Unraveling Eastern Mediterranean Daily Maximum / Minimum Temperature's Shifts Linked to Shifting Synoptic Systems' Regimes

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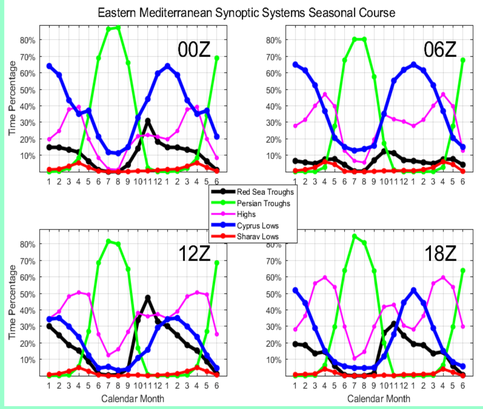
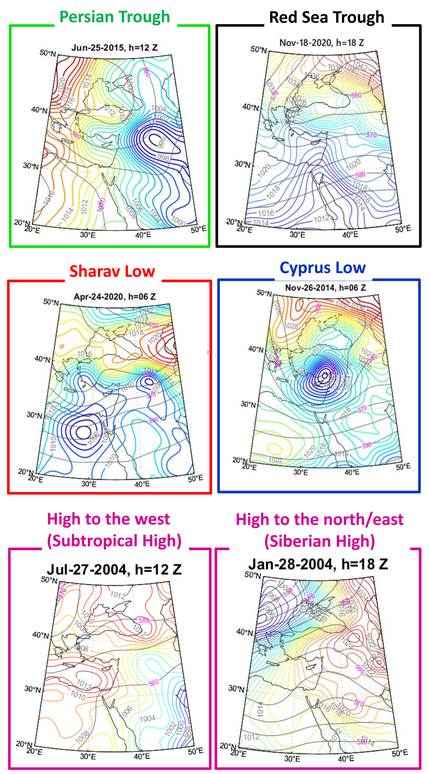
Motivation. We introduce a new set of predictors for average daily maximum and minimum temperatures (TMAX, TMIN) on a monthly scale - the frequency of occurrence of regional weather patterns, or synoptic systems, The aim of this study is to find correlations between TMAX/TMIN and the frequency of occurrence of governing synoptic systems over the Eastern Mediterranean. A synoptic classification performed on a sub-daily scale [1] makes it possible to quantitatively relate TMAX to the frequencies of afternoon (hottest time) synoptic systems, and TMIN - to predawn (coldest time). which are produced quite well using GCM/RCM [2].

Synoptic systems. The semi-objective daily synoptic classification algorithm developed for 12Z [3] and applied in numerous studies over the past two decades has been extended for a sub-daily synoptic classification at 00Z, 06Z, 12Z and 18Z using the NCEP-NCAR reanalysis data [4].

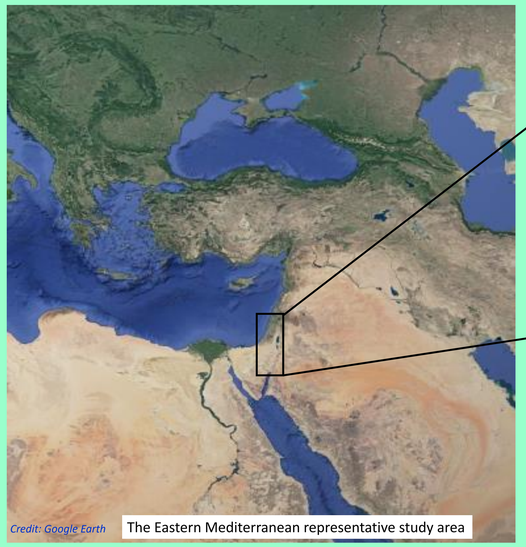


Examples of synoptic systems

Warm season AMJJAS Cool season ONDJFM



Step 1. Synoptic systems and synoptic regimes

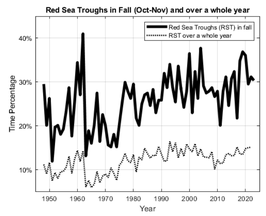


The original 12Z definitions for the 19 EM synoptic systems comprising 5 major synoptic classes (Cyprus Lows, Red Sea Troughs, Persian Troughs, Sharav Lows and Highs) have been retained.

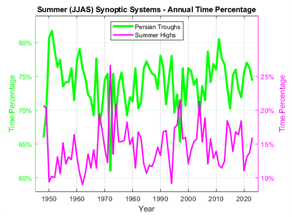
The synoptic systems' definitions are common for 00Z, 06Z, 12Z and 18Z as based on their SLP patterns, but their wind speeds and temperatures are different. The resulting sub-daily synoptic classification revealed sharp differences between the daytime and nighttime percentages of synoptic systems, as well as profound differences in their long-term changes.

Counting occurrences of the synoptic systems on the sub-daily scale - at 00Z, 06Z, 12Z and 18Z - allows to refine their trend data, as comparing to the original study [3] where these occurrences were counted at 12Z only.

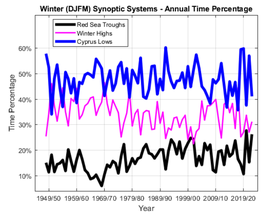
Considering the long-term trends of these refined data, we cannot see any profound tendency, apart from that of the Red Sea Troughs which nearly doubled since 1970s: →



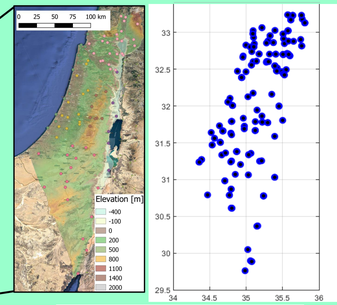
Slightly different patterns of occurrences between prior and after the 1970s can be noticed for the summer synoptic systems - Persian Troughs and Highs (Subtropical High): →



The same is valid for winter Highs (Siberian High): →



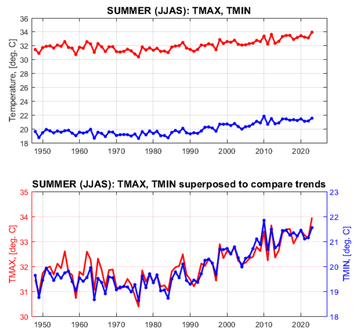
Step 2. Maximum and minimum temperatures, 1948-2023



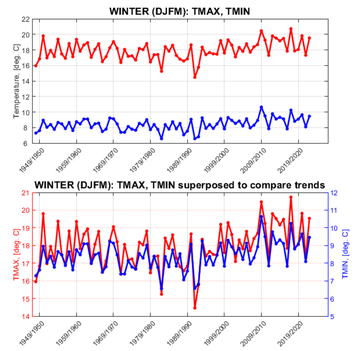
Location of 186 IMS weather stations

TMAX, TMIN time series. We combined 186 daily maximum and minimum temperature (TMAX, TMIN) records (at h = 2m) between 1948–2023 from the Israel Meteorological Service database [5] into data records for 103 locations. Then, missing data at each location were filled-in based on the most correlated neighboring station in each calendar month. Finally, we averaged the 103 completed data records into two regional monthly time series: one for TMAX and one for TMIN.

The EM regional TMAX and TMIN time series can be considered well represented by averaging daily TMAX and TMIN records from these 103 locations, as they cover the whole diversity of the EM topoclimatic zones: coastal plain with high rainfall; mountain ranges with many hours of sunshine and short but intense rainfall, deep valleys, steppes and deserts.



Until the 1970s, summer TMAX had higher variability than TMIN, although neither followed any particular trend. Since the 1970s, both TMAX and TMIN have shown similar long-term patterns of the increase by about 3 degrees C.



Winter temperatures TMAX dropped slightly until 1991/1992 (unusually rainy and cold winter). If we exclude that and the following cold winters, 1991/1992 and 1992/1993, TMAX shows very high variability between 17 ÷ 20.5 degrees C, while no trend is observed for the last 15 years.
Winter temperatures TMIN showed a very slight decrease until 1991/1992 and 1992/1993, and from 1993/1994 a high variability between 8 ÷ 10.5 degrees C.

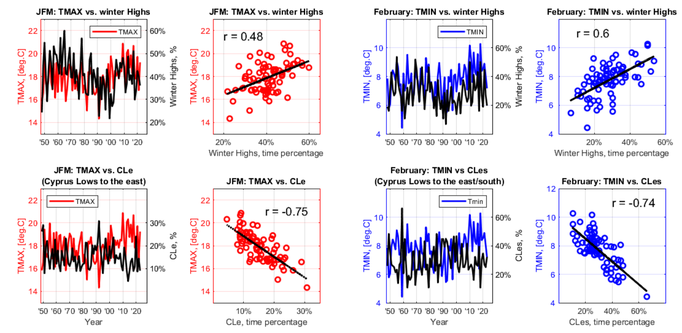
Step 3. Correlation between long-term synoptic system frequencies and maximum and minimum temperatures

TMAX, TMIN vs. synoptic systems. The daily maximum temperature TMAX is usually observed at 14:00 local time, which in the study region corresponds to 12Z. Therefore, in the present research, TMAX was tied to synoptic classes at 12Z.

The daily minimum temperature TMIN is mostly observed at 5:00 a.m. local time which in the study region corresponds to 03Z. This moment is midway between the standard 00Z and 06Z of the NCEP/NCAR reanalysis. To tie TMIN to synoptic classes at 03Z, we estimated percentages for each synoptic class at 03Z as its averaged percentages at 00Z and 06Z.

Main Results. We have considered correlations between TMAX, TMIN and frequency of occurrences (time percentage) of synoptic systems in individual calendar periods and in various groups of months. The most prominent results are as follows:

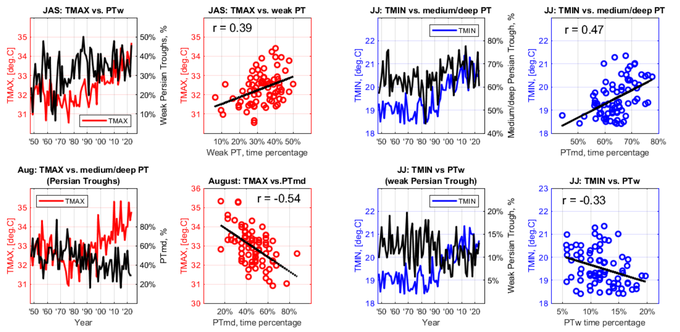
Winter:
Examples of positive and negative correlations of TMAX and TMIN
with Synoptic Systems frequencies of occurrences



For **winter TMAX**, both the **positive** and the **negative** strongest correlations with synoptic patterns were found in **JFM.** The **positive** correlation was with the frequency of occurrence of **winter Highs** (r = 0.48), while the **absolute correlation maximum** was negative, with the frequency of occurrence of **Cyprus Lows to the east (CLe)** (r = -0.75).

For **winter TMIN**, both the **positive** and the **negative** strongest correlations with synoptic patterns were found in February. The **positive** correlation was with the frequency of occurrence of **winter Highs** (r = 0.6) while the **absolute correlation maximum** was negative, with the frequency of occurrence of Cyprus Lows to the east & south (CLes) (r = -0.74).

Summer:
Examples of positive and negative correlations of TMAX and TMIN
with Synoptic Systems frequencies of occurrences



The summer **TMAX** was found to be best **positively** correlated in **JAS,** with the frequency of occurrence of **weak Persian Troughs (PTw)** (r = 0.39), while the **absolute correlation maximum** was negative, in August, with the frequency of occurrence of **medium/deep Persian Troughs (PTmd)** (r = -0.54).

For summer **TMIN**, both the **positive** and the **negative** strongest correlations with synoptic patterns were found in JJ. The **positive** correlation with the frequency of occurrence of combined **medium/deep Persian Troughs (PTmd)** (r = 0.47) was as well the **maximum absolute correlation** for summer **TMIN,** while the best negative correlation was weedy, with the frequency of occurrence of **weak Persian Troughs (PTw)** (r = -0.33).

Conclusions. This search for correlations between Eastern Mediterranean (EM) daily maximum and minimum temperatures (TMAX, TMIN) and the frequency of occurrence of regional synoptic systems was conducted for both individual calendar months and different groups of months in the EM winter (DJFM) and summer (JJAS). The highest absolute correlations were found in winter up to 0.75 (JFM and February) and in summer about 0.5 (June&July and August). This provides a basis for future studies of optimal regressions for TMAX/TMIN based on monthly dynamics among their best-correlated synoptic systems predicted by GCM/RCM.

References:
[1] I. Osetinsky-Tzidaki and E. Fredj, 2021: Zooming-in Evaluation of the GPM IMERG Final Run Product with Subdaily Synoptic Classification for Mixed Climates: An Example of Israel, [Link];
[2] I. Osetinsky and P. Alpert, 2004: Evaluation of GCM/RCM by the classified synoptic systems' approach, [Link];
[3] I. Osetinsky, 2006: Climate Changes over the E. Mediterranean – A Synoptic Systems Classification Approach, PhD Thesis, [Link];
[4] E. Kalnay and Coauthors, 1996: The NCEP/NCAR 40-Year Reanalysis Project. Bull. Amer. Meteor. Soc., 77, 437–472, [Link];
[5] IMS - Israel Meteorological Service database, [Link].