The case of severe weather in Greece on 16 and 17 July 2017 - Evaluation of the prognostic guidance provided by ECMWF and COSMO numerical weather models

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Abstract Nowadays there is a profound increase in the number of natural disasters attributed to extreme weather events which is significantly impeding progress towards sustainable development. In dealing with a risk of an emergency threatening life or property, a weather-forecast office would use a range of forecast tools to assess the threat and provide the necessary forecasts and warnings. In this paper, using as case study the severe weather occurred in Greece on 16 and 17 July 2017, we discuss the capability of the ECMWF/EPS and the COSMO-LEPS forecasts as also the ECMWF/HRES and COSMO.GR7 deterministic forecasts to provide forecasters with reliable prognostic guidance. To do so we used these models' consecutive runs from Friday 14-7-2017 (two days before the event) until Monday 17-7-2017 (last day of the event). The effectiveness of these forecasts (rainfall spatiotemporal distribution and intensity) was then evaluated with the accumulated precipitation at ground (H-SAF/PR-OBS-5), with MSG products (RGB Airmass, Cloud Top Height) provided by EUMETSAT, with lightning / metar data and also with weather radar products.

1 Introduction

From the climatic point of view, the weather in Greece during the summer period (April-October) is stable, the sky is almost clear and it does not rain except scarce intervals with rapid rains or thunderstorms of small duration mainly in mainland areas (HNMS 2018). But how does a meteorologist manage a significant deviation from what is expected?

Key tools in the work of the forecaster - meteorologist are the numerical weather prediction models. The European Center for Medium-Range Weather Forecasts (ECMWF) has a leading role in developing these models. ECMWF provides Member States with forecasts that National Meteorological Services can use to issue early warnings (ECMWF 2018a). More detailed warnings can be issued by National Meteorological Services, using local observations and additional information from their own short-range forecast models.

National Meteorological Services, using local observations and additional information from their own short-range forecast models, can issue more detailed warnings to Civil Protection and the general public.

The intense phenomena that occurred on 16 and 17 July 2017 (Fig.1) were the reason for assessing the prognostic guidance provided by the forecasting products of the operational numerical models available in Hellenic National Meteorological Service-HNMS (ECMWF and COSMO models).

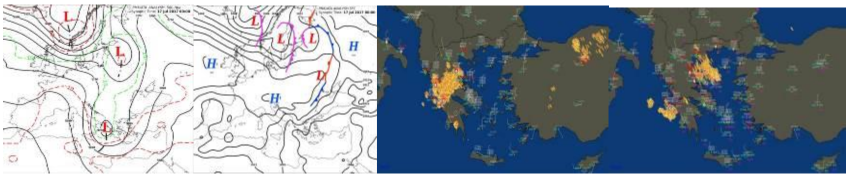

Fig. 1. 500 hPa and surface analysis at 17-7-2017/00 UTC, metar/lightning depiction at 16-7-2017/18 UTC and 17-7-2017/06 UTC.

The precipitation thresholds established by Meteoalarm for Greece (Meteoalarm 2018a) are used to determine the degree of danger of extreme weather events (IPCC 2018). The categorization is described by a four-color code (green, yellow, orange, red).

2 Data and Methodology

The available numerical prediction products at HNMS (ECMWF and COSMO) two days before the event, i.e. from 14 July 2017 to the end of the weather event on 17 July 2017, are assessed against H-SAF satellite precipitation products (PR-OBS-5, HSAF 2018a), with MSG satellite products provided by EUMETSAT, with lightning/metar data, as well as with the HNMS radar network. ECMWF high resolution deterministic forecasts (ECMWF 2018b), Ensemble Prediction System-EPS probabilistic forecasts (Buizza 2006), Extreme Forecast Index-EFI charts (ECMWF 2015), the operational regional model of HNMS COSMO.GR7 (COSMO 2018) and the Limited-area Ensemble Prediction System COSMO-LEPS (Montani et al. 2010) are exploited. The parallel utilization of ensemble prediction systems and deterministic forecasts provides users with early warnings of a potentially severe weather event and, as the phenomenon is approaching, more detailed information, both for the areas to be affected and for the intensity.

By comparing the H-SAF satellite precipitation charts (HSAF 2018b, Fig. 2) with the observed accumulated precipitation of selected HNMS meteorological stations (Table 1), we conclude that the measurements of the ground stations and the estimates of the satellite products are generally in agreement with the exception of Tanagra and Kalamata stations where the observed precipitation is underestimated by HSAF (product restrictions described in HSAF 2108c).

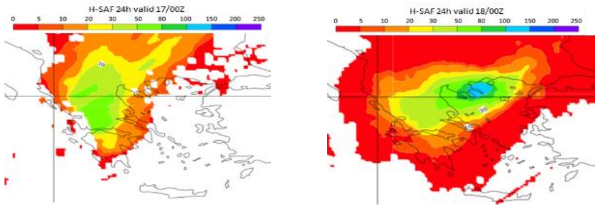

Fig. 2. H-SAF 24h accumulated precipitation of 17-7-2017/00UTC (data in west parts not available) and 18-7-2017/00UTC.

In the present work, the verification is subjective and approximates that of the Weather Forecasting Officers in the Meteorological Centers, who under pressure of time assesses incoming information for decision making.

Table 1. Observed accumulated precipitation at selected HNMS meteorological stations and Meteoalarm Awareness Levels (Meteoalarm 2018b).

	12h Precipitation amount (mm)				24h Precip. amount (mm)			12h Precipitation amount (mm)				24h Precip. amount (mm)	
	16/7/2017		17/7/2017					16/7/2017		17/7/2017			
W.Greece-E.Aegean	06 UTC	18 UTC	06 UTC	18 UTC	16/7 2017	17/7 2017	N.Greece-E.Contin.	06 UTC	18 UTC	06 UTC	18 UTC	16/7 2017	17/7 2017
Araxos	\	33,7	4,6	\	33,7	4,6	Thes/niki	1,4	17,3	17,8	34,0	18,7	51,8
Andravida	\	11,6	37,1	7,6	11,6	44,7	Larissa	1.9	47.6	23.9	26.6	49.5	50.5
Kalamata	\	\	43,0	9,6	\	52,6	Anchialos	\	0,7	38,8	11,8	0,7	50,6
Limnos	\	\	\	62.2	\	62.2	Skyros	\	\	33.4	2.6	\	36.0
							Tanagra	\	\	65,2	2,9	\	68,1
							Elefsina	\	\	3,2	0,3	\	3,5

		GREEN	YELLOW	ORANGE	RED
24h Precip. amount (mm)	W.Greece-E.Aegean	H < 20	20 ≤ H < 60	60 ≤ H < 100	H ≥ 100
	N.Greece-E.Contin.-S.Aegean	H < 15	15 ≤ H < 40	40 ≤ H < 75	H ≥ 75
12h Precip. amount (mm)	W.Greece-E.Aegean	H < 15	15 ≤ H < 50	50 ≤ H < 80	H ≥ 80
	N.Greece-E.Contin.-S.Aegean	H < 10	10 ≤ H < 30	30 ≤ H < 60	H ≥ 60

3 Results

3.1 Evaluation of precipitation products

The forecast precipitation products available on 14 July 2017 are compared with the corresponding satellite precipitation products of 2nd 12h of 16 July 2017 (Fig. 3). Especially in the case of EPS probabilistic charts and EFI products, the results are shown in Table 2.

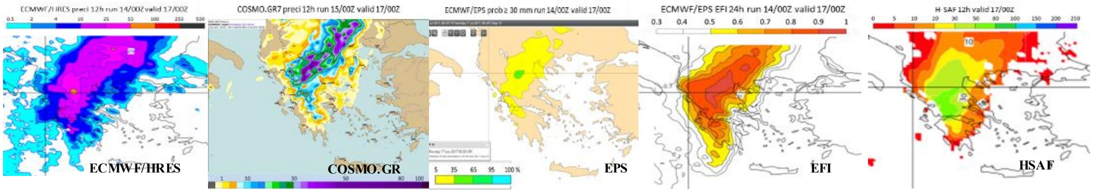

Fig. 3. Available forecast precipitation charts of ECMWF/HRES, COSMO.GR, EPS (>30mm), EFI (24h) on 14-7-2017 and H-SAF products on 16-07-2017 (2nd 12h).

The available forecast precipitation charts on 17 July 2017 are compared with the corresponding 1st 12h satellite products on 17 July 2017 (Fig. 4).

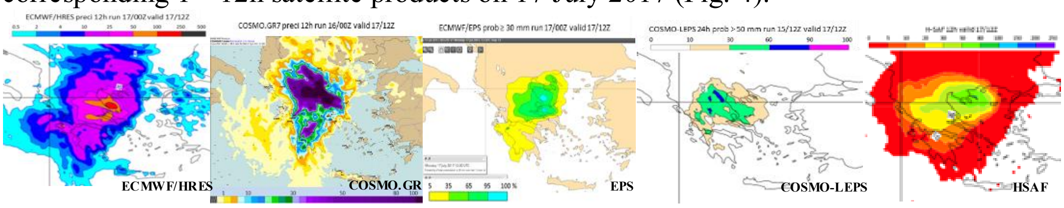

Fig. 4. Available forecast precipitation charts of ECMWF/HRES, COSMO.GR, EPS (>30mm), COSMO-LEPS (24h) on 17-7-2017 και H-SAF on 17-07-2017 (1st 12h).

During this period, the ECMWF (HRES, EPS) forecasts adequately approach the distribution of precipitation in space and generally overestimate it. In the initial run of the COSMO (GR.7, LEPS) models there was a sign occurring an extreme weather event in the area of Halkidiki, which is currently excluded (not shown here). Table 2 applies with the difference that in the red awareness level the phenomena that occurred were local.

Table 2. ECMWF/EPS, EFI, COSMO-LEPS, observed precipitation and Meteoalarm correlation.

Correlation for 16-7-2017/12UTC to 17-7-2017/12UTC				Correlation for 17-7-2017/00UTC to 17-7-2017/12UTC		
Event probability (ECMWF/EPS)	**Extreme Forecast Index**	**Observed precip. amount**	**12h Meteoalarm Awareness Level**	**Event probability (COSMO-LEPS)**	**Observed precip. amount**	**24h Meteoalarm Awareness Level**
5 – 35 % ≥ 30 mm	0.7 – 0.8	20 – 30 mm	YELLOW	10 – 30 % ≥ 50 mm	30 – 50 mm	YELLOW
35 – 65 % ≥ 30 mm	0.8 – 0.9	30 – 50 mm	ORANGE	30 – 60 % ≥ 50 mm	50 – 80 mm	ORANGE
65 – 95 % ≥ 30 mm or 5 – 35 % ≥ 50 mm*	0.9 – 1	50 – 80 mm	RED	60 – 90 % ≥ 50 mm or 10 – 30 % ≥ 100 mm*	80 – 100 mm	RED

*Probabilistic charts for the 50 mm (left) and 100 mm (right) threshold are not shown here.

In the 2nd 12h of July 17 (Fig. 5), it seems rather the failure of models to identify the intense phenomena that occurred in the wider area of Halkidiki. The initial run of the COSMO model is better than the latter. On the contrary, EFI's prognostic guidance is very good for central Greece, as the maps are 24h and take into account the 1st 12h of July 17th.

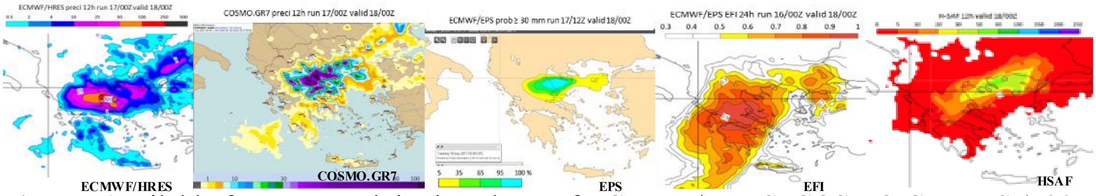

Fig. 5. Available forecast precipitation charts of ECMWF/HRES, COSMO.GR, EPS (>30mm), EFI(24h) on 17-7-2017 and H-SAF products on 17-07-2017 (2nd 12h).

Taking into account the H-SAF products in conjunction with the corresponding ECMWF/EPS charts (not all shown here), Table 3 was produced for runs from 13-7-2017/00UTC to 17-7-2017/00UTC. It is evident that 96 hours earlier (taking reverse from 17-7-2017/00UTC) there was a clear amplified signal focusing on the time of the occurrence of intense phenomena in order for the Meteorologist to issue early warnings.

Table 3. Probability of 12h accumulated precipitation exceeds 30 and 50mm thresholds in consecutive runs of ECMWF/EPS model.

	P(%) > 30mm					P(%) > 50mm				
	Time before the event									
Forecast	96 hr	72hr	48hr	24hr	00hr	96hr	72hr	48hr	24hr	00hr
16/12 UTC	5-35	5-35	35-65	5-35		5-35	5-35	5-35	-	
17/00 UTC	5-35	35-65	35-65	35-65		-	5-35	5-35	35-65	
17/12 UTC	35-65	35-65	65-95	95-100	95-100	5-35	35-65	35-65	65-95	65-95
18/00 UTC	5-35	5-35	35-65	65-95	95-100	5-35	5-35	5-35	35-65	65-95
18/12 UTC	-	-	5-35	-	-	-	-	-	-	-
Based on run	13/00 UTC	14/00 UTC	15/00 UTC	16/00 UTC	17/00 UTC	13/00 UTC	14/00 UTC	15/00 UTC	16/00 UTC	17/00 UTC

3.2 Forecaster Diagnostic Analysis

In the context of nowcasting, the watch of weather evolution in areas of special interest is important issuing emergency warnings by the Forecaster. By comparing the cloud top heights with the maximum radar reflectivity (Fig. 6 left), we conclude that the weather system structure has all the characteristics of a Mesoscale Convective System-MCS (Houze 2004). The RGB-Airmass satellite product (MSG) is selected to display areas with high Potential Vorticity-PV (Kerkmann et al. 2010) to locate convection amplification (Hoskins et al. 1985, Browning and Roberts 1994) in areas where it is not covered by radar and in a time scale smaller than the model step.

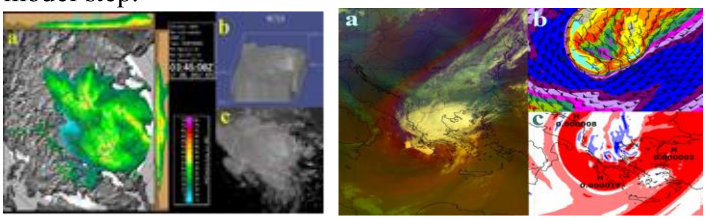

Fig. 6. Left: (a) Max reflectivity (dBz), (b) Cloud Top Height (m), MSG, 17-7-2017/0345 UTC. Right: (a) RGB-Airmass, (b) Winds and (c) PV at 300hPa (ECMWF) at 17-7-2017/06UTC.

4 Conclusions

From the above consideration of the numerical forecast products, the following conclusions are drawn regarding the prognostic guidance of the available weather models at HNMS:

1. Overall, the ability to predict precipitation phenomena that occurred was high, as all available prognostic products had early focus on the event.
2. Regarding the ensemble products, positive prognostic correlations have emerged between the probability of occurrence of an event, EFI products, the observed precipitation and Meteoalarm Awareness Levels (Table 2). This may limit the areas of high impact that the Forecaster needs to focus on in advance. The prognostic guidance of the probability products at least three days earlier (in operational time) as shown in Table 3 was evident.
3. Generally, due to the synoptic situation, intense phenomena were expected in much of Greece, however, all of the precipitation forecasting products predicted the most intense of them in a different place than eventually occurred.
4. The fact that the ECMWF (HRES, EPS) global models had stable forecasts for successive runs shows that the causes of their failure should be sought in small-scale convection phenomena (perceived by the forecaster under the framework of diagnostic analysis) rather than in uncertainties of the initial conditions (ECMWF 2015).

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