Response of the Indus Watershed to Climate Change in Central Asia
Lu Zhang, Alfredo Ruiz-Barradas, Sumant Nigam
Department of Atmospheric and Oceanic Science, University of Maryland, College Park

Motivation and Study Area
The uncertain impacts of climate change on the Indus River and its drainage basin has been historically understudied. This drainage basin is divided among 4 different countries and home to over 200 million people. Therefore, understanding the regional trends and magnitude of climate change is crucial to the future welfare of this transboundary region.

Glacial/Snowmelt vs. Precipitation Fed Rivers
The Indus River is a glacial / snowmelt fed river while rivers such as the Ganges are more precipitation driven. Illustrated by figure 1, the glacial wastage of Western Himalayan glaciers significantly contributes to the total Indus river streamflow. Consequently, the changing dynamics of Western Himalayan Glaciers are additional components that determines the health of the Indus River and its drainage basin.

The Indus River Basin

Many previous research has highlighted the uncertain trends in climatology within the Indus Basin, including:
- **Karakoram Anomaly**: Karakoram glaciers in the Western Himalayas experienced a positive mass balance since the late 1990s and remained mostly stable from 2003 - 2008
- Average winter precipitation has been increasing since the 1960s
- Average summer precipitation has been decreasing since the 1960s
- Mean summer surface temperature has slightly decreased since the 1960s

Datasets Analyzed / Procedures

<table>
<thead>
<tr>
<th>Variable Analyzed</th>
<th>Dataset Name</th>
<th>Spatial Resolution</th>
<th>Temporal Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Temperature</td>
<td>CRU TS 4.00</td>
<td>0.5° * 0.5 degree</td>
<td>Seasonal (Monthly) 1851 (1901) - 2005</td>
</tr>
<tr>
<td>Average Precipitation</td>
<td>TRMM 3B42v7</td>
<td>0.5° * 0.5 degree</td>
<td>Seasonal (Monthly) 1998 - 2017 TRMM 2013 - 2017 GPCP</td>
</tr>
<tr>
<td>Mean Monthly Precipitation, Mean Monthly Accumulation, Mean Monthly Storage</td>
<td>University of Delaware (U.Del.) Grid monthly Time Series</td>
<td>0.25° * 0.25 degree</td>
<td>Seasonal (Monthly) 1985 - 1998</td>
</tr>
<tr>
<td>Snow Water Equivalent, Snow Melt</td>
<td>U.Delaware Terrestrial Water Budget Time Series</td>
<td>0.25° * 0.25 degree</td>
<td>Seasonal (Monthly) 1985 - 1998</td>
</tr>
</tbody>
</table>

Discussion / Observations

- In the 1990s, the Upper Indus Basin (UIB) has experienced below average temperatures for all seasons except for winter. Below average temperatures was especially severe for the spring seasons.
- In the 2000 – 2010 decade, this UIB is warming at a slower rate compared to its surrounding regions, with below average summer temperatures.
- The UIB has experienced cooler summers since the 1990s. This led to below average snow melt and could be a factor behind the Karakoram Anomaly.
- As the glaciers in the UIB are winter accumulation glaciers, the slight increase of winter precipitation may be another factor driving the Karakoram Anomaly.

Results

**Snowmelt Climatology (mm/day/decade) (U.Delaware Dataset)**

**Snowmelt Climatology Trends (mm/day/decade) (U.Delaware Dataset)**

Future Works

Overall results of this study highlighted the magnitude and general pattern of climate change within the Indus Basin Region. This paved the way for the implementation of more extensive types of analysis. A weak point within this project is the low temporal resolution chosen to track changes in the climatology. In future works, a time series that incorporates area averaged changes in climatology will provide a more detailed representation that does not rely on intervals containing numerous years. Eventually, additional outside climatological factors (winds, sea level pressure, sea surface temperatures) can also be studied to determine its connection to climatological trends within the Indus Basin.

References