

Assessment of the reliability of satellite precipitation products for real-time monitoring of extreme precipitation

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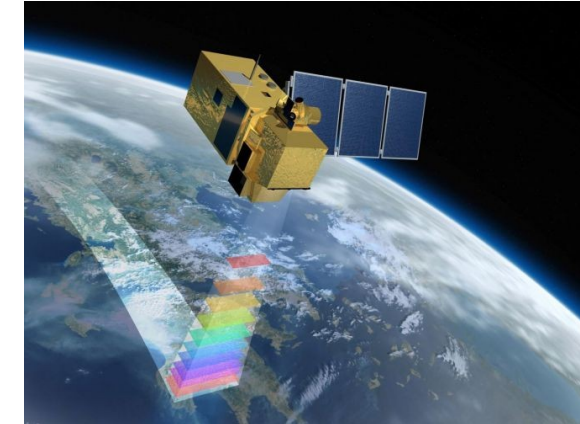
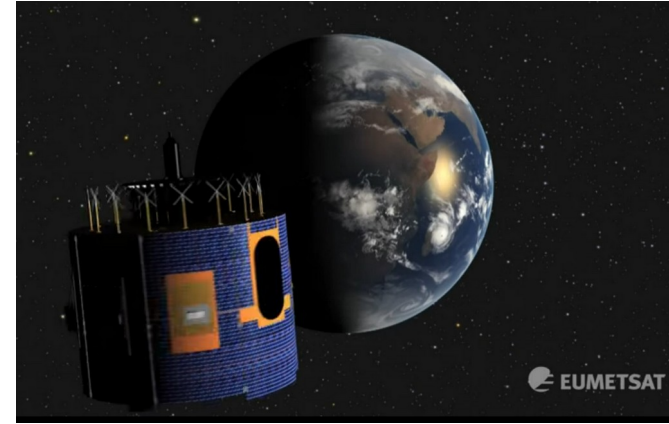


Institute of Meteorology and Water Management
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- High temporal resolution
- High spatial resolution
- Large spatial coverage
- Accurate precipitation estimates
- Near-real-time availability

No observing system can maximize all requirements simultaneously. In operational meteorology, improving one requirement often comes at the expense of another.

The Era of Earth Observation and A Resolution Dilemma



Continuous monitoring from geostationary orbit

Global coverage from polar-orbiting missions

Multi-sensor observations supporting weather and hydrology

But... no single satellite system provides both high spatial and high temporal resolution at the same time

Modern precipitation monitoring relies on the synergy between geostationary VIS/IR imagers and low-Earth-orbit microwave observations.

From Cloud Observations to Rainfall Estimates



SAT (Satellite-based precipitation – combination of EUMETSAT NWC SAF products developed by IMGW) (SEVERI IR + VIS)	Real-Time
H61B (Satellite-based precipitation – MW-IR combination of EUMETSAT H SAF product) (SEVERI IR + PMW adjustment)	Near Real-Time
PDIR-Now (SEVERI IR + Artificial Neural Network)	Near Real-Time
IMERG Final (PMW + IR + gauge adjustment)	Research/Climate Product

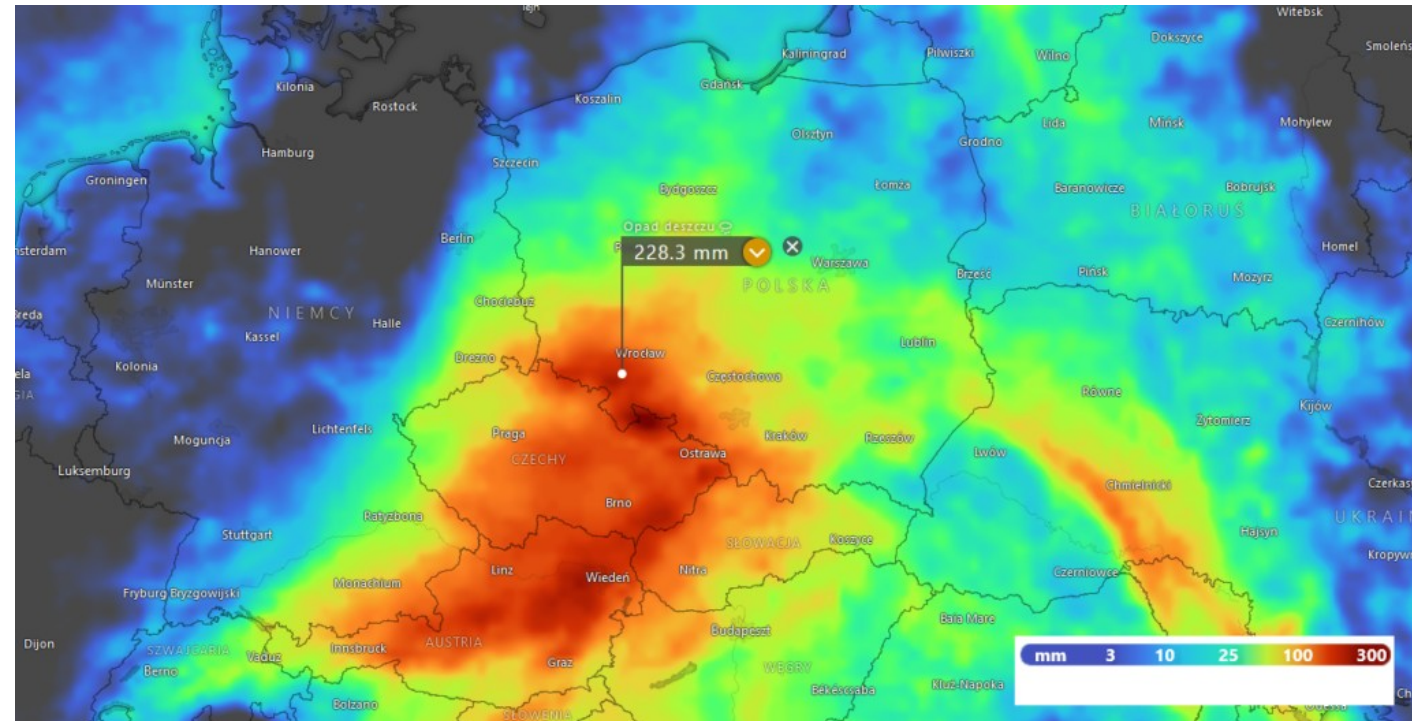
September 2024 Flood Event: A Natural Stress Test



A rare opportunity to evaluate satellite precipitation products under extreme hydrometeorological conditions.



Kłodzko [Source: PAP / Maciej Kulczyński]



Total precipitation forecast by the ECMWF model for central Europe, including Poland, from Thursday, September 12, through Monday, September 16. Source: [windy.com/ECMWF](https://www.windy.com/ECMWF)

Case study

- focus on extreme rainfall associated with cyclone Boris
- time: 13-16 September 2024
- area: the upper and middle Odra River basin in Poland
- evaluation period: 13–16 September 2024

Satellite products:

- SAT
- PDIR-Now
- H61B
- IMERG Final

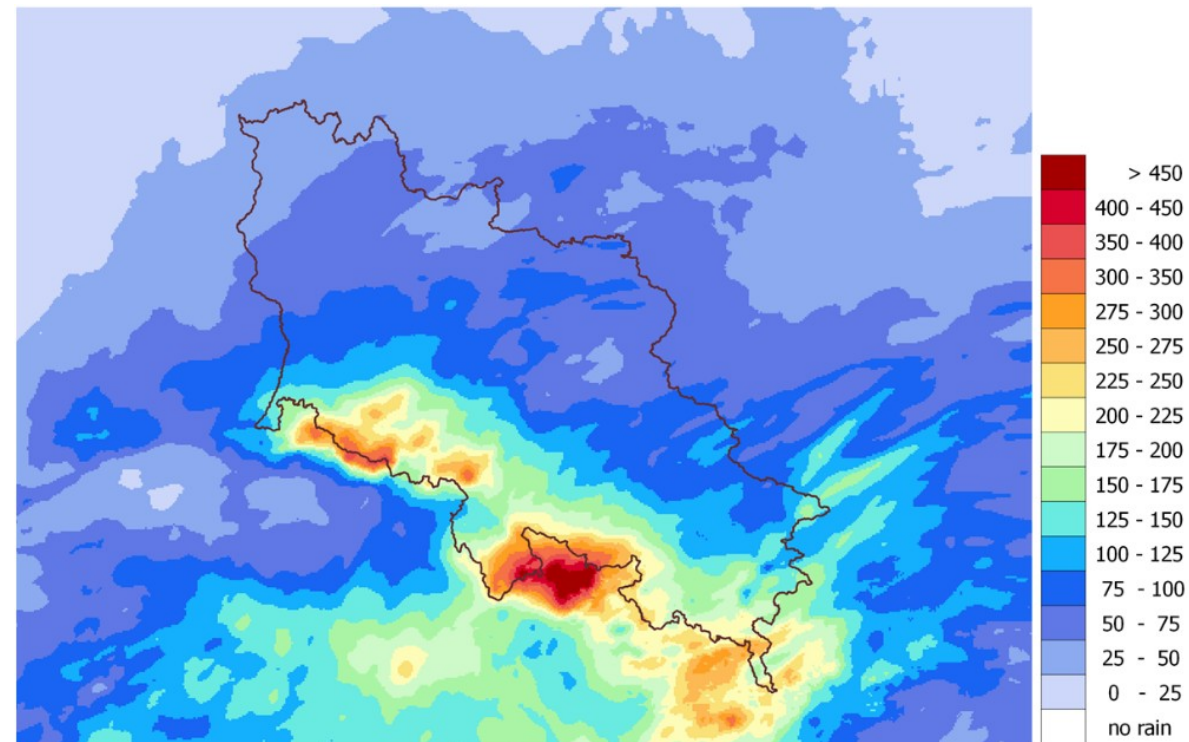
Observations of IMGW:

- GAU
- RAD
- RAD Adj

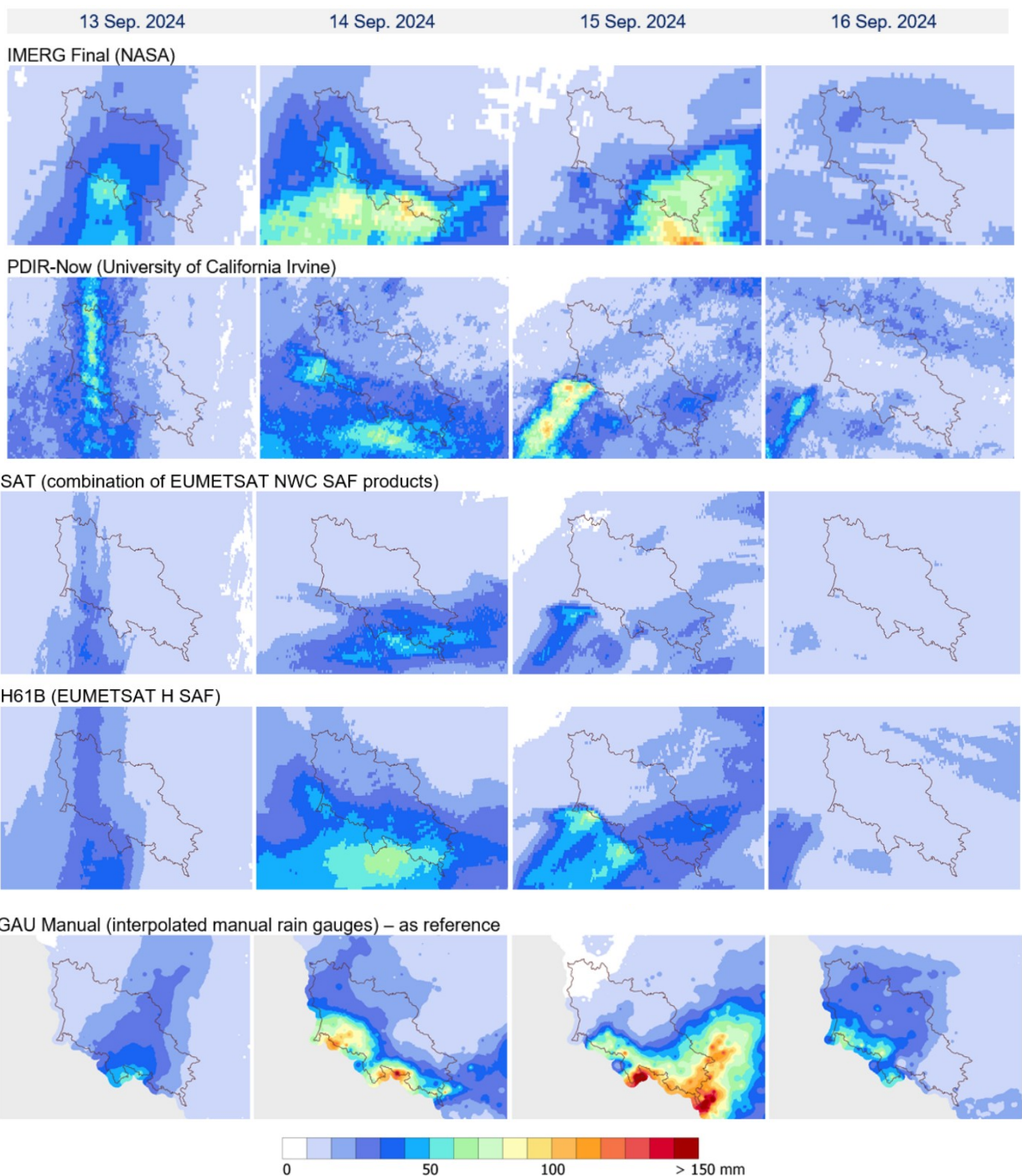
All products were aggregated to daily accumulations prior to evaluation

Reference data

GAU Manual (Hellmann) daily totals



Field of precipitation accumulation during the flood of 13–16 September 2024 (4 d)



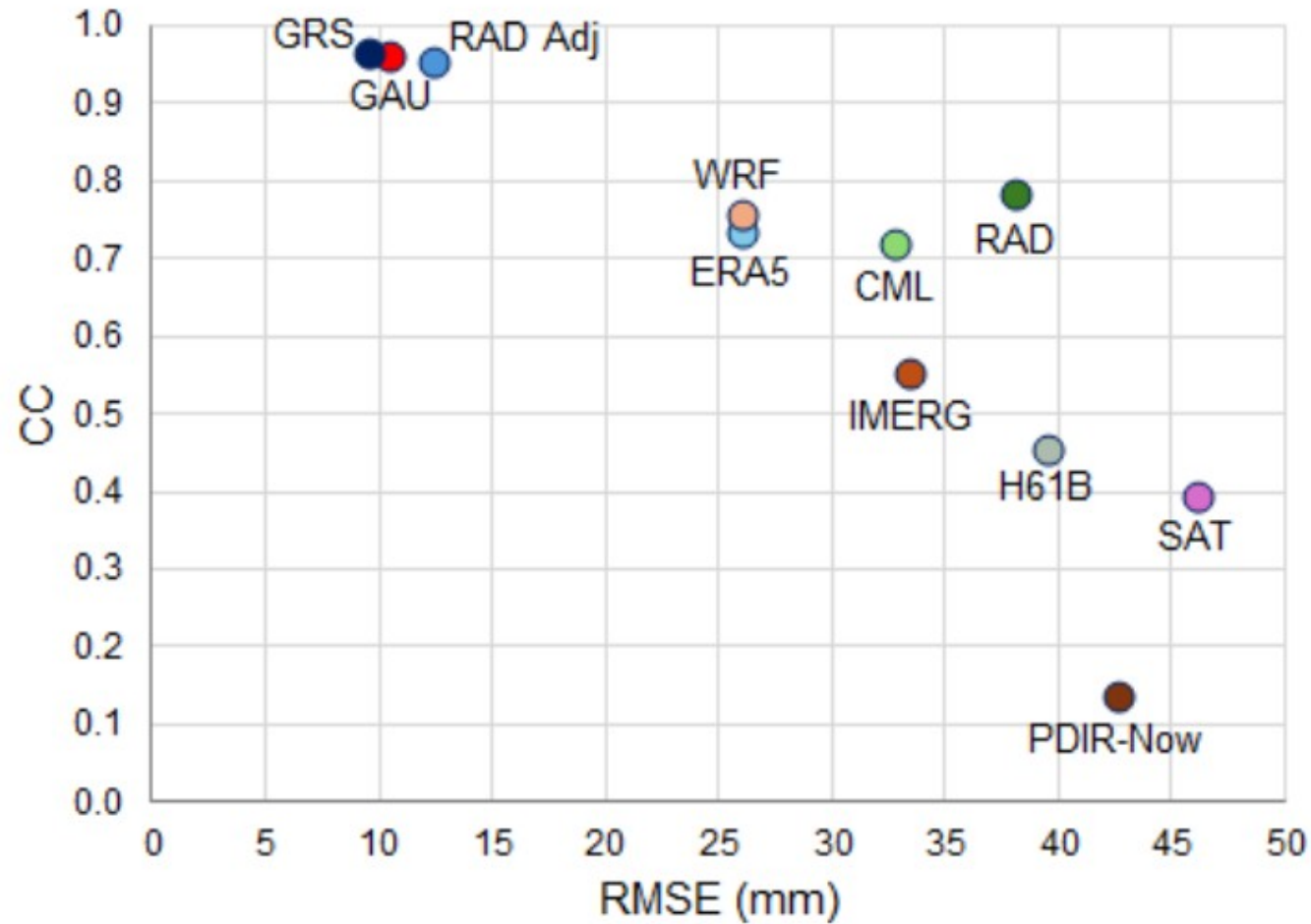
Results



Measurement/ estimation technique	Mean (mm)	CC (–)	RMSE (mm)	RRSE (–)	Bias (mm)
GAU Manual	41.78	–	–	–	–
GAU	38.27	0.963	10.40	0.29	–3.50
RAD	16.07	0.784	38.08	1.06	–25.71
RAD Adj	36.65	0.956	12.42	0.35	–5.13
SAT	10.02	0.395	46.06	1.28	–31.76
H61B	18.77	0.455	39.46	1.10	–23.00
IMERG	27.15	0.552	33.40	0.93	–14.63
PDIR-Now	20.23	0.138	42.57	1.18	–21.55

Values of statistics for daily precipitation accumulations from 13 to 16 September 2024 against data from manual rain gauges (GAU Manual) as reference.

Szturc J. et al., Hydrology and Earth System Sciences, 29, 5405–5427, 2025, <https://doi.org/10.5194/hess-29-5405-2025>



Scatter plot comparing CC vs. RMSE for each measurement and an estimation technique for daily precipitation accumulations from 13 to 16 September 2024 against data from manual rain gauges (GAU Manual) as reference.

- Reliability analyses indicate that satellite data are generally of limited usefulness, with the exception of IMERG precipitation estimates.
- All satellite-based precipitation products, including IMERG, struggled to accurately capture the most extreme rainfall accumulations.
- Additional data sources and calibration maybe improved the estimates but did not fully overcome the inherent limitations of satellite-based rainfall retrievals.
- Extreme precipitation remains particularly challenging because rainfall is inferred indirectly from cloud-top or atmospheric signals rather than observed directly.
- The results highlight a fundamental trade-off between the broad spatial coverage provided by satellite observations and the higher accuracy of ground-based measurements.

Thank you.

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