Network-wide robust and resilient metaheuristic trajectory optimization under thunderstorm disruptions

Julien Lavandier, Daniel Delahaye, Daniel Gonzalez-Arribas, Javier Garcia,
Manuel Soler, Emre Koyuncu, Muhammmet Aksoy, Andr es Munoz, Jordi Pons,
Xavier Prats, Raymund Zoop, Alex Kuenz

EUROPEAN PARTNERSHIP

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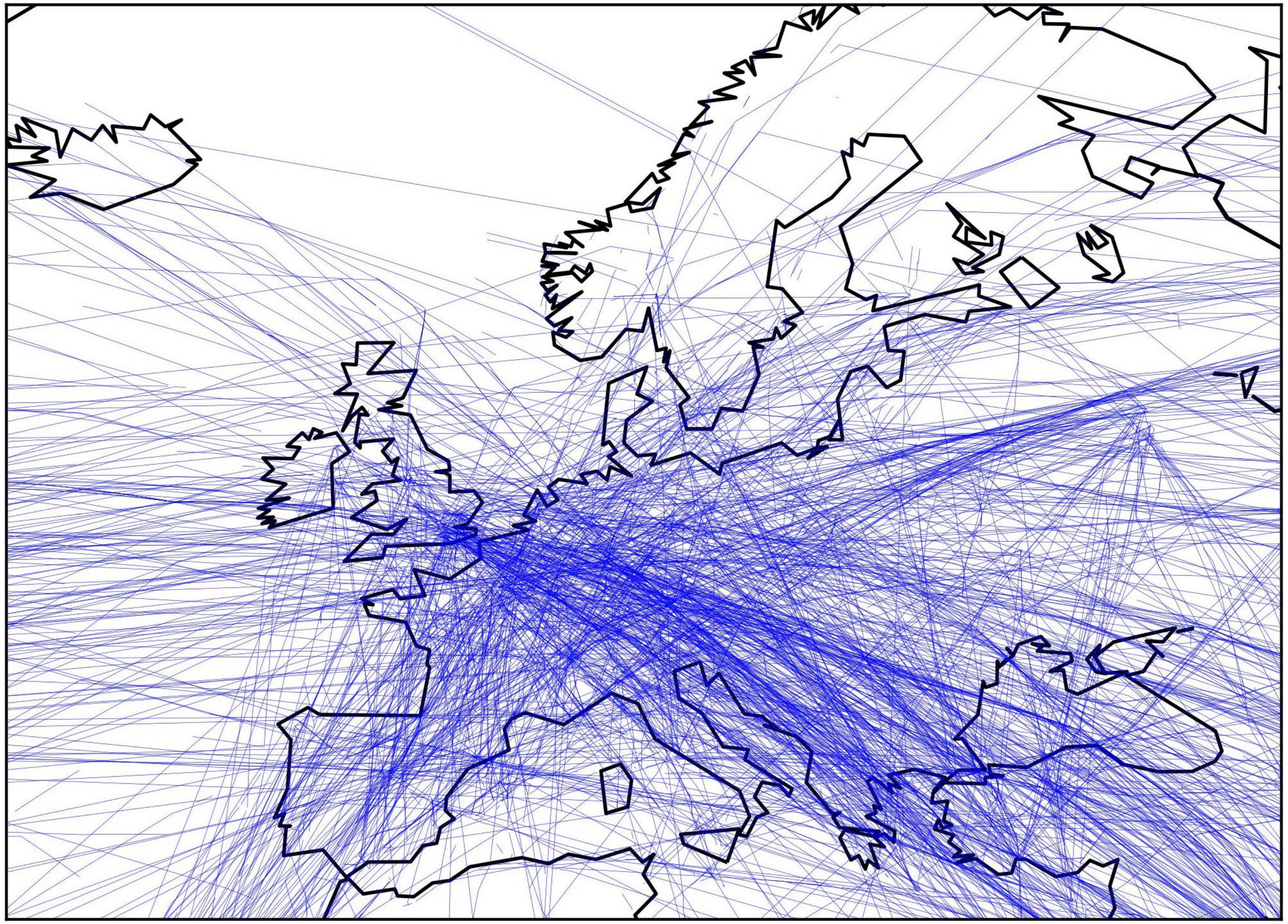
European air traffic

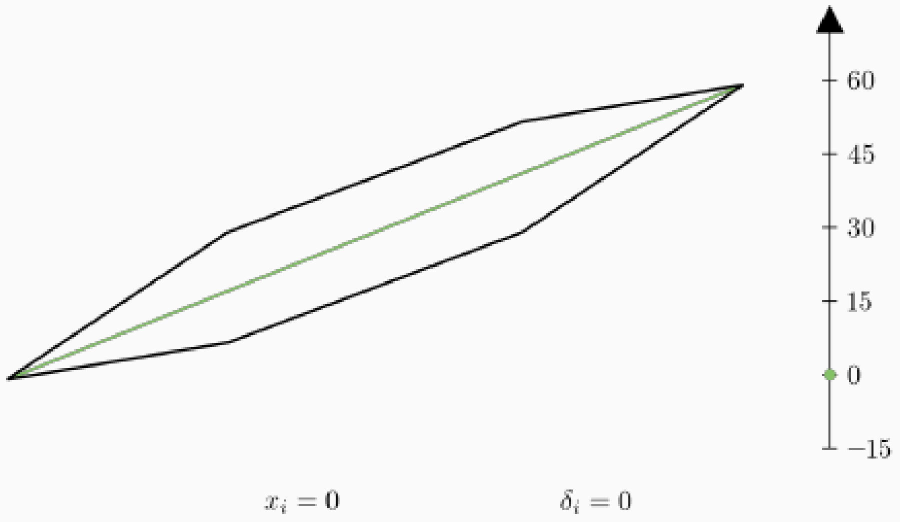
12,000 flights / 4 hours



Problem

- Goal: organize air traffic
- Why? Airspace capacity limited and increasing demand
- How? Change time of departure and route

Decision variables

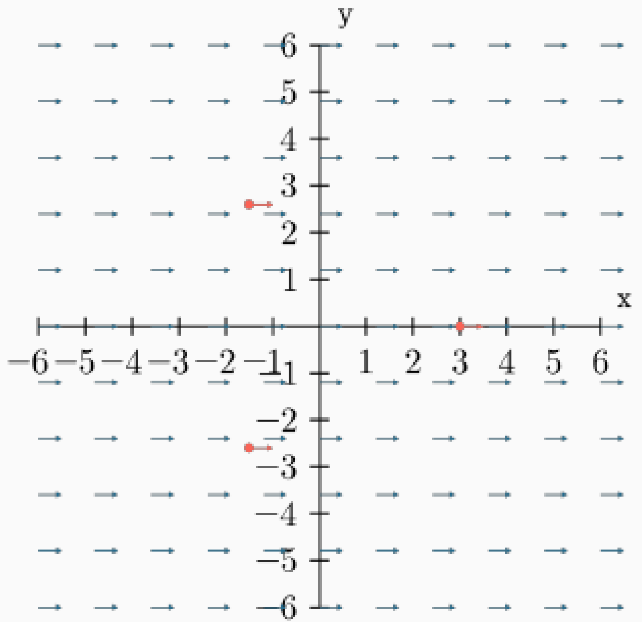


Objective: minimize

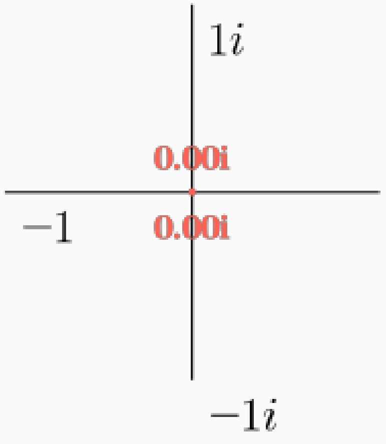
$$\sum_{\text{flights}} \text{complexity(flights)} + \overbrace{\mathbf{w}}^{\text{trade-off weighting parameter}} \sum_{\text{flights}} \text{deviation cost},$$

Complexity metric

Toy example 1: 3 Parallel flights



$$X=\begin{bmatrix} 300 & -150 & -150 \\ 0 & 260 & -260 \\ 100 & 100 & 100 \end{bmatrix} V=\begin{bmatrix} 25 & 25 & 25 \\ 0 & 0 & 0 \end{bmatrix}$$

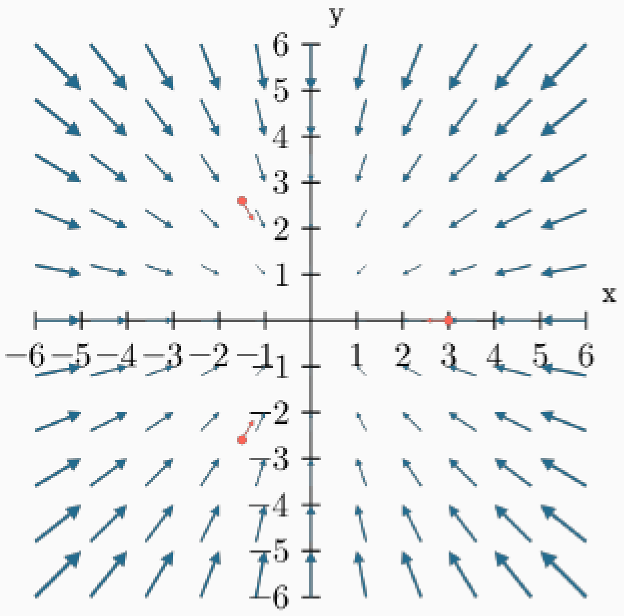


Complexity

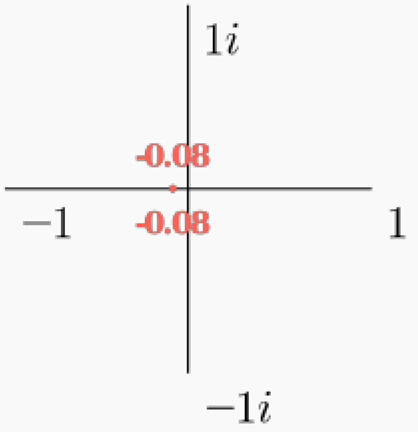
0.00

Complexity metric

Toy example 2: 3 Converging flights



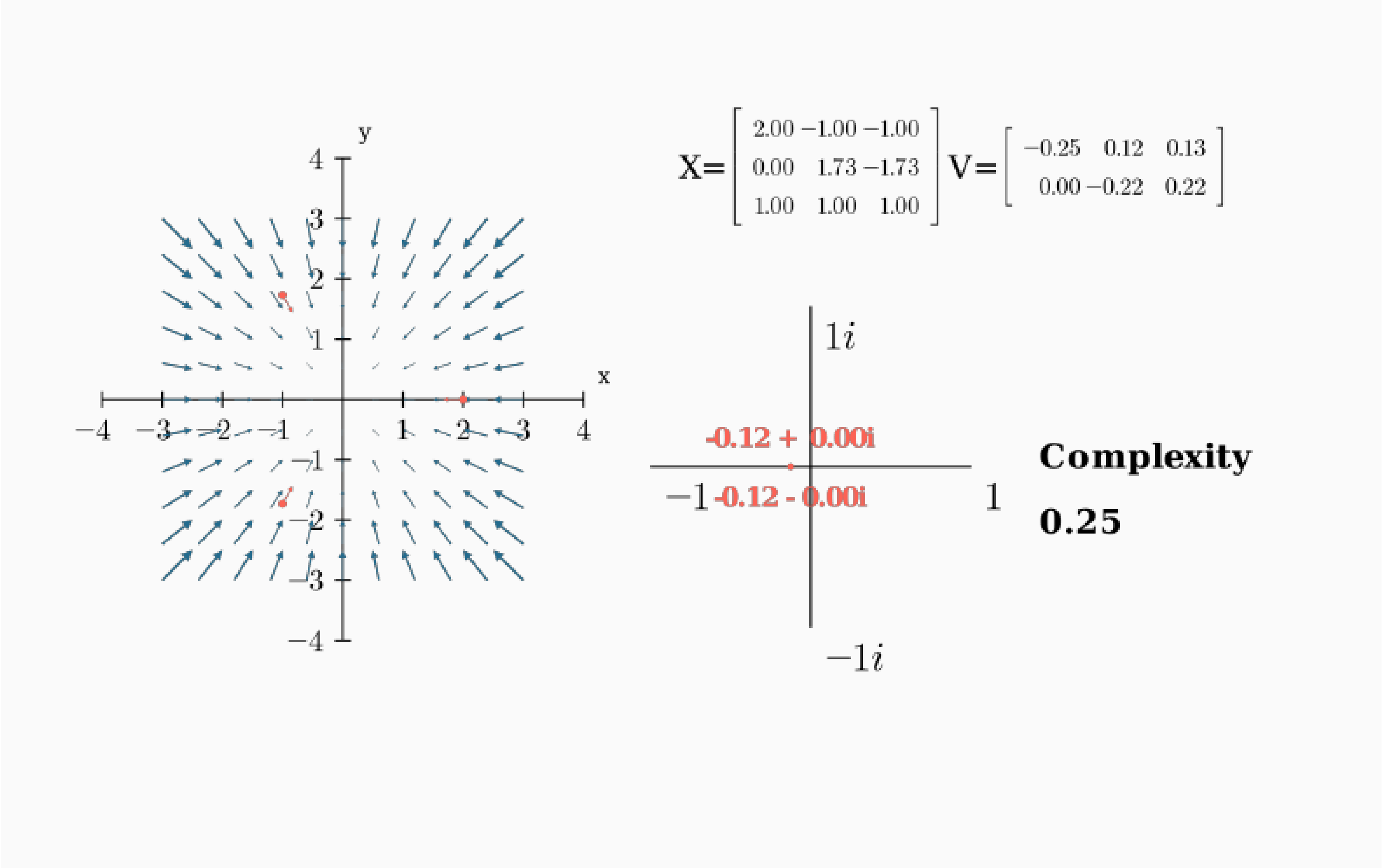
$$X=\begin{bmatrix} 300 & -150 & -150 \\ 0 & 260 & -260 \\ 100 & 100 & 100 \end{bmatrix} V=\begin{bmatrix} -25 & 12 & 12 \\ 0 & -22 & 22 \end{bmatrix}$$



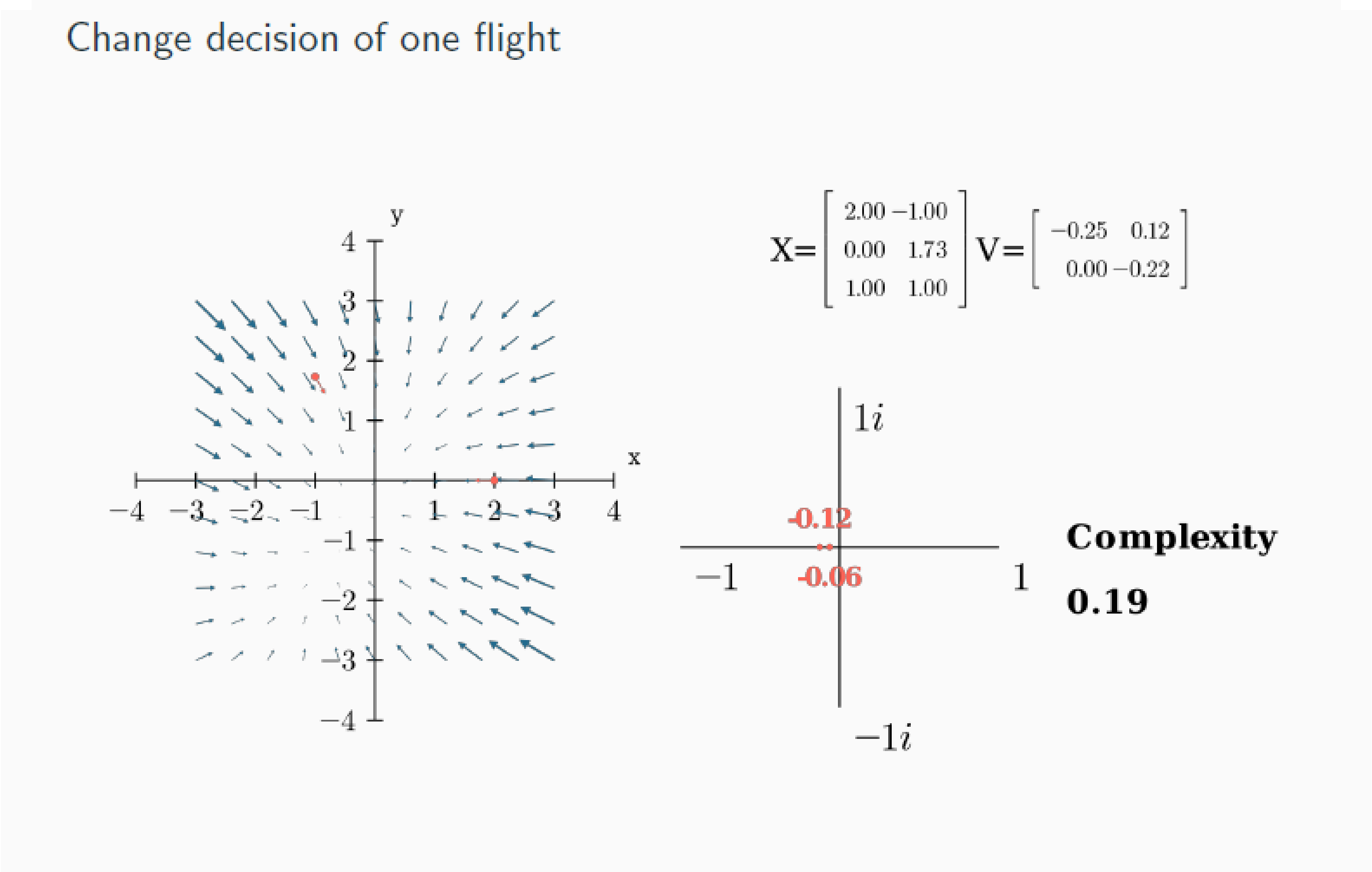
Complexity

0.17

Complexity interdependence



Complexity interdependence



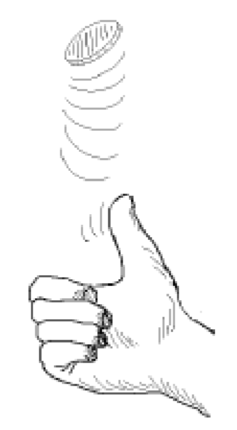
Problem difficulty

- High combinatorics:
  - $x \in \{1, \dots, 5\}^{12000}$
  - $\delta \in \{-15, 14, \dots, 59, 60\}^{12000}$
- Objective function
  - High computation time of the complexity (for each trajectory point of each flight
  - Complexity interdependence

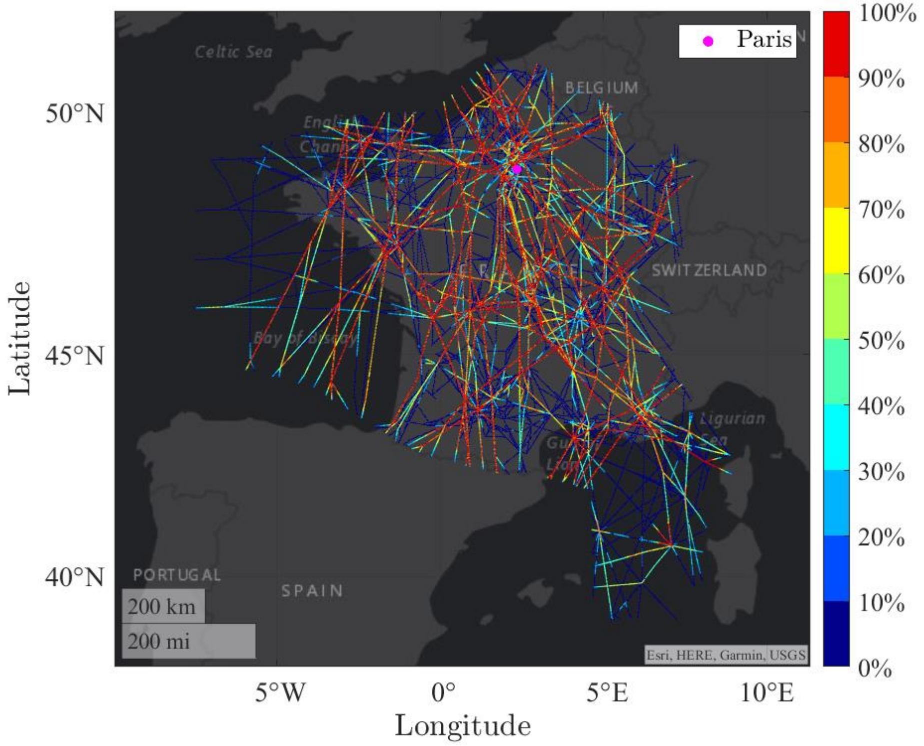
Simulated annealing

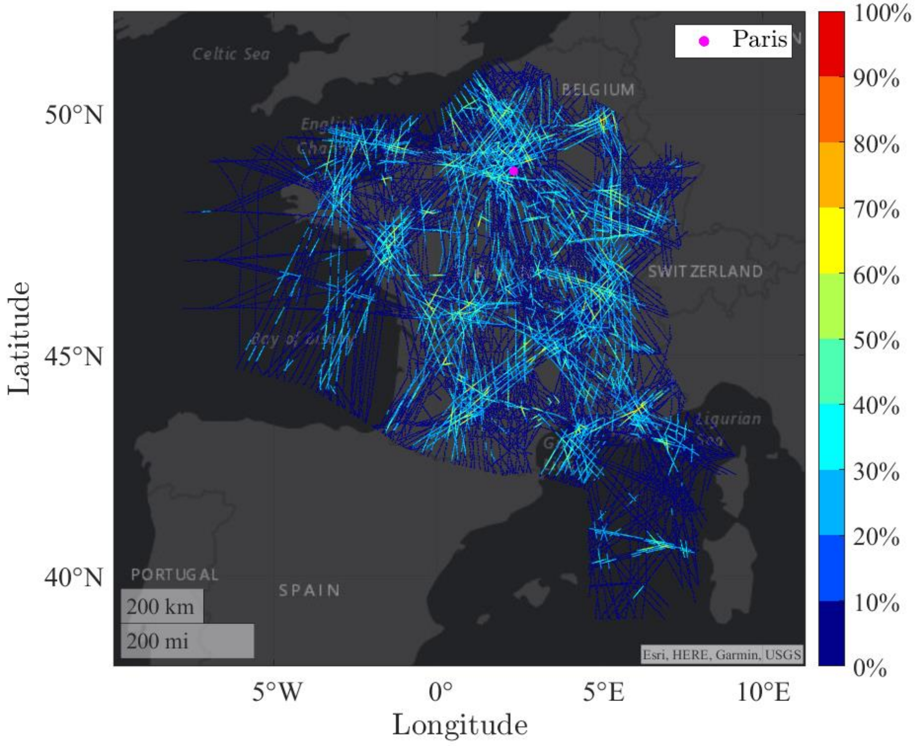
Algorithm (iteration t):

1. Randomly choose $s' \in N(s)$
2. • If $f(s') \leq f(s), x_T(t+1) =: s'$
   • else, $x_T(t+1) =: \begin{cases} s' & \text{with probability} e^{\frac{f(s)-f(s')}{T(t)}} \\ s & \text{otherwise} \end{cases}$

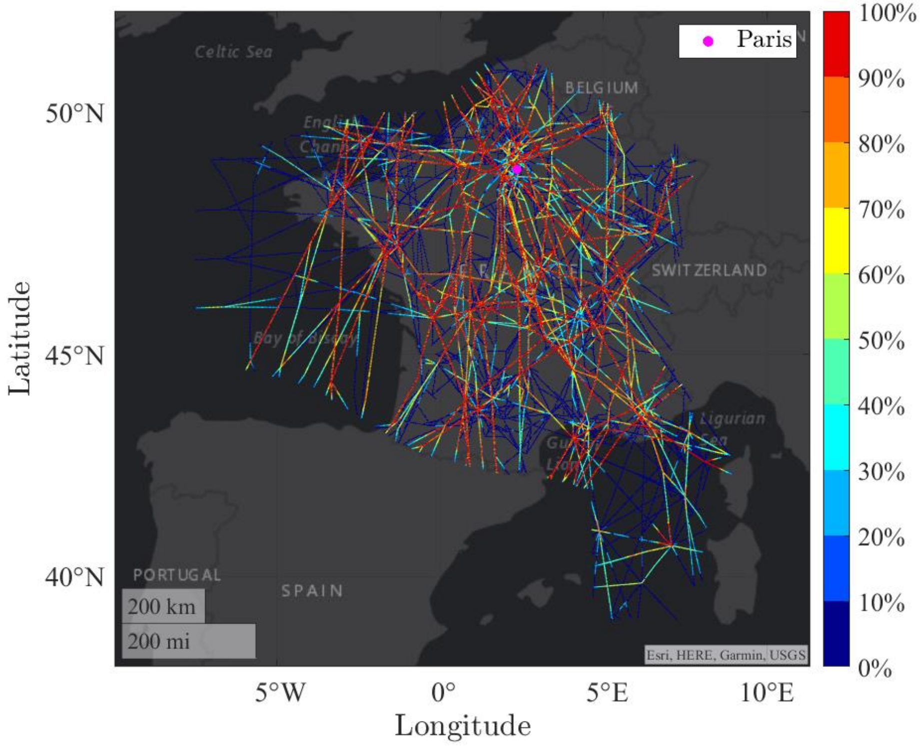


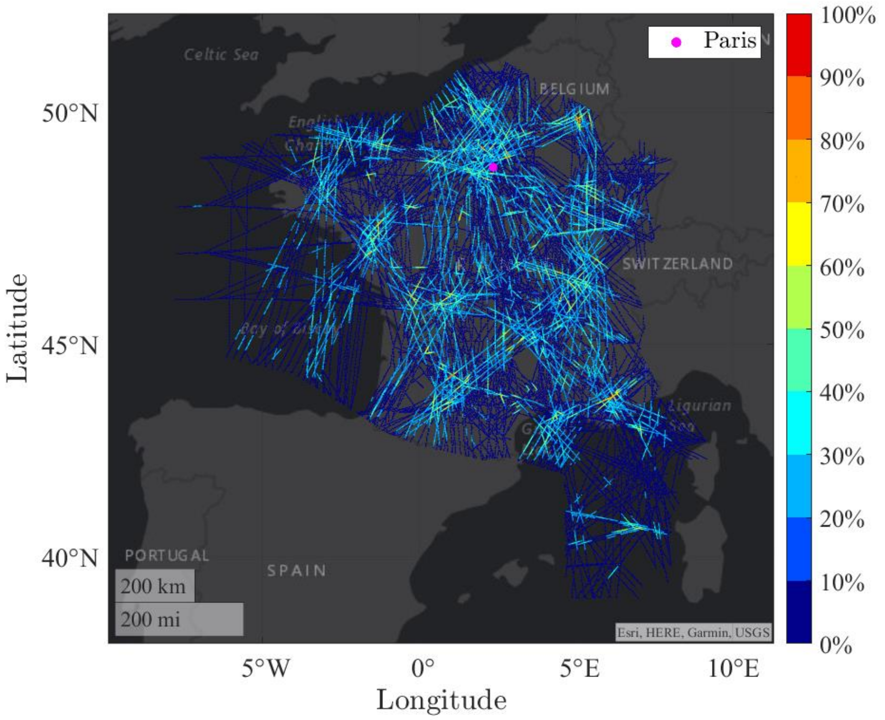
France air traffic before and after CPU optimization





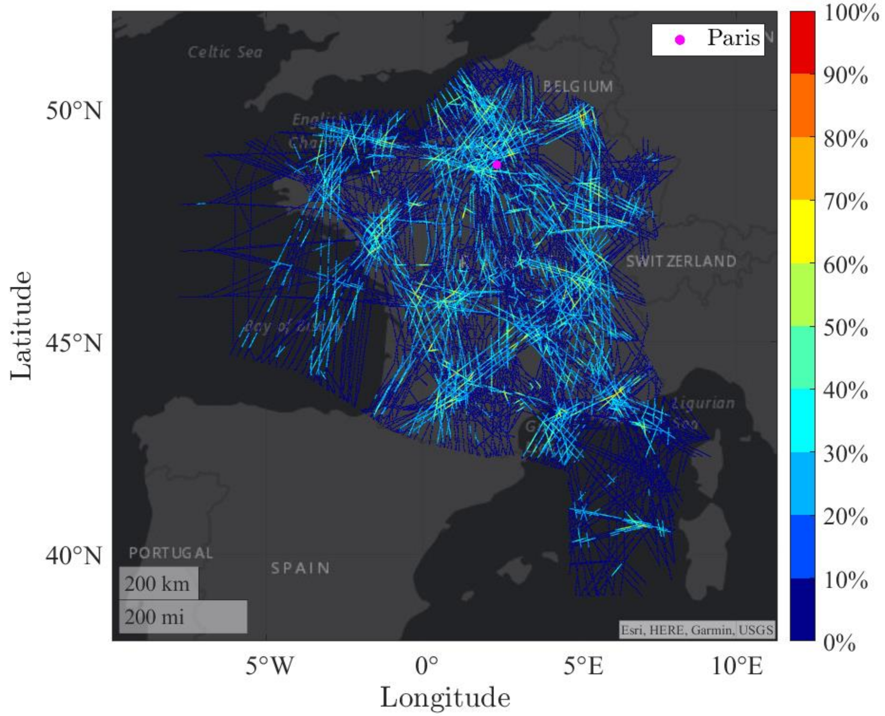
France air traffic before and after GPU optimization



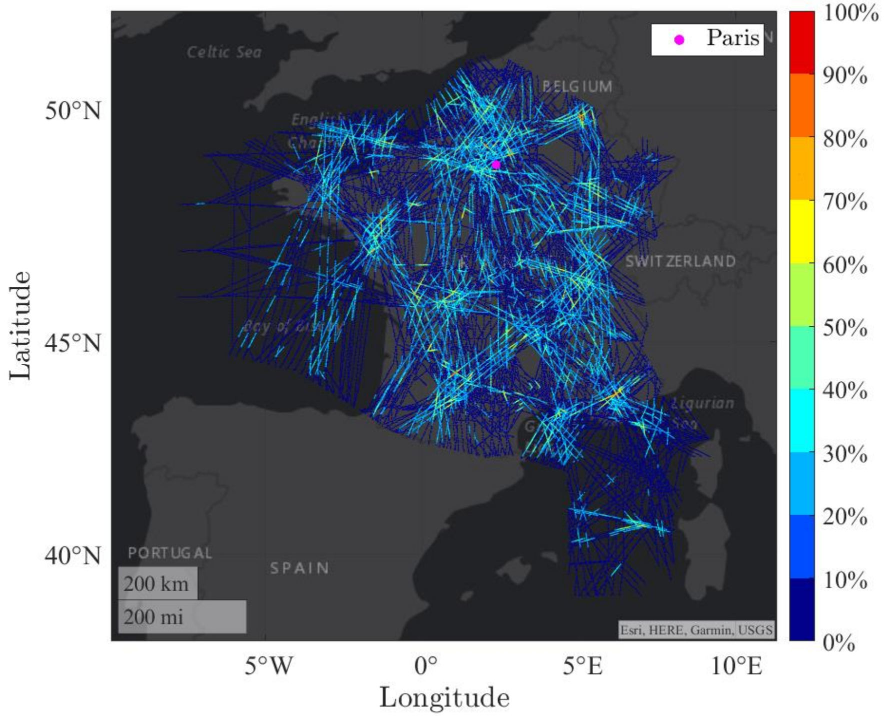


CPU vs GPU air traffic complexity

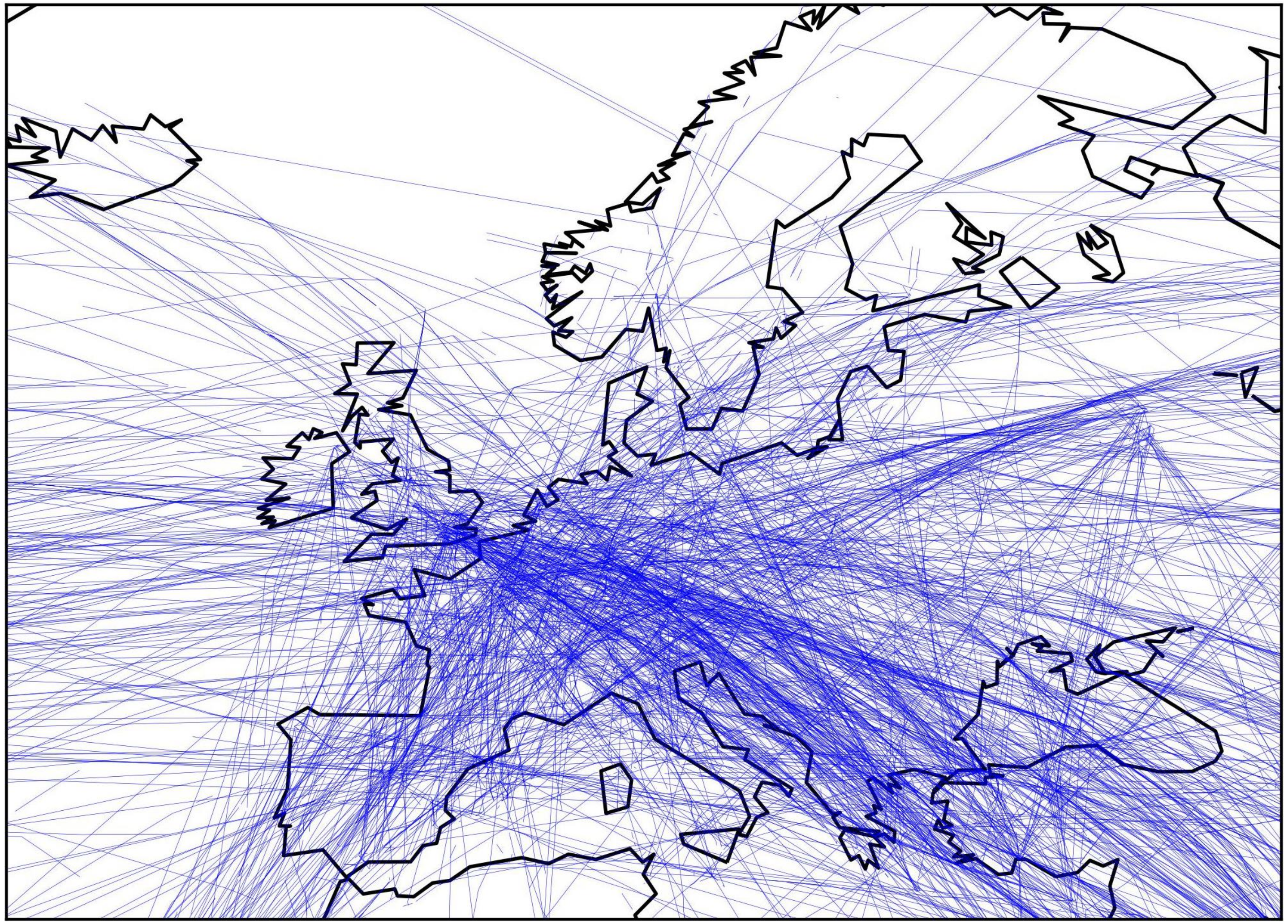
CPU implementation (12 ± 2 minutes)



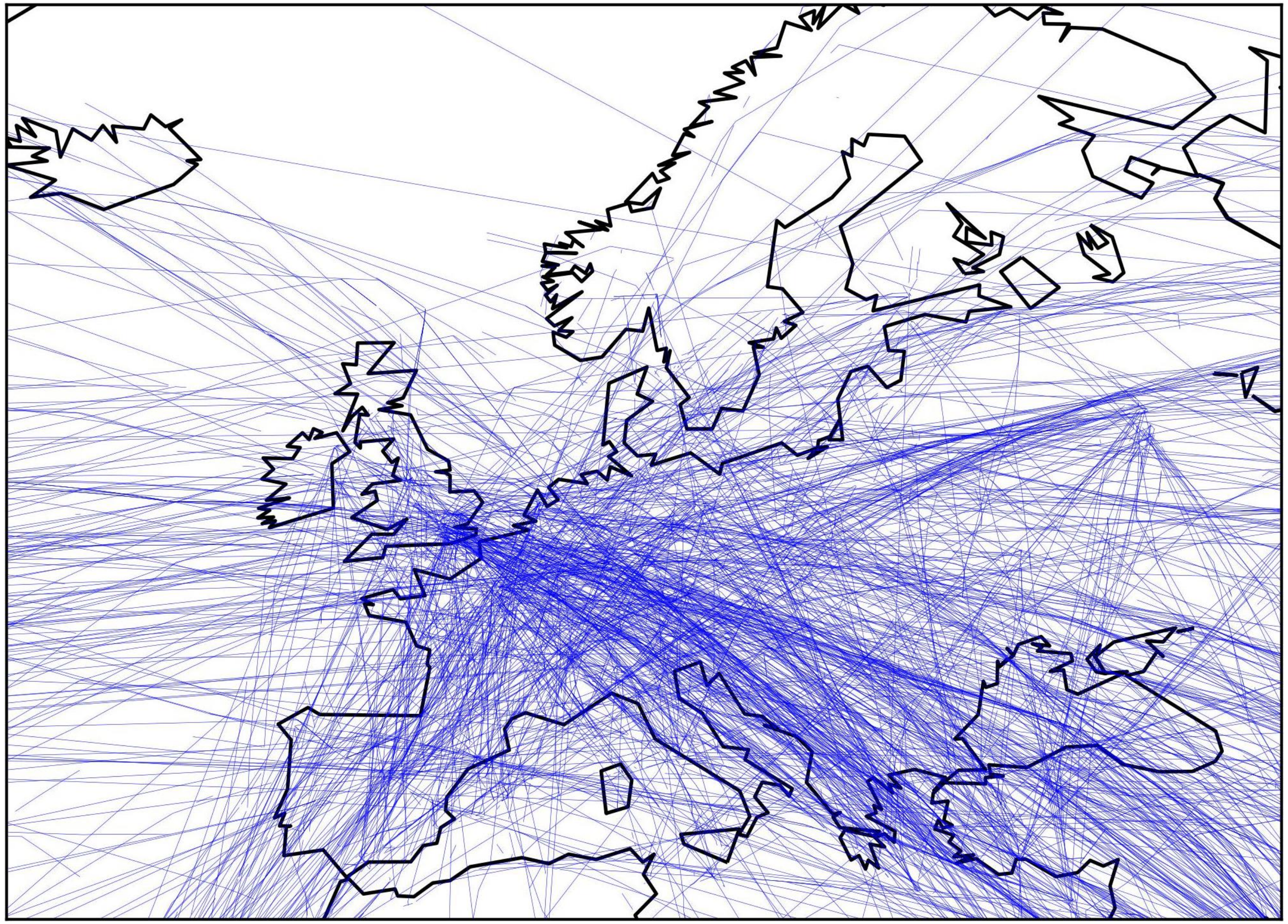
GPU implementation (20 ± 8 minutes)



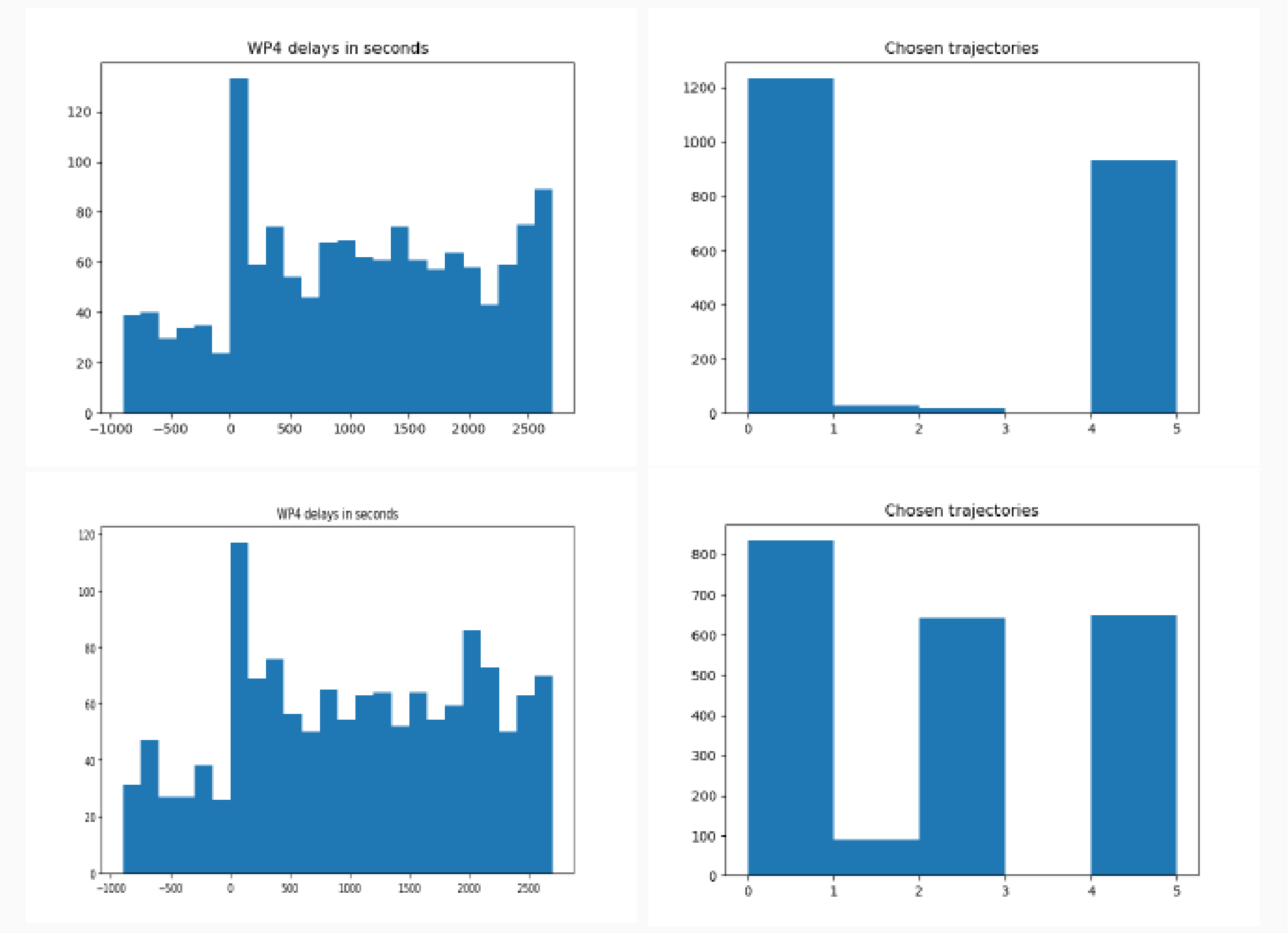
European air traffic before optimization



European air traffic after optimization



European airspace study case: 07th and 10th of June 2018



Conclusion

- GPU complexity calculation requires hardware in 64 bit architectures,
- Different neighborhood search using the selection of complex flights.

SESAR JOINT UNDERTAKING

THANK YOU FOR YOUR ATTENTION

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