Climate dynamics investigations for the Carpathian Basin with the REMO regional climate model

Theses of the PhD dissertation

Gabriella Szépszó

Eötvös Loránd University
Faculty of Science

Ph.D. School for Earth Sciences
School leader: Prof. Dr. József Nemes-Nagy

Geography–Meteorology Program
Program leader: Prof. Dr. Mária Szabó

Supervisor:
András Horányi, PhD

Hungarian Meteorological Service
Climatology Division, Regional Climate Modelling Group

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1. Introduction

Climate change and adaptation to its impacts are essential socio–environmental problems recently; at the same time, steps have been based either on the principle for preparing for any possibility or on the scenario kept intuitively the most likely for years. However, neither of these strategies is sustainable for long term, instead a focussed adaptation to the climate change impacts is indispensable, i.e., the quantitative information about the direction and degree of the future changes.

It is generally accepted that the only scientifically sound way to understand the behaviour of the climate system and furthermore estimate its future evolution is provided by its numerical modelling. Global climate models are providing solid basis and realistic projections for the large-scale climate characteristics, however, they are at the moment largely insufficient for detailed regional scale estimations. Recently, reliable simulation of important processes over a target region becomes possible by development of regional climate models which have already been widely and successfully used in the weather forecast since 70s.

Nevertheless, it is not sufficient to investigate the future meteorological changes using climate models, if future impacts on the areas vulnerable to climate change (e.g., human health, transportation) are estimated intuitively. For that purpose, quantitative impact assessments have to be carried out, and climate model results can provide proper input data to that. Further challenge is to “train” both the scientific community and the decision makers that the quantitative assessments necessarily possess uncertainties, which have to be taken into account as the model results, even though this requires new approaches. Last year some initiatives started in Hungary which aim to realize the adaptation to climate change impacts on objective basis. Their establishment could be important milestone in the history of the climate change researches in Hungary. Main goal of my PhD dissertation was to present how the REMO regional climate model, which was adapted at the Hungarian Meteorological Service (OMSZ) in 2004, could contribute to this objective.

2. Main objectives

Primary objective of my doctoral research was to adapt the REMO regional climate model (RCM) developed by the Max Planck Institute for Meteorology (in Hamburg) at the Hungarian Meteorological Service (OMSZ), then to validate its applicability over the Carpathian Basin and to estimate the main climate change features of Hungary.

Due to the unavoidable uncertainties of meteorological modelling, climate projections cannot be based on a single regional model simulation. As a consequence, additional goal of the dissertation, which has relevance pointing out from its scope, is to compare the REMO results with the outputs of further RCMs and to provide practical approaches for quantifying the simulation uncertainties and taking them into account in the impact studies.

3. Methodology

As first step, the REMO model was installed to the supercomputer of OMSZ. To check its adaptation, some short technical and scientific tests were performed over the Carpathian Basin on the computers of Max Planck Institute and OMSZ, afterwards their results were inter-compared. It was also investigated how the departures between the results of the two experiments evolved during the integration.

Since a climate model integration for several decades requires long time and the computing capacity of OMSZ is limited, it is important to apply such a grid distance, with which the multi-decadal climate simulations can be realized in time and it represent sufficiently the climate features of the target area. REMO applies the hydrostatic approximations, therefore, it is not recommended to use it beyond 10 km resolution. The model is investigated on 11-18 km resolution range in detail, further simulation was achieved on 25 km resolution. The results are compared to observation data of some stations in Hungary.

At the beginning of the integration, the model variables related to the hydrological cycles are not in the proper physical balance and certain time is needed to reach this state. The length of the so-called spin up period is affected by the parametrization of soil processes, furthermore, the initial and lateral boundary conditions (LBCs). To investigate this issue, two simulations were performed applying initial and boundary conditions deriving from different datasets. Temperatures of different soil layers were evaluated to investigate after how many time the originally large difference in the deepest layer reduces.

After the preparatory phase, REMO was executed for a longer past period to obtain an overview about its applicability via comparing its results to observations. A domain covering Central and Eastern Europe is defined, which includes the watersheds of the Danube and Tisza rivers, and its lateral boundary is situated far from high mountains. REMO was integrated over the selected area on 25 km horizontal resolution and 20 vertical levels for 1957–2000, using ERA-40 re-analyses as LBCs. The temperature and precipitation results were validated against the E-OBS gridded observational database for 1961–1990; additionally, a supplementary analysis was carried out focussing on Hungary for 1971–2000, where the homogenized and gridded datasets prepared in the framework of the CARPATCLIM project were used as reference.

Climate change simulation was accomplished 1951–2100 using the same integration domain and resolution. The LBCs were taken from the ECHAM5/MPI-OM coupled global climate model run forced by A1B (medium) emission scenario for 2001–2100. The results are also evaluated against observations, since this validation provide information about the common behaviour of ECHAM and REMO what is especially interesting for the future projections. Further intercomparison was achieved with the lateral boundary fields in case of both experiments to assess what impact the different LBCs have on the regional results and what the added value of the RCM is with respect to the global fields. The model results for 21st century are evaluated for temperature and precipitation in detail for two future periods: 2021–2050 is interesting in the planning for the next decades and 2071–2100 is relevant to long-term adaptation strategies. Projection results are introduced on the one hand as changes with respect to 1961–1990, and on the other hand, also some future values are expressed based on the observed reference and the simulated changes.

To assess the uncertainties, REMO results were compared to outputs of further RCMs applied in Hungary and available in Europe. Two examples were shown for quantifying the uncertainties of meteorological modelling and applying them into impact studies.

4. Theses

1. Firstly, REMO was adapted to the IBM supercomputer of OMSZ and some short technical and scientific tests were performed. Further experiments were carried out to find the optimal model settings. The simulation results are introduced in chapters 4.1 and 4.2 of the dissertation and references [1], [2]:

    - The model was adapted successfully; acceptable departures were found between the results of the test integrations done in the computers of Max Planck Institute and the Hungarian Meteorological Service. The two simulations characterised the climatological features of the Carpathian Basin in similar way. The departures did not indicate any growing at the end of the 1.5-year integration time.
    - The possible finest – 11 km in average – horizontal resolution of REMO had not noticeable added value in the territory of Carpathian Basin to the results obtained by applying 18 or 25 km resolution.

- Maximum 4 years are needed to spin up of the model variables, using observation-based LBCs.

2. Temperature and precipitation results of the ERA-40 driven REMO simulation were evaluated with the E-OBS and CARPATCLIM gridded observation datasets. Measurement-based re-analysis data describe appropriately the past climate, thus validation serves information primarily about performance of the regional climate model. The investigations are detailed in chapter 4.3.1 of the dissertation and references [2], [3], [4], [5].

   - REMO with re-analysis forcings produced systematically higher past temperature values with 1-3 ºC in comparison to the measurements, especially over southeastern part of Europe and in summer. The overestimation was far lower in winter. An underestimation was concluded over the highly elevated areas.
   - The overestimation reached 3 ºC over Hungary in summer and autumn, while it was smaller in spring and winter: 1.5 and 0.5 ºC, respectively.
   - The re-analysis fields describe the climate conditions in Hungary with high accuracy, however, the systematic (seasonally varying, 0.5–3.6 ºC) heating introduced by the regional model to the LBCs led to the significant overestimation.
   - The precipitation was exaggerated, apart from the northeastern and northwestern areas of the model domain, the Carpathian Bain and the autumn.
   - North from Hungary the overestimation is dominant, while in South underestimation was seen in autumn and summer, therefore, negligible (1-2 mm) error was concluded over the country. Contrary to that, REMO overestimated the spring and winter precipitation amounts with 10-30 %. The evaluation with the CARPATCLIM data slightly modified the conclusions drawn according to E-OBS dataset: REMO characterised with lower errors the spring and winter sums and larger departures the autumn precipitation for 1971–2000.

3. Temperature and precipitation results of the ECHAM5/MPI-OM-driven climate change simulation were also validated with observations for the periods of 1961–1990 and 1971–2000. The results are discussed by chapter 4.3.1 of the dissertation and references [4], [5], [6] in detail:

   - The LBC characteristics largely determine the behaviour of the regional climate model. With ECHAM drivings, the temperature overestimation disappeared in the REMO results, whereas the precipitation overestimation enhanced.

- With ECHAM LBCs, REMO described the temperature with 1 ºC error in average over major part of the domain, providing slight underestimation in North and similar overestimation in South. There were only minor differences between the model results and the observations over Hungary.
- Systematic departures were seen between the results of the regional and global climate models over Hungary: REMO added approximately 1 ºC to the ECHAM temperature fields. This heating improved the regional results, since the initial temperature values of ECHAM were somewhat lower than the measurements.
- REMO overestimated the precipitation amount, its magnitude and spatial extension exceeded that of the re-analysis driven experiment. Apart from summer, 10-50 % overestimation was indicated for Hungary. Using E-OBS data as reference, REMO provided too low summer values over the whole country, while in comparison with CARPATCLIM data some overestimation over northern region and underestimation over southern one were concluded.
- It was shown that the model produced similar error characteristics for every temperature and precipitation category. It confirms that delta method can be applied at the future projection results.

4. Future temperature and precipitation projection results of REMO are investigated for 2021–2050 and 2071–2100 considering 1961–1990 as reference. The results are discussed by chapter 4.3.2 of the dissertation and references [5], [6] in detail:

   - REMO provides lower temperature change over Hungary than ECHAM for both future periods. The regional model produces the largest warming in summer and autumn, which reaches 1.5 and 4 ºC for 2021–2050 and 2071–2100, respectively. The projected increases are significant for every gridpoint in Hungary.
   - The occurrence of temperature indices with high thresholds – e.g., summer days, hot days, warm nights – will increase with 10-20 days for the near-future and with more than 30 days for the far-future, especially over the northern part of Hungary. Simultaneously, the temperature indices with low thresholds are expected to continuously reduce, for instance, extremely cold days can vanish over some areas by the end of the century. The projected changes are significant for each index and every gridpoint in Hungary.
   - According to the REMO results, the change of annual precipitation amount will not exceed 5 % by the end of century. At the same time, seasonal precipitation cy-

cle is going to be more balanced: in summer only 5% decrease is expected for 2021–2050, while 26 % (summer) reduction and 31 % winter increase are foreseen for 2071–2100. The model results are significant only for summer and winter in 2071–2100.

- The reduction of precipitation events is projected in every season except in winter, while the days with daily precipitation exceeding 10 mm will increase apart from summer. At the same time, longer dry periods are simulated by the end of the century, especially in spring and summer, over the southern and eastern regions of Hungary. The projected changes are not significant with the exception of some gridpoints.

5. The outcomes are compared to 10-25-50 km resolution RCM results available in Hungary and from the ENSEMBLES EU project for the periods of 1961–1990, 2021–2050 and 2071–2100. Comparative assessment was carried out with the results of simulations achieved in the PRUDENCE project using A2 and B2 emission scenarios for 2071–2100. Two examples were shown for quantifying the uncertainties of meteorological modelling and applying them into impact studies. The joint evaluation is presented in chapter 5 of the dissertation and references [7], [8], [9] in detail:

   - REMO characterized the past climate in the Carpathian Basin with similar model errors as the investigated RCMs. Concerning mean temperature and different temperature indices, REMO projected similar significant changes like the other RCMs.
   - According to the different RCM results, no obvious tendencies were seen for mean precipitation and precipitation indices: only summer decrease is projected uniformly by all the applied RCMs. Based on the REMO results, summer precipitation reduction will be compensated mainly by winter increase. Although it was not confirmed by the RCMs used in Hungary, the most regional simulations of the ENSEMBLES project showed same changes.
   - Interpretation of the climate simulation results is complete only with quantification of the uncertainties. The comparison of the RCM results available in Hungary with the PRUDENCE results indicated, that the deviation of the future precipitation projections are basically due to model differences (especially in the precipitation parameterization) and the scenario choice does not influence the results. As a consequence, the most plausible method to quantify the simulation uncertainties is utilizing the results of minimum two, but rather more regional climate models.

- Producing probabilistic information based on the complete ensemble of climate change simulations is an optimal approach for using quantified uncertainty information in impact studies. Selection of representative projections is another method to be used in practice. In this case, the most typical future paths are considered among all possibilities, and their results are applied for objective impact studies. At the same time, hydrological simulations based on RCM results indicated that essentially different future meteorological conditions do not lead inevitably to largely different impacts.

5. Conclusions

It was introduced in the dissertation how the future climate change can be estimated by modelling tools. Comparing the results of the REMO regional climate model with observations, it was concluded, that similarly to other RCMs, REMO characterizes properly, with small errors the climate features of Hungary. Consequently, it can be used for estimation of future climate change. Conclusions drawn based on REMO projection results are confirmed by most available European regional climate models. It was demonstrated that the model results are applicable in planning the adaptation to climate change impacts. The presented research provides a complete methodology, which point towards development of solid adaptation strategies and should have considerable effect on preparation of the adaptation in Hungary.

Main publications

[1] Szépszó, G., 2006: Adaptation of the REMO model at the Hungarian Meteorological Service (in Hungarian). Proceedings of the 31st Scientific Days for Meteorology, 125–135.

[2] Szépszó, G., 2007: Detailed evaluation of the applicability of the REMO regional climate model (in Hungarian). Project Report, NKFP-3A/082/2004.

[3] Szépszó, G., 2008: First results with the REMO regional climate model at the Hungarian Meteorological Service. CLIVAR Exchanges 46, 13 (3), 24–26.

[4] Szépszó, G., 2011: Diagnostic study of the influence of lateral boundary conditions for the REMO RCM simulations over the Carpathian Basin. Advances in Science and Research 6, 87–94.

[5] Szépszó, G., 2012: Estimation of the climate change in Hungary – REMO regional climate model results (in Hungarian). Természet Világa 143, 12, 547–550.

[6] Szépszó, G., Horányi, A., 2008: Transient simulation of the REMO regional climate model and its evaluation over Hungary. Időjárás 112, 3–4, 203–231.

[7] Horányi, A., Bartholy J., Krüzselyi I., Pieczka I., Pongrácz R., Szabó P., Szépszó G., Torma Cs., 2011: Ensemble evaluation of the regional climate model results applied at Hungary (in Hungarian). Proceedings of the 36th Scientific Days for Meteorology, 113–128.

[8] Szépszó, G., 2008: Regional change of climate extremes over Hungary based on different regional climate models of the PRUDENCE project. Időjárás 112, 3–4, 265–284.

[9] Szépszó, G., Lingemann, I., Klein, B., Kovács, M., 2014: Impact of climate change on hydrological conditions of Rhine and Upper Danube rivers based on the results of regional climate and hydrological models. Natural Hazards 72, 1, 241–262. DOI: 10.1007/s11069-013-0987-1.

Further publications in the topic of the dissertation

Bartholy, J., Horányi A., Krüzselyi I., Pieczka I., Pongrácz R., Szabó P., Szépszó G., Torma Cs., 2011: The expected climate change based on dynamical model results (in Hungarian). In: Klímaváltozás – 2011: Klímaszcenáriók a Kárpát-medence térségére (eds.: Bartholy, J., Bozó, L., Haszpra, L.), 170–234.

Krüzselyi, I., Bartholy, J., Horányi, A., Pieczka, I., Pongrácz, R., Szabó, P., Szépszó, G., Torma, Cs., 2011: The future climate characteristics of the Carpathian Basin based on a regional climate model mini-ensemble. Advances in Science and Research 6, 69-73.

Szabó, P., Horányi A., Krüzselyi I., Szépszó G., 2011: Regional climate modelling activities of the Hungarian Meteorological Service: the ALADIN-Climate and REMO models (in Hungarian). Proceedings of the 36th Scientific Days for Meteorology, 88–101.

Szépszó, G., 2005: The adaptation and first validation of REMO regional climate model at the Hungarian Meteorological Service. Technical documentation, 37 pp.

Szépszó, G., 2006: Investigation of the spin-up with the REMO model (in Hungarian). Hungarian Meteorological Service, internal research report.

Szépszó, G., 2007: Detailed review of possibilities for the dynamical downscaling of global climate models (in Hungarian). Project Report, NKFP-3A/082/2004.

Szépszó, G., Bölöni G., Horányi A., Szűcs M., 2013: The numerical weather prediction models: spatial and temporal scale, data assimilation discretization, parametrization, probabilistic forecasts, climate modelling (in Hungarian). In: Alkalmazott számszerű előrejelzés (eds.: Weidinger, T., Gyöngyösi, A.Z.), online teaching book, ELTE Department of Meteorology.

Szépszó, G., Horányi A., Lakatos M., 2011: Assessment of observed climate tendencies, future change and its uncertainties in Hungary. Scientific report on the survey of the Hungarian Meteorological Service entitled „Questionnaire on the climate change".

Szépszó, G., Tóth H., 2005: Review of global climate models (in Hungarian). Project Report, NKFP-3A/082/2004.

Presentations given in Hungarian and international conferences, events

Szépszó, G., Tóth H.: Regional climate modelling: an international overview and plans at Hungary (in Hungarian). Internal training, Hungarian Meteorological Service, Budapest (Hungary), April 2005.

Szépszó, G.: The adaptation of the REMO regional climate model at the Hungarian Meteorological Service. Conference on „Climate change. Impacts and Responses in Central and Eastern European Countries", Pécs (Hungary), 11 November 2005.

Szépszó, G.: The REMO regional climate model and its adaptation at the Hungarian Meteorological Service (in Hungarian). 31st Scientific Days for the Meteorology, Budapest (Hungary), 24–25 November 2005.

Szépszó, G.: The facts and open issues of the climate change (in Hungarian). FINE (Young Scientists for the Nuclear Energetic) Meeting, Balatonfüred (Hungary), 10 March 2007.

Szépszó, G.: Achilles' heel of the Hungarian Science: the Climate Research (in Hungarian). Foundation meeting of the Section of Atmospheric Dynamics at the Hungarian Meteorological Society, Budapest (Hungary), 24 January 2008.

Szépszó, G.: Evaluation of the results of REMO regional climate model. Regional Climate Modelling Workshop, Budapest (Hungary), 4–6 February 2008.

Szépszó, G.: PRUDENCE results for the Hungarian National Climate Strategy, Part II. Regional Climate Modelling Workshop, Budapest (Hungary), 4–6 February 2008.

Szépszó, G.: Climate Modelling: The only chance for the estimation of the climate change (in Hungarian). Section of Earth Sciences at the Hungarian Academy of Science, Budapest (Hungary), 19 February 2008.

Szépszó, G.: Regional change of extreme characteristics over the Carpathian Basin based on different regional climate models. European Geosciences Union General Assembly, Vienna (Austria), 14–18 April 2008.

Csima, G., Horányi A., Szépszó G.: Regional climate modelling (in Hungarian). Hungarian Meteorological Service, Internal training, Budapest (Hungary), 23 April and 6 May 2008.

Szépszó, G.: Preliminary results based on climate change simulation with the REMO model over the Carpathian Basin. 8th Annual Meeting of the EMS / 7th European Conference on Applied Climatology, Amsterdam (The Netherlands), 29 September – 3 October 2008.

Szépszó, G.: Climate Change – can we know, what will be on the day after tomorrow (in Hungarian)? University of Pécs, 1st Elementary School, Pécs (Hungary), 30 January 2009.

Szépszó, G.: Climate change estimations over Hungary based on regional climate models (in Hungarian). Hungarian Meteorological Society, Budapest (Hungary), 16 April 2009.

Szépszó, G., Csima, G., Horányi, A., Szabó, P.: Uncertainties in the climate projections – from the climate modelling perspective. Conference on Facing the Future, the Climate Summit in Copenhagen and beyond, Central European University, Budapest (Hungary), 4 November 2009.

Szépszó, G., Bartholy, J., Csima, G., Horányi, A., Hunyady, A., Krüzselyi, I., Pieczka, I., Pongrácz, R., Szabó, P., Torma, Cs.: The future climate characteristics of the Carpathian Basin based on a regional climate model mini-ensemble. 10th Annual Meeting of the EMS / 8th European Conference on Applied Climatology, Zürich (Switzerland), 13–17 September 2010.

Szépszó, G.: Applicability and limitation of the regional climate model results. Section of Agro- and Biometeorology at the Hungarian Meteorological Society, Budapest (Hungary), 28 October 2010.

Szépszó, G., Zsebeházi G.: Applicability of the regional climate model results of ENSEMBLES project (in Hungarian). 36th Scientific Days for the Meteorology, Budapest (Hungary), 18 November 2010.

Szépszó, G.: Climate Change (in Hungarian). József Attila Culture Center in Angyalföld, Budapest (Hungary), 30 June 2011.

Szépszó, G., Horányi A., Kovács M., Krüzselyi I., Szabó P.: Applicability and limitation of the regional climate model results (in Hungarian). Disaster Management, Budapest (Hungary), 23 September 2011.

Szépszó, G.: About climate change for advanced users: climate modelling and the expected change (in Hungarian). Klauzál Gábor Culture Center, Budafok-Tétény (Hungary), 29 September 2011.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: The modern climate research – Does the quantity turn into quality (in Hungarian)? Section of the Hungarian Meteorological Society in Szombathely (Hungary), 25 October 2011.

Szépszó G.: Weather, climate, meteorology (in Hungarian). Török Ignác Secondary School in Gödöllő (Hungary), 28 October 2011.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: Applicability of the regional climate model results (in Hungarian). Hungarian Science Festival, Disaster Management, Budapest (Hungary), 8 November 2011.

Szépszó, G.: Future climate change characteristics based on the regional climate models results in Hungary (in Hungarian). National Working Group of Climate Change, Budapest (Hungary), 15 November 2011.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: Results and challenges of the regional climate modelling (in Hungarian). Internal training, Hungarian Meteorological Service, Budapest (Hungary), 30 November and 7 December 2011.

Szépszó, G.: Dilemma of the modern climate research: is many indeed more? Climate Section of the Hungarian Meteorological Society, Budapest (Hungary), 12 January 2012.

Szépszó, G., Krüzselyi I., Szabó P., Bartholy J., Pongrácz R., Pieczka I., Torma Cs., 2012: Changes of climate extremes over Hungary: future. Internal training, Hungarian Meteorological Service, Budapest (Hungary), 1 and 14 March 2012.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: Future climate change impacts for the Carpathian Basin based on regional climate model results (in Hungarian). Presentation at the meeting on the climate change surveys of the Hungarian Meteorological Service, Budapest (Hungary), 21 March 2012.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: Climate change at the Lake Balaton in the 21st century based on regional climate model results (in Hungarian). Hungarian Hydrological Society, Székesfehérvár (Hungary), 17 April 2012.

Szépszó, G., Horányi, A.: Uncertainties in meteorological modelling: is it a weakness or strength? T4 (Turbulence, transfer, transport, and transformation: interactions among environmental systems) Conference, Eötvös Loránd University, Budapest (Hungary), 24 May 2012.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: Climate change in numbers (in Hungarian). 4th Climate Summit in Hungary, Budapest (Hungary), 7 June 2012.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: Climate change characteristics in Hungary using regional climate models (in Hungarian). Conference of III. Danube-region Cohesion, Dunaújváros (Hungary), 6 September 2012.

Szépszó, G.: Quantification methods of the uncertainties in the meteorological forecasts (in Hungarian). Department of Hydrodynamic Systems in Budapest University of Technology and Economics, Budapest (Hungary), 12 September 2012.

Szépszó, G., Kovács, M., Krüzselyi, I., Szabó, P.: Climate change in the Carpathian Basin. Kick-off meeting of the SEERisk project, Budapest (Hungary), 13 September 2012.

Szépszó, G.: Future precipitation projections based on regional climate model results (in Hungarian). Environmental Science Committee of the Presidium of the Hungarian Academy of Sciences, Budapest (Hungary), 27 September 2012.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: Changes of climate extremes in the next decades for the Carpathian Basin (in Hungarian). Presentation at the meeting entitled ”Extreme weather events – possible social answers”, Budapest (Hungary), 7 March 2013.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: Future climate change over Hungary based on regional climate model results (in Hungarian). Risk Assessment Working Group, Budapest (Hungary), 18 April 2013.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: Applicability of the different gridpoint dataset in the regional climate modelling (in Hungarian). Working Committee on Climate of the Meteorological Scientific Committee, Budapest (Hungary), 28 May 2013.

Szépszó, G., Kovács M., Krüzselyi I., Szabó P.: Future change of precipitation conditions over Hungary based on regional climate model results. Conference of the WAHASTRAT project, University of Szeged, Szeged (Hungary), 14 June 2013.

Szépszó, G., Krüzselyi I., Szabó P., Zsebeházi G.: Application and maintenance of large database in climate change research (in Hungarian). BigData Day Symposium, Wigner Datacenter, Budapest (Hungary), 12 September 2013.

Szépszó, G., Krüzselyi I., Szabó P., Zsebeházi G.: Climate change from the viewpoint of the meteorologists (in Hungarian). Budapest Science Meetup, Budapest (Hungary), 12 September 2013.

Szépszó, G., Krüzselyi I., Szabó P., Zsebeházi G.: Expected impacts of climate change (in Hungarian). Conference on Walnut Culture in Lengyeltóti, Lengyeltóti (Hungary), 14 September 2013.

Szépszó, G., Krüzselyi I., Szabó P.: Climate change projections for city of Veszprém (in Hungarian). Stakeholder consultation of the ORIENTGATE project entitled „Implement knowledge on climate change into planning process", Veszprém (Hungary), 2 October 2013.

Szépszó, G.: Evaluation of the climate models (in Hungarian). Meeting of the Climate Section at the Hungarian Meteorological Society entitled "The Physical Science Basis – IPCC Assessment Report approved 27 September 2013", Budapest (Hungary), 14 November 2013.

Szépszó, G.: Future climate change projections (in Hungarian). Presentation at the meeting of the Climate Section at the Hungarian Meteorological Society entitled "The Physical Science Basis – IPCC Assessment Report approved 27 September 2013", Budapest (Hungary), 14 November 2013.

Szépszó, G.: Global view of the climate change based on IPCC AR5 (in Hungarian). Internal training, Hungarian Meteorological Service, Budapest (Hungary), 20 and 27 November 2013.

Szépszó, G.: Impact of climate change on precipitation conditions in Hungary (in Hungarian). World Wetlands Day, Ministry for Rural Development, Budapest (Hungary), 31 January 2014.

Posters presented in international conferences

Szépszó, G.: First results with the REMO regional climate model at the Hungarian Meteorological Service. 2nd International Conference on Earth System Modelling, Hamburg (Germany), 27–31 August 2007.

Szépszó, G.: Validation of the REMO regional climate model over the Carpathian Basin. 28th Session of IPCC, Budapest (Hungary), 9–10 April 2008.

Szépszó, G.: Validation of the REMO regional climate model over the Carpathian Basin. European Geosciences Union General Assembly, Vienna (Austria), 14–18 April 2008.

Szépszó, G., Bartholy, J., Csima, G., Horányi, A., Hunyady, A., Pieczka, I., Pongrácz, R., Torma, Cs.: Validation of different regional climate models over the Carpathian Basin.

8th Annual Meeting of the EMS / 7th European Conference on Applied Climatology, Amsterdam (The Netherlands), 29 September – 3 October 2008.

Szépszó, G., Csima, G., Horányi, A., Szabó, P.: What details can the regional climate models add to the global projections in the Carpathian Basin? 2nd Lund Regional-scale Climate Modelling Workshop, Lund (Sweden), 4–8 May 2009.

Szépszó, G.: Analysis of the influence of lateral boundary conditions based on REMO RCM simulations over the Carpathian Basin. 10th Annual Meeting of the EMS / 8th European Conference on Applied Climatology, Zürich (Switzerland), 13–17 September 2010.

Szépszó, G.: High-resolution regional climate model simulations with the REMO model over the Carpathian Basin. 11th Annual Meeting of the EMS / 10th European Conference on Applications of Meteorology, Berlin (Germany), 12–16 September 2011.

Szépszó, G., Kovács, M., Krüzselyi, I., Szabó, P.: Main climate dynamics activities at the Hungarian Meteorological Service. Conference on "End User Needs for Regional Climate Change Scenarios" of COST-ES1102 action, Kiel, (Germany), 7–9 March 2012.

Szépszó, G., Krüzselyi, I., Szabó, P., Zsebeházi, G.: From the RCM results to their interpretation for the users. International Conference on Regional Climate – CORDEX 2013, Brussels (Belgium), 6 November 2013.