Methods and Results of Statistical Analysis of Baltic Sea Monitoring Data Obtained by Alg@line System

- V. A. Rozhkov (SPbSU)
- S. Kaitala (SYKE)
- Y. P. Klevantsov (SPbB “SOI”)
- E. N. Litina (SPbSU, SPbB “SOI”)
- E. A. Zakharchuk (SPbSU, SPbB “SOI”)

Multidimensional information

$$\Xi(r,t)$$

***i*-th measurement**

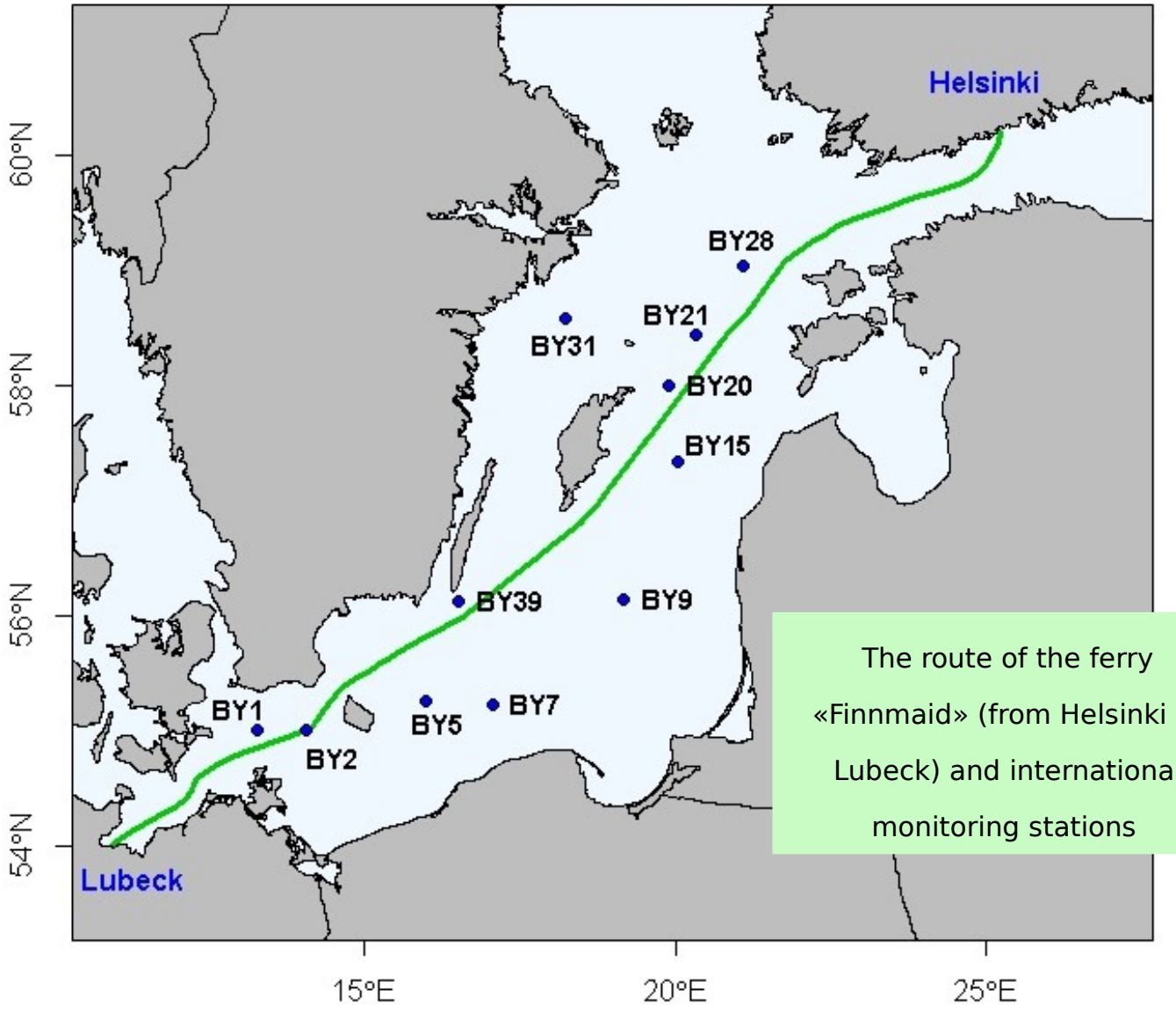
$$\xi(r_i,t_i)$$

The dimensionality reduction of two-dimensional space ($r_{i,\,ti)}$ in one-dimensional space is achieved due to dependence

$$r_i = ct_i$$

The generalized Fourier series

$$f(x) = \sum_{k=1}^{N} a_k \exp(i\lambda_k x)$$



The route of the ferry «Finnmaid» (from Helsinki to Lubeck) and international monitoring stations

Table 1

Distribution of ferry "Finnmaid" cruises from Helsinki to Lubeck and back by years and months 2009-2012

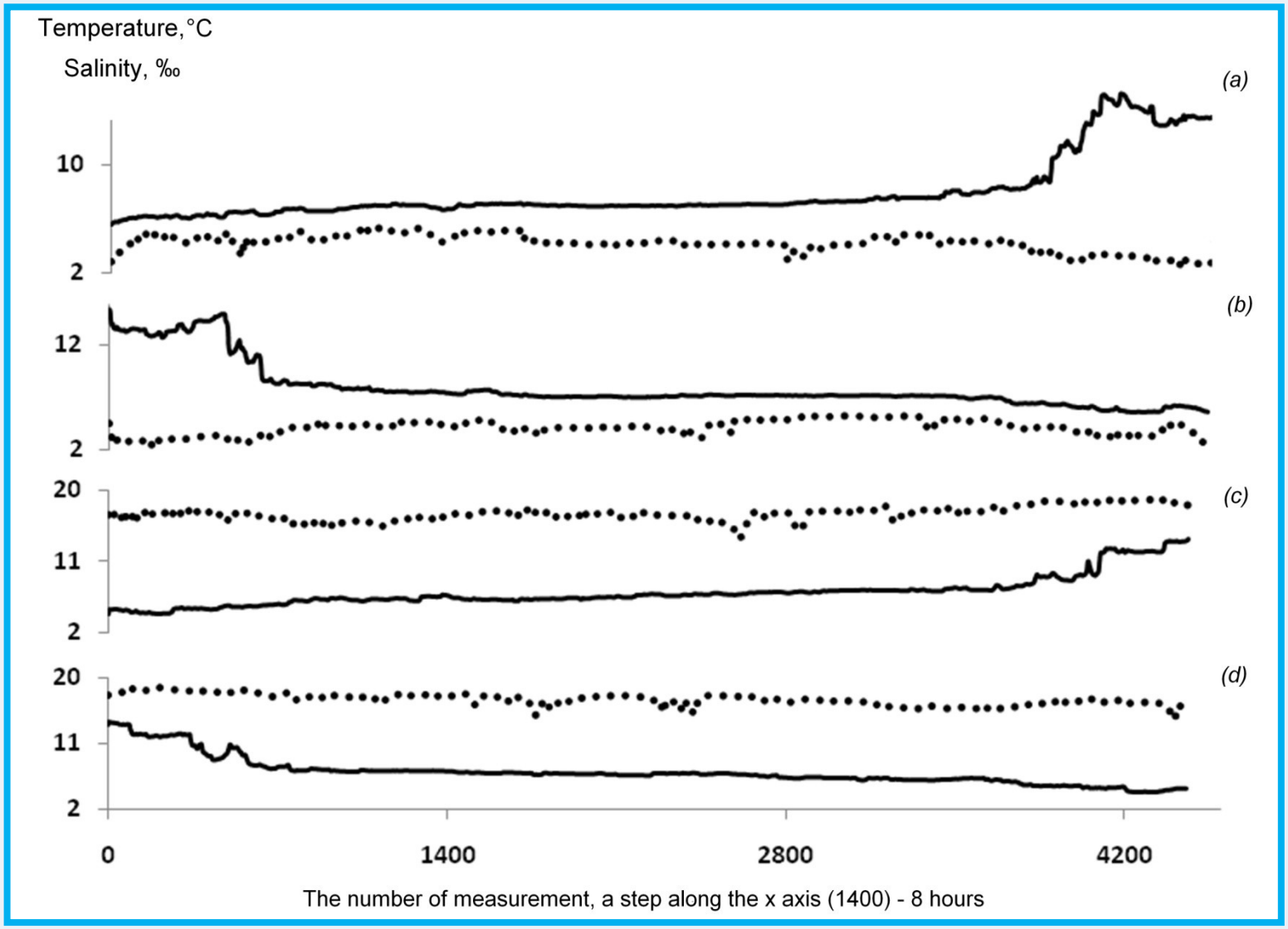
Year	Months												Per year
	1	2	3	4	5	6	7	8	9	10	11	12	
2009	11	14	16	17	14	11	7	9	11	11	8	-	130
2010	7	16	18	11	13	12	12	11	7	12	12	6	136
2011	19	6	13	3	15	14	14	11	11	8	5	-	119
2012	14	1	7	13	10	11	11	19	12	17	16	14	145

Table 2

Time distribution of the start (1), end (2) and duration (in hours) (3) ferry cruises Helsinki-Lübeck and back (4 - 6 respectively) by month in 2009

Para-meters	Months										
	1	2	3	4	5	6	7	8	9	10	11
1	16.00-16.30	16.00-16.30	16.00-16.30	12-18	11-18	11-15	15.02-15.14	12-15	15.11-15.36	12-16	13-16
2	18.20-18.50	18.10-18.40	15-18	4-20	13-20	17.18-17.47	17.14-17.29	17.14-17.31	17-21-17.40	17.20-18.05	18.21-19.21
3	26.10-26.39	25.50-26.39	25.40-26.39	26.00-27.10	25.40-26.49	25.40-26.39	26.00-26.19	25.50-26.19	26.00-26.29	25.50-26.19	26.00-26.59
4	2.00-2.30	2.10-2.40	2.10-2.50	01-16	01-16	01-14	01-14	01-14	01-15	01-15	2.20-2.40
5	4-8	4.10-4.39	4.10-4.39	3-6	3-15	3.00-3.39	3.10-4.39	3.10-4.39	3.10-3.19	3.10-4.49	4.10-5.37
6	25.50-26.19	25.40-26.19	25.50-26.29	25.30.26.29	25.30-26.29	25.40-26.29	25.40-26.19	25.50-26.29	25.40-26.09	25.30-26.59	25.55-27.11

Spatial-temporal variation of water temperature (dashed line) and water salinity (solid line) during the cruise ferry «Finnmaid» Helsinki – Lubeck in 13.01.09 г. *(a)*, Lubeck – Helsinki 15.01.09 *(b)*, Helsinki – Lubeck in 23.07.09 *(c)*, Lubeck – Helsinki 25.07.09 *(d)*.



$$\xi(r_i, t_i)$$

Here:

1. Rhythmic is used in the sense of regularity of

- cruises (the route is set, duration is limited to 26 hours, beginning and end of the cruise vary in time depending on the season, direction "there" and "back" allows to trace not one, but two days within the range (5-7 days) of synoptic variability;

- diurnal temperature variation of water and air.

2. Trend is used in the sense of deterministic function characterizing

the spatial variations of the $\xi_s(r)$ -component on the given part of section (algebraic, i.e. the linear, non-linear trend);

the temporal changes of the $\xi_s(t)$ -component on the given time interval (for day, year it is trigonometric trend).

3. Stochasticity has a different meaning depending on the selected probability model (regression, almost PCRP, autoregression-moving average and so on).

Probabilistic model

$\varphi_k(r)$

$$\xi(r,t) = \sum a_k(t)\varphi_k(r)$$

Trend

$$\xi(t) = m(t) + \varepsilon_t$$

P.L . Chebyshev's polynomials

$$\phi_0(r) \equiv 1, \quad \phi_1(r) = r - \frac{m+1}{2}, \quad \phi_{k+1}(r) = \phi_1\phi_k - \frac{k^2(m^2-k^2)}{4(4k^2-1)}\phi_{k-1},$$

k=1,2,…m-1

$$a_k = \frac{\sum_{j=1}^{m} \zeta(r_j)\varphi_k(r_j)}{\sum_{j=1}^{m} \varphi_k^2(r_j)} \qquad (\zeta(r), \varphi_k(r))$$

Orthonormal system of basis functions

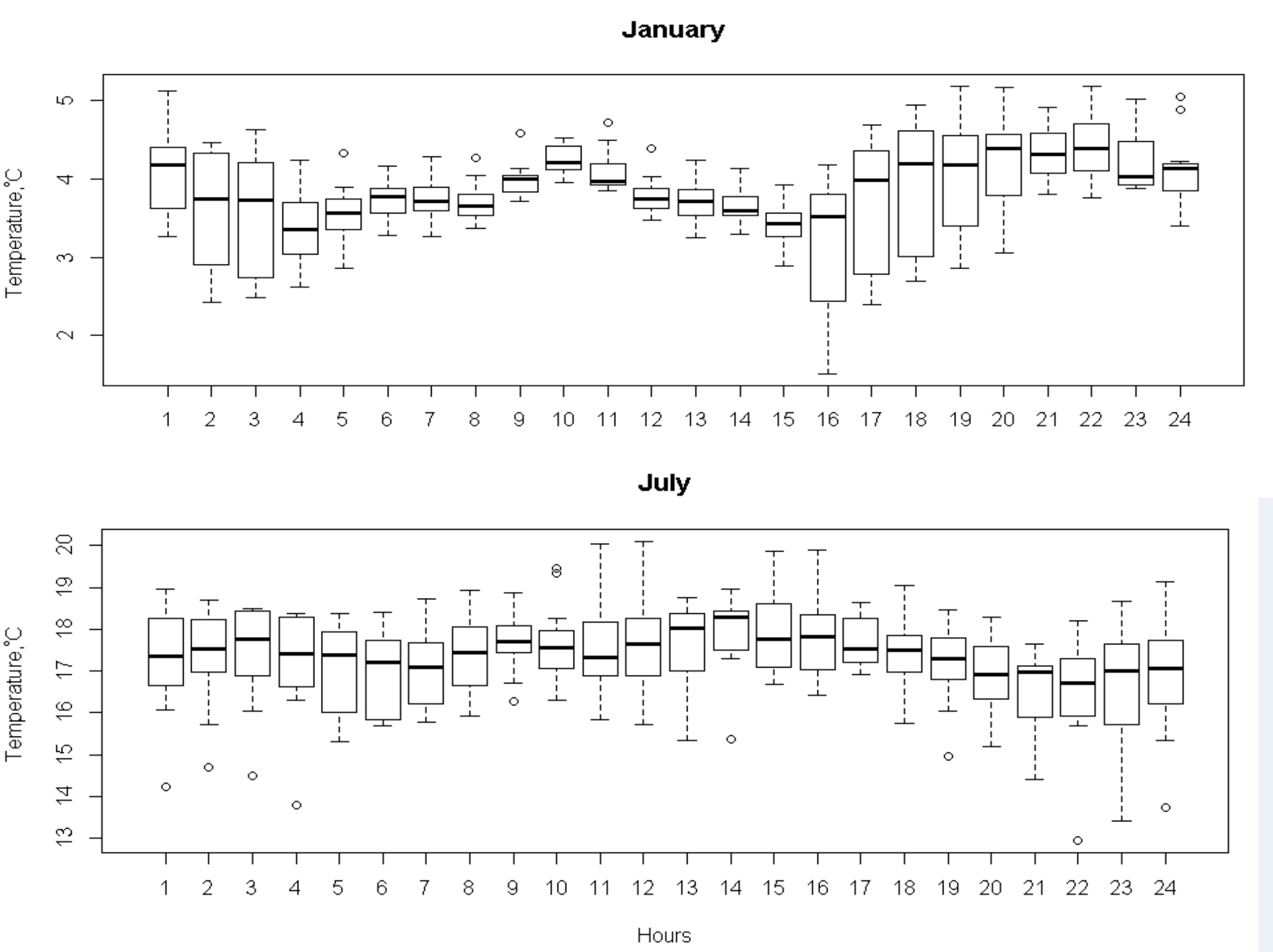
$$\hat{\varphi}_k(z) = \frac{\varphi_k(z)}{\sqrt{\sum_{j=1}^{m} \varphi_k^2(z_j)}} \qquad \sum_{j=1}^{m} \hat{\varphi}_k^2(z_j) = 1.$$

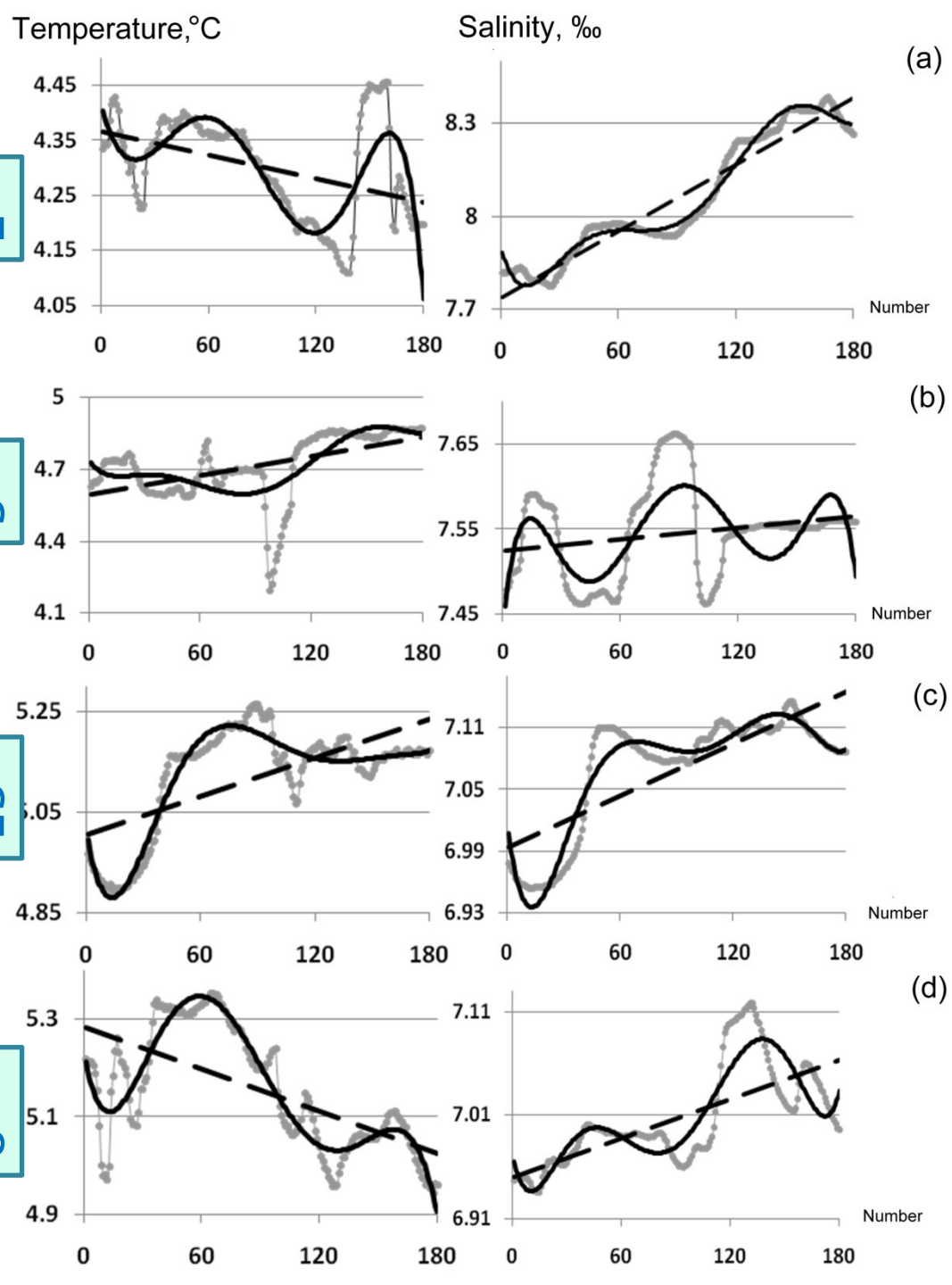
Linear regression

$$\xi(t) = \beta_0^* + \beta_1^*(t) + \varepsilon$$

The parabolic regression

$$m(t) = \sum a_k \cos(\omega_k t + \varphi_k) \qquad \xi_t = \sum_k \xi_k \exp(-i\omega_k t)$$

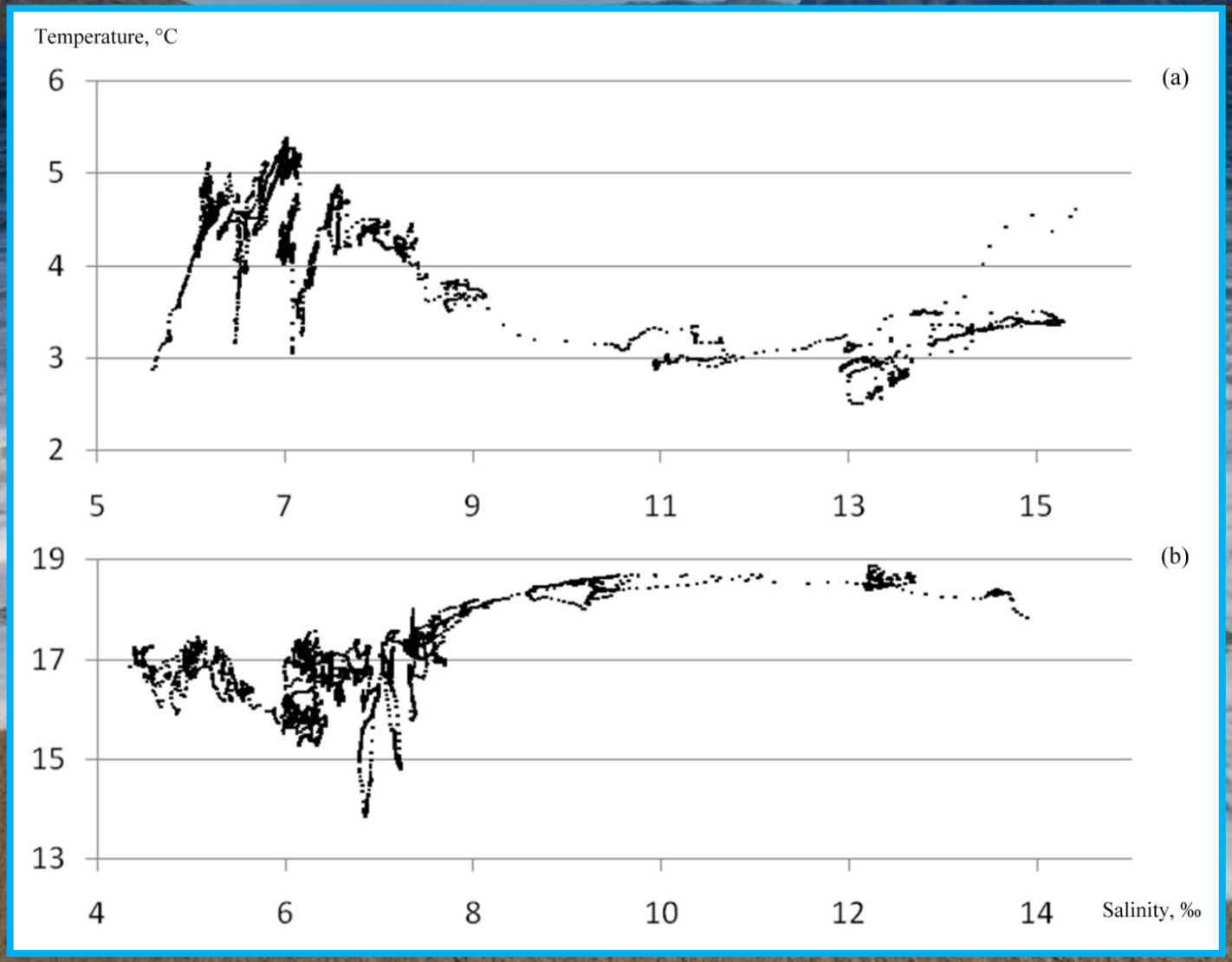

January
Temperature,°C
2
3
4
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
July
Temperature,°C
13 14 15 16 17 18 19 20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours



Graphs of hour-long intervals of temperature T, oC and salinity S, o/oo

variations near the international stations BY2 *(a)*, BY5 *(b)*, BY15 *(c)*, BY28 *(d)*: in cruise Helsinki-Lubeck 13.01.09; dt ≈ 20 sec, dN = 60 measurements = 20 min; trends: linear (dotted line), polynomial (solid line)

TS-diagram of the entire cruise Helsinki-Lübeck 13.01.09 (a) and Helsinki-Lübeck 23.07.09 (b)



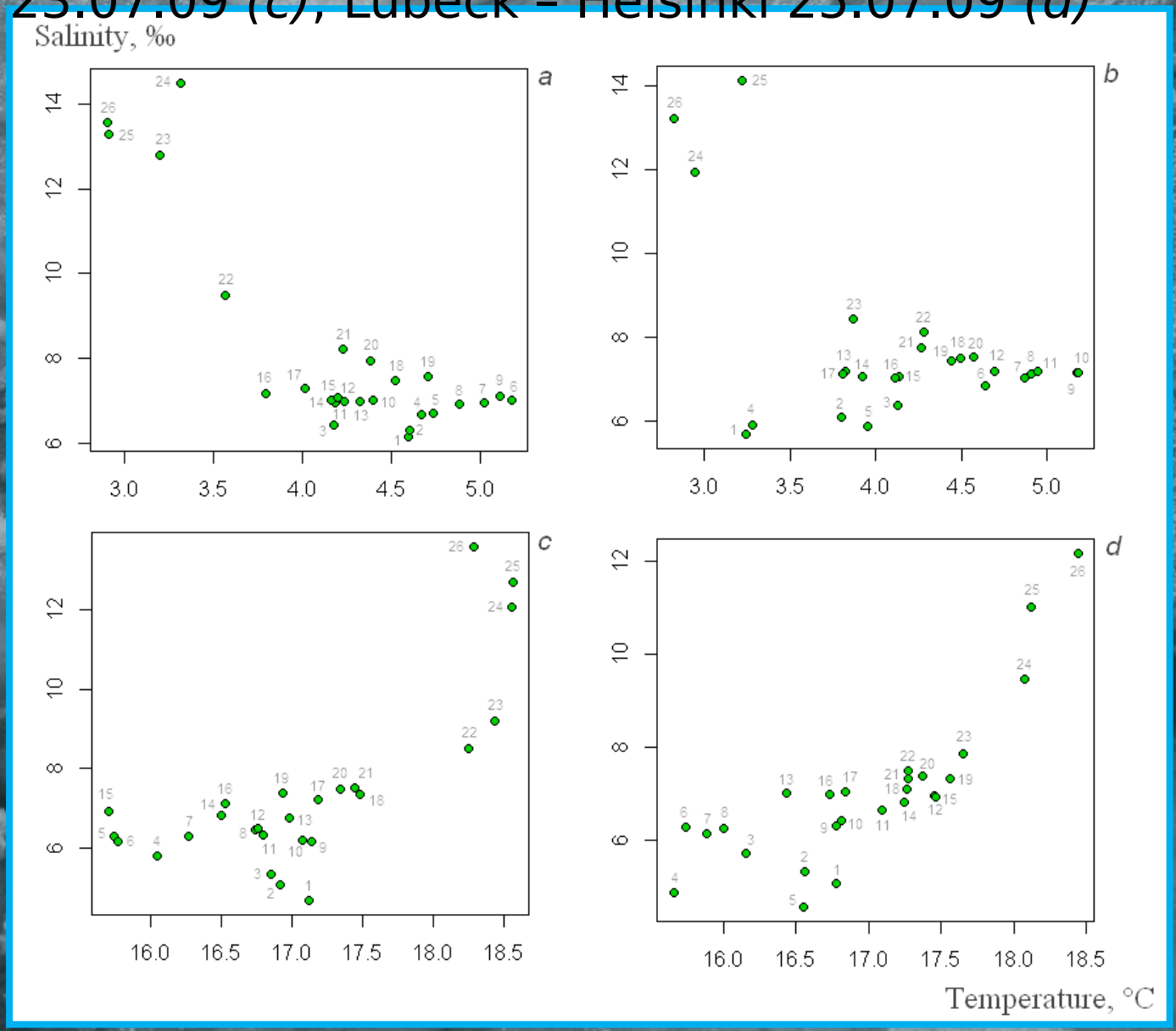
$$T = \psi(r),\ S = \varphi(r)$$

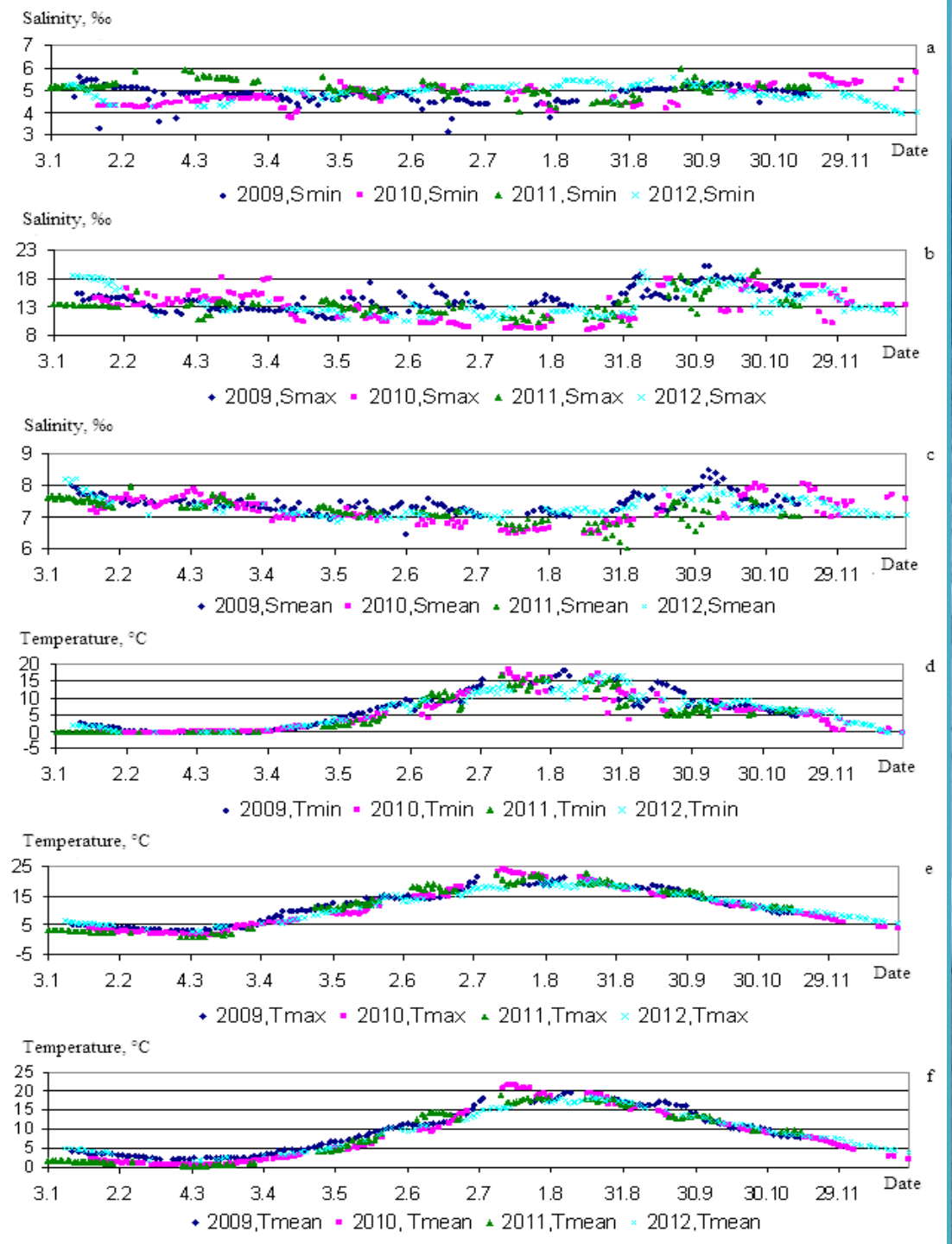
$$T = f(S)$$

$$T = \psi(t),\ S = \phi(t)$$

$$T = f(S)$$

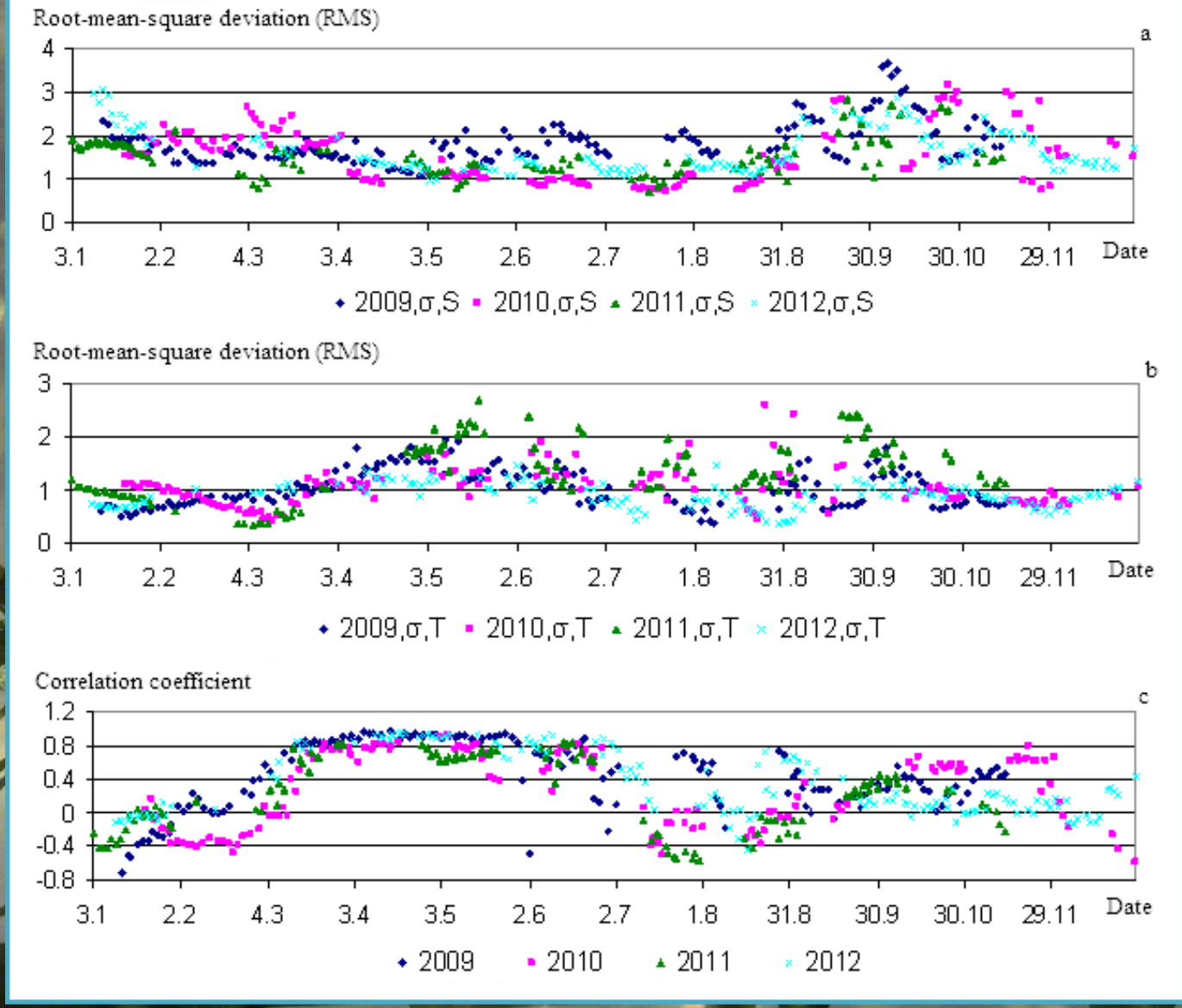
TS-diagram of hourly average values. Helsinki – Lubeck 13.01.09 *(a)*, Lubeck – Helsinki 15.01.09 *(b)*, Helsinki – Lubeck 23.07.09 *(c)*, Lubeck – Helsinki 25.07.09 *(d)*





The annual variations of temperature and salinity from 2009 to 2012. Minimal values of salinity (a) and temperature (d), maximal values of salinity (b) and temperature (e), mean values of salinity (c) and temperature (f)

Sequences RMS values for the variables salinity (a) and temperature (b), and the correlation coefficient between them (c)




Thank you for your attention!