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Observational and numerical study of the Vardaris wind regime in northern Greece

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ABSTRACT

The Axios Valley, located in central-northern Greece, is surrounded by complex topography that plays a significant role in the modification of wind flow, both in terms of speed and direction. The characteristic wind regime of this valley is Vardaris, a northwesterly wind that prevails in this region, especially during the cold period of the year. Vardaris is well known for its consistent direction and high intensity, as well as for the effective advection of cold and dry air, often resulting to significant damages in local infrastructures and agriculture. A field campaign under the name AXIOS took place during the period from November 2007 through May 2008 in order to examine this particular wind flow. The analysis of the in situ observational data, which was funded by the research program THESPIA-KRIPIS, showed that topography plays a key role in intensifying Vardaris, generating gusts that approximated 30 m s^{-1} during the experimental period. The air temperature and humidity fields were also found to be significantly influenced. In addition to the observational study, an intense Vardaris episode was simulated with the Weather Research and Forecasting (WRF) model at high horizontal resolution. Results revealed that the model was able to reproduce the favorable environmental conditions that lead to Vardaris occurrence, providing a useful insight on the physical mechanisms explaining its structure.

1. Introduction

Topography is documented as a well-known parameter generating thermally and dynamically driven wind flows (Whiteman and Doran, 1993; Steenburgh et al., 1998; Mayr et al., 2007; Koletsis et al., 2010; Shimada et al., 2012; Lennard, 2014). Gap flows and wind channeling, in particular, are two widely recognized manifestations of wind flow modification due to topography. Wind channeling refers to the phenomenon of wind inside a valley blowing along the valley's axis (Weber and Kaufmann, 1998; Kossmann and Sturman, 2003; Carrera et al., 2009; Deacu et al., 2010). This phenomenon has been reported in several regions around the world, including the St. Lawrence River Valley in Canada (Carrera et al., 2009), the Tennessee Valley in the United States (Eckman, 1998), the mountainous area near Basel in Switzerland (Weber and Kaufmann, 1998), the Kongsfjorden–Kongsvegen Valley in Norway (Esau and Repina, 2012), the upper Rio Negro Valley in Argentina (Cogliati and Mazzeo, 2006), and the upper Rhine Valley in Germany (Gross and Wippermann, 1987). The physical mechanisms that are responsible for the generation of channeled winds are presented in the early work of Whiteman and Doran (1993), also discussed in the more recent study of Carrera et al. (2009). Briefly, these mechanisms are the thermally driven channeling, downward momentum transport, forced channeling, and pressure-induced channeling.

The definition of gap flow or gap wind dates back to the beginning of the 1930s (Reed, 1931). Simply put, this term is used to describe the flow of wind between indentations in orography, resulting either from purely horizontal topographical constrictions (level gaps) or from both horizontal and vertical constrictions, such as mountain passes (Mayr et al., 2007). Gap winds develop primarily due to the pressure gradient existing in the along-gap direction (Colle and Mass, 1998; Steenburgh et al., 1998; Mayr et al., 2007). The presence of these winds has been reported in several areas around the globe, including the Strait of Juan de Fuca (Colle and Mass, 2000) and the Columbia Gorge (Sharp and Mass, 2004) in the United States, the Cook Strait in New Zealand (Reid, 1996), the Gulf of Tehuantepec in Mexico (Steenburgh et al., 1998) and the Shelikof Strait in Alaska (Lackmann and Overland, 1989). In the majority of these studies, maximum wind speeds were reported well downstream of the narrowest constriction, at the end of the gap exit, contrary to the Venturi effect, which is often used as an explanation for the occurrence of strong gap winds (Reed, 1931). A comprehensive review of the knowledge acquainted for gap flows through the Mesoscale Alpine Programme is available in Mayr et al. (2007).

The Axios Valley is a major topographical feature of central-northern Greece (Fig. 1a). It owes its name to the Axios River that flows from FYROM through Greece and into the Thermaikos Gulf (Fig. 1b). The fairly high mountains and hills that surround the valley play a significant role in the modification of wind flow. Indeed, the Axios Valley has

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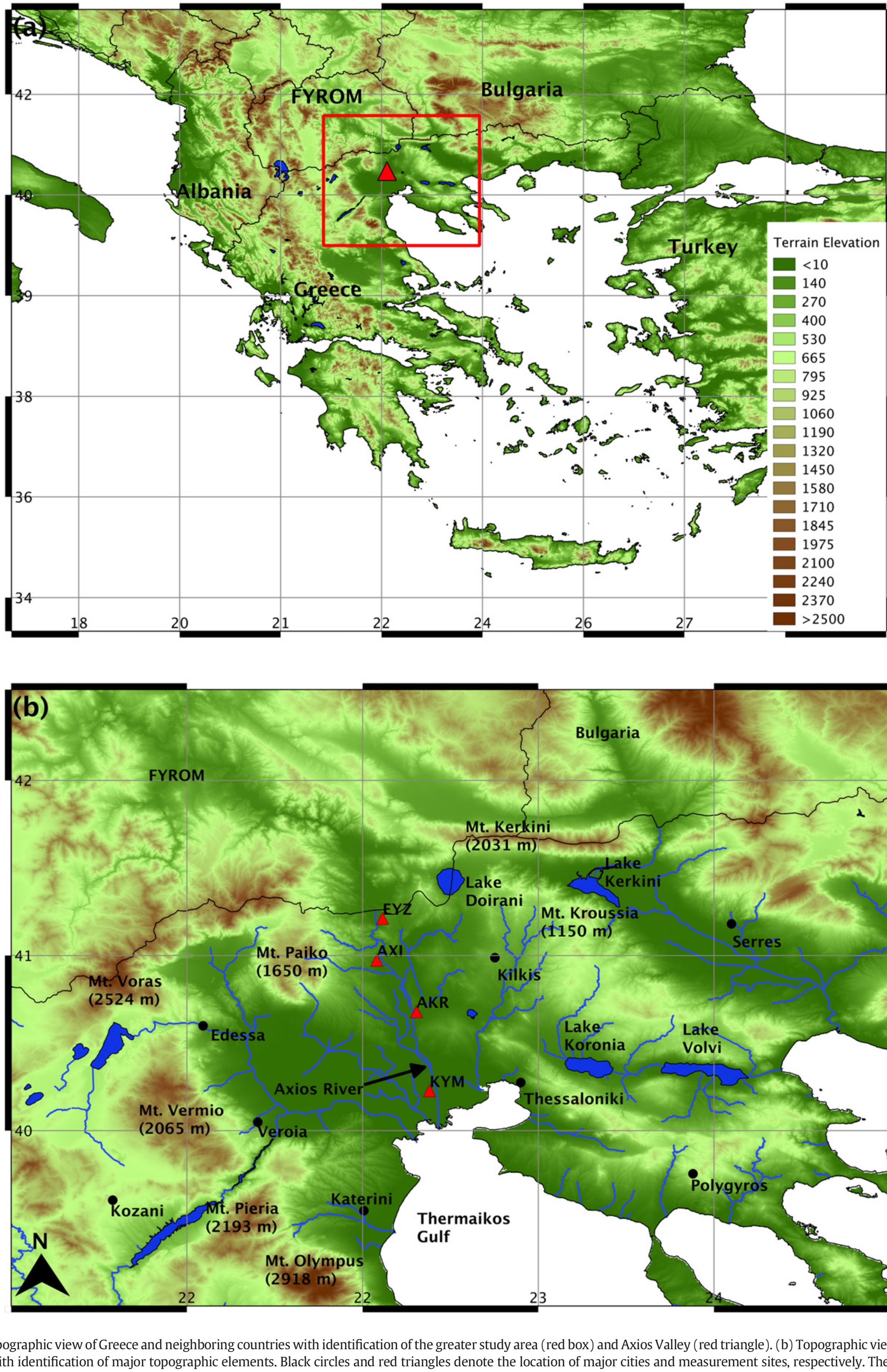

Fig. 1. (a) Topographic view of Greece and neighboring countries with identification of the greater study area (red box) and Axios Valley (red triangle). (b) Topographic view of the greater study area with identification of major topographic elements. Black circles and red triangles denote the location of major cities and measurement sites, respectively. The legend for elevation is common to both maps.