Integrating Weather Prediction Models into ATM Planning (IWA)

Anastasia Lemetti, LIU

Tatiana Polishchuk, LIU

Raúl Sáez, UPC

Xavier Prats, UPC

LINKÖPING UNIVERSITY

SESAR JOINT UNDERTAKING

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

IWA Project

Integrating Weather Prediction Models into ATM Planning

Supported by the SESAR Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 783287.

- Evaluate the impact of different weather conditions on route planning in TMA and on staff scheduling at Remote Tower Center
- Study optimization techniques to support efficient decision-making for aviation authorities developed by LiU together with LFV (Swedish ANSP)
- Study and apply probabilistic models and the corresponding weather data
- Prototype and test the mathematical tools which will help take into account the influence of bad weather conditions on the developed optimization techniques solutions

Stockholm Arlanda Airport

41 active airports in Sweden

Stockholm Arlanda (ESSA)

Major international airport

Largest in Sweden

Serves ~ 27 million pax per year

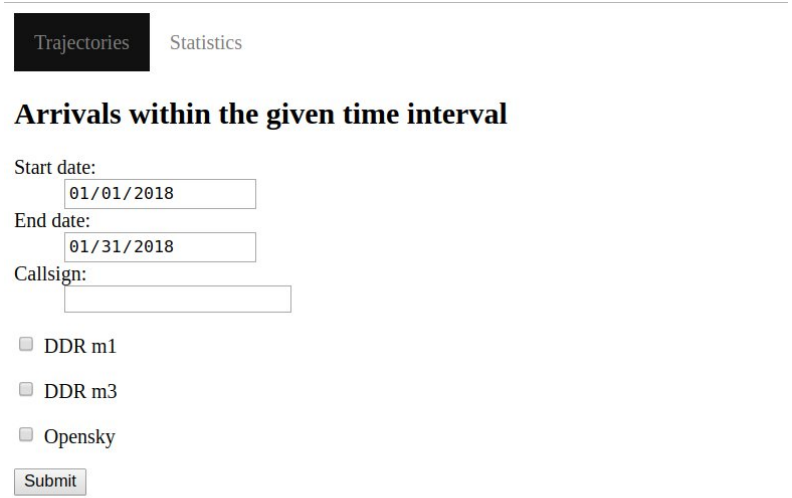
Flight Data

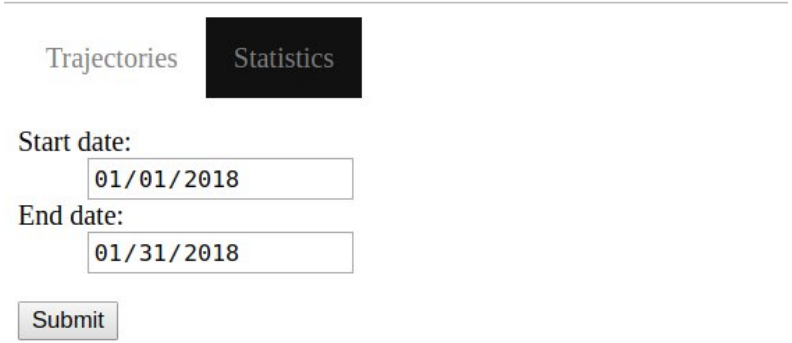
- EUROCONTROL **DDR2** (so6 m1, m3 formats)
- **OpenSky Network** (states, tracks formats)

TMA

- DDR2: about 10-15 waypoints inside TMA
- Opensky tracks: about 60-80 waypoints inside TMA
- Opensky states: ~900 points inside TMA

Software Tool for Flight Data Analysis

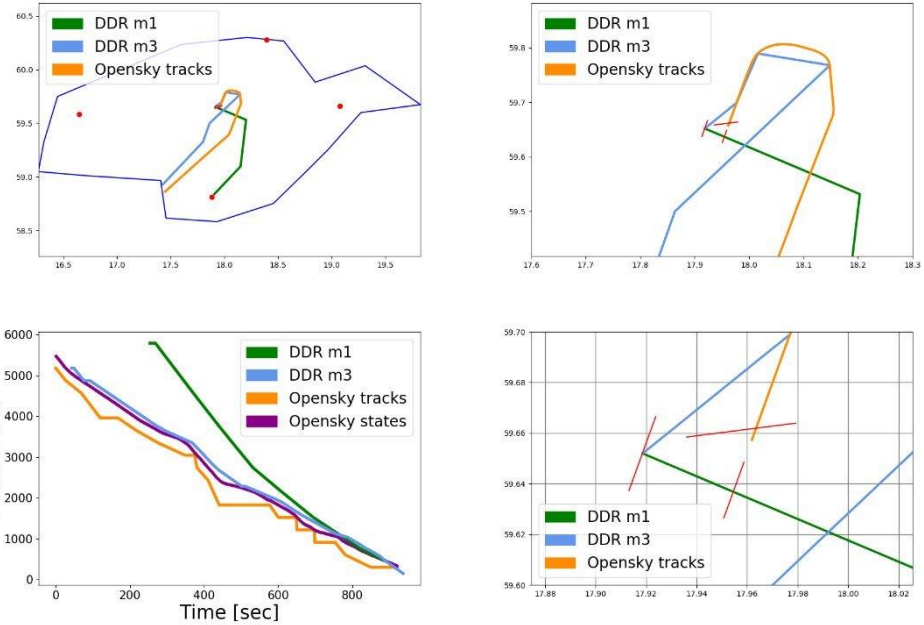




Software Tool – Trajectories Results

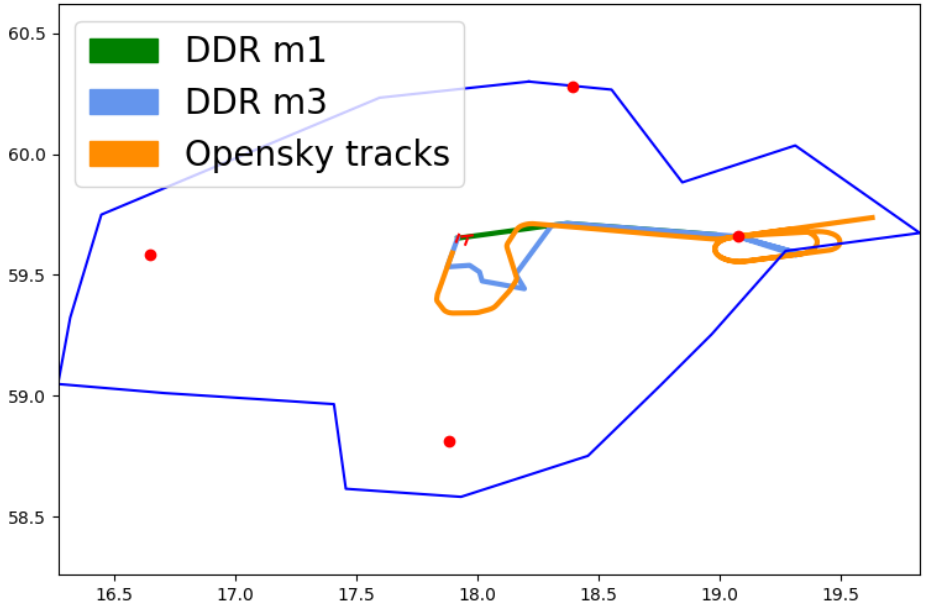
Trajectories | Statistics

Begin date: 2018-01-01 **End date:** 2018-01-01 **Callsign:** SAS410



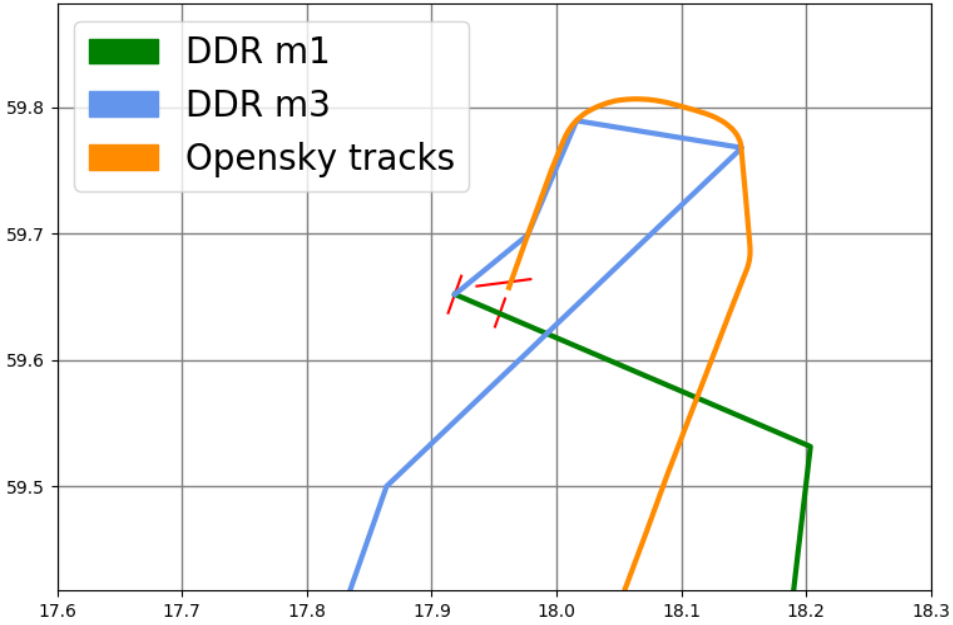
Horizontal Accuracy

- SAS 964
- February 26, 2018



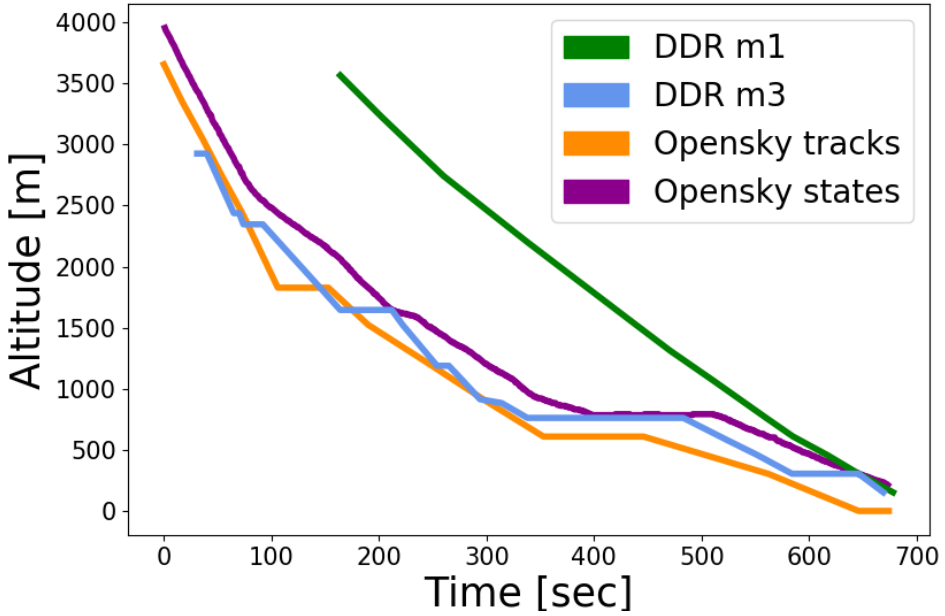
Landing Accuracy

- SAS 410
- January 01, 2018



Vertical Accuracy

- AFL 2386
- December 25, 2018



Software Tool – Statistics Results

Trajectories | Statistics

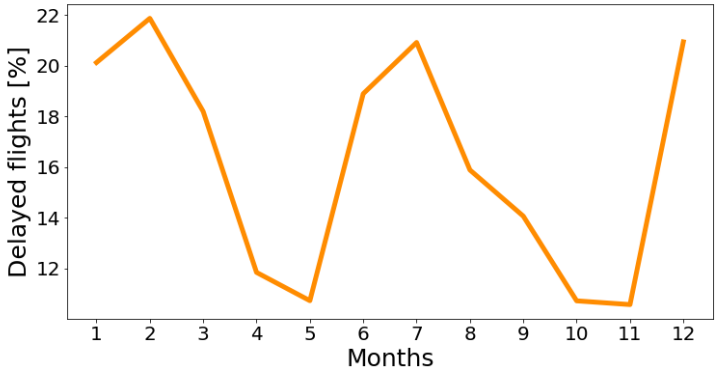
Begin date: 2018-01-01

End date: 2018-03-31

PI name	PI value	Data source
Number of flights	27865	DDR
Total arrival delay	170 days, 11:31:26	DDR
Average arrival delay	8.8 min	DDR
KPI 14 1B (% of arrivals delayed ≤ 5 minutes versus schedule)	51.9 %	DDR
KPI 14 2B (% of arrivals delayed ≤ 15 minutes versus schedule)	80.0 %	DDR
Total departure delay	137 days, 15:28:51	DDR
Average departure delay	7.1 min	DDR
Average additional time in TMA	3.5 min	DDR
Number of flights	22665	Opensky
Percentage of flights considered as level flights inside TMA	56.3 %	Opensky
Average number of level segments inside TMA	1.0	Opensky
Average distance flown level inside TMA	2.7 NM	Opensky
Average time flown level inside TMA	0.7 min	Opensky

Punctuality of Arrivals

- Data source - DDR2 (2018)
  m1 - flight plans
  m3 - actual arrival times
- Calculated percent of flights delayed > 15 min
- Problematic months: January, February, July, December

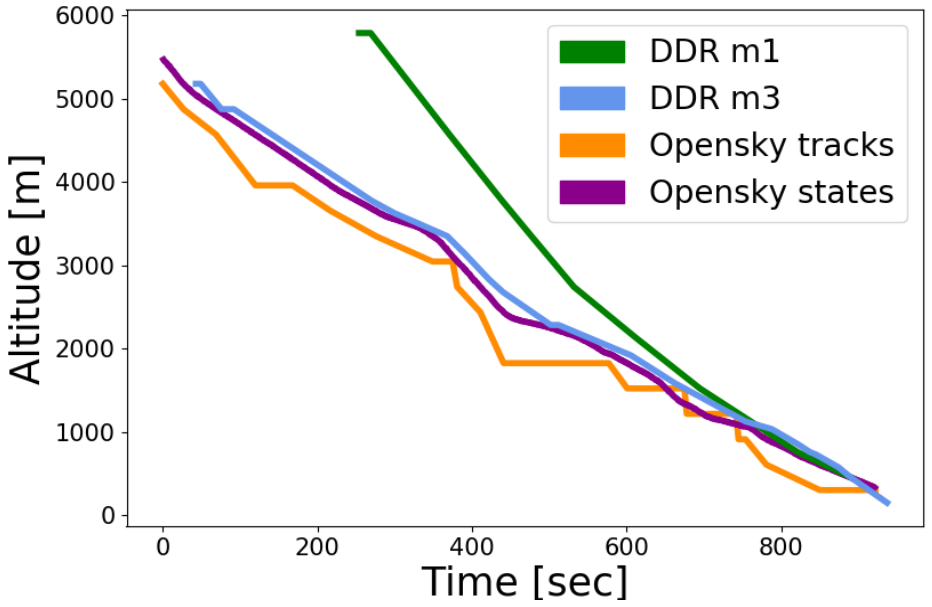


Vertical Flight Efficiency

Data source - Opensky states (more accurate)

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

Average time flown level: 4-5%



SAS410 on January 01, 2018

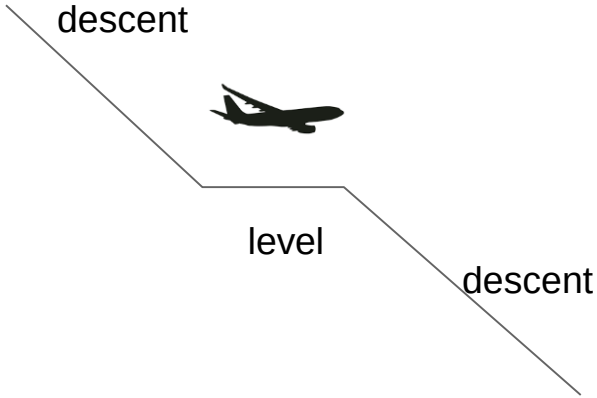
Fuel Consumption

- Calculated using BADA v4 methodology
- xml file with aircraft performance data
- Different models depending on engine type and engine rating (max climb, max cruise, idle, no rating)
- General formula: $F = \delta \cdot \theta^{\frac{1}{2}} \cdot W_{mref} \cdot a_0 \cdot L_{HV}^{-1} \cdot C_F$

  δ - pressure ratio,

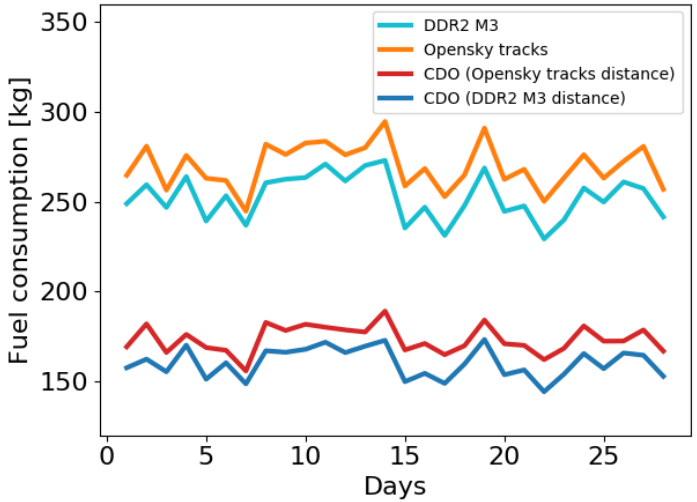
  θ - temperature ratio, W_{mref} - weight force

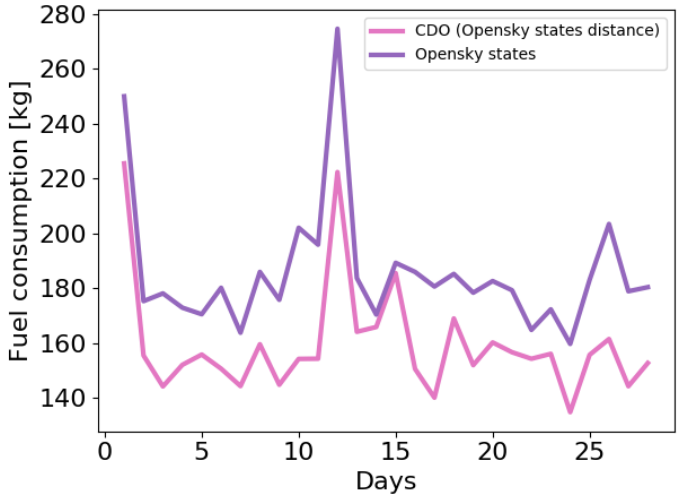
  a_0 - speed of sound , L_{HV} - fuel lower rating, C_F - fuel coefficient
- Thrust computation $T = \delta \cdot W_{mref} \cdot C_T$
- Idle thrust at descent



Fuel Burn in Vertical Plane

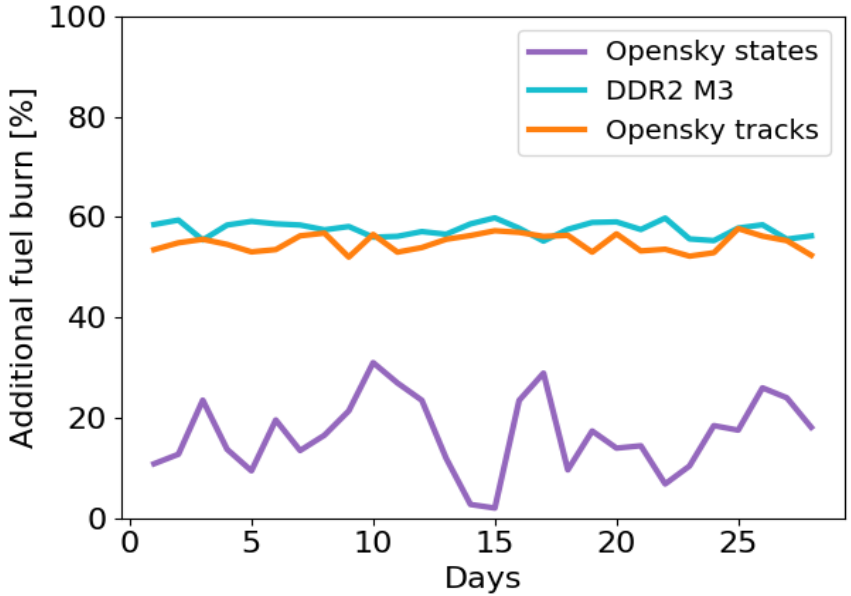
- Absolute values (in kg) for the average fuel consumption over the arrivals in February 2018





Fuel Burn in Vertical Plane

➢ Average fuel consumption over the arrivals in February 2018



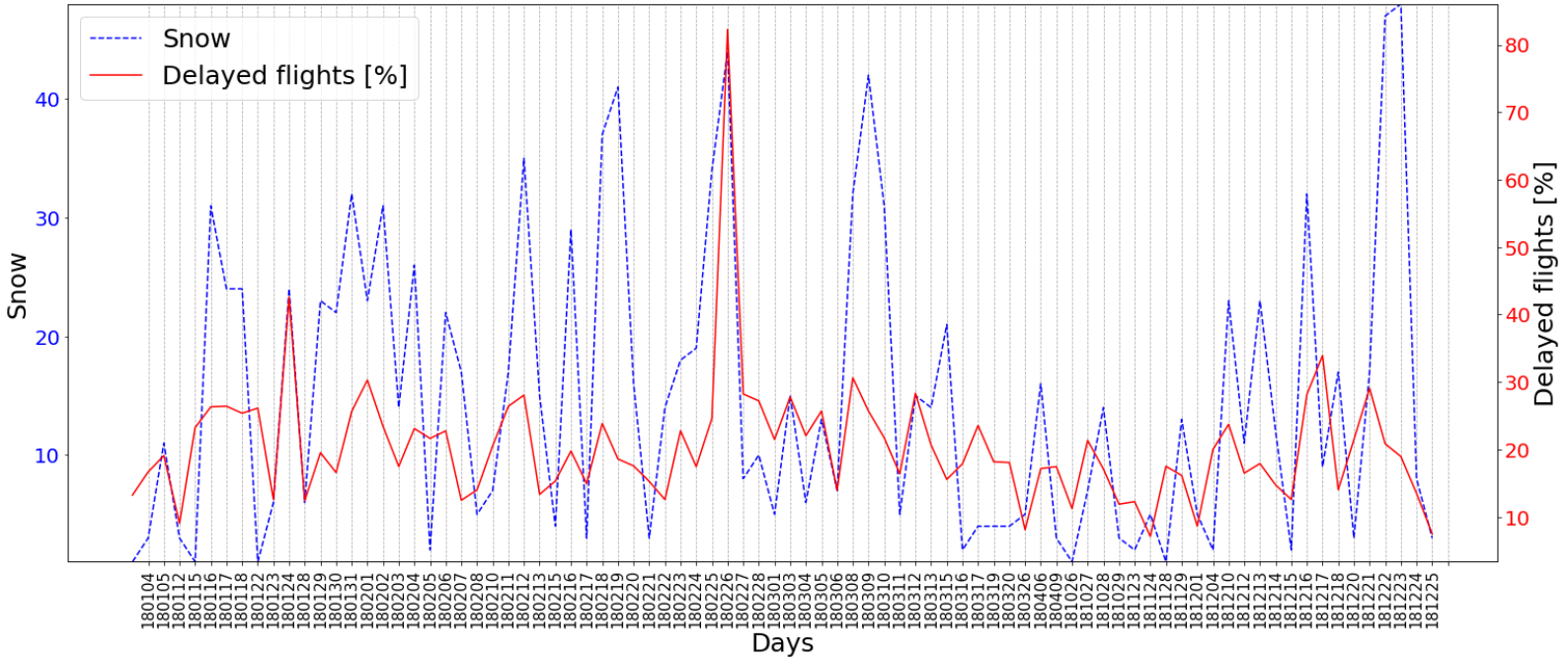
Weather Data

- National Oceanic and Atmospheric Administration (NOAA)
  - GRIB format, edition 2
  - horizontal resolution of 30 miles (48 kilometers) between grid points
  - surface and pressure level fields
  - 4 times per day
- Meteorological Aviation Routine Weather Report (METAR)
  - text format
  - Arlanda
  - 48 times per day

Weather Metrics

- Visibility
- Wind gust
- CAPE (Convective Available Potential Energy)
  - CAPE is the energy a parcel of air has for upward motion, measured in joules per kilogram of air (J/kg)
- Snow

Snow and Percent of Delayed Flights by Days



February 26, 2018

Traffic chaos as icy blast hits Sweden

The Local
news@thelocal.se
@thelocalsweden

26 February 2018
09:57 CET+01:00

weather
winter
snow
arlanda
live blog

Share this article

Snow on the E4 road on Monday. Photo: Christine Olsson/TT

Even the Swedish prime minister got caught up in the snow chaos on Monday. Here's The Local's live blog of the "beast from the east".

10:00 Flights cancelled

More than 20 departures from Arlanda Airport north of Stockholm have been cancelled as a result of snow on Monday, to cities including Düsseldorf, Warsaw, Åre Östersund, Gothenburg, Rome, Amsterdam and Frankfurt. Keep an eye on your flight status here.

For those of you who will still be able to fly today, make sure you head to the airport early as an accident on the E4 motorway between Stockholm and Arlanda this morning is causing long queues.

Swedavia
@Swedavia

During Monday morning there may be disruptions in air traffic to and from Stockholm Arlanda due to heavy snow. You can find current arrival and departure times on the website and in the app.
For more information about your trip, please contact your airline or tour operator.

6:54 AM - Feb 26, 2018

Regression Analysis

Percent of Delayed Flights vs. Weather Metrics

Step	R^2_{adj}	*F-stat.*	*Prob. (F-stat.)*	*Snow*		*Visibility*		*Wind gust*		*CAPE*	
				coef.	*p-value*	*coef.*	*p-value*	*coef.*	*p-value*	*coef.*	*p-value*
1	0.175	18.25	1.58e-13	0.263	0.0	0.033	0.485	0.011	0.0	0.0	0.268
2	0.177	24.34	3.18e-14	0.264	0.0	0.037	0.437	0.011	0.0		
3	0.178	36.25	6.22e-15	0.264	**0.0**			0.012	**0.0**		

Significant weather metrics: snow and wind gust

Regression Analysis

Average Time Flown Level vs. Weather Metrics

Step	R^2_{adj}	*F-stat.*	*Prob. (F-stat.)*	*Snow*		*Visibility*		*Wind gust*		*CAPE*	
				coef.	*p-value*	*coef.*	*p-value*	*coef.*	*p-value*	*coef.*	*p-value*
1	0.114	11.48	1.01e-08	0.003	0.001	-0.003	0.04	-0.035	0.67	0.006	0.0
2	0.113	14.88	4.26e-09	0.003	0.0	-0.002	0.08			0.006	0.0
3	0.108	20.69	3.50e-09	0.004	**0.0**					0.005	**0.0**

Significant weather metrics: snow and CAPE

Conclusions

- Facilitating software tool developed
- Evaluated flight efficiency for Stockholm Arlanda arrivals
- Analysed the dependency between certain KPI - weather metric pairs
- Revealed correlation between some weather metrics and airport PIs
- Average extra fuel burn due to vertical inefficiency estimated (more accurately)
- Compared DDR2 and Opensky data

Future Work

- **Short term:** impact of different factors such as ATM automation or other weather conditions on the arrival (and departure) delays, vertical efficiency and associated fuel waste
- **Longer term:** integration of the advanced weather prediction methodologies developed within SESAR projects (e.g. PNOWWA, TBOMET) into the evaluation of operations and route planning within TMA
  - in collaboration with University of Sivilia

Future Work

- **Short term:** impact of different factors such as ATM automation or other weather conditions on the arrival (and departure) delays, vertical efficiency and associated fuel waste
- **Longer term:** integration of the advanced weather prediction methodologies developed within SESAR projects (e.g. PNOWWA, TBOMET) into the evaluation of operations and route planning within TMA
  - in collaboration with University of Sivilia

THANK YOU!