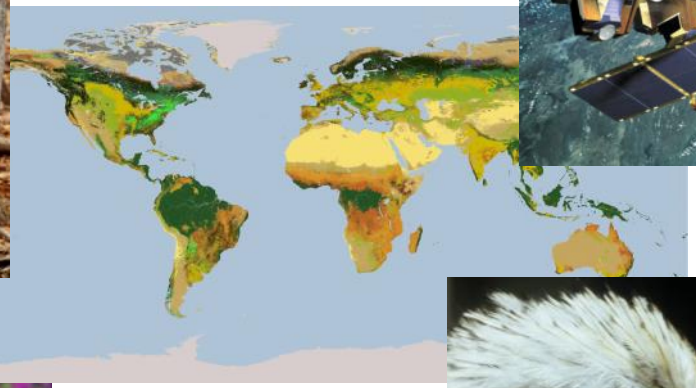
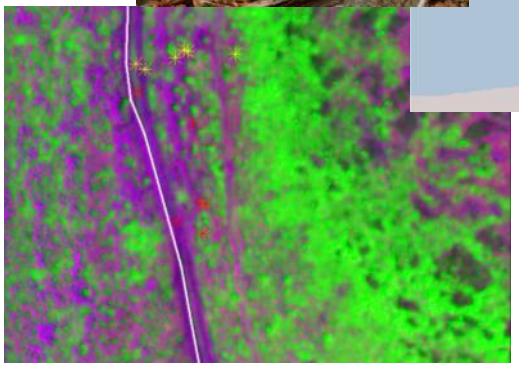
Integrating global species distributions, remote sensing and climate data to model change in species distributions





Remote-sensing supported global terrestrial biodiversity monitoring

Walter Jetz
Yale University

Remote-sensing supported global terrestrial biodiversity monitoring

PIs:	Walter Jetz (Yale U), Rob Guralnick (CU Boulder, Brian McGill (U Maine), Rama Nemani (NASA Ames), Forrest Melton (NASA Ames)
Postdocs, Students:	Dr. Mao-Ning Tuanmu (Yale U, NASA-funded), Dr. Adam Wilson (Yale U, YCEI-funded), Dr. Benoit Parmentier (NCEAS/ U Maine, iPlant-funded), Brian Stucky (CU Boulder, NASA-funded)
Others:	Jeremy Malczyk (Yale U), Map of Life Team (Yale, Boulder), Dave Thau (Google)

National Center for Ecological Analysis and Synthesis

NASA

iPlant Collaborative

Google earth engine
a google.org project
earthengine.googlelabs.com

NEX YCEI

Intergovernmental Platform on Biodiversity & Ecosystem Services

ipbes
Science and Policy for People and Nature

Platform work programme 2014–2018: Objectives and associated deliverables

Objective 1: Strengthen the capacity and knowledge foundations of the science-policy interface to implement key functions of the Platform:

(a) Priority capacity-building needs to implement the Platform's work programme matched with resources through catalysing financial and in-kind support
(b) Capacities needed to implement the Platform work programme developed
(c) Procedures, approaches for participatory processes for working with indigenous and local knowledge systems developed
(d) Priority knowledge and data needs for policymaking addressed through catalyzing efforts to generate new knowledge and networking

Objective 2: Strengthen the science-policy interface on biodiversity and ecosystem services at and across subregional, regional and global levels:

(a) Guide on production and integration of assessments from and across all scales
(b) Regional/subregional assessments on biodiversity, ecosystem services
(c) Global assessment on biodiversity and ecosystem services

Objective 3: Strengthen the science-policy interface on biodiversity and ecosystem services with regard to thematic and methodological issues:

(a) One fast track thematic assessment of pollinators, pollination and food production
(b) Three thematic assessments: land degradation and restoration; invasive alien species; and sustainable use and conservation of biodiversity and strengthening capacities/tools
(c) Policy support tools and methodologies for scenario analysis and modelling of biodiversity and ecosystem services based on a fast track assessment and a guide
(d) Policy support tools and methodologies regarding the diverse conceptualization of values of biodiversity and nature's benefits to people including ecosystem services based on an assessment and a guide

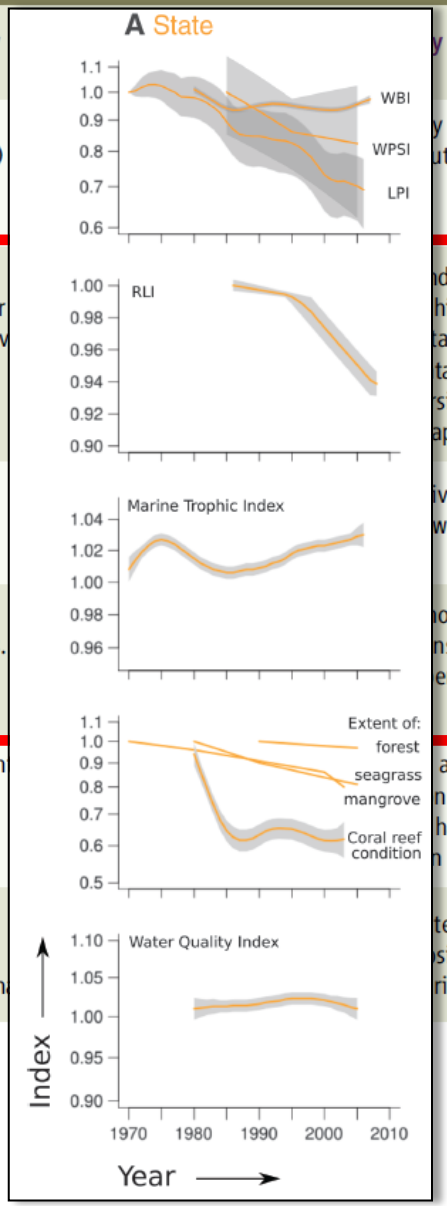
Objective 4: Communicate and evaluate Platform activities, deliverables and findings:

(a) Catalogue of relevant assessments
(b) Development of an information and data management plan
(c) Catalogue of policy support tools and methodologies
(d) Set of communication, outreach and engagement strategies, products and processes
(e) Reviews of the effectiveness of guidance, procedures, methods and approaches to inform future development of the Platform

Essential Biodiversity Variables

Examples of candidate Essential Biodiversity Variables

EBV class	EBV examples	Measurement and scalability		Relevance for CBD targets and indicators (*1,9*)
Genetic composition	Allelic diversity	Genotypes of selected species (e.g., endangered, domesticated) at representative locations.	y species and ut little global	Targets: 12, 13. Indicators: Trends in genetic diversity of selected species and of domesticated animals and cultivated plants; RLI.
Species populations	Abundances and distributions	Counts or presence surveys for groups of species easy to monitor important for ES, over an extensiv network of sites, complemented with incidental data.	nder way for hically a collected for ta integration sity ap of Life).	Targets: 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15. Indicators: LPI; WBI; RLI; population and extinction risk trends of target species, forest specialists in forests under restoration, and species that provide ES; trends in invasive alien species; trends in climatic impacts on populations.
Species traits	Phenology	Timing of leaf coloration by RS, with in situ validation.	ives work,	Targets: 10, 15. Indicators: Trends in extent and rate of shifts of boundaries of vulnerable ecosystems.
Community composition	Taxonomic diversity	Consistent multitaxa surveys and metagenomics at select locations.	nonitoring sites nsion). erspectral RS	Targets: 8, 10, 14. Indicators: Trends in condition and vulnerability of ecosystems; trends in climatic impacts on community composition.
Ecosystem structure	Habitat structure	RS of cover (or biomass) by heigh (or depth) globally or regionally.	available with n and Ranging). habitats mapped n situ data.	Targets: 5, 11, 14, 15. Indicators: Extent of forest and forest types; mangrove extent; seagrass extent; extent of habitats that provide carbon storage.
Ecosystem function	Nutrient retention	Nutrient output/input ratios measured at select locations. Combine with RS to model region	tes exist for N sition areas and rivers.	Targets: 5, 8, 14. Indicators: Trends in delivery of multiple ES; trends in condition and vulnerability of ecosystems.



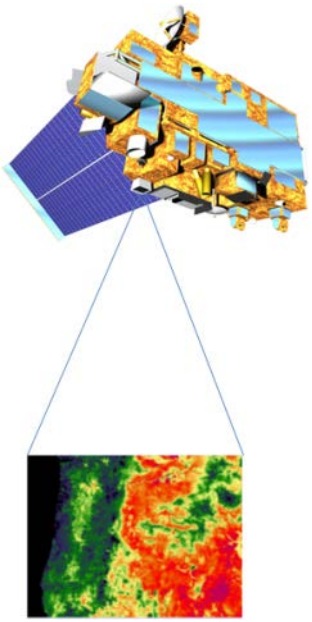
ECOLOGY

Essential Biodiversity Variables

H. M. Pereira,[1*†] S. Ferrier,[2] M. Walters,[3] G. N. Geller,[4] R. H. G. Jongman,[5] R. J. Scholes,[3] M. W. Bruford,[6] N. Brummitt,[7] S. H. M. Butchart,[8] A. C. Cardoso,[9] N. C. Coops,[10] E. Dulloo,[11] D. P. Faith,[12] J. Freyhof,[13] R. D. Gregory,[14] C. Heip,[15] R. Höft,[16] G. Hurtt,[17] W. Jetz,[18] D. S. Karp,[19] M. A. McGeoch,[20] D. Obura,[21] Y. Onoda,[22] N. Pettorelli,[23] B. Reyers,[24] R. Sayre,[25] J. P. W. Scharlemann,[26,27] S. N. Stuart,[28] E. Turak,[29] M. Walpole,[26] M. Wegmann[30]

"Biodiversity Indicators"

Global Biodiversity Monitoring



How to achieve a globally representative and generalizable biodiversity monitoring for scientifically rigorous assessment of change?

What can remote sensing contribute?

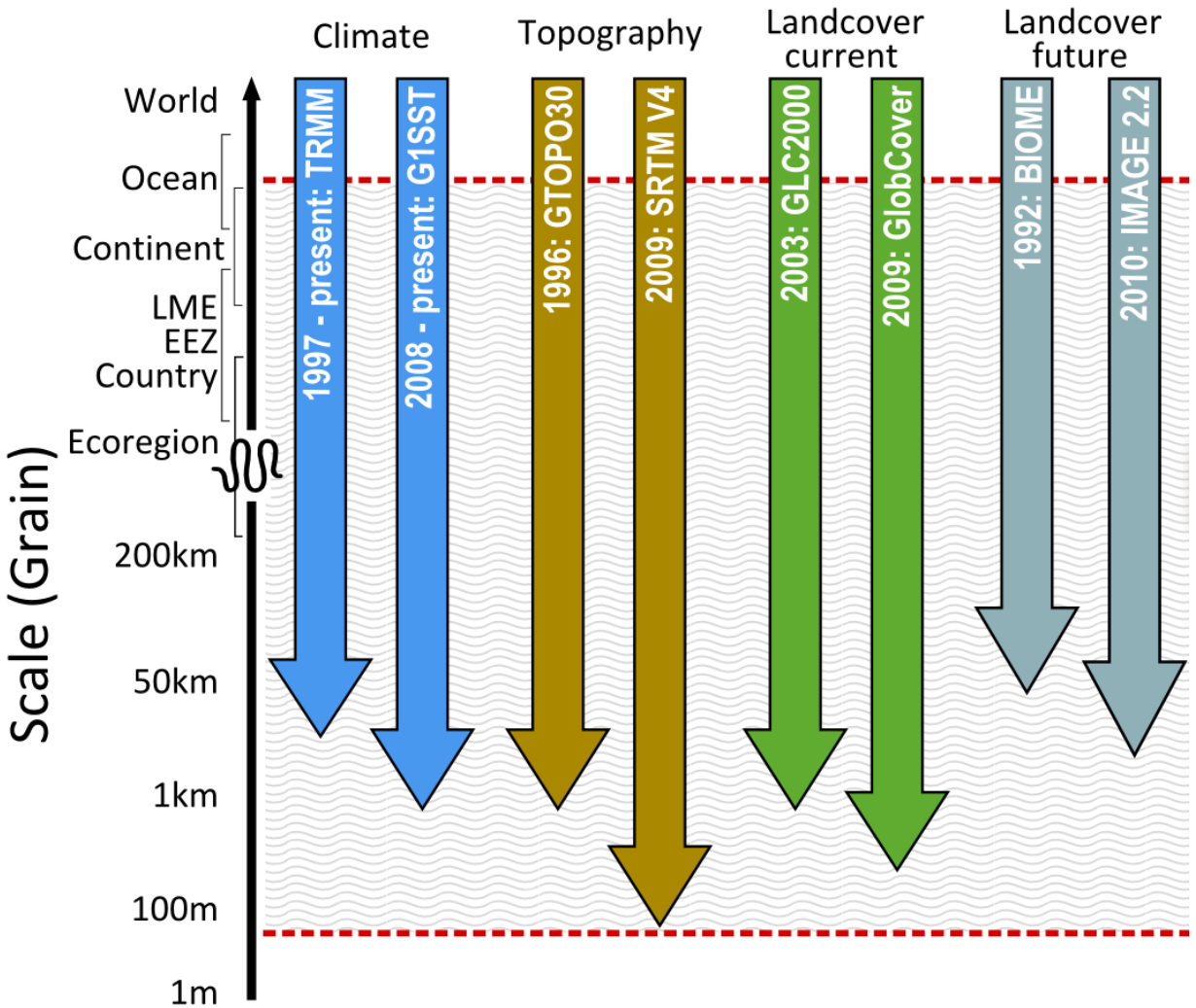
Global Biodiversity Monitoring

I. Providing representative baselines: species distributions, communities, environment

II. Quantifying environmental change

III. Detecting, monitoring biodiversity change

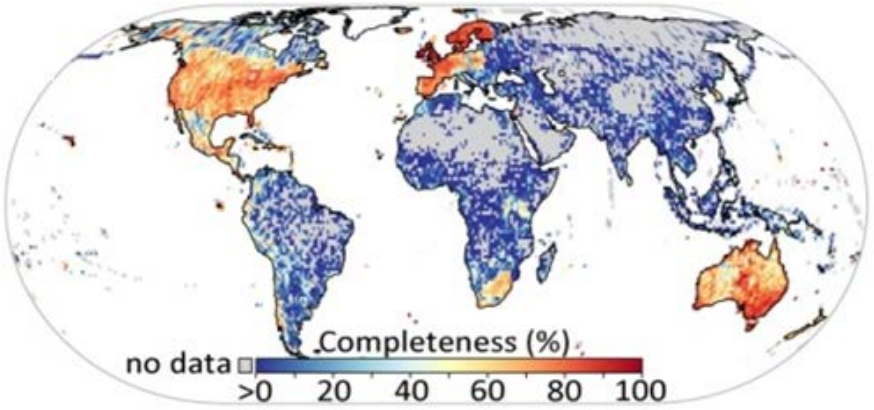
Species Distributions

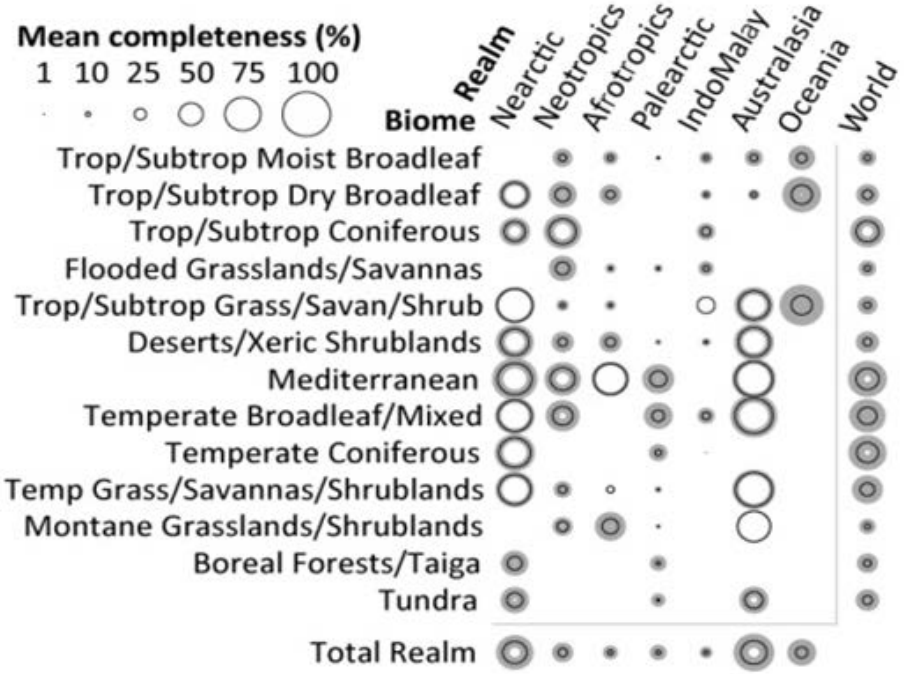


Hurlbert and Jetz (PNAS 2007)
Jetz et al. (Conservation Biology 2008)

Species Distributions

MOL
MAP OF LIFE





Meyer et al., submitted

Species Distributions

Yale

eoL

NSF

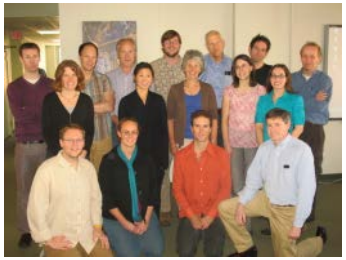
MOL
MAP OF LIFE

NASA

BiK F | Biodiversität und Klima Forschungszentrum
Biodiversity and Climate Research Centre

SENCKENBERG
world of biodiversity

iPlant Collaborative™



GEO GROUP ON EARTH OBSERVATIONS

google.org

Jetz et al. 2012, TREE

Full global-extent 90m DEM

Contents lists available at ScienceDirect

ISPRS Journal of Photogrammetry and Remote Sensing

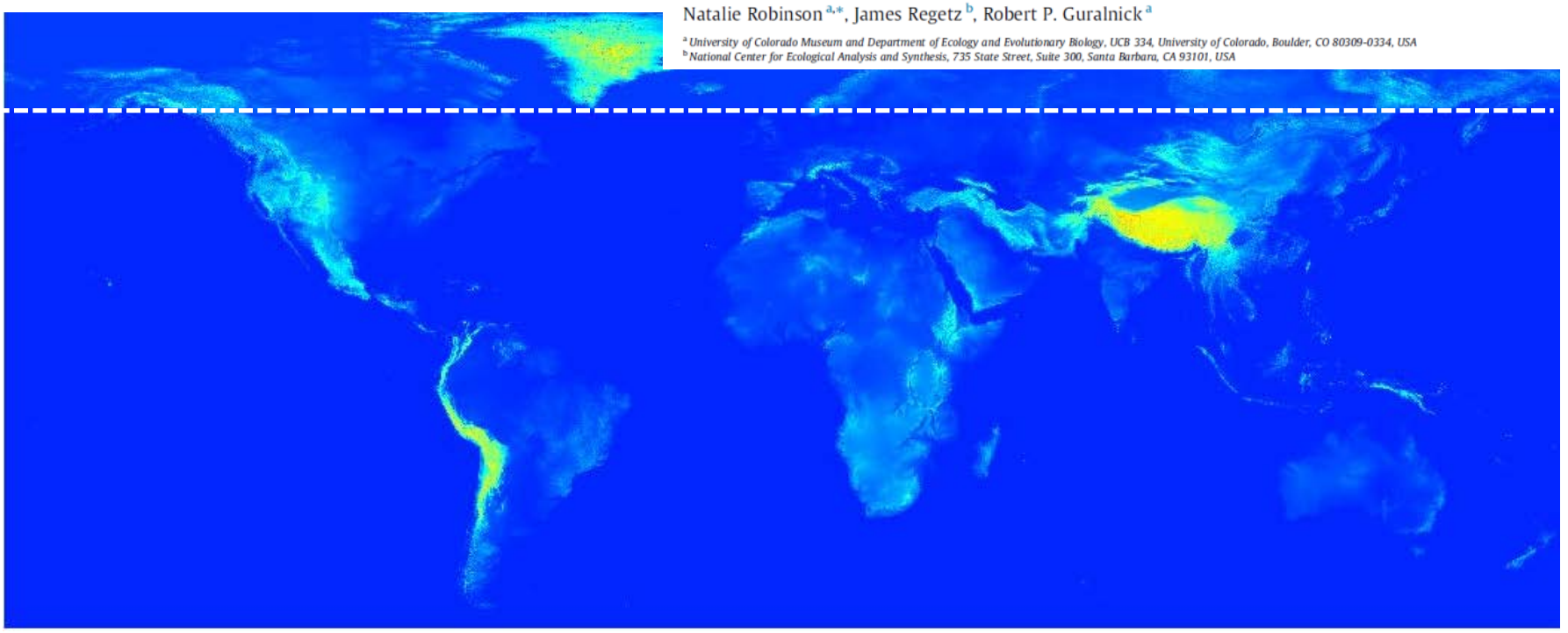
journal homepage: www.elsevier.com/locate/isprsjprs

EarthEnv-DEM90: A nearly-global, void-free, multi-scale smoothed, 90m digital elevation model from fused ASTER and SRTM data

Natalie Robinson [a,*], James Regetz [b], Robert P. Guralnick [a]

[a] University of Colorado Museum and Department of Ecology and Evolutionary Biology, UCB 334, University of Colorado, Boulder, CO 80309-0334, USA
[b] National Center for Ecological Analysis and Synthesis, 735 State Street, Suite 300, Santa Barbara, CA 93101, USA

ASTER GDEM V2

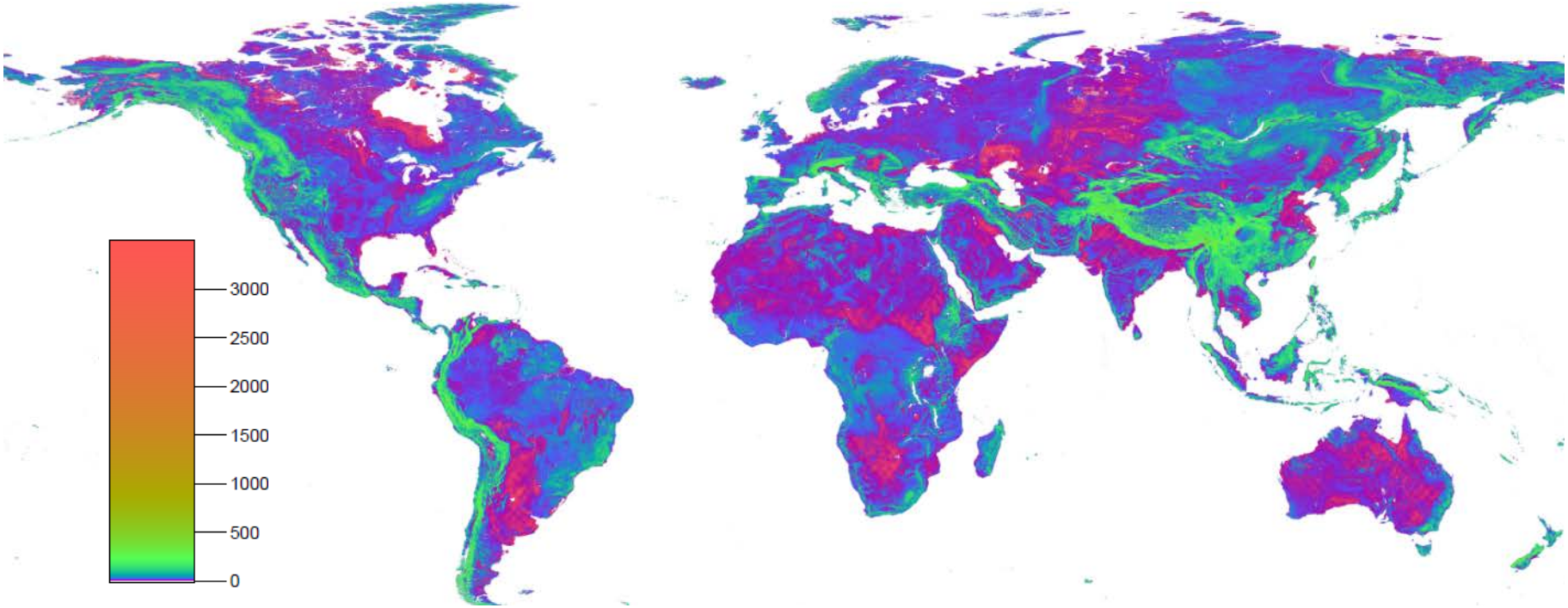


SRTM V4

Blended, void-filled, multi-scale smoothed

For global derivation of terrain variables and distribution modeling

Terrain variables



Median roughness, 1km

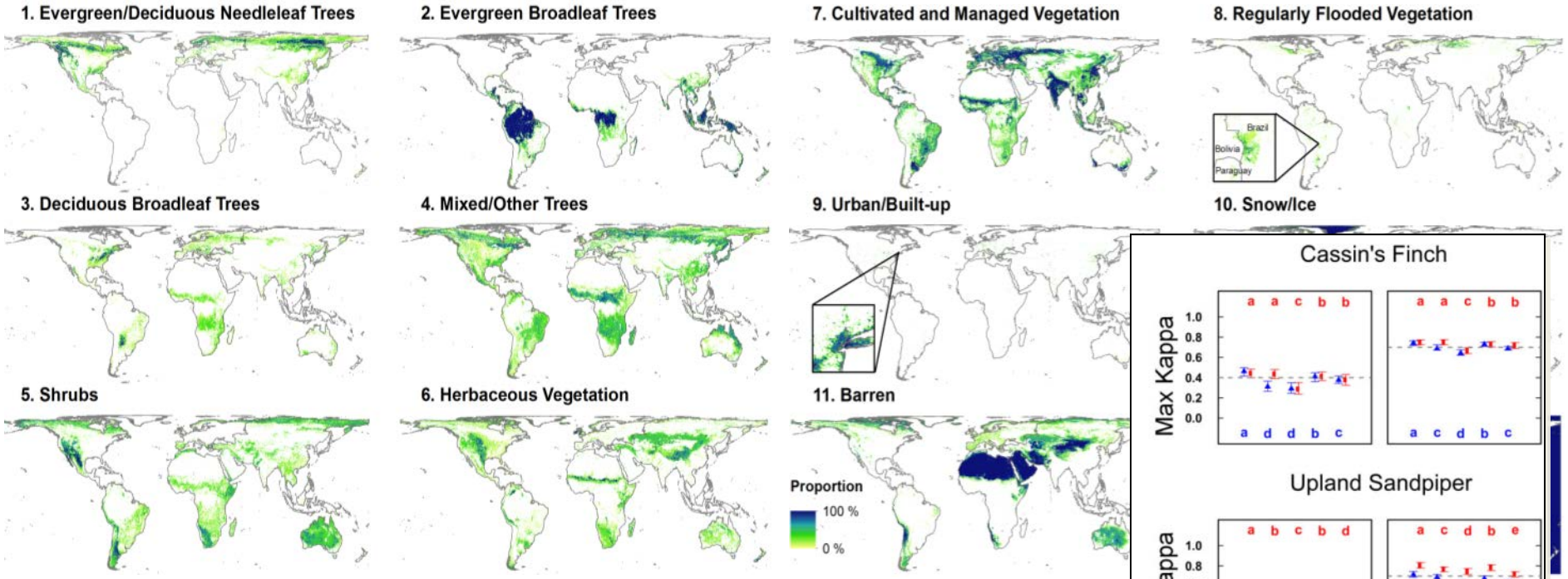
Consensus land cover

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2014)

RESEARCH PAPER

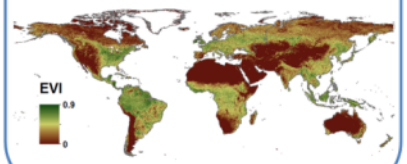
A global 1-km consensus land-cover product for biodiversity and ecosystem modelling

Mao-Ning Tuanmu* and Walter Jetz

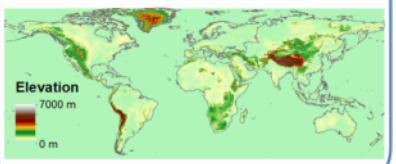


Heterogeneity metrics

95th percentile of EVI
(MOD13Q1; 2001-05; 250m)



EarthEnv-DEM90[1]
(3 arcsec; ~90 m)



GlobCover 2005-06
(v2.2; 23 types; 10 arcsec)

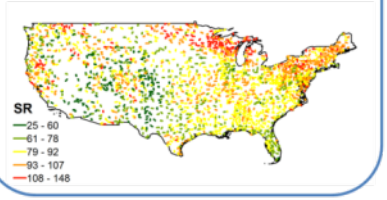
Texture Measure [2]
First-order
Coefficient of Variation (cv)
Range (range)
Skewness (skew)
Standard Deviation (std)
Second-order
Angular Second Moment (ASM)
Contrast (CON)
Correlation (COR)
Dissimilarity (DIS)
Entropy (ENT)
Maximum (MAX)
Variance (VAR)
Homogeneity (HOM)

Heterogeneity metrics
(30 arcsec; ~1 km)

Topography-based Metrics
Coefficient of Variation (DEM_cv)
Range (DEM_range)
Skewness (DEM_skew)
Standard Deviation (DEM_std)

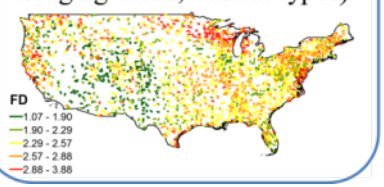
Landcover-based Metrics
of landcover types (GBC_rich)
Pielou evenness (GBC_even)
Shannon diversity (GBC_shan)
Simpson diversity (GBC_simp)

Species richness
(BBS; 1997-2011)

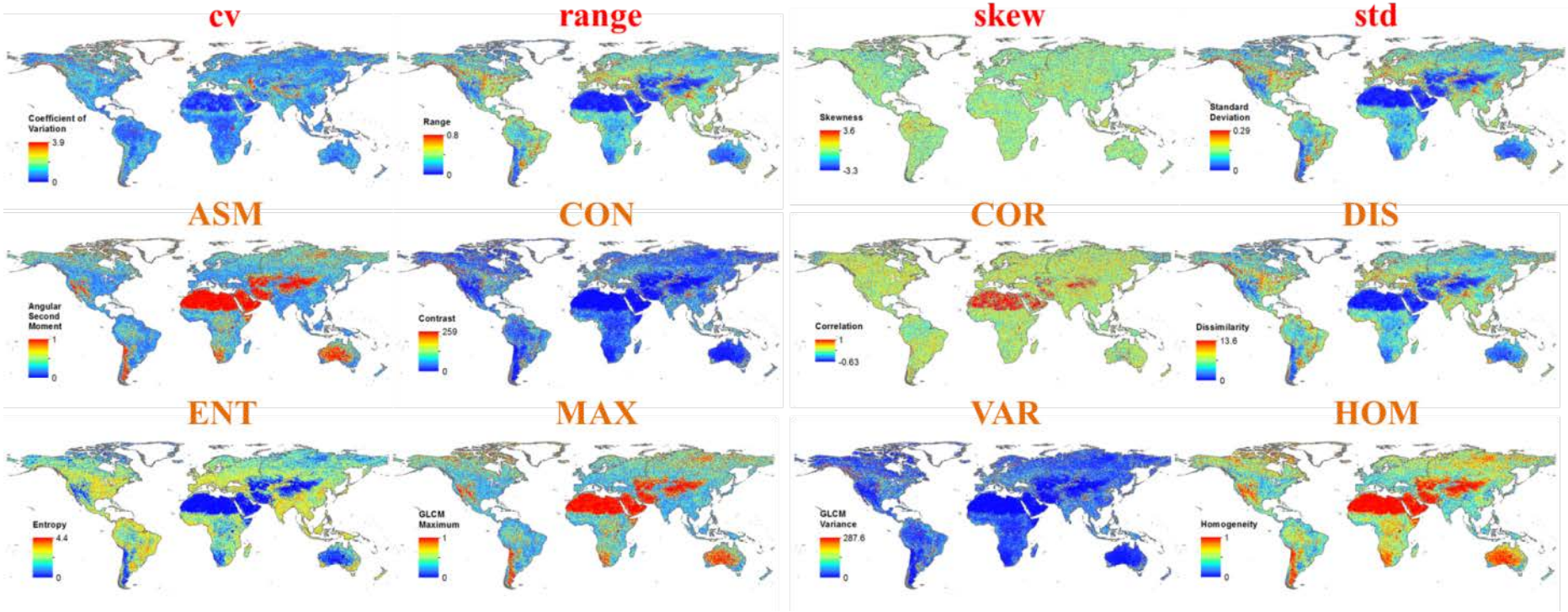


GLMs & SLMs
Stop & route levels

Functional diversity
(diet, body size, activity time,
foraging niche, habitat types)



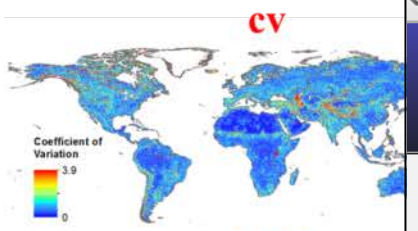
Heterogeneity metrics

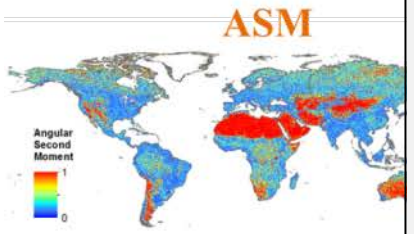


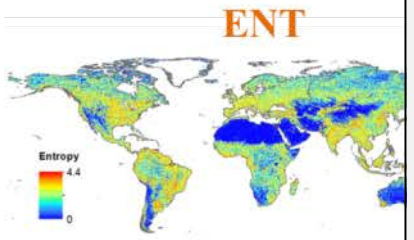
First- and second-order texture measures calculated at ~1-km resolution

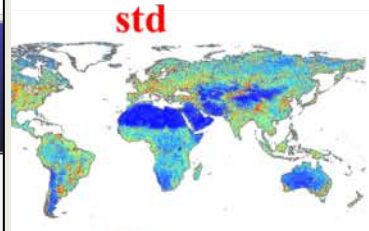
Utility for biodiversity modeling: Models built with texture measures, compared to those built with conventional metrics, generally explain more deviance in bird species richness and functional diversity across the conterminous US.

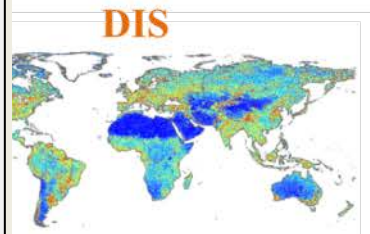
Heterogeneity metrics

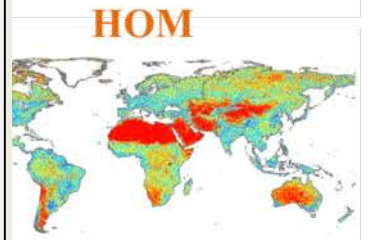


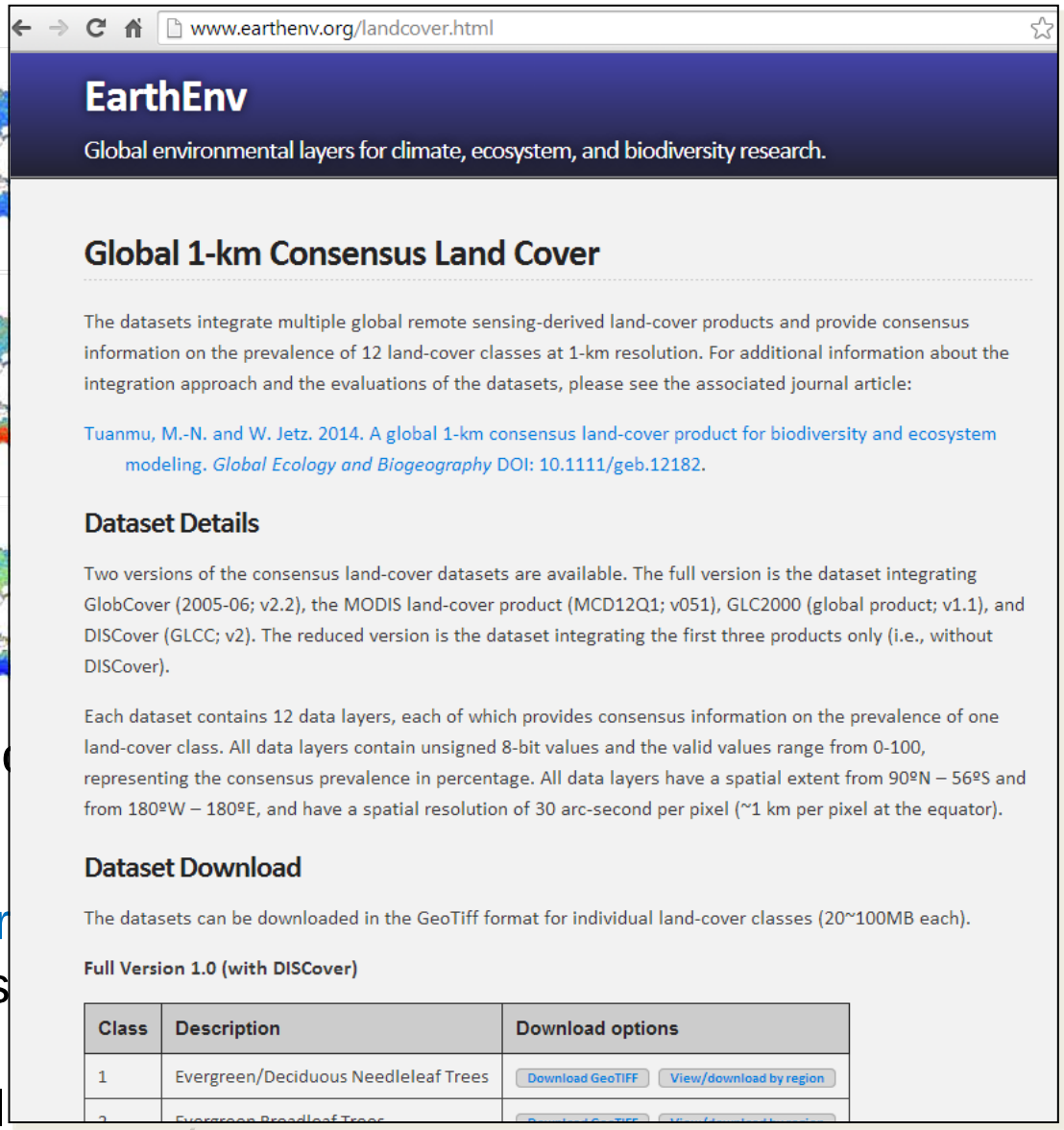












www.earthenv.org/landcover.html

EarthEnv

Global environmental layers for climate, ecosystem, and biodiversity research.

Global 1-km Consensus Land Cover

The datasets integrate multiple global remote sensing-derived land-cover products and provide consensus information on the prevalence of 12 land-cover classes at 1-km resolution. For additional information about the integration approach and the evaluations of the datasets, please see the associated journal article:

Tuanmu, M.-N. and W. Jetz. 2014. A global 1-km consensus land-cover product for biodiversity and ecosystem modeling. *Global Ecology and Biogeography* DOI: 10.1111/geb.12182.

Dataset Details

Two versions of the consensus land-cover datasets are available. The full version is the dataset integrating GlobCover (2005-06; v2.2), the MODIS land-cover product (MCD12Q1; v051), GLC2000 (global product; v1.1), and DISCover (GLCC; v2). The reduced version is the dataset integrating the first three products only (i.e., without DISCover).

Each dataset contains 12 data layers, each of which provides consensus information on the prevalence of one land-cover class. All data layers contain unsigned 8-bit values and the valid values range from 0-100, representing the consensus prevalence in percentage. All data layers have a spatial extent from 90ºN – 56ºS and from 180ºW – 180ºE, and have a spatial resolution of 30 arc-second per pixel (~1 km per pixel at the equator).

Dataset Download

The datasets can be downloaded in the GeoTiff format for individual land-cover classes (20~100MB each).

Full Version 1.0 (with DISCover)

Class	Description	Download options
1	Evergreen/Deciduous Needleleaf Trees	Download GeoTIFF · View/download by region
2	Evergreen Broadleaf Trees	Download GeoTIFF · View/download by region

First- and sec n resolution

Utility for texture measures metrics, generally ess and functional

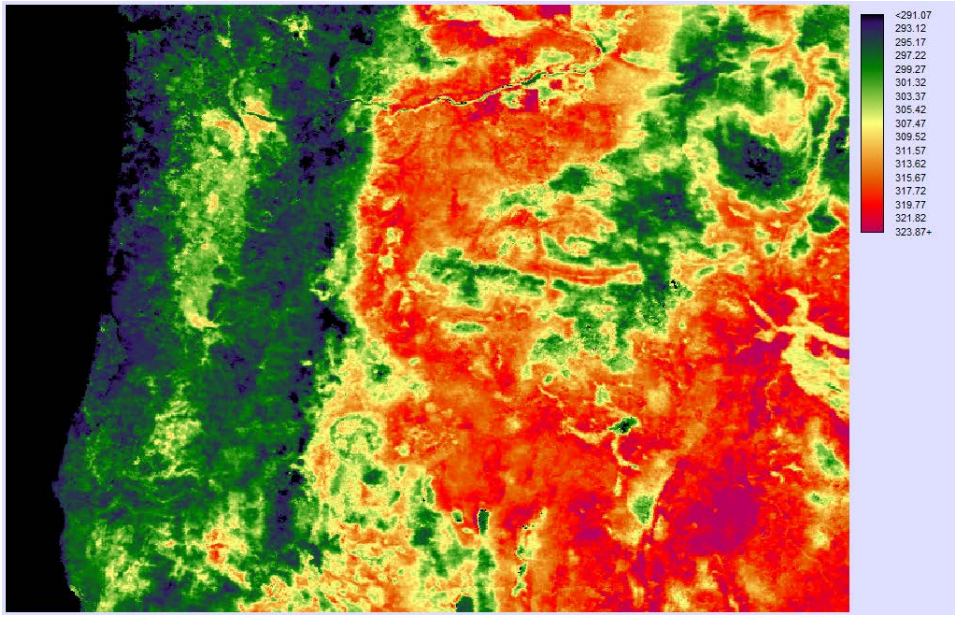
Global Biodiversity Monitoring

I. Providing representative baselines: species distributions, communities, environment

II. Quantifying environmental change

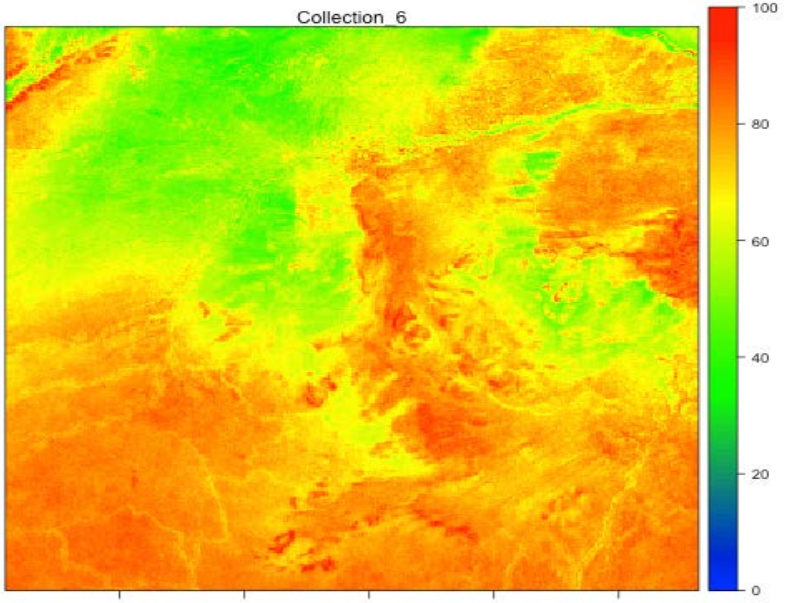
III. Detecting, monitoring biodiversity change

Temperature & Precipitation



Satellite-Station Data Fusion

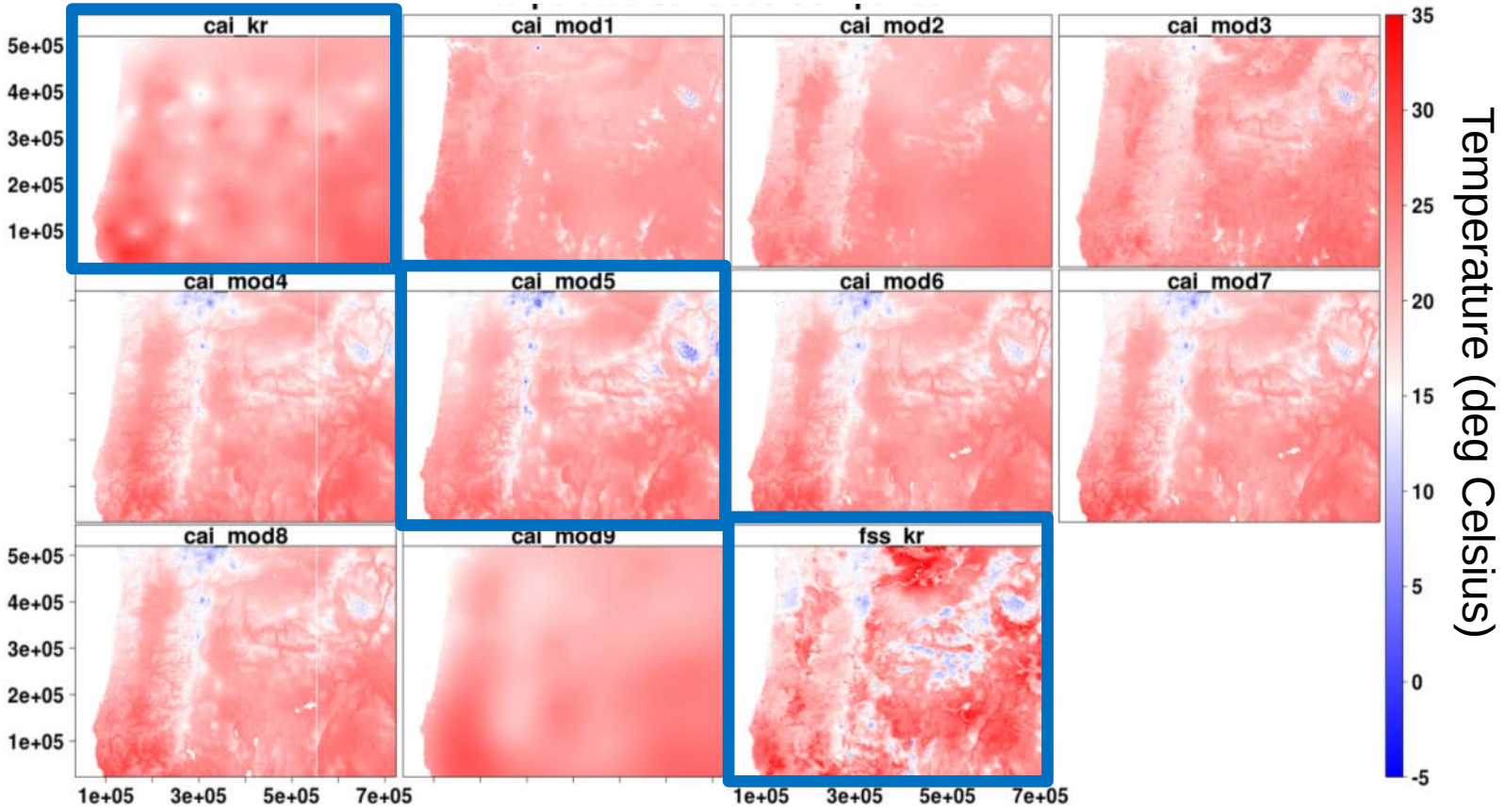
Temperature:
MODIS LST (MOD11A1)



Precipitation:
MODIS Cloud Product
(MOD06, MOD09)

Goal: Develop daily 1km surfaces of tmax, tmin, and ppt with MODIS and climate station data (1980-2014).

Air Temperature

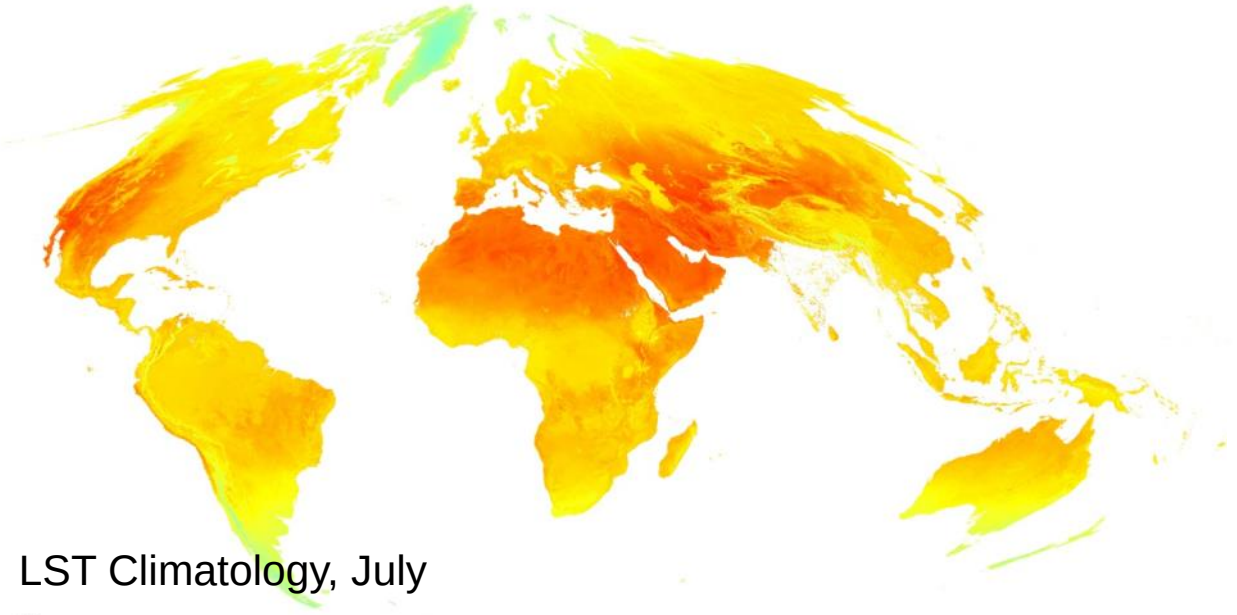


Max. temperature, 1 Sep. 2010
Climate aided interpolation
Comparison of models

cai_mod1	TMax~ f(elev)
caii_mod2	TMax~ f(LST)
cai_mod3	TMax~ f(elev, LST)
cai_mod4	TMax~ f(lat) + f(lon) + f(elev)
cai_mod5	TMax~ f(lat, lon, elev)
cai_mod6	TMax~ f(lat, lon) + f(elev) + f(N_w, E_w) + f(LST)
cai_mod7	TMax~ f(lat, lon) + f(elev) + f(N_w, E_w) + f(LST) + f(LC1)
cai_mod8	TMax~ f(lat, lon) + f(elev) + f(N_w, E_w) + f(LST) + f(LC3)
cai_mod9	TMax~ f(x)+f(y)
cai_kr	CAI_kr: y_var ~ tmax

Air Temperature

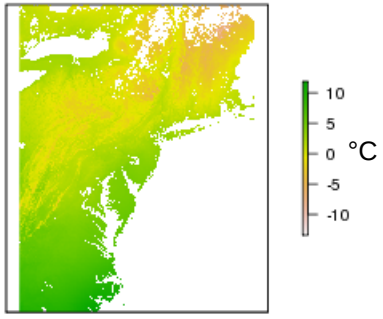
- Fusion of MODIS LST (monthly climatologies) and observations from meteorological stations (daily)
- Global MODIS data processing and testing of models for data fusion on NEX
- Current work focused on addressing data gaps in India / NW Amazon due to persistent cloud cover during June – Aug



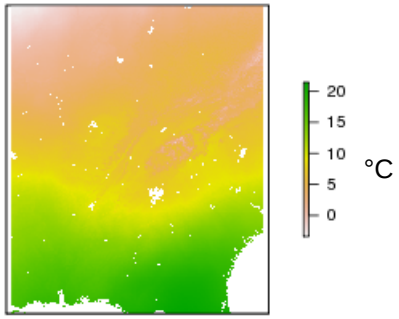
LST Climatology, July

MODIS Terra/Aqua combined

Northeast U.S.

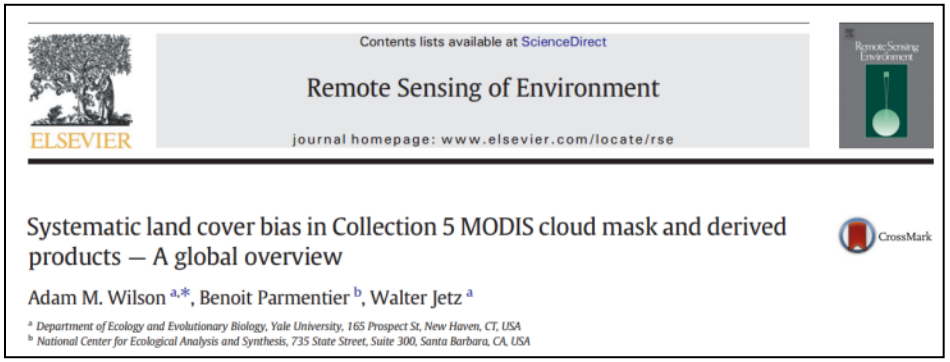


Southeast U.S.



Sample results, air temp., Jan 1., 2010, (GAM Fusion approach)

Cloud Cover



Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

ELSEVIER

Systematic land cover bias in Collection 5 MODIS cloud mask and derived products – A global overview

Adam M. Wilson [a,*], Benoit Parmentier [b], Walter Jetz [a]

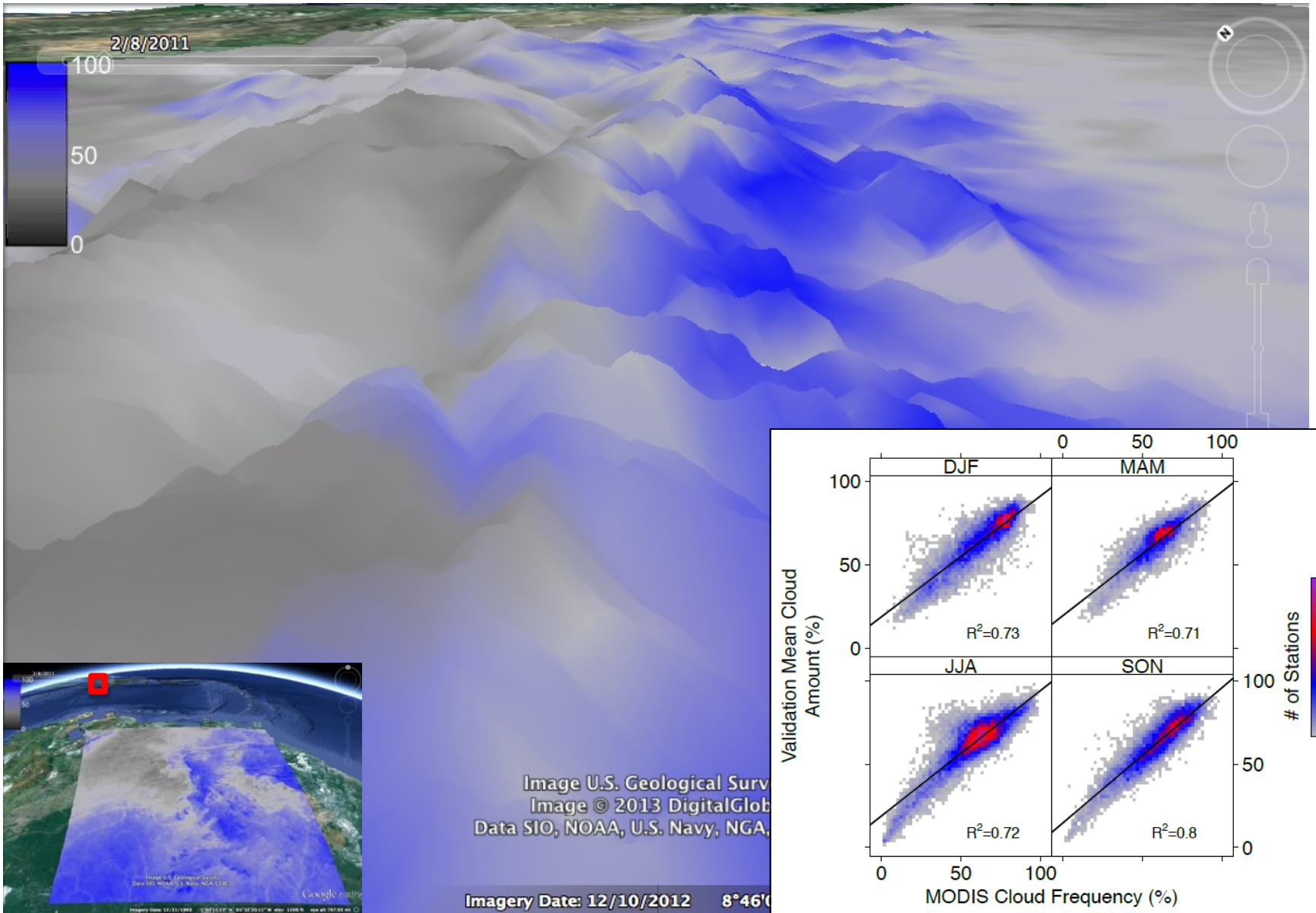
[a] Department of Ecology and Evolutionary Biology, Yale University, 165 Prospect St, New Haven, CT, USA
[b] National Center for Ecological Analysis and Synthesis, 735 State Street, Suite 300, Santa Barbara, CA, USA

Solar radiation
Precipitation
Evaporation
Soil Moisture
Leaf-wetness
Drought-stress
Photosynthetic Activity
Animal Behavior
Growth rate

- Clouds directly affect energy and moisture transport, which in turn affect many biological processes.
- Cloud dynamics can vary drastically over small spatial (~2 km) grains due to atmospheric circulation, topography
- Existing cloud products available only at relatively coarse spatial grains (8-110 km).
- Here: a new MODIS-derived 1-km cloud climatology (MODCF) for use in ecological and species distribution modeling.

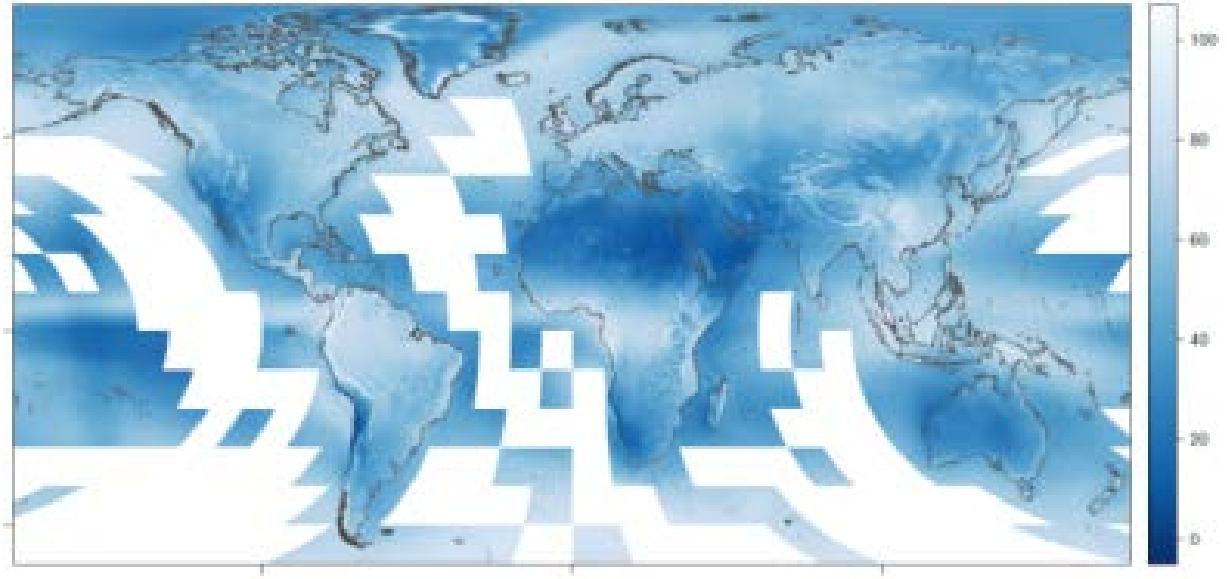
Cloud Cover

MOD35 Cloud Frequency (%) in February

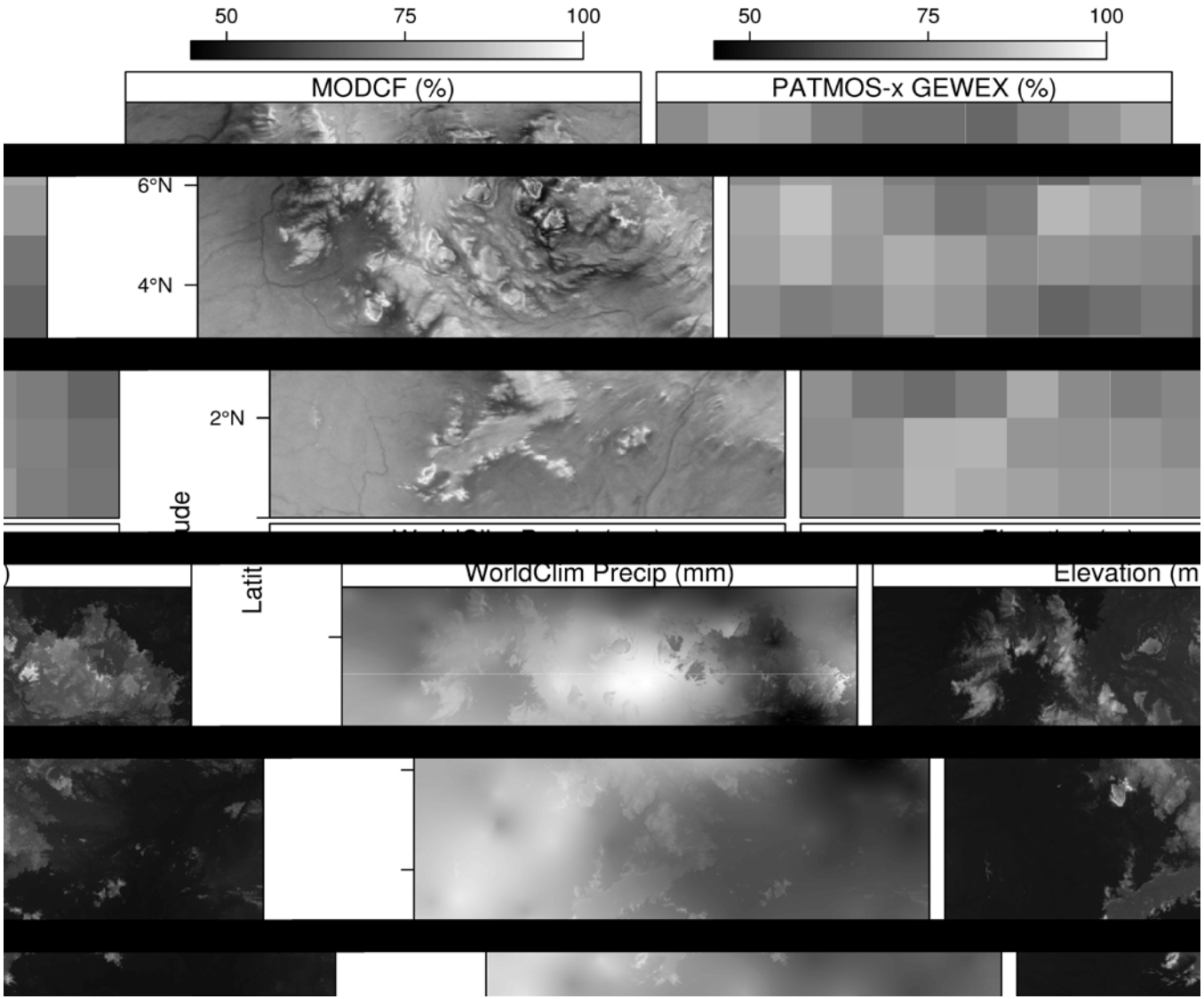


Cloud Cover

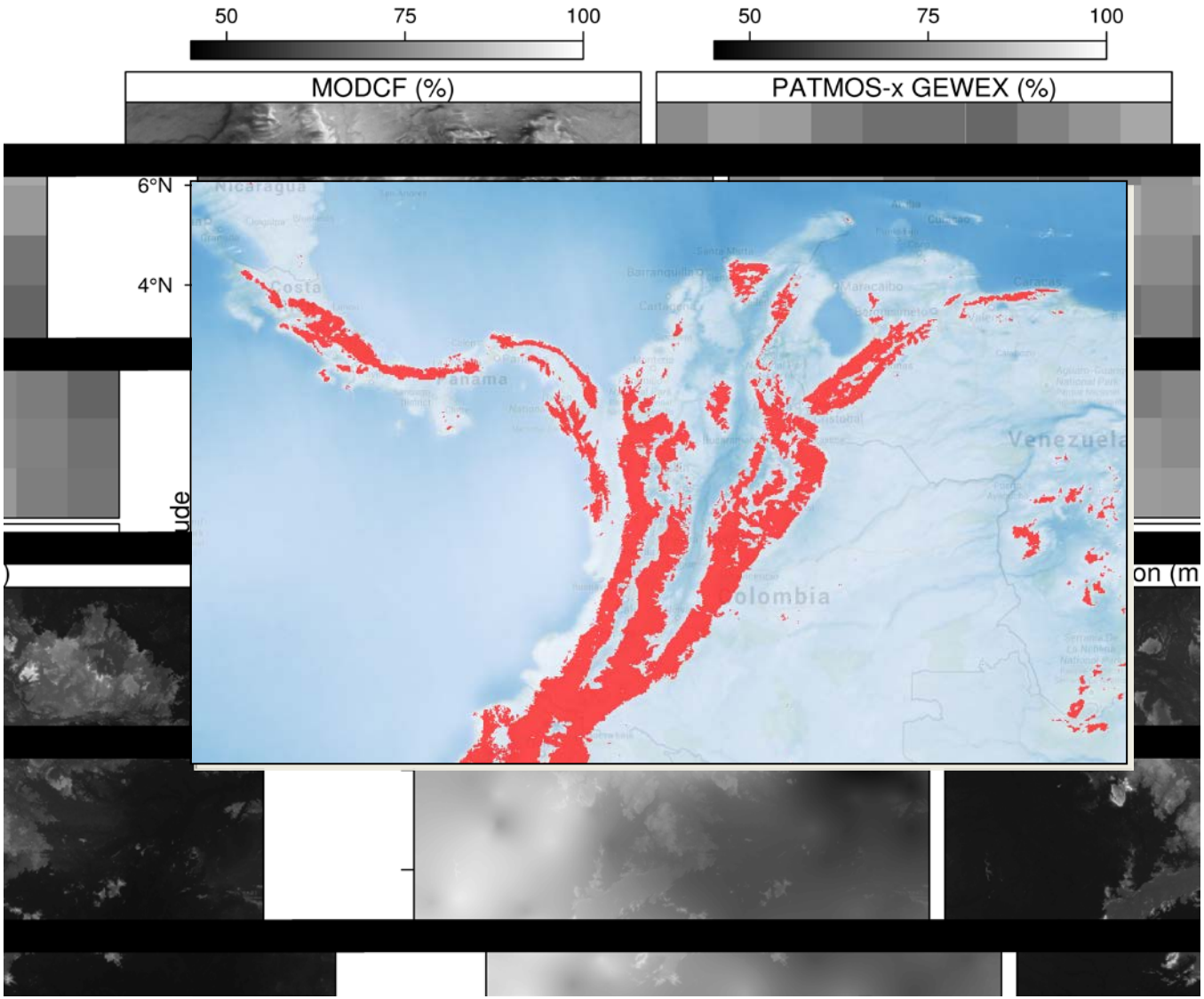
Mean Annual Cloud Frequency (2000-14) (%)



Cloud Cover


50
75
100
50
75
100
MODCF (%)
PATMOS-x GEWEX (%)
6°N
4°N
2°N
WorldClim Precip (mm)
Elevation (m

Cloud Cover


50
75
100
50
75
100
MODCF (%)
PATMOS-x GEWEX (%)
6°N
4°N
Nicaragua
Costa
Panama
Venezuela
Colombia
Maracaibo
Caracas
Barranquilla
Santa Marta

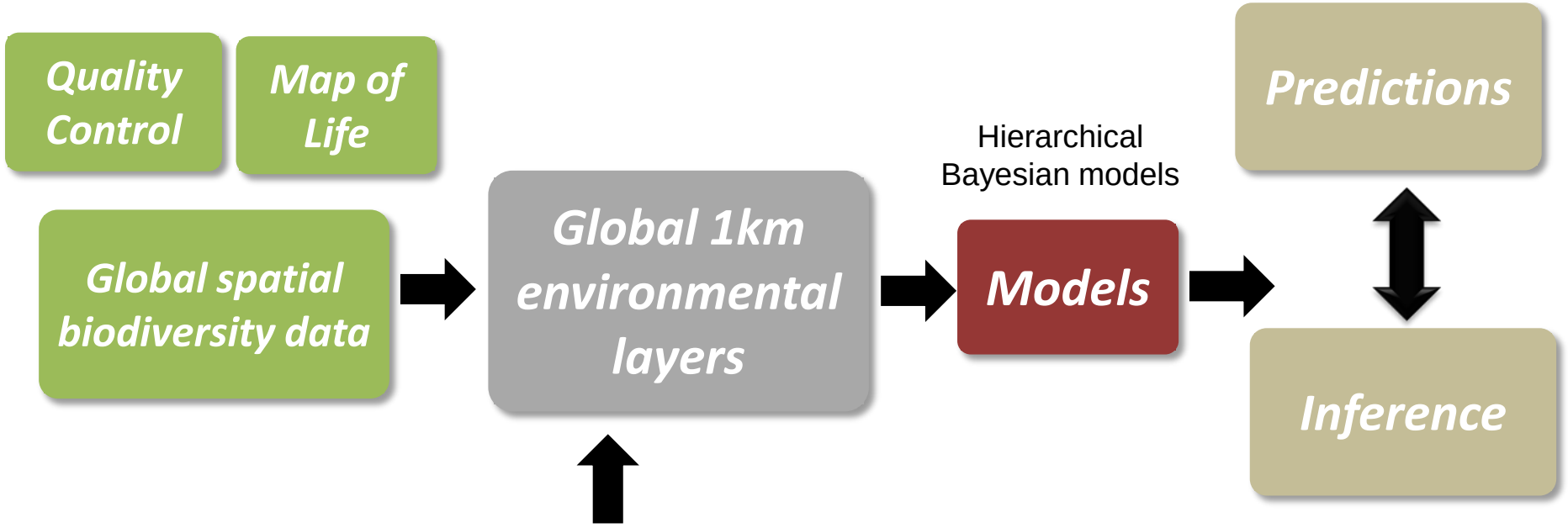
Global Biodiversity Monitoring

I. Providing representative baselines: species distributions, communities, environment

II. Quantifying environmental change

III. Detecting, monitoring biodiversity change

I. Sample- and model-based Biodiversity Monitoring



Change in:
Species niches
Species distributions

1980s - 2014

1km Environment (static,14/20y)

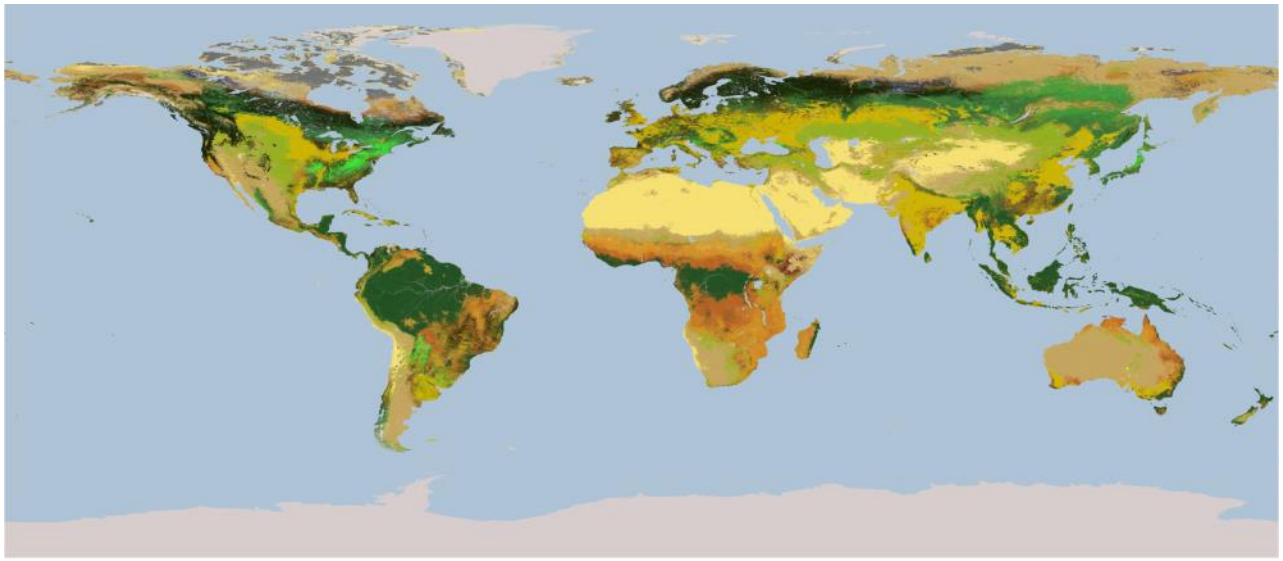
- Topography: √
- Land cover: Consensus √
- Terrain: √
- Radiation: in progress
- Habitat Heterogeneity: √
- Net primary productivity: √

1km Climate
(daily 1980/2001-2014)

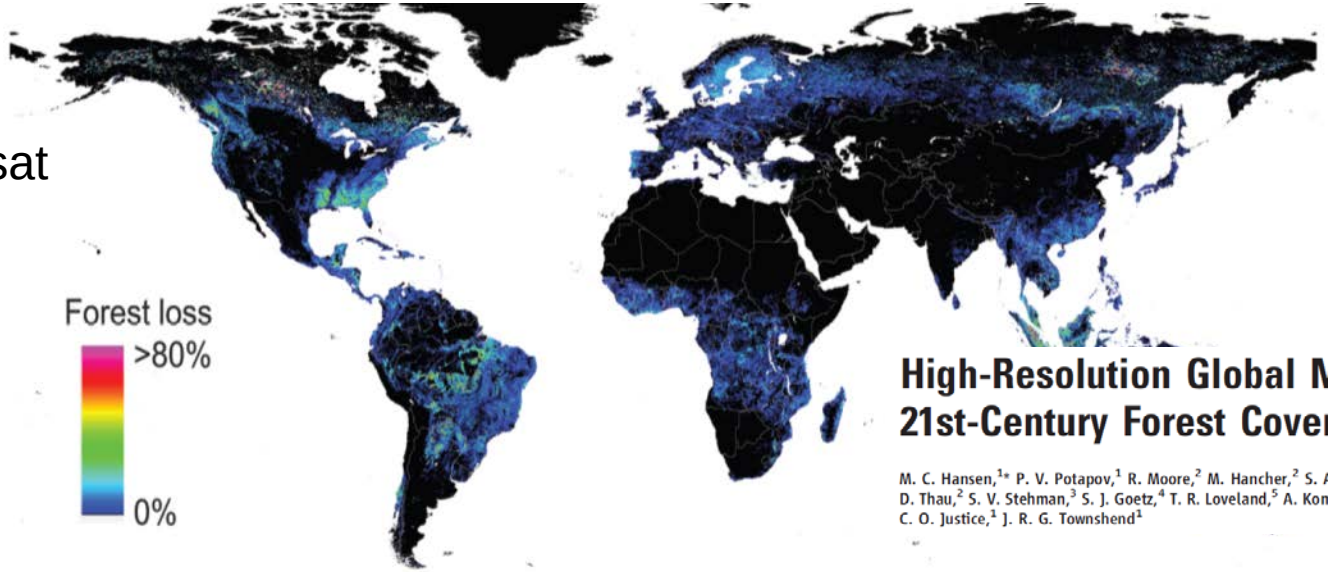
- Temperature: 2014!
- Cloud cover: close!
- Precipitation: 2014!
- Bioclimatic variables: in progress
- Extreme events : in progress

II. Range-, Land-cover based Biodiversity Monitoring

1km MODIS
Land cover



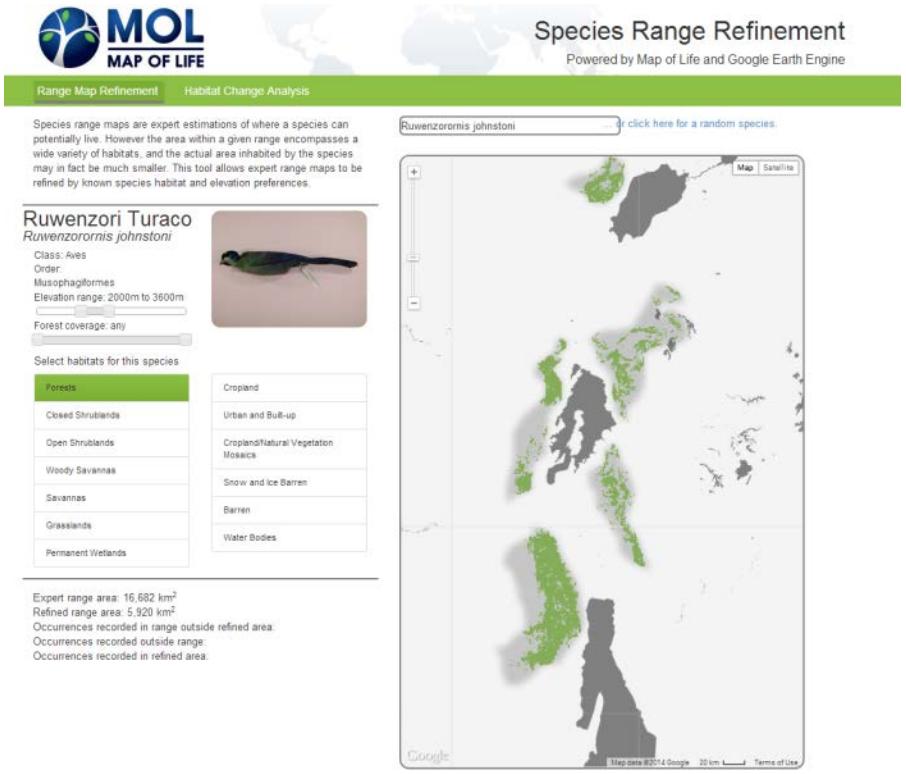
30m Landsat
Tree cover



High-Resolution Global Maps of 21st-Century Forest Cover Change

M. C. Hansen,[1]* P. V. Potapov,[1] R. Moore,[2] M. Hancher,[2] S. A. Turubanova,[1] A. Tyukavina,[1] D. Thau,[2] S. V. Stehman,[3] S. J. Goetz,[4] T. R. Loveland,[5] A. Kommareddy,[6] A. Egorov,[6] L. Chini,[1] C. O. Justice,[1] J. R. G. Townshend[1]

II. Range-, Land-cover based Biodiversity Monitoring



coming soon to: mol.org

Thanks!