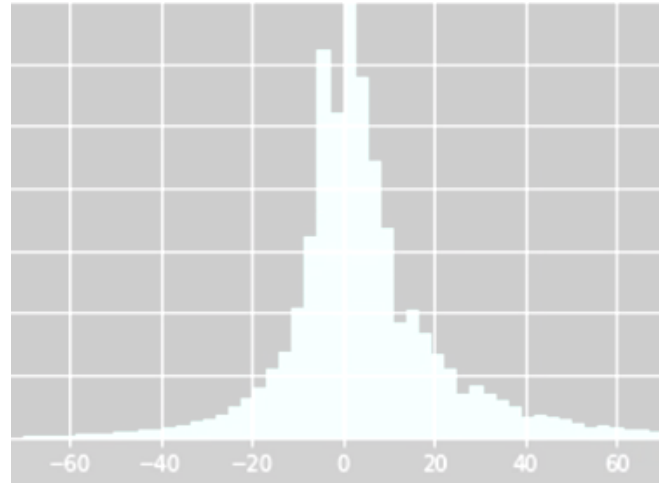
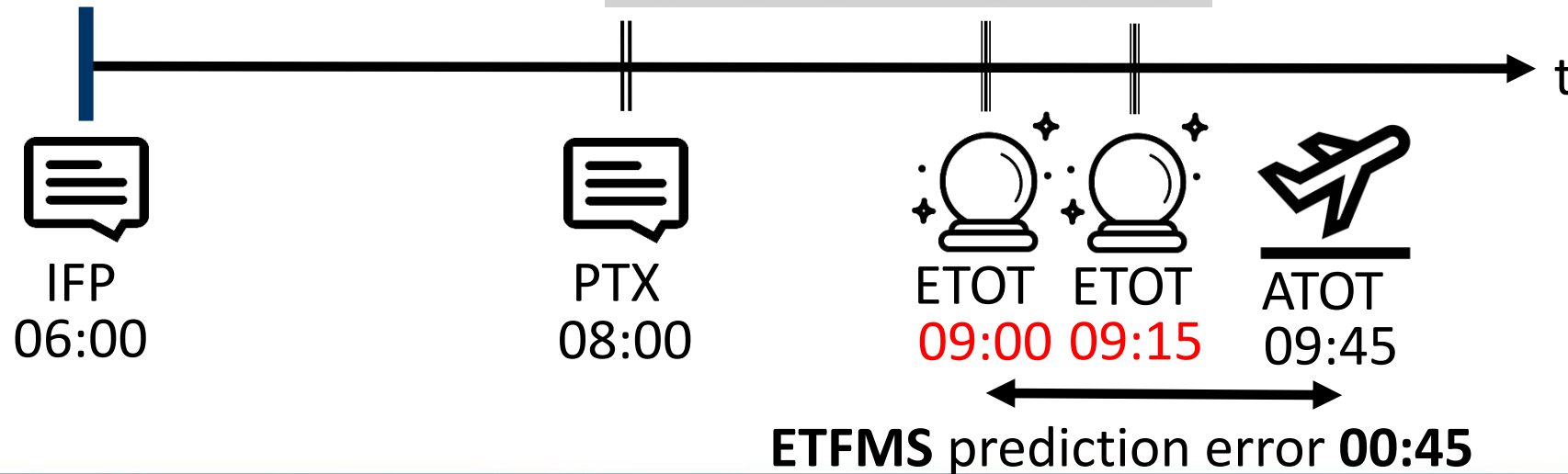




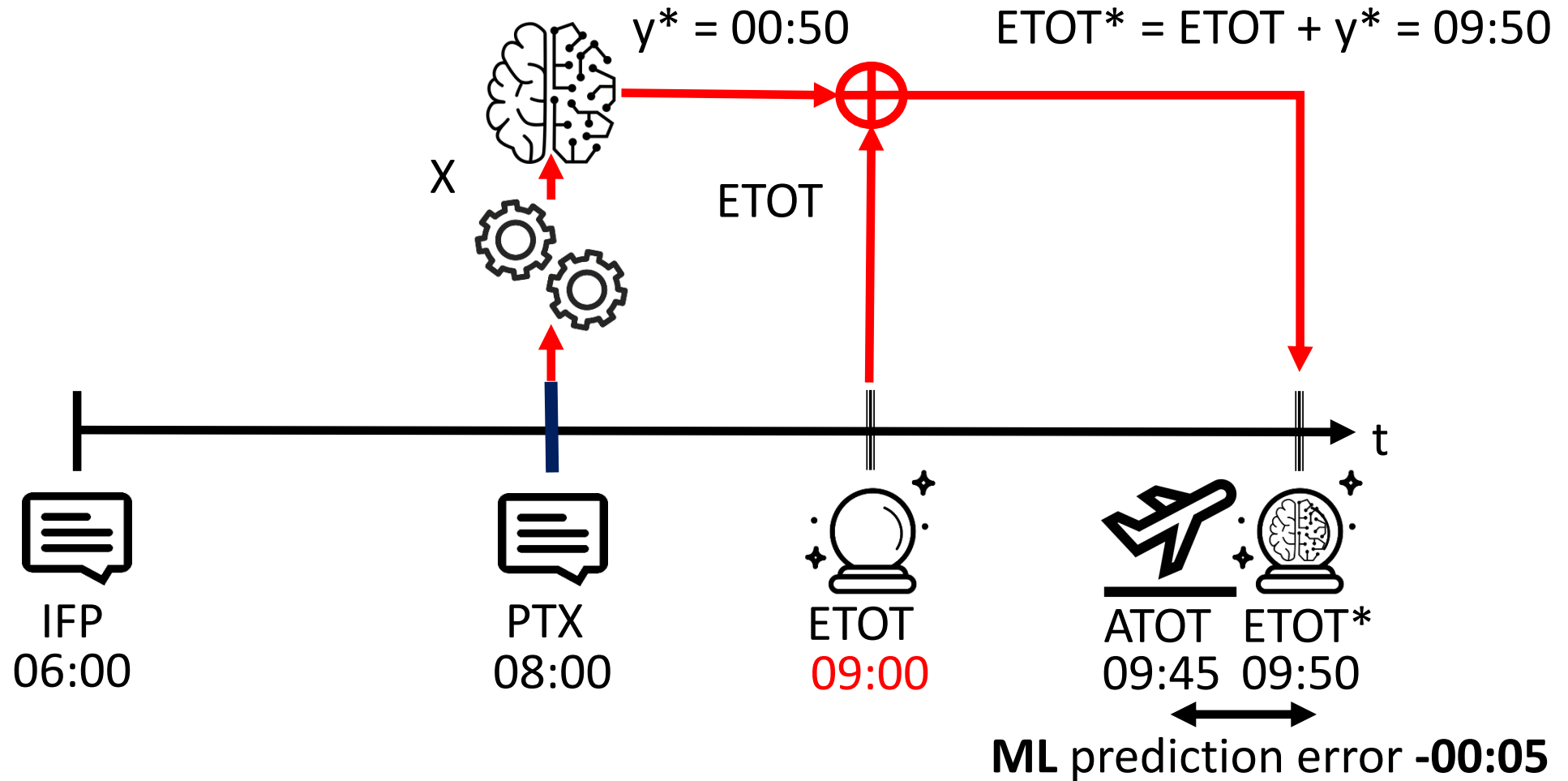
Take-off time prediction



IFP: Initial Flight Plan
PTX: Periodic Transmission
ETOT: Estimated Take-off Time
ATOT: Actual Take-off Time
ETFMS: Enhanced Traffic Flow
Management System



Take-off time prediction



Features

- **Flight-related features**

- Departure airport
- Destination airport
- Airline
- Time available to perform the turn-around
- ATFM delay assigned to the flight (if any)

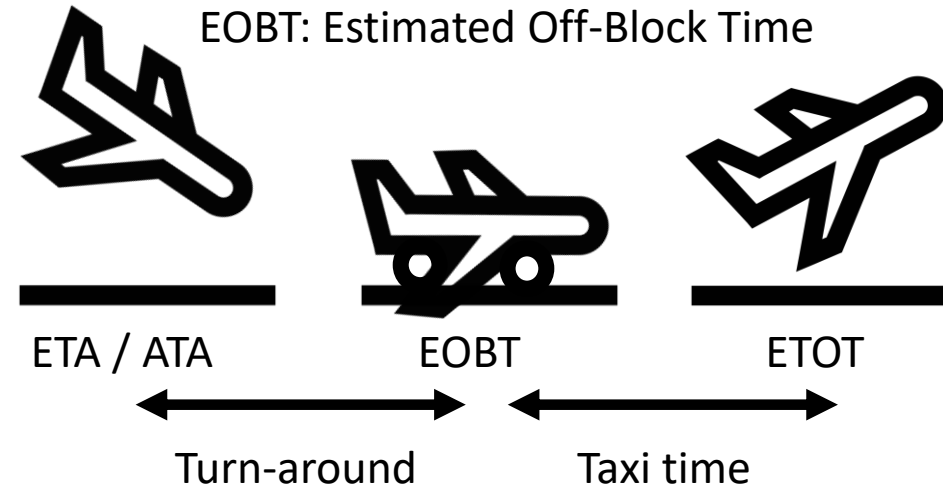
- **Airport congestion features**

- Number of operations planned near ETOT

- **Airport delay state features**

- Distribution of delays in the last hour

ETA: Estimated Time of Arrival
ATA: Actual Time of Arrival
EOBT: Estimated Off-Block Time



- **Weather features**

- Temperature
- Visibility

- **Basic calendar features**

- Hour of the day
- Day of the week
- Month of the year

Models

Gradient Boosted Decision Trees
(**GBDT**)

Microsoft
LightGBM

Each **example** corresponds to one **ETFMS message**

input shape = (batch size, # of features)

Recurrent Neural Network
(**RNN**)

 **Keras**

Each **example** includes the sequence of ETFMS messages for one **flight, from IFP to take-off**

input shape = (batch size, **# of messages**, # of features)

Results

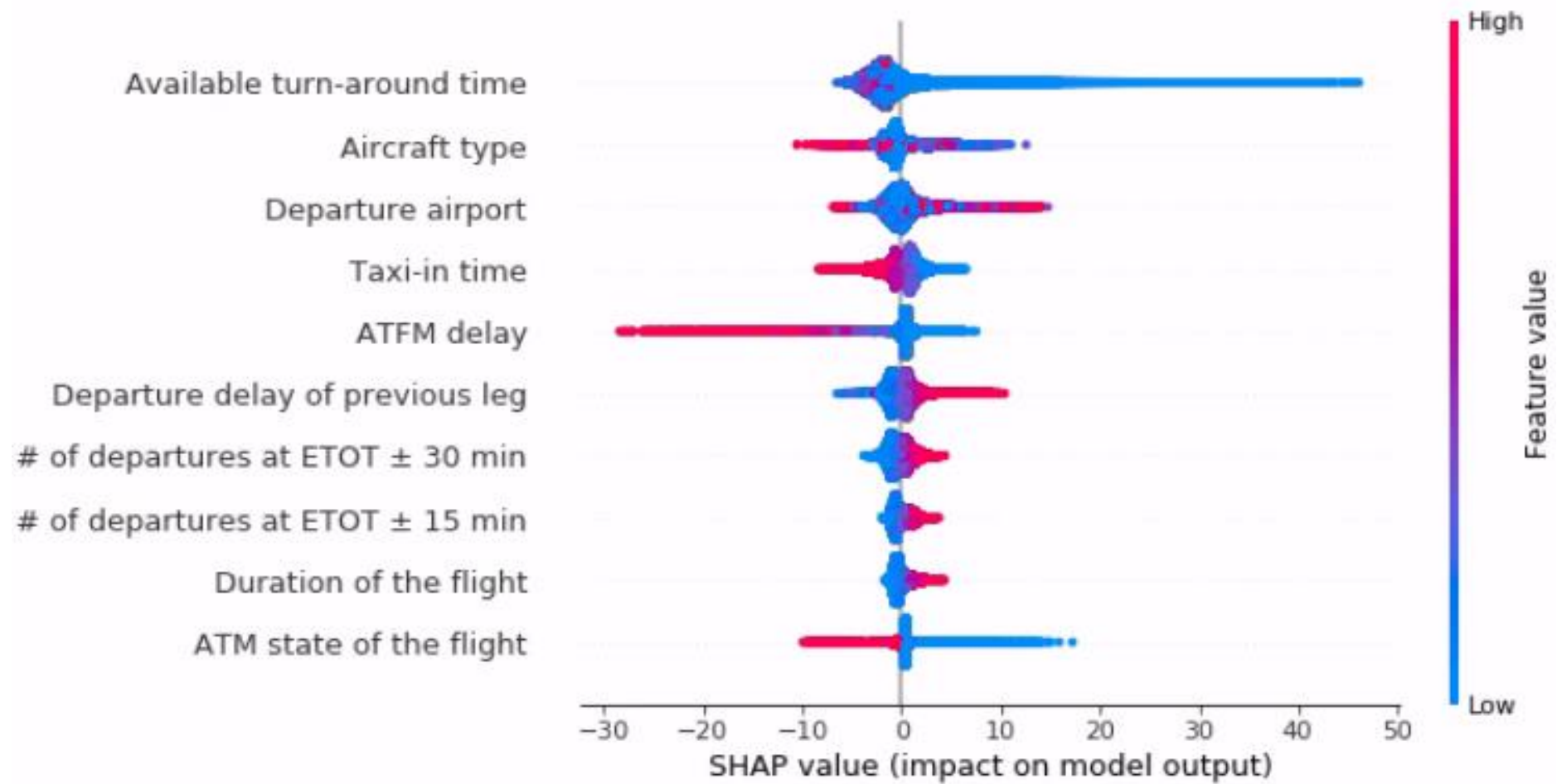
- Only flights **crossing MUAC airspace**
- **January of 2016 to December of 2018**
- 70-10-20 train-validation-test split

Metric	ETFMS	lightGBM	Benefit
MAE	13.84	10.40	25%
STD	21.54	17.48	19%
Q1	3.00	2.57	14%
Q2	7.23	5.95	18%
Q3	17.00	11.87	30%

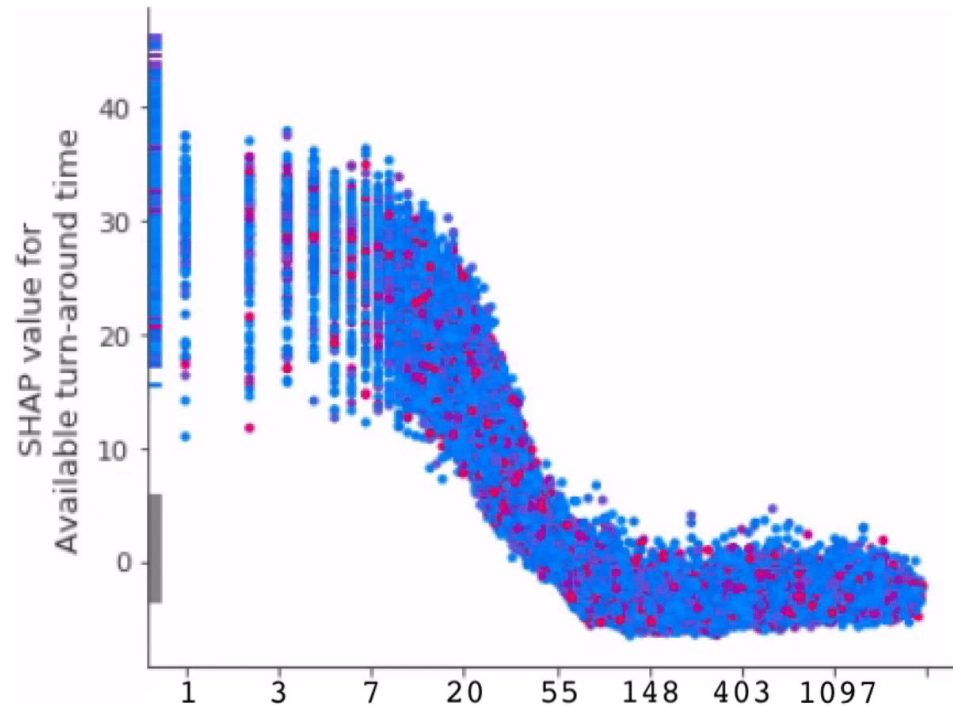
Time to ETOT	ETFMS MAE	lightGBM MAE	Benefit
[0, 30)	6.34	5.12	19%
[30, 60)	10.18	8.21	19%
[60, 120)	14.02	10.0	28%
[120, 180)	15.09	10.64	30%
[180, 240)	16.19	11.51	29%
[240, 300)	17.63	12.40	30%
[300, 360)	18.70	12.98	31%

More details: Dalmau. R et al., (December 2019), *Improving the Predictability of Take-off Times with Machine Learning*, Proceedings of the 9th SESAR Innovation Days (SIDs), Athens, Greece

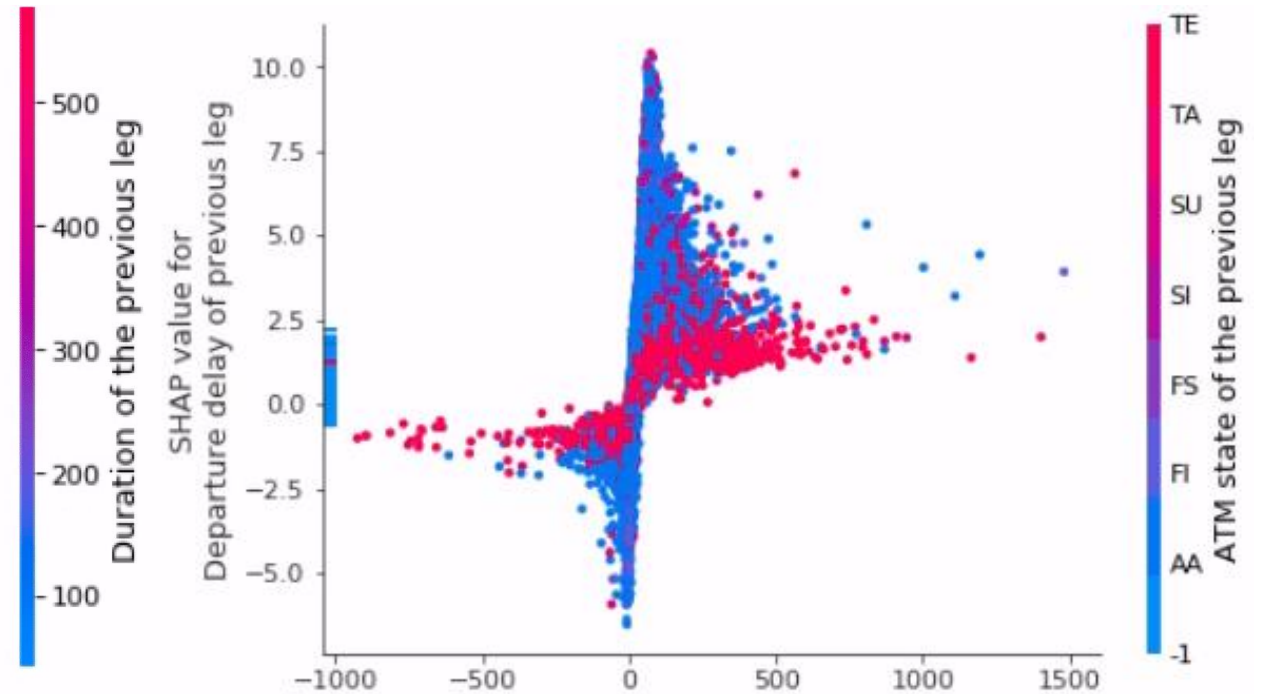
Results



Results



Available turn-around time



Departure delay of previous leg

Future work directions

- Include data specific from **airlines**
 - Crew schedules
 - Catering status
 - Boarding status
- Include data specific from **airports**
 - Gates utilization
 - Departures/Arrivals sequence
- Consider features capturing network effects
- ...