Real-Time Satellite Data Processing at IMGW-PIB in Poland Using CSPP

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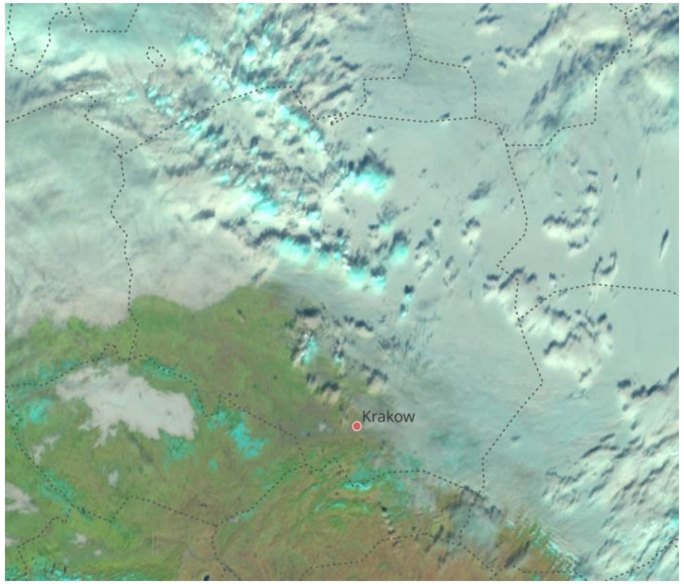
19/05/2025, Darmstadt, Germany

Department of Satellite Remote Sensing IMGW-PIB Kraków



1. Geostationary Satellites (GEO)

Data acquisition: Continuous reception of satellite observations with updates every 5–15 minutes for near real-time monitoring.

Satellite missions: MSG (Meteosat Second Generation), MTG (Meteosat Third Generation)

2. Polar-Orbiting Satellites (LEO)

Data acquisition: Reception of high-spatial-resolution satellite data providing detailed atmospheric and environmental observations.

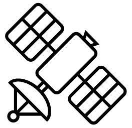
Satellite missions:

USA: NOAA-20/21, NPP, Aqua
Europe: MetOp-B/C, Sentinel-1, AWS-PFM, SG-A1
China: FY-3D/E

Our Infrastructure:

1. **Antenna System:** 3.8m dish for high-gain signal reception.
2. **High-Availability Computing:** A resilient cluster of servers ensuring 24/7 data continuity and processing.

Currently, we have only one main antenna for polar satellites, but another one will be installed later this year.



Users of Satellite Data (Real-Time Applications)

Meteorology: Real-time satellite data are used by meteorologists to monitor local weather conditions, including storm development, precipitation, and rapidly evolving cloud systems.
Hydrology: Hydrologists use satellite observations for continuous monitoring of rainfall, soil moisture, and flood extent, supporting early warning systems and water resource management in local catchments.
Climatology: Climate scientists and analysts use satellite data to monitor temperature trends, vegetation stress, and short-term climate anomalies such as heatwaves and droughts.
Coastal protection: Coastal managers and environmental agencies use satellite data to monitor shoreline dynamics and sea conditions, including sea surface temperature, wave activity, and coastal changes, supporting coastal risk management.

Satellite data are first received by the antenna, then transferred to the processing server, and finally distributed to users.

Satellite Data for Operational Decision Support

Fully automated processing (24/7)

We run fully automated processing chains using **CSPP**, PyTroll, MEOS, CGS (Sentinel-1), NWC SAF, CSPP, 2met, and proprietary software.

Product generation

We generate a wide range of products, including RGB imagery and composites from Meteosat, MODIS, and VIIRS.

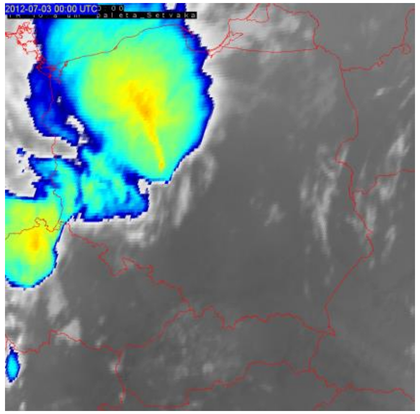
We also use SAF products (NWC SAF, H SAF, LSA SAF, OSI SAF), Sentinel-1 SAR data, and Sentinel-5P observations.

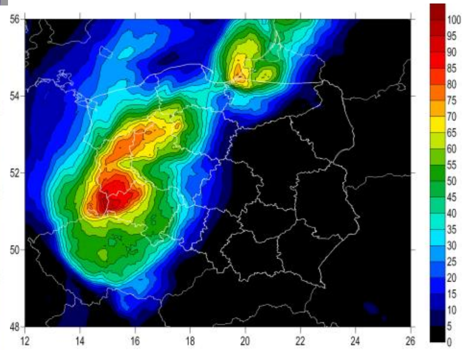
Data are available in standard Level 1 and Level 2 formats (netCDF, HDF, ASCII).

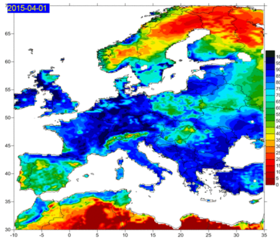
Operational use of data

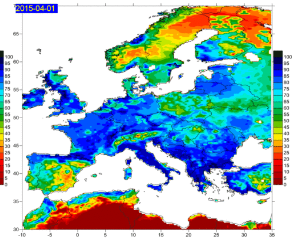
The products are used in daily weather situation analysis and hazard briefings.

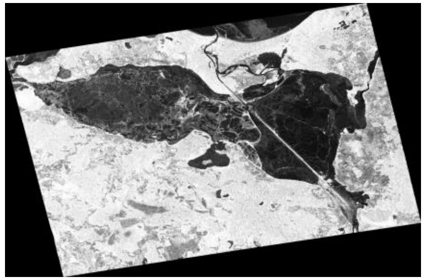
Visual products supporting operational services: cloud cover, precipitation, flooding, wildfire

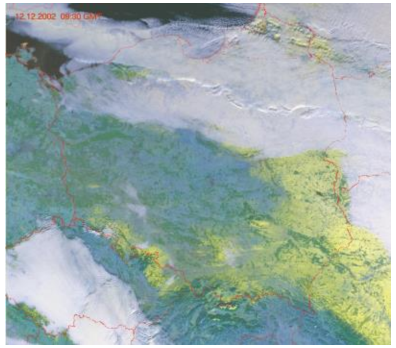












Satellite Data Reception

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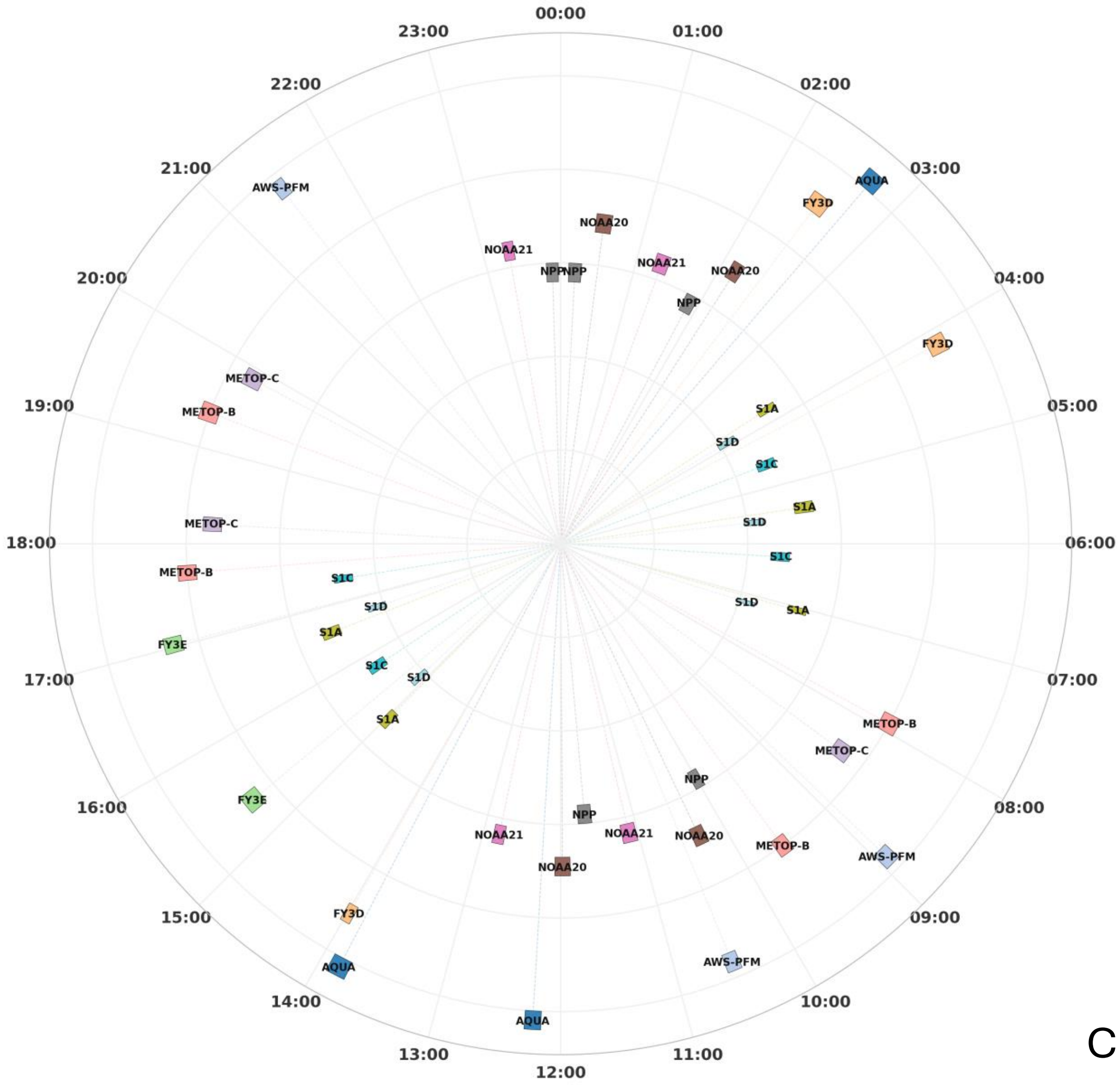
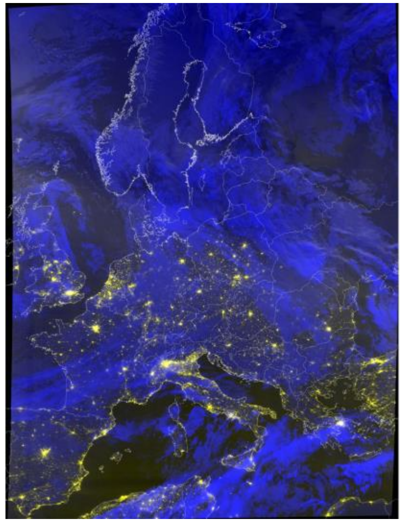
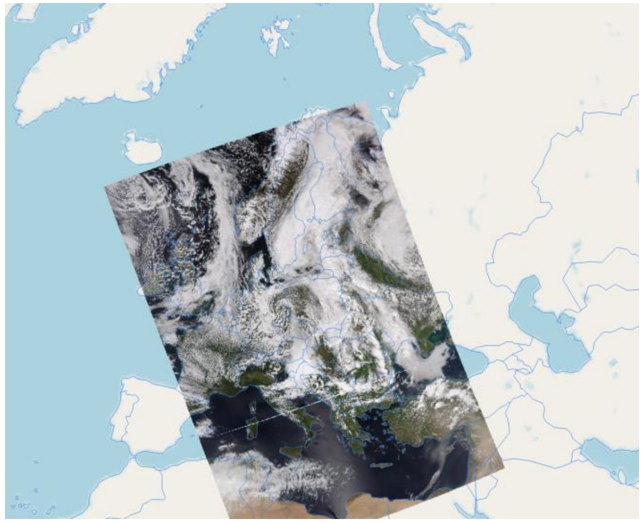


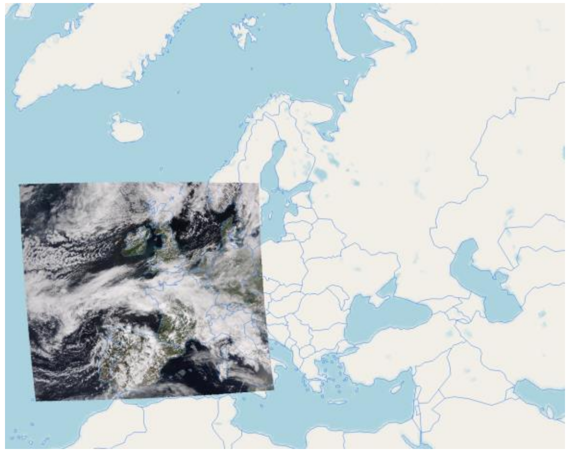
Nighttime satellite transmission



Eastern satellite transmission



Central satellite transmission



Western satellite transmission

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During routine operations, we currently use the following software: CSPP Sensor Data Record, HEAP, MIRS, VIIRS Active Fire, and Polar2Grid. All processing is performed on a single server with 12 CPUs and 128 GB of memory. We plan to add more software in the future, which will require more processing power. Therefore, an HPC system will be used. Before that, we decided to perform benchmarking to determine the optimal number of CPU cores required for each program.

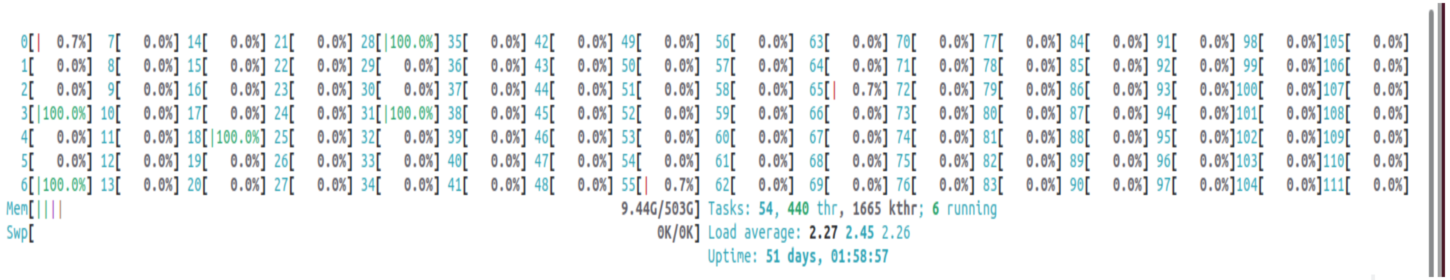
Benchmarking scheme:

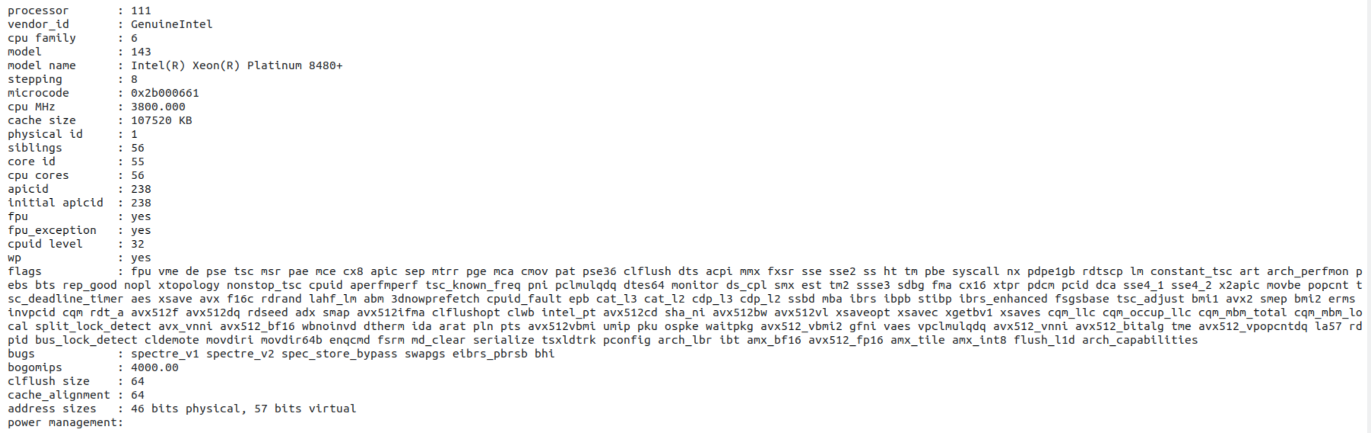
Each program is run 10 times. We analyze execution time, memory usage, and CPU utilization for different numbers of CPU cores, ranging from 1 to 12.

Benchmark software:

- VIIRS, ATMS, CrIS, and OMPS SDR Version 4.1.1 Software
- CSPP HEAP NUCAPS CrIS/ATMS IASI/AMSU-A/MHS Retrieval Package Version 3.0
- CSPP MiRS Microwave Retrieval Software Version 4.0
- VIIRS ATMOSphere EDR Version 1.0

HPC (High-Performance Computing)





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model           : 143
model name      : Intel(R) Xeon(R) Platinum 8480+
stepping        : 8
microcode       : 0x2b000661
cpu MHz         : 3800.000
cache size      : 107520 KB
physical id     : 1
siblings        : 56
core id         : 55
cpu cores       : 56
apicid          : 238
initial apicid  : 238
fpu             : yes
fpu_exception   : yes
cpuid level     : 32
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx pdpe1gb rdtscp lm constant_tsc art arch_perfmon pebs bts rep_good nopl xtopology nonstop_tsc cpuid aperfmperf tsc_known_freq pni pclmulqdq dtes64 monitor ds_cpl smx est tm2 ssse3 sdbg fma cx16 xtpr pdcm pcid dca sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm 3dnowprefetch cpuid_fault epb cat_l3 cat_l2 cdp_l3 cdp_l2 ssbd mba ibrs ibpb stibp ibrs_enhanced fsgsbase tsc_adjust bmi1 avx2 smep bmi2 erms invpcid cqm rdt_a avx512f avx512dq rdseed adx smap avx512ifma clflushopt clwb intel_pt avx512cd sha_ni avx512bw avx512vl xsaveopt xsavec xgetbv1 xsaves cqm_llc cqm_occup_llc cqm_mbm_total cqm_mbm_local split_lock_detect avx_vnni avx512_bf16 wbnoinvd dtherm ida arat pln pts avx512vbmi umip pku ospke waitpkg avx512_vbmi2 gfni vaes vpclmulqdq avx512_vnni avx512_bitalg tme avx512_vpopcntdq la57 rdpid bus_lock_detect cldemote movdiri movdir64b enqcmd fsrm md_clear serialize tsxldtrk pconfig arch_lbr ibt amx_bf16 avx512_fp16 amx_tile amx_int8 flush_l1d arch_capabilities
bugs            : spectre_v1 spectre_v2 spec_store_bypass swapgs eibrs_pbrsb bhi
bogomips        : 4000.00
clflush size    : 64
cache_alignment : 64
address sizes   : 46 bits physical, 57 bits virtual
power management:
```

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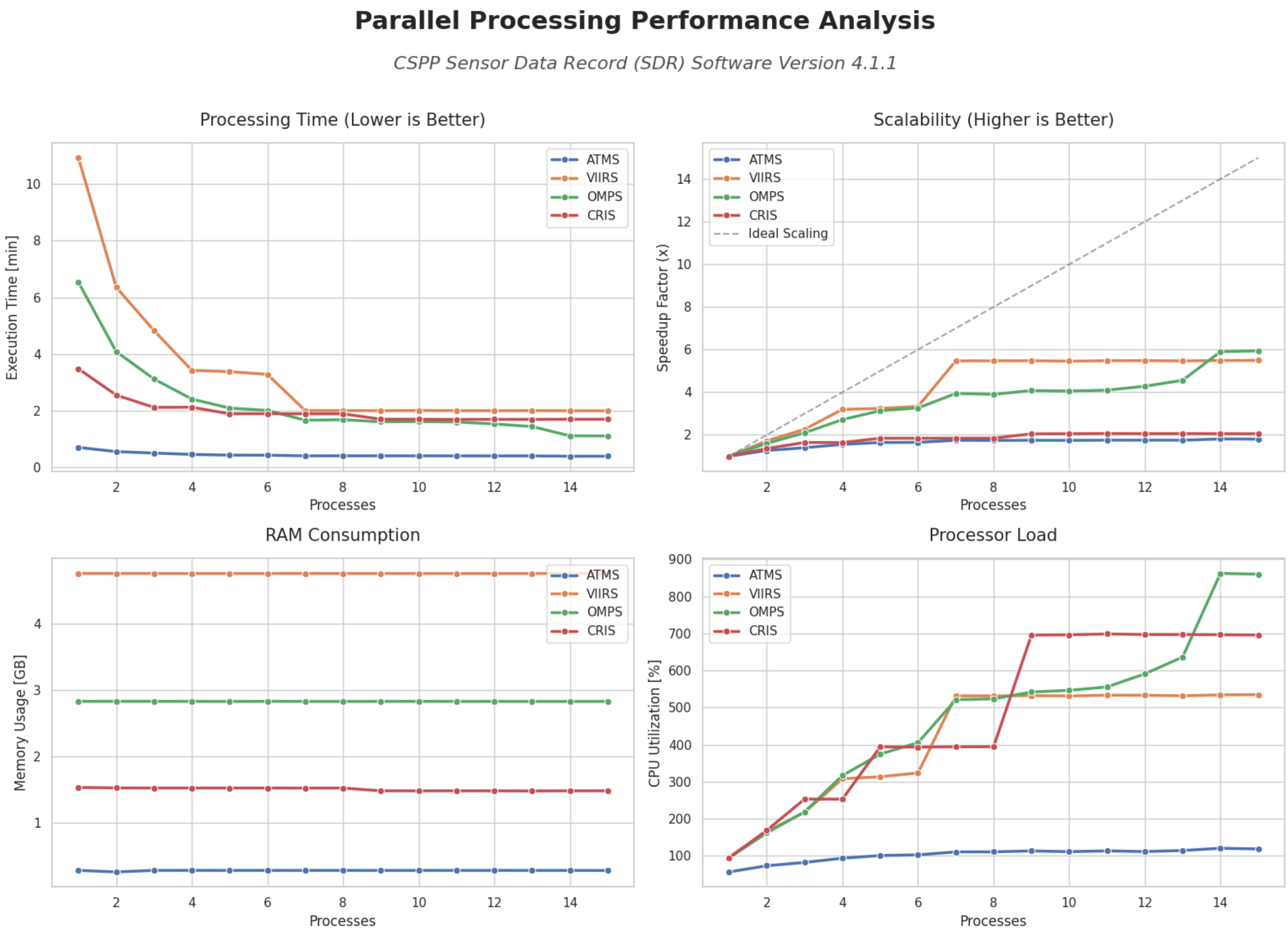
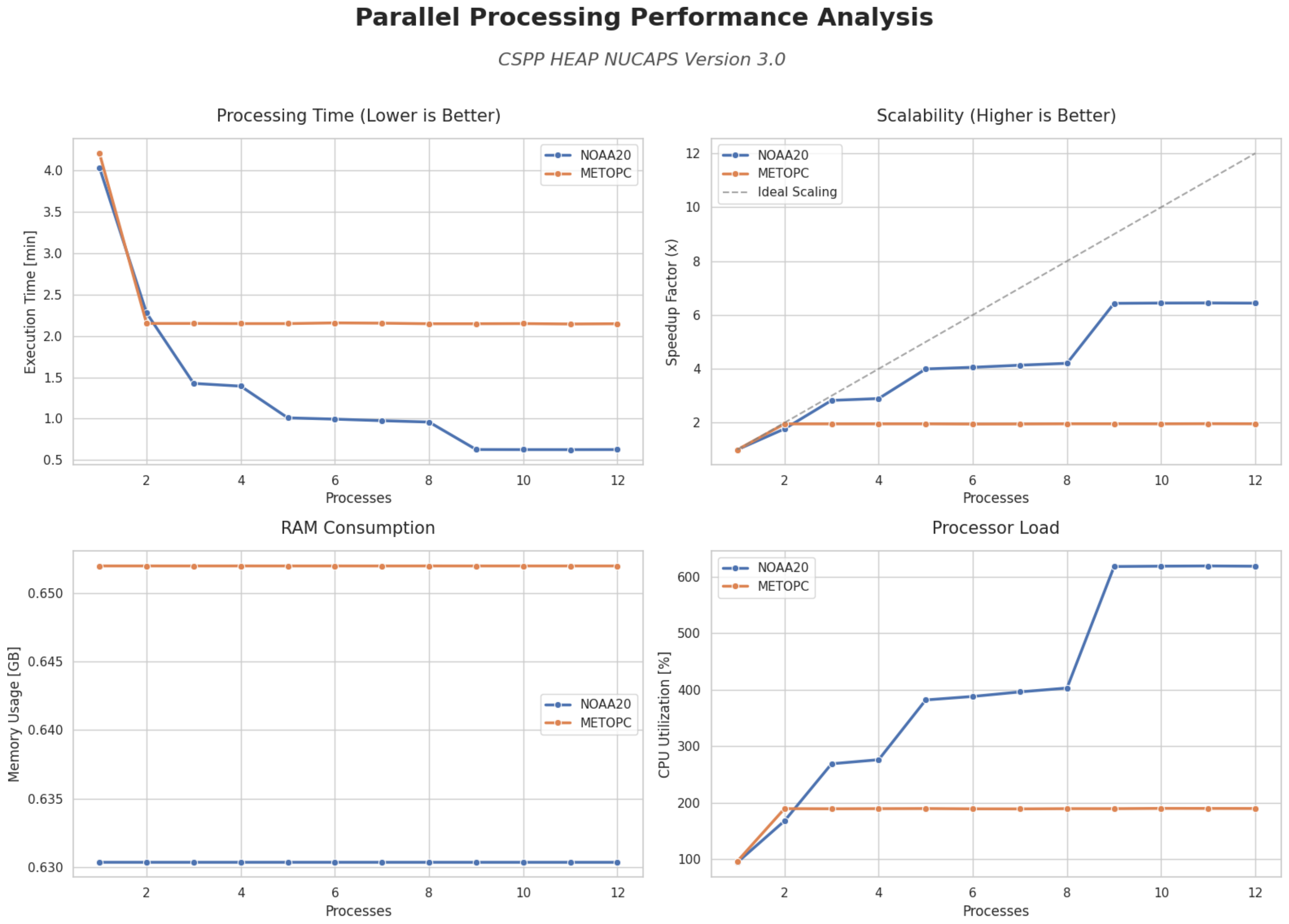
CSPP SDR benchmarking shows that:

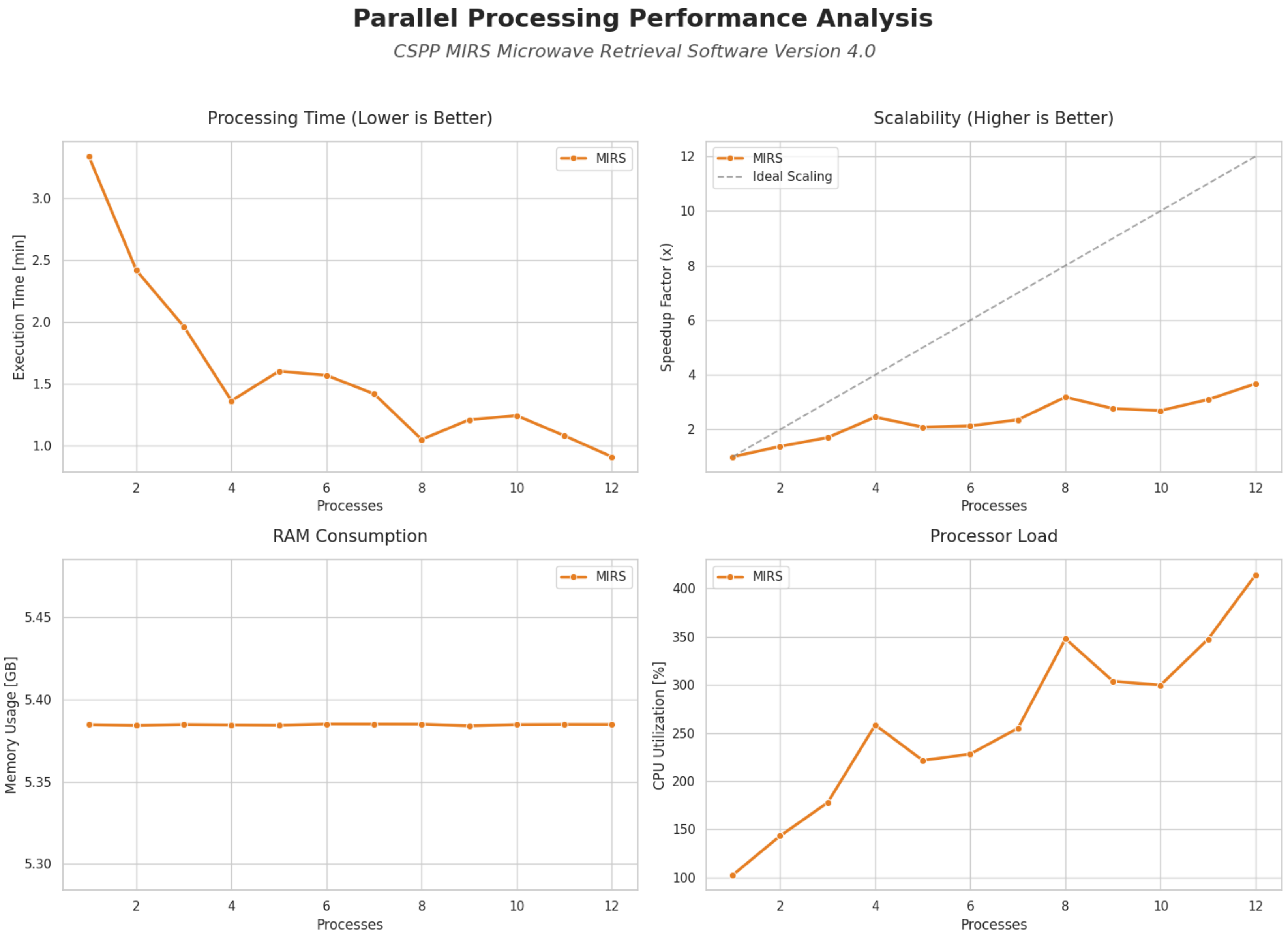
1. As expected, ATMS is the least demanding instrument in terms of both CPU and memory usage.
2. VIIRS is the most computationally demanding instrument, while OMPS and CrIS require noticeably fewer resources.
3. All four instruments reach a performance plateau at approximately 8 CPU cores.
4. None of the instruments are able to achieve 100% CPU utilization.



A comparison of HEAP performance for NOAA-20 and MetOp data shows that NOAA-20 performs better in almost all aspects.



MIRS shows slight instability, with noticeable fluctuations in execution time, CPU utilization, and speedup with increasing CPU count.



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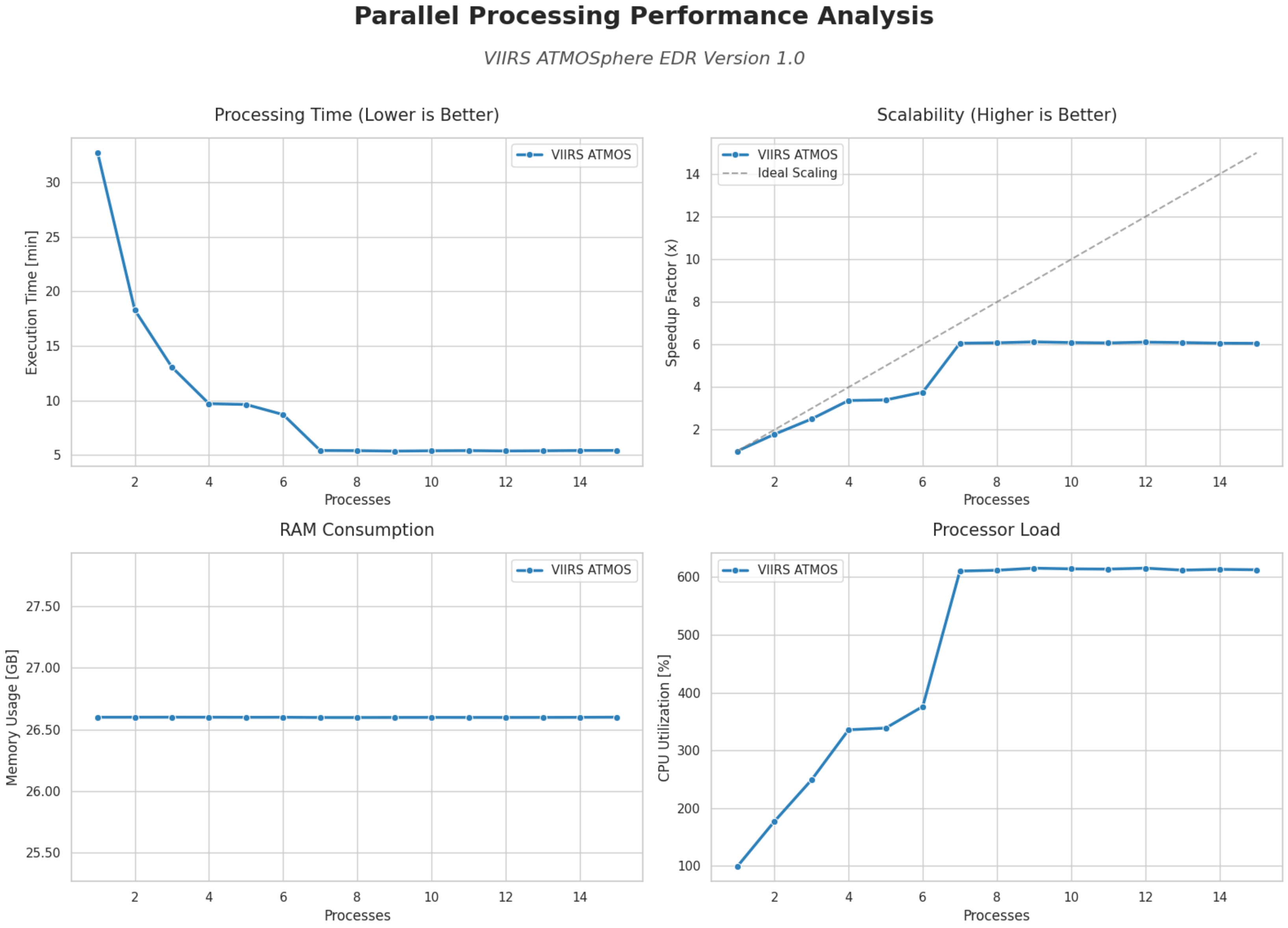

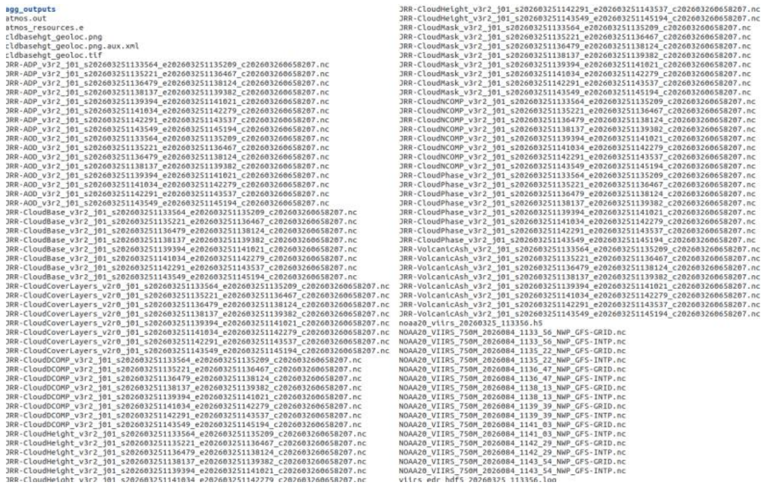

For VIIRS ATMS, the large number of output products and the VIIRS spatial resolution lead to long computation times.

From the user's point of view, it would be better to include an option for selecting products during computation.

RGB Products from Polar Satellites

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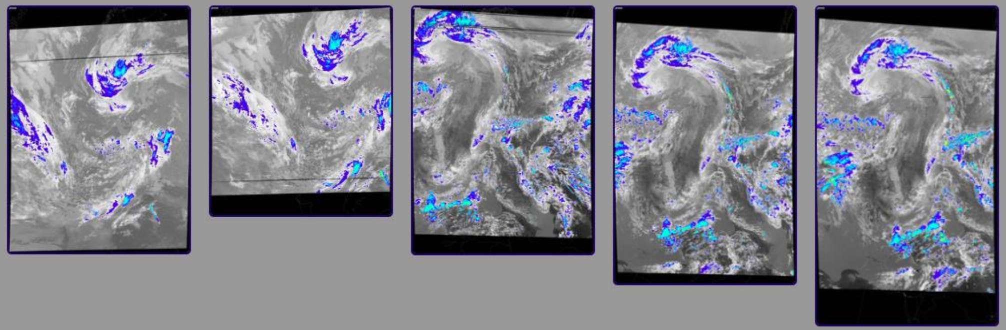
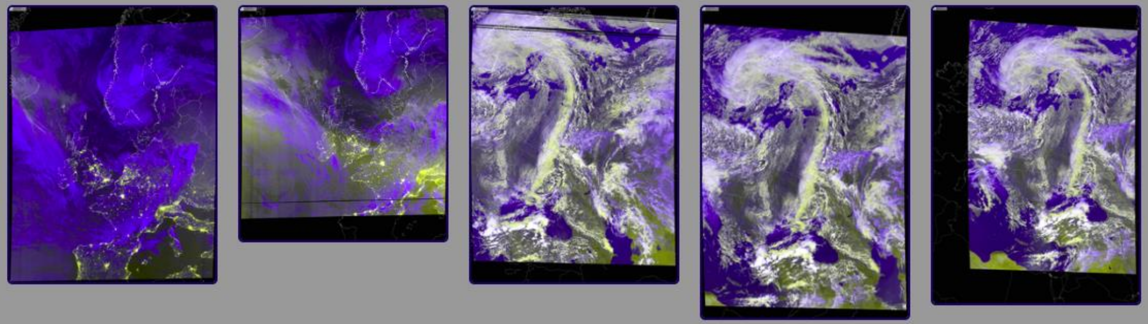
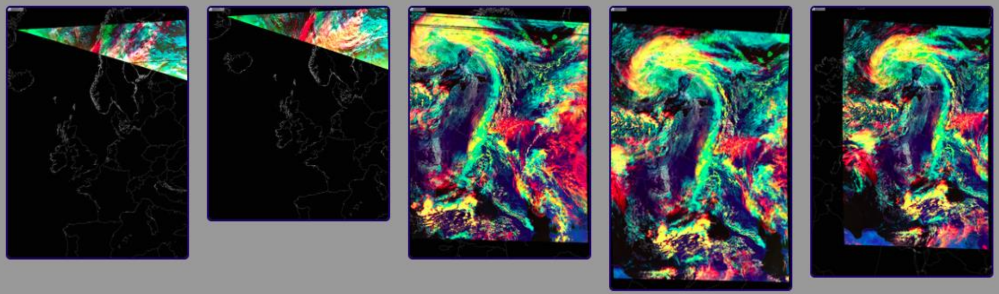
Continuous processing and visualization of VIIRS RGB products and cloud microphysical properties, which provide information about cloud microphysical characteristics such as particle size, liquid water content, and cloud phase (ice or liquid).



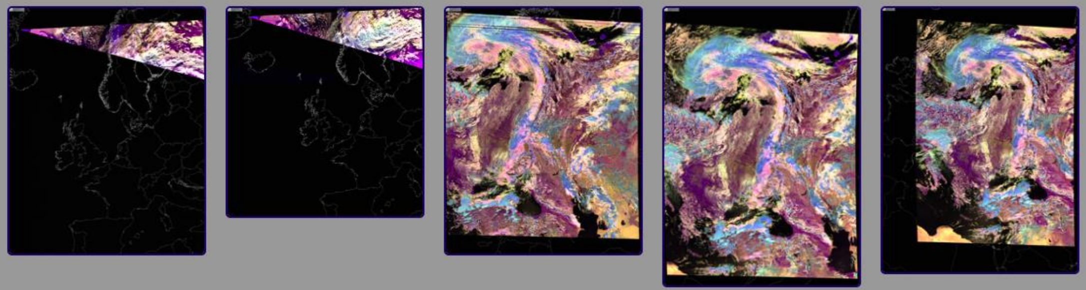
Ostatnie 5 zobrazowań VIIRS w kompozycji 'IR enhanced'



Ostatnie 5 zobrazowań VIIRS w kompozycji 'night overview'



Ostatnie 5 zobrazowań 'Cloud type'



Ostatnie 5 zobrazowań 'Cloud phase'

The last 5 satellite images from VIIRS

Impact of Spatial Resolution on Cloud Top Feature Detection

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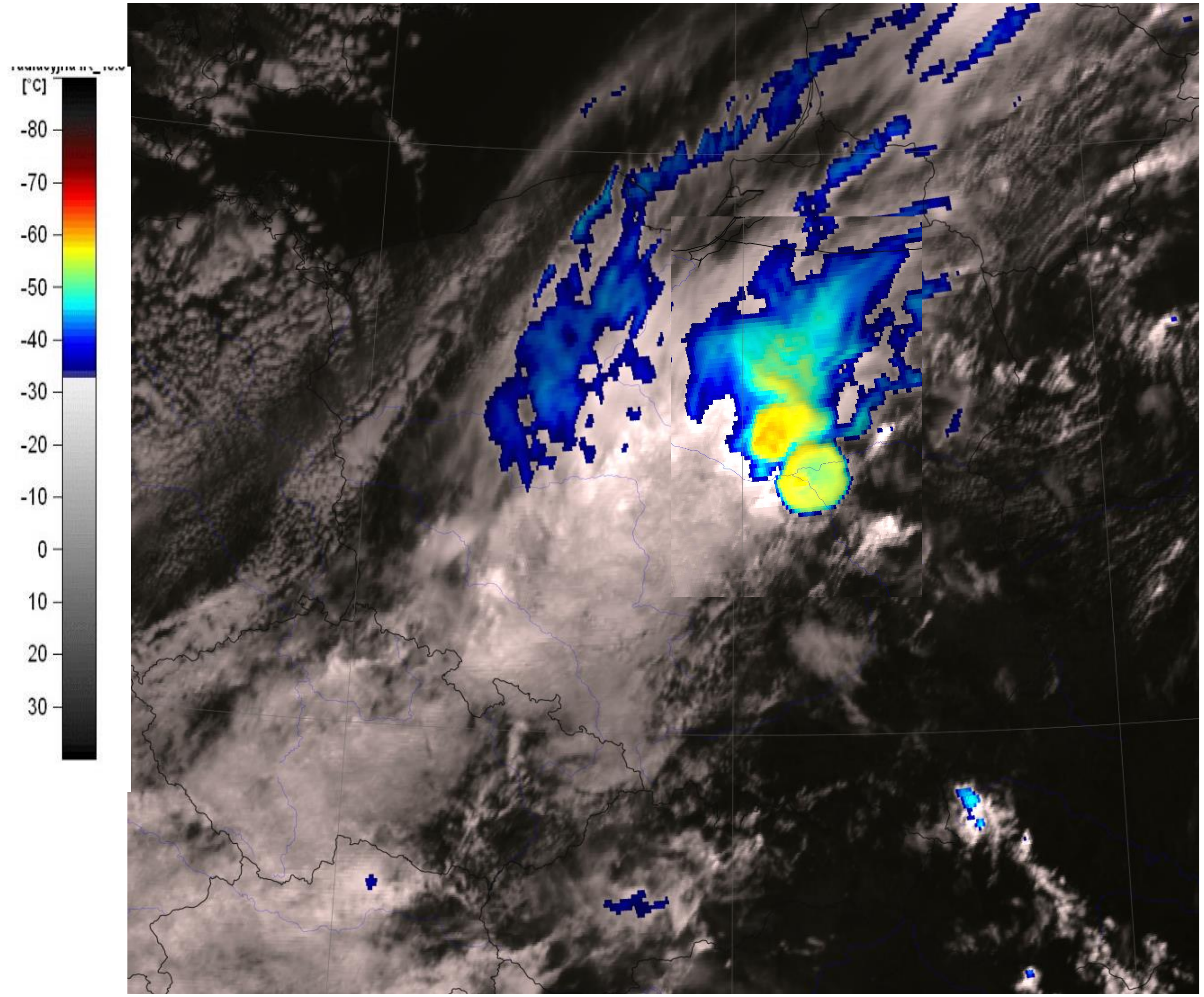
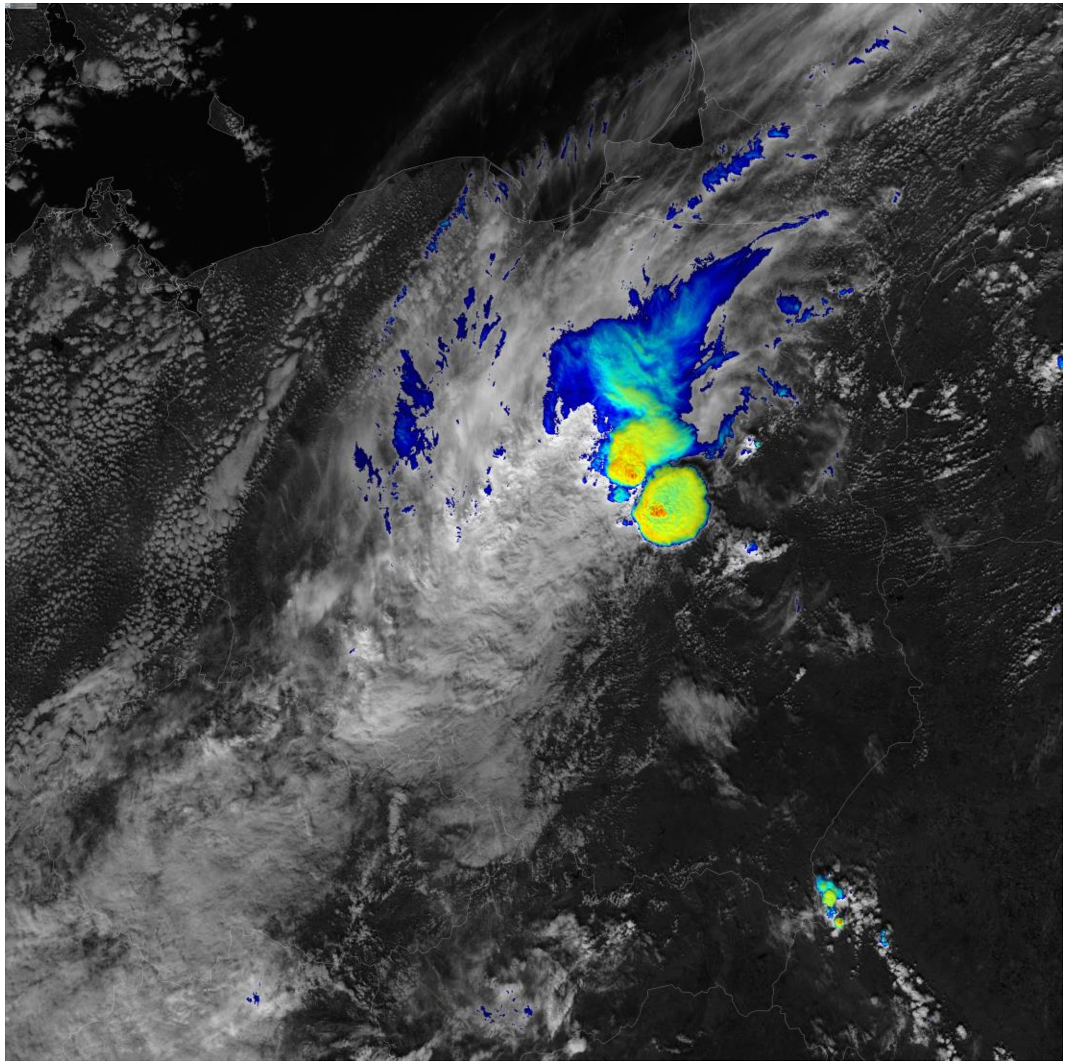
FCI, 2 km



VIIRS, 750 m



Higher spatial resolution allows for more detailed observation of cloud features and physical processes

Źródło: ZTS

Impact of Spatial Resolution on Cloud Top Feature Detection

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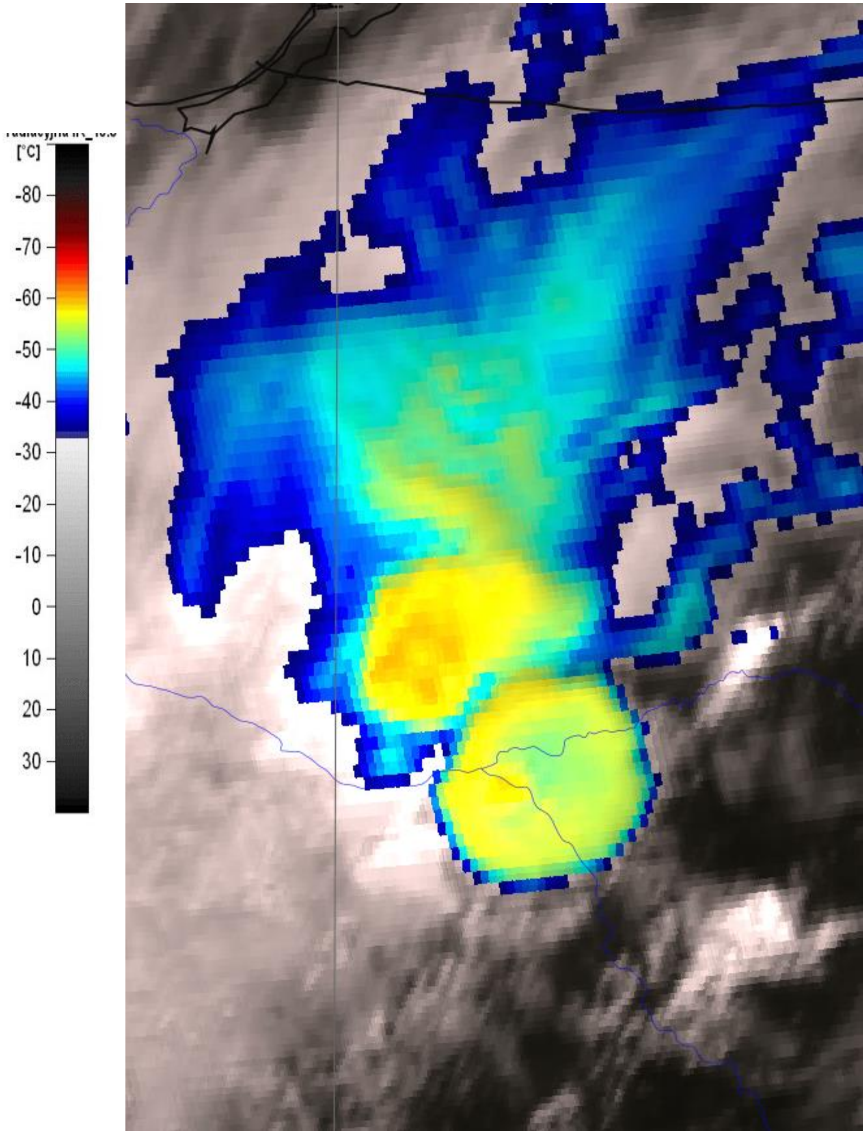
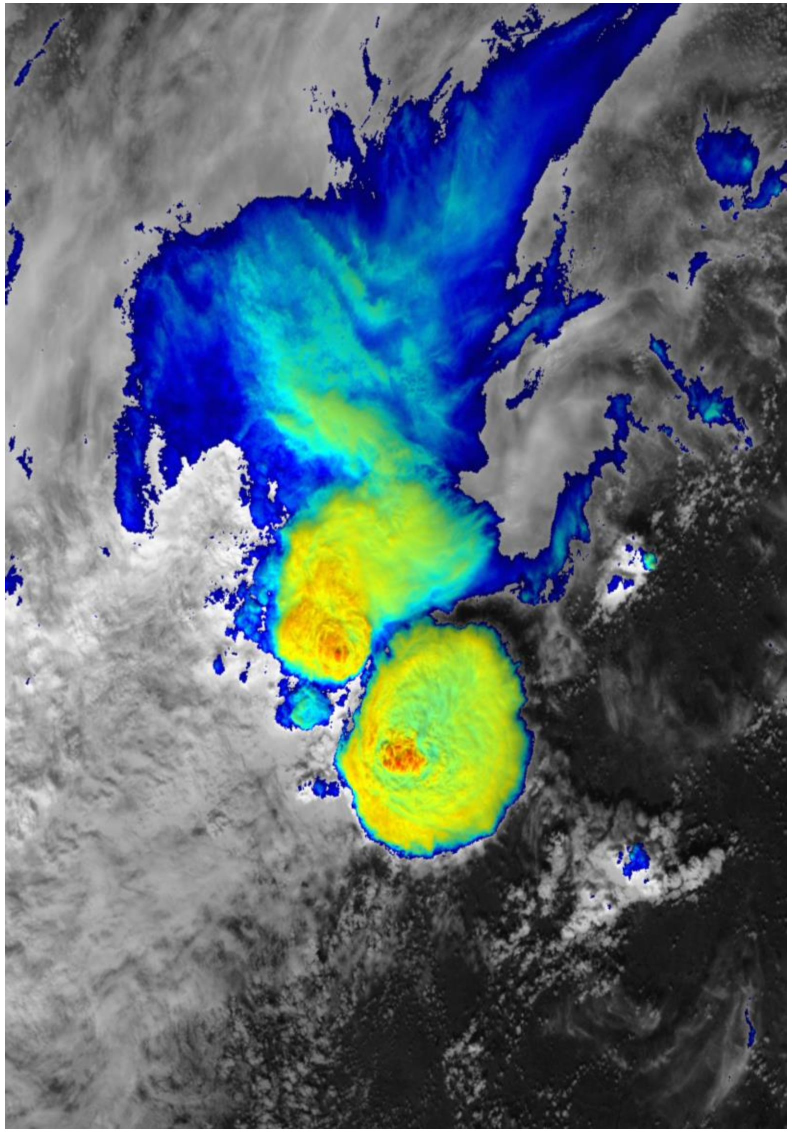
FCI, 2 km



VIIRS, 750 m



Lower Cloud Top Temperatures (CTT) indicate stronger upward vertical motion, leading to intense deep convection, rapid vertical cloud development, and increased severe weather potential, including large hail, damaging winds, and heavy precipitation.

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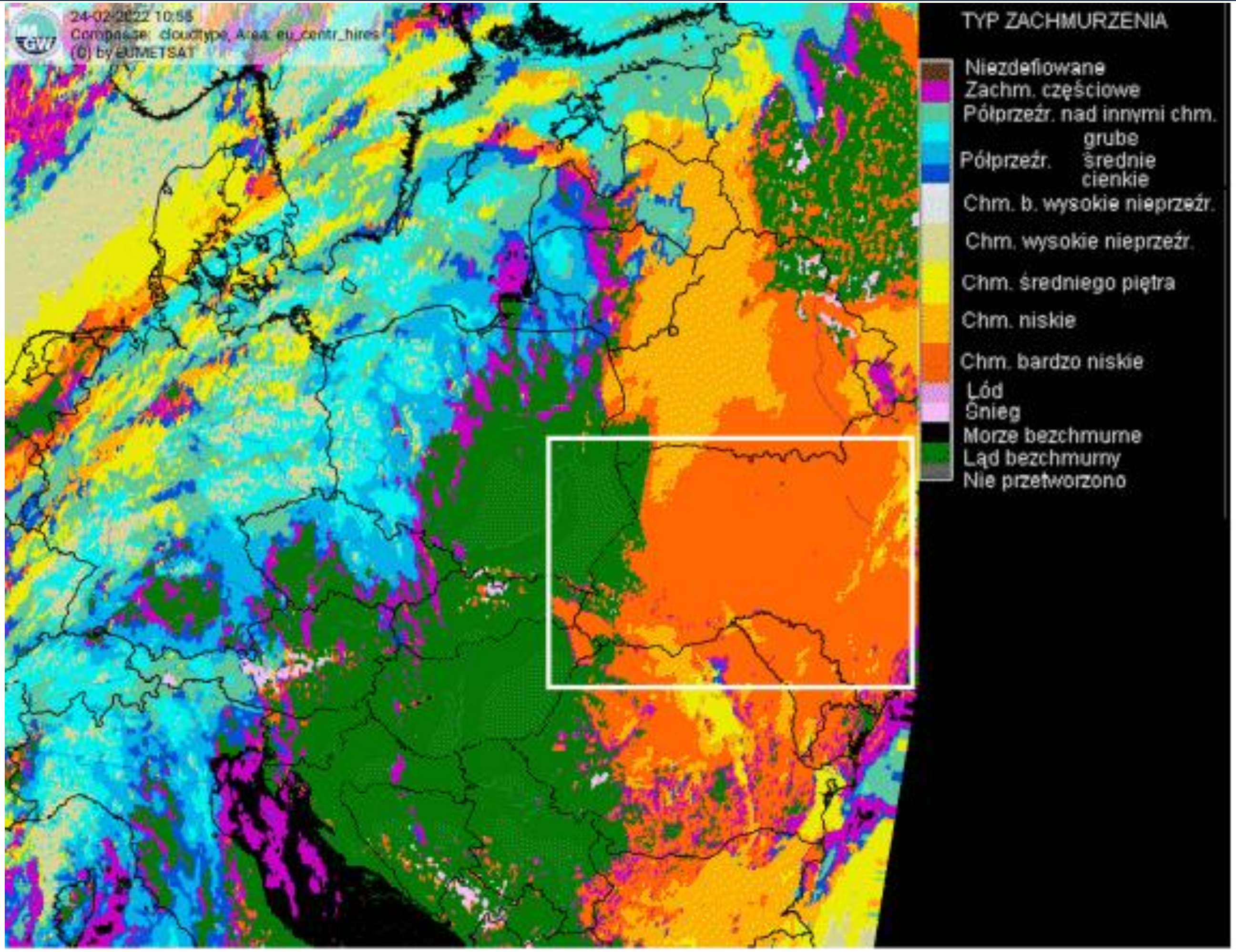
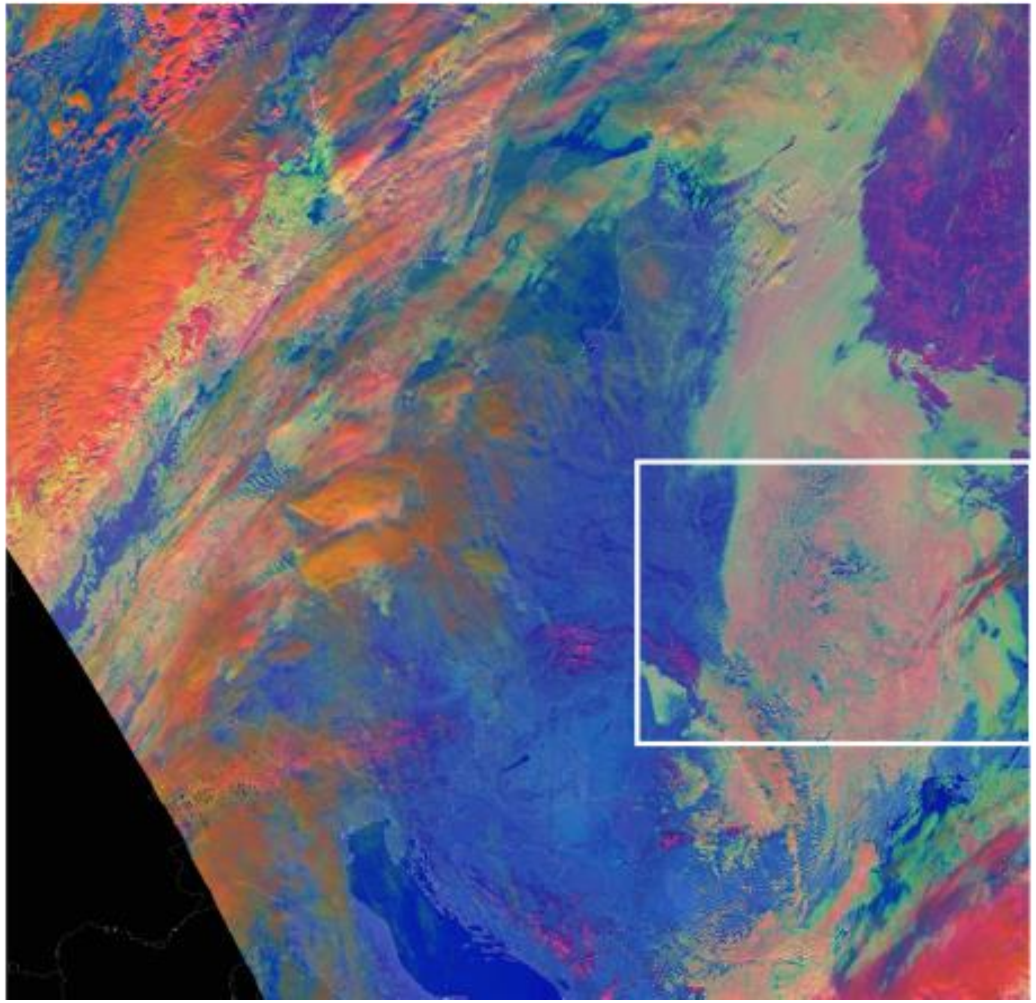
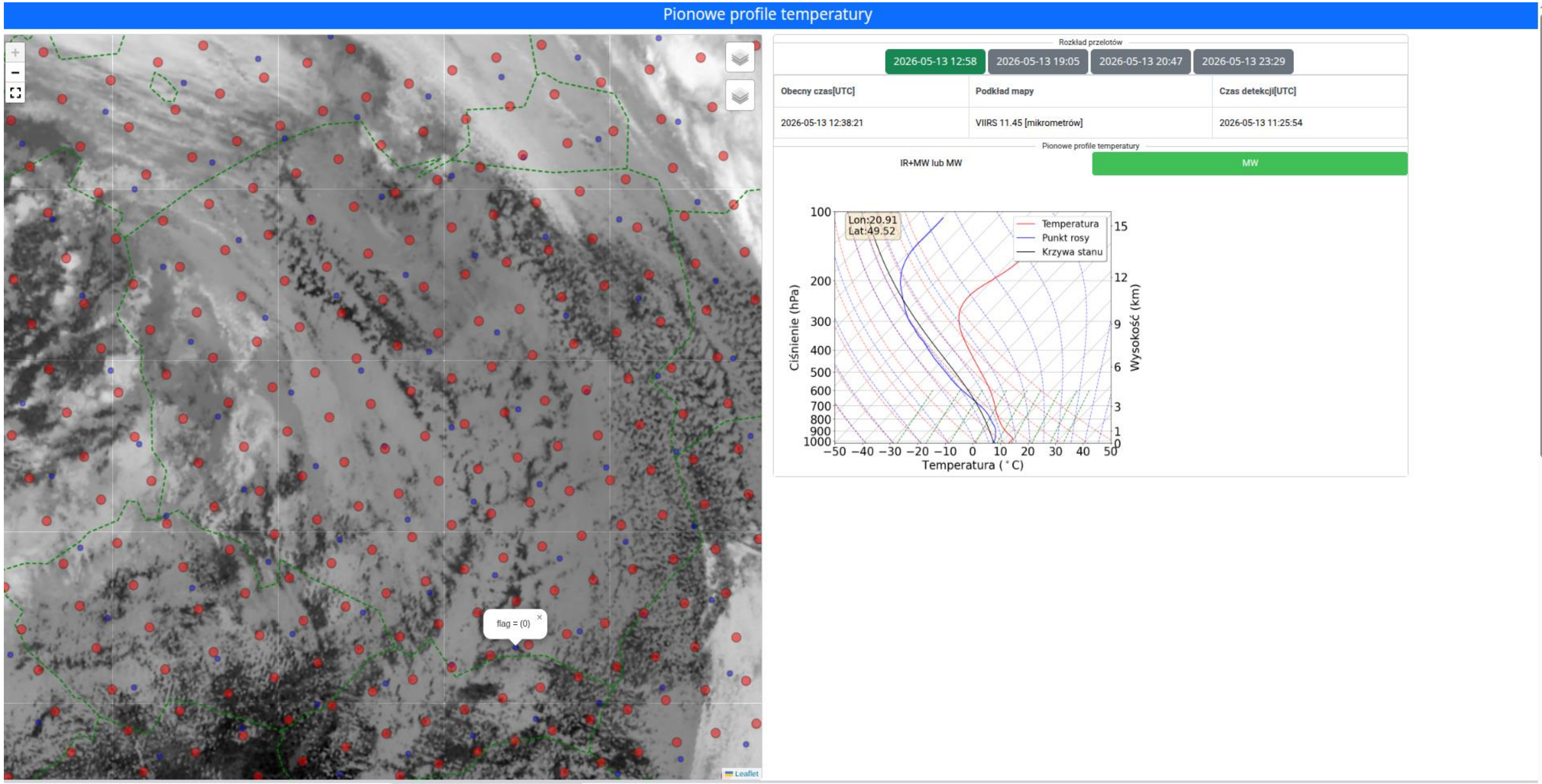




Compared with MSG, polar satellites enable better distinction between cloud-covered and cloud-free areas due to their higher spatial resolution.

A web service providing vertical profiles of temperature and dew point to support forecasters, using both the HEAP algorithm (for hyperspectral and microwave instruments) and MIRS (for microwave instruments).



Vertical profile of temperature and moisture (HEAP and MIRS)

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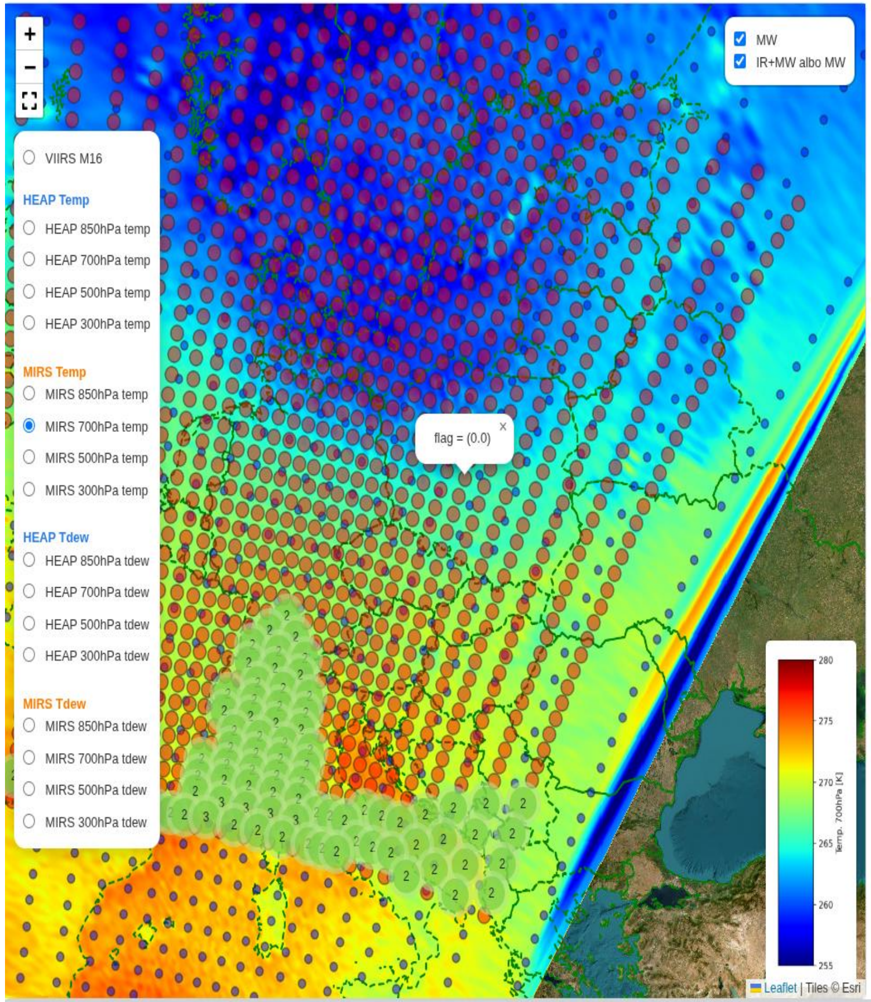
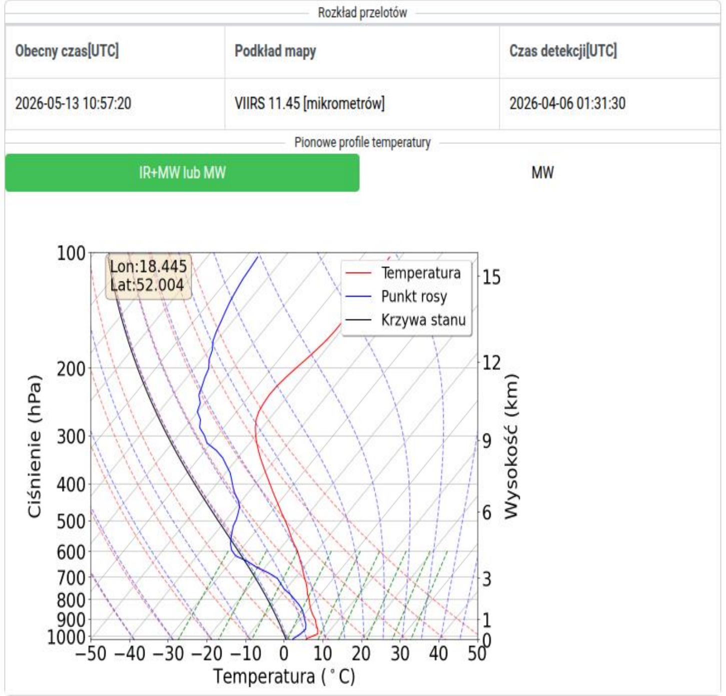
Based on feedback from the forecasting department, we plan to implement temperature and dew point maps at various pressure levels, at least for 300, 500, 700, and 850 hPa.

Currently, GFS (a global numerical weather prediction model) is used as the initial condition source for HEAP and MIRS. A better solution would be to enable the use of local versions of models such as ICON, COSMO, or ALARO.





Vertical profile of temperature and moisture (HEAP and MIRS)

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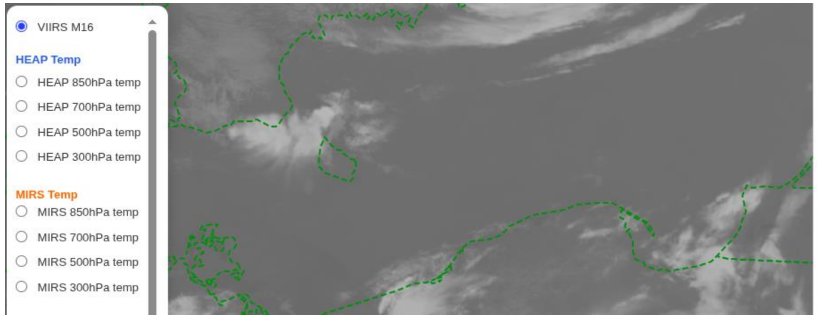
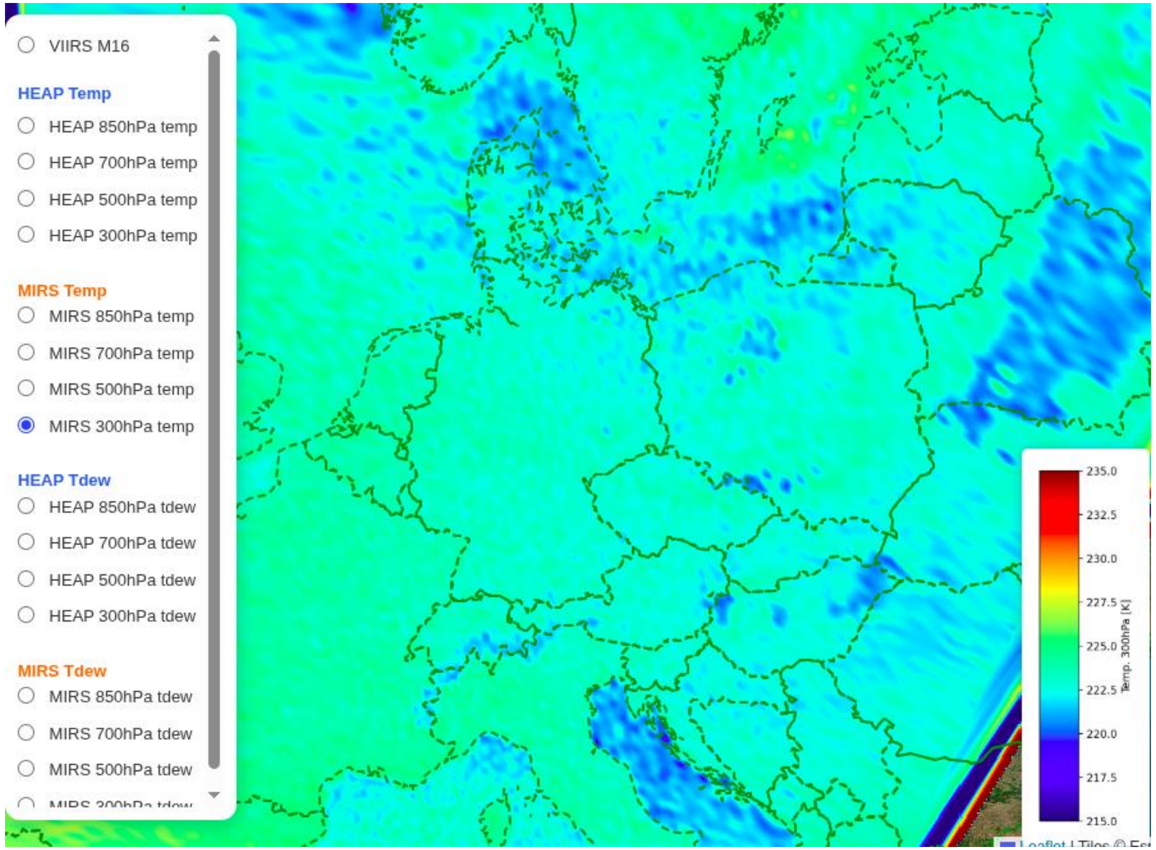
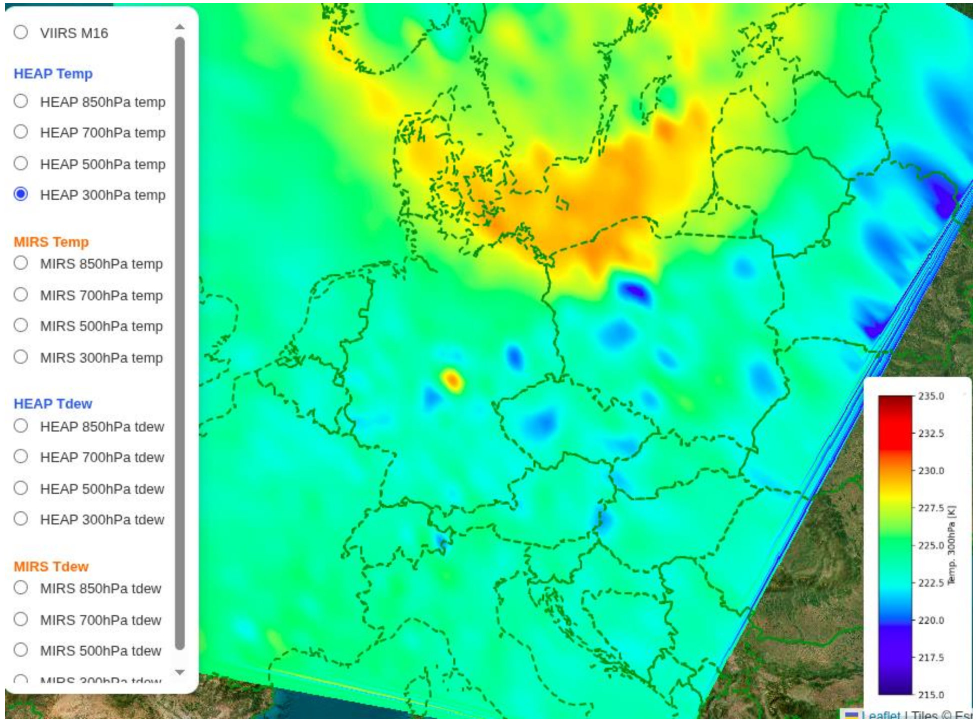
Over water surfaces, MIRS sometimes appear to have problems estimating temperature at upper atmospheric levels (for example, 300 hPa), probably due to detectable surface influence.

MIRS appears to underestimate temperature values, especially in comparison with HEAP estimates.







On the other hand, initial observations suggest that HEAP may overestimate temperature at the 300 hPa level over ocean surfaces.

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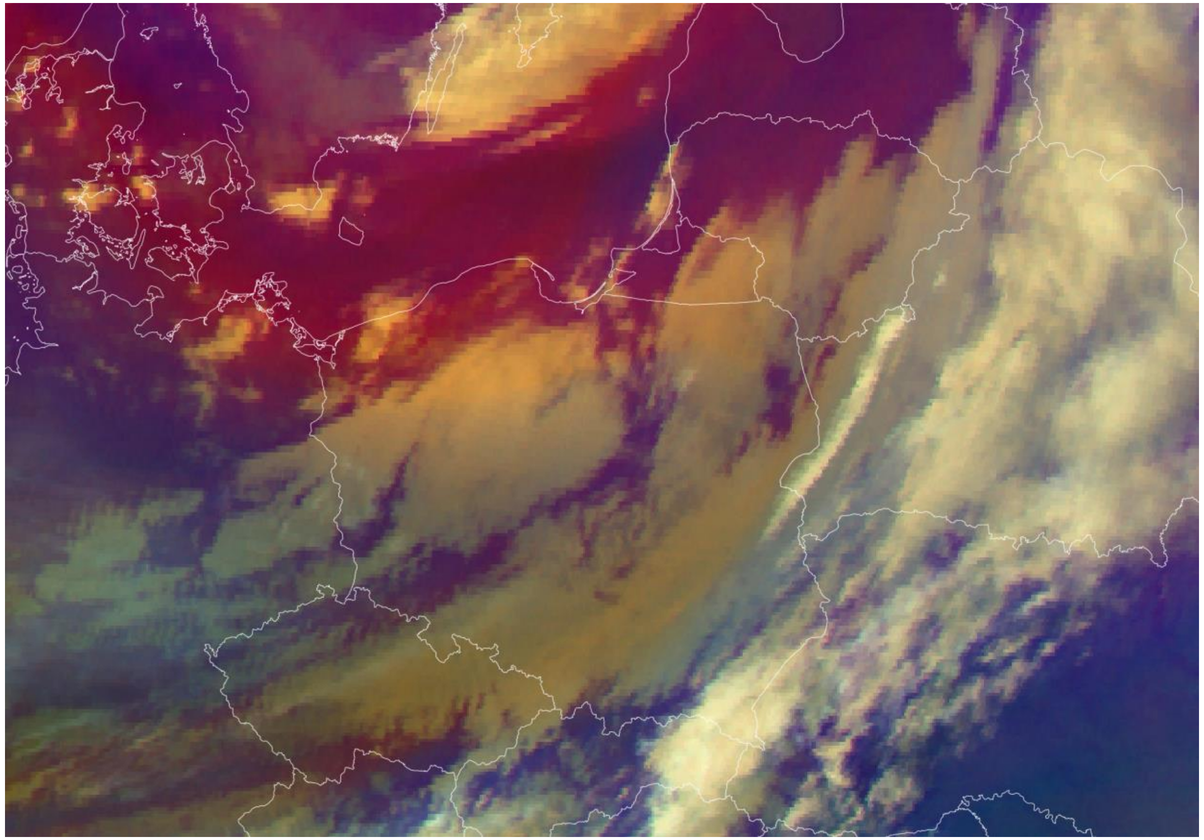
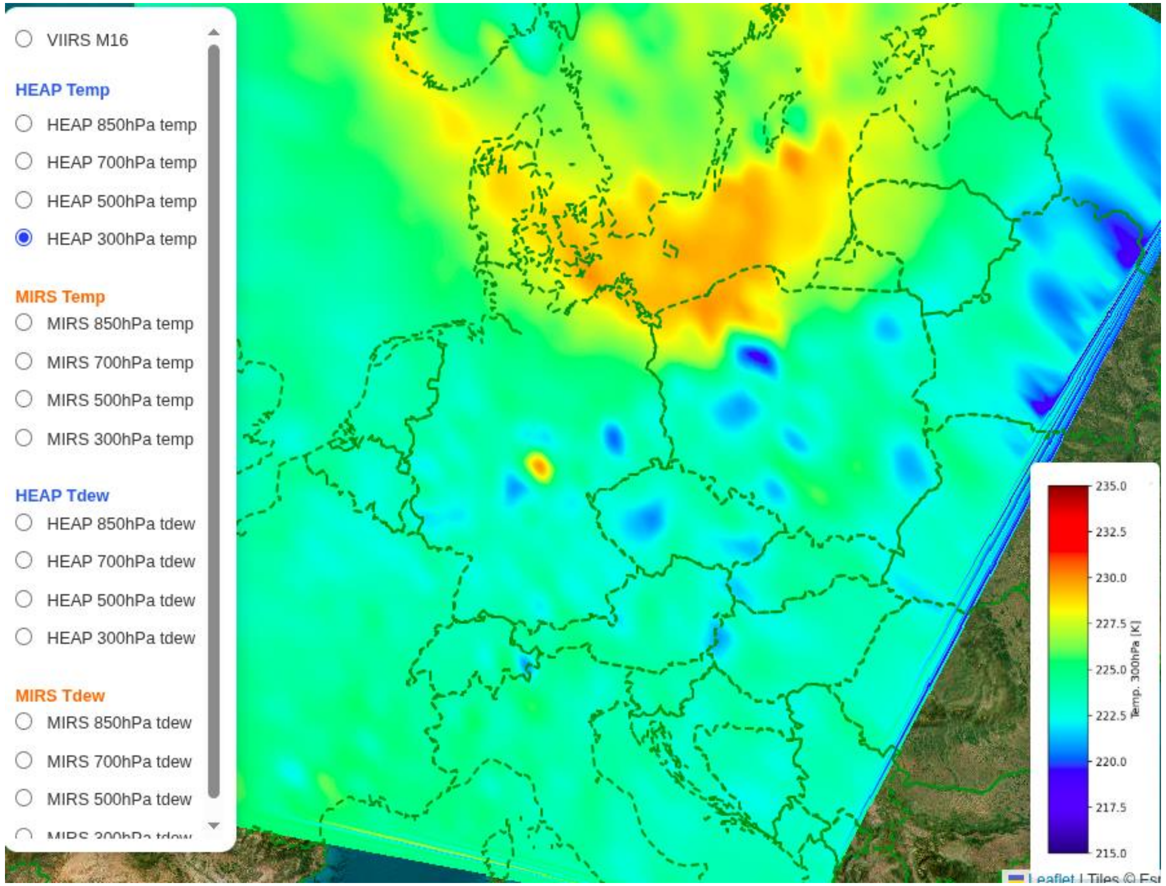
However, the RGB Airmass product shows red colors in this area, which usually indicate dry and warm air in the upper troposphere or stratosphere, often associated with dry air intrusions and atmospheric dynamics.





Monitoring of atmospheric chemical composition

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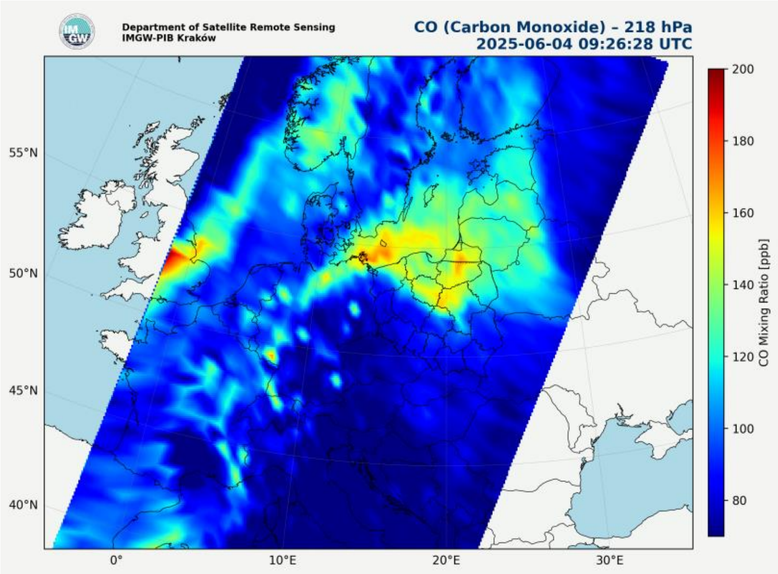
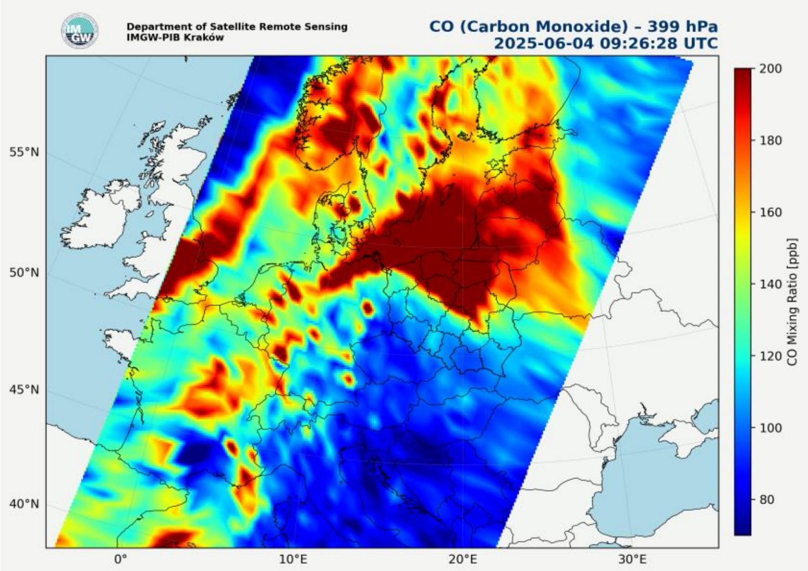
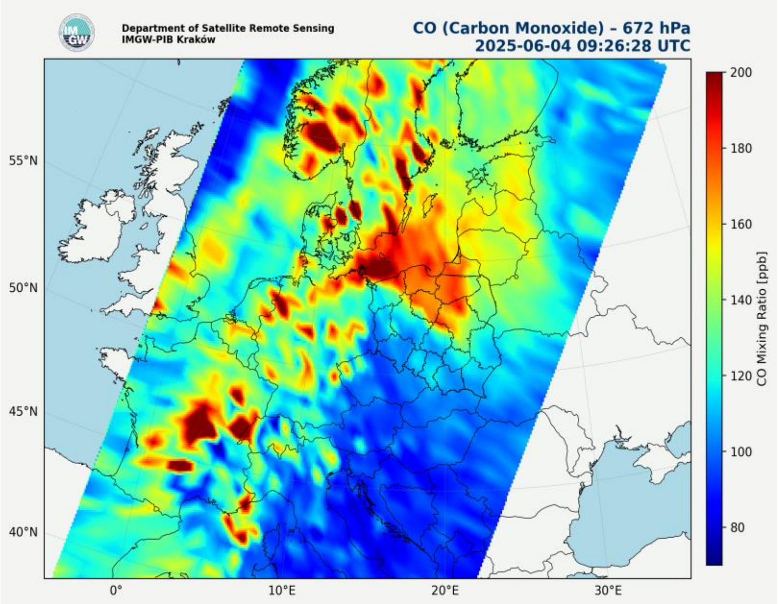
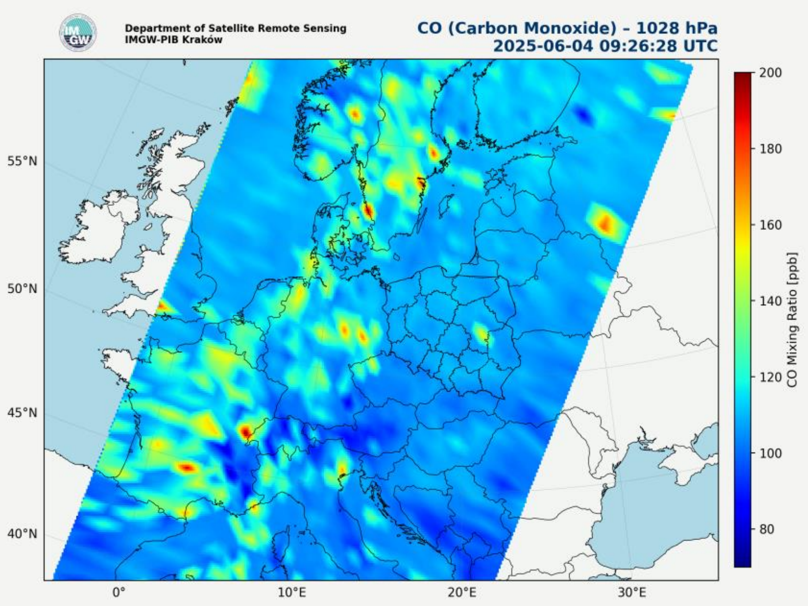
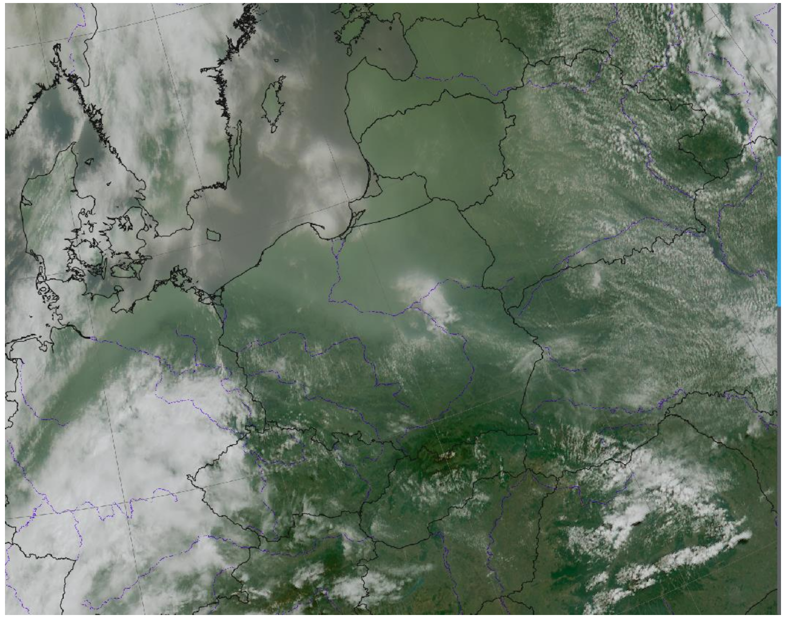








Wildfire smoke and ash from Canada were transported across the Atlantic and observed over Europe in June 2025 using satellite-based atmospheric monitoring systems.



Hyperspectral atmospheric products enable monitoring of the vertical profile of carbon monoxide.

On average, cloud cover in Poland is about 70%, which is why microwave (MW) satellite data are particularly useful.

Microwave instruments provide observations of physical processes occurring within clouds.

Microwave instrument ATMS

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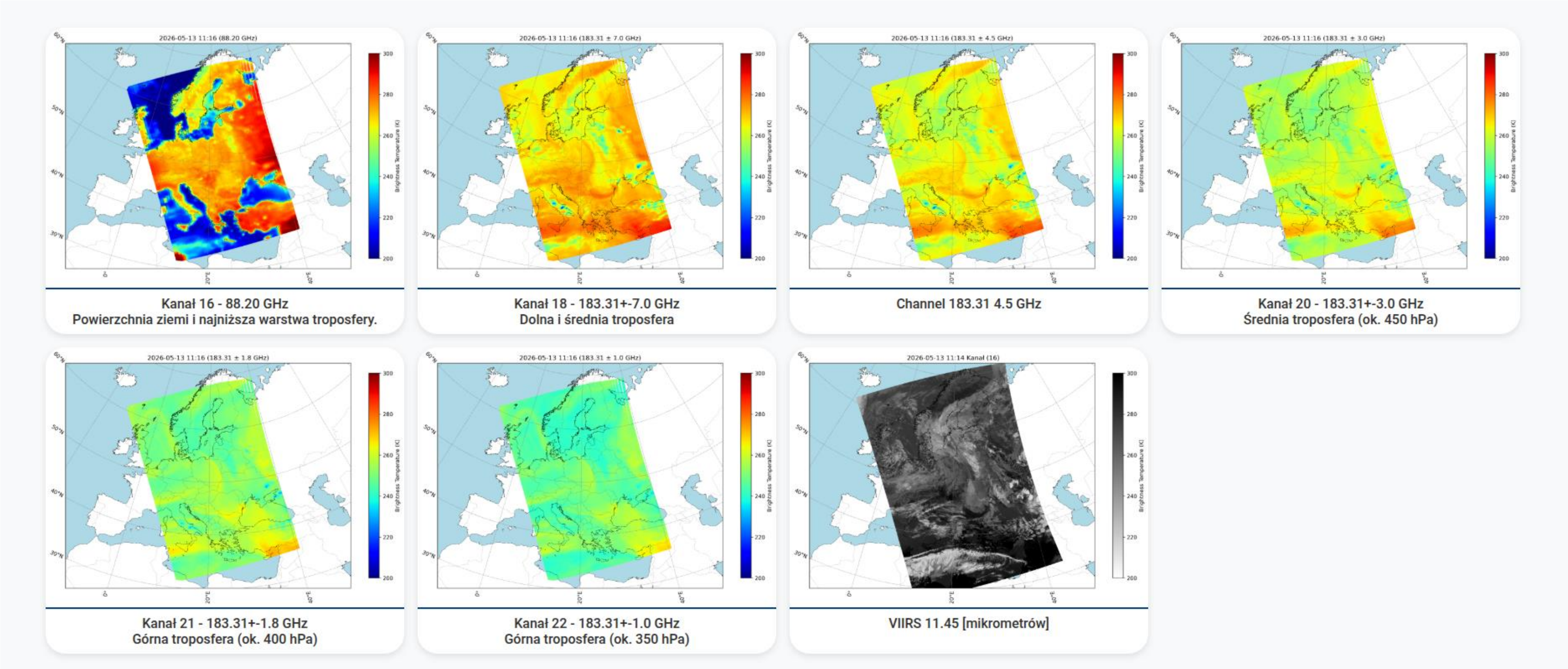
ATMS channels 16, 18, 19, 20, 21, and 22 (88.20 GHz; 183.31 ± 7, 4.5, 3, 1.8, and 1 GHz) primarily represent atmospheric water vapor and hydrometeors at different atmospheric levels.



We use **Polar2Grid** to perform limb correction on the ATMS brightness temperature channels, removing scan-angle-dependent biases.

Is it possible to include support for AMSU-A and MHS instruments (MetOp-B/C), and in the future for MWS (MetOp-SG)?

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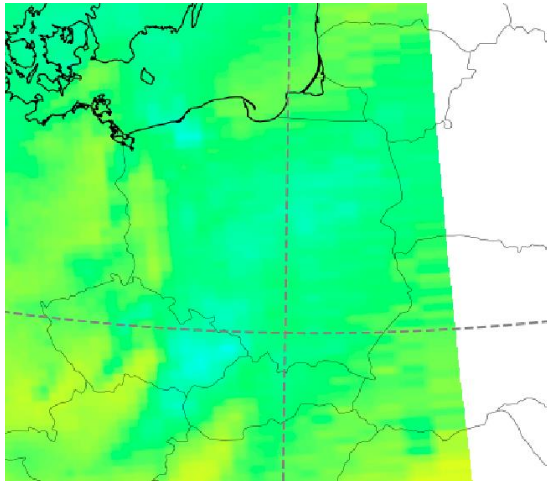
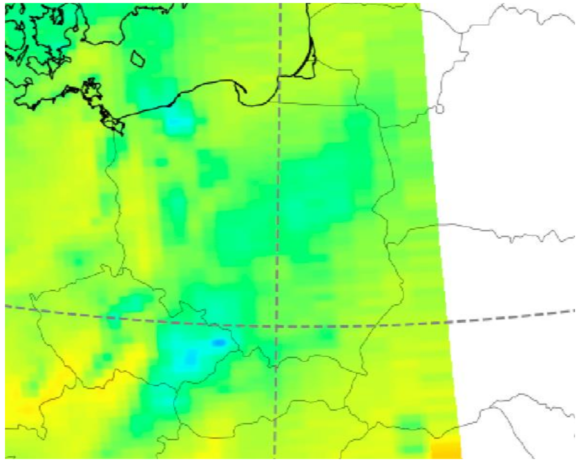
Genoa cyclone over Poland (2025)

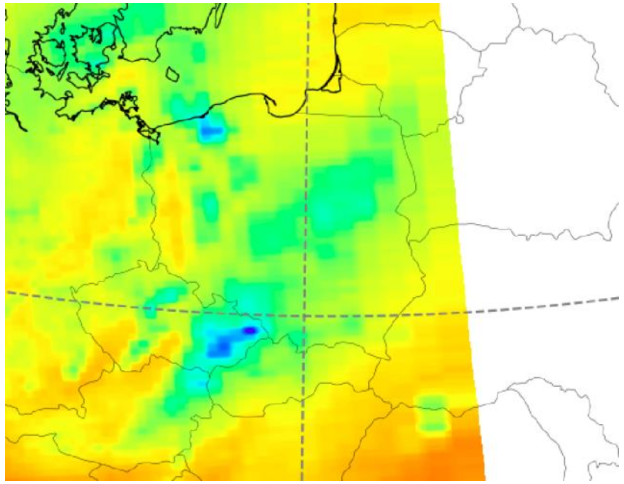
An intense Mediterranean low-pressure system (Genoa low) that affected Poland, bringing strong winds, heavy precipitation, and challenging forecasting conditions.



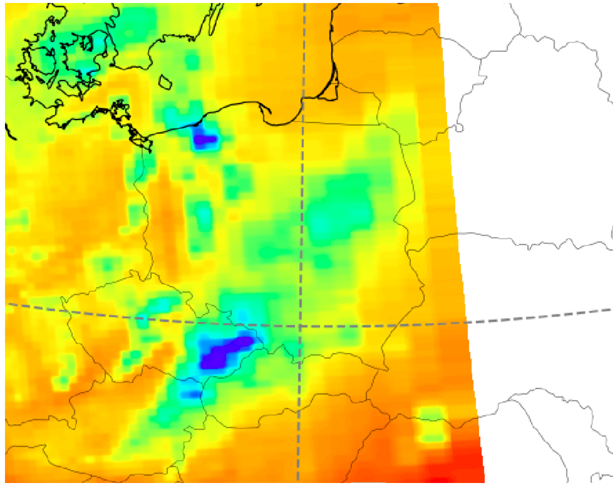
7 km



6 km



5 km

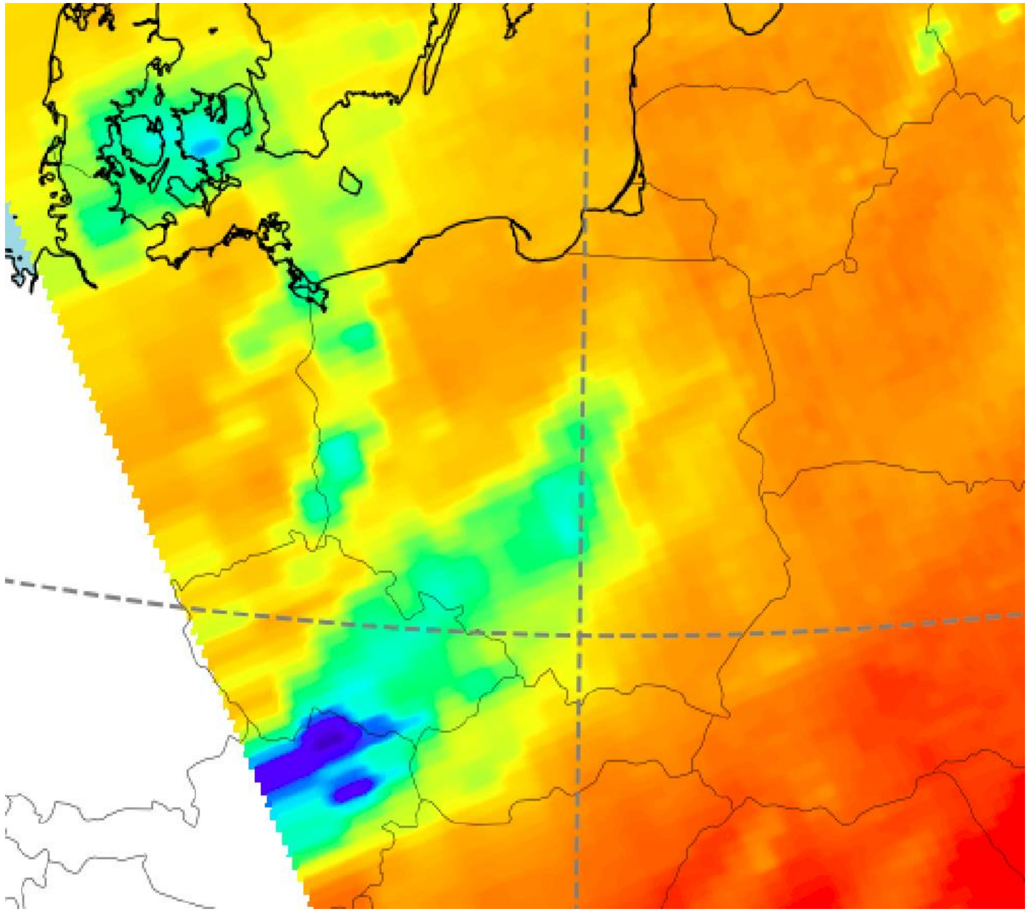


3.5 km

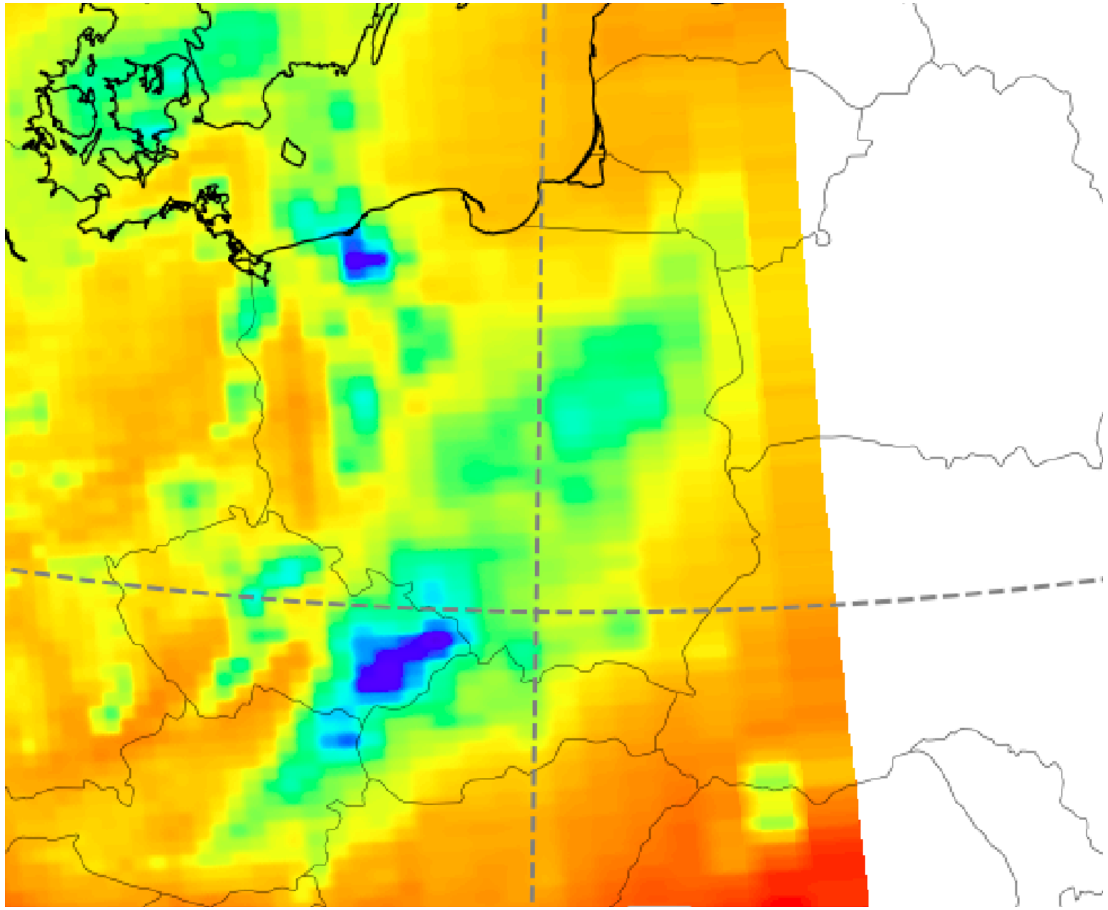
The coldest areas (blue colors in the images) correspond to regions where hydrometeors (precipitation) and/or ice crystals are present.

Genoa cyclone over Poland (2025)

10:42



12:23



We are also able to track the movement of hydrometeors (precipitation) and/or ice crystals.

Polish service with active fires: Poland, Italy, Turkey, Greece

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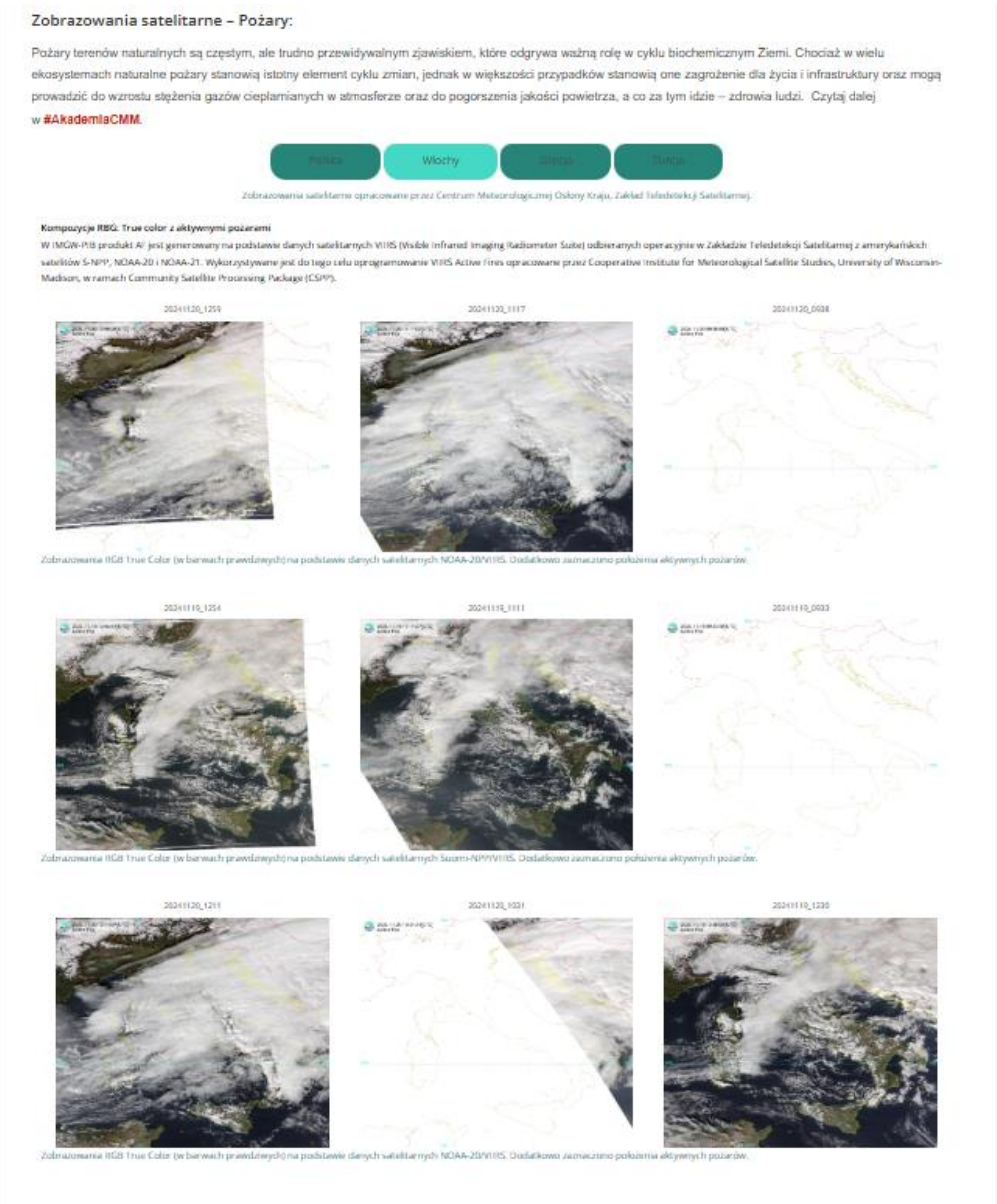
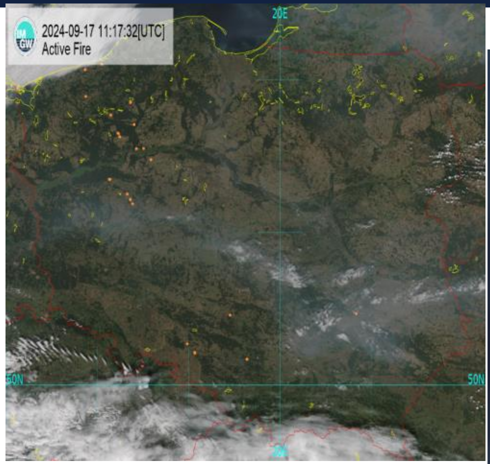


CSPP VIIRS Active Fire product in operational use

- Web interface displaying potential fire detections from the VIIRS instrument
- Operational warning bulletins issued during fire risk events

Polish service with active fires: Poland, Italy, Turkey, Greece

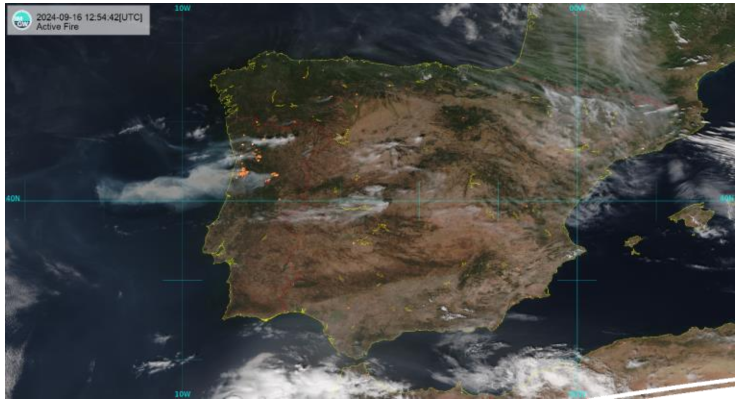


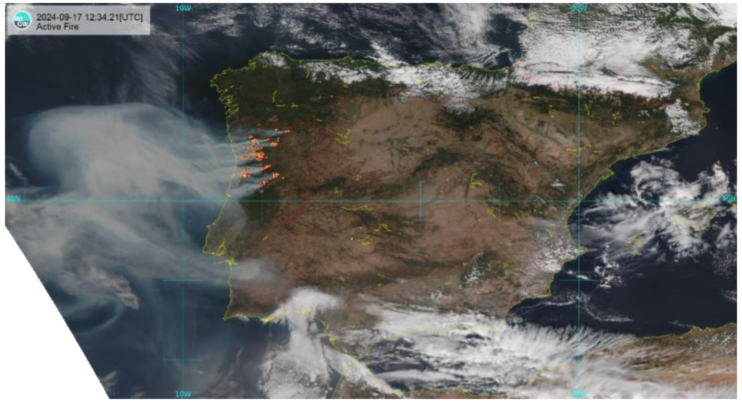
Domains:

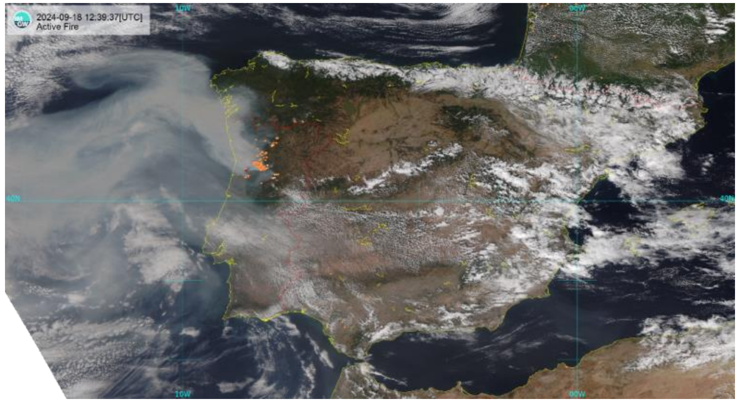
- Operational:
  - The whole overpass
  - Poland
  - Greece
  - Turkey
- Upon request
  - Any area within the overpass

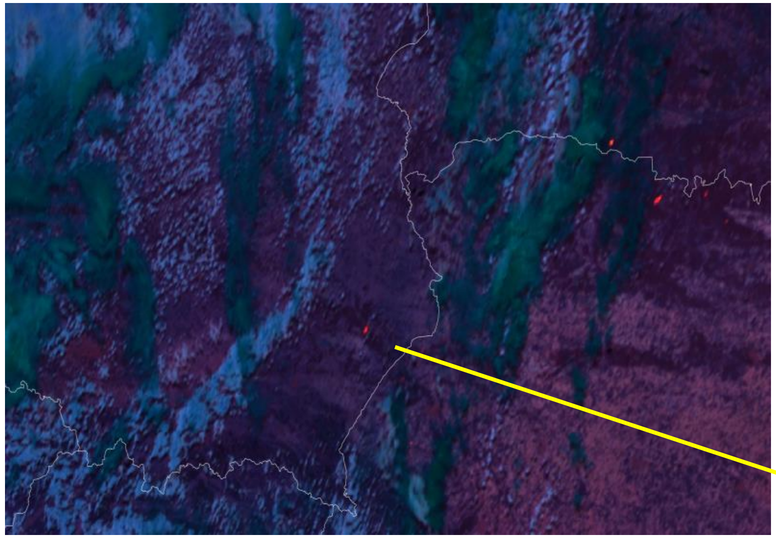
Temporal resolution: several times per day.

We monitor fires across Europe because many of these countries are popular summer tourist destinations for Polish travellers.

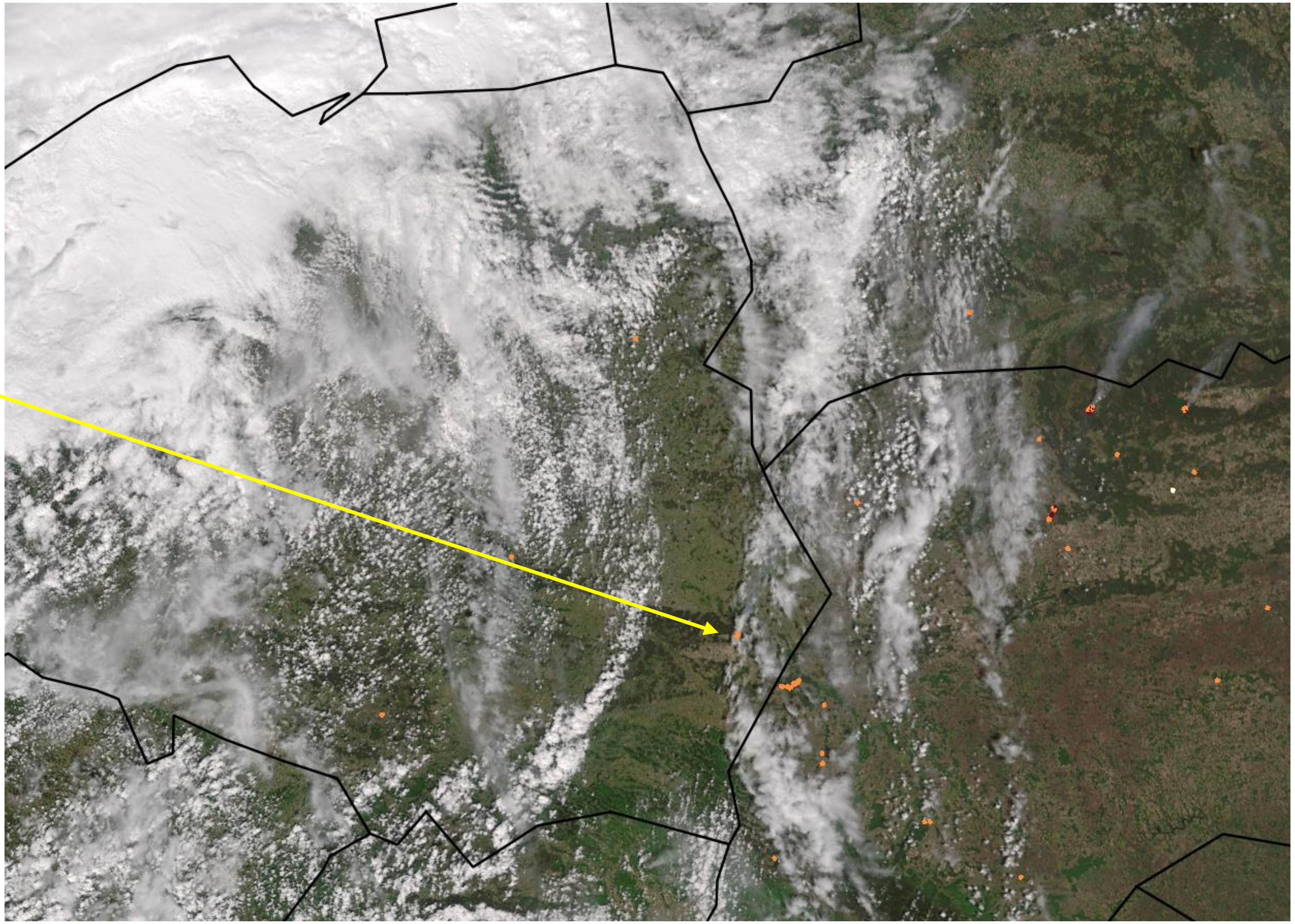


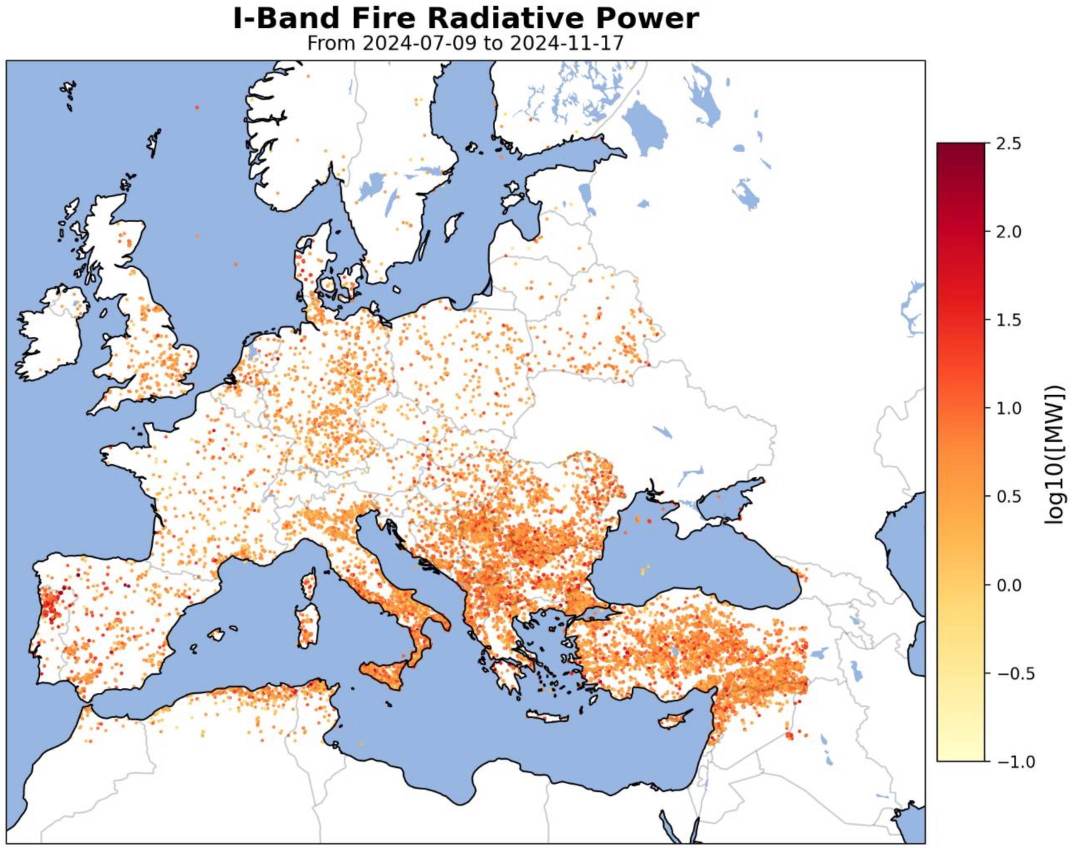


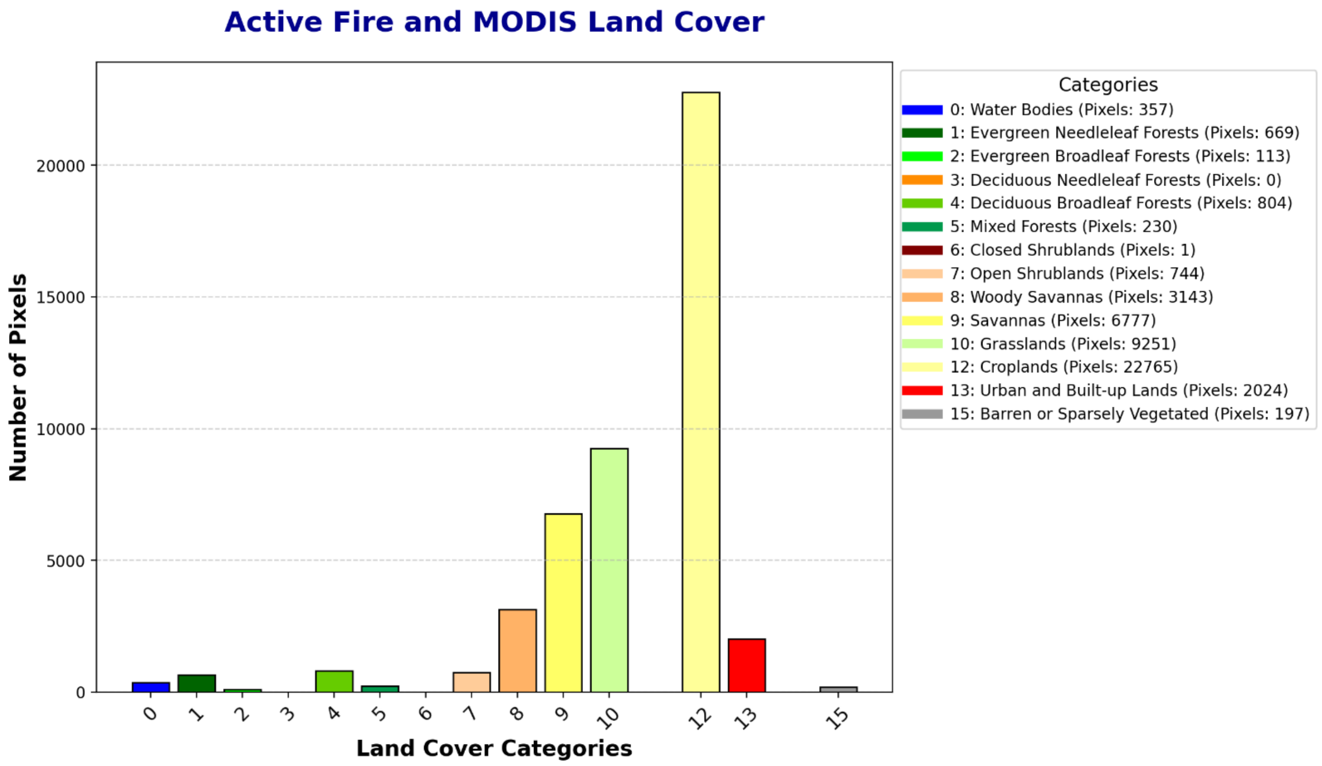




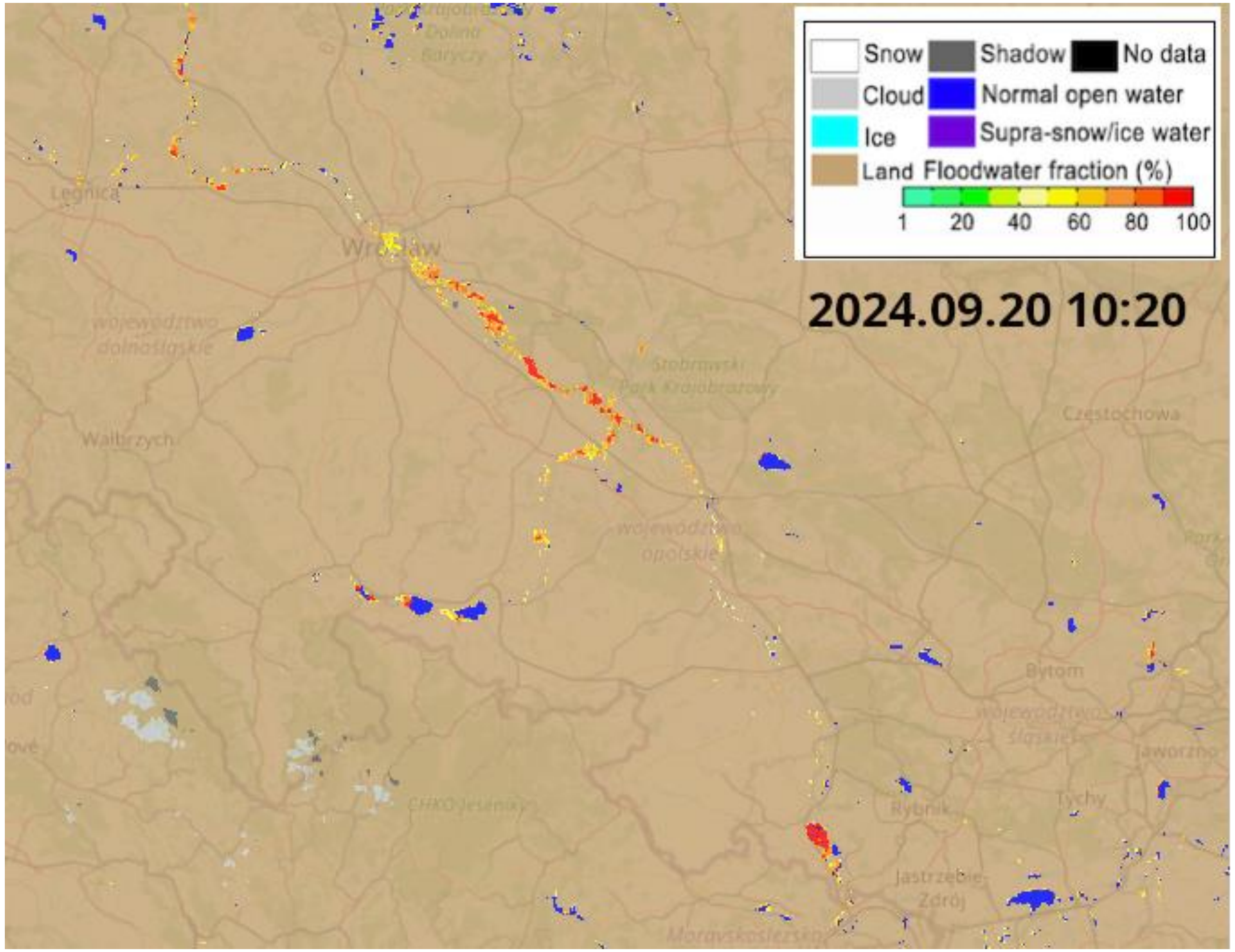
6 May 2026

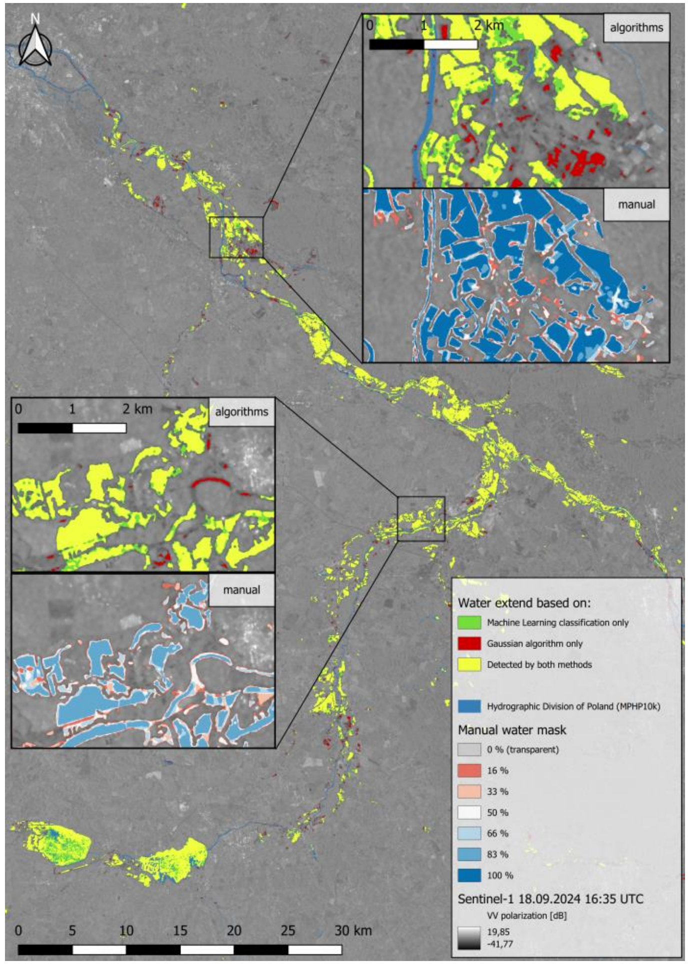






We can use the AF product and merge it with, for example, MODIS land cover products in order to better understand land types associated with fire occurrence and to estimate the probability of future fire events.





VIIRS Flood Detection software is designed to detect flooded areas, but due to the spatial resolution of the VIIRS instrument, in Poland it can only be used to detect large-scale floods.

Cloud Base Height (CBH) product

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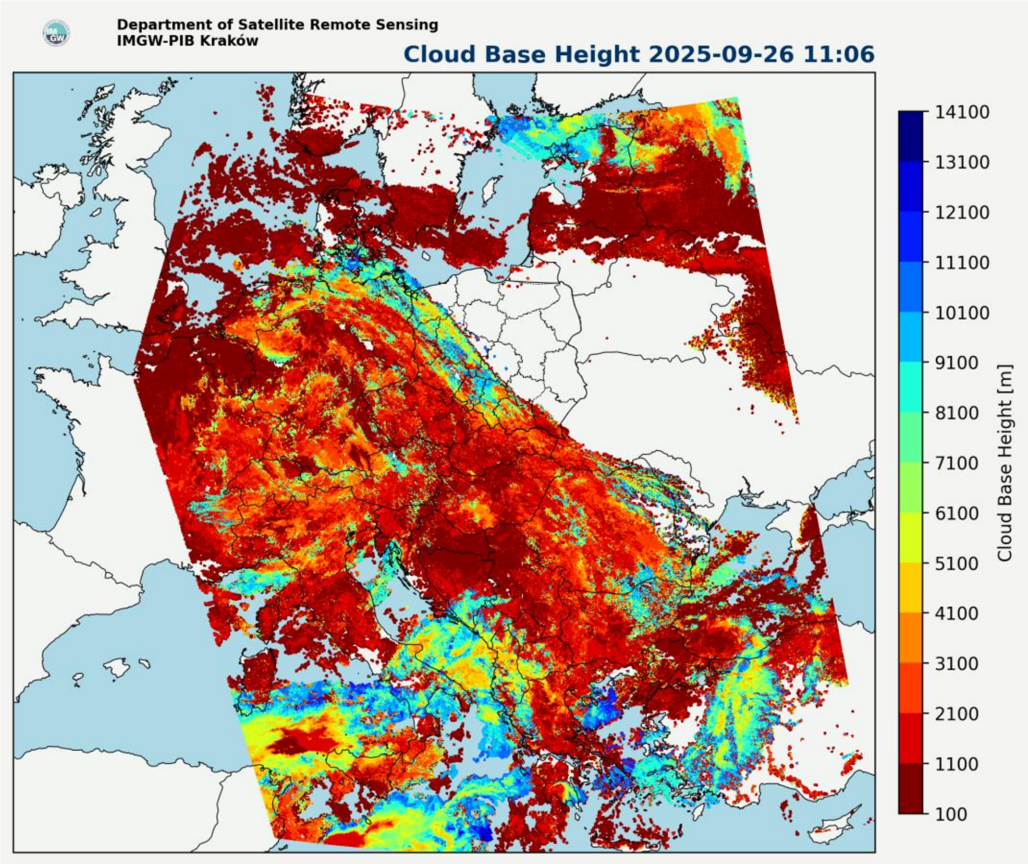

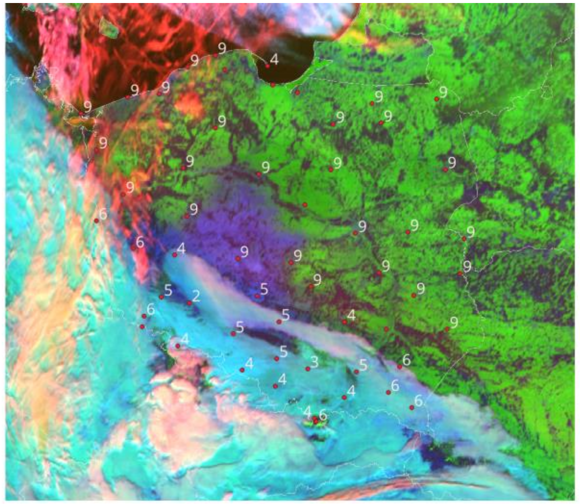

Comparison of ceilometer data (Cloud Base Height) with Cloud Type composition for 2026-02-01, 12:00 UTC. The HPOD variable was used (Cloud base height for CL CM, encoded according to WMO Code Table 1600):

- **0** – 0 to 50 m
- **1** – 50 to 100 m
- **2** – 100 to 200 m
- **3** – 200 to 300 m
- **4** – 300 to 600 m
- **5** – 600 to 1000 m
- **6** – 1000 to 1500 m
- **7** – 1500 to 2000 m
- **8** – 2000 to 2500 m
- **9** – Above 2500 m or no clouds
- **/** – Cloud base height unknown

We can use **ceilometer** data to compare **cloud base heights** with the **Cloud Base Height (CBH)** product from the **CSPP VIIRS Atmosphere (ATMOS).**

→ To do this, historical data need to be processed.

Dziękuję / Thank you

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19/05/2026, Darmstadt, Germany

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