Black Sea freezing in 2006-2020 and relation to winter temperature

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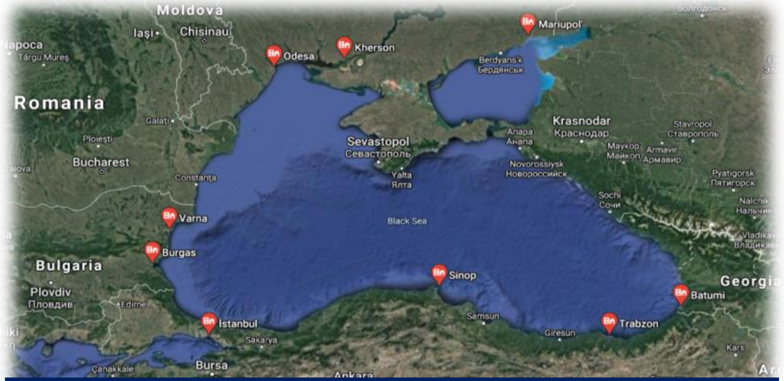
Introduction and scope

The Black Sea is a large deep water basin on the border between European and Asian continents lying in the continental mid-latitude climate zone. It is an important climatic factor for all borderline countries. The open plane in north direction enables the propagation of the Siberian High influence in winter. From the other side, the Mediterranean Sea influence is significant through the Mediterranean cyclones passing frequently the area.

Black Sea freezing is observed regularly in the northern part and near the Kerch Straits and occasionally spread during cold winters to south reaching Romanian coast (Simonov and Altman, 1991).

At present the Black Sea MFC modelling system does not include representation of the sea ice, and this is justified as the formed ice is basically frozen riverine water rather than sea ice. One more reason is that these events occur in relatively short time periods and limited areas. The last point is that the observed global warming makes these episodes even more rare. During last years there were several anomalies: since 1972 rare freezing was observed, but the 2012 was extremely cold and the Black sea ice covered area reached Constanta in Romania. 2017 was also anomalously cold in this area. There is not a thorough recent study of the areas covered regularly with ice in the Northern Black Sea, and our aim is to fill this gap and to check to what extent the sea ice occurrence is important to be taken into account from numerical models.

Romanian coast near Constanta in February 2012



Locations of the meteorological stations used in the study

Data used in the study

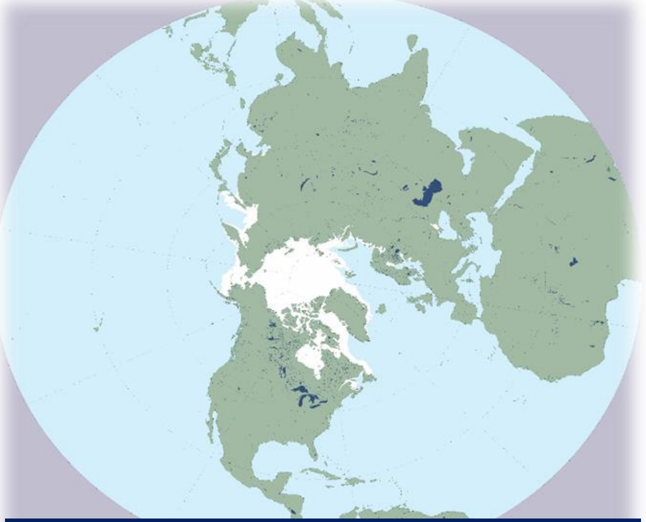
The analysis combines data for several sources:

1) Historical publications for the temperatures and ice cover in the area (Simonov and Altman, 1991) for the period 1925-1985

2) Synoptic measurements for the period 1950-2020 in 9 meteorological stations along the Black Sea coast – Burgas, Varna, Odesa, Herson, Mariupol, Batumi, Trabzon, Sinop and Istanbul from the NOAA data set Global Surface Summary of the Day – GSOD (data.nodc.noaa.gov)

3) Ice cover data product Multisensor Analyzed Sea Ice Extent - Northern Hemisphere (MASIE-NH) of the US National Snow and Ice Data Center at 4 km spatial resolution, period 2006-2020 (www.nsidc.org)

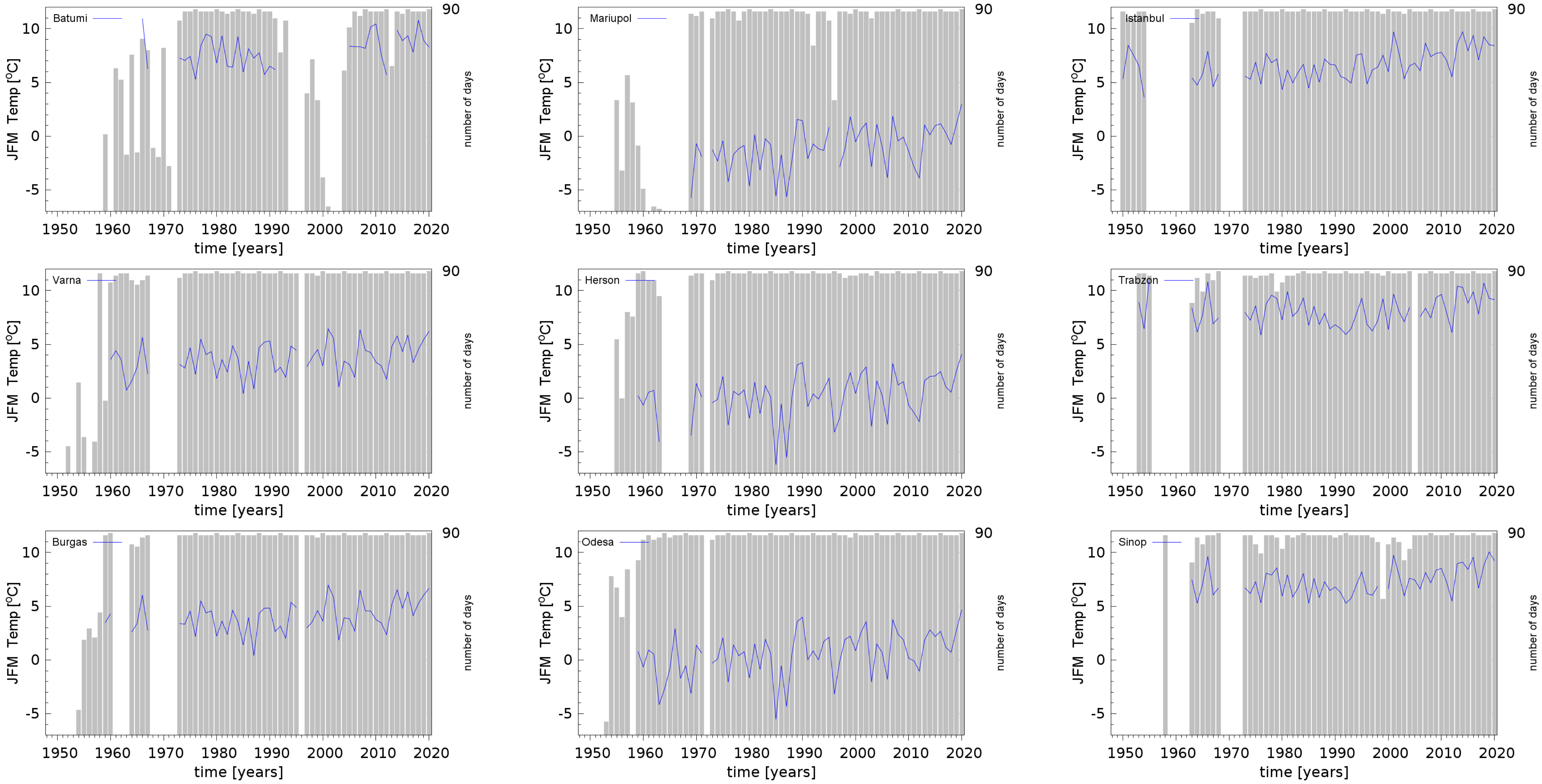
4) ERA5 Monthly reanalysis data (climate.copernicus.eu)



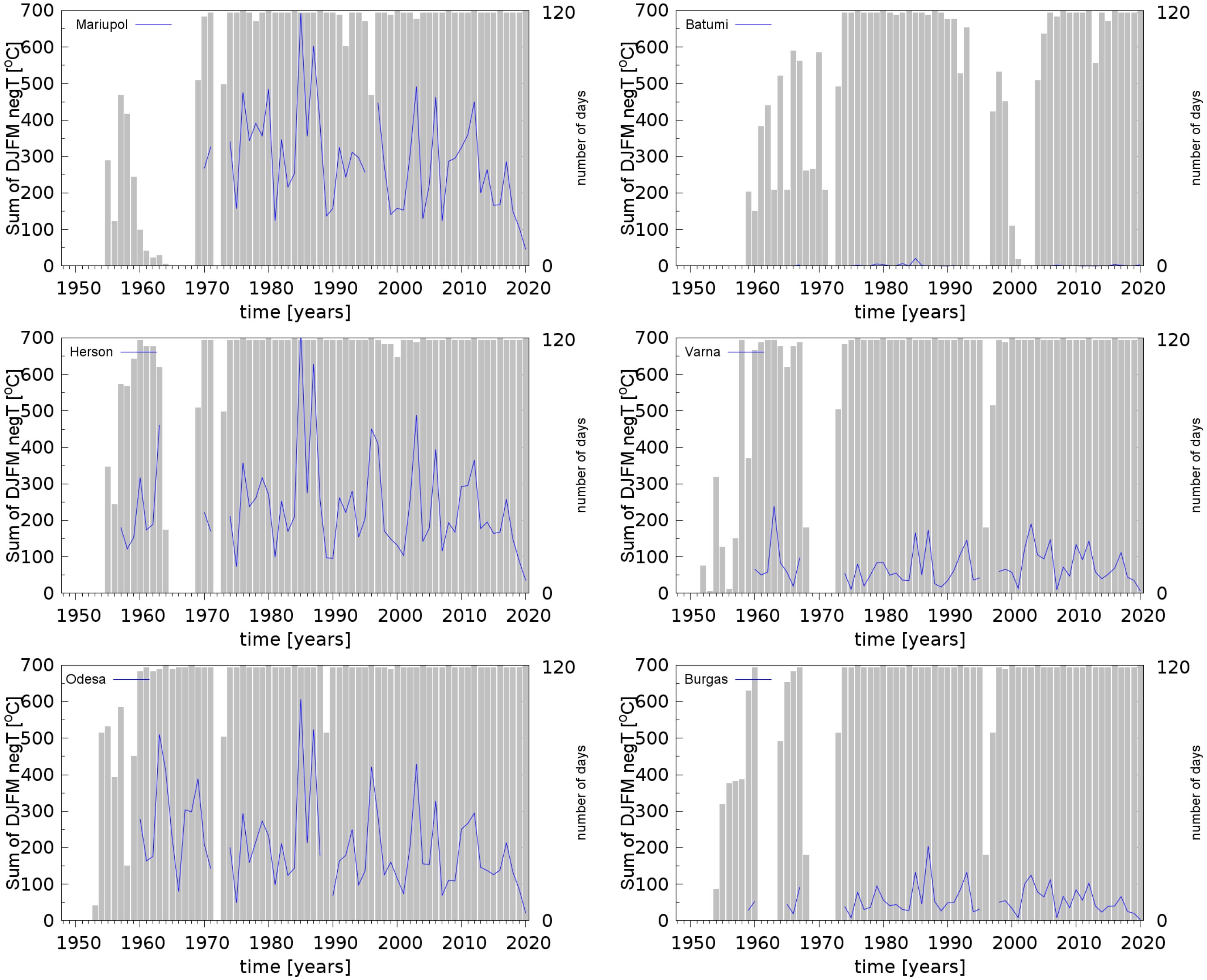
Region covered by MASIE-NH

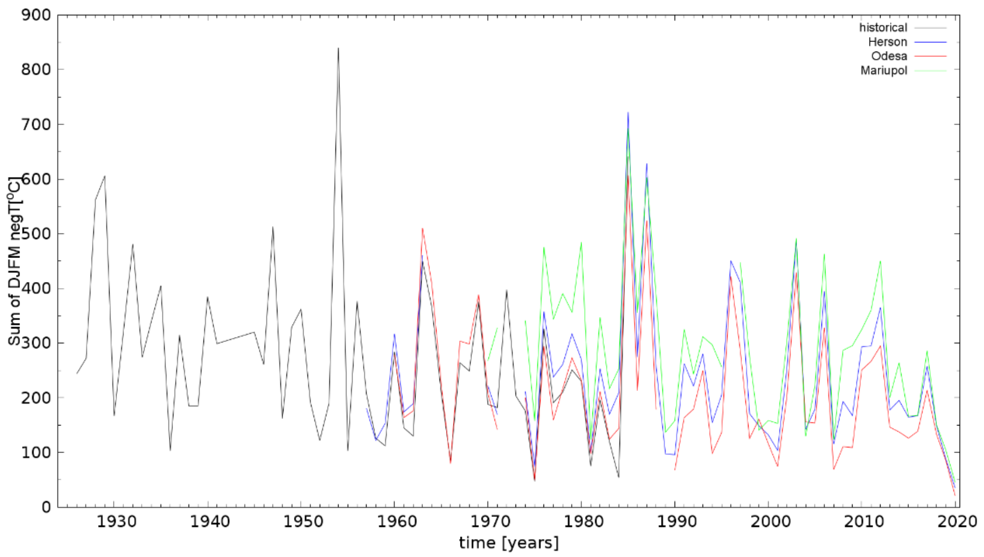
Analysis of the winter temperature (mean value for the months January, February and March) in the 9 meteorological stations

The graphs bellow show significant interannual variability. As expected the north-coast stations (Odesa, Herson and Mariupol) are much colder than the south ones (Istanbul, Sinop and Trabzon), and the one eastern (Batumi) is similar to the south ones. Burgas and Varna winter temperature on the west coast is in between. Overall, the variations in the 9 stations are very similar and in phase, suggesting that the winter conditions are uniform in the entire area. Interesting fact to notice also is the slight tendency for milder winter.



Winter intensity is estimated by the sum of the negative temperatures during the period December, January, February and March. In Odesa, Mariupol and Herson every winter the temperature falls bellow zero, on the contrary - in Istanbul, Sinop and Trabzon very rare (not shown here). Burgas and Varna on the west coast are similar to the north but Batumi on the east is like the southern stations.





Winter intensity (WI) in the period 1925-2020.

The graphs above combines the historical data for the northern coast of the Black Sea with the synoptic measurements in Odesa, Herson and Mariupol for the near past period. There is an overlapping period 1960-1985, where it is seen that the curves evolve very similar. The conclusion is that we can use the three chosen stations to represent long-term variations in the winter conditions in the area.

Only the severe winter cause negative temperatures in Istanbul, Sinop, Trabzon and Batumi. Such winter was for example the 1984/1985. In the past decade the relatively cold winters were the 2002/2003, 2005/2006, 2011/2012 and 2016/2017. An extremely cold winter was 1953/1954.

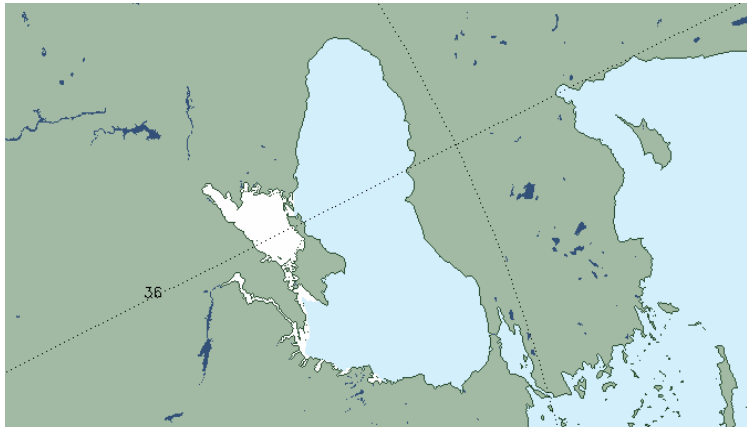
The analysis shows that the "cold" weather in winter decreases from north to south and from west to east: the freezing days are almost absent in the Trabzon station.

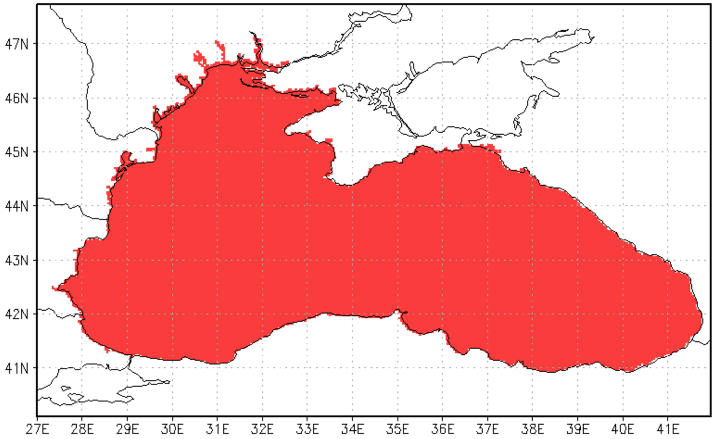
Another interesting observations is that the negative trend after 2000. Also, the peaks in the last three decades decrease in height. This definitively reflects the warming trend in the period.

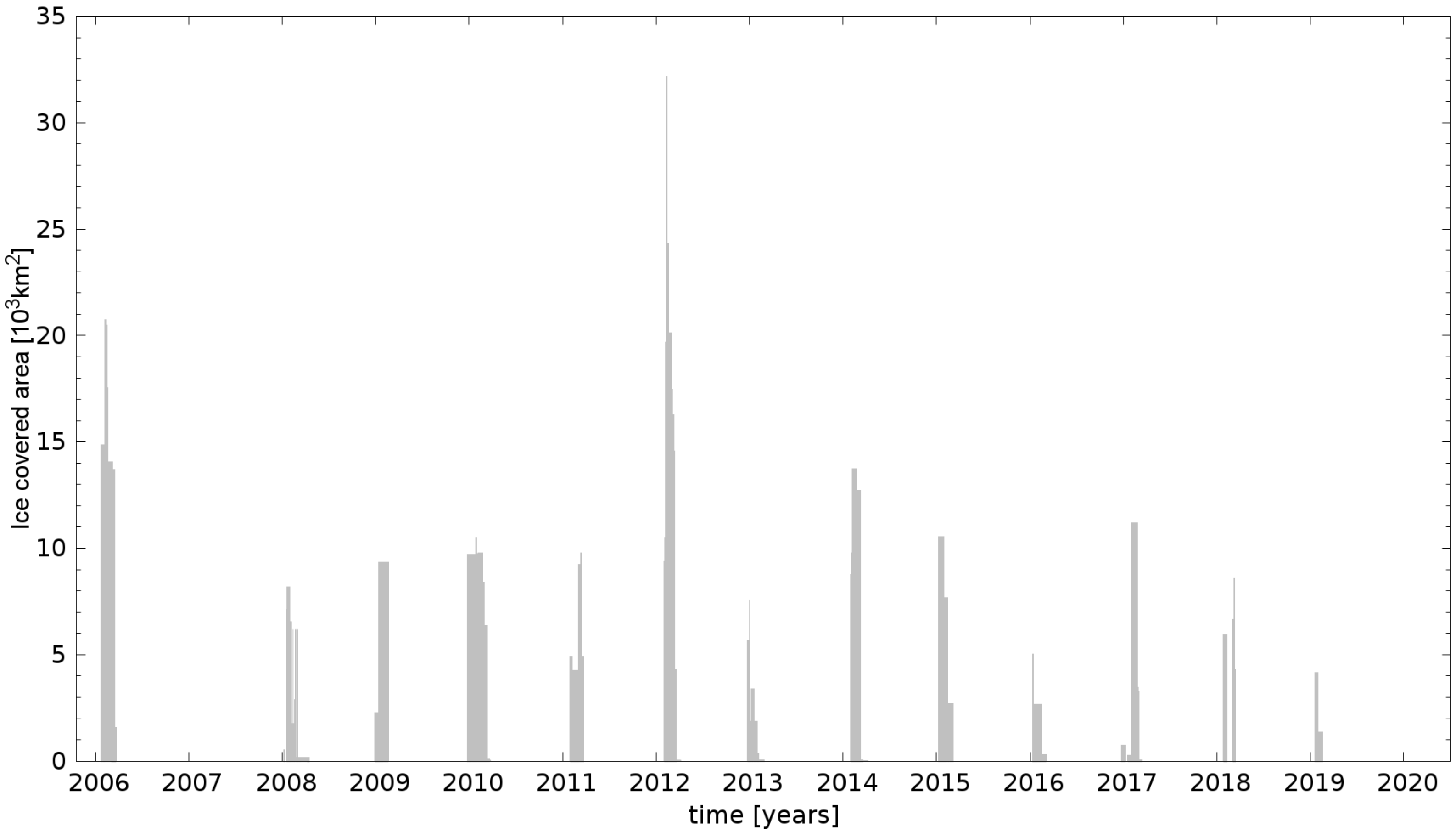
Analysis of the sea ice extent variability.

Data for the ice extent are taken from the US National Snow and Ice Data Center product Multi-sensor Analyzed Sea Ice Extent - Northern Hemisphere (MASIE-NH). This provides daily sea ice data from January 1st, 2006 to the present. The satellites used for this research are ALOS, AQUA, DMSP, ENVISAT, GOES, MSG, and RADARSAT-2. Parameters measured by these sensors include sea ice, ice edges, ice extent, and ice growth/melt. Spatial coverage in the study is the entire Northern Hemisphere specified as N 90° to N 0° and E 180° to W - 180°. Raster data pixels (grid cells) are 4 km x 4 km thus 16 km^2 each (MASIE, Technical References).

The available geotiff image in polar stereographic projection is processed to Mercator projection and using the mask for the Black Sea pixels, only the “sea” pixels with ice are counted. Thus the average and maximal sea ice extent for the four months in the winter season (December to March) are calculated. One can note that the mas contains also the lakes and the major rivers estuaries. The results are shown on the right graph for each daily image. In 2007 winter no ice was observed, and maximal area is reached in February 2012 but for relatively short period. The ice coverage in 2006 and 2010 for example is less than that in 2012, but stays for a longer period of time. The conclusion is that almost every year freezing in the north Black Sea occurs.







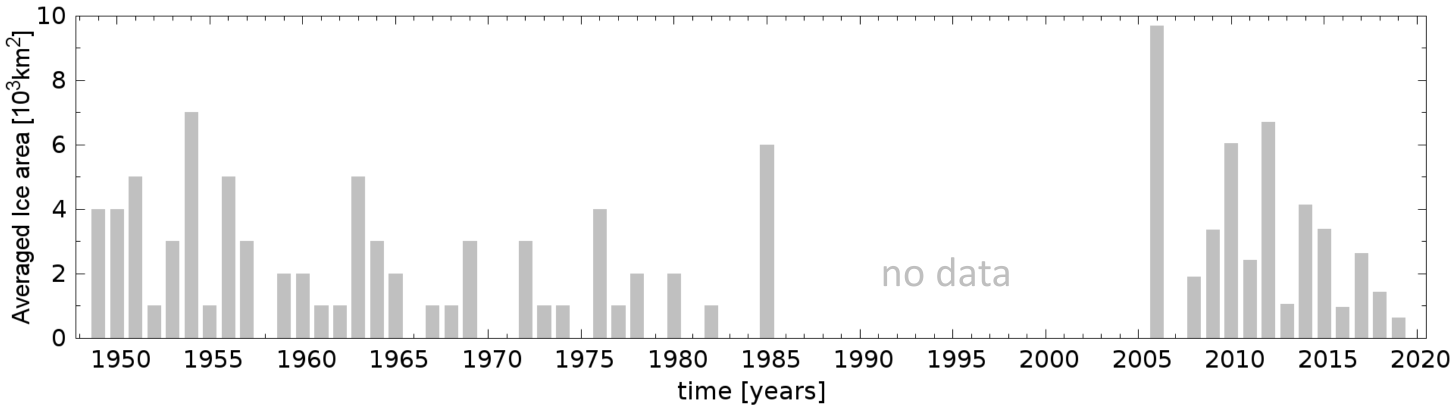
Averaged and maximal ice extent variability.

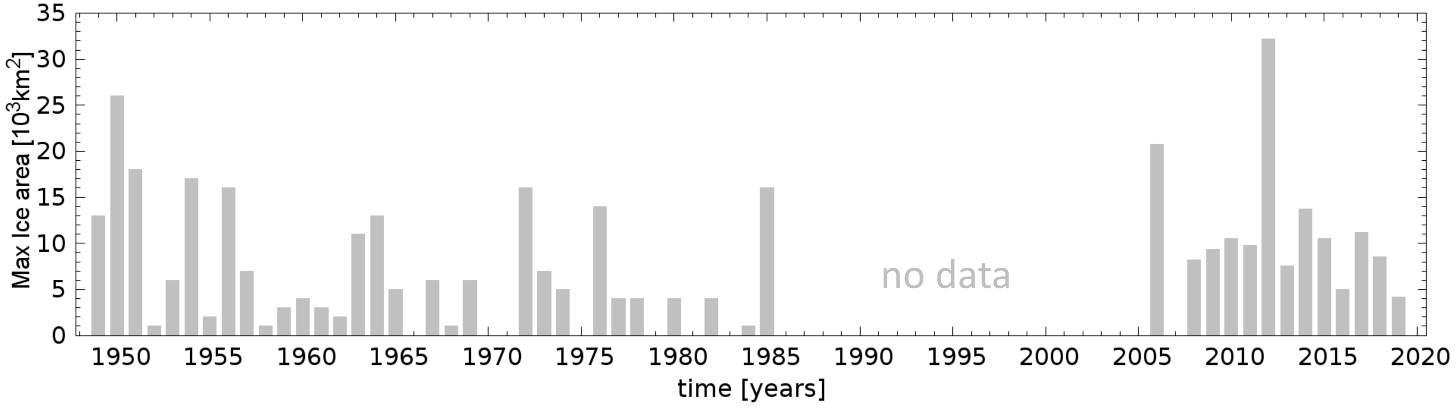
The plot bellow shows combined historical data from 1950-1985 for sea ice extend and data from MAISIE-NH in the period 2006-2020, processed as described in the previous slide. Nevertheless global warming trend, it is clear that the freezing occurs rather regularly which leads to the conclusion that it is result from synoptic situations rather than the seasonal averages.

The variation in the ice extent are in agreement with the variations of the winter intensity (the sum of the freezing days temperature with opposite sign). This allows us to make a classifications of the winter in the region using the extend of the ice and the threshold values for the winter intensity as in the table.

WI value	Winter type
[0, 200]	Mild
[200, 400]	Moderate
[400, -]	Cold

In the right the winter in the 1926 to 2020 are listed and the type according to the above classification is given. Note that since 2003 no “cold” winter conditions are observed, and the relative colder moderate winters are classified as Moderate*.

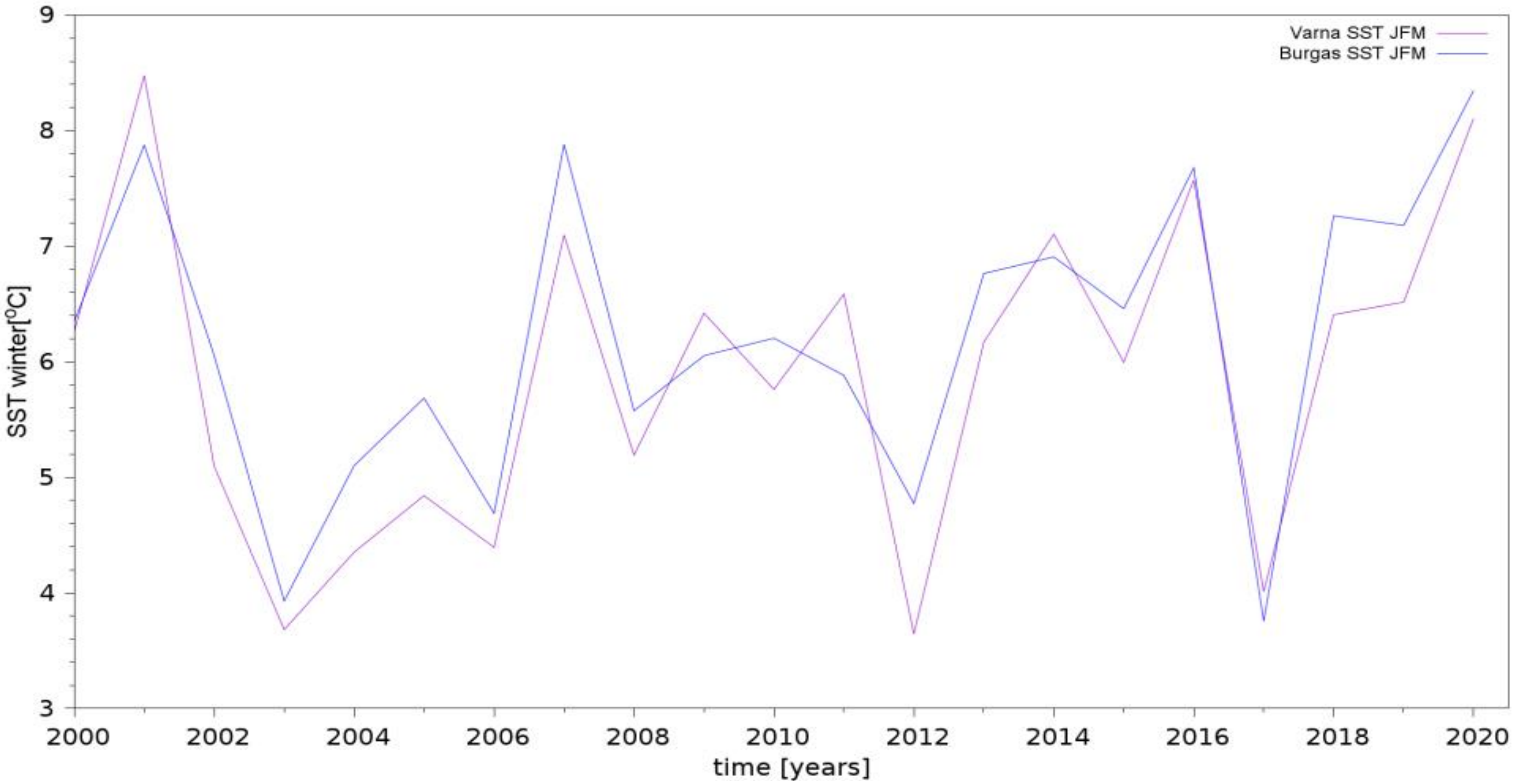




Year	Winter type	1959	Mild	1990	Mild
1926	Moderate	1960	Moderate	1991	Moderate
1927	Moderate	1961	Mild	1992	Moderate
1928	Cold	1962	Mild	1993	Moderate
1929	Cold	1963	Cold	1994	Mild
1930	Mild	1964	Moderate	1995	Moderate
1931	Moderate	1965	Moderate	1996	Cold
1932	Cold	1966	Mild	1997	Cold
1933	Moderate	1967	Moderate	1998	Mild
1934	Moderate	1968	Moderate	1999	Mild
1935	Cold	1969	Moderate	2000	Mild
1936	Mild	1970	Mild	2001	Mild
1937	Moderate	1971	Mild	2002	Moderate
1938	Mild	1972	Moderate	2003	Cold
1939	Mild	1973	Moderate	2004	Mild
1940	Moderate	1974	Mild	2005	Mild
1941	Moderate	1975	Mild	2006	Moderate*
1945	Moderate	1976	Moderate	2007	Mild
1946	Moderate	1977	Mild	2008	Mild
1947	Cold	1978	Moderate	2009	Mild
1948	Mild	1979	Moderate	2010	Moderate
1949	Moderate	1980	Moderate	2011	Moderate
1950	Moderate	1981	Mild	2012	Moderate*
1951	Mild	1982	Mild	2013	Mild
1952	Mild	1983	Mild	2014	Mild
1953	Mild	1984	Mild	2015	Mild
1954	Cold	1985	Cold	2016	Mild
1955	Mild	1986	Moderate	2017	Moderate
1956	Moderate	1987	Cold	2018	Mild
1957	Moderate	1988	Moderate	2019	Mild
1958	Mild	1989	Mild	2020	Mild

Sea surface temperature variation

The available data from synoptic daily measurements of the sea surface temperature (SST) in Burgas and Varna meteorological stations allow us to calculate the winter months mean SST for the period 2000-2020. The winter months are taken from January to March. The two curves show rather similar in-phase behavior: in Varna the winter SST is generally lower but not always. The comparison of SST with the sea-ice cover together with the winter air temperature and WSI variation reveals that the different sources of data confirm the anomalous cold and warm years: the winters in 2003, 2012 and 2017 were especially cold and on the contrary, the winters in 2001, 2007 and 2020 were very warm.



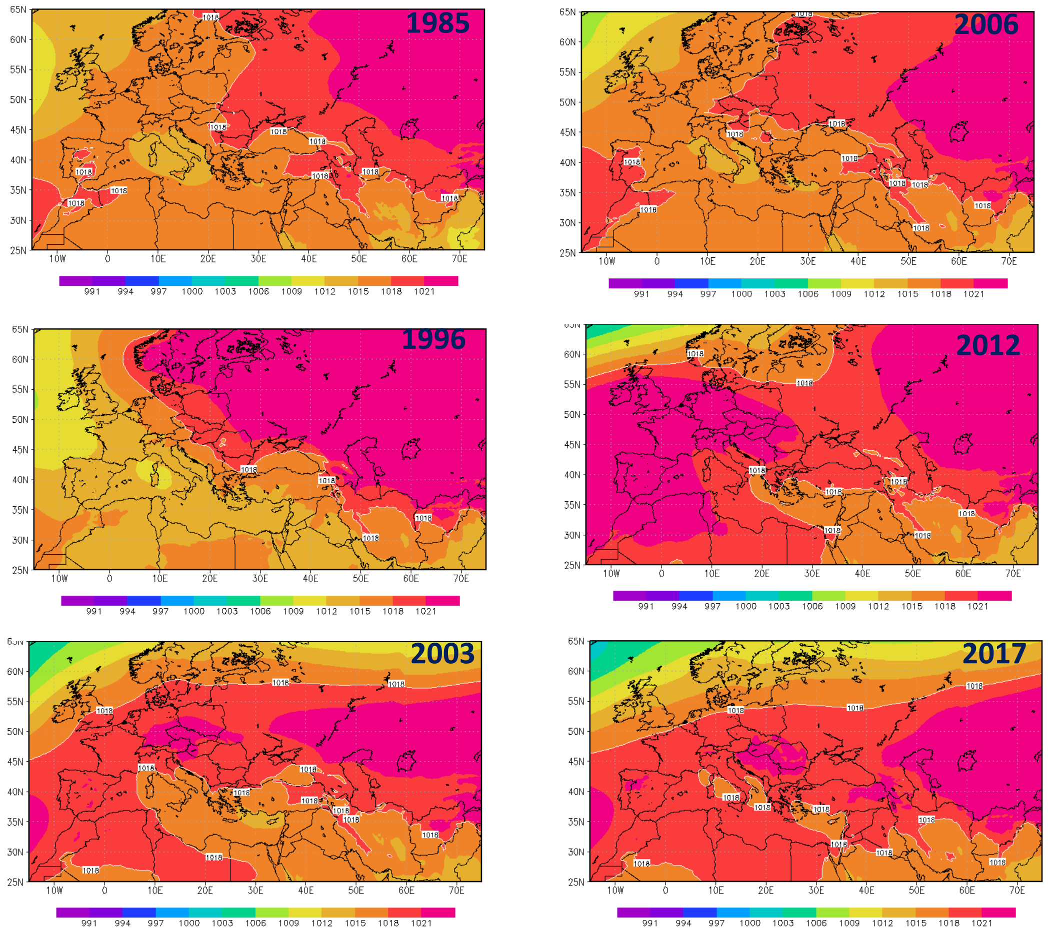
The influence of the Siberian High

From the winter classification it could be noted that “cold winter” conditions usually last only one season and the following winter is either mild or moderate. Rarely there are two cold winters in sequence. In this region the very cold synoptic situations are due to the Siberian High expanding to the west and reaching the Central Europe.

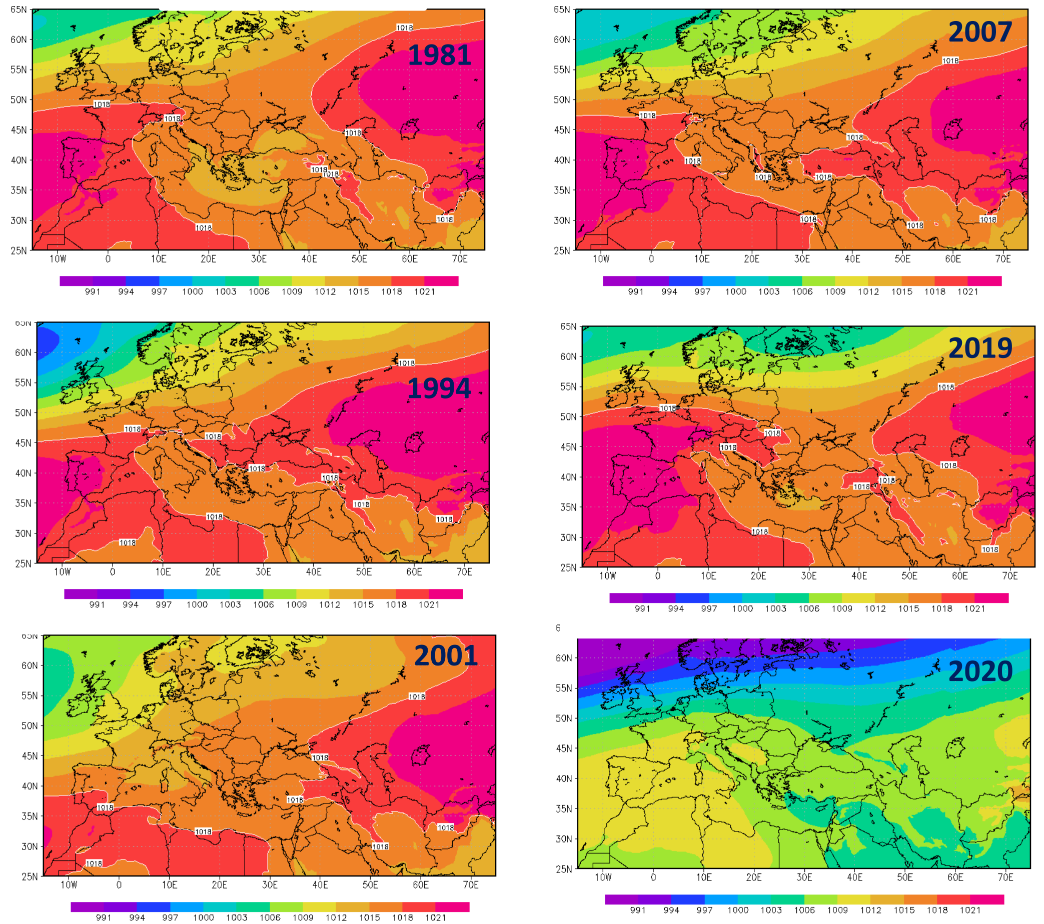
That is why we examined the seasonal mean sea level pressure for several years with anomalous cold and warm situation. It appears that in the “cold” winters the Siberian High expanded over the Black Sea region, and on the contrary in “mild” winter conditions the Siberian High is less intense. There is a mean difference of 3 HPa for the two different part and about 300 in the Winter Intensity. The position and intensity of the Siberian anticyclone is also shown as the 1018 isobar. One can conclude that the the “cold” winter are associated with intense Siberian High expanding over Northeastern Europe, and the “mild” winter – with less intense Siberian High and more intense Iceland and Arctic Low.

“Cold” Winter			“Mild” Winter		
year	$MSLP_{mean}$	WI	year	$MSLP_{mean}$	WI
1985	1018.52	641	1981	1015.9	75
1987	1018.09	524	1990	1021.53	70
1996	1019.83	423	1994	1018.81	98
2003	1019.42	436	2001	1017.53	74
2006	1017.92	328	2007	1017.46	69
2012	1019.27	295	2019	1016.91	85
2017	1020.15	215	2020	1006.31	20
mean	**1019.02**	**409**	**mean**	**1016.35**	**70**

“Cold” Winter



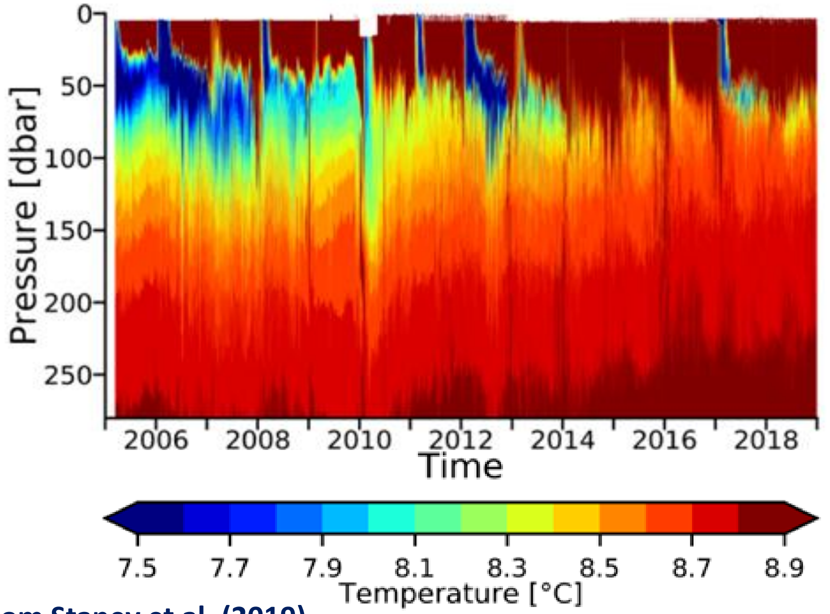
“Mild” Winter



Black Sea respond to atmospheric variations

The Black Sea has peculiar characteristics regarding the vertical stratification and it responds to the atmospheric thermal regime in a unique way: the winter cooling of surface water triggers the winter convection and the formation of the cold intermediate layer (CIL). The colder the winter, the thicker this layer. Stanev et al. (2019) showed that in the last 15 years the CIL constantly diffuses, fed only in the cold winters, 2006, 2012 and 2017. This is in accordance with the results from the previous slides.

Then the question is what is the feedback: the Black Sea “dumps” the seasonal signal amplitude and perhaps this is the reason to observe single “cold” winter conditions. This analysis requires further attention.



From Stanev et al, (2019)

CONCLUSIONS AND FUTURE PLANS

- We have used synoptic observations from 9 coastal Black Sea meteorological stations in order to analyze the interannual-to decadal variations in the mean winter temperature . Our study shows that the variations are very similar and in phase, suggesting that the winter conditions are uniform in the entire area.
- There is a slight tendency for milder winter in the last 4 decades in all 9 stations.
- Along the north coast (Odesa, Mariupol and Herson) every winter the temperature falls bellow zero, and along the south coast (Istanbul, Sinop, Trabzon and Batumi) only the severe winter cause negative temperatures. For example - 1984/1985 was extremely cold and in the past two decades there are 4 very cold winters - 2002/2003, 2005/2006, 2011/2012 and 2016/2017.
- The sum of daily negative temperatures with opposite sign for the winter season is used to define the winter intensity (WI). It presents a negative trend after 2000 reflecting the global warming tendency.
- Satellite observations are used to estimate the sea ice cover area and it is found that in the north part freezing is observed rather regularly. In 2007 winter no ice was observed, and maximal area is reached in February 2012 but for relatively short period. The ice cover in 2006 and 2010 for example is less than that in 2012, but stays for a longer period of time. The conclusion is that the freesing results from extremely cold synoptic situations rather than seasonal extreme.
- The variation of the winter season ice extent are in agreement with the variations of the winter intensity estimated from the temperature. The two data time-series were used to classify the winters’ severity in the period 1925-2020 as cold, moderate and mild.
- Since 2003 no real “cold” winter conditions are observed, but 2006, 2012 and 2017 are cool.
- Analysis of the winter mean sea level pressure for the climate reanalysis ERA5 leads to the conclusion that the “cold” winter conditions are associated with intense Siberian High expanding over Northeastern Europe, and the “mild” – with less intense Siberian High and more intense Iceland and Arctic Low.
- The winter 2019/2020 is anomalous, the mildest from the analyzed period and the MSLP field shows unusual position of the climate centers of action. Future analysis is foreseen to investigate thorough the impact of the Siberian High, as well as the “buffer” role of the Black Sea.

REFERENCES

National Ice Center and National Snow and Ice Data Center. Compiled by F. Fetterer, M. Savoie, S. Helfrich, and P. Clemente-Colón. 2010, updated daily. *Multisensor Analyzed Sea Ice Extent - Northern Hemisphere (MASIE-NH), Version 1*. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: https://doi.org/10.7265/N5GT5K3K. [May 6th 2019].

Simonov A. and Altman E (eds), 1991, Hydrometeorology and Hydrochemistry of the USSR Seas. Vo. IV. Black Sea. Issue 1. Gidrometeoizdat, St. Petersburg (in Russian)

Stanev, Emil V., et al. “Climate Change and Regional Ocean Water Mass Disappearance: Case of the Black Sea.” Journal of Geophysical Research: Oceans, July 2019, p. 2019JC015076. DOI.org (Crossref), doi:10.1029/2019JC015076.