Meteorological forcing and coastal flooding: The case of Evros River delta

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Semi-enclosed and shallow coastal embayments are, in particular, sensitive to sea level variations due to meteorological forcing, as in in the case of Venice Lagoon in North Adrairic (Italy) (Tirgo and Davis, 2002) and the estuarine reaches of the Swan River at Fremantle (W. Australia) (Eliot, 2012) (Australia). Moreover, future extreme sea levels (ESLs) and flood risk along European coasts have been assessed in association to climate change (i.e., global warming) by Vousdoukas et al. (2017). The present contribution aims to investigate the role of meteorology and hydrology in the occurrence coastal floods in the case of Evros deltaic plain.
This work comes as a contribution to the Evros river flood risk management considering the role of meteorological tide to the inundation of the lower Evros delta area.

The transboundary Evros River, the largest river in the Balkan Peninsula with catchment of approximately 53,000 km^2, is shared between three countries, i.e. Bulgaria (66%), Turkey (27.5%) and Greece (6.5%). Its deltaic plain, shared between Greece (90%) and Turkey (10%) covers an area of 188 km^2 that is characherised by a rather smooth relief lying in low elevations <5 m and incorporating a number of lagoons and water bodies. About half of the deltaic plain is cultivated.

Evros basin exhibits a Mediterranean climate across the coast and a continental type climate at its North Eastern part. The average precipitation in the basin is approximately 1,380 mm/yr and the mean annual freshwater discharge in the downstream part, after dam controlling, has been calculated to be in the order of 340 m^3/s (Karditsa and Poulos, 2019). However, the Evros river is characterized by high inter-annual flow fluctuation supporting the development of frequent flood events (Tzortziou et al., 2015), during which water discharge exceeded 2,500 m^3/s (Angelidis et al., 2010). The latter has been associated with temporarily flooding both at the riparian and –mainly- the downstream part of the Evros Delta (Mentzafou et al., 2018). For this reason, during the last years, iimportant efforts have been made regarding flood risk management plans (e.g. Markantonis et al., 2013; Angelidis et al., 2010; nevertheless, the Evros river management remains problematic. The latter is also associated with the presence and the operation of a large number of flow regulation dams, from which 25 large dams have been constructed for the production of hydroelectric power and watering, and a significant number of smaller ones for irrigation purposes.

The deltaic coast has been developed at the semi-protected embayment of Alexandroulolis Gulf (NE Aegean Sea), which is exposed to wind-induced waves approaching from the west (4.1%), southwest (10.7%) and south (4.4%) directions; the maximum wave conditions (significant wave heights up to 6 m and periods of 11 s) belong to SW direction due to its maximum fetch distance (some 270 km) (Karditsa and Poulos, 2013). In terms of With respect to the most frequent occurring waves the southerly incoming waves are associated with the most significant wave heights and wave energy flux (P).The receiving marine basin i.e. NE Aegean Sea is an essentially tideless environment, yet, with mean sea level may of 0.8 m (HHS, 2005) due to meteorological forcing associated with southerly winds.

For the need of the present investigation, the following parameters were investigated: (i) the interannual wind speed and wind direction changes for the period 1979-2018, based on the ECMWF ERA-Interim reanalysis dataset (Dee et al. 2011) on a 0.125x0.125° grid for a broader area; (ii) the correlation between wind direction and sea level set up (meteorological tide) based on Hellenic National Hydrographic Service (HNHS) data for the examined flood event periods; (iii) the relationship between meteorological tide and the spatial occurrence of flood events in the lower part of Evros delta utilizing satellite (Landsat 5 and a Landsat 8) imagery.

The results showed that according to the long-term analysis of the wind, there is a statistically significant increase for the frequencies of the southerly winds for the cold period of the year (November to March). In addition, from the analysis of the relationship between tide heights and the wind field, it is found that the tide is significantly higher for S, SW and wind directions, while it maximizes for southerly winds. Additionally, the linear-circular correlation between wind direction and tide height on 3-hourly lag basis, becomes important for wind directions for up to 3 days before the tide measurement and maximizes for zero lag, indicating that previous meteorological conditions can trigger the piling up of the water. These foundlings are in agreement to the occurrence of extended flood events in the lower part of the Evros deltaic plain; on the contrary, it was found that during winds of other (not southerly) directions either flood events was not observed or they were not restricted to the lower part of deltaic plain but covered a much wider area along river route.

In the summer image of Figure 1a water bodies cover 12%. The flood event of January 2015 (Figure 1b) took place after a 4-day predominance of south winds being associated with and meteorological tide of 1 m. In this case, water bodies expanded by 18% covering 14% cultivated areas and 4% vegetated areas. Similarly, in Figure 1c, the impact of the March 2018 flood event in the Evros deltaic plain is presented, occurring after 4 days winds of southerly winds imposes meteorological tide reached 1.23 m. Land cover analysis revealed that some 34% of the Evros delta was flooded by the specific event. The drowned area corresponds to approximately 22% of agricultural land and 8% of vegetated area, whilst, the majority of the flooded area (~75%) belongs to the Turkish part.

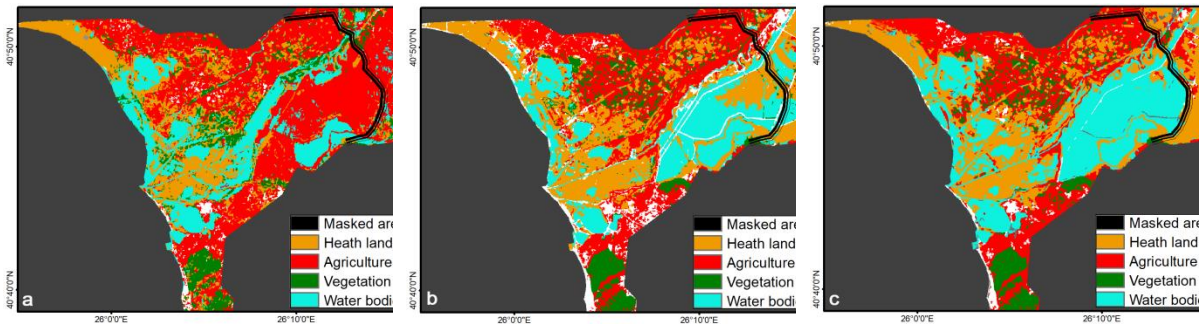

Fig. 1. Satellite images (a) 15/08/2005, (b) 23/01/2015, (c) 20/03/2018, showing the flooded area (nearshore water bodies) of the Evros deltaic plain

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