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Vegetation response to precipitation across the aridity gradient of the southwestern United states

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ABSTRACT

Atmospheric water demand affects a variety of factors, including primary production and the terrestrial water balance. Precipitation gradients from arid to humid regions also impact the water balance and play a large role in vegetation dynamics. Focusing on a 23-year period (1989–2011), we examine precipitation during the growing season in conjunction with the Normalized Difference Vegetation Index (NDVI) series for 21 satellite scenes spanning across the southwestern United States. We classify the satellite scenes into three different groups, based on the United Nations Aridity Index (AI). Group 1 is categorized as relatively humid with $AI \geq 0.65$, group 2 is intermediate with $0.50 \leq AI < 0.65$, and group 3 is relatively dry with $AI < 0.50$. We target three types of vegetation covers: shrubland, pasture, and grassland. On a long-term basis, we find significant positive trends in the NDVI series for all types of vegetation in groups 1 and 2. The magnitude of the trend in NDVI decreases with the aridity level. However, neither the total precipitation nor the number of precipitation events (>3 mm and >13 mm) changed during this time. We also use cross-correlation analyses to establish the lagged behavior of the three types of vegetation in relation to precipitation amount and number of events. The vegetation response is similar between precipitation amount and number of precipitation events. However, in the arid region, we find distinct responses to precipitation depending on the vegetation type. The magnitude and significance of the vegetation response to precipitation patterns increase with environmental aridity. There is thus a meaningful disparity of vegetation behavior in time and space.

1. Introduction

Ongoing climate change is being attributed to multiple factors, and evidences of climate change impact are reported widely around the globe (Huntington, 2006). The increasing emission of greenhouse gases is recognized to be the main driver of climate warming. As a result, during the period of 1880–2012, IPCC (2014) reported a global increase in temperature of 0.85 °C. Furthermore, based on different greenhouse gases emission scenarios, IPCC (2014) projected the global mean surface temperature to rise by the end of the current century. Likewise, meaningful changes are projected in future precipitation regimes. Although the magnitude varies within the emission scenarios, changes in climate are expected to significantly impact arid ecosystems. However, the projected changes in precipitation amount vary widely, depending on the models and their underlying assumptions (O'Gorman, 2012). Any potential benefit from an increase in precipitation amount would likely be offset by an increase in evapotranspiration due to increased temperature (Maestre et al., 2012). This suggests complex perturbations in the hydrologic cycle in the future.

Water stress on vegetation is one of the ways of characterizing the amount of available moisture. Based on simulations from different multi-model ensembles, Seager et al. (2007) projected a consistently drier climate in the southwestern United States for the 21st century. In contrast, Maestre et al. (2012) reported several gaps in our knowledge regarding future impacts of climate change on drylands, and highlighted the need to consistently determine these impacts. Specifically for the southwestern United States, Weiss et al. (2004) emphasized the lack of studies addressing vegetation dynamics in relation to climate variability. Relying on model outputs

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