Causal Analysis of Vertical Flight Inefficiency During Descents

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Workshop ITA-MIT on big data analytics for air transportation

Introduction

- Continuous descent operations (CDOs) are among the top priorities of ICAO’s Global Air Navigation Plan (GANP);

- CDOs have proven to deliver significant economical and environmental benefits.

Fuel and time benefits of CDOs and CCOs:

- Melby and Mayer (2008) estimate that operators could save about US$ 380 million per year with CDOs and CCOs in USA.
- Knorr et al. (2011) estimate that the benefits of CDOs along with en route speed reductions are in the order of 100 kg of fuel and 3 minutes per flight.
- Pamplona, Fortes and Alves (2015) estimate fuel savings in the order of 30% with CDOs.
- Howell and Dean (2017) estimate time and fuel reductions in the order 30-40% where time-based separation and CDOs were implemented.

Literature Review

Focus on the horizontal flight profile:

- Liu et al. (2017) employ a clustering algorithm and statistical models to analyze the causal factors of horizontal flight inefficiency. Considered factors were adverse weather, wind, Miles-in-trail (MIT) restrictions and traffic patterns fixed effects.

Research Question

What are the causes of non-continuous descents?

Considered factors:

- Airspace structure;
- Weather;
- Demand;
- Miles-in-trail (MIT) restrictions;
- Aircraft Type.

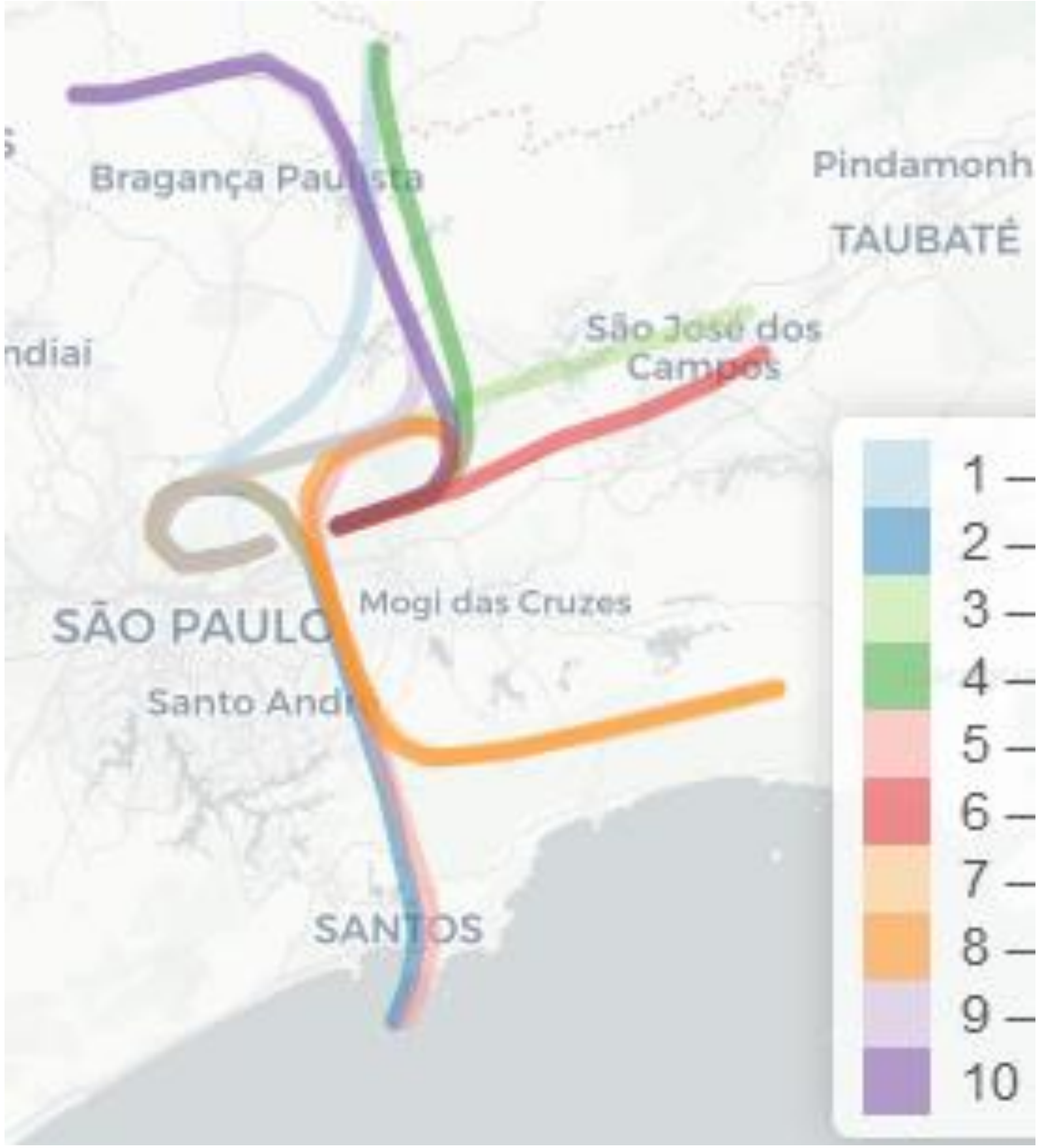
Data

- Flight trajectories: FlightRadar24
- Weather conditions: METAR
- Miles-in-Trail restrictions: CGNA (DECEA)
- Study case: Guarulhos (GRU) and Congonhas (CGH)
- Period of analysis: 09/18/2017 to 11/14/2017

Methodology

- **Trajectory clustering**
  - ➢ DBSCAN
  - ➢ Traffic patterns
- **Linear regression model**
  - ➢ Vertical profile inefficiency metric (KPI19) is the dependent variable;
  - ➢ Categories of independent variables are <u>traffic patterns, adverse weather, demand and aircraft type.</u>

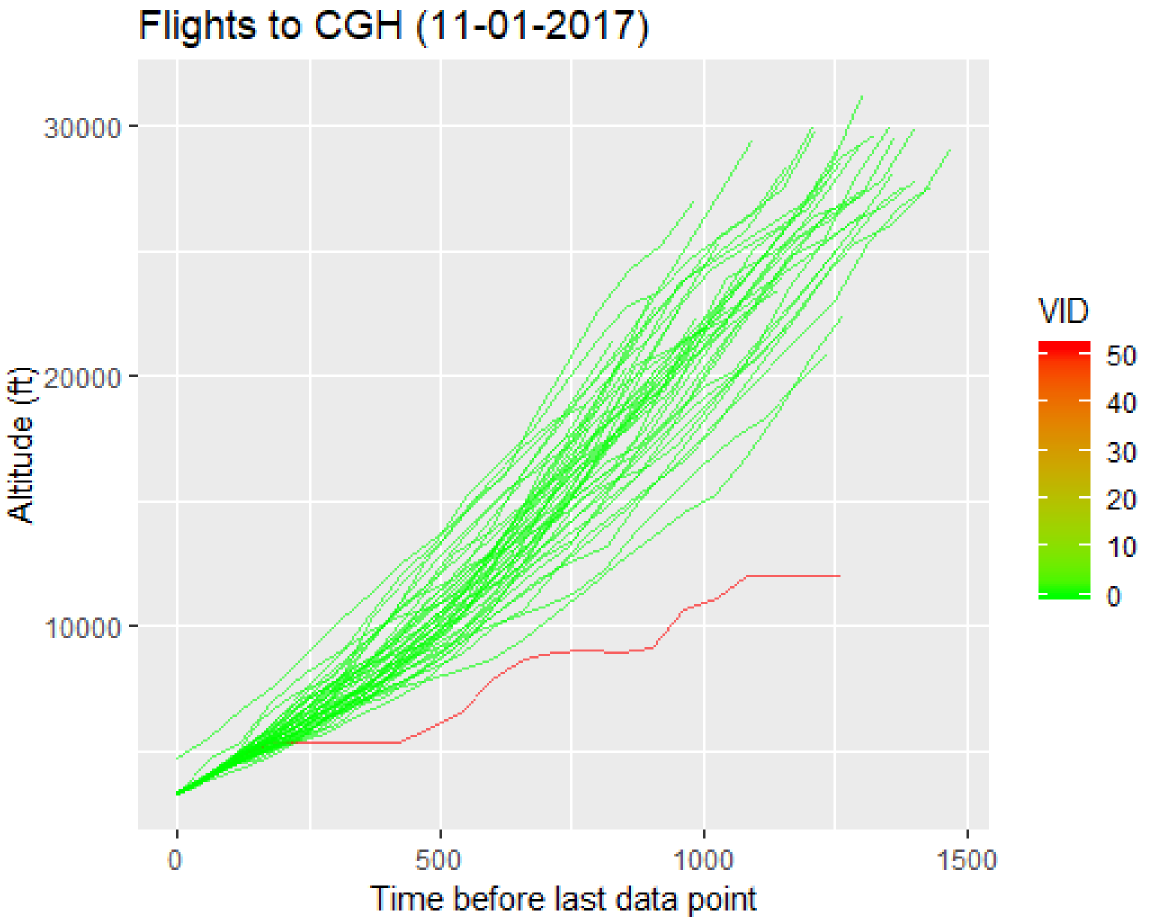
Nominal Routes



Vertical Inefficiency (VID)

KPI19 - Level-off during descent

$$VID = \frac{distance\ in\ level\ flight}{total\ descent\ distance}\ x\ 100$$



Data overview

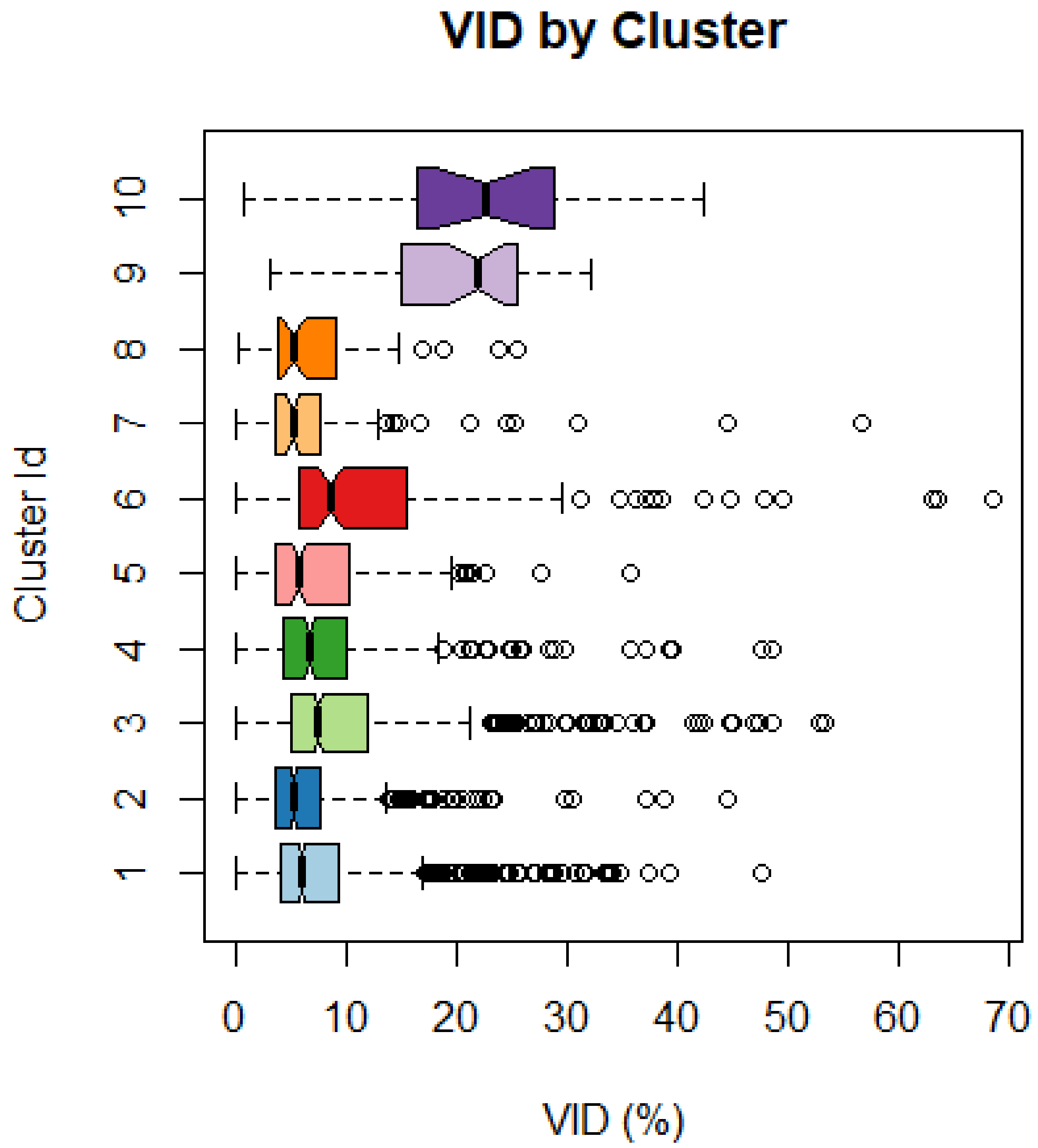
GRU

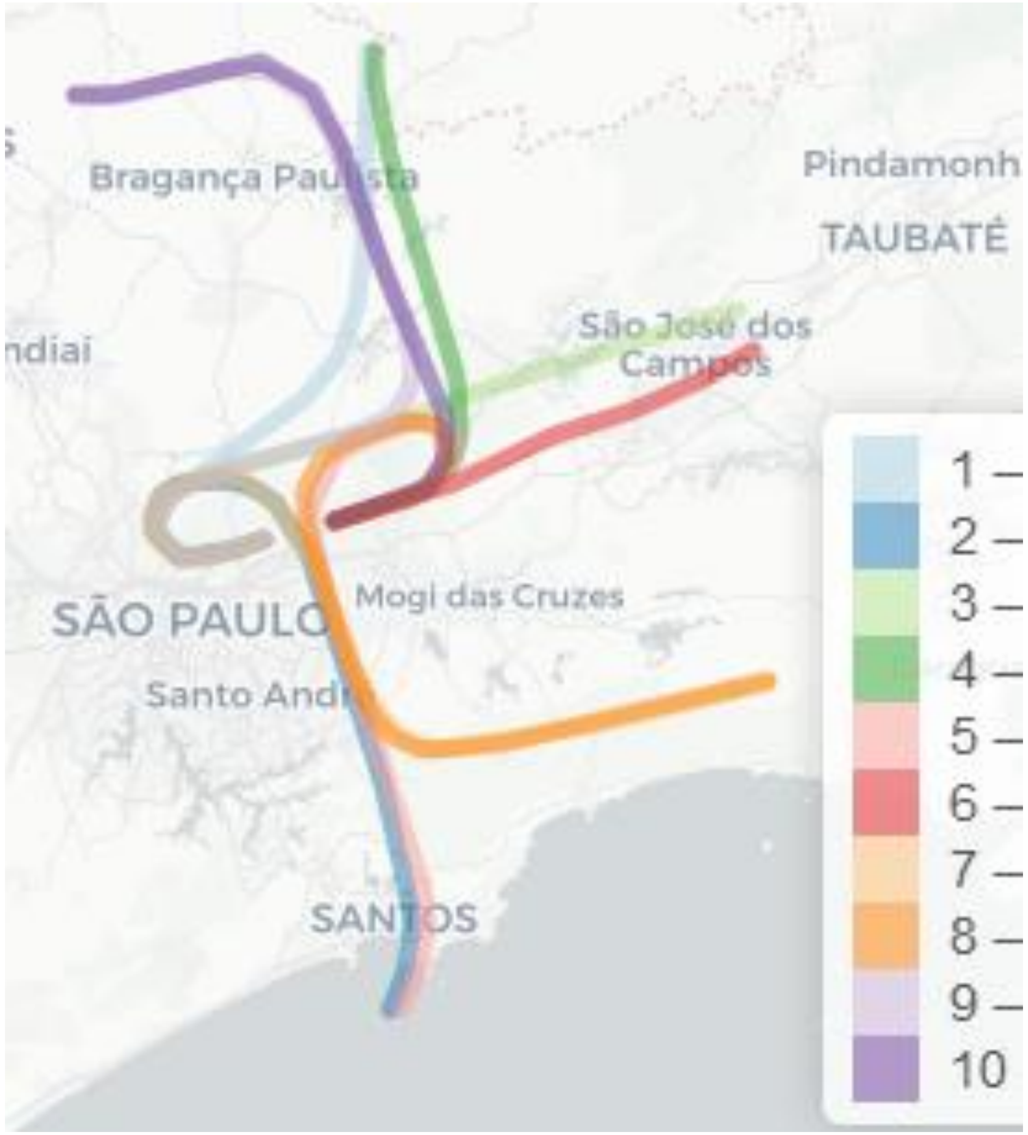
- 11591 flights
- Average Inefficiency: 5.7 %
- ~ 50% were CDOs according to the adopted methodology

CGH

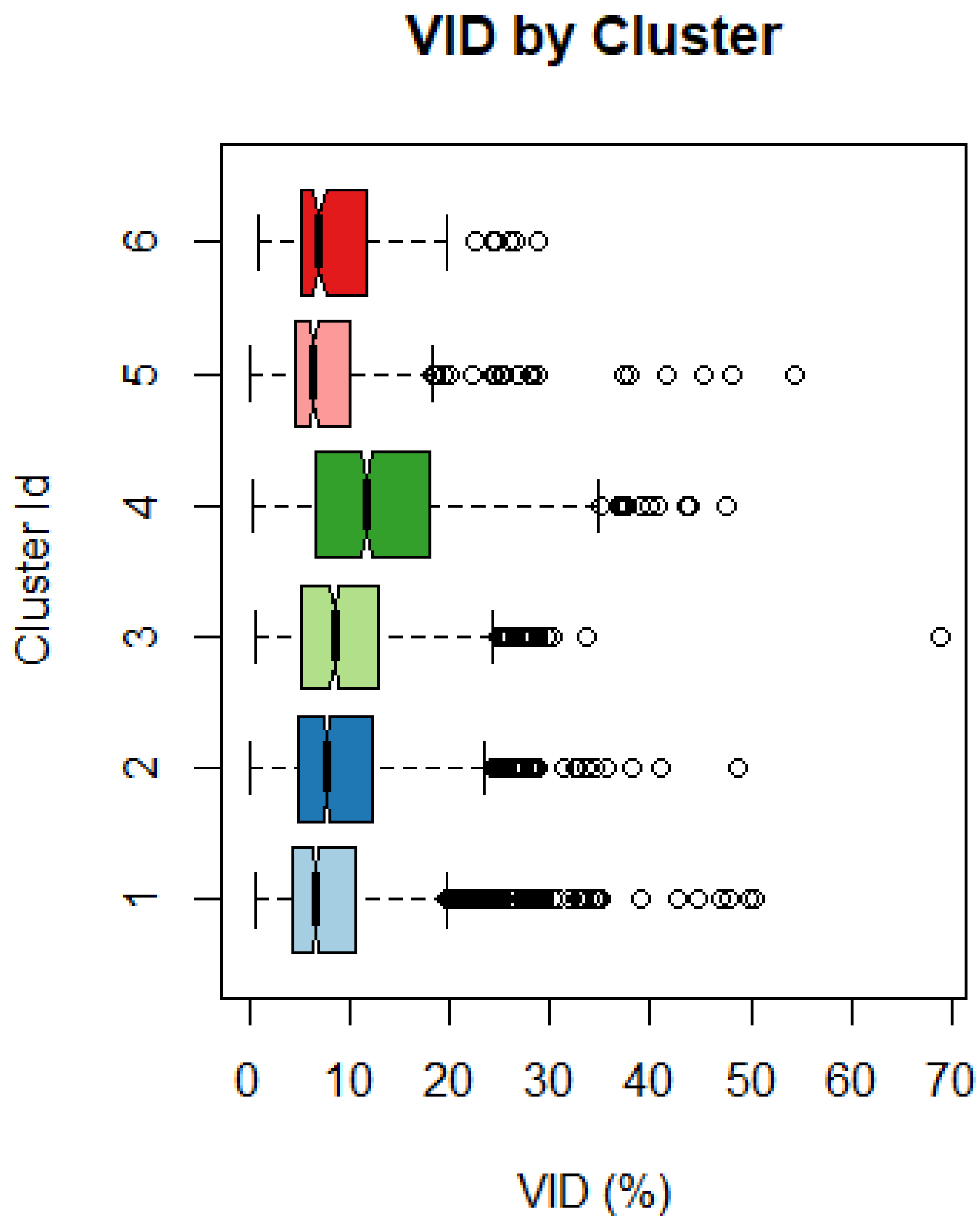
- 7468 flights
- Average Inefficiency: 7.42 %
- ~ 34 % were CDOs according to the adopted methodology

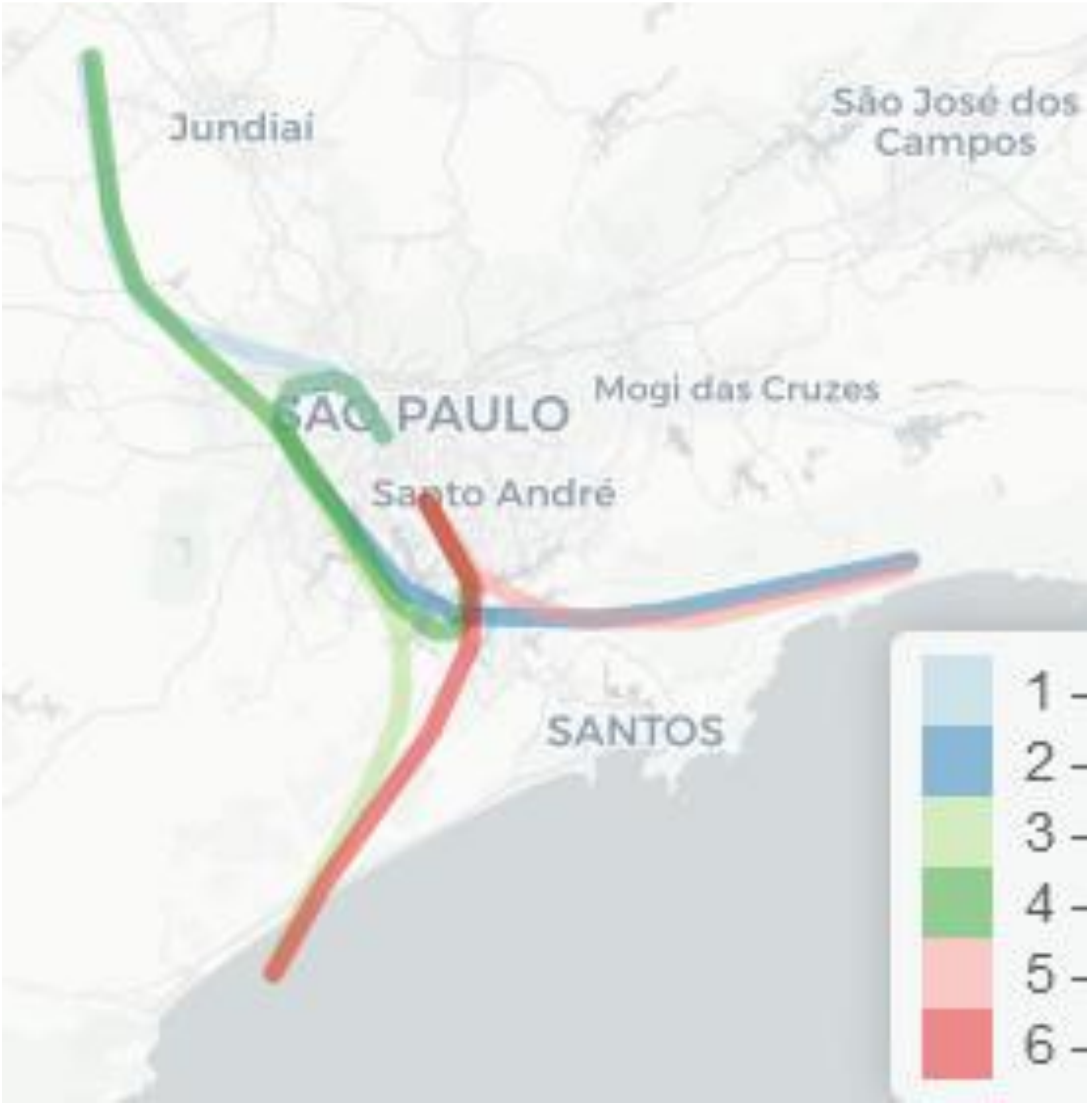
Data overview (GRU)





Data overview (CGH)

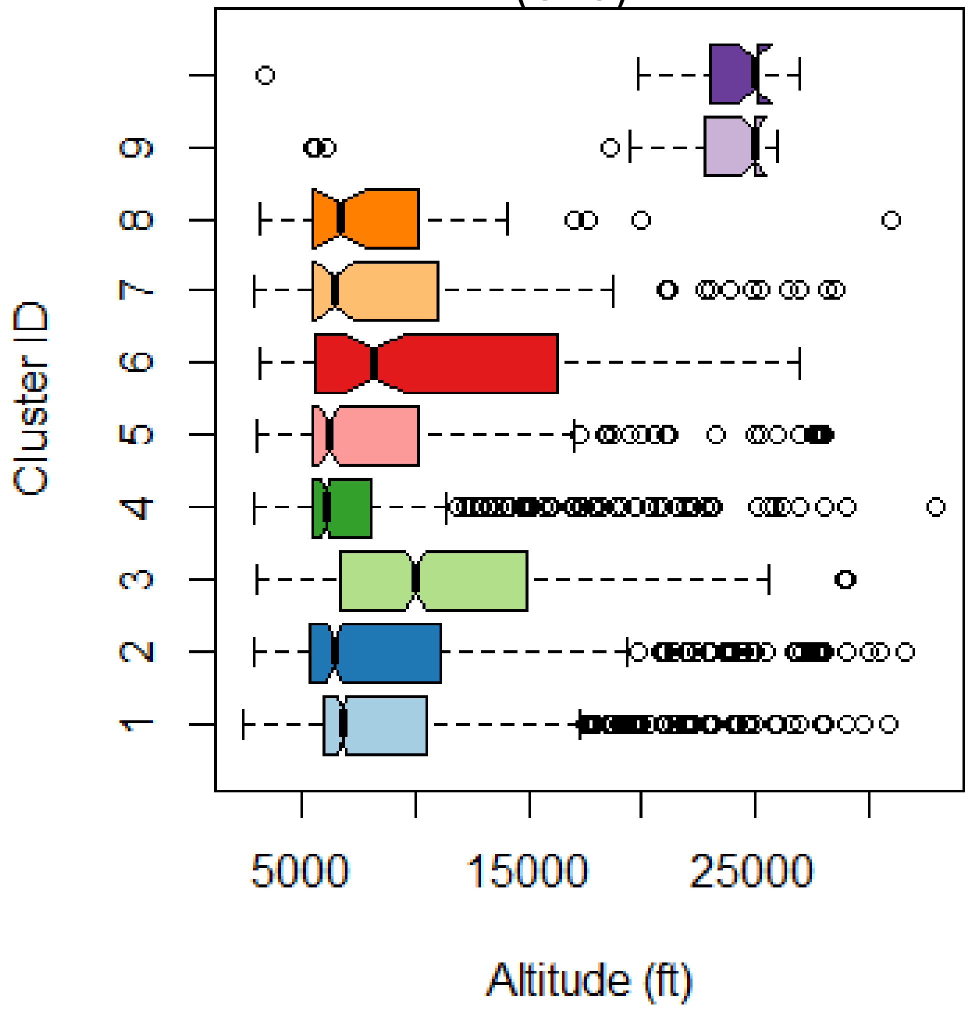




Data overview

Mean altitude of level offs by cluster

(GRU)



Mean altitude of level offs by cluster

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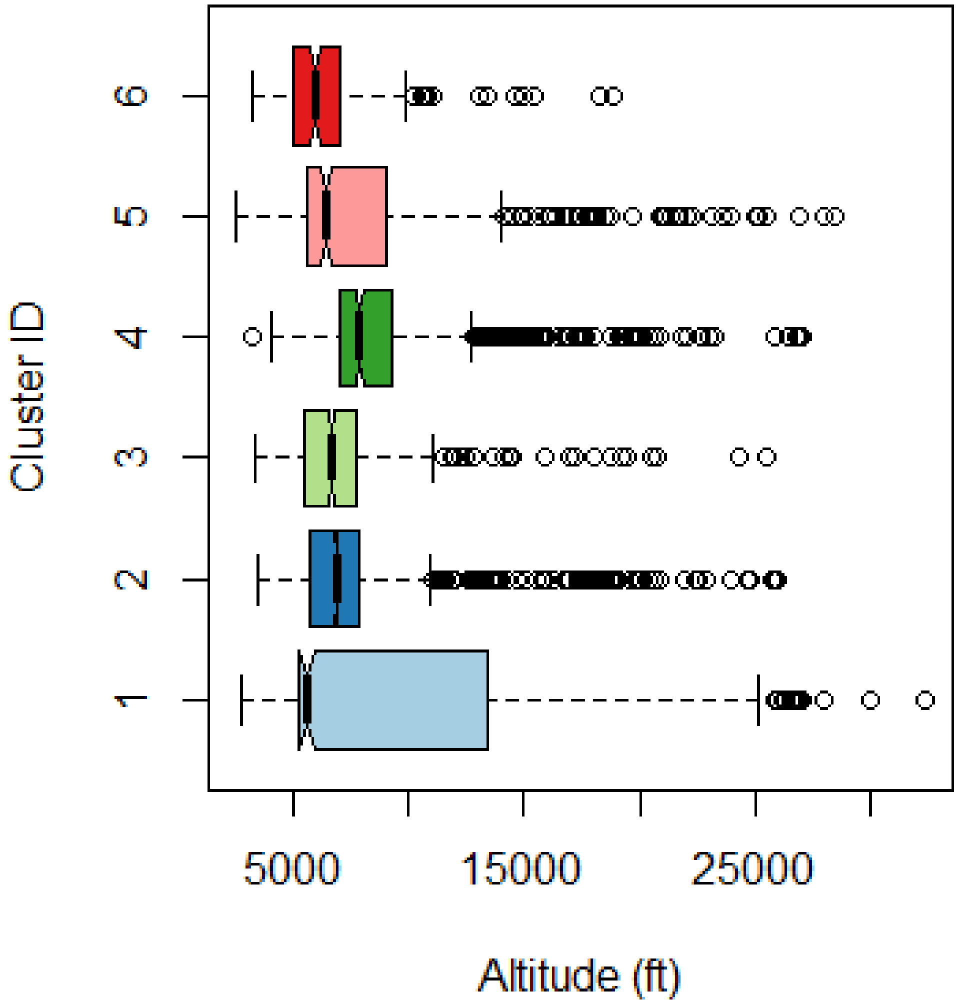

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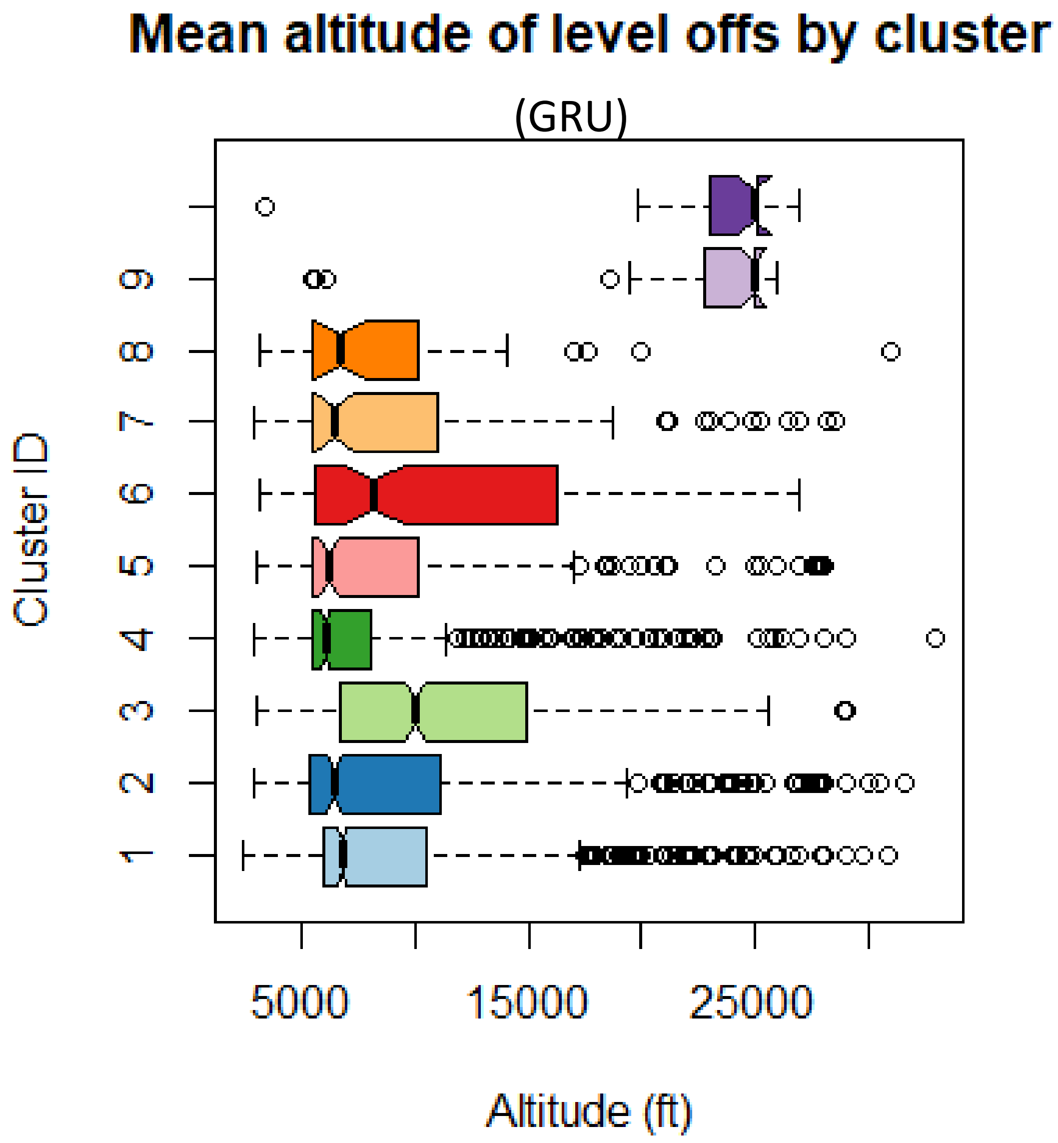

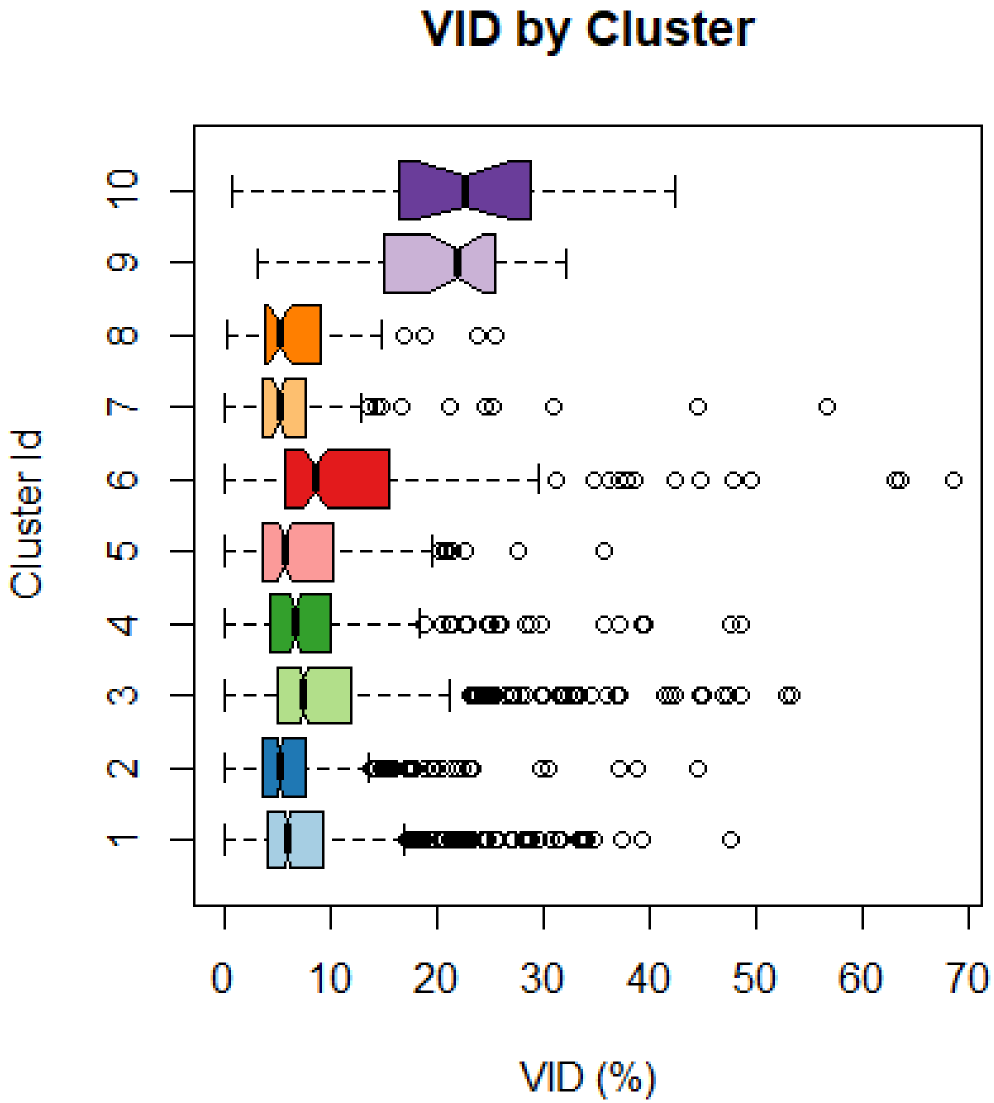

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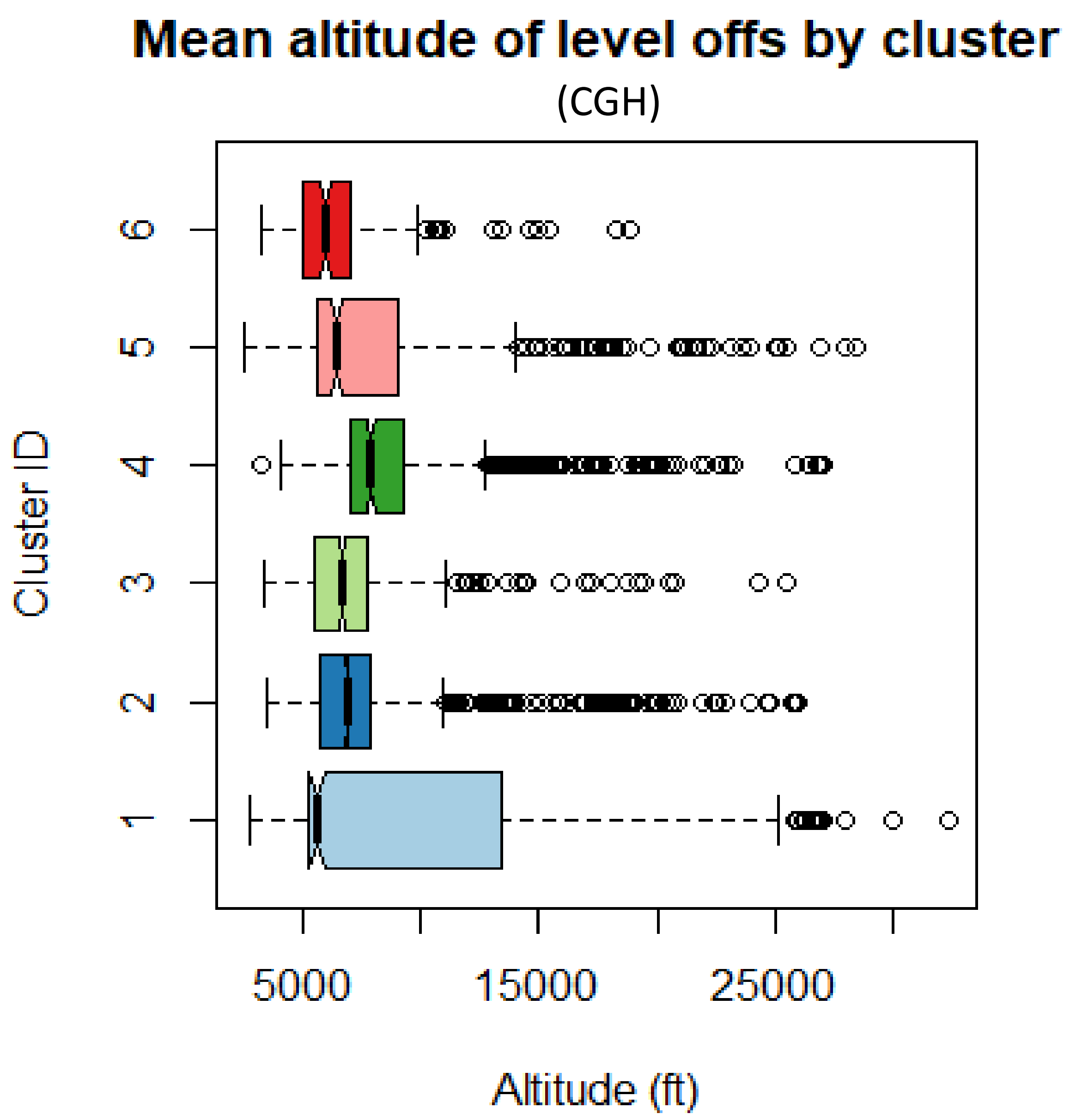

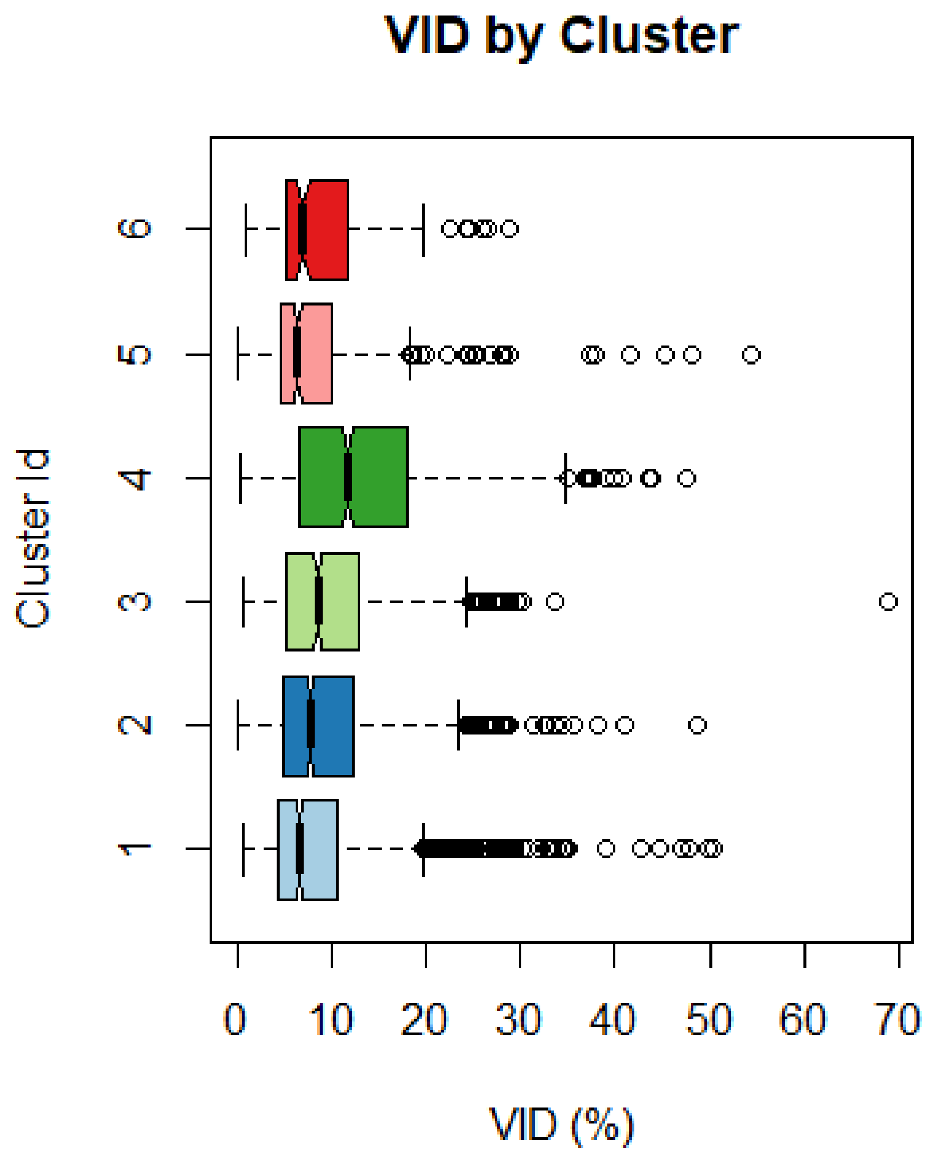

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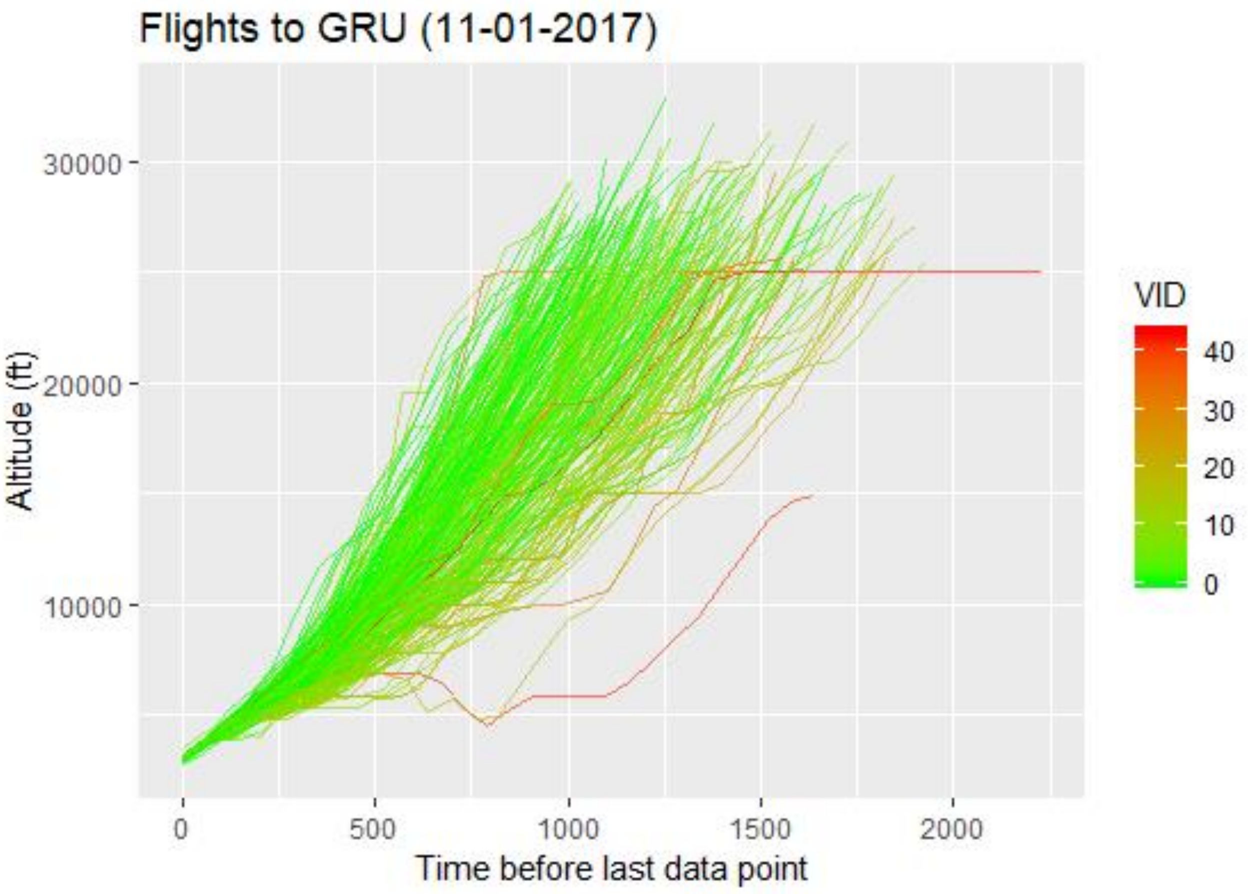

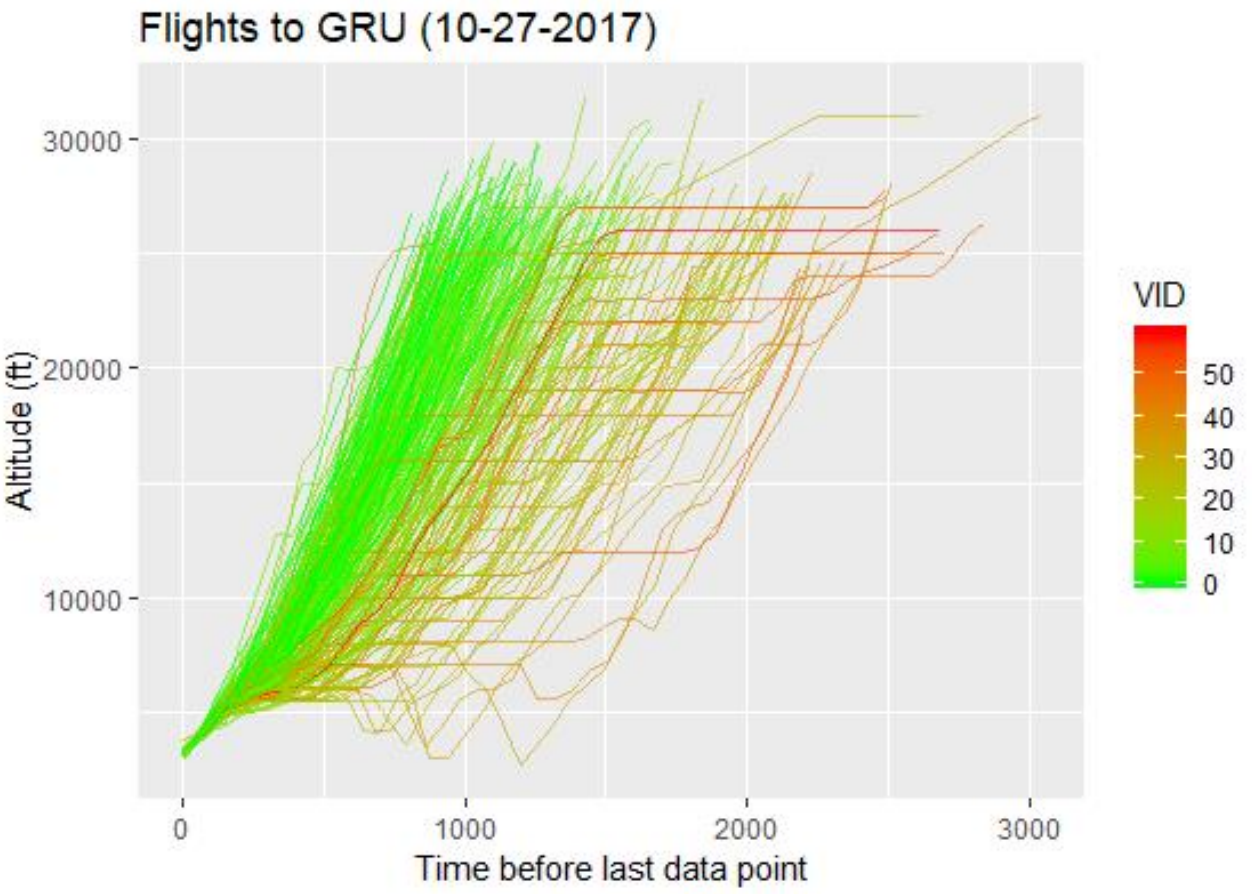

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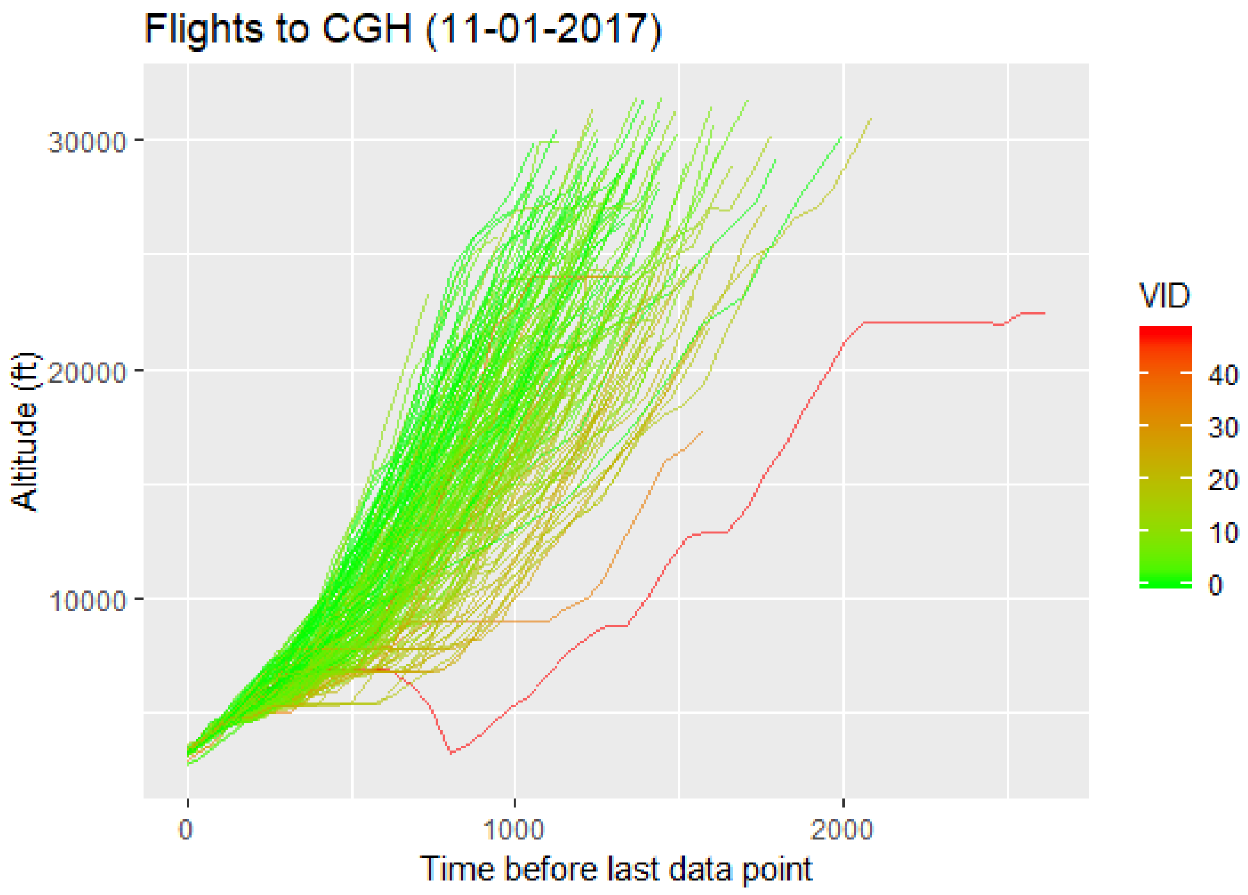

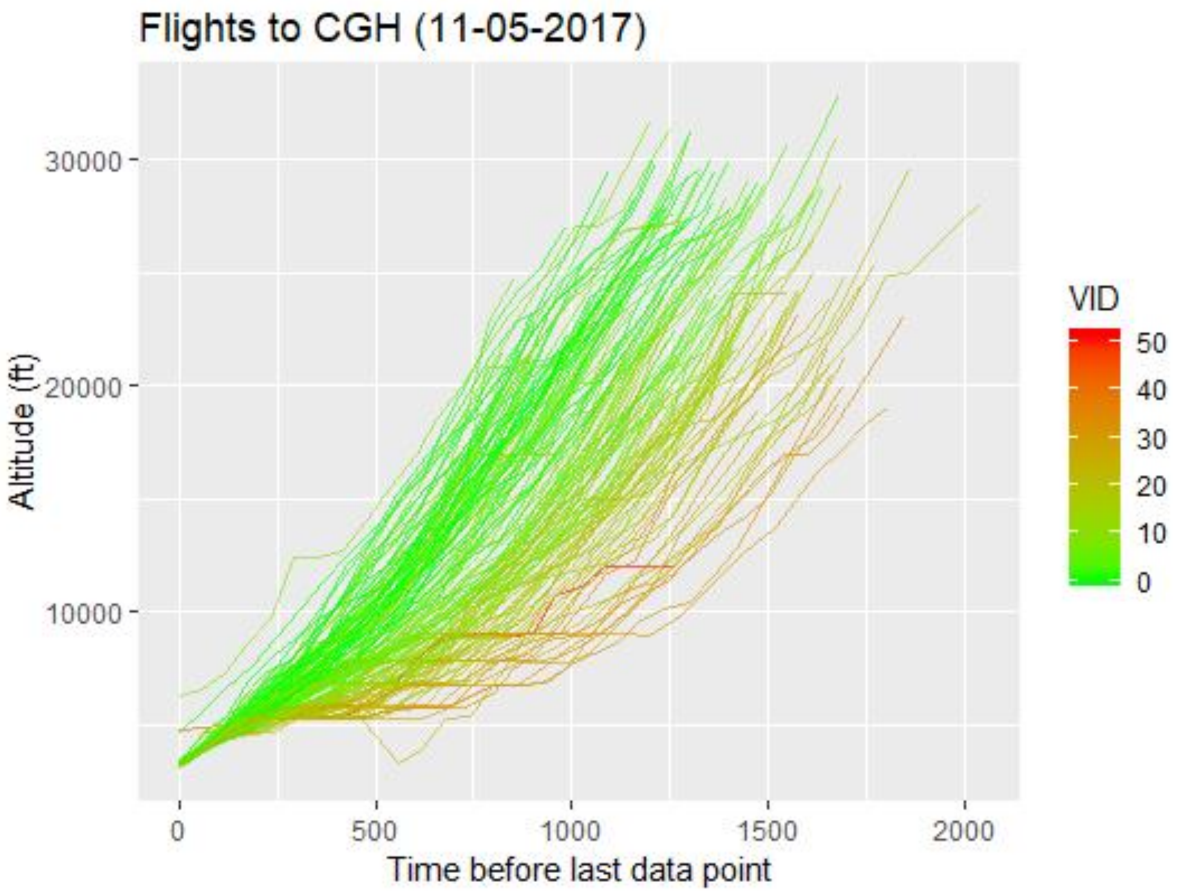

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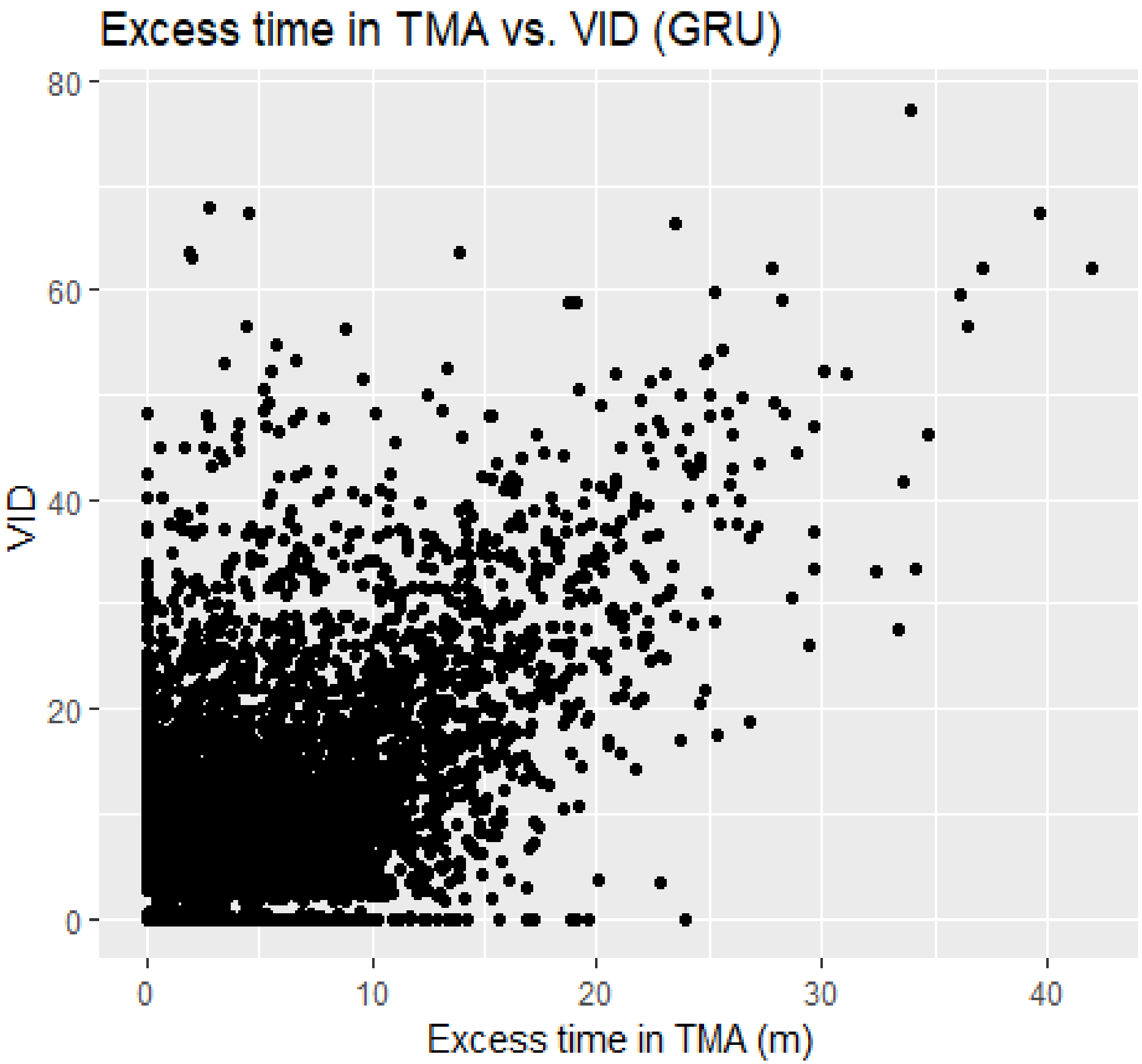

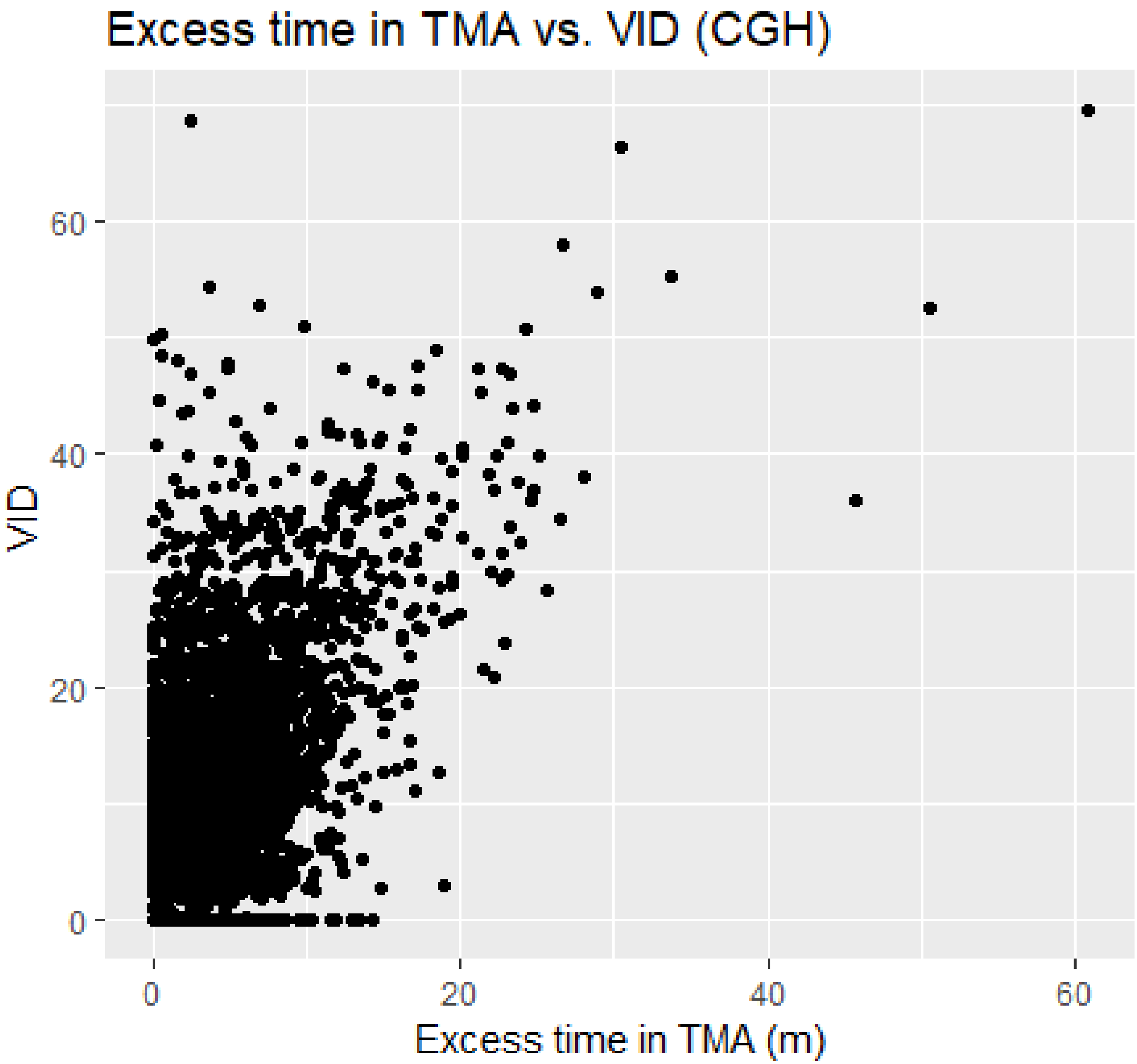

Variables

ARR_CGH ; DEP_CGH; ARR_GRU; DEP_GRU	Demand variables indicating the number of aircrafts in each situation.
MIT	Dummy. Indicates the occurrence of MIT restrictions.
WX	Dummy. It is 1 when the METAR reports rain, thunderstorm or cumulonimbus clouds.
LIFR	Dummy. It is 1 when the METAR reports visibility below one nautical mile or ceiling below 500 feet.
traffic_pattern	Dummy. Indicate the nominal route. Outliers' group is the baseline.
aircraft_type	Dummy variable for each aircraft type.

	(CGH) VID	(GRU) VID
ARR_CGH	0.5766***	0.0408
ARR_GRU	0.0090	0.6285***
DEP_CGH	-0.1828**	-0.0790
DEP_GRU	-0.0879	0.0180
WX	2.2777***	1.9076***
LIFR	0.6571	6.8187***
MIT	-0.0018	1.0787***
traffic_pattern_1	-13.4724***	-7.9272***
traffic_pattern_2	-11.8569***	-8.9315***
traffic_pattern_3	-11.8940***	-5.8325***
traffic_pattern_4	-6.6355***	-7.5604***
traffic_pattern_5	-14.0560***	-7.2626***
traffic_pattern_6	-14.3918***	-5.1383***
traffic_pattern_7		-8.3522***
traffic_pattern_8		-7.6021***
traffic_pattern_9		3.7426***
traffic_pattern_10		2.2068
Aircraft type dummies	*yes*	*yes*
R2_Adj	0.2544	0.2417
RMSE	7.5023	7.7184
N_Obs	7468	11591

Estimation Results

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# p<0.25, * p<0.10, ** p<0.05, *** p<0.01

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Conclusions and Limitations

- Airspace structure mainly determines VID;
- Convective weather significantly impacts VID;
- MIT restrictions and low IMC may increase VID;
- Wind speed and direction were not considered.

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