Application of Copernicus Satellite Data for Soil Moisture Monitoring and Drought Mapping within the Baltic Sea Open Data Framework

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Institute of Geodesy and Cartography

Remote Sensing Centre

Copernicus Europe's eyes on Earth

European Commission

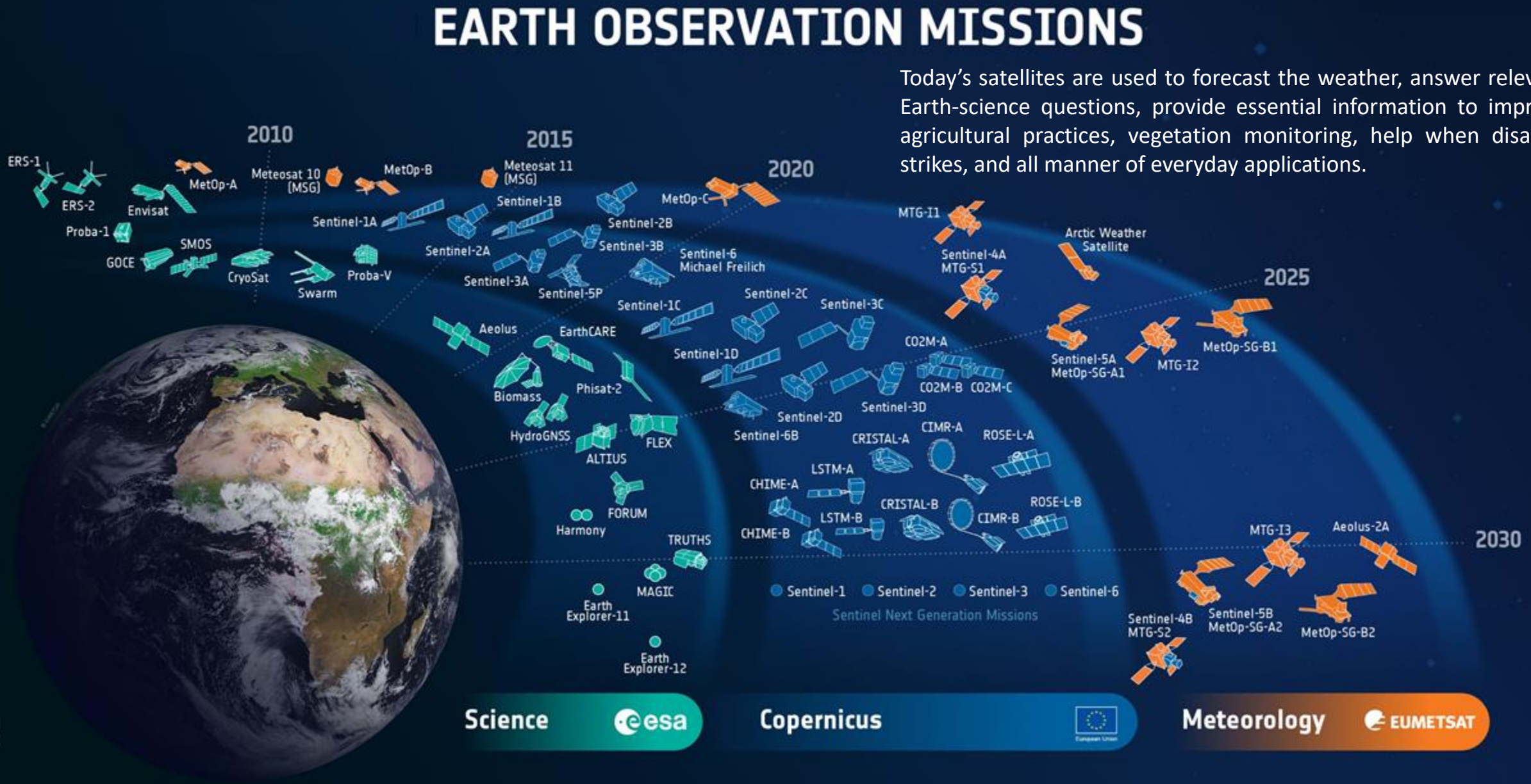
Ministry of Science and Higher Education
Republic of Poland

IGiK

Program Copernicus

- Copernicus is the European Union's Earth Observation Program, managed by the European Commission in partnership with ESA (European Space Agency).
- It provides high-quality, free, and open data for monitoring the Earth's environment and understanding climate change.
- Copernicus utilizes a series of satellites called **Sentinels**, designed specifically for Earth observation.
- These satellites deliver continuous, near-real-time data on land use, ocean monitoring, air quality, disaster response, and more.
- All satellite data and services are **free and open to the public**, enabling widespread use for environmental, social, and economic benefits.

The need for information from satellites is growing at an ever-increasing rate…



Today's satellites are used to forecast the weather, answer relevant Earth-science questions, provide essential information to improve agricultural practices, vegetation monitoring, help when disaster strikes, and all manner of everyday applications.

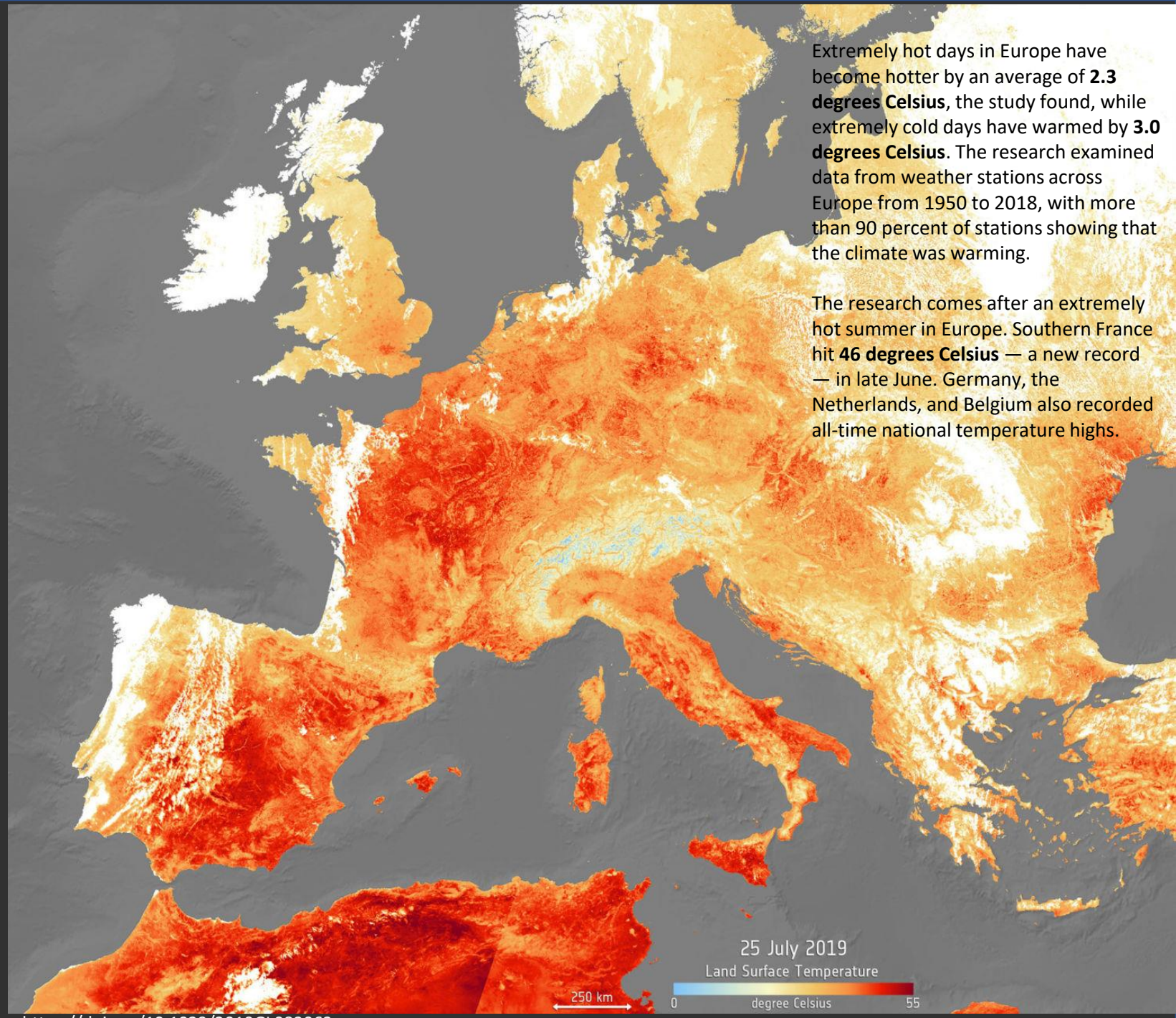
Motivations

Accessibility and Transparency: By providing free and open access to satellite data, Copernicus enables end users—including researchers, businesses, governments, and citizens—to obtain accurate, up-to-date information without restrictions. This transparency fosters trust and encourages a collaborative approach to addressing global challenges such as climate change, natural disasters, and urban development.

Collaboration Across Sectors: The open framework allows a wide range of stakeholders—governments, private companies, academic institutions, and non-profit organizations—to collaborate more effectively. Shared access to data ensures that resources are used efficiently and that collective efforts to address global issues are coordinated and data-driven.

Enhancing Public Awareness: Copernicus satellite data can help increase public awareness of critical environmental issues such as deforestation, air quality, and ocean pollution. This empowers citizens and organizations to take action, advocate for policy changes, and participate in sustainable practices. It also enables informed public dialogue around climate change and environmental stewardship.

Informed Decision-Making: Copernicus data delivers high-resolution, reliable environmental and climate information, which is essential for making informed decisions in fields like agriculture, urban planning, disaster management, and resource management. End users can rely on this data to monitor and forecast environmental conditions, optimizing their strategies and interventions.



Extremely hot days in Europe have become hotter by an average of **2.3 degrees Celsius**, the study found, while extremely cold days have warmed by **3.0 degrees Celsius**. The research examined data from weather stations across Europe from 1950 to 2018, with more than 90 percent of stations showing that the climate was warming.

The research comes after an extremely hot summer in Europe. Southern France hit **46 degrees Celsius** — a new record — in late June. Germany, the Netherlands, and Belgium also recorded all-time national temperature highs.

https://doi.org/10.1029/2019GL082062

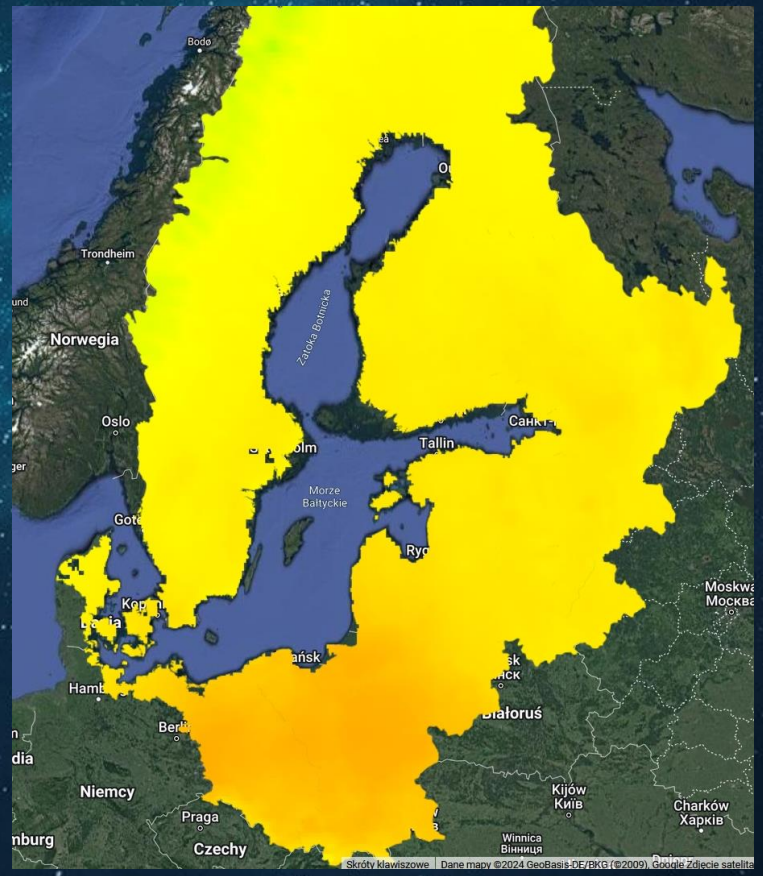
FPCUP Open Data Framework for the Baltic Sea Drainage Basin

Aim of the project: webpage platform dedicated environmental monitoring at the catchment area with an open-source and free-of-charge satellite observations as well as meteorological registrations.

Extent: The Baltic Sea covers 415,266 square kilometers, while its catchment area - at **1.7 million km²** - extends over an area about four times as large as the sea itself. In Germany, Denmark and Poland as much as 60-70% of the Baltic's catchment area consists of **farmland**. Forests, wetlands and lakes make up between 65% and 90% of the catchment area in Finland, Russia, Sweden and Estonia.

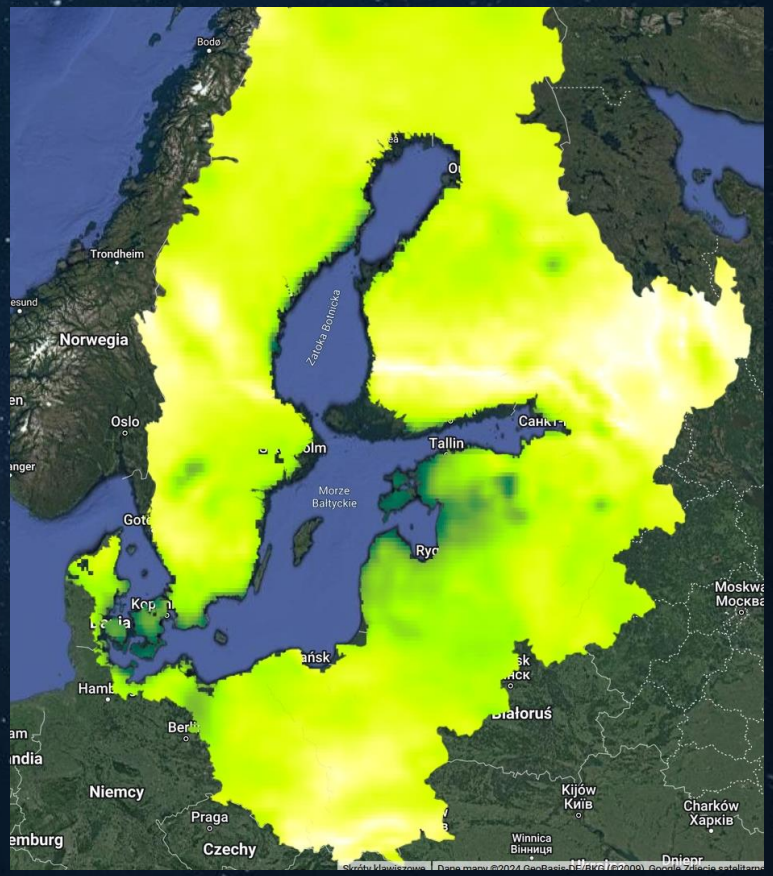
SENTINEL-2 VEGETATION INDEX NDVI
APRIL-SEPTEMBER 2023 MOSAIC

ERA5 LAND 2m TEMPERATURE
AUGUST 15, 2023



[K]

ERA5 LAND WIND SPEED 10m ABOVE SURFACE
JULY 15, 2023



[m/s]

The Importance of Soil Moisture & Drought Mapping with Satellites

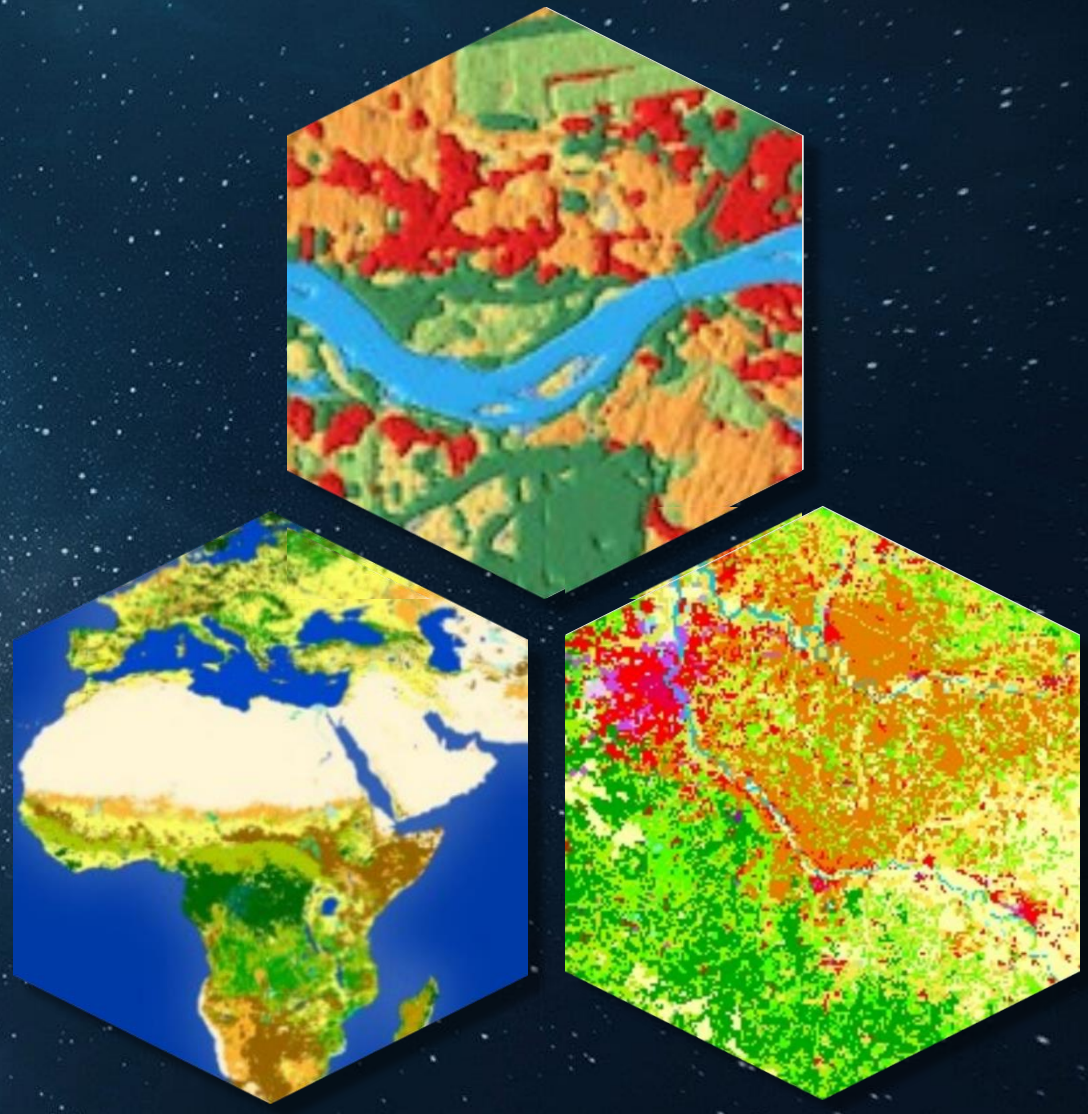
Early Warning Systems: Provides real-time monitoring of soil moisture and drought conditions, essential for early detection and response to water stress and droughts.

Agricultural Productivity: Poland's economy heavily depends on agriculture, with around 60% of its land area being used for farming.

Soil moisture: On average, Poland experiences moderate to low soil moisture levels during the summer months, particularly in the southern and central parts of the country. The average soil moisture content in these areas can range from 15% to 25% in the top 30 cm of soil

•The Institute of Geodesy and Cartography (IGiK) utilizes satellite data for **monitoring soil moisture** and **mapping drought frequency**, which has been the Institute's domain of research for many years, dating back to the 1990s.

Support Land Cover/Land Use Products



Input dataset

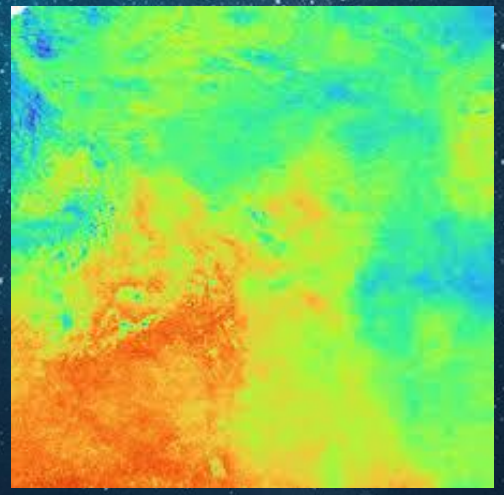
Copernicus data for soil moisture monitoring

- Sentinel-1 GRD collected from 2021 to present

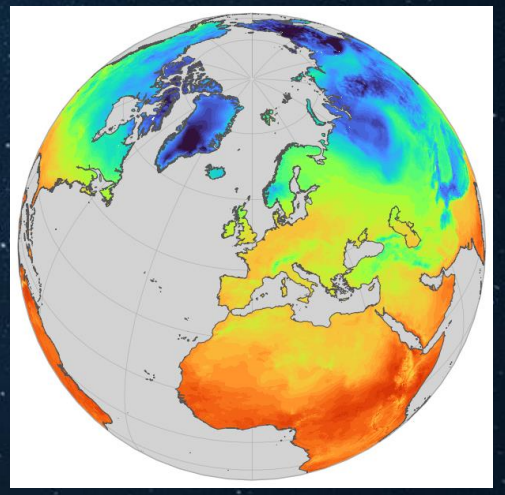
Copernicus data for drought mapping

- Land Monitoring Service (LMS) component **Land Surface Temperature**
- ERA5-Land daily air temperature and total precipitation

C-band Synthetic Aperture Radar (SAR) instrument at 5.405GHz, 12-day revisit time, 6-day in tandem (S1A + S1B) , dual-polarization VV/VH



Synthesis of Thermal Condition Index 2021-present (raster 5 km), global, 10-daily



ERA5 reanalysis dataset land-based observations from 1959 onwards, spatial resolution of 0.1° (~9 km), hourly temporal resolution,

Soil moisture modelling

Soil Moisture Retrieval Using the σ° Indices from Sentinel-1

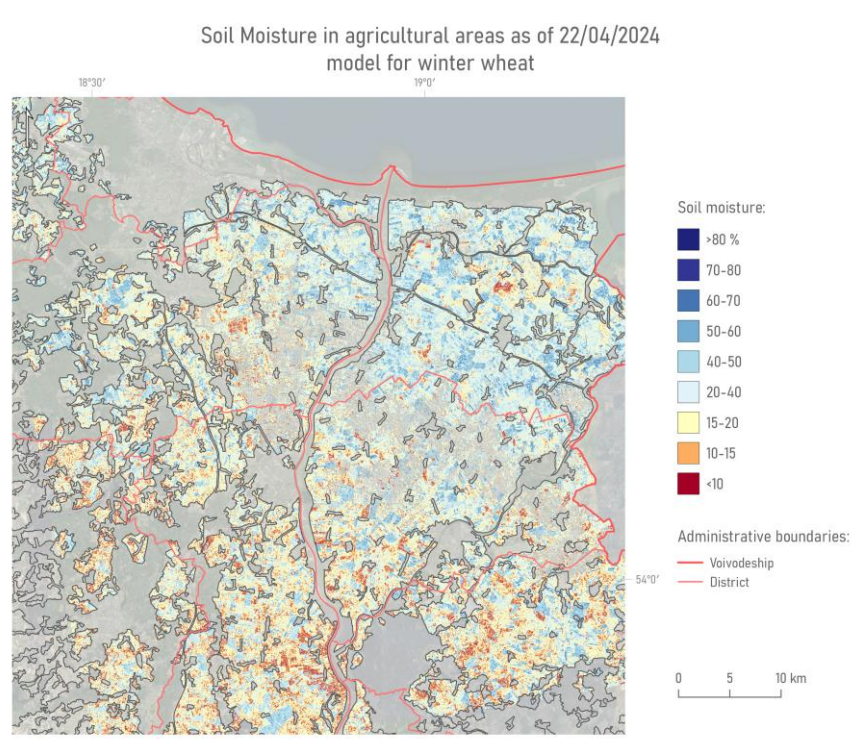
Substituting the vegetation descriptor by the index σ° VH−VV and the index σ° VV/VH

$$\tau^2 = \exp(-2(\sigma^\circ \text{ VV/VH})/\cos(\theta))$$

Replacing vegetation descriptor in equation by σ° VV/VH values we receive:

$$\sigma^\circ \text{ VH} = -18.9 + 0.33\tau^2 \text{ SM} - 0.14(1 - \tau^2)\cos(\theta)\,\sigma^\circ(\text{VH–VV})^2$$

$$\text{SM} = (\sigma^\circ \text{ VH} + 18.9 - 0.14(1 - \tau^2)\cos(\theta)\,\sigma^\circ(\text{VH–VV})^2/(0.33\,\tau^2)$$



Dabrowska-Zielinska K., Musial J., Malinska A., Budzynska M., Gurdak R., Kiryla W., Bartold M., Grzybowski P., 2018, Soil Moisture in the Biebrza Wetlands Retrieved from Sentinel-1 Imagery, Remote Sensing 2018, Vol. 10(12), 1979. https://www.mdpi.com/2072-4292/10/12/1979

Dabrowska-Zielinska K., Budzynska M., Gurdak R., Musial J., Malinska A., Gatkowska M., Bartold M., 2017, Application of Sentinel-1 VH and VV and Sentinel-2 for soil moisture studies, Proceedings of SPIE, Volume 10426, Active and Passive Microwave Remote Sensing for Environmental Monitoring; 104260C (2017). https://doi.org/10.1117/12.2278613

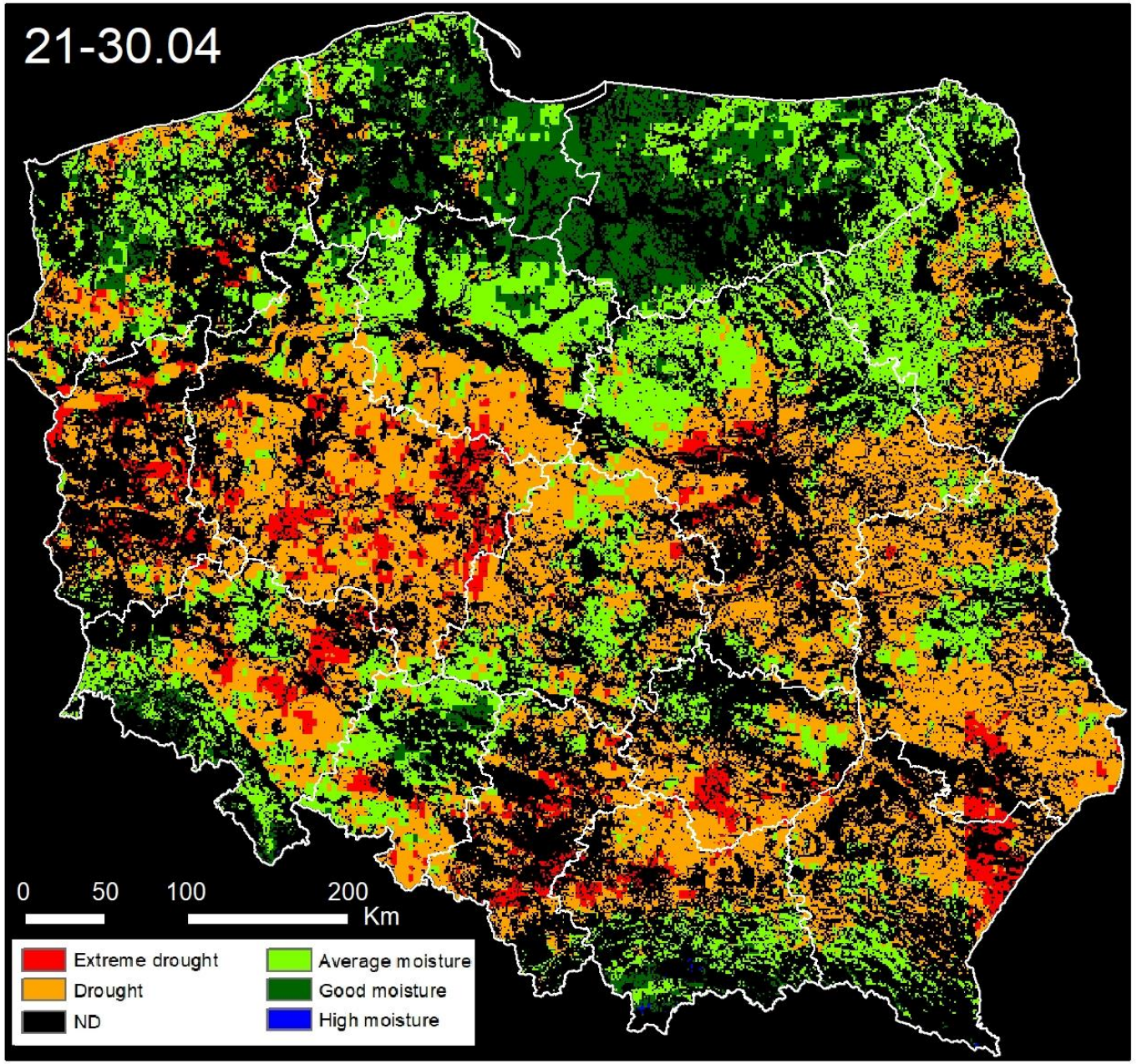
Drought mapping

The system for monitoring crop growth conditions has been elaborated at the Remote Sensing Centre, Institute of Geodesy and Cartography. It determines crop conditions with the use of the index based on Copernicus data resampled to 1 km^2 spatial resolution.

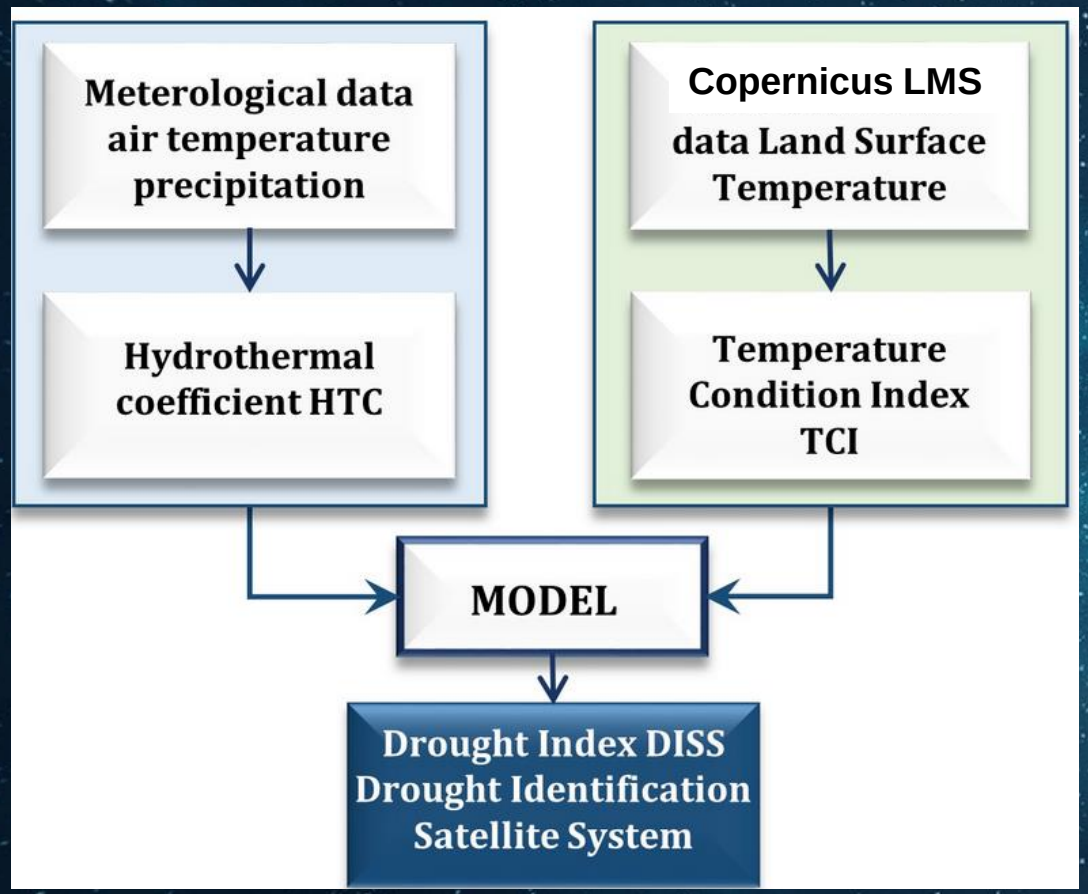
The index, called *Drought Identification Satellite System* – DISS is a function of *Temperature Condition Index* – TCI and meteorological index characterizing climatic conditions on the territory of Poland (*Hydrothermal Coefficient* – HTC). DISS drought index is generated at the succeeding ten-day periods within vegetation season, starting from the end of March.

Index values are divided into five ranges, characterizing particular level of moisture: extreme drought (red); drought (orange); average moisture (light green); good moisture (dark green) and high moisture (dark blue).

COPERNICUS LAND MONITORING SERVICE TCI
TCI INPUT TO CREATE SATELLITE DROUGHT SYSTEM - IGIK DISS



Drought mapping



The variability of the right side of the equation is based on TCI, while MedHTC30 is a fixed element characterizing the climatic aspect of a specific area. For the whole territory of Poland, the MedHTC30 image with a resolution of 1 km was prepared using interpolated meteorological data

$$DISS_t = MedHTC30 * \exp\left(a + b * TCI_t + c{*}TCI_{t-1} + d{*}TCI_{t-2}\right)$$

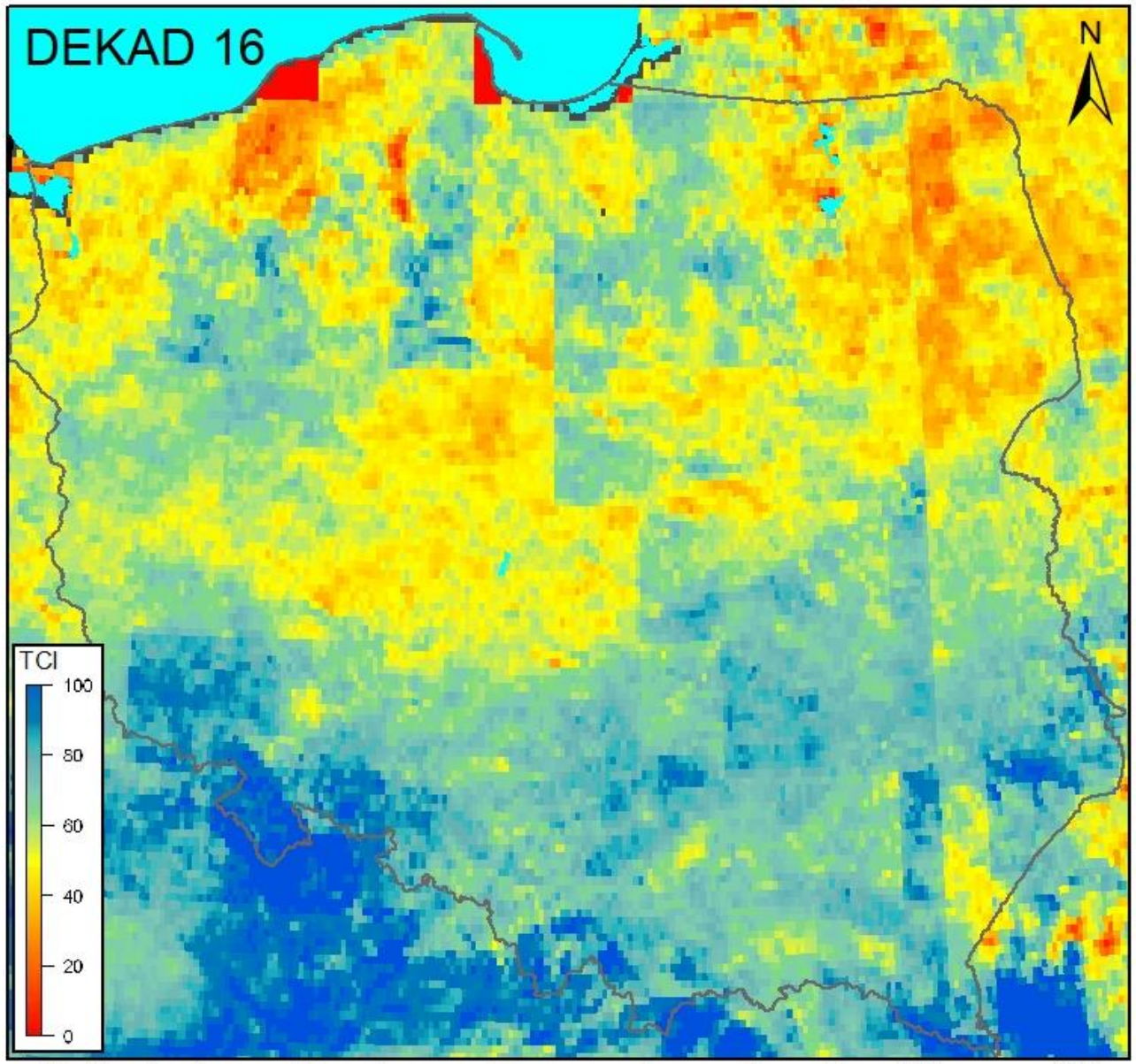
where t is the ten-day time point in the growing season; and a is negative while b, c, and d are positive.

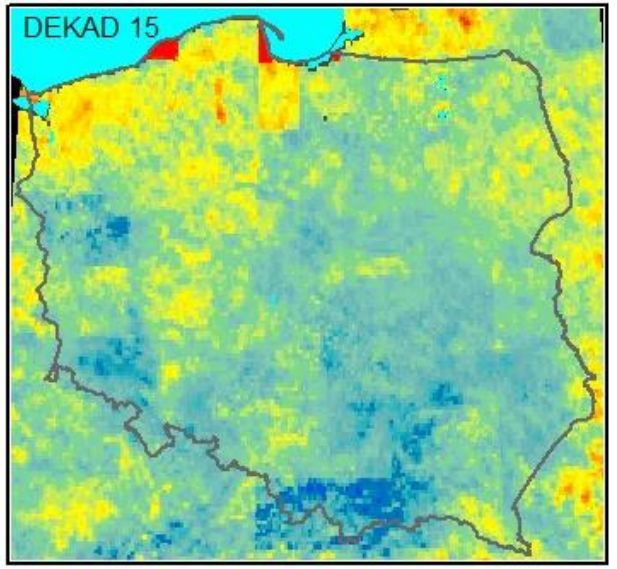
Dabrowska-Zielinska, K.; Malinska, A.; Bochenek, Z.; Bartold, M.; Gurdak, R.; Paradowski, K.; Lagiewska, M. Drought Model DISS Based on the Fusion of Satellite and Meteorological Data under Variable Climatic Conditions. *Remote Sens.* **2020**, *12*, 2944. https://doi.org/10.3390/rs12182944

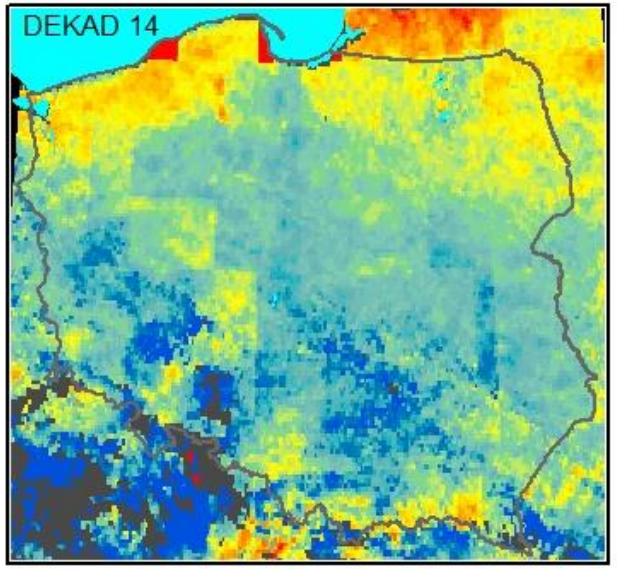
Dabrowska-Zielinska K., Bochenek Z., Malinska A., Bartold M., Gurdak R., Lagiewska M., Paradowski K., 2021, Drought Assessment Applying Joined Meteorological and Satellite Data, Proceedings of the 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS, Brussels, Belgium, 11–16 July 2021, pp. 6591-6594. https://doi.org/10.1109/IGARSS47720.2021.9553739

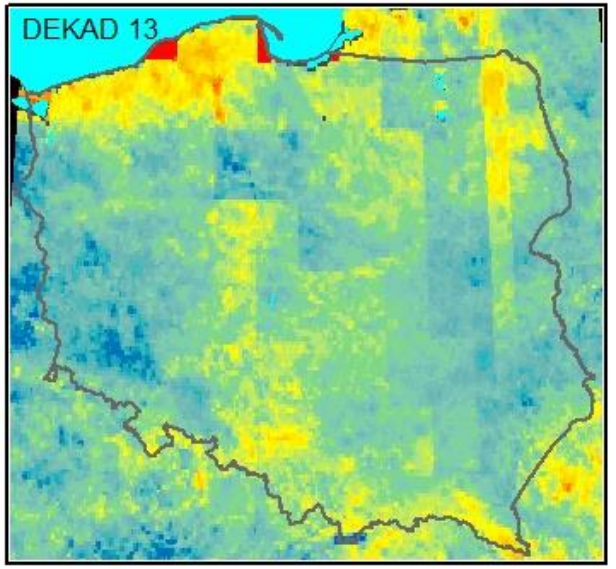
COPERNICUS TCI 10-daily synthesis from April to June 2023

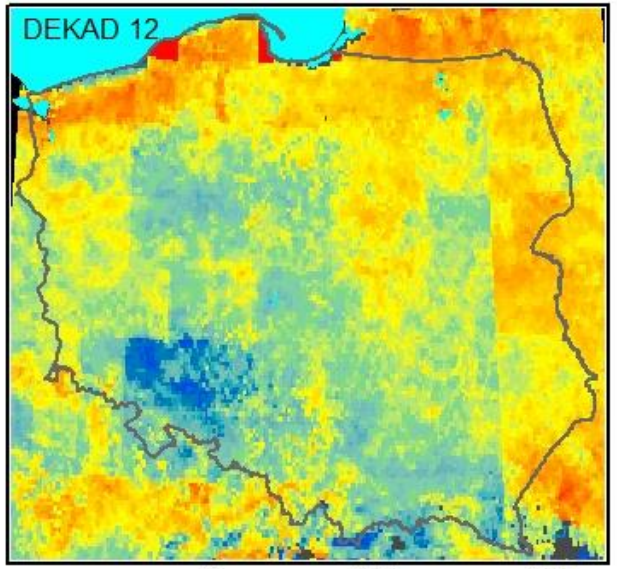
TCI equals 0 represents a very poor condition (severe deviation from the optimal temperature for vegetation), and 100 represents an optimal temperature condition.











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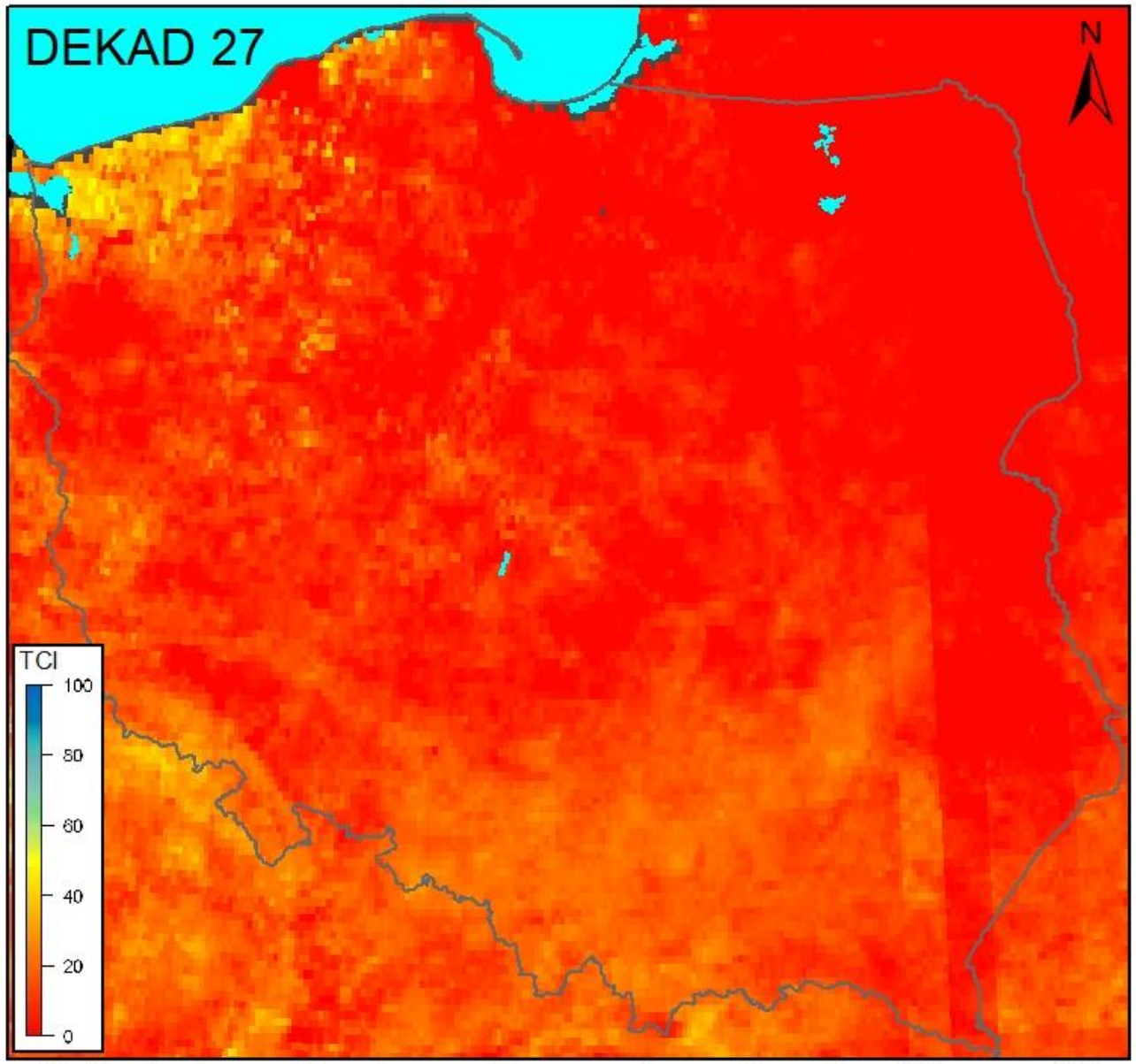
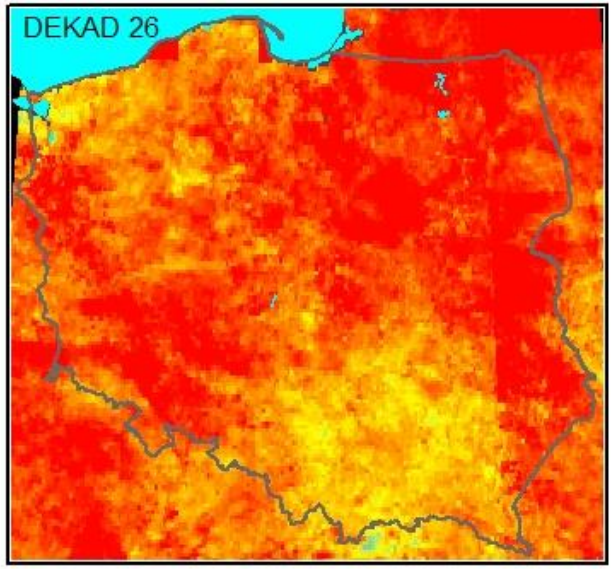
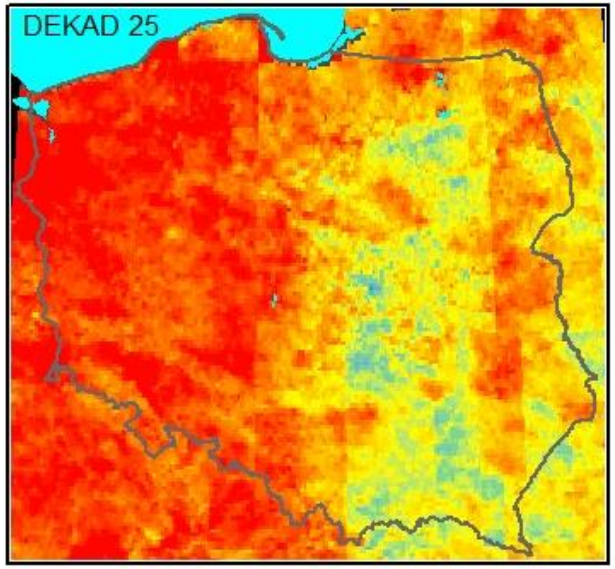
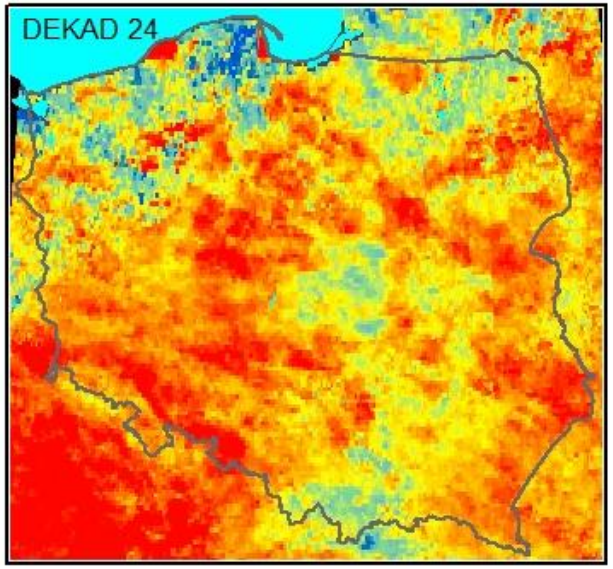
COPERNICUS TCI 10-daily synthesis from August to September 2023

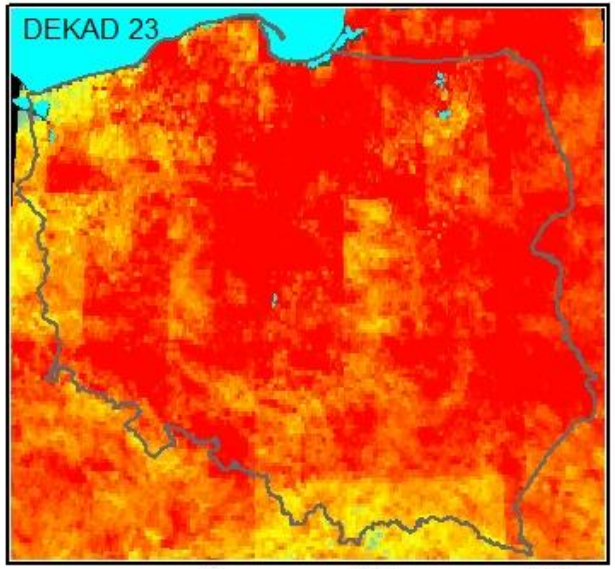
TCI helps to quantify temperature deviations in a more user-friendly way for agricultural and ecological monitoring.











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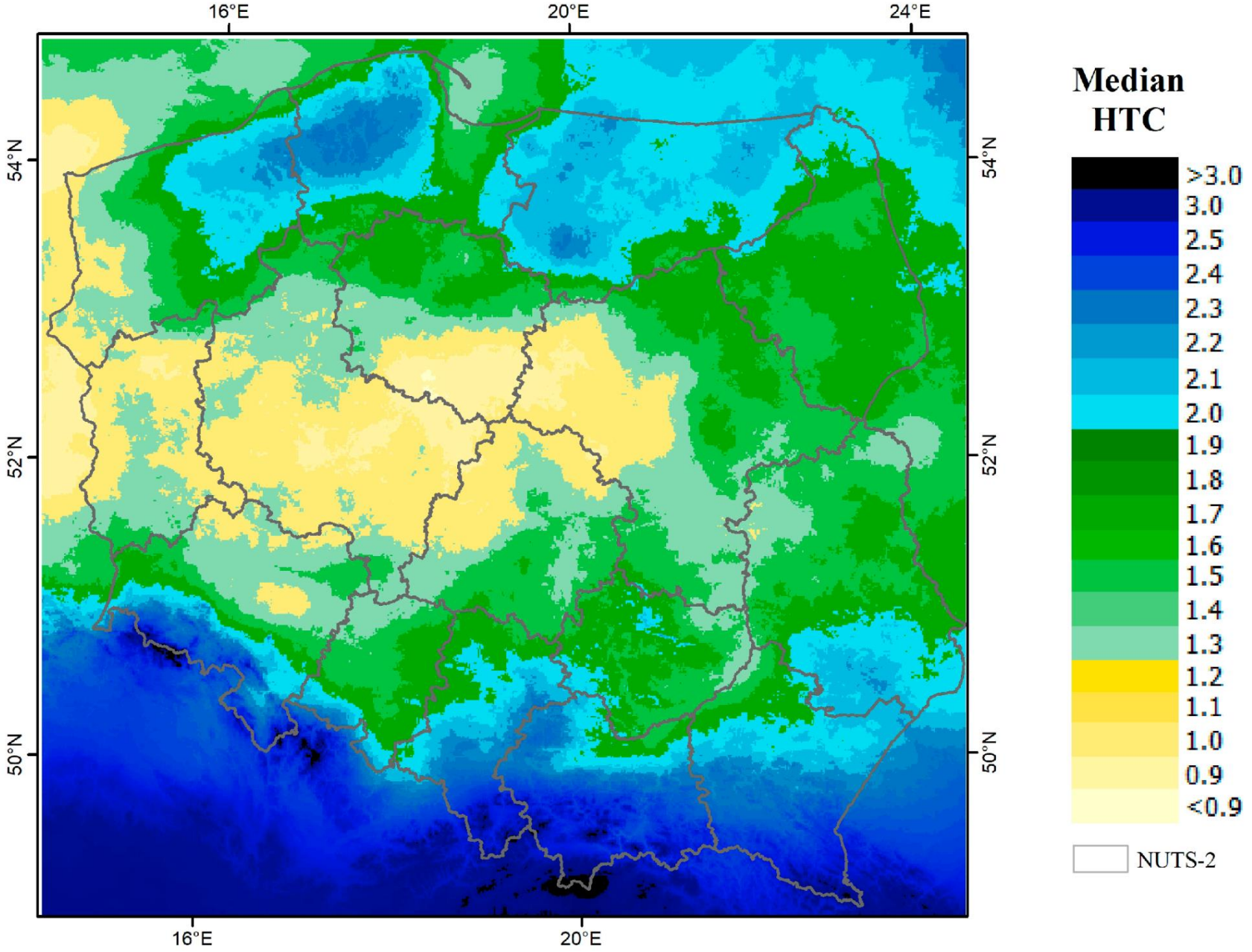
Remote Sensing Centre

0 50 100 200 Km

0 200 400 Km

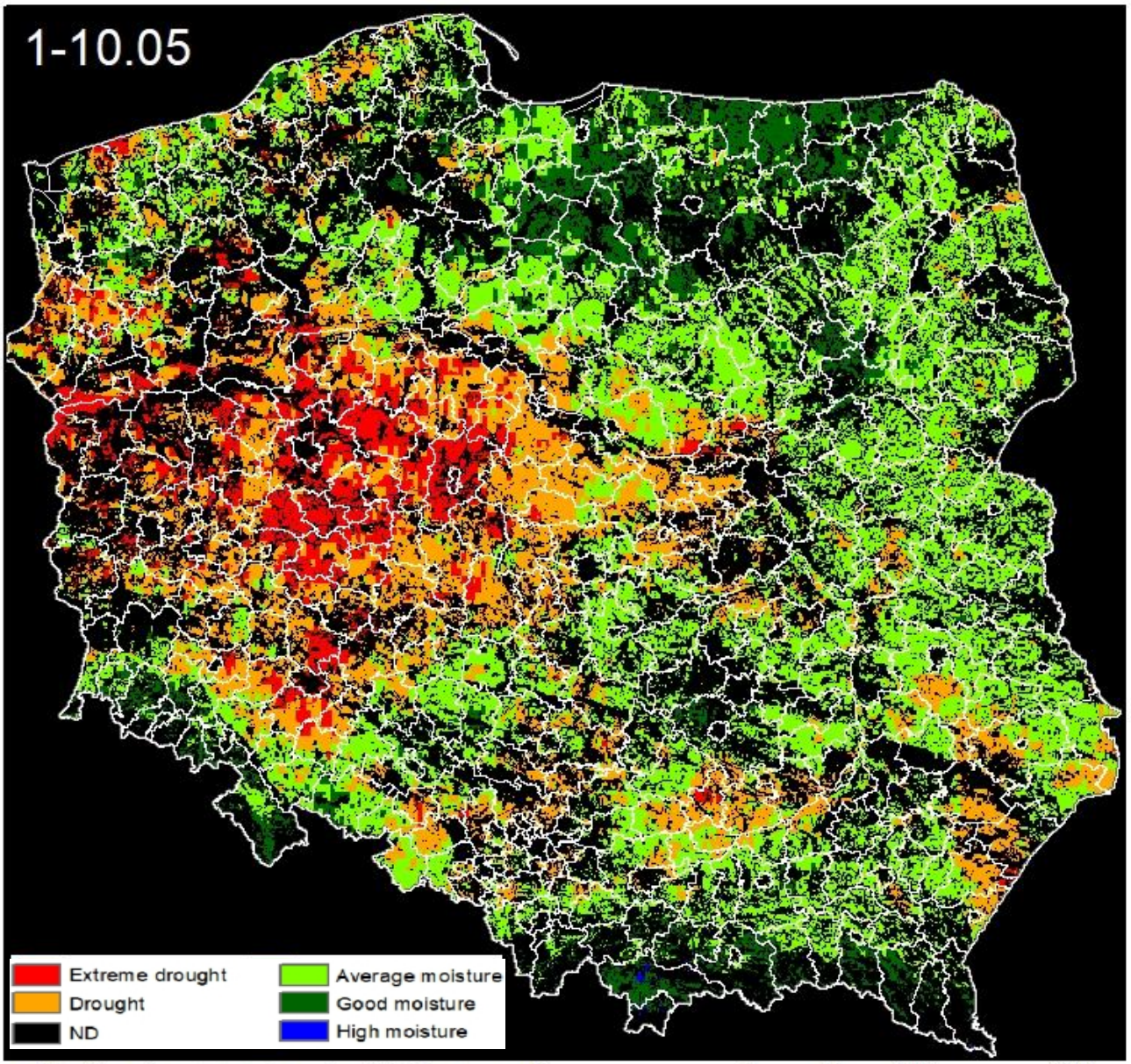


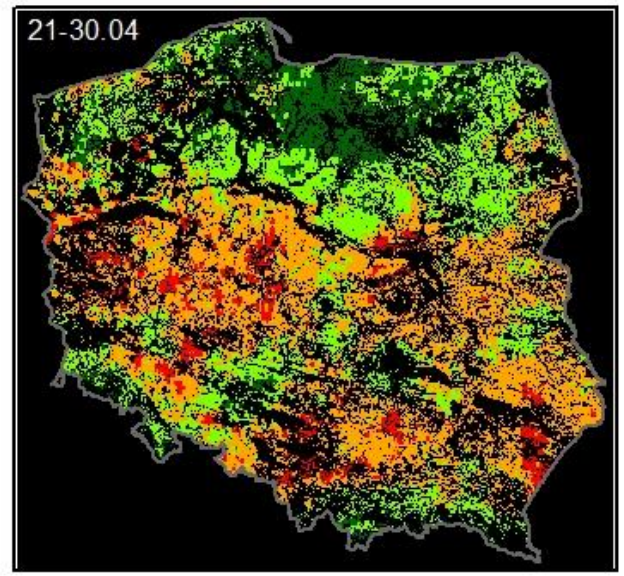
The median of HTC informs about the average atmospheric conditions (in relation to precipitation and air temperature). To obtain the median HTC values for the entirety of Poland, a database of 1 km raster images of HTC was created using the daily interpolated temperature and precipitation from the meteorological stations in the period 2001–2023. These images refer to the growing season (from the end of April to September) and were formed with a 10 day step.

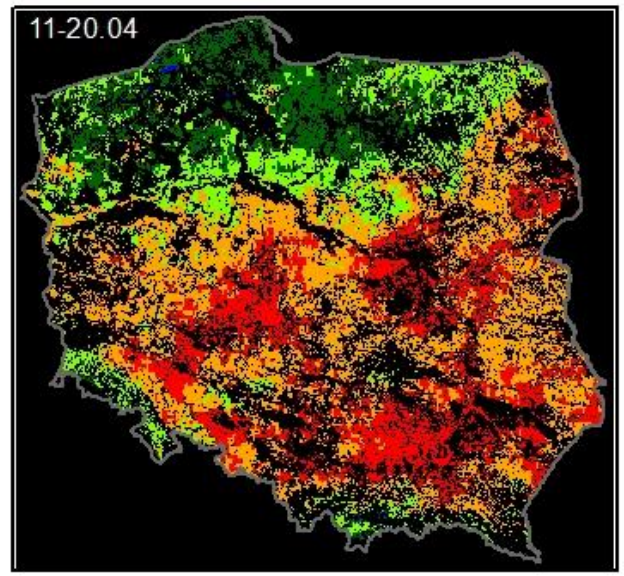
The spatial distribution of HTC median values in Poland is related to climatic conditions, which are influenced by Poland's topography. The lowland areas in western and central Poland are characterized by the prevailing water deficit (HTC median < 1.0), while the upland and mountain areas located in southern Poland, due to higher and more frequent rainfall, reveal good moisture conditions (HTC median > 1.0). Moreover, a high HTC median appears in northern Poland (Masurian and Pomeranian regions), where hilly landscapes filled with numerous lakes modify the climatic conditions, thus increasing the amount of rainfall.

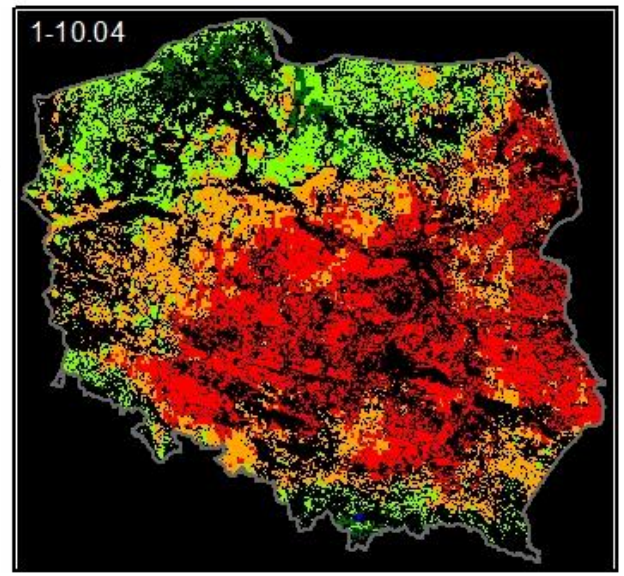
The same conditions are observed along the Baltic sea coastline—high HTC values are caused by the impact of a maritime-type climate in the northern part of the country.

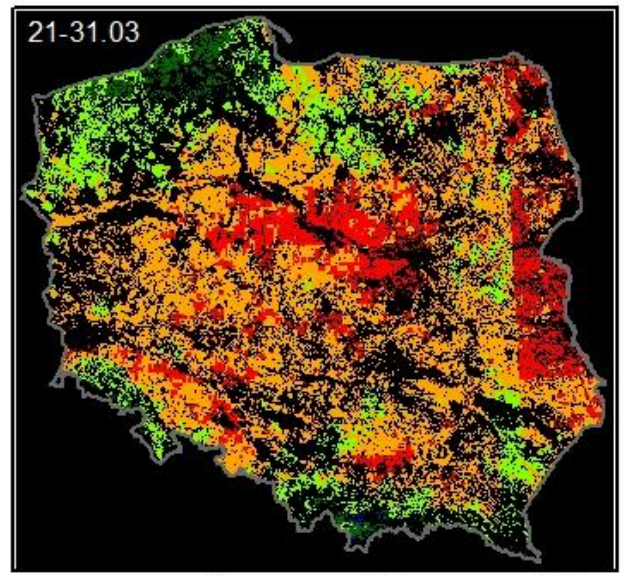
COPERNICUS DISS



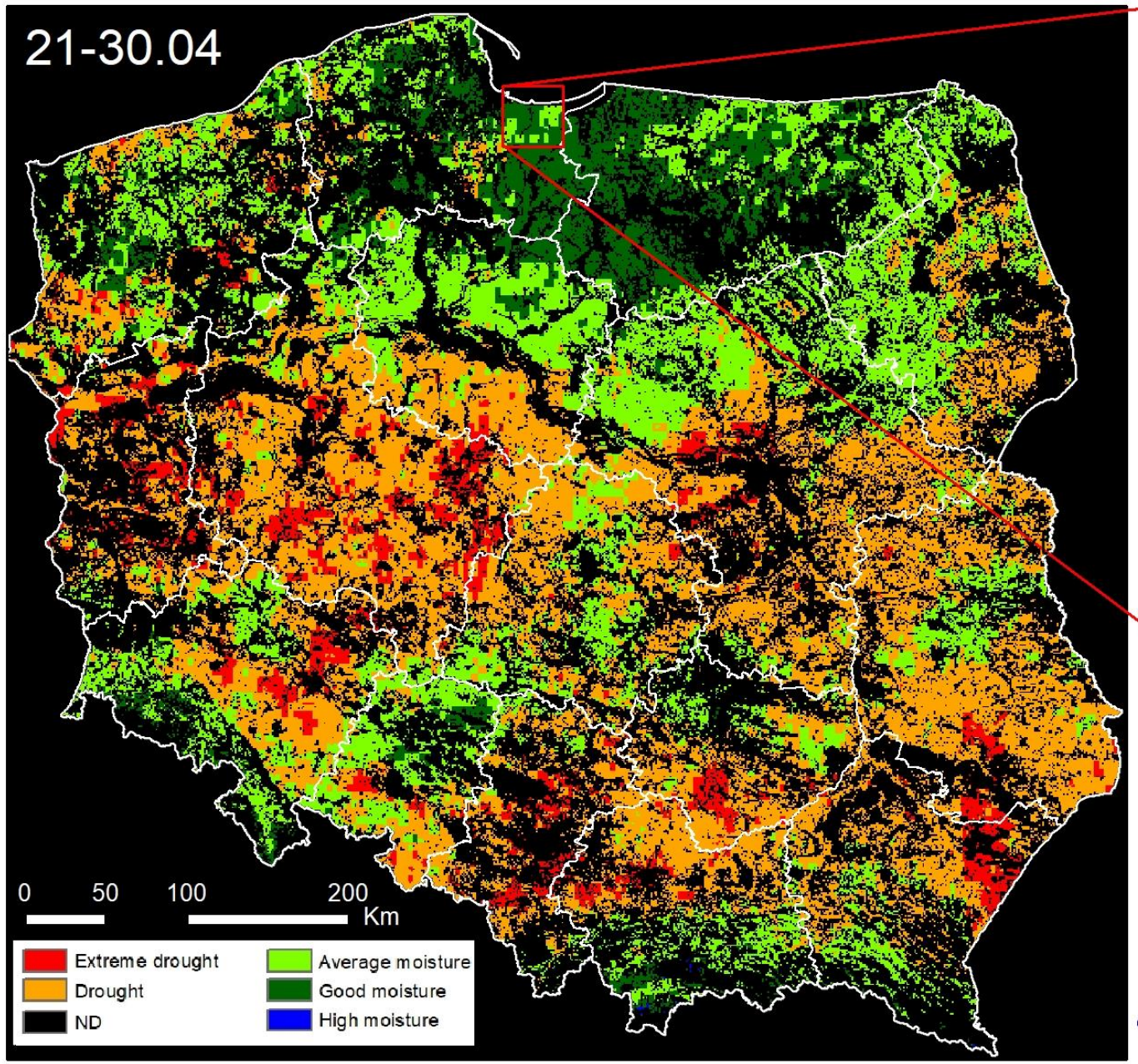






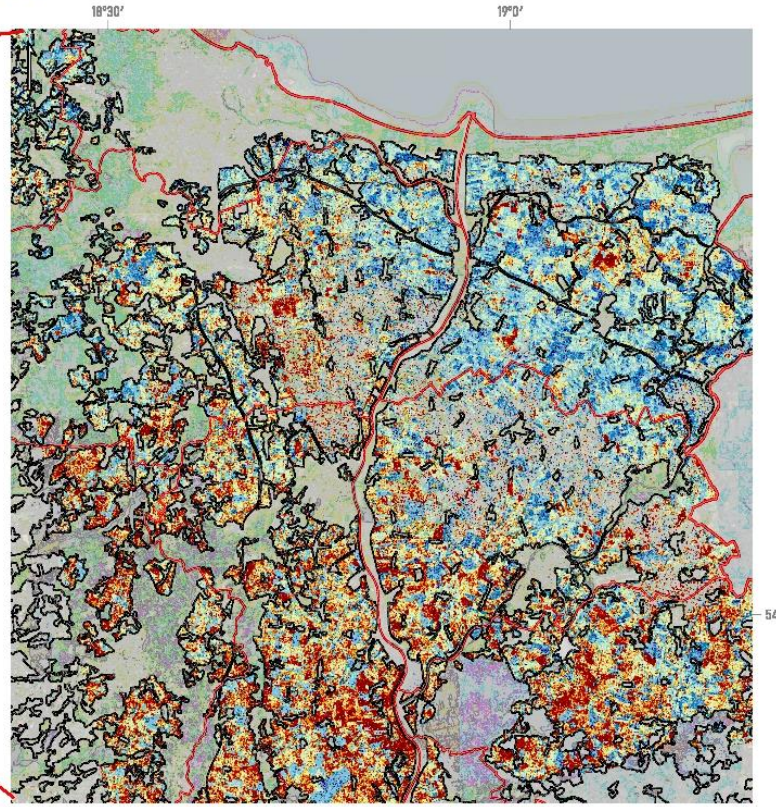


COPERNICUS LAND MONITORING SERVICE TCI
TCI INPUT TO CREATE SATELLITE DROUGHT SYSTEM - IGIK DISS

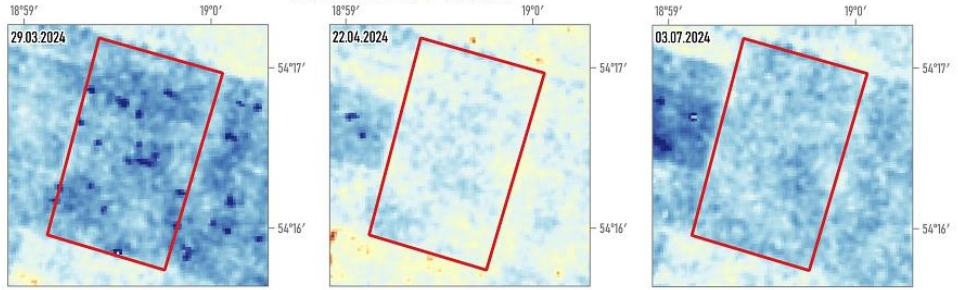


Copernicus Sentinel-1

Soil Moisture in agricultural areas as of 22/04/2024
model for winter wheat



Water Cloud Model - IGiK
Selected Fields



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Remote Sensing Centre

Layers:
administrative data
Orto-photomaps
TCI maps
Drought maps
Soil moisture maps

Copernicus – Sentinel-1
Copernicus – Sentinel-2

POL/ENG menu

https://balticservice.granado.pl temporary address

Copernicus - Sentinel-1

Copernicus - Sentinel-2

Wskaźnik satelitarnej identyfikacji suszy rolniczej

2024 (IGiK) 01.05 - 10.05.2024

2023 (IGiK) 01.03 - 10.03.2023

2022 (IGiK) 21.03 - 31.03.2022

2021 (IGiK) 01.03 - 10.03.2021

Wskaźnik kondycji roślin TCI 2024 (CLMS)

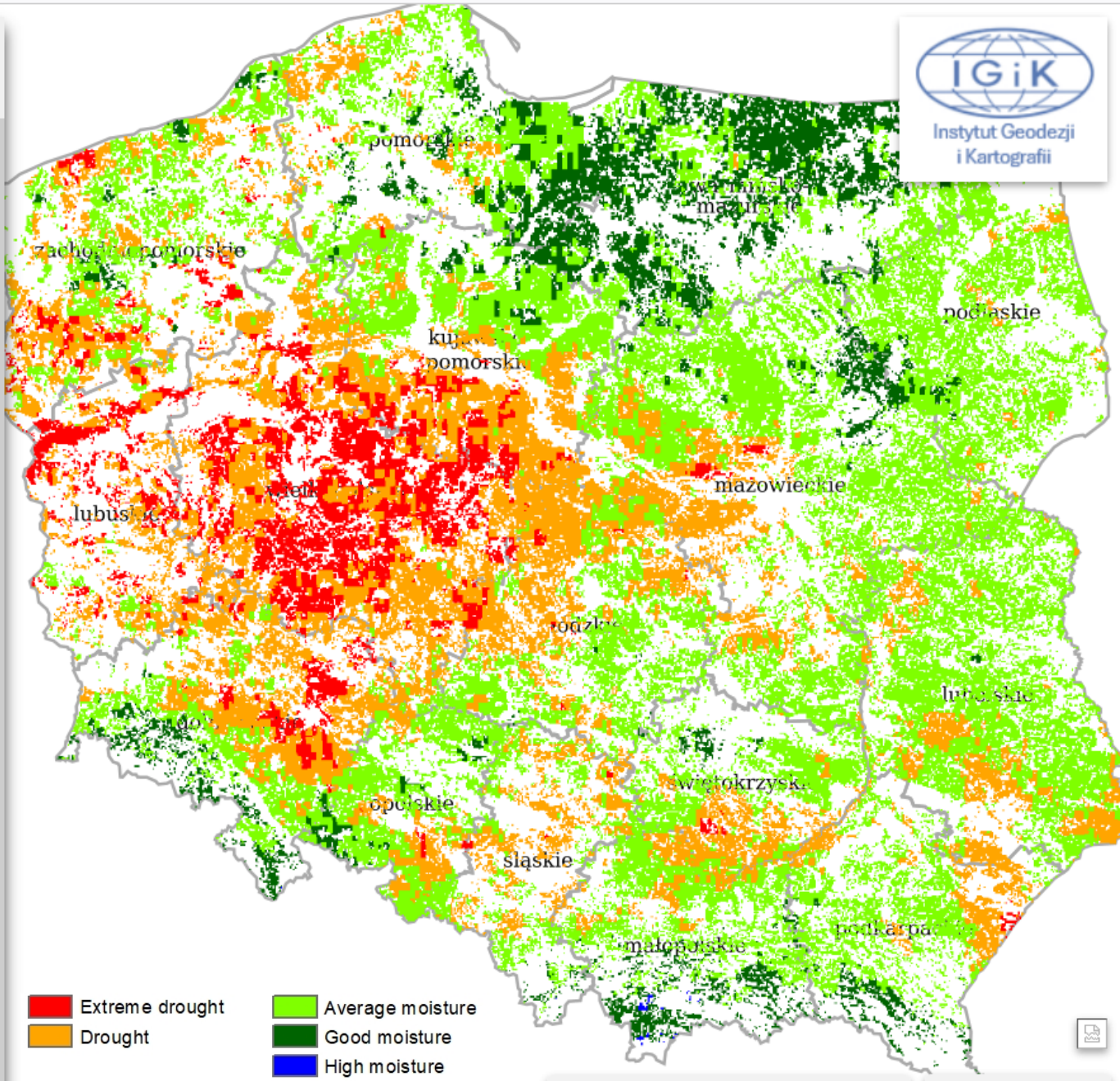
Wskaźnik kondycji roślin TCI 2023 (CLMS)

Wskaźnik kondycji roślin TCI 2022 (CLMS)

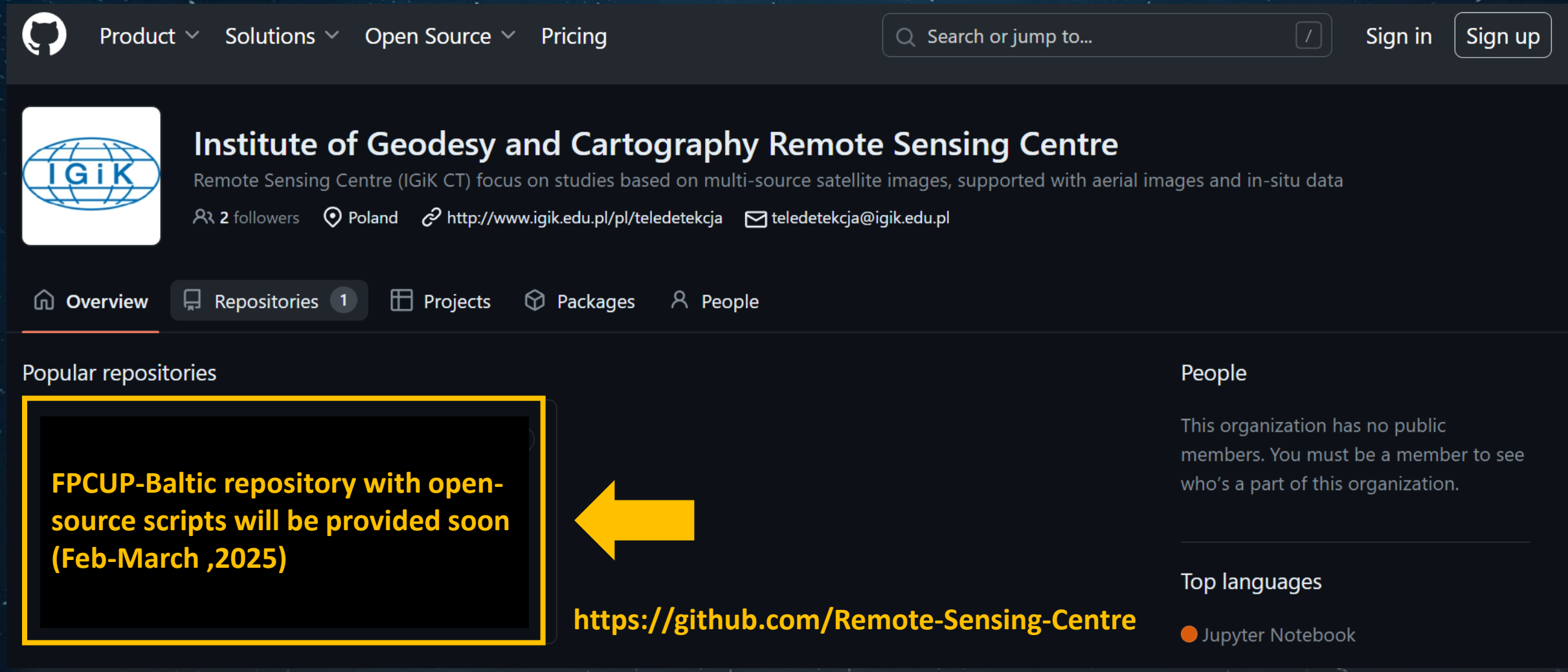
Wskaźnik kondycji roślin TCI 2021 (CLMS)

Mapy i ortofotomapy

Administrative data



GitHub repository open-access



Application of Copernicus Satellite Data for Soil Moisture Monitoring and Drought Mapping within the Baltic Sea Open Data Framework

Maciej Bartold, Konrad Wróblewski, Dariusz Ziółkowski, Katarzyna Dąbrowska-Zielińska

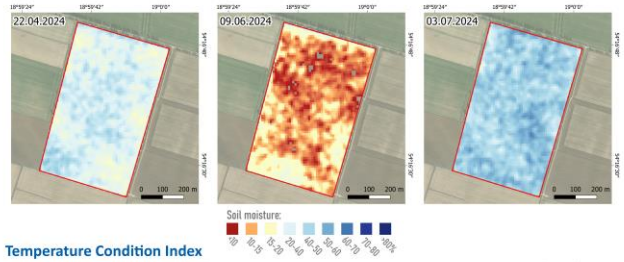
Remote Sensing Centre, Institute of Geodesy and Cartography

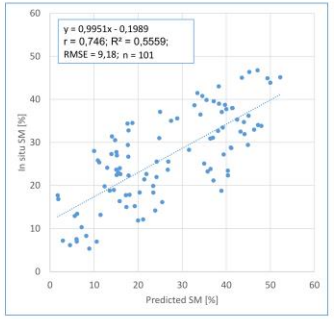
Aim of the project

The main objective of this action is to foster innovative service development for sustainable management in the Baltic Sea catchment area. The innovation will aim at both open-source development to meet the needs of governmental agencies as well as promote the use of Copernicus data in business applications. As part of the collaboration, hydrological conditions and drought frequency and soil moisture variability were monitored.

Soil moisture modelling - Sentinel-1

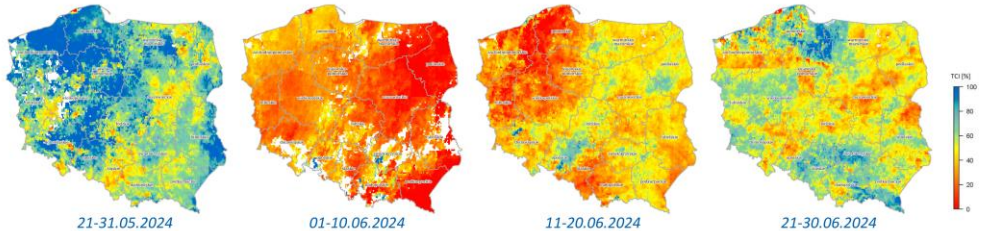
Soil moisture product for the FPCUP Baltic project used data from the Sentinel-1A satellite (GRDH product in VV and VH polarizations) from March to October 2023 and March to early July 2024.





Temperature Condition Index

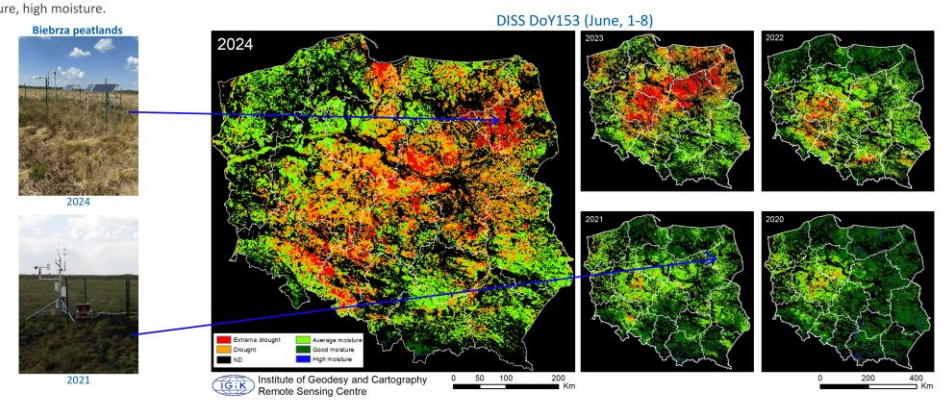
Temperature Condition Index (TCI), a resource of the Copernicus Land Monitoring Service (CLMS), providing information on Earth's thermal conditions with a spatial resolution of 5km. Updated every 10 days, it combines surface temperature information from a variety of sources, including satellite observations and ground-based measurements, to provide an integrated picture of the planet's thermal dynamics. Displayed in the range 0-100, where 0-20 are lower temperatures, 20-60 are average values, 60-100 are higher values, increased thermal activity.



21-31.05.2024 *01-10.06.2024* *11-20.06.2024* *21-30.06.2024*

Drought Identification Satellite System

The Drought Identification Satellite System (DISS), with a spatial resolution of 5km^2, developed on the basis of Copernicus Land Monitoring Service (CLMS) data, is based on the TCI and the Hydrothermal Coefficient (HTC) meteorological index. DISS values are divided into five ranges: extreme drought, drought, average moisture, good moisture, high moisture.



European Union's Caroline Herschel Framework Partnership Agreement on Copernicus User Uptake under grant agreement No FPA 275/G/GRO/COPE/17/10042,project FPCUP (Framework Partnership Agreement on Copernicus User Uptake), Action 2020-3-24, Open Data Framework for the Baltic Sea Drainage Basin, SGA grant 16.

Thank you for your attention

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