Collaborative Labelling of Earth System Features in EO Data for Weather & Climate Applications

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Earth System Features in EO Data for Weather & Climate

What is a Feature?

- In classical ML and data science, a "feature" is any input variable. For Earth System Features in EO data, these can include temperature, wind speed, cloud type, etc.
- In computer vision and object detection, a "feature" is an identifiable object with a clear boundary in space and time — **something that exists here and now**.

Earth System Features in EO Data for Weather & Climate

Not a Feature:

Continuous variable.

Yes a Feature:

Identifiable object, clear spatio-temporal boundary.

Examples of Features for Early Warning + Nowcasting

Earth System Feature Detection Workshop Proceedings:

- Mesoscale Convective Systems
- Tropical Storms
- Extratropical Cyclones
- Supercells
- Convective Initiation Zones
- **Overshooting Tops**
- Gravity Waves
- Cumulus top glaciating
- Blowing Snow Events
- Radiation Fog
- Lightning
- Lightning NOx Plumes
- Landslides and slope failure zones
- SeaSurface Height Anomalies
- Flooded Areas

Examples of Features for Weather Forecasting

Earth System Feature Detection Workshop Proceedings:

- Atmospheric Rivers
- Surface Roughness Anomalies (wind / land)
- Cloud Type, Cloud Phase
- Cloud Optical Depth Anom.
- Cloud Streets
- Atmospheric Blocking
- Open, Closed Cell Clouds
- Land Surface Temp. Anomalies
- Stratospheric Warming Events
- Cut-Off Lows
- Anticyclones
- Polar Lows
- Contrails
- Cold Air Intrusion
- Sting Jets

ML Applications for Earth System Observations

1. Access to long time series of expert-labelled features, together with the tools to explore them, adds value across weather and climate domains.
2. These datasets are high-quality training data for ML Applications; supporting more accurate nowcasting and warning generation, improved medium-range forecasting, refined climate information services, robust evaluation of model outputs.
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Why the Prioritisation of Features?

"A major limitation to expanding the success of [ML] to a greater variety of weather and/or climate phenomena is the lack of large, reliable, high quality labelled datasets."

Prabhat, Karthik Kashinath et al., 2021

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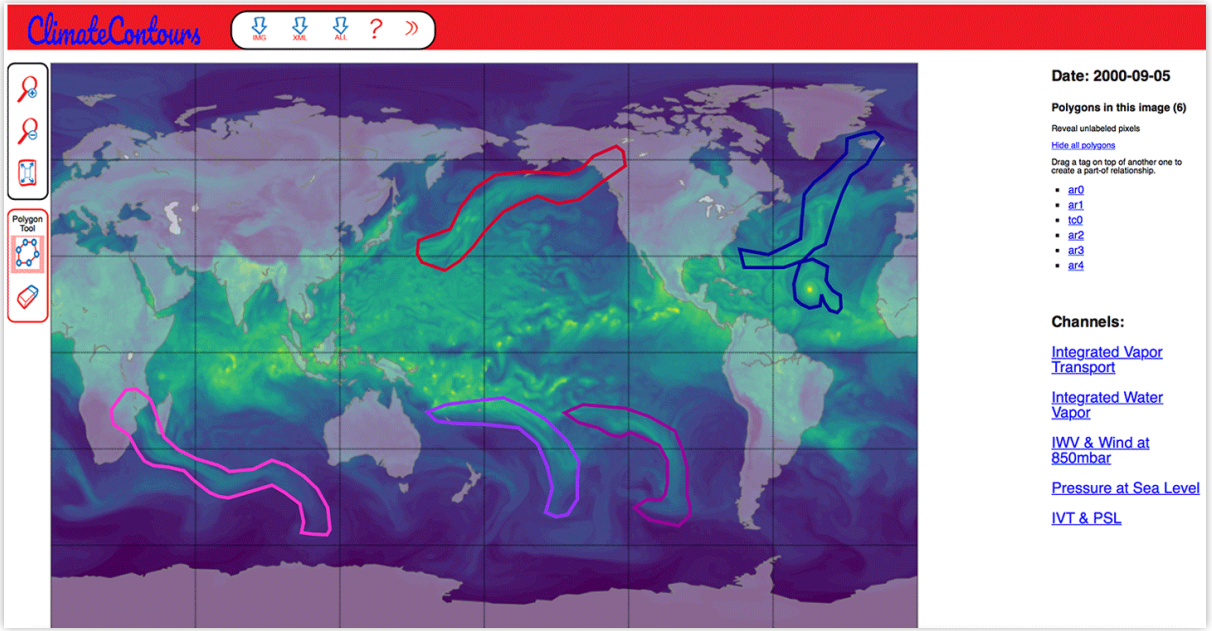
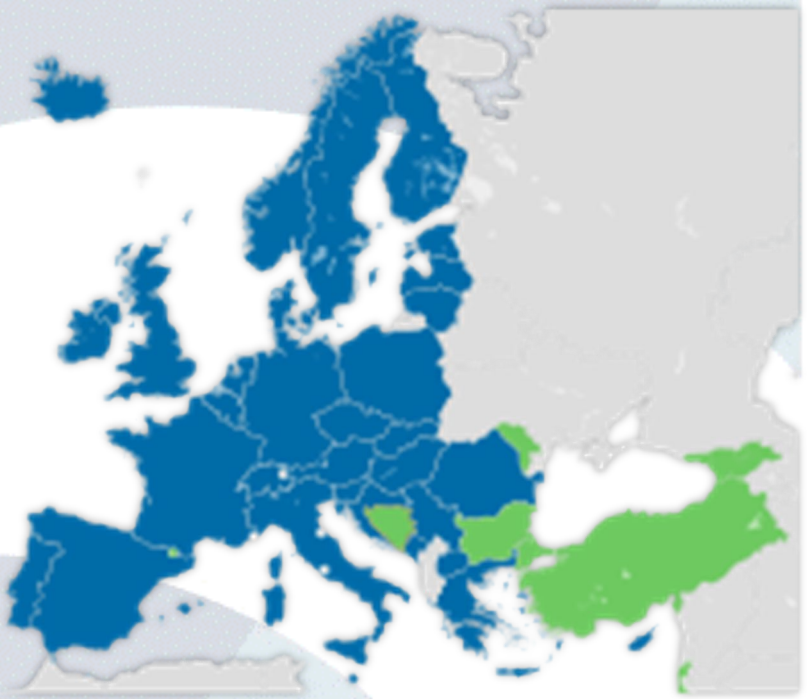


EUMETNET

Cooperative network of 33 European NMHSs (National Meteorological and Hydrological Services) established to organize joint programs, share data, and harmonize forecasting efforts.

Key for fostering a more integrated, efficient approach to weather and climate-related challenges.



EUMETNET

EUMETNET-AI

Artificial Intelligence and Machine Learning for Weather, Climate and Environmental Applications (E-AI)

High level programme objectives:

- In context of AI/ML in weather, climate and environment, enhance collaboration of European NMHSs and external partners.
- Share the developments that take place under E-AI using a commonly-used permissive open-source licence.

Coordinating Member for E-AI: DWD (Roland Potthast)

EUMETNET

E-AI Working Group on Data Curation: “Gap Analysis”

- GAP ANALYSIS: structured questionnaire to capture information on **data challenges that were preventing or slowing domain experts** from seamless ML-driven workflows.
- Via the E-AI mailing list, a request was sent to **400+** members to participate in a 1-hour interview, during which time I would ask structured questions and complete the questionnaire “in real time”.
- Six months later, I have responses from 17 domain experts across nowcasting and forecasting (n=11), and climate (n=6)… a response rate that reflects the universal scarcity of expert time.

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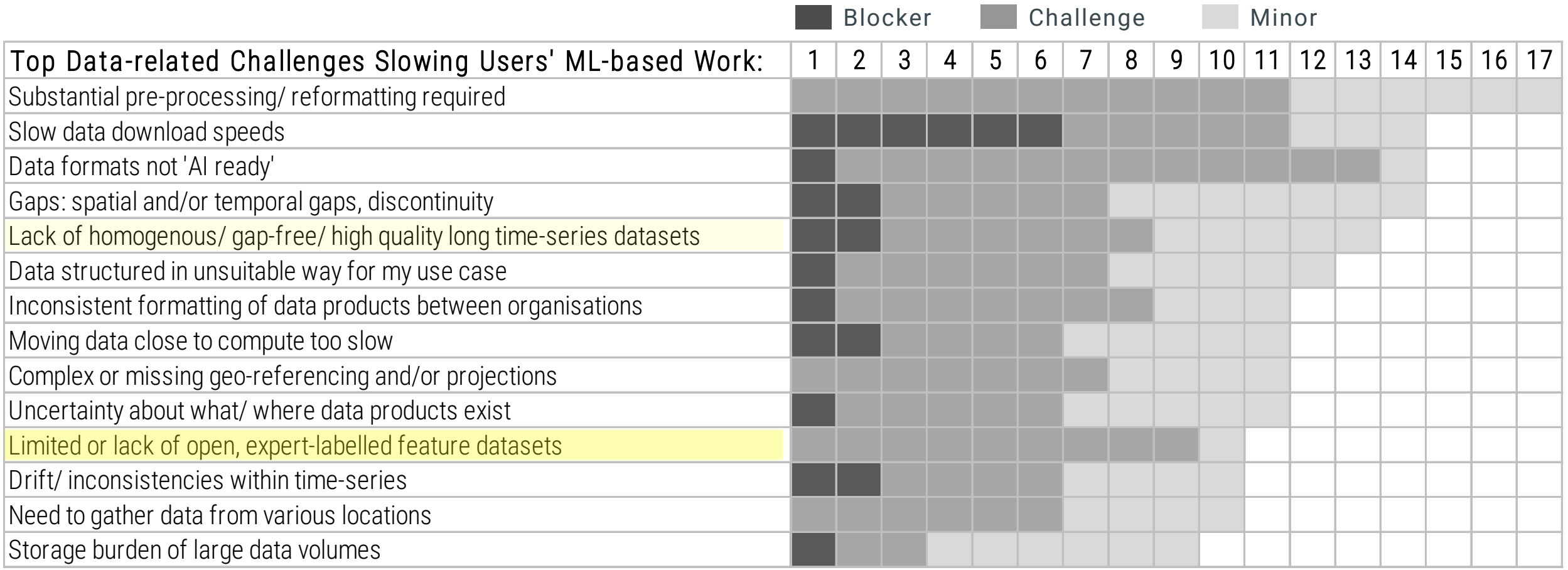
Gap Analysis Preliminary Findings:

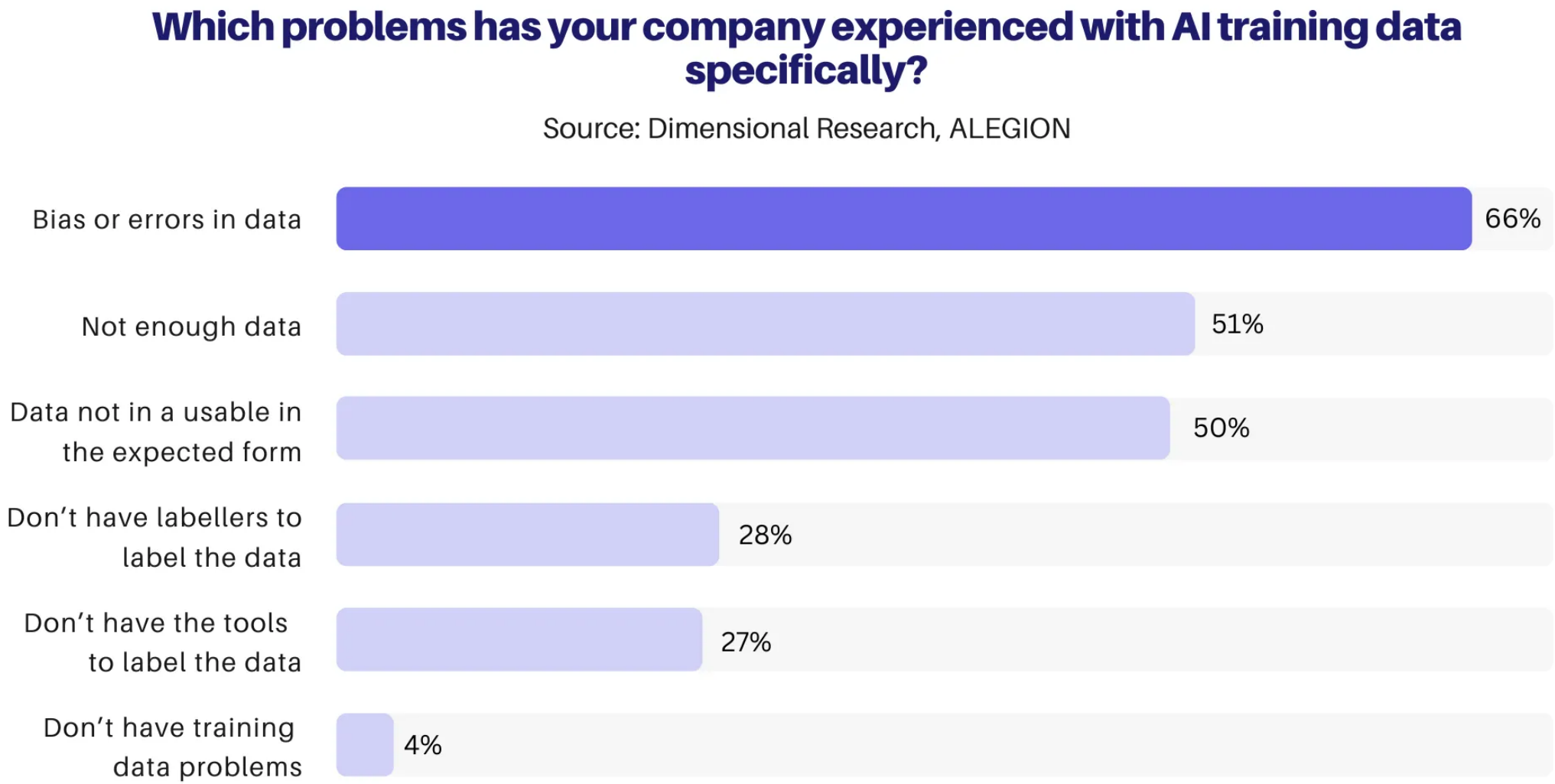


The majority of respondents who flagged a lack of open labelled feature datasets as a challenge work in nowcasting and forecasting (66.7%), but the problem also affects experts working in climate, marine, and air quality domains.

ML Applications for Earth System Observations

- Through the literature, E-AI Gap Analysis, and EUMETSAT user engagement, we know that ready access to expert-quality databases of labelled features is a desired requirement.
- Quantity vs quality: open, human-expert-labelled, and well curated feature datasets are vanishingly rare.
- If EUMETSAT are to support generation and sharing of a feature database, this means new platforms, new tools, and – importantly – **new skills**.
- What is the cost/ risk of not “doing this well”?

Lessons from the private sector…



The Unseen Cost of "Low Quality" Large Datasets: Tenyks(2023),Medium

Lessons from the private sector…

Improve the model or the data?

Source: Andrew Ng Talk

	Steel defect detection	Solar Panel	Surface Inspection
Baseline	76.2%	75.68%	85.05%
Model-centric	+0% (76.2%)	+0.04% (75.72%)	+0.00% (85.05%)
Data-centric	**+16.9%** (93.1%)	**+3.06%** (78.74%)	**+0.4%** (85.45%)

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Earth System Features in EO Data for Weather & Climate

The Ripple Effect of Poor Data Labeling:

- Compromised Model Accuracy
- Propagation of Bias (scalability)
- Financial Costs of Rework
- Delayed Deployment
- Loss of Trust and Reputation

Key Factors Leading to Poor Data Labelling:

- Inadequate Training of Annotators.
- Lack of Clear Instructions for Labelling Tasks.
- Insufficient Quality Control.

Earth System Features in EO Data for Weather & Climate

Model training and fine-tuning unavoidably requires expert-quality manually labelled samples. **However:**

- Labelling is often manual, tricky, and incredibly time-consuming.
- Labelling also requires data preparation tools and a designated annotation platform; helpful to also be able to visualise, store, and organise features and labels.

It makes no sense for NMHSs to do this separately, especially when the E-AI and European Weather Cloud (EWC) provide practical means for collaboration between Member States.

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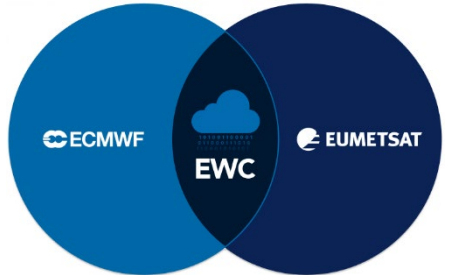

Feature•Space

Collaborative Feature Labelling Platform for ML Applications

EUMETSAT
FeatureSpace for Collaborative Labelling

Darmstadt

25 - 27 March 2026

As part of Machine learning (ML) activities for detection and forecasting of extreme events, EUMETSAT is committed to support its member states by providing data, tools, and community platforms. This includes the development of the Joint Working Environment for Feature Identification in the European Weather Cloud, including a Collaborative Label Space for global atmospheric and Earth surface feature tracking.

This in-person training workshop will take place 25-27 March 2026, and will be hosted by EUMETSAT at the headquarters in Darmstadt. After a general introduction to the Joint Working Environment, two sessions will run in parallel — one for developers, the other for labelers.

The event aims to bring together researchers, developers, and stakeholders from the domains of climate and weather from EUMETSAT member states. Preference will be given to national meteorological services, but all meteorological organisations may nominate participants. Researchers from marine, terrestrial, and atmosphere domains are also welcome.

Workshop VI Europe English

Target Audience
Primary: Researchers, developers, and stakeholders from the domains of climate and weather from EUMETSAT member states. Secondary: Researchers from marine, terrestrial, and atmosphere domains.

Hosted by
EUMETSAT

Contact

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Expected Learning Outcomes

- Leverage the European Weather Cloud for Earth Observation data preparation using S3 buckets.
- Navigate and use tools on the **LabelStudio** platform, including SAM2.
- Accurately label key features in the prepared Earth Observation data.
- Export Feature labels for downstream ML model development on the European Weather Cloud.


Germany

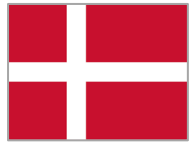

Bulgaria


Norway


Romania


Spain


Italy


Denmark


Czechia


Croatia

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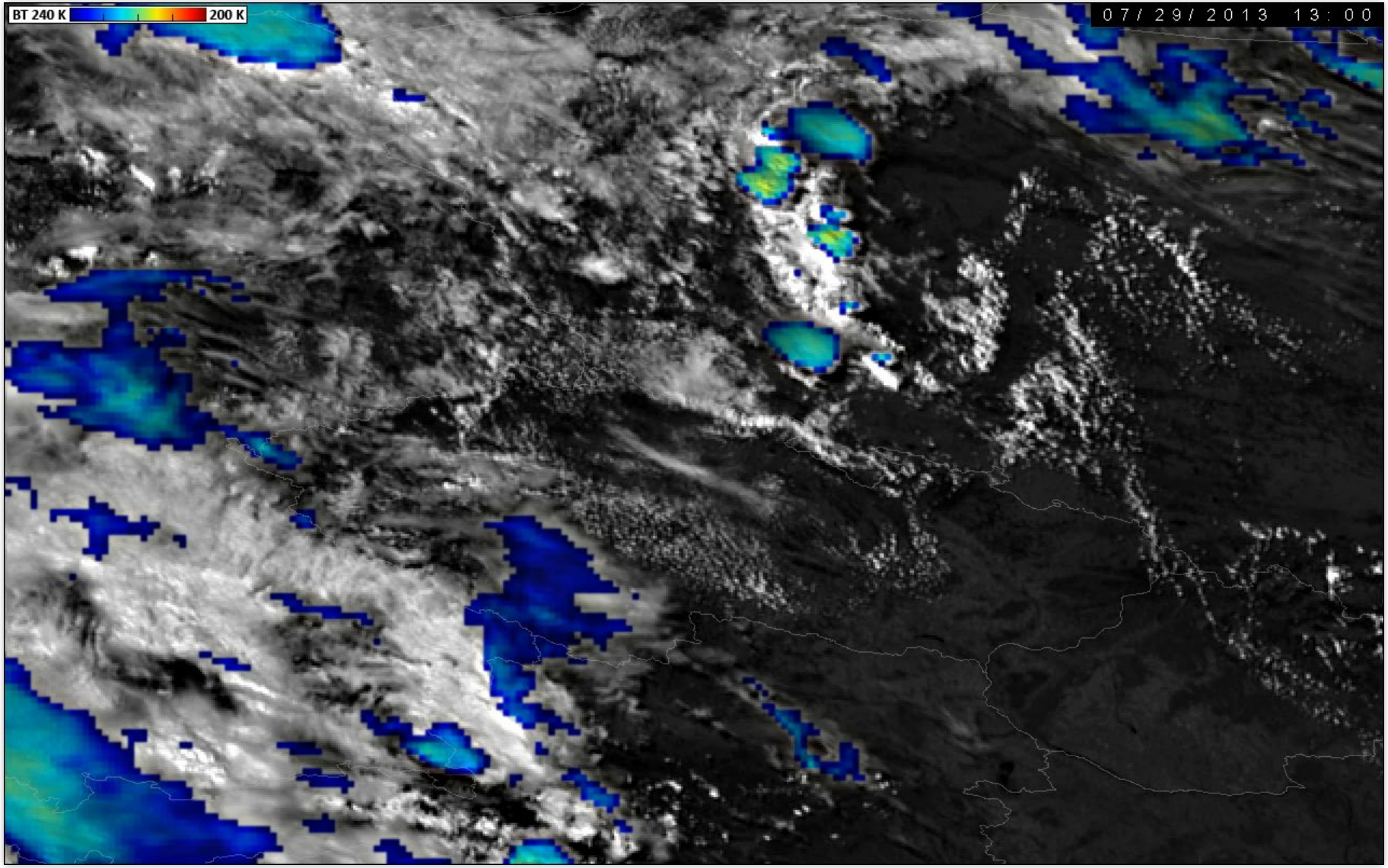
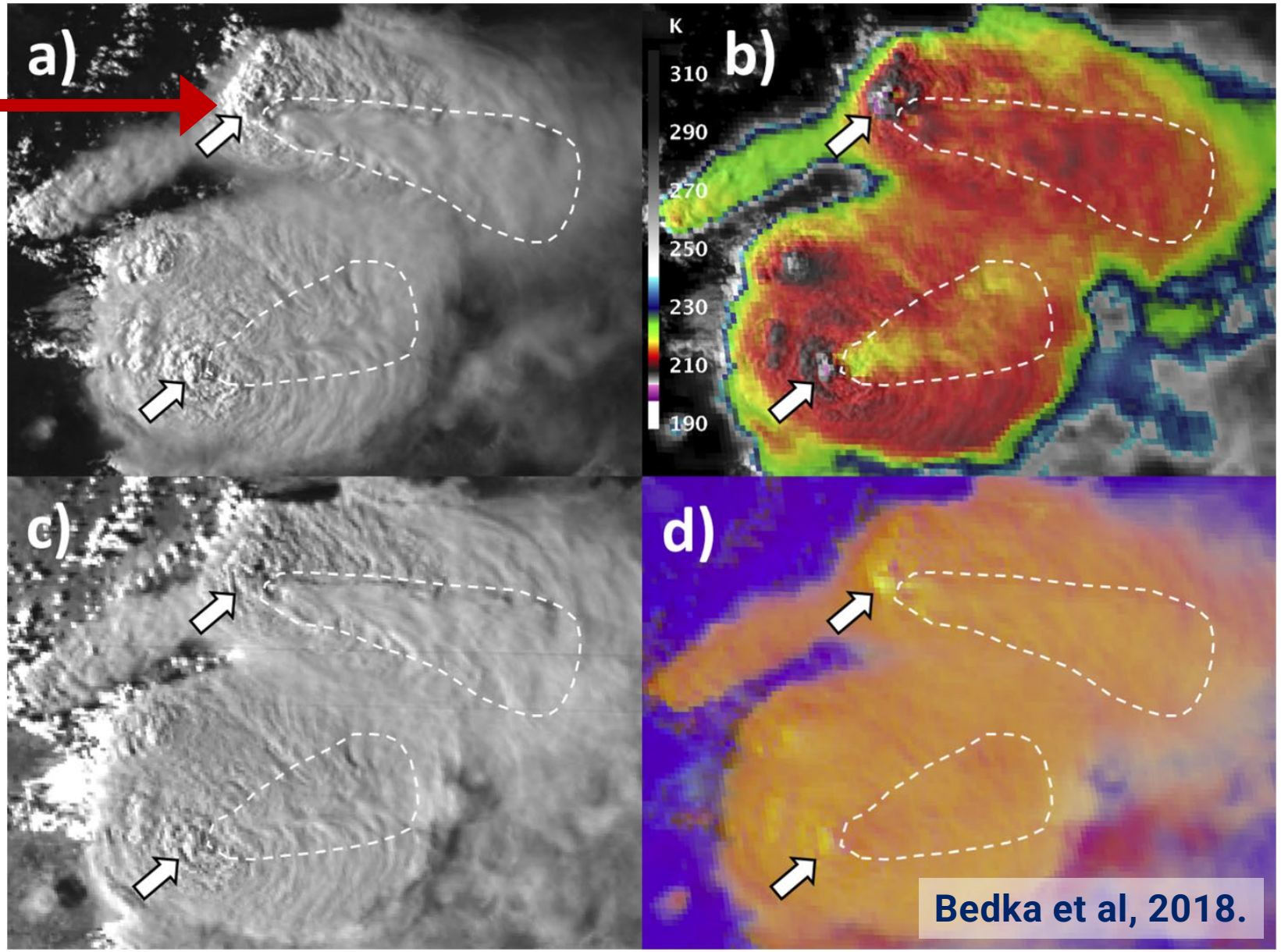


FeatureSpace for Collaborative Labelling

This storm produced hail over 18 cm in diameter…

Photo by Victoria Druetta, Argentina, 08.02.2018



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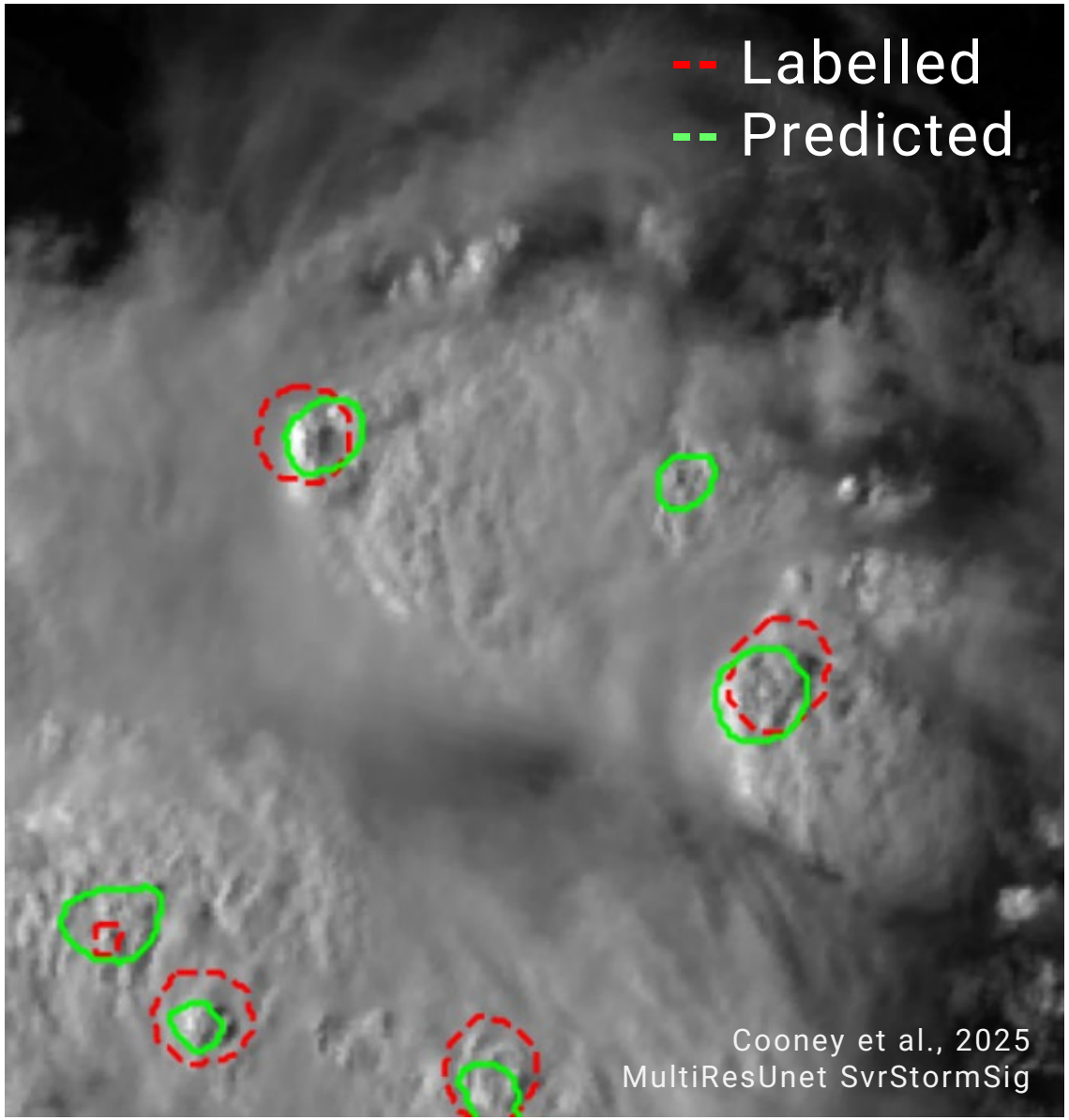

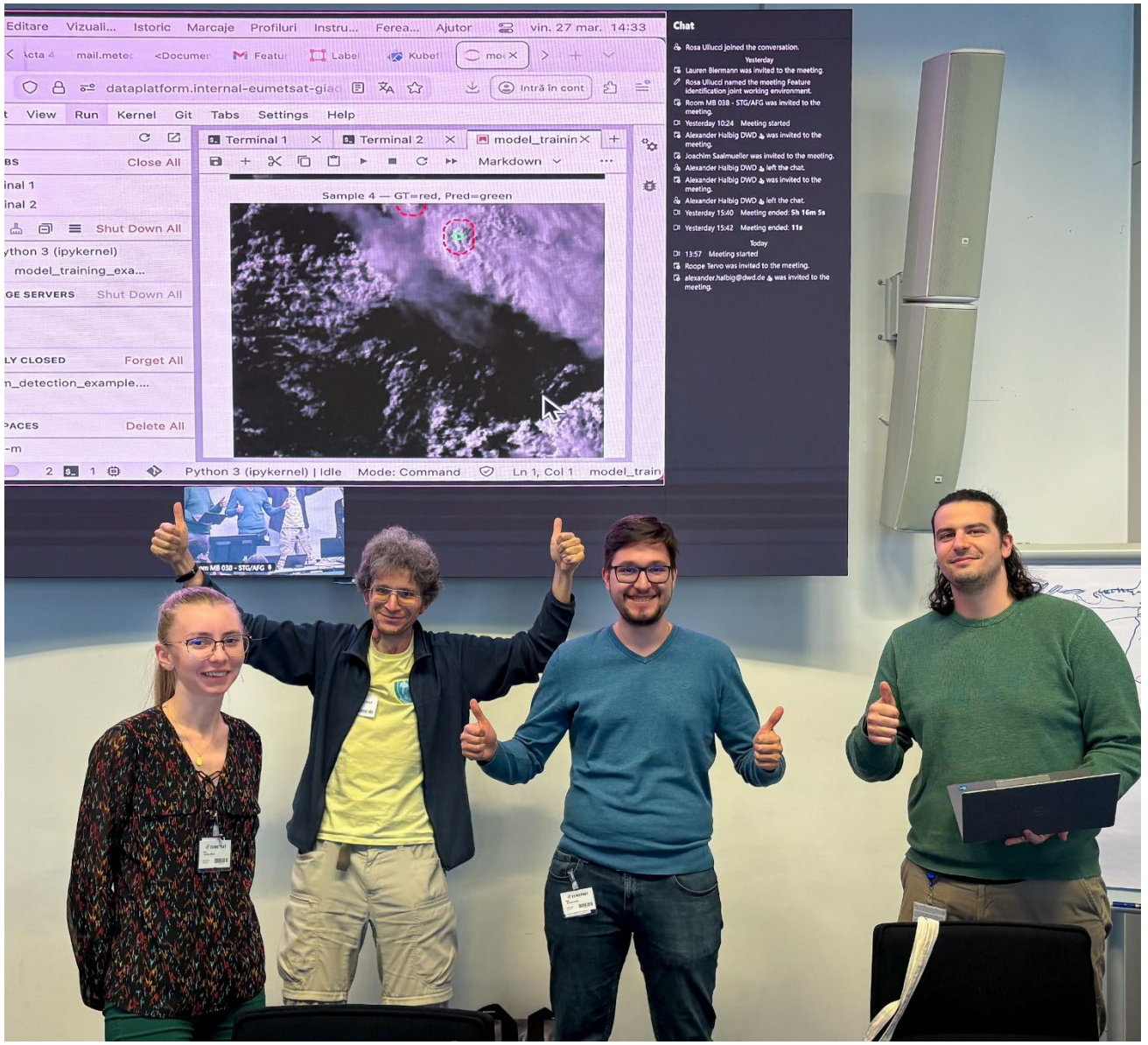

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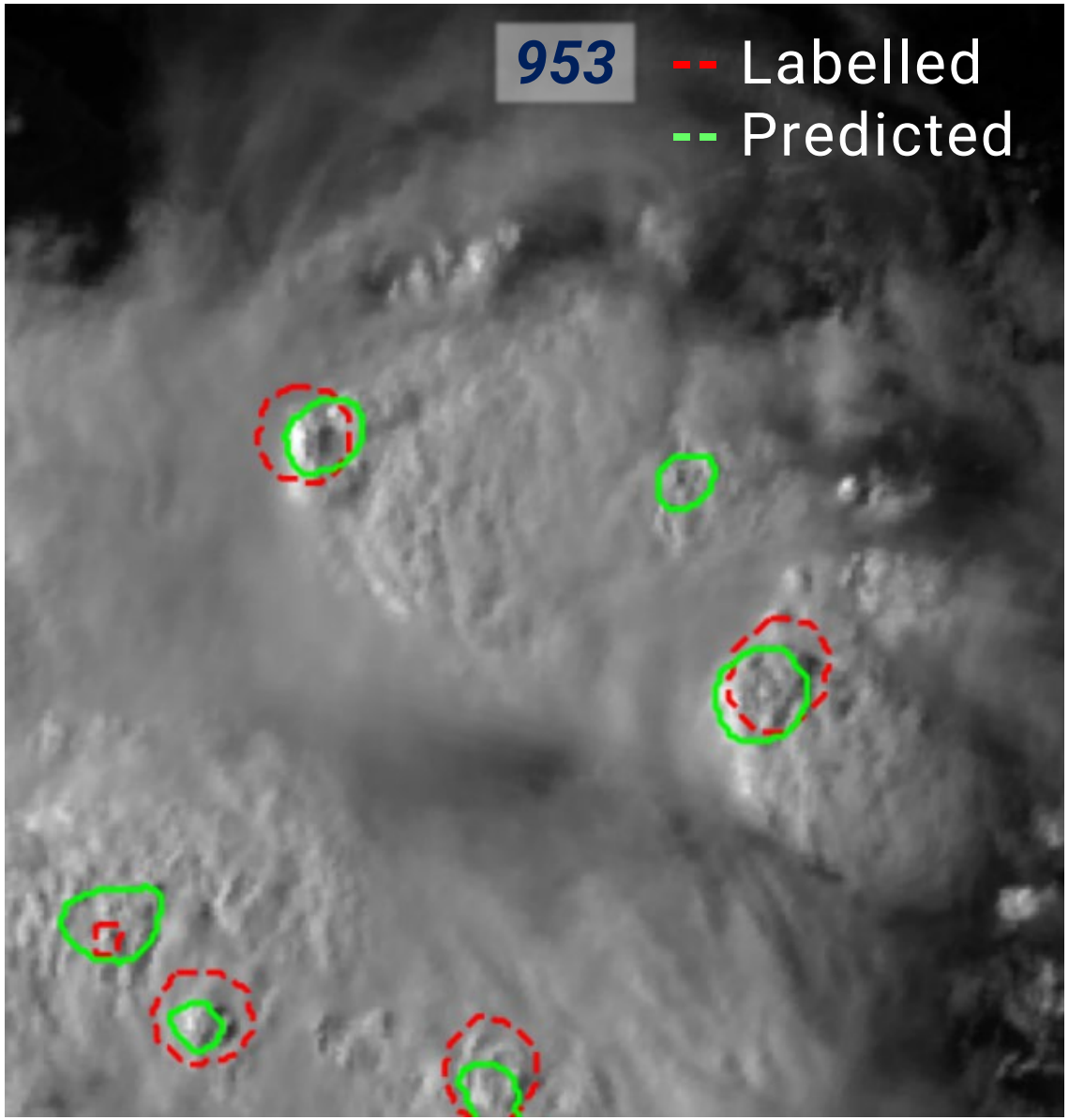

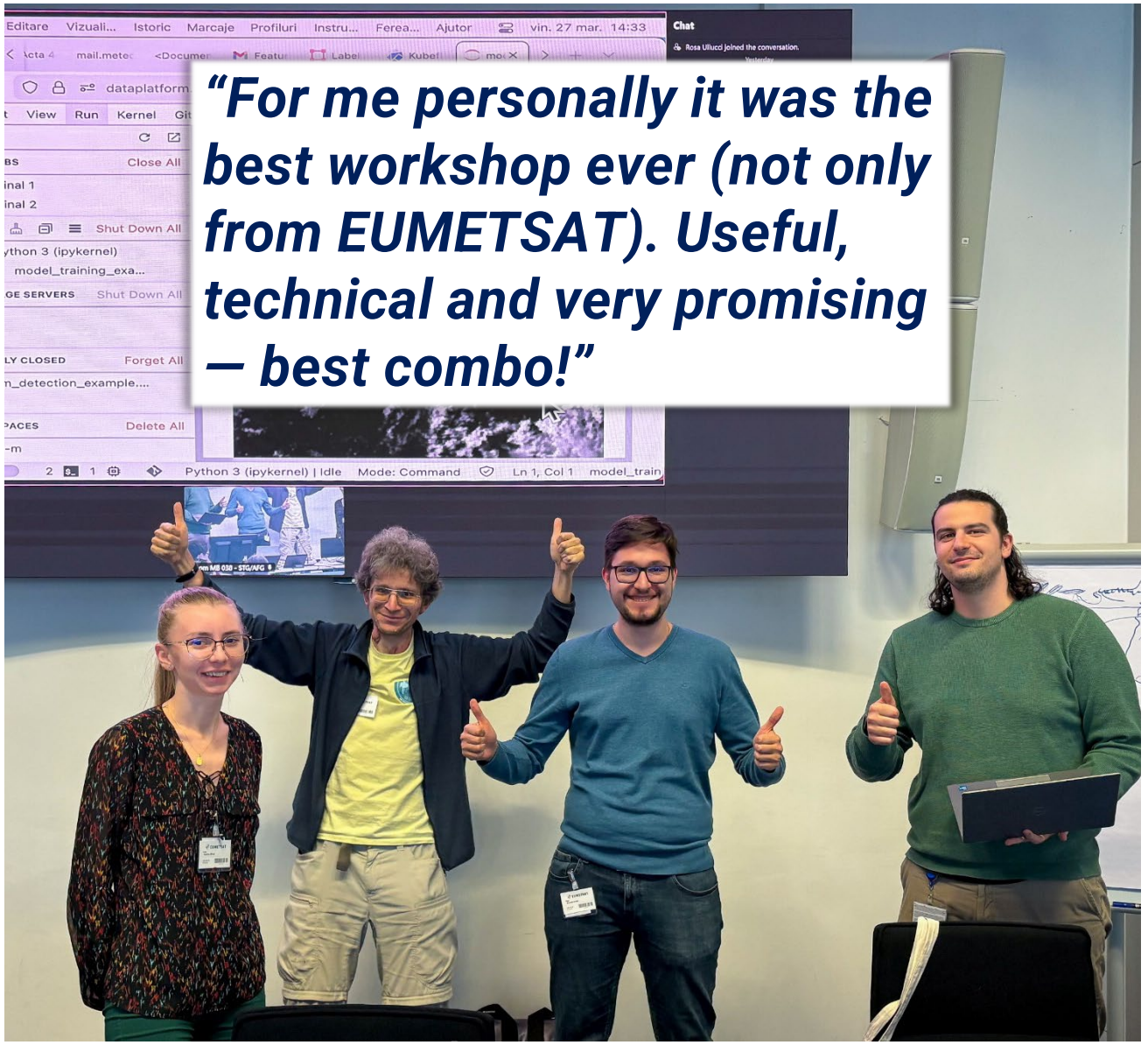

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FeatureSpace for Collaborative Labelling

- It is not up to EUMETSAT to decide which features are ‘important’ – if our member state user has flagged a feature as valuable, it’s valuable.
- Through the EWC and LabelStudio, the Feature Space provides data, platform, and tools by which users can label their priority features [*and pull these into their models*].

European Organisation for the Exploitation of Meteorological Satellites

- EU•MET•SAT is an operational organisation formed in 1986, services the needs of member states for timely, accurate weather and climate data.
- Currently:
  - 30 member states
  - India, China, Japan, Korea, Canada and the USA.
  - 12 active satellites

Polar Orbiting LEO and Geostationary Satellite Fleet:

METOP –B, -C , SGA1
(Local Equator Crossing Time - 9:30 AM)

LOW EARTH, SUN-SYNCHRONOUS ORBIT
EUMETSAT POLAR SYSTEM (EPS) / FIRST AND SECOND GENERATION

SENTINEL-3A & -3B (98.65° incl.)

LOW EARTH, SUN-SYNCHRONOUS ORBIT
COPERNICUS SATELLITES DELIVERING MARINE AND LAND OBSERVATIONS

JASON-3 & SENTINEL-6 (63° incl.)

LOW EARTH, NON-SYNCHRONOUS ORBIT
OCEAN SURFACE TOPOGRAPHY MISSION, SHARED WITH CNES/NOAA/EU

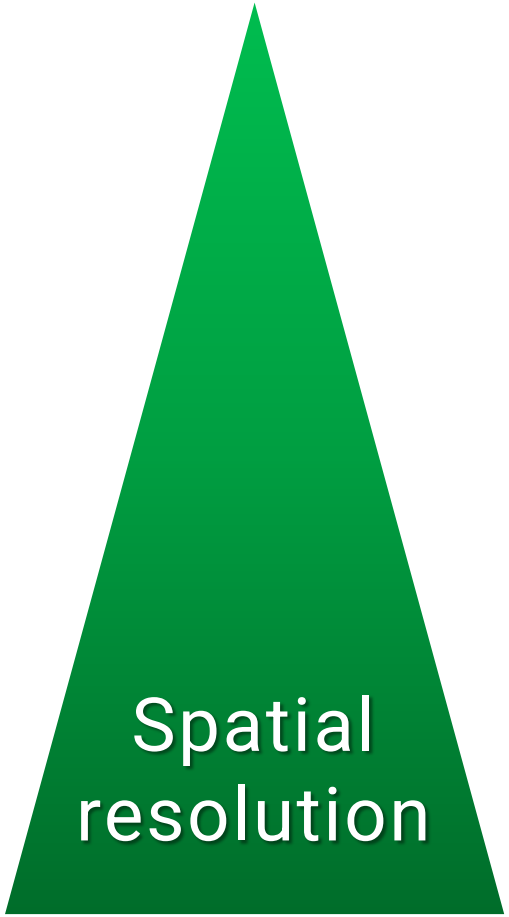
METEOSAT-10, 11, 12, 13

GEOSTATIONARY ORBIT	MULTI-SATELLITE SYSTEM
METEOSAT 2ND GENERATION	FULL DISC IMAGERY MISSION (15 MINS) (METEOSAT-11 (9.5°E)) RAPID SCAN SERVICE OVER EUROPE (5 MINS) (METEOSAT-10 (0.5° W))
METEOSAT 3RD GENERATION	FULL DISC IMAGERY MISSION (10 MINS) (METEOSAT-12 (0°)) ATMOSPHERIC SOUNDING IR (30 MINS) UV (60 MINS) (METEOSAT-13 (0°))

METEOSAT-9 (46° E)

GEOSTATIONARY ORBIT
METEOSAT 2ND GENERATION: PROVIDING INDIAN OCEAN DATA COVERAGE SERVICE (IODC)

Hierarchy of Data



L1 EO measurements

L2 EO data products

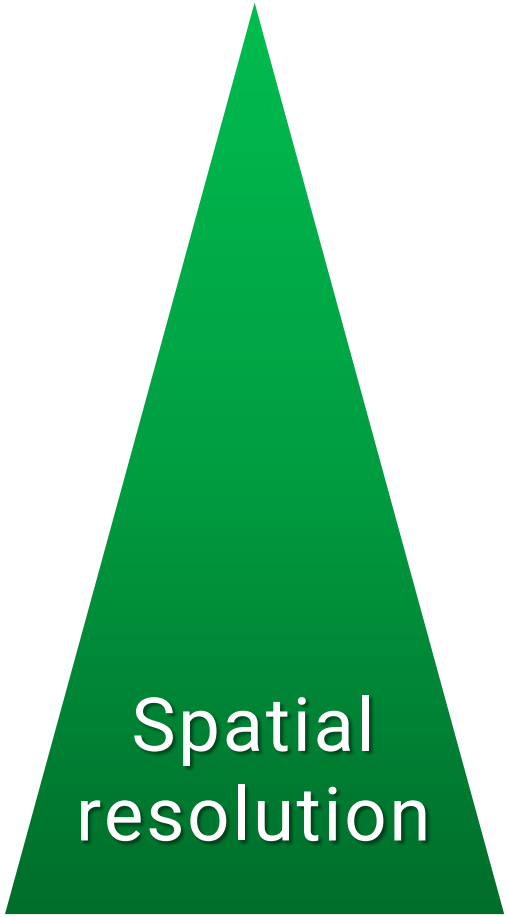
L3 Merged EO product

CDR ★

L4 Model blended

Reanalysis

Hierarchy of Data



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Observation-level inference (sensor constrained)

Lack of homogenous/ gap-free/ high quality long time-series datasets

Extra·ordinary datasets: CDRs

- EUMETSAT generates Climate Data Records from past and current satellite data.
- State-of-art data processors are used to ensure the data coming from different sources form a coherent series.

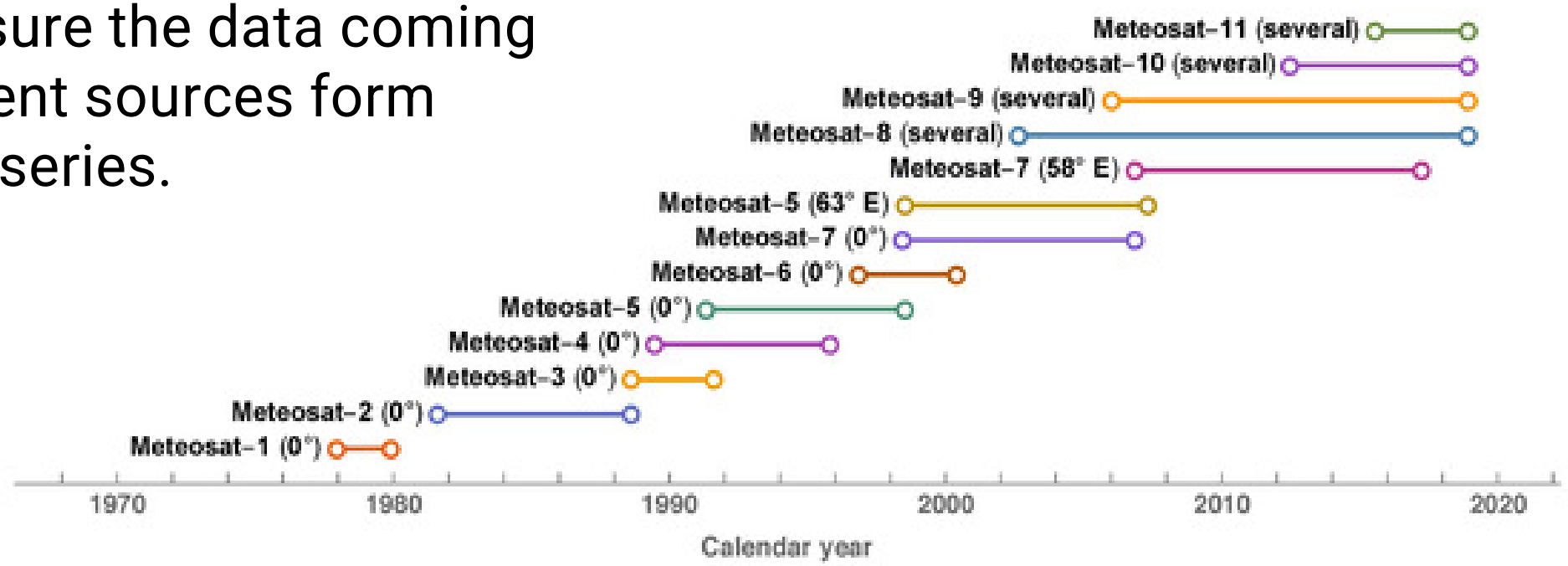
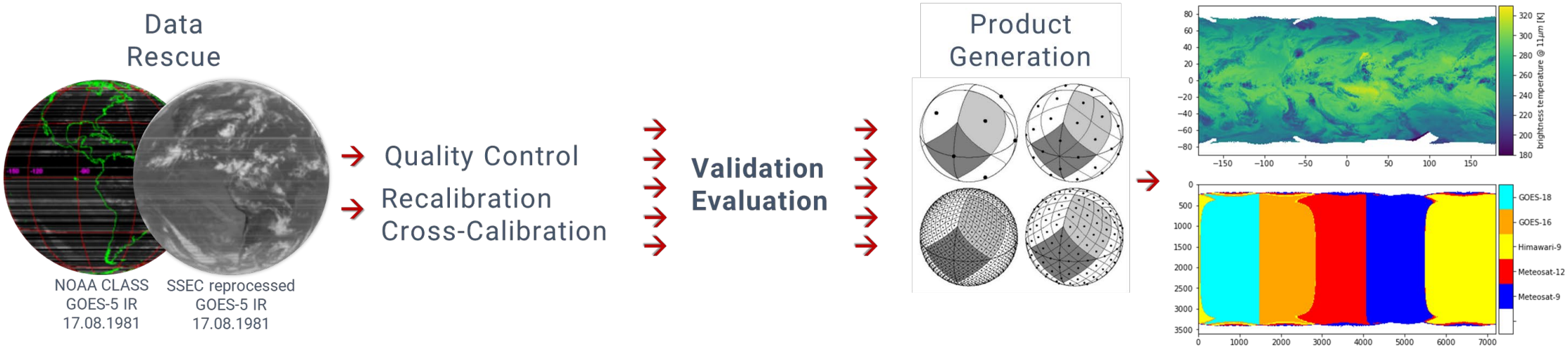


Fig. from Quast et al. (2019). Climate Data Records from Meteosat First Generation Part II: **Retrieval of the In-Flight Visible Spectral Response.**

Extra·ordinary datasets: CDRs

- The steps in establishing these operational CDRs involve a rigid research-to-operations process.
- CDR are only published after this process and a successful review of all data and documents.
- Example: GEO-Ring L1g



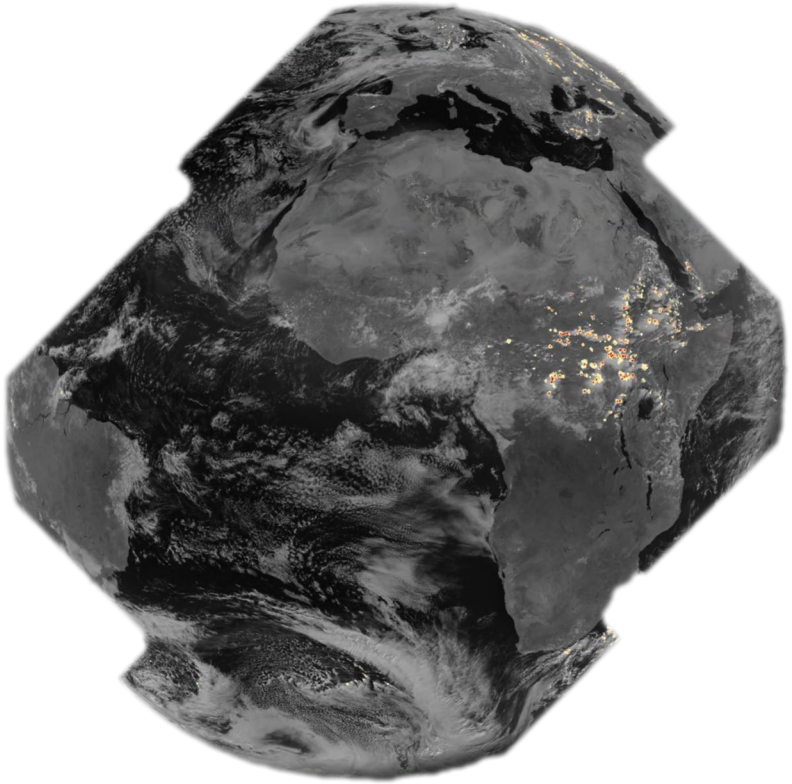
Extra·ordinary datasets: CDRs

LEO	IASI	Ozone (O3)	Metop-A and B	2007 - 2023
LEO	IASI	All Sky Temperature and Humidity Profiles	Metop-A and B	2007 - 2023
LEO	IASI	Sulphur Dioxide (SO2)	Metop-A and B	2007 - 2023
LEO	IASI	Carbon Monoxide FORLI-CO	Metop-A and B	2007 - 2023
LEO	AVHRR	CLARA-A3 cLoud, Albedo, surface RAdiation	Metop + NOAA	1979 - 2020
LEO	SSMIS	Global Sea Ice Concentration	Metop + NOAA	2023 - 2026
GEO	SEVIRI	Cloud Properties	MSG	2004 - 2019
GEO	GEOring	GIRAFE Global Interpolated RAinFall	Multi	2002 - 2022
GEO	MVIRI + SEVIRI	SARAH Surface Radiation DataSet Heliosat	MSG + MFG	1983 - 2020
GEO	SEVIRI	Atmospheric Motion Vectors	MSG	2008 - 2020

Where we are today: MTG-I

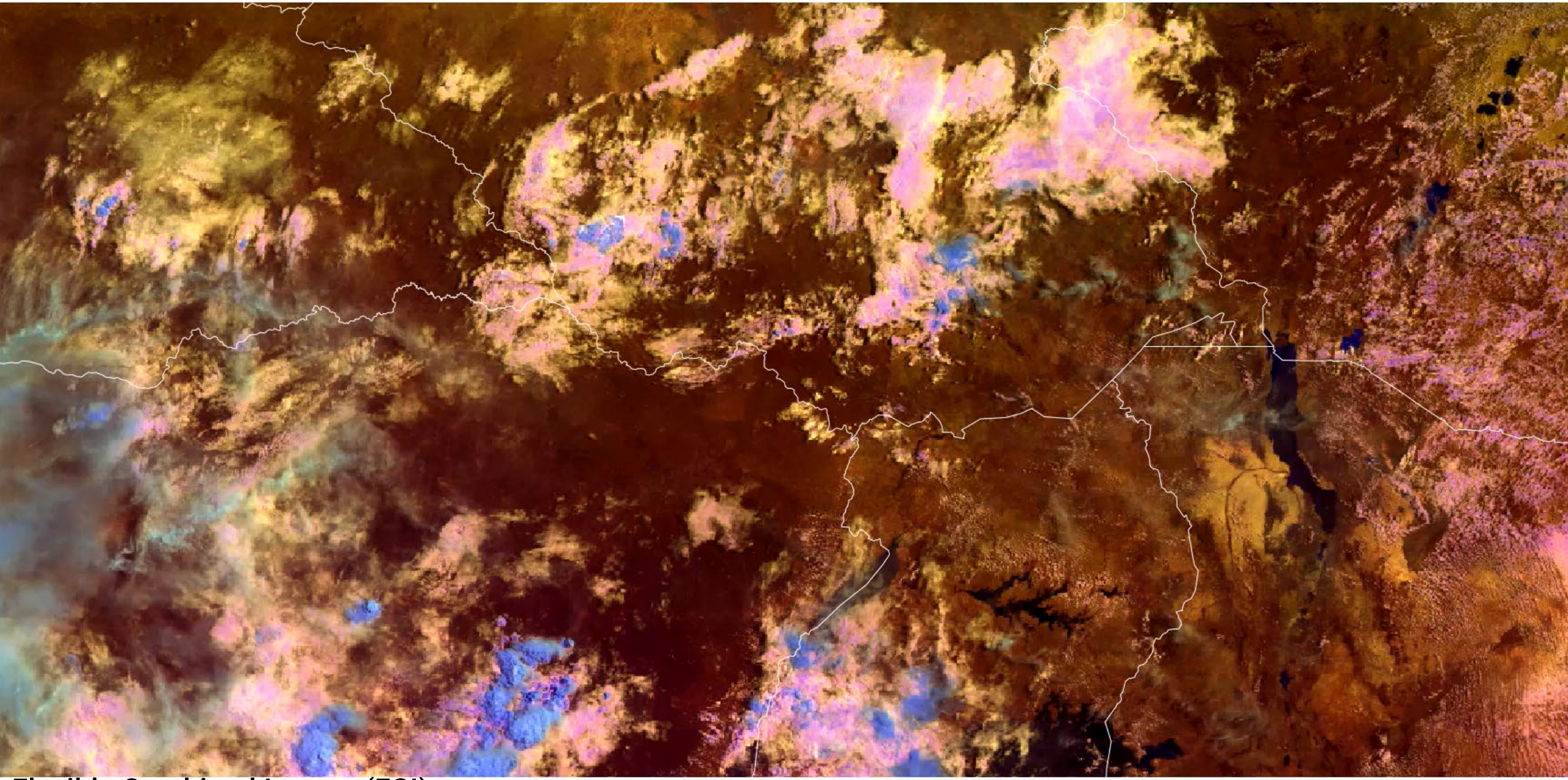
Meteosat Third Generation (MTG)
‘Next Gen’ EUMETSAT geostationary satellites

FCI bands	
VIS 0.4	1.0 km
VIS 0.5	1.0 km
VIS 0.6	**1.0 km** **0.5 km (HR)**
VIS 0.8	1.0 km
VIS 0.9	1.0 km
NIR 1.3	1.0 km
NIR 1.6	1.0 km
NIR 2.2	1.0 km 0.5 km (HR)
IR 3.8	2.0 km 1.0 km (HR)
WV 6.3	2.0 km
WV 7.3	2.0 km
IR 8.7	2.0 km
IR 9.7	2.0 km
IR 10.5	**2.0 km** **1.0 km (HR)**
IR 12.3	2.0 km
IR 13.3	2.0 km



Lightning Imager

Where we are today: FCI Vis 0.6



Flexible Combined Imager (FCI)

2025-05-02 08:00:00 UTC

EPS-Sterna secures support of all member states

Thank you!

Questions are welcome.

lauren.biermann@eumetsat.int