Modelling the Karakoram Anomaly: Glacier-Climate Interactions & Climatic Drivers

Session Of The Third Pole Climate Forum And Meeting Of The Third Pole Rcc-network Task Team
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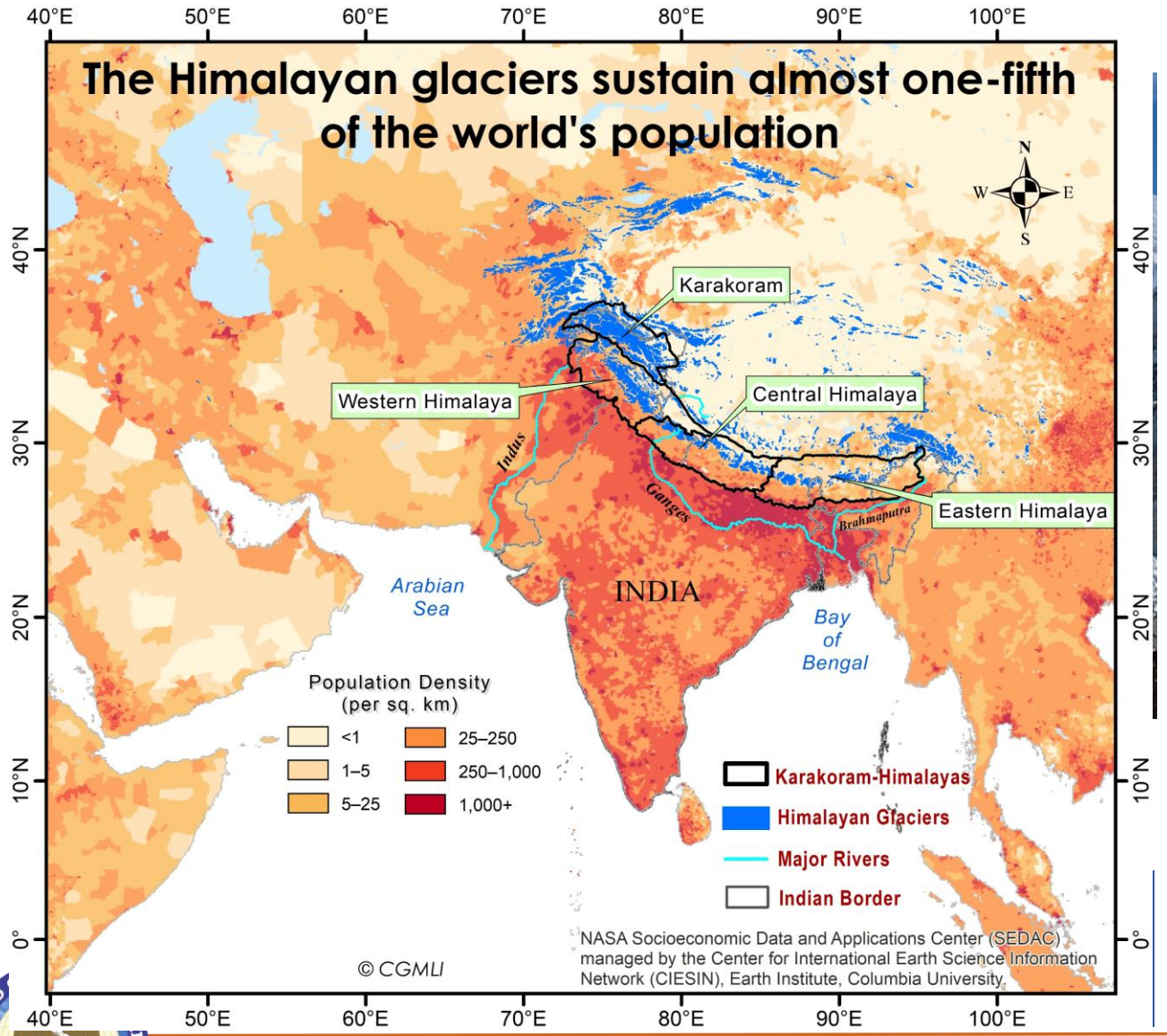
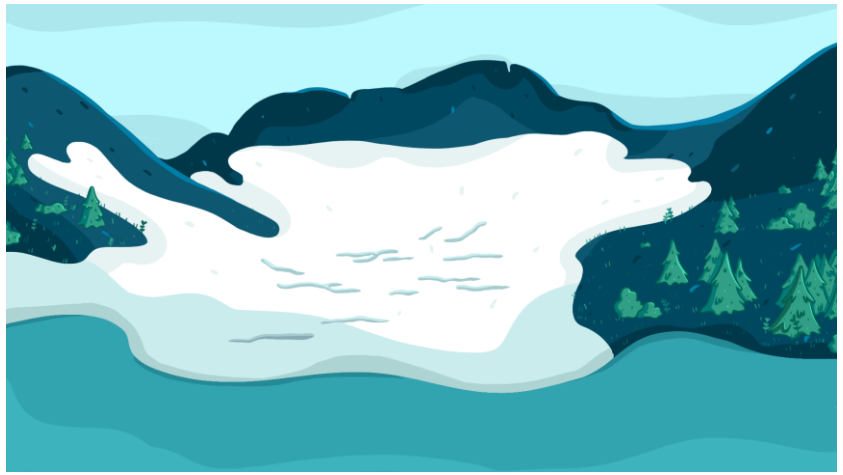
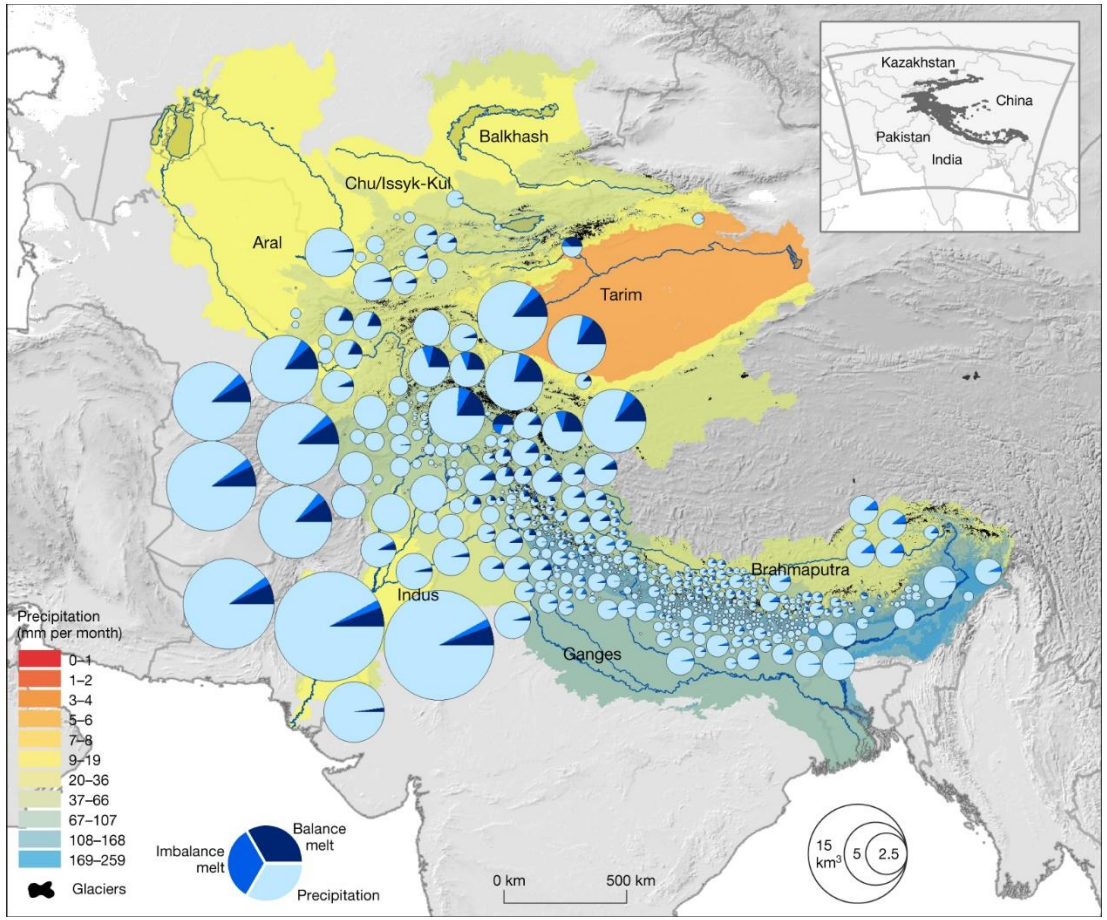
Why care about Himalayan Glaciers ?



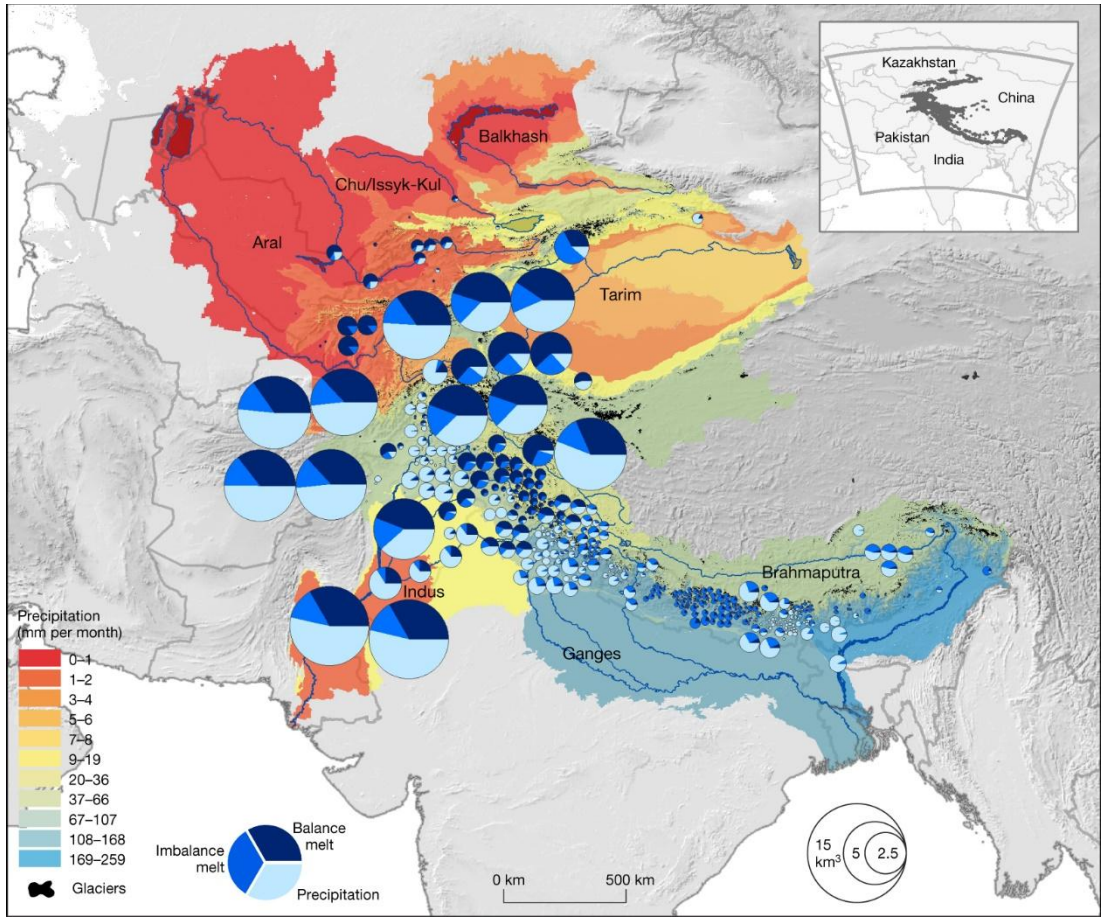
Rising temperatures threatening Himalayan glaciers!



Glaciers act as buffer to drought



Precipitation and glacial melt inputs in an average year



Precipitation and glacial melt inputs in a drought year

Pritchard, *Nature, 2019*

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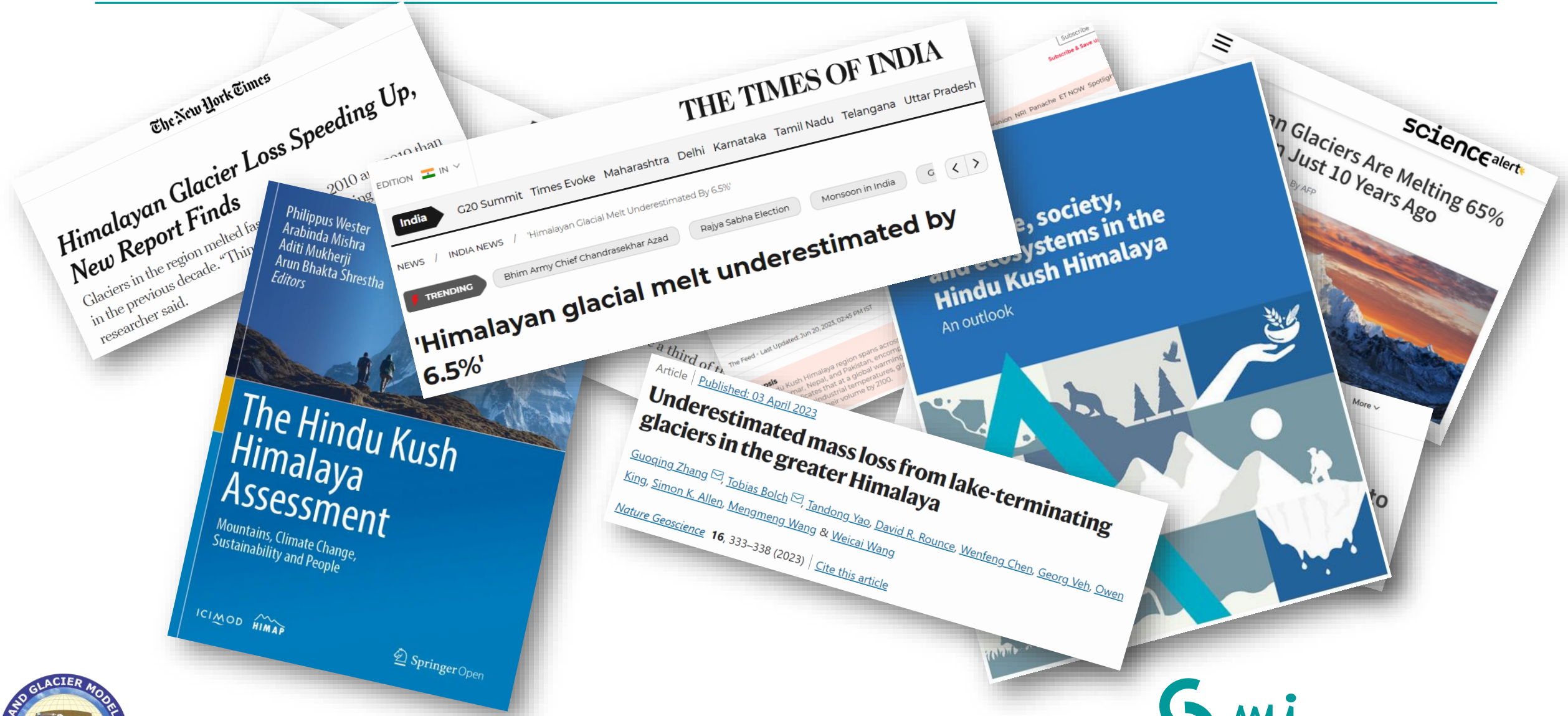
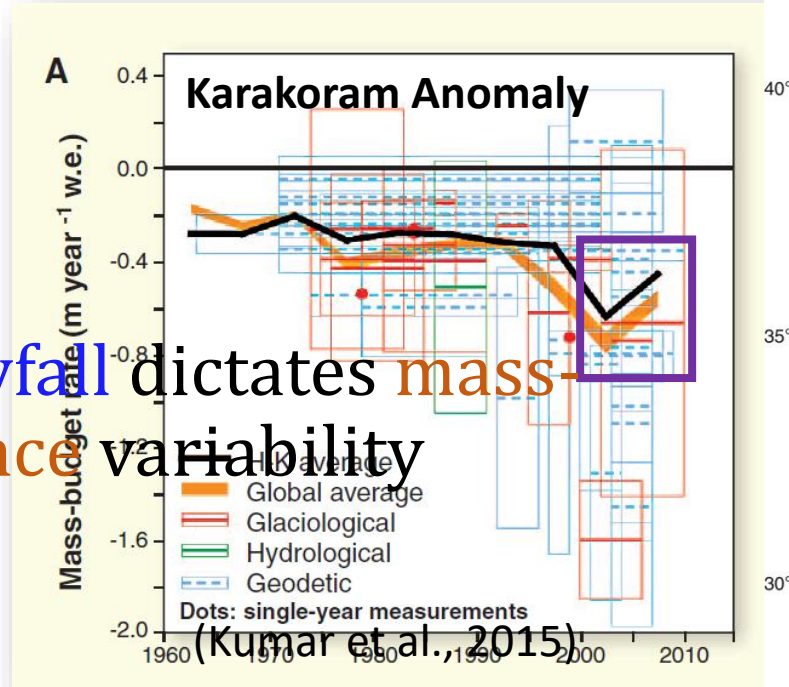
Why care about Himalayan Glaciers ?

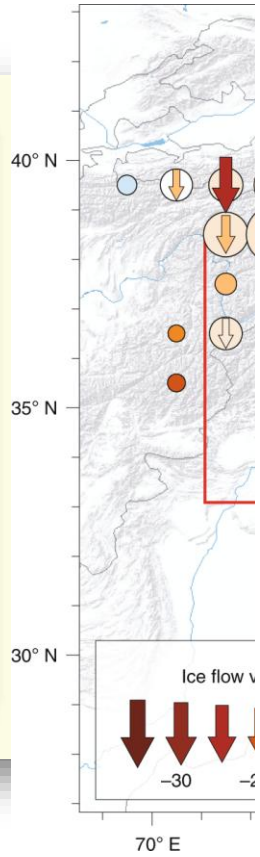


Karakoram Anomaly – A silver lining?

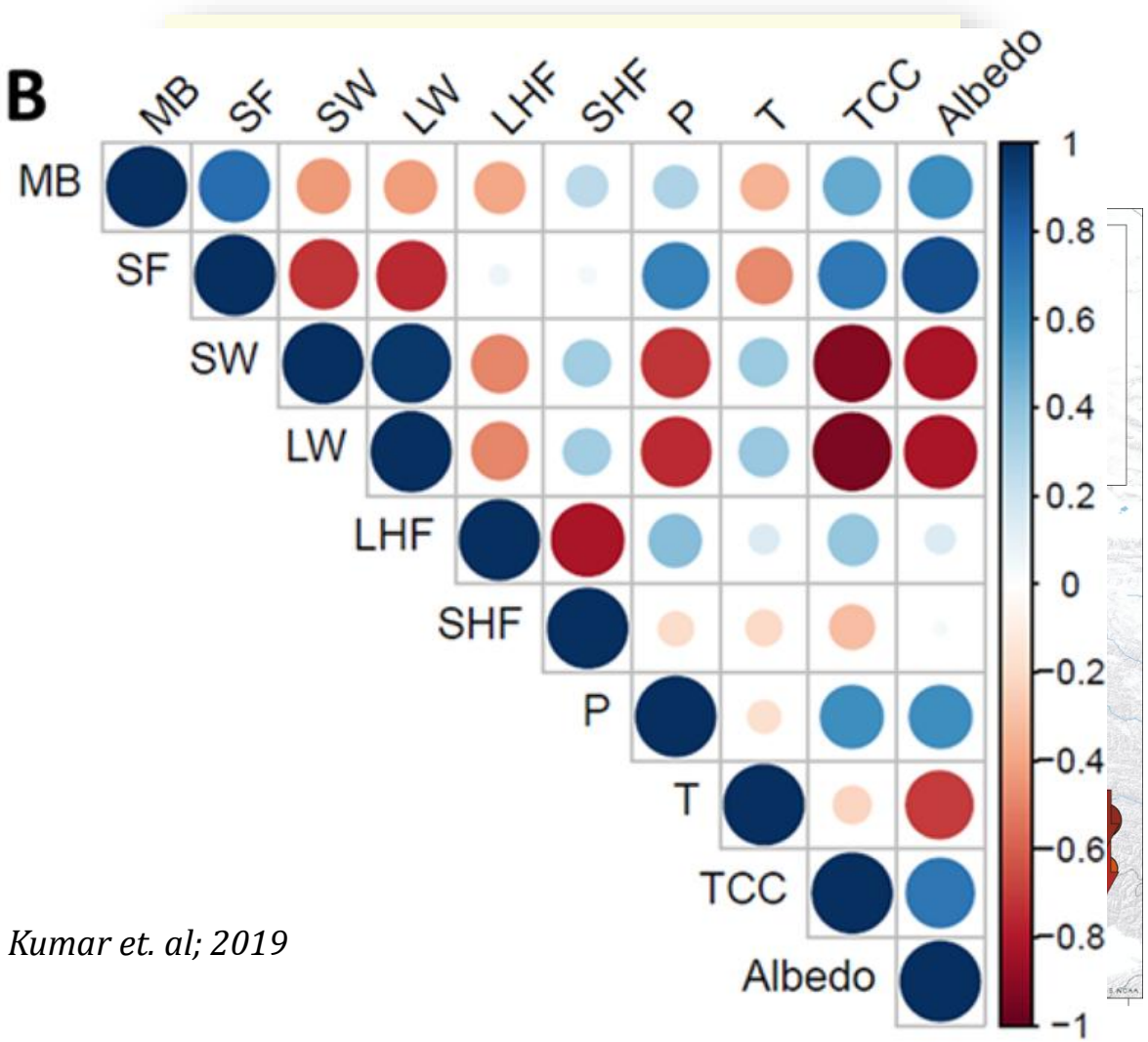
Recent resurgence in the mass-balance of KH glaciers reported since the turn of the 21st century.



(Kumar et al., 2015)



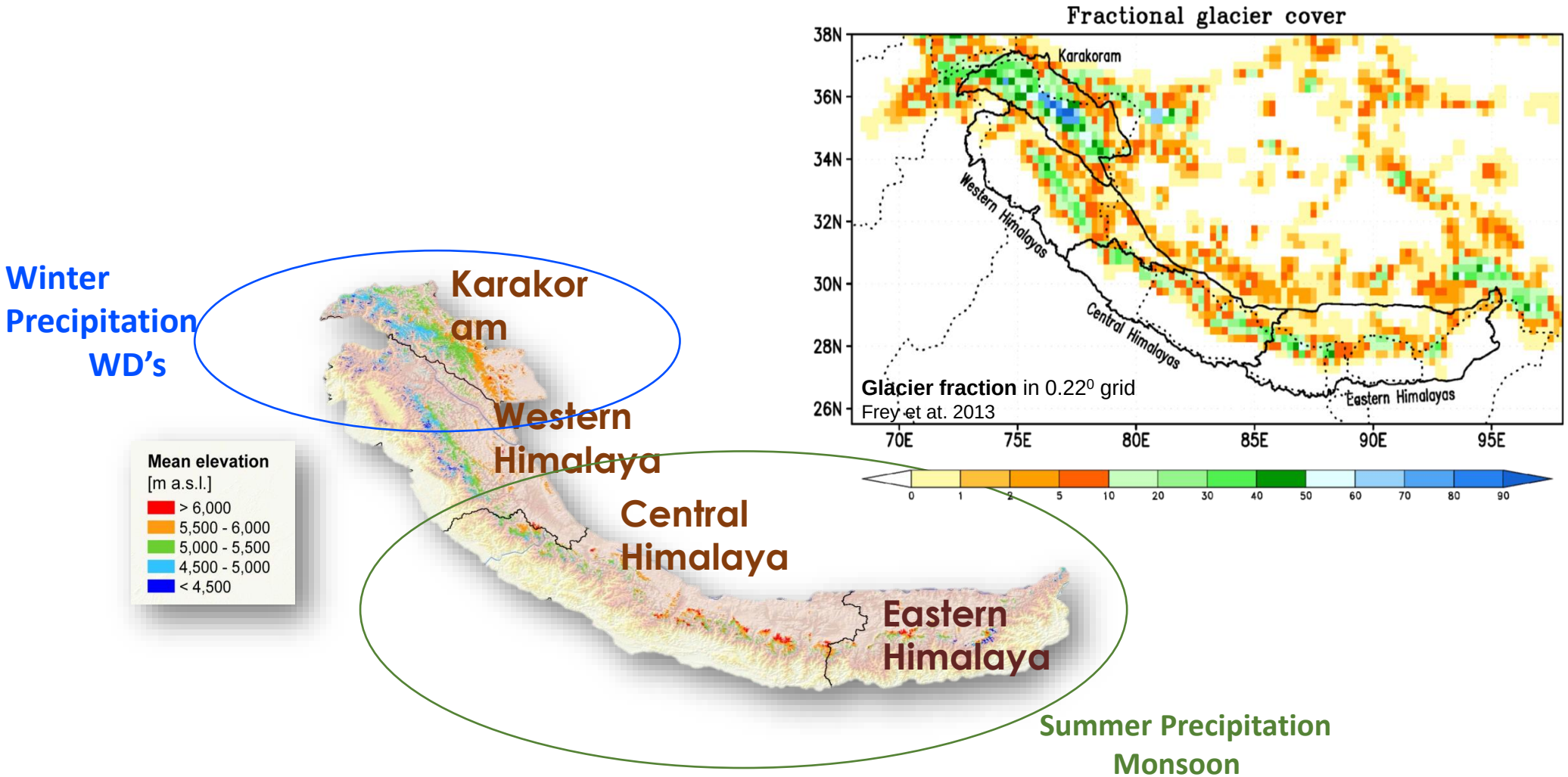
Snowfall dictates mass-balance variability



Kumar et. al; 2019

Tarnotti et al., 2020

STUDY REGION



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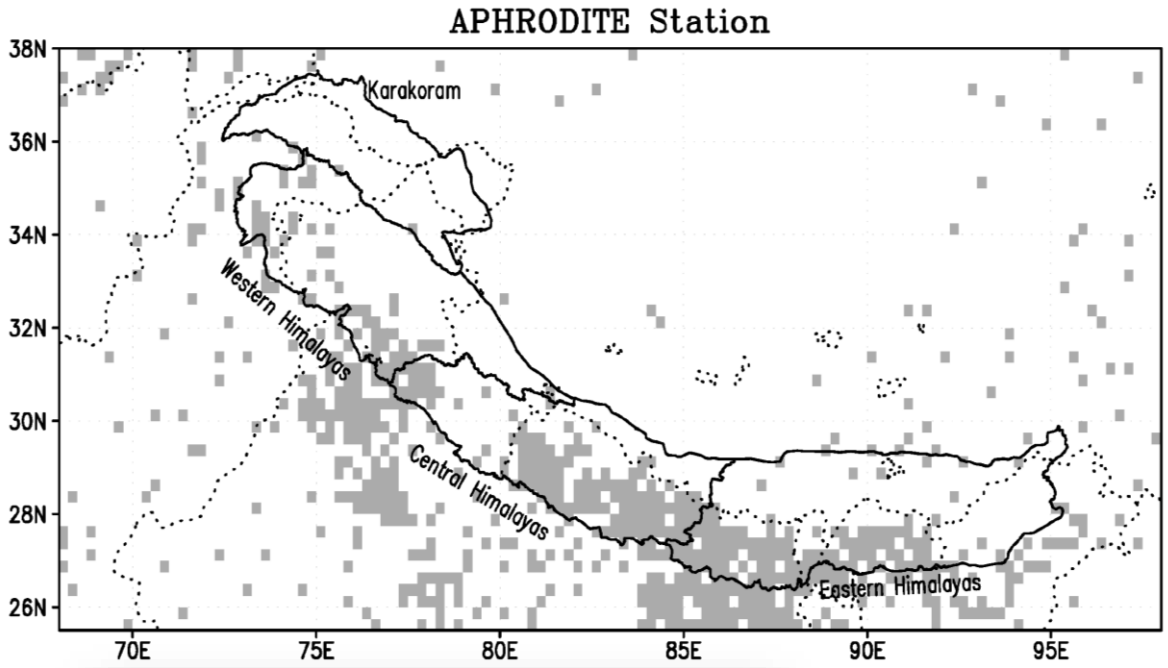
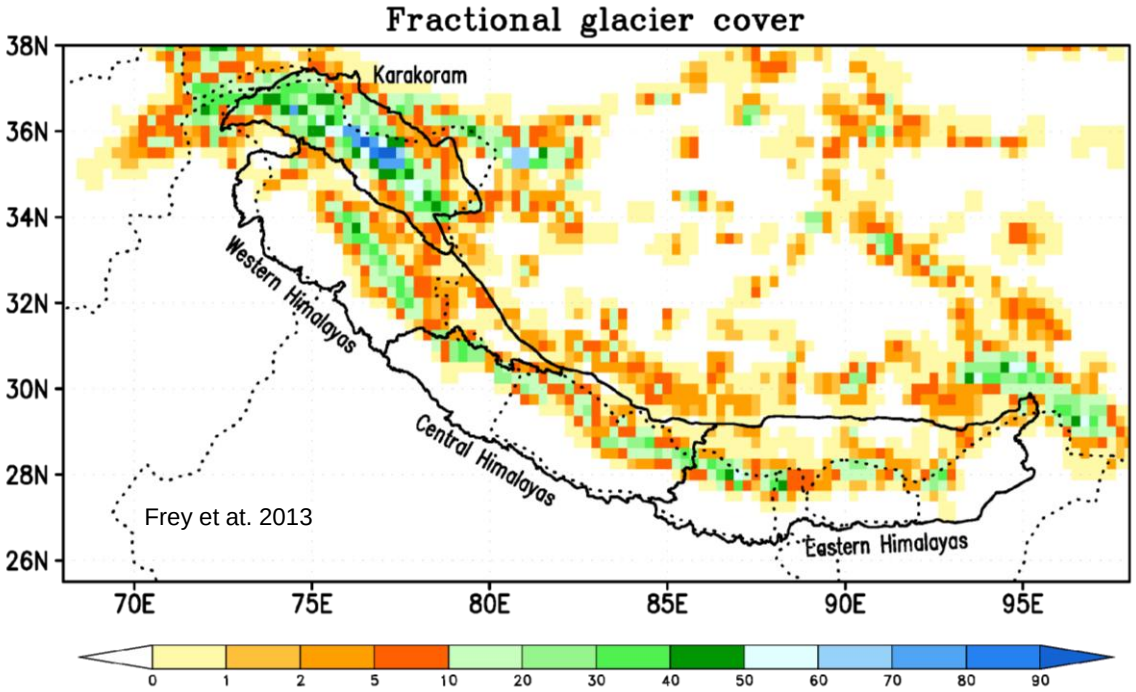
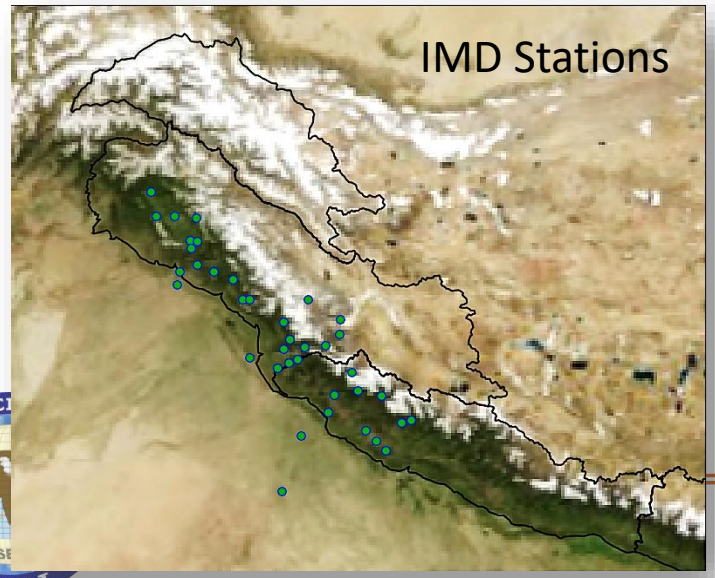
OBSERVATION CHALLENGES







Limited number of measuring stations over the glacierized region. No gauge station over Karakoram.

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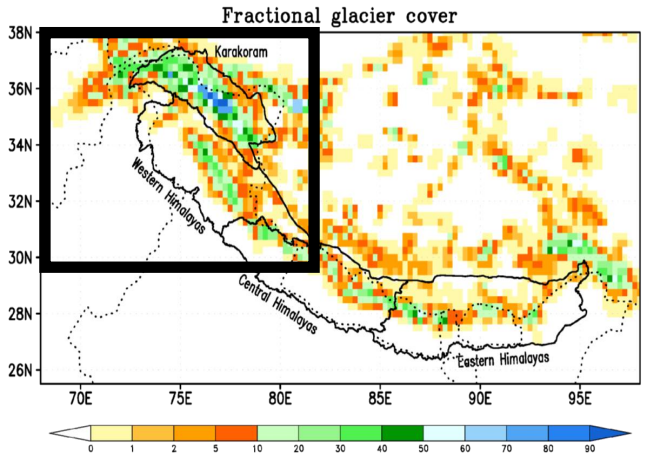
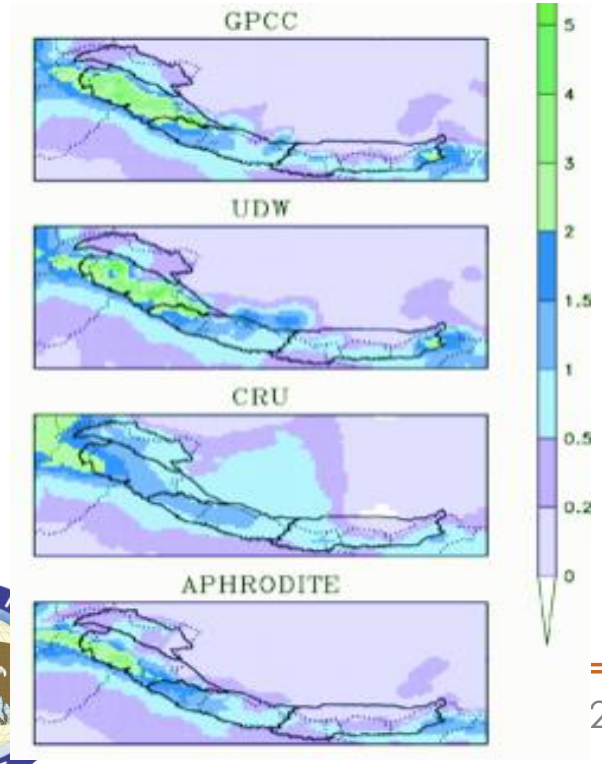
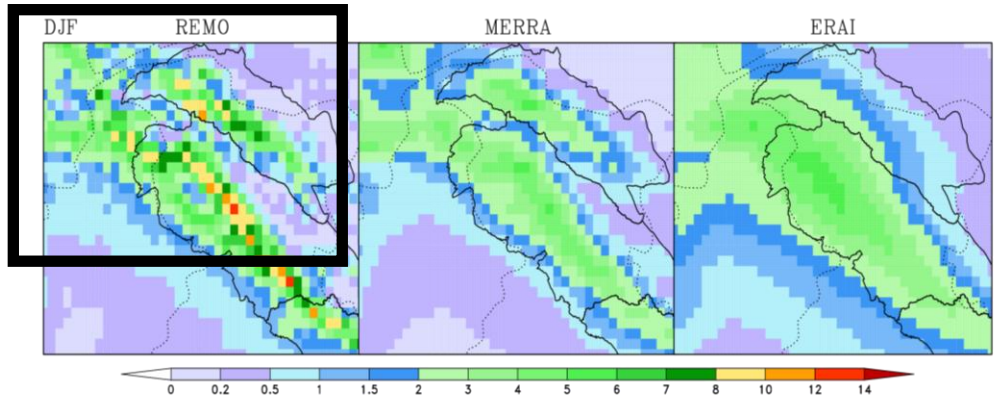
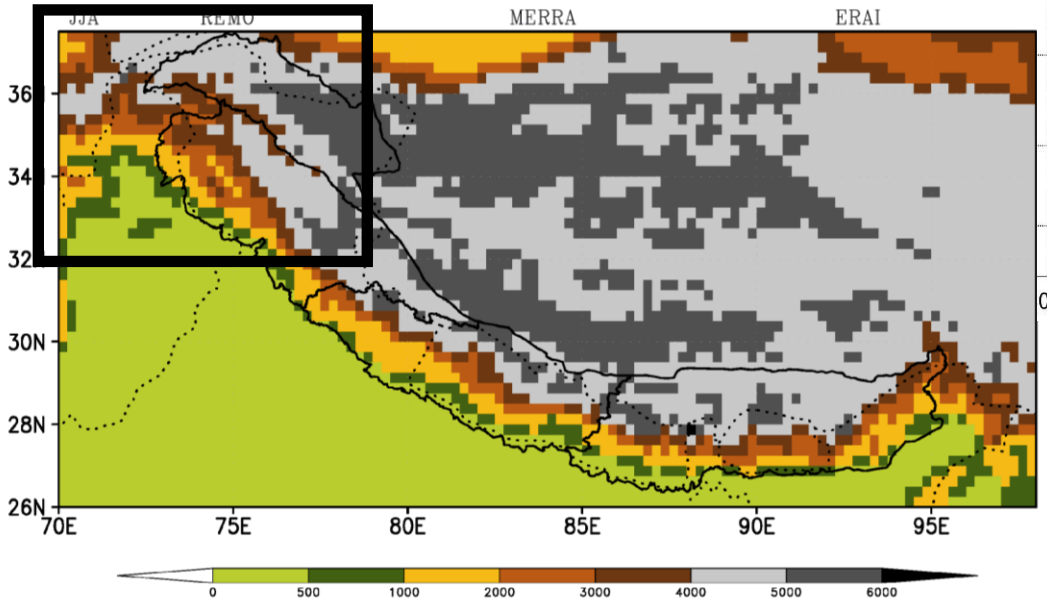
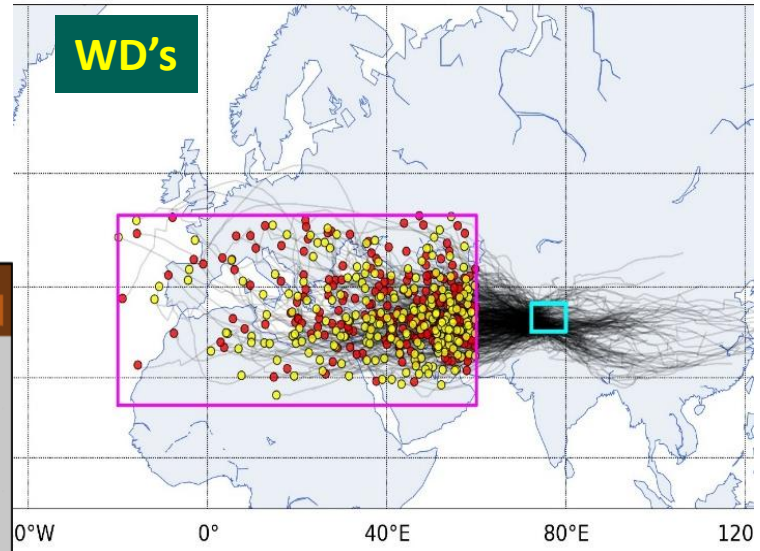
SEASONAL PRECIPITATION











Javed & Kumar, 2022 J. of Climate

Kumar et al., 2015 GRL

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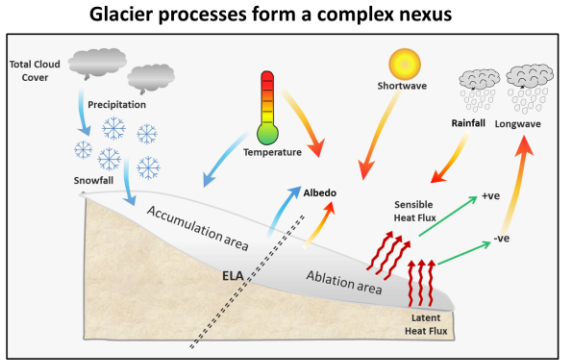
Coupled Glacier-Atmosphere Modelling

Problems

- Interactive role of the glaciers in the climate system
- Direct and Indirect feedback mechanism
- Poor representation in today's climate models

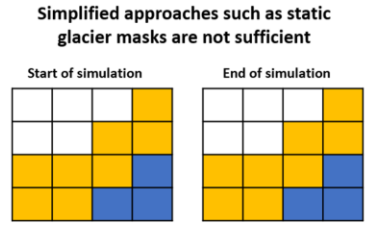
Solutions

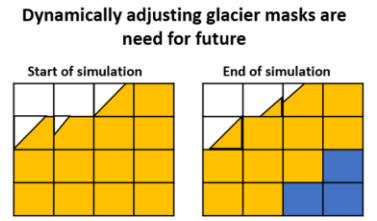
- More sophisticated approach is necessary, as contribution of glacial melt-water is important
- Interactive glacier scheme for regional climate modeling
- Glacier mass balance and area changes on a sub-grid scale, accounting for direct physical feedback mechanisms



Replicating these complex processes is a challenge for the modelling community

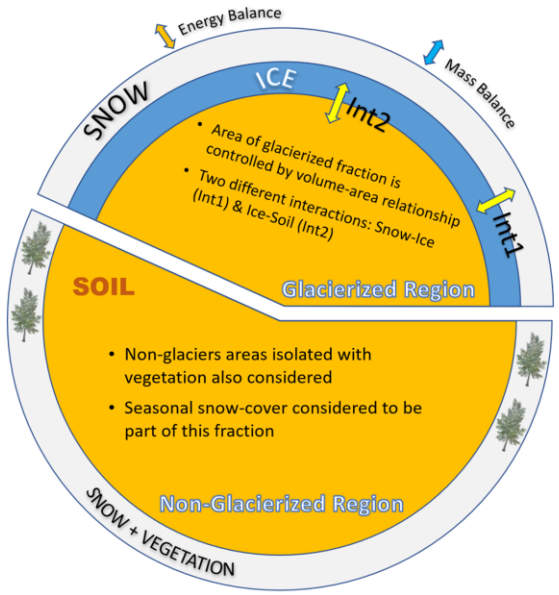
A major lacuna in the understanding of glacial processes



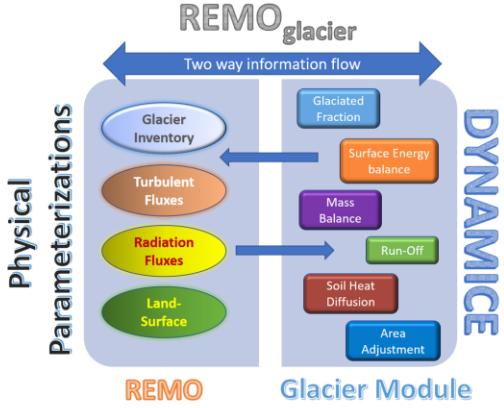


REMO$_{glacier}$ has the capability to fill these knowledge gaps

Dynamical Glacier Scheme DYNAMICE



Energy balance and runoff taken into account for mass balance estimations



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REMO$_{glacier}$ for mass-balance studies !

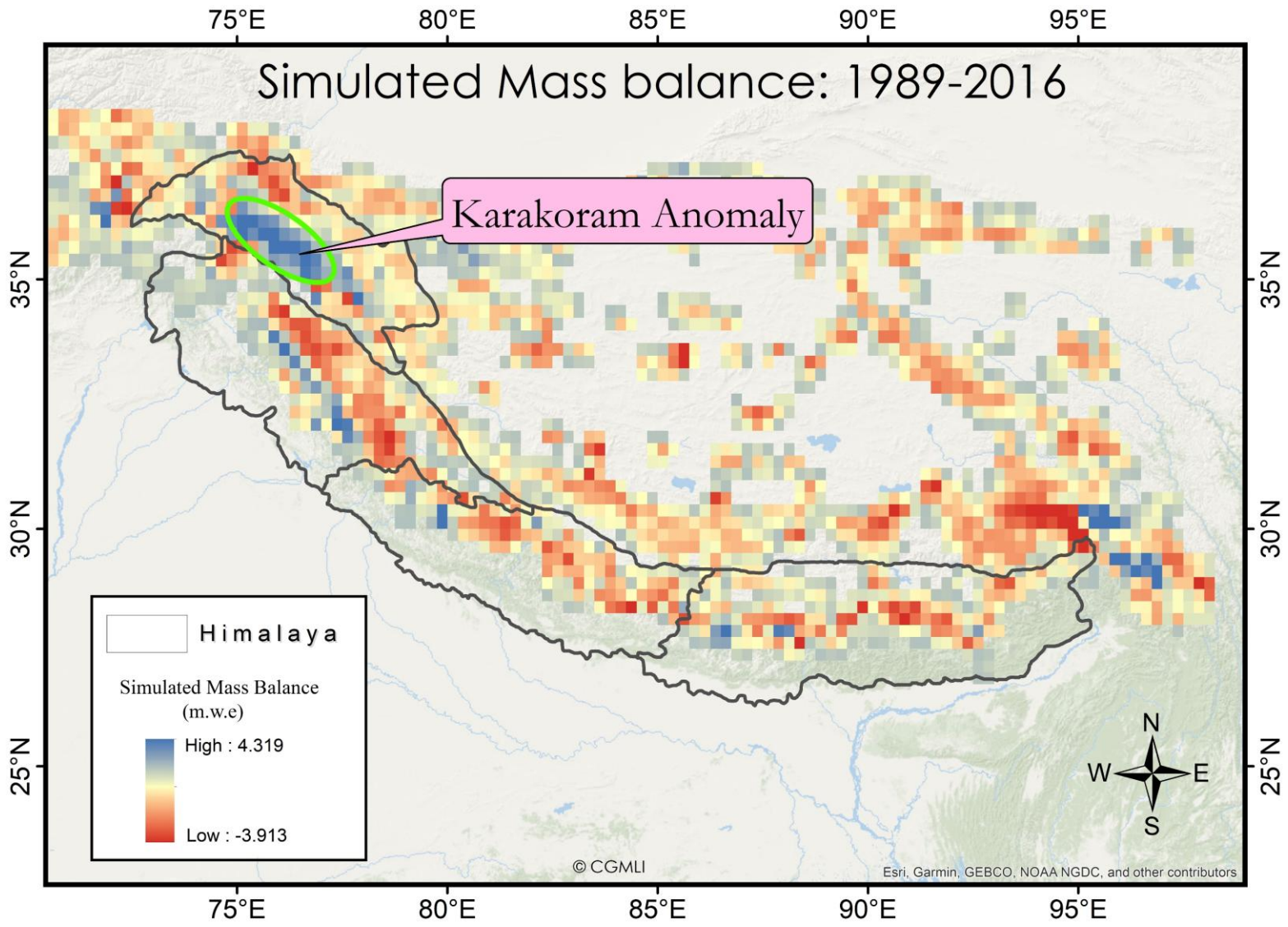
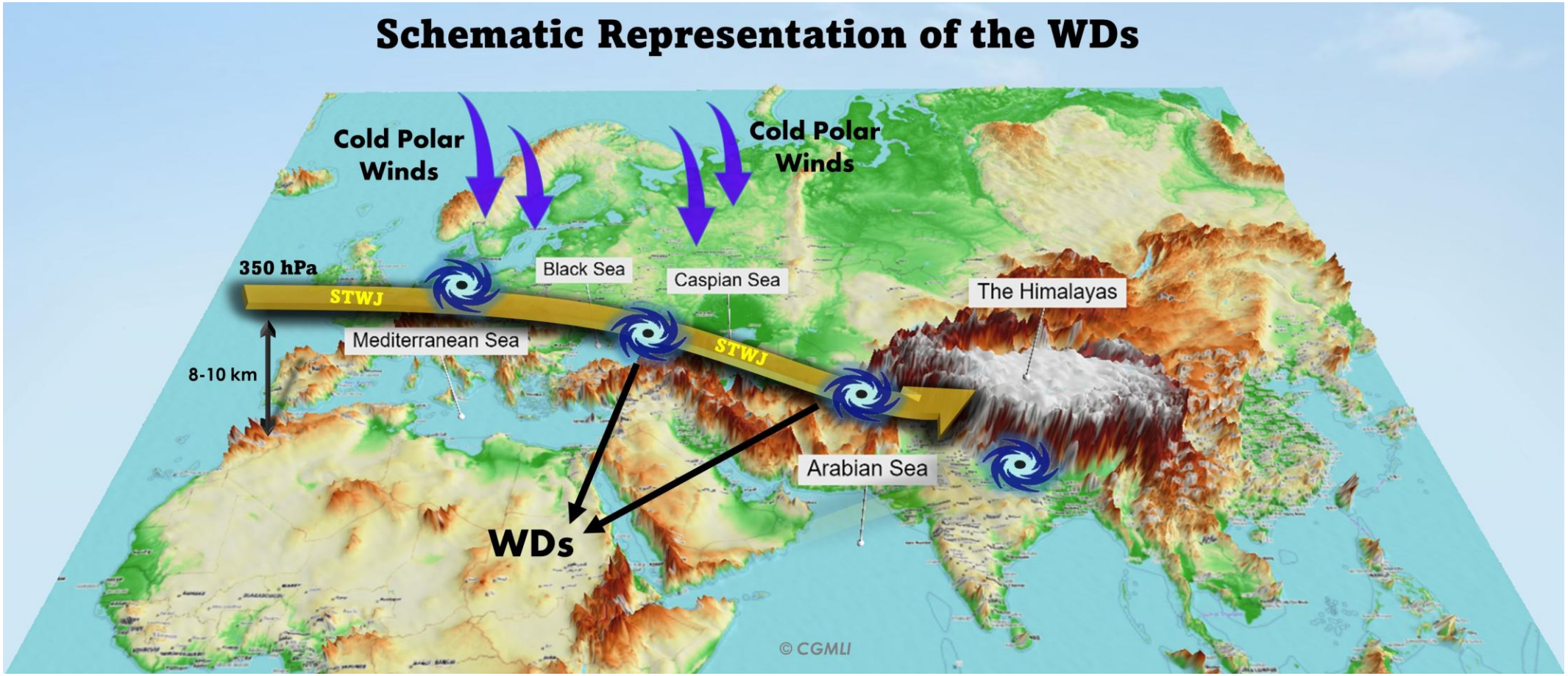


Figure adapted from Kumar et al., 2015 and Kumar et al., 2019

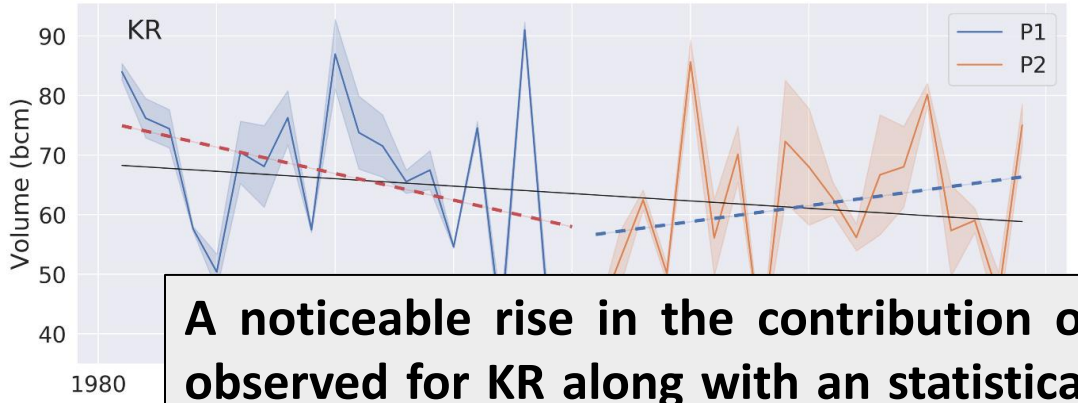
What are Western Disturbances (WDs)?



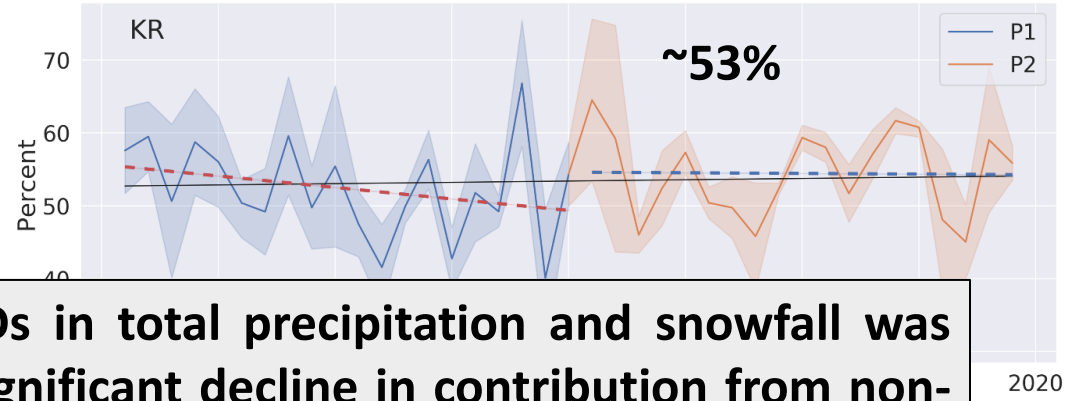
- **WDs** are large-scale (≥1000 km), upper-atmospheric (8–10 km) cyclonic systems from the Mediterranean that **travel east** with the subtropical **westerly jet**, until impeded upon by the **Himalayas**.
- Their **formation is triggered** by cold polar air mixing with warm, moist air, with boreal winter enhancing these conditions.

Volume of WD associated precipitation

(a) Volume of WD-Snowfall

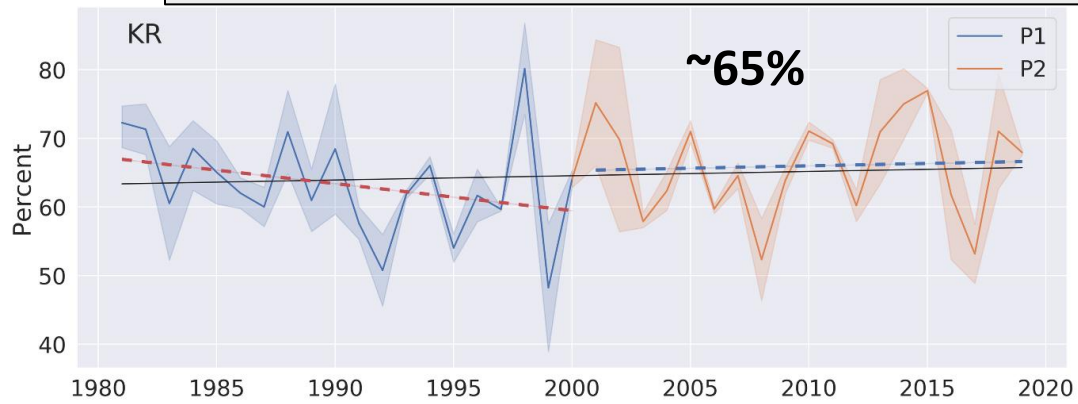


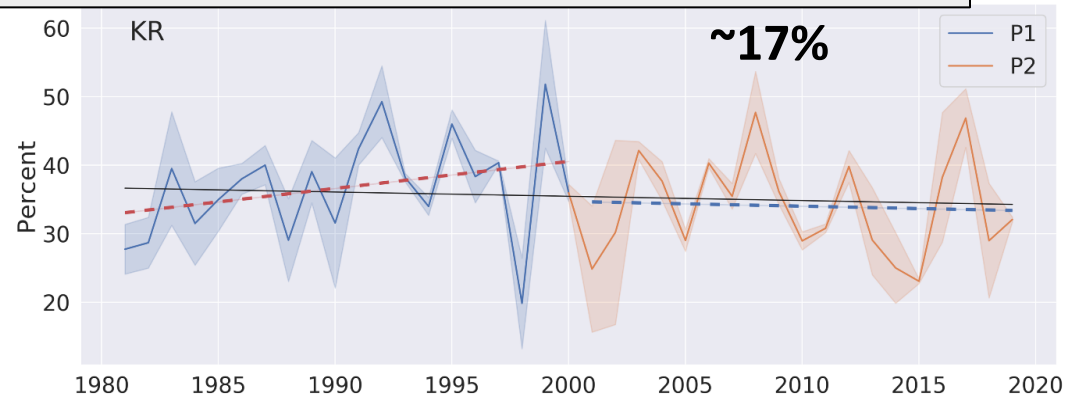
(e) WD-Snowfall Contribution in Total Seasonal Precipitation



A noticeable rise in the contribution of WDs in total precipitation and snowfall was observed for KR along with an statistically significant decline in contribution from non-WD sources. This key finding coincides with the Karakoram Anomaly period.

(c) WD-Sr





Javed et al., 2022; *Journal of Climate*

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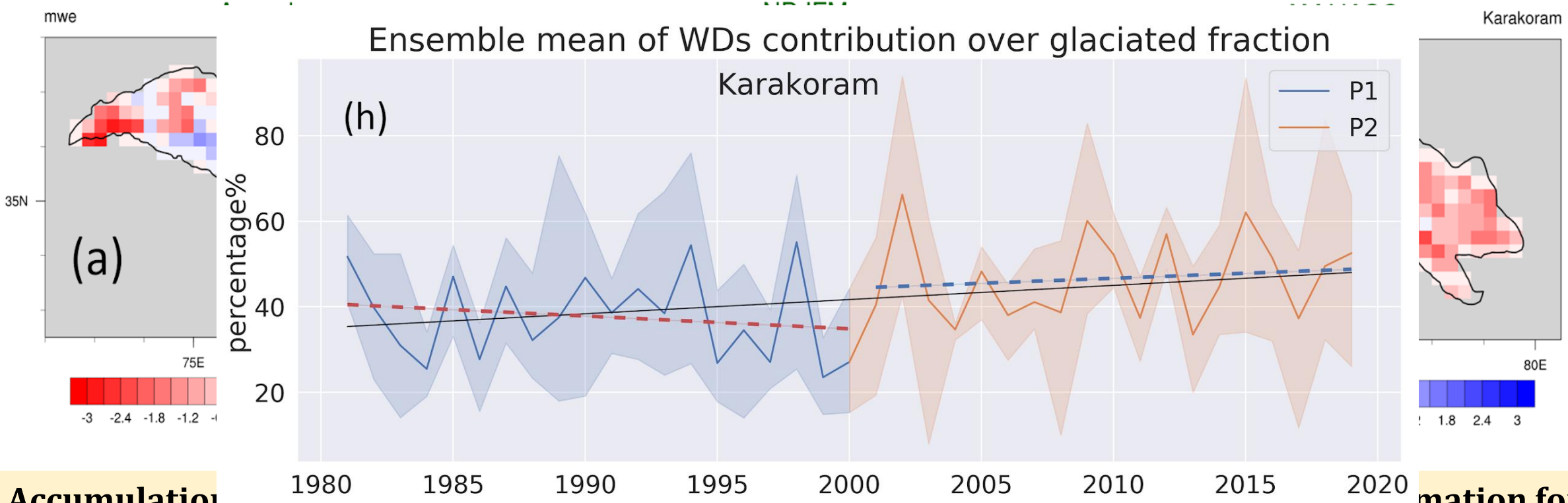
The “Karakoram Anomaly” connection !



Accumulation during the WD, Precipitation plays a significant role in the annual mass budget estimation for

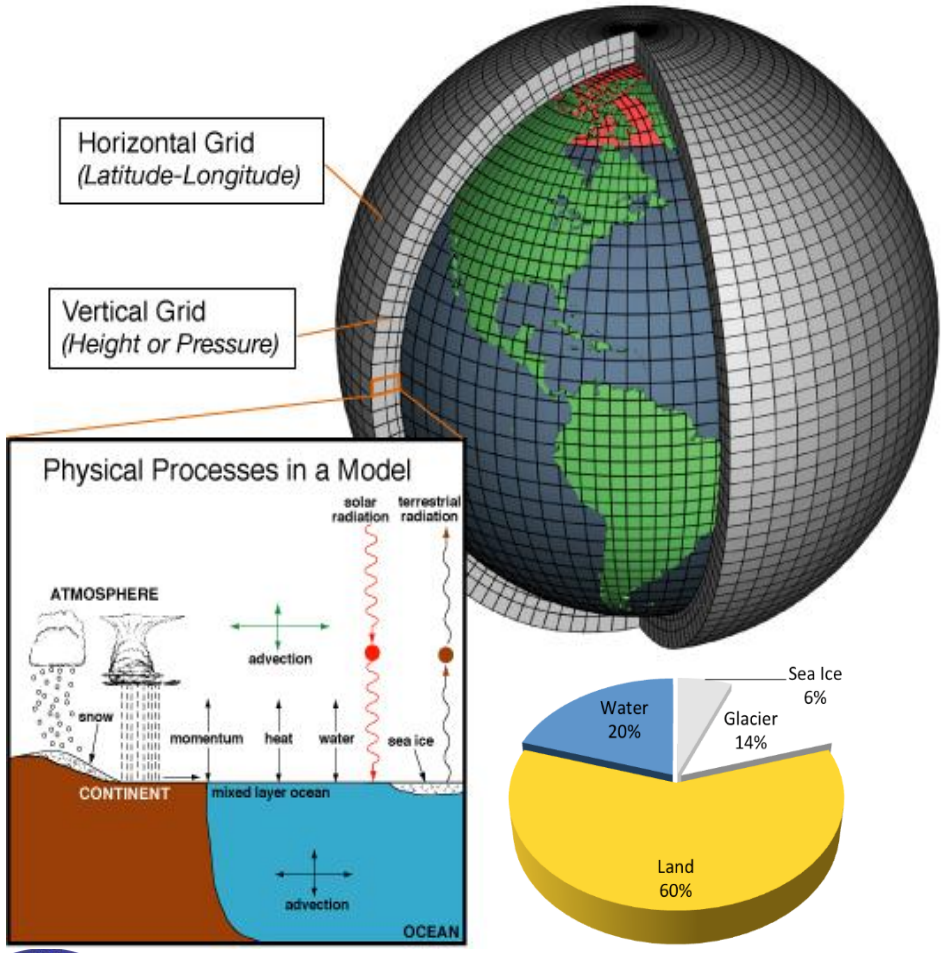
The ensemble mean contribution of WDs over the glaciated region rose from ~37% in P1 to about ~47% in P2, a relative jump of about ~27%.

Javed et al., 2022; *Journal of Climate*

Way Forward: Hybrid Modelling

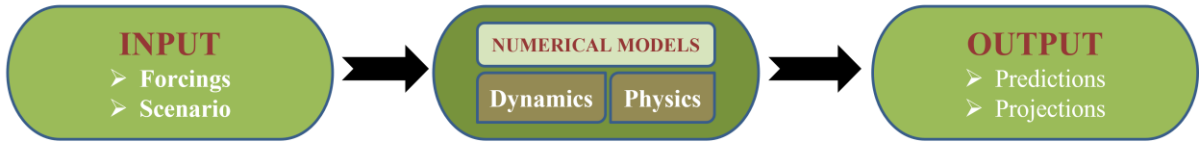
- Enhance In-Situ & Remote Sensing Observations
- Integrating Glacier Sub-grid Variability in Climate models
- Physics-informed machine learning (PIML) Framework

Global Climate Models

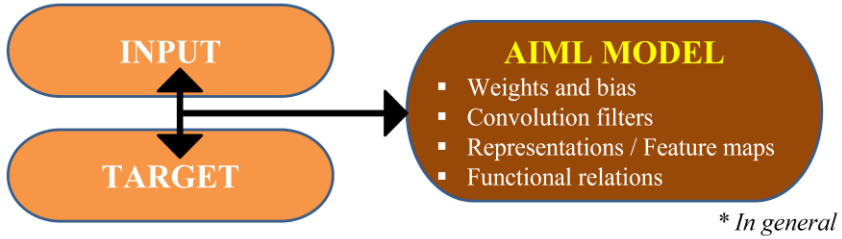


Glacier representation in ESM grid

In numerical models:-



In AIML*:-



** In general*

To explore Physics-informed machine learning (PIML)

- Enhancing data resolution at a cheaper computation.
- Extreme events detection and analysis

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LIQUIDICE

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LINKING AND QUANTIFYING THE IMPACTS OF CLIMATE CHANGE ON INLAND ICE, SNOW COVER, AND PERMAFROST ON WATER RESOURCES AND SOCIETY IN VULNERABLE REGIONS

About

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Recognising the central role played by snow, ice and permafrost in the global climate system, the LIQUIDICE project joins expert cryospheric observers and modellers to:

1. comprehensively re-assess the past and future century-plus of climate-induced high impact changes to the Greenland ice sheet and climate vulnerable locations across the Alps, Norway, High Mountain Asia (HMA) and Svalbard, including permafrost areas and their ecosystems;
2. develop new, expanded and harmonised data from satellite Earth Observation (EO) and ground stations;
3. use these data to improve and test a hierarchy of ice sheet and glacier models with Earth System Models (ESMs);
4. through these steps, yield new process understanding, and ultimately
5. inform water resource, hydropower, and socio-economic strategies through clear and transparent communication of results and uncertainties.

The project's strengths lie in new multidisciplinary collaborations across **18 research institutions**, from **eight European countries** (Poland, Italy, Denmark, Germany, Spain, Sweden, Norway, United Kingdom) **and India**, encompassing expertise in field observations, satellite EO techniques, ESM development and application, and socio-economic analysis.

Institute of Geophysics Polish Academy of Sciences

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AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2015GL063392

Key Points:
- Regional climate model coupled with dynamic glacier parameterization scheme
- Mass balance and ELA for Karakoram-Himalayas glaciers

Supporting Information:
- Text S1 and Table S1

Response of Karakoram-Himalayan glaciers to climate variability and climatic change: A regional climate model assessment

Pankaj Kumar[1], Sven Kotlarski[2], Christopher Moseley[3], Kevin Sieck[3], Holger Frey[4], Markus Stoffel[5], and Daniela Jacob[1]

[1]Climate Service Center 2.0, Helmholtz Zentrum Geesthacht, Hamburg, Germany, [2]Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland, [3]Max Planck Institute for Meteorology, Hamburg, Germany, [4]Department of Geography, University of Zurich-Irchel, Zurich, Switzerland, [5]Institute for Environmental Sciences, University of Geneva, Geneva, Switzerland

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Journal of Climate

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Sections

Editorial Type: Article

Article Type: Research Article

Does the Recent Revival of Western Disturbances Govern the Karakoram Anomaly?

Aaquib Javed, Pankaj Kumar, Kevin I. Hodges, Dmitry V. Sein, Aditya K. Dubey, and Gaurav Tiwari

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Snowfall Variability Dictates Glacier Mass Balance Variability in Himalaya-Karakoram

Pankaj Kumar[1*], Md. Saquib Saharwardi[1], Argha Banerjee[2*], Mohd. Farooq Azam[3], Aditya Kumar Dubey[1] & Raghu Murtugudde[4]

Thank You for your kind attention!