INTERFACING

An **INteracTion mEtRic For An effiCient traffIc demaNd manaGement**: requirements for the design of data-driven protection mechanisms

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Aslogic

EUROCONTROL ZOOM – TC2 3rd workshop

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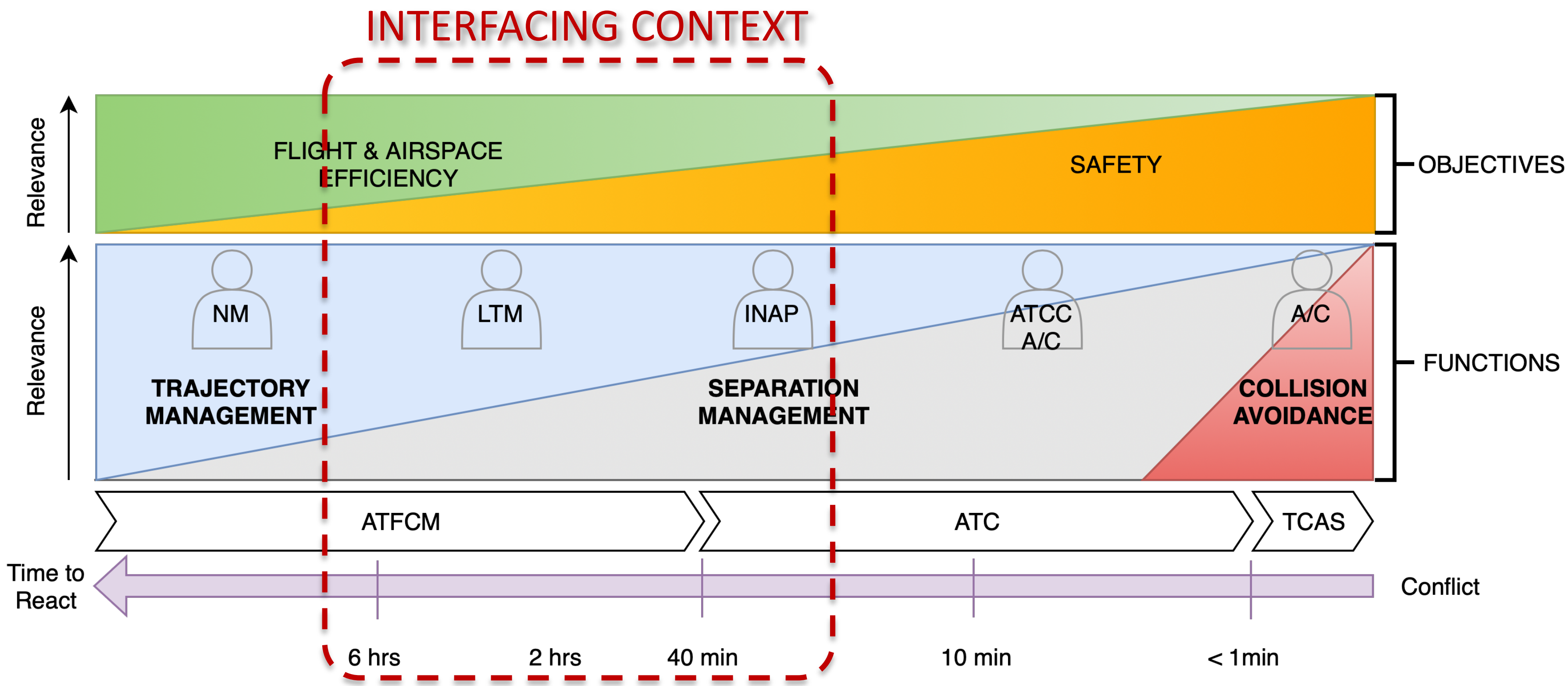
Outline

- Introduction
- INTERFACING concept
- Validation and Results
- Conclusions and next steps

Introduction: ATM Context & motivation



Limited integration

- **loss of effectiveness** due to the limited integration between the layered planning DST's

Lack of metrics

- **no interaction metrics** in a time frame ranging from the LTM and the INAP.

Network effects

- negative effects at **network level** due to lack of analysis of interdependencies among local measures

INTERFACING objectives

GOAL

To enhance Demand Capacity Balancing with a digitalization tool to gain a better understanding of mitigation measures efficiency, such as regulation

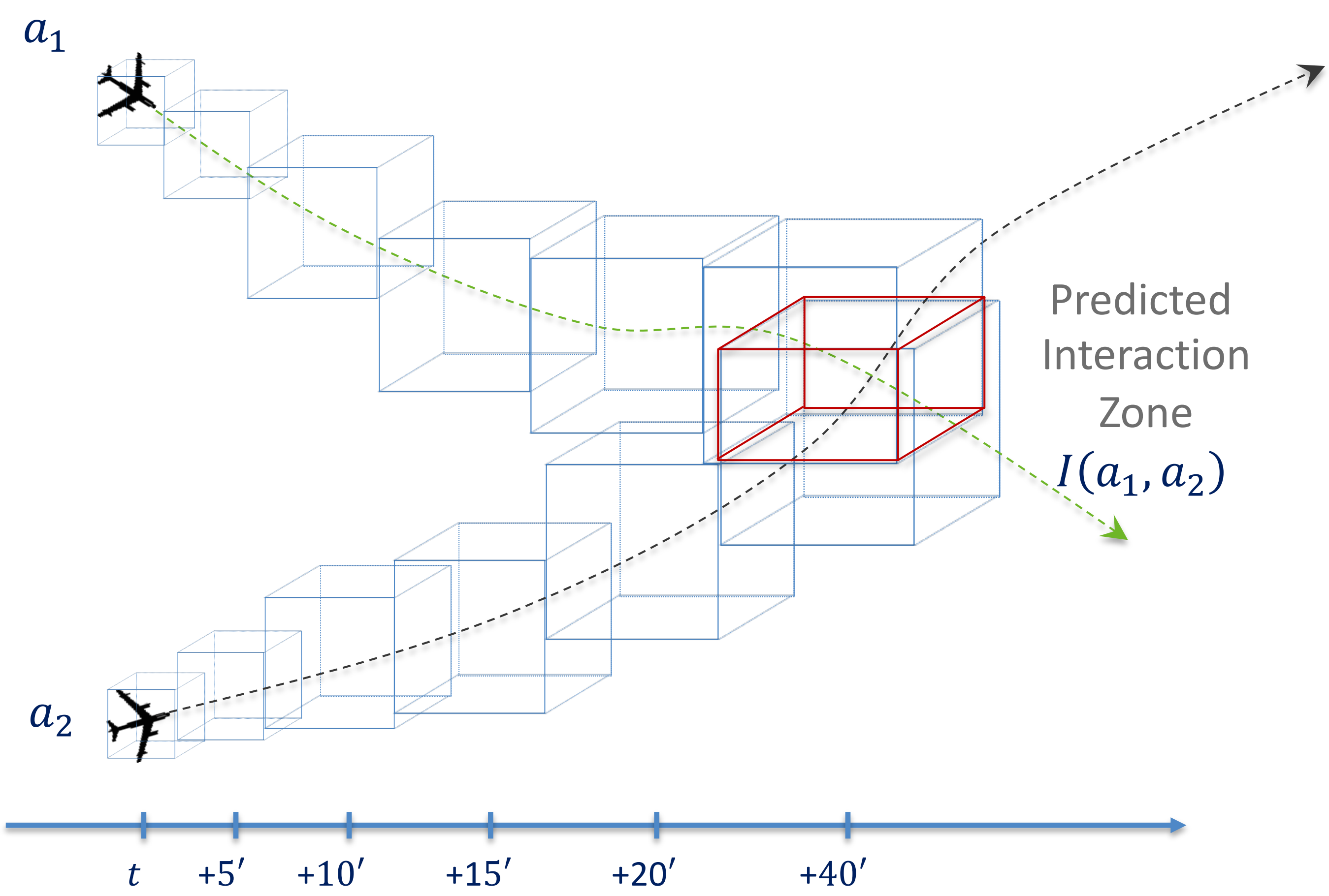
A formal probabilistic framework

- To detect and characterize at network level the flight interactions and their interdependencies by considering TP uncertainty.

New interaction metrics

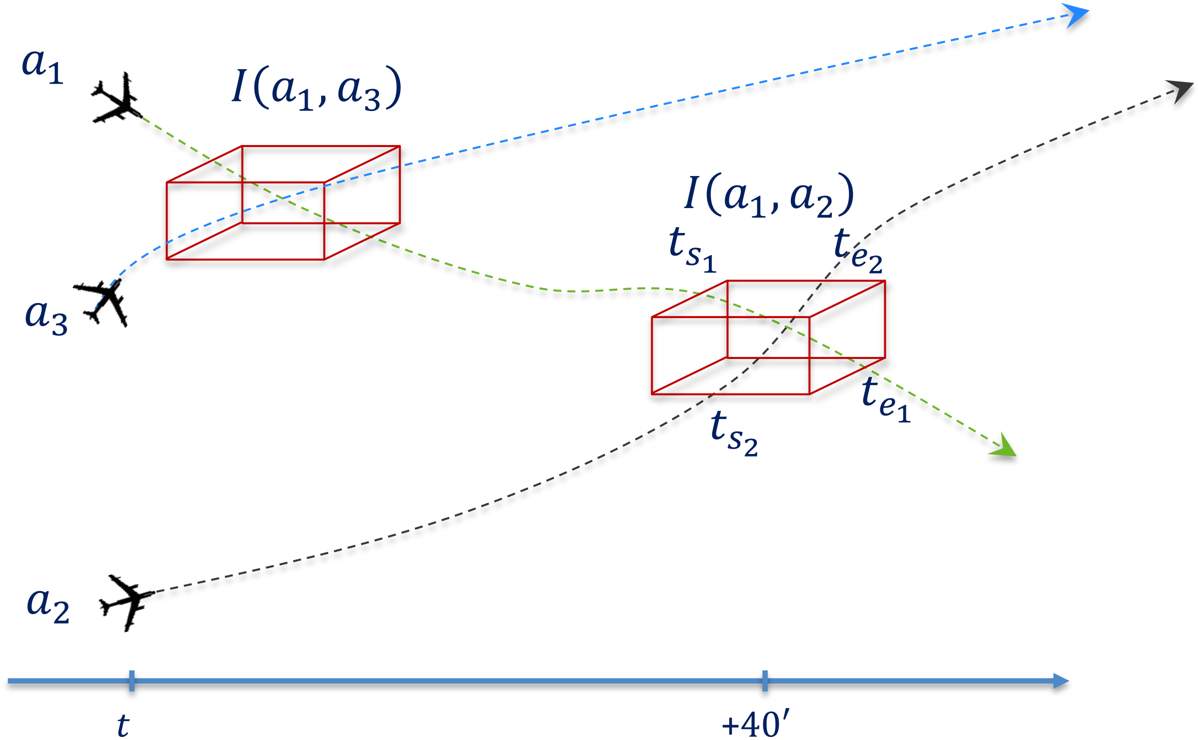
- To pave the way for the design of mitigation measures for a smooth fine tuning of traffic demand at micro level while considering the effects at macro level in order to improve the network performance.

O1: To identify Interaction Zones



Spatiotemporal interactions: identification of airspace volumes in which more than one aircraft could co-exist

O2: Interaction Zones interdependencies



Analysis of the spatiotemporal interdependencies among the Interaction Zones

INTERFACING objectives

O1: To identify Interaction Zones

O2: Identify Interaction Zones interdependencies

O3: Local and Distributed Interaction Metric

- sector entry and occupancy metrics to be enhanced with the new interaction metrics that provide a spatio-temporal characterization of the Interaction Zones

O4: Efficient Regulation support

- by enhancing Demand Capacity Balance with a supporting tool aimed to predict the positive and negative impact of upstream/downstream Interaction Zones dynamics

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INTERFACING concept

Probabilistic framework

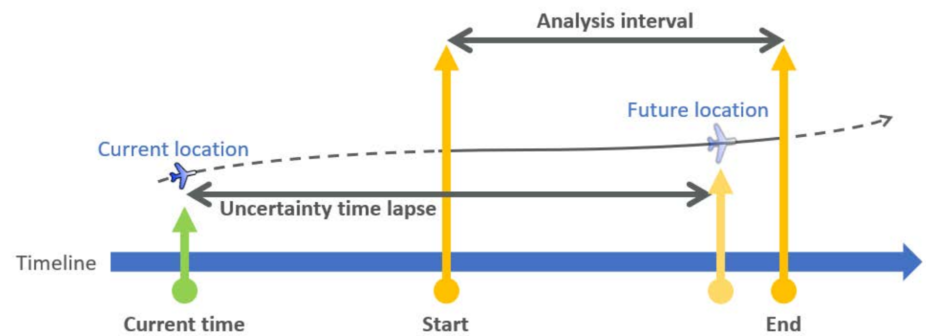
- **Characterization of the interaction zones** that may appear,
- **Existence Probability**, the probability that the detected interactions zones will finally take place,
- **Complexity** of each interaction zone,
- **Interdependencies** between interaction zones.

A Demonstration suite

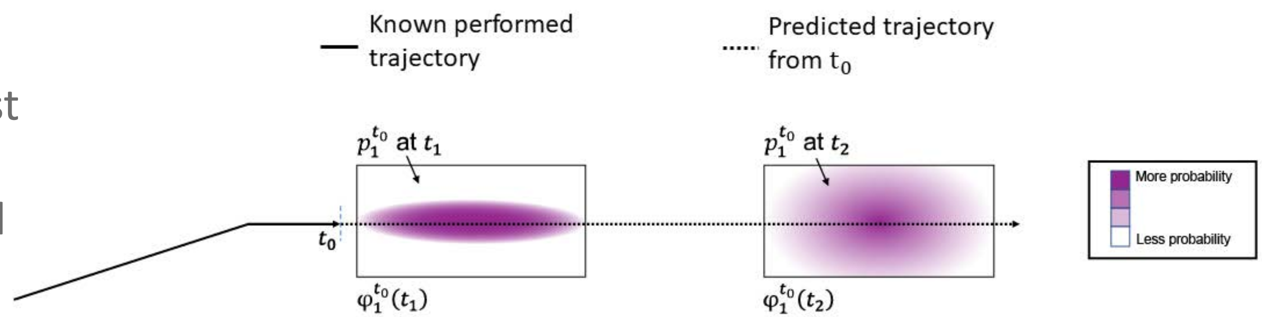
- A library of functional blocks that works as a pipeline to facilitate the federation of the developed features with existing tools (e.g. RNEST)
- **AsloEarth**, a visualization tool to graphically show the results and metrics produced by the interaction zone analysis.

Dealing with uncertainty in space and time

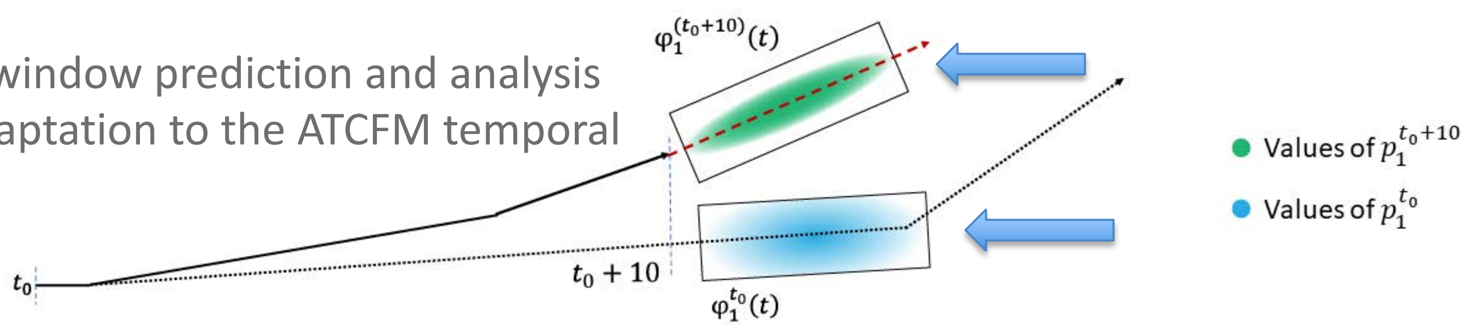
The Detection Window is the time interval in which INTERFACING analyses the aircraft position uncertainty and looks for IZs.



INTERFACING uses the last known trajectory data (periodically ingested and updated)



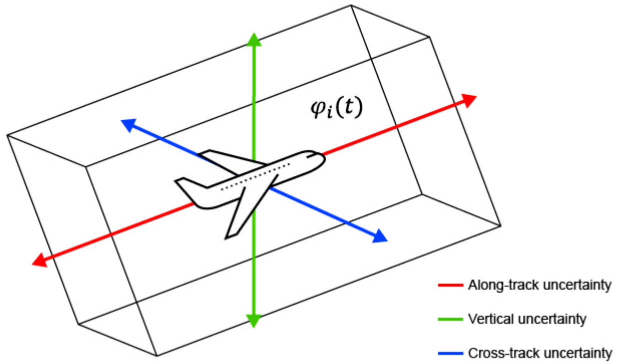
Sliding time window prediction and analysis for better adaptation to the ATCFM temporal phases



Pairwise Interaction Zone

Spatial Characterization

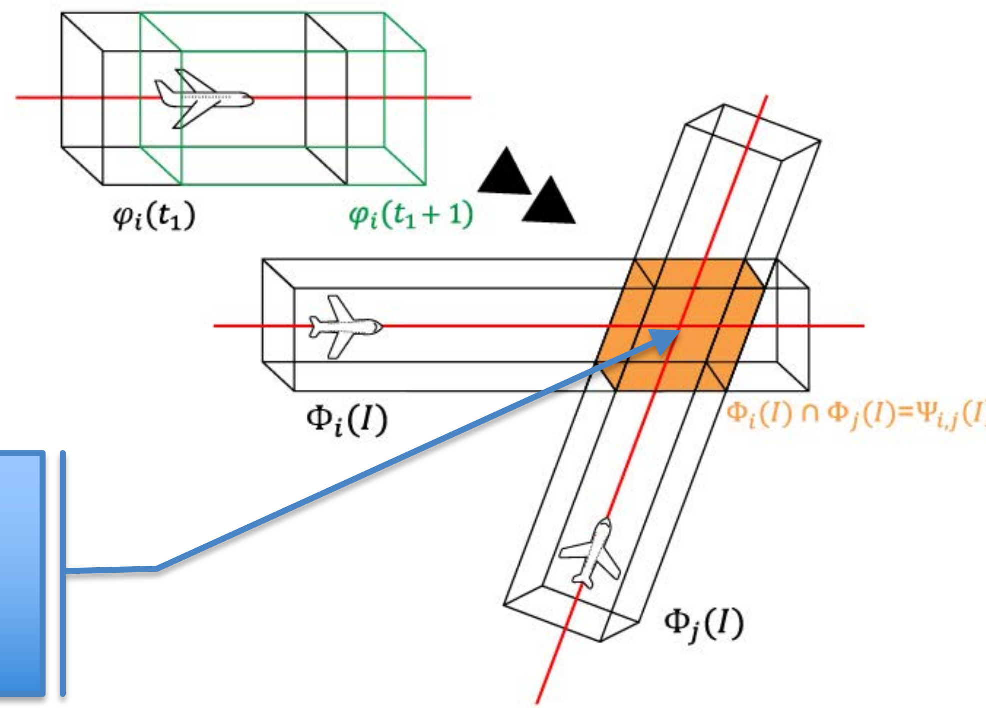
Spatio-temporal Characterization



$$\varphi_i(t)\colon \mathbb{R} \longrightarrow U_i \subseteq \mathbb{R}^3$$

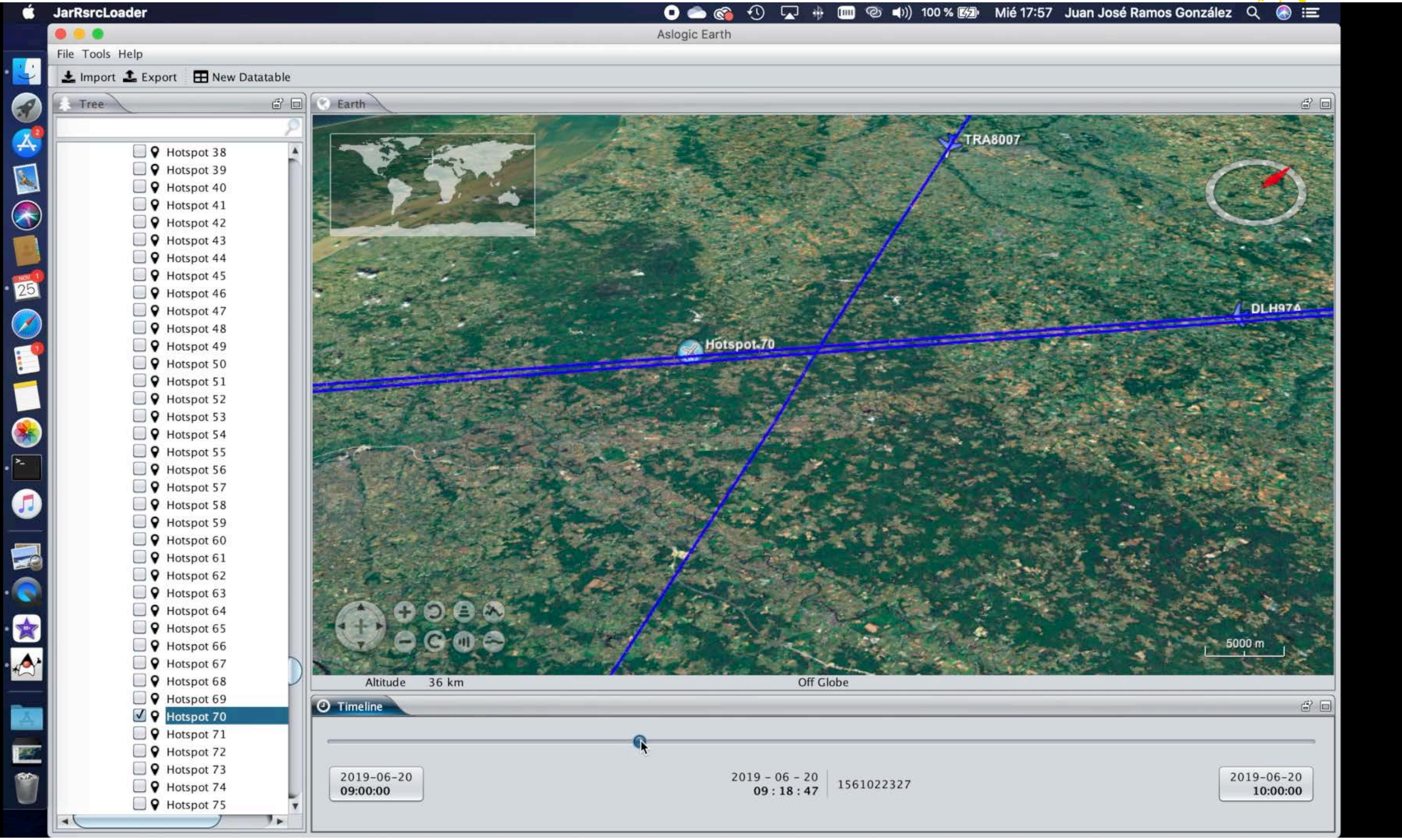
$$I = \left[t_{i+k}, t_{i+(k+l)}\right] \quad with \quad k + l \leq th$$

$$\Phi_i(I) = \bigcup_{t\in I} \varphi_i(t)$$



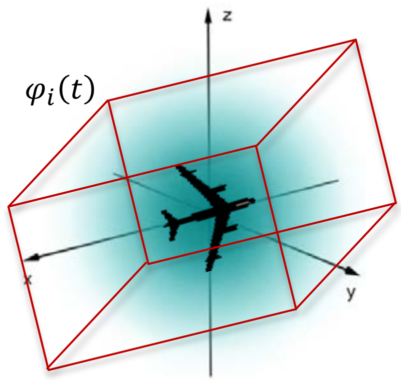
Pairwise Coexistence Interaction Zone

Pairwise Interaction Zone



Pairwise Interaction Zone

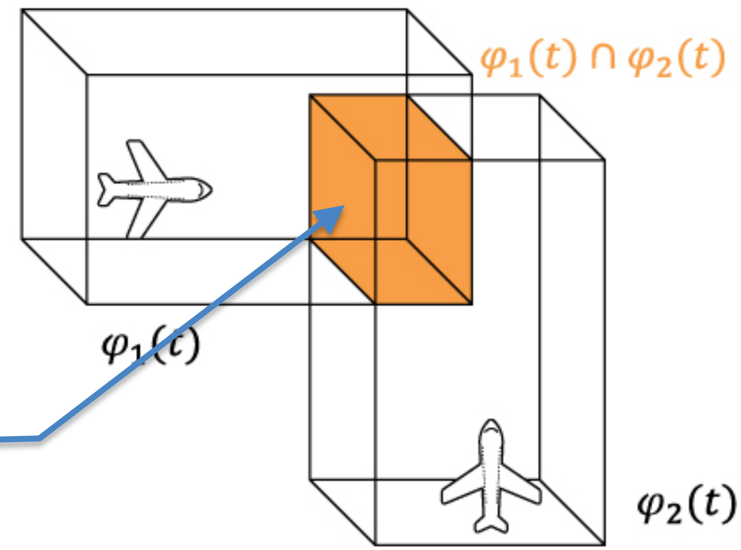
Probabilistic Characterization → Existence Probability



$$\varphi_i(t)\colon \mathbb{R} \longrightarrow U_i \subseteq \mathbb{R}^3$$

$$\int_{\varphi_i(t)} p_i(\mathrm{t}, \vec{x})\, d\vec{x} = 1$$

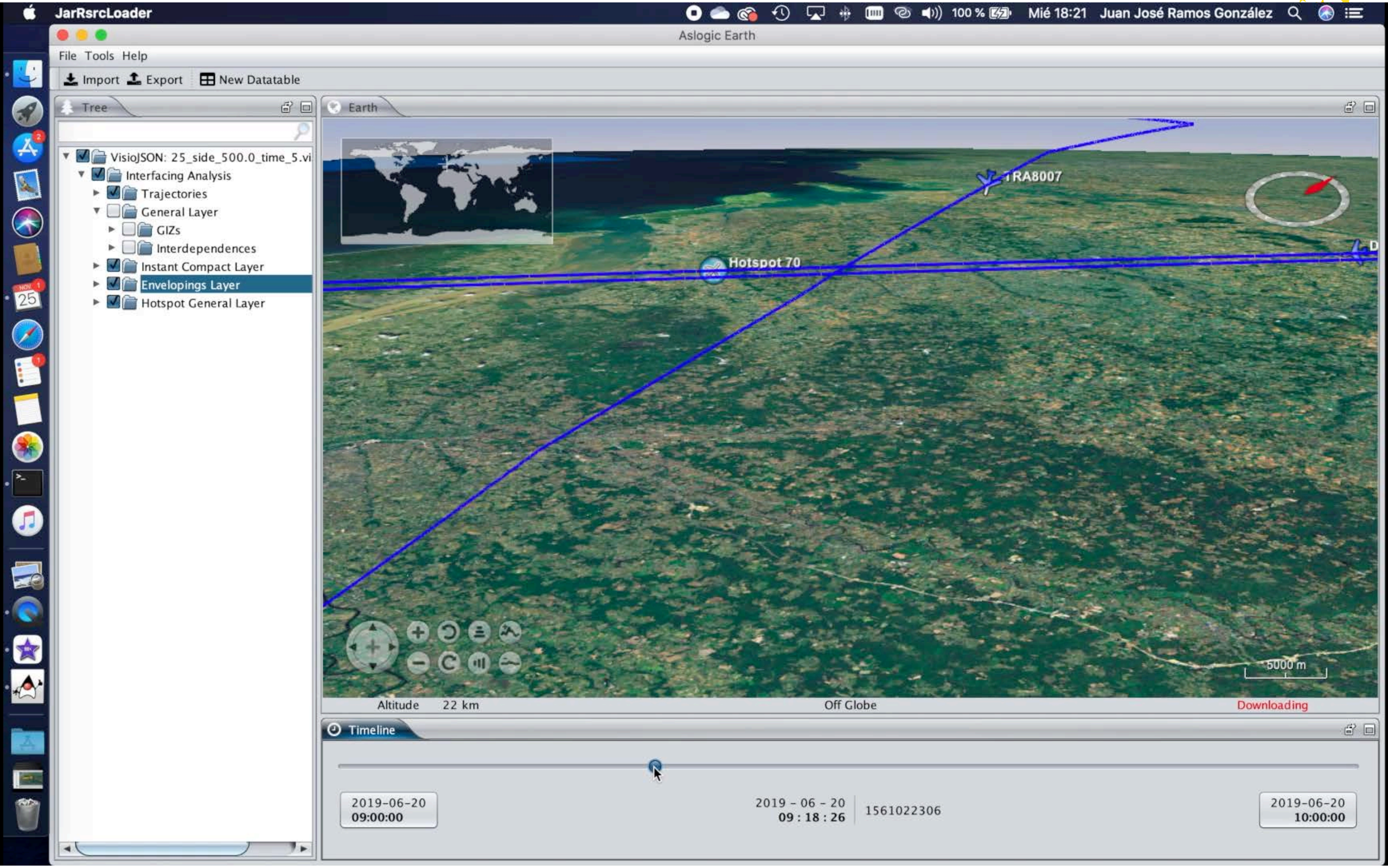
$$I = \left[t_{i+k}, t_{i+(k+l)}\right] \quad with \quad k + l \le th$$



Pairwise Coexistence Interaction Zone

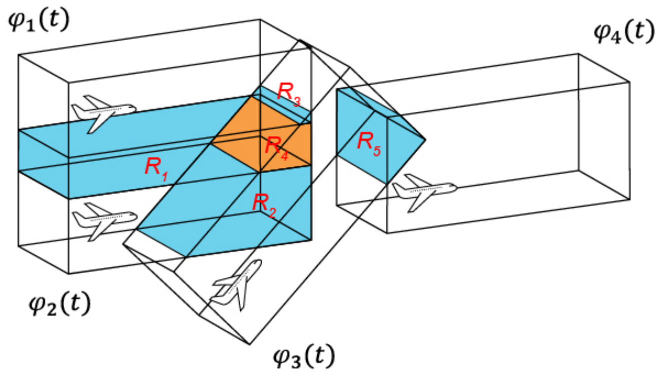
$$EP(\mathrm{t}) = \int_{\varphi_1(t)\cap\varphi_2(t)} p_1(t, \vec{x})\, d\vec{x} \cdot \int_{\varphi_1(t)\cap\varphi_2(t)} p_2(t, \vec{x})\, d\vec{x}$$

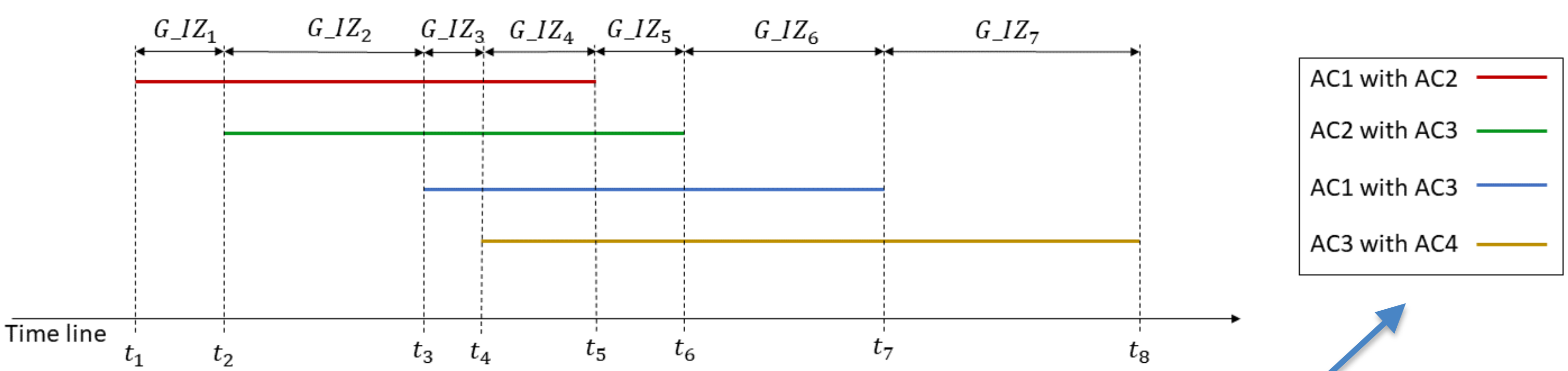
Pairwise Interaction Zone



Generalized Interaction Zone

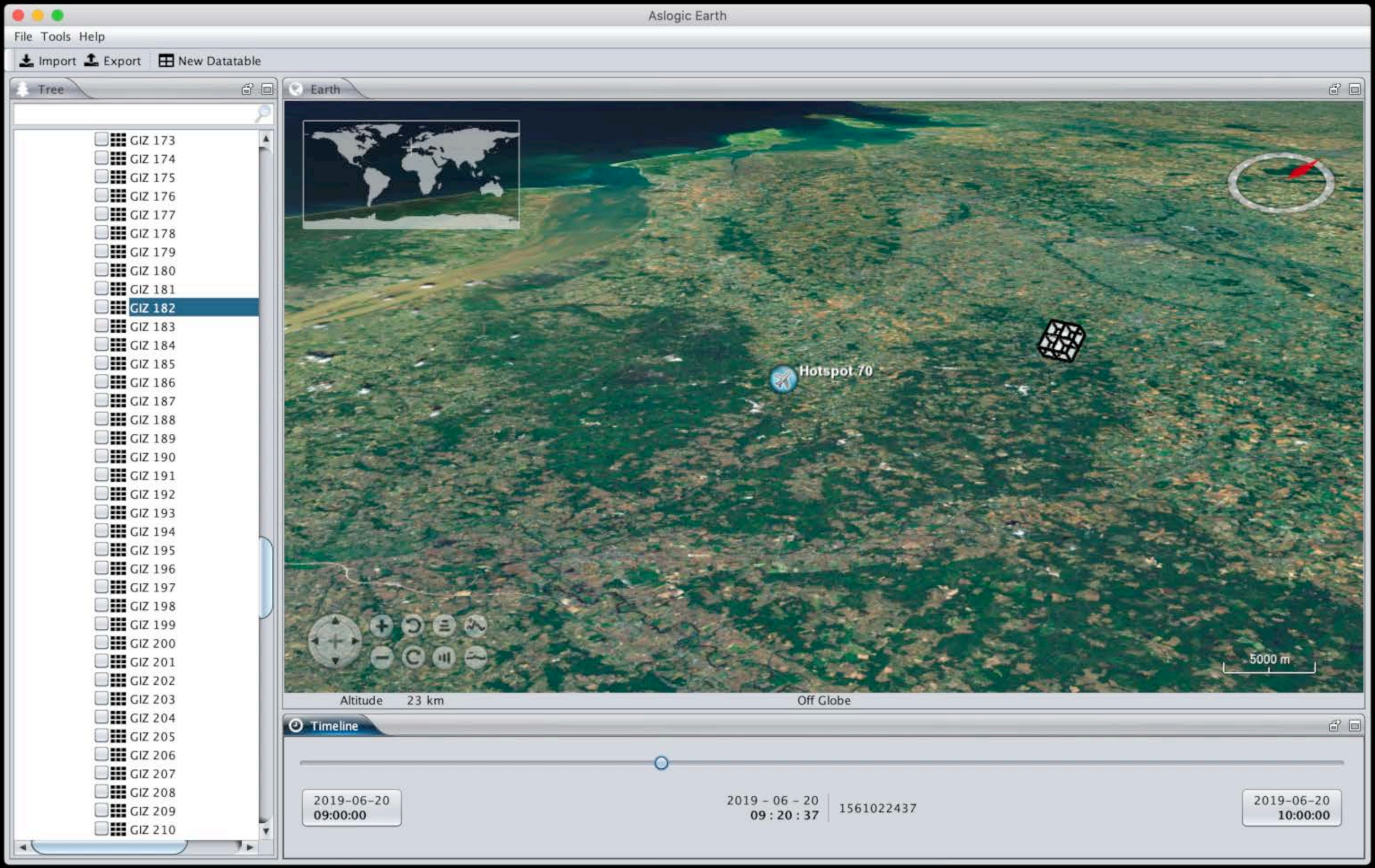
Spatial Characterization → Spatio-temporal Characterization





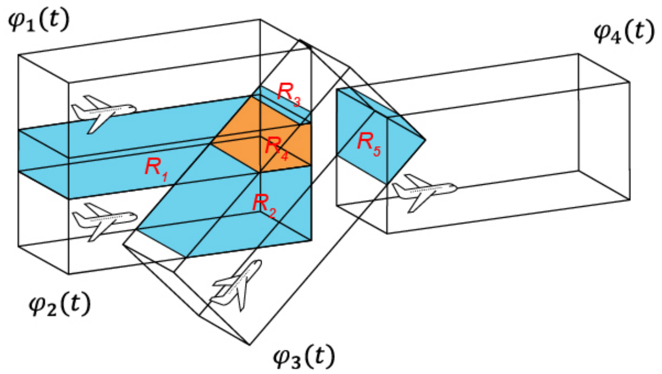
Pairwise Interaction Zones

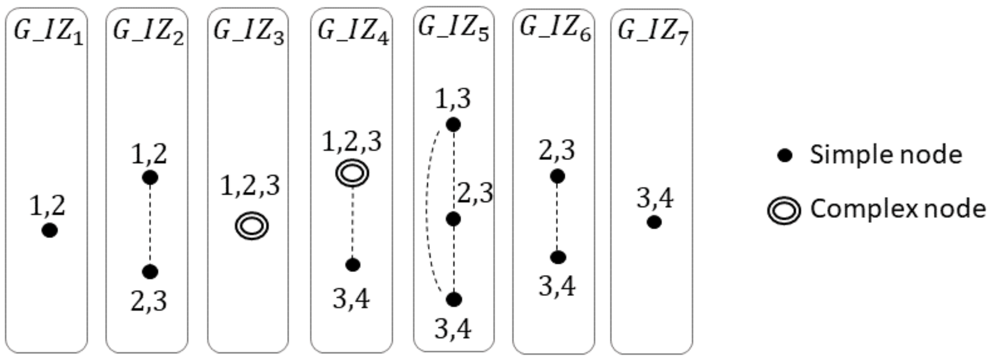
Generalized Interaction Zone

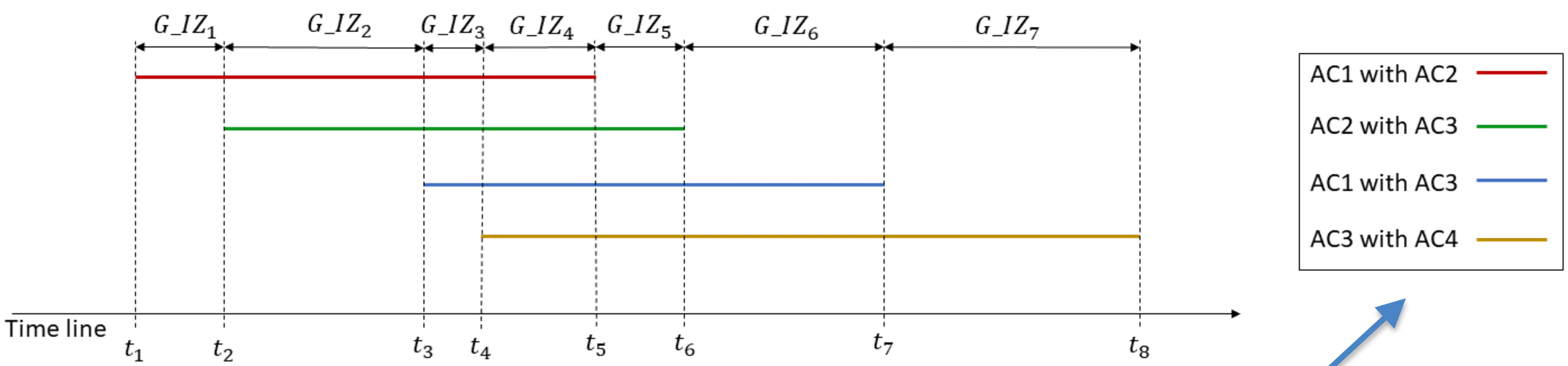


Interaction Zone Graph

Spatio-temporal Characterization → Intrinsic structure (Nodes)





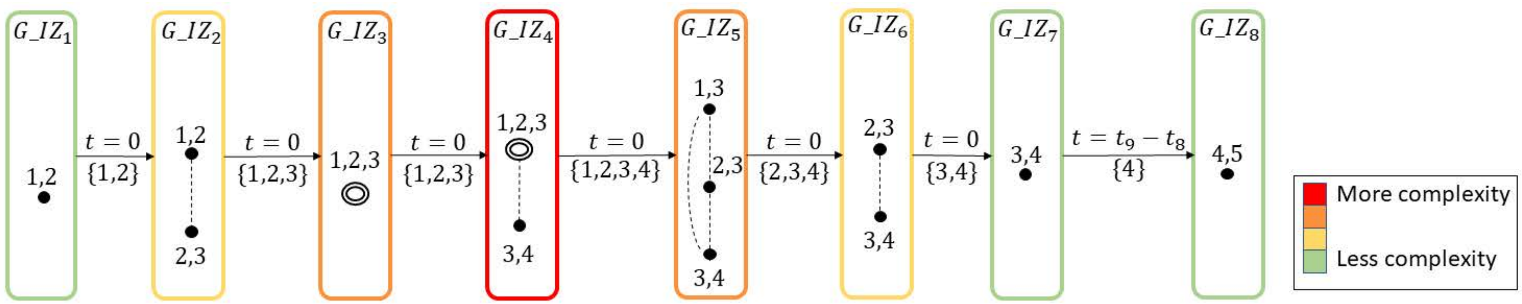


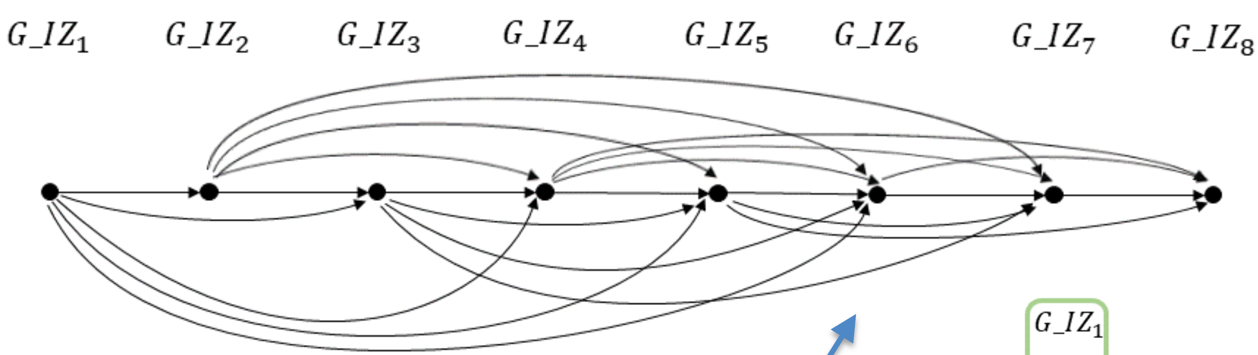
Pairwise Interaction Zones

Interaction Zone Graph

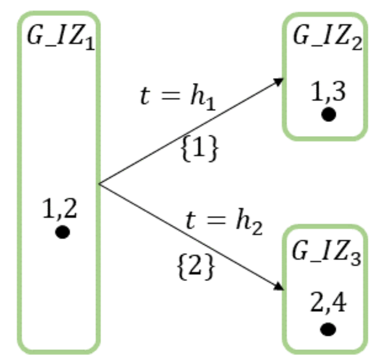
Graph nodes

Interaction Zone Interdependencies

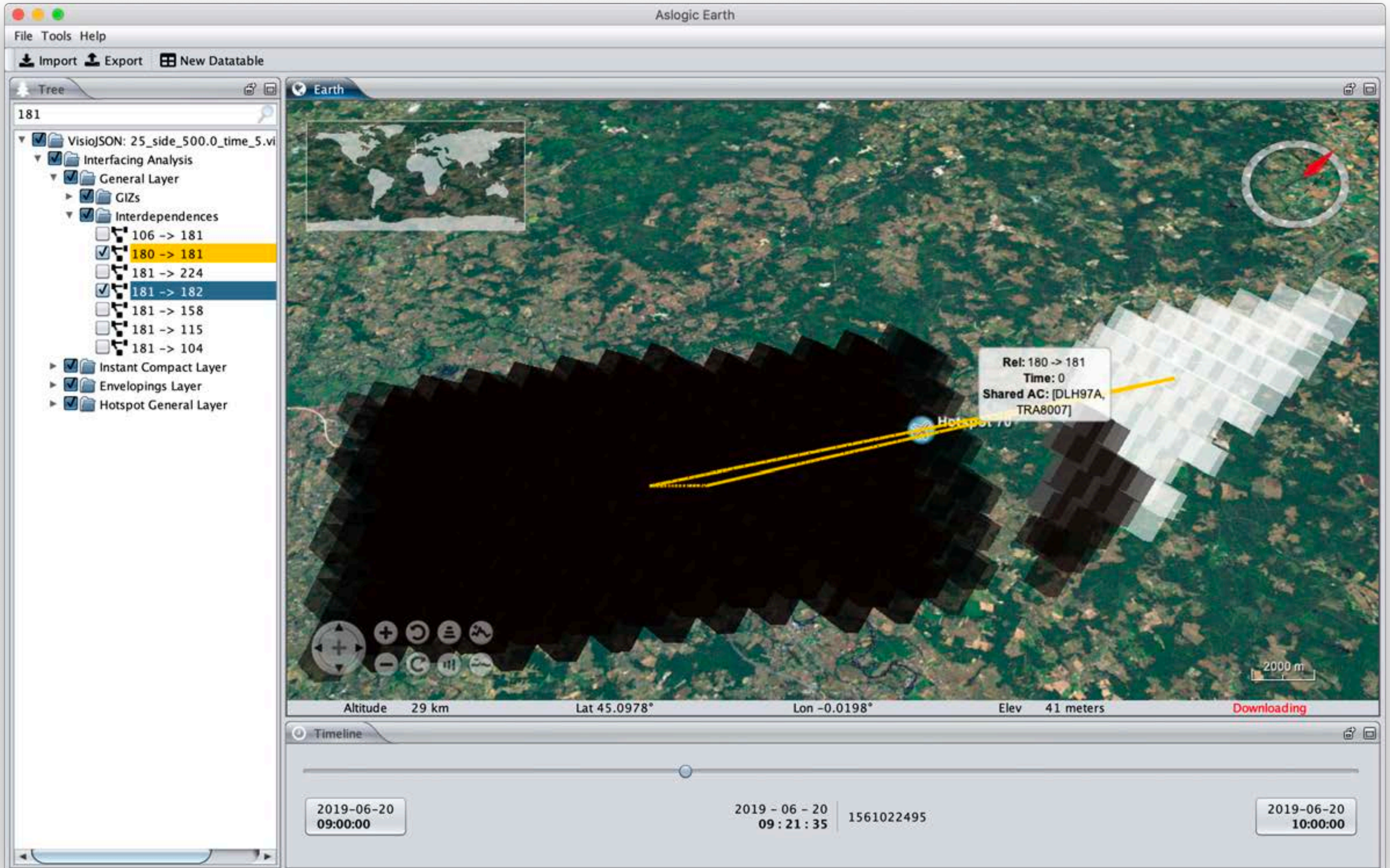




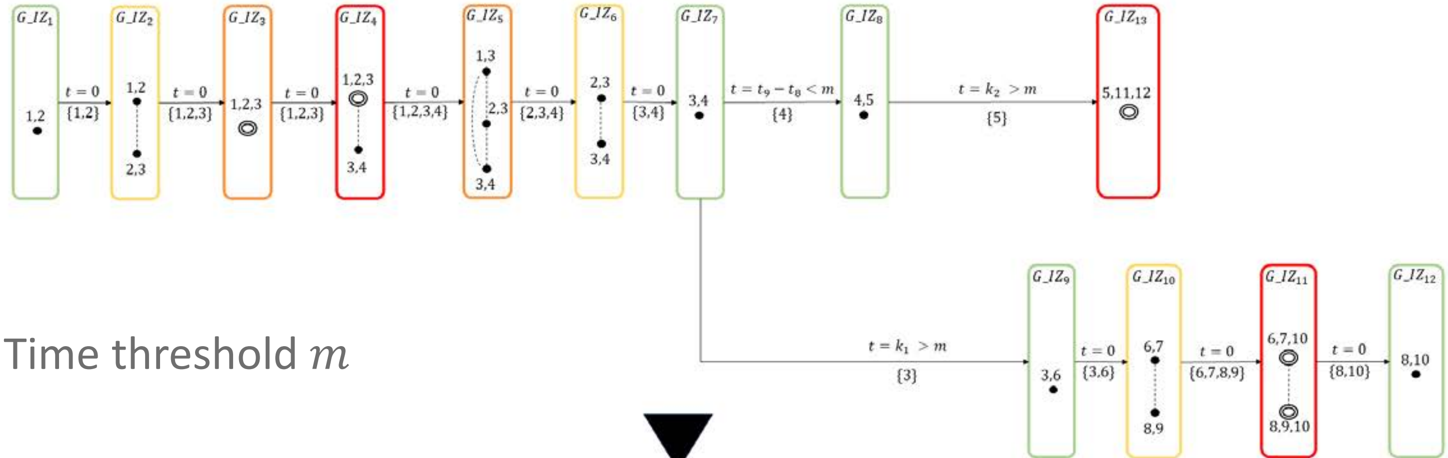
Interaction Zone Interdependency Flows



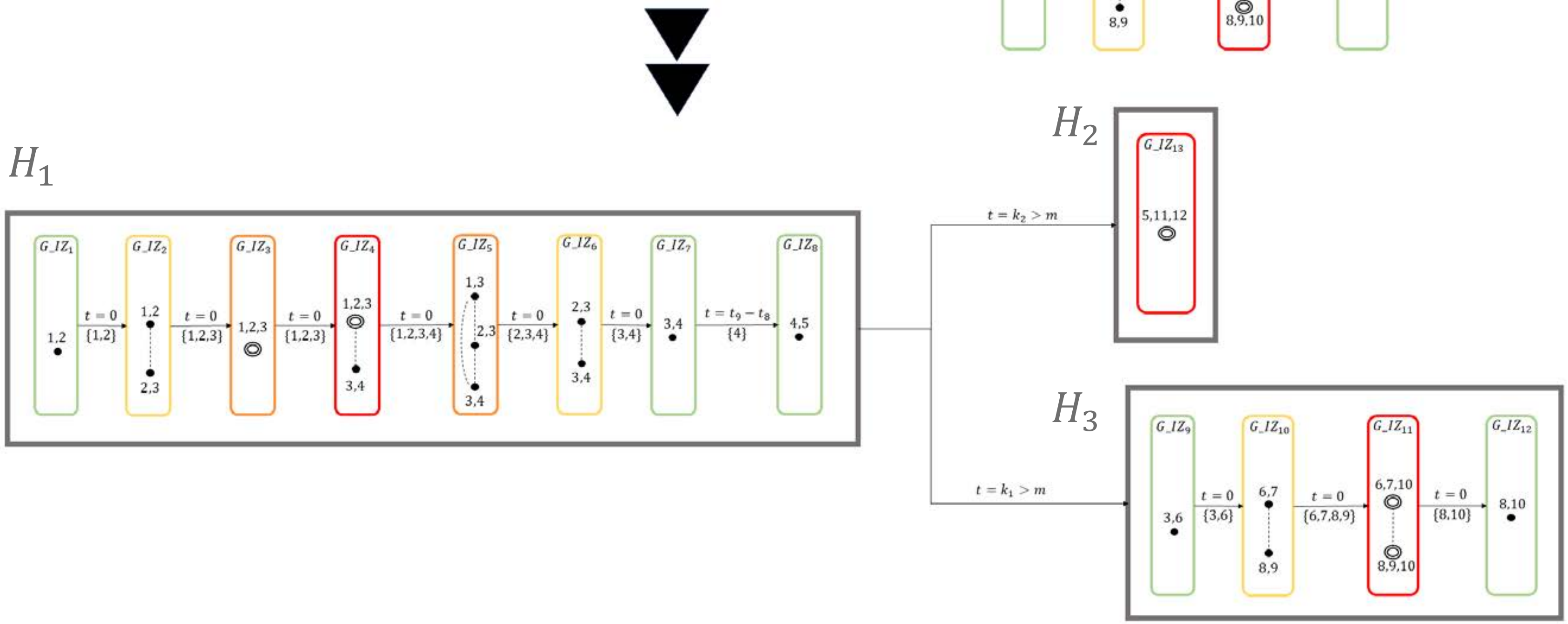
Interaction Zone Graph



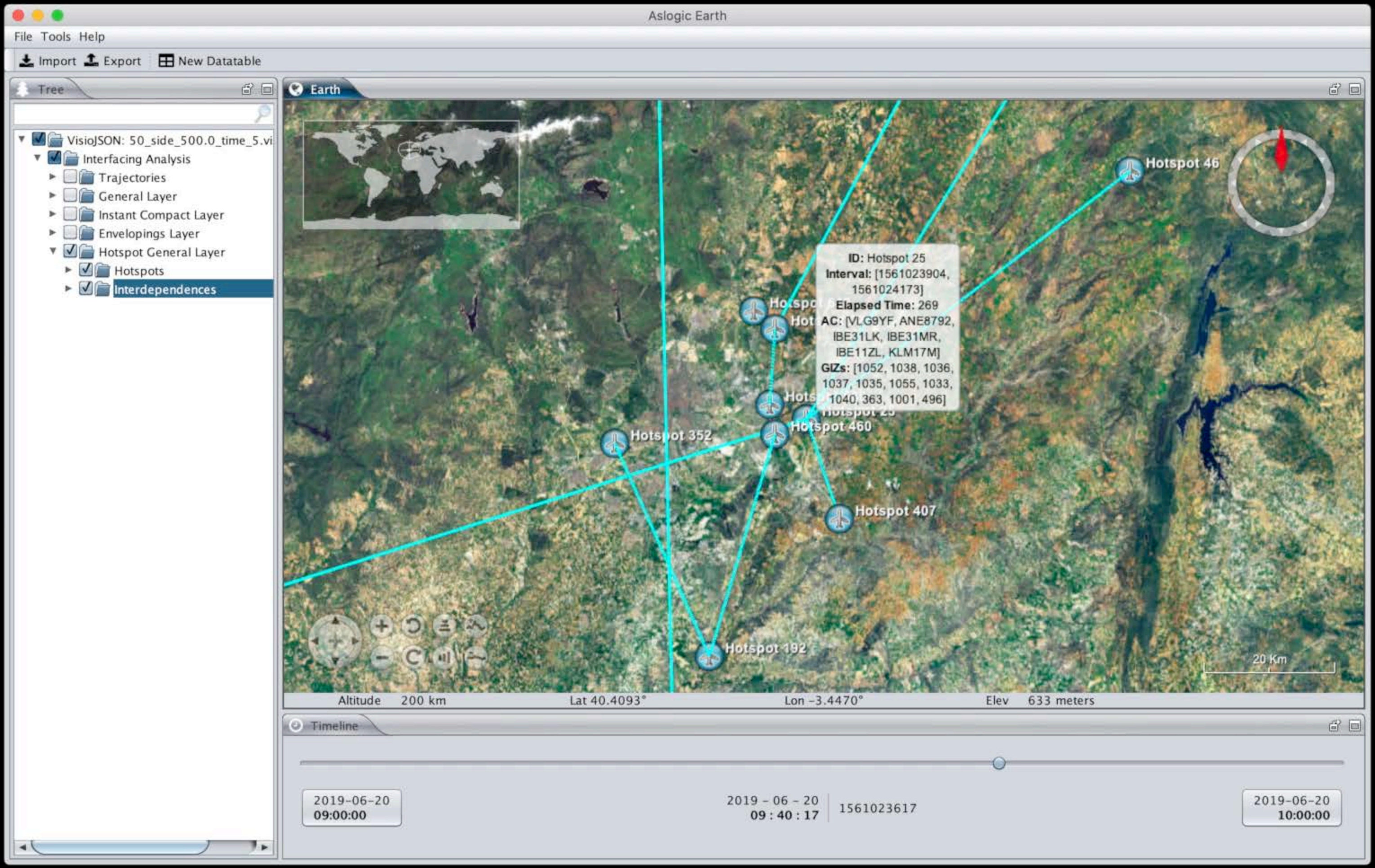
Hotspot: Interaction Zone aggregation



Time threshold m



Hotspot: Interaction Zone aggregation



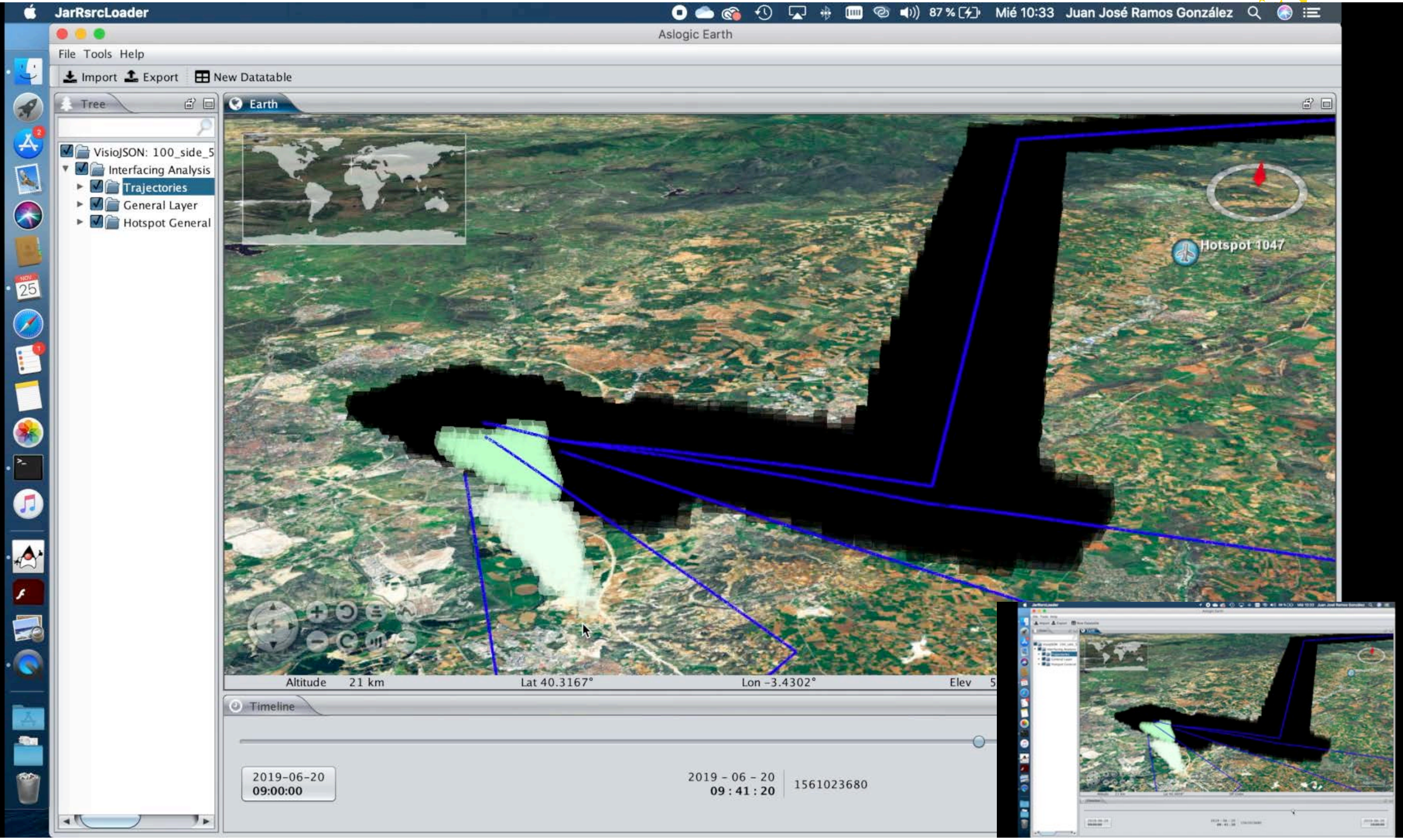
Interaction Zone Metrics

KPI	Name	Description
M1	Spatio-temporal characterization	time interval when an *IZ* occurs and the airspace location where it happens
M2	Existence probability	the probability of an *IZ* to actually occur
M3	Involved Aircrafts	number of aircrafts that are interacting in a *IZ*
M4	Complexity	Calculated from the intrinsic structure (graph nodes) at the *IZ*

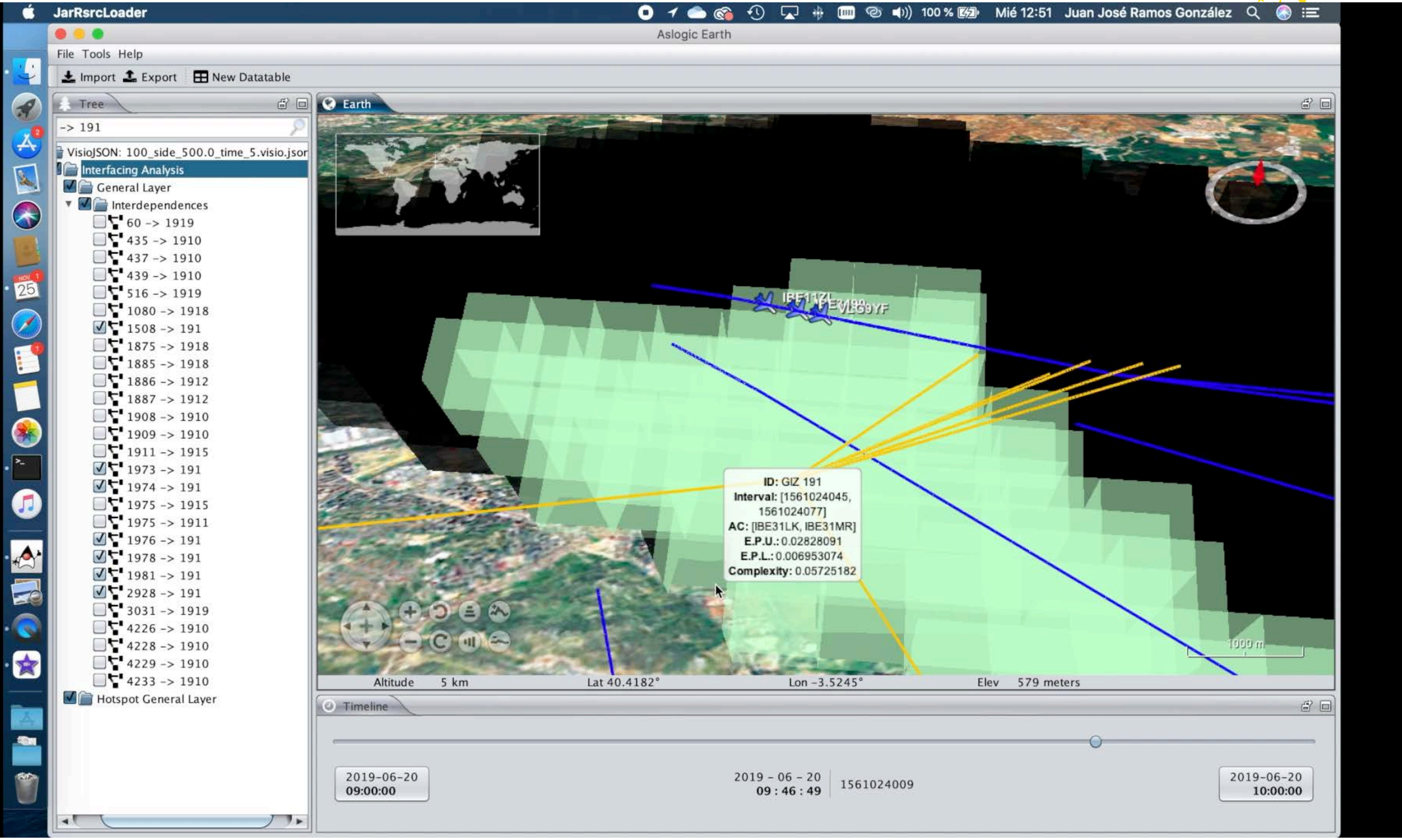
These metrics can be aggregated for airspace volumes.

For example, an airspace sector can be analysed with the aggregated information of all the *IZ*s it contains.

Interaction Zone Metrics



Interaction Zone Interdependencies



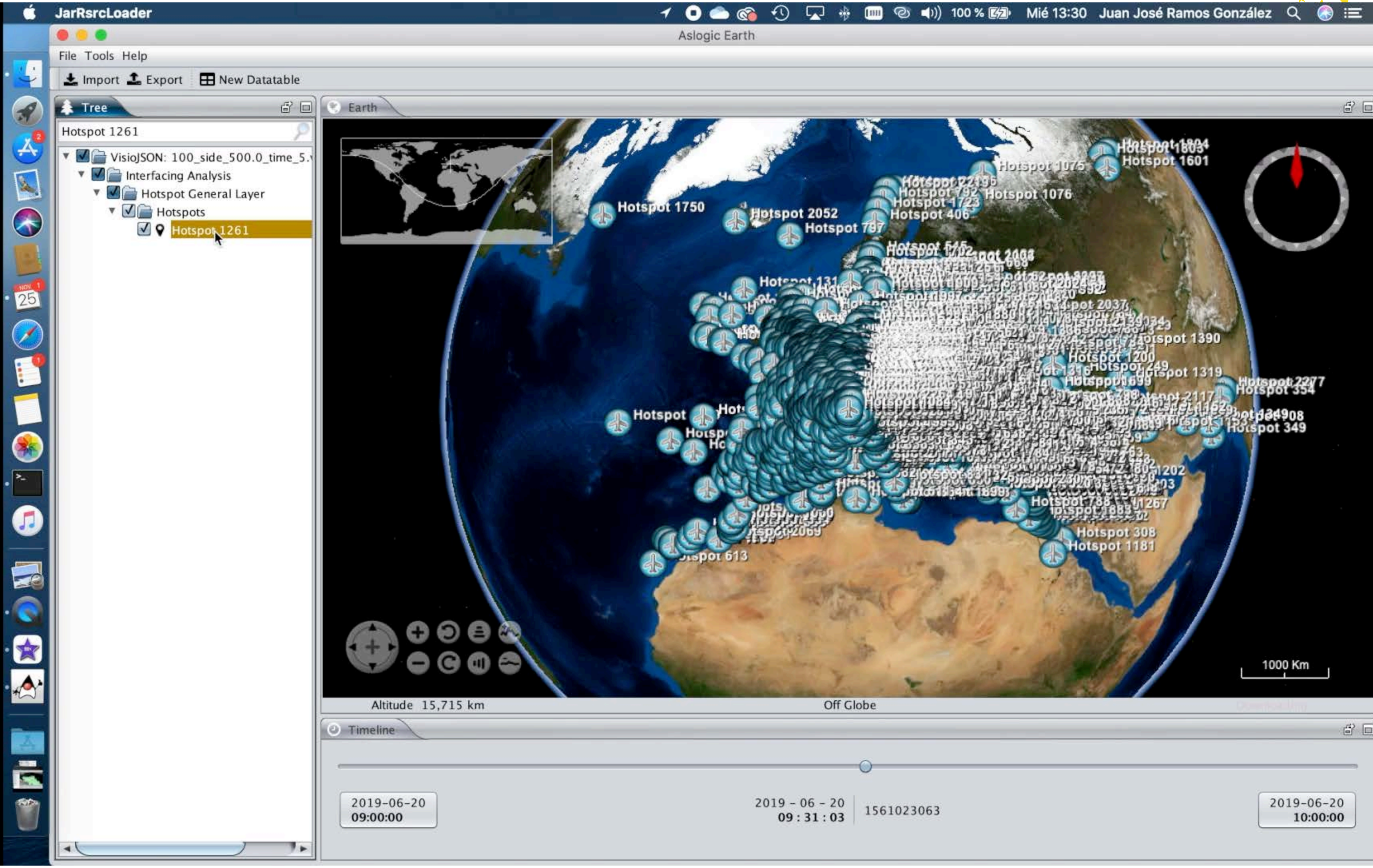
Hotspot Metrics

KPI	Name	Description
M5	Elapsed time	time calculated as the difference between first *IZ* start and last *IZ* end
M6	Time separation	Time separation between hotspots that are related because of sharing aircrafts
M7	Shared Aircrafts	Which and how many aircraft are shared amongst hotspots
M8	Persistence	Areas where a number of hotspots tend to happen recurrently

Time separation might be useful to analyse the downstream effect of mitigation measures.

A hotspot lasting for too long might require specific measures on the involved aircrafts

Hotspot Metrics



Project objectives vs proposed metrics

	Objective	Metrics
O1	To identify Interaction Zones	M1, M2, M3, M4
O2	Identify Interaction Zones interdependencies	M5, M6, M7
O3	Local and Distributed Interaction Metric	M2, M3, M4, M8

O4: Efficient Regulation support

- The proposed metrics can provide a measure of the positive and negative impact of upstream and downstream Interaction Zones dynamics

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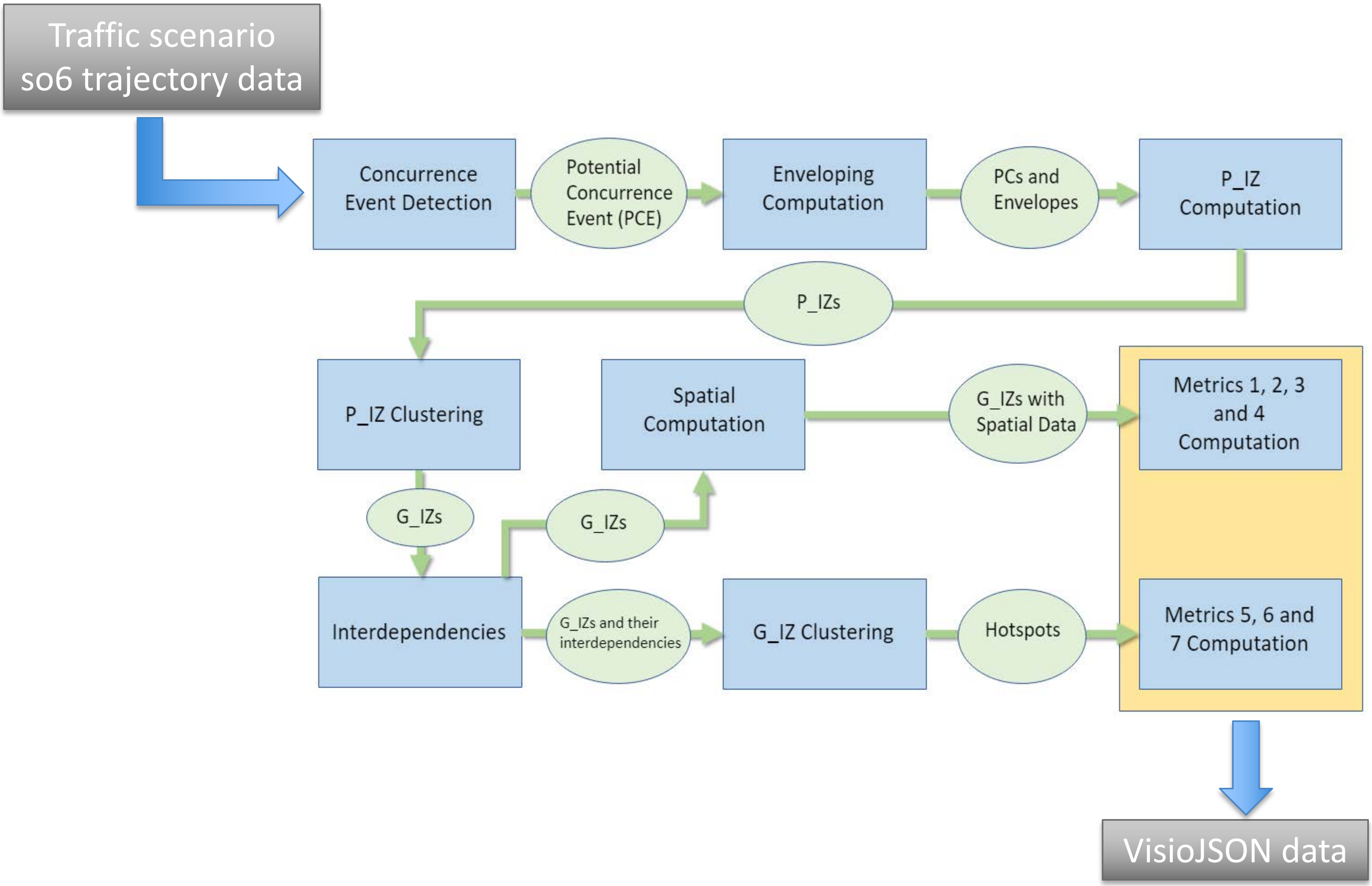
INTERFACING algorithm workflow



Real scenarios, quantitative and qualitative validation

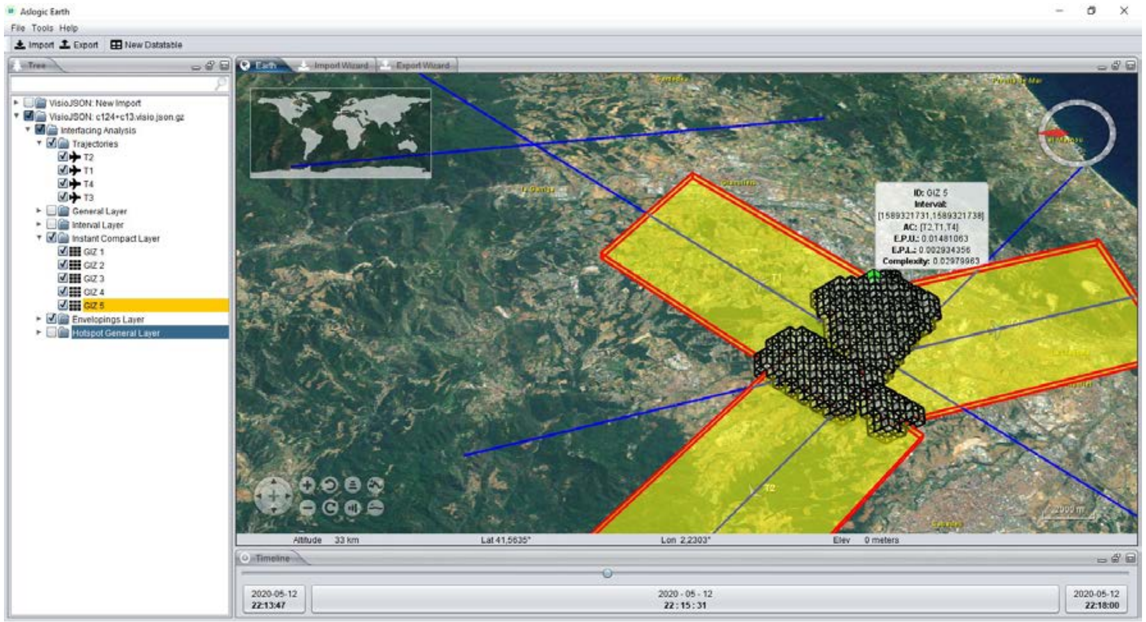
Approach: analyse how indicators based on INTERFACING metrics react to changes in the traffic density.

Case study: m1 version of June 2019 SO6 files from DDR2 repository. Time filters are applied to focus on peak periods (high traffic concentration)

Quantitative analysis: variations of the Spatial Discretization (minimum voxel side length) and the Time Discretization tuning parameters. Changing these parameters will modify the results of the algorithm and its execution time performance.
Goal: trade-off analysis between algorithm speed and result's accuracy.
Benchmark: default setup with a minimum voxel side of 300 meters and a time discretization of 3 seconds.

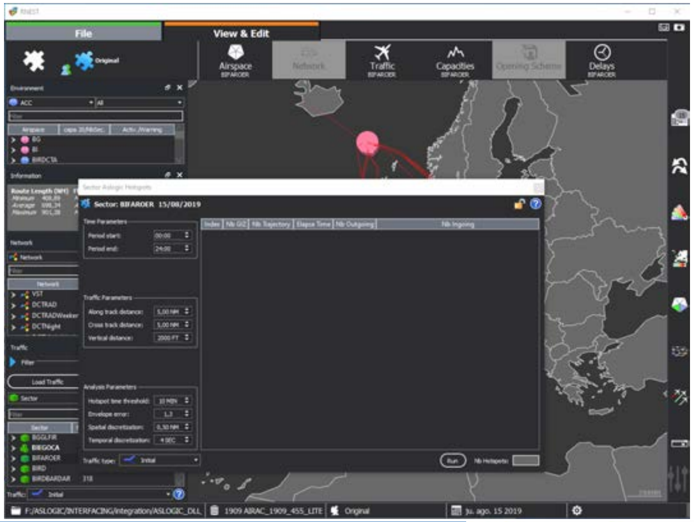
Qualitative analysis: Assess the behaviour of metrics in front of various traffic densities and clustering parameters (hotspots).
Goal: analyse how metrics behave in front of traffic density variation.
Assessment: obtain sound and explainable trends in the results.

Demonstration suite



AsloEarth is a visualization tool that serves to graphically show the results and metrics Interfacing is handling with. For example, animated trajectories, interaction zones and hot spots.

Working on R-NEST integration



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Conclusions and next steps

Expected impact from interaction zones and metrics

- Enhancement of the DCB for the sake of ATC Minimum Intervention
- Improve transparency and efficiency of DCB network services

Main contributions to the TC-2 topics

- Development of tools for the identification of ‘hotspots’ and the evaluation of different ATFCM measures
- Bridging the gaps between the temporal phases of ATFCM
- Optimising and integrating local planning activities with a view to assess, contain and communicate their network effects

Conclusions and next steps

Next steps

- *Analysis and assessment activities*. INTERFACING algorithms operate at trajectory level, to take benefit of the TBO concept and also of the most advanced avionic enablers (EPP, what-if EPP):
  - Assess the performance of interaction management at Network level
  - Enrich Network Performance Indicators
  - Learn from data
  - Supporting tools to ATCo for mid and short-term conflict detection
  - Support *Sectorless* ATM concept.
- Automated tools for supporting decision making
  - Trajectory-based DCB measures at the ATM network level
  - Empower the Integrated Network Management and the Extended ATC Planning function
  - Conflict Resolution support.

INTERFACING

An Interaction Metric for an Efficient Traffic Demand Management: requirements for the design of data-driven protection mechanisms

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