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APPLICATION OF GIS TECHNOLOGY TO SATELLITE AND METEOROLOGICAL DATA PRESENTATION AND ANALYSIS

ZASTOSOWANIE GIS DO PREZENTACJI I ANALIZY DANYCH SATELITARNYCH I METEOROLOGICZNYCH

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STRESZCZENIE: Zadanie prezentacji danych meteorologicznych, satelitarnych i wyników modelu numerycznego nie jest zadaniem łatwym, ze względu na różnice w rozkładzie przestrzennym i czasowym, lub różnice w dokładności pomiaru. Geograficzne Systemy Informacyjne (GIS) umożliwiają zarówno wizualizację informacji meteorologicznych w formie mapy, ale również ich przetworzenie i analizę.

W pracy przedstawiono przykłady wykorzystania metod GIS do wizualizacji parametrów meteorologicznych wyznaczanych z danych satelitarnych, numerycznych modeli i standardowych danych synoptycznych opracowane w Zakładzie Badań Satelitarnych IMGW. Dla Polski przygotowywane są warstwy tematyczne takie jak: pola temperatury powierzchni Ziemi i temperatury wierzchołków chmur na podstawie satelitarnych danych NOAA/AVHRR, klasyfikacja zachmurzenia z danych NOAA/AVHRR, intensywność i zasięg opadu z danych mikrofalowych NOAA/AMSU, pola temperatury i wilgotności na różnych poziomach otrzymane z danych NOAA/ATOVS, temperatura i opad na podstawie wyników analizy modelu numerycznego Aladin.

Produkty te są przedstawiane w postaci map z nałożonymi dodatkowymi informacjami geograficznymi i granicami administracyjnymi państw. Dane z depesz SYNOP i TEMP konwertowane są do warstw tematycznych pozwalając na weryfikację parametrów meteorologicznych otrzymywanych na podstawie danych satelitarnych.

SŁOWA KLUCZOWE: satelity meteorologiczne, NOAA, opad, intensywność i zasięg opadu, Geograficzne Systemy Informacji

1. INTRODUCTION

The appropriate estimation of precipitation is vital for the agriculture, communication and water management. Main source of information concerning the precipitation comes from the hydro-meteorological network. The precipitation is highly variable in time and space therefore the satellite data are the important additional source of information.

The satellites NOAA-15, 16 and 17 are equipped with the microwave radiometers (AMSU) that are very useful for atmosphere sounding i.e. evaluation precipitable water and ice crystals distribution. There has been significant progress in developing methods using microwave information over the sea and oceans. However, the methods of sounding in microwave spectrum over land are still inadequate.

The research on developing the algorithms allowing to use the microwave soundings from the satellite measurements for precipitation characteristics has been performed in the Satellite Research Department of the Institute of Meteorology and Water Management since the year 2000. Several data types were used in analysis, i.e. radiosondes, synoptic data, numerical model data and soundings in visible, infrared and microwave spectral ranges from the NOAA 15, 16 and 17 satellites.

This paper focuses on the GIS methods used to derive precipitation and other parameters of the atmosphere from various source of data. The products are made available to the meteorological office via Intranet. It is planned in the future that all thematic layers will be available for manipulation and analysis via GIS web server.

2. METEOROLOGICAL DATA

The variety of meteorological data used in the work is presented in the Table 1 and shows the potential problems caused by different spatial resolution, frequency – temporal resolution and scale.

2.1. Radiosondes and Synoptic Data

Vertical profiles of temperature, dew point as well as geopotential height from TEMP, at standard pressure levels (925, 850, 700, 500, 300, 200 hPa) were used to calculate air relative humidity and cloud water content. Water vapour mixing ratio, relative humidity and liquid water contents and consequently – cloud liquid water path (LWP) were calculated at the standard pressure levels. SYNOP data provided information concerning temperature, dew point temperature at the surface, as well as present and past weather, cloud cover and cloud type. Precipitation data was used from SYNOP at 12.00 GMT (precipitation sum for the last 6 hours).

2.2. Satellite Data

Satellite data come from the polar orbiting NOAA satellite system. The Advanced Very High Resolution Radiometer (AVHRR/3) is an imaging instrument used for global measurement providing the characteristics of cloud cover, sea surface temperature, ice, snow and vegetation cover. AVHRR has 5 channels in the visible and infrared between 0.63 and 12.0 micrometers [11].

High InfraRed Sounder (HIRS/3) measures radiation in 1 visible and 19 infrared channels. The different weighting functions of each radiometer having their maximum at different pressure levels allow the derivation of temperature and humidity profiles, surface temperature and total ozone content.

Table 1.

Meteorological and climatological data

Data Type	Range	Resolution	Frequency	Scale
SYNOP	Europe	synoptic/	1 h	regional
KLIMAT	Poland	climatic stations	3 h	regional
			6 h/12 h/24 h	
AEROLOGICAL SOUNDING	Poland/Europe	aerological stations	1x – 4x /day	global
NOAA/AVHRR		1 km		regional
NOAA/AMSU	Central Europe	40/17 km	6x /day	regional
NOAA/HIRS		17 km		regional
SAFIR (lightning detection system)	Poland	1 km	1 min	regional
NUMERICAL WEATHER PREDICTION MODEL	Central Europe	13 km	6/12 h	mesoscale

Advanced Microwave Sounding (AMSU) sounder consists of 3 radiometers. The first two – AMSU-A1and AMSU-A2 provide measurements in 15, in the range of 23.8 GHz to 89 GHz. The third – AMSU-B provides data in 5 channels; in frequencies 89 GHz, 150 GHz and 183 GHz. Passive microwave instruments provide an information about precipitation, since precipitation directly influences the radiation field. The drawback of passive microwave instruments is their low spatial resolution.

2.3. Numerical Weather Prediction Data from Aladin Model

The ASCII output from the numerical weather prediction model ALADIN was used to create the thematic layers – temperature distribution at 7 pressure levels (surface, 925, 850, 700, 550, 450, 300 hPa). Also the forecasted precipitation at +03h and +06h (stratiform, convective) were imported from ASCII grid and rasterised using gridding procedure. Figure 1 shows a good example of combining different information. In the background there is a False Colour Composite (FCC-channels 321) from the AVHRR/3 radiometer on board NOAA 16. The clouds appear in white to blue colours, sea in black and land in shades of green and brown. Several different thematic layers are laid on top of the FCC; the locations of the SYNOP stations are shown as blue and yellow dots, respectively. Yellow dots show the marked SYNOP stations with the recorded precipitation over 1 mm. The labels show the recorded precipitation. The recorded lightning from Safir system is shown in red.

3. SOFTWARE

Several specialised software packages are used in order to process different types of data. Initially, the satellite data are processed using the Advanced ATOVS Processing Package (AAPP) created and distributed by EUMETSAT [1], [2], [3], [13]. Received AVHRR and ATOVS data are transformed to the AAPP level 1d format. All necessary

decommutation, calibration, geo-referencing and identification of cloud contamination are performed by the package. The obtained albedo and brightness temperatures of AVHRR, HIRS and AMSU data are mapped to HIRS grid. AAPP has been implemented on Alpha DEC workstation with Digital UNIX system. Routines allow the automatic control of the AAPP package control for the current satellite. Finally all data sets are in the form of an ASCII (x, y, z), where x – longitude, y – latitude and z – albedo or brightness temperature. The separate files are created for AVHRR, HIRS and AMSU data with some auxiliary information such as logistic Crosby test, precipitation probability, satellite and sun angles, land cover type, etc.

Inverted Coupled Imager package (ICI) [8], [9], [10] allows to retrieve the vertical temperature and humidity as well as water vapour and the total ozone content. ICI package has been developed by the NWP Satellite Application Facility (SAF) responsible for developing the software and numerical weather prediction models. It is very closely related to AAPP using the level 1d data.
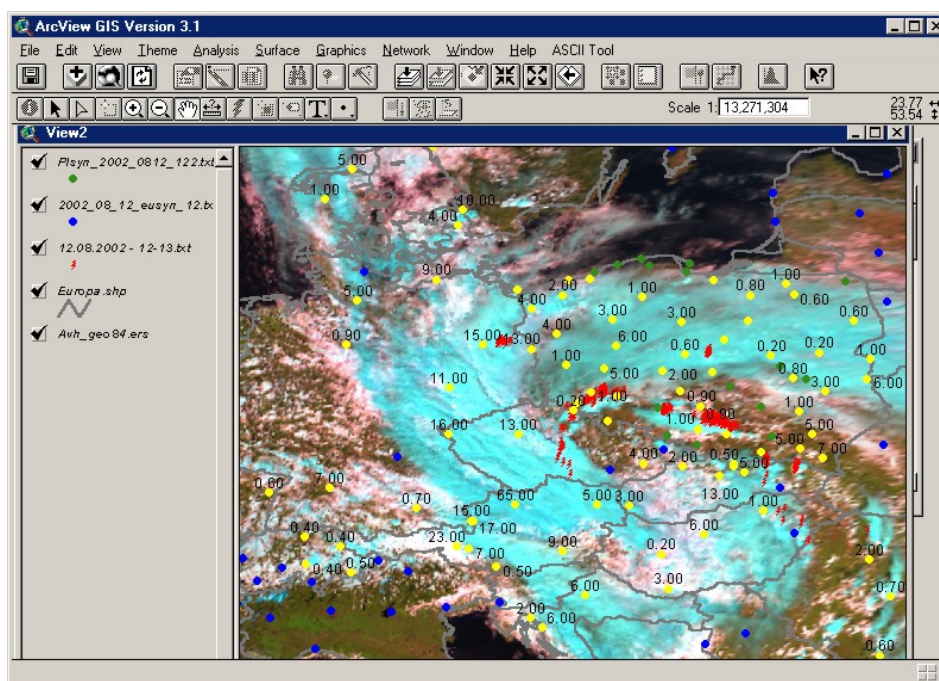

Fig. 1. Satellite data with the SYNOP stations overlay, 12.08.2002 (ArcView)

ER Mapper is the commercial software package used for the raster images processing and visualisation. It also allows presenting raster data with the vector layers. The ASCII files with satellite or numeric model data are imported and rectified using triangulation procedure and later the regressive algorithms are used for different parameters. ArcView 3.1 and ARCGIS 8.3 packages are used in order to combine the ground data with the satellite-derived parameters (Fig. 1.).

4. THE USE OF GEOGRAPHICAL INFORMATION SYSTEMS (GIS) METHODS

Firstly the analysis of the data types and characteristics are performed in order to evaluate the efficiency of each thematic layer creation. In the analysis the size, spatial, spectral and temporal data analysis was accounted for the different satellite radiometers. Secondly, the consistent and homogeneous processing system for satellite (Fig. 1) and numeric data were defined. This included definition of the projection (geographic) allowing merging the different thematic layers of raster and vector data.

Based on the regression algorithms described in previous works [4], [5], [6], [7], [11] the products are made available as Microwave Sounding Service and TOVS Sounding Service. The maps of Liquid Water Path (LWP), Total Precipitable Water (TPW), Scattering Index (SI) used for detection of convective cloud systems, Precipitation Probability (PP) and precipitation intensity – Rain Rate (RR) are created for the current satellite pass of the polar orbiting satellites NOAA 15, 16 and 17. The Fig. 2, 3, 4, 5 and 6 show examples of these products created for the NOAA16 pass on 12.08.2002. This day was chosen due to synoptic situation that caused flooding in Central Europe.

There was a deep low-pressure centre over the Central Europe with the clouds over the East Germany and Czech Republic (Fig. 1) with very intensive rainfall that caused flooding. The synoptic stations recorded the rainfall of 30 mm/6h, in some places even 60 mm/6h. The convective cloud systems were correctly identified on microwave images (see Fig. 4). The LWP derived from these data was very high above 2.5 kg/m^2 (see Fig. 2).
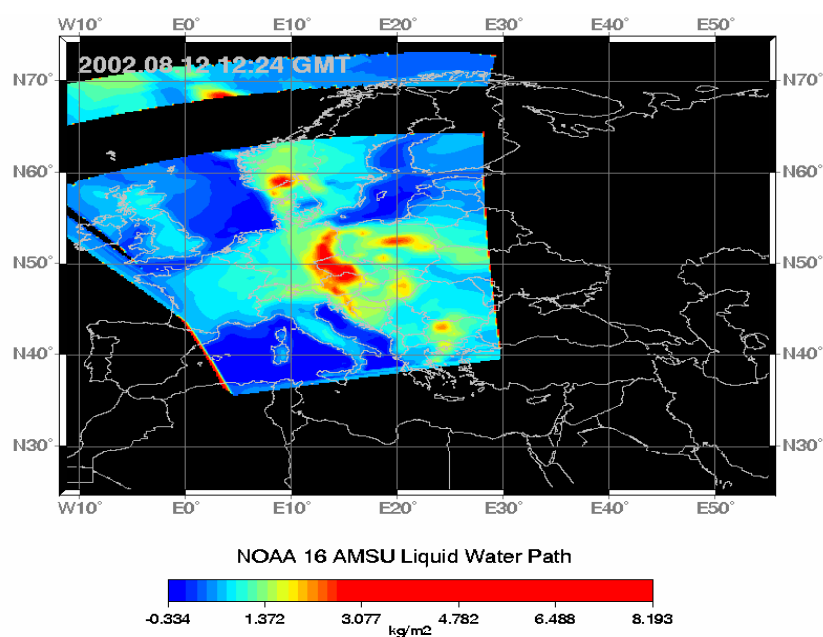

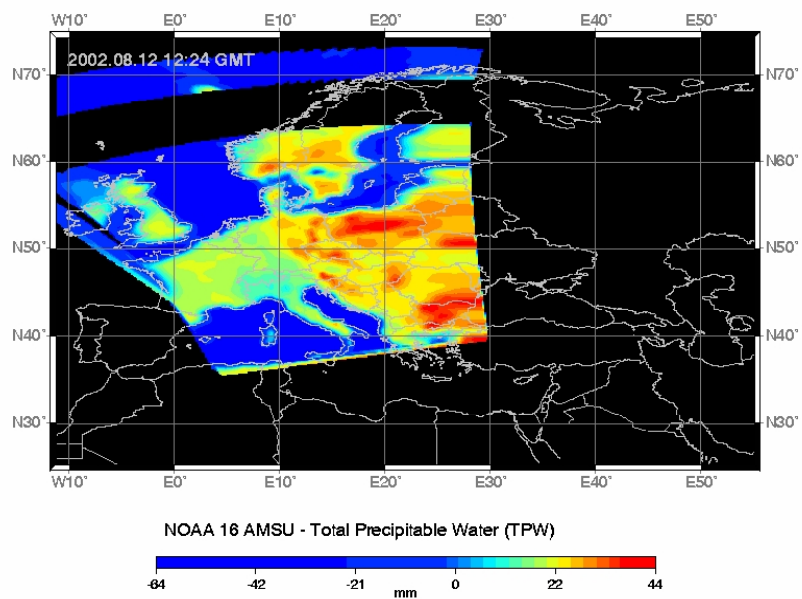Fig. 2. LWP – Liquid water Path, NOAA 16, 12.08.2002, 12:24 GMT

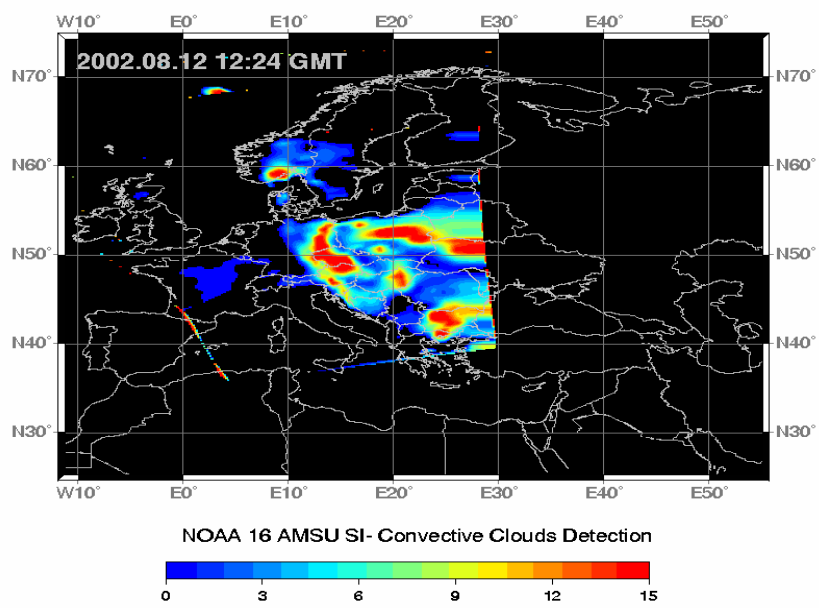Fig. 3. TPW – Total Precipitable Water, NOAA 16, 12:24 GMT

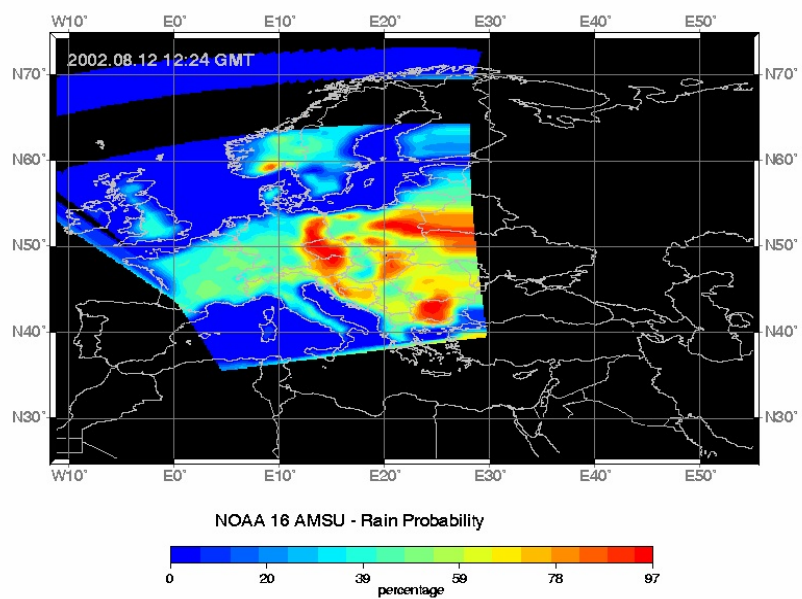Fig. 4. SI – Convective cloud systems detection NOAA 16, 12.08.2002, 12:24 GMT

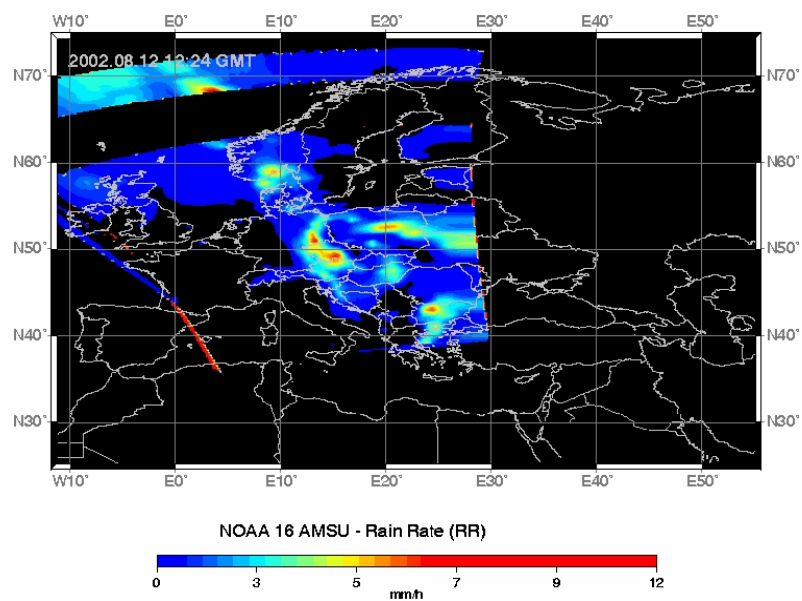Fig. 5. PP – Precipitation probability NOAA 16, 12.08.2002, 12:24 GMT

Fig. 6. Rain Rate – RR, calculated from the satellite microwave data (AMSU)
– NOAA 16; 12:24 GMT. (ErMapper)

The TOVS Sounding Service is based ICI package and comprises fields of temperature, dew point temperature, geopotential height at four pressure levels as well as a field of total ozone amount. As an example, temperature field at 300 hPa and total ozone distribution is presented on the Fig. 7 and 8 respectively.
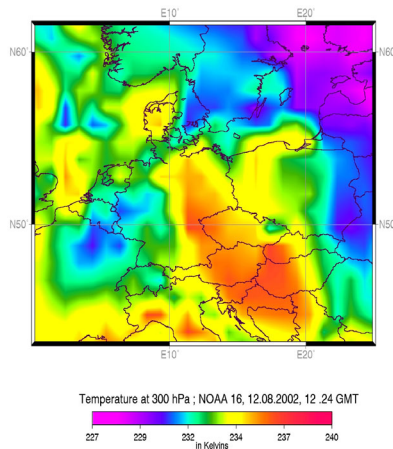

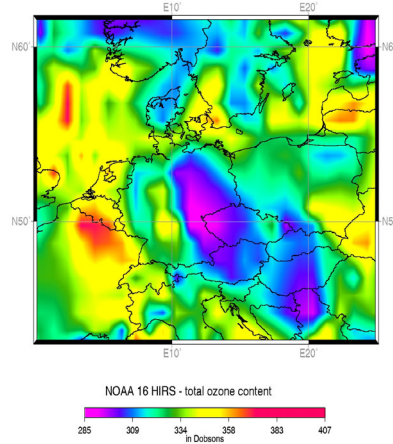Fig. 7. Temperature field at 300 hPa retrieved using ICI

Fig. 8. Total ozone distribution map retrieved using ICI

The simple Precipitation Probability classification into three classes allowed overlay the classes of rainfall probability (Fig. 9) over the satellite image of clouds. It shows the potential of the system for presenting the analysed data reducing the number of information in an operational work.
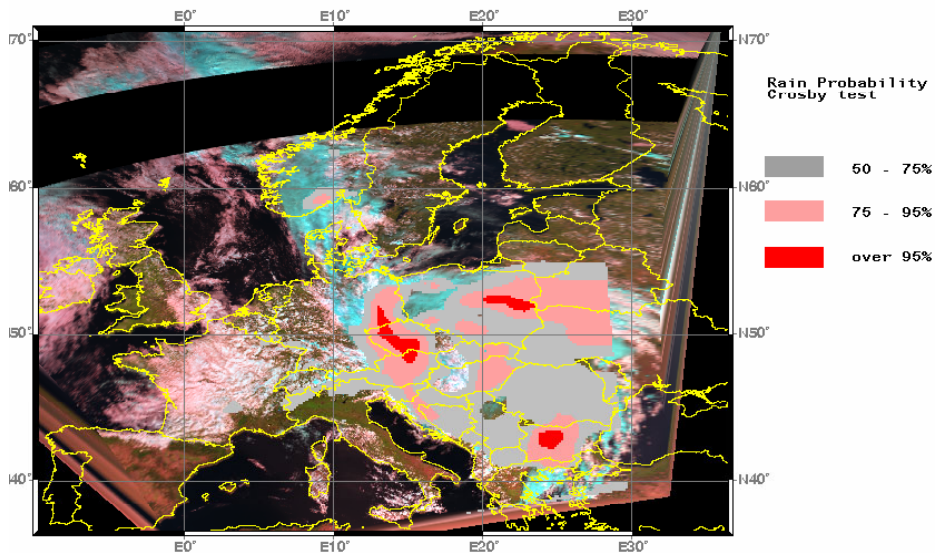

Fig. 9. Rain probability classes (50–75%, 75–95%, over 95%) overlaid on the False Colour Composite

5. CONCLUSIONS

The humidity and temperature fields from microwave data are an important supplementary information for the standard radiosonde network. The algorithms for convective clouds' identification are very useful in extreme situations. This still requires the quantitative analysis of the longer period and verification against the radar data. It is clear that the derived system for the joint visualisation and analysis of meteorological data from different sources plays an important role in performing these tasks. Presenting the concise analysed information from the abundant data is especially important in the operational service.

Geographic Information System methods proved very useful for joint analysis and presentation of satellite as well as meteorological data. They allow presenting the integrated information from NOAA satellite sensors (AVHRR, HIRS and AMSU) transformed to the suitable projection; creating composite images using different spectral channels and overlaying with the vector data (geographic and administrative boundaries); developing the suitable algorithms for various meteorological parameters calculation, testing and verification. Finally, these methods allow combining different data (raster and vector) and their Internet distribution.

6. ACKNOWLEDGEMENTS

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APPLICATION OF GIS TECHNOLOGY TO SATELLITE AND METEOROLOGICAL DATA PRESENTATION AND ANALYSIS

S u m m a r y

The data from various sources such as satellite observations, ground measurements and NWP models provide the continuous information on the state of the atmosphere that are used for weather analysis and forecast. Combining these data into one system encounters problems due to the data variable range as well as temporal and spatial resolution. On the other hand such a system can be a useful tool for the data analysis and visualisation.

The paper presents the progress in the Geographic Information Systems (GIS) technology application in the Satellite Research Department in Poland for preparation and visualisation of the products derived from various sources including NOAA satellites, NWP analysis and ground measurements.

Several thematic layers called meteorological products are prepared for Poland. Precipitation intensity and range are derived from microwave data. Temperature and humidity fields at different pressure layers are obtained from ATOVS data. High resolution visible and infrared data are used for cloud cover detection, temperature and precipitation fields are created from the numerical model (Aladin) analysis. Finally, ozone distribution is mapped using HIRS data.

These products can be presented in the form of maps with additional overlays such as geographical data and administrative boundaries. Moreover, the SYNOP and TEMP data are converted into thematic coverages supporting the products' verification.

KEY WORDS: meteorological satellites, NOAA, precipitation, rain intensity and range, Geographic Information Systems

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