How to visualize OGC Moving Features with STINUUM

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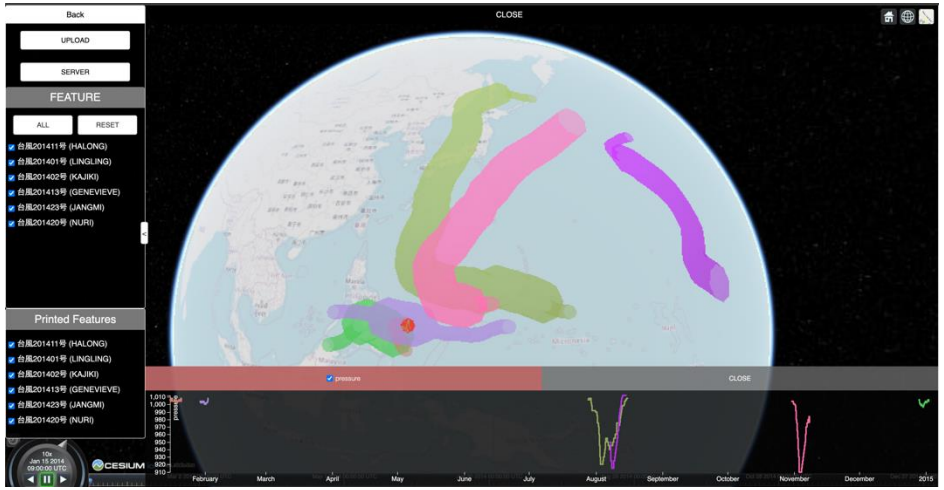
A brief explanation of STIUUM and install it

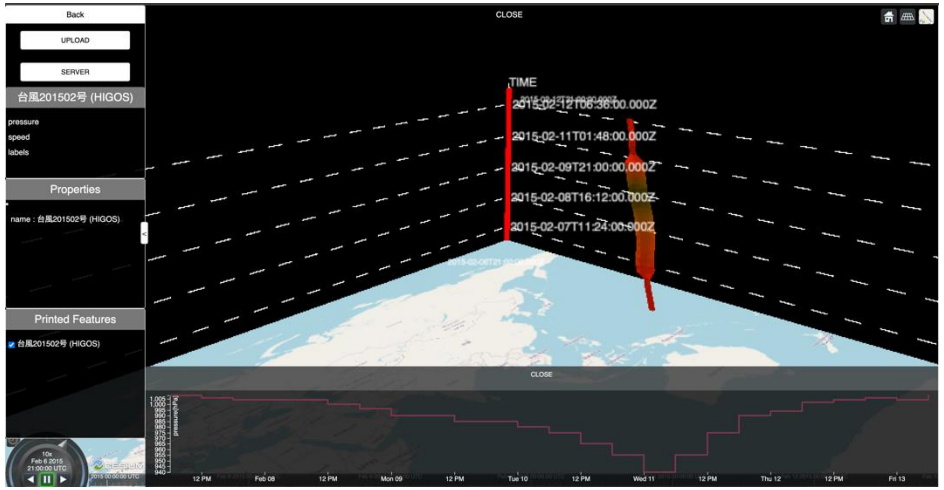
1. What is STINUUM?
2. System structure of STINUUM
3. Install STINUUM

Introduction of STINUUM

- **What is STINUUM (Spatio-Temporal continua on Cesium)**
  - https://github.com/aistairc/mf-cesium/tree/mf-cesium_api
  - STINUUM is a JavaScript library to visualize and analyze moving objects on Cesium
  - STINUUM renders OGC Moving Features JSON (MF-JSON) data to explore the trajectories of moving objects across space and time
  - The main characteristics of STINUUM are as follows:
    - Diverse geometry types to represent movements
    - Multiscale data analysis in space and time
    - Highly accessible and lightweight deployment



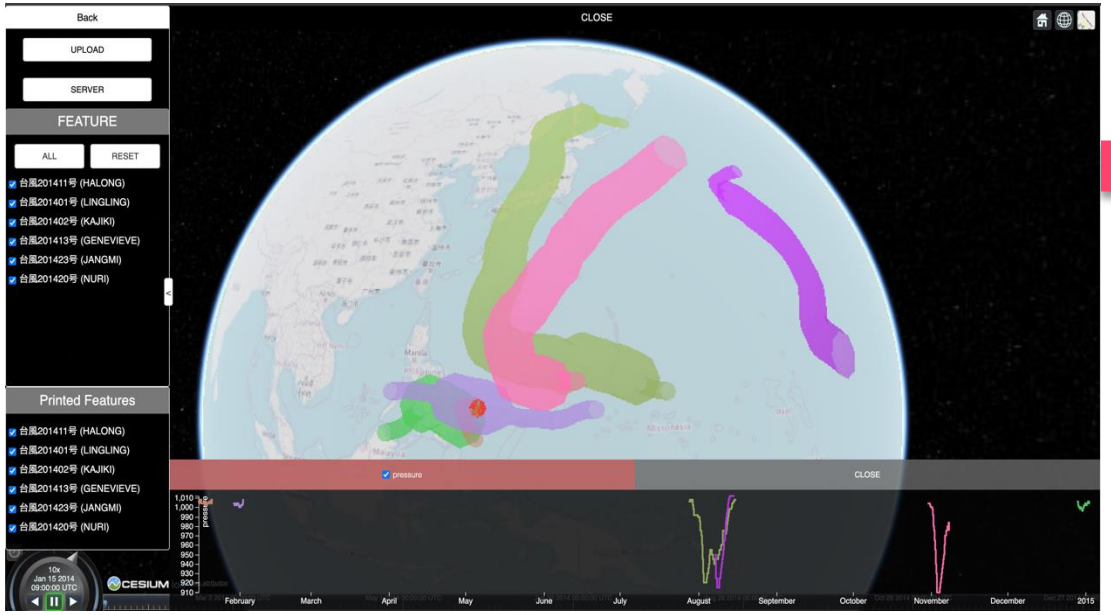
Visualize the Moving Feature

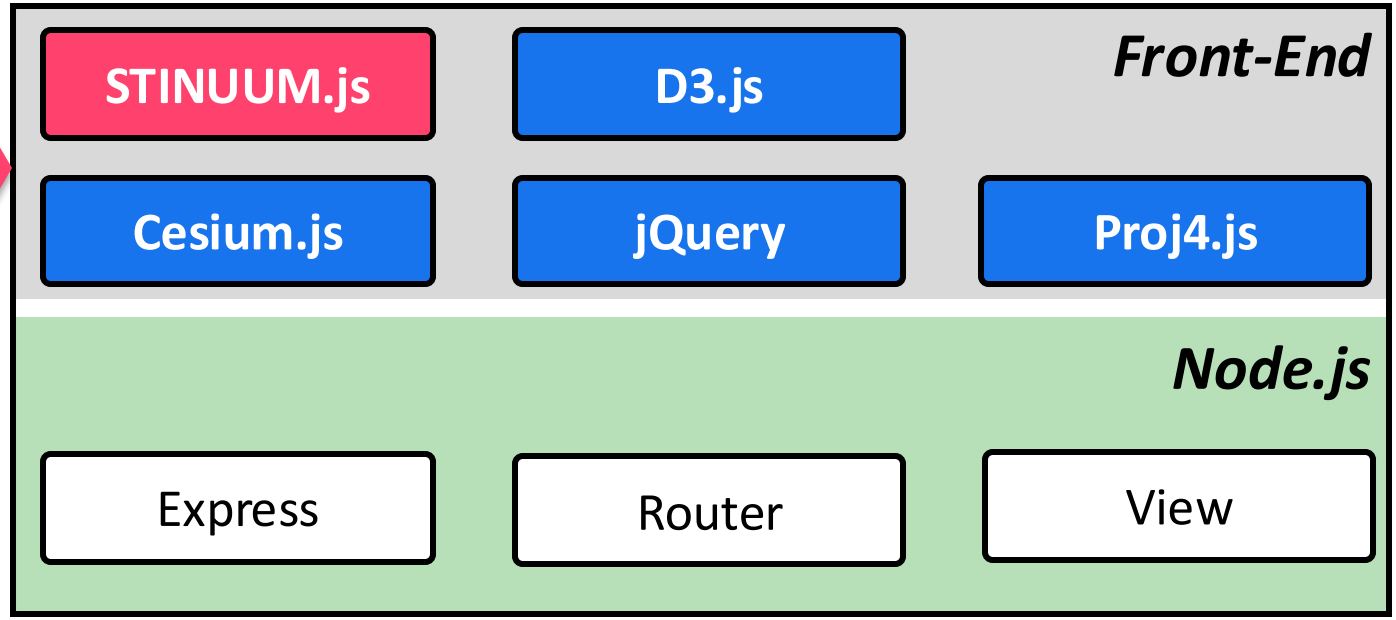


Visualize the Moving Feature in *Space-time map*

Introduction of STINUUM

- **System structure of STINNUM**
  - **STINUUM.js**: Provides functionality for visualizing and controlling moving features
  - **Cesium.js**: Provides animation control and visualization tools for visualizing moving features
  - **D3.js**: Creates graphs using *TemporalProperties* object
  - **Pro4.js**: Used for coordinate transformations in *TemoproalGemetry* object
  - **jQuery**: Used for UI creation and controls
  - **Node.js**: Used to run and deploy web applications using **STINUUM.js**





Installation

- **Install STINUUM**
  - URL: https://github.com/aistairc/mf-cesium/tree/mf-cesium_api
  - git clone https://github.com/aistairc/mf-cesium
    - git fetch origin → git checkout mf-cesium_api
  - Install nvm(Please refer to the README)
    - Windows
      - Download the nvm-setup.zip in https://github.com/coreybutler/nvm-windows/releases
        - » https://github.com/coreybutler/nvm-windows/wiki
      - Unzip nvm-setup.zip and run nvm-setup.exe
    - MacOS (using terminal)
      - brew install nvm
      - Open the .bash_profile or .zshrc
        - » vi ~/.bash_proflie
      - Add the environment value of nvm
        - » export NVM_DIR="$HOME/.nvm" [-s "/usr/local/opt/nvm/nvm.sh"] && . "/usr/local/opt/nvm/nvm.sh" *# This loads nvm* [-s "/usr/local/opt/nvm/etc/bash_completion.d/nvm"] && . "/usr/local/opt/nvm/etc/bash_completion.d/nvm" *# This loads nvm bash_completion*

Installation

- **Install STINUUM**
  - Install nvm
    - Ubuntu (using terminal)
      - sudo apt install curl
      - curl https://raw.githubusercontent.com/creationix/nvm/master/install.sh | bash
      - source ~/.bashrc
    - Check installed nvm with terminal
      - nvm –v
    - Install node.js
      - nvm install 20.10.0
      - nvm use 20.10.0
      - node –v
  - Install STINUUM
    - 1) Cd /path_to/mf-cesium/Stinuum Web
    - 2) npm install
  - Start STINUUM
    - node app.js

Installation

- **How to connect to the OGC API-Moving Features**
  - docker pull ghcr.io/taehoonk/pygeoapi-mf-api:latest
  - docker pull ghcr.io/taehoonk/pygeoapi-mf-api-mobilitydb:latest
  - docker-compose up
    - **localhost:5050**

Installation

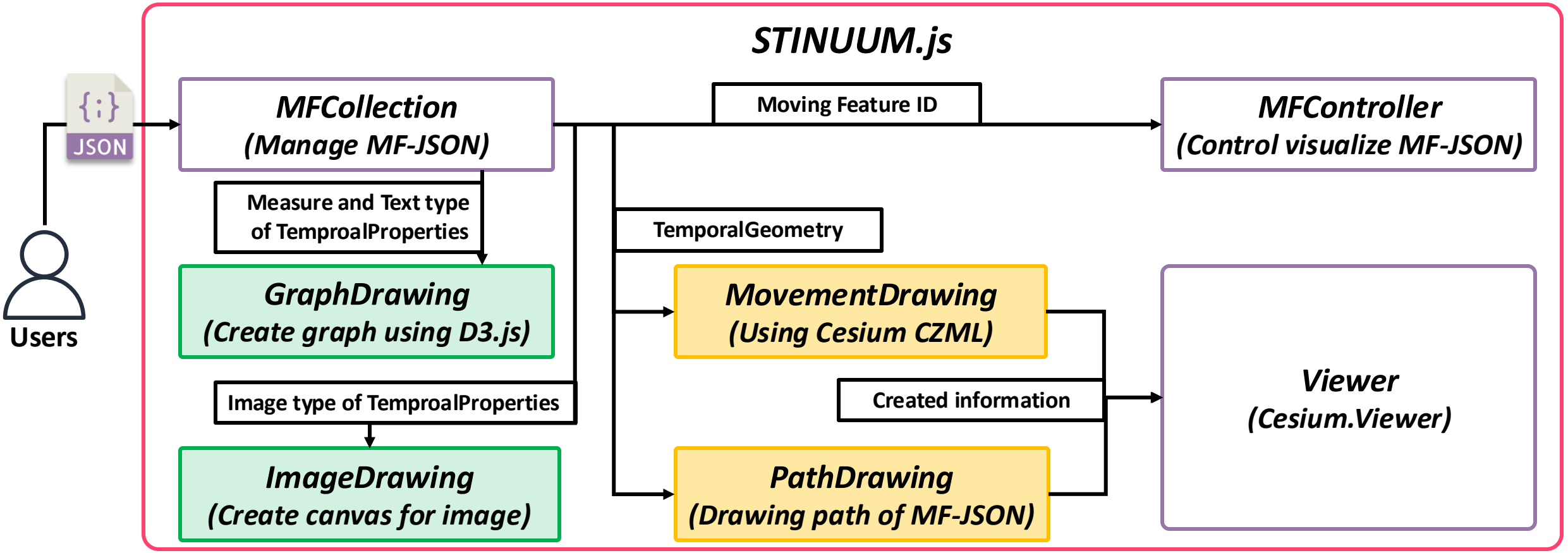
- **MF-API Handler**
  - URL: https://github.com/aistairc/mf-cesium/tree/mf-cesium_api/MFAPIHandler
    - cd **/path_to/mf-cesium/MFAPIHandler**
    - pip install –r **requirements.txt**
  - Simple program to register the Moving Feature data using OGC API-Moving Features
    - Register new Moving Feature Collection
    - Uploading the Moving Feature data

Explain how to extend STINUUM using the OGC MF-JSON

1. Components of STINUUM
2. How to visualize MF-JSON data in the STINUUM
    1. Visualize TemporalGeometry object
    2. Visualize TemporalProperties object
        1. Measure, Text types
        2. Image type

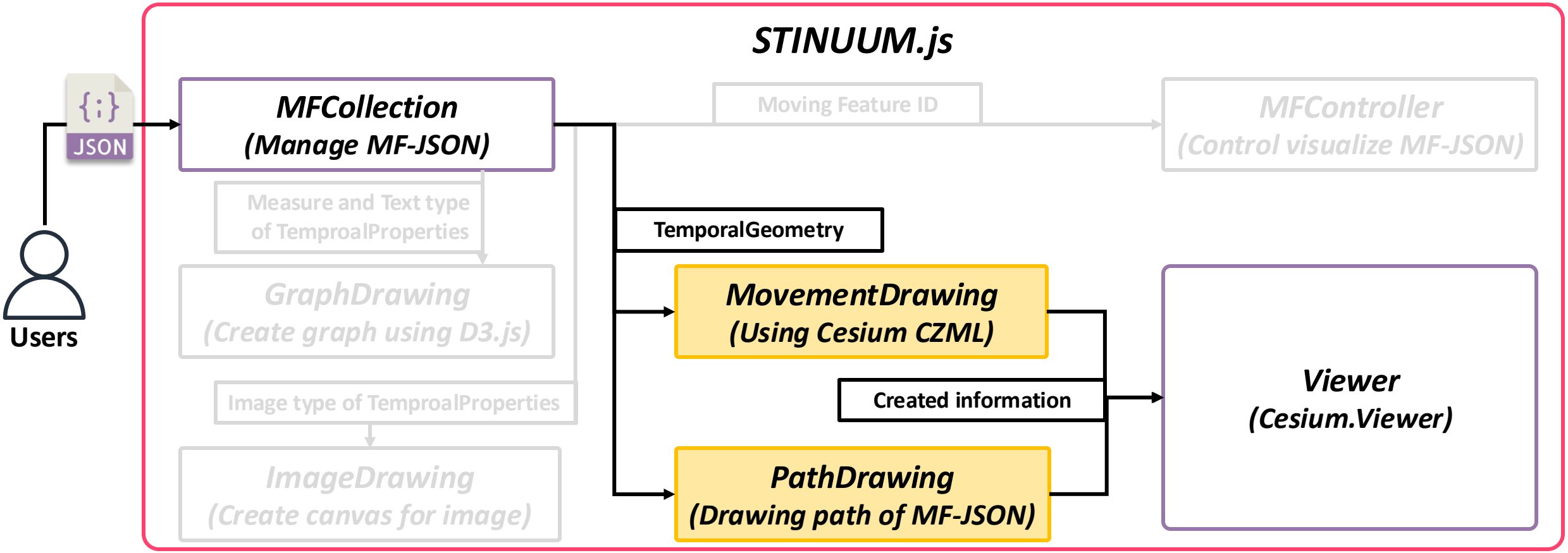
Introduction of STINUUM

- **Components of STINNUM**
  - **STINUUM.js** provides fundamental methods to handle MF-JSON data



Introduction of STINUUM

- **How to visualize MF-JSON data in the STINUUM**
  - Visualize *TemporalGeometry* object



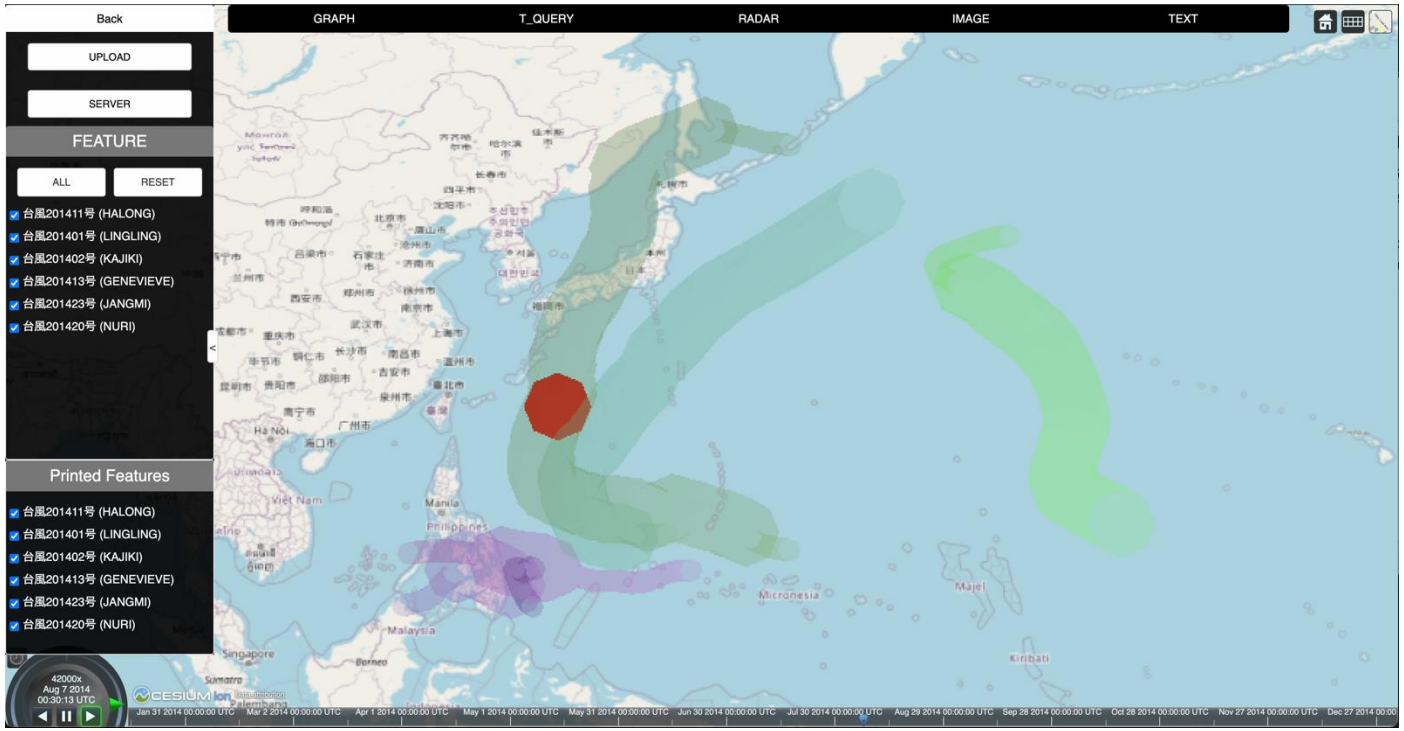
Introduction of STINUUM

- **How to visualize MF-JSON data in the STINUUM**
  - Visualize *TemporalGeometry* object
    - Converting the *TemporalGeometry* information to CZML format and visualizing it
      - CZML is a data format used to represent moving objects in Cesium
      - Easily visualize moving objects in Cesium without complex implementation using APIs

```
"temporalGeometry": {
  "type": "MovingPolygon",
  "datetimes": [
    "2011-07-14 22:01:01",
    "2011-07-14 22:01:12",
     ...
  ],
  "coordinates": [
    [[ 139.757083,  35.627701, 0.5 ],
     [ 139.757399,  35.627701, 2.0 ],
     [ 139.757555,  35.627688, 4.0 ],
     [ 139.757651,  35.627596, 4.0 ],
     [139.757083,   35.627701, 0.5 ]],
    ...
  ],
}
```

TemporalGeometry of Moving Feature

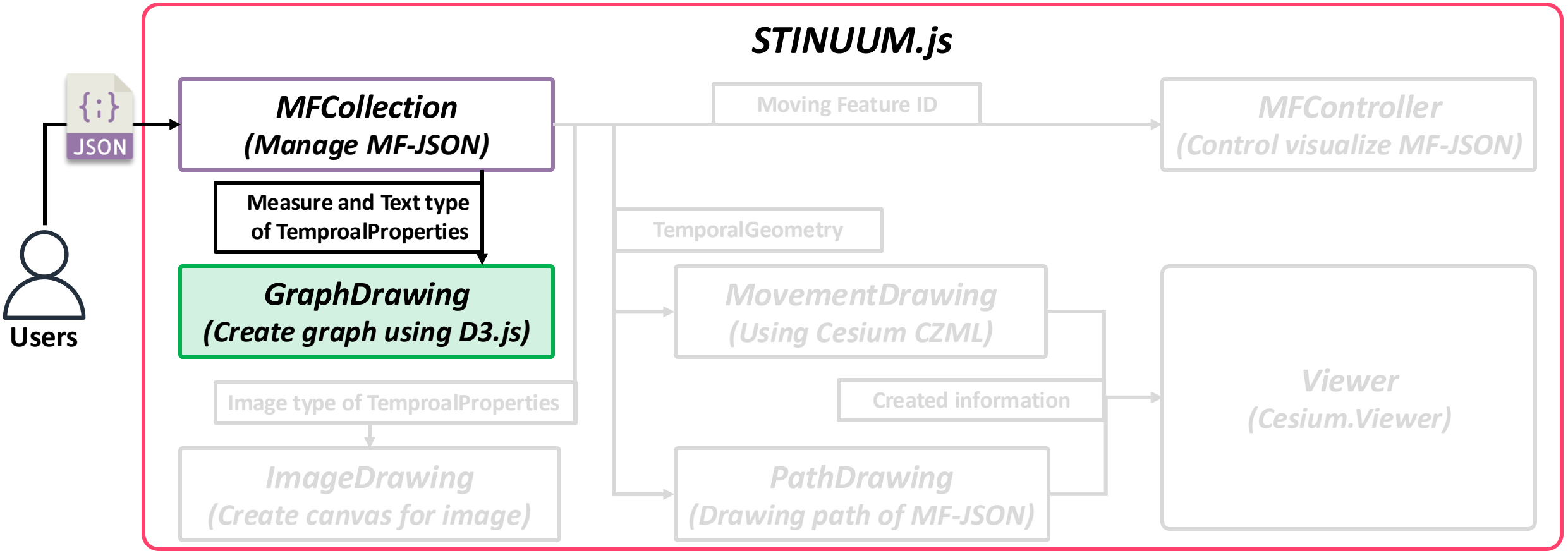
Converting



Visualize temporal geometry (MovingPolygon) in Cesium

Introduction of STINUUM

- **How to visualize MF-JSON data in the STINUUM**
  - Visualize “Measure” and “Text” types of *TemporalProperties*

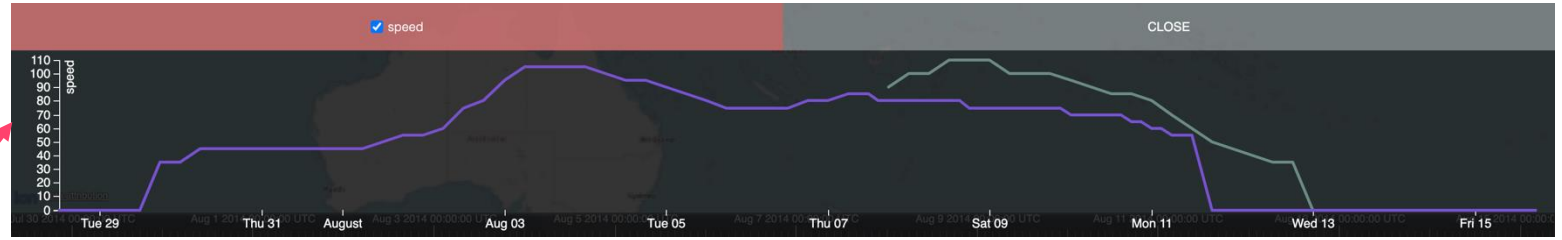


Introduction of STINUUM

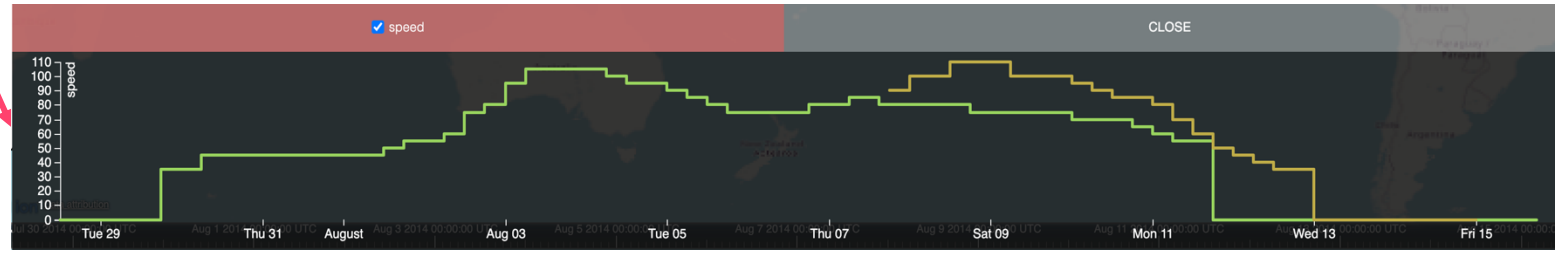
- **How to visualize MF-JSON data in the STINUUM**
  - Visualize *TemporalProperties* object
    - Using the **D3.js** to create a graph for the “Measure” and “Text” types of temporal property
      - x-axis: time information in the selected temporal property
      - y-axis: value information in the selected temporal property
    - The interpolation of each temporal property is displayed using the functions supported by **D3.js**
      - Discrete, Step, Linear, Regression

```
"temporalProperties": [
 {
  "datetimes": [
    "2011-07-14 22:01:01",
    "2011-07-14 22:01:12",
     …
  ],
  ”speed": {
      “type”: “Measure”,
      “form”: ””
      “values”: [ 100, 200, 300, … ],
      ”interpolation”: “Linear”
  }
}, …
]
```

TemporalProperties of Moving Feature



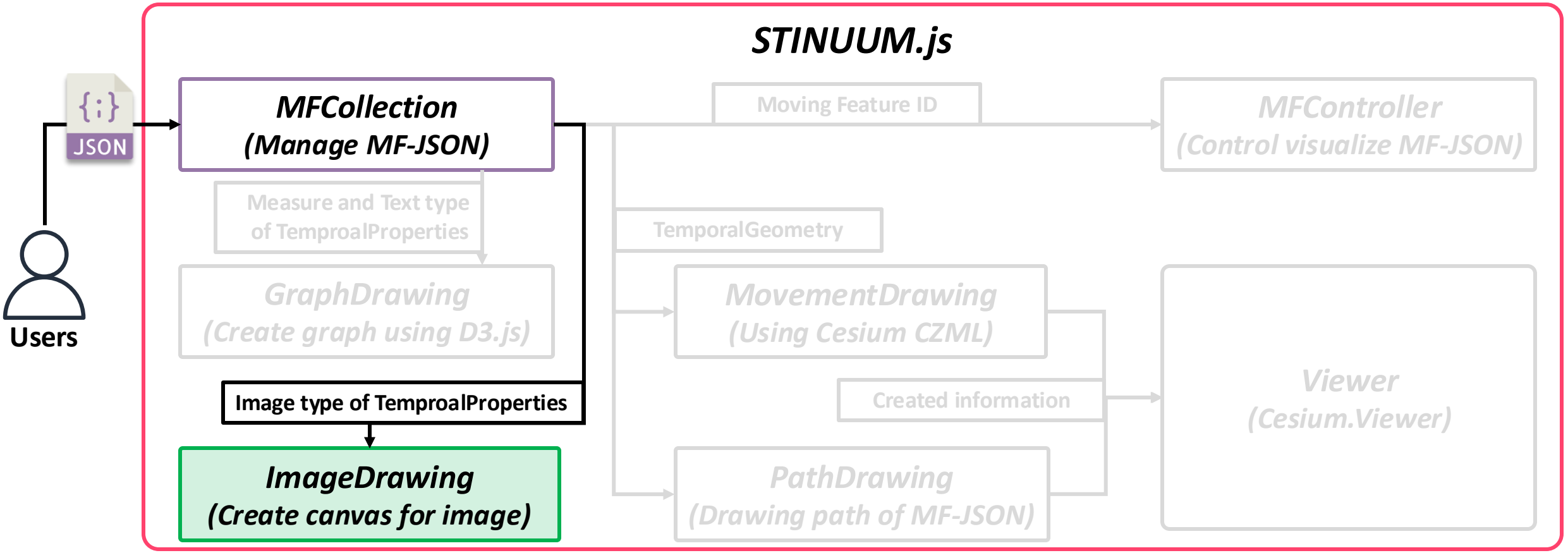
Linear graph of speed



Step graph of speed

Introduction of STINUUM

- **How to visualize MF-JSON data in the STINUUM**
  - Visualize “Image” type of *TemporalProperties*

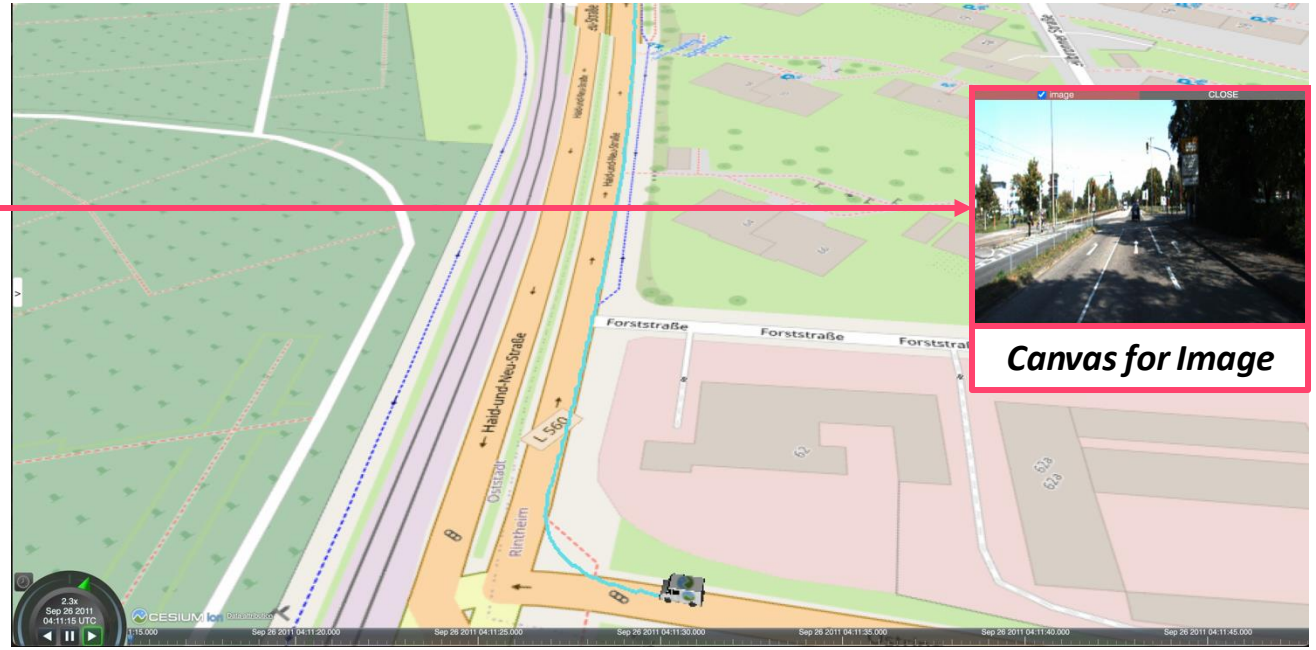


Introduction of STINUUM

- **How to visualize MF-JSON data in the STINUUM**
  - Visualize *TemporalProperties* object
    - Using the HTML Canvas to display the “Image” type of temporal property
      - Visualize images that match the date-time in the selected temporal property using **Cesium.EventHandler**

```
"temporalProperties": [{
 "datetimes": [
  "2011-07-14 22:01:01",
  "2011-07-14 22:01:12",
   …
 ],
 ”image": {
    “type”: “Image”,
    “values”: [
       "VBORw0KGgoAAAANU……”,
       "VBORw0KGgoAAAANU……”,
        …
     ],
    ”interpolation”: “Step”
 }
}, …]
```

TemporalProperties of Moving Feature



Display the image with Moving Feature

Practice visualization with different types of MF-JSON files

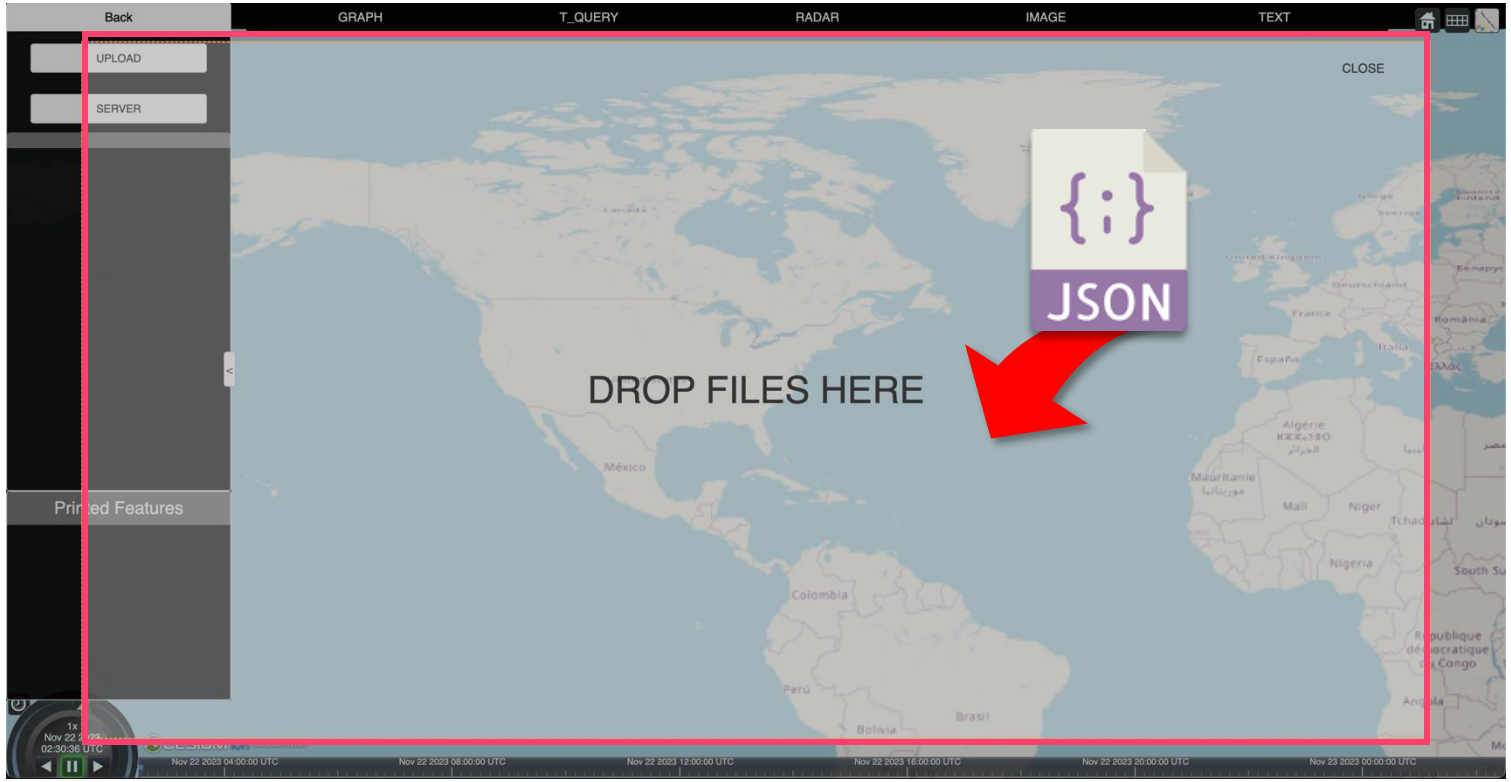
1. Notice about sample data location (MF-JSON data)
2. MF-JSON data upload
3. Visualize the temporal geometry of the moving feature
4. Animate the visualized moving feature
5. Select sub-temporal geometry (Time query)
6. Change the view modes (static map, global view, space-time cube view)
7. Visualize the temporal property (Measure type)
8. Visualize the Measure type with temporal geometry (highlight)
9. Visualize the temporal property (Text type)
10. Visualize the temporal property (Image type)

Practices STINUUM with MF-JSON

- **Notice about sample data location (MF-JSON data)**
  - Path of file: **/path_to/mf_ceisum/Stinuum Web/data/MF-JSON Prism/PracticeDataSet**
  - Sample Moving Feature data
    - **mfjson_point_car_with_image.json** & **mfjson_point_for_mf_api_server.json**
      - MF-JSON temporalGeometry type: MovingPoint
      - Hompage: https://www.cvlibs.net/datasets/kitti/index.php
      - Vehicle movement information with image in German
        - » Create MF-JSON using data
          - KITTI data
    - **mfjson_polygon_multiple_typhoon.json**
      - MF-JSON temporalGeometry type: MovingPolygon
      - Data of typhoon movement
    - **mfjson_point_from_mobilitytwin.json**
      - MF-JSON temporalGeometry type: MovingPoint
      - Hompage: https://mobilitytwin.brussels/
      - Information on public transportation in Brussel

Practices STINUUM with MF-JSON

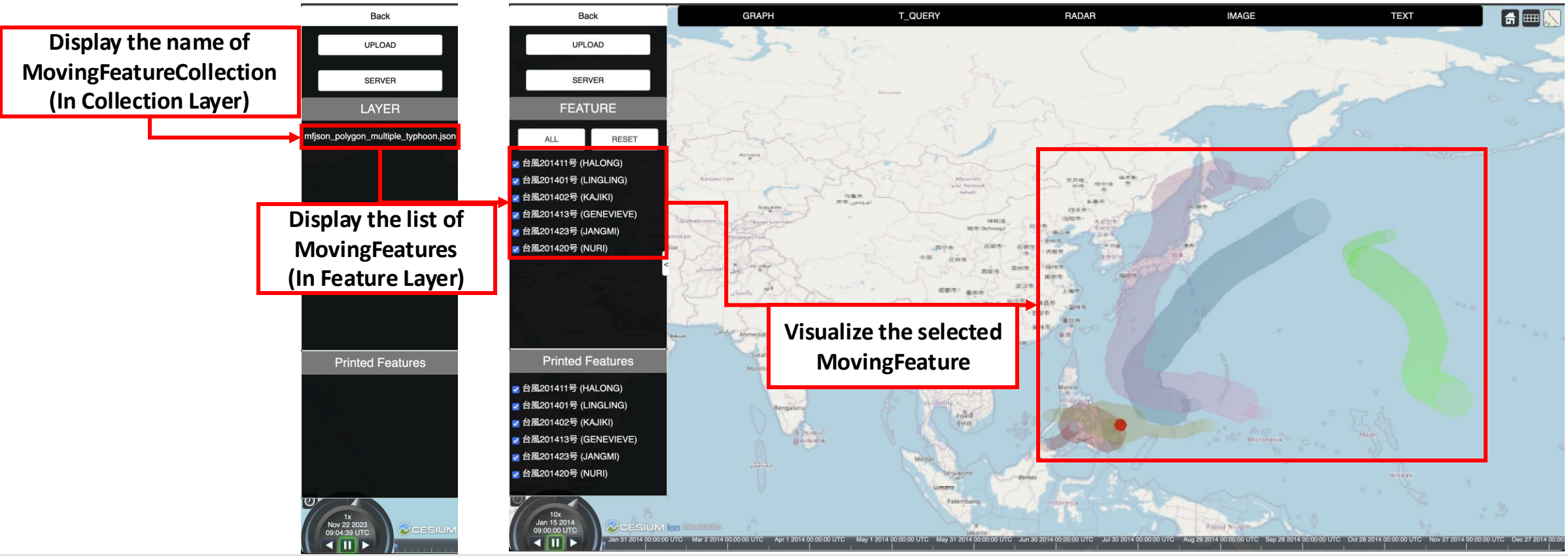
- **MF-JSON data upload**
  - Visualize MF-JSON file by dragging and dropping
    - Path of file: **Stinuum Web/data/MF-JSON Prism/PracticeDataSet/mfjson_polygon_multiple_typhoon.json**
    - Visualization using text information of MF-JSON



Upload MF-JSON using file

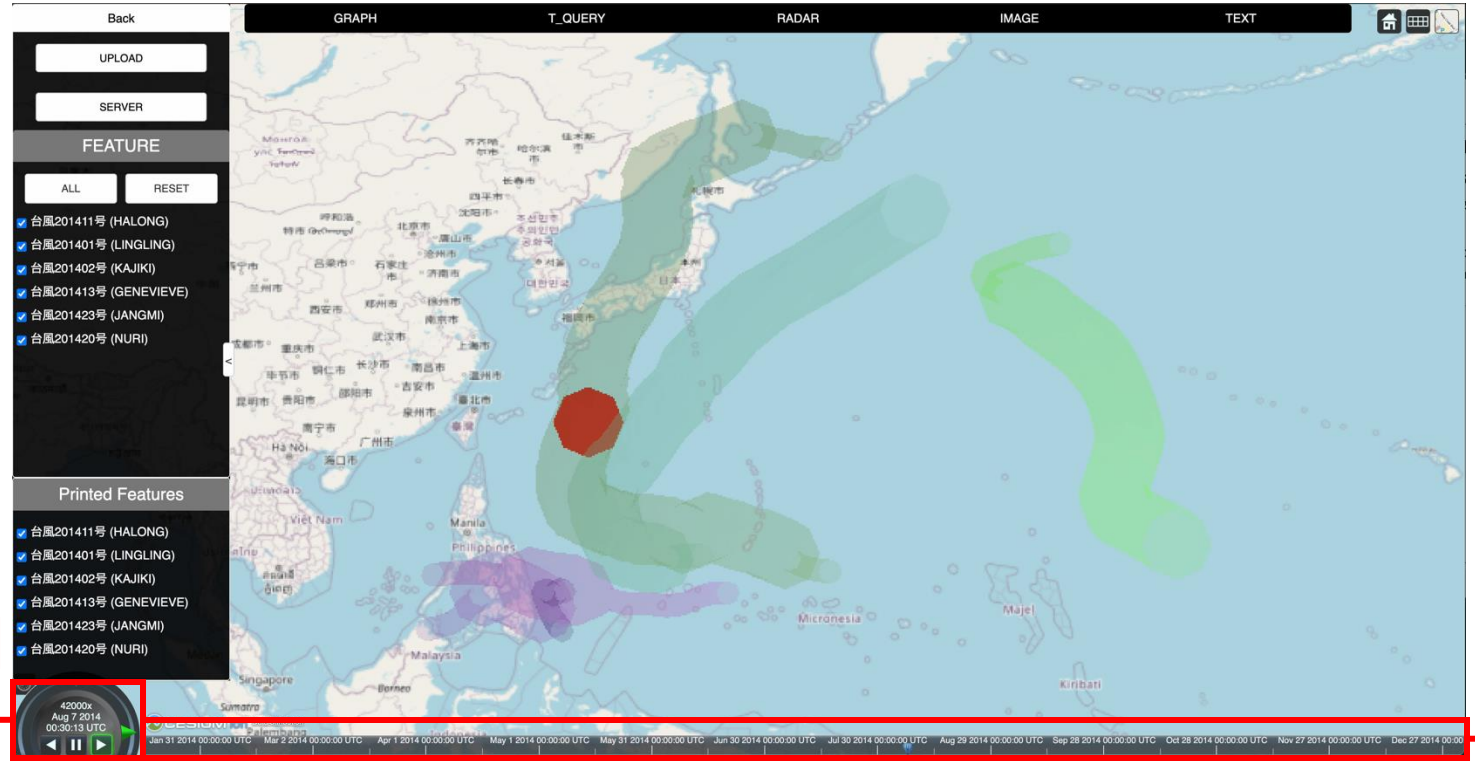
Practices STINUUM with MF-JSON

- **Visualize the temporal geometry of the moving features**
  - When the MF-JSON upload is complete, you'll see the information in the left menu (Collection Layer)
  - Click the uploaded **MovingFeatureCollection** (or **MovingFeature**) object instance
    - A list of **MovingFeatures** will be displayed (Feature Layer)



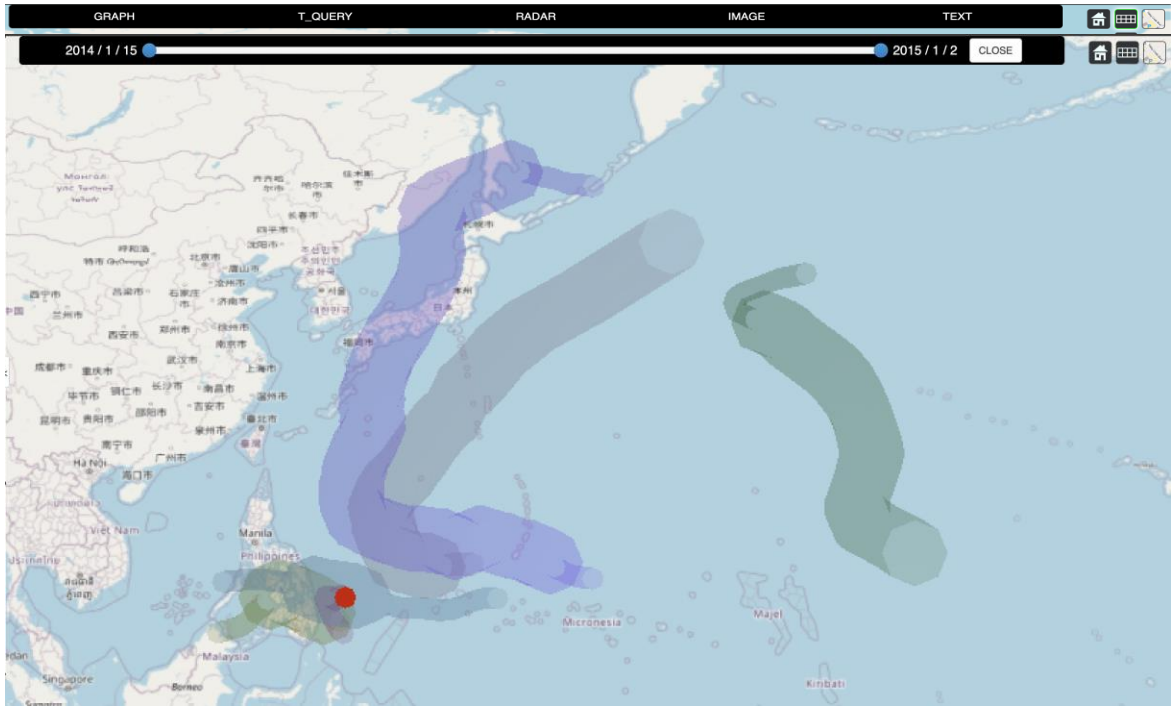
Practices STINUUM with MF-JSON

- **Animate the visualized moving feature**
  - Animating visualized moving features using the animation function provided by Cesium
    - Dynamically visualize the trajectory of the moving features according to time

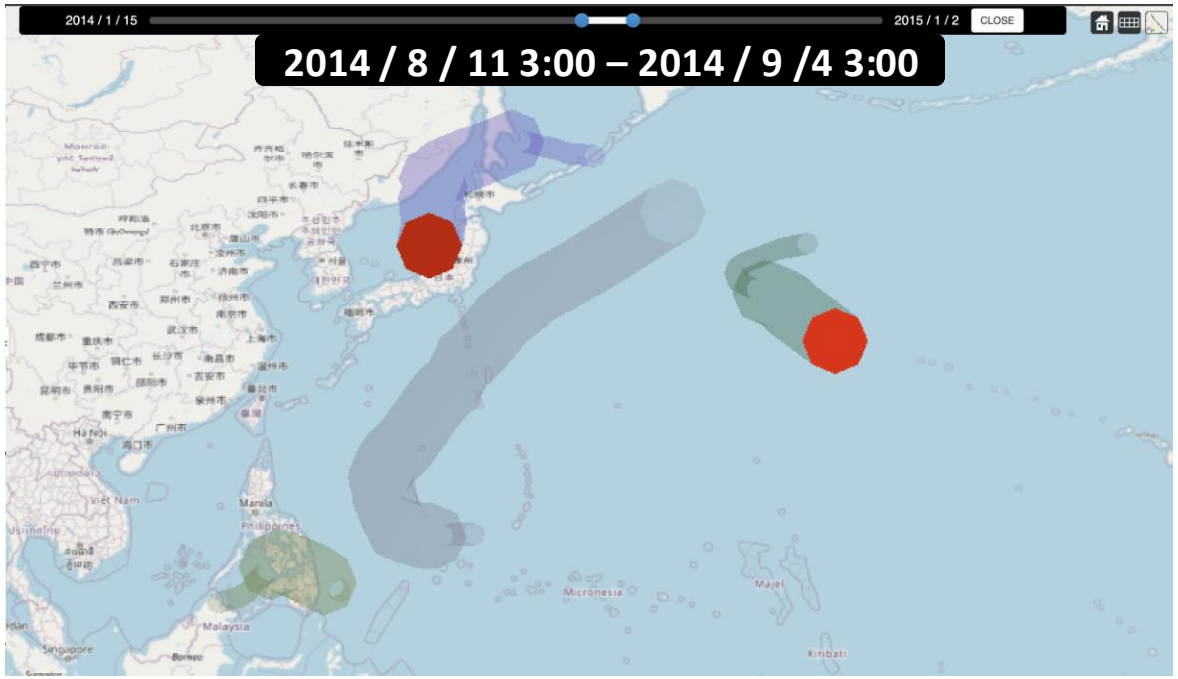


Practices STINUUM with MF-JSON

- **Select the sub-temporal geometry (time query)**
  - The time query is used to check the movement of the moving features in a specific time period
    - The temporal property is also displayed in a specific time period



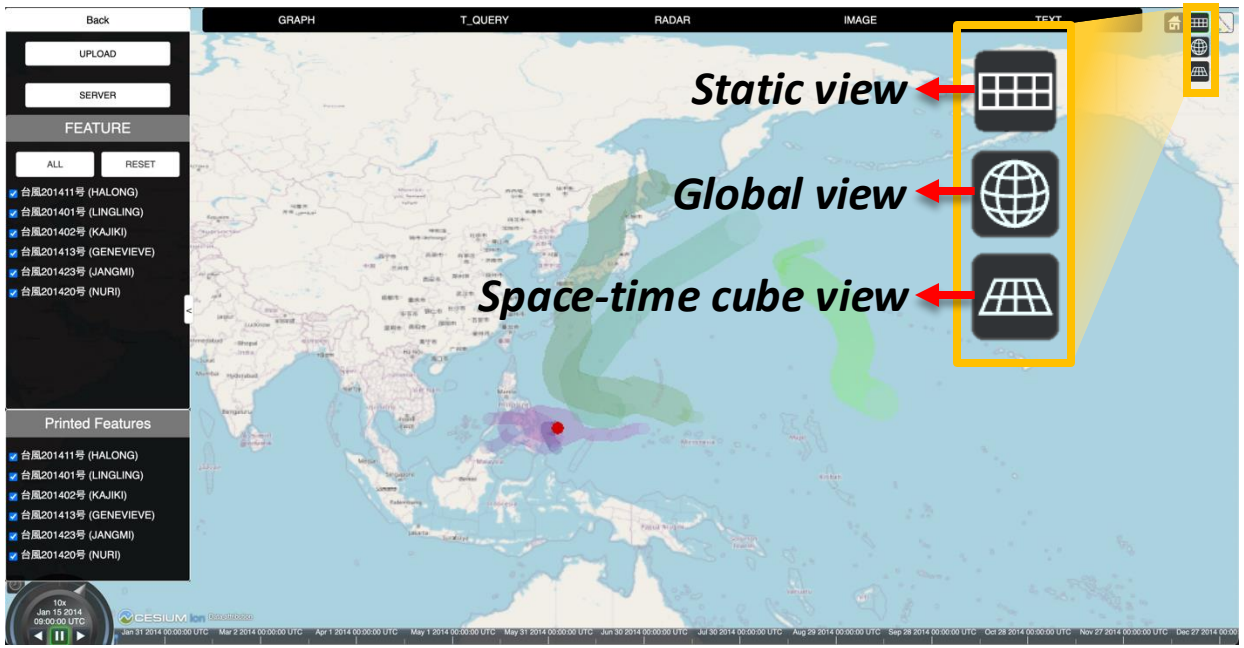
Trajectories display for the entire time period



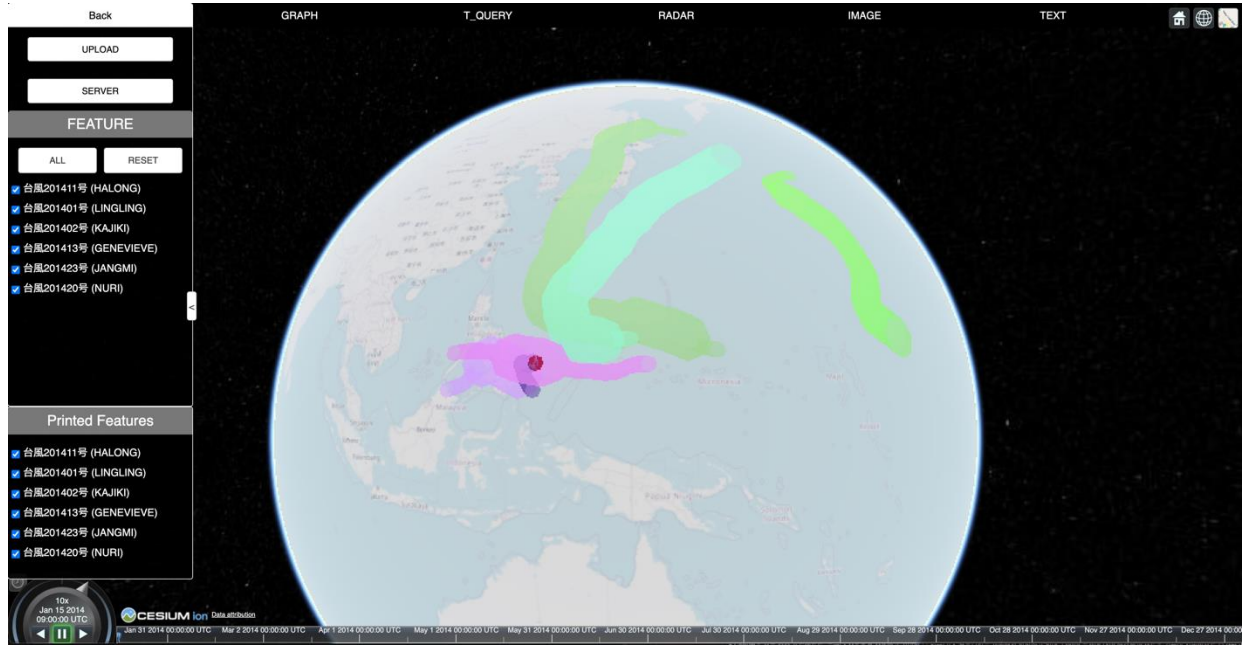
Time query results

Practices STINUUM with MF-JSON

- **Change the view modes (Static, Global, and Space-time cube view)**
  - STINUUM supports three view modes: Static, Global, and Space-time cube view
    - Users can select (and change) the view mode using the map toolbox in the top right corner
    - **Static view**: (Default) The map is viewed top-down with an orthographic projection
    - **Global view**: A traditional 3D perspective view of the globe



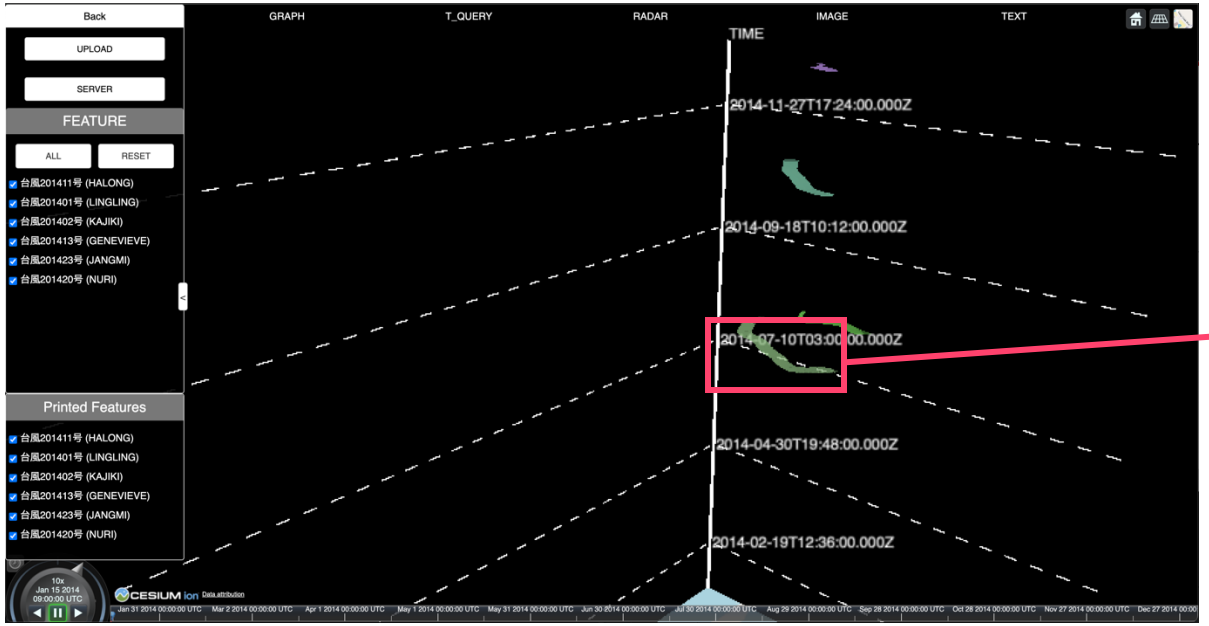
Static View (2D Map)



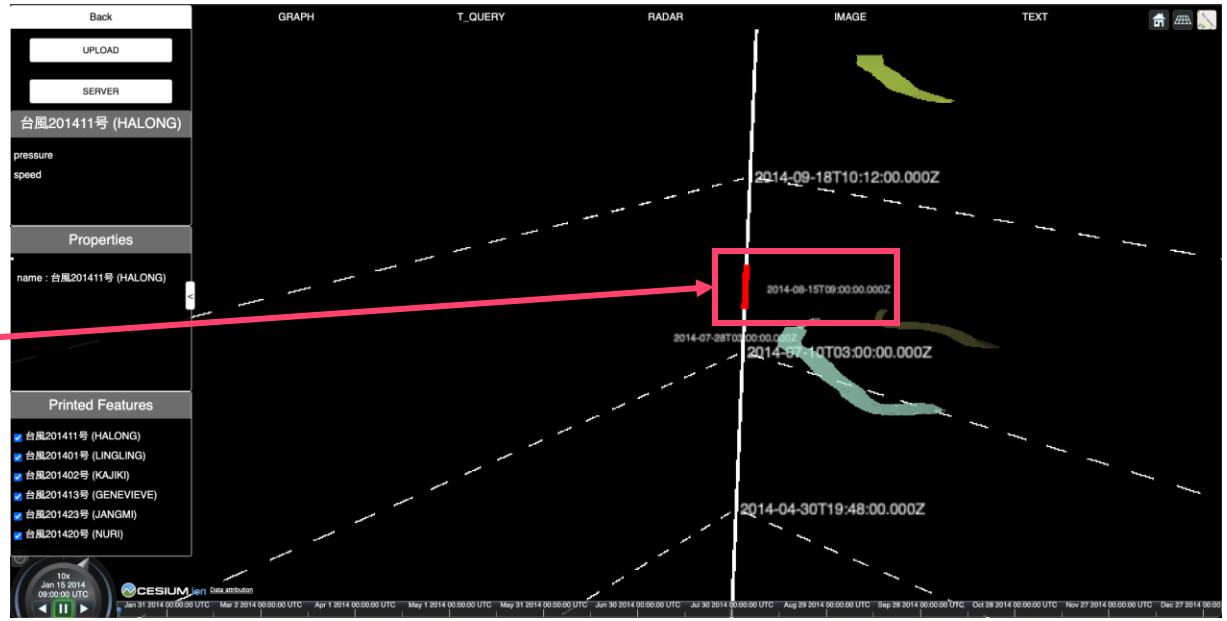
Global View (3D Map)

Practices STINUUM with MF-JSON

- **Change the view modes (Static, Global, and Space-time cube view)**
  - **Space-time cube view**
    - A map that converts the z-axis to a timeline instead of the z-coordinates of moving features
      - X and Y axis (location) + Z axis(time)
    - Easy to analyze objects moving at the same location
    - When clicking on a specific object, the time information for that object is displayed on the z-axis



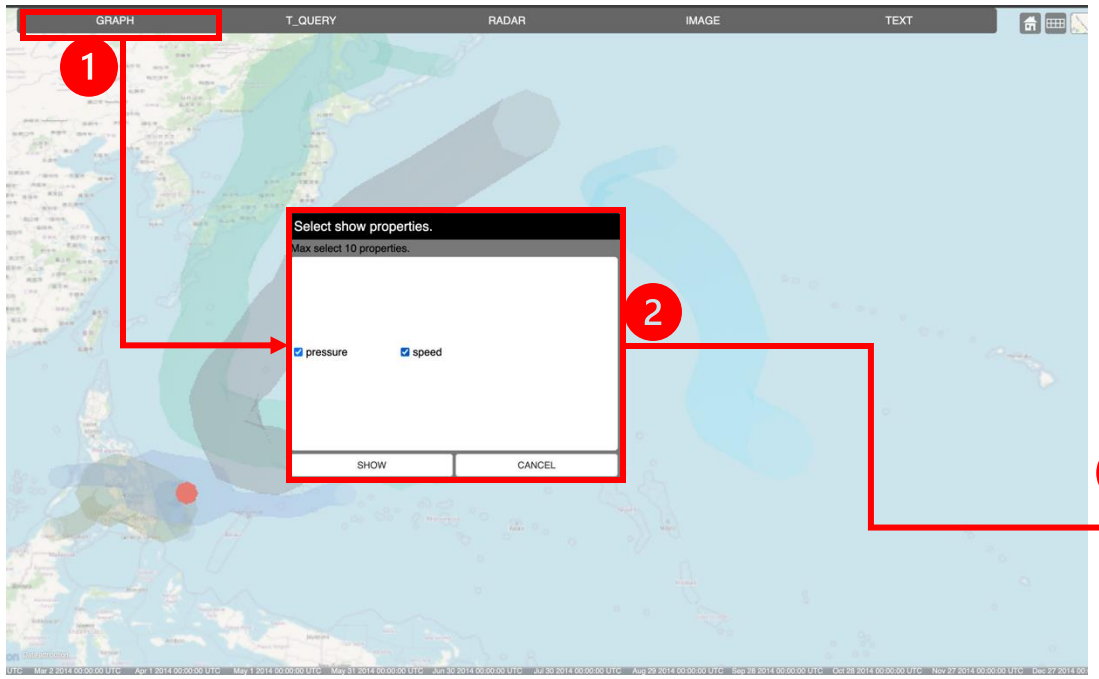
Space-time View (Time based Map)



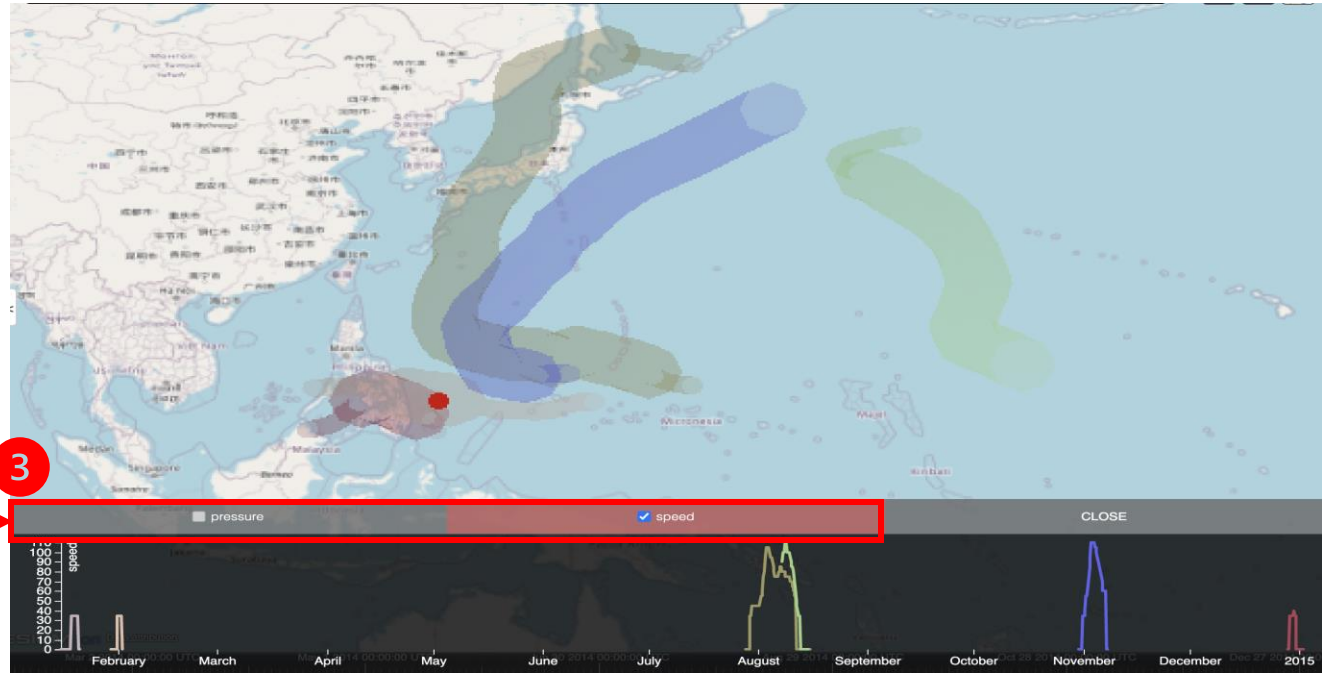
Display the time of selected MovingFeature

Practices STINUUM with MF-JSON

- **Visualize the temporal property (Measure type)**
  - STINUUM supports graphing and analyzing the temporal properties of moving features.
    1) Display the list of properties included in the moving feature
    2) Select the one (or more) property
    3) Visualize property information as a graph



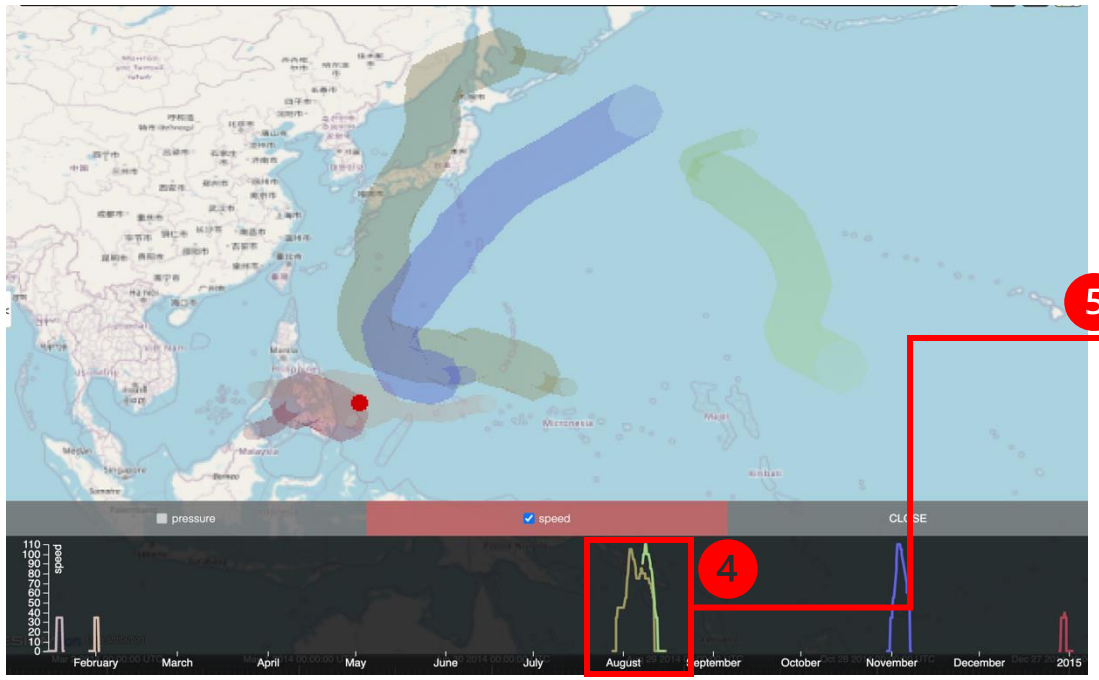
Select property to graph



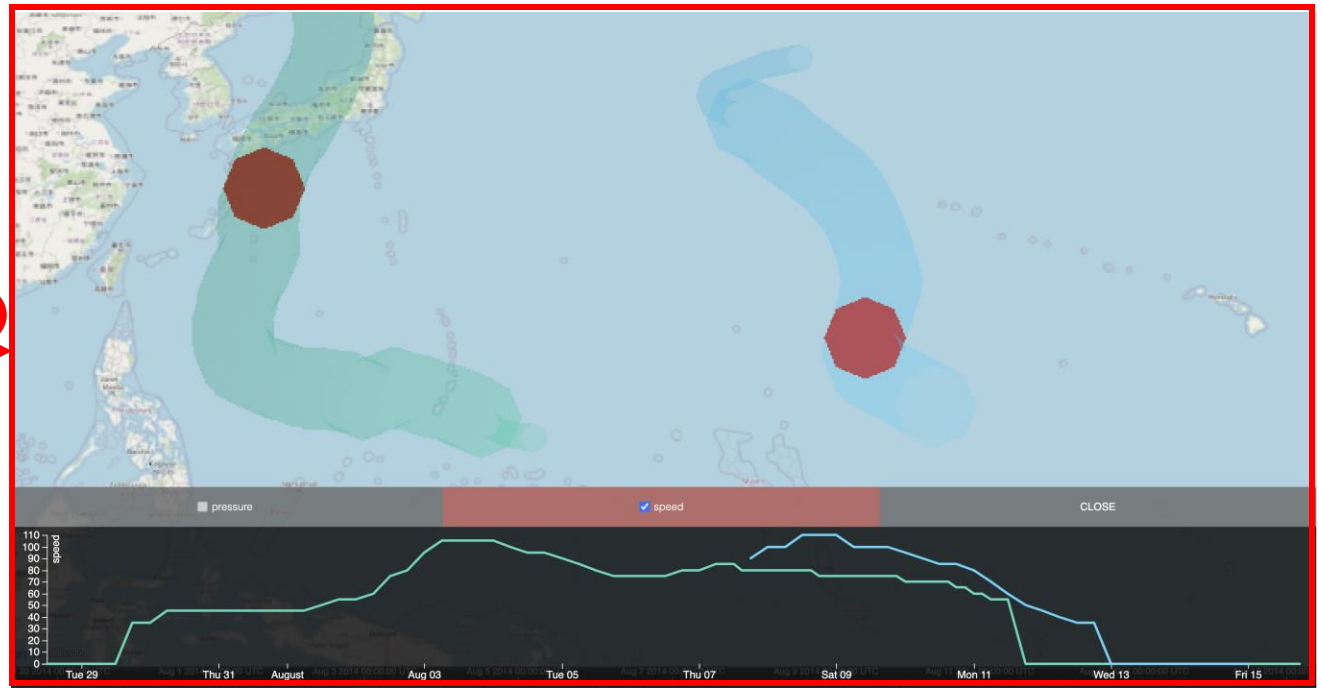
Display selected properties as graph

Practices STINUUM with MF-JSON

- **Visualize the temporal property (Measure type)**
  - STINUUM supports graphing and analyzing the temporal properties of moving features.
    4) Drag the specific area in Graph
    5) Display only the graph of the dragged area



Drag the specific area



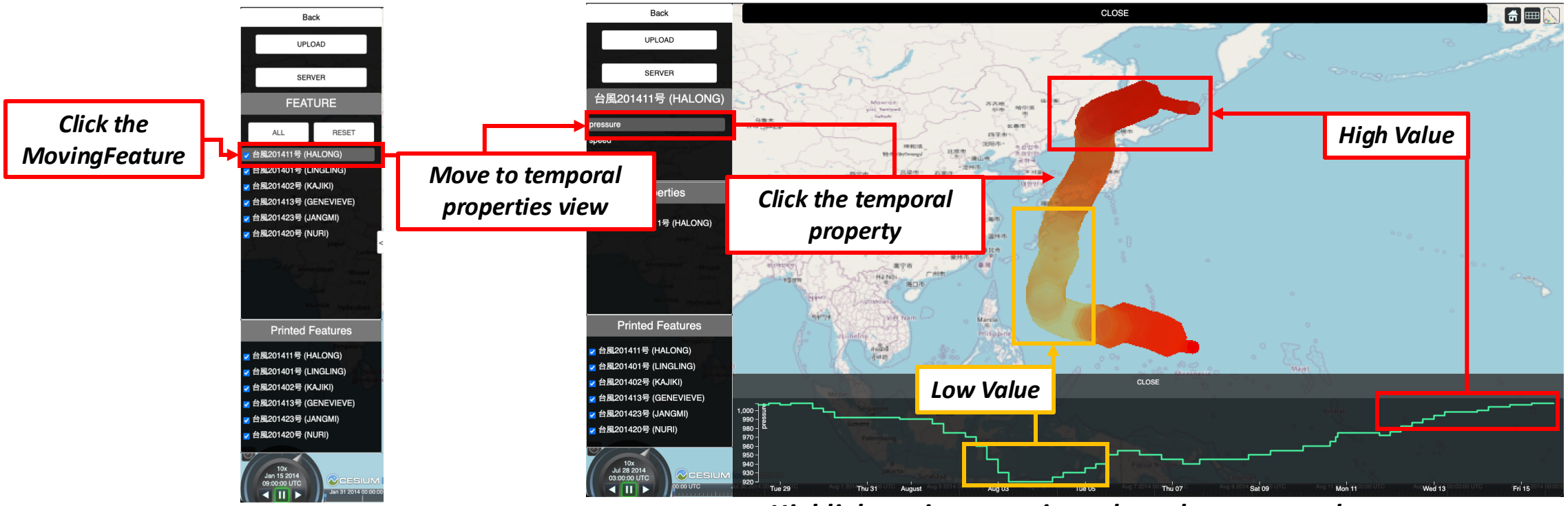
Display the graph included the dragged area

Practices STINUUM with MF-JSON

- **Visualize the Measure type with temporal geometry (highlight)**
  - STINUUM supports the highlighting function with the temporal property
    - The color of the trajectory is represented by different colors depending on the value of the selected property

Low Value ***High Value***

    - At the bottom, the selected property is displayed as a graph.

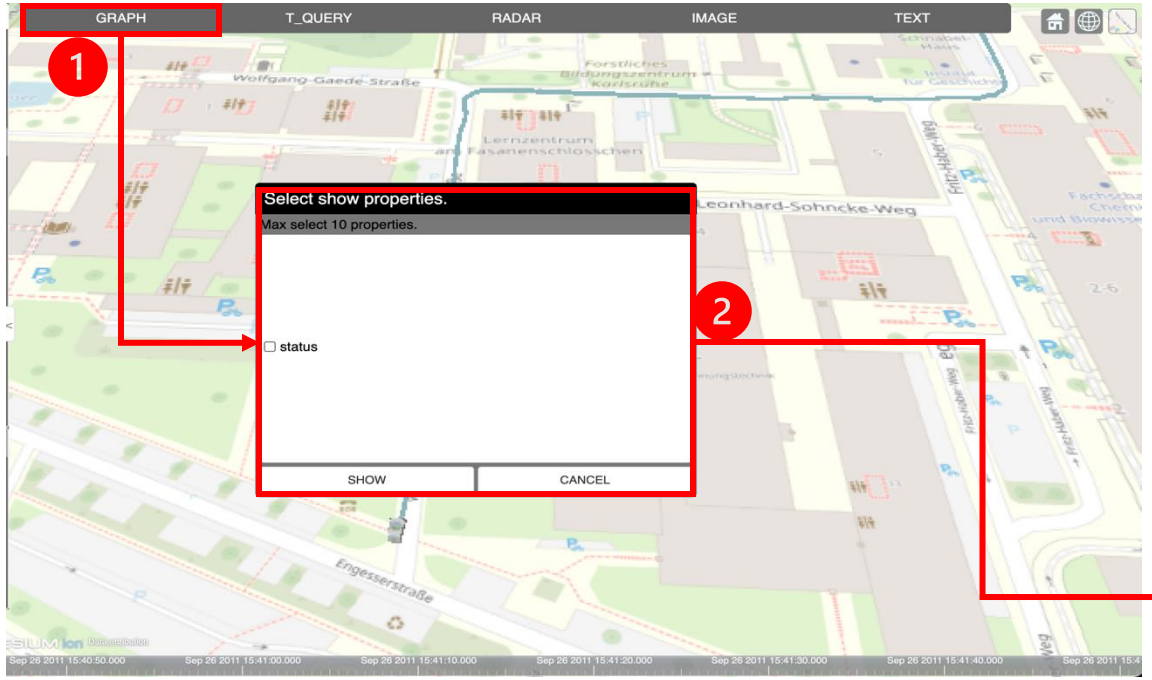


Highlight trajectory using selected property values

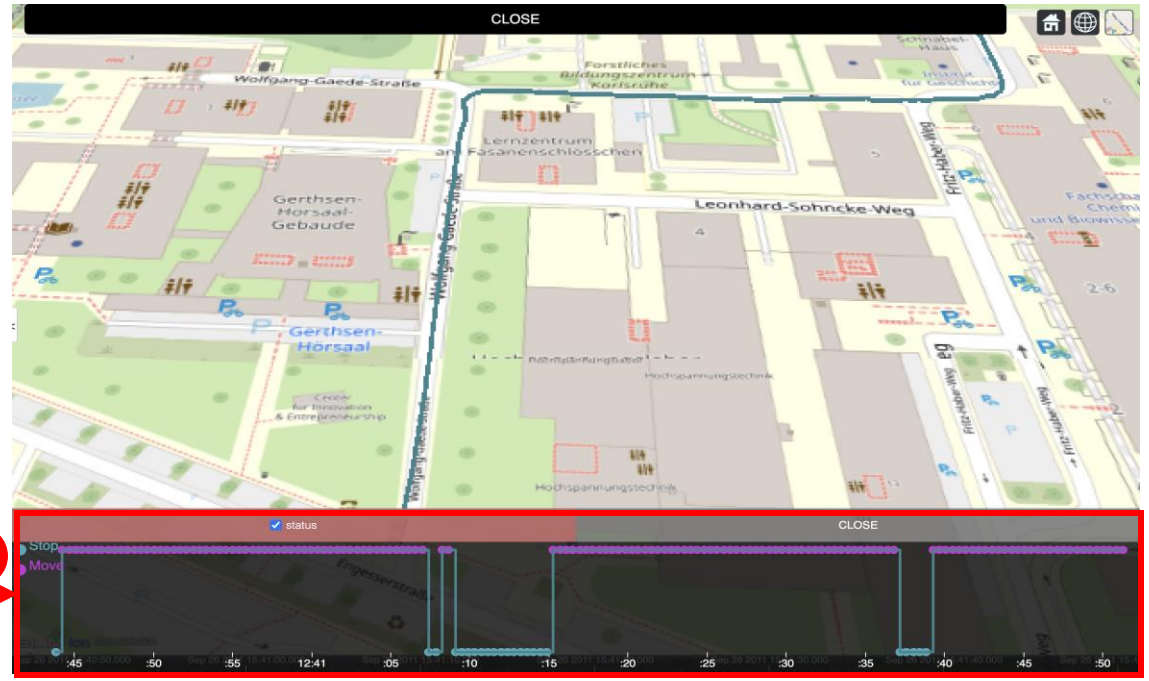
Practices STINUUM with MF-JSON

- **Visualize the temporal property (Text type)**
  - Upload the new MF-JSON
    - Path of file: **Stinuum Web/data/MF-JSON Prism/PracticeDataSet/mfjson_point_car_with_image.json**

    1) Display the list of properties included in the moving feature
    2) Select the one (or more) property
    3) Visualize property information as a graph



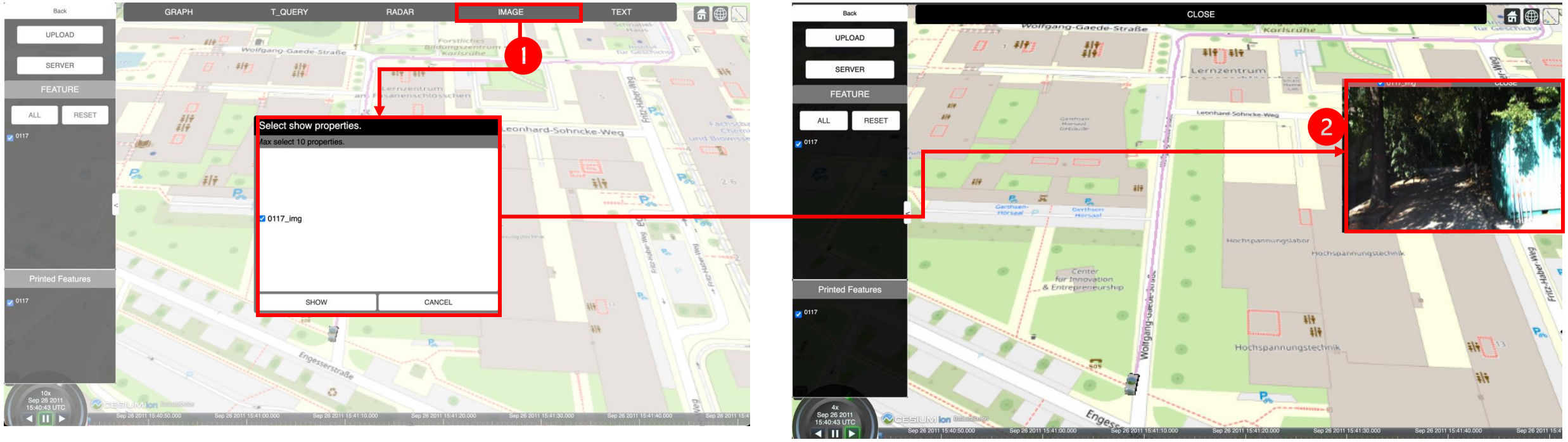
Select property to graph



Display selected properties as graph

Practices STINUUM with MF-JSON

- **Visualize the temporal property (Image type)**
  - STINUUM supports the visualization of image data with temporal properties.
    - All Images have time information
    - As time progresses in Cesium, the corresponding image is displayed



Connect with the installed pygeoapi to practice APIs

1. Environment setup to connect pygeoapi and mobilitydb
2. Register MF-JSON data with MF-API-Handler
3. Get all MovingFeatureCollection from pygeoapi (/collections)
4. Get selected MovingFeatures (/collections/{c_id}/items)
5. Get and visualize the selected MovingFeature (/collections/{c_id}/items/{mf_id})
6. Get and visualize the TemporalGeometry (/collections/{c_id}/items/{mf_id}/tgsequence)
7. Get and visualize the TemporalProperty (/collections/{c_id}/items/{mf_id}/tproperties)
8. Get and visualize the result of TemporalGeometryQuery
    1. (/collections/{c_id}/items/{mf_id}/tgsequence/{tg_id}/acceleration)
    2. (/collections/{c_id}/items/{mf_id}/tgsequence/{tg_id}/velocity)
    3. (/collections/{c_id}/items/{mf_id}/tgsequence/{tg_id}/distance)

Practices STINUUM with OGC API-MF

- **Environment setup to connect pygeoapi and mobilitydb**
  - Setting the server address and parameters related to the OGC API-Moving Features
    - Using system.json file in the project's root path

      > Path of file: **Stinuum Web/system.json**

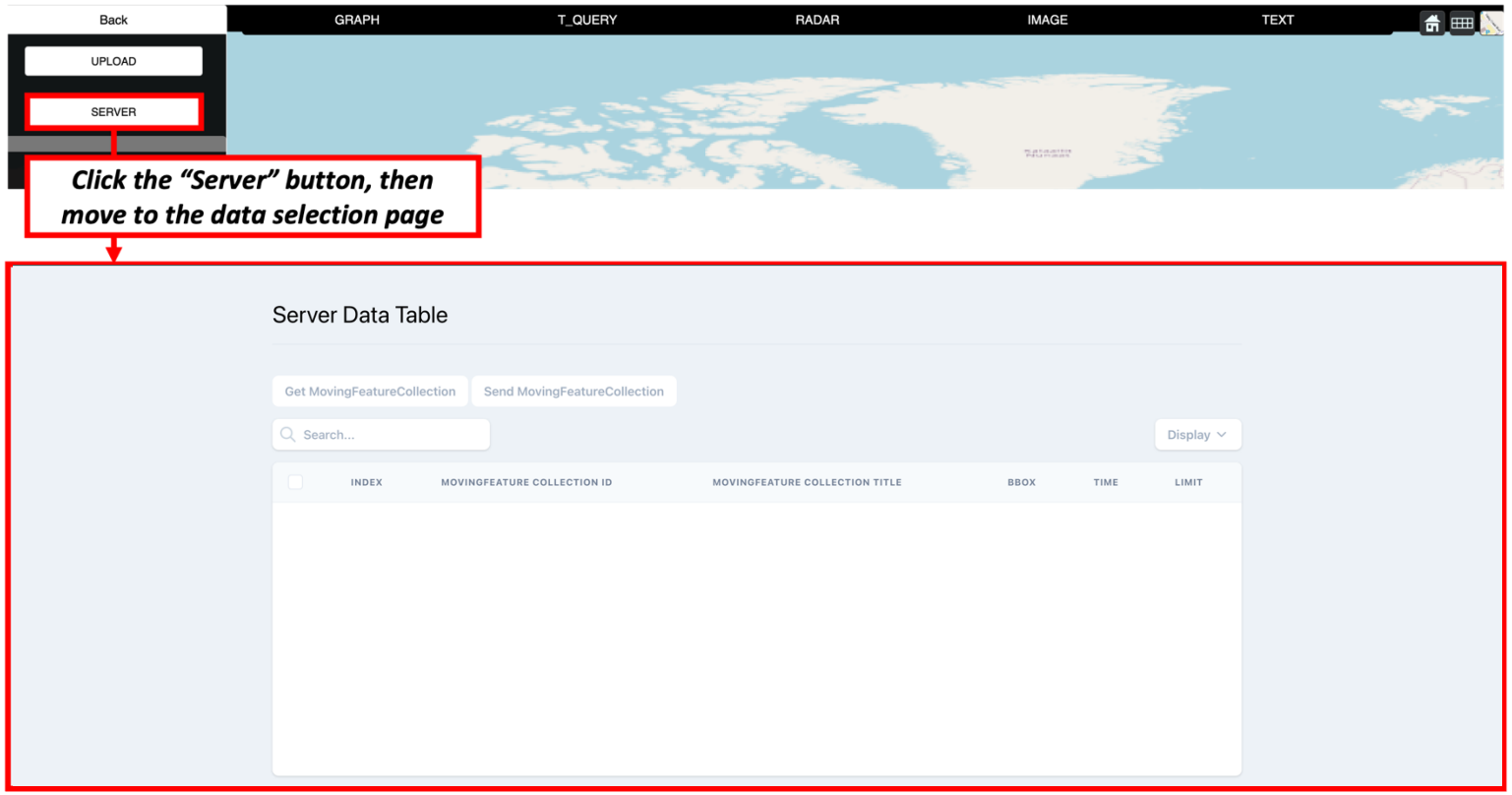
      - **pygeoapi_server_url**: pygeoapi address to connect (default localhost:5050)
      - **mf_limit**: number of moving features to import at once (default 10)
      - **mf_tg_limit**: number of temporal geometry to import at once (default 100)
      - **mf_tp_limit**: number of temporal properties to import at once (default 100)

Practices STINUUM with OGC API-MF

- **Register MF-JSON data with MF-API-Handler**
  - How to use MF-API Handler
    - It is created with Jupyter Notebook and can be executed in order to register data
    - Connect to pygeoapi (Run Cell 2)
      - Set the address of the pygeoapi
        - » pygeoapi_server_url = "**localhost:5050**"
    - Register new MovingFeatureCollection (Run Cell 3)
      - Setting the parameters required to register MovingFeatureCollection
        - » default_mf_collection_json = {
          "title": "**Your_Collection_Title**",
          "updateFrequency": **1000**,
          "description": "**Test**",
          "itemType": "**movingfeature**"
          }
    - Uploading the MF-JSON (Run Cell 4)
      - Path of file: **Stinuum Web/data/MF-JSON Prism/Practice/mfjson_point_for_mf_api_server.json**
      - Set the path to the file of the MF-JSON to be registered
        - » mf_json_path = "**path_to_mf-json**"

Practices STINUUM with OGC API-MF

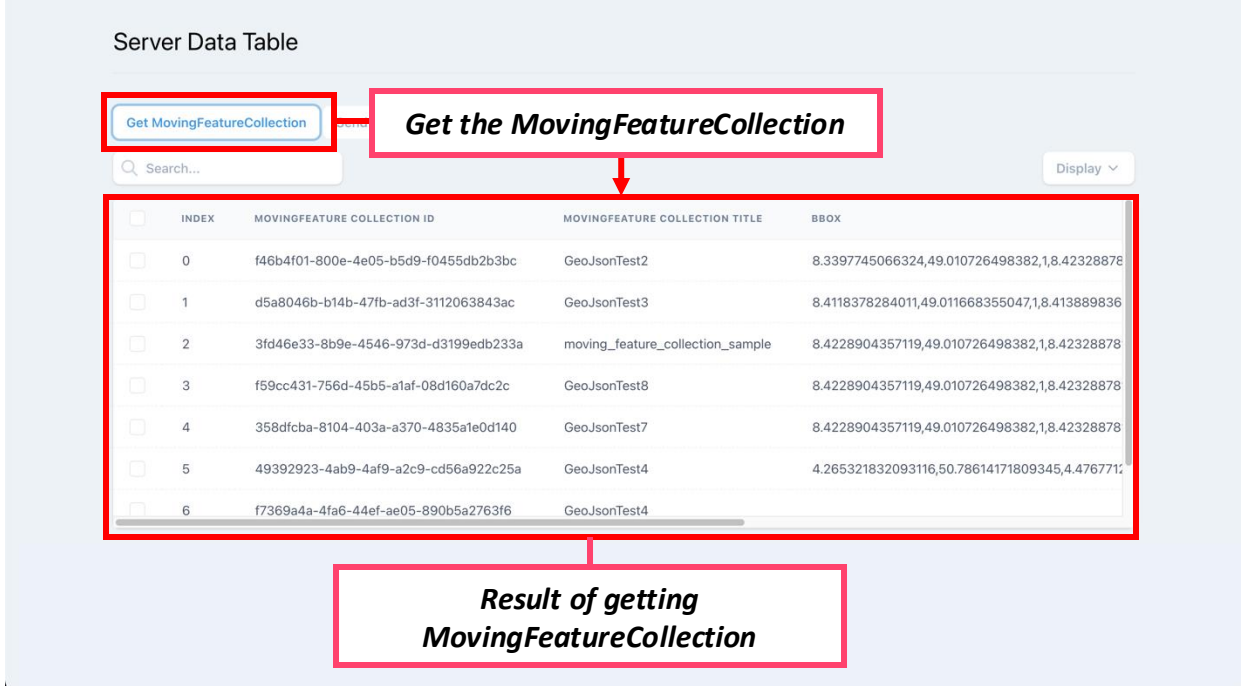
- **Connect to pygeoapi from STINUUM**
  - STINUUM provides a connection function for pygeoapi
    1) After running STINUUM, click the "***SERVER***" button in the menu on the left
    2) If a connection to the pygeoapi is possible, move to the data selection page automatically
       - localhost:8080/dataSelect



Practices STINUUM with OGC API-MF

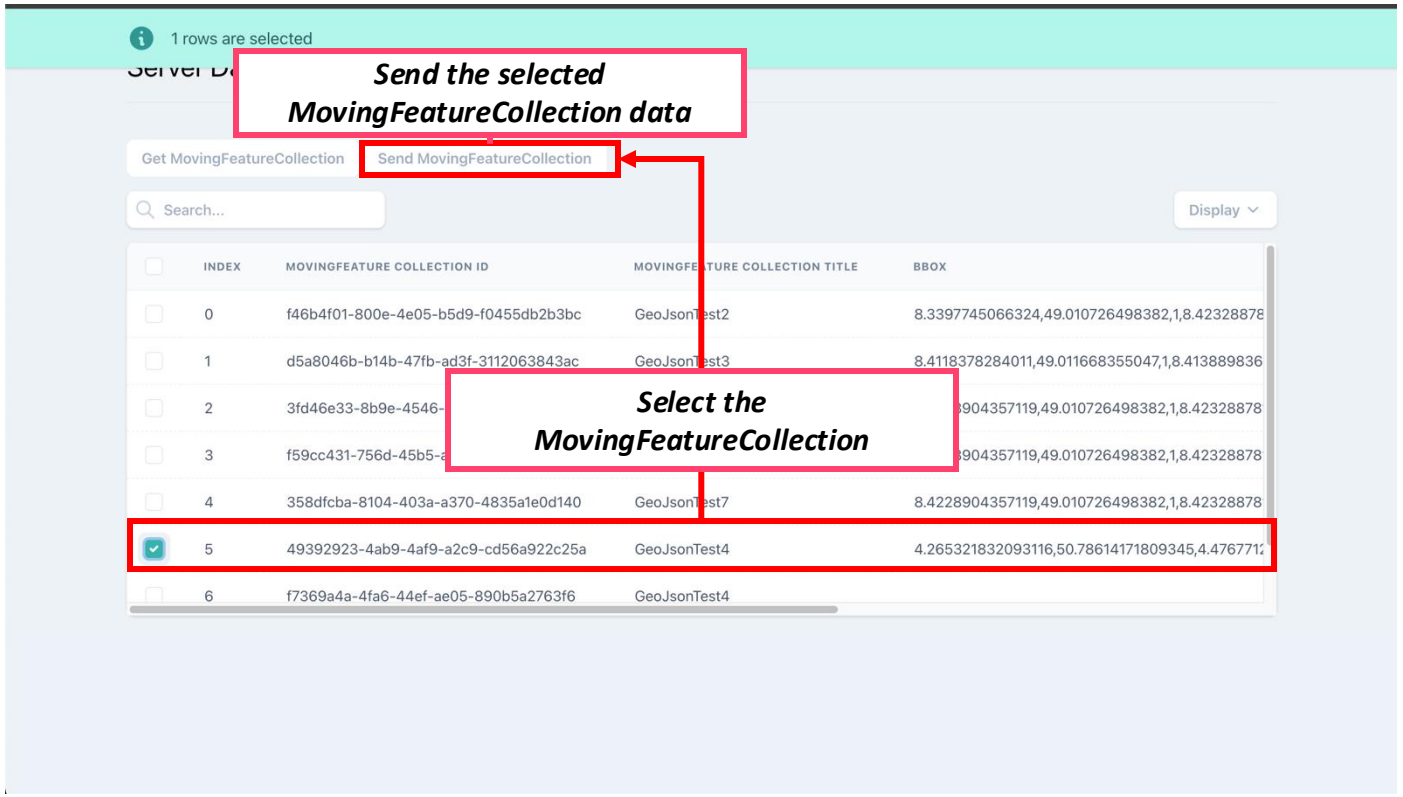
- **Get all MovingFeatureCollection from pygeoapi**
  - Users can get the **MovingFeatureCollection** from pygeoapi
    1) Click the "***GET MovingFeatureCollection***" button
    2) Receive a list of **MovingFeatureCollection** from pygeoapi
    3) If it succeeds, the result is added to the bottom table

Query Information	
GET	/collections



Practices STINUUM with OGC API-MF

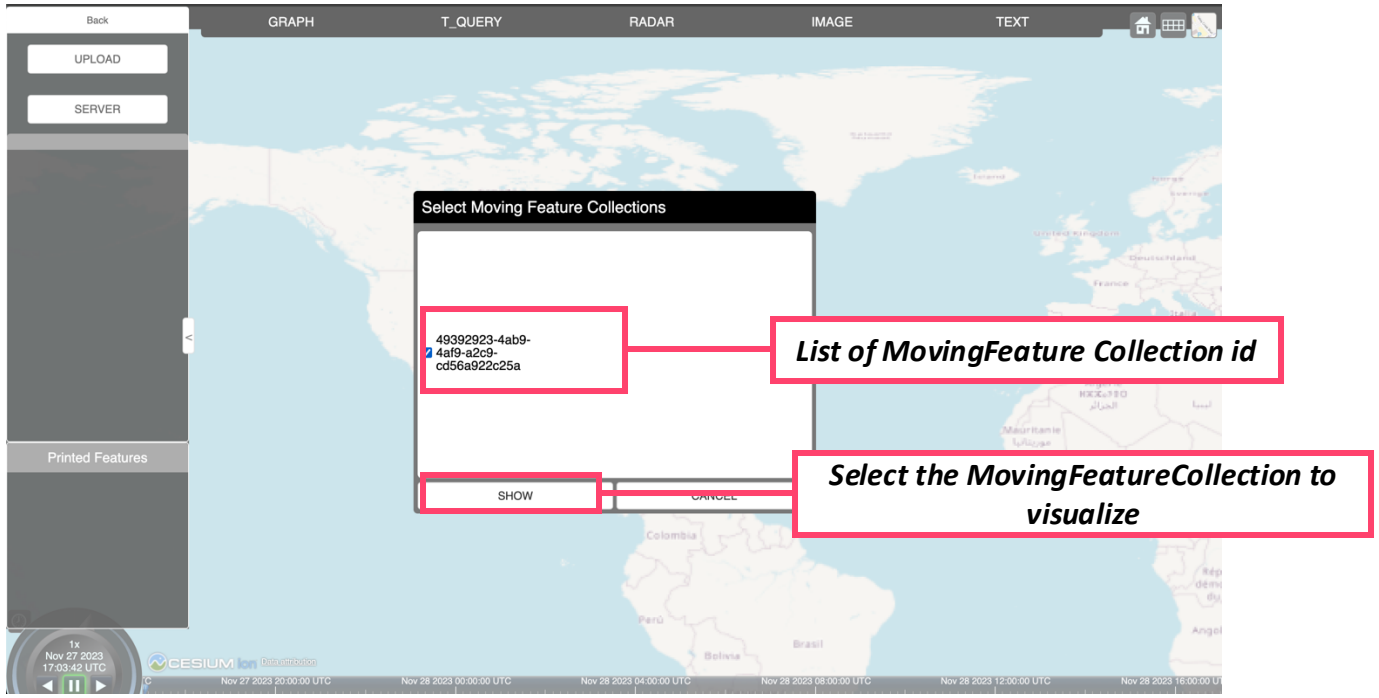
- **Send the MovingFeatureCollection data to the main page**
  - Select one or more rows that users need to get the **MovingFeatureCollection**
    - And then click the ***"Send MovingFeatureCollection"*** button to sends the selected column values to the main page
      - localhost:8080/main



Practices STINUUM with OGC API-MF

- **Get the MovingFeature list from the selected MovingFeatureCollection**
  - STINUUM displays a list of **MovingFeatureCollection** IDs from pygeoapi
    1) Select one or more IDs and then click the "***SHOW***" button to get the **MovingFeatureCollection** data
    2) Add the **MovingFeatureCollection** data to the left menu (Collection Layer)
    3) Click on an ID displayed in the collection layer, the included **MovingFeature** information is visualized

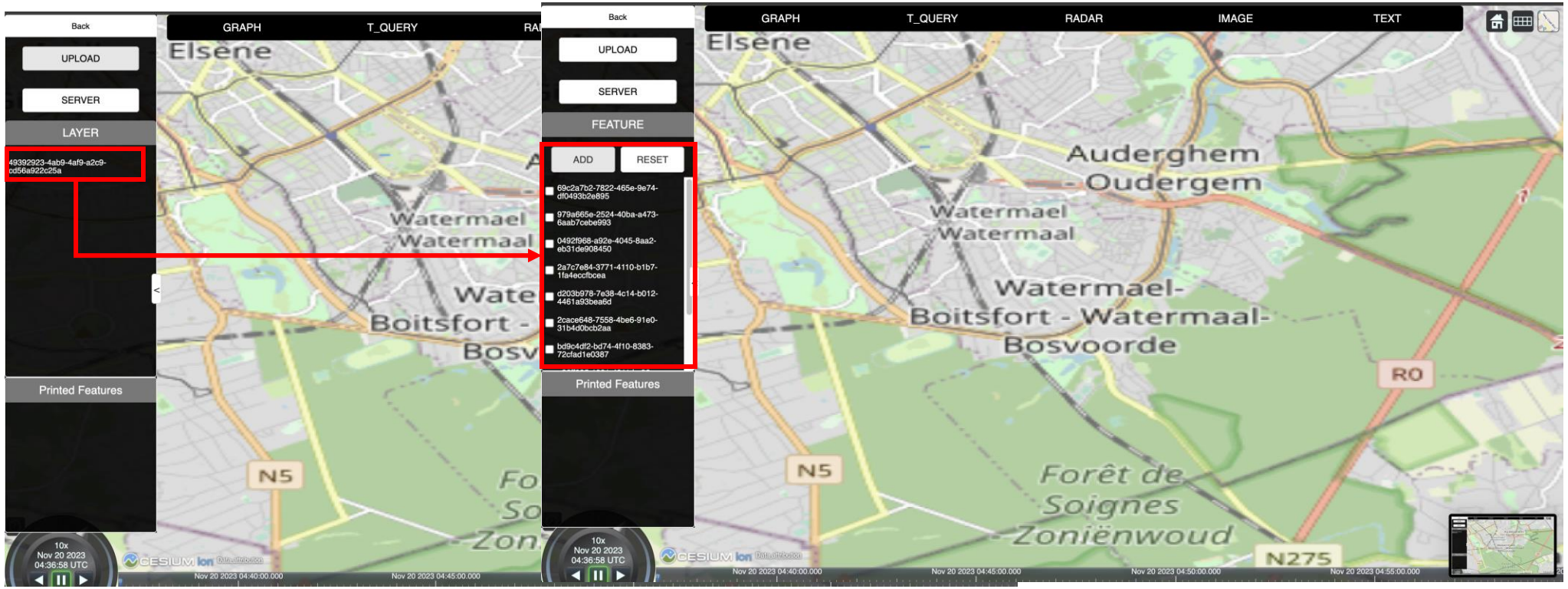
       → From now on, users can use STINUUM's features to analyze moving features



Practices STINUUM with OGC API-MF

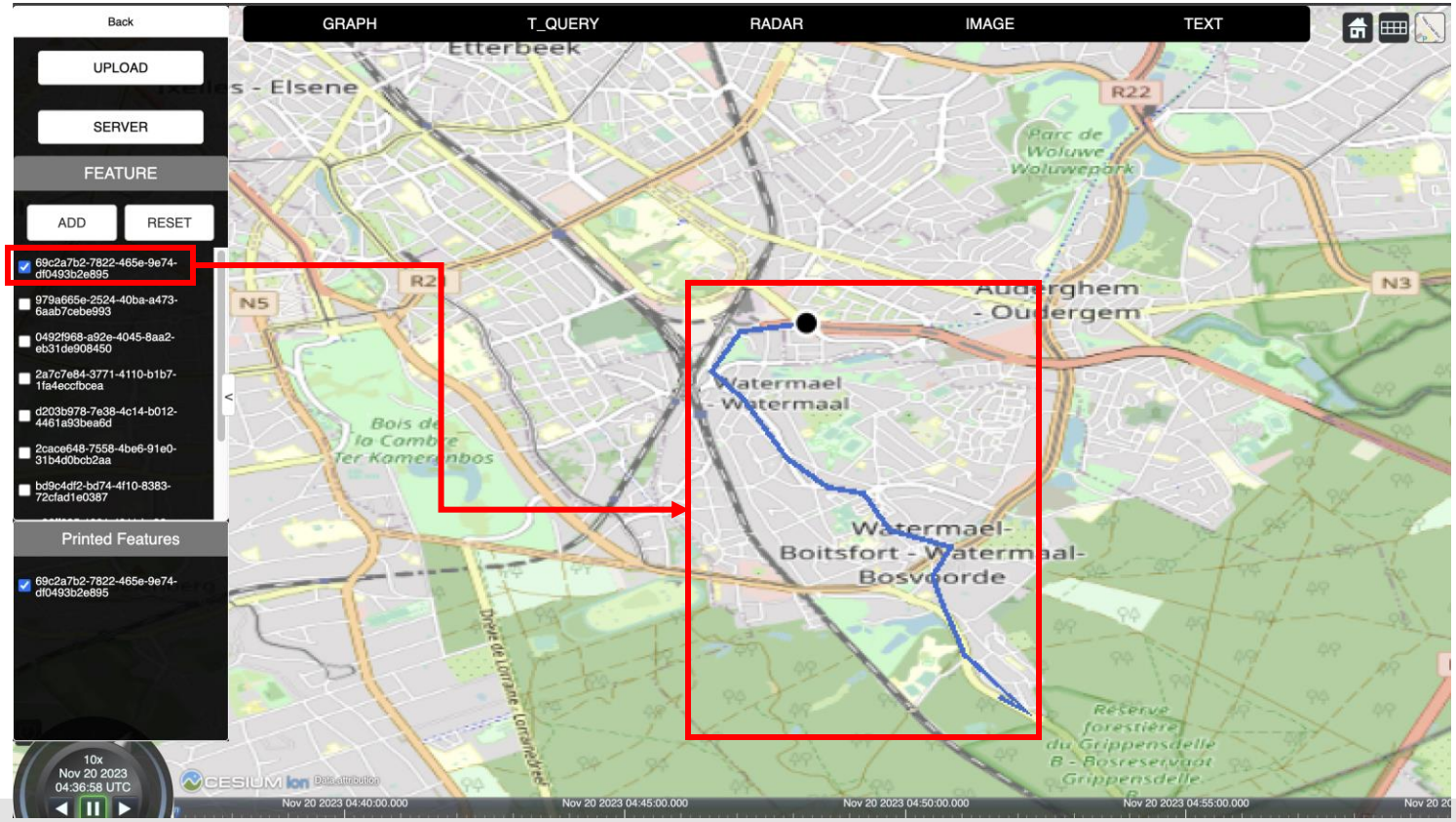
- **Get selected MovingFeatures**
  - Click a **MovingFeatureCollection** item in the Collection Layer
  - Get each **MovingFeature** information from pygeoapi

Query Information	
GET	/collections/{c_id}/items
c_id	ID of Selected Moving Feature Collection
Parameters information	
limit	mf_limit (default 10)
datetime	Datetime of selected Moving Feature Collection



Practices STINUUM with OGC API-MF

- **Get and visualize the TemporalGeometry**
  - Click the check box of **MovingFeature** from the Feature Layer
  - Get the **TemporalGeometry** data from pygeoapi

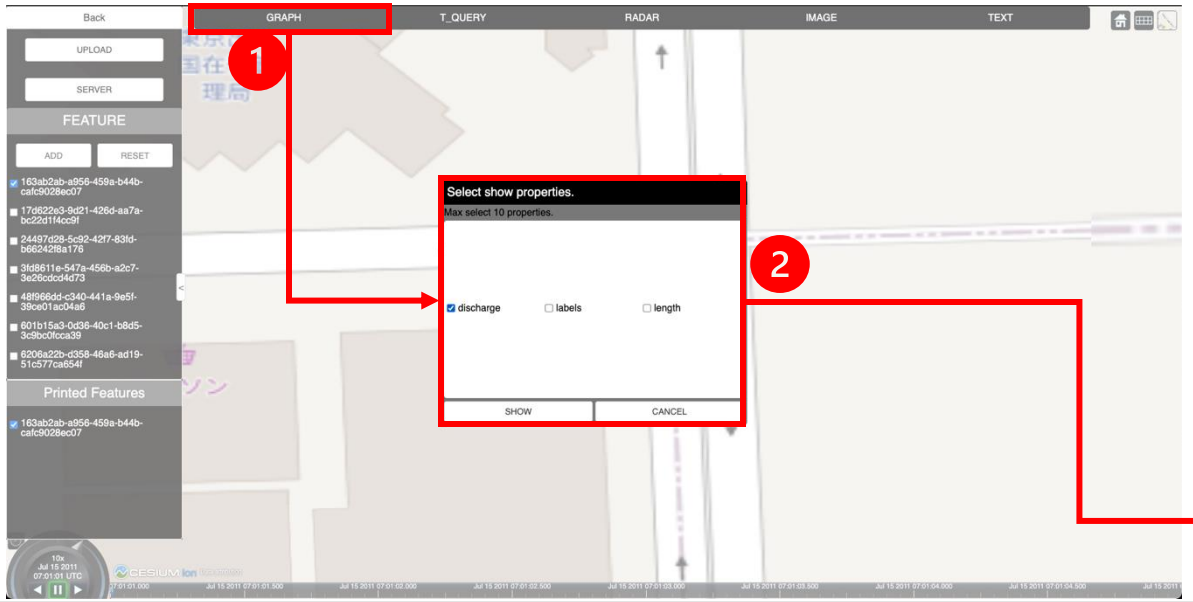


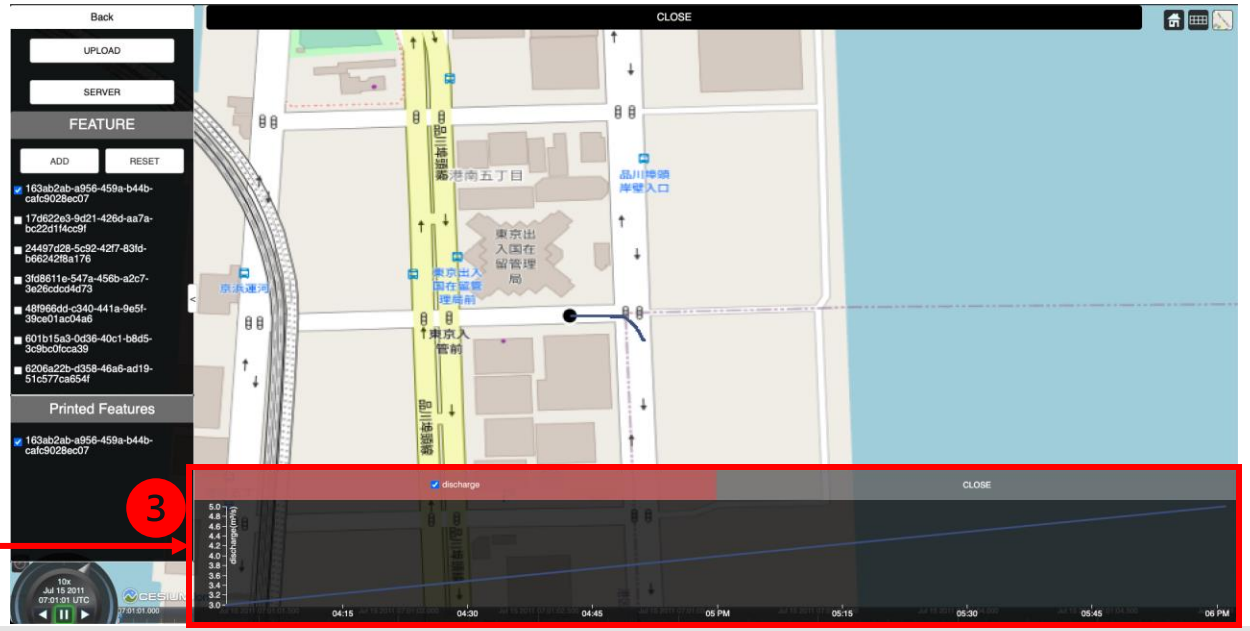
Query Information	
GET	/collections/{c_id}/items/mf_id/tgsequence
c_id	ID of Selected Moving Feature Collection
mf_id	ID of Selected Moving Feature
Parameters information	
limit	mf_tg_limit (default 100)
datetime	Datetime of selected Moving Feature

Practices STINUUM with OGC API-MF

- **Get and visualize the TemporalProperties**
  1) Click the ***GRAPH*** button: Display the list of temporal property included in the **MovingFeature**
  2) Select a temporal property
  3) Visualize temporal property data as a graph

Query Information	
GET	/collections/{c_id}/items/mf_id/tproperties
c_id	ID of Selected Moving Feature Collection
mf_id	ID of Selected Moving Feature
Parameters information	
limit	mf_tp_limit (default 100)
datetime	Datetime of selected Moving Feature

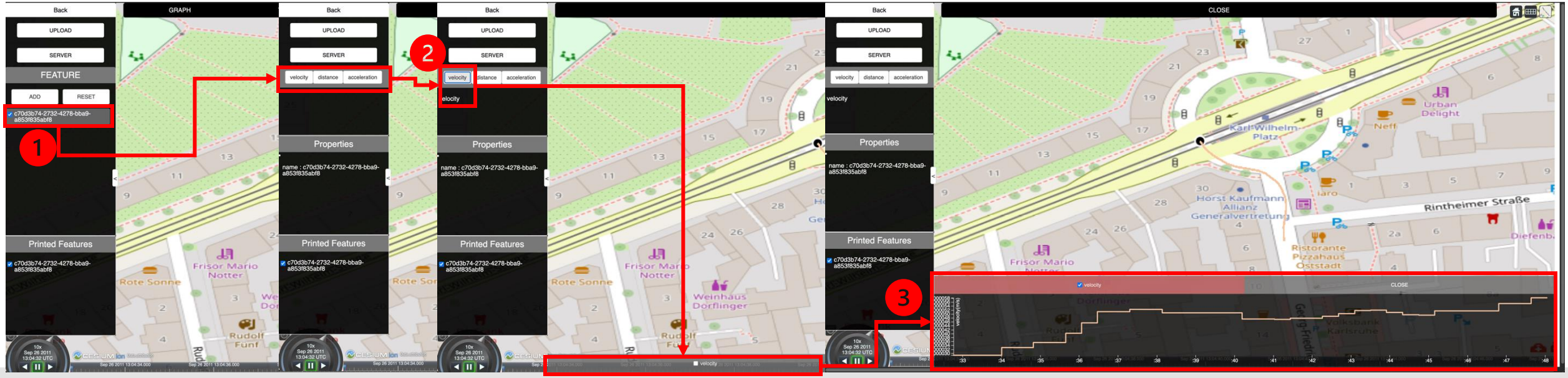




Practices STINUUM with OGC API-MF

- **Get and visualize the TemporalGeometryQuery result**
  1) Click the **MovingFeature** from the Feature Layer
  2) Select a type of **TemporalGeometryQuery**
     - velocity, distance, acceleration
  3) Visualize the result as a graph

Query Information	
GET	/collections/{c_id}/items/{mf_id}/tgsequence/{tg_id}/velocity
c_id	ID of Selected Moving Feature Collection
mf_id	ID of Selected Moving Feature
tg_id	ID of selected TemproalGeometry
Parameters information	
limit	mf_tp_limit (default 100)
datetime	Datetime of selected Moving Feature



Thank you