

ESTIMATING VEGETATION PRODUCTIVITY FOR THE CONTERMINOUS UNITED STATES USING SATELLITE OBSERVATIONS

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WHY THIS RESEARCH

- VEGETATION PRODUCTIVITY IS A MEASUREMENT USED TO DEFINE THE STATE OF VEGETATION OVER TIME AND ACROSS ECOSYSTEMS
- THESE ECOSYSTEMS ARE CRITICAL FOR THE FUTURE OF SOCIETY, FOR EXAMPLE :
 - GRASSLANDS FOR BEEF AND DAIRY PRODUCTION
 - AGRICULTURE FIELD FOR SUPPORTING CROPS,
 - FOREST FOR TIMBER
- THESE ARE JUST A FEW EXAMPLES OF **THE IMPORTANCE OF MONITORING VEGETATION PRODUCTIVITY**

WHY THIS RESEARCH

- TO ESTIMATE ANNUAL VEGETATION PRODUCTION OVER LARGE AREAS USING SATELLITE DATA
- TO FACILITATE THE GENERATION OF FUTURE DATA FOR UPCOMING YEARS

OBJECTIVES

1. PRODUCE A DATASET OF AN ESTIMATE FOR ANNUAL VEGETATION PRODUCTIVITY FOR THE CONTERMINOUS U.S.
2. GENERATE A REPRODUCIBLE WORKFLOW FOR FUTURE YEARS.

METHODOLOGY

- **ENHANCED VEGETATION INDEX (EVI) – GREENNESS VALUE FROM TERRA-MODIS (MODERATE-RESOLUTION IMAGING SPECTRORADIOMETER)**

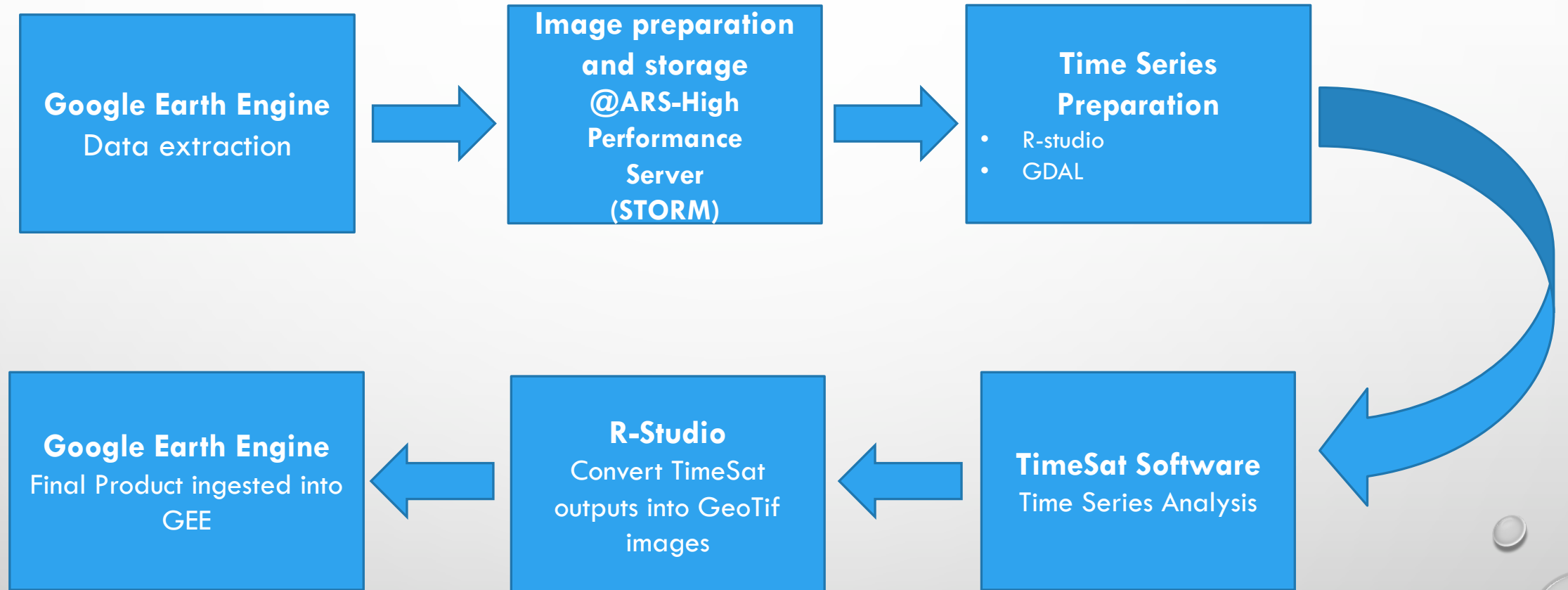
Greenness value

$$EVI = G \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + C_1 \rho_{red} - C_2 \rho_{blue} + L}$$

*Ratio of Red, Blue, Near-IR
and coefficients*

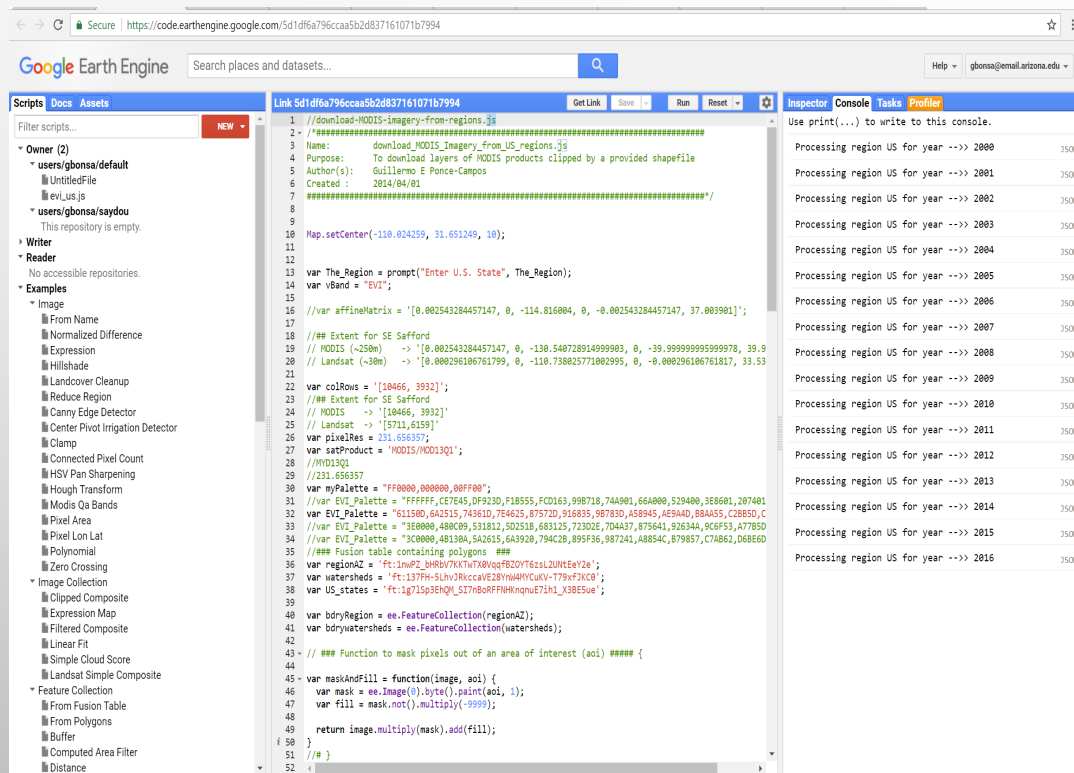
- TIMESAT – TIME SERIES ANALYSIS
- R-STUDIO

THE WORKFLOW



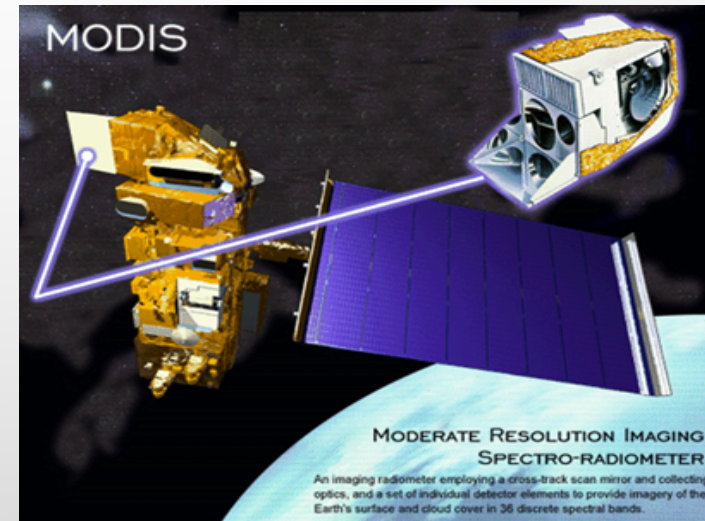
GOOGLE EARTH ENGINE (GEE) AND MODIS

- GOOGLE EARTH ENGINE (GEE)



```
1 //download-MODIS-imagery-from-regions.js
2 //#####
3 Name: download_MODIS_imagery_from_US_regions.js
4 Purpose: To download layers of MODIS products clipped by a provided shapefile
5 Author(s): Guillermo E Ponce-Campos
6 Created: 2014/04/01
7 #####
8
9
10 Map.setCenter(-110.024259, 31.651249, 10);
11
12
13 var The_Region = prompt("Enter U.S. State", The_Region);
14 var vBand = "EVI";
15
16 //var affineMatrix = "[0.002543284457147, 0, -114.8126004, 0, -0.002543284457147, 37.003901]";
17
18 //## Extent for SE Safford
19 // MODIS (-25m) -> "[0.002543284457147, 0, -130.540728914999903, 0, -39.999999999999978, 39.9
20 // Landsat (-30m) -> "[0.000296106761799, 0, -110.73802571002995, 0, -0.000296106761817, 33.53
21
22 var clLands = "[10466, 3932]";
23 //## Extent for SE Safford
24 // MODIS -> "[10466, 3932]";
25 // Landsat -> "[5711, 6159]";
26 var pixelRes = 231.656357;
27 var satProduct = "MODIS/MOD13Q1";
28 //MOD13Q1
29 //231.656357
30 var myPalette = "FF0000,000000,00FF00";
31 //var EVI_Palette = "FFFFFF,C7E945,DF923D,F19555,FC0163,998718,74A061,66A000,529400,3E8601,207401
32 var EVI_Palette = "611500,6A2515,740610,764625,873720,916835,987820,AC6945,AE9440,80A655,CC8550,C
33 //var EVI_Palette = "3E0000,480C09,531812,5D2518,683125,723D2E,7D4437,875641,926344,9C6F53,A7785D
34 //var EVI_Palette = "3C0000,48130A,5A2615,6A3920,794C28,89F36,987241,AB854C,879857,CTA862,DBE86D
35 //### Fusion table containing polygons ###
36 var regionA2 = "ft:imp2_dh96v7XkTW70VqgPEZ0YfEzLJW8vE4y2e";
37 var watersheds = "ft:137fH-sLw38CvAEZ3DfW4WVC4Uv-179v47f0C";
38 var US_states = "ft:1g7I5p3EHQI_S17n80RFNHnqnuE7iR1_X8E5ue";
39
40 var bdyRegion = ee.FeatureCollection(regionA2);
41 var bdywatersheds = ee.FeatureCollection(watersheds);
42
43 // ### Function to mask pixels out of an area of interest (aoi) ##### {
44
45 var maskAndFill = function(image, aoi) {
46   var mask = ee.Image(0).byte().paint(aoi, 1);
47   var fill = mask.not().multiply(-9999);
48
49   return image.multiply(mask).add(fill);
50 }
51 //# }
52
```

- ENHANCED VEGETATION INDEX (EVI) – GREENNESS VALUE FROM TERRA-MODIS (MODERATE-RESOLUTION IMAGING SPECTRORADIOMETER)



- MODIS (MODerate-resolution Imaging Spectroradiometer)

RSTUDIO

INTEGRATED DEVELOPMENT ENVIRONMENT

The screenshot displays the RStudio IDE interface. The top menu bar includes File, Edit, Code, View, Plots, Session, Build, Debug, Profile, Tools, and Help. The main editor window shows R code for processing binary data into a raster format. The Environment pane on the right shows the current workspace with variables like vBinToMatrix, vMatrixToRaster, and vFinalRaster. The Console pane at the bottom shows the execution of the processMultiBand function, including file paths and program output.

```
sign
vFlatBinary = readBin(vFileCon, double(), n=vN, size=4, endian="little", signed=TRUE)
#Convert information from binary file into a Matrix
vBinToMatrix <- matrix(vFlatBinary, nrow=nRow, ncol=nCol, byrow=TRUE)
#Convert Matrix into RasterLayer using a raster template to get all the information
vMatrixToRaster <- raster(vBinToMatrix, template=vRasterTemplate)
# Write raster as geotif
vFinalRaster <- writeRaster(vMatrixToRaster, varFile, format="GTiff",...
}
...
16:36 processMultiBand(vFiles, ty, vSeq, vOutFolder, vName)
R Markdown
```

```
vBinToMatrix <- matrix(vFlatBinary, nrow=nRow, ncol=nCol, byrow=TRUE)
#Convert Matrix into RasterLayer using a raster template to get all t...
vMatrixToRaster <- raster(vBinToMatrix, template=vRasterTemplate)
# Write raster as geotif
vFinalRaster <- writeRaster(vMatrixToRaster, varFile, format="GTiff",...
}
for (varFile in varAllFiles) {
print (paste("Processing file => ",varFile,sep=""))
# Open binary file output (connection to file) from Timesat
vFileCon <- file(varFile, 'rb')
# Use connection to read binary data using data type, number of eleme...
vFlatBinary = readBin(vFileCon, double(), n=vN, size=4, endian="littl...
#Convert information from binary file into a Matrix
vBinToMatrix <- matrix(vFlatBinary, nrow=nRow, ncol=nCol, byrow=TRUE)
#Convert Matrix into RasterLayer using a raster template to get all t...
vMatrixToRaster <- raster(vBinToMatrix, template=vRasterTemplate)
# Write raster as geotif
vFinalRaster <- writeRaster(vMatrixToRaster, varFile, format="GTiff",...
}
getwd()
```

```
Working...
Finished writing data
File format 32-bit real
[sbonsa@storm settings]$ TSF_seas2img.x64 US_Timesat_Landcover_settings_TS.tpa 11 391 414 -9999 -9999 US_Yr2016_SI 3
-----
Program TSF_seas2img
Program for generating images from TIMESAT seasonality files
Arguments: infile seaspar datemin datemax misseason misspix nameout filetype

TIMESAT version 3.3
Copyright Per Jonsson and Lars Eklundh
per.jonsson@mah.se, lars.eklundh@nateko.lu.se
Feb. 2017
-----
Opening US_Yr2016_SI_season1
Opening US_Yr2016_SI_season2
Opening US_Yr2016_SI_nseas
Opening US_Yr2016_SI_errors.txt
Opening US_Yr2016_SI_both_seasons
Working...
Finished writing data
File format 32-bit real
[sbonsa@storm settings]$
```

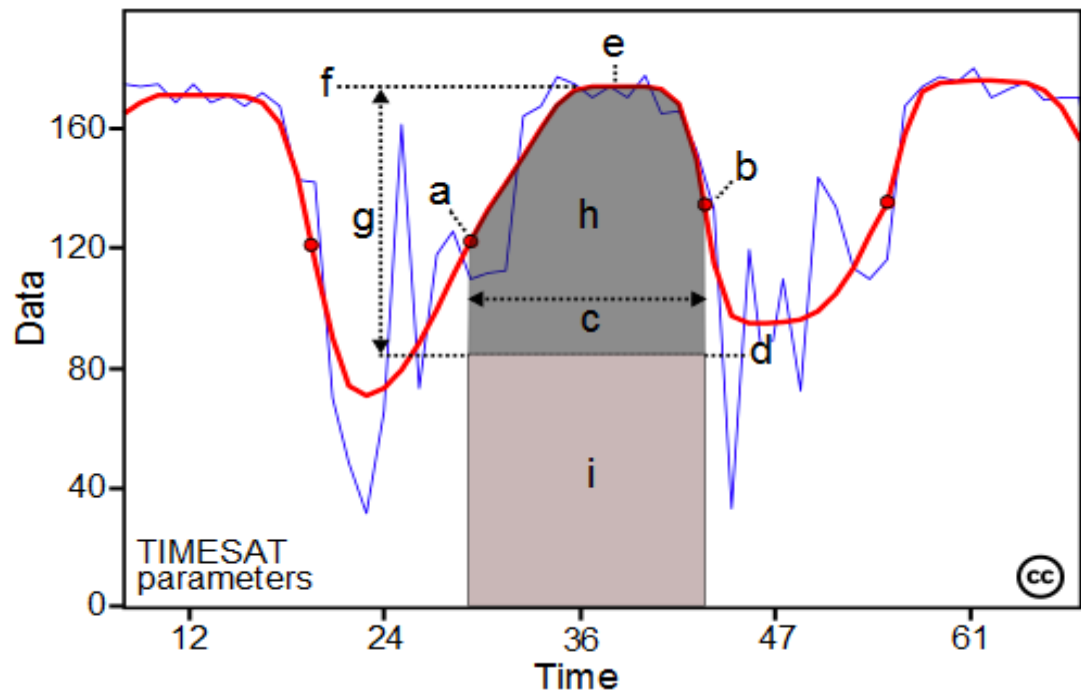
- Image processing
- Time series preparation
- Output images generation



TimeSat

One pixel over time, raw EVI data (blue), smoothed (brown).

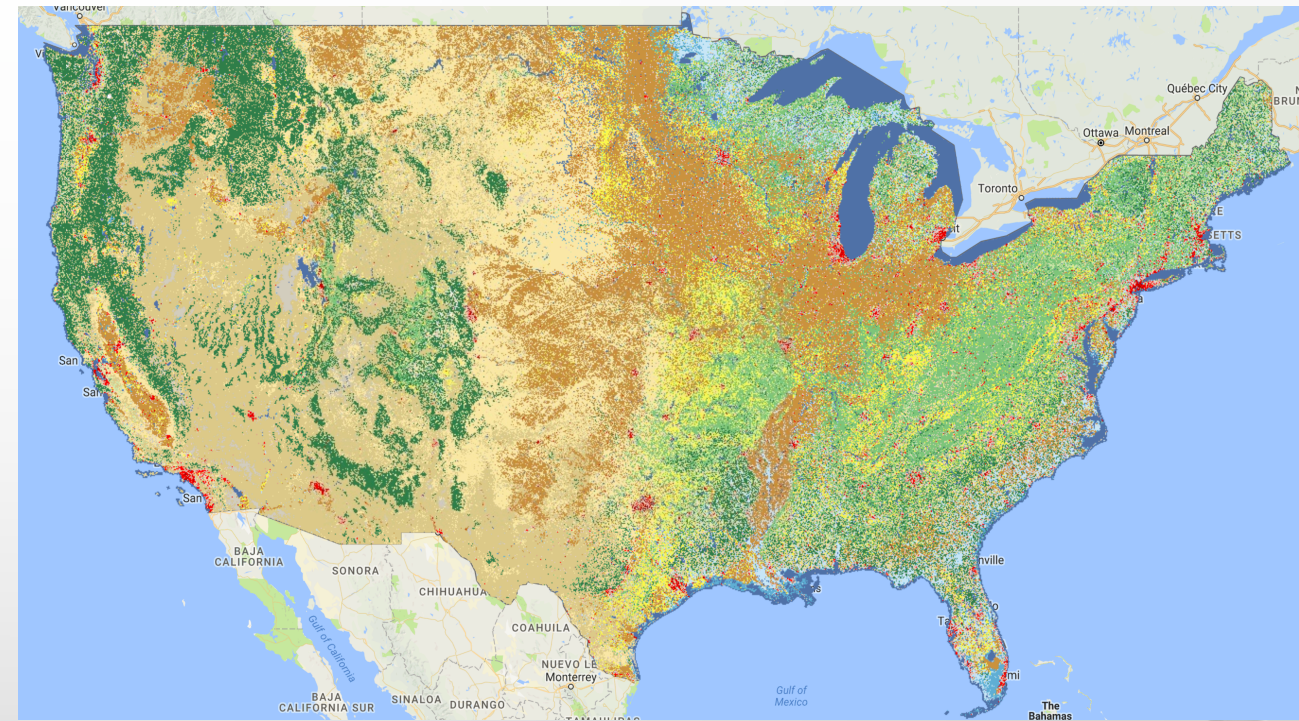
Output values from TimeSat for each pixel



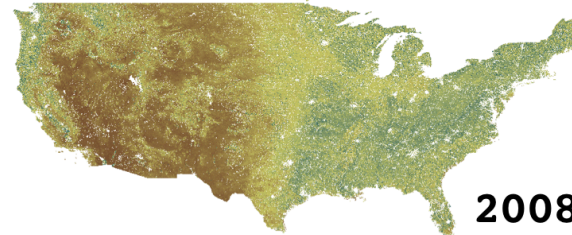
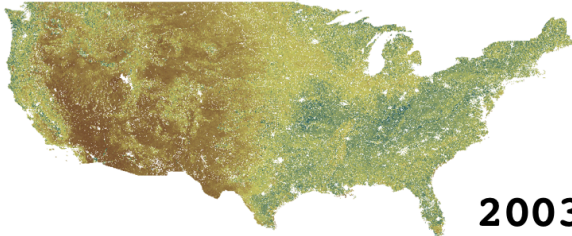
- FIGURE 1. SOME OF THE SEASONALITY PARAMETERS GENERATED IN TIMESAT: (A) BEGINNING OF SEASON, (B) END OF SEASON, (C) LENGTH OF SEASON, (D) BASE VALUE, (E) TIME OF MIDDLE OF SEASON, (F) MAXIMUM VALUE, (G) AMPLITUDE, (H) SMALL INTEGRATED VALUE, (H+I) LARGE INTEGRATED VALUE. THIS FIGURE IS LICENSED UNDER A [CREATIVE COMMONS ATTRIBUTION-NONCOMMERCIAL-NODERIVS 2.5 SWEDEN LICENSE](https://creativecommons.org/licenses/by-nc-nd/2.5/sweden/). IT IS FREE TO COPY AND USE IN OTHER WORK

National Landcover Dataset (USGS,2011)

Landcover classes (E.g. Forest, Agriculture, Grasslands, etc.) are used to support TimeSat parameterization. Each class can have its own parameters for time series analysis.



RESULTS: OBJECTIVE 1

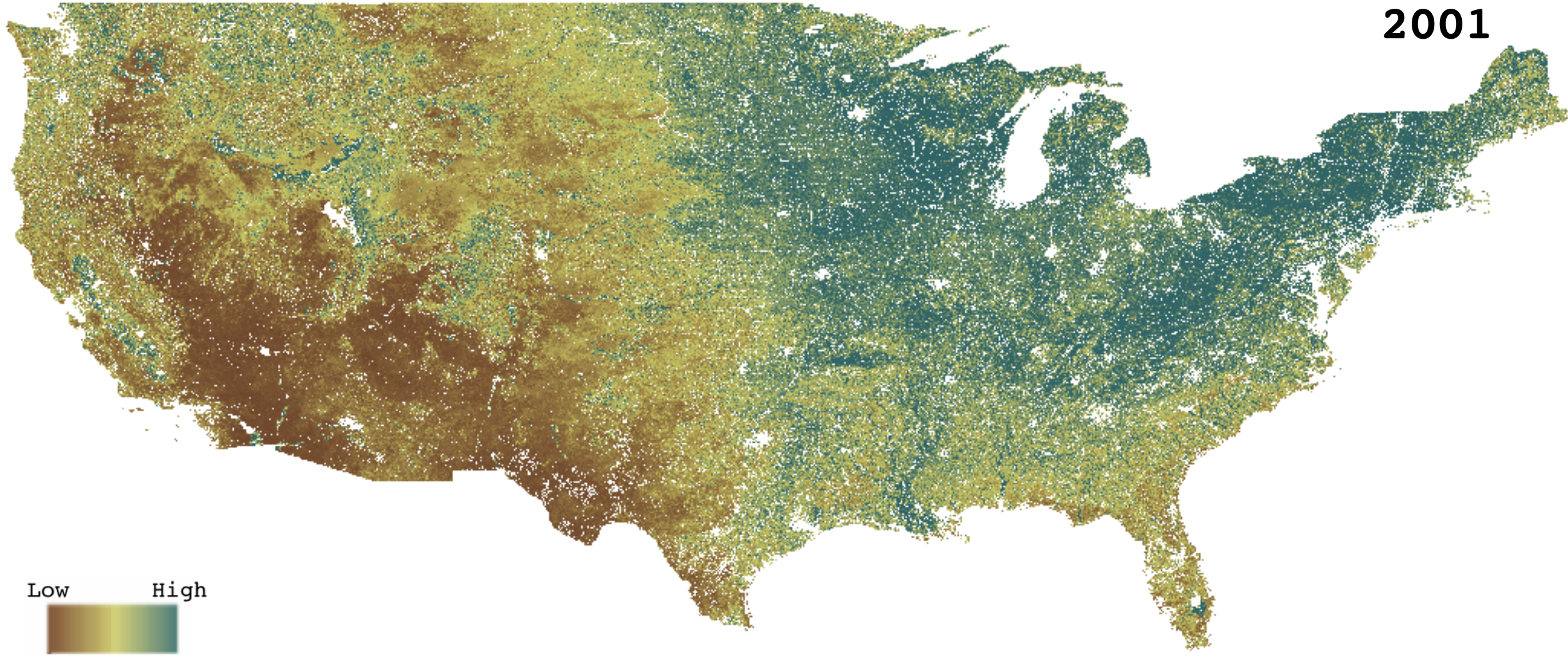


Estimated Productivity



Estimated Productivity

2001

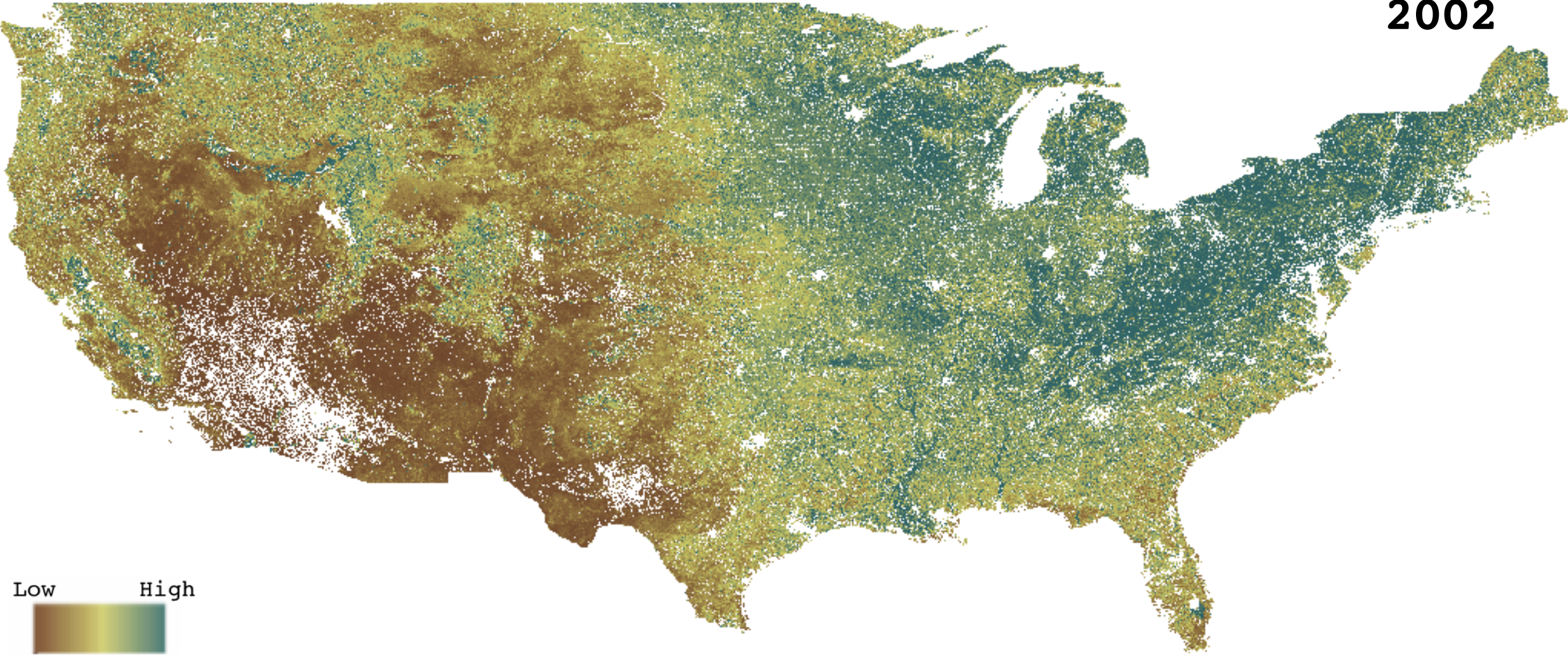


Low High



Estimated Productivity

2002

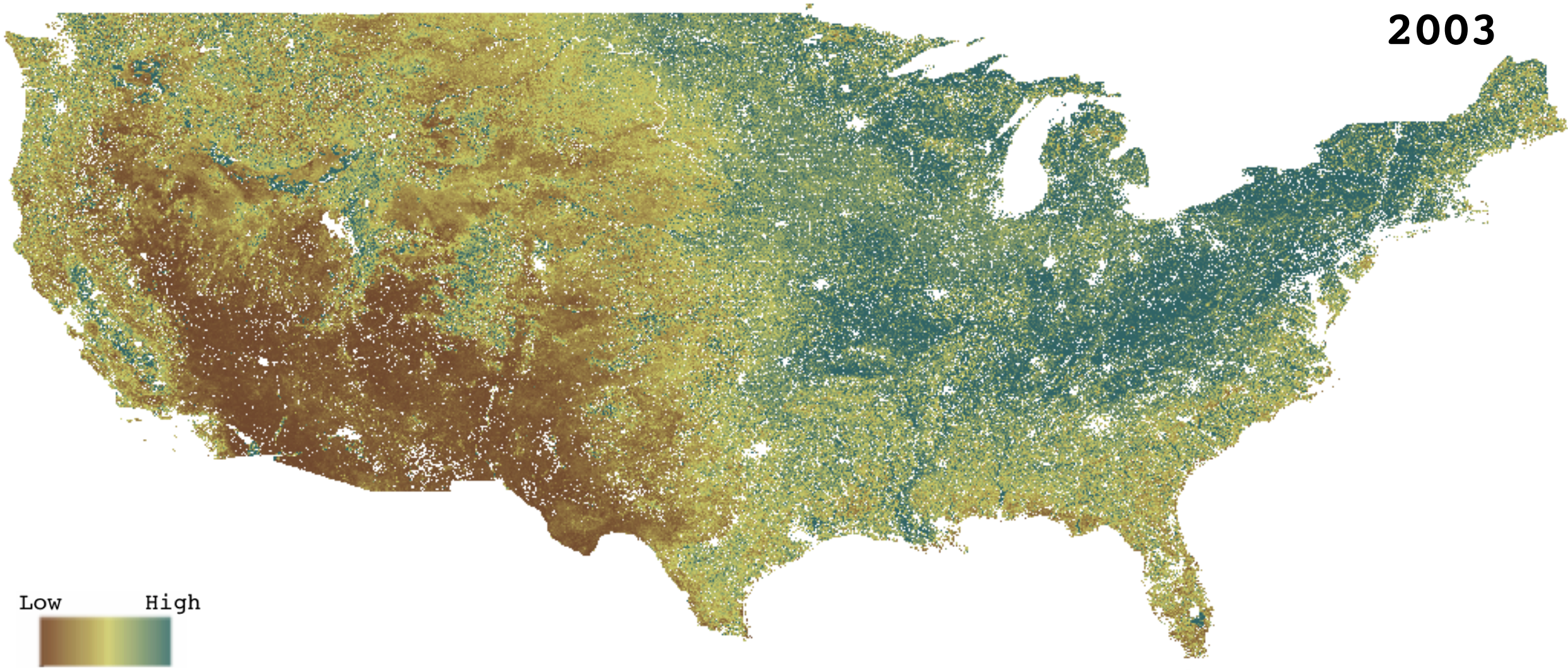


Low High



Estimated Productivity

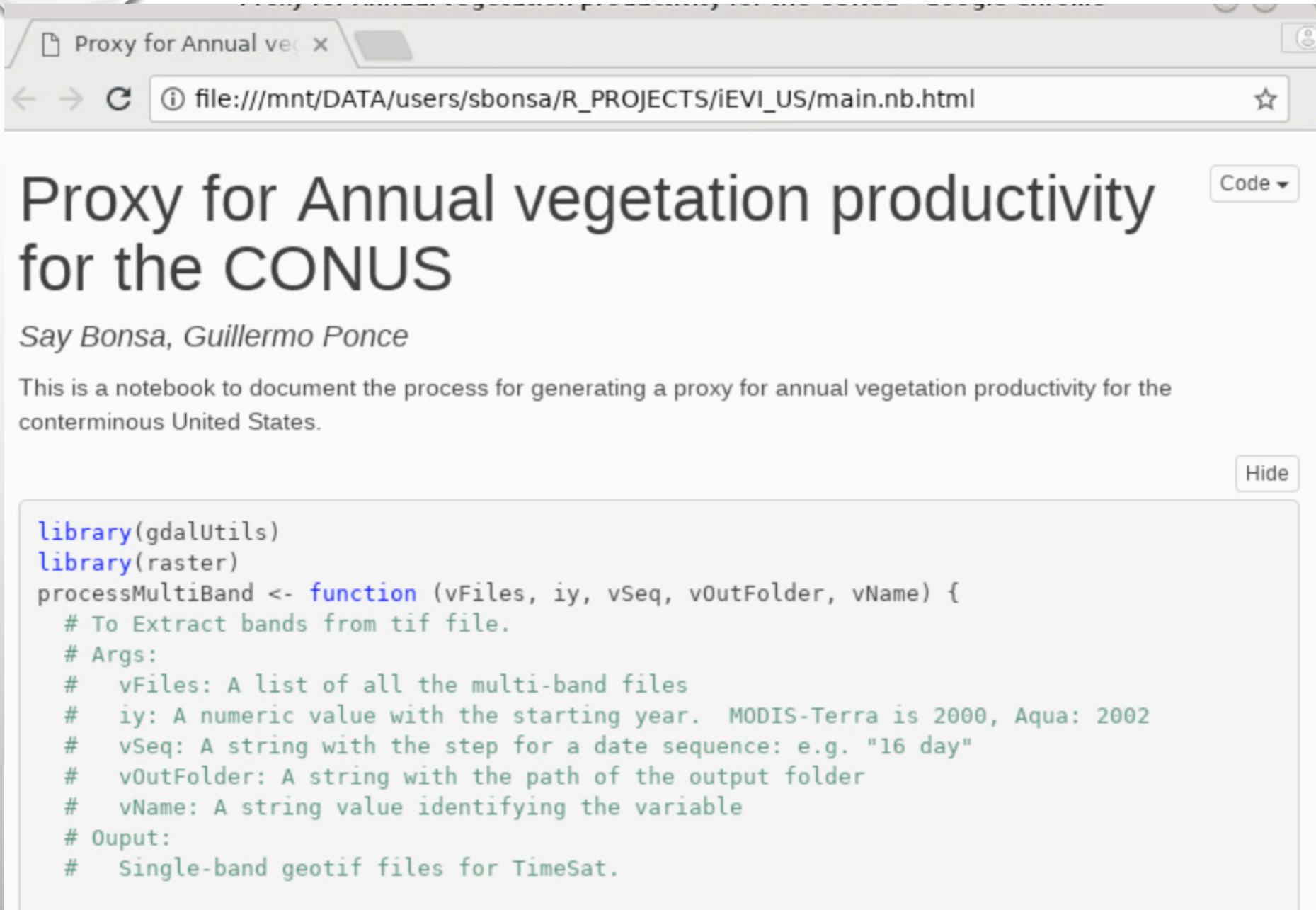
2003



Low High



RESULTS: OBJECTIVE 2



The screenshot shows a web browser window with the address bar containing the file path: `file:///mnt/DATA/users/sbonsa/R_PROJECTS/iEVI_US/main.nb.html`. The page title is "Proxy for Annual vegetation productivity for the CONUS". Below the title, the author is listed as "Say Bonsa, Guillermo Ponce". A brief description states: "This is a notebook to document the process for generating a proxy for annual vegetation productivity for the conterminous United States." A code block is visible, containing R code for library loading and a function definition.

```
library(gdalUtils)
library(raster)
processMultiBand <- function (vFiles, iy, vSeq, vOutFolder, vName) {
  # To Extract bands from tif file.
  # Args:
  #   vFiles: A list of all the multi-band files
  #   iy: A numeric value with the starting year. MODIS-Terra is 2000, Aqua: 2002
  #   vSeq: A string with the step for a date sequence: e.g. "16 day"
  #   vOutFolder: A string with the path of the output folder
  #   vName: A string value identifying the variable
  # Output:
  #   Single-band geotif files for TimeSat.
```

Processes were documented as a **R-Notebook** for reproducibility

TAKE HOME MESSAGE

- DATASET WILL BE AVAILABLE IN GOOGLE EARTH ENGINE
- CAN BE USEFUL FOR SCIENTISTS INTERESTED IN VEGETATION AT REGIONAL SCALES
- WORKFLOW CAN BE ADAPTED FOR OTHER TIME SERIES DATASETS, (E.G. CLIMATE)
- VERY EASY TO UPDATE FOR FUTURE USE
- FUTURE WORK WILL BE PERFORMED FOR VALIDATION.



ACKNOWLEDGEMENTS

DR. GUILLERMO PONCE

DR. CHANDRA HOLIFIELD COLLINS

USDA-ARS SWRC

ARIZONA SPACE GRANT

Thank you!

