Wind wave regime of eastern European seas

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ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

RFBR


Longitude East 15° of Greenwich
30° East
45° East
60° East
North Cape
Magerøya
Sørøya
Lopphavet
Hammerfest
Vardø
Vadsø
Tromsø
Jan Mayen
(Norway)
NORWEGIAN SEA
ARCTIC CIRCLE
Vesterålen
Lofoten
Vestfjorden
3,753 ft.
6,936 ft.
Kebnekaise
Kiruna
Lake Inari
Tana
Murmansk
Lake Imandra
Kola
Peninsula
Scandinavia
Lapland
Mezhdusharskiy I.
New Zemlya
Kara Strait
Vaygach I.
Kolguyev I.
Cape
Kanin Nos
Chesha Bay
Nar'yan Mar
Vorkouta
WHITE SEA
Luleå
Oulu
Lake Oulu
Kemi
SWEDEN
Umeå
FINLAND
Gulf of Bothnia
Vaasa
Lakes Region
Trondheimsfjorden
Trondheim
5,892 ft.
Sundsvall
Ålesund
NORWAY
8,100
Galdhøpiggen
Pori
Tampere
Åland
Turku
HELSINKI
Lake Ladoga
Lake Onega
Lake Vyg
Petrozavodsk
Arkhangel'sk
Mezen'
Pechora
6,217 ft.
RUSSIAN FEDERATION
Ural Mountains
Faroe Islands
(Denmark)
Suduroy
Shetland Islands
(U.K.)
Bergen
OSLO
Drammen
STOCKHOLM
Gulf of Finland
TALLINN
ESTONIA
Lake Peipus
Petersburg
Lake Beloye
Sukhona
Severnaya Dvina
Syktyvkar
Vologda
Viatka
Kudymkar
Kama Reservoir
Orkney Islands
Isle of Lewis
Wick
Boknafjorden
Stavanger
Kristiansand
Skagerrak
Vänern
Vättern
Norrköping
Göteborg
Gotland
Novgorod
Rybinsk Reservoir
Iaroslavl
Kostroma
Nijni Reservoir
Perm'
Pskov
LATVIA
RIGA
Ivanovo
Nizhniy Novgorod
Yoshkar-Ola
Izhevsk
Yekaterinburg
SCOTLAND
Aberdeen
NORTH
SEA
Hebrides
Perth
Glasgow
Edinburg
British Isles
UNITED KINGDOM
ULSTER
Belfast
Newcastle
DENMARK
COPENHAGEN
Malmö
Kalmar
Oland
BALTIC SEA
KALININGRAD
(RUSSIAN FED.)
Gdansk
LITHUANIA
VILNIUS
MINSK
Tver
MOSCOW
Vladimir
Smolensk
Ryazan'
Kaluga
Tula
Cheboksary
Kazan'
Kama
Samara Reservoir
Simbirsk
Saransk
Tol'yatti
Ufa
Chelyabinsk
IRELAND
DUBLIN
Liverpool
Manchester
WALES
ENGLAND
Birmingham
Cork
Cardiff
LONDON
CELTIC SEA
Plymouth
Southampton
English Channel
Le Havre
Brest
Rennes
Nantes
Frisian Is.
NETHERLANDS
AMSTERDAM
Rotterdam
Hamburg
BERLIN
POLAND
WARSAW
BELARUS
Pripet
Gomel'
Bryansk
Orel
Penza
Saratov Reservoir
Samara
Orenburg
Oral
Ural'sk
Kursk
Lipetsk
Tambov
Saratov
Volga
Dusseldorf
Antwerp
BRUSSELS
Lille
BELGIUM
GERMANY
Frankfurt
Leipzig
Elbe
Oder
Vistula
PRAGUE
CZECH REP.
Krakow
Lviv
KIEV
Belgorod
Kharkiv
Voronezh
Aktyubinsk
Dnieper
Don
Volgograd
KAZAKHSTAN
PARIS
LUX.
Seine
Stuttgart
Strasbourg
Munich
Danube
VIENNA
BRATISLAVA
SLOVAKIA
Carpathians Mts.
MOLDOVA
CHISINAU
Dnipropetrovsk
Donetsk
UKRAINE
Rostov-na-Donu
Caspian Depression
FRANCE
Loire
BERNE
LIECHT.
SWITZ.
Geneva
AUSTRIA
BUDAPEST
HUNGARY
ROMANIA
Odesa
Sea of Azov
Krimea
Krasnodar
Elista
Atyrau
Astrakhan'
Aral Sea
Lyon
15,781 ft.
Mt Blanc
Milan
Alps
SLOVENIA
LJUBLJANA
ZAGREB
Venice
BELGRADE
BUCHAREST
Sebastopol
Stavropol'
Maykop
18,510 ft.
Elbrus
Bay of Biscay
Bordeaux
Massif Central
Rhone
Turin
Florence
CROATIA
BOSNIA & H.
SARAJEVO
SERBIA
Danube
BLACK SEA
Caucasus
Groznyy
Makhachkala
UZBEKISTAN
Nukus
Toulouse
Montpellier
Nice
M.C.
Marseille
Pyrenees
11,168 ft.
Aneto
AND.
Bilbao
Vigo
Valladolid
Douro
Zaragoza
Ebre
Gulf of Lions
Corsica
S. M.
ITALY
VAT.
ROME
ADRIATIC SEA
MONTENEGRO
PODGORICA
KOSOVO
SKOPJE
F.Y.R.O.M.
(Former Yugoslav Rep. of Macedonia)
SOFIA
9,596 ft.
Musala
BULGARIA
Bosporus
Sinop
GEORGIA
TBILISI
CASPIAN
Lake Garabogaz
Urgench
Porto
Coimbra
PORTUGAL
LISBON
MADRID
Tage
Valencia
Barcelona
Balearic Is.
Menorca
Mallorca
Ibiza
SPAIN
Sierra Morena
Córdoba
Naples
Bari
TIRANA
ALBANIA
9,551 ft.
Olympus
Salonica
Istanbul
ANKARA
TURKEY
YEREVAN
ARMENIA
AZERBAIJAN
BAKU
TURKMENISTAN
Turkmenbashi
Kara-Kum
Turkmenabat
16,854 ft.
Mt Ararat
Bursa
Anatolia (Asia Minor)
Izmir
Lake Van
Lake Urmia
15,781 ft.
Tabriz
SEA
ASHGABAT
Mary
Sardinia
Corfu
Seville
11,424 ft.
Mulhachén
Gibraltar (U.K.)
Strait of Gibraltar
Ceuta (Spain)
Tangiers
Mélilla (Spain)
RABAT
Fès
Casablanca
MOROCCO
MEDITERRANEAN SEA
ALGIERS
Annaba
Chlef
Oran
Tlemcen
Constantine
7,336 ft.
ALGERIA
TUNIS
TUNISIA
Sfax
Gabès
Palermo
10,902 ft.
Etna
Messina
Sicily
VALLETTA
MALTA
Peloponnesus
ATHENS
GREECE
AEGEAN SEA
8,340 ft.
Crete
Rhodes
Antalya
Konya
Kayseri
Adana
Mersin
Gaziantep
Tigris
Euphrates
Aleppo
NICOSIA
CYPRUS
10,131 ft.
SYRIA
LEBANON
BEIRUT
DAMASCUS
Al Mawsil
Kirkuk
IRAQ
BAGHDAD
Gorgan
Mt Damavand
18,606 ft.
TEHRAN
Qom
Kermanshah
Salt Desert
IRAN
Mashhad
Herat
AFGH.

Aims & Tasks

The aim is an assessment of wind waves parameters and their multiannual variability on the Black Sea, Baltic Sea and Caspian Sea

Tasks:

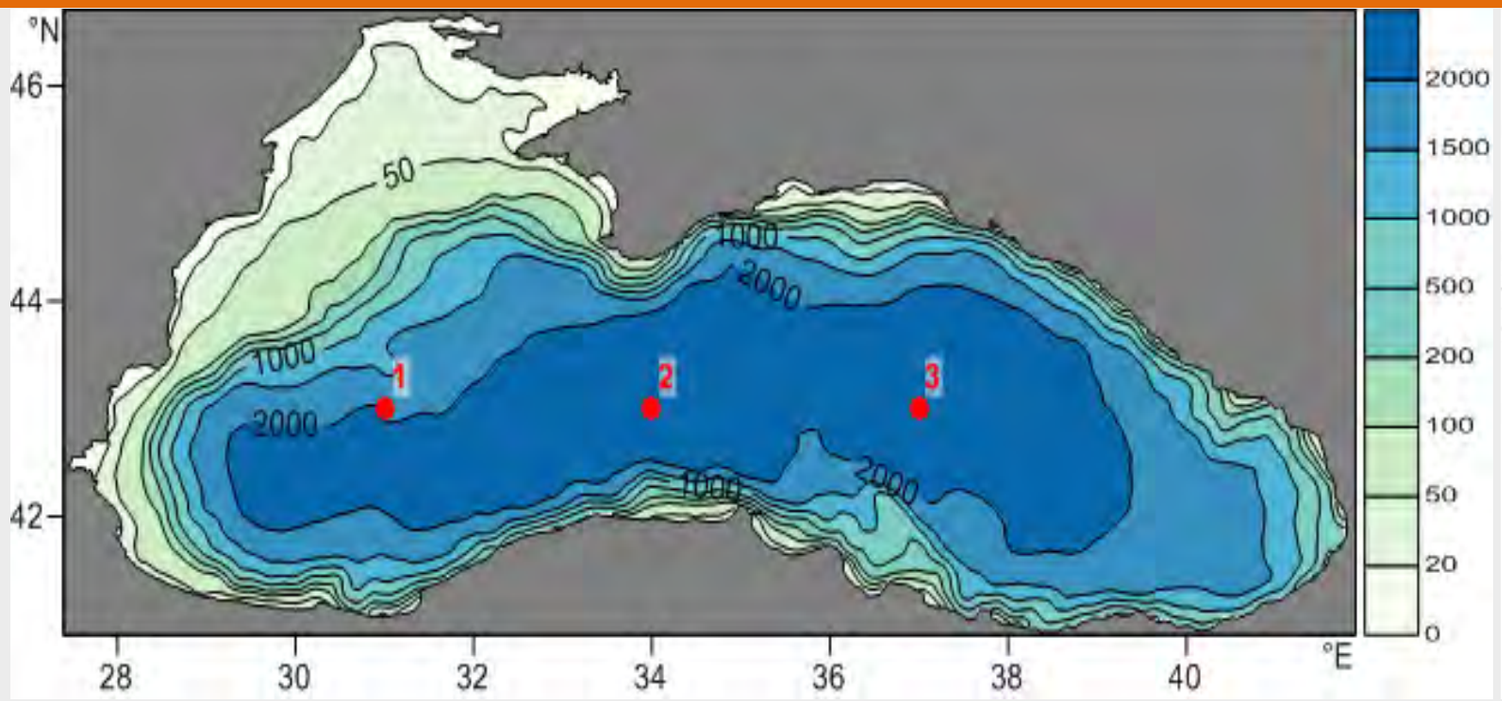
- Preparation of a digital terrain model of the sea's bottom and coasts
- Preparation of a meteorological dataset
- Simulation of wind waves on the seas
- Evaluation of seasonal average and extreme parameters
- Evaluation of multiannual trends
- Analysis and interpretation of results

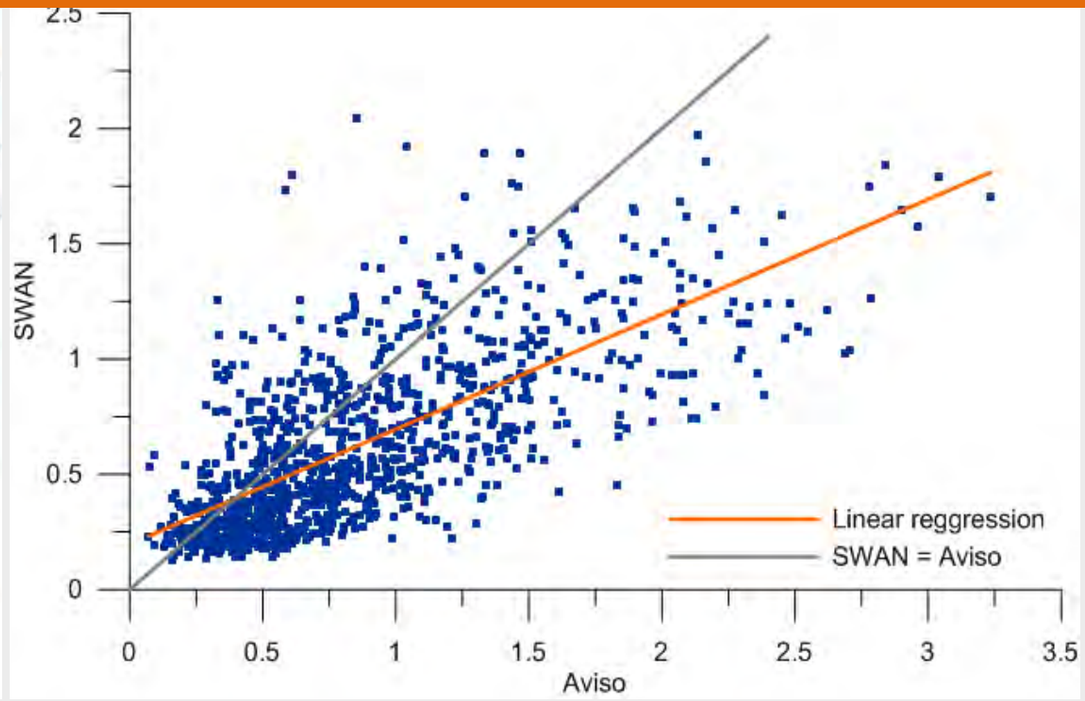
Data & methods

Computational grid	NCEP/NCAR reanalysis	SWAN wind-wave model
❖ *Basis - nautical chars* ❖ *Digitized by Golden Software MapViewer* ❖ *Matrices with 5 km spatial resolution*	❖ *Timespan from 1948 to 2010* ❖ *1,875° × 1,9046° spatial resolution* ❖ *6 h timestep*	❖ *Exponential wave growth [Komen et al., 1984]* ❖ *JONSWAP bottom friction [Hasselmann et al., 1973]* ❖ *Triad wave-wave interactions* ❖ *Diffraction* ❖ *Directional resolution - 1°* ❖ *30 min timestep*

MODEL VALIDATION

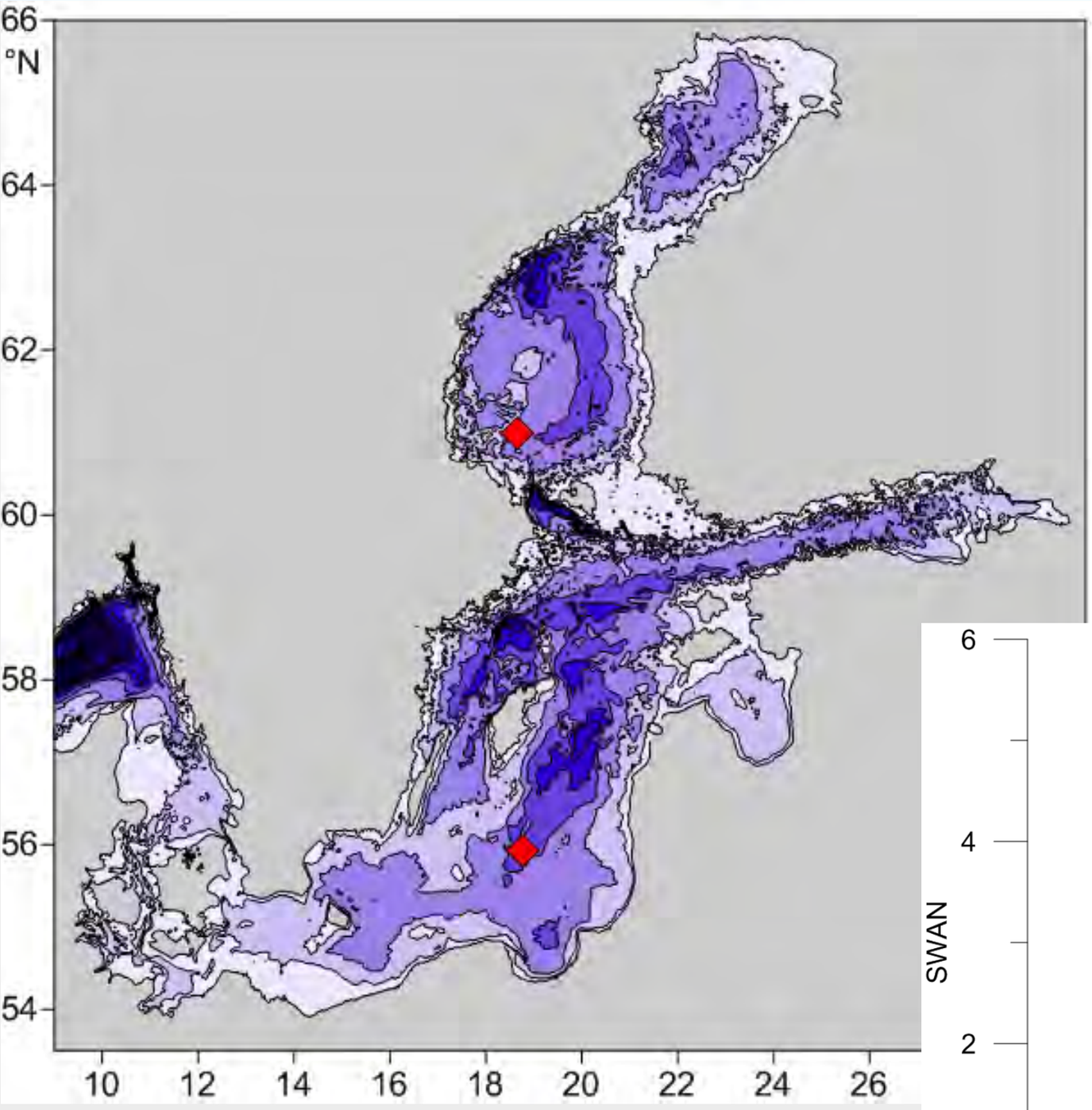
SWAN vs AVISO



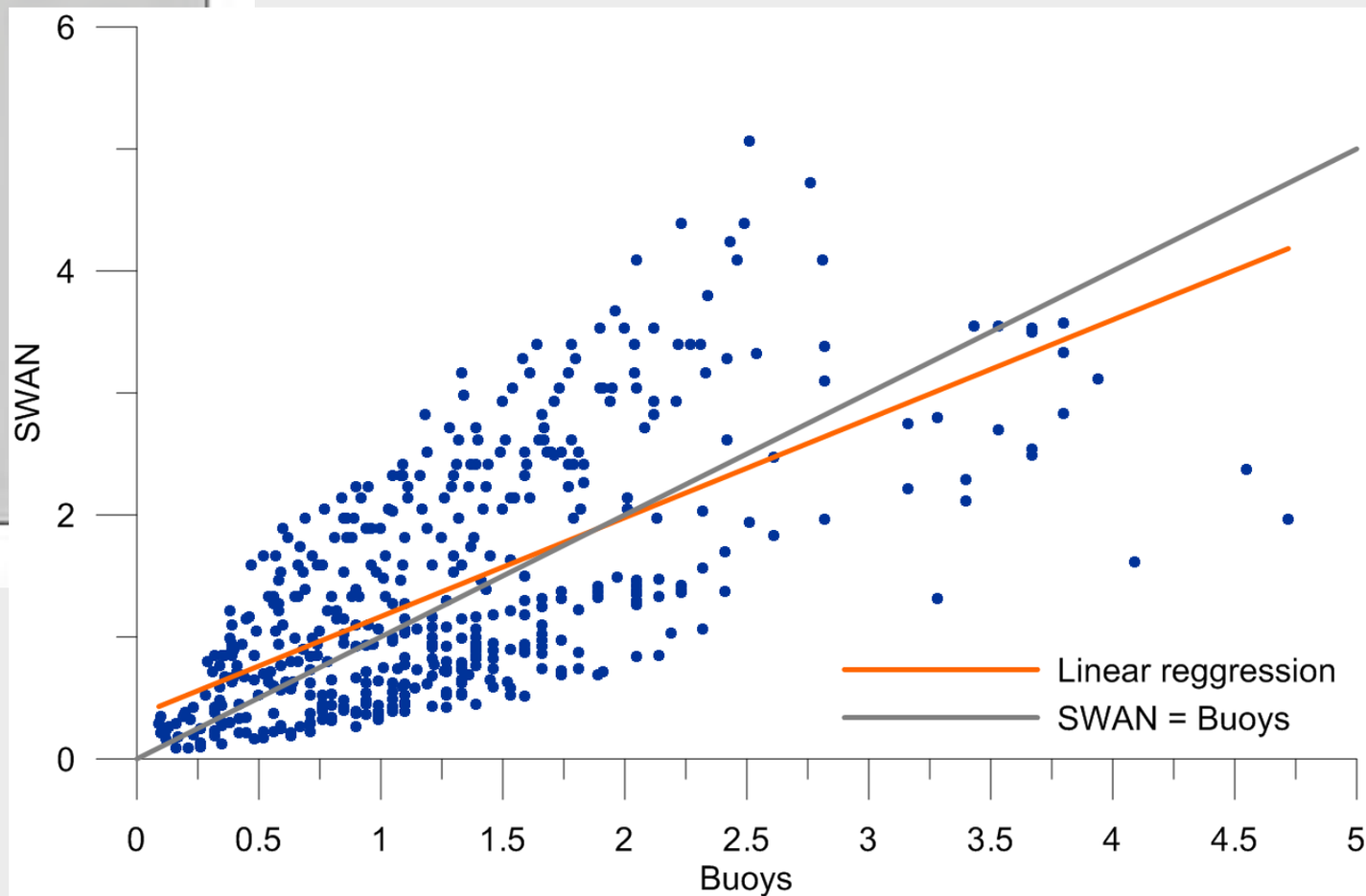


Point #		1	2	3
Coordinates		43° N, 31° E	43° N, 34° E	43° N, 37° E
Maximal observed 5-day average SWH		3.2363	2.8370	2.6223
Maximal calculated 5-day average SWH		1.9205	2.0455	1.5582
Average observed 5-day average SWH		0.8908	0.8569	0.8211
Average calculated 5-day average SWH		0.6368	0.6576	0.5745
Minimal observed 5-day average SWH		0.0708	0.1293	0.1389
Minimal calculated 5-day average SWH		0.1300	0.1427	0.1568
Deviation between observed and calculated 5-day average SWH	Maximal	1.6690	1.5245	1.5400
	Average	0.3423	0.3144	0.3256
	Standard deviation	0.3061	0.2817	0.3006
	Minimal	0.0007	0.0039	0.0017
Correlation coefficient (95% confidence)		0.7258	0.7149	0.7022

SWAN vs buoys



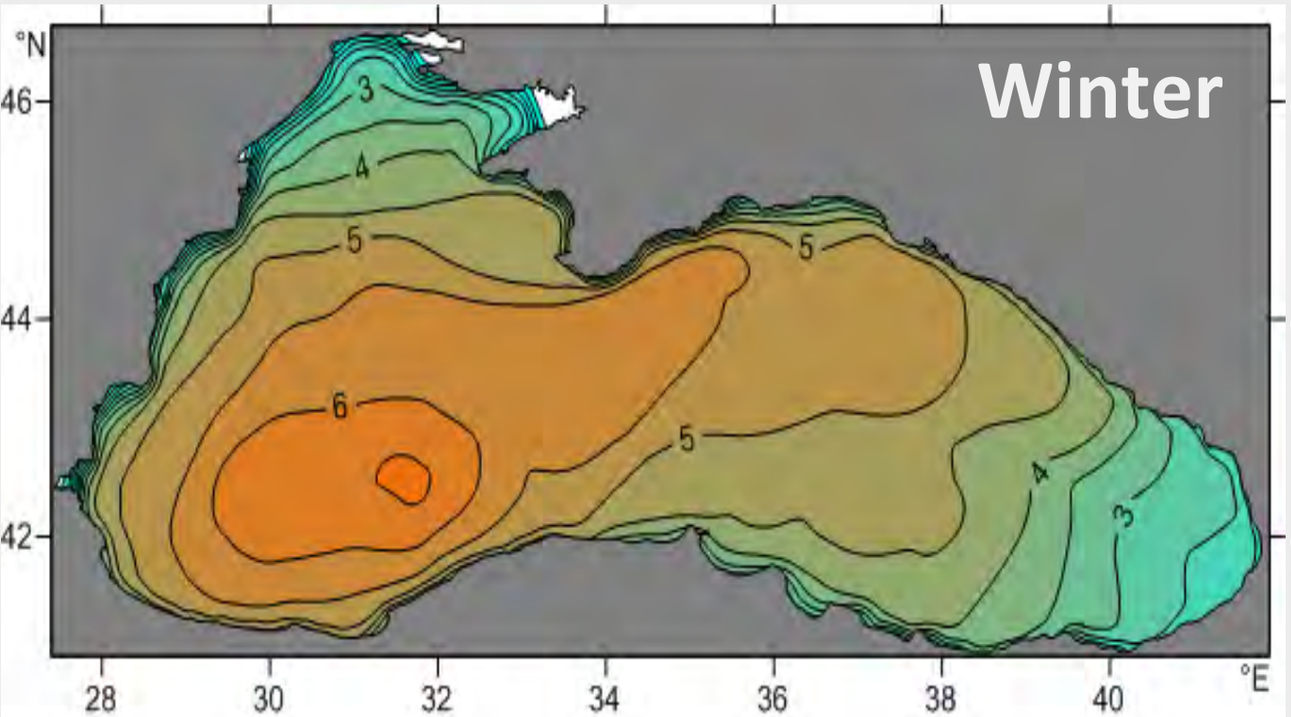
Deviation between modelled and observed SWH	Maximal	2,76
	Average	0,63
	Std. deviation	0,45
	Minimal	0,01

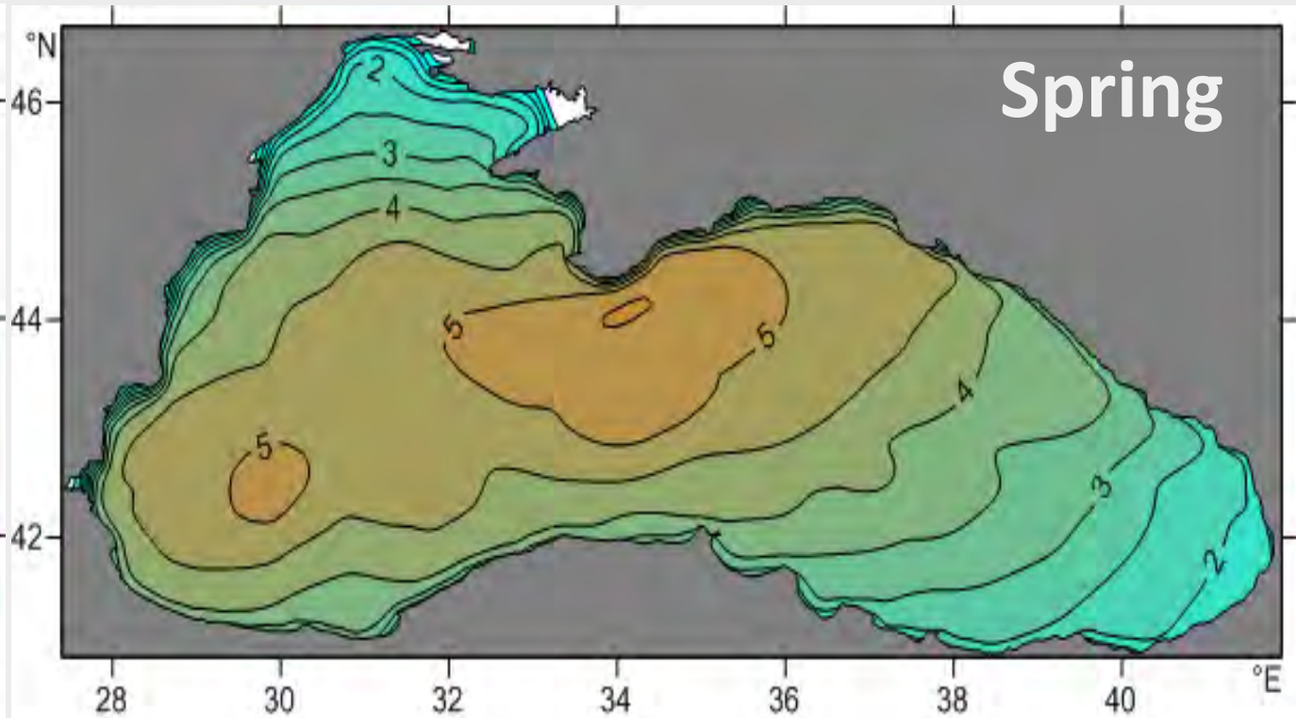


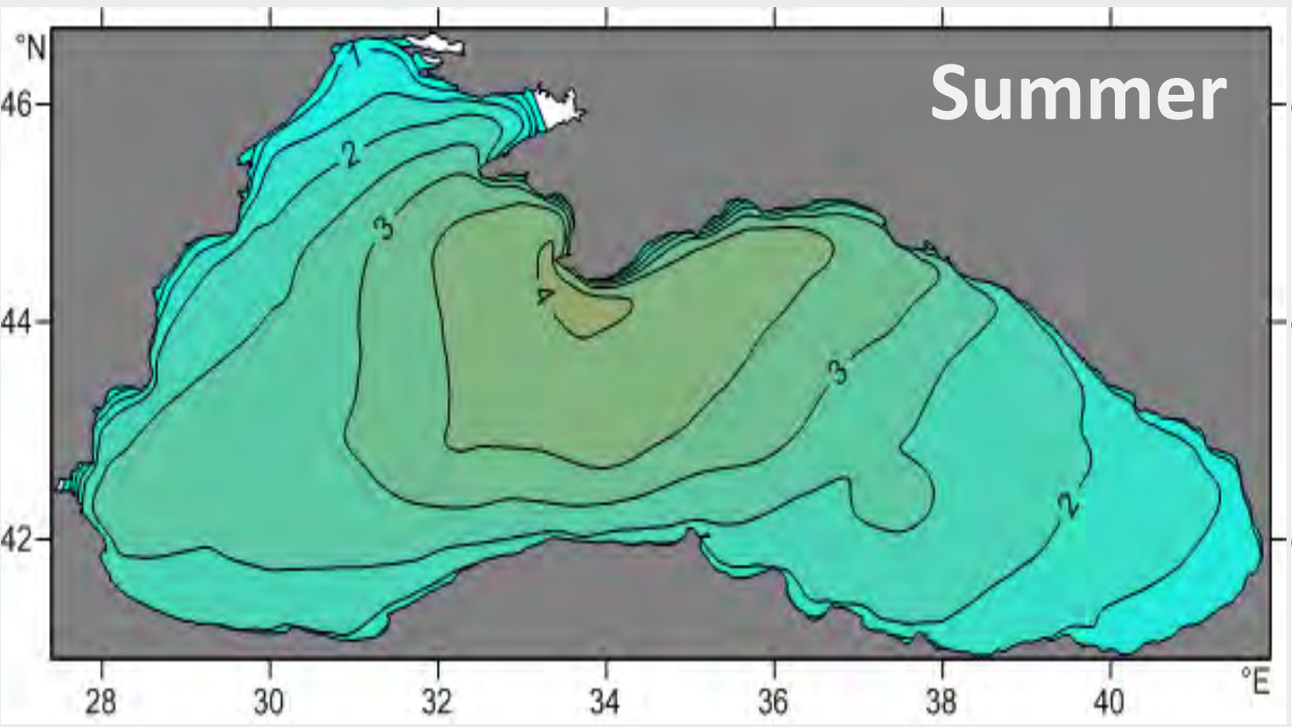
ecDS
Environment Climate Data Sweden

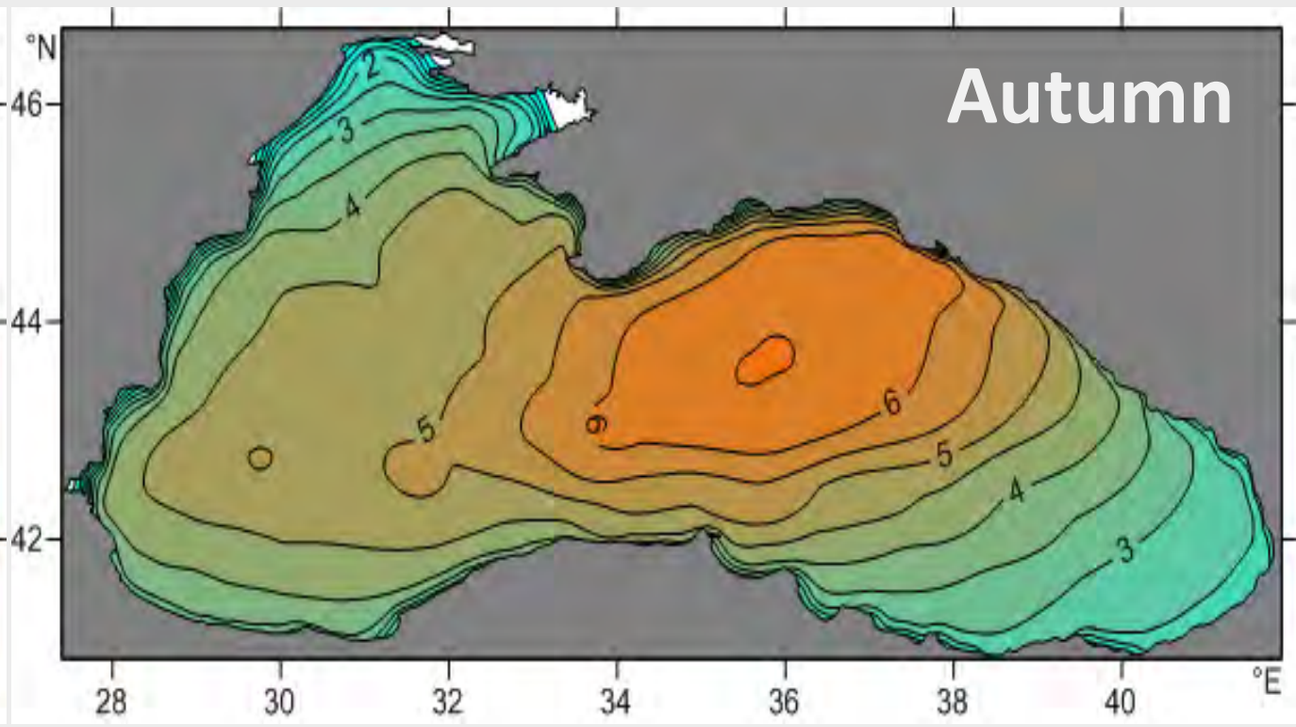
RESULTS

Seasonal SWH maxima on the Black Sea

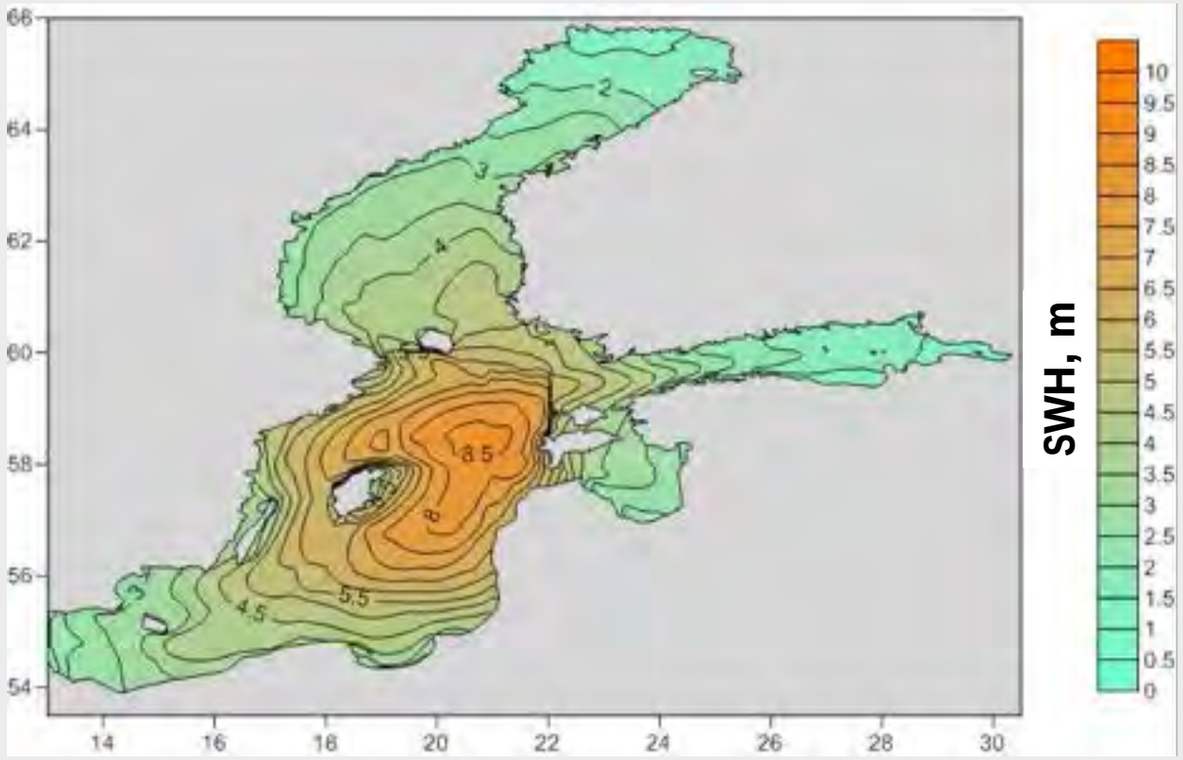


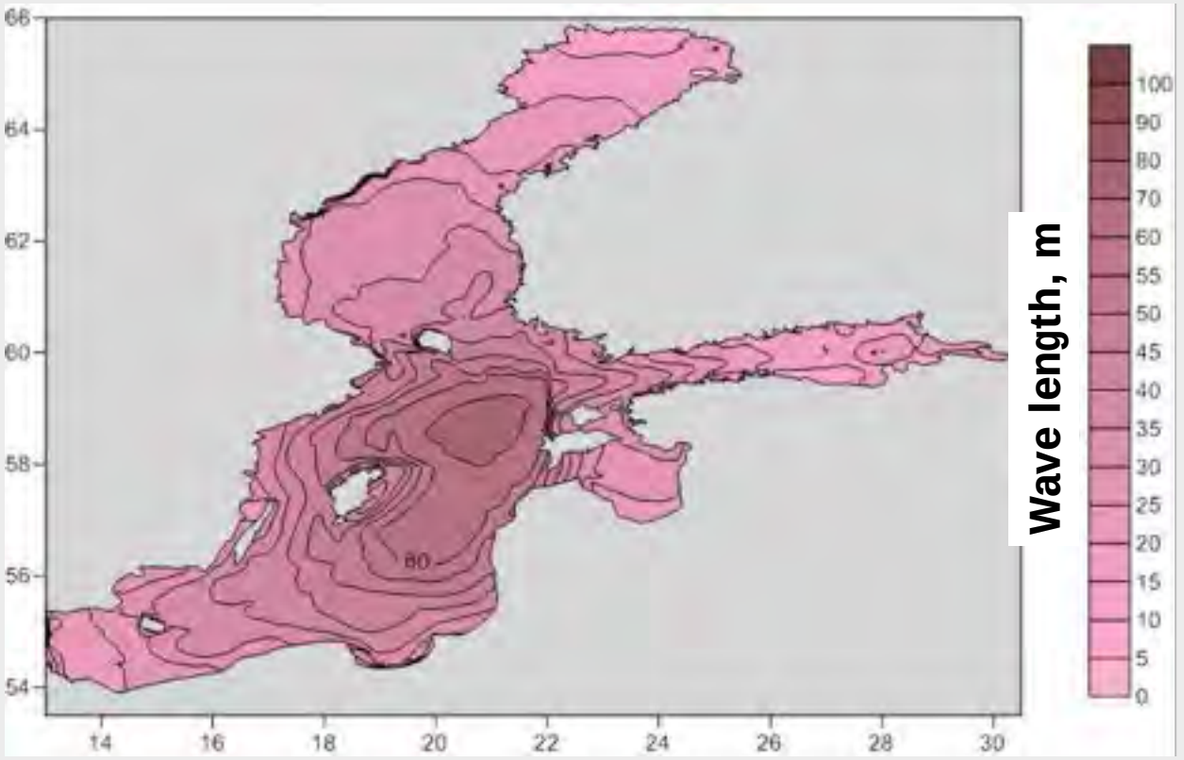


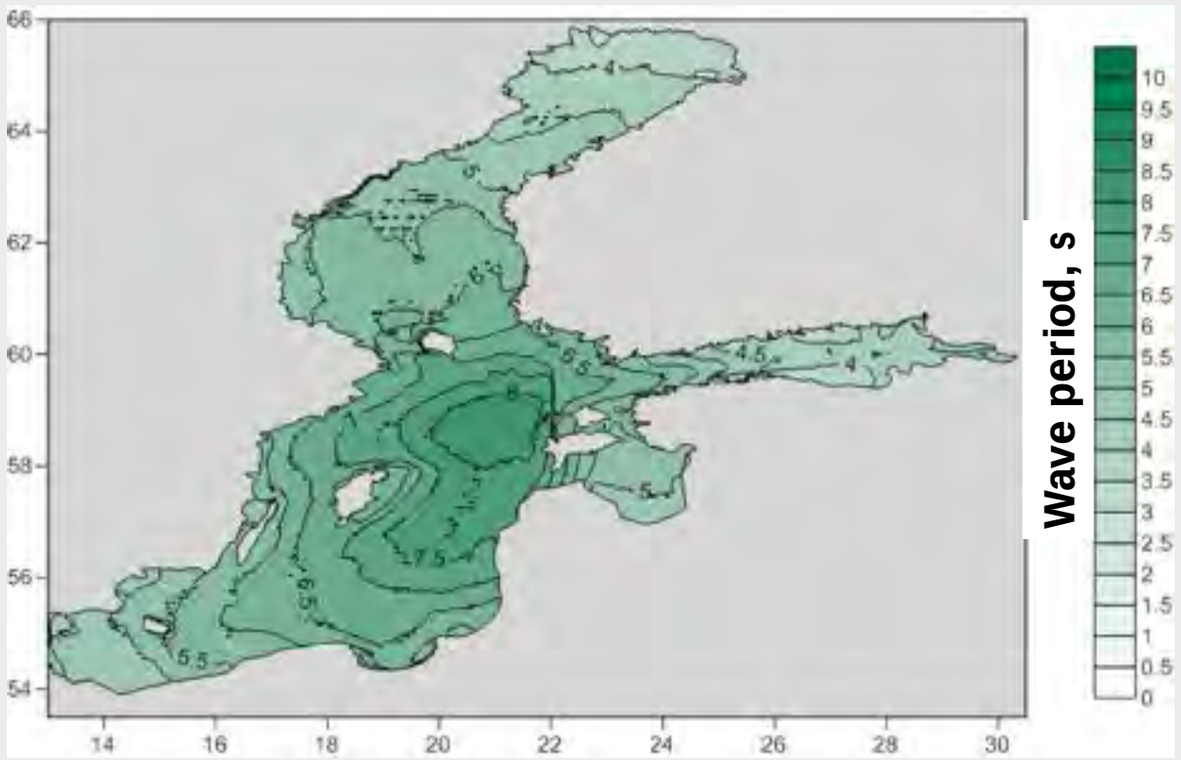


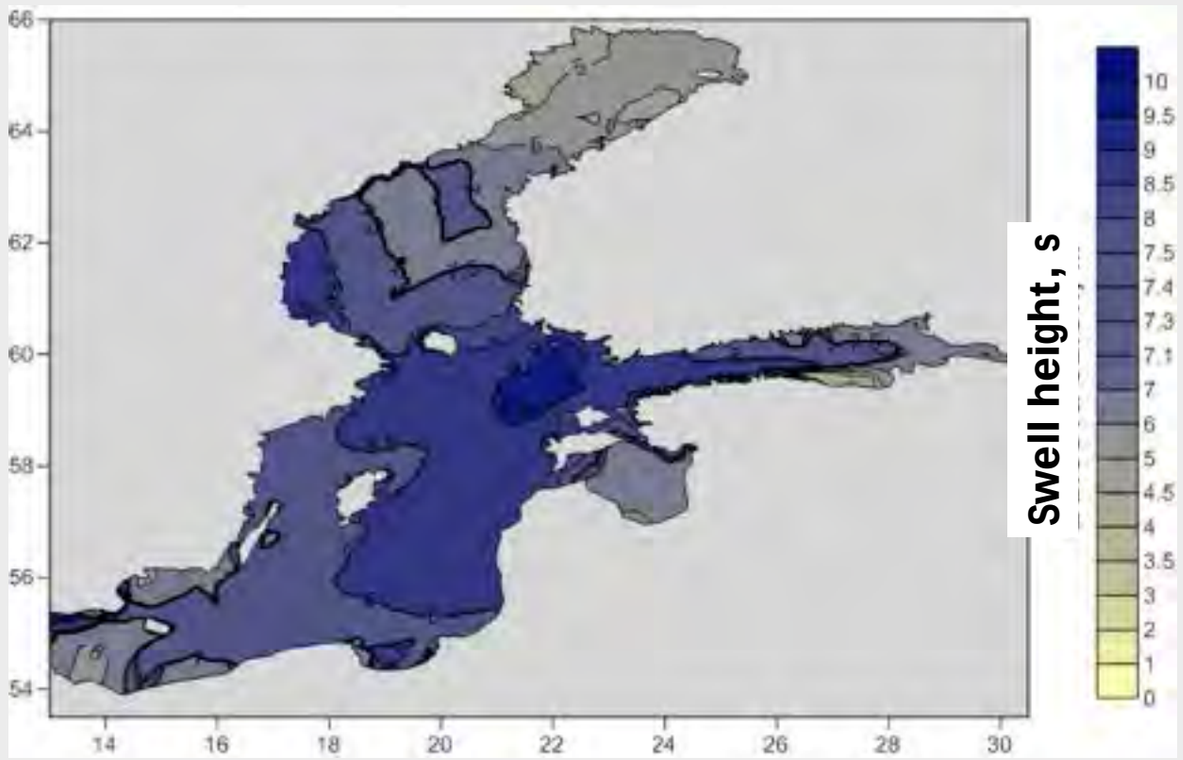


Total maxima on the Baltic Sea



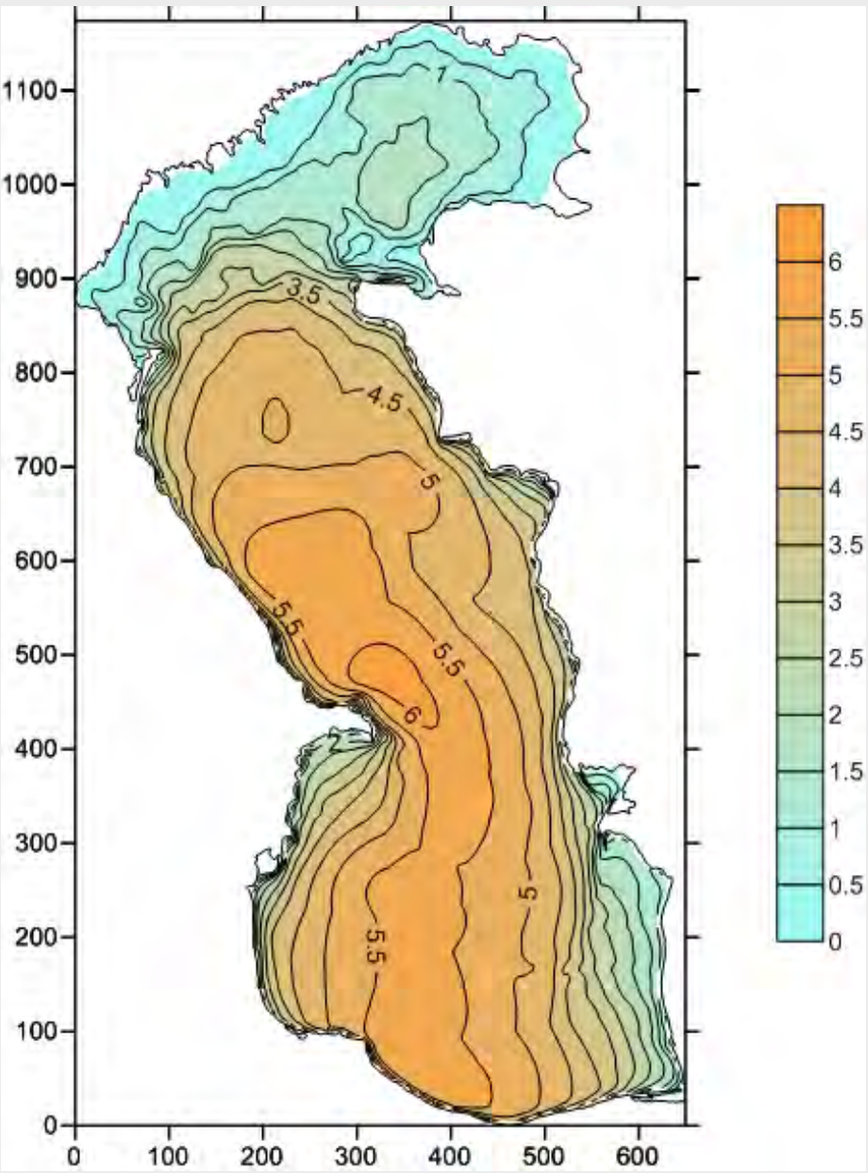




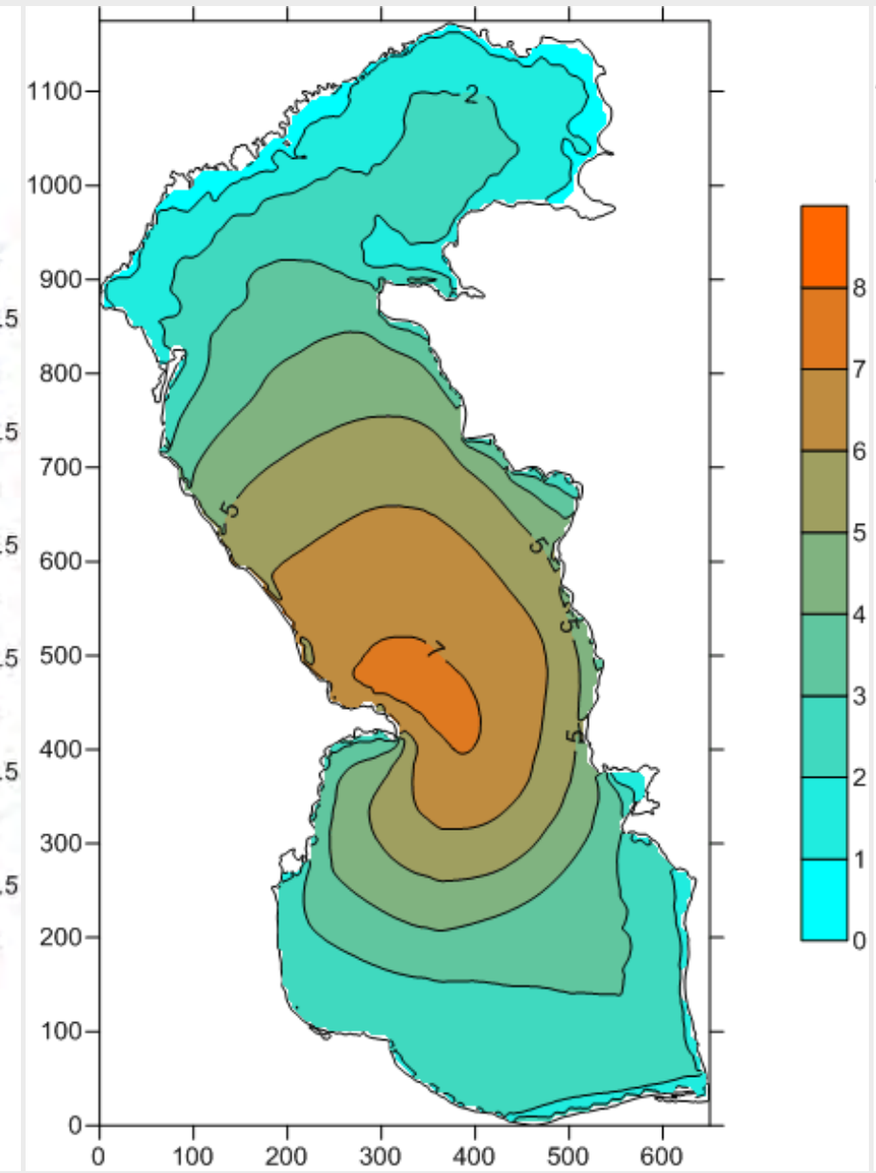


Total maxima on the Caspian Sea

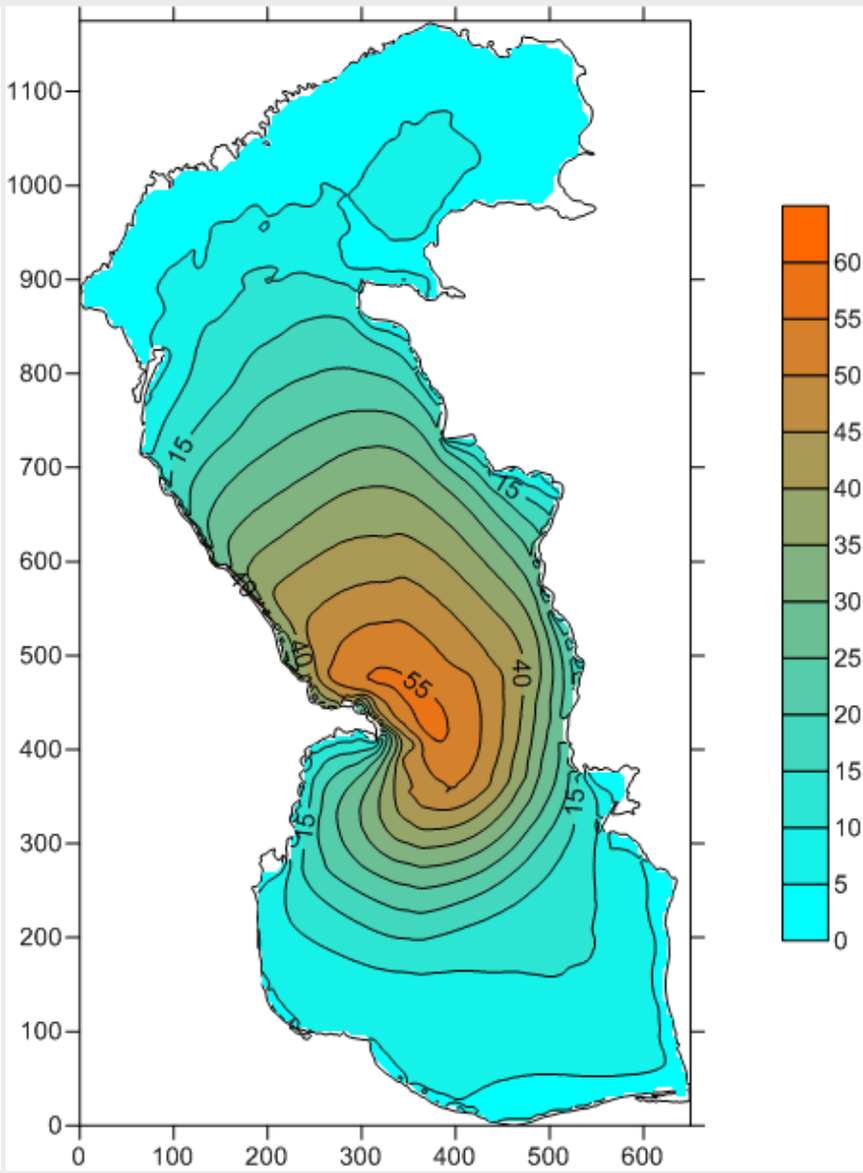
SWH, m



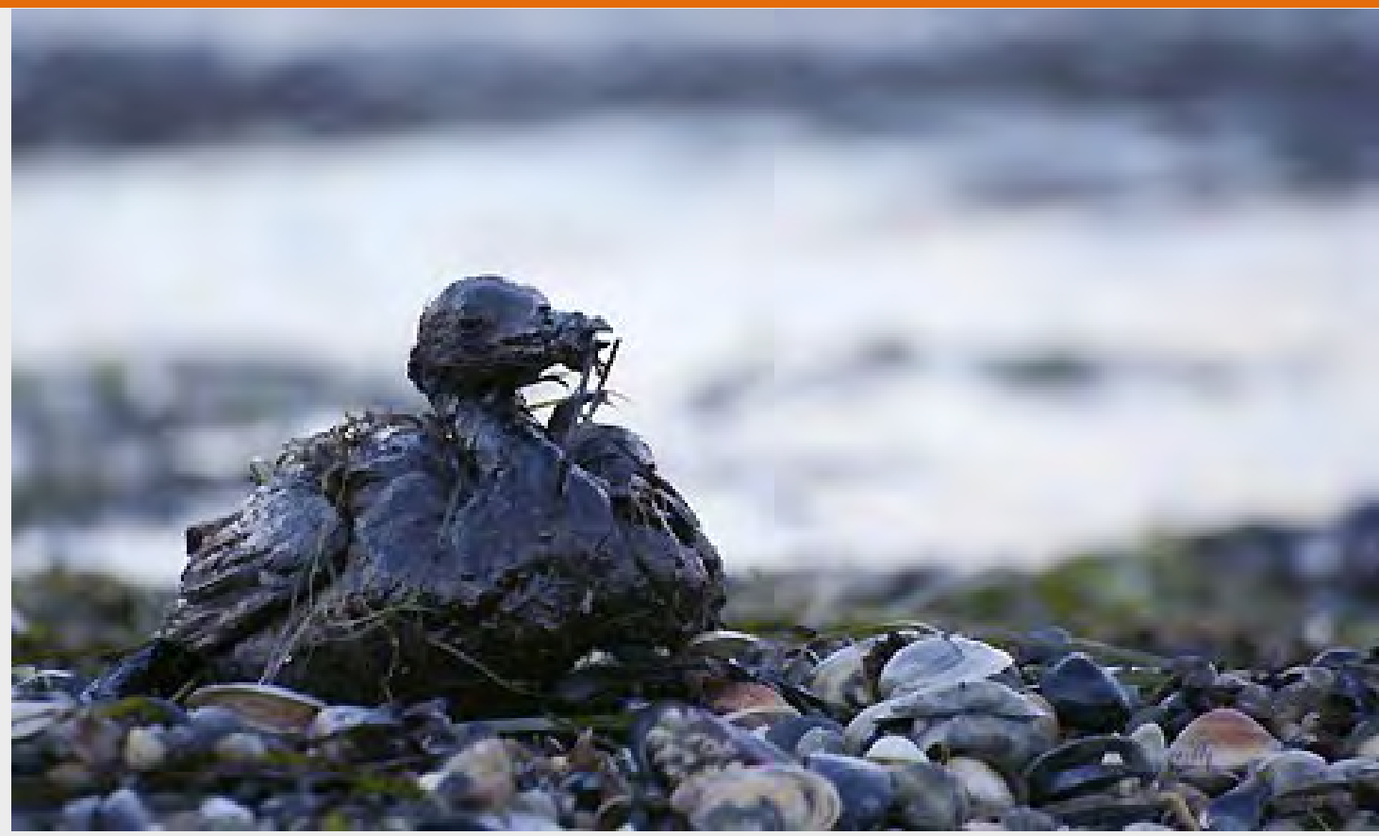
Wave period, s



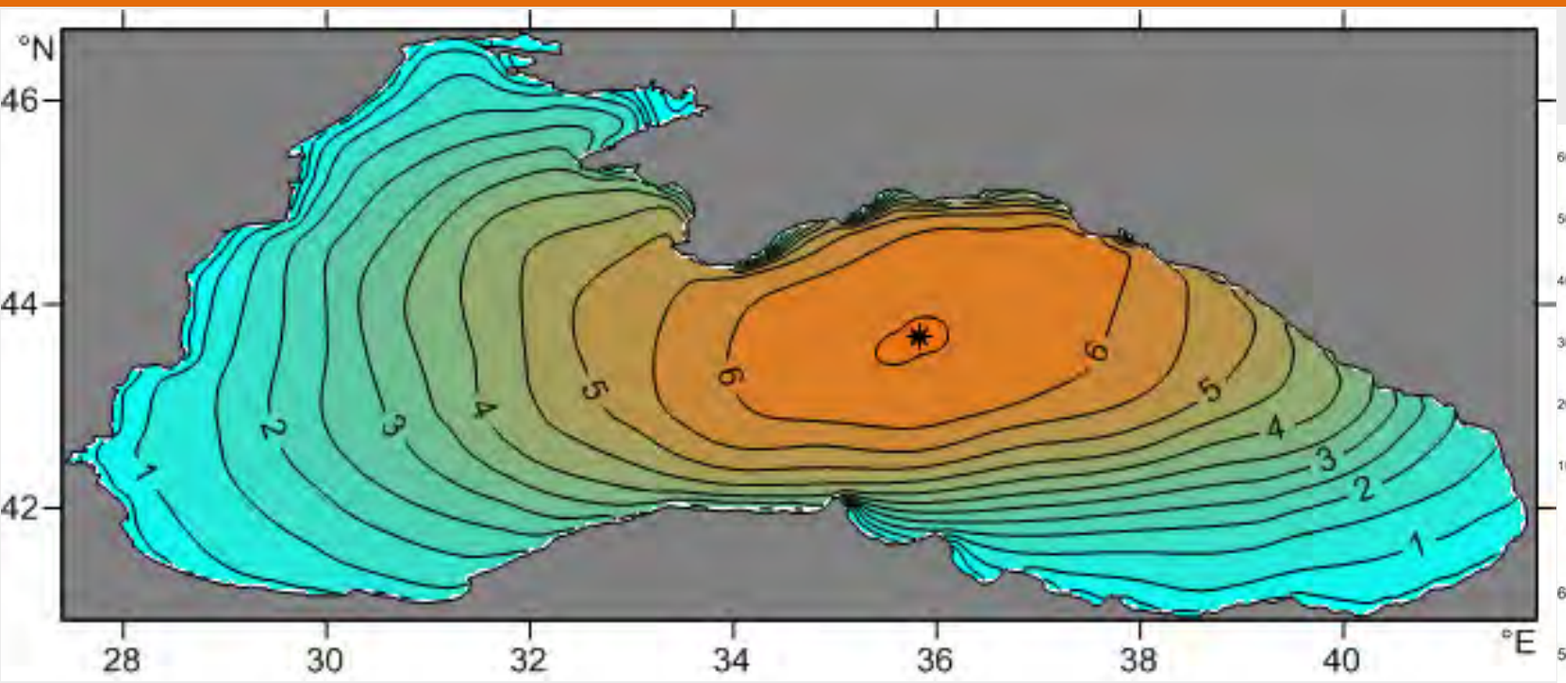
Wave length, m

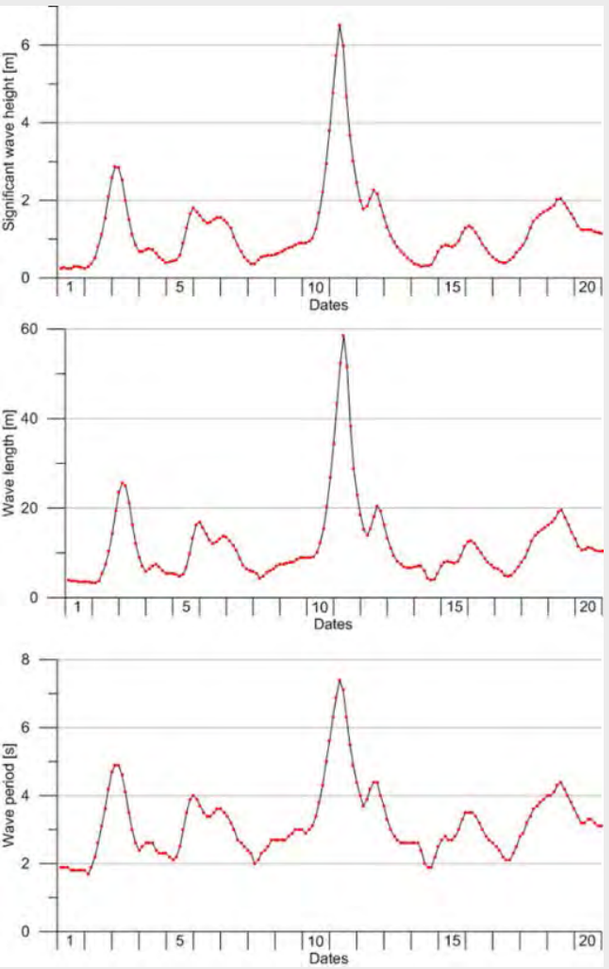


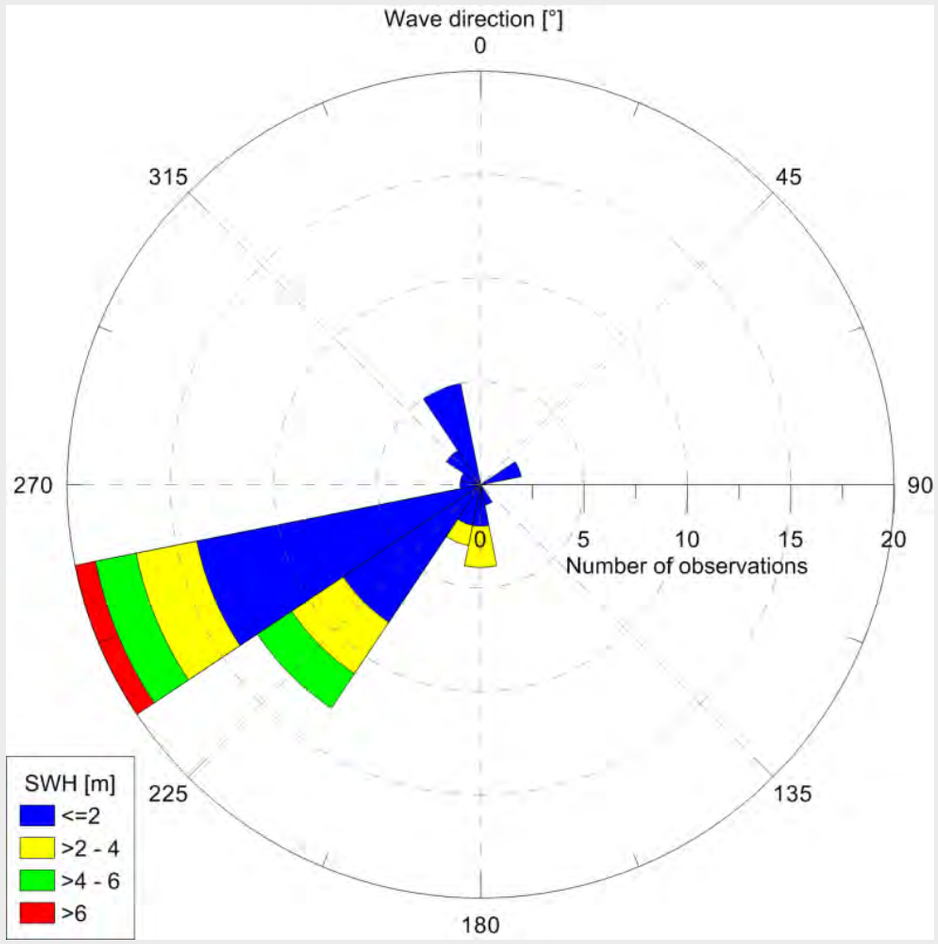
11 November 2007 storm

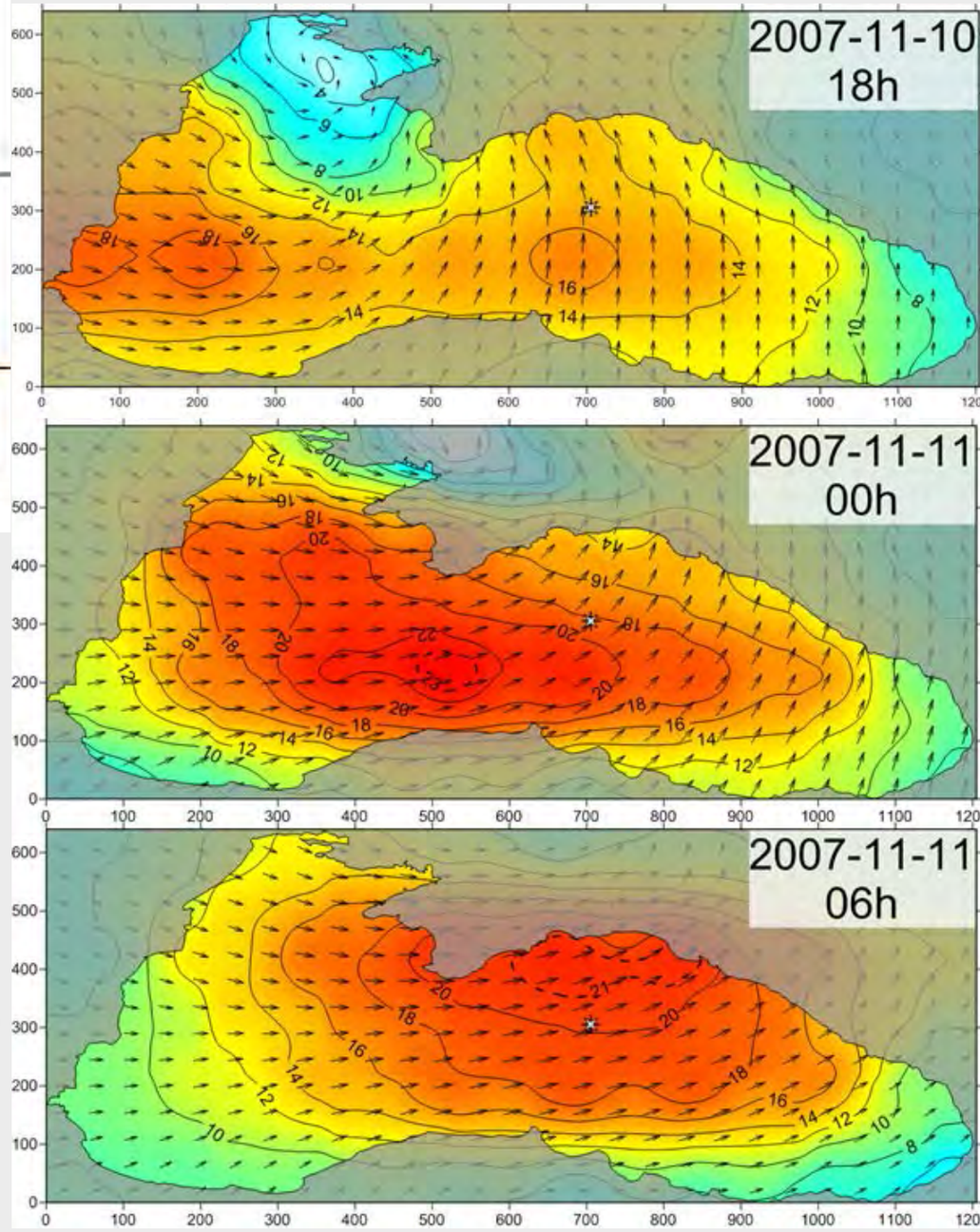


11 November 2007 storm

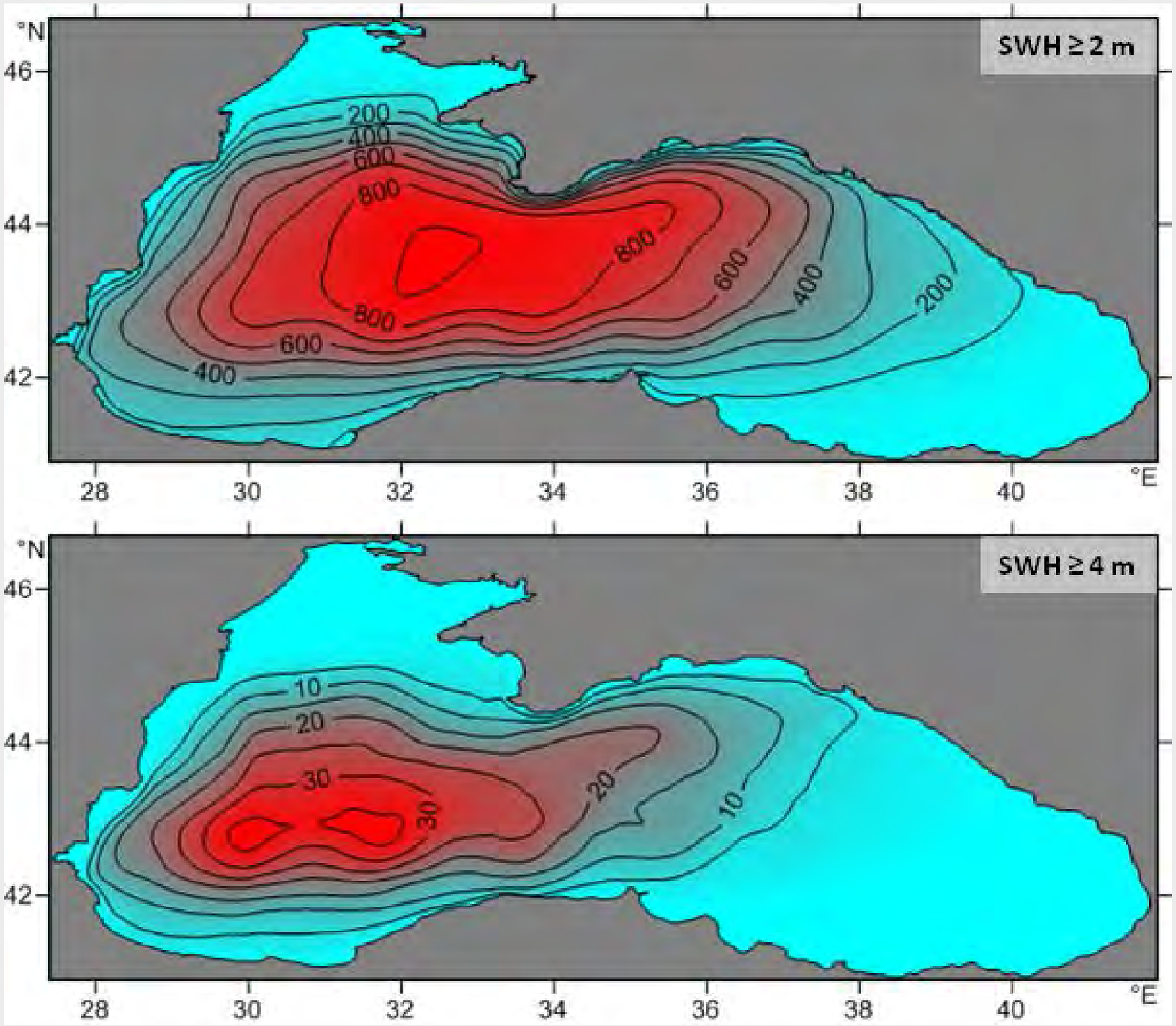






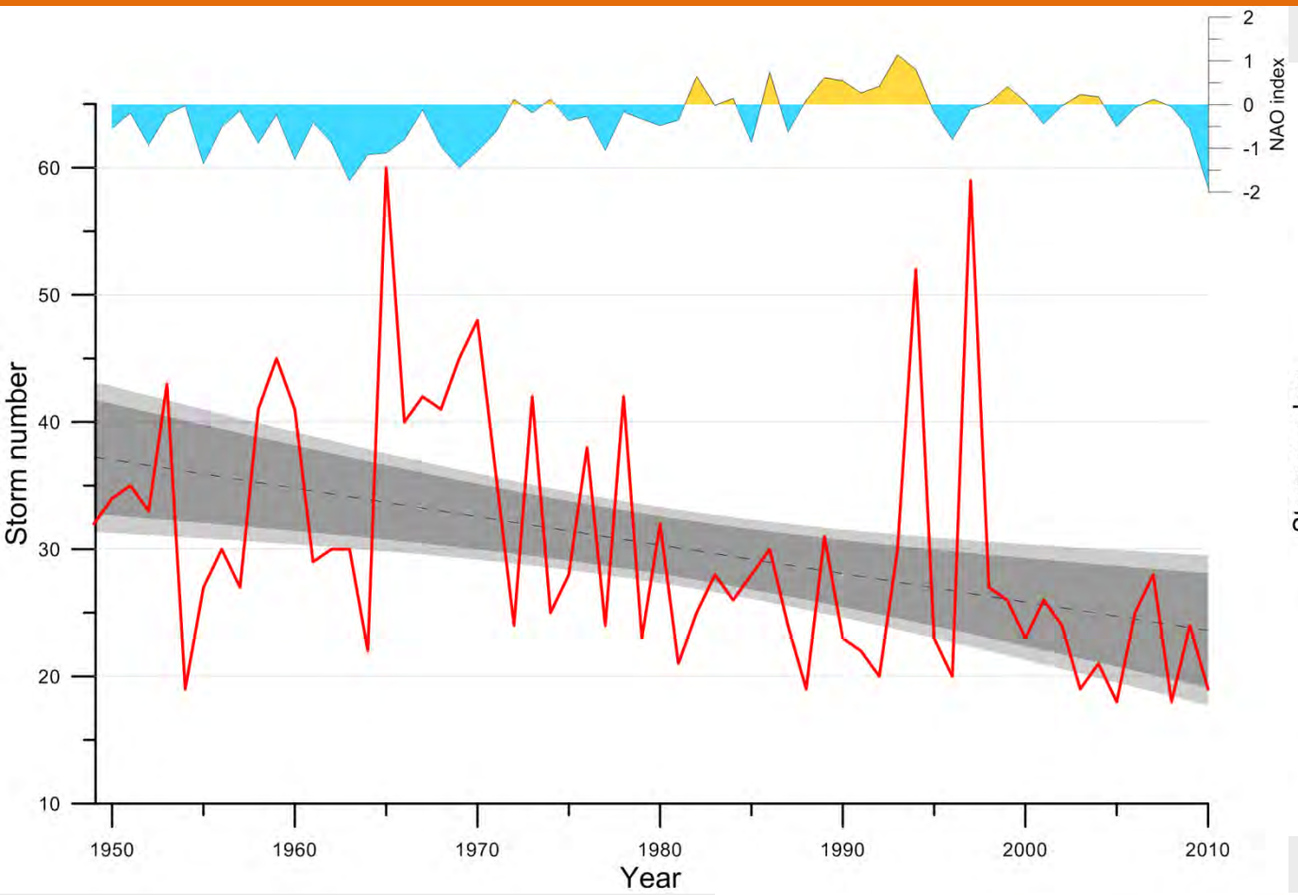


Total storm duration

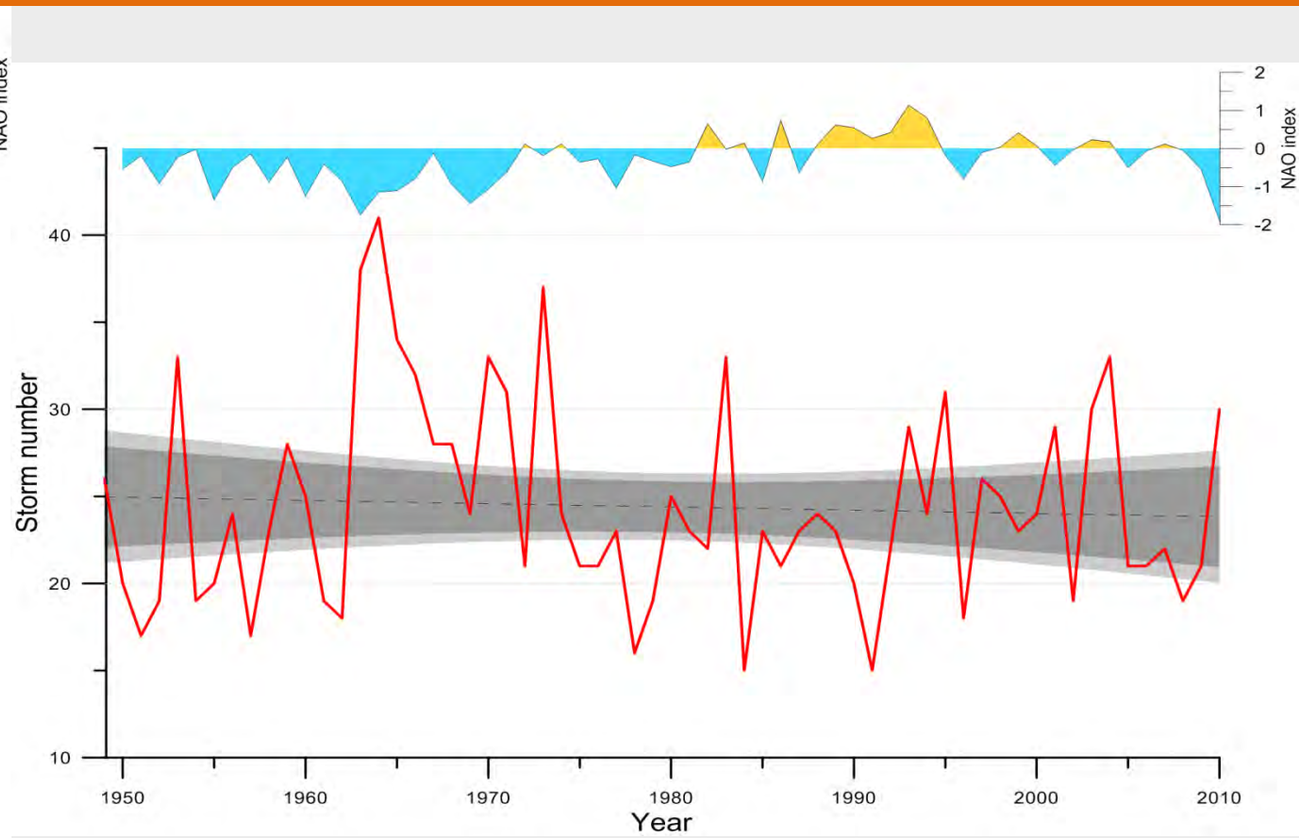


[days]

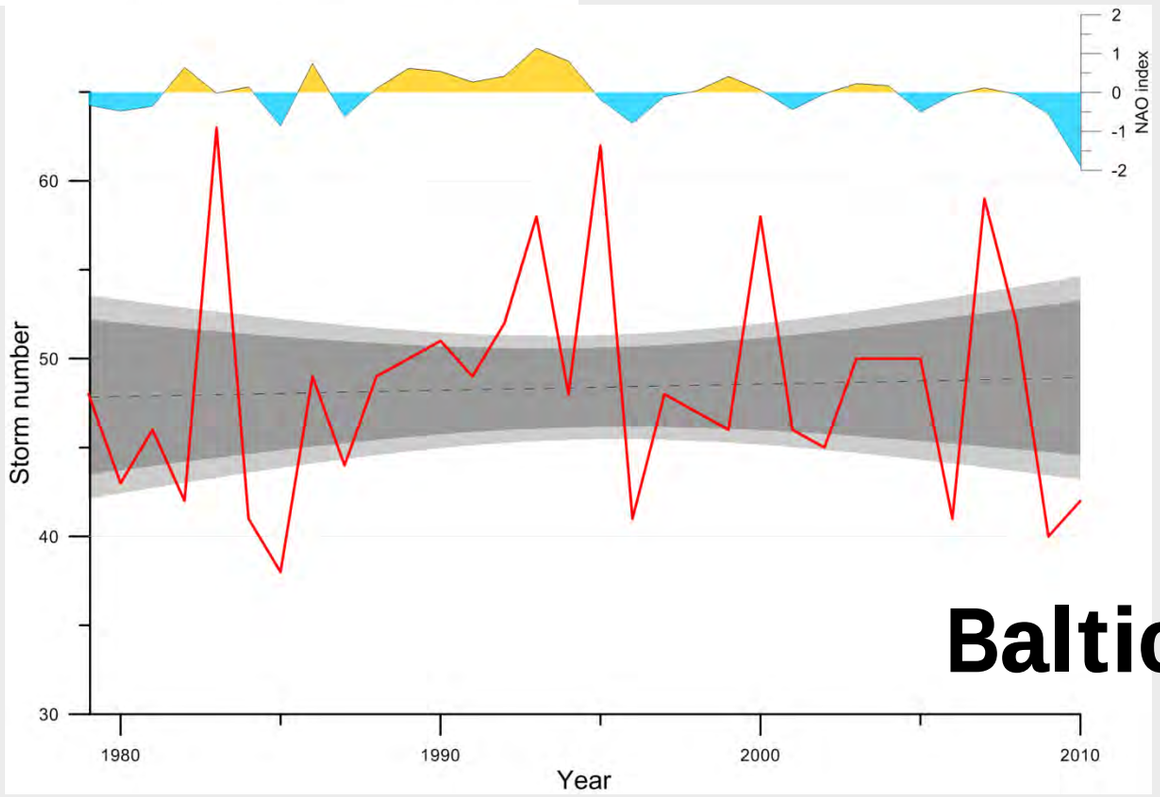
Interannual storminess variability



Caspian Sea



Black Sea



Baltic Sea

Conclusions

1. Wave parameters of the Black Sea, Baltic Sea and Caspian Sea were simulated continuously from 1948 to 2010.
2. Seasonal extreme wind parameters and their spatial distribution were assessed.
3. Trends of interannual storminess activity derived. Storminess decreases in the Caspian Sea, remanes stable in the Black Sea and increases in the Baltic Sea.

Further reading

Nat. Hazards Earth Syst. Sci., 14, 2883–2897, 2014
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doi:10.5194/nhess-14-2883-2014
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Wind waves in the Black Sea: results of a hindcast study

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Thank you!

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