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HINDCASTING OF WIND AND WAVE CLIMATE OF SEAS AROUND RUSSIA

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What is the Wave Climate?

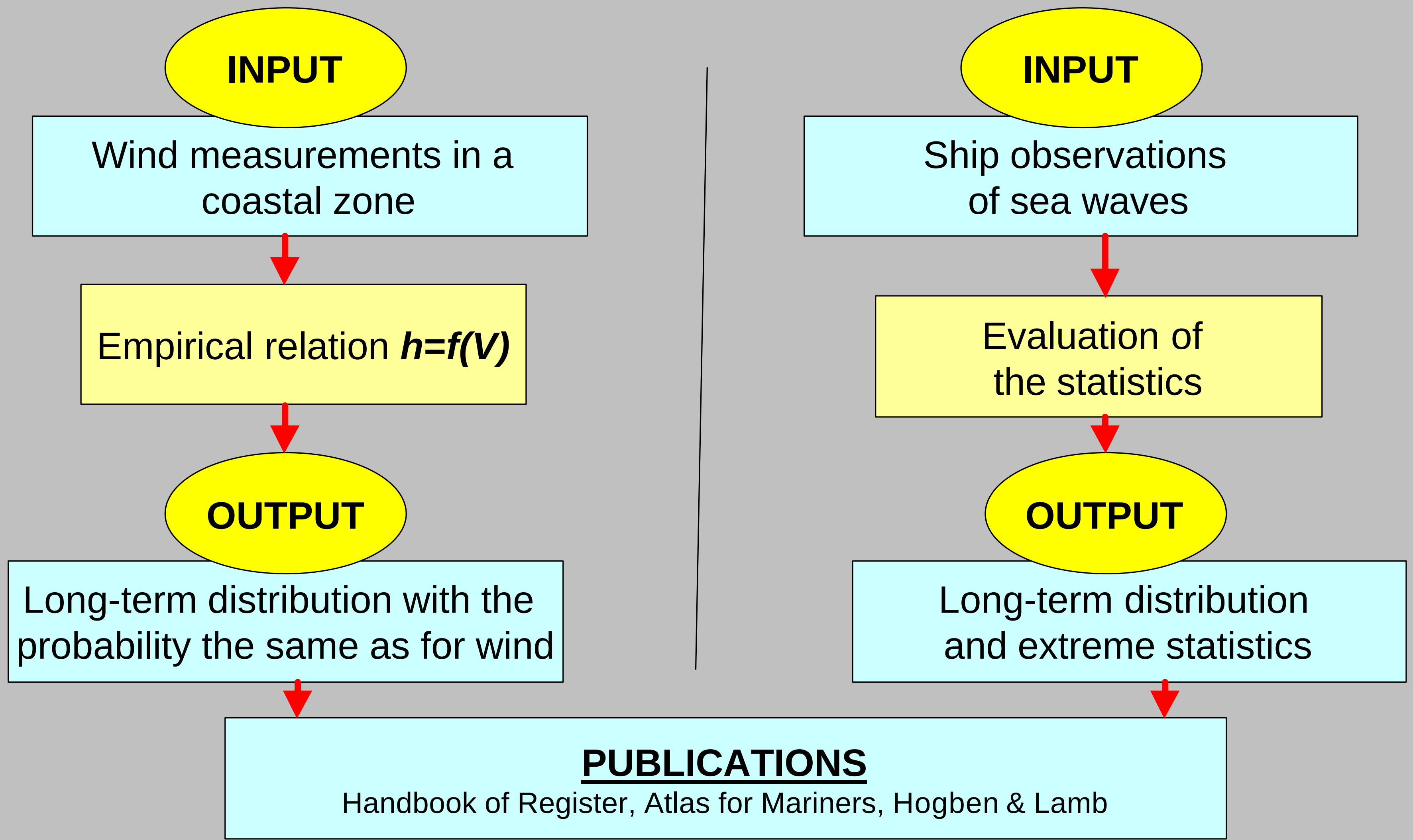
The ensemble of sea states, including synoptic, annual and inter-annual variability

WAVE CLIMATE INVESTIGATIONS

BEFORE?

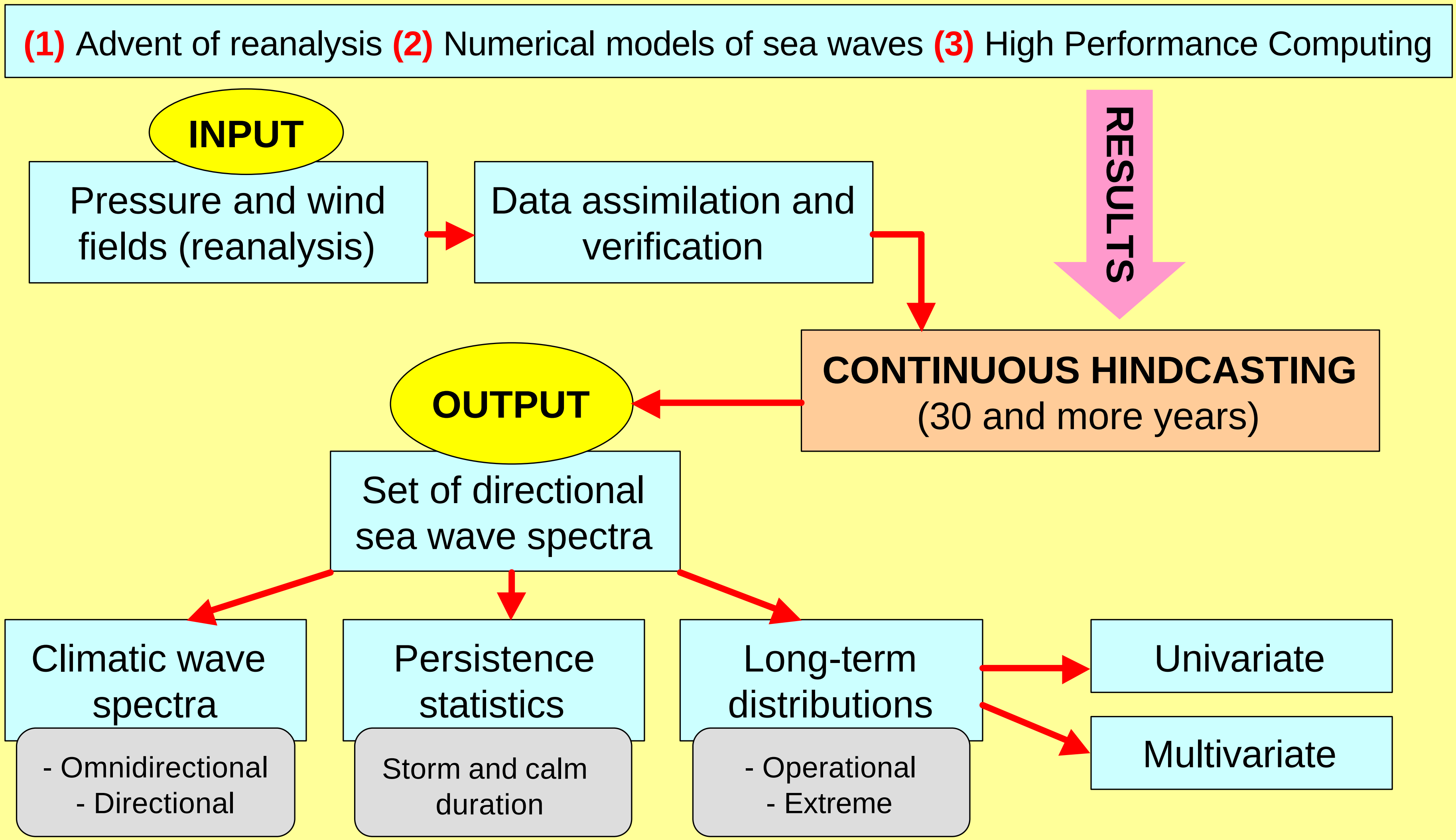
NOW!

BEFORE…



THEREFORE: Wave climate is long-term distribution

NOW!

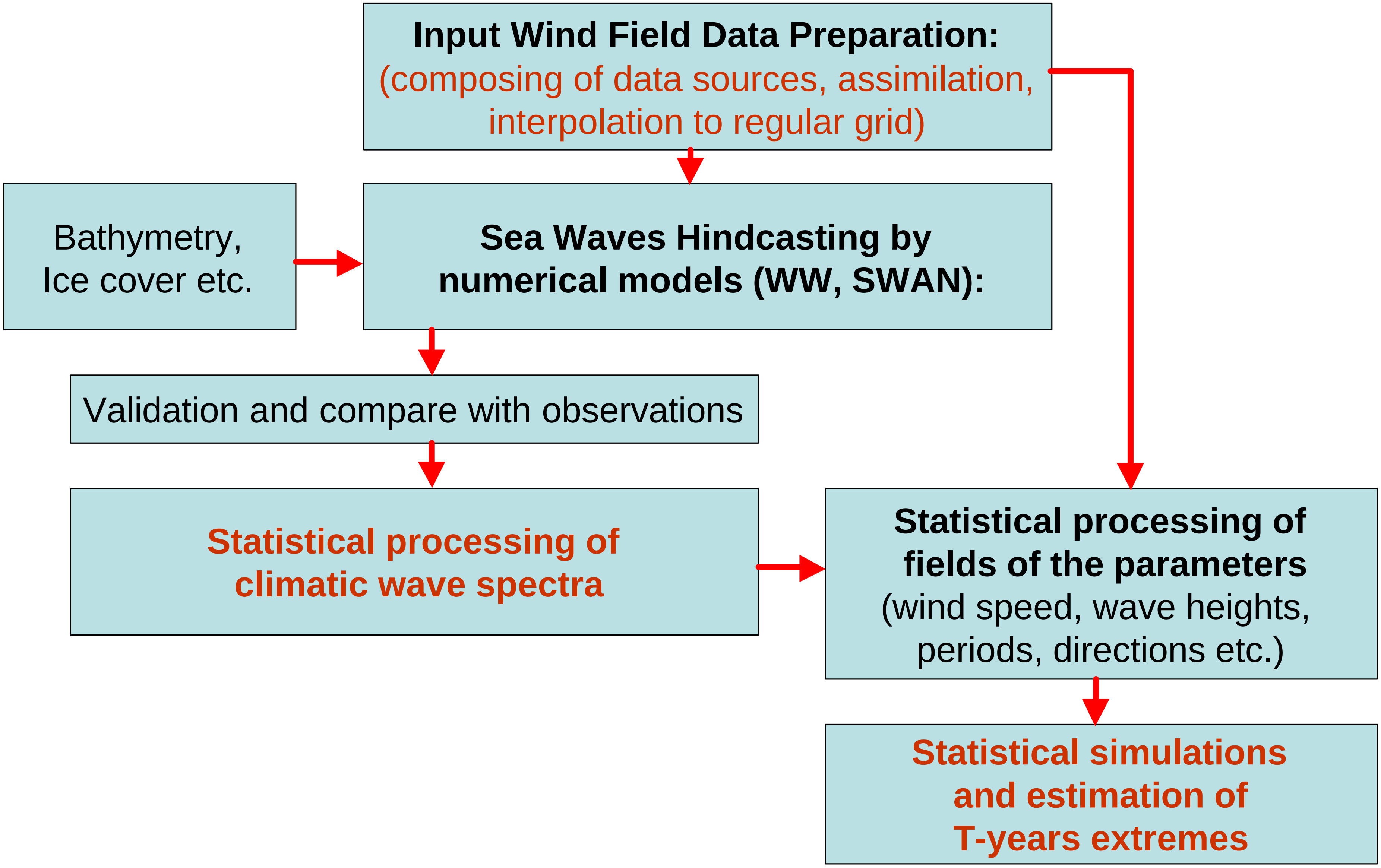


THEREFORE: Wave climate is a set of directional spectra and descended from them spatio-temporal statistics

Wave Climate Hindcasting in Seas around Russia

Sea	Years	Lat., N	Long.,E.	Model	Grid step	
					?x	?y
Barents	1970-1999	60°-81°	30°W-60°N.	WW-III (1.18)	0.5^0	1.5^0
Okhotsk	1970-1995	35°-65°	135°-165°	“	1.6^0	0.7^0
Caspian	1990-1995	36.5°-47.2°	48°-55.6°	“	0.2^0	0.2^0
Azov	1989-1998	45°-47.3°	34.7°-39.4°	“	9 nm	
Azov	1979-1998	“	“	“	3 nm	
Baltic	1979-2000	53.8°-66.1°	9°-30°	“	10 nm	
North	1983-1998	50°-70°	5°W.-10°E.	WW-III (2.22)	15 nm	
Black	1974-2003	40.9^0-46.5^0	27.5^0-42.7^0	SWAN C.III. V.40.11	10 nm	
Ladoga lake	1994-2003	59.9^0-61.8^0	29.9^0-33.0^0	SWAN C.III. V.40.31	2 nm	

Stages of wind and wave climate description



The problem of wind data input:
differences between climatic reanalysis and synoptic data

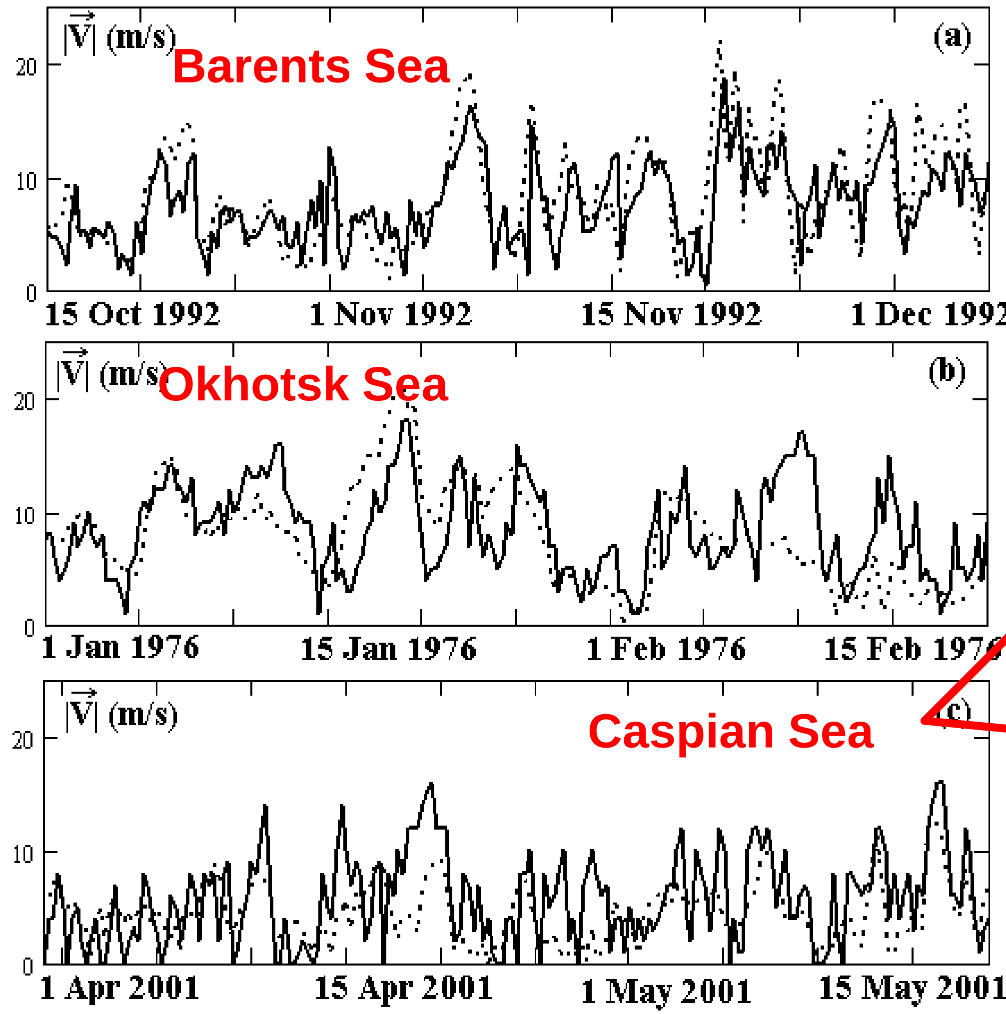
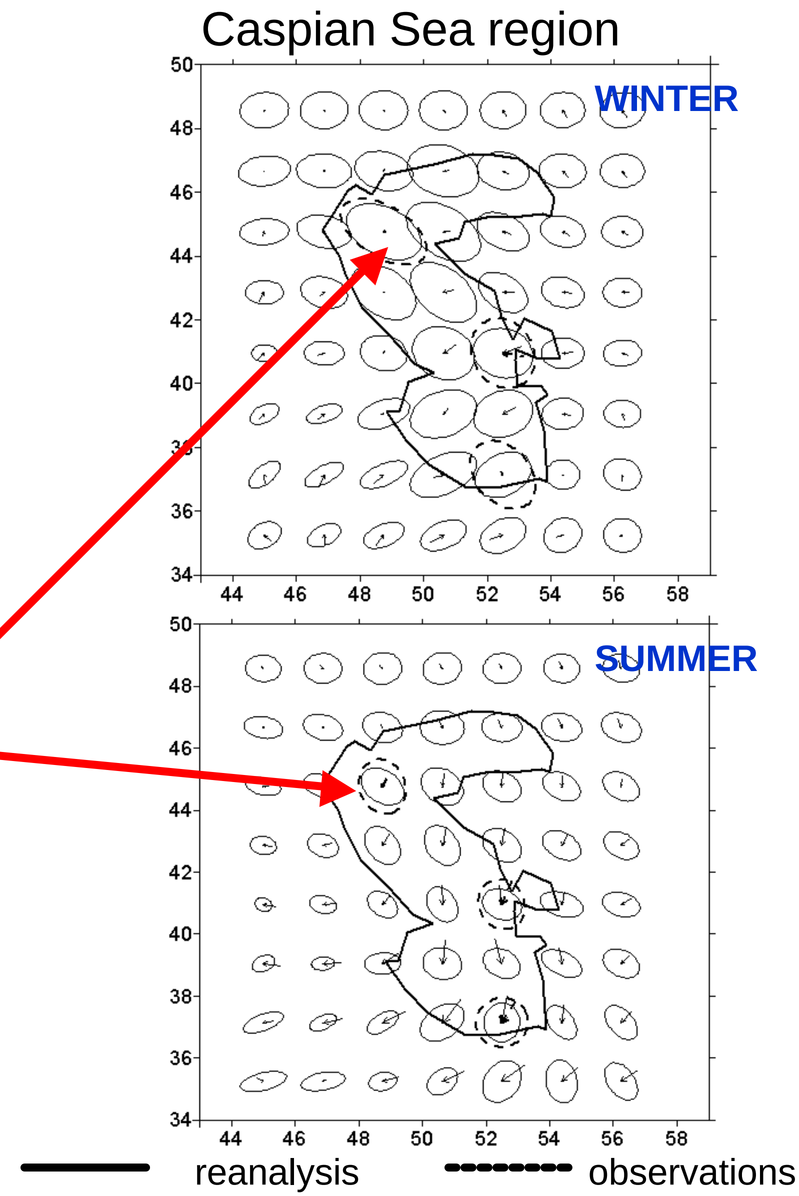
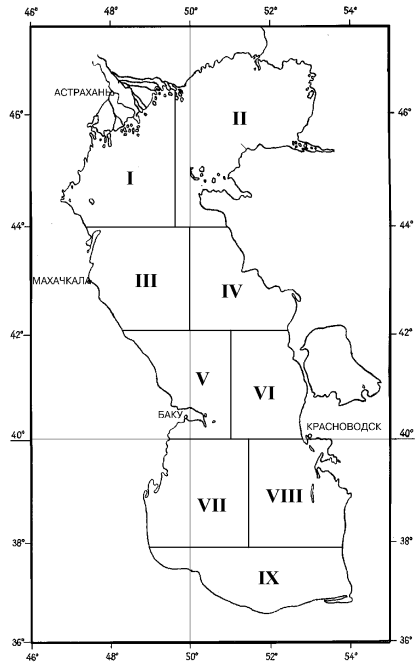


Fig. 1. Comparison of wind speed value time series.
Solid line – Measurements, *Dot line* – Reanalysis.
(?) – Barents Sea (Sental Banken, 740.5N–310.0E),
(b) – Okhotsk Sea (Odoptu, 58006'N, 143028' E.),
(?) – Caspian Sea (Tuleny island, 440 30N', 470 40'E)

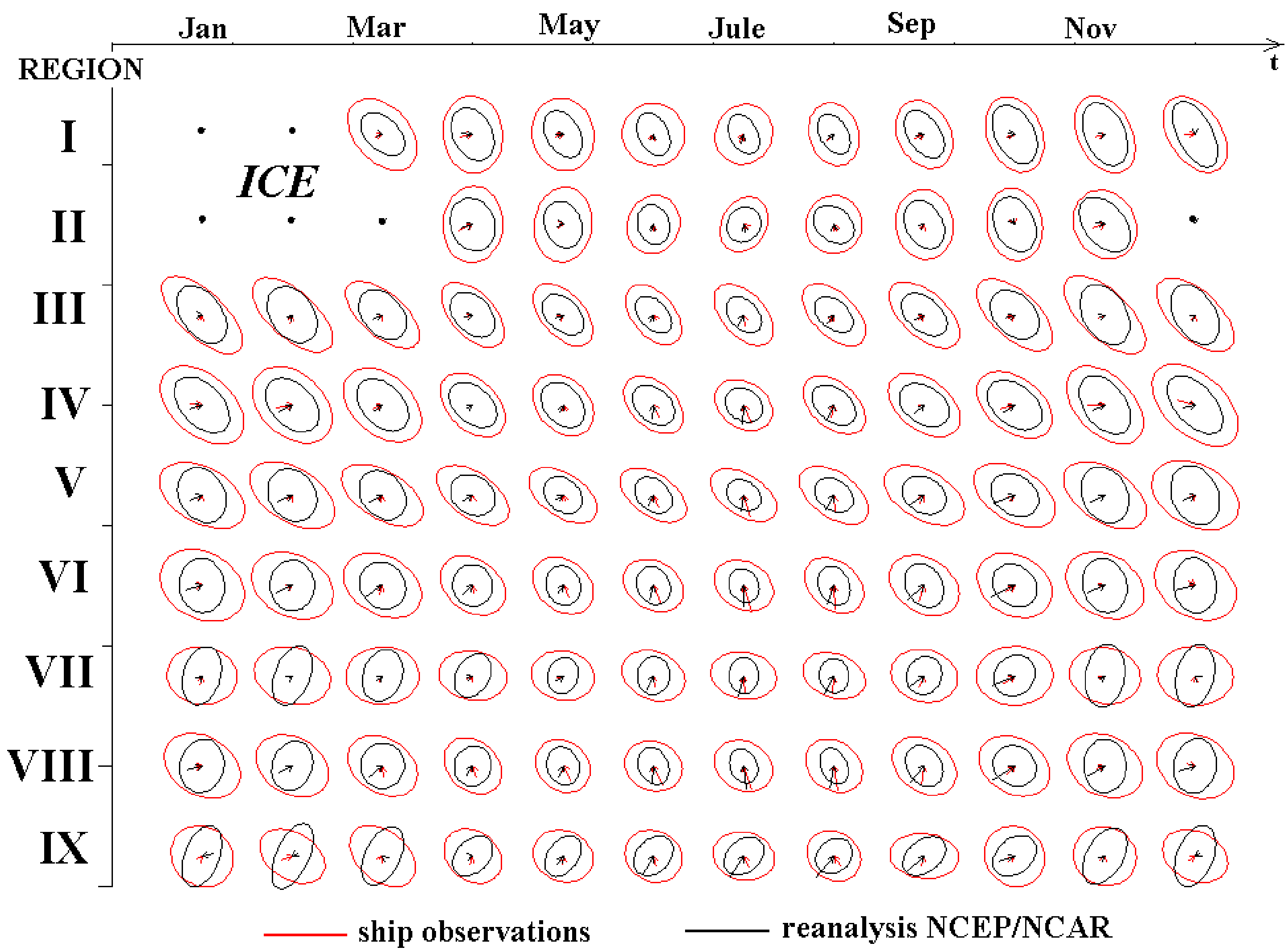


Caspian sea: differences between reanalysis and observations

REGIONS of the Caspian sea



Comparison of monthly mean wind speed and tensor of r.m.s.

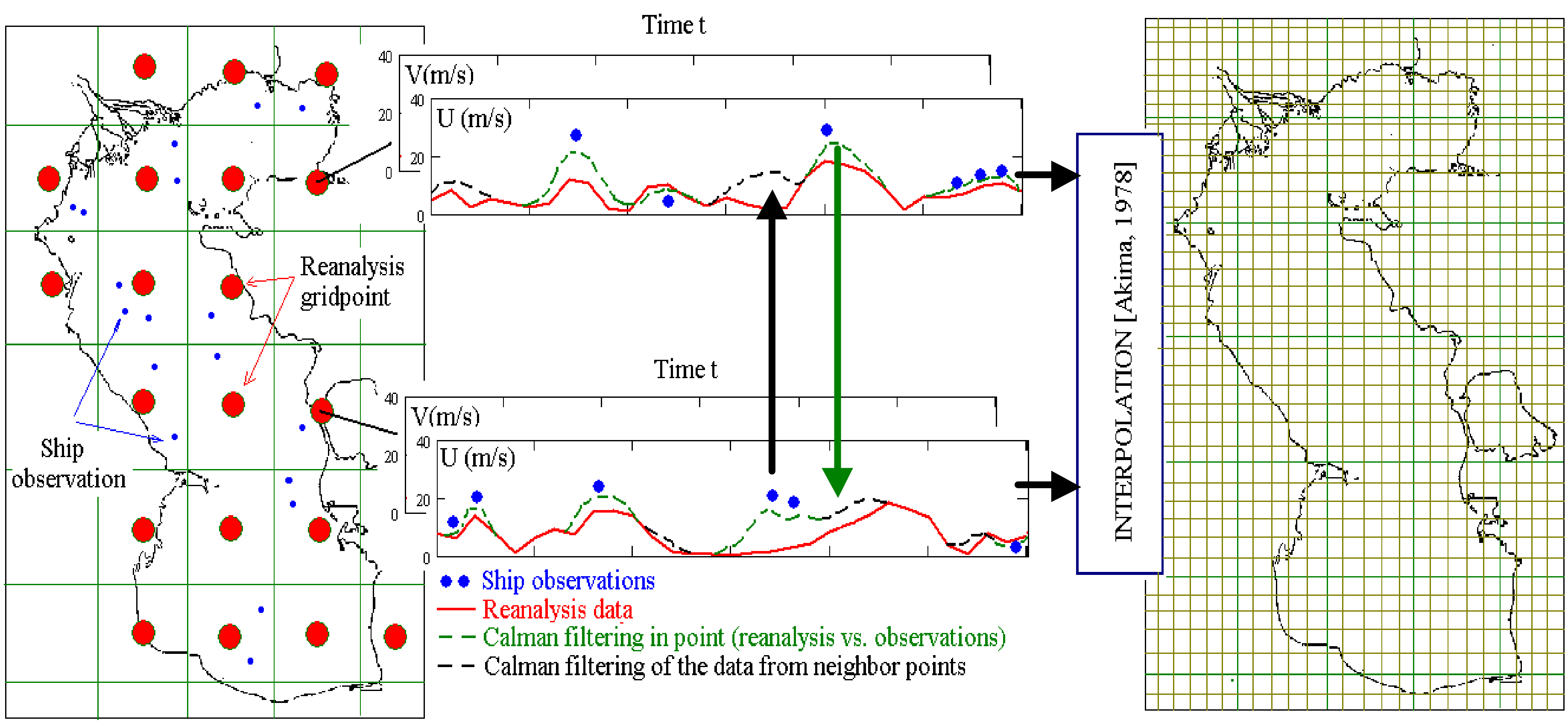


Procedure of Data Assimilation and Interpolation

$$\vec{V}(\vec{r},t)=\sum_{j=1}^{R}\Psi_{t,j}(\vec{r})\vec{V}(\vec{r},t-j)+\Sigma(\vec{r},t)\vec{\varepsilon}(\vec{r},t)$$ - Stochastic model of reanalysis data (with noise $\vec{\varepsilon}$)

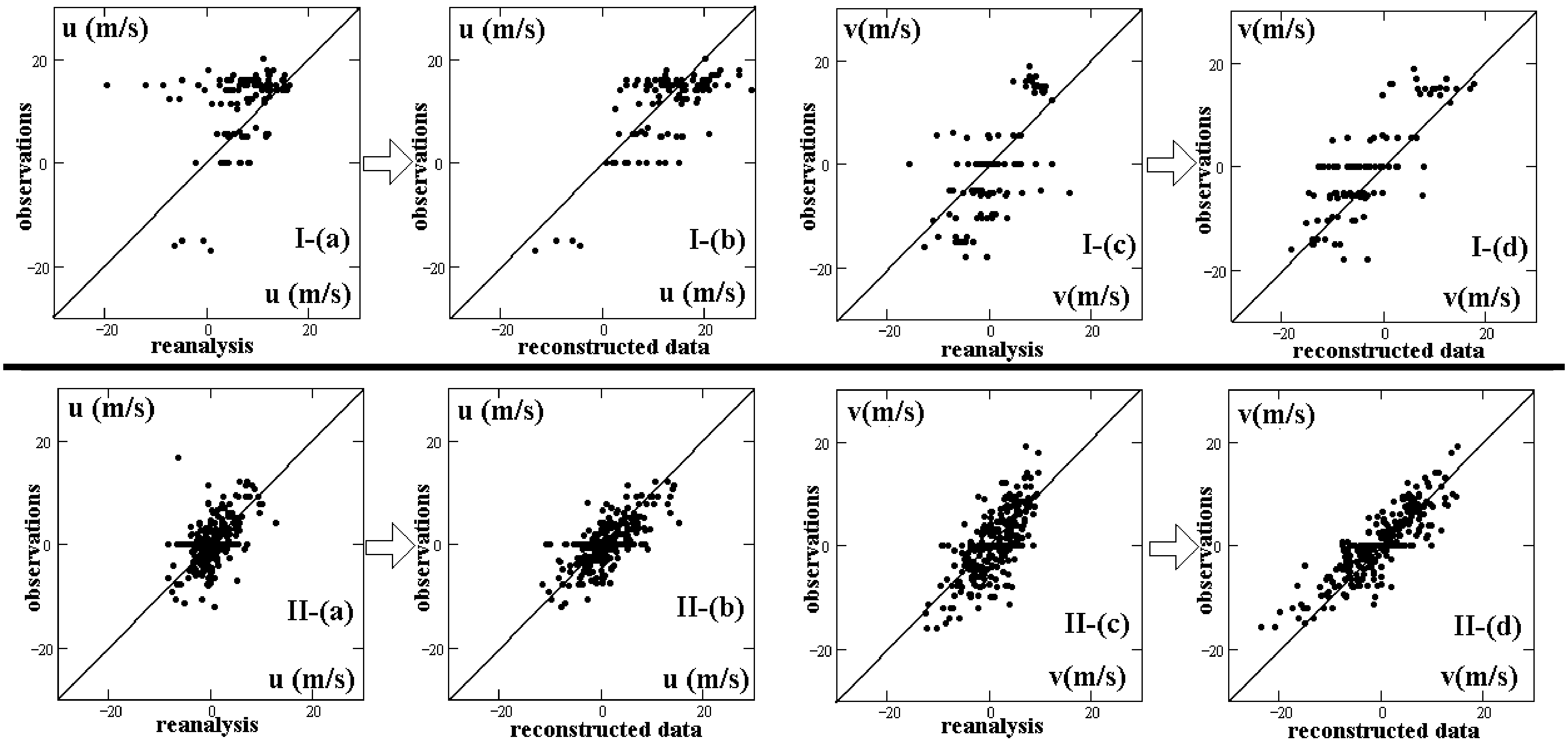
$$\vec{V}_s=\mathrm{H}\vec{V}(\vec{r}_k,t_0)+\vec{\delta}$$ - Equation of measurements (with noise $\vec{\delta}$)

$$\vec{V}^*(\vec{r}_k,t_0)=\vec{V}(\vec{r}_k,t_0)+\Re_{\vec{V}}(\vec{r}_k,t_0)(\vec{V}(\vec{r}_k,t_0)-\vec{V}_s)$$ - Kalman filter equation



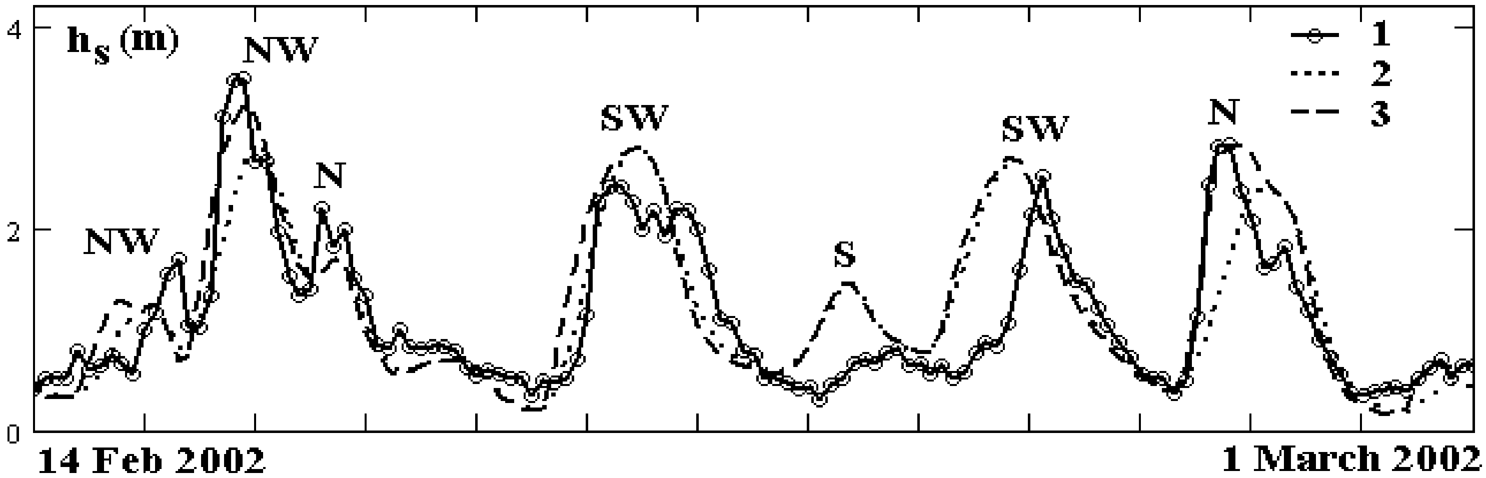
Validation of Assimilation Procedure

Krasnovodsk GMS (SE-Caspian), 1954-1990, severe storms only

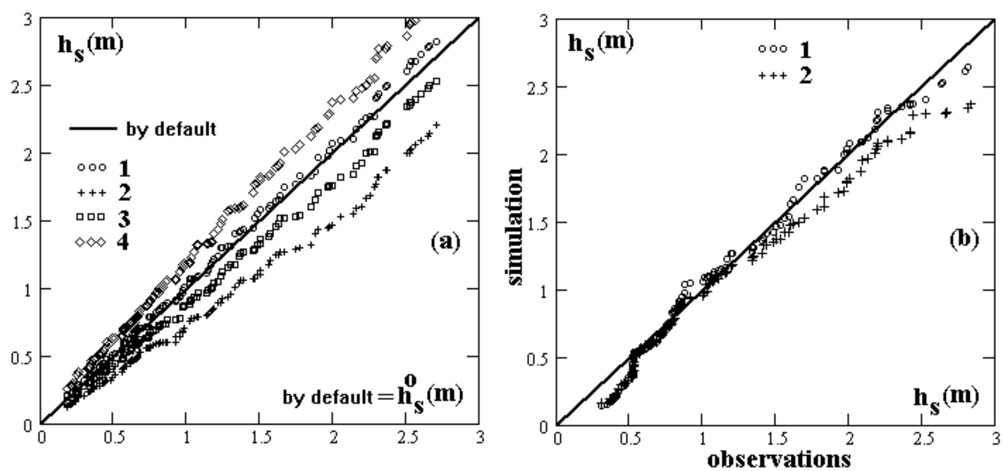


Tuleny Island GMS (N-Caspian), March-May 2001 (each 3 hours)

Validation of Hindcasting Procedure with Assimilated Wind Data



Parts of significant wave height time series. North Caspian, point 44.10N, 48.49E (depth 24 m).
1 – measurements. 2 - SWAN with step 1 hour. 3 – SWAN with step 15 minutes.



Variants	C_{ds}	S_{pm}
By default	2.36	3.02
1	2.85	3.62
2	2.85	2.42
3	1.86	2.42
4	1.86	3.62

Q-Q plots of SWAN calculations for N. Caspian (February, 2002).
(?) – values from table, (1-4 – the same as in table), (b) – different time steps; 1- 15 minutes, 2 – 1 hour.

Genetic classification as a tool for wave spectra modeling

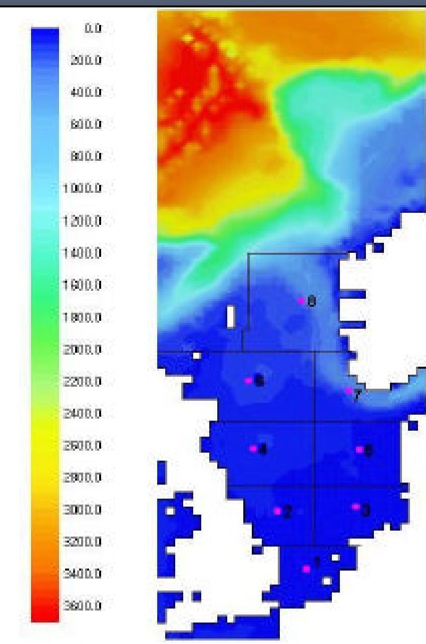
The techniques for decreasing of data dimensionality

- Formal orthogonal expansions
- Clustering
- Classification with learning

INITIAL DATA:

North Sea Region
Directional wave spectra
(24 directions ? 25 frequencies each)

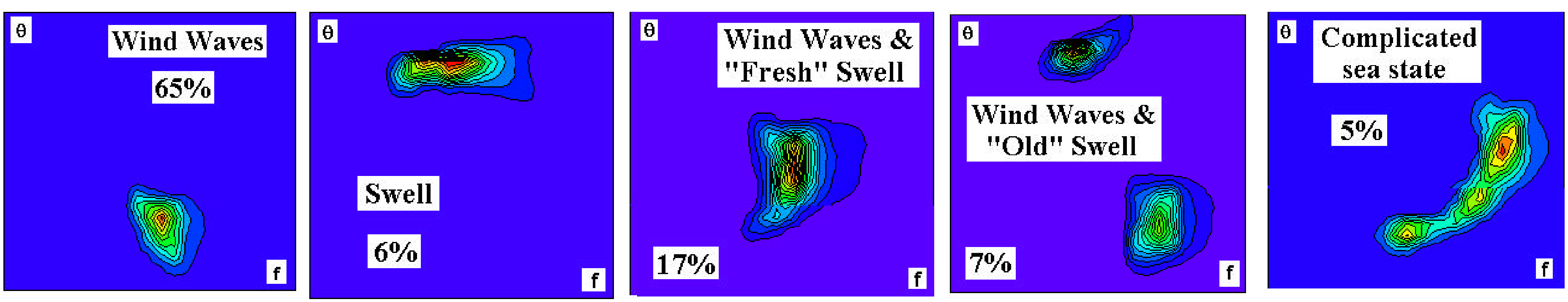
Continuous hindcasting: WW 2.22, 3 hours, 1983-1998



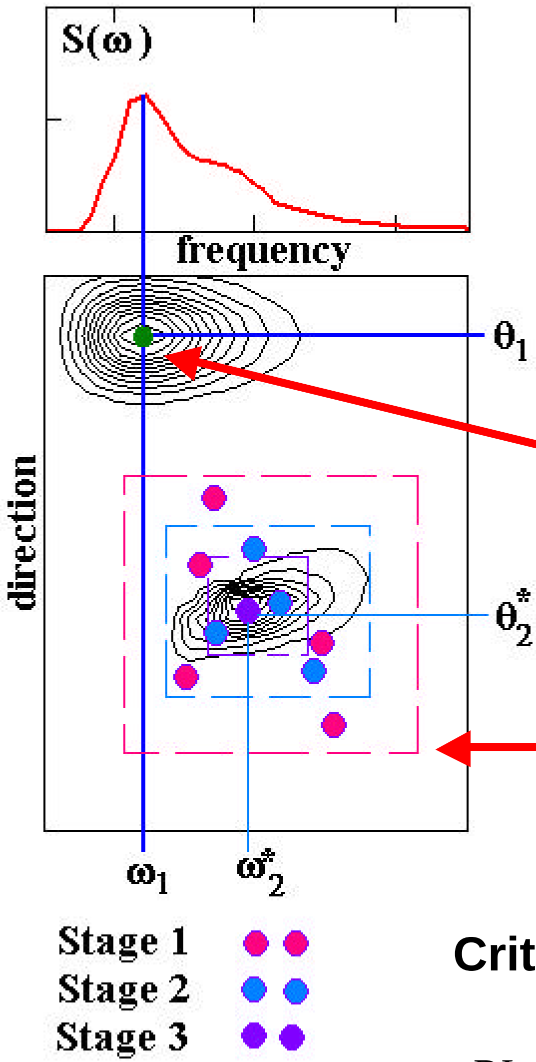
Genetic systems of classes

Classification of climatic spectra (probabilities for point 2)

I II III IV V



How to construct the classification rules?
Parameterization technique for directional spectra



Dataset of Initial Spectra

↓

Smoothing

↓

Model of multipeaked spectrum

$$S(\omega,\theta)=\sum_p \gamma_p S_p(\omega,\theta\,|\,\Xi_p)$$

→ Approximation

$$S(\omega,\theta)\equiv S(\omega)G(\omega,\theta)$$

$$S(\omega)=\alpha g^2\omega^{-k}\exp\left[-B\omega^{-n}\right]\gamma^{\beta(\omega)}$$

$$G(\omega,\theta)=C_m(\omega)\cos^{2m(\omega)}(\theta/2)$$

↓

Estimation of prevailed peak position on the data sheet directly

↓

Estimation of secondary peaks positions and other parameters γ_p, Ξ_p by means of multistage Monte-Carlo optimization

→ Control of significance of the peaks has been obtained

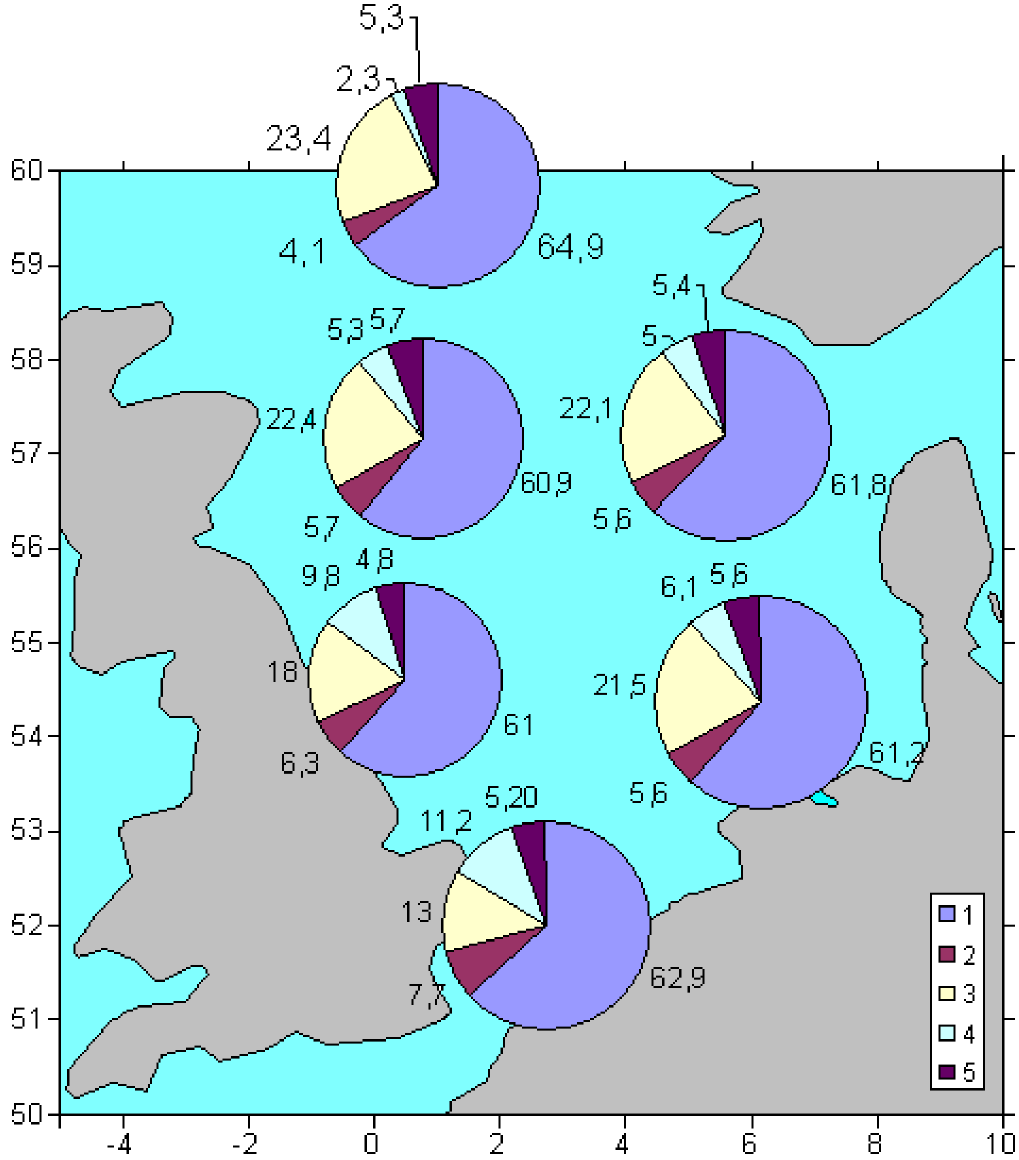
↓

Set of spectral parameters for classification

Criterion of optimization:

$$DI=\sum_i\sum_j\frac{\left|S(\omega_i,\theta_j)-S_{ij}^*\right|}{S_{ij}^* m_{00}}\xrightarrow[\langle \gamma_k,\omega_m^{(k)},\theta_{\max}^{(k)},n_{fields}\rangle]{}\min$$

Results: Occurrence for different classes of the spectra

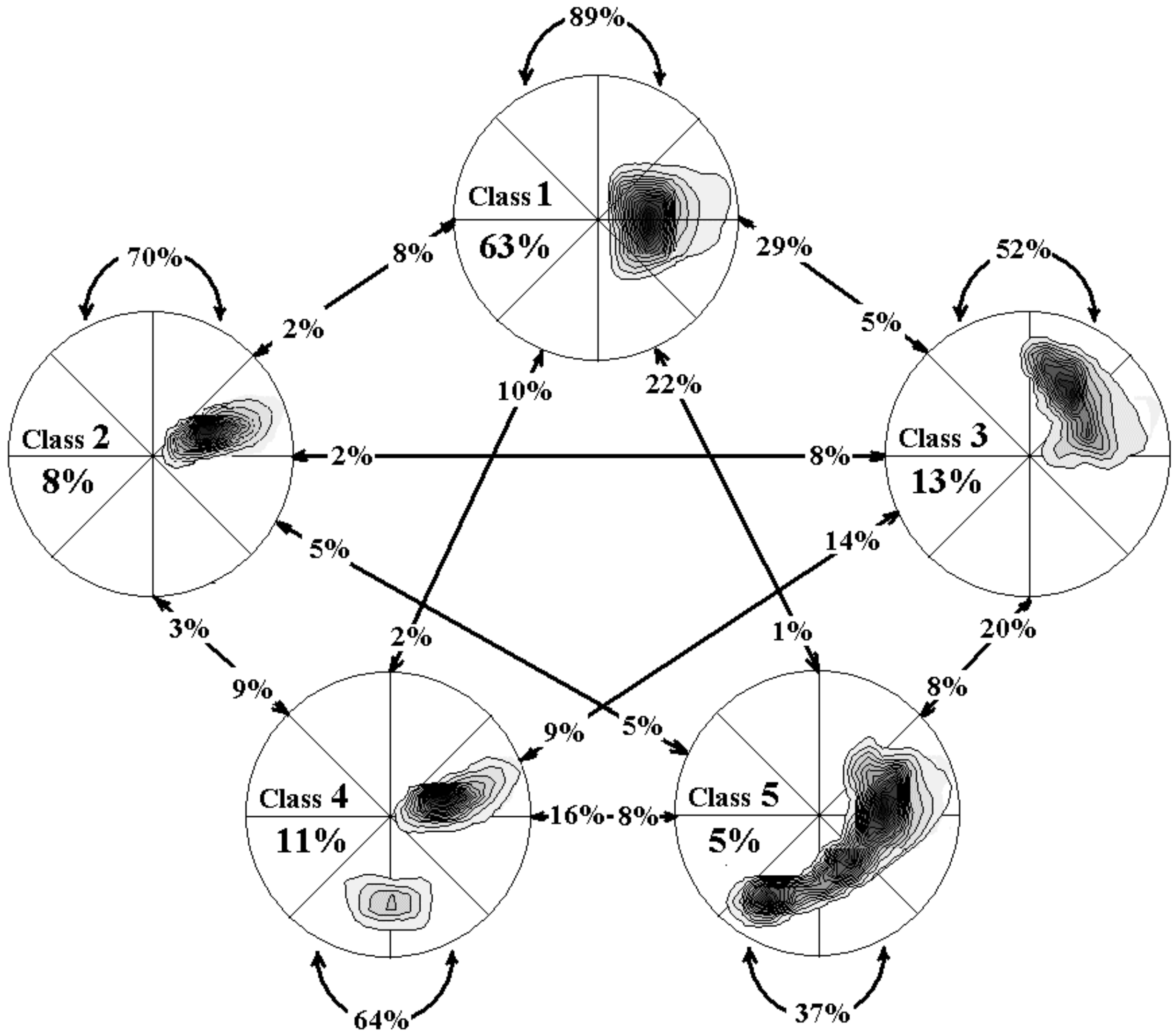


Computations for all the months, 1983-1998

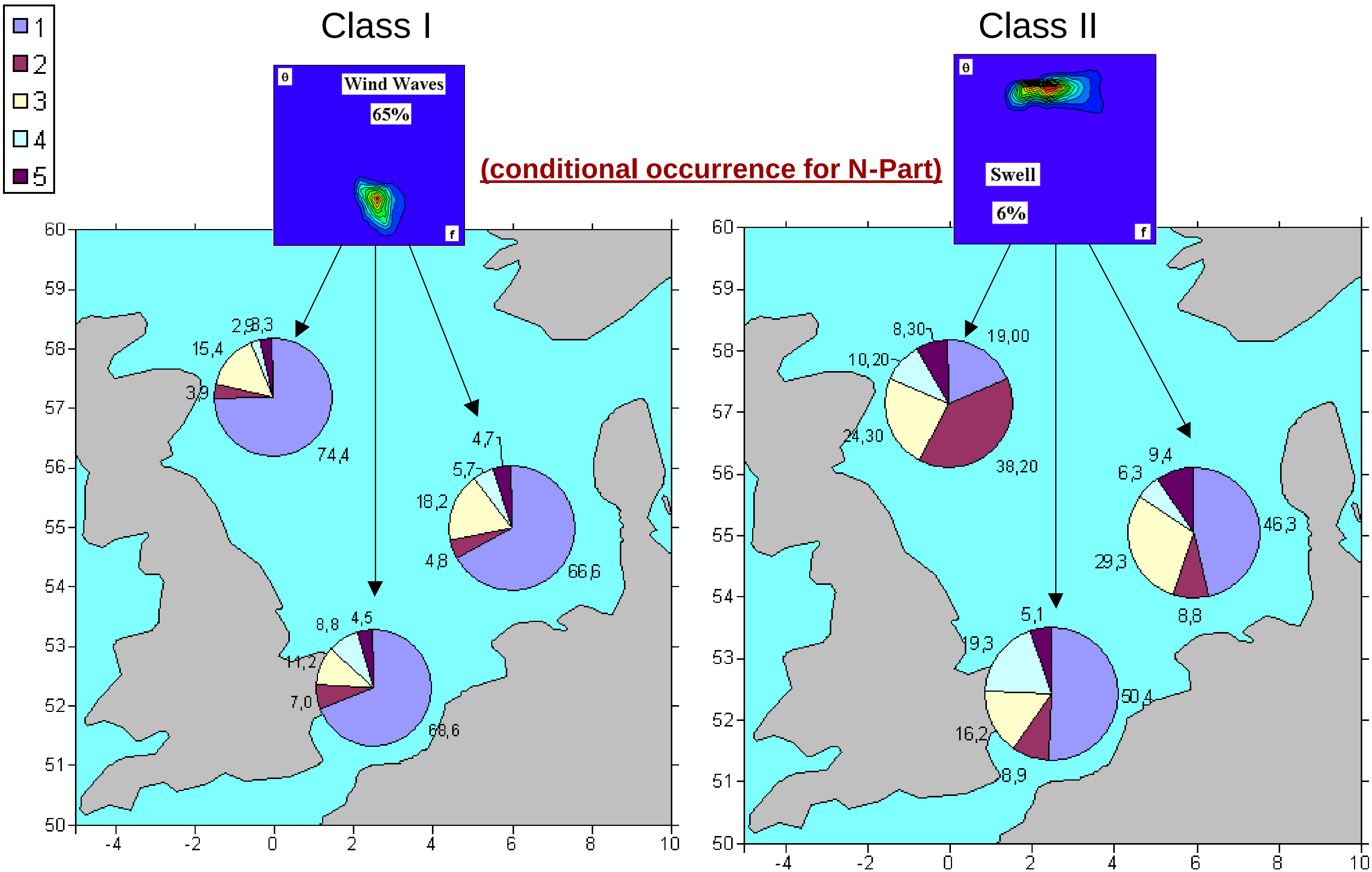
1 – Wind waves
2 – Swell
3 – Sea with fresh swell
4 – Sea with old swell
5 – Complicated sea

“Star” representation of Markov probability model of the variability of directional spectra

SW-part of the North Sea

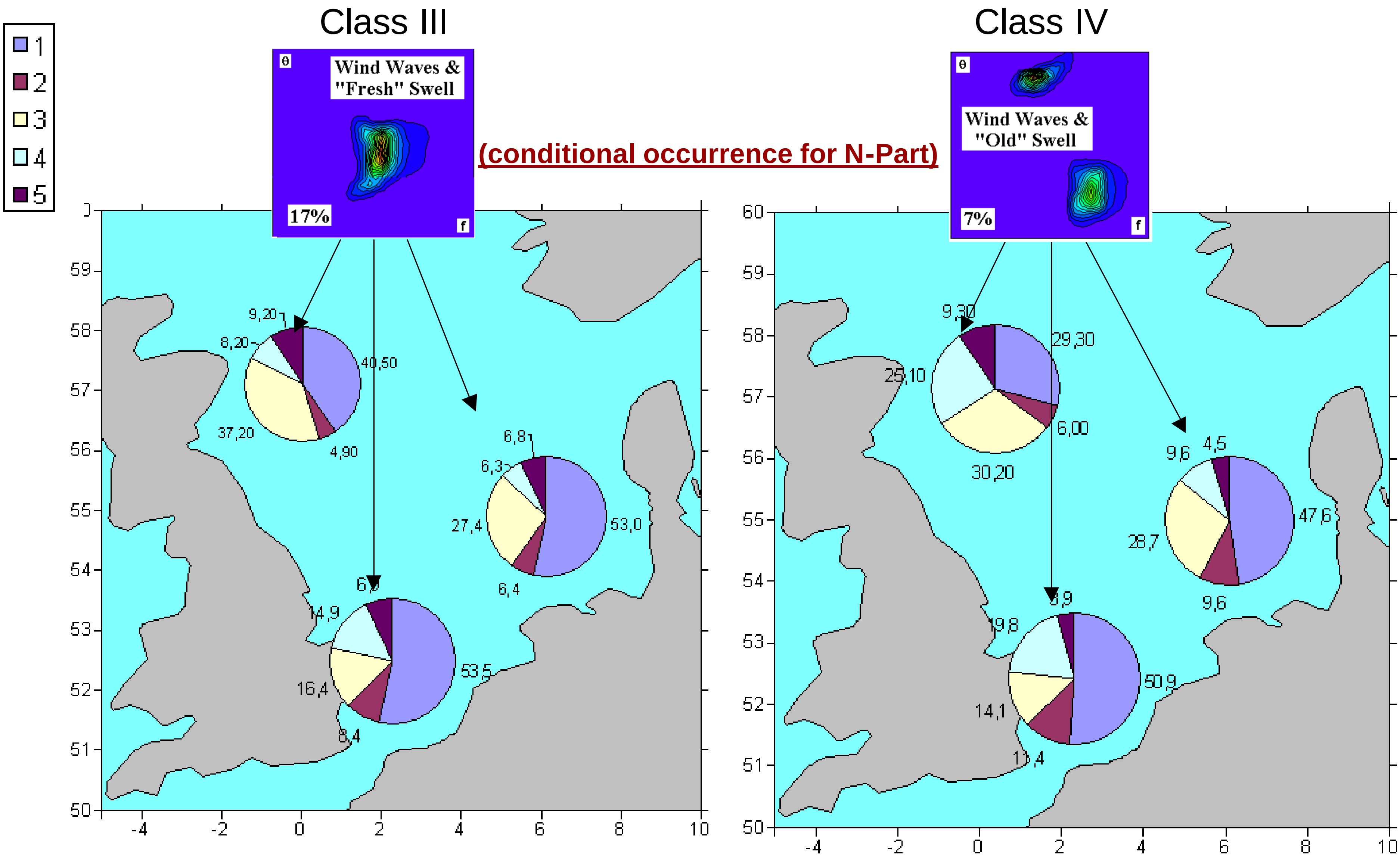


Conditional Spatial Distribution of Sea Wave Spectra



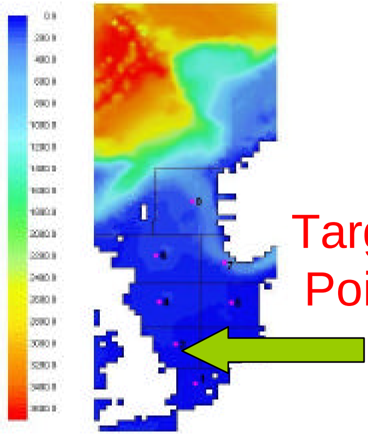
Joint Spatial Distribution of Sea Wave Spectra

(conditional occurrence for N-Part)

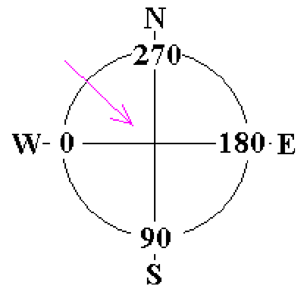


Approximation of ensemble of the climatic spectra

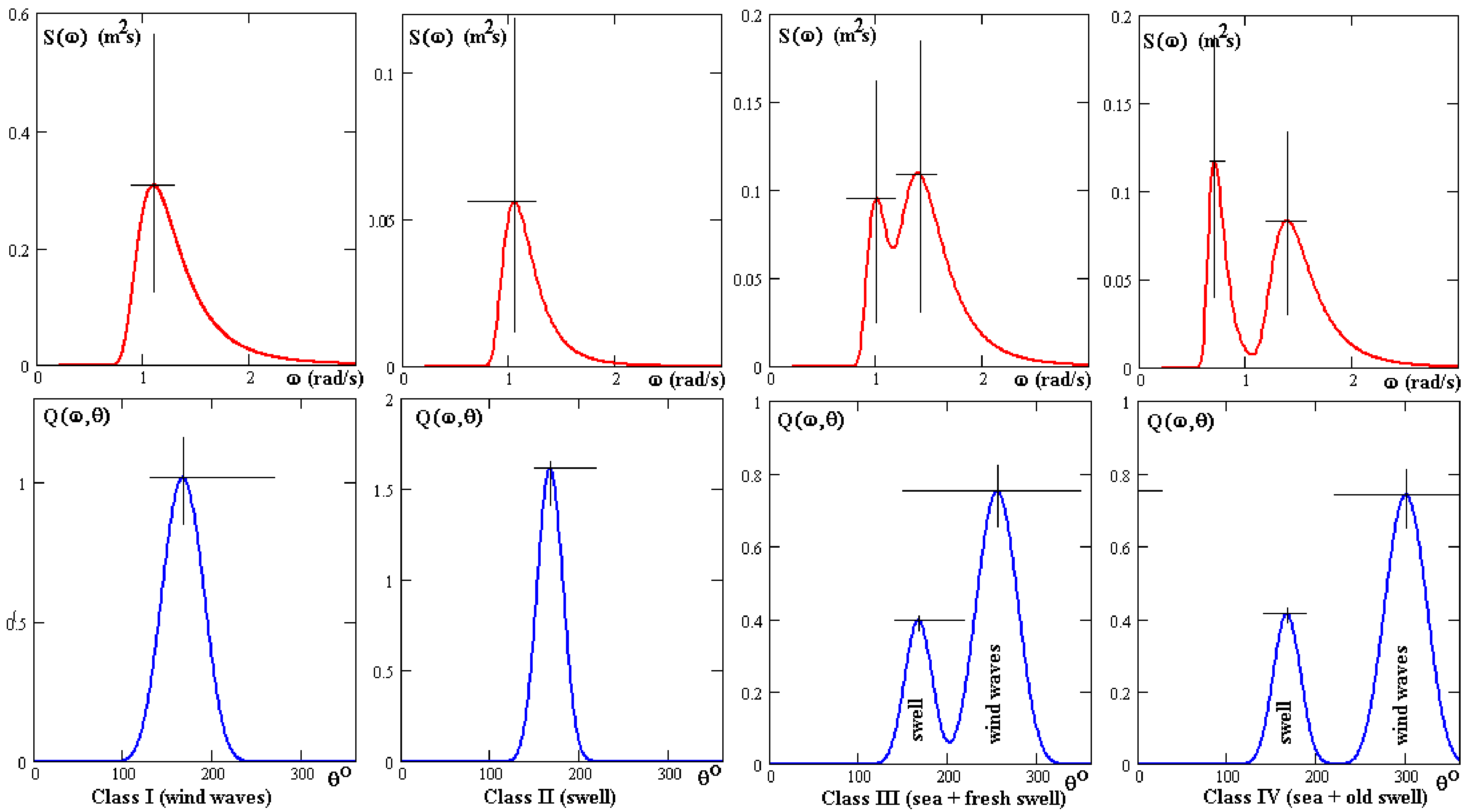
(statistical linearization technique)



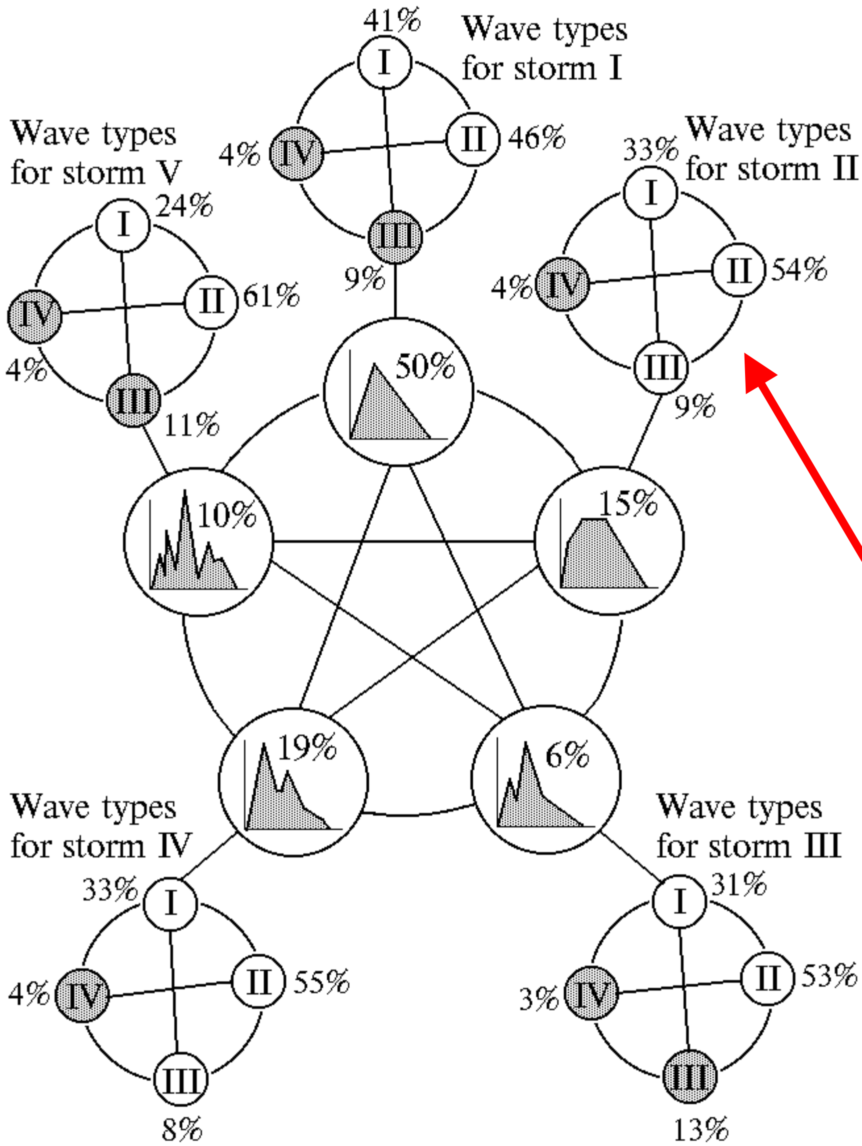
Target Point

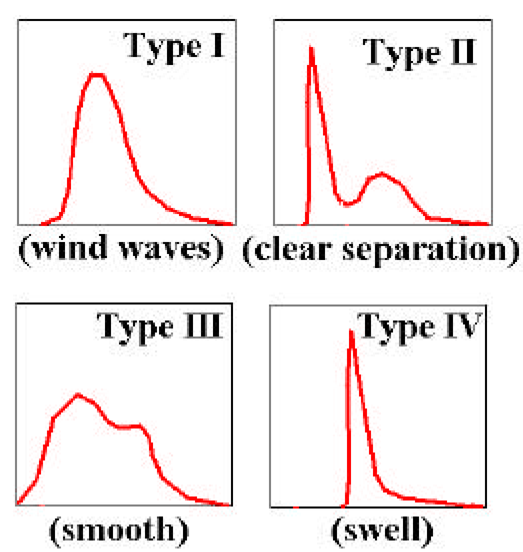


Notation of the directions - WW 2.22



Comparison with measured data: climatic spectra and storms in a Black Sea





How to compute the extremes in a point?

Some methods for extreme estimation

IDM Approach

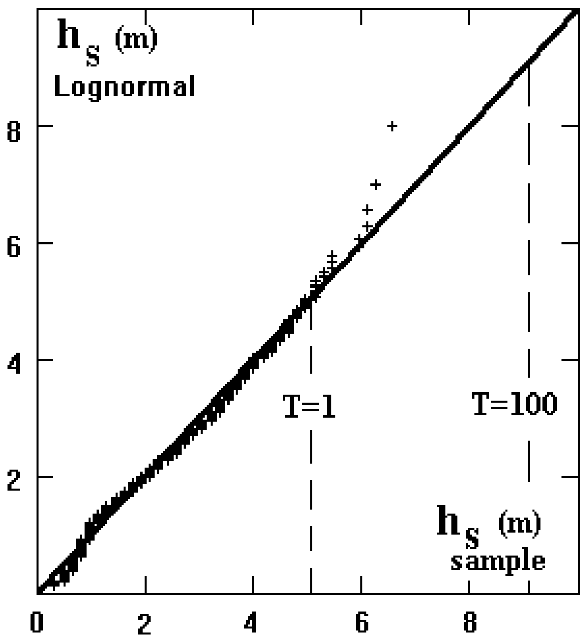
$$h_T = F^{-1}(p(T))$$

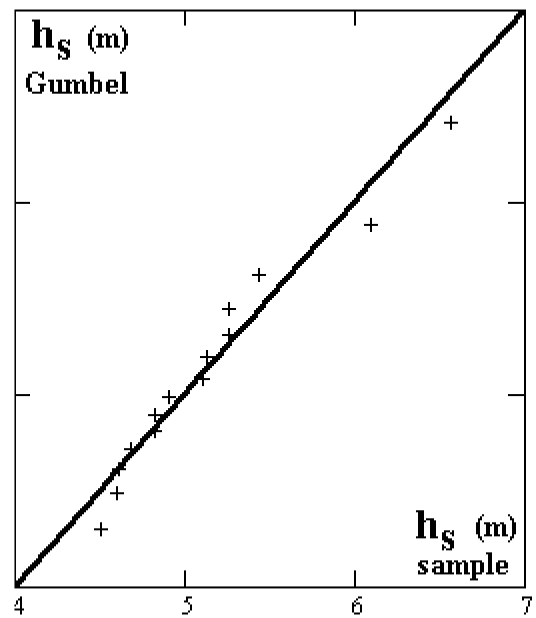
AMS Approach

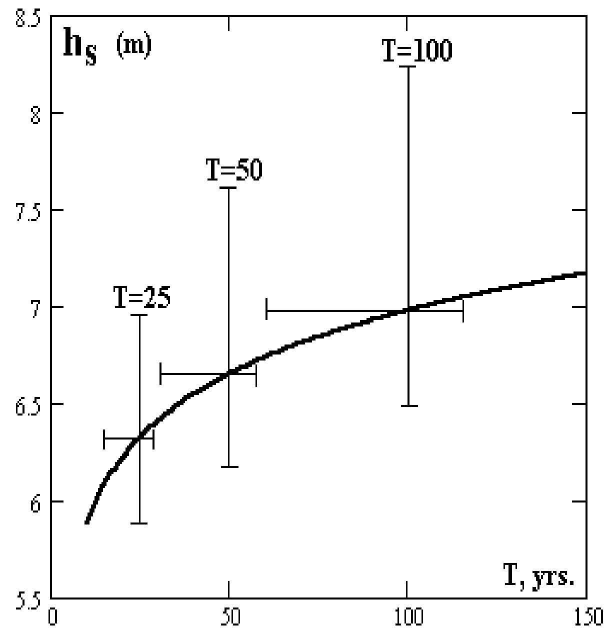
$$F_{\max}(x) = \exp\{-\exp\{-a_N[x-b_N]\}\}$$

POT Approach

$$F(h) = \sum_k p_k G^k(h)$$

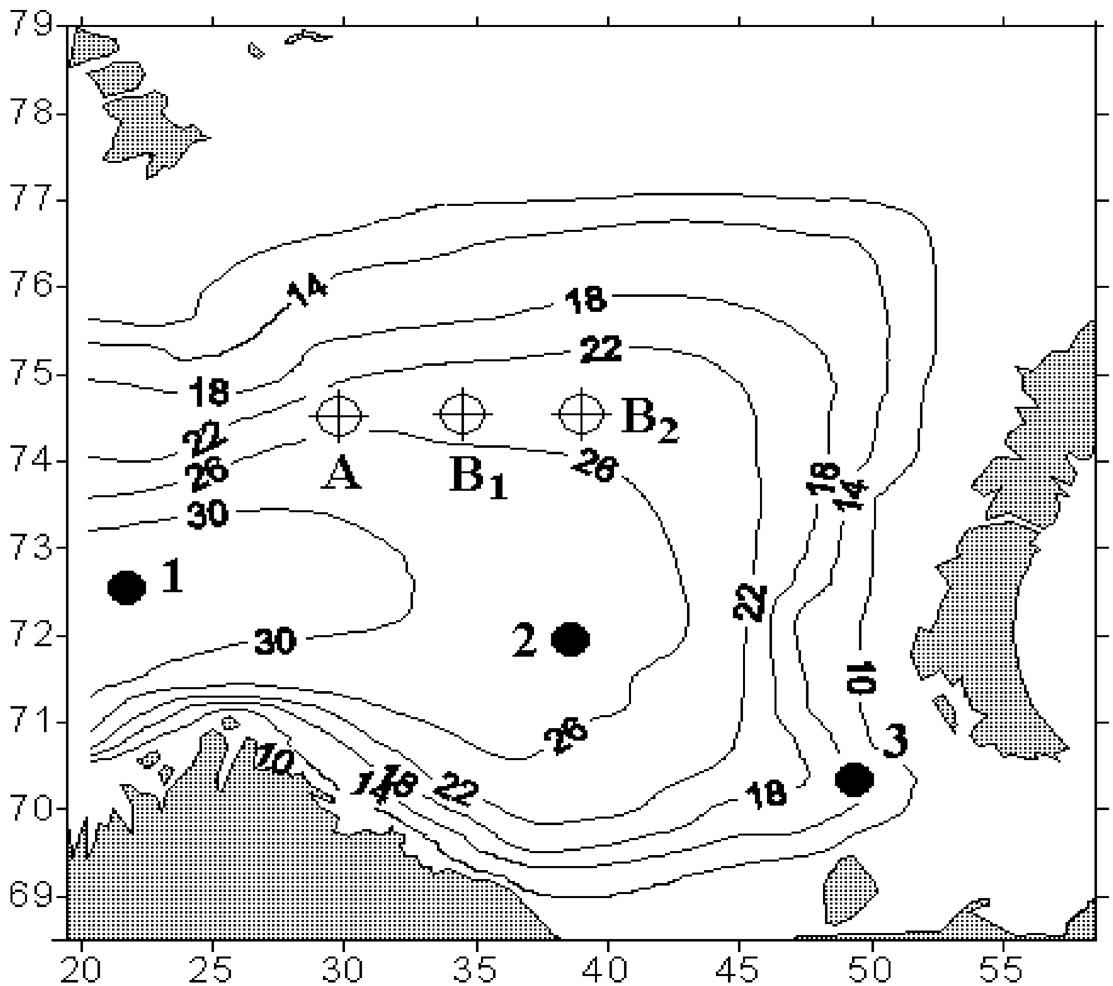




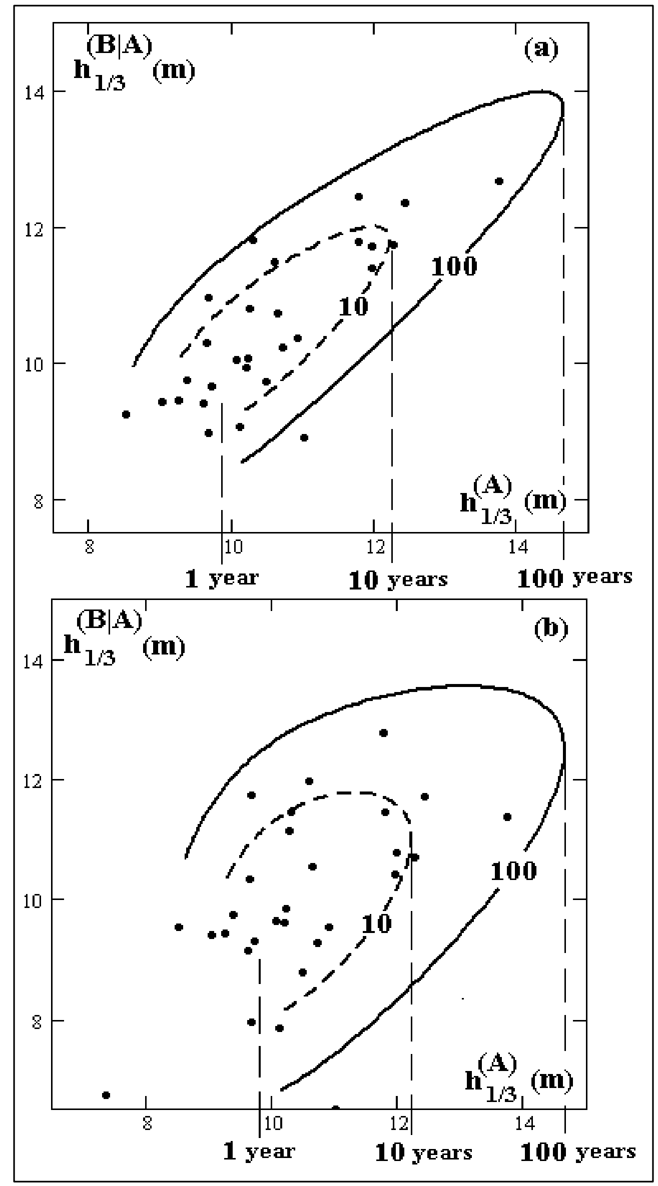


How to compute the extremes in a field?

BOLIVAR – approach on the base of multiscale stochastic simulation of wave fields



100-years maxima waves in a Barents sea



RUSSIAN REGISTER OF SHIPPING.

“Wind and wave climate of Barents, Okhotsk and Caspian Seas. Handbook”. Saint-Petersburg, 2003, 213pp.

CONTENT

Part 1. Methods of wind and wave climate calculations.

Part 2. Reference data of wind and wave climate of Barents, Okhotsk, and Caspian seas

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The following statistics is presented in the part 2:

- *Extreme winds with return periods 1, 5, 10, 25, 50 and 100 years. (Omnidirectional and for 8 directions)*
- *Storm and weather windows durations of wind speed .*
- *Wave heights, periods, lengths (mean, significant, 3%, 1%, 0.1%) and wave crests with return periods1, 5, 10, 25, 50 and 100 years.*
- *Storm and weather windows durations of wave heights . (Mean, rms, max for months).*
- *Probability of wave heights and direction for months.*
- *Joint probability of wave heights and mean periods and regressions.*

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SUMMARY

- Hindcasting is the main tool for wave climate investigations.
- Confidence of wind reanalysis is quite different for various basins and even their parts.
- Ship data assimilation is a useful approach for improvement of wind data input.
- Continuous 30 years (and sometimes more) hindcasting was performed for a lot of seas near Russia.
- Wave climate is a set two-dimensional spectra and descended from them spatiotemporal statistics.
- Genetic classification of two-dimensional climatic wave spectra performed.
- Markov probability model is used for investigation of the variability of directional climatic spectra.
- Approach to calculations of wave extremes on a point and field is elaborated.
- New Handbook of Wind and wave climate of Barents, Caspian and Okhotsk seas is based on hindcasting, and published by Russian Register of shipping.