GeoPAT 2.0 – Software for Pattern-Based Spatial and Temporal Analysis of Large Earth Science Datasets

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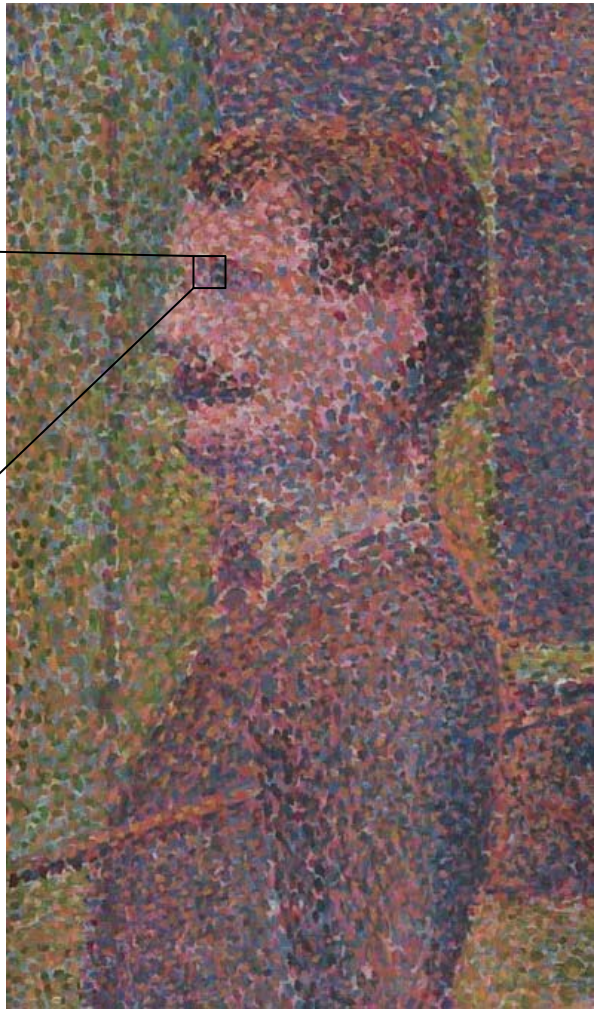
ESTF 2017

What is GeoPAT?

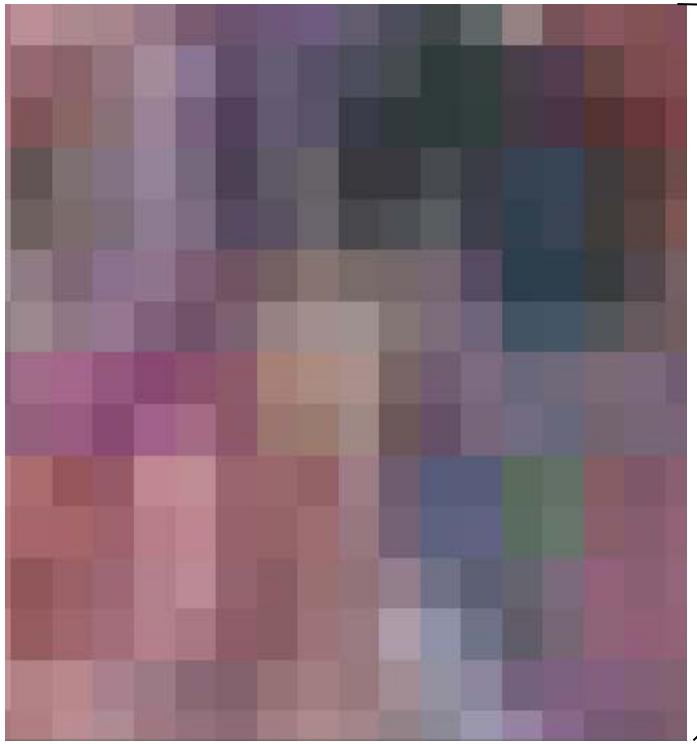
GeoPAT (Geospatial Pattern Analysis Toolbox) is a standalone suite of modules written in C and dedicated to analysis of large Earth Science datasets in their entirety using spatial and/or temporal patterns.

Global scale, high resolution spatial datasets are available but are mostly used in small pieces for local studies. GeoPAT enables studying them in their entirety.

To comprehend a global character, entire high resolution spatial data needs to be analyzed



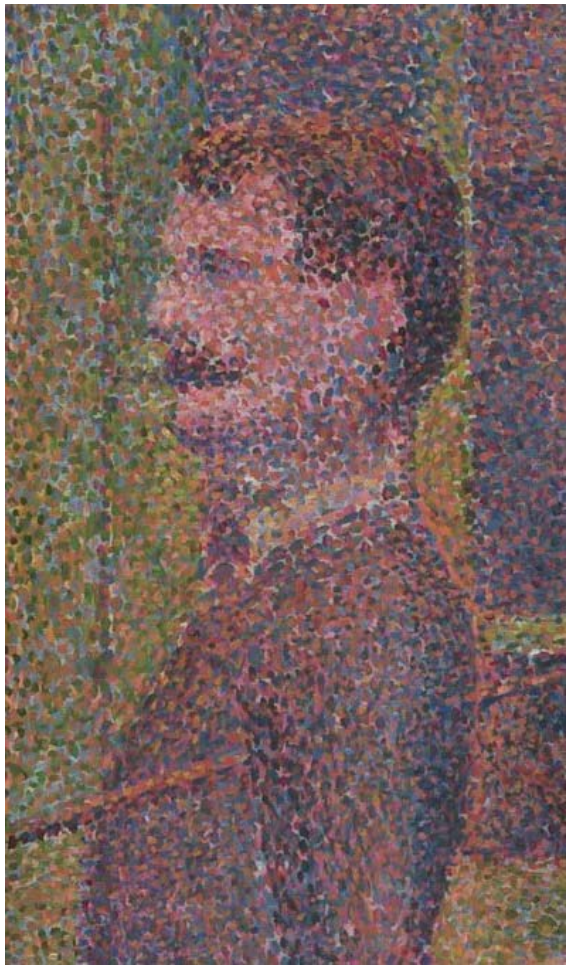
High resolution spatial data at local scale tells nothing about global properties



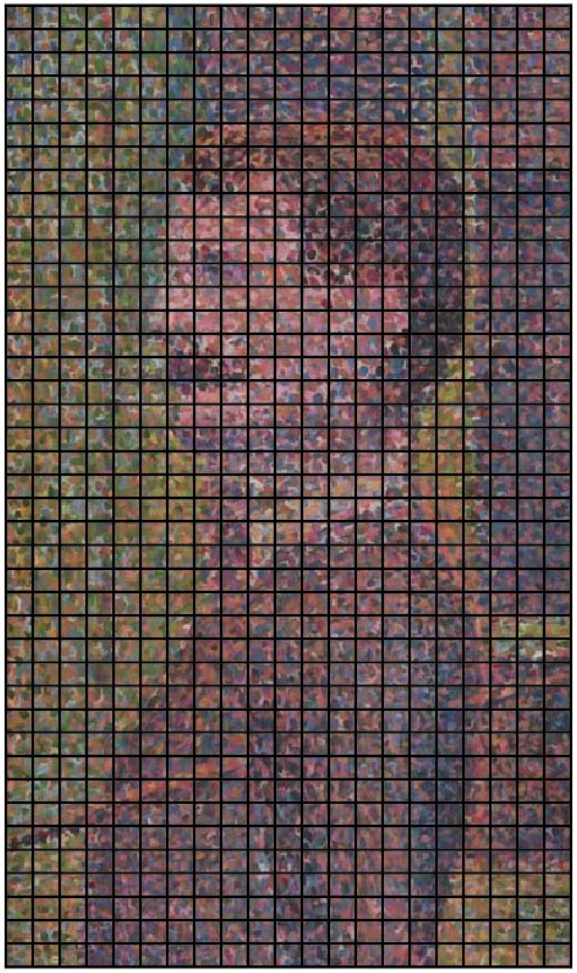
GeoPAT's core idea

Tessellate global spatial data into grid of square blocks of original cells (pixels). This transforms data from its original form (huge number of cells each having simple content) to a new form (much smaller number of supercells/blocks with complex content).

billions of small `simple` cells



millions of large *complex* cells



Complex cell contains a pattern of original variable.

GeoPAT provides means for succinct description of such patterns and for calculation of similarity between patterns.

This enables spatial analysis such as clustering, segmentation, and search to be performed on the grid of complex cells (local patterns)

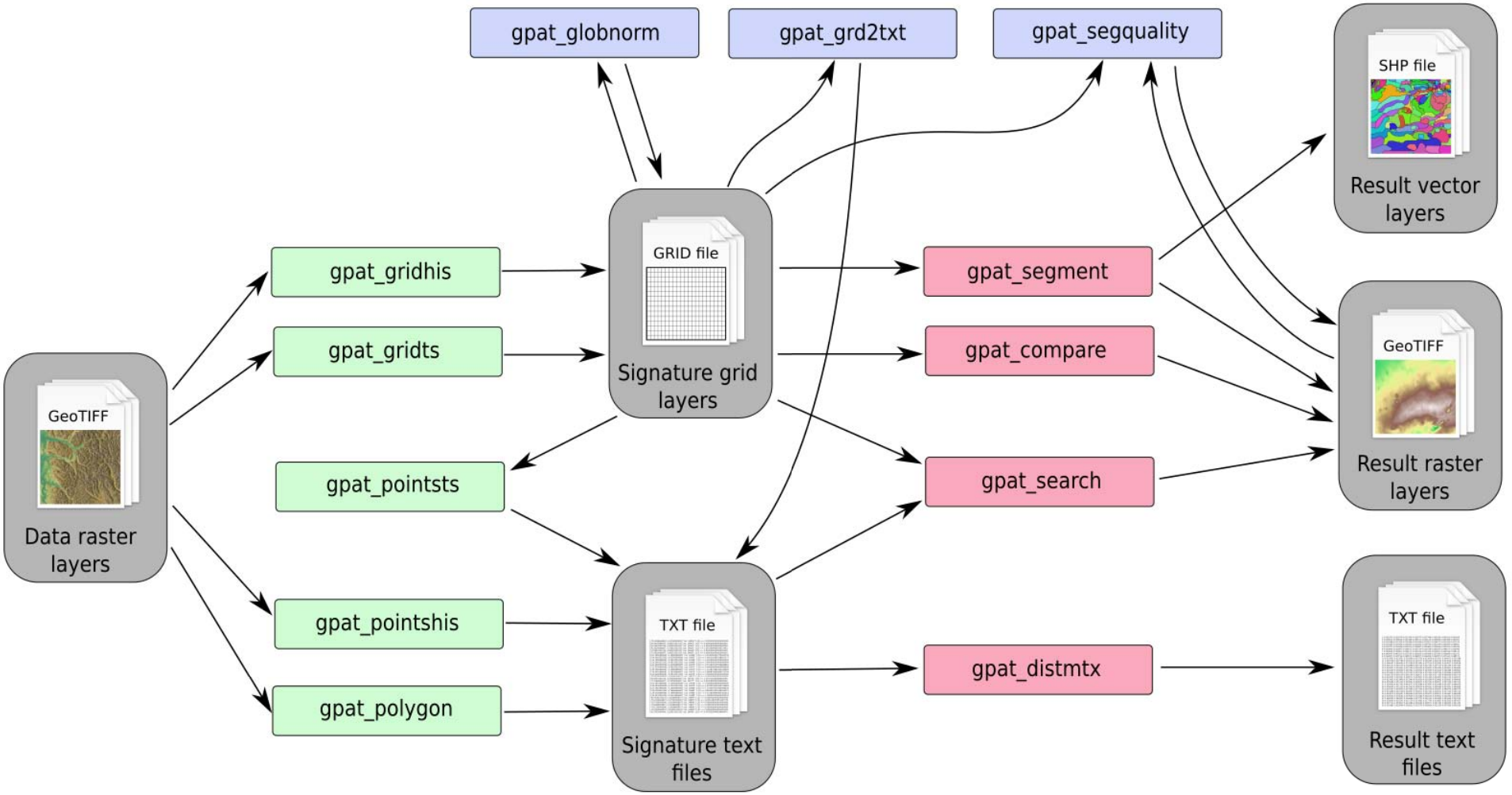
Working with data compressed to necessary minimum GeoPAT can analyze large data using modest resources.

GeoPAT 2 versus GeoPAT 1

GeoPAT 2 is a completely new software (not an update) based on an idea first implemented in GeoPAT 1.

ELEMENT	GeoPAT 1	GeoPAT 2
System/Environment	GRASS GIS/ Linux	STANDALONE Linux/Windows
Input data format	Categorical raster	Any numerical structure
Type of patterns	spatial	spatial, temporal, spatio-temporal
Type of analysis	search, change, clustering	Search, change, clustering, segmentation

GeoPAT architecture



What datasets can GeoPAT 2 handle and what analyses it can perform?

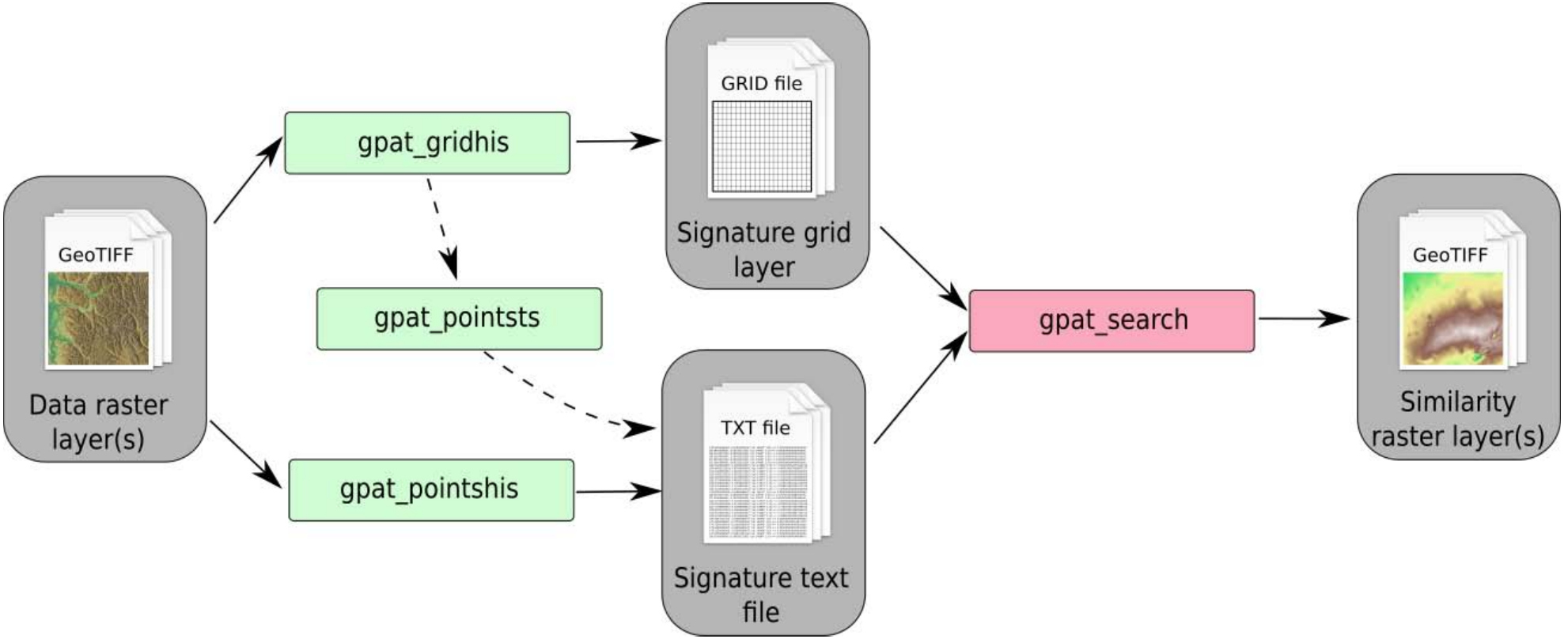
DATASETS

1. Land cover (CCI-LC, GlobCover, NLCD, EOSD-Canada)
2. Topography (SRTM, NED)
3. High resolution (1 m/pixel or less) image or LIDAR
4. Global climate (WorldClim)
5. Global phenology (EVI)

ANALYSES

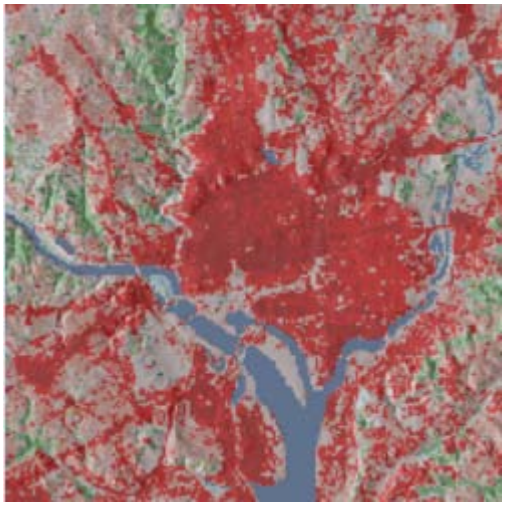
1. Spatial search
2. Change detection
3. Clustering/classification
4. Segmentation/classification

Using GeoPAT for search

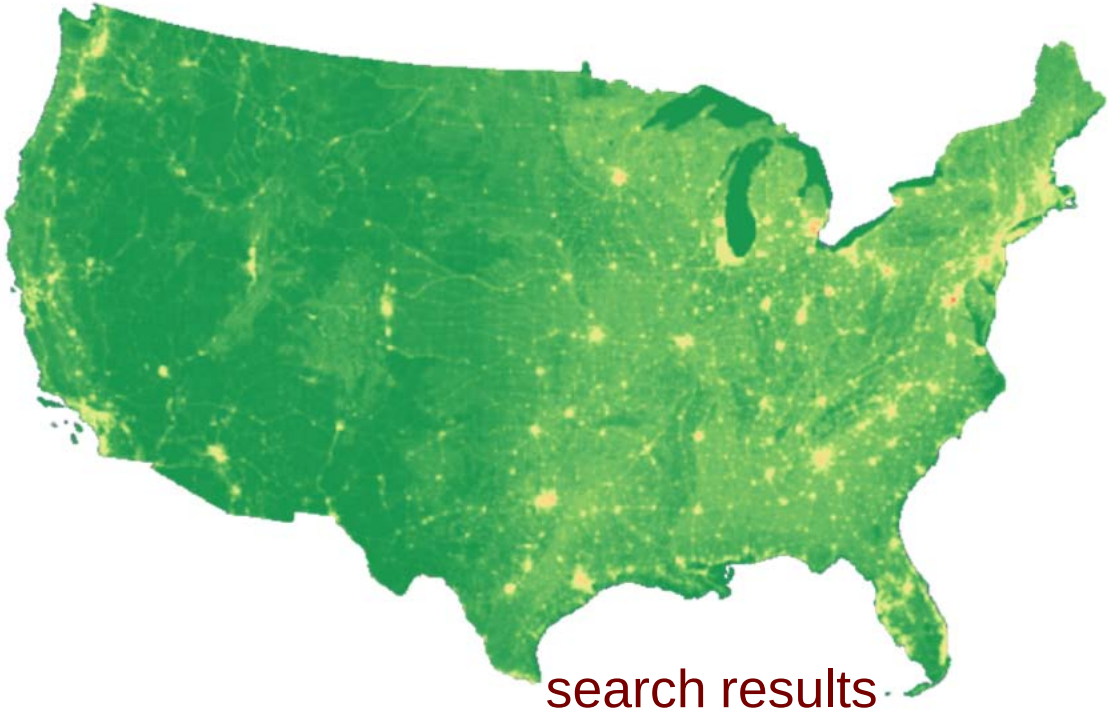


Using GeoPAT to search for spatial patterns similar to a query: U.S. land cover

Dataset: National Land Cover Dataset (NLCD) res 30m/cell



query – Washington DC



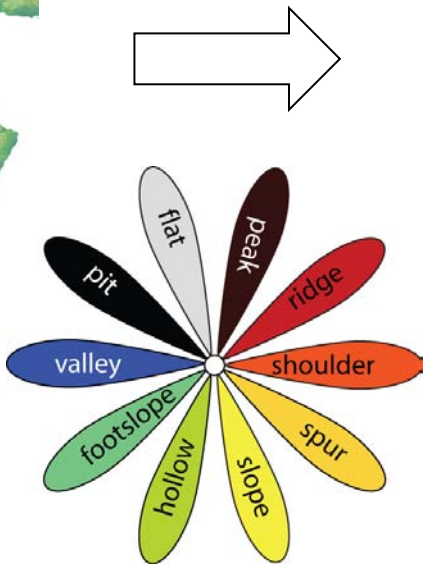
search results

You can perform your own search on NLCD at
sil.uc.edu/webapps/landex_usa/

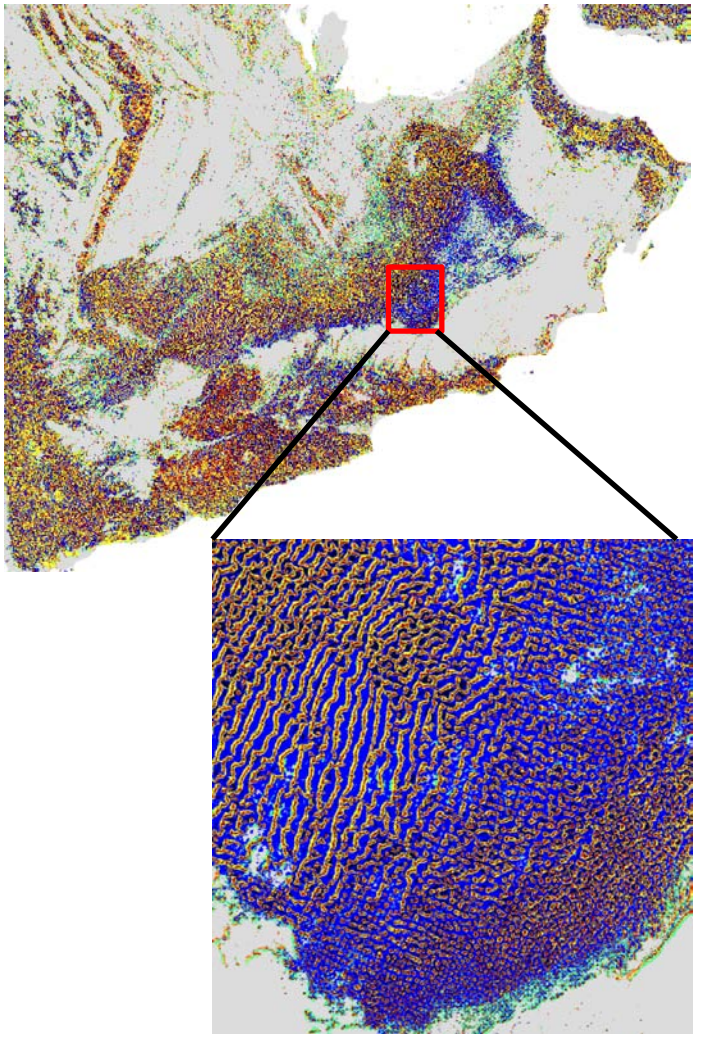
Using GeoPAT to search for spatial patterns similar to a query: global topography

Dataset: Shuttle Radar Topography Mission (SRTM) res 90m/cell

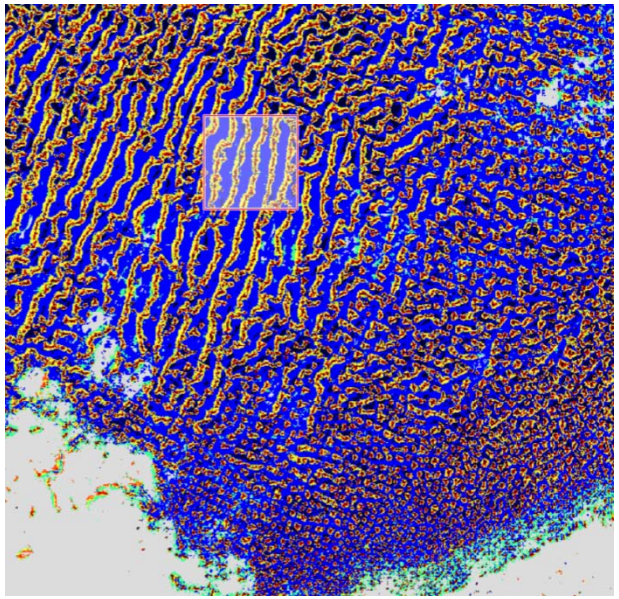
Original data: topographic map

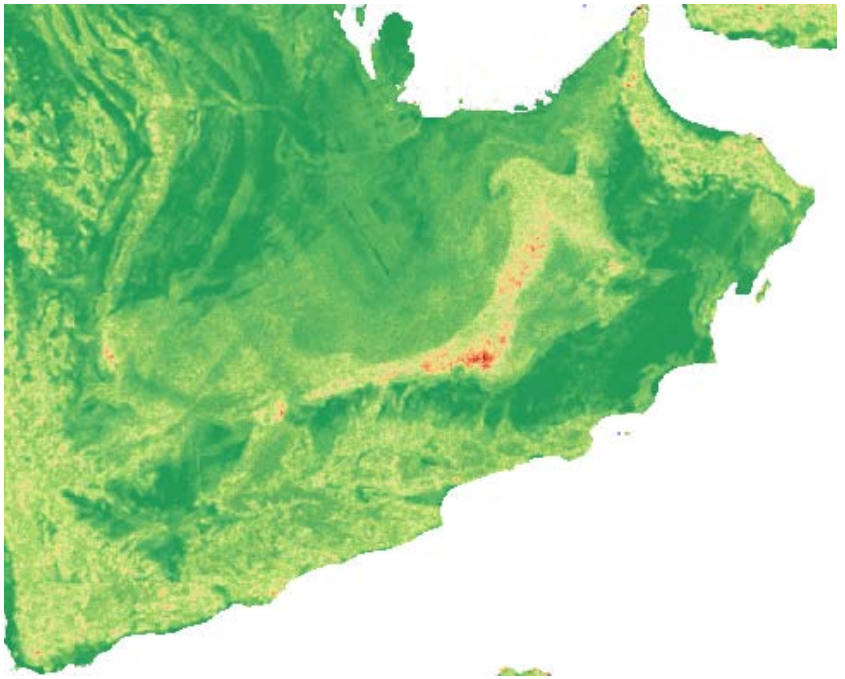


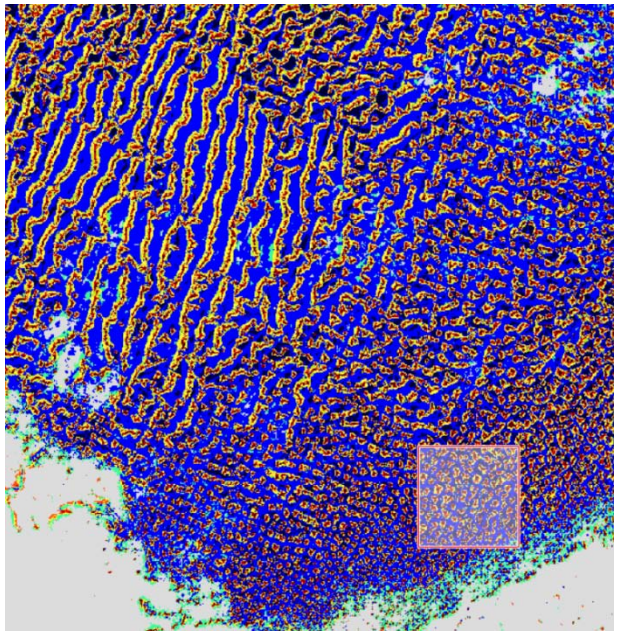
Converted data: geomorphons map



Search of global topography continue



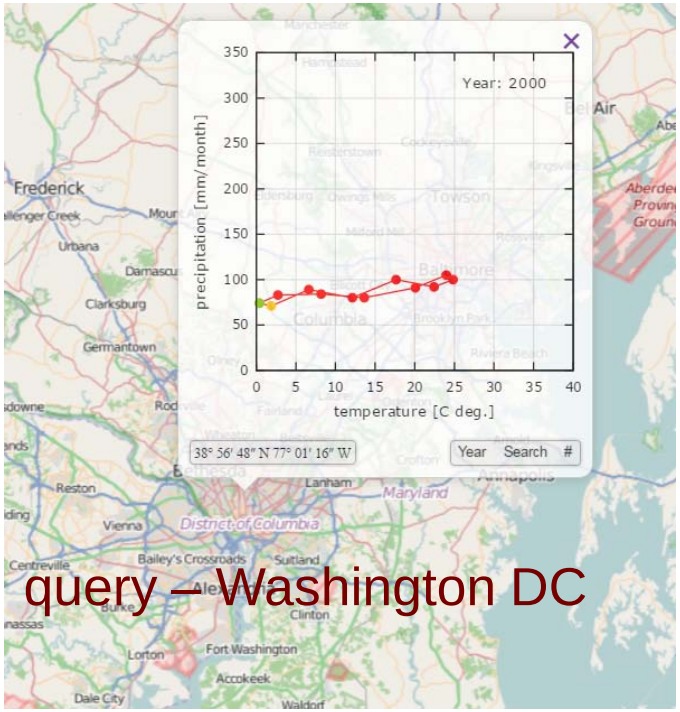




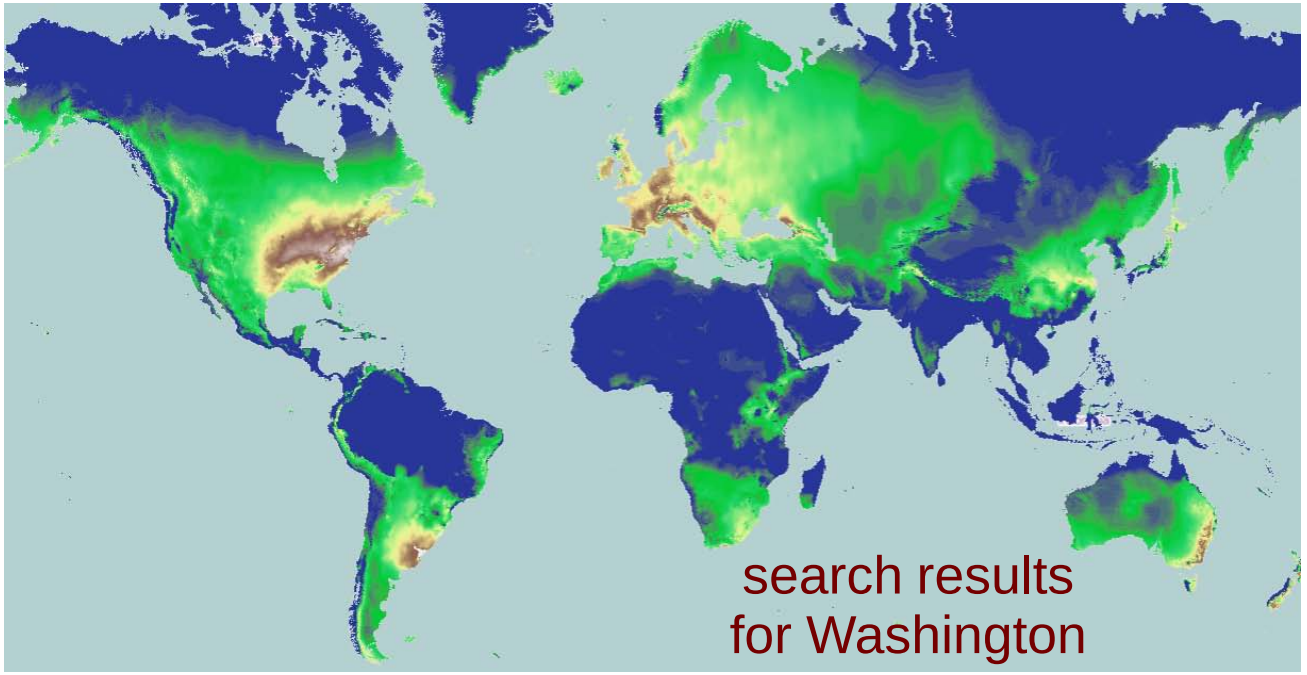
Examples computed online by TerraEx (http://sil.uc.edu/webapps/terraex/) (beta)

Using GeoPAT to search for temporal patterns similar to a query: global climate

Dataset: WorldClim res 4km/cell



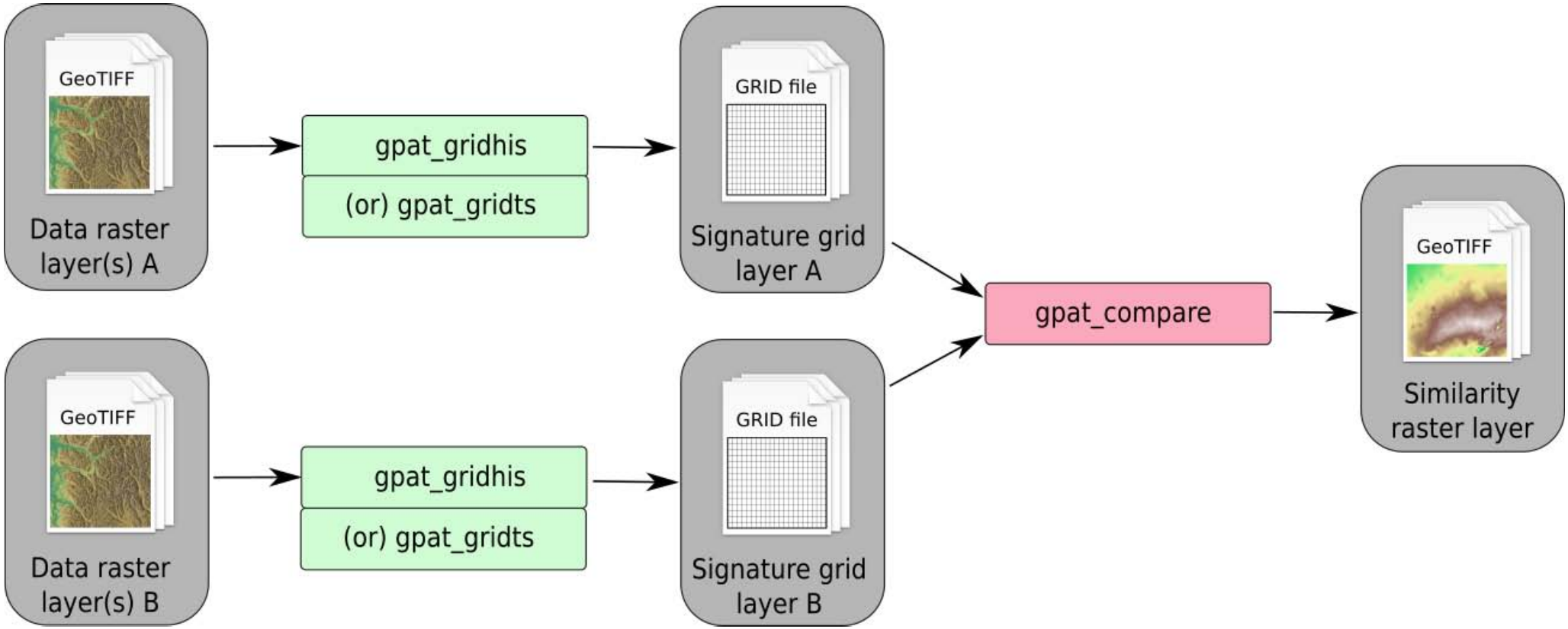
query – Washington DC



search results for Washington

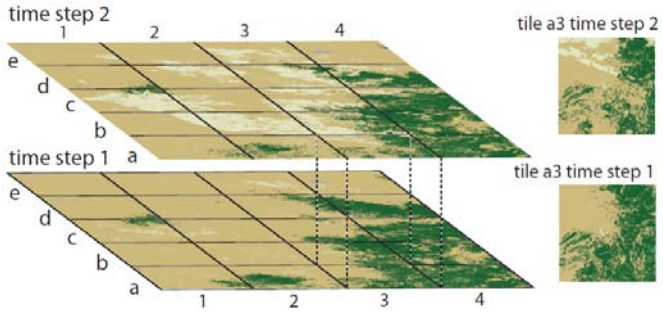
You can perform your own search on global climate at sil.uc.edu/webapps/climateex

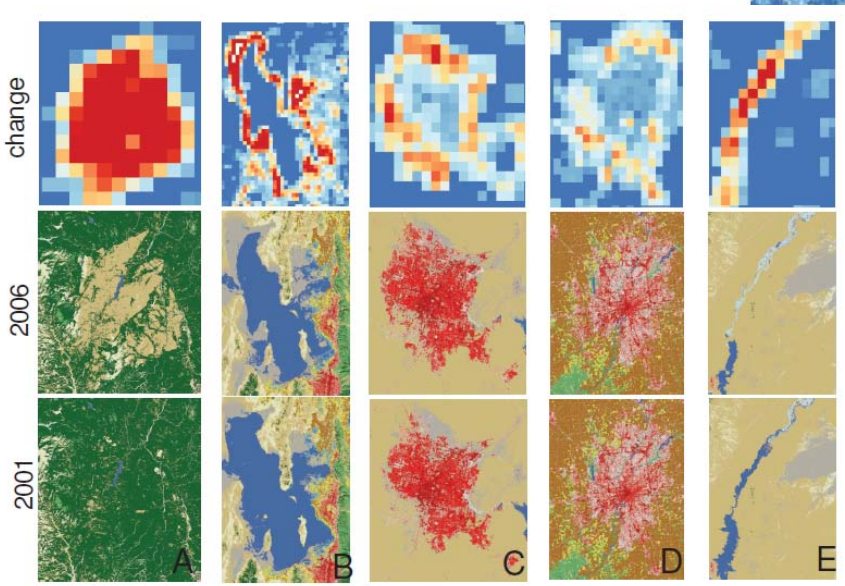
Using GeoPAT to calculate change

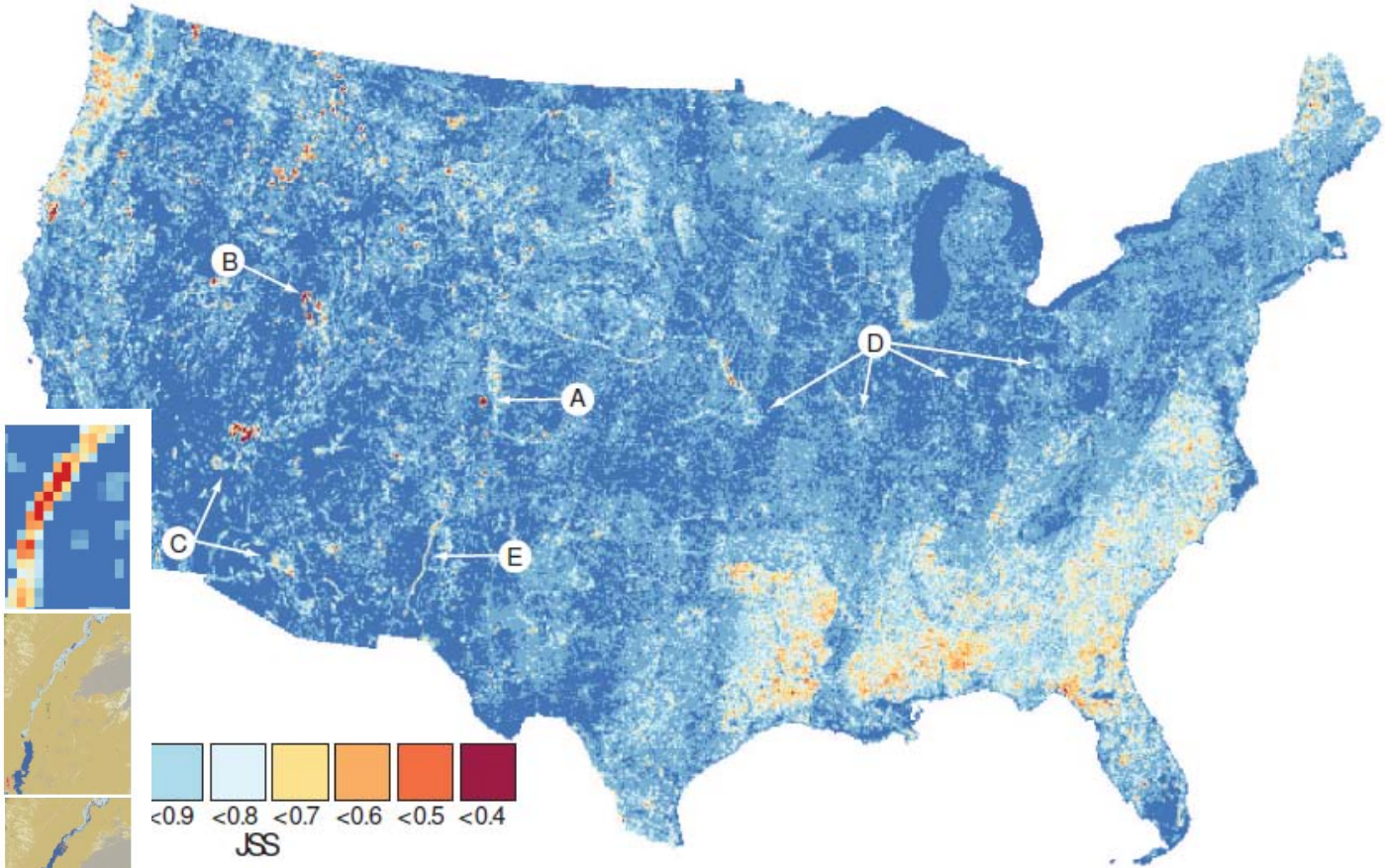


Using GeoPAT to calculate change: U.S. land cover

Dataset: NLCD 2001 and 2006 res 30m/cell



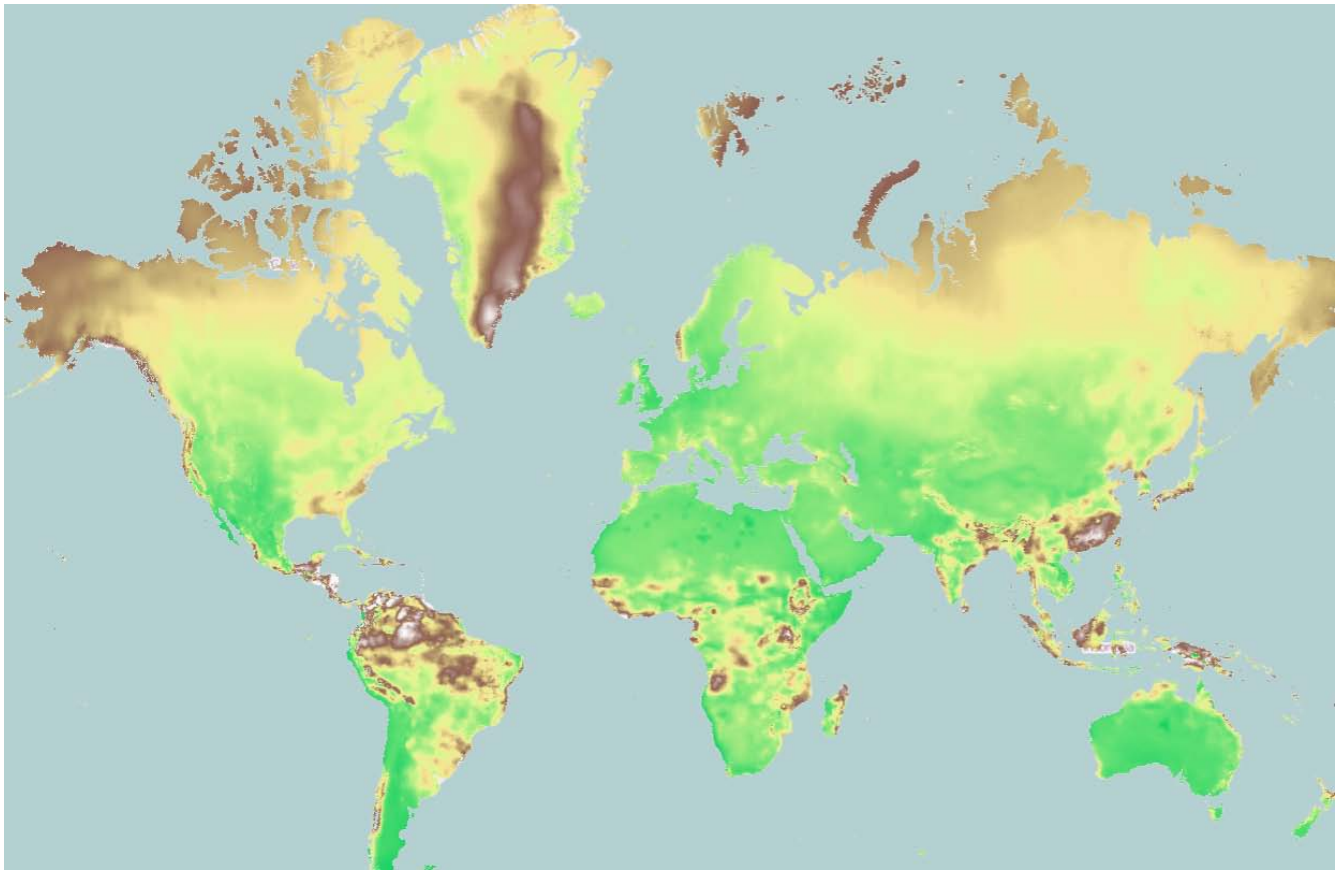




You can explore this map of change in more details at sil.uc.edu/webapps/dataeye_usa/

Using GeoPAT to calculate change: Global climate

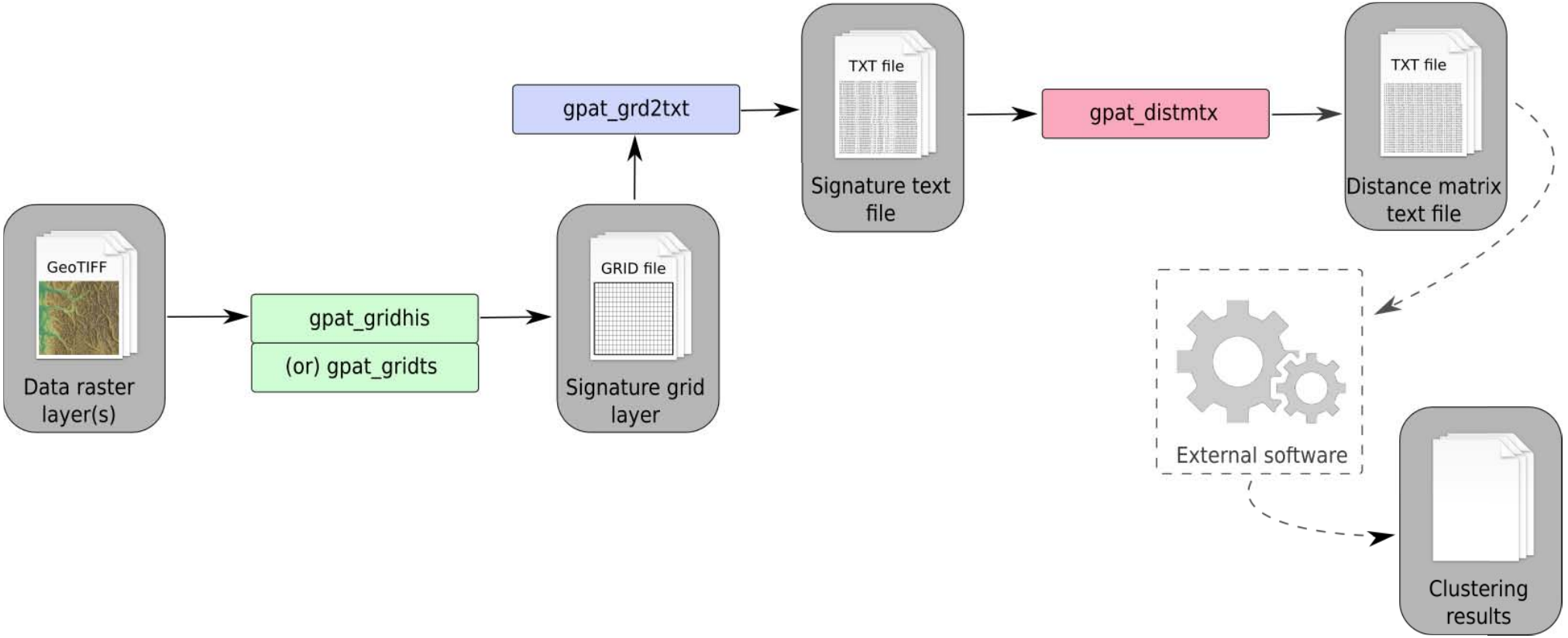
Dataset: WorldCilm 2000 and 2070 res 4 km /cell



Climate change 2000 -2070

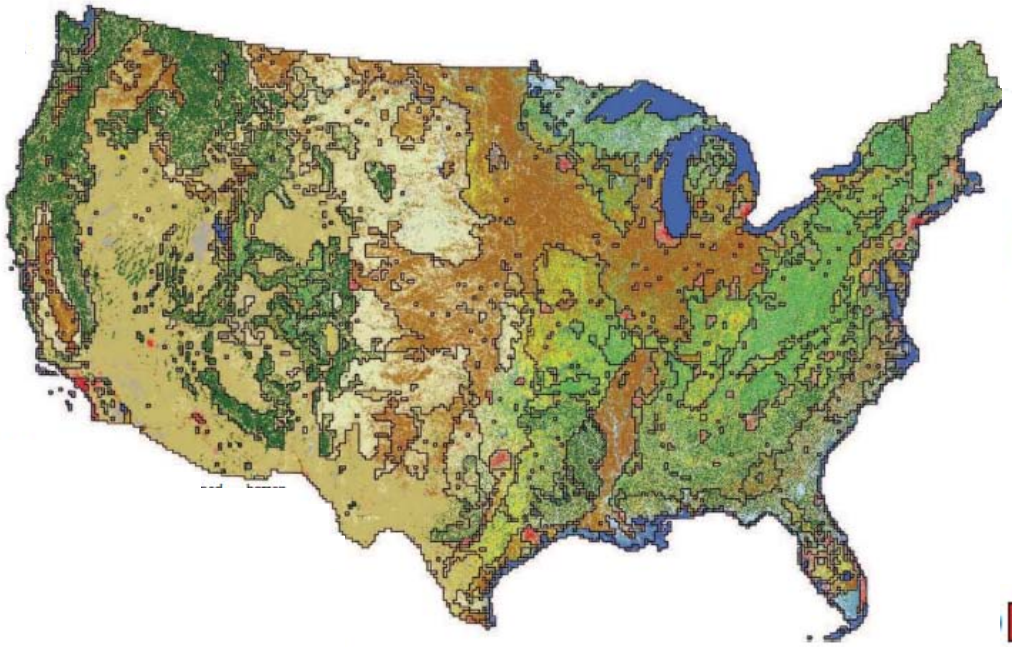
You can explore global climate change at more details at sil.uc.edu/webapps/climateex

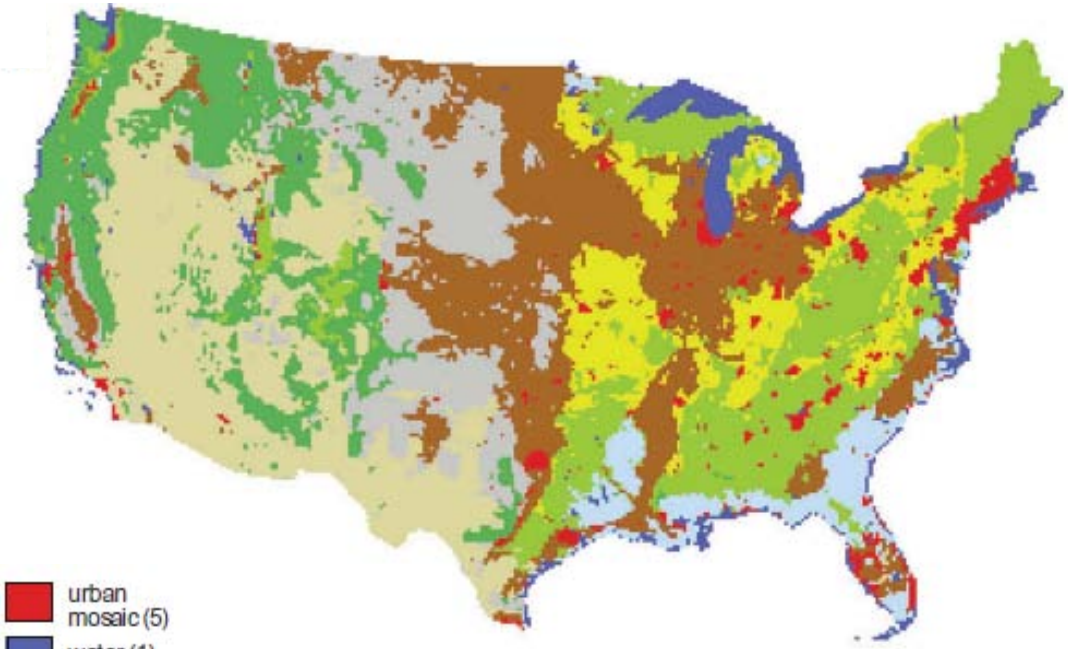
Using GeoPAT for clustering



Using GeoPAT to find regions with similar spatial pattern via clustering: U.S. land cover

Dataset: NLCD res 30 m /cell

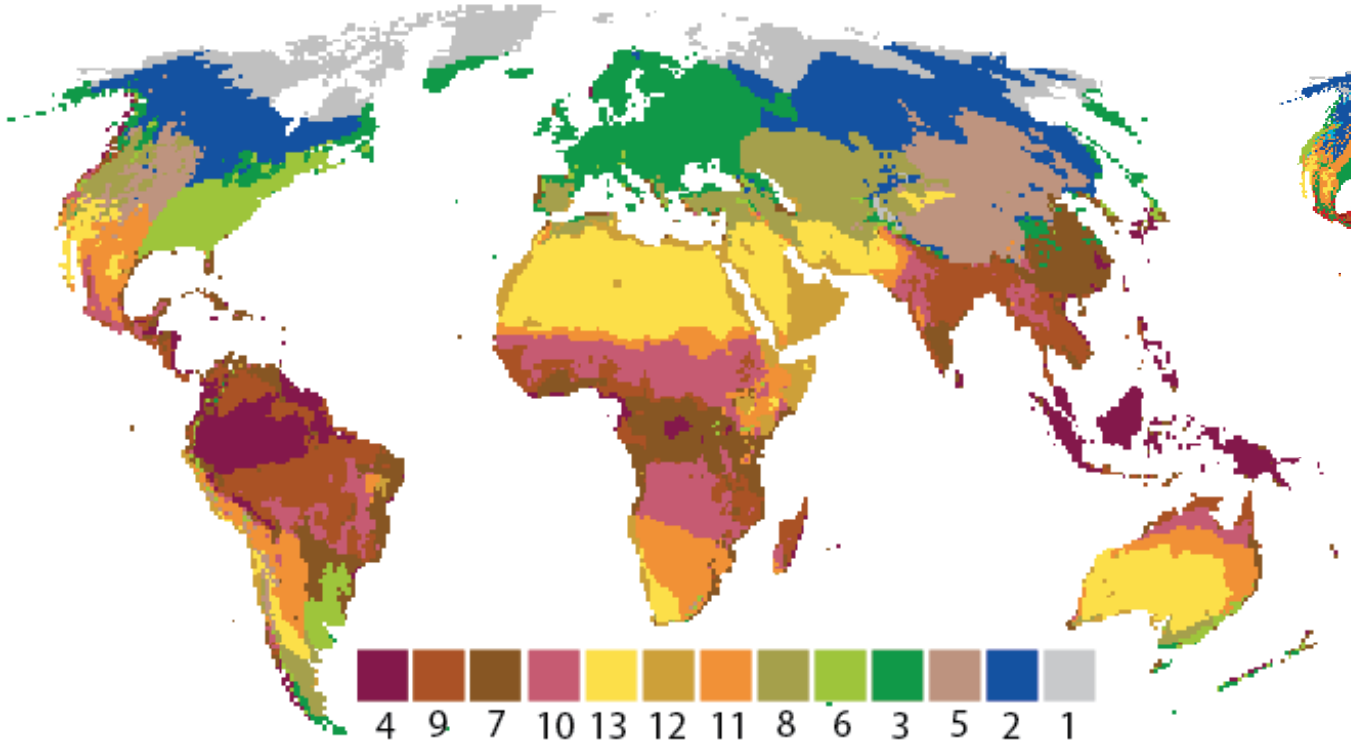


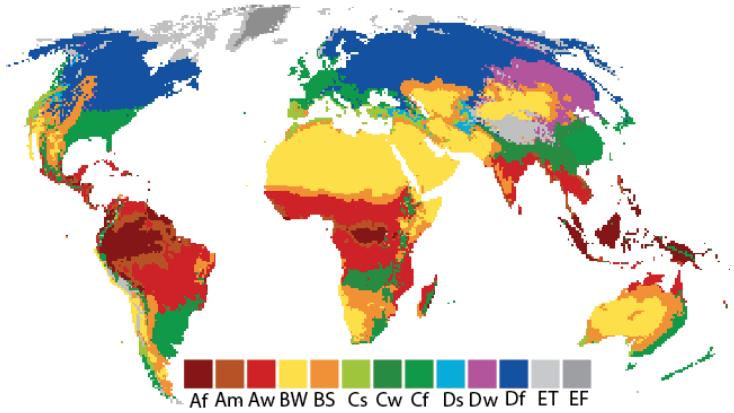


Clustering all local patterns of NLCD into nine clusters yields a generalization of US land cover.

Using GeoPAT to find regions with similar spatial pattern via clustering: Global climate

Dataset: WorldClim res 4 km /cell

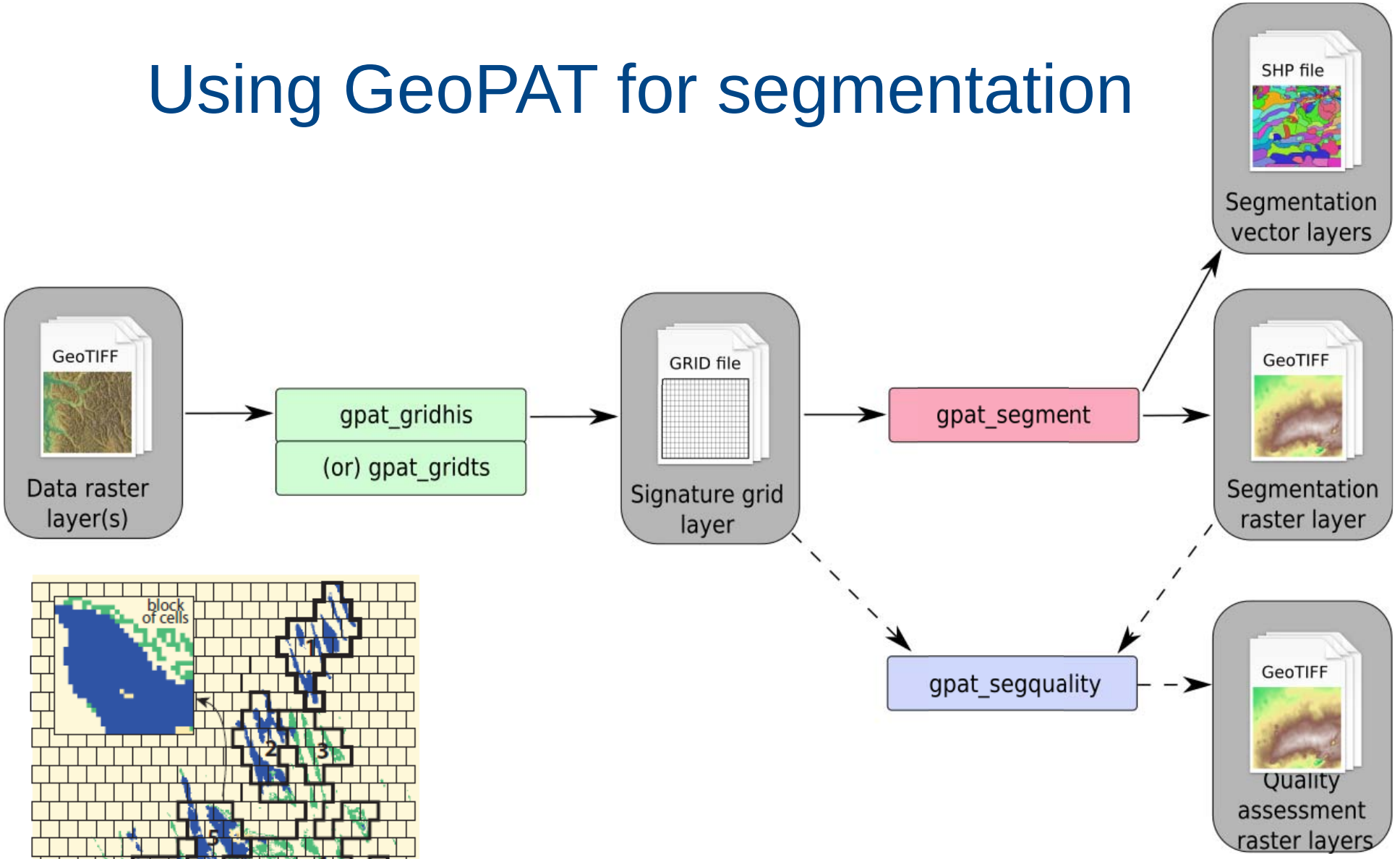


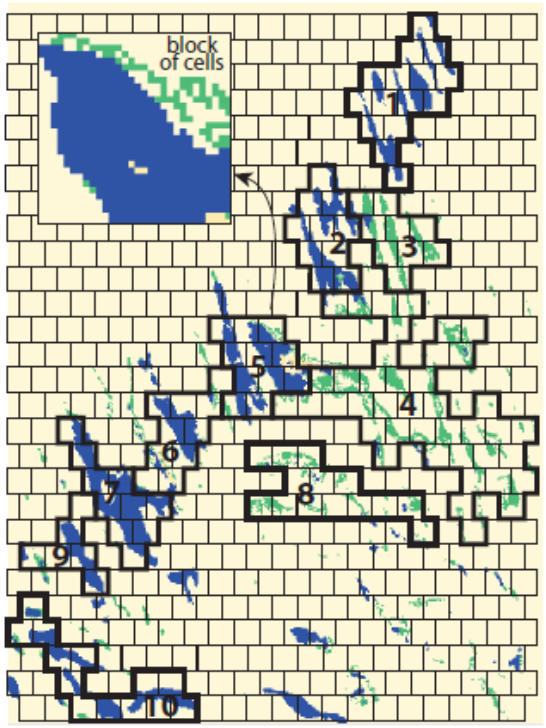


Standard, Koppen-Geiger climate classification

Global climates clustered using a concept of climate as time series (temporal pattern) and utilizing the Dynamic Time Warping (DTW) as similarity function

Using GeoPAT for segmentation

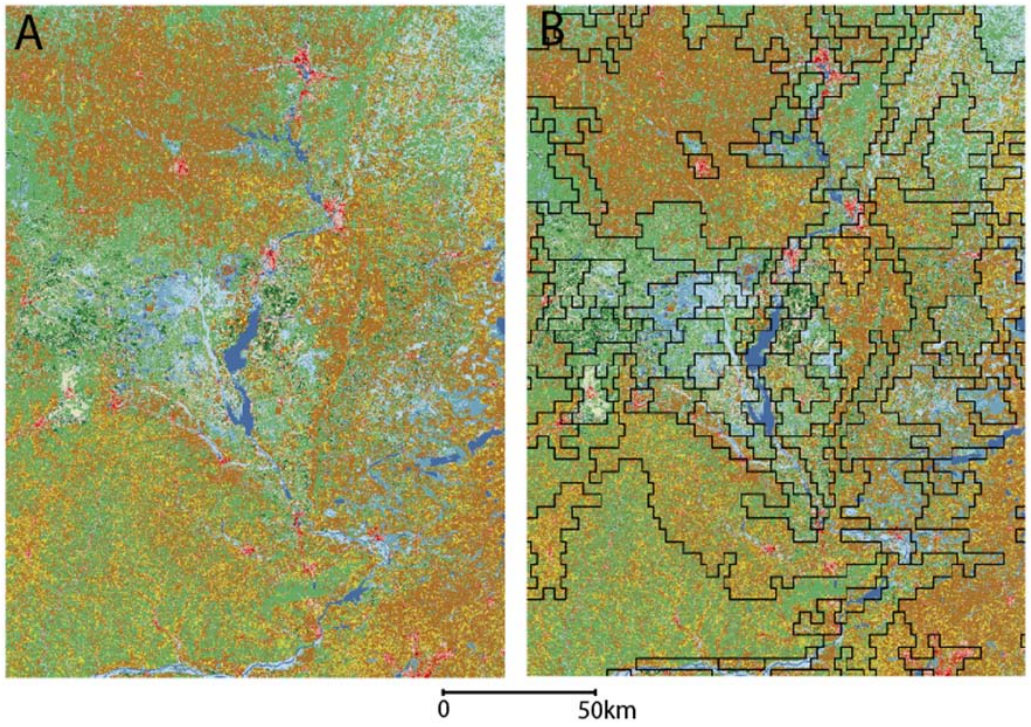




Illustrating pattern-based segmentation

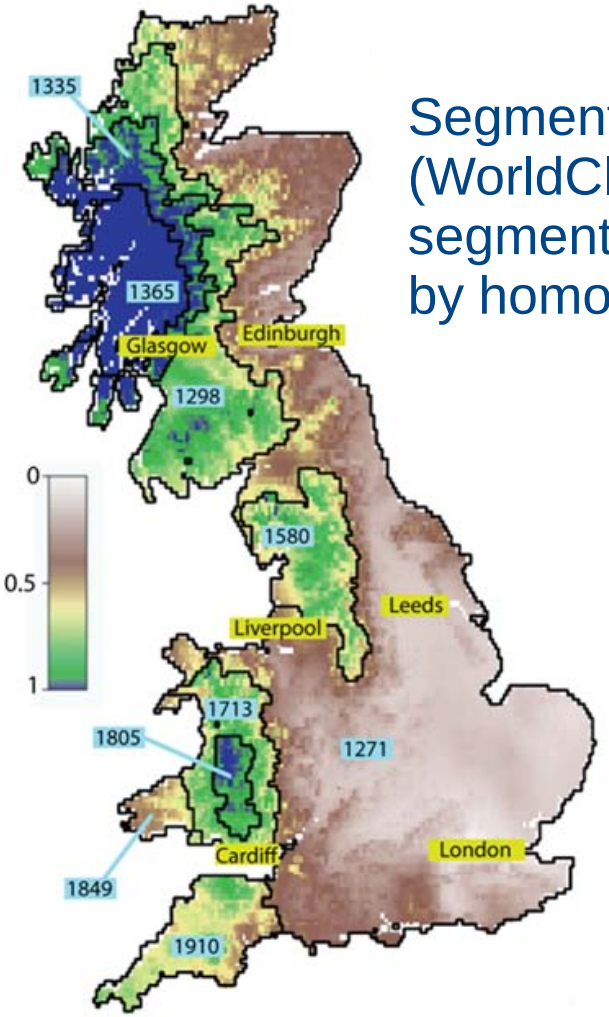
Pattern-based segmentation – perhaps the most useful analysis using GeoPAT

Segmentation on the basis of homogeneity of spatial patterns



Segmenting land cover (NLCD) pattern
Each segment is characterized by homogeneous pattern of land cover categories.

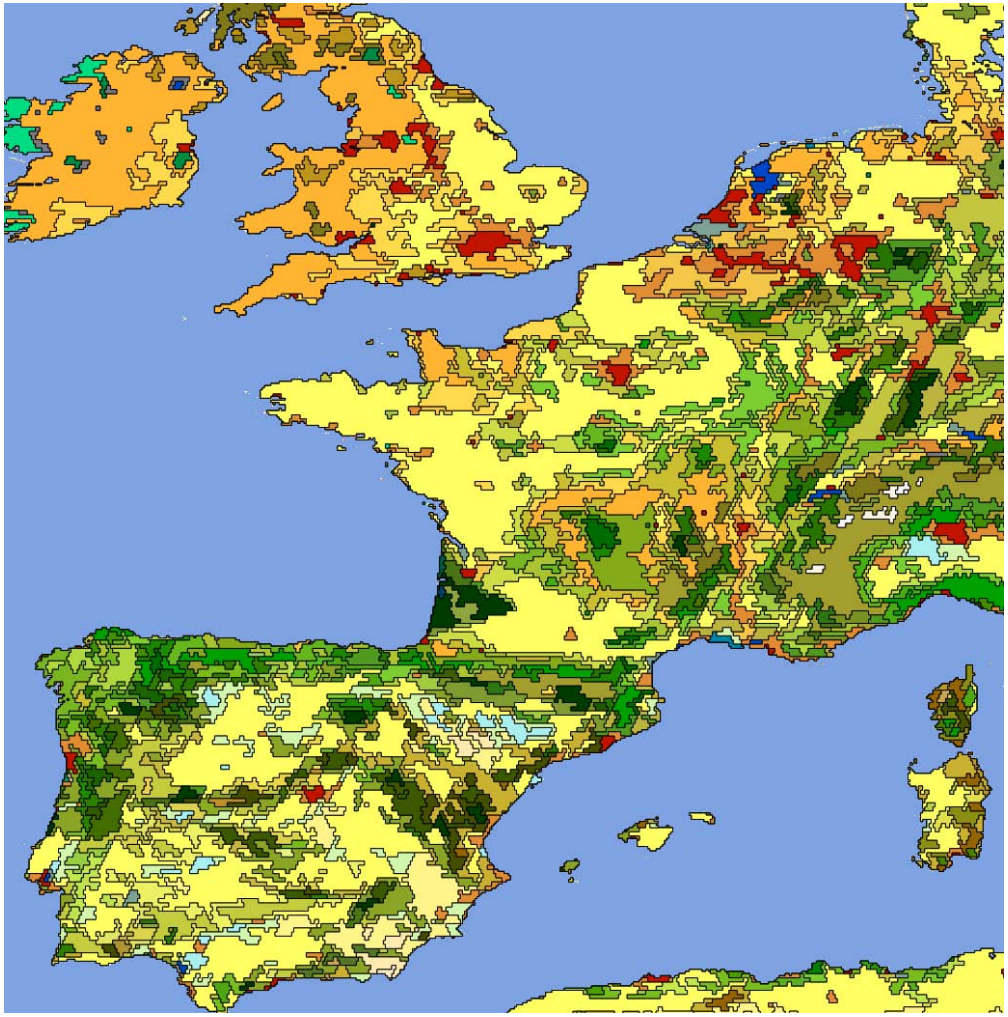
Segmentation on the basis of homogeneity of temporal patterns



Segmenting climate (WorldClim). Each segment is characterized by homogeneous climate.

Using GeoPAT to segment and classify land cover patterns worldwide

Dataset: Land cover (CCI-LC) res 300 m /cell
Calculations for entire world, western Europe is shown for details



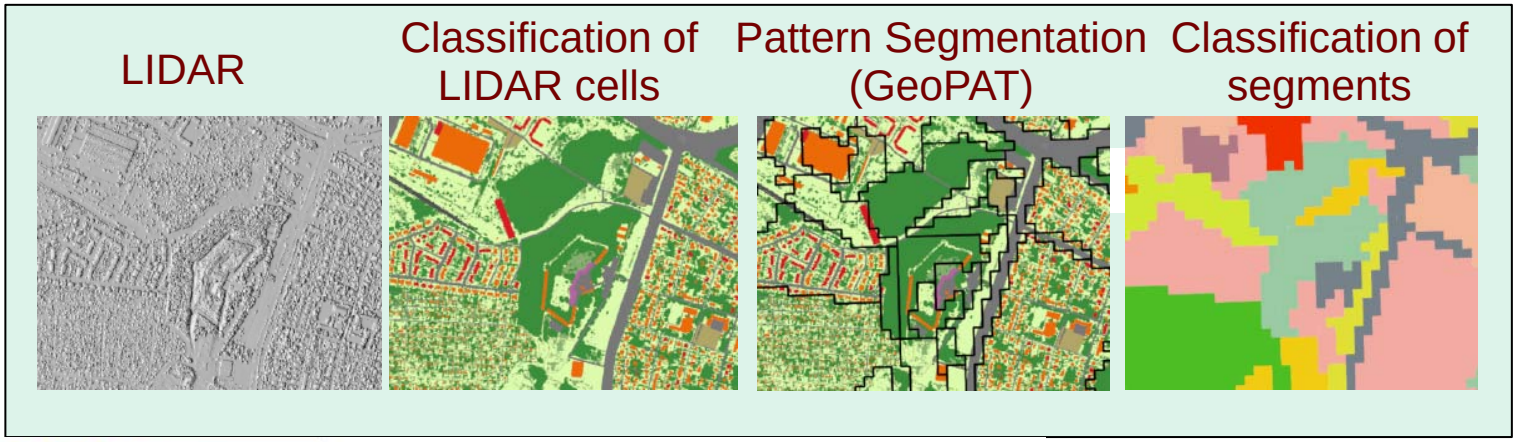
~100,000 segments delineated worldwide using 9 km as local scale of a pattern

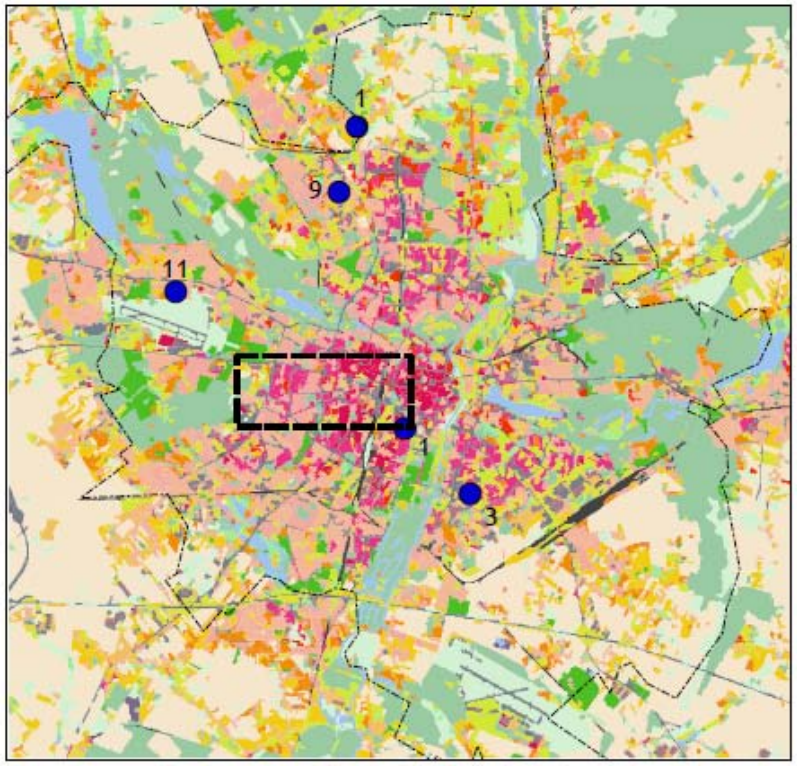
Segments worldwide classified to ~600 categories based on pattern

Using GeoPAT to segment and classify urban structure types

Dataset: LIDAR res 12 point/m^2

22000 X 21000 raster based on LIDAR measurement in a city of Poznan is used to derive urban structure types (USTs)

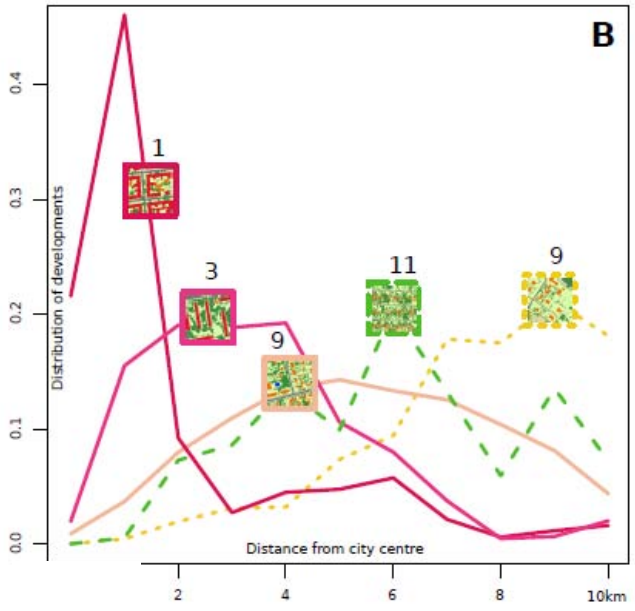




Urban structure types

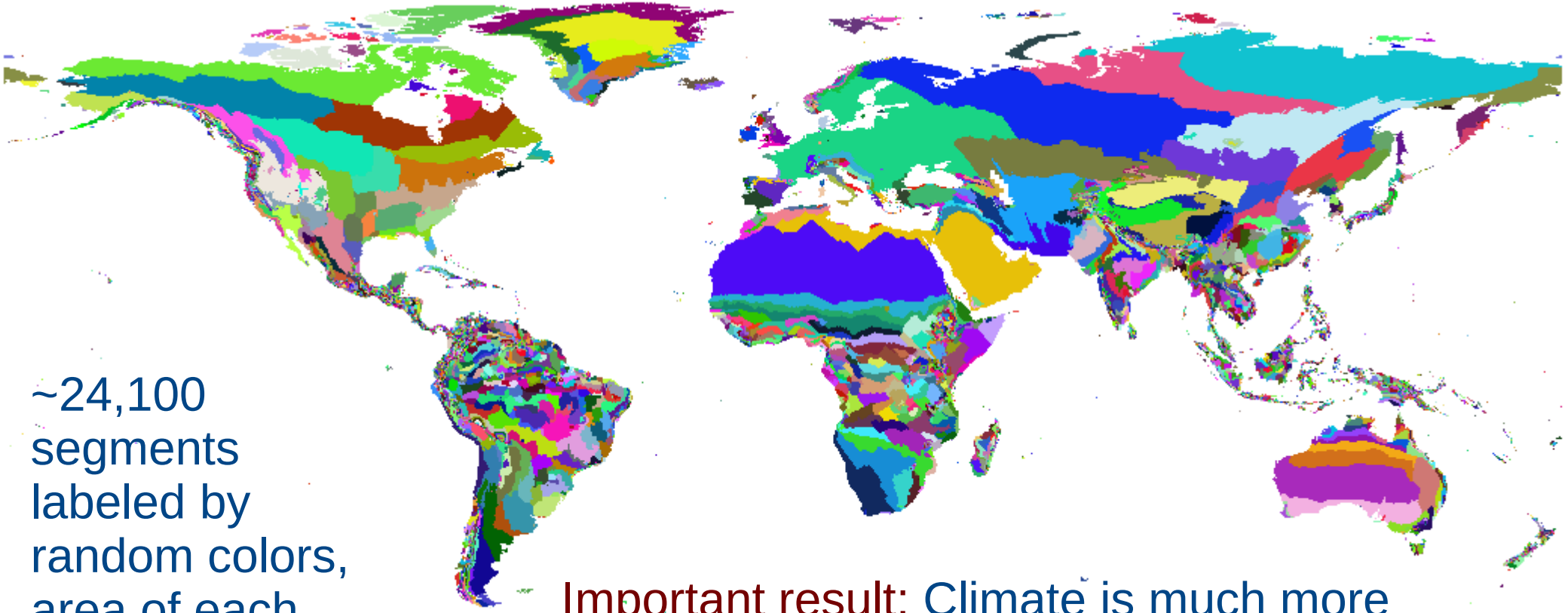
1 City-centre dense developments
2 Multi-family emerging developments
3 Multi - family regular developments with hi
4 Large roads and hard grouns
5 Large surface halls/buildings
6 Single-family large-parcels developments
7 Single-family regular and ribbon developme
8 Single-family and ribbon emerging develop
9 Single-family irregular developments (indivi
10 Single-family irregular emerging developme
11 Allotment gardens
12 Grasslands/trees open spaces poorly develc
13 Open spaces - under developent
14 Arable open spaces
15 Forestes/parks
16 Brushwoods
17 Grassland open spaces
18 Barren lands
19 Rail roads
20 Water

0 1 2 3 4 5 6 7 8 km



Using GeoPAT to segment climates worldwide

Dataset: WorldClim 4 km/cell

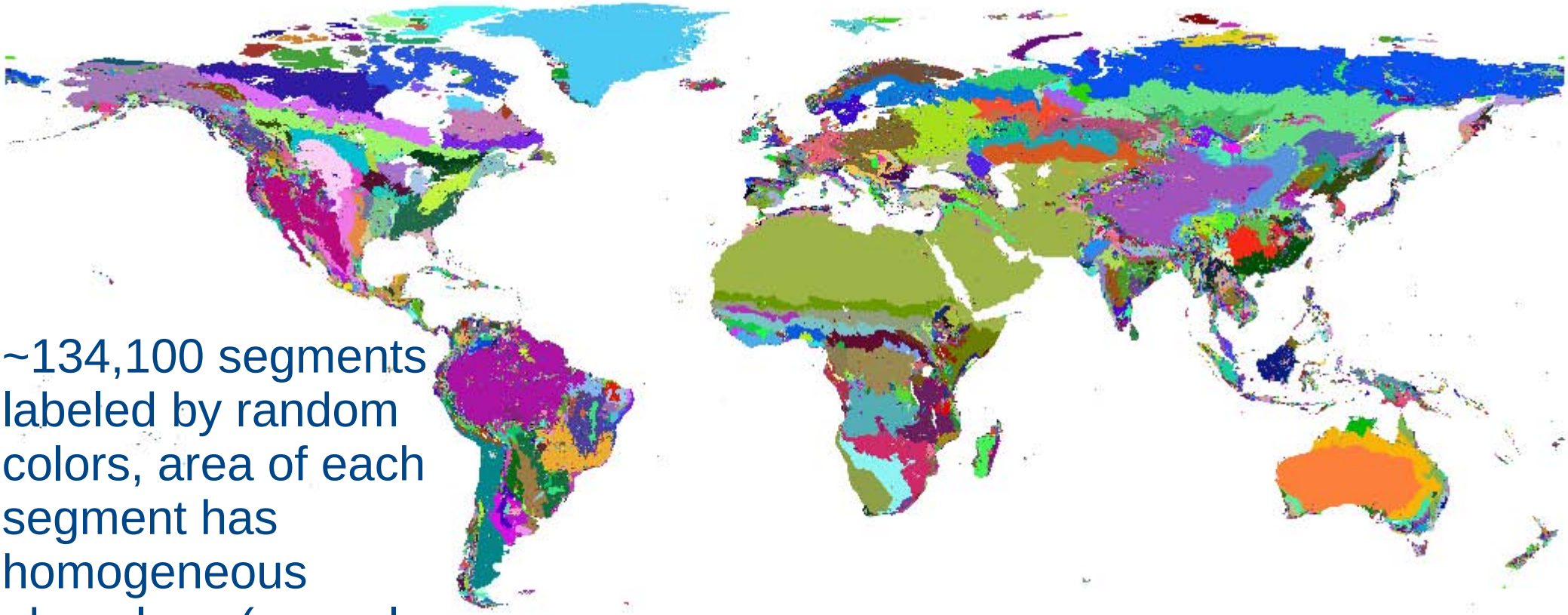


~24,100 segments labeled by random colors, area of each segment has homogeneous climate.

Important result: Climate is much more inhomogeneous in equatorial regions than suggested by classical Koppen-Geiger classification. This inhomogeneity is due to large differences in amount and timing of precipitation.

Using GeoPAT to segment phenology

Dataset: EVI time series 4 km/cell

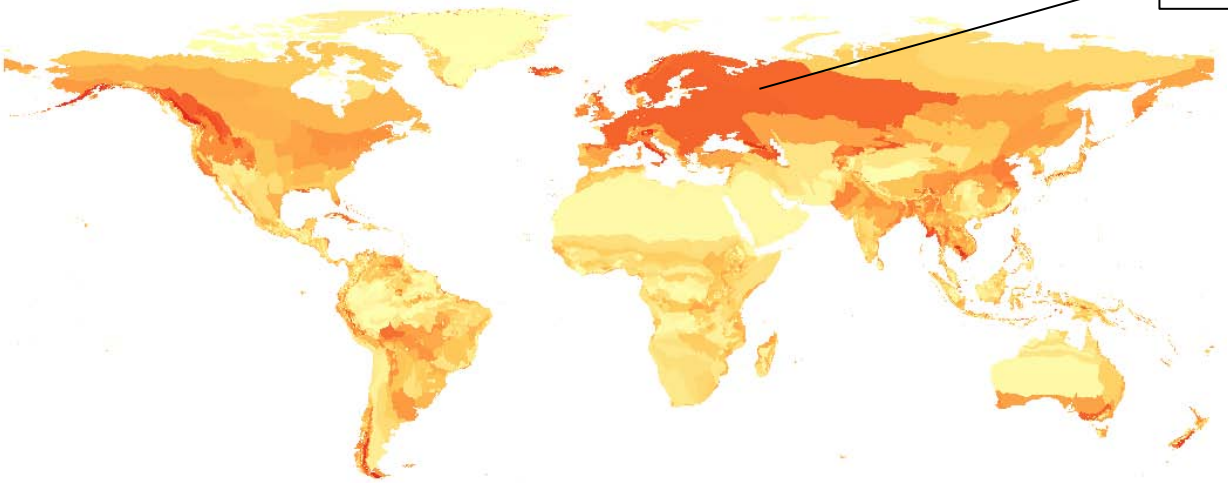


~134,100 segments labeled by random colors, area of each segment has homogeneous phenology (annual progression of EVI).

Important result: First regionalization of phenology worldwide. Could be compared to regionalization of climate (next slide)

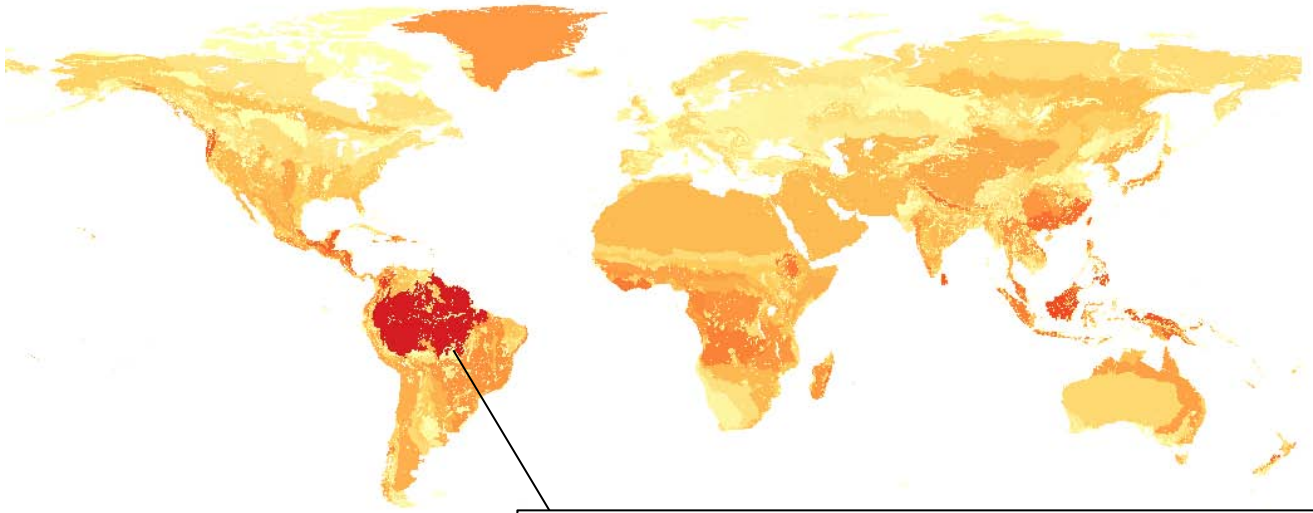
Climate versus phenology

This region has relatively homogeneous climate but varies in phenology



Inhomogeneity of phenology in climate segments

The redder the color the more inhomogeneous is the segment



Inhomogeneity of climate in phenology segments

Amazon region is characterized by a single phenology but many different climates (vegetation annual progression insensitive to differences in precipitation)

Summary

GeoPAT is an idea-driven rather than data-driven software

GeoPAT fills a niche devoted to analysis of large spatial datasets in their entirety.

GeoPAT achieves its goal by starting from radical compression of original data leaving only information necessary to complete its tasks

GeoPAT does not require supercomputer or cloud computing because core calculations are performed on a grid orders of magnitude smaller than a grid of original data. It works well on a moderate server.

GeoPAT is an open and free software

Binaries for Linux and Windows are available for download.

Summary 2

Examples of public data that could be used by GeoPAT

1. Land cover (NLCD, GLC30, GlobCover, CORINE, EOSD)
2. Topography (NED, SRTM)
3. Croplands (USDA CropScape)
4. Urban Structure Types (UST) (National Map, LIDAR)
5. Global climate (WorldClim)
6. Phenology data (EVI)

Examples of problems that could be addressed using GeoPAT

1. Ecology (delineation of ecoregions, climate versus phenology)
2. Forestry (conservation planning and management)
3. Agriculture (identify spatio-temporal patterns of usage of U.S. croplands)
4. Climate (climate change)