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Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
Gilles Gawinowski / EUROCONTROL	Project Member	15-01-2021
Stephane Pierre / EUROCONTROL	Project Member	15-01-2021
Thierry Durigneux / DSNA	Project Member	15-01-2021
Daniel Delahaye / ENAC	Project Member	15-01-2021
Marta Sanchez / CRIDA	Project Coordinator	15-01-2021
Danlin Zheng / CRIDA	Project Member	15-01-2021
Marie Carre / Swiss	Project Member	15-01-2021
Jonathan Biedermann / Swiss	Project Member	15-01-2021
Aurelie Peuaud/SopraSteria	Project Member	15-01-2021
Manuel Soler/UC3M	Project Member	15-01-2021
Aniel Jardines/UC3M	Project Member	15-01-2021
Laure Raynaud/MeteoFrance	Project Member	15-01-2021
Lucie Rottner/MeteoFrance	Project Member	15-01-2021
Yan Xu/University of Cranfield	Project Member	15-01-2021
Florenci Rey/EarthNetworks	Project Member	15-01-2021
Ahmed Khassiba/ENAC	Project Member	15-01-2021

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Thierry Durigneux / DSNA	Project Member	05-03-2021
Daniel Delahaye / ENAC	Project Member	05-03-2021
Marta Sanchez / CRIDA	Project Coordinator	05-03-2021
Danlin Zheng / CRIDA	Project Member	05-03-2021
Marie Carre / Swiss	Project Member	05-03-2021
Jonathan Biedermann / Swiss	Project Member	05-03-2021
Aurelie Peuaud/SopraSteria	Project Member	05-03-2021
Manuel Soler/UC3M	Project Member	05-03-2021
Aniel Jardines/UC3M	Project Member	05-03-2021
Laure Raynaud/MeteoFrance	Project Member	05-03-2021
Lucie Rottner/MeteoFrance	Project Member	05-03-2021
Yan Xu/University of Cranfield	Project Member	05-03-2021

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Florenci Rey/EarthNetworks	Project Member	05-03-2021

Approved for submission to the SJU By - Representatives of all beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Elodie Bastié / DSNA	Project Member	18-03-2021
Gilles Gawinowski / EUROCONTROL	Project Member	16-03-2021
Ahmed Khassiba / ENAC	Project Member	18-03-2021
Marta Sanchez / CRIDA	Project Coordinator	15-03-2021
Juan Simarro/ AEMET	Project Member	16-03-2021
Jonathan Biedermann / Swiss	Project Member	17-03-2021
Aurelie Peuaud/SopraSteria	Project Member	18-03-2021
Manuel Soler/UC3M	Project Member	17-03-2021
Laure Raynaud/MeteoFrance	Project Member	17-03-2021
Yan Xu/University of Cranfield	Project Member	18-03-2021
Florenci Rey/EarthNetworks	Project Member	18-03-2021

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

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ISOBAR

ARTIFICIAL INTELLIGENCE SOLUTIONS TO METEO-BASED DCB IMBALANCES FOR NETWORK OPERATIONS PLANNING

This document is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 891965 under European Union's Horizon 2020 research and innovation programme.

Abstract

The current edition of this document corresponds to the intermediate OSED of ISOBAR and describes:

- The detailed operational environment (§3.2);
- The detailed operating methods (§3.3);
- The list of operational requirements (§4);
- The detailed B2B service and associated requirements (§5);

of new concept of ISOBAR.

The major objectives of the ISOBAR concept are:

- An enhanced and harmonised storm forecast tailored to ATFCM needs;
- Probabilistic characterization of DCB imbalances;
- Demand prediction taking into account AU needs and reaction to weather forecasts;
- Automated DCB Solver;
- AI-based DCB solutions.

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1 Executive Summary

The major objective of the ISOBAR concept aims at developing Artificial Intelligence solutions to meteo-based DCB imbalances, in order to improve the network performance to achieve mutual benefits within a philosophy of Collaborative Decision Making.

Network prediction and performance is very sensitive to weather and the uncertainty in its prediction. In addition, current ATFCM operations are not evaluated from a systematic perspective. These two factors together lead to a strong dependency on the experience of human operators. ISOBAR addresses these challenges through the contribution to an Artificial Intelligence (AI)-based Network Operations Plan, by including in its scope an enhanced weather prediction tailored to ATFCM, ATM and weather data integration, demand and capacity imbalance characterisation and imbalance mitigation prescription.

ISOBAR will focus on elements to prevent and deconflict chaotic situation on Pre-Tactical D-1 phase and continuous plan re-adjustment on D-0. Decision-making will be triggered on High or Very High Convective Area Risk prediction on D-1 and a Collaborative Process from D-1 to D-0 with a continuous reassessment and refinement taking advantages of digitalisation of the support tools.

Summing up, the project aims at integrating enhanced convective weather forecasts in order to predict imbalances between capacity and demand as well as employing AI to prescribe mitigation measures at local and network level.

To achieve this vision, four objectives are set:

1. Reinforce ATFCM processes with probabilistic weather Information

   To enhance ATFCM process at pre-tactical and tactical levels (-24h up to execution, with a focus on later tactical phase, closer to execution time) by integrating adaptive scenarios into the local traffic manager (local) and network management (network) roles within the demand and capacity balancing function due to convective weather cells.

2. Characterisation of Demand and Capacity Imbalances due to convective weather

   Precise characterisation of demand and capacity imbalances due to convective weather cells from pre-tactical level to tactical levels depending on the input of probabilistic forecasts of weather cells by using applied AI methods and ATM and weather data integration. It will be based on AI libraries capable of predicting probabilistic capacity decay values and provision of probabilistic demand variability associated to probabilistic forecasts of weather cells.

3. Produce an Hotspot Solver considering Airspace Users business needs

   Development of an automated engine that explore a weather scenario from the Playbook catalogue (defined and agreed at the strategical level by NM, ANSPs, AUs) and select combined DCB measures (flow rate, TFV regulation, re-routing, …) and flight candidates for solving convective weather-related demand and capacity imbalances, considering AUs preference and effectiveness of ATFCM measures, based on in-flight feedback and the post-analysis of the executed operations. It will be based on AI libraries capable of prescribing adaptive ATFCM actions considering AU preferences, where expected and actual impacts in terms of demand and capacity shall be measured via online simulations and post-analysis respectively. It is proposed to start a Catalogue of Routes generated using Historical Data, as a first step to test the benefits of the AI prescription, which will be improved by implementing virtuous processes, and thus customizing Routings by City pair and by AU. Then the system will learn progressively and will improve the Catalogue of Routes that would present more and more reliable options

4. A collaborative approach to manage convective weather operations

Contrary to nominal operation conditions, solving critical issues that have a wider impact on operations needs the design, the coordination and the implementation of network oriented DCB solutions.
The identification of areas where the operations degrade to critical state triggers a common solution involving all stakeholders to jointly support the network recovery. The solution allows identifying the most appropriate stakeholder(s) to drive the DCB solution design, local solution or network oriented.
ISOBAR project explores the process and the roles of partners when all collaboratively contribute to manage critical weather situations and the transition back to normal operations

2 Introduction

2.1 Purpose of the document

This document provides the requirements specification, covering functional, non-functional and interface requirements related to ISOBAR.

2.2 Scope

This is the OSED ISOBAR describing the concepts of AI solutions to meteo-based DCB Imbalances for network operation planning.

2.3 Intended readership

This document is aimed at the following stakeholders:

- The SJU and EUROCONTROL;
- The Cross-Border Weather Operation Initiative led by EUROCONTROL;
- The SJU SESAR PJ07, PJ09;
- AU, ANSP and MET representatives.

2.4 Background

The concept definition is built on:

- SESAR wave2 PJ09 Solution 49: This project defines the framework to manage critical situations including weather events in terms of procedure, process, roles & responsibilities, workflow.
- Cross-Border Weather Operation Initiative: This project aims to manage better adverse weather across the network with the cooperation of all the network's key players.

Solution 49 and Cross-Border weather operations provides interesting features for the weather problem detection & resolution. In particular, Solution 49 provides:

- Gate management/cross-border flow monitoring;
- Netspot/delineation of linked- hotspots;
- Formalization of the collaborative process.

Compared to the SESAR Solution 49 that has defined the Gate and Netspots principles, in ISOBAR the additional work will consist of:

- Identify and design the Gates to manage flows at the network level, to establish the capacity thresholds, and to assess the performance of this mechanism to monitor flow and apply flow rate.
- Assess the Netspot management in the collaborative process to manage convective weather situations.

Cross-Border weather operations provides:

- Operational requirements for meteo forecast;
- Principles for the resolution of weather operations illustrated with a concrete French Reims/Aix ACC scenario;
- Formalization of the collaborative process;
- Timeline/process.

ISOBAR will re-use and will adapt the Cross-Border procedure and process but will provide AI components to digitalize the process, detection and resolution of weather problems. Cross-Border requirements for meteo forecast will be re-used fully.

ISOBAR will re-use and will adapt the Solution 49 process and conceptual elements dealing with critical situation management but instantiated for weather operations management. In particular, the concept of Gate and Netspot has been started in Solution 49. Since this solution is going to be closed, the development continuation is now performed in-house in EUROCONTROL and in ISOBAR.

2.5 Structure of the document

This document is divided into 5 chapters:

- Chapter 1 gives a general description of the document structure and scope;
- Chapter 2 gives an introduction to the document;
- Chapter 3 gives a description of the operational concept; detailed operating method; description of the operational environment; description of the operational processes/use-cases;
- Chapter 4 gives a description of operational requirements; INTEROP (B2B services) requirements;
- Chapter 5 details the B2B service requirements, the interfaces and data flows between the AI components of the ISOBAR solution;
- Chapter 6 includes the references.

2.6 Glossary of terms

Term	Definition	Source of the definition
	The Coldspot represents a traffic volume with available capacity highlighted to explicitly absorb more traffic, in particular flight candidates for re-routing.	
	The identification of linked hotspots at network level rises the appearance of a Netspot. The geographical delineation of a Netspot is represented by a group of Traffic Volumes and/or Flows.	
Gate	A Gate is a vertical surface made of an ad hoc geographical line, perpendicular to the flow to be	SESAR W2 Solution 49

Term	Definition	Source of the definition
	captured, and a range of levels. For in-depth analysis, the network Gate can be divided into smaller surfaces to analyse sub-flows.	
Playbook	Catalogue of weather scenarios defined and agreed by NM, ANSPs and AUs at the strategical level	Cross-Border Weather Operations
Protection Hotspot	The Protection Hotspot represents non overloaded traffic volume but protected: new/unplanned flight needs formal acceptance from FMP	
System	The term “system” in all requirements refers to the NM/FMP platform with integrated new functions provided with ISOBAR engine. It refers to an advanced ATFCM HMI upgraded with ISOBAR AI components.	
Weather Scenario	A weather scenario is composed of: - Static part: the principles and rules to apply DCB measures - Dynamic part: the set of measures provided by the AI Hotspot Solver	Cross-Border Weather Operations & enriched by ISOBAR

Table 1: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
A/C	Aircraft
ADEP	Airport of Departure
ADES	Airport of Destination
AO	Aircraft Operator
APT	Airport
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Management
AU	Airspace User
CASA	Computer Assisted Slot Allocation (algorithm used by the Network Manager to respond to network constraints)
Cb	Cumulonimbus

Acronym	Definition
CNS	Communication Navigation and Surveillance
CONOPS	Concept of Operations
CR	Change Request
DCB	Demand Capacity Balancing
EATMA	European ATM Architecture
E-ATMS	European Air Traffic Management System
EC	Entry Count
EPS	Ensemble Prediction Systems
FCDI	Flight Delay Criticality Indicator
FMP	Flow Management Position
GRIB	General Regularly-distributed Information in Binary form
HPAR	Human Performance Assessment Report
INP	Initial Network Plan
INTEROP	Interoperability Requirements
KPA	Key Performance Area
KPI	Key Performance Indicator
MDI	Minimum Departure Interval
MIT	Miles-In-Trail
MV	Monitoring Value
NMF	Network Management Functions
NIMS	Network Information Management System
NMOC	Network Manager Operations Centre
NOP	Network Operations Plan
NWP	Numerical Weather Prediction
OC	Occupancy Count
OI	Operational Improvement
OPAR	Operational Performance Assessment Report
OSED	Operational Service and Environment Definition
OTMV	Occupancy Traffic Monitoring Values
PAR	Performance Assessment Report
PIRM	Programme Information Reference Model

Acronym	Definition
QoS	Quality of Service
RBT	Reference Business Trajectory
SAC	Safety Criteria
SAR	Safety Assessment Report
SBT	Shared Business Trajectory
SecAR	Security Assessment Report
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SPR	Safety and Performance Requirements
STAM	Short Term ATFCM Measures
SWIM	System Wide Information Model
TFV	Traffic Volume
TS	Technical Specification
TTA	Target Time of Arrival
TTG	Time To Gain
TTL	Time To Lose
TTO	Target Time Over
tTTA	Tactical Target Time of Arrival
tTTO	Tactical Target Time Over
WP	Waypoint
Wx	Weather

Table 2: List of acronyms

3 Operational Service and Environment Definition

3.1 ISOBAR a summary

This chapter will be developed in the Final OSED version.

SESAR Solution ID	SESAR Solution Title	OI Steps ID	OI Steps Title	Enabler ID	Enabler Title	OI Step/Enabler Coverage

Table 3: Scope and related OI steps/enablers

High Level Concept of Operations Requirement ID	High Level Concept of Operations Requirement	Reference to relevant Concept of Operations Sections e.g. Operational Scenario applicable to the Project

Table 4: Link to Concept of Operations

3.1.1 Deviations with respect to the SESAR Solution(s) definition

This chapter will be developed in the Final OSED version.

3.2 Detailed Operational Environment

This chapter will be developed in the Final OSED version.

3.2.1 Operational Characteristics

This chapter will be developed in the Final OSED version.

3.2.2 Roles and Responsibilities

This chapter will be developed in the Final OSED version.

3.2.3 CNS/ATS Description

This chapter will be developed in the Final OSED version.

3.2.4 Applicable Standards and Regulations

This chapter will be developed in the Final OSED version.

3.3 Detailed Operating Method

3.3.1 Previous Operating Method

The recent Cross-Border Weather Operation initiative has developed the following procedures:

- Improved convective-weather forecast.
- Definition of standardized convective information to provide to the NMOC/FMP for decision-making.
- Definition of a collaborative process with involved actors (including METservice) and timeline from pre-tactical D-1 to D-0.
- Definition of the playbook principles, i.e. strategical agreement with NM, ANSPs and AUs, to define a set of scenario solutions (weather scenarios).

The elements should have been implemented in operations during Summer 2020, but due to the covid situation, this was delayed.

There is one more advanced implementation that provides a multi-model convective weather information to a FMP position using web services. It has been developed by the company Metsafe within the Reims En-route Center in the SESAR KTN Engage project "MET Enhanced ATFCM".

In the Cross-Border initiative, additional elements have been identified for improvements and are under study:

- More integrated use in the NMOC/FMP workspace with DCB information (currently the convective-weather forecast is provided by email).
- Taking advantage of recent AI techniques that could improve the prediction quality for the generation of convective-weather forecast.
- The induced propagation of weather-related imbalances, which does not exist.
- The digital selection of weather scenario from the Playbook (catalogue of weather scenarios) to resolve weather problems, which does not exist.
- The capability to monitor flows, which does not exist.
- The capability to manipulate objects representing the problem (Netspot), which does not exist.
- The capability to manage workflow and collaborative process with modern groupware tools, which does not exist.

3.3.2 New ISOBAR Operating Method

In summer 2018, there was a significant deterioration in the regularity and continuity in the European network due to adverse convective weather conditions, which led to significant delays and a reduction in the quality of service.

The diagnosis of the causes led to the initiative of Cross-Border Weather Operation[1] to identify a set of improvements to better manage the ATM system performance deterioration in critical weather situations. A set of improvements were identified:

- To expand the geographical scope of weather-related procedures eastwards and westwards from the concerned area;
- A network-centric weather procedure was established utilizing a single weather forecast for all participants (new partnership with EUMETNET). It will not replace national meteo services but will give all actors a network-wide forecast;
- A procedure to improve collaboration, planning and dissemination of information with the ultimate intention of reducing the number of weather regulations and increasing lead times of application (published 2-3 hours ahead), rather than at the last minute. This also increases stability, since weather-based regulations often risk making matters worse, as many aircraft are already airborne or locked into the departure sequence;
- Better planning re-routes to avoid weather phenomena. The procedure, led by the Network Manager, is starting at least D-1 to include basic planning and raising situational awareness amongst participants by collaboration.

ISOBAR will continue developing and enhancing this process through the contribution to an Artificial Intelligence (AI)-based Network Operations Plan, by including in its scope an enhanced weather prediction tailored to ATFCM, ATM and weather data integration, demand and capacity imbalance characterisation and imbalance mitigation prescription. Digitalisation is the cornerstone cementing the service-based architecture of the future European ATM system.

ISOBAR will develop **four AI components** in the DCB supply chain to manage critical weather operations at pretactical and tactical level (-24h up to the execution, with a focus on later tactical phases). The AI components that will underpin the ISOBAR collaborative ATFCM processes, focusing on weather-related DCB imbalances, are:

1. **AI Meteo Engine**: Reinforce ATFCM processes with probabilistic weather Information

   Forecasts of probability of convection will be improved for tactical lead times by increasing the update frequency and the spatial resolution. To do so, the probability of convection forecasts will be adapted to high resolution numerical weather prediction systems and to nowcasting systems. Then new probability of convection forecasts will be calculated by merging forecasts from the different prediction systems. It will convert the outputs of high-resolution numerical weather products to convective information able to feed storm prediction and build image-like feature maps from the output of the meteo engine and ATM data sources, in the spatial and temporal granularities required at local and regional levels of ATFCM.

2. **AI Hotspot Detection**
   This component will develop a methodology to predict the capacity reduction and the demand re-adjustment that will allow to determine predicted imbalances and hotspots.
   - Weather Capacity Reduction: a methodology will be developed to obtain spatial-temporal correlation between historical weather data and airspace capacity values in

[1] Following the NM User Forum 2018 and a dedicated Weather Forum hosted by EUROCONTROL.

order to develop a model capable of learning the weather capacity reductions in the airspace system due to convective weather.

- Weather Demand Adjustment: a methodology will be developed to determine the demand variability associated to probabilistic forecasts of weather cells.
- Predicted Imbalances: an imbalance library capable of taking the weather demand and capacity forecast outputs will identify where the imbalance will occur within the airspace system within a given period.

3. AI AU Preference

This corresponds to the characterisation of AUs actions in response to adverse weather results in a catalogue of weather scenarios (Playbook) and reactions, linking weather scenarios to re-routing demands. These scenarios are the basis on ISOBAR for AI Hotspot Solver. Based on historical data, the machine learning approach will automatically learn, for a given situation, which trajectory is preferable for an airline.

4. AI Hotspot Solver

The AI Hotspot Solver will be developed to minimize overloads in sectors. The objective is first to identify trajectories involved in Hotspots and to change them for minimizing the associated overload. From selected weather scenarios in the Playbook, the AI Hotspot Solver may propose a combination of several actions like route change, taking into account convective cells locations and the current wind, or slot change to delay the entry of aircraft in sectors or altitude change. The solution will consider AUs preference (provided by the AI AU Preference) and effectiveness of ATFCM measures, based on in-flight feedback and the post-analysis of the executed operations.

These four technical AI components will serve a new approach to consider the operational management of critical weather operations:

- Digitalisation of the Support Tools;
- Visualization of a synthetic convective-weather map provided by B2B service;
- Enrich audio teleconference by electronic media to exchange information using B2B Service;
- Tool to manage interactive sessions;
- Visualization of the propagation of imbalances;
- Visualization of Gates - Cross-Border Flow Monitoring;
- Delineation of Netspot - linked-clusters;
- Multiple weather scenarios Solver-based;
- Timeline to manage set of measures associated to a weather scenario;
- Distributed & Multi What-if;
- A collaborative approach to manage convective weather operations.

AI-based Automation is introduced to reduce uncertainty in the information acquisition process and to provide operators support in the information analysis and decision and action selection, thanks to the development of the technological components of ISOBAR.

Contrary to nominal operation conditions, solving critical issues that have a wider impact on operations needs the design, the coordination and the implementation of network oriented DCB solutions. The identification of areas where the operations degrade to critical state triggers a set of common scenarios involving all stakeholders to jointly support the network recovery.

ISOBAR solution allows identifying the most appropriate stakeholder(s) to drive the DCB solution design, local solution or network oriented. ISOBAR will explore the process and the roles of partners when all collaboratively contribute to manage critical situations and the transition back to normal operations.

While in the normal context, FMP actors play the main role deciding the local solution to apply, in the critical context NMOC actor will play a reinforced and pivotal role guiding the solution decision-making in full collaboration with FMP local actors. This central role will better support the detection and recovery of critical situations to normal situations and provision of optimized solutions at the global level.

3.3.2.1 Gate Concept

The Gate aims at capturing flows in order manage flow monitoring and flow regulation. The Gate is a perpendicular surface made of a geographical traffic volume horizontal line at a reference location, perpendicular to the flow to be captured. The flow passing the Gates can be defined by ADEP/ADES, range of levels, and sub-flows can be excluded, included or exempted. The possibility to specify directional or bi-directional flows within the Gate allows the FMP/NMOC to capture a large amount of flights that may affect the selection location and that will pass through the Gate. This mechanism seems promising to build a robust flow management at the network level. It complements the traditional sector-centric monitoring approach. Workload methodologies (EC/OC) can be applied to a Gate, which allows to measure the load, assign capacity thresholds and detect imbalances.

Compared to the SESAR Wave 2 Solution 49 that has defined the concept principle, in ISOBAR the additional work will consist to identify and design the Gates to manage flows at the network level, to establish the capacity thresholds, and to assess the performance of this mechanism.

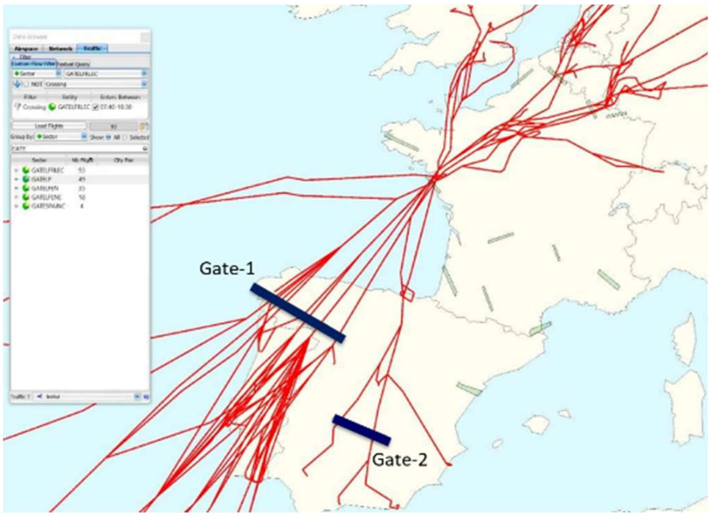


Figure 1 : Gates to manage Flows

3.3.2.2 Netspot Concept

The identification of linked hotspots at network level rises the appearance of a Netspot. The geographical delineation of a potential Netspot can be represented by a group of Traffic Volumes and/or Flows.

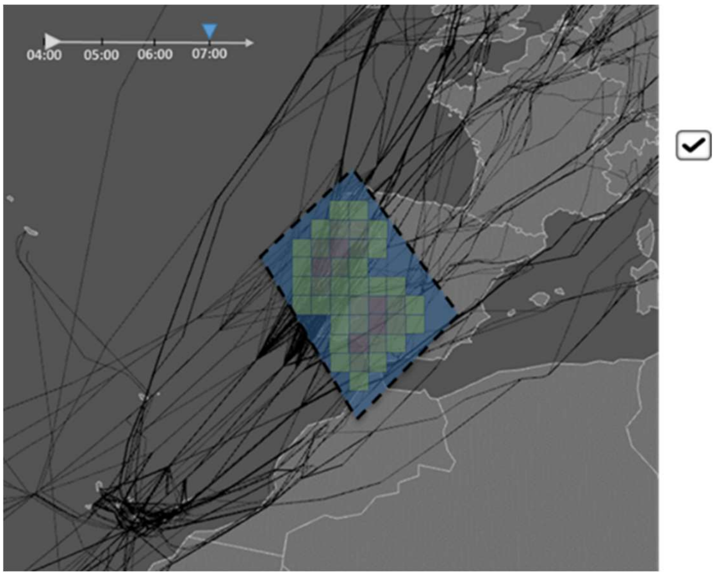


Figure 2 : Netspot delineation of linked Hotspots

The Netspot represents the reference for all concerned actors and stakeholders indicating that:

- a congestion is propagating at the network level moving to a non-nominal or critical situation;
- a global strategy will be coordinated and implemented to resolve it.

The Netspot concept element is particularly interesting when cross-border and inter-ACC-coordination is required.

Compared to the SESAR Wave 2 Solution 49 that has defined the Netspot principle, in ISOBAR the additional work will consist to assess this mechanism in the collaborative process to manage convective weather situations.

3.3.3 AI Components

This chapter describes the output of the four AI components from an operational point of view.

3.3.3.1 AI Meteo Engine

Methodology

The AI Meteo Engine will provide meteorological forecasts at network and local levels. The final aim is to improve the forecasting accuracy of storms based on convective indicators. Figure below illustrates the full methodology corresponding to the AI Meteo Engine.

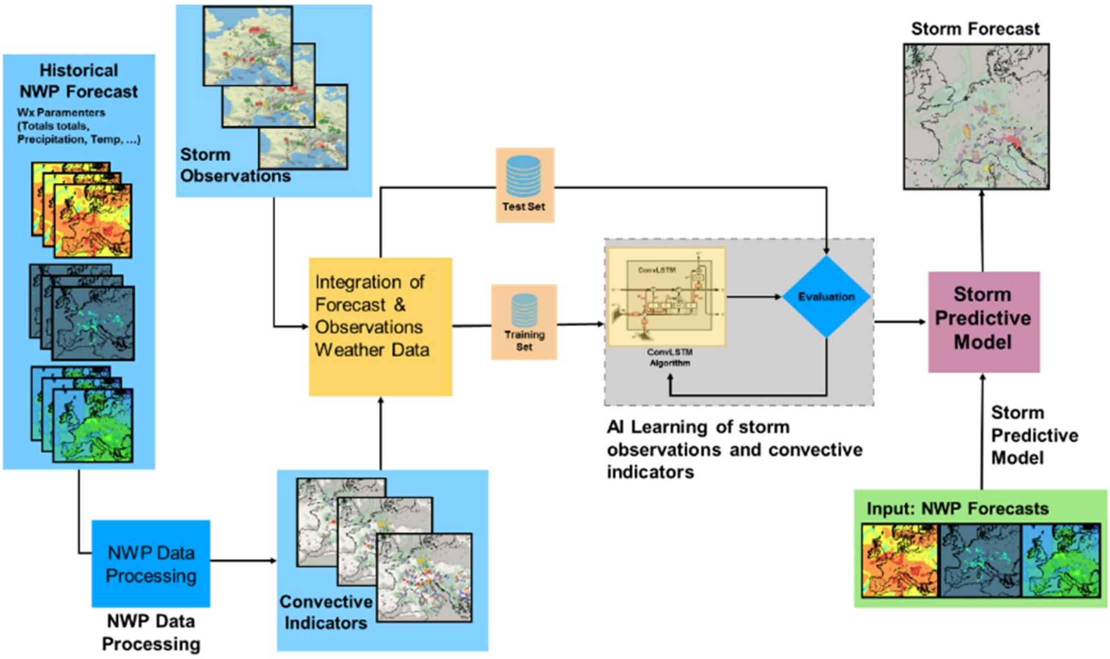


Figure 3 : ISOBAR Meteo Engine Methodology

The approach proposed is based on the post-processing of Numerical Weather Predictions (NWPs), which uses mathematical models of the atmosphere and oceans to predict weather based on current conditions. Ensemble Prediction Systems (EPS)[2] will be used to obtain probabilistic forecasts of convective weather. These models will be the most innovative available for the geographical areas of interest, ensuring that the models' outputs can be transformed in convective indicators:

- AROME-EPS and AROME-PI ((Brousseau, Seity, Ricard, & Léger, 2016) (Bouttier, Vié, Nuissier, & Raynaud, 2012)) for France region;
- and AEMET gSREPS (García-Moya, y otros, 2011), (Quintero Plaza & García-Moya Zapata, 2019), for the Iberian peninsula.

The models can provide hourly data for forecasts beyond the timely needs of ATFCM process. gSREPS runs twice a day, whereas AROME-EPS runs four times a day and the deterministic model AROME-PI runs hourly providing 15-min outputs with a 6h forecast range. ISOBAR will focus on improving regional models and working on the harmonisation of outputs and their integration, proposing a solution able to be fed from high-resolution regional models and to produce integrated data usable at network level.

Post-processing of high-resolution NWP products will deliver convection probabilities. To improve forecasts for tactical lead times, the outputs of the EPSs will be compared with the nowcasting (weather forecasting on a very short term mesoscale period) data and adapted accordingly:

[2] Ensemble forecasting is a method used in NWP providing probabilistic forecast to give an indication of the range of possible future states of the atmosphere. A set (or ensemble) of forecasts is produced using Monte Carlo analysis.

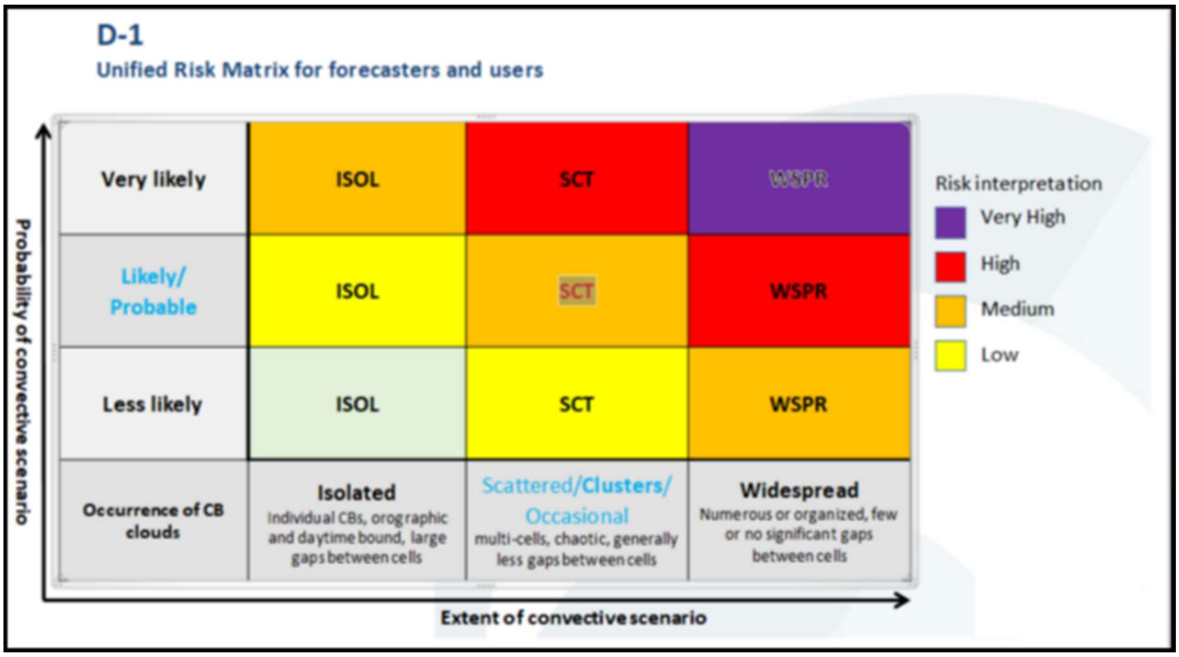
1. In the case of French models, an object-based post-processing (Raynaud, Pechin, Rottner, & Destouches, 2019) method will be proposed. Object-based metrics are used to compute weights for time-lagged ensemble forecasts, based on their performance at early forecast ranges;
2. In the case of the Spanish region, the convection probability will be updated by weighting members of the generating EPS system that are closer to most updated observations.

These methods will provide convection forecasts with hourly outputs. In order to match with the observation network, results will be interpolated to recreate them with steps consistent with the storm observation data (15 min), by using optical flow interpolation[3]. Once there are time consistent observations, the outputs of the different models will be merged to create a consistent spatial mosaic. This part of the engine will be focussed on the spatial and temporal harmonisation of convection indexes.

Finally, historical convection probabilities along and storm observations (based on Rapid Developing Thunderstorms (RDT) data) will be used to train a time-lagged model to identify weather conditions that are conducive to the development of storms by using a ConvLSTM (convolutional Long Short-Term Memory neural network) to identify spatial and temporal correlations between NWP parameters, convection probabilities and storms. The output of this model will be a probabilistic characterisation of storm occurrence tailored to the ATM requirements at each step of the ATFCM process.

Provision of Operational Information

The convective weather information needs to be presented in a digestible and operational form to the NMOC and FMP. A convection risk matrix will synthetize the extent of convection scenario versus the probability of convection scenario (occurrence of Cb clouds), cf figure below. The Cb risk matrix interpretation shall be generated by the AI AI Meteo Engine for each area of Cb forecast.



[3] Optical flow is the pattern of apparent motion of image objects between two consecutive frames caused by the movement of an object or camera. It is described by a 2D vector field in which each pixel/grid point of the frame (in our case, weather variables) has an associated displacement vector.

Figure 4: Cb Risk Matrix Interpretation

The probability of convection scenario shall be structured as:

- Less likely;
- Likely/probable;
- Very Likely.

The extent of convective scenario shall be structured as:

- Isolated (individual Cb, orographic and daytime bound, large gaps between cells);
- Scattered/Clusters/Occasional (multi-cells, chaotic, generally less gaps between cells);
- Widespread (numerous or organized, few or not significant gaps between cells).

The Cb risk matrix interpretation shall be indicated by a color:

- Purple, Very High (Widespread & Very Likely)
- Red, High (Scattered/Clusters/Occasional & Very Likely) or (Widespread & Likely);
- Orange, Medium (Isolated & Very likely, Scattered/Clusters/Occasional & Likely) or Widespread & Less likely);
- Yellow, Low (Isolated & Likely) or (Scattered/Clusters/Occasional & Less Likely).

The Meteo Map shall be displayed in a digestible way in order to highlight ATCFM meaning (figure below):

- Area of Cb forecast shall be superimposed on the European geographical map;
- Area of Cb forecast shall be coloured according the Cb risk matrix interpretation (purple, red, orange, yellow);
- For each area of Cb forecast, a label shall indicate the nature of extent of the convective scenario (isolated, scattered, widespread) and the overshooting top (alt. FL related) of the Cb.

The area of Cb forecast including geographical delineation shall be generated by the AI Meteo Engine.

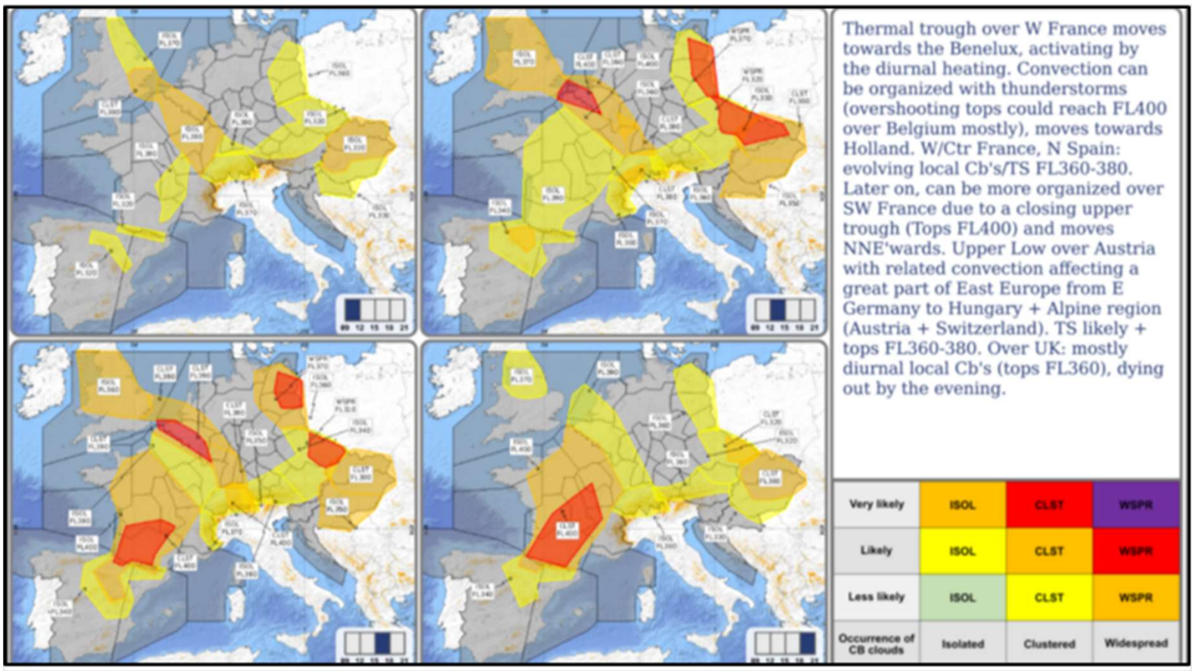


Figure 5 : Cb forecast Map

A pre-tactical CB forecast shall be provided at:

- D-1 at 0900 UTC covering the tactical day 09-12;12-15;15-18;18-22 UTC.

A tactical forecast shall update the D-1 forecast:

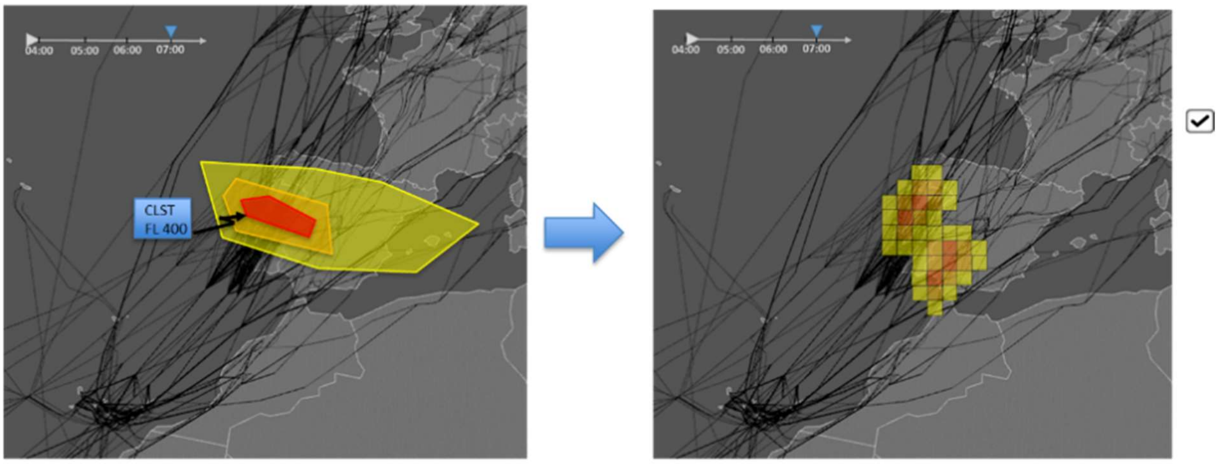
- D-0 at 0700 UTC covering the tactical day 09-12;12-15;15-18;18-22 UTC.
- D-0 at 1200 UTC covering the tactical day 12-15;15-18;18-22 UTC.

3.3.3.2 AI Hotspot Identification

Methodology

The AI Hotspot Identification provides accurate geographical and temporal information on the propagation of imbalances with sliding window. It will support the NMOC and FMP to understand the global picture of how imbalances are aggregated and propagated, in particular on cross-border ANSPs.

The convective indicator map generated by the AI Meteo Engine is translated in a congestion indicator map representing the imbalance impacts.



Convective Indicator Map
(Meteo view)

Congestion Indicator Map
(Imbalance view)

Figure 6 : Convective Indicator map translated into Congestion Indicator map

Provision of Operational Information

The AI Hotspot Detection provides:

- The predicted capacity reduction (Wx Capacity Reduction).
  This Wx capacity reduction is related to the concerned Traffic Volume Capacity. It can be referred to a sector or to a Gate. The NMOC/FMP actors can visualize the Wx capacity reduction and make comparison with the defined capacity thresholds (MV, OTMV) and if necessary can decide to adjust the Capacity Threshold to reflect the weather prediction.

- The predicted demand adjustment (Wx Demand Adjustment).
  The Wx demand adjustment is related to the predicted trajectories entering in a Traffic Volume. It can be referred to a sector or a Gate. The NMOC/FMP actors can visualize the Wx Demand Adjustment, and make comparison with the initial demand.

- The predicted imbalance.
  The NMOC/FMP actors can visualize the predicted imbalance associated to a traffic volume (sector, Gate).
  - From the imbalance information, the FMP identifies and notifies the Hotspots;
  - From the Hotspots information, the NMOC/FMP identifies and notifies the Netspot.

3.3.3.3 AI AU Preference

Methodology

AI AU Preference identifies the most preferred AU trajectories in response to convective weather considering historical preferences of airspace users and constraints imposed by available capacity in selected traffic volume (Coldspot). Based on historical data, the Machine Learning approach will automatically learn, for a given situation, which trajectories is preferable for an airline.

The outcome of this process will be an adaptive proposal prescribing alternative trajectory re-routing.

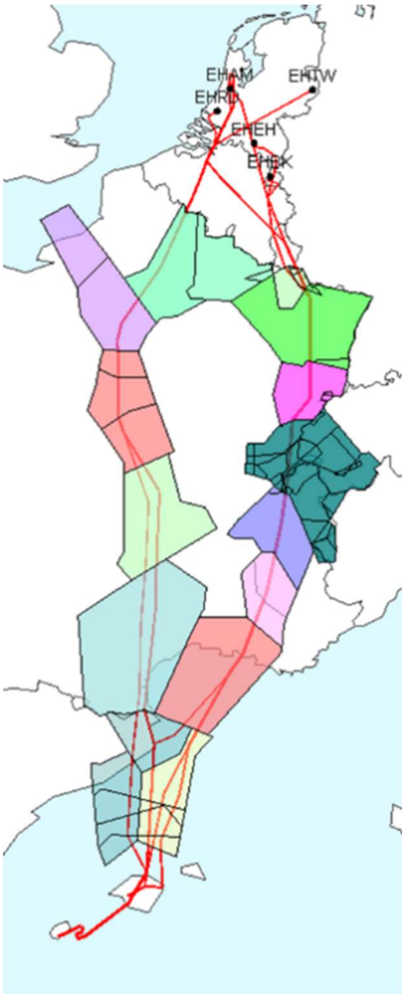


Figure 7 : Alternative Trajectories proposed by the AI AU Preference

It is proposed to start a Catalogue of Routes generated using Historical Data. This methodology, far from being perfect, can be further improved by implementing virtuous processes, and thus customize Routings by City pair and by AO. In a flow / subflow to be treated, it can therefore be shown the possible city pairs at +5 NM, + 10 NM, or address specific City peers to manage the problem in question. Then the AI system will improve the Catalogue of Routes that would present more and more reliable options. Of course, the AU preferences and alternatives will not take into account the latest winds, but in any case when looking for an optimum Network, the AI Hotspot Solver (see next section) takes into account what they are used to doing globally.

Provision of Operational information

As inputs, for a selected flight, it is required a set of alterative trajectories. In addition, selected traffic volume with available capacity for re-routing is imposed.

In outputs, the AI AU Preference provides the preferred trajectory for re-routing.

3.3.3.4 AI Hotspot Solver

Methodology

The main idea developed by the initiative ‘Cross-Border Weather Operations’ is to consider that in the same way of «managing peak traffic demand» in normal situations, proposing options to deconflict «unmanageable local weather situations» will improve a lot «chaotic situations», local and network (upstream and downstream).

Anticipating a convective weather situation in the D-1 pre-tactical phase in order to prepare in a collaborative process with all concerned actors a robust solution to manage the situation is the key. However, in today’s operation, most AUs do not have a pretactical cell D-1. In consequence, it is not possible to involve them in the D-1 pre-tactical NM/ANSP collaborative process.

To overcome this limitation, a Playbook (Catalogue of weather scenarios) has been designed, discussed and agreed at the strategical level with NM, ANSPs and AUs in order to produce weather scenarios agreement in principle. It is very important to note that the notion of transparency is essential for the notion of Playbook. Stakeholders should have a fully transparent view of how and why weather scenarios and flight candidates were selected and implemented.

If there is at D-1 high convective activity forecasted during peak hours on key blocks or very high convective forecasted in a sensitive area, NMOC/FMP will select weather scenarios from the Playbook catalogue (figure below).

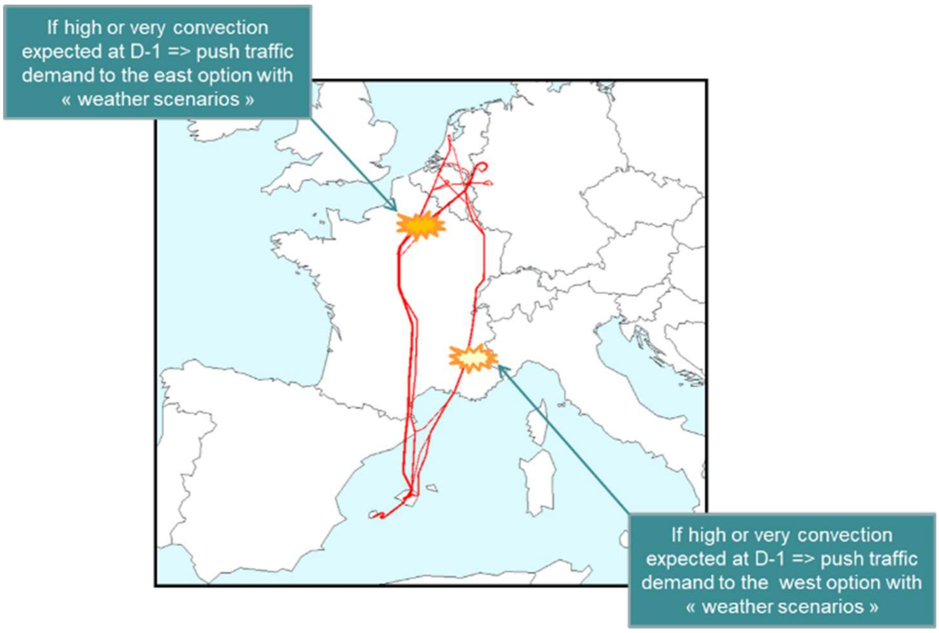


Figure 8 : Example of French weather scenarios extracted from the Playbook

Based on the weather scenario selected by the NMOC/FMP, The AI Hotspot Solver will propose to the end users different alternatives of combined measures to resolve the Netspot.

The AI Hotspot Solver will prescribe a global optimum based on the following methodology:

❖ Step 1: Common flights located in different TFV/hotspots can be envisaged part of the flow/sub flow contributing to multiple overloads. The AI Hotspot Solver decreases the pressure on the flow/sub flow:
  - The AI Hotspot Solver explores local and/or cross-border possible offloading (such as late climb, early descent profiles);
  - The AI Hotspot Solver proposes a rate imposed on a flow/Gate during the saturated period.

❖ Step 2: Once the pressure on flow/sub flow is decreased, if the updated severity of the imbalance is still severe, the AI Hotspot Solver explores the best course of actions:

  - the AI Hotspot Solver regulates the local hotspots not solved with local offloading, but not for the flights of the flow/subflow already regulated.

  - the AI Hotspot Solver considers possible re-routing at different scales (step 1: candidates with – 5 NM more, step 2: candidates with – 10 NM more,…) processing the AI AU preferences.

The AI Hotspot Solver will take into considerations additional rules to avoid constraints on these flights:

- Priority Flight (FDCI) to inform the AI Hotspot Solver ‘do not penalize this flight’;

- Flights that should be excluded from constraints (delay and/or rerouting):

  - Flight from/to protected airports / regulated airport:

  - Long-haul flights ;

  - European long distance (i.e. Scandinavia/ Canary Islands – fuel issue for rerouting).

In tactical D-0 phase, the weather scenario will be reassessed and the AI Hotspot Solver will make fine-tuning adjustment using the complete DCB catalogue of measures acting both on SBT and RBT:

- Regulation;
- Rerouting;
- Airborne STAM;
- Etc.

The complete catalogue of Playbook Measures for pretactical (D-1) and tactical (D-0) phases is described in the table hereafter.

DCB MEASURE at NMF TIMEFRAME	APPLICATION	PROBLEM TO BE SOLVED	WHERE THE PROBLEM IS	DESIRED EFFECT	TIME HORIZON		
					D-1	D-0 H-6h to H-2h	D-0 H-2h to H-20'
Dynamic Airspace Configuration	Group of Sectors	Upcoming traffic overload	Group of Sectors	*To solve a demand capacity imbalance without affecting the AUs trajectories			

DCB MEASURE at NMF TIMEFRAME	APPLICATION	PROBLEM TO BE SOLVED	WHERE THE PROBLEM IS	DESIRED EFFECT	TIME HORIZON		
					D-1	D-0 H-6h to H-2h	D-0 H-2h to H-20'
CASA Regulation	Individual Flights/Flows	Large demand over capacity situation that impacts a significant number of aircraft	SECTOR/ APT	*To limit the number of flights departing per hour to reduce the number of a/c entering an over capacity sector/airport.	SBT	SBT	
Ground Level Capping (A/C ON GROUND)	Flows/Individual Flights	Capacity Overload in a sector.	SECTOR	*To offload an overloaded sector by transferring the excess of flights into a lower loaded sector or to solve a peak of complexity.		SBT	
Re-routing/ Re-filing (FPL Modification)	Flows/Individual Flights	*Capacity Overload in a sector *Need to reduce delays for those flights with enroute delays	SECTOR	*To Offload an overload sector *To Reduce the enroute delays	SBT	Re-filing (up to 2 hours before the EOBT) -SBT	Re-routing SBT/RBT

DCB MEASURE at NMF TIMEFRAME	APPLICATION	PROBLEM TO BE SOLVED	WHERE THE PROBLEM IS	DESIRED EFFECT	TIME HORIZON		
					D-1	D-0 H-6h to H-2h	D-0 H-2h to H-20'
Ground Delay	Individual Flights	Capacity Overload in a sector	SECTOR	*To limit the number of flights departing during a period of time to reduce the number of a/c entering an over capacity sector/airport		SBT	
Take-Off Not Before	Individual Flights	Low demand over capacity situation that impacts a small number of aircraft knowing the finish time	EVOLUTION SECTOR	*To limit the number of flights departing until a specific time stamp to reduce the number of a/c entering an over capacity sector/airport		SBT	
Take-Off Not After	Individual Flights	Low demand over capacity situation that impacts a small number of aircraft knowing the start time	SECTOR	*To limit the number of flights departing after a specific time stamp to reduce the number of a/c entering an over capacity sector/airport		SBT	

DCB MEASURE at NMF TIMEFRAME	APPLICATION	PROBLEM TO BE SOLVED	WHERE THE PROBLEM IS	DESIRED EFFECT	TIME HORIZON		
					D-1	D-0 H-6h to H-2h	D-0 H-2h to H-20'
MDI / Targeted CASA	Flows	Too many aircraft that include a high proportion of departing flights coming into a sector.	EVOLUTION SECTOR	*To move or diffuse traffic in a congested area and time period *To alleviate an overload in a sector between TMA and en-route airspace acting on flights departing			RBT
TTA	Individual Flights	Too many aircraft arriving at the airport during a specific time interval	APT	*To Manage at the point of congestion. Improve the predictability of the aircraft at the entry of the congested area. *To Simplify ATM situation to ensure separation provision and reduce workload		SBT	
TTO	Individual Flights	Too many aircraft arriving at a point during a specific time interval	WP	*To limit the rate to the point *To improve the predictability of the aircraft at the entry of the congested area.		SBT	
MIT	Flows	A problematic flow (i.e. airport departures) in a sector	SECTOR	*To achieve a reduction of sector complexity, mainly for arrival hubs.			speed regulation RBT

DCB MEASURE at NMF TIMEFRAME	APPLICATION	PROBLEM TO BE SOLVED	WHERE THE PROBLEM IS	DESIRED EFFECT	TIME HORIZON		
					D-1	D-0 H-6h to H-2h	D-0 H-2h to H-20'
Air Level Capping (A/C ON AIR)	Individual Flights	Capacity Overload in a sector.	SECTOR	To offload an overloaded sector by transferring the excess of flights into a lower loaded sector or to solve a peak of complexity.			RBT
Speed Regulation/ TTL/ TTG/Holding	Individual Flights	Too many aircraft arriving at the airport during a specific time interval	SECTOR/ APT/WP	*Arrival optimisation *Implement an Arrival Manager Sequence *Optimise the use of available capacity *To achieve a reduction of sector complexity, mainly for arrival hubs.			RBT
tTTA	Individual Flights	Aircraft not following the predefined sequence to an airport	APT	*Manage at the point of congestion. improve the predictability of the aircraft at the entry of the congested area *Simplify ATM situation to ensure separation provision and reduce workload *Fine tuning of the workload by acting on individual trajectories			RBT
tTTo	Individual Flights	Aircraft not following the predefined sequence to a WP	WP				RBT

DCB MEASURE at NMF TIMEFRAME	APPLICATION	PROBLEM TO BE SOLVED	WHERE THE PROBLEM IS	DESIRED EFFECT	TIME HORIZON		
					D-1	D-0 H-6h to H-2h	D-0 H-2h to H-20'

Table 5 : Catalogue of DCB Measures

Provision of Operational information

The NMOC/FMP actors will guide the AI Hotspot Solver with the definition of several parameters to provide:

- Identification of the weather scenario to consider;
- Identification of the Netspot to consider:
  - Identification of the Hotspots eligible to be potentially regulated.
- Identification of the Gates to consider to apply a flow rate;
- Identification of the Coldspots to consider as potential traffic volume candidates for the re-routing;
- Identification of the Protection Hotspot as potential traffic volume candidates for STAM Measures.

In outputs, the AI Hotspot Solver provides for each weather scenario, a set of measures (regulation, flow rate, rerouting, ….) to resolve the Netspot.

The NMOC/FMP will be able to run what-if for the different alternatives of weather scenarios and to assess the network impact.

3.3.4 Digitalisation of the Front-End Support Tools

3.3.4.1 Visualization of a synthetic convective-weather map provided by B2B service

In today’s operation, the convective map is received by email, the information is static and cannot be integrated in the live DCB environment. It is proposed to develop capabilities to receive and display formalized convective-weather information in the DCB working environment.

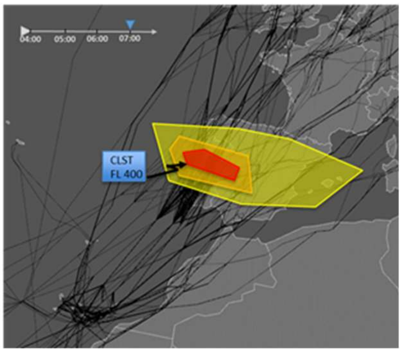


Figure 9 : Visualization of the convective-weather map

In addition, the convective weather information will be displayed in the Sector Configuration Monitor showing the time evolution. It allows to display an overview of the convective weather colour state according to the convective risk matrix for various sector configuration at once.

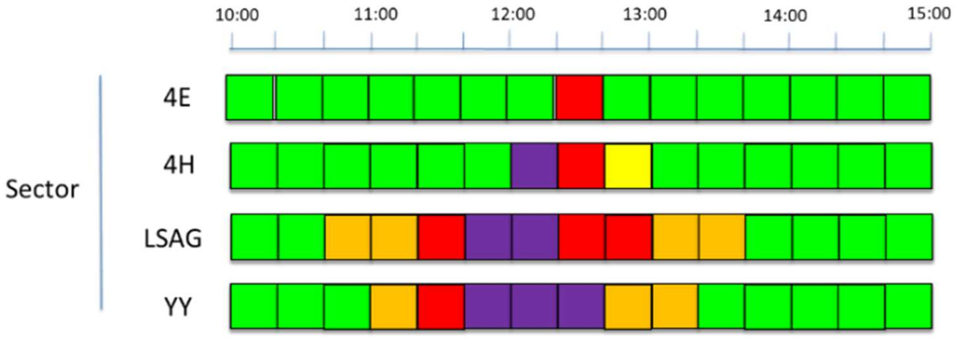


Figure 10 : Visualization of the convective weather information in the Sector Configuration Monitor

3.3.4.2 Visualization of the propagation of Imbalances

The propagation of imbalances is displayed in a 2D geographical map. A time axis allows to move at different prediction times. The colors indicate the severity of the imbalances.

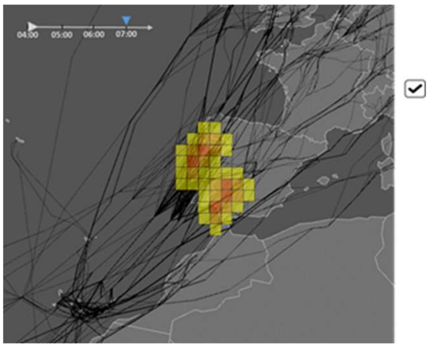


Figure 11 : Visualization of the propagation of imbalances

3.3.4.3 Visualization of Gates – Cross-border Flow Monitoring

The end-users can edit gates and access to the gate flow information. The gate colours indicates the severity of the overloaded flow or available capacity.

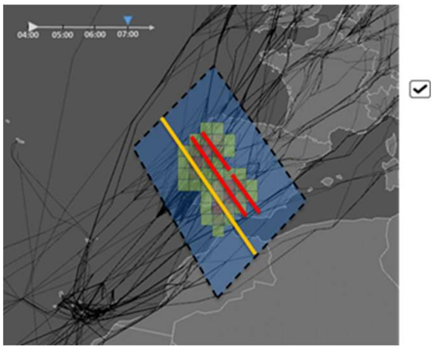


Figure 12 : Function to manage gates

3.3.4.4 Visualization of Netspot – linked-clusters delineation

The end-users is able to determine and to display the delineation of a cluster of linked Hotspots: the Netspot.

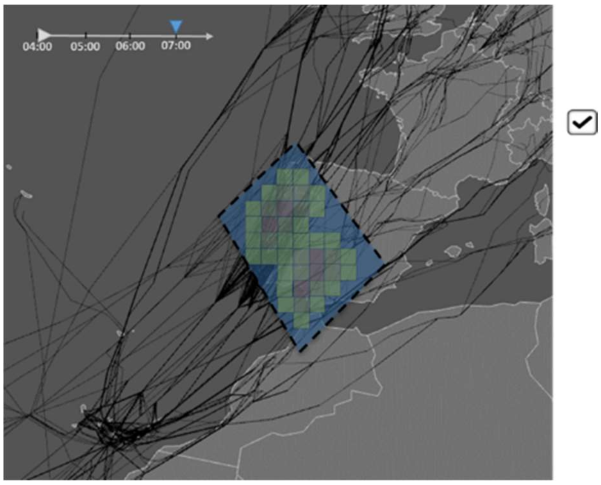


Figure 13 : function to edit and display the Netspot

3.3.4.5 AI Hotspot Solver

The AI Hotspot Solver generates and displays the proposed set of measures:

- On a geographical map.

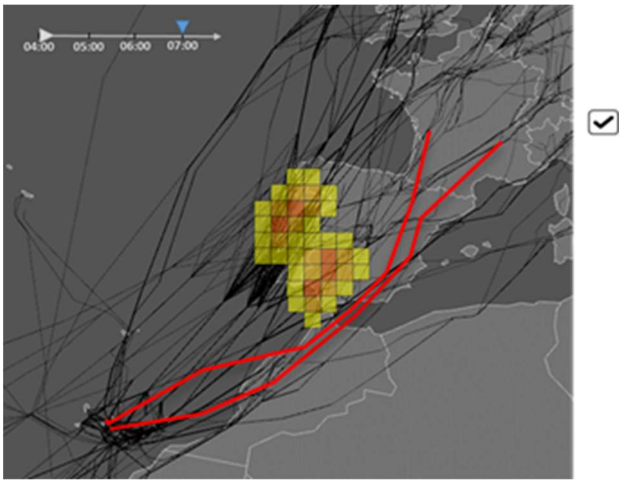


Figure 14 : Visualization of the proposed solutions

- On a timeline

  The AI Hotspot Solver generates solutions (weather scenarios) in a script format in order to present information digestible by the end-users. The set of measures is displayed in a list of individual measures attached to a timeline.

  End-users can easily understand and manipulate the timeline to analyse and adjust the weather scenarios. The timeline is shareable with others concerned actors. Important milestones as time of implementation or time-out can be defined. Free text notes can be added as well.

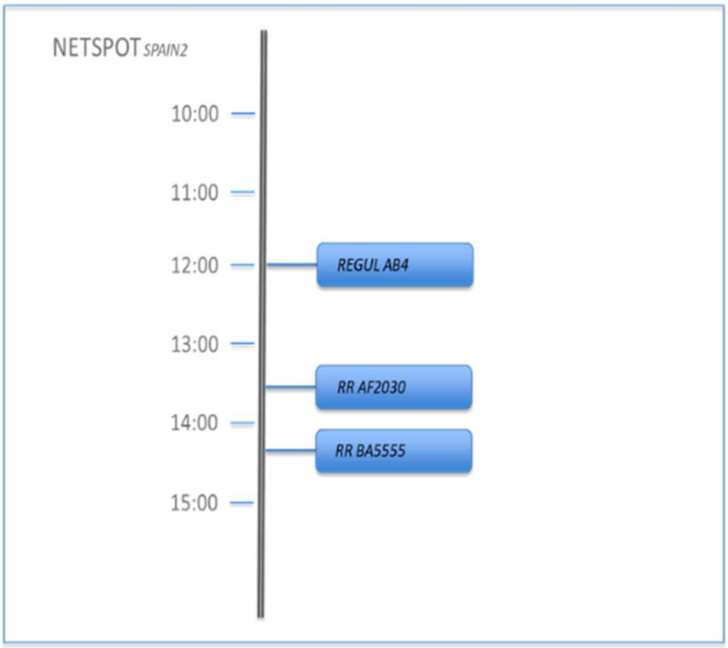


Figure 15 : Timeline

3.3.4.6 Multiple what-if

A multiple what-if capability is proposed to assess and compare different weather scenarios. Performances indicators and TFV/Flow onload/offload are displayed.

Figure 16 : Multiple what-if assessing the performance of weather scenario alternatives

3.3.4.7 Interactive Groupware

Shareable information and interactive collaboration are keys to allow several actors to build common situation awareness and decision-making. Groupware capabilities are developed to ease the interactivity as:

- Drawing and mark-up in order to ease the share understanding of human actors;
- 3D visualization in order to better understand the problem and proposed solutions;
- Audio/Computer Integration in order to take advantage of both direct human communication and digital information exchange.

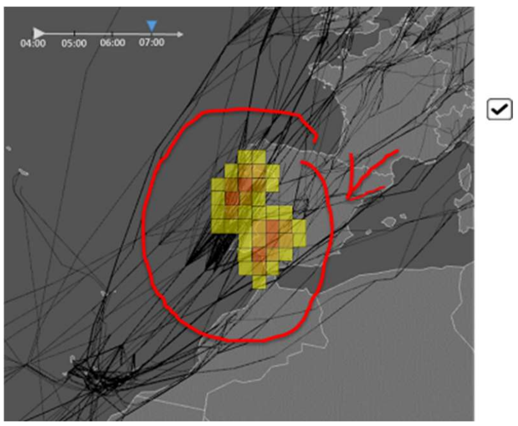


Figure 17 : Drawing and mark-up

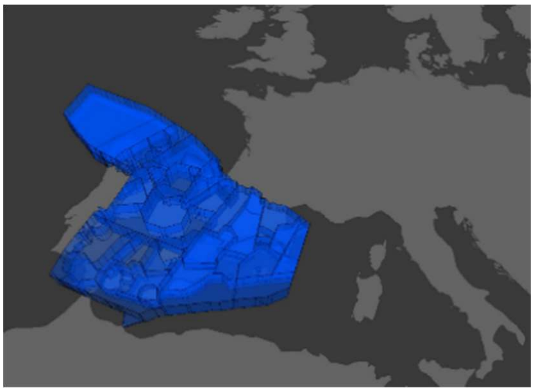


Figure 18 : 3D visualization

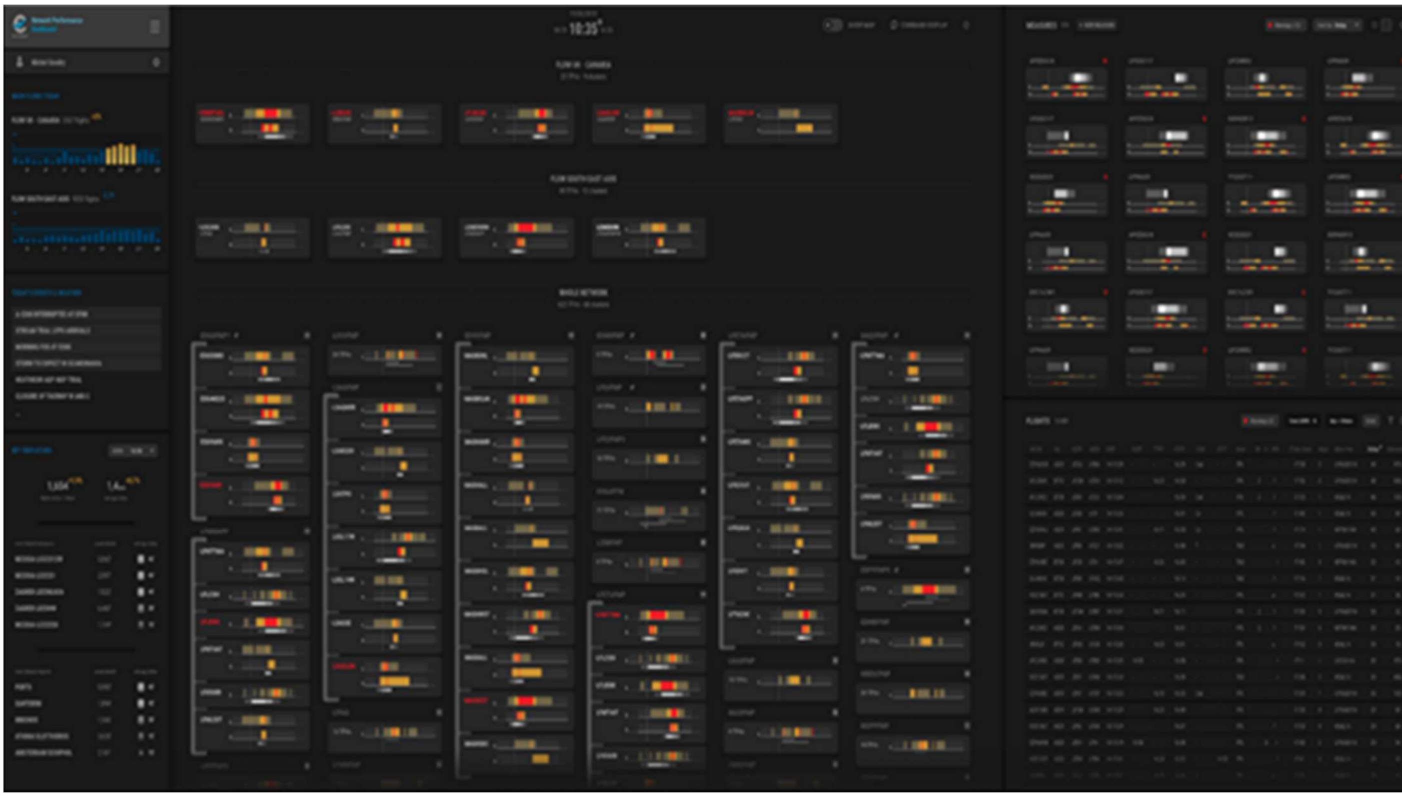


Figure 19 : NM Dashboard & Computer Telephony Integration

3.3.5 Collaborative approach to manage convective weather operations

3.3.5.1 General Principles

Management of convective weather operations is a process taking place on the D-1/D-0. The goal is to detect critical weather traffic situation during the entire course of operations, by continuous and pro-active traffic monitoring to identify and manage networks events.

NMOC/FMP monitors the convective weather forecast and imbalances across the network, the network gates, the cluster of linked imbalances and the evolution of the regional performance targets on KPIs.

The combination of the operational expertise, the emergence of imbalances, clusters of linked imbalances/hotspots and the degradation of the regional performance KPIs shall trigger the identification of a potential Netspot by the Network Manager.

NMF team agrees on the Netspot to manage and prepares alternative weather scenarios from the analysis of expected traffic, Airspace Use Plan and Airspace configuration.

The collaborative process from D-1 to D-0 is supported by a formalized timeline (figure below):

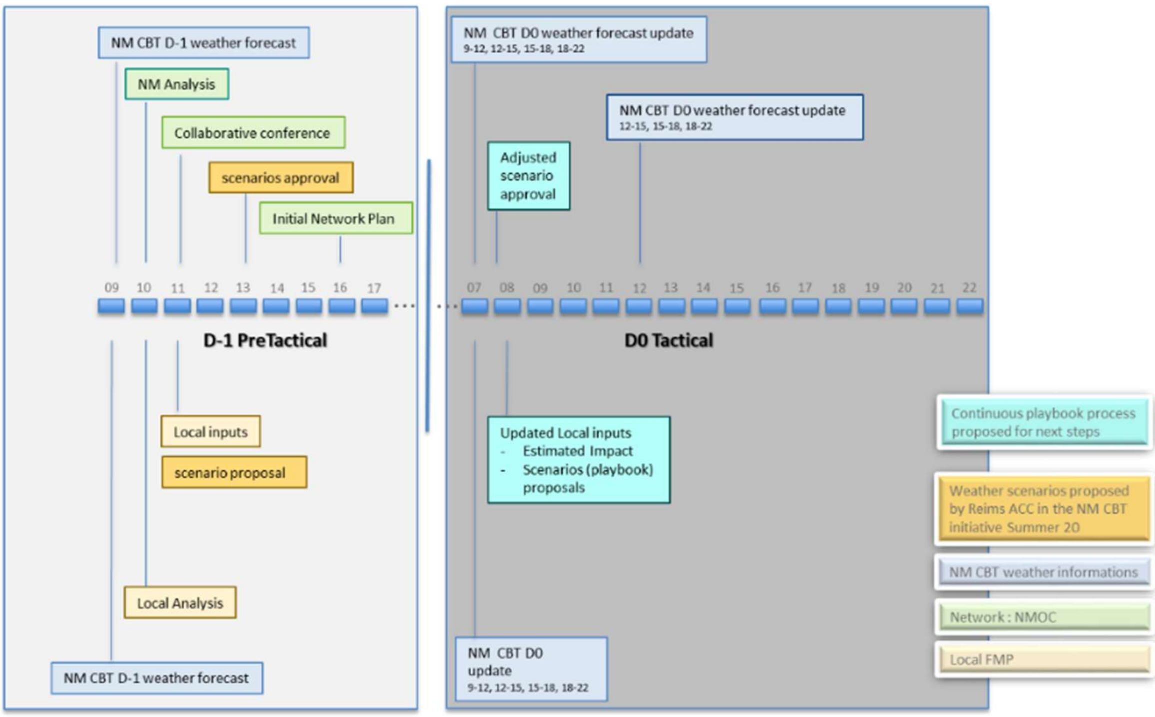


Figure 20 : Timeline supporting the Collaborative Process (this Timeline was initially developed by Reims ACC in the NM CBT initiative summer 2020)

3.3.5.2 Procedures, Roles and Responsibilities to handle the convective weather operations management (Detection)

The Management of Convective Weather Operations for the detection is decomposed in several steps:

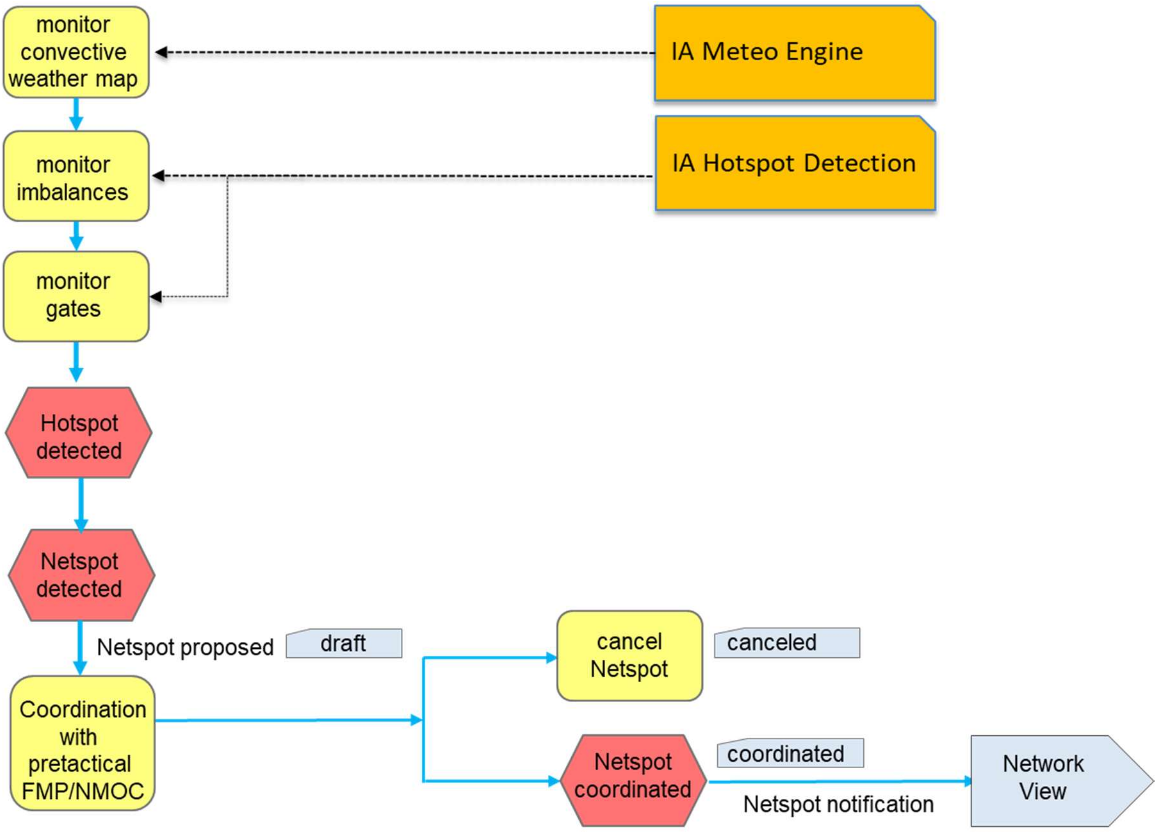


Figure 21 : The management of Convective Weather Operations (Detection)

Monitor Convective Weather Information

NMOC and FMP monitor the convective information provided by the AI Meteo Engine and analyze the convective risk matrix with the probability of convective scenario and the extent of convective scenario (the area of Cb forecast). At this step, the objective is to prevent and deconflict weather chaotic situation on Pre-Tactical D-1 phase. It will triggered only on High or Very High Convective Area Risk prediction on D-1.

The monitoring is performed both on the geographical map and in the sector configuration monitor (see section 3.3.4.1) (figure below):

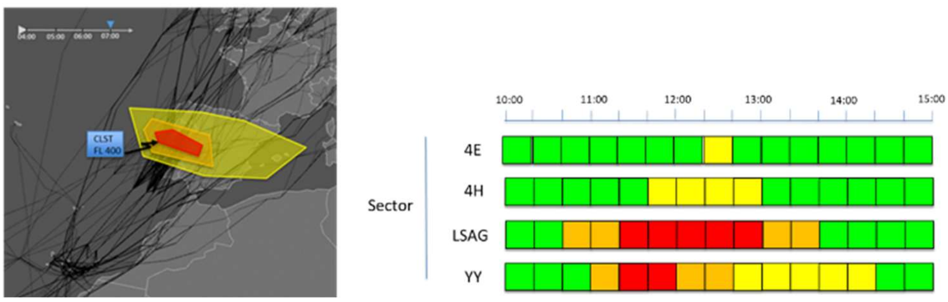


Figure 22 : High risk convective area predicted on D-1

Monitor the Imbalances

At pre-tactical and tactical phases, the NMOC/FMP monitors the information provided by the AI Hotspot Detection and identifies the weather-related imbalances.

- The FMP/NMOC starts to analyze the Wx Capacity Reduction, the Wx Demand Adjustment and the associated imbalances. If necessary, the FMP adjusts the capacity threshold of the traffic volume to take into account the weather information prediction (Wx Capacity Reduction). It means that the MV (EC) or OTMV (OC) will be adjusted.

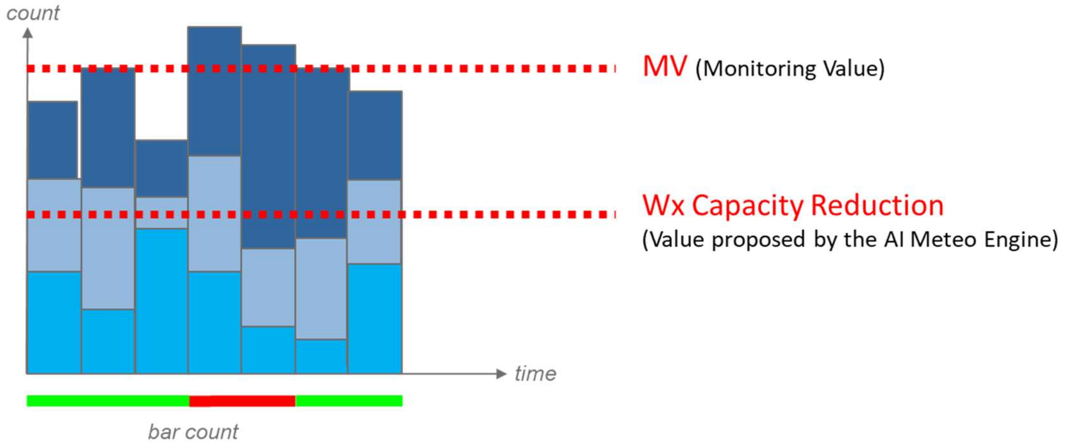


Figure 23 : Visualization of the Capacity Reduction proposed by the AI Hotspot Detection (Wx Capacity Reduction)

- The adjustment of the capacity threshold (MV, OTMV) is now confirmed and communicated to the NM system in order to provide a robust network view to all actors. It gives the imbalances view for each Traffic Volume.

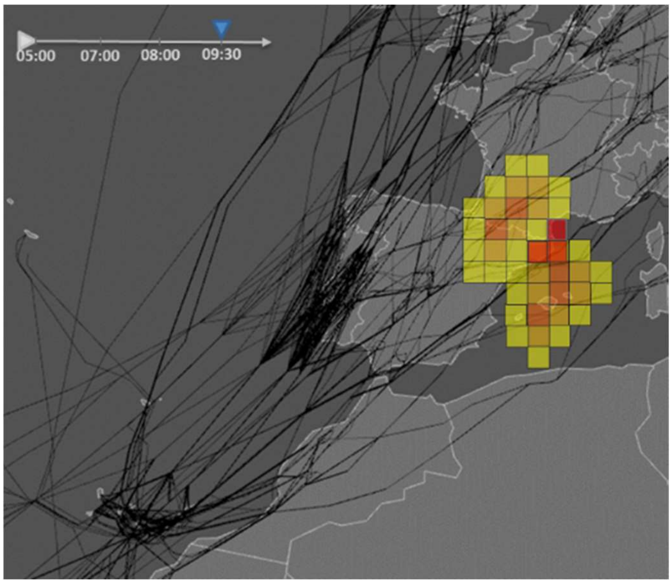


Figure 24 : Imbalance propagation

Monitor the Gates

The FMP/NMOC analyzes the situation at the sector level, and at the Gate level to understand the flow congestion. The FMP/NMOC can have access to all the Gates defined in the NM system using filtering to select the ones to visualize. FMP/NMOC can focus their analysis in the areas highlighted by Gates with high flow rate, looking at the network impact through different ACCs and flow axis.

The FMP/NMOC starts to analyze the Gates:

- Analyse the distribution of the flights along the Gates, indicate the busiest ones and those likely to offer solutions;
- Analyze the vertical distribution of the flights passing through the Gates;
- Analyse the contribution of flights passing a Gate and contributing to several overloaded sectors.

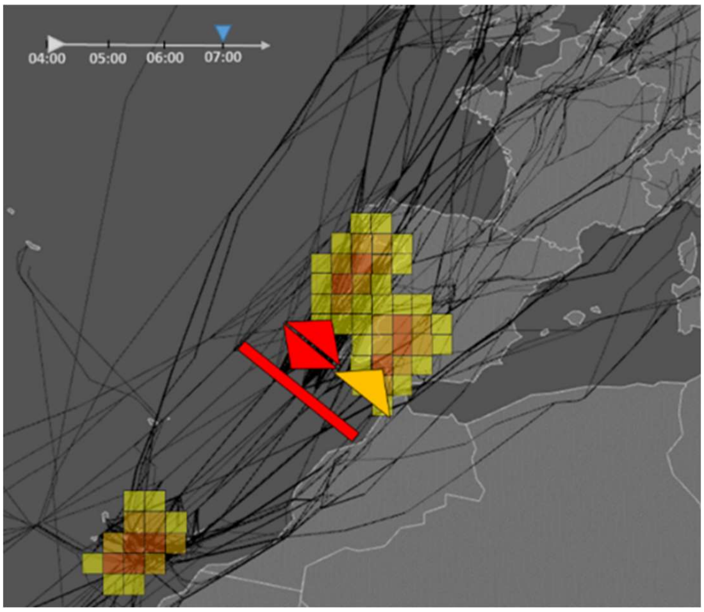


Figure 25 : Analysis the Gate to explore the level of congestion severity along the flow

The monitoring of both sectors and Gates provides a robust indication on the prediction of linked imbalance clusters. Based on the AI Hotspot Detection and network operational expertise, the emergence and propagation of network imbalances, linked clusters and/or the degradation of the regional performance KPIs shall trigger the identification of potential Hotspots and Netspots (linked Hotspots).

Determination of Hotspots

The FMP defines the Hotspots to be managed, and in case of linked-Hotspots and cross-border situation that represent a network dimension, he will define a Netspot. Hotspots are communicated to the NM system.

NMOC receives from local FMP adjusted Capacity Threshold (MV, OTMV) and confirmation of Hotspots. This information allows NMOC to build a robust network situation.

Define a Netspot

The identification of linked Hotspots at network level rises the appearance of a Netspot. The geographical delineation of a potential (i.e. draft) Netspot can be represented by a group of Traffic Volume and/or Flow. The Netspots do not have any predefined boundaries and HMI support tools shall allow the FMP/NMOC to manually identify the potential (i.e. draft) Netspot geographical boundaries.

This consists of manually drawing an outline to represent a grouping of identified Hotspots. System evolution towards automated assistance should be envisaged in a further step.

The shape of the Netspot delineation represents also all stakeholders involved, and so therefore it represents the reference to coordinate the Netspot with the concerned actors.

At this stage, the Netspot is in a 'draft' status.

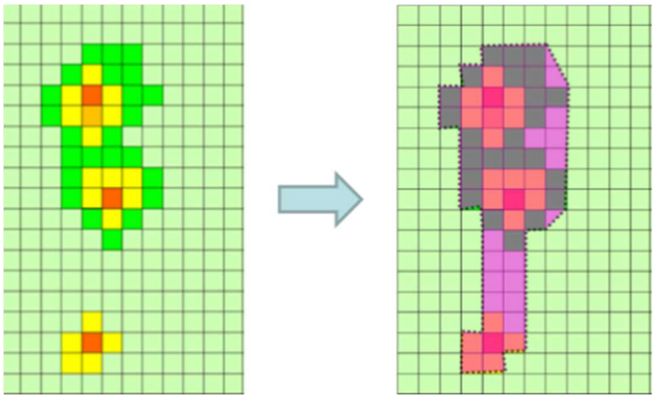


Figure 26 : From Hotspots to a Netspot

The Netspot concept is particularly interesting when inter-ACC-coordination is required. In the figure below, different areas of imbalance propagation are identified demonstrating a propagation through two different axes from one source (Canaries).
The propagation through the two axes will be captured in a draft Netspot representing the area to coordinate with concerned actors in order to determine the final Netspot.

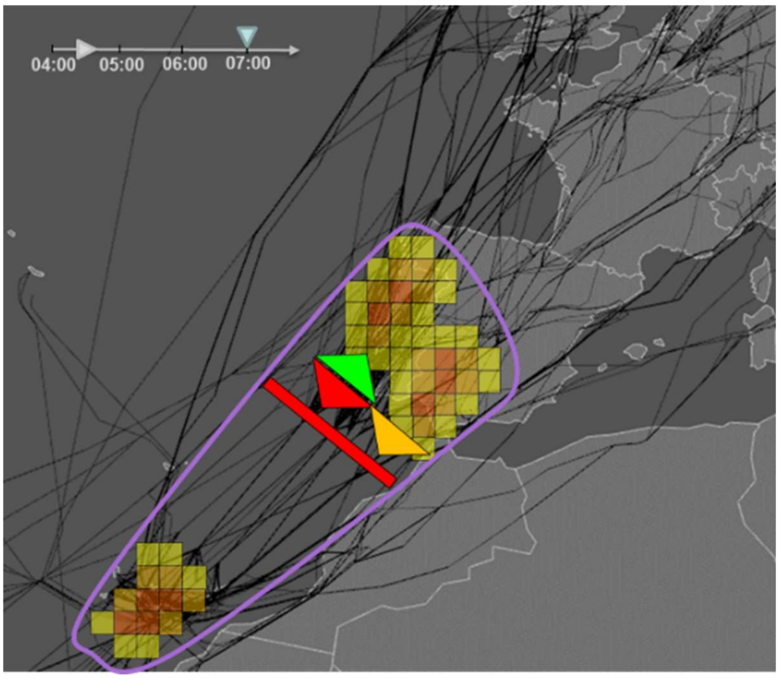


Figure 27 : Definition of a Netspot (grouping of Traffic Volume and/or Flow)

The definition of a Netspot is mandatory for NMOC.

Netspot proposal to concerned actors

NMOC decides to notify the Netspot to the concerned FMPs. NMOC sends a request for a Netspot proposal to the concerned FMPs. It will trigger a collaborative process.

At this stage, the Netspot is in a ‘proposal’ status.

Coordination of the Netspot

The collaborative coordination process shall allow the concerned actors (i.e. NMOC and FMPs) to exchange information and to discuss the characteristics of the identified draft Netspot (list of actors, delineation, start time, end time, severity, etc.) resulting in the confirmation/adjustment/cancellation of the Netspot. When an agreement is reached amongst the actors, the NMOC shall publish the Netspot on the NOP to inform all NMF & AU stakeholders. It means that the acceptance of collaboratively decided and necessary resilience measures shall be acted by the Netspot agreement.

The coordination of a Netspot is mandatory for NMOC.

Publish the Netspot in the NOP

NMOC publishes the Netspot on the NOP. The NOP publication of a Netspot is mandatory for NMOC.

The Netspot represents the reference for all concerned actors and stakeholders indicating that:

- a congestion is propagating at the network level moving to a non nominal or critical situation;
- a global strategy will be coordinated and implemented to resolve it.

At this stage, the Netspot is in a ‘coordinated’ status.

After publication, the NMOC monitors the published Netspot continuously until its resolution.

3.3.5.3 Procedures, Roles and Responsibilities to handle the convective weather operations management (Resolution)

The Management of Convective Weather Operations for the resolution is decomposed in several steps (see Figure 28):

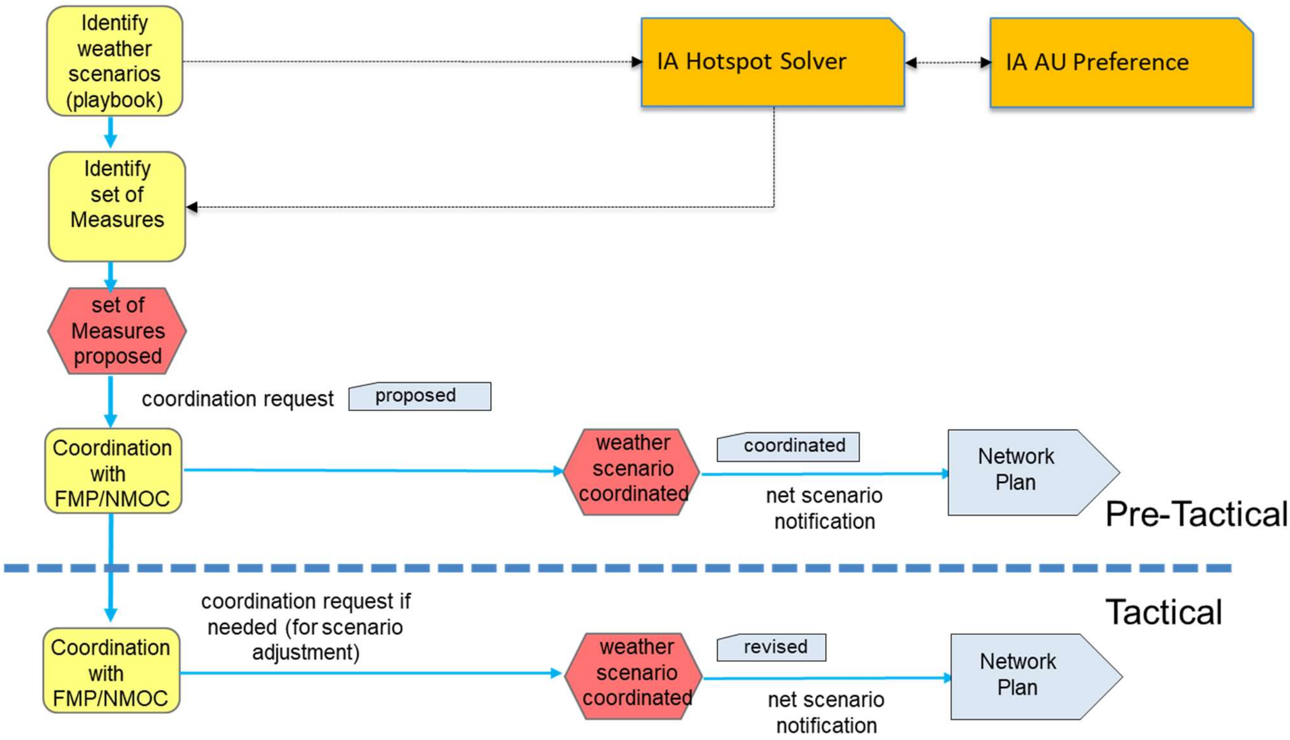


Figure 28 : Resilience Transition Management Process (Resolution)

Identify Weather Scenarios in the Pre-Tactical Timeframe

At PreTactical D-1, NMOC/FMP select the weather scenarios to apply according to the analysis of the Netspot. Several weather scenarios are provided to the AI Hotspot Solver.

The NMOC/FMP define the parameters to be considered by the AI Hotspot Solver for each weather scenario:

- List of Gate eligible to apply a flow rate;
- List of Hotspots involved in the Netspot and eligible to apply a regulation;
- List of Coldspots eligible to host rerouting trajectories;
- List of Protection Hotspot eligible for STAM Measures.

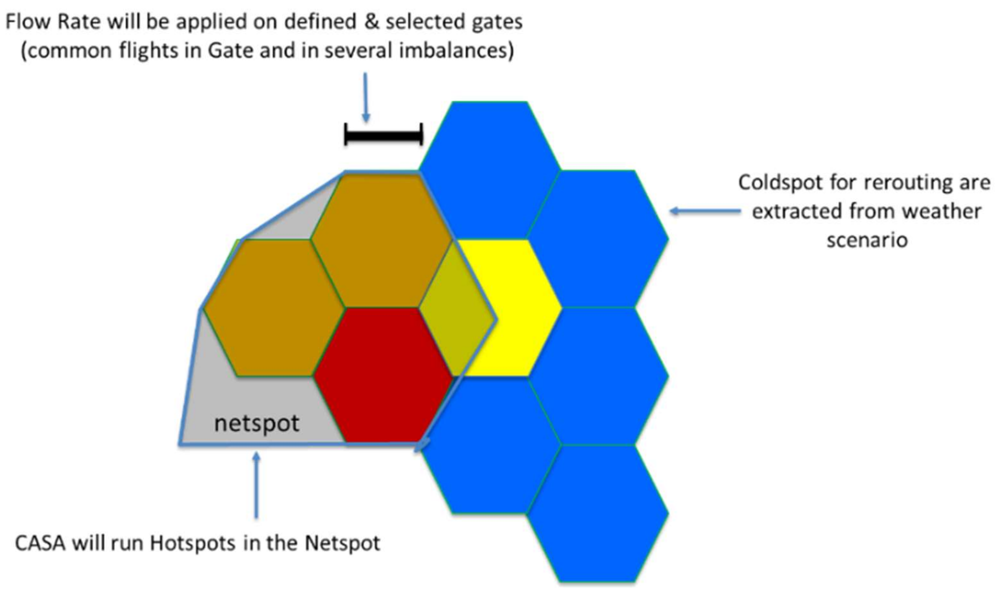


Figure 29 : Configuration of the AI Hotspot Solver

Identify Set of Measures

The AI Hotspot Solver provides to the NMOC/FMP a set of measures for each weather scenario selected.

The set of Measures are based on:

- CASA Regulations;
- Flow Rate;
- Flight Rerouting.

NMOC/FMP analyze the proposed set of measures and can make adjustment if necessary.

The status for the weather scenario with the associated set of measures is "draft".

Coordination with FMPs actors in the Pre-Tactical Timeframe

NMOC/FMP initiate a collaborative process to coordinate the proposed weather scenarios with the concerned actors involved. At this stage, the status for weather scenario is "proposed". It allows:

- To share a common view (Hotspot, Netspot, Weather Scenarios/Set of Measures);
- All actors to analyze the performance impact assessment;
- To fine-tune the proposed weather scenarios (i.e. contained measures, agree on weather scenario alternatives ranking for applicability).

Once, the agreement is concluded among concerned actors, the status for weather scenarios is "coordinated". Coordinated weather scenarios are stored in NOP and are visible for all NMF actors.

Refinement and implementation of the Weather Scenarios in the Tactical Timeframe

In Tactical Day the developed network plan is assessed to ensure the applicability of the ranked weather scenarios. The revision of the network plan could be triggered depending of:

- The evolution of the predicted imbalance;
- The traffic demand accuracy evolutions;
- The time constraints (timeline, horizon) for application;
- The revision process is fully coordinated between the Network Manager and the concerned local FMPs

Monitoring in real-time the implementation of Weather Scenarios

After assessing the applicability, the designed network plan is activated for implementation. Once the network plan is implemented, the Network Manager monitors the situations:

- The Network Manager determines the need of revision in order to:
  - Adapt the current active Weather Scenario to fit the situation evolution;
  - Activate an alternative Weather Scenario more adapted to solve the identified Netspot;
  - Design a new Weather Scenario if no coordinated alternative is available.

3.3.6 Operational Scenarios

Three operational scenarios are described:

- France scenario;
- France/Spain Cross-border scenario.
- Spain Scenario.

Operational scenarios cover all environments and possible operations that are relevant for the ISOBAR new operating method and associated concepts.

3.3.6.1 Convective Weather affecting En-Route Sectors in France

Purpose

The aim of this operational scenario is to describe an operational context that will serve as a basis to identify and to develop the future operating methods and process in ISOBAR.

It describes a convective weather situation and how the “Local FMP & Network” team could better manage weather situations: avoid the cascading effects across the network, and together look for a “global optimum” gain.

The following use case focuses on how we could better use the network according to expected weather situations. The chosen date to illustrate it, is the 26th of July 2019.

Scenario summary

On the pre-tactical day, the FMP Reims and FMP Aix detect series of imbalances with status to very high and/or high (during peak demand of traffic) due to convective weather starting to pop up from West to East France.

The following sections present the operational scenario sequence.

Scenario description

PRE-TACTICAL D-1

On the pre-tactical D-1, FMP Reims and FMP Aix detect that imbalances due to convective weather are starting to pop up from West to East France.

Situation at D-1 – 09:00 UTC:

NMOC and ANSP/FMP receive the weather/convective events forecast generated by the ***AI Meteo Engine***. Severe Weather alerts are announced in some French areas with maximum risk of convection for the En-Route *Cluster CB act top FL 400.*

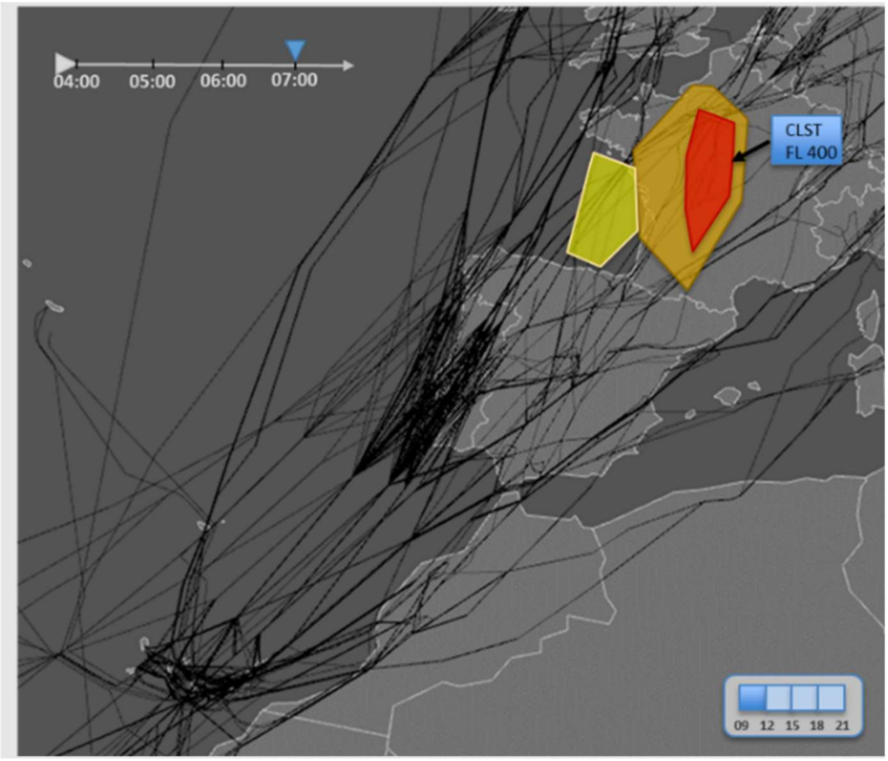


Figure 30 : Weather forecast at D-0 at 09:00 UTC

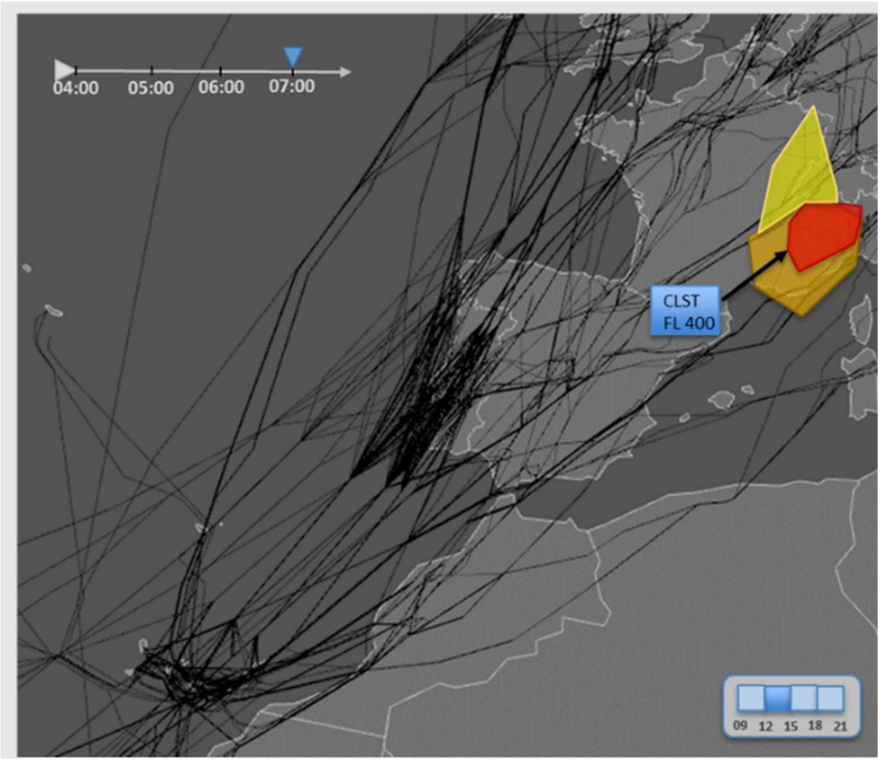


Figure 31 : Weather forecast at D-0 at 12:00 UTC

<u>Situation at D-1 – 10:00 UTC:</u>

- NMOC and Pre-tactical FMP Reims start the analysis of the weather forecast and predicted convective events. They analyse the information provided by ***AI Hotspot Detection*** that determines the capacity reduction and propagation of imbalances.
    - The weather capacity reduction is forecasted to start at D-0- 09:00 UTC. The high risk convection is located in the France North East (URMN). The AI Hotspot Detection determines the weather capacity reduction, the weather demand adjustment and the resulting imbalances.
      Pre-Tactical FMP adjusts the Capacity Threshold (MV/OTMV) to the concerned traffic volumes and analyzes the corresponding imbalances.
    - At D-0-12:00 UTC, the high-risk convective situation is moving from North East to South East.

Pre-Tactical FMP Reims analyses the predicted propagation of imbalances at D-0-09:00 UTC and declares some Hotspots in the Reims ACC area.

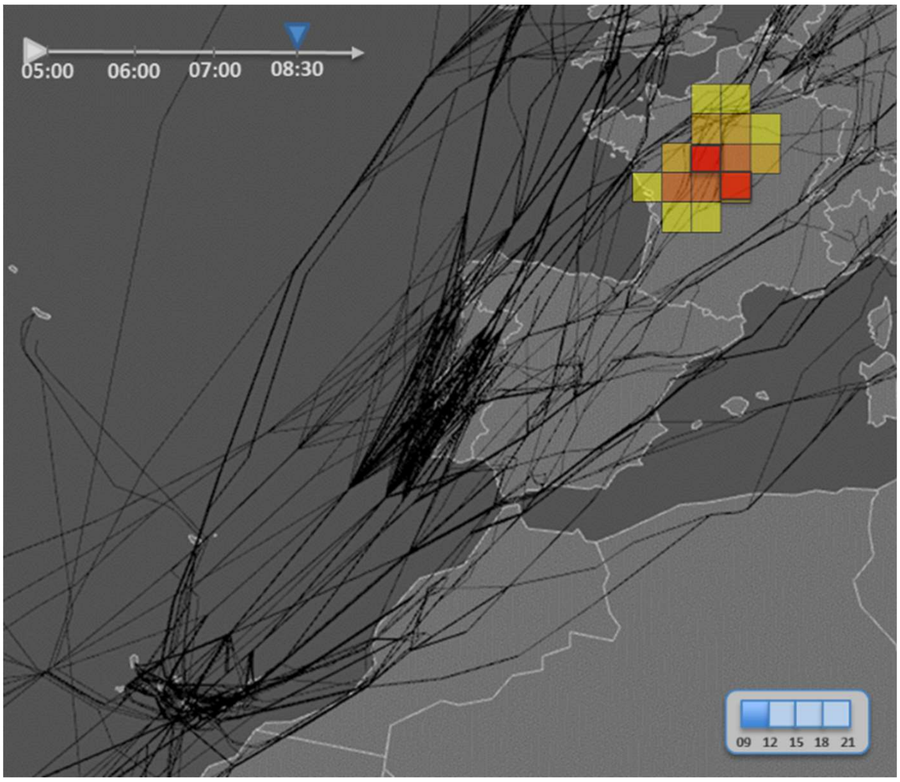


Figure 32 : Forecast of Imbalance at D-0 – 09:00 UTC

The evaluation of the Hotspots propagation is done by visualizing different time-horizon-predictions. Due to the propagation of predicted degradation, the identification of linked Hotspots at network level rises the appearance of a Netspot. The geographical delineation of a potential Netspot can be represented by a group of Traffic Volumes and/or Flows. The shape of the Netspot delineation represents also all stakeholders involved, and so therefore it represents the reference to coordinate the Netspot with the concerned actors.

Then Pre-Tactical FMP identifies a Netspot with involved Hotspots. The Netspot and Hotspots are notified to the NM system.

The high-probability (> 80%) of this severe and extended convective event will trigger the decision to anticipate and prepare solutions on D-1.

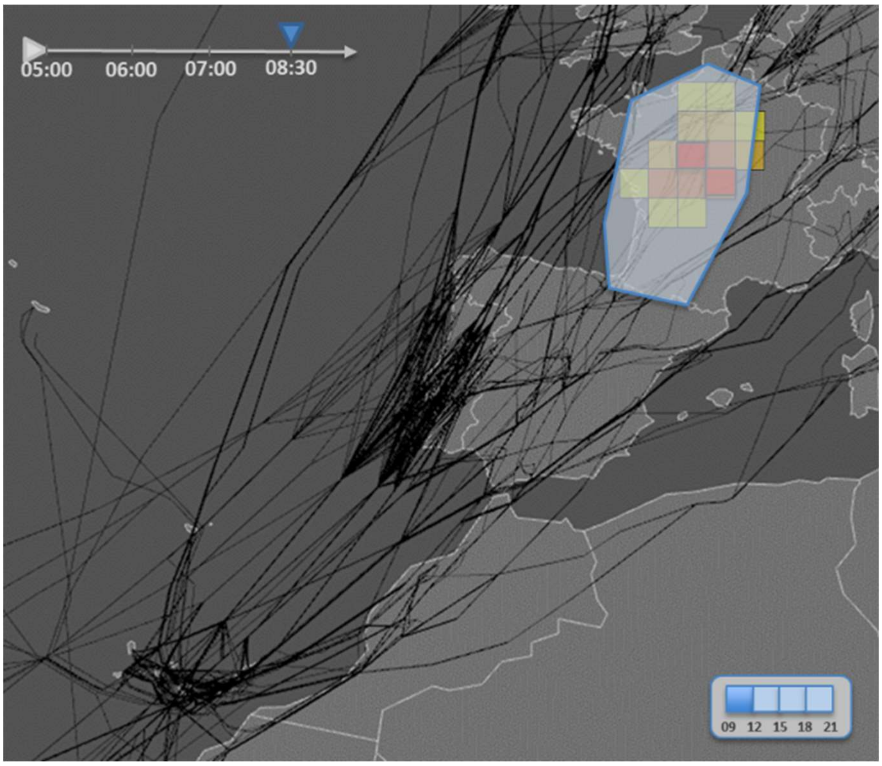


Figure 33 : Creation of a *Netspot-1* at D-0-09:00 UTC

Pre-Tactical FMP Aix analyses the predicted propagation of imbalances at D-0-12:00 UTC and determines a second Netspot area to manage.

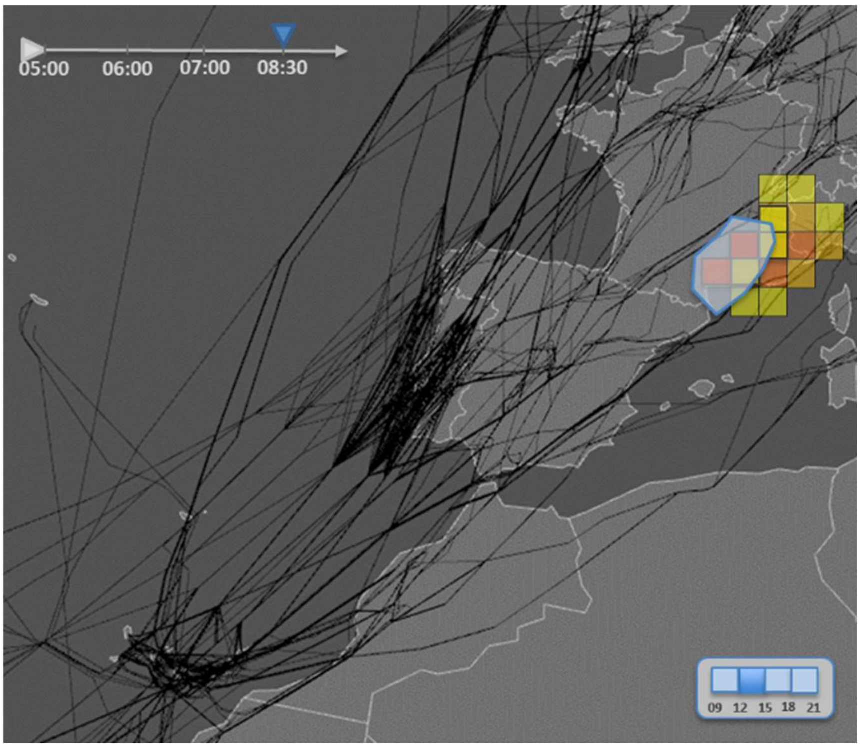


Figure 34 : Creation of a *Netspot-2* at D-0-12:00 UTC

At this step, using the ***AI Meteo Engine*** support tools, Pre-Tactical FMP at Reims and Aix have identified the high-probability of convective weather problems, evaluated the capacity reduction and temporal/geographical propagation/extension of the imbalances on Block (set of sectors).

Pre-Tactical FMP identifies the Netspot delineation of the concerned areas (weather-based Imbalance) to manage.

Pre-Tactical FMP Reims and Pre-Tactical FMP Aix send two Netspots (*Netspot1, Netspot-2*) proposal to the concerned actors to support a collaborative coordination *(Netspot status = draft).*

Pre-Tactical FMPs start to investigate the resolution of their respective Netspots, selecting weather scenarios from the Playbook. Pre-Tactical FMP Reims selects the weather scenario "French flip-flop". The weather scenario "French flip-flop"pushes traffic demand to the East or West option. Pre-Tactical FMP Reims justifies the proposed weather scenario with available capacity in URME group of sectors with no convective activity at 09:00-11:00 UTC.

Pre-Tactical FMP configures the parameters to run the Solver: Netspot Name, Hotspots to apply potential regulation, Gates to apply potential flow rate, Coldspots eligible for the rerouting options.

Pre-Tactical FMP runs the AI Hotspot Solver exploring the "French flip-flop" weather scenario. This support tool suggests the best combination of measures (flow rate, TFV regulation, re-routing, …) and flight candidates according to the weather scenarios description.

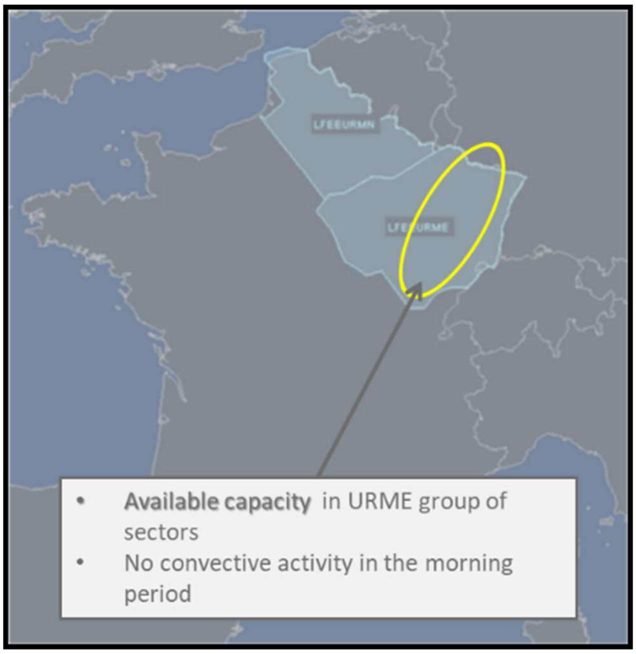


Figure 35 : Identification of available capacity in URME group of sectors with no convective activity at 09:00-11:00 UTC

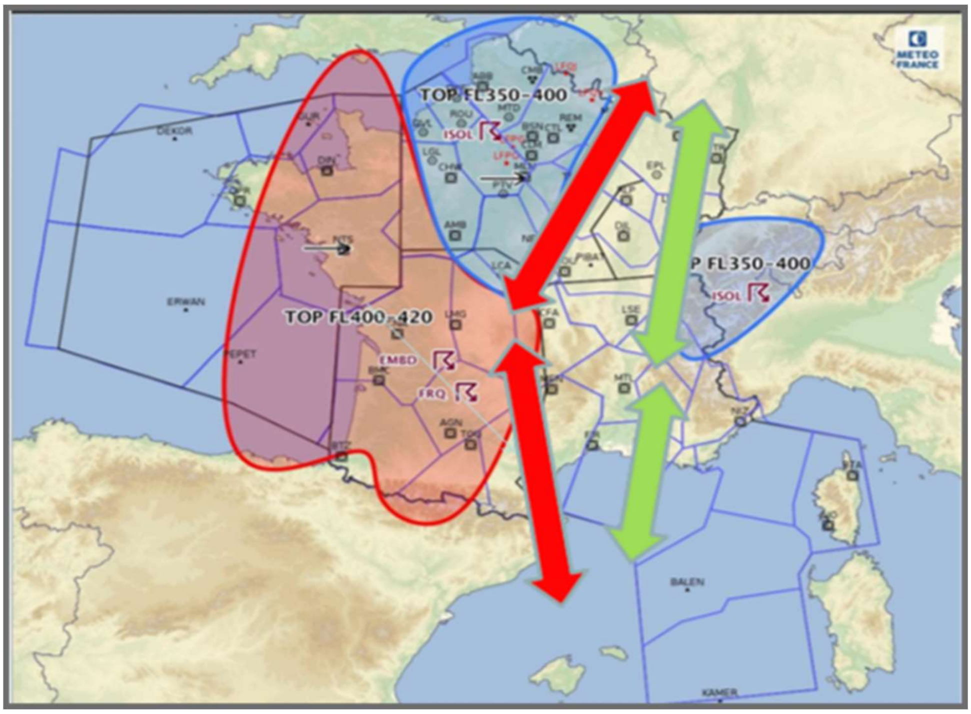


Figure 36 : Use network opportunities to move flows from West to East to better manage collectively traffic flows

To resolve *Netspot-1* with convection located in the North East (URMN), the weather scenario proposes:

- Pretactical block regulations 5R and 4N;
- Rerouting of those flows to the East options.

Figure 37 : Block Regulation of 5R and 4N / Reims ACC

Pre-Tactical FMP Reims analyzes the DCB measures and flight candidates proposed by the ***AI Hotspot Solver*** for rerouting and Block regulation.

Look for possibles candidates
EDDL-LEPA
Düsseldorf > Palma

List a set flight candidates

ENTRY	ARCID	ATYP	ADEP	ADES
04:11A	RYR8664	B738	EDDK	LEPA
04:24A	BEL7ZQ	A319	EBBR	LEPA
04:32A	TUI2W	A321	EDDL	LEPA
04:56A	TRA89A	B738	EHAM	LEBL
05:12A	EWG47Y	A321	EDDL	LEBL
05:28A	EWG520	A320	EDDK	LEBL
05:51A	TRA16Y	B737	EHEH	LEBL
05:53A	TFL585	B738	EHRD	LEPA
06:48A	DTR761	A320	EKBI	LEPA
07:00A	SAS4685	B737	ENGM	LEBL
07:05A	KLM85J	B738	EHAM	LEBL
07:20A	JTG527	B737	EKBI	LEPA
07:41A	RYR5LR	B738	EBBR	LEBL
07:48A	JAF36B	E190	EBAW	LEPA
08:14A	NAX4CW	B763	ENGM	LEBL
08:32A	VLG8989	A320	EBBR	LEBL
08:55A	JAF97J	B738	EBBR	LEPA
08:56A	KLM65H	B738	EHAM	LEBL
09:19A	VLG83PJ	A320	EHAM	LEBL
10:10A	TRA66Y	B738	EHEH	LEBL
10:21A	OOPRM	C510	EBAW	LEIB
10:31A	TRA86R	B737	EHRD	LEIB
11:08A	LGL617	B737	ELLX	LEPA
11:08A	BEL3LM	A319	EBBR	LEBL
11:08A	TRA81J	B738	EHAM	LEBL

Identify clearly
onloaded areas

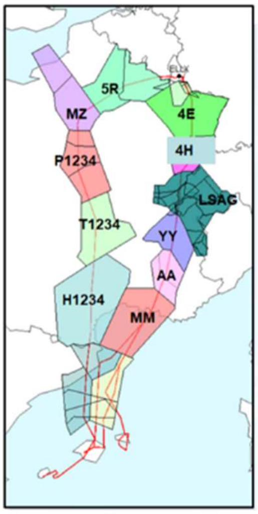


Figure 38 : Selection of flight candidates for rerouting

In the same way, Pre-Tactical FMP Aix develops the resolution of *Netspot-2* and proposes a weather scenario based on the identification of available capacity in the East area with no convective activity at 12:00-15:00 UTC.

To resolve *Netspot-2* with convection located in the South East (AB sector group), the weather scenario proposes:

- Implementation of Pre-tactical regulations on LFMAB12 and LFMAB34 with rate MV- X% (to be determined/ regarding weather conditions and staffing situation);
- Rerouting of flows to avoid AB sector group towards West or East options.

<u>Situation at D-1 – 10:30 UTC:</u>

NMOC analyzes the weather situation and the Netspots proposed by the Pre-Tactical FMP Reims/Aix.

<u>Situation at D-1 – 11:00 UTC:</u>

Due to the very-high convective risk areas, NMOC decides to call a collaborative coordination process with the concerned Pre-Tactical FMPs and MET information service provider to manage the proposed Netspot (*Netspot-1, Netspot-2*):

The collaborative coordination process shall allow the concerned actors (i.e. NMOC and Local FMPs) to exchange information and to discuss the characteristics of the identified Netspot resulting:

- in the confirmation or not of the potential Netspot;
- agreement of proposed solutions;
- understanding of the performance impact assessment.

In this collaborative process, NMOC plays a pivotal role in partnership with:

- Met information service provider;
- Pre-Tactical FMPs (ANSP).

NMOC consolidates the local options to network driving solutions and anytime the NMOC has the final decision.

Pre-Tactical FMP Reims/Aix present their analysis using digital support tools allowing the actors to dynamically exchange information:

- Characteristics of the convective weather and the related DCB impacts (80% probability severe convective event), Sectors affected, estimated Capacity reduction, Imbalance propagation, Netspot delineation, start time/end time severity, ….);
- Characteristics of the proposed solutions (possible areas of capacity for rerouting/rerouting opportunity, selected weather scenarios, when measures will be applied, …);
- Performance impact assessment (impact on staffing situation, Impact on military activity, …)

Digital support tools allow the actors to dynamically exchange information.

To resolve *Netspot-1* with convection located in the North East (URMN), the weather scenario, proposed measures and flight candidates are accepted and will be implemented (09:00-12:00 UTC):

- Pretactical block regulations 5R and 4N;
- Rerouting of those flows to the East options.

In the same way, the resolution of the *Netspot-2* proposed by Pre-Tactical FMP Aix is agreed and accepted. The weather scenario will be implemented (12:00-15:00 UTC):

- Implementation of Pre-tactical regulations on LFMAB12 and LFMAB34 with rate MV- X% (to be determined/ regarding weather conditions and staffing situation);
- Rerouting of flows to avoid AB sector group towards West or East options.

NMOC concludes to the confirmation and agreement of the proposed Netspot and proposed weather scenarios.

NMOC establishes a detailed timeline for the implementation and monitoring of the Netspots resolutions.

Situation at D-1 – 13:00 UTC:

Netspot-1 and *Netspot-2* are agreed and published on the NOP *(Netspot status = coordinated*).
Weather scenarios are approved and published in the NOP.

Situation at D-1 – 16:00 UTC:

D-1 Information is published in the Initial Network Plan (INP). Measures already applied in pre-tactical will be published in the INP.

TACTICAL D-0

- On the Tactical D-0, NMOC reassesses the situation and adjusts the Network Plan (weather scenario). If there is a significant evolution, NMOC can call a teleconference to review the course of action.
  - If in line with the D-1 forecast, pre-agreed measures will be coordinated with the concerned FMPs and/or adjusted as necessary before implementation.
  - Continuous monitoring of the situation and necessary adjustments will be carried on along the day.

Situation at D-0 – 07:00 UTC:

A tactical forecast updating the D-1 forecast is provided and covers the tactical day 09-12;12-15;15-18;18-22 UTC.

The weather scenario is adjusted. In Tactical Day the developed network plan is assessed to ensure the applicability of the ranked Scenarios.

The Revision of the network plan could be triggered depending of:

- The evolution of the predicted imbalances,
- The traffic demand accuracy evolutions,
- The time constraints (timeline, horizon) for application.

The revision process is fully coordinated between the Network Manager and the concerned local FMPs. After assessing the applicability, the designed network plan is activated for implementation.

Situation at D-0 – 12:00 UTC:

A further forecast is provided updating the D-0 – 07:00 UTC forecast covering the tactical day 12-15;15-18;18-22 UTC.

The weather scenario is adjusted.

3.3.6.2 Convective Weather affecting En-Route Sectors on Cross-border Spain/France Southwest Axis

Purpose

The aim of this operational scenario is to describe an operational context that will serve as a basis to identify and to develop the future operating methods and process in ISOBAR.

It aims at describing a convective weather situation with cascading effects across the network.

The current scenario is based on a convective day, the 27th of august 2019.

Scenario summary

On the pre-tactical day, the Network Manager detects a series of imbalances due to convective weather starting to pop up over:

- the Balearics;
- Barcelona;
- Barcelona airspace;
- expanding over the French Pyrenees.

The following sections presents the operational scenarios sequence.

Scenario description

PRE-TACTICAL D-1

On the pretactical D-1, NMOC detects that imbalances with reason convective weather are starting to pop up over

- the Balearics;
- Barcelona;
- Barcelona airspace;
- expanding over the French Pyrenees.

Situation at D-1 – 09:00 UTC:

NMOC and ANSP/FMP receive the weather/convective events forecast generated by the ***AI Meteo Engine***. Severe Weather alerts are announced for the En-Route "*Cluster CB act top FL 380-400, LECP / LECB / LECM*" and Palma & Barcelona airports.

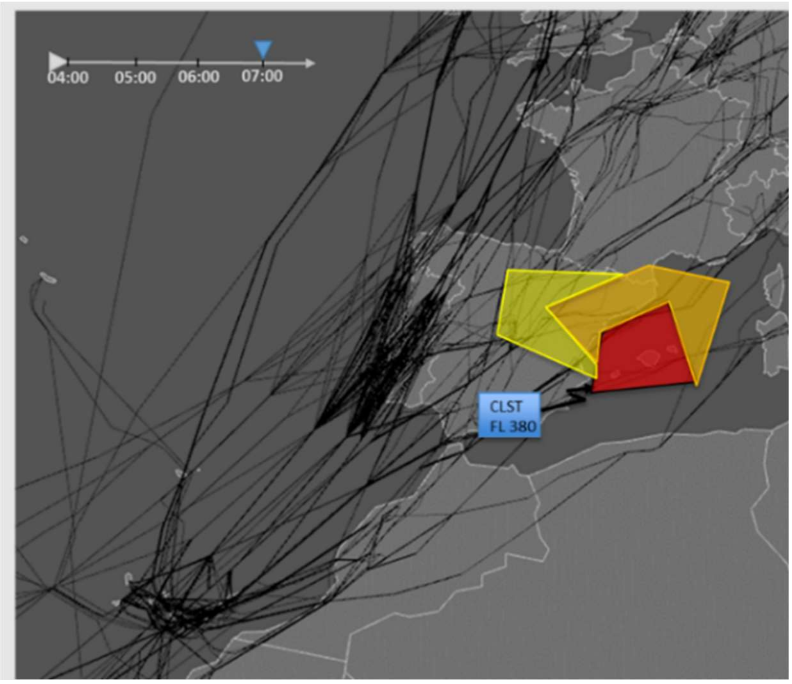


Figure 39 : Weather forecast at D-1 at 09:00 UTC

Situation at D-1 – 09:30 UTC:

- Concerned Pre-Tactical FMP and NMOC start the analysis of the weather forecast and predicted convective events. The resulting capacity reduction is forecasted to start at D-0-0830 UTC. The ***AI Hotspot Detection*** determines the induced capacity reduction, the demand adjustment and the resulting imbalances.
- NMOC is starting to analyse the situation and observe the different time horizons.
    - NMOC visualizes predicted imbalances with high-risk convective situation on the Balearics at D-0, 08:30 UTC.
    - At D-0 - 09:30 UTC, additional imbalances pop up, in particular in Barcelona and French Pyrenees sectors.

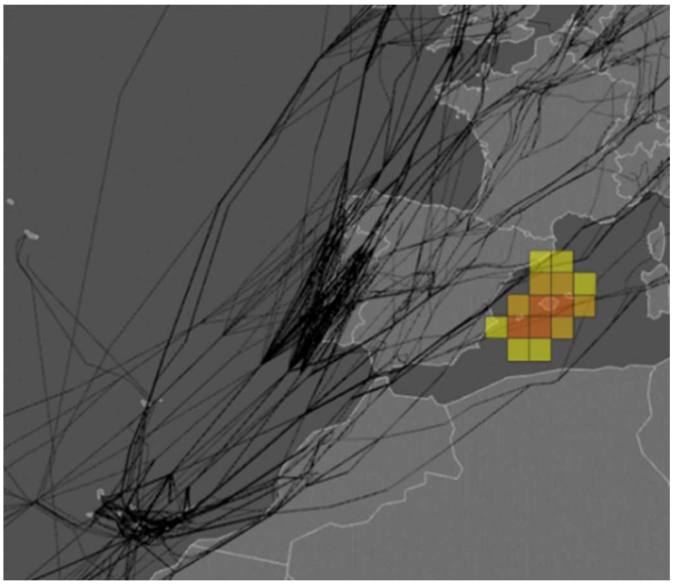


Figure 40 : Forecast of Imbalance at D-0 – 08:30 UTC

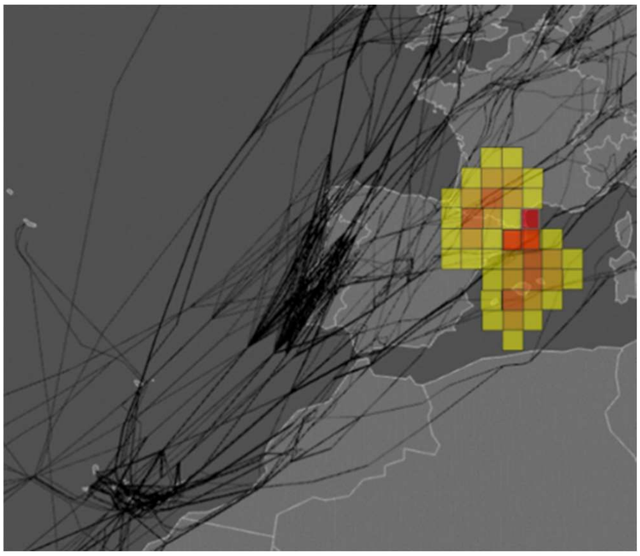


Figure 41 : Forecast of Imbalance at D-0 – 09:30 UTC

- NMOC analyzes the imbalances characteristics, and the Hotspots declared by local FMPs, to determine the start/end time of the event and the severity of the overload. NMOC looks at different sources of information and analyzes in detail the entry counts, occupancy counts and flight list.

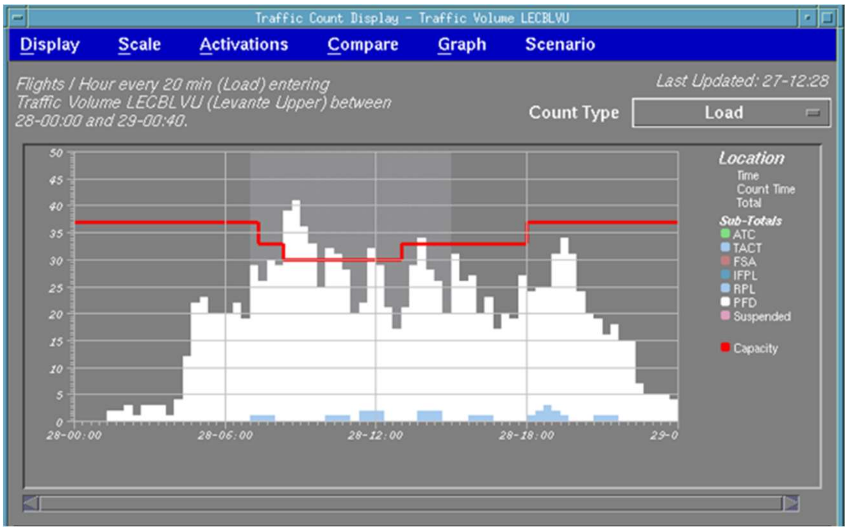


Figure 42 : Sector LECBL Entry Counts showing a capacity drop (OTMV threshold adjusted to the weather event) and Imbalance on D-0 08:30 UTC

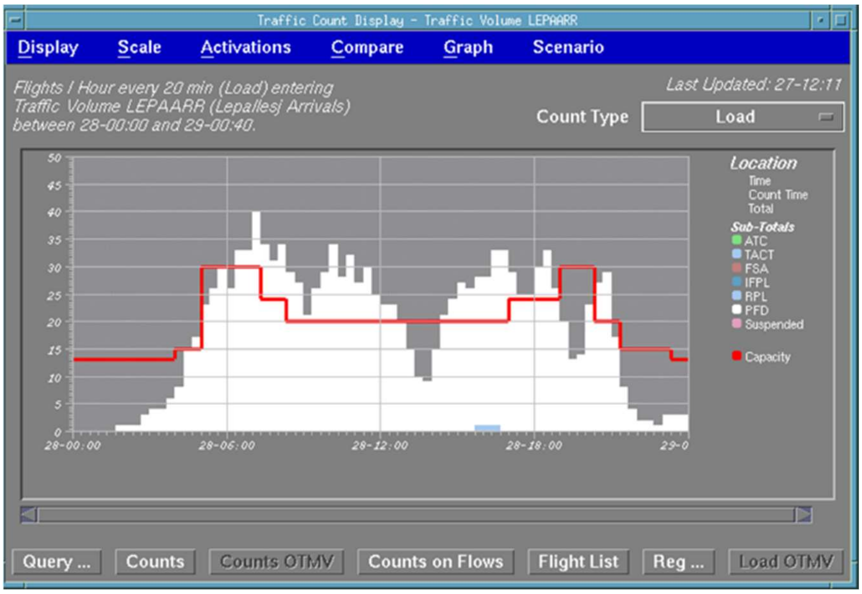


Figure 43 : Sector LEPAARR Entry Counts showing a capacity drop (OTMV threshold adjusted to the weather event) and Imbalance on D-0 08:30 UTC

In addition, NMOC monitors the Gates. The NMOC identifies the imbalance in the areas highlighted by Gates with high flow rate, looking at the network impact through different ACCs and flow axis. NMOC monitors the Gates according to the shape of the affected area:

- In black, directly affected area (Figure 44);
- In green, wider area with opportunity for Re-routing (Figure 45).

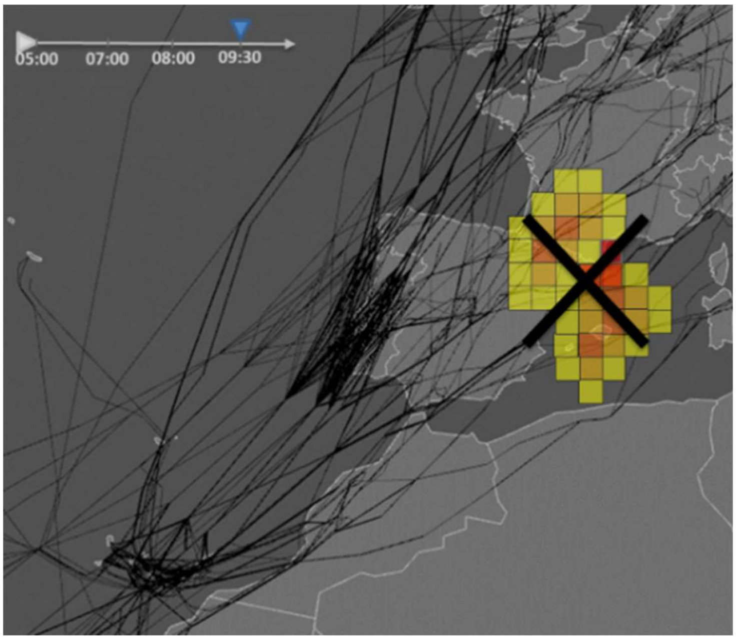


Figure 44 : Monitoring of Gates (Flow Monitoring) to visualize the directly affected area (in black)

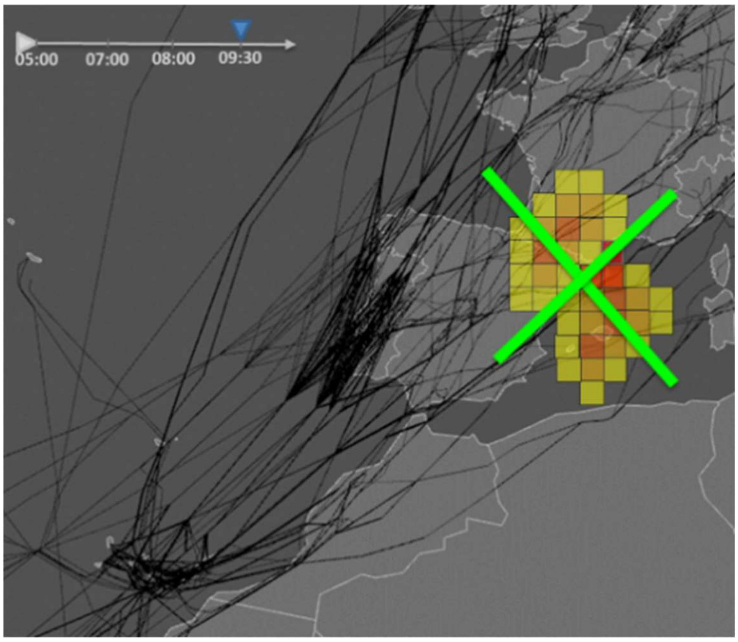


Figure 45 : Monitoring of Gates (Flow Monitoring) to visualize the wider area with opportunity of re-routing (in green)

The evaluation of the network degradation propagation is done by visualizing different time-horizon-predictions.

Due to the propagation of predicted degradation, the identification of linked clusters at network level rises the appearance of a Netspot. The geographical delineation of a potential Netspot can be represented by a group of Traffic Volumes and/or Flows. The shape of the Netspot delineation represents also all stakeholders involved, and so therefore it represents the reference to coordinate the Netspot with the concerned actors.

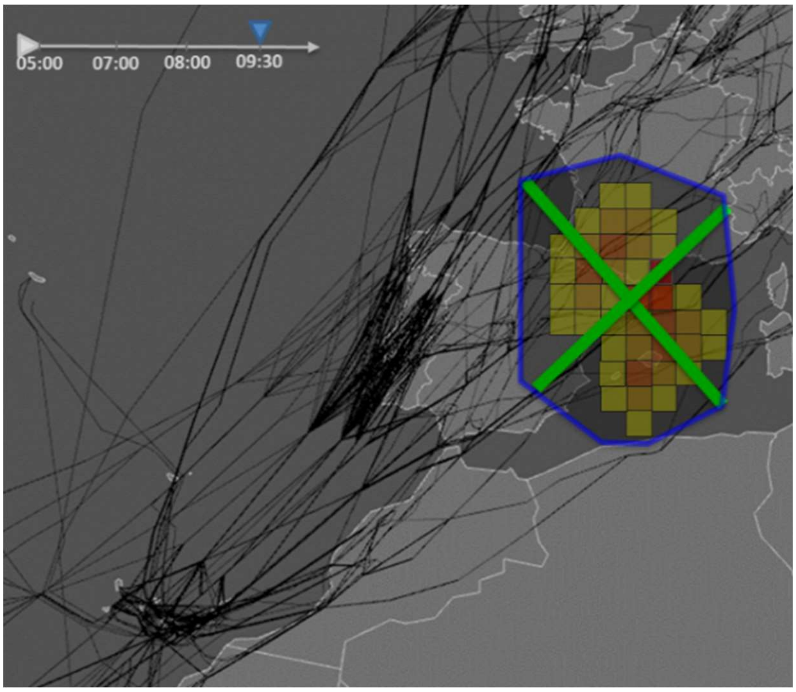


Figure 46 : Creation of a Netspot

Situation at D-1 –10:00 UTC:

NMOC sends a Netspot proposal to the concerned actors to support a collaborative coordination. The concerned FMPs are:

- LECM FMP;
- LEBL FMP;
- LEPA FMP;
- LECS FMP;
- LFBB FMP;
- LFMM FMP.

NMOC starts to investigate the resolution of the Netspot selecting weather scenarios in the Playbook (the Playbook contains all the possible weather scenarios that were agreed at the strategical level with concerned stakeholders - NM, ANPS, AU).

NMOC uses the ***AI Hotspot Solver*** to explore combined measures (flow rate, TFV regulation, re-routing, ….) according to the weather scenario description.

This support tool suggests the best set of measures with flight candidates to the NMOC actors.

The selected weather scenarios will be mainly based on:

- Pretactical block regulations with rate (to be determined/ regarding weather conditions and staffing situation);
- Rerouting of those flows to avoid congested sectors to the West or East options;
- Regulation of specific flows.

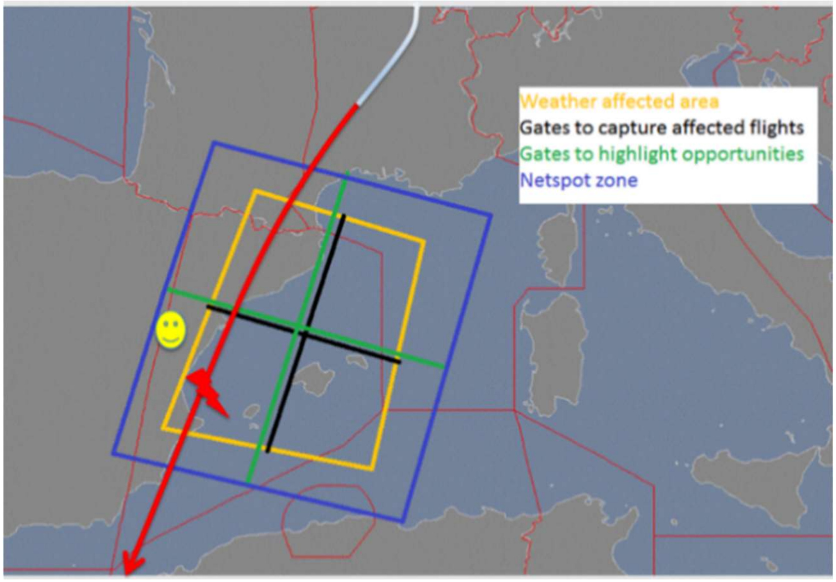


Figure 47 : NMOC and FMPs to identify alternative routes to build the Weather Scenario

Several weather scenarios should co-exist in the Pre-Tactical Network Plan.

NMOC runs multiple what-if simulations to assess the network performance of the proposed weather scenario alternatives.

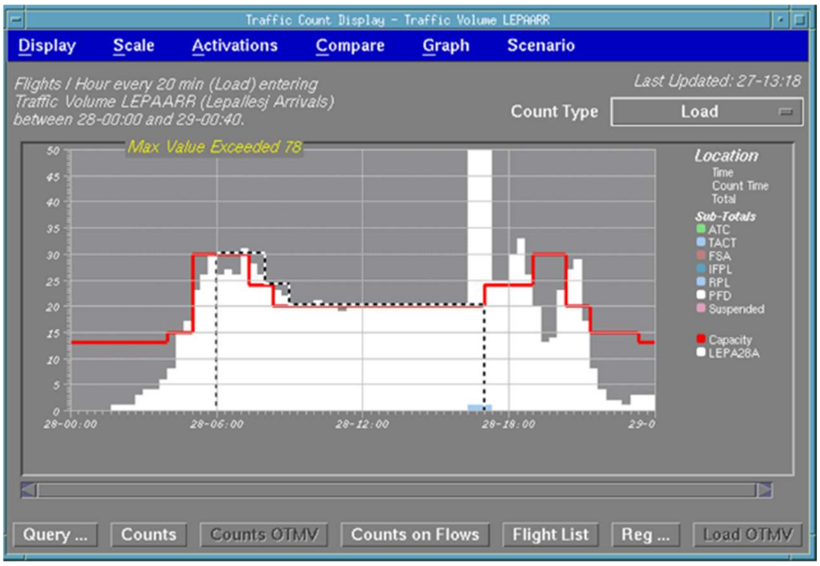


Figure 48 : Simulated Entry Counts with a proposed Weather Scenario

NMOC starts to assess the network performance impact assessment taking into account:

- Which sector may be affected;
- When measures may be applied;
- Estimated capacity reduction;
- Possible areas of capacity for rerouting;
- Impact on staffing situation;
- Impact on military activity;

- Identify re-routing opportunity/scenarios (weather scenario).

Situation at D-1 – 11:00 UTC:

Due to the very-high convective risk areas, NMOC decides to call a collaborative coordination process with the concerned Pre-Tactical FMPs and MET information service provider to manage the proposed Netspot.

NMOC presents its analysis using digital support tools allowing the actors to dynamically exchange information:

- Characteristics of the convective weather and the related DCB impacts (risk probability, severity of the convective event), Sectors affected, estimated Capacity reduction, Imbalance propagation, Netspot delineation, start time/end time severity, ….)
- Characteristics of the proposed solutions (Possible areas of capacity for rerouting/rerouting opportunity, selected weather scenarios, when measures will be applied, …)
- What-if/Performance impact assessment (Impact on staffing situation, Impact on military activity, …)

In this collaborative process, NMOC plays a pivotal role in partnership with:

- Met information service provider;
- Pre-Tactical FMPs (ANSP).

All actors agree on the proposed NMOC solutions. NMOC concludes to the confirmation and agreement of the proposed Netspot, proposed weather scenarios and proposed set of measures and flight candidates.

NMOC establishes a detailed timeline for the implementation and monitoring of the Netspots resolutions.

Situation at D-1 – 13:00 UTC:

Netspot is agreed and published on the NOP *(Netspot status = coordinated*).
Weather scenarios and proposed measures are approved and published in the NOP.

Situation at D-1 – 16:00 UTC:

D-1 Information is published in the Initial Network Plan (INP). Measures already applied in pre-tactical will be published in the INP.

TACTICAL D-0

- On the Tactical D-0, NMOC reassess the situation and adjusts the Network Plan (weather scenario). If there is a significant evolution, NMOC can call a teleconference to review the course of action.
- If in line with the D-1 forecast, pre-agreed measures will be coordinated with the concerned FMPs and adjusted as necessary before implementation.
- Continuous monitoring of the situation and necessary adjustments will be carried on along the day.

<u>Situation at D-0 – 07:00 UTC:</u>

A tactical forecast updating the D-1 forecast is provided and cover the tactical day 09-12;12:15;15-18;18-22 UTC.

The weather scenario is adjusted. In Tactical Day the developed network plan is assessed to ensure the applicability of the ranked Scenarios.
The Revision of the network plan could be triggered depending of

- The evolution of the predicted imbalances,
- The traffic demand accuracy evolutions,
- The time constraints (timeline, horizon) for application.

The revision process is fully coordinated between the Network Manager and the concerned local FMPs. After assessing the applicability, the designed network plan is activated for implementation

<u>Situation at D-0 – 12:00 UTC:</u>

A further forecast is provided updating the D-0 – 07:00 UTC forecast covering the tactical day 12:15;15-18;18-22 UTC.

The weather scenario is adjusted.

3.3.6.3 Convective Weather affecting En-Route Sectors in Spain

Purpose

This scenario describes a specific baseline operational context that will serve as a basis to identify and to develop the future operating methods and process in ISOBAR.

Similarly to the scenario focussed on en-route sectors in France, it describes a convective weather situation and how the "Local FMP" and NMOC team could better manage weather situations: avoid the cascading effects across the network, and together look for a "global optimum" gain.

To illustrate the scenario, meteo and flight details has been adapted using as a reference historical data from Tuesday 27th of August 2019.

Scenario Summary

From the pre-tactical day (D-1) to midday of the day of operations (D-0), the Spanish FMP at Barcelona ACC analyses a series of demand and capacity imbalances resulting from convective weather and solve them in collaboration with Network Manager and benefiting from:

- Improved meteo forecast inputs and
- Higher visibility of Airspace Users' needs and processes.

Scenario Description

The scenario is focussed on Barcelona ACC (represented in light blue in the figure below).

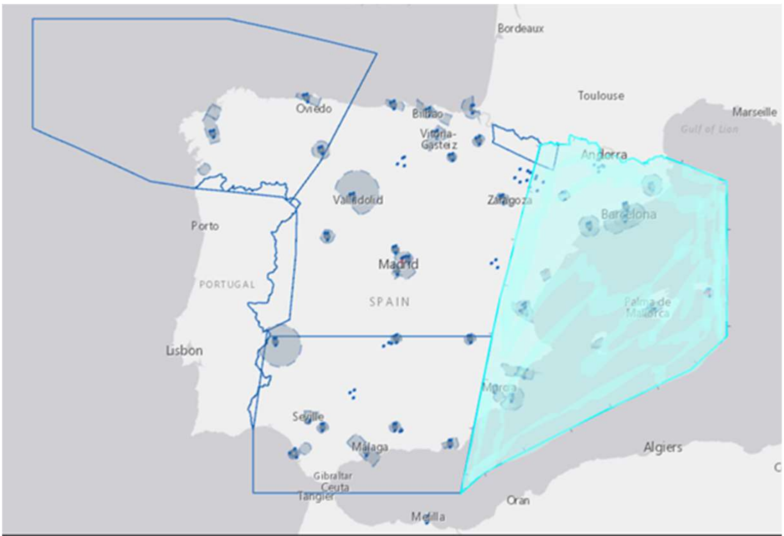


Figure 49: Barcelona ACC as part of Spanish FIR

It spans from 9:00 UTC on D-1 (Monday 26th of August 2019) to 12:00 UTC on D-0 (Tuesday 27th of August 2019). The actors involved are the local FMP and the NMOC.

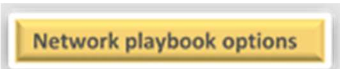
Figure 50illustrates the overview of the scenario steps, indicating:

- Weather forecast updates

- Local (FMP) relevant actions

- Network level (NMOC) relevant actions

- Weather scenarios and associated playbook (pre-set and agreed)



- Local playbook adjustments

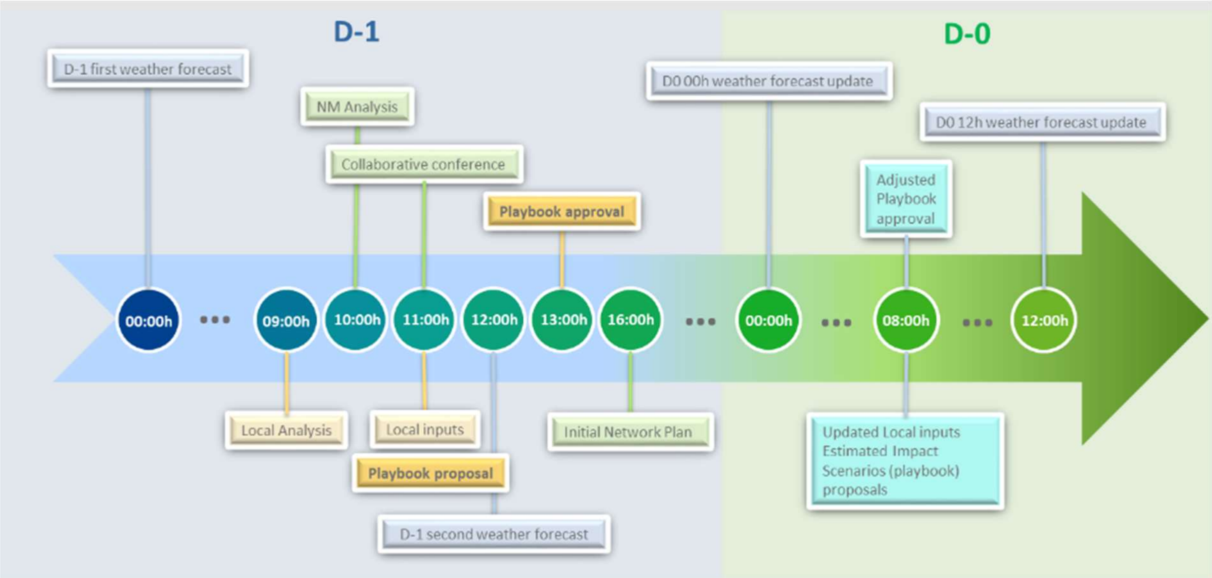


Figure 50: Spanish Operational Scenario Steps

Situation at D-1 – 09:00 UTC:

ANSP/FMP analyses the latest weather/convective events forecast available for D-0 generated by the ***ISOBAR AI Meteo Engine***. These are hourly forecasts for D-0 presented according to Cb risk matrix colour codes (see Figure 4 in section3.3.3.1).

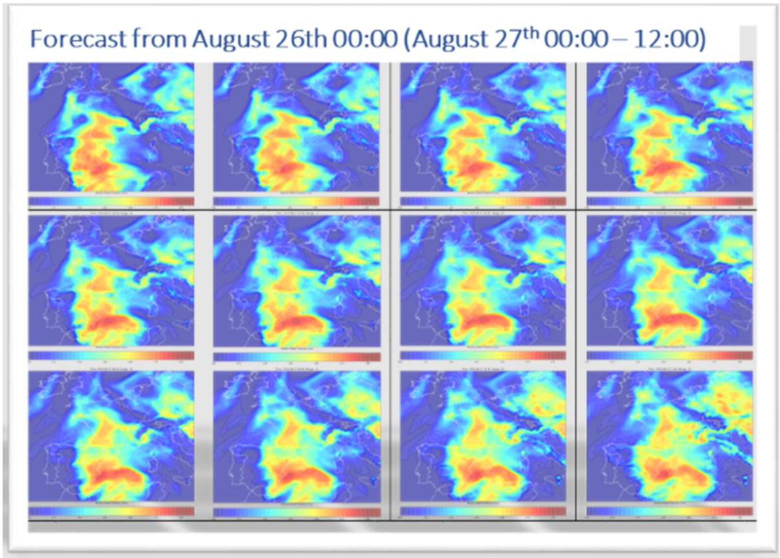


Figure 51: Hourly Convective Weather Forecast at D-1 (00:00 to 12:00 of D-0)

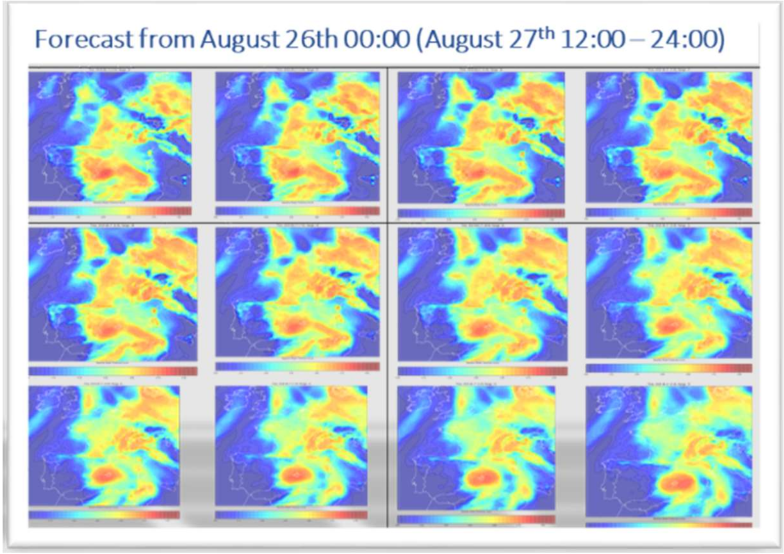


Figure 52: Hourly Convective Weather Forecast at D-1 (12:00 to 24:00 of D-0)

Severe weather alerts are forecasted with high risk of convection for various en-route sectors within LECB ACC route West and East. In view of the expected weather event evolution, the local FMP starts analysing more in detail LECBGO2 sector, where it is expected high risk of convective event (very likely probability of scattered Cb clouds) from 9:00 to 13:00 at D-0, with top of Cb at FL380.

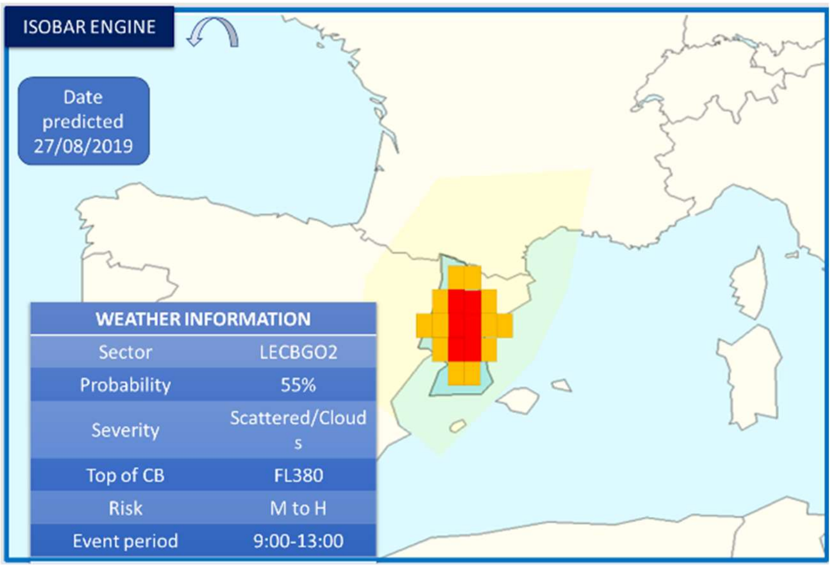


Figure 53: Weather Forecast from AI Meteo Engine at 9:00 UTC D-1

Local FMP starts gathering information on flights impacted, i.e. those crossing the sector during the event period. He/she also estimates capacity reduction in percentage and subsequent DCB imbalance, and analyses past similar events and mitigation solutions with support of automated tools. Spanish FMP sends information to NMOC regarding its view on the Netspot and potential applicable solutions.

Situation at D-1 – 10:00 UTC:

NMOC also addresses the analysis of the weather forecast and predicted convective events. ISOBAR engine supports the process and displays the expected estimated capacity reduction and imbalance.

An imbalance is detected from 10:00 to 12:00 on D-0, when occupancies are expected to exceed the available capacity.

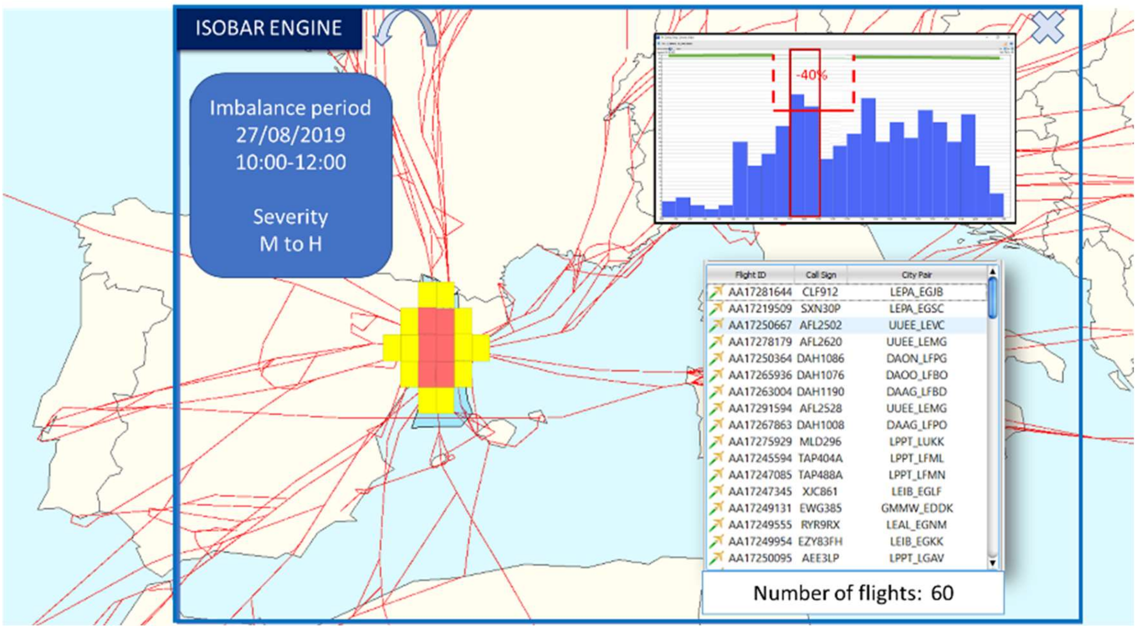


Figure 54: Netspot delineation at 10:00 UTC D-1 for 10:00 to 12:00 UTC D-0

NMOC analyses the information provided by ***AI Hotspot Detection*** in terms not only of the capacity reduction of most impacted sectors, but also in terms of propagation of imbalances.

The evaluation of the network degradation propagation is done by visualizing different time-horizon-predictions. NMOC performs a selection of potential mitigation solutions and configures the proposed weather scenario for D-0, including flight candidates to be included in the solution. NMOC also analyses the Netspots and solutions proposed by the Spanish FMP.

Situation at D-1 – 11:00 UTC:

Due to the high convective risk areas, NMOC decides to call a collaborative coordination process with the concerned FMPs, MET information service providers and concerned Airspace Users to manage the proposed Netspot.

As already described as part of the French scenario, the collaborative coordination process, in which NMOC plays a pivotal role, shall allow the concerned actors (i.e. NMOC and Local FMPs) to exchange information and to discuss the characteristics of the identified Netspot resulting:

- in the confirmation or not of the potential Netspot;
- agreement of proposed solution;
- understanding of the performance impact assessment.

The information is exchanged digitally and a common and dynamic (evolution in time) view is shared:

- Event expected and probability according to latest available forecast;
- Imbalance period;
- Severity of imbalance (estimated capacity reduction);
- Sectors impacted;

- Traffic impacted;
- Identification of available capacity in adjacent sectors (re-routing opportunities);
- Potential sets of DCB measures (including data on historical measures and current available alternative optimal routes/ flight plans shared by Airspace Users);
- Expected performance impact of each solution:
    - Number of flights regulated, total delay/ average flight delay;
    - Number of flights re-routed, total delay/ average flight delay and total extra-miles/ average extra-miles per flight.

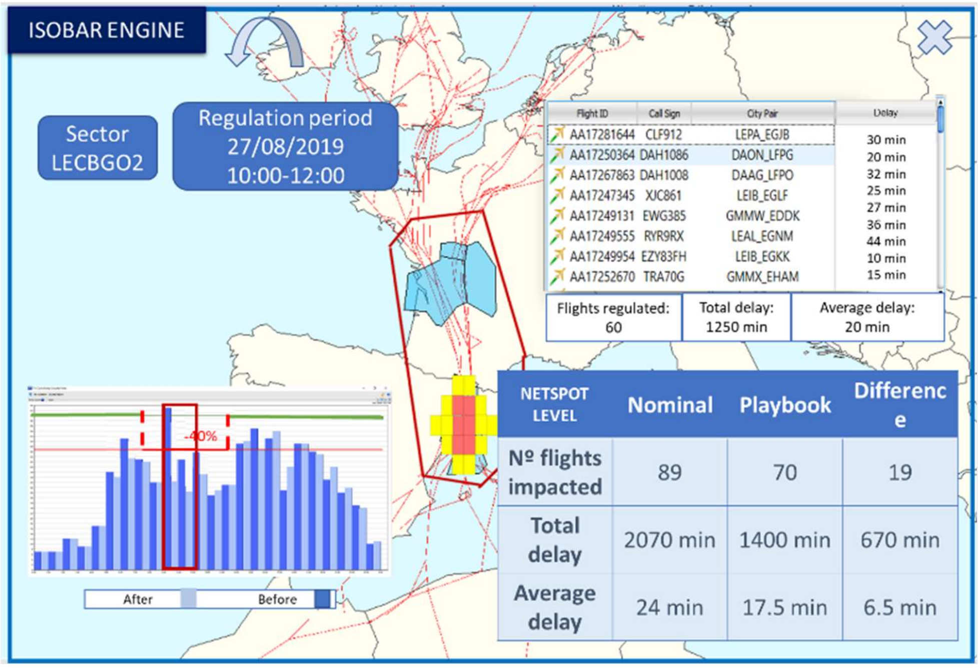


Figure 55: Common Information on weather scenario proposal for LECBGO2 sector at 11:00 UTC on D-1

Thanks to the ISOBAR forecast also available for the AU flight planning systems (via B2B), AU can compute the possible routes for each flight, taking into account the weather and possible ATC constraints already published. AU checks which flights are affected by the high convective risk area. For each flight, AU has several routes available for each city pair (company routes, optimised routes provided by CFSP). AU provides a number of routes that can be considered for rerouting by the AI AU Preference (example see below)

		Vr	To	Rt	Via	Typ	Reg	CI	Altr	Dis	AF	TripF	Tim	PrfC	OvrC	DlyC	TotC	Min
1	*	1	EDDH	01		LXCS1	HBJBG	50	EDDW	502	378	2201	1.16	0	0	0	0	3913
2		5	EDDH	80Q	OPTIMIZED-OVF	LXCS1	HBJBG	50	EDDV	502	340	2362	1.16	65	0	0	65	4196
3		3	EDDH	802	OPTIMIZED-	LXCS1	HBJBG	50	EDDV	565	405	2329	1.24	102	162	0	264	4146
4		2	EDDH	11		LXCS1	HBJBG	50	EDDV	511	234	2901	1.18	296	0	0	296	4765
5		4	EDDH	80P	OPTIMIZED-OVF	LXCS1	HBJBG	50	EDDV	605	333	2846	1.30	352	239	0	591	4683

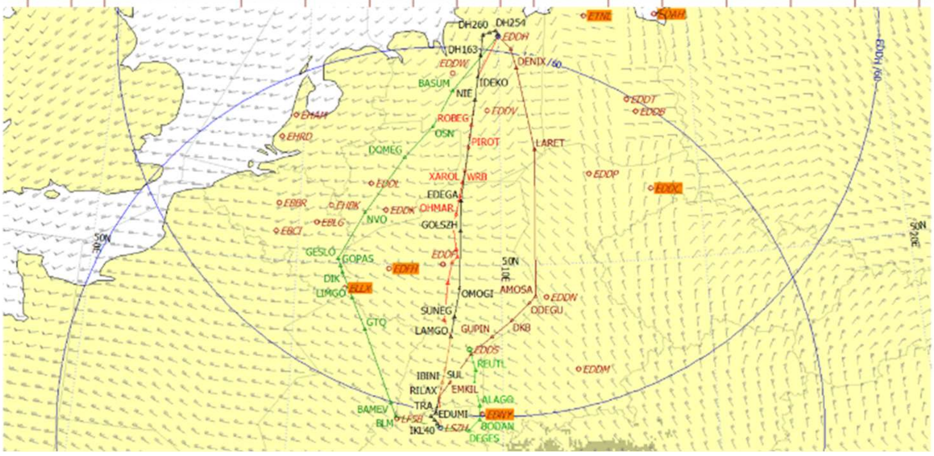


Figure 56 : AU provides a number of routes that can be considered for rerouting by the AI AU Preference

AU receive a reroute proposal e.g. from the routes already sent or a new proposal that has been identified by ISOBAR as the most efficient route to avoid the risk area. The AU may consider the route in order to avoid delays, increase flight efficiency and safety by taken into account the business priorities.

To resolve the Netspot with center on LECBGO2, the weather scenario proposes:

- 19 Weather regulations, with rate 0 at different time periods in LEIB, LEPA, LEAL, LERS;
- 8 traffic diverted, due to several affected sectors in LECB, regulated with reduced capacity (LVU, LVL, BAS, LVS, CCC, GO1, GO2, GO3, DDI, P2R).

NMOC consolidates the local options to network driving solutions in the weather scenario **proposal**.

<u>Situation at D-1 – 13:00 UTC:</u>
At 12:00 UTC D-1 an updated forecast is received. It confirms previous forecast and increases the probability of the event to 70%. With these data, the weather scenario, Netspot and proposed playbook are approved and published on the NOP *(Netspot status = coordinated*).

<u>Situation at D-1 – 16:00 UTC:</u>
As already described in the French scenario, D-1 Information is published in the **Initial Network Plan** (INP). Measures already applied in pre-tactical phase are also published in the INP.

<u>Situation at D-0 – 08:00 UTC:</u>
All actors work with the latest forecast issued at 00:00 UTC on the day of operations (D-0). The INP is also reviewed in view of the most up-to-date demand data. Changes to the published weather scenario may occur if:

- There are significant changes in the weather forecast and/ or demand and thus on the estimated imbalance, decreasing the estimated efficiency of the weather scenario solutions and thus making the NOP inoperative ;
- It is estimated that adjustments of the weather scenario can lead to important performance benefits in view of the latest forecasts of weather, demand and capacity.

The changes along D-0 shall take into account that the decrease in lead times for the publication of measures does not affect negatively the total performance benefits expected from their application. At anytime the NMOC has the final decision about changes in the agreed weather scenario, commensurate to the evolution of the situation.

Situation at D-0 – 12:00 UTC:
Both Spanish FMP and NMOC follow the established and detailed timeline for the implementation of the Netspot resolutions. From the time of weather scenario measures application onwards the evolution of the situation and the efficiency of the selected measures are monitored. All observations are gathered to be analysed during post-ops and used to feed the automated tools and improve their learning capabilities.

3.3.7 Use Cases

It is proposed to define a single use-case to describe the complete process, which will be illustrated in three operational scenarios.

The Use Case represents a particular flow of events, actors and actions that can take place in the particular environment corresponding to the ISOBAR Detailed Operating Method.

UC#	UC Title	UC Description
UC-01	Detection of Netspot in the pre-tactical (D-1). Reassessment and Adjustment of the Network Plan in the tactical phase	In the pre-tactical phase, monitoring of convective weather information and predicted imbalances triggers the detection of a deterioration of the network performance and the transition from a nominal to a critical weather situation. A weather scenario is defined and coordinated to resolve the Netspot. In the tactical phase, the weather situation and DCB impact are reassessed. If necessary, the weather scenario is re-adjusted accordingly.

UC-01 –Detection and Resolution of a Netspot in Pre-Tactical Phase (D-1) and re-assessed in the Tactical Phase (D-0)

N°	Action	Description	Actor	Information	Type	Time
	Pre-Tactical Timeframe	Detection of Netspot in pre-tactical (D-1): all flights are before EOBT, so anything that			Context	

N°	Action	Description	Actor	Information	Type	Time
		is up to around 14H00 UTC of day -1				
1.0	Analyse the convective forecast information	NMOC/Pre-tactical FMP receives and analyses the weather/convective event forecast generated by the ***AI Meteo Engine.*** Predictive convective information is displayed on NMOC/FMP position on geographical map and in the sector configuration monitoring tools.	NMOC Pre-tactical FMP	*AI Meteo Engine*	Analysis	D-1 09:00 UTC
2.0	Decision-making triggered on Very-High convective risk	NMOC/Pre-tactical FMP detects High or Very High Convective Area Risk prediction on D-1. It will trigger the following actions in order to prevent and deconflict chaotic situation on Pre-Tactical D-1 phase.	NMOC		Action	D-1 09:00 UTC
3.0	Analyse the imbalances due to convective weather	***AI Hotspot Detection*** provides information to NMOC/Pre-Tactical FMP: weather predicted capacity reduction, weather predicted demand adjustment, weather predicted imbalance. NMOC/Pre-tactical FMP analyses the induced weather capacity reduction and the DCB network impact (imbalance forecast) at the different time horizon.	NMOC Pre-tactical FMP	*AI Hotspot Detection*	Analysis	D-1 09:30 UTC
4.0	Analyse the Network Gates	In addition, NMOC/Pre-tactical FMP monitors and analyzes the impact on the Gates. It supports the identification of Gates with high flow rate, looking at the network impact through different ACCs and flow axis. The evaluation of the network degradation propagation is	NMOC Pre-tactical FMP	*Gates*	Analysis	D-1 09:30 UTC

N°	Action	Description	Actor	Information	Type	Time
		done by visualizing different time-horizon predictions.				
5.0	Adjust the Capacity Threshold (MV, OTMV)	After analysis, the Pre-Tactical FMP decide to adjust the Capacity Threshold (MV, OTMV) taking into account the predicted weather capacity reduction and confirm the value of this Capacity Threshold (MV, OTMV).	Pre-tactical FMP	*Capacity Thresholds (MV, OTMV).*	Action	D-1 09:30 UTC
6.0	Re-assess the imbalances at the network level	NMOC re-assess the imbalance situation at the network level. It is based on a robust network view fed by the capacity threshold confirmation.	NMOC	*Imbalances*	Action	D-1 09:30 UTC
7.0	Define Hotspots	Analysing the confirmed imbalance situation, the Pre-Tactical FMP declares Hotspots. Hotspots are notified to the NM system.	Pre-tactical FMP	*Hotspots*		
8.0	Define a Netspot	NMOC analyzes the declared Hotspots due to the weather situations and identifies linked Hotspots (cluster) at the network level. The geographical delineation of the Netspot can be represented by a group of TFV and/or Flows.	NMOC	*Netspot draft*	Action	D-1 09:30 UTC
9.0	Propose a Netspot	NMOC publishes a Netspot to the concerned local FMPs	NMOC	*Netspot Proposed*	Action	D-1 09:30 UTC
10.0	Access to the Netspot	Pre-tactical FMP have access to the published Netspot Information and starts to analyse the Netspot situation	Pre-tactical FMP	*Netspot*		D-1 09:30 UTC
11.0	Select the weather scenarios from the Playbook	NMOC/Pre-tactical FMP selects weather scenarios from the Playbook	NMOC Pre-tactical FMP	*Weather Scenarios*	Action	D-1 10:00 UTC

N°	Action	Description	Actor	Information	Type	Time
12.0	Preparation of weather scenarios	NMOC/Pre-Tactical runs the ***AI Hotspot Solver*** to identify combined measures (flow rate, TFV regulation, re-routing,…) and flight candidates (taking into account AU Preference) to implement the weather to resolve the Netspot. NMOC/Pre-Tactical FMP makes the performance assessment to assess the network impact of the proposed weather scenarios.	NMOC	*AI Hotspot Solver*	Action	D-1 10:00 UTC
13.0	Call for a Collaborative Coordination	NMOC decide to call a collaborative coordination with the concerned Pre-tactical FMPs. These actors will discuss and analyse the confirmation of the Netspot and proposed weather scenarios.	NMOC Pre-tactical FMP	*Netspot Coordinated*	Action	D-1 11:00 UTC
14.0	Confirm the weather scenario and proposed measures	NMOC and Pre-Tactical FMPs agree on the weather scenarios to implement, establishing a common understanding of the proposed solutions and network impact/performance assessment.	NMOC Pre-tactical FMP	*Selection and approval of Weather Scenarios and proposed measures*	Action	D-1 11:00 UTC
15.0	Rank the weather scenarios	Several weather scenarios can be selected as alternatives and are ranked. NMOC plays a pivotal role to manage the ranking.	NMOC Pre-tactical FMP	*Ranked Weather Scenarios*	Action	D-1 11:00 UTC
16.0	Publish Weather Scenario	NMOC publishes the selected weather scenario and proposes measures with flight candidates in the NOP	NMOC	*Weather scenario and proposed measures are published in the NOP.*	Action	D-1 13:00 UTC

N°	Action	Description	Actor	Information	Type	Time
17.0	Publish the Netspot in the NOP	NMOC publishes D-1 information in the Initial Network Plan. Measures already applied in pre-tactical will be published in the INP.	NMOC	*All NMF & AU actors have access to the published Netspot and weather scenarios information*	Action	D-1 16:00 UTC
	Tactical Phase D-0 :	reassessment and adjustment of the D-1 Network Plan			Context	
18.0	Re-assess the Network Plan	NMOC and FMP reassess the traffic situation and adjust the weather scenarios. A tactical forecast updating the D-1 forecast is provided and cover the tactical day 09-12;12-15;15-18;18-22 UTC. The weather scenario is adjusted. In Tactical Day the developed network plan is assessed to ensure the applicability of the ranked Scenarios. The Revision of the network plan could be triggered depending of: • The evolution of the predicted imbalances, • The traffic demand accuracy evolutions, • The time constraints (timeline, horizon) for application. The revision process is fully coordinated between NMOC and the concerned local FMPs. After assessing the applicability, the designed network plan is activated for implementation.	NMOC FMP	*AI Meteo Engine* *AI Hotspot Detection* *Imbalances* *Hotspots*	Analysis	D-0 07:00 UTC & 12:00 UTC

N°	Action	Description	Actor	Information	Type	Time
19.0	Call for a collaborative conference	If needed NMOC call for a collaborative conference to discuss re-adjustment of weather scenarios.	NMOC FMP	*Weather Scenarios*	Action	D-0
20.0	Publish the Scenario in the Network Plan	NMOC publishes the updated weather scenarios in the NOP NM Network Plan.	NMOC	*Netspot, weather scenarios coordinated and updated*	Action	D-0
	Completed	The use case ends				

3.3.8 Differences between new and previous Operating Methods

The new operating method proposes several axes of improvement:

- Use of AI machine learning technics to improve the convective-weather prediction;
- Use of AI machine learning technics to predict the weather-related propagation of the imbalances in the network;
- Use of AI machine learning to select the AU preferred trajectory for rerouting;
- Use of AI machine learning technics to propose solutions to resolve the weather imbalances;
- Digitalisation of end-users support tools;
- Introduction of novel principles to monitor and manage flows;
- Improvement of the Collaborative process and workflow.

The following table provides a comparative summary of the improvements with regard to the current operating method.

Activities (in EATMA) that are impacted by the SESAR Solution	**Current Operating Method**	**New Operating Method**
Meteo Forecast	Deterministic prediction is based on the use of numerical weather forecasting models, which simulate the behavior of the atmosphere by relying on equations of	Historical convection probabilities along and storm observations (based on Rapid Developing Thunderstorms (RDT) data) will be used to train a time-lagged model to identify weather conditions that are conducive to the development of storms by using a ConvLSTM (convolutional Long Short-Term Memory neural network) to identify spatial and temporal correlations between NWP parameters, convection probabilities and storms. The output of this model will be a probabilistic characterisation of storm occurrence tailored to the ATM requirements (spatial and

Activities (in EATMA) that are impacted by the SESAR Solution	Current Operating Method	New Operating Method
	physics and thermodynamics.	temporal granularities) at each step of the ATFCM process.
Hotspot Detection	Relying on operator experience	Predicting the weather capacity reduction and weather demand adjustment induced by convective-weather prediction are keys to predict the propagation of imbalances in the network. This becomes possible with the use of advanced data science and AI prediction techniques (machine learning) to predict how convective-weather will impact the DCB imbalances at the network level.
Hotspot Solver	Relying on operator experience	It is proposed to develop an AI Hotspot Solver (automated aid-tool) to identify set of measures to be apply for a weather scenario. It will be based on AI supported techniques. This model will explore the catalogue of measures exploring millions of combined measures to learn and find optimized solutions. In addition, it will take AU preferences into account to propose delay and rerouting measures.
AU Preference	None	It is proposed to develop machine learning technique to provide AU preferred route to apply rerouting measures.
Digitalisation of Support Tools	None	A set of tools are developed for the end-users (NMOC/FMP): - HMI Groupware to support the collaborative process and information exchange; - HMI Synthetic convective weather map; - HMI to visualize weather capacity reduction and propagation of weather imbalances; - HMI to visualize Gates and Flow monitoring; - HMI Timeline to visualize and to manage the set of Measures provided by the AI Hotspot Solver; - HMI what-if to assess the network impact of a set of measures for different weather scenarios.
Monitoring and Analysis of network-oriented congestion	None	A set operational capabilities have been proposed: - Gates to monitor the flow; - Netspot object to manipulate linked-clusters.
Collaborative Process	Workflow defined in the Cross-Border	Refinement of the collaborative process to manage complex cross-border weather critical situations.

Activities (in EATMA) that are impacted by the SESAR Solution	Current Operating Method	New Operating Method
	Weather Operation Initiative	

4 Safety, Performance and Interoperability Requirements (SPR-INTEROP)

[REQ]

Identifier	REQ-OSED-ISOBAR.1010
Title	Traffic Demand information
Requirement	The NM/FMP shall be able to see the information about the traffic demand through the system (ISOBAR Engine), including: - Baseline demand - Local plans for the day of operation - Entry counts - Occupancy graphs (requires capacity information)
Status	<in progress>
Rationale	The NM/FMP shall be supported by the system to monitor the traffic situation.
Domain	Demand
Type	Data

[REQ]

Identifier	REQ-OSED-ISOBAR.1020
Title	Meteo - Traffic Demand Map

Requirement	The Meteo Map shall have the option to display the weather forecast combined with the traffic demand data for the different sectors. The following information is expected to be presented:
	• Weather information
	  ○ Risk matrix
	  ○ Weather phenomena
	  ○ Probability of occurrence
	  ○ Severity
	  ○ Altitude
	• Demand information
	  ○ Predicted traffic
	  ○ Sector load
	  ○ Flight information

Status	<in progress>
Rationale	Facilitating the understanding of the meteo situation by providing more context through more complete views.
Domain	Demand/Weather
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.2010
Title	Capacity information
Requirement	The NM/FMP shall be able to see the information about the baseline capacity values of the sectors through the system (ISOBAR Engine), in terms of: - Declared/nominal capacity - Actual capacity - Average capacity data which shall be included in the bar chart as a function of time
Status	<in progress>
Rationale	The NM/FMP shall be supported by the system to monitor the capacity situation.
Domain	Capacity
Type	Data

[REQ]

Identifier	REQ-OSED-ISOBAR.2020
Title	Sector configuration
Requirement	The system shall provide clear basic information about which sectorization is being considered and which is being predicted, highlighting the sectors affected by the convective weather.
Status	<in progress>
Rationale	Improving the clarity and facilitating the decision-making process since this requirement is linked to the capacity reduction determination and helps understanding if measures are required.
Domain	Capacity
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.2030
Title	Capacity reduction estimation
Requirement	The NM/FMP shall be able to see the estimations on the capacity reduction expected on a given scenario and the reasons behind it through the system (ISOBAR Engine).
Status	<in progress>
Rationale	Required for situation awareness and allows to inform the FMP / NM / ACCs that problems may happen.
Domain	Capacity
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.2031
Title	Display capacity reduction correlated with weather severity
Requirement	The severity of the weather and how the capacity is affected by it shall displayed at the same time, allowing the user to see it at first sight.
Status	<in progress>
Rationale	Required for situation awareness and allows to inform the FMP / NM / ACCs that problems may happen.
Domain	Capacity
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.2032
Title	Capacity reduction estimation: Proposed reduction
Requirement	The system shall include a function to confirm or accept the proposed capacity reduction.
Status	<in progress>
Rationale	The NM/FMP shall be supported by the system to monitor and validate the capacity reduction.
Domain	Capacity
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.2040
Title	Sector availability
Requirement	A list of all the available sectors and configurations and a map where each sector is located shall be included.
Status	<in progress>
Rationale	This information helps the user by providing a more complete view and facilitates the understanding of the situation.
Domain	Capacity
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3010
Title	Define Network Gates
Requirement	NMOC and FMP actors shall be able to define network Gates in an HMI support tool (ISOBAR engine).
Status	<in progress>
Rationale	To monitor the propagation of a traffic degradation along flows in the network, the NMOC and the FMP defines network Gates to analyses the flow entries through the Gate, and therefore, to identify the flights or groups of flights that may interact together or overload an area. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR. 3011
Title	Predefined Network Gates
Requirement	NMOC and FMP actors shall be able to define Pre-defined Gates that are placed at strategic locations across the network.
Status	<in progress>
Rationale	The aim is to focus on locations that regularly have a non-nominal or critical state event. To monitor the propagation of a traffic degradation along flows in the network, the NMOC and the FMP defines network Gates to analyses the flow entries through the Gate, and therefore, to identify the flights or groups of flights that may interact together or overload an area. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR. 3012
Title	Predefined Ad-hoc Gates
Requirement	NMOC and FMP actors shall be able to define Ad-hoc Gates created at specific locations confronted to unplanned events.
Status	<in progress>
Rationale	The ad-hoc Gates aim at refining/fine-tuning non-nominal and critical states analysis (e.g. Weather systems…) based on local inputs (FMP). To monitor the propagation of a traffic degradation along flows in the network, the NMOC and the FMP defines network Gates to analyses the flow entries through the Gate, and therefore, to identify the flights or groups of flights that may interact together or overload an area. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR. 3013
Title	Capacity Model for Network Gate 1/2
Requirement	A capacity model shall provide the flow capacity of the Network Gate.
Status	<in progress>
Rationale	NMOC/FMP determines peak periods and busiest locations on the axis throughout the day. To do so, a flow rate is associated to the network Gate (e.g. by hours, by 20 min), counting the number of flights passing through the Gate at a given period. This rate is compared to the flow capacity, determined by a capacity model dependant of the dynamicity of the flow. Requirements from S49.
Domain	DCB
Type	Data

[REQ]

Identifier	REQ-OSED-ISOBAR. 3014
Title	Capacity Model for Network Gate 2/2
Requirement	Traffic crossing the Gate at the same time but at different points shall be considered as part of the same time period.
Status	<in progress>
Rationale	Traffic crossing the Gate at the same time but at different points is considered as part of the same time period. Requirements from S49.
Domain	DCB
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3015
Title	Network Gate Features
Requirement	NMOC and FMP actors shall be able to define the features of network Gates: • Gate ID • Time activation • Selection of Exclusion/inclusion/Exempted sub-flows • Selection of ADEP/ADES flow • Specify directional or bi-directional flow • Range of levels • Define rate/peak thresholds • Establish active and inactive sectors being intersected by a Gate and corresponding counts. • Geographical line or central axis in case of sliding Gate
Status	<in progress>
Rationale	Complete features to specify the Gates is needed. Requirements from S49.
Domain	DCB
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3016
Title	Subdivision and Aggregation of Network Gates
Requirement	NMOC and FMP actors shall be able to subdivide a Gate into several Gates and to aggregate several sub Gates into one Gate.
Status	<in progress>
Rationale	A network Gate can be divided into smaller surfaces to analyse sub-flows (or vice versa). Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3017
Title	Publish Network Gates
Requirement	NMOC and FMP actors shall be able to publish the network Gates in the NOP Gates Repository
Status	<in progress>
Rationale	Network Gates are stored in the NOP Gate Repository Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3018
Title	Select Network Gates
Requirement	NMOC and FMP actors shall be able to select from the NOP Gate Repository the Gates to monitor.
Status	<in progress>
Rationale	NMOC and FMP can have access to all the network Gates defined using filtering to select the ones to visualize. In particular NMOC can have access to his own Gates but also to ones of others FMP. Conversely, FMP should prefer to visualize only his own Gates. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3019
Title	Monitor Network Gates
Requirement	NMOC and FMP actors shall be able to monitor the network Gates.
Status	<in progress>
Rationale	The Gate monitoring is based on the rate excess severity (green, orange, red), informing about the predicted flow entries compared to the defined capacity threshold rate. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3020
Title	Network Gates Sliding
Requirement	NMOC and FMP actors shall be able to make a Gates sliding along any sort of axis (pre-determined, ad hoc…) to analyse the predicted flow entries.
Status	<in progress>
Rationale	Gates sliding along any sort of axis (pre-determined, ad hoc…) to analyse the predicted flow entries. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3021
Title	Network Gates Visualization
Requirement	NMOC and FMP actors shall be able to visualize the vertical distribution of the flights passing through the Gates.
Status	<in progress>
Rationale	Visualization of the vertical distribution of the flights passing through the Gates. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3030
Title	Imbalance Methodology
Requirement	The Hotspot Detection AI shall generate the Imbalance through a defined methodology to determine the propagation of the imbalance.
Status	<in progress>
Rationale	To monitor the propagation of a traffic degradation along flows in the network, the NMOC monitors and analyses the flow entries through the Gate. Then if severity is orange/red, NMOC analyses the complete pictures to understand how imbalance clusters are linked.
Domain	DCB
Type	Data

[REQ]

Identifier	REQ-OSED-ISOBAR.3031
Title	Imbalance Thresholds
Requirement	A classification of the imbalance severity shall be determined through the pre-defined Thresholds.
Status	<in progress>
Rationale	Imbalance Thresholds are defined to determine the imbalance severity: • Green: normal and nominal • Orange: normal and non-nominal • Red: critical
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3032
Title	Detection of Imbalance
Requirement	NMOC shall detect the Imbalance using methodology (generated by the AI Hotspot Detection) and figures.
Status	<in progress>
Rationale	To monitor the propagation of a traffic degradation along flows in the network, the NMOC monitors and analyses the flow entries through the Gate. Then if severity is orange/red, NMOC analyses the complete pictures to understand how imbalance clusters are linked. The emergence and propagation of imbalances, linked clusters and/or the degradation of the regional performance KPIs shall trigger the identification of a potential imbalance.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3040
Title	NMOC mandatory role
Requirement	NMOC shall have a mandatory role to detect imbalance, i.e. propagation of a network imbalance.
Status	<in progress>
Rationale	NMOC has an increase role of responsibility to monitor the Imbalance.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3050
Title	Definition of a Netspot
Requirement	NMOC shall be able to define a Netspot in an HMI support tool (ISOBAR engine).
Status	<in progress>
Rationale	The geographical delineation of a potential (i.e. draft) Netspot can be represented by a group of Traffic Volume and/or Flow. The Netspot do not have any predefined boundaries and HMI support tools shall allow the NM ops to manually identify the potential (i.e. draft) Netspot geographical boundaries. This consists of manually drawing an outline to represent a grouping of identified overloads. System evolution towards automated assistance should be envisaged in a further step. The shape of the Netspot delineation represents also all stakeholders involved, and so therefore it represents the reference to coordinate the Netspot with the concerned actors. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3051
Title	Netspot delineation
Requirement	The delineation of the Netspot shall be adjusted to take into account the hotspot evolution.
Status	<in progress>
Rationale	The weather situation will evolves impacting the hotspot indentification, then the Netspot delineation. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3052
Title	Netspot status
Requirement	The Netspot shall be managed with different status: - Draft: The Netspot is defined by NMOC locally - Proposed: The Netspot is proposed to the concerned actors - Coordinated: the Netspot has been coordinated with the concerned actors and has been published in the NOP
Status	<in progress>
Rationale	The Netspot is managed with different status. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3053
Title	Netspot coordination
Requirement	NMOC shall coordinate the Netspot with the concerned FMPs.
Status	<in progress>
Rationale	NMOC coordinates the Netspot with the concerned actors. This collaborative process will confirm/adjust/cancel the Netspot proposal. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3054
Title	Netspot publication
Requirement	NMOC shall be able to publish the Netspot in the NOP.
Status	<in progress>
Rationale	NMOC is responsible to publish the Netspot in the NOP if the Netspot has been confirmed with the concerned actors. Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3055
Title	Netspot notification
Requirement	The NOP shall notify the Netspot to all stakeholders.
Status	<in progress>
Rationale	When the Netspot published, a notification will be sent to all stakeholders Requirements from S49.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3056
Title	Netspot Eligibility
Requirement	A Traffic Volume shall refer to an unique Netspot for a determined duration.
Status	<in progress>
Rationale	The same traffic volume cannot stay in two Netspots at the same time.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3057
Title	Netspot Eligibility (2)

Requirement	The FMP/NM shall define a Netspot with a minimum and maximum duration to be eligible.
Status	<in progress>
Rationale	A minimum and maximum duration must be defined by FMP/NM for the Netspot to be eligible.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3060
Title	B2B Services
Requirement	NMOC and FMP actors shall be able, through B2B interoperable service, to: - Publish/Get Gate - Publish/Get Netspot - Coordinate Netspot - Coordinate weather scenarios
Status	<in progress>
Rationale	A set of B2B services is needed to manage network imbalances.
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3070
Title	Performance Dashboard
Requirement	NM actors shall been able to visualize the Performance Dashboard displaying: - Gates - Netspot - Weather Scenarios -
Status	<in progress>
Rationale	NMf actors must been able to visualize the Performance Dashboard displaying the Gates, Netspot, Performance Indicators, Thresholds, Targets of the different stakeholders in order to design solution accommodating the different PIs
Domain	DCB
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.3080
Title	Imbalances probability
Requirement	The NM shall be able to see the probability of occurrence of a predicted imbalance through the system (ISOBAR Engine).
Status	<in progress>
Rationale	The addition of this probability helps to provide more context on the predicted imbalance information.
Domain	DCB
Type	Data

[REQ]

Identifier	REQ-OSED-ISOBAR.3090
Title	Network Impact Assessment Sharing
Requirement	Network Impact Assessment shall be shared with the concerned actors in the Netspot resolution in order to raise the situation awareness and understanding of the scenario/solution proposed
Status	<in progress>
Rationale	Impact Assessment is shared with the concerned actors in the Netspot resolution in order to raise the situation awareness and understanding of the scenario/solution proposed
Domain	DCB
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4010
Title	Pre-Tactical Multiple weather scenarios Alternatives
Requirement	In the Pre-Tactical frame, NMOC as pivotal role and pre-tactical FMP shall be able to prepare multiple alternative weather scenarios to resolve the Netspot. The NMOC shall initiate the proposition of alternative scenarios and to take the final decision in the coordination process with the concerned actors.
Status	<in progress>
Rationale	NM actors must been able to anticipate different scenarios to resolve the Netspot.
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4020
Title	Ranked Alternative weather scenarios
Requirement	NM actors shall be able to rank the different alternative weather scenarios using what-if impact assessment and to select the most probable weather scenario.
Status	<in progress>
Rationale	NM actors must be able to rank the different alternative scenarios using a what-if and to select the most probable scenario.
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4030
Title	Publication of the alternative weather scenarios
Requirement	The alternative weather scenarios shall be published in the NM Initial Network Plan (INP).
Status	<in progress>
Rationale	Alternative scenarios must be published in the Initial Network Plan (INP) to disseminate the information to all stakeholders.
Domain	Playbook
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4040
Title	Coordination of the alternative weather scenarios
Requirement	The alternative scenarios shall be coordinated with all actors concerned by the Netspot resolution through a digital collaborative tool augmented with an audio channel.
Status	<in progress>
Rationale	All actors concerned by the Netspot resolution must be involved in the resolution of the problem.
Domain	Playbook
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4050
Title	AI Hotspot Solver
Requirement	The alternative weather scenarios to resolve the Netspot shall be generated by an AI Hotspot Solver.
Status	<in progress>
Rationale	An automated support tool will generate and propose alternative solutions to operators (NMOC, pre-tactical FMP, FMP).
Domain	Playbook

Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4060
Title	Adjustment of AI Alternative weather scenarios by Operators
Requirement	NMOC/Pre-tactical FMP/FMP shall be able to adjust the alternative weather scenarios proposed by the AI Hotspot Solver (what-if function)
Status	<in progress>
Rationale	Operators must be able to adjust the scenarios proposed by the AI Hotspot Solver.
Domain	Playbook
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4061
Title	Playbook and weather scenario Format
Requirement	The Playbook and weather scenarios shall be structured in a formalized way (script-like) to ease: - Digestible understanding by operators - Digitalization of the process
Status	<in progress>
Rationale	The scenario is structured in a formalized way (script-like) to ease: - Digestible understanding by operators - Digitalization of the process
Domain	Playbook
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4070
Title	What-if
Requirement	NMOC/Pre-tactical FMP/FMP shall be able to assess the network performance impact of the different scenarios using what-if.
Status	<in progress>
Rationale	Operators will use what-if to perform the network impact assessment of scenarios to resolve the Netspot.
Domain	Playbook
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4080
Title	Weather Scenario status
Requirement	The elaboration of weather scenarios shall be managed with different status: - Draft: weather scenario is elaborated in a private mode - Proposed: weather scenario is proposed to concerned NM actors - Coordinated: weather scenario is published in the Network Plan
Status	<in progress>
Rationale	Detailed network impact assessment is needed to analyze the solution
Domain	Playbook
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4090
Title	Adjustment of the selected weather scenario in the tactical frame
Requirement	NMOC/Pre-tactical FMP/FMP shall be able to adjust the selected weather scenario in the tactical frame or to select another scenario.
Status	<in progress>
Rationale	In the tactical frame, the NMf actors can adjust the scenario to resolve the hotspot/Netspot.
Domain	Playbook
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4100
Title	Updated weather scenario published in the Network Plan
Requirement	In the tactical frame, any update of the weather scenario shall be published in the Network Plan
Status	<in progress>
Rationale	A scenario update will be published in the Network Plan to inform all the stakeholders
Domain	Playbook
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4110
Title	Predefined and Agreed weather scenario
Requirement	Weather scenario in principle shall be predefined and agreed with NM, ANSPs, AUs at the strategical level as a catalogue of weather scenarios (Playbook) to resolve the most frequent and repetitive occurrence of convective weather situations
Status	<in progress>
Rationale	Agreement in principle of the scenario process/philosophy with NM, ANSPs, AUs
Domain	Playbook
Type	Data

[REQ]

Identifier	REQ-OSED-ISOBAR.4120
Title	Playbook: Catalogue of Weather Scenarios
Requirement	Catalogue of Weather Scenarios (Playbook) shall be based on set of measures: - Traffic Volume regulation - Flow regulation - Better planned re-routing (improving re-routing options) - Airborne STAM (Level Cap, …)
Status	<in progress>
Rationale	Catalogue of Scenario is based on set of measures: - Sector regulation - Flow regulation - Better planned re-routing (improving re-routing options) - Airborne STAM (Level Cap, …)
Domain	Playbook
Type	Data

[REQ]

Identifier	REQ-OSED-ISOBAR.4130
Title	Increasing Regulation Lead Time
Requirement	The anticipation of weather scenario selection shall increase the lead time of application of necessary tactical weather regulations.
Status	<in progress>
Rationale	The new process increases the lead time of application of necessary tactical weather regulations.
Domain	Playbook
Type	Data

[REQ]

Identifier	REQ-OSED-ISOBAR.4140
Title	Increasing Re-routing options
Requirement	AI AU preference shall provide a method of improving the effect of re-routing options for aircraft operators during identified convective activity
Status	<in progress>
Rationale	Re-routing options for aircraft operators during identified convective activity must be improved by AI AU Preference
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4150
Title	What-if: Rerouting options
Requirement	A list of the available trajectories shall be provided by clicking at a flight and be displayed on the flow map with the addition of the sectors.
Status	<in progress>
Rationale	To analyze if rerouting is possible regarding adjacent sectors capacity and identify key flights that can be re-routed easily helping to mitigate the hotspot.
Domain	Playbook
Type	Data/Functional

REQ]

Identifier	REQ-OSED-ISOBAR.4151
Title	What-if: Rerouting options Ranking
Requirement	The alternative trajectories shall be ranked by AU preference: - Unsatisfying: -1 - Indifferent: 0 - Satisfying: 1 - Very satisfying: 2
Status	<in progress>
Rationale	Identify ranking of the alternative routes
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4152
Title	What-if: Impact of re-routing
Requirement	The system shall include a flight detailed view that includes the impact of the different rerouting options on the operations affected (what-if): - Time - Fuel consumption
Status	<in progress>
Rationale	The inclusion of this view contributes to a better and easier understanding of the impact of the different rerouting options.
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4153
Title	What-if: Potential impact to flights
Requirement	The NM/FMP shall be able to see estimations of the possible impact to flights from the different weather scenarios through the system (ISOBAR Engine).
Status	<in progress>
Rationale	Understanding the impact to flights may help with the creation of specific measures to solve any over demands.
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4160
Title	What-if: Sector configuration
Requirement	The system shall have an option to display the different sector configurations available with the estimated impact for every possibility.
Status	<in progress>
Rationale	Analyzing the different reconfiguration options allows a better understanding of the capacity and the staffing (available capacity) and therefore the different options to modify it. It can also enable to first decide on a better local solution that might ease the problems for the neighbouring ACC.
Domain	Playbook
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4170
Title	Mitigation measures impact on airlines
Requirement	A chart with an expected satisfaction score for each impacted airline (sum over all deviated impacted flights from the same airline) shall be provided by the what-if impact assessment.
Status	<in progress>
Rationale	Guarantee a fair level of expected satisfaction among impacted airlines. Requires as an input the level of satisfaction with each alternative trajectory (or delay) for each airline affected. This information is provided by the what-if impact assessment to NM/FMP/AU.
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4180
Title	Mitigation solution proposal
Requirement	The system shall provide the different mitigation solutions available and the option to manually assess/introduce a possible solution.
Status	<in progress>
Rationale	This functionality helps improving the resolution options provided by the system.
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4190
Title	What-if: Request for Mitigation
Requirement	The system shall include an option for the user to request to compute a mitigation solution.
Status	<in progress>
Rationale	To verify the effectiveness of a proposed (by system or manually) mitigation solution to resolve the Hotspot/Netspot.
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4200
Title	Mitigation solution impact estimation (what if)
Requirement	The NM/FMP shall be able to see the estimations on the impact of the different mitigation solutions available through the system (ISOBAR Engine).
Status	<in progress>
Rationale	This functionality helps with the understanding of the impact of the different mitigation solutions available and, therefore, contributes to the improvement of the decision-making process.
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4210
Title	Nominal mitigation presentation
Requirement	The NM/FMP shall be able to see the different nominal scenarios and their corresponding possible mitigation measures through the system (ISOBAR Engine).
Status	<in progress>
Rationale	Analyzing these types of scenarios and the different solution options will help improving the decision-making process.
Domain	Playbook
Type	Data/Functional

REQ]

Identifier	REQ-OSED-ISOBAR.4211
Title	Compare nominal/reference scenario
Requirement	The NM/FMP shall be able to easily compare the impacts of the nominal/reference scenario with respect the solution scenario proposed by ISOBAR engine (with different mitigation measures for each scenario).
Status	<in progress>
Rationale	Assess and compare the network performance impact of nominal/reference scenario.
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4220
Title	Preferred sectors
Requirement	A list of the sector or preferred sectors to be used shall be included in the coordination system with airlines and ANSPs.
Status	<in progress>
Rationale	Reduction of the workload during coordination.
Domain	Playbook
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.4230
Title	Mitigation measures: AU
Requirement	Coordination shall be established between the AU and NM both during the negotiation of the mitigation measures through the system and the final notification through the publication of the measures in the NOP.
Status	<in progress>
Rationale	This coordination is required for a better involvement and give better service to the AU.
Domain	Playbook
Type	Coordination

[REQ]

Identifier	REQ-OSED-ISOBAR.4240
Title	AU preferred FPL
Requirement	The AU shall provide the NM with not one but the several preferred FPL using the certified NM communication channels for FPL submission.
Status	<in progress>
Rationale	This information contributes to the adequate resolution of the expected imbalances taking into account different AU preferences. This information shall be provided both during the development of the Hotspot mitigation solver AI and also in real time at D-1 in pre-tactical phase for a coordinated solution.
Domain	Playbook
Type	Coordination

[REQ]

Identifier	REQ-OSED-ISOBAR.5010
Title	Convection Risk Matrix
Requirement	The convection risk matrix shall represent the Cb risk interpretation: probability of convection scenario (occurrence of Cb clouds) versus the extent of convective scenario.
Status	<in progress>
Rationale	The convection risk matrix represents the Cb risk interpretation: probability of convection scenario (occurrence of Cb clouds) versus the extent of convective scenario.
Domain	Weather
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5020
Title	Probability of Convection Scenario
Requirement	The probability of convection scenario shall be structured as: - Less likely - Likely/probable - Very Likely
Status	<in progress>
Rationale	The probability of convection scenario is structured as - Less likely - Likely/probable - Very Likely
Domain	Weather
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5030
Title	Extent of Convective Scenario
Requirement	The extent of convective scenario shall be structured as: - Isolated (individual Cb, orographic and daytime bound, large gaps between cells) - Scattered/Clusters/Occasional (multi-cells, chaotic, generally less gaps between cells) - Widespread (numerous or organized, few or not significant gaps between cells)
Status	<in progress>
Rationale	The extent of convective scenario is structured as: - Isolated (individual Cb, orographic and daytime bound, large gaps between cells) - Scattered/Clusters/Occasional (multi-cells, chaotic, generally less gaps between cells) - Widespread (numerous or organized, few or not significant gaps between cells)
Domain	Weather
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5040
Title	Cb Risk Matrix Interpretation
Requirement	The Cb risk matrix interpretation shall be indicated by a color: - Purple: Very High: (Widespread & Very Likely) - Red: High (Scattered/Clusters/Occasional & Very Likely) (Widespread & Likely) - Orange: Medium (Isolated & Very likely, Scattered/Clusters/Occasional & Likely, Widespread & Less likely) - Yellow: Low (Isolated & Likely, Scattered/Clusters/Occasional & Less Likely)
Status	<in progress>
Rationale	The Cb risk matrix interpretation is indicated by a color.
Domain	Weather
Type	Functional

[REQ]

Identifier	REQ--OSED-ISOBAR.5050
Title	AI Meteo Engine
Requirement	The area of Cb forecast including geographical delineation shall be generated by the AI Meteo Engine.
Status	<in progress>
Rationale	The area of Cb forecast including geographical delineation is generated by the AI Meteo Engine.
Domain	Weather
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5060
Title	Colored Area of Cb forecast
Requirement	The CB risk matrix interpretation shall be generated by the AI Meteo Engine for each area of Cb forecast.
Status	<in progress>
Rationale	The area of Cb forecast including geographical delineation is generated by the AI Meteo Engine.
Domain	Weather
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5070
Title	Meteo Map
Requirement	Area of Cb forecast shall be superimposed on the European geographical map with the option of showing the different sectors.
Status	<in progress>
Rationale	The Meteo Map is displayed in digestible way in order to highlight ATFCM meaning.
Domain	Weather
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5071
Title	Meteo Map: Risk matrix intepretation
Requirement	Area of Cb forecast shall be colored according the Cb risk matrix interpretation (purple, red, orange, yellow) in a way that allows the identification of the sectors involved.
Status	<in progress>
Rationale	The Meteo Map is displayed in digestible way in order to highlight ATFCM meaning.
Domain	Weather
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5072
Title	Meteo Map: Nature of convective scenario
Requirement	For each area of CB forecast, a label shall indicate the nature of extent of the convective scenario (isolated, scatttered, widespread) and the overshooting top (alt. FL related) of the Cb.
Status	<in progress>
Rationale	The Meteo Map is displayed in digestible way in order to highlight ATFCM meaning.
Domain	Weather
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5073
Title	Meteo Map: Vertical slider
Requirement	The map shall include a vertical profile of the weather (vertical slider).
Status	<in progress>
Rationale	The Meteo Map is displayed in digestible way in order to highlight ATFCM meaning.
Domain	Weather
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5074
Title	Meteo Map: TS and Cb probability
Requirement	The system shall include an option to display TS and Cb probability on hourly blocks.
Status	<in progress>
Rationale	The Meteo Map is displayed in digestible way in order to highlight ATFCM meaning.
Domain	Weather
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5075
Title	Meteo Map: Overlay
Requirement	The map shall include an overlay of significant fixes, airports and boundaries.
Status	<in progress>
Rationale	The Meteo Map is displayed in digestible way in order to highlight ATFCM meaning.
Domain	Weather
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5076
Title	Meteo information in the Sector Configuration Monitoring
Requirement	The Sector Configuration Monitoring shall display the color convective information in selected time window with time evolution.
Status	<in progress>
Rationale	The color convective information is displayed in the Sector Configuration Monitoring to allow the NMOC/FMP to have a synthetic overview.
Domain	Weather
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5080
Title	Pre-Tactical Cb Forecast
Requirement	A pre-tactical CB forecast shall be provided the D-1 at 0900 UTC covering the tactical day 09-12;12:15;15-18;18-22 UTC.
Status	<in progress>
Rationale	A pre-tactical CB forecast is provided the D-1 at 0900 UTC covering the tactical day 09-12;12:15;15-18;18-22 UTC.
Domain	Weather
Type	Data/Functional

REQ [REQ]

Identifier	REQ-OSED-ISOBAR.5081
Title	Tactical Cb Forecast I
Requirement	A tactical forecast shall update the D-1 forecast at 0700 UTC covering the tactical day 09-12;12:15;15-18;18-22 UTC.
Status	<in progress>
Rationale	A tactical forecast updates the D-1 forecast at 0700 UTC covering the tactical day 09-12;12:15;15-18;18-22 UTC.
Domain	Weather
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5082
Title	Tactical Cb Forecast II
Requirement	A tactical forecast shall update the D-1 forecast at 1200 UTC covering the tactical day 12:15;15-18;18-22 UTC.
Status	<in progress>
Rationale	A tactical forecast updates the D-1 forecast at 1200 UTC covering the tactical day 12:15;15-18;18-22 UTC.
Domain	Weather
Type	Data/Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5090
Title	Weather scenario identification
Requirement	The system shall identify if the current weather scenario has occurred previously with similar conditions.
Status	<in progress>
Rationale	Potentially improving the quality of the mitigation measures and speeding up the decision-making process (e.g., referring to both weather parameters within the risk matrix such as the weather phenomena, altitude, severity, probability of occurrence and also DCB and resolution variables such as traffic demand, capacity probability and reduction and the proposed alternative resolutions within the playbook).
Domain	Weather
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5100
Title	Alert function
Requirement	The system shall include a function that alerts the user in case a problem is detected.
Status	<in progress>
Rationale	This alert functionality, that is for instance, the detection of an imbalance of demand and capacity due to weather phenomena, helps lessening reliance on constant monitoring.
Domain	Weather
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5110
Title	Adjacent areas weather
Requirement	The NM/FMP shall be able to see the weather forecast for the adjacent areas involved through the system (ISOBAR Engine).
Status	<in progress>
Rationale	To facilitate and improve the understanding of the situation.
Domain	Weather
Type	DataFunctional

[REQ]

Identifier	REQ-OSED-ISOBAR.5120
Title	Lightning and precipitation data
Requirement	Lightning and precipitation density forecast map from Weather Forecast Model shall be provided as a loop with a "play" button.
Status	<in progress>
Rationale	It provides the information about which model run is being displayed and the time lapses involved.
Domain	Weather
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5130
Title	Accuracy of forecast
Requirement	The system shall include a slider to remove low probability weather forecasts.
Status	<in progress>
Rationale	This functionality helps improving the clarity of the system by removing unnecessary information.
Domain	Weather
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.5140
Title	Meteo forecast change
Requirement	In the case of a change in the meteo forecast in close proximity to tactical time, the Met agency shall inform the ATSU.
Status	<in progress>
Rationale	Changes in the meteo forecast can be very impactful, especially the closer it gets to tactical times. The proposed channel of communication would be the teleconference.
Domain	Weather
Type	Coordination

[REQ]

Identifier	REQ-OSED-ISOBAR.5150
Title	Meteo information: AU
Requirement	The information about weather phenomena, severity and vertical levels shall be linked to the AU system.
Status	<in progress>
Rationale	The information about weather phenomena, severity and vertical levels is linked to the AU system. B2B is proposed as the channel of use.
Domain	Weather
Type	System

[REQ]

Identifier	REQ-OSED-ISOBAR.5160
Title	Weather information: Refresh rate
Requirement	An adequate refresh rate shall be defined according to the weather information updates from provider sources and also for the resolution and granularity of the presented airspace (within ECAC area).
Status	<in progress>
Rationale	An adequate refresh rate is always critical for the adequate operation of the system.
Domain	Weather
Type	System

[REQ]

Identifier	REQ-OSED-ISOBAR.6010
Title	Collaborative Process with Augmented Reality
Requirement	The Collaborative process shall be supported with Augmented reality: - Interactive map (displaying traffic situation: meteo, imbalances, scenario, impact assessment, ...) - 3D map - Drawing to support analysis and explanation
Status	<in progress>
Rationale	Today the coordination of solution is based on a teleconference. It must be replaced by a modern digital environment but still keeping the audio channel.
Domain	Others
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.6020
Title	Timeline Structure
Requirement	A timeline shall be proposed to visualize the temporal organization of a weather scenario (set of measures, timestamp - coordination, implementation -, measures status ….)
Status	<in progress>
Rationale	A timeline is needed to visualize the temporal organization of a scenario (set of measures, timestamp - coordination, implementation -, measures status ….)
Domain	Others
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.6030
Title	Type of environment
Requirement	The NM/FMP shall be able to differentiate, through the system (ISOBAR Engine),between arrival and en-route operating environment.
Status	<in progress>
Rationale	This functionality provides context on the analysis of a particular situation.
Domain	Others
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.6040
Title	Severity of situation
Requirement	The NM/FMP shall be able to see, through the system (ISOBAR Engine), a type of chart that represents, by using different colours, the combination of severity, probability and how early you need to act regarding the situation.
Status	<in progress>
Rationale	Properly assess and display the severity of the different situations.
Domain	Others
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.6050
Title	Timeline
Requirement	The system shall include a time-slider for the different functionalities that allow to work in a continous sequence according to the time step.
Status	<in progress>
Rationale	This feature increases the usability of the system by providing the information with more granularity according to the time-horizon.
Domain	Others
Type	Functional

[REQ]

Identifier	REQ-OSED-ISOBAR.6060
Title	Names of sectors indicated
Requirement	The system shall include a functionality that shows the name of each sector when passing the mouse on top of it on the map.
Status	<in progress>
Rationale	This feature increases the clarity and easy access to the information on the map.
Domain	Others
Type	System

[REQ]

Identifier	REQ-OSED-ISOBAR.6070
Title	Response time
Requirement	Response time values shall be lower than 0.5 seconds.
Status	<in progress>
Rationale	It refers to the refreshing time of the system to monitor the update of all sources of information. The time for the update of each data source depends strictly on each data source provider.
Domain	Others
Type	System

[REQ]

Identifier	REQ-OSED-ISOBAR.6071
Title	Time granularity
Requirement	The time granularity (refresh time) of the predictions and data of the system should be: - Optimum performance: 30 minutes - Acceptable performance: 1 hour
Status	<in progress>
Rationale	At this point in time it is not too relevant, but coming to the operations, it will become more and more important to increase the time granularity of the provided prediction and data.
Domain	Others
Type	System

[REQ]

Identifier	REQ-OSED-ISOBAR.6080
Title	Geographical coverage
Requirement	The geographical coverage of the system shall be: - Optimum performance: ECAC area - Acceptable performance: ACC area
Status	<in progress>
Rationale	Meeting the needed geographical coverage is critical for the adequate operation of the system.
Domain	Others
Type	System

[REQ]

Identifier	REQ-OSED-ISOBAR.6090
Title	Geographical granularity
Requirement	The geographical granularity of the system shall be: - Optimum performance: Per sector, per route and per flow affection. - Acceptable performance: Per sector.
Status	<in progress>
Rationale	Meeting the needed geographical granularity is critical for the adequate operation of the system. However, at D-1, the accuracy of the model could be the limitating element since there is no point in providing high level of granularity if it is not matched by geographical accuracy.
Domain	Others

Type	System

[REQ]

Identifier	REQ-OSED-ISOBAR.6100
Title	Scale adaptability
Requirement	The system shall be scalable to multiple and larger areas: - Optimum performance: From sector to all Europe. - Acceptable performance: From sector to all flights concerned.
Status	<in progress>
Rationale	The scalability of the system is critical for its future implementation.
Domain	Others
Type	System

5 ISOBAR B2B Service Requirements

5.1 Data Flow Exchange Concept Definition

5.1.1 General Context of ISOBAR B2B Services

The B2B Service is an interface provided for system-to-system access to services and data, allowing the services and data consumers to retrieve and use the information in their own systems.

One of the main objectives of ISOBAR is to develop an operational and technical roadmap for ancillary services providing an AI-based adaptive input to the Network Operations Plan. The present Intermediate OSED describes the interoperability features of the ISOBAR B2B solution focusing on the solution at NM level. The rationale for that is that the level of detail for the solution at FMP level would require incorporating the particularities of each ANSP internal processes, which is not part of the scope of ISOBAR. ISOBAR proposes a harmonised local procedure that needs being matured and agreed to be transposed into detailed processes at FMP level. When those steps are covered, then the task of developing B2B service requirements at FMP level could be undertaken.

Based on the requirements included both in previous section 4 and in current section, the ISOBAR prototype will mimic as much as possible this B2B services architecture and perform an initial validation of the functionalities provided.

5.1.2 General Description of the Services and Data Flow

The proposed ISOBAR functionalities are structured in several services:

1. Convective Weather Prediction: it provides services to disseminate convective weather information on D-1/ D-0 timeframe (*subsystem AI Meteo Engine*).
2. Weather-based Hotspot Detection: this service provides information on the demand and capacity impact relating to convective weather situations (*subsystem AI Hotspot Detection*).
3. Gate and Netspot Management: it provides services to manage the Gates and Netspots (subsystem NIMS).
4. Hotspot Solver: this service provides automated solutions to resolve imbalances at the network level (*subsystem AI Hotspot Solver*).
5. AU Preferred Alternative Trajectories: it provides services to identify alternative trajectories based on the AU most preferred route (*subsystem AI AU Preferences*).

The table below summarizes for each service the list of functions provided with the associated data flows. This table is correlated with the architecture models (Figure 57, Figure 58 and Figure 59):

Id	Name	Issuer	Intended Addressees	Information Element	Sub-system	Rationale	Service Identifier
01	ConvectiveWeatherNotification	AI Meteo Engine	NIMS, NM, FMP, AI Hotspot Detection	Convective Weather Information *List of Polygons* *Polygon Id* *Polygon coordinates* *ColorSeverity* *Top CB* *DurationHourMinute*	AI Meteo Engine	*AI Meteo Engine sends geographical and temporal delineation of predicted convective weather.*	Convective Weather Detection
02	ConvectiveTrafficVolumeNotification	AI Hotspot Detection	NIMS	Wx Impacted Traffic Volume *TrafficVolumeId* *ColorConvectiveWeather* *DurationHourMinute*	AI Hotspot Detection	*AI Hotspot Detection sends the Traffic Volume impacted by the convective prediction*	Weather-based Hotspot Detection
03	ConvectiveTrafficVolumeRequest	NM, FMP	NIMS	Wx Impacted Traffic Volume *TrafficVolumeId* *DurationHourMinute*	AI Hotspot Detection	*FMP/NM/AU actor can request Traffic Volume impacted by the convective prediction*	Weather-based Hotspot Detection

Id	Name	Issuer	Intended Addressees	Information Element	Sub-system	Rationale	Service Identifier
04	ConvectiveTrafficVolumeReply	NIMS	NM, FMP	Wx Impacted Traffic Volume *TrafficVolumeId* *ColorConvectiveWeather* *DurationHourMinute*	AI Hotspot Detection	*The NIMS sends a reply to inform about the color convective prediction attached to the Traffic Volume*	Weather-based Hotspot Detection
05	WxCapacityReductionNotification	AI Hotspot Detection	NIMS	Wx Capacity Reduction *TrafficVolumeId* WxCapacityReduction *DurationHourMinute*	AI Hotspot Detection	*AI Hotspot Detection determine the Wx Capacity Reduction according to the predicted convective weather information.*	Weather-based Hotspot Detection
06	WxCapacityReductionRequest	NM, FMP	NIMS	Wx Capacity Reduction *TrafficVolumeId* *DurationHourMinute*	AI Hotspot Detection	*FMP/NM/AU actor can request Wx Capacity Reduction attached to a Traffic Volume*	Weather-based Hotspot Detection

Id	Name	Issuer	Intended Addressees	Information Element	Sub-system	Rationale	Service Identifier
07	WxCapacityReductionReply	NIMS	NM, FMP	Wx Capacity Reduction *TrafficVolumeId* *WxCapacityReduction* *DurationHourMinute*	AI Hotspot Detection	*The NIMS sends a reply to inform about Wx Capacity Reduction predicted in the Traffic Volume*	Weather-based Hotspot Detection
08	WxDemandAdjustmentNotification	AI Hotspot Detection	NIMS	Wx Demand Adjustment *TrafficVolumeId* *List of Flights*	AI Hotspot Detection	*AI Hotspot Detection determines the Wx Demand Adjustment according to the predicted convective weather information.*	Weather-based Hotspot Detection
09	WxDemandAdjustmentRequest	NM, FMP	NIMS	Wx Demand Adjustment *TrafficVolumeId* *DurationHourMinute*	AI Hotspot Detection	*FMP/NM actor can request Wx Demand Adjustment attached to a Traffic Volume*	Weather-based Hotspot Detection

Id	Name	Issuer	Intended Addressees	Information Element	Sub-system	Rationale	Service Identifier
10	WxDemandAdjustmentReply	NIMS	NM, FMP	Wx Demand Adjustment *TrafficVolumeId* *List of Flights* *DurationHourMinute*	AI Hotspot Detection	*The NIMS sends a reply to inform about the list of flights predicted in the Traffic Volume*	Weather-based Hotspot Detection
11	HotspotSolverRequest	NM, FMP	AI Hotspot Solver	Configuration Netspot id List of TFV for regulation List of gates for flow rate List of TFV for rerouting	AI Hotspot Solver	*FMP/NM actor sends a request to configure and to run the AI Hotspot Solver.*	Hotspot Solver
12	HotspotSolverReply	IA Hotspot Solver	NM, FMP	Weather Scenario Netspot Id List of Measures	AI Hotspot Solver	*The AI Hotspot Solver sends a reply providing a weather scenario to resolve the Netspot*	Hotspot Solver

Id	Name	Issuer	Intended Addressees	Information Element	Sub-system	Rationale	Service Identifier
13	AUPreferredAlternativeTrajectoriesRequest	NM, FMP, AI Hotspot Solver	AU AI Preference	List of TFV Initial Trajectory	AI AU Preference	*FMP/NM actor or technical AI Hotspot Solver requests AU preferred alternative trajectories in selected list of Traffic Volumes*	AU Preferred Alternative Trajectories
14	AUPreferred AlternativeTrajectoriesReply	AU AI Preference	NM, FMP, AI Hotspot Solver	Alternative Trajectories	AI AU Preference	*The AI AU Preference sends a reply providing proposed alternative trajectories taking into account AU Preference*	AU Preferred Alternative Trajectories
15	NetspotPublication	NM, FMP	NIMS	Netspot *NetspotName* *ActionUpdate* *List of TFV Name* *NetspotStatus{draft, coordinated, canceled}* *StartTime* *EndTime*	NIMS	*FMP/NM defines and publishes a Netspot due to a cluster of Hotspots*	NetspotManagement

Id	Name	Issuer	Intended Addressees	Information Element	Sub-system	Rationale	Service Identifier
16	NetspotListRequest	NM, AU, FMP	NIMS	Netspot *List of TFV Name* *Start time* *End time*	NIMS	*FMP/NM/AU actor can request the list of declared Netspots. It will return if there is a Netspot for a requested TFV*	NetspotManagement
17	NetspotListReply	NIMS	NM, FMP, AU	Netspot *List of Netspot*	NIMS	*The NIMS sends a reply to inform about the list of Netspot for the requested TFV*	NetspotManagement
18	GatePublication	NM, FMP	NIMS	Gate *Gate Name* *TFV Name*	NIMS	*FMP/NM defines and publishes a Gate in the NIMS Gate Repository*	GateManagement

Id	Name	Issuer	Intended Addressees	Information Element	Sub-system	Rationale	Service Identifier
19	GateListRequest	NM, FMP	NIMS	Gate *List of TFV Name*	NIMS	*FMP/NM actor can request the list of declared Gates in the NIMS Gate Repository*	GateManagement
20	GateListReply	NIMS	NM, FMP, AU	Gate *List of Gate*	NIMS	*The NIMS sends a reply to inform about the list of Gates*	GateManagement

Table 6 List of ISOBAR B2B services

The flow charts below show the location of each function listed in the table above:

Figure 57 ISOBAR Architecture Model 1

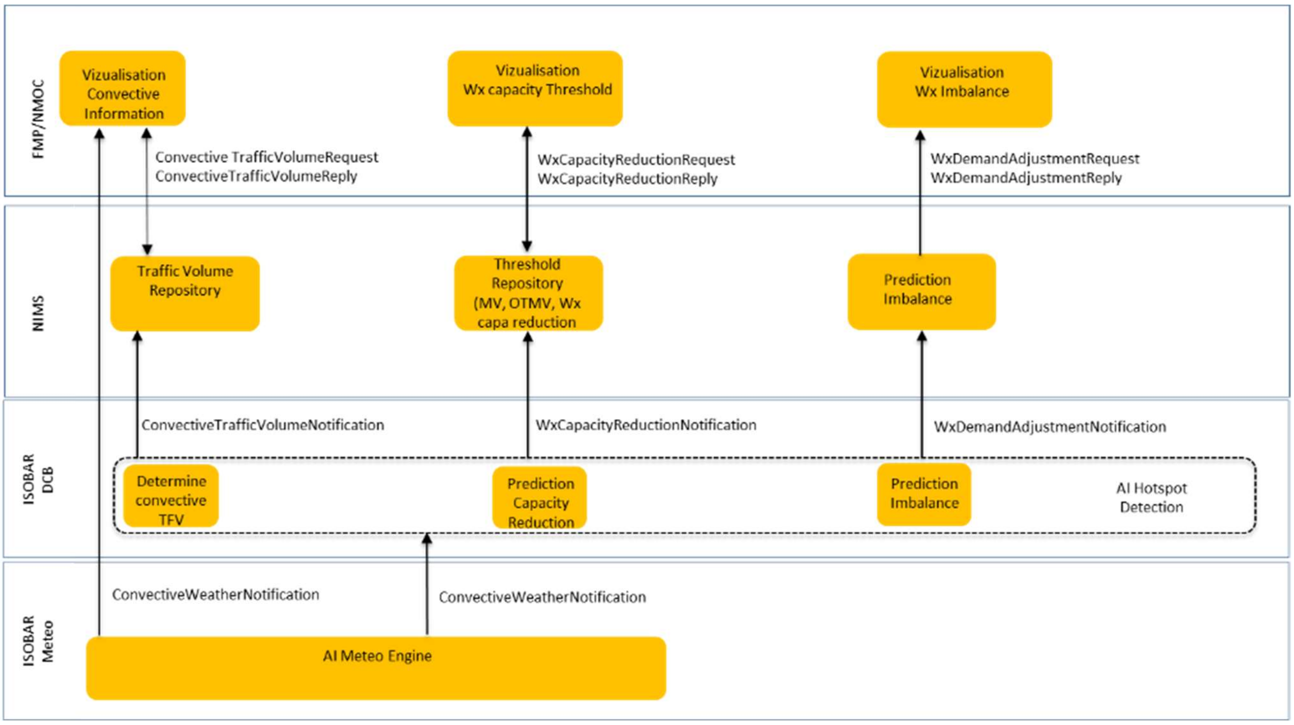


Figure 58 ISOBAR Architecture Model 2

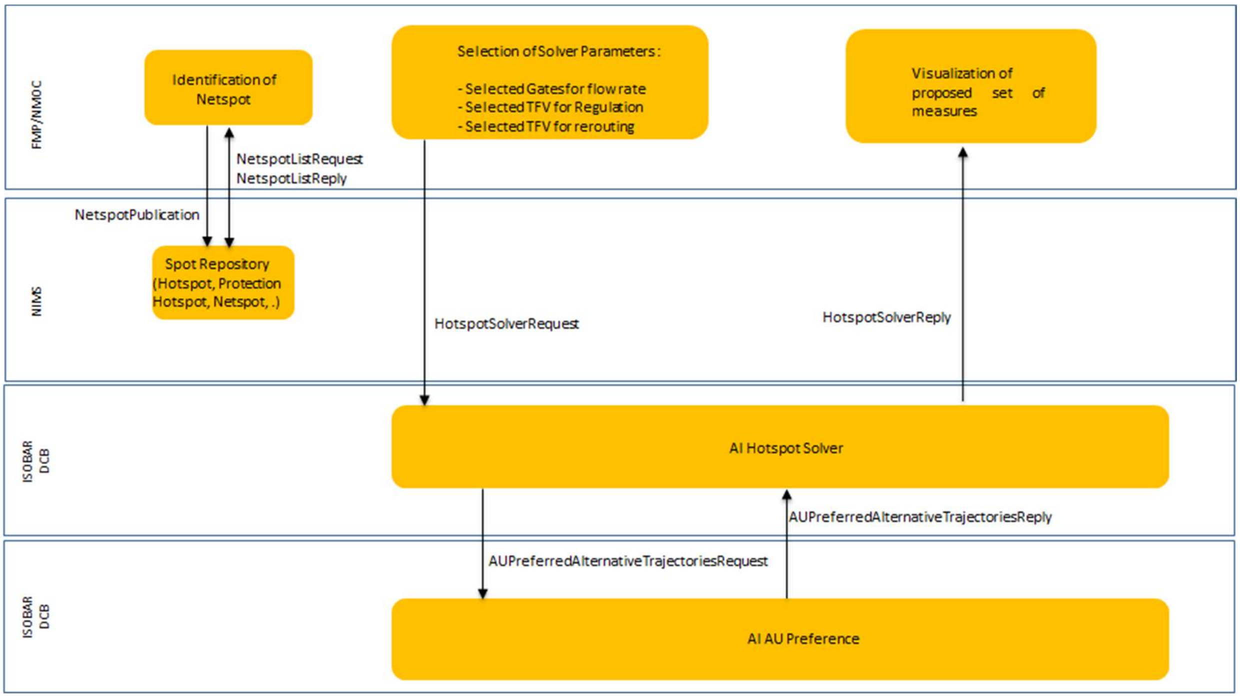


Figure 59 ISOBAR Architecture Model 3

5.2 AI Components Description

This section intends to describe each of the AI components (subsystems introduced in section 5.1) in terms of service/function provision and data format. The last subsection gives an overall picture of the interrelations between all the components, that is, the flow exchange illustrated in the charts.

5.2.1 METEO AI component

The METEO AI component will enable traffic managers to obtain a probabilistic forecast of convective weather up to 36 hours in advance. The aim is for this product is to help stakeholders make decisions one day before the day of operations.

5.2.1.1 Conceptual Module Definition

The METEO AI component will take as an input the raw ensemble forecasts provided in GRIB file format and will provide as an output a probabilistic prediction of the occurrence, severity and altitude of thunderstorms. GRIB (General Regularly-distributed Information in Binary form) is a concise data format, standardized by the World Meteorological Organization and is commonly used in meteorology to store historical and forecast weather data. The AI Meteo component will be based on a supervised learning algorithm that has been trained with historical thunderstorm observations from satellite images and lightning. The resolution of the AI METEO Engine model will be equivalent to the resolution of the GRIB file input (1hr x 2.5km x2.5km). The output of the AI METEO Engine is flexible and will be provided in several formats, i.e. graphical or numeric representation, consistent with the needs of the other work packages within the ISOBAR Project.

5.2.1.2 Data Flow Exchange and Service/Functions Provision Process

Figure 60 shows the data flow of the METEO AI architecture. The grey box represents the GRIB files containing the weather forecast provided by the MET Provider. The METEO AI component will take the GRIB files as input, and apply the AI algorithm, previously trained using historical data. The METEO AI component will output both numerical and graphical representation of the convection prediction.

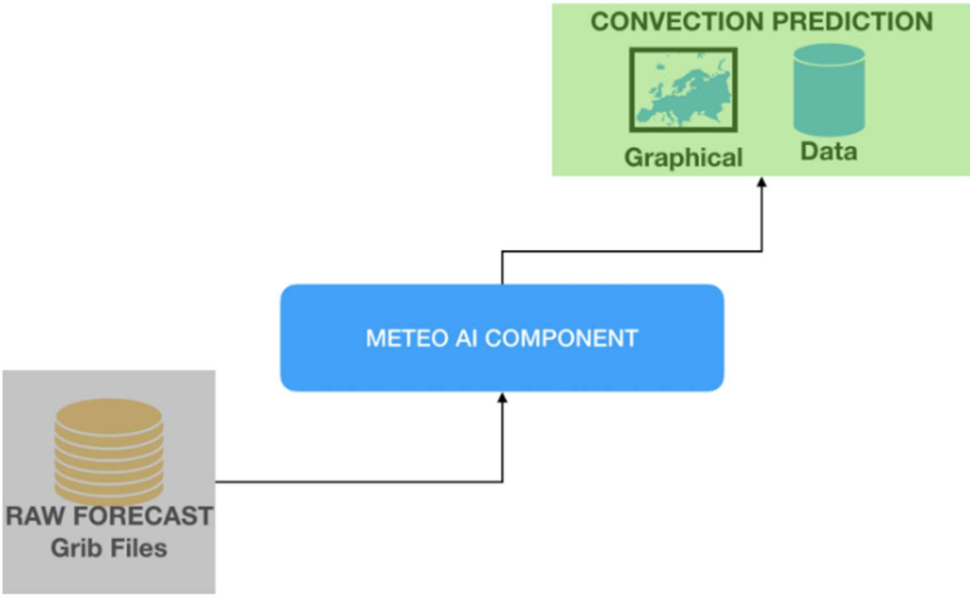


Figure 60 METEO AI architecture

INPUT: Numerical Weather Prediction (NWP) forecasts from MET Provider.

OUTPUT: Probabilistic convection prediction from METEO AI component.

Meteo AI Component model provides the following outputs for every point of the GRIB file grid:

- Probability of Convective weather;
- Probability of convective weather severity (Low, Moderate, High, Very High);
- Probability of convective weather cloud top for various Flight Level ranges (Above 390, 390 - 340, 340-300).

This weather information will be provided on map format, with a resolution equivalent to the GRIB input data (1hr x 2.5km x 2.5km). The raw output from the METEO AI Engine will be further processed to create a Convection Weather Publication to be provided to the final users.

Convection Weather Notification

The *ConvectiveWeatherNotification* output functionality will send to users in push mode information about the expected convective areas, including not only the shape and location of them but also the temporal occurrence and the severity. The Meteo AI engine output will be compatible with the convection risk matrix defined in Figure 4.

The list of output data expected is:

- PolygonID.
- PolygonCoordinates {Point1(lat, lon), …, PointN(lat, lon)}.
- ColorSeverity (in line with Convection Matrix).
- Cloud Top Altitude.
- CBDurationHourMinute (in hours or minutes).

5.2.2 Hotspot detection AI Component

The Hotspot detection AI component will help traffic managers identify hotspots in the network due to convective weather. Early identification of these problematic areas in the network, will allow stakeholders to plan accordingly and improve their mitigation response.

5.2.2.1 Conceptual Module Definition

The Hotspot detection AI component consists of three sub-modules: the Demand, Capacity and Imbalance modules. Each one is responsible for an essential task in the hotspot detection process described in the following paragraphs.

The **Demand module** will take as input the convective predictions from the METEO AI component and provide a prediction of demand. The demand module will provide an AI traffic demand prediction based on machine learning algorithms that have been trained on historical traffic demand and convective weather events. The demand module will capture shifts in traffic demand due to convective weather conditions.

The **Capacity module** will take as input the convective prediction from the METEO AI component and provide a sector/Netspot/gate capacity reduction prediction due to convective weather. The capacity module is based on AI algorithms that have been trained with historical traffic capacity data and convective weather events. The capacity module will capture the reduction in capacity due to convective weather conditions.

The **Imbalance model** will take as input the predictions from the Demand and Capacity modules and provide predictions on areas of the network with demand-capacity imbalance, or hotspots. The Imbalance module will provide the traffic flows and airspace sectors disruptions due to convective weather.

5.2.2.2 Data Flow Exchange and Service/Functions Provision Process

As described in the previous section, the forecast of the probability of storms occurrence (Convection Prediction Data) computed in the METEO AI is input in the Hotspot detection AI, in particular into the Demand and Capacity AI modules. The calculated demand and capacity information is then considered in the imbalance module to determine the hotspot areas. In Figure 61, grey box denotes input in the Hotspot detection AI, blue boxes are the Hotspot detection modules, and green boxes are the outputs from the hotspot detection AI.

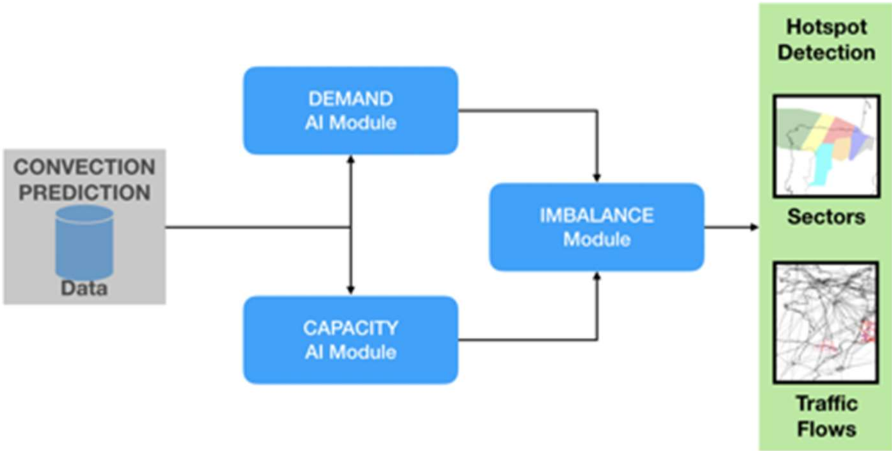


Figure 61 Hotspot Detection AI architecture

INPUT: Probabilistic convection prediction from METEO AI Component, see section 5.2.1.2 of the METEO AI Component.

OUTPUT: Airspace sectors and traffic flows impacted by convective weather. The expected data are:

- List of Traffic {id, waypoints, time over}.
- List of Sectors/Gates Capacity {id, capacity value, Time Range (from- to)}.
- List of Sectors/Gates Congestion {id, imbalance value, Time Range (from- to)}.

In the following paragraphs there is a description of the internal functions of the AI Hotspots Detection module.

ConvectiveTrafficVolumeNotification

Description: *ConvectiveTrafficVolumeNotification* function will notify when a Traffic Volume is impacted by convection. Traffic Volume affected is assigned with the duration in time and with the colour denoting its severity.

Data expected:

- TrafficVolumId.
- ColorConvectionWeather.
- DurationHourMinute (in hours or minutes).

ConvectiveTrafficVolumeRequest

Description: *ConvectiveTrafficVolumeRequest* function allows the user (FMP/NM/AU) to request information about if a Traffic Volume is affected by convection, also indicating the duration of that effect.

Data expected:

- TrafficVolumId.
- DurationHourMinute from (in hours or minutes).

ConvectiveTrafficVolumeReply

Description: *ConvectiveTrafficVolumeReply* function will return the color convective prediction of a Traffic Volume.

Data expected:

- TrafficVolumId.
- ColorConvectionWeather.
- DurationHourMinute from (in hours or minutes).

WxCapacityReductionNotification

Description: *WxCapacityReductionNotification* function will notify when a Traffic Volume is impacted by a capacity reduction due to convection. Traffic Volume affected is assigned with the weather capacity reduction value and with the duration of the situation.

Data expected:

- TrafficVolumId.
- WeatherCapacityReduction.
- DurationHourMinute from (in hours or minutes).

WxCapacityReductionRequest

Description: *WxCapacityReductionRequest* function allows the user (FMP/NM/AU) to request information about capacity reduction in a Traffic Volume impacted by convective weather, also indicating the duration of that effect.

Data expected:

- TrafficVolumId.
- DurationHourMinute from (in hours or minutes).

WxCapacityReductionReply

Description: *WxCapacityReductionReply* function will return the prediction of the capacity reduction in a Traffic Volume when this is affected by weather convection.

Data expected:

- TrafficVolumId.
- WeatherCapacityReduction.
- DurationHourMinute (in hours or minutes).

WxDemandAdjustmentNotification

Description: *WxDemandAdjustmentNotification* function will notify the list of flights adjusted by convection effects per Traffic Volume.

Data expected:

- TrafficVolumId.
- List of flights.

WxDemandAdjustmentRequest

Description: *WxDemandAdjustmentRequest* function allows the user (FMP/NM/AU) to request information about demand adjustments in a Traffic Volume impacted by convective weather, also indicating the duration of that effect.

Data expected:

- TrafficVolumId.
- DurationHourMinute (in hours or minutes).

WxDemandAdjustmentReply

Description: *WxDemandAdjustmentReply* function will send the list of flights adjusted by convection effects in a specific Traffic Volume.

Data expected:

- TrafficVolumId.
- List of flights.
- DurationHourMinute (in hours or minutes).

5.2.3 Gate and Netspot Component

5.2.3.1 Conceptual Module Definition

The Gate and Netspot are key elements to manage properly detection and resolution of convective weather situations.

The Gate supports the monitoring of the flow and cross-border traffic interactions. It allows the operational actors to build a robust understanding of the propagation of critical situations at the network level.

The Netspot supports the identification of cluster of linked hotspots created by the convective weather propagation. Then, the Netspot element will be the reference to manipulate in the collaborative process among FMP/NM actors.

5.2.3.2 Data Flow Exchange and Service/Functions Provision Process

The following headings describe the internal functions of this component aiming at covering the module functionalities.

NetspotPublication

Description: Allows the user to update the Netspot NM Repository for a given [List of traffic volume, duration] pair.

Note that the *NetspotPublication* service is used to *Create*, *Update* or *Delete Netspots* and to update the status of the Netspot (draft, coordinate, canceled).

The Netspot can be updated geographically (list of Traffic Volume) and temporally (start time, end time).

If a Netspot with a corresponding weather scenarios (set of Measures) is to be deleted in an update request, the Netspot and all *measure.sourceNetspot* references to it will also be deleted.

Data expected:

- NetspotName.
- ActionUpdate : {create, update, delete}.
- List of {TrafficVolumeName}.
- NetspotStatus {draft, coordinated, canceled}.
- StartTime YYMMDDHHMM.
- EndTime YYMMDDHHMM.

NetspotListRequest

Description: Requests the list of Netspots in an area of interest and in a time interval that have been created during runtime by a User through the *HotspotPublication.*

The area of interest is composed of a list of Traffic Volumes. All the Netspots implied in the requested list of traffic volumes and for a specific duration (Start Time, EndTime) will be requested.

Data expected:

- List of {TFV name}.
- StartTime YYMMDDHHMM.
- EndTime YYMMDDHHMM.

NetspotListReply

Description: Returns all Netspot (filtered by the request parameters) that have been created during runtime by a User through the *NetspotPublication.*

Empty Netspot lists are returned where no corresponding Netspot have been created in the system.

Data expected:

- List of {Netspots}.

GatePublication

Description: Allows the user to update the Gate NM Repository for a given [traffic volume, duration] pair.

Note that the *GatePublication* service is used to *Create*, *Update* or *Delete* Gates.

Data expected:

- GateName.
- UpdateAction: {create, update, delete}.
- AttachedTrafficVolume.
- Start time YY.MM.DD.HH.MM.
- End time YY.MM.DD.HH.MM.

GateListRequest

Description: Requests the list of Gates that have been created in an area of interest and in a time interval during runtime by a User through the *GatePublication.*

The area of interest is composed of a list of Traffic Volumes. All the Gates implied in the requested list of traffic volumes and for a specific duration (Start Time, EndTime) will be requested.

Data expected:

- List of {Trafic Volumes}.
- StartTime YYMMDDHHMM.
- EndTime YYMMDDHHMM.

GateListReply

Description: Returns all Gates (filtered by the request parameters) that have been created during runtime by a User through the *GatePublication*.

Empty Gate list is returned, where no corresponding Gate have been created in the system.

Data expected:

- List of {Gates}.

5.2.4 Hotspot Mitigation AI Component

Once demand and capacity have been predicted by the corresponding AI-based components (following AI-based weather forecast), the FMP/NM role comes into play by analyzing these predictions (through the functions *WxCapacityReductionRequest/Reply* and *WxDemandAdjustmentRequest/Reply*) in order to adjust the monitoring values (adjusted capacities) of traffic volumes (sectors) under his responsibility.

Based on the imbalance between the predicted demand and the adjusted capacity of each sector, the FMP/NM decides which sectors to consider as hotspots. The FMP/NM uses the gate tool in order to identify the flows common to these hotspots and subsequently to assess if these emerging hotspots (with the list of their common flights) are to be declared as a Netspot. If there is no strong interrelation between hotspots throughout the network (i.e. there is only a few common flights), then no Netspot is declared (through the function *NetspotPublication*), and imbalances are to be solved at the local level only. However, if the network effect is evaluated as high (i.e. there is a large number of flights common to several hotspots), a Netspot is declared, and the FMP/NM calls a DCB hotspot solver (through the function *HotspotSolverRequest*), with appropriate parameters, in order to mitigate these hotspots. Through the function *HotspotSolverReply*, the solver returns to the FMP/NM DCB measures to mitigate the declared Netspot.

5.2.4.1 Conceptual Module Definition

The DCB hotspot solver is a decision-support tool based on mathematical optimization and/or artificial intelligence that seeks for DCB measures to offload sectors identified as hotspots. The DCB measures returned by the solver satisfy one or several additional criteria, e.g. they minimize total delay or total cost of DCB measures.

<u>Two modes of use:</u>

The solver can be called in one of two modes: “what-if” or “automatic” mode. The FMP/NM may call the DCB hotspot solver several times, with different parameters manually selected each time, following a “what-if” mode of use, to assess the performance of specific DCB measures. Alternatively, the FMP/NM can call the solver with an “automatic” mode of use, where more degrees of freedom are given to the solver to search for optimal DCB measures.

A high-level description of the functional interactions between the DCB hotspot solver, the demand and capacity prediction modules and the human FMP/NM is given in Figure 62.

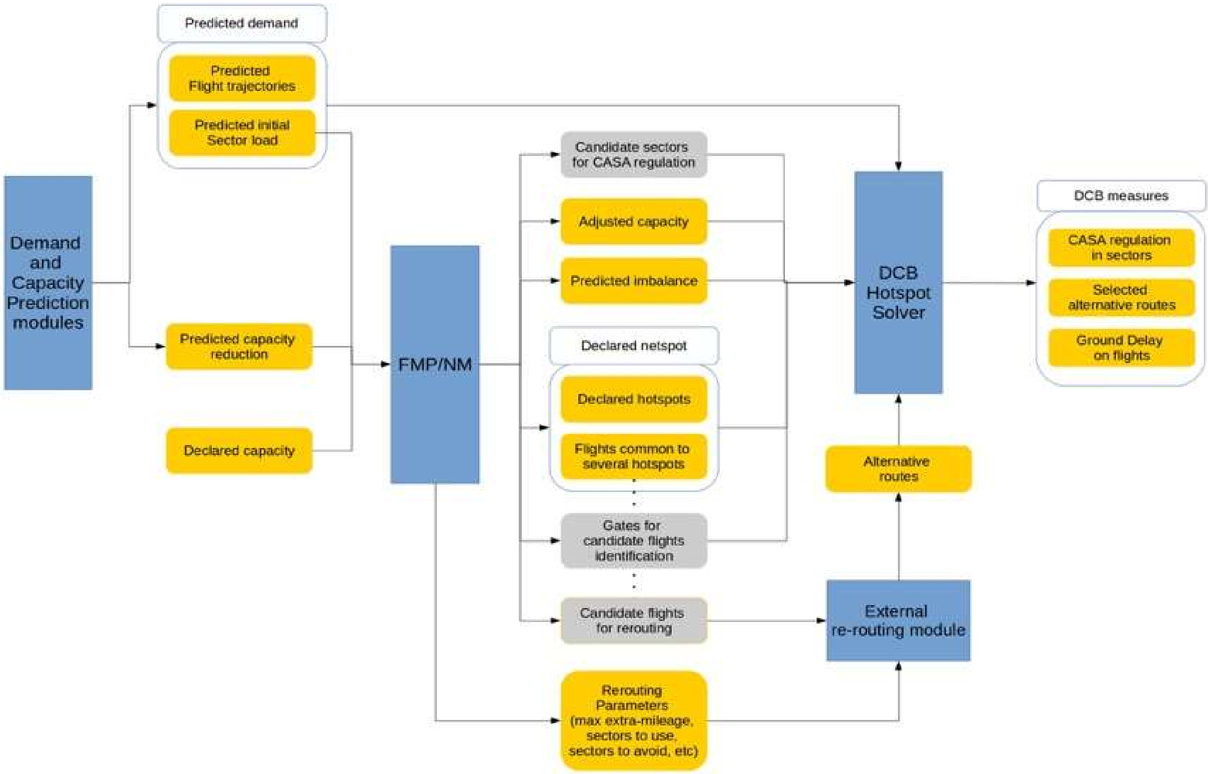


Figure 62 Hotspot Mitigation AI Architecture

In Figure 62 human actors and technical modules related to the DCB hotspot solver are represented as blue boxes. Main inputs and outputs are shown as orange rounded rectangles. Grey rounded rectangles show optional inputs to the solver that are only applicable in the "what-if" mode of use. The grey rectangle "Candidate flights for rerouting" represents a mandatory input to the external re-routing module. In the "what-if" mode of use, these candidate flights can either be directly selected by the user or identified by a pre-processing function associated to the solver, using the gates selected by the user ("Gates for candidate flights identification").

In the "automatic" mode, the solver can request the external rerouting module (through the function *AUPreferredAlternativeTrajectoriesRequest*) to return alternative trajectories for all "flights common to several hotspots".

A more detailed description of inputs, parameters, and outputs of the DCB hotspots solver is given below.

Solver inputs

The main inputs to the solver are the following:

- Traffic demand forecast;
- Alternative routes;
- Airspace configuration and declared/adjusted capacity;
- Declared Netspot;
- Solver parameters.

Traffic demand forecast

The solver is fed with a complete description of air traffic demand within the airspace and the time period of interest. The demand consists of a set of flights, each represented by its trajectory. One possible data format is the SO6 traffic file format from EUROCONTROL R&D / DDR2 database.

Alternative routes

Each flight should have a list of alternative horizontal routes that are flyable. These alternative routes should be computed offline and provided to the solver as an input, to ensure fast processing during the solution search. A standalone rerouting module can be called by the solver at a pre-processing step through the function AUPreferredAlternativeTrajectoriesRequest to compute these alternative routes according to parameters set by the FMP/NM.

During the solution search, the solver should be able to try rerouting some flights through the selection of predefined alternative horizontal routes.

Airspace configuration and declared/adjusted capacity

The solver should be fed with a description of the airspace configuration (sector opening scheme) and the declared or adjusted capacity of each sector.

Initial air traffic load

In addition to flight trajectories, and declared/adjusted sectors' capacities, the solver should be fed with the initial load of each sector (i.e. the load before the effect of any DCB measure is computed by the solver), expressed using an operational metric such as hourly entry count or occupancy count.

Using a trajectory file (e.g. SO6 format) of a given flight and airspace description files, it is possible using the simulation software from EUROCONTROL, called network strategic modelling (*NEST*), to generate an airspace/traffic intersection file (e.g. T5 format) that determines the entry and exit times of that flight to every crossed sector. Traffic intersection files can be used to compute the traffic load (in terms of entry or occupancy count) in each sector.

Declared Netspot

The FMP/NM should indicate to the solver the declared Netspot which is made of:

- the hotspots to mitigate, i.e. the overloaded sectors with the time frame of imbalance for each sector,
- and the list of flights common to several hotspots (alternatively, these flights can be identified by the solver at a pre-processing step).

Solver parameters

As a set of parameters, the FMP/NM can input:

- a list of candidate gates that can be used by the solver to identify candidate flights for rerouting or ground delay,
- a list of candidate sectors where to apply CASA regulation,

- a list of candidate flights that can be rerouted or delayed.

In the “what-if” mode of use, the solver should restrict its search on DCB measures related to gates, sectors and flights selected by the FMP/NM, at the price of not completely mitigating the Netspot, i.e. some imbalanced sectors (tolerated by the FMP/NM) may still exist.

In the “automatic” mode of use, the solver can ignore these gates and sectors and possibly propose DCB measures related to other gates and sectors.

Additional rules need to be taken into account when identifying candidate flights for rerouting and/or delay. For example:

- Priority flights (declared by Airspace Users using Flight Delay Criticality Indicator (FDCI)) should not be penalized by the solver;
- Specific flights should not be considered for delay and/or rerouting, such as:
    - Flights from/to protected/regulated airports;
    - Long-haul flights;
    - European long-distance flights (e.g. Scandinavia/Canaria) due to fuel issues in case of rerouting.

The user should specify additional parameters that will be used when calling function *AUPreferredAlternativeTrajectoriesRequest* (executed by the external rerouting module), such as:

- Maximum extra-mileage for re-routing (5 NM, 10 NM, etc.),
- a list of sectors to be avoided when re-routing flights: alternative routes should avoid these sectors,
- a list of sectors to be used for re-routing: alternative routes should cross these sectors.

Solver outputs

The DCB measures computed and returned by the solver, through the function *HotspotSolverReply* are the following:

- **CASA regulation** applied to a sector. This measure follows the basic rule of CASA, where the capacity of a sector is limited to a given number of aircraft entries during a regulation period. The regulation period is divided into equal-length slots. Each slot is allocated to one aircraft. For this allocation, aircraft are treated as first-planned, first-served, based on their estimated entry time to the regulated sector. The updated entry time of each aircraft to the regulated area implies a delay in the take-off time. Hence, the ETOT of a regulated flight is updated to a CTOT.
- **Re-routing flights**. This can be done by selecting (cherry-picking) some flights and choosing alternative routes for them (from the set of alternative routes).
- **Delaying flights.** This can be done by selecting (cherry-picking) some flights and delaying them.

Also, the solver outputs a summary of the impact of DCB measures on each flight:

- rerouted with such alternative route reference, such extra distance (and such AU preference level if available),
- regulated/delayed with such amount of time,
- modified with such total delay/extra cost, etc.

The format of DCB measures returned by the solver is described in the following Table 7 Format of DCB measures returned by Hotspot mitigation AITable 7.

Object	DCB measure	Time period	Comments
Sector Id	CASA regulation: XX hourly entry count.	From start time to end time (regulation period).	Examples: • User-defined sector. • User-defined regulation period.
Flight Id	Ground delay: XX minutes	Initial ETOT: DDHHMM CTOT: DDHHMM	Examples: • User-selected flight. Reason: Cherry-picking ground delay. OR: • CASA regulation in sector Id from start_time to end_time.
Flight Id	Re-routing: • initial route: initial_route_id • updated route: updated_route_id • extra distance: +/- xx NM • initial route preference level: initial_route_pref • updated route preference level: updated_route_pref	ETOT/CTOT	Examples: • User-selected flight. Reason: Cherry-picking re-routing.

Table 7 Format of DCB measures returned by Hotspot mitigation AI

5.2.4.2 Data Flow Exchange and Service/Functions Provision Process

The following paragraphs describe the internal functions of the Hotspot Mitigation AI component.

HotspotSolverRequest

Description

The user calls the hotspot solver to compute DCB measures in order to mitigate selected Netspots, according to one of two modes: “automatic” or “what-if”.

The user should define the list of Netspots for which to compute mitigation measures.

Also, the user is required to define the region and time period of interest, that are respectively the geographical and temporal extent encompassing the selected Netspots.

All flight trajectories that enter or occupy the region of interest, during the time period of interest, are considered by the DCB hotspot solver to mitigate the selected Netspots.

The airspace configuration (given by the sector opening scheme) of the region of interest, during the time period of interest, is considered by the DCB hotspot solver.

The declared/adjusted capacity of each sector within the region of interest, during the time period of interest is considered by the DCB hotspot solver.

The function HotspotSolverRequest triggers automatically (during a pre-processing phase) the function AUPreferredAlternativeTrajectoriesRequest in order to obtain a set of alternative trajectories for each flight candidate for rerouting.

Data expected:

- List of {Netspot};
- Region of interest;
- Time period of interest: start time (DDHHMM), end time (DDHHMM);
- List of flight trajectories that enter/occupy the region of interest, during the time period of interest;
- Airspace configuration of the region of interest, during the time period of interest;
- Declared/adjusted capacity of each sector in the region of interest, during the time period of interest;
- Selected mode: “automatic” or “what-if”;
- Required parameters for the “what-if” mode:
  - List of {TFV name} for CASA regulation;
  - List of {Gate name} to identify candidate flights for rerouting or ground delay.
- Additional parameters for the rerouting module:
  - List of {TFV name} to use for rerouting;
  - List of {TFV name} to avoid when rerouting.

HotspotSolverReply

Description:

This function returns the list of DCB measures (with details on each measure as described in Table 7) to solve the selected List of {Netspot}.

The solver indicates whether all hotspots/Netspots are mitigated or not. Also, a performance report is returned, specifying for example, the total ground delay, the distribution of ground delay among flights and AUs, and the average preference level of each AU, with rerouted flights.

The solver returns the expected load of each sector within the region and time period of interest, in case all computed DCB measures are implemented.

Data expected:

- List of DCB measures as described in Table 7;
- Performance report of the DCB measures;
- Expected load of each sector in the region of interest, during the time period of interest.

5.2.5 AU Preference AI Component

At NM/FMP there is a lack of available historical AU behaviour data and/ or also preference regarding to a Flight Plan selection path when operating a given city pair (with a given aircraft).

On another hand, to sustain the global ISOBAR concept and mitigation solver, it is required to get not only the “preferred” path for a given triplet (city-pair, aircraft type, operator), but a set of alternative paths that can be used for the mitigation purposes facing weather linked imbalances. This is very relevant when considering efficient demand prediction.

As the capability for the “path” extend is still on-going, it can either refer to route (2D) or track (3D) for geospatial concern, or to trajectory (4D) if it includes the temporal dimension.

5.2.5.1 Conceptual Module Definition

The idea of the AU preference component is to provide:

- Preferred path for a given triplet (city-pair, aircraft, operator);
- Alternatives paths for a given triplet (city-pair, aircraft, operator).

The idea beyond the “alternatives” is to provide alternative flight liable to be used during specific (degraded) weather condition. Thus, the way to provide such alternatives should capture the meteorological effect onto those paths selection.

The provision of AU preference in path prediction aims at providing a demand prediction with enough liability from a pre-tactical (D-1) to a tactical projection. Indeed when combined for the planned slots (including operated city-pair/aircraft type and operator) on a given (and sliding) horizon planning, the provision of predicted paths (from historical learning) will support the demand characterisation.

Moreover the hotspot mitigation / solver is expecting some alternatives (trajectories highly expected) to propose efficient mitigation actions or options. That is the reason why the AU preference module shall not only provide the preferred path but also a set of alternatives paths.

Here below are proposed the schematic diagrams for the AU preference AI component. The first one concerns the AI component building (training) (Figure 63) and the second one the use of this module for path prediction (Figure 64).

Since options are still under study, those diagrams reflect their implementation according to the following hypothesis:

- HYP1: consider the inclusion of the weather features as a direct input for the AI component.
- HYP2: consider the use of weather features to derive alternative paths through a complementary module.

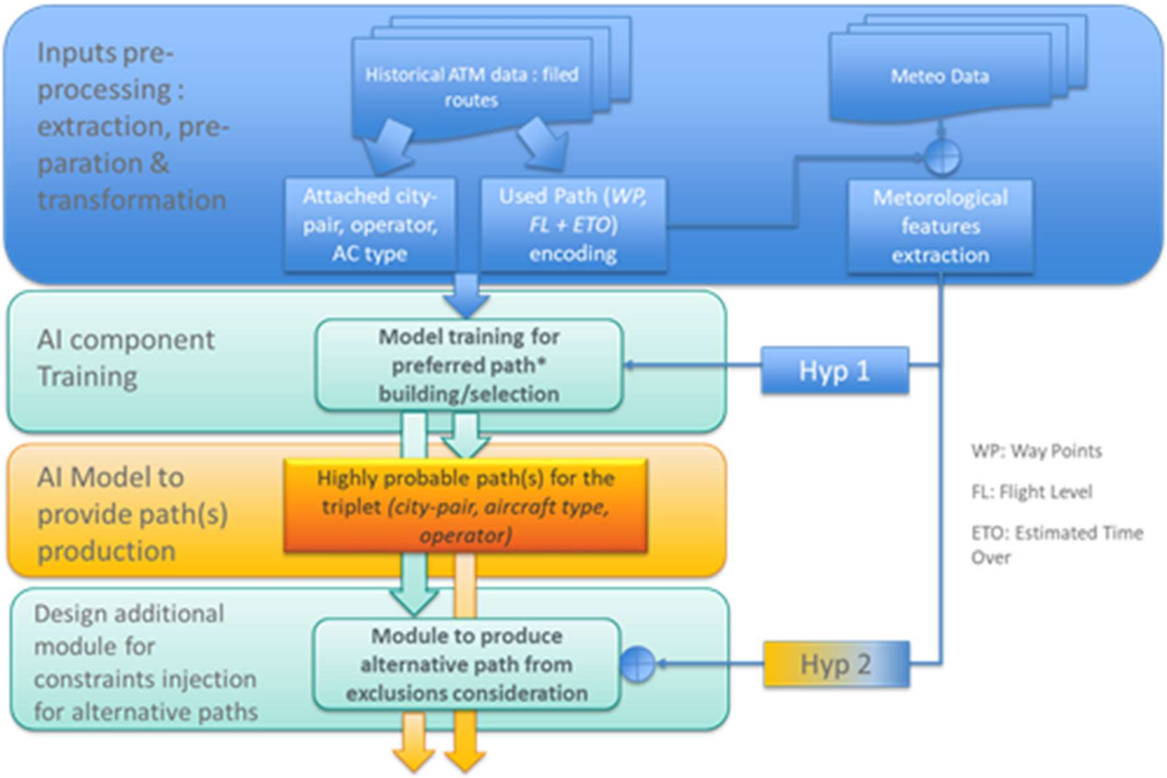


Figure 63 Block diagram for AU preference component: Training

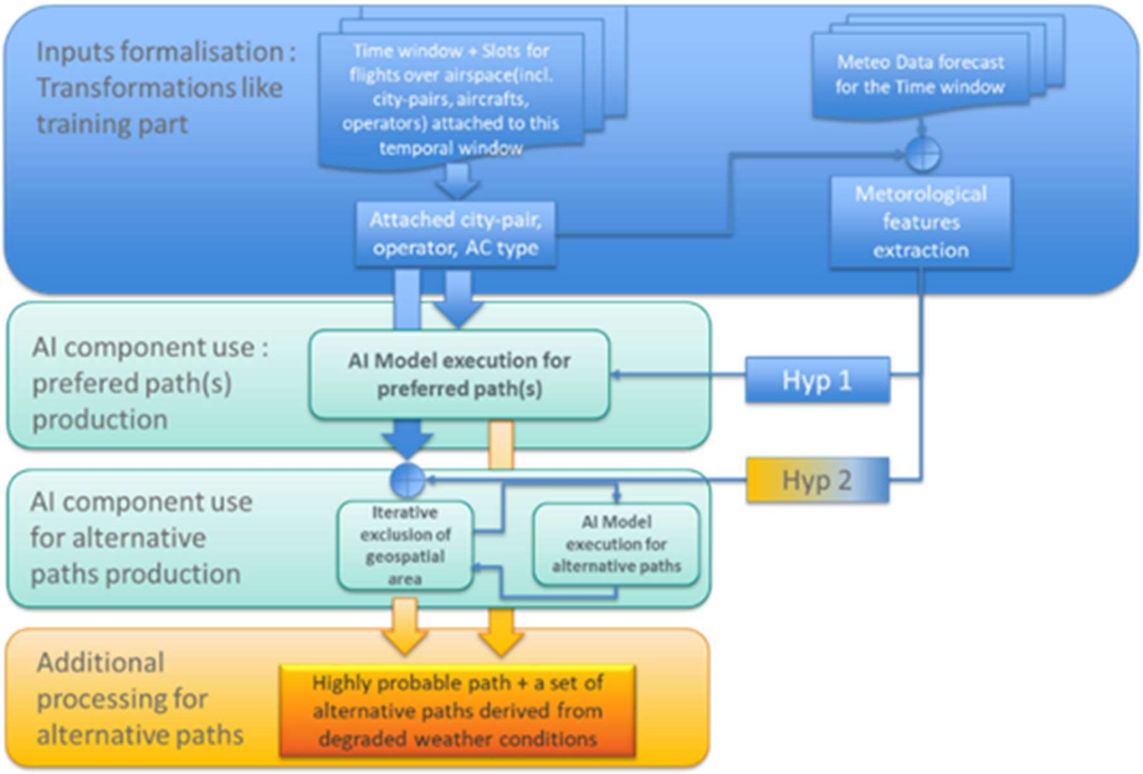


Figure 64 Block diagram for AU preference component: Prediction

Concerning the hypothesis, the choice of one versus another will result from an on-going feasibility study. One major criterion will be the capability to generalize an AI component generation rather than duplicate it at the triplet level (city-pair, aircraft, operator):

- HYP1: may probably induce the duplication of AI component generation for each of the triplet.
- HYP2: will reduce the specific model's creation by handling multiple triplets within a single model building.

5.2.5.2 Data Flow Exchange and Service/Functions Provision Process

For the training purpose, the AI AU Preferences module needs the historical ATM data for the city-pairs operated and liable to be operated for the selected airspace domain (= airspace volume from ground level to a maximum altitude over a given geographic area) onto which the demand will have to be predicted. This includes "internal" operated city-pairs within the airspace domain, but also flights whose path is liable to cross the airspace domain.

Those historical data should contain "at the best" the first flight plan filed by AU. As those data are not recorded for all databases (particularly EUROCONTROL R&D / DDR2 databases), the module will manage a compromise between the planning domain coverage for the AU preference or the use of a most complete coverage but using flight plan filed and validated (the ones available in EUROCONTROL ATM database).

The AI component module will provide the highly probable path for a set of given triplet (city-pairs, operator, aircraft type). The demand prediction will use those planned / preferred trajectories to derive demand characterization (metric To Be Defined):

- A temporal extend / time horizon is required (*and a geospatial one, unless the further provided planned slots (crossing the airspace domain) implicitly provide this information*). The paths attached to the flights during this window horizon will be provided.
- To get the flights path prediction, it is needed as input the slots definition over the previous time horizon: (DAY, DEP-TIME, DES-TIME, city-pair, Aircraft type, Operator), attached to this temporal interval, i.e. slots whose temporal extend intersect the temporal window under study.
- To provide alternative paths representative of convective weather constraint options, meteorological history is needed.
- To provide the highly probable path for the given temporal extend (planning horizon) it is used the weather forecast for the targeted time horizon up to D-1 of the time horizon start.

The table below summarises the inputs and outputs used for the AU preference AI component for trajectory provision over a temporal extend (time horizon)

AU preference Training	Inputs	Outputs	Used by
ATM	History of flights Flight ID, ADEP (ICAO), ADEP (long/lat), ADES (ICAO), ADES (long/lat), AC Type, AC Operator, Requested FL, Actual Distance Flown (nm) **Temporal** : TBC (due to availability) **Airspace Domain** : crossing the selected airspace domain (TBC)	Hyp 1 : - N models for highly probable paths predictions N : *could be the result of the sum(city_pairs)*operatore_per_city_pairs*_aircraft_type_per_city_pairs* *format : TBD*	AU preference prediction
ATM	History of Flight Plan filed Flight ID, Sequence, long/lat, FL, Time Over, of each WP. **Temporal** : TBC (due to availability) **Airspace Domain** : crossing the geographic area + max altitude (TBC)		
ATM	History of Flight Plan flown (optional) Flight ID, Sequence, long/lat, FL, Time Over, of each WP. **Temporal** : identical to filed ones **Airspace Domain** : identical to filed ones	Hyp 2 : - M models for highly probable path generation. M < N/20 at least. - A module for alternative path generation (that uses previous model + exclusions) *format : TBD*	
METEO	History of (actual) meteo conditions severity , Top of cloud/Altitude at each of the geographical location (long/lat) *grid step TBC (each 0.25°)* . **Temporal** : TBC (due to availability) **Airspace Domain** : across the selected airspace domain (TBC)		
AU preference Prediction	**Inputs**		**Used by**
ATM	Slots : Planned Take-Off, Planned Landing, ADEP (ICAO), ADEP (long/lat), ADES (ICAO), ADES (long/lat), AC Type, AC Operator **Temporal** : sliding horizon planning **Airspace Domain** : crossing the geographic area + max altitude (TBC)	Preferred path for the inputs slots. Format : *Path = route(2D) up to trajectory (4D) characterization (trajectory targetted)*	Demand prediction/characterization
METEO	Weather forecast : severity , Top of cloud/Altitude, probability of convection at each of the geographical location (long/lat) : *grid step (0.25°)* **Temporal** : every hour for the 24H from the start of horizon planning **Airspace Domain** : across the selected airspace domain (TBC)	Alternatives paths (number is liable to be dependant of the triplet (city, ac, operator)). Format : *Path = route(2D) up to trajectory (4D) characterization (trajectory targetted)*	Solver : mitigation component WP4

Table 8 General Inputs / outputs for the AU preference AI component train and use (prediction)

Thus, in terms of operational expectation, the AU preference AI component will respond to a:

AUPreferredAlternativeTrajectoriesRequest

Description: A request for the provision of an alternative path/trajectory, attached to a selected flight (liable to be re-routed), based on possible historical preference(s) of the associated AU. Added to a flight identification (that can be expressed/derived as a triplet (city-pair, aircraft type, operator), some additional constraints will have to be provided for this purpose. Those constraints could be either exclusion traffic volumes (mainly expressed as geographical areas) resulting from hotspot detection or imposed volumes, coming from coldspot identification (mainly expressed as geographical areas).

Data expected:

- (ATM data) Flight ID: identifier that we are liable to link to a triplet (city-pair, aircraft, operator);

- *Optional: rather than an ID, an alternative request could be required through the provision of a direct triplet identifier;*

- (Weather/ Regulations) Geographical Constraints for alternative provision:
    - List and geographical identification of exclusion or imposed airspace volumes for path/trajectory provision. Formalism TBD, but shall indicate the geographical constraints to provide an alternative route (up to an alternative trajectory);
    - *Optional: those geographical constraints could be derived from weather forecast grid, through the use of some thresholding method (TBD) in terms of probabilistic and severity level attached to an exclusion area/volume for instance.*

Note: no temporal constraints are described here above since the trajectory alternative request and the provision of geographical constraints are considered to be temporally consistent, i.e. for the requested flight (attached to the alternative request) it is expected to have consistency between geographical constraint and the slot attached to the flight. If not, thus some complementary information will be required attached to the previous inputs, about the flight slot (for ATM data) and the time extend of the respective geographical constraints provided.

The AU preference AI component in response to the request will provide a:

AUPreferredAlternativeTrajectoriesReply

Description: As a reply, an alternative trajectory (if possible from the historical point of view[4]) will be provided to answer a AUPreferredAlternativeTrajectoriesRequest. This trajectory will be provided as an alternative path (from route (2D) up to trajectory (4D): capability still under study). This alternative will be provided to the AI Hotspot Solver that will use it as a Hotspot solving capability.

Data provided:

- Alternative Flight Plan attached to the Flight ID (or triplet) request:

    - Successive Geographical WP: route (2D);

    - Additional provision (under study) for trajectory (4D):

        - Successive Estimated Time Over route WP (from departure time);
        - Successive Flight Levels attached to route WP.

5.2.6 AI Components Interrelation and Dependencies

The following diagram presents the internal data exchanges between the ISOBAR AI components and the interrelation with NM Systems, focused on AI components outputs. The diagram is based on the description of the AI components presented in section 5.2. (references to this document sections are mentioned for each AI component). The following assumptions are applicable to the ISOBAR AI

[4] In some case, due to low populated history attached to a given triplet, it could not be possible to provide an alternative realistic route/trajectory. This case shall be considered from an operational point of view, as alternatives considered from the same Aircraft type or same Operator preferences could be proposed.

Components internal and external data exchanges at the level of this intermediate OSED. These assumptions will be confirmed while maturing the concept in the final OSED, which may lead to updates of this section:

- The Gate and the Netspot objects are defined by user (NM or FMP) through a Gate tool not represented in the diagram;
- The AI Meteo Engine, AI AU Preferences Engine and the AI Hotspot Mitigation Solver described respectively in sections 5.2.1, 5.2.5 and 5.2.4 are represented following the description provided in the current OSED issue.

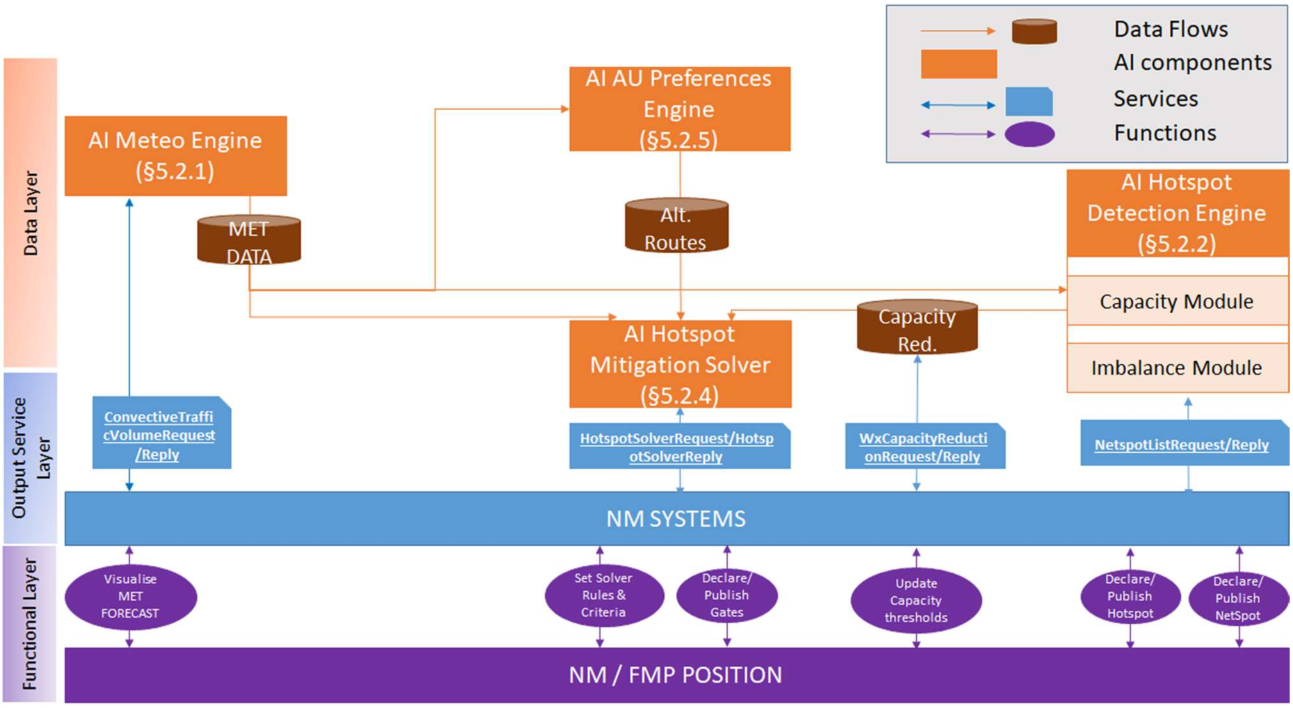


Figure 65 ISOBAR AI Components Internal Data Exchanges and Output Interrelation with NM Systems

5.2.6.1 Data Layer

This paragraph details the data highlighted in the main diagram above, which are the main internal data exchanged between the ISOBAR AI Components.

Assumptions: as the architecture is not yet mature, it is assumed that data shall be provided on a B2B service mode, upon solicitation from the consumer to the provider. It however may be better in the future to envisage a broadcast distribution of the data. This point shall be matured throughout the project, notably by tasks 1.3 and 5.3, leading to update of this section accordingly.

DATA	DATA Content	Provider	Consumer(s)
MET DATA	Contains the Probabilistic Prediction of thunderstorms with several parameters such as - Probability of Occurrence - Severity - Altitude (top of cloud) - Position(s) These data will be sent to consumer upon solicitation of the consumer(s).	AI Meteo Engine	- AI AU Preferences Engine - AI Hotspot Mitigation Solver Capacity Module of the AI Hotspot Detection Engine
Alternative Routes	Contains the Alternatives Routes for a given triplet (city-pair, aircraft, operator) with weight of the most preferred one. These data will be sent to consumer upon solicitation of the consumer.	AI AU Preferences Engine	AI Hotspot Mitigation Solver
Capacity Reduction	Contains the Capacity Reduction for a given area due to weather prediction. These data will be sent to consumer upon solicitation of the consumer.	Capacity Module of the AI Hotspot Detection Engine	AI Hotspot Mitigation Solver

Table 9 Data format for Data Layer

5.2.6.2 Output Service Layer

This paragraph details the services to connect ISOBAR AI components outputs with the NM Systems, in order to feed the NM & FMP Positions.

In each service description, appears in bold the parameters to be filled from the user when using the service.

Note: The term "User" refers to both NM and FMP. When the user concerns only one of them, then the role is precised to avoid ambiguity.

Service	Service Description	Linked Functionality	Provider
ConvectiveTrafficVolumeRequest/Reply	This service "on-demand" is triggered when the user wants to retrieve the Weather Probabilistic Prediction of	Visualise MET FORECAST	AI Meteo Engine

Service	Service Description	Linked Functionality	Provider
	Thunderstorms over a **given area and a timeframe.** The expected output on user side is a geographical map with color codes		
HotspotSolverRequest/HotspotSolverReply	This service "on-demand" is triggered when the user wants a support for decision to solve **a given Netspot**[5]. Two modes are possible : - Automatic : no further inputs is required - What-if : **solver rules and criteria** are to be set by the user This service will call a request to the AI AU Preferences component to get the alternatives routes.	Solve Netspot (not displayed on diagram)	AI Hotspot Mitigation Solver
WxCapacityReductionRequest/Reply	This service "on-demand" is triggered when the user wants to retrieve the predicted capacity reduction in case of a thunderstorm occurrence for his analysis, **over a given sector and/or gate and/or Netspot.**	Update Capacity Thresholds	Capacity Module of the AI Hotspot Detection Engine
NetspotListRequest/Reply	This service "on-demand" is triggered when the NM wants to analyse a list **of hotspots published and gates set by the gate tool** and assess if a Netspot has to be declared	Declare/ Publish Netspot	Imbalance Module of the AI Hotspot Detection Engine

Table 10 Data format for Output Service Layer

[5] Assumption is that the AI Hotspot Mitigation Solver is designed to support Netspot solution only. To be confirmed while maturing the concept.

5.2.6.3 Input Service Layer

The following diagram presents the interrelation between AI ISOBAR components with NM Systems, focused on AI components required inputs. The diagram is based on the description of the AI components presented in section 5.2. (references to this document sections are mentioned for each AI component).

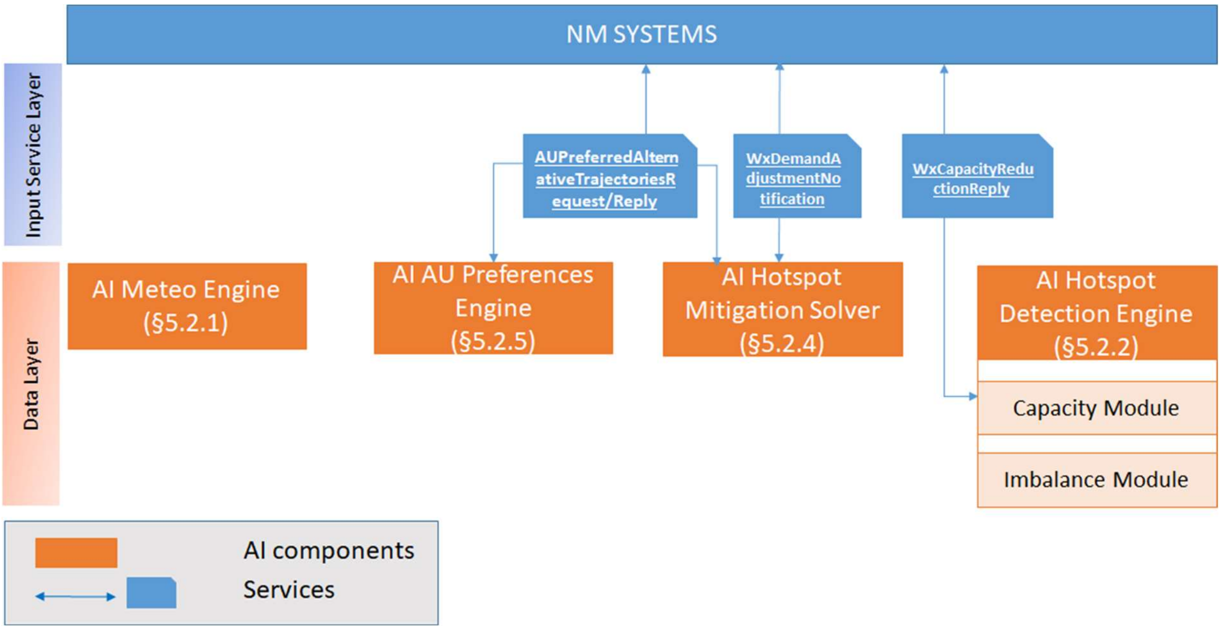


Figure 66 ISOBAR Input interrelation with NM Systems

Service	Service Description	Linked Functionality	Consumer
AUPreferredAlternativeTrajectoriesRequest/Reply	This service will be automatically triggered by the AI component upon solicitation of the AI hotspot Mitigation Solver (upon a Call AI Solver Request – refer to §5.2.6.2). The service is used to retrieve traffic information on which alternatives are requested, i.e. DAY, DEP-TIME, DES-TIME, city-pair, Aircraft type, Operator	Solve Netspot (not displayed on diagram)	AI AU Preferences Engine
	This service will be automatically triggered upon solicitation of the AI hotspot Mitigation Solver (upon a Call AI Solver Request – refer to §5.2.6.2).	Solve Netspot (not displayed on diagram)	AI Hotspot Mitigation Solver

Service	Service Description	Linked Functionality	Consumer
	This service is used to retrieve complete traffic demand over the Netspot to analyse		
WxDemandAdjustmentNotification	This service will be automatically triggered upon solicitation of the AI hotspot Mitigation Solver (upon a Call AI Solver Request – refer to §5.2.6.2). This service is used to retrieve current traffic load over the Netspot area	Solve Netspot (not displayed on diagram)	AI Hotspot Mitigation Solver
WxCapacityReductionReply	This service will be automatically triggered by the AI component upon Capacity Reduction Request - refer ts §5.2.6.2. or upon solicitation of the AI hotspot Mitigation Solver (after a Hotspot Solver Request – refer to §5.2.6.2) The service is used to collect declared initial capacity of the sectors / gates / traffic volumes under analysis to compute the expected reduction	Update Capacity Thresholds	Capacity Module of the AI Hotspot Detection Engine

Table 11 Data format for Input Service Layer

5.3 Service Requirements

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.1010
Title	Probability of storm
Requirement	Probability of storm occurrence shall be available for the hotspot detection module to compute the traffic demand due to convection. The probability of storm is needed at least with 1 hour time granularity and 0.25x0.25 km spatial granularity.
Status	<in progress>
Rationale	Hotspot due to convection needs the probability of storm to be computed.
Domain	Demand
Type	Data

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.1020
Title	Sectors/gates information
Requirement	Sector/gates information shall be available for the hotspot detection module to compute the traffic demand per sector/gate. The sectors/gates boundaries attributes are: vertical domain (min, max), coordinates (latitude, longitude), name.
Status	<in progress>
Rationale	Hotspot detection module needs the geographical area where the demand is computed.
Domain	Demand
Type	Data

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.1030
Title	Traffic Information
Requirement	Historical traffic information shall be available for the hotspot detection module to create the demand AI model. Traffic attributes are: waypoints (latitude, longitude), altitude, timestamp, city pair, operator, aircraft type
Status	<in progress>
Rationale	Hotspot detection module needs the traffic to compute the AI model.
Domain	Demand
Type	Data

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.2010
Title	Probability of storm
Requirement	Probability of storm occurrence shall be available for the hostpot detection module to compute the drop-down capacity due to convection. The probability of storm is need at least with 1 hour time granularity and 0.25x0.25 spatial granularity.
Status	<in progress>
Rationale	Hotspot due to convection needs the probability of storm to be computed.
Domain	Capacity
Type	Data

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.2020
Title	Sectors/gates information
Requirement	Sector/gates information shall be available for the hotspot detection module to compute the traffic drop-down capacity due to convection per sector/gate. The sectors/gates boundaries attributes are: vertical domain (min, max), coordinates (latitude, longitude), name.
Status	<in progress>
Rationale	Hotspot detection module needs the geographical area where the capacity is computed.
Domain	Capacity
Type	Data

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.2030
Title	Traffic Information
Requirement	Historical traffic information shall be available for the hotspot detection module to create the capacity AI model. Traffic attributes are: waypoints (latitude, longitude), altitude, timestamp, city pair, operator, aircraft type.
Status	<in progress>
Rationale	Hotspot detection module needs the traffic to compute the AI model.
Domain	Capacity
Type	Data

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3010
Title	Netspot Publication
Requirement	NMOC/FMP shall be able to publish a Netspot in the NM system. The Netspot attributes are: - NetspotName - ActionUpdate {create} - List of TFV Name - NetspotStatus {draft, coordinated, canceled} - StartTime - EndTime
Status	<in progress>
Rationale	NMOC/FMP needs to publish a Netspot containing a list of linked-Hotspots.
Domain	DCB
Type	Data/Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3020
Title	Netspot Update
Requirement	NMOC/FMP shall be able to update the attributes of a declared Netspot and to notify the changes in the NM system: - List of Hotspots - Start time - End time - Action Status {create, update, delete} - Nespot Status {draft, coordinated, canceled)
Status	<in progress>
Rationale	NMOC/FMP needs to update attributes of the declared Netspot: - To update the list of Hotspots - To update the start time - To update the end time - To update or delete the Netspot - To update the status {draft, coordinated, canceled)
Domain	DCB
Type	Data/Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3030
Title	Netspot Request
Requirement	NMOC/FMP shall be able to retrieve the list of Netspot declared in the NM system.
Status	<in progress>
Rationale	NMOC/FMP needs to access the list of declared Netspots.
Domain	DCB
Type	Data/Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3040
Title	Gate Publication
Requirement	NMOC/FMP shall be able to publish a Gate in the NM system. The Gate attributes are: - Gate Name - Traffic Volume Name
Status	<in progress>
Rationale	NMOC/FMP needs to publish a Gate to the NM system.
Domain	DCB
Type	Data/Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3050
Title	Gate Update
Requirement	NMOC/FMP shall be able to update a declared Gate in the NM system. It will consist of creating a new Traffic Volume associated to this Gate. The Gate attributes are: - Gate Name - New Traffic Volume Name
Status	<in progress>
Rationale	NMOC/FMP needs to update attributes of the declared Gate. It will allow to change the geographical delineation of the gate.
Domain	DCB
Type	Data/Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3060
Title	Gate Request
Requirement	NMOC/FMP shall be able to retrieve the list of Gates declared in the NM system.
Status	<in progress>
Rationale	NMOC/FMP needs to access the list of declared Gates.
Domain	DCB
Type	Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3070
Title	AU Rerouting
Requirement	Rerouting trajectory must be accessible for AU to adjust/refile flight plan.
Status	<in progress>
Rationale	Alternative trajectories must be published and accessible for AU.
Domain	DCB
Type	Data

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3080
Title	Hotspot detection
Requirement	Hotspot identification due to convection shall be published. This will identify the affected region and traffic.
Status	<in progress>
Rationale	Hotspot location is needed along the ISOBAR CORE and via B2B accessible for NMOC/FMP.
Domain	DCB
Type	Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3090
Title	AI-based Netspot solving in automatic mode
Requirement	NMOC/FMP shall be able to call the DCB hotspot solver in an automatic mode. The main solver parameter in the automatic mode is the Netspot to mitigate.
Status	<in progress>
Rationale	NMOC/FMP shall be able to solve the Netspot using AI techniques, without specifying expert insights, so as to find "the best possible" AI-generated DCB measures.
Domain	DCB
Type	Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3100
Title	AI-based DCB measures: Evaluation
Requirement	NMOC/FMP shall be able to evaluate the network-wide impact of a set of DCB measures returned by the solver, according to different KPIs.
Status	<in progress>
Rationale	NMOC/FMP needs to assess with high-fidelity the ATFCM effectiveness of the DCB measures returned of the solver, according to wide range of indicators.
Domain	DCB
Type	Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3110
Title	DCB measure: Publication
Requirement	NMOC/FMP shall be able to select and publish/implement a set of (or a single) DCB measure, either proposed by himself or generated by the AI-solver.
Status	<in progress>
Rationale	DCB Netspot solving is a time-continuous process. At some time steps, the NMOC/FMP may need to implement given DCB measures, so that they become part of the environment.
Domain	DCB
Type	Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.3120
Title	DCB measure: Publication
Requirement	NMOC/FMP shall be able to select and publish/implement a set of (or a single) DCB measure, either proposed by himself or generated by the AI-solver.
Status	<in progress>
Rationale	DCB Netspot solving is a time-continuous process. At some time steps, the NMOC/FMP may need to implement given DCB measures, so that they become part of the environment.
Domain	DCB
Type	Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.4010
Title	AI-based Netspot solving in guided/what-if mode
Requirement	NMOC/FMP shall be able to call the DCB hotspot solver in a guided/what-if mode. The solver parameters in the what-if mode are: - Netspot - Sectors candidate for CASA regulation - Sectors to avoid in case of rerouting - Selected gates to identify common flights among hotspots.
Status	<in progress>
Rationale	NMOC/FMP needs to solve the Netspot for different what-if scenarios using an AI-based solver guided by his own insights as an operational expert.
Domain	Playbook
Type	Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.4020
Title	AI-based DCB measures: Retrieval
Requirement	NMOC/FMP shall be able to retrieve the DCB measures computed by the hotspot solver, in both modes: automatic and guided/what-if. Details on each DCB measures shall be provided: - Type of measure (rerouting, ground delay, CASA regulation). - Related object (flight, sector). - Other details (alternative trajectory id, ground delay length, regulation period, etc).
Status	<in progress>
Rationale	NMOC/FMP needs to know the AI-generated DCB measures to solve the Netspot, in both modes: automatic and what-if.
Domain	Playbook
Type	Data/Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.4030
Title	DCB measures: Feedback
Requirement	NMOC/FMP shall be able to feed back the final selected DCB measures to the AI solver, in addition to the recorded DCB evaluation outcomes (reflected by the defined KPIs).
Status	<in progress>
Rationale	The DCB AI solver needs to learn from NMOC/FMP experience in assessing different KPIs of DCB solutions, thus fine tuning the solver algorithms.
Domain	Playbook
Type	Functional

[REQ]

Identifier	B2B-REQ-OSED-ISOBAR.5010
Title	DCB measures: Feedback
Requirement	Weather prediction shall be available for AU to update the flight planning system to improve data quality and situation management.
Status	<in progress>
Rationale	Weather prediction shall be published and via B2B accessible for AU.
Domain	Weather
Type	Data

6 References and Applicable Documents

6.1 Applicable Documents

Content Integration

[1] SESAR ATM Lexicon

Content Development

[2] EUROCONTROL B4.2 D106 Transition Concept of Operations SESAR 2020

System and Service Development

[3] EUROCONTROL B.04.03 D102 SESAR Working Method on Services

[4] EUROCONTROL B.04.05 Common Service Foundation Method

[5] EUROCONTROL NM 24.0.0 - NOP/B2B Reference Manuals – FlowServices, B2B/24.0.0/Flow, Edition 24.0.0.4.96, 02/06/2020

Performance Management

[6] SESAR 2020 PJ19.04: Performance Framework (2019) https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c9cd5e06&appId=PPGMShttps://orbite.eurocontrol.int/Pages/default.aspx

Validation

[7] SESAR 1 03.00 D16 System Engineering methodology

[8] European Operational Concept Validation Methodology (E-OCVM) - 3.0 [February 2010]

System Engineering

[9] SESAR 2020 Requirements and Validation Guidelines

6.2 Reference Documents

[10] SESAR S2020 PJ09-W2 DNMS Solution 49, OSED

[11] ISOBAR D1.1 “Operational Framework” Initial OSED