10-year record of atmospheric composition in the high Himalayas: source, transport and impact

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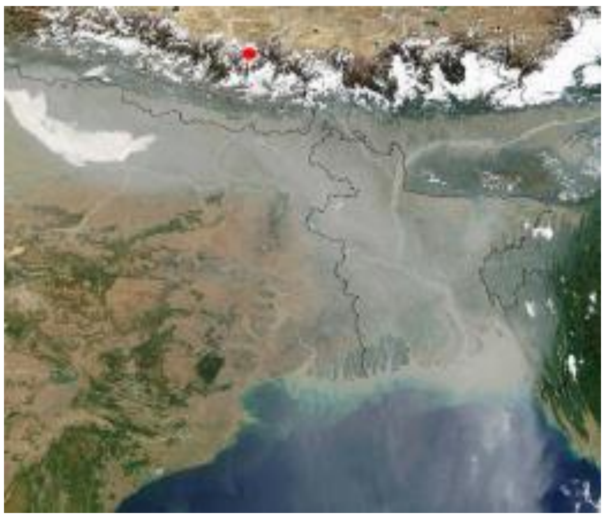

European Geosciences Union
General Assembly 2016
Vienna | Austria | 17–22 April 2016
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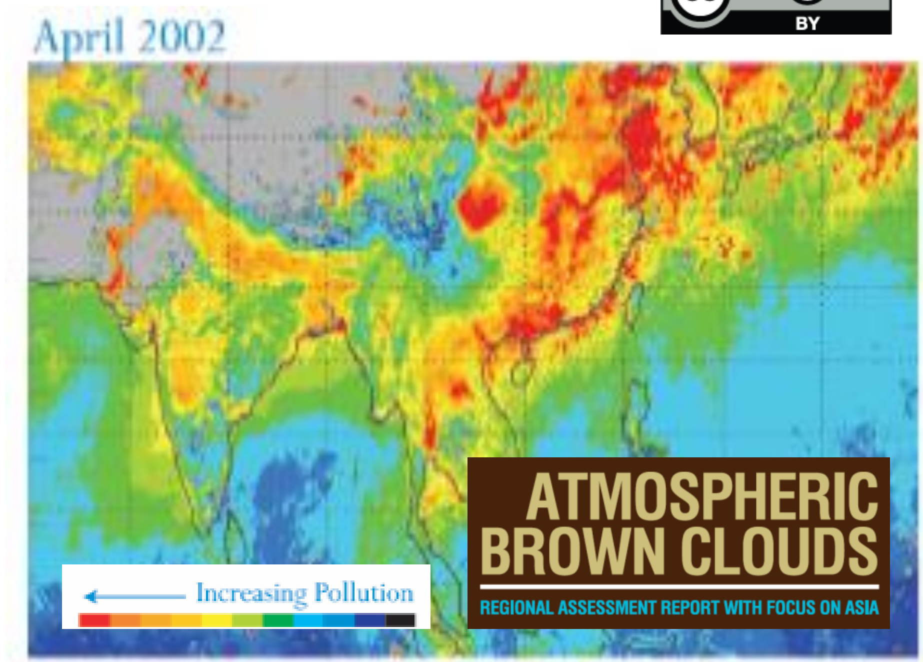
Motivation scientific questions

- South Asia represents a global "hot-spot" for **air-quality** and **climate impacts**.
- Since the end of the 20th Century, field experiments and satellite observations identified a **thick layer of atmospheric pollutants extending from the Indian Ocean up to the atmosphere of the Himalayas**.



Scientific questions

- Which are the **typical variability of climate forcers/pollutants** in Himalayas?
- Which are the **main sources**? Which **processes** favour the transport of polluted air-masses to Himalayas?
- How **natural processes** (e.g. stratosphere-to-troposphere exchange, mineral dust transport) affect atmospheric composition in Himalayas?
- Which are the **interactions** with atmospheric composition variability in Himalayas and the **South Asian Monsoon System**?
- Which is the **impact on Himalayas climate/cryosphere** of anthropogenic pollution?

The Nepal Climate Observatory @ Pyramid

Lat: 27°57'N, Lon: 86°48'E; 5079 m asl

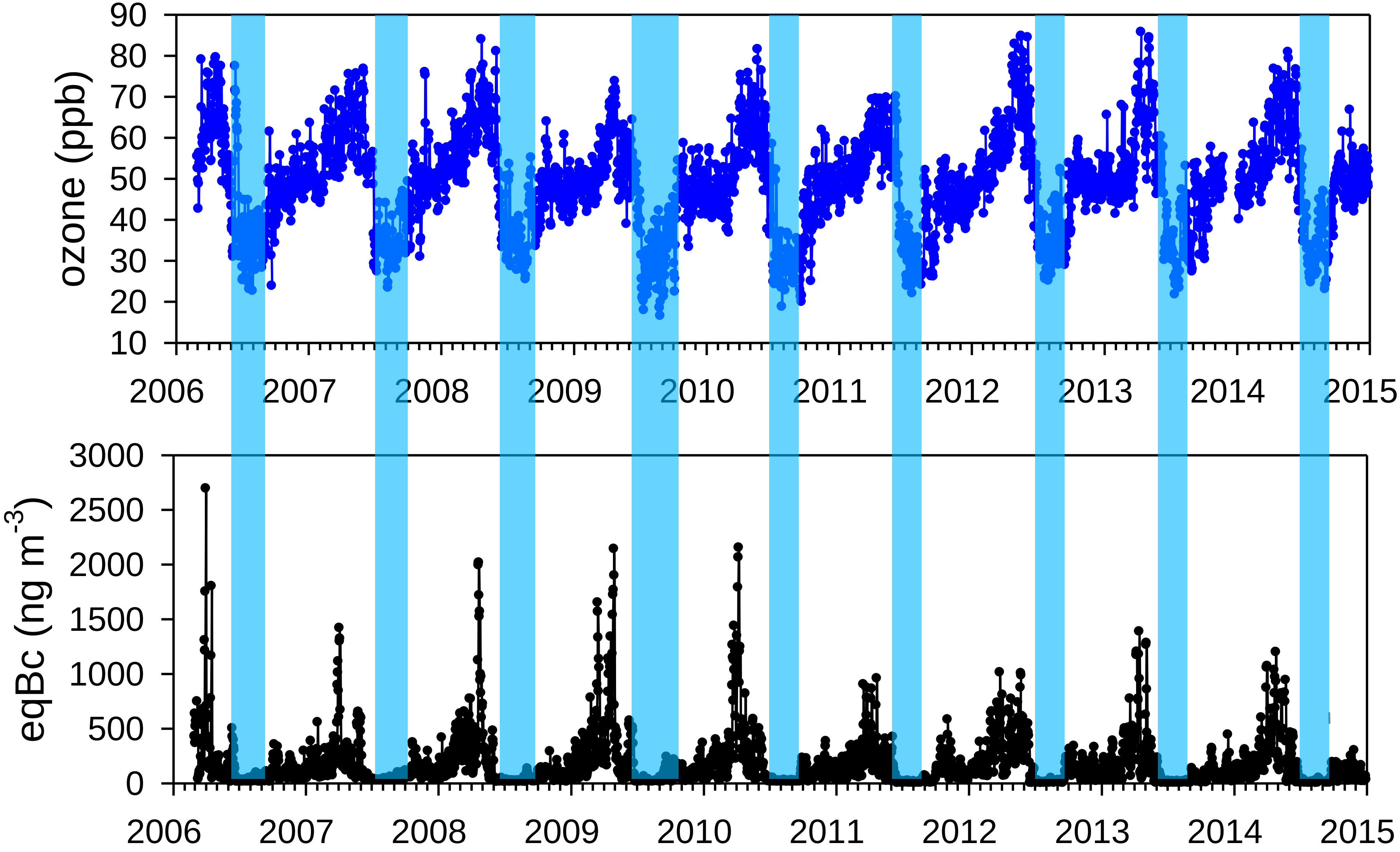
Operative 2006 - 2015

- •Aerosol number concentration and size distribution (SMPS + OPC, CPC)
- •Black carbon concentration (MAAP)
- •Total and back scattering coefficient (Nephelometer)
- •Aerosol optical depth (CIMEL)
- •On-line PM10-PM1 (β absorption, since 2012)
- •Surface ozone
- •Sulphur dioxide (since 2012)
- •Halogenated gases (flask sampling)
- •Atmospheric Hg (since 2102)
- •Chemical mass closure of aerosol (filter sampling)
- •Global solar irradiance (SW + IR)
- •Meteo parameters

Variability of eqBC and surface ozone

Summer monsoon

Data avallabile @ GAW/WDCGG and GAW/WDCA-EBAS



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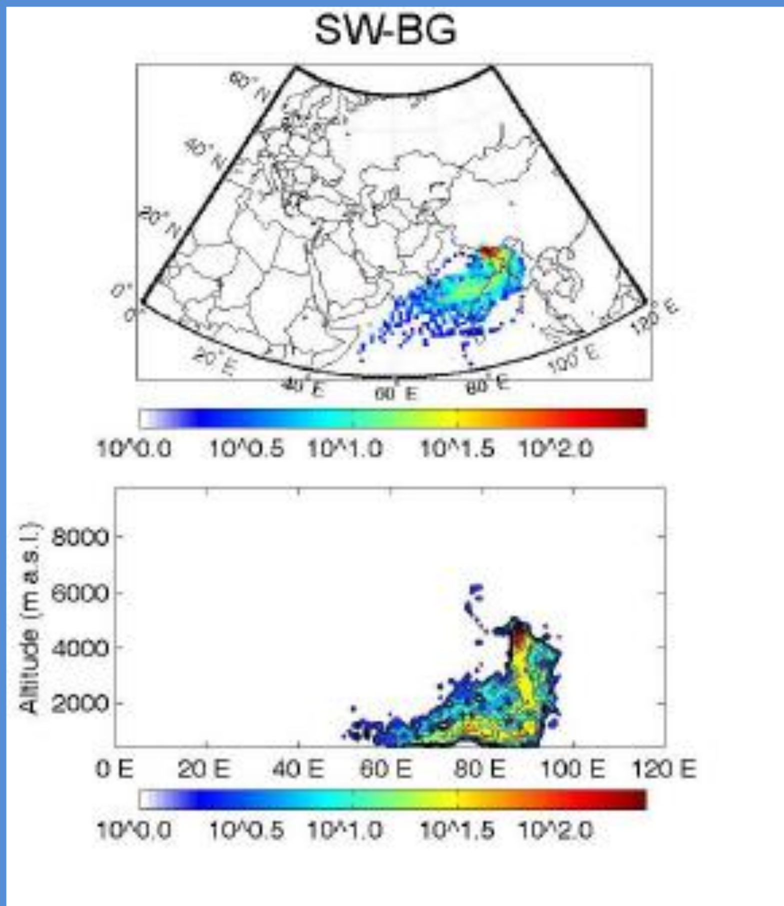
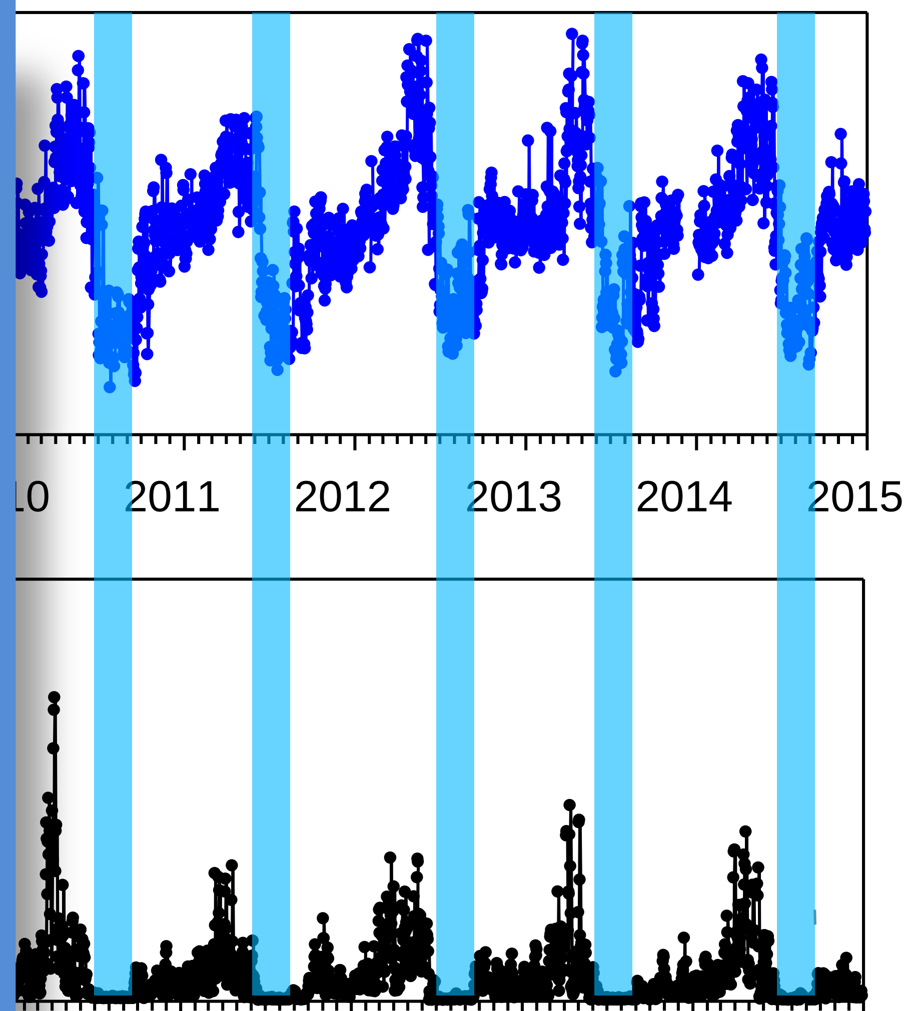


...and GAW/WDCA-EBAS



5-day back-trajectories were calculated every 6 h (at 05:45, 11:45, 17:45 and 23:45 NST) with the Lagrangian Analysis Tool LAGRANTO. Based on the 6-hourly operational ECMWF analyses

Variability of eqBC and surface ozone

Summer monsoon   Winter season

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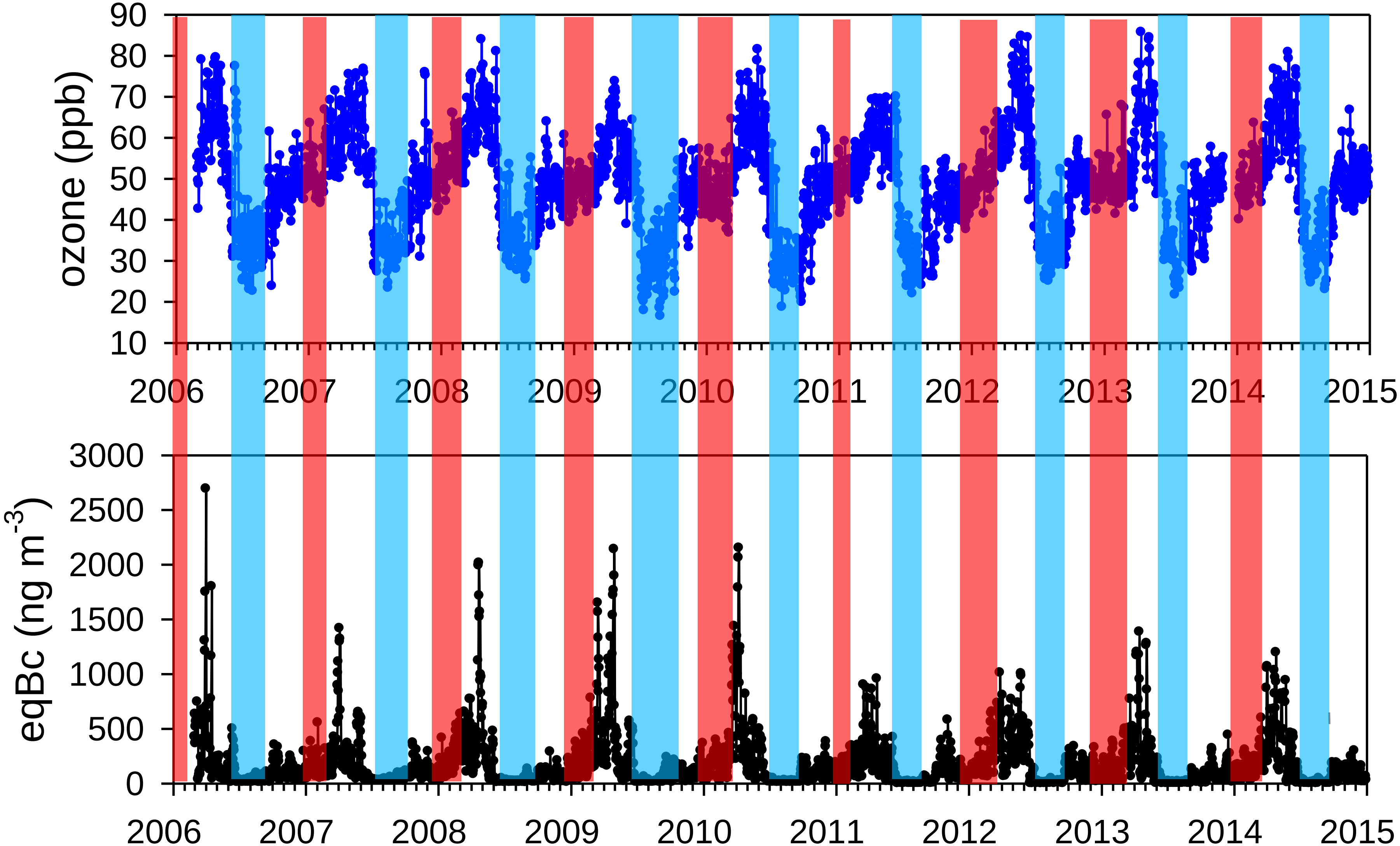

Variability of eqBC and surface ozone

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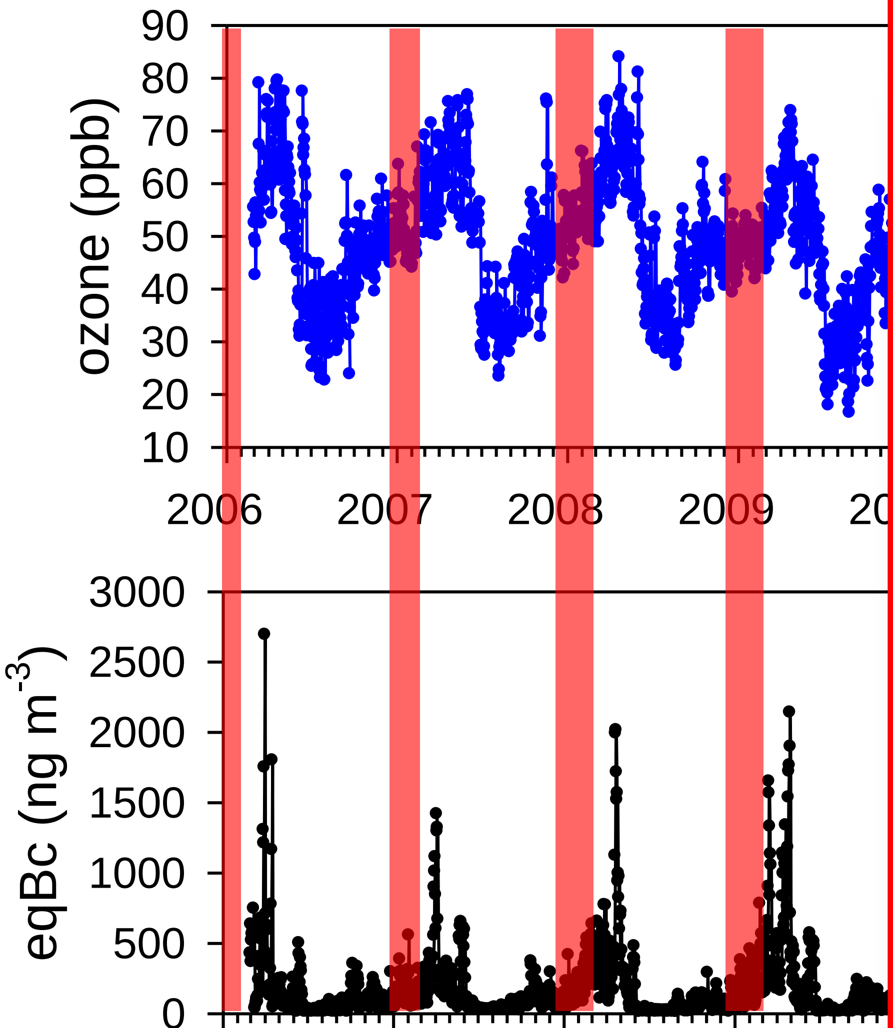

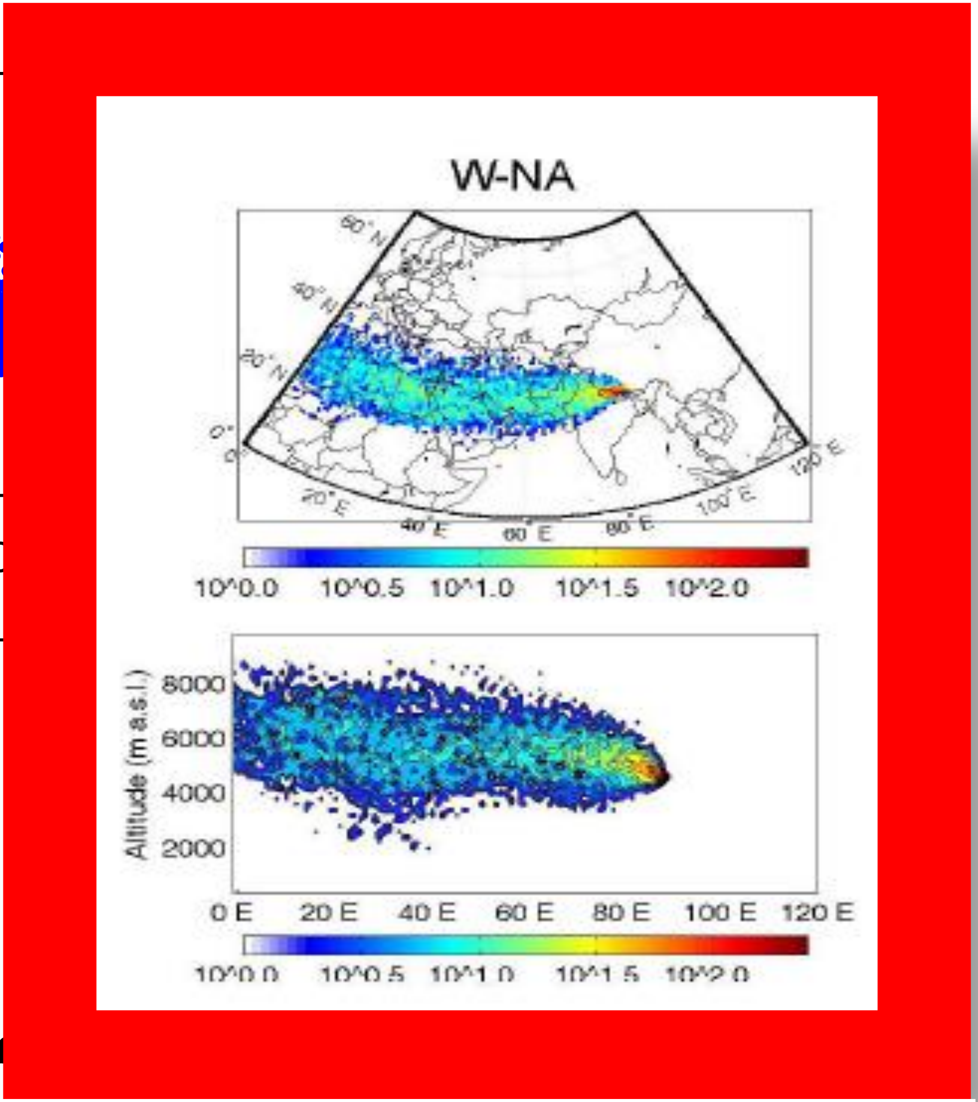

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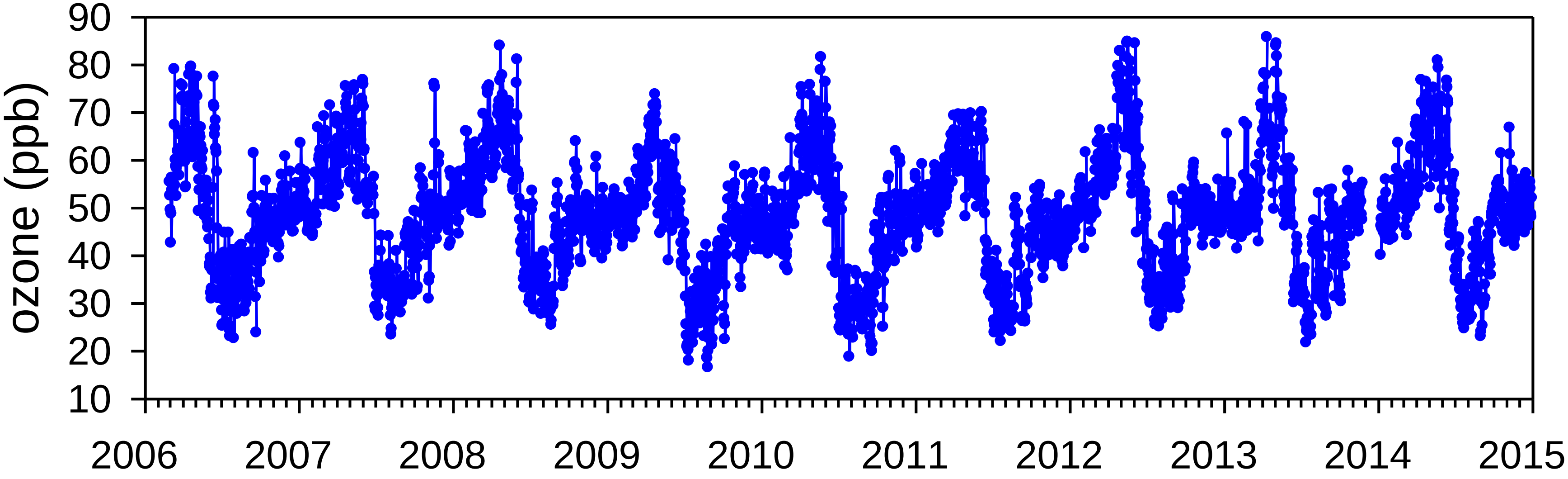
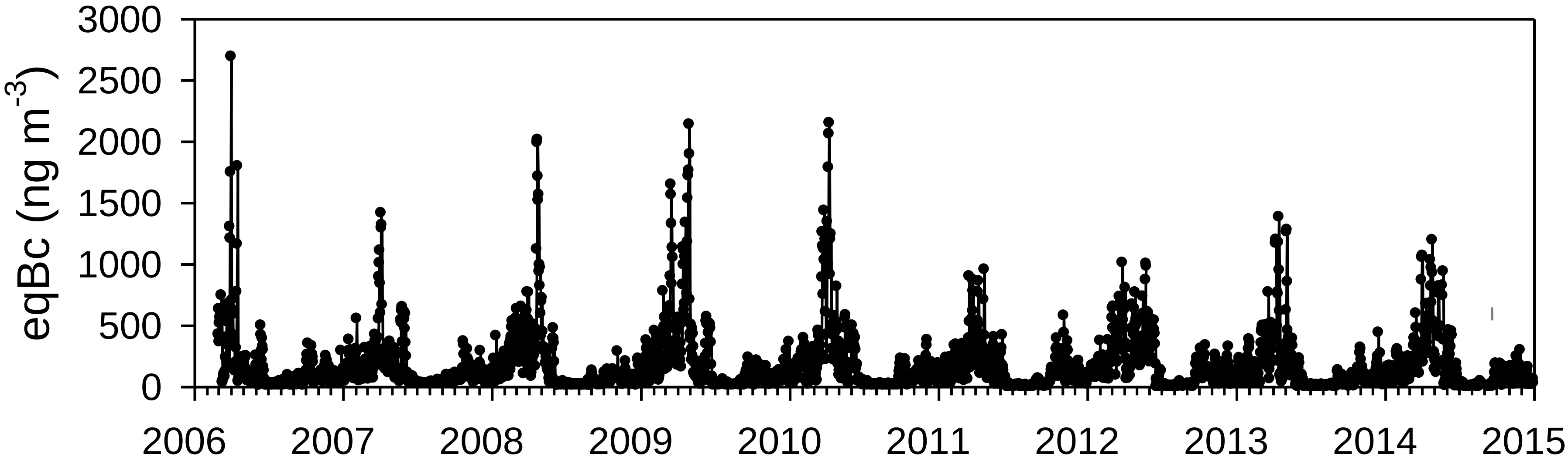
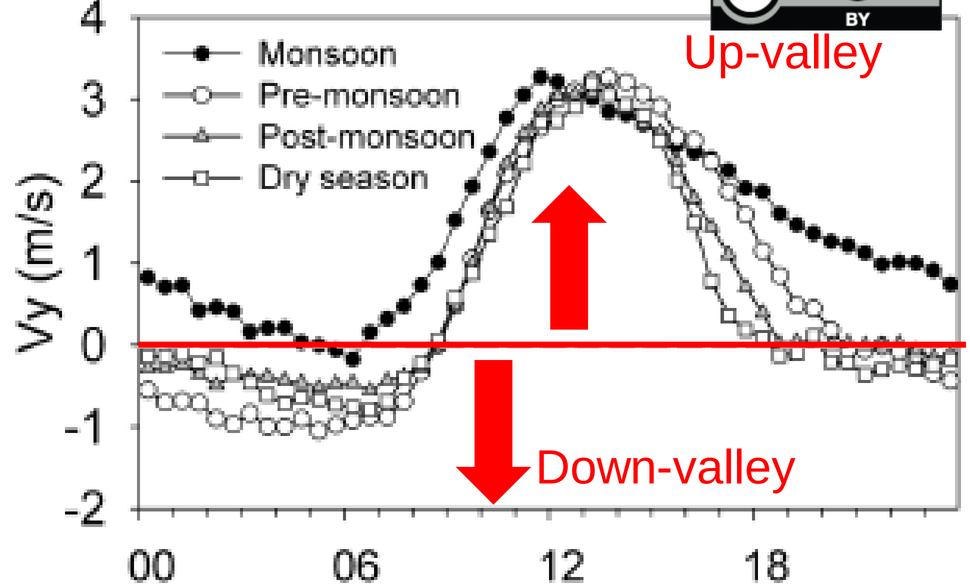
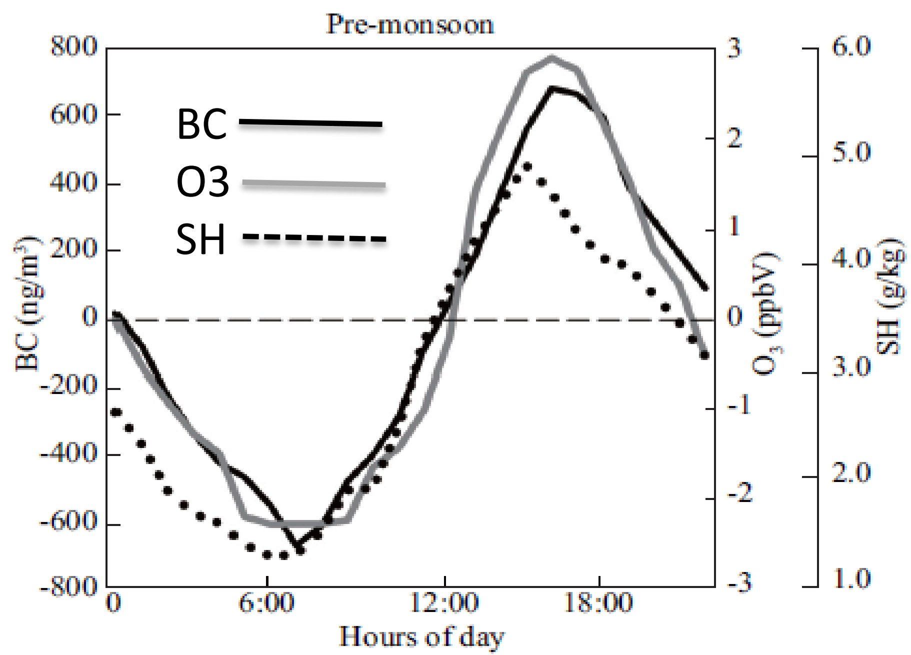




SLCF/P variability: role of thermal wind circulation



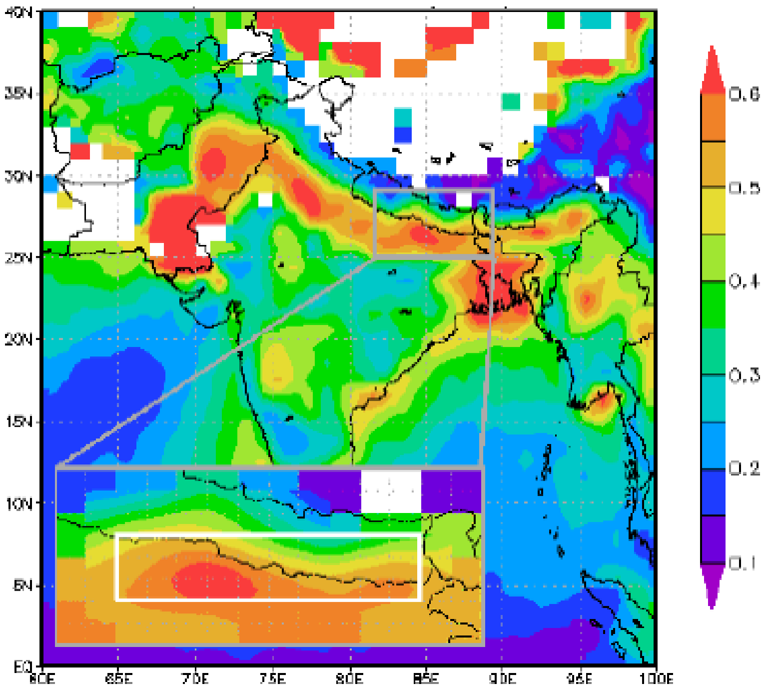


SLCF/P variability: role of thermal wind circulation

Atmospheric Brown Cloud hot-spot in the Himalayas

P. Bonasoni et al.: Atmospheric Brown Clouds in the Himalayas

Atmos. Chem. Phys., 10, 7515–7531, 2010



At NCO-P, a day was considered affected by ABC hot-spot if:

(i) Upvalley wind ($V_y>0$ ms^{-1}) were well developed;

(ii) BC, aerosol scattering coefficient and PM1 values significantly greater (at the 2σ confidence level) than seasonal background value;

(iii) ABC hot-spots were present over Himalaya foothills (daily MODIS AOD @ 550 nm >0.4).

50 days (7% of data-set) were identified as being influenced by direct ABC transport to NCO-P, 87% during pre-monsoon, 9% during the winter and 4% in post-monsoon.

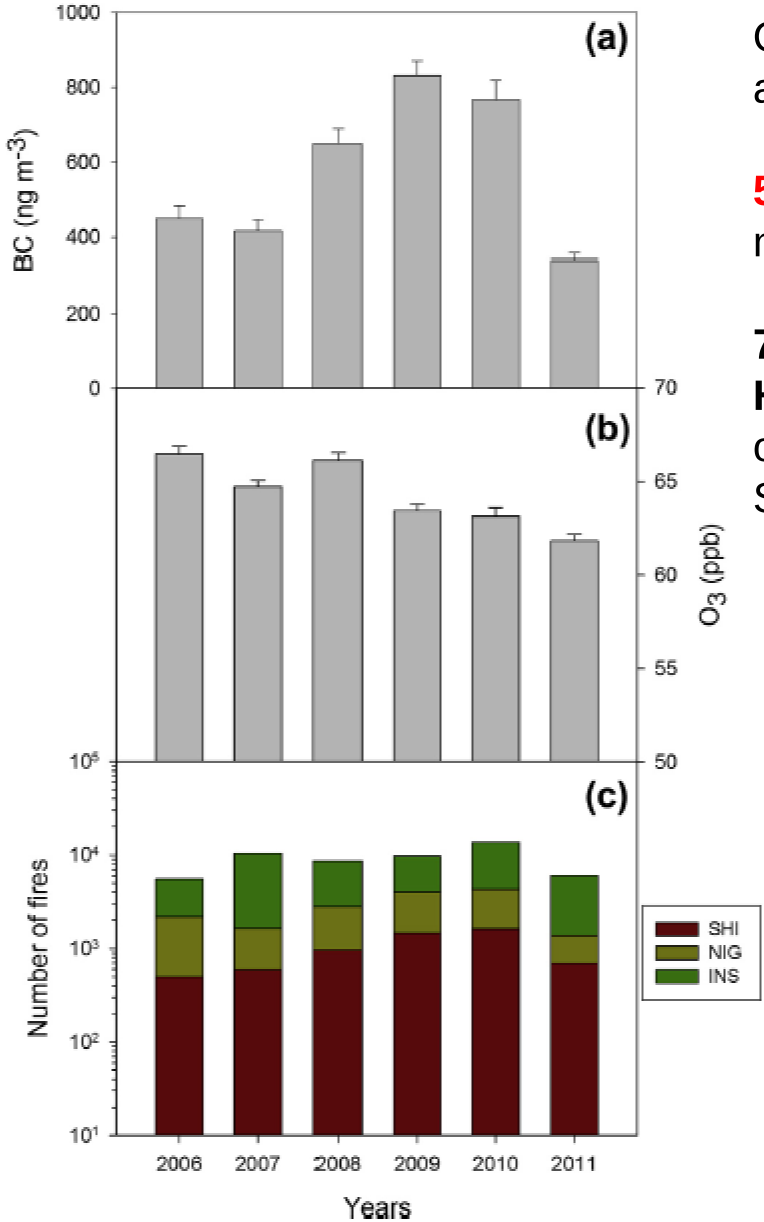
Table 2. Seasonal average (mean ± standard deviation) of BC, aerosol scattering coefficient, PM_1, coarse particle number and O_3 at NCO-P during the period March 2006–February 2008. Seasons are defined following Table 1. In the last column, means ± standard deviations are reported for the Atmospheric Brown Cloud hot-spot episodes identified at NCO-P during the pre-monsoon season (see Sect. 4.1).

	Pre-Monsoon	Monsoon	Post-Monsoon	Winter	ABC hotspots
BC (ng m^{-3})	316.9±342.9	49.6±60.9	135.3±78.5	118.4±80.9	1974.1±8[illegible]
Scattering coefficient (Mm^{-1})	11.9±10.5	2.2±3.5	5.0±2.9	3.4±1.6	57.7±28.2
PM_1 (µg m^{-3})	3.9±4.0	0.6±1.0	1.5±0.8	1.3±1.8	23.5±10.2
Coarse (cm^{-3})	0.37±0.37	0.09±0.02	0.07±0.05	0.16±0.14	0.64±0.33
O_3 (ppbv)	60.9±8.4	38.9±9.6	46.3±5.0	51.2±5.4	69.2±10.4

+522%

+14%

Open fire influence to acute pollution at NCO-P (2006 – 2011)

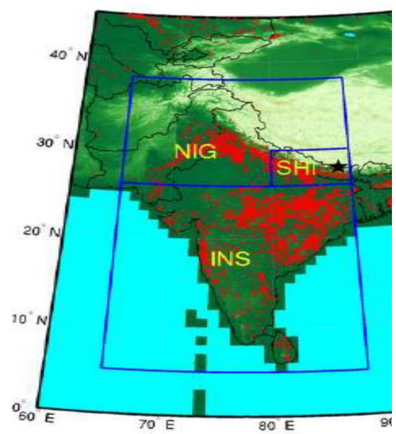


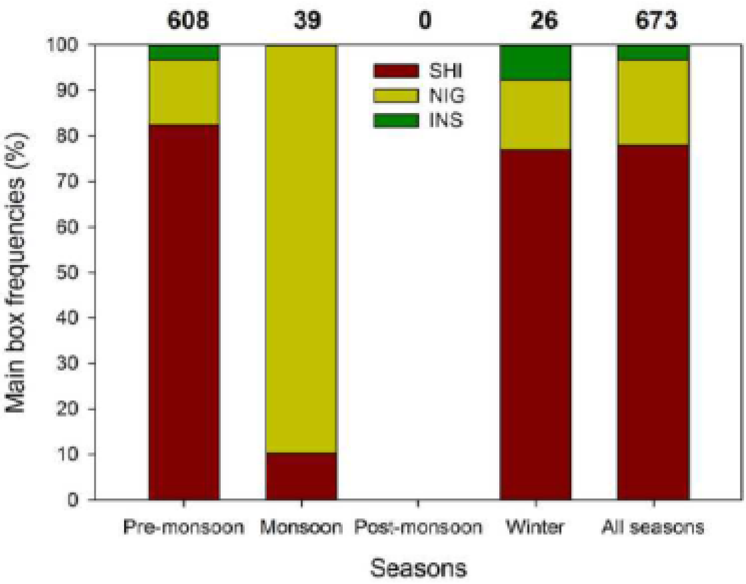
Over the 6-year period, linear correlation exists among BC and the number of fires over SHI (r: 0.81) and INS (r: 0.82)

56% of the polluted days observed at NCO-P showed air-masses crossing active fires over South Asia.

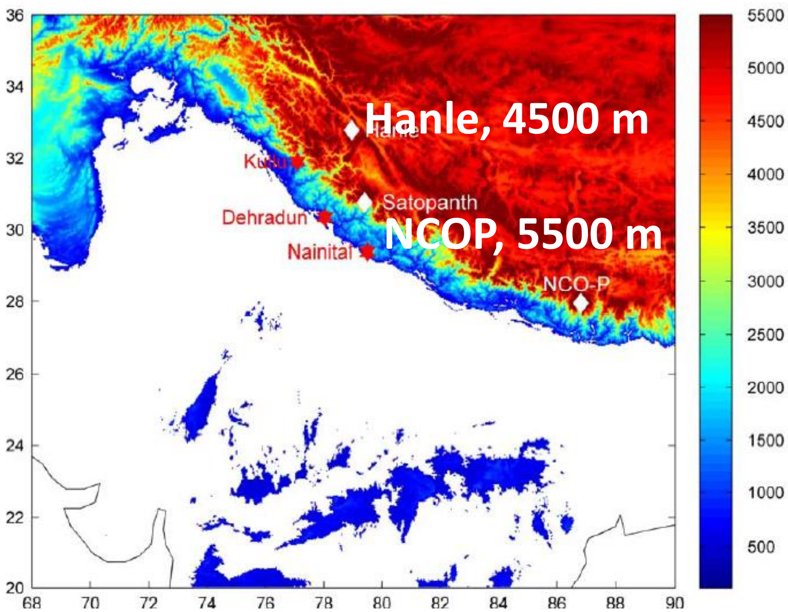
78% of the fires have been overpassed over the South Himalayas region, with the remaining as being distributed over Northern Indo-Gangetic Plain (19%) and Indian Subcontinent (3%).

Putero et al., Env. Poll., 2013





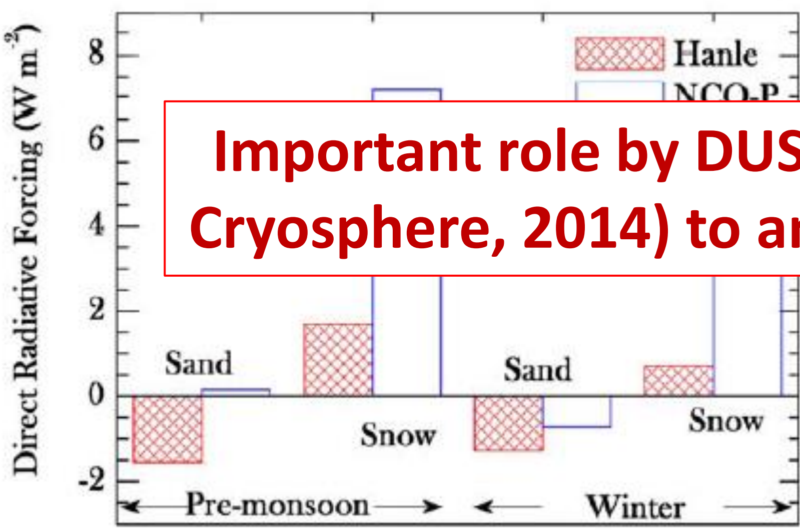
Climate impacts of pollution transport to Himalayas: BC deposition on snow



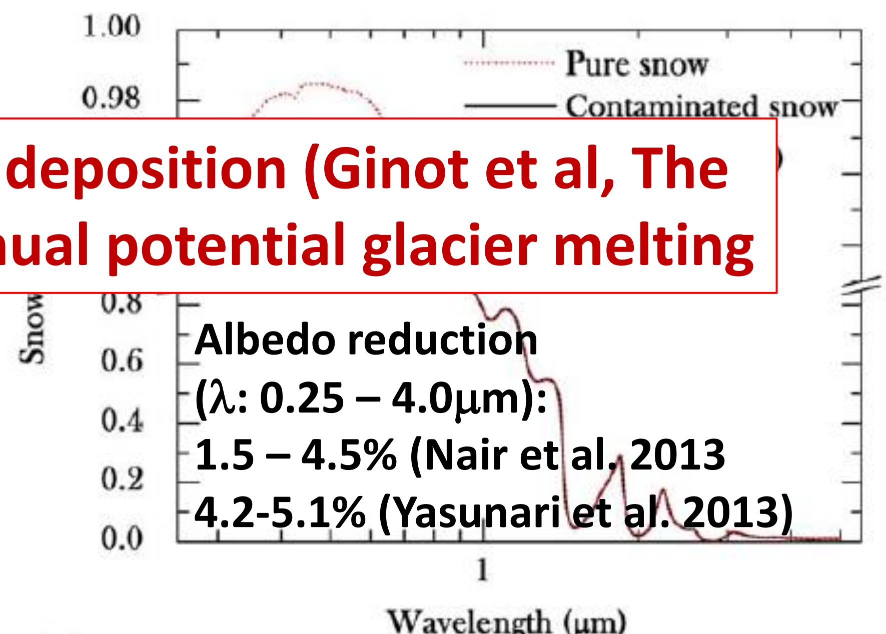
Nair et al., Tellus, 2013

Based on the optical and physical properties of aerosols at Hanle, clear sky direct radiative forcing (DRF) at the TOA: **1.69 W m^{-2} over snow surface and 1.54W m^{-2} over sandy surface** during pre-monsoon

For BC in snow from 10 to 200 μg kg^{-1}, averaged forcing (At TOA) due to snow darkening: **0.87 -10.2 Wm^{-2} (fresh snow) and 2.6 -28.1 Wm^{-2} (aged snow).**



Important role by DUST deposition (Ginot et al, The Cryosphere, 2014) to annual potential glacier melting



Albedo reduction (λ: 0.25 – 4.0μm):
1.5 – 4.5% (Nair et al, 2013
4.2-5.1% (Yasunari et al. 2013)

EGU2016, 17-22 April, Vienna, Austria

Summary

- 10 yr of atmospheric composition observations are available at the NCO-P WMO/GAW station in Nepali Himalayas
- Atmospheric composition and SLCF/P variability in high Himalayas are characterised by an evident seasonality
- During a notable fraction of time (especially during the pre-monsoon) acute pollution events (O_3> 80 ppb and eqBC > 500 ng m^{-3}) are systematically observed
- Himalayan valleys represent a “direct” channel for SLCF/P transport to high Himalayas
- Open fires in South Asia, especially in the Himalayas foothills, appeared to have a significant role in affecting the occurrence of pollution events
- The transport of pollutant to high Himalayas affect the surface radiative forcing and snow/glacier albedo with severe implication for cryosphere.

Acknowledgements

Several Research Projects, Institutions and colleagues made possible the execution of this research activity.

A special thank is due to the EV-K2-CNR technical staff (Gianpietro Verza and Marcello Alborghetti) and to the Nepali staff working at NCO-P (Laxman Adhikary, Kaji Bista, Pema Sherpa, Tenzing Chhottar Sherpa, Lhakpa Tshering Sherpa, Lakpa Tenzi Sherpa and Hari Shrestha)

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Thank you!