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Effects of the Etesian wind regime on coastal upwelling, floods and forest fires in the seas of the old world

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Abstract

The Etesian wind regime dominating the climate of the Aegean Sea in summer often influences a larger area extending from the Balkans and the Black Sea to the Levantine Basin of the Eastern Mediterranean. The steady dry northerly winds descending from the Balkans in summer often incite forest fires in the Aegean Sea region, while the moist air picked up from the sea and trapped against the mountainous eastern Black Sea coast results in severe floods. The intense upwelling on the southern Black Sea and the eastern Aegean Sea result from steady winds aligned with the coast. Case studies based on recent observations and model simulations illustrate these events.

Keywords: Etesian, upwelling, floods, forest fires, Aegean, Black Sea, modeling

Introduction

The summer Etesian wind regime often develops to gale force winds, veering from NE to N and NW respectively in the north, central and south Aegean (Tyrlis and Lelieveld 2013; Tyrlis *et al.* 2014), fed by northerly winds from the Balkan gap and northeasterly winds from the Black Sea area. The typical wind pattern affects the entire region, often intensified south, at the elevated island of Crete (Figure 1a).

Data and Methods

Case studies in the present context emphasize the region-wide influence of Etesian winds by making use of surface wind, sea surface temperature and satellite data, as well as atmospheric and ocean models. Operational weather forecasts at the IMS-METU (http://linux-server.ims.metu.edu.tr/metuwrf/) are used for the analyses. The NEMO model (domain: 40.92°-47.30°N, 27.43°-42.00°E at 2.5 km horizontal resolution and 60 z-levels), developed for Black Sea hincasts and operational use in the MyOcean2 European project, includes inputs from major rivers, seasonal T,S profile boundary conditions specified at the Bosphorus, and is driven by surface fluxes based on the atmospheric data of the University of Athens (IASA) at 1 hr intervals and 0.05° horizontal resolution. SST satellite data are obtained from MHI, Ukraine. Daily observations of sea surface temperature are obtained at the İnebolu (41.98°N 33.76°E) station of the Turkish State Meteorology Service. ERA-interim reanalysis surface atmospheric data for the region have been obtained from the ECMWF.

Results

Strong air-sea interactions during the Etesian wind regime are all too significant in this sensitive region of continental/marine climates. Often the sustained wind pattern is suitable to create forest fires in the region especially in the central and southern Aegean (Koletsis *et al.* 2009; 2010), e.g. in 25 August 2012 when the government of Greece declared a state of emergency as the blaze reached Athens, verified by wind patterns (Figure 1a). It was however rather surprising to evidence a completely different extreme event happening at the same time in the eastern Black Sea, where the winds diverged with a northwesterly orientation. The moisture picked up by winds from the northern steppes was trapped against the steep Anatolian and Caucasian mountain ranges (Figure 1b) and precipitated by orographic uplift against the southeast coast, leading to the extreme flooding event on August 21, 2012 in the southeast (Figure 1c). Precipitation of about 230 mm was received in two days, equivalent to few months of annual rainfall. Several times in the summer of 2012 the pattern was repeated, and a similar flooding extreme event had occurred earlier on July 7, 2012, associated with a small-scale cyclone trapped in the mountainous eastern Black Sea region. The storm created the worst floods in 70 years in Krasnodar and Krymsk, Russia, with rainfall amounting to 270 mm/day and a death toll of more than hundred people.

In the Aegean Sea, circulation features such as the persistent upwelling along the eastern shores and the jet-like boundary currents on the western shores, largely owing their existence to the northerly Etesian winds, are well known (Theocharis *et al.* 1999; Olson *et al.* 2007; Sayın *et al.* 2011). In the Black Sea, the SW-NE oriented section of the southwest coast, aligned with the NW wind pattern in much of summer (Figure 1a) is favorable for Ekman drift currents in offshore direction leading to coastal upwelling (Sur *et al.* 1994).

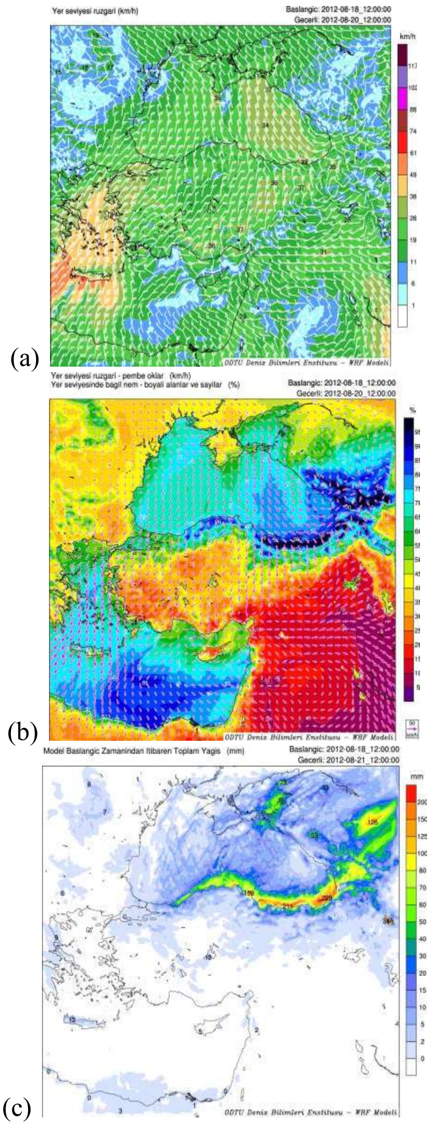
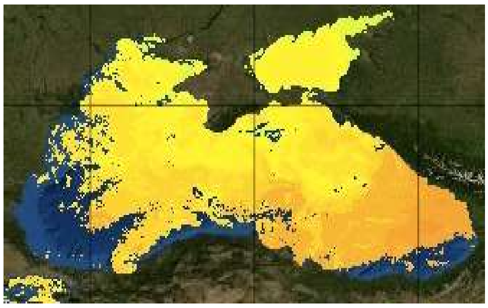
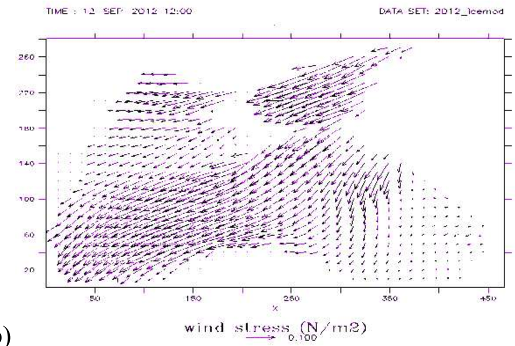


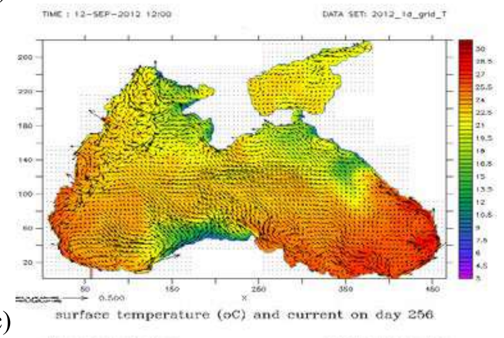
Figure 1. Atmospheric model forecasts of (a) surface winds (km/h), (b) surface relative humidity (%) and wind (km/h) on 20 August 2012 and (c) total precipitation (mm) during 18-21 August 2012



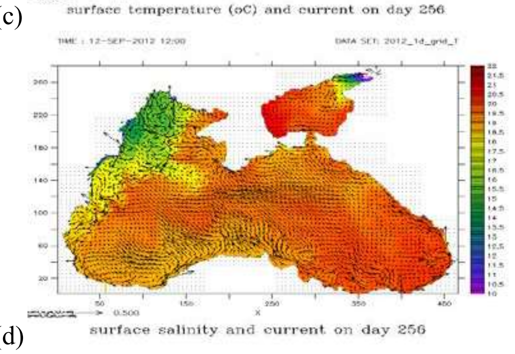
(a)



(b)



(c)



(d)

Figure 2. September 12, 2012 (a) satellite SST image, (b) surface winds and ocean model hindcasts of (c) surface currents and temperature, (d) surface currents and salinity

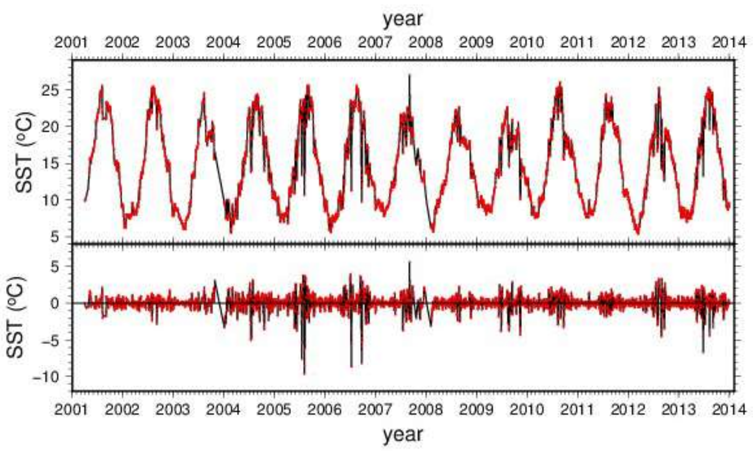
A typical situation is shown in the satellite image of Figure 2a, where cold waters with temperatures of 15°C are detected adjacent to the coast, in contrast to the 22-26°C in the rest of the basin. The upwelling is subject to some intermittency under changing winds, and located downstream of the meandering coastal jet (i.e. the 'rim-current') which often separates from the coast and transits offshore of the upwelling area (Sur *et al.* 1994; Özsoy and Ünlüata 1997, 1998).

The mainly cyclonic circulation of the highly stratified Black Sea is buoyancy and wind driven (Özsoy and Ünlüata 1997, 1998). A distinctive feature of the Black Sea thermal stratification is the subsurface Cold Intermediate Water (CIW) usually found above the pycnocline, upwelled in summer in the southwest as well as around Crimea (Figure 2a). Also shown in the same figure are the surface winds (Figure 2b), temperature (Figure 2c) and salinity (Figure 2d) produced by the NEMO model continuous hindcast for the years 2010-2014, confirming the observed features.

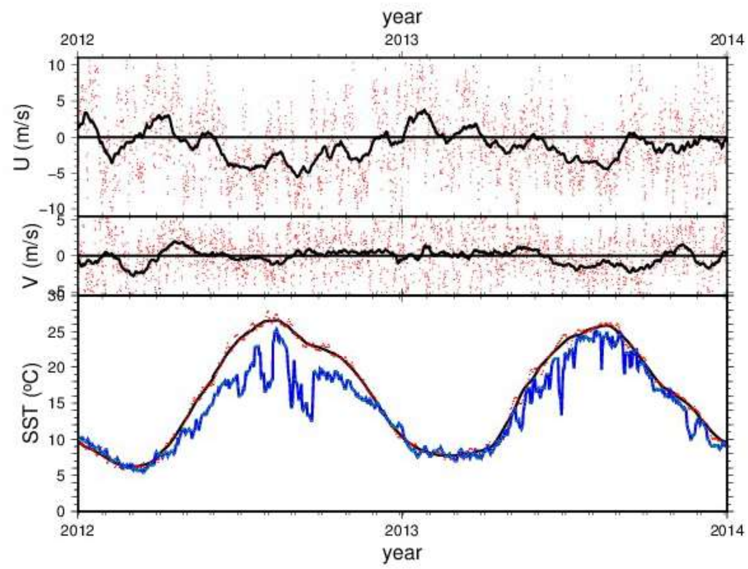
Daily observations of SST at the İnebolu indicate very frequent and persistent upwellings during repeated episodes in the summer season (Figure 3a). What are seen as many spikes and dropouts in the time-series are actually many cases of upwelling, with temperature drops to as low as 11^{o}C, as a result of the cold intermediate water (CIW) surfacing at the coast. SST data high-pass filtered at cutoff period of 30 days indicate high frequency events (Figure 3a). The enlarged plots of the observed SST (Figure 3b, lower panel, blue) reveal sharp dropouts of temperature lasting from few days to few weeks, which differ strongly from the regional average SST in the ECMWF reanalysis (black). Figure 3b, upper two panels display along-shore and cross-shore components of the wind at the ECMWF grid point near the İnebolu station, after the wind vector has been rotated by 40° to be aligned with the coast. It is clear that the main component of the wind is along-shore and blows from the northeast in summer, favorable to upwelling.

Discussion

The regional influences of the Etesian winds are well known, but perhaps not sufficiently appreciated. Forest fires are incited in the Aegean, while floods occur concurrently in the Black Sea. We try to demonstrate the climatic significance of some of these concurrent events. For instance, in continuing fisheries studies in the Black Sea (http://hamsi.ims.metu.edu.tr), the role of upwelling events have not been investigated. Yet, Black Sea fisherman near İnebolu are very well aware that they can not go out to fish Palamut (pelamydes) during periods of persistent northerlies which lead to upwelling. It was only revealed to us during this study that local towns people of İnebolu have been going to the coast at night with searchlights to collect half-dizzy fish suffering shock by the cold waters during upwelling (Figure 4).



a)



(b)

Figure 3. (a) İnebolu daily (upper) and high-pass filtered (lower) SST time series, (b) along-shore and cross-shore components of wind velocity at 42.2°N, 32°E based on ERA-interim reanalysis (ECMWF) rotated clockwise by 40° (upper two panels, red dots are original unfiltered data points), the SST based on the reanalysis (black) and the İnebolu meteorological station time-series data (blue) (lower panel)

Figure 4. İnebolu people searching for fish near the coast at night (photos: Sinan Çevik)

Acknowledgements

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