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AI-Driven Air Traffic Flow Management for Weather and Capacity-Constrained Operations

An Integrative Approach for Next-Generation ATFCM Tools

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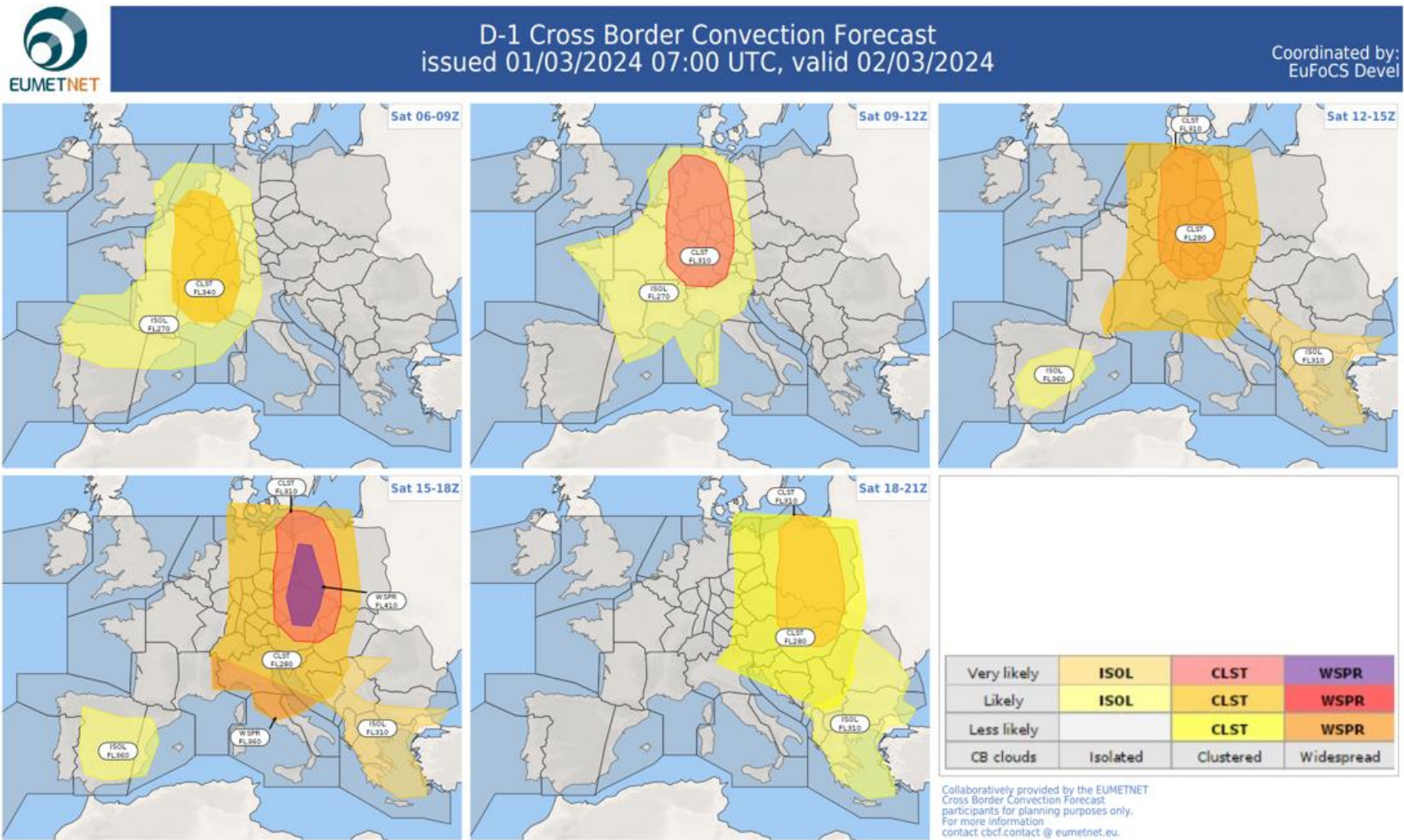
SIDs – 3rd December 2025



Overview

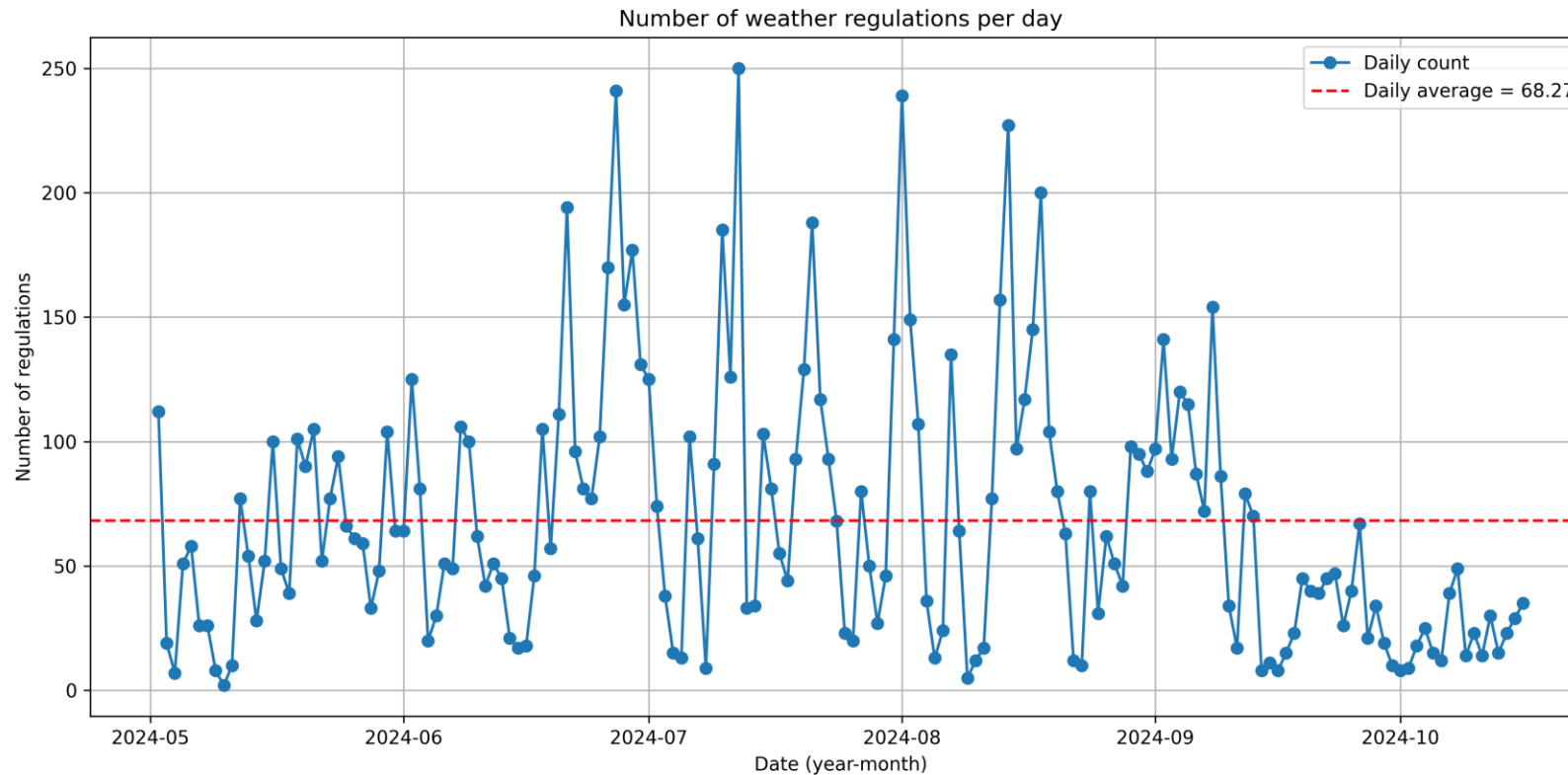
- Introduction: problem setup, business need, and research goal
- Model versions (2023 – 2025)
- Methodology – ISOBAR 2025
 - Data sources & features
 - Model architecture & ecosystem
- Results – ISOBAR 2025
 - Algorithms selection
 - Model performance (D0 vs D-1)
 - Feature importance & SHAP
 - iFlow integration & UI

Where it all started...



Weather Regulations Distribution

- MET summer: May – October

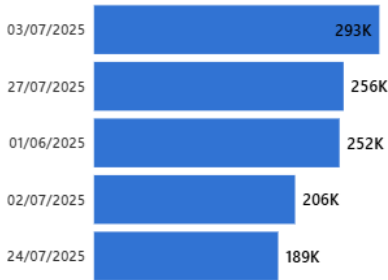


Delay Overview: 1st May – 31st August 2025

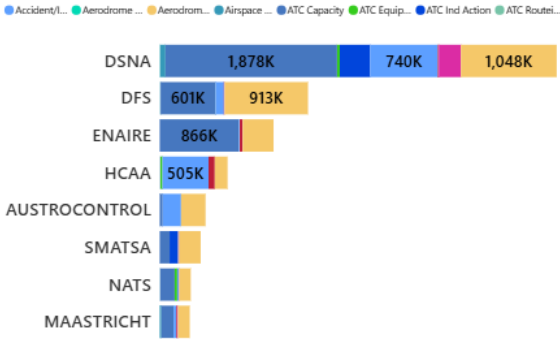
-27% +4% -19% -24%

	En-Route Delay Minutes	Airport Delay Minutes	% Delayed Flights	Delay Per Flight
01/05/2025				
31/08/2025	11,659,917	3,323,216	21%	3.55

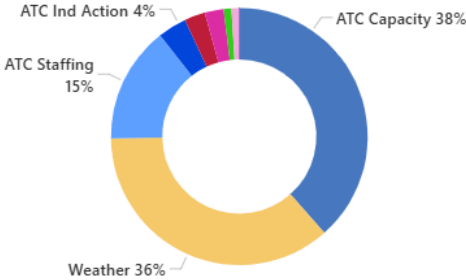
Highest En-Route Delay Days



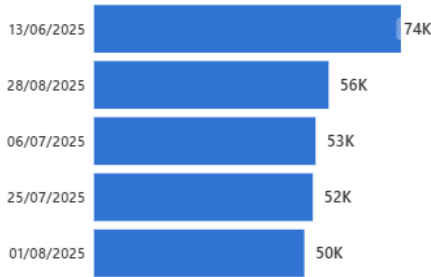
Highest En-Route Delay Generators



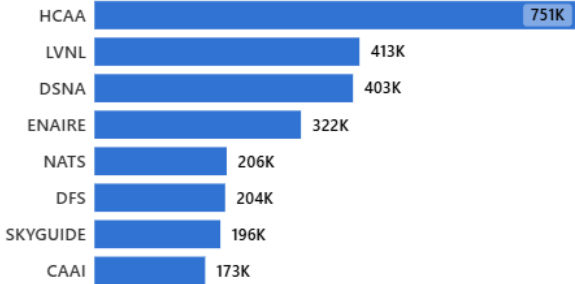
Delay Share of En-Route Regulation Reasons



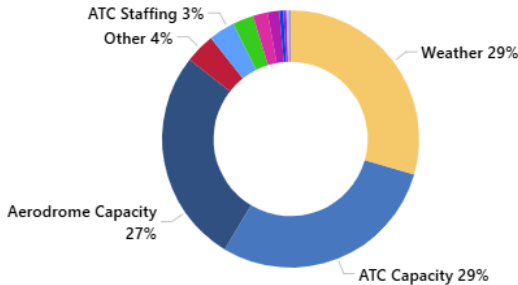
Highest Airport Delay Days



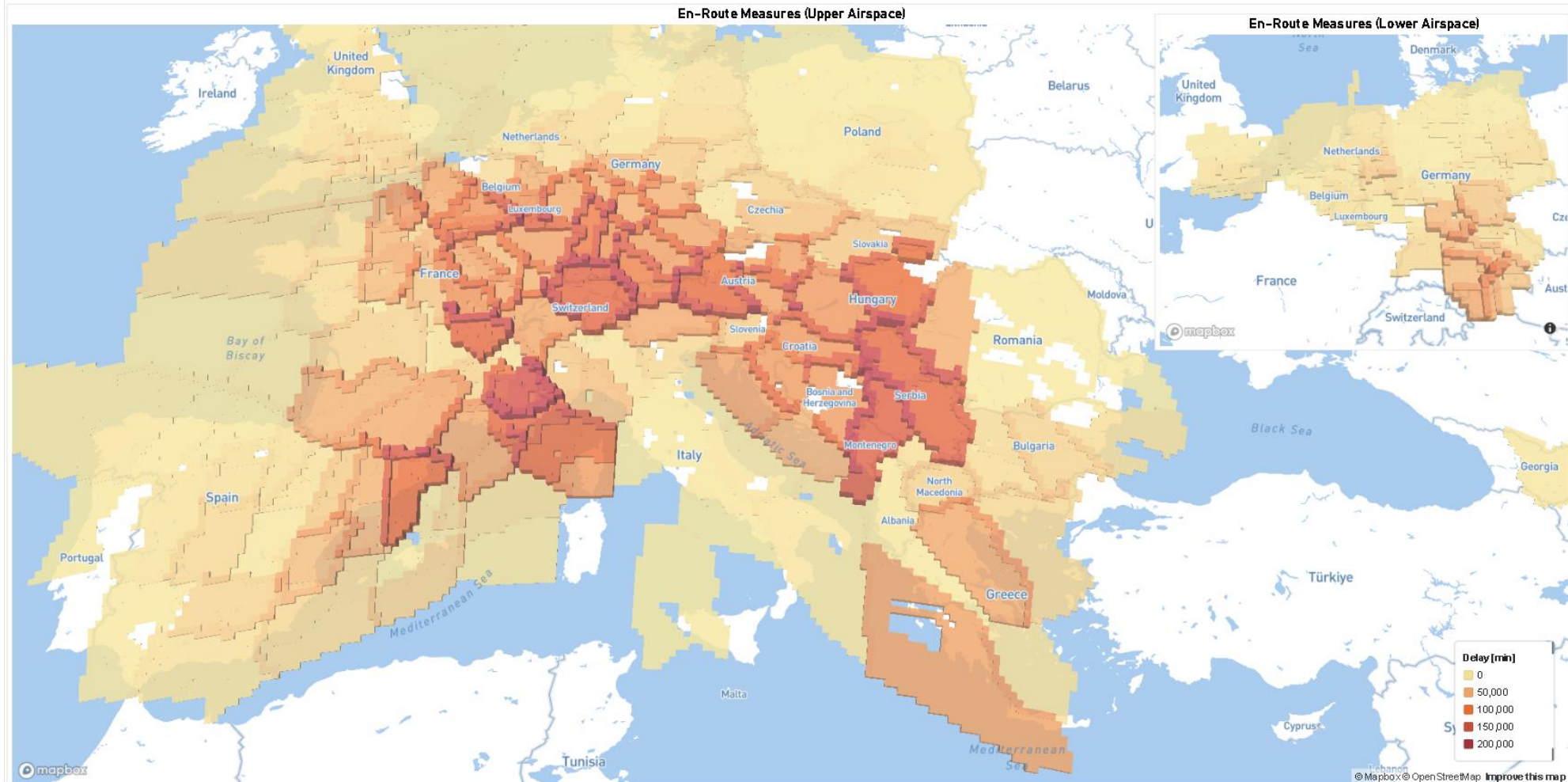
Highest Airport Delay Generators



Delay Share of Airport Regulation Reasons

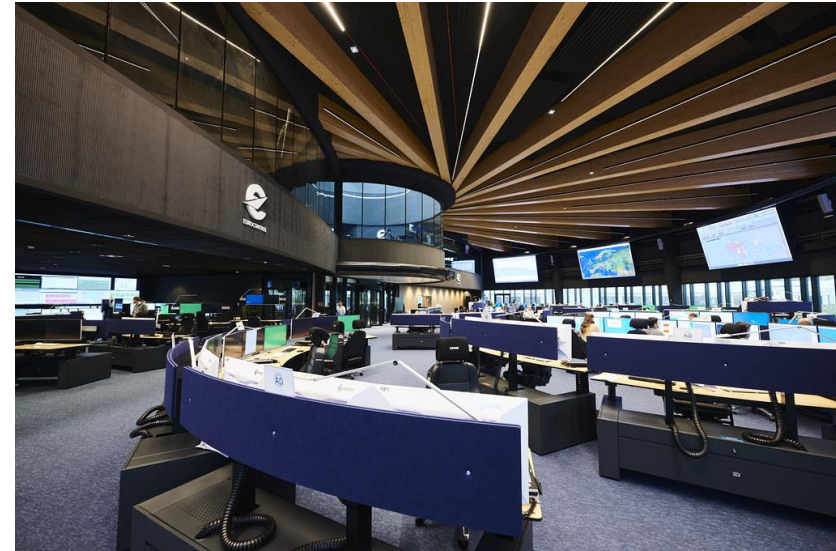


Geographic Distribution of En-Route ATFM Weather Delay: 1st May – 31st August 2025



ISOBAR Motivation

- **Goal:** anticipate **Air Traffic Flow and Capacity Management (ATFCM)** delays caused by **convective weather** – Cumulonimbus (Cb) clouds.
- **End-users:** **Network Manager Operations Centre (NMOC)** staff, responsible for monitoring and managing air traffic flow and capacity in the European airspace.



ISOBAR Context

- ISOBAR is a **ML-powered** tool that predicts **ATFCM regulations** caused by **convective weather** events for the NMOC. When a regulation is expected, it also predicts the associated **reduction in capacity** required.
- ISOBAR is an **operational** tool, deployed in iFlow – the future flow function front-end, part of iNM.
- ISOBAR is integrated into:
 - 2018 – 2025: Cross-Border Weather Procedure (CBWP)
 - 2025 – onwards: Capacity and Weather-Based Operations (CWBO)



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ISOBAR Versions 2023 – 2025



NETWORK
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ISOBAR Versions

- ISOBAR 2023:
 - First model version
 - Weather source: EUMETNET
- ISOBAR 2024:
 - Weather source: iCONV – integration postponed due to other priorities
- ISOBAR 2025:
 - TFV activations filtering
 - Prediction horizon extension
 - D0 – tactical (already present)
 - D-1 – pre-tactical (new!)
 - Weather source: EUMETNET



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Methodology ISOBAR 2025 Focus



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Data Sources & Features

Data Source	Feature	Description	Type	Units	Encoding
EMN forecast	cloud_top_height	Altitude of Cb cloud upper boundary	numerical	m	-
	valid_hour	Forecast time of validity (hour)	numerical	h	-
	has_CONVECTIONFRACTION_ISOL	Isolated convection	boolean	-	one-hot
	has_CONVECTIONFRACTION_CLST	Clustered convection	boolean	-	one-hot
	has_CONVECTIONFRACTION_WSPR	Widespread convection	boolean	-	one-hot
	has_LIKELINESS_likely	Convection occurrence likely	boolean	-	one-hot
	has_LIKELINESS_less likely	Convection occurrence less likely	boolean	-	one-hot
	has_LIKELINESS_very likely	Convection occurrence very likely	boolean	-	one-hot
	has_risk_very_high	Very high convective risk	boolean	-	one-hot
	has_risk_high	High convective risk	boolean	-	one-hot
	has_risk_medium	Medium convective risk	boolean	-	one-hot
	has_risk_low	Low convective risk	boolean	-	one-hot
	has_risk_very_low	Very low convective risk	boolean	-	one-hot
	is_amendment	Indicates amended forecast	boolean	-	one-hot
	is_tact_prediction	Indicates tactical prediction horizon	boolean	-	one-hot
Airspace data	tv_impacted_id	Impacted TFV (unique ID)	categorical	-	ordinal
Regulations & capacity	capacity	Actual capacity of TFV	numerical	ac/hr	-
	capacity_reduction	Difference between regulated and expected capacity	numerical	ac/hr	-
TFV activations & monitorability	is_monitorable	Indicates monitorability of TFV	boolean	-	one-hot
	is_activated	Indicates activation of TFV	boolean	-	one-hot
	is_tact_activated	Indicates activation type	boolean	-	one-hot

Weather Forecasts

- Forecasts every 3h

- Information provided:
 - Polygons with coordinates (Cb)
 - Cloud top height – altitude dimension
 - Impact level of Cb

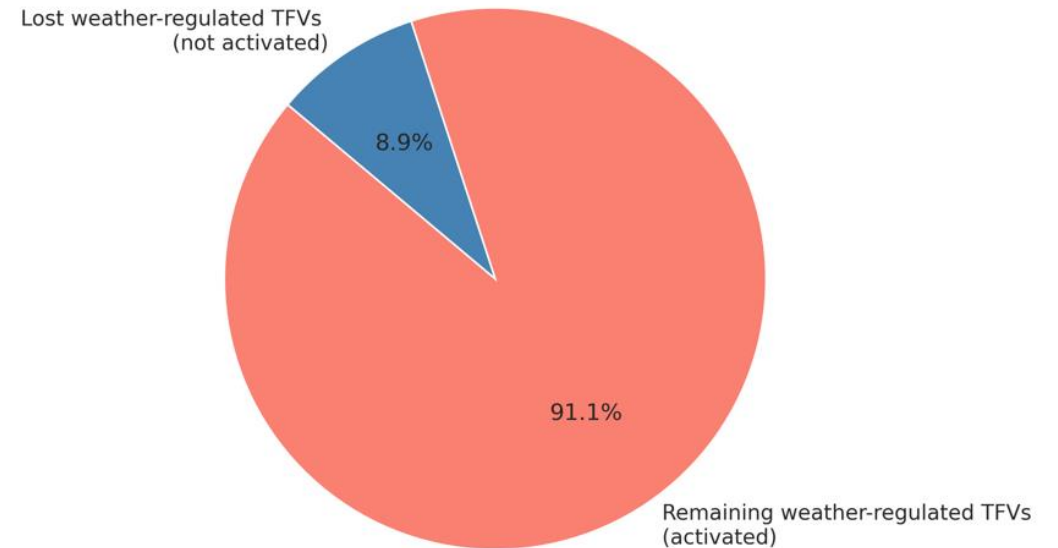


- Forecasts every 1h

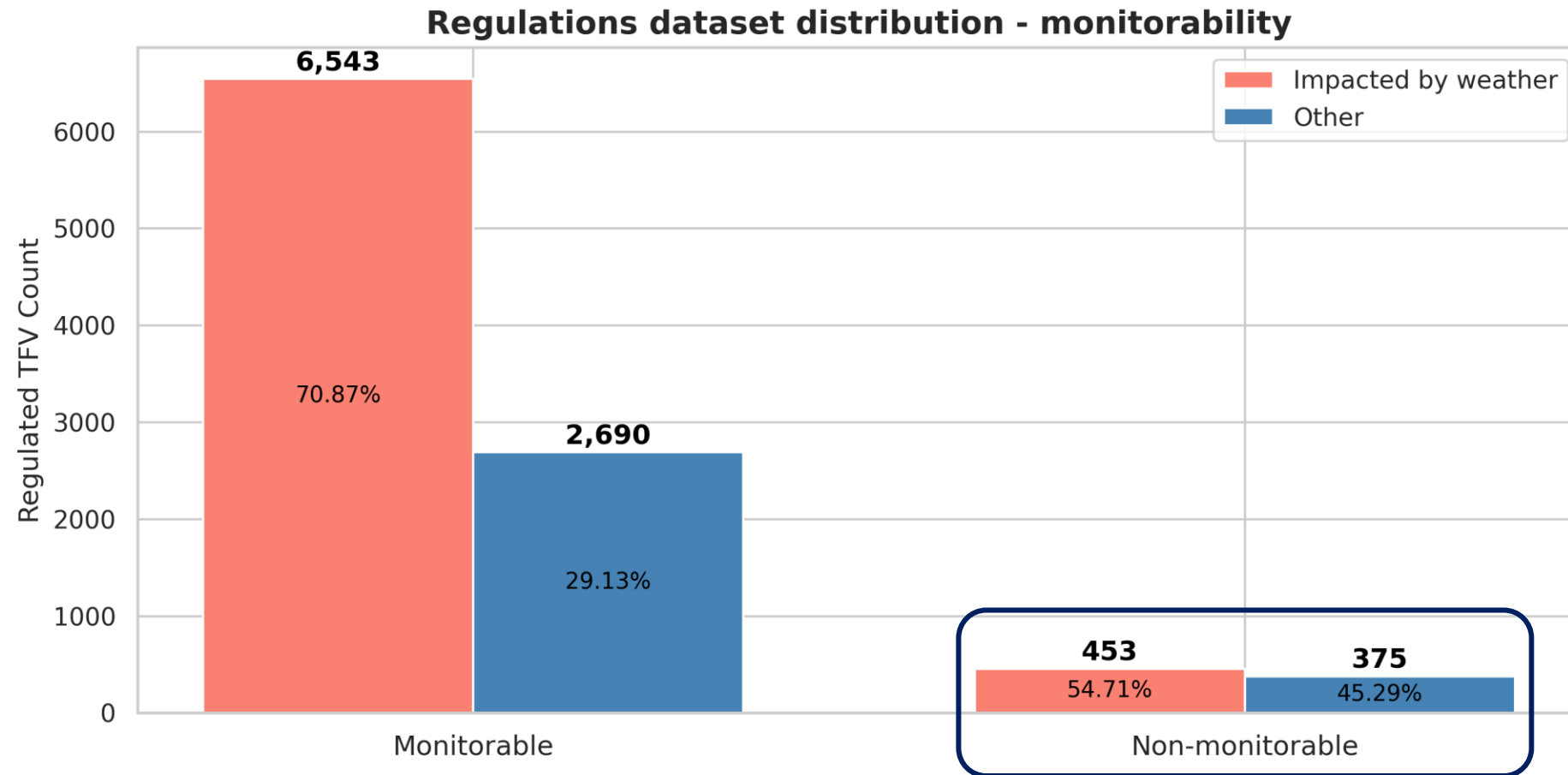


Traffic Volume Characteristics

- **Monitorable/non-monitorable**
- **Activated/non-activated**
- NMOC (stakeholders) insights:
 - “A regulated TV is activated in 90% of the cases”
 - NMOC staff only work with activated TVs
- Idea: Filtering out non-activated TVs will significantly reduce FP predictions!

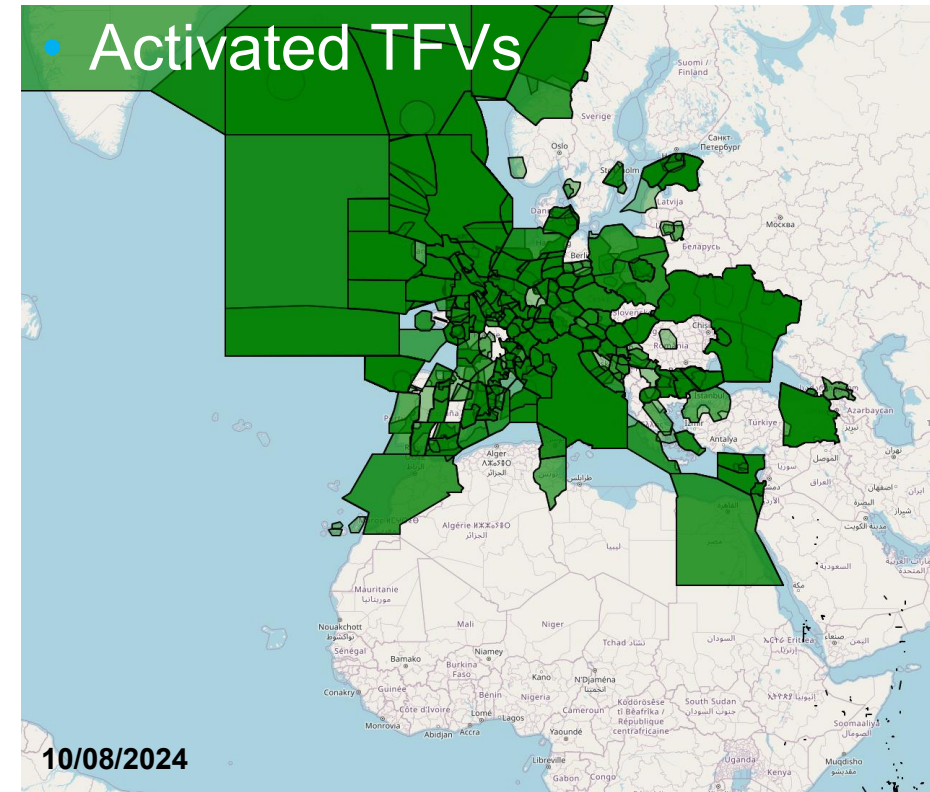
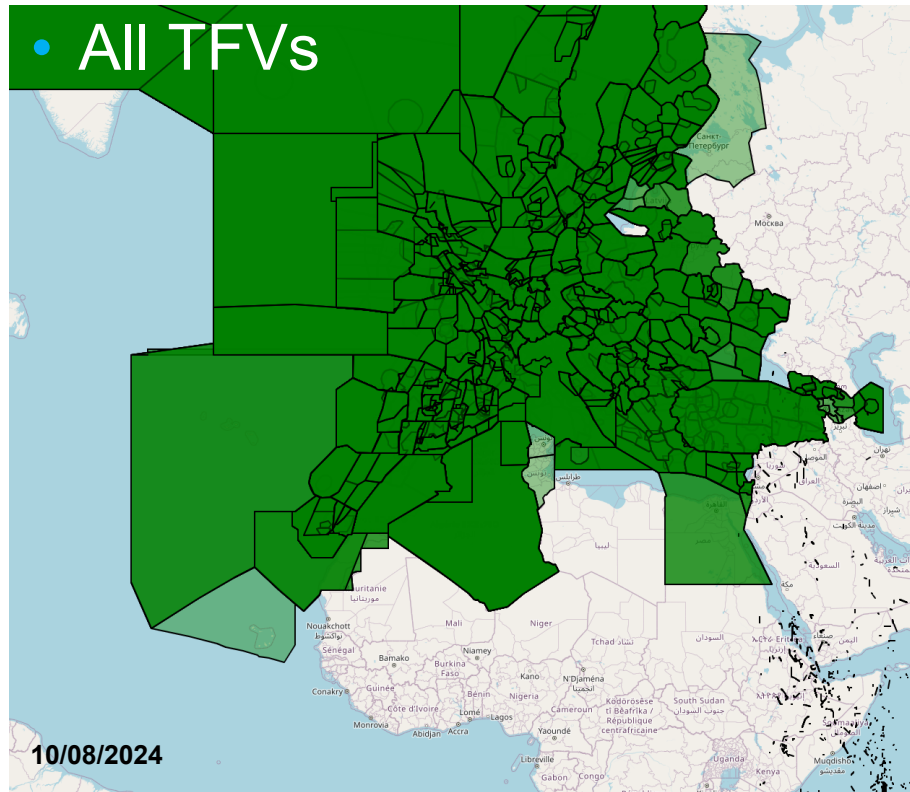


Traffic Volume Monitorability



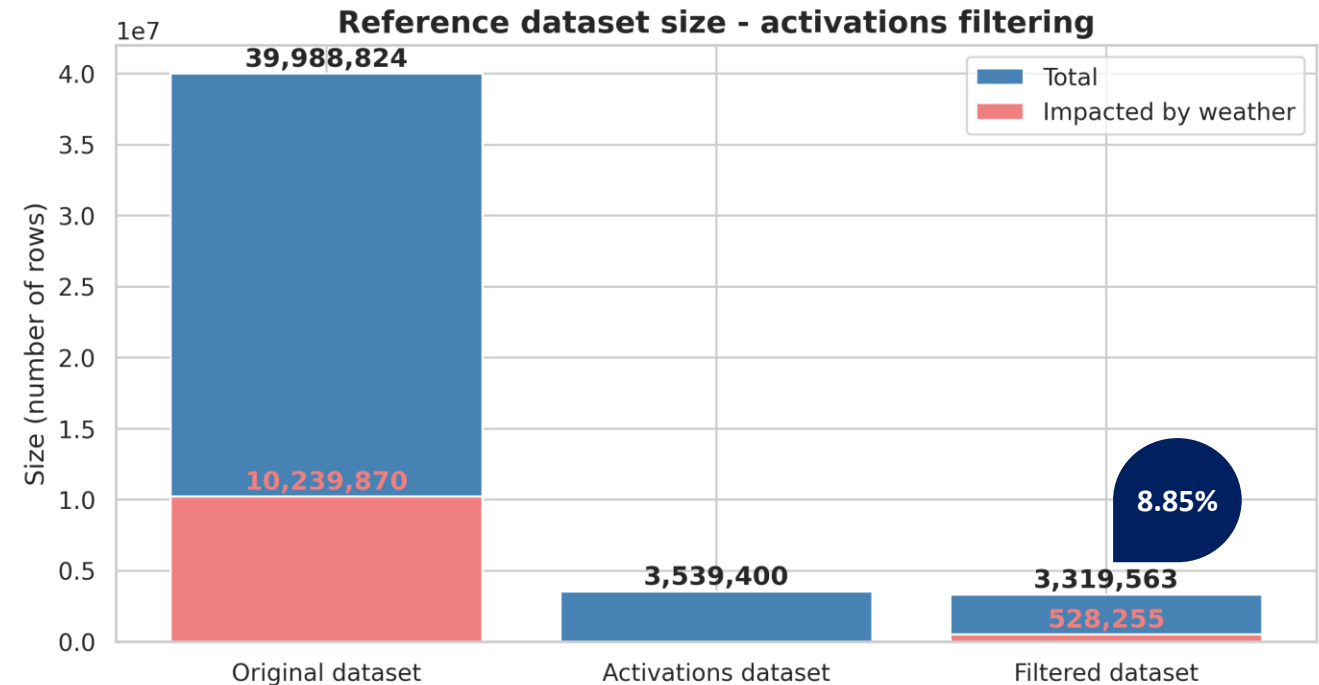
Traffic Volume Activations

- Training dataset impact – activations

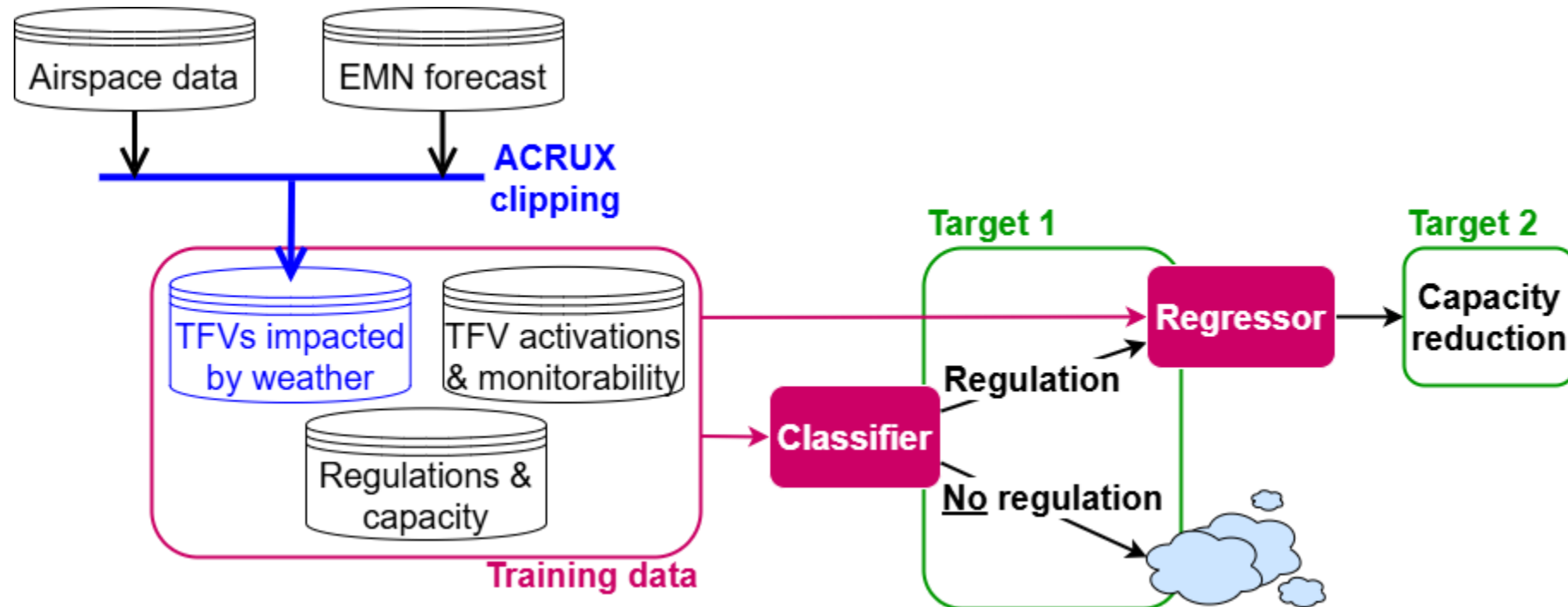


Traffic Volume Characteristics – Conclusions

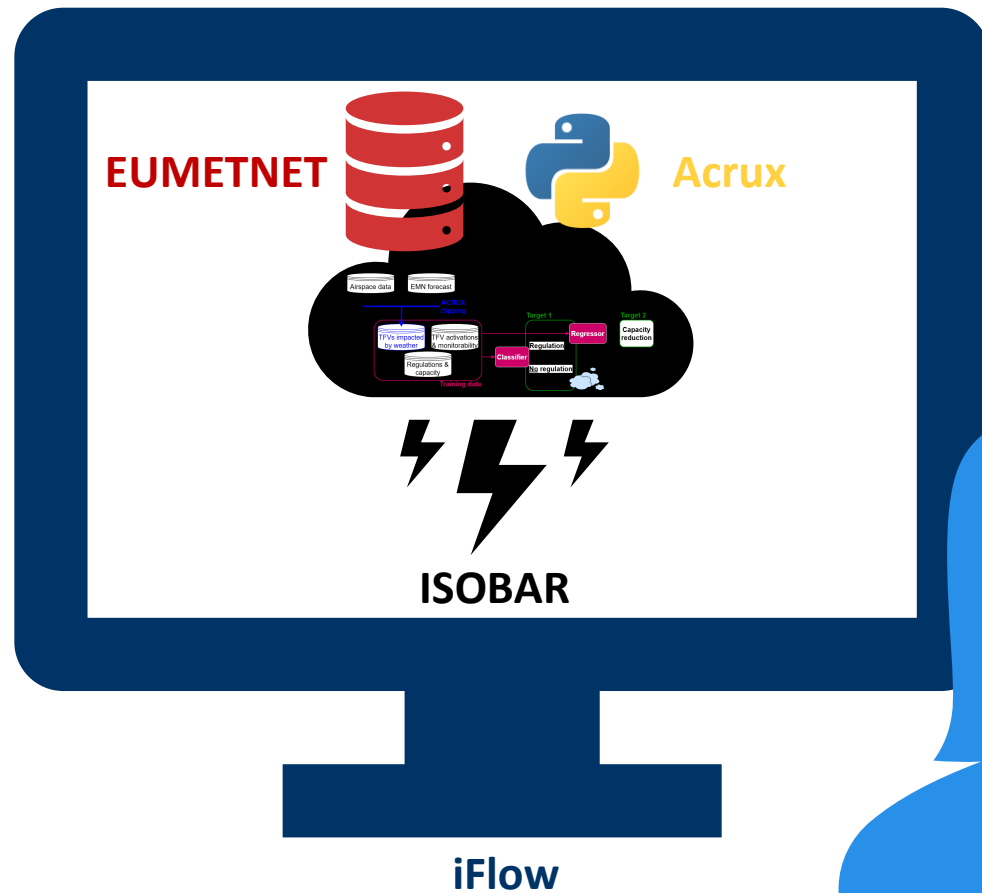
- Monitorability: feature
- Activations: filter
- ISOBAR 2023 & 2024:
 - Monitorable TVs
 - Activated & non-activated TVs
- ISOBAR 2025:
 - Monitorable & non-monitorable TVs
 - Activated TVs



Model Architecture



Model Ecosystem



- Many actors involved:
 - External data sources (APIs)
 - Library dependencies
 - Platform deployment
 - *Operational* stakeholders





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Results ISOBAR 2025 Focus



ML Algorithms Selection

- Classifier:

Model	Accuracy	Precision	Recall	PR-AUC	F1	MCC	TT (s)
XGB	0.976	0.864	0.593	0.532	0.702	0.704	7.442
RF	0.974	0.832	0.566	0.492	0.673	0.673	9.922
ADA	0.972	0.881	0.467	0.437	0.609	0.629	3.635
SVM	0.972	0.912	0.450	0.437	0.602	0.629	0.326
LR	0.971	0.917	0.437	0.428	0.591	0.622	3.914

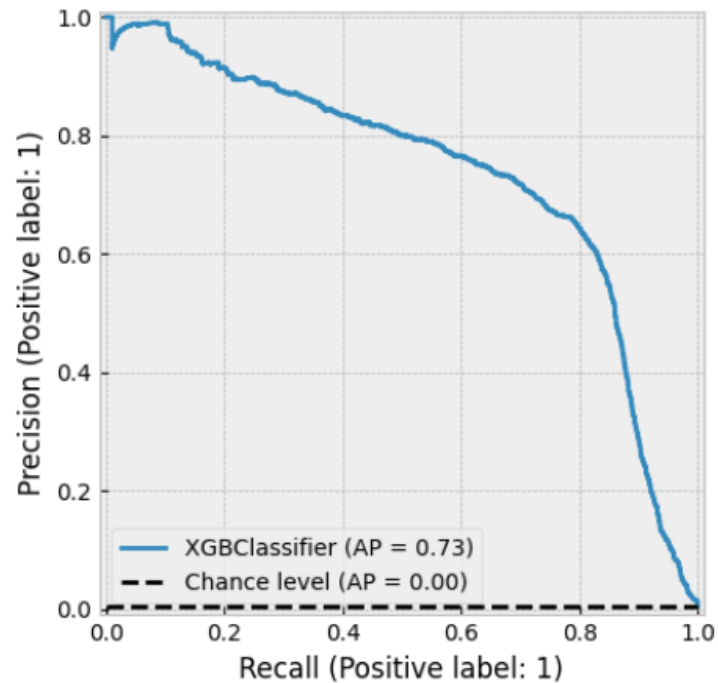
- Regressor:

Model	MAE	MAPE	RMSE	R2-score	TT (s)
XGB	0.471	0.687	1.624	0.518	6.304
RF	0.347	0.697	1.656	0.495	30.233
LR	0.695	0.873	1.938	0.315	0.213
Ridge	0.695	0.872	1.938	0.315	0.156
Lasso	0.854	0.919	2.340	-0.0006	3.660

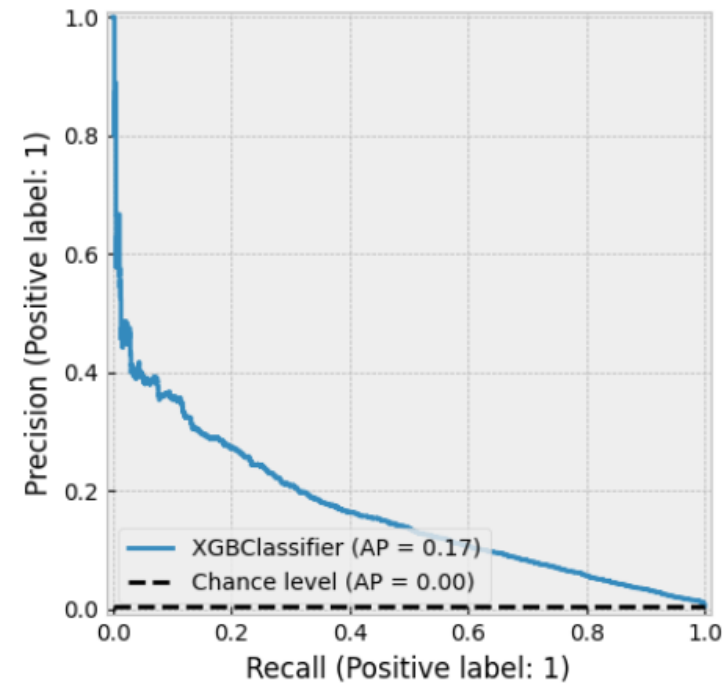
Model Performance – Prediction Horizon

- PR-AUC:

- Tactical (D0) = 0.733

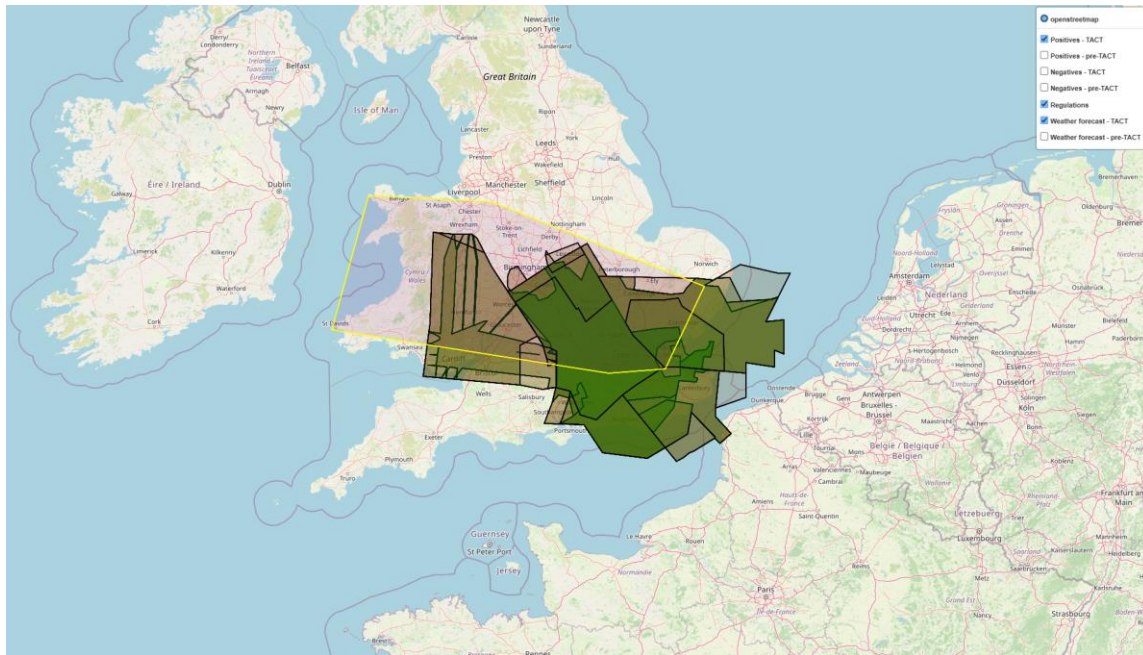


- Pre-tactical (D-1) = 0.167

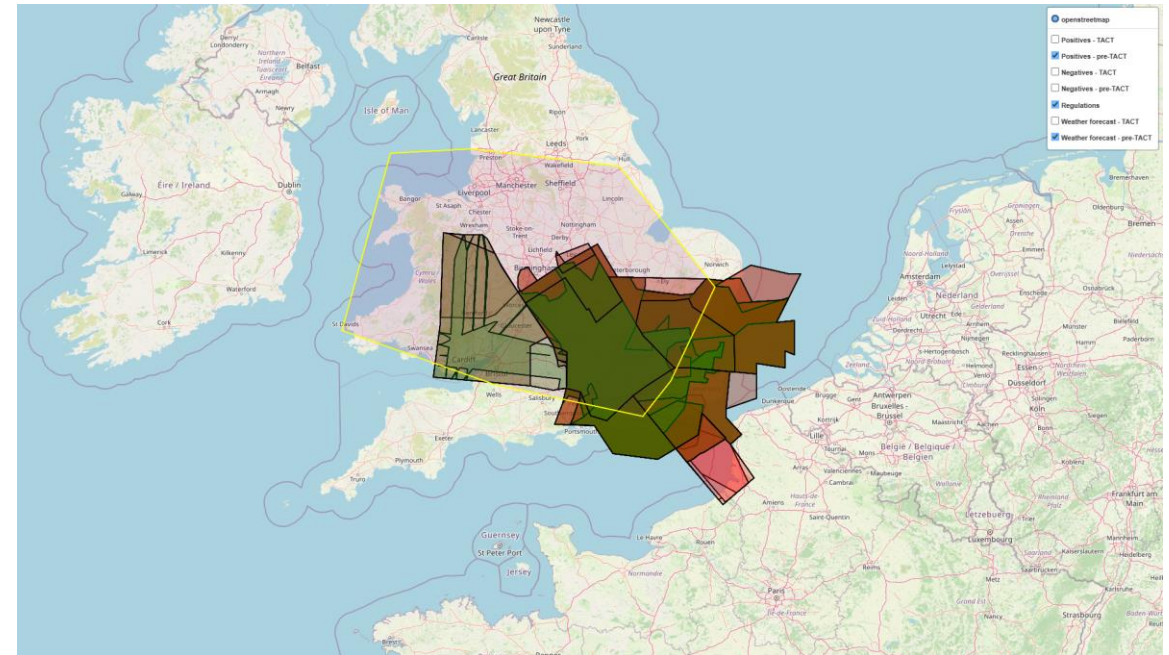


Model Performance – Prediction Horizon

- Mapping:
 - Tactical (D0)



- Pre-tactical (D-1)

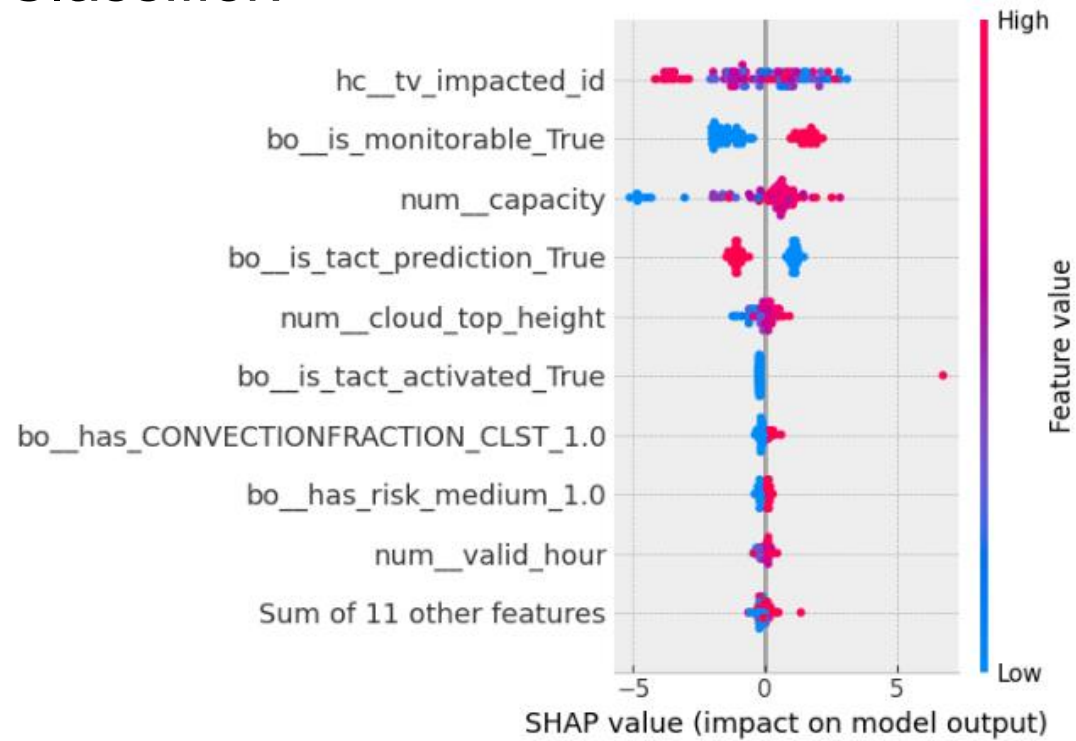


Feature Importance

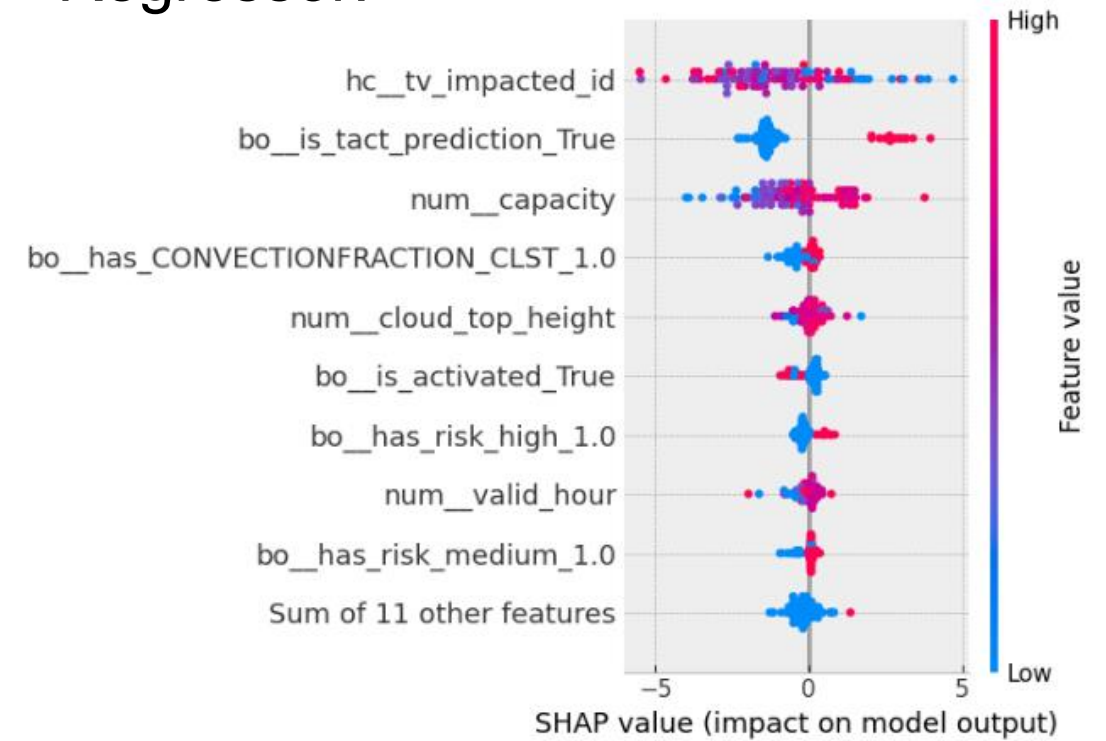
Sub-model	Feature	Weight (F-score)
Classifier	tv_impacted_id	7825.0
	capacity	5930.0
	cloud_top_height	3305.0
	valid_hour	1488.0
	has_CONVECTIONFRACTION_CLST	563.0
Regressor	tv_impacted_id	1528.0
	capacity	877.0
	cloud_top_height	869.0
	valid_hour	489.0
	is_activated	215.0

SHAP Analysis

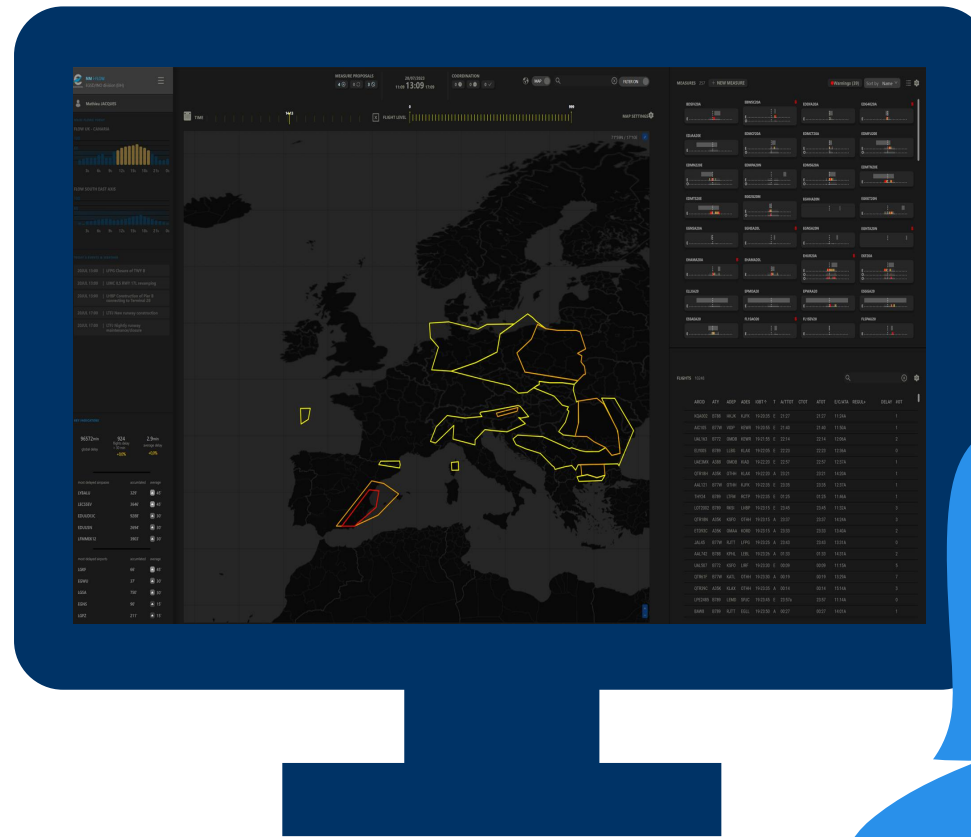
- Classifier:



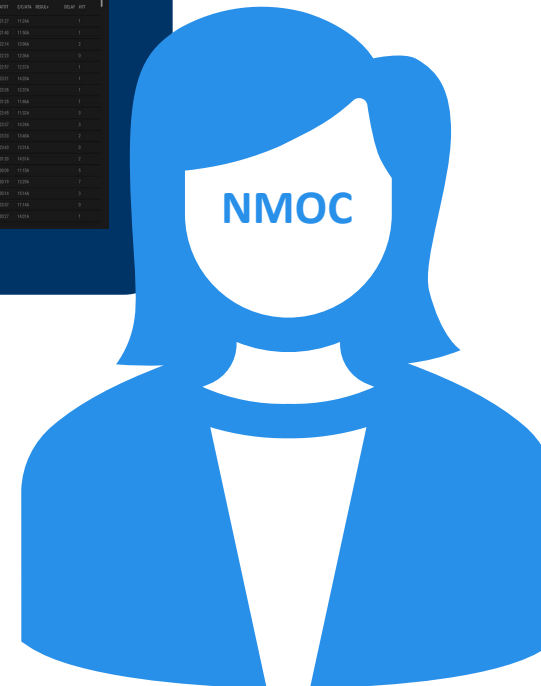
- Regressor:



ISOBAR & iFlow Integration



iFlow



TV:EDG2BL07

TV:EDG5PFA

TYEDMAN, S.

TECHNICAL

TV:EDMC52

[Show details \(graph\)](#)

Add to selection



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Thank you!

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