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A Statistical Analysis of Daily Snow Depth Trends in North America

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Abstract: Several attempts to assess regional snow depth trends have been previously made. These studies estimate trends by applying various statistical methods to snow depths, new snowfalls, or their climatological proxies such as snow water equivalents. In most of these studies, inhomogeneities (changepoints) were not accounted for in the analysis. Changepoint features can dramatically influence trend inferences from climate time series. The purpose of this paper is to present a detailed statistical methodology to estimate trends of a time series of daily snow depths that account for changepoint features. The methods are illustrated in the analysis of a daily snow depth data set from North America.

Keywords: changepoints; genetic algorithms; snow trends; storage model; time series

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1. Introduction

Snow is a viable proxy through which one may study climate change, as the associated modifications to precipitation and temperature patterns are believed to be strongest during the cold season in the mid and high latitudes where snowfall is prominent [1–5]. The rate at which climate is changing in polar regions is thought to exceed the rate at which natural systems can adapt [6]. Global climate models indicate that snow cover changes will considerably impact the cryopsheric portion of the water budget [7–9]. Snow is a vital environmental and geophysical quantity and is sensitive to climate change since its magnitude and extent depend on both temperature and precipitation [10–12].

Snow depth is the measured (or estimated) depth of a snow pack at a location, and takes into account the accumulation, ablation, and evolution of a snow pack. Therefore, snow depth should not be confused with snow cover (presence/absence) or new snowfall. Satellite data over the Northern Hemisphere suggest that snow cover has lessened since the mid-1980s [6,13–18]. Snow depth analyses complement snow cover change studies, providing further information on hydrological resources, surface energy, soil processes, and ecological systems [12,19]. Trend estimates in snow depths [12,13,20,21] and new snowfall [22–25] over various portions of the United States and Canada have been previously computed and related to climate variability [8,18,26–28].

When assessing long-term trends in snow depths, one should consider the temporal homogeneity of the data ([21,23,29,30]). Snow depth series often have discontinuities induced by changes in measuring location, equipment, or methods. These discontinuities—the so-called changepoints (breakpoints)—are crucial in constructing a realistic trend estimate at any one location ([21,24,30]). We do not attempt to attribute causes to any identified changepoints—they could be due to climate shifts, measuring changes, station moves, etc.; see [29] for additional discussion.