Linking Atmospheric Pollution to Cryospheric Changes over "The Third Pole" Region

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Air Pollution & Atmospheric Brown Clouds

Haze

Accelerated Glacier melt

Yao et al., 2010 NCC
Atmospheric Brown Clouds – Impact

**Impacts of Atmospheric Brown Clouds (ABCs)**

### Human health
- ABC exposure is probably associated with significant health effects.
- e.g., indoor: ~400,000 deaths a year in India and China each, and outdoor: up to 500,000 in both.

### Water
- Weakened Asian monsoon
- 20% decrease in rainfall in the Indo-Gangetic plain since the 1980s

### Glacier melting
- Accelerated melting of Hindu Kush-Himalayan-Tibetan glaciers due to black carbon deposition on snow/ice, and atmospheric heating.

### Climate change
- 6% decrease in solar energy reaching the surface in China and India since pre-industrial times
- 20–50% increase in heating of the lower atmosphere (up to 3 km)

### Agriculture
- Surface dimming (cooling), reduction of photosynthetically active radiation (PAR), change in rainfall (drying)
- Increasing ground level ozone and significant loss in crop yield

*From ICIMOD Atmospheric Brown Cloud Regional monitoring and assessment*
Black Carbon and Climatic Effects

Ramanathan et al, 2007 & Bond et al., 2013
Monitoring Network: A Prototype

TRAP Himalayas
Transport of Atmospheric Pollution across the Himalayas

Zhongba 仲巴
Lhasa 拉萨
Nam Co 纳木错
Jomsom 乔姆索
Lumbini 蓝毗尼
Pokhara 博卡拉
Kathmandu 加德满都
Dhunche 东启
Atmospheric Pollution and Cryospheric Change

Aerosol: 30      Glacier: 14       Snow cover: 6
## Observational parameters, instrumentation, and temporal resolution

<table>
<thead>
<tr>
<th>Research content</th>
<th>Sampling/Observational parameters</th>
<th>Instrumentation</th>
<th>Frequency</th>
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</thead>
<tbody>
<tr>
<td><strong>Online measurement</strong></td>
<td><strong>Aerosol optical properties</strong></td>
<td>CIMEL Sunphotometer</td>
<td>hourly</td>
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<tr>
<td></td>
<td><strong>Aerosol concentration: PM$<em>{2.5}$, PM$</em>{10}$</strong></td>
<td><strong>Thermo RP1400</strong></td>
<td>hourly</td>
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<td></td>
<td><strong>Gaseous precursors: SO$_2$, No$_x$, CO, O$_3$; Toxic gas (Atmospheric mercury) BC</strong></td>
<td><strong>Thermo 42I, 43I, 45I, 49I analyzer; Tekran 2537</strong></td>
<td>hourly</td>
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<td><strong>Total suspend particles: EC/OC, brown carbon (BrC), inorganic ions, trace element, and isotopes, and organic tracers.</strong></td>
<td><strong>Aethalometer AE33</strong></td>
<td>hourly</td>
</tr>
<tr>
<td><strong>Filters</strong></td>
<td></td>
<td><strong>TSP sampler (KC-120H)</strong></td>
<td>3-6 days</td>
</tr>
<tr>
<td><strong>Glacier &amp; Snow cover</strong></td>
<td><strong>Snow/ice samples: Dust, EC/OC, BrC, WSOC, inorganic ions, trace element, and isotopes, and organic tracers.</strong></td>
<td><strong>ASD Handheld 2 spectroradiometer</strong></td>
<td>1-2 times per year</td>
</tr>
</tbody>
</table>
# Atmospheric Pollution and Cryospheric Change

<table>
<thead>
<tr>
<th>Logo</th>
<th>Name</th>
<th>Monitoring Content</th>
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<tbody>
<tr>
<td><img src="image" alt="Super Station Logo" /></td>
<td><strong>Super Station</strong></td>
<td>Meteorology, Trace Gas, Active Aerosol sampling, Passive Sampling</td>
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<td><img src="image" alt="Station Logo" /></td>
<td><strong>Station</strong></td>
<td>Meteorology, Active Aerosol sampling, Passive Sampling</td>
</tr>
<tr>
<td><img src="image" alt="Site Logo" /></td>
<td><strong>Site</strong></td>
<td>Low resolution active sampling + Passive sampling</td>
</tr>
</tbody>
</table>
Atmospheric Pollution and Cryospheric Change

Everest

Sun Photometer

PM2.5

Nam Co
Aims and Tasks

- Characterize the chemical composition and levels of atmospheric pollutants, depict their spatial and seasonal variation over the HTP.
- Identify the sources of atmospheric pollutants and reveal the transport pathway and mechanisms of trans-boundary atmospheric pollution to the HTP.
- Investigate the role of atmospheric pollutants (deposited as LAIs) in the melting of glacier and snow cover and further quantify the contribution of LAIs to the glacier and snowpack melting. Determine the fate of environment-relevant pollutants within glacier and snowpack and their scavenging process during snow/ice melting.
- Assess the impact of atmospheric pollution on the cryospheric changes over the HTP.
Basic Design

Modeling & Assessment

Atmospheric Pollution and Its Effect on Cryospheric Changes

Laboratory Analysis

Monitoring & Sampling
Trans-Himalayan Filters

A filter sample at Kathmandu
Before VS After

April 5-10, 2013
BC and OC in aerosols

Chen et al., In Preparation
Seasonal variation of BC and OC

Kathmandu

Nam Co

Chen et al., In Preparation
Mass Absorption Cross section (MAC): BC

Chen et al., In Preparation
Comparison of MAC
Seasonal Variation of MAC

Li, et al., 2016, Atmos. Environ.
Source of BC to Glacier snow: Isotopic Signature

Trans-Himalayan Pollution Plume: An Event

Lüthi et al., 2015, Atmos. Chem.
Trans-Himalayan Pollution Plume: An Event

Pollution Event
13–19 March

Clean Period
30 March–5 April

Lüthi et al., 2015, Atmos. Chem. Phys.
Trans-Himalayan Pollution Plume: An Event

Pollution Event 13–19 March

Clean Period 30 March–5 April

Lüthi et al., 2015 Atmos. Chem. Phys.
Trans-Himalayan Pollution through the Valleys

Cong et al., 2015, Atmos. Chem. Phys.
About 10-40% of atmospheric BC in the southern TP is from anthropogenic emission from South Asian

WRF-Chem simulating in 2013

Yang et al., In Preparation
Climatic Effects of Carbonaceous Aerosols

RegCM4.3.5 simulating

0.1 ~ 0.5 °C warming!

Ji et al., 2015, Climate Dynamics
Climatic Effects of Carbonaceous Aerosols

Effects of BC-snow radiative feedback

RF
1-6 W/m²

 Increasing Tem.
0.1-1.5 °C

 Snow melt
10-25 mm (w.e.)

RegCM4.3.5 + SNICAR

Ji et al., 2016. ACCR
Role of BC, Dust and Others in Glacier Melt

July 16, 2012

Aug. 26, 2012
Total melt = BC (11%) + Dust (38%) + Others

Qu et al., 2015. ACP
No.12 Glacier in Qilan

- Total melt
- BC (37%)
- Dust (32%)
- Others

2013

(a) (b) (c) (d)

2014

(e) (f) (g) (h)

Glacier ablation (mm)
-250 - 0
0 - 250
250 - 500
500 - 750
750 - 1,000
1,000 - 1,250
1,250 - 1,500
1,500 - 1,750
1,750 - 2,000

Li et al., 2016, TC
Summary of Major Research Achievements

- Atmospheric pollutants are sourced from burning of biomass and fossil fuel, and dust emission, peak at winter and pre-monsoon.

- Atmospheric pollution is accumulated in the southern foot of Himalayas.

- Episodic cross-Himalayan pollution can be transported through the major south-north valleys and by being lifted and advected over the Himalayas.

- Melting glaciers are important sources releasing legacy pollutants into downward ecosystems.

- BC and dust can be accumulated in glacier surface, and further enhancing glacier melt during ablation seasons.

Kang & Zhang et al., In Preparation
Thank you!

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