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Supplement of

Insights into the chemical and physical drivers of surface ozone in the Trans-Himalaya

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Sect. S1: Formulae of O_3 exposure indices

- MDA8 (μgm^{-3}) = $max(\frac{1}{8}\sum_{j=i}^{i+7}[O_3]_j)$ where, *j*=0, 1, …, 23 h
- M7 (ppbv) = $\frac{1}{n}\sum_{i}^{n}[O_3]_i$, for 09:00–15:59 h
- AOT40 (ppm h) = $\sum_{i}^{n}([O_3]_i - 40) \times \Delta t, if\ [O_3]_i \geq 0.04\ ppmv$ for 07:00–17:59 h (Δt=1 h as hourly averaged O_3 is used)
- SUM06 (ppm h) = $\sum_{i}^{n}[O_3]_i \times \Delta t, if\ [O_3]_i \geq 0.06\ ppmv$ for 07:00–17:59 h (Δt=1 h as hourly averaged O_3 is used)
- W126 (ppm h) = $\sum_{i}^{n}(\frac{[O_3]_i}{1+4403exp\ (-0.126\times[O_3]_i)}) \times \Delta t, if\ [O_3]_i > 0\ ppmv$ for 07:00–17:59 h (Δt=1 h as hourly averaged O_3 is used)
- OSDMA8 = Annual maximum of 6-month running mean of MDA8

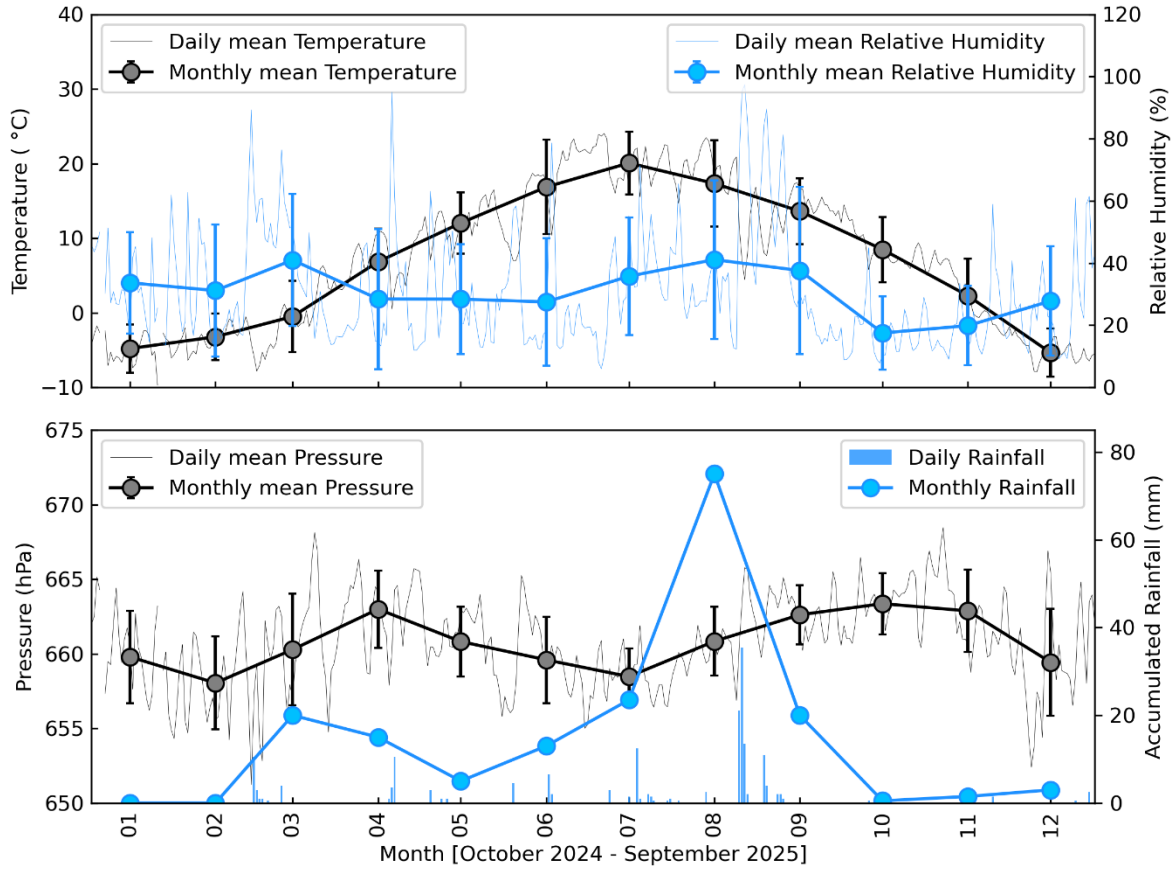


Figure S1: Temporal variation of meteorological parameters (daily and monthly) at Leh town over the study period.

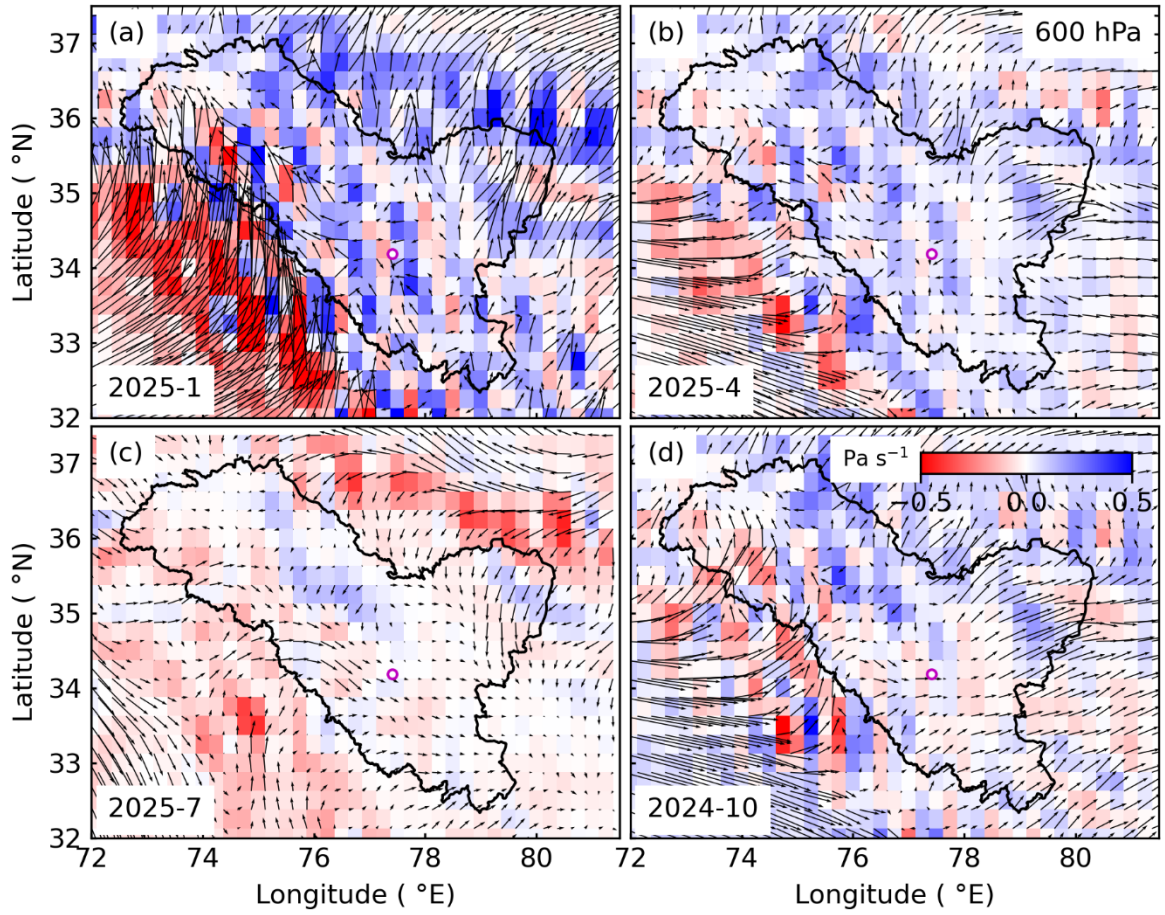


Figure S2: Synoptic winds at 600 hPa for different months representing different seasons. Magenta circle depicts the study site. Background colour map shows vertical wind (Pa s^{-1}).

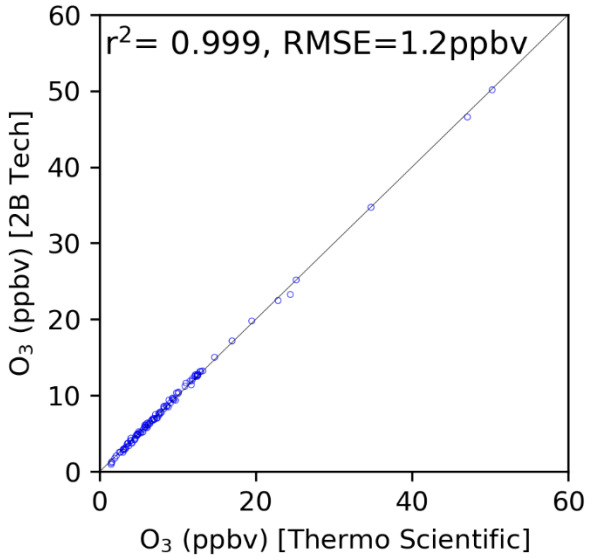


Figure S3: Comparison of O_3 measured from 2B Tech and Thermo Scientific analyser operated through single inlet in ambient conditions.

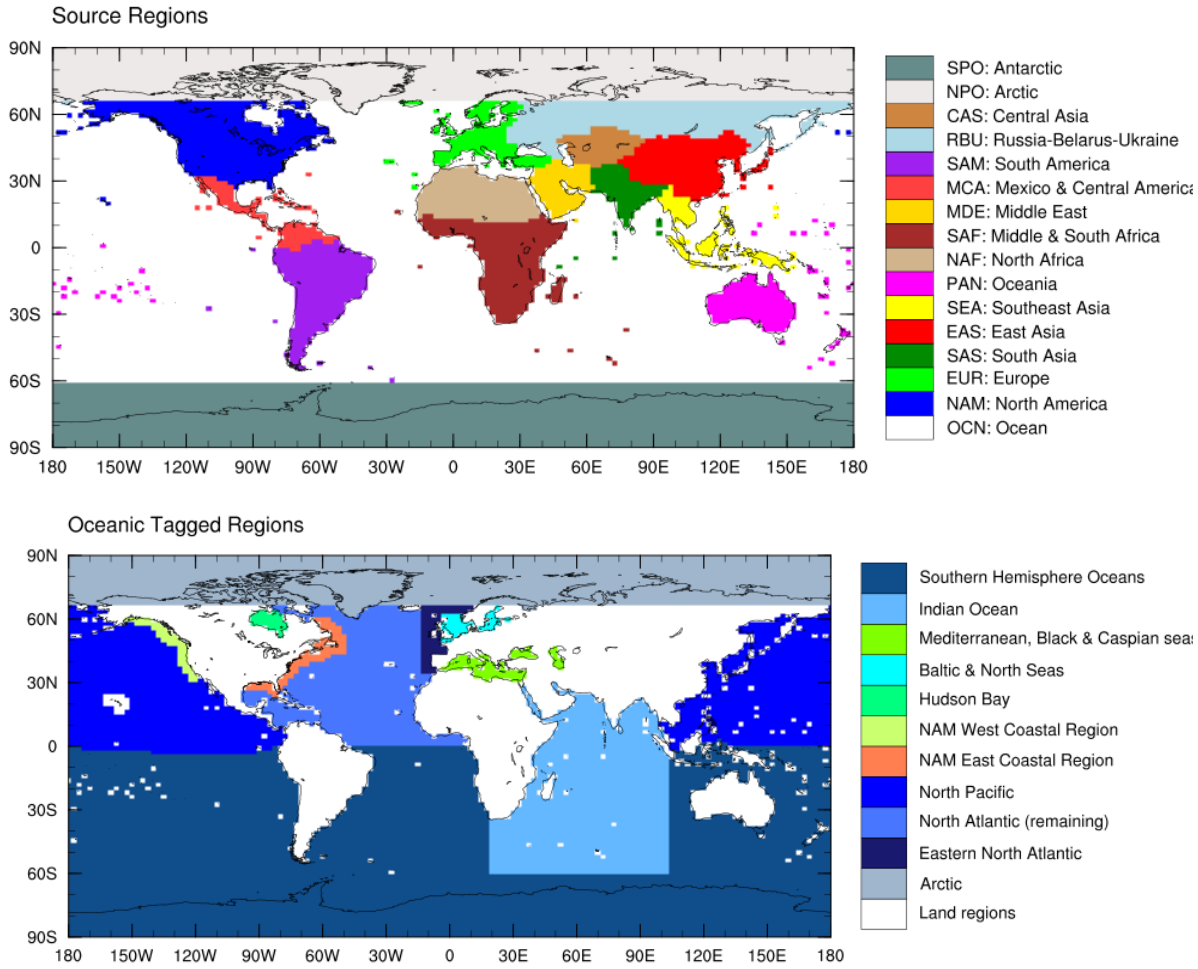


Figure S4: Different source regions as defined for the CAM4-Chem simulations. The land-based (top panel) and oceanic regions (bottom panel) are shown separately to avoid too much cluttering in a single figure. The definitions of land regions are corresponding to the HTAP (Hemispheric Transport of Air Pollution) tier 1 regions.

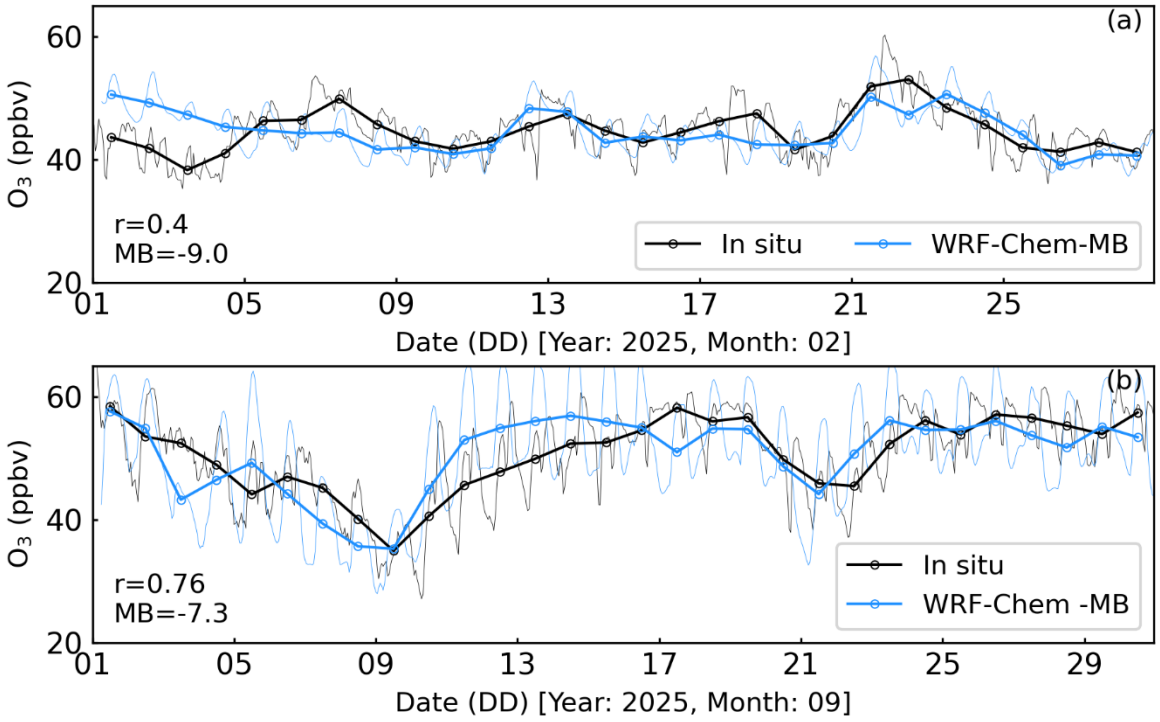


Figure S5: Comparison of WRF-Chem simulated O_3 with the measurements over the study region. While thin lines represent hourly values, thick lines with scatter represent daily mean. Correlation coefficient, r and mean bias (MB) are corresponding to daily mean.

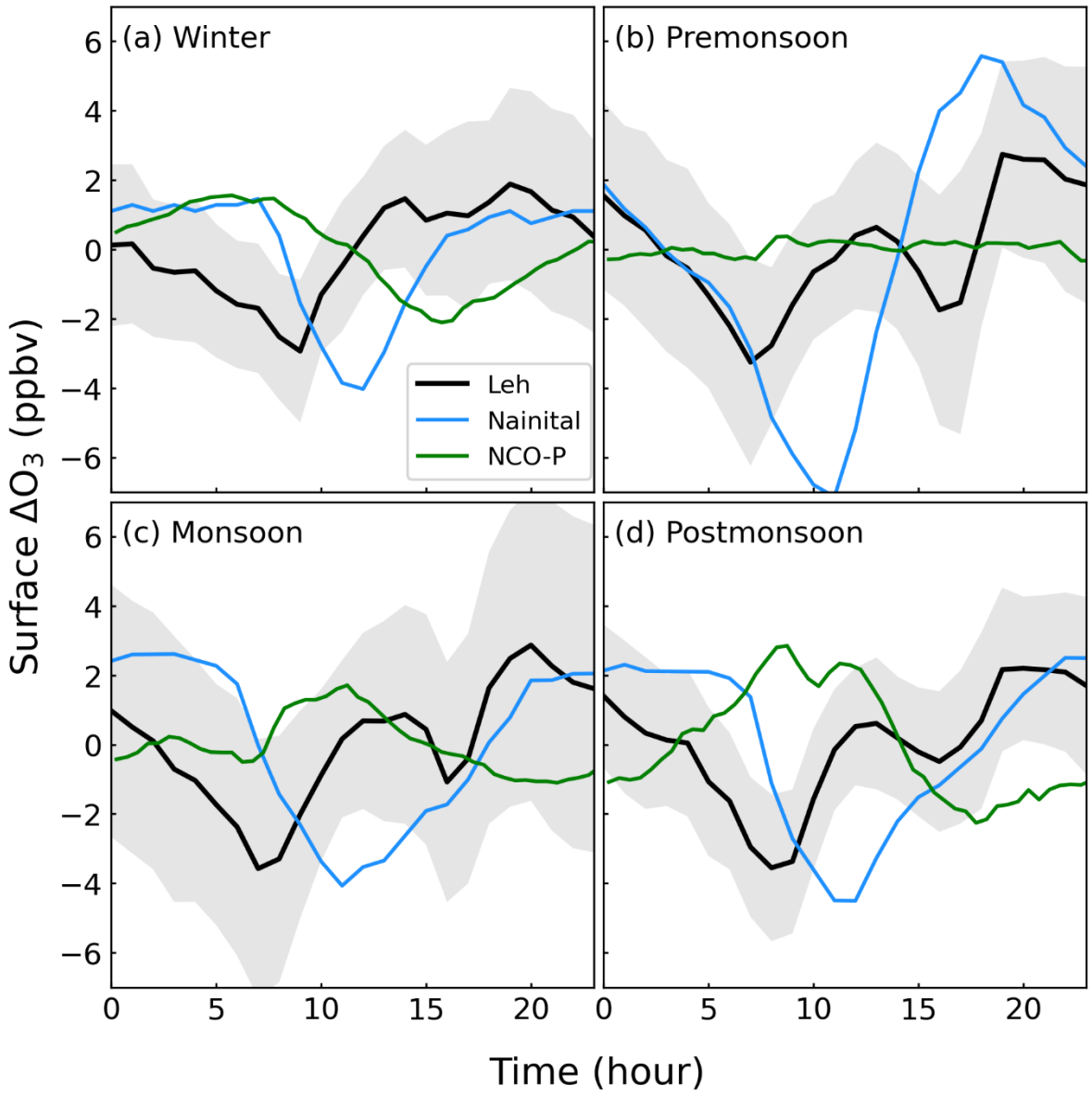


Figure S6: Mean diurnal pattern of ΔO_3 at the study site (black) for different seasons: Winter (DJF—December-January-February), premonsoon (MAM—March-April-May), monsoon (JJAS—June-July-August-September), postmonsoon (ON—October-November). The shaded region represents standard deviation. Diurnal variations observed at cleaner high-altitude sites, Nainital (1.9 km amsl) and NCO-P (5 km amsl), are also shown (Sarangi et al., 2014; Cristofanelli et al., 2010). Post-noon enhancement seen at Nainital during premonsoon season could be due to the influence of transport from an elevated regional boundary layer over nearby IGP (Indo Gangetic Plain) region.

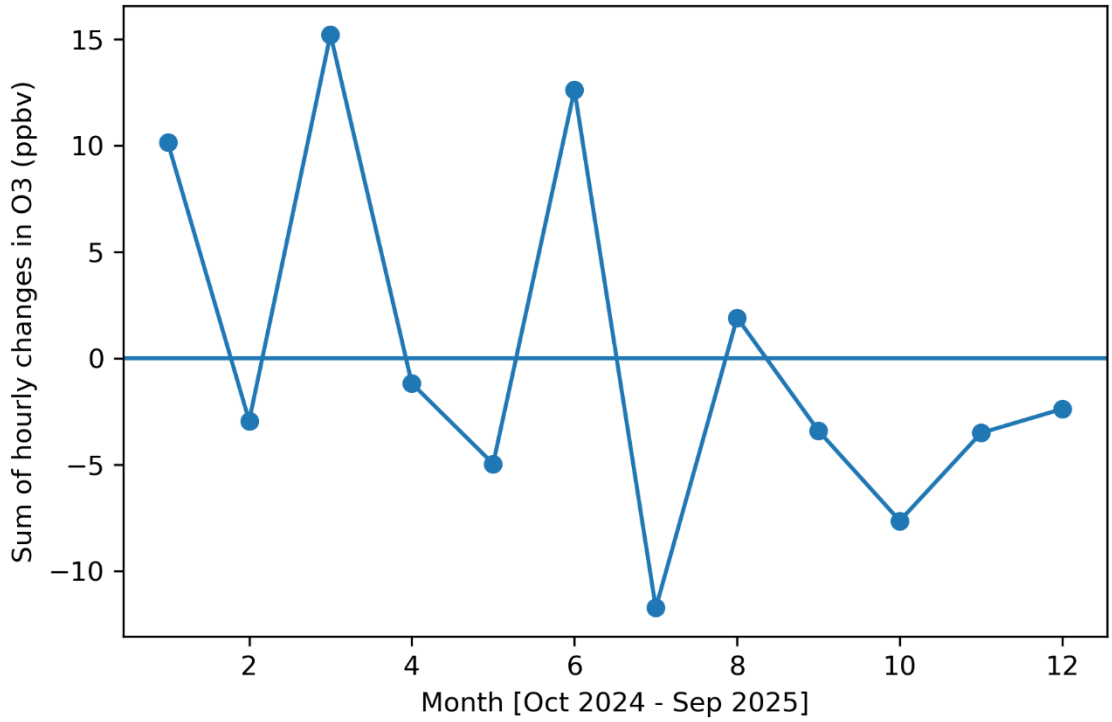


Figure S7: Sum of hourly change in observed O_3 over the study region.

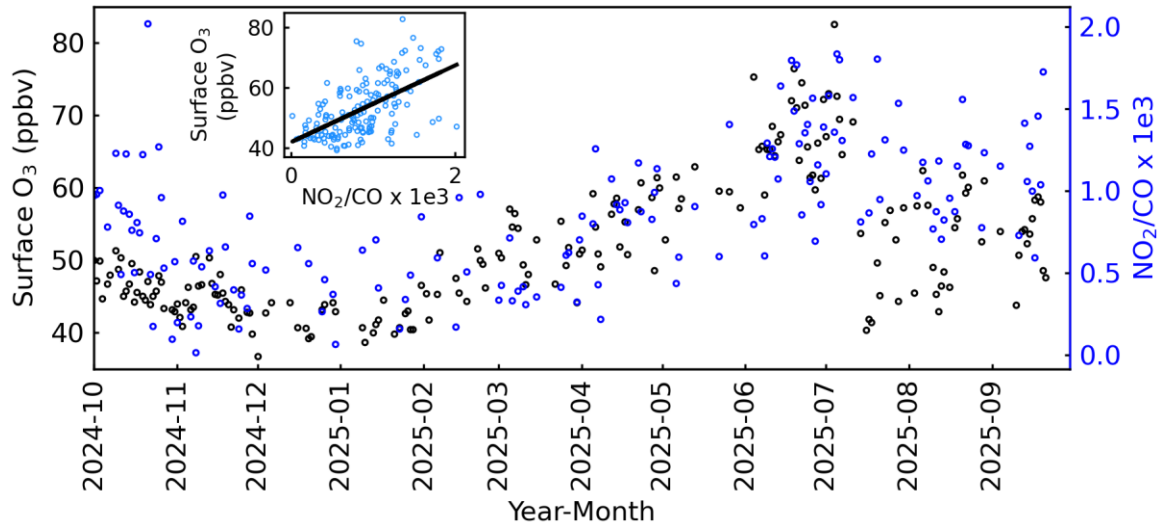


Figure S8: Variations of surface O_3 and ratio of NO_2/CO from TROPOMI over the study region. Inset shows the linear association of O_3 with NO_2/CO.

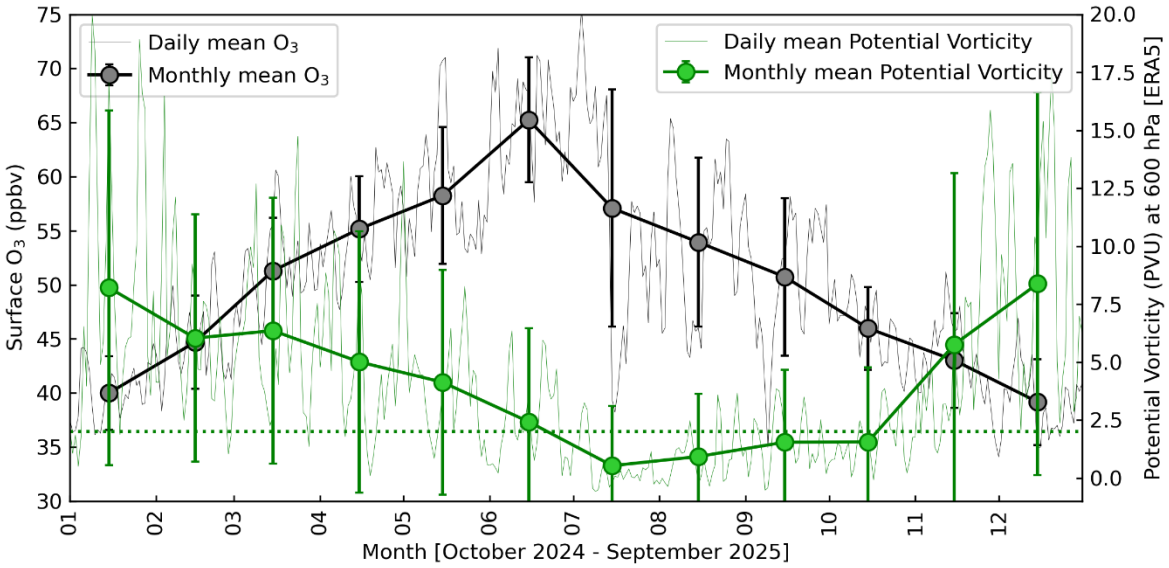


Figure S9: Variations of surface O_3 and potential vorticity (PVU =10^{-6} K kg^{-1} m^2 s^{-1}) at 600 hPa at study site. The dotted green line suggests 2 PVU, above which air is considered to be stratospheric.

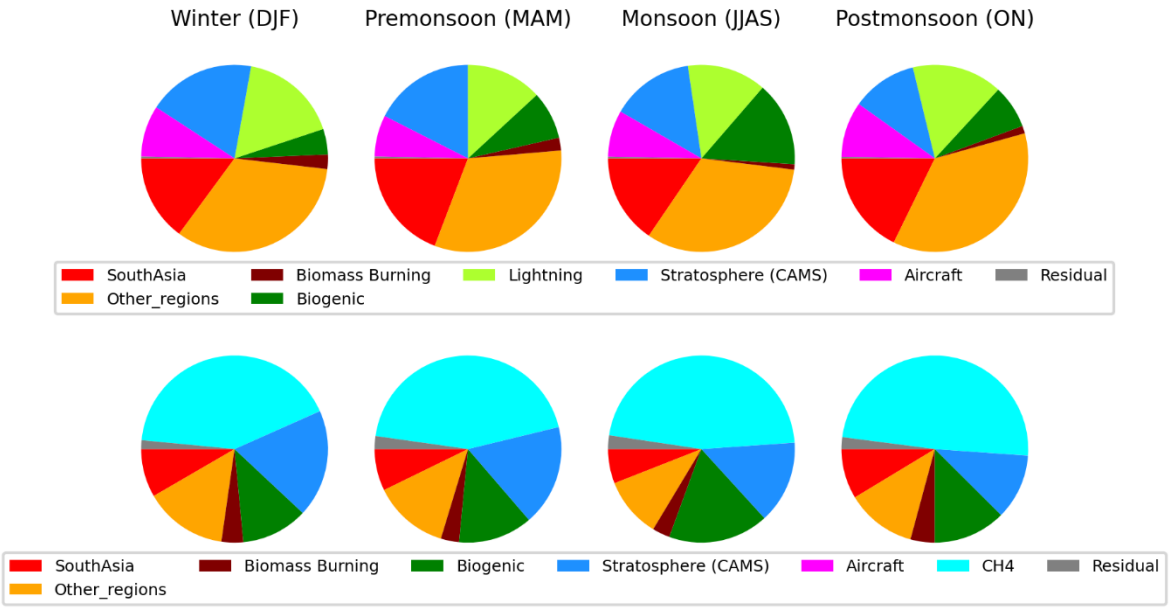


Figure S10: Contribution of various sources to surface O_3 over the study region based on NO_x (top panel) and VOC (bottom panel) tagging in the CAM4-Chem model simulations.

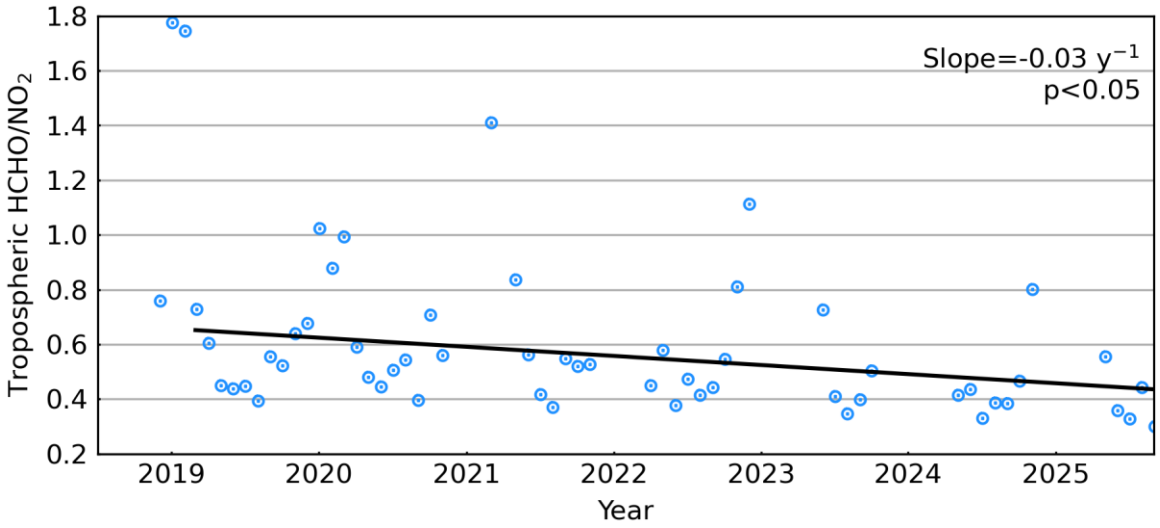


Figure S11: Monthly mean ratio of tropospheric HCHO/NO_2 over Leh region (77.41°–77.70° E; 34.08°–34.23° N) during 2018–2025. Note that the initial three points are excluded in the linear fit (black line) as two of them appear to be outliers with very high values of 1.7–1.8.

Table S1: Various emission tags used in the CAM4-Chem simulations.

Regional land-based tags	**Regional oceanic tags**	**Process-based tags for global sector**
Central Asia	Arctic	Aircraft
East Asia	Eastern North Atlantic	Biogenic
Europe	North Atlantic (remaining)	Biomass Burning
Mexico and Central America	North American East-Coastal zone	Lightning
Middle East	North American West-Coastal zone	Stratosphere
North Africa	North Pacific	
North America	Baltic and North Seas	
Russia-Belarus-Ukraine	Hudson Bay	
South Asia	Indian Ocean	
Southeast Asia	Mediterranean, Black, and Caspian Seas	
Rest of the world	Southern Hemisphere Oceans	

Table S2: Monthly mean O_3 along with standard deviation observed at Leh.

Month	**Mean O_3 (ppbv)**	**Standard deviation (ppbv)**
Oct-2024	46.0	3.8
Nov-2024	43.0	4.4
Dec-2024	39.2	4.0
Jan-2025	40.0	3.4
Feb-2025	44.7	4.3
Mar-2025	51.3	4.9
Apr-2025	55.2	4.9
May-2025	58.3	6.3
Jun-2025	65.2	5.8
Jul-2025	57.1	11.0
Aug-2025	53.9	7.8
Sep-2025	50.7	7.3