NeoMetSys

Clustering & Complexity measures of European traffic

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Outline

- **FC2A project: a short reminder**
- **Bundling**
- **Airstream Structure**
- **Airstream Building**
- **Complexity**
- **Data & Scenarios**
- **Questions**
- **Opinion Poll**

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FC2A project: a short reminder (1/2)

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FC2A project: a short reminder (2/2)

Combining bundling/attraction mechanism and Airstreams concept

- Bundling is providing backbone of the Airstreams network

- Airstreams shapes are built thanks to the traffic aggregated for a given instance

  or

- Traffic is allocated to the Airstream Network considering the city pairs (ADEP-ADES) of the flights

  depending on the bundling mechanism

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Bundling mechanism: 2 ways to go

Trajectory approach

- Trajectories are acquired as ordered lists of plots, or timestamped positions.
- A smoothing spline expansion of each sampled trajectory is done (current implementation, is using cubic splines)

City pair approach

Focus is given on **air link** (direct route) between each city pairs rather than individual flights.

It is characterized by:

- Pair of arrival and destination airports (no order);
- Direct route length;
- Number of flights using this air link during a time period (one day).

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Bundling: Trajectory approach (1/4)

Clustering algorithm improvements

- Switch from K-means to K-medoïds for robustness to outliers.

- Use a parallel version for processing large samples:
  - Small, fixed size batches are randomly drawn from the complete dataset.
  - K-medoïds are applied on each batch in parallel.
  - Only the best clustering is kept.
  - The above procedure is iterated until convergence.

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Bundling: Trajectory approach (2/4)

Sample is 33k flights

50 medoïds
30 cycles

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Bundling: Trajectory approach (3/4)

Sample is 33k flights

100 medoïds
30 cycles

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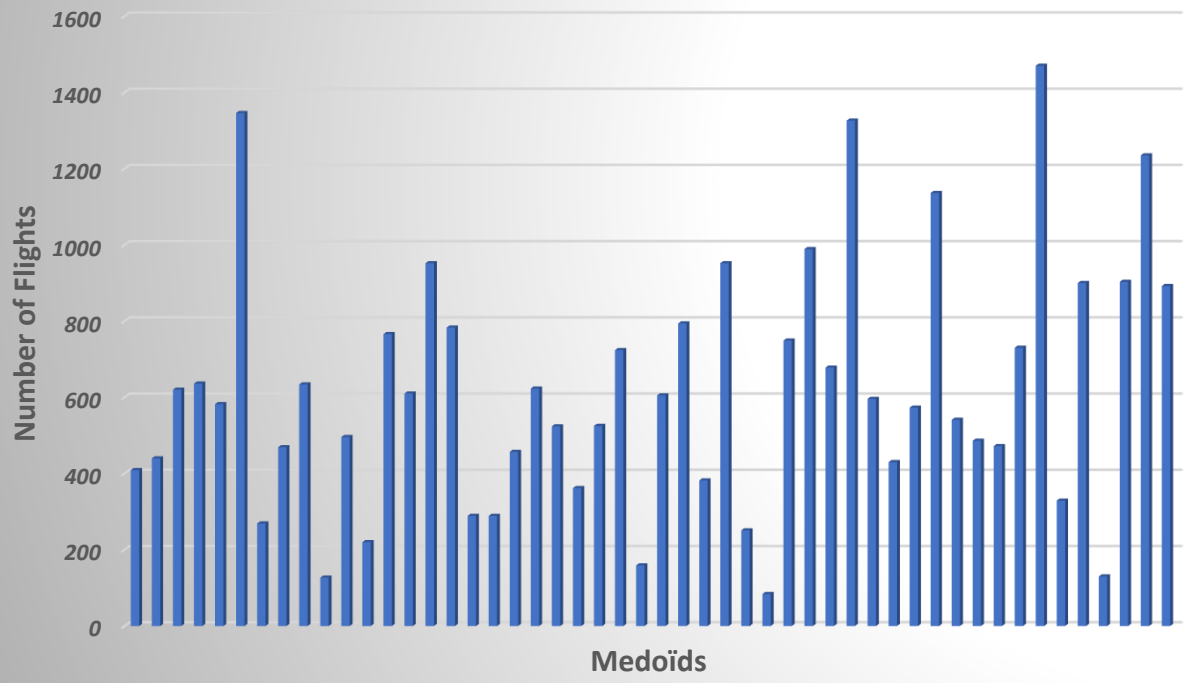
Bundling: Trajectory approach (4/4)

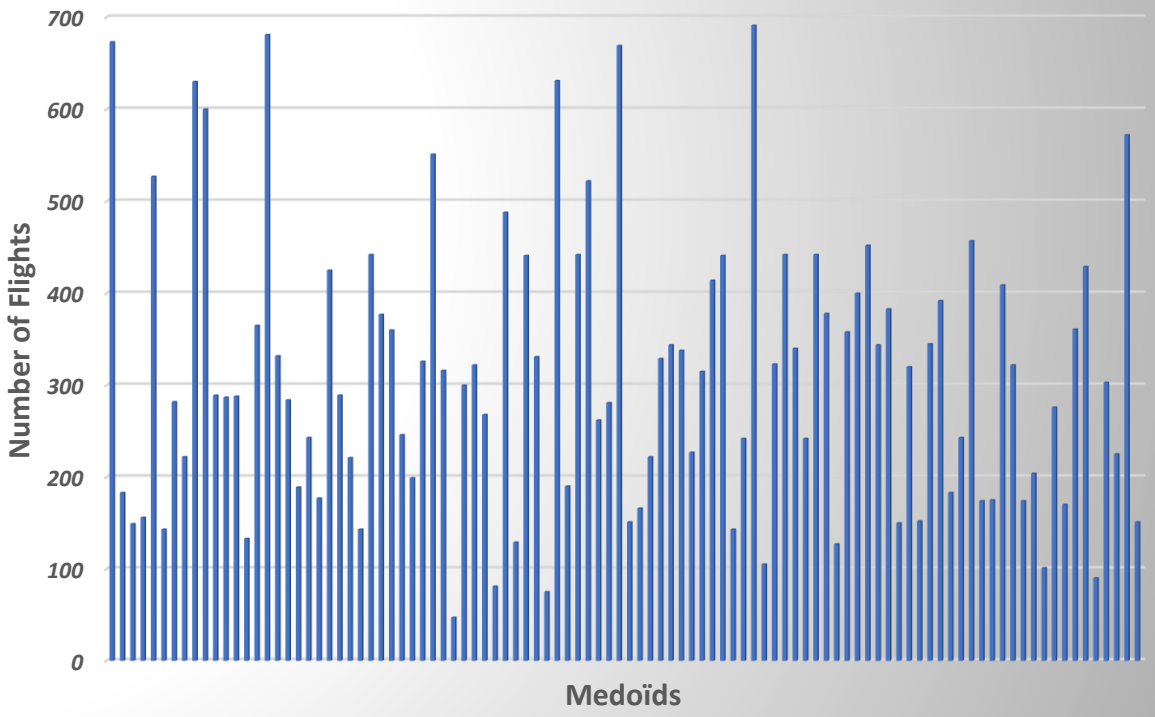
50 medoïds
30 cycles

100 medoïds
30 cycles

Cluster I



Cluster III



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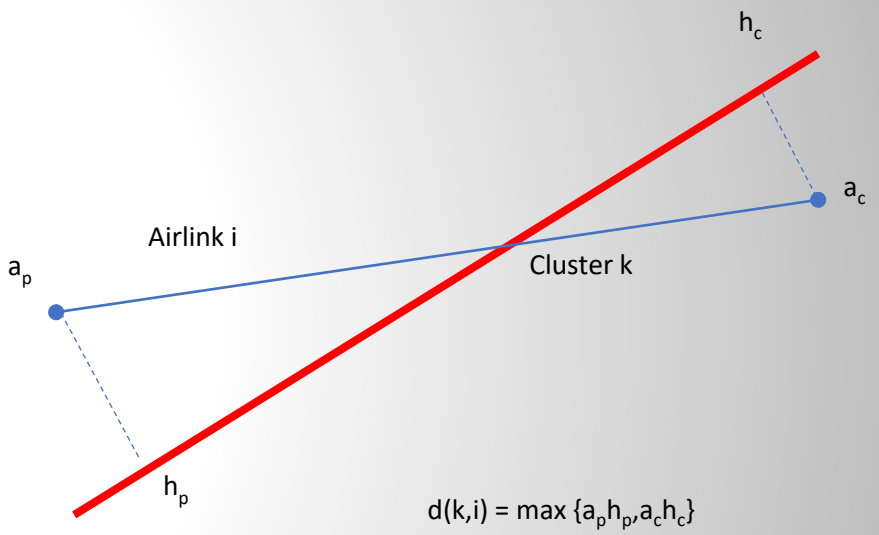
Bundling: City pair approach (1/4)

Phase 1

Choose the airlink with the greatest distance to compose the initial cluster and search for other airlinks for which two criteria should be evaluated:

- The angle should be in a range of at most 5 degrees aligned with the cluster axis;
- The relative distance should be lesser than a given parameter.



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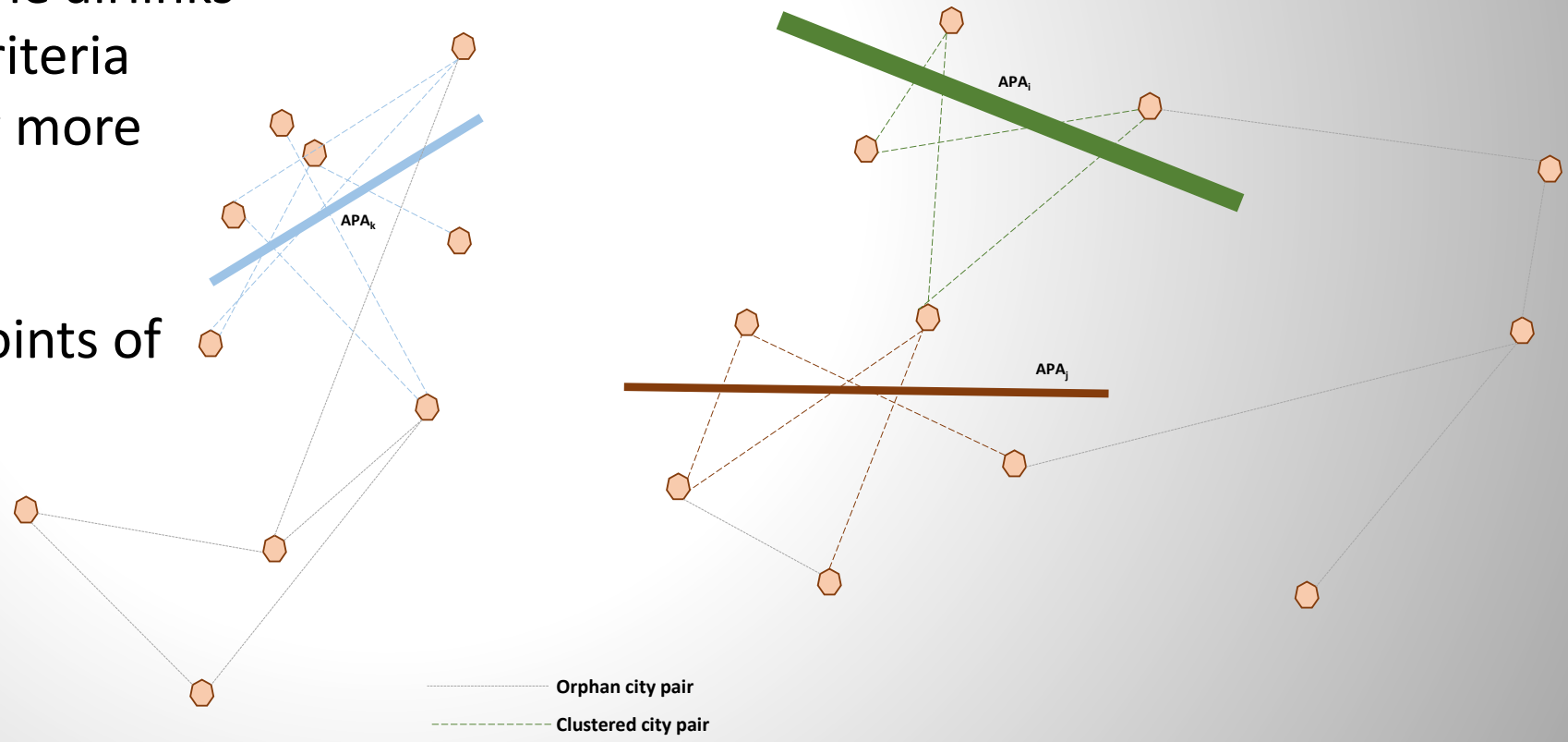
Bundling: City pair approach (2/4)

Phase 2

- Release all airlinks associated with clusters and try to allocate the airlinks again using the 1st and 2nd criteria (this last one with a possibly more restrictive parameter).

- Determination of the end points of the Reference Track



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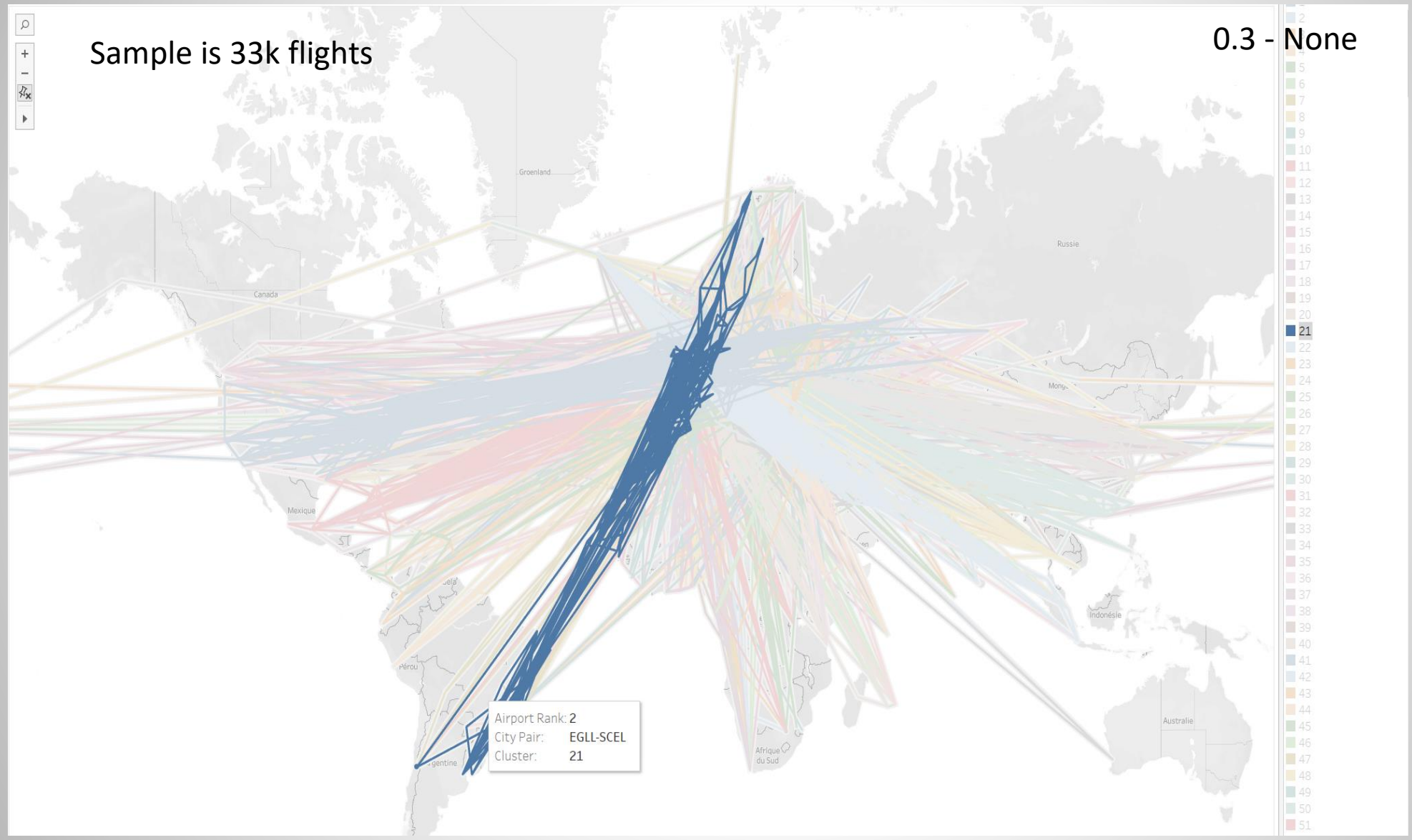
Bundling: City pair approach (3/4)



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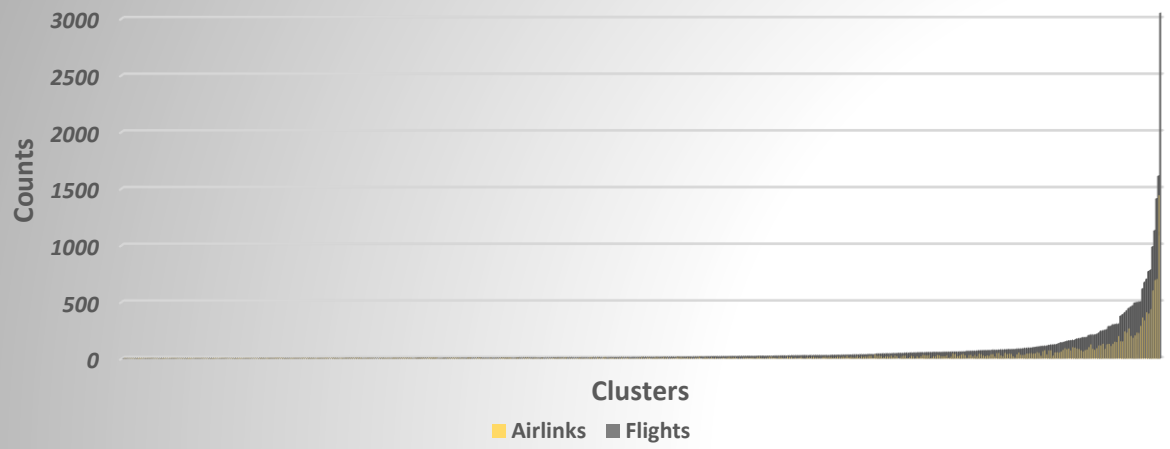
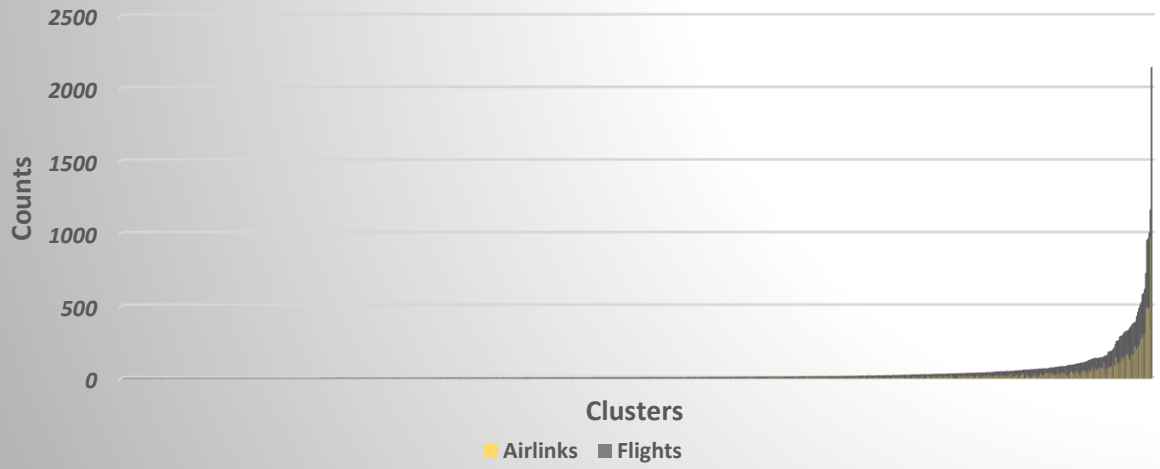
Bundling: City pair approach (4/4)

Relative distance variations 0.3 - 0.3



Relative distance variations 0.3 - 0.15

Relative distance variations 0.3 - None



	0.3 – 0.3	0.3 – 0.15	0.3 - None
Traffic aggregated by clusters*	96.6%	93.2%	94.5%
Total number of Clusters*	264 (3048)**	346 (2319)**	350 (2144)**
Total number of orphan flights	1121	2236	1801

* A cluster should aggregate at least 10 flights

** Maximum number of flights aggregated by one cluster

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Airstream Structure: Basics

- Section is rectangular;
- Internal lanes are dedicated to a speed interval and/or aircraft types;
- Peripheral lanes are added automatically to all the levels;
- Lane lateral separation is 5 NM;
- Lane vertical separation is 1000 feet;
- Airstream will serve all the traffic aggregated (i.e. unlimited capacity).

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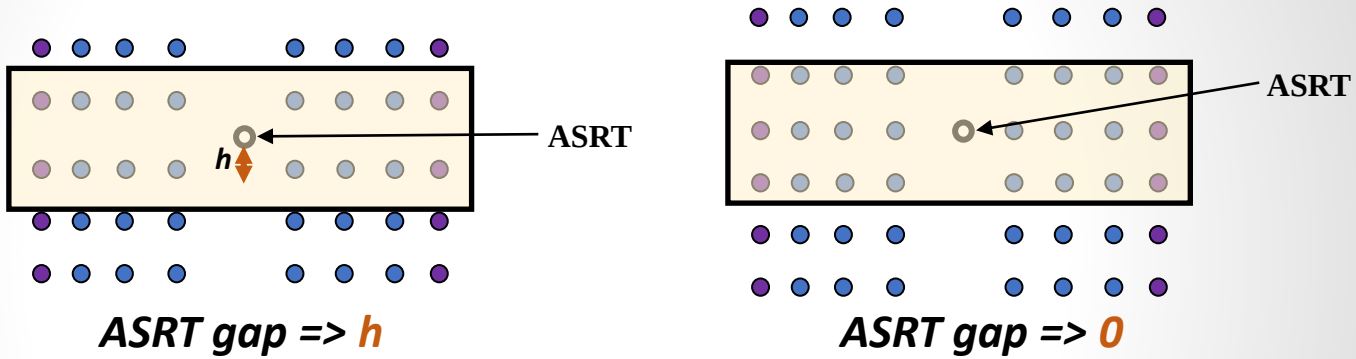
Airstream Structure: Complements

- 2 adjacent internal lanes (i.e. same direction, same level and next to each other) share a speed interval (i.e. overlap in speed) to allow overtaking;
- Vertical gap is 0;



- Lateral buffer (i.e. distance between peripheral lane and edge of the Airstream structure) is equal to lane lateral separation.
- Vertical buffer (i.e. distance between upper/lower lanes and edge of the Airstream structure) is equal to the lane vertical separation.

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Airstream Building: Initial thoughts (1/2)

Build the properties that can be associated to the lanes (define families);

	Max Speed	Min Speed	Max RFL	Min RFL	Aircraft type list
Family 1					
Family 2					
Family 3					
Family 4					
Family 5					
…					
…					

Families are sorted regarding their performances, e.g. Min Speed of the n^{th} Family is close to the Max Speed of the n^{th}-1 Family

First Step

Sort the traffic (*demand going from an airport to another - i.e. considering the direction but not yet the trajectories*) into the various families without considering the time dimension. As an initial approximation, it should give the "biggest" structure of the Airstream (i.e. maximum number of lanes expected).

	Family type	Nb of aircraft	Direction
Lane L1	1	50	Left
Lane L2	2	34	Left
Lane L3	3	160	Left
Lane L4	4	200	Left
Lane R1	1	70	Right
Lane R2	2	38	Right
…			
…			

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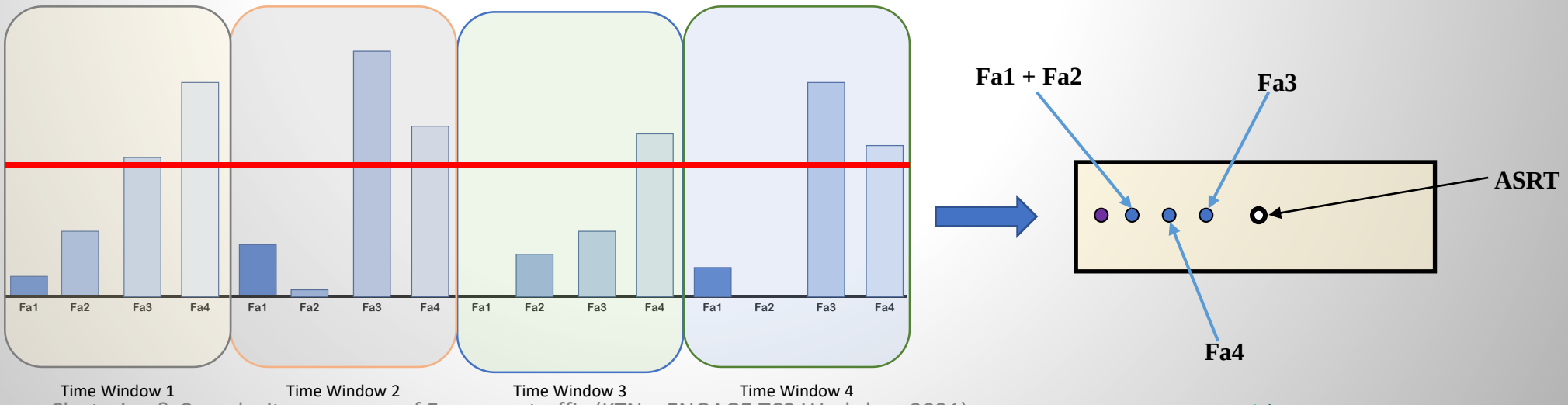
Airstream Building: Initial thoughts (2/2)

Second Step

Refine the initial structure slicing the day of traffic considering a time interval and orientation (i.e Left or Right):

- Evaluate the "*occupancy count*" of the Families for these time windows thanks to the orientation. The flight is considered belonging to the time window if:
  - Domestic flight => either its take-off time or landing time is inside the time window;
  - Incoming flight => landing time is inside the time window;
  - Outgoing flight => take-off time is inside the time window;
  - Transiting flight => not yet defined



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Airstream Building: What's next

To be further investigated

- Algorithms to calculate the distance for aggregating flights to an ASRT;
- Geographical limits of the individual Airstream;
- Criteria to define the families (e.g. a family is dedicated to single level of Airstream or more);
- Families are referring to generic aircraft types (i.e. common to all samples) or to list of flights (i.e. specific to a sample).

To be studied

- Altitude balancing in airstream (optimise structure using the z dimension);
- Extension to network (consider interaction with other Airstreams to segregate in altitude).

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The way to go?

- What is the best altitude interval to set the Airstream network?
- Is a static generic categorisation (e.g. colour coding: blue, green, red …), associated with specific technical characteristics, of the lanes of an Airstream needed?
- Is the categorisation evolved with traffic (i.e. always the same or adapted to the traffic sample) ?
- What are the most relevant parameters to define the families/lane colours?
- Is vertical evolution allowed in Airstream or only longitudinal one?
- How to estimate flight path to/from Airstream and departure/destination (considering airport not in the axis of the Airstream)?

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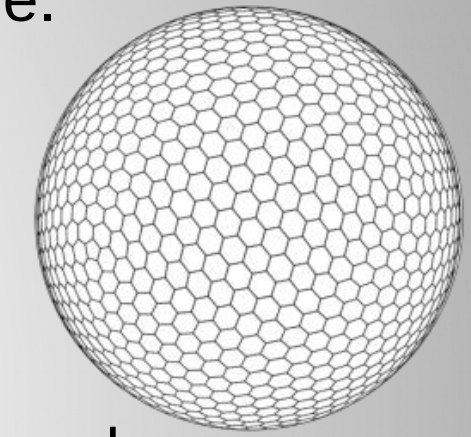
Complexity

Complexity computation improvements

- Use of a new complexity indicator especially tailored for data on sphere.



- In a preprocessing phase, samples are allocated to hexagonal (or pentagonal) cells of fixed size.

- At each cell center, a local linear model is computed, using a kernel based on the spherical distance.

- The matrix obtained when fitting the local model is used to compute the complexity as the distance to a multiple of the identity matrix (most complex situation as it describes a quasi-random traffic pattern).

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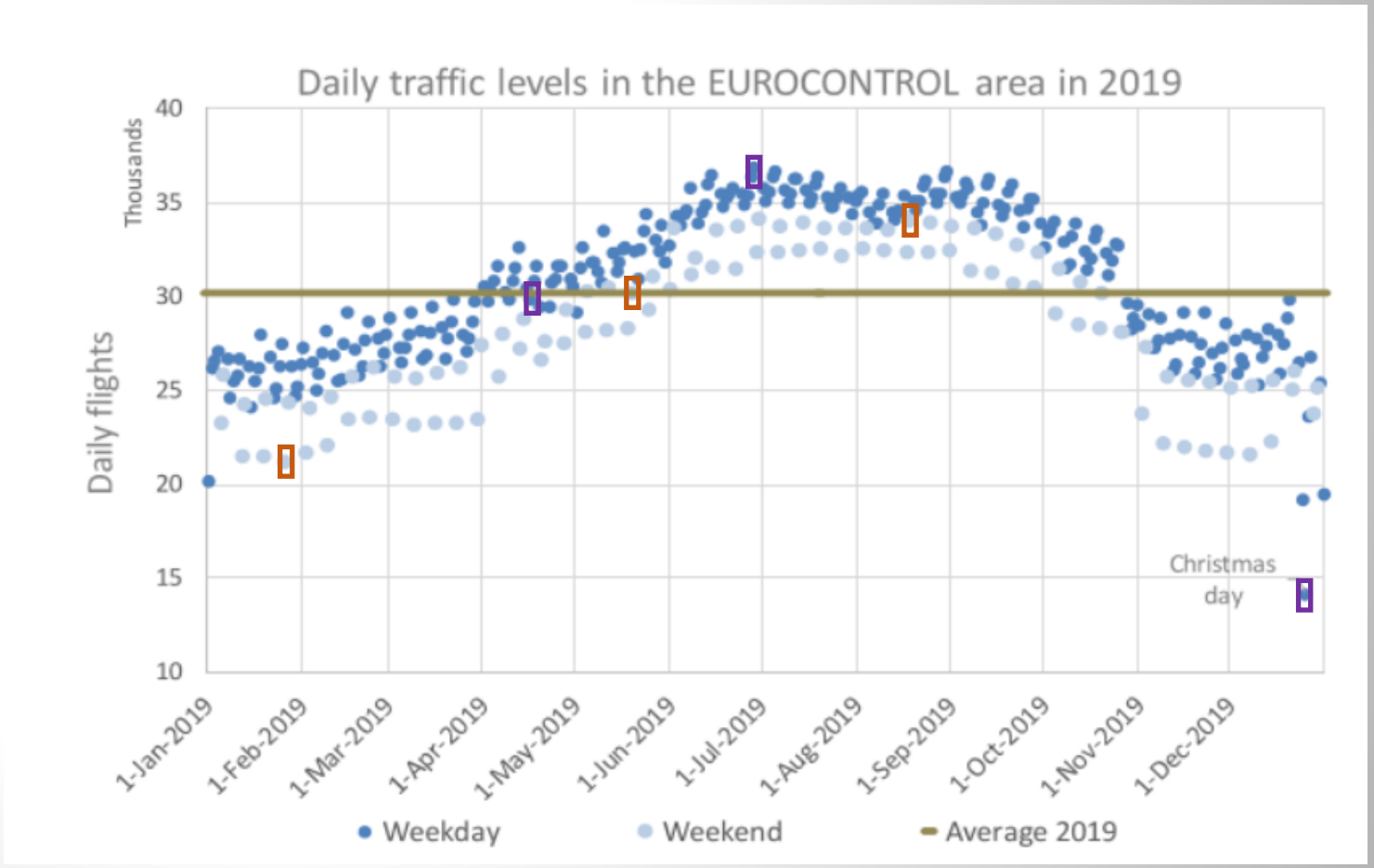
Data & Scenarios: Reference

2019 days collection (weekday and *weekend*);

- *January* 27th (low)
- April 15th (average)
- *Mai* 19th (average)
- June 28th (peak)
- *August* 18th (peak)
- December 25th (low)



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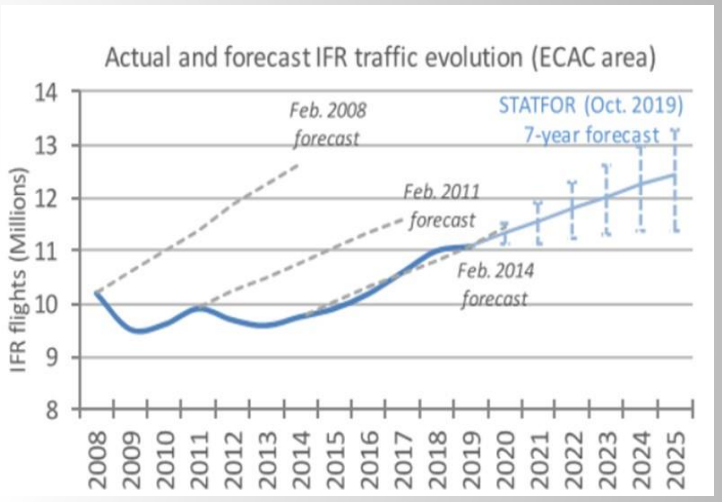
Data & Scenarios: Use Cases

Simulated traffic for a 2030/2035 projection

- STATFOR's 7- year forecast (October 2019) considering 2019 traffic recovered by late 2024.

- Societal constraint scenario

  Decrease/suppression of flights on targeted city-pairs (% depending on the distance of the city pair).



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The way to go?

- What could be the criteria to select a city pair for which alternative transport means can be used.
- What could be the criteria to evaluate the variation of traffic for these city pairs.

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Opinion Poll

Bundling & Airstream Building

- What is the best altitude interval to set the Airstream network?
- Is a static generic categorisation (e.g. colour coding: blue, green, red …) , associated with specific technical characteristics, of the lanes of an Airstream needed?
- Is the categorisation evolved with traffic (i.e. always the same or adapted to the traffic sample) ?
- What are the most relevant parameters to define the families/lane colours?
- Is vertical evolution allowed in Airstream or only longitudinal one?
- How to estimate a simple flight path to/from Airstream and departure/destination (considering airport not in the axis of the Airstream)?

Modelling Use Cases

- What could be the criteria to select a city pair for which alternative transport means can be used.
- What could be the criteria to evaluate the variation of traffic for these city pairs.

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