Relation of Eurasian snow with regional India summer monsoon rainfall

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1. Introduction

Relationship of preceding winter/spring Eurasian snow with the Indian summer monsoon rainfall has been widely recognized. However, previous studies have tended to mainly focus on the snow-monsoon teleconnection using all-India averaged summer monsoon rainfall index (AISMR) (Bamzai and Shukla, 1999; Zhang et al., 2019), while devoting less effort to examining the regional features over India. Some of the earlier investigations that examined the spatial distribution of Indian rainfall association with antecedent Eurasian snow (Parthasarathy and Yang, 1995; Fasullo, 2004) were constrained by the coarse spatial resolution of rainfall data over India. Snow-monsoon relationships are complex due to the significant spatio-temporal variations of both snow (Bamzai and Shukla, 1999) and monsoon (Hrudya et. al. 2021). As a result, AISMR index is not appropriate to delineate the specific regions over India that are responsible for the well-known snow-monsoon relation. Recent multiple high-resolution gridded rainfall datasets along with the reanalysis datasets, provide prospects to appraise regional aspects of snow-monsoon link over India. In the present study, we attempt to answer a question- Do European Centre for Medium-Range Weather Forecasts ERA5 reanalysis data capture the spatial characteristics of snow-monsoon relation over India?

2. Data

Reanalysis: (i) Monthly rainfall and snow water equivalent (SWE) for the period 1980–2007 are obtained from the ERA5 reanalysis dataset at 0.25° spatial resolution (Hersbach et al. 2020). Observation: (i) Daily rainfall grid point data developed by India Meteorological Department (IMD) across the Indian landmass (Pai et al., 2014), (ii)National Snow and Ice Data Center (NSIDC) archived SWE data from Scanning Multi-channel Microwave Radiometer (SMMR) and Special Sensor Microwave/Imager (SSM/I) for the period November 1980-2007. This dataset has been enhanced using snow cover frequencies, and is gridded to the Northern and Southern 25km Equal-Area Scalable Earth Grids (Armstrong et al., 2002). SWE is hereafter referred to as snow.

3. Results

The analysis in the study is conducted for 1980-2007 due to availability of NSIDC SWE data for this period. The seasonal averages are defined as: December to March of the following year (DJFM) as winter season, April-May (AM) as spring season and June-September (JJAS) as summer monsoon season. Correlation coefficient (CC) between snow averaged over Eurasian domain (50- 70°N; 20-140°E) and the ensuing summer monsoon season rainfall at each grid point over India using ERA5 and corresponding observed data (OBS) is illustrated, both for winter (Fig.1a-b) and spring (Fig.1c-d) snow respectively. CC between snow and rainfall over India (Fig.1) is hereafter referred to as snow-monsoon relation. Winter snow-monsoon relation (OBS) (Fig.1b) is characterized by a 'Negative-Positive-Negative' (NPN) tri-polar spatial structure demonstrated as significant negative CC over the northern and south-western regions of India as well as over the parts of peninsular India, whereas positive CC is observed over east-central India. Spring snow-monsoon (OBS) relation (Fig.1d) is substantially weak and also the regional features vary from winter snow-monsoon (OBS) relation (Fig.1b). The tri-polar pattern of winter snow-monsoon (OBS) (Fig. 1b) relation is captured in ERA5 (Fig.1a), although regions with significant CCs and their spatial extent in ERA5 markedly deviates from that of corresponding observation. Although the spring snow-monsoon (OBS) relation (Fig.1d) is substantially weak, it is robust in ERA5 (Fig.1c) with tri-polar spatial pattern consistent with the winter snow-monsoon (ERA5) relation (Fig.1a).

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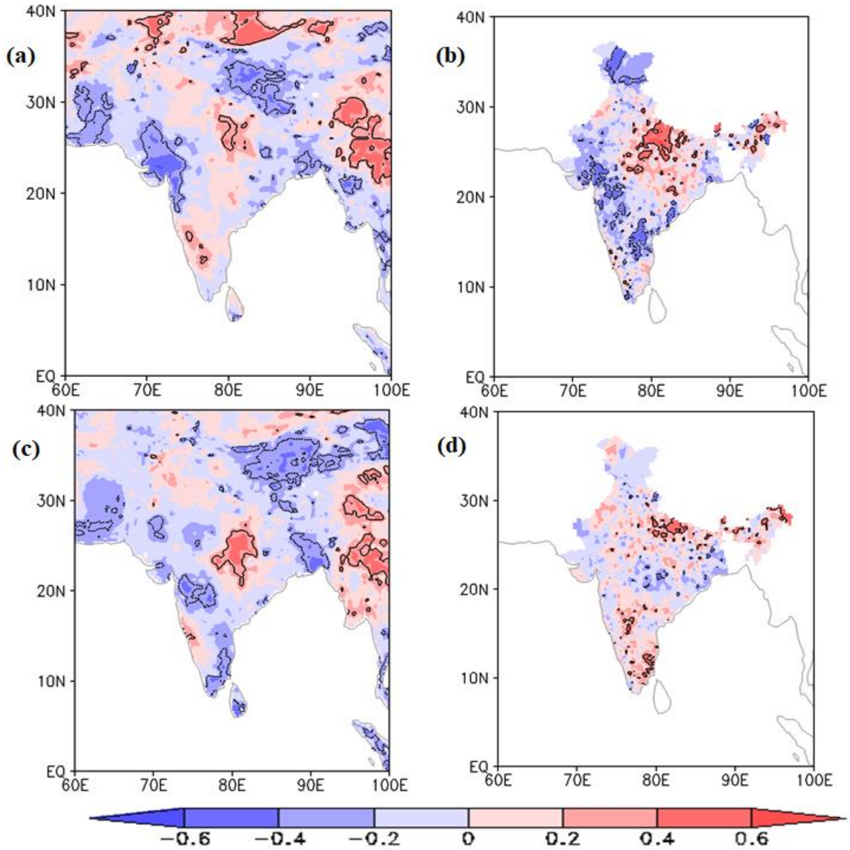

Figure 1: (a) Correlation coefficient (shaded) of ERA5 summer monsoon (JJAS) rainfall at each grid point over India and neighbourhood with the preceding winter (DJFM) snow averaged over the region of Eurasia [20°-140°E, 50°-70°N], based on 1980-2007.
(b) Same as (a) except with IMD observed rainfall data at each grid point over Indian main land and satellite snow (NSIDC) data.
(c) Same as (a) except with preceding spring (AM) snow.
(d) Same as (b) except with preceding spring (AM) snow.
Black solid contours represent significance at 95% confidence level.