Carbonaceous Particle Concentrations Since the Pre-Industrial Era from Asian Ice Cores

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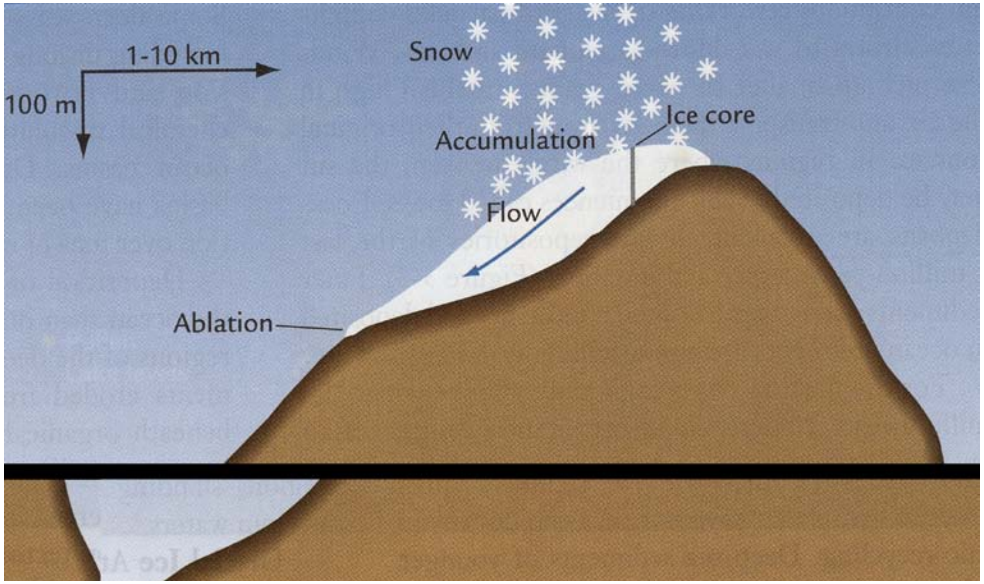
Justification

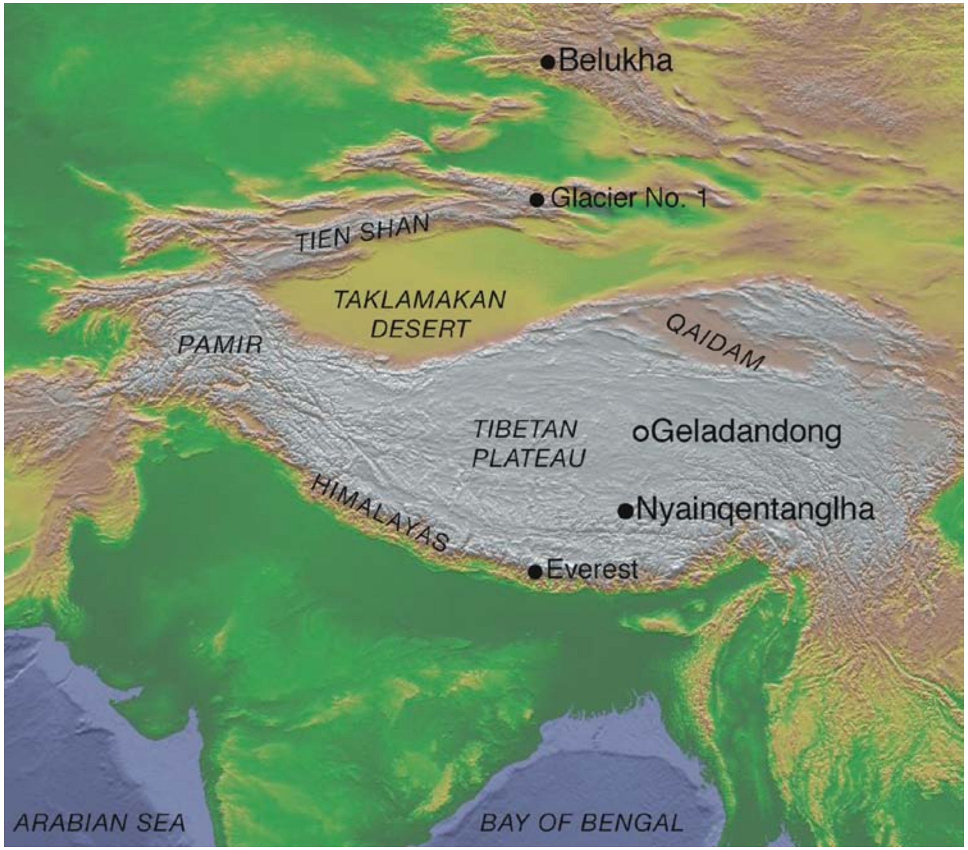
- Historical records of carbonaceous particles (CP) are needed to assess the role of CP in climate change
- Studies currently rely on estimated inventories of CP (e.g., Streets et al., 2001; Novakov et al., 2003; Ito and Penner, 2005; Ramanathan et al., 2005)
- More quantitative measurements of CP emissions and atmospheric concentrations as a function of time are needed (e.g., Novakov et al., 2003; Hansen and Nazarenko, 2004)
- Interested in atmospheric concentrations of CP, and their affect on snow and ice (Hansen and Nazarenko, 2004)
- Asia is of particular interest (Ramanthan and Carmichael, 2008; Flanner et al., 2007)

Why Ice Cores?



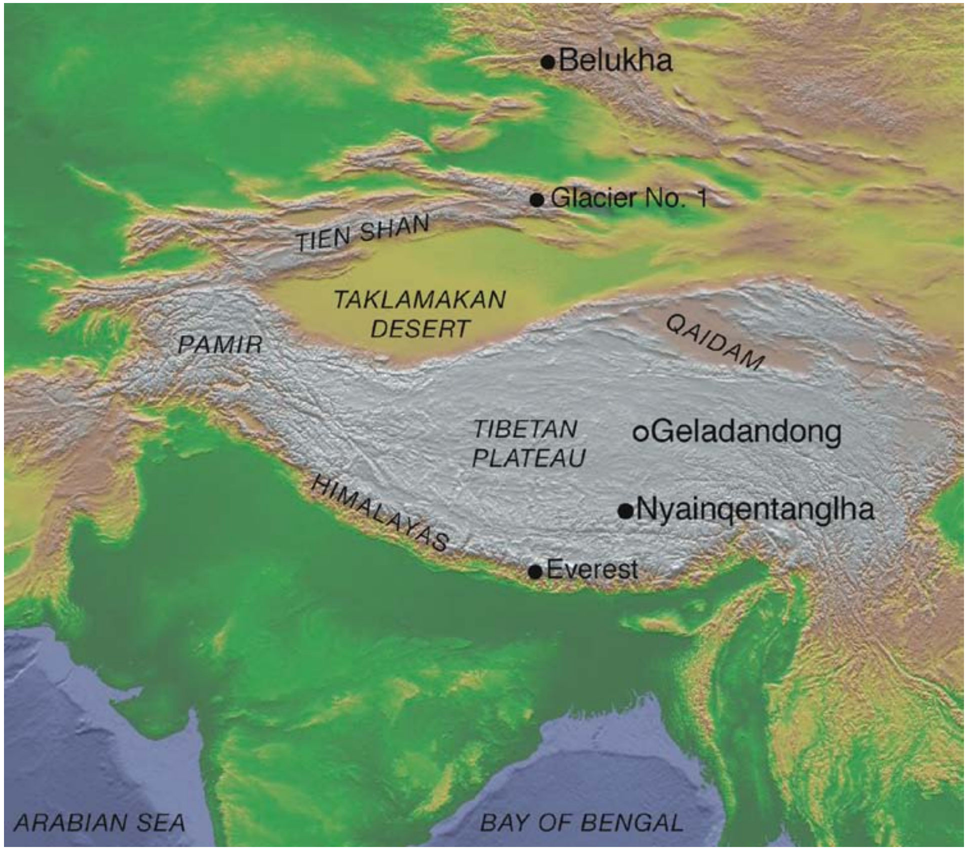
W.F. Ruddiman

- Ice cores provide high-resolution archives of past atmospheric and environmental conditions
- Preserve information about natural and anthropogenic atmospheric composition, and aerosol and contaminant transport and deposition.
- Previous studies have used ice cores to reconstruct carbonaceous particle histories (Chylek et al., 1992; Cachier and Pertuisot, 1994; Lavanchy et al., 1999; Jenk et al., 2006; McConnell et al., 2007; Ming et al., 2008; Schwikowski et al., in prep.)

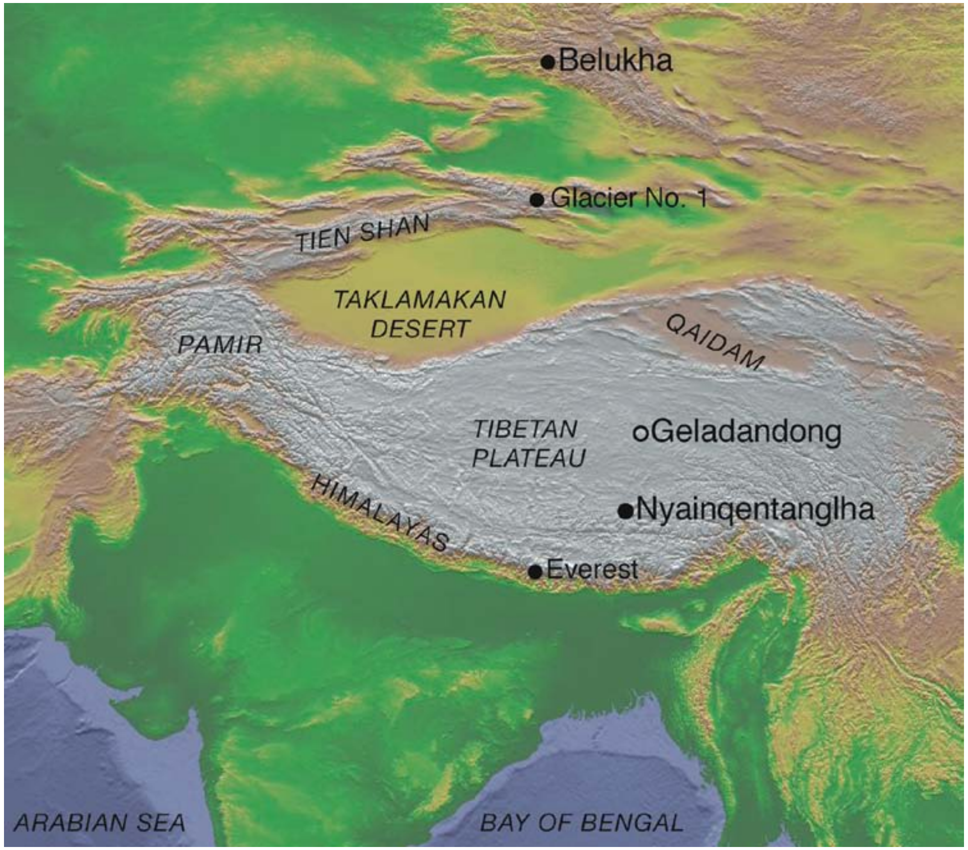


Mt. Nyainqentanglha
5860 m asl
124 m long ice core

Ice Core Sites

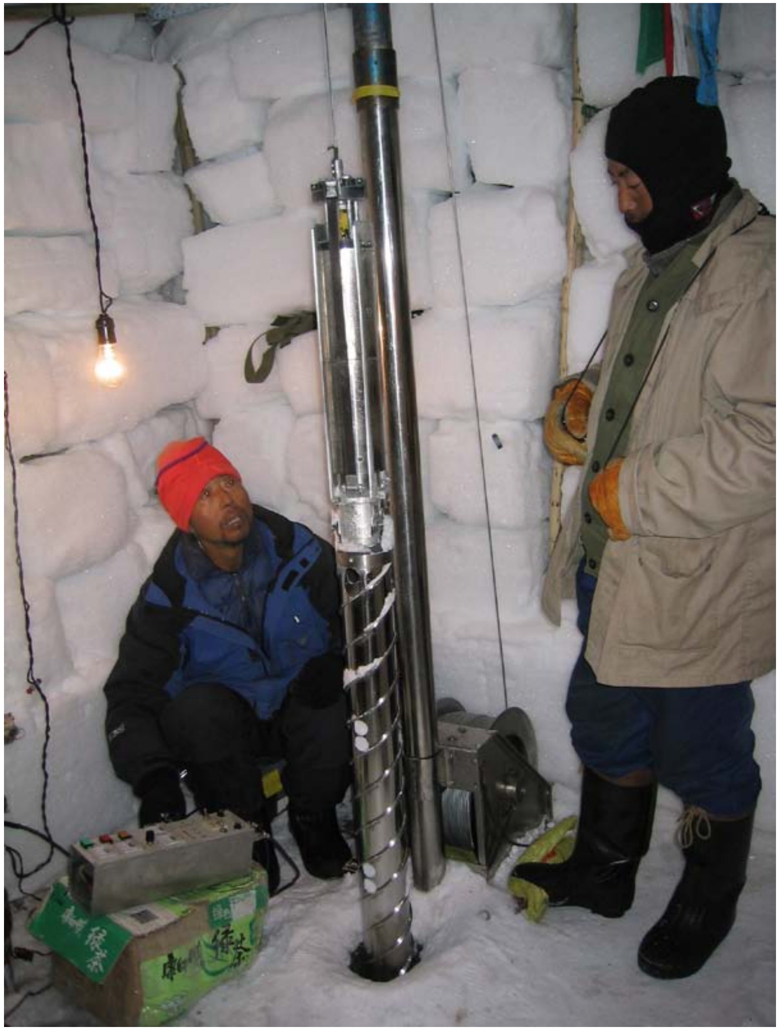


Belukha
4062 m asl
140 m long ice core



Mt. Geladandong
5745 m asl
146 m long ice core

Ice Core Collection



Sampling (follows after Lavanchy et al., 1999)

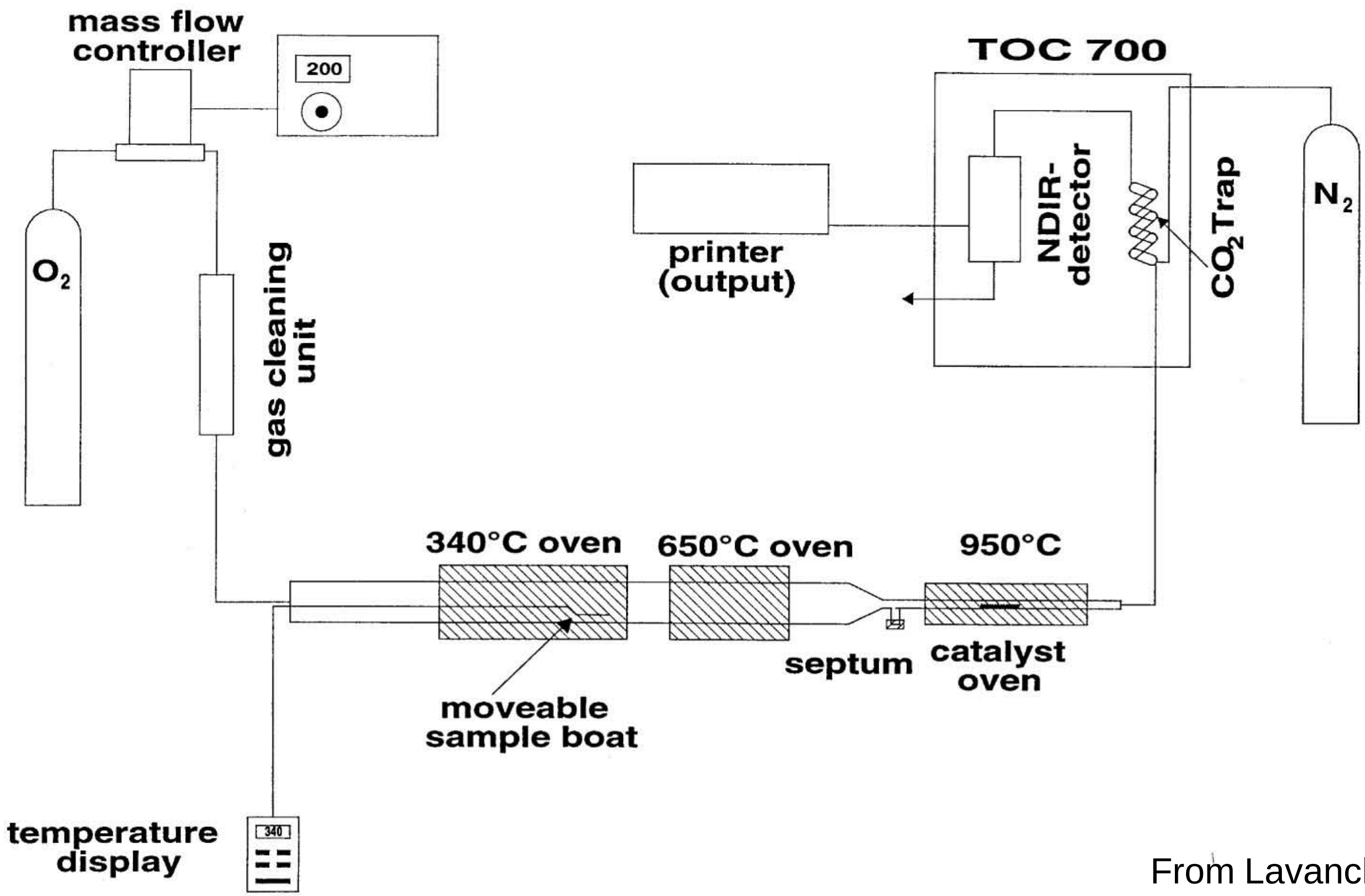
Sampling for Nyainqentanglha and (Belukha)

- 35 cm (70cm) long samples; 125-250 g (150-350 g)
- Ice samples rinsed with MQ H_2O to remove any potential contamination
- Samples melted in PTFE bottles
- Samples filtered through pre-fired Pallflex 2500-QAO-UP Tissuquartz filters with a vacuum filtration unit (water extracted filters)
- Filters acidified with 1mL 30% HCl (60 μL 1.6 M HCl) to remove carbonates
- Dried under a laminar flow hood, and then stored at -20°C until analysis
- Prior to analysis samples were heated to 70°C to eliminate potential volatile C adhered to the filters

Methods based on Cachier et al., 1989 and Lavanchy et al., 1999

Organic Carbon: 340°C for 42 minutes, pure oxygen

Elemental Carbon: 650°C for 32 minutes, pure oxygen



From Lavanchy et al., 1999

<u>Organic and Elemental Carbon</u>

- Sunset Laboratory OCEC Analyzer

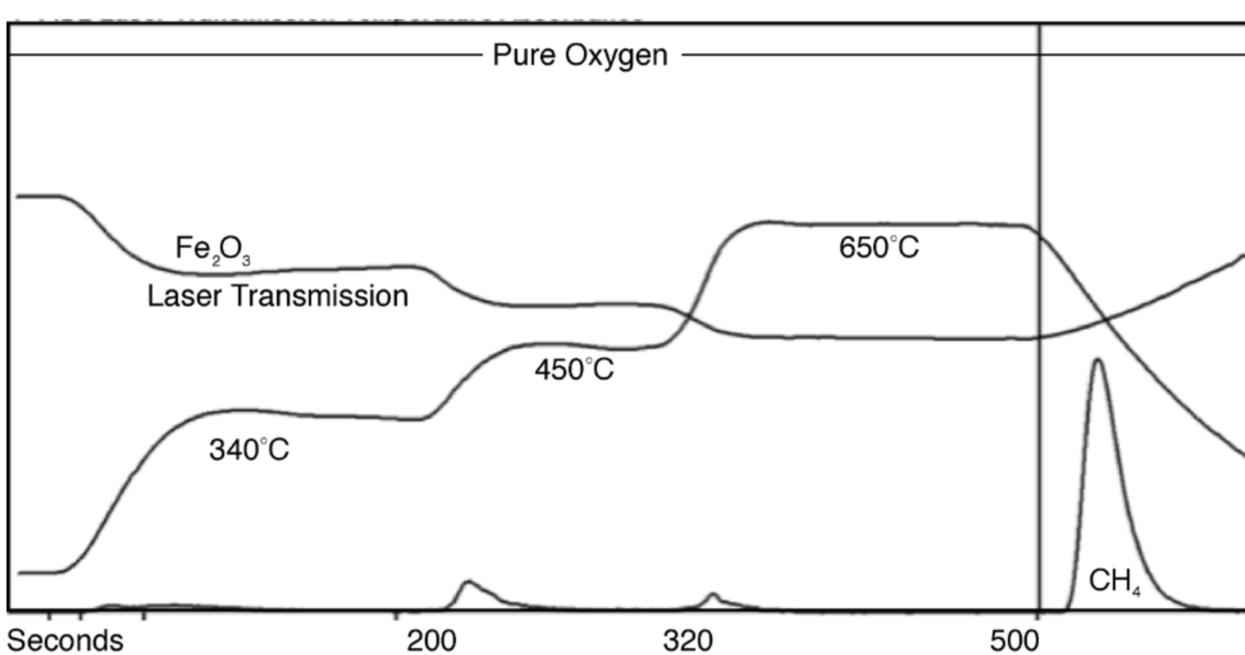
Difficulties using NIOSH method:

- Early oxidation of EC in He atmosphere
- Optical changes to the dust

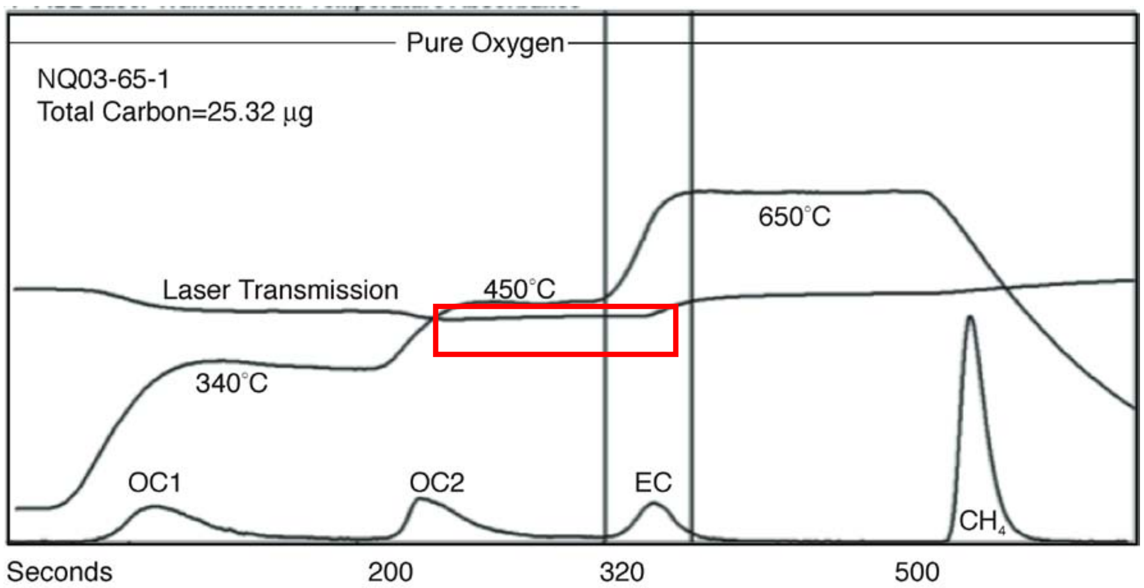
Filters analyzed with pure O_2

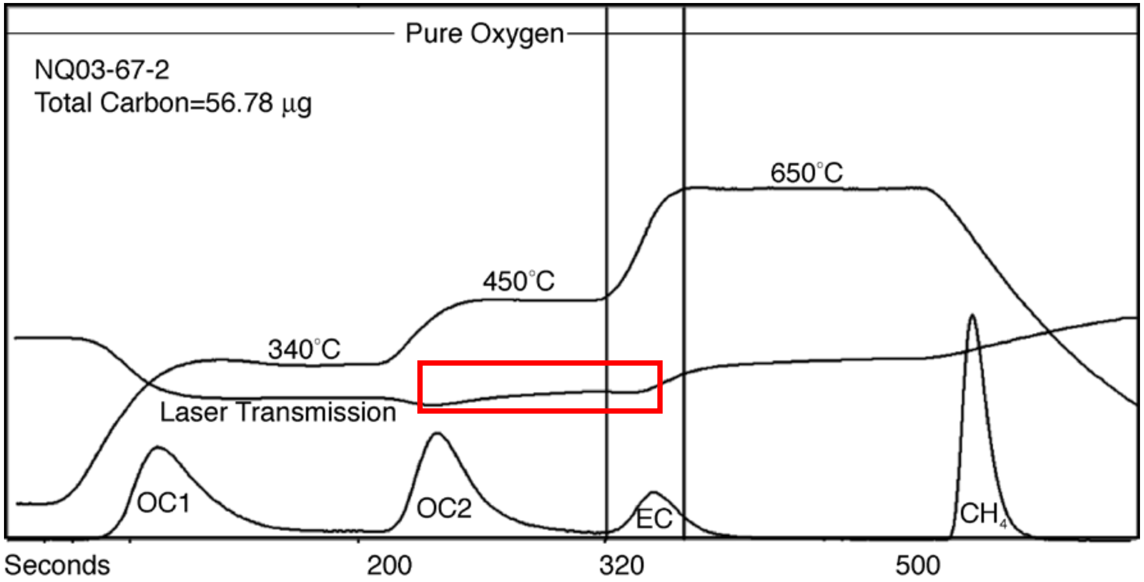
Organic C:
340°C 180 s
450°C 120 s

Elemental C:
650°C 180 s



Typical Samples





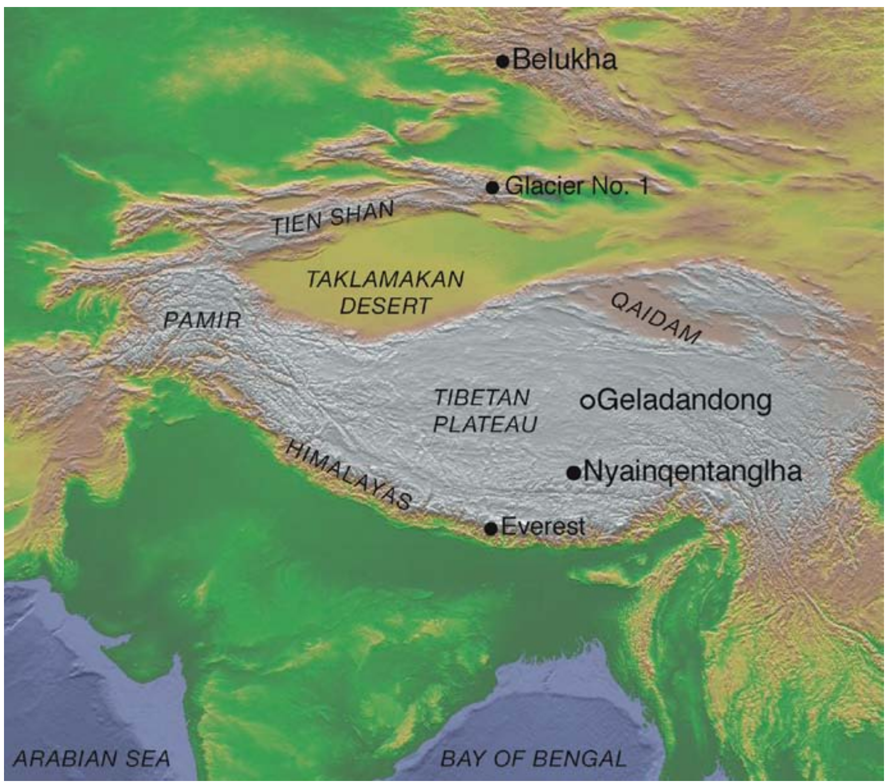
Carbon Concentrations from Mid-Latitude Ice Cores

Site	Time Period	n	OC (ug/L)	EC (ug/L)	TC	Reference
Everest	1951-2001	143	-	~17 (2-50)	-	Ming et al., 2008
Nyainqentanglha*	~1800-2003**	80	341 (20-1796)	75 (7-684)	417 (28-2480)	Kaspari et al., in prep.
Belukha	1950-2001	41	102 (27-174)	34 (8-39)	138 (60-311)	Schwikowski, Henderson et al., in prep.
	1775-1950	88	74 (26-174)	19 (8-39)	92 (34-212)	
Colle Gnifetti, Swiss Alps	1950-1975	14	291 (150-484)	68 (25-130)	360 (195-614)	Lavanchy et al., 1999
	1759-1950	40	138 (53-391)	29 (4-81)	167 (66-450)	

*core not yet fully analyzed

average (min-max)

**core not yet dated- rough estimate



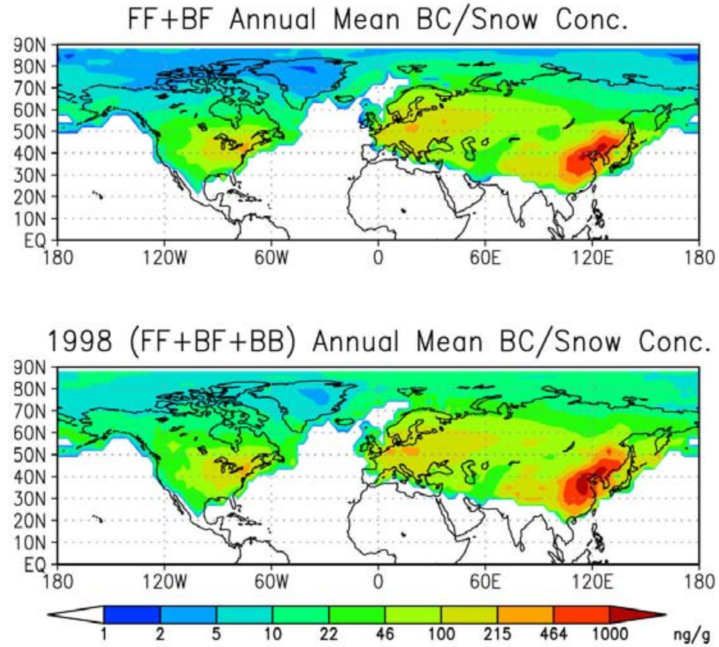
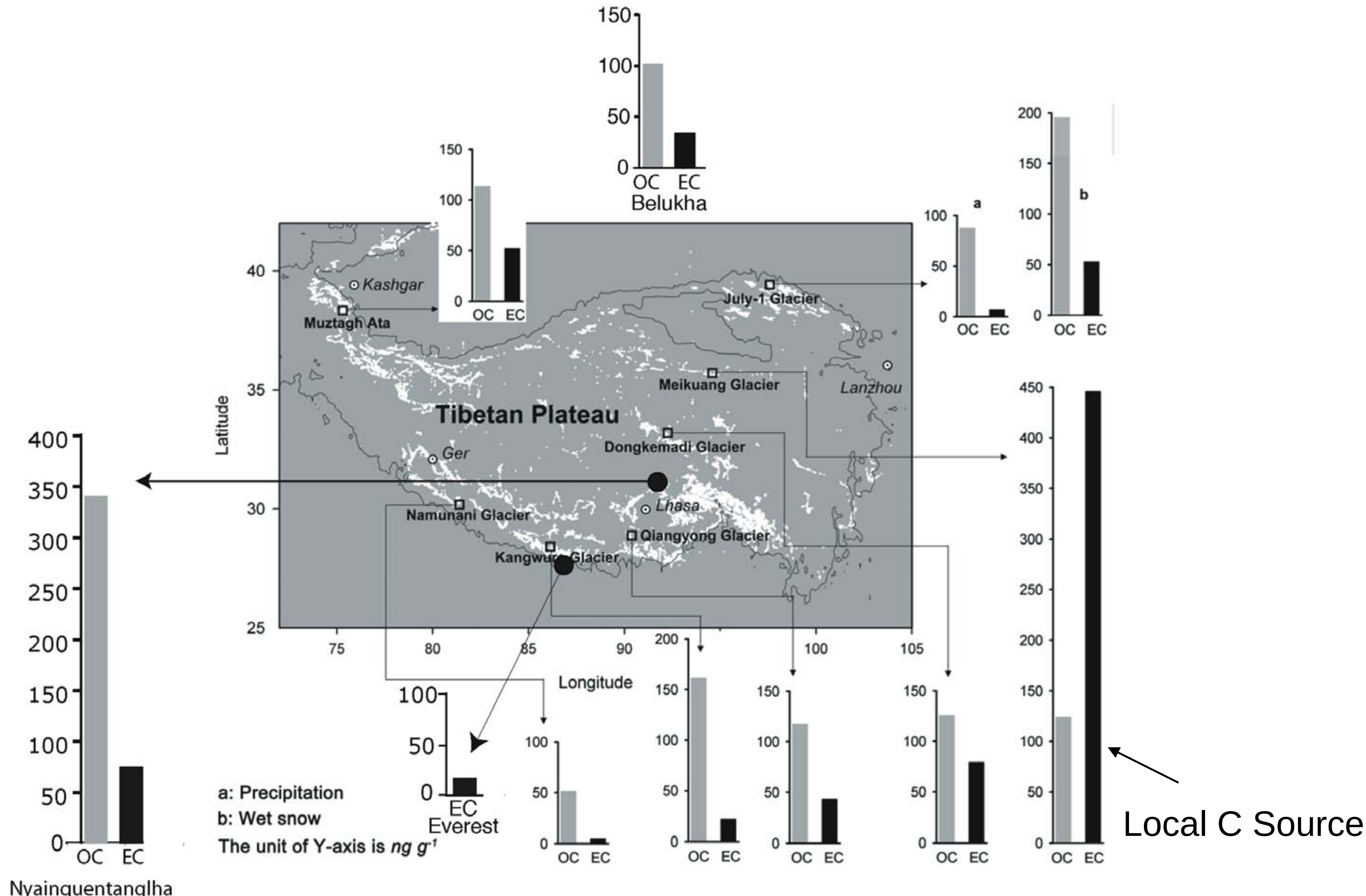


Figure 5. Annual mean predicted BC concentrations in snow (ng BC per g of ice) using central estimate (top) fossil fuel and biofuel sources only, and (bottom) fossil fuel, biofuel, and 1998 biomass burning emission sources.

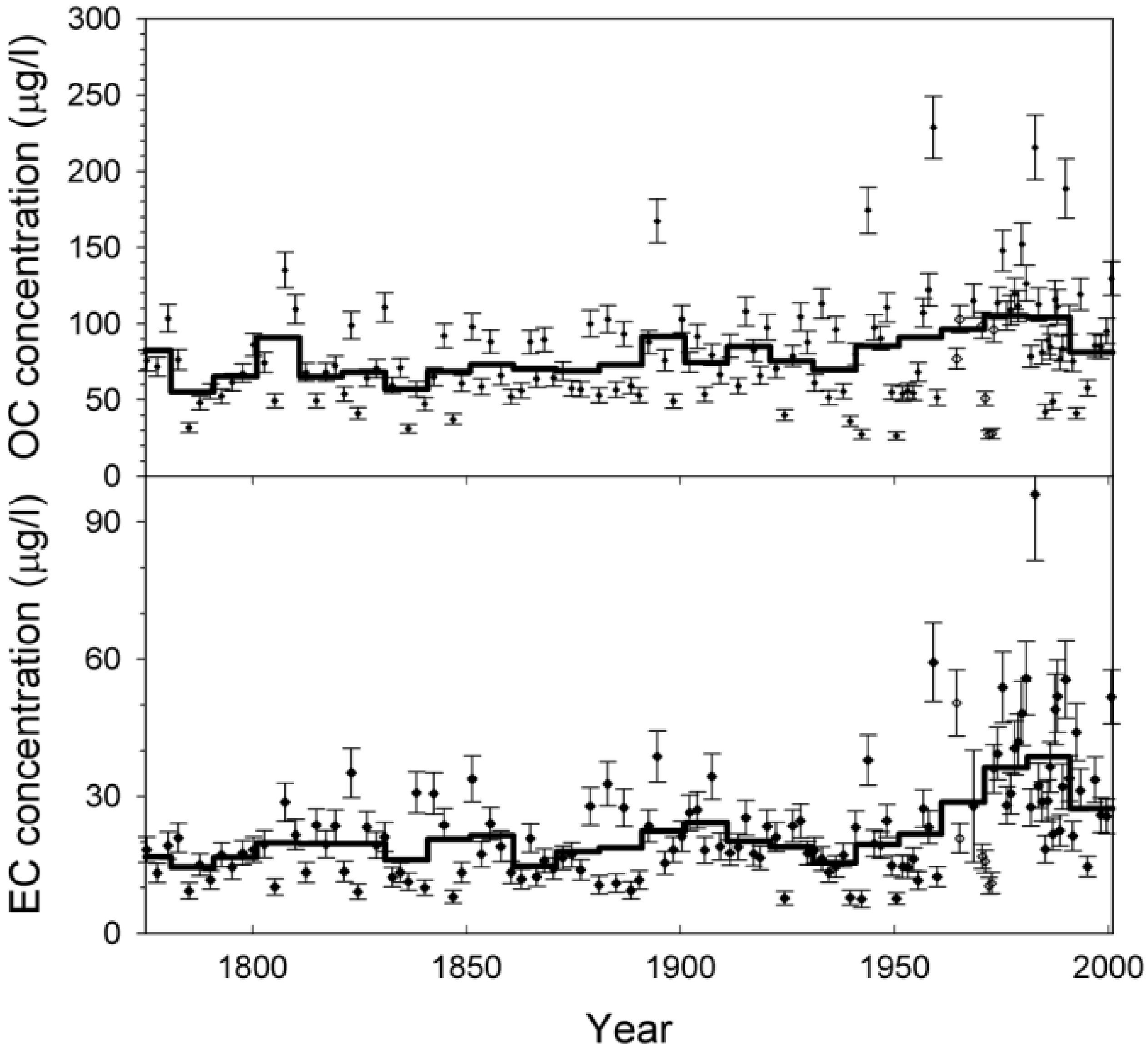
From Flanner et al., 2007

Organic and Elemental Carbon from Tibetan Plateau Snow Samples

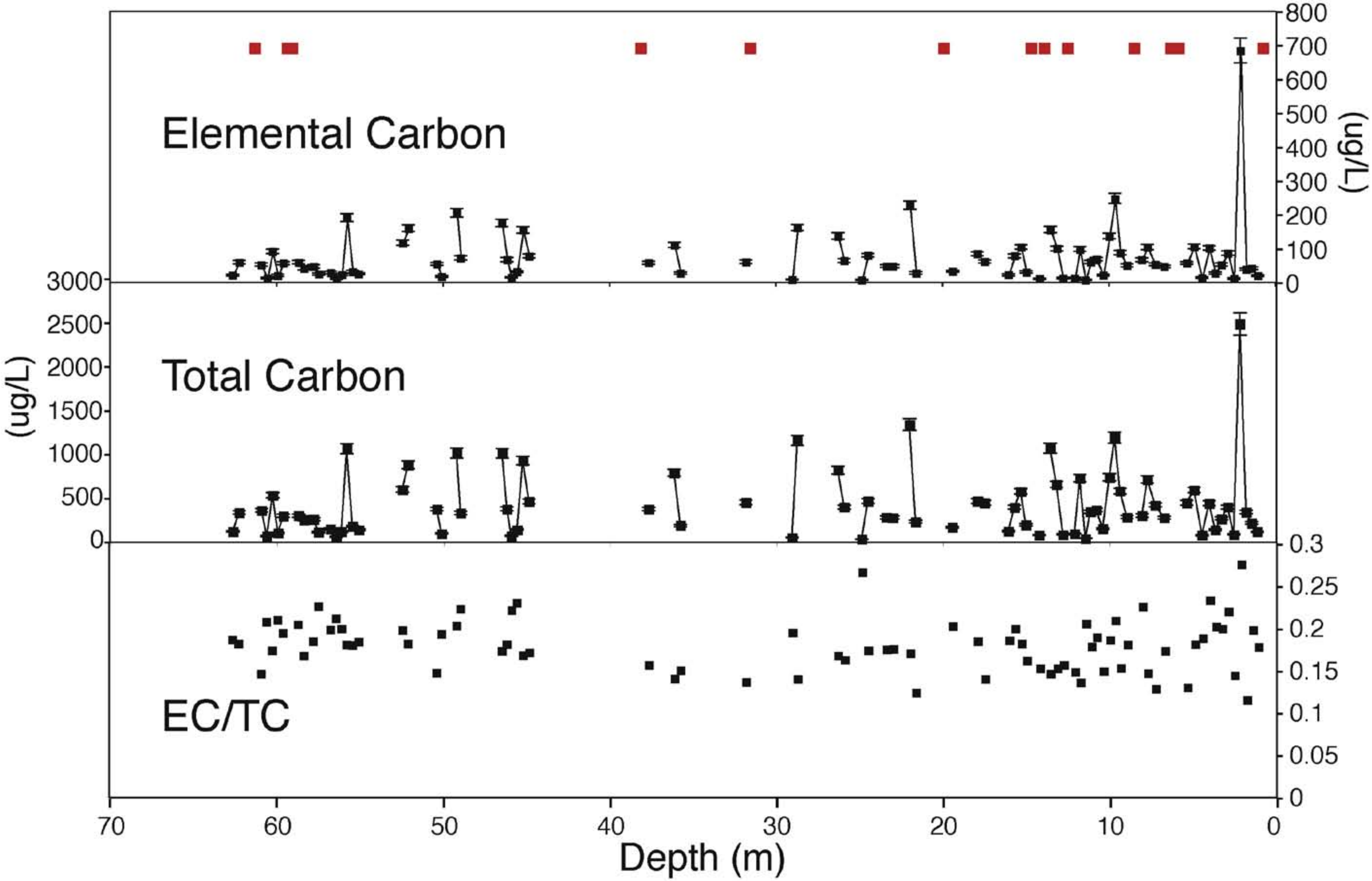


Modified from Xu et al., 2006

Belukha

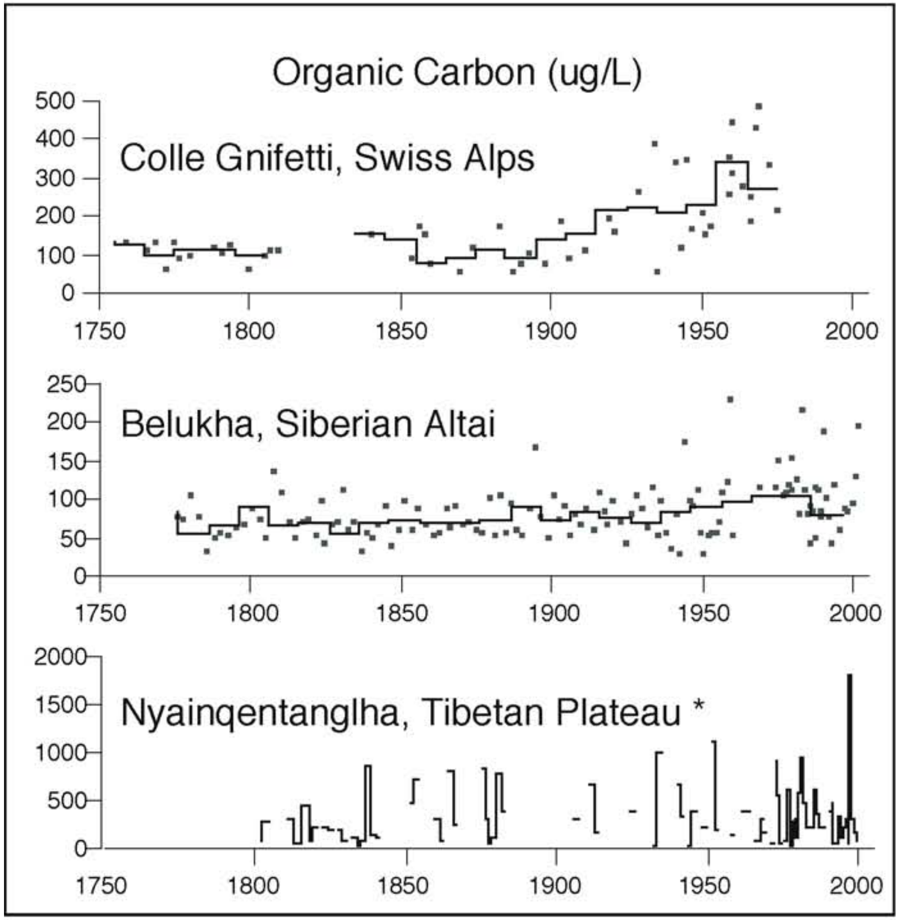


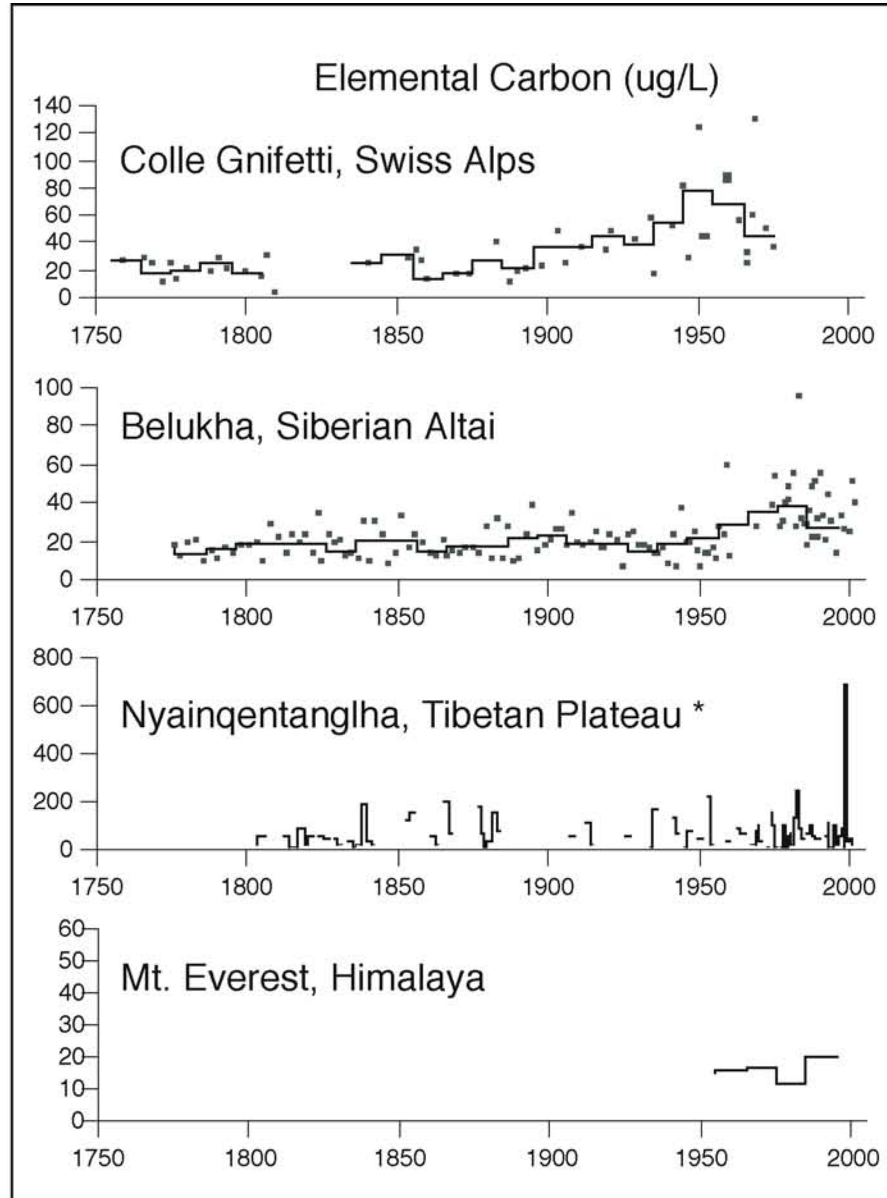
From Schwikowski and Henderson et al., in prep.



Elemental Carbon
Total Carbon
EC/TC
(ug/L)
(ug/L)
800
700
600
500
400
300
200
100
0
3000
2500
2000
1500
1000
500
0
0.3
0.25
0.2
0.15
0.1
0.05
0
70
60
50
40
30
20
10
0
Depth (m)

Temporal Variations in OC and EC from Mid-Latitude Ice Cores

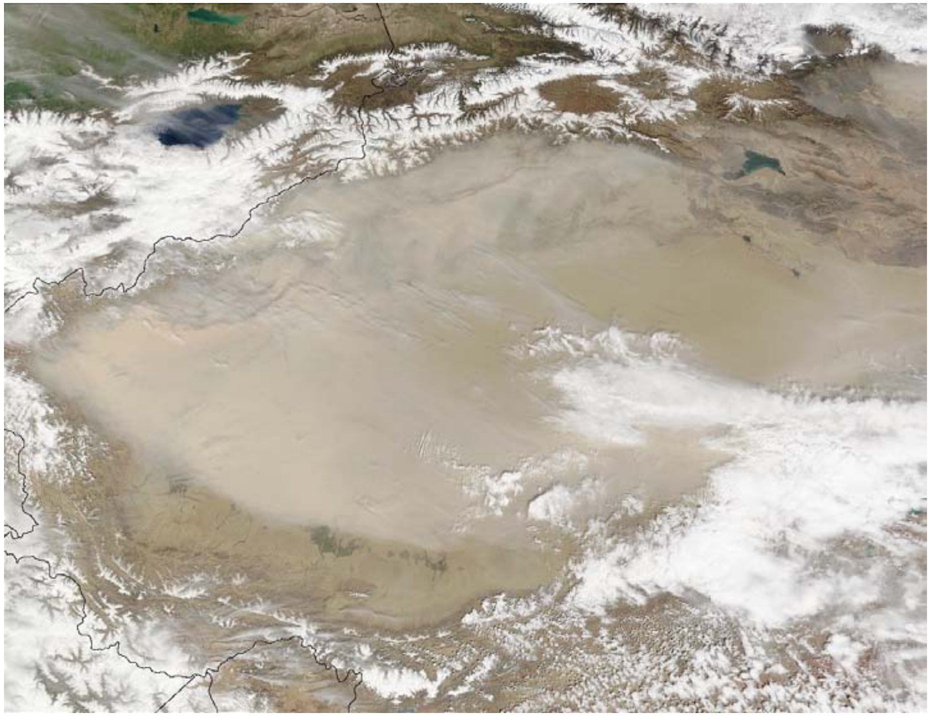




* estimated age scale

Dust

Atmosphere



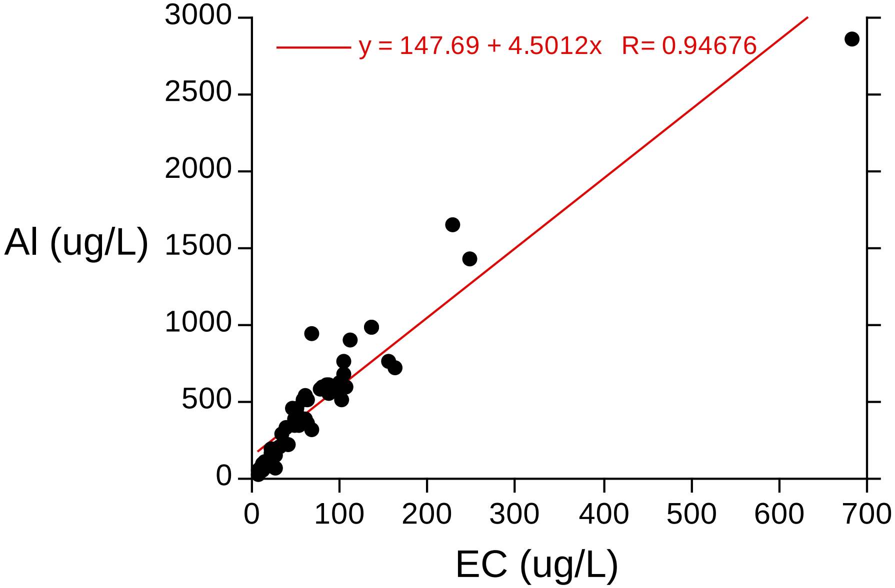
Dust storm over Taklamakan Desert

Snow Albedo

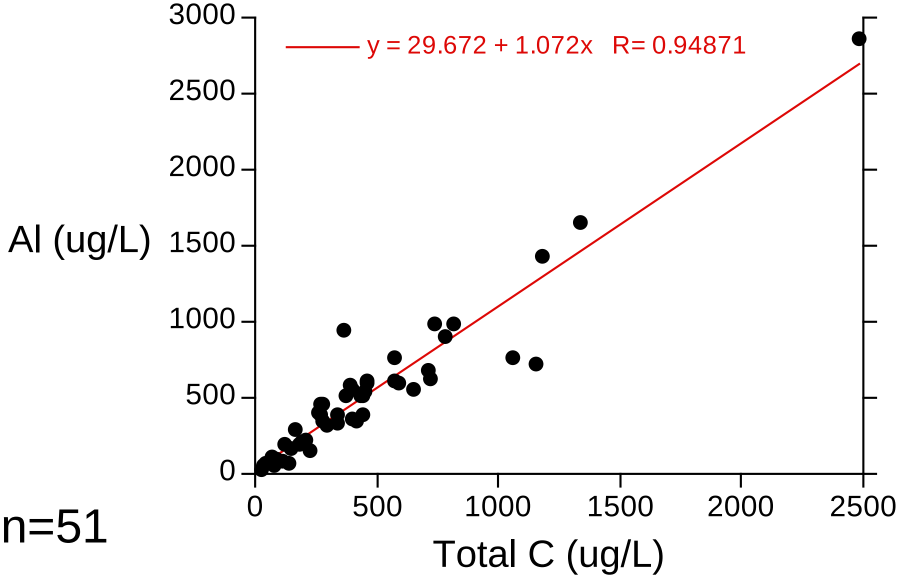
Dust/EC in ice
Mt. Nyainqentanglha

Strong Association Between Dust and C Concentrations

Filters Analyzed for Dust via Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES)



n=51



- Carbon is transported with the dust (joint transport)
- Dust has a carbon component
- Melting in the core results in trapping of dust and carbon in the same layers
- Analytical artifact

Optical Absorption of EC relative to Dust

"*Dust loadings must exceed BC concentrations by at least a factor of 100 if the dust is to make a significant contribution to the overall optical absorption*." -Hansen et al., 1993

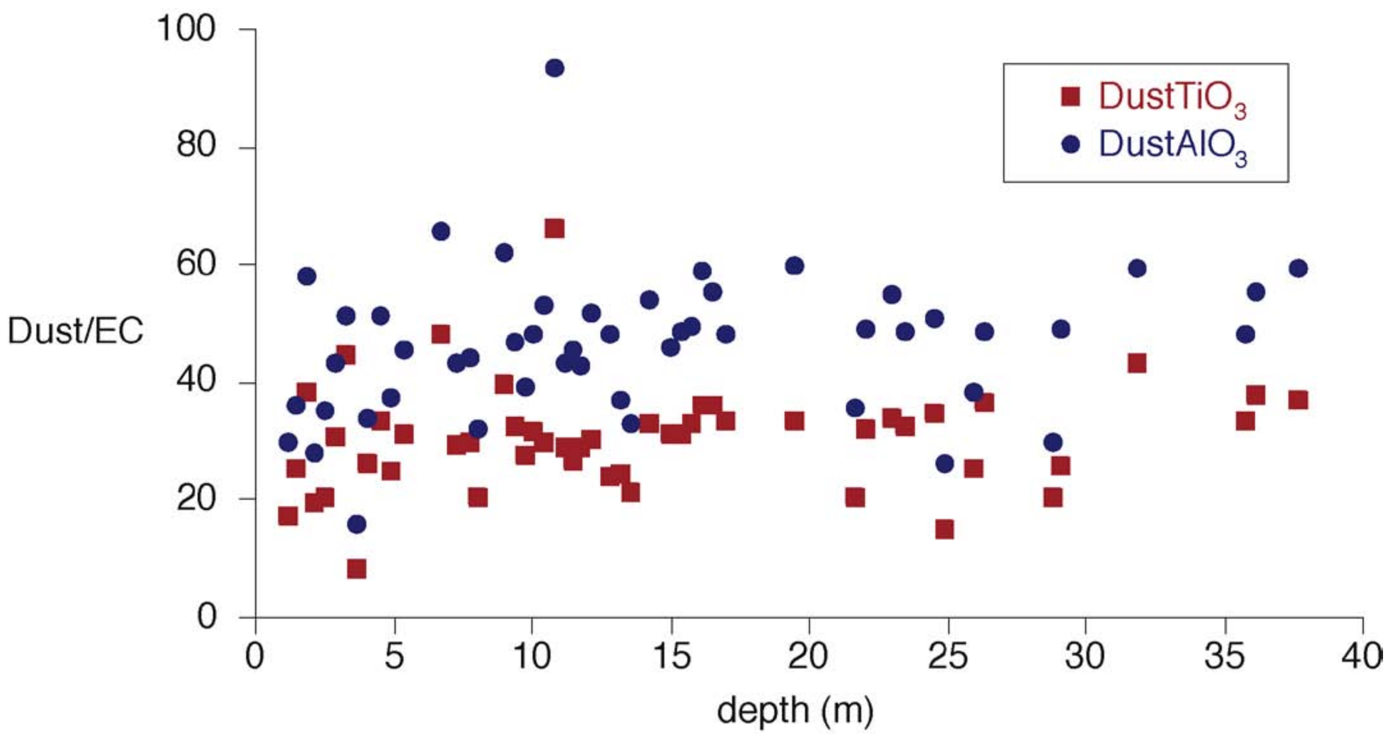
Ti/Al on the filters=.025-.03 Ti/Al_{UCC}=.04 (Wedepohl, 1995)

TiO_2=0.59% of UCC AlO_3=15% of UCC

UCC=upper continental crust

Doesn't account for optical contributions from OC

EC dominating the optical absorption in the atmosphere?



Summary and Future Work

• OC and EC concentrations at Belukha have increased since 1950, likely related to biomass and fossil fuel burning.

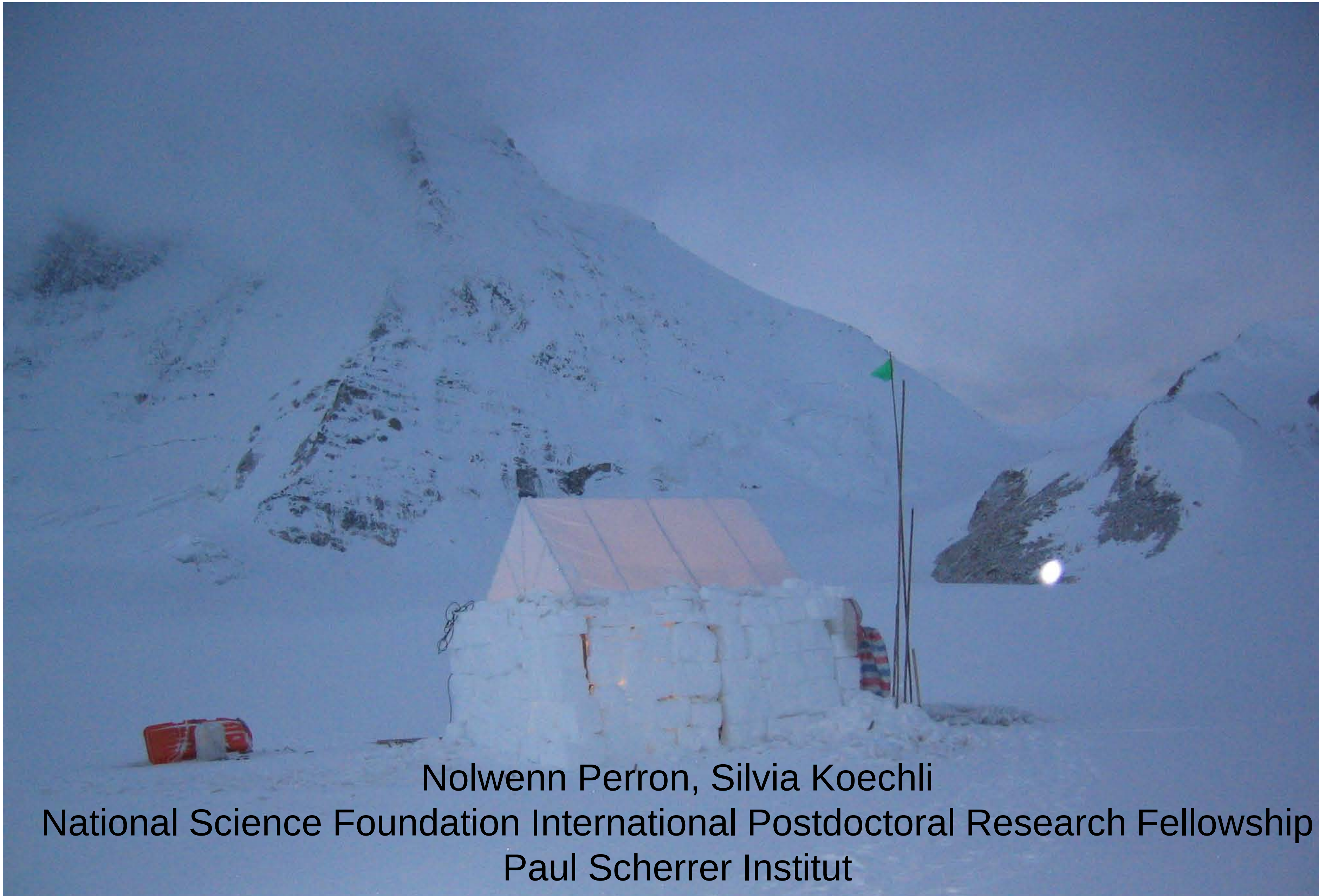
• Preliminary data from Nyainqentanglha does not indicate a clear trend in OC and EC concentrations. OC concentrations at this site are notably high.

• There is a strong correlation between CP and dust concentrations in the Nyainqentanglha ice core.

• The ratio of dust to EC (~20-60) suggests that EC dominates optical absorption in the atmosphere. Both EC and dust affect the albedo of snow and glaciers.

•Continue analysis and interpretation of the Nyainqentanglha and Geladandong ice cores.

Acknowledgements



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