CLIMATE CHANGE IMPACTS ON THE ENERGY SYSTEM UNDER THE FOSSIL FUEL CURSE

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**With a big thanks to J.Kozlova, S.Krasheninnikow, and the whole GEPL-team*

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BACKGROUND

Technical physics + data science

Area of interest: research of power and heat supply technologies [transfer processes in a solid oxide fuel cell, thermal modelling of (SOFC + thermal power) units]

Subject of the study: national energy system under the climate change

MOTIVATION

1. **Adaptation knowledge** is still limited
2. Energy transformation processes are quite **long-termed**
3. **Need for renovations**/innovations in power industry is evident
4. Trying to get advantages of a **traditional system approach**

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Is there a way to put decarbonising steps among adaptation measures?

PROBLEMS CONSIDERED

1. Heating/cooling demand
2. Thermal efficiency deterioration
3. Renewables potential
4. Cogeneration
5. Electricity load
6. Reliability assessment
7. Renewables integration

Integral effects

"Typical-day" effects

Operating mode effects

INTEGRAL EFFECTS

1. Heating/cooling demand
2. Thermal efficiency deterioration
3. Renewables potential

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Effect of the climate change on

- the national **energy balance**

and

- an overall **renewables potential**

INTEGRAL EFFECTS-1

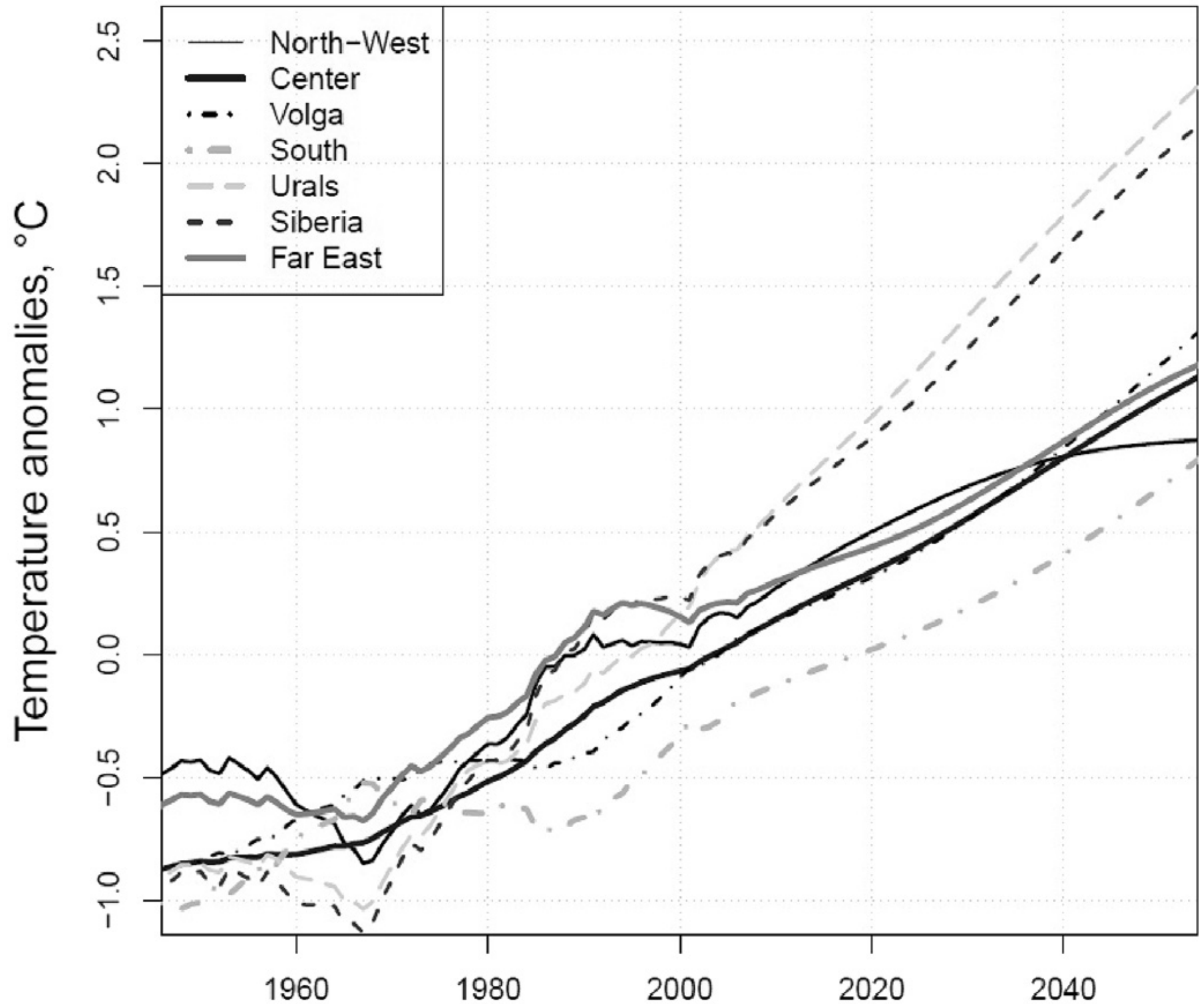
1. Heating/cooling demand
2. Thermal efficiency deterioration

Climate modelling

Carbon box model + Regression model

*Comparison with General Climate Models projections (CMIP5 simulations data, RCP2.6 & RCP4.5 scenarios)

INTEGRAL EFFECTS-1



INTEGRAL EFFECTS-1

Energy modelling

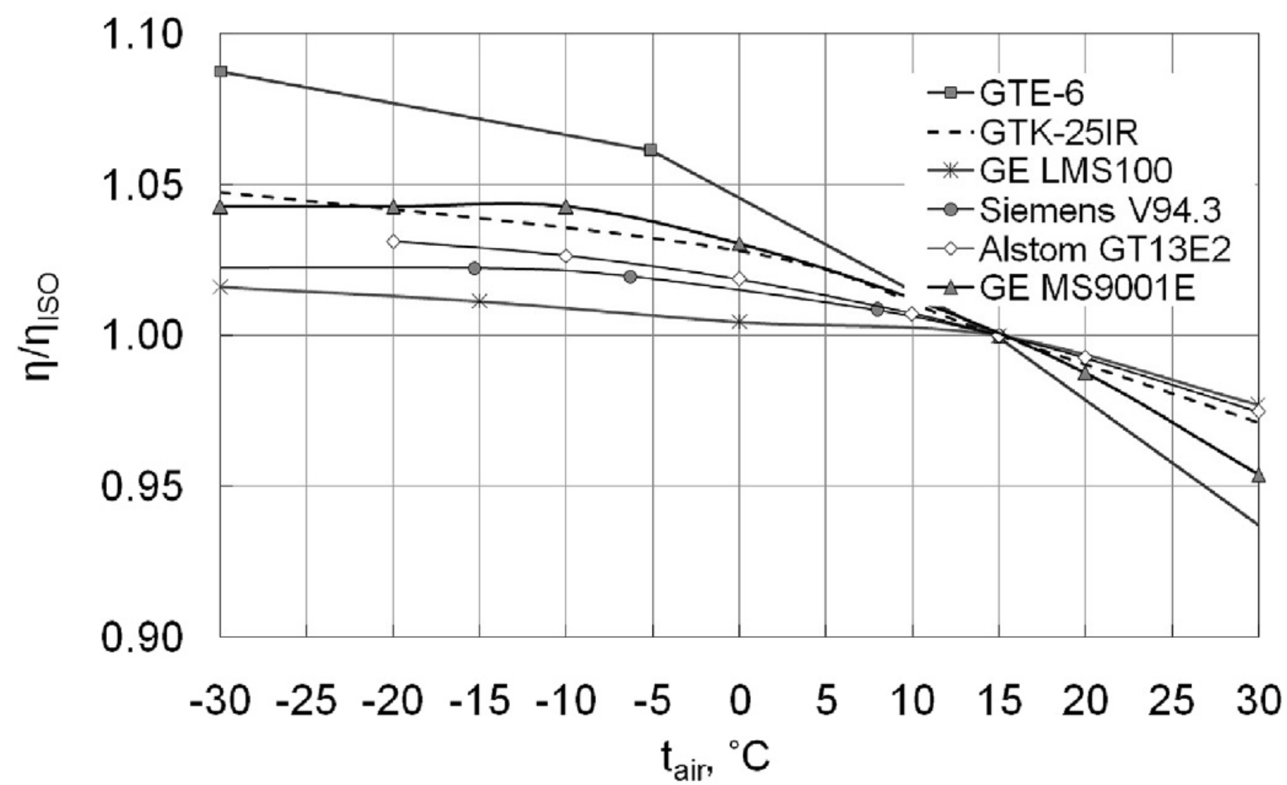
- Heating/cooling **degrees-days** concept

Integral of the heat/cold deficit throughout the year

INTEGRAL EFFECTS-1

Energy modelling

- Heating/cooling **degrees-days** concept
- Technical characteristics of **industrial gas turbines**

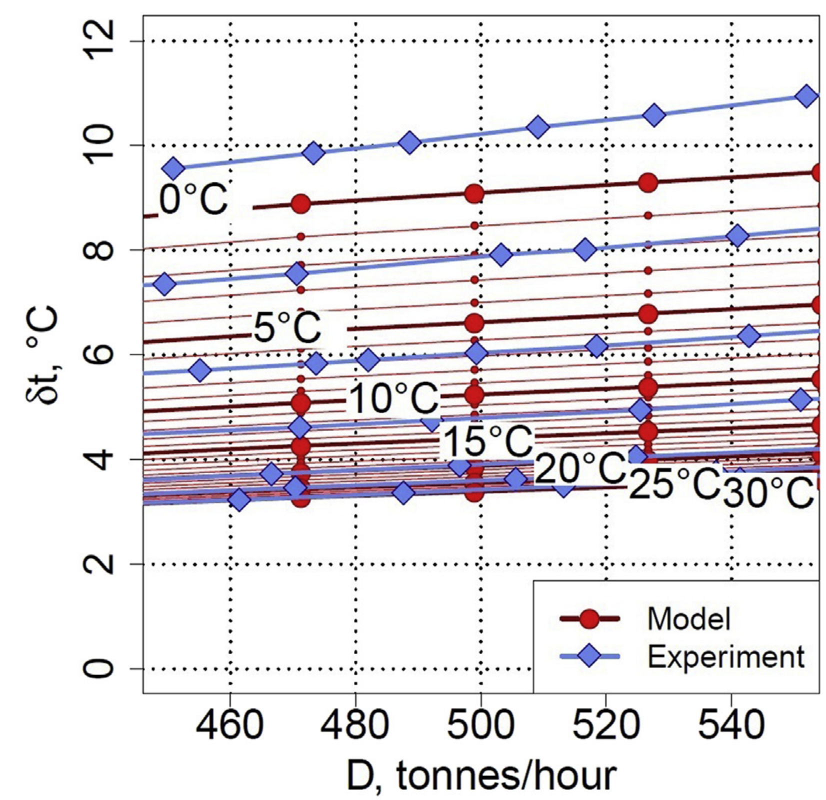


INTEGRAL EFFECTS-1

Energy modelling

- Heating/cooling **degrees-days** concept
- Technical characteristics of **industrial gas turbines**
- Implementation of the **condenser model*** representing two-phase heat transfer in the steam power unit circuit

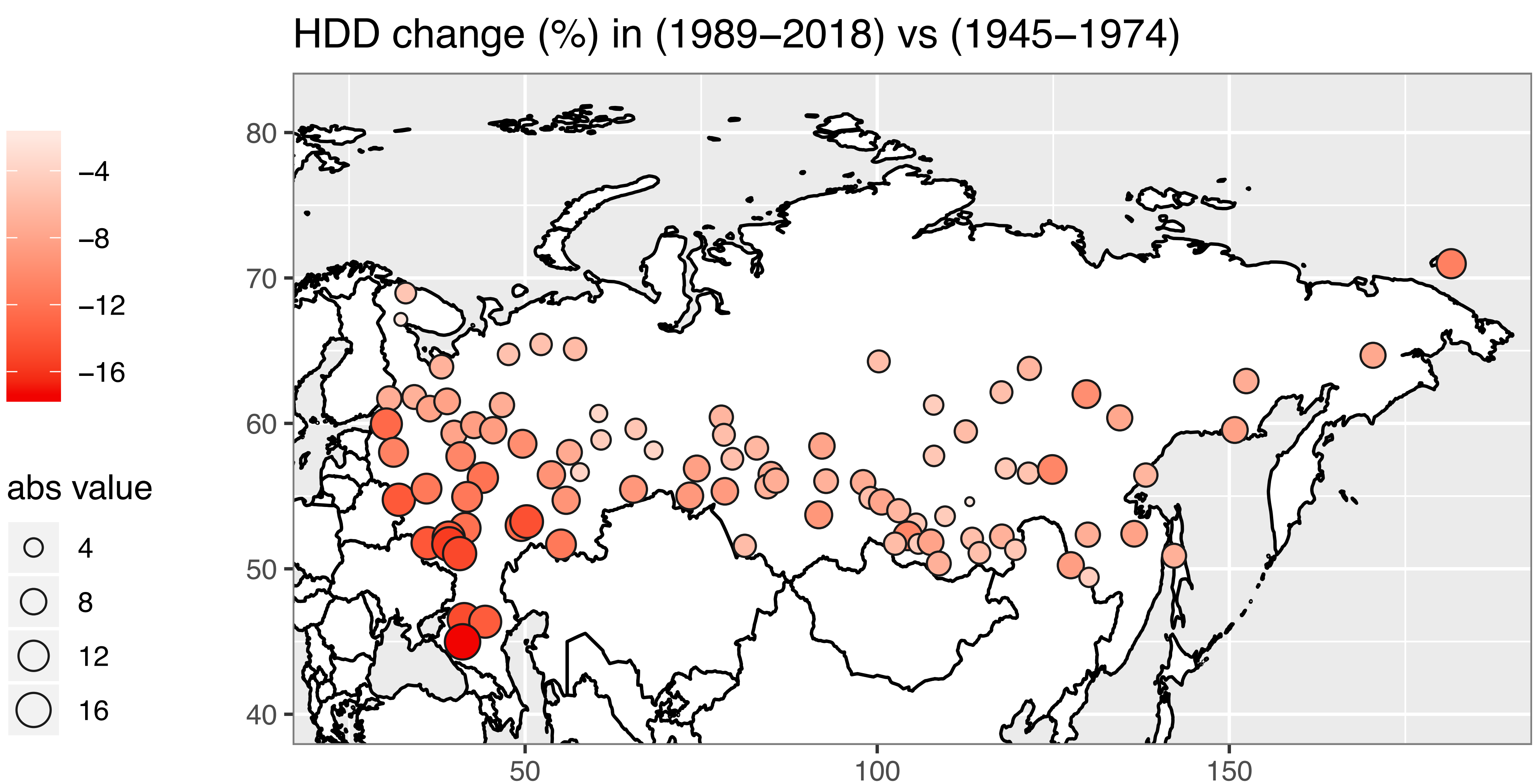
$$\Delta P_{el} \approx \frac{\partial P_{el}}{\partial p_c} \cdot \frac{\partial p_c}{\partial t_c} \cdot \frac{\partial t_c}{\partial t_{water}} \cdot \frac{\partial t_{water}}{\partial t_{air}} \Delta t_{air}$$



*Available via github: @ekatef energy-VulnPowInd

INTEGRAL EFFECTS-1

Heating demand has decreased significantly



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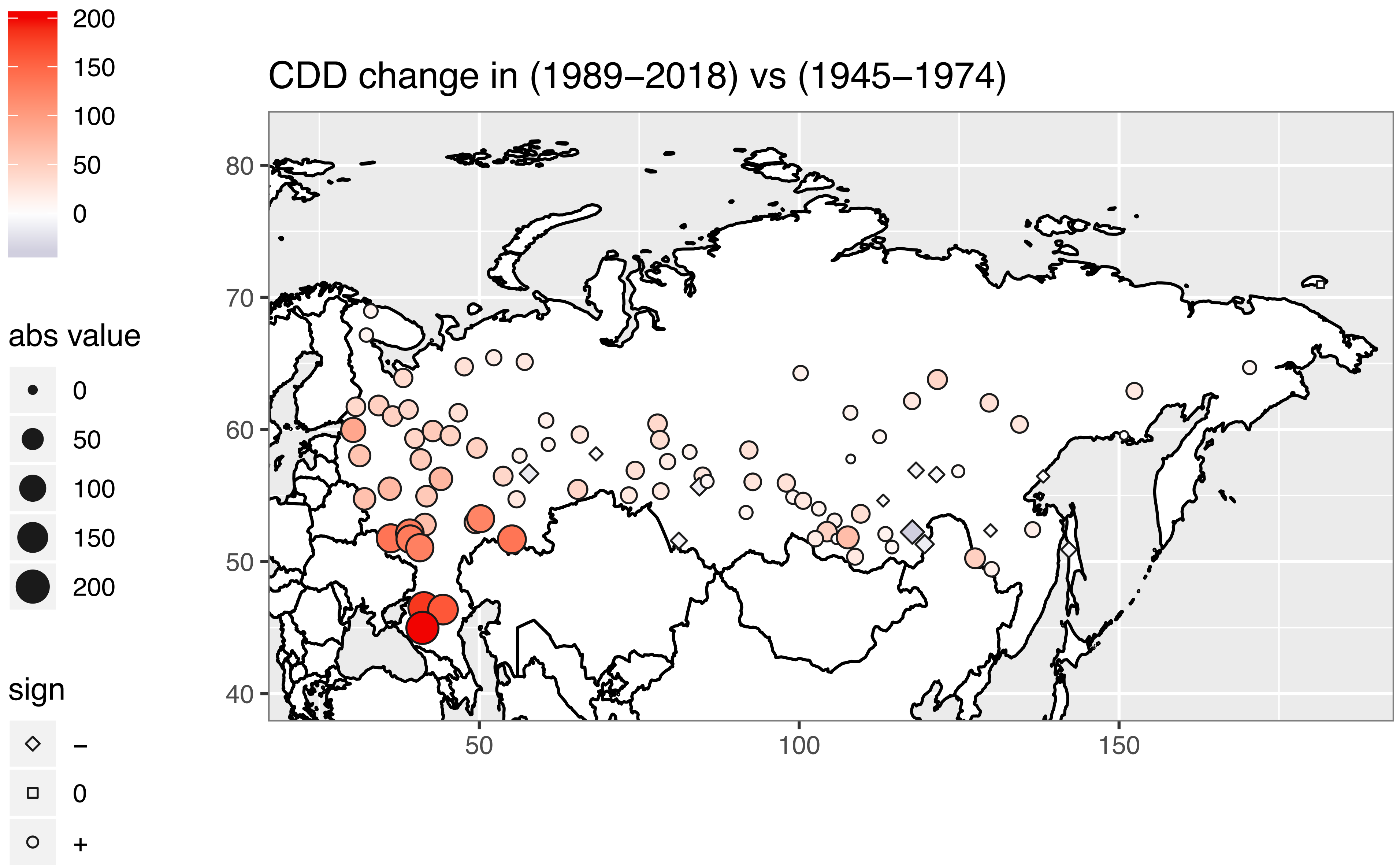
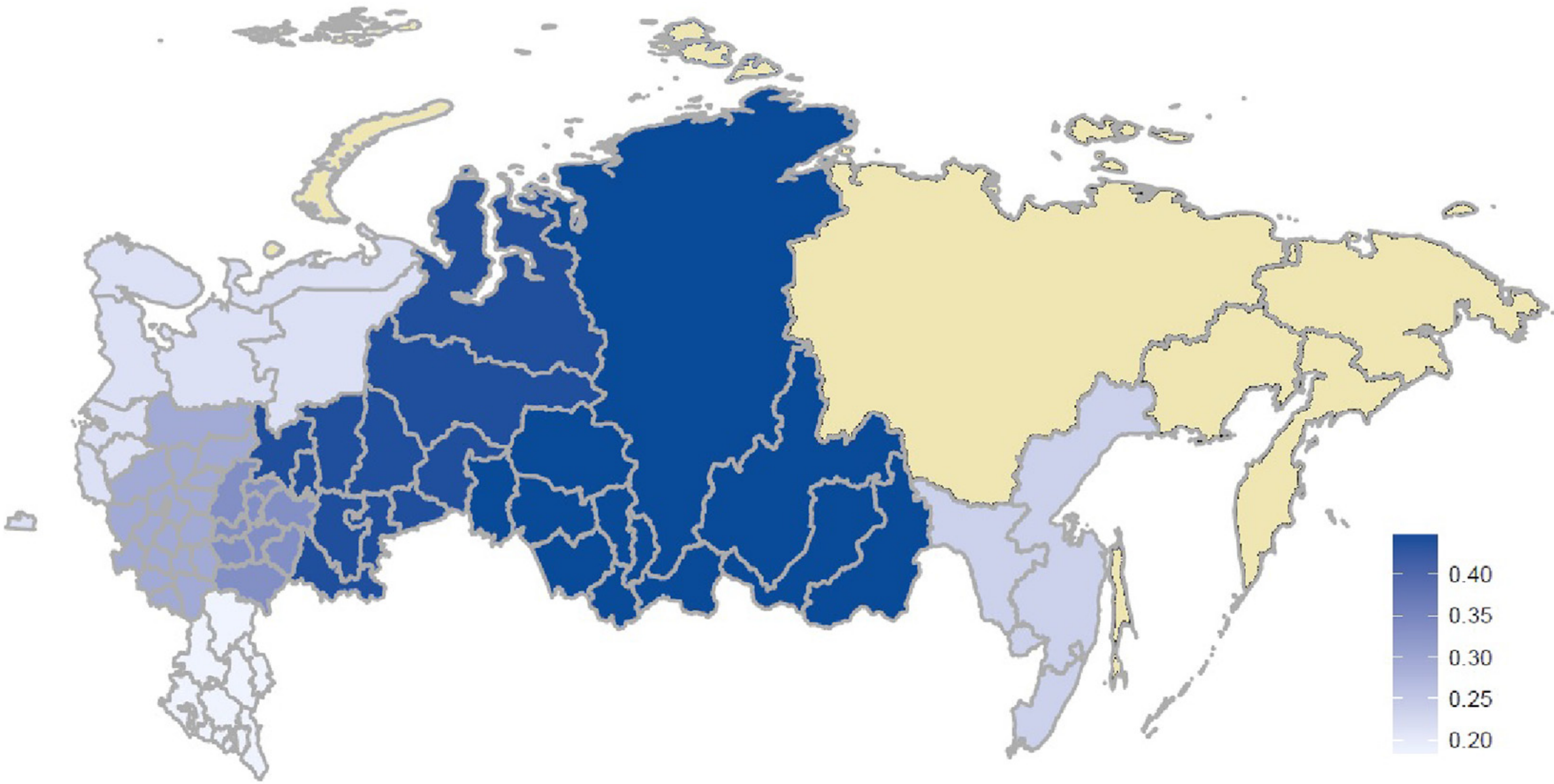
INTEGRAL EFFECTS-1

Rather minor effect on the annual cooling demand



INTEGRAL EFFECTS-1

Steam turbines are impacted noticeably



Power drop of the steam turbines operating on thermal power plants to 2050

INTEGRAL EFFECTS-2

Renewables potential (hydropower and wind)

Assess the **sign** and an **order of magnitude** of the climate change impact

Energy modelling

Technical characteristics of industrial power plants

INTEGRAL EFFECTS-2

Renewables potential (hydropower and wind)

Assess the **sign** and an **order of magnitude** of the climate change impact

Climate modelling

Ensemble estimations based on the General Climate Models projections (CMIP5 simulations data, RCP2.6 & RCP4.5 scenarios)

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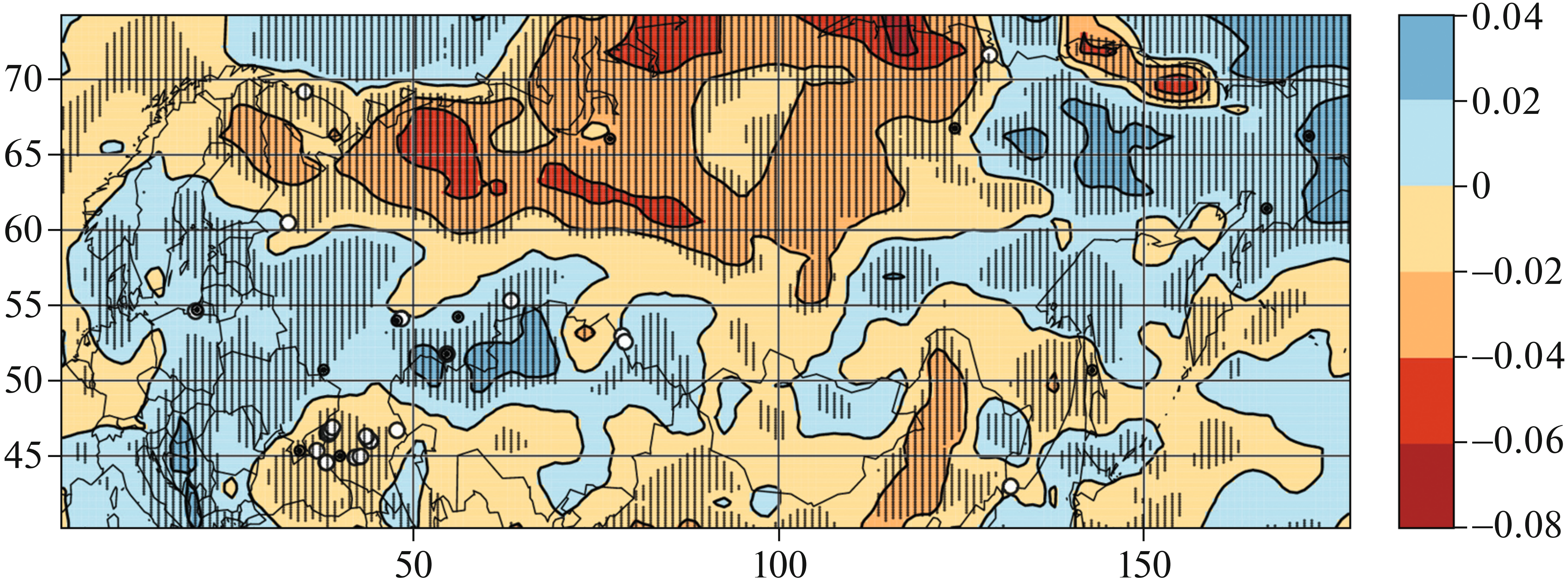
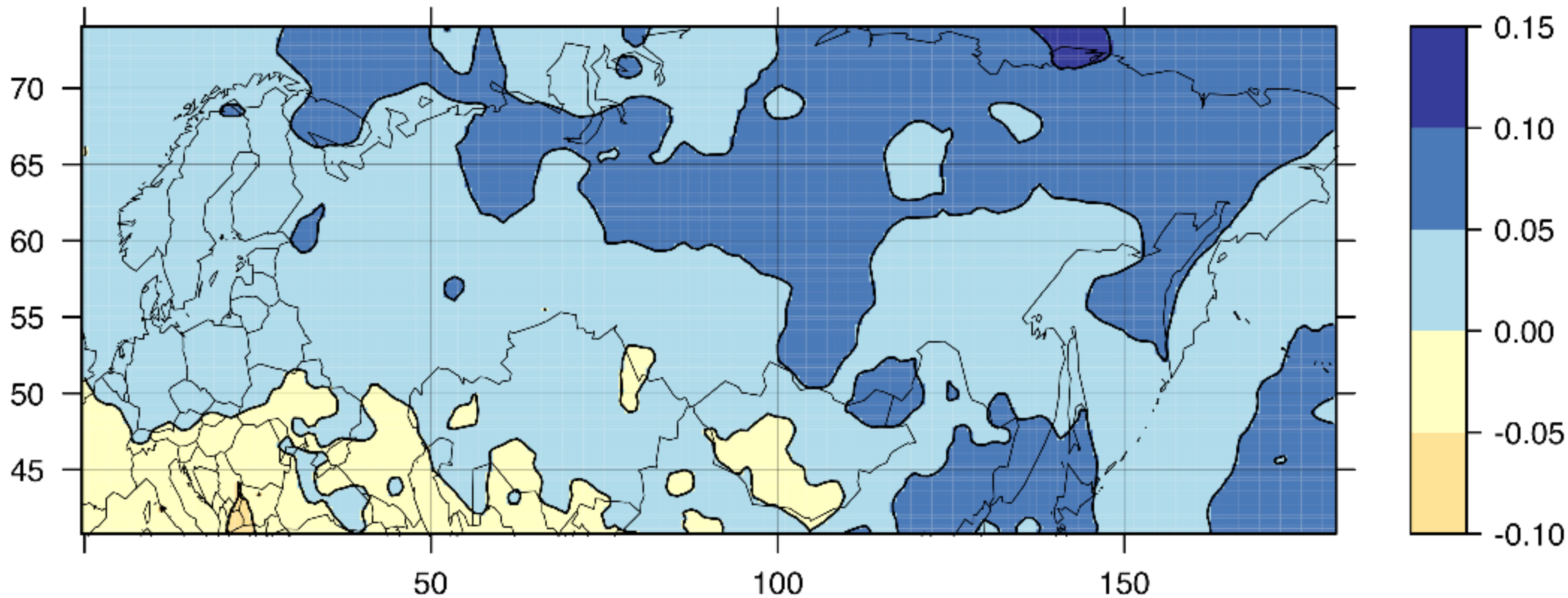
Models discrimination

INTEGRAL EFFECTS-2



Projections of the relative change of the annual average wind speed to 2050
(optimistic climate scenario RCP2.6)

INTEGRAL EFFECTS-2



Projections of the relative change of the annual precipitation amount to 2050
(optimistic climate scenario RCP2.6)

INTEGRAL EFFECTS-2

Some **increase in runoff and improve conditions** of the hydropower operation across Russia is likely, **except for the most southern regions**.

A tendency to **wind speed decrease** in the European part of the country and in the southern part of West Siberia may be concluded with a certain confidence. The robust finding for the wind speed is the increasing trend in Primorye region.

INTEGRAL EFFECTS: SUMMARY

- The power drop of the steam turbines* and gas turbines** is quite noticeable
- A space heating demand decrease clearly dominates the climate change impact of the national energy balance
- The climate change seem to be quite safe in terms of an impact on the renewable potential

* 0.2..0.3 and 0.4..0.6 percent points per 1ºC for the thermal and nuclear power plants respectively

**0.1 percent points per 1ºC

"TYPICAL-DAY" EFFECTS

1. Cogeneration
2. Electricity load

What adaptation challenges are the "united" power systems likely to face?

"TYPICAL-DAY" EFFECTS-1

Cogeneration

Centralised structure of the power systems ⇨

Focus on the stations observation records

Climate modelling

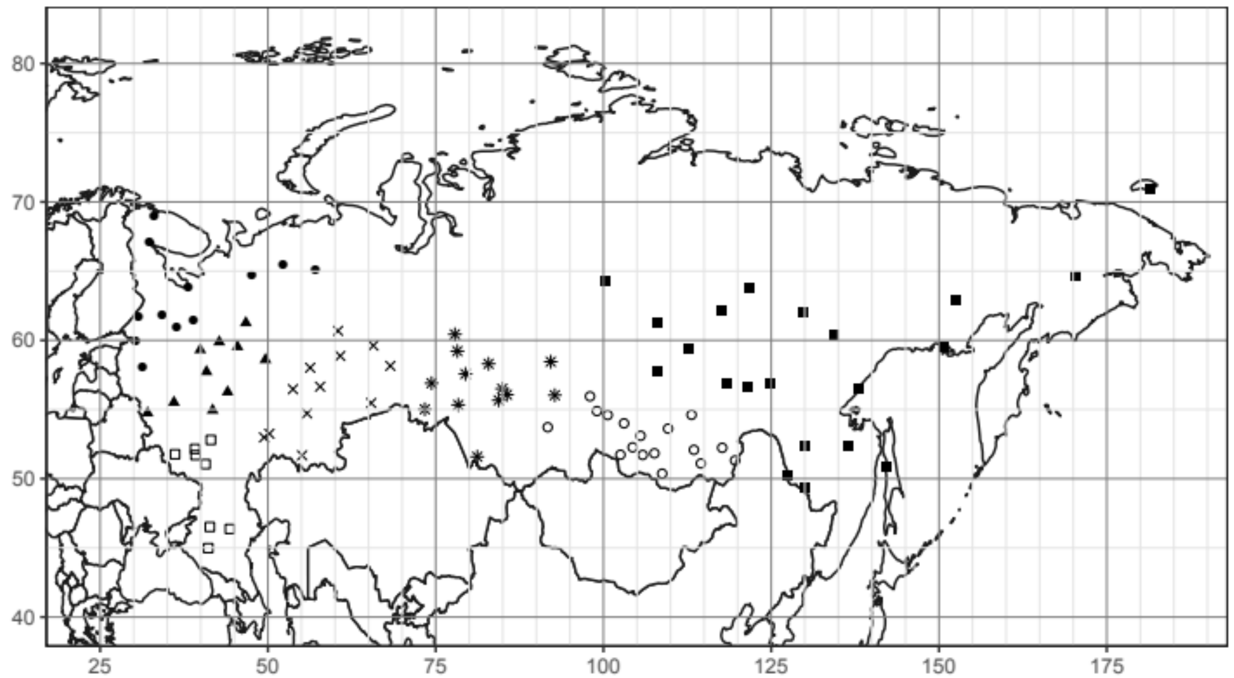
Assessment of the probability distribution functions for the past

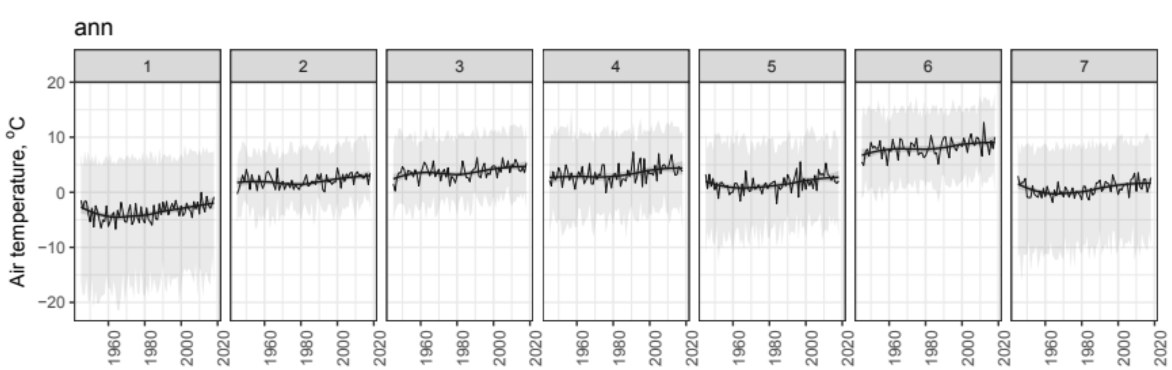
+

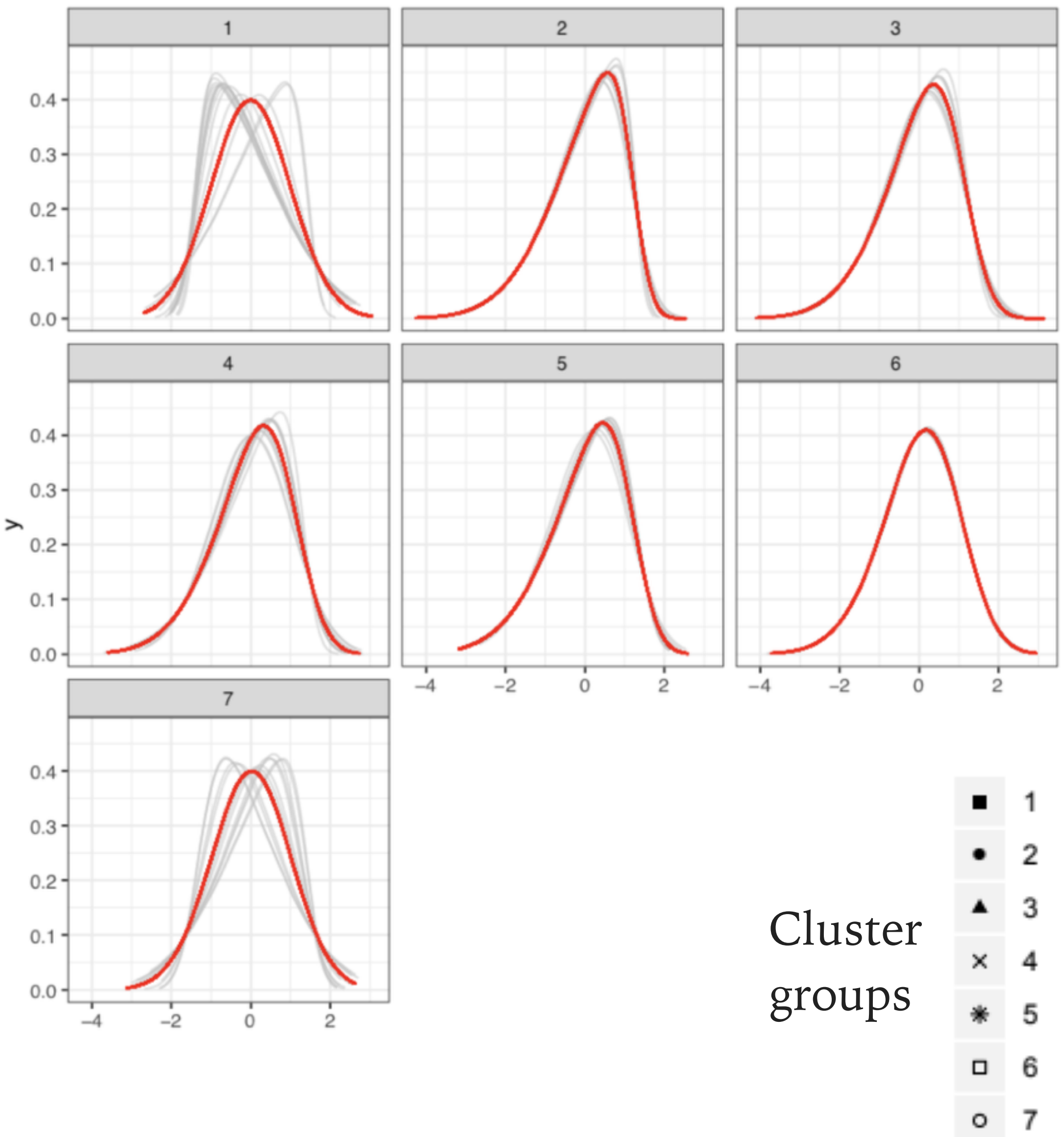
Morphing approach for the future

"TYPICAL-DAY" EFFECTS-1

Cogeneration





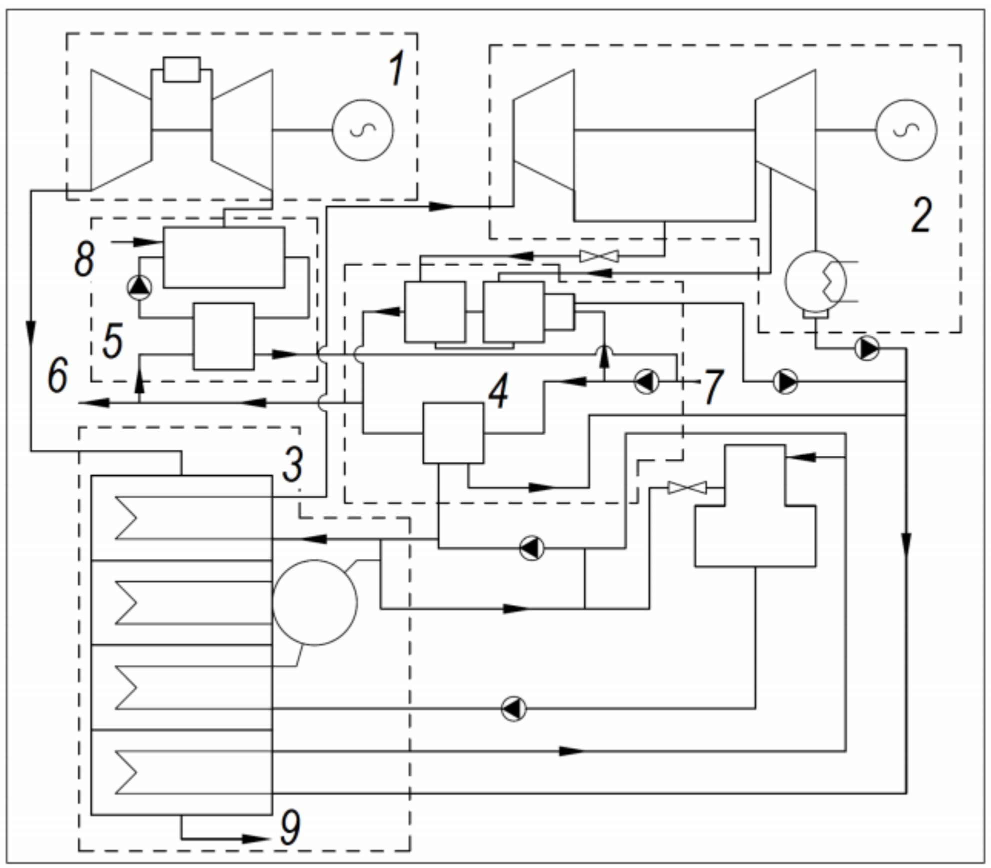


Cluster groups

"TYPICAL-DAY" EFFECTS-1

Energy modelling

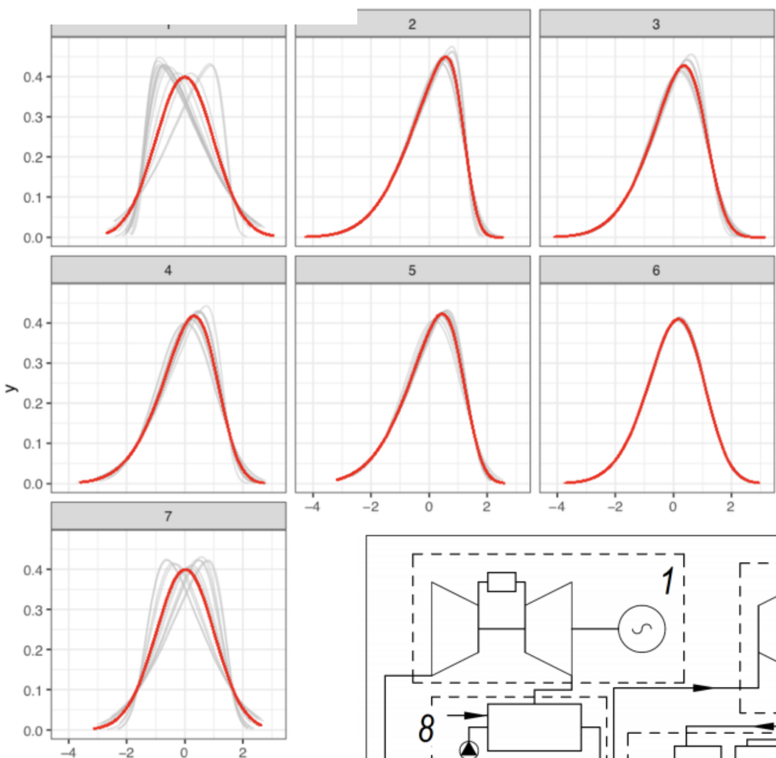
Engineering-level model of the thermal power plant

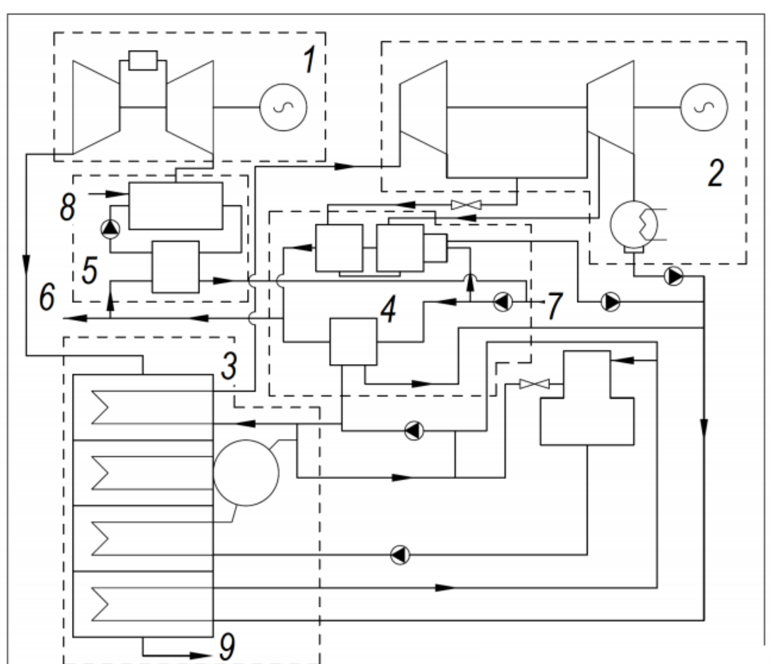


- *Heat and mass transfer*
- *Design of the plant elements*
- *Technical characteristics of the real power equipment*

“TYPICAL-DAY” EFFECTS-1

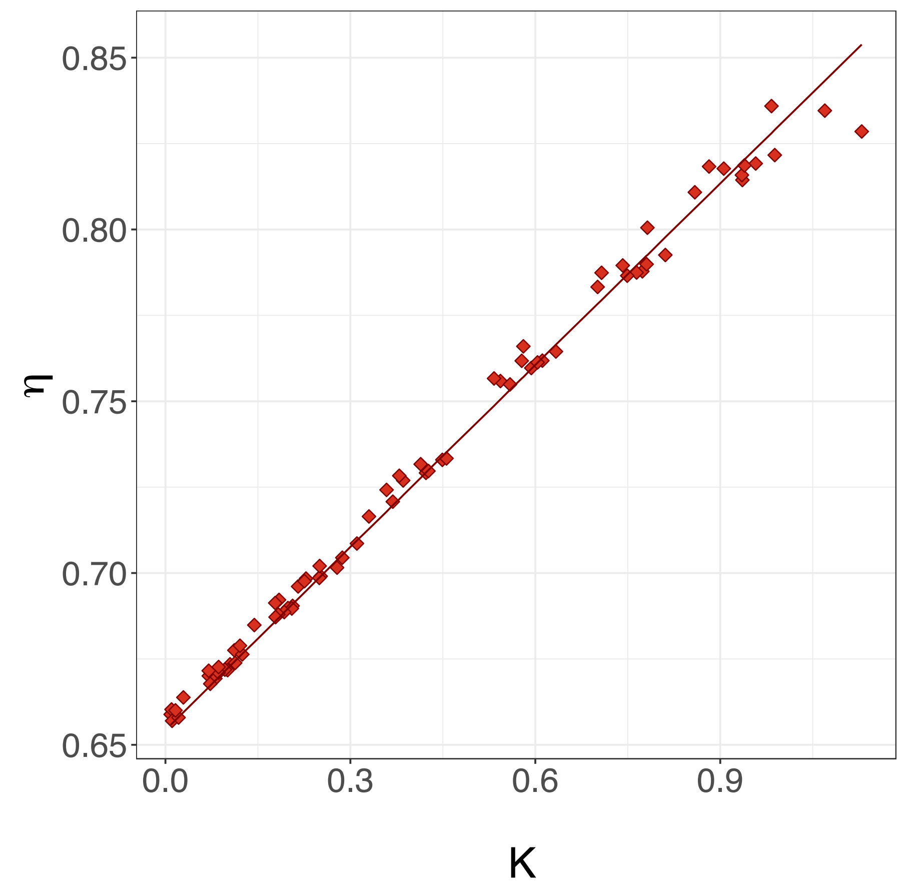
Climate data





CHP model

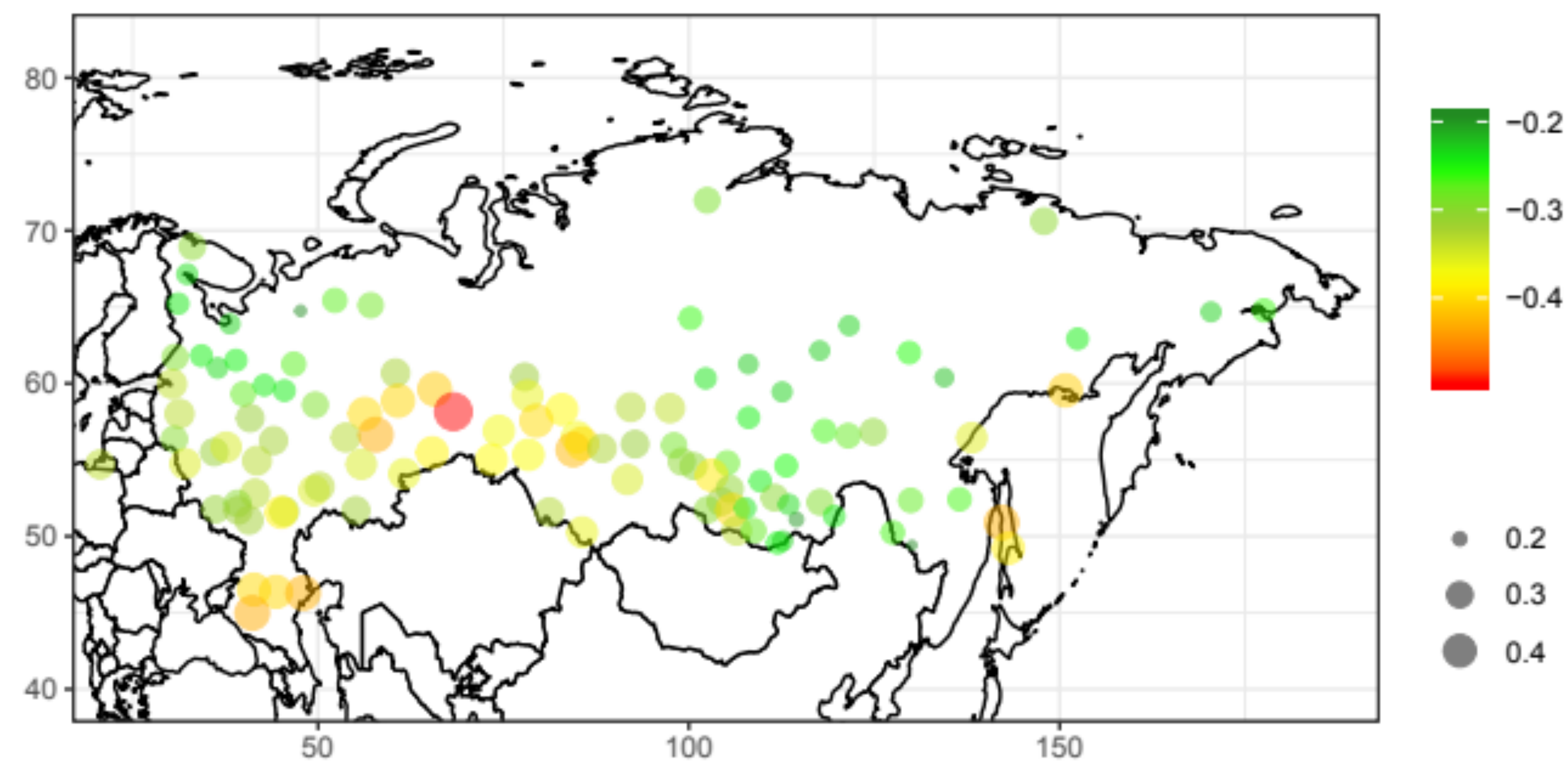
Generalised CHP representation



"TYPICAL-DAY" EFFECTS-1

Cogeneration

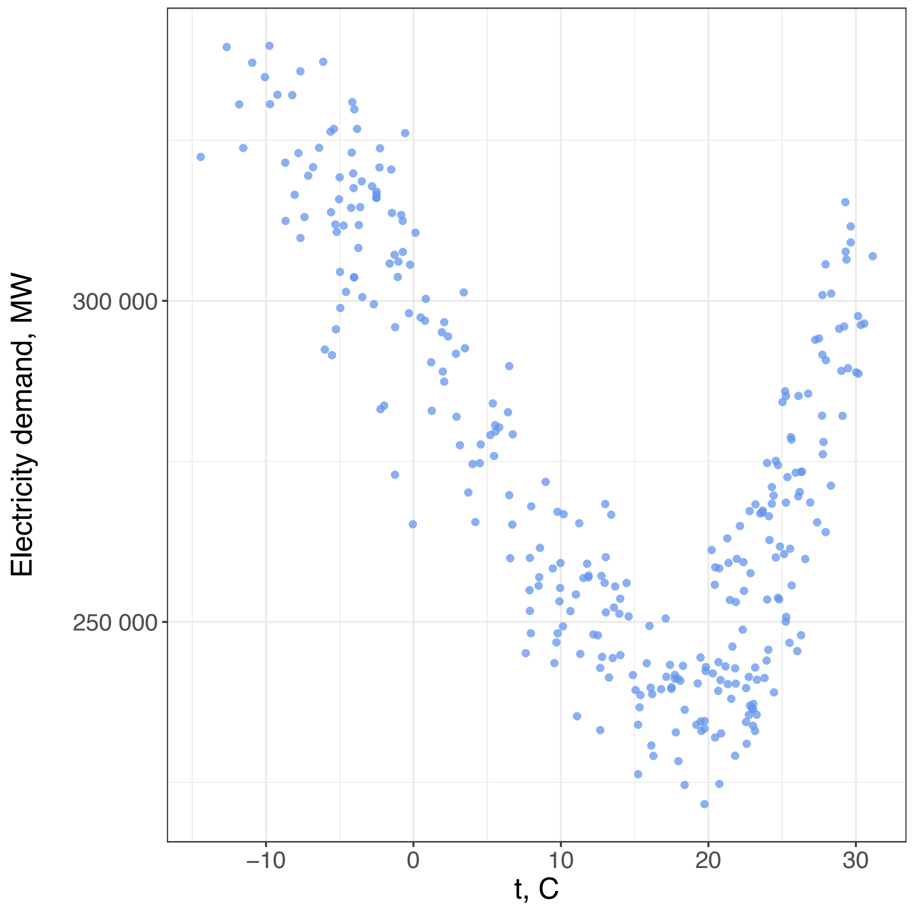
Decrease of the heating demand means a considerable CHPs' efficiency drop



CHPs' efficiency drop per 1°C annual warming

“TYPICAL-DAY” EFFECTS-2

Electricity load



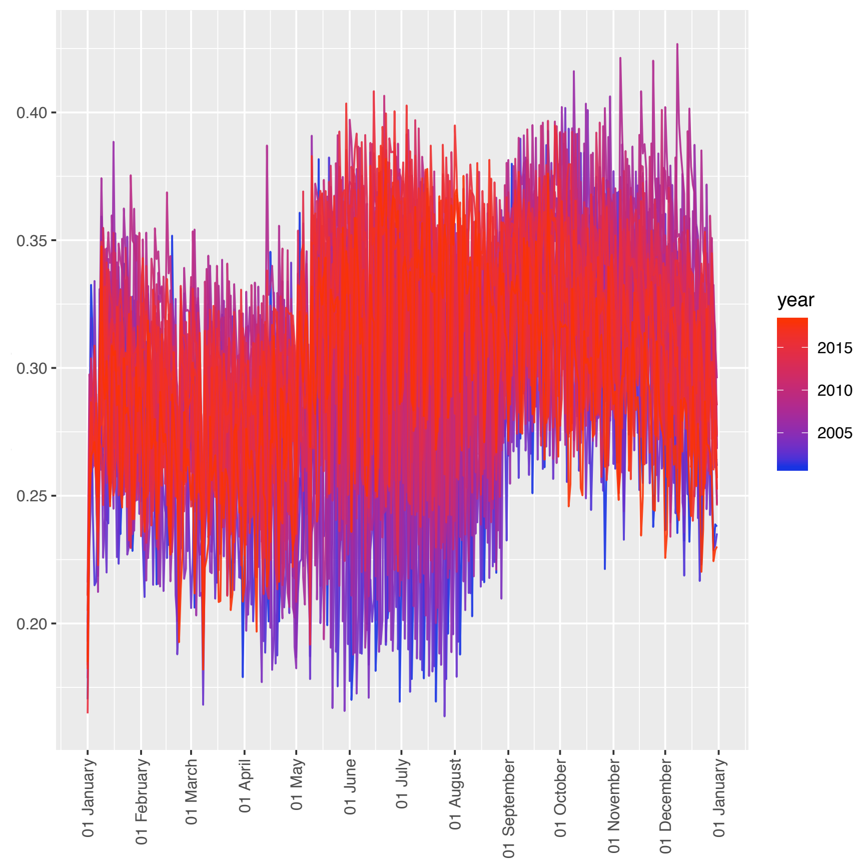
Dependence of the electricity demand on the daily ambient air temperature in the South energy system (5-days moving average filter applied)

Mean 10-years (T_m) and threshold (T_h) daily ambient air temperature of the warm period

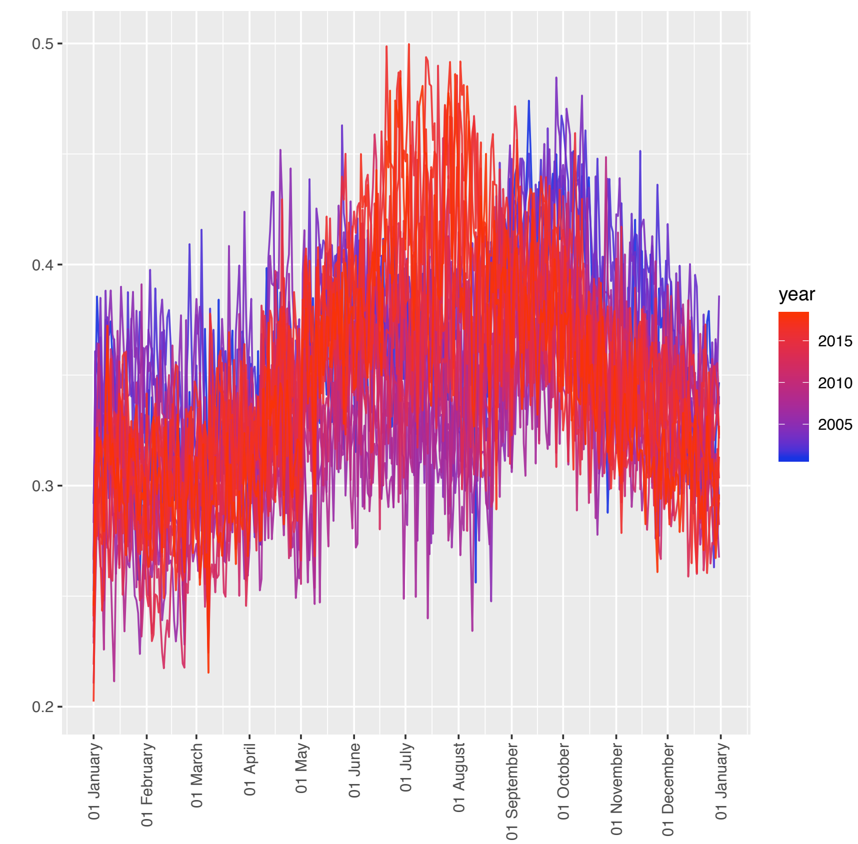
Power system	T_m, deg. C	T_h, deg. C	Years used in T_h estimation
Noth-West	13.9	–	–
Center	18.1	20	2010, 2013, 2016, 2018
Middle Volga	18.3	21	2010, 2012, 2013, 2016
South	23.6	20	2009-2018
Urals	18.5	22	2012, 2015, 2016
Siberia	15.8	–	–
East	15.5	–	–

"TYPICAL-DAY" EFFECTS-2

Electricity load



Center

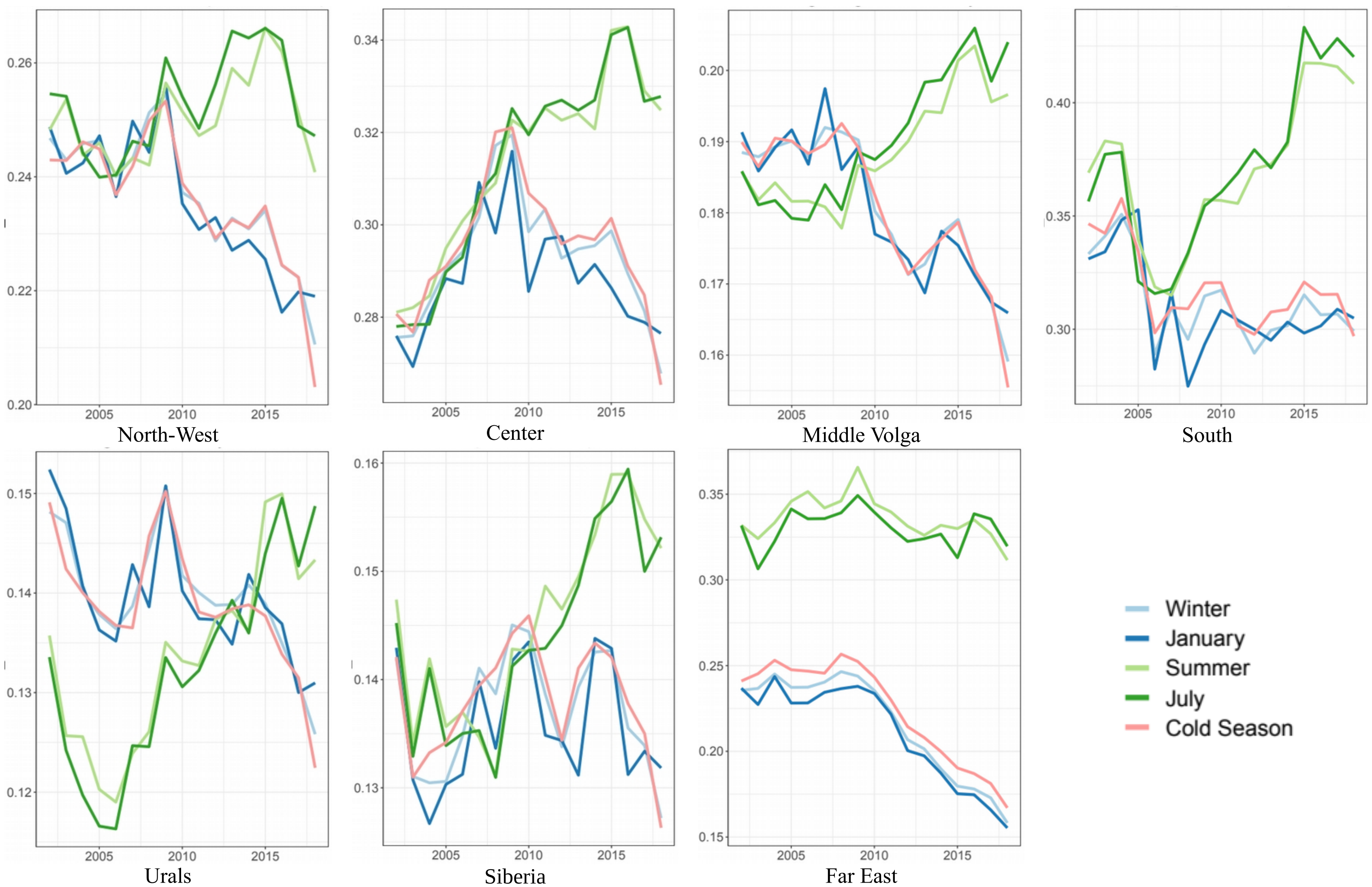


South

The annual profiles of the dimensionless diurnal electricity demand amplitude

"TYPICAL-DAY" EFFECTS-2

Electricity load



The dimensionless diurnal electricity demand amplitude across the national power systems in 2002-2018

"TYPICAL-DAY" EFFECTS-2

Electricity load

- Electricity load patterns are changing both on the large (annual) and short (daily) time scales
- A part of these changes is very likely associated with the climate change

"TYPICAL-DAY" EFFECTS: SUMMARY

- Winter climate change is still resulting in an efficiency decrease of the cogeneration use
- Summer changes might result in reliability problems

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Energy systems modelling is needed urgently

OPERATING MODE EFFECTS

1. Electricity load
2. Reliability assessment
3. Renewables integration

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Climate modelling

Gridded datasets of good quality are essential

Energy modelling

Energy system models

THANK YOU FOR YOUR ATTENTION!

Any questions?

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