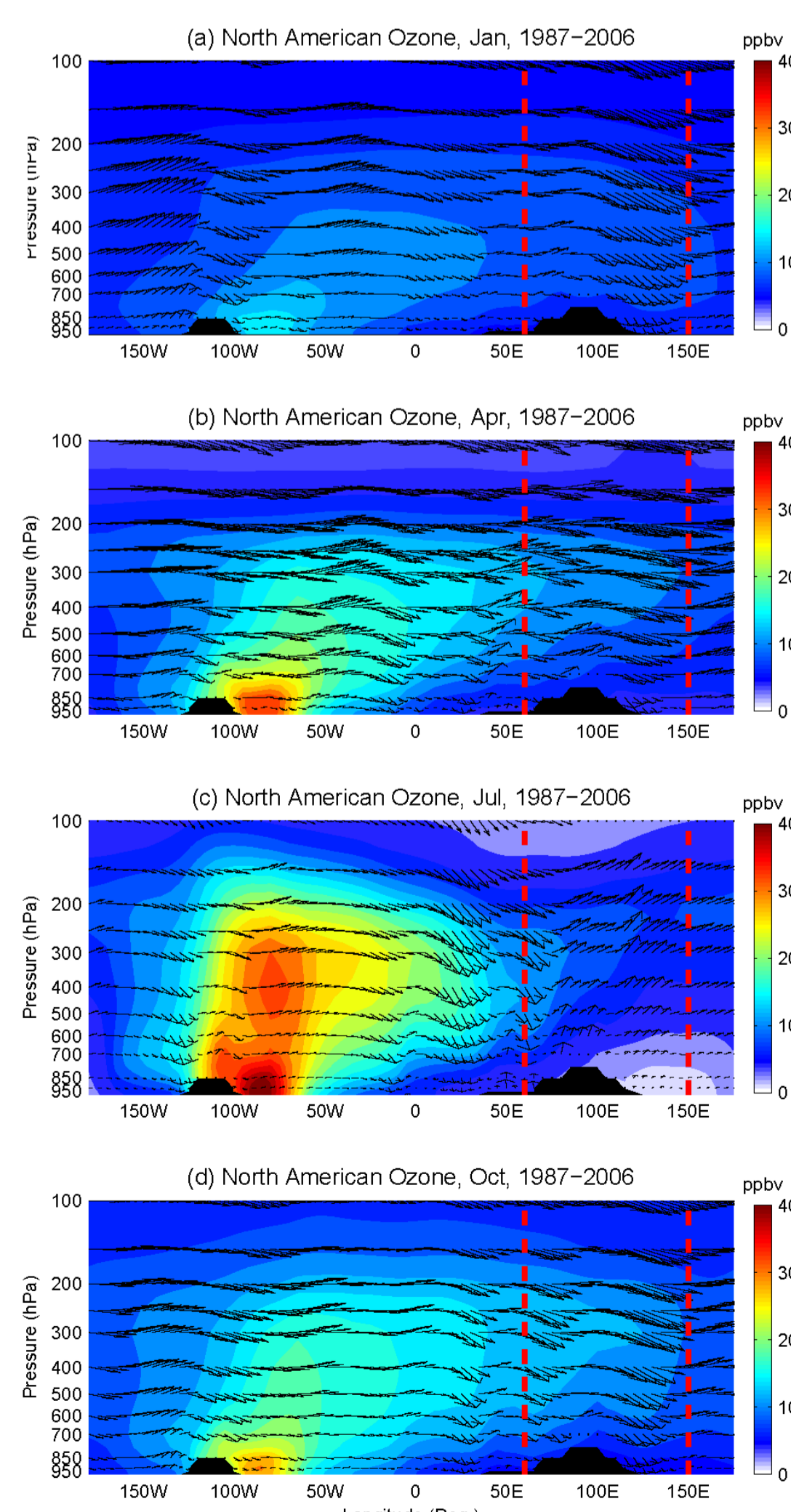


Fig. 2. NA ozone (color, in ppbv) overlaid with corresponding winds (arrows) in longitude-altitude distribution. East Asia is between the red lines.

- We find that there is a close correlation between the surface NA ozone over East Asia and the intensity of the East Asian monsoon in winter (Fig. 3). Spatially, the correlation is dominant over the northern and southeastern China, southern Japan and the western Pacific.
- The interannual variation in surface NA ozone over East Asia in spring is related to the East Asian monsoon in the previous winter (Fig. 4), although the correlation is weaker than in winter.

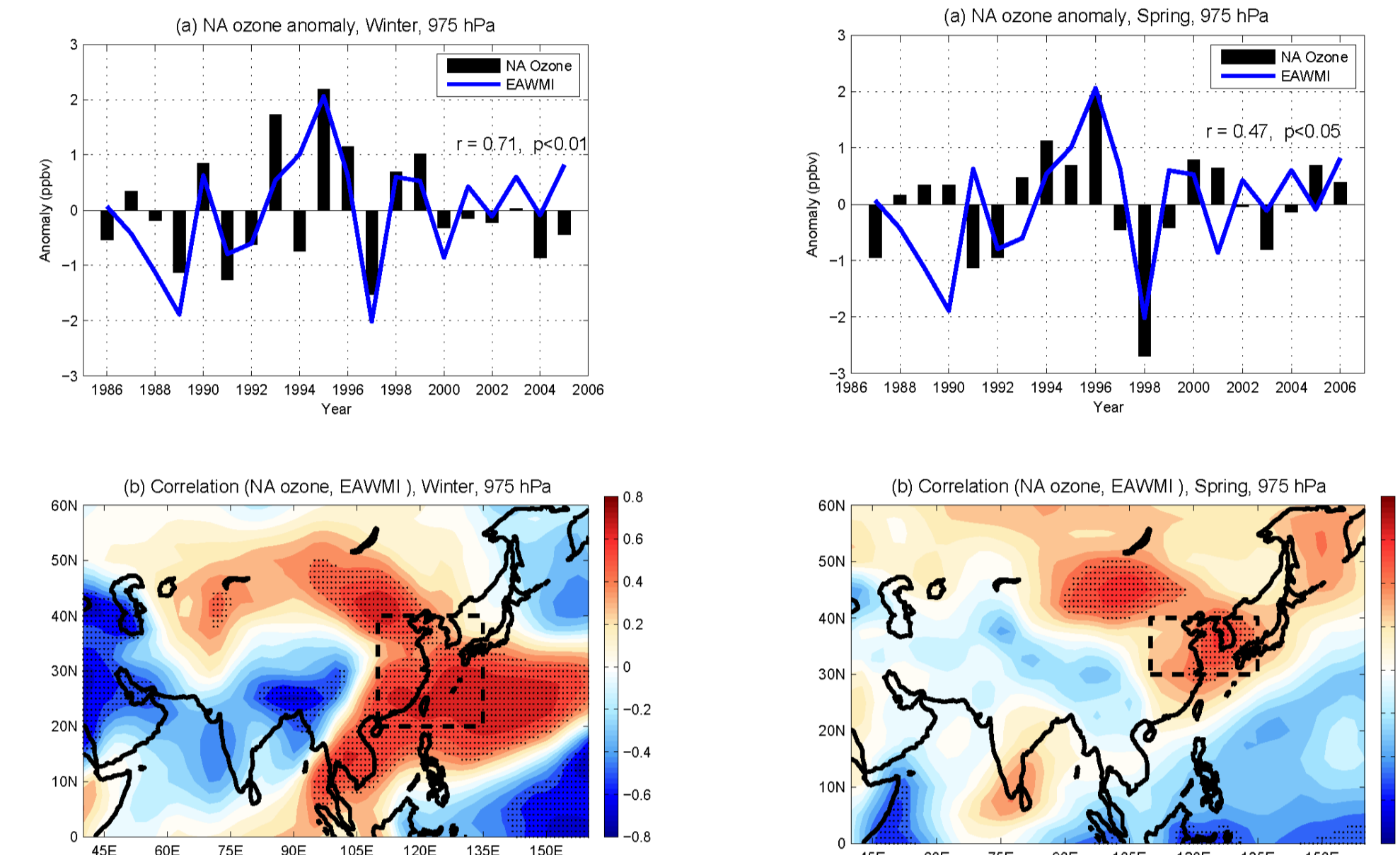


Fig. 3. (left). (a) NA ozone anomaly (in ppbv) over the boxed area in (b) in winter at 975 hPa between 1986 and 2005 (in bars). The blue line is a East Asian winter monsoon index (EAWMI). (b) Correlation between NA ozone and the EAWMI at 975 hPa in winter between 1986 and 2005. Dotted areas are statistically significant at the 95% level. Fig. 4. (right), the same as Fig. 3, but for spring season.

(See Zhu et al. (2017) for more information)

4. Influence of African Ozone on East Asia

- The tropospheric ozone from Africa appears mostly in the middle and upper troposphere in low latitudes over East Asia (Fig. 5).
- In the East Asian upper troposphere, the African ozone contribution is greatest during Jan.-May and is lowest during Jul.-Sep. (Fig. 5).

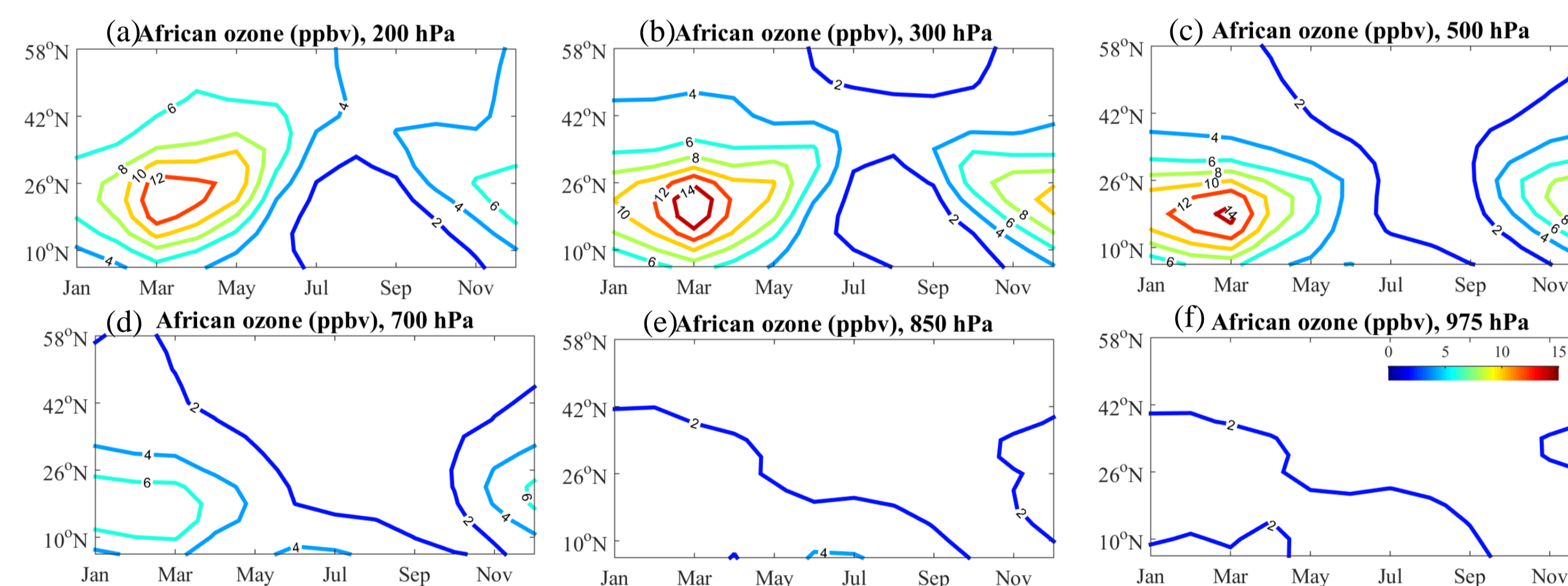


Fig. 5. GEOS-Chem simulated African ozone over EA varying with season and latitude at (a) 200 hPa, (b) 300 hPa, (c) 500 hPa, (d) 700 hPa, (e) 850 hPa, and (f) 975 hPa averaged over 60-145°E from 1987 to 2006.

- The Hadley circulation and the subtropical westerlies build up the dominating pathways of African ozone to EA in the middle and upper troposphere (Fig. 6).

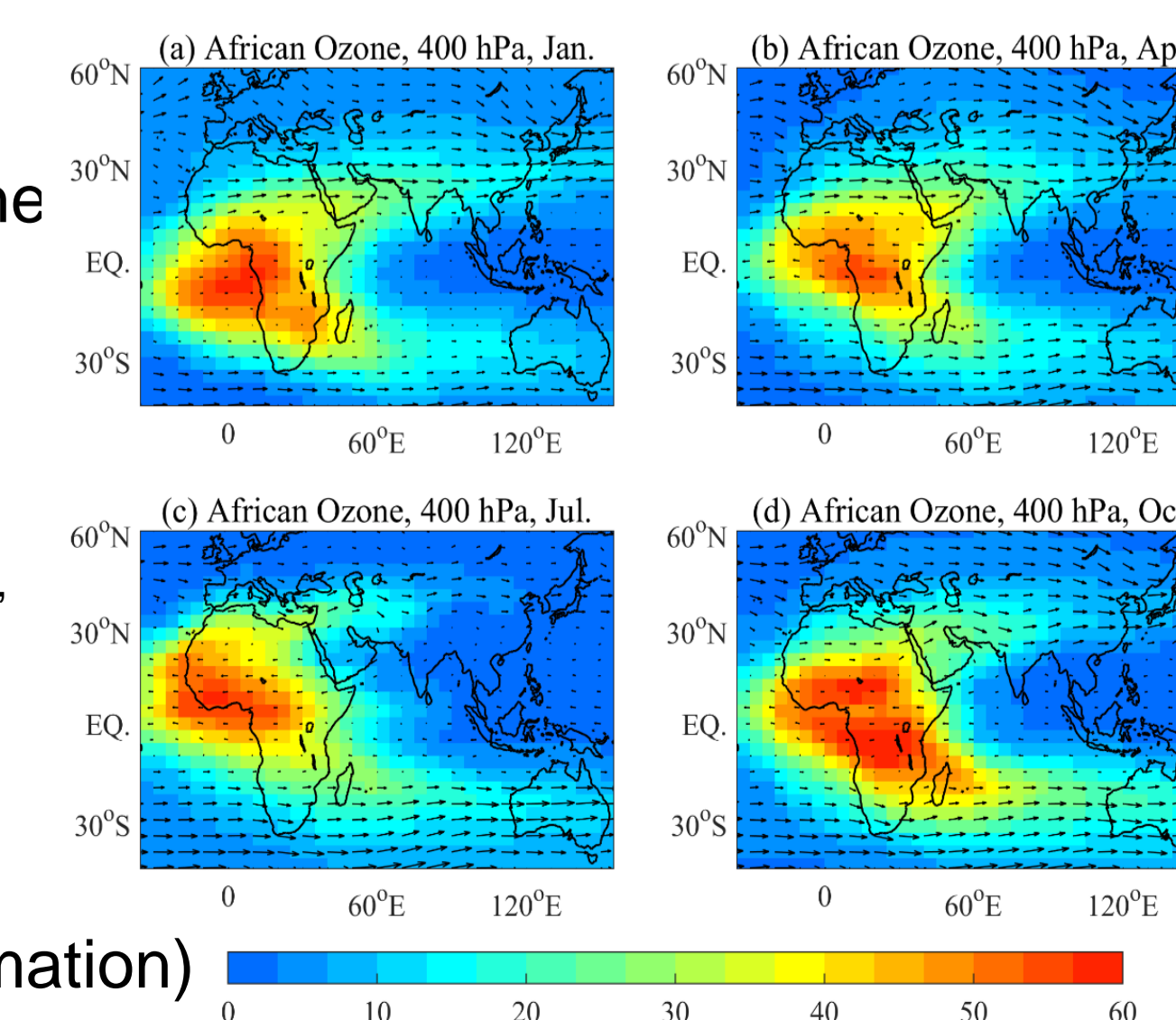


Fig. 6. Horizontal distributions of African ozone (in ppbv, in color) overlaid with winds (in arrow) at 400 hPa in (a) January, (b) April, (c) July, and (d) October. The ozone values are the means from the 20-year GEOS-Chem simulation.

(See Han et al. (2018) for more information)

5. Comparison of the Influences between NA and European Ozone

- The influences of imported NA ozone and European ozone vary with season similarly (Fig. 7).
- The influence of NA ozone is larger and reaches higher altitudes than European ozone.

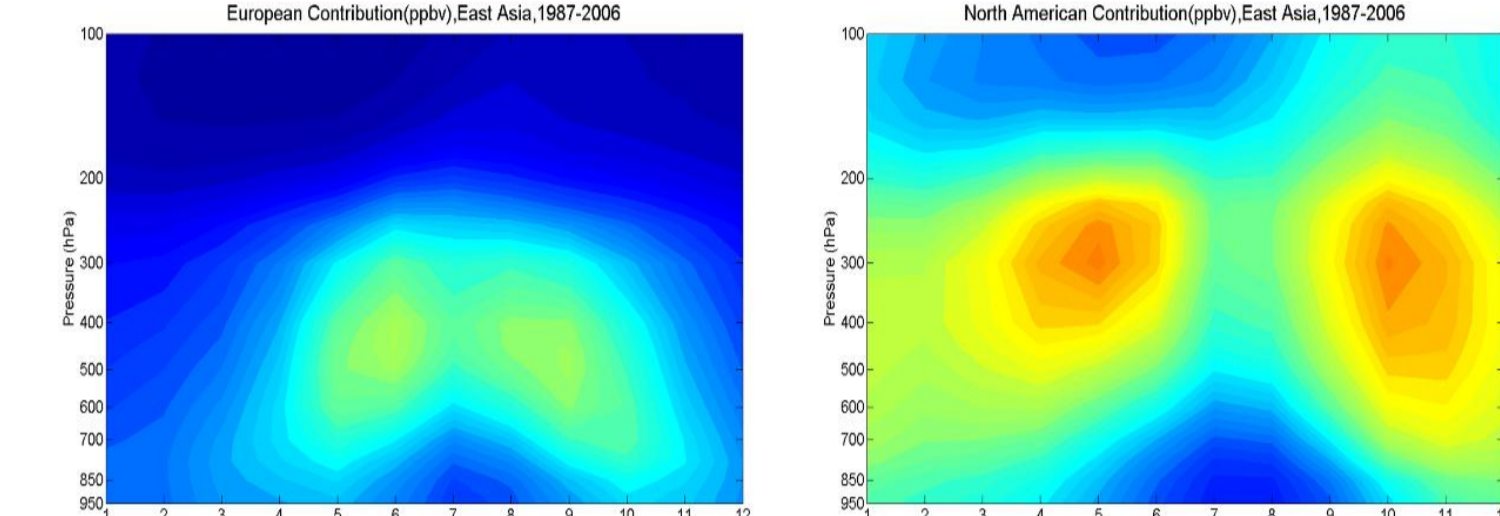


Fig. 7. (left) Seasonal variation of the vertical distribution of imported European ozone over East Asia. (right) for the North American ozone.

6. Influence of Imported Ozone on East Asia

- Fractionally, the influence of imported ozone is larger in winter and smaller in summer (Figs. 8 and 9).
- Maximum influences appear in the upper troposphere in winter and spring and appear in the middle troposphere in summer and autumn.

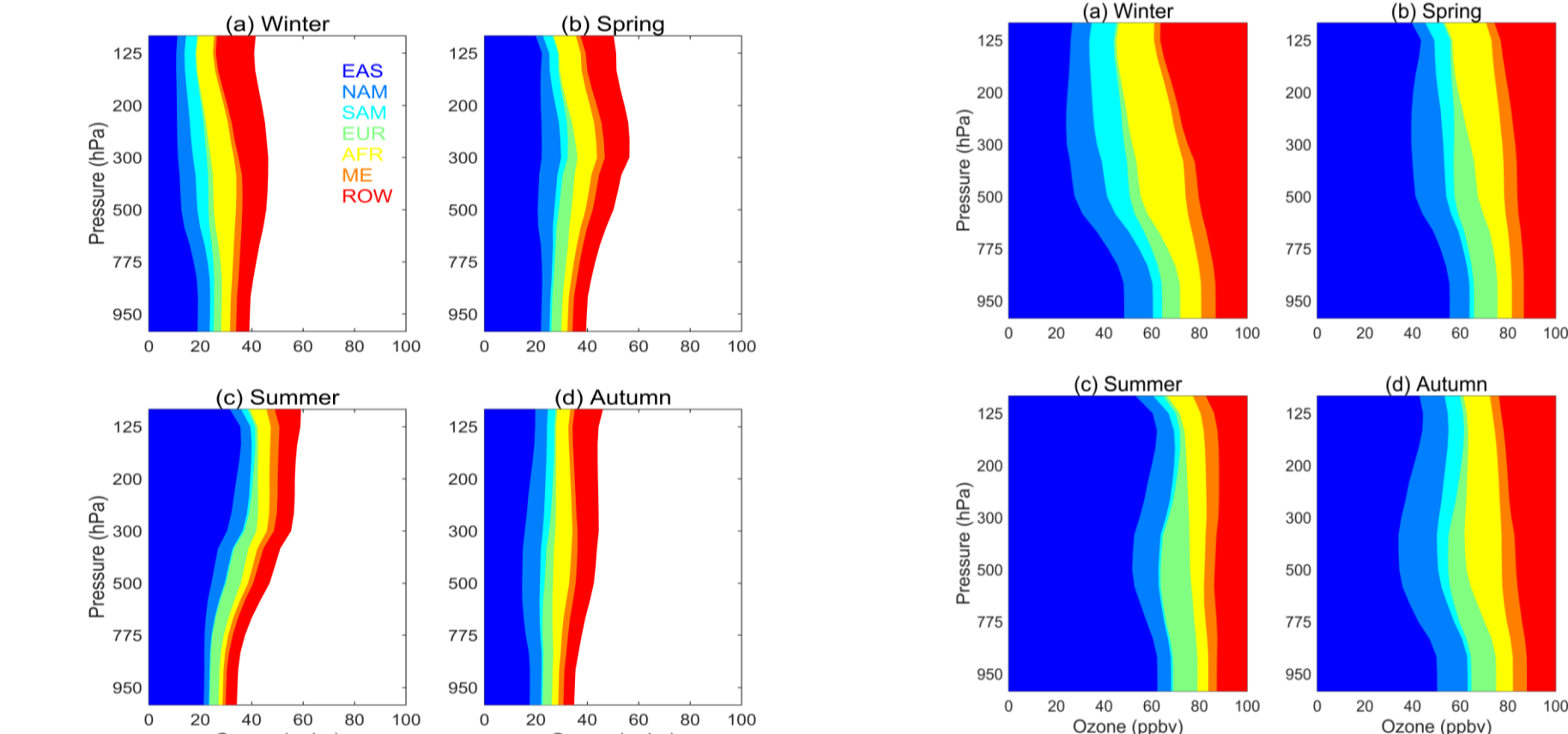


Fig. 8. Mean vertical distribution of ozone concentration (ppbv) from different regions to ozone over East Asia by season.

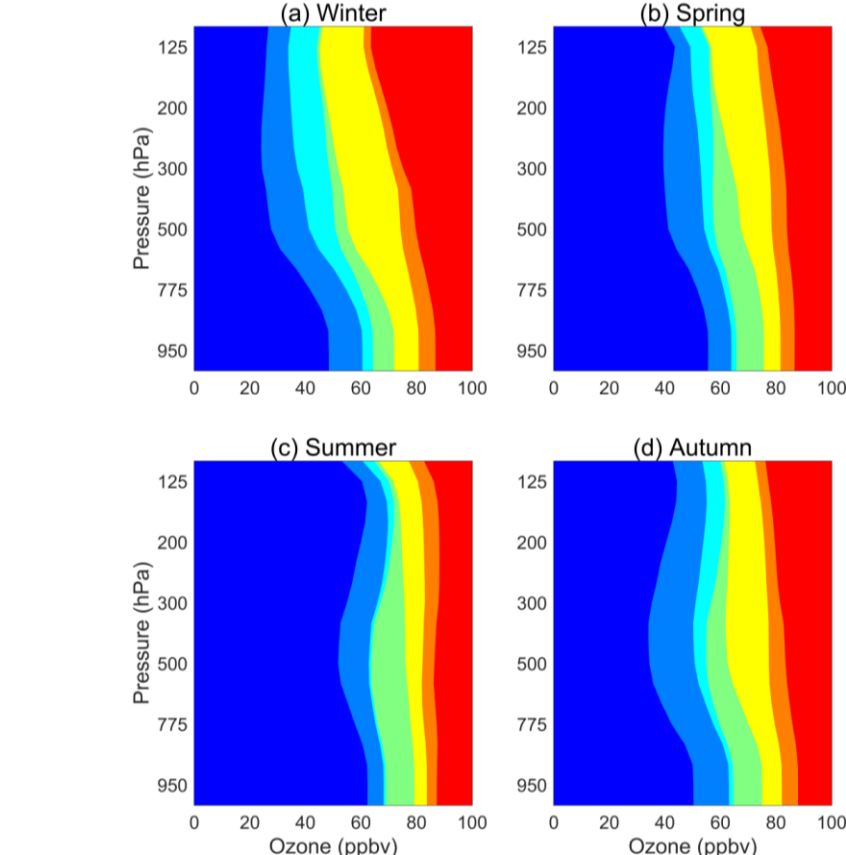


Fig. 9. Mean vertical distribution of fractional contribution (%) of ozone from different regions to ozone over East Asia if not considering stratospheric influence.

7. Conclusions

- Imported ozone varies greatly with longitude, latitude, altitude and season.
- In East Asia, imported ozone from North America (NA), Europe, and Africa is usually high over the free troposphere in spring and fall and is low over the surface in summer.
- In East Asia, the influence of NA and European ozone prevails over north of 30°N, while the influence of African ozone prevails south of 30°N.
- Varying with season in magnitude, imported ozone is generally lifted by updrafts in the source regions (for example, a head of the NA trough), then it is brought to the lower troposphere by the downdrafts behind the Asian trough. In summer, the European trough becomes strong can divert NA, European, and African ozone from reaching East Asia.
- The distribution of imported ozone over East Asia results from collective effects of emissions in the source regions, the meteorology and chemistry in the source regions, EA, and along the transport pathways.

References

- Zhu, Y., Liu, J., Wang, T., Zhuang, B., Han, H., Wang, H., Chang, Y., Ding, K., The impacts of meteorology on the seasonal and interannual variabilities of ozone transport from North America to East Asia. *Journal of Geophysical Research*, 122, doi:10.1002/2017JD026761, 2017.
- Han, H., Liu, J., Yuan, H., Zhuang, B., Zhu, Y., Wu, Y., Yan, Y., and Ding, A., Characteristics of intercontinental transport of tropospheric ozone from Africa to Asia, *Atmospheric Chemistry and Physics*, 18, 4251-4276, <https://doi.org/10.5194/acp-18-4251-2018>, 2018.

For more information, please contact Jane Liu at Janeji.liu@utoronto.ca