What causes the observed surface O_3-temperature relationship?

Effect of the eddy-driven jet on surface-level transport

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Key findings:

- The correlation between O_3 and temperature is strongly positive in the Northern Hemisphere mid-latitudes with insignificant correlations elsewhere
- Transport drives the O_3-temperature relationship
- The eddy-driven jet and its effect on transient cyclones play a major role in mid-latitude surface-level temperature and composition

Background and questions

There are reported differences in the sign and magnitude of the correlation coefficient calculated between ozone (O_3) and temperature, r (T, O_3), and the slope of O_3 versus temperature, dO_3/dT. Studies have largely focused on populated regions such as Eastern North America (e.g., Rasmussen et al. 2012), but there have not been studies of spatial variations of the O_3-temperature relationship across the globe.

→ **What is the O_3-temperature relationship across the Northern Hemisphere?**

→ **What processes control spatial variations in the O_3-temperature relationship?**

Data and methods

Modeled O_3: NASA's Global Modeling Initiative chemical transport model (GMI CTM) simulations (1° lat x 1.25° lon) with daily variations in temperature-dependent chemistry and emissions and without these variations ("transport-only simulation")

Temperature: Daily maximum 2-meter temperature (0.5° x 0.625°) from MERRA-2 data

Eddy-driven jet: Defined as the latitude of maximum 500 hPa U-wind (0.5° x 0.625°) from hourly MERRA-2 data

Observed O_3: Hourly, station-based observations derived from the Air Quality System (United States), National Air Pollution Surveillance (Canada), and European Monitoring the Evaluation Programme networks

Cyclones: Extratropical cyclone center locations from the MAP Climatology of Mid-latitude Storminess database

Our analysis focuses on the Northern Hemisphere (with an emphasis on the mid-latitudes) for JJA 2008-2010.

Hourly data are sampled during the early afternoon (1300-1400 hours local time).

Statistical significance of r (T, O_3) is evaluated with a two-sided Student's t-test for autocorrelated data.

Spatial variations of the O_3-temperature relationship

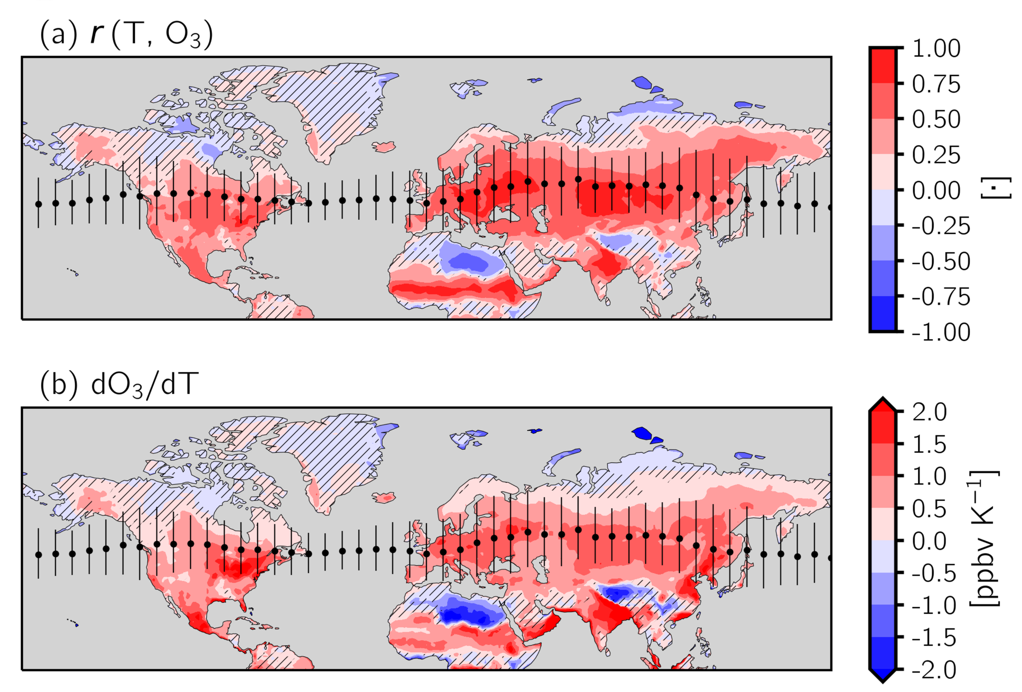

Fig. 1. The modeled O_3-temperature relationship expressed in terms of **(a)** r (T, O_3) and **(b)** dO_3/dT. Hatched regions in **(a-b)** indicate significance with α = 0.05. Error bars show the mean latitude and variability of the jet.

Temperature and O_3 are significantly positively correlated in the mid-latitudes, and elsewhere the correlations are insignificant or significantly anticorrelated (**Fig. 1a**).

The latitudinal gradient of the observed values of r (T, O_3) across four regions in the Northern Hemisphere supports the simulated values from the GMI CTM (**Fig. 2**).

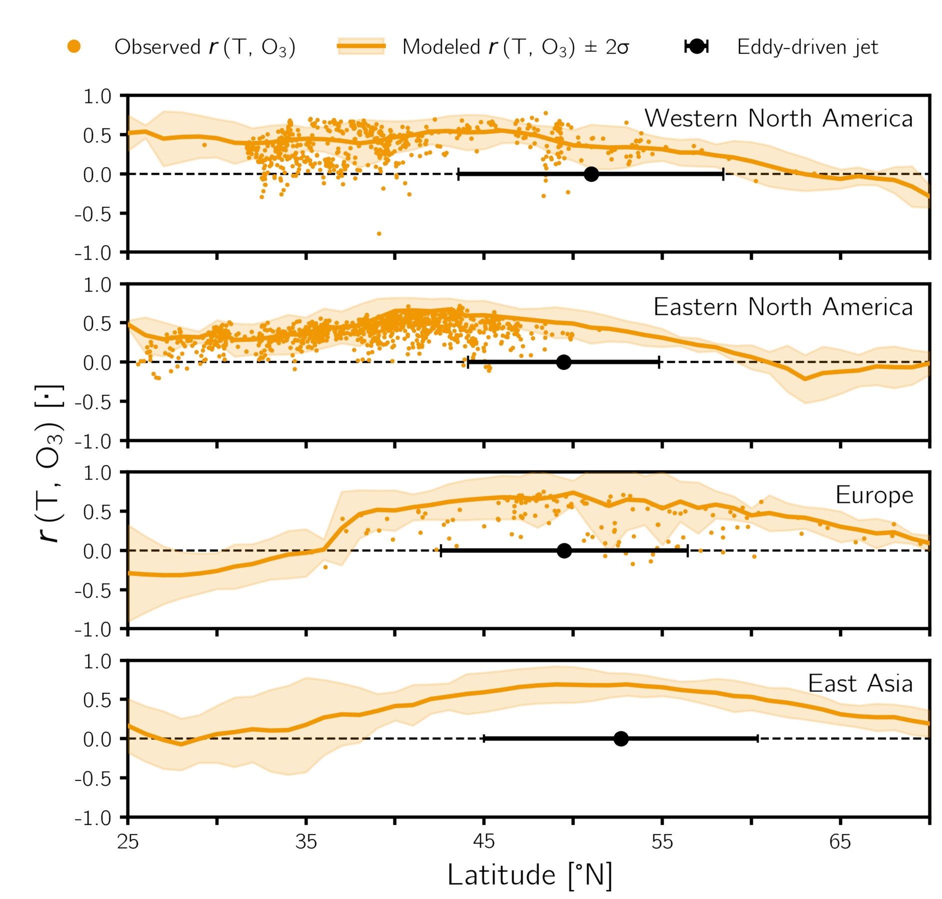

Fig. 2. Observed and zonally-averaged modeled r (T, O_3) over four continental regions indicated in the panels. The dashed grey lines delineates positive from negative values of r (T, O_3). The scatter points and error bars show the the jet latitude and its variability.

Kerr et al. (2019) demonstrated that transport, not chemistry or emissions, controls the O_3-temperature relationship on daily timescales in the United States.

The transport-only simulation shows that transport drives the O_3-temperature relationship, shown in terms of r (T, O_3) in **Fig. 3**, across the Northern Hemisphere.

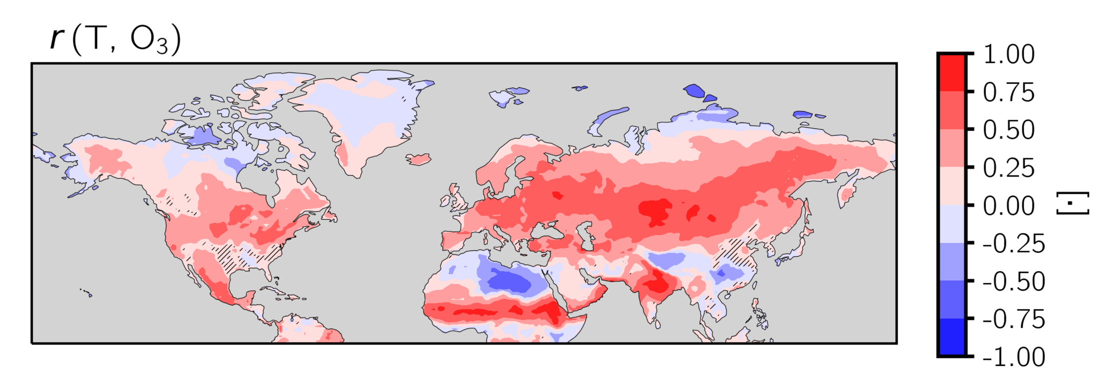

Fig. 3. r (T, O_3) from the transport-only GMI CTM simulation. Hatching denotes regions where significant correlations in **Fig. 1a** became insignificant in the transport-only simulation.

Role of the eddy-driven jet

Surface O_3 variability and r (T, O_3) have been linked to the eddy-driven jet stream latitude over Eastern North America (e.g., Barnes and Fiore 2013; Shen et al. 2015).

We find that r (T, O_3) peaks at the latitude of the jet across the Northern Hemisphere (**Fig. 1**).

Regardless of whether the jet is in a poleward (PW) or equatorward (EW) position, above-average O_3 concentrations reside south of the jet and below-average concentrations north of the jet (**Fig. 4**).

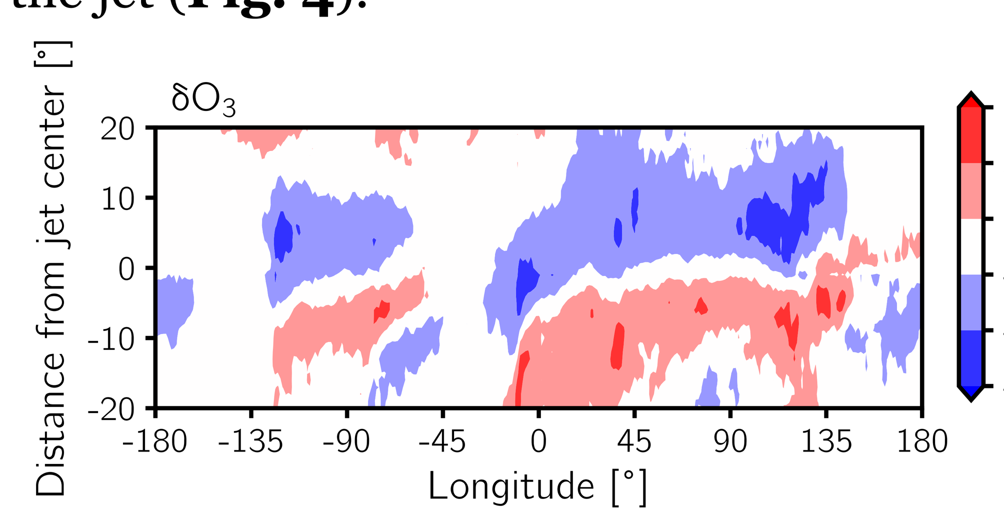

Fig. 4. The mean O_3 anomaly in the vicinity of the jet, calculated as the difference in O_3 between daily O_3 at the grid cell corresponding to the distance and longitude indicated and the climatological mean at that grid cell.

Jet-cyclone relationship

The movement of the jet impacts surface-level temperature and O_3 by altering cyclone tracks (Leibensperger et al. 2008).

The frequency of surface-level cyclones shifts with changes in the jet latitude (**Fig. 5a**), meaning that there are fewer cyclones EW of the jet if the jet is PW. This, in turn, increases O_3 and temperature EW of the jet (**Fig. 5b-c**).

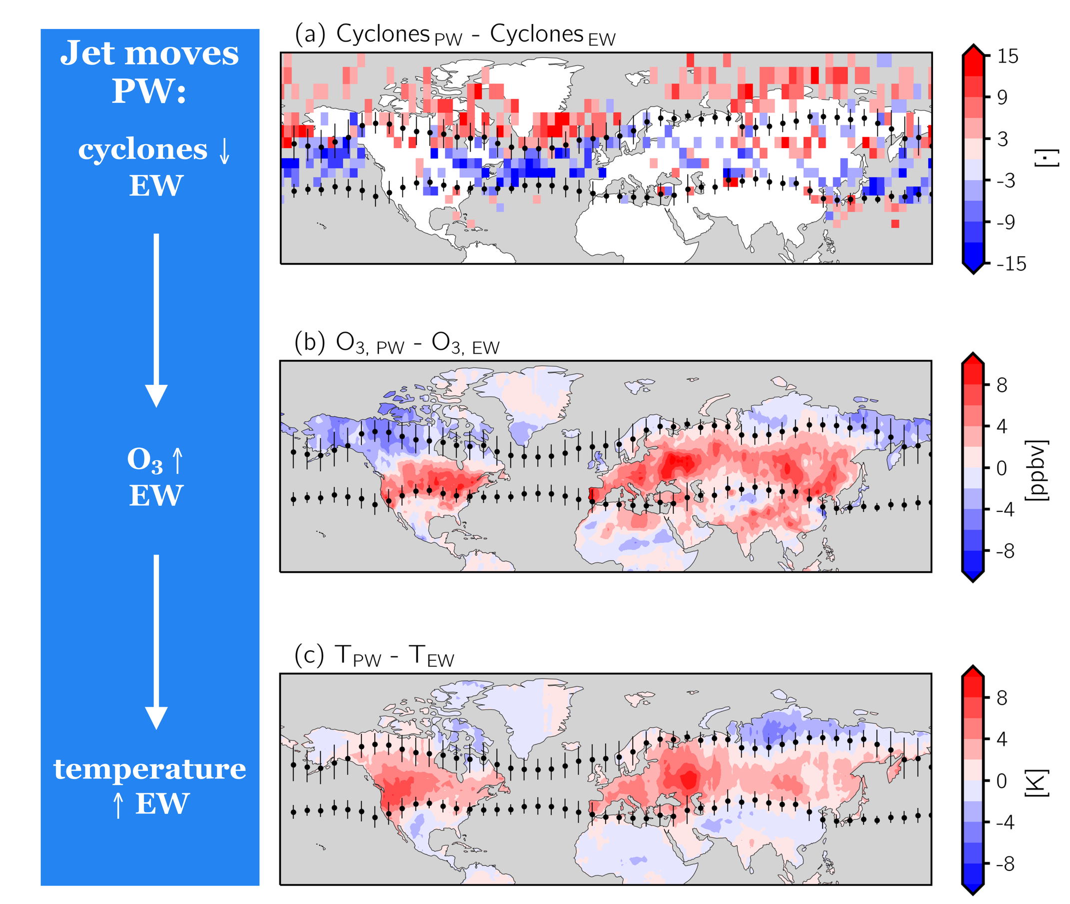

Fig. 5. Difference in **(a)** cyclone frequency, **(b)** O_3, and **(c)** temperature for days with PW and EW jets. The mean latitude and variability of PW and EW jets are shown for reference.

Regions within the range of the jet that obey the flow diagram shown alongside **Fig. 5** have r (T, O_3) > 0.

Future work will better understand the O_3-temperature relationship outside of the mid-latitudes and the effects of cyclones and their impact on ventilation.

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