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Building network resilience to capacity bottlenecks, growing adverse weather impacts and instability: the CWBO story

Severe convective weather – a growing network problem

In Summer 2025[1] the European aviation network finally recovered to exceed pre-COVID summer flight levels, and traffic in Summer 2026 proved to be 2.4% higher year-on-year, with further growth predicted over the coming years.

To cope with busy traffic, the network – and the millions of people travelling across Europe by air every day, on over 37,500 flights on the busiest of summer days – rely on a smoothly functioning system in which EUROCONTROL, as the Network Manager (NM), coordinates air traffic flows across Europe from its NMOC, the Network Manager Operations Centre. However, across the network, staff shortages, industrial action, technical issues and adverse weather can quickly lead to flight delays and cancellations that spread from one country to another.

Of these, severe convective weather has become an increasing challenge, as Figure 1 shows:

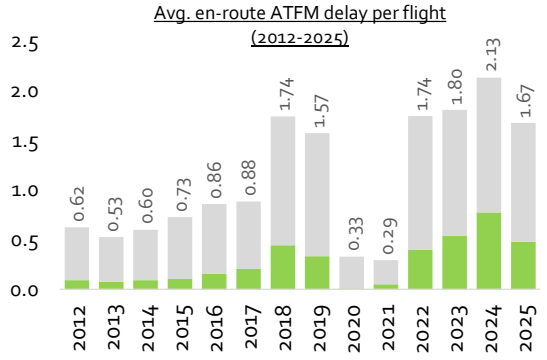

Figure 1: En-route ATFM delays attributed to weather (full year)

By 2024, the share of weather in average en-route air traffic flow management (ATFM) delays had risen notably comparing pre- to post-COVID, to reach an all-time high, a 47% increase on Summer 2023. Within the busy summer 2024 period, there were 32 'high delay' days in the network (defined as ones that alone generated over 200K minutes of delay). And on 14 of these days, more than 150K minutes of delay were attributed to severe convective weather, compared to eight days in Summer 2023. In total, around 15% of the Summer 2024 period saw operations in the network disrupted specifically by adverse weather conditions, and the share of en-route ATFM delay attributed to weather had increased to 43% of the total en-route delays, making it the largest delay category after ATC capacity constraints.

Figure 2 provides a breakdown of daily en-route ATFM delays in 2024. Each data point represents a single day. The x-axis shows the proportion of flights affected by en-route ATFM delay, while the y-axis shows the average en-route ATFM delay per delayed flight. Green data points indicate days on which weather-related delays accounted for more than 40% of the total en-route ATFM delay.

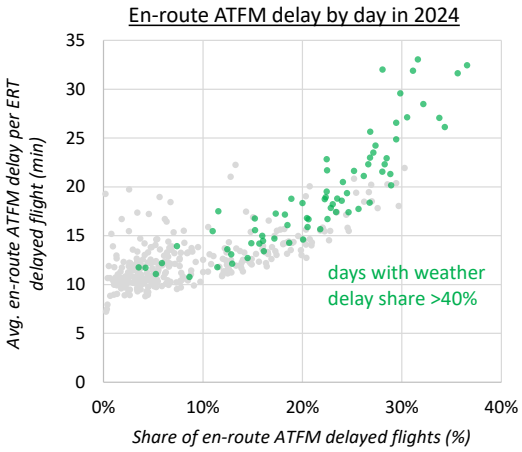

Figure 2: Daily En-route ATFM delay distribution (2024)

The figure clearly shows that days with a high proportion of weather-related delays not only affect a larger share of

[1] 'Summer' is defined in this paper as 1 June-31 August in all cases.

flights, but are also associated with substantially higher average delays per delayed flight.

Combined with existing capacity issues, the impact on operations in 2024 was exponential, and highlighted the pressing need to move forward on mitigating measures. Following several years of high ATFM delay, NM presented five priority areas for network operations in Spring 2025 (see Figure 3), with a particular focus on improving summer performance, introducing for the first time an Adverse Weather Management objective at network level.

Figure 3: Summer 2025 'think Network' objectives

Taking a network view: the best way to address convective weather and capacity bottlenecks

To deliver on this new objective, NM worked between Autumn 2024 and Summer 2025 in close partnership with all operational stakeholders, following the established collaborative decision-making (CDM) approach with States, air navigation service providers (ANSPs), airports and airspace users on what would become a new procedure entitled Capacity and Weather Based Operations (CWBO), which would be applied between 1 May and 15 October. CWBO was expressly designed to tackle the growing problem of capacity and weather constraints, with closer cooperation with meteorological forecasters and ANSPs, improved forecasting, and a stronger regional and network-level approach to operational decision-making. All parties recognised that managing adverse weather from a network perspective could deliver significant advantages, given that storm systems can extend across several area control centre (ACC) boundaries, evolve rapidly, and create interdependent capacity constraints that cannot be addressed effectively by individual ACCs in isolation.

Figure 4 below shows one such major delay day in 2024, the convective weather systems that developed over Europe on 21 and 22 May 2024.

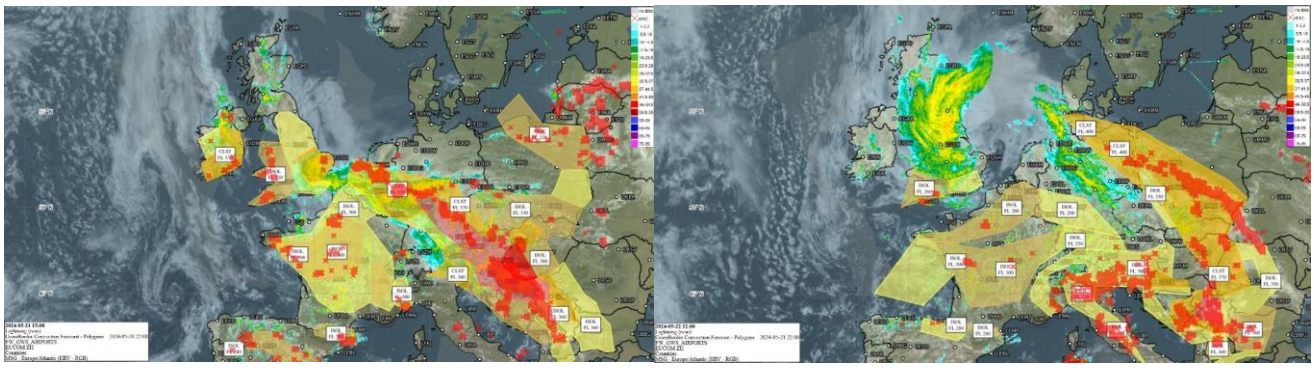

Figure 4: Convective system over Europe 21-22 May 2024

A local ACC perspective is largely limited to tactical adjustments within its own airspace. While such measures may be necessary, they can also result in uncoordinated reroutings, uneven sector loading and secondary impacts on adjacent units. Taking a network-level approach, on the other hand, would enable earlier collaborative decision-making and more effective demand-capacity balancing across the affected region, supporting more efficient use of available airspace capacity, and reducing the risk of disruptions spreading across the network.

2025: CWBO helps significantly mitigate capacity and weather impacts

CWBO was designed to combine meteorological forecasts, real-time updates and expected traffic demand to identify emerging capacity shortfalls, particularly those caused by convective weather affecting en-route operations. It relies on close coordination between the NMOC and ANSPs, airports, airlines and meteorological service providers, and is used by the NMOC to manage air traffic flows in predefined circumstances – due to severe convective weather, turbulence, staff shortages or congestion in certain parts of Europe.

Figure 5 below shows CWBO in practice, with the NMOC triggering the rerouting of flights out of airspaces that are impacted by severe weather or capacity shortfalls on the day before operations. This selection is reviewed on the day of operations based on the latest information available, always looking to optimise any demand-capacity balance.

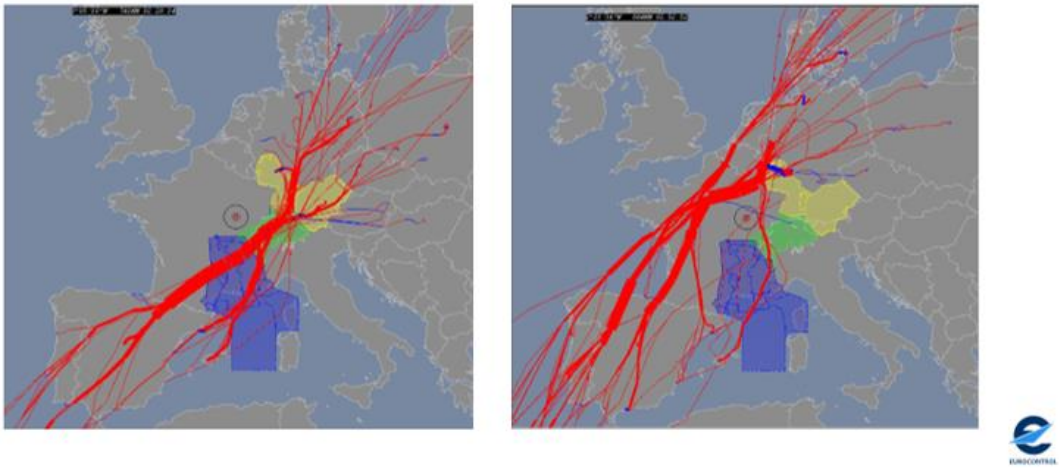

Figure 5: Rerouting traffic flows from constrained areas

First introduced in Summer 2025, CWBO proved immediately effective in reducing network instability and unpredictability during disruptive days by:

- limiting last minute changes
- preventing delays from spreading across Europe
- helping airlines and airports plan more reliably.

When demand is expected to exceed capacity beyond predefined thresholds, CWBO applies a trigger system, with three triggers introduced to initiate this procedure:

- Trigger 1 → Manage severe weather
- Trigger 2 → Manage significant weather accompanied by capacity reductions in the area
- Trigger 3 → Manage capacity shortages in a coordinated way.

T1 and T2 indicate a developing or anticipated imbalance and initiate enhanced monitoring, stakeholder coordination and preliminary flow-management planning, depending on forecast confidence and proximity to real-time operations.

T3 reflects a confirmed and more significant impact scenario, where a capacity or staffing shortfall is imminent and a coordinated rerouting of specific flows will avoid high delays and volatility on the day of operation.

In combination, the application of the three CWBO triggers by the NMOC together with other operational actors proved effective in saving almost 900,000 minutes of delay[2]

[2] Delay savings generated by CWBO for the network are calculated taking into account the en-route regulations that have been offloaded by the CWBO reroutings, and the delay reduction in all other flights in each of these regulations thanks to the freed-up slot. When a congested area is offloaded by one flight that is rerouted out of this area, this reduces the delay for all other flights that are still routing via the area due to lack of options. This is

in 2025 – but also revealed limitations in managing instances of major network instability (defined as days in which total delays exceeded 80,000 minutes). In such cases, airlines reroute hundreds of flights simultaneously, exacerbating an already highly volatile situation.

Assuming an average ATFM delay cost of €130 per minute, those 900K minutes of delay saved corresponded to a cumulative economic benefit of approximately €117 million[3].

2026: An additional CWBO trigger to manage network instability on top of tackling capacity bottlenecks and adverse weather

NM's analysis of Summer 2025 operations showed the need to pay additional attention to when certain ATFM delay thresholds are exceeded, as these cause network instability, and make recovery to normal network operations significantly more difficult. In such instances, the overloading of one airspace typically sees aircraft seek to reroute to adjacent areas that have capacity – but which can themselves be quickly overwhelmed as well by unexpected demand. This creates a snowball effect whereby delays increase rapidly, flights are cancelled, passengers miss connections, and airports become increasingly congested.

To address this, for 2026 a new trigger was added to the CWBO framework:

- Trigger 4 → Take rapid same-day interventions when delays in a specific airspace become critical, or when total European ATFM delay approaches the defined critical instability threshold of 80K minutes of delay in the network or 20K minutes of delay in a single ACC.

T4 is a last-resort measure allowing the NMOC to apply a targeted rerouting of selected flights to rebalance demand and capacity, with the priority shifting from local optimisation to preserving network stability.

Overall, the CWBO triggers provide a mechanism that supports timely, proportionate and coordinated responses to weather and capacity constraints, helping limit the propagation of local disruptions into wider network congestion.

It is important to highlight that the CWBO initiative depends strongly on close collaboration with affected ANSPs that are willing to accommodate additional traffic, coordinated by the NMOC which acts as an impartial broker among all stakeholders.

Over 2026, 'extended CWBO' has proven extremely valuable. Compared to the 900K delay minutes avoided in 2025, 2026 has seen over three times that amount saved to date, with the total delay saving calculated at around 3.1M minutes from the start of the procedure on 1 May until the end of August, 1M of which were attributable to the capacity (T3) and new stability (T4) measures[4]. This increase was made possible thanks to greater buy-in from operational stakeholders before the start of the summer, which reduced the need for one-to-one coordination once the NMOC had seen a need to reroute flights.

The overall impact of CWBO in 2026 has clearly played a major part in reducing network instability and operational unpredictability during disruptive periods, limiting late operational changes, preventing the propagation of delays across the European network, and enabling more robust planning for airlines and airports. Taking again that average ATFM delay cost of €130 per minute, those 3.1M delay minutes over the course of May-August 2026 have saved over €400 million so far for all actors.

measured through the delay improvements thanks to the free slots that were previously occupied by the CWBO-rerouted flights for all regulations that are offloaded.

[3] Estimated cost savings are calculated by multiplying CWBO delay savings by the estimated network average ATFM delay cost (€130 per minute in 2025). The value is based on the University of Westminster study "European airline delay cost reference values" and is adjusted annually using the EU27 average inflation rate. The study covers direct airline delay costs, including crew, fuel, maintenance, fleet utilisation, passenger assistance, and reactionary network effects. The network average should be treated as an indicative reference only, as delay costs can vary significantly depending on aircraft characteristics, route type, airline operations, and delay duration. For further details, see Section 16 of EUROCONTROL Standard Inputs for Economic Analyses.

[4] In calculating improved network stability, NM estimates the delay saving in each regulation, the airline behaviour in rerouting out of each regulated airspace to avoid delays, and the proportion of flights that airlines would otherwise have rerouted due to delay.

Limitations to tackle: The speed of CDM, and forecasting challenges

Despite having delivered substantial improvements, CWBO does however have its limitations. Under the umbrella of the SES performance targets, ACCs are naturally highly focused on local problems and targets, and these sometimes do not align with taking a network perspective. NM's longstanding 'think Network' campaign has, with increasing success, argued the benefits of taking a network view as much as possible – and indeed, CWBO delay reattribution between supporting ANSPs and supported ANSPs has certainly alleviated this dilemma to some extent. However, with CDM as the basis of NM's interaction with its stakeholders, and hence also for NMOC's use of CWBO, pre-agreed CDM to accelerate tactical coordination in case of capacity issues is only accepted by some ANSPs – while others wish to be contacted for each new case, which does delay the speed of a positive response.

A good illustration of this was the recent response to wildfires in France in July 2026. Although fires had been raging for quite some time near Bordeaux, eventually forcing some operational staff at Bordeaux ACC to be evacuated and posing an imminent risk to the data processing centre serving all French ACCs, collective CDM in this instance still took over three days. In the meantime, the NMOC deployed all other possible means to support Bordeaux operations, and offloaded the area with high workload in daily coordination.

Another limitation is that of forecasting, although here CWBO has made notable advances. Prior to the introduction of CWBO, a major constraint was the absence of a harmonised network-wide meteorological forecast followed by all actors. Although EUMETNET's Cross-Border Convection Forecast (CBCF) then and now provides useful support, it requires manual processing, thus posing significant resource limitations for many actors, and is moreover based on the aggregation of national forecasts that are produced using different forecasting parameters. Within the CWBO framework, however, progress has been made thanks to NMOC's network-level meteorological expertise. NMOC MET specialists have bridged this gap by interpreting and consolidating these forecasts through a network-centric lens, providing operational stakeholders with a consistent and actionable assessment of expected weather impacts, and supporting more effective decision-making.

While some reroutings to avoid convective weather areas and capacity bottlenecks have seemingly added to fuel burn, this was observed to be less than fixed summer routings (Seasonal RADs) for capacity reasons, or the ad hoc reroutings airlines make when avoiding weather or delays. Since stability has also improved, the reduction in mass reroutings has resulted in better route length management overall.

CWBO, looking forward

In addition to delivering significant operational benefits and strengthening network-centred management of capacity and weather impacts, CWBO has also proven to be an effective platform information exchange enabling active tactical collaboration between the NMOC and operational stakeholders. Thanks to network-level meteorological expertise and agile reporting interfaces supporting pre-tactical, tactical and post-operational coordination and data-driven decision-making, CWBO has improved the speed and efficiency of NMOC and ACC workflows, while already deploying tools such as iFlow, which has been developed as part of the future iNM (integrated Network Management) suite.

Overall, the application of CWBO is having a significant positive effect on the network, along with the six other objectives in NM's 2026 edition of its 'think Network' campaign (see Figure 6 below), which once again urges all operational stakeholders to aim to take a network view in their decision-making.

Figure 6: Summer 2026 'think Network' objectives

Since CWBO was first deployed in 2025, a cumulative total of around 4M minutes of delay have been saved, and stability in the network has been improved by 14% on more challenging days with weather and capacity bottlenecks; this has had a notable effect on resilience, and reduced the number of flight cancellations compared to 2024. While convective weather remains inherently difficult to predict, improved forecasting, faster data integration, greater operational flexibility and continued commitment to coordinated network-level decision-making are all playing their role in mitigating delays better.

Conclusions

- The CWBO approach and its first three Triggers has strengthened the tactical resilience of the European aviation network faced with capacity bottlenecks and adverse weather by:
  - improving adaptability, responsiveness and decision-making
  - minimising uncontrolled mass reroutings
  - preventing reactionary delays.
- Thanks to the new Trigger 4, CWBO has also proven to be highly effective in tackling overall network instability, as demonstrated by the observed stability improvement (14% better on challenging days), as well as positive feedback from stakeholders.
- Discussions after the summer are now focusing on further improving network resilience by applying the current processes with enhanced stakeholder alignment which is designed to ease the coordination needed, in particular for exceptional circumstances such as the wildfires near Bordeaux ACC in July 2026.