Flight trajectory data analytics for characterization of air traffic performance

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Brazil, August 20 and 21

Workshop ITA-MIT on big data analytics for air transportation

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- Air Traffic Management (ATM) - key element of air transportation

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safety, efficiency and environmental impact

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- Demand will double by 2035, reaching 7.2 billion passengers

safety, efficiency and environmental impact

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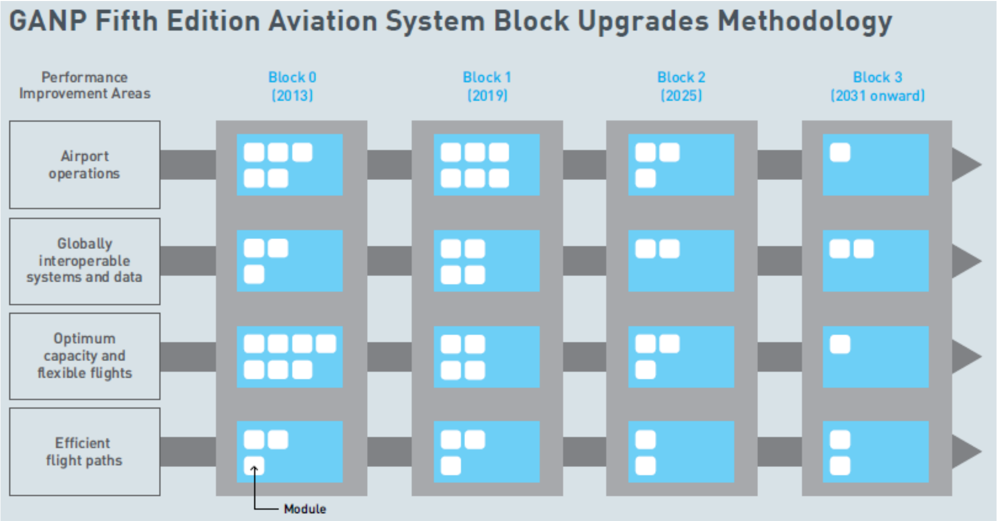
- Demand will double by 2035, reaching 7.2 billion passengers
- Technological and operational improvements for modernization of the ATM system have become necessary

safety, efficiency and environmental impact



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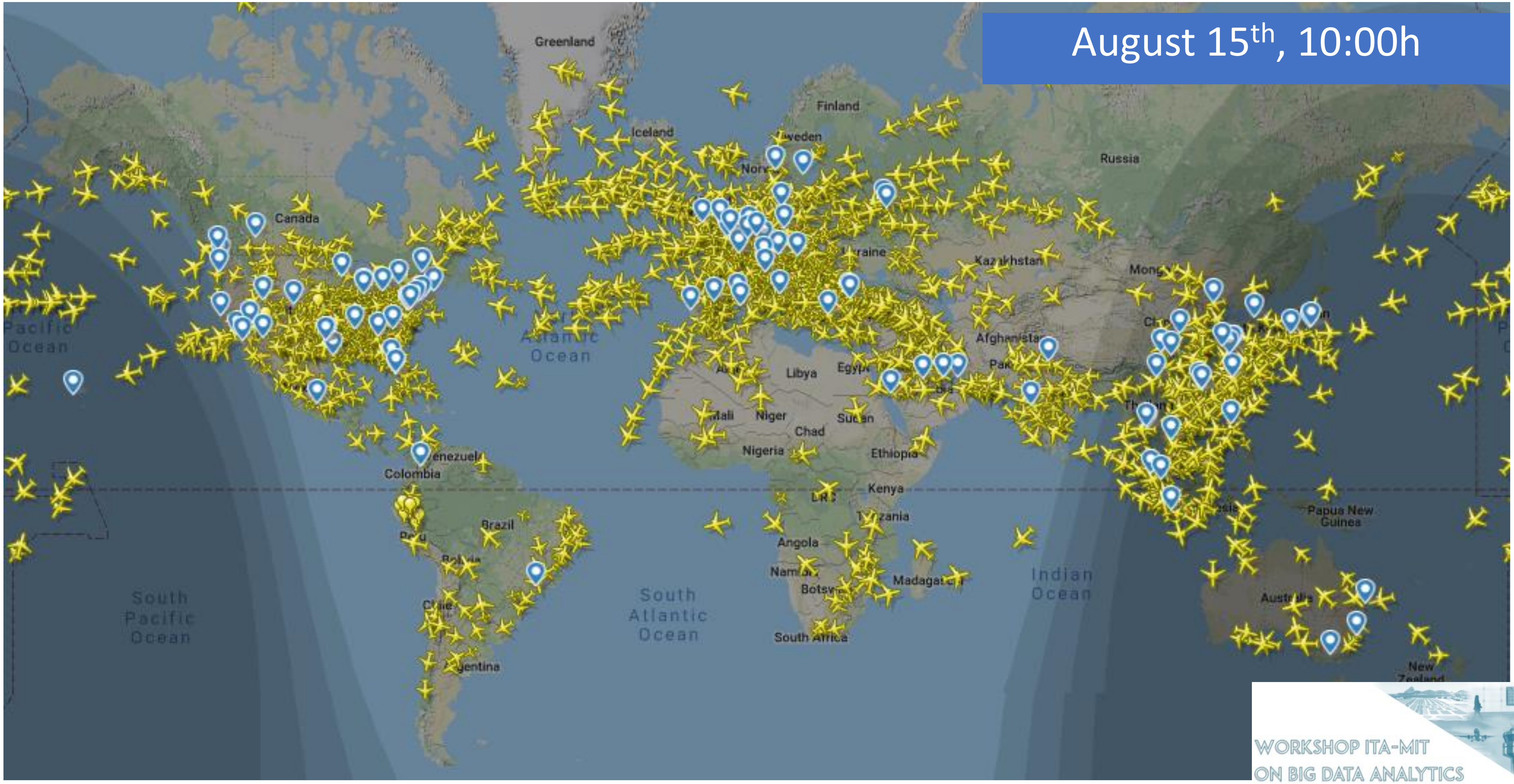
Introduction

August 15th, 10:00h



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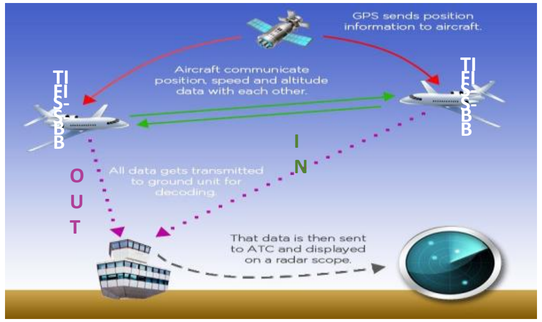
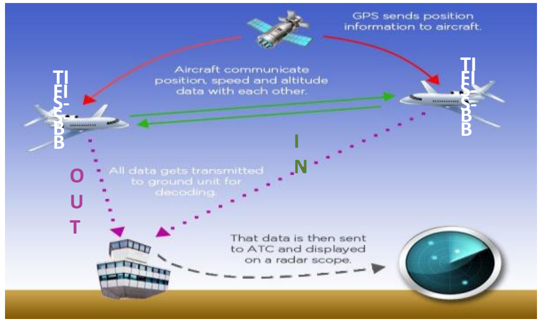


New technologies and operational procedures

Introduction

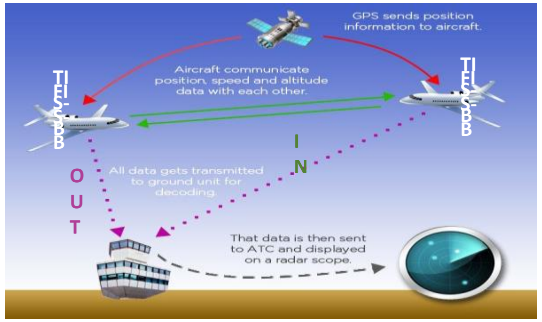


New technologies and operational procedures

PROJETO TMA-SP Neo

Agile - GRU

Introduction



New technologies and operational procedures

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Leveraging **operational data** is also key to improve ATM and increase the performance of air traffic operations

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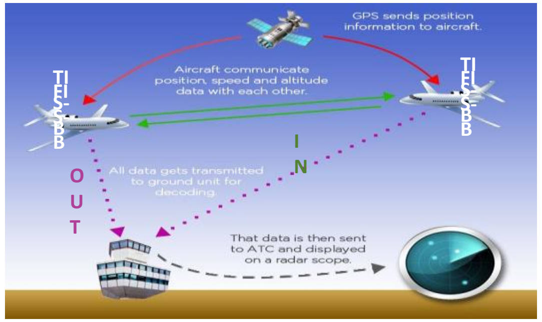

New technologies and operational procedures

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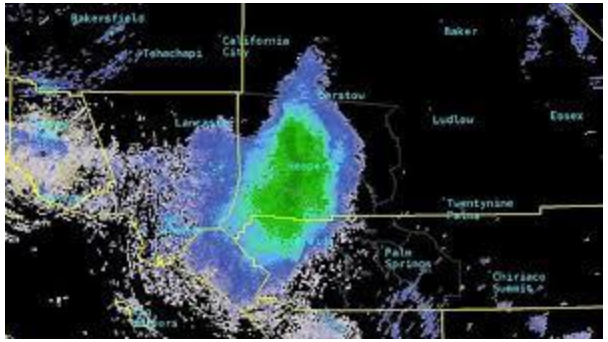
Introduction

Motivation

- Analytics techniques - assessing the air traffic performance at different dimensions and better understanding how this performance is affected by various operational factors

$$HTE_{kt} = \beta_1\, DEMAND_{kt} + \beta_2\, LIFR_{kt} + \beta_3\, WX_{kt} + \beta_4\, GUSTS_{kt} + \beta_5\, MIT_{kt} + \beta_6\, NC_{kt} + \beta_7\, k_t + u_{kt}$$



Introduction

Motivation

- Analytics techniques - assessing the air traffic performance at different dimensions and better understanding how this performance is affected by various operational factors
- Sources of inefficiencies / new models and tools - better predict and control the performance of the system

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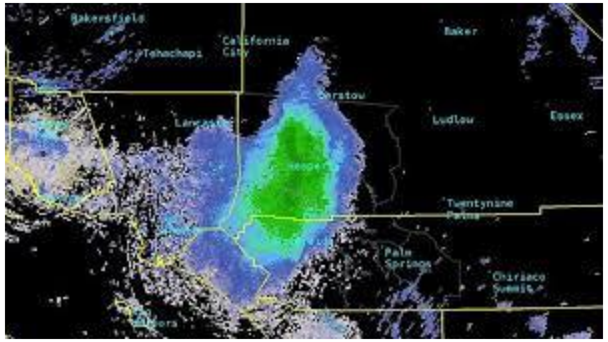

Introduction

Literature review

- Trajectory data mining - variety of domains (vehicles, people, animals etc)

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Characterization

(1) Gariel et al., (2) Liu & Hansen, (3) Murça, (4) Ren & Li, (5) Marcos et al.

Prediction

(1) Hong & Lee, (2) Marcos et al., (3) Tastambekov et al., (4) Wang et al., (5) Murça and Hansman

2011

2015

Introduction

Literature review

- Trajectory data mining - variety of domains (vehicles, people, animals etc)
- Previous work on flight trajectory data analytics has focused on a single flight phase
- Air traffic behavior and performance dependencies between different scales are not explored

Characterization

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Prediction

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2011

2015

Methodology

Data description

Main dataset

- The raw dataset - 44 days (2017)
- FlightRadar24 tracking service
- flight ID timestamp, latitude, longitude, altitude, speed, origin airport, destination airport and aircraft type

Complementary datasets

- Meteorological Weather Report (METAR)
- Historical traffic management initiatives from Brazilian Air Navigation Management Center (CGNA)

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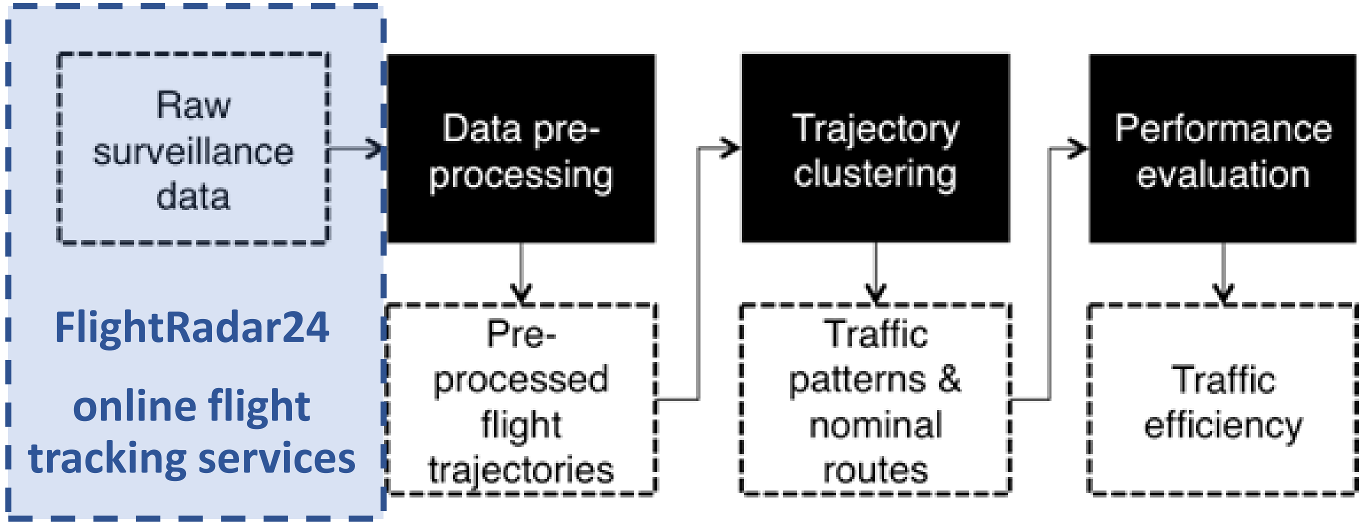
Methodology

Air traffic performance characterization

Step 0 Step 1 Step 2 Step 3



Automatic extraction of data

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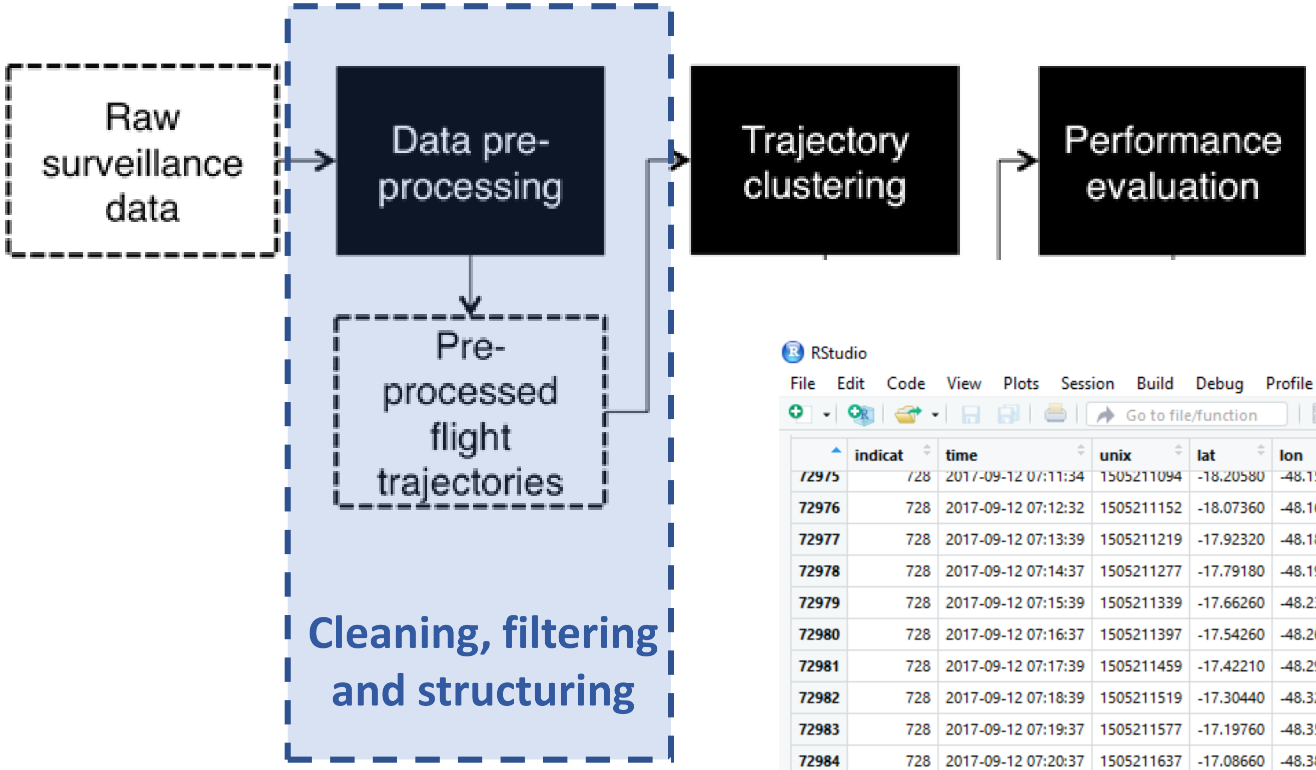
Methodology

Air traffic performance characterization

Step 1



vector-based representation

$$F_i = (x_{i1}, y_{i1}, x_{i2}, y_{i2}, \ldots, x_{in}, y_{in})$$

RStudio

File Edit Code View Plots Session Build Debug Profile Tools Help

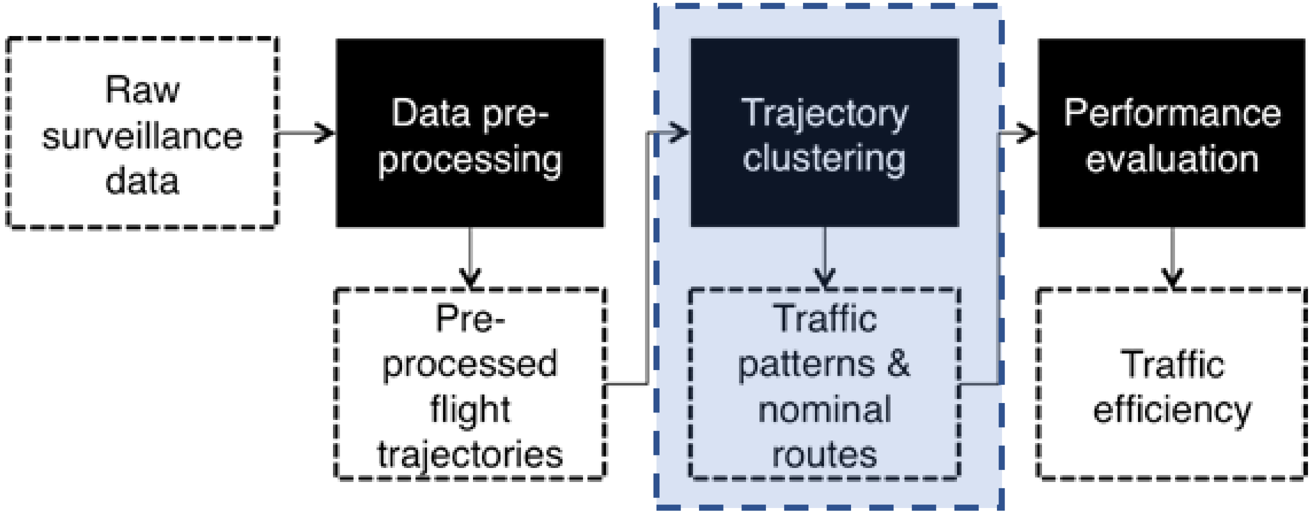
Go to file/function Addins

	indicat	time	unix	lat	lon	alt	head	speed	equip	regist	orig	dest	id_iata	id_icao	code1
72975	728	2017-09-12 07:11:34	1505211094	-18.20580	-48.15340	36000.000	354.00000	490.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F
72976	728	2017-09-12 07:12:32	1505211152	-18.07360	-48.16700	36000.000	354.00000	490.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F
72977	728	2017-09-12 07:13:39	1505211219	-17.92320	-48.18240	35400.000	354.00000	491.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F
72978	728	2017-09-12 07:14:37	1505211277	-17.79180	-48.19680	33500.000	350.00000	473.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F
72979	728	2017-09-12 07:15:39	1505211339	-17.66260	-48.23020	31225.000	345.00000	462.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F
72980	728	2017-09-12 07:16:37	1505211397	-17.54260	-48.26180	29200.000	345.00000	447.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F
72981	728	2017-09-12 07:17:39	1505211459	-17.42210	-48.29360	27150.000	345.00000	434.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F
72982	728	2017-09-12 07:18:39	1505211519	-17.30440	-48.32430	25175.000	345.00000	420.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F
72983	728	2017-09-12 07:19:37	1505211577	-17.19760	-48.35250	23350.000	345.00000	409.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F
72984	728	2017-09-12 07:20:37	1505211637	-17.08660	-48.38160	21450.000	345.00000	398.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F
72985	728	2017-09-12 07:21:38	1505211698	-16.98030	-48.40940	19650.000	345.00000	389.0000	A320	PR-AVP	CGH	BSB	O66170	ONE6170	48A6F

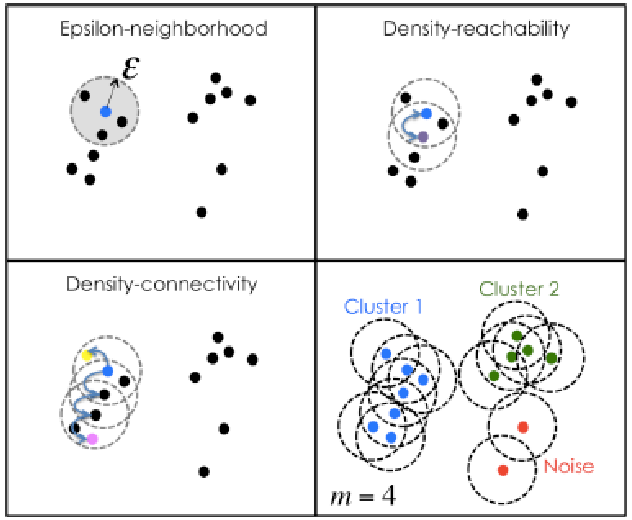
Methodology

Air traffic performance characterization

Step 2



DBSCAN



Clustering is an unsupervised learning method that aims at identifying groups of similar observations without prior knowledge

Methodology

Air traffic performance characterization

Step 3

Raw surveillance data → Data pre-processing → Pre-processed flight trajectories → Trajectory clustering → Traffic patterns & nominal routes → Performance evaluation → Traffic efficiency

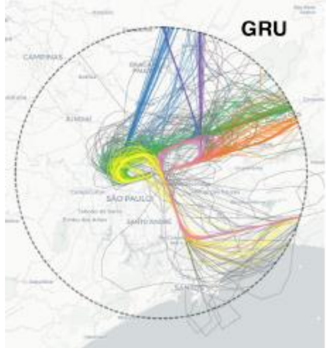
$$HTE_T = \frac{\sum_{i;t(i)\in T} s_i}{\sum_{i;t(i)\in T} S_i}$$

$$TTE_T = \frac{\sum_{i;t(i)\in T} l_i}{\sum_{i;t(i)\in T} L_i}$$

Horizontal and Temporal Traffic Efficiency

- **Performed trajectory**
- **Cluster centroid**

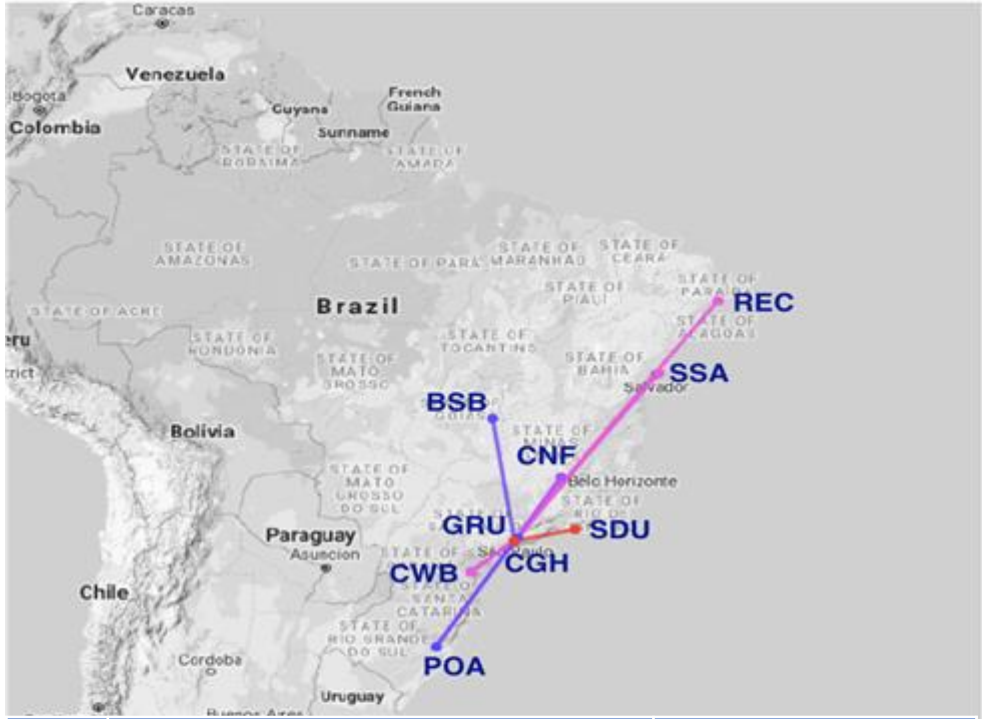
- GANP´s indicators
- Other indicators according to the interest of the user



Methodology

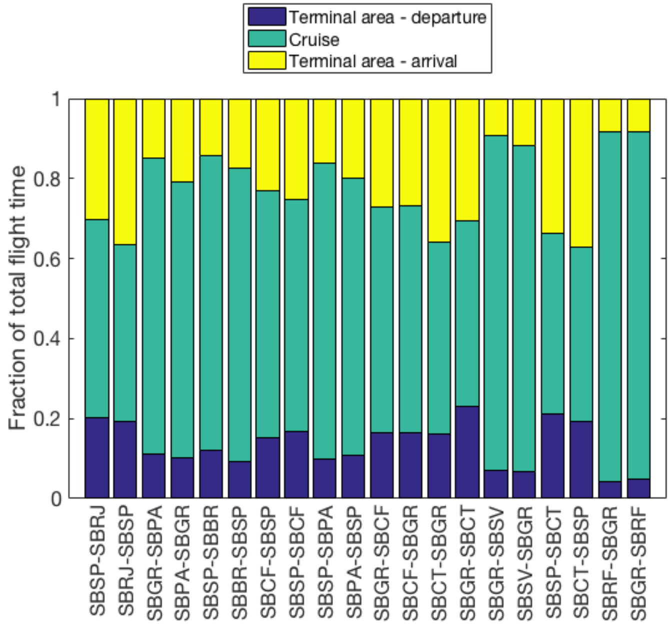
Case study

Top-20 OD pairs in Brazil

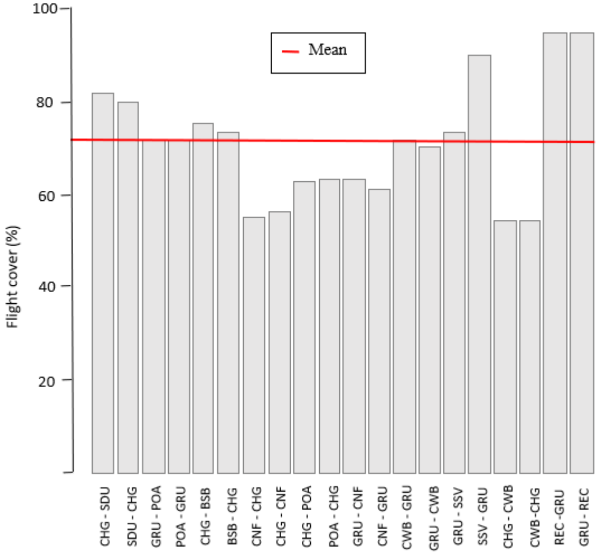


Rank	Origem - Destinity pair	Movements
1	Sao Paulo (CGH) – Rio de Janeiro (SDU)	19278
2	Rio de Janeiro (SDU) – Sao Paulo (CGH)	19167

Flight time by flight phase



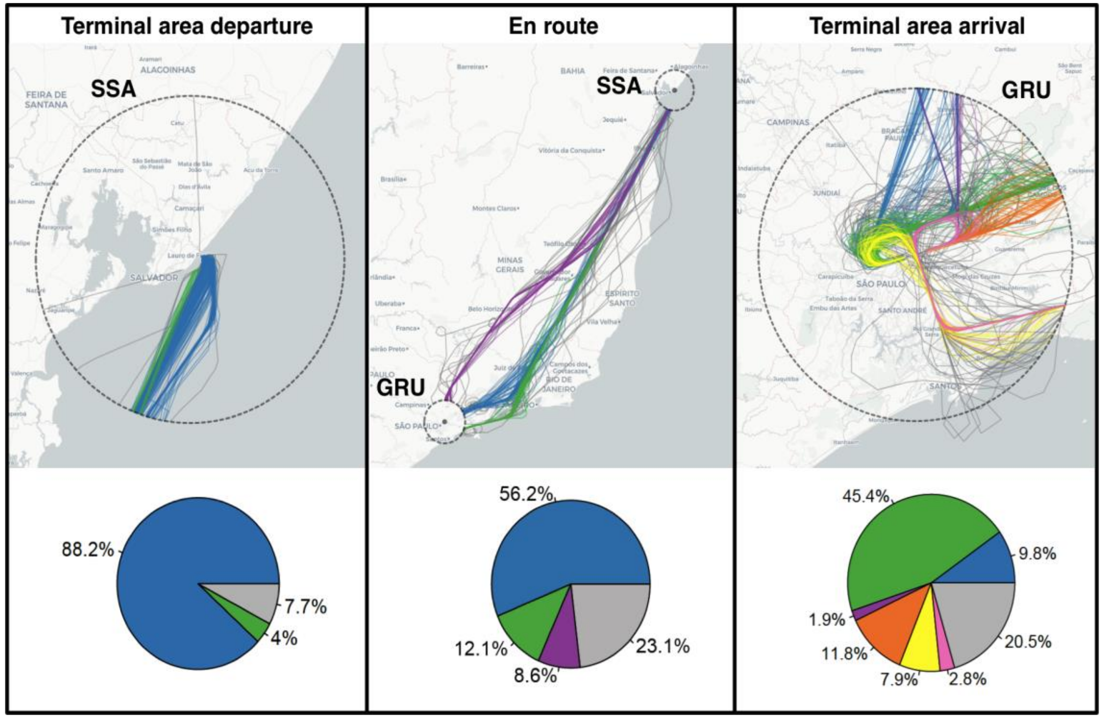
Coverage of flight operations (%)



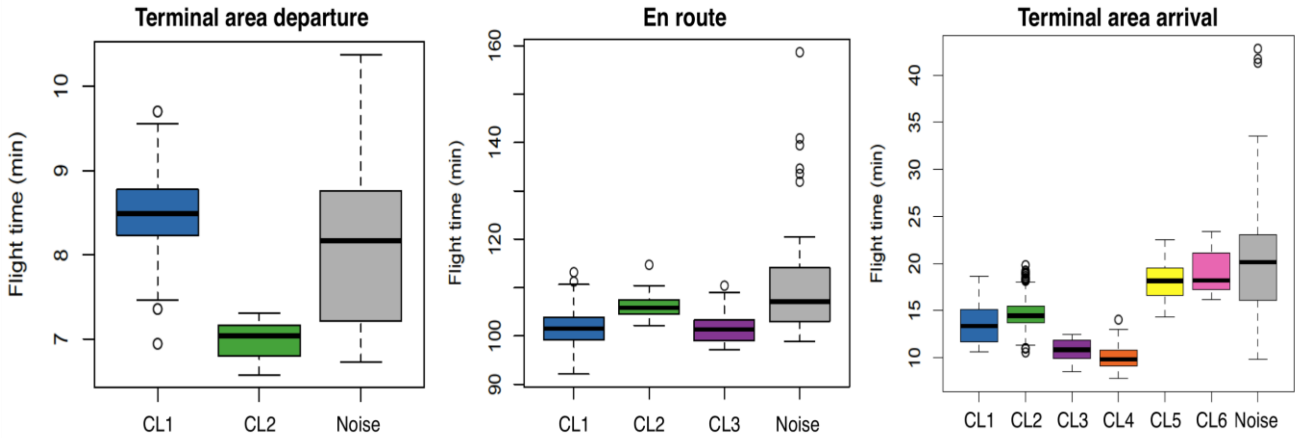
Results and discussion

Identification of air traffic patterns

Clusters of trajectories identified for the SSA-GRU pair



Distribution of flight times for the SSA-GRU pair

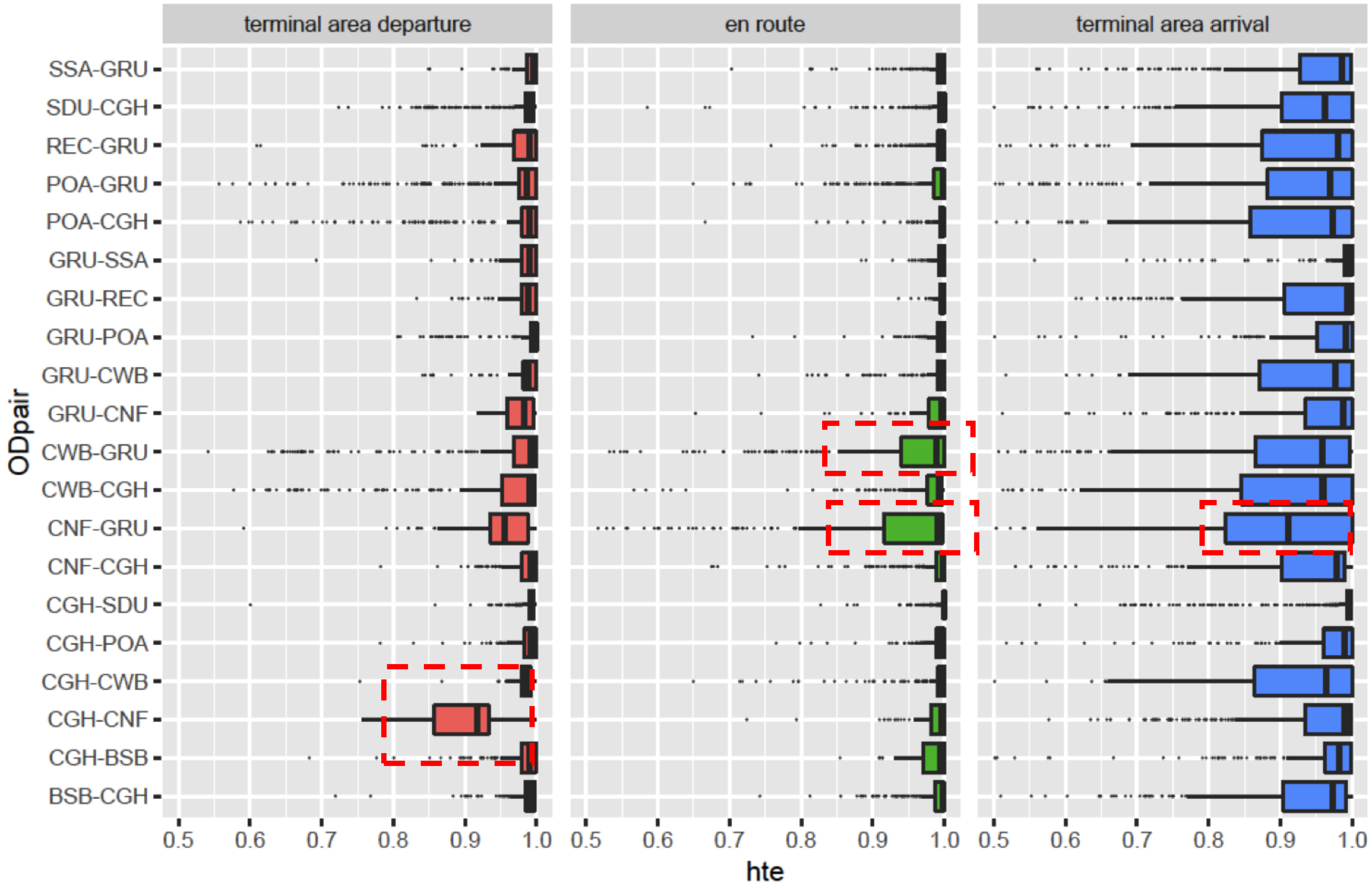


- Number of clusters identified by flight phase
- % of noise

Results and discussion

Assessment of traffic flow efficiency

HTE by flight phase for the top-20 OD pairs in Brazil



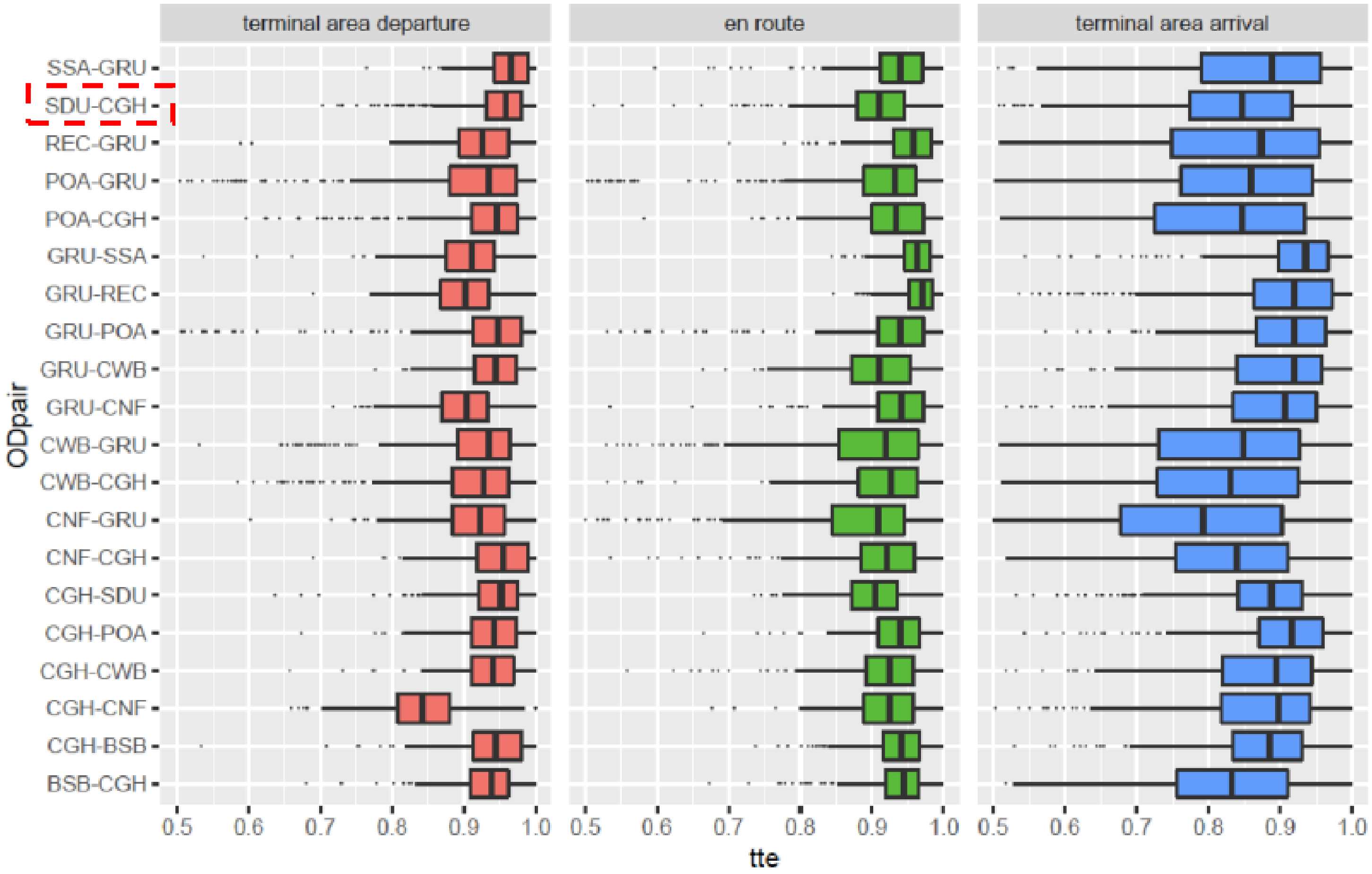
HTE 0.0 (Totally inefficient → 1.0 (Full efficient)

- Terminal area arrival phase - lowest efficiencies on average and highest variability in traffic flow efficiency; trajectories are less predictable; more complex operations
- Some traffic flows stand out

Results and discussion

Assessment of traffic flow efficiency

TTE by flight phase for the top-20 OD pairs in Brazil



- Similar behavior - HTE and TTE tend to be correlated

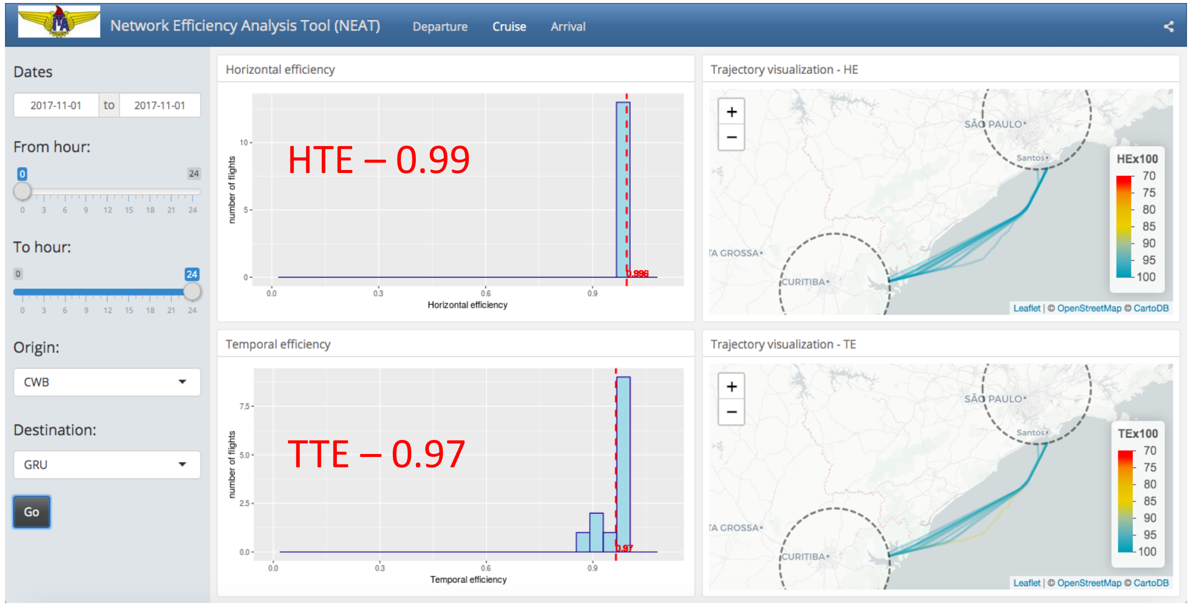
- SDU-CGH – suggest that delays on this route are more likely to be absorbed with speed control than route changes

Results and discussion

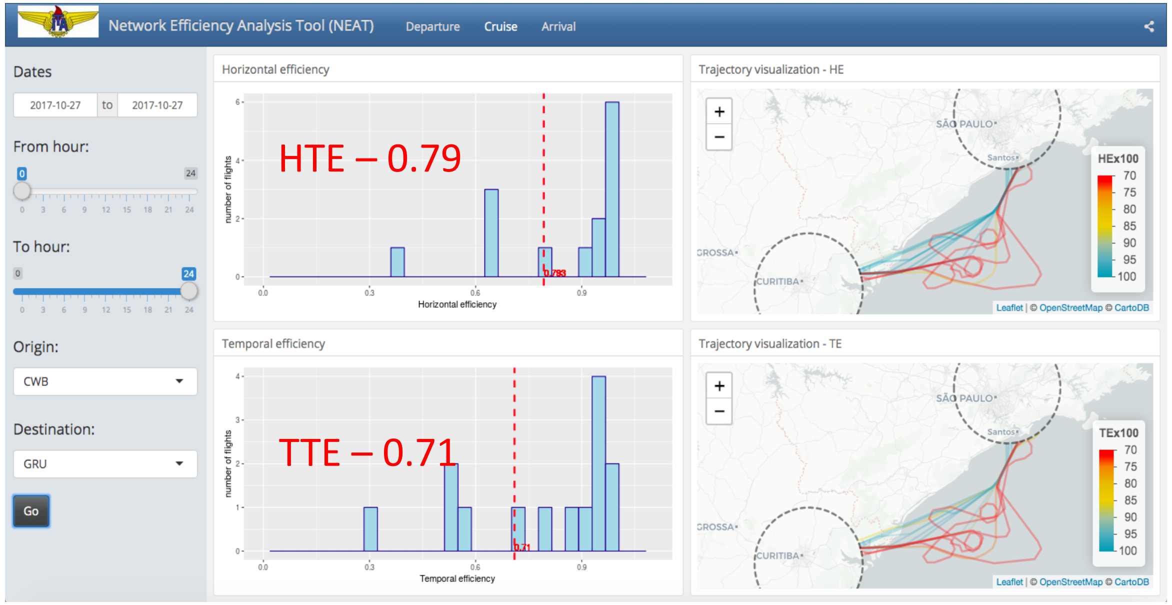
Network Efficiency Analysis Tool (NEAT)

interactive prototype tool for
air traffic performance analysis

Case 1 - clear weather day



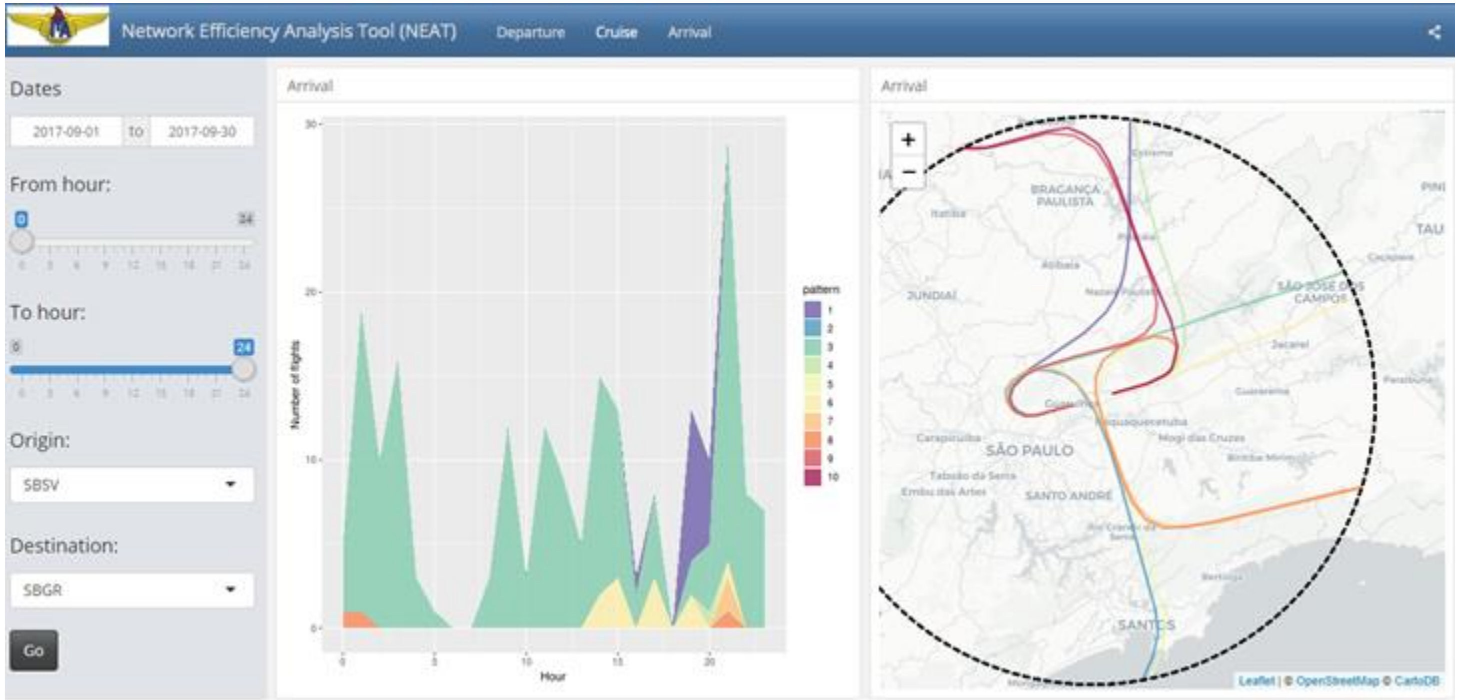
Case 2 - day with convective weather impacts



Functionality 1 - Assessment of traffic flow efficiency

Results and discussion

Network Efficiency Analysis Tool (NEAT)



NEAT´s prediction

Airspace design (complex)

Functionality 2 - Predict the performance of the system

Summary and next steps

Flight trajectory data analytics

- assessing the air traffic performance
- better understanding how this performance is affected by structural/operational factors
- sources of inefficiencies / new models and tools
- predict and control the performance of the system

prototype tool improvement by including new indicators/features

Thanks a lot!

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