From Static to Dynamic Visualization of the Sea Surface Height on a Web GIS Application

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Motivation (General)

- The Climate is changing
- Ice loss in Greenland and Antarctica
- Extreme weather phenomena
- The Oceans are getting affected
  and they affect the climate

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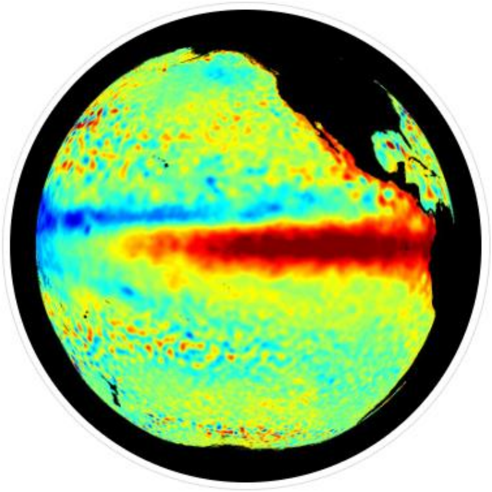
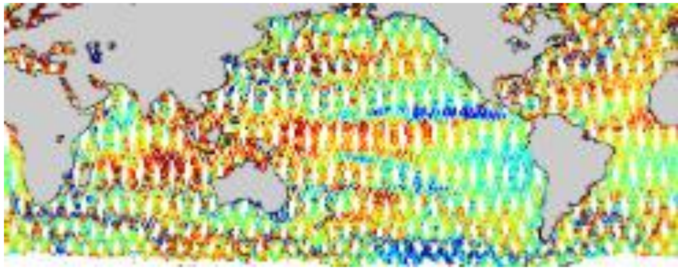
Sea Surface Height

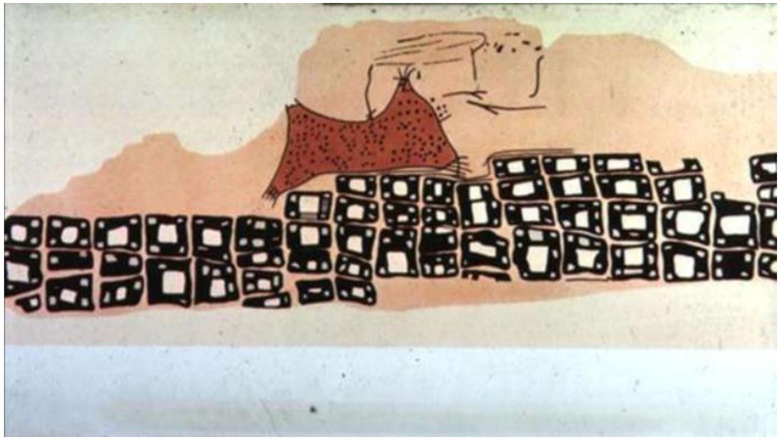
- Ocean Topography
- Sea Surface Height ➔ How much heat is stored in the ocean
- Sea Surface Height ➔ water level of the ocean, indicator for ocean water volume
- **Sea Surface Height Anomaly ➔** difference with respect to reference level (typically 1993)
- **Dynamic phenomenon** (Change through time)
- **Different phenomena ➔Different time scales**
- **Different spatial scales**



Visualization



- A vast amount of spatial data are produced daily
- One of the best way of extracting information is by visualizing the data
- The vision is the most dominant sense within the human sensory system
- One of the oldest visualization techniques is **Cartography** (6200BC)



Geographic Information Systems

- The invention of the computers led to the development of the Geographic Information Systems (GIS

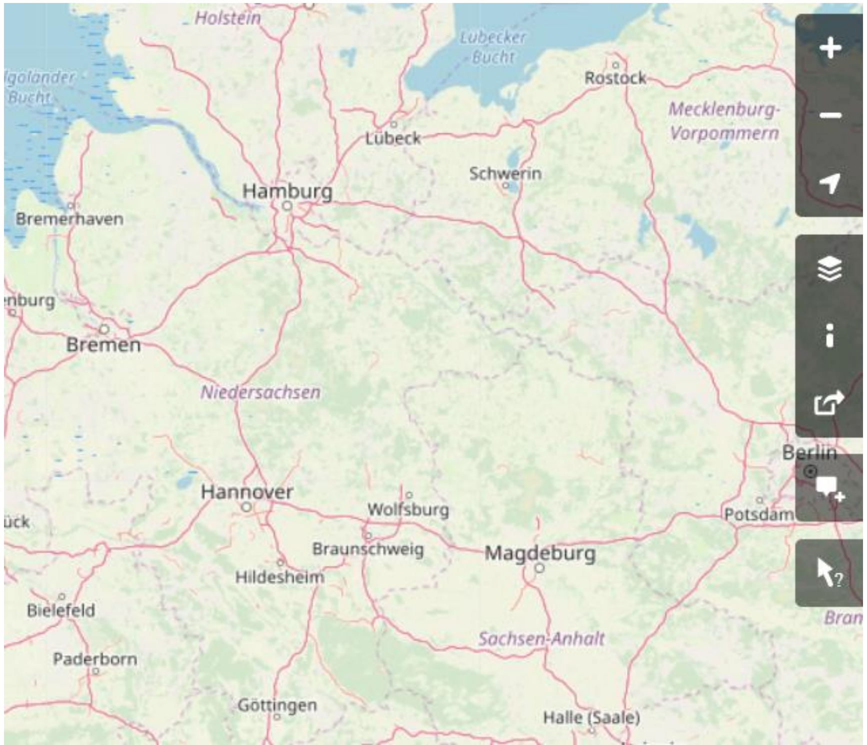
"Geographic Information Systems (GISs) are computer-assisted systems for the capture, storage, retrieval, analysis and display of spatial data".

(Clarke, 1984)

- The first GIS analysis: Charles Picket (France, 1832)

Interaction

- Advancement of the computer + Digital revolution ➔Interactivity
- Some scholars believe that even paper maps are interactive (rotate, move, draw, point)
- The digital environment affords a wider array of interactions



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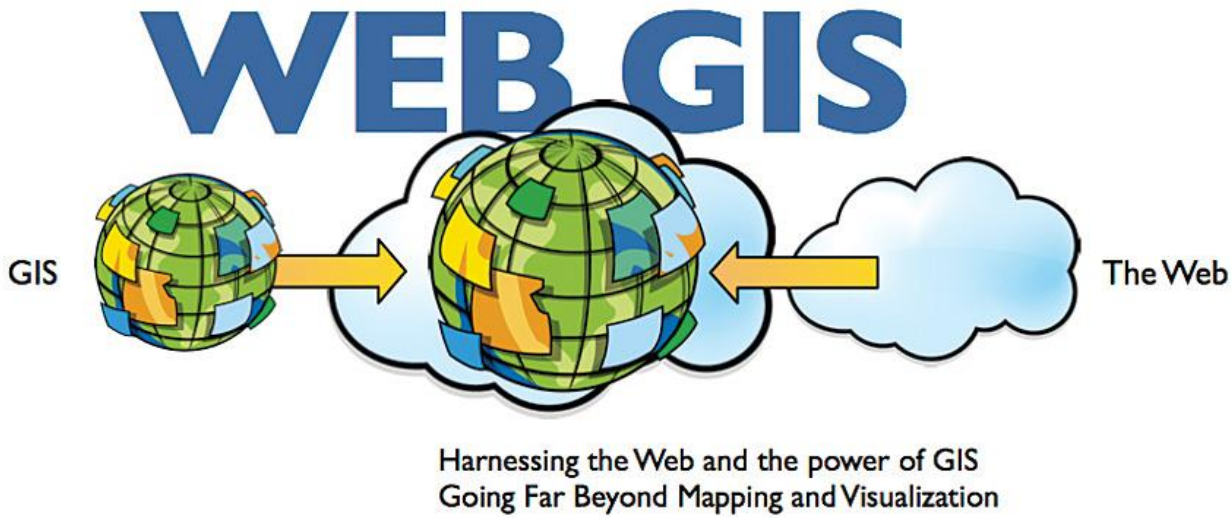
Web GIS

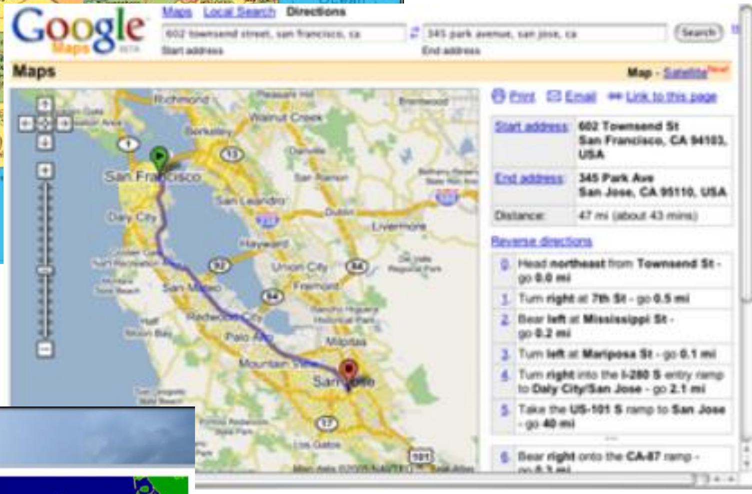
- Late 1980s the World Wide Web was invented
- The number of Web applications is in the rise and the GIS related are as well
- Main advantage:
  Provides the opportunity to the user to access, analyze and visualize geographic information from anywhere at any time



Web GIS (Visualization)

Static
- Early 1990s
- Simple images

Interactive
- AJAX
- Google Maps, Microsoft Virtual Earth, Yahoo Maps



Dynamic
- Animation
- First formats: GIF, SVG

OGC Standards

- Combine data from multiple sources
- Platform independence
- Not only for the user but also for software programs
- Need for interface standardization (Interoperability)
- Foundation of Open Geospatial Consortium
- WMS, WFS, WCS, WMTS, WPS, CSW etc
- Maybe now also a **WVMS**

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Research Questions

Main:

” What is an optimal WebGIS-architecture for making an interactive - dynamic visualization of the sea-surface height phenomenon?”

Sub-questions:

- Sea surface height is a dynamic phenomenon (2.5D + time), what **animation** technique should be used and why?
- What elements of **interactivity** are relevant to a web mapping application and which ones should be implemented?
- What type of **architecture** is more appropriate for an implementation with these characteristics?

Research Scope

- No extended data analysis
- Interactivity ➔ Literature review/related work
- No usability test
- 2D + Time (Height represented with color)
- The architecture will be based on existing applications

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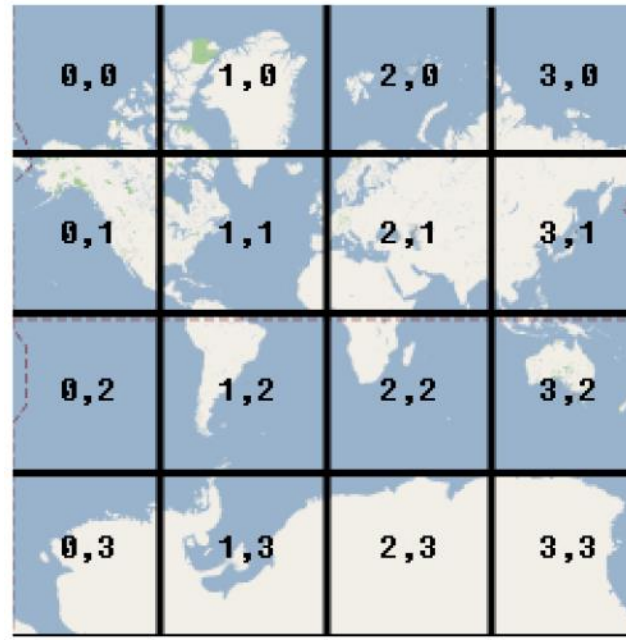
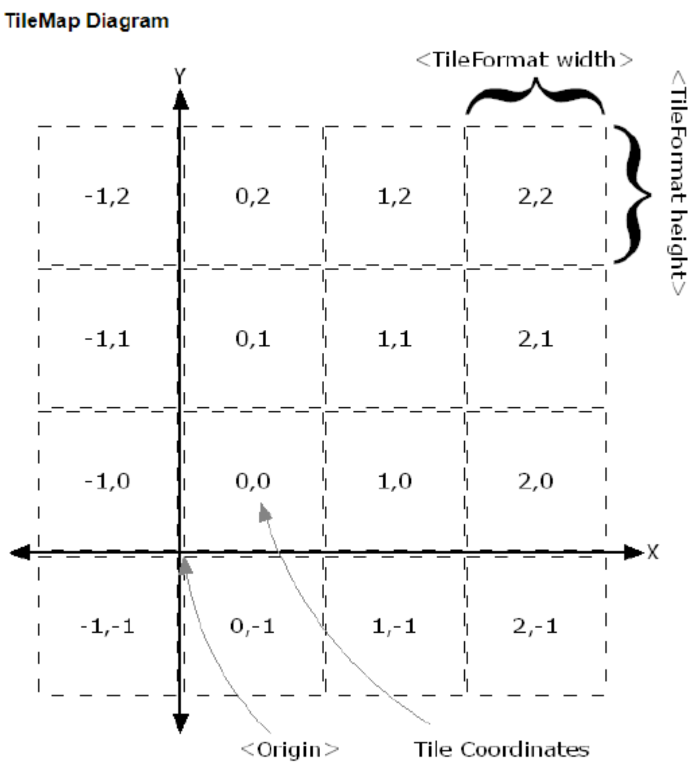
Google Maps

- One of the first applications that introduced the tiled web maps (for zooming and panning)
- The tiling scheme that it was used is standardized

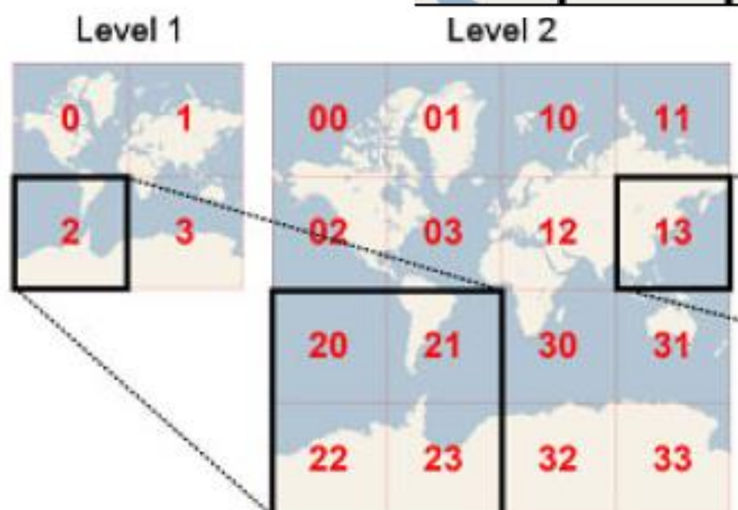
Google Maps (Tiling Scheme)

- 256x256 pixels
- Origin (Upper left corner)





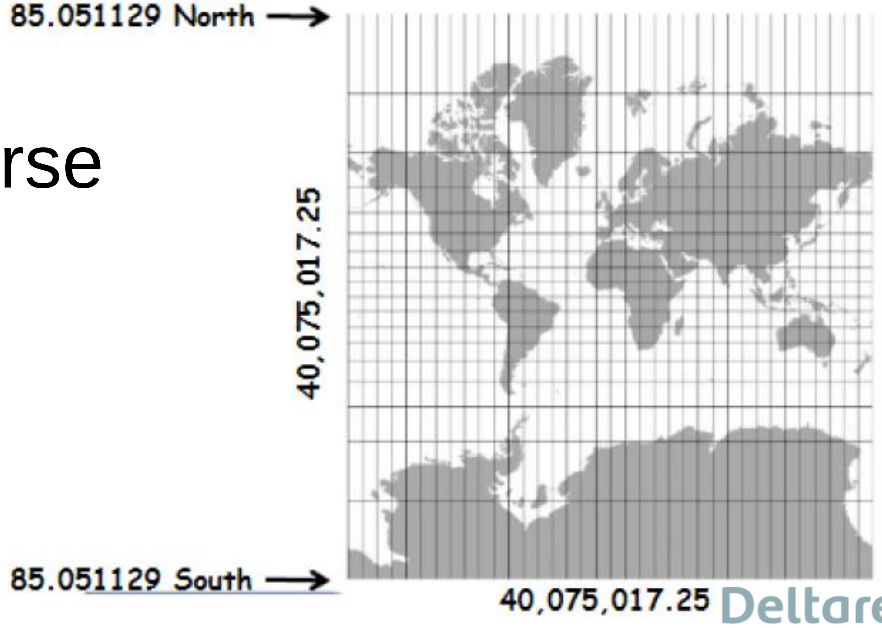
TMS



Bing Maps

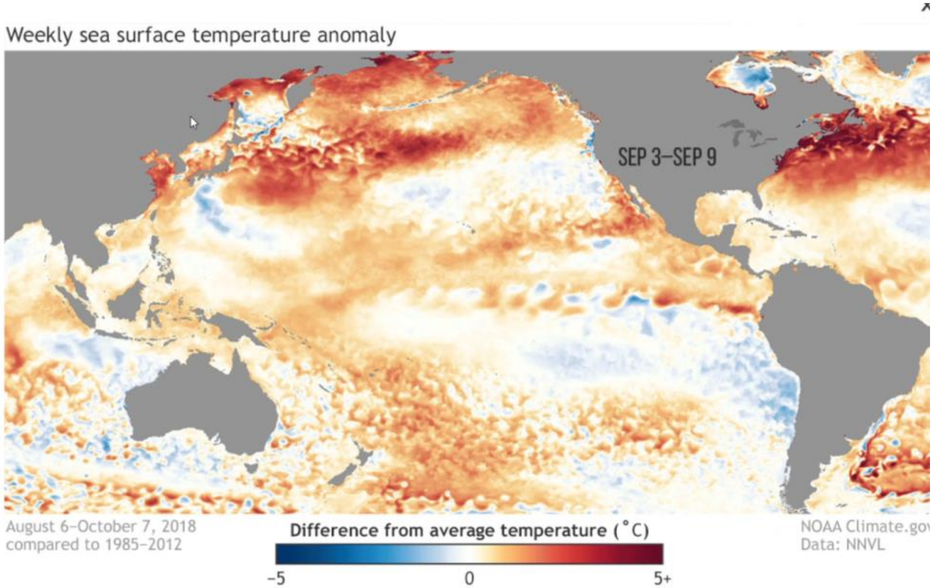
Google Maps (Web Mercator)

- Based on Original Mercator Projection (Cylindrical + con-formal)
- WGS 84 ellipsoid
- Spherical Mercator equation (decreased computational cost)
- Non conformal
- Lines of constant course are not straight



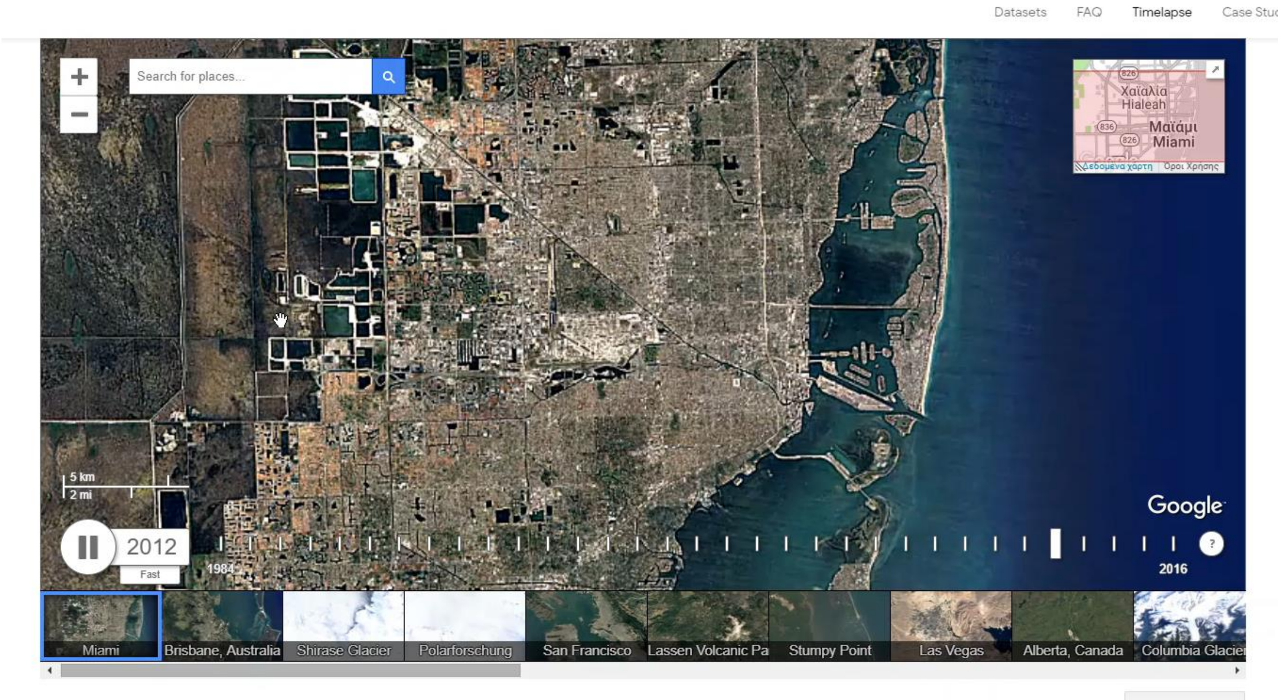
Animated Web Maps (Slideshow/GIF)

- Slideshow (CSS3/WebGL):
+ Good quality, interactive
- Storage requirements
- GIF:
+ Storage requirements
- Limited interactivity



Animated Web Maps (Video)

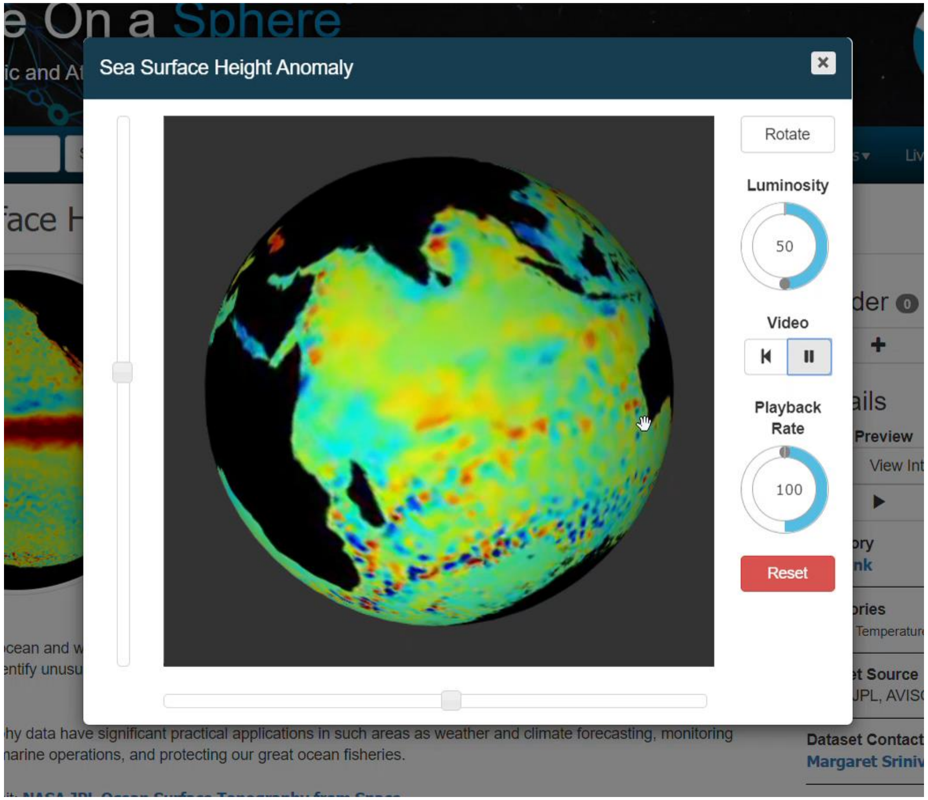
+ Interactive, Storage requirements
- Weird tiling scheme (1480x800), not interactive enough



Time Machine

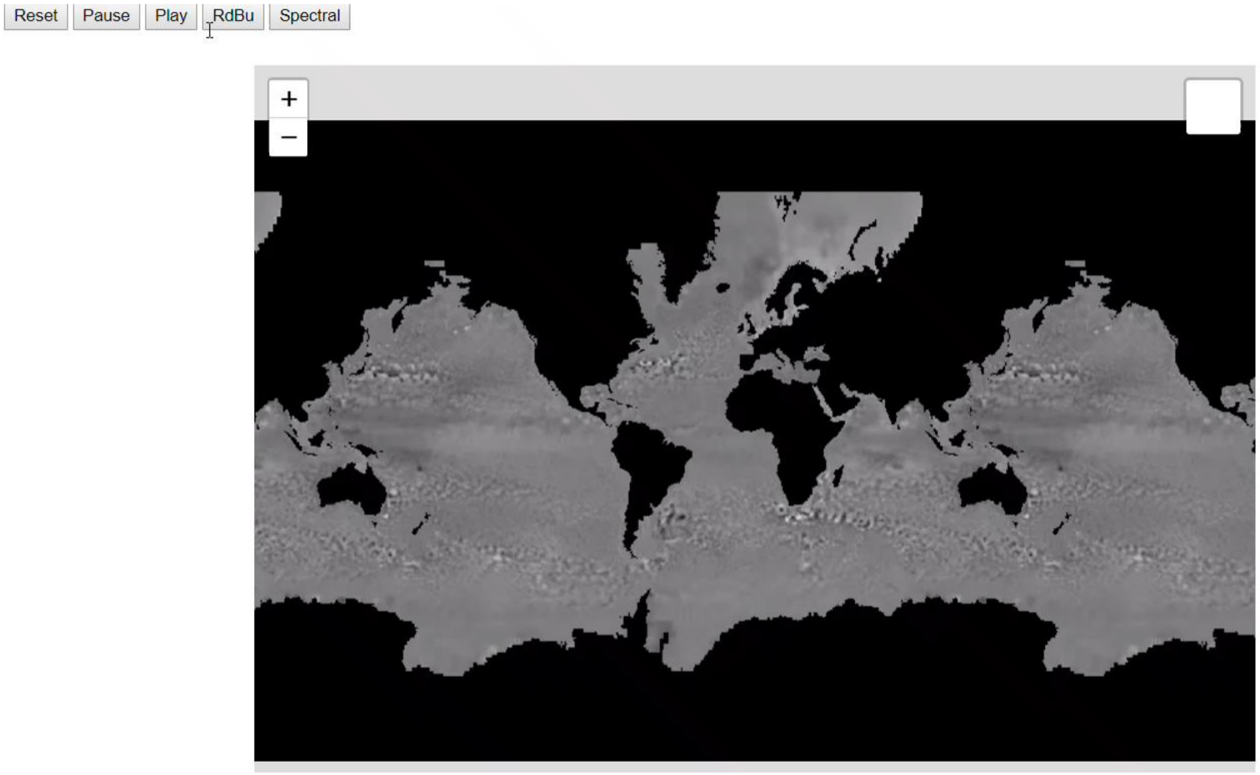
Animated Web Maps (Virtual Globe + Video)

+ More immersive experience
- Limited interactivity



What This Application Looks Like?

Animation (Time Machine Implementation)
+ Google Maps Tilling Scheme
+ Extra Interactivity (Coloring, querying, zoom in time)



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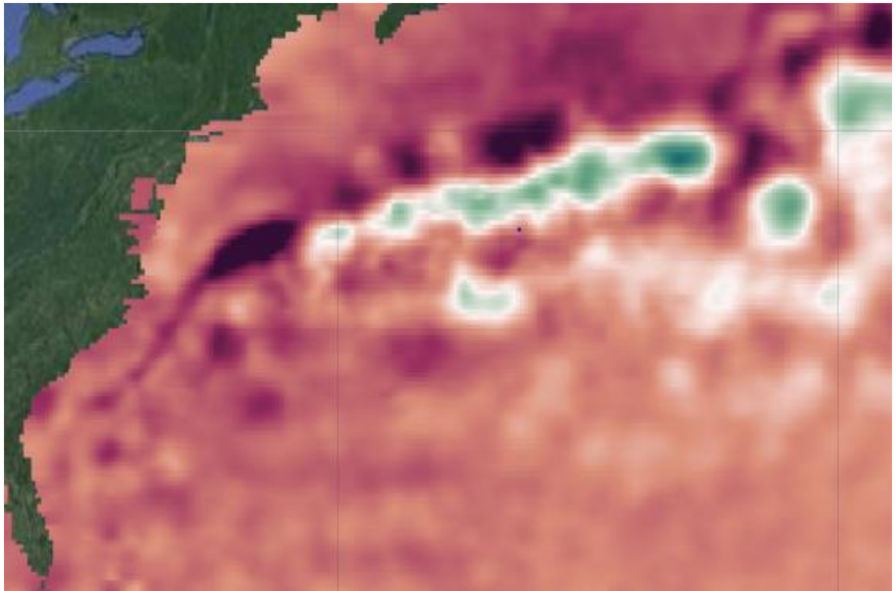
Dataset

"JPL MEaSUREs Gridded Sea Surface Height Anomalies Version 1609" NASA provided dataset

- NetCDF format
- Spatial resolution: 0.17 degree
- Temporal resolution: 5 days
- Time span: 25 years
- 11.07 GiB in compressed TIFF files



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Methodology (General)

- Answers the research questions
- 3 parts (animation, interactivity, architecture)
- Comparison between the different options and selection of the best solution

Animation (Part 1)

Animation Technique	Compression	Proprietary Status	Browser Compatibility	Interactivity Options
GIF	o	o	+	-
Slideshow	-	o	o	+
Video	+	o	o	+

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Animation (Part 2)

- Compression Standards
- Containers
- HTML5 video element

	Compression and Quality	Proprietary Status	Browser Compatibility	Encoding Speed
OGG/Theora	-	o	o	+
MP4/H.264	-	-	+	+
MP4/H.265	o	-	-	o
WebM/VP8	-	+	o	o
WebM/VP9	o	+	o	o
WebM/AV1	+	+	-	-

Interactivity Elements (Handling the x and y coordinates)

- Zooming and Panning
- Tiling

Tiling Scheme	Storage Space	Synchronization Efficiency	Existing Technology Compatibility
Google Maps (256)	o	-	+
Mapbox (512)	+	o	+
Time Machine	-	+	-

Interactivity Elements (Handling the z coordinate)

- Video Filters & Canvas API ➔ CPU
- WebGL ➔ GPU

Coloring Options	Implementation Complexity	Performance	Multi Color Pallets
Video Filters (CSS3)	+	o	-
Canvas API	+	-	+
WebGL API	-	+	+

Interactivity Elements (Handling the Time Dimension)

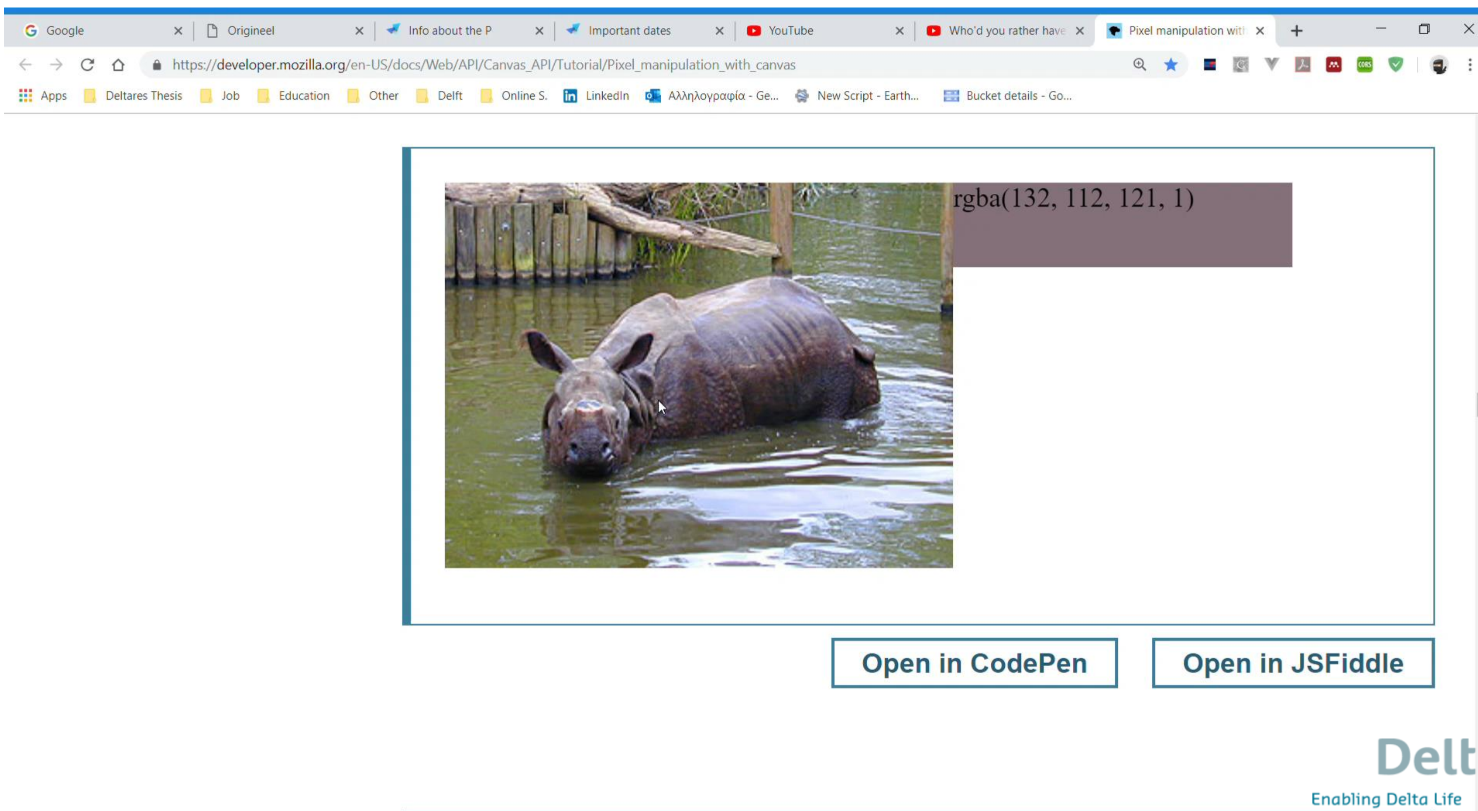
Zooming in time: Like the zooming in space (global → continental→ regional etc)➔ (yearly→ monthly→ weekly etc)

Coarse Data ➔ Dense Data

Tiling Scheme	Implementation Complexity	Performance	Storage Requirements
Aggregation on Server (Multiple Directories)	+	+	-
Aggregation on Client (One Directory)	-	-	+

Interactivity Elements (Querying Capabilities)

The canvas element ➔ color picking technic ➔ color values ➔height values.



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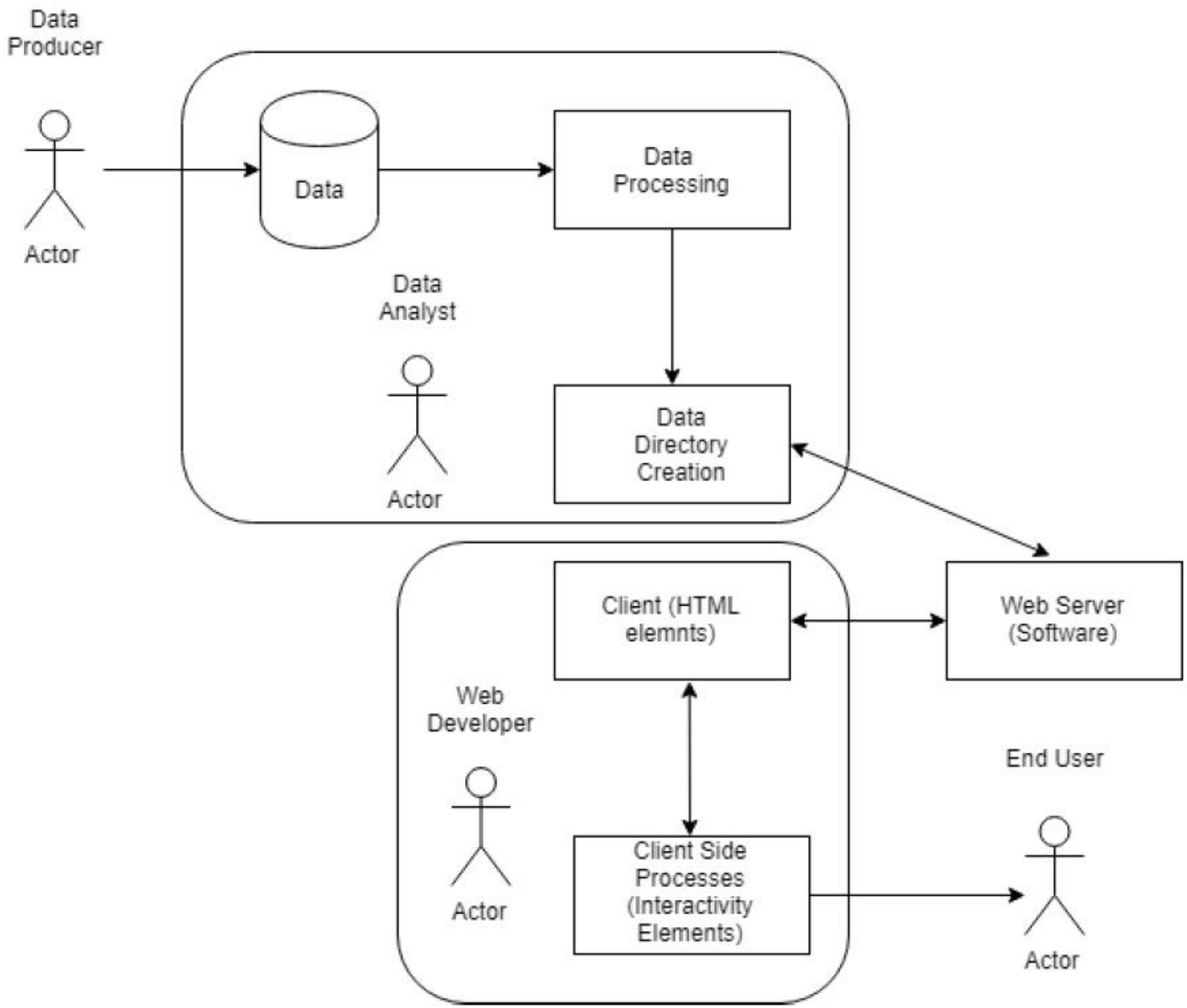
System Architecture



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Implementation/Results (General)

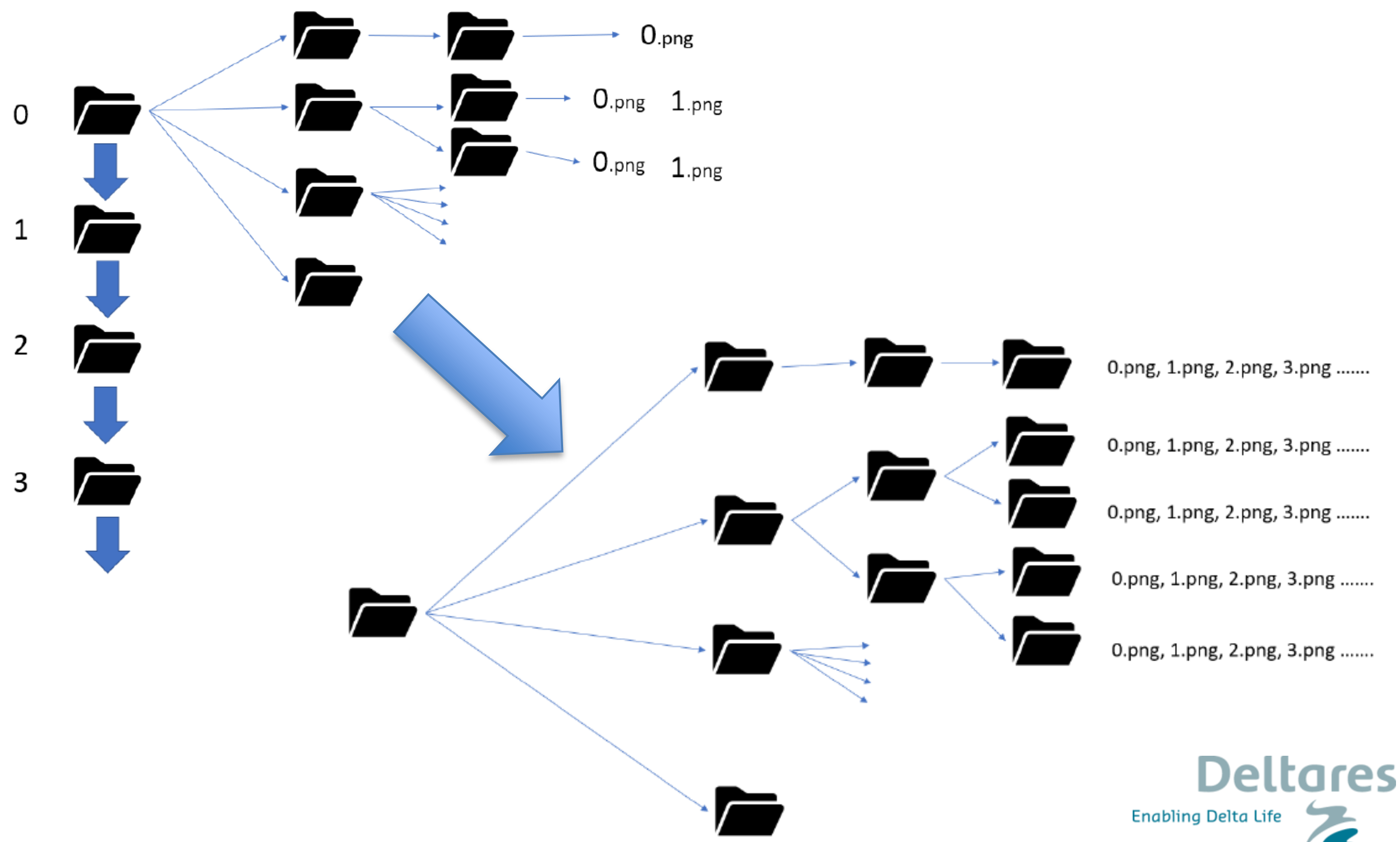
- Same Structure as the Methodology
- Its part will have 3 sections:
    - Tools Used
    - Implementation
    - Results

Animation (Part 1)

Tools Used: FFmpeg, Python

Implementation:

ffmpeg.exe -framerate 10 -i videoTilesPerMonth_mp4/0/0/%03d.png -codec : vlibx264 -crf 22 -r 10 videoTilesPerMonth_mp4/0/0/0.mp4



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Animation (Part 2)

Results:

Comparison Element	WebM/VP9	Mp4/H.264
Example File size (KB)	515	863
Bitrate (kbps)	330	270
Example Encoding Time (s)	1467	427

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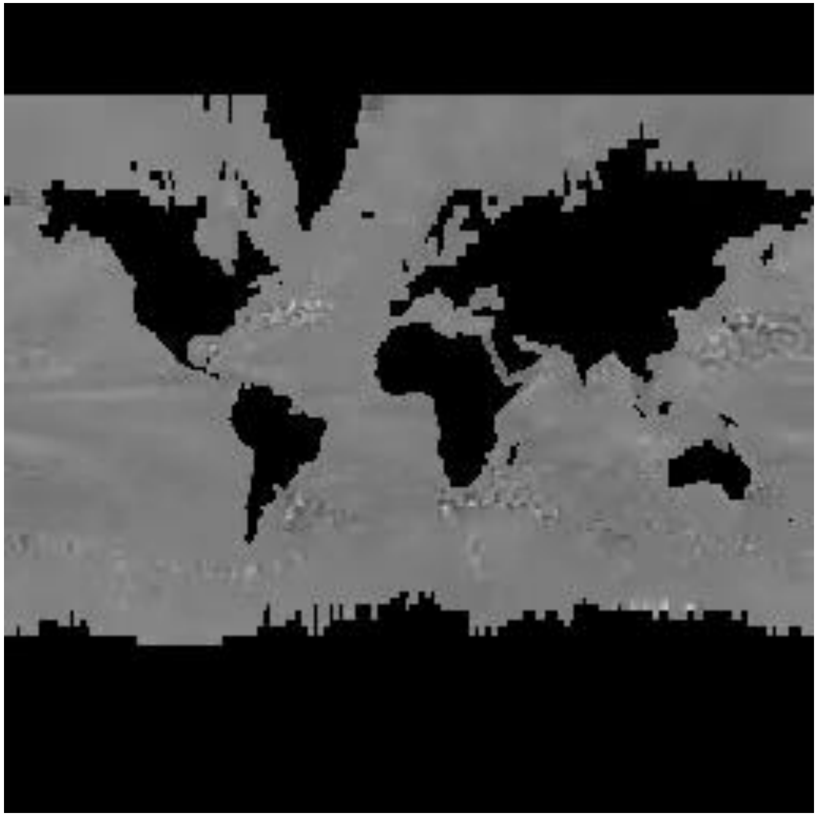
Animation (Part 3)

Results:

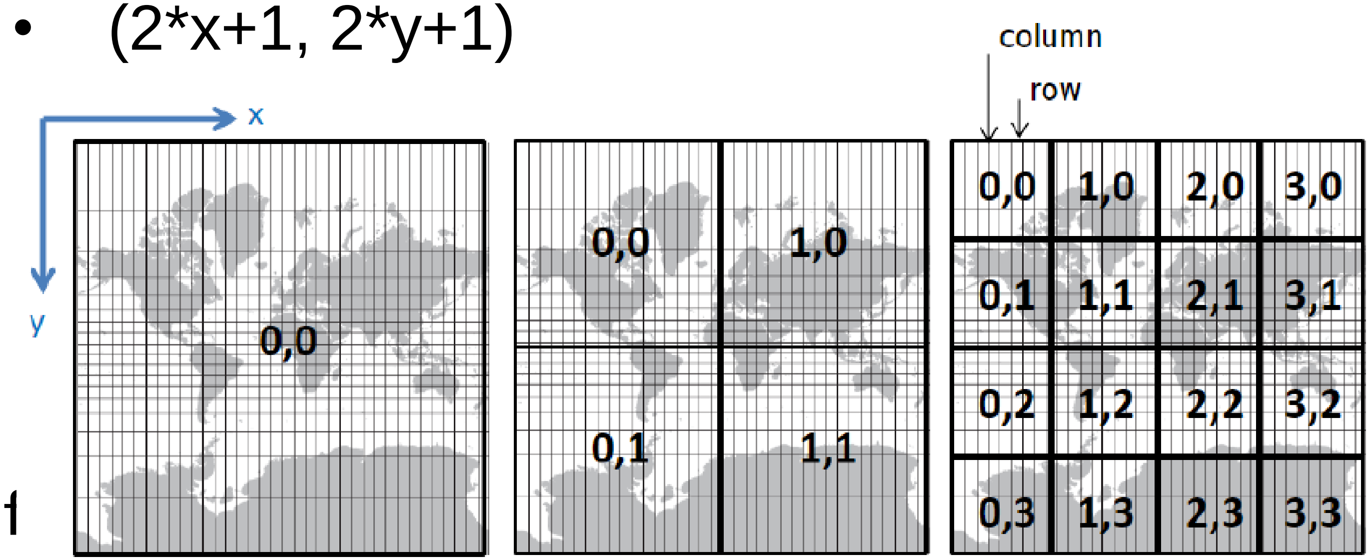


Handling the x and y coordinates (Part 1)

Tools Used(Server Side): Google Earth Engine

Implementation (Server Side):

- For 256x256 pixels: Export.map.CloudStorage(image, polygon, bucket, file format, zoom levels)
- For 512x512 pixels:
    - (2*x, 2*y)
    - (2*x, 2*y+1)
    - (2*x+1, 2*y)
    - (2*x+1, 2*y+1)



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Handling the x and y coordinates (Part 2)

Tools Used(Client Side): Leaflet, Timing Object (advanced stopwatch)

Implementation (Client Side):

- gridLayer(tile size, min/max zoom, bounds, buffer, opacity)

Src: ”videoTiles/’+ coords.z + ’/’ + coords.x + ’/’ + coords.y + ’.mp4”

- Sync:

var to = new TIMINGSRC.TimingObject();

var sync = MCorp.mediaSync(tile, to);

Handling the x and y coordinates (Part 3)

Results:

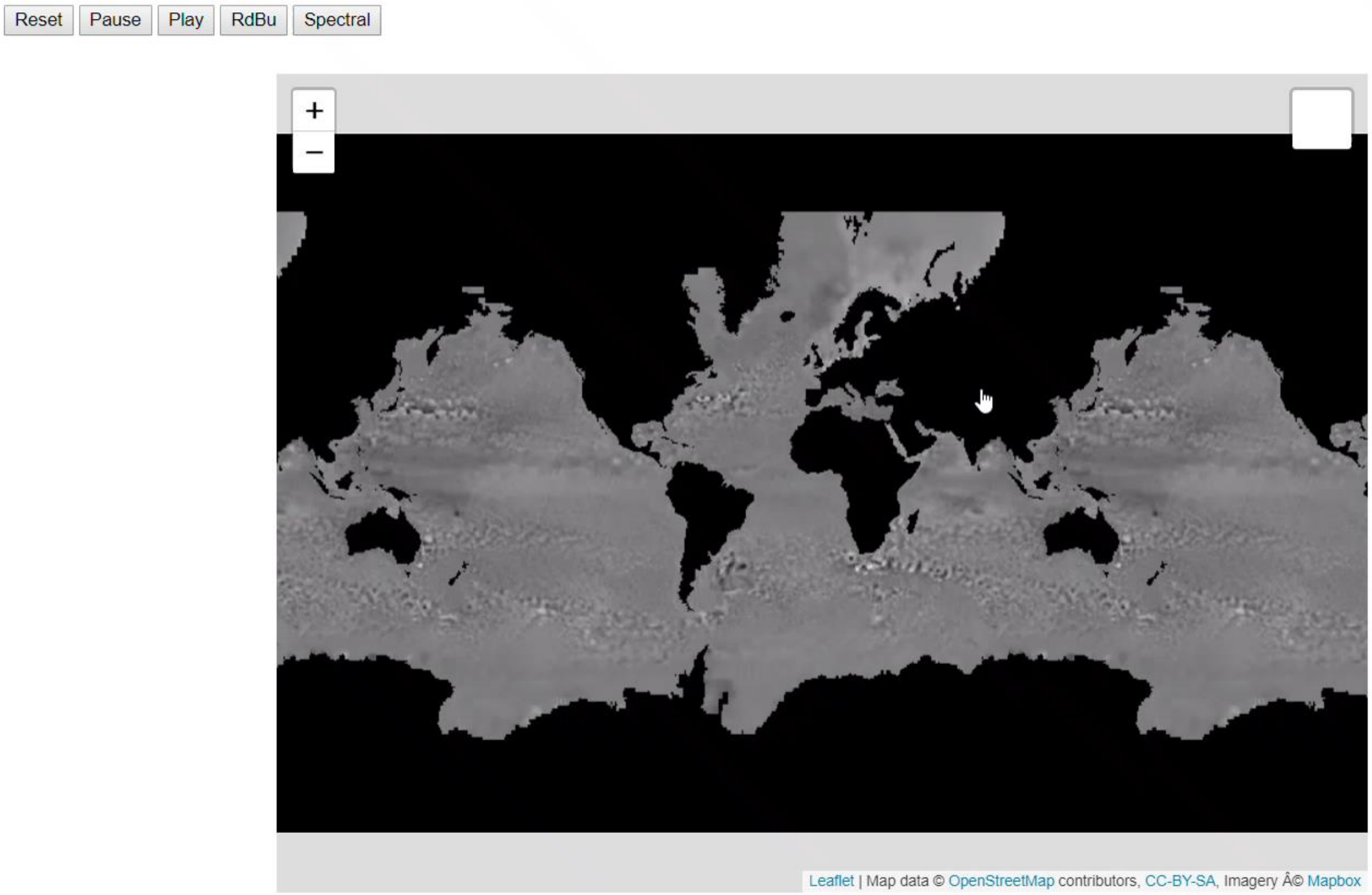
Directory size: 27.5 MB (512x512)
31.5 MB (256x256)

- 15s rule

Comparison Element	256x256	512x512
Loading time of zoom in (from level 1 to level 2)	1.8s	1.5s
Loading time of zoom out (from level 2 to level 3)	1.5s	1.1s
Loading time of panning one row (zoom level 3)	1.9s	1.1s

Handling the x and y coordinates (Part 4)

Results:



Handling the z coordinate (Part 1)

Tools Used: Canvas API, d3.js

Implementation:

- Create Two canvas elements
- Select pallet (eg. Spectral)
- Interpolation within the colors of the pallet
- ctx1.drawImage(video)
- ctx1.getImageData
- data[i] = color.r
- data[i+1] = color.g
- data[i+2] = color.b
- ctx2.putImageData

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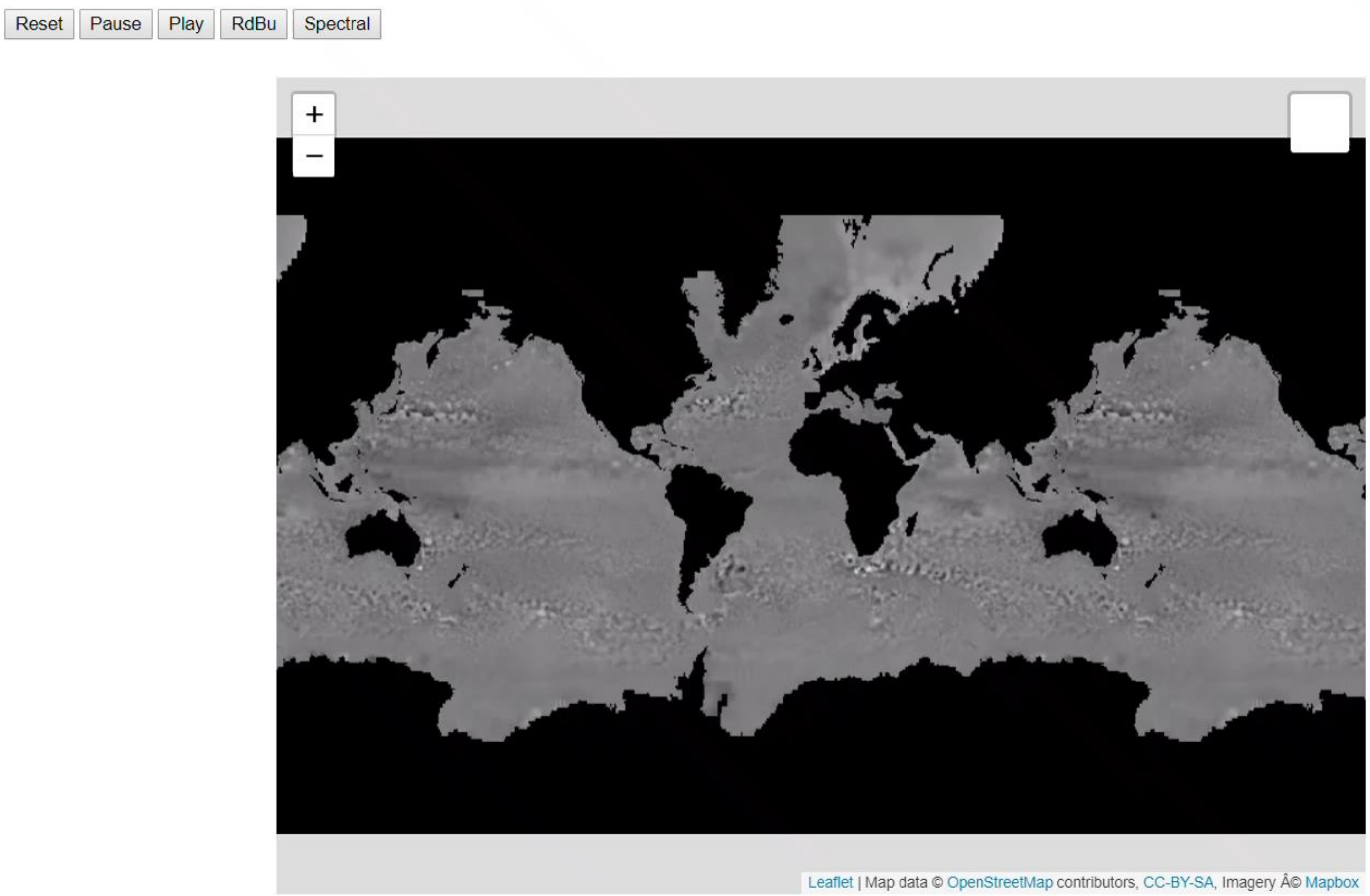
Handling the z coordinate (Part 2)

Results:

Comparison Element	256x256	512x512
Loading time of zoom in (from level 1 to level 2)	1.9s	1.5s
Loading time of zoom out (from level 2 to level 3)	3.9s	2.8s
Loading time of panning one row (zoom level 3)	2.7s	1.6s
Change of color (zoom level 3)	0.1s	0.1s

Handling the z coordinate (Part 3)

Results:



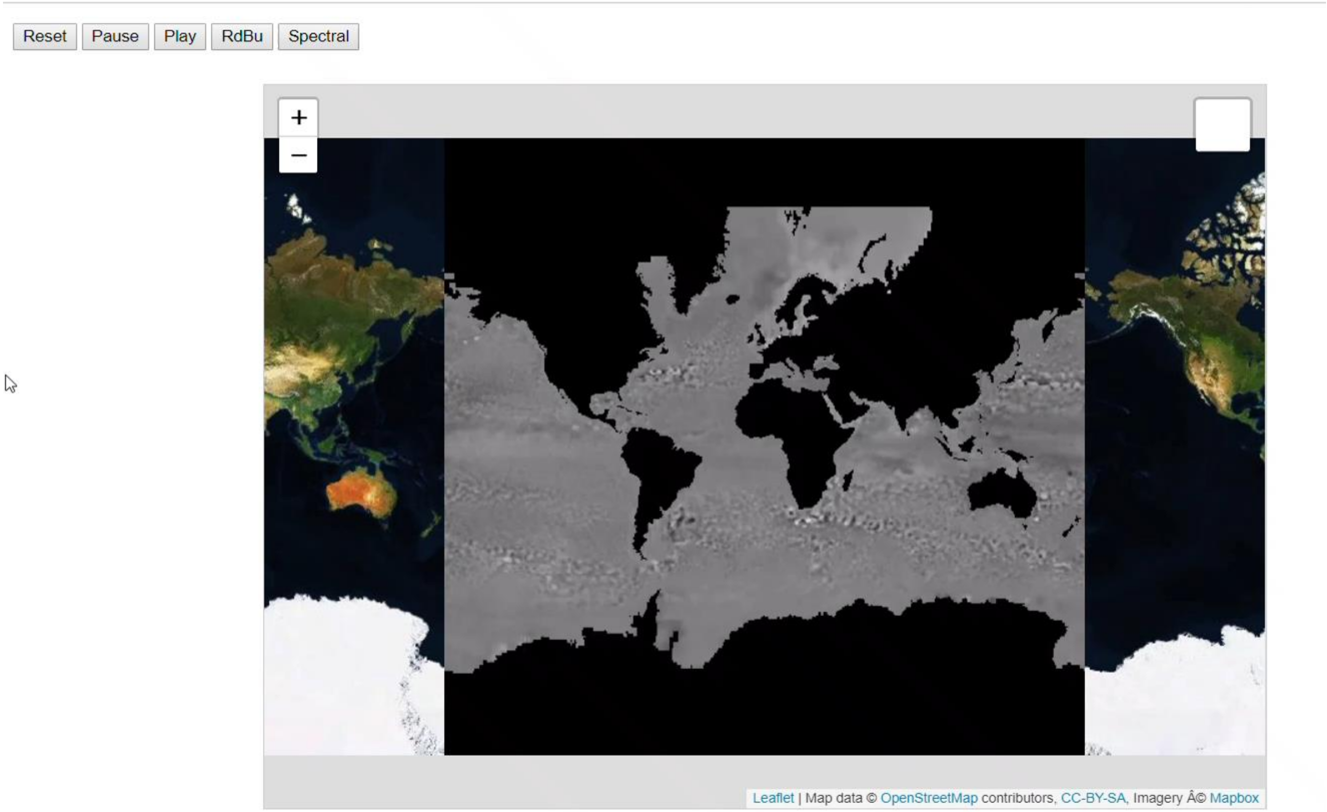
Handling the Time Dimension

Tools Used: Google Earth Engine

Implementation:

- ee.Filter.calendarRange
- Mean (per month/per year)

Results:



Querying Capabilities (Part 1)

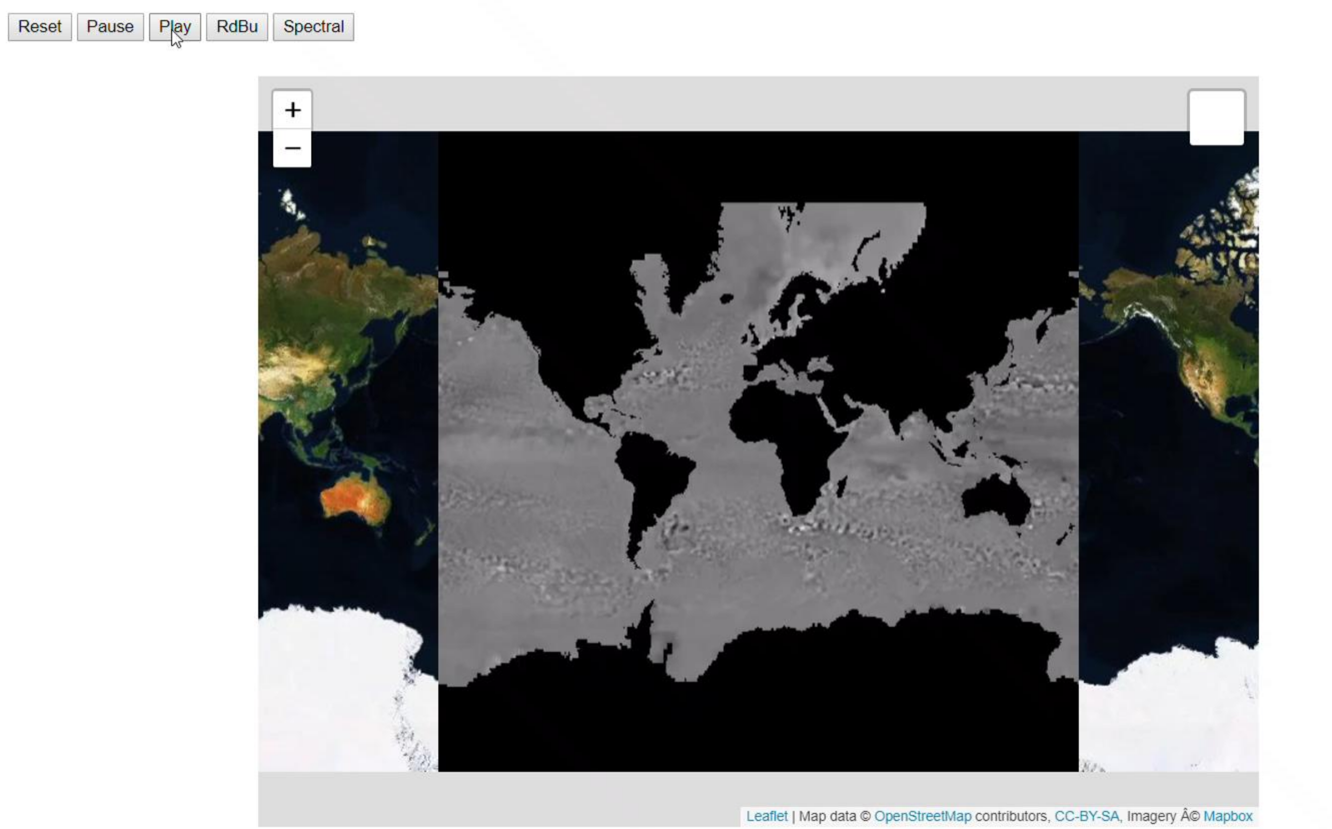
Tools Used: Leaflet, Canvas API
Implementation:

- canvas2.getContext('2d’)
- ctx2.getImageData(x, y, 1, 1)
- Interpolate the color in order to take the Height

The main challenge was to get access to the canvas

Querying Capabilities (Part 2)

Result:



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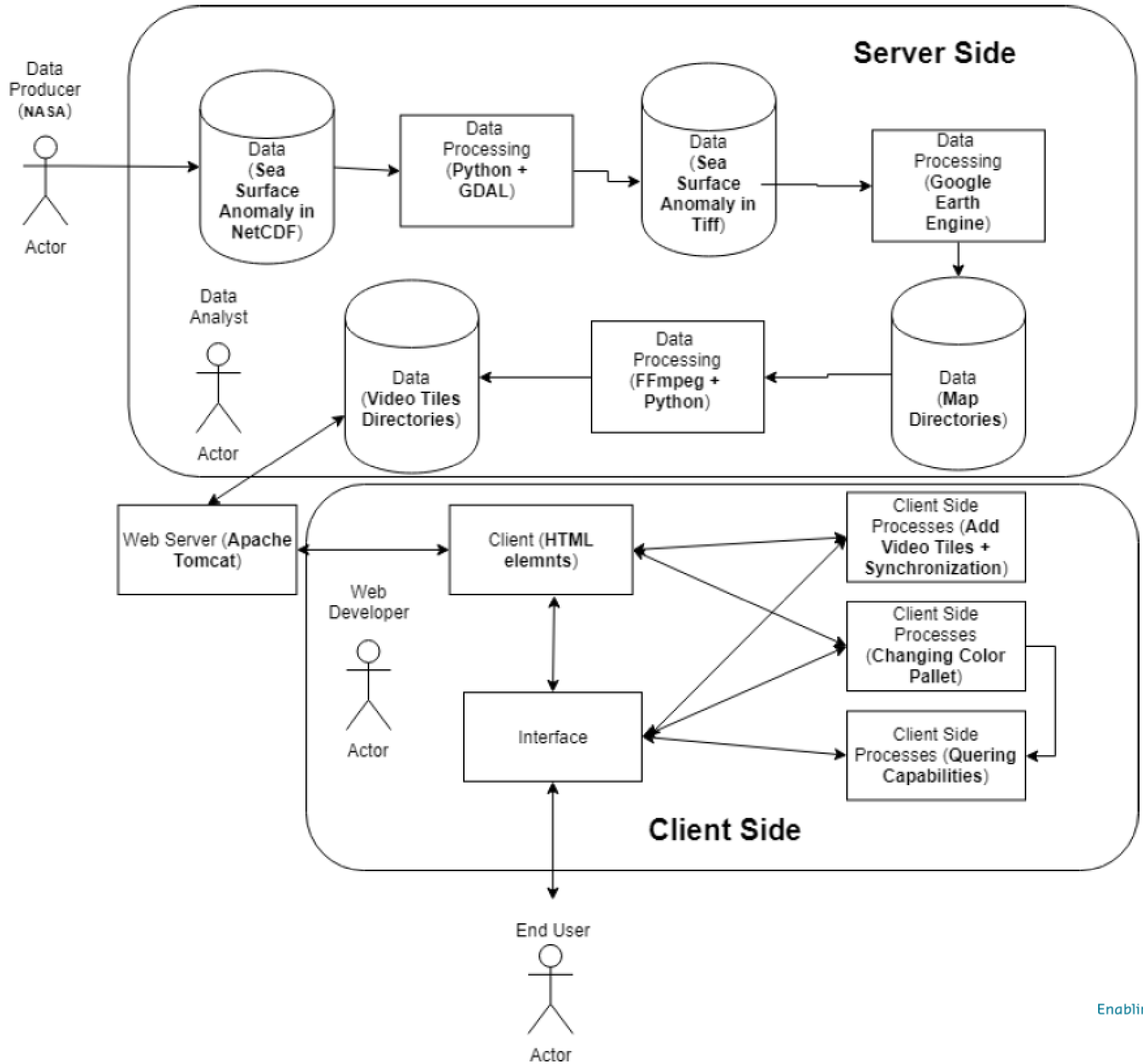
System Architecture



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Conclusions (Part 1)

Main research question: *What is an optimal WebGIS-architecture for making an interactive - dynamic visualization of the sea-surface height phenomenon?*

- Google Earth Engine Timelapse(Only other similar implementation)
- Comparison of the presented architecture with the Timelapse:
  - Similar Animation technique but better quality
  - Better storage handling
  - Better tiling scheme
  - Extra complication with the syncing but solved for the bigger part
  - More interactivity elements
  - More meaningful handling of time dimension

Conclusions (Part 2)

*Sea surface height is a dynamic phenomenon (2.5D + time), what type of **animation** should be used and why?*

- Slideshow, GIF, **Video**
- **WebM,** *mp4***,** Theora
- VP8, **VP9,** *AV1, H.264,* H.265, OGG

*What **elements of interactivity** are relevant to a web mapping application and which ones should be implemented?*

- Handling the x and y coordinates
  - Google Maps(256x256), **Mapbox(512x512)**, Time Machine (1480x800)
  - **Timing Object**

Conclusions (Part 3)

- Handling the z coordinate
  - CSS3 Filters, **Canvas API,** *WebGL API*
- Handling the time dimension
  - **Server Side**
  - Client Side
- Querying capabilities
  - **Canvas API**

What type of **architecture** is more appropriate for an implementation with these characteristics?

- Server Side only for preprocessing
- The web server is only for handling the video requests
- Client Side for interactivity elements (majority)

Contribution to the Field of Geomatics

- Dynamic Visualizations
- Video Tiles
- Video Syncing for fluid animation
- Zoom in Time
- Complex interactivity elements
- Real life application: RWS – Bathymetry
- Scientific Contribution:
  - Video Map - visual stories of change
  - Video Map - generating and visualizing video map tiles from EO data

Discussion

- Corrupted Videos
- Syncing issues
- Tiles freezing
- Coloring with Canvas API is rather slow
- Due to client-based architecture it is rather heavy for the user’s computer

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Future Work

Towards a Reliable Working Prototype:

- Improved Use of Timing Object
- Create Interface
- Usability Test

Improving the Working Prototype:

- Use of WebGL API
- Improved querying options
- WVMS

New Applications Ideas

- 3D instead of 2D + color
- Vector data
- No preprocessing of the dataset
- Virtual globe

Thank You!

Questions?

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