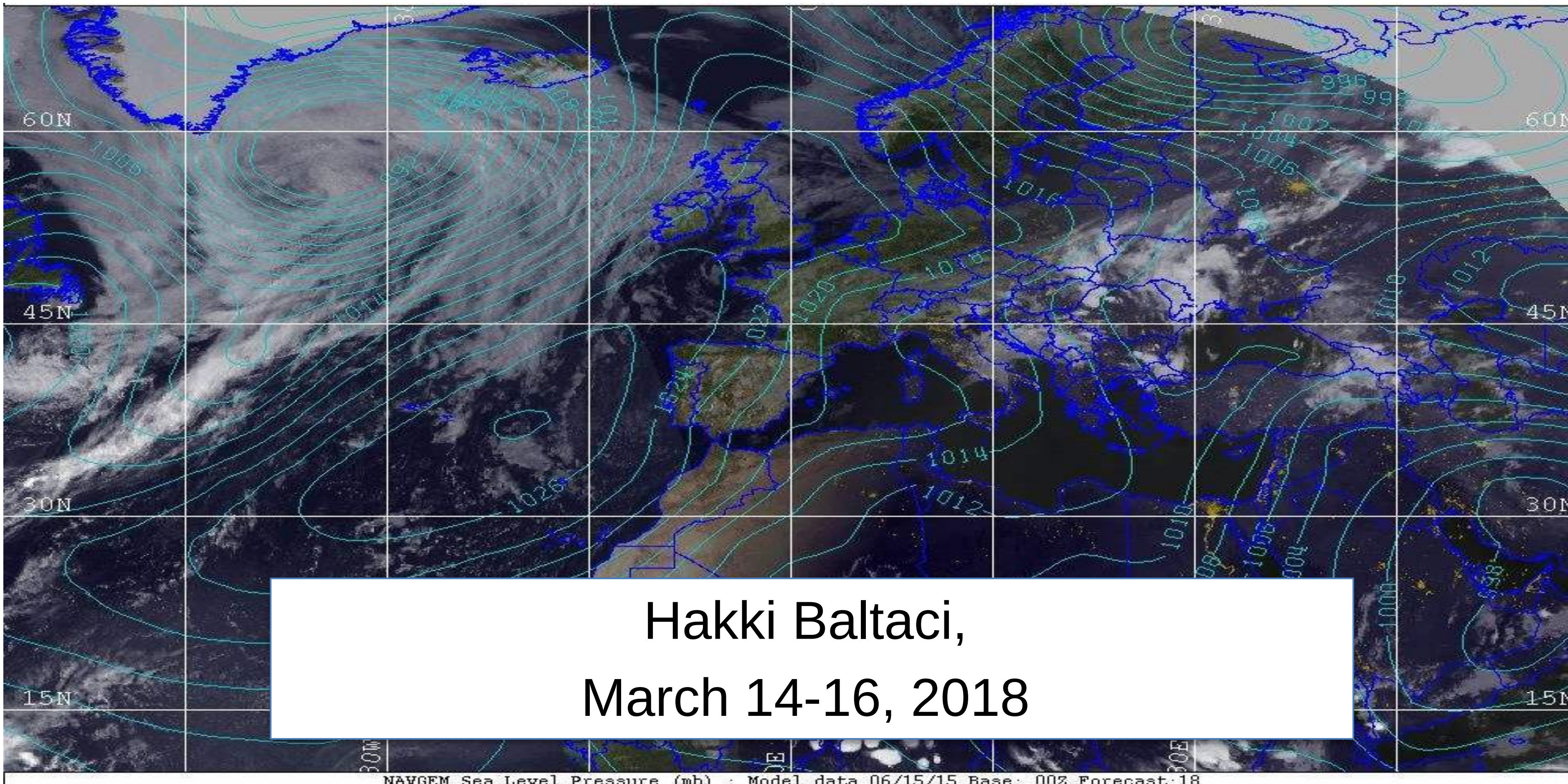
The Climatology, precipitation types and atmospheric conditions of extreme precipitation events in western Turkey



Hakki Baltaci,
March 14-16, 2018

Outline

- Introduction "Motivation and Purpose"

- Part-1: *The climatology, precipitation types and atmospheric conditions of extreme precipitation events in western Turkey*

Literature Review

The occurrence of extreme precipitation events (EPEs) and background physical mechanisms triggering these episodes become a fundamental issue in the last decade due to its great impacts on agriculture, health, energy, and tourism.

Many researchers investigated the role of large-scale circulations (e.g. ENSO, PDO) on EPEs and synoptic characteristics of EPs over the selected regions.

Owing to the spatial complexity, rugged topography, and land-sea interactions of the Mediterranean Basin, many devastating flash floods occurred in the various part of the region in the last decade. Therefore, researchers have analyzed the atmospheric conditions that cause these extraordinary events by focusing on the selected flood days.

Literature Review (cont.)

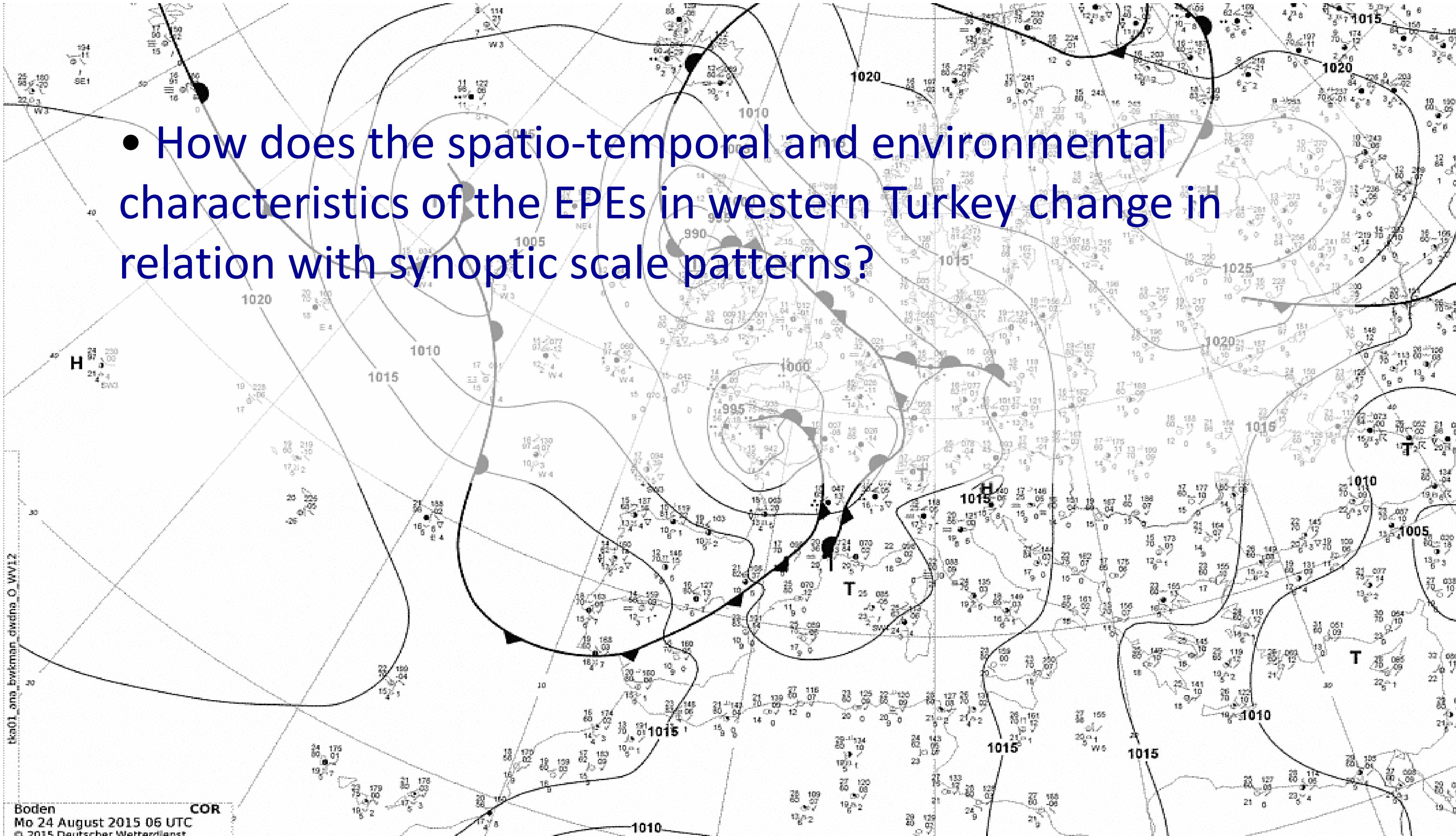
Although a number of prior studies have focused on the synoptic characteristics of the EPEs ending up with life or economic losses over Turkey, climatological characteristics of these EPEs and underlying causes were not studied in detail.

Turkey and its sub-basins are mainly influenced by EPEs in all seasons in the variety of the atmospheric conditions such as baroclinic waves and cyclones, MCSs, land-sea interactions and orographic forcing.

The aim of this study is to document the spatio-temporal and environmental characteristics of EPEs, and investigate the synoptic-scale patterns associated with EPEs.

Research Question

- How does the spatio-temporal and environmental characteristics of the EPEs in western Turkey change in relation with synoptic scale patterns?



Research Area and Tools

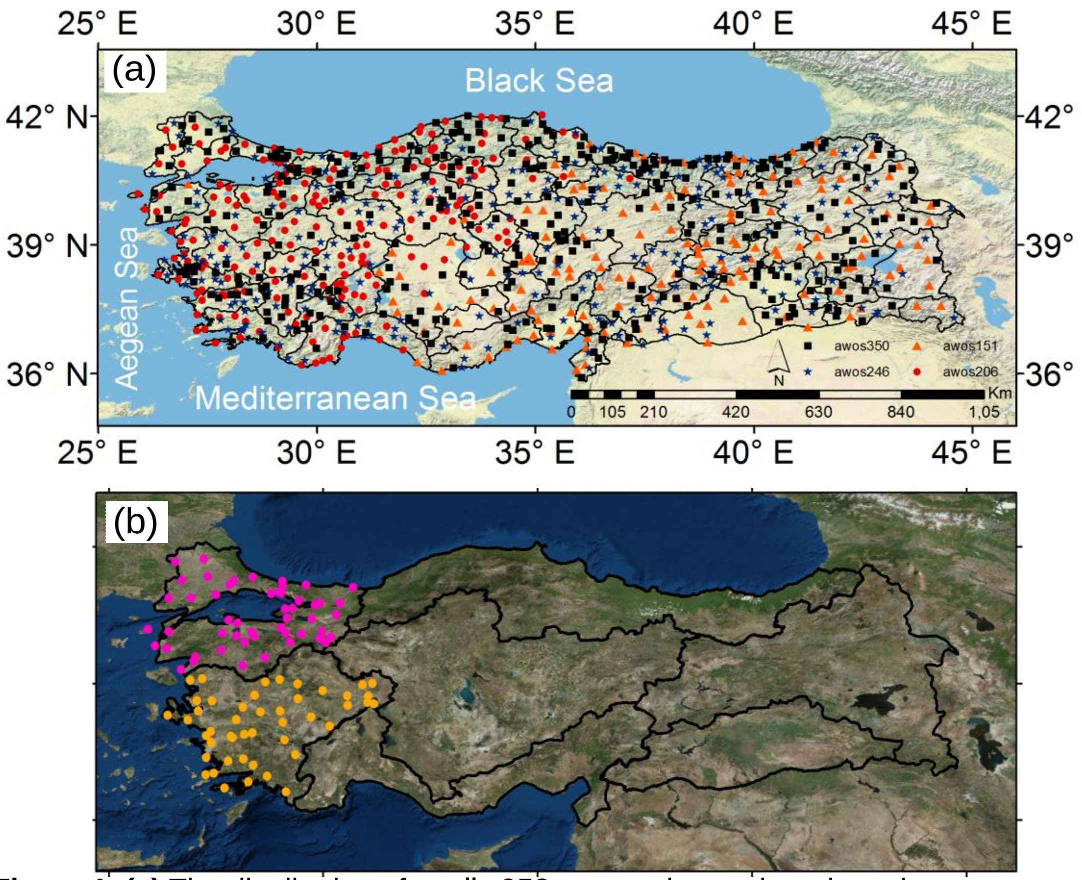


Figure 1. (a) The distribution of totally 953 automatic weather observing systems (AWOS) over Turkey depending on the four projects (AWOS 206, 151, 246 and 350) and **(b)** the locations of the 51 (pink points) and 47 (light brown points) AWOS stations, at Marmara and Aegean regions. Hourly precipitation data of these 97 stations were provided by the Turkish State Meteorological Service (TSMS) for the period of 2006-2015.

AWOS 206: TEFER project (Turkey Emergency Flood and Earthquake Recovery) 120 classical Obervations → new automated ones During 2003 and 2004.

AWOS 151: installed in the central and eastern Part of Turkey during 2009. 120 classical Obervations → new automated ones

AWOS 246 and 350: By 246 AWOS, new Districts were aimed to be meteorologically Covered. Later due to the high topographical Differences, 350 new AWOS stations were mainly located at the higher elevation Points and started to operate since 2016.

To obtain climatological perspectives of EPEs in Turkey, hourly precipitation records of 206 AWOS stations were selected and as a result of the quality control, missing data days and relocation of the stations; precipitation data of 97 stations in western Turkey were selected for 2006-2015 time period.

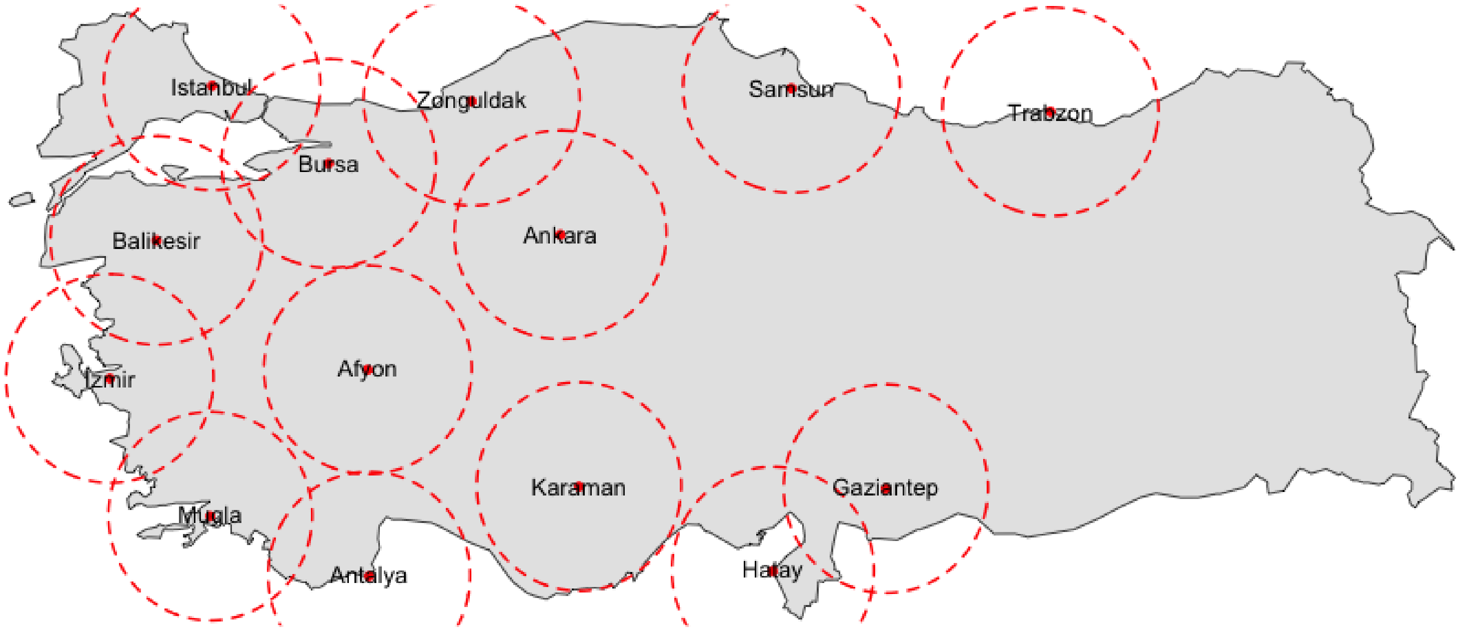
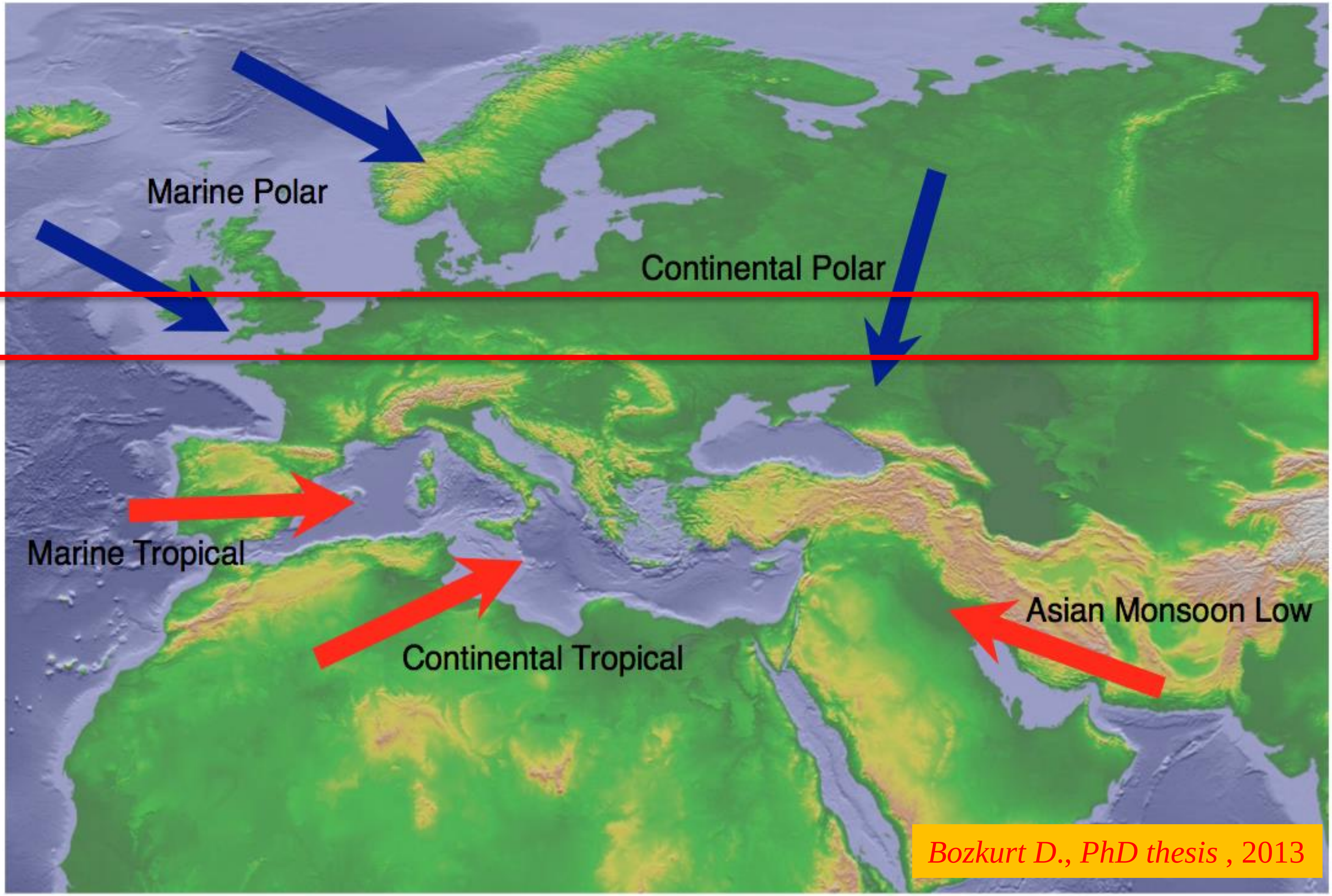


Figure 2. The distribution of 14 radar network over Turkey. Precipitation products of six radars (Istanbul, Bursa, Balikesir, Izmir, Mugla, and Afyon), which were taken from TSMS were evaluated manually to describe the characteristics of the precipitation types.

First C band radar installation: Ankara, 2000.
2003: Istanbul, Zonguldak, Balikesir radars installation
2007: Izmir, Mugla, Antalya, Hatay, Samsun, and Trabzon radars
2013: Bursa, Afyon, Karaman, Gaziantep C band radars
We used Istanbul, Zonguldak, Anakara and Balikesir radar 8-min PPI and MAX products to check the characteristics of EPEs (cyclonic, convective or sea-effect originated).

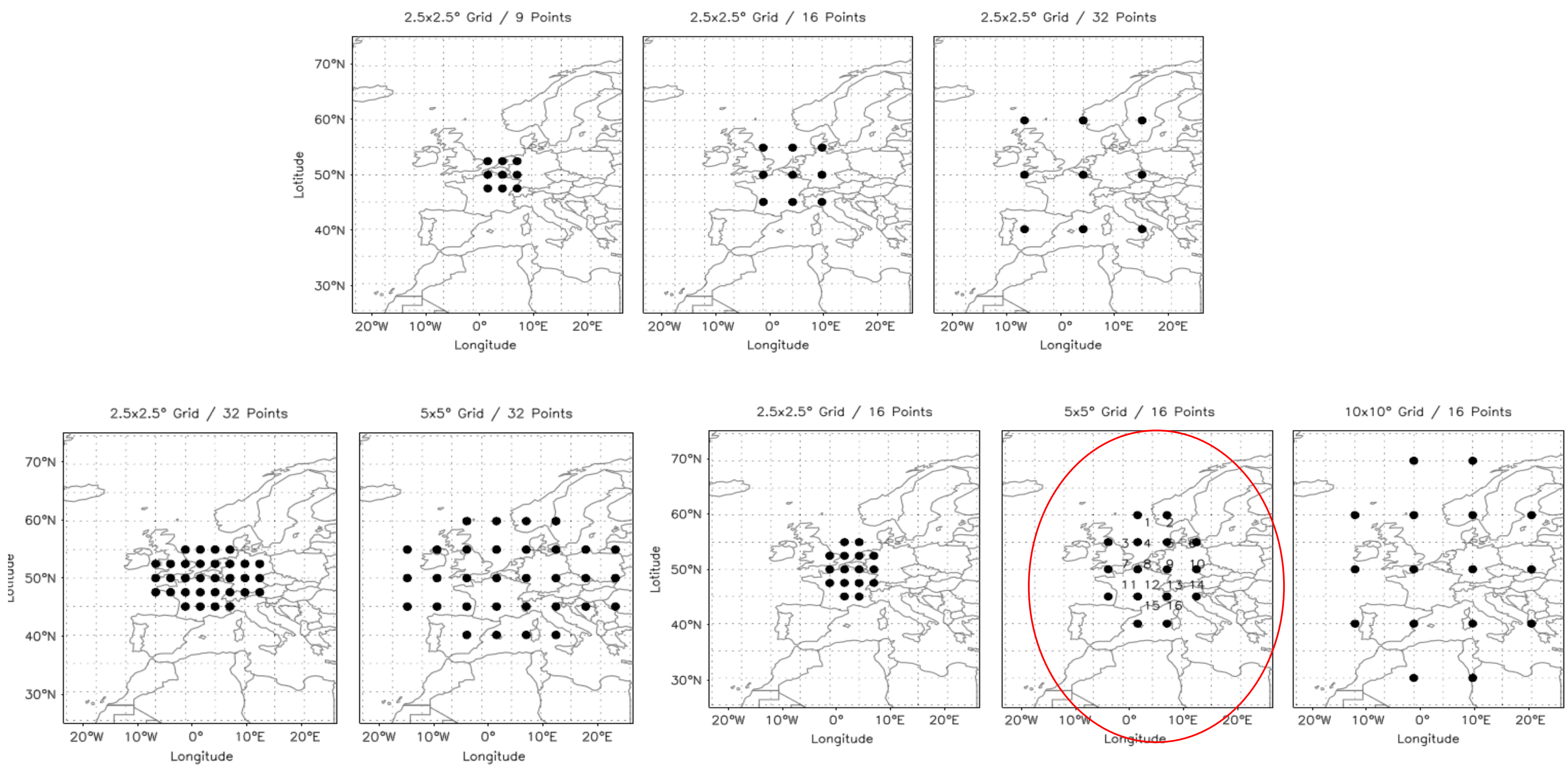
1st research tool: Lamb Weather Type Methodology



Bozkurt D., PhD thesis , 2013

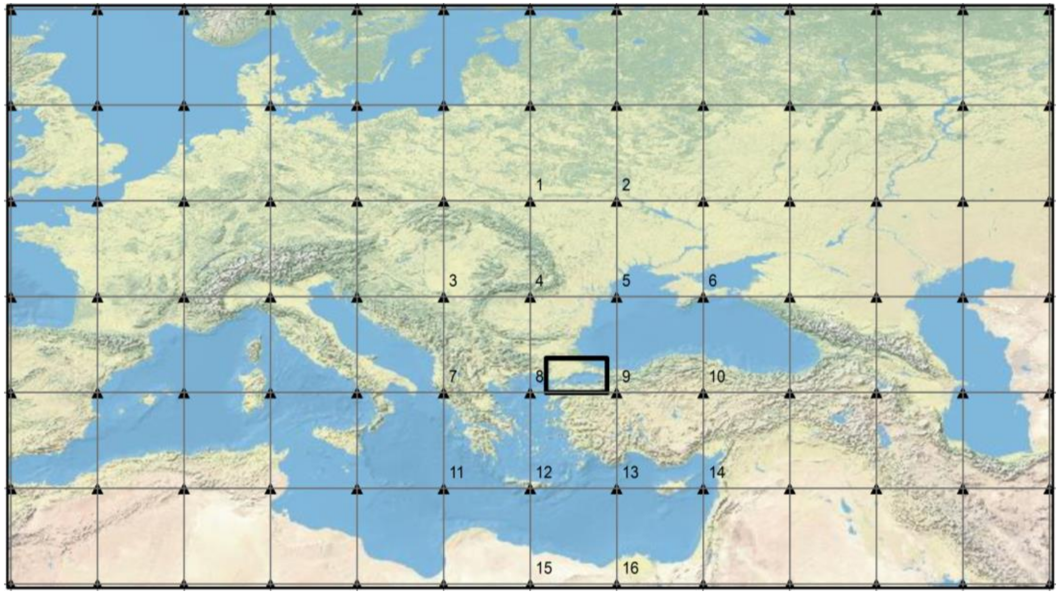
Hath et al., Annals of the New York Academy of Sciences , 2008

1st research tool: Lamb Weather Type Methodology



Sensitivity analysis for different grid points (Demuzere et al., 2009)

1st research tool: Lamb Weather Type Methodology



Grid numbers which have used in the study

$$WF = \left[\frac{1}{2}\left(p_{12} + p_{13}\right) - \frac{1}{2}\left(p_4 + p_5\right)\right] \quad (1)$$

$$SF = 1.305\left[\frac{1}{4}\left(p_5 + 2^* p_9 + p_{13}\right) - \frac{1}{4}\left(p_4 + 2^* p_8 + p_{12}\right)\right] \quad (2)$$

$$FF = \left(WF^2 + SF^2\right)^{0.5} \quad (3)$$

$$WSV = 1.12^*\left[\frac{1}{2}\left(p_{15} + p_{16}\right) - \frac{1}{2}\left(p_8 + p_9\right)\right] - 0.91^*\left[\frac{1}{2}\left(p_8 + p_9\right) - \frac{1}{2}\left(p_1 + p_2\right)\right] \quad (4)$$

$$SSV = 0.85^*\begin{bmatrix}\frac{1}{4}\left(p_6 + 2^* p_{10} + p_{14}\right) - \frac{1}{4}\left(p_5 + 2^* p_9 + p_{13}\right) \\ -\frac{1}{4}\left(p_4 + 2^* p_8 + p_{12}\right) + \frac{1}{4}\left(p_3 + 2^* p_7 + p_{11}\right)\end{bmatrix} \quad (5)$$

$$Z = WSV + SSV \quad (6)$$

LWTs methodology

Pure Types	Directional Types	Hybrid Types	
U	N	CN	AN
C	NE	CNE	ANE
A	E	CE	AE
	SE	CSE	ASE
	S	CS	AS
	SW	CSW	ASW
	W	CW	AW
	NW	CNW	ANW

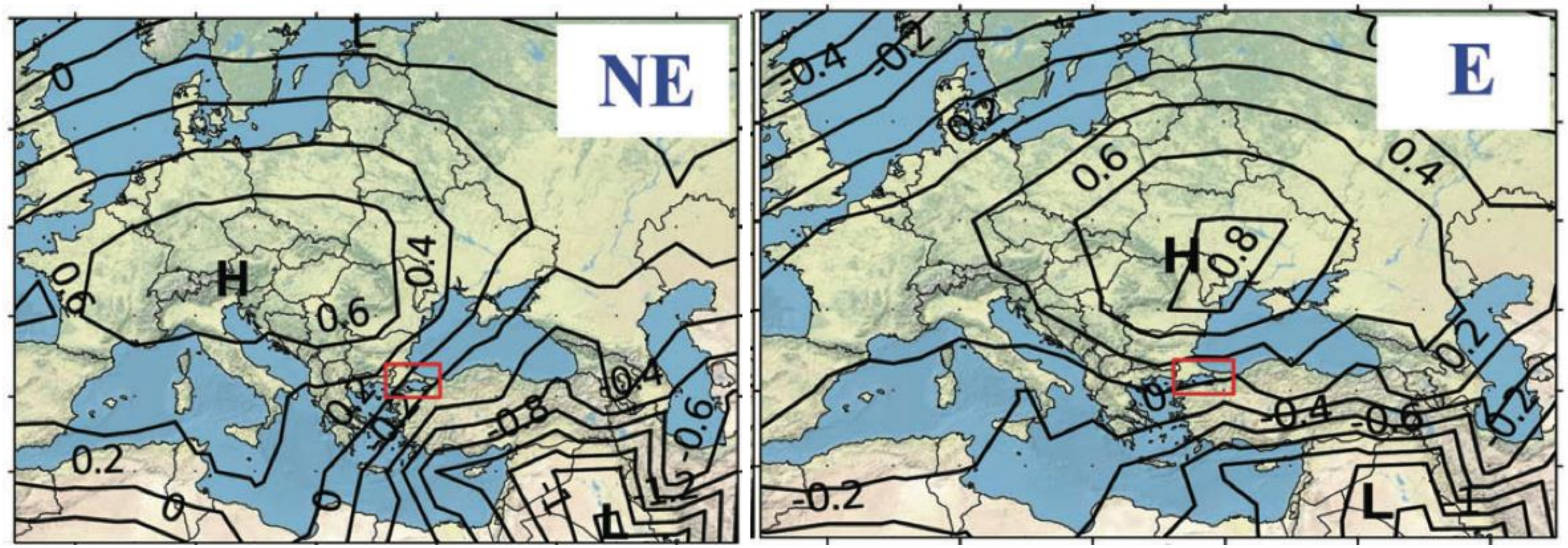
D=arctan(SW/WF) if WF<0

D=arctan(SW/WF)+180 if WF>0

Visualization of CTs (26 + 1)

Baltacı et al., IJOC, 2015

Analysis of atmospheric CTs

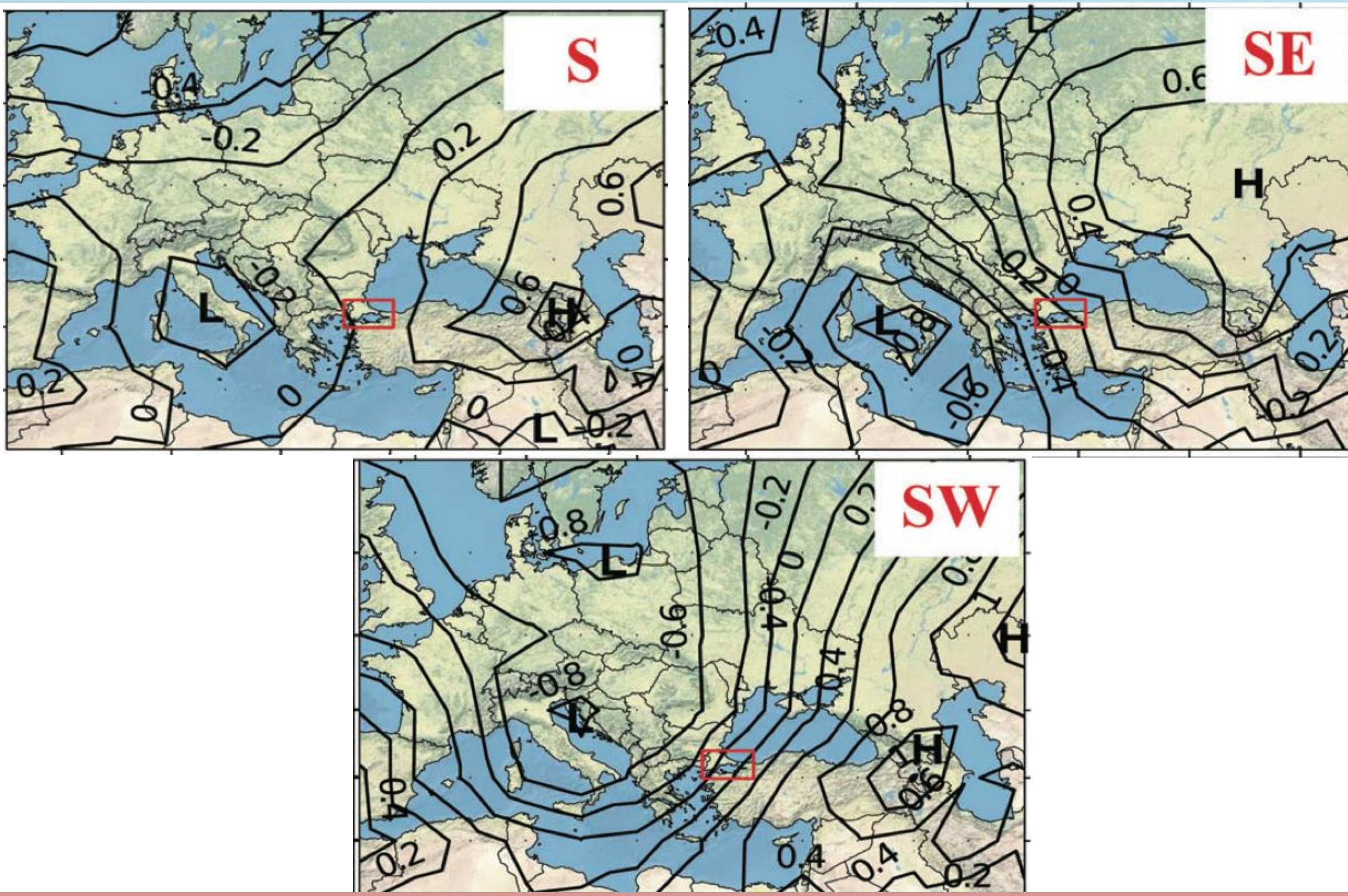


Synoptic features are a prominent blocking high over Eastern Europe and a low centred in the Middle East.

Accordingly, at least slightly positive MSLP anomalies are observed at the northern half of the Mediterranean basin along with Marmara Region; while MSLP over eastern Mediterranean Sea exhibits negative anomalies

Baltacı et al., IJOC, 2015

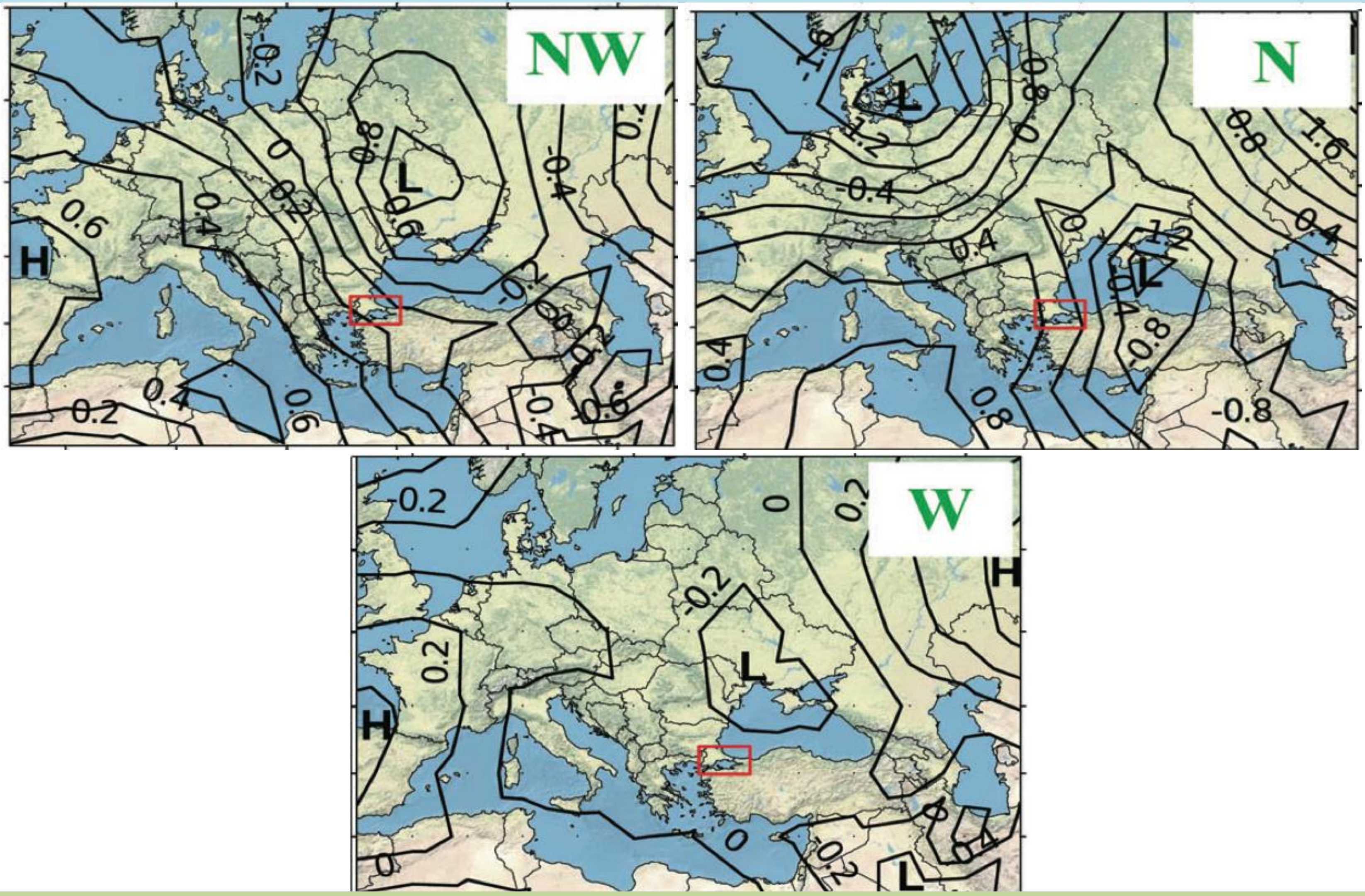
Analysis of atmospheric CTs



All of southerly types have a low around Italy. MSLP around the Central Mediterranean and Aegean Seas take on negative anomaly values. It is again slightly negative in the region Marmara, except for S pattern.

Baltacı et al., IJOC, 2015

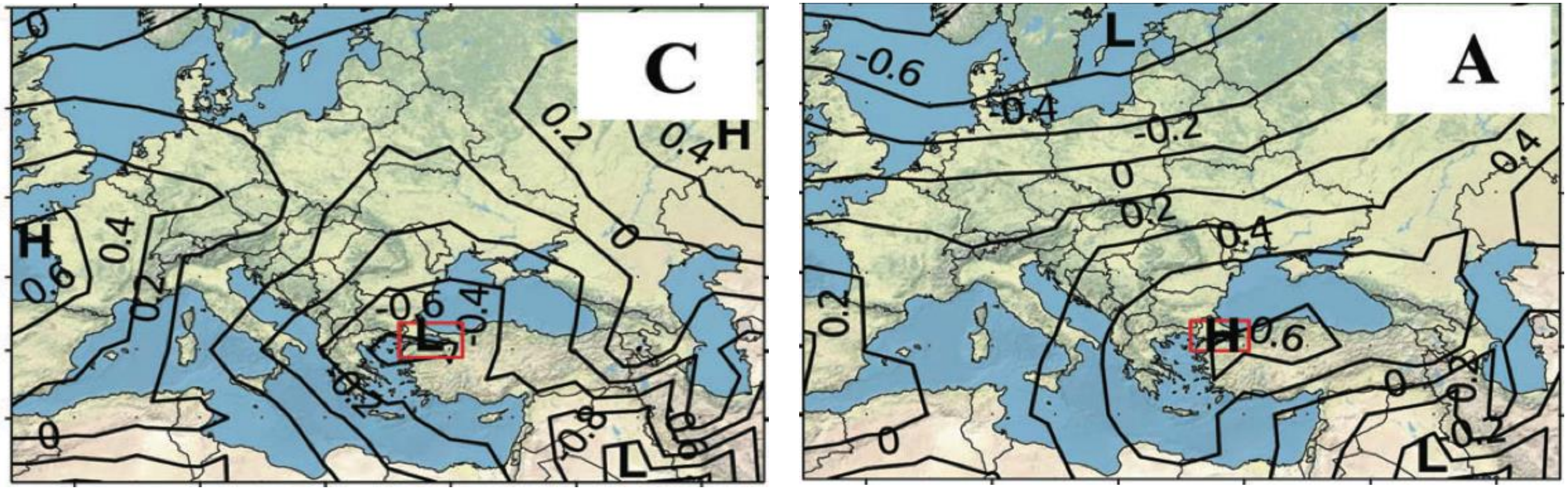
Analysis of atmospheric CTs



A low is observed around the northern edge of the Black Sea. This configuration leads to negative MSLP anomalies over the Black Sea and the Marmara Region, except for N pattern

Baltacı et al., IJOC, 2015

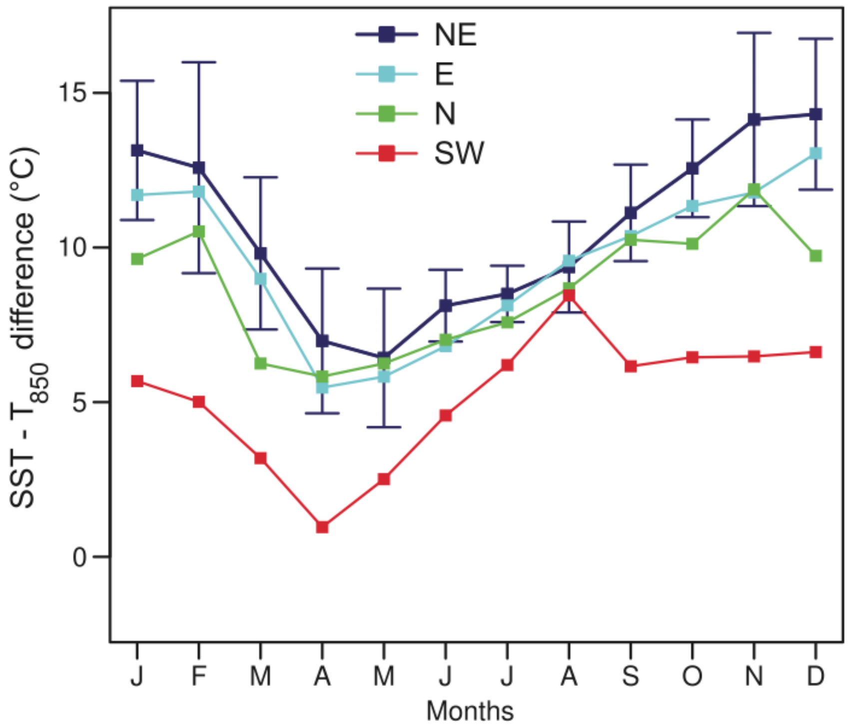
Analysis of atmospheric CTs



Cyclonic and **A**nticyclonic patterns, where a low and high are located, respectively, very close to the region of Marmara

Baltacı et al., IJOC, 2015

SST- T_{850}



- Primary factor is sea-effect precipitation is known to be the temperature difference between sea surface and air at 850 hPa level
- SST-T_{850} difference becomes higher, convective instability and the chance of precipitation increase
- Monthly variation of this parameter over southwestern BS during types N, NE and E indicates a maximum in November and December followed by the other 4 months in DJF and SON.

- This is clearly reflected in the large daily precipitation potentials of NE during these seasons in the eastern half of Marmara.

Baltacı et al., IJOC, 2015

Identification of EPEs and precipitation characteristics

Largest 10% of the daily precipitation amounts of each station separately as its own extreme.

We defined EPEs types by using the LWT technique and the radar outputs.

For LWT, basic air flows coming from the sea and generating extreme precipitation, defined as sea-effect precipitation. The cyclones, which generate severe precipitation over a defined region, are also characterized with cyclonic EPEs.

Convective EPEs as the precipitation bands coming from the terrestrial areas.

Marmara sea-effect EPEs: N and NE CTs were considered as Black-Sea effect EPEs.

Aegean sea-effect EPEs: W and SW CTs were considered as Aegean-Sea effect EPEs.

Climatology of EPEs in western Turkey

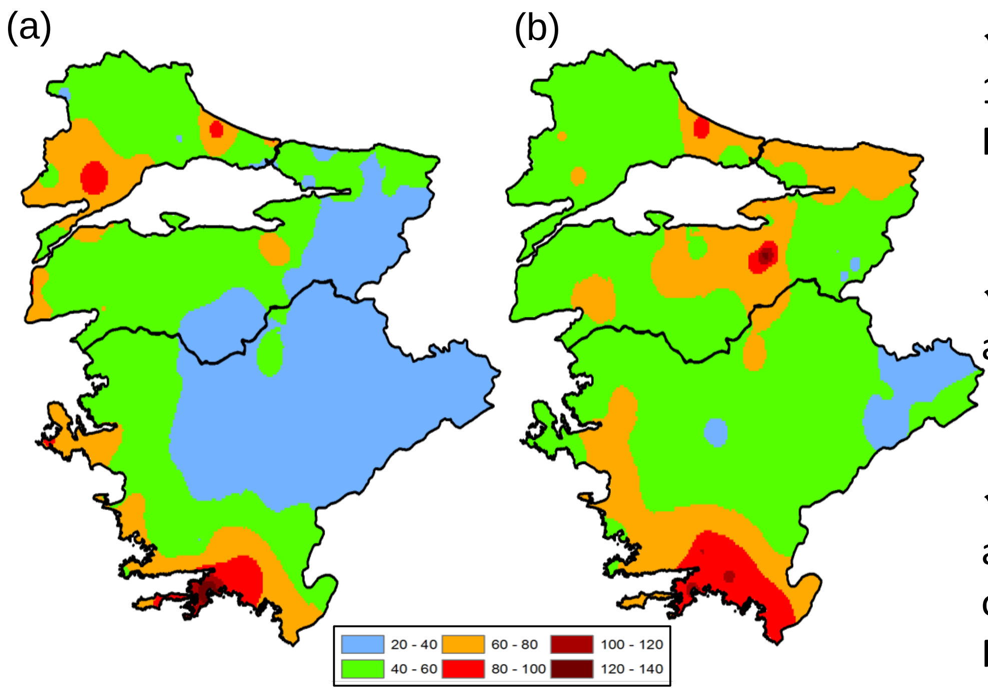


Figure 3. (a) Maps show the threshold values (in mm) of the stations during 2006-2015 when precipitation exceeded the 90th percentile generating an EPE. **(b)** the contribution of total EPs of a station to its annual mean precipitation (mm).

- ✓ Highest daily precipitation rates exceeding 100 mm are observed on the southern Aegean Region
- ✓ The lowest limits are observed in the semi arid continental areas of the Aegean and Marmara
- ✓ We observe that the largest normalized annual amounts of EPEs is located mainly on the southwest of Aegean, middle-south and northeast of the Marmara Region with values larger than 60 mm.

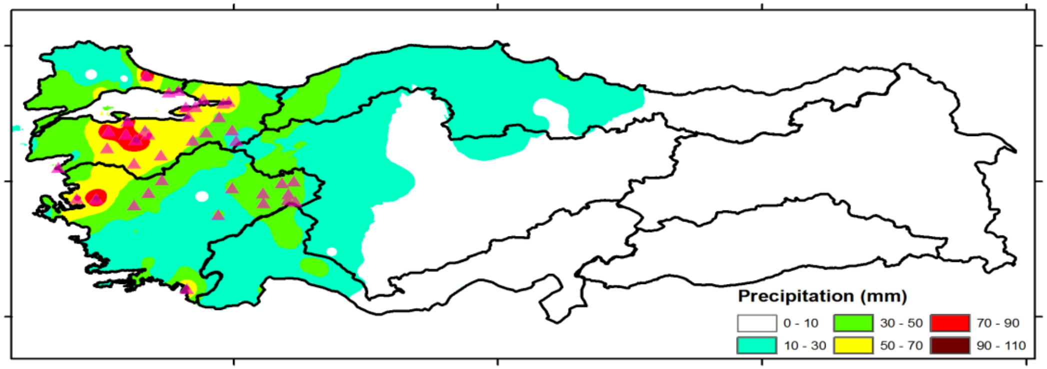
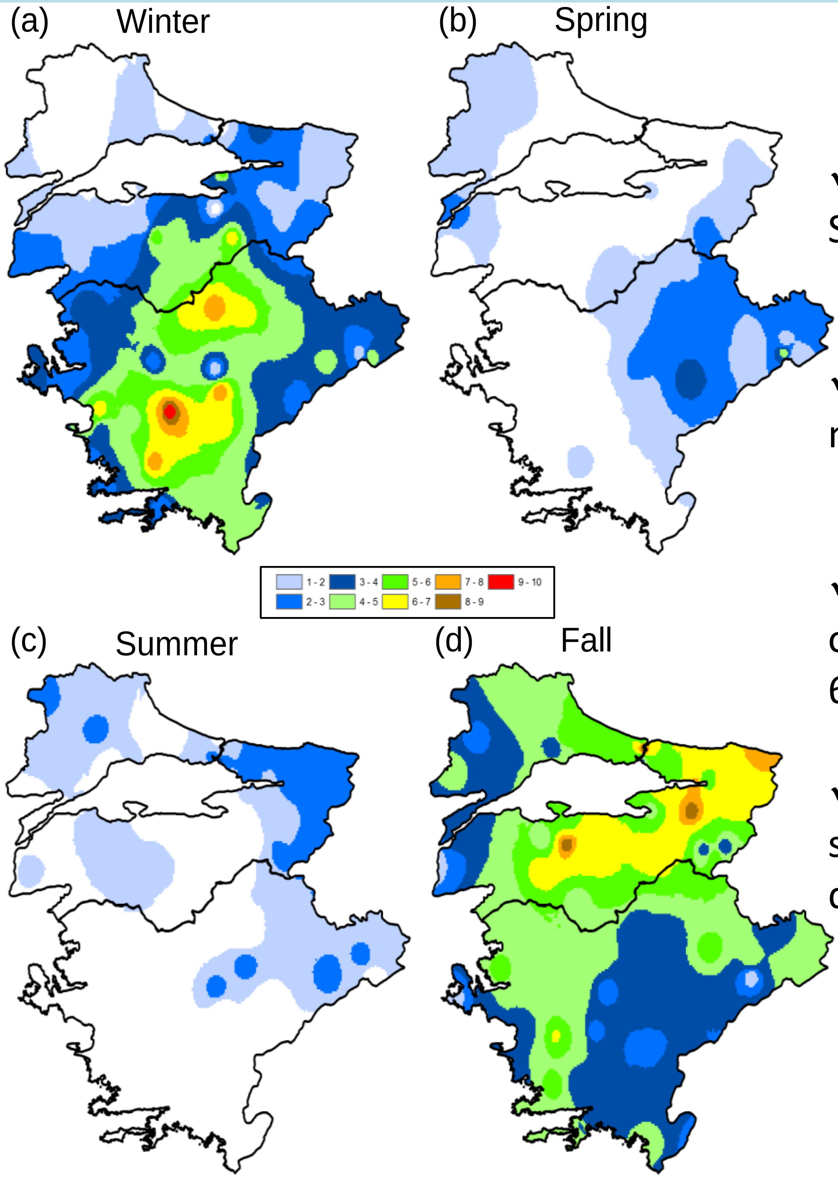


Figure 4. Daily total precipitation amounts over Turkey on October 28, 2010 (mm, in shaded) and the stations exceeding their 90th percentile threshold (triangle).

- ✓ It is interesting that interior areas of the Aegean and Marmara now exhibit between 40-60 mm. The reason of this can be the convective precipitation, generating intensified rain that can accumulate higher amounts of precipitation during a single rainstorm

Seasonal distribution of EPEs



- ✓ For EPEs, winter (DJF) and autumn (SON) are more Significant than the other seasons.
- ✓ During winter, two cores over Aegean result in more than 6 extreme precipitation days
- ✓ In fall, an area extending from northeast to south of Marmara receive a frequency considerably higher than 6 days.
- ✓ From this point of view, we mainly focused atmospheric systems generating EPEs and effecting Aegean region mainly during winter and Marmara Region during fall

Figure 5. Seasonal distribution of the counts of the days for the stations when precipitation exceeded their 90th percentile during an EPE case for **(a)** winter, **(b)** spring, **(c)** summer, and **(d)** autumn seasons.

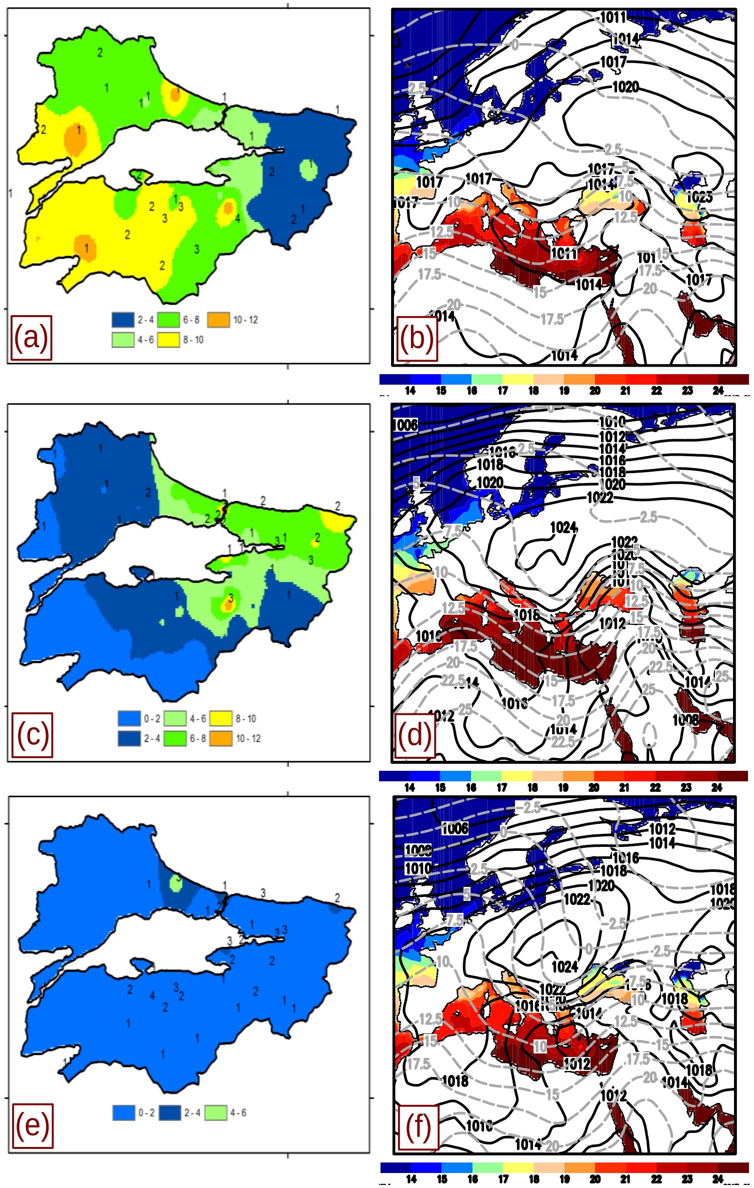


Figure 6. (a) Daily mean precipitation values of cyclonic precipitation types (mm, shaded) and the counts of EP days for the stations of Marmara during the autumn of 2006-2015. **(b)** Composites of the daily mean sea level pressure (MSLP, solid lines), sea surface temperature (SST, colored), and air temperature at 850-hPa (dashed lines) for the average of 18 extreme precipitation days over Marmara. **(c)** same as **(a)** but for the sea-effect (NE) precipitation types. **(d)** same as **(b)** but for the 14 extreme precipitation days. **(e)** same as **(a)** but for the convective (E) precipitation types. **(f)** same as **(b)** but for the 11 extreme precipitation days.

	Total extreme precipitation numbers	Black Sea-effect EPEs		Cyclonic EPEs	Convective EPEs			Other CTs
Season/CTs		N	NE	C	E	SE	S	
Winter	109	0	1% (1)	33% (16)	12% (5)	0%	0%	54%
Spring	43	0%	7% (2)	33% (9)	7% (3)	0%	9% (1)	44%
Summer	65	8% (2)	32% (13)	23% (11)	2% (1)	0%	0%	35%
Fall	267	0%	**15% (14)**	**17% (18)**	**21% (11)**	6%	1%	40%

During cyclonic CTs, highest daily mean precipitation amounts exceeding 8 mm are shown to exist on the southwestern parts of the region. Synoptic composite maps are analyzed, low pressure located over Aegean Sea and west of Marmara. Sea surface temperature varies between 19 and 20 C.

During NE types, north and northeast part of Marmara gets higher daily mean precipitation amounts. Totally 28 extreme precipitation cases in the northeastern stations exceed their threshold level. Our results indicate that as a consequence of the combination of a high pressure center located over eastern Europe and low pressure center over southern Turkey, strong northeasterly flows can be generated owing to high pressure gradient force bringing significant amounts of moisture from the relatively warm Black Sea (21 C)

Strong easterly flows coming from flat areas meet with highland barriers producing higher amounts of orographic enforced convective EPs

	Total extreme precipitation numbers	Aegean Sea-effect EPEs		Cyclonic EPEs	Convective EPEs		Other CTs
Season/CTs		W	SW	C	E	SE	
Winter	200	7% (2)	11% (4)	**61% (35)**	0%	0%	21%
Spring	52	8% (3)	17% (3)	21% (7)	4% (3)	0%	50%
Summer	24	8% (1)	0%	17% (3)	4% (1)	0%	71%
Fall	180	1% (1)	18% (9)	43% (28)	2% (3)	2%	34%

During C types, daily precipitation amounts are found to be higher in the southern corner of the region (above 14 mm) and we observe higher EP cases close to the coastal stations. During appropriate synoptic conditions, more deepened LPC is located over Aegean Sea. Cold air aloft coming from north can meet with the relatively warm Aegean Sea and the convergence of warm air above the cold air can generate cyclogenesis which can result in heavy precipitation.

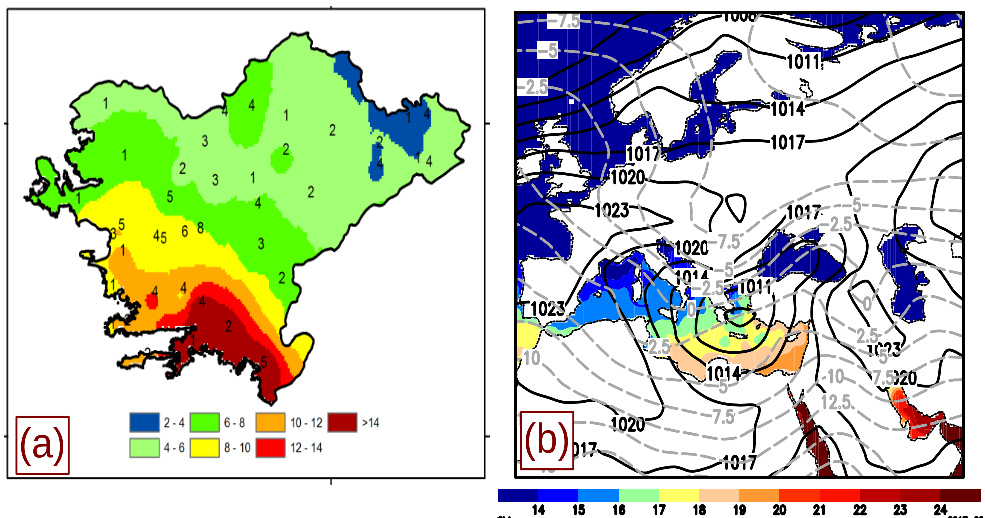


Figure 7. (a) Daily mean precipitation values of cyclonic precipitation types (mm, shaded) and the counts of EP days of the Aegean stations for the winter months during 2006-2015. **(b)** Composites of the daily mean sea level pressure (MSLP, solid lines), sea surface temperature (SST, shaded), and air temperature at 850-hPa (dashed lines) for the average of 35 extreme precipitation days over Aegean.

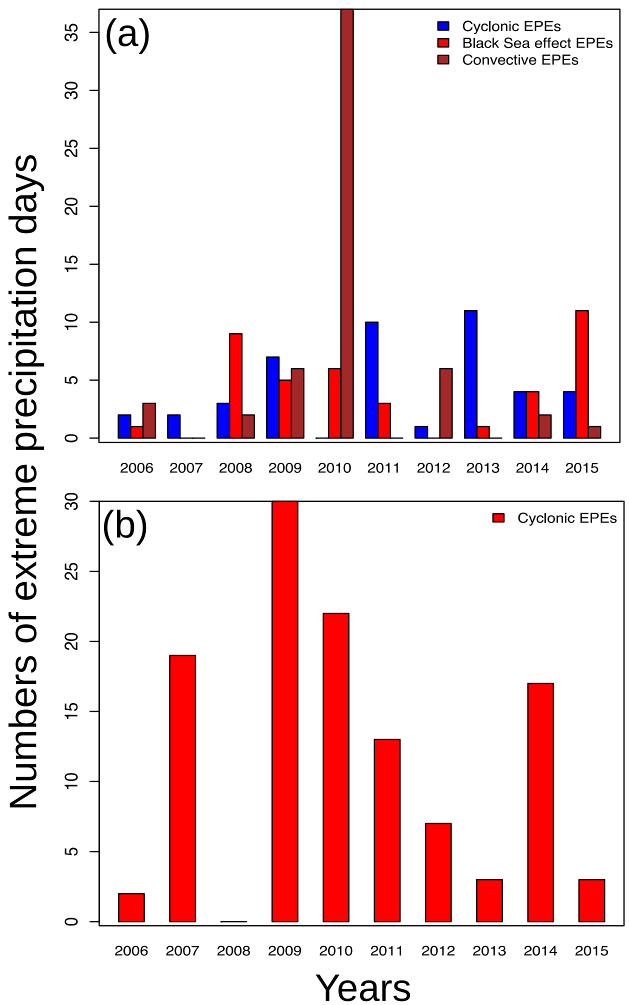


Figure 8. Annual distribution of the total counts of EPEs as well as precipitation characteristics for **(a)** Marmara in autumn and **(b)** Aegean in winter months.

In terms of Marmara, cyclonic CTs were more active in 2009,2011 and 2013 years. On the other hand, highest counts of Black Sea effected EPEs happened during 2008 and 2015 years. It is known that 2010 was a wet year for Marmara and dense daily rainfall amounts were generated by convective activity.

For Aegean, this region had been under the influence of mid-latitude cyclones during the years 2009 and 2010. One reason of this could be the negative phase of NAO pattern, where warm and moist air over the Mediterranean Sea can be transferred to the Aegean region by strong westerly or southwesterly flow.

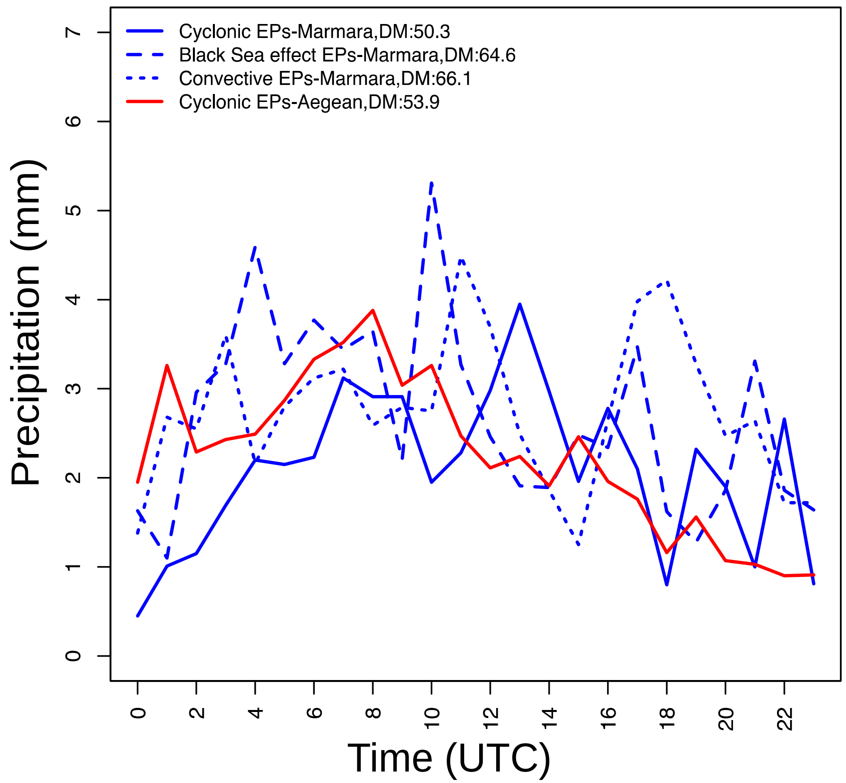


Figure 9. Average hourly precipitation amounts (mm) of EP days according to cyclonic, Black-Sea affected and convective types in Marmara for autumn and cyclonic EPs for Aegean in winter. DM indicates the daily mean precipitation amounts (mm) associated with the count of days ended-up with extreme precipitation.

In Marmara, highest daily mean extreme precipitation is shown to occur under the convective types, and followed by Black-Sea effected and cyclonic CTs. During convective activity, we showed a peak during afternoon hours of the day. Main reason of this event is found as diurnal heating and explained with Clausius-Clapeyron (C-C, link between precipitation intensity and temperature)relation. For the Black Sea effected EPs, we observe an hourly peak of the precipitation close to noontime and this suggests that when maximum solar radiation reaches the sea surface, significant amount of moisture and heat are transferred by northerly flows to Marmara

Results

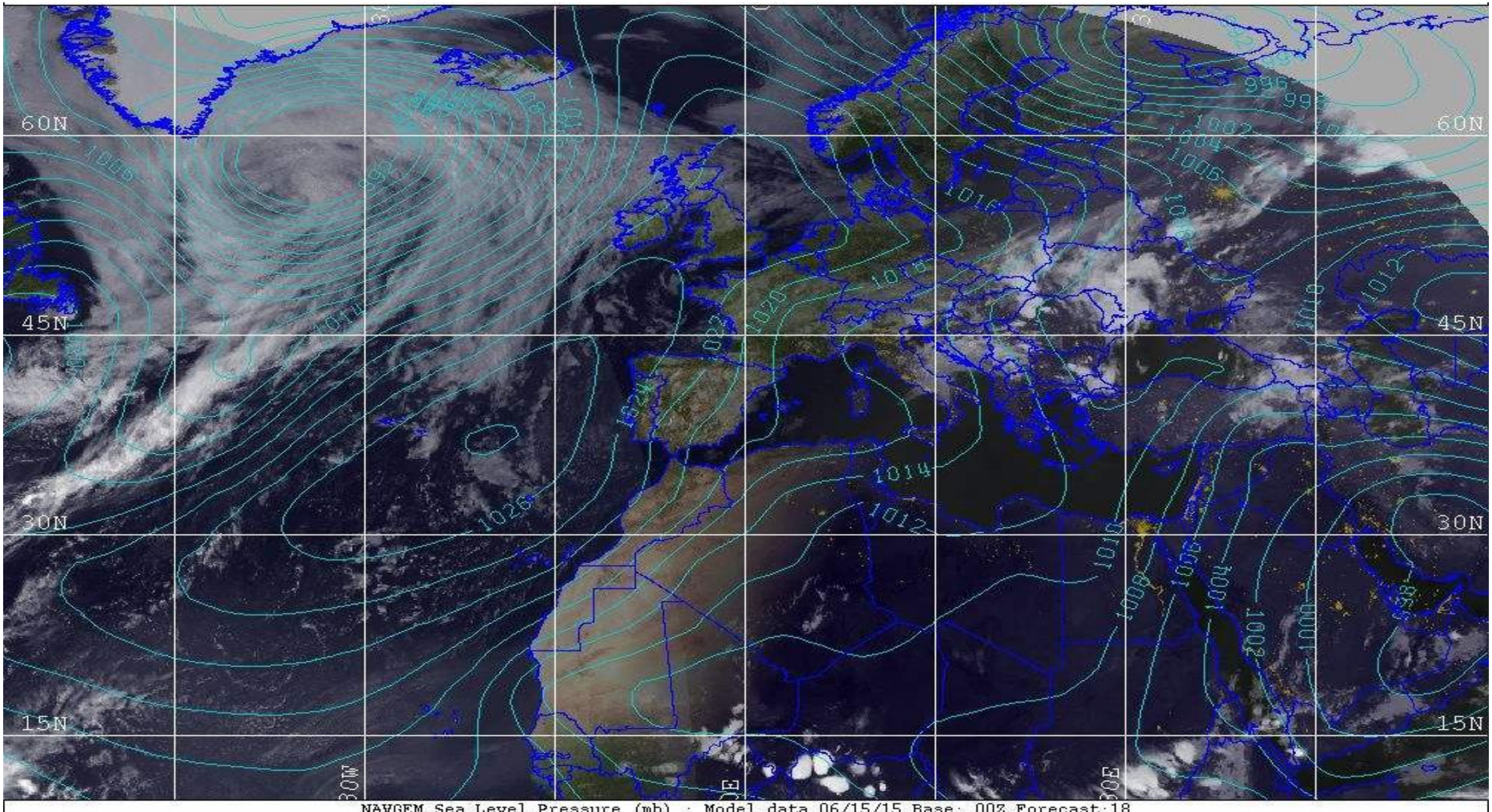
- While highest EP threshold limits are shown to exist at the seaside stations of western Turkey (above 80 mm), the lowest limits are observed at the semi-arid continental areas of the Aegean and Marmara regions. Seasonal numbers of the EP days showed that Marmara and Aegean areas of Turkey are more influenced from these intense rainfall episodes during autumn and winter months, respectively.

- During autumn, convective, cyclonic and sea-effect originated EPEs represent 21%, 17%, and 15% of total extreme precipitation numbers occurring in the stations of Marmara. If the region has the proper synoptic conditions (HPC over Balkan Peninsula and LPC over eastern Mediterranean) and diurnal heating, convective types of EP mainly occur at the south of Marmara during afternoon and evening times of the day. Daily extreme precipitation amounts are more common in the southwestern parts of Marmara when the cyclone is located over Marmara. Additionally, as a consequence of the interaction between HPC over eastern Europe and LPC over central Anatolia, strong moisture can be transferred by the northeasterly flows and this can result in higher daily precipitation records that was sea-effect originated are shown to develop at the northeast parts of Marmara.

Results

- At Aegean region, 61% of the total EPs occur from the cyclonic activity during winter and torrential rainfall is found to be experienced at the majority of the stations, especially those located in the south. This condition can be explained by cold air transfer from north that meet with the relatively warm Aegean Sea and thus, convergence of warm air above the cold air generates cyclogenesis which results in heavy precipitation.

Thank You


60N
45N
30N
15N
NAVGEM Sea Level Pressure (mb) : Model data 06/15/15 Base: 00Z Forecast:18