

A Trajectory Clustering Framework to Analyse Air Traffic Flows

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**SESAR Innovation Days 2017
November 29th, Belgrade**



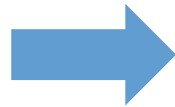
Overview

- **Introduction**
- **Applications**
- **The framework**
- **Results**
- **Conclusions and future work**

Introduction



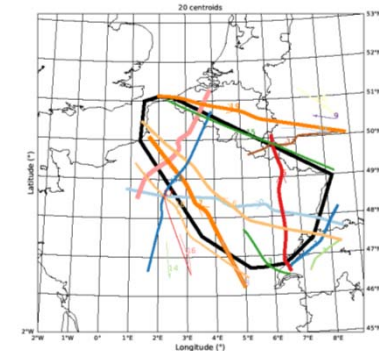
Trajectories



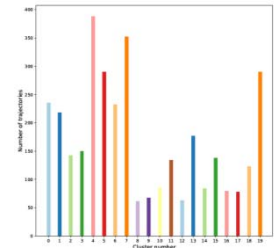
Traffic flow
identification
and
characterisation



Flows



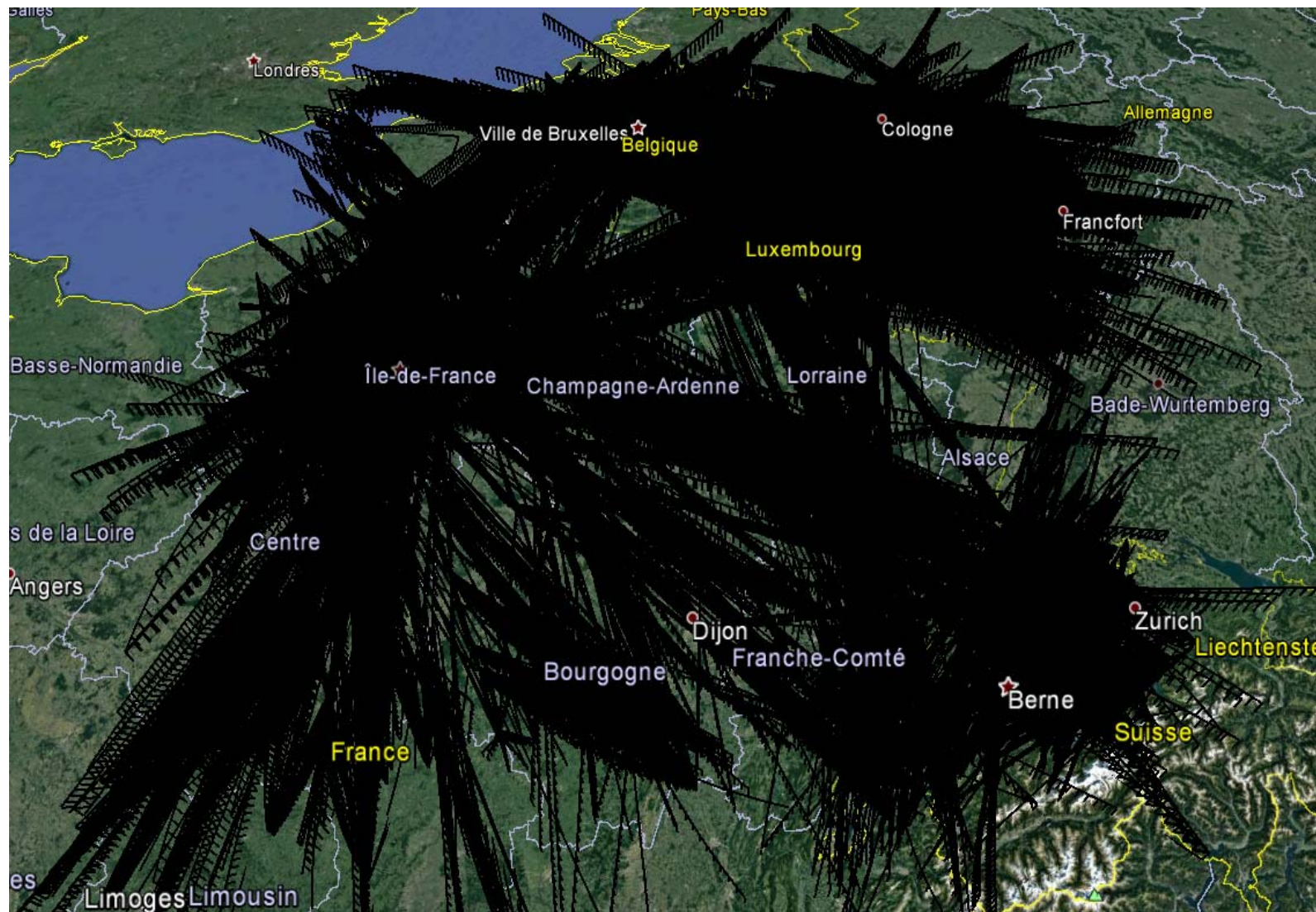
Cluster	7	8
Avg. Heading (°)	325	336
Avg. Alt (ft)	36199	32753
Avg. Length (NM)	255	75
Flights/hour	14.7	2.5
Main orig/dest	LFPG-EGLL 5% (17)	LFMN-LFPO 39% (24)
Main origin	LFPG 16% (56)	LFMN 43% (26)
Main destination	EGKK 17% (59)	LFPO 89% (54)
Main A/C type	A319 22% (76)	A320 62% (38)



- **Flow:** Group of similar trajectories (cluster)
- **Centroid:** Trajectory representing a flow (mean trajectory)
- **Outlier:** trajectory not belonging to a flow (noise)

Statistics

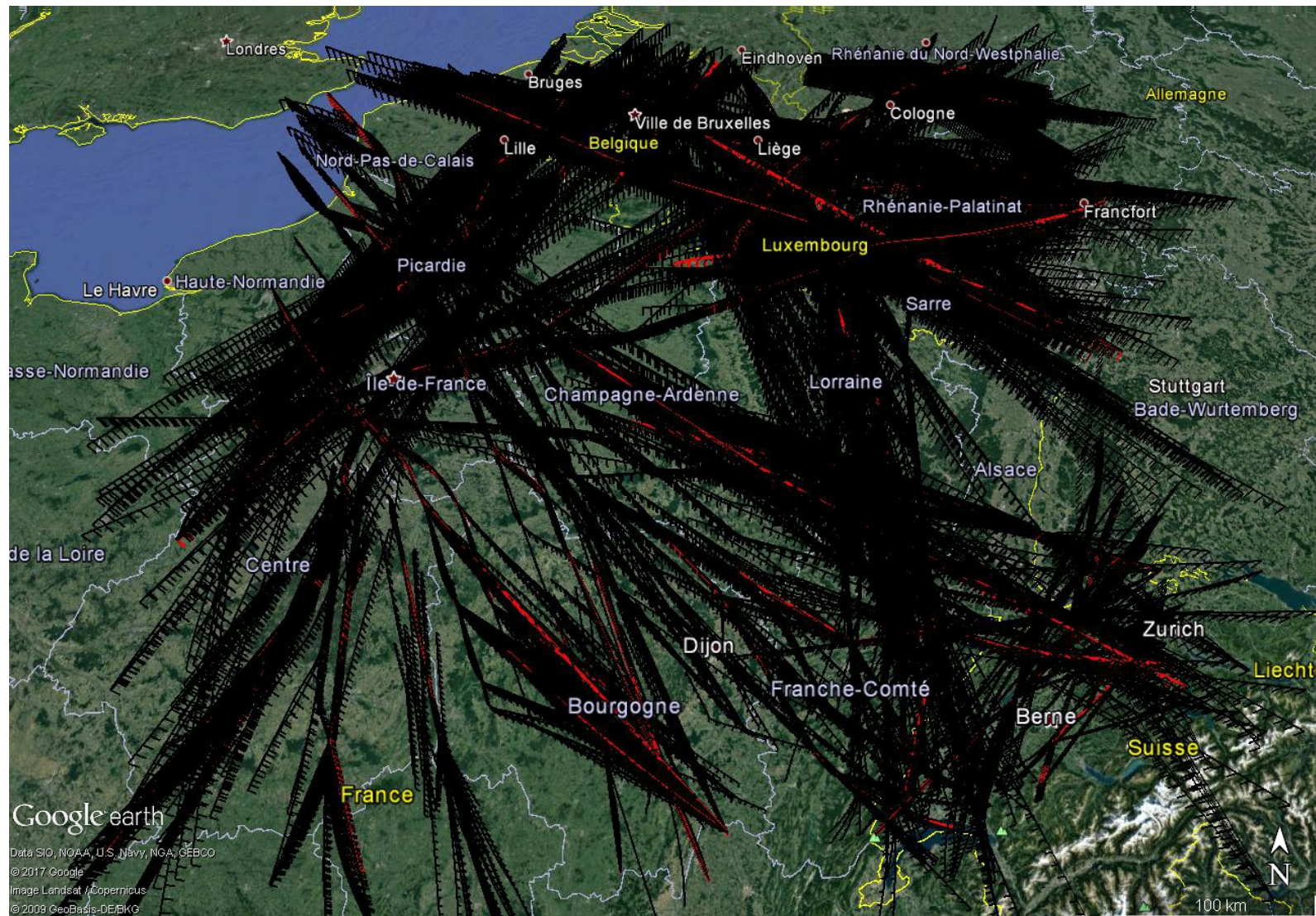
Flow identification – Traffic over Reims (26/06/2015)



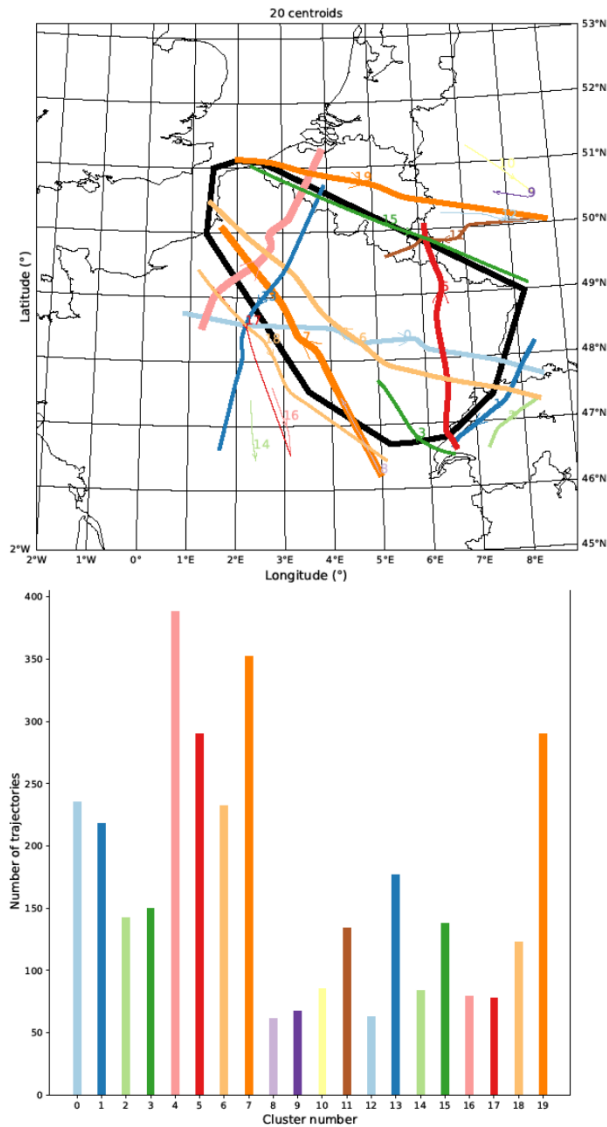
Flow identification- Use case example

- 3D clustering
- Flows with at least 30 trajectories (min_cluster_size)
- Altitude > 300FL
- Distance between trajectories: SSPD

Flow identification - Results



Flow statistics

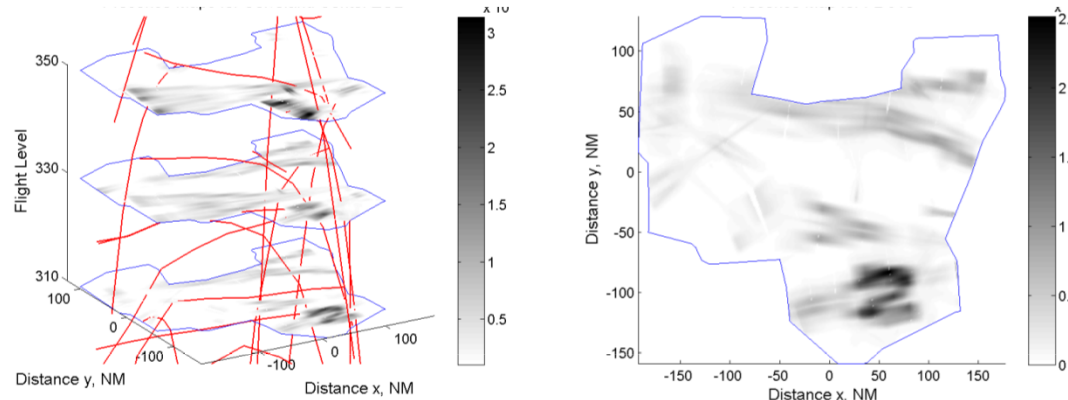


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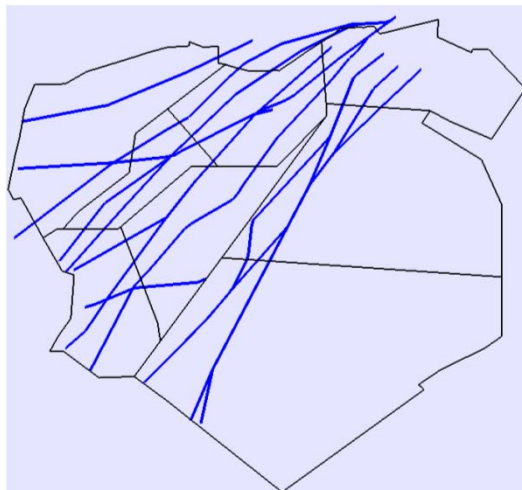
Applications

Complexity
Management

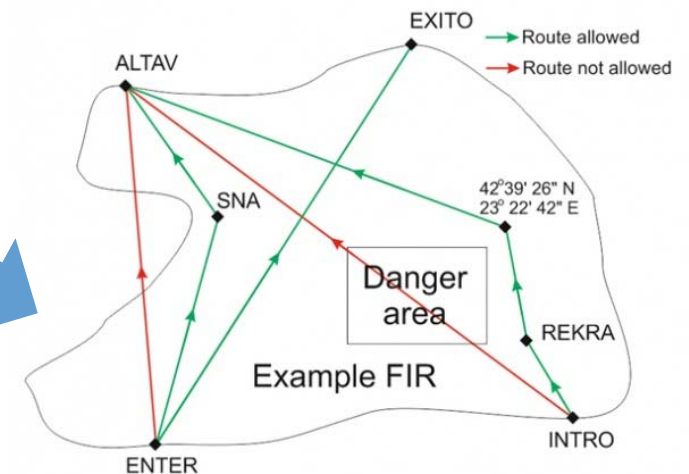
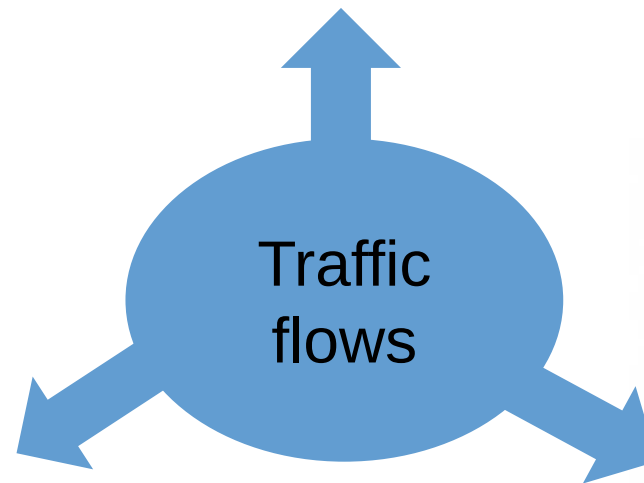
Aircraft Proximity Maps based on Data-Driven Flow Modeling, E. Salaün et al.



Airspace design /
management

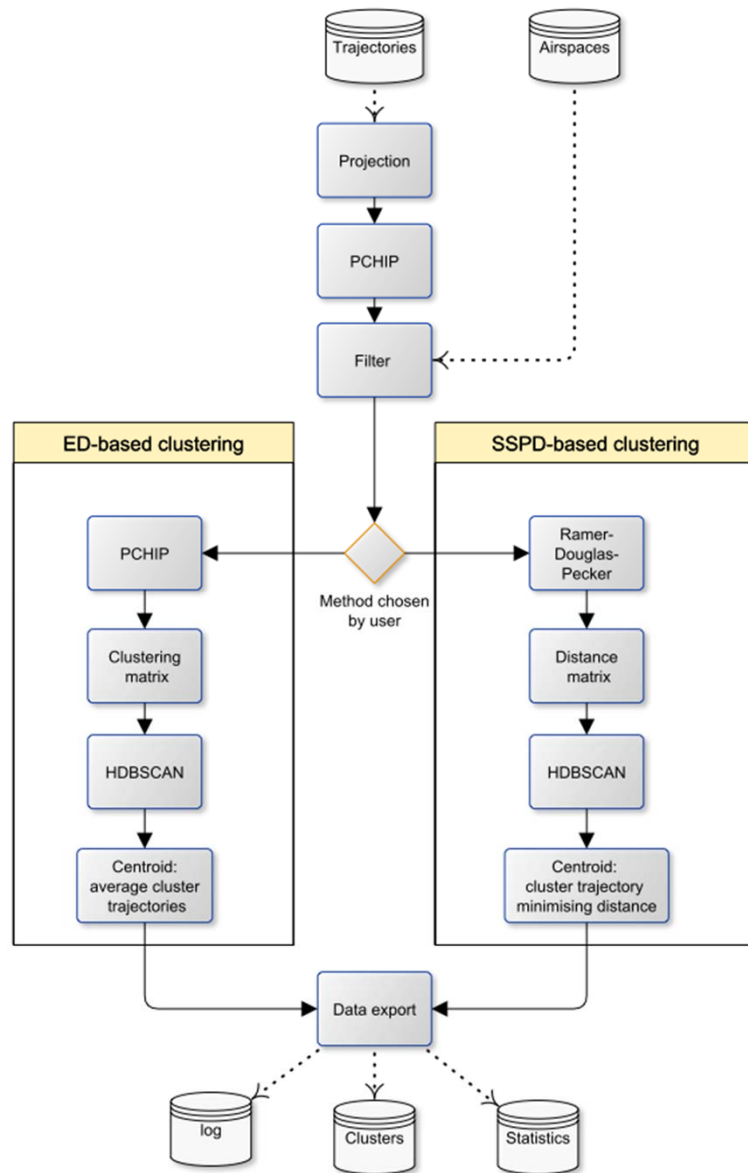


Free route
flow patterns



Flow Conforming Operational Airspace Sector Design, G. R. Sabhnani et al.

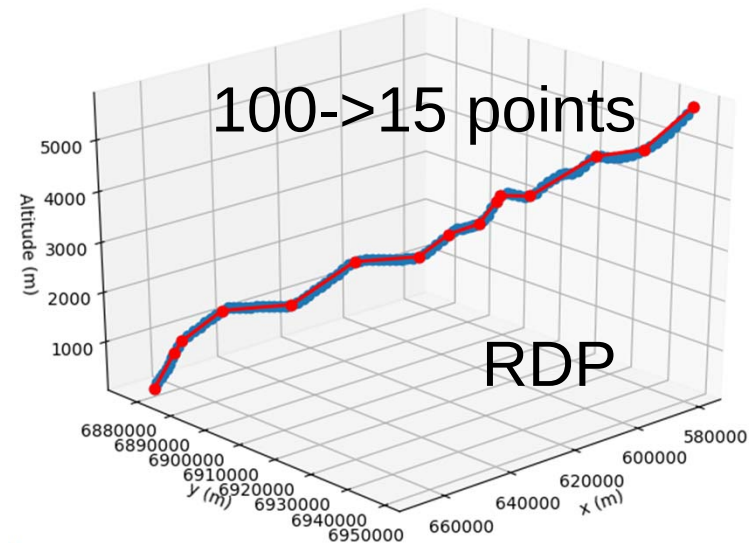
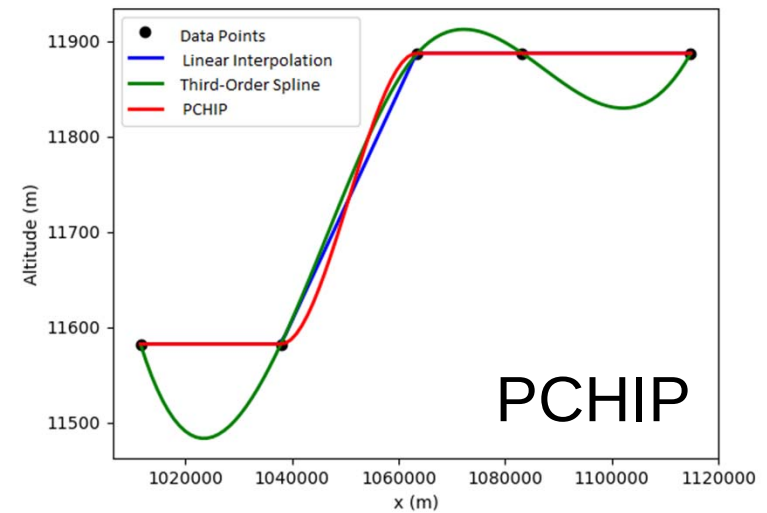
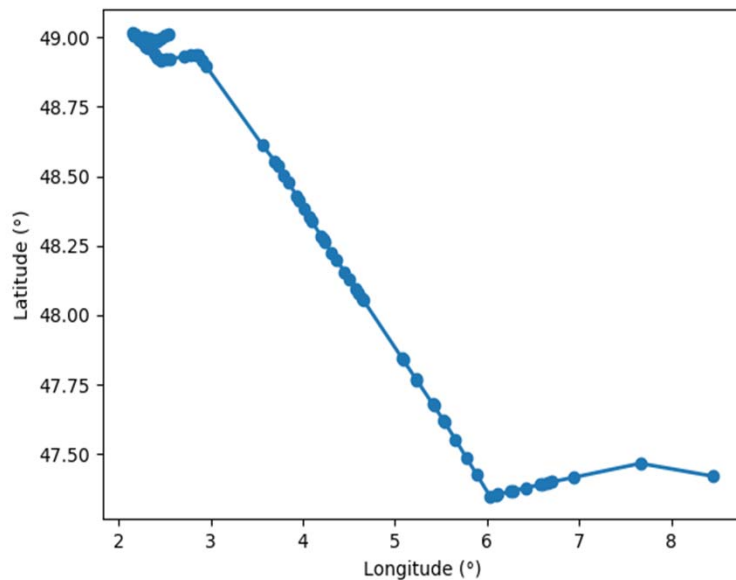
The framework



- Data provided by Eurocontrol  (DDR2, AIXM)
- Implemented in Python 3.6
- Based on publicly available algorithms (e.g. PCHIP, HDBSCAN)

Trajectory pre-processing (PCHIP, RDP)

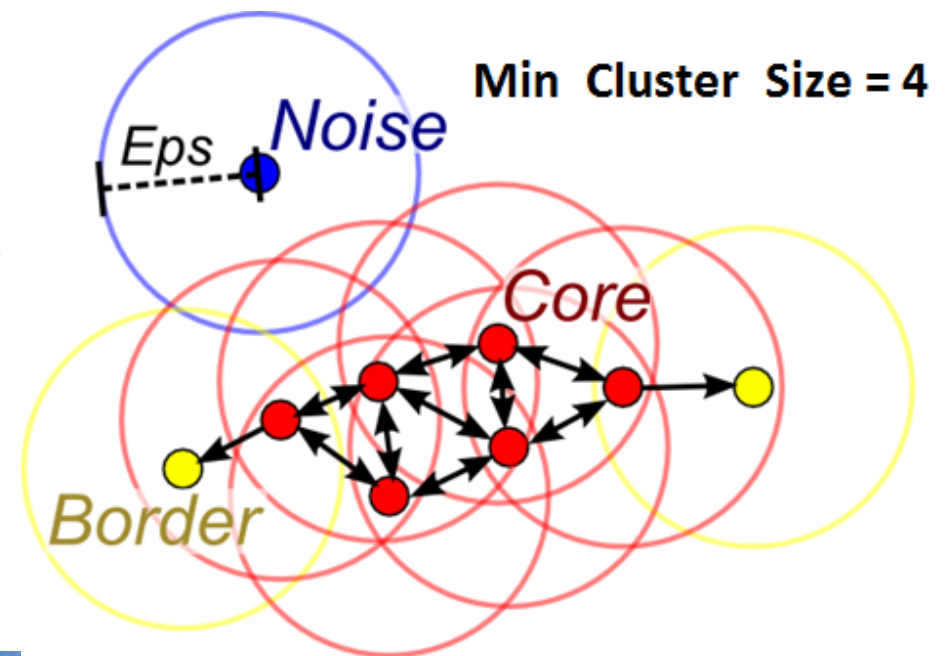
DDR2 Trajectory



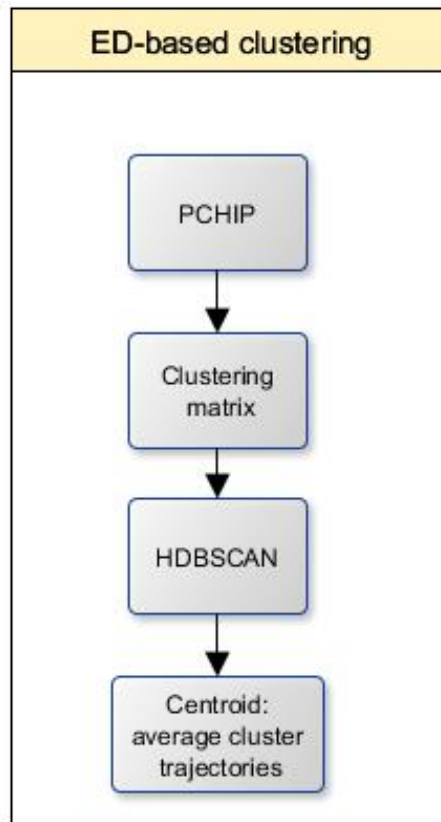
Clustering algorithm (HDBSCAN)

- **DBSCAN (Density-Based Spatial Clustering of Applications with Noise)**
- **HDBSCAN (Hierarchical DBSCAN)**
 - Clusters with different densities
 - Only one parameter (Min_Cluster_Size)
- **Distances**
 - Euclidean
 - SSPD (Symmetrized Segment-Path Distance)

DBSCAN



Euclidean-based clustering

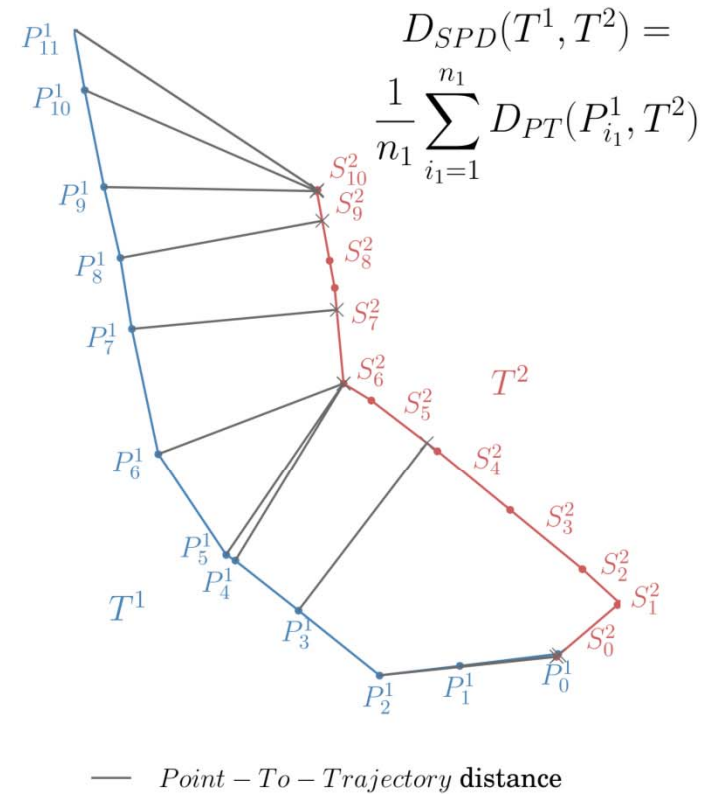
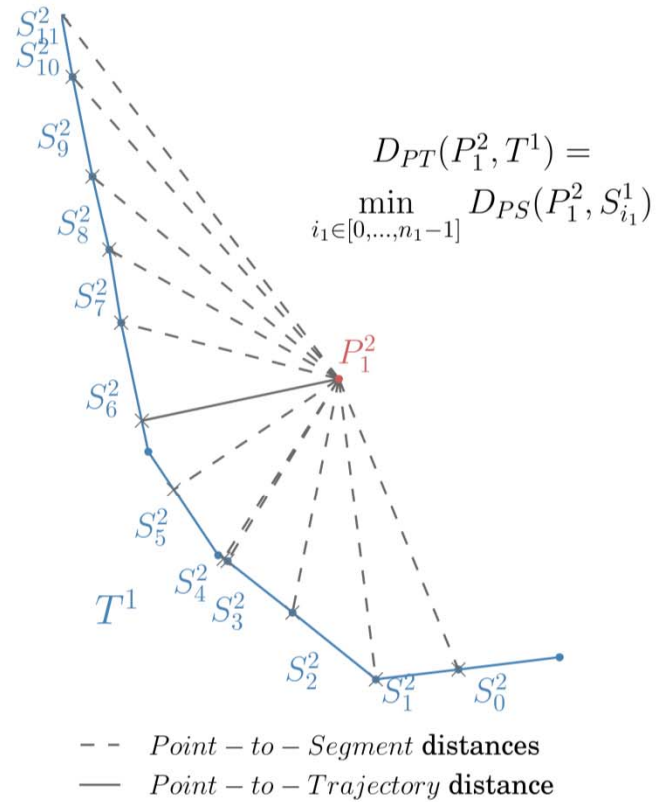


$$\begin{bmatrix} x_{11}y_{11}z_{11}h_{11}x_{12} & \dots & x_{1n}y_{1n}z_{1n}h_{1n}x_{1n} \\ \vdots & \ddots & \vdots \\ x_{N1}y_{N1}z_{N1}h_{N1}x_{N2} & \dots & x_{Nn}y_{Nn}z_{Nn}h_{Nn}x_{Nn} \end{bmatrix}$$

(+) Fast to compute (3 min for 9000 trajectories)

(-) Distance between trajectories may be inaccurate

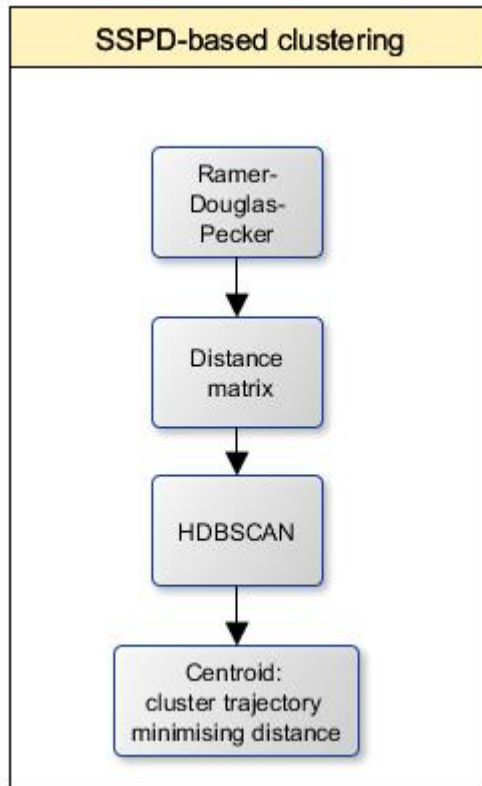
SSPD (Symmetrized Segment-Path Distance)



$$D_{SSPD}(T^1, T^2) = \frac{D_{SPD}(T^1, T^2) + D_{SPD}(T^2, T^1)}{2}$$

Review & Perspective for Distance Based Clustering of Vehicle Trajectories, Philippe Besse et al.

SSPD-based clustering



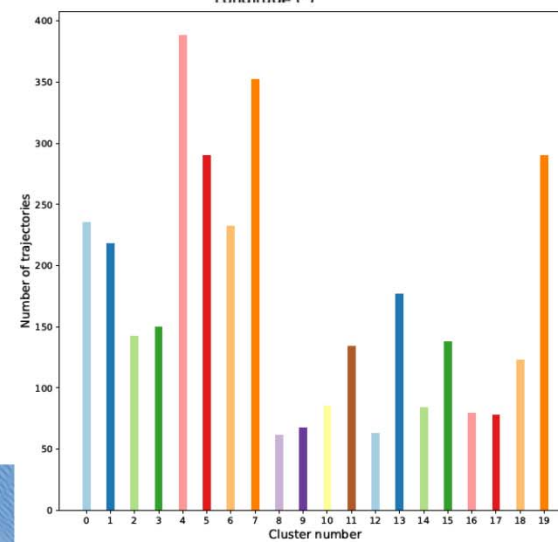
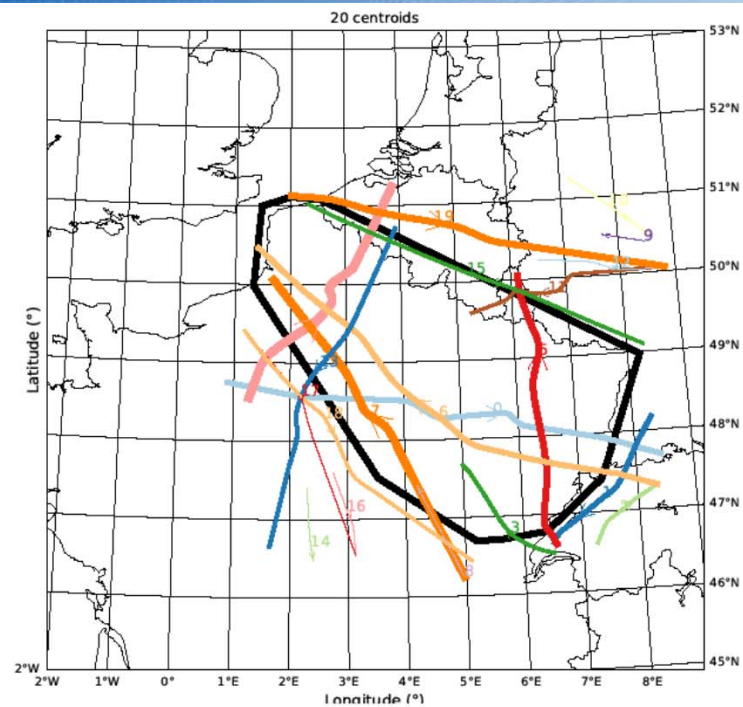
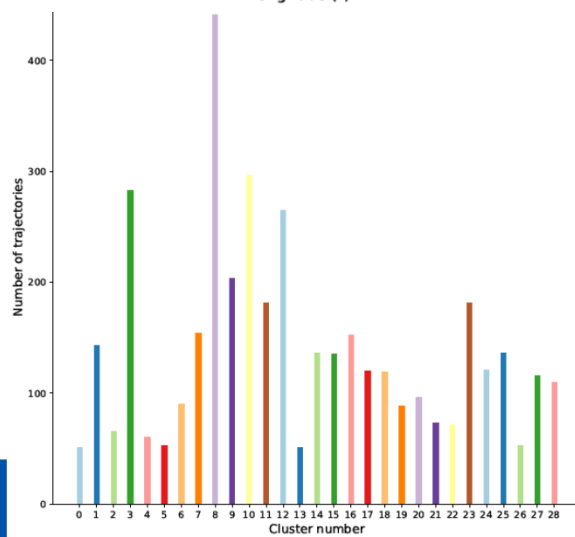
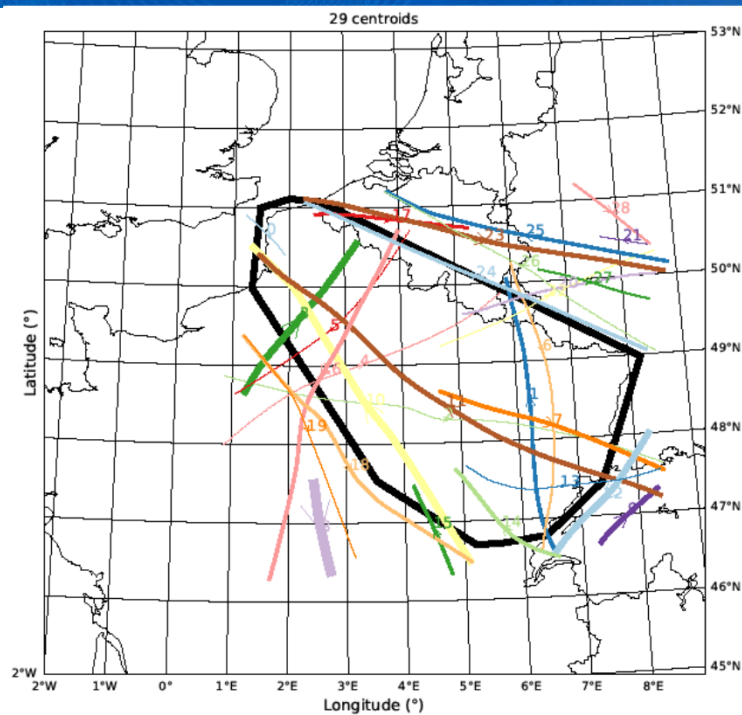
(+) SSPD more representative of global shape difference and physical distance between trajectories

(+) No need to sample N points per trajectory

(-) SSPD computationally expensive

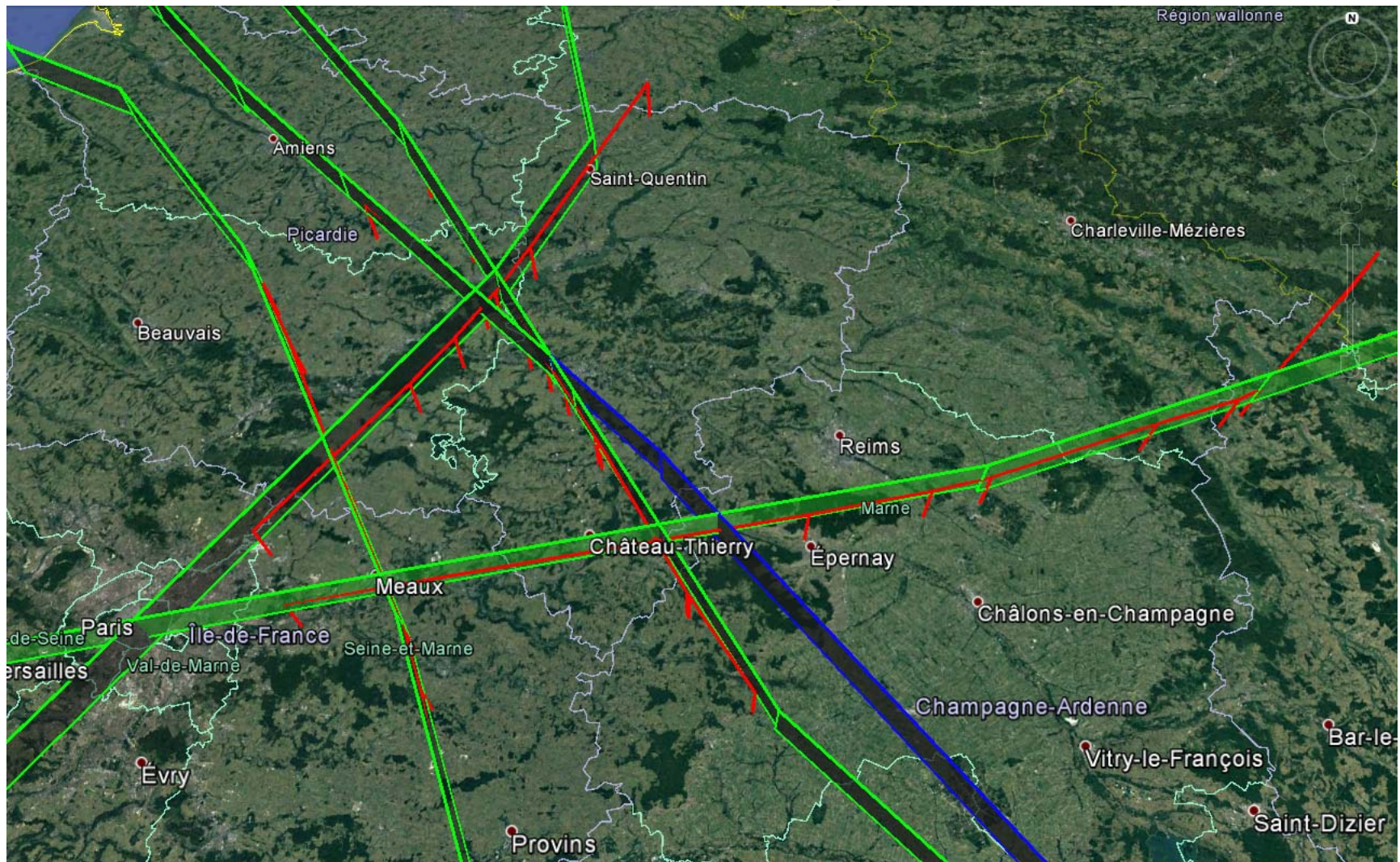
(-) Trajectory direction not considered (separation flows opposite direction in en-route)

Results comparison – ED vs SSPD clustering



Results – Flows vs Routes (LFEEXR sector)

Centroids (in red) and routes (in green and blue)



Conclusions and future work

- **Method choice depends on the use case**
- **Flows match existing operational routes**
- **Outlier analysis needed**
- **Operational V&V needed**
- **Comparison with NM B2B flows for Traffic Volumes**
- **Performance (SSPD) to be improved**
- **New clustering approaches to be implemented (TRACCLUS)**

Questions?