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Potential for forecasting pan-European hydrological drought using climate system diagnostics

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Hydrological droughts have significant human and environmental consequences due to their persistence and typically wide geographical region of influence. Water shortages impact upon agricultural, industrial and domestic users, and the ecological integrity of river systems. Forecasting of these extreme hydrological events at seasonal or multi-seasonal time-scales is necessary to increase human preparedness and, thus, to improve management of water supplies and mitigation of water-related hazards. Research to date has shown that, over seasonal time-scales, rainfall and temperature anomalies in northern extra-tropical regions may be forecast through prior knowledge of the behaviour of slowly varying components of the climate system (NAOI, ENSO, SST etc.). However, the extent to which hydrological drought across Europe at a variety of scales responds to ocean-atmosphere variability has received very limited attention. This paper reviews the potential of climate system diagnostics for pan-European forecasting of hydrological drought by drawing together findings from the global literature and primary research by the authors on hydroclimatological associations between climate and river flows in Western Europe.

The theoretical basis of seasonal climate forecasts is that the lower atmosphere is forced by slowly-evolving boundary conditions that induce climate system inertia. Statistical models assume antecedent, current or predicted future values of climate variables (diagnostics) provide a fundamental source of predictability. The inertia of such climate forcing mechanisms coupled with the 'hydrological memory' of river basin water stores offers prospects to forecast droughts with seasonal lead times and also to identify anomalous climate system conditions that may lead to river flow extremes

several months later. A conceptual model of the links between ocean-atmosphere-land surface-drought is presented to provide a clear process framework for remote forcing of hydrological response. Through review of the current state-of-the-art, the following research gaps are identified that require to be addressed to realise the potential for pan-European drought forecasting: (1) identification of hydrologically-meaningful climate system diagnostics; (2) realisation of the limitation of atmospheric indices (e.g. NAOI) and search for alternative and/ or improved indices; (3) exploration of lagged hydroclimatological associations and detrended relationships; (4) identification of stationairty of relationships; (5) need for a multivariate approach cf. current focus on an individual climate system diagnostic; (6) assessment of predictability of different drought indices; and (7) understanding of the chain of causality cf. non-process-based statistical pattern matching. The potential for forecasting of river flows in Western Europe is further illustrated by quantifying hydroclimatological links between: (1) regional climate [temperature and rainfall] and atmospheric circulation [NAOI, AOI, and zonal and vector vapour flux anomalies], and the discharge of two British rivers from 1974-97; and (2) air-mass frequencies and river flow regime classes for river basins across Western Europe from 1974-1990.