Atmospheric dust deposition record in ice core and snow pit from the East Rongbuk Glacier of Mt. Everest

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Backgrounds

Dust and Climate Couplings

Mineral dust is an important part of the climate system. To understand the past climate changes it is therefore necessary to have an accurate quantitative reconstruction of the past atmospheric dust deposition record. Because long-range air transported dust by air mass can be captured by the falling snow, most ice cores come from both polar and high altitude mountain have a role as dust archives. Dust in ice cores provide one of the most detailed and best preserved sources of climatic and environmental information. The dust record of EPICA Dome C reflected the glacial-interglacial climate changes over the past 800,000 years.

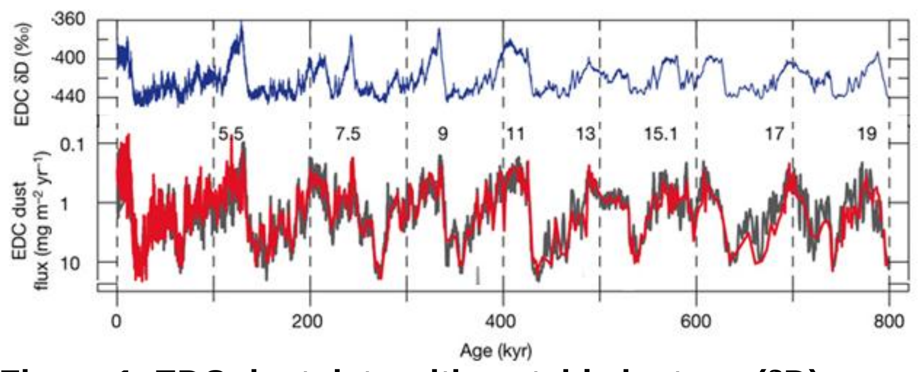


Figure 1. EDC dust data with a stable isotope (δD)

The Himalaya is a massive mountain system separating the Indian subcontinent from the Tibetan Plateau and stretches across six countries: Bhutan, China, India, Nepal, Pakistan and Afghanistan. The Himalaya encompasses about 15000 glaciers, which store about 12,000 km^3 of freshwater and form the source of several large rivers. The East Rongbuk Glacier on Mt. Everest, which is the highest peak in the world, is located in the Himalaya of southern Tibet.

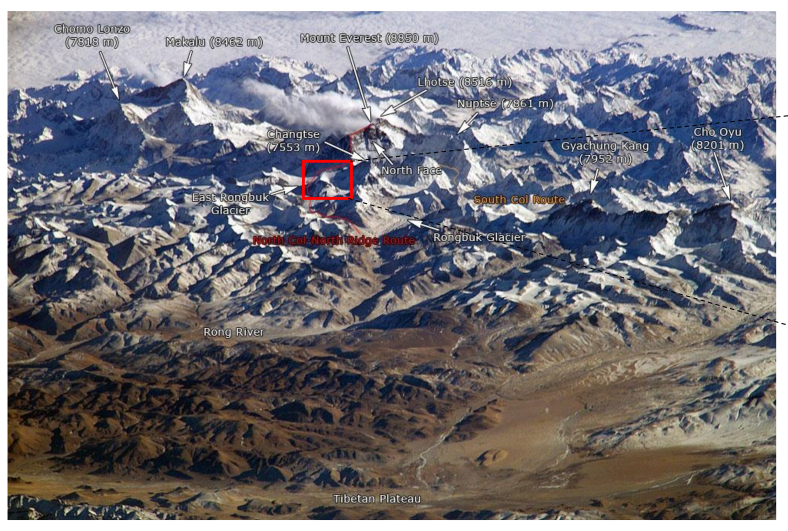


Figure 2. Skyview of the Himalaya mountains

The central Asia as global dust source

The central Asian region is one of the major global dust source areas in the Northern Hemisphere. Dust aerosol over the Tibetan Plateau could be an important factor in the Asian summer monsoon and might affect the radiation balance by absorbing and scattering solar radiation. Thus, ice cores in the Himalaya preserve atmospheric dust deposits and contribute to reconstruction of environmental change.

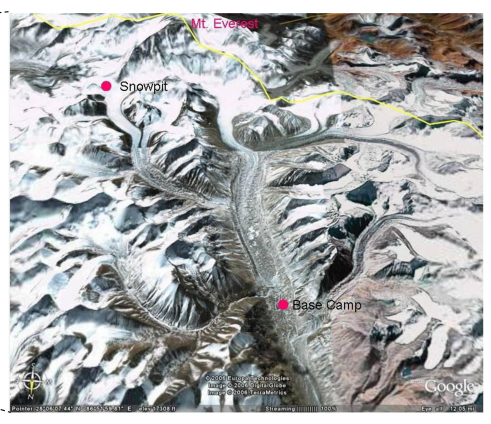


Figure 3. Sampling location

Ice core and snow pit samples

The study site lies on **the East Rongbuk Glacier (ERG)**, the northeastern slope of Mt. Everest (Qomolangma) in the Himalayas. A **108.8 m-long ice core** to bedrock was recovered in September 2002 at 6518 m (28°03´ N, 86°96´ E), and a **2.1 m-depth snow pit** was collected at 6576 m (28°01´ N, 86°57´ E) in September 2005, respectively. The ice core and snow pit samples were analyzed for soluble ions, stable isotopes (δD and δ^{18}O), and trace elements. In addition, the snow pit samples were measured selected persistent organic pollutants such as organochlorine pesticides and polychlorinated biphenyls. The samples were dated by combining the depth profiles of stable isotopes, major ions (Ca^{2+}, SO_4^{2-}), Al content, and large volcanic signs. The snow pit cover from the fall of 2004 to the summer of 2005 and the ice core dated to AD 1534 at 98 m.

Instrumental Analysis

The measurements of dust concentration and size distribution were performed using a Multisizer 3 Coulter Counter set up in a class 10 clean bench in a class 1000 clean room in KOPRI. The instrument connected with a 100 μL aperture tube. The 10 mL sample is made conductive solution by adding an equal volume pre-filtered 4% NaCl electrolyte solution. At least three counts were performed on each volume of 500 μL.

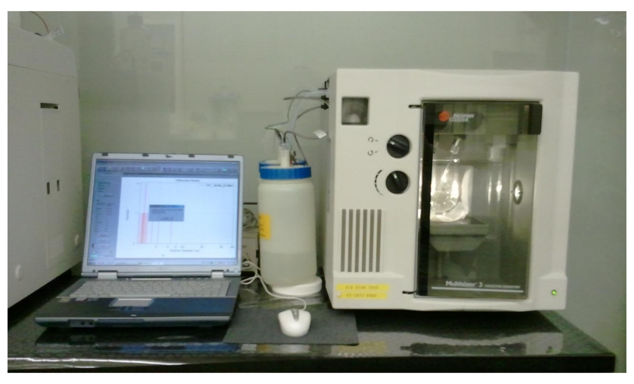


Figure 4. Multisizer 3 Coulter Counter

Particle size distribution

The particle size is expressed by the diameter of number and volume size distribution. Particle size from 2 μm to 10 μm were considered for statistical analysis. The mass was calculated from measured volume and assuming a particle density of 2.5 g/cm^3.

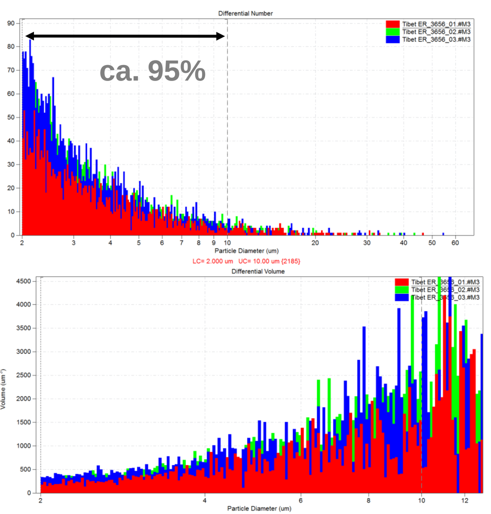
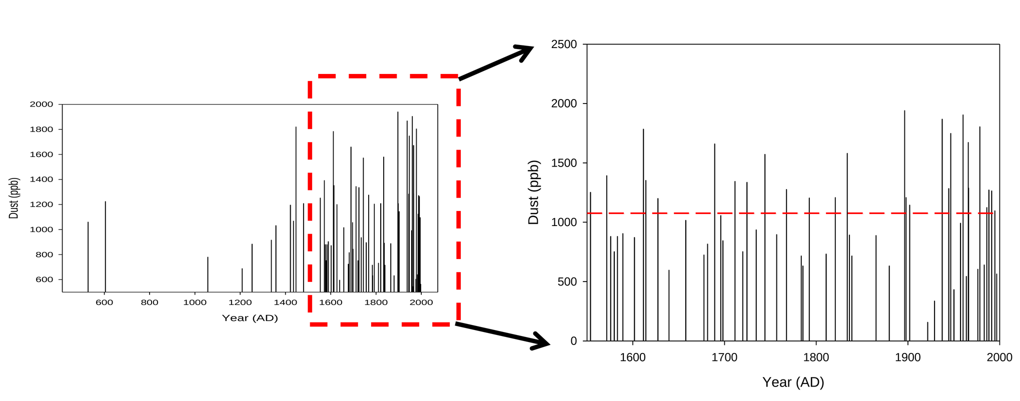


Figure 5. Number vs. Volume Size Distribution

Results and Discussion

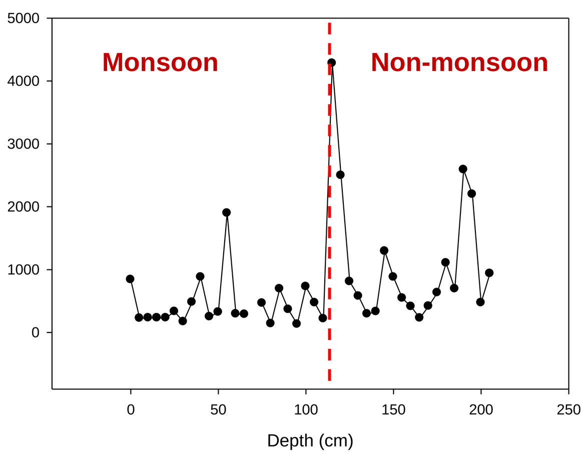
Ice core

A total of 67 samples were analyzed and these samples cover the period AD 528-1997. The dust concentrations of the ERG ice core ranged from 157 to 1940 g mL^{-1} with the mean concentration of 1075 ng mL^{-1}. The mean diameter was 6.03 μm ranging from 4.03 to 6.63 μm. The dust concentration of the ERG ice core was higher than those of Antarctic and Greenland ice cores.



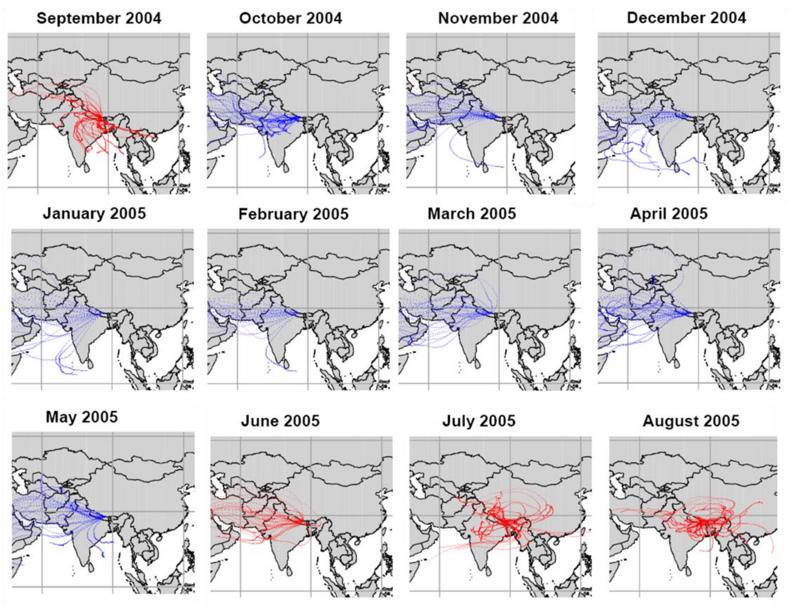
Snow pit

A total of 42 samples were analyzed and these samples cover approximately one full year from September 2004 to August 2005. The mean dust concentrations of the ERG snow pit were 757 g mL^{-1}, ranging from 131 to 4280 g mL^{-1}. Depth distribution of dust in a snowpack can reflect variations in atmospheric deposition and are significantly influenced by meteorological patterns. The peak concentrations of dust at the 105-120 cm depth interval were related to monsoon snow deposition.



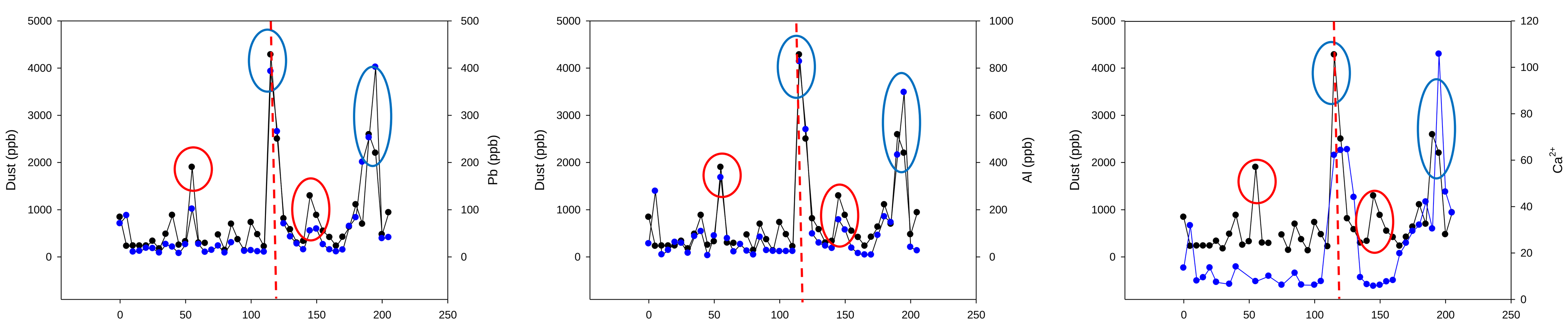
Monthly backward air trajectory

The monthly trajectories are presented to assess the origin of air masses arriving at the sampling site for one year between September 2004 and August 2005. In the non-monsoon seasons, Mt. Everest controlled by the westerly winds and influenced by air from the arid and semi-arid regions. Air masses during the summer monsoon season generally came from India and China.



Correlation between dust concentration and other proxies

The concentration of dust in snow depends on a number of factors such as the primary supply of mineral particles, which related to climate and environmental conditions in the source region, the snow accumulation rate, the long-range transport, and the cleansing of the atmosphere associated with the hydrological cycle. Correlation analysis showed that the concentration of dust positively and strongly correlated with the concentrations of various metals such as Al, Ba, Co, Cu, Mn, Ni, Pb, Rb, Sr, Th, U, V, Zn, Mo, Cd, Sn, Sb, Tl, Bi, Sc, Cr, and As (r=0.567-0.914, p<0.001). δ^{18}O was not correlated with the concentration of dust (r=0.273, p>0.05). Soluble ions (Na^+, NH_4^+, F^-, Cl^-, NO_3^-, SO_4^{2-}) also were not correlated with dust concentration, but Ca^{2+} ion was related with dust concentration (r=0.561, p<0.001).



Conclusion

In summary, this study reports the concentrations of dust (insoluble particles) in ice core and snow pit collected from the East Rongbuk Glacier in Mt. Everest. Particularly, dust deposition in snow pit were correlated with the concentrations of various metals. In addition, dust deposition record reflected significant meteorological patterns in the Himalaya regions.

Acknowledgement

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