On the critical need for mountain observatories to monitor and detect amplified climate change in British Columbia (BC)’s Mountains

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Outline

- Mountainous regions and amplified warming
- Distribution of weather stations in mountainous regions
  - Mountains of BC, Canada
  - Mountains of Nepal
- Elevational dependence of air temperature in the Cariboo Mountains Region (CMR), BC
- Summary
World’s mountains

Mountains derived from US Geological Survey Mapping Division, GTOPO30
Comparison of daily average temperature trends between the Northern Hemisphere (Land) and three high elevation regions (Colorado Rockies, Swiss Alps and Tibetan Plateau) during the latter half of the 20th century

Rangwala and Miller; 2012 (Climatic Change)
Mechanisms for elevational warming

Schematic of the relative vertical profile in atmospheric warming expected resulting from various mechanisms.
Impacts of amplified warming

- Water resources and hydrology
- Ecosystems
- Water supply & Livelihood

Photo: Anna Wilson, Science

Photo: Nabin Baral

Photo: http://www.activeremedy.org/mountain-ecosystems-are-crucial-for-fresh-water-27
Observation sites in BC

Stations < 1000 m
Observation sites in BC

Stations >1500 m

Legend
- Stations (>1500 m)
- Rivers
- Lakes
- Watersheds

Elevation (masl)
- High: 4189
- Low: 1

N.00.06
N.00.05
N.00.09

140°0'0"W
135°0'0"W
130°0'0"W
125°0'0"W
120°0'0"W
115°0'0"W
0
125
250
500 km
Observation sites in BC

Stations >2000 m
Distribution of Obs. sites in BC

Elevation distribution of BC

- **Hypsometric Curve**
- **Mean Elevation**
- **Average Timberline Elevation**

Stations above timber line 1.5%

Stations above mean elevation 17%
Observation sites in Nepal

Stations <1000 m

Legend
- Stations (<1000 m)

Elevation (masl)
- High : 8773
- Low : 0

Nepal Boundary
Observation sites in Nepal

Stations >1000 m

Legend
- Stations (>1000 m)

Elevation (masl)
- High : 8773
- Low : 0

Nepal Boundary
Distribution of Obs. sites in Nepal

Elevation distribution of Nepal

- Stations above timber line 0.5%
- Stations above mean elevation 13%
Operation of high elev. stations in BC

Agencies
- BC Hydro
- Environment Canada
- BCEnv Snow Pillow

Stations with elevation >1,500 m

No. of years with data availability

CAMnet stations

- It is a mesoscale (~100 km) network of 12 weather stations + 2 radio repeaters
- First four stations deployed in 2006
- Most weather stations are situated in the Cariboo Mountains
- There is a paucity of meteorological stations at high elevations and remote sites; CAMnet intends to fill part of this gap
- Long term goal is to detect climate change at high elevations and impacts to snow/ice
CAMnet stations in the CMR (Cariboo Mountains Region)

Distribution of weather stations with elevation [m] in the Cariboo Region

Legend
- CAMnet Stations
- BCRFC's Snowpilow Stations
- Environment Canada Stations
- Wildfire Mgmt. Branch Stations
- Prince George
- North Thompson River
- Mt. Sir Wilfrid Laurier
- Barkerville
- Quesnel River Basin

No. of Stations

Elevation (m)

0 500 1000 1500 2000 2500 3000

0 20 40 60
Distribution of weather stations with elevation [m] in the Cariboo Region

Number of Stations (>1500 m in Cariboo)

- ARDA
- CAMnet
- EC
- ENV-ASP
- FLNRO-FERN
- FLNRO-WMB
- MoTie
Validation of gridded data

<table>
<thead>
<tr>
<th>Station</th>
<th>Tmin</th>
<th>Tmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Browntop</td>
<td>0.98</td>
<td>0.98</td>
</tr>
<tr>
<td>QRRC</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
<td>Spanish</td>
<td>0.97</td>
<td>0.99</td>
</tr>
<tr>
<td>UCC</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
<td>Average</td>
<td>0.98</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Climate trends in Cariboo Mountains

Minimum Air Temperature

Sharma & Dery; 2016 (Atmosphere-Ocean)
Climate trends in Cariboo Mountains

Sharma & Dery; 2016 (Atmosphere-Ocean)
Elevational Dependency of Air Temp.

- **Tmin. has increased in CMR**
  
  Range: 0.002 - 0.74°C decade$^{-1}$

- **Higher the elevation, greater are the Tmin. trend magnitudes**

- **Tmax. has increased in CMR**
  
  Range: 0.06 - 0.30°C decade$^{-1}$

- **Lower the elevation, greater are the Tmax. trend magnitudes**

Sharma & Dery; 2016 (Atmosphere-Ocean)
Seasonal dependency

Tmin.

Higher the elevation, strong and significant minimum air temperature trends for all seasons

e.g. winter up to 1.30° C decade$^{-1}$ at above 2500 m

Sharma & Dery; 2016 (Atmosphere-Ocean)
T_{max}. Lower the elevation, stronger are maximum air temperature trends.

Sharma & Dery; 2016 (Atmosphere-Ocean)
Mountainous regions are significant for their resources and role they play in the environment; they are highly sensitive to anthropogenic warming.

There exists a paucity of climate stations in the mountainous regions both in developing and developed countries (e.g. BC and Nepal).

In BC, government monitored high elevation stations, once operating in already under sampled area, were shut-down creating more gaps in terms of observed climate data.
Summary

- Stations established by academic institutions such as universities (e.g. UNBC) are helpful to fulfill the data gaps; however need long term support to continue maintaining such stations.

- The elevational dependency of temperature in the Cariboo Mountains indicates higher elevation regions warming at a faster rate than lower elevation.

- Elevational dependency shows opposite pattern of minimum and maximum temperature trends.

- These changes matter because they affect local hydrology, ecology and, therefore society and economy.
Recommendations

- There is a need of more in-situ observing stations: higher elevations surface observation sites are very limited.

- Remote sensing can fill large gaps in meteorological data in remote areas; however it could not provide what we obtain from in situ data. Furthermore there is still need of in situ data for validation of those products.

- Partnership among different data generating agencies is recommended.

- When using the results, one should be careful on the elevational warming because of less number of sampling data that ultimately affect the accuracy of gridded and of modelled datasets.
Acknowledgements
CAMnet weather stations
a.) Castle Creek Glacier (2105 m)

b.) Plato Point, Quesnel (728 m)