The Evaporative Demand Drought Index. Part I: Linking Drought Evolution to Variations in Evaporative Demand

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ABSTRACT

Many operational drought indices focus primarily on precipitation and temperature when depicting hydroclimatic anomalies, and this perspective can be augmented by analyses and products that reflect the evaporative dynamics of drought. The linkage between atmospheric evaporative demand E_0 and actual evapotranspiration (ET) is leveraged in a new drought index based solely on E_0—the Evaporative Demand Drought Index (EDDI). EDDI measures the signal of drought through the response of E_0 to surface drying anomalies that result from two distinct land surface–atmosphere interactions: 1) a complementary relationship between E_0 and ET that develops under moisture limitations at the land surface, leading to ET declining and increasing E_0, as in sustained droughts, and 2) parallel ET and E_0 increases arising from increased energy availability that lead to surface moisture limitations, as in flash droughts. To calculate EDDI from E_0, a long-term, daily reanalysis of reference ET estimated from the American Society of Civil Engineers (ASCE) standardized reference ET equation using radiation and meteorological variables from the North American Land Data Assimilation System phase 2 (NLDAS-2) is used. EDDI is obtained by deriving empirical probabilities of aggregated E_0 depths relative to their climatologic means across a user-specific time period and normalizing these probabilities. Positive EDDI values then indicate drier-than-normal conditions and the potential for drought. EDDI is a physically based, multiscalar drought index that that can serve as an indicator of both flash and sustained droughts, in some hydroclimates offering early warning relative to current operational drought indices. The performance of EDDI is assessed against other commonly used drought metrics across CONUS in Part II.

1. Introduction

a. Drought, ET, and E_0

Drought severely affects society, ecology, and economies, with impacts felt across sectors and hydrologic and political boundaries at time scales that vary from weeks to years. Across sectors, drought is essentially an extended imbalance between moisture supply and demand—relative to long-term mean conditions for the period in question—in favor of demand. Physically, it is manifest as deficits in moisture fluxes and storages, including precipitation (Prcp) in meteorological drought; streamflow [runoff (RO)] and surface storage depletion in hydrologic drought; and, traditionally, evapotranspiration (ET) and soil moisture (SM) in agricultural drought. Agricultural and meteorological droughts are also revealed as a surplus in atmospheric evaporative demand E_0 (also sometimes referred to as "potential evaporation"). The E_0 physically integrates radiative and advective forcing variabilities and, further, reflects water availability through land surface–atmosphere feedbacks that affect partitioning of the available energy at the surface into latent and sensible heat fluxes. Across the energy-limited range of the hydroclimatic spectrum, E_0

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