Complex Event Recognition & Forecasting

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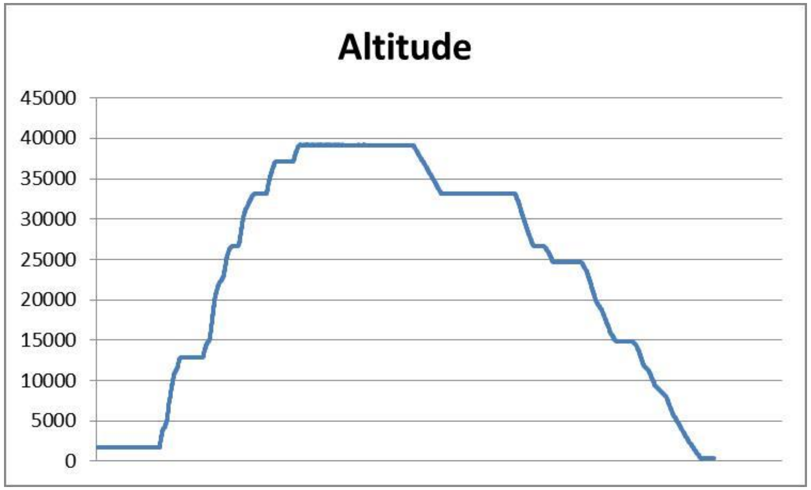
Complex Event Recognition in TP

- Composite events of interest – collections of events that satisfy some pattern.
  - The ‘definition' of a composite event imposes temporal, logical and, in this research, spatial constraints on sub-events coming from sensors or other composite events
- Difficulties such as lack of ground-truth in certain complex events (i.e, ToC, ToD)



Definition of Events

- Events at Flow Management:
  - **Capacity imbalance (Hotspot)**
  - **Regulation**
- Events at flights (at trajectories):
  - Complex
    - **Top of Climb / Top of Descent ***
    - **Trajectory Change Point (Speed) ***
    - **Hold Entry/ Exit *****
    - **STAR entry / SID entry *****
    - **Aircraft not following planned route *****
    - **Takeoff Runway / Destination Runway *****
  - *Not Complex*
    - *FIR / Terminal Boundary Crossing Point*
    - *Trajectory Change Point (Altitude)*
    - *Hold on ground*
    - *Turnings (radius and direction) vs straight flight (great circle)*

Sources of error/uncertainty

- No source of “ground truth”, options:
  - Manual identification of samples for each event
  - Significant effort
  - Different criteria

Flow Management Scenario

- From the perspective of the Air Navigation Service Provider (or Network Manager), ATM can be **(extremely)** simplified into a <u>Demand and Capacity Balance</u> problem (**DCB**)
  - Capacity depends on the service providers, and can be maximized with limits. Changes in capacity are slow.
  - Demand depends on the flying aircrafts, and may vary drastically in short intervals.

Flow Management Scenario

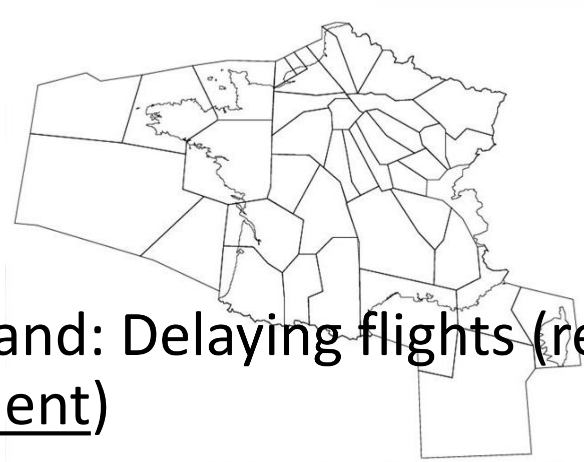
- What happens when D>C?
  - The nominal capacity of the system is not enough, and because of safety it shouldn't be exceeded.
  - Consecuently, some flights must be delayed before taking off (regulation)
  - Delays are expensive, and problematic
    - Planes may arrive not in time for their next flight (rprimary delays vs reactionary delays).

Flow Management Scenario

- What happens when C>>D?
  - Inefficient resource management
  - Extra cost
  - Collateral safety risks due to low workload -> lack of attention may arise.
- The ideal situation is C>D, with a small buffer

Flow Management Scenario

- What can be done to balance D and C?
  - Actions on capacity: Up to a limit, can be increased by opening more sectors (ANSP)



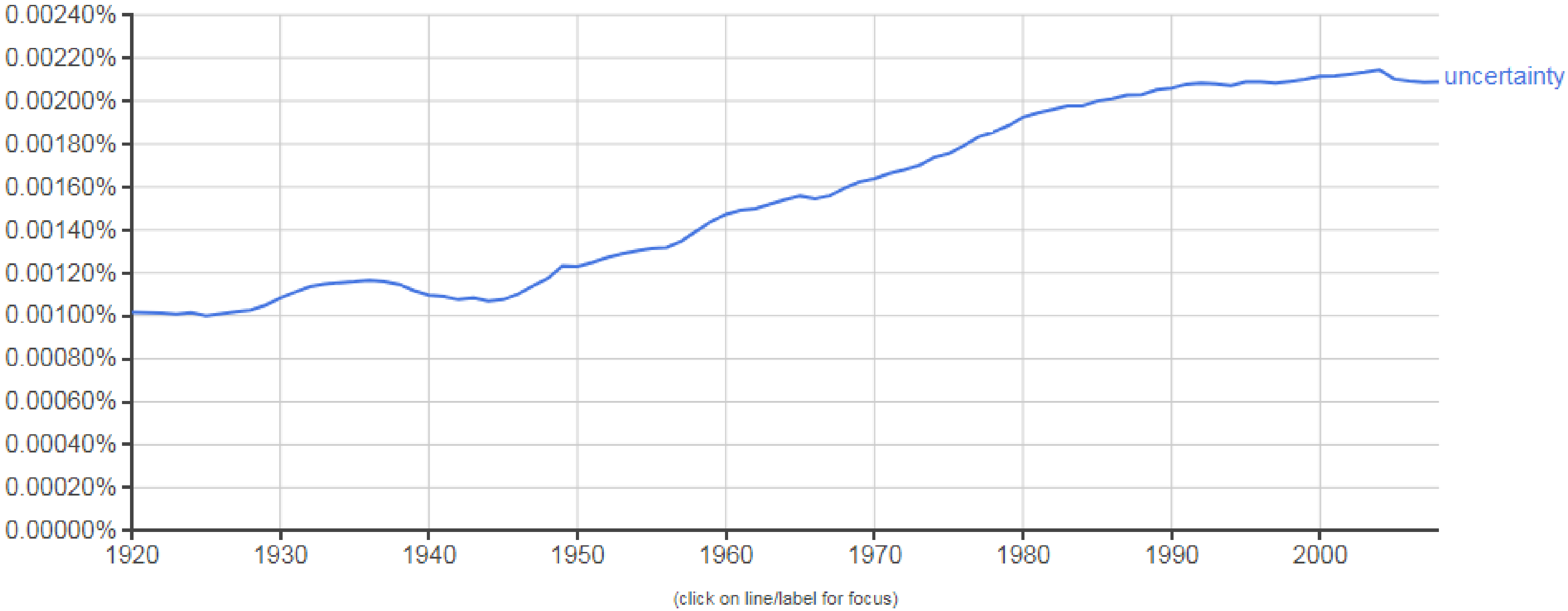
  - Actions on demand: Delaying flights (regulation), by NM (Flow Management)

Flow Management Scenario

- As capacity is much less dynamic than demand, is essential to have a good traffic (demand) forecast
- Current forecast are inaccurate, not linking different flights of one aircraft during day of operations.
- Consequences:
    - Inefficient Capacity Plan
    - Inefficient Flow Management

Some references: Uncertainty

- Source: Google Books Ngram Viewer



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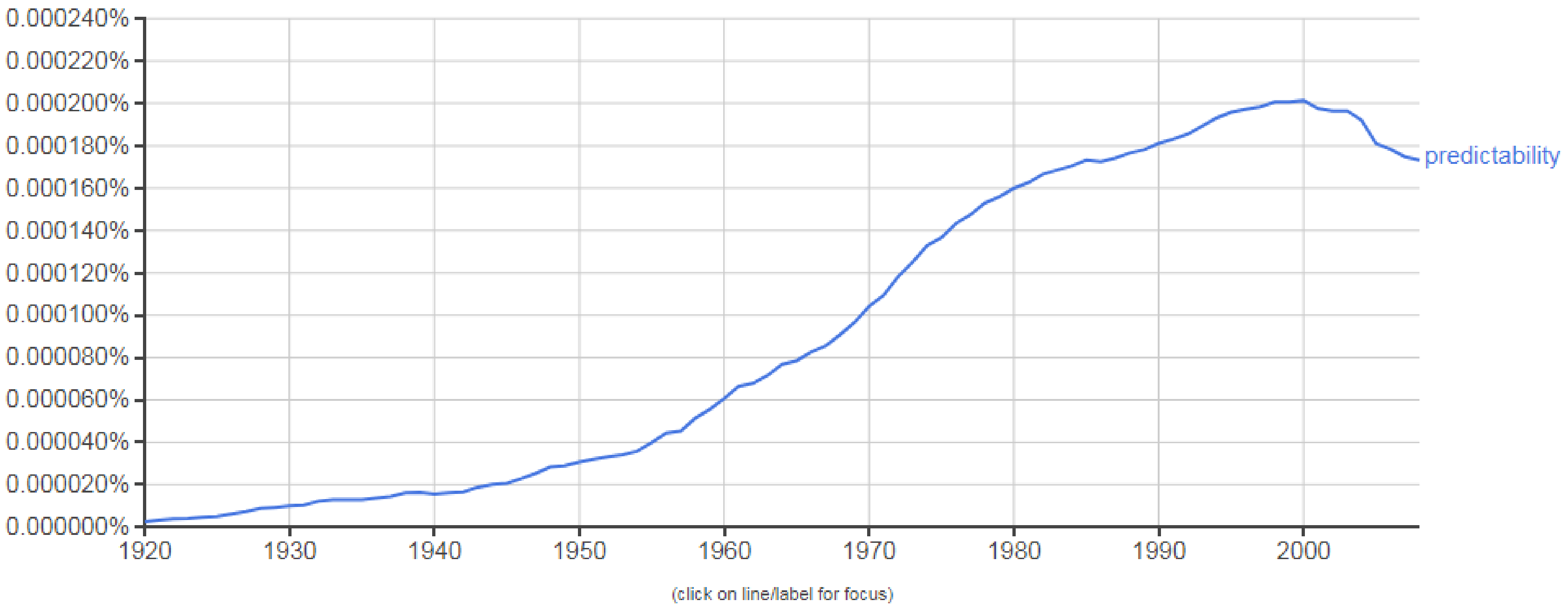
Some references: Predictability

- Source: Google Books Ngram Viewer



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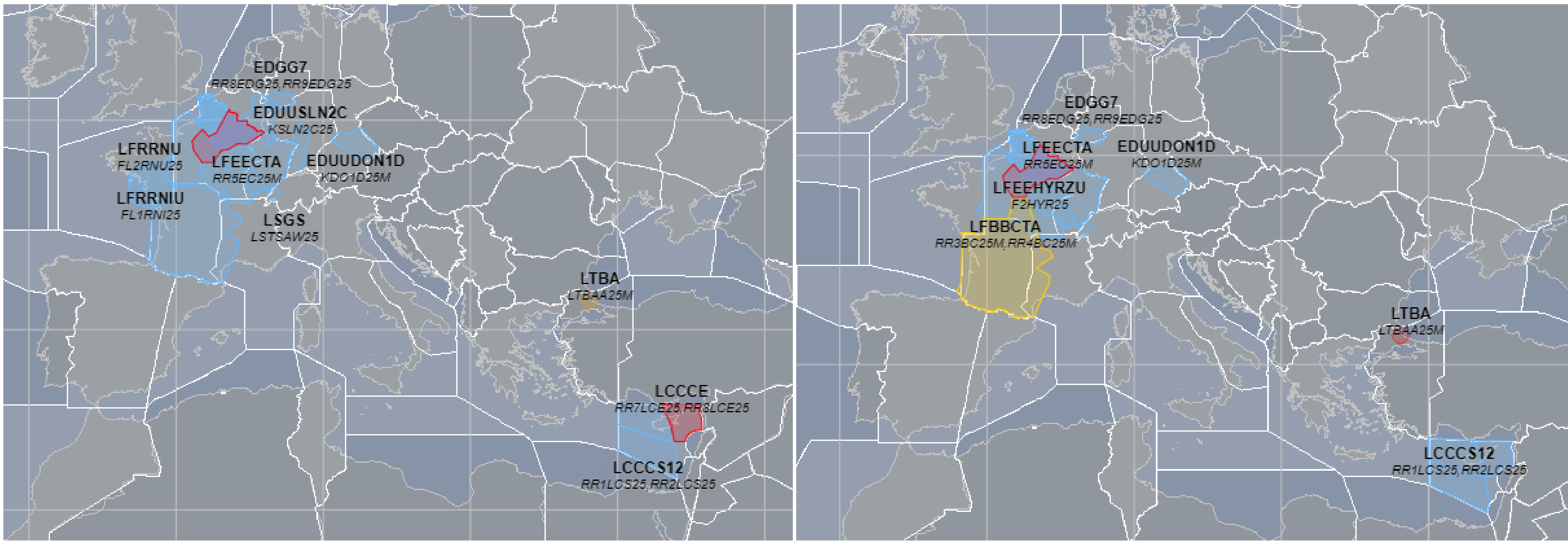
Uncertainty effects on Traffic

- Forecast vs reality (from NOP; any given day)



Expected   Observed

Are regulations patterns predictable?

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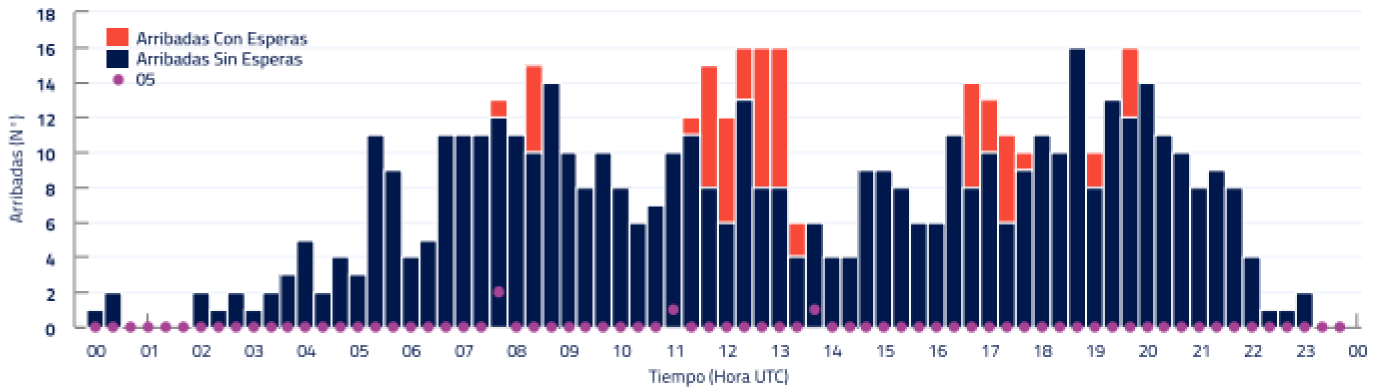
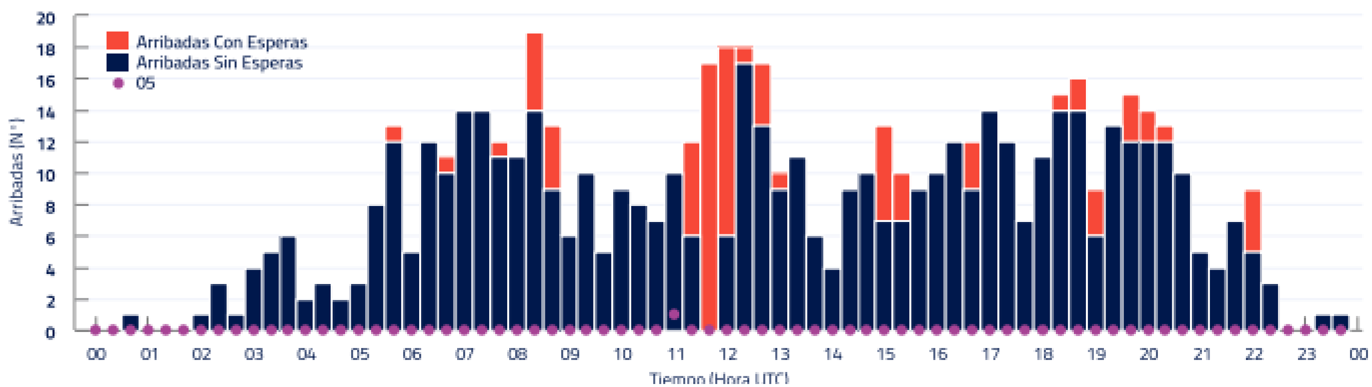
Uncertainty effects on traffic

Holdings (any given day)

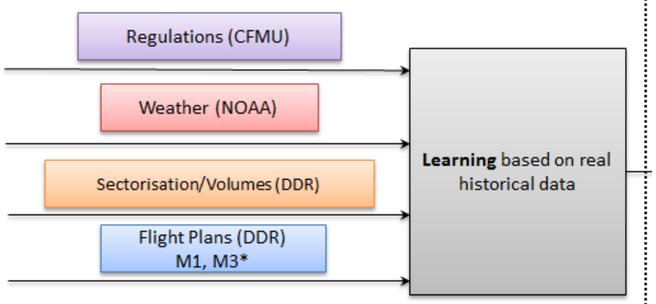




Are holding patterns predictable?

FM01 - Regulations detection and prediction

MODELLING



In this scenario, we suggest the use of M1 flight plans, since we do not know the influence M3 flight plans could have on regulation prediction. However, you could choose to use M3 flight plans if you find it convenient

All weather forecasts from NOAA are available, however, we recommend you to use the -24h prediction

FM01 Overview

Regulation detection and prediction capability is useful for reproducing **Flow Management Behavior**.

The regulations are consequences of specific situations mainly due to an **excess of demand vs capacity** in sectors, or due to different **weather conditions**.

Excess of capacity vs demand and weather conditions are not the only ones that provoke a regulation but they are the ones which are going to be predicted with datAcron.

FM01 - Regulations detection and prediction

FM01 Validation

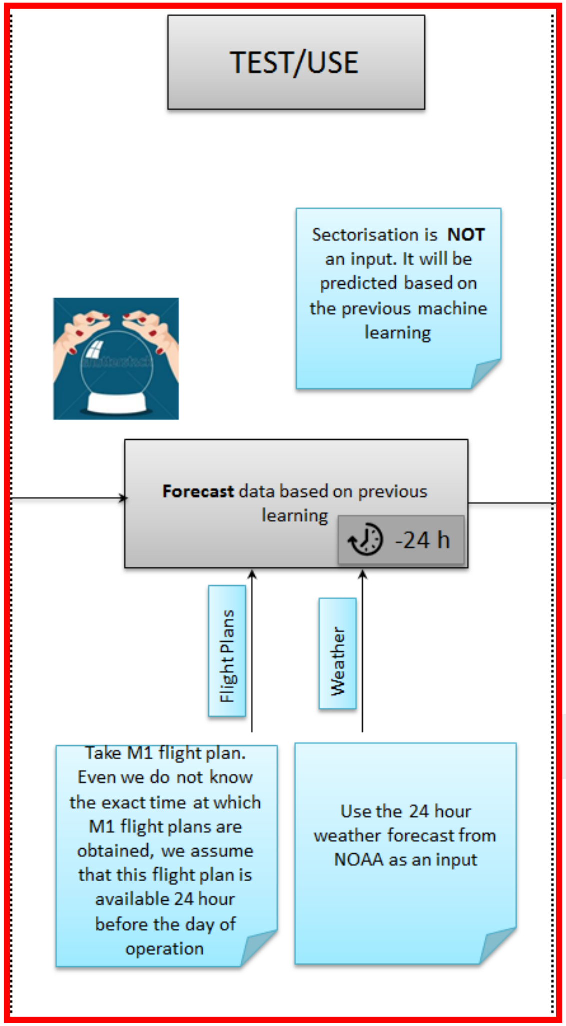
The validation aims to explore the ability of datAcron to predict regulations based on the behaviour of the flights when they cross specific sectors or with specific weather conditions.

Dataset

Nominal conditions:
01/05/2016 – 07/05/2016

Capacity problems:
10/07/2016 – 16/07/2016

Weather problems:
12/06/2016 – 18/06/2016



Workflow

Select time period and area

WP1: - loads the corresponding files
- measure the processing **time**
- provide the **number of flights** selected, and the **information loaded** in the system for them

WP3-WP4: - **predicts regulations**
- measure the processing **time**
- provide the **file with regulations**:

Field	Example
1. Regulation ID	EDDFA01
2. Regulation Start	04:40:00
3. Regulation End	07:20:00
4. Sector	EDGGFMP1
5. Regulation Reason Code	W
6. Reference Location Type	AD
7. Delay*	20

and the sectorization predicted

Metrics

WP6 - **Usability** of the system

WP6 – **Performance**: times are in the specified validation ranges (<10 seconds)

WP6 – **Completeness**: there are no blank loss of information comparing with raw data

WP6 – **Accuracy**: comparing predicted regulations with real regulations

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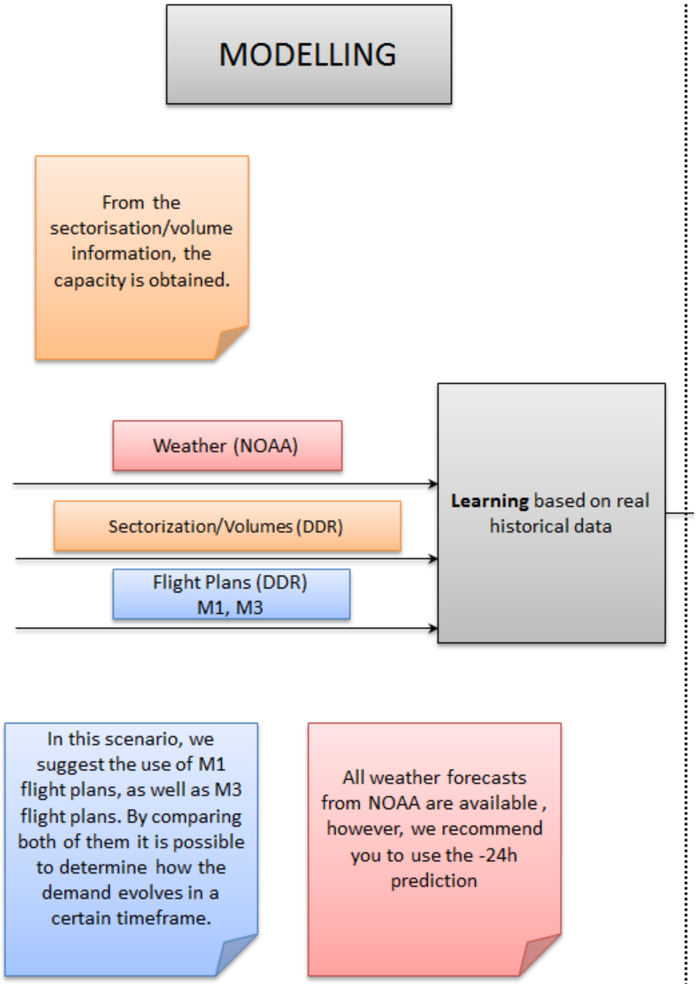
FM02 - Imbalances detection and prediction



FM02 Overview

This scenario objective is to demonstrate how datAcron events' detection and prediction capability is useful for detecting **demand and capacity imbalance** by means of indicators monitoring.

Those indicators are based on **real demand** (Hourly Entry Count: for a given sector is defined as the **number of flights entering in this sector during one hour**) and declared **capacity** (Maximum number of flights allowed to enter in a sector during one hour) of the current configuration of airspace, by calculating them **from the initial flight plan** (deregulated traffic), denoted as M1 below, instead of the real flight plan.

FM02 - Imbalances detection and prediction

FM02 Validation

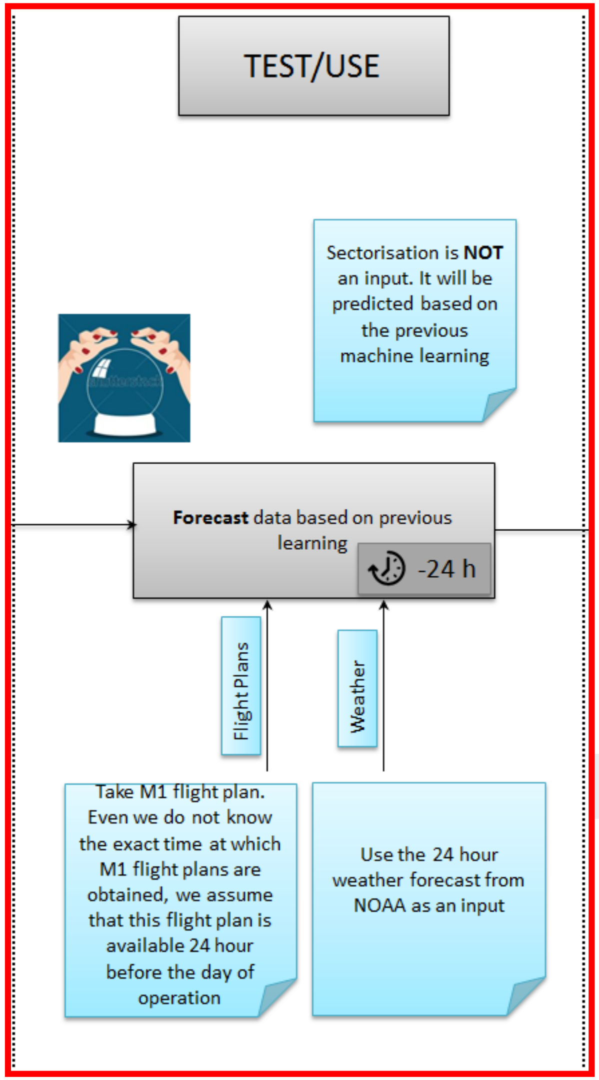
The validation aims to demonstrate how datAcron events' detection and prediction capability is useful for detecting demand and capacity imbalance by means of indicators monitoring.

Dataset

Nominal conditions:
01/05/2016 – 07/05/2016

Capacity problems:
10/07/2016 – 16/07/2016

Weather problems:
12/06/2016 – 18/06/2016



Workflow

Select time period and area

WP1: - loads the corresponding files
- measure the processing **time**
- provide the **number of flights** selected, and the **information loaded** in the system for them

WP2: - reconstruct trajectories
- measure the processing **time**

WP3: - entry and exit times for each flight per sector and calculate the demand in each sector.
- measure the processing **time**

WP4: - events of excessive demand (**imbalances**)
- measure the processing **time**
- provide the **file with imbalances**:

Field
1. Imbalance ID
2. Imbalance Start
3. Imbalance End
4. Sector

Metrics

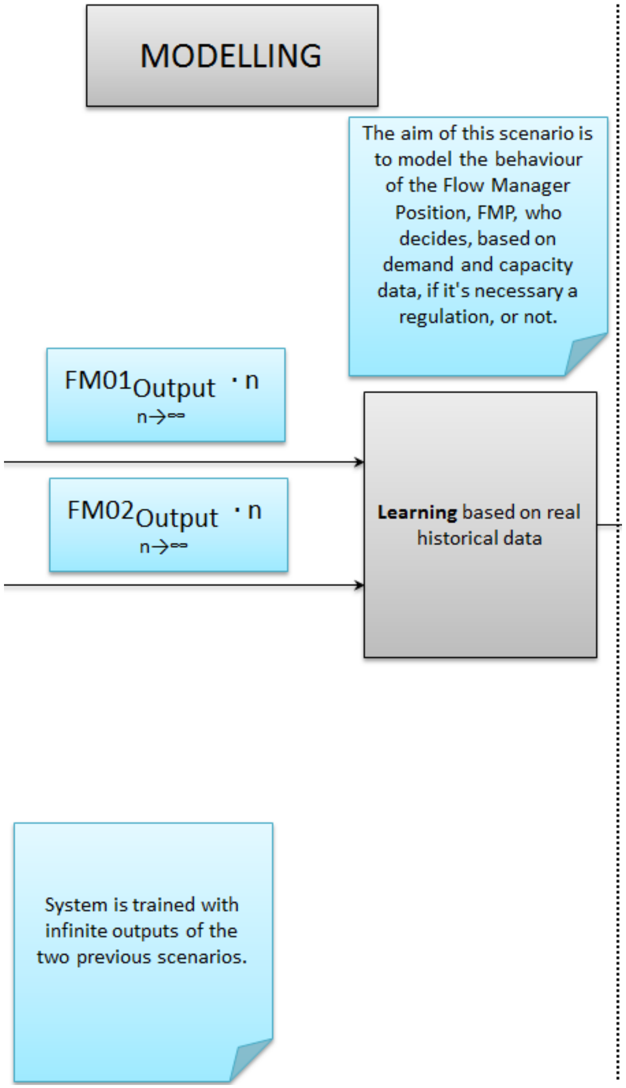
WP6 - **Usability** of the system

WP6 – **Performance**: times are in the specified validation ranges (<10 seconds)

WP6 – **Completeness**: there are no blank loss of information comparing with raw data

WP6 – **Accuracy**: comparing predicted imbalances with real ones

FM03 - Resilience assessment



FM03 Overview

This scenario will **compare** each **detected imbalance** (from the scenario **FM02**) with the **decision taken** by the flow manager assessed by means of the scenario **FM01** (a real imbalance with a regulation application to solve it may be found, but also it is possible to find an imbalance without any regulation because the flow manager considered that the system was able to absorb it).

Once these situations are characterized, datAcron will establish patterns of those which get a better system behaviour characterization.

FM03 - Resilience assessment

FM03 Validation

The validation aims to explore the ability of datAcron to:

(1) detecting the cases when flow managers did not issue regulations despite the demands exceeding the capacities,

(2) investigating the properties of these cases, and

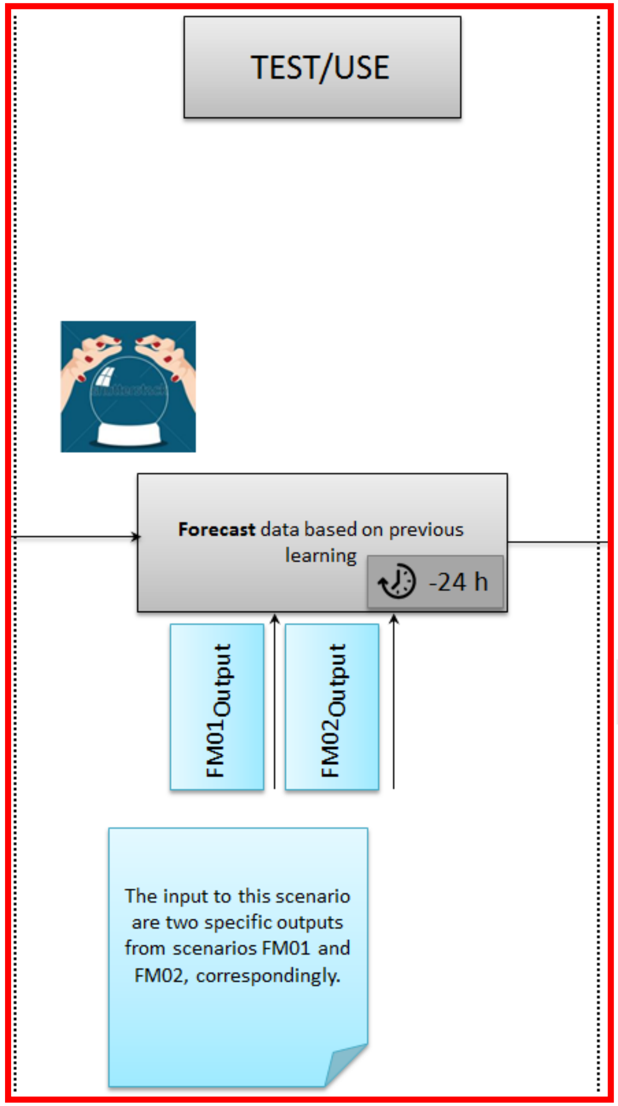
(3) discovering the conditions when an excess of the demand over the capacity can be tolerated without issuing a regulation.

Dataset

Nominal conditions:
01/05/2016 – 07/05/2016

Capacity problems:
10/07/2016 – 16/07/2016

Weather problems:
12/06/2016 – 18/06/2016



Workflow

Select time period and area

WP1: - loads the corresponding regulation and imbalances from FM01 and FM02

- measure the processing **time**
- provide the **number of regulations and imbalances loaded to the system**

WP3-WP4 - Explore when an imbalance results in a regulation as well as the cases in which do not

- measure the processing **time**
- obtain correlation between regulations (FM1) and imbalances (FM2) predicted

Metrics

WP6 - **Usability** of the system

WP6 – **Performance**: times are in the specified validation ranges (<10 seconds)

WP6 – **Completeness**: there are no blank loss of information comparing with output from FM1 and FM02

WP6 – **Accuracy:** percentage of imbalances with/without a regulation associated to it correctly predicted, by comparing it with raw data

FM02 – Problem Statement

- Hotspots may imply a regulation or not
- Hotspots forecasting has been formulated as predicting the most likely sector configuration per ACC across Europe *(to be combined with traffic forecast)*
- Train a classifier using the following:
  - 1. The initial (M1) flight plans.
  - 2. The geometry of the airspaces (DDR entities).
  - 3. The opening scheme (configuration annotation).

FM02 – Feature Engineering

- We constructed features on three levels:
  - 1. Airblocks
  - 2. Sectors
  - 3. Configurations
- The features are extracted for three types of intervals:
  - 1. 5 minutes
  - 2. 10 minutes
  - 3. 20 minutes
- Each such interval represents a training example

FM02 – Airblock features

- The day and hour of each training example.
- The number of aircrafts passing through each airblock.
- The mean and standard deviation of the number of aircrafts passing through the airblocks of the area control center.
- The max number of aircrafts passing through a single airblock.
- The total number of aircrafts passing through the entire ACC.
- The airblock id holding the most flights.

FM02 – Sector features

- All airblock features are now calculated per sector.
- The number of airblocks in the sector.
- The capacity of the sector.
- The difference between sector capacity and the mean number of aircrafts.
- The difference between sector capacity and the max number of aircrafts.

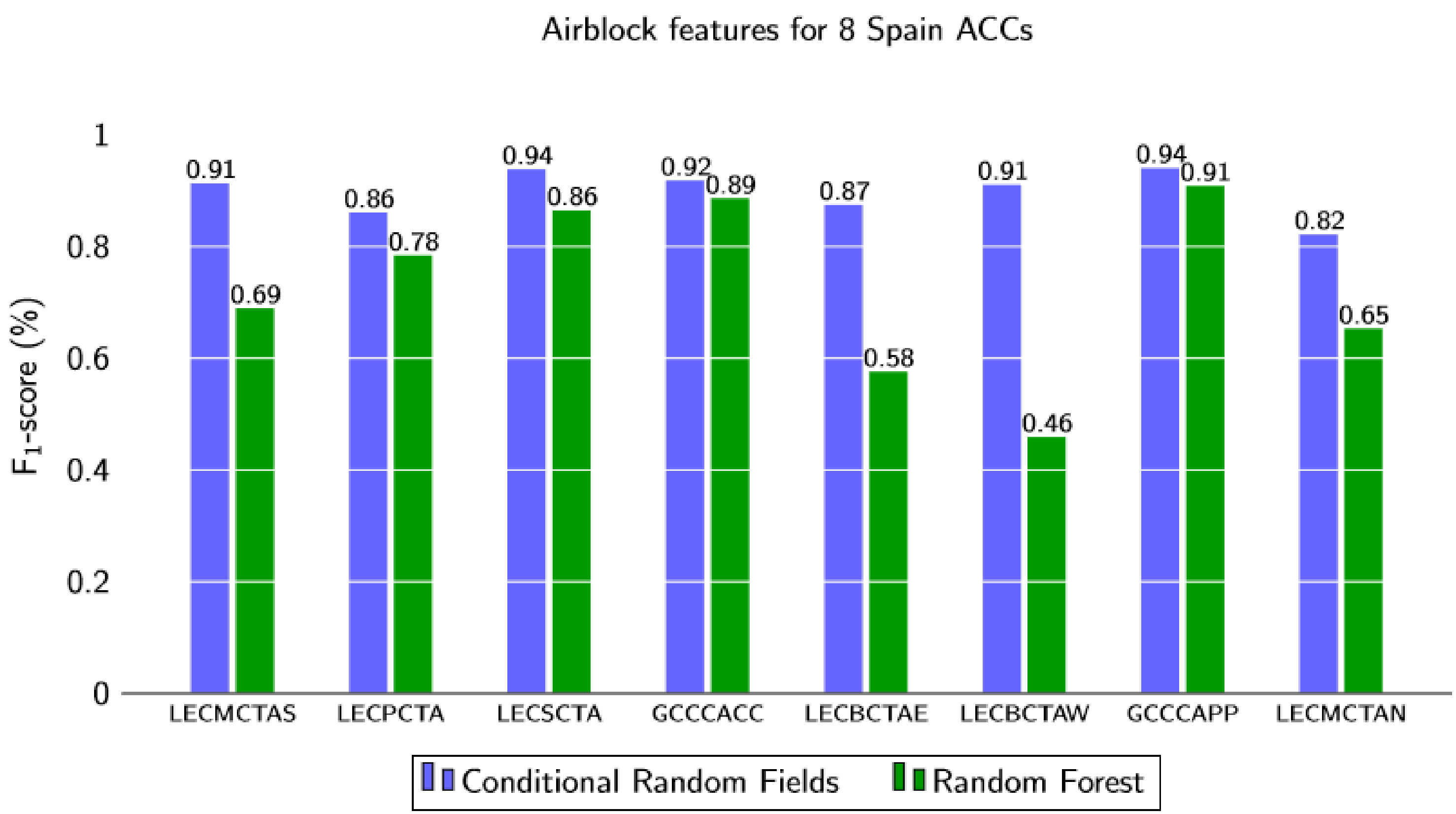
FM02 – Configuration features

- All airblock features are now calculated per configuration.
- The number of sectors for each configuration.
- The sector id in the configuration holding the most flights.
- The sum of the sector capacities in the configuration.
- The mean of the sector capacities in the configuration.

FM02 – Experimental setup

- We used two classifier types:
  - Random forest (RF)
  - Conditional Random Fields (CRF)
- CRFs is known to handle well sequential data.
- RFs has good results without much hyperparameter tuning.
- One classifier was trained for each combination of feature level and interval type.
- April 2016 data were used for training the classifiers.
  - Flight plans and the DDR entities for AIRAC cycle 411.
- The classifier predictions concern 20-minute periods.
- We performed 4-fold cross validation on weekly basis, 3 weeks training, 1 week testing.
- The statistics are micro-averaged over all classes.

FM02- Early Experimental results using airblocks



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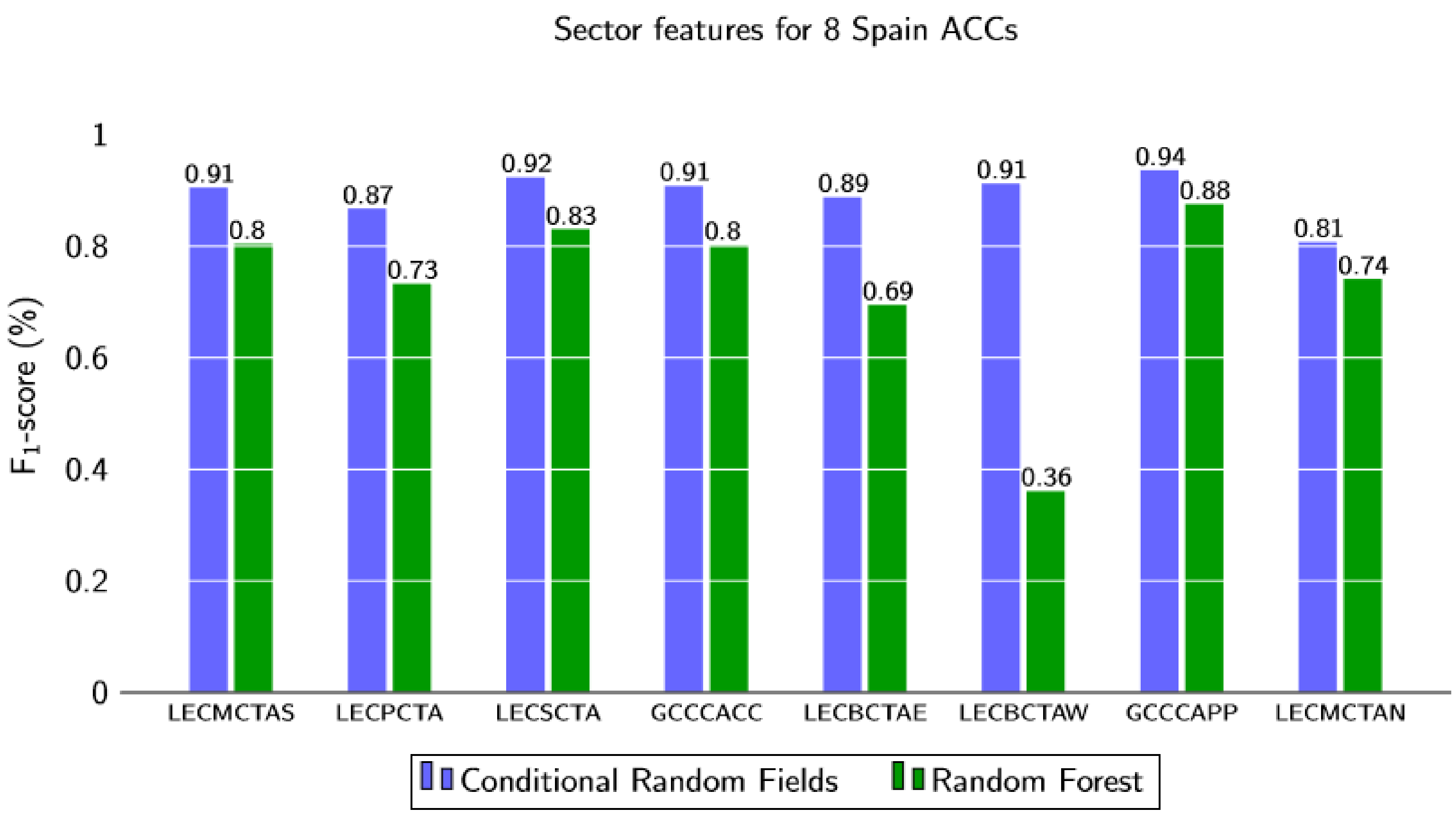
FM02- Early Experimental results using sectors



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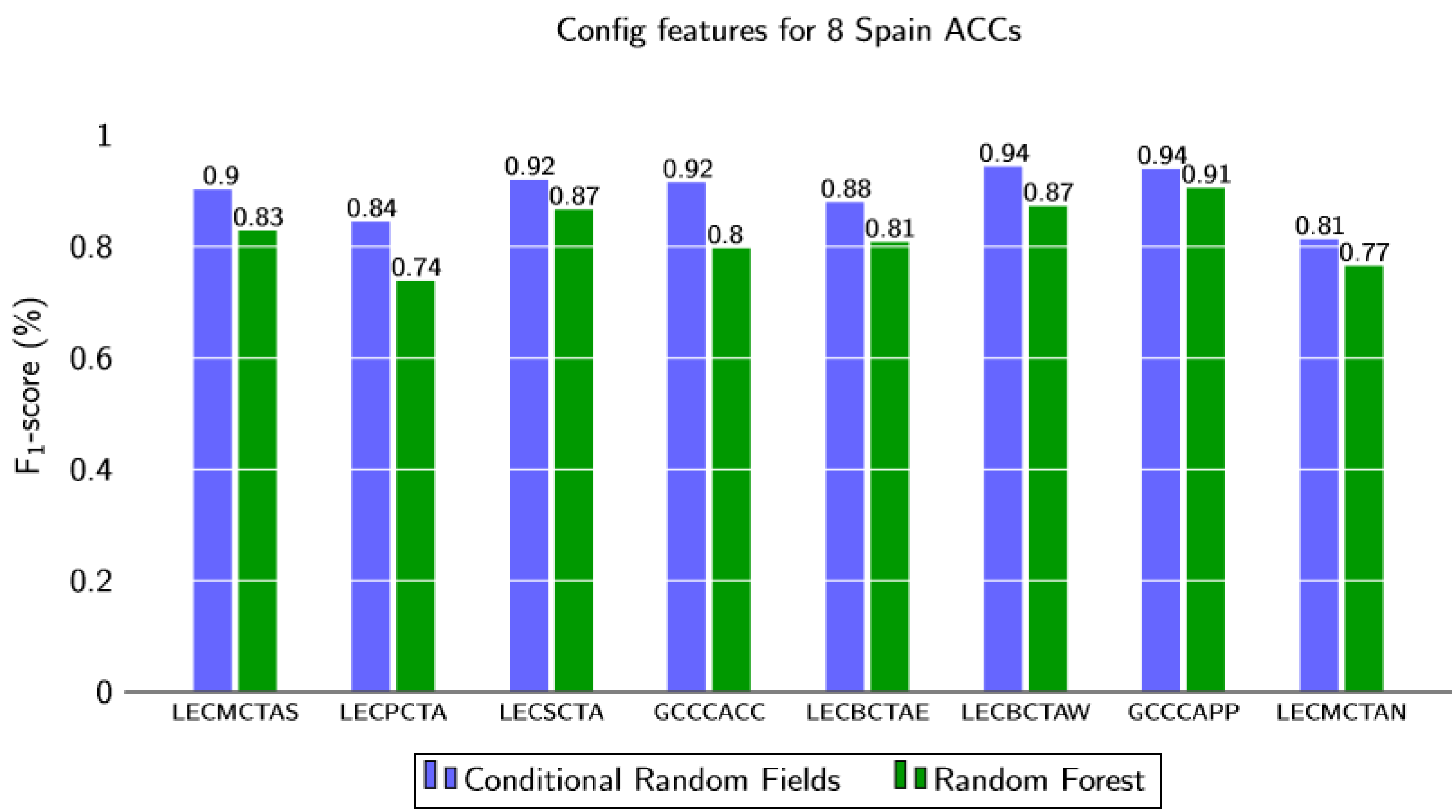
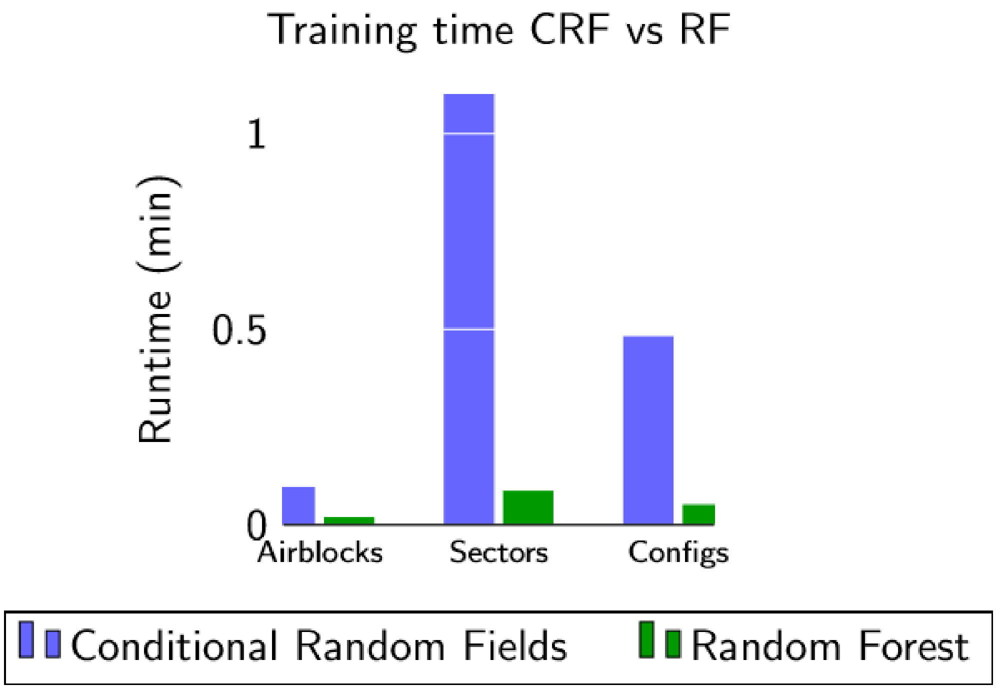
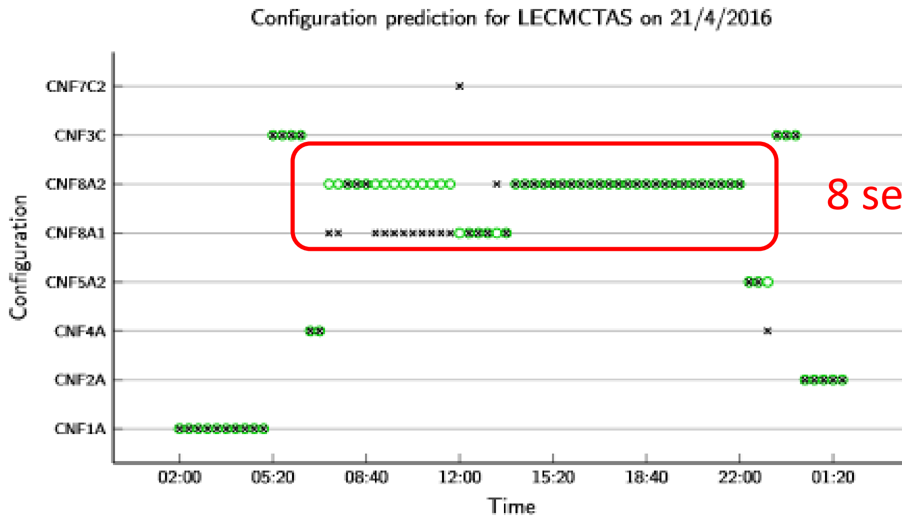
FM02- Early Experimental results using configurations



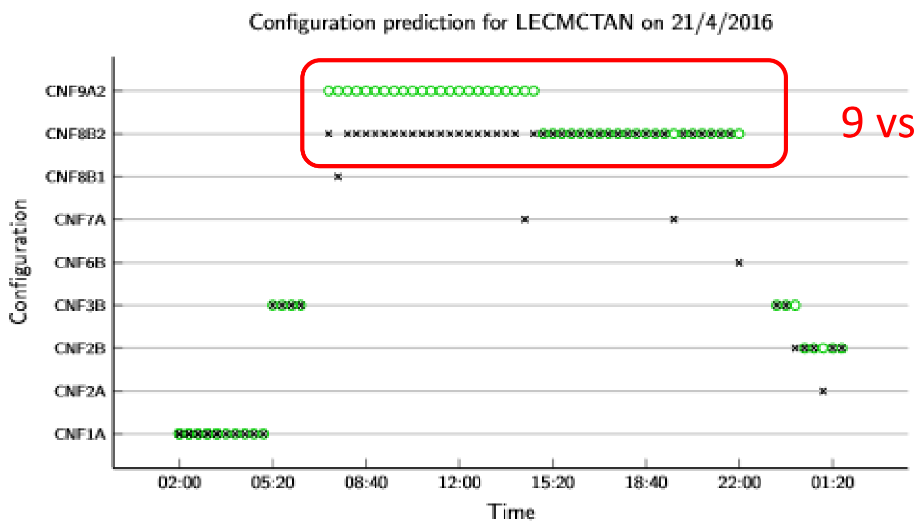
FM02- Training time



FM02- Results for Madrid ACC



8 sectors config



9 vs 8 sectors config

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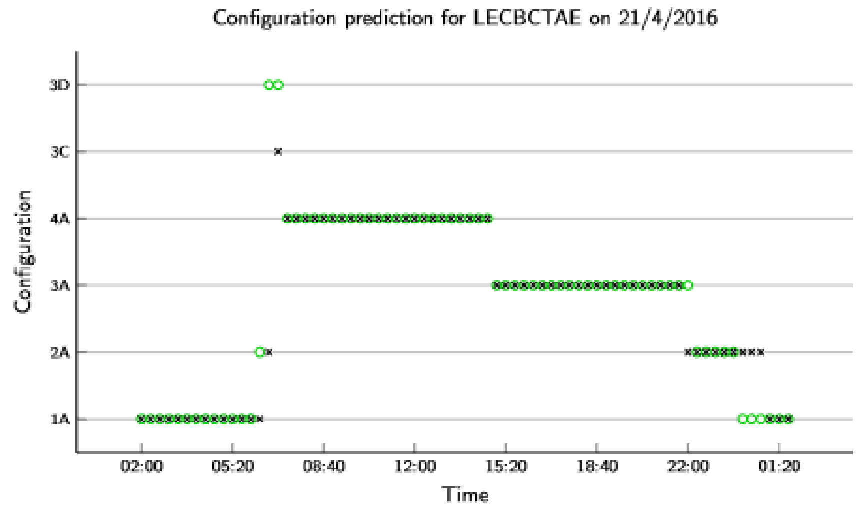
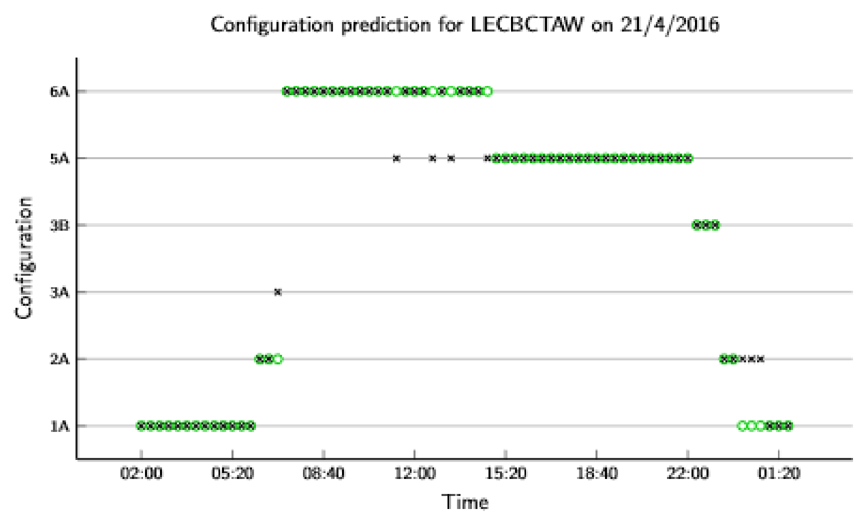
FM02-Results for Barcelona ACC





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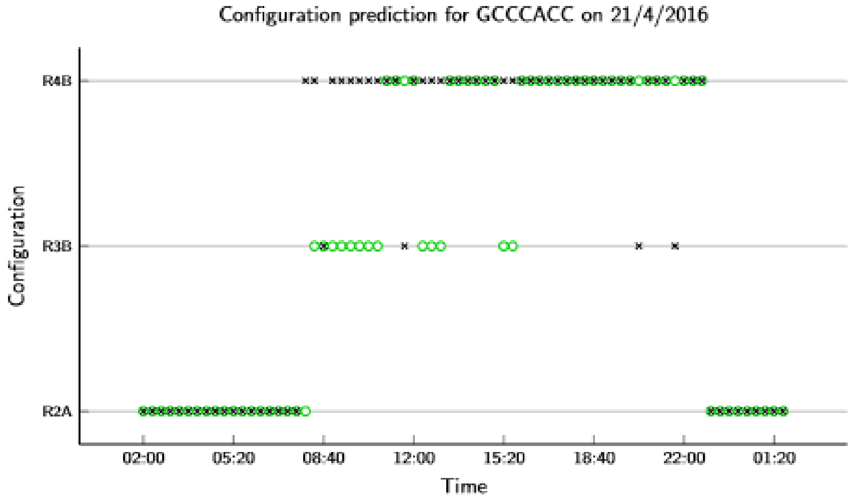
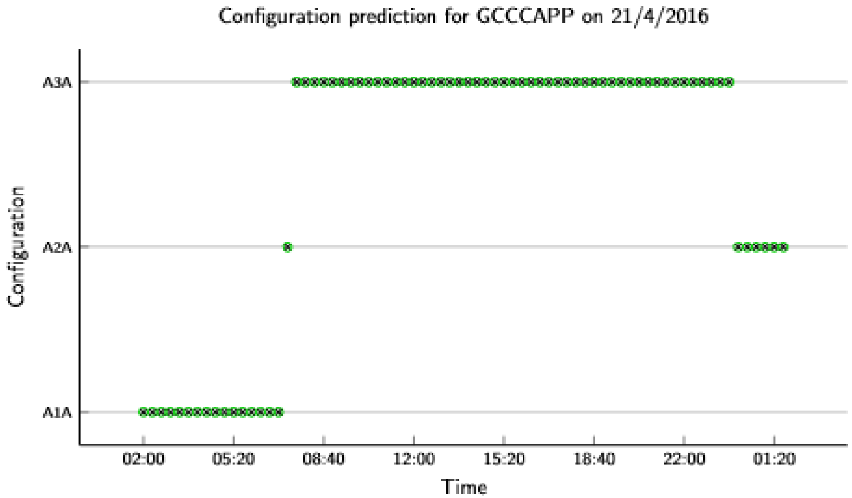
FM02-Results for Canarias ACC





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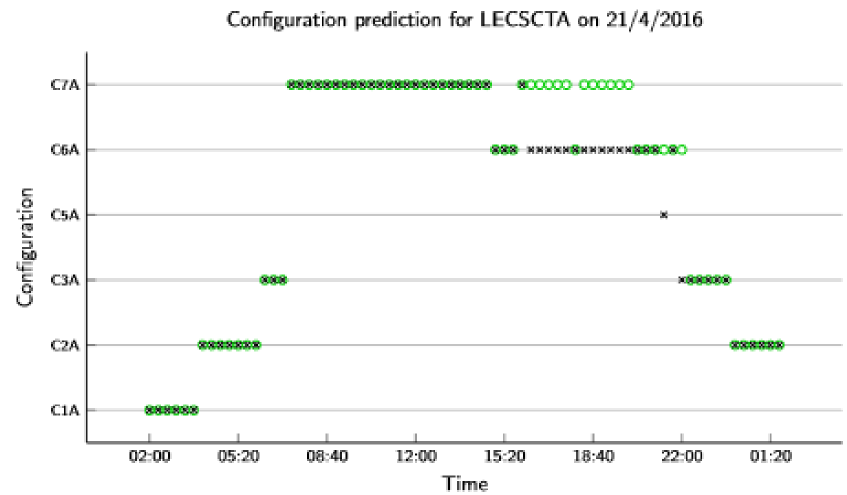
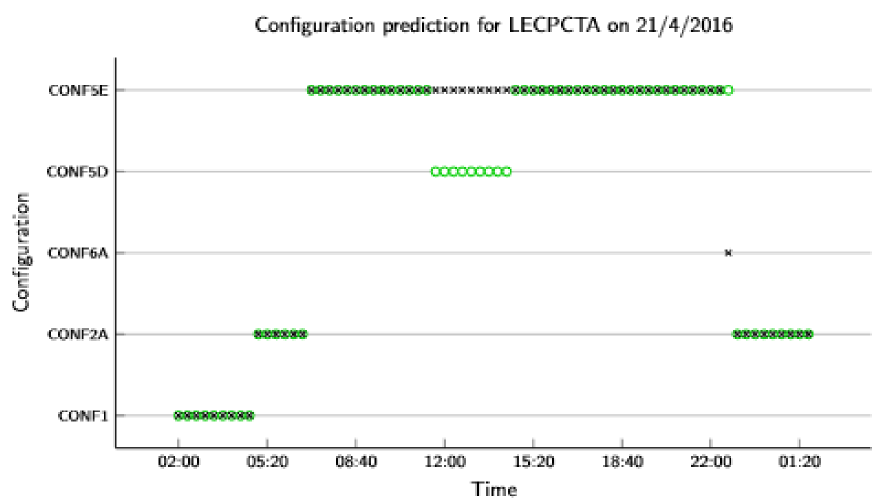
FM02-Results for Sevilla and Palma ACCs





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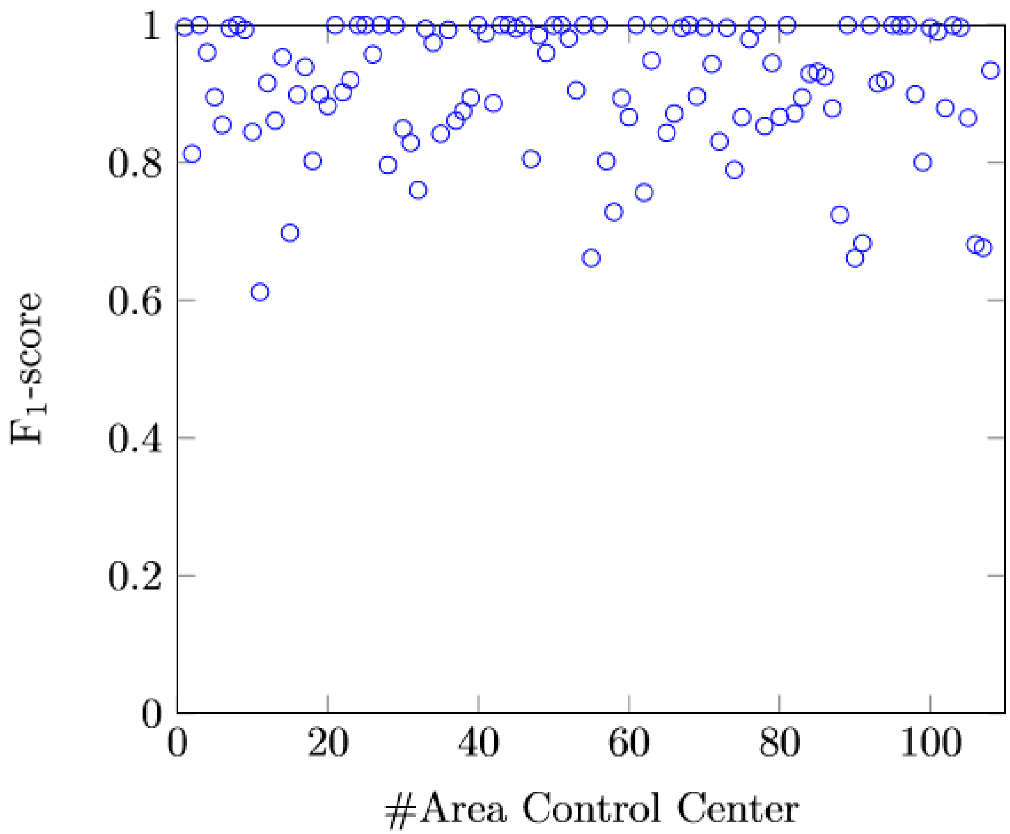
FM02-Results for all ACCs



Thank you!
Questions?

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