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Spatio-temporal trends in coastal upwelling across NW Africa, 1981-2010

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In the early 1990's it was hypothesized that coastal upwelling across the eastern boundary currents may increase as a result of global warming. Since then, numerous studies have sought to elucidate the spatial and temporal trends in coastal upwelling intensity. Across the Canary Current (10-36°N), a conflicting signal (i.e. a positive/negative/no trend) in published results has emerged. We surmise this to be the consequence of (1) minor methodological differences, (2) differences in the temporal periods considered (intra- and inter-annual) and (3) the use of different data sets/sources. Here, we present seasonal upwelling estimates across the most recent 30-year climatic 'normal' period (1981-2010) based on the more commonly used wind stress and sea-surface temperature (SST) methodologies, and reinforce this analysis with traditionally 'lesser-used' sources (including sea-surface height, horizontal current velocity and vertical water column motion). For the wind-stress upwelling index we use six data sources (ERA-Interim, NCEP/NCAR, 20CR, PFEL, ICOADS and MERRA) and for the SST index we use three (HadISST, Reynolds OISST and ICOADS). We also utilize the sparse coastal meteorological and tide-gauge stations scattered across the NW African coastline. Additionally, we examine sea-surface height data from four sources (AVISO, GODAS, SODA and GRACE), horizontal current velocity from two sources (GODAS, SODA) and vertical water column motion from the GODAS dataset as further proxies for upwelling estimation. Generally, across summer, the numerous indices correlate reasonably well and display consistent spatial patterns and the same year-to-year oscillations, although the trend directions across the entire period sometimes diverge. Nevertheless, we conclude there is enough corroborating evidence to suggest there is a positive (negative) tendency in upwelling poleward (equatorward) of 20°N, but are cautious that these trends aren't ubiquitously significant. We suggest that further warming is necessary for the upwelling intensification process to be fully realized, although as a year-round phenomenon, the current upwelling magnitudes (without the need for intensification) are sufficient to impact coastal SST trends. We further relate coastal upwelling to overlying atmospheric pressure and temperature fields and basin-scale oscillations (NAO, EA, AMO). The NAO exerts a strong, significant control across much of the NW African coastline throughout winter but displays a much weaker effect throughout summer.