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Interrelation of Extreme Climatic Events with Air Masses in Antakya (Hatay, Turkey)

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ABSTRACT: *Due to its mechanism and effects, climatic events have been significant facts for humanbeings all times. In this study,the interrelation between the extreme climatic events in Antakya, air masses and, their routes was examined. Using the data related with extreme climatic events received from Turkish State Meteorological Service (TSMS) and NOAA HYSPLIT model (Hybrid Single-Particle Lagrangian Integrated Trajectory), it was aimed to determine the relation between air masses their routes, and the extreme climatic events in Antakya. The routes of air masses that generate the extreme climatic conditions in 96 hours back trajectory plane at 500, 1500 and 3000m heights, according to HYSPLIT model, are given to enable the comparison in terms of altitude and event. During the analysis carried out for various climatic parameters, it was determined that Siberian and Azore anticyclone played an active role for maximum and minimum temperatures, maximum precipitation, and highest snow thickness and during fastest wind periods. The field of study was influenced by the continental polar air mass during the periods of heavy colds in particular, when Azore dynamic cyclone was dominant the highest pluvial period as a flood disaster has been occurred. Furthermore, it was understood that extreme climatic conditions, in particular maximum precipitation periods resulted in severe material damages in the territory.*

Keywords: *Extreme climatic conditions, Air masses, HYSPLIT model, Antakya.*

I. INTRODUCTION

No doubt that climate, which influences many of the activities of human beings on earth, includes the extreme events in its scope of inspection (Turkes, 2001). Even if it is not right to analyze the extreme climatic events as a clue for climatic change based on current data, it is more important to raise concern over the subject and to take such a possibility into consideration (Turkes, 2001). Extreme air and climatic events have become more conspicuous in recent years for causing great loss of life and property (Changnon et al, 1999; Easterling et al, 1999; Rodrigues et al, 2006) and many scientific researches were conducted over the issue (Vellinga and Versevel, 2000; Alpert et al, 2002; Sensoy et al, 2004; Thomas et al, 2007; Karl and Easterling, 2009; CDC, 2011; Samuels et al, 2011; IPCC, 2012; Sillmann et al, 2013; Herring et al, 2014). Regardless of frequency, substantial effects of any extreme climatic event on natural and human life caused many regional studies to be conducted related with the issue (Zhang et al, 2005).

Either extreme or normal, climatic events in Turkey are influenced by the status of pressure centres and the seasonal changes of air masses coming from different directions (Ardel et al, 1969; Erinc, 1996; Turkes, 2006; Erol, 2014). And various atmospheric oscillations in particular North Atlantic Oscillation (NAO) arising as a result of interrelation oceans and atmosphere are held responsible for such changes (Turkes and Erlat, 2006; Turkes, 2010; Lopez et al, 2011; Karakoc and Tagil 2014; Topuz et al, 2014). Turkey which is included in the zones of influence that vary depending on seasons shows characteristics of a transition zone. Maximum precipitations are one of the primary climatic events that occur in Turkey.

While the annual precipitation in Turkey varies %13,8 and % 35,6 (Turkes, 2006), this rate of change for the Mediterranean Region which includes the study zone is %25 according to Olgen (2010). Kocman (1993), drew attention on the fact that the areas with change coefficient varying from 20% to 25% have an extensive coverage.

This coefficient pattern was found as % 26 for Antakya station which is included in the field of study. Even though there is no direct relation between coefficient of variation and extreme climatic events, it can be claimed that extreme climatic events occur more frequently in the middle latitudes with higher coefficient of variation (Peterson et al, 2012).

Extreme climatic events are influenced by the positions of pressure centres. Siberian thermic high and Monsoon thermic low pressure centres and, Iceland, Aleut dynamic low and Azores and Hawaii dynamic high pressure centres are dominant pressure centres in the Northern Hemisphere where Turkey is also located (Turkes and Erlat, 2003; Krichak and Alpert, 2005; Turkes and Erlat, 2005; Wickens, 2013). Low altitude (for ex: 500 m) dominant air streams are mostly influenced by Siberian anticyclone, polar front cyclones and Mediterranean cyclones (Turkes, 2010). There are many studies containing air masses and climatic characteristics, trends and prediction models that are effective in the Mediterranean and East Mediterranean Regions (Attard et al, 1996; Bethoux et al, 1999; Xoplaki et al, 2003; Karabulut and Cosun 2009; Karabulut, 2012). Alpert et al (2008), While a change in average temperatures for the Mediterranean for 100 years in a range of 1,5 to 4 C˚ is predicted, they stated that a negative trend has been dominant for the precipitations for the last 50 years.

The climatic conditions in the period between October and May which many extreme climatic events occur in Turkey is directed by the frontal systems depended on the air masses that reach to Mediterranean basin from various regions and anticyclone formations (Kocman, 1993; Turkes, 2010). The air mass with a maritime polar (mP) characteristic that heads for the Mediterranean is the air mass that influences Mediterranean most frequently and for the longest period during this period. This air mass may sometimes stay in the Mediterranean basin for as long as it could gain new characteristics and modifies. This air mass also called as “Mediterranean Air Mass (MED)” is marked as unstable due to rise of temperature and increase of humidity content (Kocman, 1993).

In Turkey, west and northwest bound air streams in general are generated by middle latitude cyclones formed throughout the polar front and northeast and east bound streams are generated by Siberian anticyclone (Erinc, 1996; Turkes, 2010; Erol, 2014). Turkes (2010), precipitations observed in East Mediterranean region, which were also included in the field of study, are related more with middle latitude cyclones since Azore anti-cyclone origin maritime Tropical (mT) masses rarely pass to the east and north of West Europe during the winter period.

Climatology studies are among the most common area of the use of spatial technologies. Climatic modelling that accelerated with global climate changes have become more important in our time. HYSPLIT trajectory model that enables monitoring of the trajectories of air masses with different period options both retroactively (backward) and prospectively (Forward) was preferred in this study due to the practicability. This model was used during this study to determine the relation between the extreme climatic events occurring in Antakya and the trajectories of air masses.

II. STUDY AREA AND DATA ANALYSIS

Study area includes Hatay province where is the southernmost of Turkey. It is surrounded by the Mediterranean from the west and, Syria from south and east (Fig. 1). In Antakya, in general, Mediterranean climate type which is dry and hot in summer and warm and rainy in winter, is observed (Korkmaz and Faki, 2009). However, there is a differentiation among the meteorological measurement stations due to topographical properties (Aytac and Semenderoglu, 2014). Amanos Mountains serve such as a barrier between the internal parts and the mild effects of the Mediterranean. While annual temperature averages vary between 15 ^{O}C and 20^{O}C and the annual average of precipitations vary between 562 mm and 1216 mm. Precipitations are concentrated commonly in winter period and, July and August are the months with highest temperature (Korkmaz 2008; Korkmaz, 2009a; Karatas and Korkmaz, 2012).

According to the study conducted by Türkeş and Tatlı (2011) using spectral clustering technique, the study area is located in the Mediterranean rainfall region of Turkey. The precipitations in the region in general are influenced by Mediterranean basin originated from frontal low pressure systems and Azores high pressure systems (Turkeş and Tatli, 2011).

Based on Thornthwaite method, Antakya has semi-humid, mesothermal third degree climatic characteristics with overwhelming lack of water in summer and close to maritime conditions (C2 B'3 s2 b'3), (Korkmaz, 2009b). Antakya has humid climate properties according to De Martonne and Gottman’s annual drought index which is based on the relation between the temperature and precipitation (value: 20.84), and Erinc annual precipitation index value is 48.23that corresponds to humid climate.

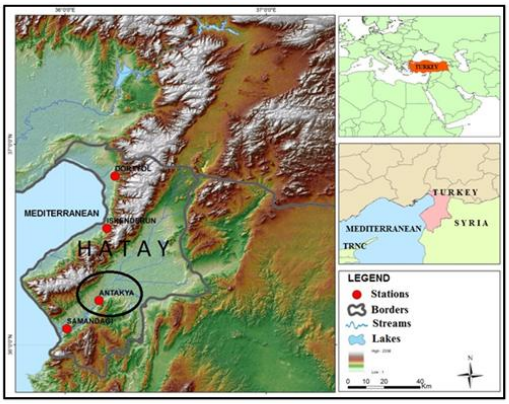


Fig. 1 The location of Hatay

In this study climatic data received from General Directorate of Meteorological Services (1950-2014) were used as a material (Table 1) and HYSPLIT model was used to determine relationship between air masses and extreme climatic events.

Table. 1 Extreme Climatic Events in Antakya (Source: TSMS)

EXTREME EVENT	VALUE	DATE
LOWEST TEMPERATURE	-14.6 C°	15.01.1950
HIGHEST TEMPERATURE	43.9C°	26.08.1962
MAXIMUM WIND	121,7 km/hr	13.01.1968
MAXIMUM SNOW THICKNESS	20 cm	22.01.1972
MAXIMUM PREC □P □TAT □ON	432,1 kg/m^2	09.05.2001
FROST THAT OCCURRED IN TURKEY IN GENERAL		30.03.2014

HYSPLIT model is used in air mass monitoring and aerosol transportation studies as well as air mass trajectories (Heinzherling, 2005; Nyanganyura et al, 2008; Anil et al, 2009; Dreher, 2009; Rozwadowska et al, 2010; Chen et al, 2013; Yuksel, et al, 2013; Diaz et al, 2014; Vijayakumar and Devara, 2014). Some researchers used the HYSPLIT back trajectory modelling to investigate when and where is the heavy material in air (Lammel et al., 2006). Draxler, developer of HYSPLIT model, modelled the distribution of volcano ashes arising out of the volcano eruption in Iceland in April 2010 and the nuclear station event in Japan in 2011 (NOAA, 2014). Simsek et al., (2014) simulated the transportation and storage of 137CS element by using HYSPLIT model after Chernobyl disaster which took place in 1986 in Ukraine and which had adverse effects in many of neighboring countries and tried to determine its effects on Anatolian peninsula. Steinhauser et al (2014) also examined the environmental impacts of Chernobyl and Fukushima nuclear accidents by using HYSPLIT model. Vecchiato et al (2015) examined the formation and movement directions of permanent organic contaminants in the Antarctic by HYSPLIT model.

According to Dreher (2009), HYSPLIT is a model which provides atmospheric trajectories, complex dispersion, and concentration simulations by using Lagrangian mechanic. Heinzerling (2005) claimed that almost all meteorological models are initial products of computational fluid dynamics programs and then it was modified to a more realistic method.

By using HYSPLIT model, spatial synoptic classification can also be performed other than the trajectory studies of air contaminants (Jorba et al, 2004; Hondula et al, 2010). Meteorological aspects of flood and freshets are also evaluated by using this method (Karabulut et al, 2007; Gustafsson et al, 2010; Alexander et al, 2012; Swiatek, 2013). There are also studies examining the relation of temporal changes of precipitations and atmospheric moisture and the trajectories of air masses (Dirican et al, 2003). Furthermore, movement directions of desert dusts can also be examined with this model (Escudero et al, 2006; Francis, 2011; Wang et al, 2011; Escudero et al, 2011). Rozwadowska et al., (2010) states that analysis carried out in altitudes close to earth may provide more real-like results by including the topographical conditions into the modelling process. Therefore, in this study 3 different potential altitude levels as 500, 1500 and 3000 m were used. Reanalysis database of HYSPLIT model was used in the study and back trajectories were analyzed.

Initially, the original location and the route followed before reaching the region of the air mass that causes the extreme climatic conditions were modelled at 500, 1500 and 3000 m levels in 96 hours before the date when the extreme climatic conditions were recorded. And then the meteorograms were produced and trajectories were visualized in Arcmap environment.

III. RESULTS AND DISCUSSION

The routes of the air mass which are active in the periods with lowest and highest temperatures, maximum snow thickness and strongest winds were determined by HYSPLIT model during the study.

3.1 Extreme Precipitation

The route of air mass on May 5th, 2001 when Antakya experienced the greatest amount of precipitation (432 kg/m^2) is given in 3 different altitude levels according to HYSPLIT model. As it can be seen in Figure 2, when such amount of snow is examined at 500 m level, it is understood that this was caused by an air mass moved from the Atlantic Ocean towards the Mediterranean passing through Gibraltar and Alboran Channel.

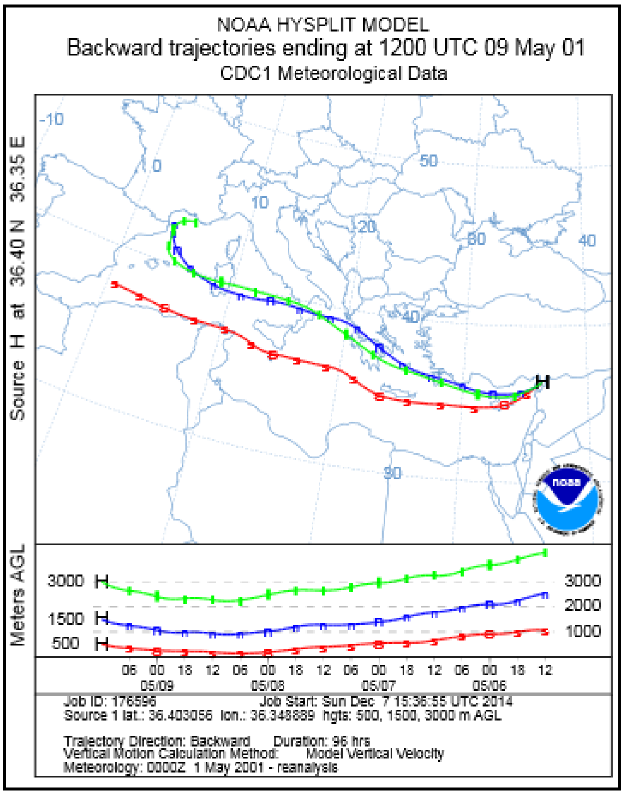


Fig. 2 Trajectories of air masses in the period with maximum precipitation (500, 1500 and 3000 m)

Unstable maritime polar (mPu) air masses and middle latitude and Mediterranean cyclones that are dominant in winter time in the Mediterranean climatic zone, which also includes Antakya are related with the winter precipitations that form the major part of annual precipitations (Turkes, 2010). The air mass where maximum precipitation can be monitored is the MED according to Kocman (1993). According to Turkes (2010), whereas this MED is basically polar originated and named for staying such for a long time in the Mediterranean basin and acquiring new characteristics. The level of instability increases depending on the increasing temperature and humidity content of this air mass due to thermodynamic modification (Turkes, 2010).

The metorogram for the period with maximum precipitation in Antakya is given below according to HYSPLIT model (Figure 3a and 3b).

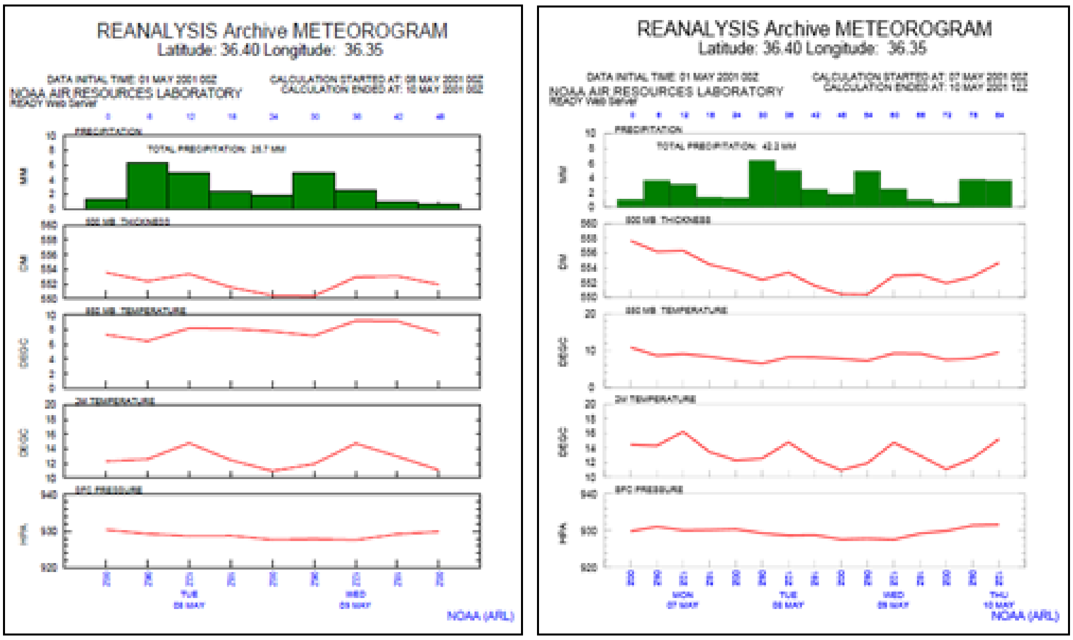


Figure 3a. The meteorogram for the period with maximum precipitation according to HYSPLIT model

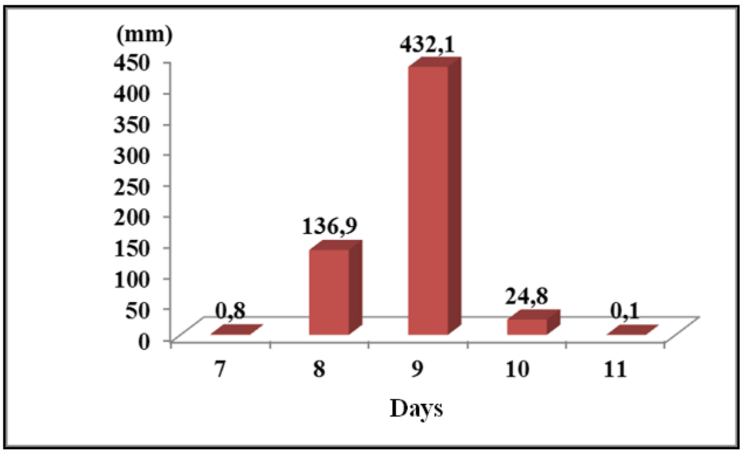


Figure 3b. Precipitation figures related with the period with maximum precipitation (Source: TSMS)

This incident, which was occurred in May 2001, was recorded in the Turkish Parliament (TBMM) minutes as “severely damaged housings 102, workplaces 20; moderately damaged housings 87 and workplaces 32; slightly damaged housings 1951 and work places 75 being a total of 2267 housings and workplaces and the total amount of damage is estimated to be around $21.5 billion” (TBMM, 2001).

3.2 Extreme Wind Speed

One of the extreme climatic events in Antakya was the strong wind on January 1968. The route of air mass on January 13th, 1968 when the wind speed was maximum in Antakya is given according to HYSPLIT model at 500, 1500 and 3000 m levels (Figure 4).

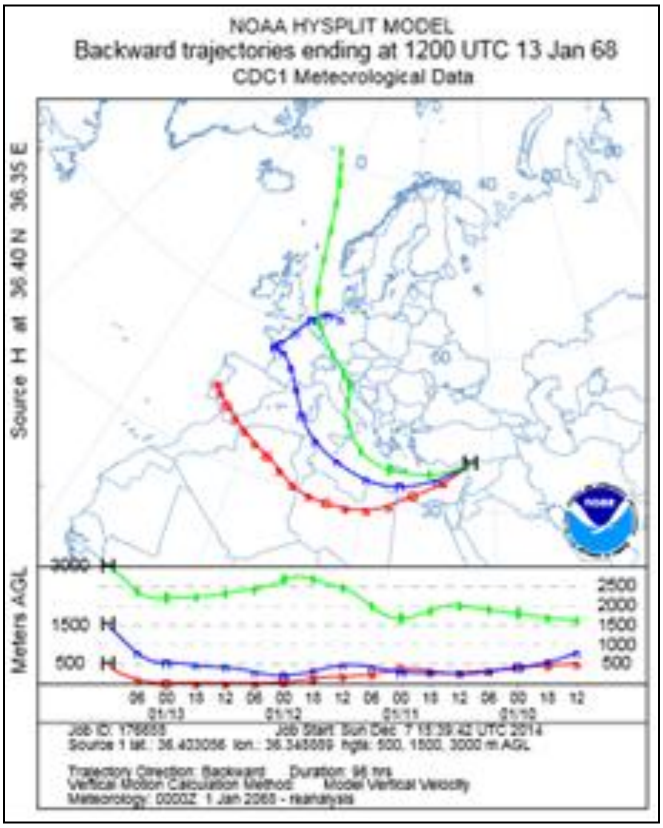


Figure 4. Trajectories of air masses in the period with, according to HYSPLIT model, highest wind speed (500, 1500 and 3000m)

The windmill for the period with maximum wind speed in Antakya is given (Figure 5). Even though the tracks of trajectories differ from modelling made for air streams at different altitudes, there is a movement from west through east and northeast influenced by the westerly winds (Figure 5).

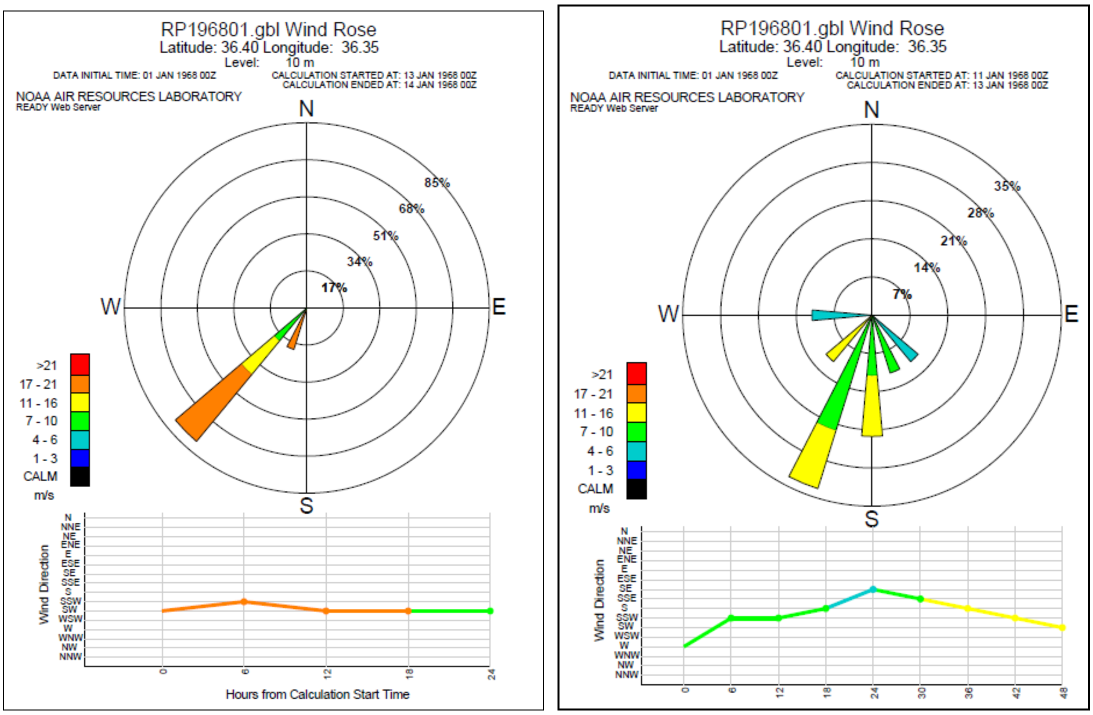


Figure 5. Windmill for the period with maximum wind speed according to HYSPLIT model

3.3 Extreme Snow Thickness

The routes of air mass on January 22, 1972 in Antakya when the snow thickness achieved the highest level (20 cm) are given for air streams at different altitudes (Figure 6). Due to the accuracy the starting time of trajectory is important. When the trajectory analysis is started with wrong start time, the true results cannot be reached. For example if we had started time of the trajectory on 22 may, it was that shown air mass came from mP region. But it came from cP exactly. According to Turkes (2010), cPk air mass, which subject to the thermodynamic modification by increasing the humidity content and temperature while passing over Black Sea, can be marked as cPKu. This cPk air mass brings heavy precipitations on the coasts of the Mediterranean by the influence of orographic lifting upon meeting the Mediterranean basin along the warm front of a Mediterranean cyclone which is bound to northeast starting from East Mediterranean. The precipitations are in the form of a snow in the interior and eastern regions (Turkes, 2010). This snow may be related with a sudden cooling by observing the meteorogram (Figure 7).

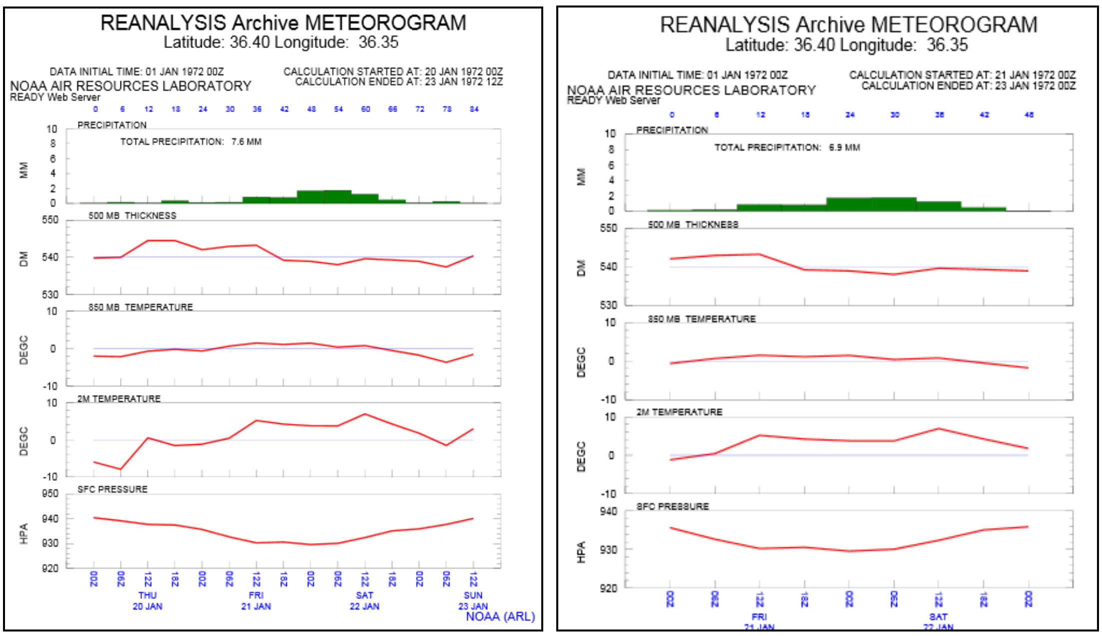


Figure 7. Meteorogram for the period with, according to HYSPLIT model, maximum snow thickness

3.4 Extreme Maximum Temperature

The route of air mass on August 26, 1962 when, the temperature in Antakya, reached to maximum (43,9 ˚C) according to HYSPLIT model, is given below at 500, 1500 and 3000 m altitudes (Figure 8).

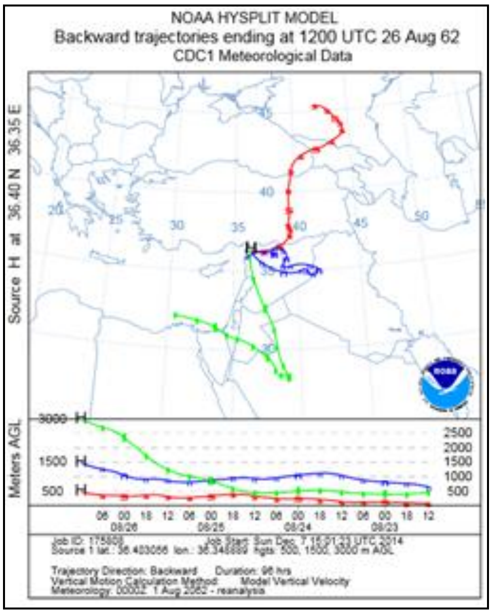


Figure 8. Tracks of trajectories of air masses during the period when, according to HYSPLIT model, maximum temperature was achieved (500, 1500 and 3000 m)

There is a sudden increase of temperature and downfall of pressure as it can be seen in the meteorogram for this period (Figure 9).

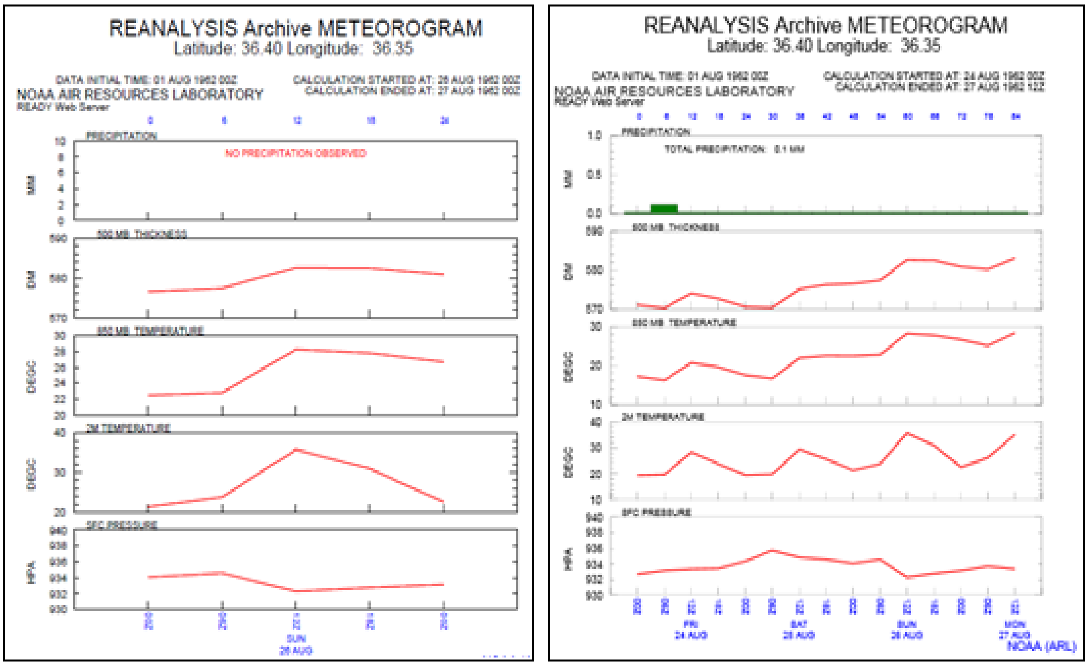


Figure 9. Meteorogram for the period with, according to HYSPLIT model, maximum temperature

3.5 Extreme Minimum Temperature

According to HYSPLIT model the route of air mass, in Antakya, on January 15, 1950 when the temperature was measured as the minimum (-14, 6 ˚C) is given below at 500, 1500 and 3000 m altitudes (Figure 10). It is possible that an air mass with continental polar (cP) characteristic became stable, according to (Turkes 2010), depending on its track over low land covered with snow and resulted in temperature inversions. The situation when temperature falls, pressure increases and thinning of air can be seen in Figure 11.

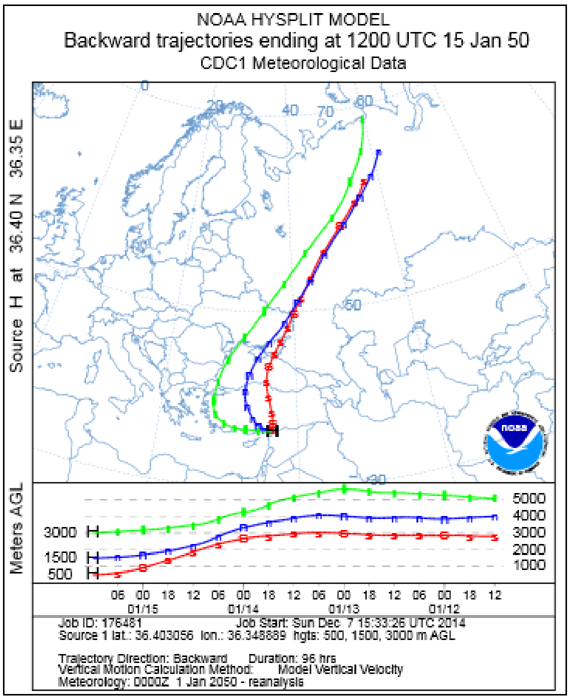


Figure 10. The tracks of trajectories of air masses in the period when, according to HYSPLIT model, the minimum temperature is achieved. (500, 1500 and 3000 m)

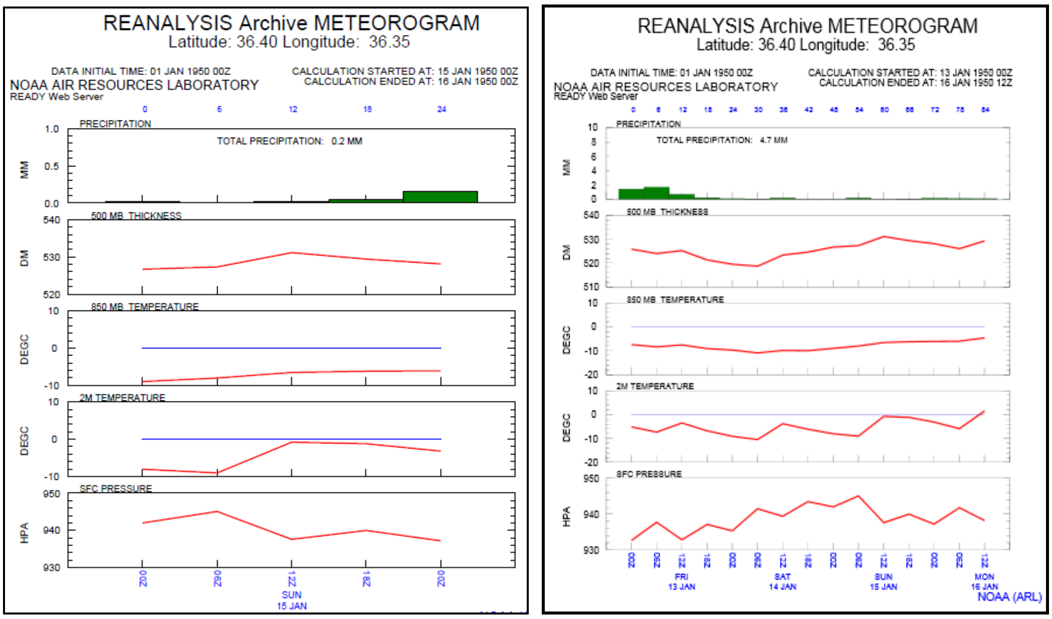


Figure 11. Meteorogram for the period when, according to HYSPLIT model, minimum temperature is achieved

3.6 Frost Events in All of Regions of Turkey in March 2014

Heavy cold, storm and frost events that influenced almost all regions of Turkey on March 29 and 30 (2014) had adverse effects on many sectors, particularly on agriculture. There were no casualties however a major part of Turkey mainly Malatya, Kahramanmaras (particularly Nurhak), Ankara, Mersin (particularly Tarsus) were affected by these adverse climatic conditions and a motion was submitted, by the members of the parliament of the regions, for the material support of the regions that suffered damage pursuant to The Law Nr: 2090 Concerning the Aids to Farmers suffering from Natural Disasters (www2.tbmm.gov.tr). It is important in terms of the measures to be taken and planning, being aware of the incoming route, direction etc., and characteristics of an air mass that caused such an enormous damage. For this purpose by using HYSPLIT trajectory model the air mass incoming route that influenced the entire Turkey was examined (Figure 12). It is understood that an air mass coming from Arctic region in the north is responsible for the climatic events that took place on March 30, 2014 when the air movement at 500 m altitude is taken into consideration.

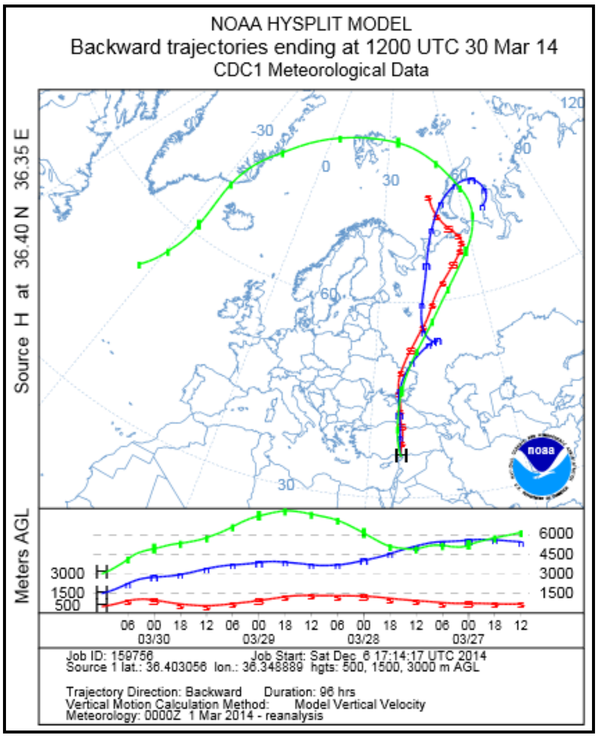


Figure 12. The trajectories of air mass, according to HYSPLIT model, on March 30,2014 (500, 1500 and 3000 m)

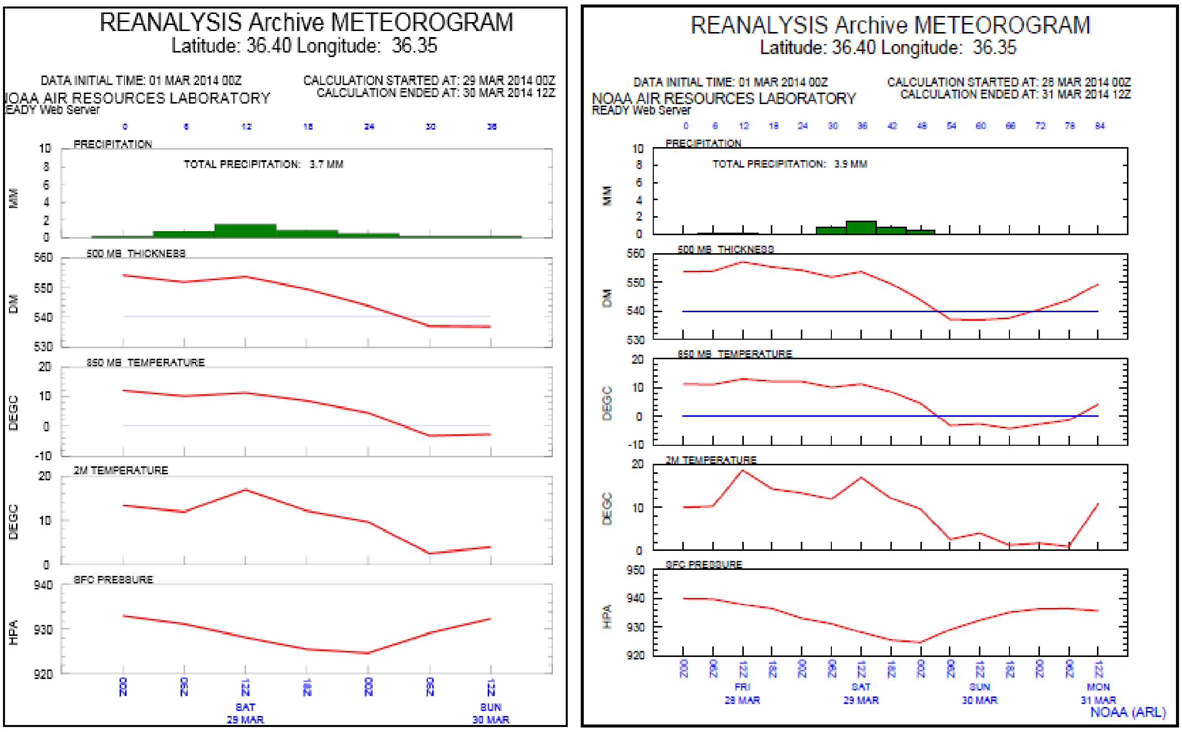


Figure 13. Meteorogram, according to HYSPLIT model, for March 30, 2014

As seen in figure 13, measurement parameters digressed from the normal course on March 30, 2014 and became abnormal. Here, the sudden increase of wind force depending on the pressure gradient difference becomes remarkable.

The diagram for the tempest on March 30, 2014 is given in Figure 14. As it can be noticed the maximum pressure gradient difference took place at the night of March 29, 2014. The wind that mostly blew from southwest (southwester) changed its direction from time to time within the same day.

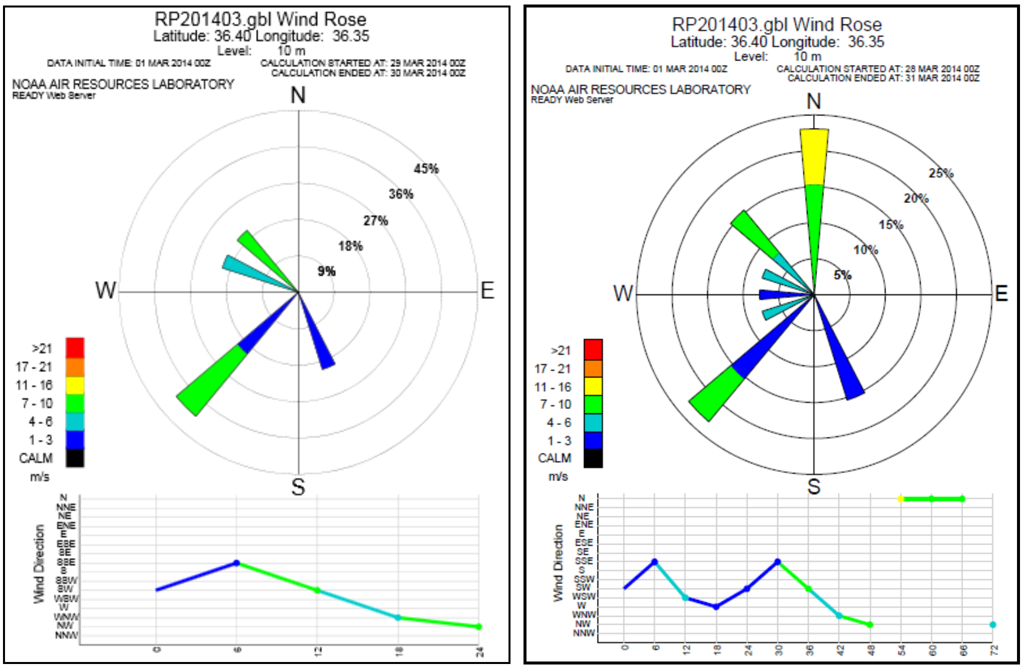


Figure 14. The windmill, according to HYSPLIT model, for March 30, 2014

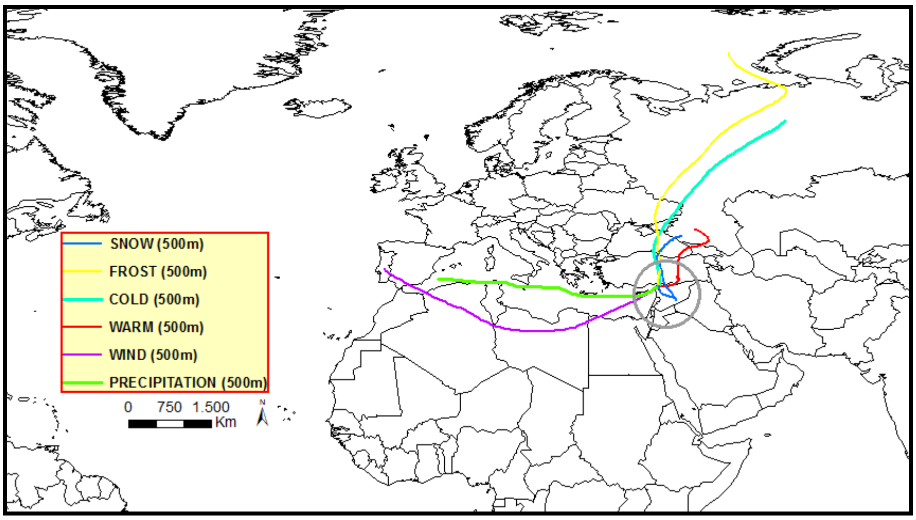
IV. CONCLUSION AND RECOMMENDATIONS

In this study, it was established that the extreme climatic events in Antakya are related with the air masses and their routes. The field of this study influenced by the continental polar air mass during periods with heavy colds in particular, when Iceland dynamic cyclone was dominant the highest pluvial period as a flood disaster has been occurred.

Although we can state the practicability of HYSPLIT model for the analysis of extreme climatic events, the analysis periods in particular for snowfall and meteorological parameters measured cumulatively should be chosen carefully. Otherwise incorrect results may be obtained. If the analysis is conducted at low height levels includes the topographical characteristics into the process (Rozwadowska et al., 2010) and many climatic events occurring close to the surface (Turkes, 2010), it allows more correct results be accomplished. It is also useful to monitor the trajectories of air streams at different altitude. Therefore, 3 different altitude (500, 1500 and 3000 m) were used in the present study.

It is impossible to link extreme climatic events directly to the climatic change based on the current data. However it would be helpful to examine the extreme climatic conditions climatologically taking this possibility into consideration.

The routes of air masses that generate the extreme climatic conditions in 96 hours back trajectory plane at 500, 1500 and 3000 m levels, according to HYSPLIT model, are given in a manner to enable comparison in terms of altitude (m) and event (Figure 15).



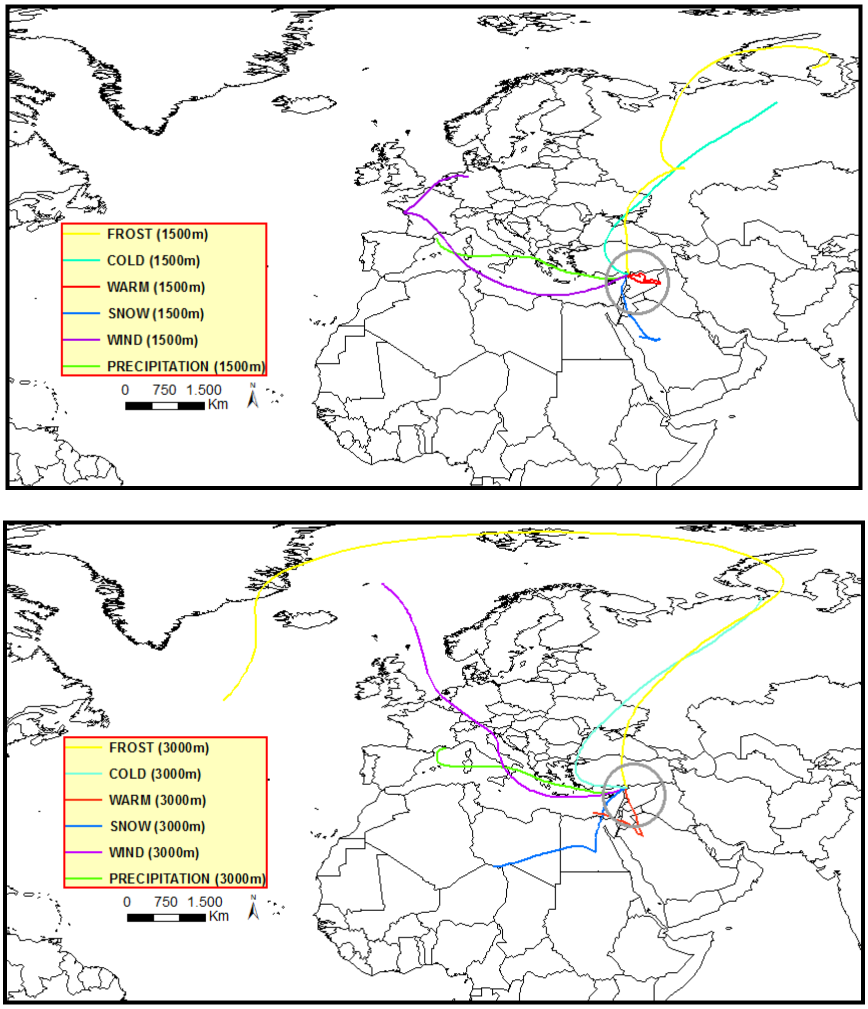


Figure 15. The routes of ait masses during the extreme climatic events in Antakya (500, 1500, 3000 m)

Extreme climatic events spark off significant loss of life and property by leading to sudden natural disasters. Antakya is an important location/geography/region to host such natural disasters for numerous times. We can list the following recommendations to minimize the possible damages and danger that may arise extreme climatic conditions:

a) To improve the accuracy and reliability of data obtained by increasing the number and enhancing the qualities of the stations.
b) To develop a common database to enable / facilitate data exchange of various state organizations.
c) To create a data integration system adding the measurements done by others (measurements done at the universities or on large agricultural lands) to the measurements records of General Directorate of Meteorological Services.
d) To generate a more frequent measurement network to determine the changes taking place in the short term.
e) To assess, the results of the measurements by various statistical methods after checking and recording, together with the routes, effects and frequencies of air masses and to develop a prediction mechanism.

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