Analysis of storm waves on the Caspian Sea

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INTRODUCTION

For the study of storm waves on Caspian Sea a spectral wave model of third-generation SWAN has been applied.With the NCEP reanalysis wind fields from 1948 to 2010 as a forcing input, the model simulates significant wave height every 3 hours, the height of the swell, the direction of wave propagation, its length and period, and the transfer of wave energy. At this step of the numerical grid in the x and y in the Caspian Sea was 5 km. Calculations are carried out for the whole year. Model output for the past time-step of one year represents the initial data for the next one. Calculations are made on supercomputers of Lomonosov Moscow State University. Such physical processes as quadruplet interactions, whitecapping, triads, bottom friction, depth-induced breaking and diffraction are considered. The simulation results are used to calculate the number of storms, their size and duration both for the whole period of calculations, and for each month. Climate variability of storms is assessed. Areas of the strongest wave storms are identified. Synoptic situations for extreme storm events are analyzed on the base of decomposition of atmospheric pressure fields to the empirical orthogonal functions. The simulation results are compared with ship observations for the waves.

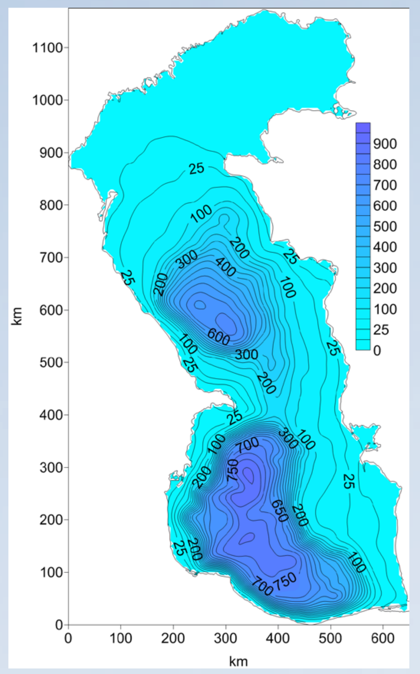
SPECTRAL WAVE MODEL

SWAN ver. 40.85

- generation wave due wind
- bottom friction
- triads and quadruplets wave interactions
- diffraction
- breaking

BATHYMETRY OF CASPIAN SEA

5 km x 5 km



WIND FIELDS

NCEP/NCAR

- ~ 1,9 x 1,9°
- 4-daily
- 1948-2010

SUPERCOMPUTER SYSTEM OF MSU

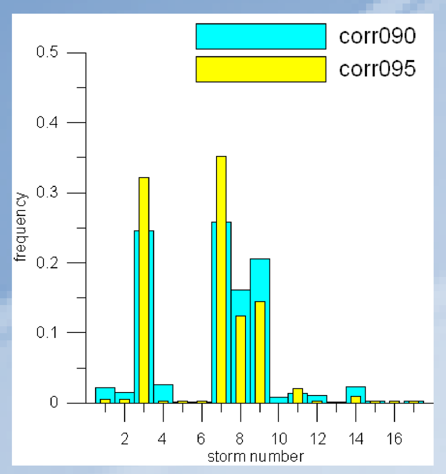
Supercomputer “Lomonosov”

- peak performance 510 TFlops
- number of processors/cores 10260/44000
- memory 73 920 Gb

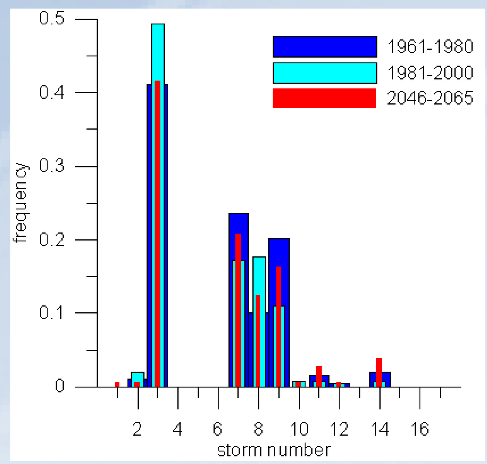
WIND AND PRESSURE FIELD REGIME FOR STORM EVENTS

Climate projection and storms frequency

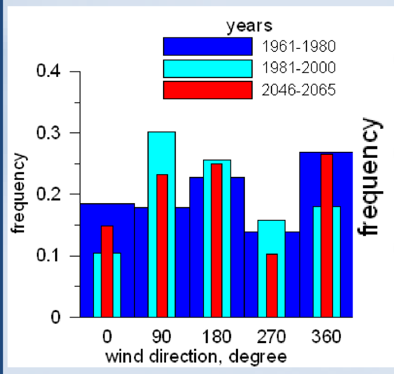
Data source: CMIP3
Data type: daily sea level pressure (SLP)
Climate model:
MPI-ECHAM5 (Max Planck Institute for Meteorology,Hamburg, Germany)
Numerical experiments ID:
- 20C3M (1961-2000);
-A2(SRES scenario) – 2046-2065
Purpose:
- to verify model ability to simulate relative frequency and number of storm events (similarity of SLP fields with corr>=0.95;
- to check possible changes of storm events frequency in 21 century;
- to look for possible time changes of strong wind regime over the sea.



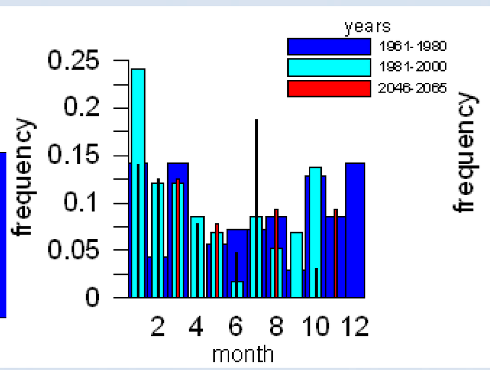
Relative frequency of storm events (table 1) with CORR>=0.95 for daily SLP. NCEP/NCAR, 1948-2011



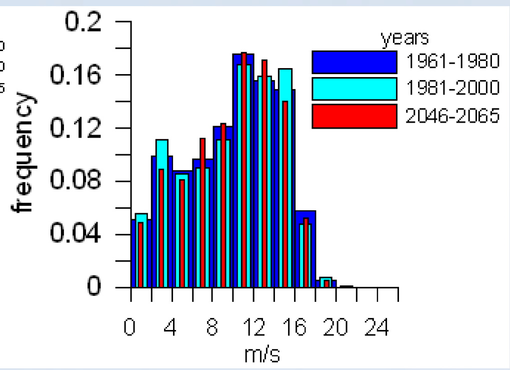
Relative frequency of storm events (table 1) with CORR>=0.95 for daily SLP. MPI-ECHAM5



Wind direction frequency for events when daily V>=15 m/s over the sea, MPI-ECHAM5



Monthly frequency for events when daily V>=15 m/s, MPI-ECHAM5



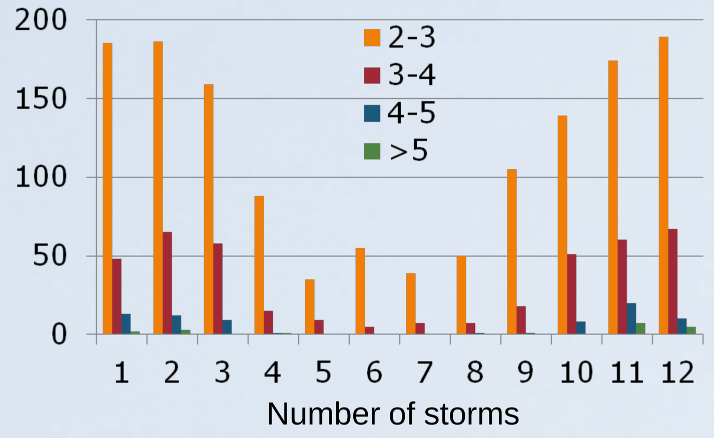
Wind speed over the sea for events when daily V>=15 m/s at least in one grid point, MPI-ECHAM5

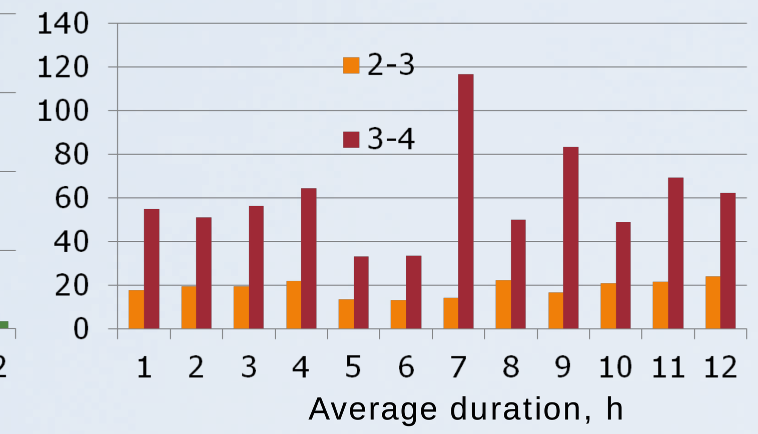
STATISTICS OF STORM WAVES

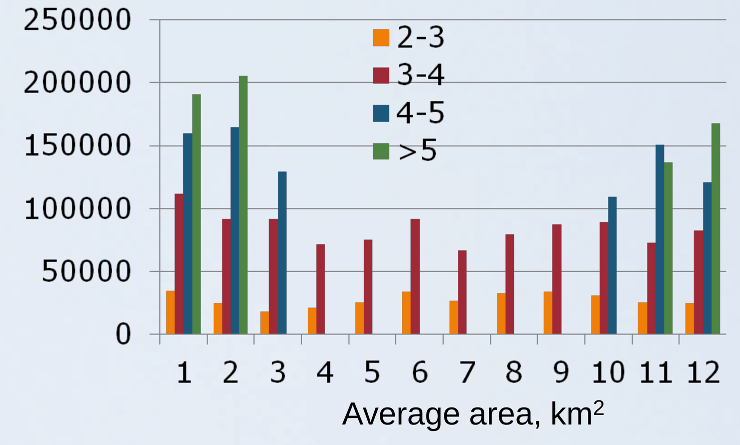
General statistics of storms for 1948-2010

Significant wave height, m	Number	Average duration, h	Average area, km²	Average path length, km
2-3	1404	20	27235	219
3-4	410	59	87687	542
4-5	75	167	141623	841
> 5	18	72	164129	691
All	1907	34	46022	317

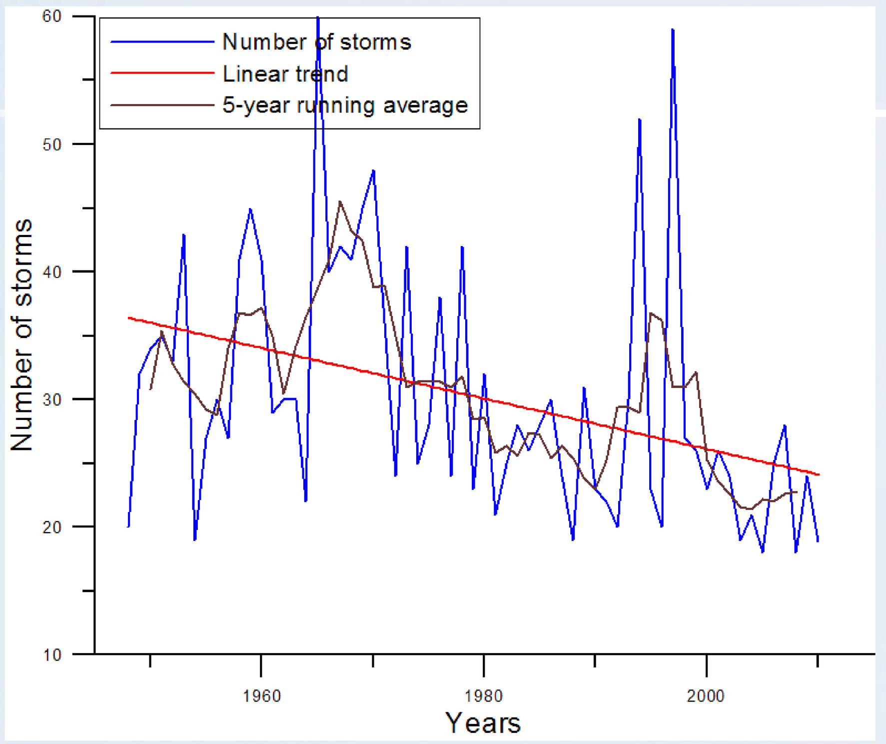
Seasonal variability of storms with different significant wave height (m)





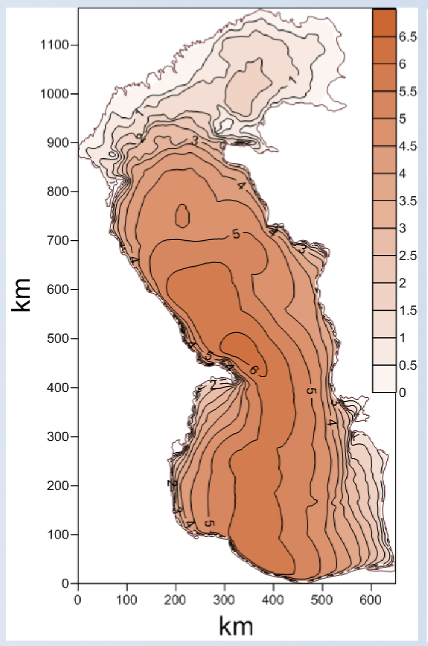


Interannual variability of storm waves with significant wave height exceeding 2 m

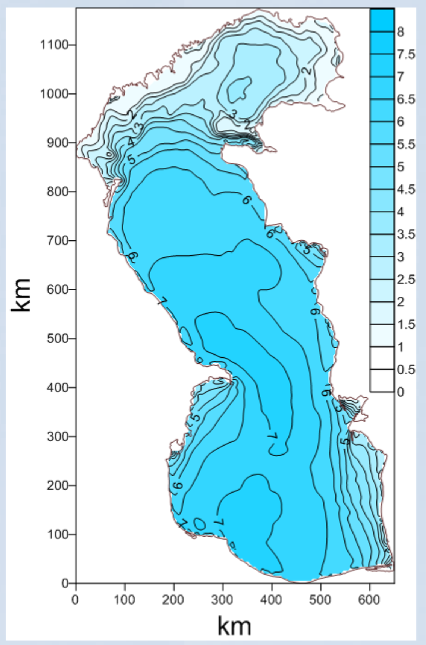


EXTREME CHARACTERISTICS OF WIND WAVES

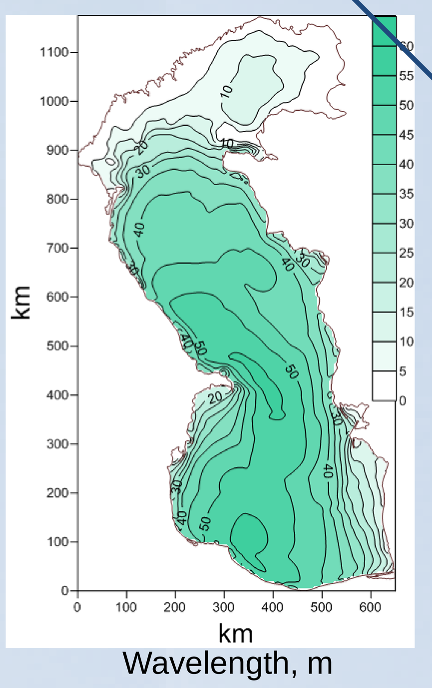
The largest calculated parameters of storm waves



Significant wave height, m



Period, s



Wavelength, m

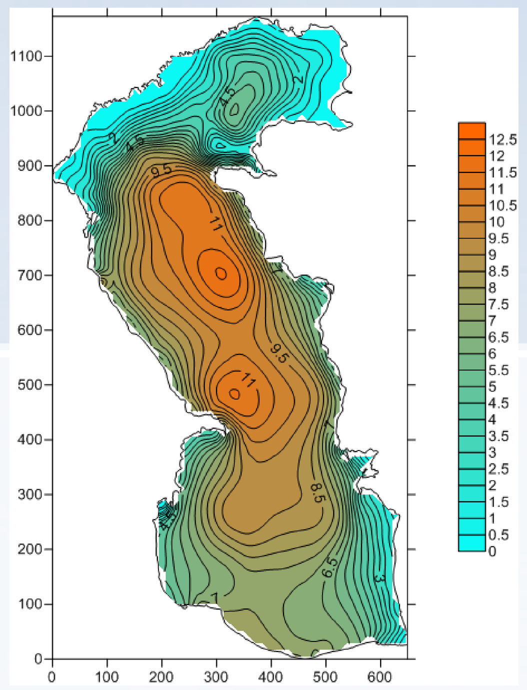
Significant wave height of a possible 1 time in 100 years

Generalized characteristic of the wave regime are regime distributions. Analysis of measurement data showed that one-dimensional distribution of wave heights and periods are described by a logarithmically normal distribution :

$$F(x) = \frac{1}{\sigma\sqrt{2\pi}} \int_x^{\infty} \frac{1}{x} \exp\left[-\frac{1}{2}\left(\frac{\ln x - \mu}{\sigma}\right)^2\right] dx$$

where μ - mathematical expectation, σ - the standard of the wave height logarithms. This distribution can be expressed in another way:

$$F(x) = \frac{s}{\sqrt{2\pi}} \int_x^{\infty} \frac{1}{x} \exp\left[-\frac{1}{2}\ln^2\left(\frac{x}{x_{0.5}}\right)\right] dx$$



where s=1/σ.
To calculate the characteristics of extreme wave was the initial distribution method (IDM, Initial Distribution Method), in which to evaluate the highest wave height is taken quintile h(p) of regime height distribution *F* (h) for a given probability p:

$$p = \frac{\Delta t}{24 \cdot 365 \cdot T}$$

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