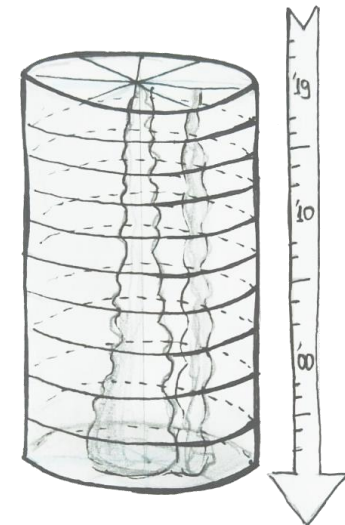


or "can the Arctic fit into cylinders?"



Cartography M.Sc.







The Guardian

'Sleeping giant' Arctic methane deposits starting to release, scientists find



## The Arctic hasn't been this warm for 3 million years

The last time CO2 concentrations reached today's level was 3 million years ago, during the Pliocene Epoch. Hear from geoscientists who see ...

2 days ago

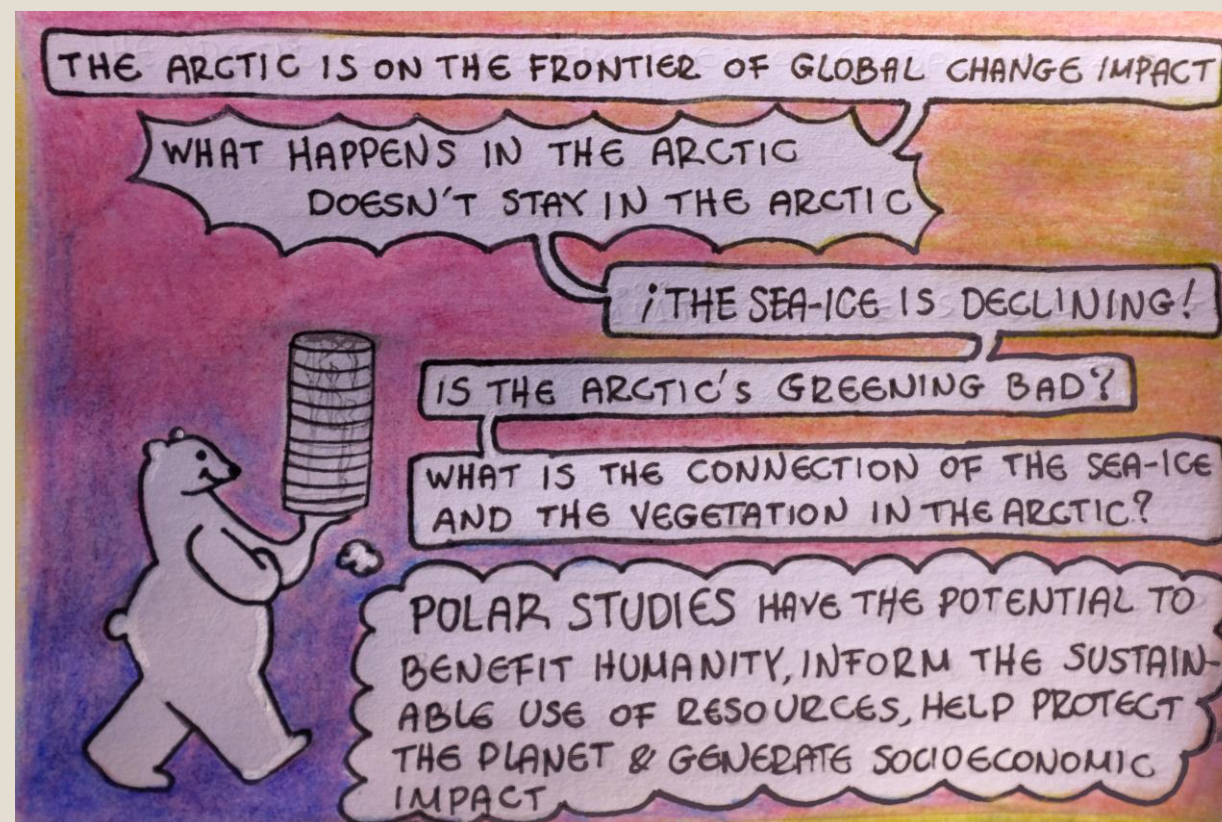


NS New Scientist

## Arctic sea ice loss could trigger huge levels of extra global warming

Arctic sea ice vanishing in summers by 2050 could trigger 0.19°C of extra global warming – almost enough to wipe out any savings from China ...

17 hours ago



# Inspiration

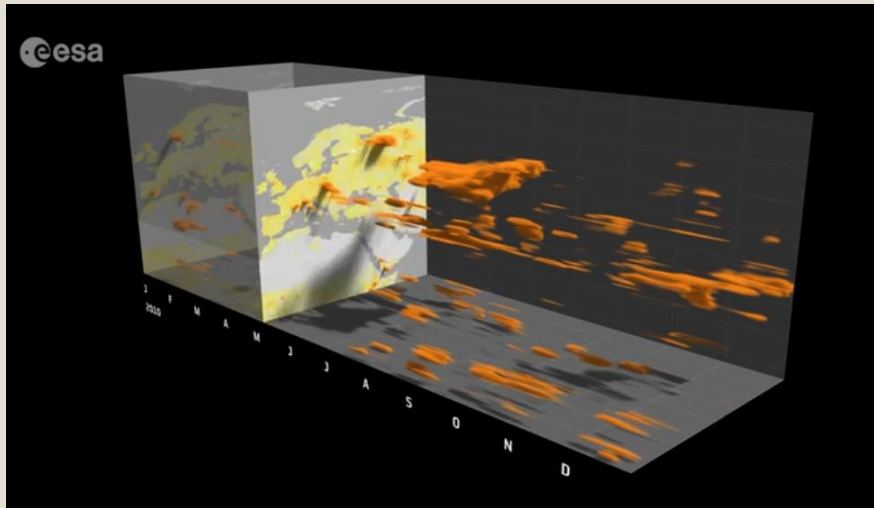
Earth Syst. Dynam., 11, 201–234, 2020  
<https://doi.org/10.5194/esd-11-201-2020>  
© Author(s) 2020. This work is distributed under  
the Creative Commons Attribution 4.0 License.

Earth System  
Dynamics



## Earth system data cubes unravel global multivariate dynamics

Miguel D. Mahecha<sup>1,2,3,★</sup>, Fabian Gans<sup>1,★</sup>, Gunnar Brandt<sup>4</sup>, Rune Christiansen<sup>5</sup>, Sarah E. Cornell<sup>6</sup>,  
Normann Fomferra<sup>4</sup>, Guido Kraemer<sup>1,2,7</sup>, Jonas Peters<sup>5</sup>, Paul Bodesheim<sup>1,8</sup>, Gustau Camps-Valls<sup>7</sup>,  
Jonathan F. Donges<sup>6,9</sup>, Wouter Dorigo<sup>10</sup>, Lina M. Estupinan-Suarez<sup>1,12</sup>, Victor H. Gutierrez-Velez<sup>11</sup>,  
Martin Gutwin<sup>1,12</sup>, Martin Jung<sup>1</sup>, Maria C. Londoño<sup>13</sup>, Diego G. Miralles<sup>14</sup>, Phillip Papastefanou<sup>15</sup>, and  
Markus Reichstein<sup>1,2,3</sup>



*Earth Interactions* • Volume 14 (2010) • Paper No. 8 • Page 1

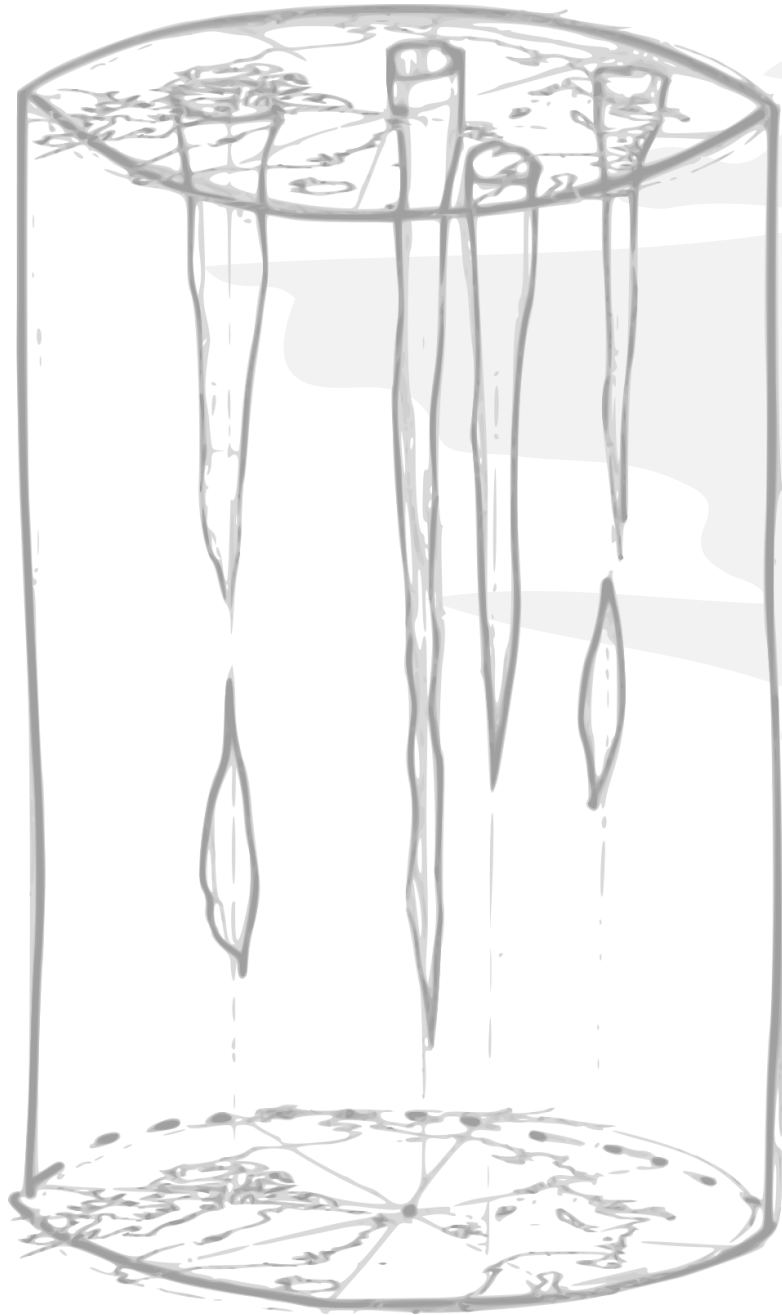
## Circumpolar Arctic Tundra Vegetation Change Is Linked to Sea Ice Decline

Uma S. Bhatt<sup>\*,+</sup> Donald A. Walker,<sup>#</sup> Martha K. Raynolds,<sup>#</sup>  
Josefino C. Comiso,<sup>@</sup> Howard E. Epstein,<sup>&</sup> Gensuo Jia,<sup>\*\*</sup>  
Rudiger Gens,<sup>++</sup> Jorge E. Pinzon,<sup>##</sup> Compton J. Tucker,<sup>##</sup>  
Craig E. Tweedie,<sup>@@</sup> and Patrick J. Webber<sup>&&</sup>

Eurographics Conference on Visualization (EuroVis) (2014), pp. 1–19  
R. Borgo, R. Maciejewski, and I. Viola (Editors)

## A Review of Temporal Data Visualizations Based on Space-Time Cube Operations

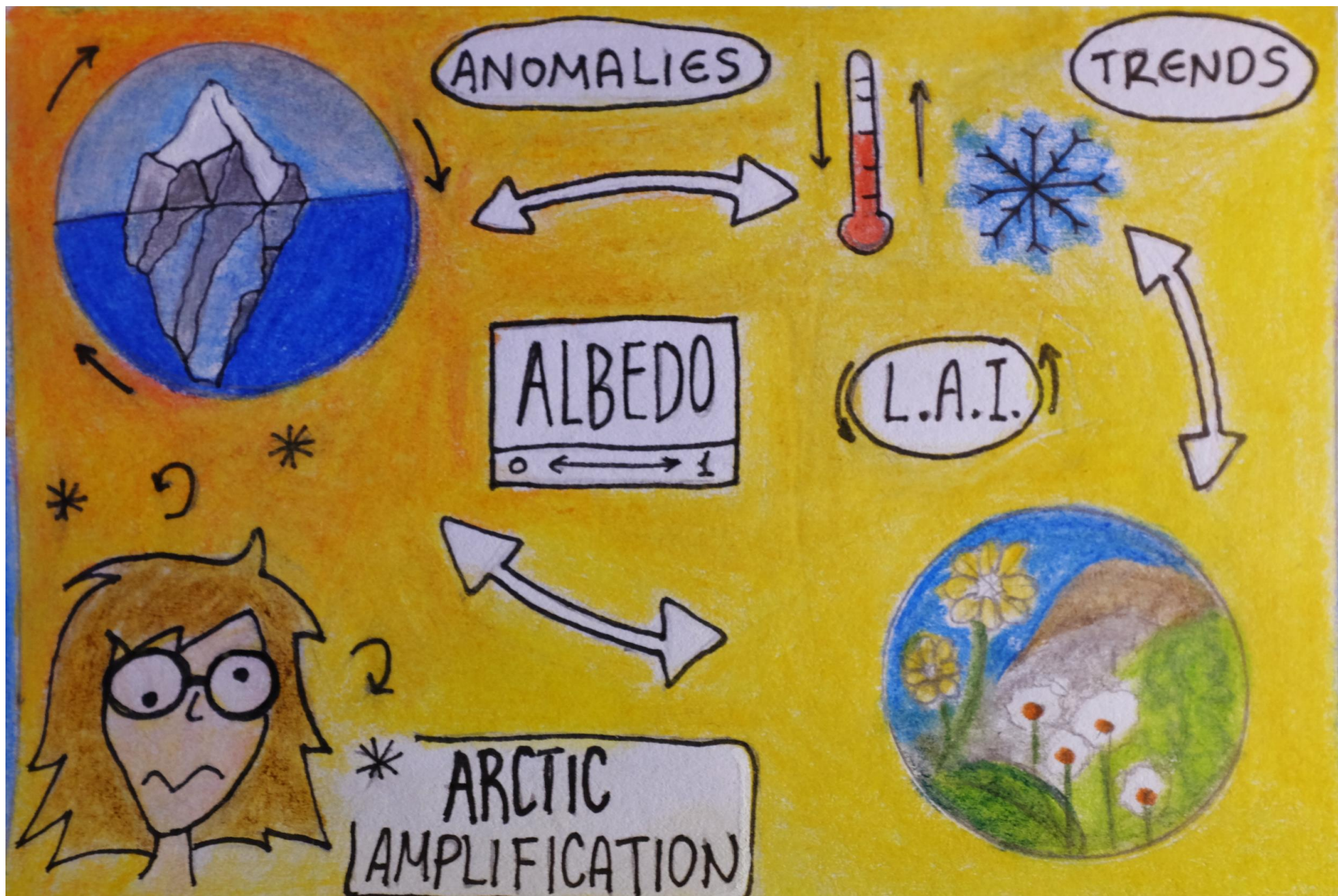
B. Bach<sup>1</sup>, P. Dragicevic<sup>1</sup>, D. Archambault<sup>2</sup>, C. Hurter<sup>3</sup> and S. Carpendale<sup>4</sup>

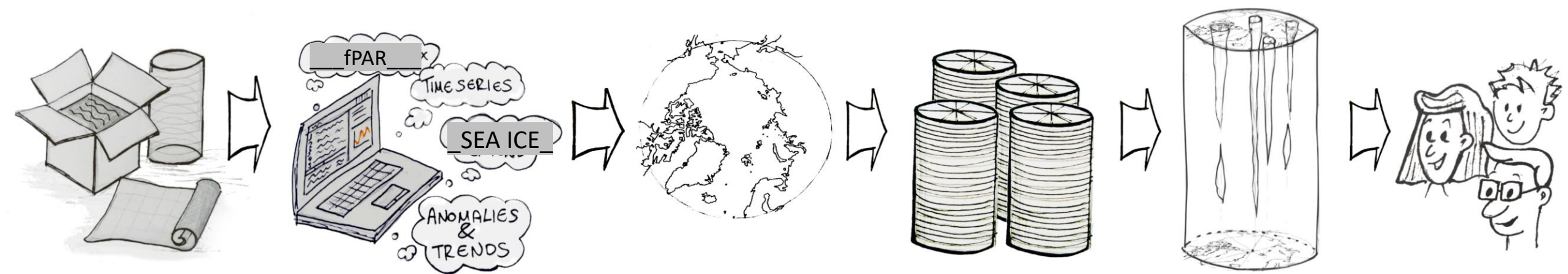


# Research Questions

- 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 most suitable way to visualize spatio-temporal environmental phenomena in the Arctic?
- Is the idea of Data Cylinders understandable enough by a broad audience?







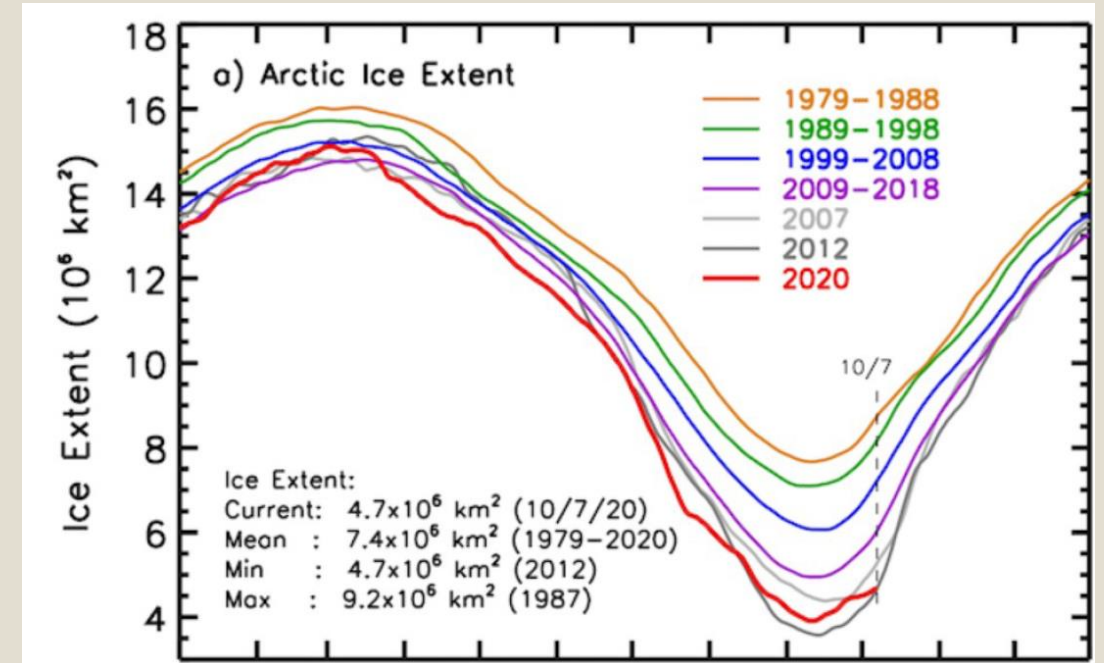
# Methodology

- Sea Ice Concentration
- fPAR
- Time Series
- Anomalies
- Development of the data cylinders
- Time Flattened and Juxtaposing Maps
- Web application

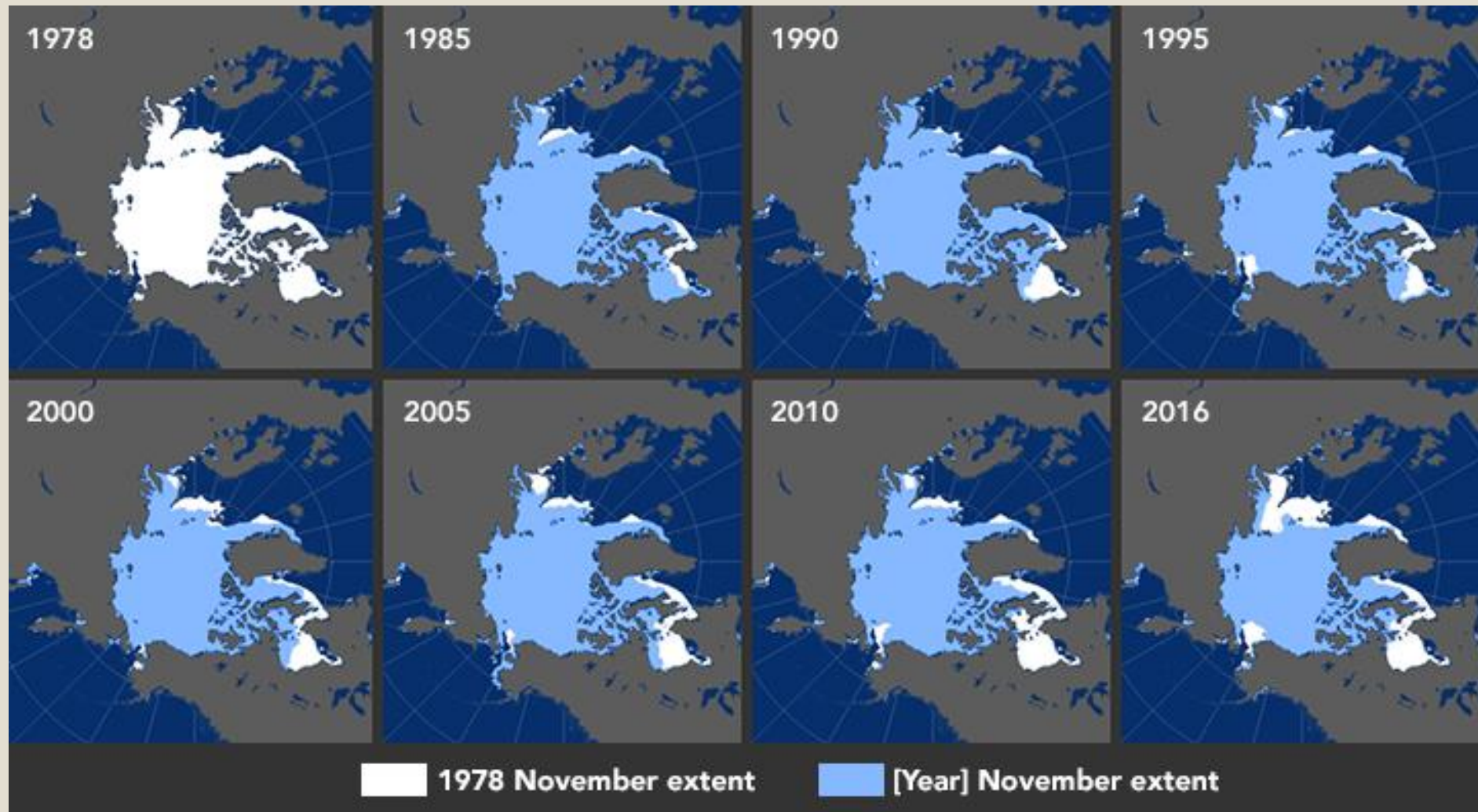


# Sea Ice

- 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%).
- 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).
- AMSR-E stopped rotating in October 2011. 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.
- The anomalies were computed as the difference of the absolute values from the mean monthly ones.



Arctic Ice Extent graph (Comiso et al., 2020)

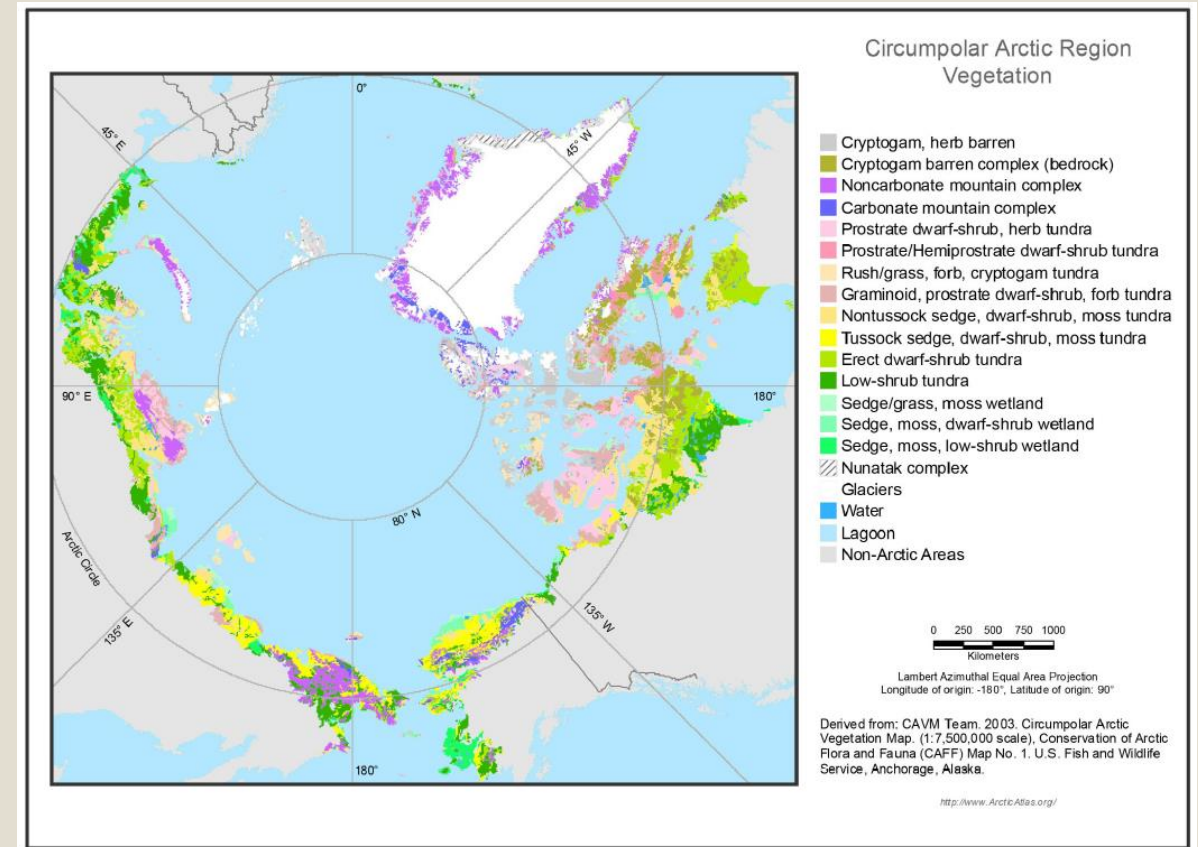


*Maps of Arctic Sea Ice Concentration (Earth Observatory, 2016)*



# Arctic Vegetation

- 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.
- Plant activity can be measured remotely via satellite observations.
- 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 anomalies were computed as the difference of the absolute values from the mean monthly ones.



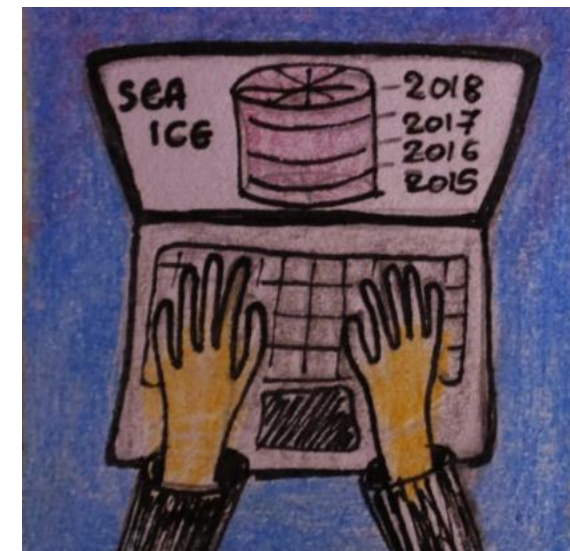
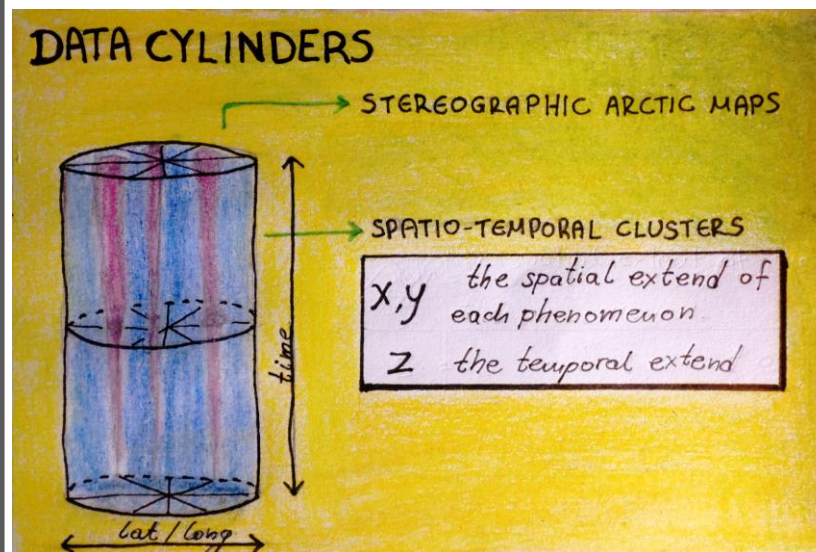
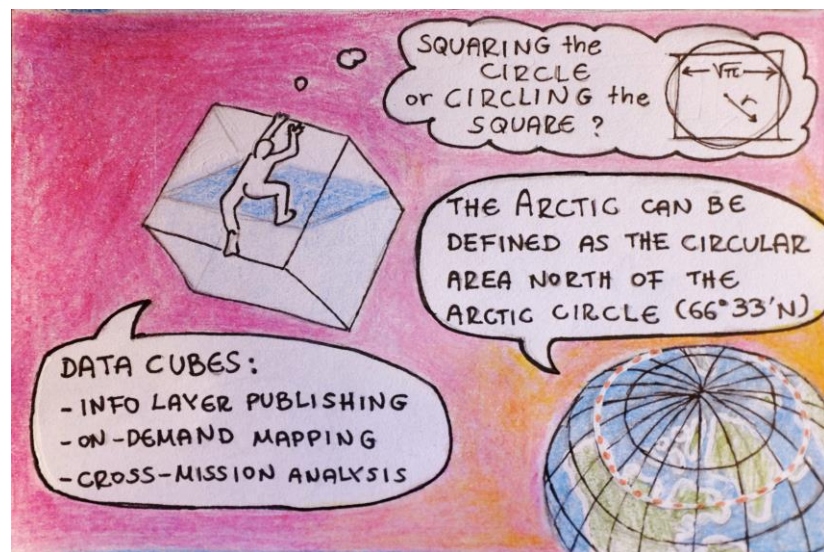
Map of Circumpolar Arctic Vegetation (Walker et al., 2005)



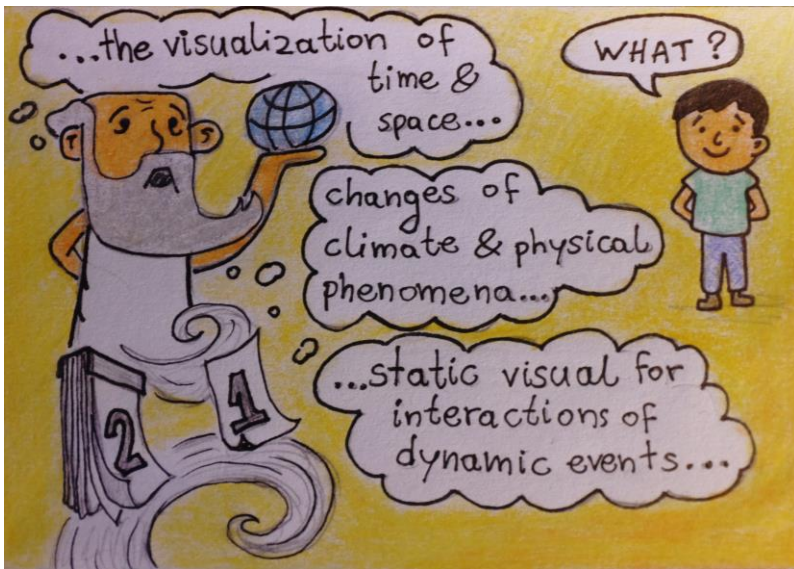
# ARCTIC VEGETATION

Examples of plants in Svalbard, photos by Danai-Maria Kontou

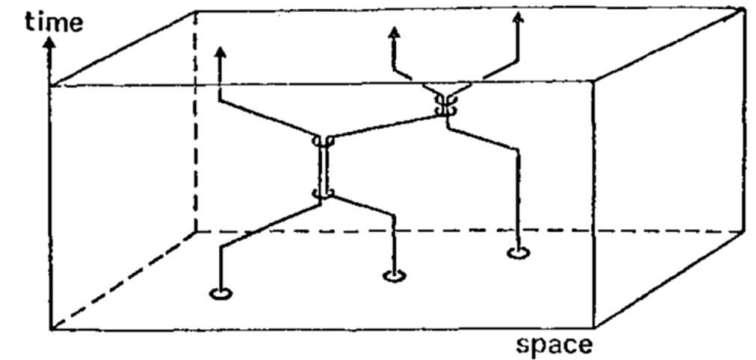




# Data Cylinders



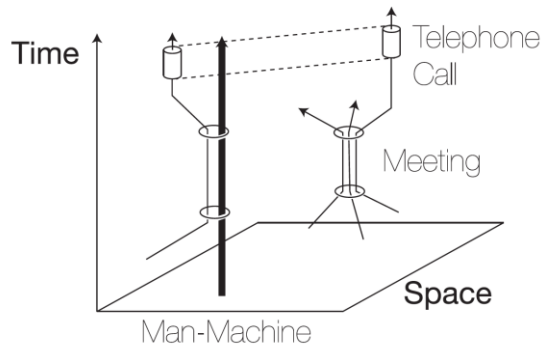
- In the 1970s Hagerstrand placed the fundamentals of time geography, which was revolutionary in social geography.
- The space-time theme is a sum of phenomena, physical or man-made.



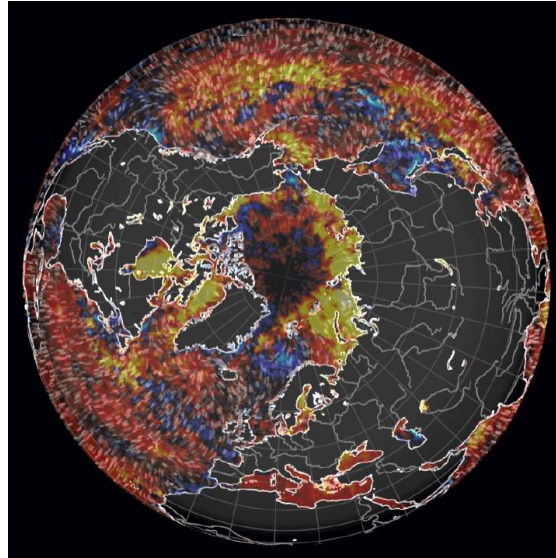
*Space Time Aquarium, after Hagerstrand (Thrift, 1977)*

# Time geography

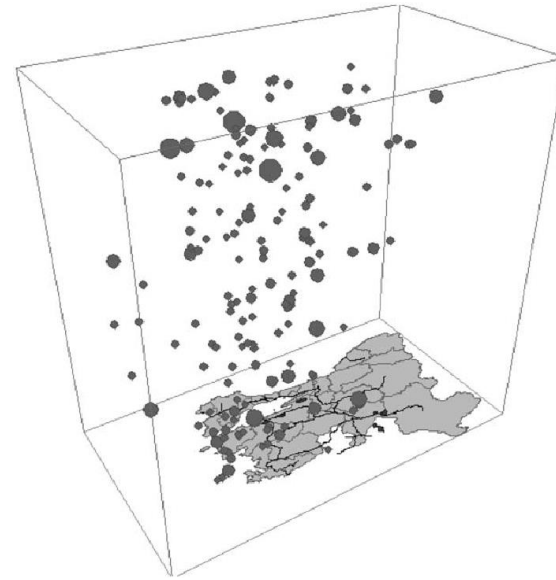




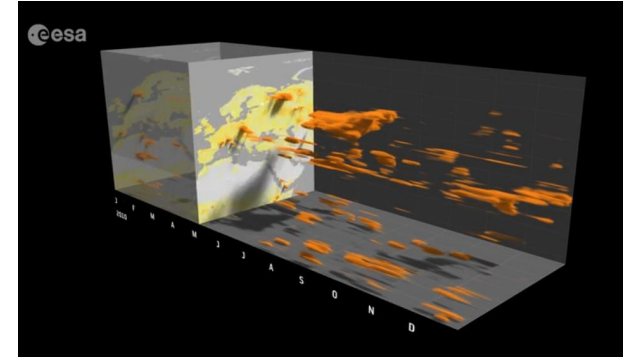
*Space Time Aquarium, after Hagerstrand  
(Bach et al., 2014)*



*Screenshot, Arctic Centred Sea Surface  
Temperature Anomaly & Peak Wave Period,  
for 1/09/2020, earth.nullschool.net*



*Spatio-temporal events represented in a  
SpaceTime Cube. (Andrienko et al., 2003)*



*Video Snapshot of the ESA's data-  
cube showing extreme events of  
temperature*

# Time-space visualizations

# Results

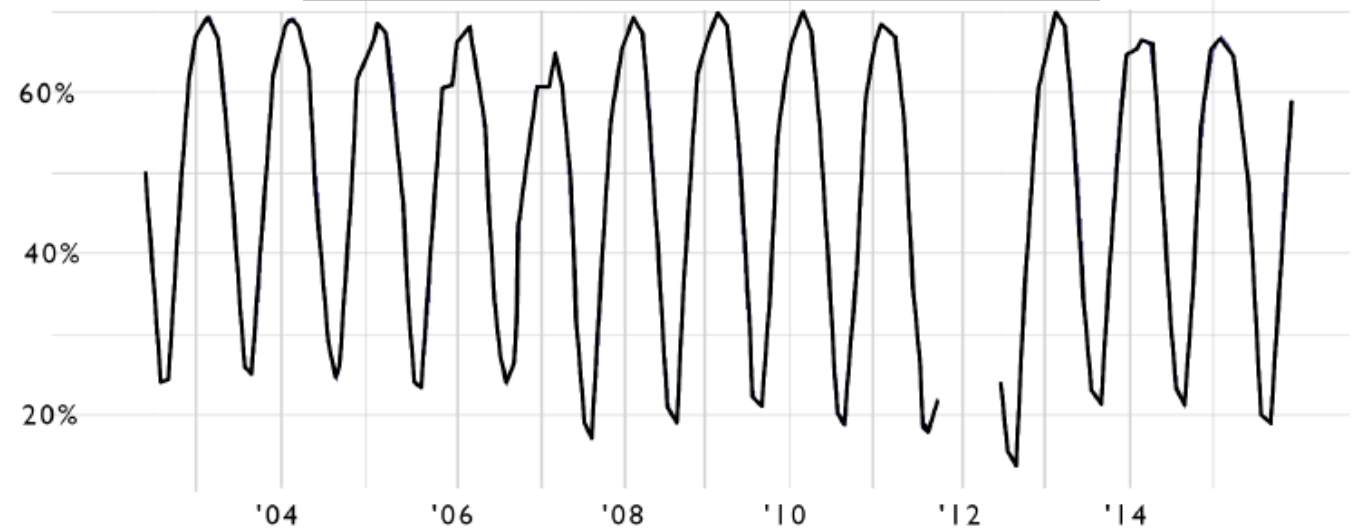
- Time Series & Anomalies graphs
- Table maps aka time juxtaposing maps
- Heat maps aka time flattening maps
- Data Cylinders
- Web application
- Poster



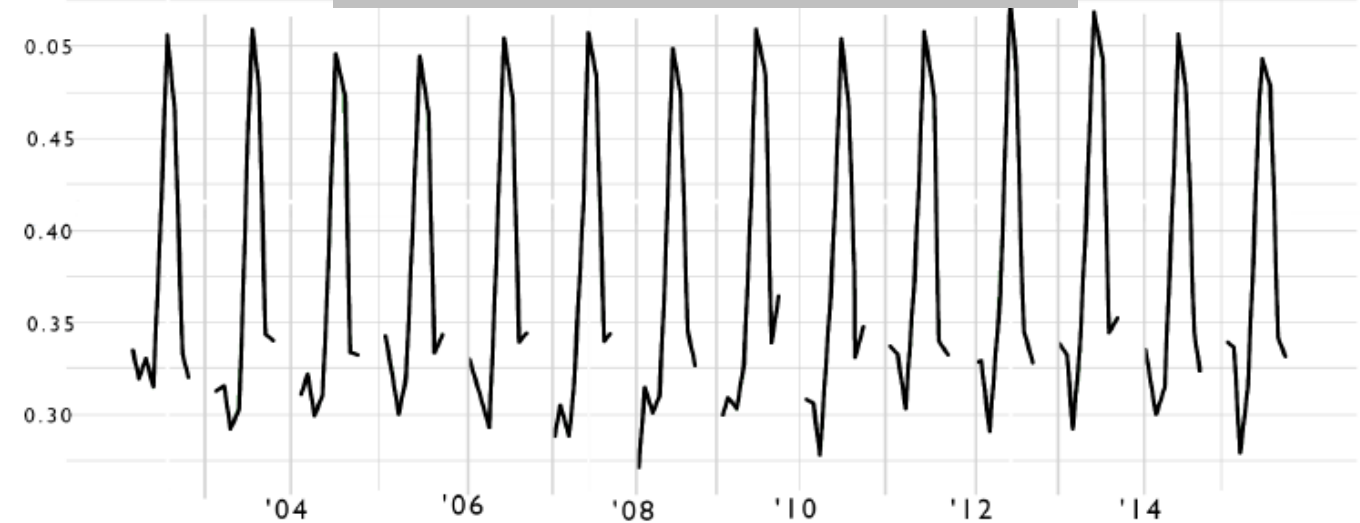
# Time Series

(for all the Arctic)

Arctic Sea Ice Time Series 2002-2015



Arctic fPAR Time Series 2002-2015

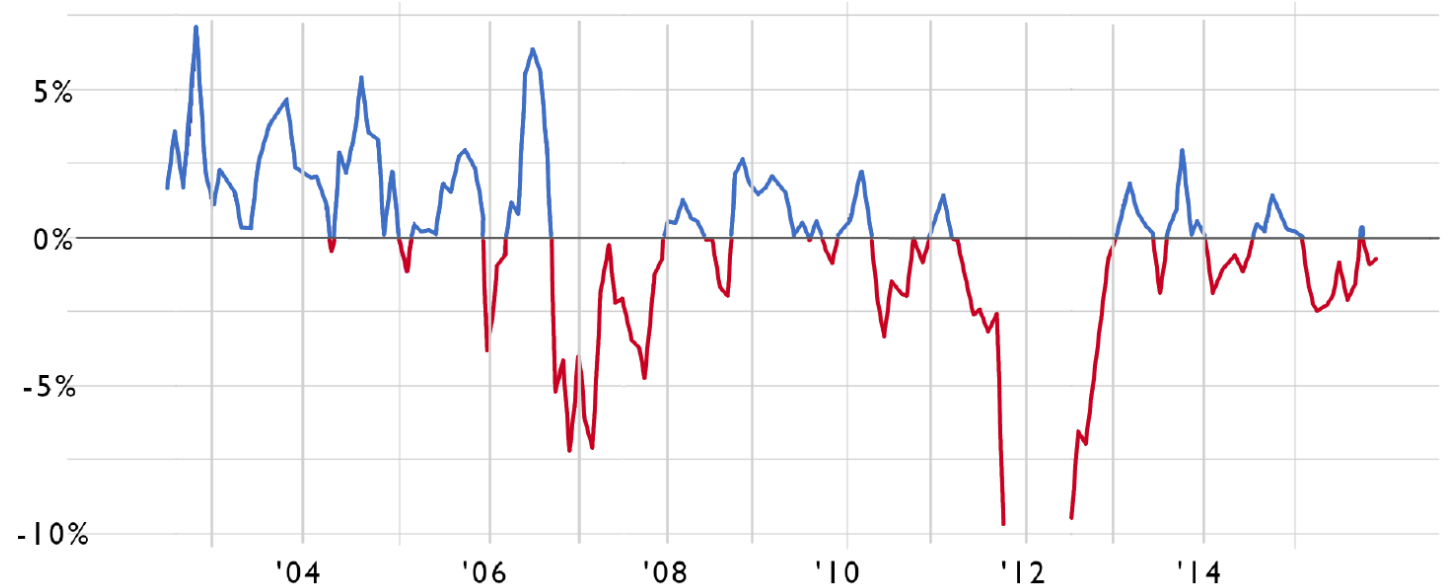


# Anomalies

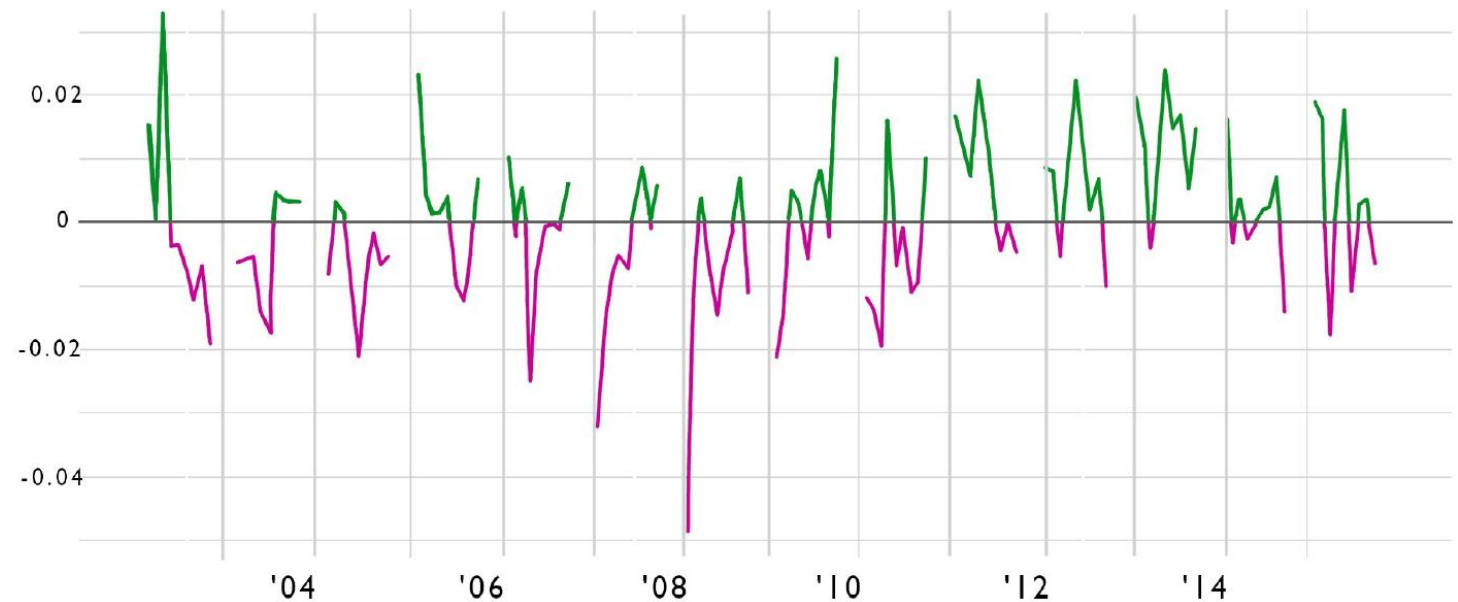
(for all the Arctic)

The anomalies were computed as the difference of the absolute values from the mean monthly ones.

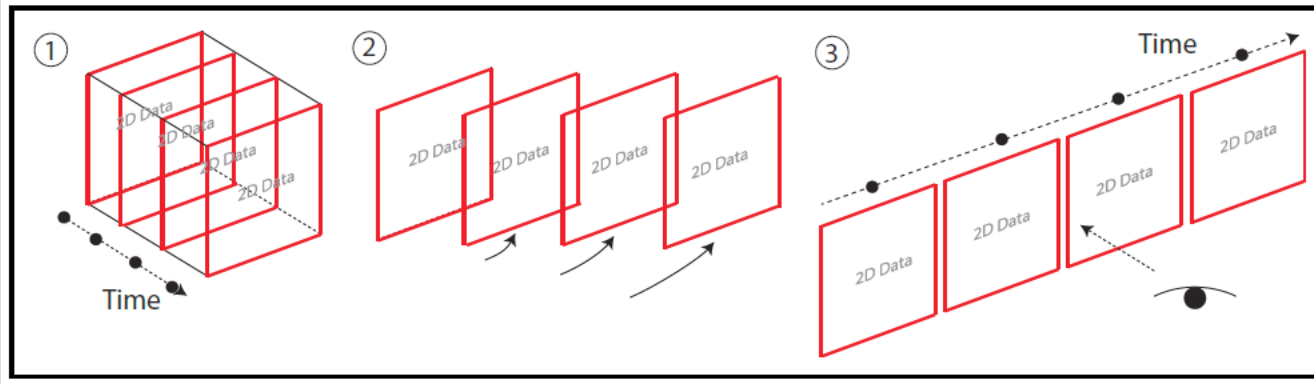
Arctic Sea-Ice Anomalies 2002-2015



Arctic fPAR Anomalies 2002-2015



# Time Juxtaposing

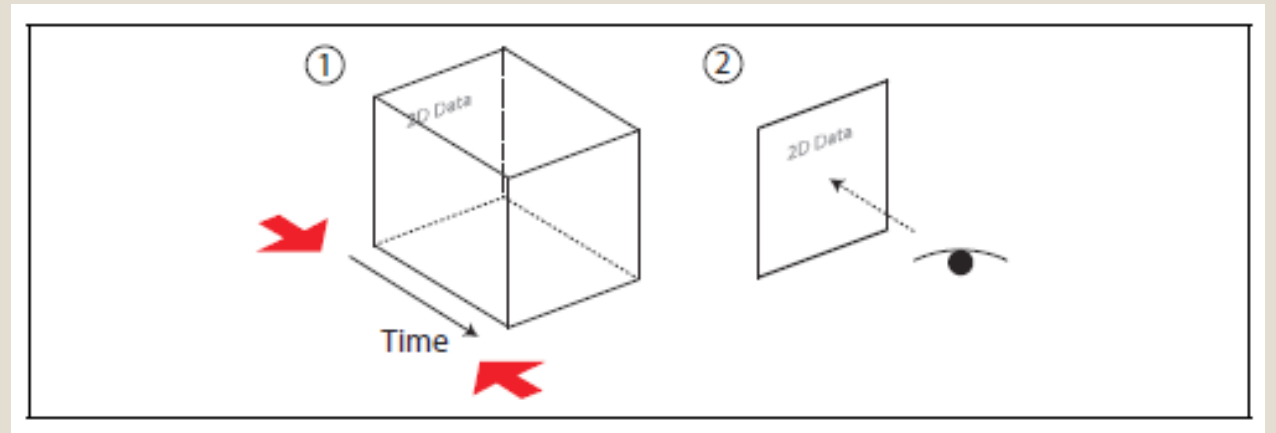


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## A Review of Temporal Data Visualizations Based on Space-Time Cube Operations

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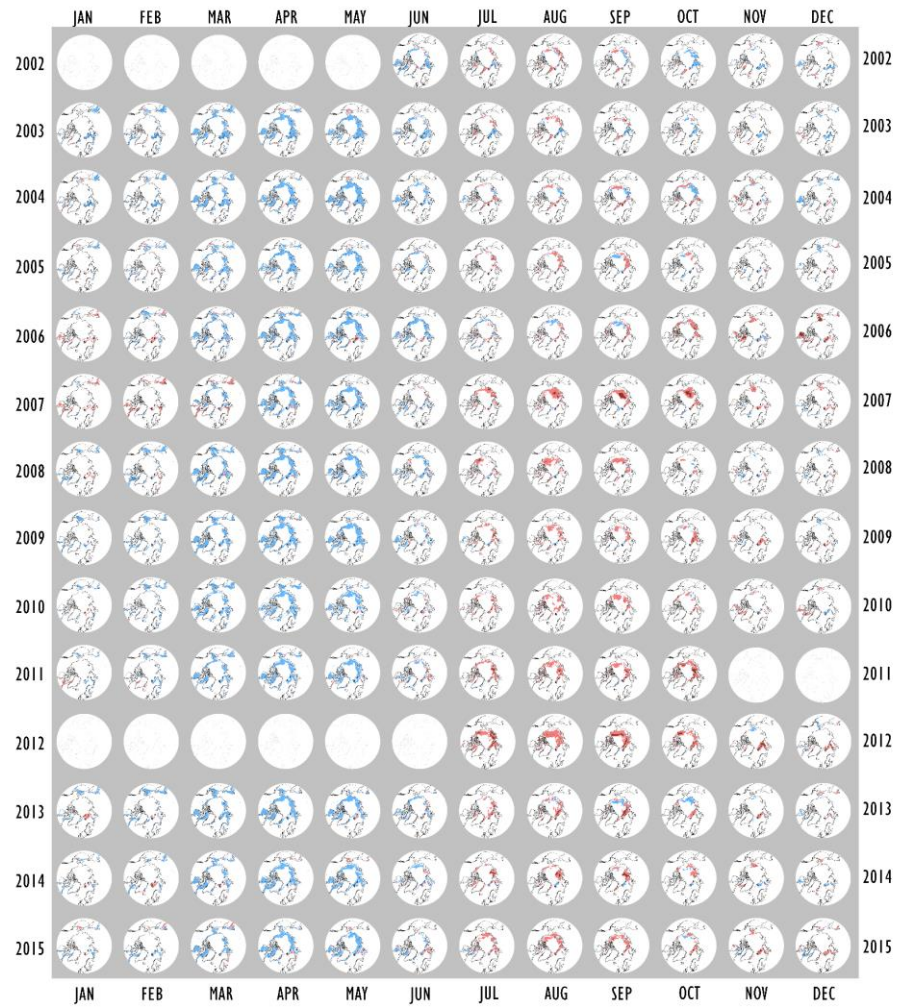
# & Time flattening





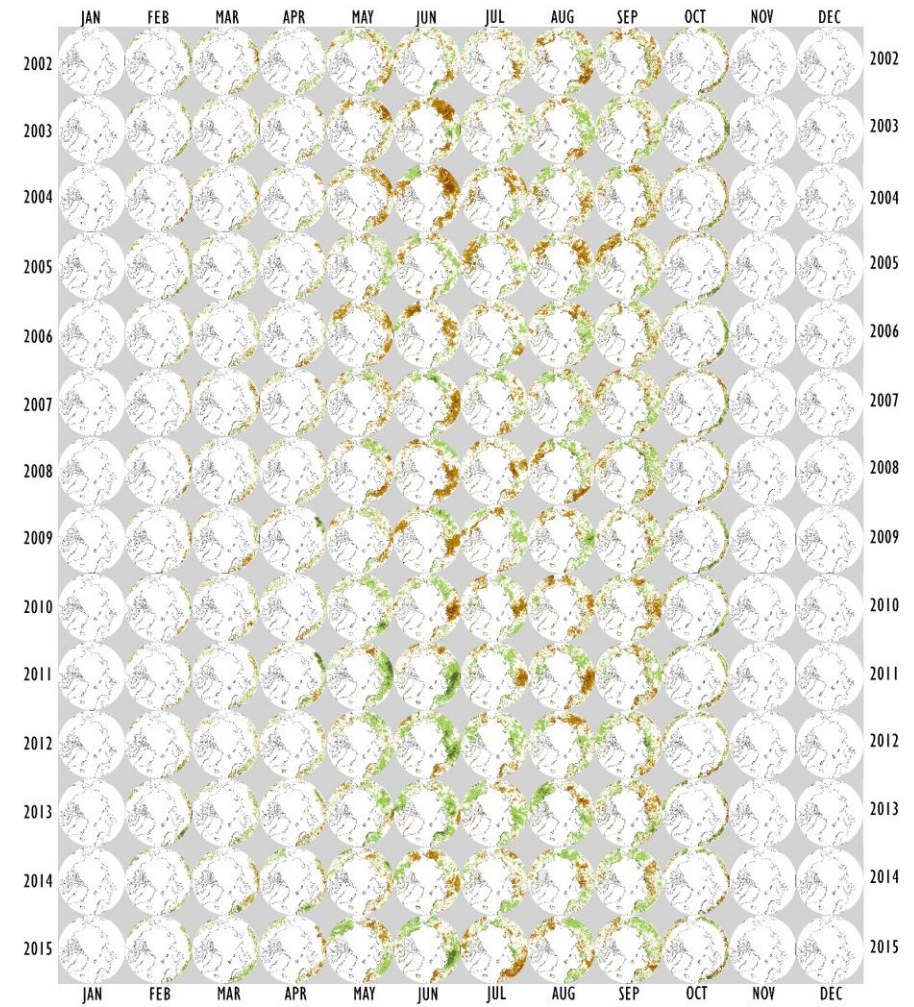
# Sea Ice Concentration

## A N O M A L I E S



# V e g e t a t i o n

## A N O M A L I E S



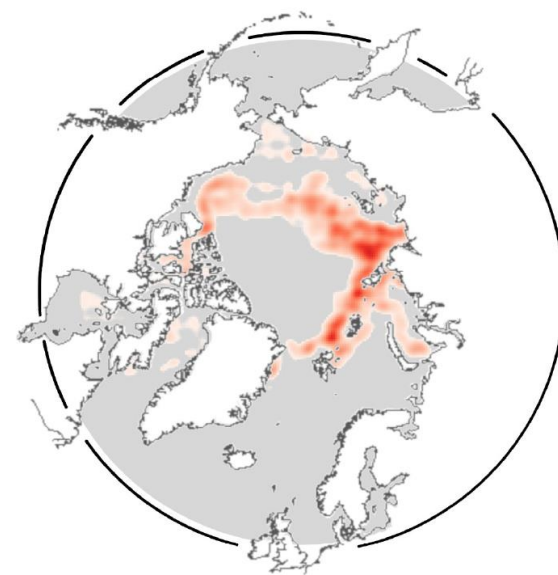
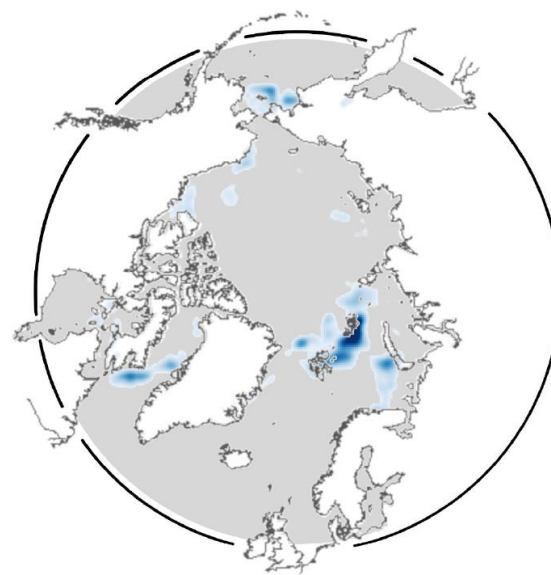
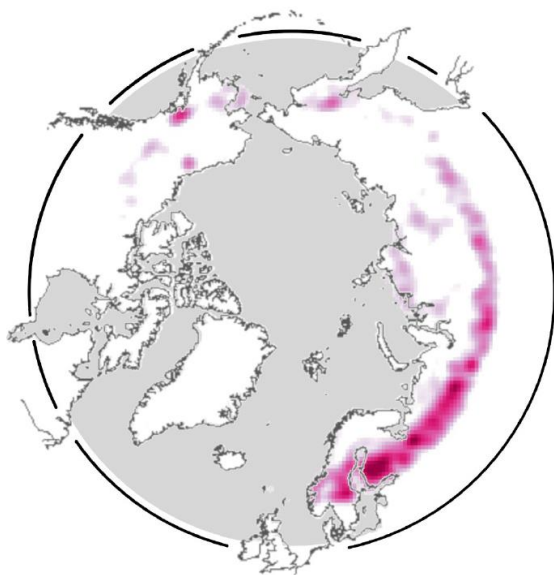
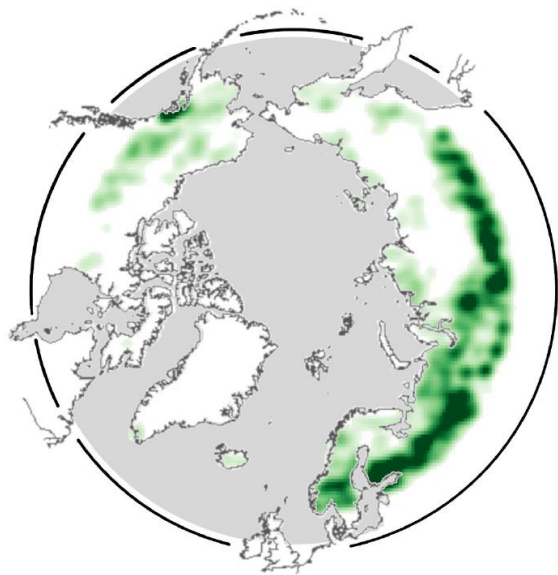
Fraction of Photosynthetically Active Radiation



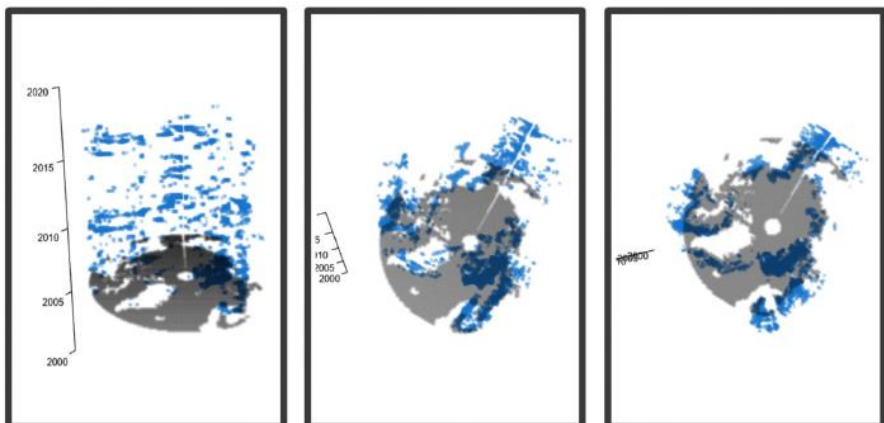
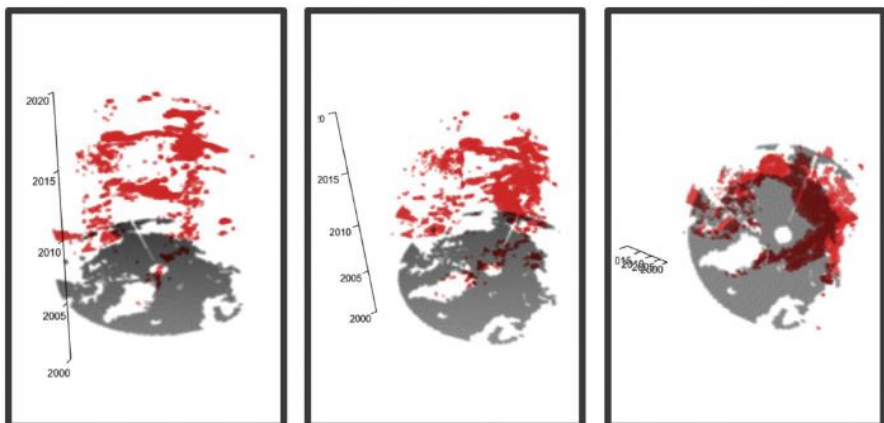
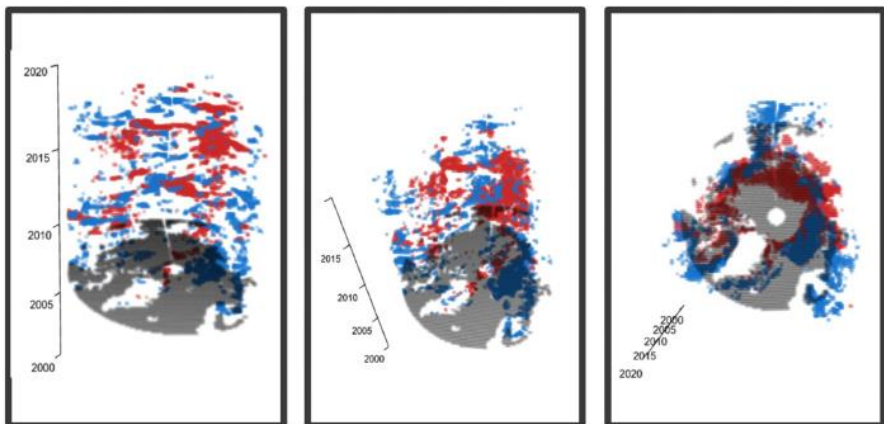
# Time flattening Anomalies

Vegetation

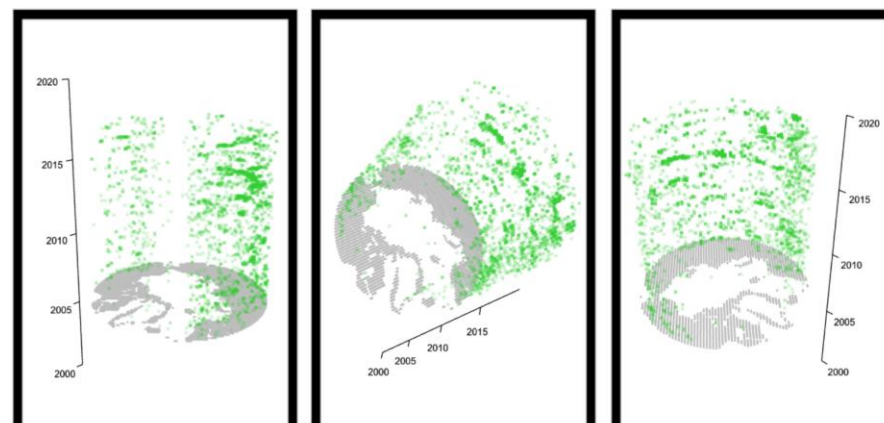
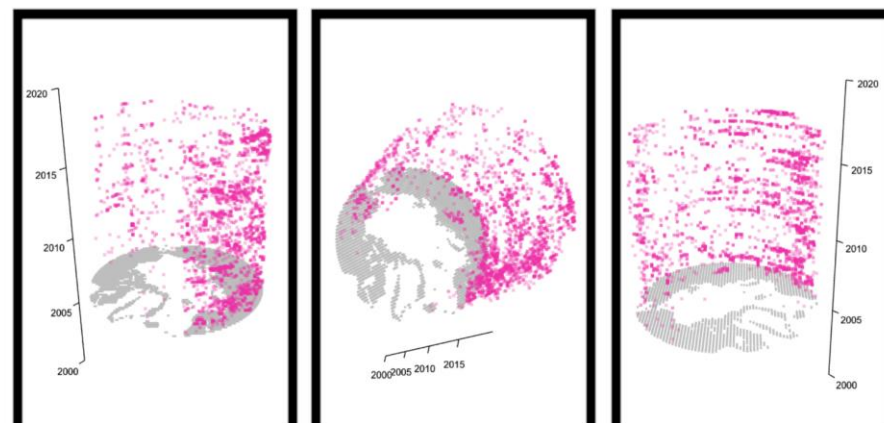
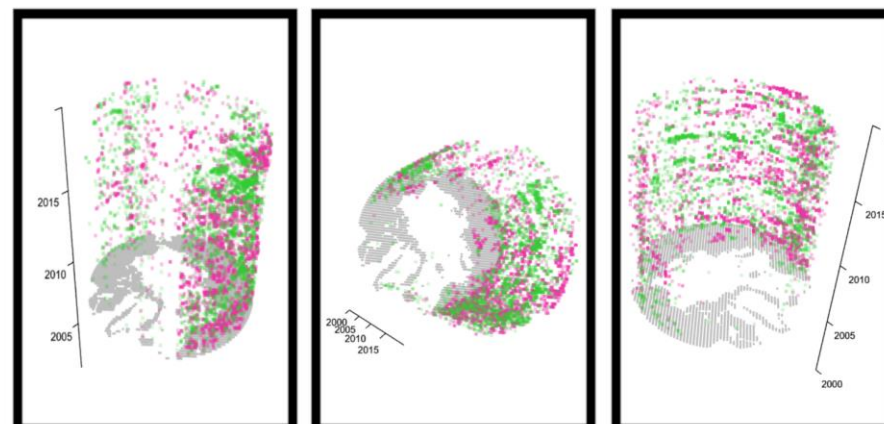
Sea Ice







# DATA CYLINDERS





# ARCTIC DATA CYLINDERS

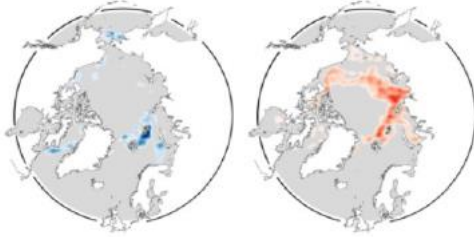
| V E G E T A T I O N | | S E A - I C E | | A B O U T |

ANOMALIES

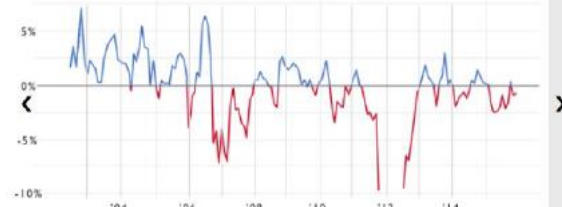
POSITIVE

NEGATIVE

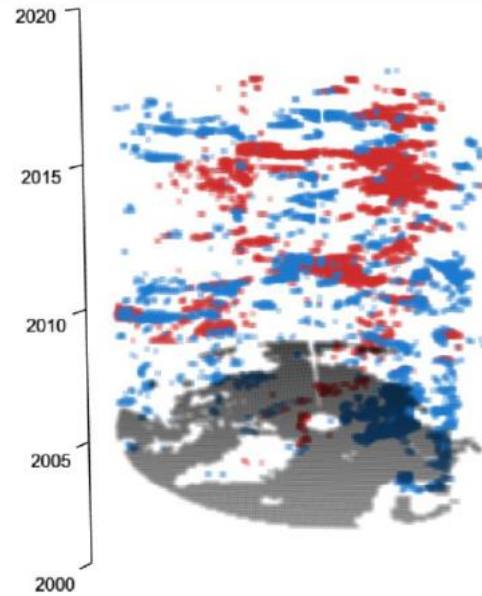
## Time Flattened Maps



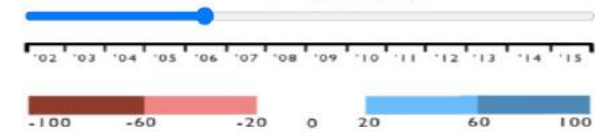
## Sea-Ice Anomalies 2002-2015



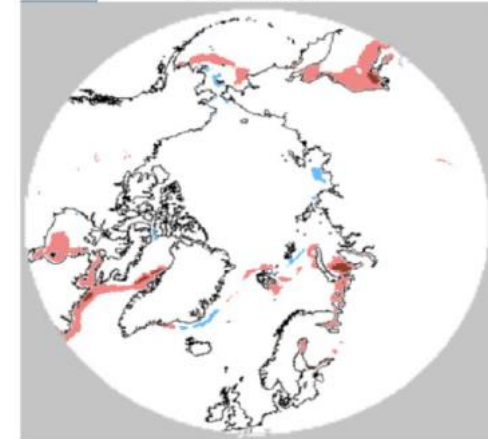
Sea ice concentration is the ocean area fraction of a covered by sea ice; the values of it are given as a real number percentage (0-100%) (0 to 100 percent ice). A value of 0 means there is no ice, while a value of 100 means the region is completely covered by ice. [ESA Sea Ice CCI](#)  
The anomalies are computed as the difference of the absolute values from the mean monthly ones.



## Sliced up maps ↓



## Feb 2007



DANAI-MARIA KONTOU, CARTOGRAPHY M.Sc.

# Web application

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

by DANAI-MARIA KONTOU

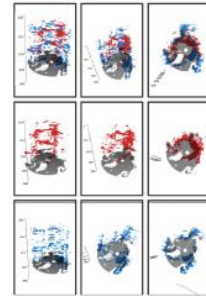
or "can the Arctic fit into Cylinders?"



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 3d 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. 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.

## 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%) (Toussard Pedersen et al., 2017).



## ARCTIC ENVIRONMENT

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).

## SPACE-TIME VISUALS

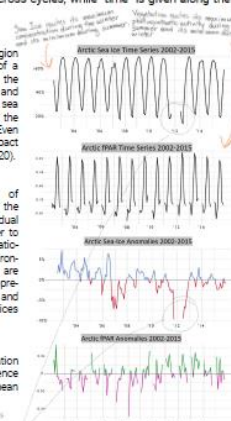
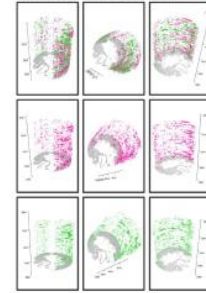
The spatio-temporal representation of climate data allows the user to look at the timing, shape and/or dynamics of individual events through space and time. In order to visualize an understandable 3d spatio-temporal visual on climate and environmental changes, the extreme events are selected. The aim of extreme event representation can be achieved by calculating and visualizing the anomalies on specific indices and fractions (Zscheischler et al., 2013).

## ANOMALIES

The anomalies of the Sea Ice Concentration and FPAR were computed as the difference of the absolute values from the mean monthly ones.

## ARCTIC VEGETATION

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, evapotranspiration and net primary production (R. Myrnes, 2015).



## 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. The analysis of sea ice concentration and FPAR and their correlation, cannot be studied independently of other climate phenomena taking place in the Arctic, such as temperature above sea and above land, snow and fires (Bhatt et al., 2010).

## THESIS CONDUCTED AT

Institute of Cartography  
Department of Geosciences  
Technische Universität Dresden



## THESIS ASSESSMENT BOARD

Chair Professor: Prof. Dr.-Ing. Dirk Burghardt

Supervisor: J.Prof. Dr. Matthias Forkel

Reviewer: Dr. Paulo Raposo (University of Twente)

## YEAR

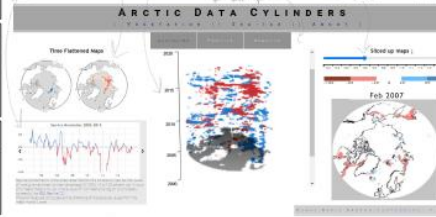
2020

## KEYWORDS

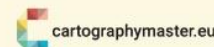
Arctic, Sea ice Concentration, Arctic Vegetation, FPAR, remote sensing, web-cartography, time geography, Data Cylinders

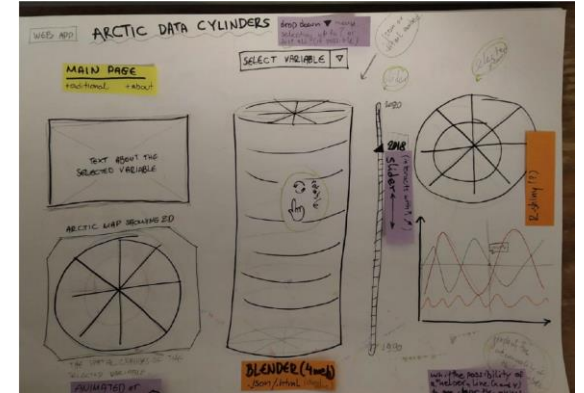
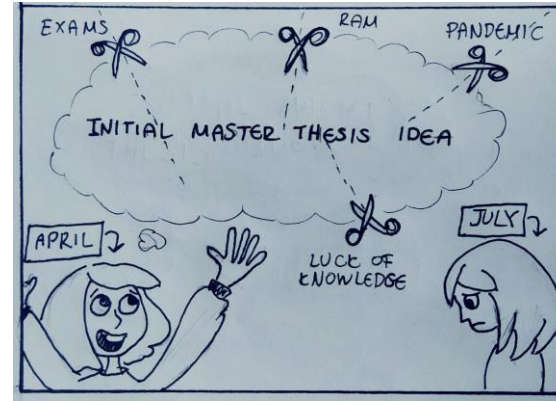
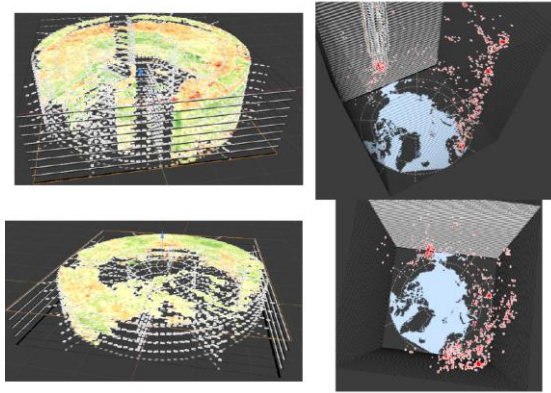
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- [3] NSIDC. (2020). All About Sea Ice. National Snow and Ice Data Center. <https://nsidc.org/cryosphere/seaice/index.html>
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Thank you for your attention...



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