



Mapping changes in Arctic permafrost landscapes with dense Landsat time-series

ESA Mapping Waterbodies from Space
ESA/ESRIN – Frascati, Italy
2015/03/18

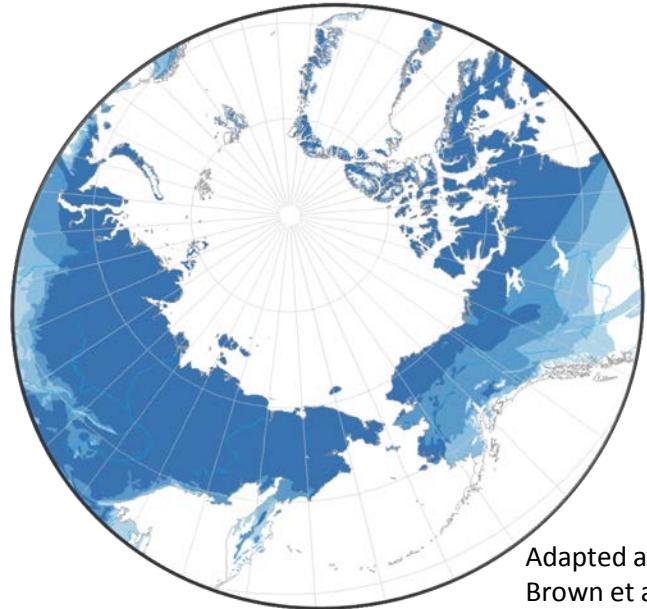
Ingmar Nitze, Guido Grosse
initze@awi.de

European Research Council



Established by
the European Commission

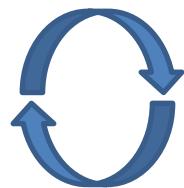
Introduction – Arctic Permafrost



Adapted after
Brown et al., 1997

Permafrost Carbon Feedback

Temperature
increase



Permafrost
degradation

Carbon release

Thermokarst/
thermoerosion

Permafrost landscapes

24 % of northern Hemisphere

Rapid dynamics in vulnerable landscape

Drastic change of climatic conditions

Large amount of water bodies

High uncertainties of process quantities

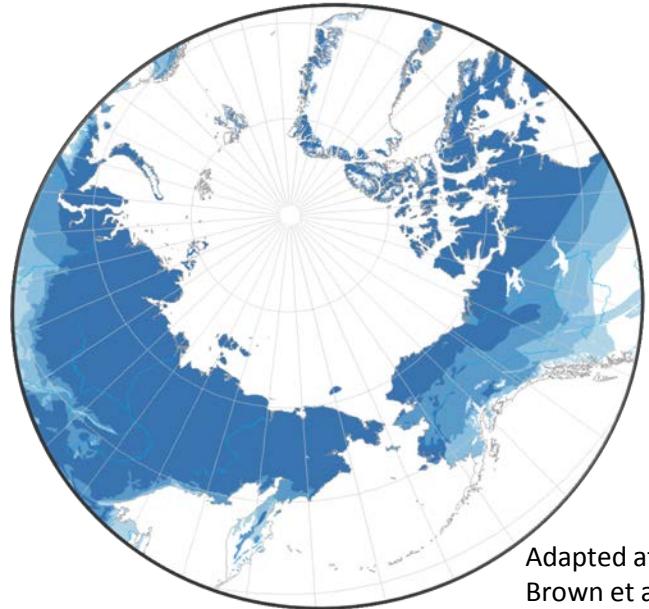
Processes

1. Ground subsidence
2. Lake formation
3. Lake expansion
4. Lake drainage
5. Vegetation emergence

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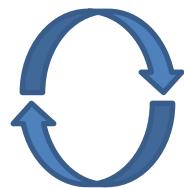
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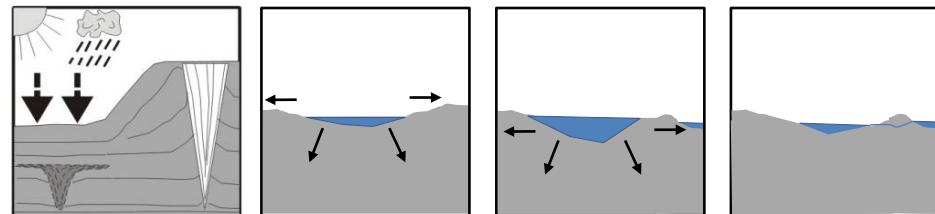
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Processes

1. Ground subsidence
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Research Goals – Study Sites

Research Goals:

Mapping landscape dynamics in permafrost regions

- a) Gradual long-term processes
 - Lake expansion
 - Coastal erosion/Transgression
 - Vegetation
- b) Rapid short-term dynamics
 - Lake drainage
 - Landslides / slumps

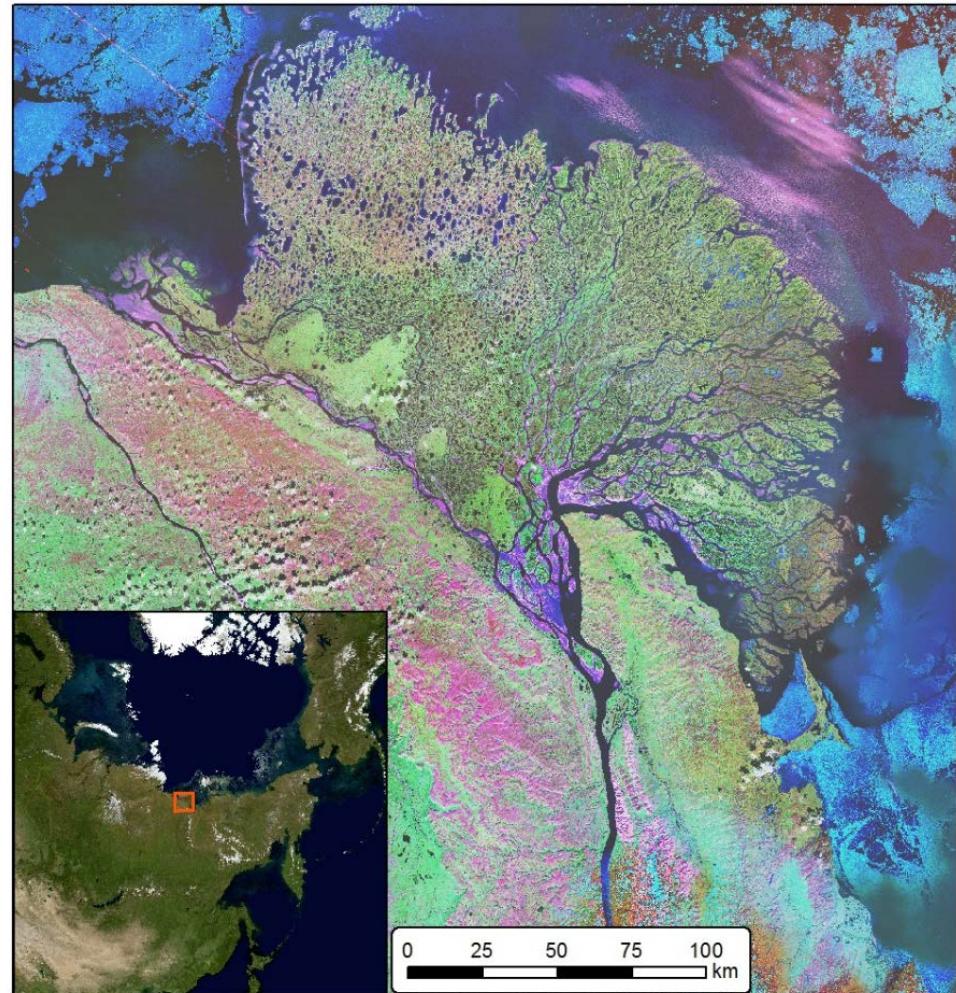
Key Methods and requirements:

Trend analysis of dense time-series

- Temporal resolution
- Spatial resolution

Robust trend analysis / regression

Process Automation



Data and Methods

Data

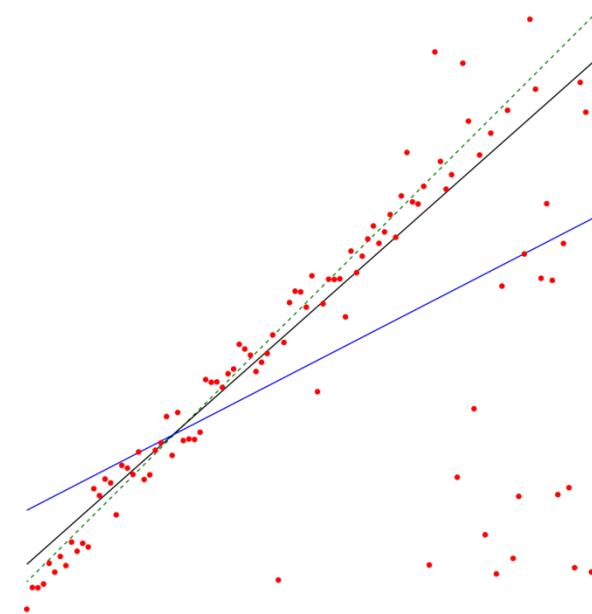
Landsat

- Spatial + spectral resolution
- Data continuity
- Consistency
- Data policy
- Mission security

	Lena Delta	Alaska Nth Slope
temporal coverage	1999 - 2014	1985 – 2014
# of images (total, <80% CC)	346	624
# of image tiles	14	10

Trend calculation

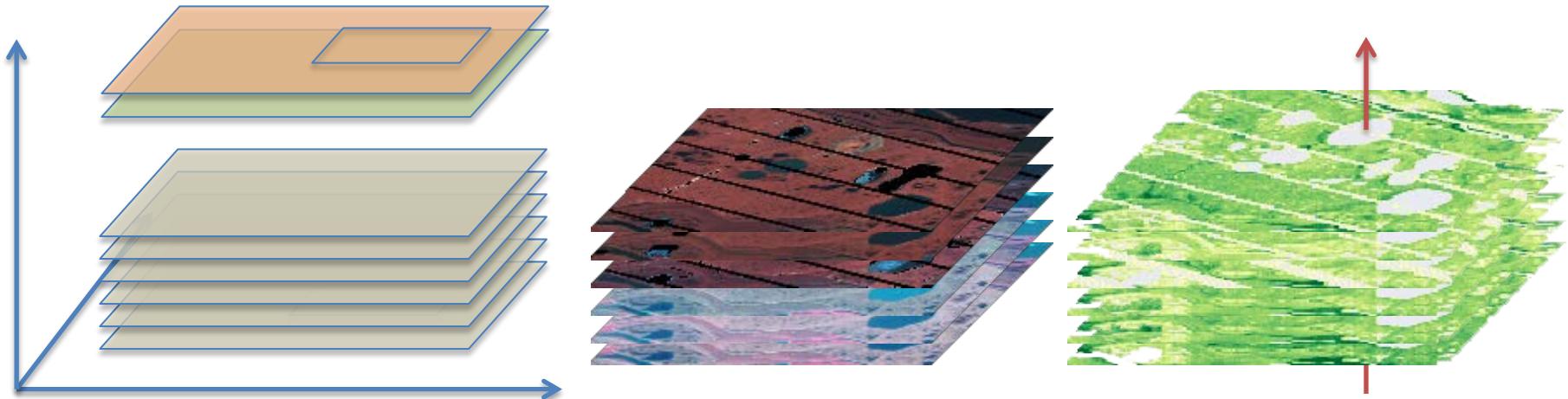
- Theil-Sen – (Sen, 1968; Theil, 1992)
- Median of Paired slopes
 - im.1 vs im.2, im.1 vs im.3, .., im.1 vs im.n
 - im.2 vs im.3, .., im.2 vs im.n,
 - im.n-1 vs im.n
- n_slopes → median
- Robust against outliers (~30 %)
- Calculate statistics



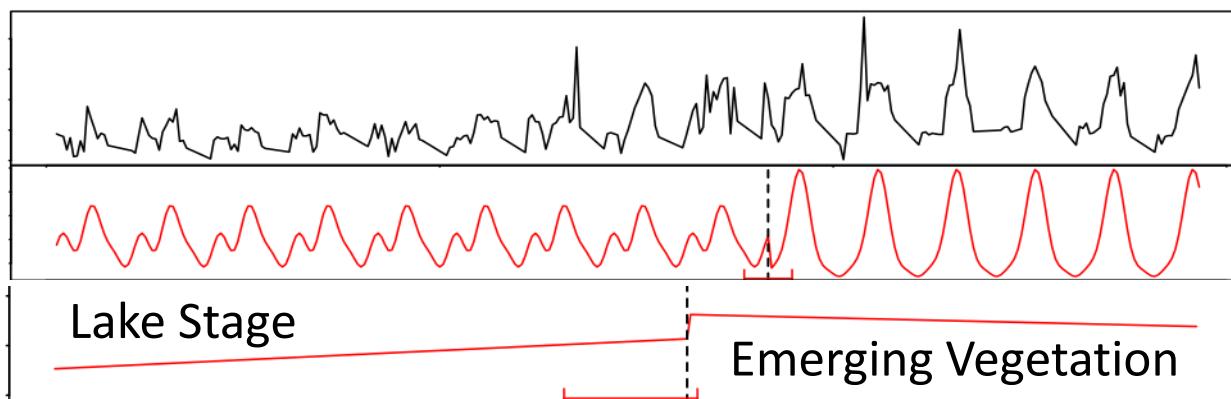
D.Eppstein

Workflow – Processing environment

Spatial analysis



Temporal analysis



Bfast-Analysis Plot: MODIS EVI Time-Series of Drained thermokarst lake, acquired from webEOM (<http://www.earth-observation-monitor.net>).

Processing Environment

100's of Landsat tiles

Repeated tasks

- Unzip, mask, reprojection, subsetting, TOA
- No manual handling possible

Automation

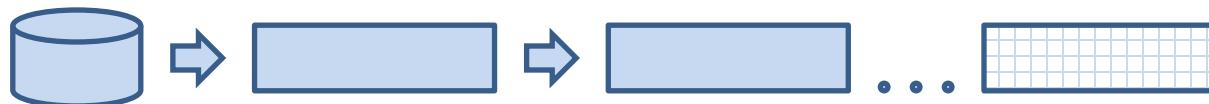
Python environment

Fmask (Zhu, 2012)

Gdal

Customised processing pipeline

A lot of code, ...



Spectral Analysis

Multispectral indices for each image

- Tasseled Cap
- NDVI
- .. many others possible

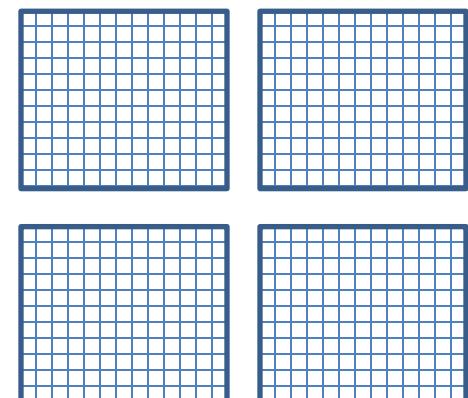


Temporal Analysis

- T-S slope calculation
- each index
- each px
- parallel processing



Map Output



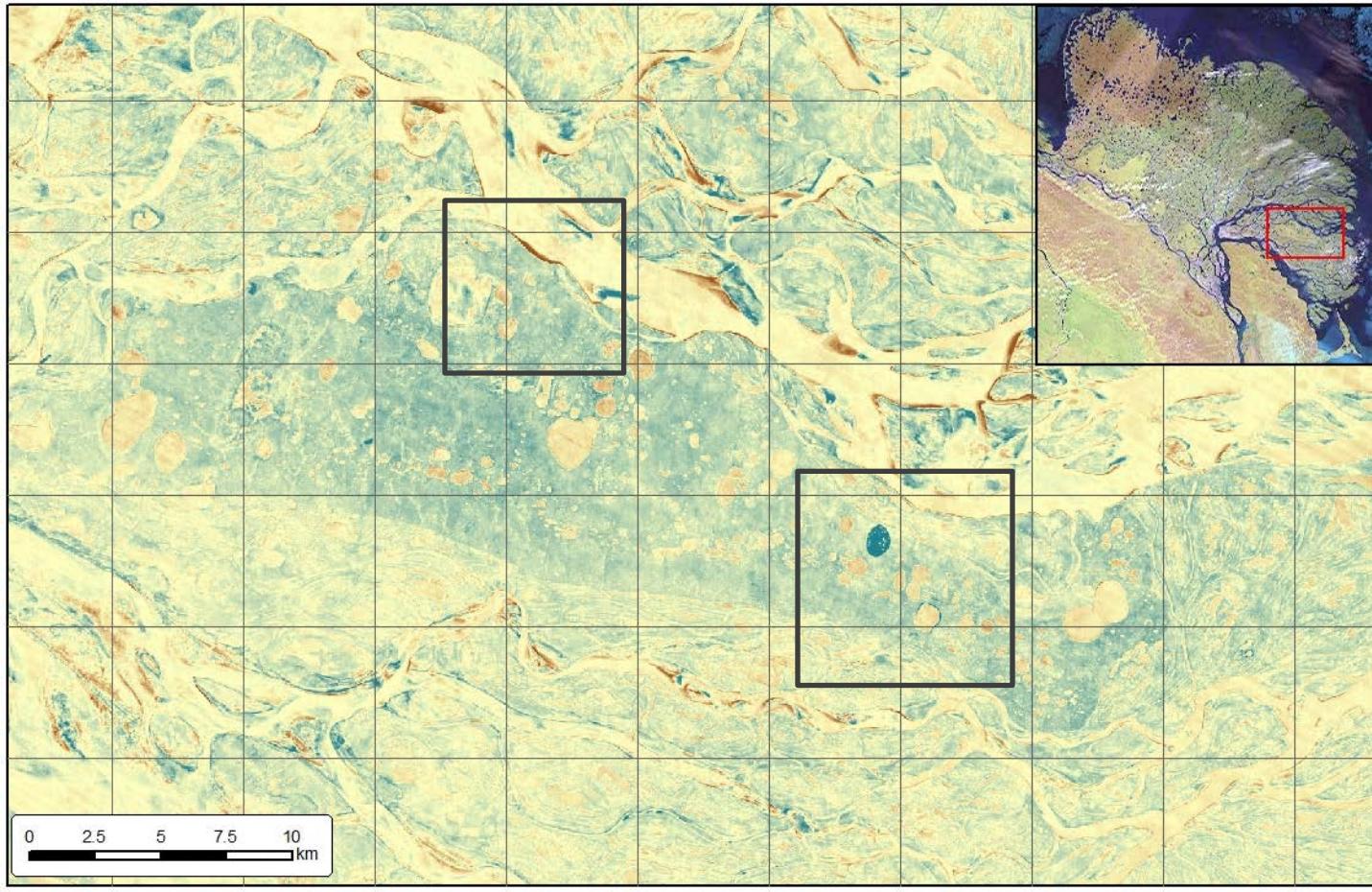
Results – Local Scale

Sobo Sise, Eastern Lena Delta

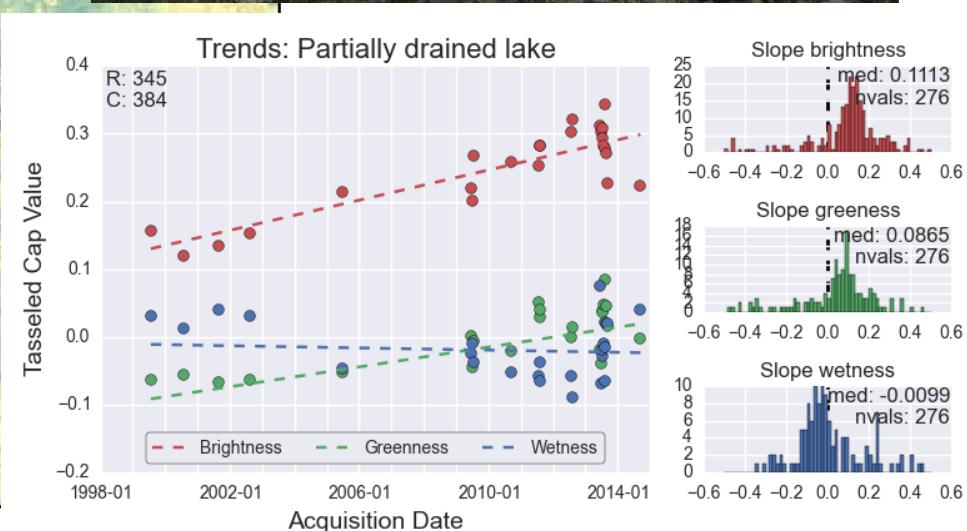
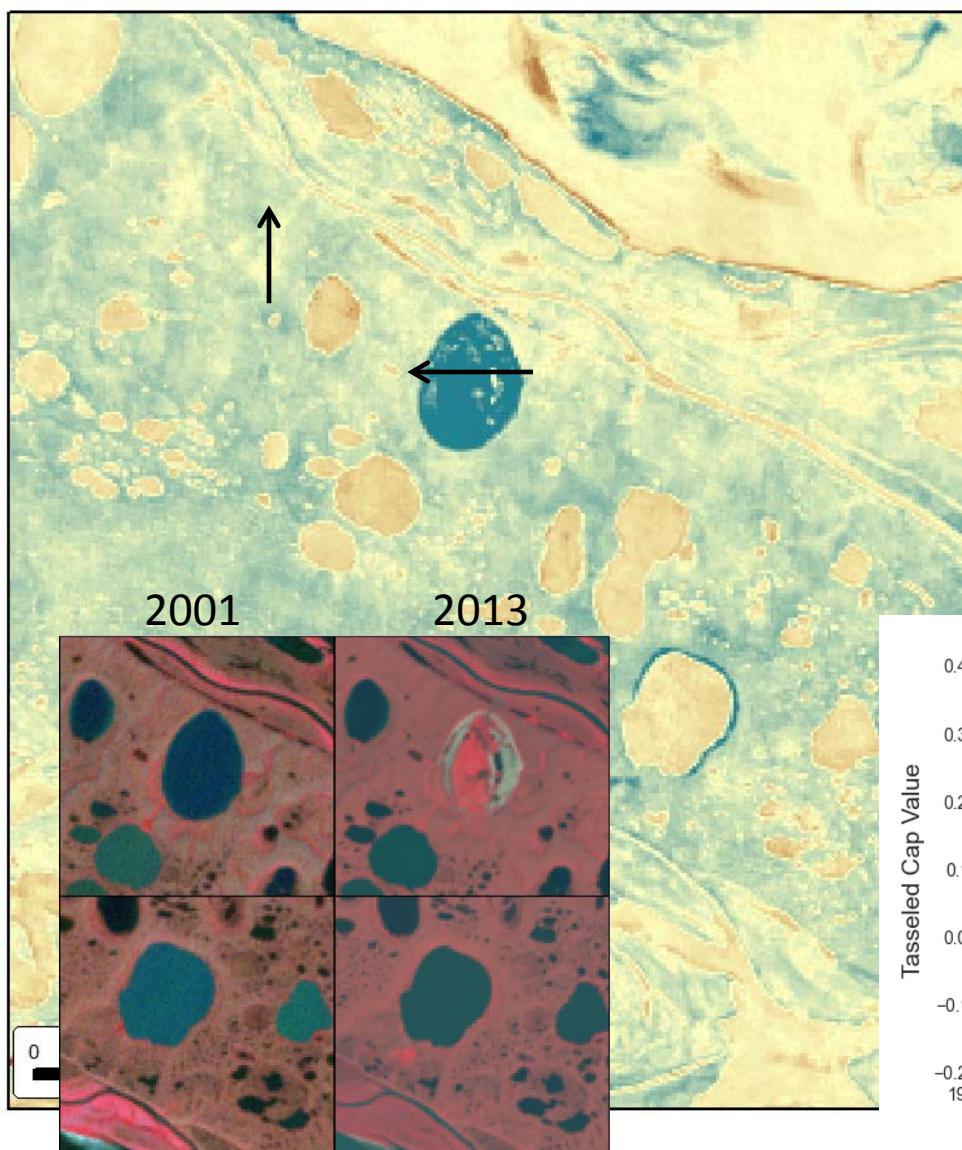
Landsat Tasseled Cap **Brightness Trend** (change per decade)

Years 1999 – 2014 - more than 140 Landsat Scenes (TM, ETM+, OLI)

~ 30 to 50 Observations



Results – Local Scale



Results – Local Scale

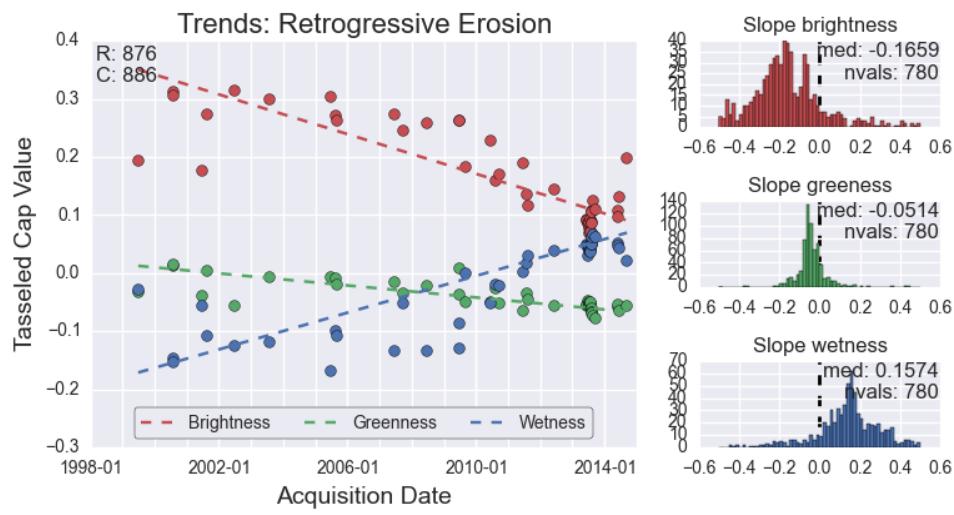
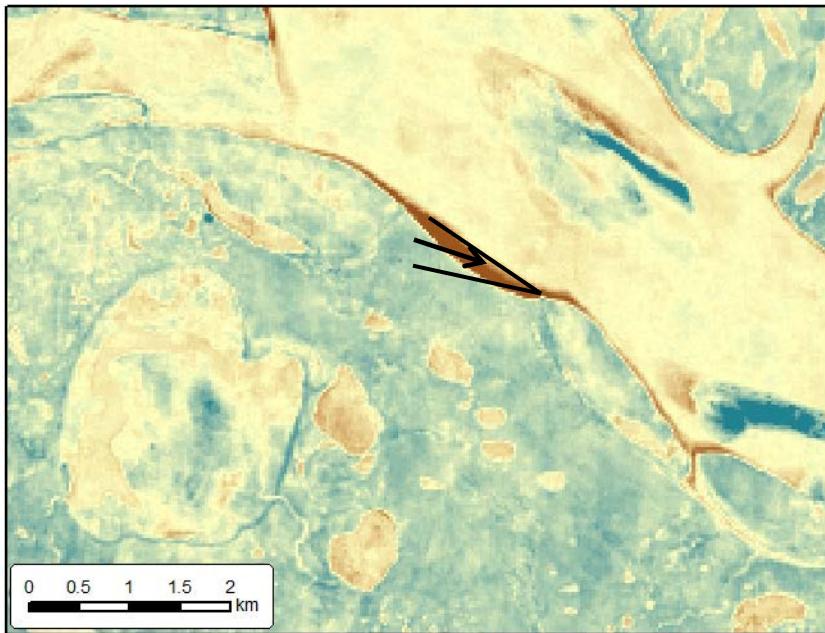
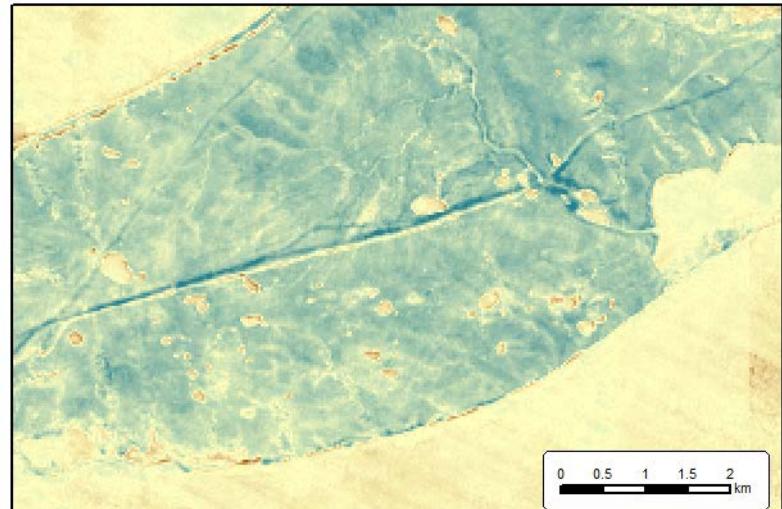
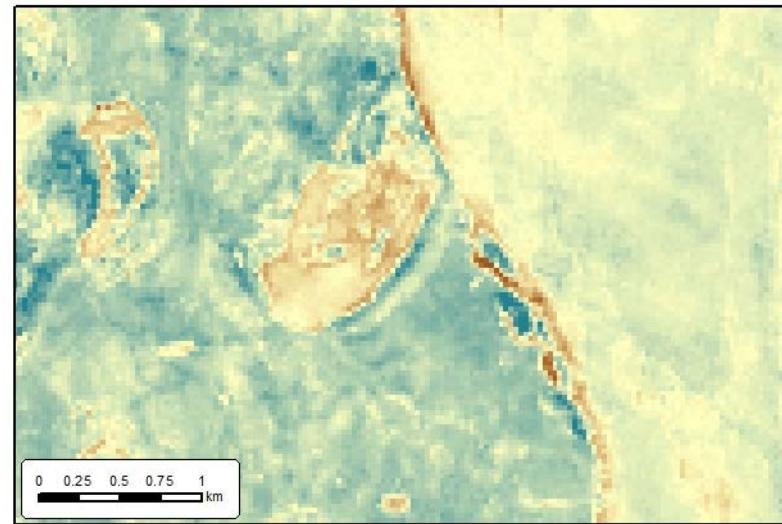


Photo: G.Grosse

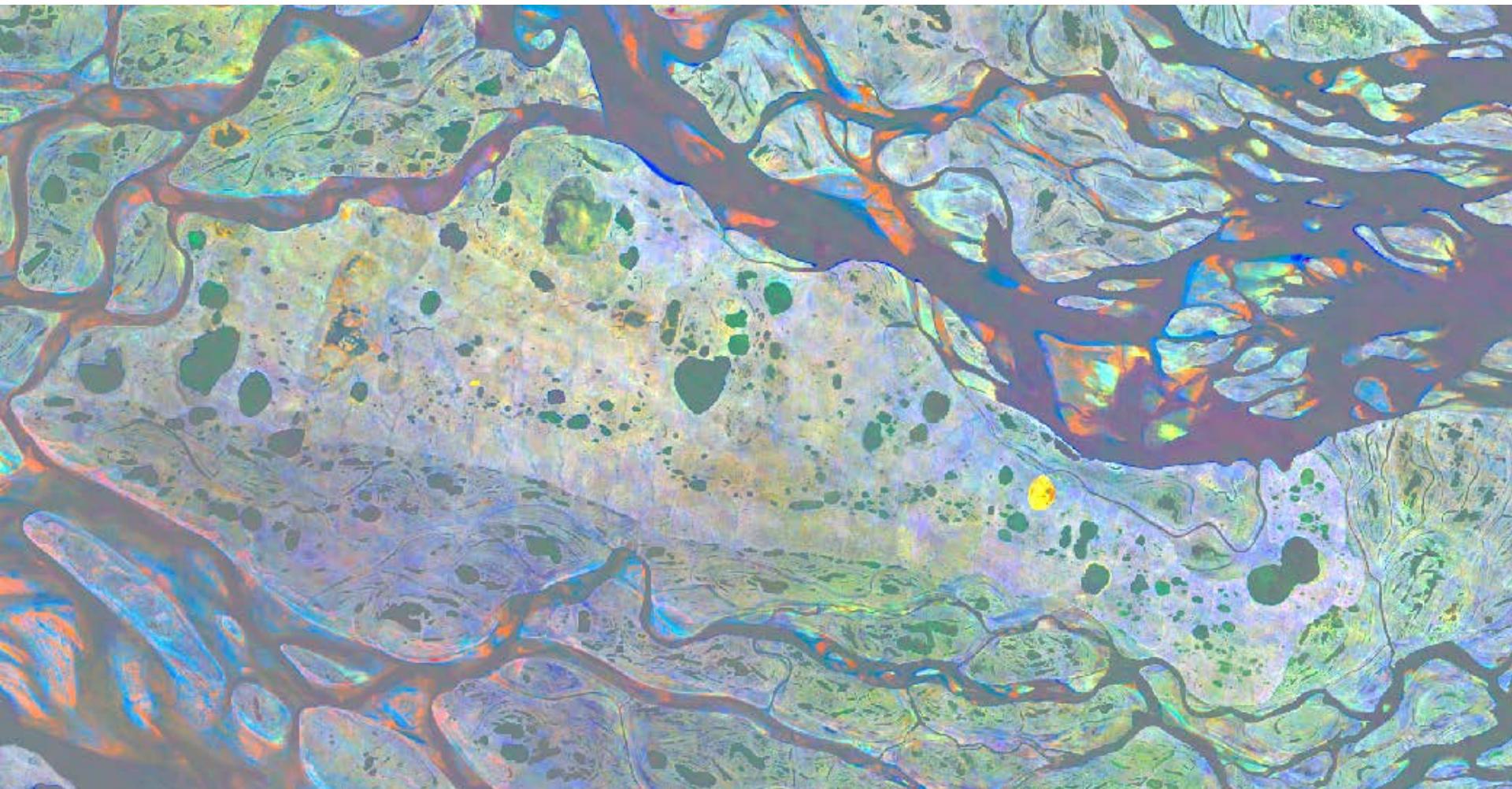
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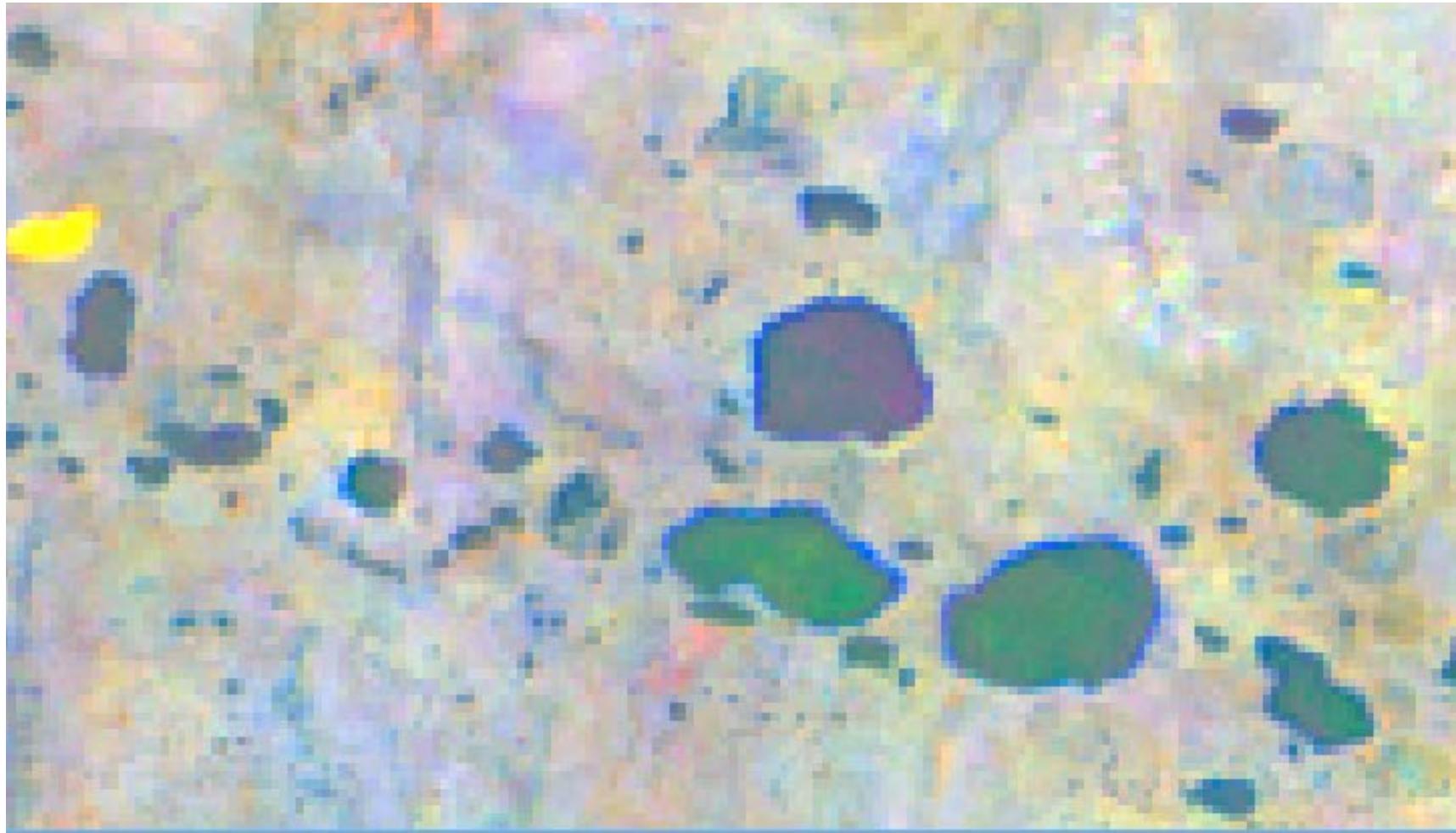
Results – Local Scale



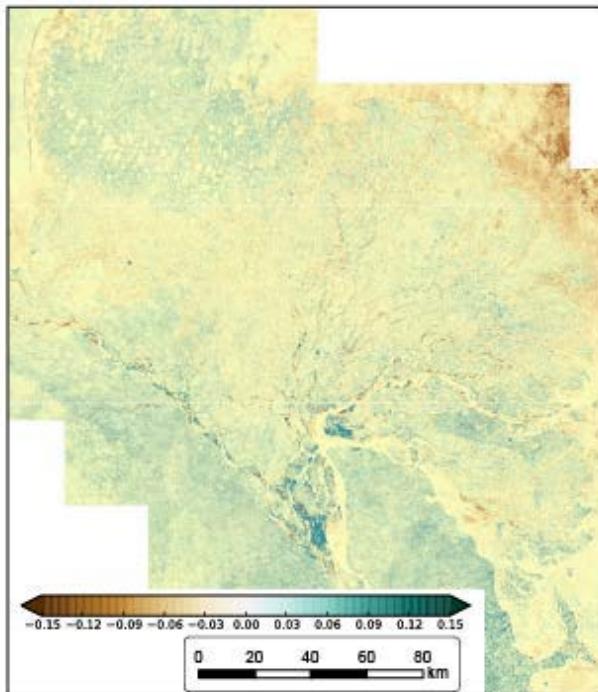
Results - Visualisation



Results - Visualisation

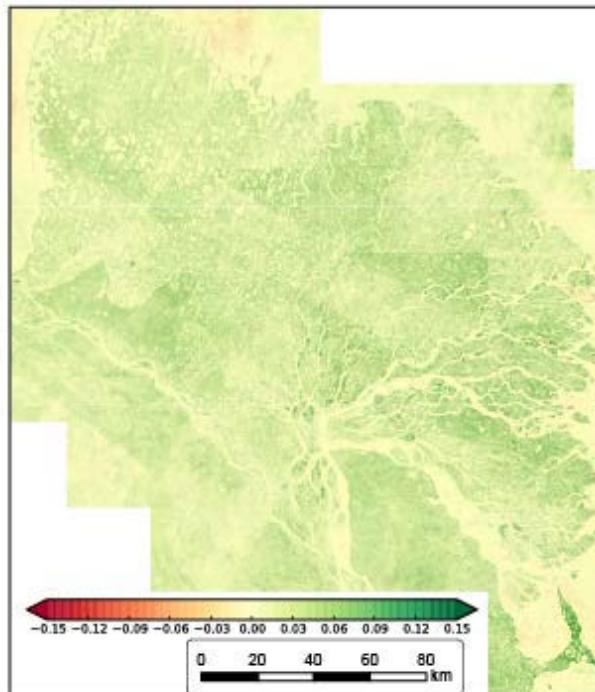


Spatial Expansion – Regional Scale



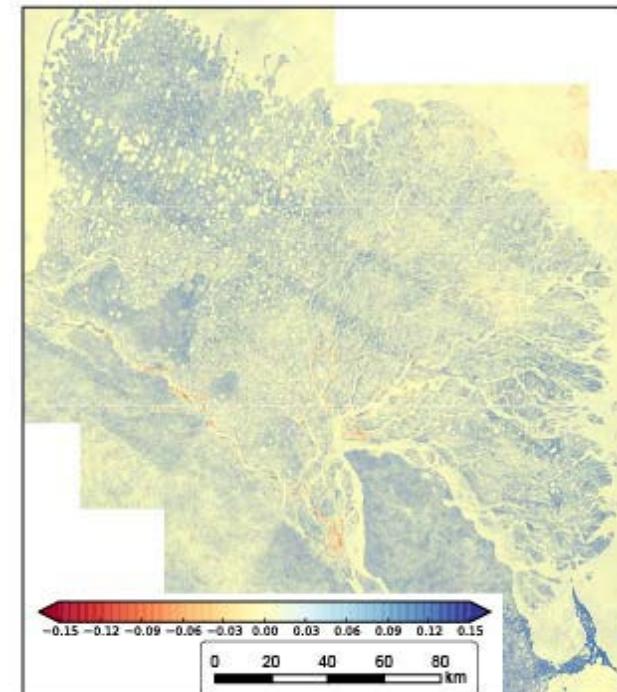
Brighter?

Active fluvial processes
Geology



Greener?

Arctic Greening



Wetter?

Geology
Tiksi Bay

Summary and Outlook

Trend detection on dense time-series

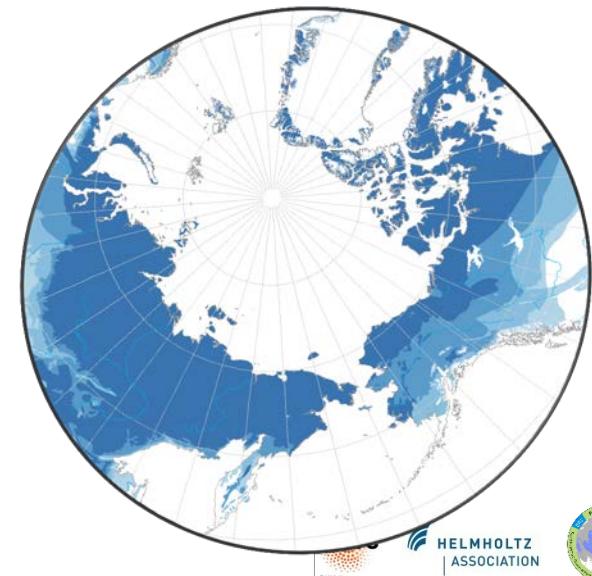
- Landsat resolution (30m)
- Robust Trend-calculation of multi-spectral indices
- Highly automated workflow
- Scalability
- Database for Process Detection

Trend based process detection

- Thermokarst cycle
- Fluvial processes
- Coastal processes
- Landslides
- ...
- Lena Delta – Alaska North Slope

Outlook

- Spatial upscaling – Pan-arctic
 - Additional Resources necessary
- Integration of Sentinel-2
- Automatic Process Detection
- Breakpoint Detection





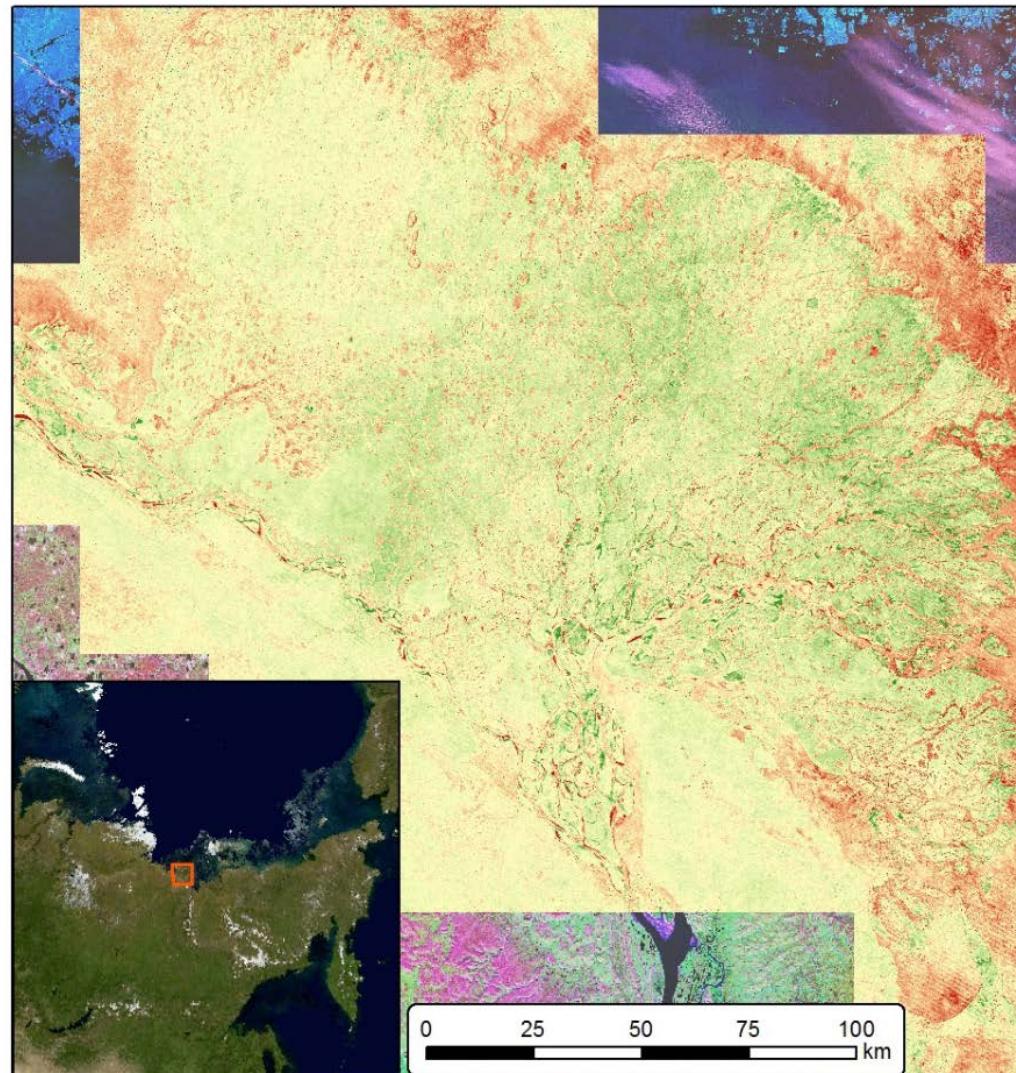
Thank You !
initze@awi.de



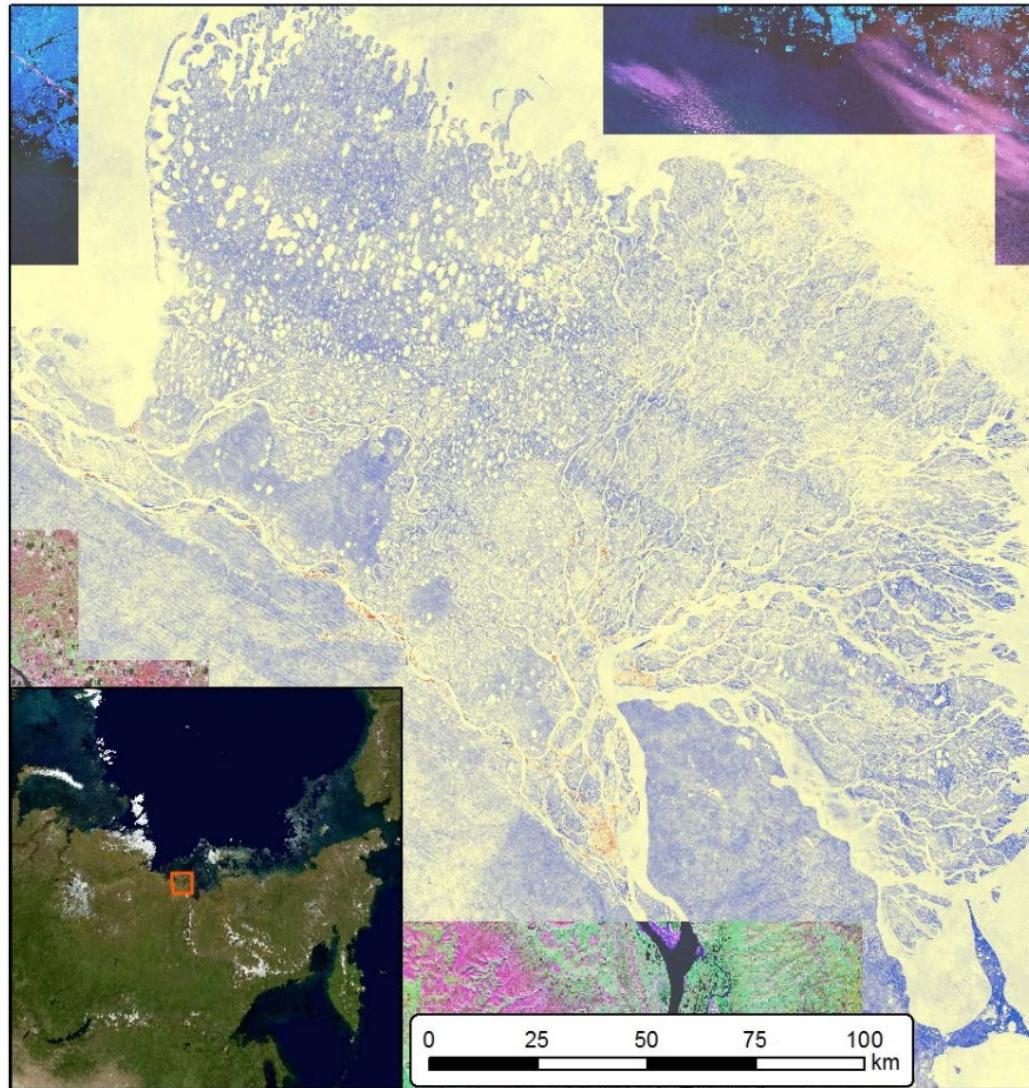
References

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- Theil, H. (1992). A rank-invariant method of linear and polynomial regression analysis. In *Henri Theil's Contributions to Economics and Econometrics* (pp. 345-381). Springer Netherlands.
- David Eppstein -
https://en.wikipedia.org/wiki/Theil%20%93Sen_estimator#/media/File:Thiel-Sen_estimator.svg

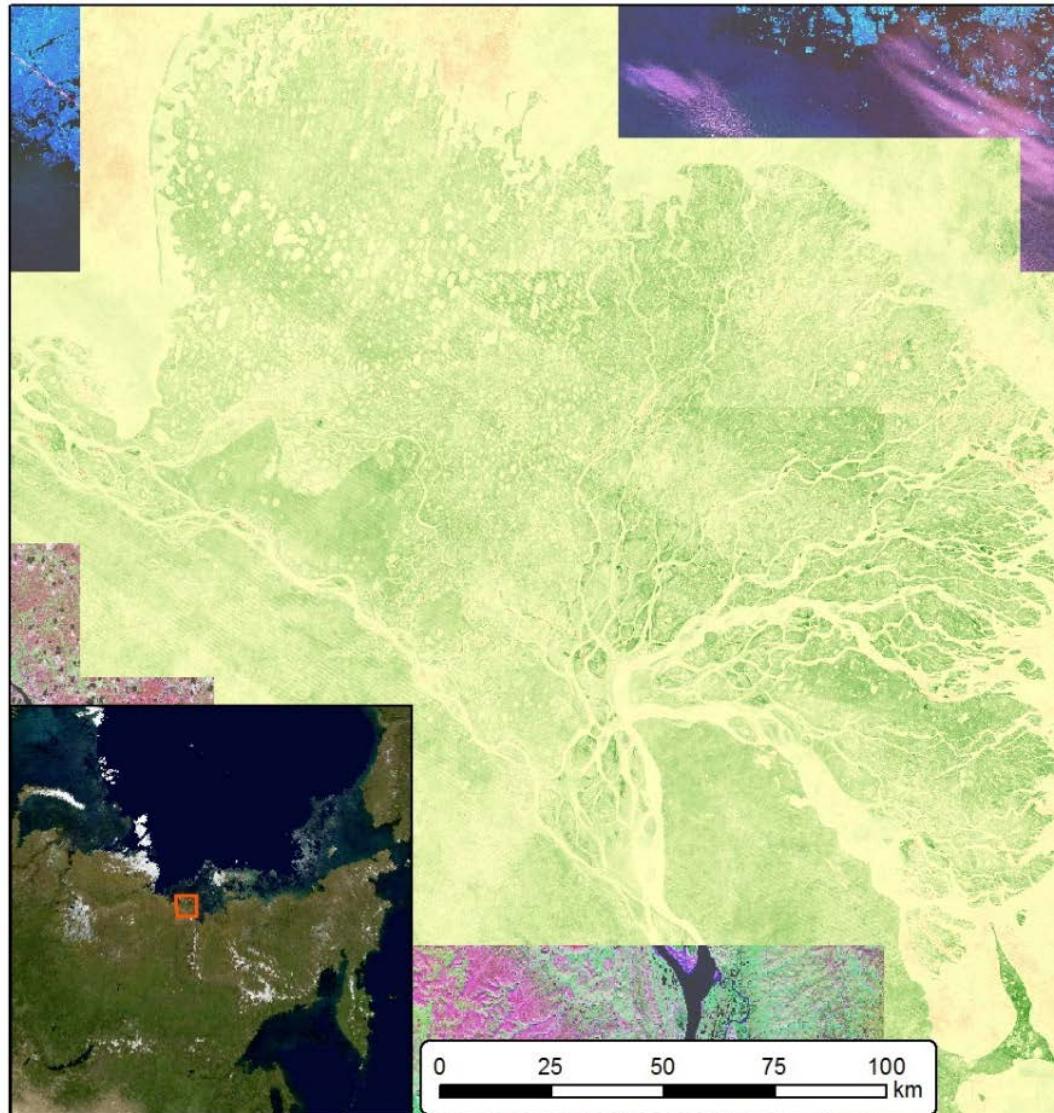
Appendix - NDVI



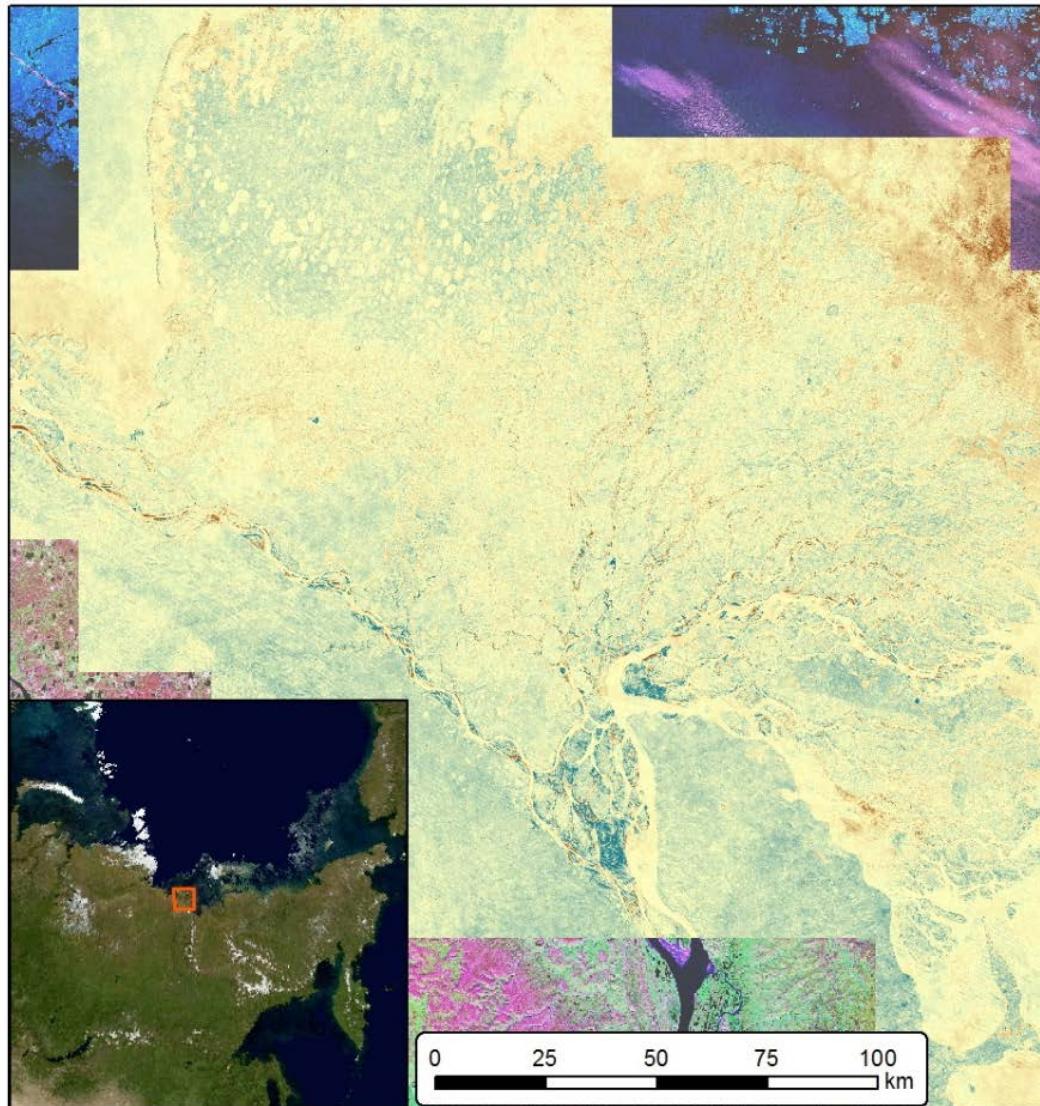
Appendix - Wetness



Appendix - Greenness



Appendix - Brightness



Appendix – N_OBS

