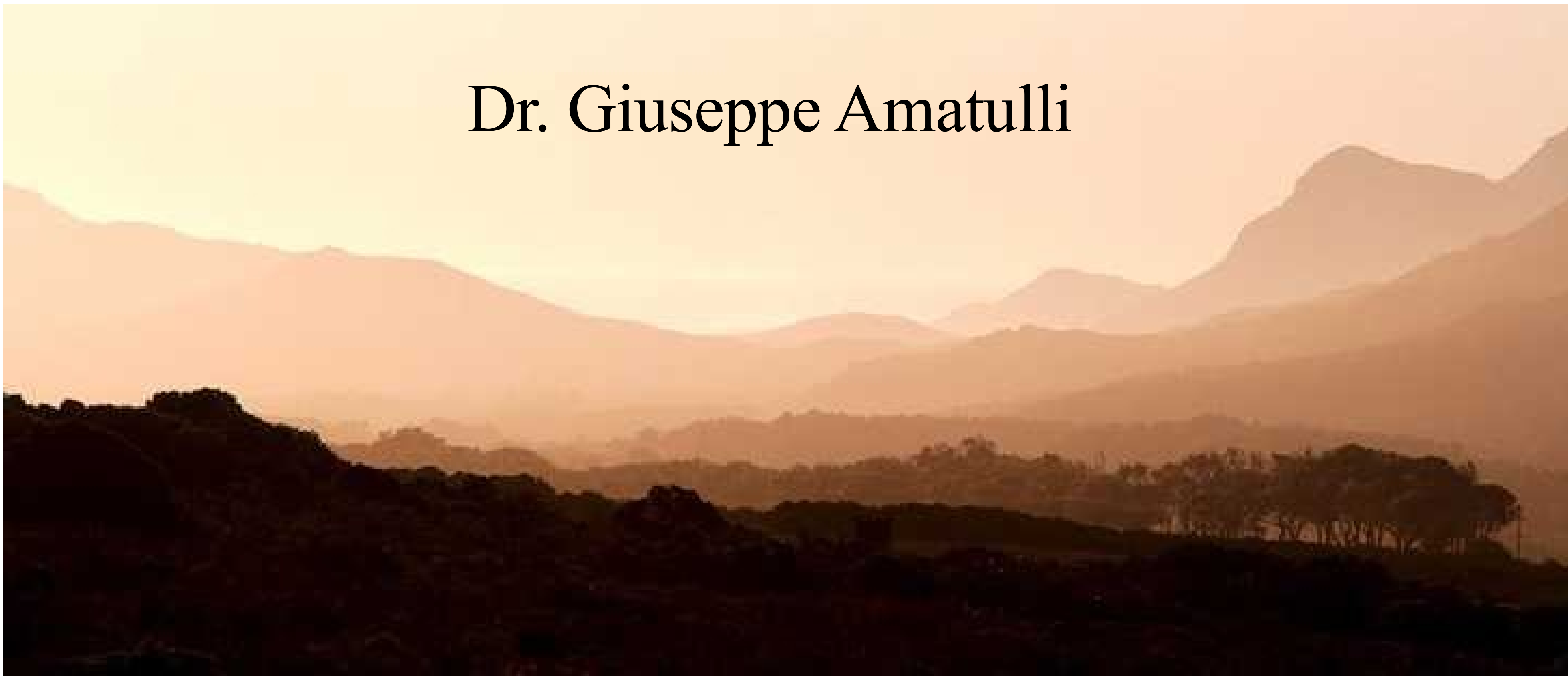
GIS and RS for Biodiversity
Biodiversity ~ f (environment)



Dr. Giuseppe Amatulli

Objectives
Biodiversity ~ f(**environment**)

A whirlwind tour of environmental data:

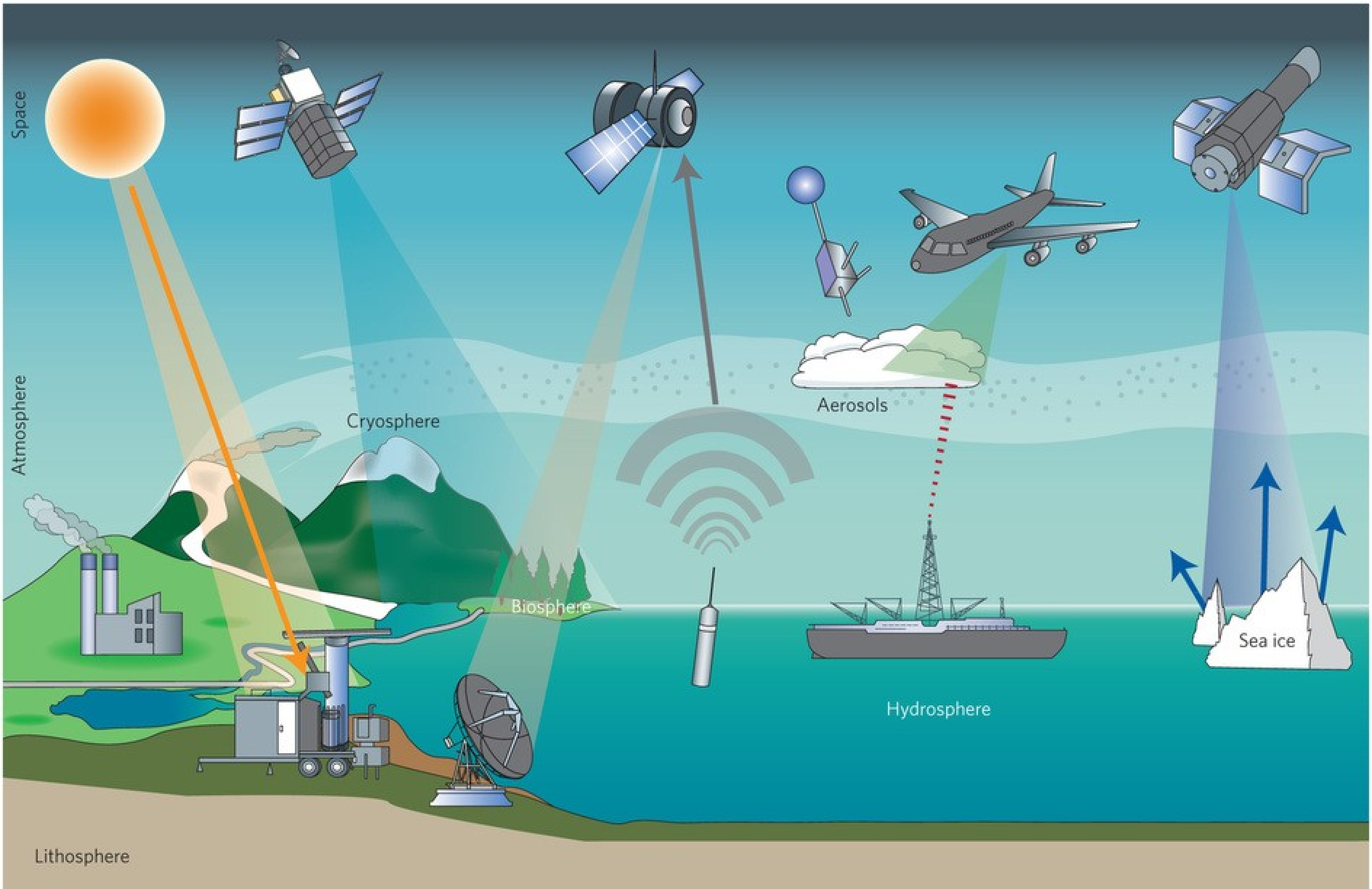
- Climate (past & future)
- Topography
- Ecosystem Parameters
- Land Cover



Key take-home messages:

1. Data deluge → incredible opportunities
2. Data complexity → biogeographers must be vigilant

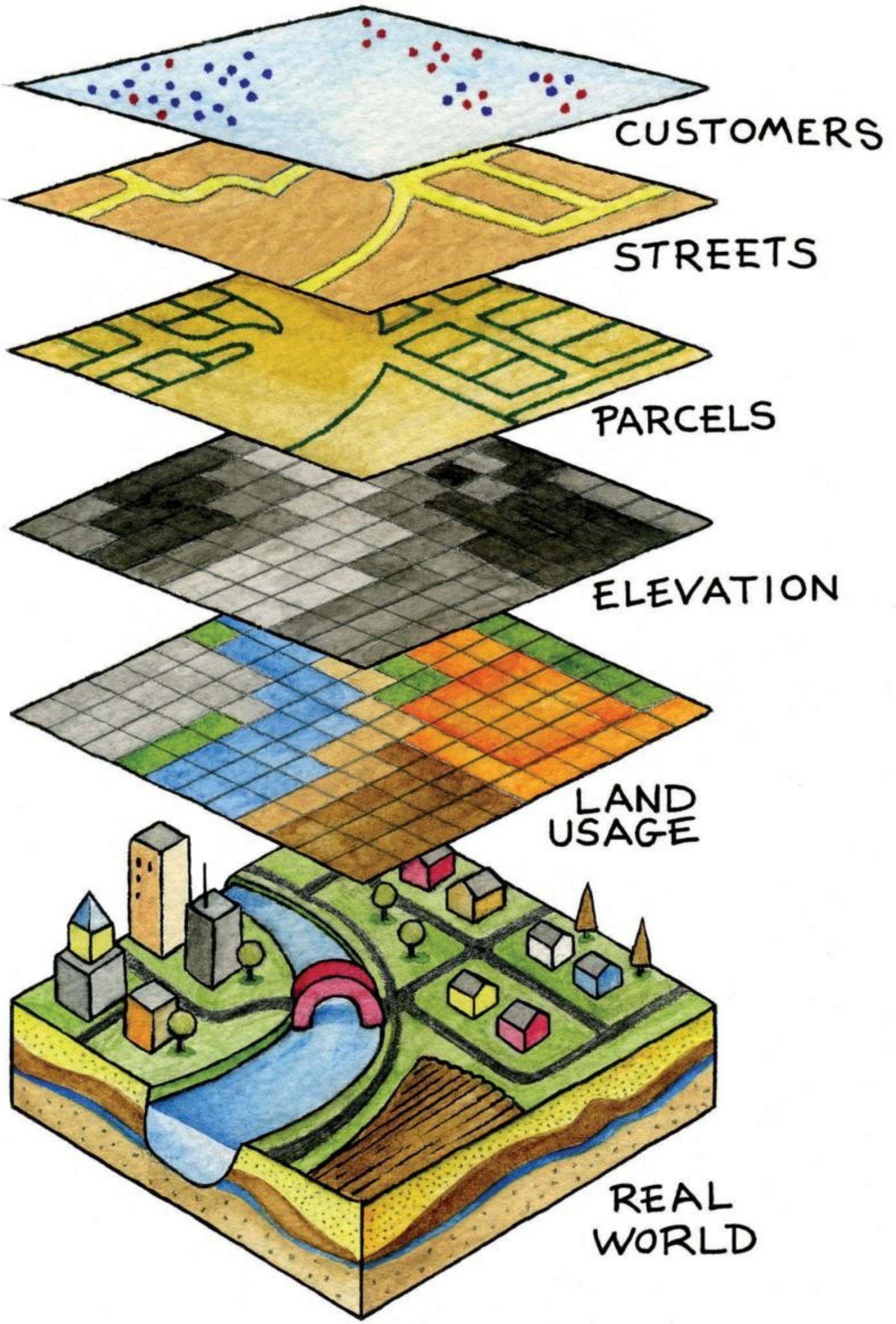
Remote sensing



Geographic
Information System

Combine:
- satellite information,
- ground true
- gps device data,
- station data

Modeling



Climate: Data Sources

Past

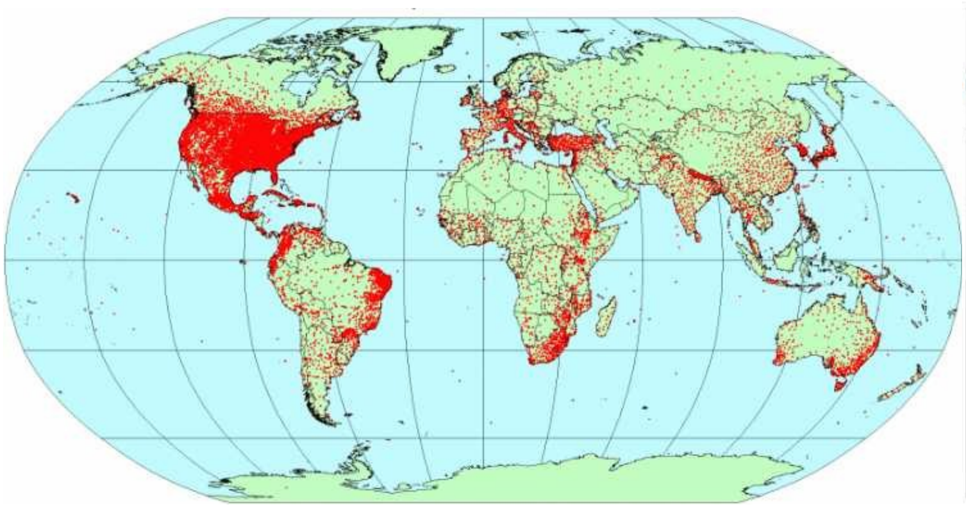
- Pre-historical (<1850): proxies (ice, pollen, trees, etc.)
- Station data (≈1850-Present):
  National archives, NCDC Global Historical Climate Network
- Gridded Station data (climate or weather):
  NCDC GHCN, CRU Data, PRISM, WorldClim
- Historical Climate Model data: CMIP5: Last Glacial Maximum – 2012
- Sub-daily Gridded 'reanalysis' model data:
  NCEP & NARR & ERA40 reanalysis

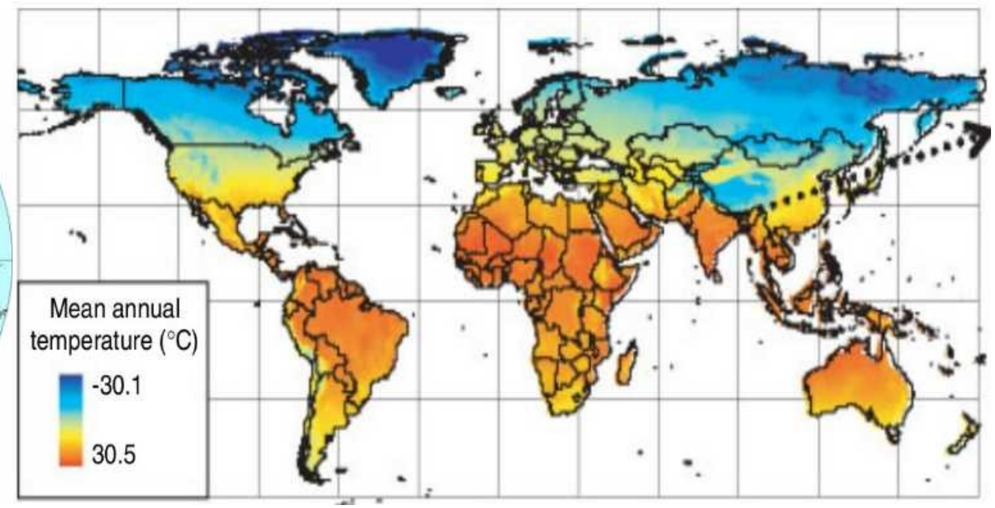
Future

- Gridded model output (hourly/daily/monthly):
  Global / Regional Climate Model (GCM/RCM)
- Station data: Downscaled to stations

WorldClim https://worldclim.org
Chelsa https://chelsa-climate.org

Station Locations → Continuous Grid

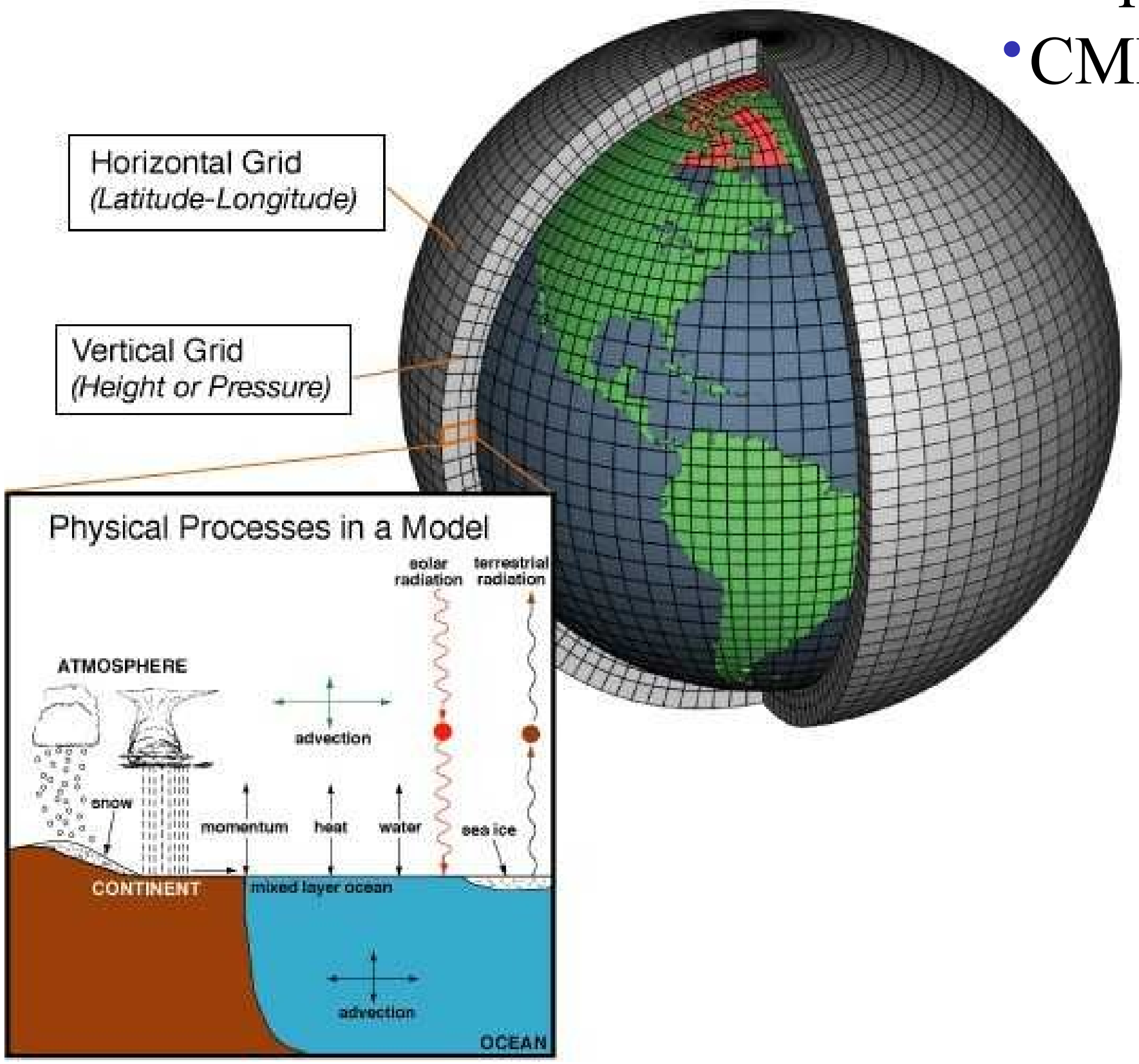




- Global ≈1km resolution monthly T_{max}, T_{min}, and Precipitation.
- Thin-plate splines (latitude, longitude, and elevation).
- No pixel-by-pixel metrics of uncertainty

Climate Models

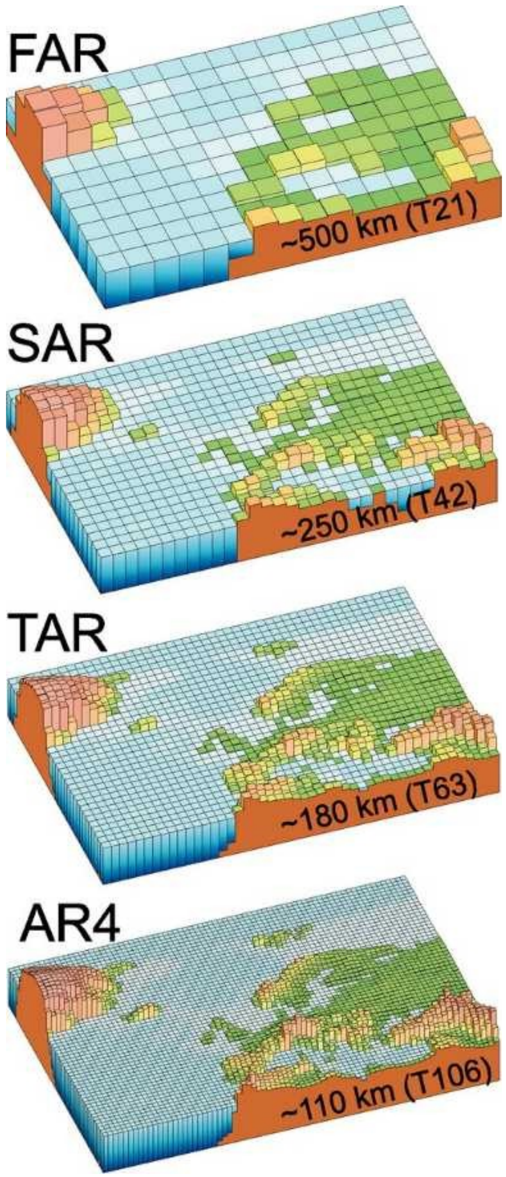
- IPCC/CMIP organize most model output
- CMIP5 released last year

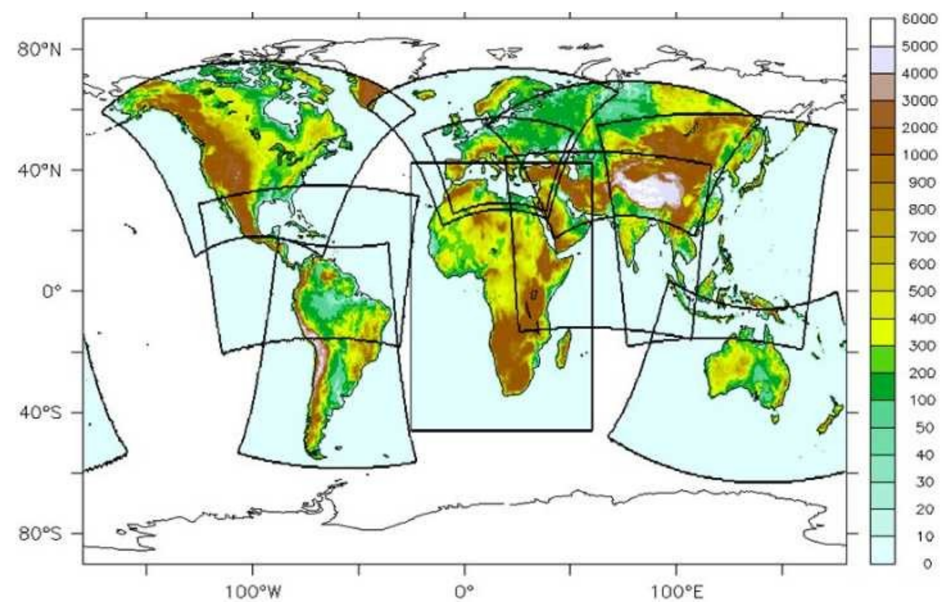


http://cmip-pcmdi.llnl.gov/cmip5/
http://nco.sourceforge.net/nco.html

Climate Models

GCM resolution increasing: CMIP5 atmosphere-land time-slices → 25km





Regional Climate Models
(AR5 CORDEX): ~50km

IPCC AR4, WGI, Chapter 1
http://www.meteo.unican.es/en/projects/CORDEX

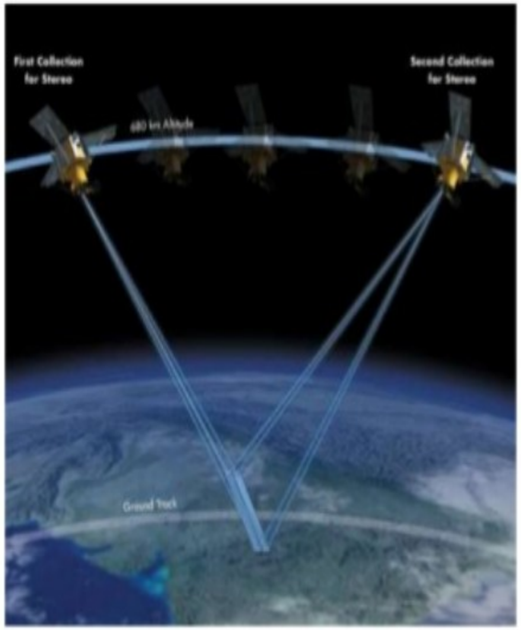
Topography complexity
(geomorphometry/geomorphology analysis)

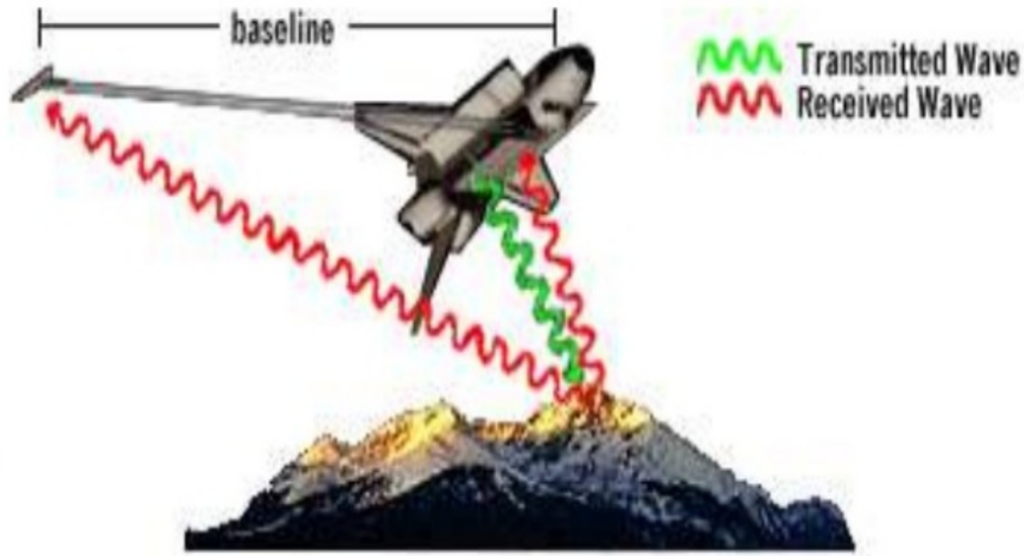




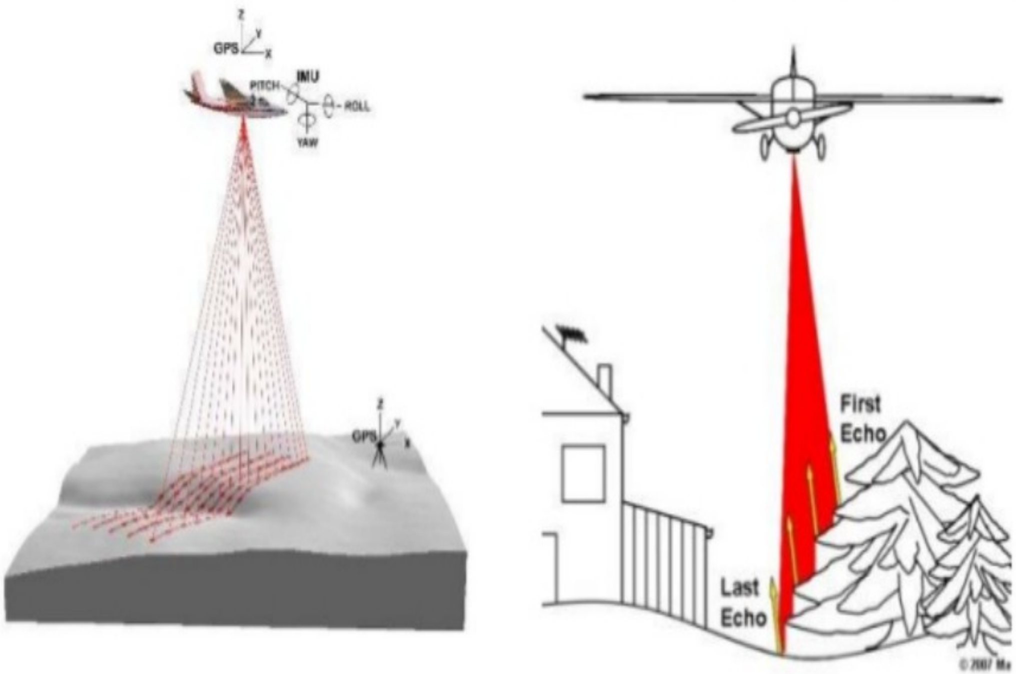

Topographic variation underpins a myriad of patterns and processes in hydrology, climatology, geography and ecology, and is key to understanding the variation of life on the planet (Amatulli et al. 2018).

How is a DEM generated?





RADAR Interferometry with 2 receivers, 60m apart



Airborne Laserscanning or LIDAR

A) From airborne or satellite remote sensing: Stereo images, RADAR or LIDAR data are used in a semi-automated process to create a DEM.

Multi-Error-Removed Improved-Terrain DEM

http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/

MERIT DEM

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER

10.1002/2017GL072874

Key Points:

- A high-accuracy global digital elevation model (DEM) was developed by removing multiple height error components from existing DEMs
- Landscape representation was improved, especially in flat regions where height error magnitude was larger than actual topography variation

A high-accuracy map of global terrain elevations

Dai Yamazaki[1,2], Daiki Ikeshima[3], Ryunosuke Tawatari[3], Tomohiro Yamaguchi[4], Fiachra O'Loughlin[5], Jeffery C. Neal[6], Christopher C. Sampson[7], Shinjiro Kanae[3], and Paul D. Bates[6]

[1]Department of Integrated Climate Change Projection Research, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan, [2]Institute of Industrial Sciences, University of Tokyo, Tokyo, Japan, [3]Department of Civil and Environmental Engineering, Tokyo Institute of Technology, Tokyo, Japan, [4]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, Japan, [5]UCD School of Civil Engineering, University College Dublin, Dublin, Ireland, [6]School of Geographical Sciences, University of Bristol, Bristol, UK, [7]SSBN, Bristol, UK

MERIT Hydro

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Water Resources Research

RESEARCH ARTICLE

10.1029/2019WR024873

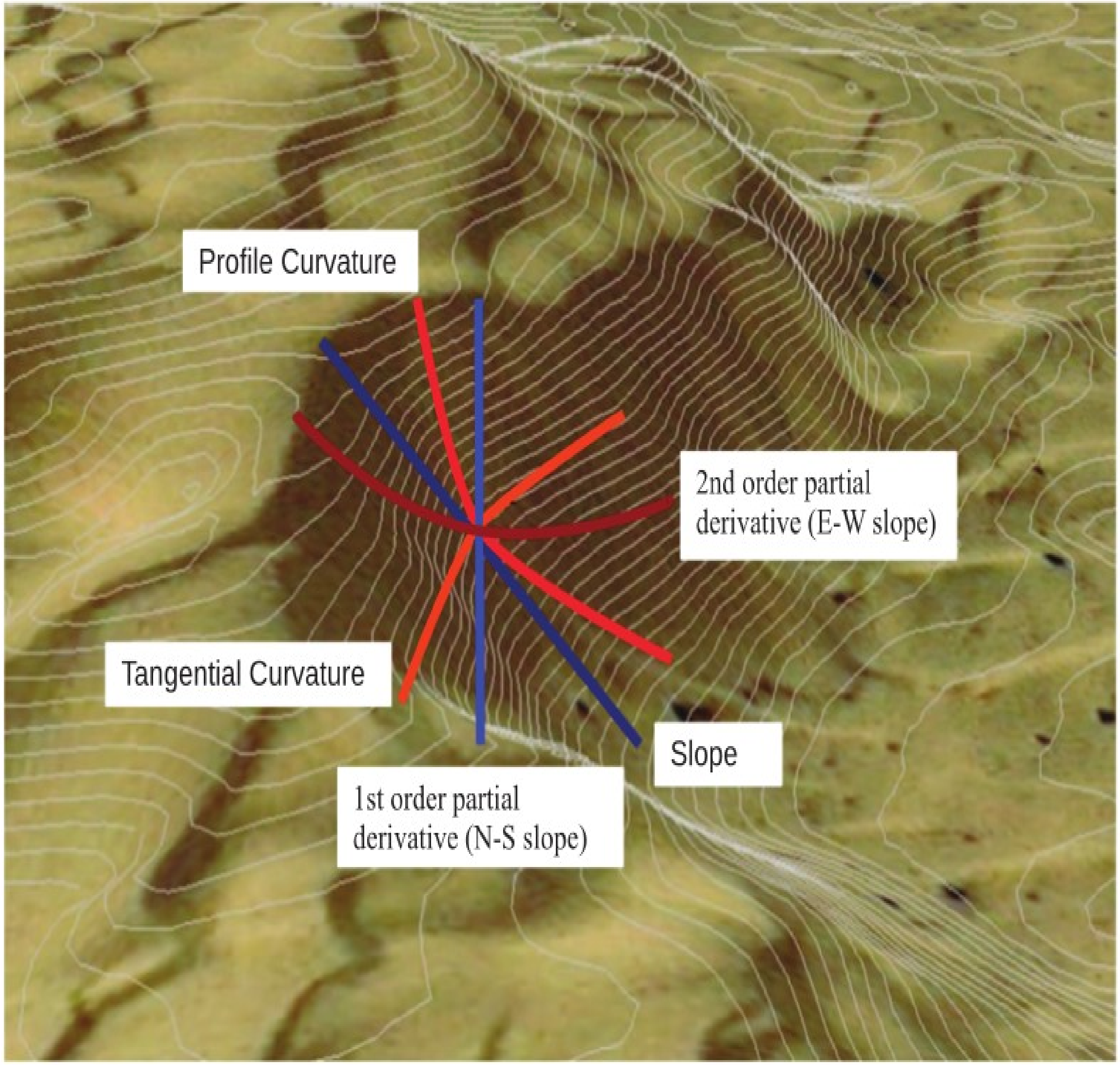
Key Points:

- A global hydrography map was generated using the latest topography dataset
- Near-automatic algorithm applicable for global hydrography delineation was developed
- Adjusted elevation and river width layers consistent with flow direction map are provided

MERIT Hydro: A High-Resolution Global Hydrography Map Based on Latest Topography Dataset

Dai Yamazaki[1,2], Daiki Ikeshima[2], Jeison Sosa[3], Paul D. Bates[3], George H. Allen[4], and Tamlin M. Pavelsky[5]

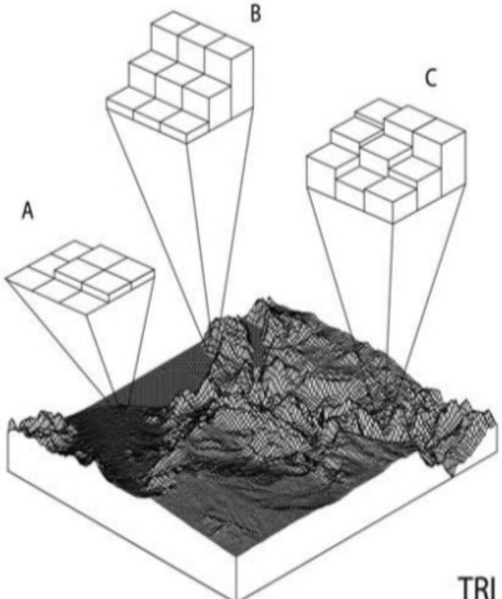
[1]Institute of Industrial Science, The University of Tokyo, Tokyo, Japan, [2]Department of Civil and Environmental Engineering, Tokyo Institute of Technology, Tokyo, Japan, [3]School of Geographical Sciences, University of Bristol, Bristol, UK, [4]Department of Geography, Texas A&M University, College Station, TX, USA, [5]Department of Geological Sciences, University of North Carolina, Chapel Hill, NC, USA



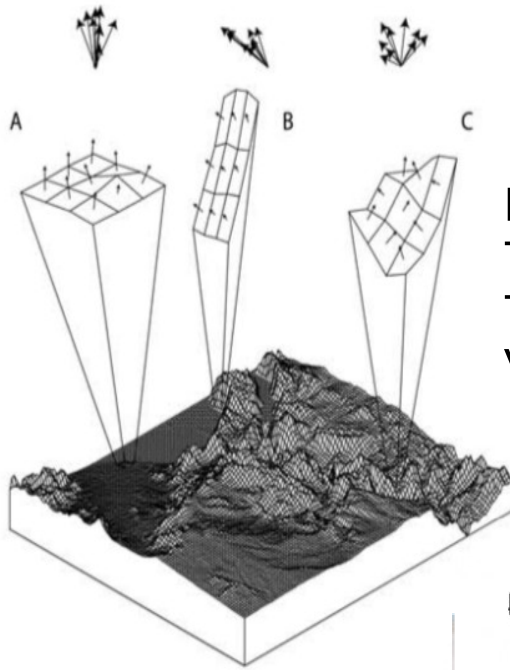
Amatulli *et al.* 2018
DOI:
10.1038/sdata.2018.
40

Figure 2. Graphical representation of landform shapes based on slope and curvature. Slope is the rate of change of elevation in the direction of the steepest descent, whereas the second order partial derivative (N-S slope) is the slope in the North-South direction. The profile and tangential curvatures identify concavity and convexity in the direction of the slope, or perpendicular to the slope. The second order partial derivatives (E-W slope) identify the curvature in the East-West direction.

Topography complexity layers
(Surface roughness and terrain forms analysis)



Sappington et al. (2007)

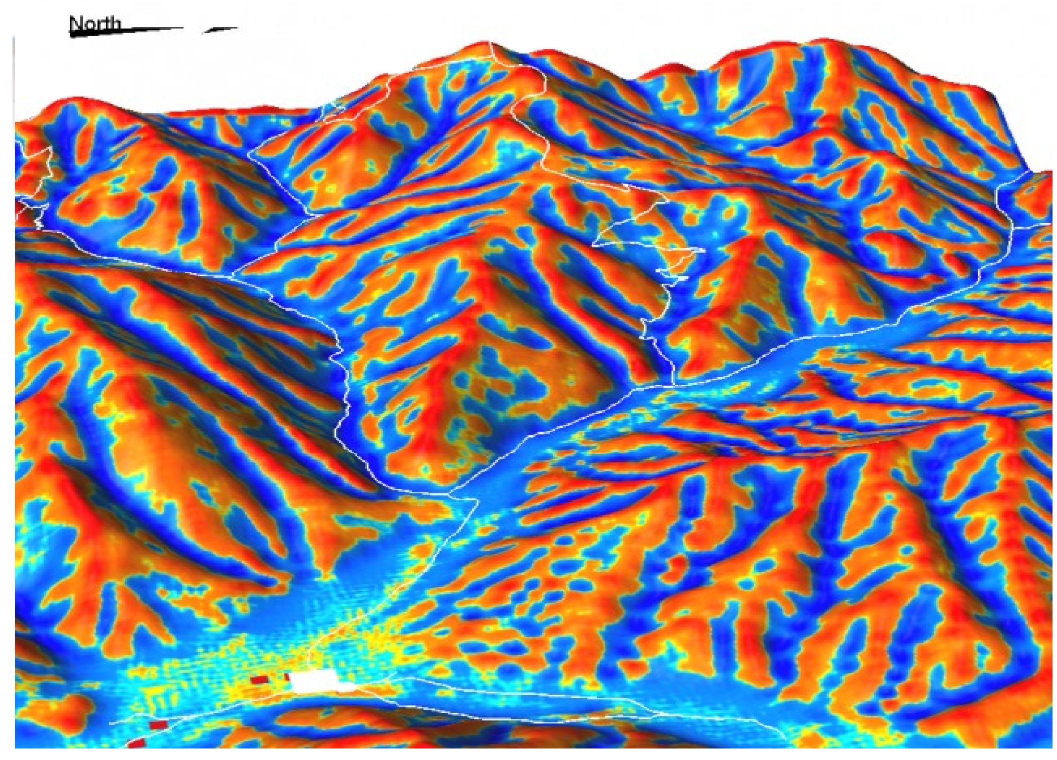


Roughness indices

Roughness - Median / SD
Topographic Position Index - Median / SD
Terrain Ruggedness Index - Median / SD
Vector Ruggedness Measure - Median / SD

Curvature

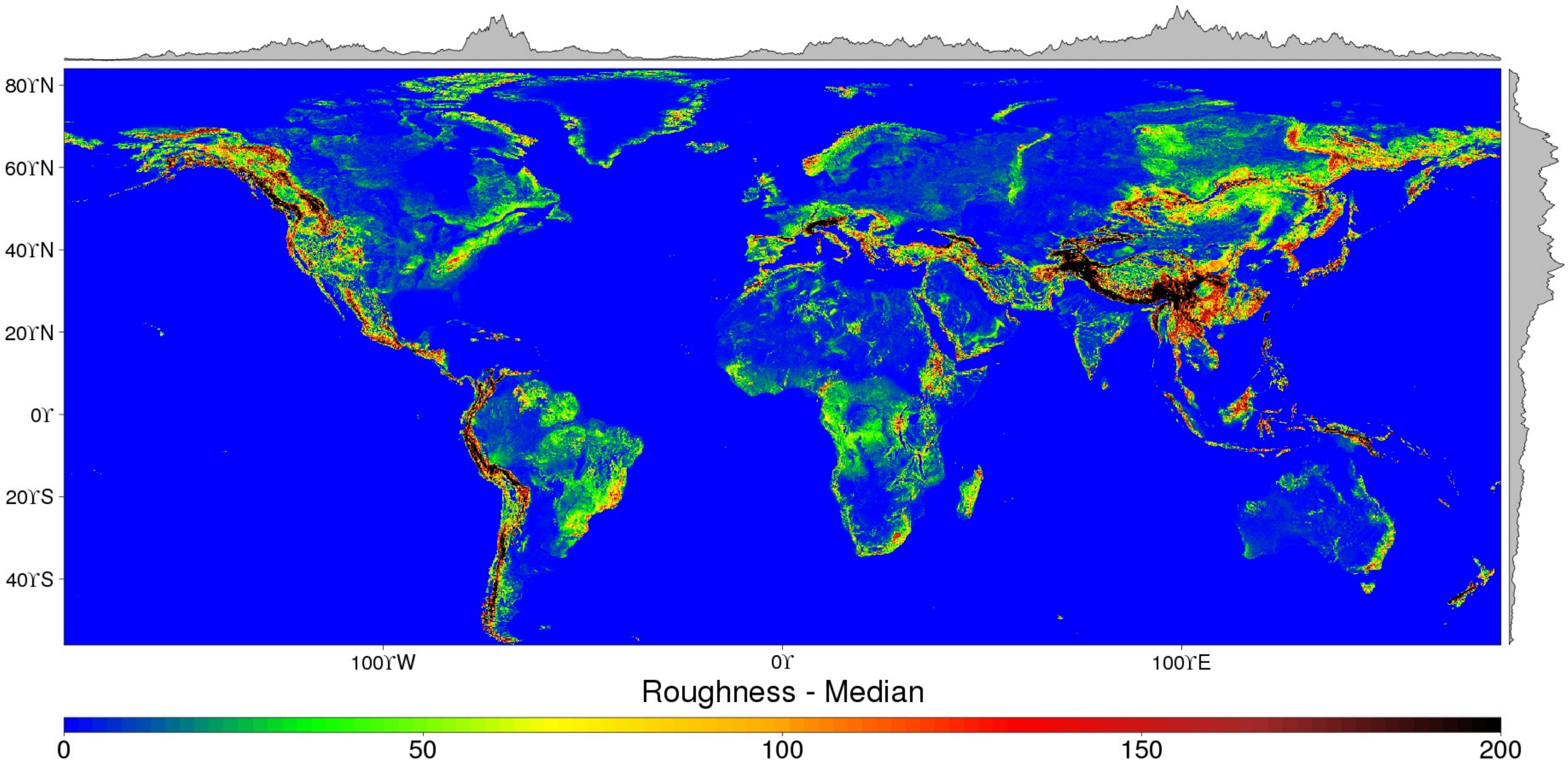
Profile curvature - Median / SD
Tangential curvature - Median / SD



Topography complexity layers

(surface roughness and geo-morphology analysis)

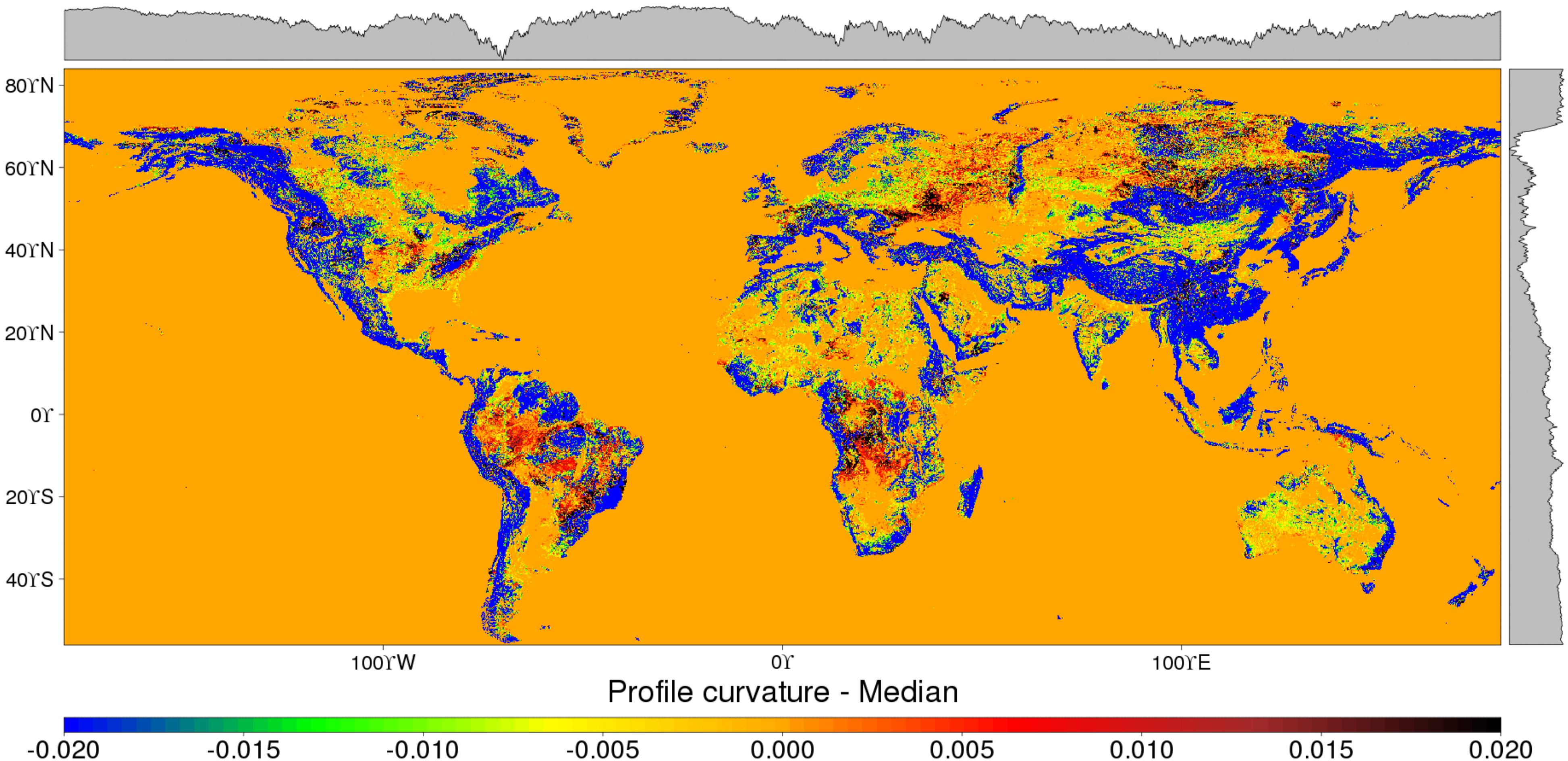
Roughness

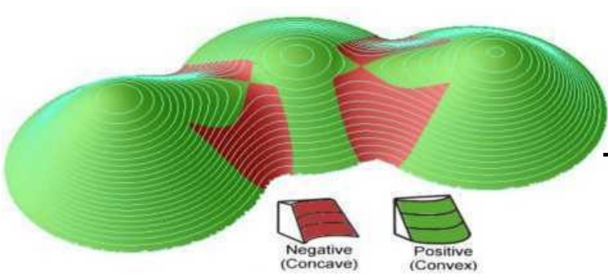


Topography complexity layers

(surface roughness and geo-morphology analysis)

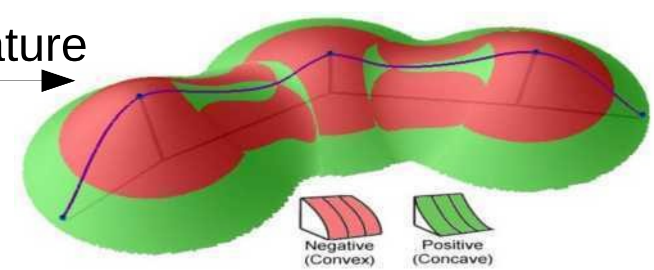
Curvature





Profile curvature

Tangential curvature



Geomorpho90m

SCIENTIFIC DATA

Check for updates

OPEN

DATA DESCRIPTOR

Geomorpho90m, empirical evaluation and accuracy assessment of global high-resolution geomorphometric layers

Giuseppe Amatulli[1,2], Daniel McInerney[3], Tushar Sethi[4], Peter Strobl[5] & Sami Domisch[6]

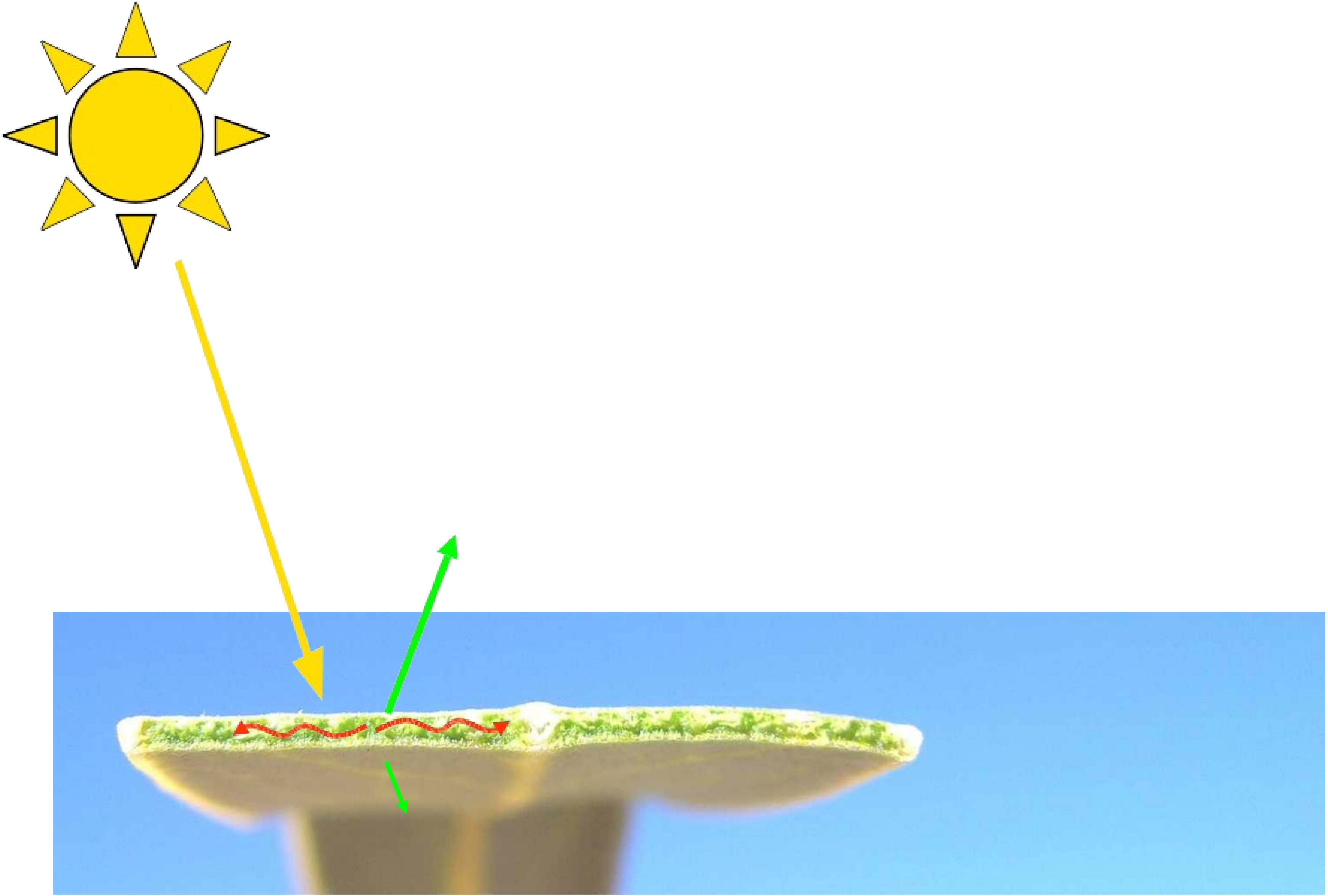
http://spatial-ecology.net/docs/build/html/GEODATA/geomorpho90m/geomorpho90m.html

OpenTopography
High-Resolution Topography Data and Tools

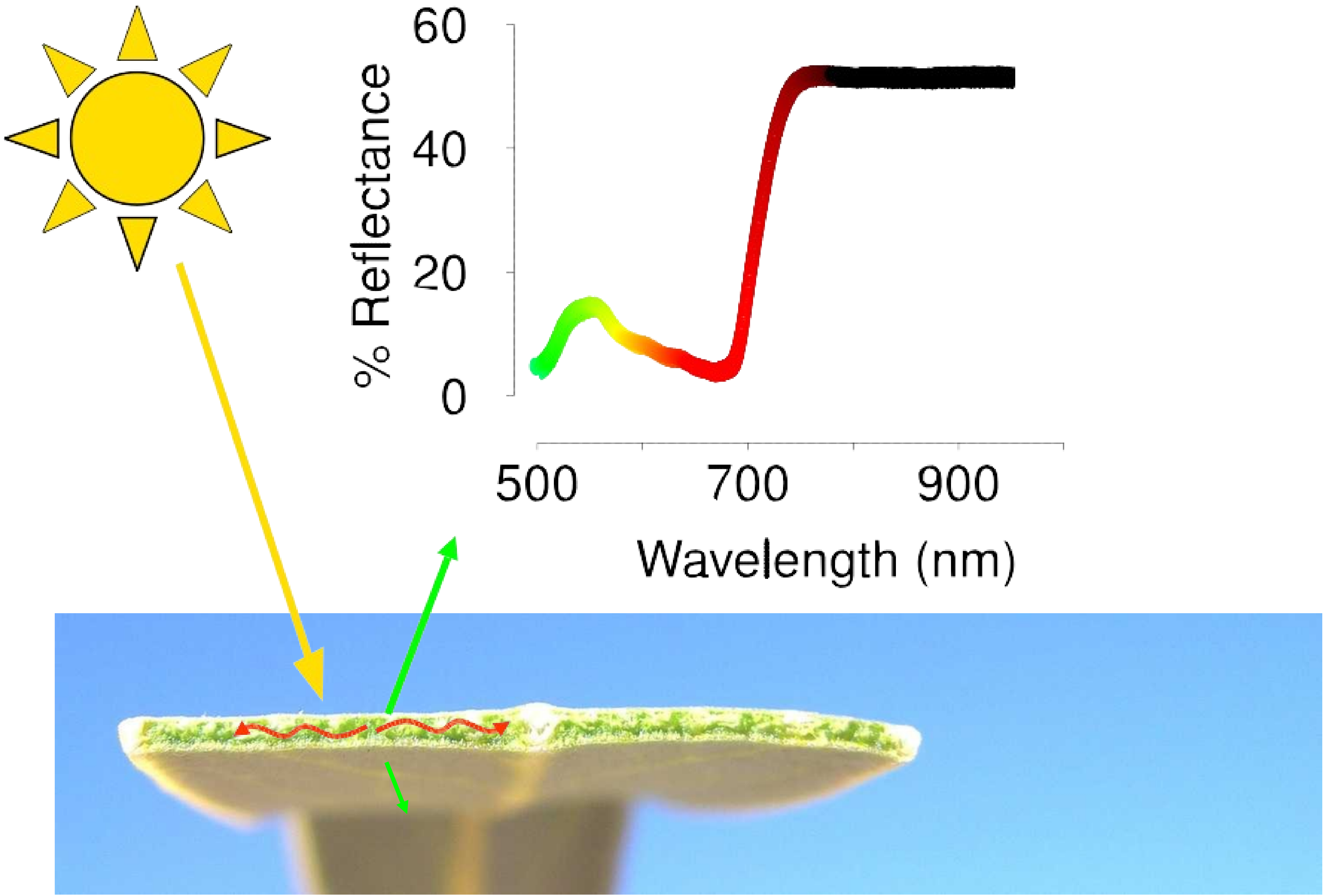
https://www.opentopography.org/

LiDAR data
DEM DATA

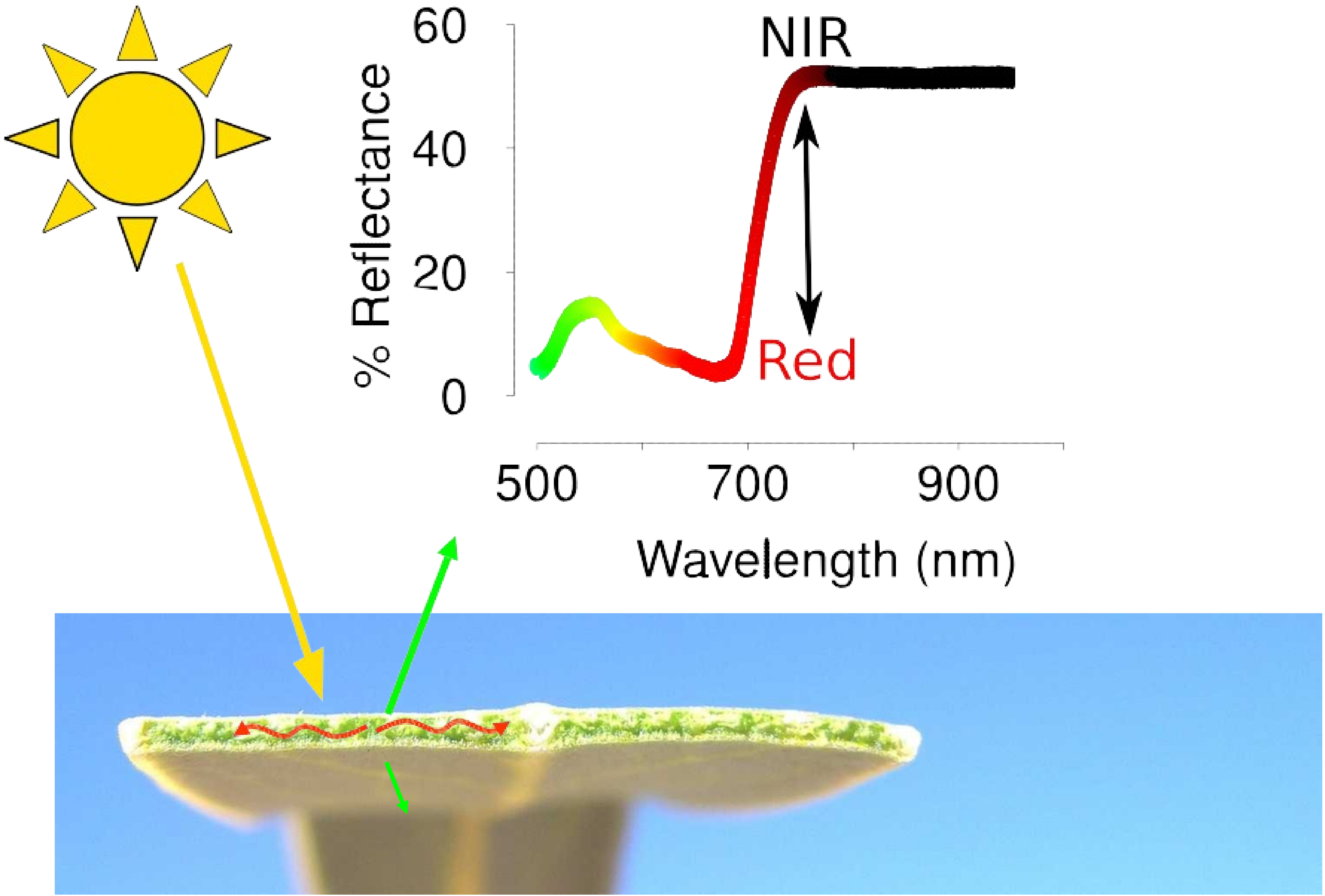
Vegetation Indices: NDVI



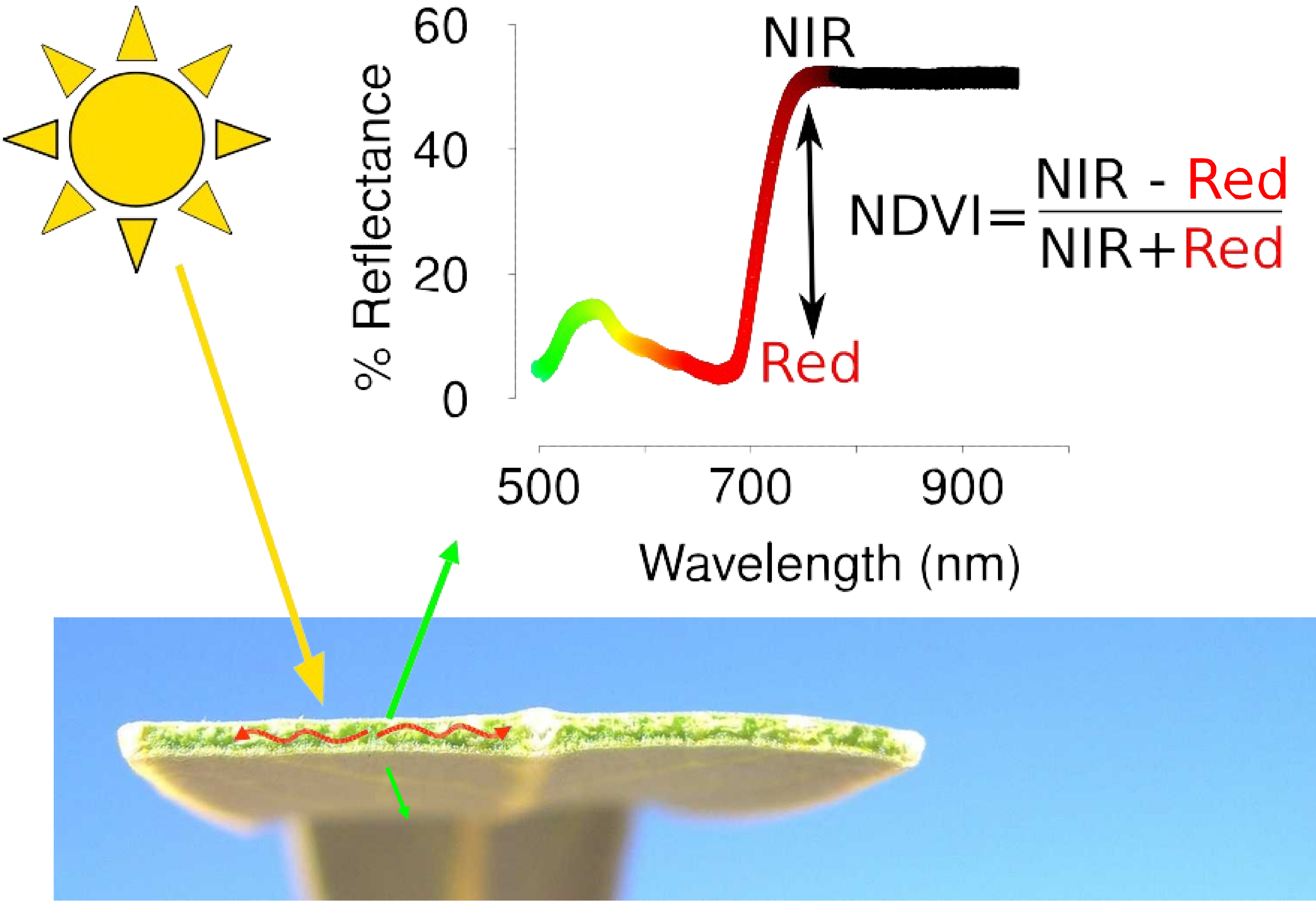
Vegetation Indices: NDVI



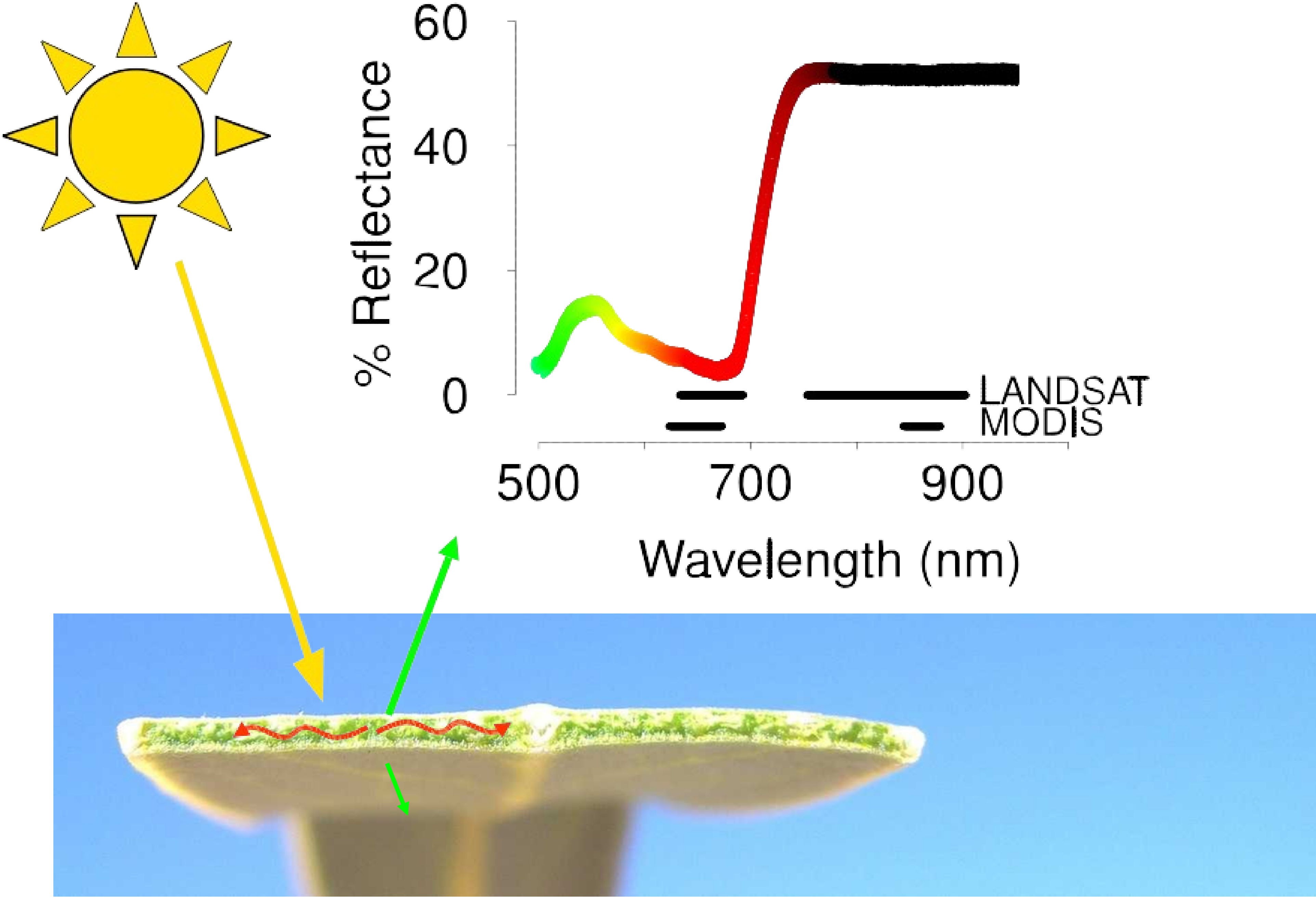
Vegetation Indices: NDVI



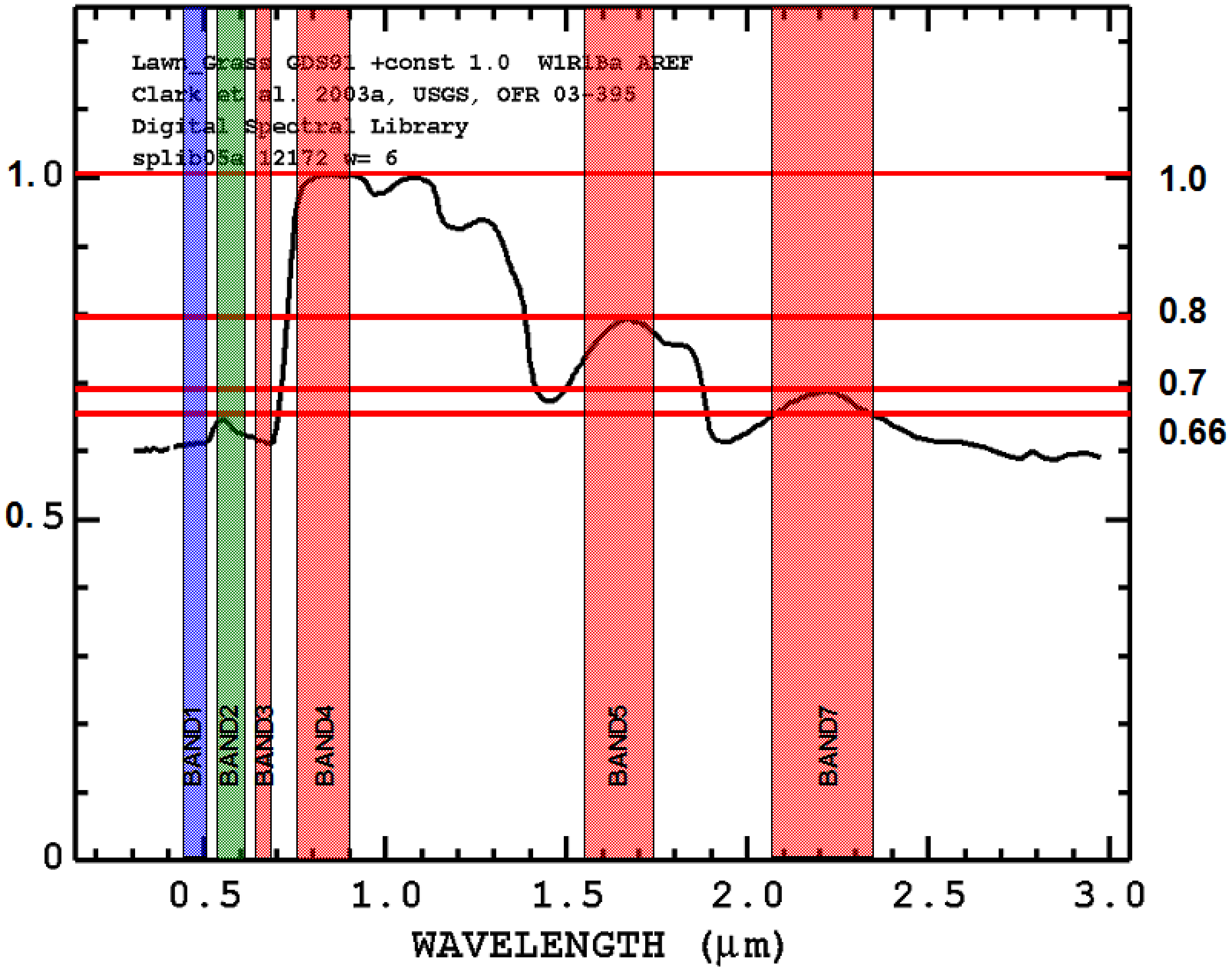
Vegetation Indices: NDVI



Vegetation Indices: NDVI



Landsat Multispectral Satellite Image

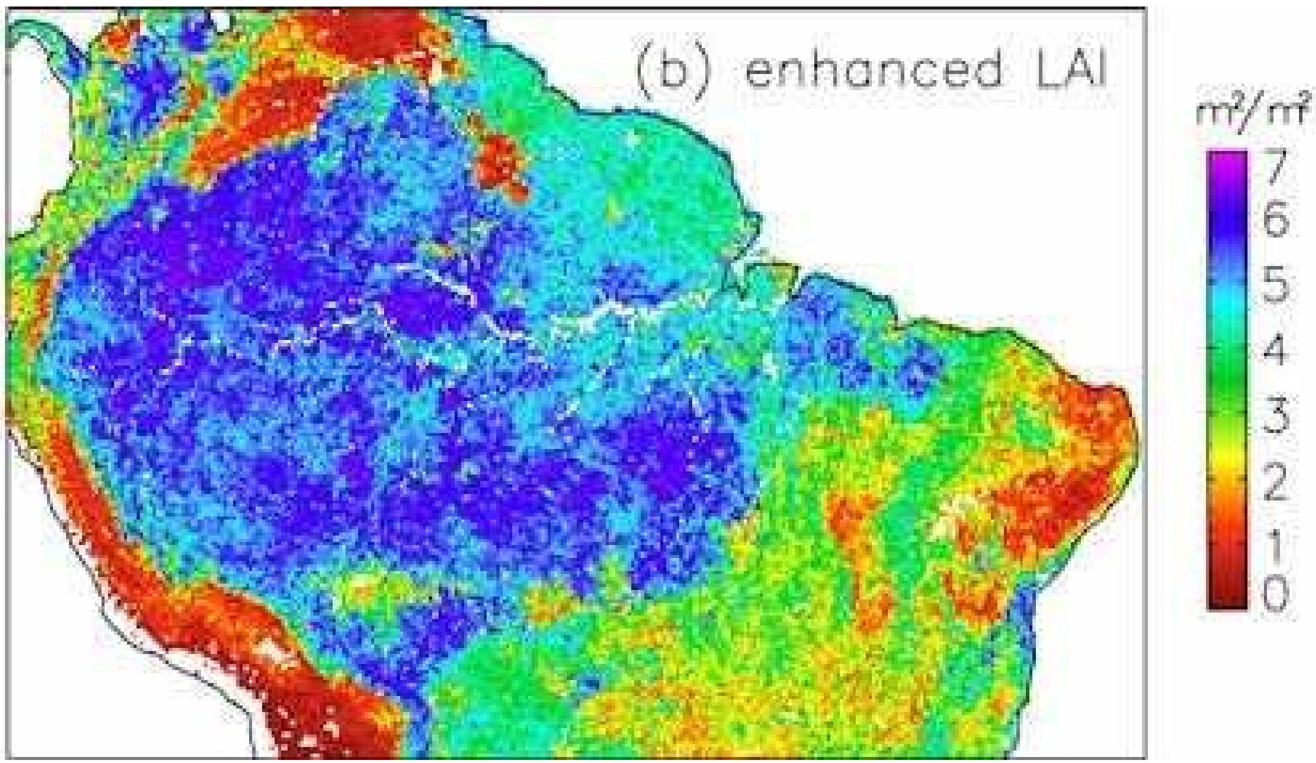


https://glad.geog.umd.edu/book/glad-landsat-ard-tools

Derived MODIS Metrics: LAI, fPAR, NPP

- Leaf Area Index ($\frac{m}{m^2}$)[12]: Reflectance + Biome Coefficients
- Net Primary Productivity (NPP)[13]: fPAR + LAI + Biome Parameters + Temperature

(fPAR = Fraction of Absorbed Photosynthetically Active radiation)



Both LAI and FPAR have been used extensively for calculation of photosynthesis, evaporation and transpiration of water, and Net Primary Productivity (NPP, which estimates how much carbon is taken in by vegetation).

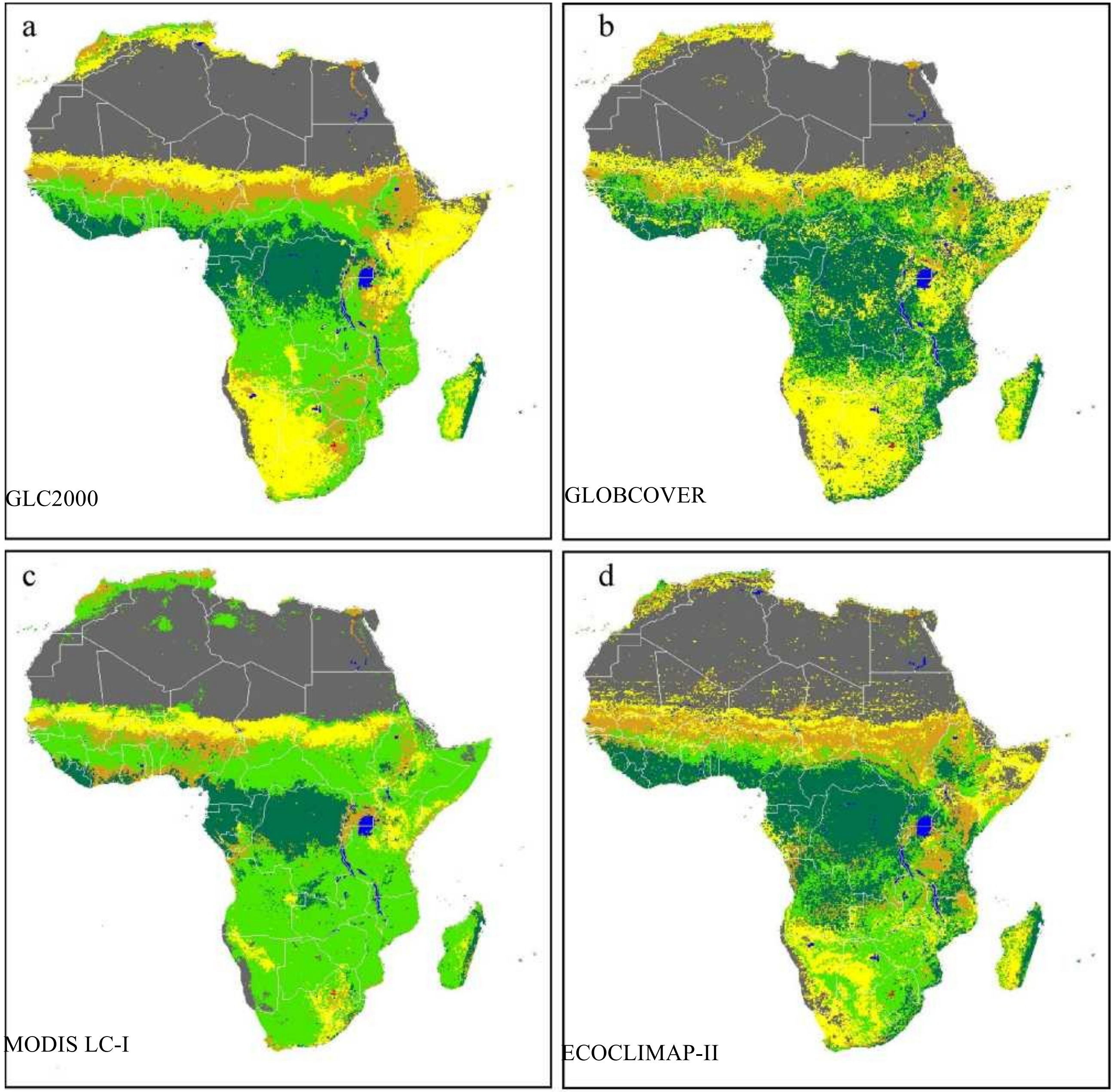
---

[12] http://modis.gsfc.nasa.gov/data/dataprod/dataproducts.php?MOD_NUMBER=15

[13] http://modis.gsfc.nasa.gov/data/dataprod/dataproducts.php?MOD_NUMBER=17

LULC: Products Matter

Comparison of four land cover maps for Africa[15]

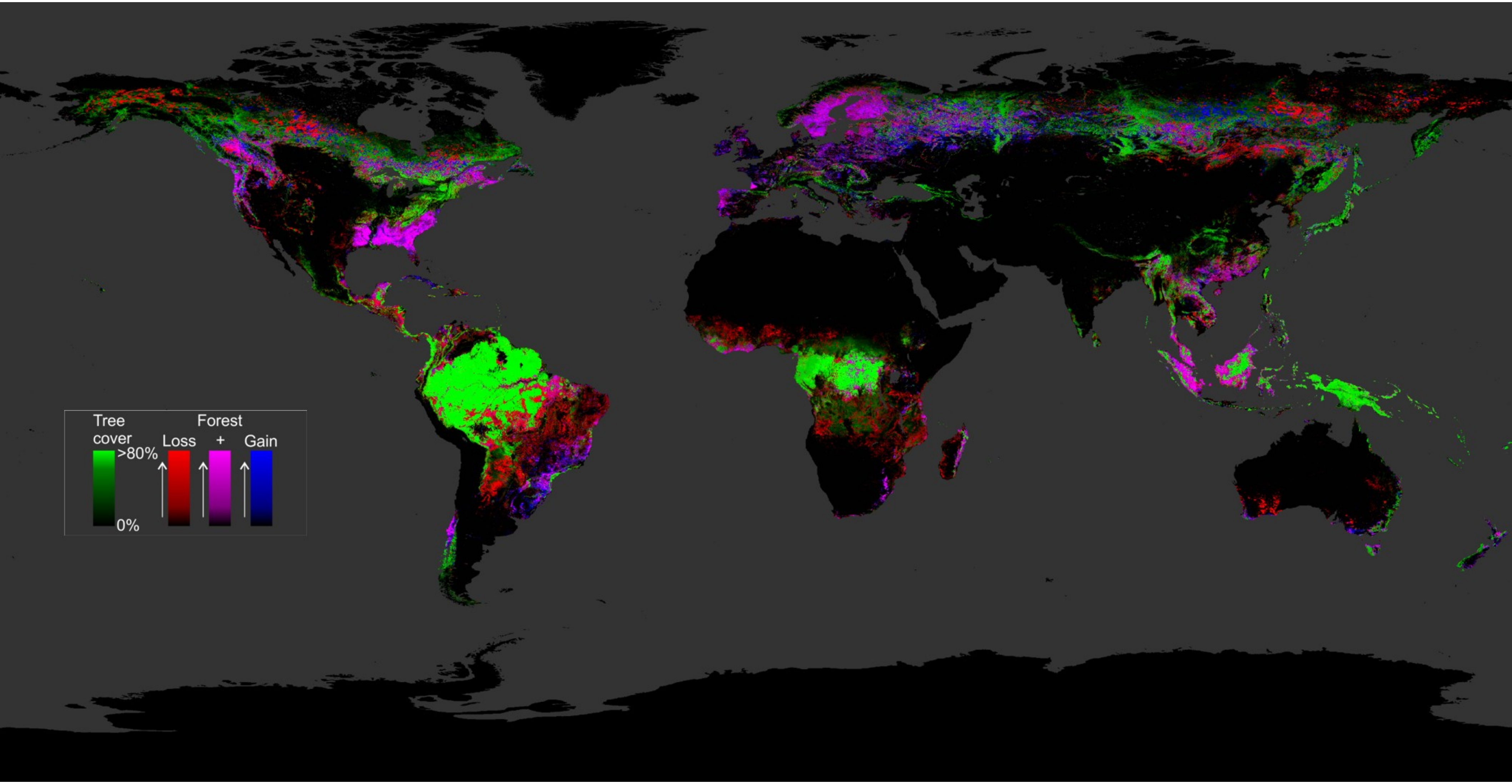


Forest
Woodland/Shrubland
Cropland
Grassland Bare Land Water Urban

[15] *Intl J of Appl Earth Observation & Geoinformation* (2011) 13(2): 207–219

Global Forest Cover Change

https://glad.umd.edu/projects/quantifying-global-forest-cover-change



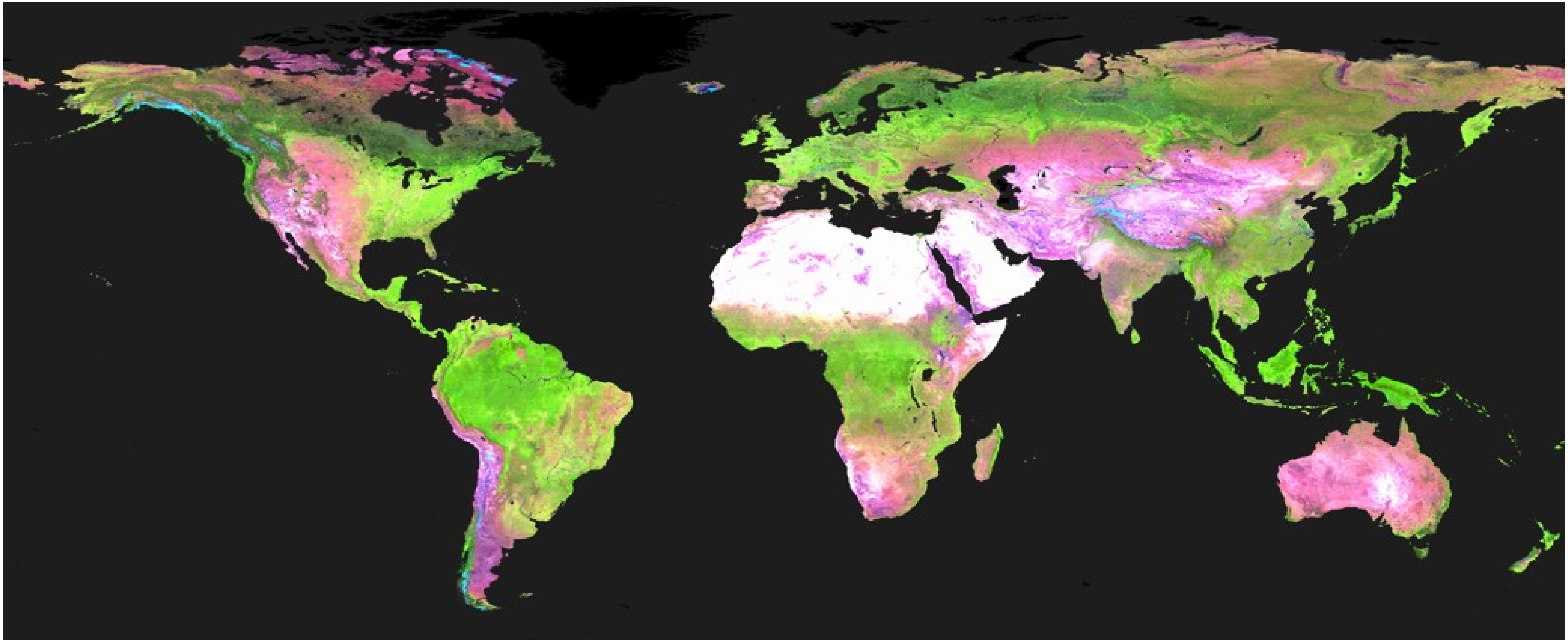
Home

GLAD Landsat ARD Tools

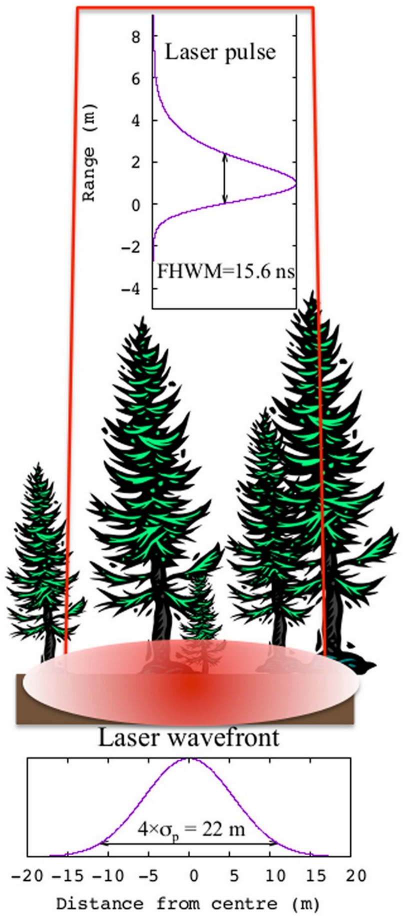
Home Software Download User Registration User Manual License and Disclaimer

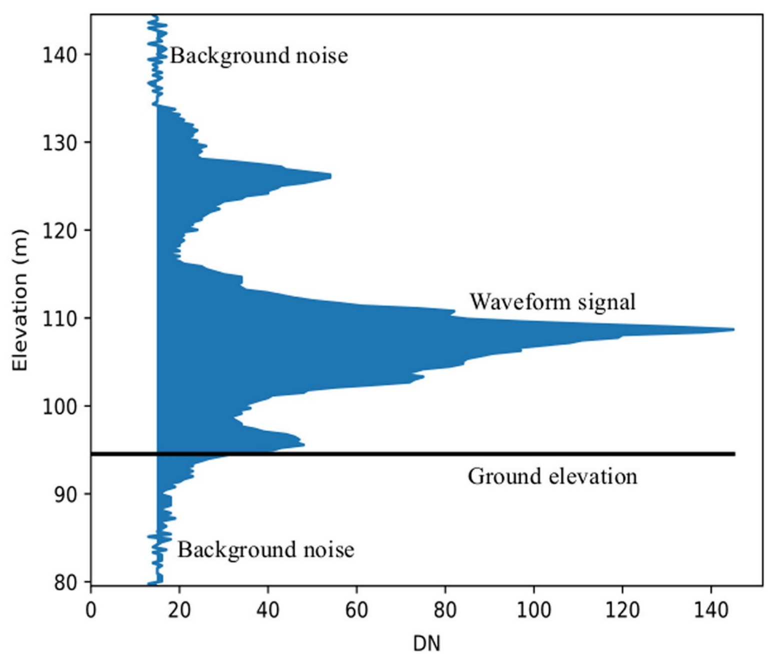
GLAD Landsat ARD Tools V1.1

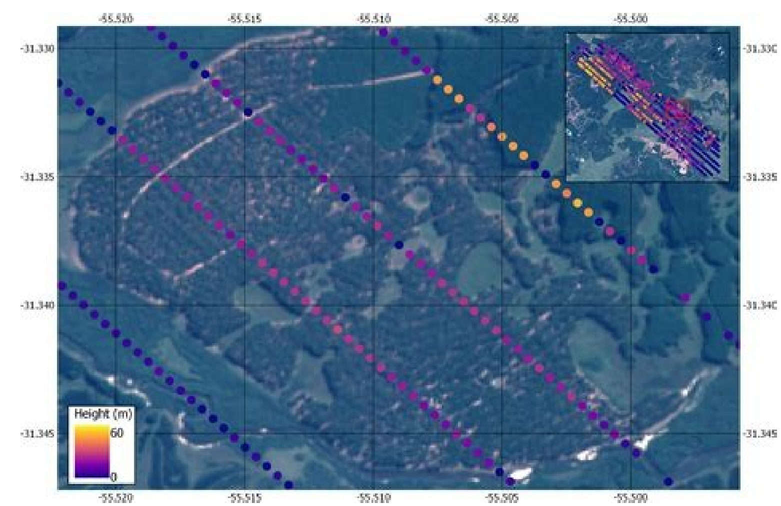
https://glad.geog.umd.edu/book/glad-landsat-ard-tools



https://gedi.umd.edu/







How to search for geographic data

Raw data (satellite images, LiDAR)
Sensor Products (LandCover, DEM)

NASA Products
MODIS Products
LANDSAT Products
Copernicus Products

https://datasetsearch.research.google.com/

Where do we go from here?

1. Data deluge → incredible opportunities
2. Data complexity → biogeographers must be vigilant

Analysis Steps:

3. Clearly define question, then seek data (not vice versa)
4. Understand source and limitations
5. Propagate uncertainties[20]!

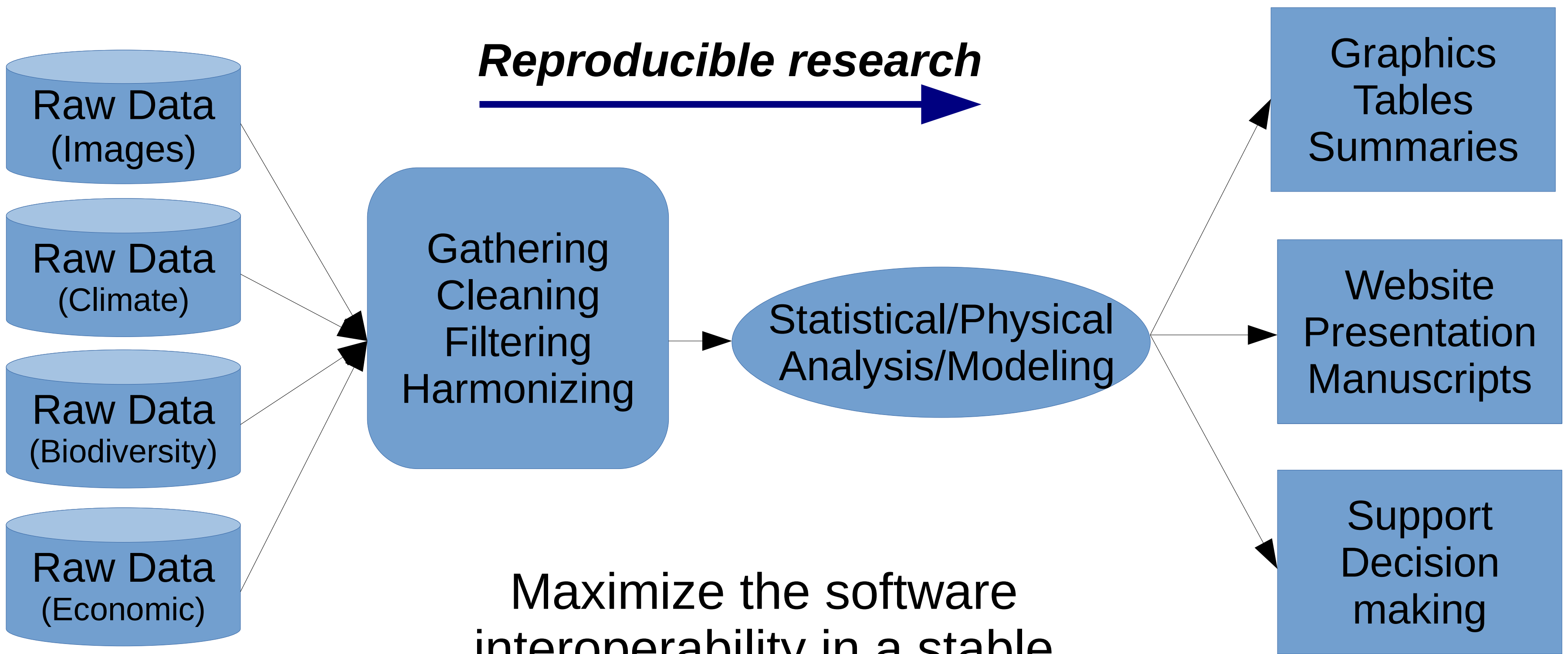
---

[20] *Global Change Biology* (2012):doi:10.1111/gcb.12090

Why use Open Source Software?
Scientific/Technical aspects: data flow

Codes that are easily published **> no license constraints**

Complex work-flows **> integrate different data analysis methods**



Maximize the software interoperability in a stable Operating System