# ABSTRACT BOOK

## 12th Seminar for Homogenization and Quality Control in Climatological Databases

## and

## 7th Interpolation Conference & the Danube-Adapt Project meeting


Headquarters of the Hungarian Meteorological Service and online, Budapest, Hungary

2026

12th Seminar for Homogenization and Quality Control in Climatological Databases and
7th Interpolation Conference & the Danube-Adapt Project meeting

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# PROGRAMME

## 5th May, Tuesday

| | | |
|---|---|---|
| 13:30-14:00 | Registration | |
| 14:00-14:10 | Welcome | |
| 14:10-14:30 | **WMO activities in support of climate data homogenisation**<br>Peer Hechler<br>*WMO* | online |
| 14:30-14:50 | **Survey on homogenization practices within WMO members**<br>Jose A. Guijarro[1], Denis Stuber[2], Reinaldo Silveira[2], Peer Hechler[3]<br>*[1]Associate member of the WMO Expert Team on Data Development and Stewardship*<br>*[2]Co-chair of the WMO Expert Team on Data Development and Stewardship*<br>*[3]WMO Scientific Officer* | online |
| 14:50-15:20 | **Theoretical Problems of Homogenization and Spatial Interpolation**<br>Tamás Szentimrey<br>*Varimax Limited Partnership, Budapest, Hungary* | onsite |
| 15:20-15:40 | Coffee break | |
| 15:40- 16:00 | **Challenges in Homogenizing Precipitation Data and Assessing Trend Representativeness**<br>Xiaolan L. Wang<br>*Climate Research Division, Environment and Climate Change Canada, Canada* | onsite |
| 16:00-16:20 | **Reconstruction of Maximum Temperature Time Series Using Machine Learning Models**<br>Eduarda Regina Agnolin, Fiorella Acquaotta<br>*Univesidade Federal de Santa Catarina UFSC, Brasil* | online |
| 17:00-20:00 | Ice breaker | |

## 6th May, Wednesday

| | | |
|---|---|---|
| 08:30-09:00 | Registration | |
| 09:00-09:20 | **Quality Control of Precipitation Data from Automatic Weather Stations using Central Integration Platform**<br>Hela Irha, Maja Piljek, Ana Šantić<br>*Croatian Meteorological and Hydrological Service (DHMZ), Ravnice 48, HR-10000 Zagreb* | onsite |
| 09:20-09:40 | **From Manual to Operational: Sustainable Homogenization of Monthly Temperature and Precipitation in Belgium**<br>Mel Brehon[1], Romain Ingels[1], Laurent Delobbe[1], Rozemien De Troch[2], Thomas Muller[2]<br>*[1]Royal Meteorological Institute of Belgium*<br>*[2]Belgian Climate Centre* | onsite |
| 09:40-10:00 | **Automated Homogenisation of monthly precipitation series for France using Climatol**<br>Gautier C., Espern-Foucaud Q., Fau R.<br>*Météo-France, Direction de la Climatologie et des Services Climatiques* | online |
| 10:00-10:20 | **Poster pitches 3min each** | |
| 10:20-10:40 | Coffee break | |

| | | |
|---|---|---|
| 10:40-11:00 | **Rescuing the Past: Automated Homogenization of Early Instrumental Records and Its Implications for Historical Climate Reconstruction**<br>Elin Lundstad<br>*Norwegian Meteorological Institute* | online |
| 11:00-11:20 | **Challenges in homogenizing long series. Two examples from the Balearic Islands.**<br>Jose A. Guijarro<br>*Retired from the State Meteorological Agency (AEMET), Spain* | online |
| 11:20-11:40 | **An operational homogenised daily temperature data set in Australia**<br>Blair Trewin, Simon Grainger, Alex Evans<br>*Bureau of Meteorology, Australia* | online |
| 11:40-12:00 | **Shifting Baselines, Shifting Trends: The Hidden Impact of Global Warming on Percentile-Based Indices**<br>Yizhak Yosef[1,2]; Enric Aguilar[3]; Pinhas Alpert[1]<br>*[1]Department of Geophysics, Tel Aviv University, Tel Aviv, Israel*<br>*[2]Israel Meteorological Service, Bet Dagan, Israel*<br>*[3]Center for Climate Change (C3), Rovira i Virgili University, Tarragona, Spain* | online |
| 12.00-14.00 | Lunch | |
| 14:00-14:20 | **A new blended rainfall database - extending the climatological observations series for UK rainfall using Rainfall Rescue data**<br>Stephen Packman<br>*UK Meteorological Office* | onsite |

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|---|---|---|
| 14:20-14:40 | **Updates from the Copernicus Climate Change Service Global Land and Marine Observations Database**<br>Robert Dunn (*UKMO*), Simon Noone (*NUIM*), Matthew Menne (*NOAA*), Nancy Casey (*CSS Inc*), Peter Thorne (*NUIM*) | online |
| 14:40-15:00 | **A new comprehensive, bias adjusted upper air dataset in the Copernicus Data Store**<br>Ulrich Voggenberger[1], Leopold Haimberger[1], Federico Ambrogi[1], Markel Garcia Diez[2], Paul Poli[3]<br>*[1]University of Vienna, Meteorology and Geophysics, Vienna, Austria*<br>*[2]Predictia, Santander, Spain*<br>*[3]ECMWF, Bonn, Germany* | onsite |
| 15:00-15:20 | **GriSt: Daily 3-km Gridded Climate Fields for Central Europe since 1961**<br>[1,2]Petr Štěpánek, [1,2]Pavel Zahradníček, [3]Agnieszka Wypych, [3]Agnieszka Sulikowska<br>*[1]Global Change Research Institute of the Czech Academy of Sciences, Brno, Czech Republic*<br>*[2]Czech Hydrometeorological Institute, Brno Regional Office, Czech Republic*<br>*[3]Jagiellonian University, Institute of Geography and Spatial Management, Department of Climatology, Kraków, Poland* | onsite |
| 15:20-15:40 | Coffee break | |
| 15:40-16:00 | **Homogenization of Mongolian Mean Wind Speed Monthly Series and Challenges**<br>Baljinnyam Nyamjantsan<br>*Research Division of Climate Change and Resource, Information and Research Institute of Meteorology, Hydrology, and Environment, National Agency Meteorology and Environmental Monitoring, Ulaanbaatar 15160, Mongolia* | onsite |
| 16:00-16:20 | **Wind direction interpolation with MISH software**<br>Kinga Bokros[1,2], Beatrix Izsák[1]<br>*[1]Department of Climate Research, HungaroMet Hungarian Meteorological Service, Budapest, Hungary*<br>*[2]ELTE Eötvös Loránd University, Faculty of Science, Doctoral School of Earth Sciences, Budapest, Hungary* | onsite |
| 19:00-22:00 | Conference dinner | |

## 7th May, Thursday

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|---|---|---|
| 08:30-09:00 | Registration | |
| 09:00-09:10 | **Welcome speeches**<br>1. Special guest from the Hungarian climate policy<br>2. HungaroMet representative<br>3. Attila Sütő (HungaroMet) | |
| 09:10-09:30 | **Homogenization with MASH - the climatological database of the Danube region**<br>Beatrix Izsák[1], Olivér Szentes[1], Tamás Szentimrey[2], Mónika Lakatos[1], Zita Bihari[1]<br>*[1]Department of Climate Research, HungaroMet Hungarian Meteorological Service, Budapest, Hungary*<br>*[2]Varimax Limited Partnership, Budapest, Hungary* | onsite |
| 09:30-09:50 | **Creation of climate database for the Danube Region: first results**<br>Olivér Szentes[1], Beatrix Izsák[1], Mónika Lakatos[1], Zita Bihari[1], Tamás Szentimrey[2]<br>*[1]Department of Climate Research, HungaroMet Hungarian Meteorological Service, Budapest, Hungary*<br>*[2]Varimax Limited Partnership, Budapest, Hungary* | onsite |
| 09:50-10:10 | **Bias adjustment of EURO-CORDEX high-resolution simulations by means of quantile delta mapping: Evaluation on the climate from the near past over Southeast Europe**<br>Hristo Chervenkov, Kiril Slavov<br>*National Institute of Meteorology and Hydrology, Bulgaria* | onsite |
| 10:10-10:30 | **Potential usability of climatological data in integrated vulnerability assessments – Development of an integrated climate vulnerability assessment framework for the Danube region**<br>Attila Sütő, Zsófia Kecskés, Pál Selmeczi, Miklós Gula<br>*HungaroMet Hungarian Meteorological Service, Budapest, Hungary* | onsite |
| 10:30-10:40 | Close up of the 12th Seminar for Homogenization and Quality Control in Climatological Databases and 7th Interpolation Conference | |
| 10:40-11:00 | Coffee break | |
| ***11:00*** | ***Beginning of the 3rd partner meeting of the Danube-Adapt project*** | |

## Posters
## 6th May, Wednesday

| | |
|---|---|
| **Quality Control and Validation System for Phenological Data**<br>Ivana Medved<br>*Croatian Meteorological and Hydrological Service (DHMZ), Ravnice 48, 10000 Zagreb, Croatia* | onsite |
| **ClimRisk: Climate Projections to 2100 for Europe with a Focus on the Czech Republic**<br>Mirek Trnka[1,2], Petr Stepanek[1,3], Petr Skalák[1], Jan Balek[2], Pavel Zahradníček[1,3], Jan Meitner[1],<br>Aleš Farda[1], Milan Fischer[1,2]<br>*[1]Global Change Research Institute CAS, Department of climate modelling and scenarios development, Brno, Czechia*<br>*[2]Mendel University in Brno, Institute of Agrosystems and Bioclimatology, Zemědělská 1, 613 00 Brno, Czech Republic*<br>*[3]Czech Hydrometeorological Institute, Kroftova 43, Brno, 616 00, Czech Republic* | onsite |
| **Climate Data Cooperation for Evidence-Based Adaptation in the Danube Region**<br>Mónika Lakatos, Zita Bihari, Sára Bordi, Beatrix Izsák, Otília Megyeri-Korotaj, Olivér Szentes<br>*HungaroMet, Department of Climate Research, Hungarian Meteorological Service, Budapest, Hungary* | onsite |
| **New Map Products in Climatological Services on the Webpage of the Slovak Hydrometeorological Institute**<br>Katarína Mikulová, Lívia Labudová, Juraj Holec, Dušan Štefánik, Kristína Szabóová, Gabriela Ivaňáková, Ivana Krčová, Jozef Rozkošný<br>*Slovak Hydrometeorologickal Institute, Jeseniova 17, Bratislava, Slovakia* | onsite |
| **Independent validation of daily precipitation in the Ukrainian gridded climate dataset ClimUAd**<br>Vladyslav Sidenko[1], Olesya Skrynyk[2,1], Liudmyla Palamarchuk[1], Dmytro Oshurok[1], Ihor Kravchenko[1], Oleg Skrynyk[1]<br>*[1]Ukrainian Hydrometeorological Institute, Kyiv, Ukraine*<br>*[2]National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine* | onsite |
| **Climate monitoring products: AgroClima and DataClima a simple and interactive way to access Drought indicators in Portugal**<br>V. Pires, C. Pereira, T. Moura, R. Deus.<br>*IPMA - Portuguese Sea and Atmosphere Institute, I.P., Portugal* | online |

# ABSTRACTS

# WMO activities in support of climate data homogenisation

Peer Hechler

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WMO and its Members regularly issue products and publications that are generated from high-quality long-term time-series data. Such products and publications include national, regional and global State of the Climate reports, analyses of climate variability and change, Climatological Standard Normals etc. Underpinning WMO activities assist Members in generating homogeneous long-term time-series data through WMO guidelines, targeted project activities and training in the domains of climate observations (Centennial observing stations, Reference climatological stations), data rescue, data exchange, basic climate statistics, climate data management (including Climate Data Management Systems), quality control and homogenisation. The talk provides specific examples of recent WMO activities in support of homogenisation, which is seen as the final step in the generation of scientifically robust climate data sets.

# Survey on homogenization practices within WMO members

Jose A. Guijarro(1), Denis Stuber(2), Reinaldo Silveira(2), Peer Hechler(3)

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Online consultations on homogenization of climate series were held within the World Meteorological Organization (WMO) on November 19 and 20 under the leadership of Peer Hechler (Scientific Officer), Denis Stuber and Reinaldo Silveira (chairs of the Expert Team on Data Development and Stewardship). More than 200 participants attended to each of the two sessions held (for Western and Eastern hemispheres), which consisted in an introduction to the problem of spurious biases on climate series and possible approaches to correct them, followed by interventions of representatives of Argentina, Hungary, Madagascar and Australia with examples of applications and challenges of homogenization in their regions.

The sessions ended with questions and answers, and an invitation to participate in an online survey implemented by Denis Stuber. Main conclusions:

- 64.3% of organizations (of the 54 WMO members which participated in this survey) are performing homogenization of climate data.
- Most of them are homogenizing both monthly and daily series.
- From those not doing homogenization, 41.7% are planing to implement it within 1 or 2 years.
- Training and network support are requested to overcome faced challenges, although lack of human resources is often a barrier.

# Theoretical Problems of Homogenization and Spatial Interpolation

Tamás Szentimrey

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To ensure the provision of high-quality meteorological data that are representative in both space and time, the following procedures and methods are required: homogenization of data series including quality control and missing data completion; spatial interpolation, gridding, real time quality control, interpolation with background information, data assimilation.

The necessary conditions and tools for developing such procedures and methods are, in principle, meteorological knowledge, a proper meteorological formulation of the problem, and - based on these - advanced mathematical methodology and corresponding software development.

In practice, the methods and software used generally originate either from general-purpose statistical procedures and tools (e.g., GIS interpolation), or from specialized meteorological methods and software (e.g., homogenization).

The main problem is that general-purpose, mathematically sound statistical procedures do not take into account specific meteorological aspects, while specialized meteorological methods typically do not fully meet strict mathematical requirements.

Consequently, the theoretical problems of the aforementioned meteorological procedures primarily arise in the mathematical methodology, and are therefore mathematical in nature.

What are these problems? It can be mathematically demonstrated that, in these procedures, the spatiotemporal climatic probability distribution plays a key role. Therefore, effective methods can only be achieved if we have a quantitative characterization of the climate - which is not surprising. However, the quantitative description of climate and the development of effective methods based on this knowledge require advanced mathematics.

From this perspective, different approaches are possible depending on the specific topic:

Homogenization: the necessary climatic information can be derived directly from the data series themselves by statistical estimation.

Spatial interpolation, data assimilation: the required climatic information can be modeled based on the available homogenized data series. Thus, not only the future climate must be modeled, but the present climate as well.

Our software MASH for homogenization and MISH for spatial interpolation were developed according to these principles.

# Challenges in Homogenizing Precipitation Data and Assessing Trend Representativeness

Xiaolan L. Wang

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This presentation draws on a series of recent studies focused on quality control and homogenization of precipitation data, as well as the assessment of precipitation trends. Precipitation is intermittent in both time and space, and highly variable spatially and across scales. Precipitation amounts are non negative and follow a non Gaussian distribution, with daily data containing many zero precipitation days. These characteristics necessitate specialized approaches for detecting and adjusting inhomogeneities.

In particular, a paired set of procedures is required to detect changepoints in monthly precipitation data, while a different procedure must be used to detect changepoints and homogenize daily precipitation series. Even quality control of precipitation data benefits from a paired approach: both the original and log transformed series must be examined for quality issues and changepoints.

This presentation highlights the challenges encountered in producing Version 2 of the Canadian Homogenized Precipitation Dataset, including a comparison with the earlier version and an assessment of sampling uncertainty. The latter includes evaluating the representativeness of the station network configuration and quantifying the impacts of missing data.

# Reconstruction of Maximum Temperature Time Series Using Machine Learning Models

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The presence of gaps in meteorological series constitutes a recurring problem in climate studies, potentially compromising the analysis of extreme events such as heat waves. In this context, this study aimed to evaluate different data reconstruction methodologies for filling gaps in maximum temperature series. Daily series from three automatic meteorological stations of the National Institute of Meteorology (INMET), located in the Southern Region of Brazil, in the cities of Curitiba, Florianópolis, and Porto Alegre, were used, considering the period from 2008 to 2025. The series presented different proportions of gaps: 8.05% in Curitiba, 5.48% in Florianópolis, and 0.40% in Porto Alegre. Four approaches were applied to reconstruct the missing data: Multiple Linear Regression, Random Forest, Multilayer Perceptron, and Support Vector Regression. The performance of the models was evaluated using statistical metrics such as the coefficient of determination ($R^2$), mean absolute error (MAE/RMAE), and mean error (RME). The results indicated that the Random Forest model showed the best performance in all analyzed stations, with high $R^2$ values (0.94–0.96) and low mean errors, indicating a high capacity to reproduce the variability of the observed series. Multiple Linear Regression showed intermediate performance, with $R^2$ values between approximately 0.52 and 0.66. Models based on neural networks (MLP) and Support Vector Regression showed inferior performance, with lower $R^2$ values and higher mean errors, especially in the Curitiba and Porto Alegre stations. Overall, the results show that machine learning-based methods, particularly Random Forest, are more efficient for reconstructing weather series with gaps, contributing to obtaining complete and more reliable climate series for studies of thermal extremes and heat waves.

# Quality Control of Precipitation Data from Automatic Weather Stations using Central Integration Platform

Hela Irha, Maja Piljek and Ana Šantić

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The integration of 350 new automatic weather stations (AWS) within the modernisation of weather observational network at Croatian Meteorological and Hydrological Service (DHMZ) has resulted in an exponential growth of data, driving the demand for advanced software solutions. To address this, the Central Integration Platform (CIP) was developed, providing a unified system for AWS network monitoring, data quality control, and visualization. This study presents the results of platform testing using data from 2025, with a particular focus on precipitation as one of the most complex parameters for quality assessment. Data from the new automatic stations were compared with older automated systems, while manual conventional measurements were used as benchmark. The dataset consists of data from meteorological stations where all three measurement systems were operational during the study period. The objective of this study is to demonstrate that the new automated network outperforms the previous system and represents an adequate and sustainable replacement for conventional meteorological stations, which are being gradually closed.

# From Manual to Operational: Sustainable Homogenization of Monthly Temperature and Precipitation in Belgium

Mel Brehon(1), Romain Ingels(1), Laurent Delobbe(1), Rozemien De Troch(2), Thomas Muller(2)

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Homogenizing long-term climate records is essential for analyzing climate trends while removing artificial shifts caused by changes in measurement practices and conditions. This presentation introduces the operationalisation of HOMER software for homogenizing 61 temperature and 110 precipitation monthly series in Belgium spanning from 1880-1954 to 2024. This work was conducted within the NOISELESS project, financially supported by the National Collaboration Programme of the Copernicus Climate Change Service (C3S).

While HOMER provides robust results, the homogenization process remains highly manual and time-consuming, posing a significant challenge for national meteorological institutes in maintaining homogenizing activities given limited resources. To address this, techniques were implemented and adapted from existing automatic homogenization methods. A key feature is the integration of a scoring system derived from BART software, developed at SMHI, to filter potential inhomogeneities. This feature enhanced metadata integration and significantly improved time efficiency. Beyond statistical refinement, our primary objective was to establish a sustainable framework for operationalisation. We prioritized procedure standardization, script maintainability, and the accessibility of methods for non-statistical users.

Our approach considers both methodological refinement and the practical challenges of operational climate data management. Key aspects include workflow optimization through automated pre-filtering of inhomogeneities, metadata integration, and designing procedures that are maintainable and accessible to non-statisticians, supporting capacity building within national meteorological institutes. This presentation explores how standardizing procedures and prioritizing code maintainability of open-source tools proposes a pathway towards a more collaborative and sustainable framework for homogenization activities.

# Automated Homogenisation of monthly precipitation series for France using Climatol

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Until now, homogenisation at Météo-France has been carried out using Prodige and HomeR, with the series being processed according to geographical distribution into batches.The last homogenisation of monthly precipitation data for France occurred between 2015 and 2022. Due to the large number of series to be processed and the limited number of human resources available for this activity, it was decided that a more automated homogenisation method with large-scale processing would be applied for the new update of these homogenised precipitation series. Climatol software by José A. Guijarro was chosen because it is free and allows metadata to be taken into account.

Work has therefore been carried out to homogenise the monthly precipitation series for mainland France using Climatol version 4.4-2 for the period from 1950 to 2024, and the input series set consists of 980 monthly precipitation series.

First, Climatol is run on the entire set in exploratory mode. Then, Climatol is launched to detect breaks in the dataset.

As part of this homogenisation effort, significant work has been done to automate the retrieval of metadata for this series set from our climatological database.

The dates of breaks detected by Climatol are corrected using nearby metadata dates for breaks with an SNHT value below a set threshold. Considering the metadata helps us to understand why certain breaks occurred on those dates for these series.

Another configuration that takes the metadata dates into account, disregarding the condition on the SNHT value associated with the break, is also tested in view of the results.The results obtained according to these three configurations are then compared and one configuration is selected. The trends in the homogenised series derived from the selected configuration and calculated over the previous homogenisation period are consistent with previous results. These new homogenized monthly precipitation series resulting from this work provide access to updated trends for this parameter in France.

# Rescuing the Past: Automated Homogenization of Early Instrumental Records and Its Implications for Historical Climate Reconstruction

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Instrumental observations from the early measurement era are essential for understanding how climate has varied over centuries, yet long-term records remain sparse outside Europe and North America. This gap constrains our ability to assess decadal climate change at a global scale and underscores the pressing need to rescue and standardize historical observations from underrepresented regions. The Global Early Instrumental Monthly Meteorological Multivariable Database (HCLIM) offers a valuable collection of such rescued data, yet systematic evaluation of automated homogenization methods applied to these records is still lacking.

This study assesses the performance of two widely used automated homogenization techniques, CLIMATOL and BART, applied to early instrumental temperature series from HCLIM. We evaluate each method across three dimensions: how data are stored in pre-processed datasets, the characteristics of breakpoints detected in homogenized series, and consistency with the 20CRv3 reanalysis. French and South Asian station networks serve as contrasting case studies, representing dense and sparse observational networks respectively.

Our results reveal modest structural differences in preprocessing between the two methods. BART retains fewer but longer and more internally consistent records (80%) compared to CLIMATOL (96%). In terms of breakpoint detection, BART identifies approximately eight times more breakpoints, reflecting greater sensitivity to inhomogeneities, with marked regional and temporal variation observed across both networks. When evaluated against 20CRv3, BART consistently shows the smallest deviations and highest agreement, particularly in the dense French network. CLIMATOL, by contrast, exhibits more variable performance depending on network density and local climate conditions. Deviations are largest in sparse regions such as Southeast Asia, confirming that station density exerts a strong influence on homogenization quality.

Taken together, these findings show that automated homogenization methods differ substantially in how they store data, detect breakpoints, and reconstruct climate series. BART achieves the highest overall accuracy, while CLIMATOL offers more balanced performance across diverse network configurations. This study advances best practices for applying automated homogenization to salvaged historical records and supports broader efforts to extend climate archives in data-sparse regions, strengthening the foundation for climate model validation, reanalysis development, and the assessment of historical extremes relevant to adaptation planning.

# Challenges in homogenizing long series. Two examples from the Balearic Islands

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The relative homogenization of climatological series is based on comparing correlated series to distinguish anomalous biases in individual stations from the variability common to all stations, inherent in the climate signal. However, we often lack access to observed series with which to make these comparisons. Typical examples include geographically isolated stations, but the same applies to very old series, when the density of observatories was much lower than it is today.

Two examples showing different approaches to homogenizing long series of monthly precipitation and temperature data are presented here from the Palma de Mallorca (1862–2015) and Mahon (1863–2015) observatories. Located in the Balearic Islands, both are still making observations, but their data have been studied up to 2015 because this is the last year covered by the 20CRv3 reanalysis, used as a reference.

Three homogenization methods have been applied: Climatol, RHtestV4 and Craddock, obtaining very disparate results that do not agree much with the location change dates available in the metadata, showing the difficulty of homogenizing isolated series.

# An operational homogenised daily temperature data set in Australia

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The Bureau of Meteorology has developed the Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) data set. The first version of this data set was released in 2012 and a major update in 2018. This is the principal data set used for climate change monitoring and assessment in Australia. It extends from 1910, when national coverage with consistent instrumentation commences, to the present, and contains data for 112 locations across Australia, 60 of which have data for the full 1910-2025 period. The data set consists of daily maximum and minimum temperature for all locations and is homogenised at the daily timescale, using a percentile-matching algorithm for adjustment to reflect the differential impact of some inhomogeneities on different parts of the temperature frequency distribution. More than 90% of the network is now automated although a small number of manual sites remain.

The ACORN-SAT data set has a regular process for annual updates. This includes the identification of potential new inhomogeneities in the last 5 years of the record, through metadata and statistical methods, and reassessment of any inhomogeneities previously identified in the last 5 years. On occasions, this will result in an inhomogeneity which had initially been found to be significant becoming insignificant with additional reference data (or vice versa). This may occur, for example, where an apparent inhomogeneity is the result of temporary land surface changes (such as excessive vegetation growth following unusually wet periods in arid or semi-arid areas) and reverses as those changes reverse. In general, adjustments are not applied in the last 2 years of the record, or the last 3 years if not supported by metadata. The annual update process also involves the merging of records where any comparison program has been completed during the previous year.

The ACORN-SAT network and data set are closely embedded into planning of the observation network in Australia. As a general policy, where a site move is required, comparison observations between the old and new sites are carried out for a minimum of 2 years. The ACORN-SAT team is also closely engaged in decisions around site selection in such cases, to identify sites which are least likely to have major inhomogeneities relative to the previous site. An extensive comparison program is also planned for the forthcoming replacement of instruments and screens across the Australian observation network. The data set also has extensive documentation, including a station catalogue which, for each of the 112 sites, includes a station history and summary of all adjustments applied at that location.

# Shifting Baselines, Shifting Trends: The Hidden Impact of Global Warming on Percentile-Based Indices

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This study examines how the choice of base period influences the magnitude of trends in percentile based extreme temperature indices. The analysis is based on a thoroughly quality controlled and homogenized daily temperature dataset. A combination of ACMANT, HOMER, and CLIMATOL was applied to ensure the robustness and consistency of the series. The study compares results obtained using a colder historical reference period (1961-1990) with those derived from a more recent and warmer period. The indices considered include the frequencies of warm and cold days and nights, as well as the duration of warm and cold spells. These indices are part of the standardized set of 27 core indices recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI), which are widely used for monitoring climate change at regional and global scales.

The study reveals that percentile-based indices are particularly sensitive to the choice of base period whereas fixed threshold indices are much less affected. For these indices, different reference periods mainly shift the intercept while leaving the slope unchanged. Our comparative analysis demonstrates that using a more recent and warmer base period significantly amplifies the negative trends in cold related indices, such as the frequency of cold days and cold spells. At the same time, it notably reduces the positive trends in warm related indices, such as warm nights and heatwaves. These effects are especially pronounced when the analysis is limited to the past 30 to 40 years.

The results highlight the importance of accounting for base period selection when using percentile-based indices for climate monitoring, particularly under ongoing climate warming.

# A new blended rainfall database - extending the climatological observations series for UK rainfall using Rainfall Rescue data

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The Met Office National Meteorological Archive contains a wealth of historic rainfall observation data in journals and weather logs, extending as far back as the 17th century, with many thousands of these observations scanned into image files. In 2020, through a University of Reading-led project called 'Rainfall Rescue', a concerted effort was made by over 16,000 volunteers to digitise the monthly rainfall data in these scanned files and make them accessible for wider use by scientists.

One objective for this project was to create a more comprehensive monthly rainfall dataset which integrated the digitised Rainfall Rescue data with data derived from MIDAS (Met Office Integrated Data Archive System) Open, an open Met Office dataset containing land surface station data back to 1853. We employed an innovative approach to identify where the same site exists in both MIDAS Open and Rainfall Rescue by utilising site metadata and rainfall trend data. Particular emphasis was placed on assessing the overlap period between candidate station pairs, requiring statistical agreement between the two datasets before any blending was undertaken. This ensured homogeneity and minimised the risk of introducing artificial discontinuities into the combined series. A methodology for constructing a new rainfall series for these validated sites was then developed that blends the data from both data sources. As a result of this initiative, the records of many sites were extended to produce a more complete and long-running monthly rainfall series to support climate monitoring and research, with scope to adopt this methodology for other climate variables.

# Updates from the Copernicus Climate Change Service Global Land and Marine Observations Database

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As part of the Copernicus Climate Change Service (C3S), we are continuing to develop the Global Land and Marine Observations Database, containing surface meteorological data records spanning the entire history of instrumental observation. These data are available on the C3S Climate Data Store, and also from the new GHCNh dataset at NOAA/NCEI. In this presentation we will give an update on our progress for the land data, focusing on subdaily observations from over 38,000 stations. We will outline developments in our data sources, coverage and merging, as well as the quality control algorithms and our future plans.

# A new comprehensive, bias adjusted upper air dataset in the Copernicus Data Store

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The Copernicus Climate Change Service (C3S) has developed the Comprehensive Upper Air Observation Network (CUON) dataset. It has been released through the Copernicus Climate Data Store (cds.climate.copernicus.eu/datasets/insitu-comprehensive-upper-air-observation-network) and aims to be a traceable and climate-quality resource for reanalysis, monitoring, and long-term atmospheric studies. The main geophysical variables included in CUON are temperature, humidity, and wind. The input observation data are the ERA5 observation feedback archive, the NOAA Integrated Global Radiosonde Archive (IGRA), the NCAR Upper-Air Database (UADB),, and additional ascents from smaller collections, including in particular the African Monsoon Multidisciplinary Analysis (AMMA) and the World Ozone and Ultraviolet Radiation Data Centre (WOUDC). Available radiosonde, ozonesonde, and pilot-balloon (PILOT) platforms are included, even if the station record contains only a single launch.The aforementioned data input is made more interoperable by augmenting the original observation values with converted values, e.g. u and v in addition to wind speed and direction, or specific and relative humidity in addition to dewpoint or dewpoint depression. The metadata were improved with balloon drift estimates and estimates of the actual launch times in addition to the nominal times. For the observation values themselves, uncertainty estimates were calculated from obs-ERA5 analysis and obs-ERA5 background values using Desroziers method. In addition bias estimates were calculated for temperature, wind and humidity values based on the RAOBCORE/RICH method (Haimberger et.al. 2007&2012). These unique features make CUON suitable as an input for climate reanalysis, in particular the upcoming ERA6 reanalysis, but also other climate applications.

In situ upper-air wind observations from pilot balloons (PILOT), which provide wind information without direct measurements, require an assumed vertical coordinate transformation. Traditionally, PILOT heights are derived from ascent rate and time since launch, or more recently from GPS, and pressure is subsequently inferred using a prescribed temperature profile, typically the ICAO standard atmosphere. This approach, applied during ERA5 data assimilation and extended in CUON v1.1.0 to non-assimilated PILOT data available only on height levels, introduces systematic geopotential and pressure offsets when compared to radiosonde observations. We show that a more physically consistent pressure assignment can be achieved by interpolating pressure from geopotential background forecasts on model pressure levels, substantially reducing offsets relative to radiosonde-derived geopotential and improving the vertical consistency of PILOT wind observations.

Humidity bias adjustments are applied to the upper-air observations by comparison with obs-bg time series and taking into account instrument metadata. They are evaluated through comparisons with microwave humidity sounder (MHS) radiances from multiple satellite missions. After the adjustments, the discrepancies with satellite data as estimated from root-mean-square errors and standard deviations, and the spatial heterogeneity of the discrepancies is substantially reduced. In collaboration with EUMETSAT, these observation - satellite comparisons will be further refined and systematically continued. A two part paper addressing distinct aspects of upper-air observation quality is in preparation: the first focuses on homogenisation and bias correction of wind observations, while the second addresses temperature and humidity bias adjustment and satellite-based evaluation.

# GriSt: Daily 3-km Gridded Climate Fields for Central Europe since 1961

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We present a gridded climate dataset covering the Czech Republic, Slovakia, Poland, and surrounding regions. The dataset spans the period from 1961 to 2025 and provides daily values of key meteorological variables—including temperature, precipitation, humidity, wind, and sunshine duration—interpolated to a 3 × 3 km grid.

The dataset was constructed using rigorous multi-stage quality control and homogenization of station time series followed by spatial interpolation techniques adapted for complex topography and varying station density across national borders. The methodology follows established international approaches while incorporating region-specific adaptations suitable for the diverse climate conditions and observational infrastructure of Central Europe.

The dataset is intended to support a wide range of climate analyses, including studies of long-term trends, extreme events, and circulation-related climate variability. It also provides an observational benchmark for evaluating and bias-correcting regional climate model simulations, thereby improving the reliability of both historical reconstructions and future projections.

Our contribution aims to strengthen cross-border data consistency, promote reuse in national and international climate services, and foster open collaboration in long-term climate monitoring across Central Europe.

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# Homogenization of Mongolian Mean Wind Speed Monthly Series and Challenges

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Accurate determination of climate change signals is a significant task and requires high-quality data series. However, various non-climatic effects, including station move, instrumentation change, and surrounding environment alteration, may cause artificial shifts in data series. This research aims to analyze the long-term variability of wind speeds in Mongolia and homogenize the data series to identify realistic trends in climate variation. The research is based on monthly mean wind speed data collected from 111 equally distributed meteorological stations in Mongolia from 1937 to 2025. To detect inhomogeneities in data series, correct inhomogeneities, and fill missing data values, the Climatol package in the R environment is used. Using specific criteria std=2 and inht=30, 295 breakpoints were detected by the homogenization tool, resulting in widespread series splitting across the country's network. These results clearly indicate that wind speed data in Mongolia is significantly affected by non-climatic variables. The major challenge in data homogenization is related to the transition from manual measurement techniques to automated measurement systems. Since the early 2000s, Automatic Weather Stations (AWS) have been introduced in Mongolia, and currently, the entire network is automated. This is a major factor in inhomogeneity in wind speed data series in Mongolia. By homogenizing wind speed data series in Mongolia, a more accurate assessment of atmospheric circulation patterns in Mongolia can be determined during nearly 90 years of data series. The results obtained in this research are a critical foundation for various purposes in renewable energy assessment, desertification, and climate modeling in Mongolia.

# Wind direction interpolation with MISH software

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Our temperature, precipitation, wind speed, humidity, global radiation and air pressure data sets, homogenized with the MASH software and interpolated with MISH, are renewed annually at the Climate Research Department of HungaroMet. Likewise, our wind direction database is updated every year. In this presentation, we will explain the steps of interpolation of the wind direction. However, it should be taken into account that we are not talking about a scalar, but a vector quantity, so wind direction must be treated together with wind speed. The MISH software consists of two main parts: modeling and interpolation. We use the data sets homogenized with the MASH software to model the climate statistical parameters. The resulting model results are used for interpolation.

The number of automatic stations measuring wind speed and direction has increased significantly in the past decade, so we have the opportunity to re-model the climate statistical parameters so that the interpolation achieves even better results. In addition, we will also renew the roughness database using the CORINE database, the novelty of which is that roughness parameters are available for both the winter and summer semesters. In this presentation, we will present the theoretical steps of interpolation and also discuss the verification results.

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# Homogenization with MASH - the climatological database of the Danube region

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Within the framework of the Danube Adapt project, we are preparing a climatological database for nine meteorological elements. While the homogenization is performed uniformly with the MASH software, the MISH software is used for the interpolation for the entire Danube river basin.

The MASH software, which was developed for homogenization of monthly and daily data series, includes also quality control and missing data completion units for the daily as well as the monthly data. Depending on the climate elements, additive or multiplicative model can be used. We will apply the version MASHv3.03 (Szentimrey, 2017), that is an interactive automatic, artificial intelligence (AI) system.

In this project, data series from near border stations will be exchanged between neighboring countries and sub-regions for cross-border harmonization.

The selected meteorological elements are the daily mean temperature (1970-2024), minimum temperature (1970-2024), maximum temperature (1970-2024), precipitation sum (1970-2024), mean windspeed (2000-2024), wind gust (2000-2024), air pressure (1970-2024), relative humidity (1970-2024) and global radiation (2000-2024).

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# Creation of climate database for the Danube Region: first results

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As part of the Danube Adapt project, we are creating homogenized and gridded daily databases for nine meteorological elements – daily mean temperature (1970–2024), minimum temperature (1970–2024), maximum temperature (1970–2024), precipitation sum (1970–2024), mean windspeed (2000–2024), wind gust (2000–2024), air pressure (1970–2024), relative humidity (1970–2024) and global radiation (2000–2024) in the Danube River Basin. For homogenization of data series, quality control and filling in the missing values we use the MASH (Multiple Analysis of Series for Homogenization) procedure (MASHv3.03 software). Then, our gridded climate datasets are generated using the MISH (Meteorological Interpolation based on Surface Homogenized Data Basis) method (MISHv1.03 software). Using MISH interpolation, we obtain a spatially representative climate database. These two methods will be applied to the entire Danube Region. In the Danube Adapt project, the covered area is so large that homogenization, followed by MISH modelling and interpolation, is carried out in several sub-regions. In the Danube Adapt project, all meteorological elements will be at a 0.1-degree grid resolution. In the project, the homogenization of temperature data series was the first to begin in the spring of 2026. In this presentation, the subregions and the first results of temperature homogenization will be presented.

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# Bias adjustment of EURO-CORDEX high-resolution simulations by means of quantile delta mapping: Evaluation on the climate from the near past over Southeast Europe

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Global climate models (GCMs) provide a physically consistent framework for simulating past, present, and future climate states, including extreme events. Regional Climate Models (RCMs) applied at higher spatial resolution over a limited area and driven by GCMs can provide more appropriate information at smaller scales, supporting more detailed impact and adaptation assessment and planning. The RCMs' output, however, may still present large biases, inherited by the driving GCM in addition to those introduced by the RCM. Persistent biases can undermine the reliability of climate projections, making it difficult for policymakers and stakeholders to make effective adaptation plans. Various methods have been created to minimize and correct these biases as sources of error in subsequent modelling chains, and their evaluation under systematically varying climate conditions has shown that statistical distribution-based methods outperform all other investigated techniques. Our study evaluates the performance of the quantile delta mapping method for bias correction across 14 EURO-CORDEX GCM/RCM combinations, employing a consistent framework that directly compares the distribution-wise bias-adjustment potential with the ERA5-Land reference in the period 1976 to 2005. The considered variables are the daily minimum, mean, and maximum temperatures, as well as the precipitation sum. To account for both longer (e.g., decadal) natural climate variability and intermodel variability, we employ a relatively long calibration period and a large number of model runs in a stricter evaluation setup with separate calibration and evaluation periods. The evaluation is performed in terms of multiyear means and annual and monthly means of the considered variables, as well as climate indices. We show that bias correction with the selected method reduces the biases in daily temperatures by up to one order of magnitude. The degree of reduction in the precipitation bias is smaller but still significant.

Keywords: Climate Modelling, EURO-CORDEX, Multimodel ensemble, ERA5-Land, Bias Correction, Quantile Delta Mapping

# Potential usability of climatological data in integrated vulnerability assessments – Development of an integrated climate vulnerability assessment framework for the Danube region

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As climate change accelerates, translating complex climatological data into actionable and up to date policy remains a critical interdisciplinary challenge. The newly developed integrated Climate Vulnerability Assessment (CVA) methodology for the transnational Danube-ADAPT project aims to serve as region-specific tool to help climate policymakers to define the actions required.

Developed through a comprehensive review of the IPCC's methodological evolution (from AR3 to AR6) and operational systems like the Hungarian NAGiS, the framework offers a step towards aligning overlapping vulnerability and risk methodological concepts.

The methodology is explicitly designed to maximize the utility of state-of-the-art meteorological outputs. Rather than obscuring climate variables within generalized composite indices, the framework utilizes freshly collected, high-resolution spatial climate data and probabilistic climate ensembles specific to the Danube river basin to construct a robust, standalone "hazard" layer. By clearly separating the dynamic, climate-driven hazard from the inherent, non-climate influenced aspects (sensitivity and adaptive capacity) of the affected system or parties, the framework ensures that the meteorological inputs directly dictate the interpretation and understanding of the impacts of climate change and the required actions. This framework is explicitly tailored to the technical capacities and experiences of the diverse project partners and fits to the specific socio-economic data that is practically available across the Danube region, while also leaving space for further development towards involving more complex socio-economic probability calculation.

Keywords: climate change, climate vulnerability adaptation, vulnerability assessment, methodology.

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# POSTERS

# A Quality Control and Validation System for Phenological Data

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Phenological data are critical indicators of the biological responses to climate change. The main objective of this paper is to provide an overview of quality control and validation protocols of phenological data used at Croatian Meteorological and Hydrological Service (DHMZ).

Phenological observations at the DHMZ have been conducted since 1951 and were originally recorded on paper forms. Since 2019, a digital phenological database has been established, which has created the need to develop a data quality control system. The system consists of three steps. The first step involves preventing the entry of dates later than the current date, thereby avoiding the input of future observations. The second step is composed of three levels: verification of time-series completeness, verification of the phenophase sequence, and verification of the occurrence intervals of individual phenophases. The third step involves a review by the phenology specialist of the errors flagged by the application. When necessary, the specialist contacts the observer to clarify any uncertainties. Following this review, the data are either confirmed or invalidated.

The implementation of this system has enhanced the reliability and consistency of the digital phenological database. This quality control approach ensures that long-term phenological records remain consistent and suitable for studies of climate change impacts.

# ClimRisk: Climate Projections to 2100 for Europe with a Focus on the Czech Republic

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ClimRisk.eu provides open climate information across multiple spatial domains covering both the Czech Republic and the broader European region. For the Czech Republic, the platform delivers highly detailed information based on localized climate observations and a high-resolution data grid with a spatial resolution of 0.5 km. In contrast, European-scale data are derived from coarser input sources, primarily the CERRA reanalysis dataset, with a spatial resolution of approximately 5 km.

Climate projections available through ClimRisk.eu are based on simulations from the latest generation of global climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). An initial ensemble of more than 30 CMIP6 models suitable for the European region was evaluated, from which a representative subset of seven GCMs was selected to form a computationally efficient mini-ensemble. Climate projections are provided for four Shared Socioeconomic Pathway (SSP) scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5). In addition, outputs from the convection-permitting regional climate model ALADIN-Climate/CZ are included to better represent localized processes and extreme precipitation. ClimRisk.eu employs the Advanced Delta Change (ADC) method, which enables effective bias adjustment of GCM simulations while preserving the physical consistency and multi-variable structure of the projections.

For users, the platform provides long-term climatological means of key meteorological variables, including air temperature, precipitation, wind speed, humidity, and solar radiation, together with a wide range of derived climate indices, including those related to extreme events. Additional variables such as soil moisture (derived using the SoilClim model) are also available, making the platform suitable for applications in forestry, agriculture, and hydrological impact studies. The platform also provides information on the uncertainty associated with future climate projections for any selected location. The platform allows users to explore climate projections interactively and download data for specific locations across Europe.

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# Climate Data Cooperation for Evidence-Based Adaptation in the Danube Region

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The Danube-ADAPT project (2025–2028) aims to establish a harmonised climate data and knowledge base for the Danube Region to support evidence-based climate adaptation policy-making.

A key output is the Climatological Baseline Database, integrating observed and projected climate information to support climate vulnerability assessments and adaptation planning across the Danube Region.

Within this framework, an observational climate database is being developed. Building on the methodology of CarpatClim database, it includes station observations processed using established methods. Data homogenisation is performed using the MASH (Multiple Analysis of Series for Homogenization; Szentimrey) method, while spatial interpolation is carried out using the MISH (Meteorological Interpolation based on Surface Homogenized data; Szentimrey and Bihari) technique, producing high-resolution gridded datasets.

The observational database has a spatial resolution of 0.1° and provides daily data on temperature (mean, maximum, minimum), precipitation, relative humidity, and sea-level pressure for 1970–2024. Solar radiation and wind speed are included for 2000–2024.

In parallel, a Future Climate Projection Database is being developed based on EURO-CORDEX simulations. After validation of historical data, suitable model simulations that adequately represent the specific climatological features of the Danube Region are selected to be included in the projection database, covering three RCP scenarios and the periods 2041–2070 and 2071–2100 at 0.1° resolution.

Together, these components ensure scientific robustness and strong support for climate adaptation planning in the Danube Region.

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# Climate monitoring products: AgroClima and DataClima a simple and interactive way to access Drought indicators in Portugal

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Public and scientific interest in climate products has increased significantly in the last decade, driven not only by greater societal awareness of climate change but also by the growing frequency of extreme weather events. In this context, IPMA, as the national authority on climate matters, reinforces its role as a reference entity in the monitoring, analysis, and communication of climate variability and climate change. To this end, IPMA has developed two complementary platforms that integrate innovative climate modeling methodologies with in situ observational data. Together, these platforms constitute essential tools for civil society, providing reliable, high-quality, and easily accessible information. They support continuous climate monitoring and facilitate climate change adaptation, strengthening planning and decision-making processes across multiple socioeconomic sectors. The analysis of in situ observation data was carried out according to the standards of the World Meteorological Organization (WMO). Missing values for air temperature and precipitation parameters were supplemented with model data, namely forced downscaling of the WRF (Weather Research and Forecasting Model) with ERA5 (ECMWF model reanalysis dataset). The temperature and precipitation data series from the considered stations were verified with homogeneity tests using the RClimDex software package. Breakpoints were identified in some stations which were validated or rejected after metadata verification. It was found that in most series, the model data input did not cause significant variations in their homogenization.

# New Map Products in Climatological Services on the Webpage of the Slovak Hydrometeorological Institute

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Innovations in the processing of climatological data have led to the introduction of new daily climatological map products on the website of the Slovak Hydrometeorological Institute (www.shmu.sk). The new products of daily maps display average, maximum, and minimum air temperature, daily totals of atmospheric precipitation, and potential evapotranspiration with a horizontal resolution of 1 km.

Within the daily map products, two new tabs have also been added – Fire Risk Indices and Bioclimatological Products. For these products, a forecast for the next 7 days is also available. For the first three days (including the day of calculation), the forecast is based on the 2-km resolution ALADIN NWP model, while for the remaining days it is based on the coarser ECMWF IFS model. The set of fire risk products includes the FWI index, which represents the risk of the occurrence and spread of forest and vegetation fires as a result of current and previous weather conditions. The second index is fuel moisture content with a diameter of 1–2.5 cm, which indicates how much water combustible material in nature contains. It is expressed as a percentage of the total mass volume. In the case of bioclimatological indicators, three new products are available: the Universal Thermal Climate Index (UTCI), the Heat Index (HI), and a map of sultry days occurrence.

The meteorological drought monitoring also has a new interface. Compared to the previous version of meteorological drought monitoring, which was based on data from meteorological stations represented as points, the current version is a raster map with a horizontal resolution of 1 km. This provides important and relatively accurate information about drought even in areas where the station network is sparse.

Several indicators are available that have proven effectiveness in operational monitoring in recent years: the Standardized Precipitation Evapotranspiration Index (SPEI), the Standardized Precipitation Index (SPI), precipitation balance compared with the 90-day normal, percentage of precipitation compared with the 90-day normal, and drought duration. For the first three products, interactive graphs are available after clicking on district towns. These graphs show the development over the last 60 days with a prediction for the next 7 days for district towns in Slovakia. The forecast for the next 7 days is available both in graphs and in map form. It is based on a probabilistic forecast using ensembles from the A-LAEF model (for the first three days) and ECMWF (for the fourth to seventh day), representing an ensemble forecast. The forecast includes the ensemble mean value (central scenario), as well as the 10th and 90th probability percentiles, representing the boundary scenarios – the so-called drier and wetter development scenarios.

Several new user functions have also been added to the all new map products. The first is the so-called tooltip. When moving the cursor over the map, a description of the category to which the given area belongs is displayed. This helps website visitors interpret the information expressed in the map using a color scale. The second function is the display/hide option for district towns, which facilitates user orientation within the map space.

# Independent validation of daily precipitation in the Ukrainian gridded climate dataset ClimUAd

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High-resolution gridded precipitation datasets are key inputs for climate monitoring, impact and sectoral studies. ClimUAd (https://uhmi.org.ua/data_repo/ClimUAd_Ukrainian_gridded_daily) is a gridded climate dataset for Ukraine (1946–2020), which provides high-resolution (0.1°×0.1°, ~10 km) daily data, including four essential climate variables: minimum, mean, maximum air temperatures and precipitation totals. It was developed from 178 meteorological station records, with quality control performed using INQC, homogenization with Climatol and spatial interpolation by means of the MISH method. The dataset is freely available for research via the Ukrainian Hydrometeorological Institute climate data repository. ClimUAd was previously statistically compared to two global products with the same spatial and temporal resolution (ERA5-Land and E-OBS), demonstrating good overall agreement. Due to the inherently high spatial and temporal variability of precipitation, the reliability of gridded products requires assessment against observations that are independent of the stations used in their construction.

This study presents an additional validation of the ClimUAd precipitation data against fully independent in-situ observations from 17 long-term stations (precipitation posts) located mainly in the western part of Ukraine that were not involved in the gridding procedure. The raw daily precipitation records at these stations were manually digitized from historical hardcopy sources. For each location, daily gridded precipitation values were extracted via inverse distance weighting from the four nearest grid points. Performance was assessed at the daily scale using bias, relative bias, mean absolute error (MAE), root mean square error (RMSE), Pearson correlation, coefficient of determination ($R^2$), standard deviation ratio, Kling–Gupta efficiency (KGE) and categorical event detection scores (probability of detection (POD), false alarm ratio (FAR) and critical success index (CSI)) at a 1 mm threshold. Monthly and annual aggregations were additionally evaluated to assess the temporal-scale dependence of skill. An identical evaluation framework was applied to ERA5-Land and E-OBS to enable direct and consistent comparison of performance across datasets.

Results indicate strong daily performance of ClimUAd with a mean correlation of 0.77 (±0.05) and mean KGE of 0.67 (±0.05) across stations, minimal systematic bias (mean ≈ −0.04 mm) and robust wet-day detection (mean POD ≈ 0.85; CSI ≈ 0.63). Agreement further improves with temporal aggregation, with monthly correlations averaging ≈ 0.89 and annual correlations showing a mean of ≈ 0.85. Comparative evaluation indicates that ClimUAd clearly outperforms ERA5-Land and moderately but consistently surpasses E-OBS in daily accuracy and overall skill, exhibiting higher correlations and KGE, lower bias, MAE and RMSE, higher CSI with comparable or stronger performance at monthly and annual scales.

These results demonstrate that ClimUAd reliably captures both variability and magnitude of precipitation across temporal scales over Ukraine, supporting its use for climatological monitoring, regional diagnostics and impact assessments. More broadly, the analysis highlights the importance of fully independent observations for rigorous validation of gridded climatological databases.