Data-Driven Occupancy Prediction in Adverse Weather Conditions using Thunderstorm and Traffic Observations

9 th SESAR Innovation Days

Universidad Carlos III de Madrid

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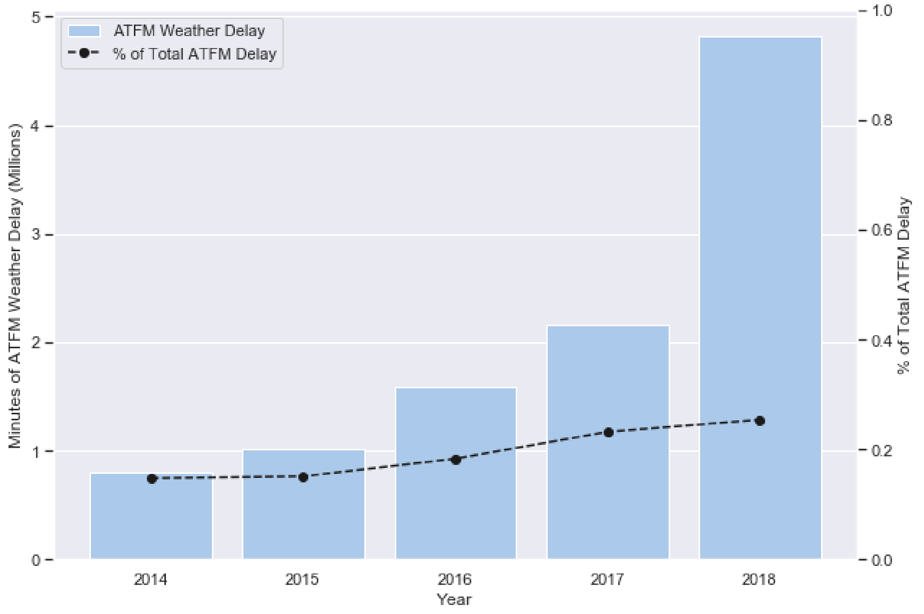
2 – 6 December 2019, Athens, Greece

ATFM Delays due to Weather

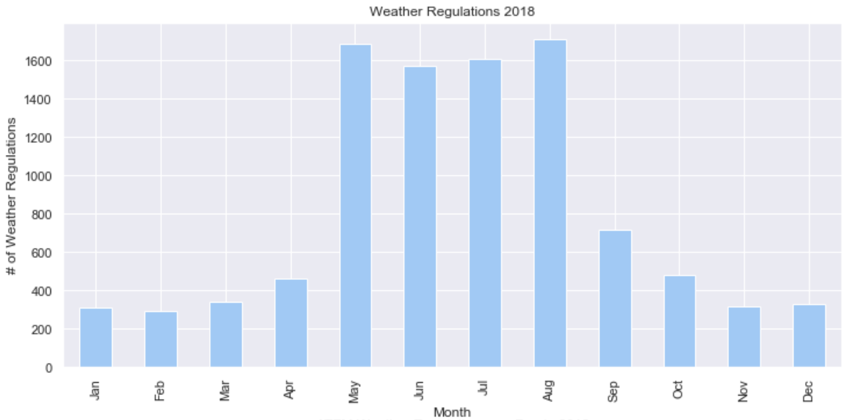
- Weather delays have increased over the last 5 years
- Weather is the 2nd cause of ATFM delay after ATC Capacity.
- Cost due to weather delay in 2018 estimated at 0.48 Billion Euros

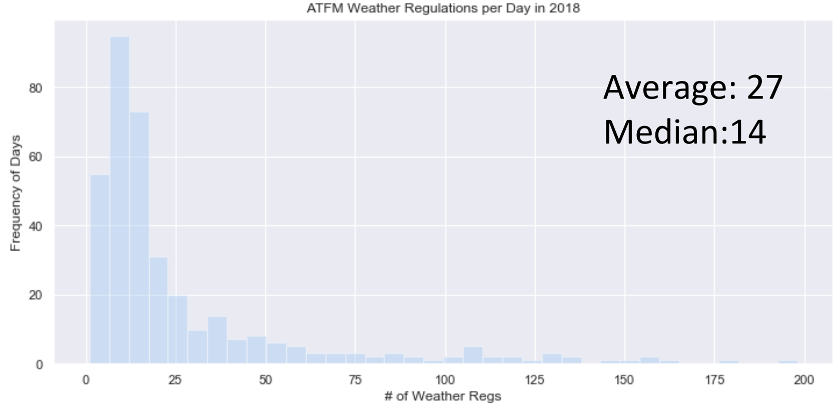


Performance Review Reports 2014-2018

2018 Weather Regulations

- Majority ATFM weather regulations occur in the summer months (May, Jun, Jul ,Aug).
- ATFM weather regulations are concentrated in a few severe days. (14 days responsible for over 1/5 of total weather regulations in 2018.)
- Convective weather (Thunderstorms) responsible for majority of weather regulations.





Research Questions

- Can we reduce delay/number of regulations due to weather?
- Can we improve ATFM operations during convective weather events?
- Can we improve weather predictability?
- Can we make better use of weather information during the pre-tactical phase?

Methodology

- Data Science
- Develop models to predict and quantify capacity and demand imbalances due to weather in the airspace network.
- Analysis of historical data:
  - Traffic
  - Weather Observations
  - Weather Forecast

Approach

Step 1:

If we had access to a "perfect forecast" how would be implement ATFM solutions?

- Could we predict values of sector capacity and demand values?
- Could we improve ATFM operations (manage traffic flows, ATFM Regulations, etc)?

Analysis of historical traffic data and weather observations. Find correlations between storms and traffic patterns.

Step 2:

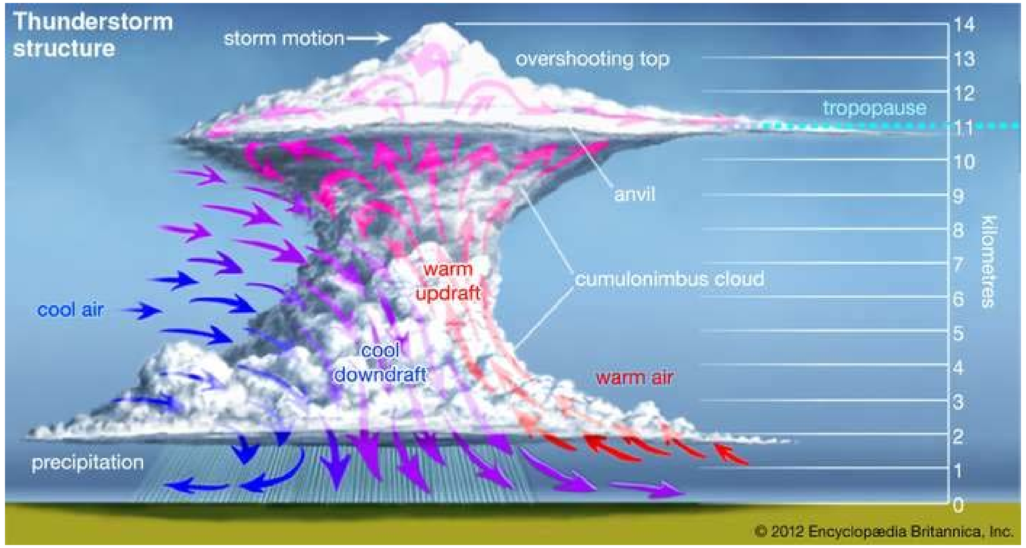
How can we still implement ATFM solutions with a probabilistic forecast?

- At what time horizon can we expect a reliable forecast, how reliable does my forecast need to be?
- How much lead time is necessary to make a significant impact on ATFM plan?

Analysis of historical weather observations and weather forecasts. Leverage Numerical Weather Prediction to anticipate storms.

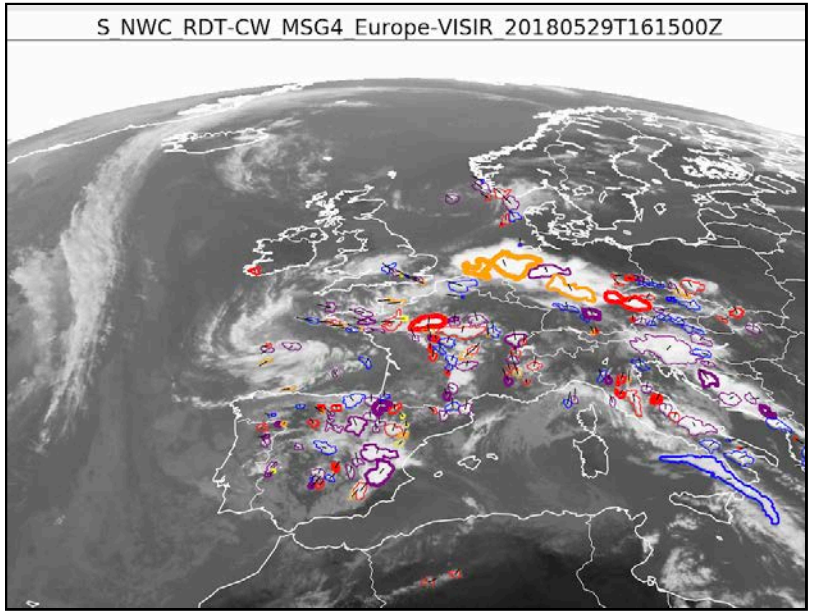
Thunderstorms

- Three ingredients:
  - Lifting force (heat)
  - Moisture
  - Unstable atmosphere (temp. lapse rate)
- Shelf cloud is formed at the condensation layer
- Top cloud spreads as updrafts reach the tropopause
- Overshoots can occur due to strong updrafts



Weather Data

- Weather observations data provided by EUMETSAT's Rapidly Developing Thunderstorm (RDT) product.
- Satellite images of convective cells available every 15 minutes
- Parameters provided for each cell: Top/Shelf Cloud Contour, Overshoots Location, Severity, Cloud Top, Phase Life, Velocity, Direction, etc.



May 29th - 162 Weather Regulations

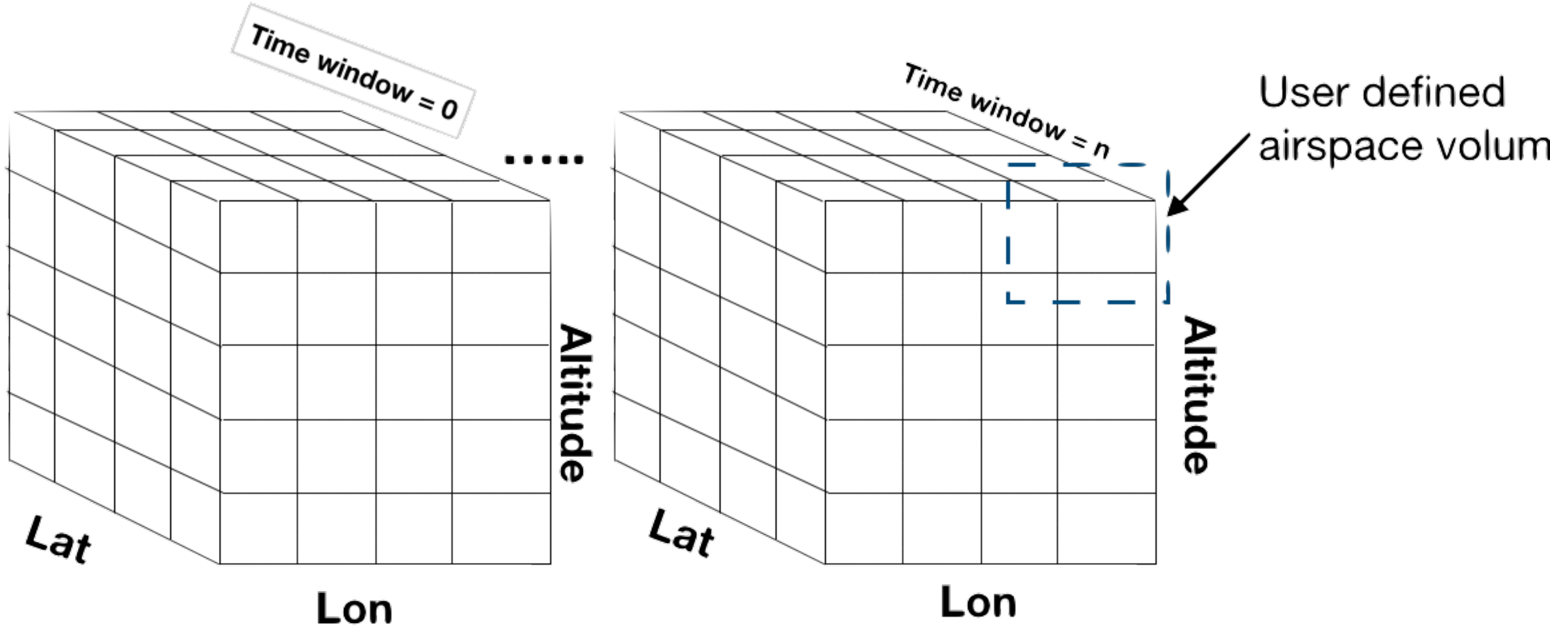
Traffic Data

- Historical flight trajectories from DDR.
- 4D Trajectory with non-uniform points
- Current Tactical Flight Model trajectory provides closest representation of actual flight.
- Unique IFPS ID of each trajectory allows us to identify and cross-reference each trajectory.

Spatio-temporal Grid

- Necessary to integrate traffic and weather data by mapping onto a common domain.
- Defined grid using latitude, longitude, altitude and time

Altitude Level	Pressure Level	Flight Level
5	<= 200	>= 390
4	200-250	390-340
3	250-300	340-300
2	300-400	300-240
1	400-700	240-100
0	700-Surface	100-Surface

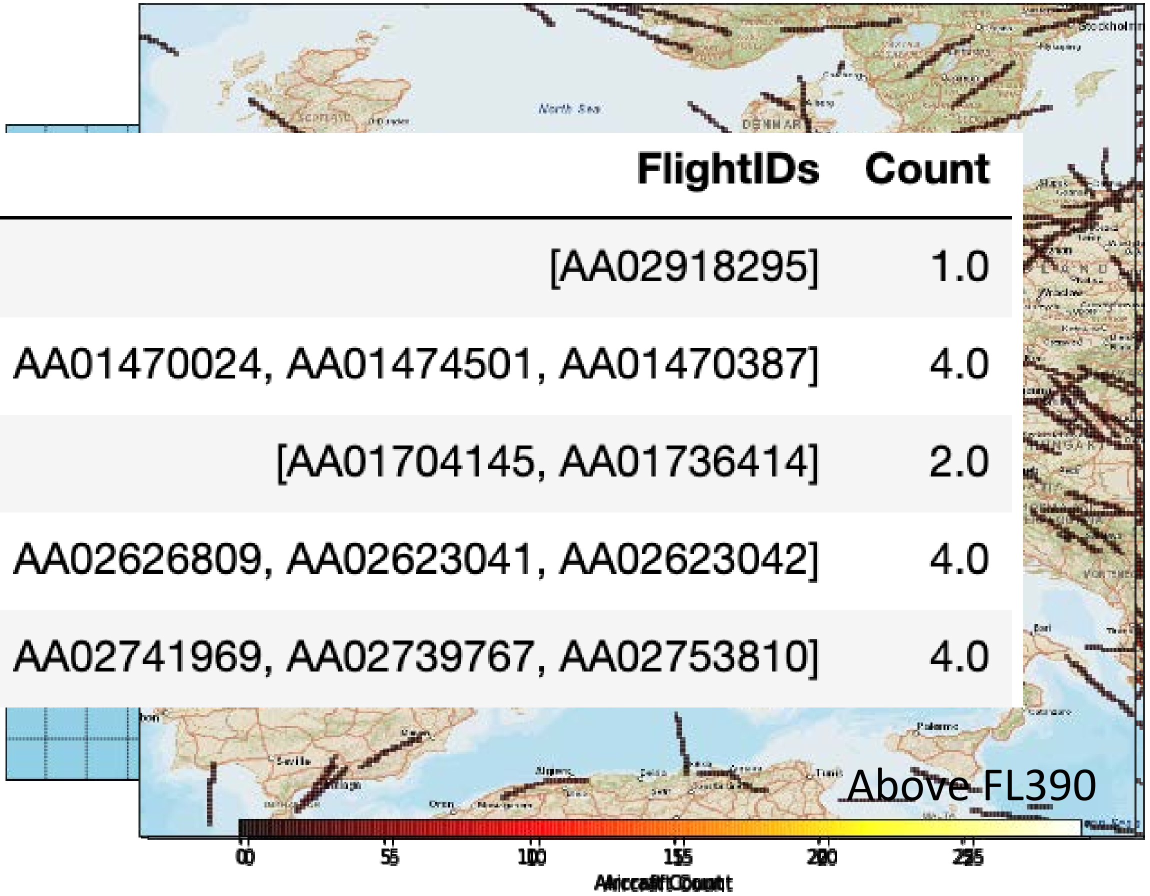


Processing Data - Weather

Time	Lon	Lat	Alt Level	Overshoot	Storm Cell	Shelf Cloud	Not Defined	Low	Moderate	High	Very High
2018-05-29 16:45:00	10.6	49.9	2	0	1	1	0	0	1	0	0
2018-05-29 13:15:00	1.9	41.7	3	0	1	0	0	1	0	0	0
2018-05-29 11:00:00	13.1	46.5	0	0	1	0	0	0	0	0	1
2018-05-29 22:15:00	17.2	45.7	1	0	1	1	1	0	0	0	0
2018-05-29 13:00:00	4.2	51.6	0	0	1	1	1	0	0	0	0

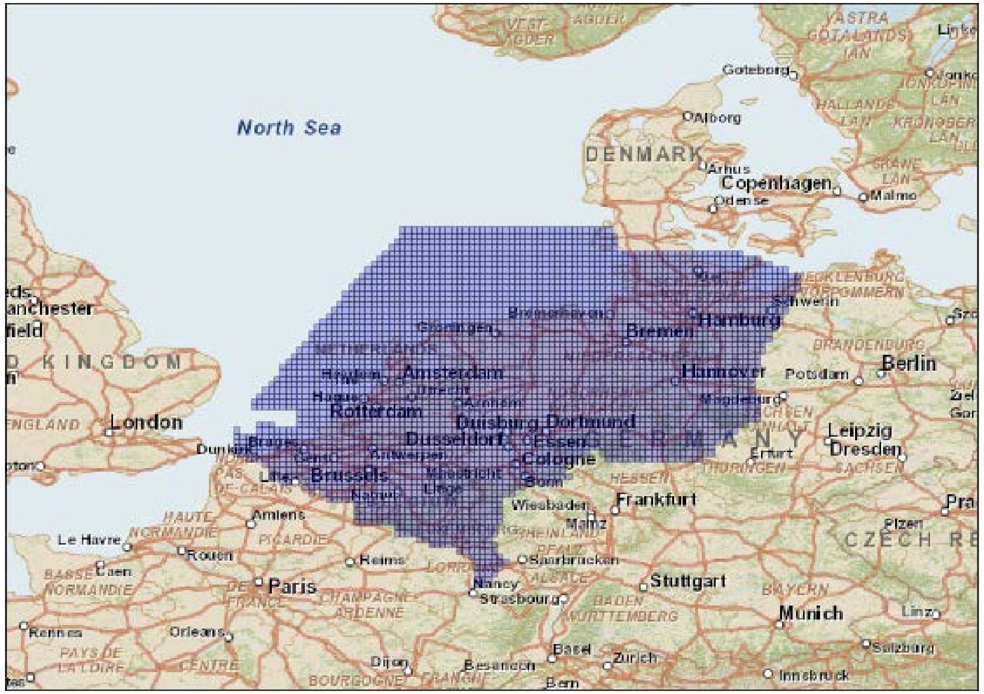
Processing Data - Traffic

	Time	Lon	Lat	AltLevel	FlightIDs	Count
	2018-06-27 08:00:00	10.0	44.0	5	[AA02918295]	1.0
	2018-05-18 09:00:00	2.0	46.0	1	[AA01469354, AA01470024, AA01474501, AA01470387]	4.0
	2018-05-25 16:00:00	-6.0	51.0	3	[AA01704145, AA01736414]	2.0
	2018-06-19 17:00:00	8.0	42.0	1	[AA02634936, AA02626809, AA02623041, AA02623042]	4.0
	2018-06-22 10:00:00	9.0	46.0	1	[AA02742016, AA02741969, AA02739767, AA02753810]	4.0



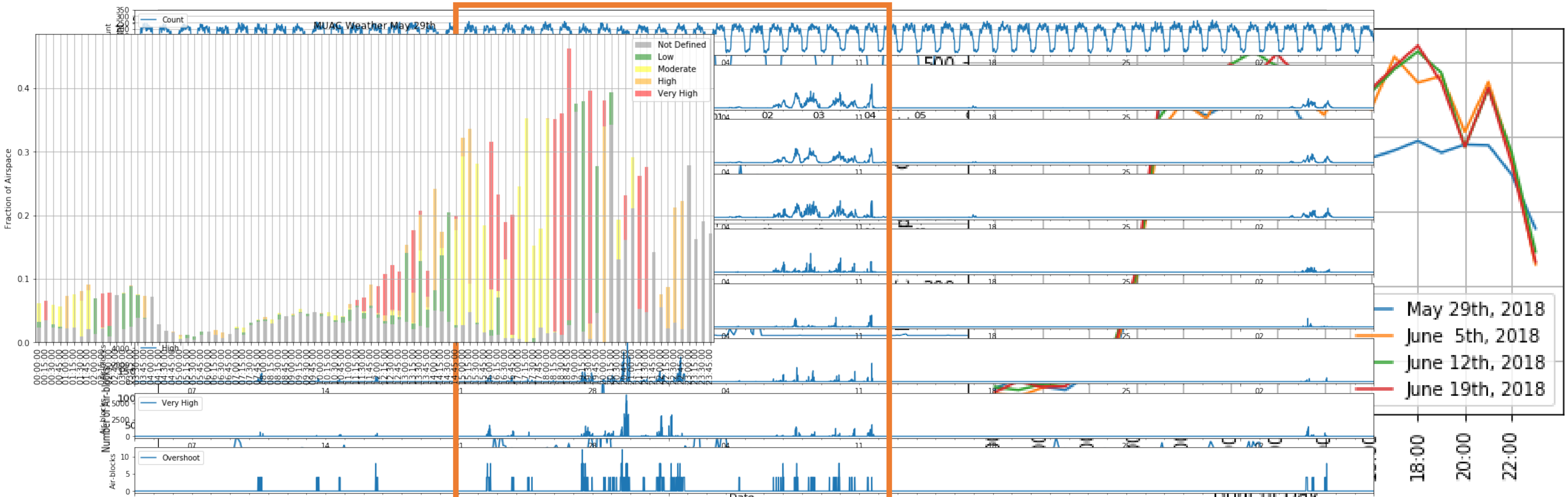
MUAC Case Study

- Maastricht Upper Area Control Center manages the upper airspace over Belgium, the Netherlands, Luxembourg and north-west Germany from FL245 to FL660 - one of Europe's busiest and complex airspace areas.
- By projecting MUAC onto our grid we are able to analyse the traffic and weather data.



3,694 air-blocks per level, 14,596 air-blocks total

Time Series Representations

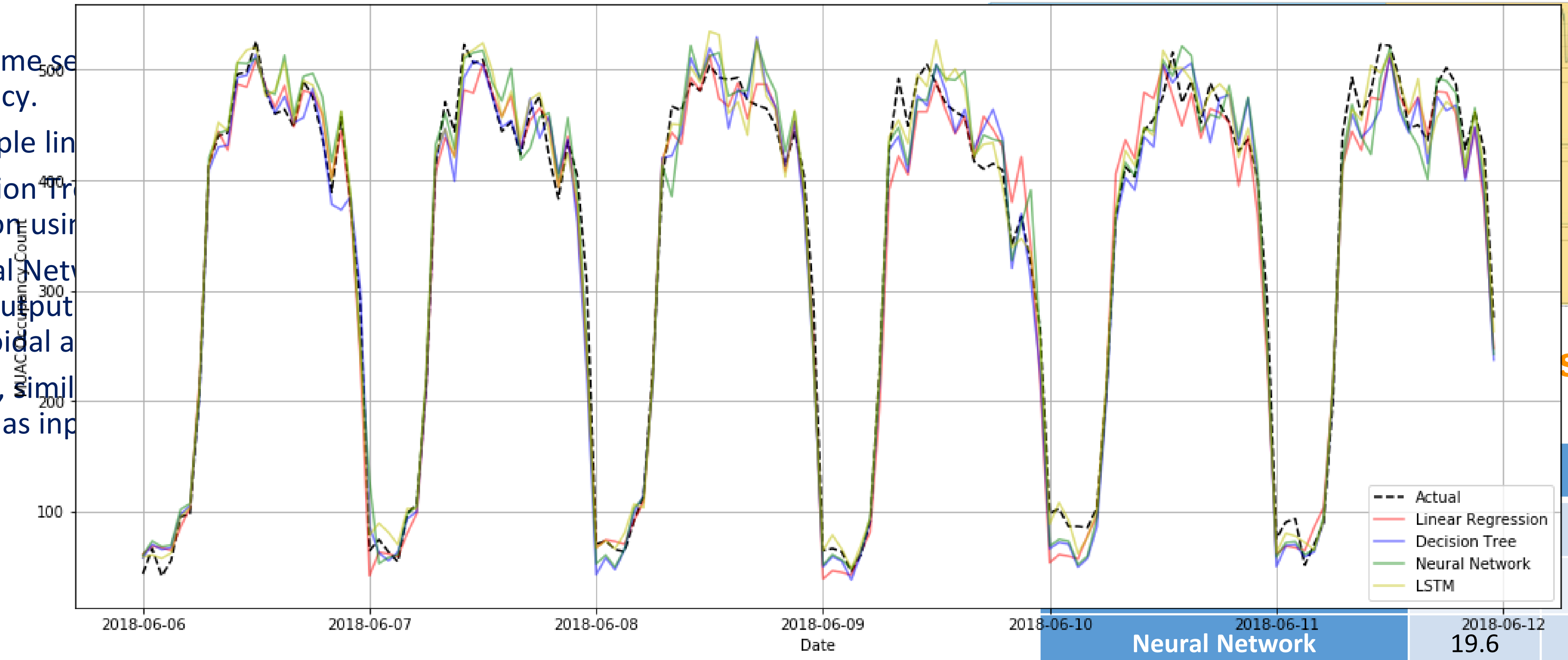


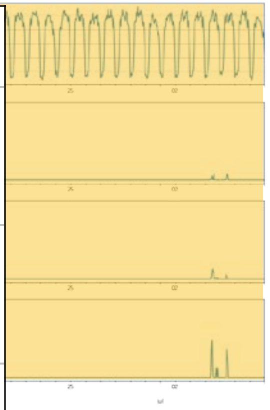
- Decrease in MUAC Occupancy on Tuesday, May 29th compared to other Tuesdays.
- Decrease can be attributed to afternoon thunderstorms.

Data Science Algorithms

MUAC Data

- Use of time se
  occupancy.
  - Multiple lin
  - Decision Tr
    fashion usir
  - Neural Netv
    and output
    sigmoidal a
  - LSTM, simil
    steps as inp

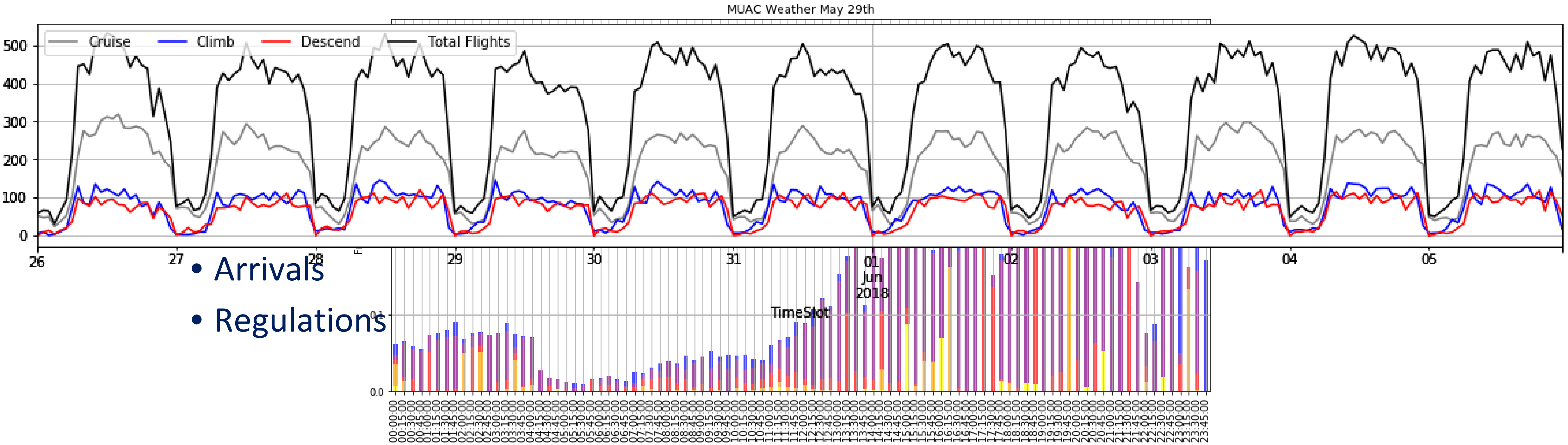




st

		R^2
		0.978
		0.980
Neural Network	19.6	0.987
LSTM	17.7	0.990

More Features…



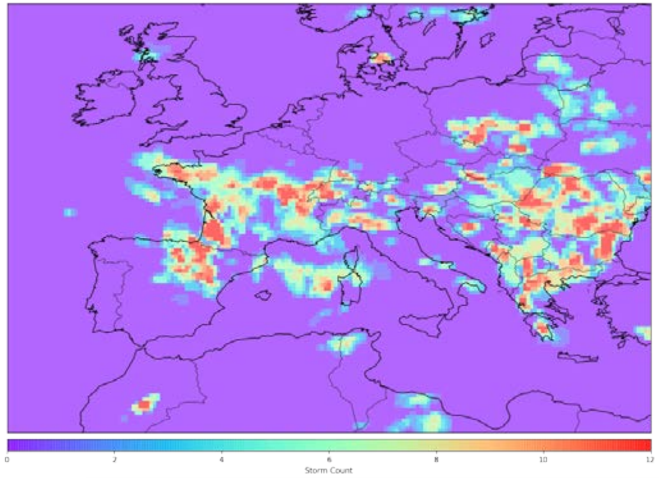
- Arrivals
- Regulations

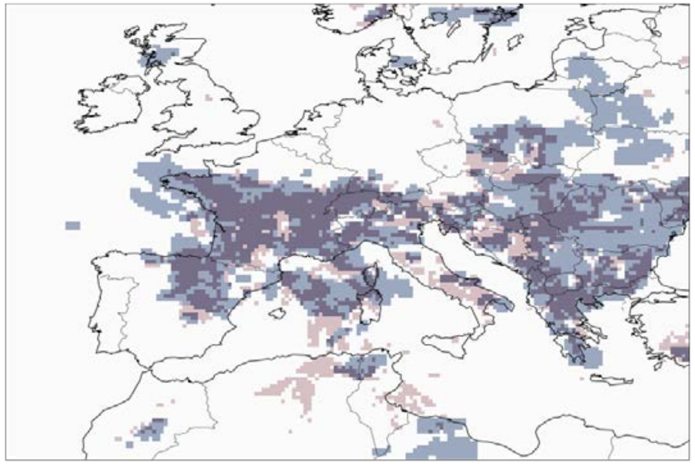
Conclusions

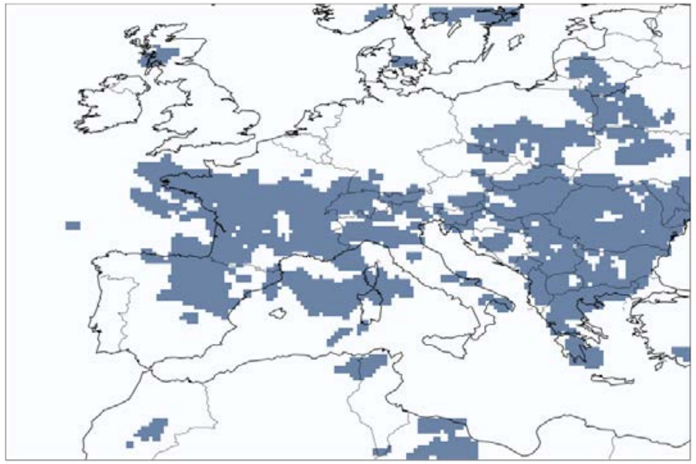
- Quantitative impact of weather is noticeable in data.
- Traffic data is highly cyclical and allows for fairly accurate modelling of time series.
- More data is needed to validate if models accurately capture impact of weather.
- Exploring correlation with other weather and traffic features.
- Exploring multi-dimensional input vs 1-D time series.

Step 2: Predicting Storms

- Integrating EPS forecast and storm observation data.
- Using ML to predict storms based on NWP forecast parameters.







Thank you

Questions?

Comments?

Suggestions?