

Convective Weather Impact on Airspace Capacity: A Comparison between Permeability and Workload Based Approaches

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HARMONIC

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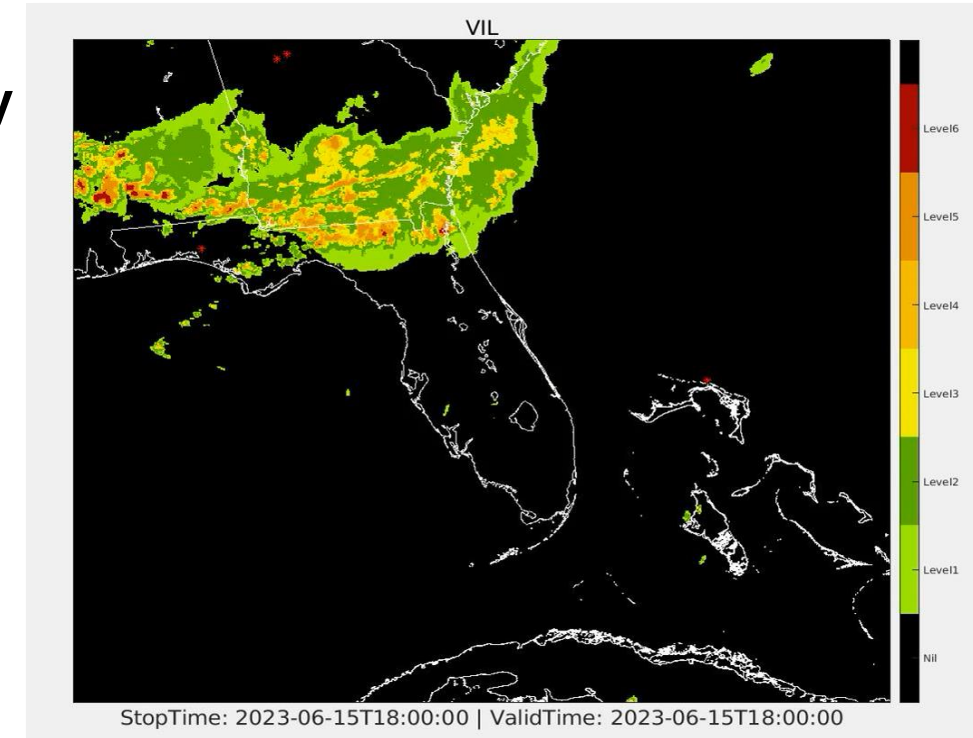
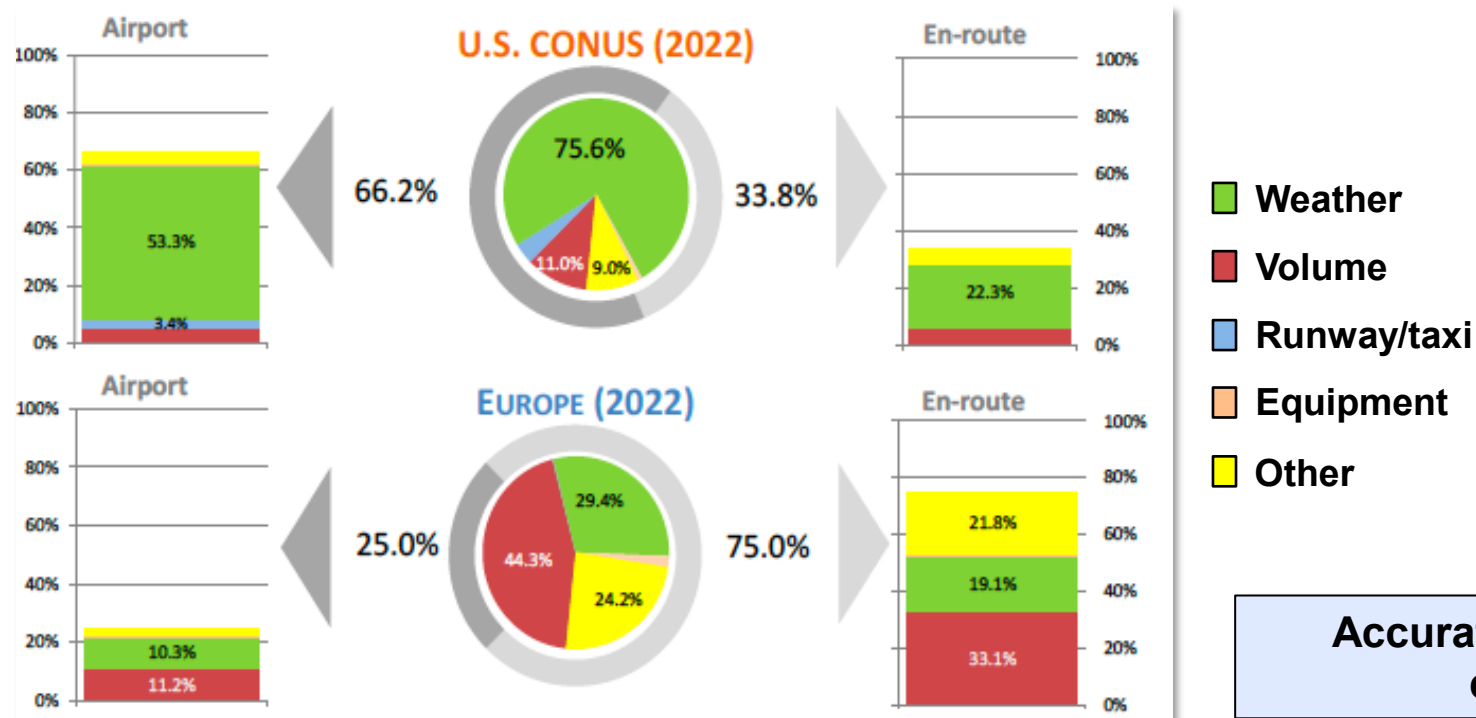
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Motivation



- Weather events disrupt air traffic operations in the United States & Europe, causing significant delays and pose a safety risk if not managed proactively
- These regions experience weather & manage it differently



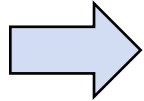
Accurately translating weather impacts into airspace capacity is key to manage these events



Outline



- Intro
- **Weather-Driven Capacity Models**
 - Permeability (US approach)
 - Workload (European approach)
- Models Comparison
- Discussion



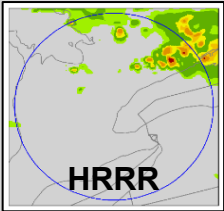


Permeability Airspace Capacity Prediction Algorithm

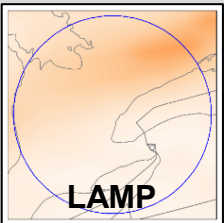
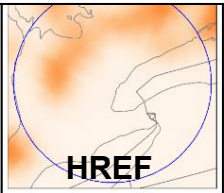


"Day of" 4-D Weather Forecasts

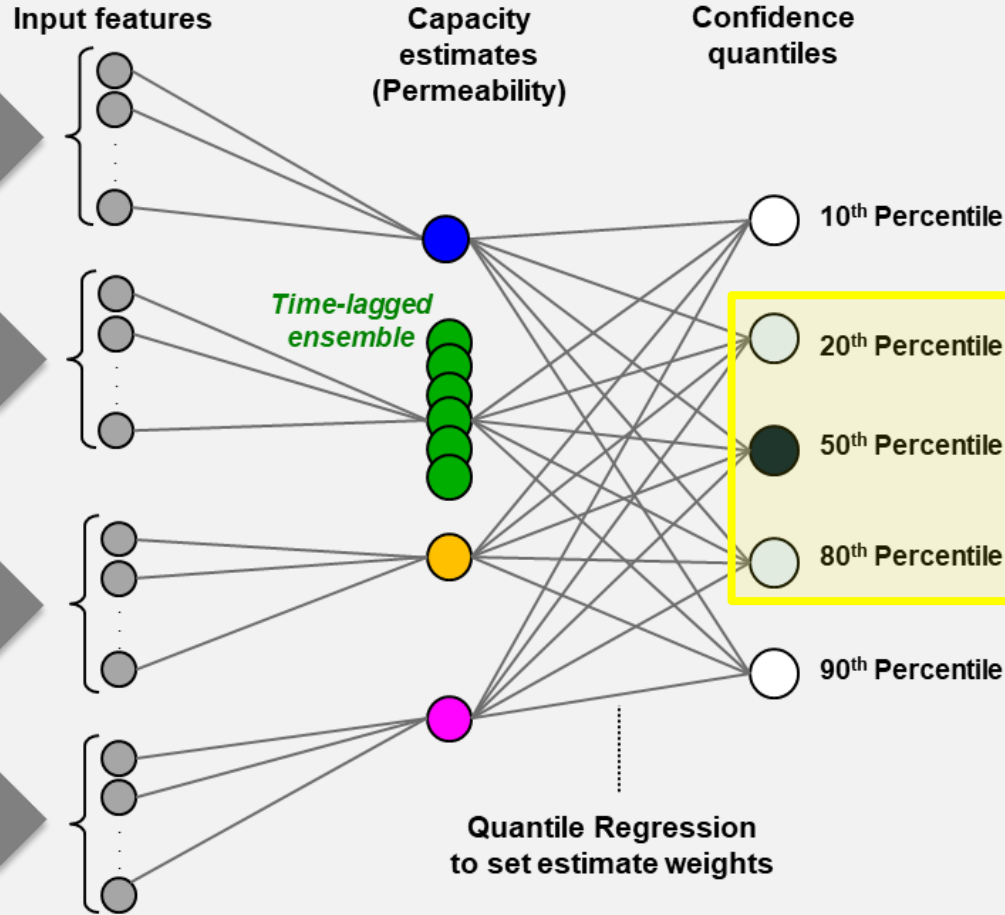
DETERMINISTIC



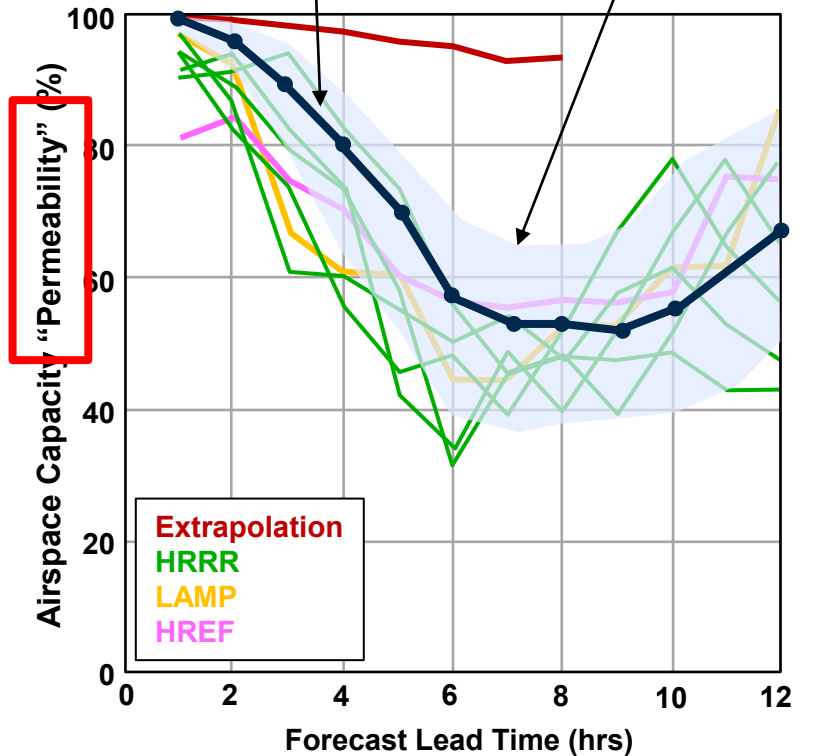
PROBABILISTIC



Feed Forward Neural Network (Pre-Trained on 3 Years of Operational Data)



Median Capacity Estimate 20th – 80th Prediction Interval

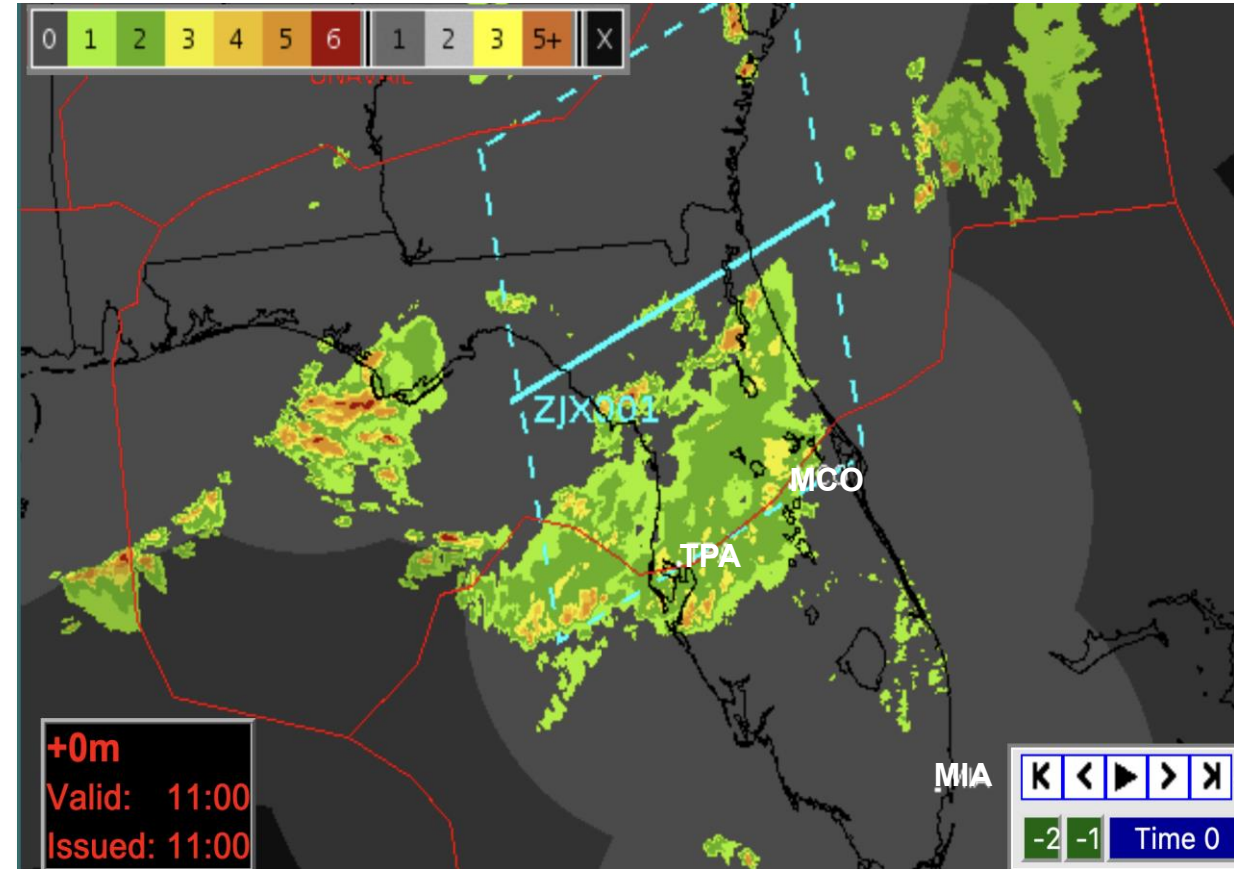
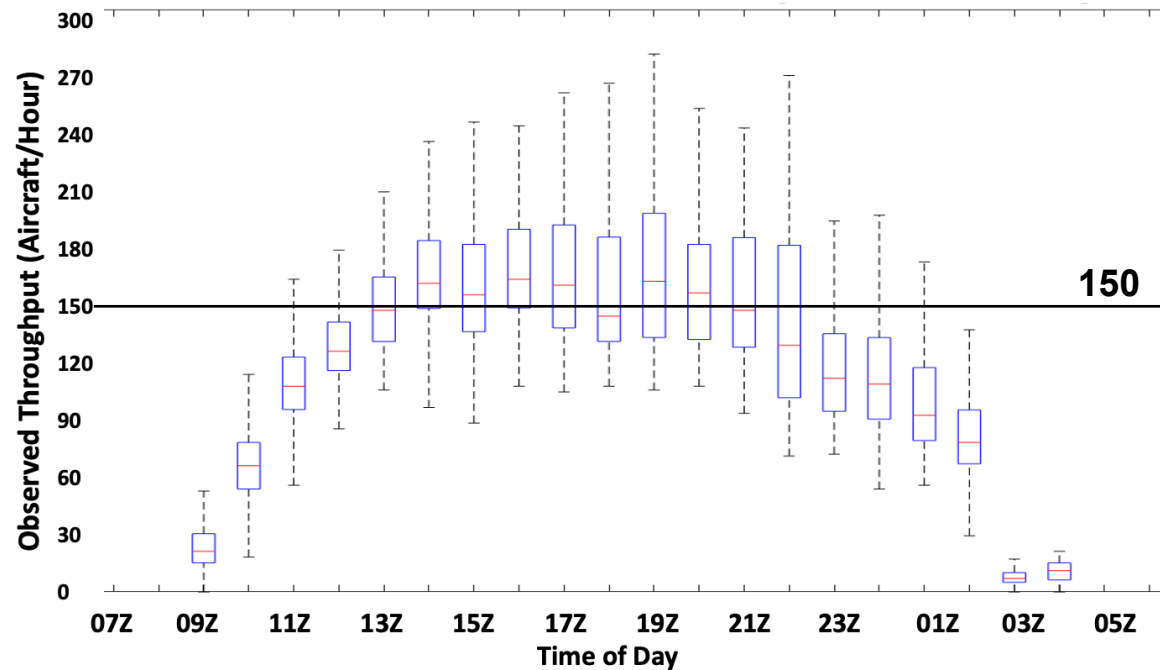




Permeability Airspace Capacity Benchmark



- Airspace capacity assessed using historical throughput over airspace evaluation box



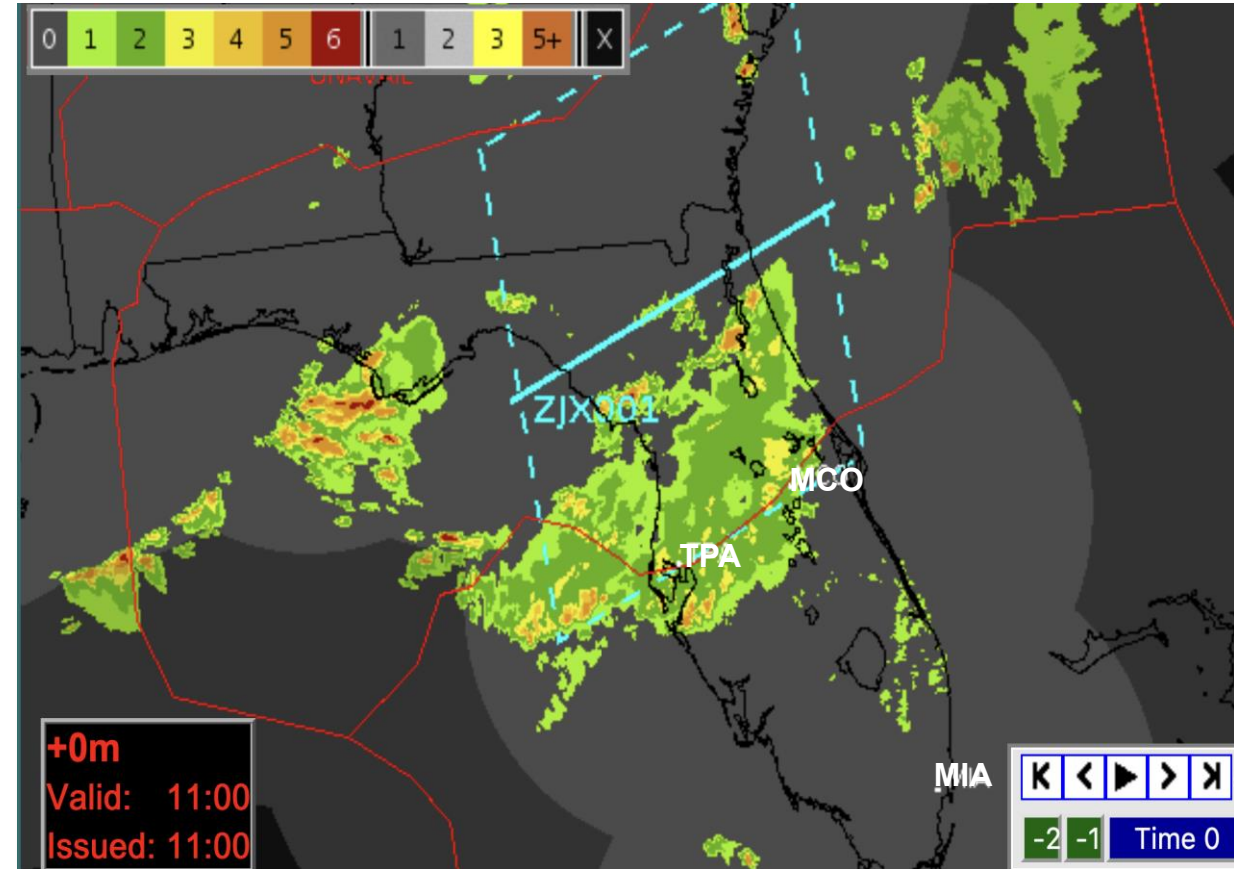
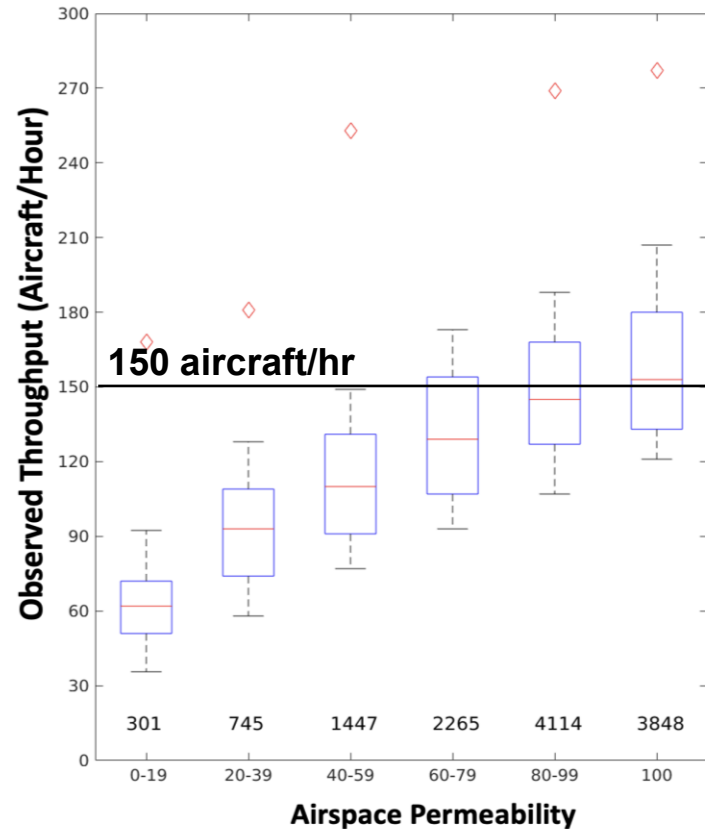
Weather impacts achievable hourly airspace throughput



Permeability Airspace Capacity Benchmark



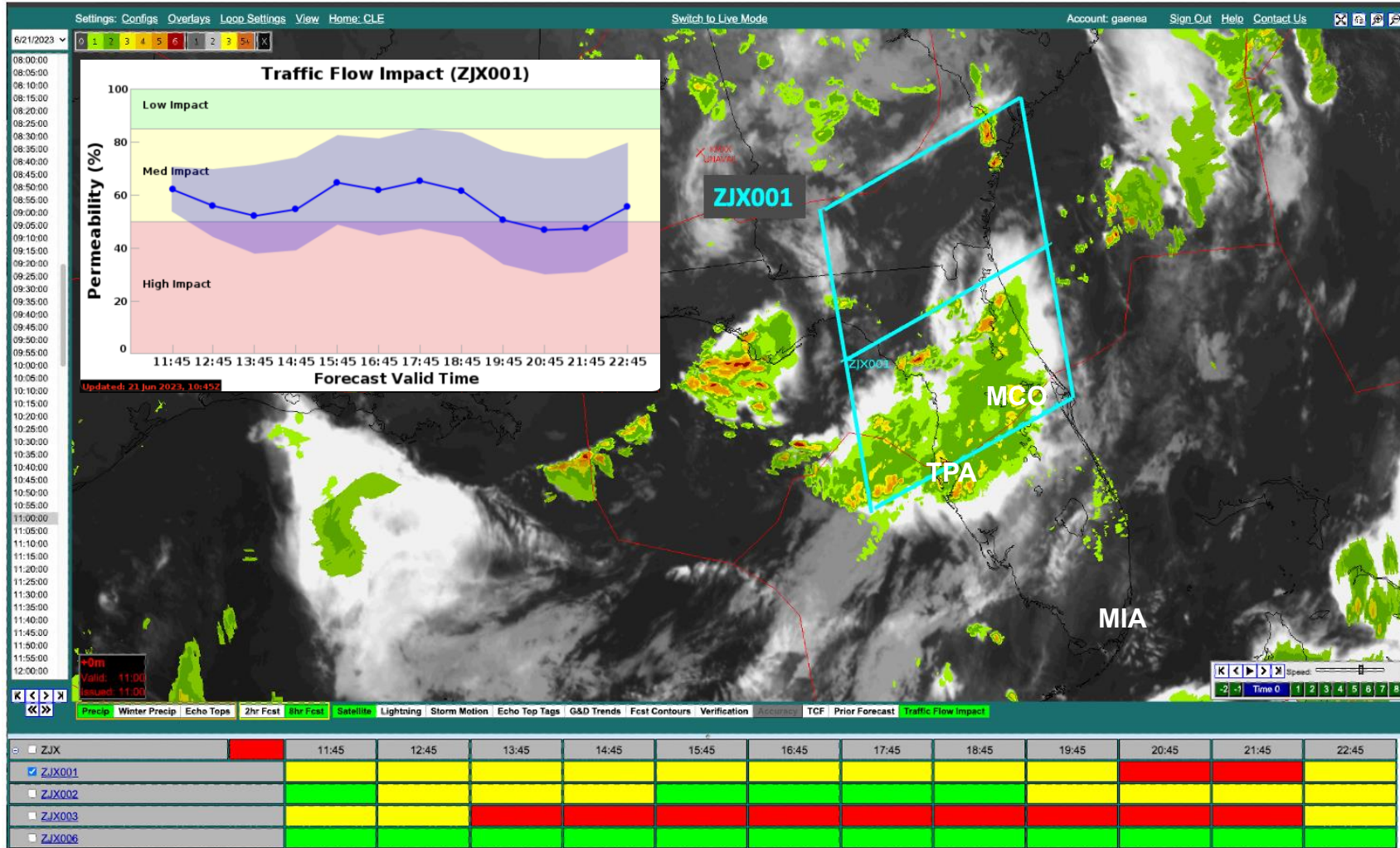
- Airspace capacity assessed using historical throughput over airspace evaluation box



Weather impacts achievable hourly airspace throughput



Traffic Flow Impact (TFI) Permeability

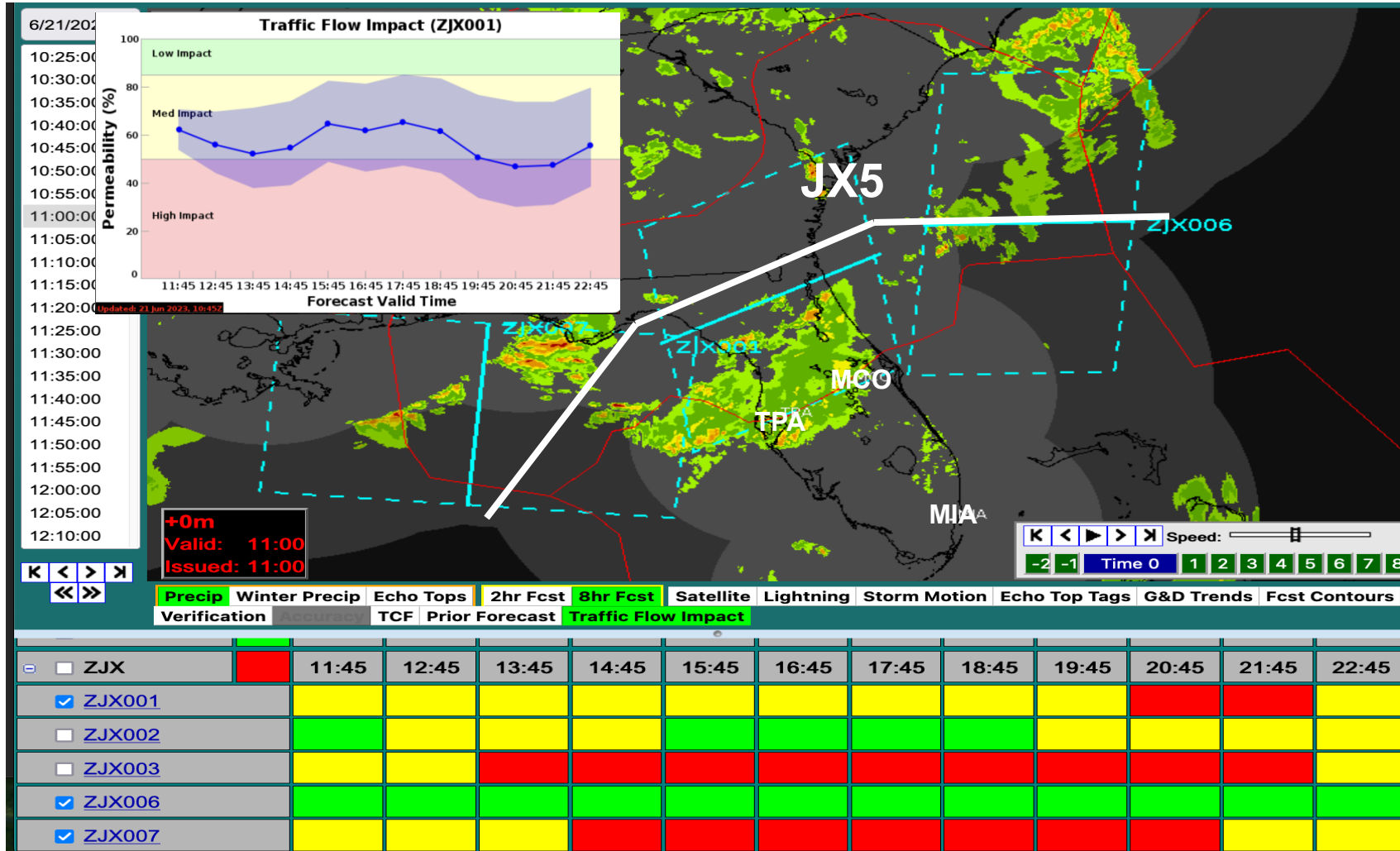


- Based on the FAA Consolidated Storm Prediction for Aviation (CoSPA) operational prototype radar mosaics
- 1 km grid resolution forecasts updated every 5 minutes for the 0-2 hour time horizon
- 3 km resolution forecasts updated every 15 minutes for 2-12 hour time horizon
- Permeability forecasts are updated every 15 minutes



Case Day

(June 21 2023)



- Significant weather impact forecasted affecting ZJX airspace
- FAA traffic managers imposed 10 hours AFP restriction to reduce demand

TFI decision support system forecasted weather impact characteristics



Case Day

(June 21 2023)



- **Observed throughput is higher than AFP rates 7 out of 10 hours (88 more flights delivered)**
- **Approximate translation of TFI permeability better matched observed throughput**
- **Less traffic would have been delayed using TFI translated rates**

Zulu Time	Observed T/put (ac/hr)	AFP Rate (ac/hr)	Observed – AFP Diff. (ac/hr)	Prop. TFI Rate (ac/hr)	Observed – TFI Diff. (ac/hr)
12	108	90	+18	112	-4
13	75	90	-15	112	-37
14	104	90	+14	95	+9
15	105	90	+15	95	+10
16	119	90	+29	107	+12
17	115	90	+25	97	+18
18	95	90	+5	97	-2
19	103	90	+13	97	+6
20	101	110	-9	102	-1
21	103	110	-7	102	+1
Total			+88		+12

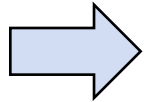
Decision-support translated airspace capacity impact better matched observed throughput



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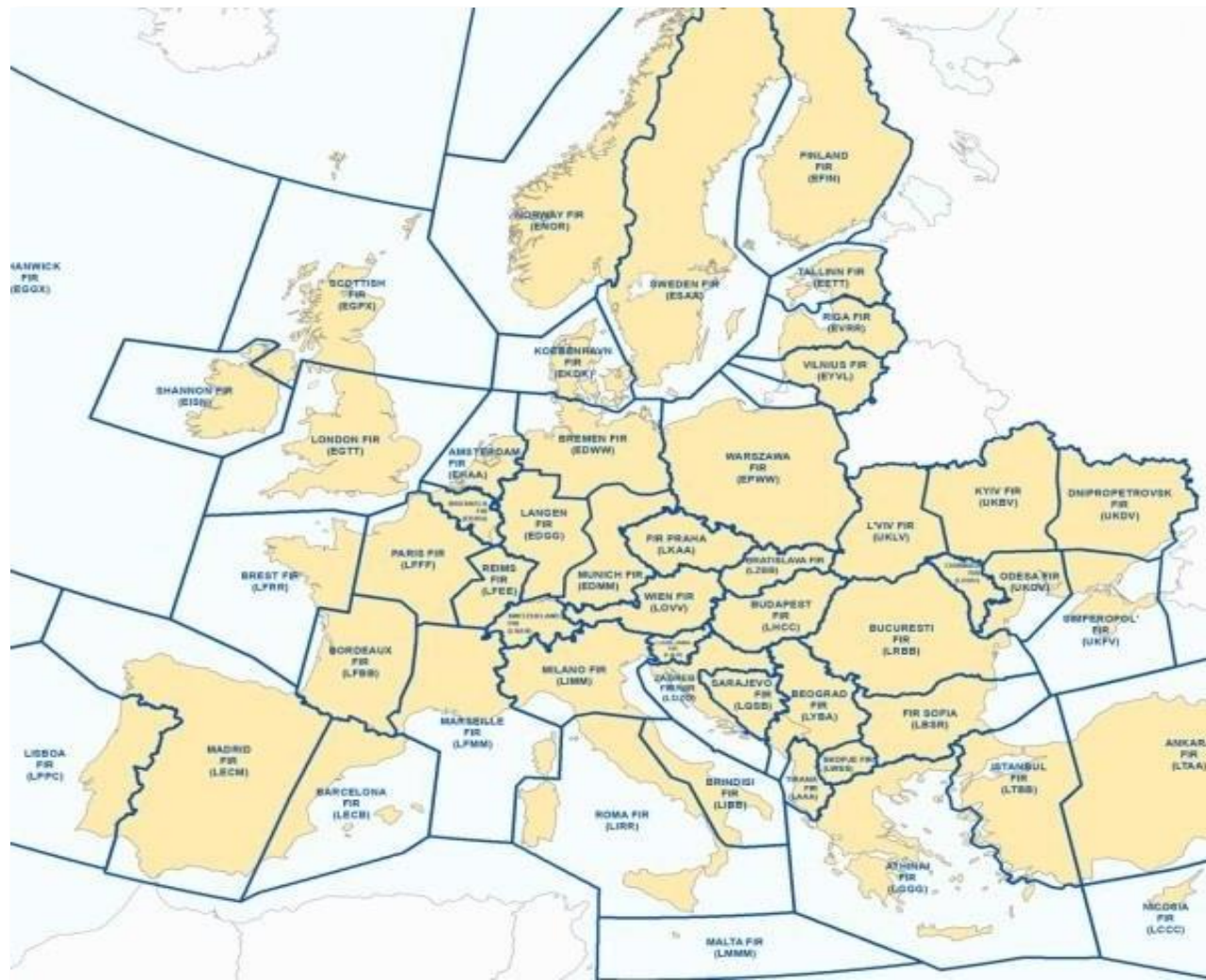




Convective Weather in Europe



- Capacity of an airspace sector is connected to the concept of ATCo Workload (max number of aircraft that can be safely managed by ATCo in 1hr)
- Convective weather increases the ATCo Workload due to additional tasks caused by the management of the pilots' maneuvers to avoid convective areas
- Additional complexity driven by involvement of several ANSPs when convective areas affect neighboring states and unexpected flight intruders (Cross-Border problem)

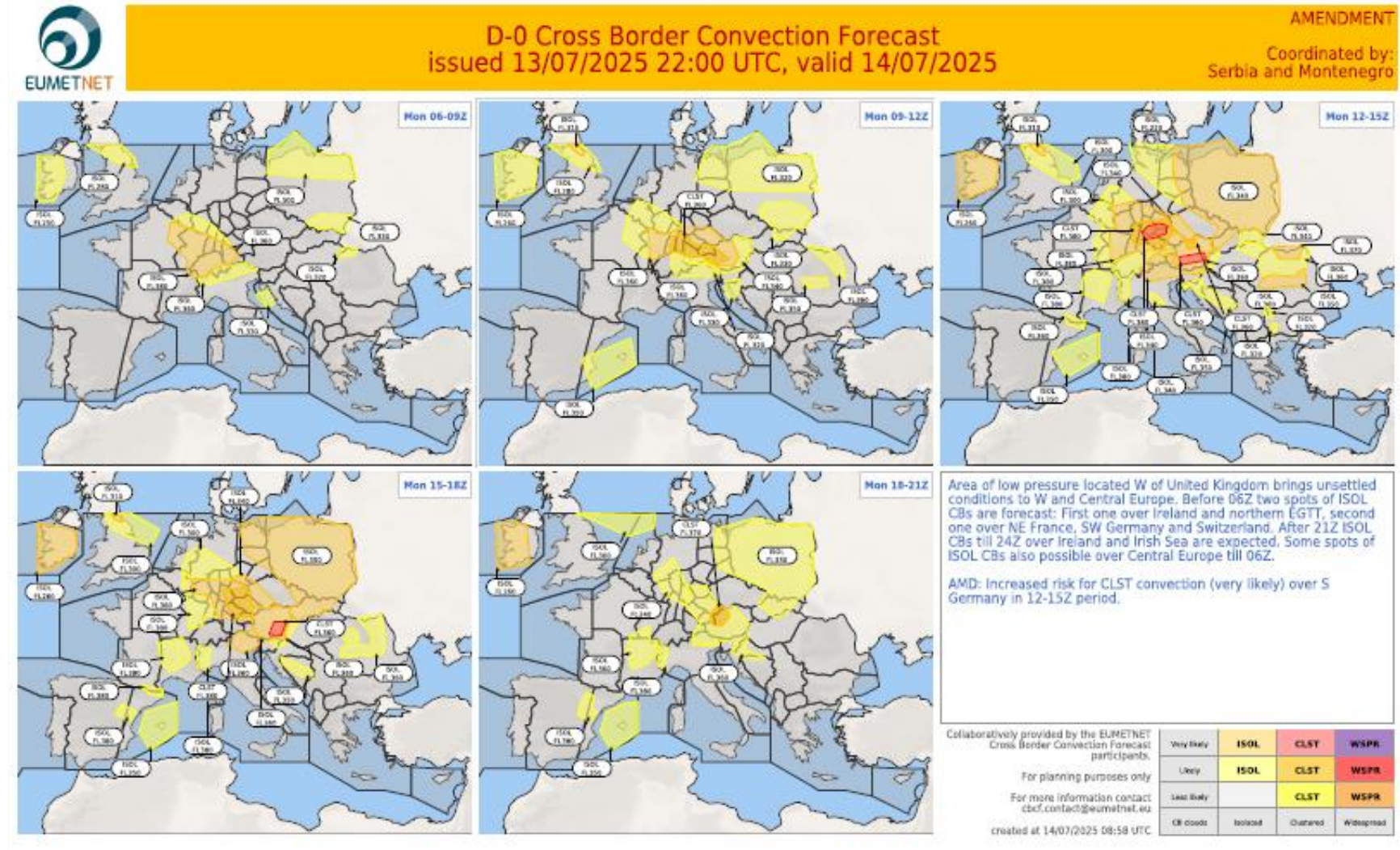




Convective Weather Mitigation in Europe



- To maintain safe workload during convective weather, **ATFCM** measures are applied by the **ANSPs**
- To mitigate the effects of the **Cross-Border** problem, **EUMETNET** coordinates the **Cross Border Convection Forecast (CBCF)**:
 - Probability forecasts of convective areas in the form of color-coded polygons
 - Issued at **D-1 (0900Z-2100Z)** and at updated at **2200Z** for the **D-0**
- CDM** environment among **Network Manager**, **ANSPs**, and airlines to coordinate mitigation strategies and apply predefined scenarios with **RAD** relaxations



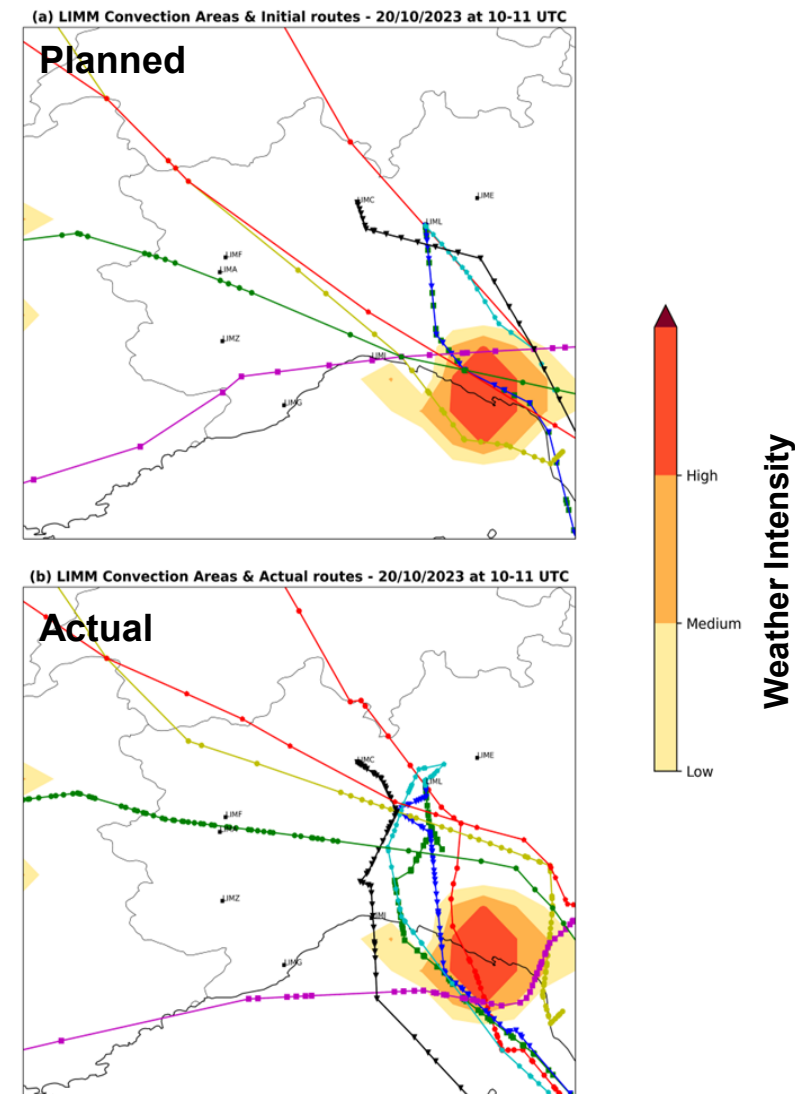


Convective Weather in the HARMONIC Project



Solution 382

- **Dynamic Airspace Configuration (DAC) concept extended including convective areas**
- **Fast Time Simulation (FTS) campaign based on Milan ACC (LIMM) airspace for a total of 58 Traffic Volumes**
- **Convective areas presented as color-coded polygons with three levels of intensity (Low-Medium-High):**
 - Summer 2023 convective weather scenarios (ERA5 Reanalysis data)
 - Replicating the shape of CBCF maps, but with increased resolution and considering a deterministic field (no probability)
 - Top fixed at FL400 to account for possible turbulence caused by overshooting cumulonimbus (CB)





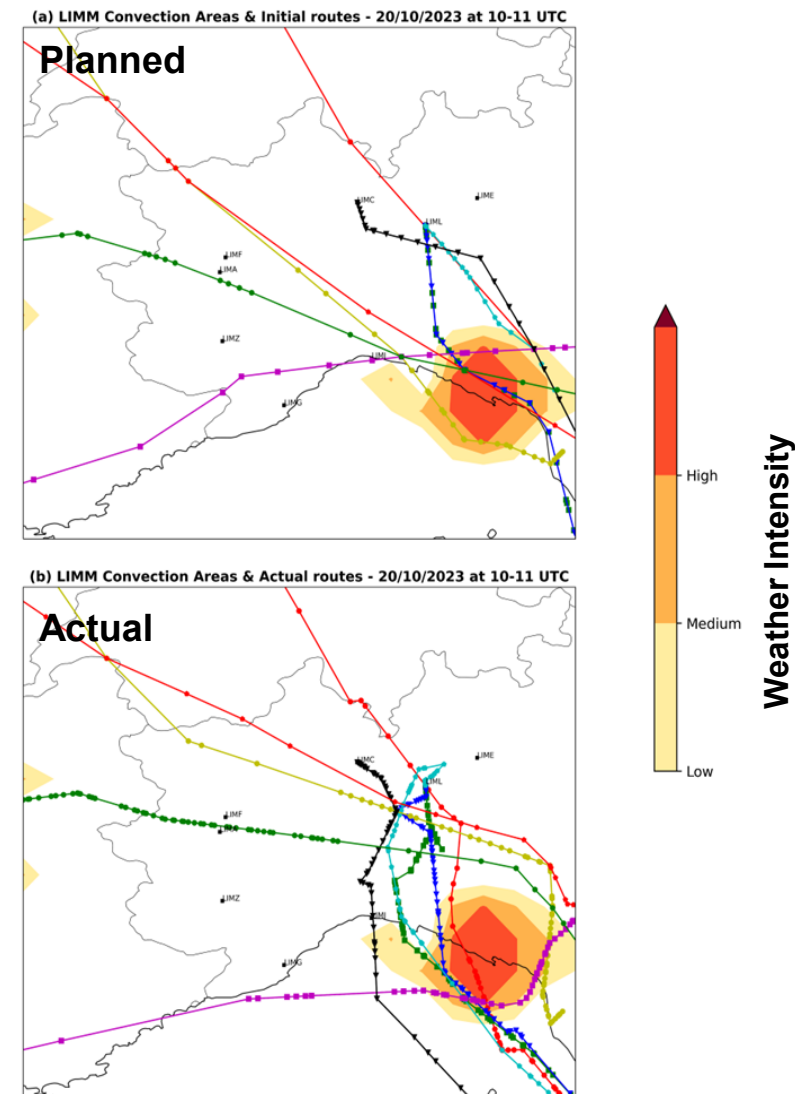
Convective Weather in the HARMONIC Project

Solution 382



- Under convective weather, aircraft deviate from planned routes, leading to longer and more complex paths
- Consider weather avoidance as a 9-second additional ATCo task (route/speed instruction, including readback)
- Task implemented progressively on planned traffic:
 - Adding 9 seconds to 50% of flights encountering a low-intensity convective area (yellow)
 - Adding another 9 seconds to 75% of flights encountering a medium-intensity convective area (orange)
 - Adding another 9 seconds to 100% of flights encountering a high-intensity convective area (red)

ATCo workload impact during convective events simulated with additional tasks/time to manage





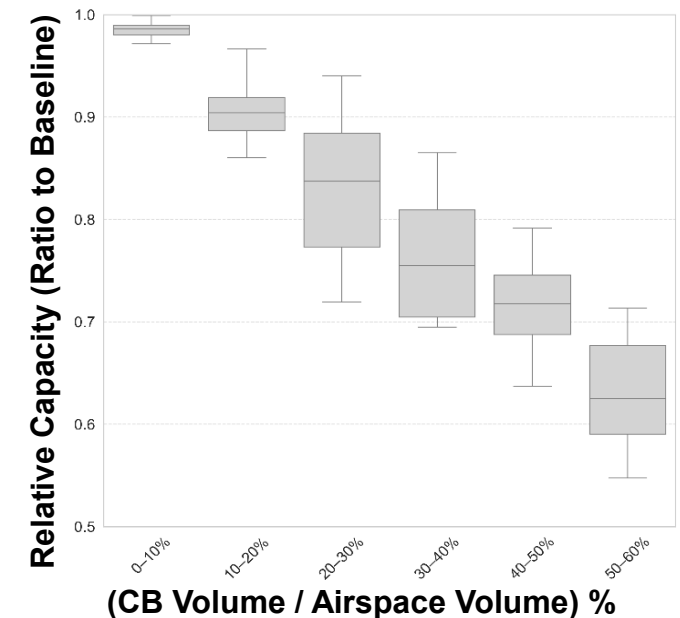
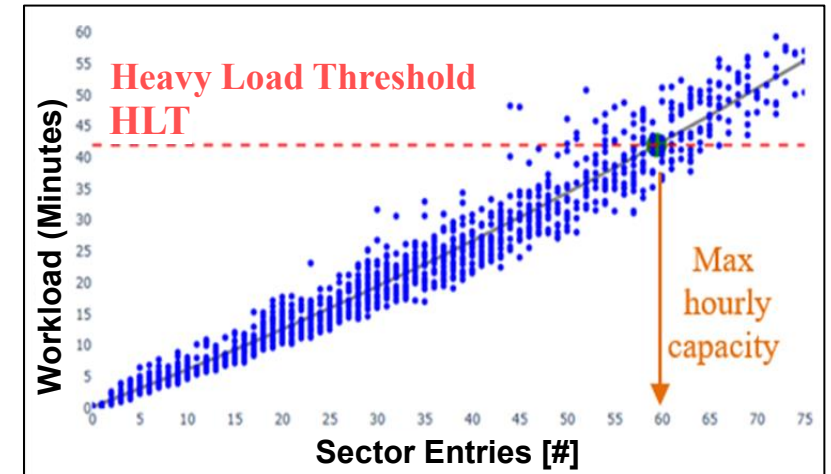
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- **Workload estimated with Fast Time Simulation campaign using:**
 - 48hrs non-convective traffic sample
 - 9 summer 2023 weather scenarios plus one non-convective as baseline
 - 58 Different LMM ACC Traffic Volumes
- **Sectors' capacity calculated applying regression methods:**
 - Capacity drops proportionally to the percentage of the sector's volume covered by the CB

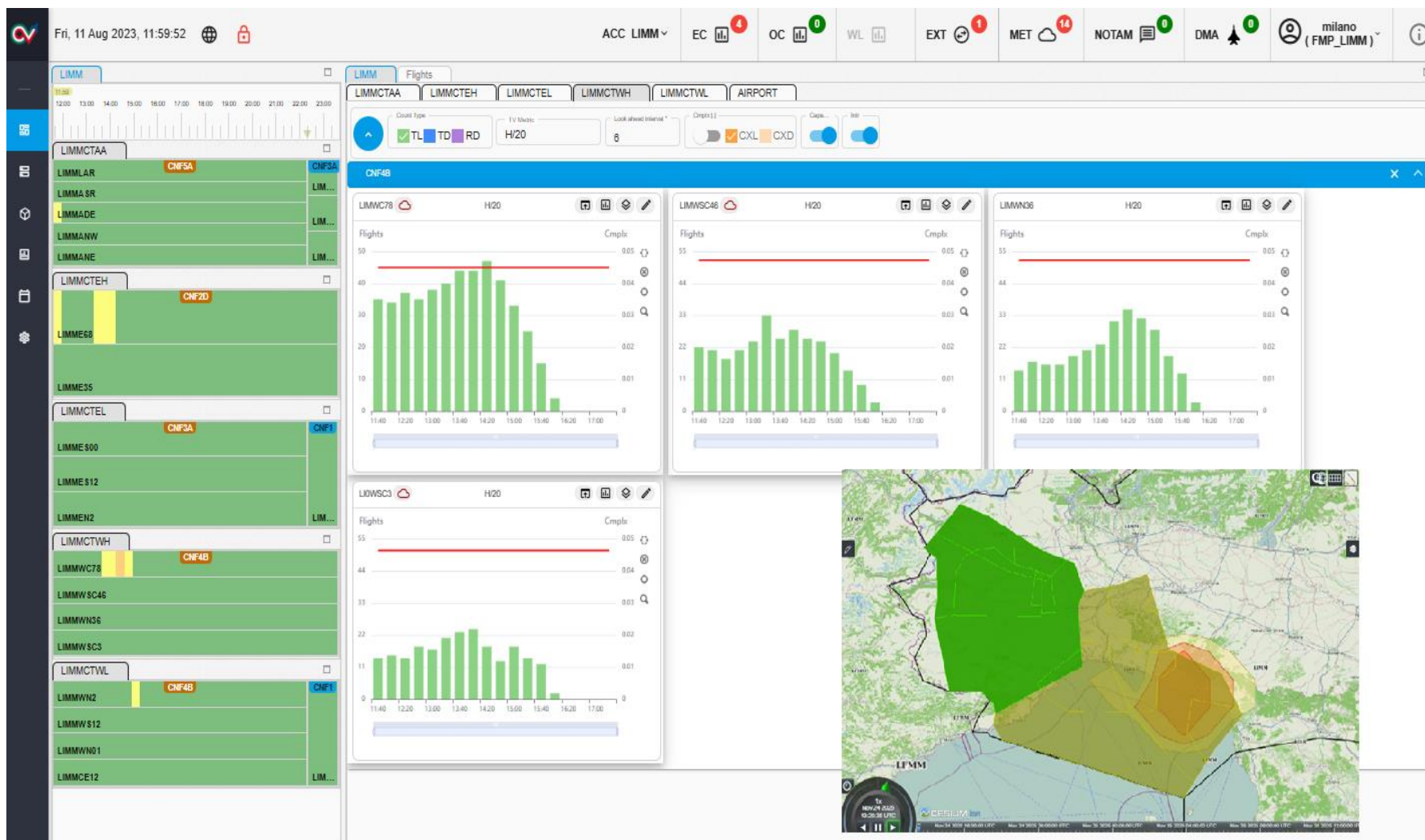
Results validated through dedicated sessions involving all ATC stakeholders





Convective Weather in the HARMONIC Project

Solution 382



ENAV Local Traffic Load Management Tool

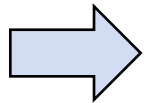
- Highlights the sectors impacted by convective weather
- Displays hourly demand-capacity with sector's overload
- Shows convective-area polygons



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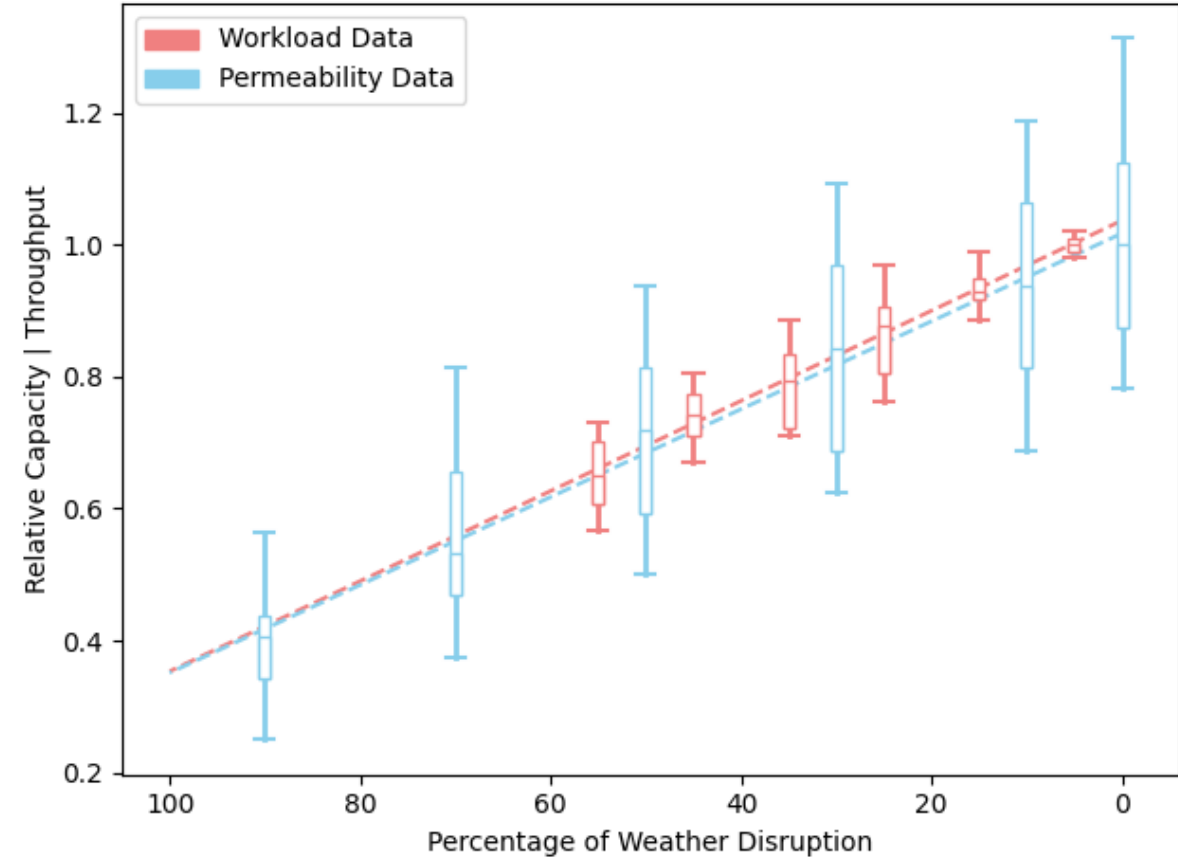
- **Models Comparison**
- **Discussion**



Models Comparison



- The TFI permeability approach uses real-time weather forecasts and weather radar data with 5-minute updates
- The Fast Time Simulation of workload uses static weather polygons, corresponding to the one-hour CBs evolution
- Comparing weather-impacted airspace capacity with observed throughput, the two models present similar results
- Relationship between airspace weather impact/coverage and achievable throughput is comparable



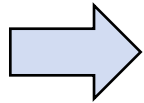
Significantly different approaches show similar airspace weather impact predictions



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Weather Impact Translation Model Roles



- Opportunities exist to leverage models' strengths
 - TFI Permeability with real-time weather updates
 - Workload approach directly ties into specific sector capacities
 - Using hybrid approach could provide powerful predictive real-time system
- Additional Opportunities
 - Greater ANSP harmonization between weather management approaches
 - Use of extended weather-aware Trajectory-Based Operations (TBO)
 - Long-range Air Traffic Flow Management techniques

Challenges in global harmonization present additional opportunities for improvements





Summary & Discussion



- **Weather is the major cause of air traffic delays, which will increase in the future**
- **Two approaches to translate convective weather into ATM impacts were presented**
- **Different approaches present similar weather impact vs airspace capacity relationship**
- **Promising results for cross validation, but**
- **Expansion to more airspaces and weather events is necessary**
- **Decision-support tools offer opportunity to better manage weather events**

