# 3D VISUALIZATION AND ANALYSIS OF PATAGONIAN GLACIERS CHANGES USING EARTH OBSERVATION DATA

DIPLOMA THESIS

## CONTEXT AND STUDY REGION

The Patagonian Andes are considered the largest glacierized area in South America, with a total glacier extent of 20,000 km². In recent years, the Patagonian glaciers have been experiencing dramatic retreats and significant losses in area and volume due to climate variability. Consequently, it is necessary to conduct research and develop tools that help to understand the current status of the glaciers and their ongoing climatic changes.

Specifically, this research focused on the Northern and Southern Patagonian Icefields, with extents of 4,200 km² and 13,000 km², respectively, where most glaciers are concentrated. Based on the Randolph Glacier Inventory 7.0, glaciers with an area greater than or equal to 10 km² were selected for these icefields, resulting in 27 Northern Patagonian glaciers and 56 Southern Patagonian glaciers.

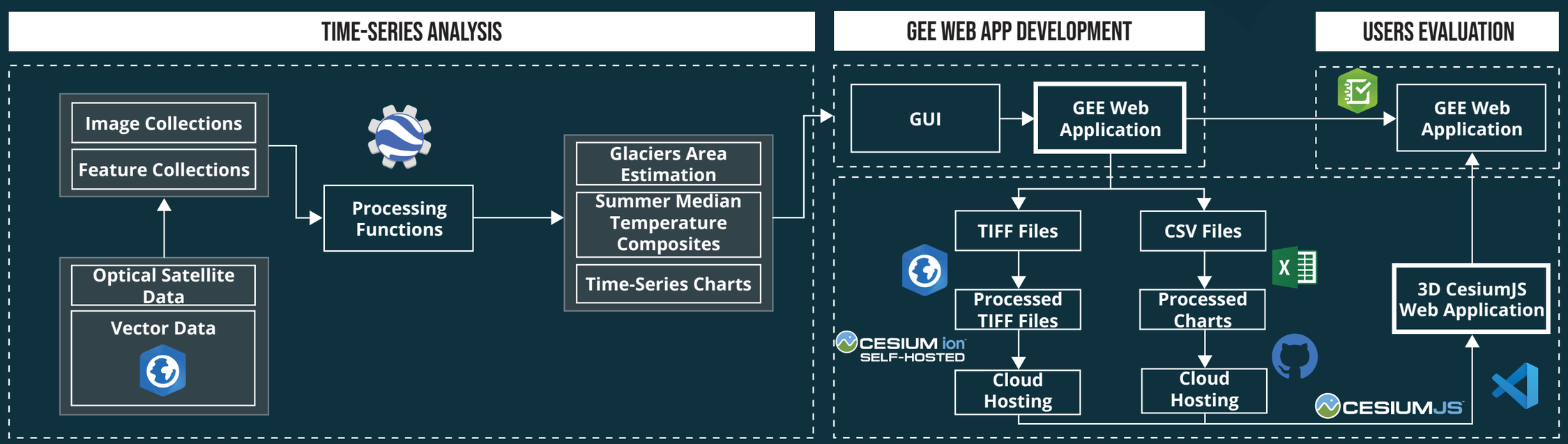
## OBJECTIVES OF THE THESIS

This diploma thesis aimed to address the lack of studies and 3D visualizations of Patagonian glaciers by developing a Google Earth Engine (GEE) web application that allowed the creation, visualization, and export of remote-sensing and time-series products to quantitative and qualitative estimate the glacier area, Land Surface Temperature, and air temperature changes of the mentioned glaciers, in the summer periods between 2018 and 2023, using Landsat 8-9, Sentinel-2, and ERA5-Land imagery.

Moreover, it aimed to develop a 3D web application using CesiumJS to dynamically visualize and compare the remote sensing and time-series products derived from the GEE web application using widgets such as swipe, side bar, and display controls.

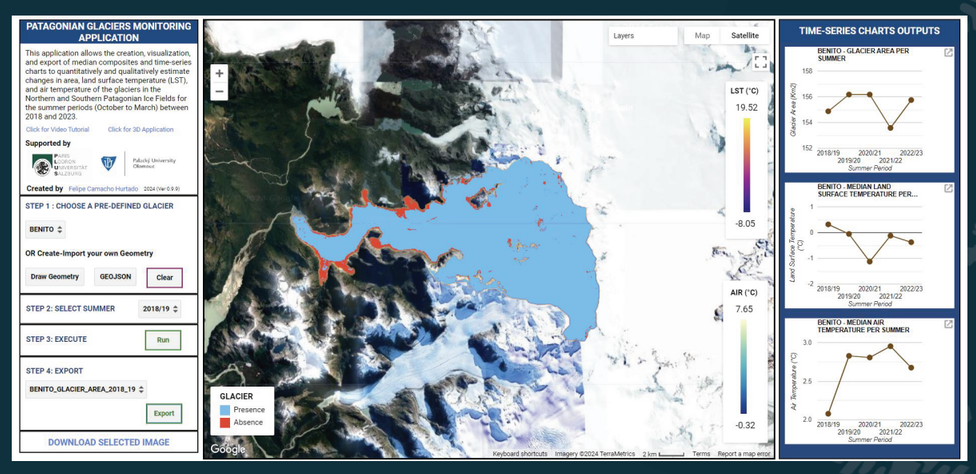
## PURPOSED METHODOLOGY

The workflow involved exporting selected glacier outlines as shapefiles via ArcGIS Pro, and creating Feature Collections along with Image Collections for Landsat 8, 9, Sentinel-2, and ERA5-Land imagery in GEE. Processing functions such as the calculation of NDSI and NDWI indices, combined with median reducers, were used to estimate glacier area changes, generate median temperature composites, and create time series charts. Subsequently, a Graphical User Interface (GUI) was designed to support the interactive creation, visualization, and export of remote sensing and time-series data products. These data were processed using Excel and ArcGIS Pro and later uploaded to Cesium Ion and GitHub. With the data hosted in the cloud, a 3D web application was developed using CesiumJS and Visual Studio Code. Finally, an evaluation of both web applications was performed through an online ArcGIS Survey123 form shared on LinkedIn.




## RESULTS AND OUTPUTS

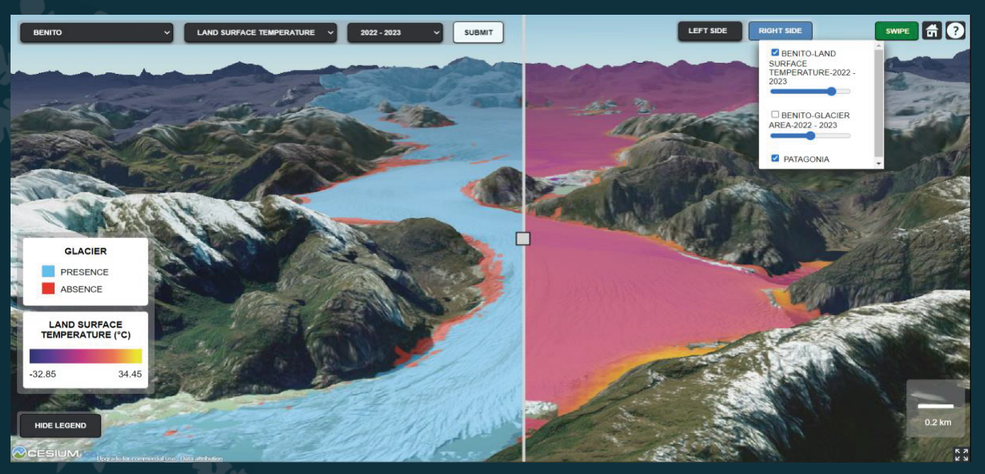
### PATAGONIAN GLACIERS MONITORING APPLICATION




GEE APP

The "Patagonian Glaciers Monitoring" GEE web application features several panels, including a main panel with general information, interactive buttons, and selectors for performing the time-series analysis. Moreover, there is a map panel for interactive visualization of the output imagery and a panel for displaying time-series charts.

### 3D PATAGONIAN GLACIERS VIEWER




3D APP

The "3D Patagonian Glaciers Viewer" CesiumJS web application allows users to visualize and compare 3D remote sensing outputs from the GEE application with a high-resolution terrain and basemap. It includes widgets like swipe, sidebar, and layer controls for examining glacier areas and temperature changes since 2018.

### TIME-SERIES ANALYSIS OUTPUTS

GITHUB

1245 summer median composites and 249 time-series charts, equivalent to the 83 analyzed glaciers, were generated through the GEE web application GUI. This data can be accessed through the application itself or the official GitHub repository, which includes as well the pre-processed and processed datasets.

### USERS EVALUATION

From 12 anonymous survey responses, the "Patagonian Glacier Monitoring Application" mostly received excellent ratings for its interface, but its performance was rated as good and fair. In contrast, the "3D Patagonian Glaciers Viewer" was very well received, with 75% rating the interface and over 50% the performance as excellent.

SURVEY

## CONCLUSIONS

In conclusion, the time-series methodology and web applications proposed and developed in this study are a major step toward improving the glaciology knowledge of the Patagonian region. They evidenced the hidden potential of GEE and 3D visualizations for scientific dissemination and the importance of GUI design when creating attractive web experiences. Furthermore, as the source code for both GEE and CesiumJS web applications is publicly available, the users will be able to extend their functionalities by introducing new data, adding widgets, or changing the Area of Interest. It is expected that with the outputs generated from this study, scientific and non-scientific communities will gain awareness of the importance of the glaciers and their ongoing changes.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Olomouc, 2024
Attachment to diploma thesis no. 1



Palacký University Olomouc
PARIS LODRON UNIVERSITÄT SALZBURG
COPERNICUS MASTER IN DIGITAL EARTH
With the support of the Erasmus+ Programme of the European Union