Evaluation of Flight Efficiency for Stockholm Arlanda Airport Arrivals

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Stockholm Arlanda Airport

41 active **airports** in Sweden

Stockholm Arlanda Airport

Stockholm Arlanda (ESSA)

Stockholm Arlanda Airport

Stockholm Arlanda (ESSA)

Major international airport

Largest in Sweden

Serves ~ 27 million passengers

IFWHEN project

Impact of Fleet Diversity and Weather on Emissions, Noise and Predictability

Supported by the Swedish Transport Agency (**Transportstyrelsen**) and in-kind participation of **LFV (Swedish ANSP)**

Targets:

- evaluate flight efficiency at Arlanda airport during the year 2018 in horizontal and vertical domains
- evaluate environmental impact (emissions, noise)
- capture inefficiencies
- understand the causes (impact or weather, staffing, scheduling, ...)
- suggest the areas for improvement

Arrival Flight Efficiency

Horizontal	Vertical
delays and additional time in TMA due to deviations from the flight plans	level flights due to deviation from CDO
associated extra fuel burn	associated extra fuel burn

KPIs

Horizontal	Vertical
	% level flights
ICAO 14.1b - % delayed <= 5 min	Average number of level segments
ICAO 14.2b -% delayed <= 15 min	KPI 19.1 - average distance flown in level flight inside TMA
Average delay	KPI 19.2 - average time flown in level flight inside TMA
Additional time in TMA	
	Fuel-based

Data

- EUROCONTROL **DDR2** (m1, m3 formats)

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- **OpenSky Network** (states, tracks)

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- **OpenSky Network** (states, tracks)
- BADA 4 for fuel consumption
- NOAA weather data

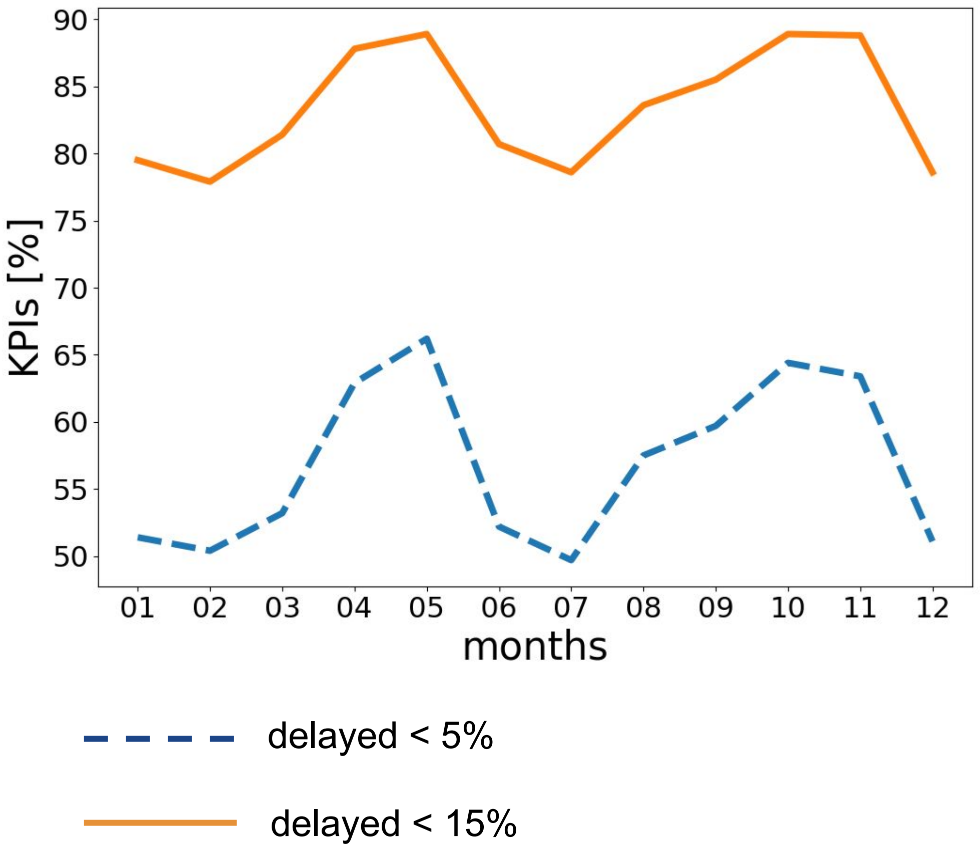
Punctuality of Arrivals in 2018

- Data source - DDR2
  m1 - flighplans
  m3 - actual

  Opensky - incomplete (~84%)

- Problematic months: January, February, July

- Correlation with traffic density and different weather conditions and other factors will be investigated further

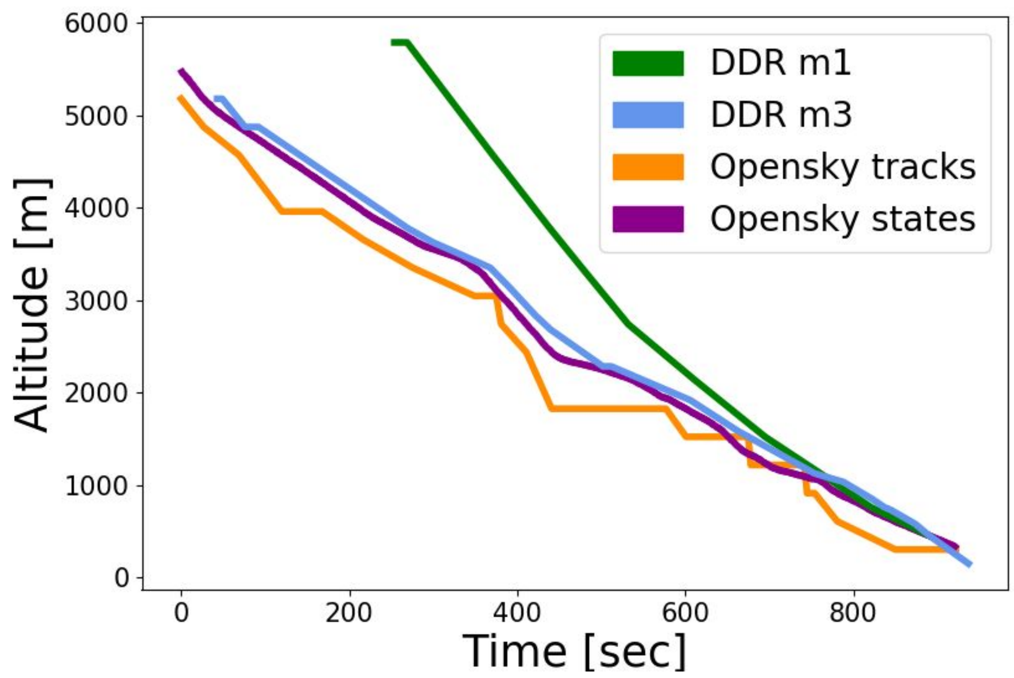


Vertical Flight Efficiency

Data source - Opensky states (more accurate)

*Problems with Opensky tracks

VFE by EUROCONTROL
Level segment=
vertical speed below 300 feet per minute
time flown level is minimum 30 seconds



SAS410 in Stockholm Arlanda airport TMA on January 01, 2018

Vertical Flight Efficiency

Months in 2018	Number of arrival flights	Percents of level flights, %	Average number of level segments	KPI 19.1, NM	KPI 19.1perc, %	KPI 19.2, min	KPI 19.2perc, %
1	7721	55	1	2.8	5	0.72	5
2	7419	52	0.87	2.72	4	0.7	5
3	8131	56	1.08	2.99	5	0.77	6
4	8944	54	1	2.77	4	0.69	5
5	9552	50	0.88	2.22	4	0.52	4
6	8923	51	0.9	2.68	4	0.69	5
7	8426	46	0.68	2.38	4	0.61	4
8	8915	47	0.73	2.25	3	0.56	4
9	8779	48	0.79	2.28	3	0.59	4
10	9162	51	0.8	2.4	4	0.64	4
11	8558	41	0.59	1.91	3	0.49	3
12	6954	49	0.73	2.68	4	0.71	5

Comparison vs. Others

Source	Month, year	Number of arrival flights	Percentage of level flights, %	Average number of level segments	KPI 19.1, NM	KPI 19.2, min
Correia’17	02/2017	7332	54	1.58	3.31	0.79
This work	**02/2018**	**7419**	**52**	**0.87**	**2.72**	**0.70**
Correia’17	06/2017	9317	51	1.49	3.46	0.75
This work	**06/2018**	**8923**	**51**	**0.90**	**2.68**	**0.69**

P. D. Correia. Analysis of Vertical Flight Efficiency During Climb and Descent. Master’s thesis, Técnico Lisboa, 2017.

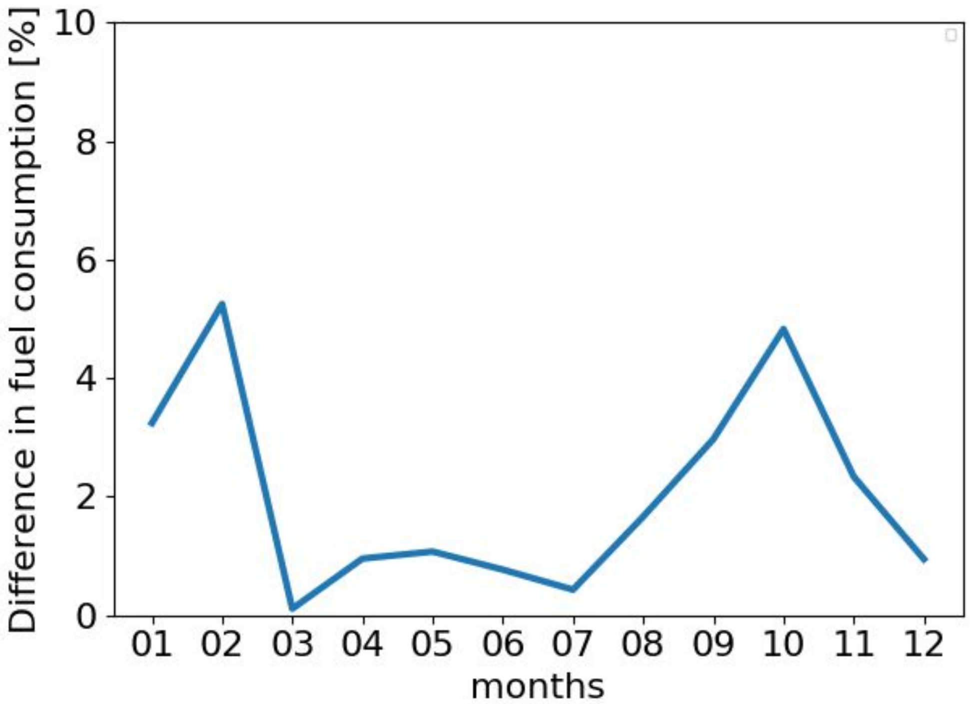
\+ EUROCONTROL PRU Report 2018:
about 50% - the share of level flights during descent
average time flown level at Arlanda ~ 1.1 min, does not contradict with our results

Fuel Consumption

- Calculated using BADA v4 methodology
- Different models depending on engine type and engine rating (max climb, max cruise, idle, no rating)
- General formula: $$F = \delta \cdot \theta^{\frac{1}{2}} \cdot W_{mref} \cdot a_0 \cdot L_{HV}^{-1} \cdot C_F$$
  $\boldsymbol{\delta}$ - pressure ratio,
  θ - temperature ratio, W_{mref} - weight force
  a_0 - speed of sound , L_{HV} - fuel lower rating, C_F - fuel coefficient
- xml file with aircraft performance data
- Thrust computation $$T = \delta \cdot W_{mref} \cdot C_T$$
- 90% of maximum landing mass is considered
- Idle thrust at descent

Fuel Burn in Horizontal Plane

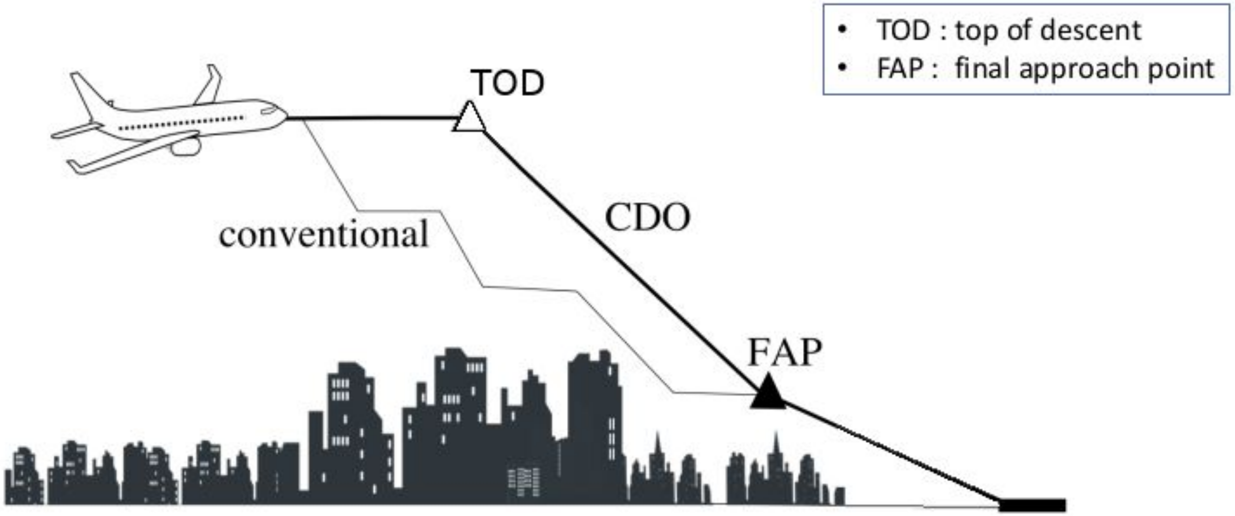
- ➢ Due to deviations from the flight plans
- ➢ DDR2 m1 used for reference trajectory, m3 for actual

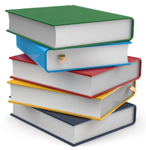


Fuel Consumption

- ➢ CDO are used as a reference trajectory (explained in Sáez et al. 2019)

CDO have shown important environmental benefits w.r.t. conventional (step-down) approaches in TMAs

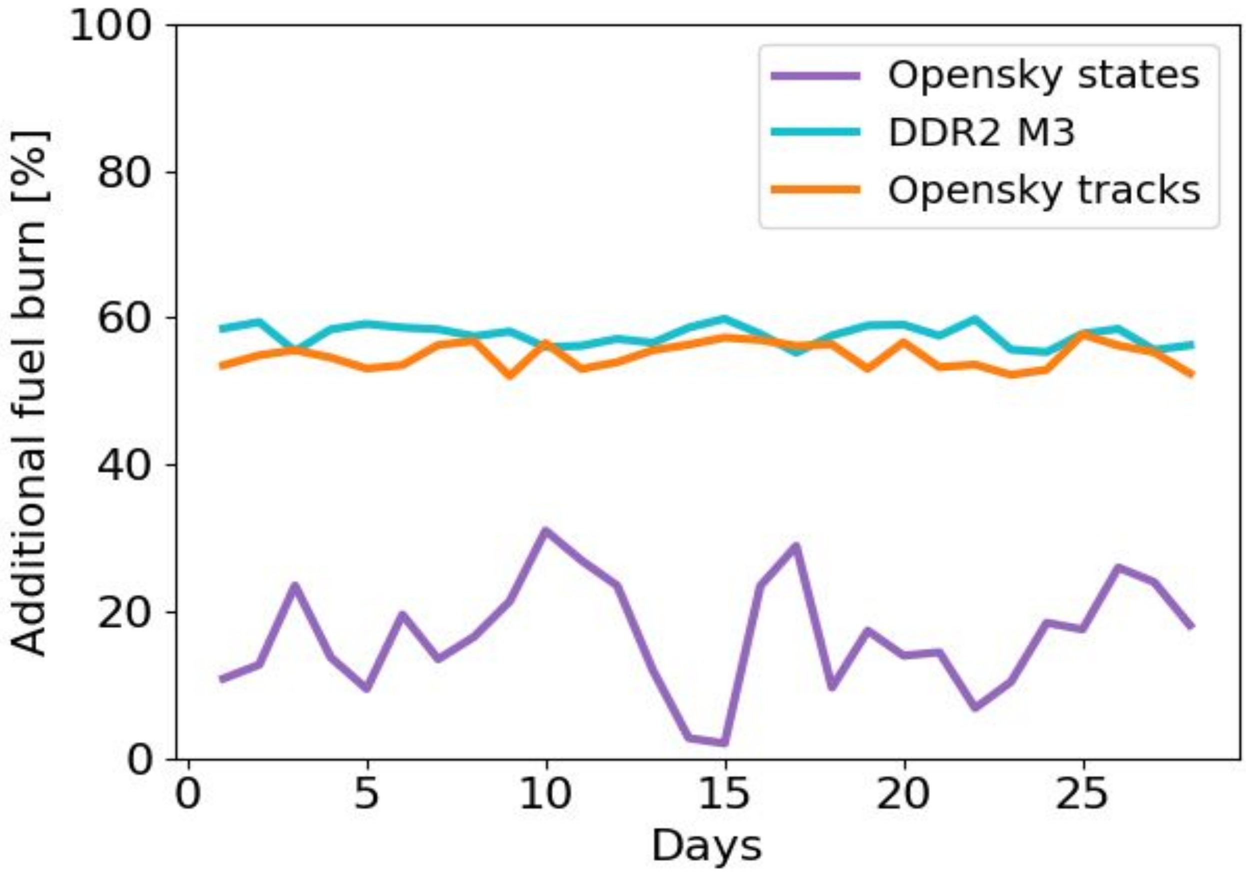




R. Sáez, X. Prats, T. Polishchuk, V. Polishchuk C. Schmidt. Automation for Separation with CDOs: Dynamic Aircraft Arrival Routes In ATM Seminar 2019.

Fuel Burn in Vertical Plane

➢ Average fuel consumption over the arrivals in February 2019

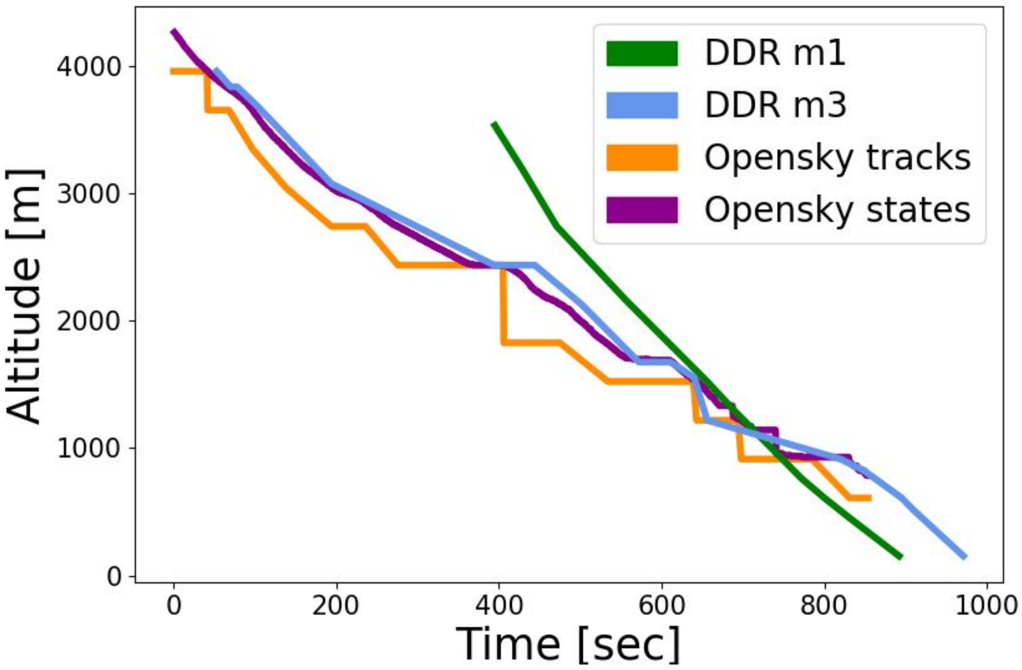


Vertical Profile

Data source - Opensky states - more accurate: ~900 waypoints inside TMA

Opensky tracks: about 60-80 waypoints

DDR2 - about 10-15 points



AFL2386 in Stockholm Arlanda airport TMA from on January 03, 2018

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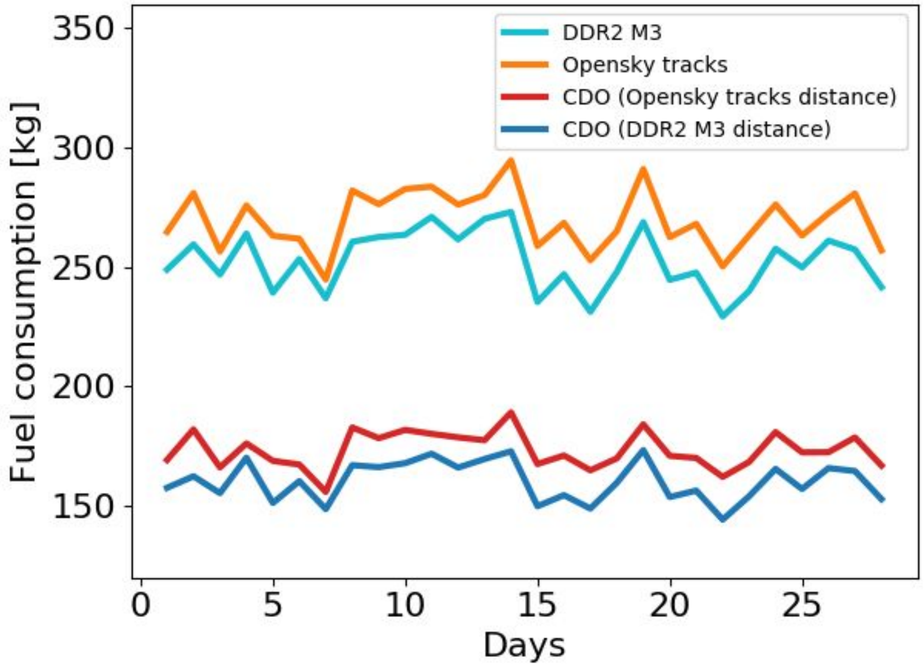
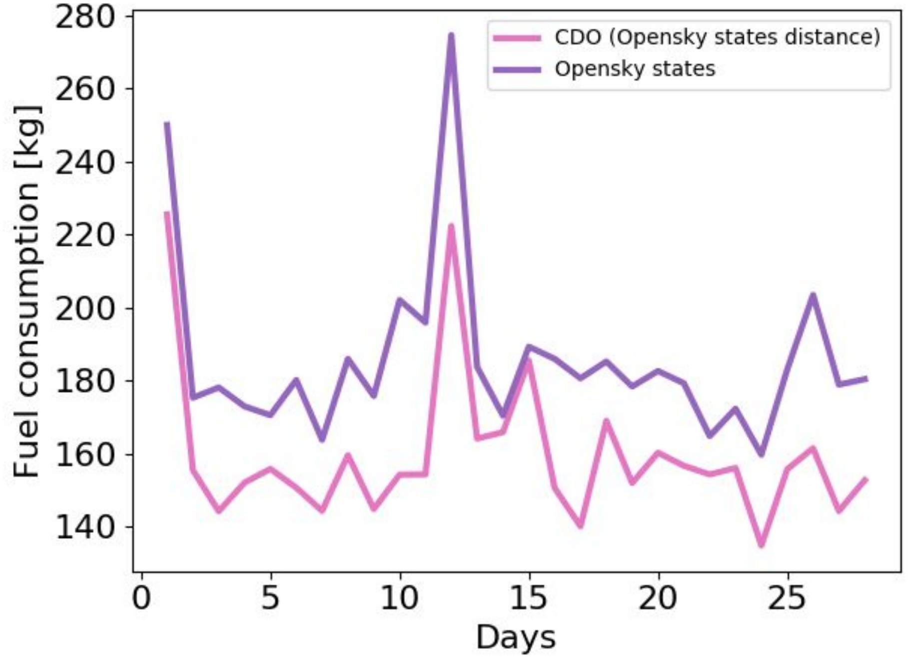
Fuel Burn in Vertical Plane

➢ Absolute values (in kg) for the average fuel consumption over the arrivals in February 2018





OpenSky data: Pros and Cons

Open source

Accurate three-dimensional aircraft positions

Precise timestamps

Incomplete

Time consuming for fuel calculations (states)

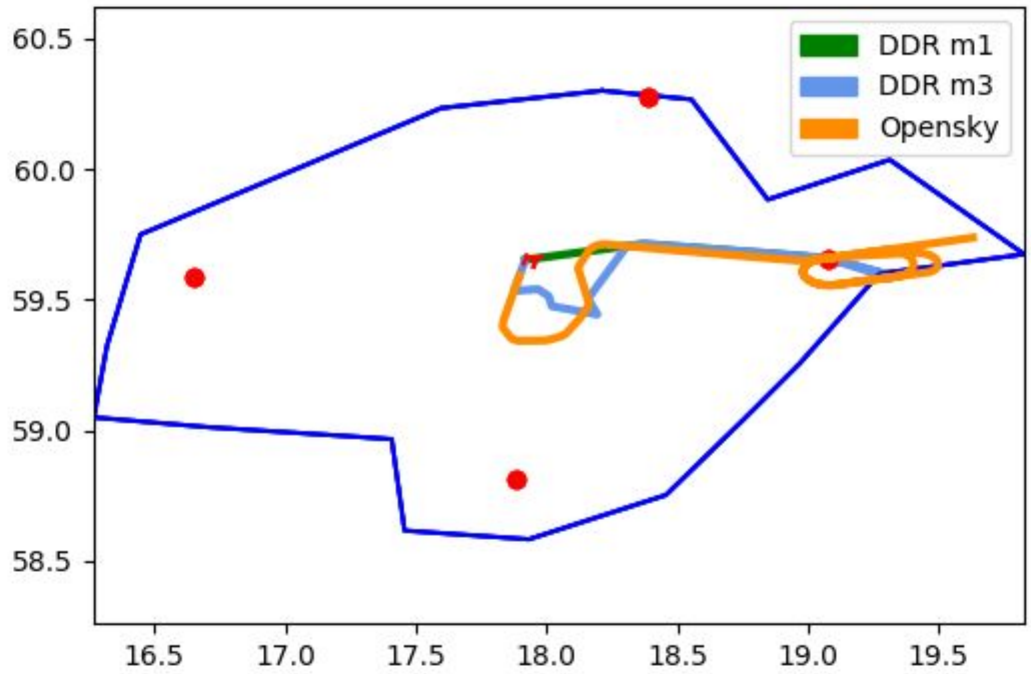
Not clean (mistakes)

Tracks methodology to be revised

Flight Id is missing in states, need for fuel calculation

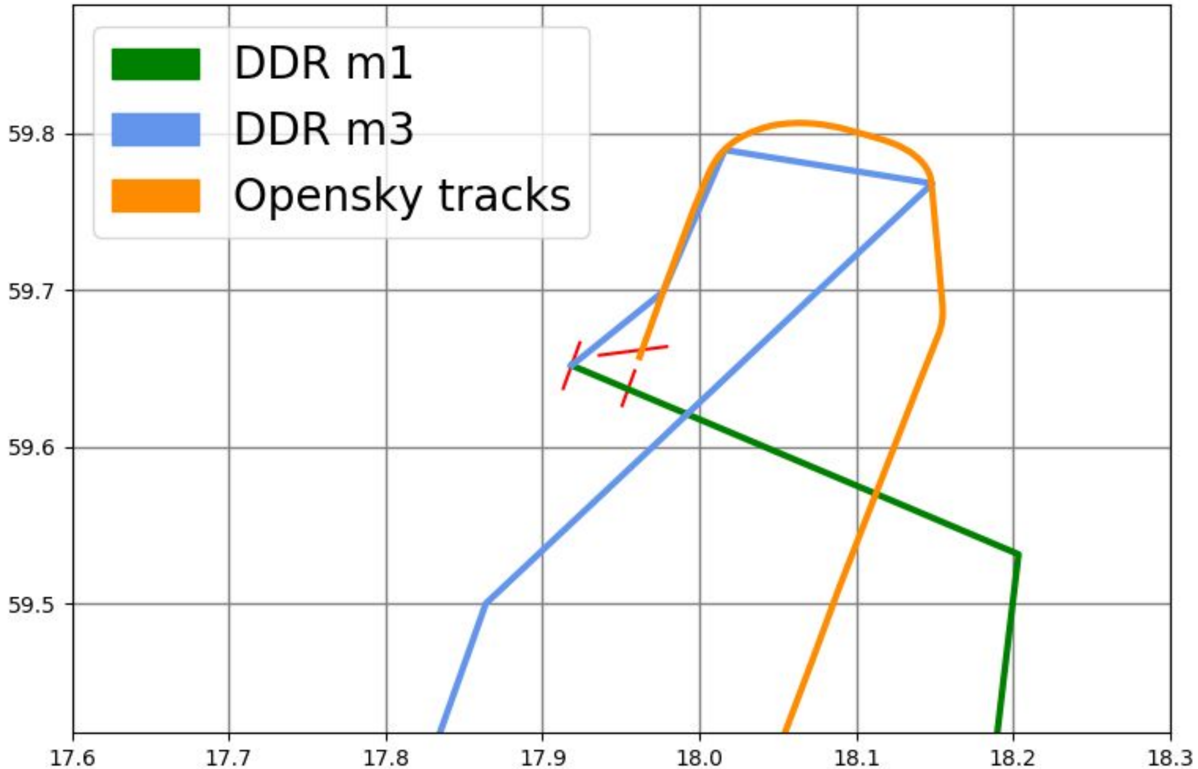
Horizontal Inefficiencies

- SAS 964
- Snowy day on February 26, 2018



Landing accuracy

- SAS 410
- January 01, 2018



Conclusions

- Evaluated performance of Stockholm Arlanda airport in horizontal and vertical domain
- Quantified the impact of vertical inefficiencies with additional fuel burn
- Shared our experience working with DDR2 and Opensky data
- Created a base to study the impact of different factors (weather conditions, traffic intensity, ATM) on different airport PIs

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THANK YOU!