An extreme thunderstorm event over Athens on February 22nd, 2013

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Abstract

The severe thunderstorm event that occurred on the 22nd February 2013 caused many flash floods with disastrous effects over almost the entire Athens basin, as the precipitation recorded by most of the synoptic meteorological stations exceeded their normal monthly climatic values. This study investigates the synoptic and dynamic environment under which the thunderstorms developed, whilst their formation and evolution are examined using radar images, lightning activity observations and satellite imagery. Apart from the favourable large scale atmospheric characteristics, the local geomorphology and the lower tropospheric conditions also contributed to the high precipitation amounts. Finally, a brief synoptic study of similar cases over Attica in the last few years is incorporated, in an effort to identify possible preconditions which may be used to recognise future events.

Introduction

The development of intense rainstorms over the Athens basin often generates extensive flooding, as the high-density infrastructure of this urban area amplifies runoff rates and limits drainage capacity. This is what happened on the 22nd February 2013 over the Athens metropolitan area, where many districts were subject to substantial damage and one fatality was recorded as the consequence of severe thunderstorms, during which the precipitation records of many synoptic meteorological stations exceeded their normal monthly climatic values. Since flash floods events arising from heavy and prolonged rainfall over Greece happen more frequently during autumn (Diakakis 2013), the fact that this case occurred in a different time of the year is an interesting topic for further analysis.

Data and methodology

Synoptic surface and upper air observations, data from the Lightning Detection System, data from Ymittos radar and MSG Satellite WV images were examined, as well as relevant dynamic fields from ECMWF.

The following discussion presents a short description and a synoptic and dynamic consideration of the event. This is followed by a brief statistical study of flash flood events over Attica in order to deduce any similarities in their synoptic situation.

Observed precipitation data

Torrential rain of an intensity not seen in decades flooded the streets of Athens on Friday 22nd February 2013, overturning parked cars and stranding dozens of motorists, including a 28-year-old woman, who died inside her car of what turned out to be a heart attack. More than eight hours of continuous rainfall starting at 01.30UTC caused two rivers to burst their banks and paralyzed public transportation, causing traffic chaos, as tens of thousands of Athenians sought to reach their offices during the morning rush hour.

The thunderstorms developed first in the area around Elefsina before moving eastwards to spread across

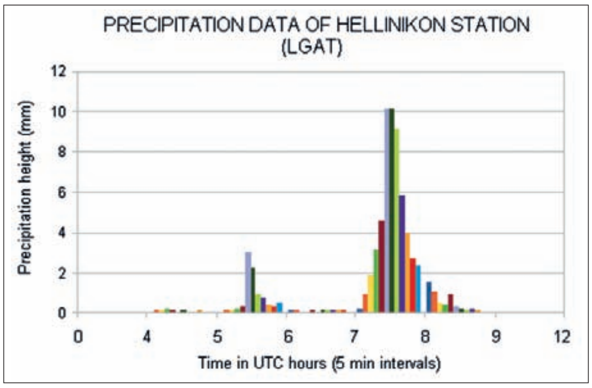


Figure 1: 5-minute precipitation height (LGAT).

most of Athens basin and them towards S. Evia. Their configuration was that of a squall line and presented a multicell structure in the radar images. They produced prolonged hailfall and a remarkable rainfall intensity and high precipitation accumulations were recorded in many meteorological stations. In particular, at Hellinikon station (LGAT) 71 mm of precipitation was recorded that day (of which almost 55 mm was recorded during 1 hour), whereas the normal mean value of February for this Station is 47 mm and the normal February mean value for the entire Athens basin is about 50 mm.

The duration of the rainfall recorded at Hellinikon Station indicates 2 maxima (fig.1), evincing the occurrence of consecutive storms. Pressure dropping and winds veering to northwest (fig.2) signal their beginning, corresponding to the pre-squall low and wake low before and after a thunderstorm outbreak (Johnson 2001). Attica's natural relief and especially the position of the mountains framed the spatial distribution of the precipitation height (fig.3).

Synoptic and dynamic context

The pre-existing circulation (before 22nd February) in the middle troposphere (500 hPa) was driven by an omega block covering the North Atlantic and part of central and northern Europe. An essentially zonal flow with strong westerly winds was present at lower latitudes from the west Mediterranean to the coast of Africa. At 00UTC on the 21st Feb a cut off low over Tunisia generated a general southwesterly flow over

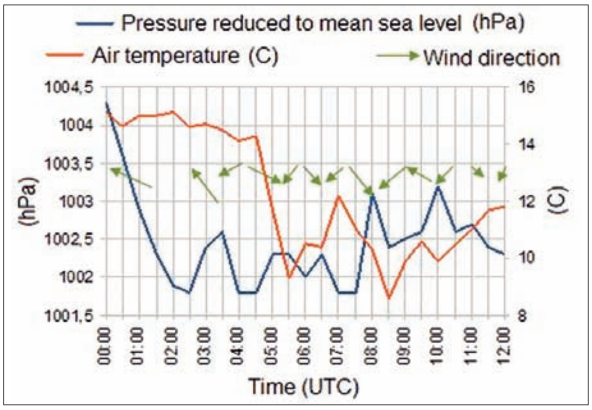


Figure 2: diagrams of Pressure, Temperature and Wind Direction (HNMS automatic station).

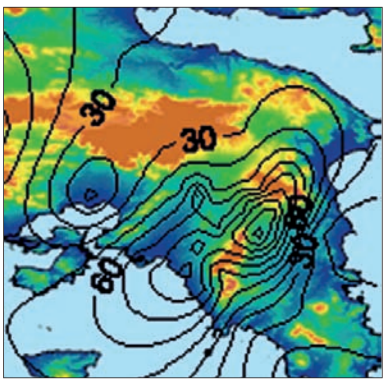


Figure 3: precipitation height contours by 10 mm (data: HNMS, NOA)

Colour: attica orography Maximum height (110 mm) is at Halandri, between Parnitha and Ymittos.

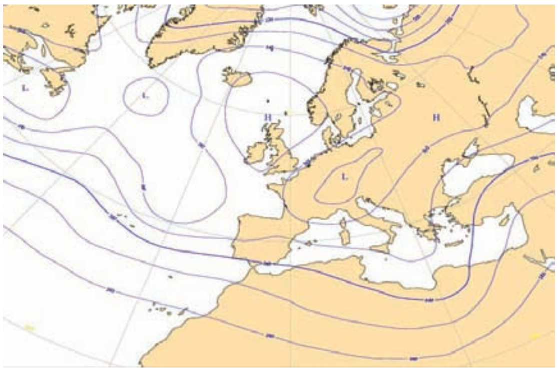


Figure 4: 00 hpa geopotential height.

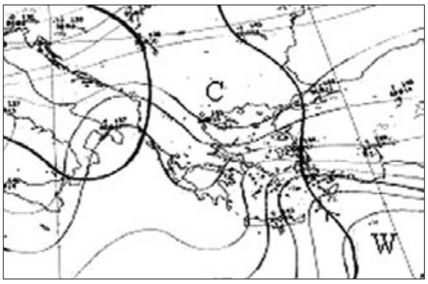


Figure 5: 850 hpa temp. (light contours) geopotential (dark).

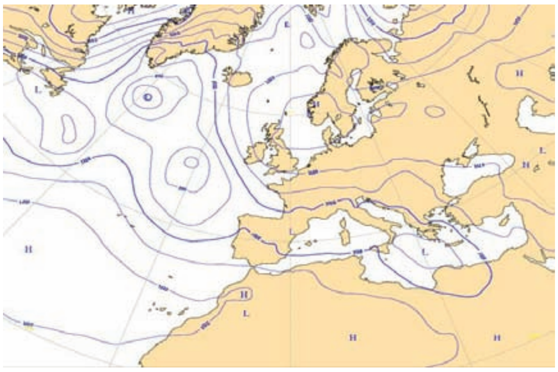


Figure 6: MSL isobaric analysis.

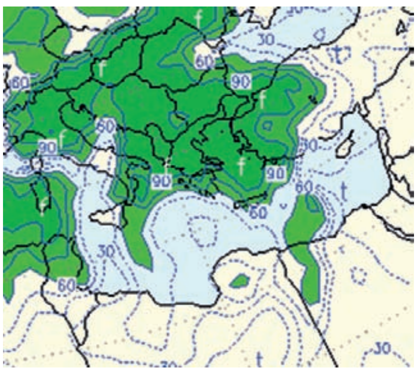


Figure 7: 700 hpa relat. humidity (f ⇢ 95%) (www.wetter3.de).

Greece, transporting along the NW current at 850 hPa not only warm air masses but also large amounts of dust from N. Africa. A surface low of 1006 hPa, originating over the Syrtis Gulf with an east-northeast motion, was located south of Sicily 12 hours later, while its related warm front affected the southwest part of the country and at 00UTC on the 22nd had reached S. Ionio with a center of 998 hpa (fig.6).

At 00UTC on the 22nd two jet streaks in the upper troposphere (300 hPa) were present over the Mediterranean maritime area; the first one located east of Attica, heading from the coast of Libya towards Black Sea with maximum velocity up to 100kts, and the second one heading from Spain towards Tunisia with winds of 50kts. At 500 hPa a cyclonic circulation formed over the eastern Mediterranean (fig.4), the southwesterly flow was retained over Greece and curvature vorticity advection was present (fig. not shown). The area south of Attica up to Crete was covered with air masses of high values of relative humidity (>95%) (fig.7). Furthermore, at 850 hPa (fig.5) warm advection towards Attica was evident while the strong south-southeasterly winds (45 kts at Heraklio station) implies the position of a low level jet east of Attica. The aforementioned advection is verified by the vertical veering of the winds (fig.9), which generated a favourable environment for the formation of a squall line in the middle and lower troposphere (Bluestein and Jain 1985) (due to lack of a tephigram, the analysis of the wind field at the basic isobaric levels is attained from ECMWF). Moreover, the air mass just above Attica region had an equivalent potential temperature greater than 30°C at 925 hPa (fig.8). The northerly winds at low levels above Viotia (fig.9) in relation with the southeasterlies over Attica, mark the position of a convergence zone just above the Athens basin, inducing upward motion and triggering strong convection.

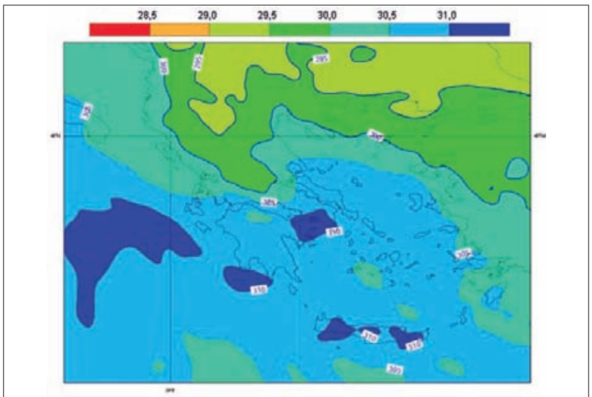
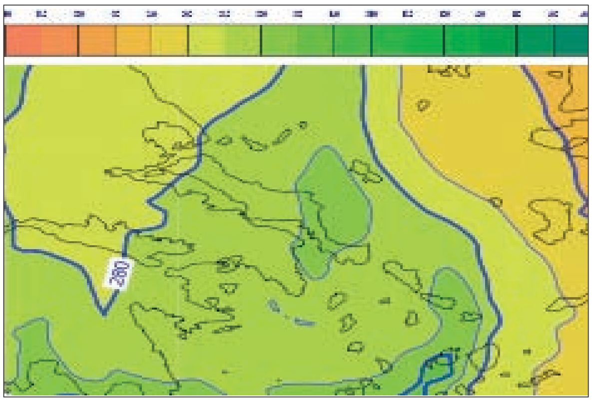
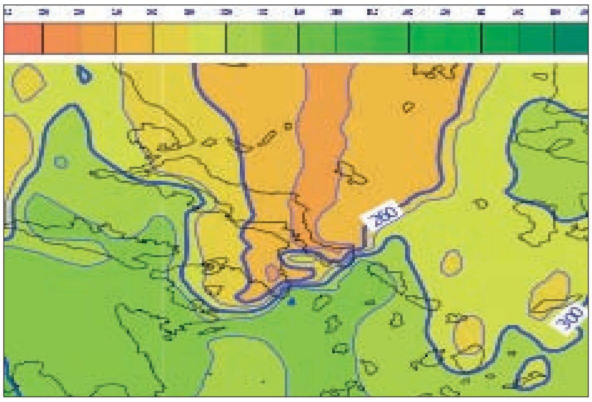


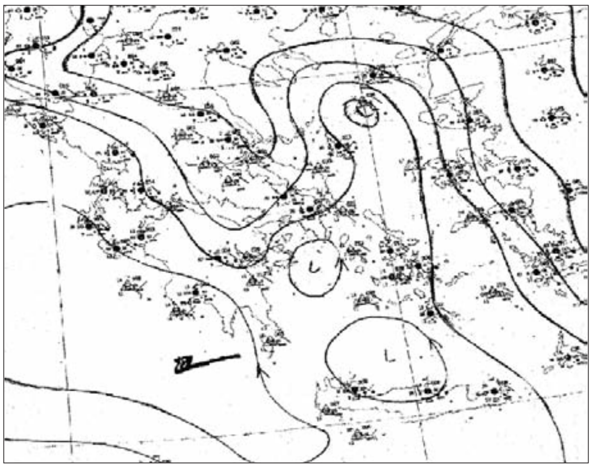
Figure 8: 925 hpa equivalent potential temperature.

(hpa)	wind direction	
	Attica	**Viotia**
300	220	
500	210	
700	180	
850	160	070
925	140	360
1000	130	340

Figure 9: wind direction (vertical profile).







At the top - Figure 10: pressure isobars at 2PVU isentropic surface

In the middle - Figure 11: pressure isobars at 2PVU isentropic surface.

Below - Figure 12: MSL isobaric analysis, Attica.

1 at 22-02-2013/0000 UTC *3 from ECMWF*
2 at 22-02-2013/0600 UTC *4 from HNMS*

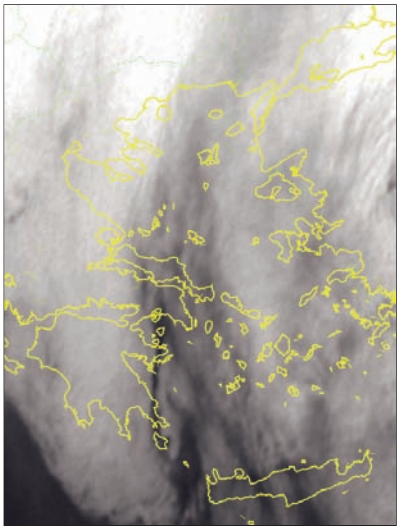


Figure 13: WV 21/22.00 UTC.

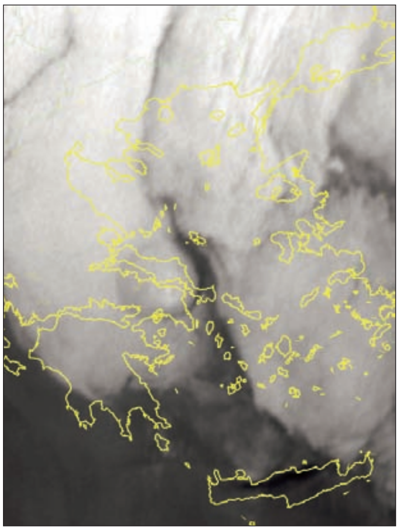


Figure 14: WV 22/02.30 UTC.

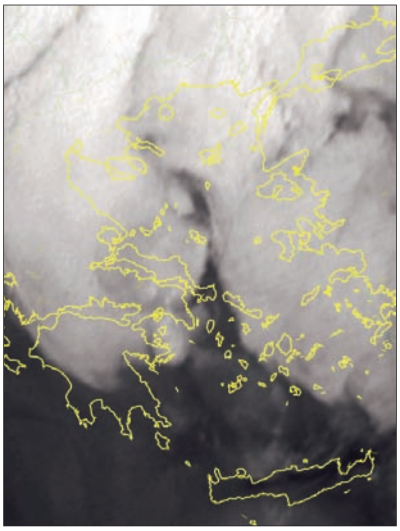


Figure 15: WV 22/03.30 UTC.

(images from MSG at IR 6.2 nm, HNMS)

The pressure analysis at the isentropic surface 2PVU (potential vorticity) depicts the following noteworthy feature: At 00UTC on the 22nd (fig.10) high pressure values covered the area above Attica up to NE Aegean Sea, whereas at 06UTC (fig.11) there was a strong pressure gradient just above Attica region. This baroclinic zone created by a small scale perturbation generated a surface low with center 998 hPa over Saronic Bay (fig.12), which provided a feeding mechanism for consecutive thunderstorm development by sustaining instability. On the other hand, the high pressure values at 00UTC, corresponding to the position of the jet stream, depict a stratospheric air intrusion at lower levels in the troposphere. The advected dry air within this intrusion resulted in the development of an unstable stratification at higher levels in the troposphere and thus an enhancement of the updrafts.

To summarize, the exceptional character of the 22nd February morning precipitation over Attica is justified by the following basic features: the crossing of a small scale perturbation in the middle troposphere, the hot and moist air masses coming from the south overhanging the relatively cold and dry ones lying over northeast Attica, the existence of a strong baroclinic zone due to a dry stratospheric air intrusion at the left side of the jet stream, as well as the enhanced upward motion and the strong low level convergence over the area. The higher sea temperature with regards to its mean value along with the previous dust transfer from Africa might have also contributed to the development of this severe convection outbreak. The storms' feedback and persistence in specific areas of the Athens basin are due to both cyclonic and orographic convergence, in addition to frictional forcing (transition from sea to land), with the result of heavy rain and hail.

The MSG SEVIRI satellite images in the WV channel support the above by depicting a narrow strip of dry air at 00UTC on the 21st (fig.13) heading from Crete up to the Saronic Gulf, extending further north, then turning anticlockwise and enclosing Attica. At 01.30UTC on the 22nd the first thunderstorm nuclei appear and during the next hour (at 02.30UTC, fig.14), the dry air encloses a wet air mass that swirls strongly over Attica until 03.30 UTC (fig.15).

Historical data

Studying the flooding history of the Athens basin during the period from October to March in the last 124 years (Diakakis 2013, Mimikou and Koutsoyannis 1995, meteoclub.gr) there are a total of 64 cases where flooding caused remarkable damage and a considerable number of casualties. Events from 1887 to 1956 are known from their consequences reported in the contemporary press, whereas the precipitation records (both accumulations and rates) for the remaining cases are verified by HNMS's climatological archive (dating back to 1957).

About 70% of the flooding events have happened during the period late autumn until December (fig.16a). More than 30% of all cases have occurred in November, which is the month with the maximum frequency of flash floods (Diakakis 2013) and heavy rainfall events over Greece (Prezerakos *et.al.* 1996, Ziakopoulos *et. al.* 1998).

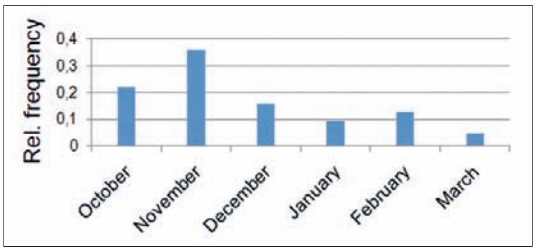
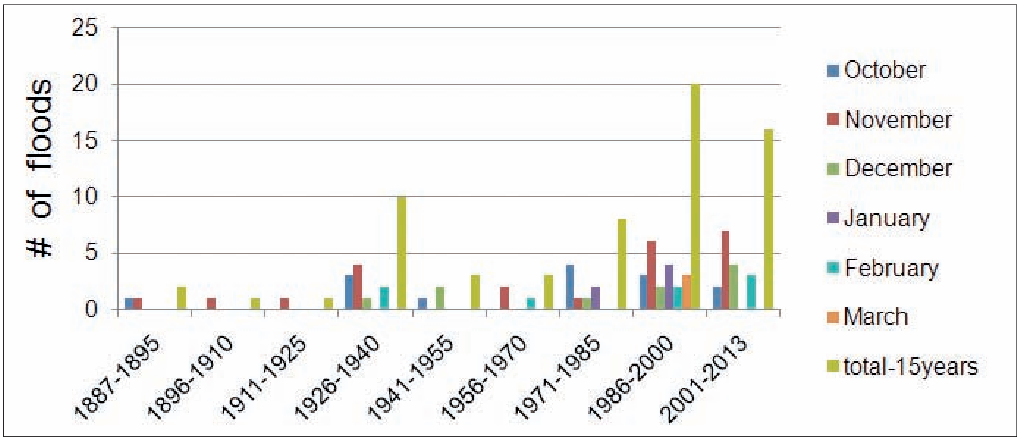


Figure 16: Attica's flash floods events from October to March (1887-2013)
◀ (a) relative frequency per month.
▼ (b) amount of events by a 15-year step.



Analysis of the flash floods inventory (fig.16b) reveals a rising tendency in flood frequency in recent decades (Diakakis 2013). Flooding in Attica is scarce from January to March; during these months there are only 17 cases and it is noteworthy that 14 of them have happened in the last 28 years.

A synoptic consideration of these 17 events signifies that in all cases preexisting warm advection and an airmass with high values of equivalent potential temperature (θw) in the southeastern part of Greece were present. In most cases, anticyclonic circulation had been established above the east Balkans and Attica was subjected to heavy precipitation, originating from warm and moist airmasses ascending the wedge of pre-existing colder ones. In a few cases, a small scale cyclonic circulation existed over Attica. In the case of 22nd Feb 2013 two of these conditions were met (warm advection from southeast and a small scale surface depression).

Conclusions

The weather event on 22nd February 2013 over Attica is a typical synoptic case of a surface depression approaching Greece from the west or southwest that usually produces high rainfall rates over the Athens basin in winter. Its severe intensity is a result of the following essential conditions: a convergence zone above Attica formed an unstable stratification of the troposphere initiating convection, a dry air intrusion enhanced the convection at higher levels of the atmosphere while a small-scale cyclonic circulation sustained the instability near the surface. The thunderstorms that developed under these circumstances produced extremely high precipitation rates including hail, during a process that persisted approximately eight hours, flooding Athens.

Acknowledgments Special thanks to our colleagues A. Papapetrou and E. Mouchasiri for providing us data.

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