Hydroclimatic Anomaly Propagation with Increasing Depth of the Soil Profile in Illinois: Implication for Land Memory Processes

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Abstract

In this study, we investigate the patterns of hydroclimatic anomalies (drought and flood) at the regional scale of Illinois, based on a comprehensive data set covering 25-year (1981-2005) monthly precipitation, soil moisture, groundwater depth, and streamflow. The focus is on the vertical (downward) propagation of hydroclimatic anomalies with increasing soil depths as well as the associated anomaly amplification or dissipation, at the monthly, seasonal, and inter-annual timescales. The characteristics of persistence and downward propagation of droughts and floods through the soil profile and unconfined aquifers are examined by using analytical crossing theory.

Introduction

The Illinois data set (Eltahir and Yeh, 1999) used in this study describes the following variables: atmospheric vapor convergence, precipitation, soil moisture (SM), water table depth (WTD), and river flow (R). The data on SM was collected by the Illinois State Water Survey (ISWS). Weekly (March = October) and biweekly (November = February) measurements were taken at 11 different soil layers with a resolution of about 20 centimeters down to 2 meters below the surface. The WTD data consists of monthly groundwater level at 19 wells isolated throughout Illinois for monitoring unconfined aquifers. These aquifers are relatively shallow and the average depth to the water table ranges between 1 to 10 meters below the surface. We investigate the propagation of hydroclimatic anomalies (flood and drought) for each of the 11 layers soil moisture, as well as for each of the three groups of groundwater wells: shallow (0-2m), intermediate (2-4m), and deep (>4m) groundwater, which were divided from the total 19 wells in Illinois based on their climatological mean WTD.

Data

The autocorrelation and spectrum of each water balance components in Illinois have been analyzed. The correlation function and spectrum of soil saturation and water table depth were computed, and then normalized by the corresponding monthly standard deviations. The autocorrelation function and spectrum of each water balance components in Illinois have been analyzed. The correlation function and spectrum of soil saturation and water table depth were computed, and then normalized by the corresponding monthly standard deviations. The autocorrelation function and spectrum of each water balance components in Illinois have been analyzed. The correlation function and spectrum of soil saturation and water table depth were computed, and then normalized by the corresponding monthly standard deviations.

Results and Conclusion

- Relative to atmospheric forcing, soil moisture and groundwater in Illinois is characterized by long duration and great magnitude of negative (drought) anomaly, while runoff anomaly is characterized by large positive anomaly with short duration, and small negative anomaly but long duration.
- Soil moisture anomaly from the surface down to 2m has correlation timescale increasing from 2 to 4 months. Shallow (0-2m), intermediate (2-4m), deep (>4m) groundwater anomalies have correlation timescales of 3, 5, 10 months, respectively.
- Unconfined aquifer amplifies the drought (climatological anomalies) and dissipates the flood anomalies (causing flood in streamflow), which results in the observed asymmetric response of the aquifers to the droughts and floods.
- Soil moisture, groundwater, and streamflow are well correlated with each other (but not with precipitation). However, they show different response to droughts and floods. Their complicated three-way interactions and feedbacks dictates the propagation of hydroclimatic anomaly within the soil profile in Illinois.

References