Numerical Study of an Intense Episode of Vardaris Wind

L. Tsopouridis, I. Pytharoulis, T. Karacostas, P. Zanis, and I. Tegoulias

Abstract This paper presents a case study of an episode of Vardaris that occurred on 10 November 2007 and caused widespread problems in Central Macedonia. It uses surface data including four stations along Axios valley (Evzonoi, Aksioupoli, Akropotamos, and Kymina), analyses and the nonhydrostatic Weather Research and Forecasting model. The episode was associated with the combination of a transient depression over Greece and an anticyclone in Western Europe. Maximum sustained wind speeds of 20.5 m/s with gusts up to 28.2 m/s appeared along Axios and at Thessaloniki airport (24 m/s with gusts up to 31.9 m/s). The model simulations with a horizontal resolution of 1 km were in good agreement with observations. The strongest winds, in excess of 30–35 m/s, were simulated between 750 and 900 hPa in the form of a jet streak. A numerical experiment showed that the occurrence of the episode was determined by the synoptic scale flow, but its maximum intensity was specified by the local conditions due to channeling.

1 Introduction

The wind called Vardaris is a strong northwesterly local wind that blows along the area of Axios Valley in southern Balkans. Vardaris is created in Axios river (Vardar) in FYROM, appearing in Greece and Central Macedonia through the central ridge of Paiko and Kerkini. Following the valley of Axios it affects Thessaloniki as a strong northwesterly wind. It is characterized by its direction, strong intensity, low temperatures and low humidity. It is of particular interest because it affects both humans and the local environment.

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Despite its importance, there are only a few studies about the Vardaris wind (Angouridakis et al. 1981; Maheras et al. 1984; Psarri 2005). More specifically, there is a lack of detailed high-resolution investigation of its spatiotemporal distribution and the relative role of the synoptic and local conditions in its development, providing a strong motivation to study this phenomenon.

A case study of an episode of the Vardaris that took place on 10 November 2007 and caused widespread problems in central Macedonia is presented. The objectives of this study are:

- To study the characteristics and causes of this event
- To investigate the relative role played by the synoptic scale meteorological conditions versus the local topography.

2 Data and Methodology

This research has been based on numerical simulations, observational data and gridded analyses. The nonhydrostatic Weather Research and Forecasting model with the Advanced Research dynamic solver (WRF-ARW Version 3.2.0) was utilized in the simulations (Wang et al. 2010). The observations are the routinely available surface measurements of the networks of the Hellenic National Meteorological Service (HNMS), the Department of Meteorology and Climatology (DMC/AUTH) and the School of Agriculture of the Aristotle University of Thessaloniki, the National Observatory of Athens (NOA), the Greek Agricultural Insurance Organization (ELGA), the Region of Central Macedonia and from four automatic meteorological stations that operated along Axios Valley in a common project between DMC/AUTH and NOA (Fig. 1). These four stations were installed at Evzonoi, Aksioupoli, Akropotamos and Kymina covering the whole area of interest within Greece. The data of Gevgeli (FYROM) were retrieved from GTS in order to cover the upstream region. The observations were used along with United Kingdom Meteorological Office (UKMO) mean sea-level pressure analyses and gridded 6-hourly operational surface and upper-air analyses of the European Centre for

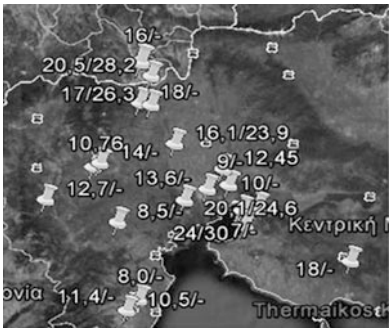

Fig. 1 Maximum observed sustained wind speed (m/s) and gust (m/s) at 10 m

Medium-Range Weather Forecasts (ECMWF). They were available at a regular grid of 0.25° lat × 0.25° lon at the pressure levels of 1,000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70 and 50 hPa.

3 Synoptic and Mesoscale Analysis

Figure 1 depicts the spatial distribution of the maximum observed 10 m sustained wind speed and wind gusts. The measurements at Evzonoi, Aksioupoli, Akropotamos and Kymina and those of HNMS were recorded at 10 m above surface. The other wind observations were transformed to a height of 10 m using the wind profile power low. Maximum wind speeds appeared along Axios river (20.5 m/s with gusts up to 28.2 m/s at Evzonoi) and at Thessaloniki airport (24 m/s with gusts up to 31.9 m/s). It is hypothesized that the latter station exhibited the strongest winds because of the existence of the sea-surface (with low friction) upstream.

The temporal evolution of the 10 m wind speed along Axios and at Thessaloniki is presented in Fig. 2. The phenomenon appeared at about 0440 UTC at Evzonoi and about 1–1.5 h later at Kymina (located about 55 km south of Evzonoi). In all stations the sustained wind speed exceeded 15 m/s, while it exceeded 10–11 m/s (corresponding to strong winds in the Beaufort scale; ≥6 BF) for about 12, 10, 10, 5, 10 h at Evzonoi, Aksioupoli, Akropotamos, Kymina and Thessaloniki airport, respectively.

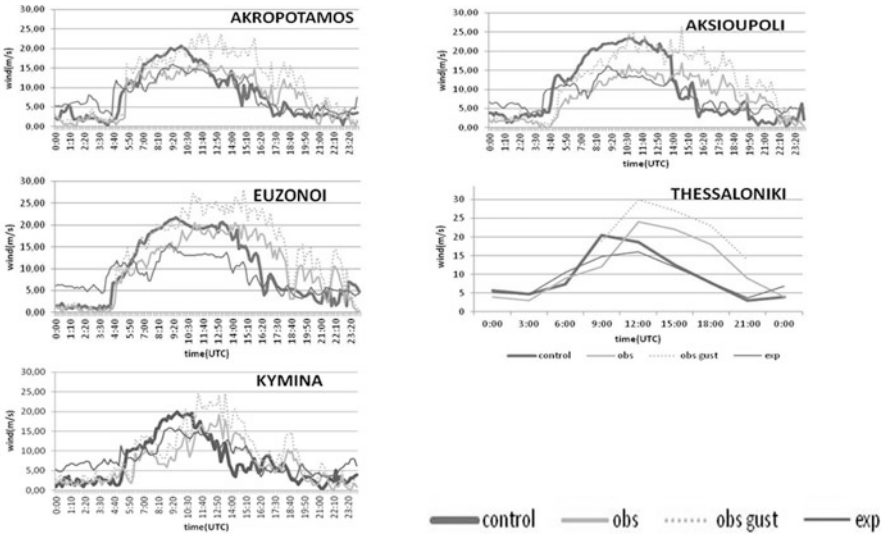

Fig. 2 Sustained wind speed (m/s) and wind gust (m/s) at 10 m above surface at (**a**) Akropotamos, (**b**) Aksioupoli, (**c**) Evzonoi, (**d**) Kymina and (**e**) Thessaloniki airport

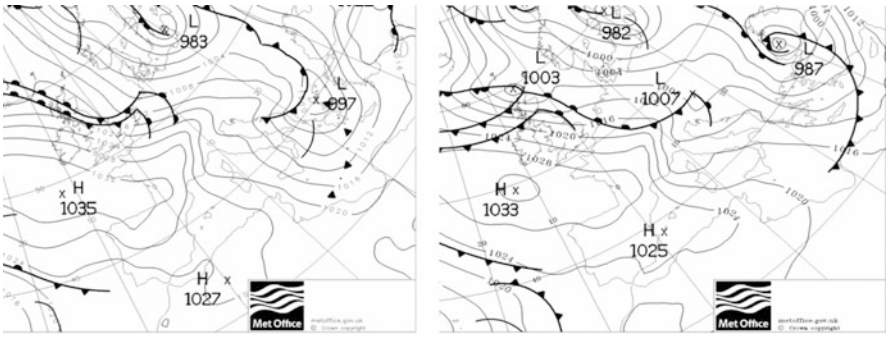

Fig. 3 UKMO mean sea-level pressure analyses (hPa) at (*left*) 06 UTC and (*right*) 18 UTC on 10/11/07

The synoptic conditions associated with this event were characterized by a low pressure system with a minimum pressure of 997 hPa centered over Thermaikos Gulf at 06 UTC on 10/11/07 (during the onset of the event) (Fig. 3 left). During the subsequent hours it moved eastward-northeastward while deepening (987 hPa at 18 UTC 10/11/07; Fig. 3 right). The interaction of the transient depression with a well-organized anticyclone over Western Europe and eastern Atlantic created a strong pressure gradient that triggered and maintained the strong northwesterlies over central Macedonia that is the Vardaris episode. A deepening trough, with geopotential heights of around 5,360 gpm, was located over Greece at 500 hPa at 12 UTC on 10/11/07 (Fig. 4 upper) and was associated with the surface cyclone. Cold air masses with temperatures below 0°C were advected at 850 hPa over the area of interest (Fig. 4 lower) behind the passage of the cold front of the cyclone (Fig. 3).

4 High Resolution Simulations

Three one-way nested domains were utilized (Fig. 5) in the simulations. The spatial resolution of the model was 15 km for D1, 5 km for D2 and 1 km for D3. The 6-hourly ECMWF analyses with a spatial resolution of 0.25° × 0.25° were used as initial and lateral boundary conditions for the domain D1. The model was initialised at 00 UTC on 9 November 2007, which is the day before the event.

Domains D2 and D3 were initialised 6 h later in order to minimize the model spin-up. The sea-surface temperatures were derived from daily NCEP SST files at the very high horizontal resolution of 0.083° × 0.083° and were kept fixed to their initial values throughout the simulations. In the vertical, 39 sigma levels (up to 50 hPa) with increased resolution in the boundary layer were used by all nests. High-resolution land use and topography (30 × 30 arc sec) were used in the control run. The WRF results have been derived from D3 in 10-min intervals.

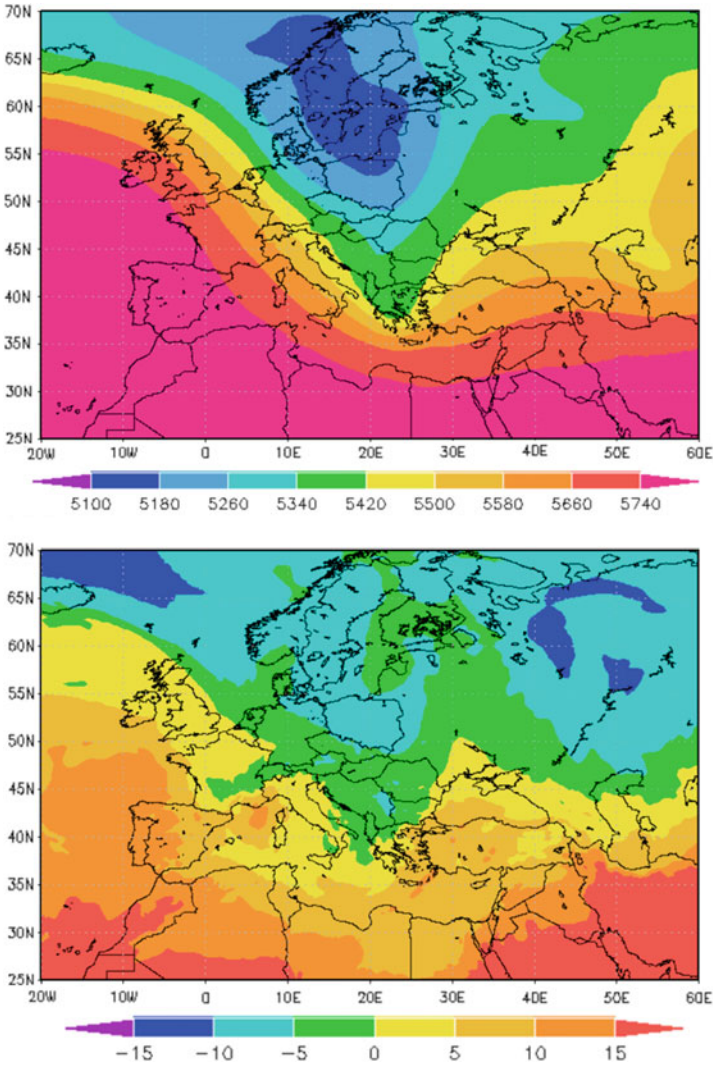

Fig. 4 Synoptic charts of (*upper*) geopotential height (gpm) at 500 hPa and (*lower*) temperature (°C) at 850 hPa, at 10/11/07 12 UTC (ECMWF analyses)

The model simulated the occurrence of the event and its onset in very good agreement with observations (Fig. 2). However, it underestimated its duration (~3 h) and generally overestimated its maximum intensity by about 1–7 m/s (except from Thessaloniki airport where underestimation occurred). The statistical analysis of the 10 m wind speed (at 10 min intervals) at Evzonoi, Axioupoli, Akropotamos and Kymina between 00 UTC 10/11 and 00 UTC 11/11 showed that the BIAS and the Mean Absolute Error ranged from −0.25 to 1.82 m/s and from 2.80 to 5.38 m/s,

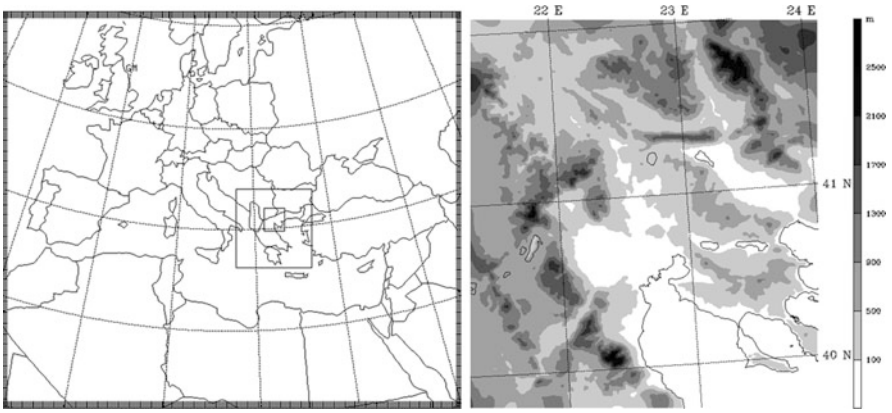

Fig. 5 The three nests used by WRF-ARW in the numerical experiments and the topography of the inner domain (d03)

respectively. Although these values seem to be higher than usual, one must take into account that the average observed 10 m wind speed was much higher than climatology and ranged from 8.0 to 10.2 m/s in the same period.

In the control run the Vardaris episode commenced at 05:00 UTC on 10/11/07 from the Greece-FYROM borders with strong northwesterly winds. In the subsequent hours it gradually affected the whole area of interest and maximum wind speeds up to about 20–24 m/s (not shown) were predicted at about 09 UTC in the areas of Evzonoi and the southern coast of Thermaikos Gulf where the airport is located (in agreement with observations). Therefore, within a few hours the wind conditions in the valley changed from absolute calm to stormy.

The temporal evolution of the vertical structure of v-wind and potential temperature at the locations of Euzonoi and Thessaloniki airport (Fig. 6) shows clearly that the initiation of the episode took place just after the passage of the cold front. The strongest winds, in excess of 30–35 m/s, were predicted between 750 and 900 hPa in the form of a jet streak. It is interesting to note the increase in the depth of the well-mixed layer and the establishment of low-static stability conditions, caused by the strong turbulence, after the episode during night hours.

Finally, the role of the synoptic scale meteorological conditions versus the local topography was investigated through a numerical experiment. The model setup was identical to the one of the control run, but the topography of the inner domain (D3) was removed (set equal to zero). Figure 2 shows that a Vardaris episode took place in the no-topography experiment about 0.5–1 h before the control run. Although the 10 m wind speed reached 15–16 m/s at all stations, the episode was weaker by about 4–7 m/s than in the control run. These results indicate that the occurrence of the episode was determined by the synoptic flow, but its maximum intensity was specified by the local conditions due to channeling in Axios valley.

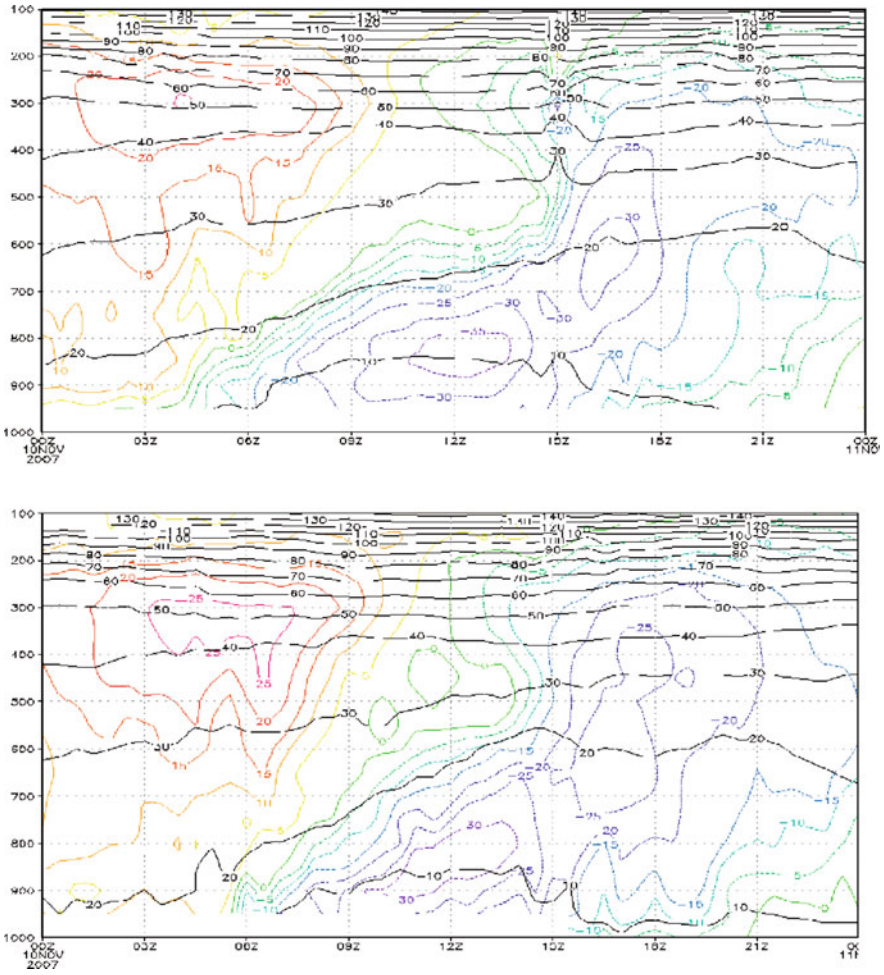

Fig. 6 Hovmoller diagrams of WRF simulated v-wind speed (m/s; coloured contours) and potential temperature (°C; *black* contours) at the locations of: (*upper*) Euzonoi (41.1°N, 22.5°E) and (*lower*) Thessaloniki airport (40.5°, 22.9°) from 00 UTC on 10/11/07 to 00 UTC on 11/11/07

5 Conclusions

The maximum wind speeds of the Vardaris wind episode that occurred on 10 November 2007 were recorded along Axios (20.5 m/s with gusts up to 28.2 m/s) and at the southern coast of Thermaikos Gulf (24 m/s with gusts up to 31.9 m/s).

The episode was associated with the combination of a transient depression over Greece and an anticyclone in Western Europe.

WRF model simulated the strongest winds, in excess of 30–35 m/s, between 750 and 900 hPa in the form of a jet streak.

A numerical experiment showed that the occurrence of the episode was determined by the synoptic scale flow, but its maximum intensity was specified by the local conditions due to channeling in Axios valley.

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References

Angouridakis V, Balafoutis Ch, Maheras P (1981) Les Vents de NW, et "Vardaris" a Thessalonique. Essai statistique. Eaux et Climats. Melanges offerts en homage a ChPEGUE. Grenoble

Maheras P, Flocas A, Karacostas Th (1984) La structure de la basse troposphere pendant le vent Vardaris a Thessalonique. Zbornik 10:241–243

Psarri L (2005) The local wind of Thesaloniki, Vardaris – an approach to the problem with classical methods and the use of artificial neural networks. MSc thesis, AUTH

Wang W, Bruyère C, Duda M, Dudhia J, Gill D, Lin H-C, Michalakes J, Rizvi S, Zhang X (2010) ARW Version 3 modeling system user's guide. NCAR-MMM, p 312