Long-term forecasting of wind- and hydropower availability in a fluctuating climate

– Implications for production management and investments in energy storager and electric power transmission

svensk titel:
Långsiktiga prognoser av vind- och vattenkrafttillgång i ett fluktuerande klimat –
Betydelse för produktionsplanering och investeringar i energilager och kraftöverföring

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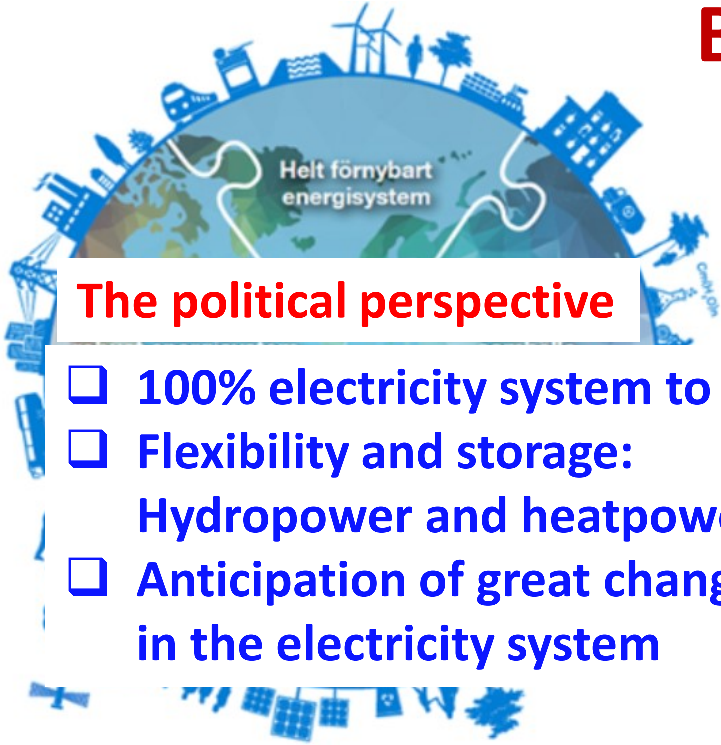
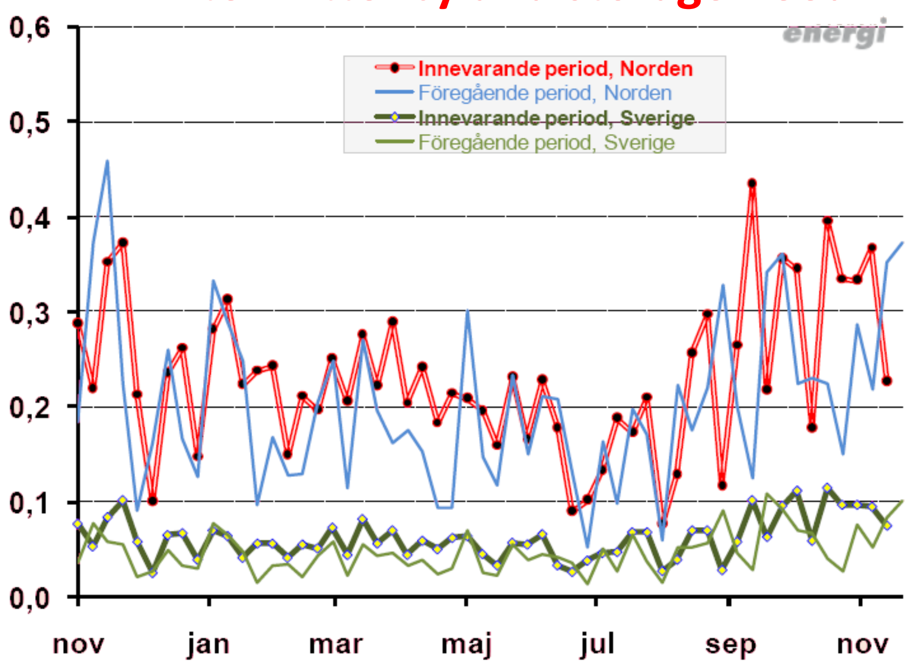
Background

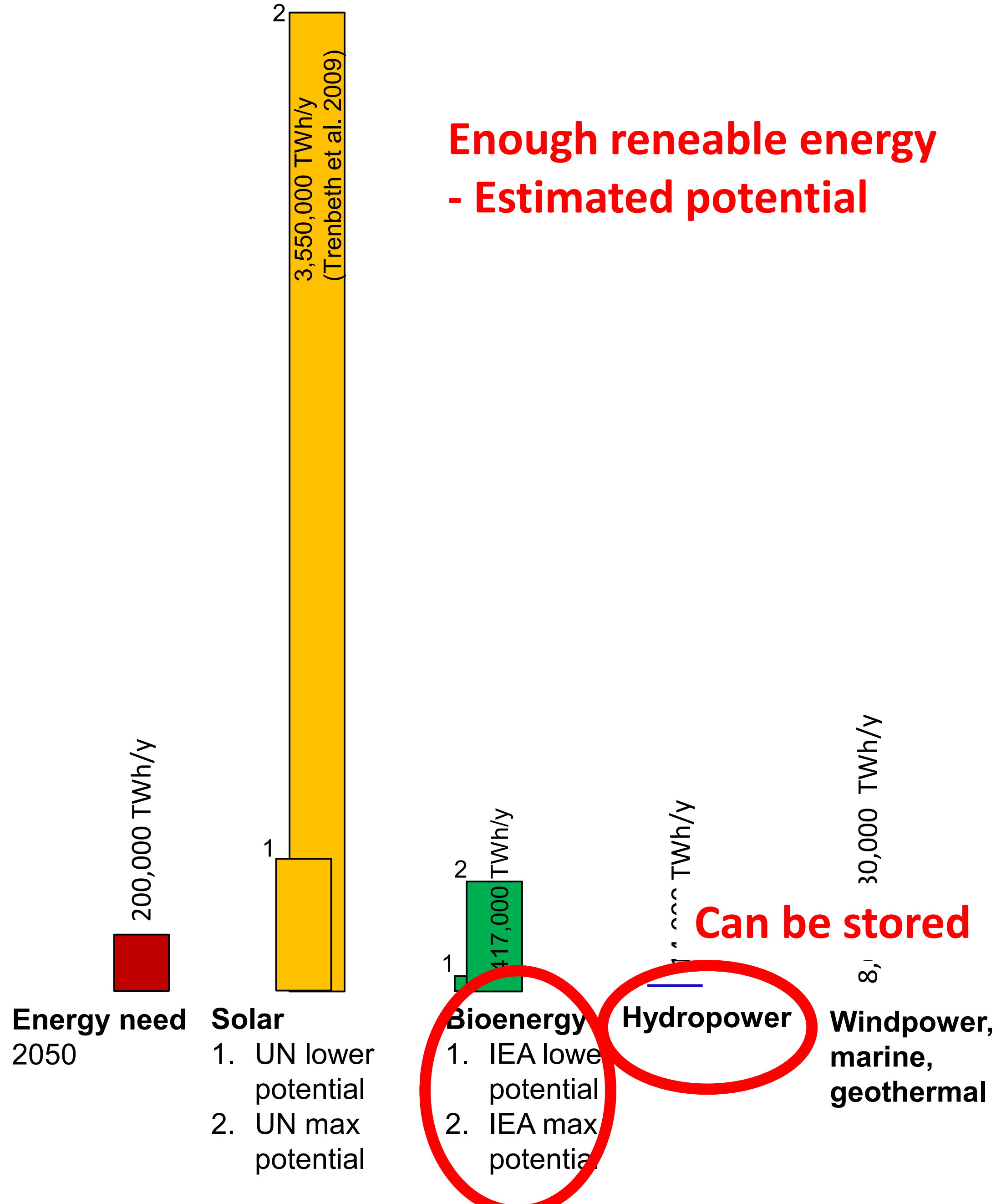


The political perspective

- 100% electricity system to 2040
- Flexibility and storage: Hydropower and heatpower
- Anticipation of great changes in the electricity system

Intermittency and storage need





Project aims

1. Analyses of the coupling of climate fluctuations and hydropower availability
    a. Spatio-temporal statistics, including spatial covariation and control of climate indicators
    b. Seasonal forecast methods

2) Importance of forecasts for production planning
    a. Development of Conphyde (”Multimetodmodellen”)
    b. Importance of forecasts methods in production planning models
    c. Planning of electrical system capacities, e.g. to avoid energy droughts

How the presentation is divided

- ❑ Anders Wörman, KTH

Spatio-temporal statistics in hydropower availability and importance of climate-driven forecasts on production management

- ❑ Cintia Bertacchi Uvo, Lund University

- ❑ Marc Girons Lopez, SMHI

Evaluation of seasonal forecasting skill over Sweden

Scope of research at KTH

1. Spatio-temporal analyses of historical hydropower potential

- Production capacity and energy storage need over Europe

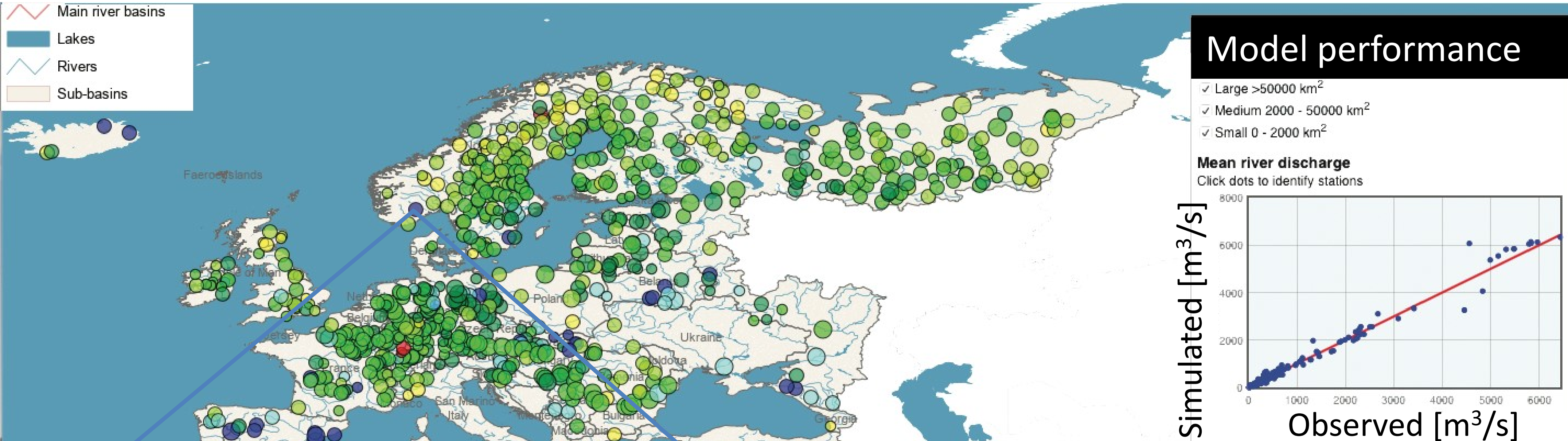
2. Implementation of climate-driven forecasts in production management models

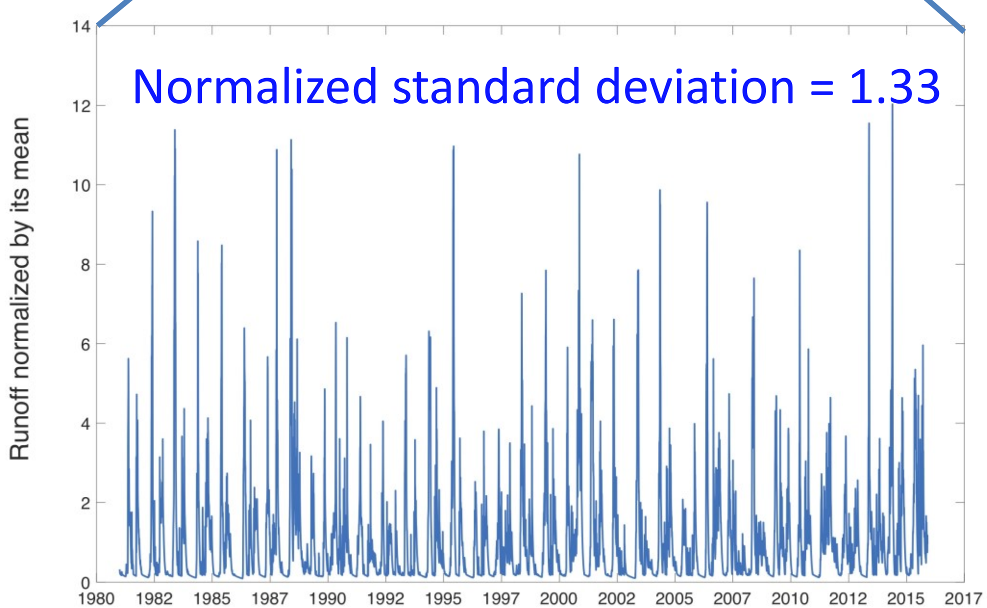
- Objectives on watershed scale, but
- economic objectives
- Multi-reservoir systems

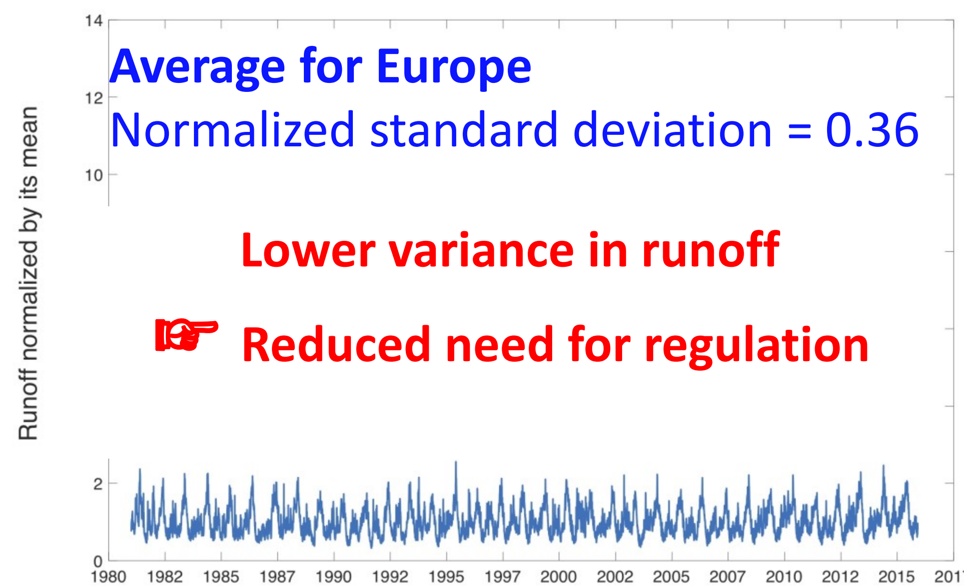
3. How does climate periodicity affect energy system functions?

Simulated runoff data for Europe

Performed by SMHI using E-HYPE: 35 years (1981 – 2015)

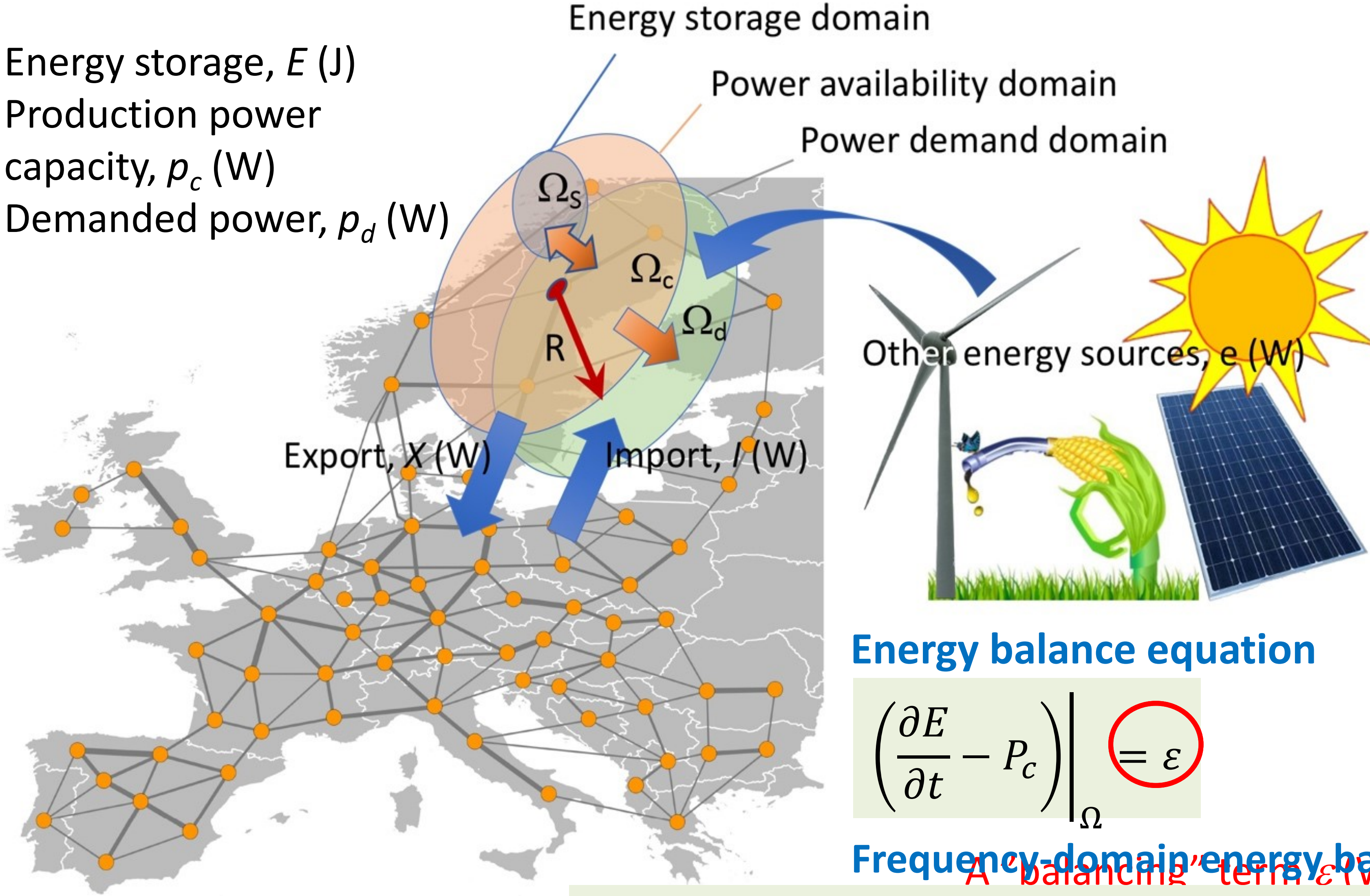






Spatio-temporal analysis of hydropower balancing

- Energy storage, E (J)
- Production power capacity, p_c (W)
- Demanded power, p_d (W)



Energy balance equation

$$\left(\frac{\partial E}{\partial t} - P_c\right)\Bigg|_{\Omega} = \varepsilon$$

A "balancing" term ε (W) required

$$\varepsilon = -X_c|_{\Omega_c} - (p_d + I + e)|_{\Omega_d}$$

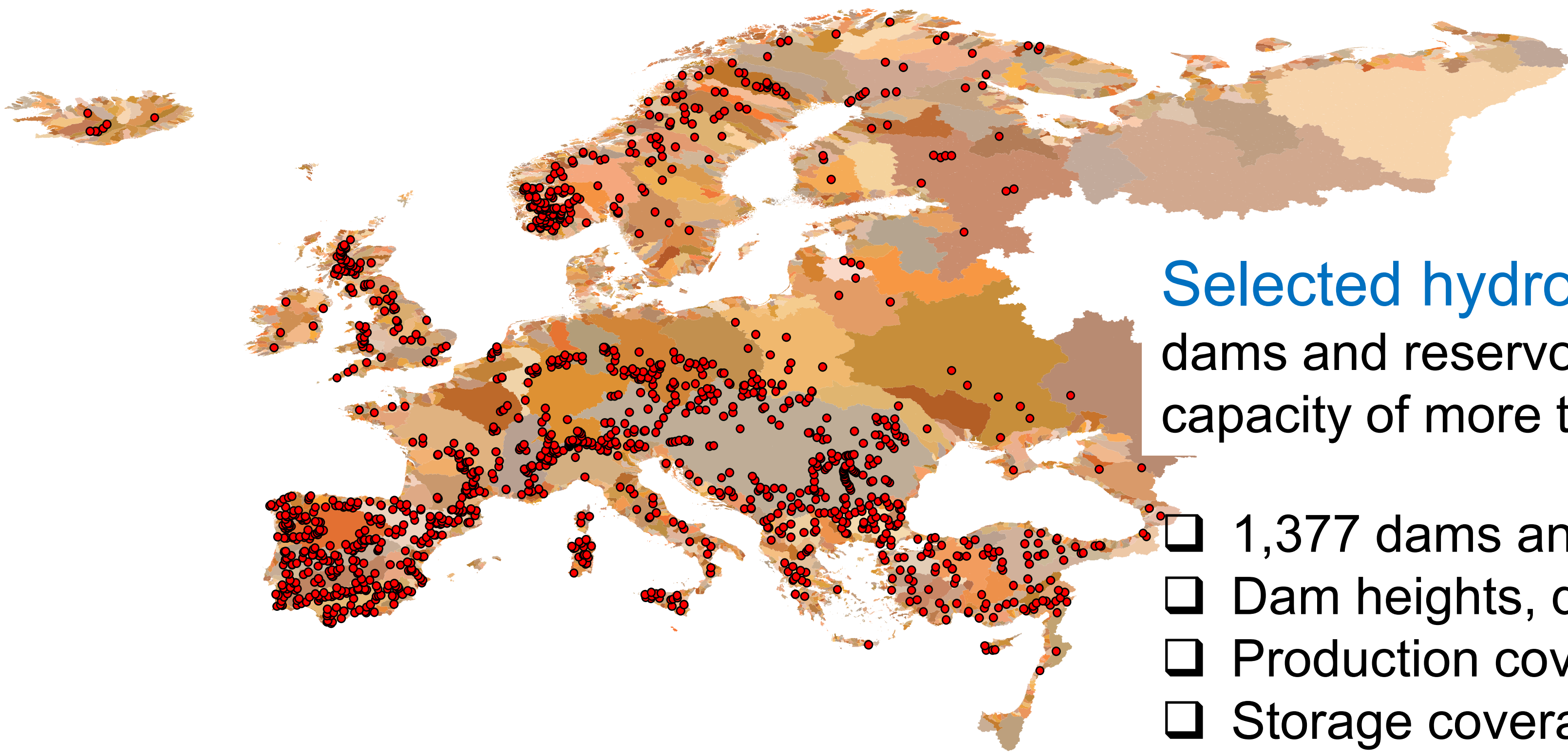
Frequency-domain energy balance

$$f^2 S(E) = \sum_{i=1}^{N} S(P_{c,i}) + \sum_{i \neq j}^{N} \mathrm{Re}\{S(P_{c,i}; P_{c,j})\}$$

Cross-spectral densities considered within coordination reach R

f = frequency (1/T)
T = period
S(…) = power spectral density
N = number of watersheds
ε = balancing term

Global Reservoir and Dam (GRanD) Database



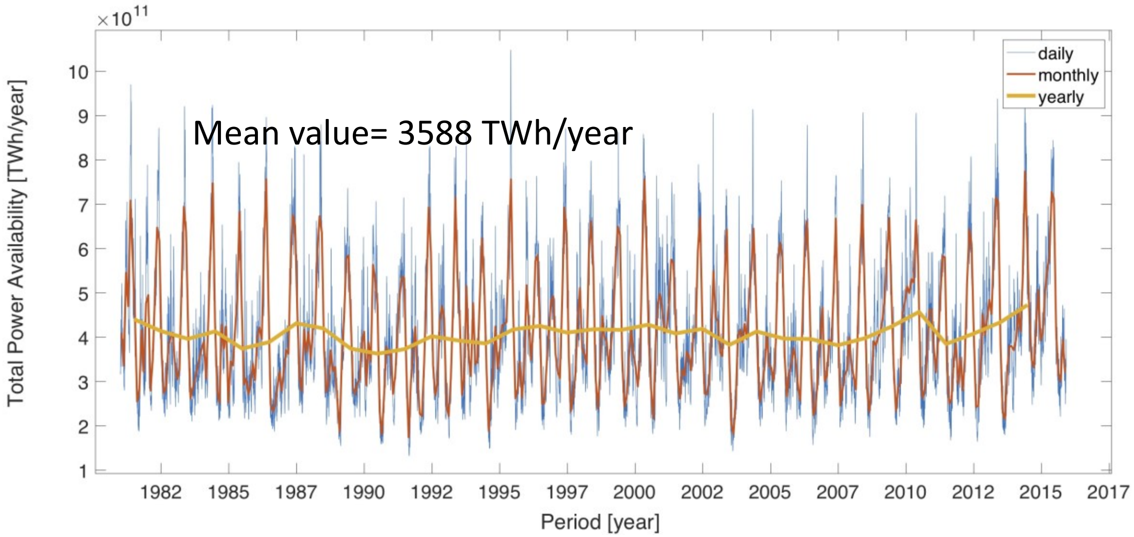
Selected hydropower system

dams and reservoirs with a storage capacity of more than 0.1 km^3

- 1,377 dams and hydropower stations
- Dam heights, discharge etc.
- Production coverage: 366 TWh/y
- Storage coverage: 81,000 GWh

Beames at al., 2019. http://globaldamwatch.org

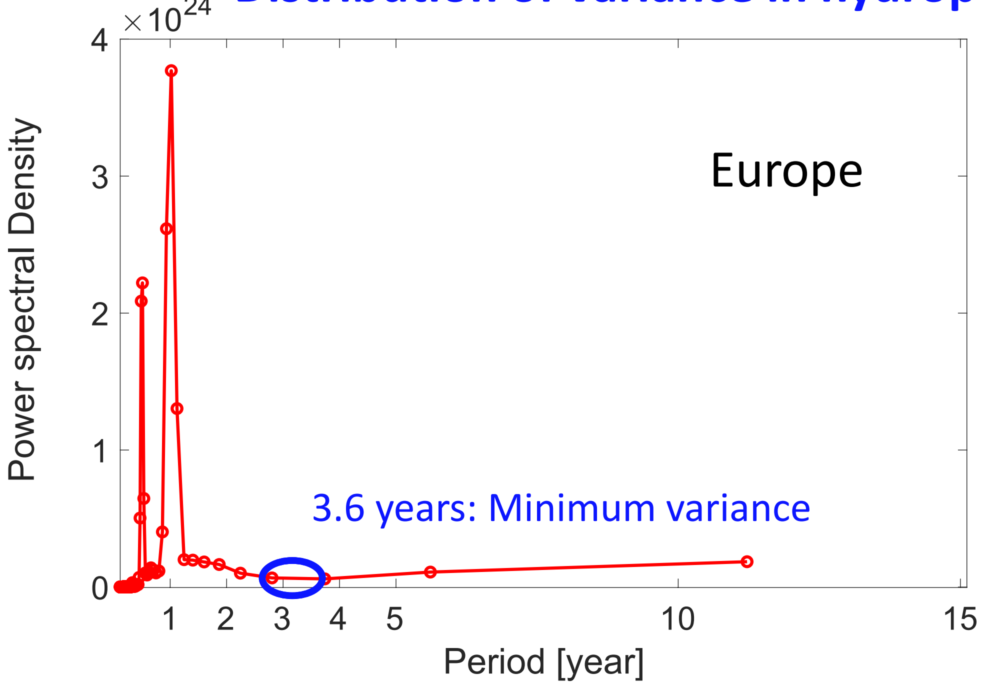
Potential energy of runoff in Europe

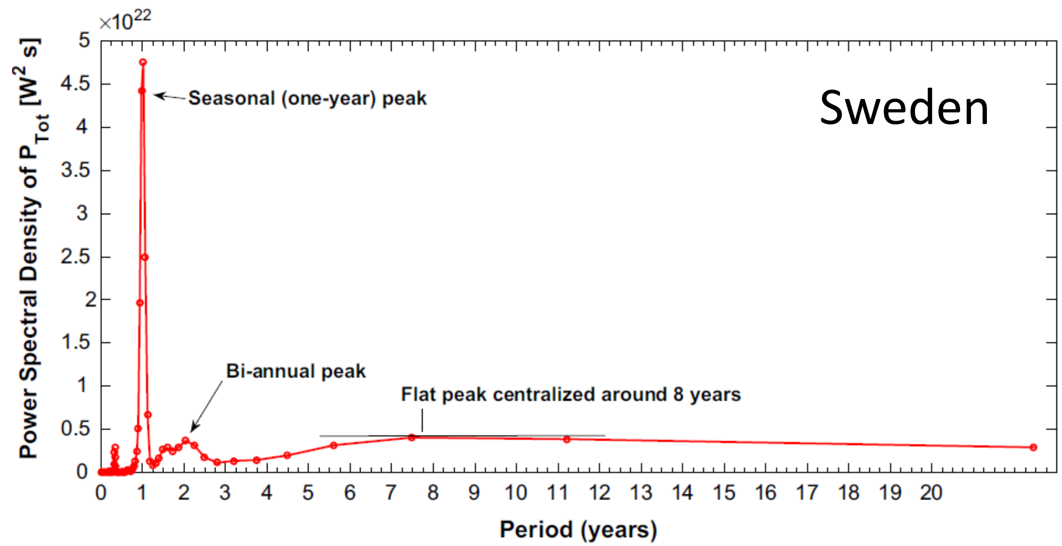


Coeficient of variation, CV	Sweden	Europe 35,408 watersheds
Daily time-series CV(P)	146%	36%
Annual time-series CV(P)	16%	5.9%
5-year time-series CV(P)	8.0%	2.4%

Difference indicate a potential for reduced variance with increasing scale

Distribution of variance in hydropower potential on periods

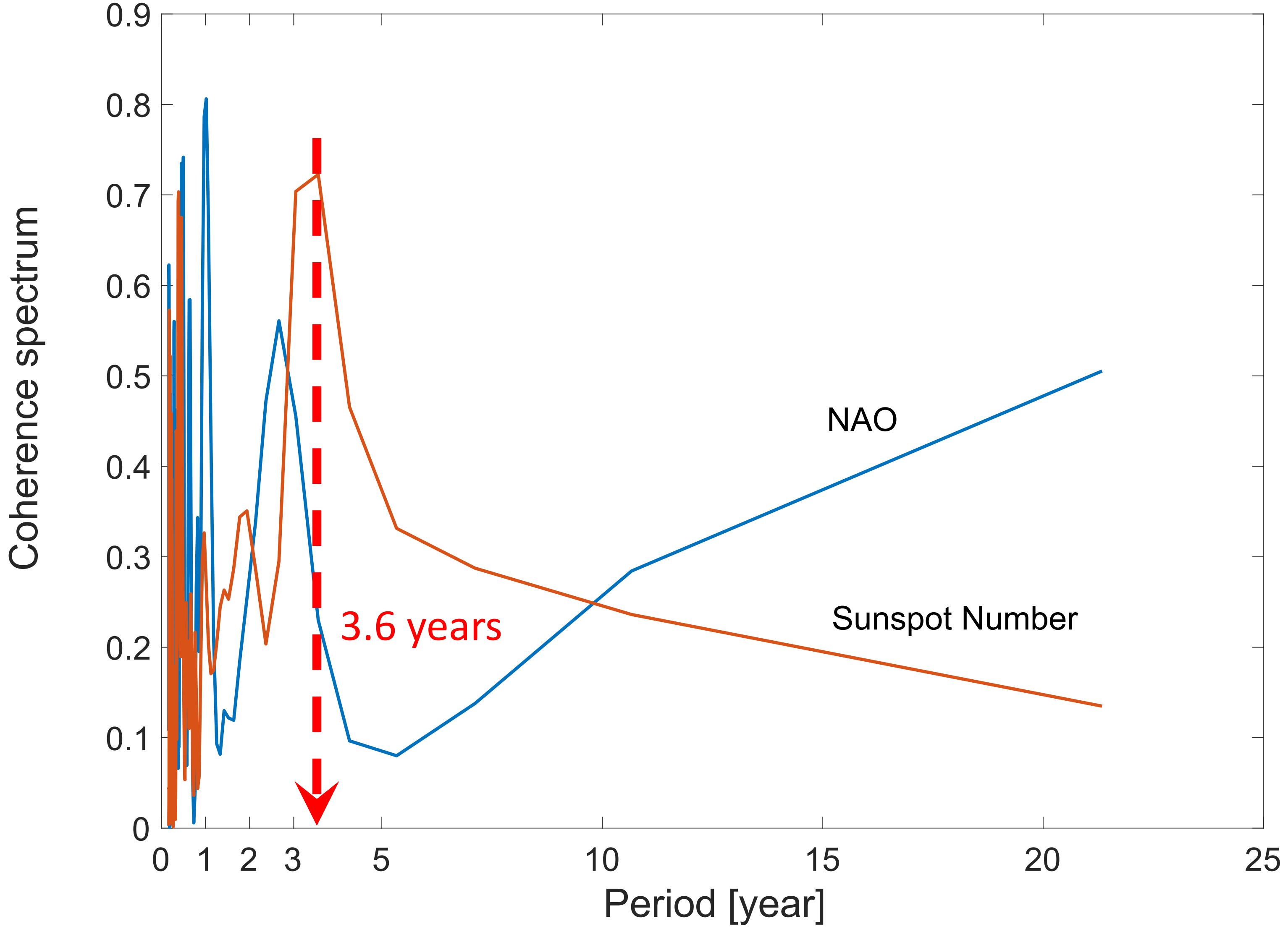




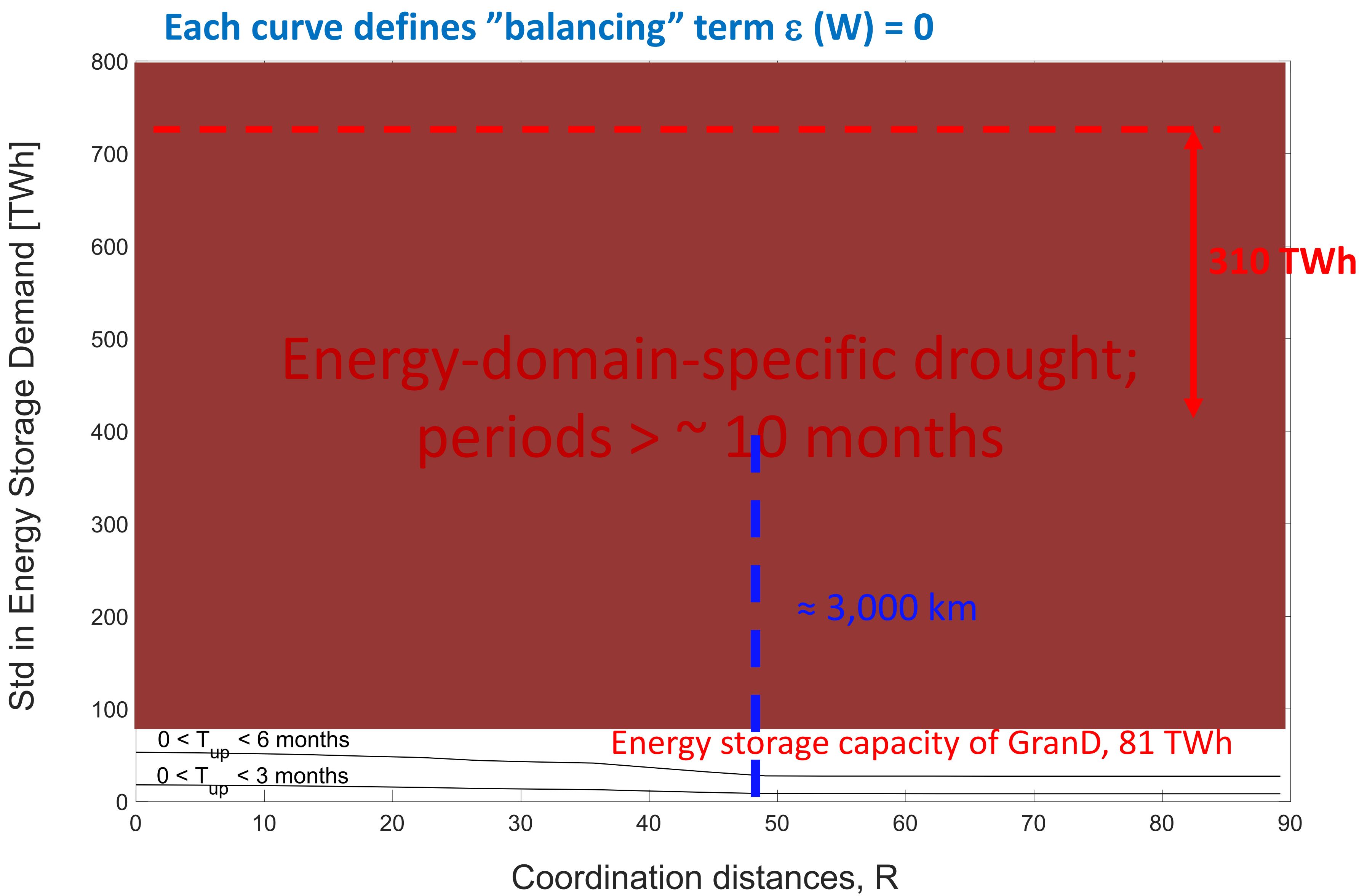
Reference: Wörman A, Lindstrom G, Riml J.2017.

Climatic control on hydropower availability

Coherence between power of all runoff in Europe and climate indicators

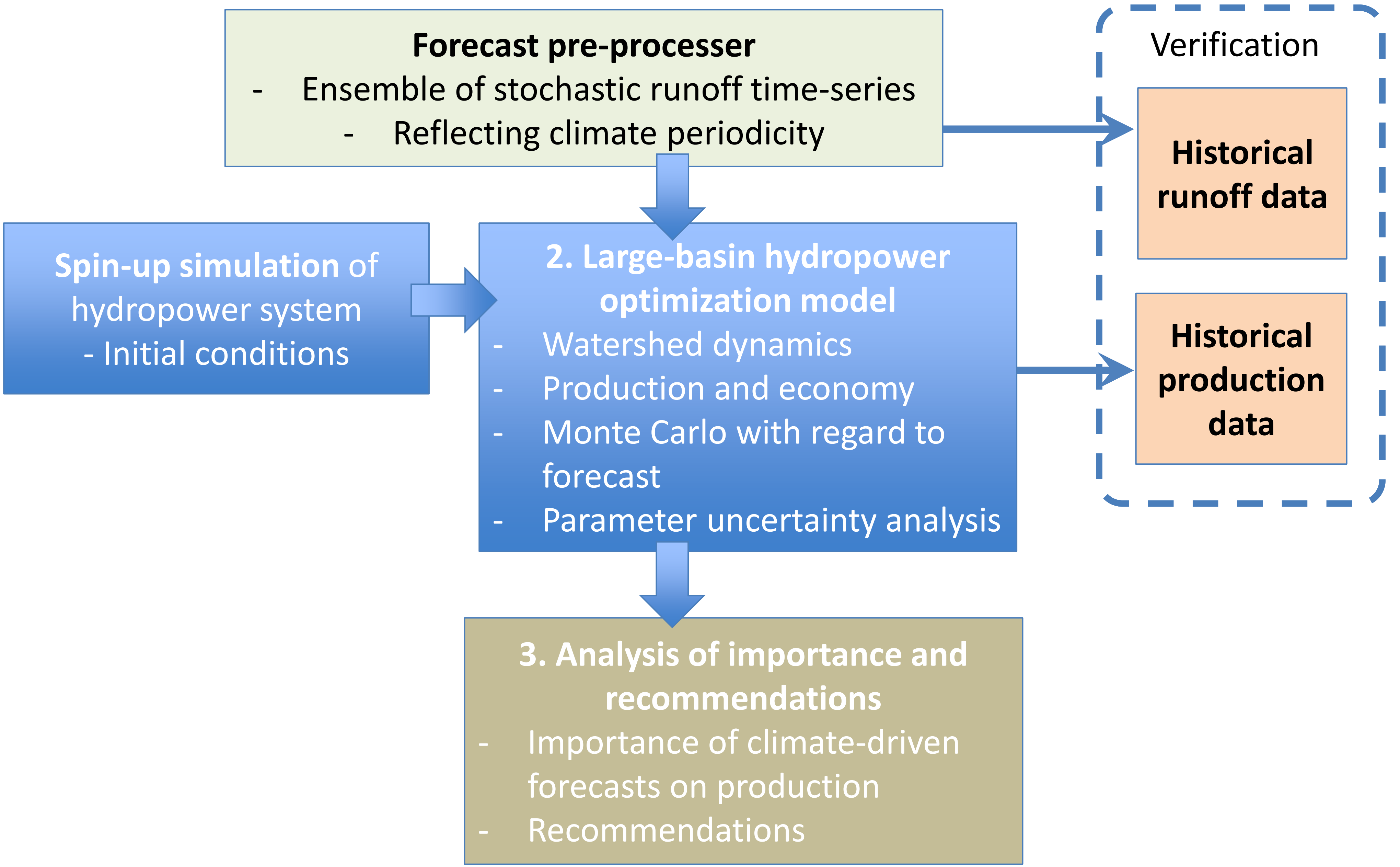


Significant decrease of energy storage demand with coordination distance

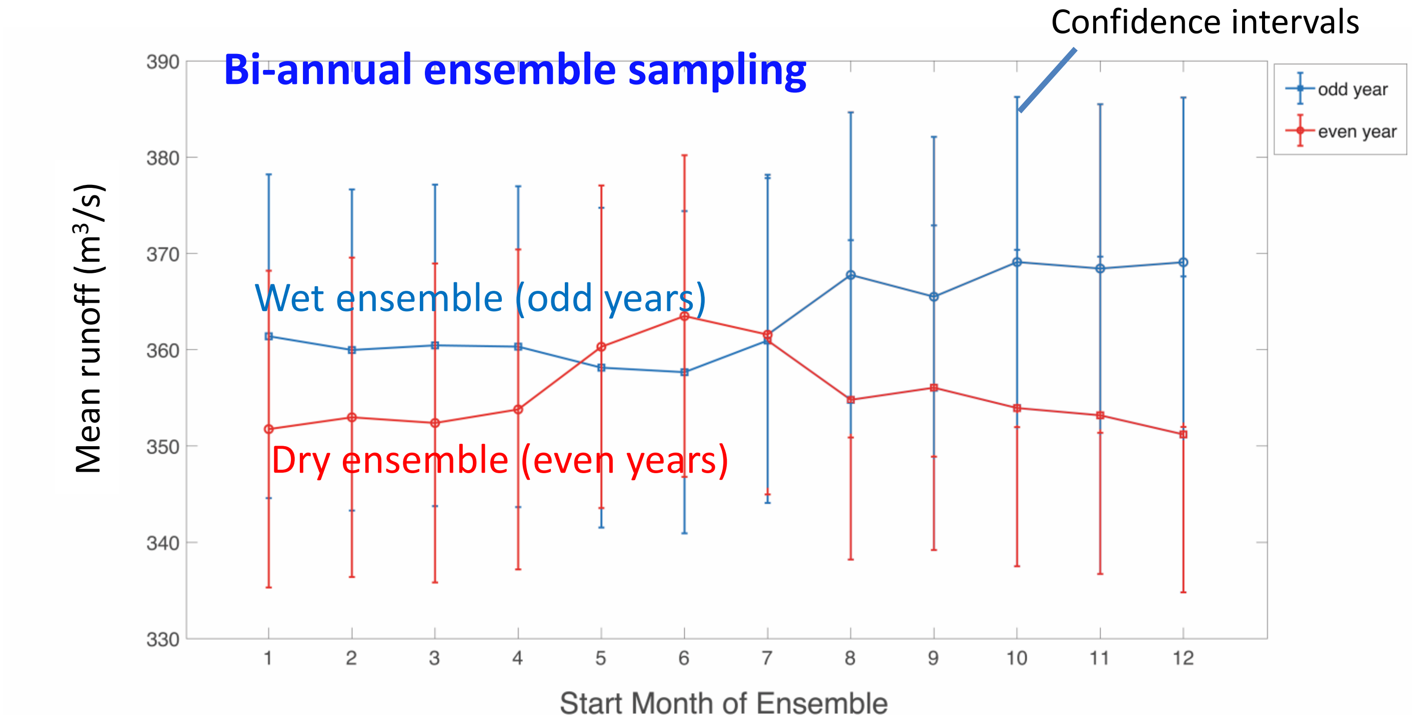


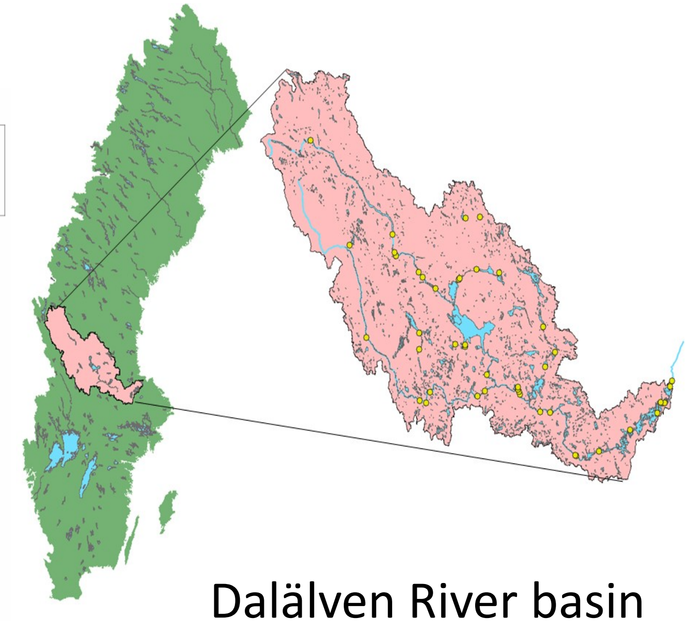
DD = Decimal degrees (43.5 - 78.7 km between 67 N to 45 N)

Development of production optimization system



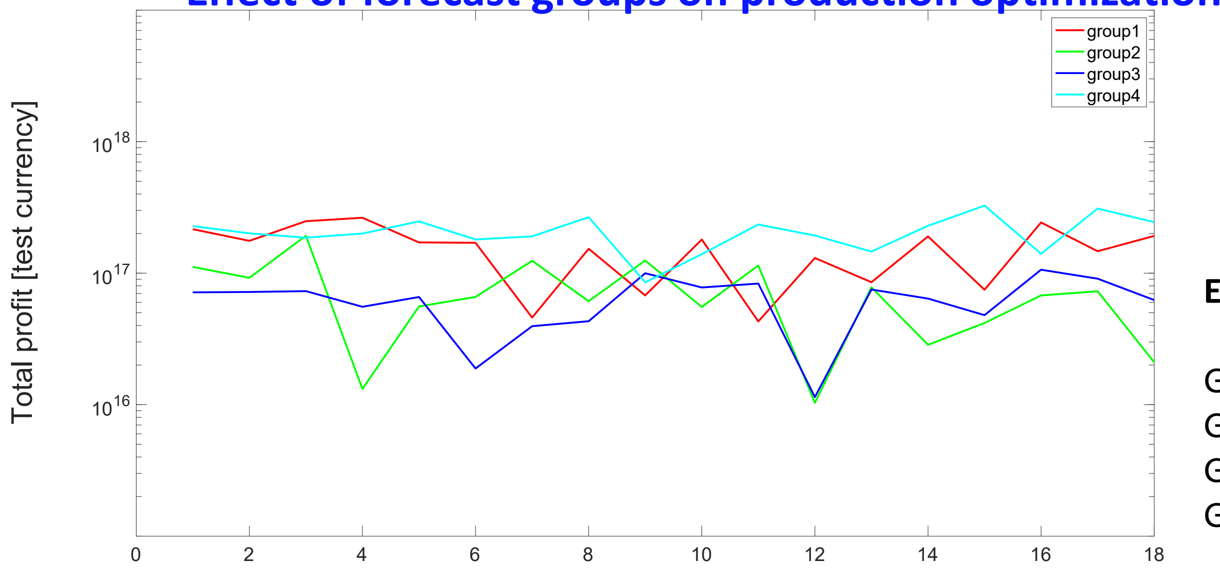
Testing on Dalälven River Basin





Dalälven River basin

Effect of forecast groups on production optimization



Ensemble classification

Group 1: Odd year, wet month
Group 2: Even year, dry month
Group 3: Odd year, dry month
Group 4: Even year, wet month

Conclusions (1/3)

- Spatio-temporal coordination of the hydropower production over Europe can potentially stand for nearly four (4) times as high energy storage gain as the storage capacity of hydropower reservoirs.

- The most significant gain from spatial coordination of hydropower production is obtained on distances up to 3,000 km.

- Forecasts of bi-annual periodicity (dry-wet years) can affect hydropower production management.