Tropical teleconnection and climate impact of tropospheric ozone variability in Antarctica

Pankaj Kumar and Jayanarayanan Kuttippurath

CORAL, Indian Institute of Technology Kharagpur, Kharagpur, West Bengal, India

Introduction

- Tropospheric ozone is a pollutant and third most important greenhouse gas, and therefore poses threats to both human health and climate.
- Photochemical production from natural and anthropogenic precursors, and transport from stratosphere are its major sources.
- Inter-hemispherical transport can also contribute to ozone budget.
- Changes in airmass transport through different climate modes contribute to inter-annual variability of tropospheric ozone.

Surface and tropospheric ozone

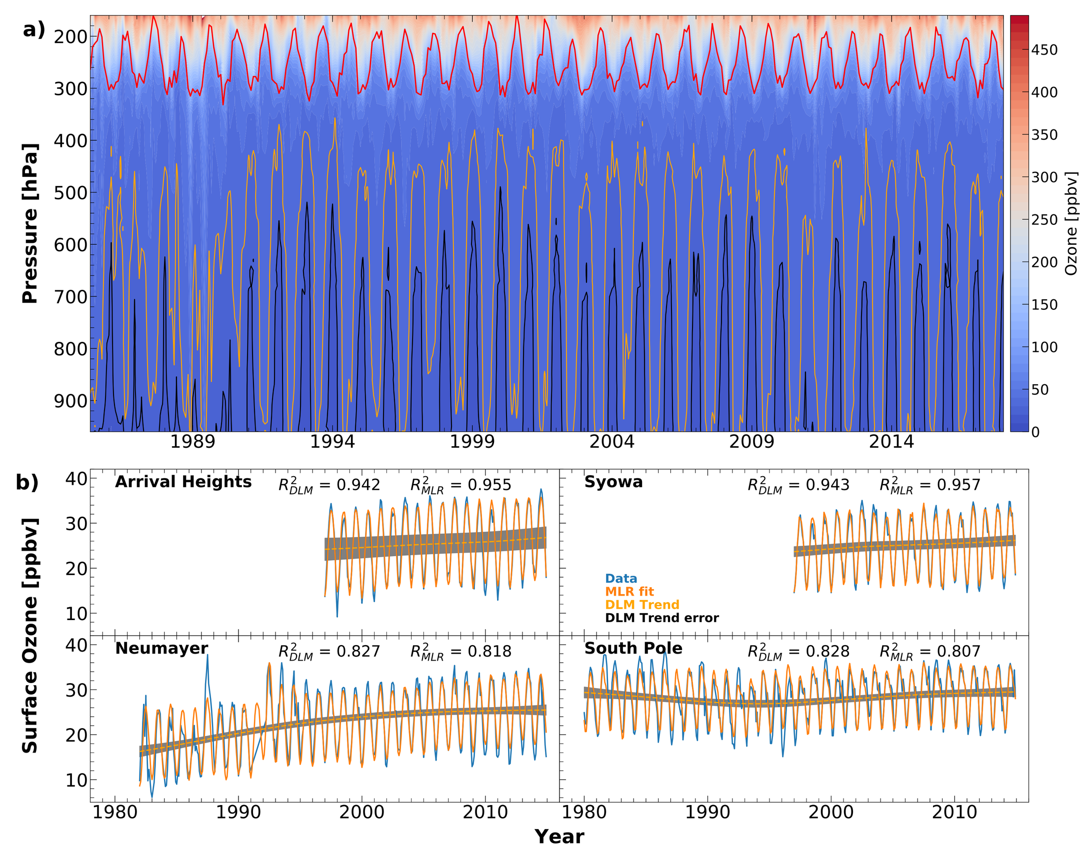

Figure 1: Timeseries of mean vertical ozone profile and surface ozone at different stations.

Research method

1. Self organising map based clustering of vertical ozone profiles [1].
2. 15 days backward trajectory with HYSPLIT.
3. Causal inference using PCMCI algorithm [2].
4. Estimation of long-term trend using simple and multivariate linear regression and Bayesian dynamic linear model [3].
5. Estimation of instantaneous radiative forcing (iRF) at the surface using RRTMG.

Ozone clustering and trajectory

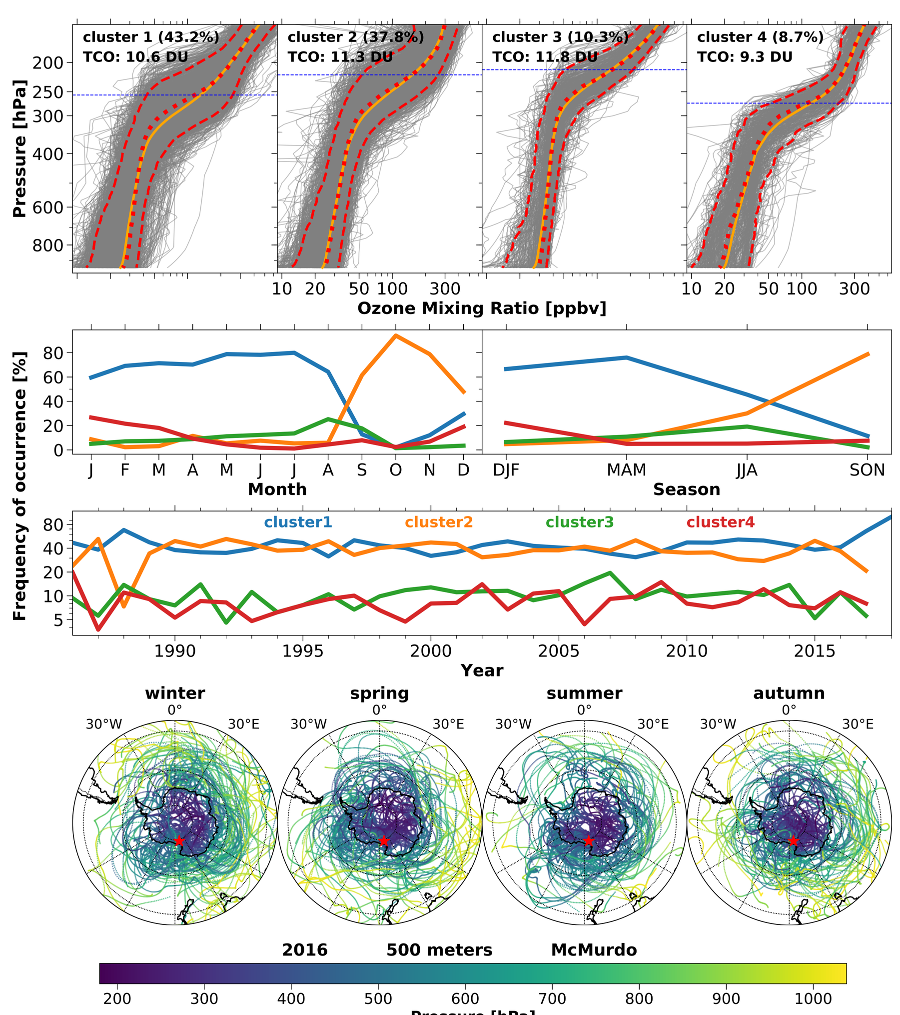

Figure 2: SOM based clusters of ozone profiles, monthly, seasonal and timeseries of frequency of occurrences of clusters and seasonwise backward trajectories for McMurdo station at 500 meters from ground level for 2016.

Causal inference

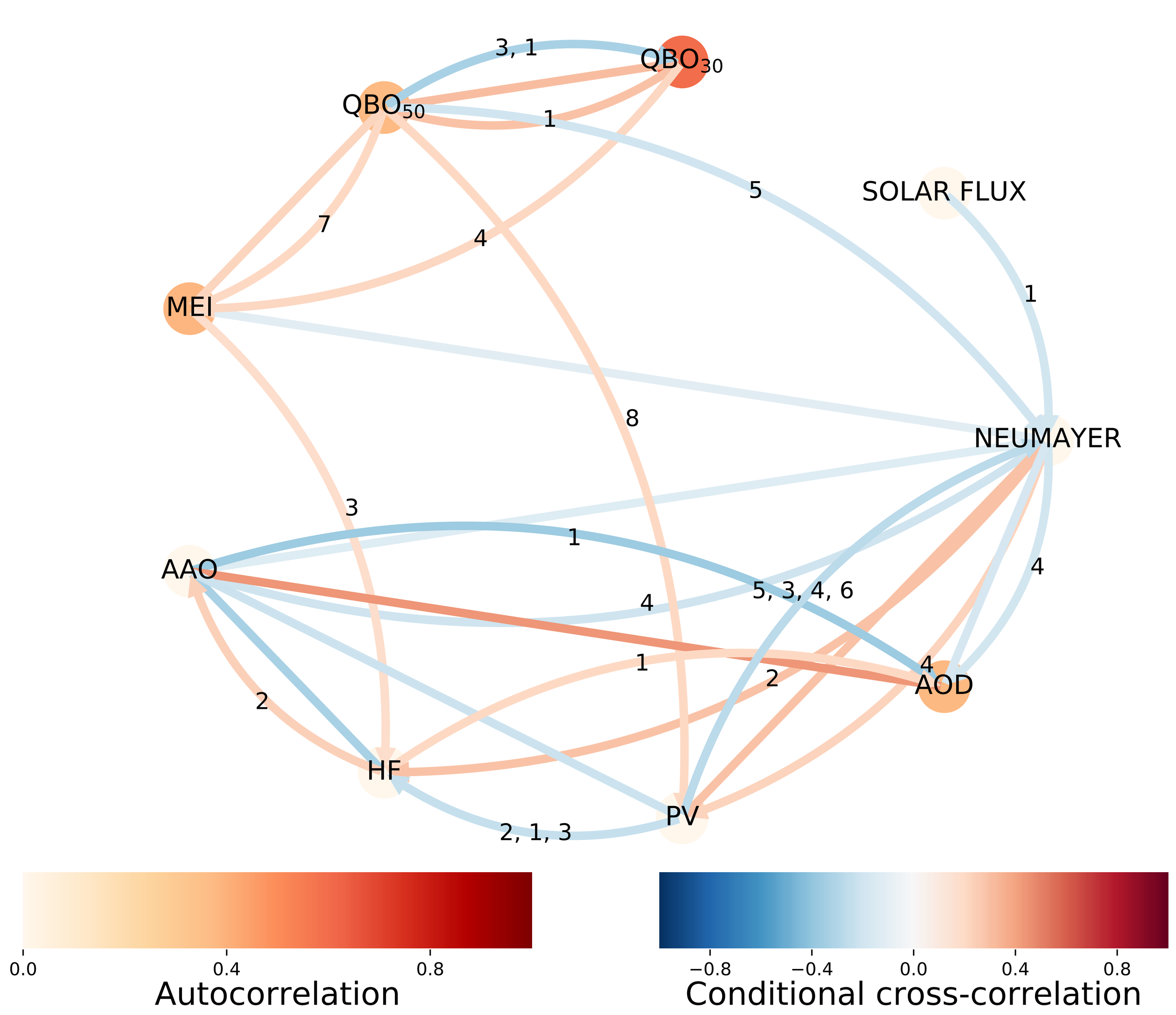

Figure 3: Causal graph for surface ozone at Neumayer.

Ozone trends

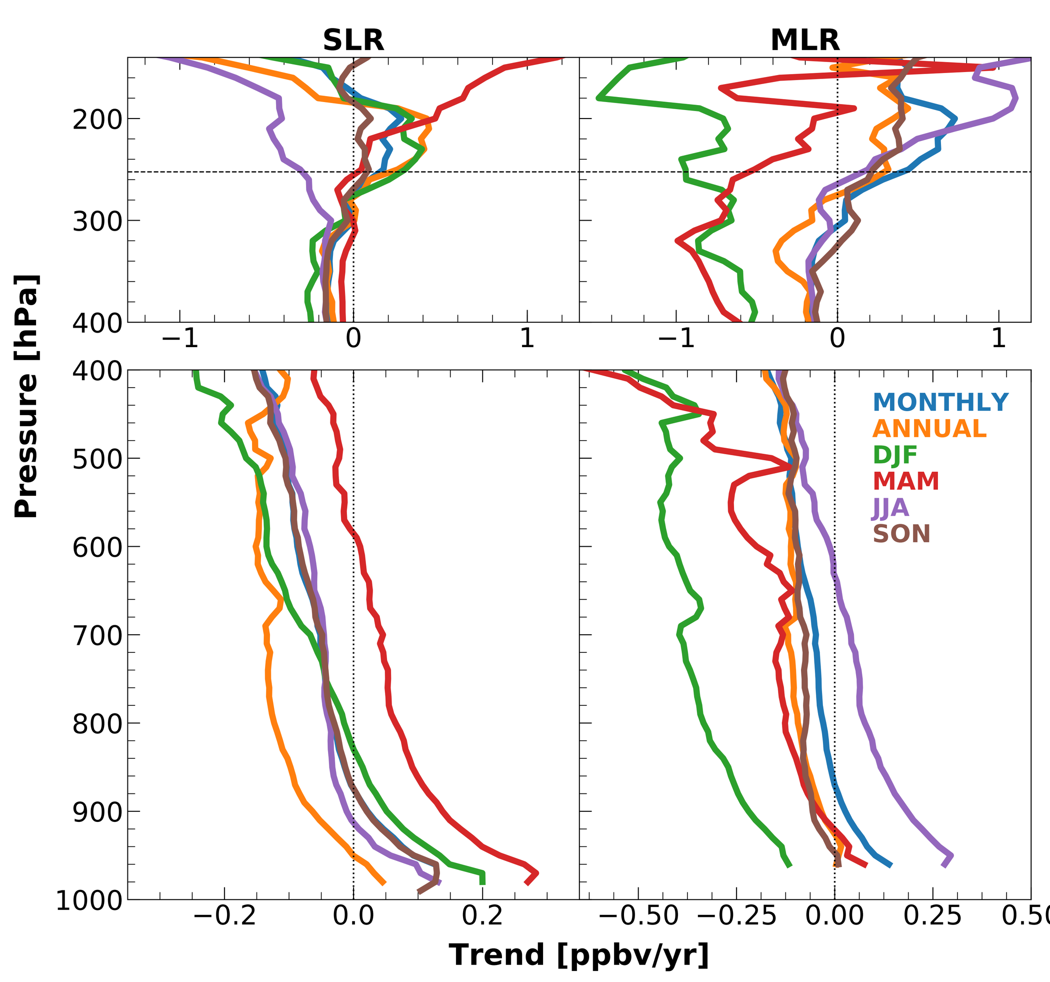

Figure 4: Vertical profile of ozone trend estimated using Simple and Multivariate linear regression.

Drivers and radiative forcing

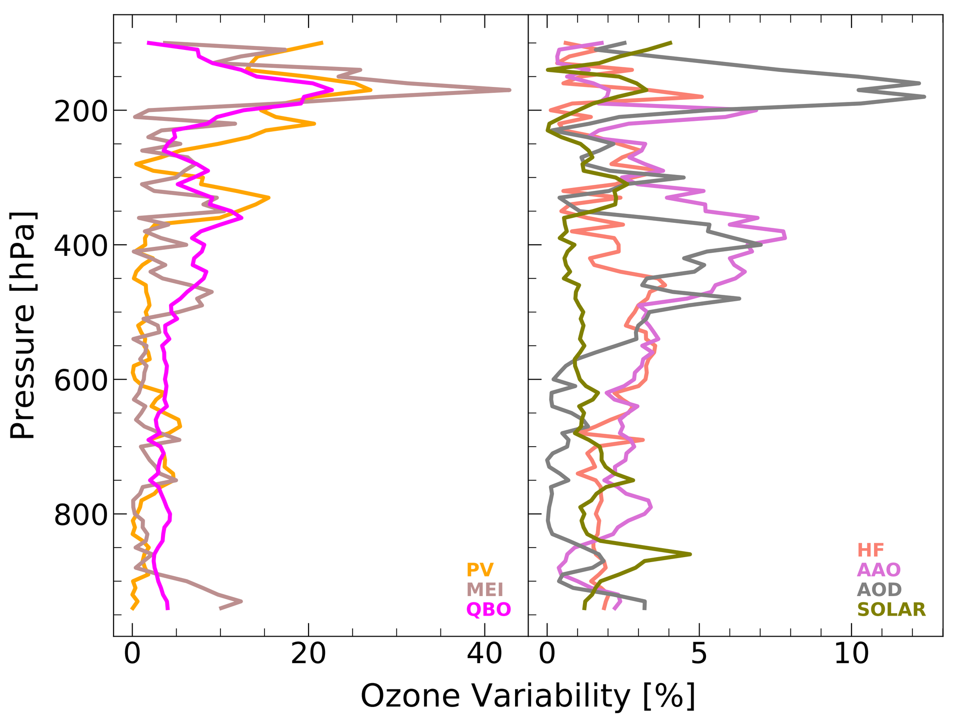

Figure 5: Contribution of different geophysical drivers to variability of ozone (% of standard deviation of ozone).

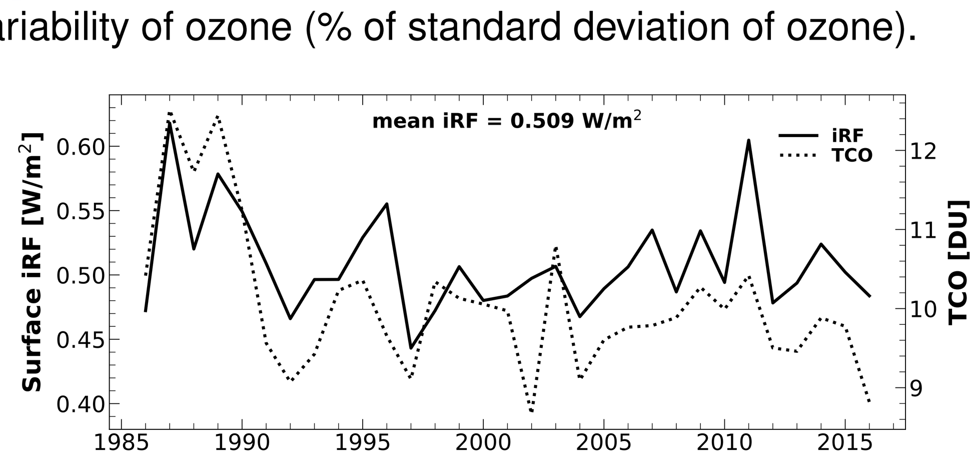

Figure 6: Annual mean timeseries of troposheric ozone column and corresponding instantaneous radiative forcing at the surface.

Conclusion

1. Changes in tropopause height modulated by polar vortex and meridional heat flux control the variations in ozone profile.
2. Long-term trend is positive in the lower troposphere and UTLS, but negative in mid-troposphere.
3. Various climate modes (ENSO, QBO and AAO) have strong influence on tropospheric ozone variability and long-term trend with the maximum contribution from QBO.
4. Tropospheric column ozone and surface instanteous radiative forcing due to tropospheric ozone decreased during 1986-1999, but it has been increasing since 2000 with the strongest increase during 2000-2011.
5. Changes in residual overturning circulation, strength of polar vortex and stratosphere-troposphere exchange induce significant variability in tropospheric ozone in Antarctica.

References

[1] STAUFFER, R. M. et al. Tropospheric ozonesonde profiles at long-term U.S. monitoring sites: 2. links between Trinidad Head, CA, profile clusters and inland surface ozone measurements. *Journal of Geophysical Research: Atmospheres*, 2017.

[2] RUNGE, J. et al. Identifying causal gateways and mediators in complex spatio-temporal systems. *Nature Communications*, 2015.

[3] LAINE, M. et al. Analysing time-varying trends in stratospheric ozone time series using the state space approach. *Atmospheric Chemistry and Physics*, 2014.

[4] KUTTIPPURATH, J. et al. Emergence of ozone recovery evidenced by reduction in the occurrence of Antarctic ozone loss saturation. *npj Climate and Atmospheric Science*, 2018.

[5] KUTTIPPURATH, J. et al. Accuracy of satellite total column ozone measurements in polar vortex conditions: Comparison with ground-based observations in 1979–2013. *Remote Sensing of Environment*, 2018.

pankaj.kmr1990@gmail.com