Numerical modeling of the Baltic sea-level variability

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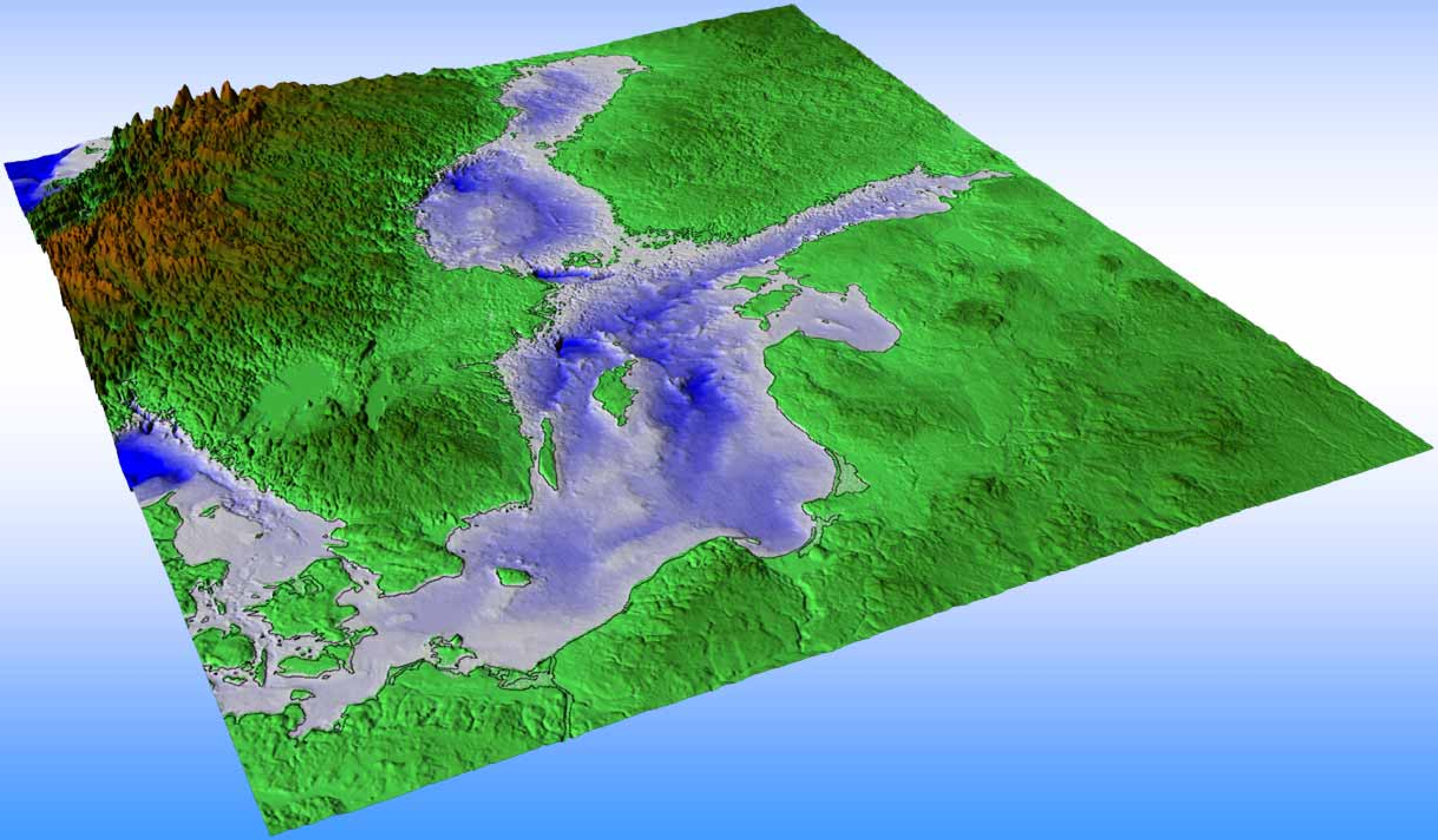
Outline:

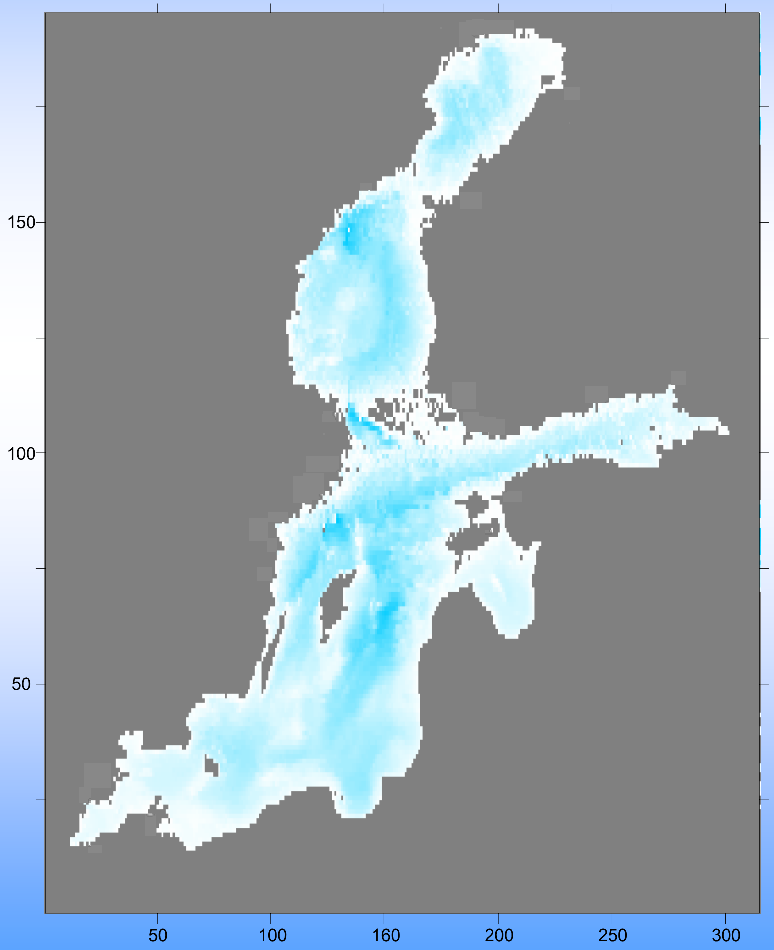
1. Digital bathymetry of Baltic Sea (GEBCO)
2. 2-D Princeton Ocean Model
3. NCEP/NCAR Reanalysis data as input to POM model
4. Analysis of contributions of forcing factors (wind and pressure) to sea level variability
5. Comparison of statistical characteristics of observational and model records (1990-2000)

GEBCO 1-minute global bathymetric grid

http://www.ngdc.noaa.gov/mgg/gebco/gebcoproducts.html



Medium resolution grid 631 * 391 → 2’ * 2’



$\Delta x \approx 1852$ m
$\Delta y = 3704$ m

The Baltic Sea is considered as a closed basin: the barotropic transport through Kattegat and tidal forcing are not taking into account

2-D version of the Princeton Ocean Model

Wind stress has been calculated from equation:

$$(\tau_x, \tau_y) = \rho_A C_D \left|\vec{\mathbf{U}}_W\right| \left(U_W, V_W\right),$$

where $\vec{\mathbf{U}}_W$ is wind velocity $(\mathrm{m \cdot s^{-1}})$, $\rho_A = 1.3\,\mathrm{kg \cdot m^{-3}}$

$$C_D = 0.0008 + 0.000065\left|\vec{\mathbf{U}}_{\mathbf{w}}\right|$$ (Wu, 1982)

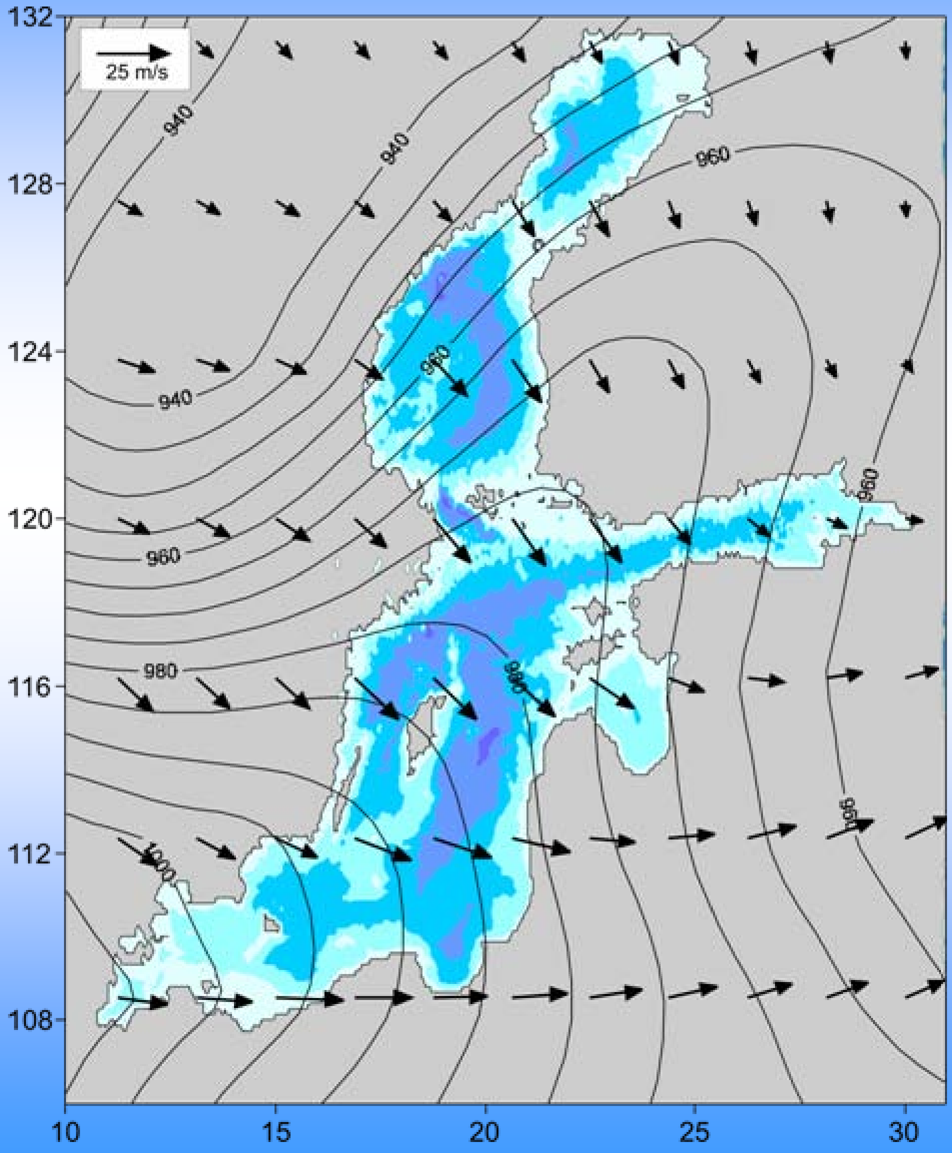
Bottom friction has been calculated from a quadratic drag equation:

$$(\tau_{bx}, \tau_{by}) = \left(C_B u_b \left|\vec{\mathbf{U}}_b\right|, C_B v_b \left|\vec{\mathbf{U}}_b\right|\right),$$

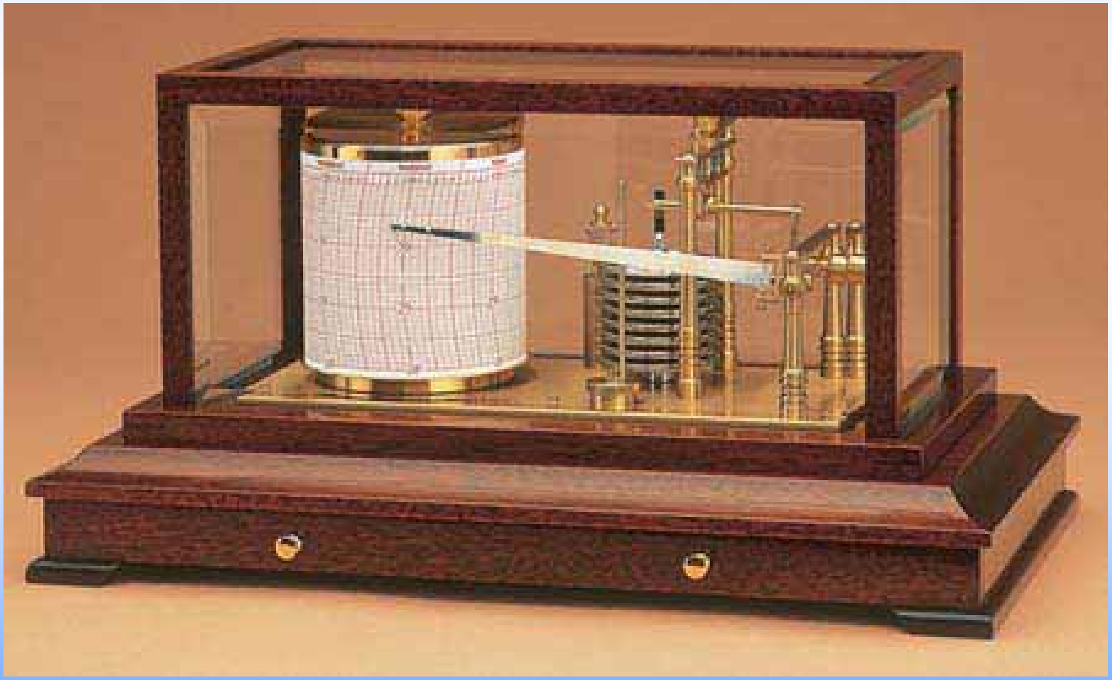
where $\vec{\mathbf{U}}_b = (u_b, v_b)$ is the current velocity near the bottom

$$C_B = 0.0025$$

Pressure and wind, 00h UTC, 23 January, 1993
NCEP/NCAR Reanalysis



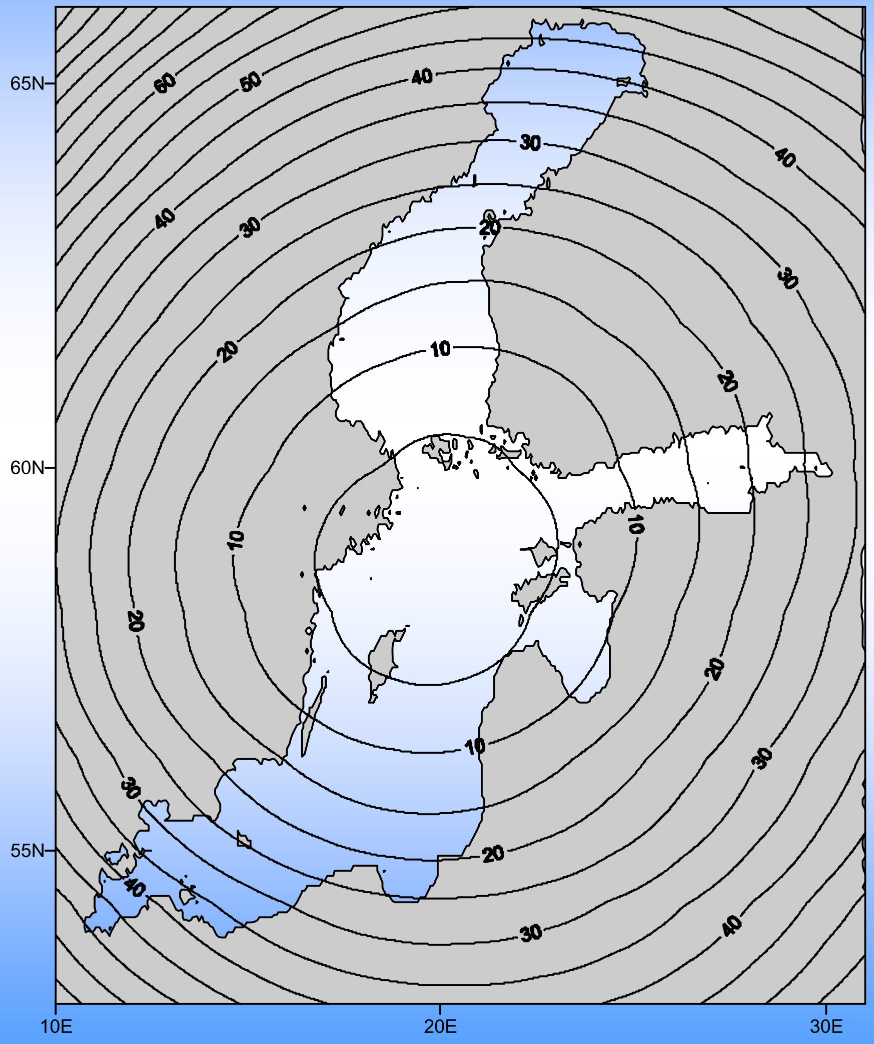
Numerical simulation of generation sea level fluctuations by atmospheric pressure forcing



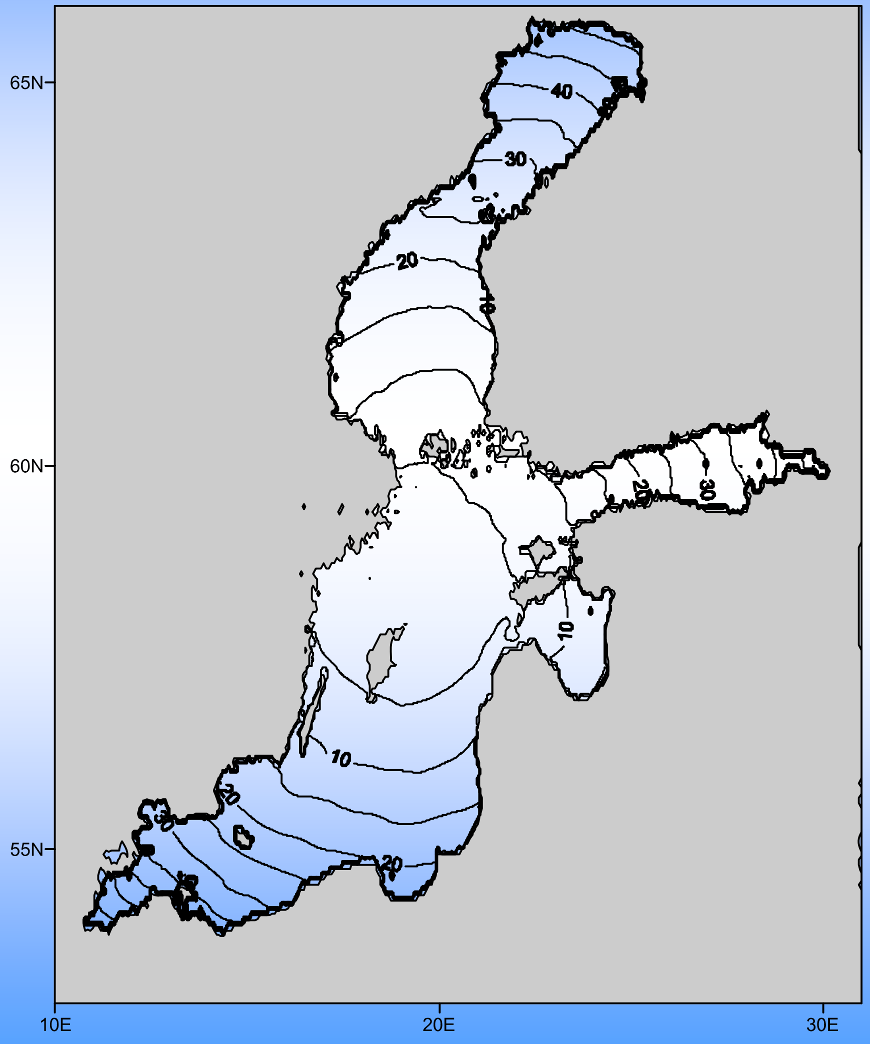
1990 - 2000

Variance

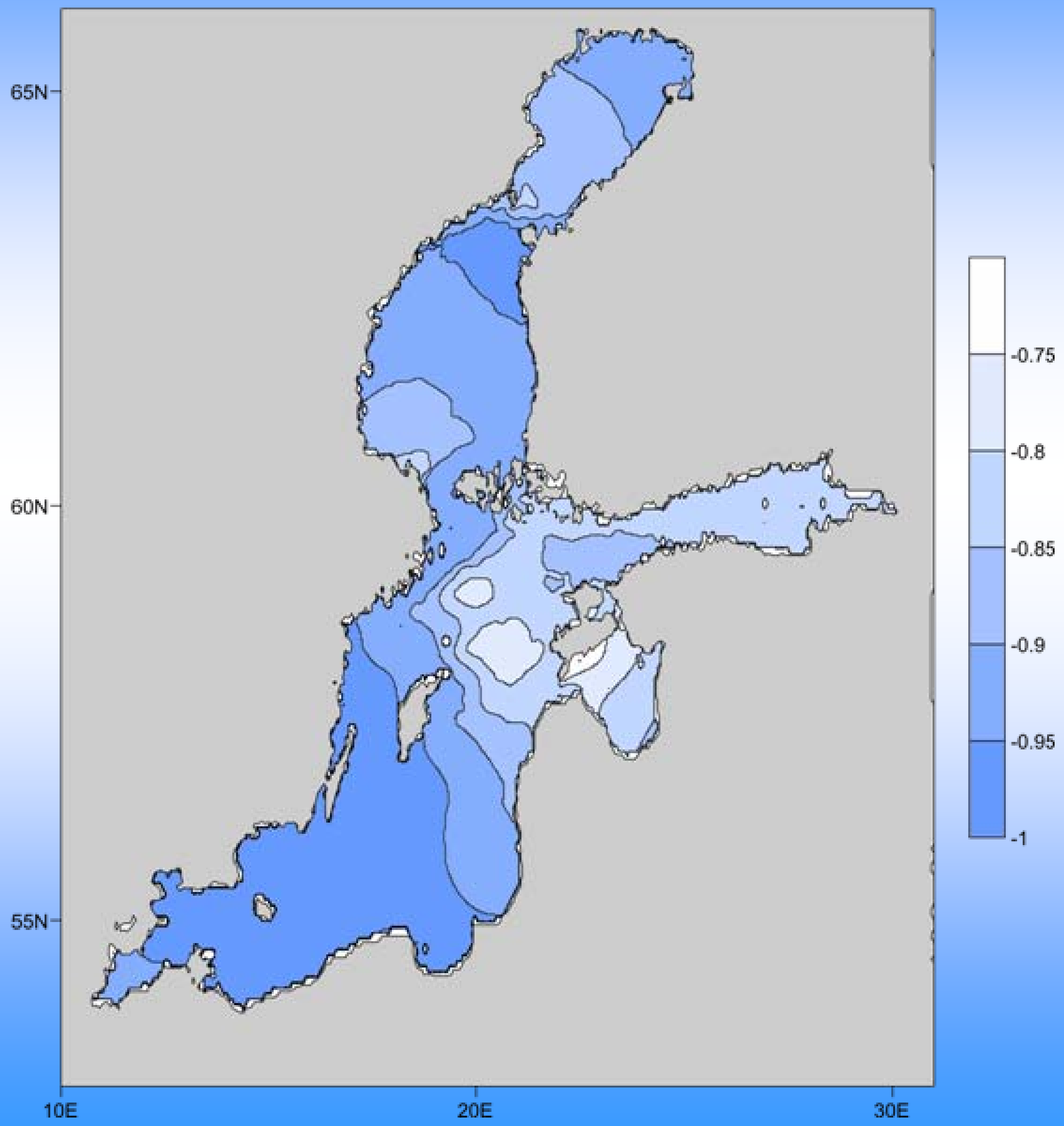
Pressure



Sea level

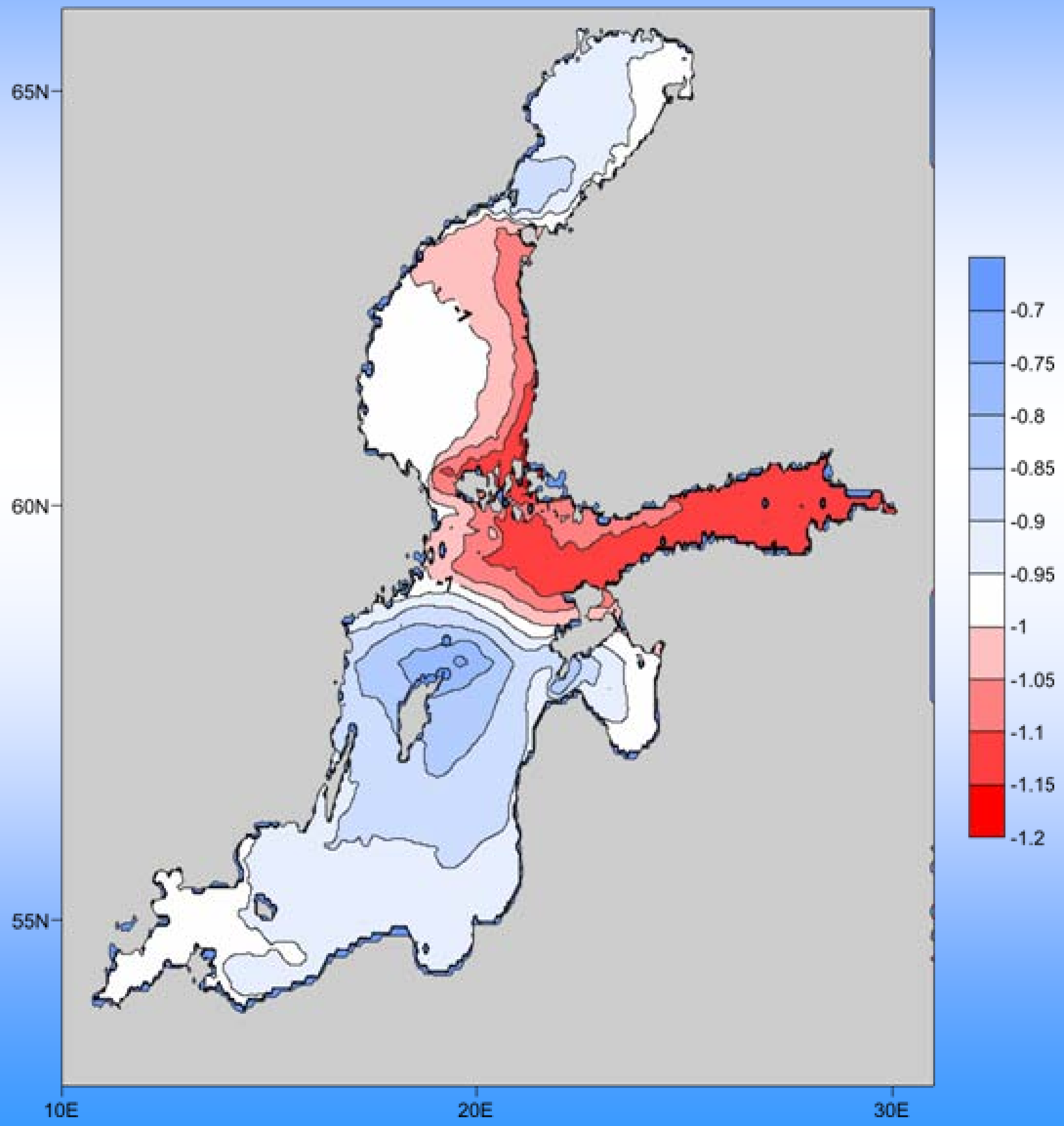


Correlation Pressure – Sea level



Regression coefficient “Pressure – Sea level”

(validity of “Inverse barometer law”)



Numerical simulation of generation sea level fluctuations by wind

1990 - 2000

Statistical parameters of relation “wind – sea level”

ς_i is the sea level variation, $\mathbf{V}_i = (u_i, v_i)$ is the wind vector

u_i is the zonal wind, v_i is the meridional wind.

Regression:

$$\varsigma_i = \alpha u_i + \beta v_i + \varepsilon_i \qquad (1)$$

$$\alpha = \frac{\langle \varsigma v \rangle \langle uv \rangle - \langle \varsigma u \rangle \sigma_v^2}{\langle uv \rangle^2 - \sigma_u^2 \sigma_v^2} \qquad \beta = \frac{\langle \varsigma u \rangle \langle uv \rangle - \langle \varsigma v \rangle \sigma_u^2}{\langle uv \rangle^2 - \sigma_u^2 \sigma_v^2}$$

$$\sigma_\varsigma^2 = \alpha^2 \sigma_u^2 + \beta^2 \sigma_v^2 + 2\alpha\beta \langle uv \rangle + \sigma_\varepsilon^2$$

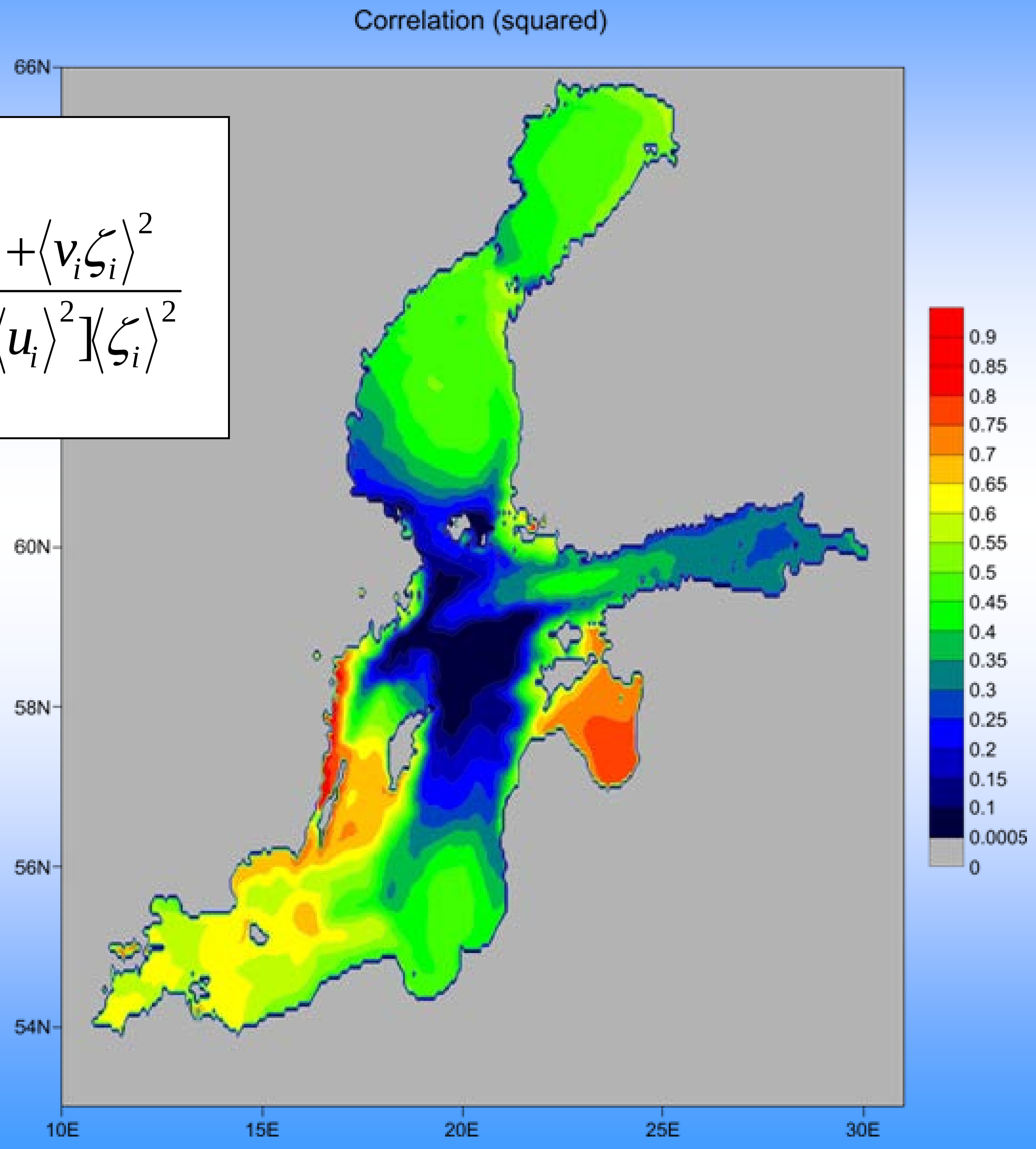
$$\sigma_\zeta^2 = \langle \zeta_i \rangle^2 \qquad \sigma_u^2 = \langle u_i \rangle^2 \qquad \sigma_v^2 = \langle v_i \rangle^2$$

Correlation:

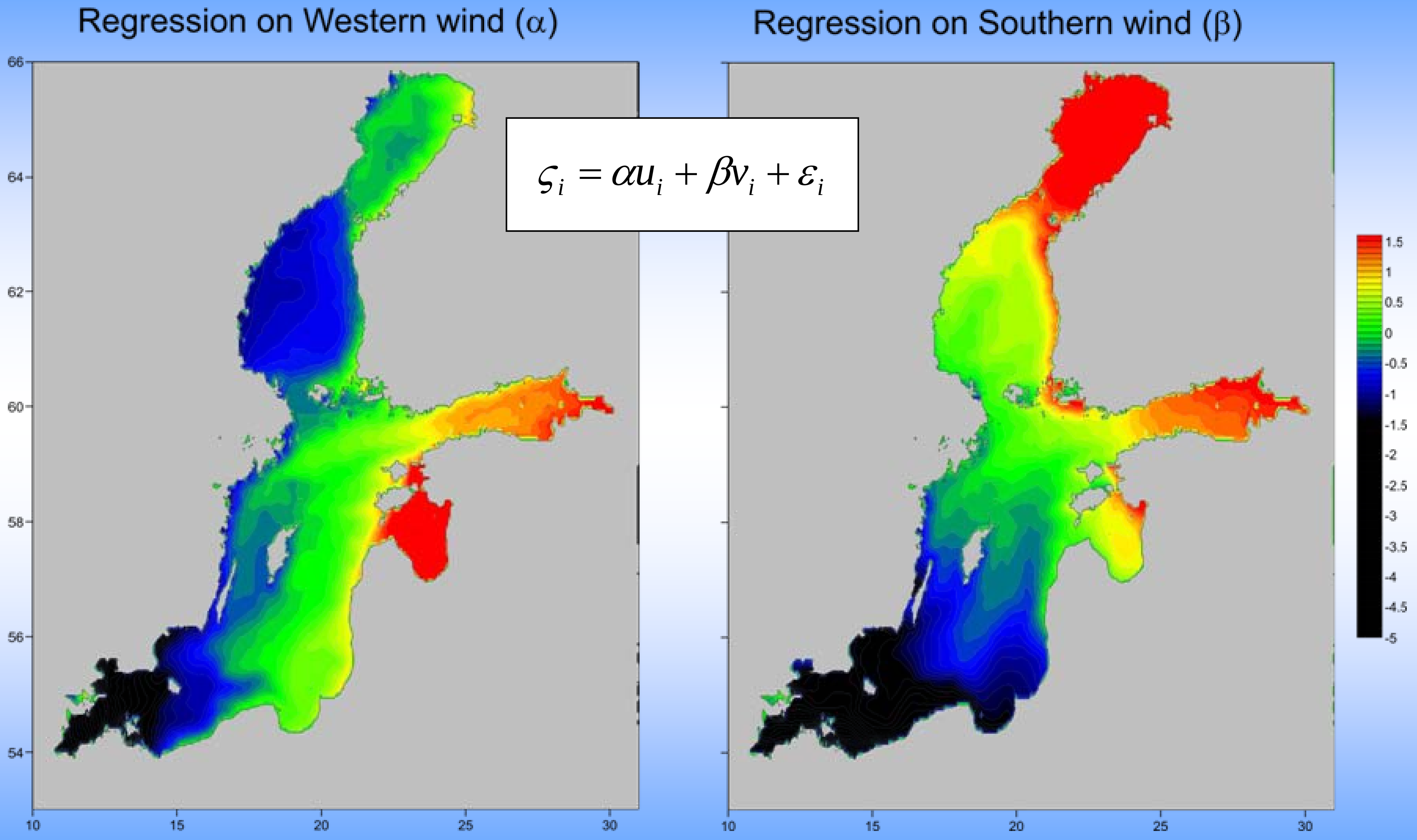
$$r^2 = \frac{\langle u_i \zeta_i \rangle^2 + \langle v_i \zeta_i \rangle^2}{[\langle u_i \rangle^2 + \langle u_i \rangle^2] \langle \zeta_i \rangle^2} \qquad (2)$$

Correlation between wind and sea level

$$r^2 = \frac{\langle u_i \zeta_i \rangle^2 + \langle v_i \zeta_i \rangle^2}{[\langle u_i \rangle^2 + \langle u_i \rangle^2] \langle \zeta_i \rangle^2}$$


Correlation (squared)

Regression coefficients “wind – sea level”

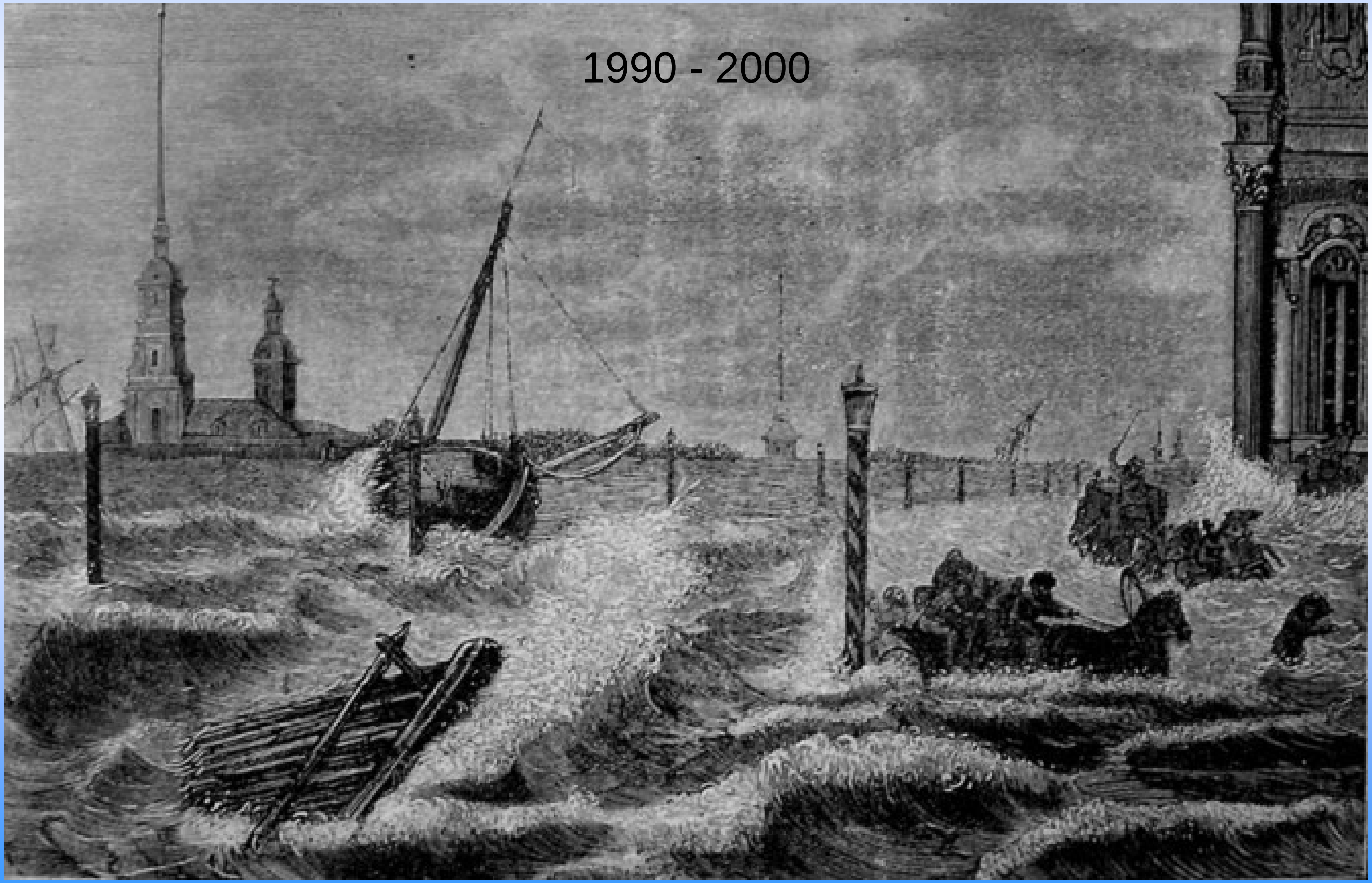


Regression on Western wind (α)

Regression on Southern wind (β)

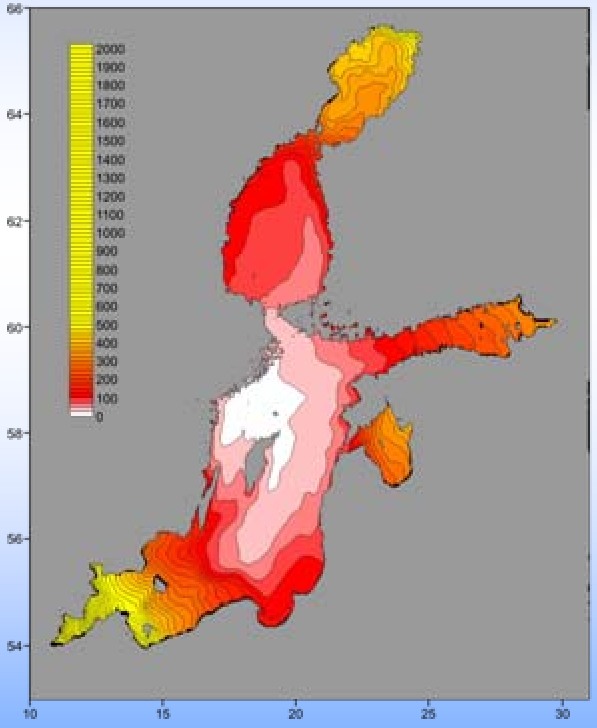
$$\varsigma_i = \alpha u_i + \beta v_i + \varepsilon_i$$

Numerical simulation of generation sea level fluctuations by wind and atmospheric pressure

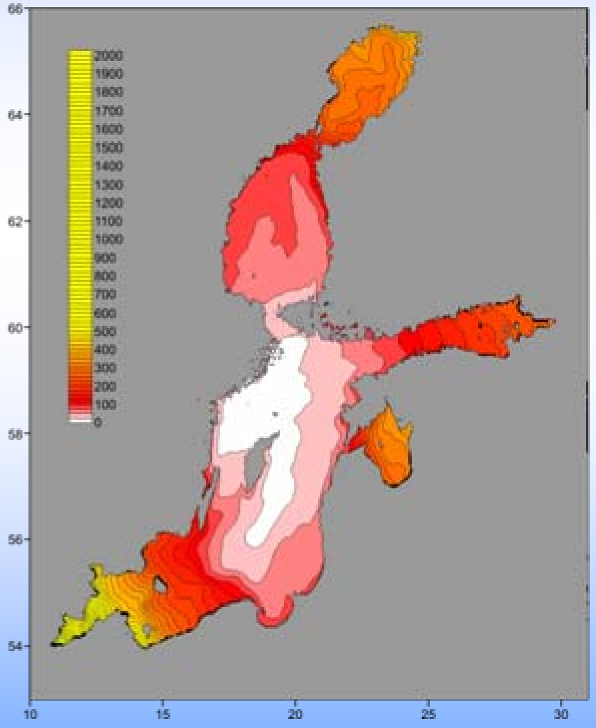


Sea level variance

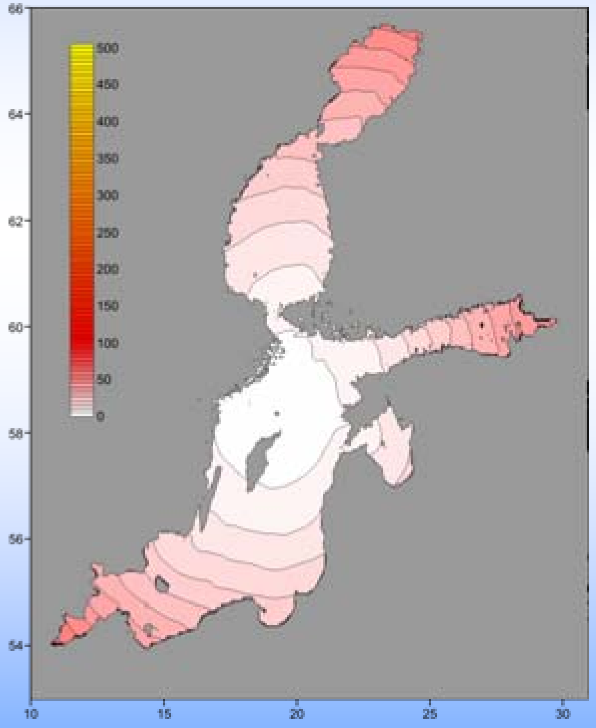
Wind and pressure forcing



Wind forcing

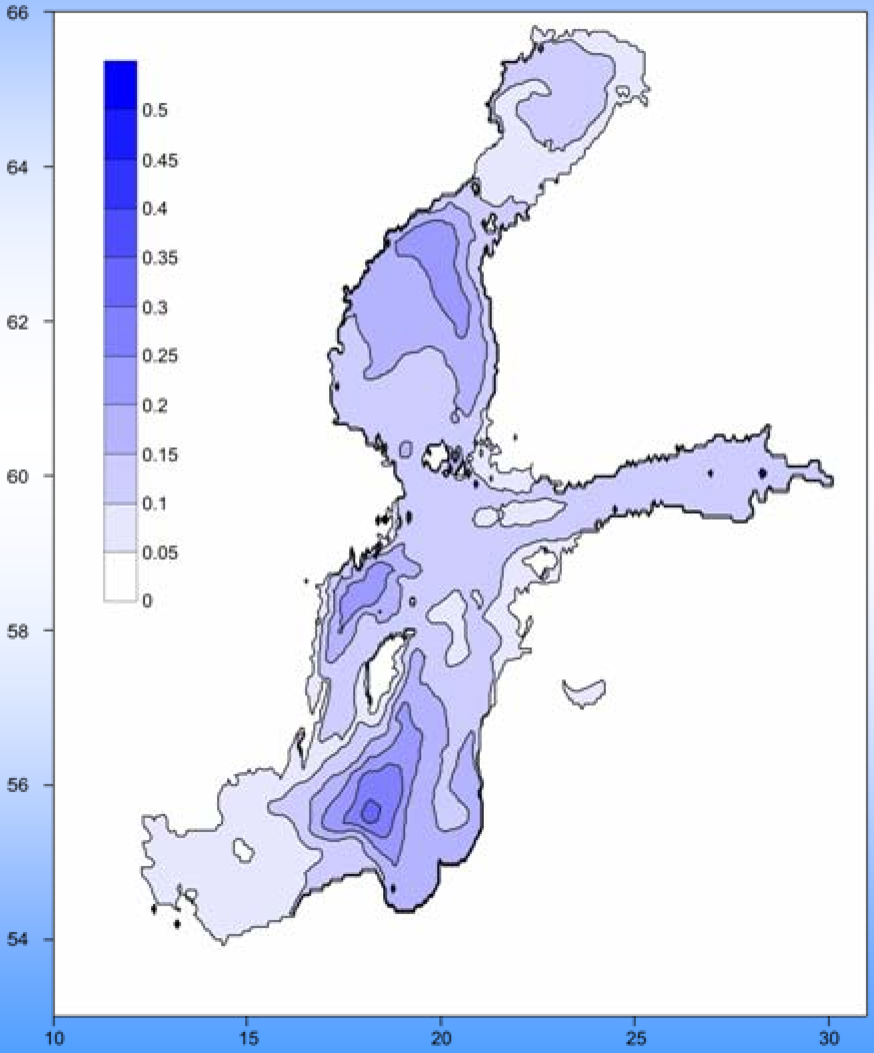


Pressure forcing

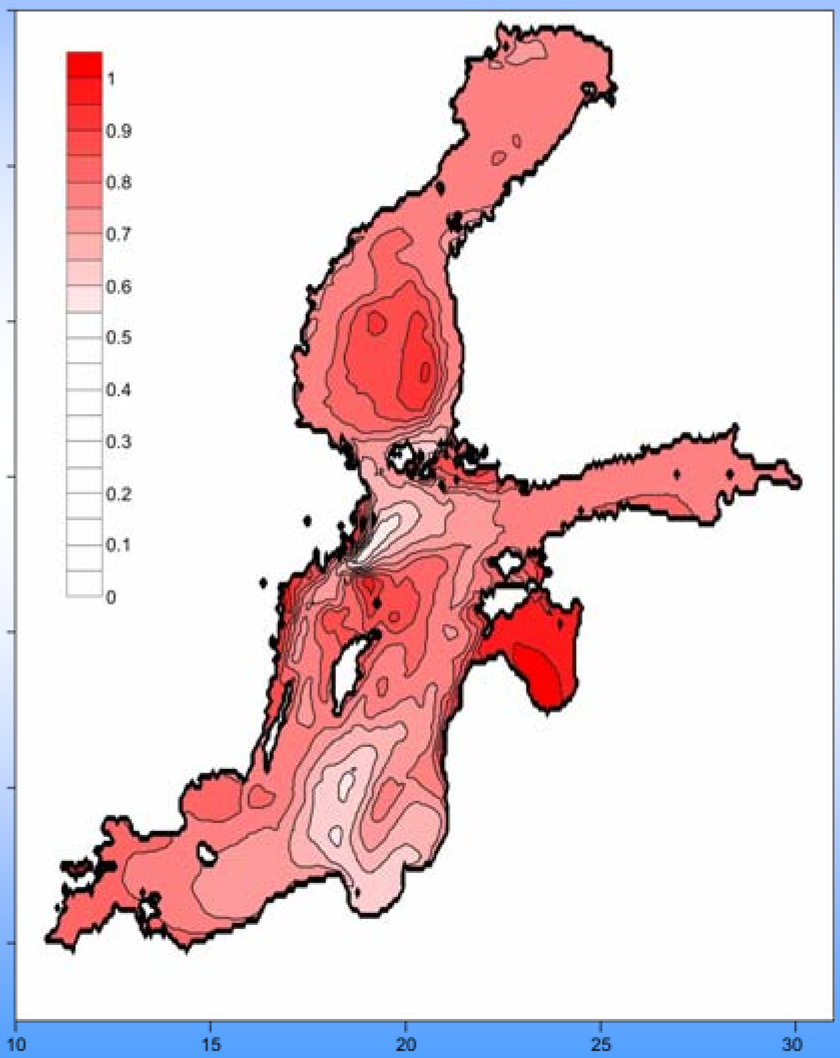


Contribution of pressure and wind into sea level variance

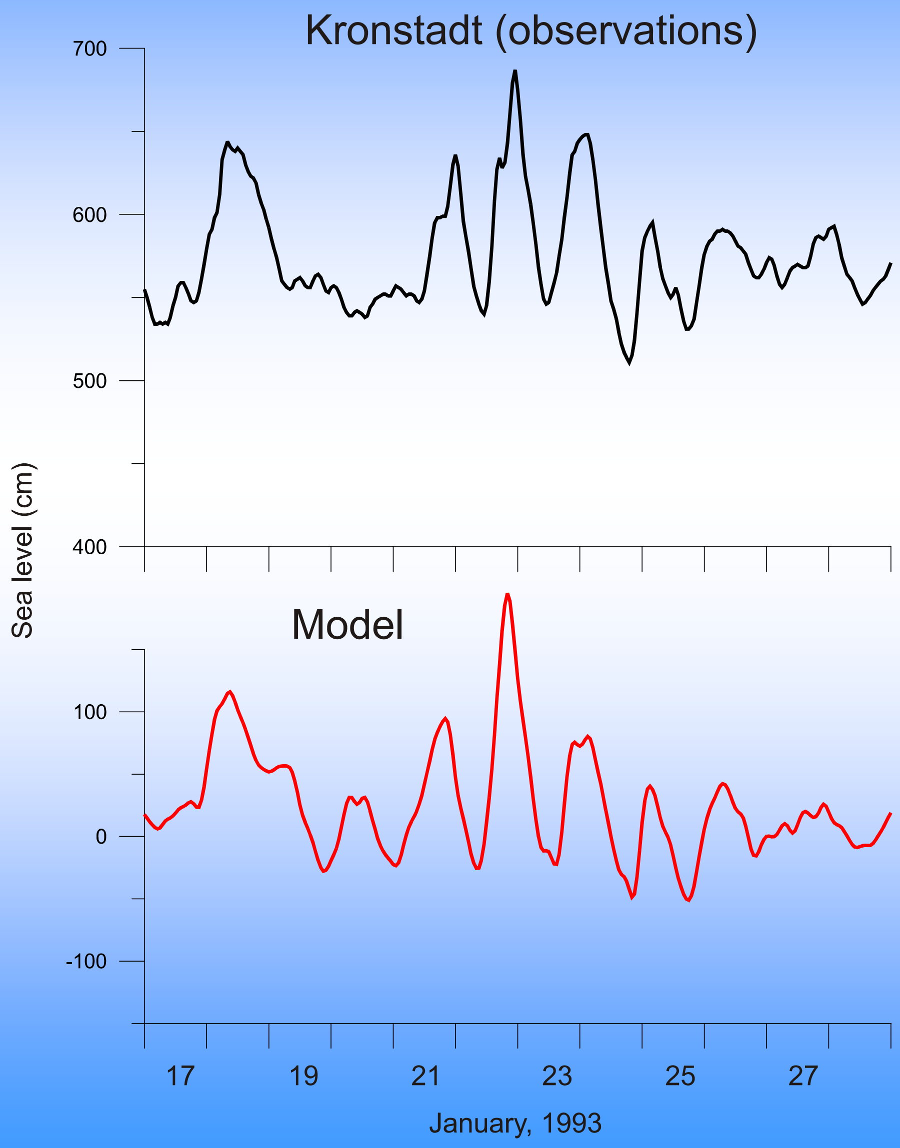
Pressure



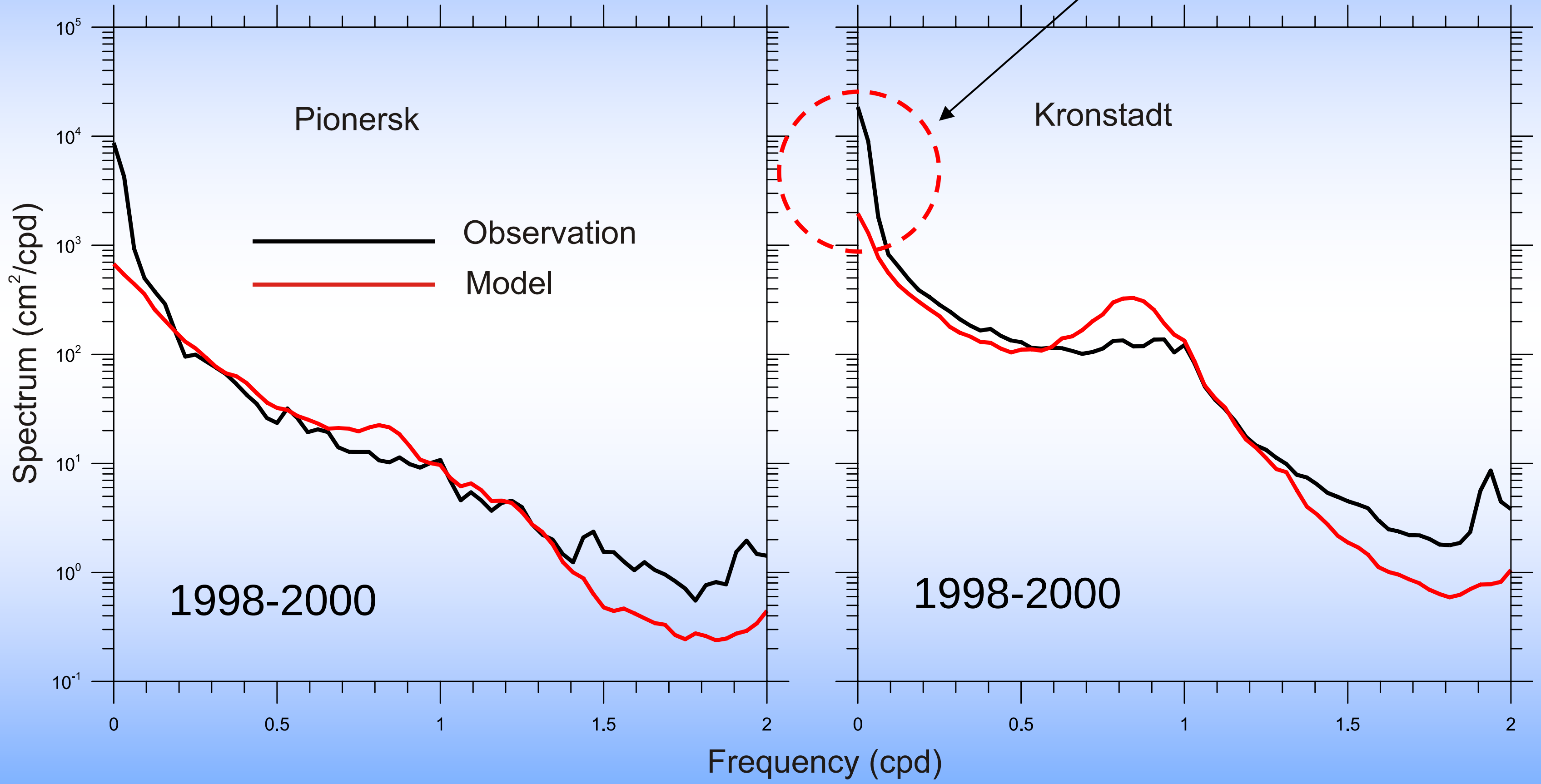
Wind



Example of simulation of flood event in Kronstadt



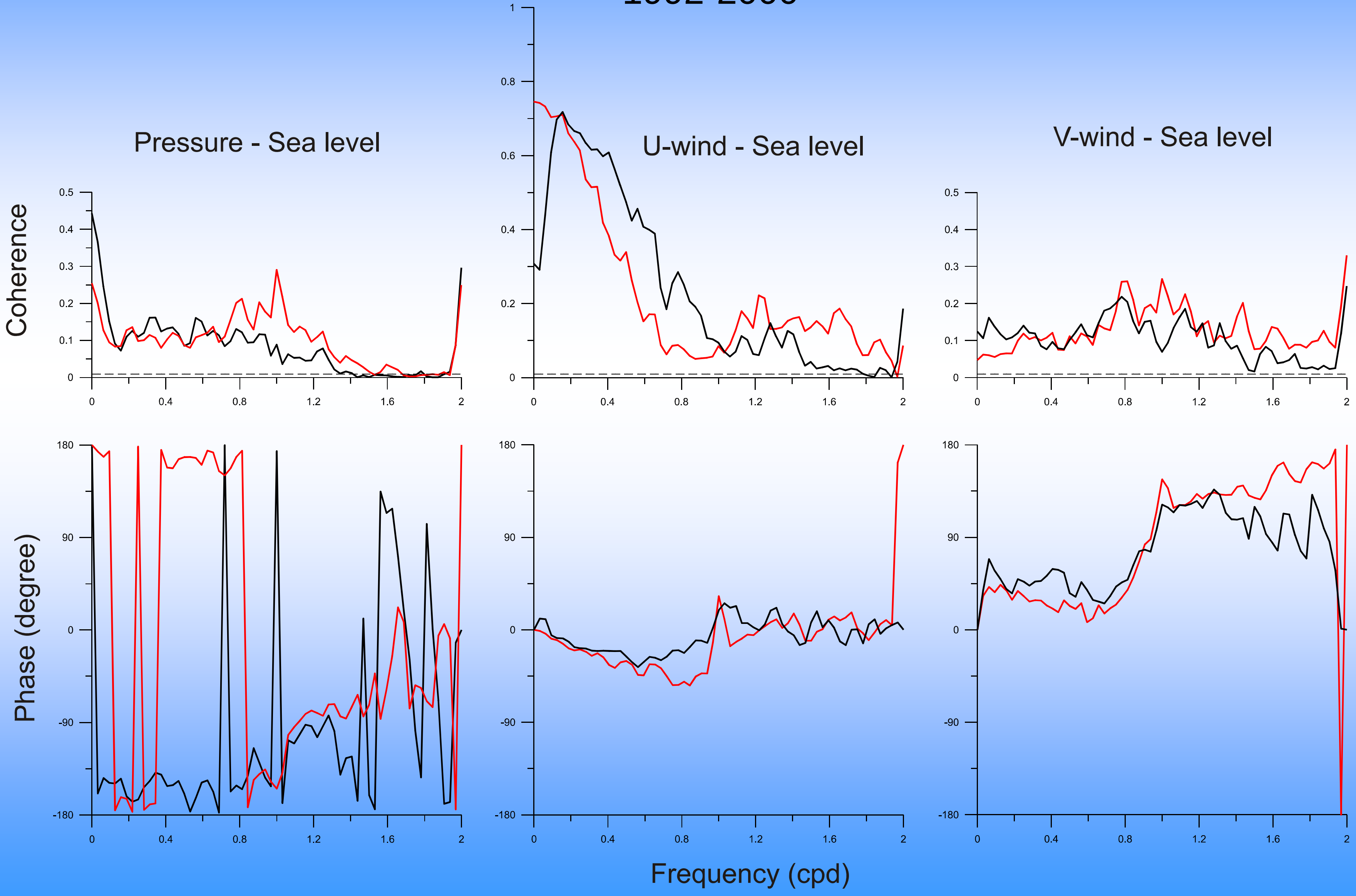
Sea level spectra



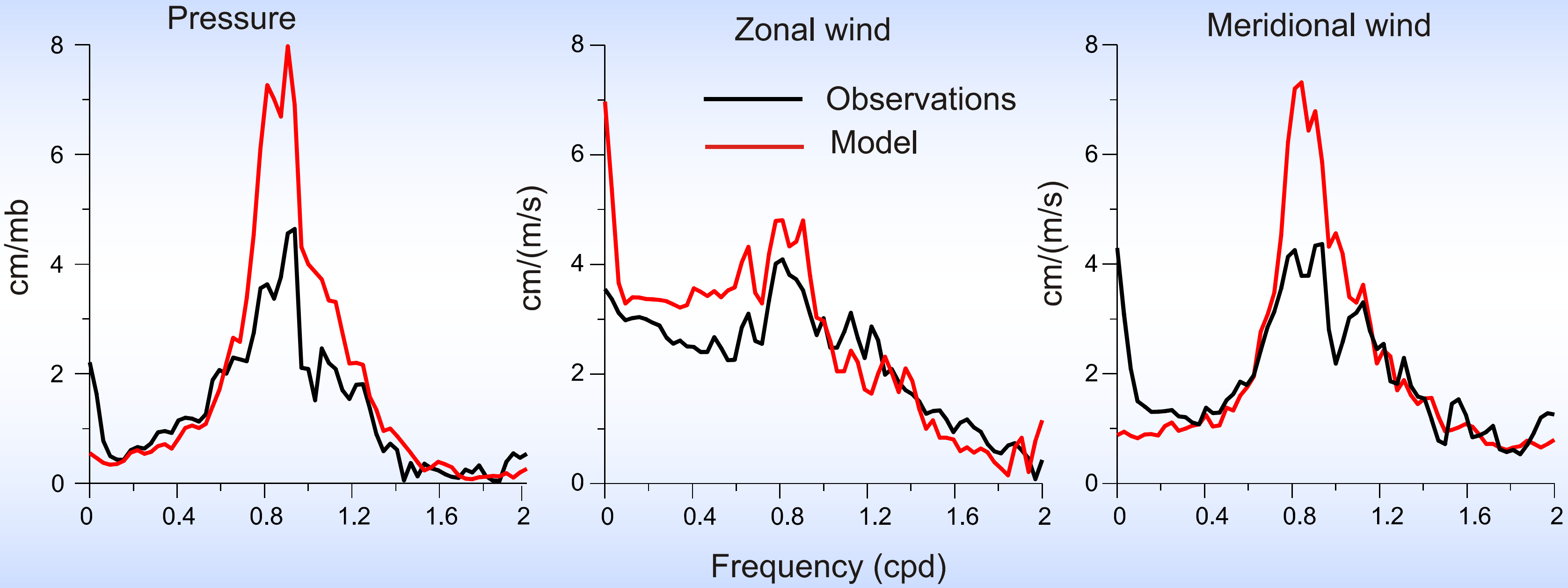
Effect of the barotropic transport between Kattegat and the Baltic Sea

Cross-spectral analysis for wind and pressure – sea level Kronstadt data (observations and modelling)

1992-2000



Sea level frequency response
(Kronstadt)



1992-2000

Conclusions:

1. Presented 2-D POM model satisfactory simulates sea level variability generated by the atmospheric forcing for frequency band 0.01 – 2 cpd

2. Wind forcing is a dominant factor in generation sea level oscillations in the Gulf of Finland: it contributes about 80% of the total sea level variance

3. For stations located inside of the Gulf of Finland the sea level frequency response turned out to be stronger for zonal winds, however, for resonant periods of 26-29 hours the meridional wind is found to be a more important forcing factor