



## **Estimating the Frequency of Sudden Stratospheric Warming Events from Surface Observations of the North Atlantic Oscillation**

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Sudden stratospheric warming (SSW) events can exhibit long-lasting surface impacts that promise improvements in medium-range to seasonal predictability. Their surface impact is dominated by the negative phase of the North Atlantic Oscillation (NAO). Hence, the question arises if stratospheric variability, and in particular the frequency of SSW events, can in turn be estimated from surface NAO conditions. This is especially relevant for the period before frequent upper air observations became available, while daily surface observations date further back. The surface impact is here quantified by NAO characteristics that are commonly observed after SSW events: a switch from a positive to a negative NAO and an extended persistence of the negative NAO, termed "NAO events". Two thirds of SSW events are found to be followed by either a persistence or switch NAO event and a quarter of SSW events are followed by both, while less than 25% of surface NAO events are preceded by a SSW event. Based on these findings, an index purely based on surface NAO observations is derived that estimates SSW frequency for the satellite era and extends it back to 1850, indicating that decadal stratospheric variability was present for the entire time series, with no significant trend. The minimum in SSW frequency in the 1990s is found to be coincident with the longest absence of NAO events since 1850, indicating that the early 1990s may potentially constitute the longest absence of SSW events for the 150-year record.