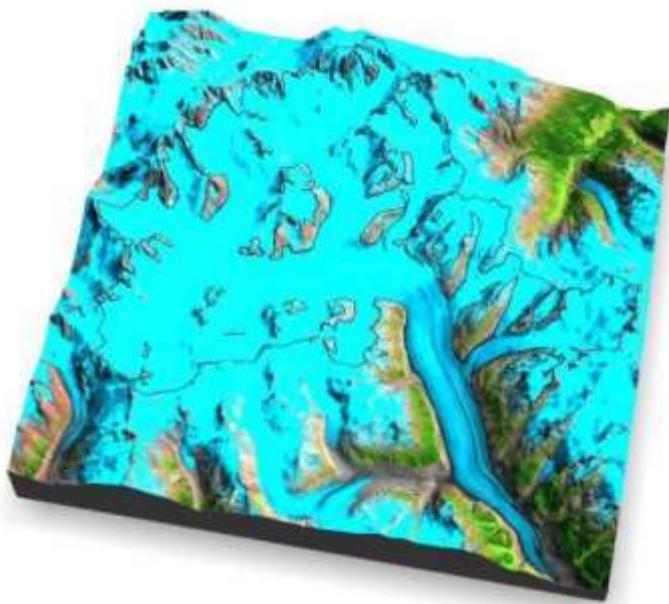


Time series analysis in Remote Sensing

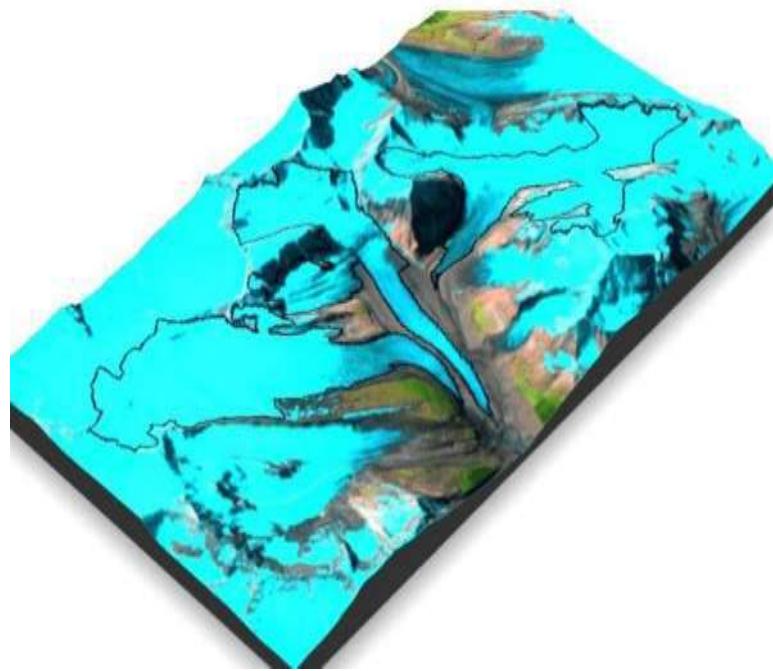
Alexandre.Bevington@gov.bc.ca

March 13, 2022

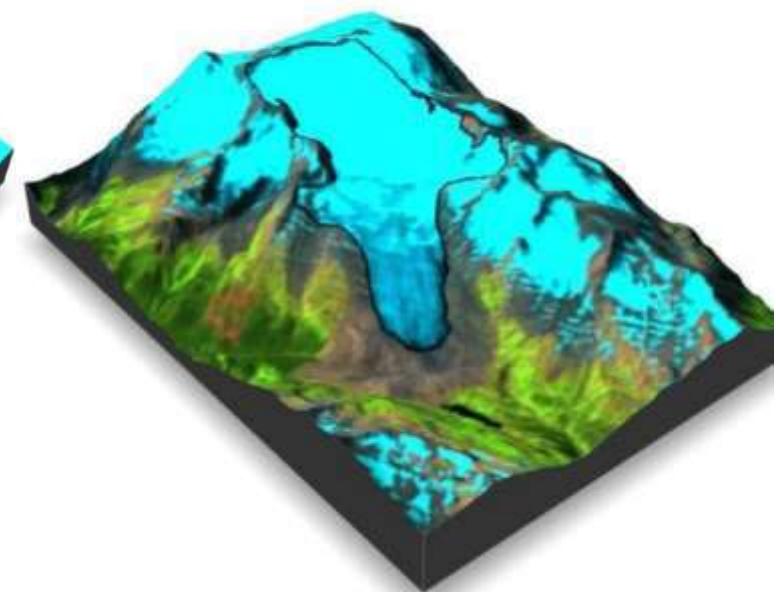
1985



1985

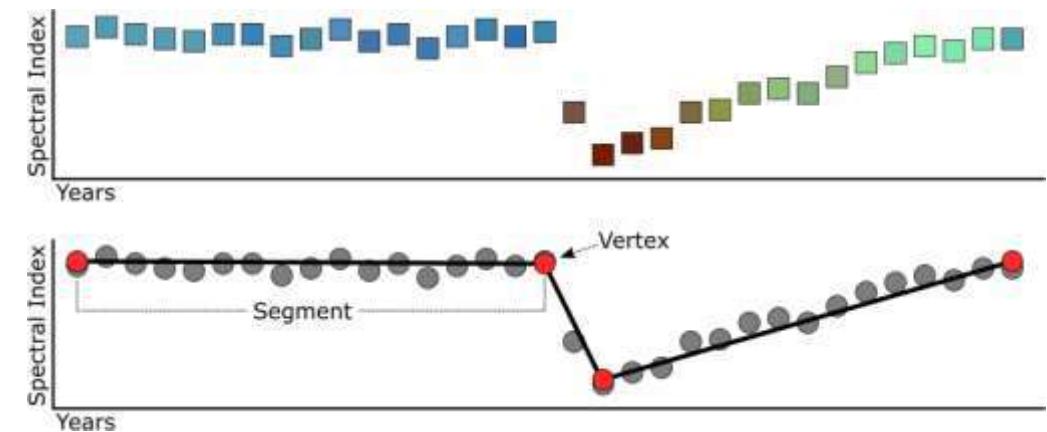
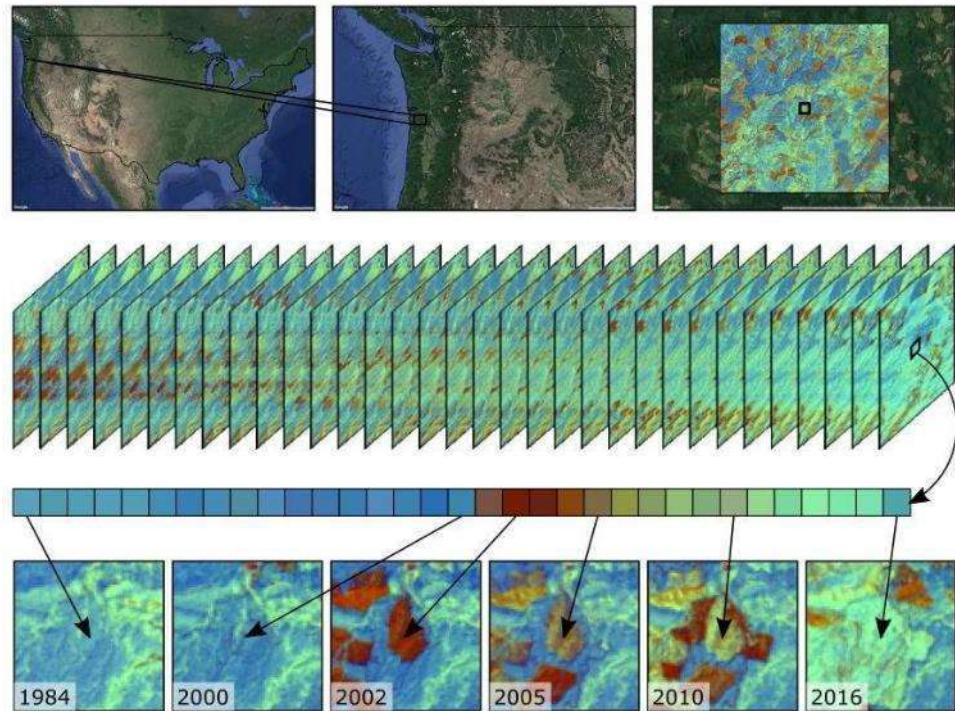


1985

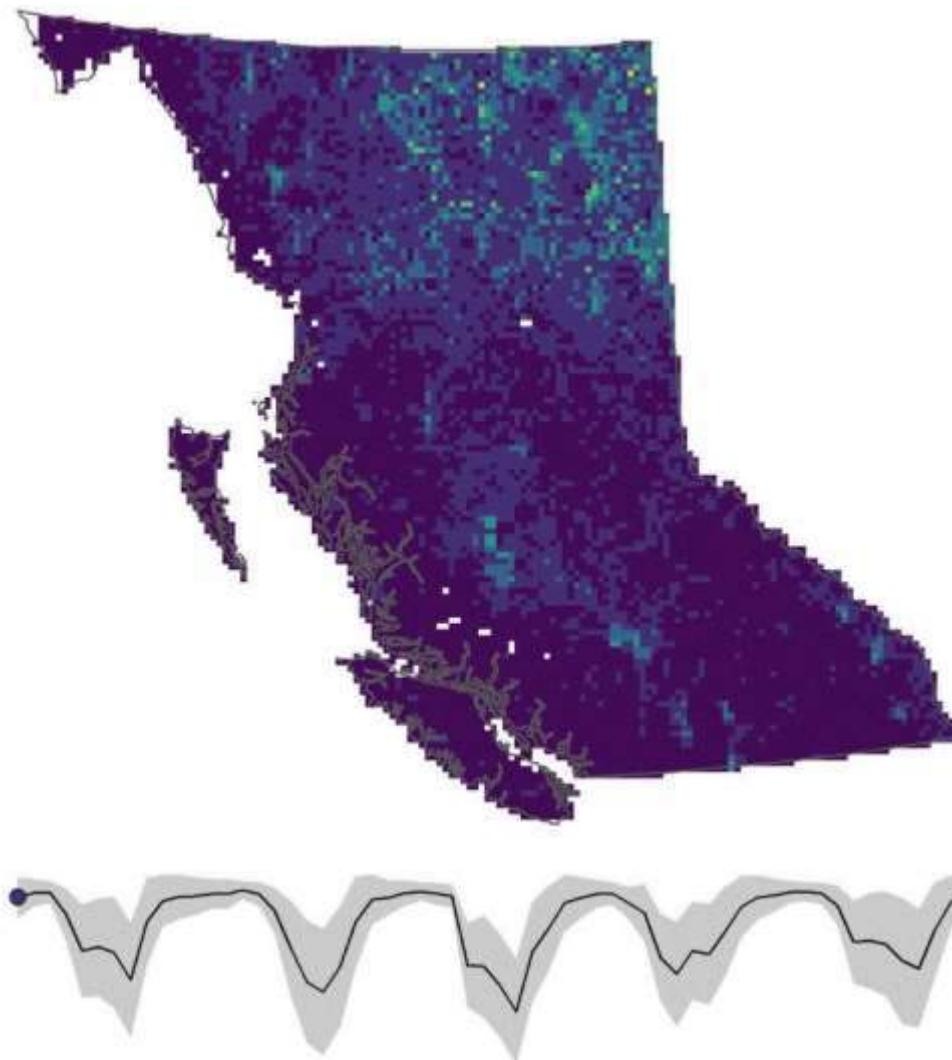


Time series

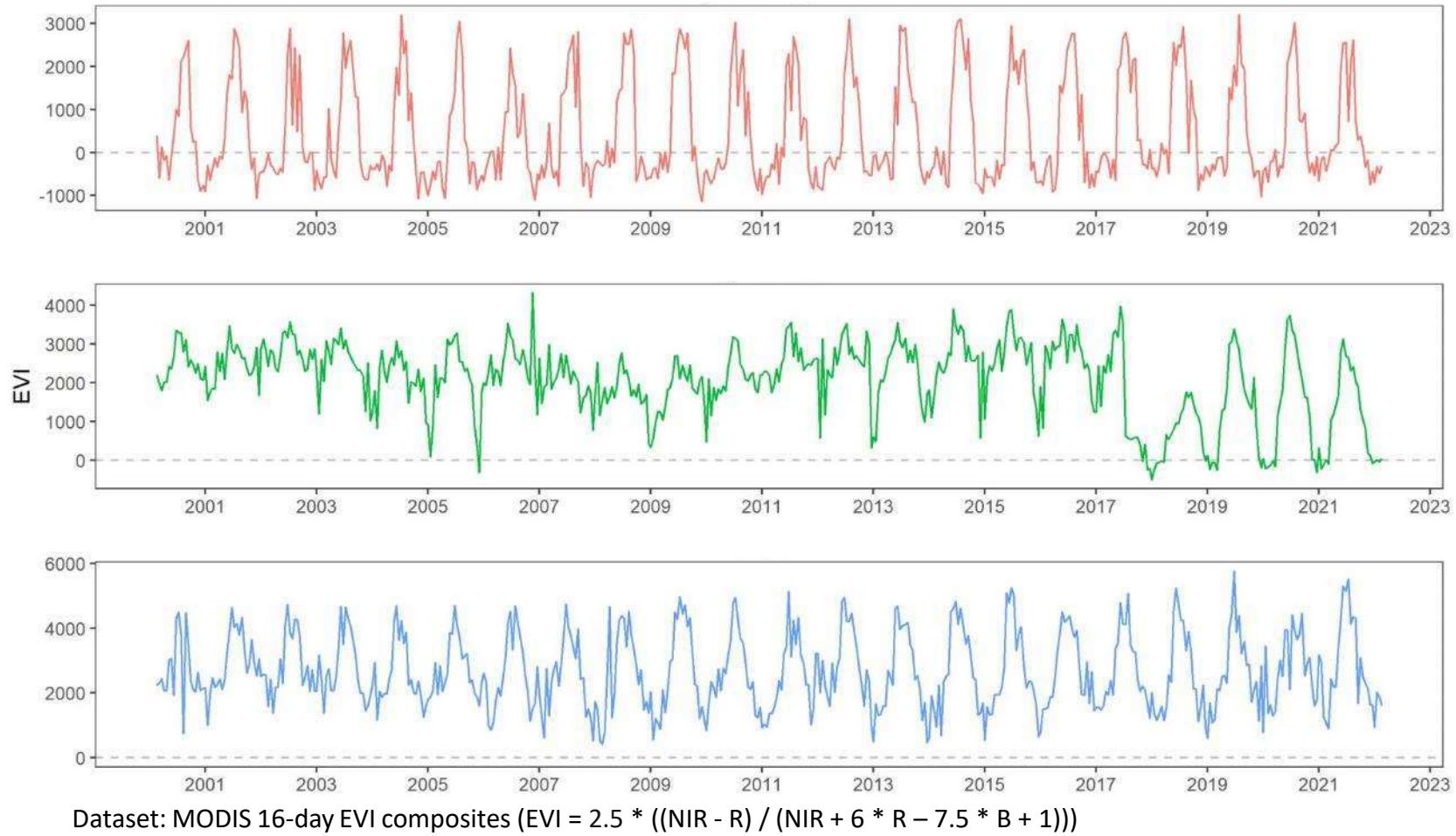
A sequence of data points at regular or irregular time intervals (e.g. weather data, stock market data, etc.)
In remote sensing, a time series is typically the spectral values of a given pixel through a temporal stack.

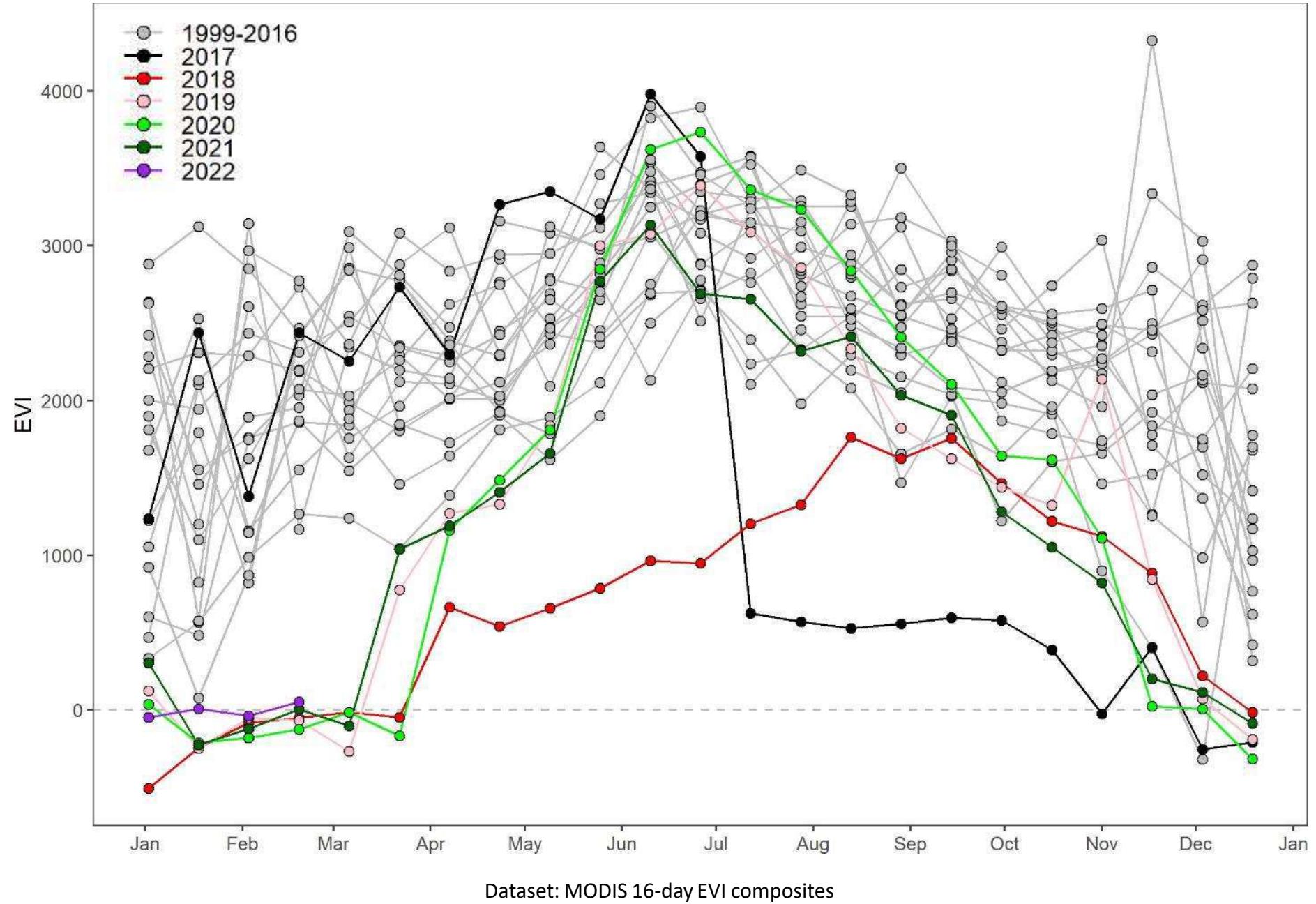


2016 January



What can you tell me about these three sites?



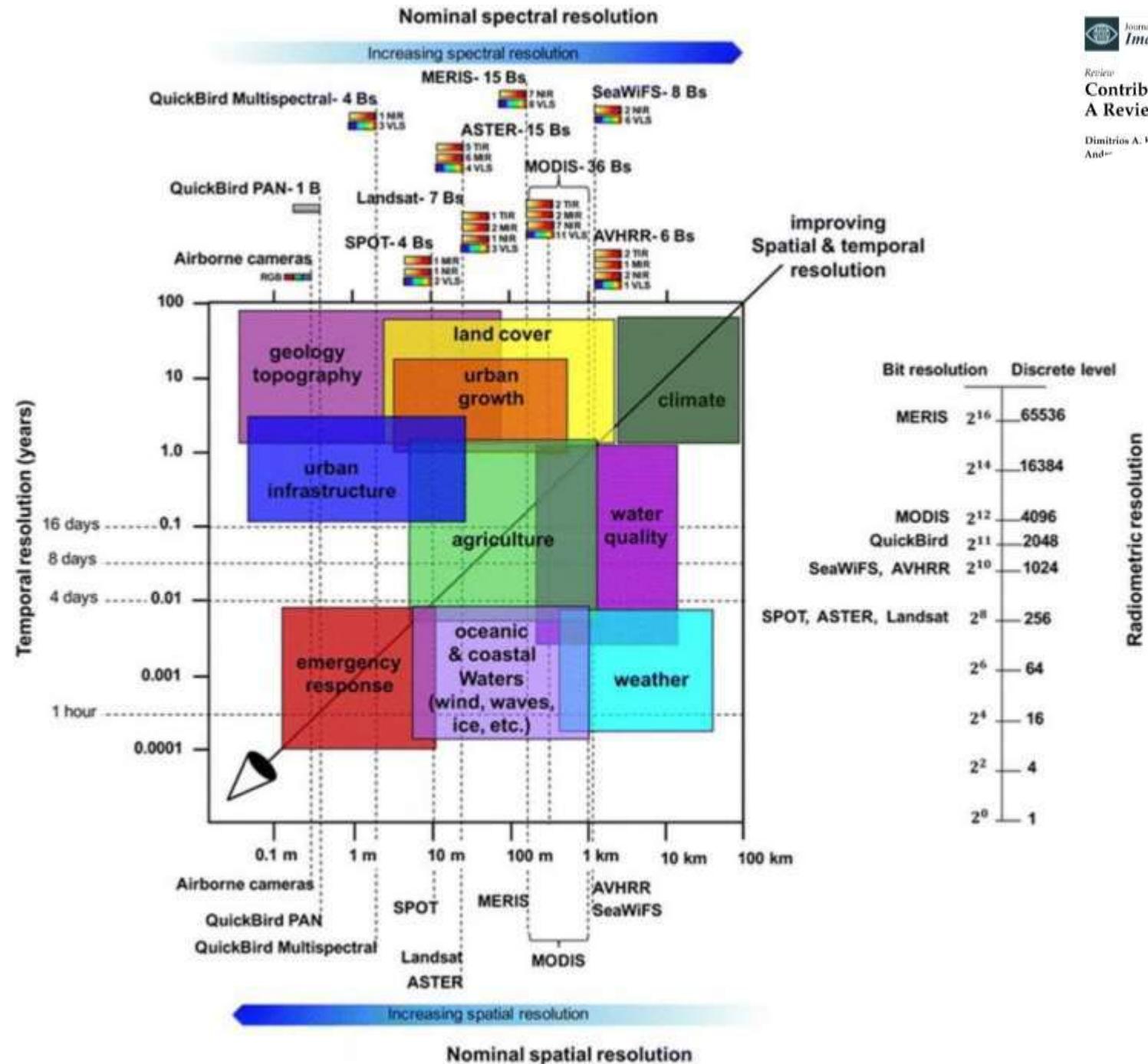


Time series analysis

- Extract pixel values from a temporal stack
- Apply function to time series for every pixel
- Example: MODIS image stack for all of BC
 - ~4,000,000 pixels
 - 365 days from 1999-2021 ~ 8000
 - Combine MODIS Aqua and Terra ~ 16000 data points per pixel time series
 - 4 million times a 16,000-point time series
- Automatic methods required
- Computationally expensive! Solution: parallel/cloud computing

Time series analysis

- Challenges
 - Contamination (e.g. clouds, fog, aerosols, smoke, shadows)
 - Spectral fidelity between sensors (e.g. Landsat 4 to 5 to 7 to 8)
 - Best practice to use calibrated Surface Reflectance data
- Return period / Temporal resolution:
 - Regular – MODIS, VIIRS, Sentinel-3
 - Dense time series, reliable
 - Irregular – Landsat, Sentinel
 - Some months or years there are no good images
 - Challenge for reliable detection
 - Sparse – Tasked satellites (WorldView, SkySat, etc.)
 - Very challenging for time series analysis!



Methods

- Temporal aggregations
- Gap filling
- Outlier detection
- Detrending
- Time series smoothing
- Harmonics
- Breakpoint detection
- Classification

Temporal aggregations

- Statistical mosaics:
 - Filter images and calculate a stack statistic
 - Filter collection (DOY, Cloud Cover, ...)
 - Mask clouds (FMASK, NDCI, ...)
 - Calculate a statistic (mean, median, etc.)
 - <https://code.earthengine.google.com/47f2685d752c1614fe6b842942c7e3dc>
- Best available pixel (BAP) mosaics:
 - Sort each pixel so the best is at the top
 - Distance to clouds and shadows masks
 - Atmospheric Opacity
 - Day of the year, ...
 - <https://code.earthengine.google.com/e27240a92ecf64bbadf8a082b91c711c?hideCode=true>



Mike Wulder

@mikewulder

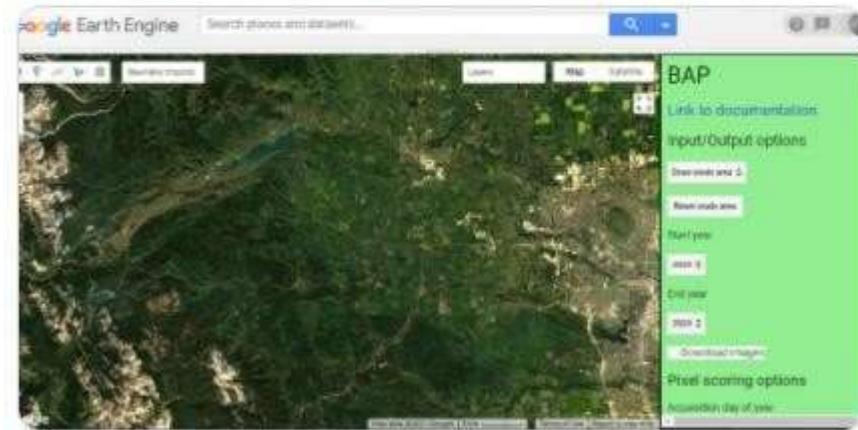
...

The best-available-pixel (BAP) tool you have been waiting for! Implemented on [#GoogleEarthEngine](#) ([#GEE](#)). [#Landsat](#)

In [#GEEBAP](#) can tune composite parameters, create a [#timeseries](#), set area of interest, AND download surface reflectance outcomes!

Try it out:

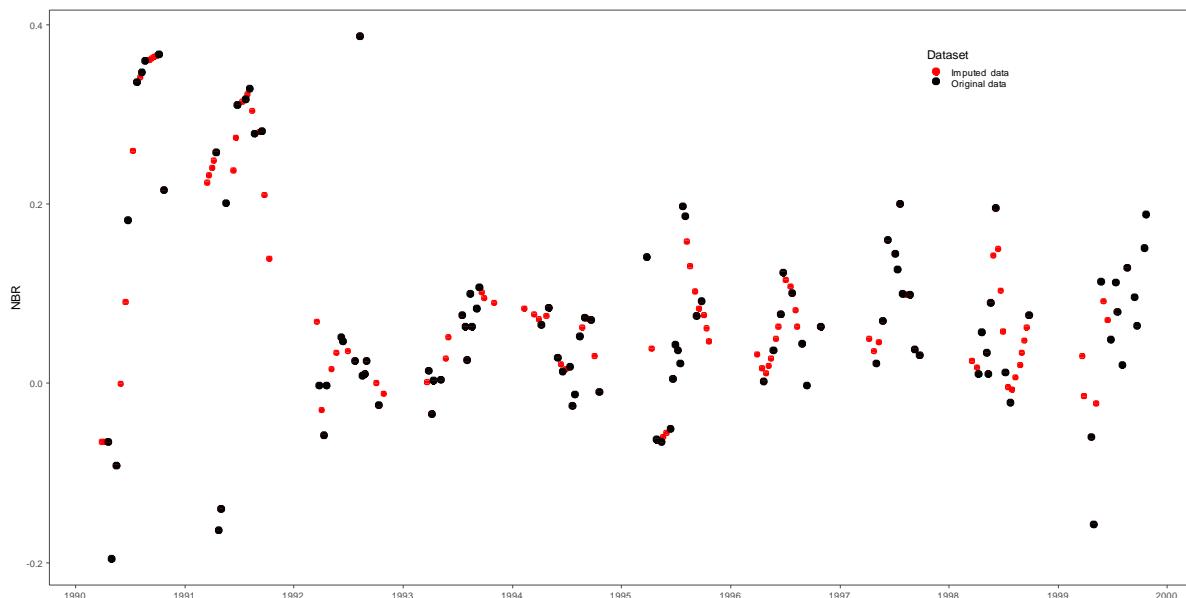
code.earthengine.google.com/e27240a92ecf64...



Saverio Francini and 7 others

11:00 AM - Apr 29, 2021 - Twitter Web App

Gap filling: Impute NoData



Gap filling: Spatial / Temporal

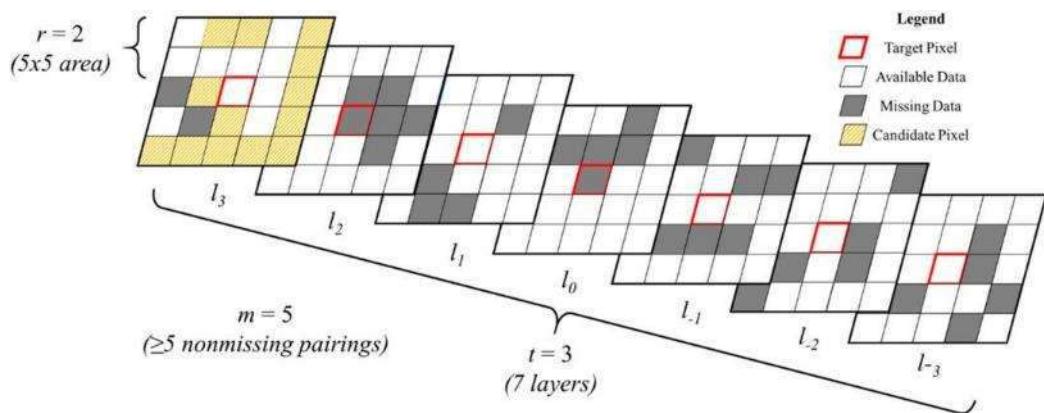
Open Access Feature Paper Article

Using Window Regression to Gap-Fill Landsat ETM+ Post SLC-Off Data

by Evan B. Brooks ^{*}, Randolph H. Wynne and Valerie A. Thomas

Department of Forest Resources and Environmental Conservation, Virginia Tech, Blacksburg, VA 24061, USA

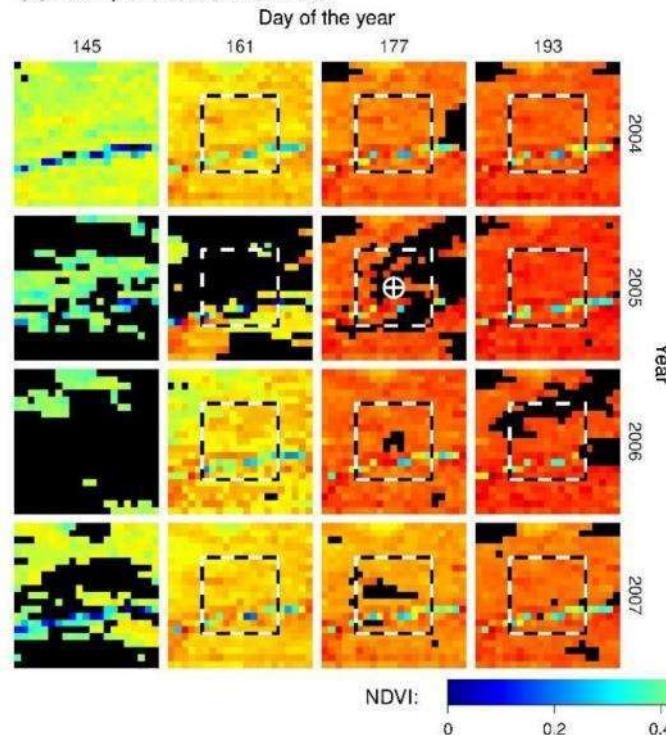
^{*} Author to whom correspondence should be addressed.



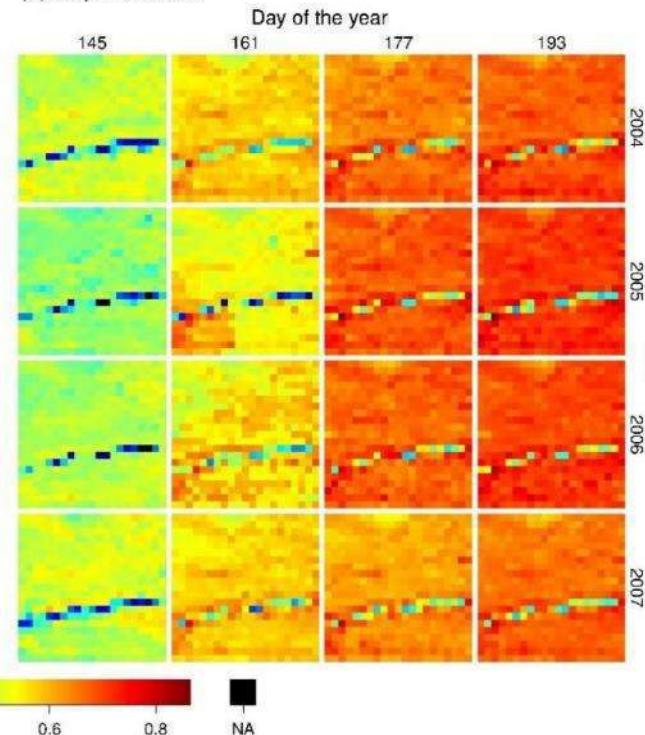
Predicting missing values in spatio-temporal satellite data

Florian Gerber^a, Reinhard Furrer^a, Gabriela Schaepman-Strub^b, Rogier de Jong^c, Michael E. Schaepman^c

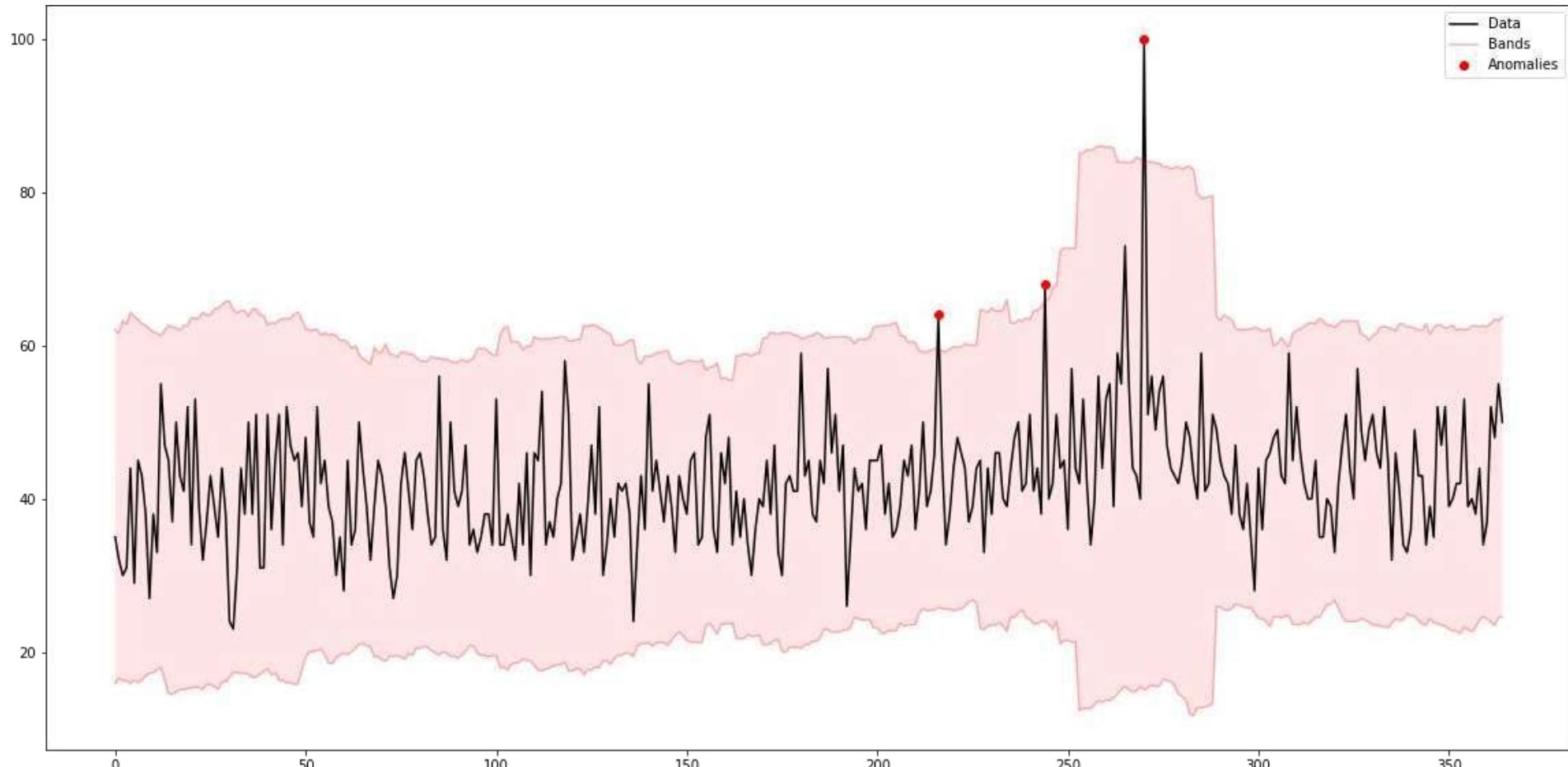
(a) Example MODIS NDVI data



(b) Gap-filled data



Outlier detection and removal



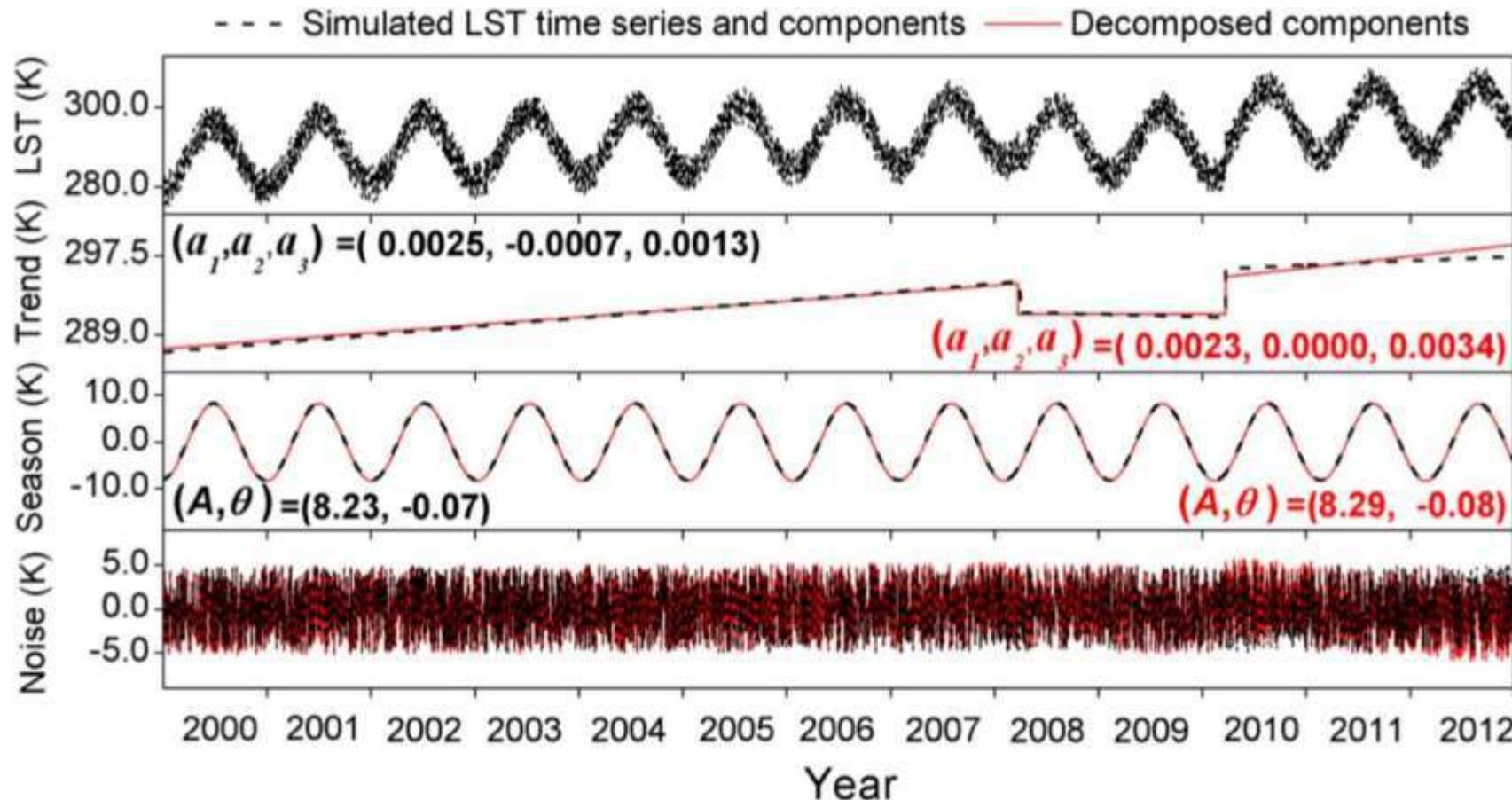
RESEARCH ARTICLE

10.1002/2015JD024354

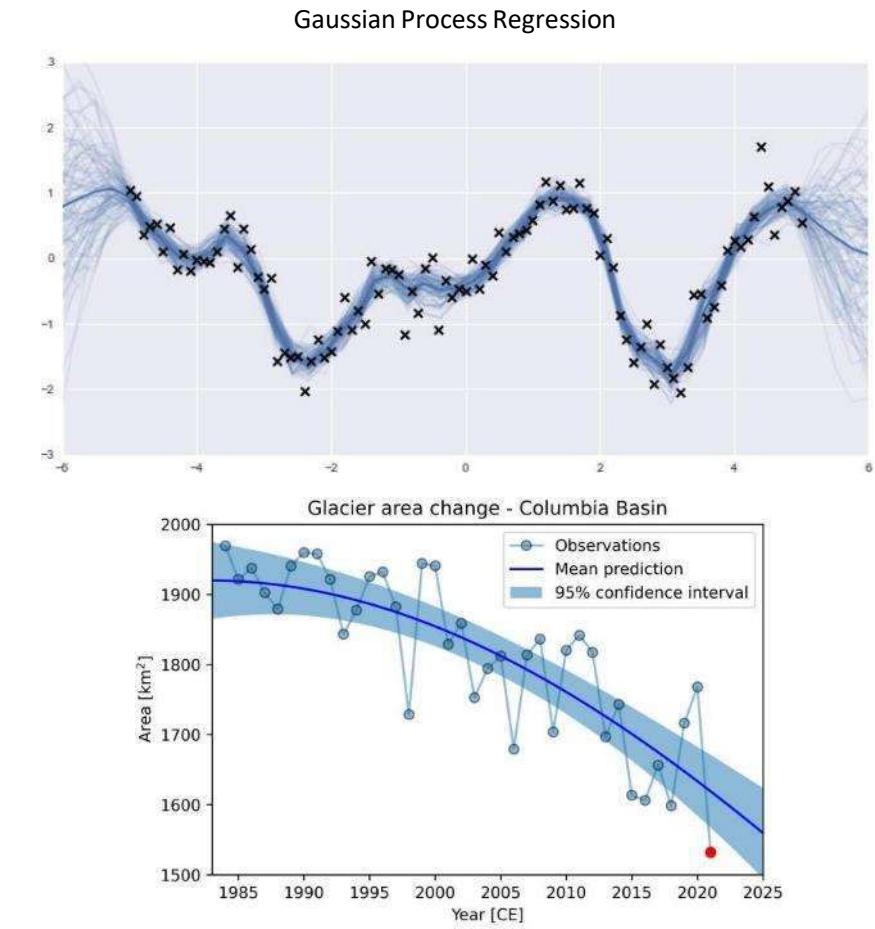
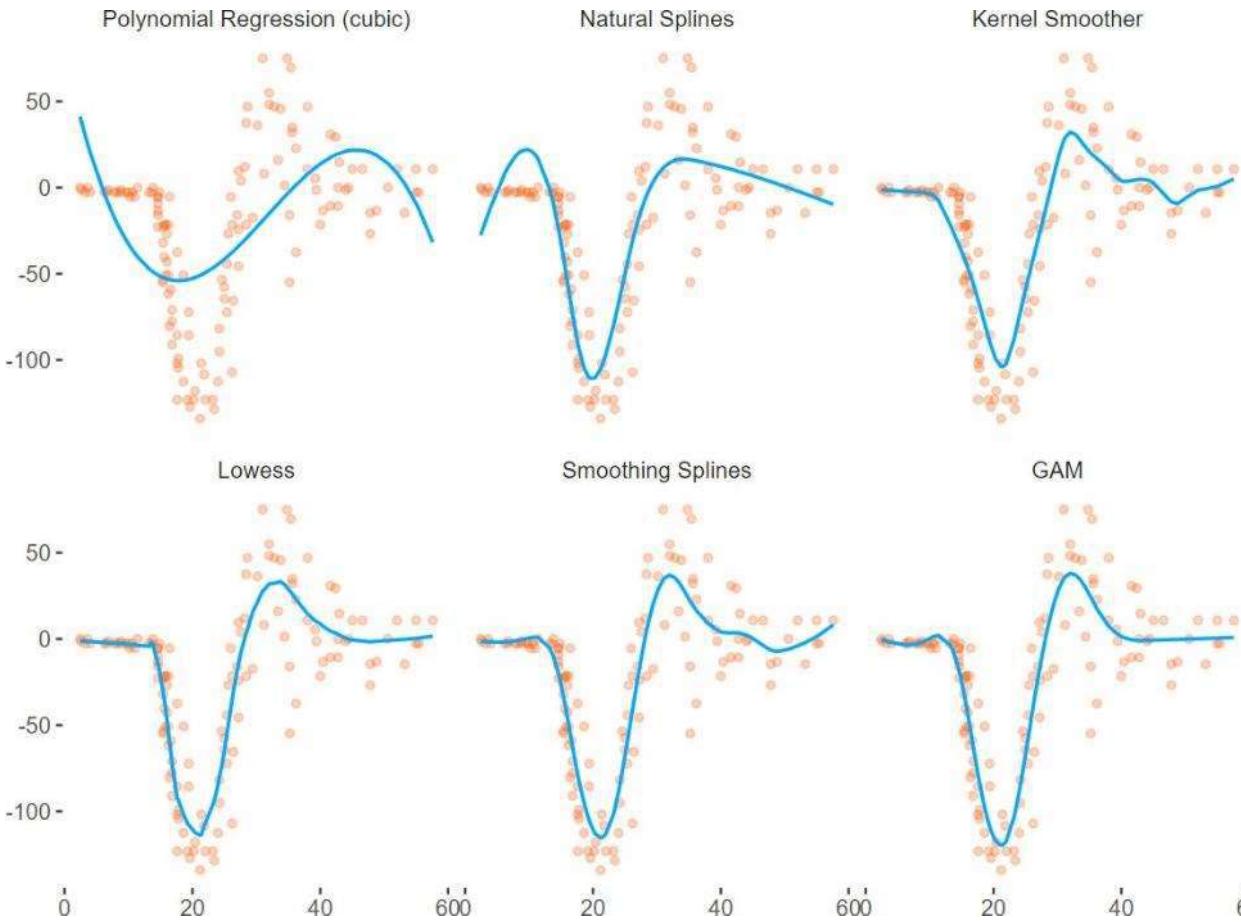
Time series decomposition of remotely sensed land surface temperature and investigation of trends and seasonal variations in surface urban heat islands

Jinling Quan^{1,2}, Wenfeng Zhan², Yunhao Chen², Mengjie Wang², and Jinfei Wang¹

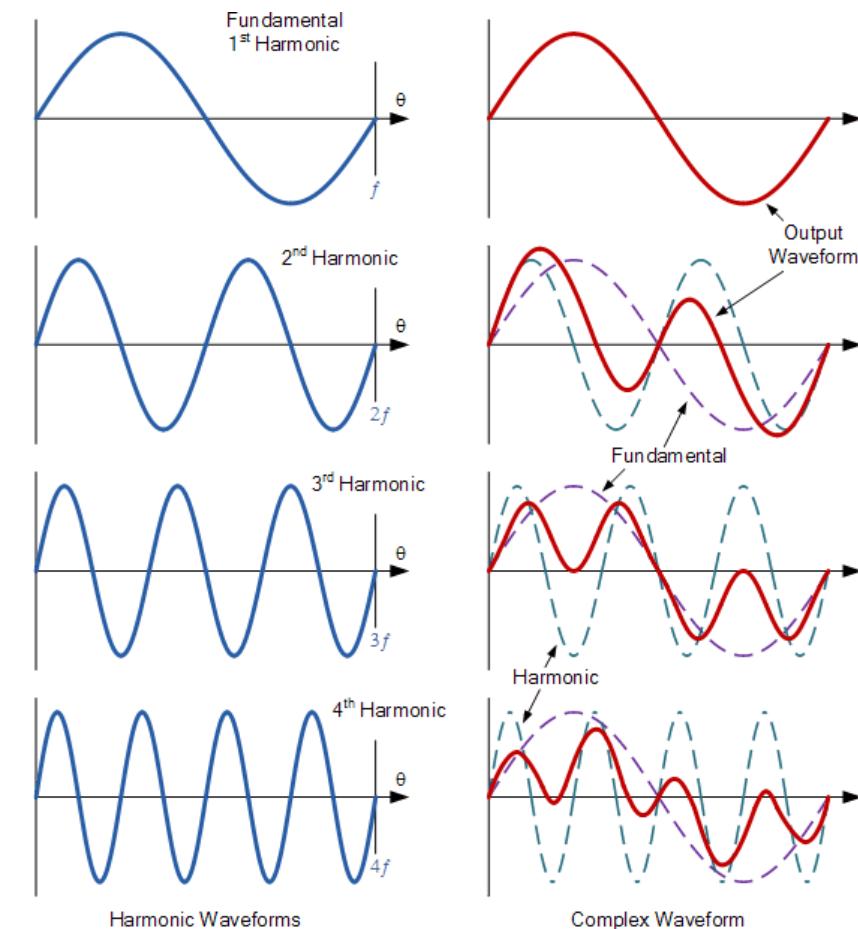
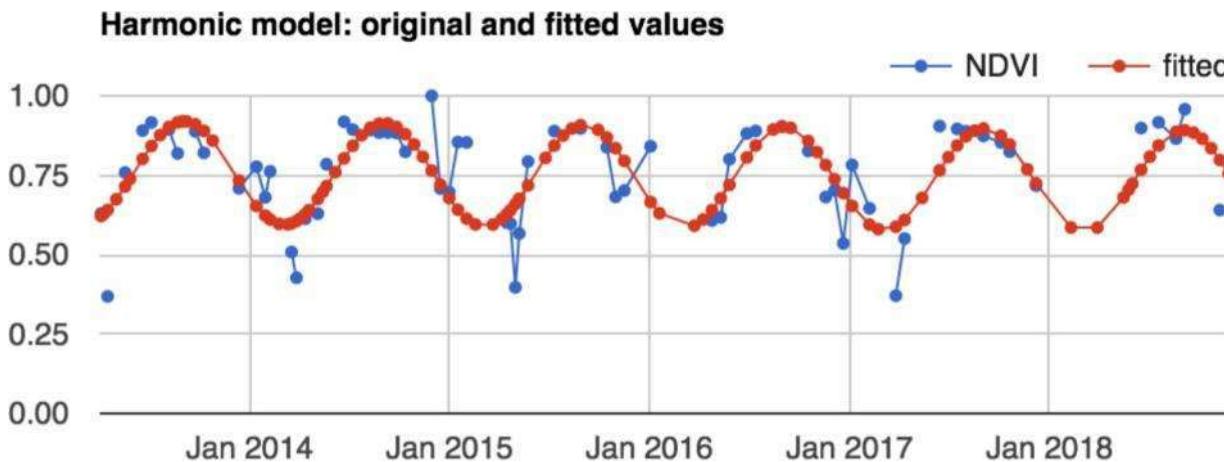
Detrend a timeseries



Time series smoothing and interpolation

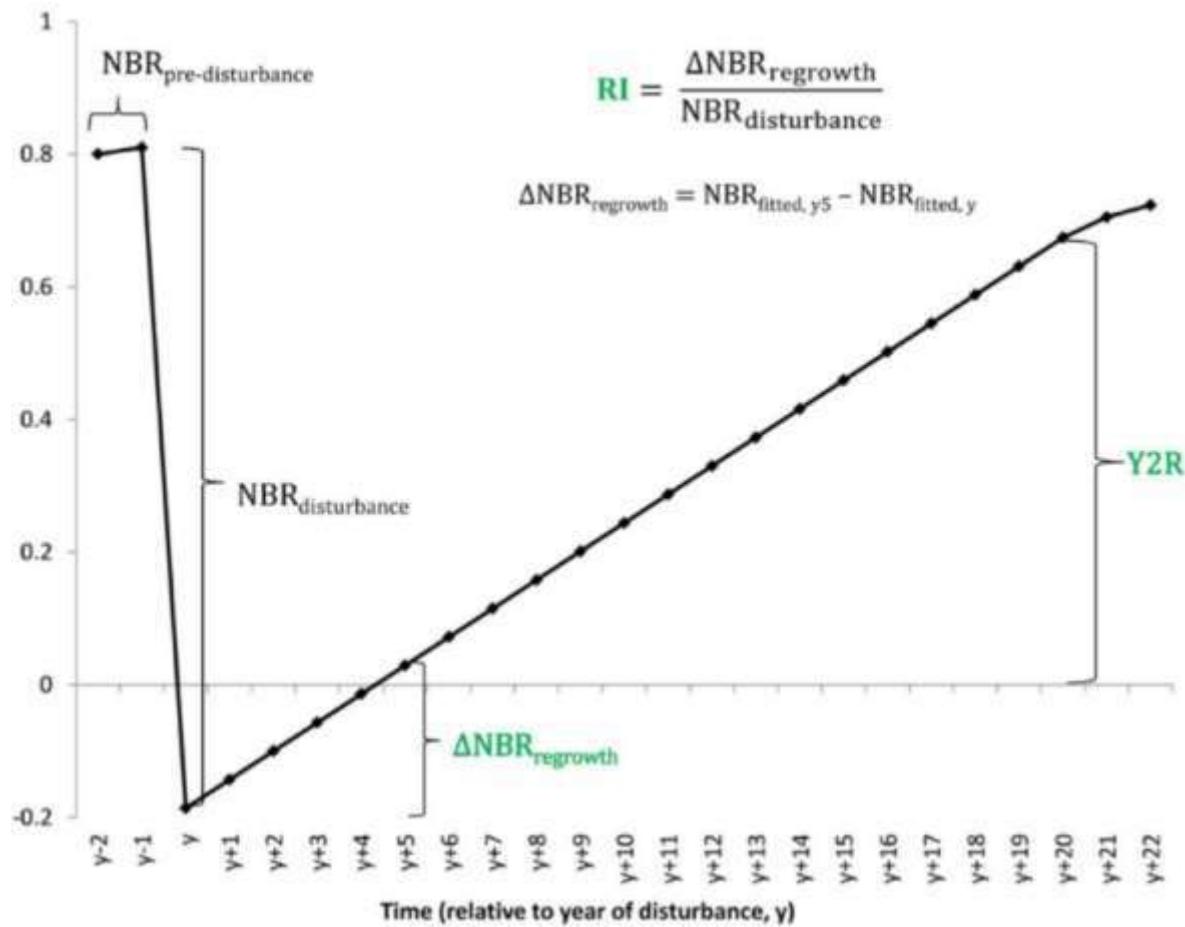


Harmonic and Seasonal Interpolation

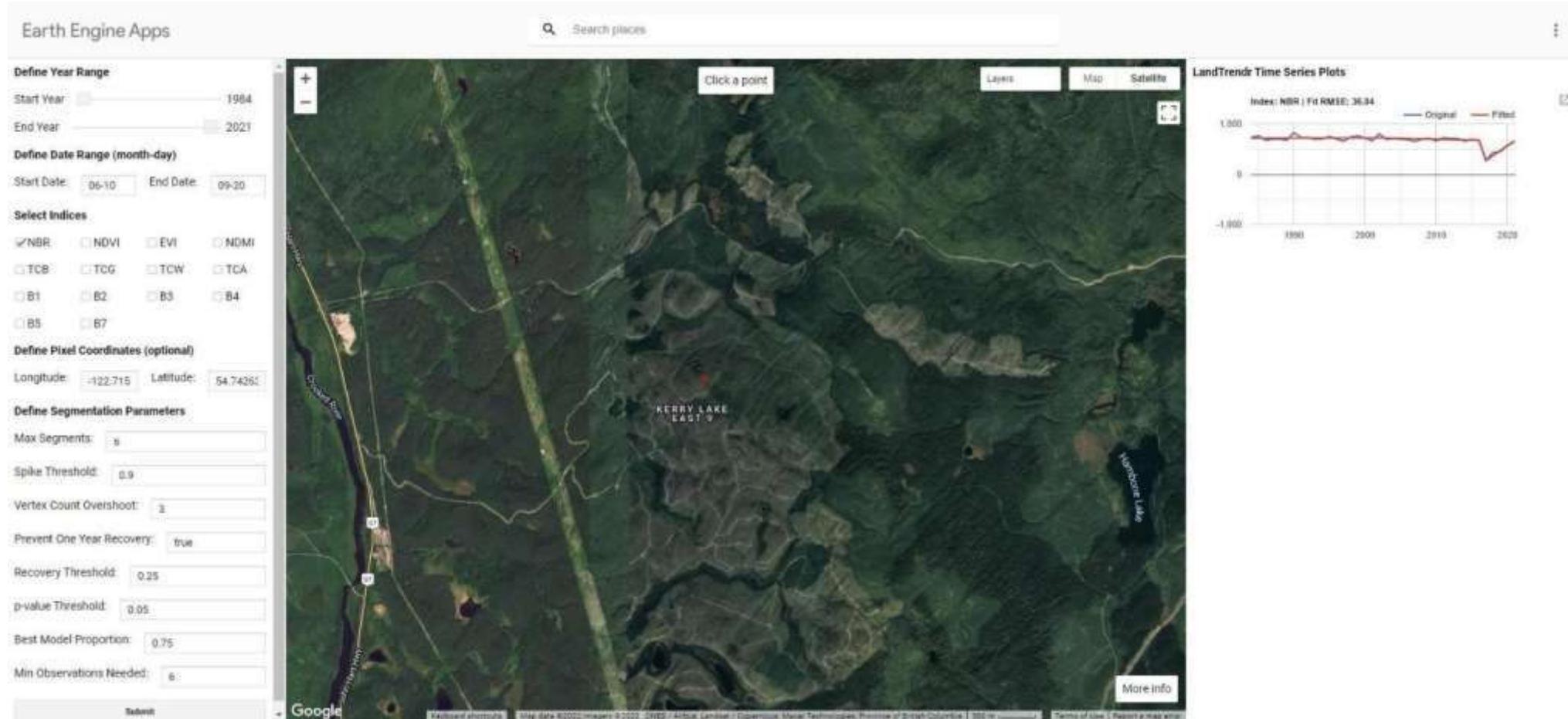


Breakpoint detection

J.C. White et al. / Remote Sensing of Environment 194 (2017) 303–321



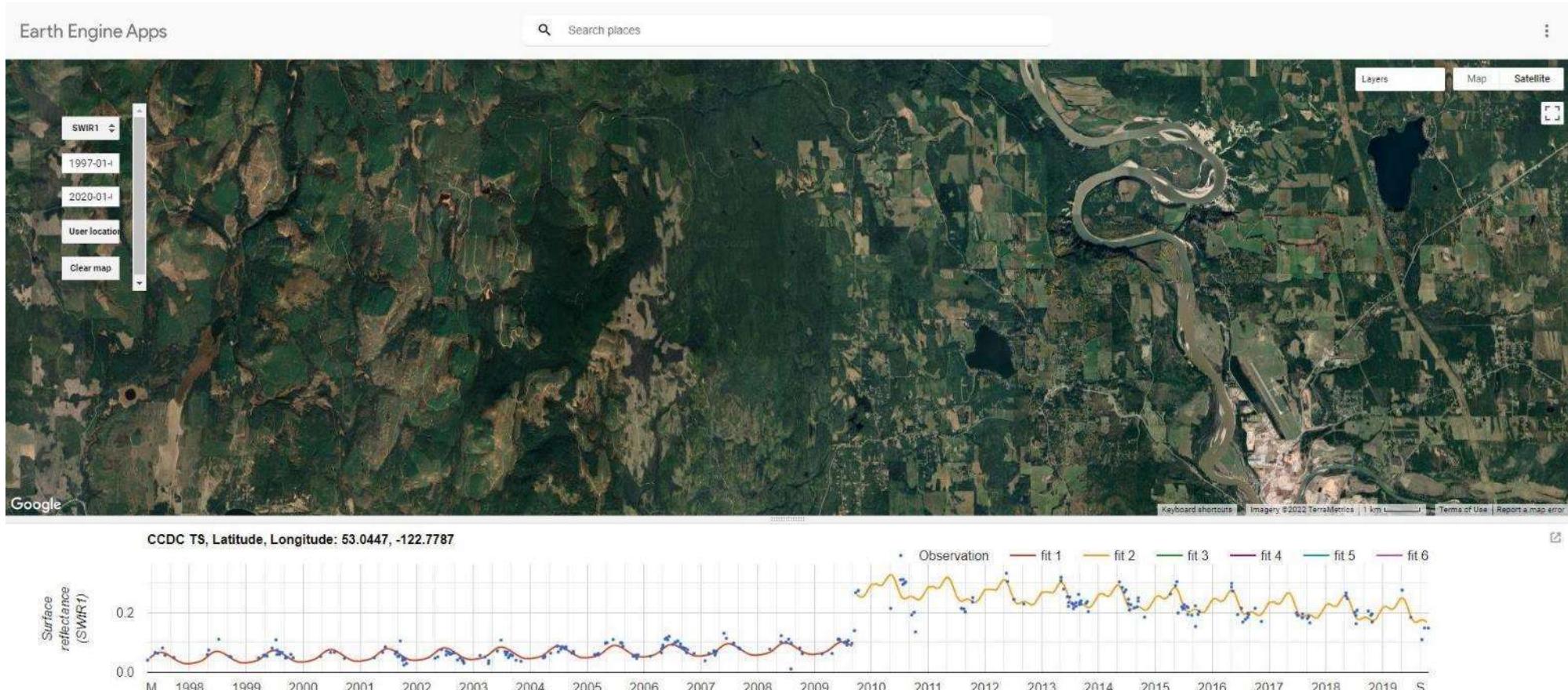
LandTrendR Algorithm



<https://emapr.github.io/LT-GEE/ui-applications.html#ui-landtrendr-pixel-time-series-plotter>

<https://emaprlab.users.earthengine.app/view/lt-gee-pixel-time-series>

Continuous Change Detection and Classification (CCDC) Algorithm



<https://parevalo-bu.users.earthengine.app/view/quick-tstools>

Time series classification



Article

Long-Term Satellite Image Time-Series for Land Use/Land Cover Change Detection Using Refined Open Source Data in a Rural Region

Cláudia M. Viana , Inês Girão and Jorge Rocha

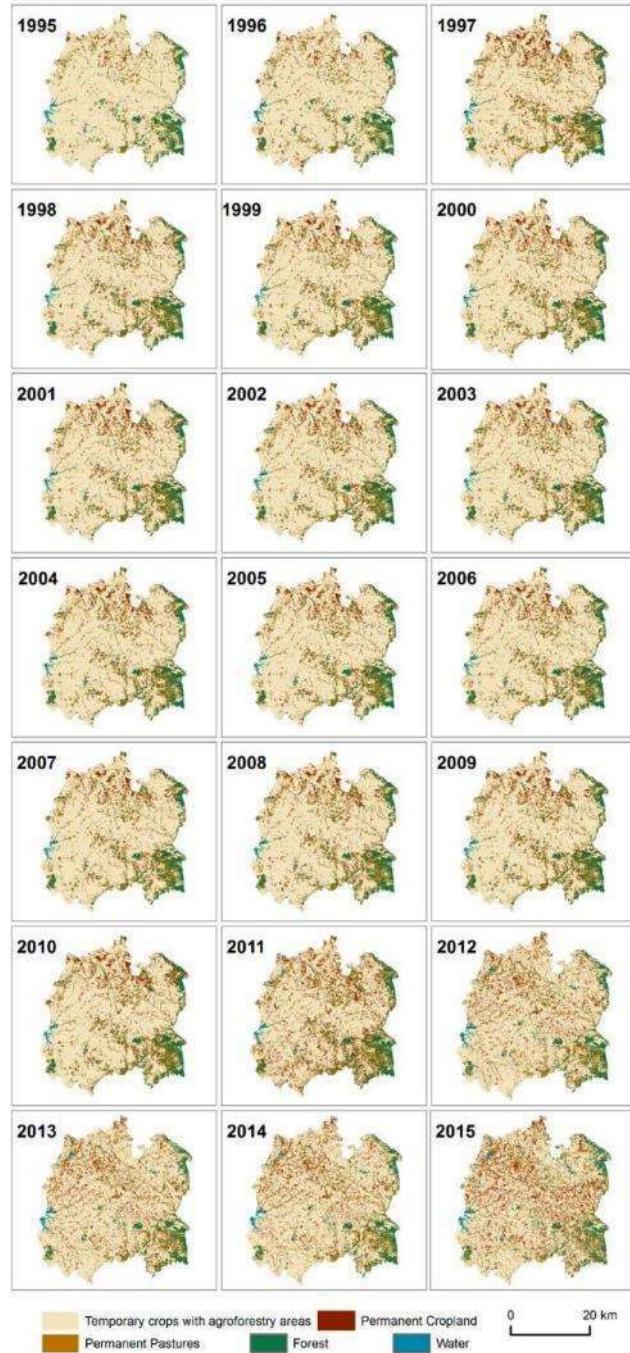


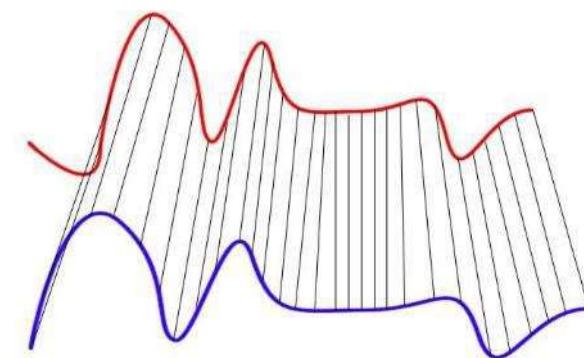
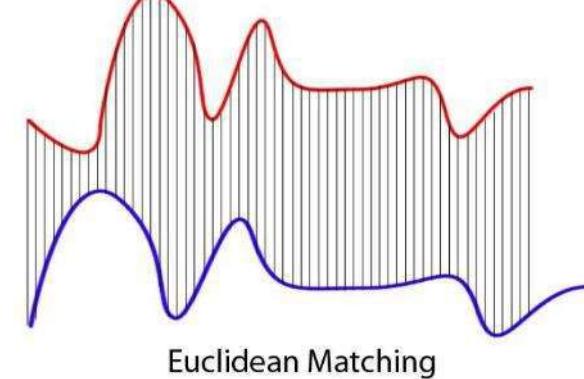
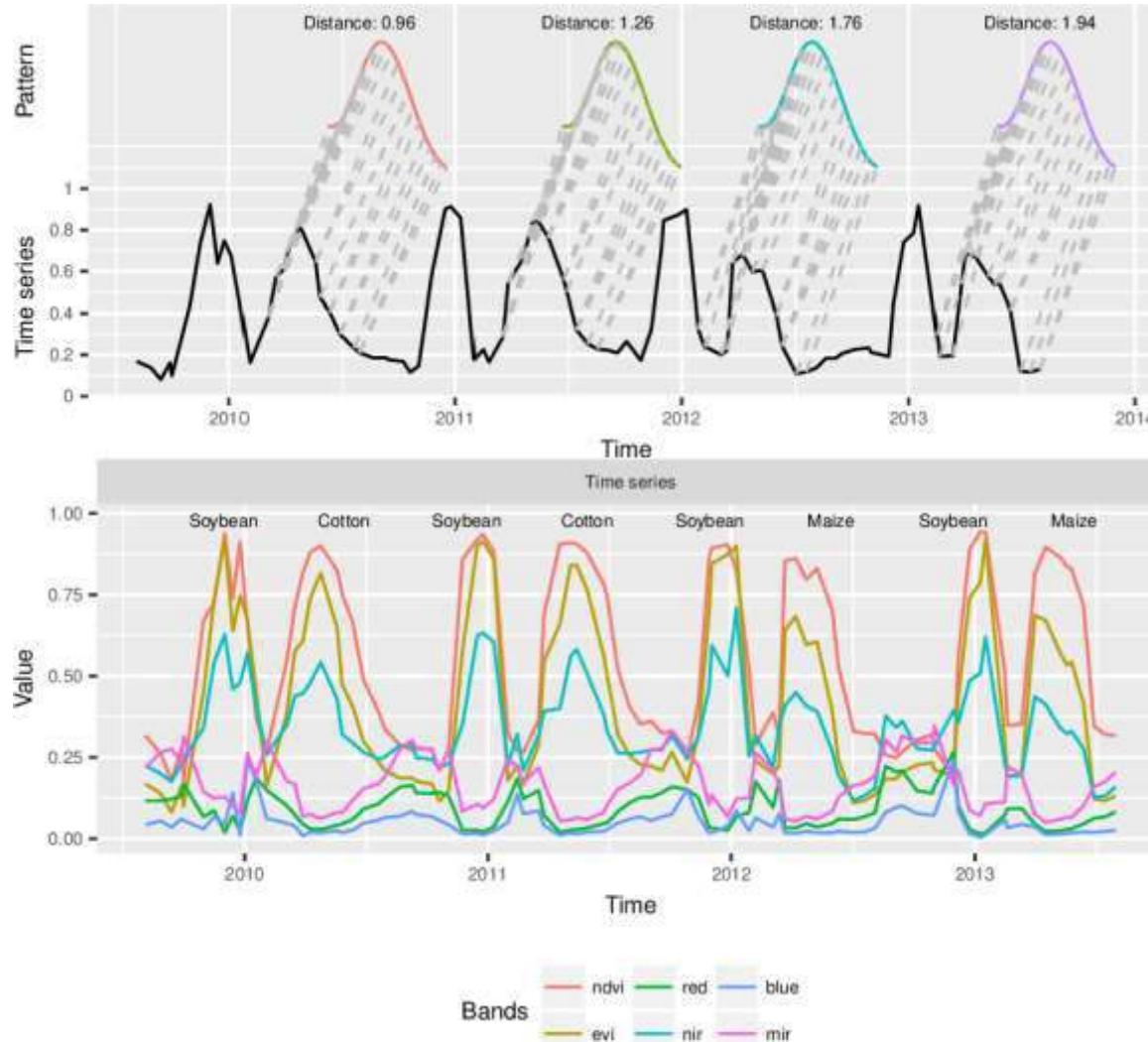
Figure 5. LULC classification maps for each period (1995–2015).



Dynamic time warping

dtwSat: Time-Weighted Dynamic Time Warping for Satellite Image Time Series Analysis in R

Victor Maus
University of Münster
Gilberto Câmara
INPE
Marius Appel
University of Münster
Edzer Pebesma
University of Münster



<https://towardsdatascience.com/dynamic-time-warping-3933f25fcdd>

Overview

- Timelapse – Powerful for visualization
- Time series – Pixel values from a stack
- Temporal aggregations – Summarizing by time period (e.g. annual mosaic)
- Gap filling – Filling missing data from clouds using temporal and/or spatial information
- Outlier detection – Detecting and removing data points that are likely errors (e.g. clouds)
- Detrending – Removing a trend to discover other information (e.g. seasonal)
- Time series smoothing – Smooth a time series using functions (e.g. linear, polynomial)
- Harmonics – Smooth a time series using harmonic functions (e.g. Fourier series)
- Breakpoint detection – Automatically detect changes in a time series
- Classification – Classify images in a time series