Impact of climate change on shallow groundwater table fluctuations

(Klimata mainības ietekme uz gruntsūdeņu režīmu Latvijā)

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The Aim Of The Study

The objective of this study is to analyze the spatiotemporal patterns of the long-term mean monthly groundwater levels in Latvia in two different time periods according to the spatially changing degree of the climatic continentality and to highlight the significance of climate change impact on groundwater level regime.

In this study the groundwater level fluctuation regime is compared between two different time periods thus allowing analysis of the impact of climate change. The periods are identified as reference period (1961-1990) and future period (2070-2100). In the reference period actual observations were summarized, but for the future period the groundwater model METUL was used.

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The structure

- **Materials and methods**
- Observations and modelled data
- Continentality as important element

Materials I

- Observations from ~200 wells (direct data)
- Climatic data for modelling (with groundwater modelling software METUL) (indirect data)
  - Observed
  - From freely chosen ENSEMBLE climate model projection HIRHAM-ARPEGE (Sennikovs & Bethers, 2009)
    - Reference period (1961-1990)
    - Future period (2070-2100)

Materials II

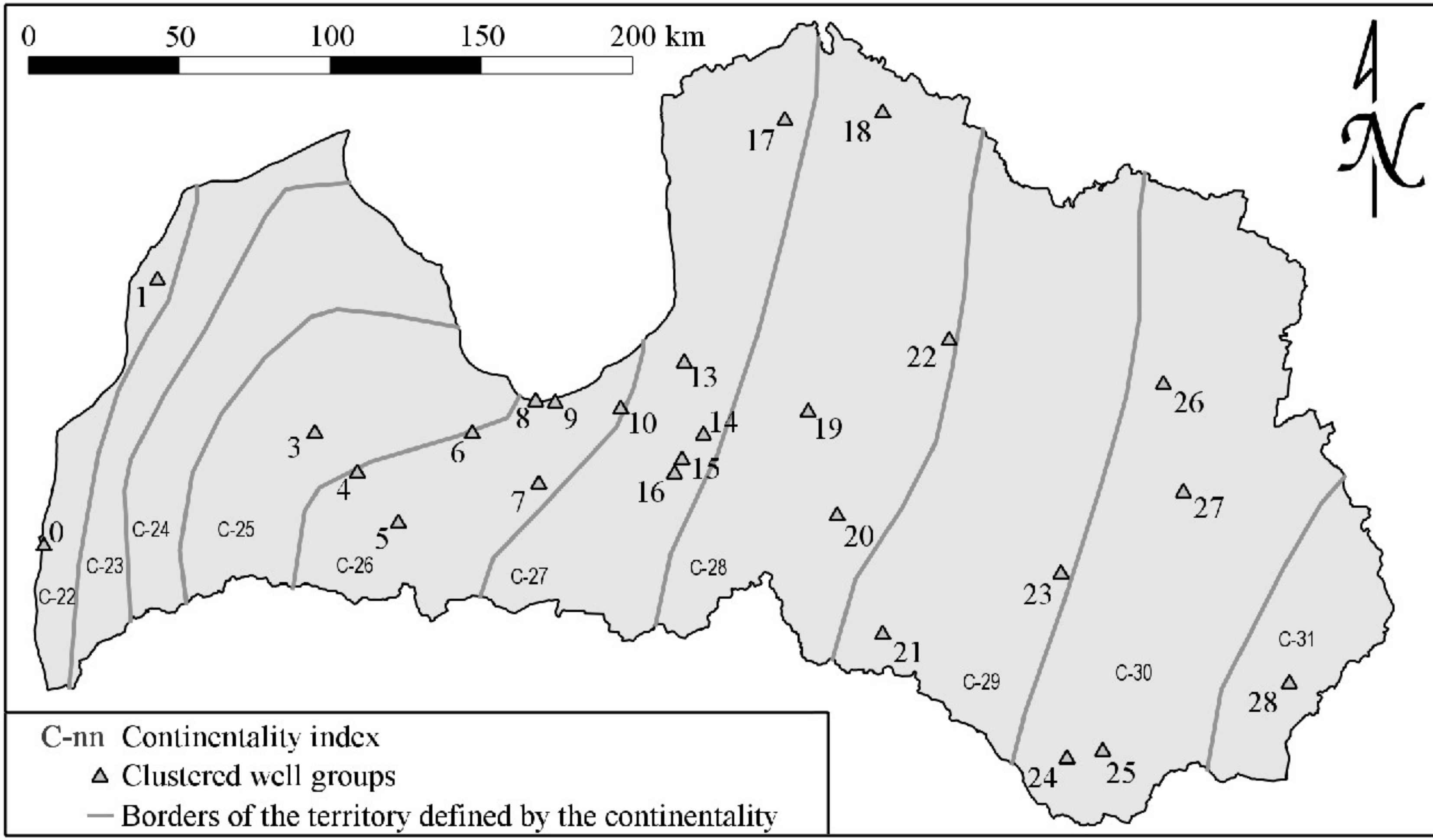
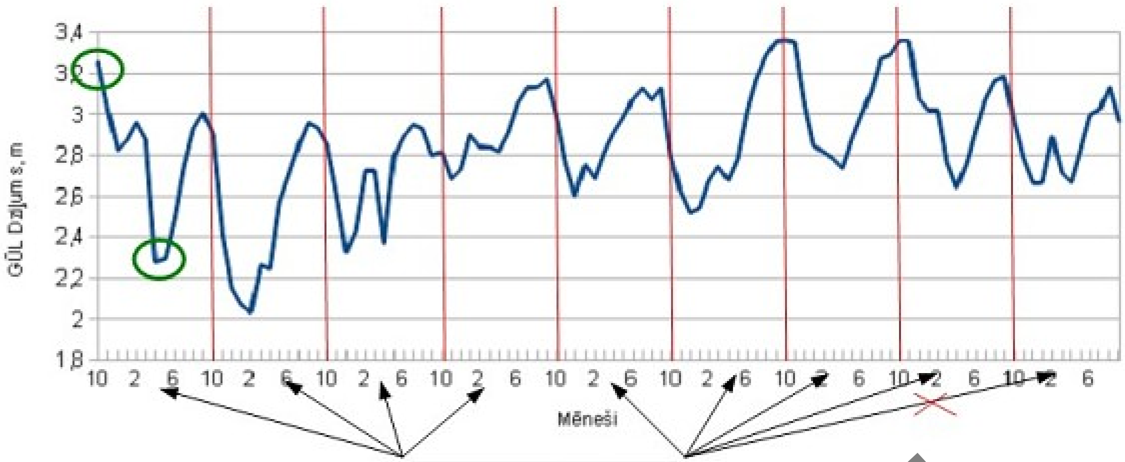


Fig. 1. Map of the clustered well group geographically weighted centres and continentality index. Wells and groundwater level data were obtained from Latvian Environment, Geology and Meteorology Centre. The information about continentality was provided from A. Draveniece dissertation

Methods I



$$l_{rel} = 1 - \frac{l_i - l_{min}}{l_{max} - l_{min}}$$

There are multiple criteries which defines validity of the time serie

Interpolating daily values

Normalizing inversely

First time

Comparing of all valid data series within the group

(<u>Finding the “best” for groundwater level modelling</u>)

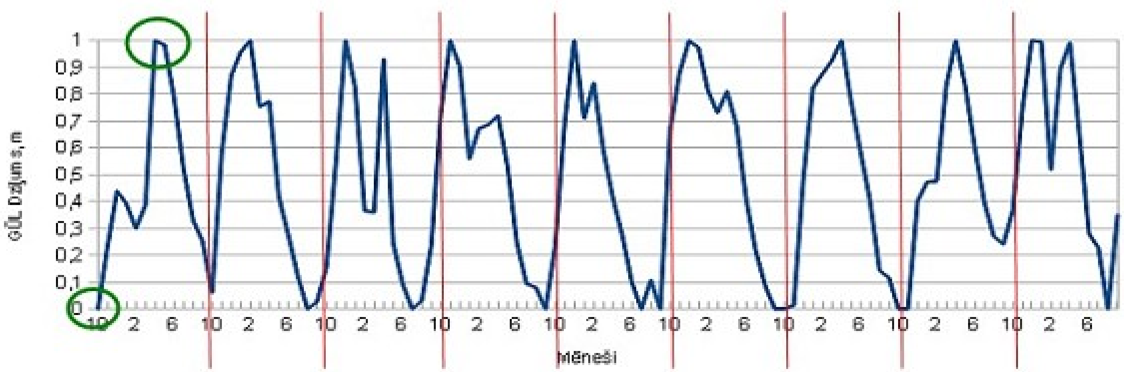


Fig. 2. Mathematical transformations of the groundwater data series

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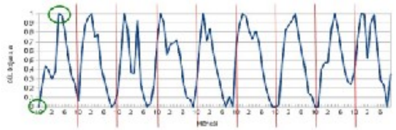
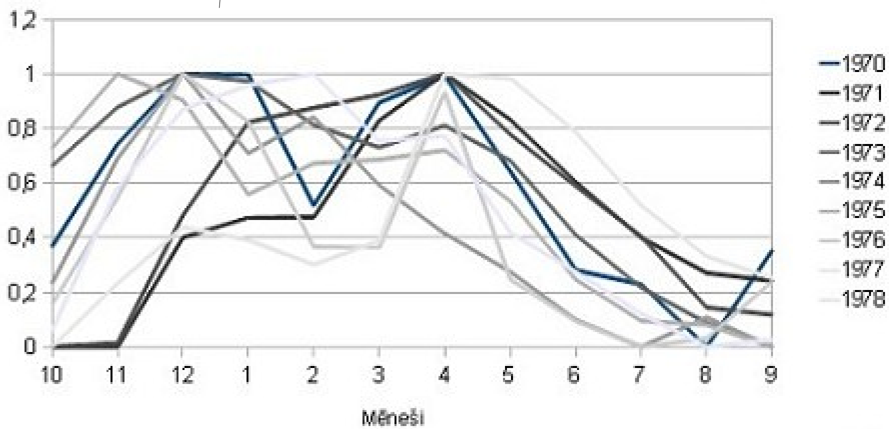
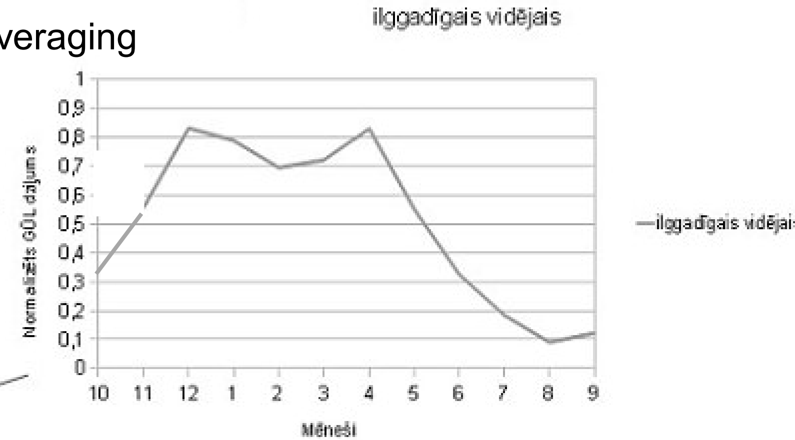
Methods II





Yearly averaging



Normalisation (not inverse)

Second time

$$l_{rel} = \frac{l_i - l_{min}}{l_{max} - l_{min}}$$

Analysing within the group

Fig. 3. Mathematical transformations of the groundwater data series (Chelmicki, 1993)

Methods III

- METUL as groundwater modelling software (Krams & Ziverts, 1993)
  - Input data – temperature, precipitation, humidity
  - Daily groundwater values

- GRASS GIS as map generator software
  - Interpolation
  - Map statistics

The structure

- Materials and methods
- **Observations and modelled data**
- Continentality as important element

Observations versus modelling

Reference period

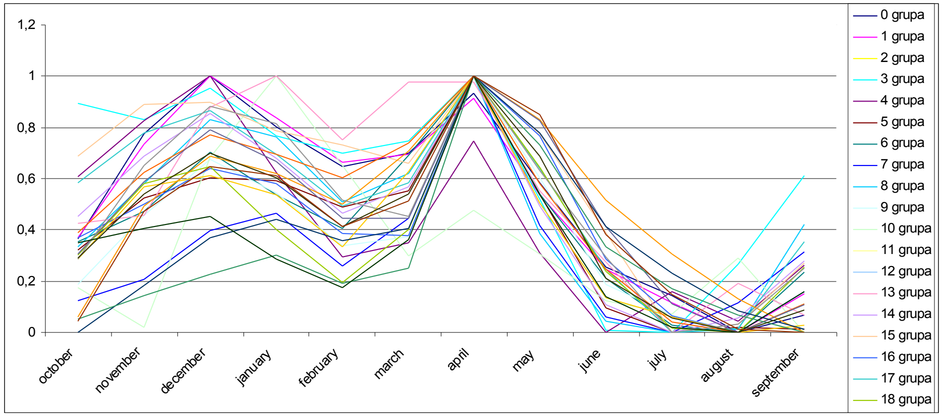


Fig. 4. Observed long term monthly mean groundwater in relative values in all groups

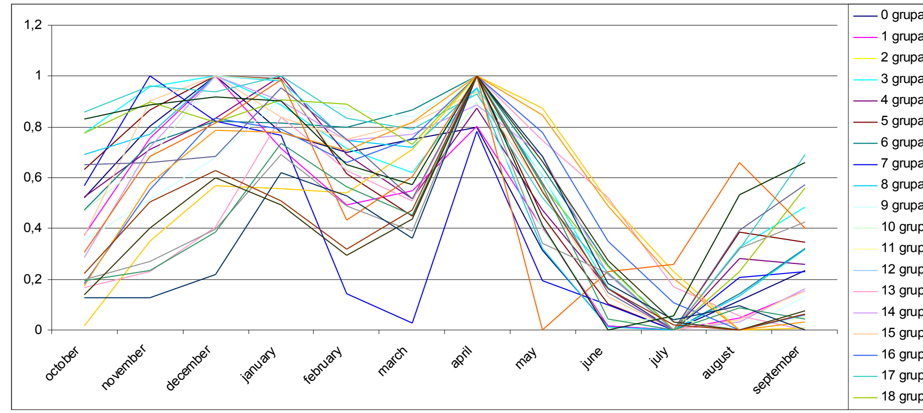


Fig. 5. Modelled on observations long term monthly mean groundwater levels in relative values in all groups

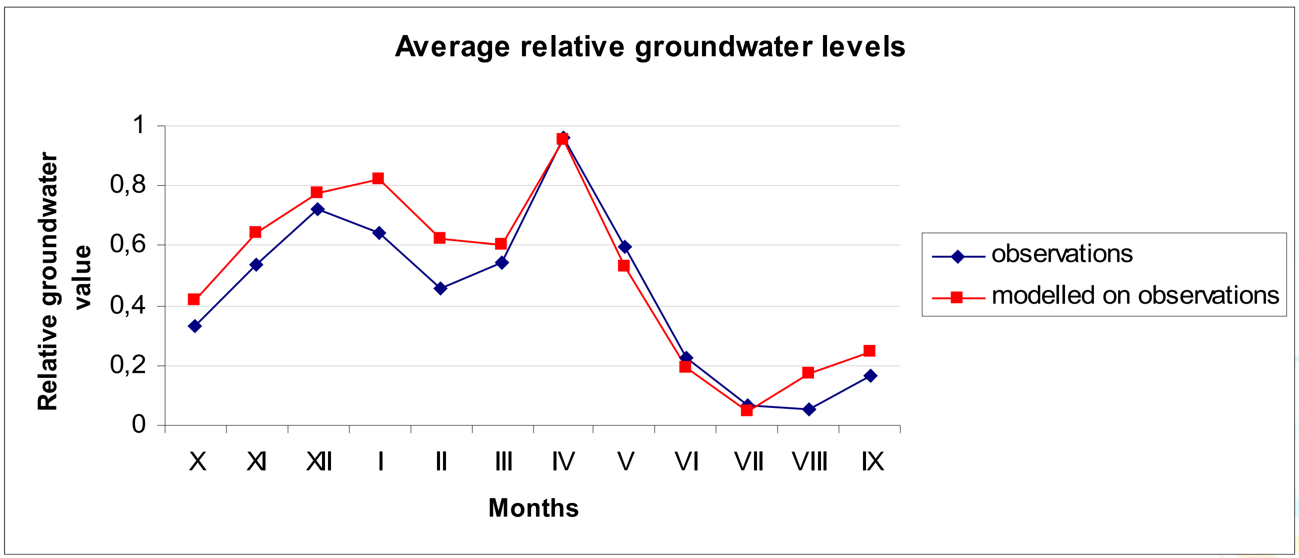


Fig. 6. Observed and modelled on observations long term monthly mean groundwater levels in relative values averaging over groups

Observations versus climate model

Reference period

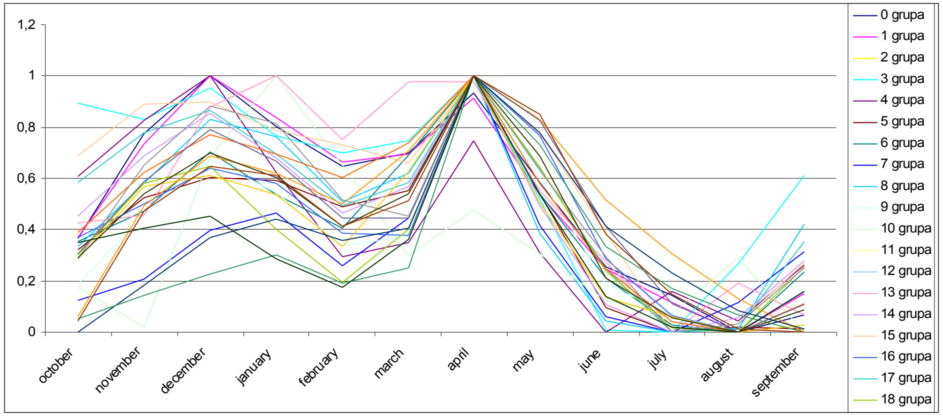


Fig. 7. Observed long term monthly mean groundwater in relative values in all groups

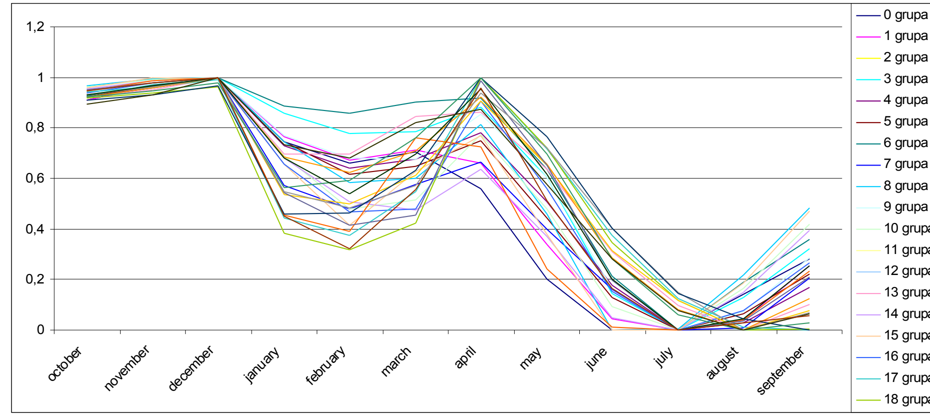


Fig. 8. Modelled on climate model long term monthly mean groundwater in relative values in all groups

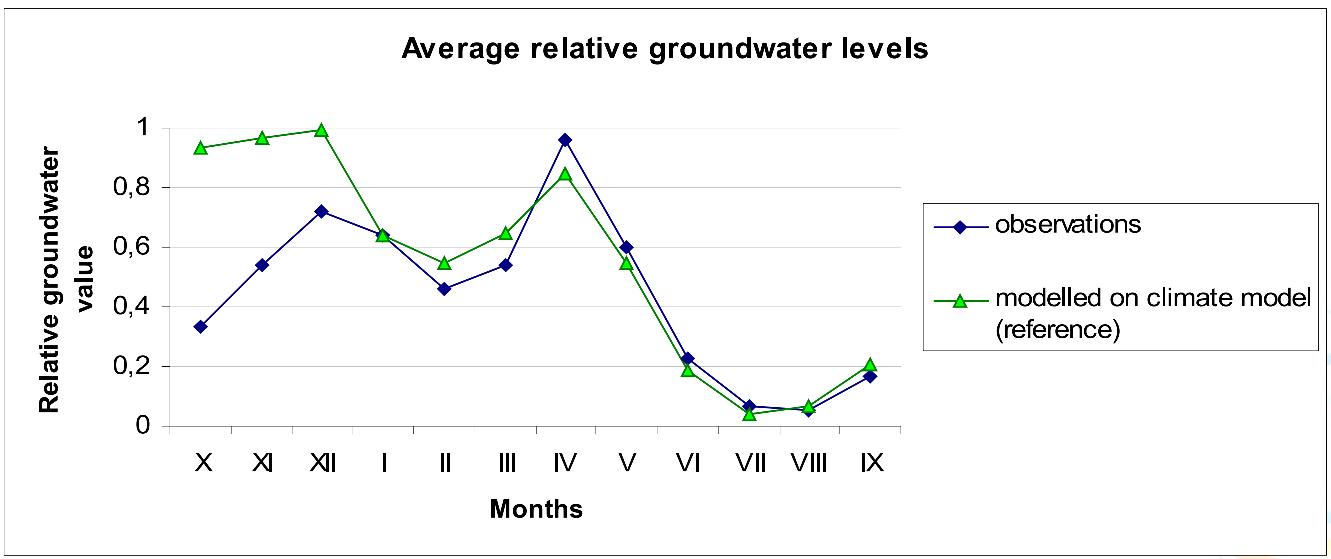


Fig. 9. Observed and modelled on climate model long term monthly mean groundwater levels in relative values averaging over groups

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Modelling versus climate model

Reference period

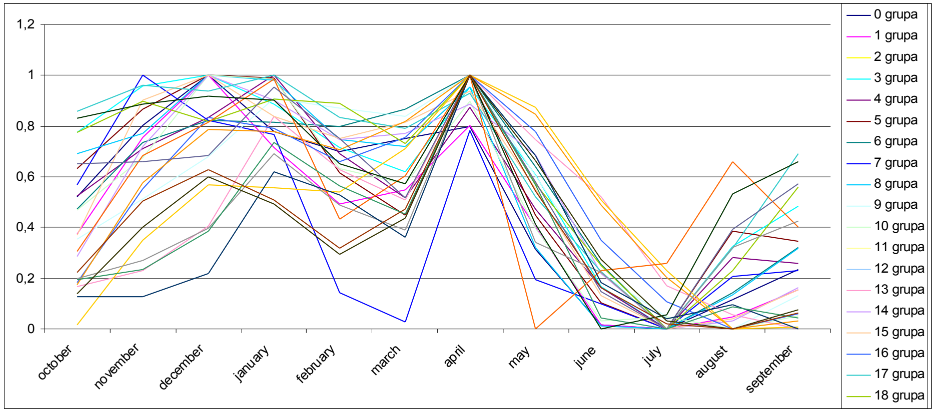


Fig. 10. Modelled on observations long term monthly mean groundwater in relative values in all groups

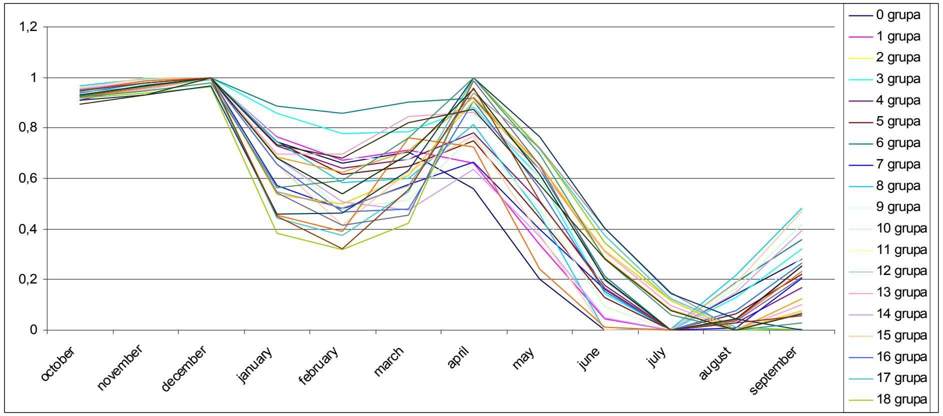


Fig. 11. Modelled on climate model long term monthly mean groundwater in relative values in all groups

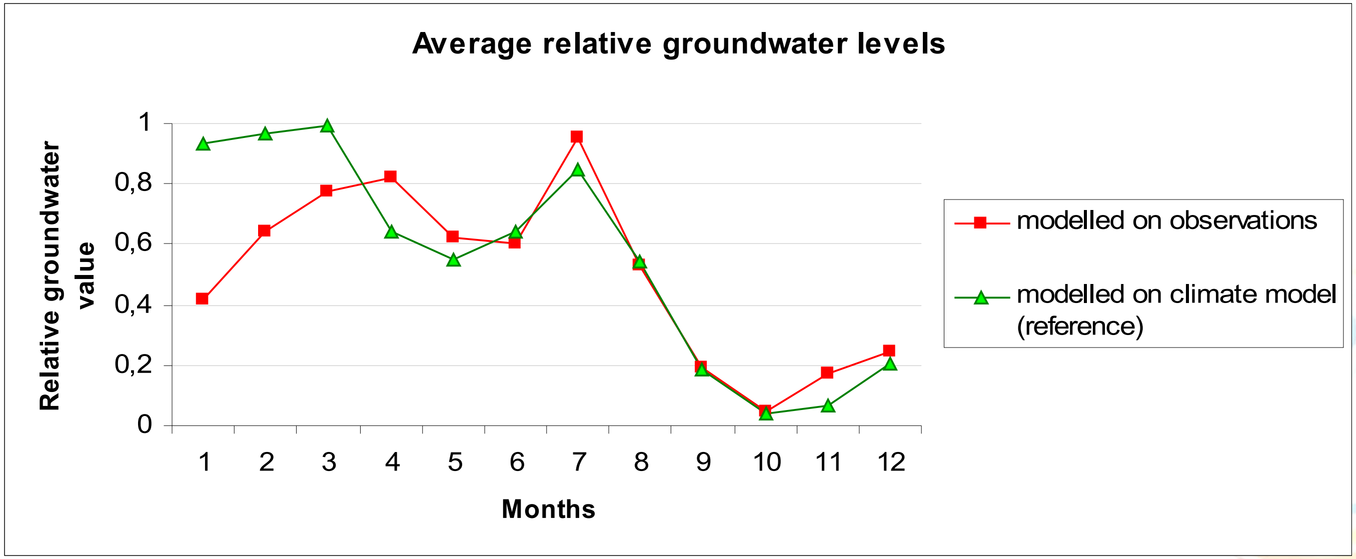


Fig. 12. Modelled on observations and modelled on climate model long term monthly mean groundwater levels in relative values averaging over groups

Future versus reference

Modelled values

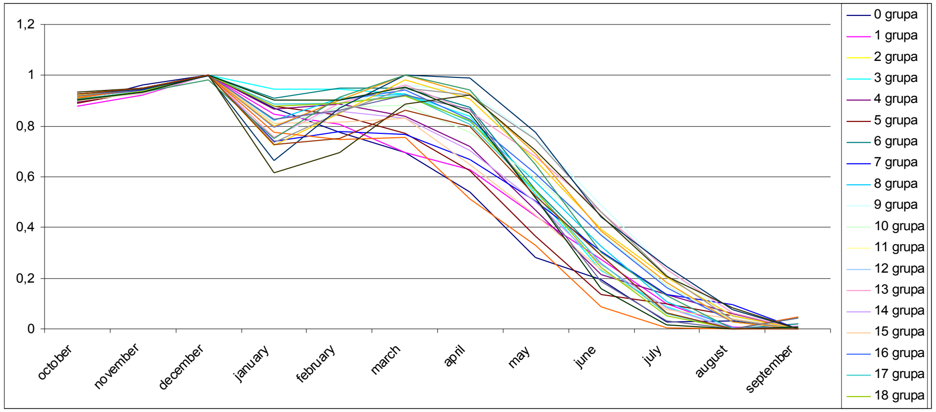


Fig. 13. Modelled on climate model long term monthly mean groundwater as relative values in all groups in future period (2070-2100)

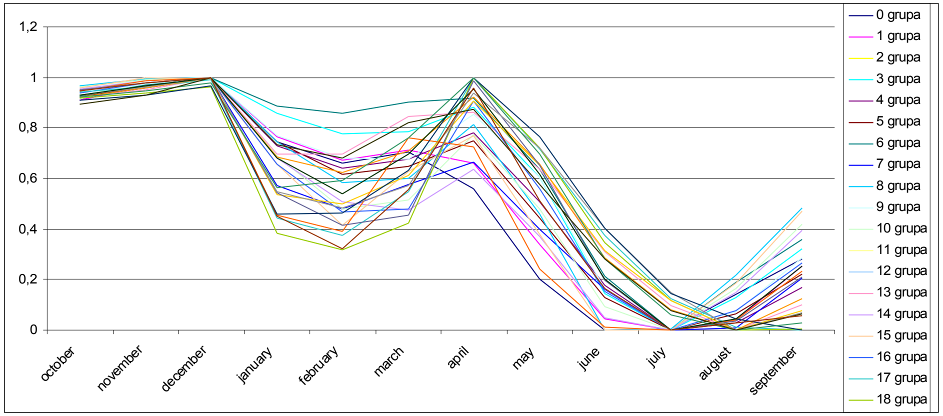


Fig. 14. Modelled on climate model long term monthly mean groundwater as relative values in all groups in reference period (1961-1990)

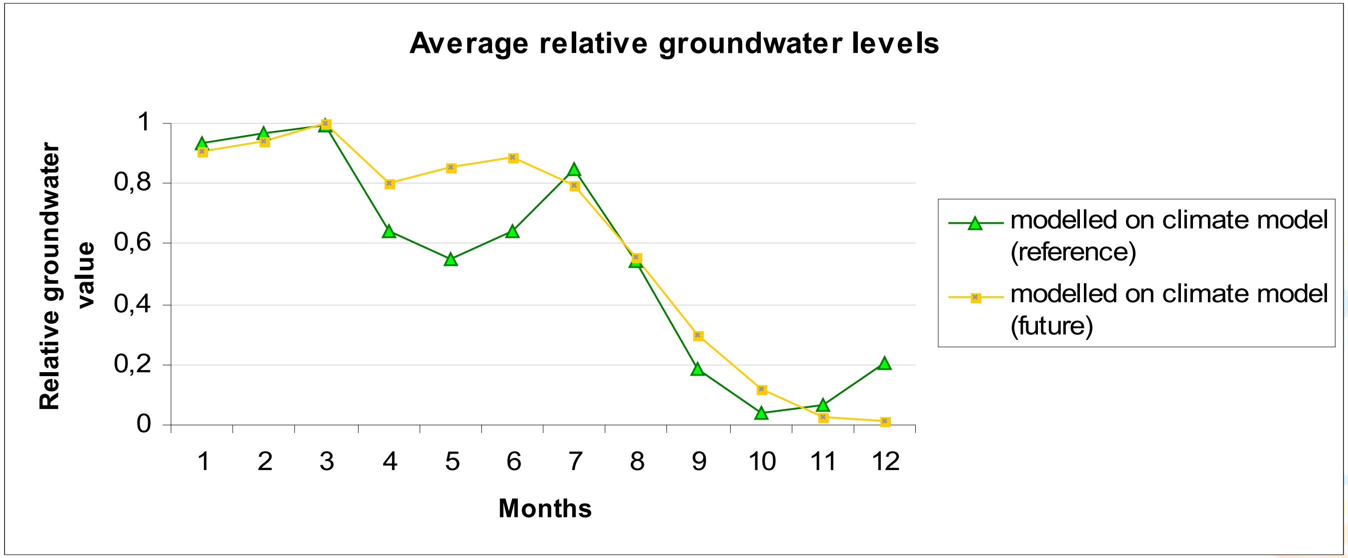


Fig. 15. Modelled on climate model long term monthly mean groundwater levels in relative values averaging over groups in two different time periods.

Summary

Fig. 16. Observed, modelled on observations and on climate model in two different time periods long term monthly mean groundwater as relative values averaging over the groups.

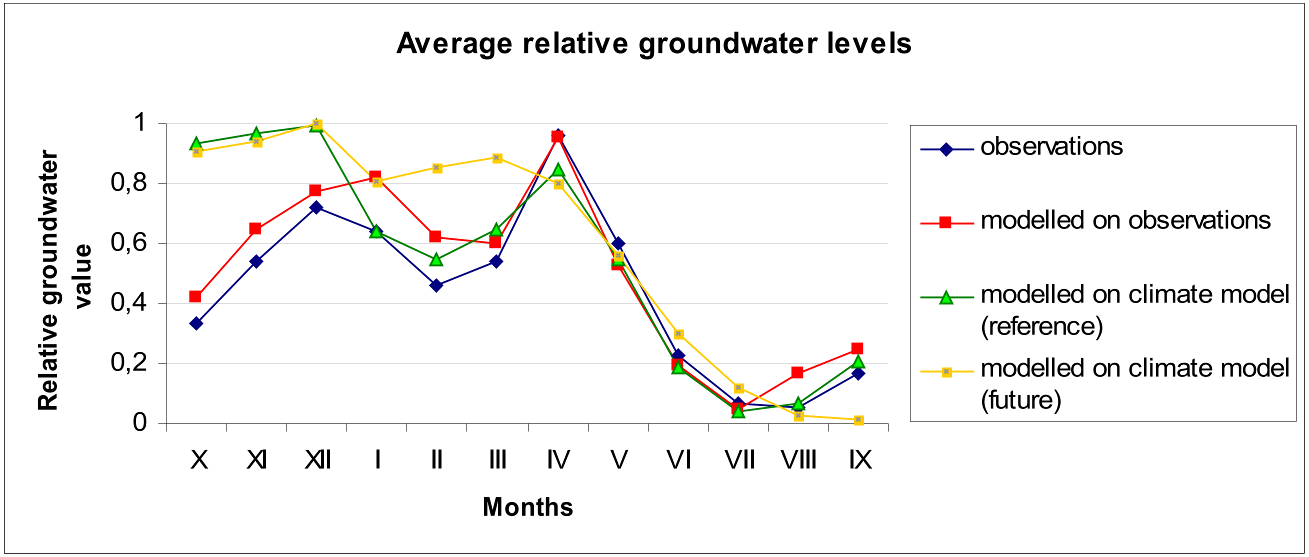
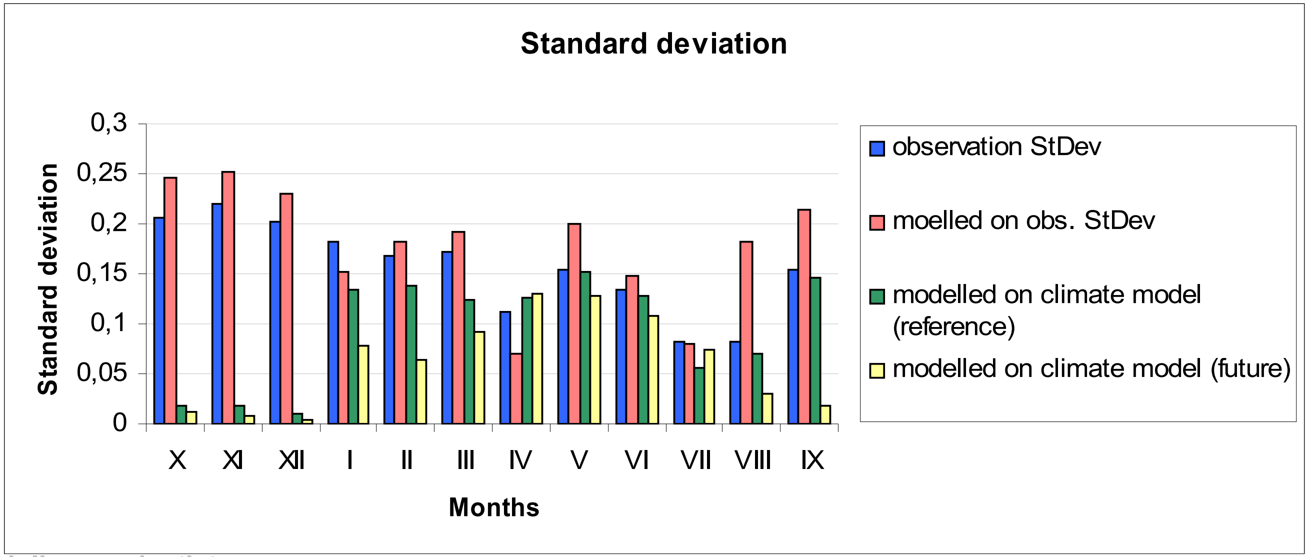


Fig. 17. Standard deviation over all groups in all four datasets. Larger standard deviation shows greater spatial variability.



The structure

- Materials and methods
- Observations and modelled data
- **Continentality as important element**

Groundwater levels in reference period. Observations and modelled ground water levels

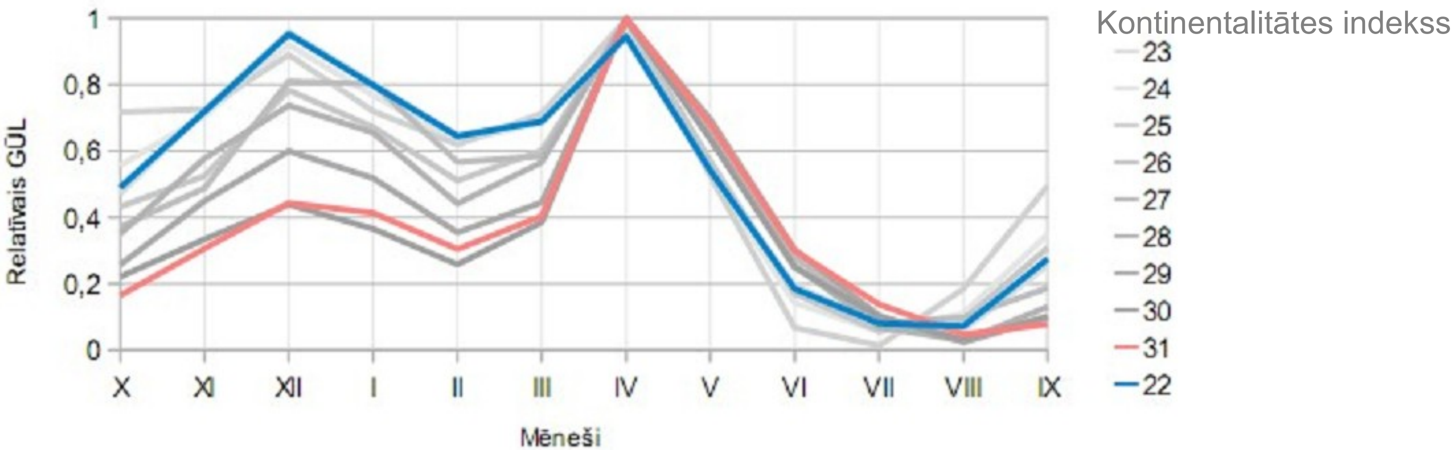


Fig. 18. Long term monthly mean relative groundwater level observations in reference period (1961-1990).

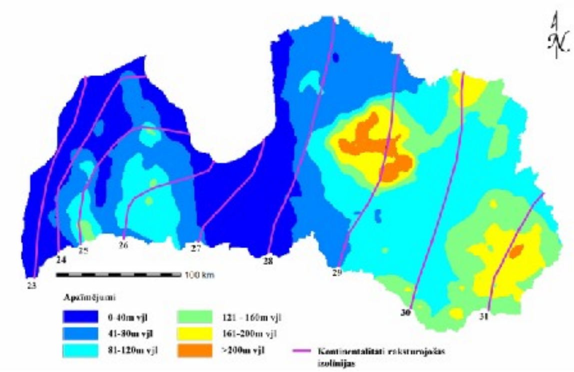


Fig. 19. Matehematically modified (with low frequency filtering) CGIAR SRTM digital elevation model and Conrad continentality index isolines by A.Draveniece.

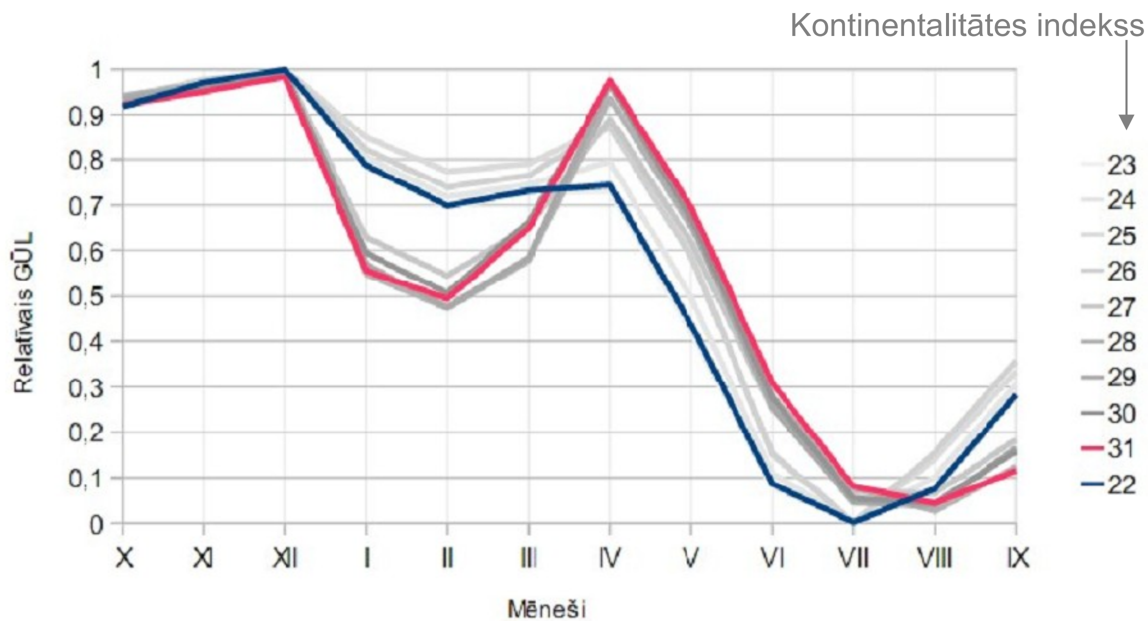


Fig. 20. Modelled long term monthly mean relative groundwater level values in reference period (1961-1990). Climate model – HIRHAM-ARPEGE

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1961-1990

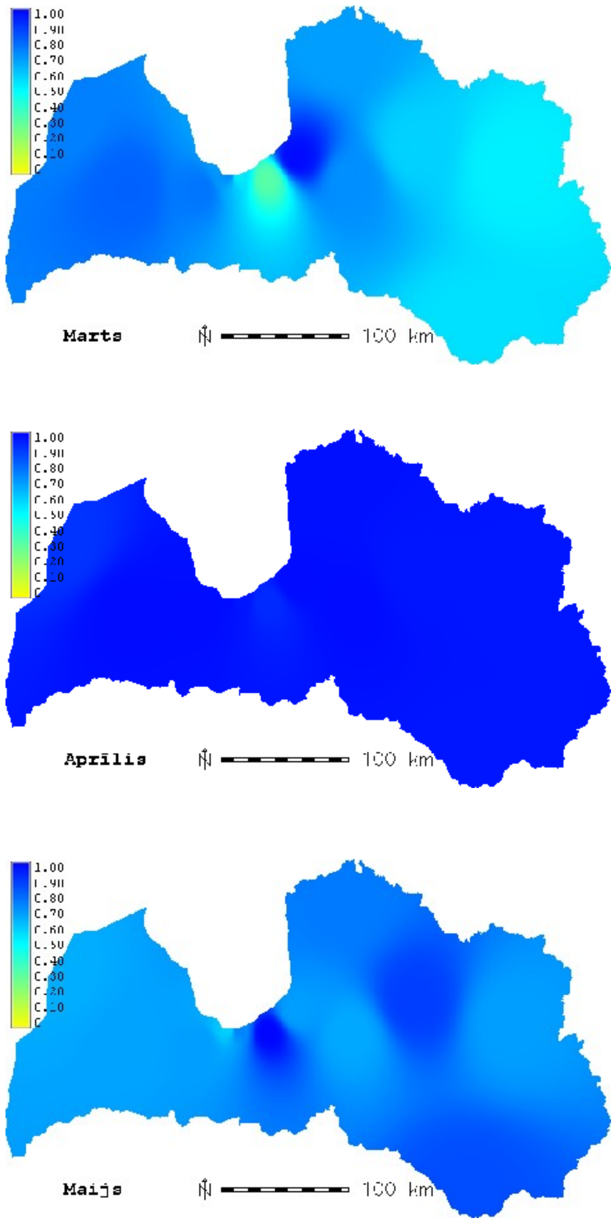

Fig. 21. Observed long term monthly mean relative groundwater levels in reference period

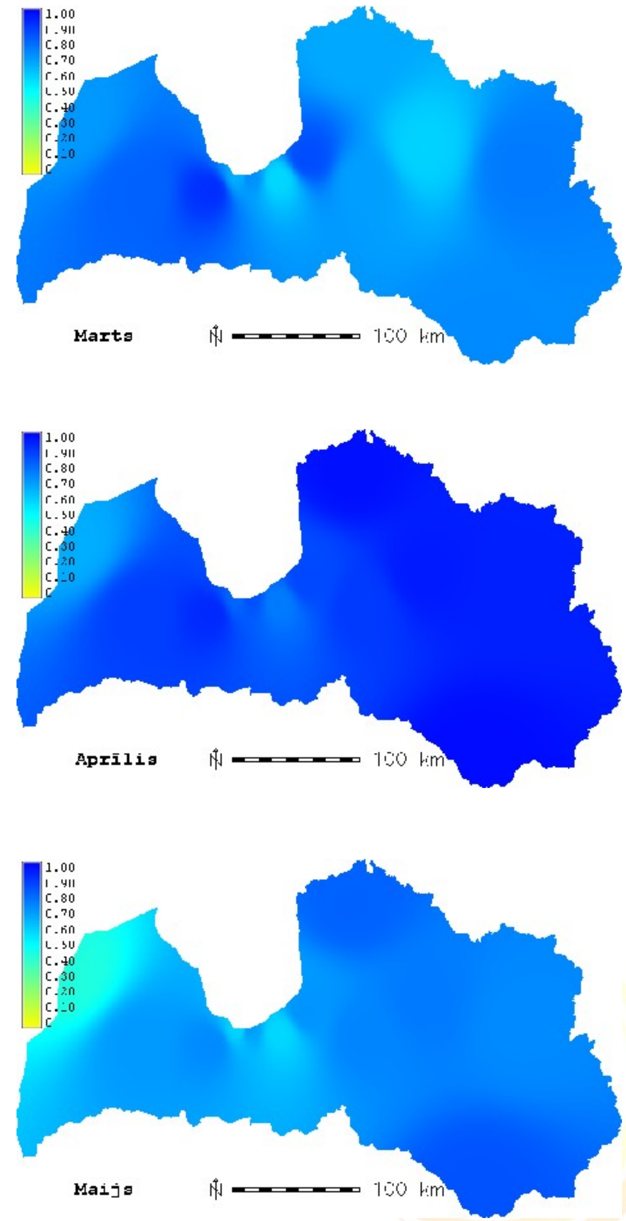

Fig. 22. Modelled long term monthly mean relative groundwater levels in reference period

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Groundwater levels in reference period. Observations and modelled ground water levels

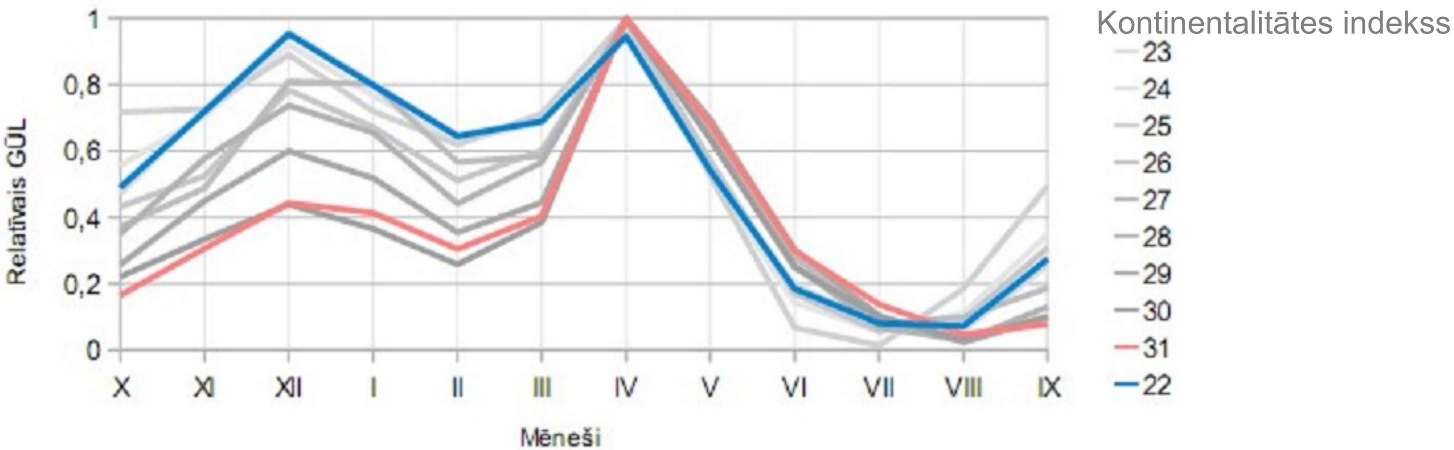

Fig. 23. Long term monthly mean relative groundwater level observations in reference period (1961-1990).

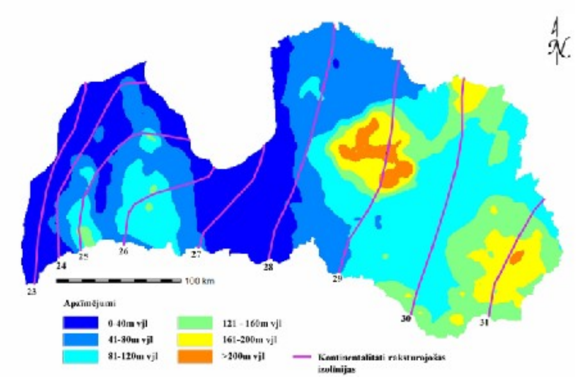

Fig. 24. Matehematically modified (with low frequency filtering) CGIAR SRTM digital elevation model and Conrad continentality index isolines by A.Draveniece.

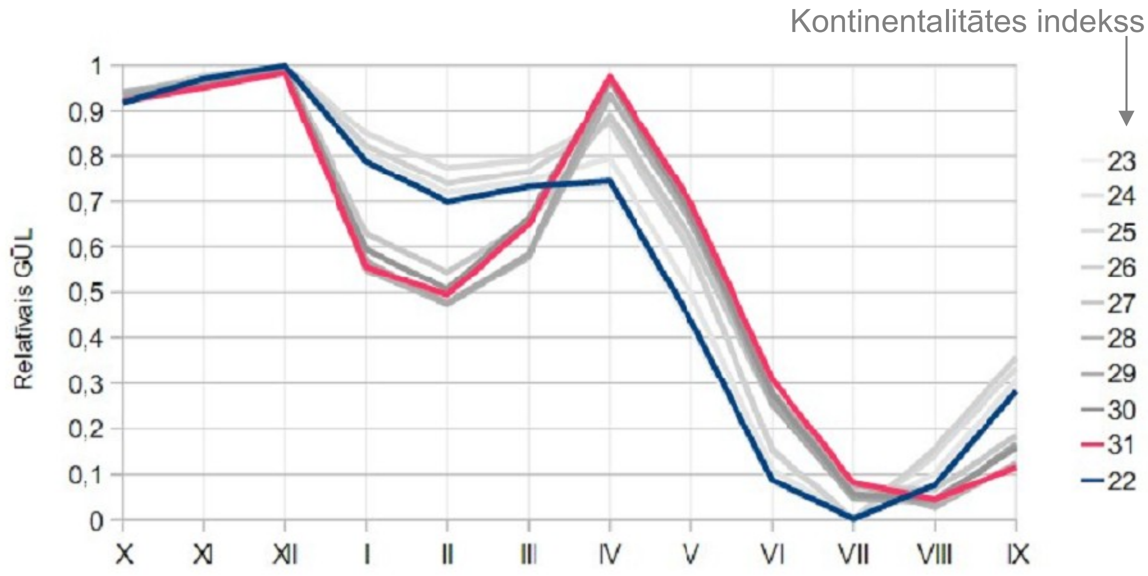

Fig. 25. Modelled long term monthly mean relative groundwater level values in reference period (1961-1990). Climate model – HIRHAM-ARPEGE

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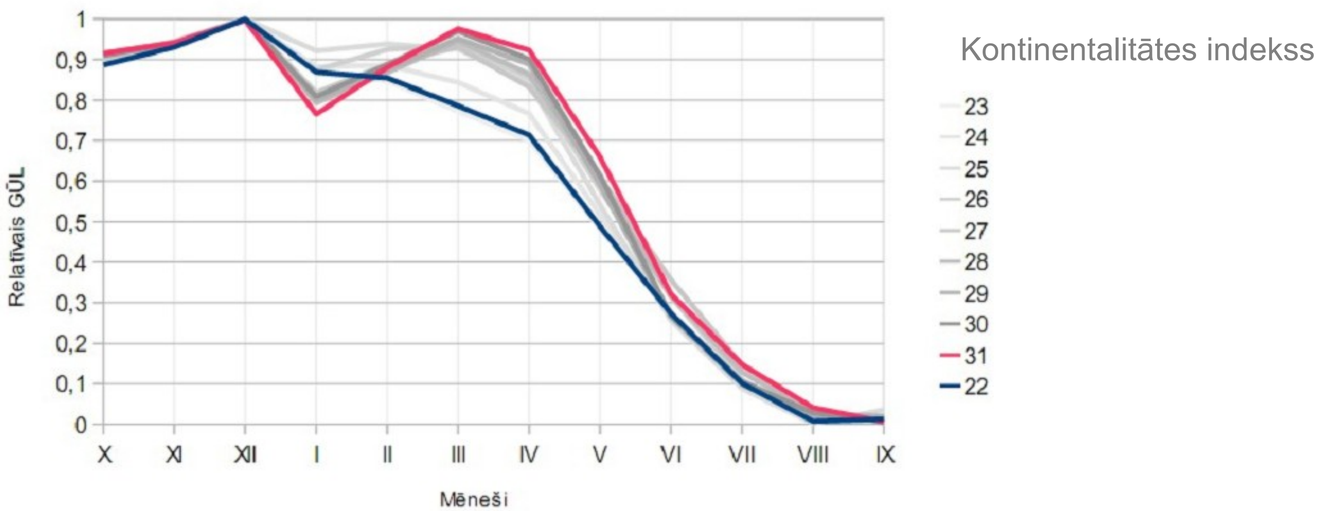

Fig. 26. Modelled long term monthly mean relative groundwater level values in <u>future</u> period (1961-1990). Climate model – HIRHAM-ARPEGE

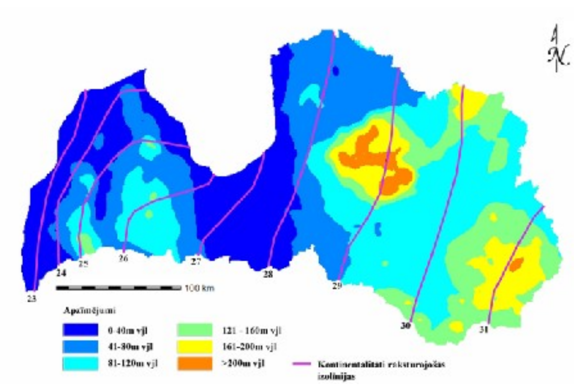

Fig. 27. Matehematically modified (with low frequency filtering) CGIAR SRTM digital elevation model and Conrad continentality index isolines by A.Draveniece.

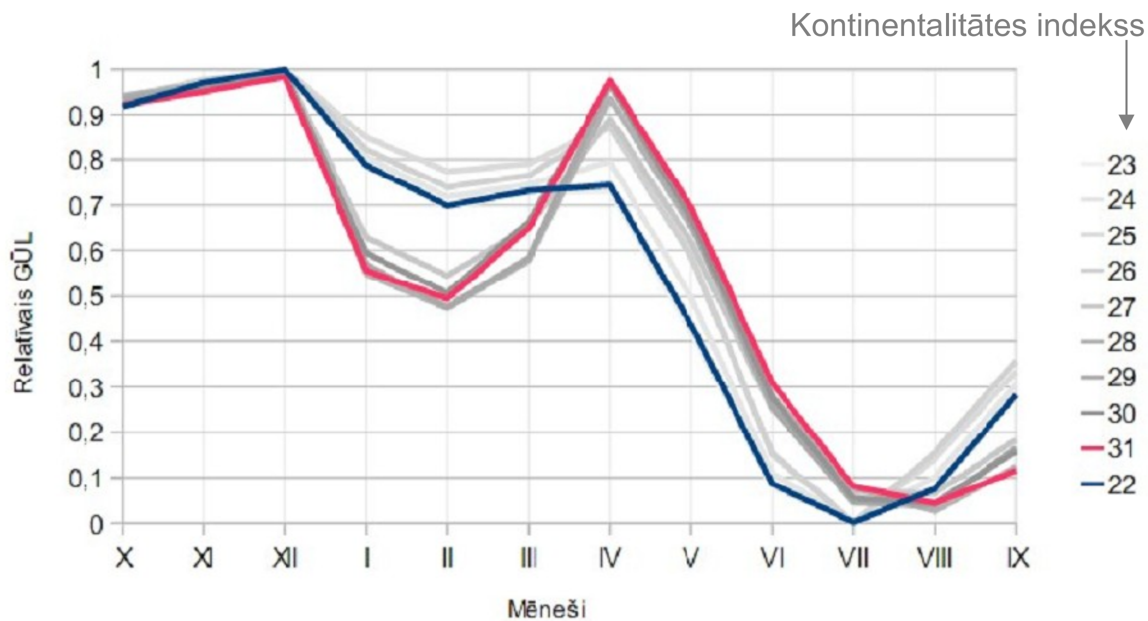

Fig. 28. Modelled long term monthly mean relative groundwater level values in <u>reference</u> period (1961-1990).

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Fig. 29. Modelled on climate model groundwater levels in reference period

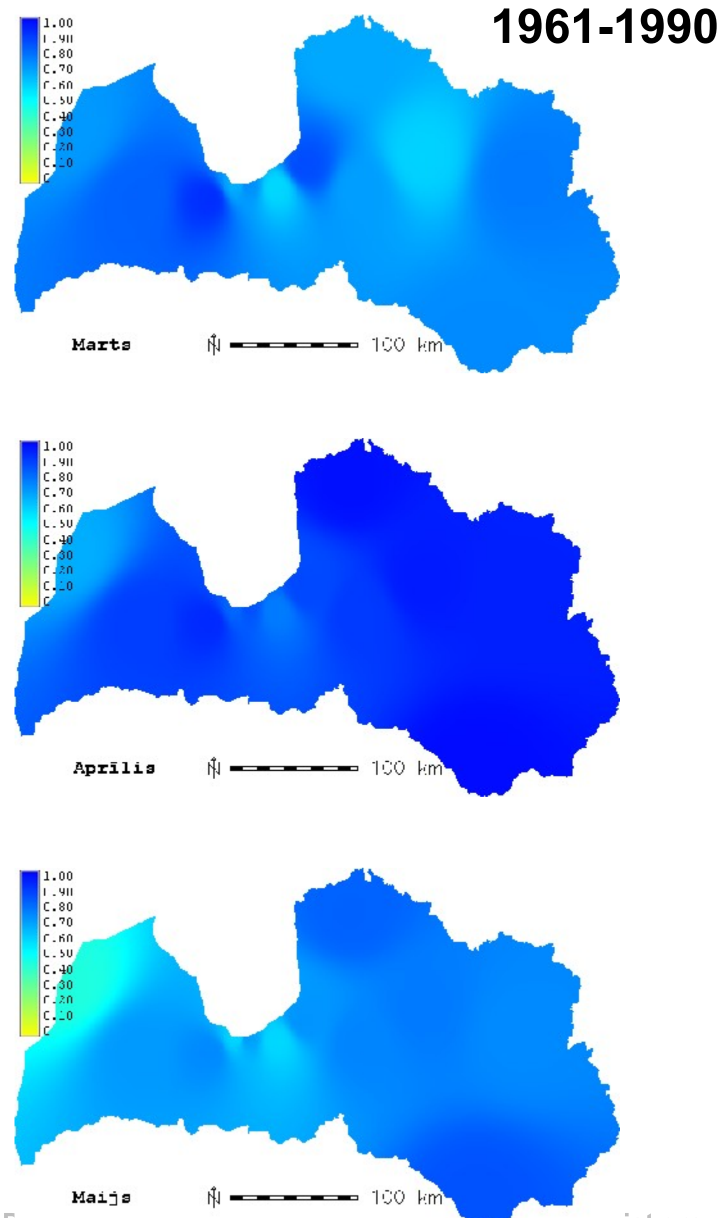
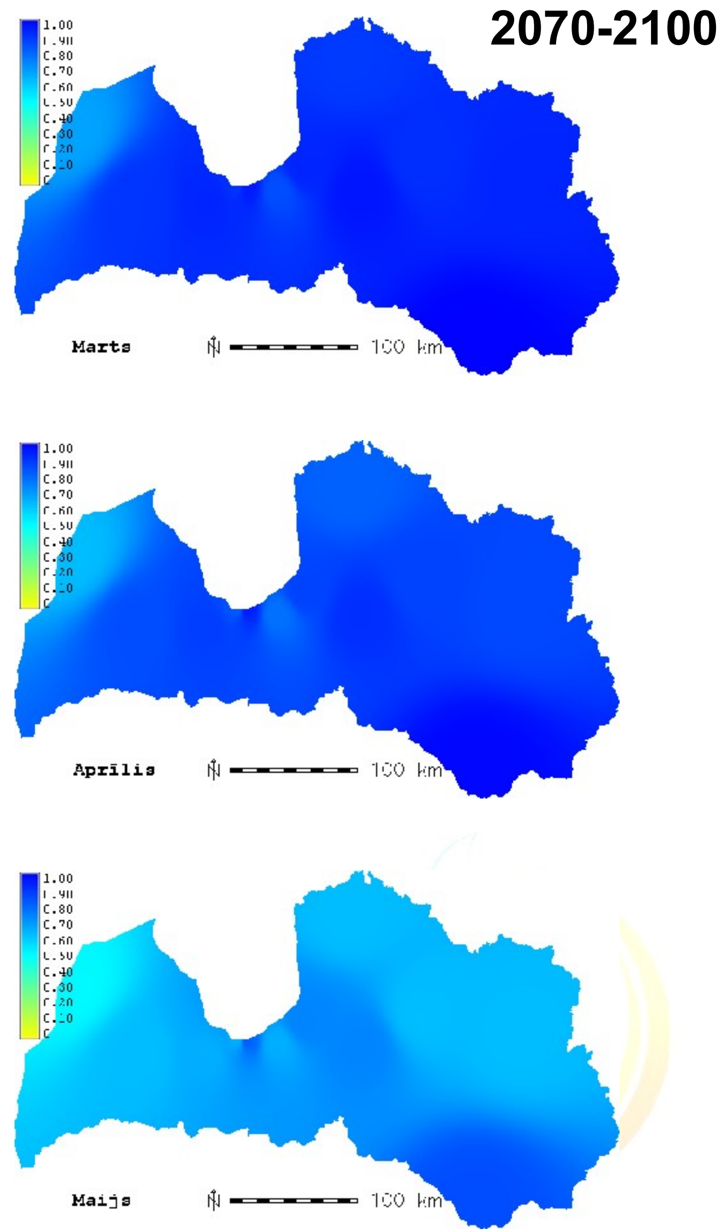


Fig. 30. Modelled on climate model groundwater levels in future period



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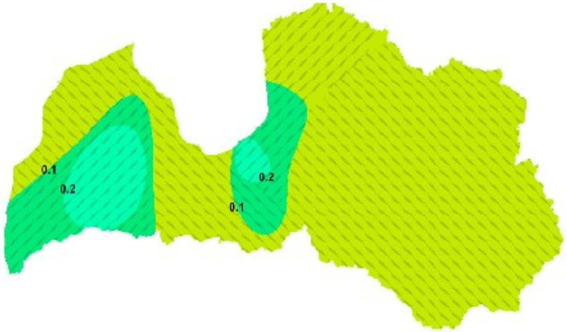
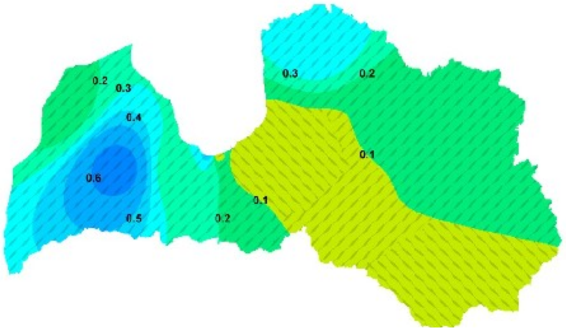
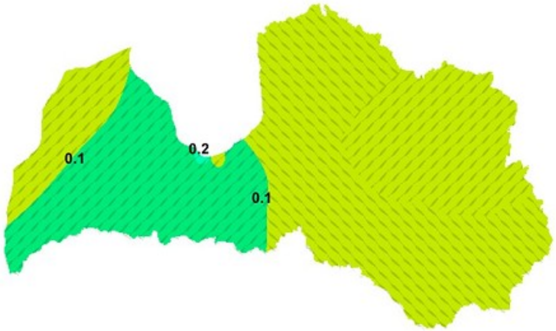
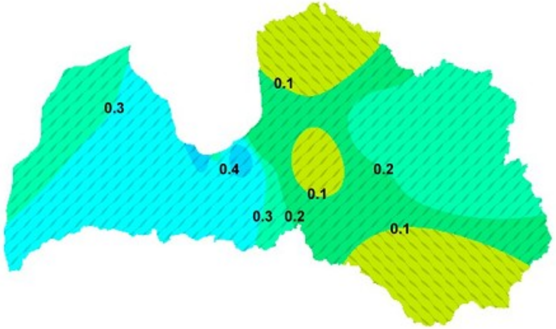
<table>
<tr><th></th><th>August</th><th>September</th></tr>
<tr><td>Observations</td><td>
</td><td>
</td></tr>
<tr><td><u>Modeled</u> groundwater levels in the <u>reference</u> period</td><td>
</td><td>
</td></tr>
<tr><td><u>Modeled</u> groundwater levels in the <u>future</u> period</td><td>
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Fig. 31. **Observed and modelled on climate model long term monthly mean relative groundwater levels in both (reference and future) periods.**

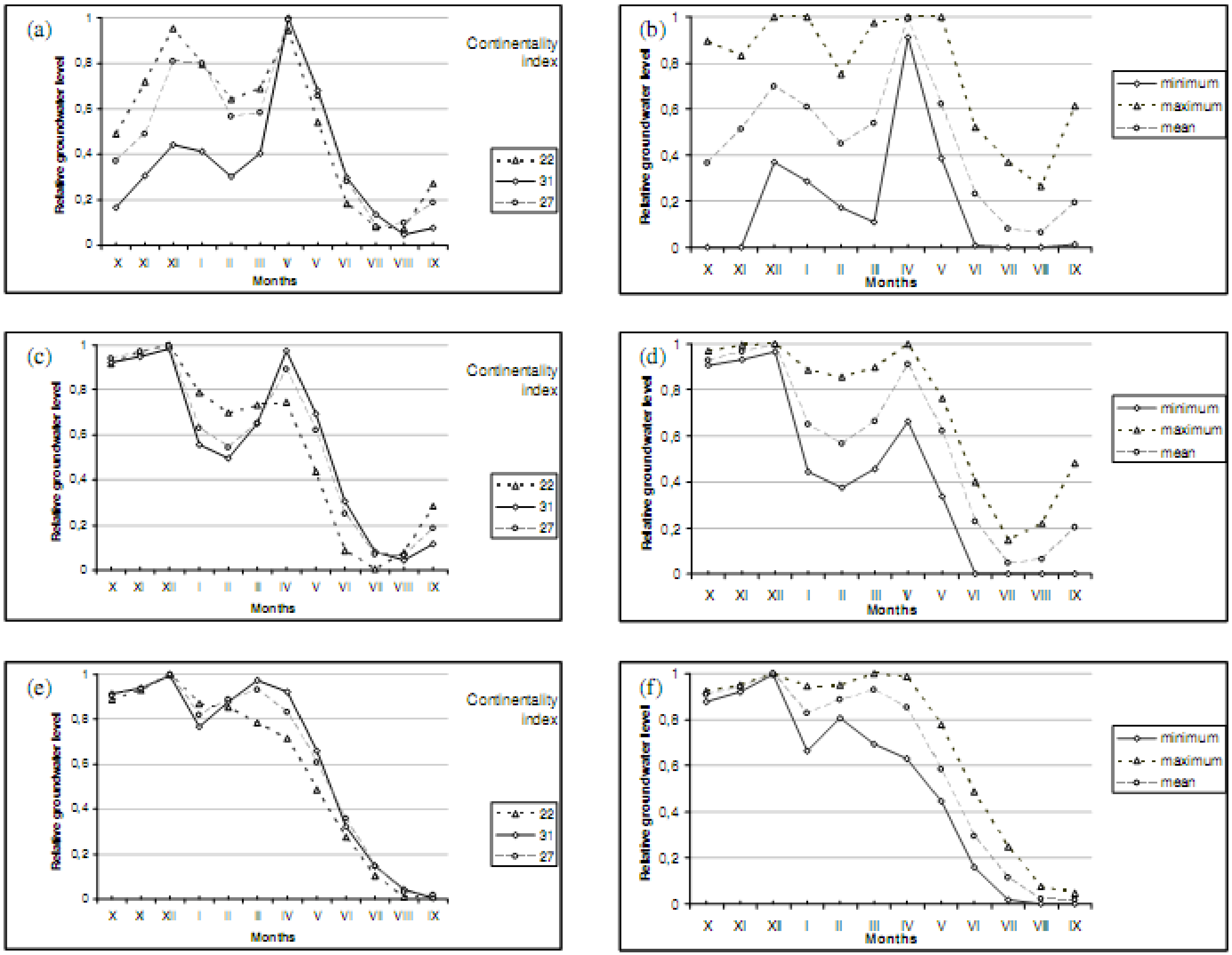

Fig. 32. (a) Observed groundwater levels by continentality index; (b) Observed groundwater levels by maximum and minimum in Latvia; (c) modelled groundwater levels in reference period by continentality index, (d) modelled groundwater levels in reference period by maximum and minimum in Latvia; (e) modelled groundwater levels in future period by continentality index, (f) modelled groundwater levels in future period by maximum and minimum in Latvia

Conclusion I

- In the reference period observed monthly mean, minimal and maximal and both in the same and future period modelled relative groundwater observations over the entire Latvia correspond to the defined M-shaped classical groundwater regime in Latvia (Толстов, 1986) representing all four crucial relative long-term mean monthly groundwater regime extremes.
- Dividing the territory of Latvia by continentality index, it was found that in the future period in the territories with continentality index lower than 24, the regime differs from classical groundwater regime creating □-shaped regime with very steep increase from September to December, and gradual decrease from December to September.
- In both periods, observed and modelled data shows that there is a temporal offset between territories with different continentality from the spring to the end of the summer. In the territories with classical groundwater level fluctuation regime the winter minimums tend to be higher and spring maximums are reached earlier in the western part of Latvia where continentality index is lower. In the future period the spring maximum occurs in March unlike the reference period, when it occurs in April. The summer minimum will be prolonged, but increase in September and October will be extremely steep.

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Conclusion II

- The spatiotemporal analysis shows an artefact around the capital city, Riga. Such artefacts should be eliminated in future research.
- The study proves the groundwater model METUL applicability to the groundwater level fluctuation studies and the model results are comparable with observations made during reference period. Future research work on ground level variability has to be focused on uncertainty assessment in METUL model using Monte-Carlo or other methods.
- It is possible to continue the research in a number of directions – separately studying other climate models, combining all modelled groundwater level time series into one using uncertainty strategies and subsequently predict possible impact of climate change describing it quantitatively with percentiles, and to obtain the absolute groundwater levels spatiotemporally.

References

- **Chelmicki, W.** 1993. The annual regime of shallow groundwater levels in Poland. Ground Water. 31(3), 383-388.
- **Draveniece, A.** 2007. Okeāniskās un kontinentālās gaisa masas Latvijā. Latvijas Veģetācija, 14, 135.
- **Krams, M. Ziverts, A.,** 1993. Experiments of conceptual mathematical groundwater dynamics and runoff modelling in Latvia. Nordic Hydrology. 24, 243-262.
- **Sennikovs, J., Bethers, U.** 2009. Statistical downscaling method of regional climate model results for hydrological modelling. In:Proceedings of 18th World IMACS / MODSIM Congress.
- **Толстов Я. Б., Левина Н. Н., Прилукова Т. М.,** и др. 1986. Изучение режима, баланса подземных вод, экзогенных геологических процессов и ведение государственного водного кадастра (подземные воды) в Латвийской ССР на 1984-1986 г. Г.(Сводный отчет за период 1976-1986 г.г.). Рига, Фонды, #10402.

The research study has been submitted in journal “RTU Zinātniskie raksti: Vides un klimata tehnoloģijas”

Thank You.

...a little demonstration...

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