Seasonal variation of short-lived climate forcers/pollutants at Paknajol, an urban area in the city of Kathmandu, Nepal

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Background

Air pollution is a major environmental challenge in South Asia, which is facing severe air-quality issues related to the presence of a large and widespread thick layer of atmospheric pollutants (the Atmospheric Brown Cloud). The **short-lived climate forcers/pollutants** (**SLCF/P**), such as black carbon and ozone, play a crucial role for what concerns the human health and the regional climate. The Kathmandu Valley in South Asia is currently considered as one of the "hot spots" in terms of air quality, with a total population greater than 2.5 million. In this work, we present one full year of measurements (February 2013 – January 2014) of black carbon (eqBC) and ozone (O_3), as well as aerosol concentration and mass, carried out at **Paknajol (27°43'4''N, 85°18'32''E; 1380 m a.s.l.)**, **an urban area in the tourist district of Thamel, Kathmandu**. The information gathered during the investigation period paint a picture of the state of air quality in Kathmandu and may be useful to implement control measurements in order to mitigate the occurrence of high pollution levels in the Kathmandu Valley.

Measurement site and experimental set-up

Figure 1. View from Paknajol site.

Measurements at Paknajol were started in February 2013,in the framework of the SusKat-ABC field campaign.

Measurement programs:

- surface O_3 (UV-absorption analyser, Thermo 49i)
- equivalent **black carbon** (eqBC, multi-angle absorption photometer – Thermo MAAP 5012)
- meteorological parameters (VAISALA WXT520)
- aerosol number concentration and size distribution (**accumulation** and **coarse** fractions, optical particle counter – FAI Instruments OPC Monitor)
- on-line 24-h resolution **PM_{10}-PM_1** (FAI Instruments SWAM, β-absorption technique)

The sampling site is placed on the top of a building (25 m a.g.l.), having a 360° free horizon in a range of 300 m. Measurements at Paknajol are representative of the Kathmandu urban hot-spot.

Results (1): diurnal cycles

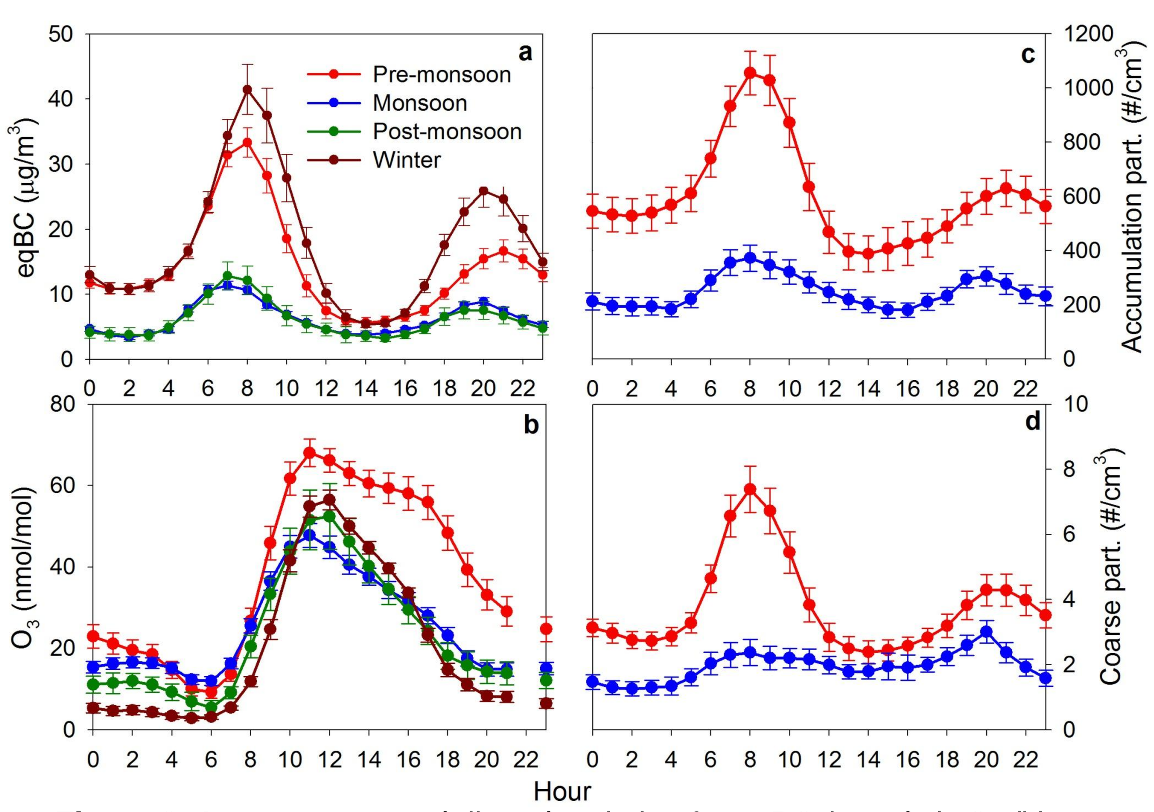


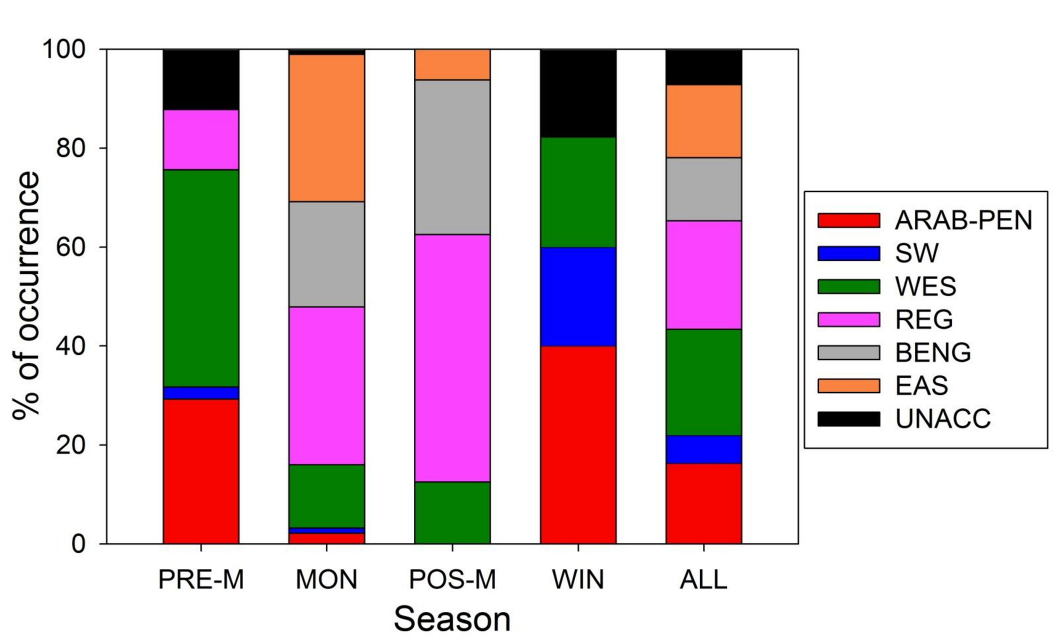
Figure 2. Average seasonal diurnal variation for eqBC (panel a), O_3 (b), accumulation and coarse particle number (c and d, respectively).

Aerosol observations had well-defined seasonal cycles, with low values during the monsoon and the highest in winter. **Diurnal cycles were strongly influenced by local sources and PBL dynamic.**

For **O_3**, the highest values were observed in the pre-monsoon, while the lowest during the summer monsoon. The **diurnal cycle** was characterized by a afternoon-evening peak, deriving from the roles of **photochemistry, PBL dynamics and wind breeze.**

Sensitivity tests using a recurrent neural network model and different subgroups of proxies suggested that the **afternoon-evening high O_3 values during pre-monsoon** were mainly due to dynamical aspects (vertical intrusion from upper layers and/or horizontal advection), while the early-morning and noon-peak mixing ratios were mainly explained by photochemistry activity.

Results (2): influence of large-scale circulation



To investigate the variability of **large-scale atmospheric dynamics**, 5-days HYSPLIT back-trajectories have been calculated at 00, 06, 12 and 18 UTC.

6 prevalent circulation patterns have been identified (Arabian Peninsula, South-westerly, Western, Regional, Bay of Bengal, Eastern).

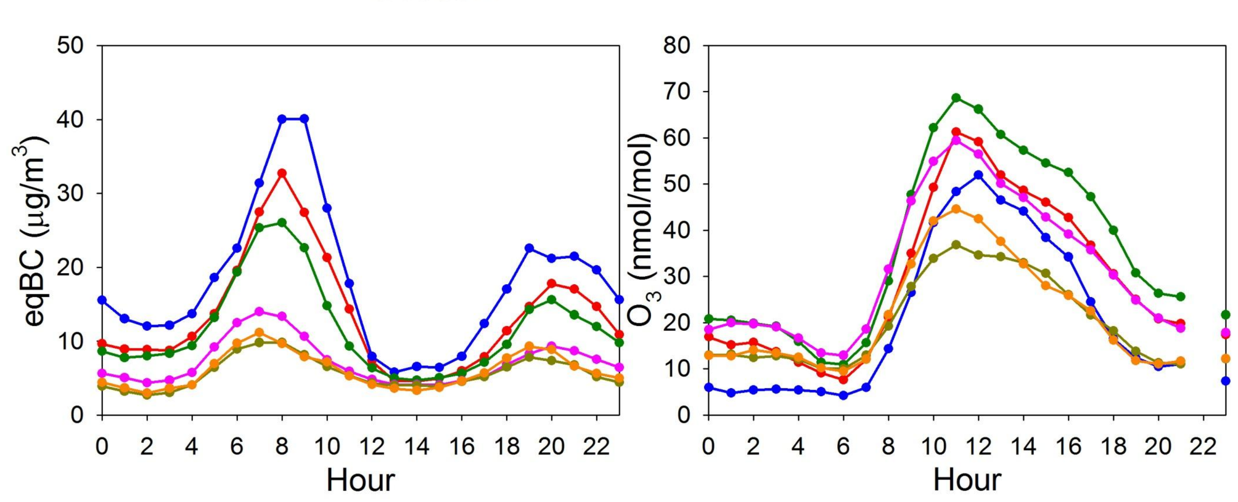


Figure 3. Percentage of occurrence of the 6 different back-trajectory clusters, divided by season (top) and diurnal variation of eqBC and O_3, as a function of the different clusters (bottom).

The diurnal variations of eqBC and O_3 have been analyzed as a function of the different clusters. For eqBC, the diurnal variation was only in part dependent on the air-mass patterns, while O_3 showed significant differences also for what concerns the shape of the diurnal variation curves and the magnitude of daily maximum and minimum values.

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Results (3): influence of major open fires

The possible impact of **large vegetation fires** has been assessed by analyzing MODIS fire events occurring in a well-defined region, roughly corresponding to Nepal. Enhanced O_3 diurnal cycles were observed when large open fires affected this region (37 days).

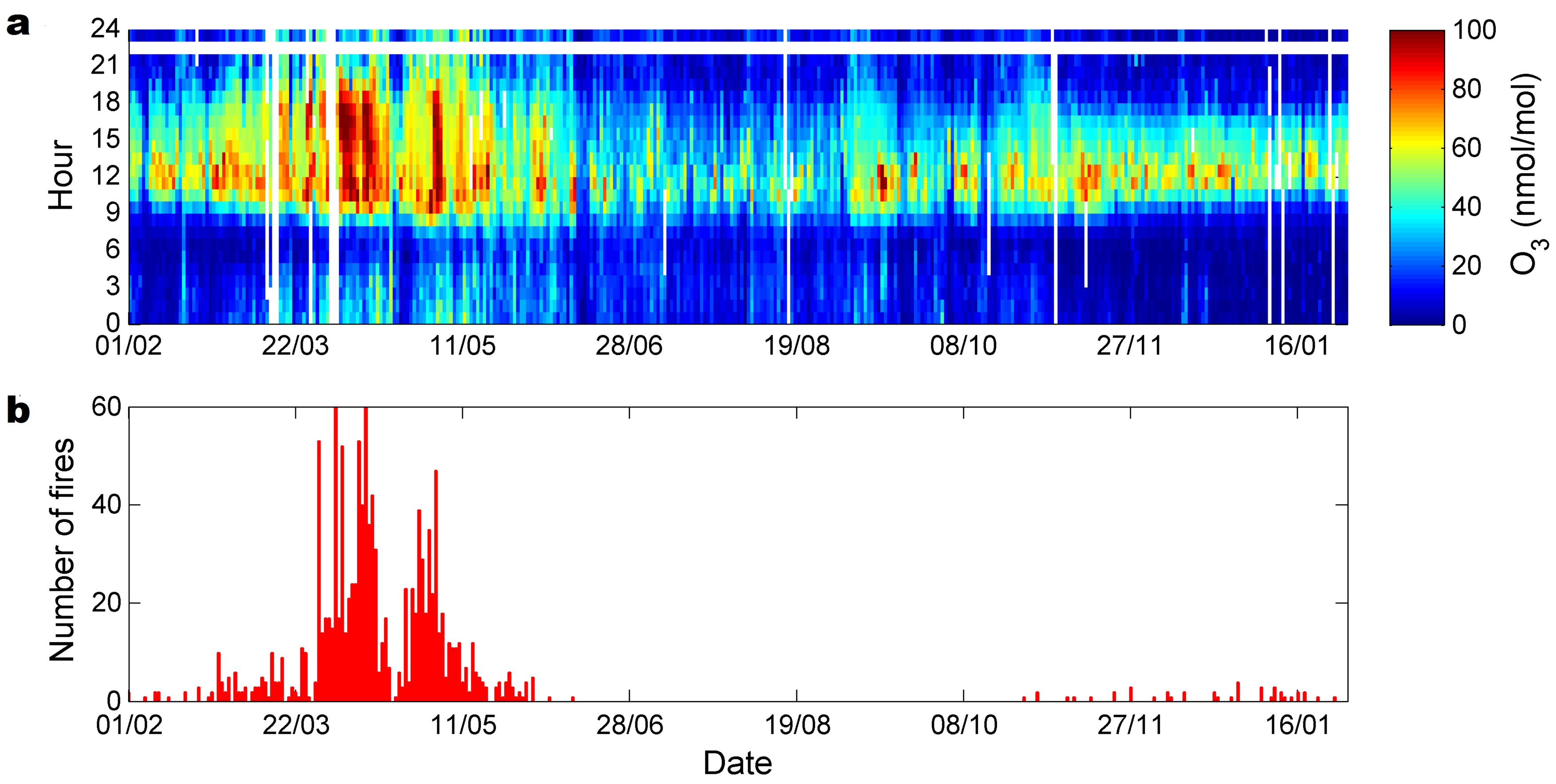

Figure 4. O_3 (panel a) diurnal variation over the entire sampling period, and the number of fires by MODIS (b) for the box [26,30]x[80,88].

Conclusions

- Very high values of SLCF/P characterized the whole measurement period, indicating the persisting poor air quality conditions in Kathmandu
- **124 days (51.4% of the investigation period) exceeded** the 24-h limit of 120 µg/m³ proposed by the Government of Nepal
- **138 days (38.5% of the dataset) exceeded the Interim Target-1, IT-1 (maximum daily 8-hour average >160 µg/m³) and Air Quality Guidelines, AQG (maximum daily 8-hour average >100 µg/m³) thresholds** defined by WHO for O_3
- The variations in the eqBC, O_3 and aerosol particle number concentrations were mainly driven by local pollution sources activity (road traffic, domestic emissions, biomass burning), and by local and large-scale dynamics and photochemistry
- Major vegetation fires significantly contributed to the enhanced O_3 levels, especially during the pre-monsoon season: by neglecting days with large open fire occurrences, all the IT-1 exceedances for O_3 were removed and 88 AQG exceedances were retained
- The large-scale circulation impacts the SLCF/P diurnal cycle
- Implementation of control measures to mitigate the occurrence of acute pollution levels in the Kathmandu Valley is highly needed

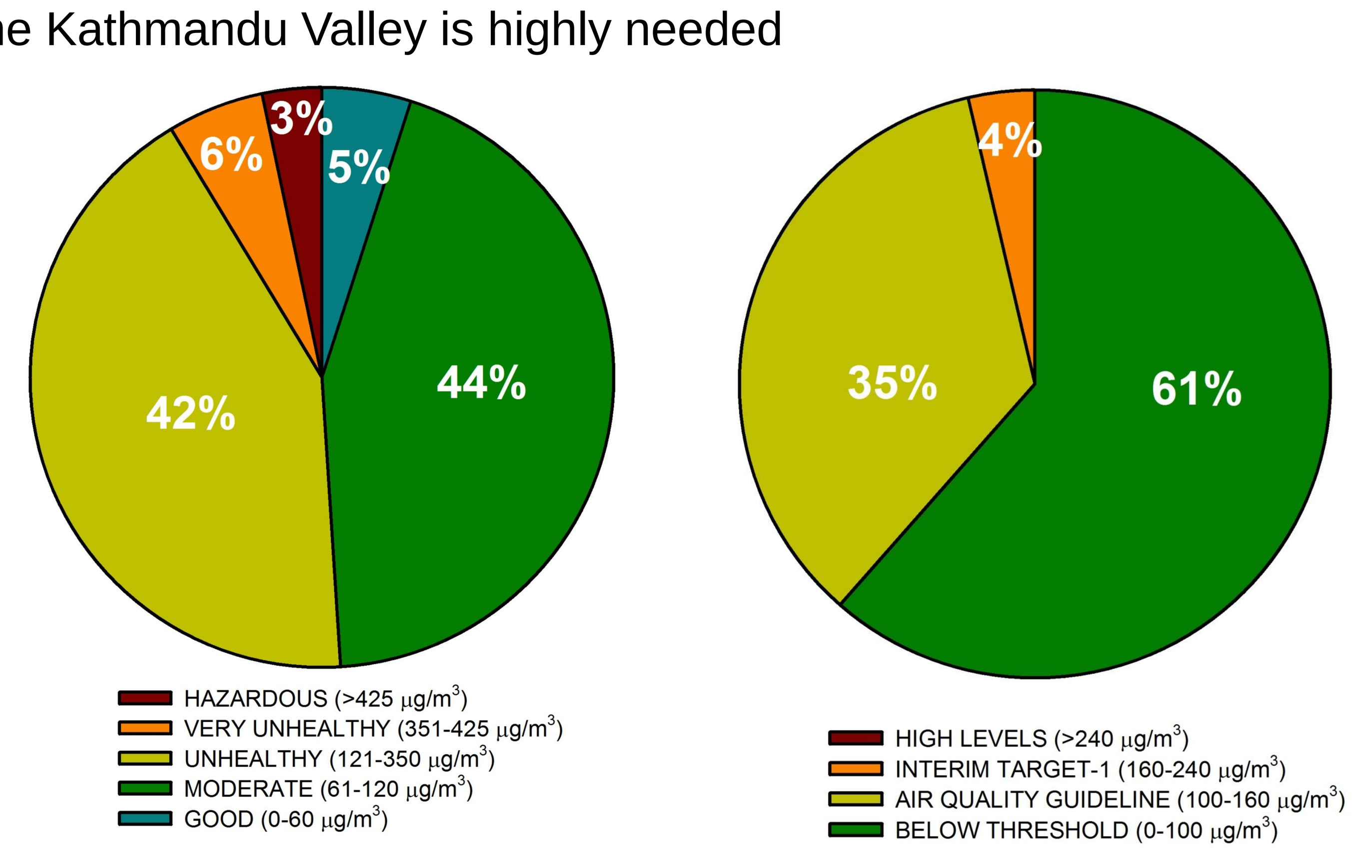

Figure 5. Pie charts indicating the Nepali Ministry of Population and Environment (MoPE) air quality categories for PM_{10} measurements (left), with the percentage of occurrence for Paknajol data, and the WHO air quality guidelines and interim targets for maximum daily 8-hour O_3 mixing ratios (right).

Acknowledgments

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Our scientific research activities are aimed at better understanding the air quality and the climatic conditions of the Kathmandu area: however, we are aware that following the recent and awful earthquakes, it is more important to support and provide help to our Nepalese friends and their families, besides the lovely Kathmandu Valley.