Cartography M.Sc.

Master thesis

Developing Data Cylinders to map changes and feedbacks between Arctic Sea Ice and Vegetation

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Statement of Authorship

Herewith I declare that I am the sole author of the submitted Master's thesis entitled:
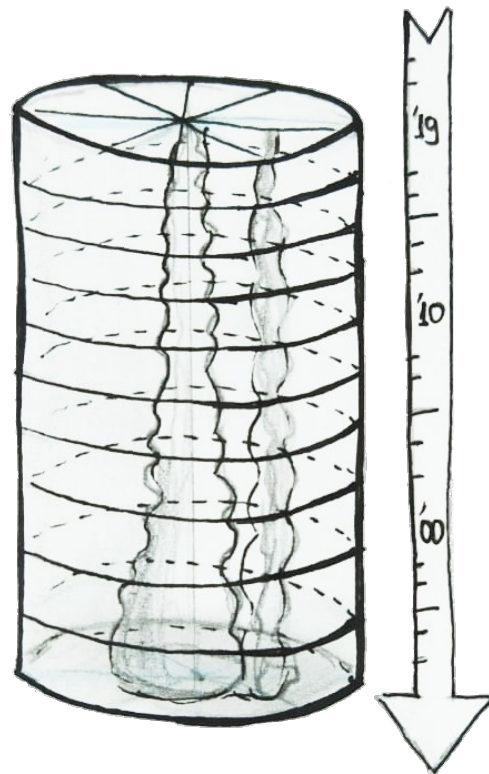
"Developing Data Cylinders to map Changes and Feedbacks between Arctic Sea Ice and Vegetation"

I have fully referenced the ideas and work of others, whether published or unpublished. Literal or analogous citations are clearly marked as such.

Dresden, 12/10/2020   Danai-Maria Kontou

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This thesis goes to Leonidas for his support and company during this journey.

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Abstract

Arctic sea ice hits second-lowest level on record in 2020 and a "new Arctic" climate era is commencing (Landrum & Holland, 2020). Living on a planet which is facing a global climate change, the understanding and the communication of those vast environmental changes have great importance. The objective of this thesis is the development of a three-dimensional spatio-temporal visual, in a cylindrical shape due to the circularity of the Arctic region, depicting the analysis of the changes of the sea ice and vegetation in the Arctic. Level4 remote sensing data is used for the vegetation and sea ice concentration in a pan-arctic scale for the needs of this research. Its main outcomes are the changes themselves mirrored through their anomalies, and the creation of one cartographic product which illustrates these phenomena in the best suitable way.

The representation of time and space in a single visual has been viewed as a challenge in the field of modern cartography throughout many decades. While data-cubes have been proposed for regional or even global geographical data visualization, the polar regions seem not suitable for such cubes. The proposed cartographic representation of the Arctic space and time into "Data-Cylinders" responds to the challenging befitting of physical phenomena along space and time.

The context of the "Data-Cylinders" includes the visualization of the changes of climatic and physical phenomena in the form of time-series. A cylinder in this case could be described as many circular maps on top of the other in chronological order. "Space" in this scenario is placed across cycles, while "time" is given along the height of the cylinder.

Keywords: *Arctic, Sea Ice Concentration, Arctic Vegetation, fPAR, remote sensing, web cartography, time geography, Data Cylinders*
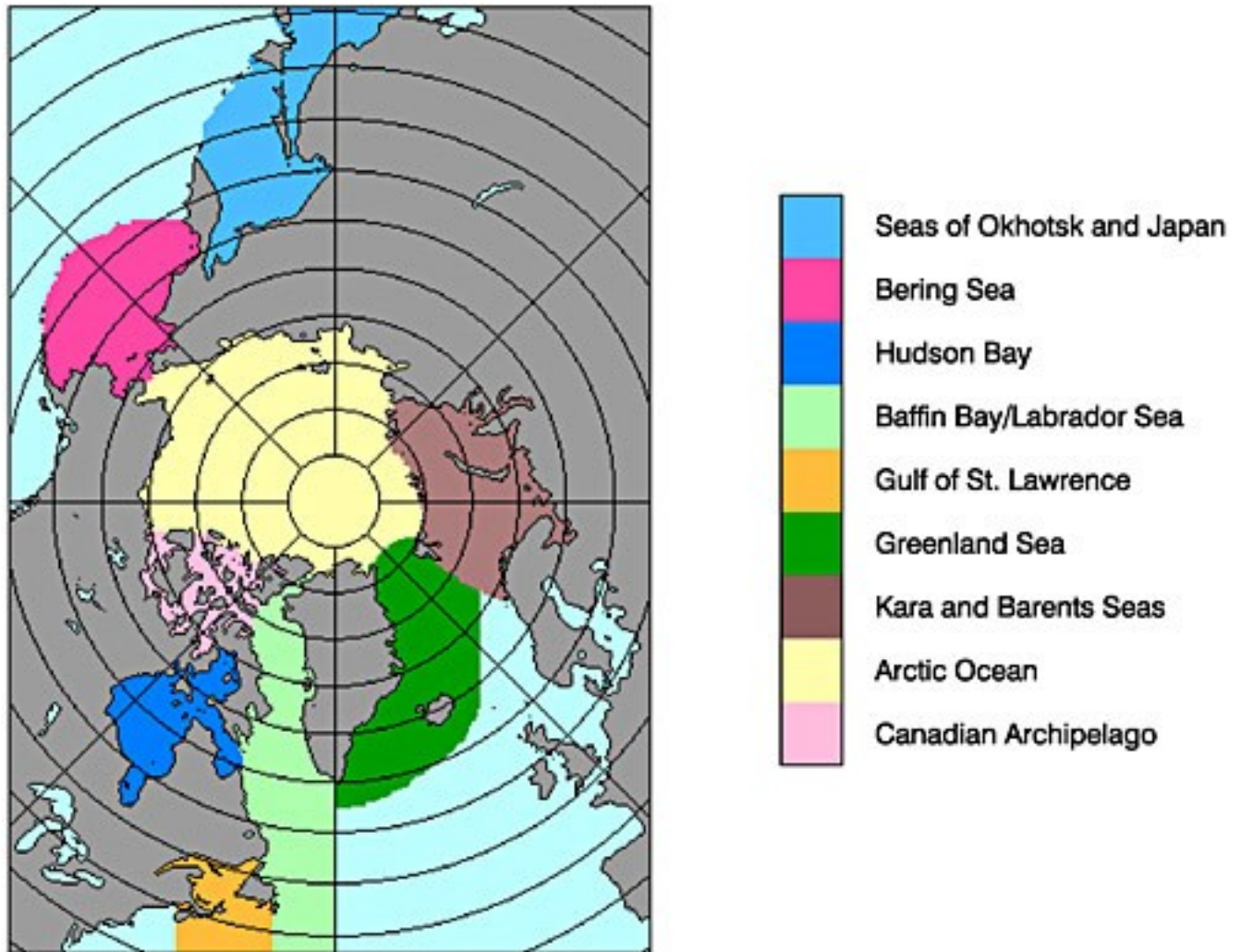
Figure 1: Map of the Arctic Sea Regions *(Mohr, 2020)*

1 Introduction

The Arctic is the northernmost region enclosing the North Pole. It consists of a large ocean surrounded by land. Due to the Arctic Ocean, its special location, climate and land is having a unique ecosystem. The sea ice in the polar regions is influencing the global climate due to its bright surface. Even a small change in this chain has a big impact on the sensitive polar regions (NSIDC, 2020). Moreover, it is expected that the higher temperatures are bringing permafrost and snow coverage loss can cause vegetation production anomalies, both greening and browning (Miles & Esau, 2016).

In 2012 "The Economist", published an article with the title "Hidden Treasures, The melting of the Arctic is both a blessing and a curse". The blessing refers to the shipping routs, to the oil and petroleum industry, and to the cargo ships and touristic cruises that are expected to open up. The curse, is referring to the environmental damage, the loss of fauna and flora occurring in the region. Among the blessings of this huge environmental catastrophe, the author mentions that the governments see the opportunities of the oil and mineral undiscovered deposits.
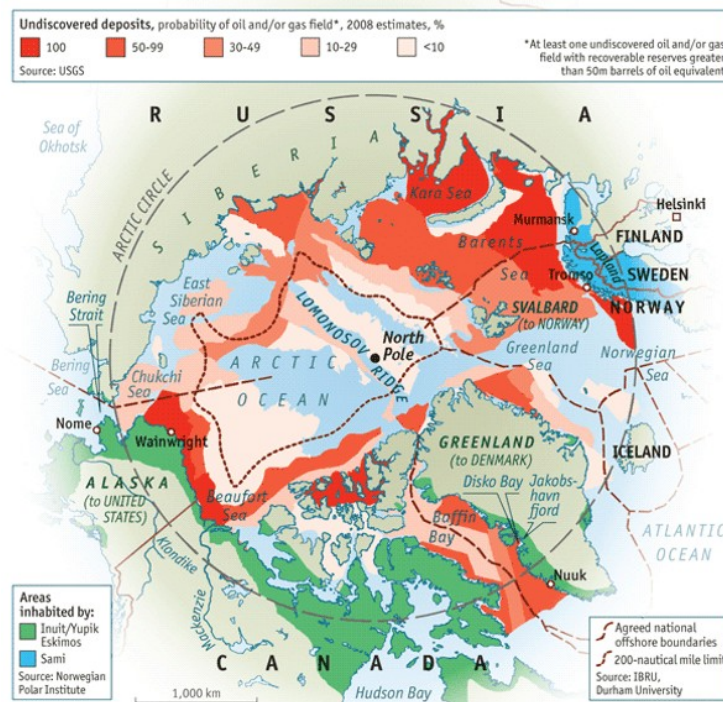
Figure 2: Undiscovered deposits, "The Economist", 2012

The described blessings by the newspaper is nothing more than another "curse" on the Arctic climate, fauna and flora and indigenous communities. The growth of the oil and shipping industry in the warming Arctic can cause further warming and pollution (Dana et al., 2008; Nong et al., 2018). In Figure 2 a map of the Arctic with the probabilities of the existence of undiscovered mineral deposits is illustrated. In this map, a large ocean area is shown which the surrounding countries may want to use for extracting petroleum.
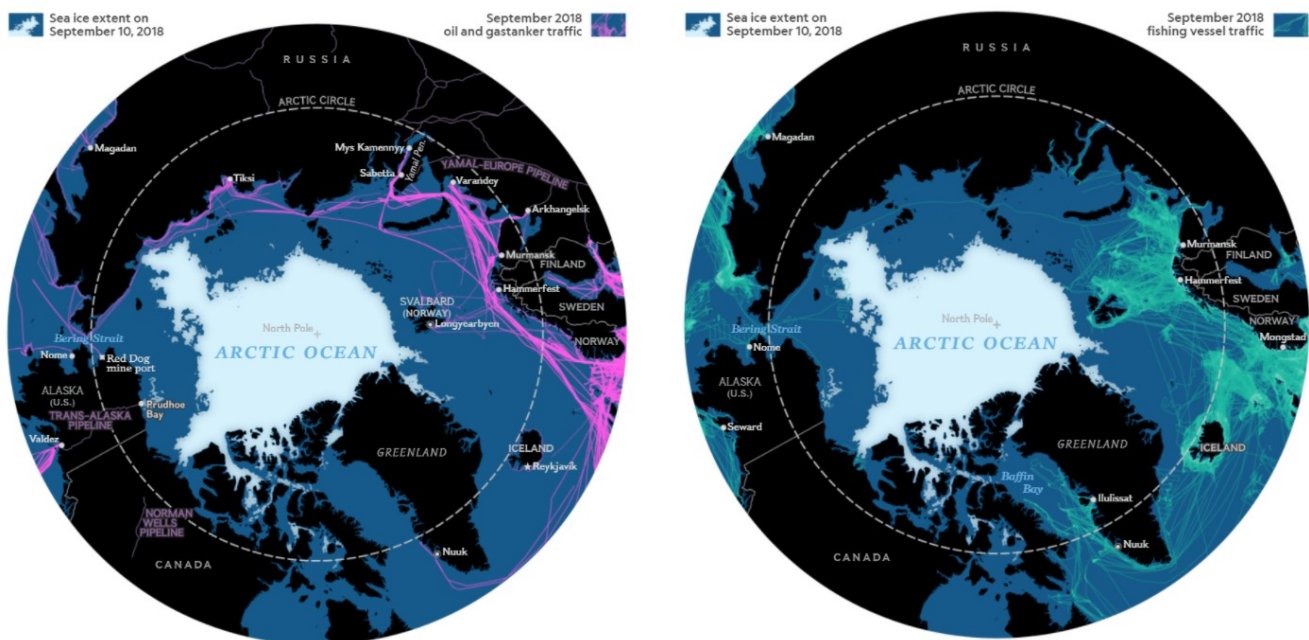
Figure 3: Arctic Maps, left: Oil and Gas tanker Traffic, right: Fishing Vessel traffic (National Geographic, 2018)

In Figure 3 two Arctic maps by National Geographic are displayed, which show the Sea Ice Extent in September 2018 and the Oil and Gas and the fishing tanker traffic. It is obvious that a sea ice free Arctic will increase the vessel routes and the petroleum industry will grow.

Among the geopolitical challenges which are caused by the melting sea ice, a warmer Arctic indicates changes and abnormalities in the vegetation. Greening and Browning of the vegetation productivity is linked to further Arctic environmental changes, such as droughts, fires, rising temperatures, and permafrost melting (Miles & Esau, 2016).

The link between sea ice and terrestrial vegetation is a new entry in the field of arctic climatological research. The first time that connectivity between sea ice and vegetation in the Arctic was researched, it was approximately only ten years ago (Bhatt et al., 2010), and this

connection was measured using NDVI (normalized difference vegetation index) from 1982 to 2008.

The representation of time and space in a single visual has always been a challenge in the field of cartography even since the medieval era (Edson, 1997). Time geography started to establise the fundamentals on the concepts of studying together space and time. Space-time aquariums proposed by Hagerstrand in the mid-1970s started a new era of spatio-temporal representations in cartography. The European Data Cube Facility (ECDF) in 2019 initiated by providing a cloud based "engine" in the form of a platform that hosts "analysis ready" data, supported by toolboxes and virtual labs. The platform allows the end-users to interact and analyze the provided data while producing data-cubes. The three-dimensional data cube contains an array of values. In this case the values are earth observed climatological data. The dimensions of the data cubes are (x) latitude, (y) longitude and (z) time. The spatial coverage the EDCF provides global and level 2 and 4 "analysis ready" data derived from several EO and non-EO sources. Lastly, the end-user's available applications and interactions with the platform are (a) information layer publishing, (b) on-demand mapping, and (c) cross-mission analysis (Mahecha et al., 2020). The three-dimensional representation of spatio-temporal data, referring to dynamic environmental changes, have a big impact on the understanding of the data. Due to the amount of the data, one visual can be presented. Although data-cubes have been proposed for regional or even global geographical data visualization, they are not a perfect fit for a polar region. This is happening due to the circular shape of the polar regions.

The visualization of changes through time of phenomena, such as vegetation and ice in the Arctic into a single visual, is significant. Understanding the volume of the changes, spotting anomalies in time, seeing into visual how more than one variable can dynamically change in time and possibly interact with each other, will help the viewer. An interactive outcome in digital form, hosted by a web application where the user is able to explore and learn, could help towards a deep understanding of climate change and its importance.

This thesis aspires to develop of a three-dimensional visual under the same philosophy the data cubes. The visualized data is derived from the analysis and research of the changes of sea ice concentration and terrestrial vegetation of the Arctic. Furthermore, aiming to a user-friendly outcome which will refer to a broad audience, the final outcome of this thesis is a web application. Last but not least, the cartographic representation of the Arctic space and time into

"Data-Cylinders" responds to the challenge befitting of physical spatio-temporal arctic phenomena into a three-dimensional visual.

A cylinder in this case could be described as many circular maps, are one on top of the other in chronological order. The "space" in this scenario is placed across the circles, while the "time" is given into the height of the cylinder. The three dimensions of the cylinders are time as height, the arctic circle as circumference, while the latitude and longitude are given by the circular dimension. The end-user of the web application can interact with the three-dimensional cylinders, by zooming in or out, rotate them and select a slice to see. The main purpose of the creation of such a web application is to act as a learning and educational material for a broad audience. The results of the user testing showed that even users with no background in environmental sciences had interest to interact with it and explore the application and its functions. Users with an academic or personal interest in environmental studies were able to understand faster the displayed phenomena and get interested in the information provided. It should also be noted that users with no background in environmental sciences were keen on the visuals even without total understanding either the concept of terrestrial vegetation or sea ice.
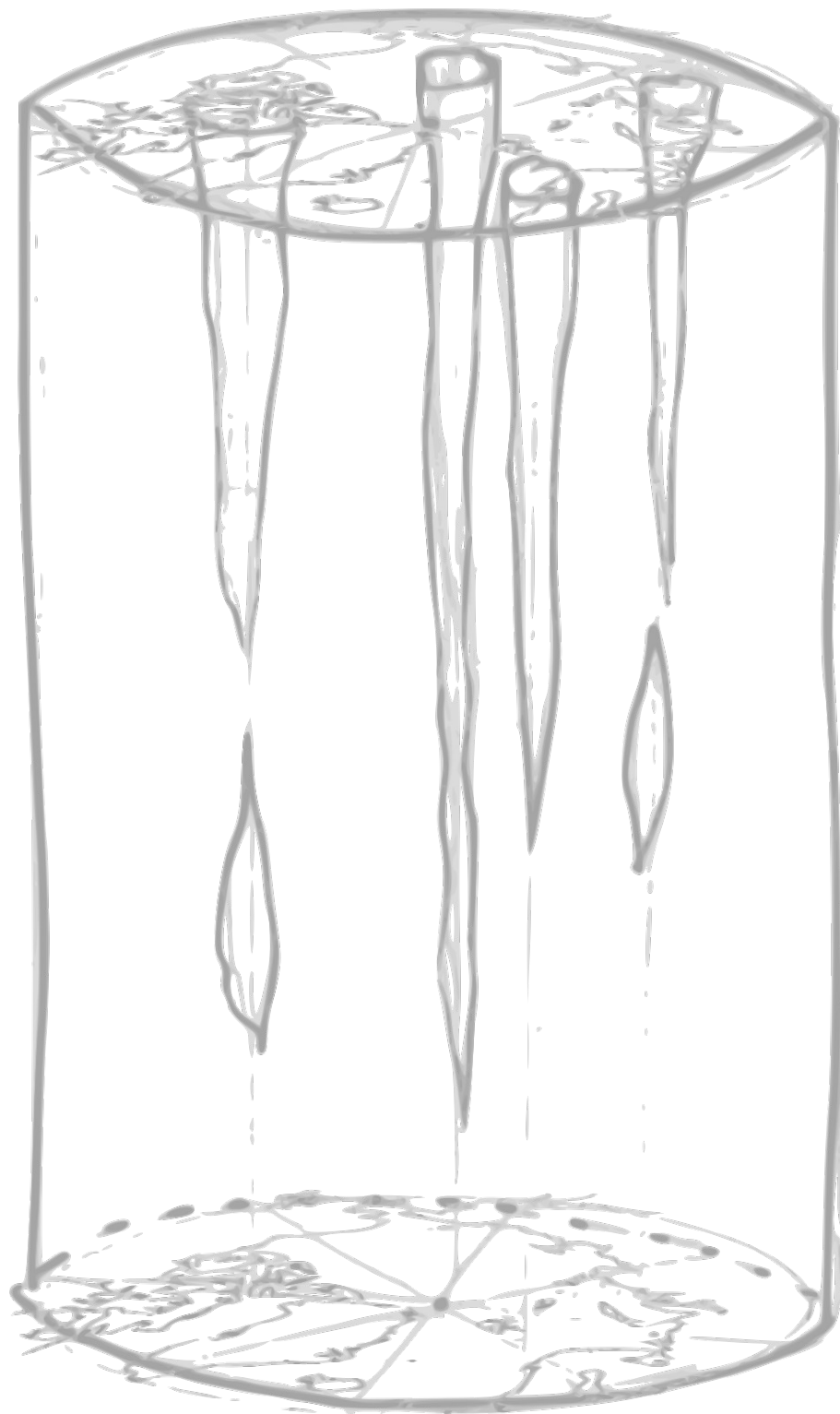
Figure 4: Hand drawn Concept of Data Cylinder

2 State of the Art

This thesis is standing at the crossroads of Time and Polar Geography, Earth System Science, Remote Sensing, Information Design and Cartography. The core research question of this thesis is how the vegetation and sea ice are changing throughout time. In addition, the cartographic challenge of this thesis is the visualization of spatio-temporal environmental data and their analysis in a stand-alone visual. These visual results are created in the form of data cylinders, which contain and present the extreme anomaly values of the fPAR and Sea Ice Concentration. In this chapter the above concepts and theory will be discussed.

Arctic Sea-Ice and Arctic Vegetation

The Arctic is warming rapidly and that affects many environmental aspects of it. The phenomenon called Arctic Amplification (AA) shows us that the Arctic warms twice more rapidly in comparison with the rest of the Northern Hemisphere. The warming has a strong impact combined with the greenhouse gases, and has feedback with the sea-ice, snow, and water vapor clouds (Francis & Vavrus, 2012). The use of satellite-derived data provides great opportunities for large-scale monitoring of environmental change, especially in regions that are remote and difficult to access, such as the Arctic (Karlsen et al., 2018). According to the National Snow and Ice Data Center "the Sea-Ice is simply a frozen ocean, any form of ice found at sea which has originated from freezing sea ice and it forms, grows and melts and mainly exists in Arctic and Antarctica." The Sea Ice can be measured and analyzed by its thickness, Volume, Concentration, along with its dynamics (NSIDC, 2020).
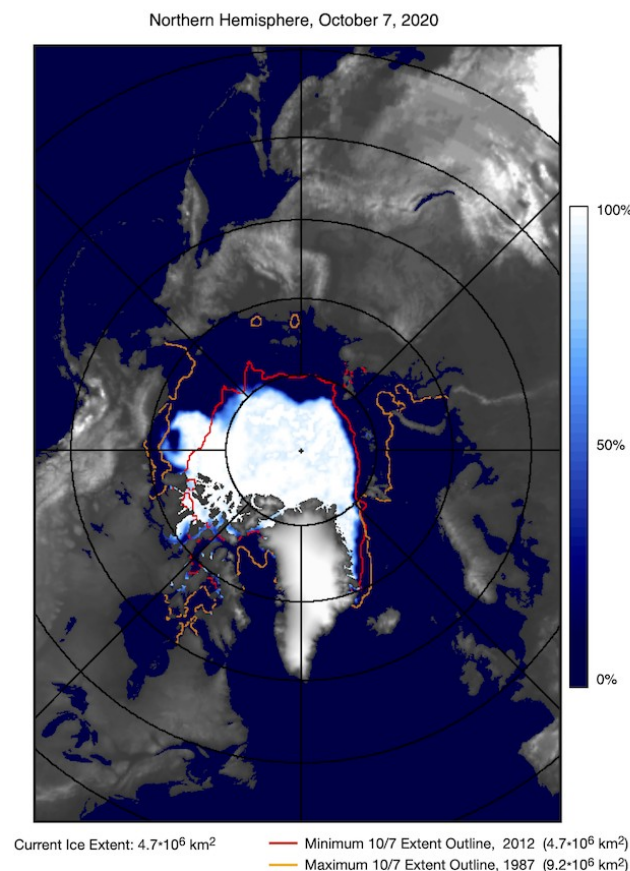
Figure 5: Current Sea Ice Extent (Comiso et al., 2020)
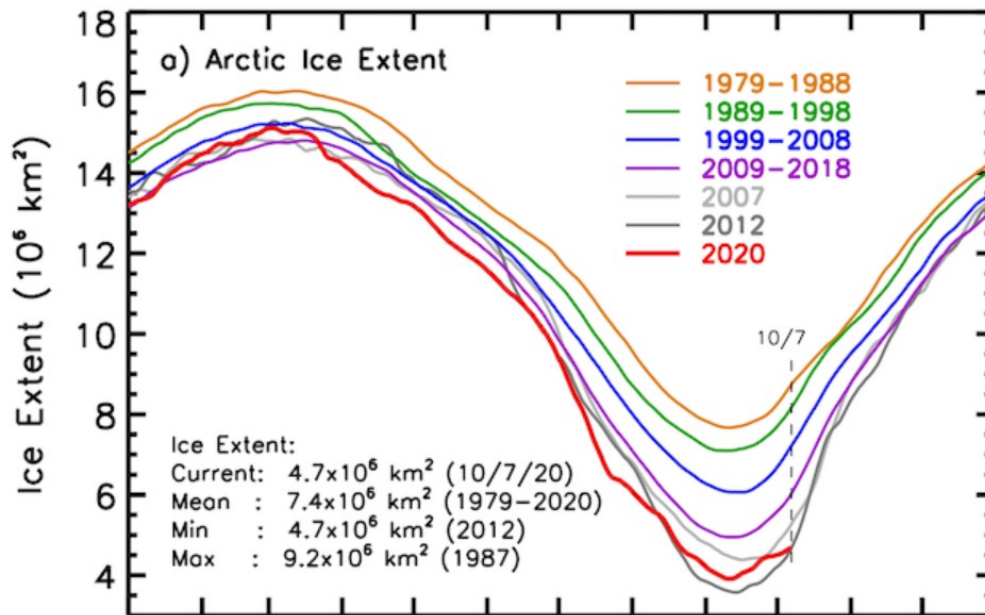
Figure 6: Arctic Ice Extent graph (Comiso et al., 2020)

In the graph of Figure 6 the Arctic Ice Extent from 1979 to date is illustrated. In this graph ist is noted that the minimum sea ice extend, which usually occurs in September, was at a record lowest in 2012 and at a record highest in 1979. During March, the maxima of the Sea Ice is one of the main components of the polar climate system. The strong decrease of the sea ice indicates that global warming could be amplified in the Arctic on account of ice-Albedo feedback (Comiso & Hall, 2014). Albedo is a non-dimensional, unitless quantity that indicates how well a surface reflects solar energy. Its values vary between 0 and 1. A value of 0 means that the surface absorbs all the incoming energy, the open ocean for example. A value of 1 means that the surface reflects all the incoming energy, packed snow surface for example. The bare sea ice is having an Albedo close to 0,5. The sea ice melts when solar radiation heats its surface. Moreover, the ice can melt if the water below the ice has temperature above the freezing point. Snow coverage is a factor which dramatically affects the sea ice, since the snow reflects all the incoming solar radiation (NSIDC, 2020).

The Arctic region supports plants such as dwarf shrubs, herbs, lichens and mosses. Warmer summer temperatures cause changes in the size, abundance and the variety of the plants. Climate and environmental changes such as the soil chemistry, soil moisture, winds, snowfall,

influence the distribution of plant communities (CAFF, 2020). Plant activity can be measured remotely via satellite observations. The most common index used for the vegetation is the Normalized Vegetation Index (NDVI). The NDVI is a proxy which is sensitive to cloud coverage. Extensive cloud coverage typically leads to an underestimation of plant productivity (Comiso & Hall, 2014). Vegetation can also be measured by coordinating it with its photosynthesis via the Fraction of Absorbed Photosynthetically Active Radiation (fPAR). The fPAR is used for calculating surface photosynthesis, evapotransipation, and net primary production. With the same fraction we can also estimate the assimilation of carbon dioxide by the vegetation included (R. Myneni, 2015).

The rise of the temperature is also having a strong impact on the Arctic Vegetation. Satellite Observations have proved the linkage between the temperature and the expansion of the vegetation in the high Arctic, which is mainly shrubs. Warmer Arctic amplifies the increase of plant productivity "greening", but can also decrease the productivity "browning" (Miles & Esau, 2016). This spatial spear of the vegetation productivity is described as greening trends. The Arctic greening in a warming scenario expects the shrubs and grasslands to shift to boreal evergreen forests (Chae et al., 2015). Moreover, in some Arctic regions the trends of vegetation productivity are negative and are linked with fire activity, cooling spring temperatures and increasing water vapor, and are expressed as browning trends (Forkel et al., 2013). Sometimes the browning in the Arctic is also connected with changes in surface hydrology, frost droughts, decline of the permafrost, industrial development. aDamaged heathland is also becoming fire prone (Phoenix & Bjerke, 2016).

All the mentioned changing factors of the arctic environment are having a strong impact not only on each other, but also on the broader climate change, the surrounding wildlife and the local communities. Pastoral communities in the Arctic are facing changes in their territories, while the widespread greening strongly affects the local ecosystems (Berner et al., 2020). The heat and moisture in the atmosphere in late autumn and early winter is mainly caused by the anomalous warmth, as well as by the ice-free ocean waters which are increasing rapidly. The decrease of autumn sea ice corresponds to the abnormal large snowfall during the winter, which is changing the atmospheric water vapor content over the high Arctic (Liu et al., 2012). Nevertheless, the Arctic sea ice is not decreasing homogeneously neither over time nor through space. Studying the trends of the Arctic sea ice in the last decades the results are showing a

non-stable behavioral trend on almost the whole of the Arctic region. However, the only region which is showing constantly positive trends in the sea ice trends is Bering Sea (Parkinson, 2008). Even though the connection between all environmental factors seems to be vast, there is a gap in the academic research on the relation between the sea ice and vegetation. Nevertheless, the vegetation of the tundra's high Arctic is highly linked to the land temperature increases, which are possibly connected with the rapid near coastal sea ice, permafrost, and glacial declines, (Bhatt et al., 2010). In the map of the Circumpolar Arctic Vegetation (Figure 7), the vegetation of each High Arctic area is described.
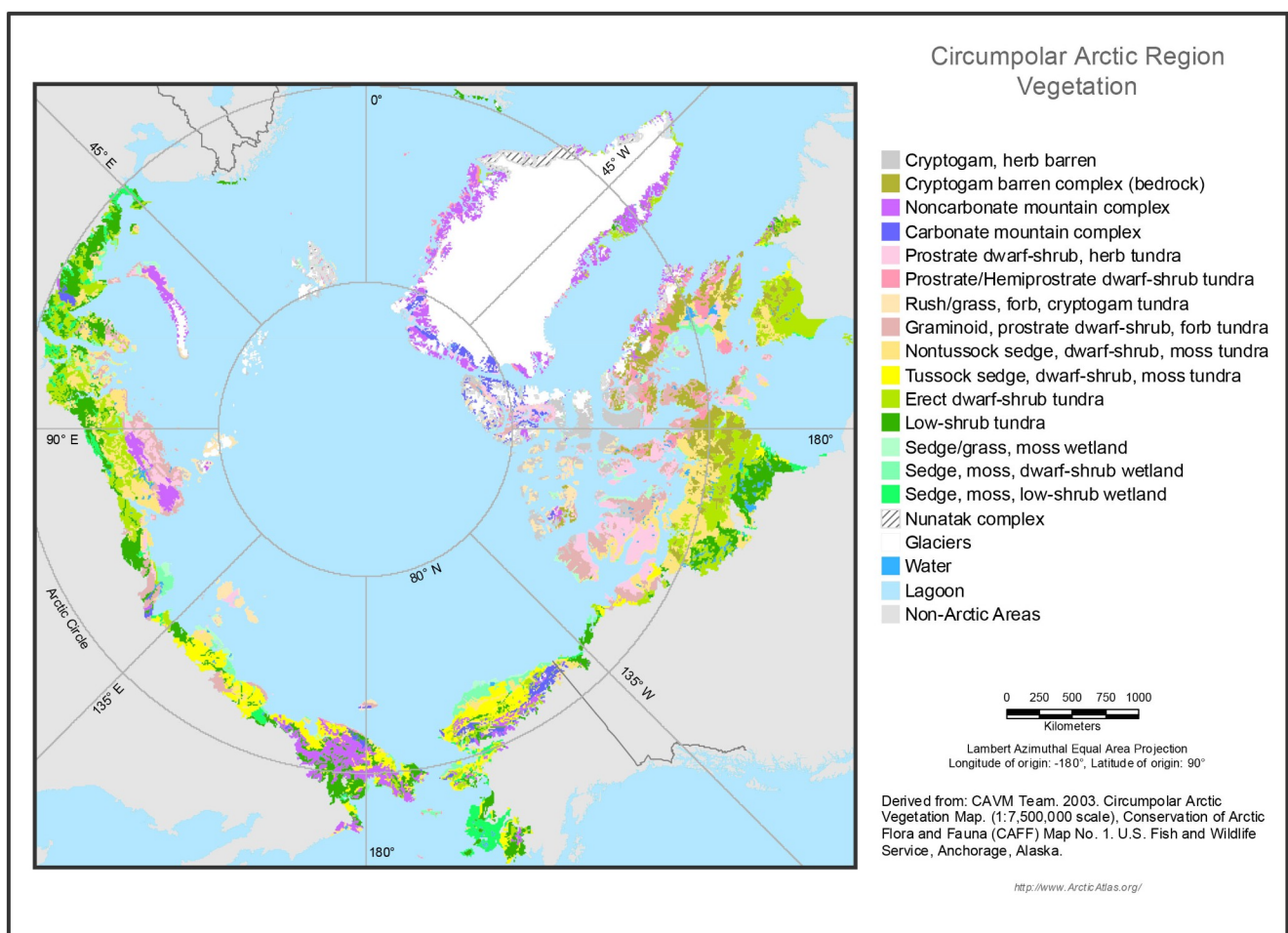
Figure 7: Map of Circumpolar Arctic Vegetation (Walker et al., 2005)

Time Geography

In the physical environment there are phenomena and movements of physical objects. These phenomena and movements are happening in temporal terms as well. In time-geography space and time are merged in one environment of study. A simple move from point A to a point B requires a certain amount of time while it is happening in space. Some actions, phenomena or moments might get merged into space and continue to occur through time, while later they might stop interacting. In the space time "aquarium" these spatio-temporal interactions can be observed (Thrift, 1977).
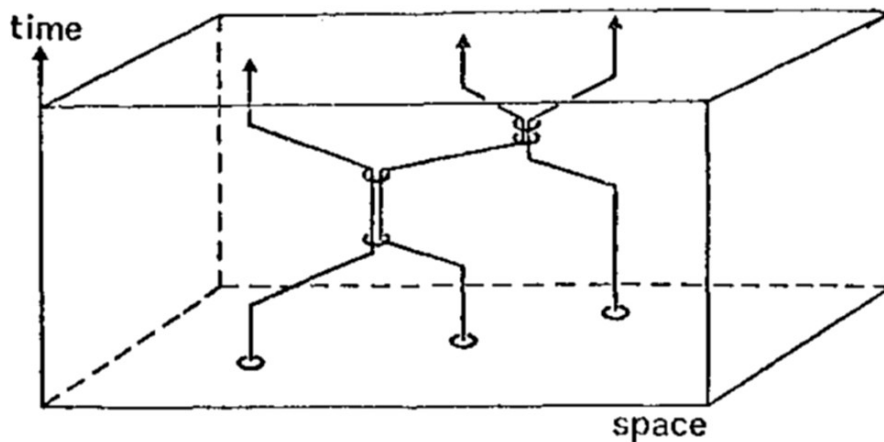
Figure 8: Space Time Aquarium, after Hagerstrand (Thrift, 1977)

The space-time theme is a sum of phenomena, be they physical or man-made. Time geography is acting as a foundation including describing phenomena happening in space and time. Starting in the 1970s Hagerstrand placed the fundamentals of time geography, which was revolutionary in social geography. Later, this discipline was highly connected with the human movements and interactions into space and time. In the 70s Time Geography is highly connected with phenomenology and location theory, but in the 1980s and 1990s it is getting connected with more specific geographical disciplines, such as anthropogeography, areal differentiation, macro-geography, transportation geography, compositional theory, contextual theory and symbolic interactionism (Lenntorp, 1999).

Since the first appearance of the time-geography concept, computer graphics have been advancing rapidly in technological terms. Along with computer technology, their use for cartographic purposes has also being rising in a way that almost everything related to cartography is nowadays being done digitally. This relation between computer graphics and cartography has opened a space for three dimensional visuals to be produced. Even from the early 1980s computers were giving opportunities to cartographers to analyze and produce maps and data whose production would have been a difficult task without them (Kraak, 1988). Cartography among its other usages has a strong aspect of communication and cognitive science. Even though, the term of a "map" has been given as "a representation, normally to scale and to a flat medium, of a selection of material or abstract features on, or in relation to, the surface of the earth or a celestial body" (ICA, 1973), maps nowadays apply more than one dimensions due to the evolution of computer technology and graphics. Different categories of maps are described by Kraak in 1988, where the permanent/paper maps were most common to most people, while virtual maps are explained as mental or conceptual maps of the reality represented in people's minds.Lastly the temporary maps are those displayed on screens, and are computer based. When in 1970s the consent of space-time aquariums and prisms was evolving, the visual representation in space-time was including linear movements along these dimensions visualized into aquariums and their possible connections visualized into prisms. As the technology allowed the analysis of environmental phenomena which are not having a linear movement into time and space but a spatial one, the concept of space time cubes (STC) was evolving as well.

In figure 9 a space time aquarium beyond the linear relationship of an object or entity and its movement between space and time is illustrated . In this visual the space time aquarium containing spatio-temporal events is shown; their magnitude is represented by the size of the cluster. This stand-alone visual concept replies to the "what", "when" and "where" of events happening in space and time. In comparison to two dimensional maps, computer-based three dimensional spatio-temporal maps have the advantages of interactivity and dynamics (Andrienko et al., 2003).
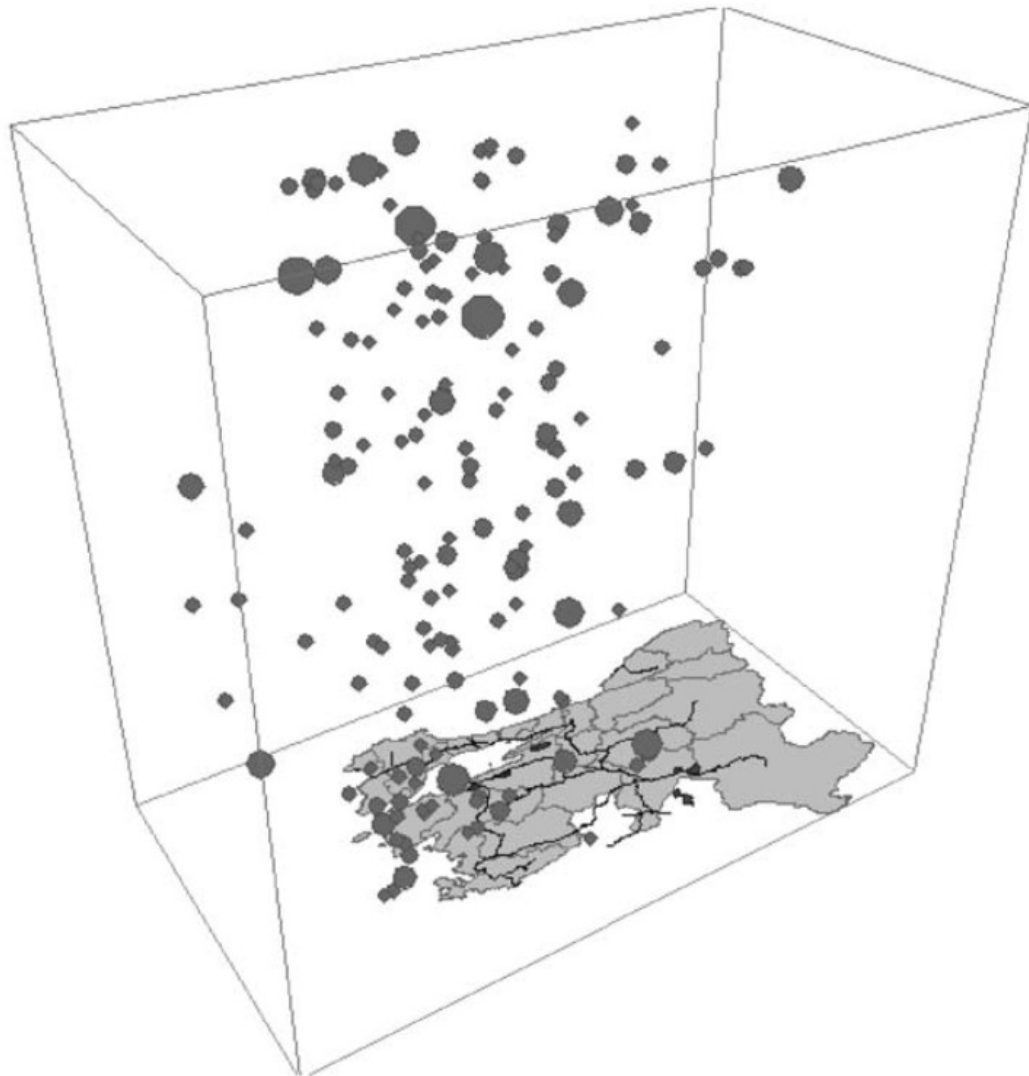
Figure 9: Spatio-temporal events represented in a Space Time Cube. The vertical position of the cluster corresponds to the times when the even occurred. Cluster size or color reflect thematic characteristics of the events. (Andrienko et al., 2003)

Research on the usability of the STC in the past has shown the high importance of the three-dimensional spatio temporal data for users with cartographic background and/or background in related academic fields. This user testing was based in the comparison between 3d STB and animated 2d maps visualizing the same data (Kveladze & Kraak, 2012). Lately, time geography and the visualization of spatio-temporal data has shown great progress. The space-time cubes and their operations, such as filtering, time or space flattening, space shifting, time juxtaposing and more, have opened up a new era in the field of time-geography visualizations.
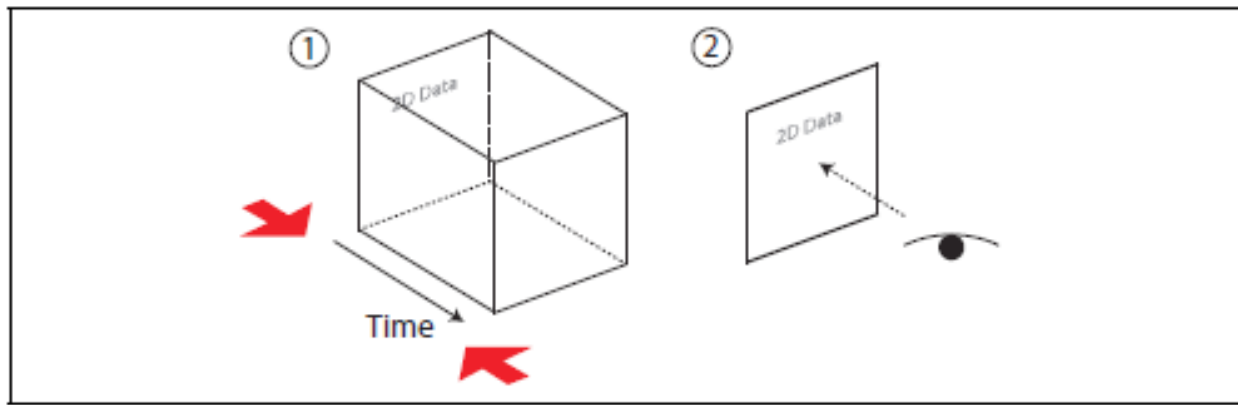
Figure 10: Time Flattening operation of a STC (Bach et al., 2014)

A space-time cube is a conceptual representation which assists in the understanding of temporal data. Considering a rectangular map, in every step of temporal changes, every frame can be understood as a slice of a space-time cube (Bach et al., 2014). The time flattening operation in an STC is collapsing the data in the axis of time. The result is a two-dimensional image. Time juxtaposing contains multiple time slices of the STC placed side by side. Figure 10 shows the operation of Time flattening of an STC, the cube is flattened in the time axis and the viewer is able to see a two dimensional result of the contained events throughout time. Figure 11 illustrates the STC operation of time juxtaposing, where the three dimensional STC is becoming a two dimensional visual, but in this case the viewer can see all the time steps aligned one next to the other.
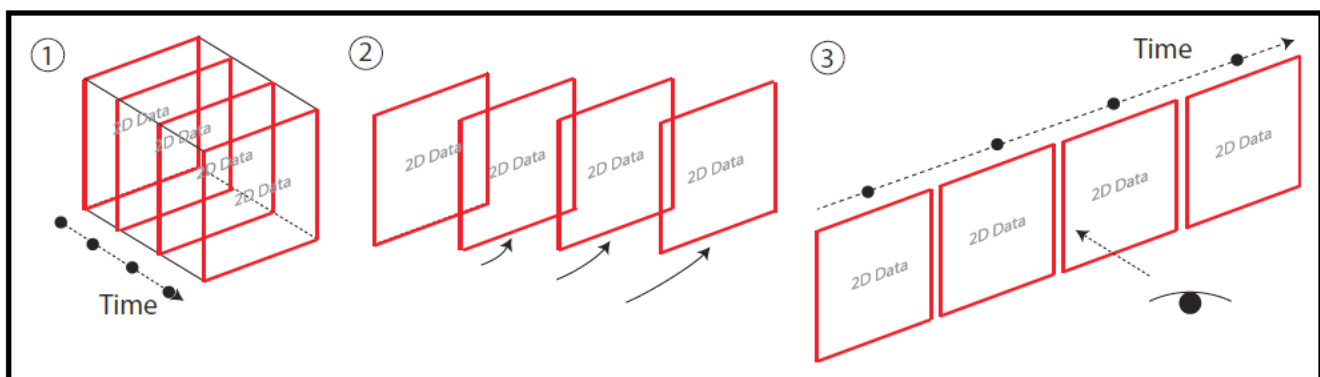
Figure 11: Time Juxtaposing operation of a STC (Bach et al., 2014)
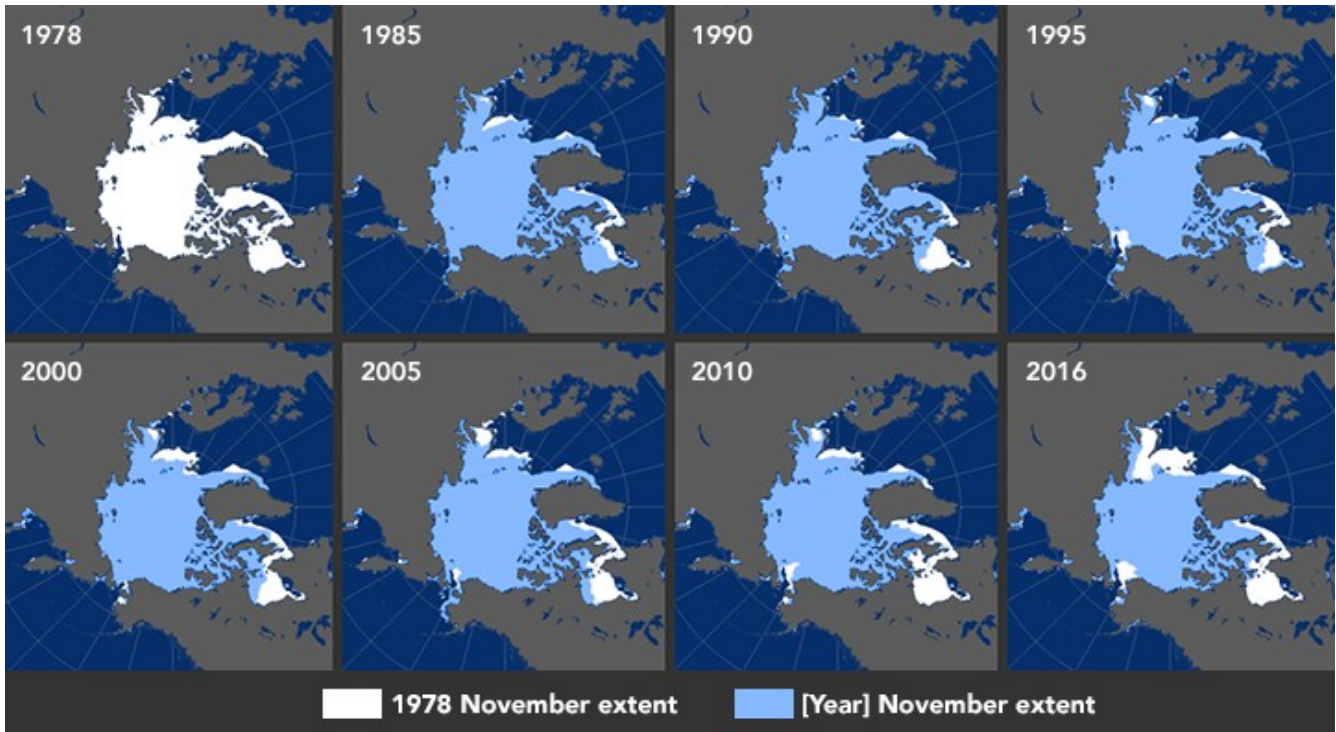
Figure 12: Example for time juxtaposing, Maps of Arctic Sea Ice Concentration (Earth Observatory, 2016)

The most common cartographic realistic three-dimensional representations are relief models, such as a simple digital elevation model and globes. Most of the times though, those examples are not holding the dimension of time. In the example of Google Earth, the implementation of time is imported as a time slider; the user can select and present historical imagery of the selected area. An other implementation of time which is staying in the three-dimensional space-time visualization is the web application of the "Earth" developed by Cameron Beccario. The Earth web application is an interactive minimal application of a visualization of global weather conditions forecast by subcomputers updated every three hours. Some of the weather phenomena are updated daily, such as the ocean surface temperatures and the anomaly from daily average. The User can select and display different phenomena for different moments in time, and can also chose between a 3d globe visual or other flat dimensions. The phenomena are visualized as animated live events. This application is falling into the representation of time and space, but the user can not display more than one time step per time.
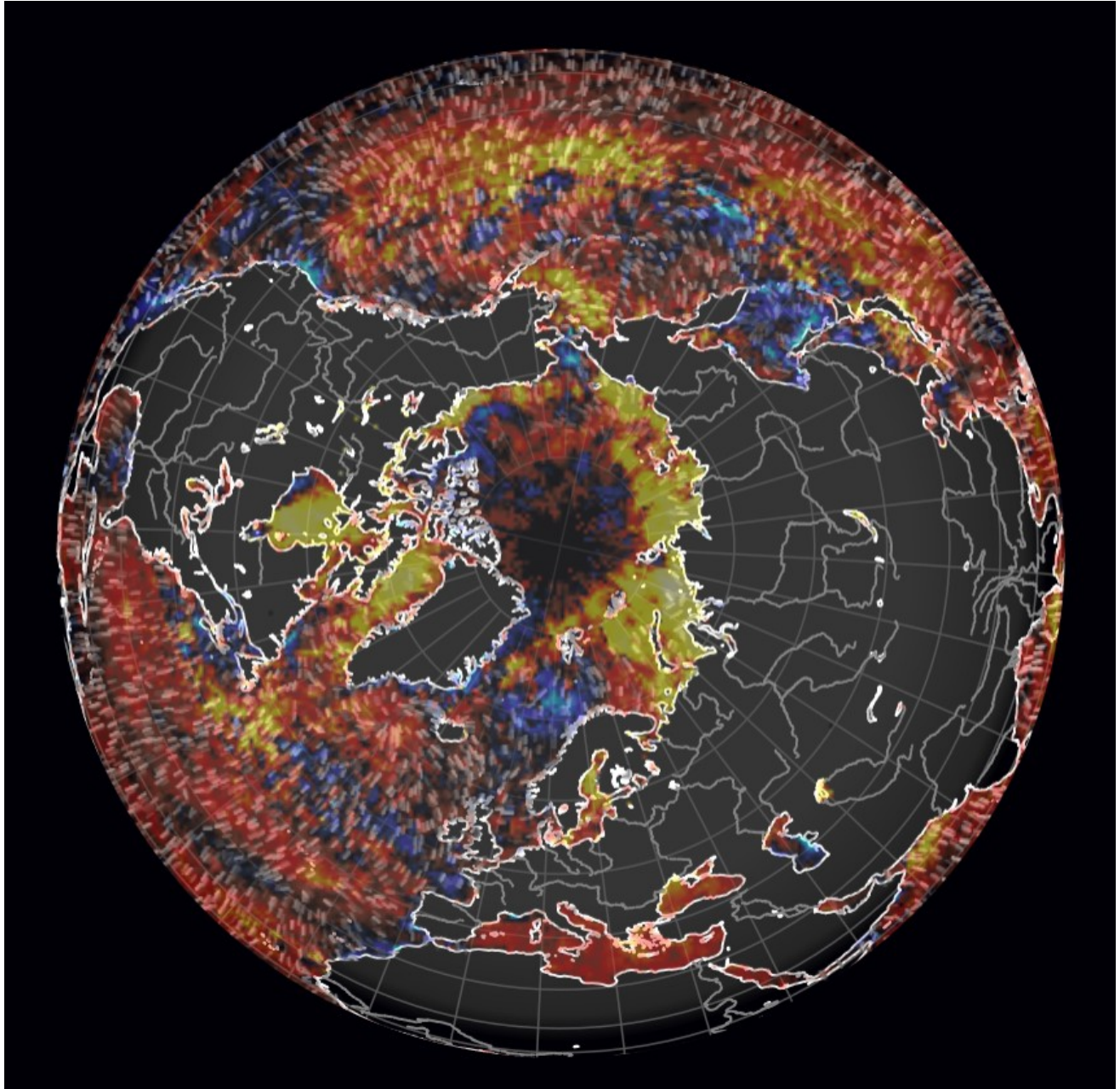
Figure 13: Screenshot, Arctic Centrered Sea Surface Temperature Anomaly & Peak Wave Period, for 1/09/2020, earth.nullschool.net

Earth System Data cubes

The spatio-temporal representation of climate data allows the user to look at the timing, shape and/or dynamics of individual events through space and time. The quantification of extreme events holding the dimensions of latitude, longitude and time in a big terrestrial area or even globally is a difficult task. In order to visualize an understandable three-dimensional spatio-temporal visual on climate and environmental changes, the extreme events are selected. The aim of extreme event representation can be achieved by calculating and visualizing the anomalies on specific indices and fractions (Zscheischler et al., 2013). In the Earth System Data Lab, the end user can not only interact with the visual, by rotating and zooming, but can also implement further analysis of the available phenomena. The hyper-dimensional result of the ESDL provides a long source of data sets which have been cubed and which are in an analysis ready stage for the end user. The data cubes are providing a cloud resource for computing and distribution (Mahecha et al., 2020).
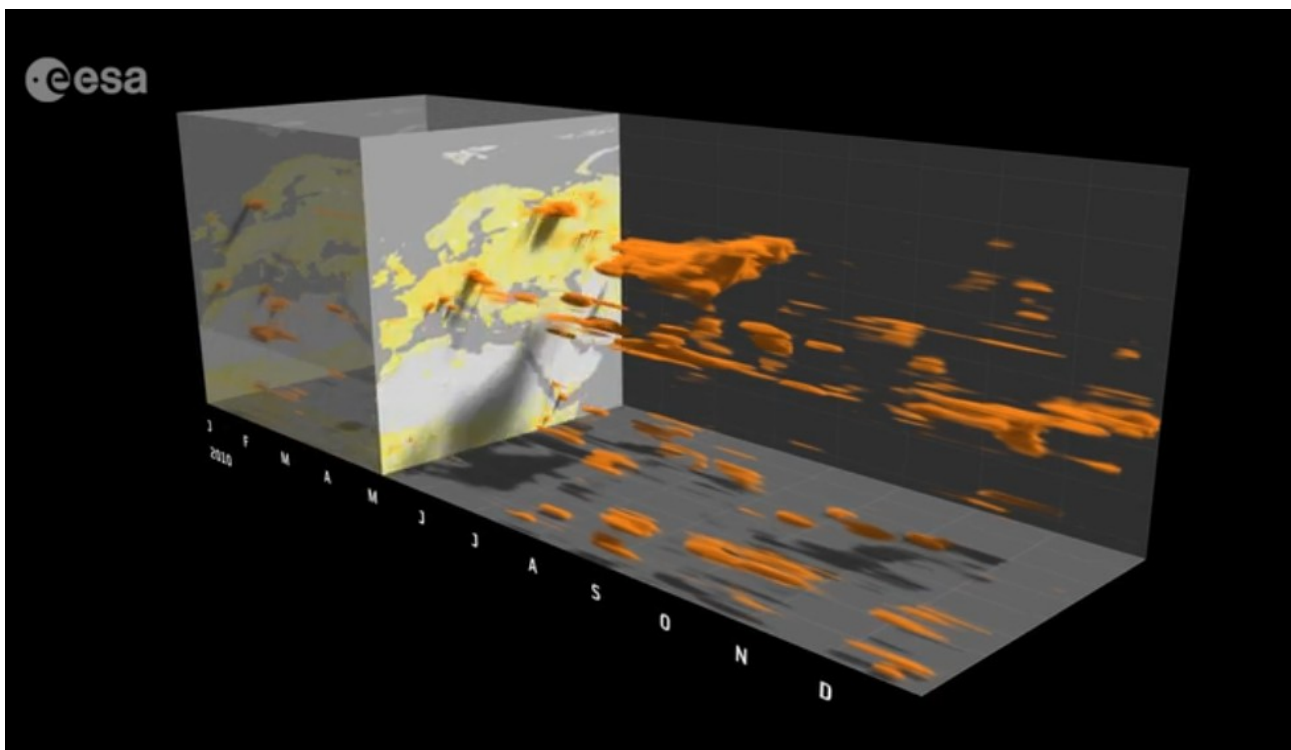
Figure 14: Video Snapshot of the ESA's data-cube showing extreme events of temperature

3   Data and Methods

This research is quantitative in essence and is based on the analysis of level 4 remote sensing data. The data used are the Arctic Sea Ice Concentration, and the Arctic Vegetation. The methodology used for the time series analysis of this data is described afterwards. Moreover, the method and technical implementation of the development of the three-dimensional arctic data cylinders is also analyzed. Finally, the methods used for the development and user experience of the web application as the final output of this thesis, are reported.

Sea Ice Concentration

Sea Ice concentration is the ocean area fraction covered by sea ice, the values of which are given as a real number percentage (0-100%). The data used for the sea-ice processing and analysis are derived from the European Space Agency's (ESA) Sea Ice Concentration (SIC) Climate Change Initiative (CCI) Climate Data Records (CDR). The Level 4 processed data used are derived from a medium resolution passive microwave satellite data-source from the Advanced Microwave Scanning Radiometer series (AMSR-E and AMSR-2). The initial process starts with the original swath data and follows a long list of further steps: the decoding of the files, the correction of the brightness temperatures, the collocation of the data, the dynamic tuning of tie points and algorithms, atmospheric corrections, the tuning of the open water filter, the gridding of the swath data, the calculation of uncertainties for smearing and gridding, the filling of areas with missing data by interpolation, and the application of masks and corrections. The data derived from the AMSR-E instrument on board the Earth Observing System (EOS) satellite Aqua covers the time period: 1st of June 2002- 4th of October 2011. It provides
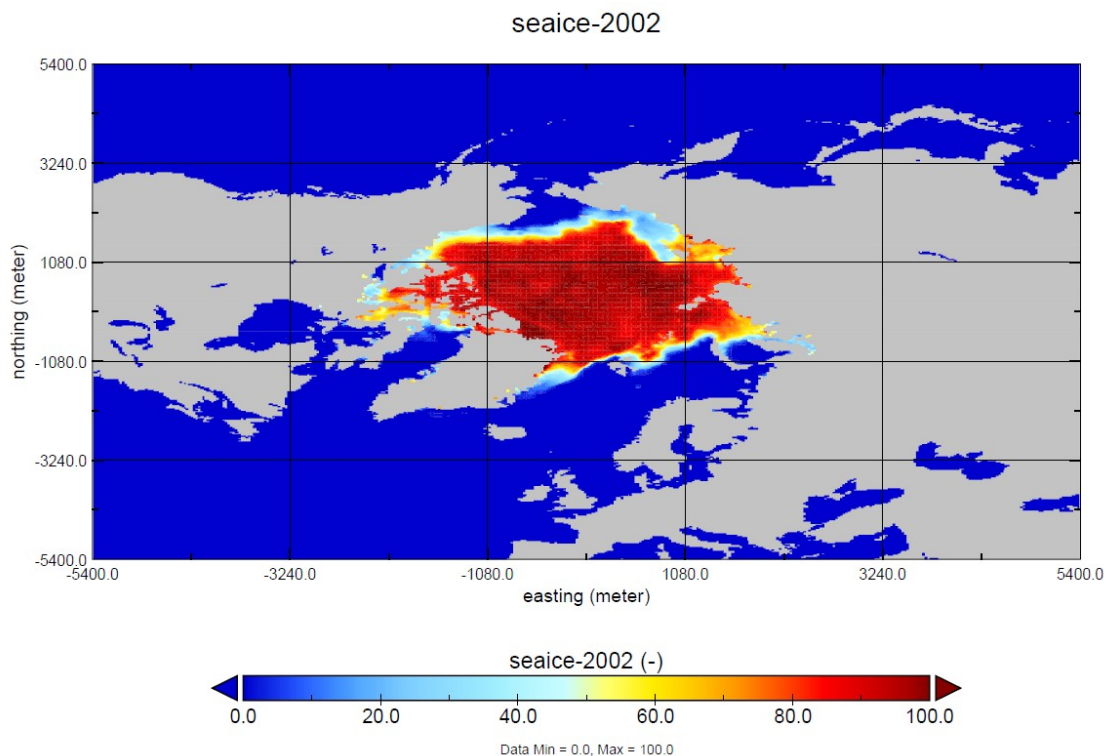
Figure 15: Example of the Sea Ice Concentration AMSR-E product for October 2002 (Panoply software)

passive microwave data measured vertically and horizontally polarized brightness temperatures at 6 different frequencies, in 12 channels. In figure 15 a panoply software of a randomly selected layer as an example of the data being used is displayed.

The grid spacing is 25km. Aqua had a life expectancy until the early 2020s, although it stopped rotating in October 2012. That causes a gap of 6 data-less months, between October 2011 and July 2012 until the AMSR2 got on board the Global Change Observation Mission-Water (GCOM-W1) satellite. This second instrument provides data from the 23rd of July 2012 until the 15th of May 2017. The projection of the SIC data is Lambert Azimuthal Equal Area (EASE2), with central Meridian on 0° and latitude on 90° (Toudal Pedersen et al., 2017).
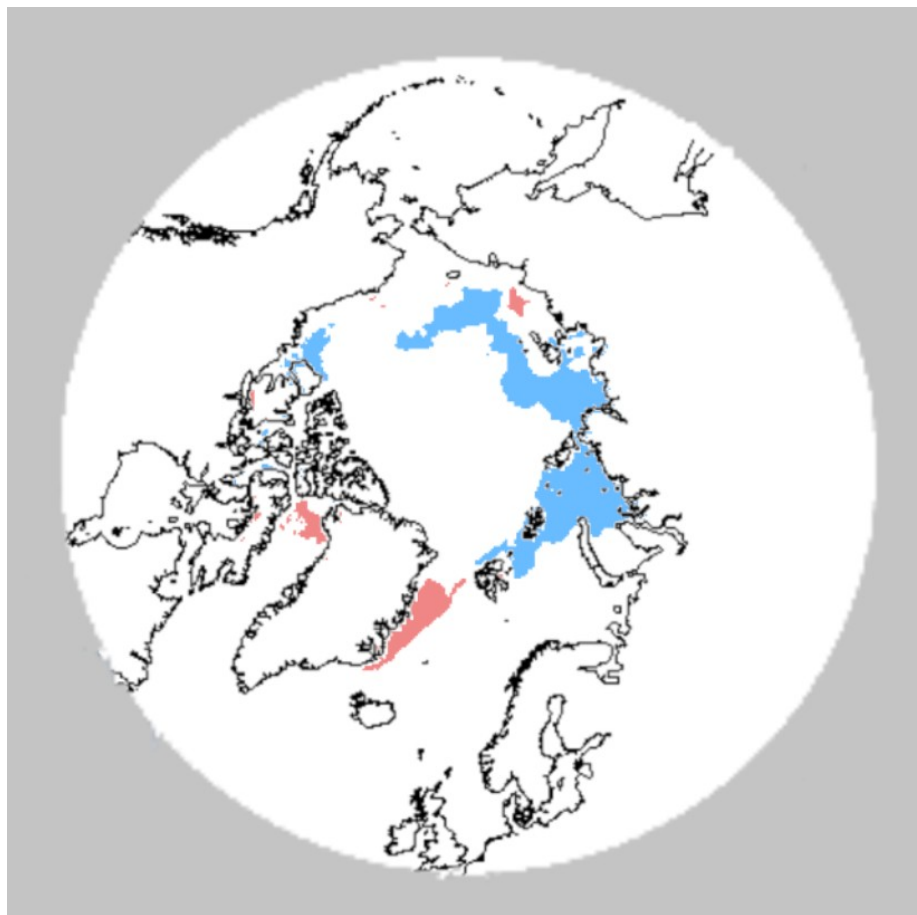
Figure 16: Example post data analysis for Arctic Sea Ice Concentration Extreme Anomalies, with blue the positive and red the negative, for October 2002

The later processing and preparation of the data, has been done in R and includes the following steps: Firstly, the data has been aggregated from daily into monthly by calculating the mean of each month. Later on, the separated raster layers have been combined into a raster-brick which holds all the 155 layers from June 2002 till December 2015. Afterwards the gap of the first 5 months of 2002 and the gap between October 2011 and July 2012 has been filled with blank layers to fill all the time steps. The final number of layers is 168 and covers the time period from January 2002 till December 2015. The next step includes the re-projection of the raster-brick into Latitude/Longitude Projection, then the raster-brick was cropped at the extent of the Arctic (60° North). The remaining polar region was re-projected into Lambert azimuthal equal area projection. Lastly, the time dimension was given to the raster-brick. In Figure 16 a map of the Arctic Sea Ice Concentration Anomalies for October 2002 is shown.

Fraction of Photosynthetically Active Radiation (fPAR)

Fraction of Photosynthetically Active Radiation absorbed by vegetation (fPAR) is defined as the fraction of incident photosynthetically active radiation (400-700 nm) absorbed by the green elements of a vegetation canopy (R. Myneni, 2015). The values of the fPAR vary from 0 to 1. The fPAR MODIS product is having a 500meter spatial resolution and derives from Terra MODIS, Aqua MODIS and Terra MODIS+Aqua MODIS sensors combined. The fPAR product has attained stage 1 validation, which means that the accuracy has been estimated by using a small number of independent measurements obtained from selected locations and time periods and ground-truth program effort. The temporal extend of the data begins from the 4th of July 2002 up to date. The product has a native resolution of 500 meters. (R. Myneni, 2015).

Fraction of Absorbed Photosynthetically Active Radiation

Fraction of Absorbed Photosynthetically Active Radiation (Percent)

0.0   0.2   0.4   0.6   0.8   0.9

Data Min = 0.0 Max = 0.9 Mean = 0.5
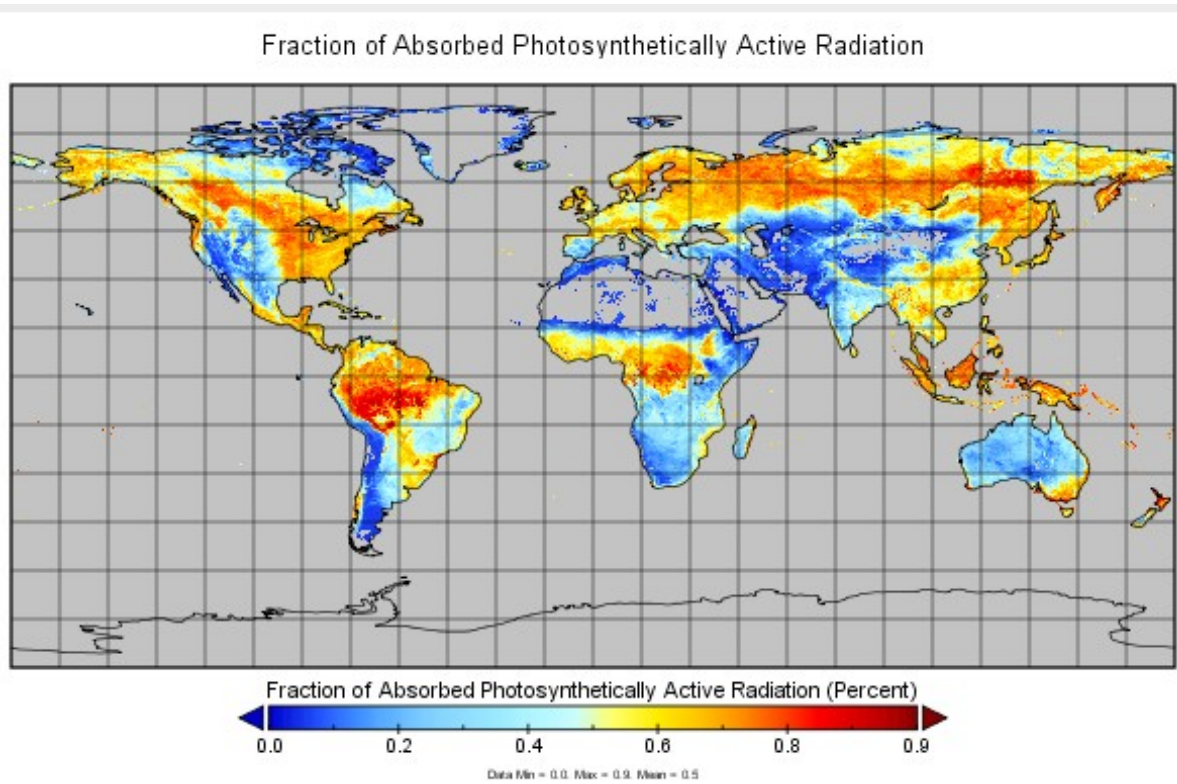
Figure 17: Example of FPAR MODIS product for July 2002 (panoply software)

A layer of the global fPAR for July 2002 in Panoply software, before any possessing is shown in Figure 17. The later process of preparation of the data has been done in R and includes the following steps: Firstly, the data were aggregated to a quarter degree. Afterwards, the daily data were aggregated into monthly by calculating the mean of each month. Later on, the separated layers were combined into a raster-brick where they were cropped into the extend of the Arctic (60° North). Then, the wanted months (July 2002 to December 2015) were subsetted from the initial raster-brick. The missing 6 first months of the year 2002 were added in this step as blank layers. The total amount of layer in this phase are 168. The next step of the preparation of the data is the re-projection of the raster-brick into the Lambert azimuthal equal area projection. Lastly, the time dimension was given by the raster-brick. In Figure 18 a map of the Arctic fPAR anomalies for July 2002 is illustrated.
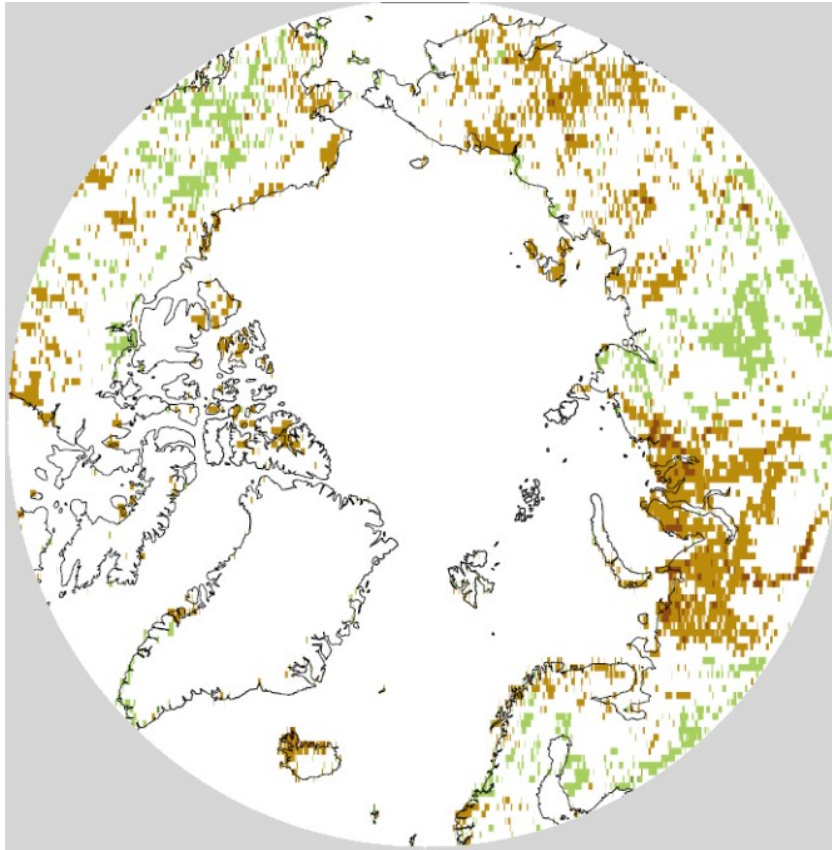
Figure 18: Example post data analysis for Arctic fPAR Extreme
Anomalies, with brown the negative and green the positive, for July 2002

Time series analysis & Anomalies

After the preparation of the data was complete and both raster bricks were equal, polar projected and with the same time range dimension, the continuation of the analysis included the time series analysis and anomalies calculation. Firstly, the monthly mean from the raster-bricks for the cells of each layer was calculated. The result was a new raster-brick of 12 layers, one for each month. The anomalies were computed as the difference of the absolute values from the mean monthly ones.

Developing an Arctic data cylinder

After the preparation and processing of the data, the next step was the development of the data cylinders. The main package used for this step was the "RGL". Rgl package is a 3d real-time rendering system for R, which provides medium to high level functions for 3d interactive graphics, including functions modeled on base graphics. The function "plot3d" allows the user to draw three dimensional scatter-plots.

To make the data readable for the required function it was necessary to convert it into a data-frame. The columns of the data-frame are latitude, longitude, time, and the values of each dateset (fPAR for the vegetation and SIC for the Sea Ice). Then, the extreme anomalies were extracted into separated data frames for the positive and negative anomalies. For the implementation of the plot3d function the dimensions used were latitude, longitude and time, for the creation of the data cylinders. In order for the user to be able to see through the data of the cylinder and not have hidden information, the type of information was shown in the form of semi-transparent points. The choice of the colors was made with the help of the application "colorbrewer" and the pallets used are color-blind friendly.

Time Flattened and Juxtaposing Maps

The time flattened produced maps are made in qGIS as heat-maps with the exported points of the extreme anomalies. The heat-map represents the magnitude of the events in specific space over time by showing a change of the event across a geographical landscape as a rasterized image. The color density of the pixels represents the magnitude of the event in the exact pixel area. The time juxtaposing maps were produced in Gimp with the exported maps for each monthly time step. The time juxtaposing table maps visualize the extreme anomalies and they are placed in a table with the years as rows and the months as columns.

Web Application Development

The web development technology used for the web application "Arctic Data Cylinders" is server-side scripting and the programming languages used were the Hypertext Markup Language (HTML) and Cascading Style Sheets (CSS), along with the scripting language JavaScript.

As a Web-based learning resource, the "Arctic Data-Cylinders" are having not only the role of informing the user but also that of enhancing his/her knowledge or even that of filling gaps in it when it comes to the scientific area of climate studies. The developed web application has a user centered design, allowing the user to interact, explore, and select between various options, reaching his/her own conclusions on the issue of climate change in the Arctic.

The user can select between the vegetation or sea-ice pages. The most important interaction in the web application is the "zoom in/out and drag/rotate" of the cylinders, which are placed in the center of the design. Furthermore, the user can select between up to two per time different monthly maps of her/his choice in order to compare them. Lastly, the user can go through a sideshow of the graphs of the time series and observe their anomalies.

Web Application User Testing

The User Experience feedback sessions were all happening via video calls, due to the special conditions created by the COVID-19 crisis all over the world. The users were asked to share their screen and think aloud. For reasons of privacy and anonymity the video calls were not recorded. The questions asked during the call did not have a structured quantitative-questionnaire form; on the contrary the whole session was based on the free thinking of the user and his/her non-structured commentary.

The average duration of every test was 30 to 60 minutes. The conversations during the testis were divided into three main categories in order to extract feedback. The first feedback

category was related to the general understanding of the user regarding the concept of the application.

The second feedback category was related to the functionality, usability and finally the web design of the page. After every round, the feedback were evaluated and applied into the web application. After the changes and additions, the web application was going through the next round of feedback. In order to have a broad collection of feedback, the users were selected on the basis of different backgrounds and levels of education in each round of the user testing.

The user testing of the web application happened in 3 rounds and lasted for one week each. In the first round the application was at an early stage. The main visuals were the cylinders and the time series and anomalies graphs. In this stage 7 people, related to the field of cartography or environmental sciences participated to give general feedback on the structure of the application, the functionality and the total information provided. In the second round of user testing, 11 persons participated, and in the third round 12 persons. The demographic variety of the users among with their mixed background was not giving the opportunity to get easily results. All of them were falling in five different nationality groups (German (7), English (8), Greek (13), Italian (2) and Pakistani (1)]. The ages of the users were varying from 19 to 60. The educational background was varying from high school graduates to have obtained a PhD.

During the user testing process the users were also asked to evaluate the importance of other additional material resulted by this thesis, in order to allow them to express their preference on the functions, visuals and information applied in the web application. It also included the additional outcomes of this thesis that are not included in the application. These outcomes were the table maps, the animation of the anomalies, and the explanatory comic that accompanies this thesis.
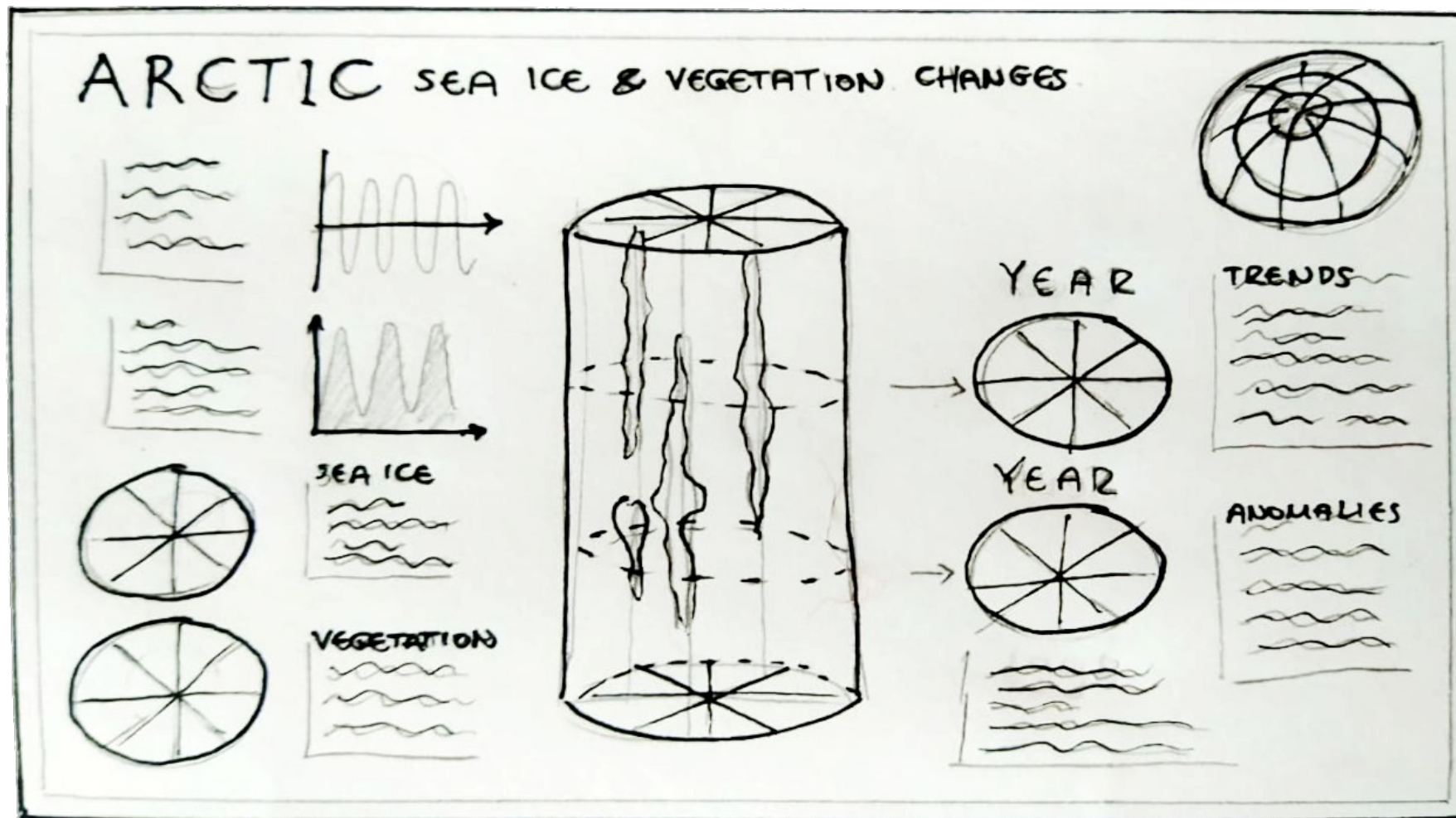
Figure 19: Draft illustration for the web application

4 Results

In this chapter, the results of the data analysis and its cartographic visualization will be reported. In the first part of this chapter, the results of the analysis of the time series and the anomalies observed are presented in graphs. In the second part of the fourth chapter the visual outcomes of this theses are presented. First of all, the overall anomalies results are fit into table-maps, one per phenomenon. These table-maps include one map per month, illustrating the anomalies in their whole range of values. Furthermore, the final visual cartographic outputs are presented, in an effort to map stand-alone visuals that depict the complex phenomena analyzed in this thesis. While the two dimensional and animation representation of spatio-temporal data is limited, the implementation of three-dimensional interactive visuals is produced in this case. Moreover, additional cartographic material has been produced as a result of the time flattening of the cylinders.

Time Series and Anomalies

In the fPAR time series (Figure 20) we can see the "cuts" caused by the winter, when the snow coverage and the limited sunlight are not allowing the data collection. The seasonality of the fPAR is easily detected, the maximum fPAR values are happening over the summer, with the highest maximum value appearing in the summers of 2012 and 2013. The minimum values of the graph are not observed right after the breaks but shortly after that is happening.

Regarding the Sea Ice time series (Figure 21), the seasonality is showing due to the maxima and minima of the concentration. The Sea Ice Concentration reaches its maximum point during the winter months and its minimum point during the summer. Due to the lack of data, there is a gap in the time series between October 2011 and July 2012. It is detected that the maximum values of the SIC are not appearing in the same months as the minima of the fPAR, but approximately one month earlier. Similarly, the maxima of the fPAR are happening slightly before the minima of the SIC.

As far as the Sea Ice anomalies are concerned (Figure 22), during the years 2002-2006 there are no significant negative anomalies; instead, the high values of the positive anomalies of these years are not repeated in the next years. In the final years of this graph, the positive anomalies have low percentages, while the negative anomalies have a dramatic presence. Moreover, we can easily detect an abrupt decrease in 2007 with no positive anomalies appearing this particular winter. Due to the lack of data, there is a gap in the time series between October 2011 and July 2012.

In the fPAR anomalies graph for 2002 to 2015 (Figure 23), some extreme positive anomalous events in the summer of 2002 are shown and an extreme negative anomaly in the winter of 2008. A general impression derived from this graph is that the first illustrated years have more negative anomalies than positive, excluding the extreme positive in the beginning of the studied years. The years after 2010 illustrate more positive than negative anomalies

The correlation between the SIC and the fPAR is close to zero. This does not mean that the sea ice and terrestrial vegetation are not related at all. Since both phenomena are highly related to temperature, more factors should be taken into consideration to study the correlation of the two phenomena.

Fapar Time Series 2002-2015
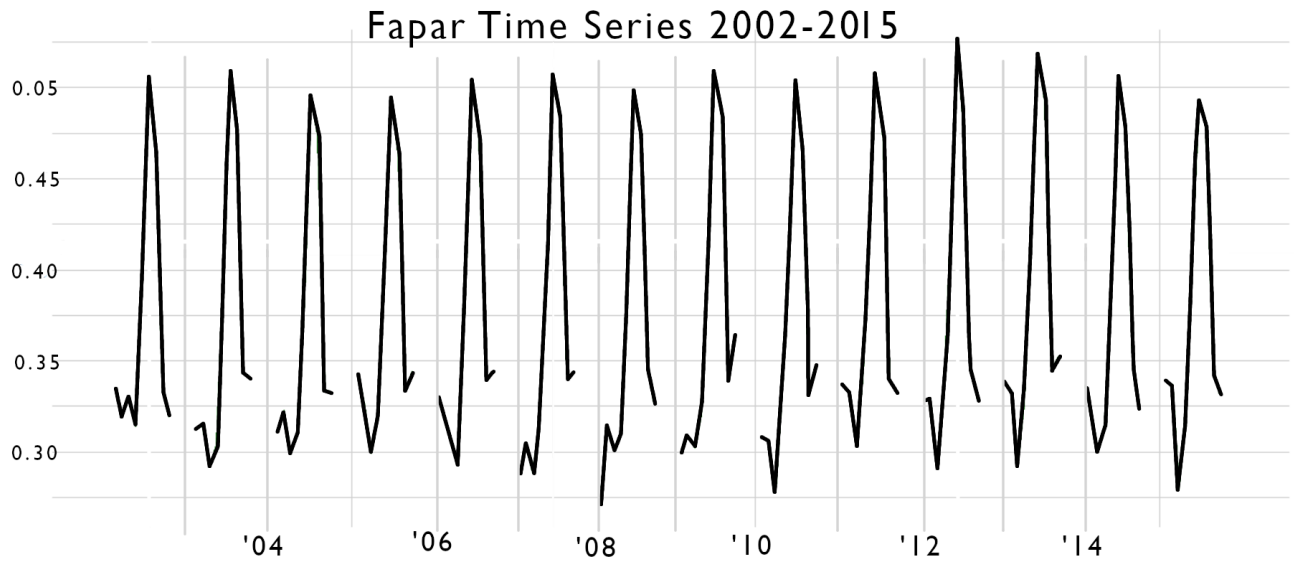
Figure 20: Arctic fPAR Time Series graph 2002-2015

Sea-Ice Time Series 2002-2015
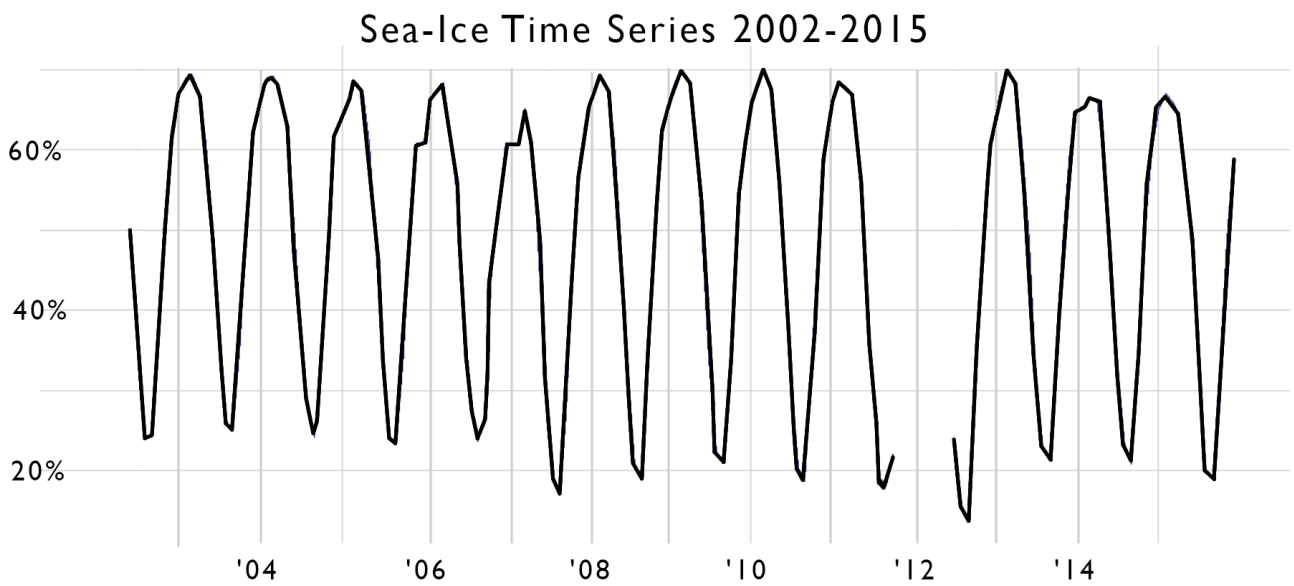
Figure 21: Arctic SIC Time Series 2002-2015

Sea-Ice Anomalies 2002-2015
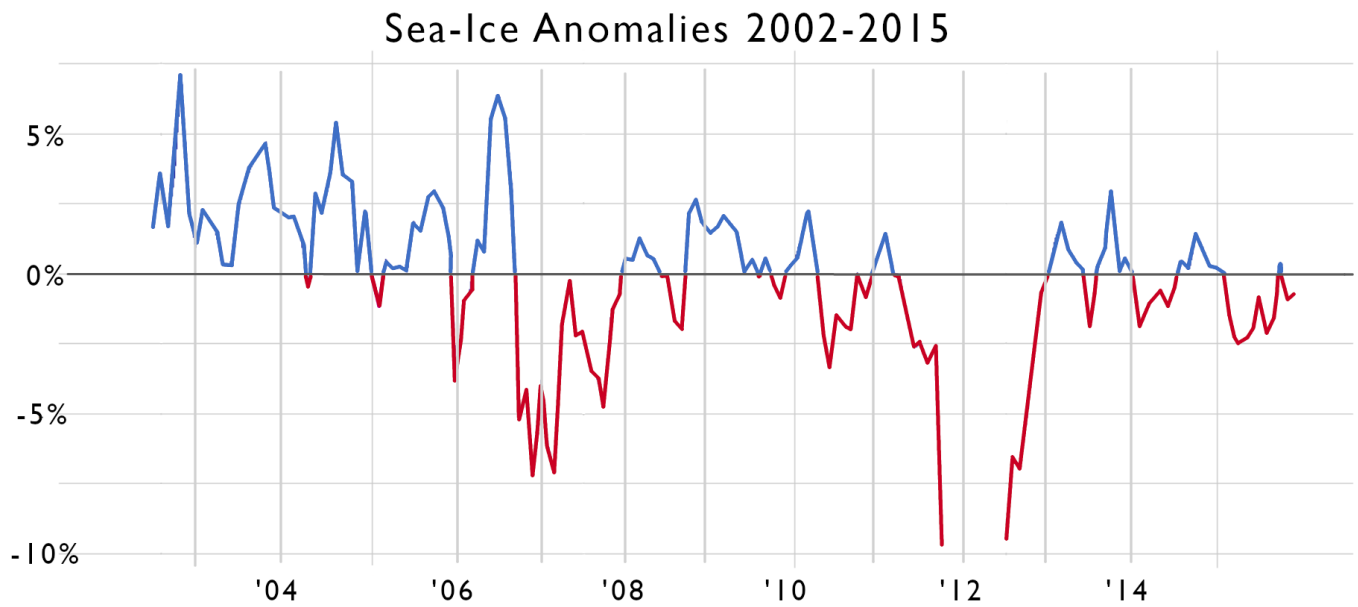
Figure 22: Arctic Sea Ice Concentration Anomalies 2002-2015

Fapar Anomalies 2002-20015
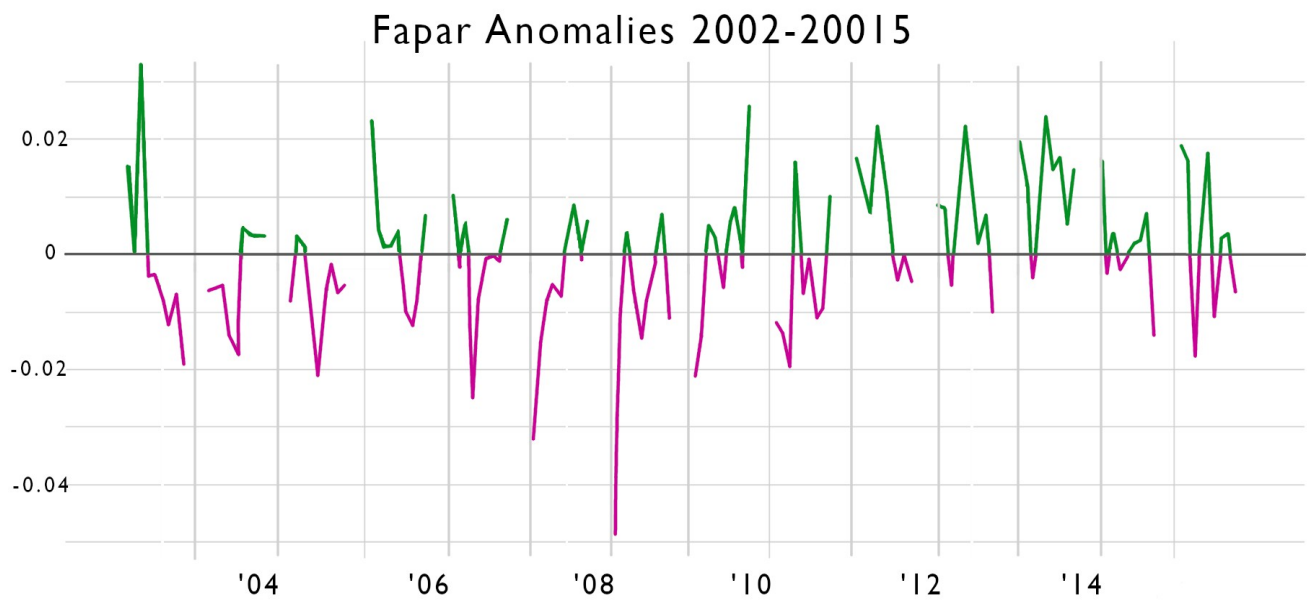
Figure 23: Arctic fPAR Anomalies 2002-2015

Cartographic Outputs/Objectives

The visualization of complex phenomena in climate studies could provide the researcher as well as the wider public with information which is not clear from graphs and tables of the row data, or illustrations and maps of a specific point in time. In this thesis, the data was first cleared from unnecessary information, such as the non-arctic areas. Later, they were aggregated and analyzed. The first visuals, the table maps, are important for the user to see general picture of the data with some color scales placed in time order. The data cylinders, the main visual outcome of this research, show the extreme anomaly values of spatio-temporal data in one three-dimensional interactive visual. The user can observe and detect when, where and the duration extreme positive or negative anomalies occurred either for the fPAR or the SIC. Finally, the time flattened cylinders, represented by heat-maps, and visualizing the magnitude of the phenomena as color saturation in two dimensions, show an overall picture of the extreme anomalies values throughout the time-period under study. In these maps, the user can detect where the extreme events happened but not when or for how long.

Time Juxtaposing aka Table maps

The form of the table maps, also described as "time Juxtaposing", allows the presentation of all the data and results in one big table. It is not a quickly readable visual, first of all due to its size and secondly due to the amount of information being included in it. The table map includes 12 columns, one for each month, and 13 rows, one for each year (2002-2015). The seasonality of the vegetation can easily be seen in these table maps.

In the fPAR table map (Figure 24), the winter months are blank. Moreover, June is the most photosynthetically active month where anomalies in the high Arctic are spotted. Due to the form of the table-map comparing different months of different years, or same months for all the years is easy. The seasonality of the vegetation can be detected due to the spreading and decrease of the illustrated anomalies towards the northern areas and back towards the

southern ones. With a quick look in the overall table-map, the years 2011-2013 are showing an unexpected greening, compared with the other years. For June 2003, 2004, 2007 and 2008, mostly in the Siberian side of the Arctic there is a big area of negative fPAR anomalies. Meanwhile, the years 2011, 2012, 2013 and 2015 show a big area of positive anomalies in Siberia and in 2015 positive anomalies can be detected in Alaska and West-North Canada as well.

In the Sea Ice Concentration table map (Figure 25), the eye of the viewer is captured by the data gap between November 2011 and June 2012. Afterwards, the second most obvious observation in the table-map is that the first 6 months of every year, more positive than negative anomalies of the SIC is shown, while the last 6 months are vice-versa, show more negative than positive anomalies. As represented in the graph of the anomalies as well, the first 3 years do not show significant negative anomalies. However, in East Siberian Sea in the autumn of 2007 there is a big negative anomaly of more than -60%. Over the next 3 years the anomalies throughout the autumn and winter months continue to be present with values between -20 to -60. In 2011, the extreme negative anomalies start to show up in Leptev Sea and Beaufort Sea. During the next year, the area of the extreme negative anomalies remains almost the same, nevertheless spreading towards the Chukchi Sea and the North Pole. In 2013, in September and October there are some surprisingly positive anomalies in Chuckhi Sea, although in Leptev Sea the values of the negative anomalies remain below -60%. Moreover, the Bering Sea show only positive anomalies except for the spring of 2003.
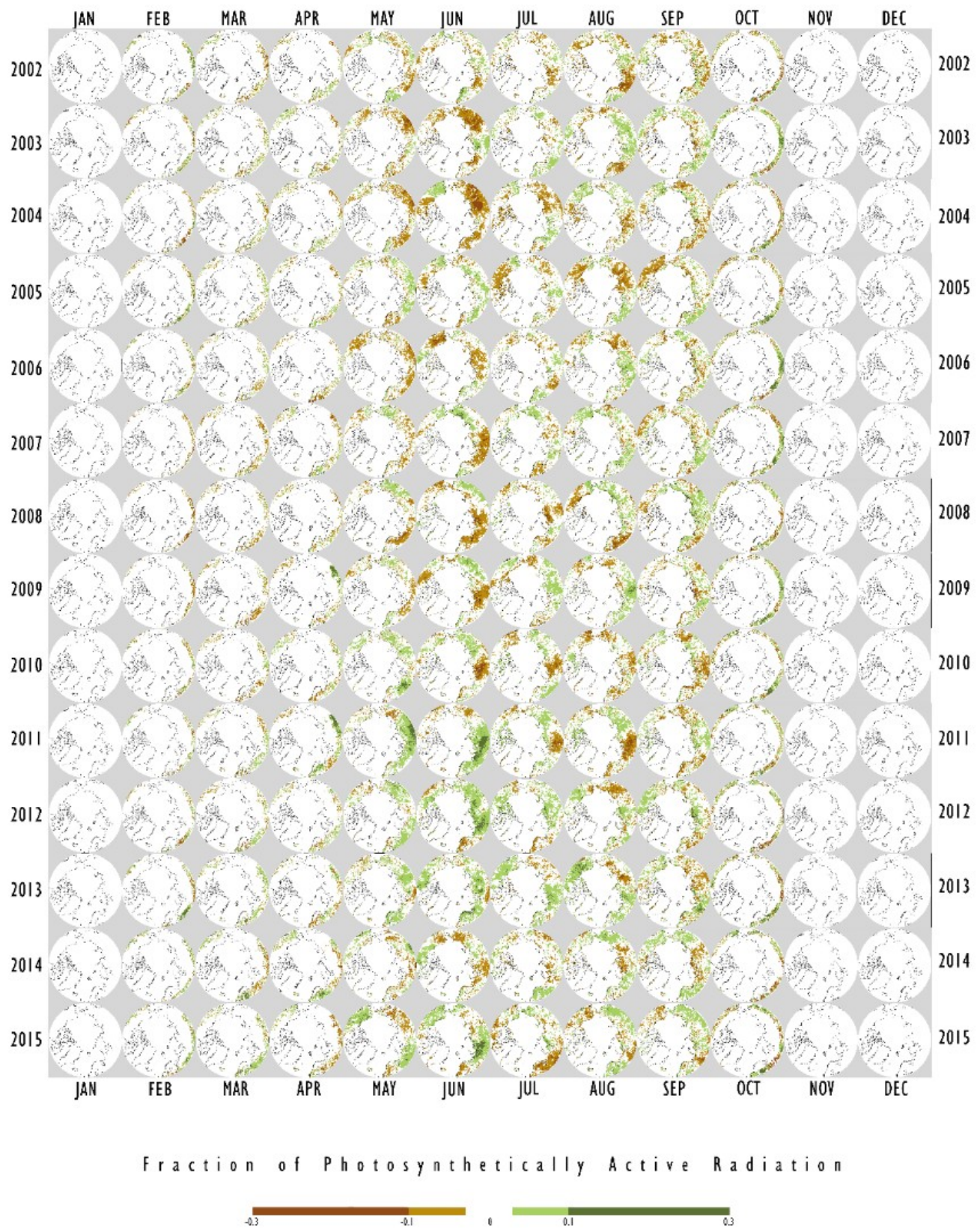
Figure 24: fPAR anomalies table-map
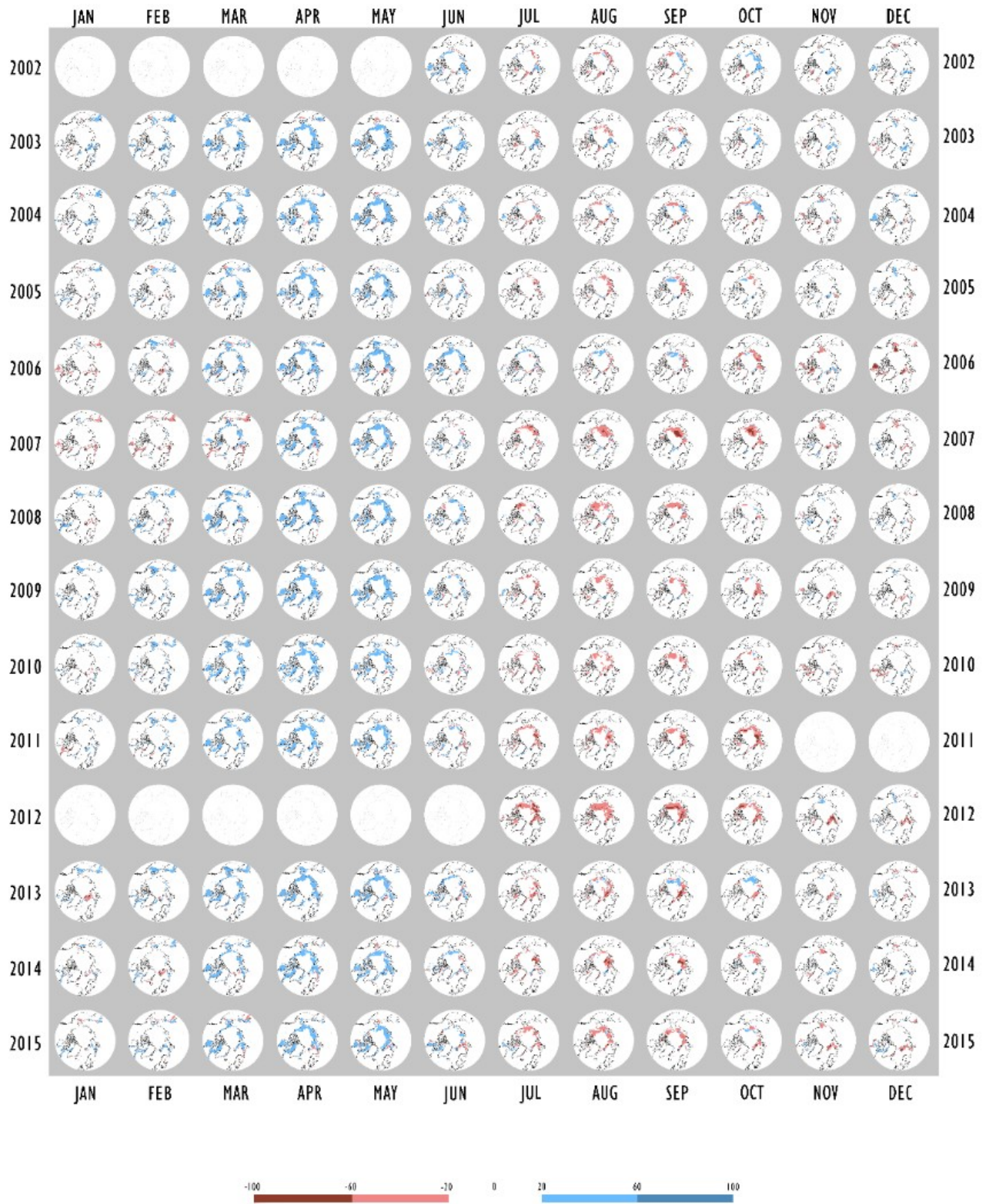
Figure 25: SIC anomalies table-map

Data Cylinders

The "Arctic Data Cylinders" are the final product of this spatio-temporal analysis of environmental Arctic data. They are three dimensional objects showing the extreme events via the lowest and highest quartile of the anomalies, which in this application are derived from the fPAR and SIC. The form of the cylinder is a result of circular arctic maps analyzed along the dimension of time (z), so an early visual result would look like a pile of circular Arctic maps one over another in time order. The final output of the cylinder is transparent, with a filled map of the Arctic at the bottom and the anomalies of each variable in translucent color. The selection of the pallets in both cases are including color-blind friendly pairs of colors. For the vegetation cylinder the pair of colors selected are green for the positive anomalies and bright pink for the negative anomalies. In the SIC cylinder royal blue was selected for the positive anomalies red for the negative ones.

The data visualization of the contained spatio-temporal clusters in the cylinders are translucent points. In the fPAR cylinders (Figure 26) we have more scattered and not clustered result of the points. In the SIC cylinder (Figure 27) though the result is more clustered and the areas showing anomalies are more homogeneous over time and space. The user can use the option of rotation and zoom in order to interact with the visual.

In the fPAR cylinder, the negative anomalies in Finland and Siberia in the first years of the visual are easily detected. Spatio-temporal clusters of negative anomalies can be spotted in west Siberia in the last years of the visual, from 2013 to 2015. Positive anomalies can be seen in East Siberia in 2011 to 2012. Negative anomalies can be seen in denser throughout the years to the Nordic Counties, West Siberia and being spreader toward the East Siberia.

In the SIC cylinder, there is a big spatio-temporal cluster in Barents Sea, between 2002 and 2005. In the Bering Sea there is a constant presence of positive anomalies. In both seas there are no negative anomalies. However, the negative anomalies are creeping in towards the north pole, meanly in the broader area of the Leptev Sea.
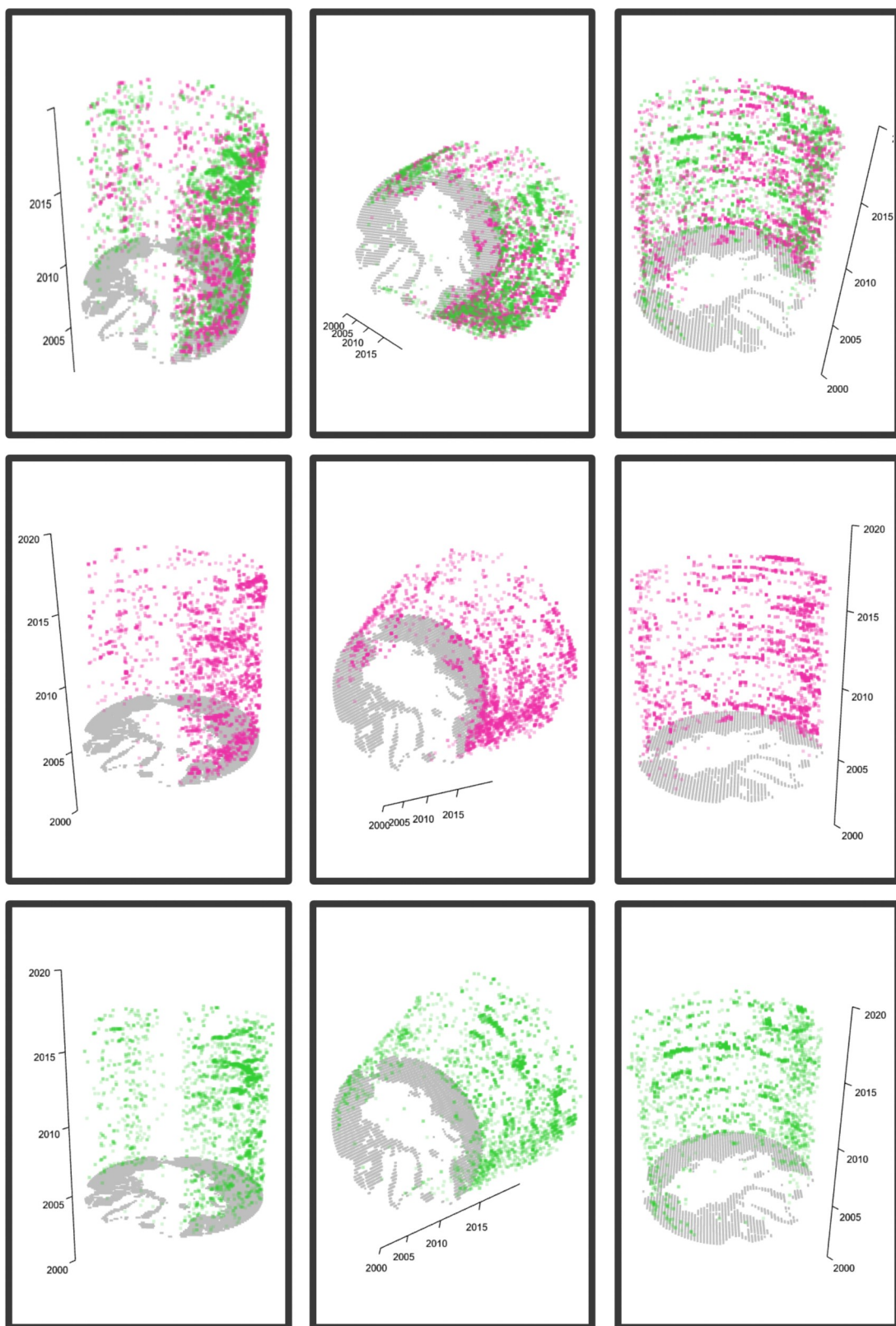
Figure 26: fPAR cylinders

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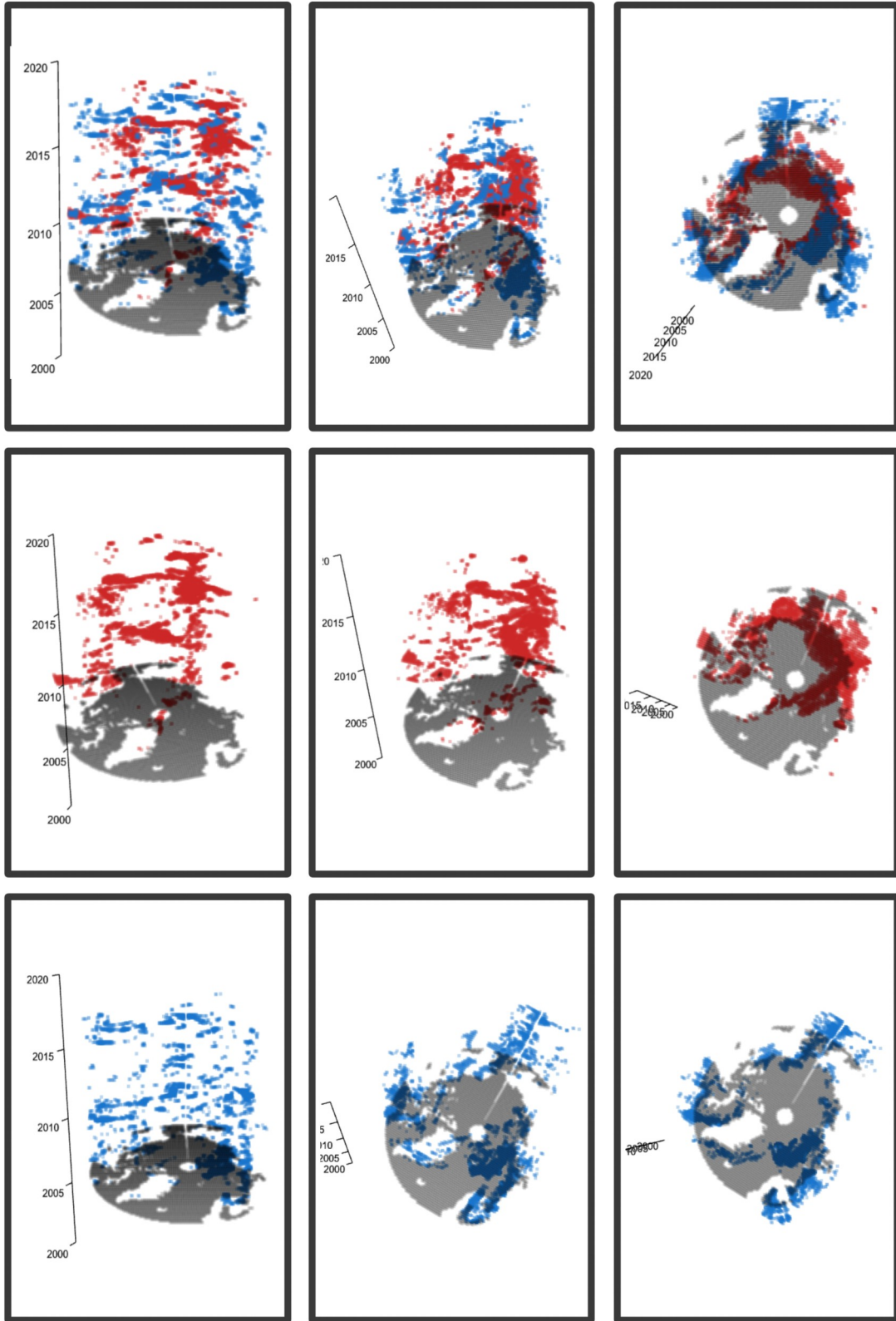
Figure 27: SIC cylinders

Time-flattened data-cylinders aka heat-maps

The time flattened data cylinders have a major importance in the understanding of the volume of the spatial distribution of the data without taking into consideration the temporality. The time flattening collapses the spatio-temporal cylinder along its time axis and has as a result a two-dimensional map, also referred as heat-map. The heat-map allows for the visualization of the magnitude of the extreme events of anomalies by changing the intensity of the color. Even if the reader can only detect the area of the extreme anomalies, and not the exact moment or time range of these events, the information extracted out of these visuals can give information which cannot be easily extracted from the other two visual categories of the visual outcomes.

In the first pair of maps (Figure 28), we see the fPAR anomalies. A quite significant result is the fact that both anomalies are happening through time in the same space. Most of the anomalies shown in both maps are observed from Norway to Siberia. Even though the positive anomalies are having a bigger distribution in space, they remain in the exact same area as the negative ones. The areas of the Nordic Countries and East Siberia which are showing both positive and negative anomalies throughout the researched years are mainly covered by agricultural land, crops and evergreen forests.

In the next pair of maps (Figure 29), we see the positive and negative anomalies of the Sea Ice Concentration. Most of the positive SIC anomalies throughout the period 2002-2015 are happening between the Kara Sea and Barents Sea. In this case, the negative anomalies do not coincide in space with the positive ones. We see the negative anomalies taking place in the broader area of Leptev sea, around the Franz Josef Land and toward the East Siberian sea, while they are expanding slightly toward the north pole.

Although, the big advantage of time flattened maps is showing the spatial distribution of the anomalies no matter the time, that is also their biggest disadvantage. Without additional material but the stand-alone one, one would assume that the phenomenon is equally distributed in time – which is not the case.
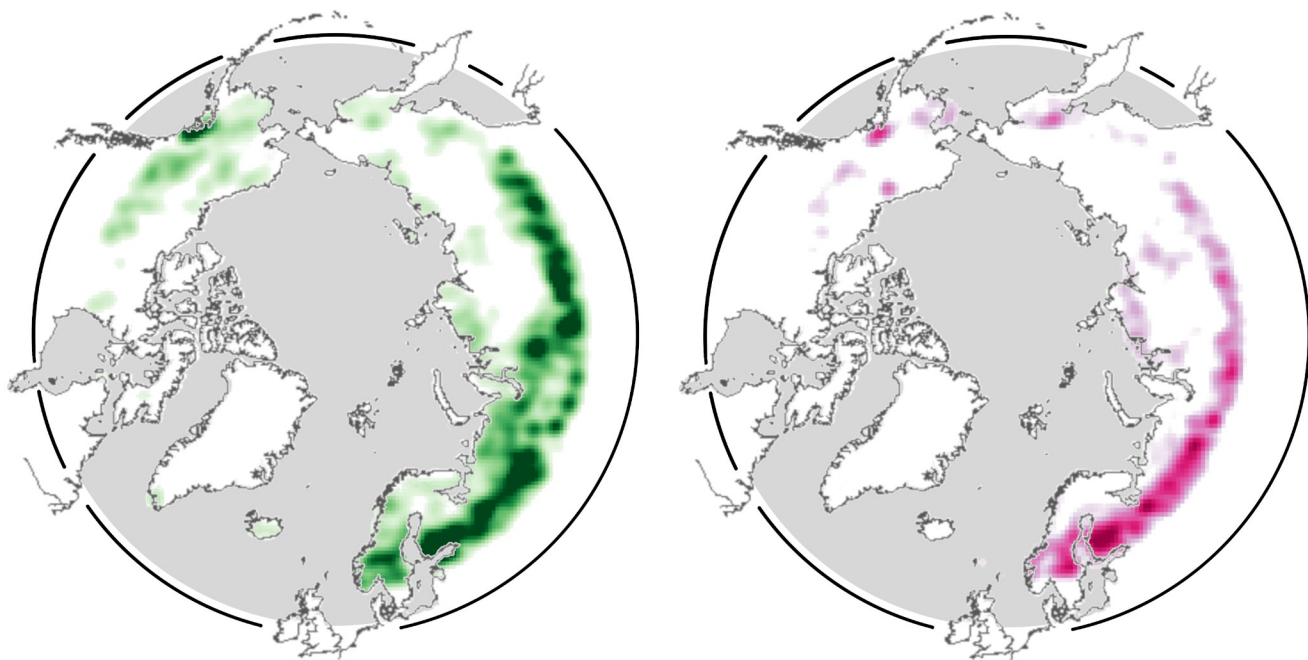
Figure 28: Arctic fPAR Time Flattened maps (heatmaps), left:positive, right: negative anomalies
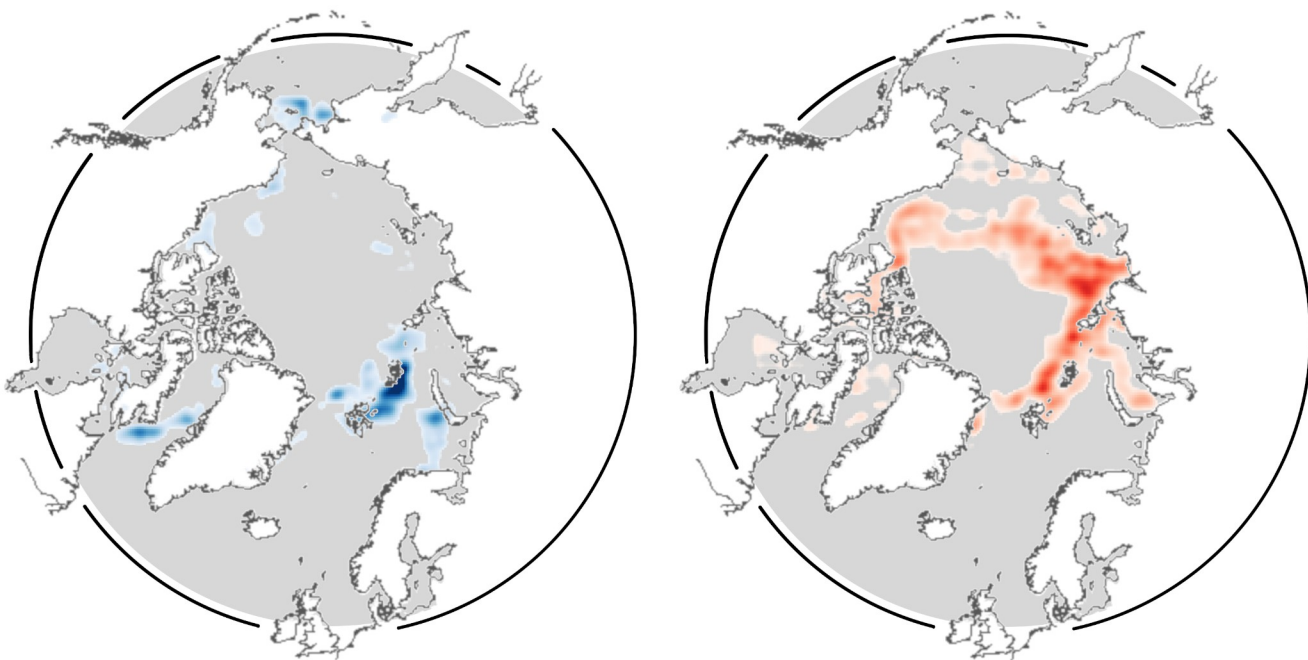
Figure 29: Arctic SIC Time Flattened maps (heatmaps), left: positive, right: negative anomalies

Web Application, Interactive outcome

The development of the web application "Arctic Data Cylinders" is one of the outcomes of this thesis. The importance of an interactive cartographic visual, which could simplify and at the same time present complex and big amount of data, is very high. The implementation of the interactivity of the three-dimensional cylinders is applied in a web application, which hosts the exported results, maps, graphs and cylinders. The user can zoom in and out, drag and rotate the cylinder, and choose up to two maps at the same time to compare the illustrated phenomena. The user can also navigate through three pages and display the vegetation related visuals, the sea-ice ones or additional educational material and information regarding the web application. The application faced three rounds of user testing, after each of which it was corrected and changed in design or functional aspects. From the early beginning the cylinder was placed in the middle of the screen, being surrounded by additional information.

During the first round of user testing various feedback was produced. At this point the web application (as shown in Figure 30) was displaying the cylinder and the option to select which anomaly and/or anomalies to display, the heat maps, the graphs and a short explanation of the displayed phenomenon. Between the first and second round of user testing, many details were changes. Among these changes, things that changed were: the color pallet into a color-blind friendly diverse palettes, and the implementation of the function for selecting a single layer of the cylinder.

In terms of general understanding, during the first round, of the concept of the application, most of the users understood the terms and were able to discuss about them in maximum 5 minutes after exploring the application. Most of the questions asked by the users were related firstly to the functions and later to the context. After a small guidance on the terms of the "anomalies" which were not explained in the application, the users were able to understand better the visuals. All needed an explanation on what the heat maps are and what they represent. Furthermore, 5 out of the 7 users clicked on all the links provided in the application, as sources of the terms for fPAR and the Sea Ice. The overall experience of the users was mentioned as "interesting" and/or "enjoyable". In terms of general understanding all users mentioned that they would not be able to understand the visualized data of the cylinders without the additional material.
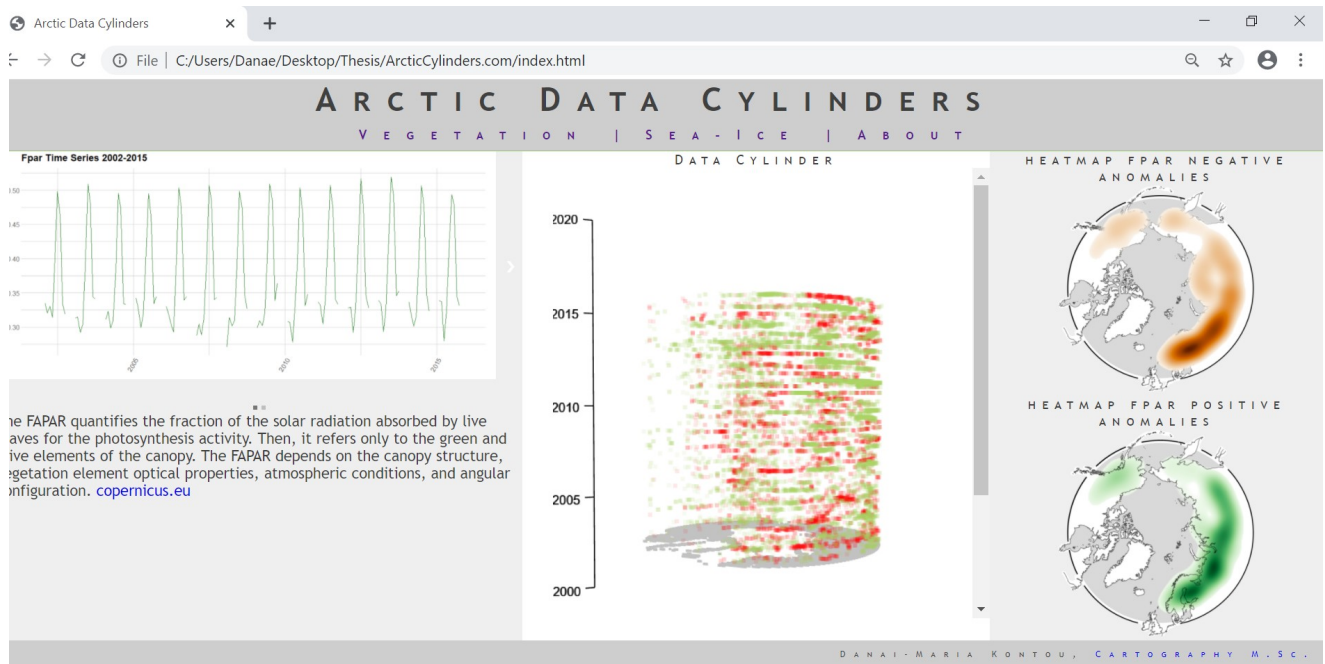
Figure 30: Screenshot of the web app during the first round of user testing

During the second round, most users enjoyed the function of the slider and were curious to further explore it. Many mentioned that they would enjoy the layers to be in an animation form on top of the sliding option. As shown in Figure 31 the new color in the selection bar of anomalies for the cylinder was much more obvious for all the users. The new naming of the "heat-maps" as "time flattened maps" was leading the users to a better understanding of this visual. All the users were asked to find in the "sea ice cylinders" the place and time with the most negative anomalies and all were able to identify it in just a few seconds. Half of the users mentioned that they were not able to easily read the graphs and they needed explanation on why the fPAR time series are having gaps every year. When the users were asked to guess a possible reason why there is a gap in 2012 in the sea ice graphs, 9 out of the 11 guessed correctly mentioning either the general lack of data or the collapse of the satellite, 2 out of the 11 guessed that this year had extreme values which could not be fit into the graph. Lastly, 7 out of the 11 clicked on the links provided. In terms of understanding feedback, many of the users replied in this round as well that they would not be able to understand what the cylinder is showing without the additional material around them.
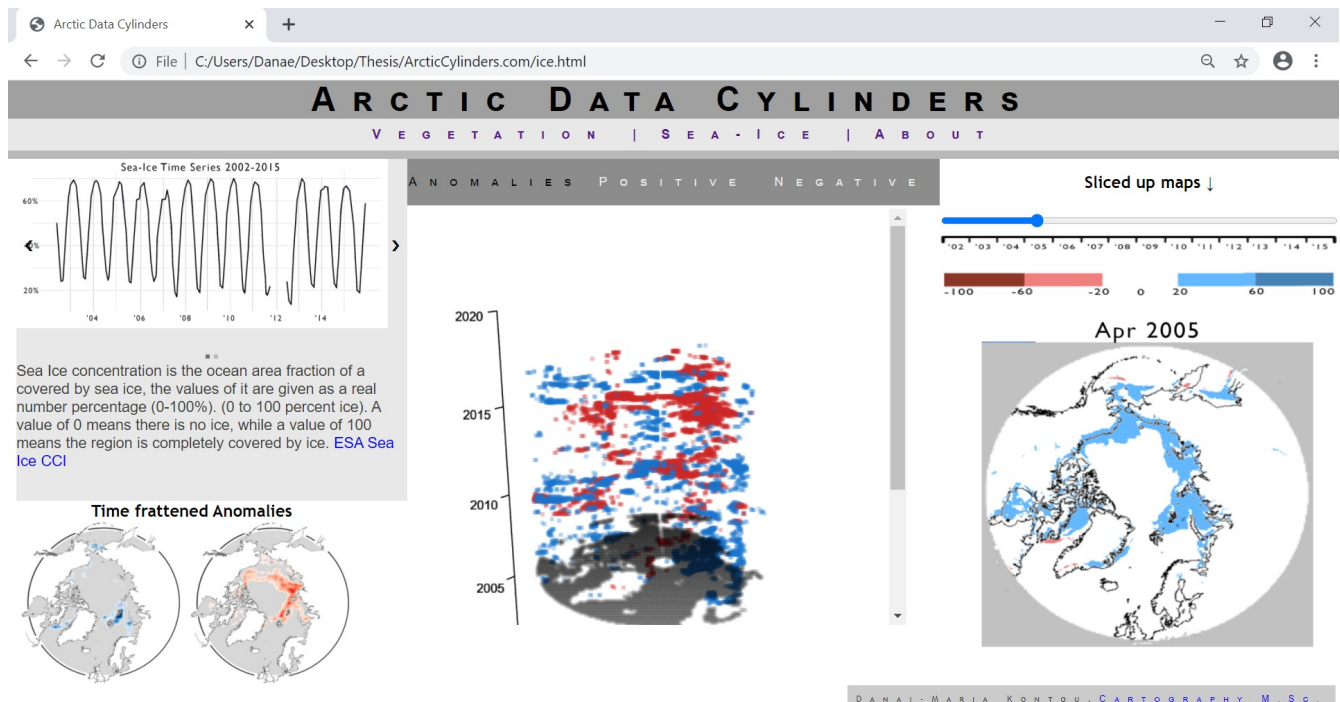
Figure 31: Screenshot of the web app during the second round of user testing

In the third round (Figure 32) the main screen part was divided in equal spaces. The graphs were changed, and their texts and numbers were highlighted. Moreover, in the "About" section, a presentation in the form of a comic was placed as explanatory material. Out of the 12 users, 10 mentioned that the About page should be placed first and that it could have helped them understand faster the application. In this round the users were in the majority comfortable using and exploring the application. They all mentioned that the entry page which is the vegetation is making them feel lost and they needed to go to the About page first and then return. Most of the users in this round mentioned that they would not be able to understand the context of the cylinder without the additional material.
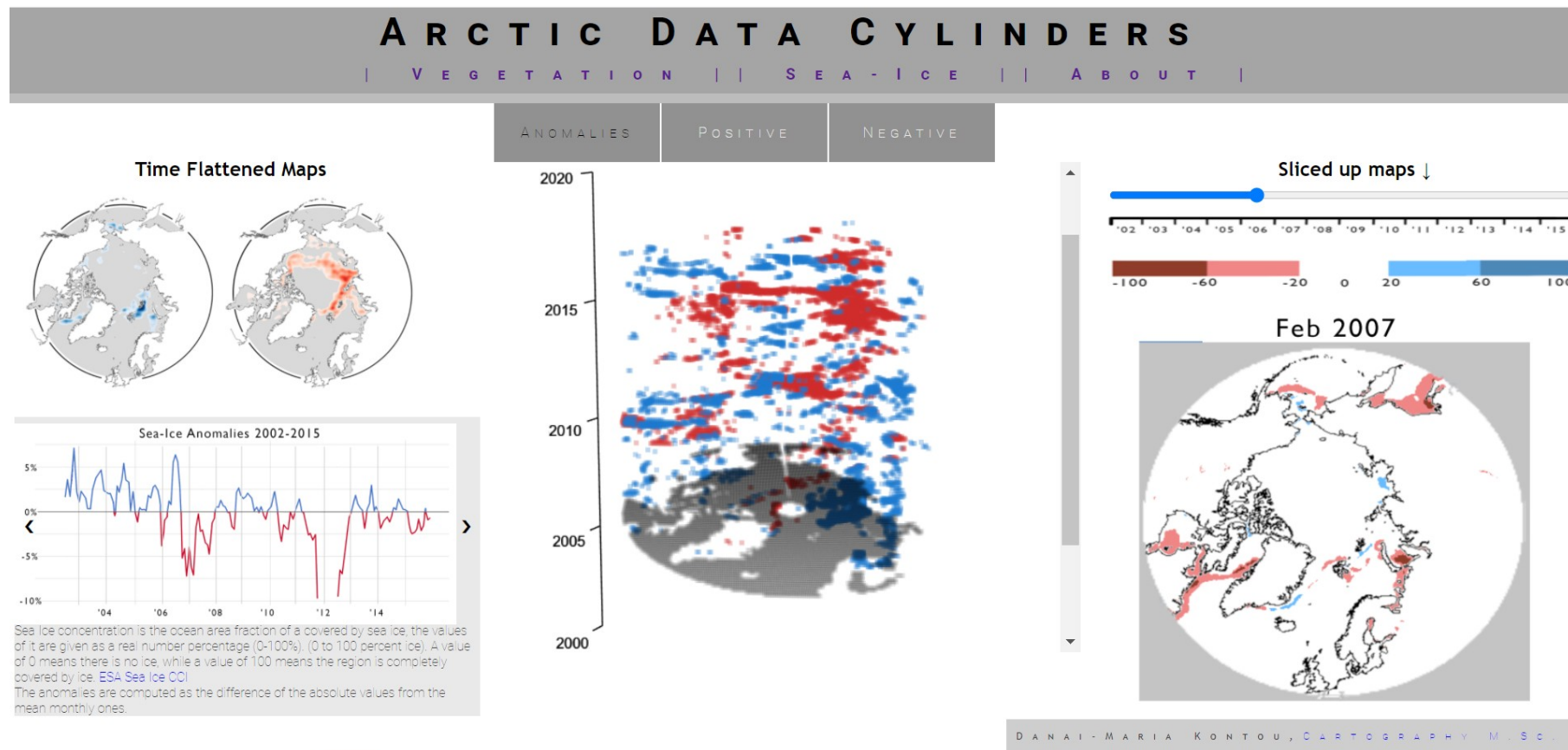
Figure 32: Screenshot of the web app during the third round of user testing

5 Discussion

This thesis aimed in addressing the following questions:

- • Which are the changes of the sea ice concentration between 2002 and 2015?
- • Which are the changes of the terrestrial vegetation between 2002 and 2015?
- • Which is the best way to visualize spatio-temporal environment phenomena?
- • Is the idea of Data Cylinders enough understandable by a broad audience?

In order to answer these questions, the following objectives were chosen:

- • Time series analysis of Sea Ice Concentration remote sensing L4 data
- • Time series analysis of fPAR remote sensing L4 data
- • Development of Arctic Data Cylinders
- • Design of an educative web application
- • User Testing in a broad audience with different backgrounds

This thesis aspires to develop a stand-alone spatio-temporal three-dimensional visual for the representation of the extreme anomalies of the Arctic vegetation and the Arctic sea ice. The final result is a web application presenting visuals which the user can interact with. Data cylinders visualize events happening in a specific space and time whereas the space time aquariums proposed by Hagerstrand illustrate only linear relations of an object into space and time (Thrift, 1977). The difference of the visualized spatiotemporal clusters of the data cylinders compared to the space time aquariums discussed by Andrienko et al. (2003) is the size and shape of the clusters themselves. The clusters of data cylinders have the same size no matter their value and they expand in only one time step per time.

Even if the options of rotate and zoom of the cylinder catch the sight of the user in the first place, the cylinders are not able to be stand-alone. The two space time cube (STB) operations (time flattening and time juxtaposing) which were used in this study, were inspired by Bach et al. (2014), and they are significant for the users to understand the presented concepts.

Three dimensional digital and interactive visuals attract the interest of the user, especially if he/she is not familiar with this kind of representations. The user study was made remotely with open questions and discussions, without quantifying the usability of the web application. The total amount of participants was 30. The demographic variety of the users together with their mixed background was not giving the opportunity to get easy results. Sometimes the limitation of the knowledge of the English language was not helping the user to understand the text explanations. Since no eye tracking or any other method of digital quantification of the usability of the application was taken under consideration, this thesis cannot have strong results in this aspect. Moreover, the users were able to interact with one final product one, and did not have a variety of different products to interact with, and select the best for them. The methodology followed for the user testing which was based on qualitative gathering of feedbacks by the users had the advantage of the users feeling free to express their thoughts and questions, while they were not hesitating to propose further recommendations. On the contrary, this method had as a result a bulky list of feedbacks after each round which wad difficult to evaluate. A mix of methods could have as result better and more clear feedbacks. Moreover, additional user testing methods, such as eye tracking could have crucial impact on the improvement of a web application with same or similar aims and visuals.

The sea ice concentration data were downloaded by ESA CCI. The time limitation of this data set is from 2002 to 2015. The data set used for the vegetation anomalies if the fPAR product from MODIS. Both data sets have different projections and coordinate systems which create possible errors in the results. Moreover, the re-projection of the SIC data into Lambert azimuthal equal area projection had as a result missing areas around the north pole and a narrow linear area from the north toward the Bering sea, approximately in the 170°W. This might did not occur significant errors in the analysis, because for the studied period the area around the north pole did not had big ice loss, but is possible to have some missing values of the sea ice anomalies.

In terms of visualization, further semantics and colors could be tested for such a complex representation. Finally, a target audience with similar demographics and other methods of user testing could produce interesting results in a future study. One of the results of the user study was that the complexity of such phenomena is not possible to be easily communicated in a

broad audience. For that reason there are two suggested ways the web application can be further developed. The first one is to have a target audience, with experience in the concepts of climate change. I this application developments in terms of interactivity and cloud analysis can be applied. The user can possibly select and analyses climate data of her/his choice, and select between several thematic visualization options, such as colors, shape, size of the spatio-temporal clusters.

6 Conclusion

The interdisciplinary focus of this thesis allowed to the analysis of remote sensing data, the creation of innovative visuals, and the development of an interactive web application. With regards to the analysis of the remote sensing data of sea ice concentration and fPAR and their correlation, as it was expected, these two phenomena cannot be studied independently of other climate phenomena taking place in the Arctic, such as temperature above sea and above land (Bhatt et al., 2010; Slonosky et al., 1997), snow (Liu et al., 2012), fires (Goetz et al., 2005) and permafrost (Lawrence et al., 2008). The results of the user testing show that the complexity of such phenomena cannot get illustrated in a single standalone visual and be understood by a broad audience with no background in environmental sciences, cartography or any other related interest or scientific background. However, the users with a specific academic or personal interest in the aspects of the web application were able to deeply understand and brainstorm on them. Last but not least, the user testing has shown that even if the three-dimensional data cylinders were attracting the user to explore their functions and learn about their content, they were not able to understand or extract information without the help of the additional materials which were provided in the application.

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Appendix

Vegetation

1. ```library(raster)``` #for reading and processing raster data -> https://rspatial.org/raster
2. ```library(ncdf4)``` #for processing netCDF files -> http://cirrus.ucsd.edu/~pierce/ncdf
3. ```library(zoo)``` #for the time series -> 10.18637/jss.v014.i06
4. ```library(rgdal)``` #for the geospatial data -> http://rgdal.r-forge.r-project.org/
5. ```library(RColorBrewer)``` #for colors -> https://cran.r-project.org/web/packages/RColorBrewer
6. ```library(ggplot2)``` #for data visualization (grammar of graphics) -> https://ggplot2.tidyverse.org.
7. ```library(tidyr)``` #for tidying up the data frames -> https://tidyr.tidyverse.org
8. ```library(rlang)``` #for Base Types and Core R and 'Tidyverse' Features -> https://rlang.r-lib.org/
9. ```library(rgl)``` #for the 3d modeling and graphs -> https://cran.r-project.org/web/packages/rgl/index.html

10. ```##____ Step#1 "Raster brick preparation & anomalies" _line:15```
11. ```##____ Step#2 "Maps" _line:47```
12. ```##____ Step#3 "Time series & Graphs" _line:70```
13. ```##____ Step#4 "Data Frames" _line:113```
14. ```##____ Step#5 "3d Cylinder making" _line:145```

15. ```path <- "C:/Users/Danae/Desktop/Thesis/data_final"```
16. ```setwd(path)```

17. ```#_____STEP #1_____PREPARATION__&__ANOMALIES_____```

    ```
    # Raster Brick with all the data combined (226layers. 2000-02-22, 2018-11-01):
    fpar.rb <- brick("MOD15A2H.A2000.2018_0d25_monthly_arctic.nc") #arctic brick
    ```
18. ```plot(fpar.rb, 6)```
19. ```   fpar.rb```
20. ```# Keep only 2002-2015 -> 168 layers```
21. ```fpar.rb <- subset(fpar.rb, 24:191)```

22. ```# Reproject```
    ```
    crs.as <- CRS("+proj=laea +lon_0=0 +lat_0=90 +x_0=0 +y_0=0 +a=6378137 +rf=298.257223563")
    ```

```r
23. ext <- projectExtent(fpar.rb, crs.as)
24. fpar.arctic.rb <- projectRaster(fpar.rb, ext,
        filename="fpar.nc", overwrite=TRUE)
25. plot(fpar.arctic.rb, 6)

26. #Export Arctic projected fPAR
        writeRaster(fpar.arctic.rb, "Arctic_fpar.nc",varname="fpar_arctic",
        overwrite=TRUE)

27. # Give date by sequence
28. ti <- seq(as.Date("2002-01-01"), as.Date("2015-12-01"), by="month")
29.     ti
30. fpar.rb <- setZ(fpar.arctic.rb, ti)
31. #plot(fpar.rb)
32. mon <- format(ti, "%m")# extract the mon

33. ##Make MEAN MONTHLY RB
34. # use zApply to compute the mean for each month
        fpar.mon.rb <- zApply(fpar.rb, by=mon, fun=mean, name="month",
        na.rm=TRUE)
35. fpar.mon.rb #12 layers January->December
36. plot(fpar.mon.rb, 6)
37.     fpar.mon.rb

38. ##Compute ANOMALIES
39. fpar.anom.rb <- fpar.rb - fpar.mon.rb
40. plot(fpar.anom.rb, 6, add=TRUE)

41. #Export Anomalies
        writeRaster(fpar.anom.rb,
        "Arctic_fpar_anomalies.nc",varname="fpar_arctic", overwrite=TRUE)
42. anom <- brick("Arctic_fpar_anomalies.nc")
43. summary(anom)


44. #_____
45. ##_____ STEP #2 _____MAPS_____

46. fpar.anom.rb <- brick("Arctic_fpar_anomalies.nc")
        #load anomalies arctic brick
47. ti <- seq(as.Date("2002-01-01"), as.Date("2015-12-01"), by="month")
48. fpar.anom.rb <- setZ(fpar.anom.rb, ti, name="date")
49.     fpar.anom.rb

50. ##ANOMALIES MAPS
51.     fpar.anom.rb
52. # <- c(-0.5, -0.1, 0, 0.03, 0.1, 0.5)
53. #cols <- c("chocolate4" ,"darkgoldenrod", "white","white",
        "darkolivegreen3", "darkolivegreen")
54. brks1 <- c(-0.5, -0.1, 0, 0.1, 0.5)
```

```r
55. cols1 <- c("red", "white", "white", "green")
56. plot(fpar.anom.rb, 18, breaks=brks1, col=cols1, add=TRUE)

57. ##Export fPAR anomalies in pdf
58. id <- 1:nlayers(fpar.anom.rb)
59.     id

60. pdf("fPAR_maps_01.pdf", width=12, height=12)
61. for (i in id) {
62. main <- paste("fPAR anomaly", ti[i])
63. r <- raster(fpar.anom.rb, i)
64. plot(r, i, breaks=brks1, col=cols1)
65. }

66. dev.off() # close the device/pdf

67. #_____
68. ##_____ STEP #3 _____TIME SERIES_&_GRAPHS_____

69. library(ggplot2)
70. library(dplyr)
71. library(hrbrthemes)

72. fpar.arctic.rb <- brick("Arctic_fpar.nc") #arctic brick

73. ti <- seq(as.Date("2002-01-01"), as.Date("2015-12-01"), by="month")
74. fpar.arctic.rb <- setZ(fpar.arctic.rb, ti, name="date")
75.     fpar.arctic.rb

76. ##Time series graph for the entire ARCTIC
77. # calculate the mean fpar over space for each layer
78. f <- cellStats(fpar.arctic.rb, stat='mean')
79. f <- zoo(f, ti)
80. plot(f, main='fPAR Time Series')
81.     f
82. x11()
83. p <- ggplot(f, aes(x=Index, y=f)) +
84. geom_line( color="darkgreen") +
85. ylab("") +
86. xlab("") +
87. ggtitle("Fpar Time Series 2002-2015") +
88. theme_ipsum() +
89. theme(axis.text.x=element_text(angle=60, hjust=1))


90. #colour the positive and negative
91. library(plotrix)
92. library(RColorBrewer)
```

```
93. f1 <- f2 <- x.anom
94. f1[x.anom < 0] <- NA
95. f2[x.anom > 0] <- NA

96. ylim <- range(cbind(f1, f2), na.rm=TRUE)
97. plot(f1, col="blue", ylim=ylim)
98. points(f2, col="red", pch=16, cex=0.3)


99. # compute mean seasonal cycle
100.    mon <- format(ti, "%m")
101.    x.msc <- aggregate(f, mon, FUN=mean, na.rm=TRUE)
102.    plot(x.msc) # mean seasonal cycle

103.    # repeat the mean seasonal cycle for every year
104.    x.msc.rep <- as.numeric(x.msc)[as.integer(mon)]
105.    x.msc.rep <- zoo(x.msc.rep, ti)
106.    plot(x.msc.rep)

107.    # compute anomalies
108.    x.anom <- f - x.msc.rep
109.    plot(x.anom, main="fPAR anomalies")
110.    summary(x.anom)


111.    #_____
112.    ##_____ STEP #4 _____DATA FRAMES_____

113.    fpar.anom.rb <- brick("Arctic_fpar_anomalies.nc")
        #arctic anomalies brick
114.    ti <- seq(as.Date("2002-01-01"), as.Date("2015-12-01"), by="month")

115.    fpar.anom.rb <- setZ(fpar.anom.rb, ti, name="date")
116.    fpar.anom.rb
117.    #Make a mask to remove ocean and areas without data
118.    mask.r <- mean(fpar.anom.rb, na.rm=TRUE)
119.    mask.r <- aggregate(mask.r, 2, FUN=mean)
        #lowering the resolution 2 times with mean
120.    plot(mask.r)
121.    bool <- is.na(values(mask.r)) # check which values are NA
122.    xy <- coordinates(mask.r)
123.    xy <- xy[!bool,]
124.    plot(xy)
125.    xy

126.    df <- data.frame(
127.    lon = xy[,1],
```

```r
128.        lat = xy[,2],
129.        fpar = raster::extract(fpar.anom.rb, xy)
130.        )
131.        dim(df)
132.        summary(df)

133.        plot(lat ~ lon, data=df)
134.        colnames(df) <- c("lon", "lat", as.character(ti))

135.        df_fpar <- gather(df, time, fpar, "2002-01-01":"2015-12-01")
136.        summary(df_fpar)
137.        df_fpar$time
138.        df_fpar$time <- as.Date(df_fpar$time)

139.        save(df_fpar, file="df_fpar.RData")


140.        #_____
141.        ##_____   STEP #5 _____3d Scatterplot_ RGL_____

142.        load("df_fpar.RData")
143.        df_fpar <- na.omit(df_fpar)
144.        summary(df_fpar)

145.        #Negative Anomalies
146.        q <- quantile(df_fpar$fpar, 0.003, na.rm=TRUE)
147.        df_fpar_q01 <- df_fpar
148.        df_fpar_q01$fpar[df_fpar_q01$fpar > q] <- NA
149.        df_fpar_q01 <- na.omit(df_fpar_q01)

150.        plot3d(df_fpar_q01$lon, df_fpar_q01$lat, df_fpar_q01$time,
           col = "maroon2", alpha=0, size="5",
           axes=FALSE, box = FALSE, xlab= "", ylab = "", zlab = "")

151.        #Positive Anomalies
152.        q <- quantile(df_fpar$fpar, 0.997, na.rm=TRUE)
153.        df_fpar_q99 <- df_fpar
154.        df_fpar_q99$fpar[df_fpar_q99$fpar < q] <- NA
155.        df_fpar_q99 <- na.omit(df_fpar_q99)

156.        plot3d(df_fpar_q99$lon, df_fpar_q99$lat, df_fpar_q99$time,
           col = "limegreen", alpha=0.2, size="5",
           axes=FALSE, box = FALSE ,xlab= "", ylab = "", zlab = "", add = TRUE)
157.        #Put time axis
158.        ax <- pretty(df_fpar_q99$ti)
159.        axis3d('z', at=ax, labels=format(ax, "%Y"), col="black")
```

```r
160.    #____SHADOW_____ with the df of ALL the fpar (not only anomalies)
161.    #plot3d(df_long)
162.    #id <- grid3d('z') # Get id values for grid
163.    gridz <- rgl.attrib(id[1], "vertices")[1,3]  # Use the first z value
164.    save <- par3d(ignoreExtent = TRUE)   # Ignore points for bbox
165.    with(df_fpar, points3d(df_fpar$lon, df_fpar$lat, gridz,
        col ="gray")) # Plot the "shadows"
166.    par3d(save)       # Restore bbox status

167.    #TOP SHADOW
168.    fp.rb <- brick("Arctic_fpar.nc")
169.    fp.r <- raster(fp.rb, layer=6)
170.    plot(fp.r)
171.    #Make a mask to remove ocean and areas without data
172.    mask.r <- mean(fp.r, na.rm=TRUE)
173.    mask.r <- aggregate(mask.r, 2, FUN=mean)
174.    #lowering the resolution 2 times with mean
175.    plot(mask.r)
176.    bool <- is.na(values(mask.r)) # check which values are NA
177.    xy <- coordinates(mask.r)
178.    xy <- xy[!bool,]
179.    plot(xy)
180.    xy
181.    ######
182.    fp.r <- data.frame(
183.    lon = xy[,1],
184.    lat = xy[,2],
185.    fpar = raster::extract(fp.r, xy),
186.    time =  ("2016-01-01"))
187.    dim(fp.r)
188.    summary(fp.r)

189.    fp.r$time <- as.Date(fp.r$time)

190.    #plot top shadow
191.    plot3d(df_fpar$lon, df_fpar$lat, df_fpar$time,
        col = "gray", alpha=0.1, size="5",
        axes=FALSE, box = FALSE ,xlab= "", ylab = "", zlab = "", add = TRUE)

192.    #_Export 3d in HTML____!!!!
193.    writeWebGL(filename="fpar_positive_cylinder.html",
        width=500, height=600)
```

Sea Ice Concentration

1. ```library(raster)``` #for reading and processing raster data -> https://rspatial.org/raster
2. ```library(ncdf4)``` #for processing netCDF files -> http://cirrus.ucsd.edu/~pierce/ncdf
3. ```library(zoo)``` #for the time series -> 10.18637/jss.v014.i06
4. ```library(rgdal)``` #for the geospatial data -> http://rgdal.r-forge.r-project.org/
5. ```library(RColorBrewer)``` #for colors -> https://cran.r-project.org/web/packages/RColorBrewer
6. ```library(ggplot2)``` #for data visualization (grammar of graphics) -> https://ggplot2.tidyverse.org.
7. ```library(tidyr)``` #for tidying up the data frames -> https://tidyr.tidyverse.org
8. ```library(rlang)``` #for Base Types and Core R and 'Tidyverse' Features -> https://rlang.r-lib.org/
9. ```library(rgl)``` #for the 3d modeling and graphs -> https://cran.r-project.org/web/packages/rgl/index.html
10. ```library(animation)```

11. ```##____ Step#1 "Raster brick preparation & anomalies" _line:19```
12. ```##____ Step#2 "Maps"   _line:81```
13. ```##____ Step#3 "Time series & Graphs"   _line:107```
14. ```##____ Step#4 "Data Frames"   _line:152```
15. ```##____ Step#5 "3d Cylinder making"   _line:175```

16. ```path <- ("C:/Users/Danae/Desktop/Thesis/data_final")```
17. ```setwd(path)```

18. ```#_____PREPARATION__&__ANOMALIES_____```

19. ```#Raster Brick of the sea-ice concentration```
20. ```#ftp://anon-ftp.ceda.ac.uk/neodc/esacci/sea_ice/data/```
    ```   sea_ice_concentration/L4/amsr/25km/v2.1/NH/```
21. ```#data combined (155layers):```
22. ```# 1/6/2002 -> 1/10/2011 <-gap-> 1/07/2012 -> 1/12/2015```
23. ```seaice.rb <- brick```
    ```   ("ESACCI-SEAICE-L4-SICONC-AMSR_25.0kmEASE2-NH-ALL-fv2.0.nc")```
24. ```plot(seaice.rb, 1)```
25. ```   seaice.rb```

26. ```# Reproject```
27. ```crs.ice <- CRS("+proj=longlat +ellps=WGS84 +no_defs ")```
28. ```ext <- projectExtent(seaice.rb, crs.ice)```
29. ```ice.arctic.rb <- projectRaster(seaice.rb, ext,```
    ```   filename="seaice.nc", overwrite=TRUE)```

```r
30. plot(ice.arctic.rb, 6)
31.     ice.arctic.rb
32. #cut to arctic
33. ext <- extent(-177.7465, 179.8674, 89.97, 89.99699)
34. arctic_ice.rb <- crop(ice.arctic.rb, ext)
35.     arctic_ice.rb
36. plot(arctic_ice.rb, 17)

37. #re-reproject
38. crs.ice <- CRS("+proj=laea +lat_0=90 +lon_0=0 +x_0=0
       +y_0=0 +ellps=WGS84 +units=m +no_defs ")
39. ext <- projectExtent(arctic_ice.rb, crs.ice)
40. ice.arctic.rb <- projectRaster(arctic_ice.rb, ext,
       filename="seaice.nc", overwrite=TRUE)
41. plot(ice.arctic.rb, 6)

42. #take time
43. ti <- getZ(seaice.rb)
44.     ti
45. mon <- format(ti, "%m")# extract the mon


46. ##FILL THE GAPS of the empty months
47. empty.r <- raster(ice.arctic.rb, 1)
48. empty.r[] <- NA

49. # make sea-ice with layers for all months
50. seaice_part1.rb <- subset(ice.arctic.rb, 1:113)
51. seaice_part2.rb <- subset(ice.arctic.rb, 114:nlayers(ice.arctic.rb))
52. seaice2.rb <- stack(empty.r, empty.r, empty.r, empty.r, empty.r,
                  1. seaice_part1.rb,
                  2. empty.r, empty.r, empty.r, empty.r, empty.r, empty.r,
                     empty.r, empty.r,
                  3. seaice_part2.rb
53. )
54. seaice2.rb <- brick(seaice2.rb)
55. ti <- seq(as.Date("2002-01-01"), as.Date("2015-12-01"), by="month")
56. seaice2.rb <- setZ(seaice2.rb, ti)
57. plot(seaice2.rb)

58. #Export Arctic projected ICE
59. writeRaster(seaice2.rb, "Arctic_ice.nc",varname="ice_arctic",
       overwrite=TRUE)

60. ice_arctic <- brick("Arctic_ice.nc")
61. plot(ice_arctic, 1)

62. ##Make MEAN MONTHLY RB
63. # use zApply to compute the mean for each month
```

```r
64. ice.mon.rb <- zApply(ice_arctic, by=mon, fun=mean,
        name="month", na.rm=TRUE)
65. ice.mon.rb #12 layers January->December
66. plot(ice.mon.rb, 1)


67. ##Compute ANOMALIES (anomaly = value - mean)
68. seaice.anom.rb <- ice_arctic - ice.mon.rb
69. plot(seaice.anom.rb, 12, add=TRUE)



70. ##Time series graph for the entire ARCTIC
71. # calculate the mean ICE over space for each layer
72. x <- cellStats(ice_arctic, stat='mean')
73. x <- zoo(x, ti)
74. plot(x, main='Sea Ice Time Series')
75.       x
76. #plot(seaice2.rb, 12)
77. #plot(approx(x, xout=seq_along(x))$y, type="l")


78. #Export Anomalies
79. writeRaster(seaice.anom.rb, "Arctic_ice_anomalies.nc",
        varname="ice_arctic", overwrite=TRUE)


80. #_____
81. ##_____   STEP #2 _____MAPS_for__ANOMALIES_____

82. library(ggplot2)
83. library(dplyr)
84. library(hrbrthemes)

85. seaice.anom.rb <- brick("Arctic_ice_anomalies.nc") #arctic brick
86. ti <- seq(as.Date("2002-01-01"), as.Date("2015-12-01"), by="month")
87. seaice.anom.rb <- setZ(seaice.anom.rb, ti, name="date")
88.       seaice.anom.rb
89. plot(seaice.anom.rb, 7)


90. ##ANOMALIES MAPS
91.       seaice.anom.rb
92. brks <- c(-100, -60, -20, 0, 20, 60, 100)
93. cols <- c("tomato4" ,"lightcoral",
        "white","white", "steelblue1", "steelblue")

94. plot(seaice2.rb, 155, breaks=brks, col=cols, add=TRUE)

95. ##Export ice anomalies in pdf
96. id <- 1:nlayers(seaice2.rb)
97.       id


98. pdf("ICE_maps.pdf", width=12, height=12)
```

```r
99.         for (i in id) {
100.        main <- paste("ICE anomaly", ti[i])
101.        r <- raster(seaice2.rb, i)
102.        plot(r, i, breaks=brks, col=cols)
103.        }

104.        dev.off() # close the device/pdf

105.        #_____
106.        ##____ STEP #3 _____TIME SERIES_&_GRAPHS_____

107.        seaice.rb <- brick("Arctic_ice.nc") #load arctic brick
108.        ti <- seq(as.Date("2002-01-01"), as.Date("2015-12-01"), by="month")
109.        seaice.rb <- setZ(seaice.rb, ti, name="date")
110.        plot(seaice.rb, 6)
111.        seaice.rb

112.        ##Time series graph for the entire ARCTIC
113.        # calculate the mean ICE over space for each layer
114.        x <- cellStats(seaice.rb, stat='mean')
115.        x <- zoo(x, ti)
116.        plot(x, main='Ice Time Series')

117.        st <- ggplot(x, aes(x=Index, y=x)) +
118.        geom_line( color="darkblue") +
119.        ylab("") +
120.        xlab("") +
121.        ggtitle("Sea-Ice Time Series 2002-2015") +
122.        theme_ipsum() +
123.        theme(axis.text.x=element_text(angle=60, hjust=1))


124.        # compute mean seasonal cycle
125.        mon <- format(ti, "%m")
126.        x.msc <- aggregate(x, mon, FUN=mean, na.rm=TRUE)
127.        plot(x.msc) # mean seasonal cycle

128.        # repeat the mean seasonal cycle for every year
129.        x.msc.rep <- as.numeric(x.msc)[as.integer(mon)]
130.        x.msc.rep <- zoo(x.msc.rep, ti)
131.        plot(x.msc.rep)

132.        # compute anomalies
133.        ice.anom <- x - x.msc.rep
134.        plot(ice.anom, main="ICE anomalies")
135.        summary(ice.anom)
```

```r
136.        s <- ggplot(ice.anom, aes(x=Index, y=ice.anom)) +
137.        geom_line( color="darkblue") +
138.        ylab("") +
139.        xlab("") +
140.        ggtitle("Sea Ice Anomalies 2002-2015") +
141.        theme_ipsum() +
142.        theme(axis.text.x=element_text(angle=60, hjust=1))



143.        ##Time series graph for the entire ARCTIC
144.        # calculate the mean ICE over space for each layer
145.        ice_ts <- cellStats(seaice.rb, stat='mean')
146.        ice_ts <- zoo(ice_ts, ti)
147.        plot(ice_ts, main='Sea-Ice Concentration  Time Series')
148.        ice_ts



149.        #_____
150.        ##_____ STEP #4 _____DATA FRAMES_____

151.        #ANOMALIES
152.        ice_anom <- brick("Arctic_ice_anomalies.nc") #arctic anomalies brick

153.        ti <- seq(as.Date("2002-01-01"), as.Date("2015-12-01"), by="month")
154.        ice_anom <- setZ(ice_anom, ti, name="date")
155.        ice_anom

156.        #Make a mask to remove ocean and areas without data
157.        mask.r <- mean(ice_anom, na.rm=TRUE)
158.        mask.r <- aggregate(mask.r, 2, FUN=mean)
           #lowering the resolution 2 times with mean
159.        plot(mask.r)
160.        bool <- is.na(values(mask.r)) # check which values are NA
161.        xy <- coordinates(mask.r)
162.        xy <- xy[!bool,]
163.        plot(xy)

164.        df_ice <- data.frame(
165.        lon = xy[,1],
166.        lat = xy[,2],
167.        ice = raster::extract(ice_anom, xy)
168.        )
169.        dim(df_ice)
170.        summary(df_ice)
171.        df_ice
172.        plot(lat ~ lon, data=df_ice)
```

```r
173.    #_____
174.    ##_____ STEP #5 _____3d Scatterplot_ RGL_____

175.    #ANOMALIES
176.    load("df_ice.RData")
177.    df_ice <- na.omit(df_ice)
178.    summary(df_ice)

179.    #Negative Anomalies
180.    q <- quantile(df_ice$ice, 0.005, na.rm=TRUE)
181.    df_ice_q01 <- df_ice
182.    df_ice_q01$ice[df_ice_q01$ice > q] <- NA
183.    df_ice_q01 <- na.omit(df_ice_q01)

184.    plot3d(df_ice_q01$lon, df_ice_q01$lat, df_ice_q01$time,
        col = "firebrick3", alpha=0.3, size="5",
        axes=FALSE, box = FALSE, xlab= "", ylab = "", zlab = "")

185.    #Positive Anomalies
186.    q <- quantile(df_ice$ice, 0.995, na.rm=TRUE)
187.    df_ice_q99 <- df_ice
188.    df_ice_q99$ice[df_ice_q99$ice < q] <- NA
189.    df_ice_q99 <- na.omit(df_ice_q99)
190.    df_ice_q99

191.    plot3d(df_ice_q99$lon, df_ice_q99$lat, df_ice_q99$time,
        col = "dodgerblue3", alpha=0.3, size="5",
        axes=FALSE, box = FALSE ,xlab= "", ylab = "", zlab = "", add = TRUE)

192.    #Put time axis
193.    ax <- pretty(df_ice_q99$ti)
194.    axis3d('z', at=ax, labels=format(ax, "%Y"), col="black")


195.    #_____ICE SHADOW_____

196.    ice.r <- raster(ice_arctic, layer=12)
197.    plot(ice.r)

198.    #Make a mask to remove ocean and areas without data
199.    mask.r <- mean(ice.r, na.rm=TRUE)
200.    mask.r <- aggregate(mask.r, 2, FUN=mean)
        #lowering the resolution 2 times with mean
201.    plot(mask.r)
202.    bool <- is.na(values(mask.r)) # check which values are NA
```

```r
203.        xy <- coordinates(mask.r)
204.        xy <- xy[!bool,]
205.        plot(xy)
206.        dfice <- data.frame(
207.        lon = xy[,1],
208.        lat = xy[,2],
209.        ice = raster::extract(ice.r, xy),
210.        time =  ("2001-12-01")
211.        )
212.        dim(dfice)
213.        summary(dfice)

214.        dfice$time <- as.Date(dfice$time)

215.        #shadow bottom
216.        plot3d(dfice$lon, dfice$lat, dfice$time,
           col = "black", alpha=0.1, size="5",
           axes=FALSE, box = FALSE ,xlab= "", ylab = "", zlab = "", add = TRUE)

217.        ######
218.        dfice <- data.frame(
219.        lon = xy[,1],
220.        lat = xy[,2],
221.        ice = raster::extract(ice.r, xy),
222.        time =  ("2016-01-01")
223.        )
224.        dim(dfice)
225.        summary(dfice)

226.        dfice$time <- as.Date(dfice$time)

227.        #shadow top
228.        plot3d(dfice$lon, dfice$lat, dfice$time,
           col = "gray", alpha=0.1, size="5",
           axes=FALSE, box = FALSE ,xlab= "", ylab = "", zlab = "", add = TRUE)

229.        #_Export 3d in HTML____!!!!
230.        writeWebGL(filename="ice_negative_cylinder.html",
           width=500, height=600)
```

HTML, JavaScript, CSS

INDEX

```html
1.  <!DOCTYPE html>
2.  <html>
3.  <head>
4.      <title> Arctic Data Cylinders </title>
5.      <link rel="stylesheet" type="text/css" href="style.css" />
6.  </head>
7.  <body>
8.      <div id="fpar" class="anom">
9.          <div id="header">
10.                 <h1> Arctic Data Cylinders </h1>
11.             </div>
12.             <div id="content1">
13.                 <div class="nav_bar">
14.                     <ul>
15.                         <li><a href="index.html" id="onclick">| About
                                |</a></li>
16.                         <li><a href="ice.html">| Sea-Ice |</a></li>
17.                         <li><a href="vegetation.html">| Vegetation
                                |</a></li>
18.                     </ul>
19.                 </div>
20.             </div>
21.             <div class="grid">
22.                 <div id="contabout">
23.                     <img id="draw" src="cylinderdraw.png" width="300"
                                        height="400" />
24.                     <div id="text">
25.                         <f>This web-app is part of my master thesis in
                                        Cartography <br> TU Dresden
                            <br></f>
26.                     </div>
27.                 </div>
28.                 <div id="cylinder">
29.                     <div class="slideshow-container">
30.                         <div class="mySlides fade">
31.                             <img src="1.JPG" width="95%" height="95%">
32.                             <div class="text"></div>
33.                         </div>
34.
35.                         <div class="mySlides fade">
36.                             <img src="2.JPG" width="95%" height="95%">
```

```html
37.                    <div class="text"></div>
38.                </div>
39.
40.                <div class="mySlides fade">
41.                    <img src="3.png" width="95%" height="95%">
42.                    <div class="text"></div>
43.                </div>
44.
45.                <div class="mySlides fade">
46.                    <img src="4.JPG" width="95%" height="95%">
47.                    <div class="text"></div>
48.                </div>
49.
50.                <div class="mySlides fade">
51.                    <img src="5.JPG" width="95%" height="95%">
52.                    <div class="text"></div>
53.                </div>
54.
55.                <div class="mySlides fade">
56.                    <img src="6.JPG" width="95%" height="95%">
57.                    <div class="text"></div>
58.                </div>
59.
60.                <div class="mySlides fade">
61.                    <img src="7.jpeg" width="95%" height="95%">
62.                    <div class="text"></div>
63.                </div>
64.
65.                <div class="mySlides fade">
66.                    <img src="8.jpeg" width="95%" height="95%">
67.                    <div class="text"></div>
68.                </div>
69.
70.                <div class="mySlides fade">
71.                    <img src="9.jpeg" width="95%" height="95%">
72.                    <div class="text"></div>
73.                </div>
74.
75.                <!-- Next and previous buttons -->
76.                <a class="prev" onclick="plusSlides(-
                       1)">&#10094;</a>
77.                <a class="next"
                       onclick="plusSlides(1)">&#10095;</a>
78.            </div>
79.            <br>
80.            <!-- The dots/circles -->
```

```html
81.                       <div style="text-align:center">
82.                           <span class="dot" onclick="currentSlide(1)"></span>
83.                           <span class="dot" onclick="currentSlide(2)"></span>
84.                       </div>
85.                       <script>
86.               var slideIndex = 1;
87.               showSlides(slideIndex);
88.
89.               // Next/previous controls
90.               function plusSlides(n) {
91.                   showSlides(slideIndex += n);
92.               }
93.
94.               // Thumbnail image controls
95.               function currentSlide(n) {
96.                   showSlides(slideIndex = n);
97.               }
98.
99.               function showSlides(n) {
100.                  var i;
101.                  var slides =
        document.getElementsByClassName("mySlides");
102.                  var dots =
   document.getElementsByClassName("dot");
103.                  if (n > slides.length) {
104.                      slideIndex = 1
105.                  }
106.                  if (n < 1) {
107.                      slideIndex = slides.length
108.                  }
109.                  for (i = 0; i < slides.length; i++) {
110.                      slides[i].style.display = "none";
111.                  }
112.                  for (i = 0; i < dots.length; i++) {
113.                      dots[i].className =
   dots[i].className.replace("
        active", "");
114.                  }
115.                  slides[slideIndex - 1].style.display = "block";
116.                  dots[slideIndex - 1].className += " active";
117.               }
118.                       </script>
119.                   </div>
120.               </div>
121.           <div id="footer">
```

```
122.                      Danai-Maria Kontou, <a

        href="https://cartographymaster.eu/">Cartography M.Sc.</a>
123.            </div>
124.        </div>
125.    </body></html>
```

ICE

```
1. <!DOCTYPE html>
2. <html>
3. <head>
4.     <title> Arctic Data Cylinders </title>
5.     <link rel="stylesheet" type="text/css" href="style.css" />
6. </head>
7. <body>
8.     <div id="fpar" class="anom">
9.         <div id="header">
10.                <h1> Arctic Data Cylinders </h1>
11.            </div>
12.            <div id="content1">
13.                <div class="nav_bar">
14.                    <ul>
15.                        <li><a href="index.html">| About |</a></li>
16.                        <li><a href="ice.html" id="onclick">| Sea-Ice
    |</a></li>
17.                        <li><a href="vegetation.html" >| Vegetation
    |</a></li>
18.                    </ul>
19.                </div>
20.            </div>
21.            <div id="content2" class="grid">
22.                <div id="main">
23.                    <div id="heatmaps">
24.                        <div id="timemaps">
25.                        <b> Time Flattened Maps</b>
26.                        </div>
27.                        <img id="heat_fpar" src="heatmap_ice.png"
    width="400" height="200" />
28.                        </div>
29.                        <div id="graphs" class="slideshow-container">
30.                            <div class="mySlides fade">
31.                                <img src="ice_ts_graph.png" width="95%"
    height="95%">
32.                                <div class="text"></div>
33.                            </div>
34.                            <div class="mySlides fade">
```

```html
35.                               <img src="sea_graph.png" width="95%"
     height="95%">
36.                               <div class="text"></div>
37.                       </div>
38.                       <!-- Next and previous buttons -->
39.                       <a class="prev" onclick="plusSlides(-
     1)">&#10094;</a>
40.                       <a class="next"
     onclick="plusSlides(1)">&#10095;</a>
41.                   </div>
42.                   <script>
43.                       var slideIndex = 1;
44.                       showSlides(slideIndex);
45.
46.                       // Next/previous controls
47.                       function plusSlides(n) {
48.                           showSlides(slideIndex += n);
49.                       }
50.
51.                       // Thumbnail image controls
52.                       function currentSlide(n) {
53.                           showSlides(slideIndex = n);
54.                       }
55.
56.                       function showSlides(n) {
57.                           var i;
58.                           var slides =
     document.getElementsByClassName("mySlides");
59.                           var dots =
     document.getElementsByClassName("dot");
60.                           if (n > slides.length) {
61.                               slideIndex = 1
62.                           }
63.                           if (n < 1) {
64.                               slideIndex = slides.length
65.                           }
66.                           for (i = 0; i < slides.length; i++) {
67.                               slides[i].style.display = "none";
68.                           }
69.                           for (i = 0; i < dots.length; i++) {
70.                               dots[i].className =
     dots[i].className.replace(" active", "");
71.                           }
72.                           slides[slideIndex - 1].style.display = "block";
73.                           dots[slideIndex - 1].className += " active";
74.                       }
```

```
75.
76.                  </script>
77.                      <div id="text">
78.                          <f>Sea Ice concentration is the ocean area fraction
    of a covered by sea ice, the values of it are given as a real number
    percentage (0-100%). (0 to 100 percent ice). A value of 0 means there is no
    ice, while a value of 100 means the region is completely covered by ice.
79.                              <a
    href="http://dx.doi.org/10.5285/f17f146a31b14dfd960cde0874236ee5">ESA Sea Ice
    CCI</a> <br>The anomalies are computed as the difference of the absolute
    values from the mean monthly ones.<br></f>
80.                      </div>
81.                  </div>
82.                  <div id="cylinder">
83.                      <div class="tab-wrap">
84.                          <input type="radio" name="tabs" id="tab1" checked>
85.                          <div class="tab-label-content" id="tab1-content">
86.                              <label for="tab1">Anomalies</label>
87.                              <div class="tab-content">
88.                                  <c> <object data="ice_cylinder.html"
    width="600px" height="500px"></object> </c>
89.                              </div>
90.                          </div>
91.                          <input type="radio" name="tabs" id="tab2">
92.                          <div class="tab-label-content" id="tab2-content">
93.                              <label for="tab2">Positive</label>
94.                              <div class="tab-content">
95.                                  <object data="ice_positive_cylinder.html"
    width="600px"                      height="500px"></object>
96.                              </div>
97.                          </div>
98.                          <input type="radio" name="tabs" id="tab3">
99.                          <div class="tab-label-content" id="tab3-content">
100.                             <label for="tab3">Negative</label>
101.                             <div class="tab-content">
102.                                 <c> <object
    data="ice_negative_cylinder.html" width="600px"
        height="500px"></object> </c>
103.                             </div>
104.                         </div>
105.                     </div>
106.                 </div>
107.                 <div id="grid2" class="grid2">
108.                     <div id="slicetitle">
109.                         <b> Sliced up maps ↓ </b>
110.                     </div>
```

```
111.                    <f></f>
112.                    <input id="slider" onchange='setImage(this)'
    type="range" min="0" max="168"                value="0" step="1" />
113.                    <img id='leg' src="legend_ice.png" width="480px"
    height="75px" />
114.                    <img id='img' src="0101c.gif" width="400px"
    height="400px" />
115.                    <script>
116.                        var img = document.getElementById('img');
117.                        var img_array = ["0101c.gif", "0211c.png",
    "0212c.png", "0301c.png", "0302c.png", "0303c.png", "0304c.png", "0305c.png",
    "0306c.png", "0307c.png", "0308c.png", "0309c.png", "0310c.png", "0311c.png",
    "0312c.png", "0401c.png", "0402c.png", "0403c.png", "0404c.png", "0405c.png",
    "0406c.png", "0407c.png", "0408c.png", "0409c.png", "0410c.png", "0411c.png",
    "0412c.png", "0501c.png", "0502c.png", "0503c.png", "0504c.png", "0505c.png",
    "0506c.png", "0507c.png", "0508c.png", "0509c.png", "0510c.png", "0511c.png",
    "0512c.png", "0601c.png", "0602c.png", "0603c.png", "0604c.png", "0605c.png",
    "0606c.png", "0607c.png", "0608c.png", "0609c.png", "0610c.png", "0611c.png",
    "0612c.png", "0701c.png", "0702c.png", "0703c.png", "0704c.png", "0705c.png",
    "0706c.png", "0707c.png", "0708c.png", "0709c.png", "0710c.png", "0711c.png",
    "0712c.png", "0801c.png", "0802c.png", "0803c.png", "0804c.png", "0805c.png",
    "0806c.png", "0807c.png", "0808c.png", "0809c.png", "0810c.png", "0811c.png",
    "0812c.png", "0901c.png", "0902c.png", "0903c.png", "0904c.png", "0905c.png",
    "0906c.png", "0907c.png", "0908c.png", "0909c.png", "0910c.png", "0911c.png",
    "0912c.png", "1001c.png", "1002c.png", "1003c.png", "1004c.png", "1005c.png",
    "1006c.png", "1007c.png", "1008c.png", "1009c.png", "1010c.png", "1011c.png",
    "1012c.png", "1101c.png", "1102c.png", "1103c.png", "1104c.png", "110c5.png",
    "1106c.png", "1107c.png", "1108c.png", "1109c.png", "1110c.png", "1111c.png",
    "1112c.png", "1201c.png", "1202c.png", "1203c.png", "1204c.png", "1205c.png",
    "1206c.png", "1207c.png", "1208c.png", "1209c.png", "1210c.png", "1211c.png",
    "1212c.png", "1301c.png", "1302c.png", "1303c.png", "1304c.png", "1305c.png",
    "1306c.png", "1307c.png", "1308c.png", "1309c.png", "1310c.png", "1311c.png",
    "1312c.png", "1401c.png", "1402c.png", "1403c.png", "1404c.png", "1405c.png",
    "1406c.png", "1407c.png", "1408c.png", "1409c.png", "1410c.png", "1411c.png",
    "1412c.png", "1501c.png", "1502c.png", "1503c.png", "1504c.png", "1505c.png",
    "1506c.png", "1507c.png", "1508c.png", "1509c.png", "1510c.png", "1511c.png",
    "1512c.png"];
118.
119.                        function setImage(obj) {
120.                            var value = obj.value;
121.                            img.src = img_array[value];
122.                            document.getElementById("slidemonth").innerHTML
    = " " + monthname[month];
123.
124.                        }
125.                    </script>
126.                </div>
127.            </div>
128.        <div id="footer">
```

```
129.                      Danai-Maria Kontou,<a
   href="https://cartographymaster.eu/">Cartography M.Sc.</a>
130.              </div>
131.          </div>
132.      </body>
133.      </html>


VEGETATION

1.  <!DOCTYPE html>
2.  <html>
3.  <head>
4.      <title> Arctic Data Cylinders </title>
5.      <link rel="stylesheet" type="text/css" href="style.css" />
6.  </head>
7.  <body>
8.      <!-- HEADER AREA -->
9.      <div id="fpar" class="anom">
10.             <div id="header">
11.                 <h1> Arctic Data Cylinders </h1>
12.             </div>
13.             <div id="content1">
14.                 <div class="nav_bar">
15.                     <ul>
16.                         <li><a href="index.html">| About |</a></li>
17.                         <li><a href="ice.html">| Sea-Ice |</a></li>
18.                         <li><a href="vegetation.html" id="onclick">|
   Vegetation |</a></li>
19.                     </ul>
20.                 </div>
21.             </div>
22.         </div>
23.         <!-- MAIN AREA -->
24.         <div id="content2" class="grid">
25.             <div id="main">
26.                 <div id="heatmaps">
27.                     <div id="timemaps">
28.                         <b> Time Flattened Maps</b>
29.                     </div>
30.                     <img id="heat_fpar" src="heatmap_fpar.png" width="400"
   height="200" />
31.                 </div>
32.                 <div id="graphs"  class="slideshow-container">
33.                     <div class="mySlides fade">
34.                         <img src="fpar_ts_graph.png" width="95%"
   height="95%">
```

85

```
35.                              <div class="text"></div>
36.                          </div>
37.                          <div class="mySlides fade">
38.                              <img src="fpar_graph.png" width="95%" height="95%">
39.                              <div class="text"></div>
40.                          </div>
41.                          <!-- Next and previous buttons -->
42.                          <a class="prev" onclick="plusSlides(-1)">&#10094;</a>
43.                          <a class="next" onclick="plusSlides(1)">&#10095;</a>
44.                      </div>
45.                      <script>
46.                          var slideIndex = 1;
47.                          showSlides(slideIndex);
48.
49.                          // Next/previous controls
50.                          function plusSlides(n) {
51.                              showSlides(slideIndex += n);
52.                          }
53.
54.                          // Thumbnail image controls
55.                          function currentSlide(n) {
56.                              showSlides(slideIndex = n);
57.                          }
58.
59.                          function showSlides(n) {
60.                              var i;
61.                              var slides =
    document.getElementsByClassName("mySlides");
62.                              var dots = document.getElementsByClassName("dot");
63.                              if (n > slides.length) {
64.                                  slideIndex = 1
65.                              }
66.                              if (n < 1) {
67.                                  slideIndex = slides.length
68.                              }
69.                              for (i = 0; i < slides.length; i++) {
70.                                  slides[i].style.display = "none";
71.                              }
72.                              for (i = 0; i < dots.length; i++) {
73.                                  dots[i].className = dots[i].className.replace("
    active", "");
74.                              }
75.                              slides[slideIndex - 1].style.display = "block";
76.                              dots[slideIndex - 1].className += " active";
77.                          }
```

```
78.
79.                    </script>
80.                 <div id="text">
81.                    <f>Fraction of Photosynthetically Active Radiation
   absorbed by vegetation (FPAR) is defined as the fraction of incident
   photosynthetically active radiation absorbed by the green elements of a
   vegetation canopy. <br>The values of the FPAR are varying from 0 to 1. <br>
82.                       <a
   href="http://doi.org/10.5067/MODIS/MCD15A2H.006">modis.gsfc.nasa.gov</a>
   <br>The anomalies are computed as the difference of the absolute values from
   the mean monthly ones.<br></f>
83.                 </div>
84.              </div>
85.              <div id="cylinder">
86.                 <div class="tab-wrap">
87.                    <input type="radio" name="tabs" id="tab1" checked>
88.                    <div class="tab-label-content" id="tab1-content">
89.                       <label for="tab1">Anomalies</label>
90.                       <div class="tab-content">
91.                          <c> <object data="fpar_cylinder.html"
   width="600px" height="500px"></object>                   </c>
92.                       </div>
93.                    </div>
94.                    <input type="radio" name="tabs" id="tab2">
95.                    <div class="tab-label-content" id="tab2-content">
96.                       <label for="tab2">Positive</label>
97.                       <div class="tab-content">
98.                          <object data="fpar_positive_cylinder.html"
   width="600px"
        height="500px"></object>
99.                       </div>
100.                    </div>
101.                    <input type="radio" name="tabs" id="tab3">
102.                    <div class="tab-label-content" id="tab3-content">
103.                       <label for="tab3">Negative</label>
104.                       <div class="tab-content">
105.                          <c> <object data="fpar_negative_cylinder.html"
   width="600px"
        height="500px"></object> </c>
106.                       </div>
107.                    </div>
108.                 </div>
109.              </div>
110.              <div id="grid2" class="grid2">
111.                 <div id="slicetitle">
112.                    <b> Sliced up maps ↓ </b>
```

```
113.                    </div>
114.                    <f></f>
115.                    <input id="slider" onchange='setImage(this)' type="range"
    min="0" max="168"                    value="0"                    step="1" />
116.                    <img id='leg' src="legend_fpar.png" width="480px"
    height="75px" />
117.                <img id='img' src="0101.gif" width="400px" height="400px" />
118.                <script>
119.                        var img = document.getElementById('img');
120.                        var img_array = ["0101.gif", "0202.png", "0203.png",
    "0204.png", "0205.png", "0206.png", "0207.png", "0208.png", "0209.png",
    "0210.png", "0211.png", "0212.png", "0301.png", "0302.png", "0303.png",
    "0304.png", "0305.png", "0306.png", "0307.png", "0308.png", "0309.png",
    "0310.png", "0311.png", "0312.png", "0401.png", "0402.png", "0403.png",
    "0404.png", "0405.png", "0406.png", "0407.png", "0408.png", "0409.png",
    "0410.png", "0411.png", "0412.png", "0501.png", "0502.png", "0503.png",
    "0504.png", "0505.png", "0506.png", "0507.png", "0508.png", "0509.png",
    "0510.png", "0511.png", "0512.png", "0601.png", "0602.png", "0603.png",
    "0604.png", "0605.png", "0606.png", "0607.png", "0608.png", "0609.png",
    "0610.png", "0611.png", "0612.png", "0701.png", "0702.png", "0703.png",
    "0704.png", "0705.png", "0706.png", "0707.png", "0708.png", "0709.png",
    "0710.png", "0711.png", "0712.png", "0801.png", "0802.png", "0803.png",
    "0804.png", "0805.png", "0806.png", "0807.png", "0808.png", "0809.png",
    "0810.png", "0811.png", "0812.png", "0901.png", "0902.png", "0903.png",
    "0904.png", "0905.png", "0906.png", "0907.png", "0908.png", "0909.png",
    "0910.png", "0911.png", "0912.png", "1001.png", "1002.png", "1003.png",
    "1004.png", "1005.png", "1006.png", "1007.png", "1008.png", "1009.png",
    "1010.png", "1011.png", "1012.png", "1101.png", "1102.png", "1103.png",
    "1104.png", "1105.png", "1106.png", "1107.png", "1108.png", "1109.png",
    "1110.png", "1111.png", "1112.png", "1201.png", "1202.png", "1203.png",
    "1204.png", "1205.png", "1206.png", "1207.png", "1208.png", "1209.png",
    "1210.png", "1211.png", "1212.png", "1301.png", "1302.png", "1303.png",
    "1304.png", "1305.png", "1306.png", "1307.png", "1308.png", "1309.png",
    "1310.png", "1311.png", "1312.png", "1401.png", "1402.png", "1403.png",
    "1404.png", "1405.png", "1406.png", "1407.png", "1408.png", "1409.png",
    "1410.png", "1411.png", "1412.png", "1501.png", "1502.png", "1503.png",
    "1504.png", "1505.png", "1506.png", "1507.png", "1508.png", "1509.png",
    "1510.png", "1511.png", "1512.png"];
121.                    function setImage(obj) {
122.                        var value = obj.value;
123.                        img.src = img_array[value];
124.                        document.getElementById("slidemonth").innerHTML = "
    " + monthname[month];
125.
126.                        }
127.
128.                </script>
129.            </div>
130.        </div>
131.        <!-- FOOTER AREA -->
```

```
132.          <div id="footer">
133.              Danai-Maria Kontou, <a
    href="https://cartographymaster.eu/">Cartography M.Sc.</a>
134.          </div>
135.      </body>
136.      </html>
```

CSS

```
1. html,
2. body {
3.      width: 100%;
4.      height: 100%;
5. }
6. body {
7.      font-family: "Trebuchet MS", Helvetica, sans-serif;
8.      padding: 0;
9.      margin: 0;
10.        }
11.       a {
12.          text-decoration: none;
13.        }
14.       h1,
15.       h2,
16.       h3 {
17.          margin: 0;
18.        }
19.       #header {
20.          background-color: #a0a0a0;
21.          color: black;
22.          font-size: 20px;
23.          letter-spacing: 20px;
24.          word-spacing: 0.3px;
25.          font-weight: 100;
26.          text-decoration: rgb(68, 68, 68);
27.          font-style: normal;
28.          font-variant: small-caps;
29.          text-align: center;
30.        }
31.       #content1 {
32.          background-color: #a0a0a0;
33.          color: black;
34.          font-size: 10px;
35.          letter-spacing: 20px;
36.          word-spacing: 0.3px;
```

```css
37.         font-weight: 100;
38.         text-decoration: rgb(68, 68, 68);
39.         font-style: normal;
40.         font-variant: small-caps;
41.         text-align: center;
42.     }
43.     /*
44.         NAVIGATION BAR (VEGETATION | SEA ICE | ABOUT)
45.     */
46.     .nav_bar {
47.         display: flex;
48.         justify-content: space-around;
49.         list-style-type: none;
50.         margin: auto;
51.         border-bottom: 10px solid #b8b8b8;
52.         padding: 0;
53.         width: auto;
54.         height: auto;
55.     }
56.     .nav_bar ul {
57.         padding: 5;
58.         list-style: none;
59.     }
60.     .nav_bar ul li {
61.         float: right;
62.         font-size: 16px;
63.         font-weight: bold;
64.         left: -2%;
65.     }
66.     #nav {
67.         float: left color: #3b3b3b;
68.         font-family: "Trebuchet MS", Helvetica, sans-serif;
69.         font-size: 10px;
70.         letter-spacing: 1px;
71.     }
72.     /*
73.         GRID & MAIN
74.     */
75.     .grid {
76.         display: grid;
77.         grid-template-columns: 30% 40% 30%;
78.         padding: 0;
79.     }
80.     #main {
81.         background: #e8e8e8;
82.         position: relative;
```

```css
83.          margin-left: 1%;
84.          box-sizing: border-box;
85.          top: 105%;
86.      }
87.      #timemaps {
88.          font-family: "Trebuchet MS", Helvetica, sans-serif;
89.          position: fixed;
90.          float: right;
91.          font-size: 20px;
92.          text-align: center;
93.          word-spacing: 0.3px;
94.          left: 8%;
95.          top: 20%;
96.      }
97.      #heat_fpar {
98.          position: fixed;
99.          left: 1%;
100.         top: 25% ;
101.     }
102.     #heatmaps {
103.         font-family: "Trebuchet MS", Helvetica, sans-serif;
104.         position: absolute;
105.         float: right;
106.         font-size: 20px;
107.         text-align: center;
108.         word-spacing: 0.3px;
109.         left: 100px;
110.     }
111.     /* Slideshow */
112.     .slideshow-container {
113.         max-width: 100%;
114.         position: relative;
115.         margin: auto;
116.         top: 2%;
117.     }
118.     /* Hide the images by default */
119.     .mySlides {
120.         display: none;
121.     }
122.     /* Next & previous buttons */
123.     .prev,
124.     .next {
125.         cursor: pointer;
126.         position: absolute;
127.         top: 50%;
128.         width: auto;
```

```css
129.          margin-top: -22px;
130.          padding: 10px;
131.          color: black;
132.          font-weight: bold;
133.          font-size: 18px;
134.          transition: 0.6s ease;
135.          border-radius: 0 3px 3px 0;
136.          user-select: none;
137.      }
138.    /* Position the "next button" to the right */
139.    .next {
140.          right: 0;
141.      }
142.    .prev {
143.          left: 0;
144.          border-radius: 3px 0 0 1px;
145.      }
146.    .prev:hover,
147.    .next:hover {
148.          background-color: #e8e8e8;
149.      }
150.    /* The dots/bullets/indicators */
151.    .dot {
152.          cursor: pointer;
153.          height: 5px;
154.          width: 5px;
155.          margin: 0;
156.          background-color: #bbb;
157.          border-radius: 10%;
158.          display: inline-block;
159.          transition: background-color 0.6s ease;
160.      }
161.    .active,
162.    .dot:hover {
163.          background-color: #717171;
164.      }
165.    /* Fading animation */
166.    .fade {
167.          -webkit-animation-name: fade;
168.          -webkit-animation-duration: 1.5s;
169.          animation-name: fade;
170.          animation-duration: 1.5s;
171.      }
172.    @-webkit-keyframes fade {
173.        from {
174.            opacity: .4
```

```css
175.            }
176.
177.        to {
178.            opacity: 1
179.        }
180.    }
181.
182.    @keyframes fade {
183.        from {
184.            opacity: .4
185.        }
186.
187.        to {
188.            opacity: 1
189.        }
190.    }
191.    /* TEXTS */
192.    h4,
193.    h5,
194.    h6 {
195.        color: #3b3b3b;
196.        font-size: 17px;
197.        letter-spacing: 7px;
198.        word-spacing: 0.1px;
199.        font-weight: 100;
200.        text-decoration: rgb(68, 68, 68);
201.        font-style: normal;
202.        font-variant: small-caps;
203.        text-align: center;
204.        border-top: 0px;
205.        border-bottom: 10px;
206.        padding: 0;
207.        margin: 0;
208.    }
209.    #text {
210.        color: #3b3b3b;
211.        font-size: 13px;
212.        word-spacing: 0.3px;
213.        font-weight: 100;
214.        text-decoration: rgb(68, 68, 68);
215.        font-style: normal;
216.        text-align: inherit;
217.        border-left: 10px;
218.    }
219.    /* CYLINDER COLUMN */
220.    #cylinder {
221.        position: relative;
```

```css
222.          color: #3b3b3b;
223.          font-size: 15px;
224.          letter-spacing: 5px;
225.          word-spacing: 0px;
226.          font-weight: 100;
227.          text-decoration: rgb(68, 68, 68);
228.          font-style: normal;
229.          font-variant: small-caps;
230.          text-align: right;
231.      }
232.      /* Cylinder selection */
233.      h8 {
234.          font-size: 10px;
235.          background: #e8e8e8;
236.          color: white;
237.          padding: 40px 0 100px 20%;
238.          margin-bottom: 50px;
239.      }
240.      label,
241.      p,
242.      a,
243.      h1,
244.      div {
245.          font-family: Roboto, sans-serif;
246.      }
247.      .tab-wrap {
248.          width: 80%;
249.          margin-left: 2%;
250.          position: relative;
251.          display: -webkit-box;
252.          display: flex;
253.          top: 0px;
254.      }
255.      input[type="radio"][name="tabs"] {
256.          position: absolute;
257.          z-index: -1;
258.      }
259.      input[type="radio"][name="tabs"]:checked + .tab-label-content label {
260.          color: black;
261.      }
262.      input[type="radio"][name="tabs"]:checked + .tab-label-content .tab-
    content {
263.          display: block;
264.      }
265.      input[type="radio"][name="tabs"]:nth-of-type(1):checked ~ .slide {
266.          left: calc((100% / 3) * 0);
```

```css
267.         }
268.     input[type="radio"][name="tabs"]:nth-of-type(2):checked ~ .slide {
269.         left: calc((100% / 3) * 1);
270.     }
271.     input[type="radio"][name="tabs"]:nth-of-type(3):checked ~ .slide {
272.         left: calc((100% / 3) * 2);
273.     }
274.     input[type="radio"][name="tabs"]:first-of-type:checked ~ .slide {
275.         left: 0;
276.     }
277.     label {
278.         cursor: pointer;
279.         color: rgba(255, 255, 255, 0.8);
280.         background-color:  #8c8c8c;
281.         box-sizing: border-box;
282.         display: inline-flex;
283.         align-items: center;
284.         justify-content: center;
285.         text-align: center;
286.         height: 60px;
287.         width: 99%;
288.     }
289.     .tab-label-content {
290.         width: 80%;
291.     }
292.     .tab-label-content .tab-content {
293.         position: absolute;
294.         top: 60px;
295.         left: 0px;
296.         line-height: 100%;
297.         display: none;
298.     }
299.     @media screen and (max-width: 800px) {
300.         h1 {
301.             padding: 40px 0 90px 10%;
302.         }
303.     .tab-wrap {
304.             width: 80%;
305.             margin-left: 10%;
306.             top: -106px;
307.         }
308.     }
309.     .follow i {
310.         margin-right: 20px;
311.         -webkit-transition: margin-right 0.2s ease;
312.         transition: margin-right 0.2s ease;
```

```css
313.    }
314.    .follow:hover {
315.        width: 134px;
316.    }
317.    .follow:hover i {
318.        margin-right: 10px;
319.    }
320.    /* RIGHT COLUMN */
321.    .grid2 {
322.        display: grid;
323.        background-image: image(02_01.png);
324.        grid-template-rows: 25% 25% 50%;
325.        padding: 0em;
326.    }
327.    /* Style The Dropdown Button */
328.    .dropbtn {
329.        background-color: #4CAF50;
330.        color: white;
331.        padding: 16px;
332.        font-size: 16px;
333.        border: none;
334.        cursor: pointer;
335.    }
336.    /* The container <div> – needed to position the dropdown content */
337.    .dropdown {
338.        position: relative;
339.        display: inline-block;
340.    }
341.
342.    /* Dropdown Content (Hidden by Default) */
343.    .dropdown-content {
344.        display: none;
345.        position: absolute;
346.        background-color: #f9f9f9;
347.        min-width: 160px;
348.        box-shadow: 0px 8px 16px 0px rgba(0, 0, 0, 0.2);
349.        z-index: 1;
350.    }
351.    /* Links inside the dropdown */
352.    .dropdown-content a {
353.        color: black;
354.        padding: 12px 16px;
355.        text-decoration: none;
356.        display: block;
357.    }
358.    /* Change color of dropdown links on hover */
359.    .dropdown-content a:hover {
```

```css
360.          background-color: #f1f1f1
361.     }
362.     /* Show the dropdown menu on hover */
363.     .dropdown:hover .dropdown-content {
364.         display: block;
365.     }
366.     /* Change the background color of the dropdown button when the dropdown
       content is shown */
367.     .dropdown:hover .dropbtn {
368.         background-color: #3e8e41;
369.     }
370.     /* Style the tab */
371.     .tab {
372.         overflow: hidden;
373.         border: 1px solid #ccc;
374.         background-color: #f1f1f1;
375.     }
376.     /* Style the buttons that are used to open the tab content */
377.     .tab button {
378.         background-color: inherit;
379.         float: left;
380.         border: none;
381.         outline: none;
382.         cursor: pointer;
383.         padding: 14px 16px;
384.         transition: 0.3s;
385.     }
386.     /* Change background color of buttons on hover */
387.     .tab button:hover {
388.         background-color: #ddd;
389.     }
390.     /* Create an active/current tablink class */
391.     .tab button.active {
392.         background-color: #ccc;
393.     }
394.     /* Style the tab content */
395.     .tabcontent {
396.         display: none;
397.         padding: 6px 12px;
398.         border: 1px solid #ccc;
399.         border-top: none;
400.     }
401.     #slicetitle {
402.         font-family: "Trebuchet MS", Helvetica, sans-serif;
403.         position: fixed;
404.         float: right;
405.         font-size: 20px;
```

```css
406.          text-align: center;
407.          word-spacing: 0.3px;
408.          right: 150px;
409.          top: 20%;
410.     }
411.    #slider {
412.          position: relative;
413.          top: -27%;
414.     }
415.    #leg {
416.          position: relative;
417.          top: -25%;
418.     }
419.    #img {
420.          position: fixed;
421.          right: 3%;
422.          bottom: 7%;
423.          margin-top: 0px;
424.          padding: 0;
425.          margin: 0;
426.     }
427.    #contabout {
428.          position: relative;
429.          left: 3%;
430.          top: 0%;
431.     }
432.    /* FOOTER */
433.    #footer {
434.          position: absolute;
435.          bottom: 3px;
436.          right: 4px;
437.          clear: both;
438.          padding: 10px;
439.          background-color: #cbcbcb;
440.          color: #3b3b3b;
441.          font-family: "Trebuchet MS", Helvetica, sans-serif;
442.          font-size: 11px;
443.          letter-spacing: 10px;
444.          word-spacing: 0.3px;
445.          font-weight: 100;
446.          text-decoration: rgb(68, 68, 68);
447.          font-style: normal;
448.          font-variant: small-caps;
449.          text-align: right;
450.     }
```

```
                               ..
                  .:72OXXXX727222227:..
                :2MBDANAIMARIAKONTOU2O2OMBBBBMX2:
              :2BBBBB8MM8XXSXSXSXXZ0OOOOOOOOOXOOMMMBBBO7:
            iXBBBMMOOOM8XSS7XXXSX2XXX2XOOXOOOXOOOOOOBBBBB2.
          2BBBZZOOOOXMOXZ2rOOXXOSX2XSSSXXOOOXOOO2OOX8BO2X2727
        :MBMOXXXXOXOXMO2XM2ri7.72OSXSXSX2SXOOOOZSXOOO8r:ir.i8BB2
       .MBBBB8XS2OOOZMMMO7O7::rri.rO2X2S2SSOOMMMXOMMMM7...::iXOXOMB2
      2OS7XZ8MBBMXXOX72X272:r7r7rrXXXXXXXSZ7277i:::ii77r2XSZOXSXXXXMB7
      rMXS227r:r7222i7:::i::ii72772Z72XOX7ZZM2.......:722MMMMXOOXSXXXOBO:
      2ZX22S77r77r7277r72777r77277i:7:rOX: :Xr:r:::i:irr::2277i2MOXSXSXSOMOr
      i8O2rr722772S27r7222222r772r77iiS2OXX2X .:::::ii::::::::::r77OOXOOOOOMM7
      :ir27.72222SX77777777i:227277ri.: .2OXOOOi....::i:irri7rrr7rir72S222SSM27S.
      .::.r222222272227rr7rririii7r::.     :XO2XSXX87i:i...7iiir77i::i.rrii::riii7728.
      :r72S2X22777777r7r7r7rrri.:7iir7272OX22S2XSXM8OOO727:rri7ri:irii7irr777ri:7722.
      .722S2272227XX7777222777i.7OOOOMMBBBBBM8BMMMMM8OMMMBOZ. :rriii777:r777727777rr722S.
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      28222727i:i:i7r:i:..2:....r2SMBi                     MB7iXOXMMr:iirr7r777r7727ri777777S.
      MS2277i727:.:::rri:.8B7:r.7MMX272                    iBZ8BX2SSO2::ir77777227727:rr77ri77
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      .O77ii::i72MX. .:i 2MZXSXXOBO...     .i27           2MOBB2XSXXM2.:7i::r777777227222777r7:2
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      ::ir..    :
```

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                    ..:r:DANAIMARIAKONTOU2020:::.
                 .::ii7vJY7..       .::    .     ......::ii:..
          .rUU5Lr:.                .    rrvusr    ..   .ivJDQd5r.
      .7suv:              .:          IB j .QQ    .7i .i.irL2IqERBgu.
   7ri:         iPj7ISuqIYJd.       sgvr. rX     .::ii.QL   iE  :jQgZr
  JBD.    iPivi.rBqr:XEirQBKrLKri.  :D:  :5    ....  QJiri.R      XB
  2i.EP1urv..:::gdXvJS::vB:    ....:.rBu.. vD     v  ::Z..i JJ..   7ZBP
  I. :1MBQU  .. ri   7. .2        r J7   12YBS.        I: .SZ  iDBBj .2
  I: .   iKQv    P   .  q.   rv7 .: rd   g7Y :irP:    r: 1B.iPRgs:   u
  5.      .QBBDIQr:    P  ii..    :E   2Lb :PrB: .. JBIBBqs:      .U
  5:       .iBBKdb7LB  7:   .  i2  7vJI:1::QYEBBZgB7B:          .1
  S:        :1  rrDANAIMARIAKONTOU2020QL7r:Q7   I v.         :U
  I:        rv    b       Rv   b :I    v.     P s.          :j
  5:        i7 .  I       Pr   P .5    1.     P r.          :u
  I:        ri .  J       1r   5 .M    q.     S r.          ij
  X:        .b    q       7r   L  M    B      J Y:          i1
  I:         M    .s      r7   1  Q   rQ      1 1:          iJ
  q:         Sr   rr      Pr   b  g.   Z7     2 1.          iU
  K:         v7   X       Zi   E  P.   B      I X           i1
  q:         7:   b       Q:   Z  U:   R      L.v           :2
  I:         :.  .S       B: i2  2:   b       K i           :U
  U:         r7  vv       Qr Ur  I: .S       .Z.i           .S
  si         is  ui       ZY q:  E. .I        qri           .X
  si         iX  P.       Ei 5:  D. iJ        i2:           .P
  77         iq  D        d7 U:  Sr iL        :Q:           .q
  rv         i.  5        ZU X.  JJ i7        .B.           .Z
  :u         ::  .7       2X X.  sU iv        B:            :I
  :S         :r ir        7j Zi  7K rY        B.            i7
   g         P i7         :Y.Zi  rS :j        2             Y:
   Q         r:ii         .riR:  id :I        i             1:
   B          KX          r.Q.  iP .b        i             5:
   B          :g          X.2: :b .g       .B.             1:
   B          :           q ii .b .Q       iBL             s:
   Q                      1 iP  B .P       DrD             ir
   B                      QiiS  B Lj       iq P            .r
   B.                     Dvrr  B g.       B. P.           7
   B.          B          v2K:  XiQ       B  P.           r
   B:          B          :ZQ.  7BX      :Q  P.           J
   Qr          B          rSg.  .B:     .B  K            L
   ZJ          B.         urYs  .Q       B :5            7
   PI          2Mq        S:.M  .B       JrD            r
   jD         .B Q.       rP R  .7      .B7            7
   SQ         g: L7       .Q P           :B            r
   7B         B  ij        B q                         7
   7Q         .B  .P       :2 I    .                   r
   iB         iK  P        7r.S   .           ..       v
   rB         iX  g.       sY:U               ..       7
   iB         B:  B.       rr.v                        v
   rB         D:  B        rr 2                        v
   rB         .P.Jv        .K.5                        s
   jD          PB.         Iis                         j
   IK          g           7K7                         2
   qu                      :B.                         I
   bY                       B                          P
   gr                       B                          Z
   gi                       i     .                    M
   Q:                                                  E
   Q:                                                  .P
   B.            :.  :7Ur...ii:.  .r.  ...:           :s
   B    :   iZ5 :dv.:7ii. .7XDiYr.vR7. bQJ7:..:L:....  ii
   B    vE.      .   .         . :: .,:s.. r7...      rr
   B.Y:       .  ..ir..     .         . :7 .:   : .s2 ..  ij
   BMs.      :1Xv:7UsjMqDP      .i       .::vri      :5. . r:
  XSj  .uXrJi.JEr.iPDiLYs2Ljb7r..... Uv   ..r:: . L77  ..   .2P:
  .Sq::Lii  :i:ii.  :     ...iuE7Ei..:i::i  ri. ::Lr::.    Rv
   iUMQgBu       :r.  . :i..  :Jr.       .7:     .JBQ
   .   .sPM7U7:      Lv: .     :..  . 7U   :vKQM2:
       PUsSPBRD2J7:. .Y.            i7  .i. .:vIXDI51sr.
           ..::DANAIMARIAKONTOU2020::.:Lv7r....
```