JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Institut für
Theoretische Physik III

Phasensynchronisation des Niederschlags im Elbe-Einzugsgebiet und seine Vernetzung

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MINERVA CENTER
for the physics of
Mesoscopics, Fractals and Neural Networks

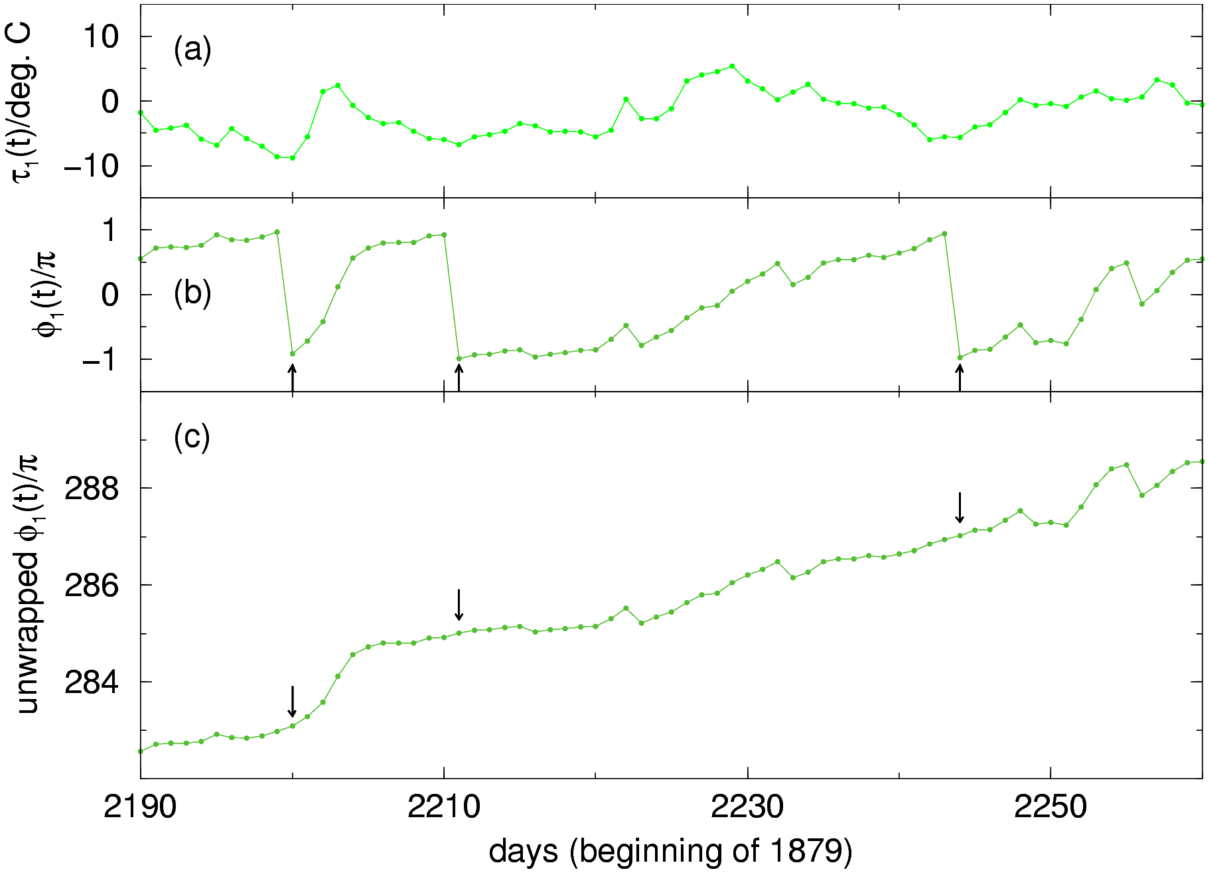
Phase Synchronization Method - Motivation

- quantification of synchronization in phases
  of two records (similarity of two met. records, delay)
- statistical accumulation of certain phase differences
- synchronization index $0 < \rho(s) < 1$
  time lag (scale, shift) s
- similar results to cross-correlation
- but complementary information expected
  since only phases are used (amplitudes are neglected)
- References:

- P. Tass et al., Phys. Rev. Lett. **81** (1998) 3291.
- M.G. Rosenblum et al. in: "Neuro-Informatics and Neural Modelling, Handbook of Biological Physics" (Eds.: A.J. Hoff, F. Moss, S. Gielen), Vol. 4 (Chapter 9), Amsterdam, 2001.
- D. Rybski et al., Physica A **320** (2003) 601.
- L. Cimponeriu et al., Phys. Rev. E **70** (2004) 046213.

Method

example: Oxford



(a) deseasoning:

$$\tau_j(t) = T_j(t) - \overline{T_j}(t)$$

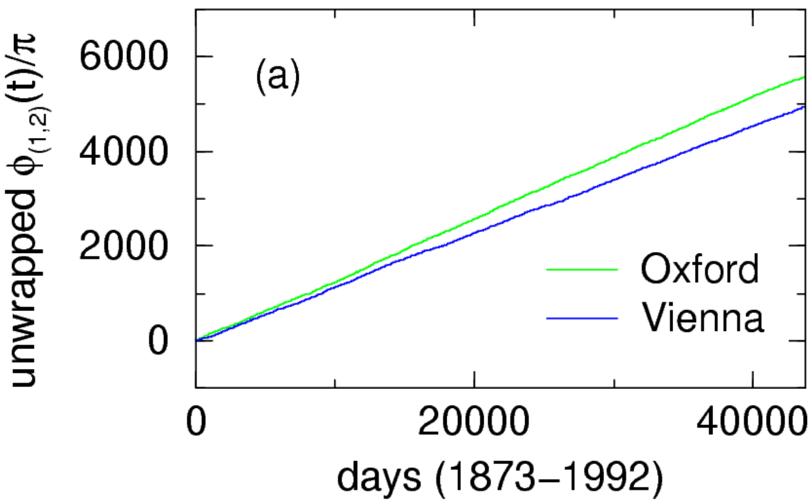
(b) phase-extraction:

$$\zeta_j(t) = \tau_j(t) + i\tau_j^{(H)}(t) = A_j(t)e^{i\phi_j(t)}$$

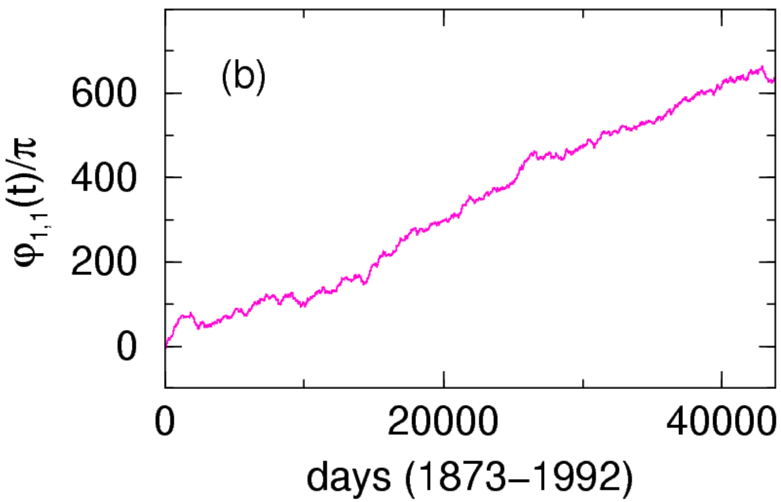
$$\tau_j^{(H)}(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{\tau_j(\theta)}{\theta - t} d\theta$$

(Hilbert-Transform)

(c) phase-unwrapping

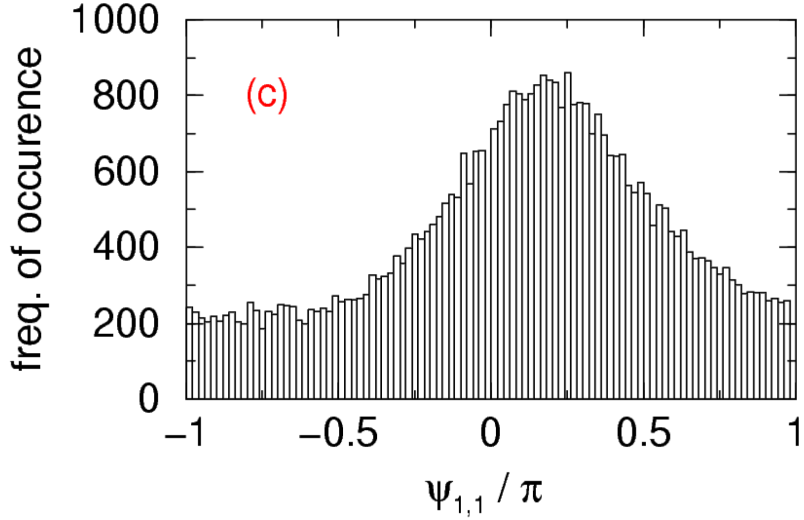


(a) unwrapped phases of both temp. records



(b) phase-difference:

$$\varphi_{n,m}(t) \quad = \quad n\phi_1(t) - m\phi_2(t)$$



see: P. Tass et al., PRL **81**, 3291 (1998).

(c) histogramm of:

$$\psi_{n,m} \quad = \quad \varphi_{n,m} \bmod 2\pi$$

significance-index:

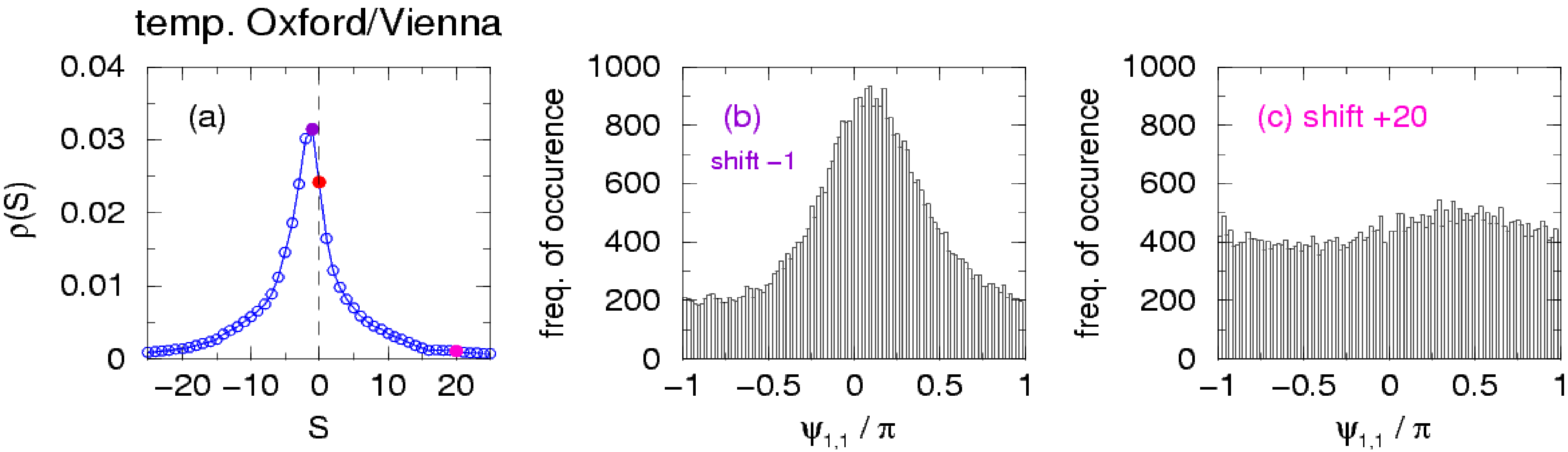
$$\rho_{n,m} \quad = \quad \frac{\ln M - E}{\ln M}$$

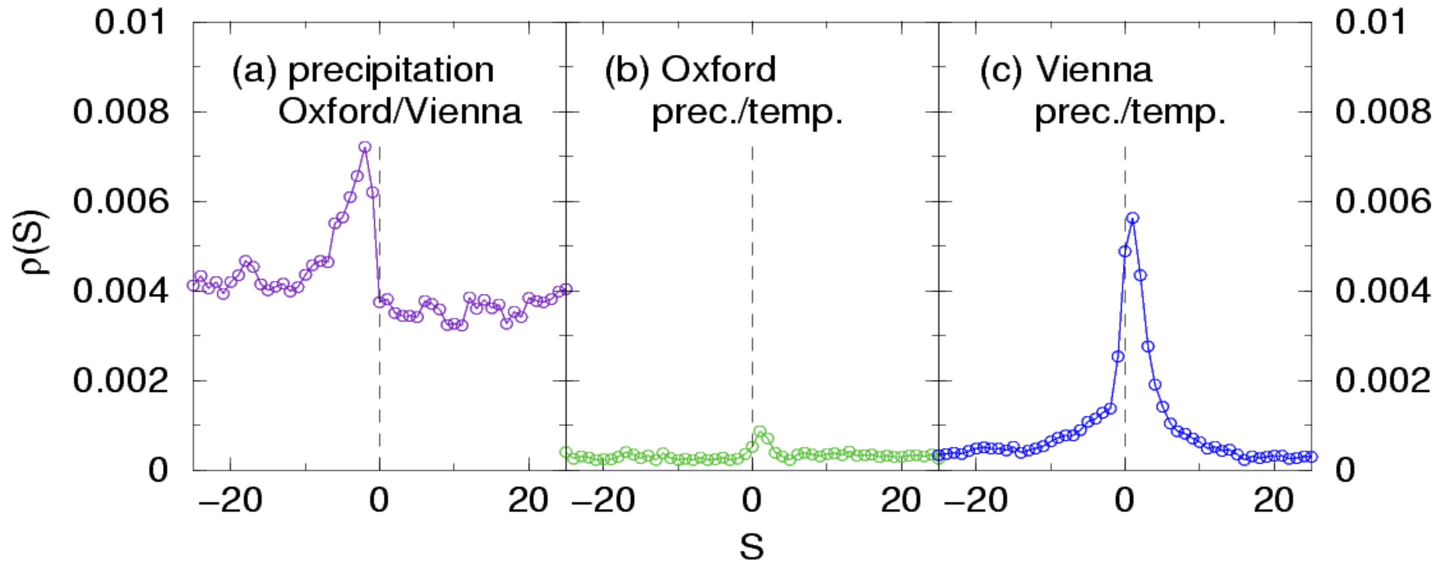
M: bins

p_k: rel. prob.

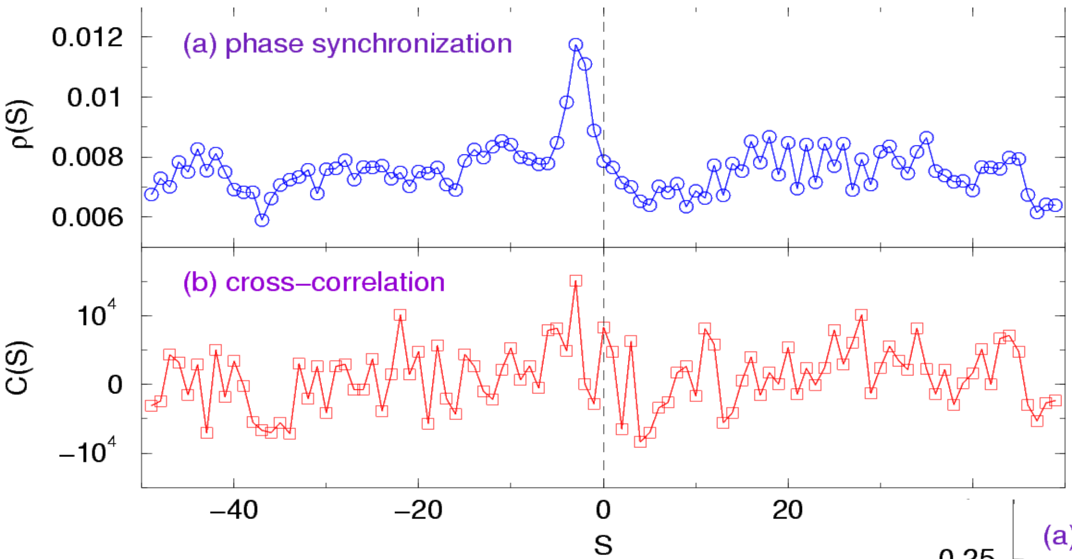
$$E \quad = \quad -\sum_{k=1}^{M} p_k \ln p_k$$

Time Lag Phase Synchronization





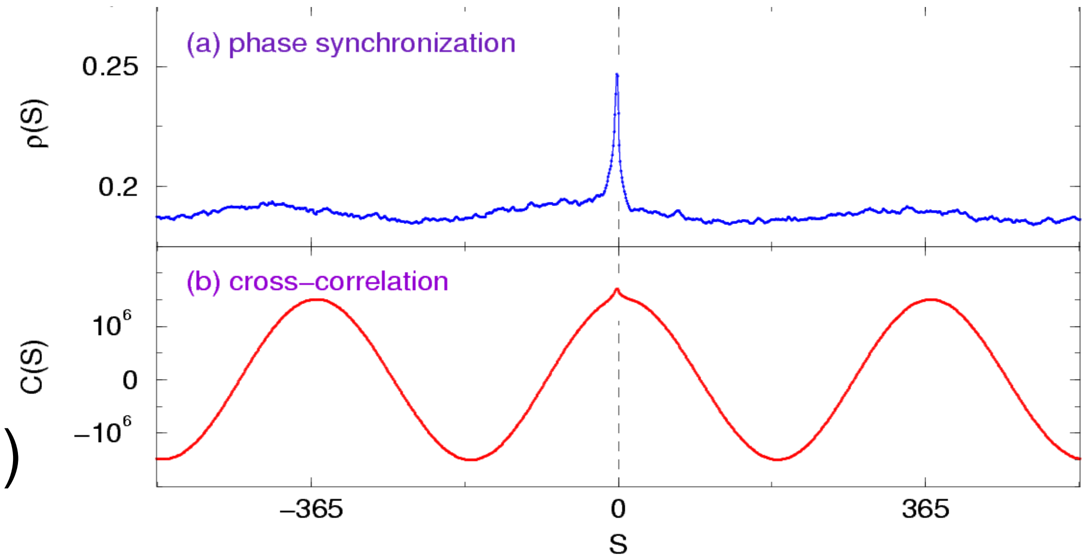
Comparison to Cross-Correlation



Wulumuqi (CHN) - Pusan (KOR): 1951-1990
daily precipitation

- alternativ to crosscorrelation-func.
- complementary information

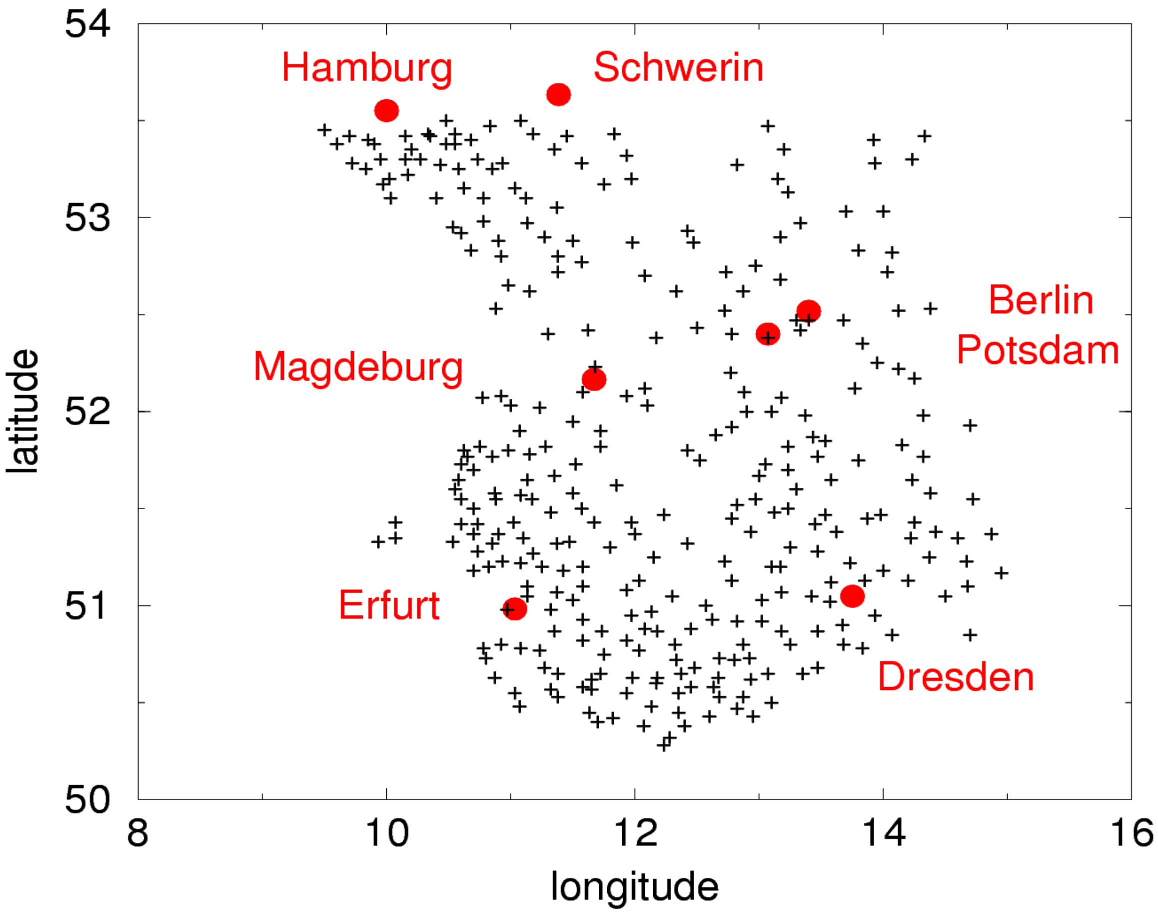
daily temperature
Oxford (GBR) - Vienna (AUT): 1873 - 1992



two types of synchronization:

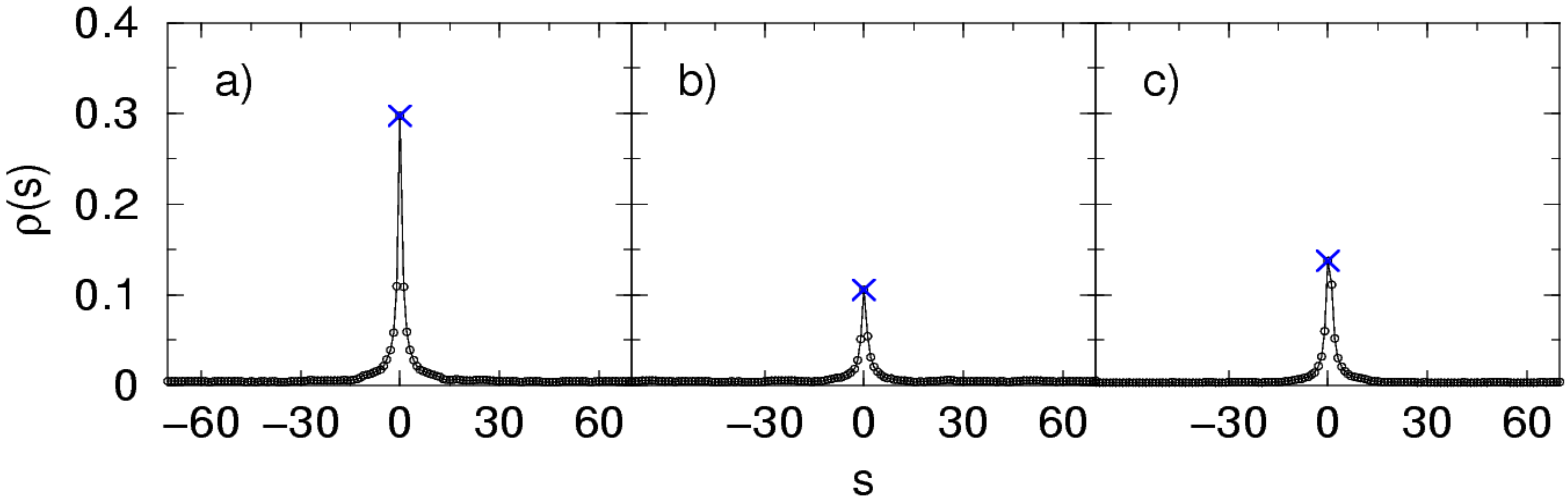
- seasonal trend (trivial)
- fluctuations

Data



- 317 meteorological stations (nodes)
- daily precipitation (rainfall)
- length: 1951-2000 (18250)
- (317*316)/2 = 50086 combinations

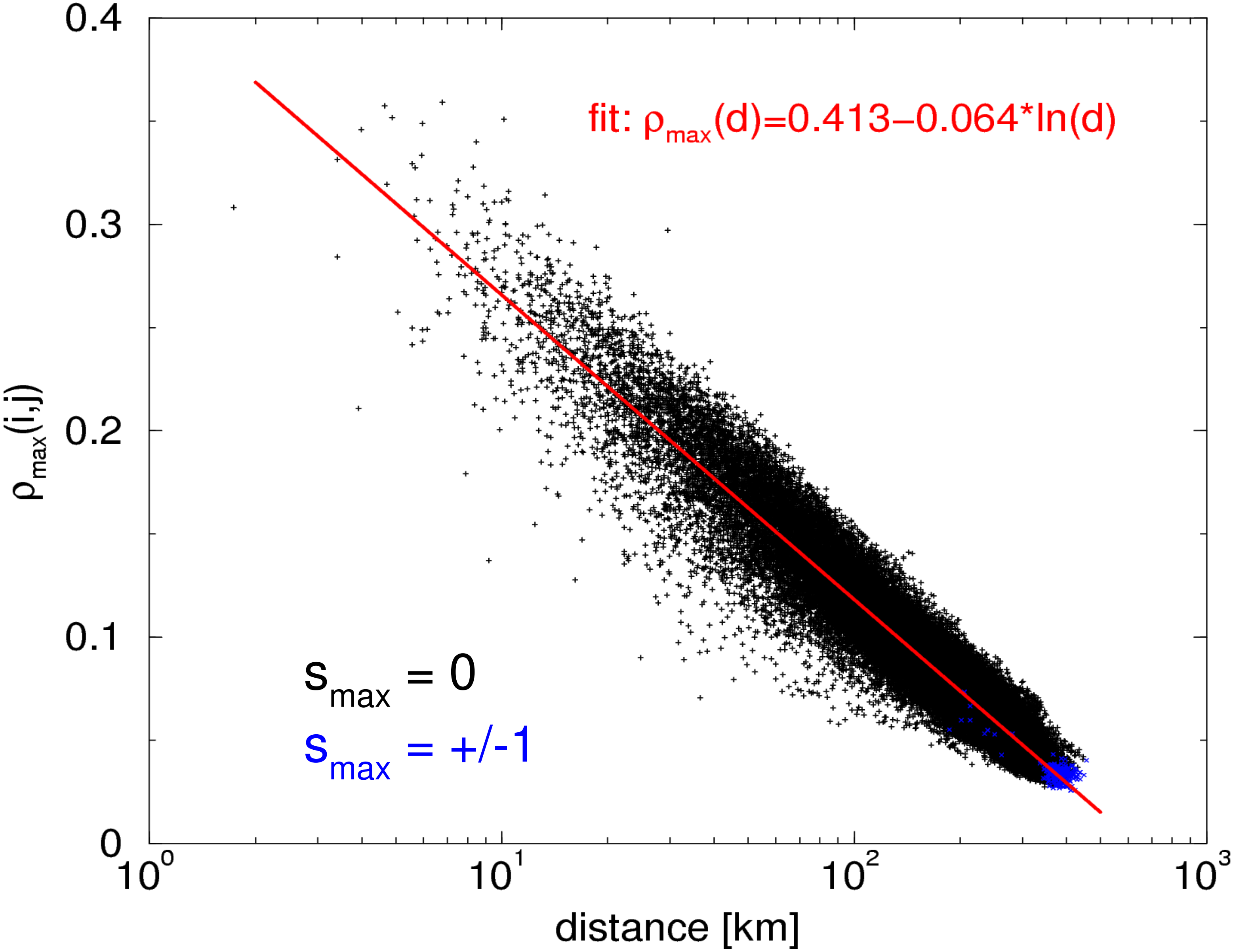
Results



a)	Loburg and Genthin	29.6 km	$\rho_{max} = 0.297$
b)	Oranienbaum and Güssefeld	124.4 km	$\rho_{max} = 0.105$
c)	Wernigerode (Hasserode) and Brocken	9.2 km	$\rho_{max} = 0.137$

- strength of optimum phase synchronization is strongly varying
- dependence on distance?

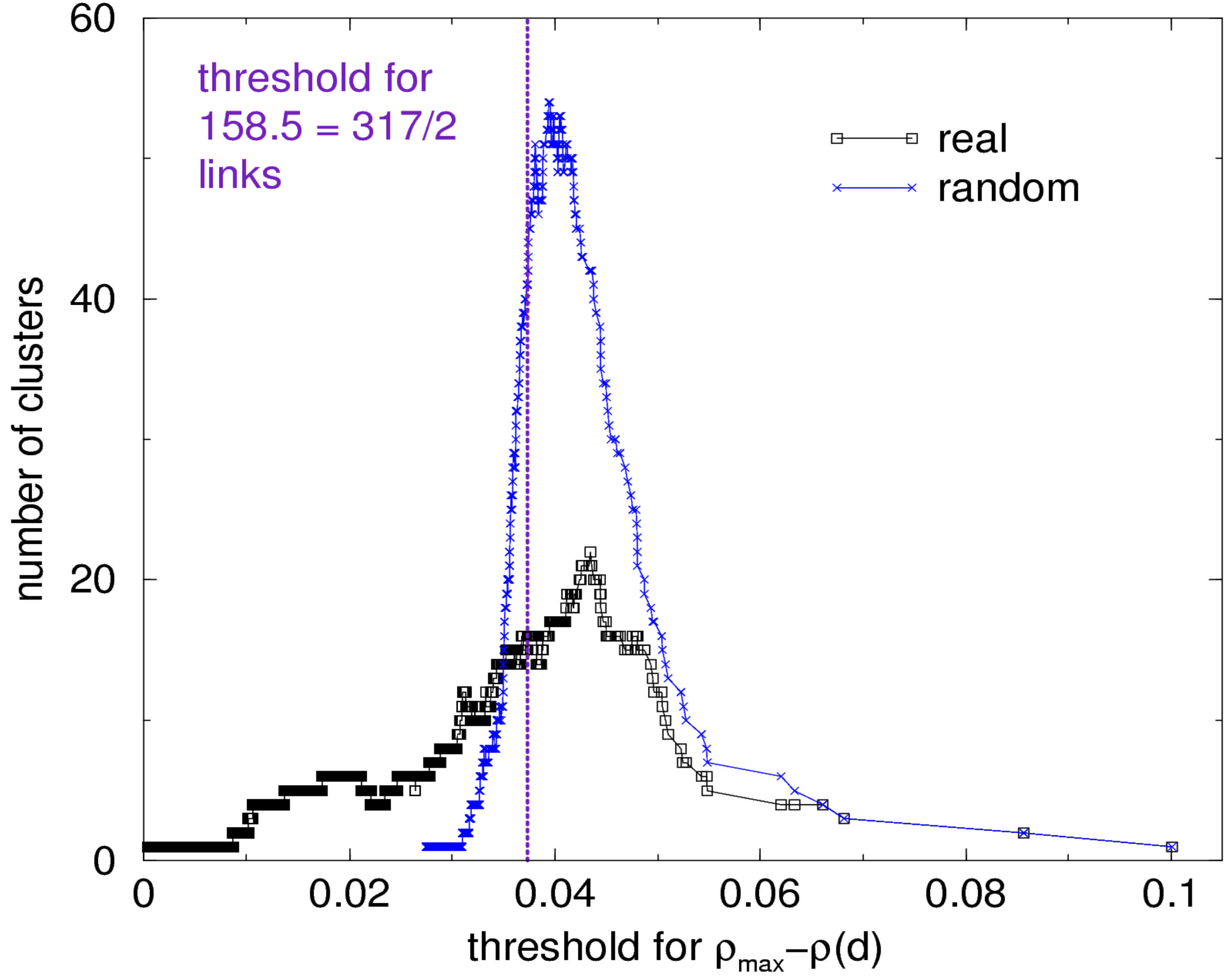
Dependence on distance



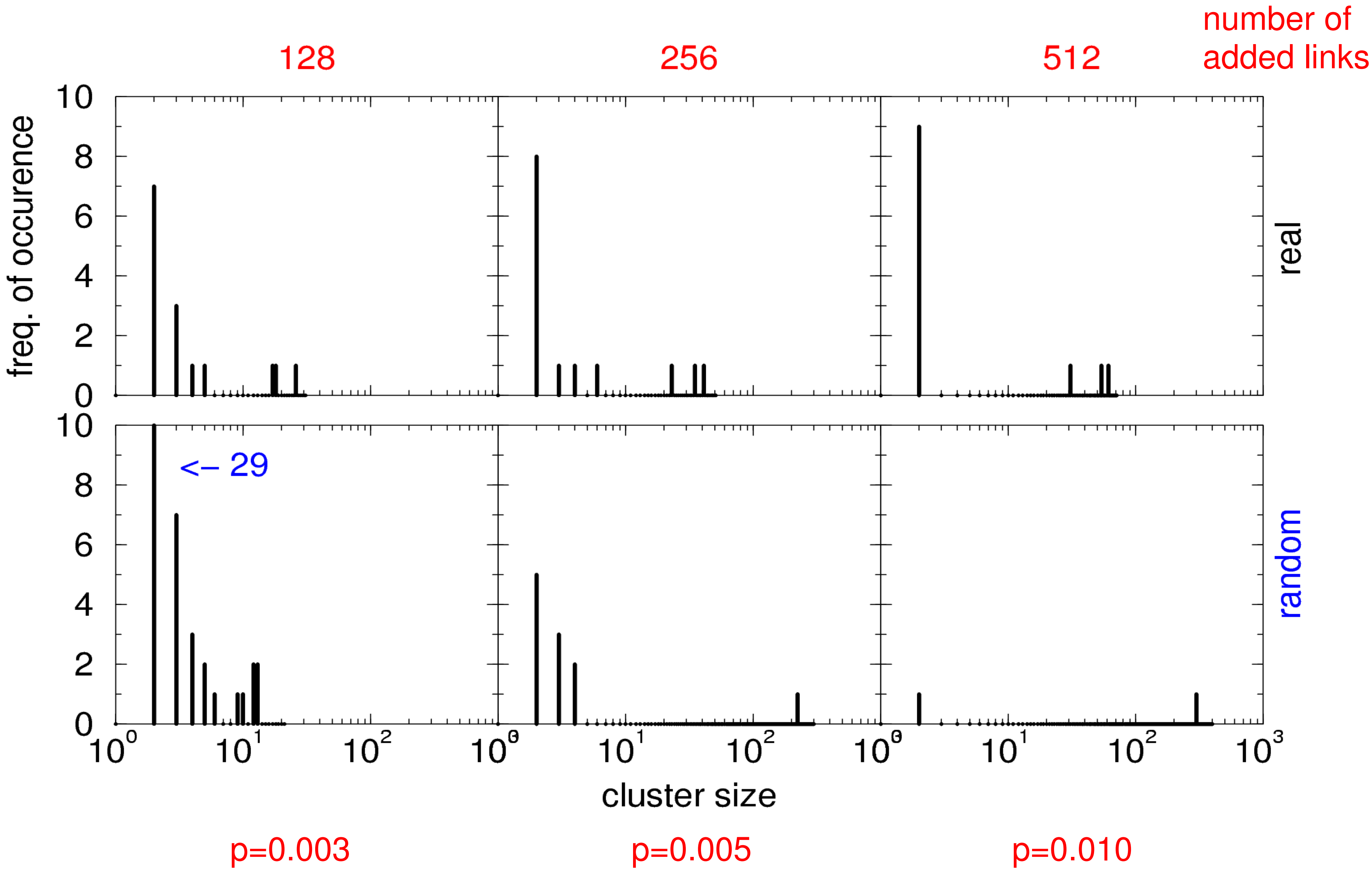
next:
connecting nodes with highest relative phase synchronization

- network
- clusters

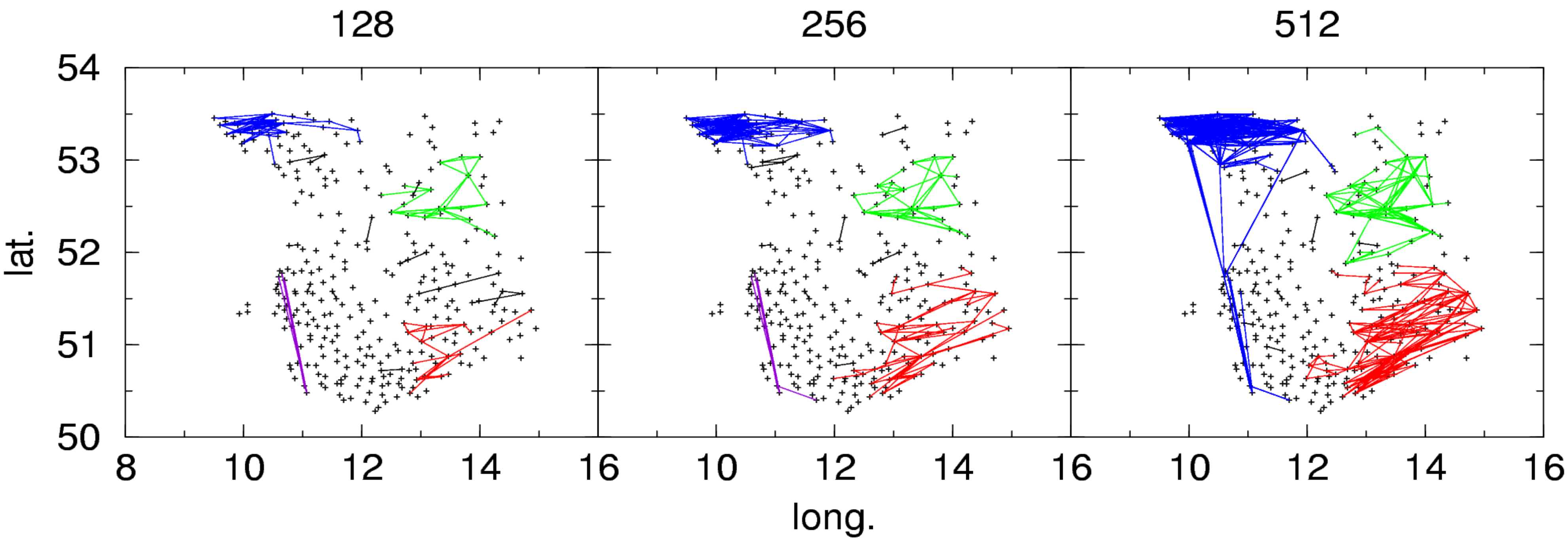
Number of clusters



Size of clusters



Climate Graphs

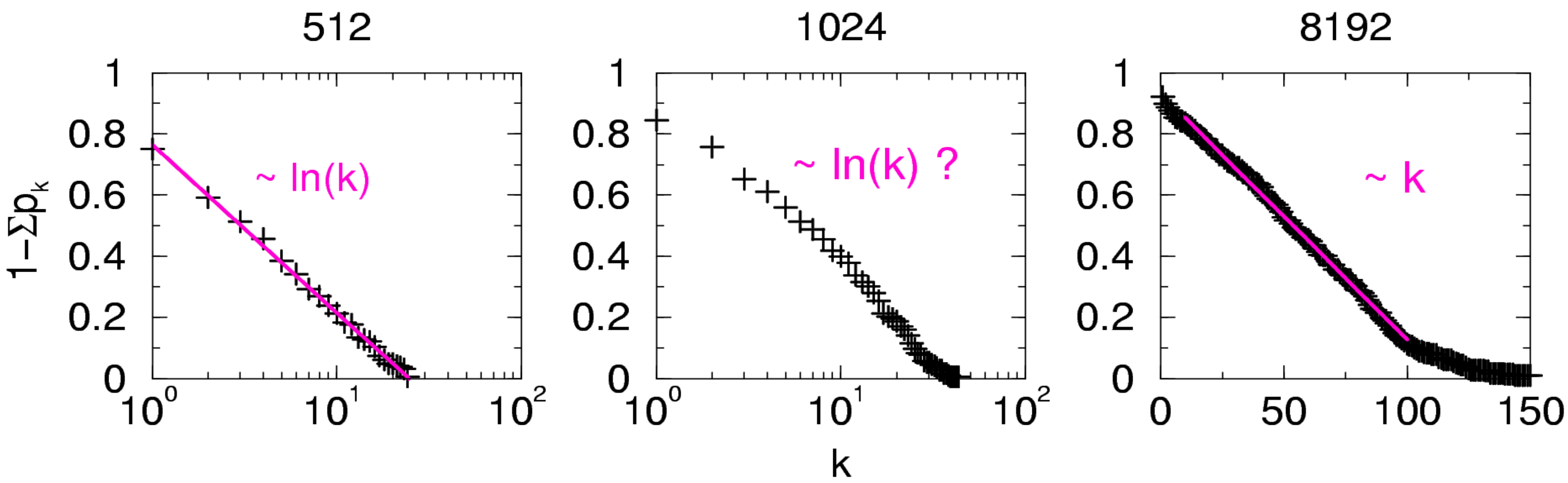


- densely connected big clusters
- clusters distinct in space
- few small clusters

522 -> 523: 2 clusters
566 -> 567: 1 cluster
p_c approx. 0.01

Degree Distribution

- number of nodes with certain amount of links (normalized)
- here: cumulative histogram



p=0.010 p=0.020 p=0.164

$p_k \sim 1/k$ ... ? ... $= \text{const.}$ ...

Summary

- network-construction by strength of phase synchronization
- subtracting trivial dependence of distance
- highly connected big clusters
- critical concentration higher than for the random case
- clusters distinct in space
- changing degree distribution (evolving network)
- References:

- A.A. Tsonis et al., Physica A **333** (2004) 497.
- J.-P. Onnela et al., Eur. Phys. J. B **38** (2004) 353.

Acknowledgements

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