



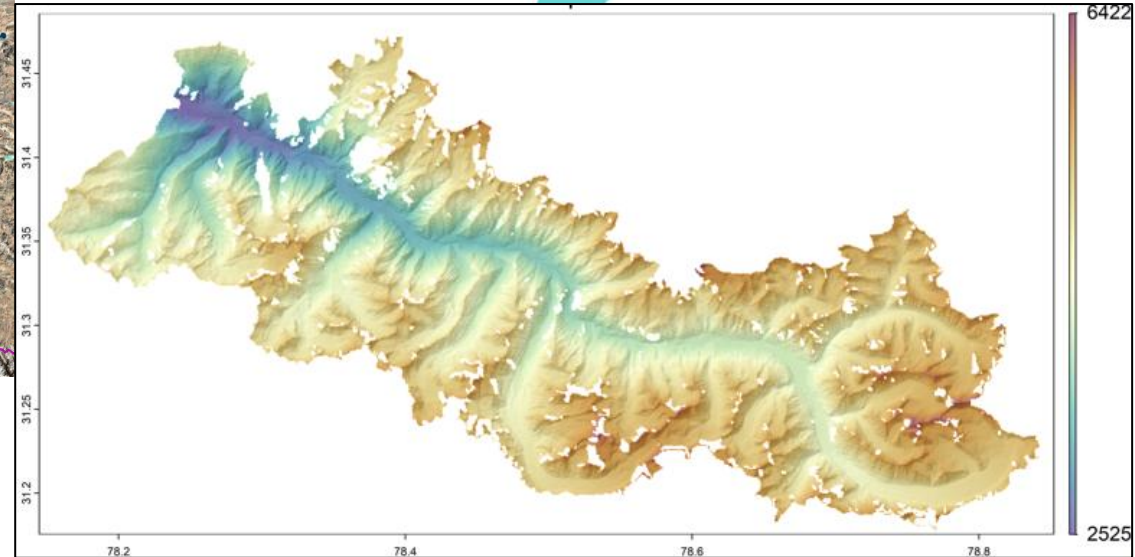
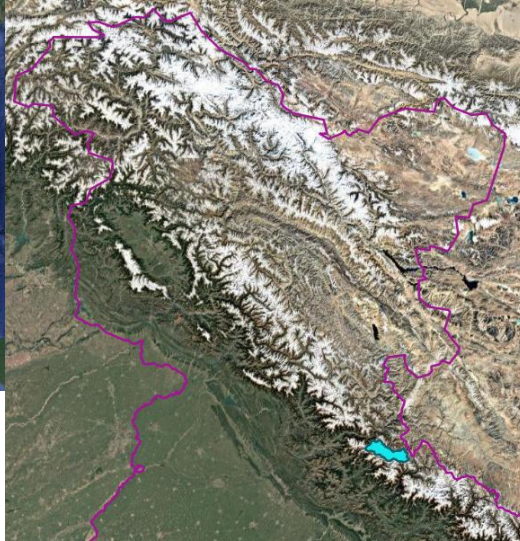
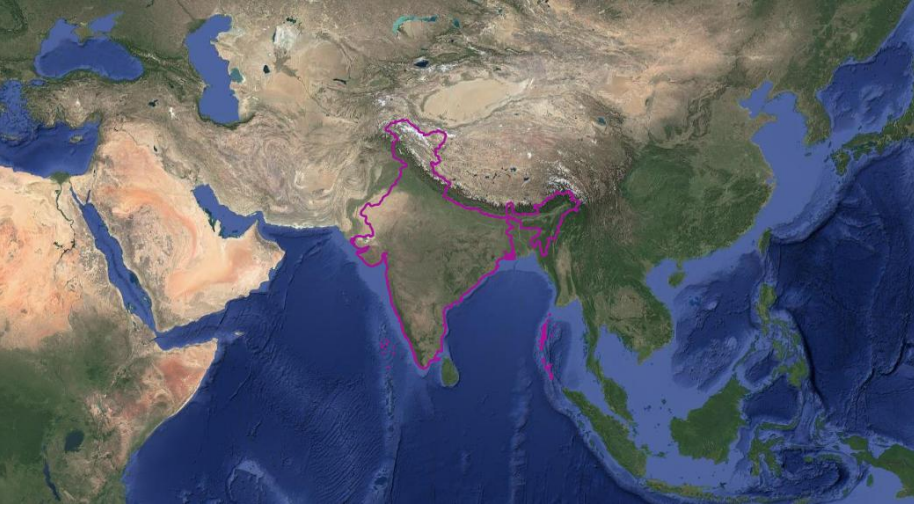
Machine Learning in the Mountains: High Resolution Season Ahead Forecasts for the Himalayas

Shairik Sengupta & Rajarshi Das Bhowmik

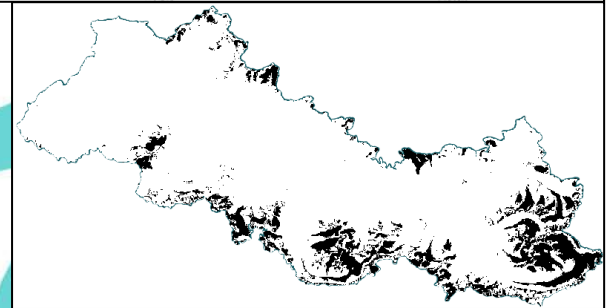
Interdisciplinary Centre for Water Research, Indian Institute of Science

Meet the Basin: Baspa

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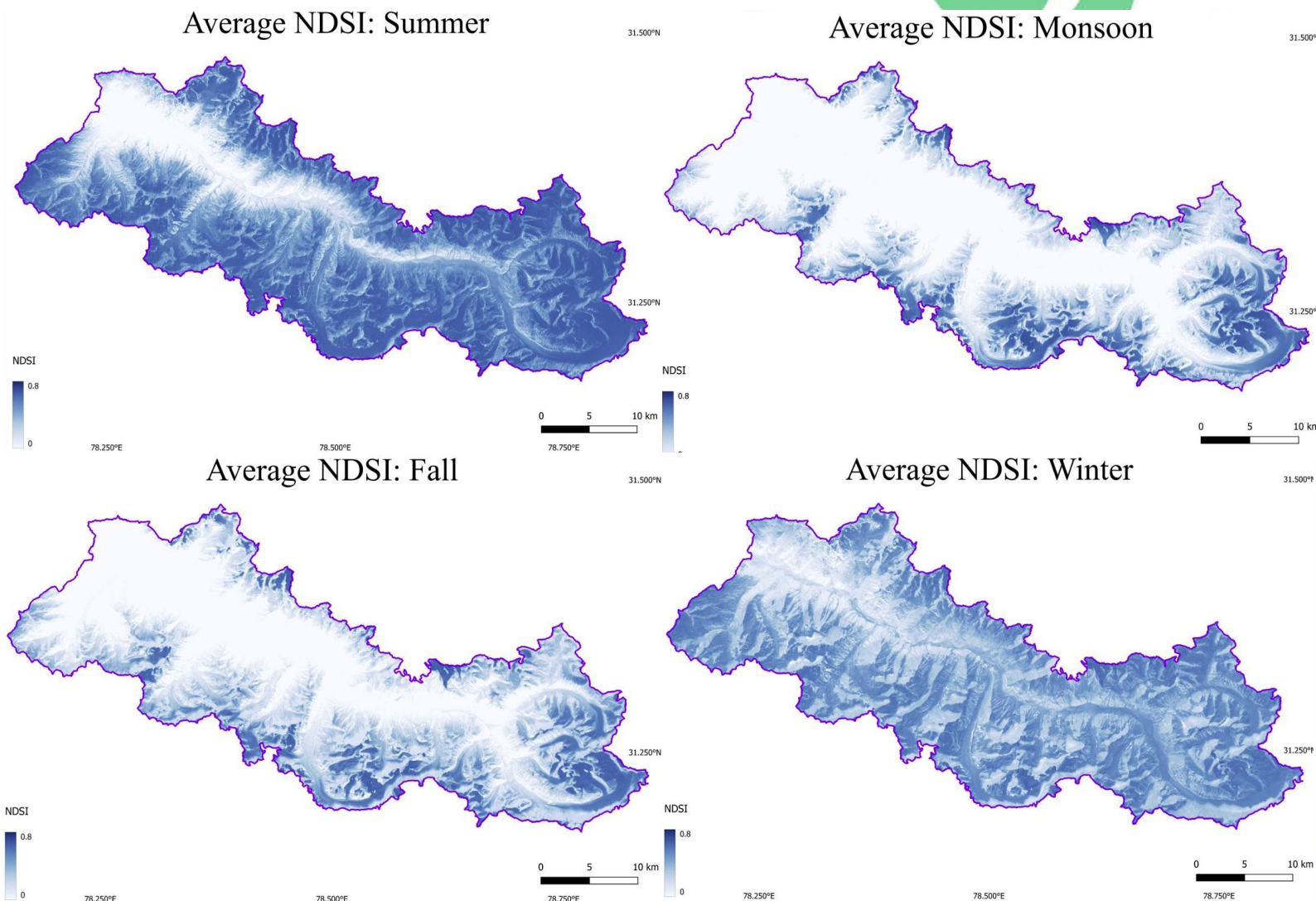
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The Challenge

- High seasonality
- High spatial variability

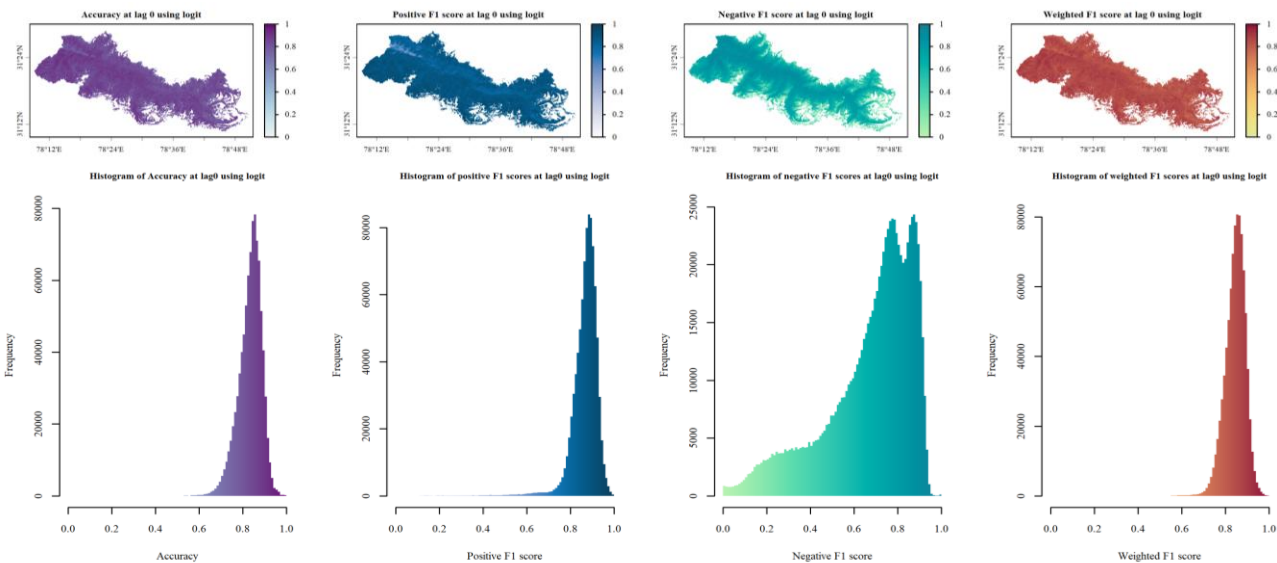
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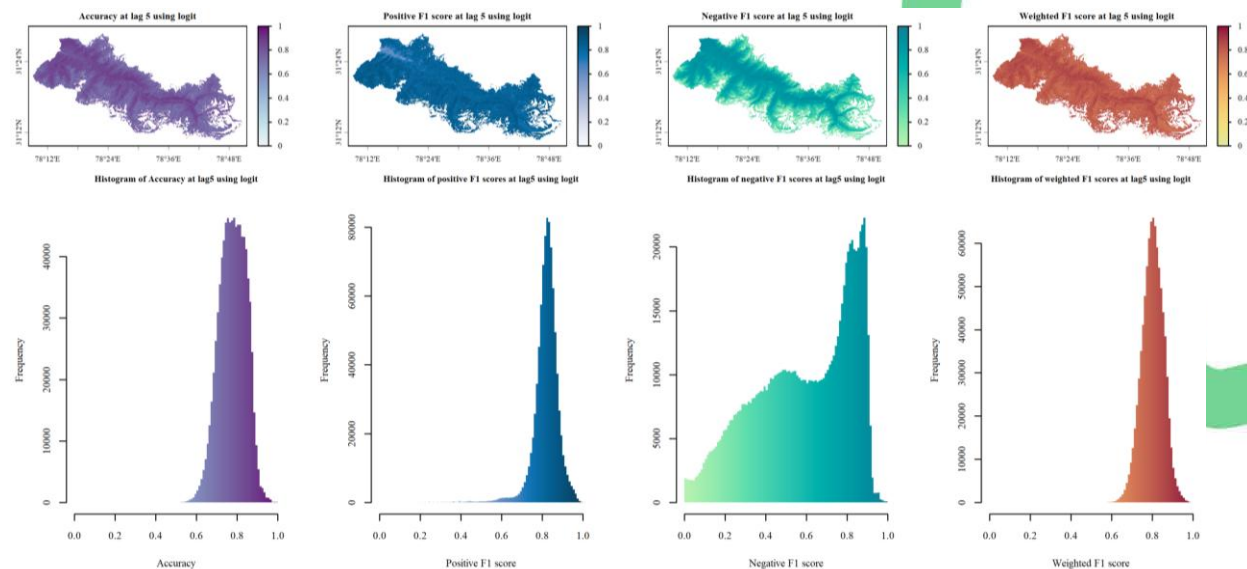
The diagram illustrates the relationship between True Negative, -ve Precision, and Score. A horizontal dotted line is shown. Below it, a box labeled "True Negative" is connected by a solid orange arrow to a box labeled "-ve Precision". A dashed orange arrow also points from the "True Negative" box to the "-ve Precision" box. A solid purple arrow points from a box labeled "ative" (partially visible) to the "-ve Precision" box. Finally, a solid green arrow points from the "-ve Precision" box to a box labeled "Score".



The Quest for a Lucky Lag

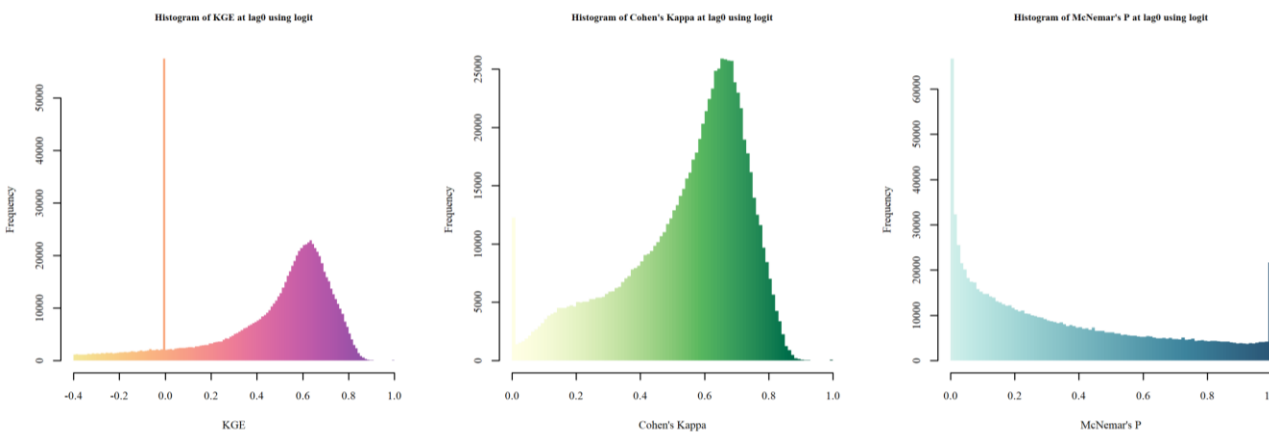
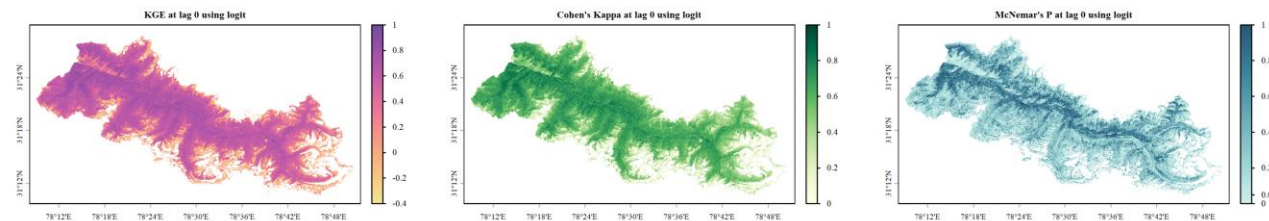
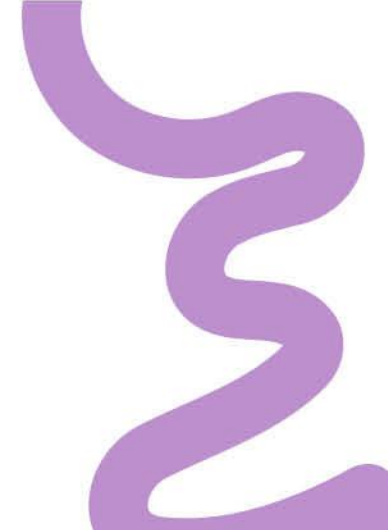


Accuracy, positive F1 score, negative F1 score, and weighted F1 score of our benchmark: the lag 0 model



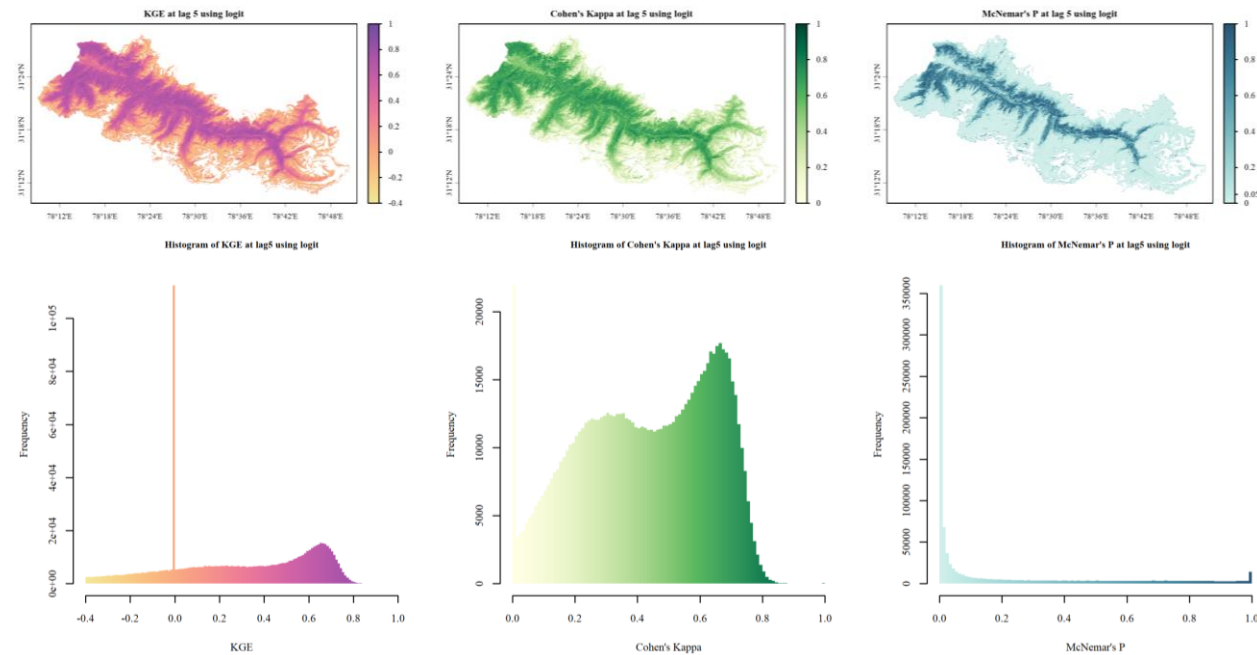
Performance of the lag 5 model

Forecasting or False Hope?



Our benchmark: the lag 0 model

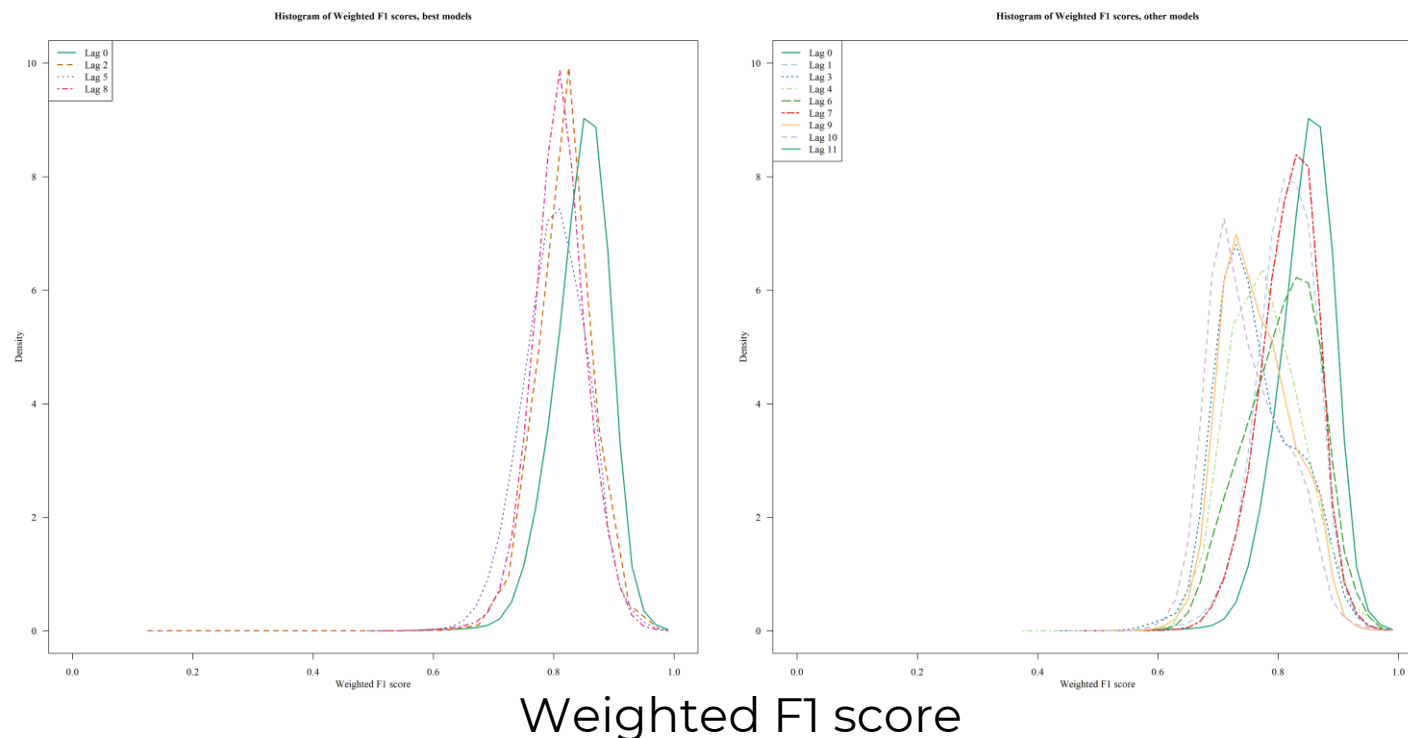
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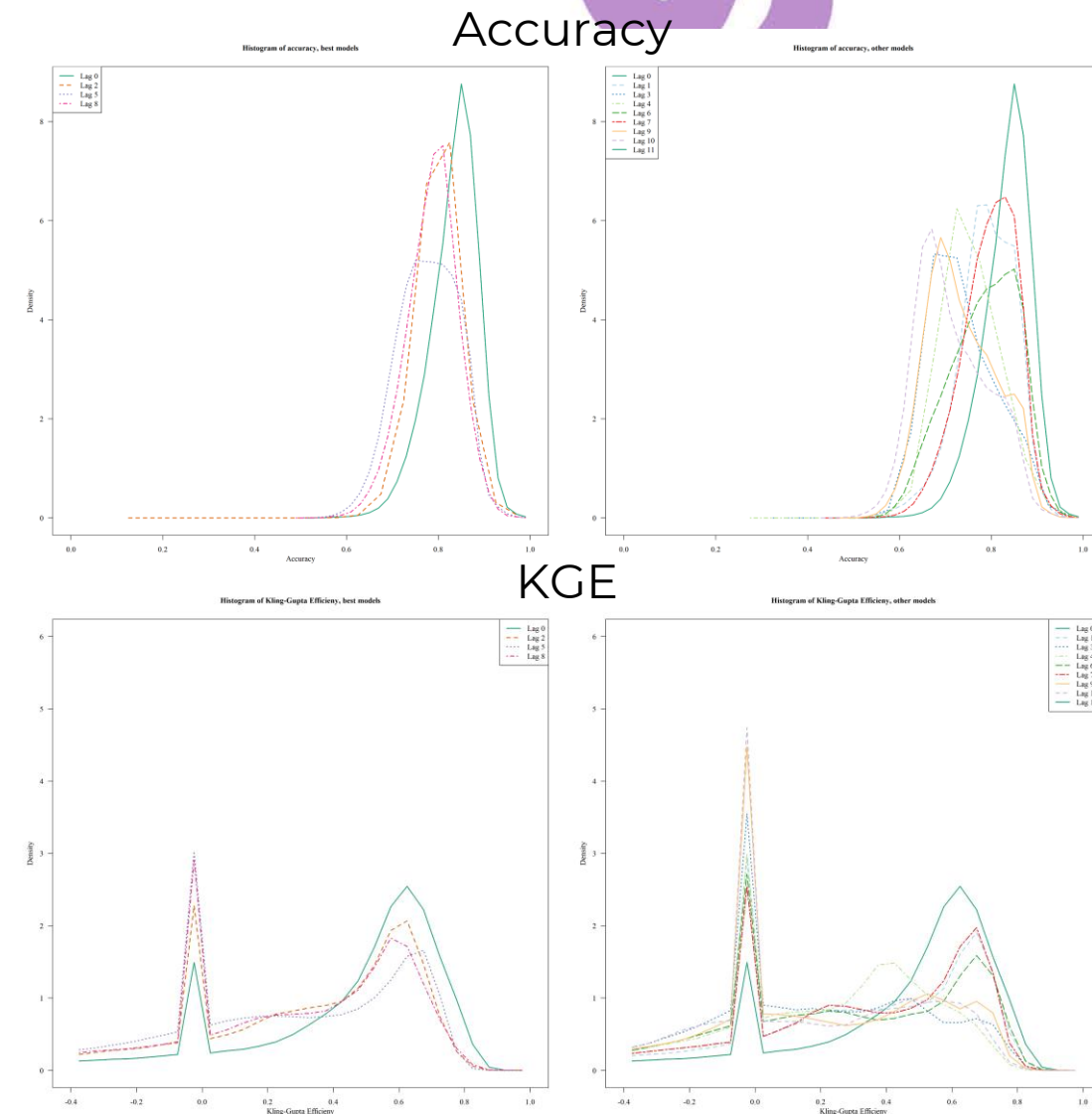
Lag 5 model: right predictions at the right place

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Did We Just Get Lucky?



Weighted F1 score



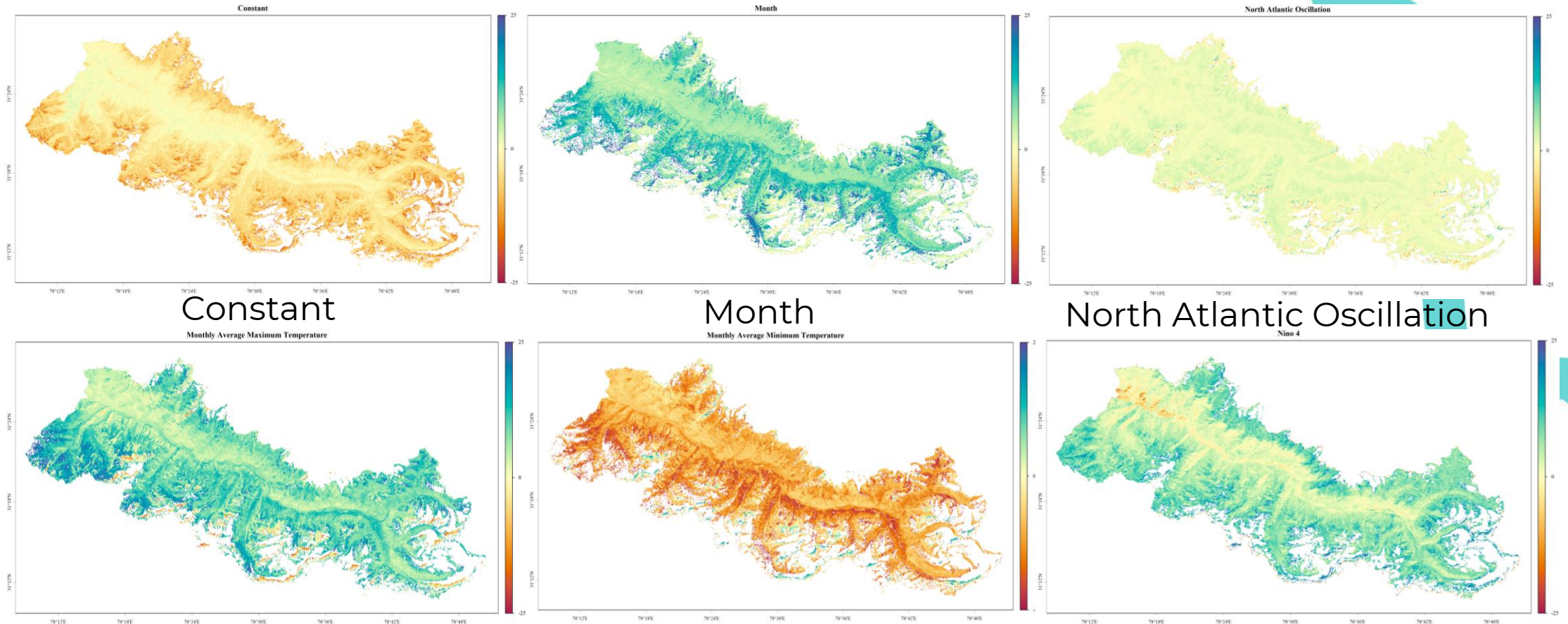
Accuracy

KGE

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Lags 2, 5, and 8 outperform all other lags, across all evaluation metrics

A Peek into the Predictor



Constant

Month

North Atlantic Oscillation

Maximum temperature

Minimum temperature

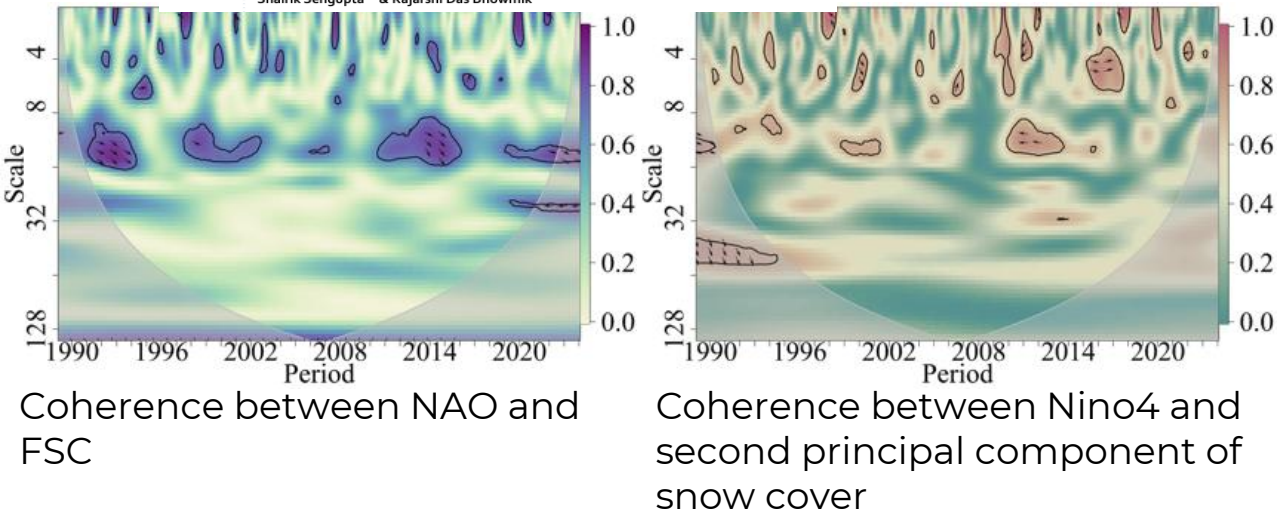
ENSO state – Nino 4

The Forces at Play

scientific reports

OPEN How seas whisper to snow: teleconnections drive spatio-temporal variability of snow cover in Western Himalayas

Shairik Sengupta^{1,2} & Rajarshi Das Bhowmik



THE TIMES OF INDIA
Rainfall in Jan 3rd lowest in Himachal since 1901

TNN / Feb 7, 2024, 09:15 IST

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Outlook
Cold Wave Conditions Prevail In Himachal, Kukumseri Records Minus 14.2 Deg C

Thick fog was witnessed in Sundernagar, Mandi and Bilaspur in the morning, reducing visibility to 500 metres while ground frost occurred in mid and higher hills, making commuting hazardous.

The Indian EXPRESS
JOURNALISM OF COURAGE
What the warmer November of 2024 means for India and the world

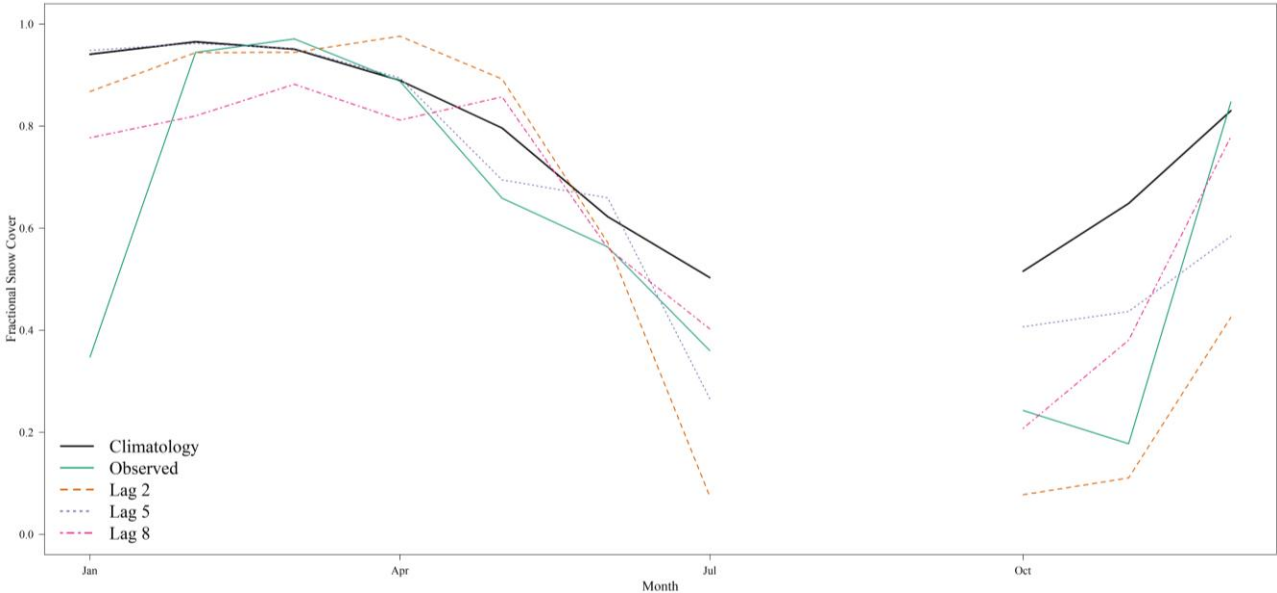
November 2024 was the second warmest November in 123 years in India. What were the main reasons behind this and what are its implications for water security and livelihoods?

Hindustan Times
Orange alert for snow and rain in Himachal for next two days; MeT issues travel advisory
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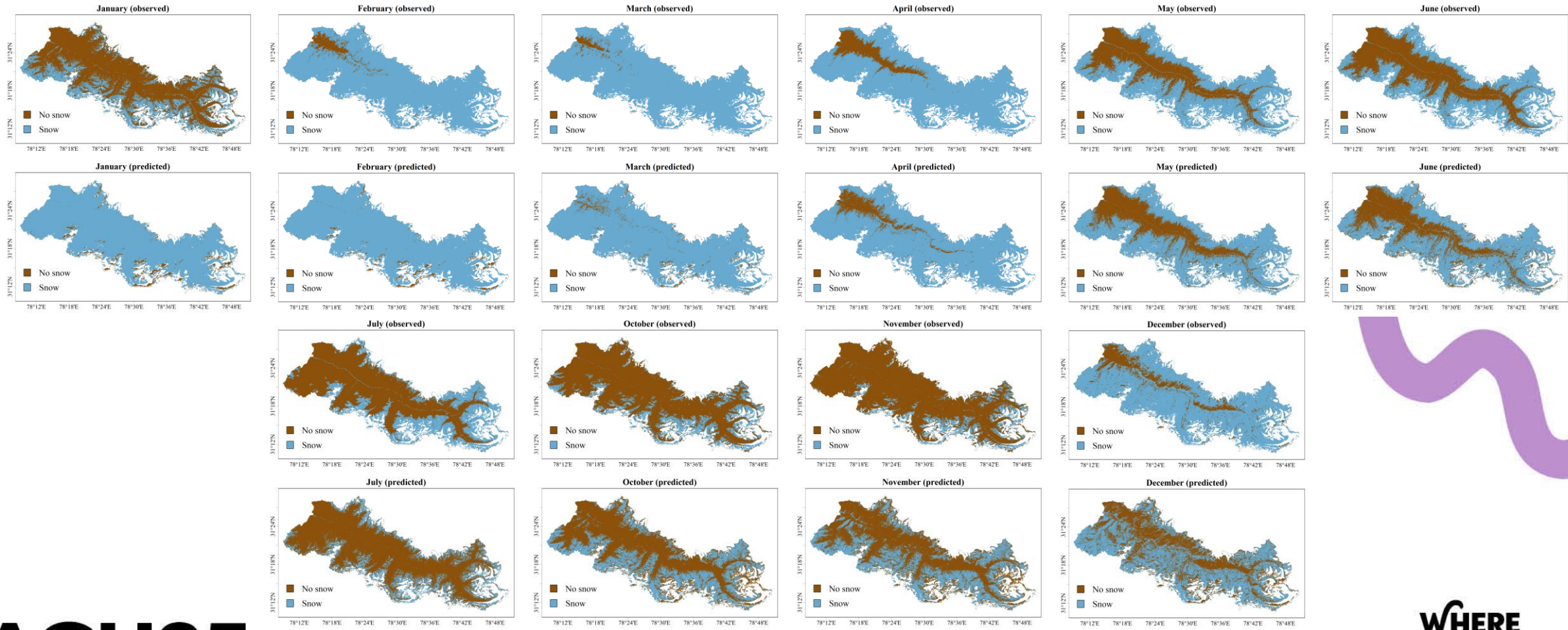
By Shalee Dogra X Shimla



Fractional Snow Cover predictions (2024)



A Reality Check



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Questions

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How seas whisper to snow:
teleconnections drive spatio–
temporal variability of snow cover
in Western Himalayas

Shakir Sengupta¹, R. Rajarshi Das Bhownick¹

The high Himalayas host a vast cryosphere, critical for both local and global environmental stability. While a few former studies have examined point-scale precipitation variabilities, others have focused on snow cover (SC) trends at regional scales. We investigate how SC in the Western Himalayas varies across spatio-temporal scales, and what factors drive these variabilities. Towards this, we derive a historical record (1980–2023) of SC for six high-mountainous watersheds from satellite (Landnet) observations. We calculate three characteristics of SC extent: Fractional SC, fractional Temporary SC, and Principal Components (PC) of Normalized Difference Snow Index. Eigen-vectors of the PCs establish the association between the spatial distribution of SC variability and basin topography. The study found that these SC characteristics are driven substantially by the North Atlantic and the Pacific at interannual time scales. The study found that several climate variability modes drive separate SC components during different seasons. In general, during winter and summer, SC variations are primarily influenced by the North Atlantic, Arctic, and Pacific. In monsoon and fall, apart from local hydroclimatic conditions, the Indian Ocean plays as a major regulator of SC, along with the Pacific. Overall findings of the study could be crucial for season-ahead SC predictions.

In the cold dry winters of the western Himalayas, water is regarded as one of the highest offerings as water is both fire and peace. All life forms – human or endangered by humans^{1,2}, residents of an environment ranging from subequatorial forests to alpine meadows, depend on the water cycle driven by the Himalayan cryosphere. Humanity's long and intimate relationship with the Himalayan cryosphere³ and its stress is reflected well in the culture of nature^{4,5}. “In current times direct or indirect anthropogenic activities have occasionally been protective^{6–10} of the Himalayan cryosphere, but could be detrimental as well, resulting in hydrological extremes^{11–14}. Insolation, temperature rise, and other environmental disasters^{15–17}. While several former studies reported that anthropogenic climate change is causing glacier melt^{18–20}, the Himalayan cryosphere still remains poorly understood. Hence, developing a holistic understanding of the natural variability of the Himalayan cryosphere is crucial for its proper protection, water sector, and overall mitigation measures.” SC in the Himalayas changes extensively over time – largely due to seasonal and sub-seasonal variations in temperature and precipitation²¹. One of the key drivers of SC is precipitation, which has been investigated by former studies. A host of these experimental studies have suggested large scale oceanic atmospheric circulations (referred to as climate variability modes) to be responsible for variations in monsoon precipitation in the high elevation of the Himalayas^{22–24}. Working a mile to the south-eastern reaches of the Indian subcontinent Monsoon (ISM), Srivastava et al., (2017) showed using a blend of isotopic proxies that the El Niño Southern Oscillation (ENSO) has been modulating the ISM for at least the last 1500 years²⁵. Singh et al., (2009) studied tree rings in the state of Himachal Pradesh and suggested that teleconnections have existed between the Pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO), and local precipitation for almost seven centuries²⁶. Sam et al., (2013) investigated more into tree rings and retrieved three centuries of isotopic (δ¹⁸O) records in snow PDSI and ENSO actually have to be in the upper sphere and present for the first time the conditions to prevail in Bhutan – India's northeastern neighbor²⁷. Gargibella et al., (2009) found the fingerprint of ENSO influence on Himalayan weather from about a century to a T decadal or core²⁸. While proxy precipitation records point towards possible connections between local and global events, only an understanding of precipitation delivery systems can truly establish the physical mechanisms of these connections. Multiple studies have shown that the Himalaya receive precipitation mostly from two major

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LETTERS

Decolonizing climate action or denying responsibility?

LETTER EDITOR Authors Info & Affiliations

BRIEFING > 1 JULY 2025 > 107,000 WORDS > 1 > PDF > DOI:10.1038/d41586-025-00000-0

LETTERS

Jacobine Leys

Plastics that pollute coastal areas affect local communities and ecosystems.

Decolonizing climate action or denying responsibility?

The Asian countries in eastern Indonesia had to develop a hybrid form of plastic production to suit their own people, the Indonesian government's development (2). Although this is generally seen as a positive step, it also means that plastic production is now controlled by local elites rather than being managed by the community. This is a problem because plastic waste management is a huge challenge for many communities, especially in rural areas where there is no formal waste management system. The Indonesian government has tried to address this by creating a national plastic waste management policy, but this has not been fully implemented. The Indonesian government has also tried to encourage local communities to manage their own plastic waste, but this has also not been fully successful. The Indonesian government needs to find a way to manage plastic waste that is sustainable and equitable for all communities.

Himalayan rivers face a hydropower surge

Hydropower Project, which aims to generate 1000 MW of hydroelectric power to meet the country's growing needs. This will require diverting water from 100 km of forest (2). But early, China's Lower Yellow River Basin has India's Brahmaputra River (3). Although hydropower can provide energy security and support the transition to clean energy, these and other Himalayan rivers are vital for biodiversity and for the livelihoods of local populations. Hydropower projects pose environmental threats. Regional authorities need robust environmental and social impact assessments, and strong regulatory frameworks, to ensure that hydropower projects do not harm the environment or local communities. The following brief and theory testing paper in collaboration with the International Union for Conservation of Nature (IUCN) and the World Wildlife Fund (WWF) discusses the potential impacts of hydropower projects on biodiversity and local communities. It also provides recommendations for how to minimize these impacts and ensure that hydropower projects are developed in a sustainable and equitable manner.

Public health risks in Asia underscored in hydropower plant approvals. Key measures to avoid construction, energy use, safety risks in projects ranging from toxic and lethal to industrial

Source: © iStockphoto.com

[illegible]Shairik Sengupta⁵² & Rajarshi Das Bhowmik[illegible]53477 | <https://doi.org/10.1038/s41598-025-18604-4> | nature portfolio 1[illegible]