Hungarian Meteorological Service

tradition
profession
innovation

DEAR READERS,

Since the foundation in 1870, Hungarian Meteorological Service (OMSZ) has provided the meteorological public services in our country. The exploration of the country's climate was initially the main scientific challenge, but the domestic cultivation of atmospheric science, the preparation of weather forecasts and the analysis of the ambient air soon became fundamental activity. The operation of our institution is determined by both international and national requirements. On the one hand, we must strive to be in compliance with the general principles established and adopted by the UN Specialized Organization World Meteorological Organization (WMO) and many other international organizations and bodies such as International Civil Aviation Organization (ICAO), European Space Agency (ESA), Intergovernmental Panel on Climate Change (IPCC) and European Environment Agency (EEA). On the other hand, it is necessary to meet the increasing social expectations. Weather, adaptation to climate change, air pollution is part of our daily lives, so our data and services play essential role in making political and economic decisions beside informing the public.

Global warming and finding the right responses gave our institution serious tasks. New challenges added to the classic areas of responsibility: to help preparation for extreme weather conditions by expanding our measuring and observation system with new instruments, improving our weather forecasts and warnings, strengthening our climate research activity and developing our air quality protection duty. However, the results of all these professional tasks can only be used properly when combined with close cooperation with the information users.

Recognizing the importance of social embedding, our institution seeks to increase the number of conscious users of meteorological information among the population as well as the state and economic spheres. We have prepared our new publication with the intention to give a comprehensive and general picture of the work of our institution, providing insight into the diverse, challenging tasks of meteorological activity.

Dr. Kornélia Radics
President of OMSZ

CONTENTS

RETROSPECT

In the frontline of European meteorological services with development based on stability

Extreme weather events of early times – especially natural disasters associated to these – or rare natural phenomena have been noted by people since ancient times. In Hungary data regarding weather observations is available since the 11th century, and since 1540 there is a reference to the course of the weather every year. Since the 18th century people of state and church with higher education collected weather data not only for practical use but also for the future, although the date and place of observations were rather arbitrary. Around this time, first attempts were made to exchange regular weather observations, instrumental measurements and later information as well.

In Hungary regular meteorological measurement activity begun in 1717 in Sopron. János Ádám Gensel, physician and scientist was the first Hungarian who record temperature and atmospheric pressure several times a day. The first European meteorological station network – the Societas Meteorologica Palatina – operated from 1780 for 12 years. One of the 40 participating stations was Buda, where observations were made by professor of mathematics Ferenc Weiss. We are proud that the station in Buda was one of the 8 stations which operated over the whole time of the network.

The first European meteorological network was terminated by the Napoleonic Wars. Not long after another military event, the Crimean War boosted the organization and exchange of weather observations, which lead to institutionalized observation and data exchange. In 1854 a devastating storm destroyed the

united English-French fleet near the Crimean peninsula in the Balaklava Bay. Soon afterwards French astronomer Le Verrier proved that by drawing observations of previous days on a map it was possible to track the cyclone which generated the storm. Following this, meteorological stations were set up and weather warning services of countries were established one after the other. The Austrian meteorological institute, which was founded in 1853, operated 14 stations over the current territory of Hungary in 1870.

On the initiation of the Hungarian Academy of Sciences and with the appointment of Guido Schenzl the „Royal Central Institute of Meteorology and Geomagnetism" was established in 1870, the tasks of which were the development of the station network, the organization of meteorological measurements as well as the study of the country's climatic conditions. Weather forecasting was included in the list of duties only years later during the directorate of Miklós Konkoly-Thege. Starting in 1891 the

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Statue „Urania" of Miklós Borsos in the garden of Storm Warning Observatory in Siófok

Forecasting Department issued a „Weather dispatch" daily. In 1900 there were already 765 meteorological stations in the territory of Hungary, 146 of which performed three observations per day. The building housing the headquarters of Hungarian Meteorological Service (OMSZ) even now, was built in 1910 at Kitaibel Pál utca 1. At the end of the 1920's upper air observations started to serve aviation meteorology. In the summer 1934 the storm warning service of Lake Balaton was established in Siófok.

In 1947 Hungary was among the first countries to join the World Meteorological Organization (WMO). In 1952 the Marczell György Observatory was inaugurated in Pestlőrinc, together with several other observatories in

„Experience and knowledge of nearly 150 years provides a solid basis."

the country. The Institute was given its current name in 1970, and consisted of three units, the Central Forecasting Institute, the Central Meteorological Institute and the Central Institute of Atmospheric Physics. The institutional structure ceased in 1992, when OMSZ was modernized considerably, by updating the observing network and the IT system and joining the important European international organizations.

In the past nearly 150 years our predecessors worked according to the scientific and technological standards of the time, thus Hungarian Meteorological Service is facing the challenges of our days as an institute with large experience. OMSZ has diverse tasks in the areas

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Sculpture „Sun-dial" of Miklós Borsos showing the time in the park of Marczell György Main Observatory

NEARLY
150 YEARS
OF OPERATION

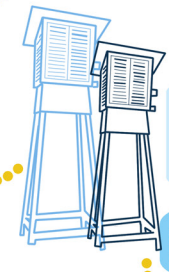
The predecessor of OMSZ was founded as Royal Central Institute of Meteorology and Geomagnetism in 1870.

300 YEARS
OF MEASUREMENT AND EXPERIENCE

The first official measurement was registered in Sopron, at the oldest station of OMSZ. Since the second half of the 18th century more and more weather stations have provided daily measurements.

HISTORICAL RECORDS IN HUNGARY FROM THE 11TH CENTURY

The first written note: "1009, Hungary: Drought. Locust invasion. (Mentioned by Milhoffer after Pap 166.)"



293
AUTOMATIC WEATHER STATIONS

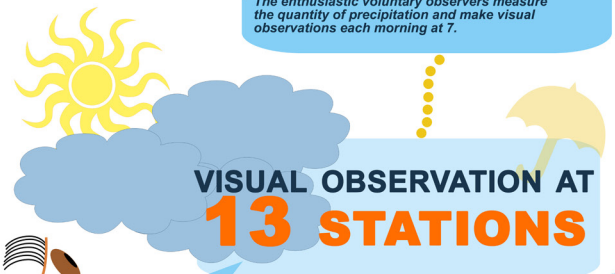
Automatic measurements are performed according to the rules of WMO at 293 locations of the country. Owing to the on-line data collection data are available real-time.

460
VOLUNTARY OBSERVERS

The enthusiastic voluntary observers measure the quantity of precipitation and make visual observations each morning at 7.

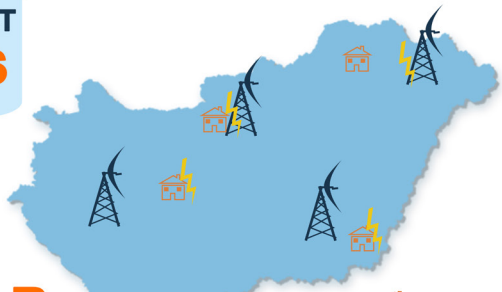
142
OF WHICH ARE SHARED WITH WATER MANAGEMENT

Hungarian Meteorological Service operates the automatic stations on the estates of General Directorate of Water Management. They are located next to rivers or lakes.



VISUAL OBSERVATION AT 13 STATIONS

The professional observers register the cloudiness, the cloud species, the height of cloud base, the visibility, the present and past weather hourly, as well as the form and quantity of precipitation at every 6 hours.



REMOTE SENSING TECHNIQE AND OBSERVATORIES

OBSERVATORY
RADAR STATION
LIGHTNING DETECTION STATION

Cross-border technique covering the entire country.
Lightning detection stations: Budapest, Napkor, Siófok, Szeged
Radar stations: Budapest, Napkor, Pogányvár, Szentes
Observatories: Budapest, Miskolc, Siófok, Szeged

STORM WARNING TO 3 LAKES

Signal system consisting of 31 lamps at Lake Balaton, 3 lamps at Lake Velence and 5 lamps at Lake Tisza ensures safety of bathers, surfers and yachtmen. In case of first degree of warning (gusts can reach 40-60 km/h) 45, while in case of second degree (gusts may exceed 60 km/h) 90 flashes/minute can be seen.

of weather, climate and ambient air, ranging from daily operational duties through research and development to education of the general public.

In connection to the operation of OMSZ – next to the professional tasks – the internal quality management and control system has to be mentioned, which is maintained in order to face the expectations at the highest possible standard. We are proud that since 2002 OMSZ has been accomplishing all of its professional activities according to the ISO 9001 quality management system. Moreover it obtained the certificate first among the European meteorological services for its overall activities. Based on the regulations of the law the quality management system – as an integral part of OMSZ – aims to increase the satisfaction of involved parties through the continuous improvement of the organization, efficiency and reliability of internal processes. Among our important costumers, in the framework of the nuclear classification our certificate issued by the Nuclear Power Plant in Paks is continuous since 2012 and is renewed every three years. In the framework of the Single European Sky (SES) initiative after the audit of the National Aviation Authority in 2006 OMSZ is managing the tasks related to aviation meteorology as a certified navigation service provider. The certification proves that the standard of service provided by OMSZ corresponds to the common requirements defined by the EU and enables it to act as aviation navigation provider in all member states of the EU. Consequently, internal controlling is not only a task of our management but the responsibility of all our colleagues.

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Relief „The meteorologist" of Margit Kovács decorates the wall of the main building of the Observatory in Gilice tér

© Hungarian Meteorological Service

Headquarters of OMSZ in downtown Budapest

„300 years in the frontline of meteorological measurements."

Measurements-Observations

The starting point for any meteorological activity is the continuous measurement and observation of the state of the atmosphere and its meteorological parameters.

The collected and controlled data serve as a basis of the findings concerning the current weather situation, investigations of the country's climate and weather forecasting. Therefore, we consider the maintenance and constant improvement of our measuring and monitoring system as a priority. In our unique professional measuring network in Central and Eastern Europe we carry out atmospheric physical and upper air (radio sounding) measurements in addition to the surface measurements and observations and we operate various remote sensing devices including weather radars, ceilometers, wind profilers, disdrometers, lightning localization network and satellite receiver.

Surface measurements

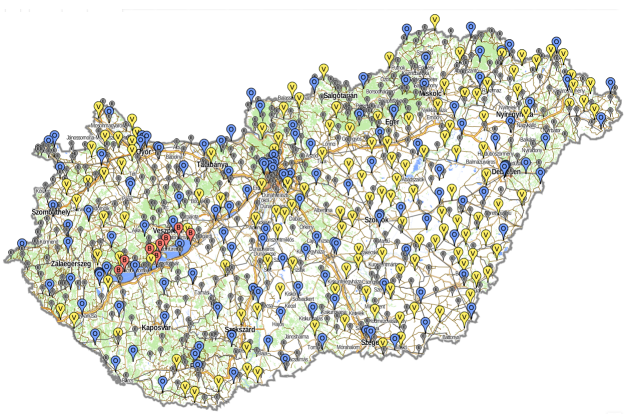
Our surface monitoring network is currently made up of 139 own, 142 jointly operated by General Directorate of Water Management and 12 other automatic weather stations and we have about 460 conventional rainfall stations. The automatic meteorological stations basically measure the weather parameters (air temperature and humidity, air pressure, wind, precipitation), but we also perform gamma-dose rate measurements at 28 sites for early detection of radioactive hazard, at three places aerosols with alpha, beta and gamma activity are

monitored and at some dozen stations we measure soil temperature and soil moisture at several layers, which are important for agriculture. We make our best to meet the needs of reliable meteorological data by installing mobile measuring stations where we flexibly adjust the measuring program, communication and power supply to user requirements. For continuous operation the network inspectors of OMSZ regularly check the technical parameters of the stations and perform the necessary maintenance.

We started modernization and development of the meteorological stations at the civil airports in 2015, which enables operation of meteorological stations at all the 4 rural international airports (Pér, Pécs-Pogány, Debrecen, Sármellék) in compliance with the regulation of ICAO (International Civil Aviation Organization) and National Transport Authority so they are capable to prepare the airport weather reports (METAR) automatically.

One of the outstanding results of recent years was the development of OMSZ's own in-house data acquisition system. We seriatim carry out the replacement of old data collectors at our stations furthermore we have also installed our own data collectors at laboratories involved in the operation of National Air Pollution Monitoring Network of the Governmental Offices. The computer program developed by OMSZ performs real-time visualization of the measured data.

Surface measurement network of OMSZ



O *automatic stations*

V *hydrometeorological stations*

E *conventional precipitation stations*

B *stations supporting storm warning at Lake Balaton*

„We also build on the enthusiastic cooperation of the amateur observers to observe the weather."

For the observation of weather, we also build on the enthusiastic cooperation of amateur observers. Through the MET-ÉSZ project we keep in touch with our volunteer observers and provide them with regular training sessions. It is a pleasure to note that the number of observers and the number of observations they carry out is growing.

Upper air measurements

To measure atmospheric state variables vertically, we regularly launch radiosondes in Budapest and Szeged at the same time as about other 750 radiosonde stations around the world. The sonde is lifted up by a hydrogen-filled meteorological balloon. The probe rises up to 25 to 30 km in about one and a half hours, while its electronic sensors are continuously measuring and its transmitter broadcasting the pressure (for certain type), temperature, relative humidity of the surrounding air and current GPS coordinates of the radiosonde to determine the direction and speed of the upper wind. The four daily ascents instead of the previous two resulted in significant progress, thanks to the recent testing and introduction of a new, more economical

Hydrometeorological station in Tarpa

radiosonde, the developing and refining of which our staff were also involved in.

Radar network

In recent years, we have put great emphasis on the development of the national weather radar network, which basically monitors rainfall, measures intensity of precipitation and tracks the atmospheric events. OMSZ operates a network of four radars, the latest of which was installed in the Southern Great Plain region near Szentes in October 2014. In addition to the installation of the new device, upgrade of the Budapest, Pogányvár and Napkor radars was also completed. We have not only developed our equipment, but also the products obtainable from the results of radar measurements. Instead of the former two-dimensional radar images, three-dimensional composite images are being made, enabling investigation of not only the horizontal properties of precipitation systems, but their vertical structure as well. The new products significantly contribute to severe weather forecasting and aviation meteorology.

The Government decided on installation of a new radar in the South Hungarian region for the proper meteorological service of a national hail prevention system – applying updraft seeding by ground-based generators – designed to reduce the significant damage caused by hail in the national economy and therefore provided additional resources for Hungarian Meteorological Service. The network of five weather radars is anticipated to provide an outstanding technical base for detecting hazardous convective cells from 2019.

„From 2019 the network consisting of five modern weather radars helps the work of the weather forecasters."

Remote sensing

It is very important to have meteorological data from not only the places where meteorological stations operate, but it is essential to know the more actual values of the more meteorological parameters are available for both the actual weather conditions as well as the forecasts and the warnings. This is the purpose of remote sensing techniques. In addition to the radars and the lightning detection system nearly 20 disdrometers help to calibrate radar precipitation data at present, while two wind profilers constantly measure the changes in wind by altitude. Recently we have installed 10 ceilometers for serving aviation needs.

Within a year, nine new surface automatic stations – with ceilometers and disdrometers – will be installed

near the Romanian border in the framework of a joint Hungarian-Romanian project, primarily to support the hail suppression system in Szatmár County.

Instrument calibration laboratory

The reliability of the measurements by the surface automated monitoring network requires regular calibration of the measuring instruments, which is performed each year for most sensors. The most important task related to the operation of the Calibration Laboratory, which calibrates the measuring instruments is to acquire the accredited status. We have set the goal that our calibration laboratory let play a kind of harmonizing role in the field of meteorological measurements in Hungary.

Maintenance at the stations: anemometers installed at 10 meters height should also been controlled

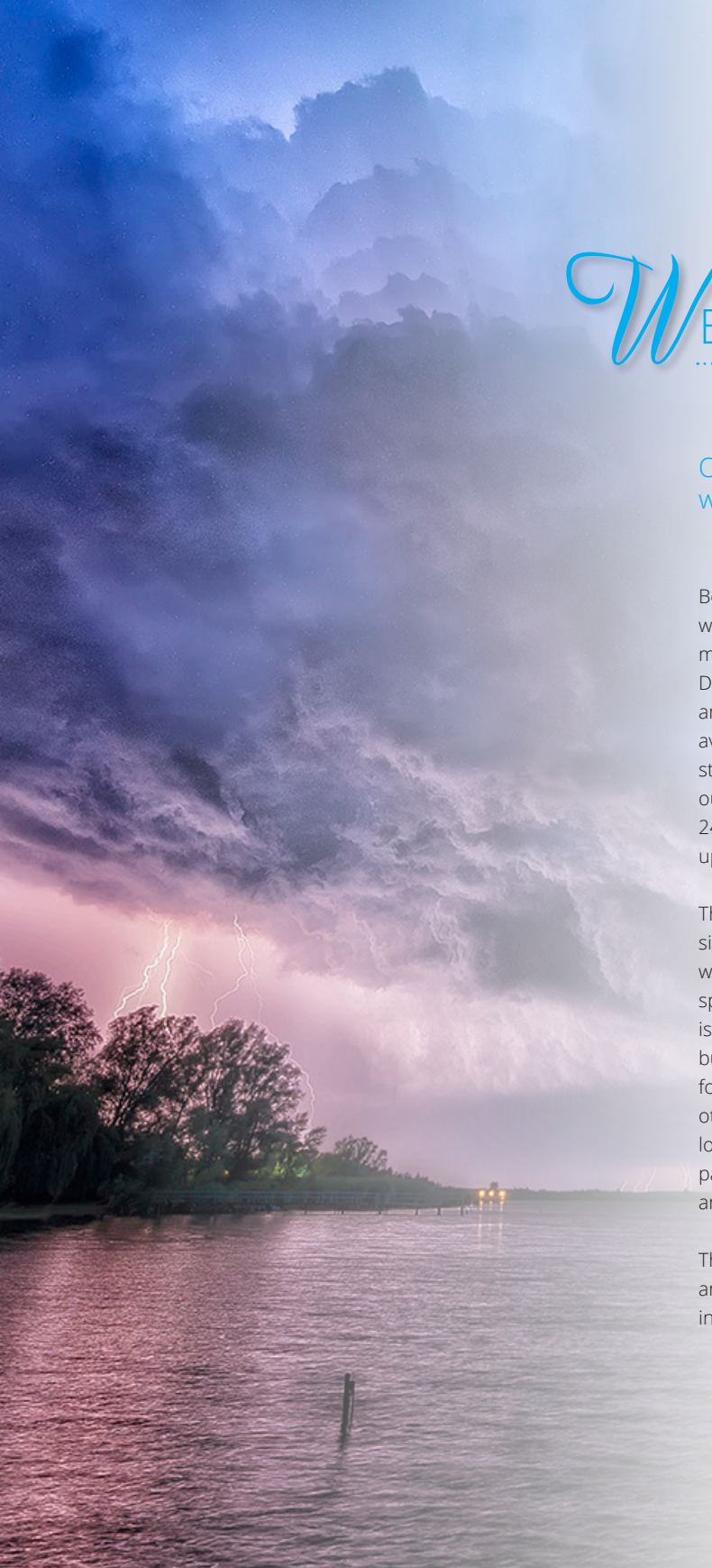
Atmospheric physical measurements

Beside measuring and observing the weather parameters it is also our task to examine the other physical parameters of the atmosphere. We perform the measurements of the total ozone content of the atmosphere, the spectral UV-A radiation and the spectral UV-B radiation and the spectral solar radiation determining transmittance of the atmosphere, the results of which are transmitted to international data centres. We keep the population informed about the measured value and strength of the UV-B radiation in the summer season. In addition to the measurements of solar radiation, we started intensive development activity for examining the possibilities for short-term forecasting of solar radiation, which is of great importance in the production of solar energy as a renewable energy source.

At the sixth meeting of the Regional Association VI of World Meteorological Organization held in October 1978, Marczell György Main Observatory was admitted to the regional radiation centers in RA VI.

Data quality control

One of the key prerequisites for the reliable measurement data from the surface automatic measuring network is the regular calibration of measuring instruments and sensors. However, sudden changes in measurement conditions cannot be excluded, which cause the credibility of measurements to become questionable, resulting in misleading conclusions. This can be eliminated by the operational data quality control activity. Our colleagues try to minimize the smaller or grater errors in the measurement data by analyzing the weather situation, the surrounding measuring stations and the measurement program of the given measuring station.



WEATHER FORECASTING

Our basic task is to provide operational weather forecasting.

Besides the general forecasts we prepare severe weather warnings to protect life and property, detailed meteorological forecasts for the catchments of Tisza and Danube rivers (for flood and inland flood prevention) and we also provide meteorological services for the civil aviation. We satisfy requests of various users from both state and economic sectors, including media. Staff of our institution monitors the weather development for 24 hours a day, analyzes the latest model outputs and updates the forecasts.

The aspect and the content of a weather forecast can significantly differ depending on whether that a severe weather warning, a general forecast or forecast with a special purpose prepared is. As for the time-range, we issue detailed forecasts for the following hours and days, but also outlooks for several weeks ahead. While some forecasts are issued for the entire country or regions, others focus on the weather characteristics of a specific location. Some users require forecast of special weather parameters, thus, a completely unique service is defined and provided upon their request.

The quality of our forecasts is constantly verified, model and methodological developments are being carried out in order to improve them.

General forecasting

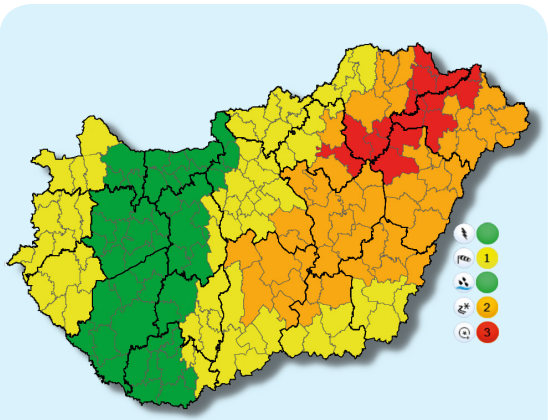
Nowadays meteorologists widely apply computer-based numerical weather prediction models, but in case of nowcasting (1-3 hour forecasts) it is very important to analyse the current weather situation of the possible highest accuracy.

Without meteorological measurements dense in both space and time it is almost impossible to tell what the weather will be, even for the next few hours. Therefore OMSZ is continuously developing the network of synoptic stations and expanding them with new instruments. Information about the course of temperature, wind, humidity and air pressure is provided by the automatic weather stations at every 10 minutes. The radar network updates the information on rainfall areas every 5 minutes, development of thunderstorms can be tracked by the help of the lightning detection network. High resolution satellite images also help the work of meteorologists owing to international cooperation. Several measurement data are processed and integrated in the MEANDER nowcasting system providing forecasts for a few hours ahead.

„A published prognosis is a result of thorough analytical and decision-making procedures."

For short and medium-range forecasts, we primarily use the model of European Centre for Medium-Range Weather Forecasts (ECMWF) and the AROME model, which is run by the supercomputer of OMSZ, but the results of other models (e.g. GFS, WRF) are also taken into account when preparing forecasts. With the spread of the ensemble technique, the role of the probability forecasting and uncertainty information concerning forecasts is continuously increasing.

A completed forecast is a result of thorough analytical and decision-making algorithms that require a number of information to be involved (data from the measurement network, satellite data, meteorological parameters of different models calculated for respective grid points and time steps, etc.). Presently, processing of all of the data would be impossible without the support of computers.



Map on alerts for districts on 17th March, 2018. The map warns of wind gusts, freezing rain and heavy blowing snow by the help of colour codes

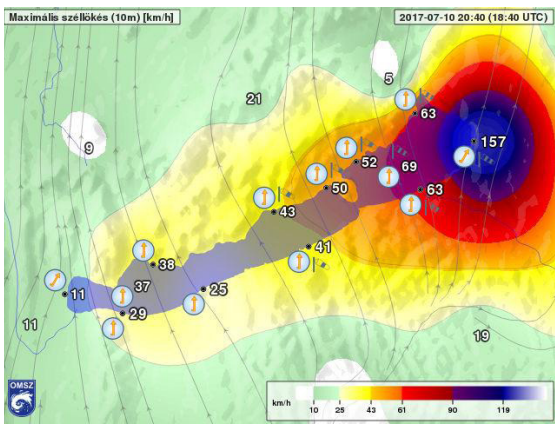
The internationally acknowledged HAWK (Hungarian Advanced Workstation) developed at OMSZ is the most important tool in the operational forecasting. The system assimilates all information necessary for the forecast preparation. It displays the data interactively in customized maps or in a graph format (meteogram) at the selected points.

Severe weather forecasting

Severe weather forecasting is aimed at protecting lives and properties. The main purpose of the system is to ensure a credible source of information for the general public, media, disaster management and other state

authorities in critical weather situations. The system provides a quick overview on current and future weather risks extended (from 2018 onwards) for the next four days, divided on districts or counties and emphasized by colour codes. The continuously updated severe weather warnings with a lead time of 1-3 hours are available on the website of OMSZ and on the Meteoalarm portal, which has been developed and operated in a frame of a European cooperation.

The pre-warnings or alerts can be related to heavy thunderstorm, torrential rain, wind gust, freezing rain, blowing snow. The severe weather warning system also consists of pre-warnings on long-lasting, high-amount rain or snow, as well as of so-called „special" warnings on occurrence of heat wave, extreme cold period or persistent dense fog.



Close to 9 o'clock in the evening on 10th July, 2017 a very powerful supercell reached Lake Balaton, from which intensive downdraft, so called downburst emerged

Storm warning for lakes

The storm warning season at the lakes of our country lasts from 1 April to 31 October each year. During this period, we ensure the safety of tourists and water transport at the lakes Balaton, Velence and Tisza. The first degree of warning is issued when wind speed is expected between 40-60 km/h and the second degree of warning if wind speed may exceed 60 km/h. For decades, there have been no fatal accidents at the lakes which would have been a result of late or missing warning.

„Severe weather forecasting is aimed at protecting lives and properties."

Aviation meteorology

Meteorological information and products supporting a variety of air transport activities enable safer, more efficient and cost-effective operation of airspace users, air navigation service providers and air traffic management. Our forecasts for aviation meteorology are used in both national and international air traffic. Our forecasting activity is performed in accordance with international standards, but we also make several other forecasts tailored to the needs of our customers, which supplement the standard products.

Based upon ICAO recommendations, we issue warning reports for the international aviation in case of conditions threatening the flights. We also prepare forecasts for four Hungarian international airports (Sármellék, Pér, Pécs, Debrecen). The meteorological support of national aviation is carried out by area forecasts, in which we provide information on severe weather events upon criteria established in cooperation with the aviation authorities.

In addition to the operational work, we are constantly improving our products to increase the safety of the flight. Since 2016, the new Aviation Meteorology website (aviation.met.hu) provides access to up-to-date and credible aviation weather reports and forecasts. On this

site, special forecasts for the needs of sport aviation are also available.

To improve the service for the most vulnerable low-level flights, we are participating in an international project aimed at providing uniform and harmonized meteorological information in Central and South-Eastern Europe through a common electronic interface for general purpose flight.

Forecasts for hydrology

Forecasts for hydrological purposes mean special applications of weather forecasts. Their most crucial element is the quantitative rainfall forecast, since the water balance of rivers, streams and lakes can be significantly influenced by the amount of rainfall. Moreover, knowing the precipitation conditions is of vital importance for flood protection and other water management tasks.

© Schmall Rafael

A supercell nearby Kaposfő on 11th July, 2017

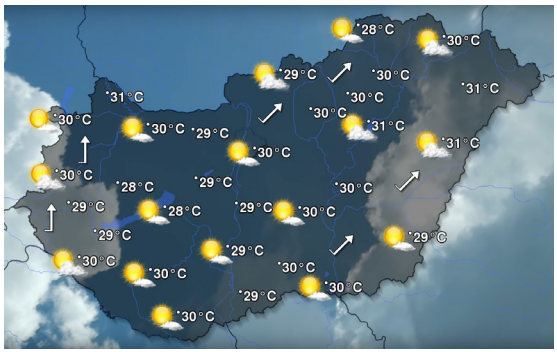
Today, precipitation forecasts rely mainly on numerical forecasts provided by various meteorological offices. Experts in hydrology receive 10 day forecasts of regionally averaged precipitation for 21 water catchment areas, which are updated twice a day. Besides, forecasts of maximum and minimum temperature as well as the altitude of 0 degree of Celsius are provided.

Weather services

The public is directly informed about the expected weather conditions through the OMSZ website (www.met.hu), where, in addition to the usual text forecasts, maps and graphs, one can find weather related articles and studies. In order to present the meteorological forecasts as clear as possible –once or twice a week – our staff prepares a short movie about the expected weather. Until now, such product was not available on the meteorological market and its preparation was possible by the re-utilization of the OMSZ TV studio and innovation of its technical facilities.

Besides state-funded tasks, we also provide special services for media, industry, transport, agriculture and for sport and free-time activities by contracts. Nearly 270 partners are regularly supplied with data and forecasts and there are approximately 200 customers requiring these products occasionally, especially when organizing events.

„Our meteorological forecasts for aviation are used in both domestic and international air traffic.”



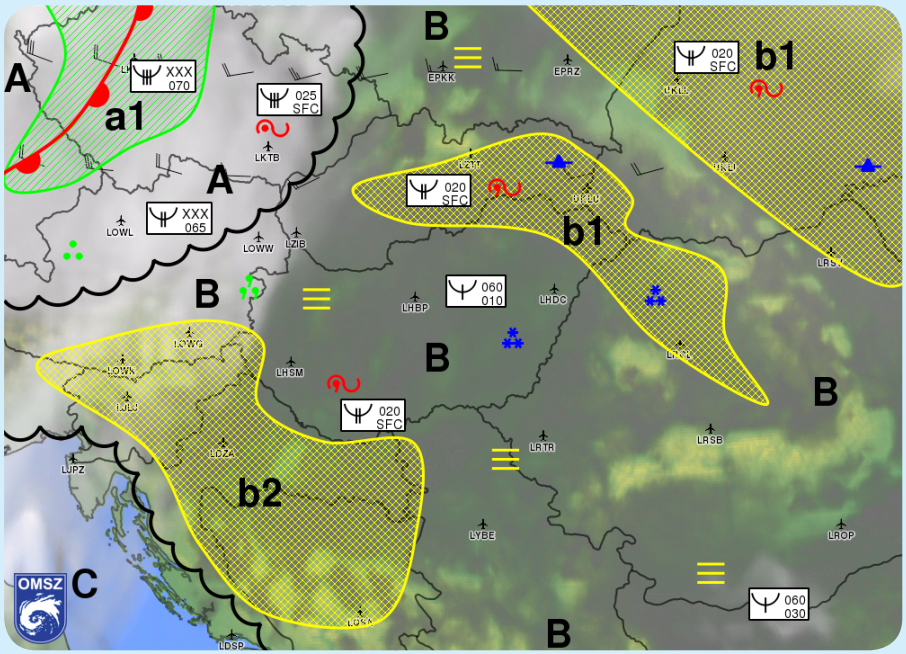
A weather forecast map compiled from short films made in the improved studio gives information on the weekly weather expected

We have contracts with more than a dozen television and radio companies. These products are generated through a continuously maintained IT background, following the needs of the partners and largely using the OMSZ's forecast database.

The most important product for energy suppliers is the forecast of the daily average temperature, upon which the probable energy consumption can be estimated. Some years ago, our partners requested only these forecasts for a few days ahead, but today we provide information to our partners for a 15 day period. In addition to daily average temperature, there is an increasing demand for the prognoses of temperature of temporal resolution of one hour and for global radiation.

For road transport, we provide a number of special forecasts such as the snowfall probability, hourly freezing rain amount, blowing snow index or the 24-hour snow amount distribution for Hungary, that help to prepare for the winter road conditions.

The weather information available on the OMSZ website also provides significant support to the agricultural sector. Maps representing the past weather, precipitation and sunshine duration conditions, but also soil moisture, soil temperature and water scarcity are shown. We also issue information on the current drought situation based on a special soil model.



Low-level significant map for small general aviation aircrafts. The territories of different weather are separated by thick black lines, while areas in yellow show the regions especially dangerous for aviation. The map informs on the fronts as well, the symbols warns of flight-limiting phenomena

Besides forecasting, we accomplish market-building and partner care tasks as well. Furthermore, we continuously evaluate and develop the forecast methods, which facilitate our operational activities.

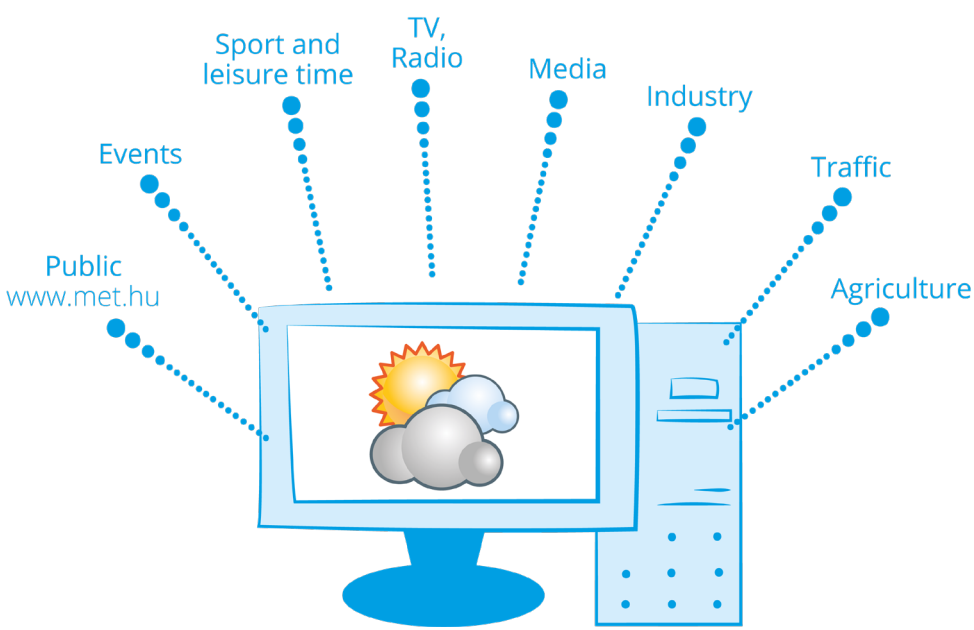
Verification of forecasts

The statistical evaluation of the forecast accuracy based on measured or observed data (verification) is important for both users and forecasters. Being aware of the errors in forecasts users can make their weather-related decisions.

The verification results motivate the forecasters to reconsider their daily routine and improve their work. Revealing the causes of a poorly managed forecast can greatly contribute to avoiding similar types of errors in the future. As forecasts are closely linked to the outputs of numerical weather prediction models, verification of forecasts also reveals their systematic errors. Case studies and long-term research can provide very useful results on the behaviour of the models applied and identify the main directions for their further development.

„The public is directly informed about the expected weather conditions through the OMSZ website: www.met.hu."

The service areas of OMSZ



CLIMATE ACTIVITIES

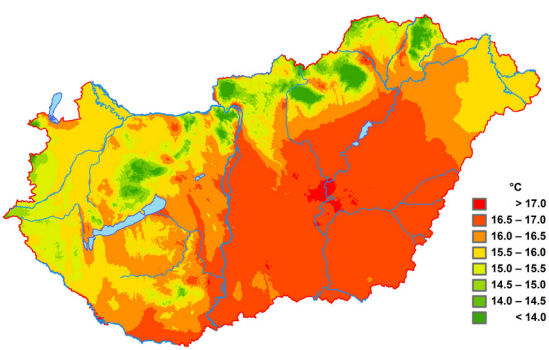
Detection of climate change requires an accurate comparison of the data we have had nowadays and measured in the past.

One of the greatest challenges of our time we have to face with is global warming and managing problems arise as its consequence. In the development of appropriate responses, adaptation and mitigation strategies, the science of meteorology – as a fundament-- plays a prominent role. To this end our Service has special responsibility for analysing the past and present climate of our country, detection of changes and preparation of future climate projections. As a result of our work a wide range of needs are met by climate services. Development of the methodology in statistical climatology, climate modelling activities, as well as climate analyses based on these tools provide correct and reliable information to contribute climate change adaptation both for general public and decision-makers.

STATISTICAL CLIMATOLOGICAL ACTIVITIES

Detection of climate change requires accurate comparison of the data measured nowadays and in the past, while the environment, instruments and methods of measurements have changed several times over the years. On the other hand, we are also curious about changes in areas where measured data are not available. Thus, it is essential to apply statistical methods to the carefully controlled data by which we

get homogenized grid data series. During the regional CarpatClim project and the establishment of the Hungarian NAGiS (National Adaptation Geo-information System) database some years ago, we created daily homogenized grid data series at 0.1° spatial resolution using the homogenization and interpolation techniques developed by us (MASH-MISH systems). Data series have been prepared for the most important meteorological variables (eg. maximum, minimum and mean temperature, global radiation, wind, relative humidity, air pressure, clouds) and other derived parameters, indices (eg. days with special rainfall and temperature thresholds, drought indices, tourism climate indices). We keep our databases up to date, taking into account additional stations can be used as a result of data recording, furthermore we extend them to other variables and to the last few years.



Average mean temperature in May (1981-2010)

Our climate specialists developing homogenisation and interpolation processes are internationally acknowledged and our methods are used in many other countries as well. Our recognition is also reflected in the fact that the great international assemble of meteorologists in this discipline has always been organized in Budapest.

Climate modelling

The idea to initiate climate dynamics research at OMSZ (besides the traditional statistical climatology) had arisen in 2003, as modelling provides the only tool to explore the potential response of the climate system to a hypothetic anthropogenic forcing. Climate projections inherently include uncertainties arising from the chaotic nature of the climate system, from imperfections of the numerical models and also from the ambiguous future evolution of human activity. Therefore, the correct interpretation of the model simulations should contain information about their likelihood. This can be achieved with the ensemble technique, i.e., with the joint evaluation of several climate model experiments.

„By adapting the regional climate models we have joined the European research network."

For this reason, two regional climate models (RCMs) were adapted at our service: ALADIN-Climate, which was developed at Météo France, and REMO model of Max Planck Institute in Hamburg. Having established the modelling fundaments OMSZ joined to the European research network and participated in international co-operations investigating climate change effects. For the assessment of 21st century climate change in Hungary, several projections have been made by ALADIN-Climate and REMO applying different anthropogenic scenarios. Furthermore, other European climate model results produced under the framework of Euro-CORDEX international collaboration have been assessed in order to reveal whether the larger ensemble modifies the uncertainty range of the future changes.

The National Adaptation Geo-information System (NAGiS) created in 2013 provides a harmonized data basis for the adaptation studies using locally run RCM results as inputs for the quantitative climate impact assessments. Thanks to the efforts of the Regional Climate Modelling Group of OMSZ, the end users have become acquainted with the probabilistic climate information and the decision making based on them.

Our projects

OMSZ is participating in numerous national and international collaborations and projects, whose purposes are to facilitate adaptation and mitigation to climate change and develop the quality of climate change services.

Several international projects foster the success of the Copernicus Climate Change Service (C3S) program – funded by the European Commission and executed by European Centre for Medium-Range Weather Forecasts (ECMWF) –, amongst OMSZ is taking part in three of them. The aim of the Data Evaluation for Climate Models (DECM) project is to assess user needs on projected climate information, to catalogue the numerous available global and regional climate simulations, to reveal scientific and data-related gaps and finally to provide recommendations for a cutting edge, user-friendly European service of climate projections. As a consortium partner, OMSZ has been responsible for the inventory of the currently publicly available climate model simulations

„The aim of our projects is mitigation of the effects of climate change."

within a broad set of criteria. The aim of the Copernicus Climate Change Service based on Surface in-situ Observations (C3Surf) project is to produce a database containing in-situ observations for Europe. OMSZ makes available a homogenised and harmonized gridded database for the Carpathian region for the planned European scale database, which was prepared in the former CarpatClim project, and develops various climate change indicators. Copernicus C3S European Tourism (CET) project serving the climate data and service needs of the tourism sector focuses primarily on urban and 3S (sun-sea-sand) tourism.

Countries participating in INTERREG project

The main expected result of the Drought Risk in the Danube Region (DriDanube) Interreg project is improved drought emergency response and better cooperation among operational services and decision making authorities in the Danube region on national and regional level, thereby increasing the adaptability to climate change. The task of OMSZ is to develop the methodology of the drought risk calculation and to create risk map for the project area.

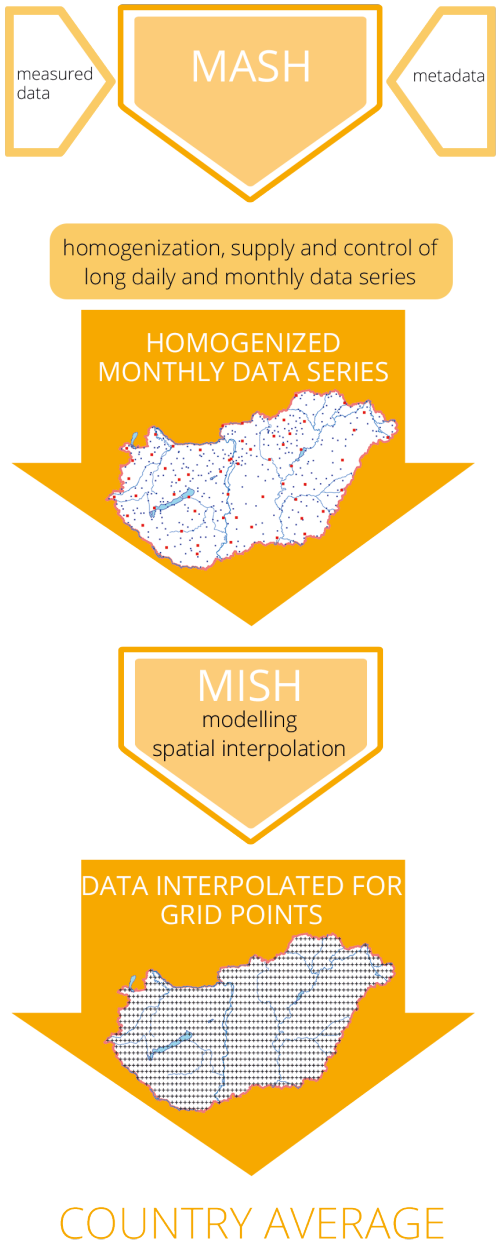
OMSZ is chairing the Pannex (Pannonian basin Experiment) regional climate co-operation, which has been widening since 2016. In the framework of this cooperation the White Paper, which contains the most

important scientific issues in the region, has been completed. Its main themes are adapting agricultural activities to weather and climate extremes, air quality in various climatic and climate conditions, sustainable development and water management. The annual meetings strengthen the development of regional research networks and create opportunities for joint projects.

In the KlimAdat project entitled „Assessment of climate change impacts in Hungary with regional climate model simulations and development of a representative climate database" (funded by the European Regional Development Fund and the Cohesion Fund), a gradual extension of the NAGiS projection basis is being achieved from 2016 to 2020. Climate model simulations following the latest anthropogenic scenarios by the newest version of ALADIN-Climate and REMO models are ongoing. The resulting projections will be incorporated into the SURFEX surface model, which can quantify the urban characteristics of climate change in detail. As a final step, a web-based geo-information system will be set up containing climate model simulations along with their uncertainties, in order to directly support further impact studies.

Climate services

For various inquiries we provide climate data to more than 100 partners each year, and prepare climate studies, data processing and special grid databases for dozens of users. To inform the general public we continuously update the homepage of OMSZ on the climate issue, prepare reports on the weather of last periods and on extreme situations. The renewed agro.met.hu site provides agri-users with more and more advanced agrometeorological information that is in line with legislative changes.



Production process of representative climatological data

ANALYSIS OF AMBIENT AIR

The effects of human activity on the composition of the atmosphere have been examined on the basis of ongoing air chemistry measurements by OMSZ for half a century.

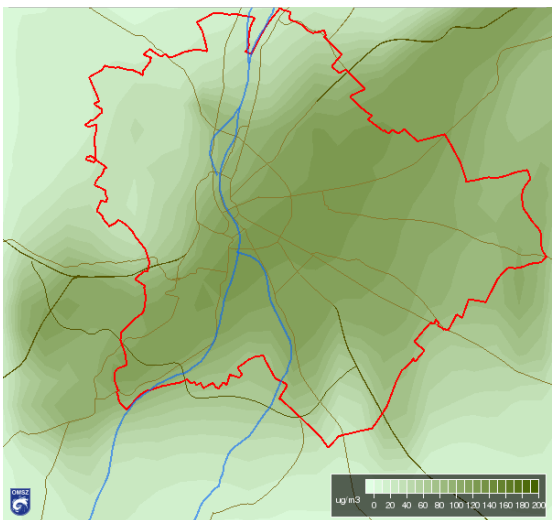
The atmosphere is a mixture, a colloidal system of several gases and microscopic-sized solid and liquid particles finely dispersed in it. The physical and chemical processes taking place in the atmosphere are determined by its composition. The effect of human activities on the atmosphere can be well detected since the industrial revolution has unfolded, and this impact has become decisive by now. Air pollution is not only an environmental problem, but it is an increasing social issue as well. Air pollution affects human health, ecosystem, built environment as well as climate. Continuous evaluation and prediction of the quality of the ambient air are rightfully demanded by people and authorities. Accurate and real-time determination of the path and concentration of air pollutants can save lives in case of accidental chemical or industrial releases. Air quality monitoring and air chemistry research have been going on for half a century at Hungarian Meteorological Service, and its duties have been enlarged with air quality protection tasks in the last years.

Monitoring of background air pollution

Air pollutants emitted by human activities remain in the atmosphere for a different length of time depending on

„The background air pollution is measured by a monitoring network of five stations."

their physical and chemical characteristics. Pollutants with long residence time can be dispersed over large distances, even in the whole atmosphere of the Earth. Air pollution of areas at large distances from emission sources is called background air pollution. The effect of local polluting areas (cities, industrial areas, motorways with high traffic) is superimposed to the background level. Background pollution may be transported or formed over long distances (on regional and global scales), thus having significant impacts on the biosphere and the climate. The air pollution level of areas far from direct pollution sources is observed by a monitoring network of five stations operated by Hungarian Meteorological Service. The stations have slightly different monitoring programs. Hegyhátsál station focuses on greenhouse gases with long residence time and thus smaller spatial variability. These measurements, also involved in international research activities are supported by EU-funded projects and performed co-operatively with National Oceanic and Atmospheric Administration of United States of America, respectively. The other stations monitor pollutants (materials causing eutrophication and acidification, tropospheric ozone, aerosols, etc.) with shorter residence time and larger spatial variability, which needs denser monitoring network. K-puszta and Farkasfa stations have prominent role, as they are members of the monitoring networks of World Meteorological Organization (WMO) and the European Evaluation and Monitoring Programme (EMEP).



NO_2 forecast for Budapest region

Certain part of the measurements is performed by automatic gas analyzers at the monitoring stations (in situ measurements). These results have real-time availability at different websites (e.g. www.levegominoseg.hu). Nevertheless, greater part of the examined components can be measured only by sampling and subsequent laboratory analysis. Precipitation, aerosol and air samples gathered by material-specific methods are taken to the laboratory in Budapest, where they are analyzed by modern chemical analytical equipments. Thus, data describing the state of the ambient air are available with a delay of a few weeks. All ambient data are issued in the monthly periodical called Ambient Air Bulletin, which are freely available on the web portal of OMSZ.

Air pollution modelling

Neither financial nor technical possibilities exist to carry out measurements in every spatial point. However, continuous spatiotemporal distribution of air pollutant concentrations can be calculated based on the known characteristics of atmospheric flows and pollutants, the localization and yield of main sources. In addition, mathematical models describing the dispersion and transition of air pollutants make the evaluation of the eventual effects of supposed releases (impact studies) and – combined with numerical weather prediction models – the estimation of the expected evolution of air pollution possible. Different models are effective to use for different problems, on the one hand to keep the

computation needs within feasible limits, on the other because the relevance of individual processes varies depending on the target and spatiotemporal scale of their application.

Based on EU regulations, in addition to air pollution monitoring, Member States prepare national regional and urban air quality reports based on model

Major sources of air pollutants contributing to acid rain

calculations. These assessments contain identification of emission sources affecting air quality of a region. These kinds of calculations are based on multi-layer model systems. At Hungarian Meteorological Service, development of an evaluation model system started in 2015. First, the EMEP chemical transport model has been adapted to calculate concentrations over Europe using the gridded emission database of EMEP as well as the meteorological data of ECMWF. The EMEP model provides us lateral and initial boundary conditions for air pollution concentration calculations. Based on this information, model calculations of finer spatial resolution (10 km x 10 km) can be done for Hungary taking into account the transboundary long-range transport of air pollutants. Model calculations for the air quality of Hungary and its big cities are performed with the CHIMERE chemical transport model. Another important condition of the model runs is an emission database of 0.1º x 0.1º resolution.

Primarily in case of accidental releases from point sources, transport and dispersion of air pollutants is calculated for European, regional as well as local scales. Operative model runs are done twice a day for Paks nuclear power plant using the regional scale FLEXPART dispersion model and given emission values. Model runs can also be manually operated via the HAWK system of OMSZ, which means, that real emission data can be put into the system by the users in case of an accident.

Air quality reference centre

Air Quality Reference Centre (LRK) performs the operative tasks of professional guidance and quality control of Hungarian Air Quality Network (OLM). By statutory designation, LRK is the national reference laboratory ensuring the traceability of air quality investigations.

LRK is an EN ISO/IEC 17025:2005 accredited calibration laboratory equipped with modern instruments. The reference centre performs the control calibration of gas analyzers of the air quality network and other organisations using different metrological quality benchmarks in its laboratory or on-site if necessary. LRK issues, handles and lists the type approval certificates for continuously working automatic gas analyzers and particulate matter monitors.

Based on its MSZ EN ISO/IEC 17043:2010 accreditation in 2016, the proficiency office of LRK plans, organises and arranges interlaboratory comparisons provided by law for workgroups who measure ambient air quality or emission, as well as comparative field-tests among air quality measuring stations.

In 2017, LRK was supplemented with an analytical laboratory for on-site air quality measurements, sampling and laboratory analysis. The accreditation of this department is in progress.

LRK is represented at EU institutes as the Hungarian national reference laboratory and participates in international interlaboratory comparisons. The

department determines and verifies the quality aims of Hungarian Air Quality Network run by the Government Offices, inspects their implementation and coordinates the operation of the measurement network. LRK fulfils the tasks of the national data centre, prepares the annual reports and complies with the obligations of the domestic and international data supply.

National emission inventories

Compilation of emission inventories is an international statutory obligation, with the main goal to evaluate atmospheric emissions relating to human-induced activities like energy production and consumption, industrial production and the use of specific materials and machines, carriage and transportation, animal husbandry and crop production, land-use and forestry as well as waste management. Greenhouse gases (carbon-dioxide, methane, nitrous-oxide and different fluorinated gases) and air pollutants (nitrogen-oxides, sulphur-dioxide, ammonia, volatile organic compounds, particulate matters, heavy metals, persistent organic pollutants) are covered in two different inventories. Emission inventories can justify that a Party complies with the emission reduction target set in the conventions and protocols.

Emissions are estimated based on internationally agreed guidebooks and guidelines in order to ensure the comparability of emissions reported by parties. Scientific progress and the decision-making requirements result in changes in the reporting obligations as well as the emission calculation methodologies. The latest methodological change in 2015 had significant effects. As the time-series consistency is very important in the inventory, in order to avoid artificial effects arising from methodological changes and to reflect the real annual changes, we had to recalculate the whole inventory time-series. We have been doing this since then in case of methodologies changes or quality improvement of activity data. Therefore, we suggest utilisation of the whole time-series of the latest inventory submission which is freely available for anyone.

Our data and emissions are regularly reviewed by international expert teams. Moreover, the fellows of OMSZ are also involved in the review processes of other states. We are proud that Hungary received one of the awards for the significant improvement of the inventory at the international annual meeting of the inventory compilers in 2017.

„Hungary received a prize at the international annual meeting of the inventory compilers in 2017.”

Emission inventories generally cover annual country data, but as a result of our latest development, air-pollutant emission data has also been made available on a 0.1° x 0.1° grid. We took part in different international workgroups, and we strengthened the co-operation within the Visegrád Group. We do our best in supporting the development of a National Greenhouse Gas Database project in the framework of Environment and Energy Efficiency Operational Programme, as well as in forecast of emissions.

Equivalence test

NUMERICAL MODELLING AND R&D ACTIVITIES

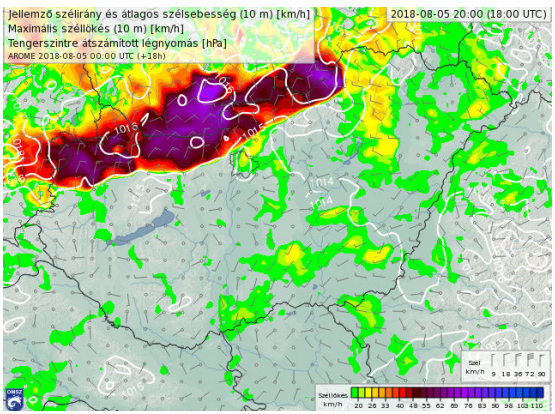
The OMSZ's own model development provides significant assistance in the production of targeted prognoses for Hungary.

HIGH RESOLUTION NUMERICAL WEATHER PREDICTION MODELS – OPERATIONS AND DEVELOPMENT

Medium range forecasts (7-10 days) issued by OMSZ are mainly based on the products of the global model developed by ECMWF (European Centre for Medium Range Weather Forecasts), however, short range (6-48 hours) forecasts with fine spatial details are made applying high resolution regional models (ALADIN, AROME) run by OMSZ.

Regional models are developed since 1992 in the framework of the ALADIN and LACE international cooperation, which means that the source code of the models is also at our disposal and we are able to carry out further developments according to our needs. Moreover, all the members of the cooperation can incorporate the developments in the official code version which is then available for all the other members. This structure not only ensures the development of the source code of the model, but improves the proficiency of the high resolution forecasts on the long term as well.

OMSZ's own model developments represent a significant added value in the production of targeted forecasts for Hungary, as these enable the best simulation of weather phenomena characteristic for the Pannonian Basin. Production of forecasts is also served by the WRF model, which is developed in the United States and is also based on the products of ECMWF to describe smaller scale atmospheric processes.



Wind forecast map from AROME model

Model development activities of OMSZ help the improvement of targeted forecasts over Hungary in three different aspects. First, as many as possible local observations (surface observations, aircraft based observations, radar and satellite information, etc.) are incorporated in the initial fields of the model. Secondly, description of small scale processes is refined according to local phenomena. Next to these so-called ensemble forecasts are produced and developed to provide probabilistic information, accounting for the larger uncertainty of smaller scale processes.

Currently the ALADIN at OMSZ model is run four times a day at 8 km horizontal resolution while the convection resolving AROME model is run eight times a day at 2.5 km resolution. The WRF model is run both at 1.5 and 2.5 km resolution four times a day. This is complemented by a probabilistic forecasting system (currently based on ALADIN, in future on AROME), which gives an estimate on the uncertainty of forecasts by a simultaneous integration of 11 forecast members. These local models ensure high flexibility regarding the temporal and spatial resolution of outputs as well as enable the production of specialized forecasts tailored to the users' needs.

Application of ECMWF forecasts

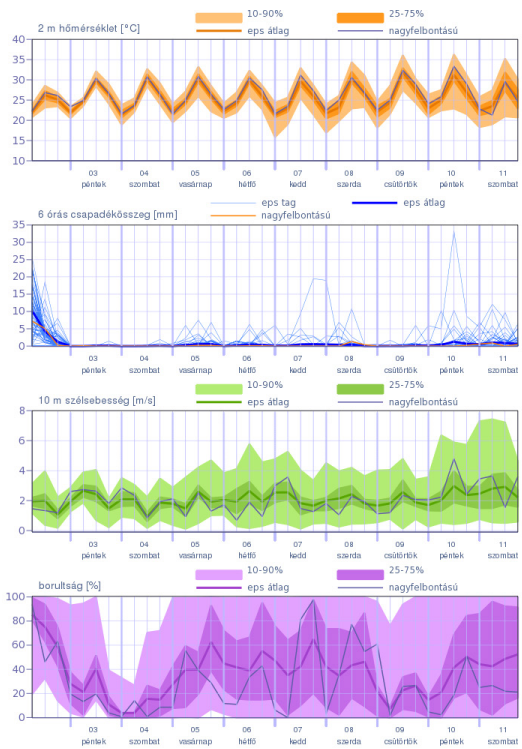
OMSZ's forecasters have been using ECMWF products since 1995. Hungary is a cooperating state of ECMWF and thus the meteorological archive and software packages developed by ECMWF are at our disposal. We participate in the Training Program of ECMWF and occasionally in the work of the Centre in Reading.

„Regional models enable generation of a great variety of special products tailor made to the users' needs."

At ECMWF 10 day forecasts are made twice a day initialized at 00 and 12 UTC at 9 km horizontal resolution.

Due to the chaotic behaviour of the atmosphere, missing observations and errors of the numerical model forecast errors considerably grow with increasing forecast time. To take account of these effects an ensemble of forecasts is run to produce probabilistic predictions. The ensemble forecasting system of ECMWF contains 51 members at a horizontal resolution of 18 km. At 00 and 12 UTC the forecast length is 15 days while at 06 and 18 UTC it is 7 days.

Several software packages used in operational practice were developed, which on one hand help the efficient use of model result during the preparation of weather forecasts, on the other hand generate



The expected evolution of values of certain meteorological parameters can be monitored on ECMWF plume diagram

specialized products for stakeholders and customers. So-called plume diagrams and meteograms, which are generated for an arbitrary location from the ensemble forecast using all 51 members for a given meteorological parameter, are applied to inform the general public and customers. An important improvement was the development of the clustering algorithm with its centre in the Pannonian Basin, which enables to group the 51 members of the ensemble forecast and get a simplified picture on the possible future states of the atmosphere.

Next to the above described operational applications ECMWF model results are used in other areas like to provide lateral boundary conditions for regional models, for the calibration of probabilistic forecasts and for synoptic climatological studies based on the reanalysis database of ECMWF.

Nowcasting developments

Nowcasting, which in practice means ultra short range forecasting (less than 3 hours) and thus issuing of warnings for severe weather events, lies on two pillars. The first pillar is the accurate numerical description of the weather situation, namely, the objective analysis. The second is the numerical solution of the equation system describing the physical laws in the atmosphere: the numerical forecast.

„Nowcasting prognosis is prepared at OMSZ in every ten minutes.”

The supercomputers of Hungarian Meteorological Service enable to apply a non-hydrostatic model which is capable to describe small scale processes like thunderstorms and local circulations. WRF is such a model, which was adapted at OMSZ. The model applies the nudging technique, which assimilates measurements and observations over several time steps. The nowcasting system developed at OMSZ derives its initial conditions from the objective analysis and the end of the nowcasting (typically a +3 hour forecast) is taken from the model.

Between the two time points a certain smoothing is applied for the fields of basic parameters. From the smoothed fields motion vectors are derived which are used to forecast the movement of precipitation systems. The outcome of the method is that the expected „current weather” parameter is computed for all grid points.

Obviously, this method could produce a realistic forecast for three hours at most, consequently it is important to repeat it frequently. Currently at OMSZ the nowcasting system is run every 10 minutes and its outputs are essential for issuing weather warnings and storm forecasting to lakes.

Verification

Verification reports are regularly prepared from the operationally used weather forecasting models and experimental runs with the OVISYS (Objective VerIfication SYStem) software package which was developed at OMSZ. The system is capable to verify surface variables as well as vertical profiles. Monthly, quarterly, half-yearly and yearly reports are produced automatically, which enable the monitoring of the models used. In addition, we can study the impacts of modifications in the models before implementation.

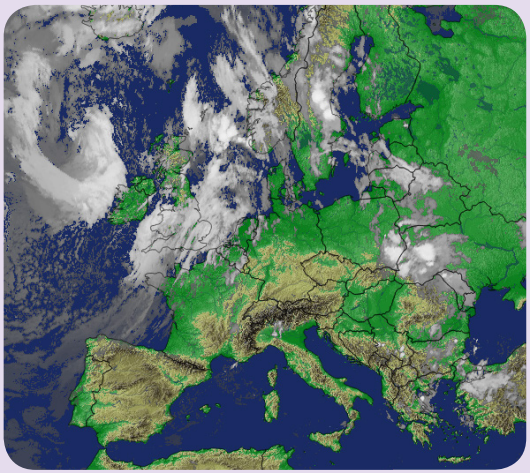
Satellite meteorology

In connection with satellite meteorology our main task is to provide weather forecasters, numerical modellers and internal and external users with satellite data and derived products. Data from several satellites are used by OMSZ: the geostationary METEOSAT, the quasi-polar orbiting MetOp, NOAA, AQUA, TERRA and Suomi NPP. While METEOSAT and METOP are operated by European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) the others are run by the United States of America. Hungary is a Member State of EUMETSAT and OMSZ is the official representative of the country.

EUMETSAT provides not only raw data for its Member States but derived atmospheric parameters as well as software packages prepared by international working groups (Satellite Application Facility, SAF). OMSZ is actively participating in these projects. The Nowcasting SAF working group is creating a software helping the weather analysis and ultra short range forecasting (nowcasting) of parameters like cloud cover, cloud

„A priority research topic is the investigation of thunderstorms by the help of satellite data."

type, cloud top height, wind fields, stability indices etc. At OMSZ the software package (SAFNWC) is run operationally, and the new versions and products are continuously tested. The Hydrology SAF is producing precipitation estimates, soil moisture and snow parameters from satellite observations for hydrological applications. The task of OMSZ in the project is to investigate the accuracy of precipitation estimates by radar data and automatic surface precipitation observations thus helping the developers. The Ozone and atmospheric chemistry SAF (O3M SAF) derives the



METEOSAT infrared image showing clouds

vertically integrated amount of trace gases and aerosols as well as intensity of UV radiation reaching the surface. The Land surface analysis SAF (LSA SAF) provides

products related to the Earth's surface and surface-atmosphere interactions from the observations of METEOSAT and MetOp satellites.

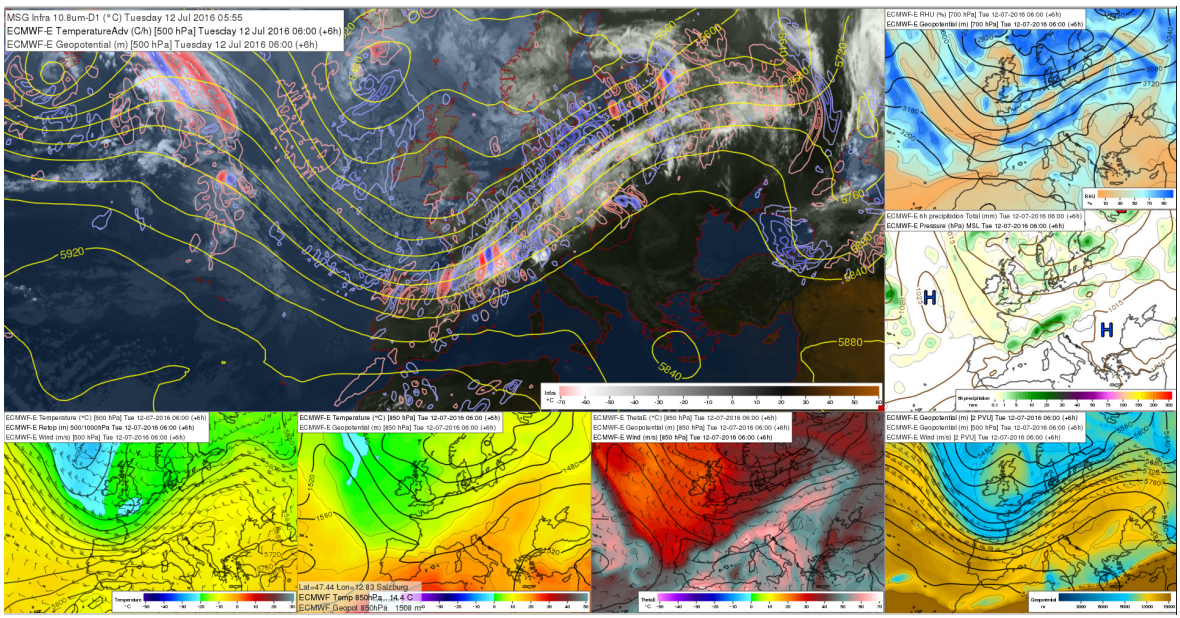
A priority research topic is the investigation of thunderstorms by the help of satellite data and the participation in the „Convective Working Group" of EUMETSAT. The development activities are mainly concentrating on the preparation for the new generation satellites, which are to be launched in the next years. The Japanese Himawari and the American GOES satellites already have those long-wave channels which will operate on the third generation Meteosat satellite (MTG) to be launched in 2021, thus we analyze the new information from these instruments.

Our colleagues regularly give internal lectures as well as presentations at training courses organized by EUMETSAT, in order to help the efficient application of satellite information. The „EUMETrain" program of EUMETSAT aims to assist online training. OMSZ actively participates in this program with preparation of training materials and case studies.

HAWK-3 METEOROLOGICAL WORKSTATION

HAWK-3 is OMSZ's in-house developed, operationally used interactive visualization system, which is widely applied by European meteorological services and partner institutes, due to its international success. The workstation enables forecasters to organize the large amount of meteorological information during the daily work. The program can visualize data on maps or on specialized meteorological diagrams (e.g. emagram, vertical cross section). Due to its specific visualizing functions HAWK-3 is a powerful tool for the overview of weather processes and numerical predictions.

Primary users of the HAWK-3 system are the forecasters, however, it is a useful tool for research tasks as well, especially for case studies and for the production of maps and figures in publications. It is indispensable for the information of the general public and for forecasting services as most weather maps on the homepage of OMSZ are prepared by HAWK-3.



HAWK-3 visualizing system is capable to customize depiction of the various meteorological parameters

The meteorological workstation is continuously developed according to the needs of forecasters, researchers and external users.

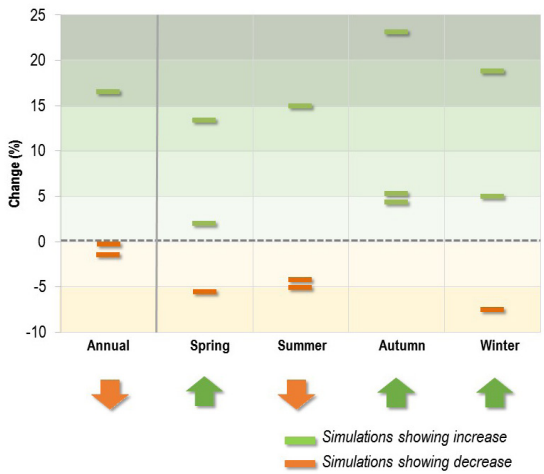
Regional climate modelling

The future change of the climate system – similarly to weather forecasting – could be investigated by numerical models, which describe the physical laws governing the system in the form of mathematical equations. The behaviour of the entire Earth system could be studied by coupled global climate models. Future climate change could be significantly influenced by human activity, however, it is not possible to accurately forecast it.

„Most of the weather maps are made by the HAWK-3 software package."

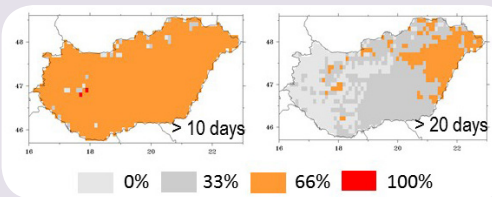
Consequently, this uncertainty is taken into consideration by different (optimistic, pessimistic) scenarios. Nowadays global climate models developed in large climate research centres are able to reliably describe the behaviour of the components of the climate system and the interactions among them, thus these can be applied to study the global characteristics of climate change. Due to their extraordinary computational needs these models could only provide limited information about the regional aspects of climate change, as even today their horizontal resolution is around 100 km. To reveal the details regional climate models are used to refine the large scale global information over a selected domain.

At Hungarian Meteorological Service two regional climate models (ALADIN-Climate which was developed in the framework of an international collaboration at Météo-France and the REMO model developed by Max Planck Institute in Hamburg) and different scenarios are used to study the possible future climatological changes of Hungary and the Pannonian Basin.



Expected change (%) of the annual and seasonal amount of precipitation in Hungary through 2021-2050 on the basis of three regional model simulations made by OMSZ. The typical change direction is indicated by arrows (orange: less precipitation, green: more precipitation). Reference: 1971-2000

Model development, interpretation of results and their efficient application in decisions are performed in the framework of several Hungarian and international projects (the actual projects are described in the section of Climate activities).



The probability of an increase in the number of summer days (Tmax>25°C) exceeding 10 and 20 days through 2021–2050 on the basis of three regional model simulations made by OMSZ. Reference: 1971–2000

INFORMATION AND COMMUNICATION SYSTEM

Meteorological information technology has two basic functions: continuous operation of the infocommunication system and preservation of meteorological data until the end of time.

For performing the professional and operational tasks of OMSZ, it is essential to maintain the prevalent operationality and ensure the security of the infocommunication (ICT) system, to provide the availability of data required by the professional departments as well as to secure the delivery and publication of meteorological data and products. Provision should be made to develop and maintain a meteorological database, numerical models and related applications. In addition, both hardware and software of the ICT system should be continously developed in compliance with national and international standards and by taking into account user requirements.

NETWORK AND TELECOMMUNICATION SYSTEMS

Meteorological data measured and observed in the domestic observation network and in the World Meteorological Organisation (WMO) World Weather Watch Global Observing System are received, processed and archived by the information and communication system of OMSZ. The same system allows the data

and products of processing to reach our partners. Our telecommunication system – adapting to special conditions of individual cases, international standards and user requirements – carries out its duties by a broad range of communication methods.

The IT network of OMSZ participates in international meteorological data exchange using a 8-Mbps-bandwith RMDCN connection. Our data center is connected to the Meteorological Telecommunication Network (GTS, WIS) via the AustroControl RTH regional center based in Vienna. Data exchange with ECMWF forecasting center is also performed via the RMDCN connection and the Internet.

Our connection with the public Internet as well as domestic networks including public administration is granted through the cloud of National Telecommunication Backbone Network (NTG). To ensure smooth communication a bandwith meeting the increasing professional and technical needs of OMSZ is available (500 Mbps full, 400 Mbps Internet).

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HPE Apollo supercomputer in the computer room of OMSZ

„The modern, reliable forecasts require continuous development of computing."

Collecting measured data from the stations is our non-stop task. Station data collectors usually measure and store sensor data every 10 minutes, but in special cases (for example at airports) one-minute data are also needed. We apply a number of IT solutions to collect data centrally. Dedicated connection (NTG) has been established to stations with special functions in addition to the core activity, while in the case of automatic stations data collection is performed through GPRS-based internet communication channels. In other cases, public Internet and special mobile applications provide adequate solution.

For proper operational safety it is essential to replace, duplicate and extend the capacity of network elements (LAN, WAN, SAN) and related active devices (switch, router) as well as to provide surge protection. Keeping our firewall and antivirus software up to date also aids to ensure continuous availability of IT systems. The consistent application of IT Policy is carried out in the light of existing laws and standards.

High Performance Computers

Meteorology is an extremely compute-intensive field of science. In order to provide modern, reliable forecasts computing needs to be constantly developed. The spatial and temporal resolution of measured and computed (modelled) data as well as the amount of data to be storeed are on an increase.

These operations require the continuous maintenance of up-to-date ICT systems and investments, and make it necessary to involve duplicate systems for data security.

„The infocommunication system of OMSZ completes his duties using an almost complete range of opportunities."

Our mainframe computer needs are basically determined by the capacity requirements of weather (LAMEPS, AROME, ALADIN, MEANDER and WRF) and climate prediction models (ALADIN-Climate and REMO) run by OMSZ.

Planned model developments in the field of numerical weather prediction demand significant increase in computation, and the required capacity cannot be provided by the present computer, which entered operational use in 2010. There are applications (KEHOP-1.1.0, GINOP-2.3.2-15) that allow for the expansion of mainframe capacity: partly by providing computing conditions for the National Hail Mitigation System, and by acquiring a computer mainly for nowcasting needs on the other hand. Regional climate models run on a 400-processor-core computer (HPE Apollo 6000) which was installed in 2017.

Data storage, data service

The IT system of OMSZ receives hundreds of megabytes of information on a daily basis. After data processing and limited area numerical model runs this data amount further increases. Thus, apart from the computing capacity the required storage capacity should also be provided, and in the case of some model runs, the use of flash storage devices with high writing and reading speed is essential.

Part of the data is so-called rapid use data (real-time or synoptic), while other types of data need to be stored for a shorter or longer period of time. The purpose of short-time storage is to control and verify, while longer, 10-day or multiple year (forever) storage provides climatic data, and is an essential prerequisite for certain meteorological research.

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The fast disk-based storage capacity of the central unit approaches 50 TB

Data output from fast disk-based storage is retained by slower, indirect-access tape-based storage. Continuous backup of fast storage devices in compliance with security standards is also a fundamental requirement for us. The capacity of the central disk unit in the main building of OMSZ and the security backup unit at Marczell György Main Observatory located in district 18 of Budapest is not sufficient anymore, but as a result of an investment in 2016 a state-of-the-art system was installed with a maximum extendable capacity of 100 TB depending on professional needs. As a result of latest developments the hardware and software renewal of the

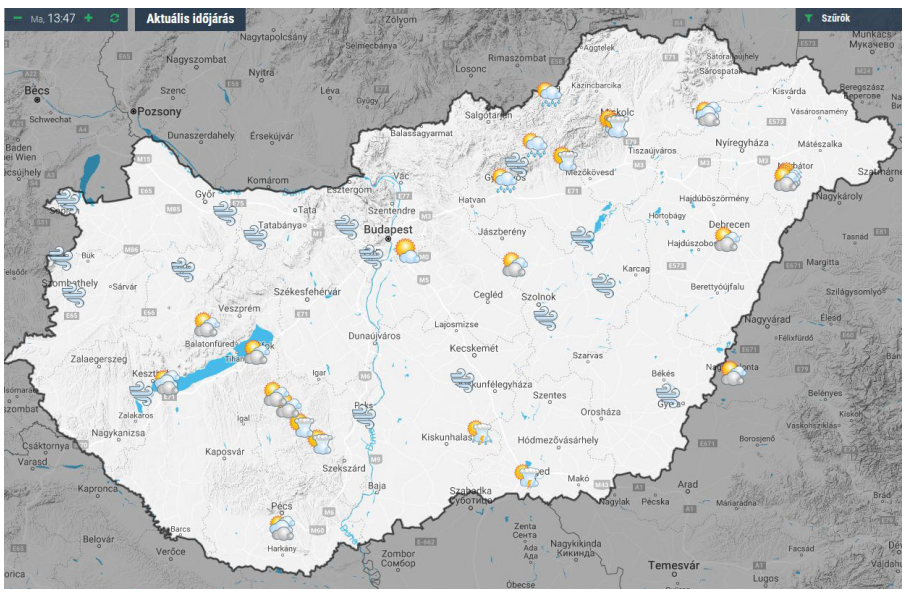
Meteora application can run on both Android and IOS platforms

Meteorological Database has been completed in addition to modernizing the server farm of the Central Process Control System which handles and stores measured and forecast meteorological data and products.

Service is provided to approximately 250 users via the central IT system. Some of the clients receive 1-2 (few bytes of) data per day, but so-called main users benefit from almost the full range of observations and forecasts, which may reach up to 1-2 GB of daily traffic.

„Meteora is an application of OMSZ developed for mobile devices, available free of charge nationwide.”

In addition to our official website, www.met.hu, which is mainly aimed at informing the general public. We are seeking to fully satisfy the need for meteorological information by operating and developing various targeted websites and the Meteora mobile application.



Observations sent via MET-ÉSZ observation system can be viewed on an advanced map

INTERNATIONAL RELATIONS

By taking part in the work of many international organizations and projects we cultivate and develop our relationships abroad.

Atmospheric processes do not relate to country borders, moreover, their discovery requires expensive supporting infrastructure – like telecommunication links, supercomputers and satellites. Therefore, meteorology needs strong international cooperation. National meteorological services already realized that in the 19th century, when different kinds of international meteorological activities actually started.

Our institute pursues four main principles in building international relations:

- contribution to the programs of World Meteorological Organization,
- implementation of European integration on expert levels,
- support to the unity of the Central and Eastern European region on international meteorological platforms,
- strengthening of bi- and multilateral cooperation.

Hungary was among the founding members of the UN specialized agency, the World Meteorological Organization, established in 1950, and of its predecessor, the International Meteorological Organization (IMO), established in 1873. Also, being the first among the Central and Eastern European countries, joined European Centre for Medium-Range Weather Forecasts (ECMWF) in 1994 as cooperating member state. Hungary further became

Hungarian Meteorological Service is a member of several international organizations

cooperating member of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) in 1999; and full member in 2008. OMSZ traditionally represents the Hungarian government in all of these three intergovernmental organizations.

„We are constantly cultivating and building our bilateral relationships with the neighboring countries."

Our service has joined several other international organizations and collaborative frameworks. Our experts contribute to carrying out international initiatives on regular and occasional basis as well. European Meteorological Services Network (EUMETNET), initially comprising meteorological services only from European Union member states, accepted OMSZ as full member in 2004, even before Hungary has joined the EU. Since then, our colleagues actively participate in the implementation of EUMETNET programmes aiming at coordinating harmonization of observational data and equipment, data quality control; and at developing unified European climate database, weather forecasting and warning system, as well as aviation meteorological services.

In 1998, OMSZ was among the first members of ECOMET which is the organization harmonizing economic activities of the national meteorological services in Europe.

We are founding members of the Regional Cooperation for Limited Area Modelling in Central Europe (RC-LACE) consortium since 1994. This group develops the ALADIN/AROME numerical weather prediction models serving as basis for our short-range weather forecasts.

OMSZ also represents our country in international bodies, such as European Monitoring and Evaluation Programme (EMEP), which analyzes and studies the long-range transport of air polluants. Our colleagues are delegates to several expert institutions of European Environmental Agency (EEA) in the fileds of modelling, measuring and assessing air quality. We continuously develop and extend our international relations by participating in the work of several international organizations and projects year after year.

Aiming at articulating regional interests, exchanging high-level information and promoting collaboration in the region, the informal conference of the Central and South-Eastern European Directors (ICCED and ICSEED) is organized each year, in which the President of OMSZ participates actively.

We maintain and further extend our bilateral collaborations with neighbouring countries. Cooperation agreements with Slovakia, Croatia, Slovenia and Romania were established in order to enhance and make more effective our common endeavours in the different areas of meteorology.

Prof. Petteri Taalas, secretary-general of WMO visited OMSZ in 2016

OUR VALUES

In addition to our core tasks, we also put great emphasis on preserving our cultural values.

LIBRARY

Beyond the nearly 150 years of meteorological literature, the latest meteorological journals are also available to readers.

The task of the scientific library of the Hungarian Meteorological Service is to collect, preserve, and give access to Hungarian and international specialized literature to the readers.

Collection of the library comprises almost ten thousand books, mainly on the subject of meteorology: besides publications presenting the science of atmospheric processes, we can find here meteorological dictionaries, maps, concordances and encyclopaedias, available both to general public and researchers. The library is the same old as the meteorological institute; therefore, we now have the chance to oversee and manage many interesting

Volumes of Societas Meteorologica Palatina belong to our book rarities

professional publications, one-hundred year old books, rarities and scientific historical curiosities collected by our ancestors during the last 150 years.

Besides these volumes, nearly twelve-thousand periodicals (journals and series) from all over the world are also available at our library. We subscribe to several international papers, part of them accessible in Hungary solely at the library of OMSZ. In addition, we are in contact with various international meteorological institutions which provide us with their professional publications as part of inter-library exchange activity.

Third element of our library stock is composed of data reports and information materials, such as Yearbooks issued since the foundation of our institute (1870) and Daily Weather Reports issued since 1893. Moreover, numerous old annual books and other data reports from many countries worldwide can be found here.

The library is open during normal working hours, with a reading room at disposal of our visitors.

Museum of Meteorology

Exciting time travel in the history of meteorological measurements.

The Museum of Meteorology was established in 1896 by initiative of Miklós Konkoly-Thege, director of the institute at that time. Basis of formation was the meteorological and astronomical material from the Millennium Exhibition organized on occasion of the thousand-year anniversary of the conquest of the country by the Hungarian troops. Mr. Konkoly-Thege repeatedly organized successful national and international collection campaigns to enlarge the volume of collection of the Museum of Meteorology and Astronomy, of which the first catalogue was published in 1902. The collection was transferred to the Observatory of Ógyalla in 1902 due to space capacity constraints, but it was retransferred to Budapest in 1908. In 1910, it was exhibited at the ground floor of the newly constructed building of the meteorological institute. The collection of the museum comprised already 744 items in 1911.

The museum's vitrines are on the corridors of the central building

The museum was renewed in 1991, when the preservation of the Meteorological Museum Collection was organized and regulated. The storage units of the safeguarded, recovered and newly collected equipment found their place in the corridors of the Headquarter building of OMSZ. Items are exhibited in a thematic manner, including meteorological devices for the upper air and surface measurements, astronomical and other specialized instruments for geodesy, atmospheric electricity and radioactivity, relic objects, awards, certificates and photos. Larger pieces are displayed separately. There are ionospheric recorder, microbarographs, anemographs, photo-registration devices, and even a primitive type of a cupboard-sized computer and hail suppression rockets.

The entire exhibition serves as resource material for historical scientific exploration. Labelling of the vitrines, boxes and displayed items is arranged in chronological order in a systematic manner, so as to provide global overview of the history of meteorology.

The Ministry of National Heritage accredited the meteorological collection in December 2002, declaring it as "Hungarian Meteorological Collection". The Museum has more than 1000 visitors each year, mainly school groups. Since 2005, our Museum can be explored in the frame of the Night of Museums event.

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Voluntary observation	met-esz.met.hu
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