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Analysis of Hail Incident for Two Different Provinces in Turkey: A Case Study Using Synoptic Analysis and Numerical Weather Prediction Model (WRF)

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Abstract:
Severe weather events in Turkey leads to the very serious damage in local and meso scales. In this study, the situations in which hail events occurred in different regions and at different times were analyzed. In the scope of the study, first synoptic analyzes were made and available situations and remote sensing data also were evaluated. Following these analyzes, for Antalya and Samsun which is located two different geographical regions, model analysis was performed by using HailCast Module of WRF (Weather Research and Forecasting Model).

Keywords: Hail, Turkey, WRF

1. INTRODUCTION:

Hail phenomenon is a severe weather event that occurs on a local scale and within a short duration. It usually comes along with strong updrafts of organized convection (supercells, multicells, mesoscale convective systems, etc.). Solid ice particles fall into the ground due to high level of kinetic energy. It generally associated with low pressure systems. There are super cooled droplets at high concentrations in the environment where the hail process occured [1; 2]. Hail phenomenon in our country is observed especially in spring and autumn and the most effective regions are the Mediterranean, Central Anatolia and Black Sea regions. In this study, a province (Antalya) from the Mediterranean Region and a province (Samsun) from the Black Sea Region were selected. In general, we can show that the negative impacts of hail are the damage caused by transportation and agriculture. Eccel et al. (2013) found that when there was a hail occured, thunderstorms had occured in the surrounding areas as well. Punge and Kunz (2016) made a spatial analyzes for hail in Southeastern Europe and found that many countries' (including Turkey, Cyprus, Bulgaria, etc.) general climate are strongly influenced by the Mediterranean and the Black Sea [3;1]. Especially, Hail is quite common in Romania [4]. There are many studies in the literature that have analyzed the hail phenomenon in terms of its climatology, detection and forecasting. In this study, we have chosen Selin and Ziegler's (2016) study, conducted a study to forecast hail by using numerical model [5]. In this study, HAILCAST hail growth module has been used in WRF-ARW. This model basicly predicts hail size at the ground level. The purpose of this study is to investigate the meteorological causes affecting two different hail events and to compare the results obtained with the numerical prediction model with real observations. One of the hail incidents occured in Antalya on 18 October 2016. Firstly, heavy rainfall started at 0830 GMT in Alanya region of Antalya. Later on, three thunders on the sea (300 meters from the coast) were seen in this area and had an effect for 5 minutes. At the same time, in Antalya-Incekum, walnut-size (about 4 cm) hail was observed. The cultivated land and citrus gardens were damaged by floods and large hail. The road is full and due to rain there are long car queues. Another hail incident that examined was occured in Samsun on 20 September 2016. Similar to the other hail event that was examined, similar size hail seen in 19 Mayis region of Samsun province. It lasted about 10 minutes. Particularly agricultural fields and hazalnut gardens were greatly damaged.

2. STUDY AREA, DATA AND METHODOLOGY:

One of the main objectives of this study is to determine the synoptic conditions that bring the two different hail incident process to the scene. In this direction, in order to investigate the construction of synoptic scale air systems, the geopotential height (contour) values of surface chart, the relative humidity of 700 mb, many index maps, vertical sounding diagrams (Skew-T Diagrams), precipitation amount maps, IR (infrared) and VIS (visible) satellite products were examined. Secondly, WRF-ARW (Weather Research and Forecasting) numerical weather analysis model with 3.8.1 edition has been used for obtaining the hail precipitation and identifying the reason behind it. Model has been run at its default physics parameter and schemes. Besides, in order to obtain the hail, AFWA diagnostics module has been activated while running the model and module can be seen at the figure 1 below. This module is created by The Air Force Weather Agency (AFWA) and it has many options and advantages. It is possible to obtain information on the following subjects;

- Hail density for both wet and dry regimes
- Temperature dependent ice collection efficiency
- Mass growth by vapor deposition or condensation
- Improved liquid water shedding threshold
- An updraft multiplier that parameterizes advection of the hail embryo across an updraft.

After activating this module, AFWA outputs of WRF is written through the default output file of model. Some useful and important outputs of this module are maximum updraft and downdraft velocity, maximum hail diameter, precipitation type, total simulation snow, ice pellet and freezing rain accumalation, surface based CAPE values and lifted indexes. Since this study has been focus on hail, CAPE and maximum hail diameter (mm) values has been investigated.

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afwa_ptype_tot_melt      = 50,
/
```

Figure.1. a) AFWA diagnostics module activation at the WRF model name list.

Model vertical velocity is employed to estimate how large of a hailstone could be supported by the updraft. Midlevel relative humidity is used to determine if dry air entrainment will lead to size sorting, enabling larger particles to get into the main updraft where hail growth can ocur.

A melting term reduces hail size based on how warm it is near the surface. Updraft helicity is used to estimate the tendency for the storm to be long-duration to allow hail size growth. When looking with details through the maximum hail diameter size and CAPE of AFWA diagnostic option, maximum hail diameter firstly has been chosen for explanation.

The following algorithm is run at each time step to determine hail size potential. Model vertical velocity is employed to estimate how large of a hailstone could be supported by the updraft. Midlevel relative humidity is used to determine if dry air entrainment will lead to size sorting, enabling larger particles to get into the main updraft where hail growth can occur. A melting term reduces hail size based on how warm it is near the surface. Then, updraft helicity is used to estimate the tendency for the storm to be long-duration to allow hail size growth [6].

On the other hand, surface based CAPE parameter of AFWA diagnostic module is the convective available potential energy (CAPE) of a parcel originating from the lowest model level. GFS final reanalysis data (FNL) which has four available data for a day (00, 06, 12, 18Z) has been used as input data for one day and each site.

On the configuration stage of model, two domains have been chosen for both sites and interaction between these domains has been let. Moreover, in order to obtain good results from WRF model has been run at 3 km resolution for the domain at the outside and 1 km resoultion has been used for the inner domain. Two domains of each site can be seen at the below.

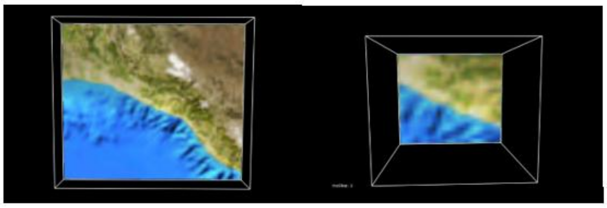

Figure 2: Two domains of Antalya region. Big 3 km resolution (left) and small 1 km (right) resolution domains.

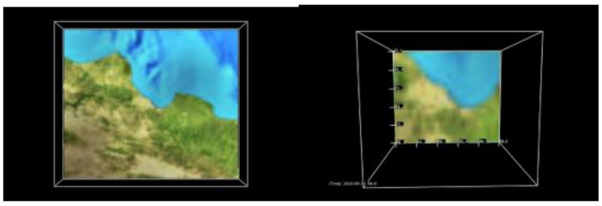

Figure.3.Two domains of Samsun region. Big 3 km resolution (left) and small 1 km (right) resolution domains

3. RESULTS AND DISCUSSION:

At first, the surface chart products have been analzyed with regard to synoptic analysis. For Antalya and Samsun provinces, the products of the days when the hail incidents were observed were obtained from Wetter3 website and then they evaluated (Fig 4)[7].

In the maps given for Antalya in Figure 4a and Figure 4b, two different front systems attract attention. It is observed that Antalya is located in front of the warm front just before the hail incident occured, and at the hours when the event took place and afterwards, the front became stationary.

If warm front shows an unstable condition with a very strong warming, precipitation intensity increases, showers and Thunderstorms can be seen. In selected event, its effect seen as large hail incident. In the other maps given for Samsun in Figure 4c and Figure 4d, no front effect was observed. A low pressure center on the Black Sea and a connected front formation are observed but the effect of the front can not to be seen for Samsun. On the other hand, it is remarkable that Samsun is located on the transition route of 1005 mb isobar.

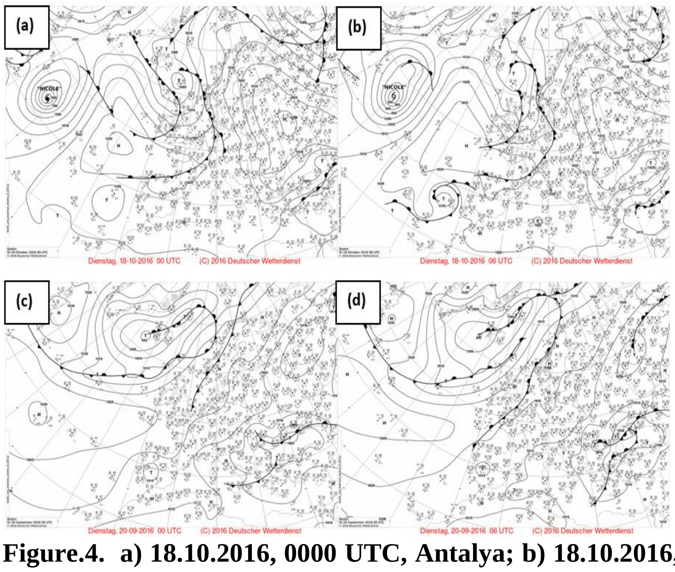

Figure.4. a) 18.10.2016, 0000 UTC, Antalya; b) 18.10.2016, 0600 UTC, Antalya; c) 20.09.2016, 0000 UTC, Samsun; d) 20.09.2016, 0600 UTC, Samsun [7].

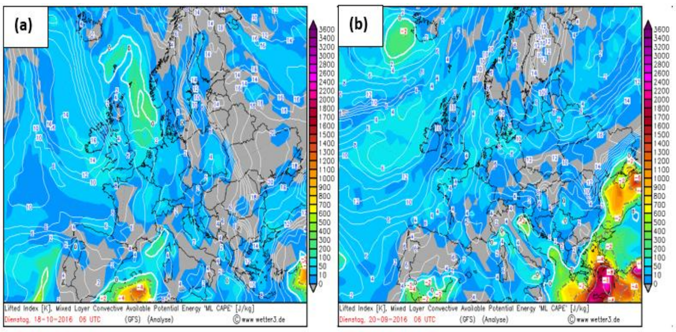

Figure.5. CAPE and LI values a) 18.10.2016, 0000 UTC, Antalya; b) 18.10.2016, 0600 UTC, Antalya [7].

In Figure 6, 700 mb Relative humidity and precipitation amount maps are given. In Figure 6a, Antalya seems to have a humidity value between 60% and 90%. In Figure 6b, the precipitation amount is around 5 mm for Antalya. In Figure 6c, Samsun has a humidity value around 60%. In Figure 6d, its precipitation amount is around 1 mm.

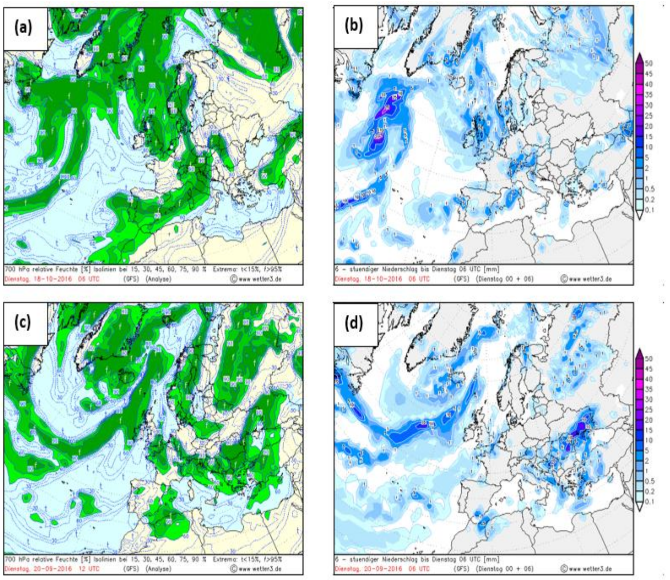

Figure.6. a) 700 mb Relative Humidity Map, Antalya; b) Precipitation Amount, Antalya; c) 700 mb Relative Humidity Map, Samsun; d) Precipitation Amount, Samsun [7].

For the analysis of vertical atmospheric data in the study, Samsun station data for Samsun were analyzed. On the other hand, Isparta station data, which is the nearest station to Antalya were used because measurements were not made in Antalya. Whole data obtained from Wyoming University websites. Some index values of both stations are given in Table 1. According to the Table 1, LI value of Antalya is not represent the real value, because the measurements are belong the near station to Antalya and Figure 5 shows that this value is negative. For Samsun, the value shows the marginal instability. SI value of Antalya is also not represent the actual situation, it should be over the value of 300. On the other hand, for Samsun, the value shows the possible severe situation. TTI value of Antalya shows a possible thunderstorm, likewise, for Samsun, shows an isolated severe thunderstorms. SAI value should be negative in the instability situations, also CAPE value should be over the value of 1000. The values given in the Table are not represent the actual situations. Figure 7 shows the satellite images for Antalya. We can see that there are dense white layers on all the maps around Antalya.

Table.1. a) Index values for Antalya and Samsun

	Lifted Index (LI)	SWEAT Index (SI)	Total Total Index (TTI)	Showalter Index (SAI)	CAPE
Antalya	2.8	94.6	48.0	2.9	0
Samsun	-1.9	269.4	51.4	-0.6	255.2

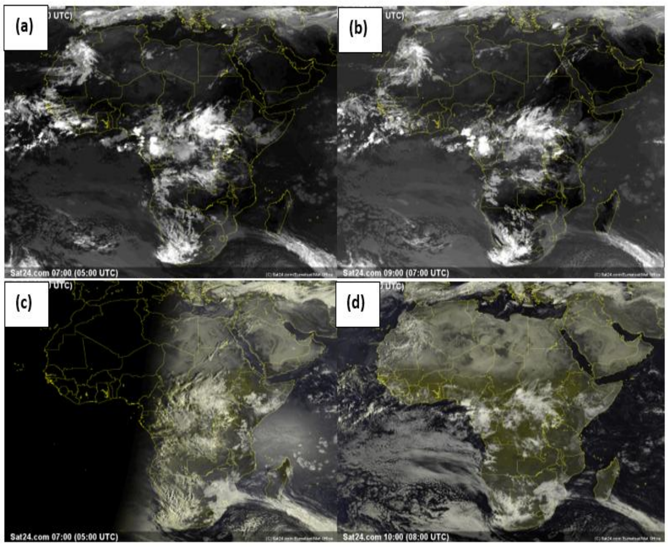

Figure.7. a) IR Satellite Image, 0700 GMT, Antalya; b) IR Satellite Image, 0900 GMT, Antalya; c) VIS Satellite Image, 0700 GMT, Antalya; d) VIS Satellite Image, 1000 GMT, Antalya [8].

In a similar way, Figure 8 shows the satellite images for Samsun. We can also see that there are dense white layers on all the maps around Samsun.

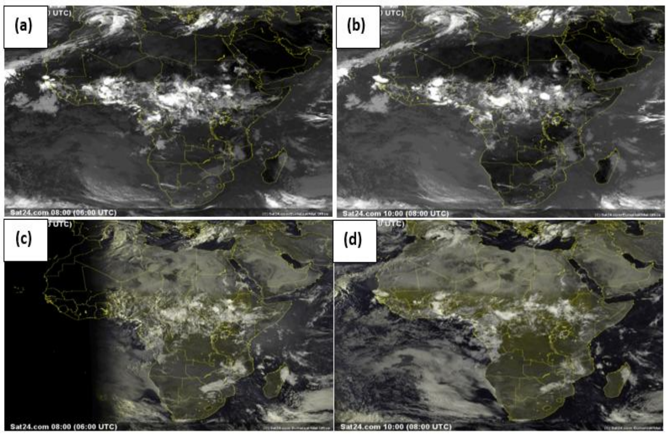

Figure.8. a) IR Satellite Image, 0800 GMT, Samsun; b) IR Satellite Image, 1000 GMT, Samsun; c) VIS Satellite Image, 0800 GMT, Samsun; d) VIS Satellite Image, 1000 GMT, Samsun [8].

On the other hand, model results and analysis of the two region has been investigated seperately in this section. All the model outputs have one hour period and inner domains which have bigger resolution has been used for this study for each region. Firstly, Antalya, İncekum, 18 October 2016 hail incidence has been investigated. According to the model results for Antalya, hail precipitation can be seen. Cloud water mixing ratio (QCLOUD variable of WRF) and maximum hail diameter size has been plotted by the help of Vapor 3D Visualization Tool. Figures can be seen at the below.

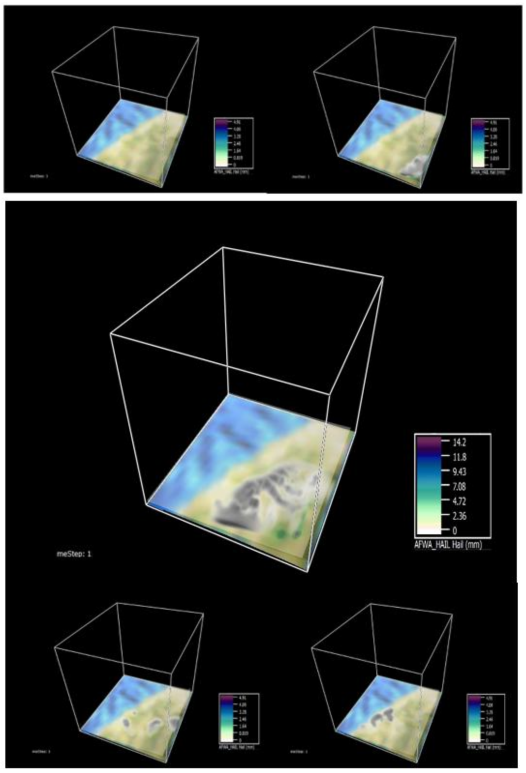

Figure.9. Hail precipitation and cloud fraction over Antalya, İncekum region (07:00, 08:00, 09:00, 10:00, 11:00, 18 October 2016).

Hail precipitation can be seen at the figure 9 which is found at the above. According to the model, especially heavy hail precipitation has occurred at the 09:00 AM. This can be seen at the middle and bigger figure of figure 9. Besides, 14 mm hail incidence has been occurred at that time over Antalya, Incekum region. While investigating hail incidence for Antalya region, CAPE has been also investigated and CAPE values can be seen at the below for the 07:00, 08:00, 09:00, 10:00 and 11:00 AM local times.

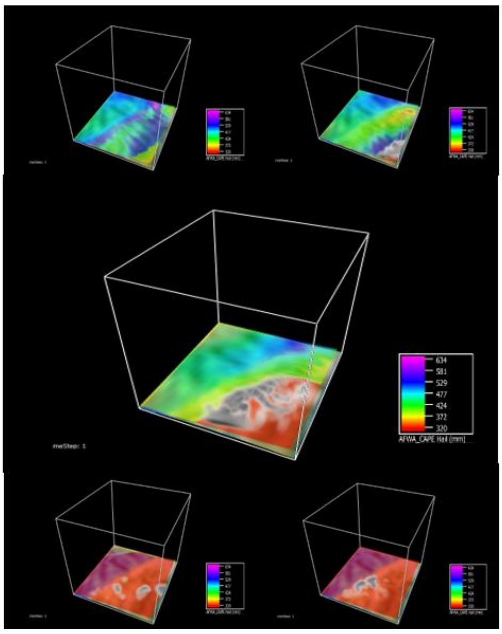

Figure.10. CAPE and cloud formation over Antalya, İncekum region (07:00, 08:00, 09:00, 10:00, 11:00, 18 October 2016).

According to the figure 10, it is very important to say that CAPE values have been beginning to decrease and are going towards to zero with hail incidence and intension of clouds. Therefore, it can be said that, hail incidence is not mainly because of the convective availability of air. This incidence may be due to the synoptic scale events like fronts. Hence, it should be investigated in bigger spatial scales. On the other hand, second hail incidence has been occured over Samsun, 19 Mayıs Mahallesi region at 20 September 2016. According to the model outputs, there has been many high level clouds for this date over Samsun. However, model couldn't succeed to produce hail incidence for this region. The reasons behind it can be probably the spatial and temporal resolution of this incidence. Hail probably has occured in this region for higher resolutions than the 1 km which is the resolution that has been chosen for our WRF model run. Moreover, hail has occured for a very short time when we compare with the Antalya, Incekum hail incidence. Nevertheless, CAPE and cloud fraction for the hail incidence time has been shown at the below.

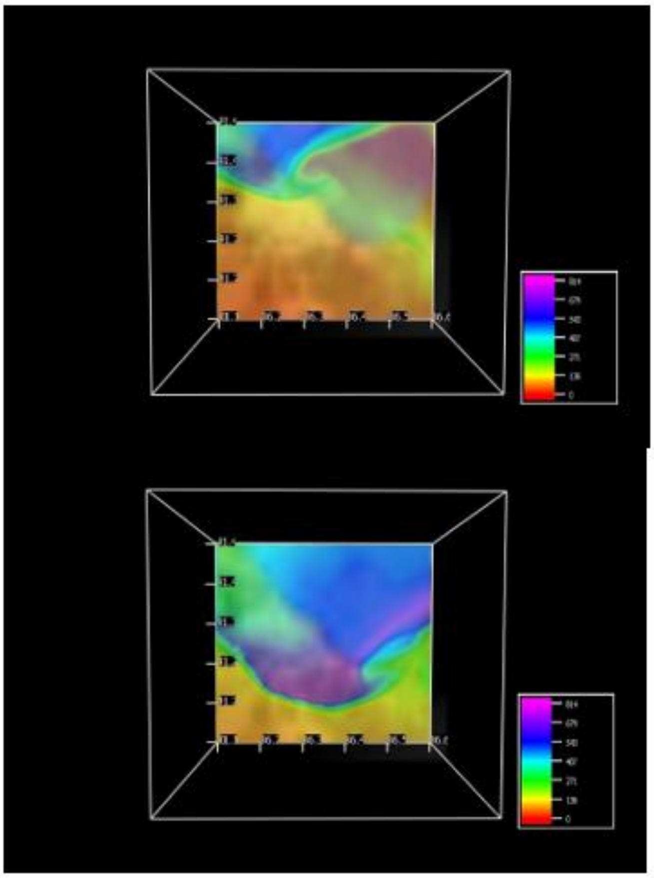

Figure.11. CAPE and cloud water mixing ratio over Samsun at 08:00 and 09:00 AM, 20 September 2016.

According to the figure 11, it is very obvious to say that CAPE values has a tendency to rise while going through the 09:00 AM. On the other hand, blur at the images is caused by the high level cloud density over this region.

4. CONCLUSIONS

Two hail incidents in two different cities have affected the life negatively and caused material damage. From a synoptic point of view, it can be seen that two different phenomena are dominated by different systems. In Antalya, frontal system (warm front) has been affected the instability and caused hail incident. In Samsun, it is more local system that happened before noon. The index values and the relative humidity quantities in the investigations do not show the exact severe weather phenomenon. However, the moments of the experience of the hail can be determined from the satellite images. Besides, in order to identify and observe hail incidents accurately by using numerical weather prediction models, temporal and spatial resolution should've been chosen very high.

5. REFERENCES:

[1]. Puskeiler, M., Kunz, M., Schmidberger, M., (2016). Hail Statistics for Germany Derived from Single-polarization Radar Data. *Atmospheric Research*, 178(179), 459-470.

[2]. Jin, H.G., Lee, H., Lkhamjav, J., Baik, J.J., (2017). A Hail Climatology in South Korea. Atmospheric Research, 188, 90-99.

[3]. Eccel, E., Cau, P, Riemann-Campe, K, Biasioli, F., (2012). Quantitative Hail Monitoring in an Alpine Area: 35-year Climatology and Links with Atmospheric Variables. *Intern ational Journal of Climatology*, 32(4), 503-517.

[4]. Machidon, O-M., (2007). The Necessity and Opportunity of the Protection from Hailstorms in the Departments of Vrancea and Galati. *Present Environ. Sustain. Dev*. 1(23).

[5]. Selin, R.D.A., Ziegler, C.L., (2016). Forecasting Hail Using a One-Dimensional Hail Growth Model within WRF. *Monthly Weather Review*.

[6]. Creighton, Glenn, et al., (2014). AFWA Diagnostics in WRF

[7]. http://www1.wetter3.de/

[8]. http://en.sat24.com/en