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Title (required)

Towards Characterising Weather-Driven Disturbances in European Air Transport for Operational Performance Monitoring

Synopsis (required)

Weather extremes increasingly drive delay, cancellation, and capacity shortfalls in European air transport, yet performance monitoring often reports outcomes without attributing them to specific meteorological causes or quantifying network propagation. This work proposes an initial, use case driven framework to detect operational disturbances, map them to relevant weather perturbations, and rank their local and network impacts.We propose a data-driven framework to detect operational disturbances and map them to specific weather perturbations, complementing existing operationall performance monitoring. By employing a use-case-driven approach across a set of distinct scenarios—including congested central European airspace and major hub operations—we identify critical monitoring parameters and develop a ranking mechanism for assessing performance impacts. The preliminary results demonstrate the framework's potential to quantify local versus network-level disturbances, establish a shortlist of essential monitoring indicators, an impact severity score, and guidance for integrating weather attribution into operational performance monitoring and resilience assessment for European stakeholders.

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Extended abstract (required)

Motivation and problem scope: Weather remains a primary driver of variability in operational performance of air traffic management (ATM), with climate change increasing the frequency and intensity of adverse weather events. Recent incidents, such as the significant operational disruption caused by snow at Amsterdam Schiphol, have underscored the critical need for a robust framework to understand and quantify the impact of meteorological events on system resilience. While existing operational performance frameworks provide excellent data on delays and throughput, they often fail to isolate the specific contribution of weather perturbations or distinguish between local and systemic effects. This research aims to bridge this gap by establishing a detection mechanism that links observed performance disturbances to their meteorological triggers, with a specific focus on the European context where complex airspace structures and high traffic density exacerbate the effects of adverse weather.

Background, research motivation, and expected results: To address the limitations of purely correlation-based studies and the complexity of full-scale simulation, we adopt a data-driven use-case analysis approach. We deliberately avoid machine learning methods in favour of a transparent, rule-based, and statistical analysis of historical performance data. The core of our approach involves defining a set of disturbance detection parameters—such as delay propagation rates, capacity utilisation deviations, and route-level deviations—and cross-referencing these with meteorological datasets. This allows us to construct a mapping mechanism that categorises disturbances not just by magnitude, but by their origin (e.g., low visibility, wind shear, snow accumulation) and their propagation potential (local vs. network). The goal is to identify a minimal set of monitoring parameters that can serve as early indicators of weather-induced performance degradation, ensuring the framework remains interpretable for operational stakeholders.

Method and approach: This work proposes an initial framework that combines disturbance detection, weather-perturbation mapping, and impact ranking using routinely available data. First, baseline “expected operations” are constructed for each airport or airspace element using historical distributions conditioned on season, day of week, and schedule structure. Disturbances are detected as statistically significant deviations in key operational time series (e.g., movement throughput, ATFM regulation rates, cancellation ratios, taxi-out, airborne holding, and reroute incidence) using robust anomaly and change-point techniques, yielding an event window with onset, peak, and recovery. Second, each detected event is mapped to one or more weather perturbation classes using a compact taxonomy. Weather indicators are extracted from regulary aviation observations (e.g. METAR/SPECI) and gridded products (e.g. reanalysis, nowcasting fields) within defined spatial buffers around airports or sector polygons. A transparent rule-based attribution score combines temporal alignment, spatial proximity, and an operational “signature” expected for each hazard (for example, snow/icing aligning with cancellations and turnaround extension; convection aligning with en-route regulations and systematic reroutes). Third, a multi-criteria severity score ranks events by local and network impact, combining magnitude (lost movements or capacity, delay minutes, cancellations), duration, spatial extent, and propagation beyond the focal node.

Experimental work: This preliminary study applies the proposed framework to a set of European use cases chosen to span airport-centric and airspace-centric disruptions. For each use case, an “event dossier” is generated containing the detected disturbance window, attributed weather driver(s), operational measures visible in the data (e.g., regulations, reroute patterns), and a harmonised set of performance indicators at both local and network levels. Sensitivity checks vary detection thresholds and attribution windows; qualitative triangulation uses contemporaneous operational and meteorological reports.

Contribution: The expected outcome is a practical, auditable monitoring concept that complements existing performance reporting with weather-specific attribution and resilience-oriented interpretation. Deliverables include (i) a shortlist of monitoring parameters that are broadly available and interpretable by airports, ANSPs, and network managers; (ii) a consistent taxonomy and attribution logic suitable for automated event tagging; and (iii) an event severity ranking that can to distinguish “high local, low network” disturbances from “moderate local, high network” disturbances. Preliminary pilot runs on the basis of use cases intended as a first step towards systematic monitoring of weather related climate impacts on European air transport operations and supports future extension to larger event sets and climate-trend analyses.

Desired presentation type (required)

oral

Is student work? (required)

no

Originating domain (required)

academic

- [ ] industrial

agency

- [ ] other

Primary field of interest (required)

Air Traffic Management (ATM)

Secondary field of interest (required)

Communications, Navigation, and Surveillance and Information Networks