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Linking the North Atlantic Oscillation to winter precipitation over the Western Himalaya through disturbances of the subtropical jet

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Abstract
Winter (December to March) precipitation is vital to the agriculture and water security of the Western Himalaya. This precipitation is largely brought to the region by extratropical systems, known as western disturbances (WDs), which are embedded in the subtropical jet. In this study, using seventy years of data, it is shown that during positive phases of the North Atlantic Oscillation (NAO+) the subtropical jet is significantly more intense than during negative phases (NAO−). Accordingly, it is shown that the NAO significantly affects WD behaviour on interannual timescales: during NAO+ periods, WDs are on average 20% more common and 7% more intense than during NAO− periods. This results in 40% more moisture flux entering the region and impinging on the Western Himalaya and an average increase in winter precipitation of 45% in NAO+ compared to NAO−. Using empirical orthogonal function (EOF) analysis, North Atlantic variability is causally linked to precipitation over North India—latitudinal variation in the jet over the North Atlantic is linked to waviness downstream, whereas variation in its tilt over the North Atlantic is linked to its strength and shear downstream. These results are used to construct a simple linear model that can skilfully predict winter precipitation over north India at a lead time of one month.

1 Introduction

The Western Himalaya and surrounding region receive a significant fraction of their precipitation during the winter months of December to March (e.g., Singh et al. 1995; Archer and Fowler 2004; Iqbal and IIyas 2013; Zaz et al. 2019) as the subtropical jet moves southwards, bringing extratropical storms known as western disturbances (WDs) to the area. WDs bring rainfall to lower elevations, where it is important for agriculture, and snow to higher elevations, where it is important for replenishing glaciers and deepening the snowpack, both of which are subsequently vital for water security during the spring and summer months. Variability in WD frequency and behaviour can thus affect the ecology, socioeconomics, and population health of the Himalayan region. WDs typically originate over the Mediterranean, Europe, or North Atlantic and travel as perturbations in the subtropical jet until they intensify upon reaching South Asia. WDs are often associated with hydro-meteorological disasters like floods, landslides and avalanches across the Himalaya and surrounding regions. Because WDs bring the majority of winter precipitation to the Western Himalaya (Midhuna et al. 2020), and because they are intimately linked with the behaviour of the subtropical jet (Hunt et al. 2018), there is the opportunity for seasonal predictability through global teleconnections that influence the position and intensity of the jet, such as the North Atlantic Oscillation (NAO) and El Niño Southern Oscillation (ENSO). The NAO is a major mode of winter variability in the Northern Hemisphere, its effect extending from North America to Europe and a large portion of Asia (Hurrell 2003) and accounts for more than 36% of the variance in mean sea level pressure during winter months (Walker and Bliss 1932).

The statistical relationship between the NAO and winter precipitation over the western Himalaya has been explored previously, but authors have disagreed on both the sign and significance of the relationship. Using a 21-year rolling window, Yadav et al. (2009) showed that the NAO is positively correlated with winter precipitation over northwest India, and that this relationship was strongest between 1940 and 1980 (when the mean correlation coefficient was 0.42).

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