

“METEOGIS”: GIS-BASED SYSTEM FOR MONITORING OF METEOROLOGICAL PHENOMENA FOR LOCAL AUTHORITIES

Anna Jurczyk, Katarzyna Ośródka, Grzegorz Tkocz, and Jan Szturc
Institute of Meteorology and Water Management, Poland

1. GENERAL DESCRIPTION

1.1 MeteoGIS approach

Real-time data constitute the most important source of information in prevention of results of natural hazards. Applying high-resolution data in connection with GIS-based techniques seems to be effective solution for this purpose. One of examples is CEDIM system that employees web and GIS technologies (Köhler et al., 2006) to visualize various natural risks in Germany. Another example can be HDSS system (Conway et al., 2004, 2006) that is developed to flash flood prediction basing on precipitation estimates and nowcasts.

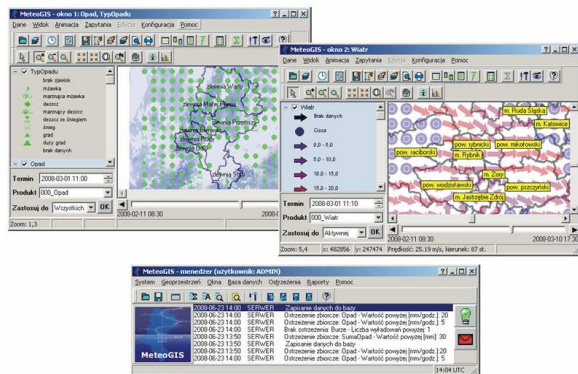


Fig. 1. View of user application of the MeteoGIS: manager window (at the bottom) and two visualization windows.

The MeteoGIS is a GIS-based system (Fig. 1) for monitoring current weather conditions and issuing user-specific warnings, as well as analysing past events (Ośródka et al., 2008). Thanks to taking full advantage of real-time data (from weather radar network, meteorological stations, NWP – numerical weather prediction model, and lightning detection system) it allows to mitigate risk from potentially hazardous weather phenomena, like strong wind, thunderstorms, heavy rain, and consequently triggered off impending floods. End users of the system are neither meteorologists nor hydrologists but government or local authority services who are interested in short-term warnings against severe weather events, especially area oriented (district, catchment, etc.).

Corresponding author: Anna Jurczyk,
 Institute of Meteorology and Water Management,
 jan.szturc@imgw.pl.

The system was developed in the Institute of Meteorology and Water Management (IMGW) for Upper Silesia Region authority (Department of Risk Management) in Poland and was implemented for real time work in 2007. In 2009 the MeteoGIS was installed in Opole Region that is neighbouring to Upper Silesia. MeteoGIS is a database application which works in client-server architecture. The system is supplied with data processed by the MeteoGIS_Input application (integrated module of the MeteoGIS) and transmitted via FTP protocol in time-schedule or immediate mode (Fig. 2).

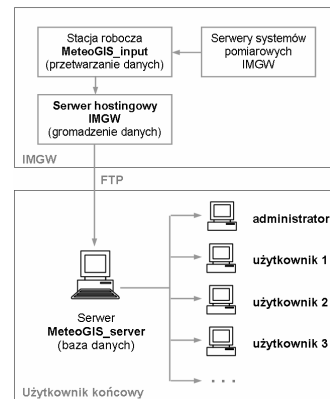


Fig. 2. General scheme of the MeteoGIS system.

1.2 MeteoGIS domains

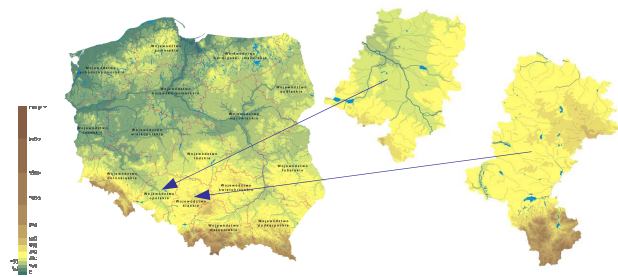


Fig. 3. Silesian and Opole Voivodeships (Regions) on map of Poland.

The MeteoGIS system can be adapted to each region, although has been developed especially for Silesian in the south of Poland (Fig. 3). The region is characterised by the highest population density in Poland and intensive industry development. Moreover it is one of the most important for flood protection as three biggest Polish rivers have their sources or upper part here (the Wisła, the Odra, and the Warta rivers).

Heavy precipitation events can easily form flash floods, especially due to the terrain topography (the Beskid Mountains).

One of the most catastrophic floods in the south of Poland was observed in July 1997, which caused 54 fatalities and material losses of the order of billions of USD. The flood inundated a large part of the country (665 000 ha of land) and the number of evacuees was 162 thousand. Historic maxima of flow rate were considerably exceeded, with a return period of the order of a thousand years and more in some river cross-sections (Kundzewicz et al., 1999).

1.3 Meteorological data sources

The MeteoGIS_Input software installed in IMGW is aimed at generating products for the MeteoGIS. The data sources are the following measurement and processing systems of IMGW:

- weather radar network POLRAD (Szturc and Dziewit, 2005),
- UK MetOffice system of weather radar data processing and precipitation nowcasting NIMROD (Weipert and Pierce, 2003),
- SAFIR 3000 lightning detection system PERUN (Bodzak et al., 2006; Konarski et al., 2008),
- NWP model COSMO-LM (Starosta et al., 2006),
- telemetric rain gauge network of IMGW.

All the data are converted into the MeteoGIS format and geographical projection, and limited to the proper domain. The data are sent to the hosting server, next downloaded by the end user and saved into dedicated SQL-database. Other meteorological data can be included into the system, not only from remote-sensing data.

The system allows meteorological information to be accessed, displayed and manipulated in a GIS environment with versatile, user-friendly image processing tools. It integrates available weather data (both analyses and nowcasts).

2. METEOROLOGICAL DATA

The MeteoGIS system allows to visualize the following meteorological parameters at ground level:

- precipitation (rate, accumulation, and type),
- wind (speed and direction),
- lightning (locations and type).

Precipitation rate. The basic precipitation data are derived from Polish weather radar network POLRAD (Szturc and Dziewit, 2005). Then the data are processed by NIMROD system (Golding, 1998), that corrects the radar data basing on data from other sources (rain gauges, ground stations, Meteosat, NWP). The NIMROD data are adjusted to rain gauge data using mean field bias algorithm. The processed radar data are merged into composites every 10 min with 1-km resolution. In overlapping areas the lowest radar beam altitude is used as a merging criterion.

Rainfall data play key role in flood protection, therefore in the case when radar data are not available, spatially interpolated raingauge measurements are employed instead.

Precipitation nowcasts are generated by the same NIMROD system as radar-based nowcasts merged with NWP-derived forecasts using a proper weighting function. The nowcasts are produced every 30 min with temporal resolution of 15 min up to 6 hours ahead. Their spatial resolution is 4-km, so they are downscaled into 1-km (Jurczyk et al., 2008). Precipitation data, both analyses and nowcasts, are displayed as spatial fields in the MeteoGIS (Fig. 4).

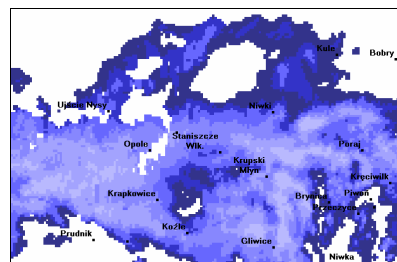


Fig. 4. Example of precipitation field (22 April 2008, 0700 UTC).

Precipitation accumulation. The precipitation accumulations are generated taking account of spatial and temporal interpolation (Jurczyk et al., 2008). The user may define any accumulation period. The accumulations can be generated from estimated data, nowcasts, or their combination. Precipitation accumulations are presented in a form of spatial fields.

Precipitation type. The precipitation type analyses and nowcasts are generated by NIMROD system every hour with 8-km resolution. The following precipitation types are discriminated: drizzle, freezing drizzle, rain, freezing rain, sleet, snow, hail, and large hail. The precipitation type field can be displayed employing standard synoptic symbols or in spatial form like precipitation field (Fig. 5).

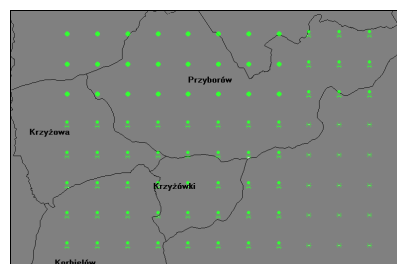


Fig. 5. Example of precipitation type field (03 April 2008, 1500 UTC).

Wind. Wind analyses for the MeteoGIS are provided by weather radar network as H-WIND product with temporal and spatial resolution 10 min and 12 km respectively. Wind field is measured at a height of 2 km, so it is estimated for a height of 10 m. Wind forecasts are delivered by NWP (COSMO-LM)

model every 12 hours with 1-hour temporal resolution and 14-km spatial resolution. Wind velocity and direction can be displayed as either symbols or spatial field (Fig. 6).

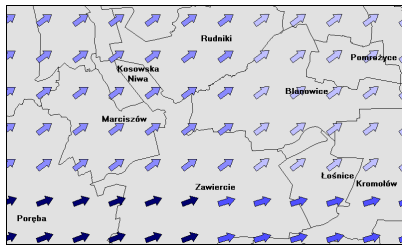


Fig. 6. Example of wind field. The arrow colour denotes wind velocity (21 April 2008, 0110 UTC).

Lightning. The lightning locations are detected by PERUN system based on Vaisala SAFIR 3000. The system comprises nine detectors placed in various locations. The system reports are generated with set up frequency and include records about each detected lightning. The 10-minute lightning reports are ingested in the MeteoGIS. The lightning field can be displayed employing symbols different for two basic types of lightning (red colours for cloud-ground lightning and yellow for cloud-cloud lightning) or in a spatial form like precipitation field (Fig. 7).

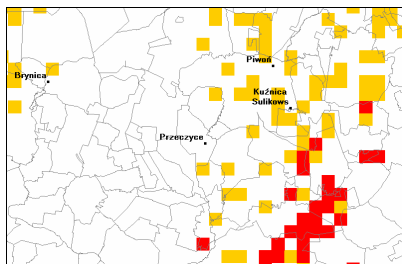


Fig. 7. Example of lightning locations (21 June 2007, 1430 UTC).

3. MAIN TASKS OF THE SYSTEM

MeteoGIS system task is to deliver the end user wide information about weather conditions in given region, through:

- monitoring of current weather,
- generation of meteorological warnings,
- support for weather analyses.

3.1 Monitoring of weather and the meteorological data visualisation

All the meteorological data fields are displayed in visualization window (Fig. 8) using GIS techniques. Any number of visualization windows can be open with selected meteorological data being loaded. Moreover the user can add any geographical map in a standard shape (SHP) format, for example maps of: catchments, administrative borders, etc. The settings

and configuration of all visualization windows can be saved as a workspace for future use.

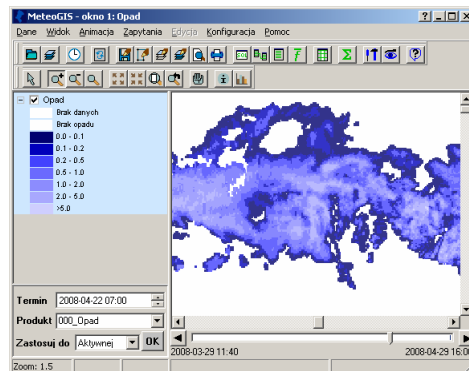


Fig. 8. Example of visualisation window of the MeteoGIS system.

The MeteoGIS provides a high degree of flexibility – apart from all standard GIS techniques for spatial data displaying, including legend wide-ranging configuration, various possibilities are available, which help the end user monitor the current weather. The following options implemented in the MeteoGIS can be useful for weather monitoring visualisation:

- meteorological data downloading from hosting server according to preset schedule,
- automatic refresh of visualization field after the new data incoming,
- animation of selected data sequences with automatic updating,
- automatic generation of precipitation accumulation.

3.2 Warnings

Meteorological warning generation is one of the most important tasks of the MeteoGIS. The warnings are to provide the public services with fast and accurate information about severe weather phenomena observed or likely to happen within a few nearest hours.

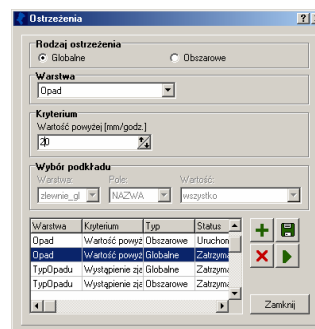


Fig. 9. Meteorological warning configuration window.

After new data incoming the MeteoGIS automatically generates customizable real-time warnings when the chosen meteorological data values exceed preset critical thresholds (Fig. 9).

Two kinds of warnings are introduced: for the whole system domain and geographical area oriented (e.g. catchments or other selected objects of GIS-layer). Warnings are triggered when predefined thresholds have been exceeded in incoming data, either analyses or forecasts. It is signalled to the user in the system manager window by displaying information in message window and switching on red colour in the indicator of meteorological warnings (Fig. 14).

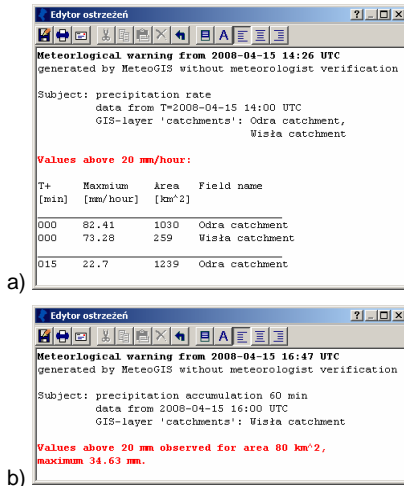


Fig. 10. Examples of meteorological warnings.

The MeteoGIS issues warnings in the form of a plain text, which can be sent as an e-mail. The warnings can be displayed for each lead-time separately as well as for the set of forecasts generated in one time-step. Examples of warning messages are presented in Figure 10.

Example of meteorological warning generated on 15th April 2008, 1426 UTC for precipitation rate from 1400 UTC, within the Odra and the Wisła River catchments is shown on Figure 10a. The warning informs that the set threshold 20 mm/h was exceeded on area of 1030 and 259 km² in these catchments with maximum rates 82.41 and 73.28 mm/h respectively. For 15 min ahead the criterion will be exceeded only for the Odra River catchment on 1239 km² with maximum 22.7 mm/h.

All meteorological warnings are stored in database and can be browsed in a dedicated report window. The warnings can be analysed and edited before being sent.

3.3 Weather analyses

The MeteoGIS providing the comprehensive set of tools for weather analysis can be efficiently applied as a support for decision makers.

The following possibilities are offered:

- adding any geographical maps as new GIS layers,
- tabular field presentation of meteorological data, where the end user has access to values for each pixel with its coordinates,

- generation of meteorological field statistics such as average, value classes numbers, for the whole system domain and selected objects of GIS layer (e.g. for selected catchment),
- SQL-queries generation using dedicated easy-to-use editors; three editors are to enable users to create different kinds of SQL-queries, such as simple or relative ones, and more advanced templates of queries (e.g. identification of area within selected Odra and Wisła catchments where precipitation rate is over preset 20 mm/h threshold),
- diagrams of data time-series for selected meteorological fields in given pixel (Fig. 11),
- read-out of all meteorological and GIS layers values in given pixel.

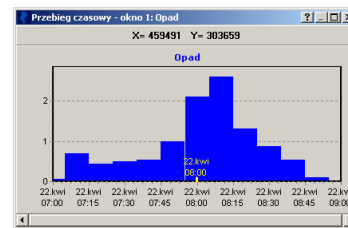


Fig. 11. Example of meteorological data time-series.

4. APPLICATION MANAGEMENT

4.1 Schedules

Some tasks can be performed in a schedule mode defined by the user. The following schedules are available in the MeteoGIS (Fig. 12):

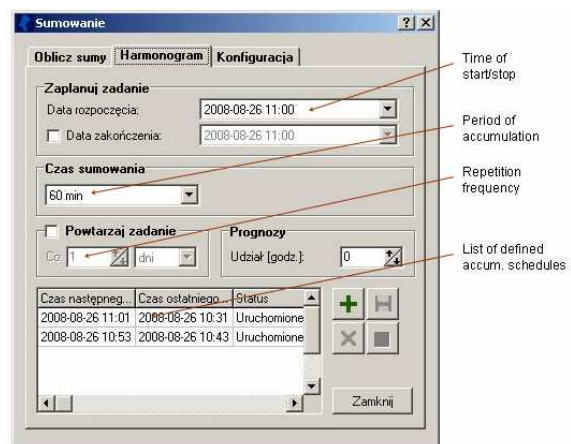


Fig. 12. Example of schedule configuration window for accumulation.

- meteorological data downloading – user sets frequency and kinds of data uploading from hosting server of IMGW to local workstation via FTP,
- generation of precipitation accumulations – both repetition time for aggregation of precipitation

data and the accumulation time period (e.g. 1-h, 3-h or others) have to be defined,

- data copying to archive – the database is divided into two parts: present (comprising data from preset time period) and historical (for events to be archived); defined kinds and time range of data is copied from present to historical part of database.

All the above tasks can be also performed in an immediate mode. All reports about performed tasks are stored in the database and can be browsed through dedicated report-windows (Fig. 13).

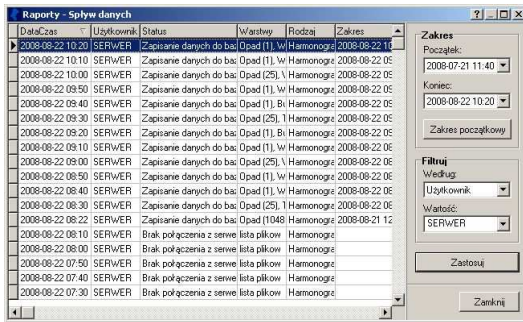


Fig. 13. Example of dedicated report-window for new data incoming.

4.2 System manager

The MeteoGIS manager is responsible for data and system running management (Fig. 14). Current information about incoming data, schedule running, and meteorological warnings is displayed in a message window of the manager.



Fig. 14. The MeteoGIS system manager.

Employing the system manager the user with administrator rights has access to tools by means of which he can manage user accounts, their workspaces, and geographical maps (GIS layers). Moreover administrator sets the MeteoGIS system parameters (e.g. parameters of data transmission from IMGW), parameters of schedules for data downloading, precipitation accumulation, and data copying to archive, and meteorological warning configuration. He is also responsible for database maintaining, the system performance monitoring, etc.

5. EXAMPLE: LOCAL EVENT OF HEAVY PRECIPITATION

Combination of meteorological data with high spatial resolution and GIS techniques allows to

analyse the data comprehensively for selected geographical objects, like districts, catchments, etc. An example of such analyses by means of the MeteoGIS is presented below. The starting point apart from precipitation rate field is administrative map of districts within the Region. If some specific districts are considered, analysis of precipitation field for them can be carried out using either in-built statistical module or GIS-based tools.

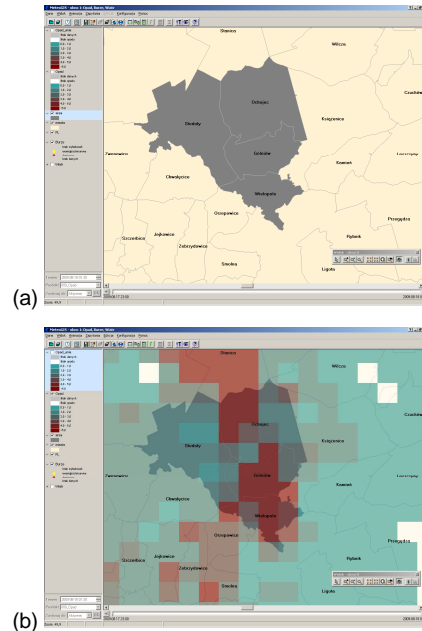


Fig. 15. Selected geographical object (a) and precipitation field (b).

In Figure 15 a geographical object consisting of three selected districts is presented. The field can be used as an overlay for meteorological data, such as precipitation rate (example from 18 August 2009, 0130 UTC is presented in Figure 15b). The precipitation data can be analysed using in-built statistical tools to get such statistical characteristics like mean, maximum and counting of pixels in relevant precipitation classes for the selected objects or the whole system domain over preset threshold for given meteorological quantity (Fig. 16).

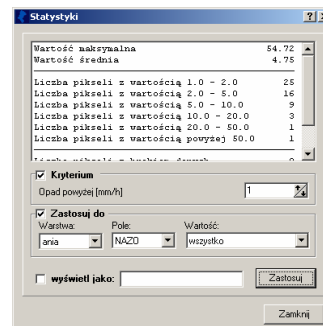


Fig. 16. Window with statistical characteristics of precipitation field for selected object.

Moreover GIS-based tools enable to conduct visual analysis of the event. Various kinds of SQL queries can be employed to perform such investigation: simple, relative and template ones. All the tools are intuitive and simple to use.

In Figure 17 an example of the simple SQL query is presented. For instance, the object like this from Fig. 15a can be selected and saved as a GIS layer, and also analysis of meteorological fields can be performed, e.g. to show precipitation rate exceeding a given threshold.



Fig. 17. Window with simple SQL query: creation of a new GIS layer for the selected object.

Relative SQL query combine two layers or results of the simple queries. A result of the relative query in this case is a field of precipitation above the threshold for selected geographical object (Fig. 18). The threshold is set to 5 mm per hour.

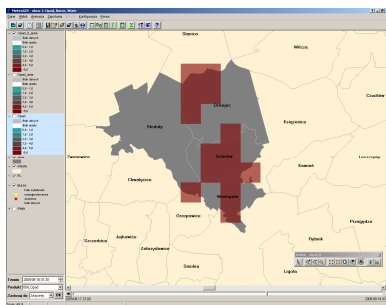
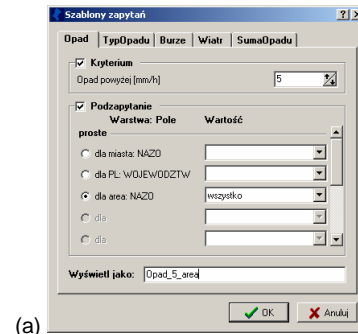
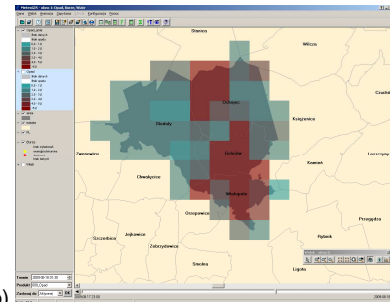


Fig. 18. A result of relative SQL query: field of precipitation above threshold for selected geographical object.

For the users not familiar with SQL syntax, preset templates of all kinds of queries (simple and relative) can be generated for more often employed queries, that user have to fill in with proper values. In Figure 19a an example for using of such template is presented. The query is related to the same area like in Figure 15a and precipitation over this area without any threshold. A result is shown in Figure 19b.



(a)



(b)

Fig. 19. Window with example of SQL template (a) and resulting precipitation field (b).

Time-related analysis of meteorological fields is possible not only by animation of subsequent data, but also by diagrams of each monitored quantity for selected location (pixel). In Figure 20 an example of hyetograph is presented, where for given pixel such diagram is available including past and predicted values.

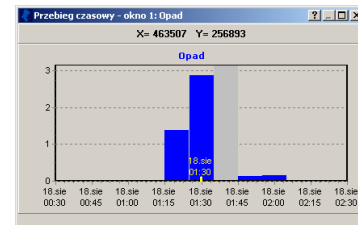


Fig. 20. Time-series of precipitation rate for selected pixel.

6. REMARKS

Providing the end user with real-time high-resolution (spatial and temporal) multi-source information and suitable processing tools is the essential condition for the risk assessment. The MeteoGIS system integrates various kinds of meteorological data from different measurement and processing systems, both analyses and nowcasts. All gathered data and information can be thoroughly analysed in order to deduce risk of natural hazards taking advantage of GIS techniques and designed tools, like warning generation, precipitation aggregation, etc.

Acknowledgment

The MeteoGIS system was developed for regional authority of Upper Silesia (Silesian Voivodeship Office in Katowice) with financial support of the Voivodeship Fund for Environmental Protection and Water Management in Katowice.

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