Characterization of dust emissions from an actively retreating glacier in Yukon, Canada

High Latitude Dust Workshop: Effects, Observations, and Modeling of HLD (February 14, 2019)
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Key Scientific Goals

➢ Perform Ground Sampling at a Pro-glacial Dust Source in the Canadian North
➢ Characterize Particle Size and Chemical Composition
➢ Calculate Vertical Dust Flux
Monitoring Dust Emissions from the Ä'äy Chù (Slims River)

• Observations have identified this location as a significant local dust source

• River was, until recently, supplied by the meltwaters of the Kaskawulsh Glacier

• River Delta: 25 km from the glacier, which is 7 km wide

• River Valley: 1000 m deep & 8 km wide, average slope of only 1:200

• Cold air drainage occurs from the substantial glacier mass of the Kaskawulsh and the St. Elias mountain range

• Smaller surrounding steep valleys also play a role in providing drainage to prolong and intensify katabatic winds

• Sediments primarily fine sands, and silts

Climate change-induced river piracy of the Ä'äy Chù (Slims River)

- Spring 2016: rapid melting of the Kaskawulsh glacier rerouted the waters of the Ä’äy Chù
- The exposed streambed produces dust
- Ground measurements were collected from this dust source May 4 – 31, 2018

The New York Times

*Climate Change Reroutes a Yukon River in a Geological Instant*

Dust Sample Collection

• **Filter samplers**
  – N-FRM Mini-Vols, ARA instruments (16 L/min)
  – $PM_{10}$ inlet
  – Changed Filters every 24 hrs
  – Samples used for elemental, mineralogical, and gravimetric analysis

• **Particle Sizing**
  – OPC Multichannel Monitor, manufactured by FAI Instruments
  – 8 optical channels $d = 0.28 – 10 \mu m$
  – Records number concentrations at 2 – 5 Hz

• **Hanby Inverted Frisbee Traps**
  – Placed at several locations near the river valley
  – Monitoring dust deposition in the areas surrounding the dust source
  – Opportunity to inform and collaborate with community members

May 2017, Shakat Tun Wilderness Camp Christmas Bay
Sampling Locations

- LU’an Man (Kluane Lake)
- A’ay Chu (Slims River)
- Island
- KLRS Outpost
- Christmas Bay

- Air Sampling + Deposition Traps
- Air Sampling Only
- Deposition Traps Only
Filter Sampling

• Down Valley site included:
  – three filter samplers
  – an OPC
  – meteorological equipment

• Mobile station was moved between sites:
  – Čăy Chù East (May 4 – 14)
  – Visitor’s Center (May 15 – 28)
  – Island (May 29 – 31)
Sampling Locations

- Filter Samples
- Soil Samples
Ambient PM$_{10}$ Concentrations

24-hr PM$_{10}$ Concentrations

![Graph showing PM$_{10}$ concentrations over time with different stations and guidelines.]

- **DV 2 m**
- **DV 4 m (OPC)**
- **DV 6 m**
- **A’ay Chu East**
- **Visitor’s Center**
- **Island**

EPA 24-hr PM$_{10}$ NAAQS

WHO 24-hr PM$_{10}$ guideline

Sampling Dates:
- May 5
- May 9
- May 13
- May 17
- May 21
- May 25
- May 29
Diurnal Trends in Dust Emissions

- Dust emissions were typically observed to take place between the early-to-mid morning and the middle of the night.
- OPC data from May 17 to 31, 2018 illustrates this trend.
- Dust activity was not restricted to daylight hours.
• Dust emissions model of *Ginoux et al. 2001*
  
  — Varied threshold velocity ($u_t$) and PSD used by parameterization
  
  — Used meteorological data collected from site

*Ginoux, P. et al., Sources and distributions of dust aerosols simulated with the GOCART model, J. Geophys. Res. 2001, 106(D17), 20255–20273*  
Vertical Aerosol Flux

- Dust emissions model of *Ginoux et al. 2001*
  - Varied threshold velocity ($u_t$) and PSD used by parameterization
  - Used meteorological data collected from site
- Compared with the gradient method of *Gillette et al. 1972* ($R^2 = 0.007$)

*Ginoux, P. et al., Sources and distributions of dust aerosols simulated with the GOCART model, J. Geophys. Res. 2001, 106(D17), 20255–20273*

SEM/EDS Analysis of PM_{10} Mineralogy

- Particle size
  \[ d = 3.86 \pm 2.27 \mu m \]
- Particle shape
  \[ AR = 1.60 \pm 0.53 \]

<table>
<thead>
<tr>
<th>Mineral Type (Peaks)</th>
<th>% Frequency (n = 115)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure Minerals</td>
<td></td>
</tr>
<tr>
<td>Quartz (Si only)</td>
<td>7.8</td>
</tr>
<tr>
<td>Calcite (Ca only)</td>
<td>7.0</td>
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<tr>
<td>Gypsum (Ca and S)</td>
<td>5.2</td>
</tr>
<tr>
<td>Dolomite (Ca and Mg)</td>
<td>4.3</td>
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<tr>
<td>Clay Minerals</td>
<td>75.7</td>
</tr>
<tr>
<td>(Si &amp; Ca, Mg, S, Al, Fe, Na, K)</td>
<td></td>
</tr>
</tbody>
</table>
Elemental Composition by Sample Type

- Elemental composition was determined using ICP-MS
- Enrichment in PM$_{10}$ as compared with deposition and bulk soil samples
- We hypothesize this is due to the size cut-off
- Deposition trap composition was highly variable
  - longer sampling time, less external mixing, possible contribution of other sources
- Note: Error bars indicate standard deviation across multiple 24-hr samples
- FF = Fine Fraction, $d < 53 \mu m$
• Enrichment of PM$_{10}$ air samples was observed as compared to dust deposition and bulk soil samples

• Note: Error bars represent propagated standard error from the calculated mass fraction for both sample types compared
Conclusions & Future Work

• Mineralogy comprises primarily clay mineral aggregates, as well as quartz, dolomite, calcite, and gypsum

• Elevated minor & trace element content and less compositional variation was observed in ambient PM$_{10}$ as compared to bulk soils and deposition

• 24-hr guidelines were exceeded at sites close to a major highway, during a relatively short campaign

• We are currently working to refine our calculated vertical dust fluxes based on experimental data & various dust model parameterizations
Thank you to the following organizations and individuals!

- **Kluane First Nations and Dän Keyi Renewable Resource Center**, without whose permission and consultation our work would not have been possible.

- **James Allen and Shakat Tun Wilderness Camp** for allowing us to install our deposition traps on their premises at Christmas Bay.

- **Sian and Lance Goodwin (Outpost Research Station)** for going above and beyond the call of duty to offer their support of our fieldwork.

- **Michael Bach and Sarah Butez** for volunteering their time to aid in the field.

- **Dr. Juliana Galhardi, Dr. Madjid Hadioui, and the Wilkinson Group** for their help performing ICP-MS analysis.

- Hayes and LÉÉ Groups
Call for Ph.D. students!

We have **TWO** fully funded Ph.D. positions available to work on this project!

Interested parties should come talk to me!

Or, email js.king@umontreal.ca
Extra Slides
Metals Extraction via Acid Digestion

- Metals must be extracted from soil samples using strong acid
- EPA Method 3051a (Microwave-assisted digestion of soils) was used
  - Extraction; samples do not decomposed completely during digestion
  - Mixture of concentrated HNO$_3$/HCl used for the digestion
  - Three NIST soil standards were processed alongside samples, for quality control
ICP-MS Analysis of Metals in Solution

- Nexion Quadrupole ICP-MS in the Wilkinson Lab
- Solutions used in analysis:
  - Calibration standards (0.5 – 200 μg/L), Quality Control standard (50 μg/L), Internal standard containing 50 μg/L Sc, Y, In, Bi
- Polyatomic & isobaric interferences may affect measurement, so optimization and correction equations are required
Particle Sizing

- PSD Maximum, \( d = 3.25 \, \mu \text{m} \)
- Fitted Peak, \( d = 3.52 \, \mu \text{m} \pm 1.69 \, \mu \text{m} \)

Graph showing the particle size distribution (PSD) with two curves: one for the PSD maximum and another for the fitted peak. The x-axis represents the particle diameter in micrometers (\( \mu \text{m} \)), and the y-axis shows the differential mass concentration (\( \frac{dM}{d\log D_p} \) in \( \mu \text{g/m}^3 \)).

Lower graph showing a color-coded timeline from May 5 to May 29, with different dates indicated and a color scale indicating the concentration of particles over time.
dN / dLogDp
SEM analysis of particle morphology

A.R. = 1.60 ± 0.53

$d = 3.86 ± 2.27 \mu m$
Effect of threshold velocity on results