Factors Determined Snow Accumulation Over the Greater Athens Area During the Latest Snowfall Events

A. Voudouri and D. Kotta

Abstract Snowfall events accompanied with snow accumulation over the Greater Athens Area (GAA) are not common. The last event in GAA took place between 7th and 9th of March 2011 (case 1). The prevailing synoptic conditions that forced this snowfall, namely the entrainment of arctic air masses, accompanied by moister and warmer air masses from the Aegean following the north-northeasterly flow, were quite similar to those of the previous intense snowfall in GAA between the 16th and 18th of February 2008 (case 2). However the effects as well as the intensity of case 1 were less than expected compared to those recorded in case 2. This study is focused not only to further investigate the mechanisms that may generate snowfall events over GAA, but mainly the key-factors that restrained the snowfall in GAA in case 1 from being intense, affecting also operational forecast. This is made through the intercomparison of both cases using available observations and numerical weather prediction products such as ensemble prediction and deterministic forecasts.

1 Introduction

Snowfall over the Greater Athens Area (GAA) in not common especially in cases where snow is persistent more than 24 h and accumulates, disrupting everyday life. According to Houssos et al. (2007) more than 50% of snow events that occurred in Athens during the period 1958–2001 lasted for one day, while only once did the event last for 4 days. Only one snow event occurred in November while the others occurred during the months December, January, February and March.

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The last snowfall event in GAA was recorded between the 7th and 9th of March 2011 (case 1) and has lasted for more than 30 h over GAA. According to the Hellenic National Meteorological Service (HNMS) data, during this interval it was snowing with small interruptions for more than 33 h over Tatoi, 24 h over Elefsina and 12 h over Spata stations. Although there are no records of significant snow accumulation over the HNMS stations, several observations across GAA reported up to 10 cm snow locally over west and north suburbs.

The synoptic evolution of the barometric systems that cause snowfall in Athens has been studied in several cases. According to Prezerakos and Angouridakis (1984) the specific characteristics of the snowfall in Athens are related to the synoptic evolution of two types, A and B. In type A, a quasi-stationary ridge on 500 hPa is established over the British Isles and north-western Europe, while in type B the ridge is over the Scandinavian countries. In both types arctic air masses are advected over Greece. A strong anticyclone, over western Europe in type A and over eastern Europe in type B, is combined with low surface pressures over eastern Mediterranean inducing a northerly surface flow. Lagouvardos and Kotroni (2002) pointed out the significance of jet streak and vorticity advection in sustaining a snowfall. Houssos et al. (2007) statistically classified snowfall events in five clusters extracting also the average values for specific meteorological characteristics of the first snow day. Louka et al. (2010) identified and analysed three stages on the physical processes that forced the 16th–18th of February 2008 (case 2) intense snowfall over the GAA.

Synoptic conditions prevailing in case 1, were quite similar to those in case 2 however both the intensity and the effects of case 1 were less than expected compared to those recorded in case 2. It should be noted that both cases originally follow type A pattern. This study is focused not only to further investigate the mechanisms that may generate snowfall events over GAA, but mainly the key-factors that restrained the snowfall in GAA in case 1 from being intense, effecting also operational forecast. This is made through the intercomparison of both cases using available observations and numerical weather prediction products.

2 Data and Synoptic Analysis

HNMS operational weather forecasts are mainly based on numerical weather prediction products (NWP) as well as upper air observations and ground-based observations obtained through a wide network of stations all over Greece. ECMWF provides daily deterministic forecasts with horizontal resolution 16 km twice per day, namely the 0000 UTC and 1200 UTC cycles. Although ECMWF provides operational medium and long range weather predictions these data can adequately describe the synoptic conditions that favor snowfall over GAA.

Ground-based observations from meteorological stations over GAA, namely Tatoi, Spata, Helliniko and Elefsina have been used in the present study. The soundings performed over Helliniko Station during case 1, as well as satellite

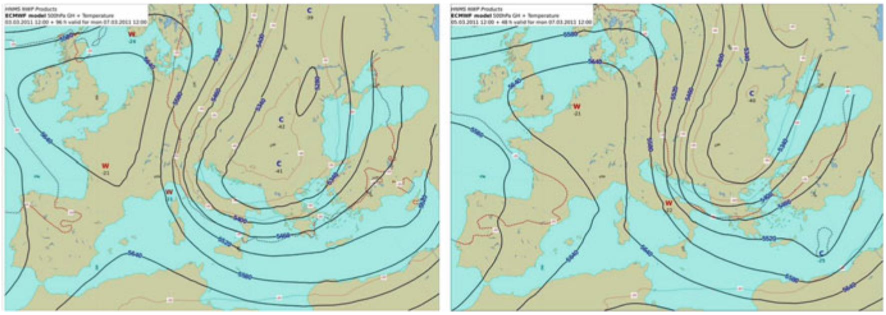

Fig. 1 ECMWF forecast of 500 hPa geopotential height and temperature for 7 March 2011 1200 UTC based on 3 March 2011 (*left panel*) and 5 March 2011 (*right panel*) 1200 UTC cycle

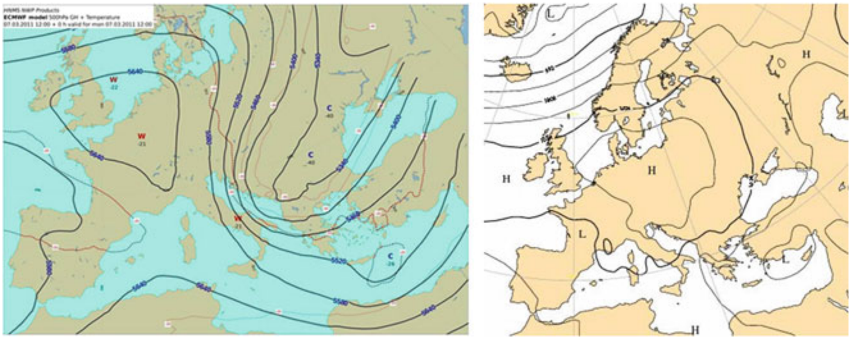

Fig. 2 ECMWF analysis of 500 hPa geopotential height and temperature for 7 March 2011 1200 UTC and MSL for the same time

images during the days of the event were gathered. Deterministic and ensemble forecasts from ECMWF forecasts based on all 0000 UTC and 1200 UTC cycles from 3 March 2011 to 7 March 2011 and analyses during the days of the event were also examined. The prevailing synoptic conditions that forced case 1 snowfall were early identified on the 3 March 2011 1200 UTC based simulation.

Figure 1 illustrates the ECMWF forecasts of 500 hPa geopotential height and temperature for 7 March 2011 1200 UTC (12 h before the beginning of the event) based on the 3 March 2011 and 5 March 2011 1200 UTC simulations, while the 7 March 2011 1200 UTC analyses of 500 hPa geopotential height, temperature and MSL pressure are presented in Fig. 2. A ridge over Western Europe and the British Isles and a low centered over NE Europe associated with an elongated trough and arctic air masses advecting towards Greece were evident. Cold surges were also predicted at 850 hPa with less than 0°C air masses covering Greece. In addition the entrainment of arctic air masses was accompanied by moister and warmer air masses from the Aegean initially following the surface northeasterly flow (Fig. 2). A considerable precipitation amount combined with low 2 m temperature was also early forecasted using the ECMWF ensemble prediction system (EPS). Figure 3 illustrates the Athens EPSgram for total precipitation, 10 m wind speed and 2 m

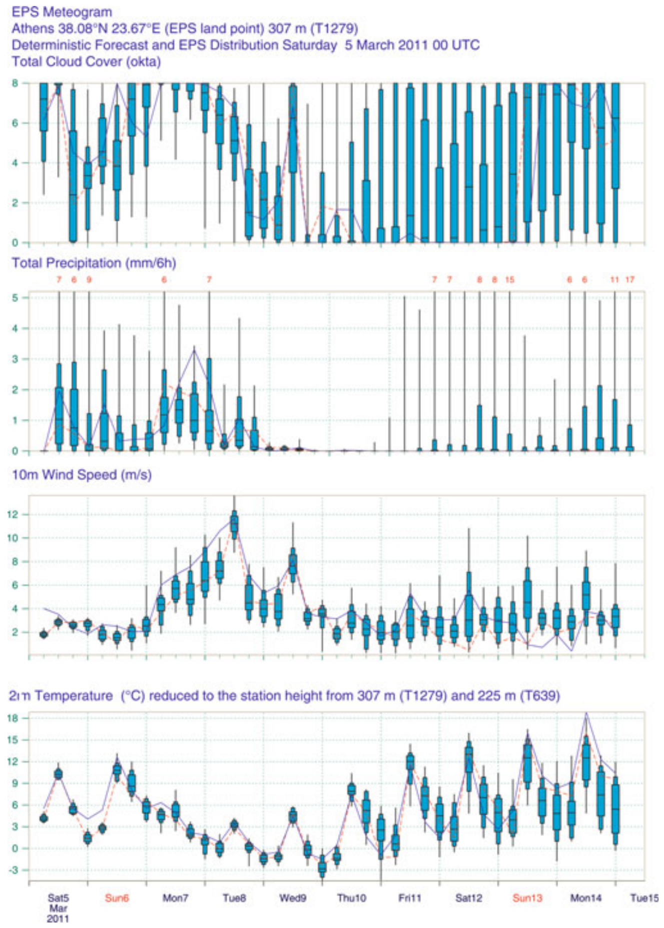

Fig. 3 Athens EPSgram based on the 5 March 2011 0000 UTC-cycle. The *red* line represents the control run (31 km resolution) of the EPS, the *blue* line represents the deterministic model run (16 km resolution) while the bars represent the percentiles of the ensemble prediction. EPS location is 12 km NW of the city centre

temperature respectively based on the 5 March 2011 0000 UTC-cycle for the control run (31 km resolution) of the EPS, the deterministic model run (16 km resolution) and the percentiles of the ensemble prediction. These conditions were quite similar to those of the previous intense snowfall in GAA of case 2 (Louka et al. 2010) indicating a forthcoming intense snowfall event of type A.

3 Discussion

The occurrence of a snowfall over GAA but mainly its intensity is important to be forecasted due to snowfall impacts on everyday life. Therefore an intercomparison of case 1 with the intense snowfall of case 2 is also performed. The average values

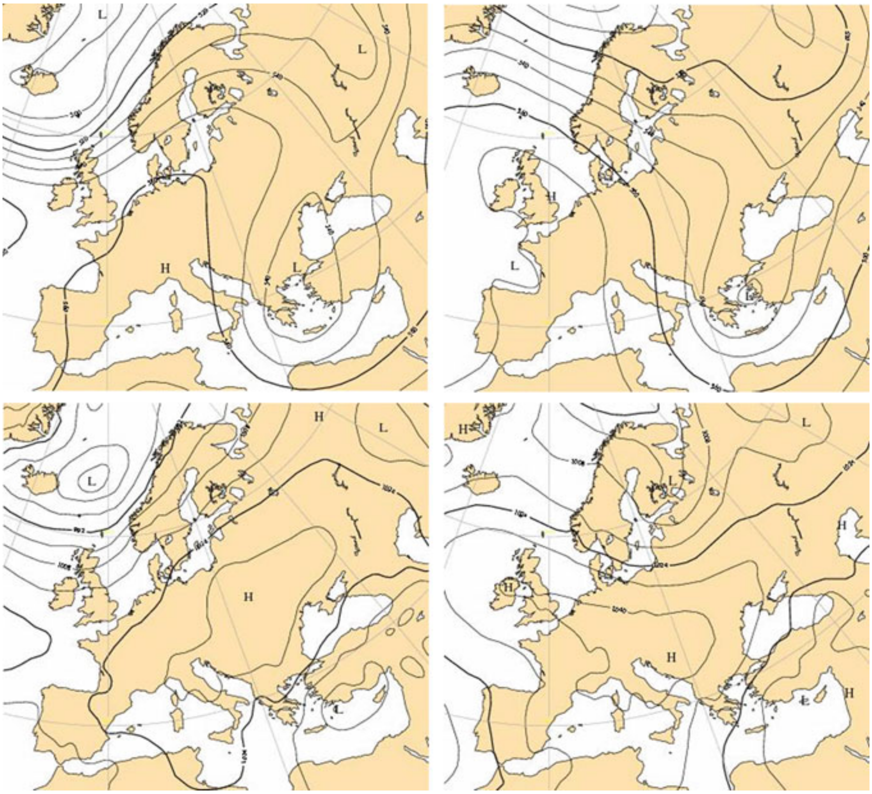

Fig. 4 Analyses of the 500 hPa geopotential height and MSL pressure on 8 March 2011 1200 UTC for case 1 (*left panels*) and for case 2 (*right panels*) on 17 February 2008 1200 UTC

of meteorological characteristic according to Houssos et al. (2007) statistical analysis as well as the synoptic conditions required according to Prezerakos and Angouridakis (1984) were fulfilled in both cases. At both cases initiation cold air masses were advected at 500 hPa with temperatures −33°C over GAA with geopotential heights in case 2 being much lower. Cold air masses intrusion was favoured (−40°C at 500 hPa) in case 2, while in case 1 the 500 hPa ridge moved eastwards and the formation of an extended cut-off low over Greece (Fig. 4) resulted to a weaker cold air masses feedback (−35°C at 500 hPa), suggesting a key-factor. It should be noted that although case 1 started as a type A event, ended as type B. Regarding the 850 hPa temperature, it reached −12°C in case 2, while in case 1 it was not lower than −8°C, with the surface temperature being also higher. Moreover the surface anticyclone in case 1 quickly extended over NE Europe establishing a NNE surface flow (strong NNE surface winds reached up to 50 kt over Central Aegean Sea). This eastwards movement of the surface anticyclone establishing the intense NNE flow in case 1 as shown in Fig. 4 could favour neither the enrichment of the atmosphere with moisture nor the “Aegean Snow effect”.

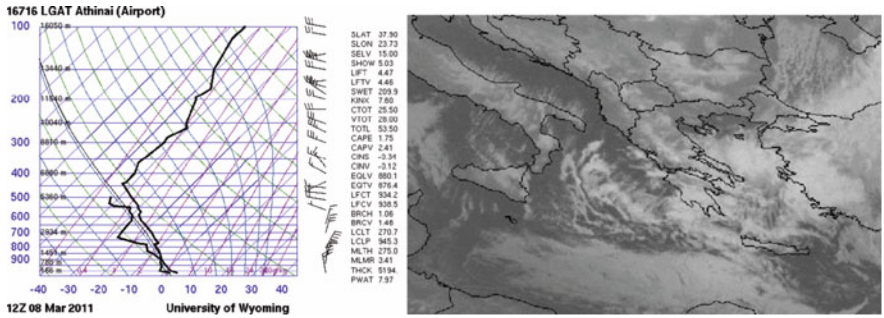

Fig. 5 Sounding at Helliniko station (lon: 23.73, lat: 37.89) on 8 March 2011 at 1200 UTC (*left panel*) (Source: University of Wyoming) and infrared satellite image on 8 March 2011 at 0600 UTC (*right panel*) (Source: Meteosat)

For snowfall events over GAA the "Aegean Snow effect" is important. As Louka et al. (2010) suggested this effect is similar to the "Great Lakes effect" (Niziol 1984) and is the main factor for intense snowfall events as in case 2. The necessary conditions according to Niziol (1984) are an unstable surface layer up to 850 mb with temperature difference $T_{sfc} - T_{850} > 13°C°$, directional wind shear between the planetary boundary layer (PBL) and 700 mb less than 30° with speeds less than 40 kt and significant moisture between the surface and 700 mb. These conditions were partly satisfied in case 1.

The sounding over Elliniko station at southern GAA at 1200 UTC on 8 March 2011 indicated a weak presence of humid air up to 750 mb (relative humidity between 56% and 98%), as well as a strong directional wind shear up to 40° and wind speed more than 40 kt between PBL and 700 mb suggesting key-factors for the intensity of the event (Fig. 5). Thus snow-band formation occurred in a much smaller scale as shown in the infrared satellite image in Fig. 5. However on 9 March 0000 UTC when snow was recorded over Elliniko station (Niziol 1984) necessary conditions were almost satisfied.

4 Conclusions

Operational forecast of the intensity of snowfall events over GAA is not an easy task. During the latest two cases the intensity of snowfall was strongly influenced by the position of the 500 hPa ridge west of Greece and the eastwards movement of the surface anticyclone. Favoring conditions for the 'Aegean snow effect', such as the temperature difference between surface and upper layers, specific wind shear and speed and the existence of significant moisture, should also be satisfied for intense snowfalls over GAA.

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