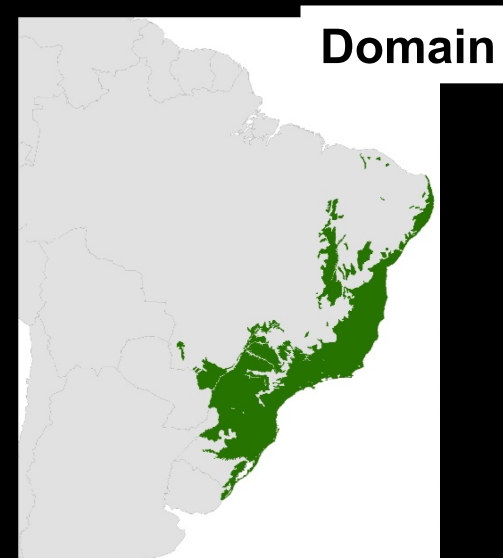
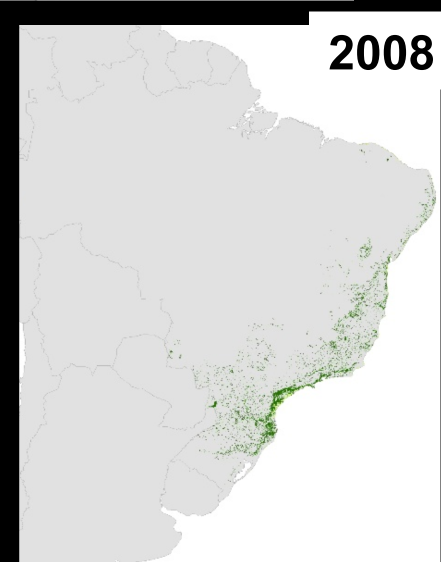
A multidisciplinary approach to biodiversity prediction in the Brazilian Atlantic Forest hotspot

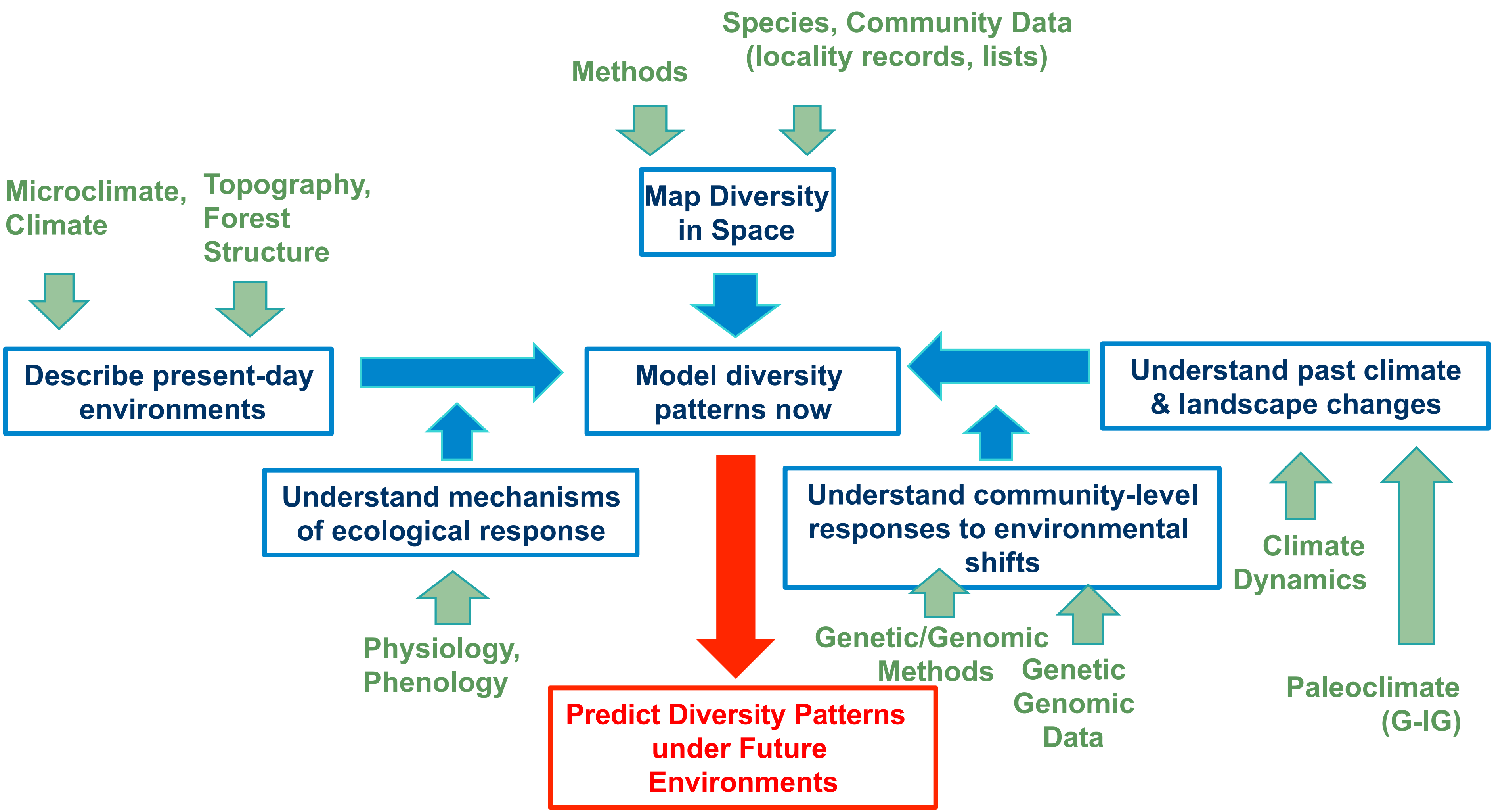
The Brazilian Atlantic rainforest





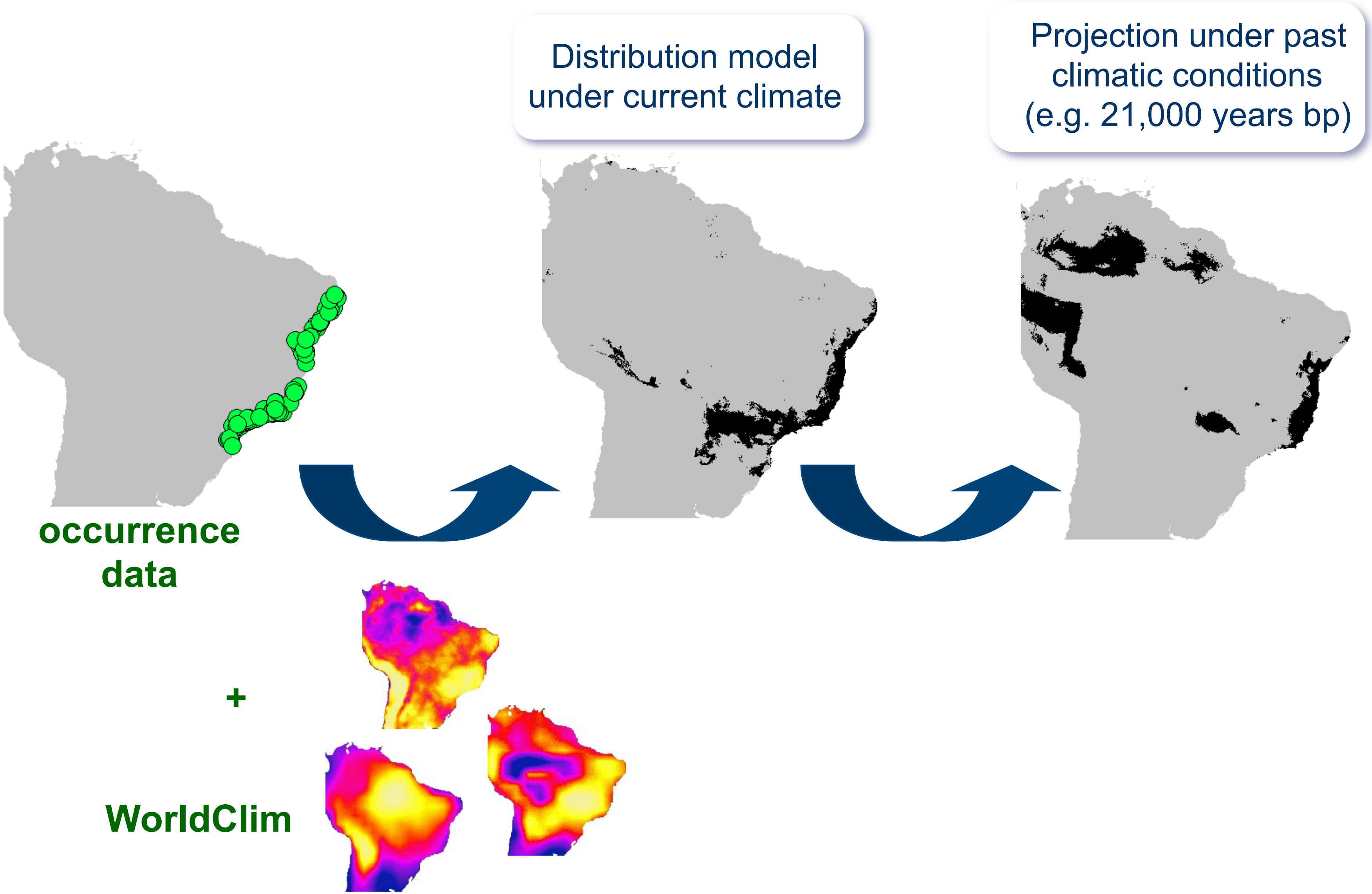
- ~1,230,000 Km^2

Framework

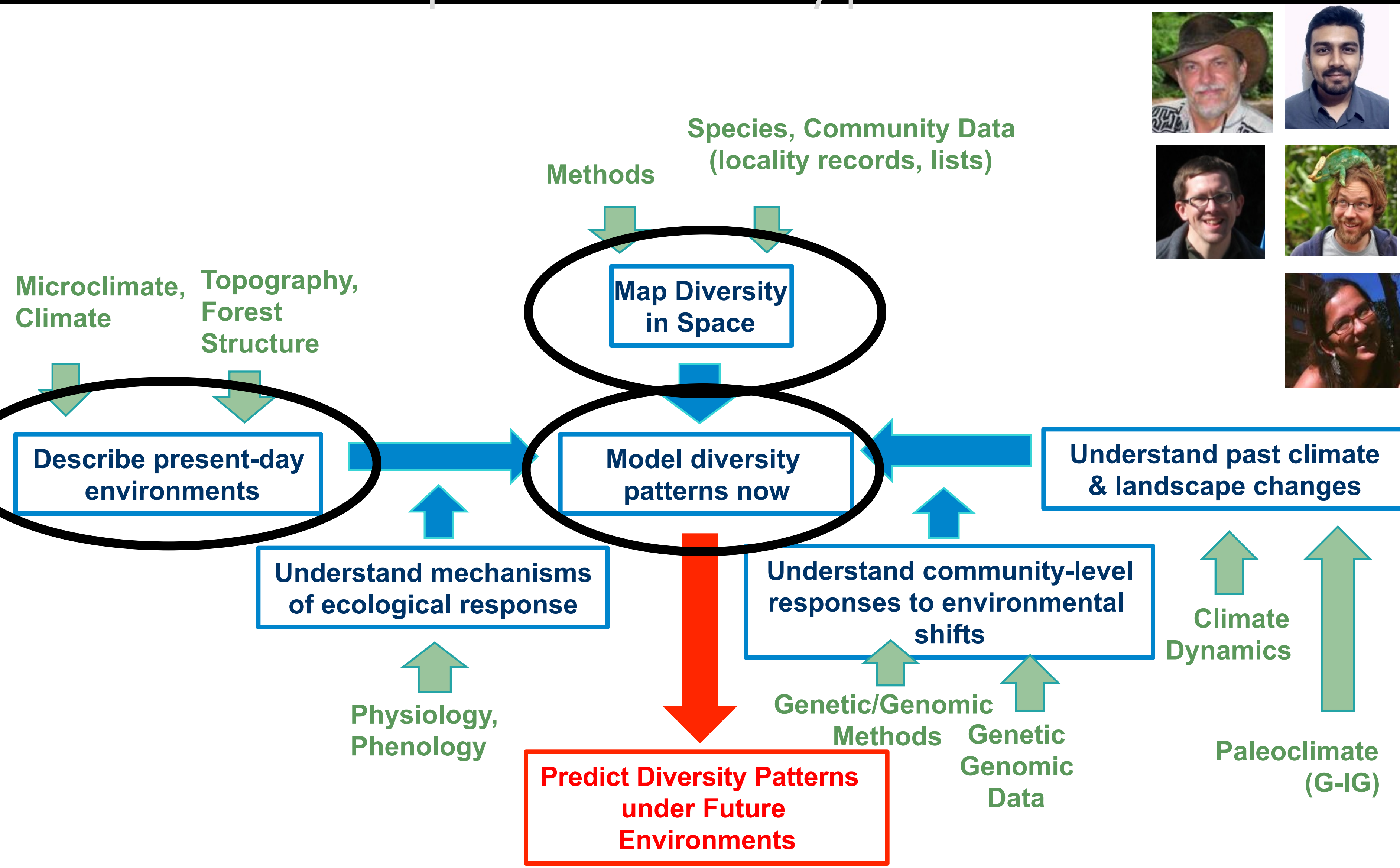


Species, Community Data
(locality records, lists)
Methods
Map Diversity
in Space
Microclimate,
Climate
Topography,
Forest
Structure
Describe present-day
environments
Model diversity
patterns now
Understand past climate
& landscape changes
Understand mechanisms
of ecological response
Understand community-level
responses to environmental
shifts
Climate
Dynamics
Physiology,
Phenology
Genetic/Genomic
Methods
Genetic
Genomic
Data
Paleoclimate
(G-IG)
Predict Diversity Patterns
under Future
Environments

Interpolated weather-station data have been heavily used to analyze biological data in the AF

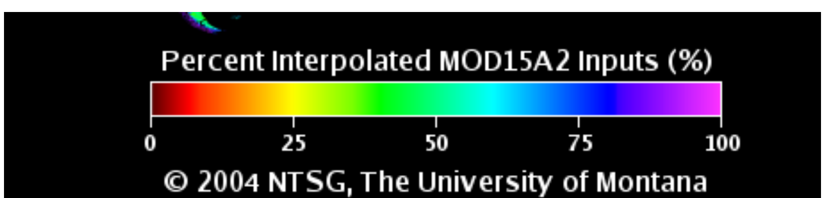


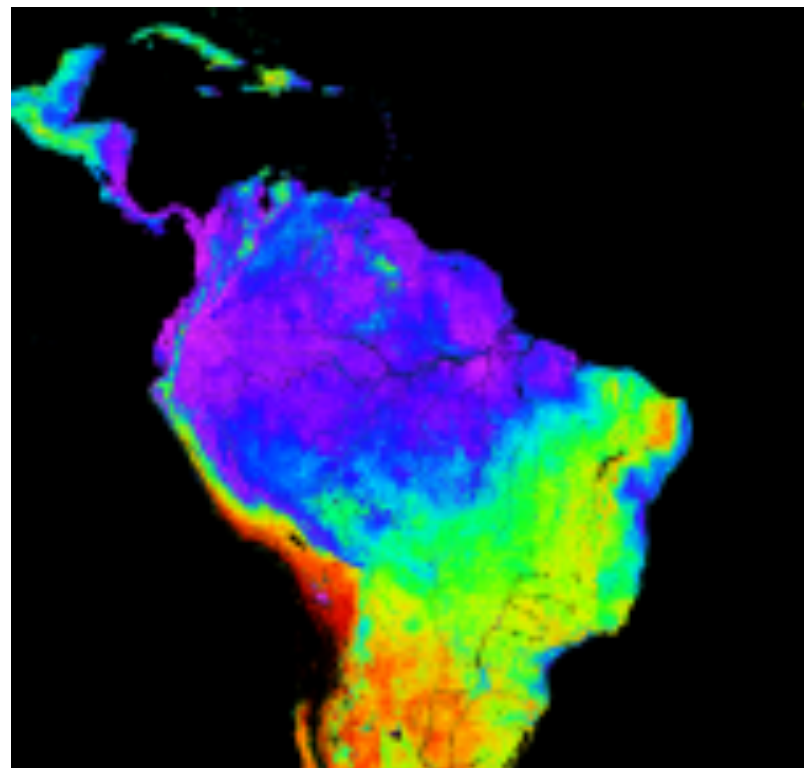
How can the incorporation of remote sensing components improve biodiversity prediction?



How can the incorporation of remote sensing components improve biodiversity prediction?

Trade-offs matter for biodiversity analyses:
Optical data (e.g. MODIS): high spatial resolution yet poor temporal coverage and cloud interference
Microwave data (e.g. AMSR-E) : high temporal coverage but poor spatial resolution





Do microwave data enable characterization of present-day environments for use in biodiversity modeling?

Methods in Ecology and Evolution

Methods in Ecology and Evolution 2014 doi: 10.1111/2041-210X.12264

Bioclimatic variables derived from remote sensing: assessment and application for species distribution modelling

Eric Waltari[1*], Ronny Schroeder[1,2], Kyle McDonald[1,3], Robert P. Anderson[1,3,4,5] and Ana Carnaval[1,3,4]

NASA products

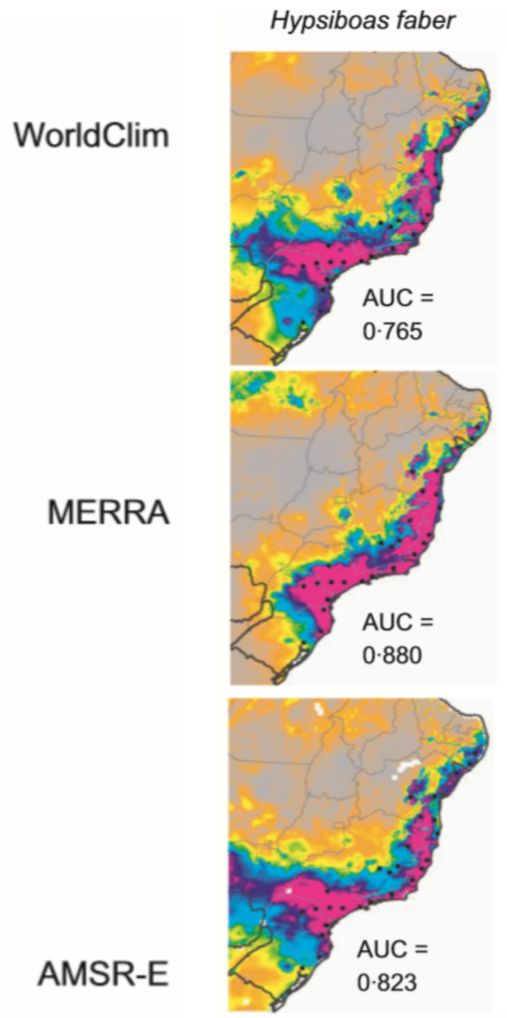
- the Modern-Era Retrospective Analysis (MERRA), which incorporates remote sensing information and a subset of the station-based data
- pure remote sensing information (Advanced Microwave Scanning Radiometer-Earth Observations, AMSR-E).

Coarse spatial resolution (MERRA 55 x 75 km. AMSR-E 25 km), high temporal frequency of data collection (near-daily at low latitudes).

Microwave data enable characterization of present-day environments for use in biodiversity modeling

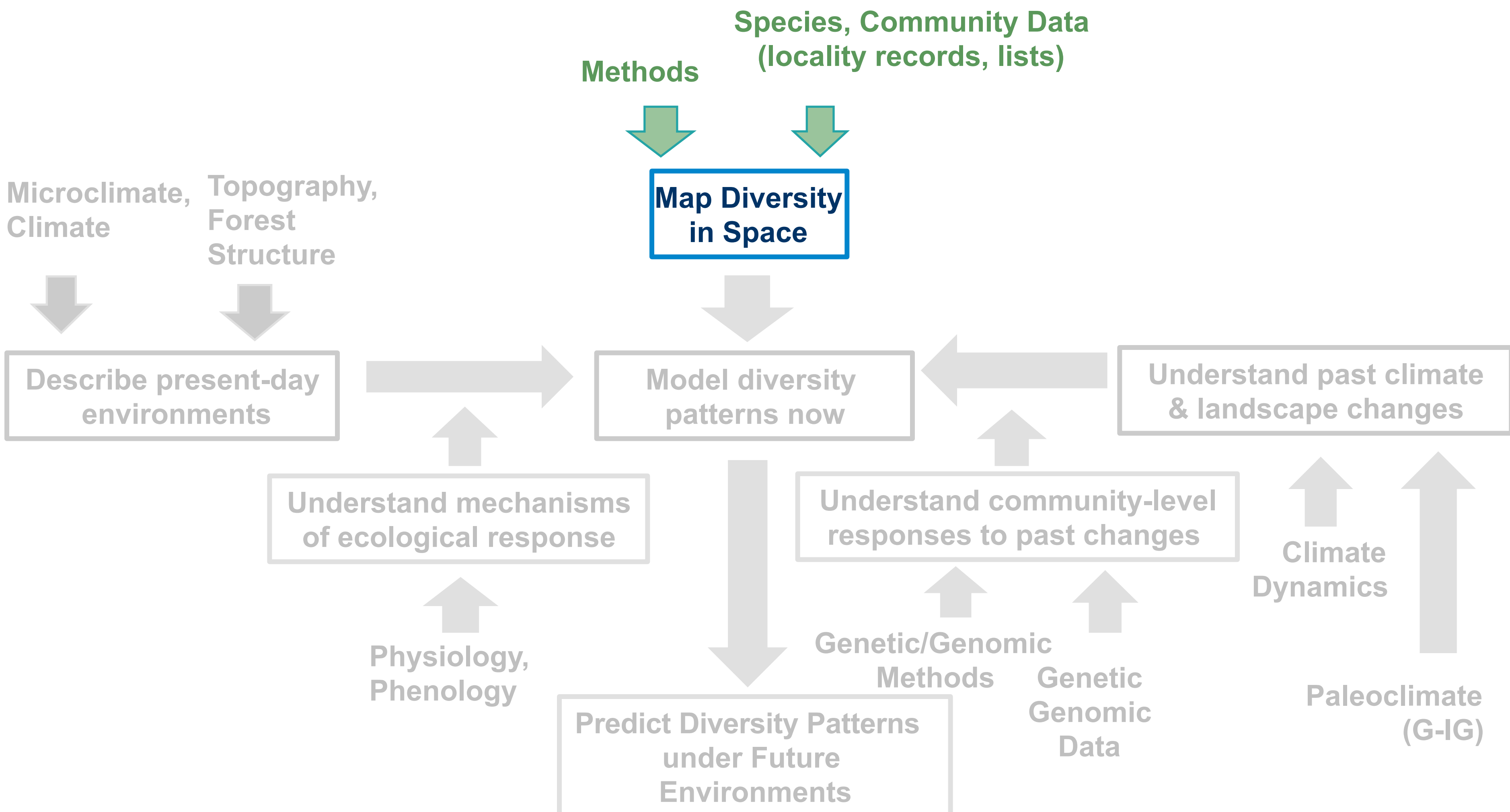
- Species Distribution Models derived from MERRA-derived layers performed better than models built with WorldClim data.

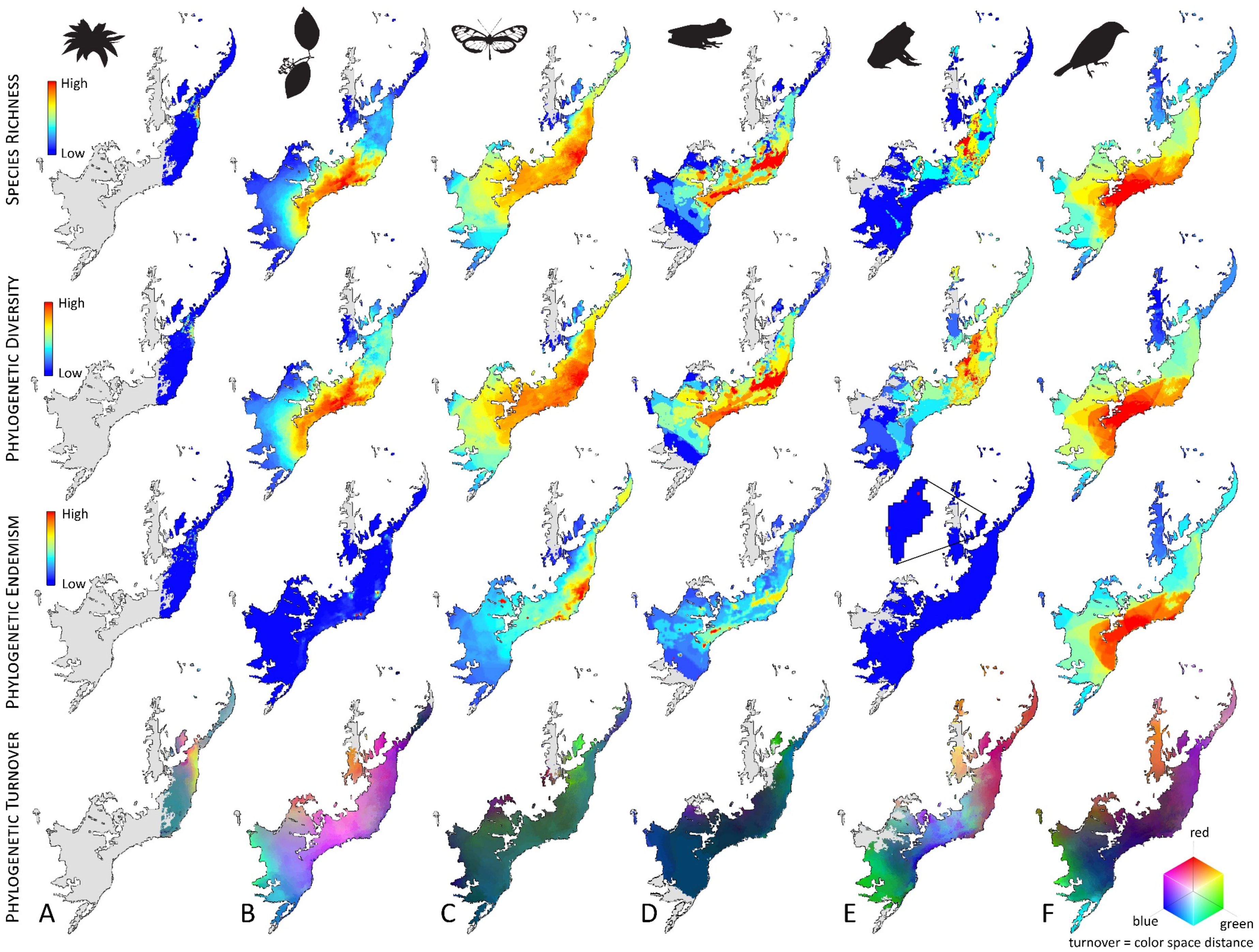
- Models constructed with AMSR-E-based layers had similar performance to models built with WorldClim.



Waltari et al. 2014. Meth Ecol Evol

Do microwave data also predict diversity patterns at larger ecological and geographical scales?



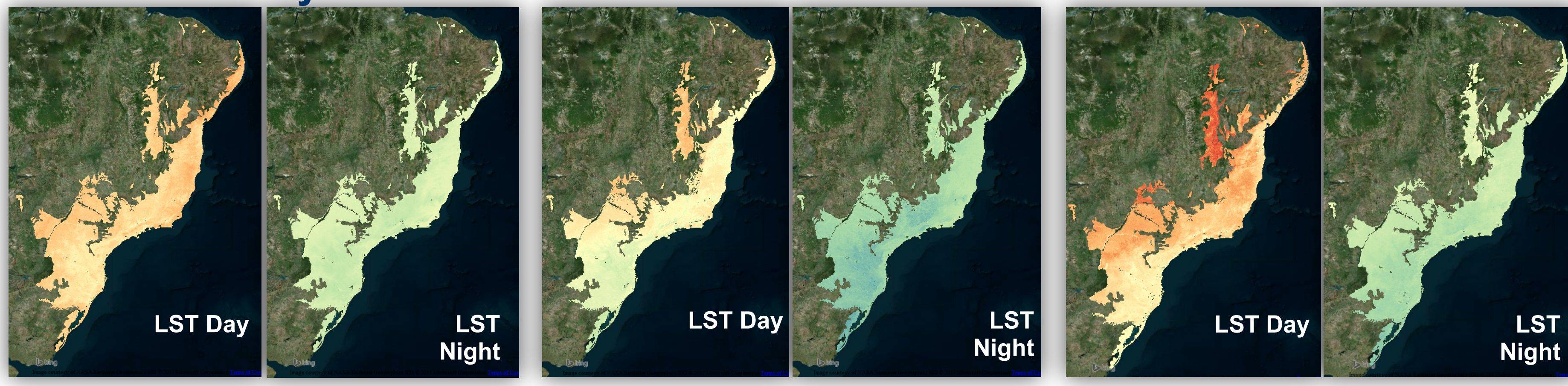


Species Richness
Phylogenetic Diversity
Phylogenetic Endemism
Phylogenetic Turnover
High
Low
High
Low
High
Low
A
B
C
D
E
F
red
blue
green
turnover = color space distance

Do remote sensing products also predict diversity patterns at larger ecological and geographical scales?

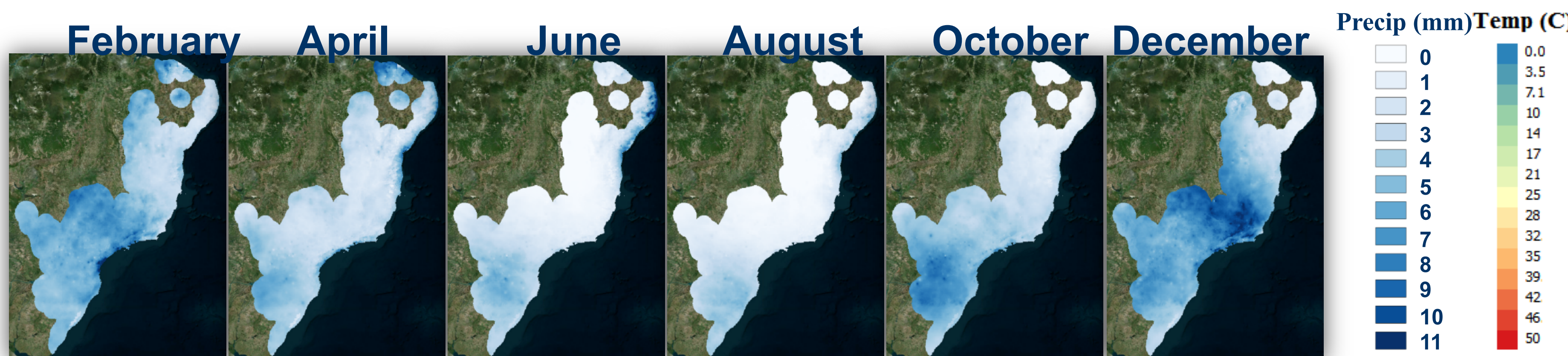
MODIS (MOD11A2_005) Mean monthly temperature (2002-2016)

February | June | October



CHIRPS Mean monthly precipitation (2002-2016)

February | April | June | August | October | December



Exploring bioclimatic variables derived from MODIS and CHIRPS (Deblauwe et al., 2016)

Do remote sensing products also predict diversity patterns at larger ecological and geographical scales?

PRELIMINARY ANALYSES BASED ON MODIS AND CHIRPS measurements

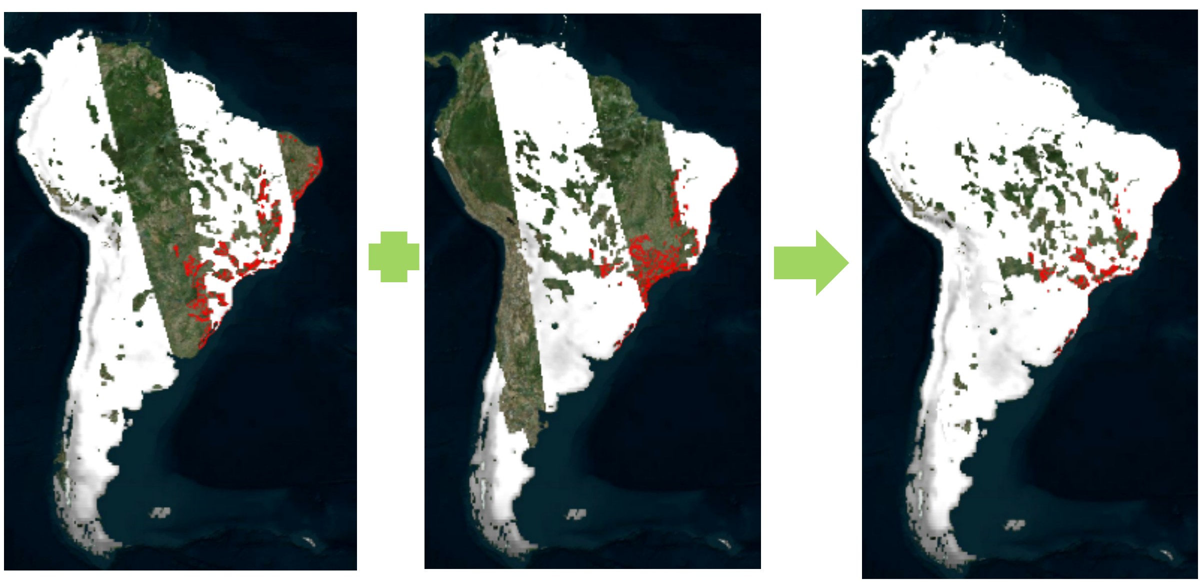
Conditional Autoregressive Models used to address spatial autocorrelation; probability of values at any given location is conditional on neighboring values.

	R^2 Phylogenetic Diversity	R^2 Phylogenetic Endemism
	0.92	0.77
	0.95	0.51
	0.94	0.46
	0.78	0.27
	0.89	0.05
	0.86	0.05

Do microwave data also predict diversity patterns at larger ecological and geographical scales?

Surface temperature from Passive Microwave Radiometry

- AMSR-E (2002-2011)
- Data collected twice a day (1:30 AM/PM)
- > 6600 files, 16 day repeat cycle
- Average of every 2 days of data taken to obtain as complete coverage as possible

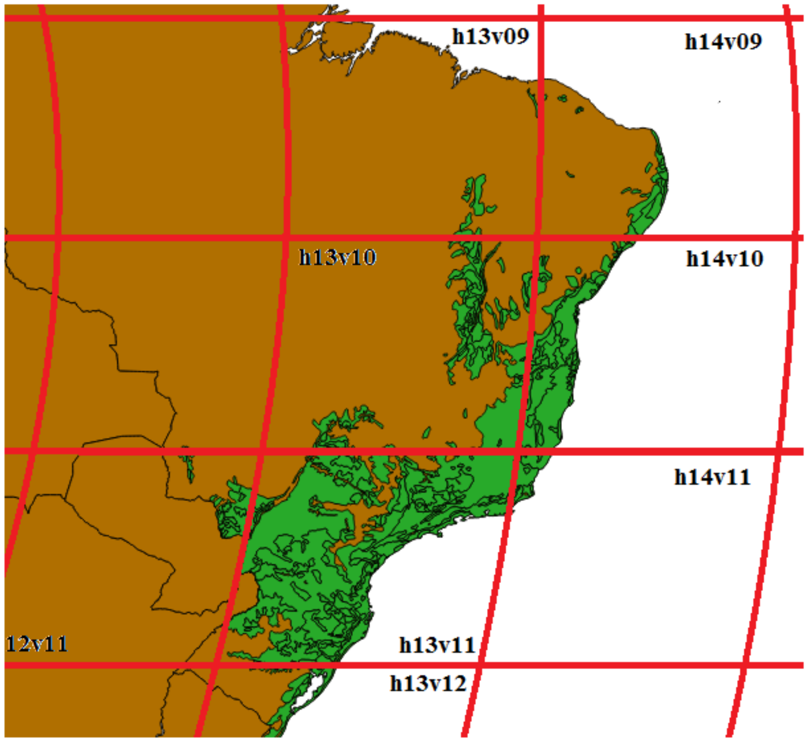


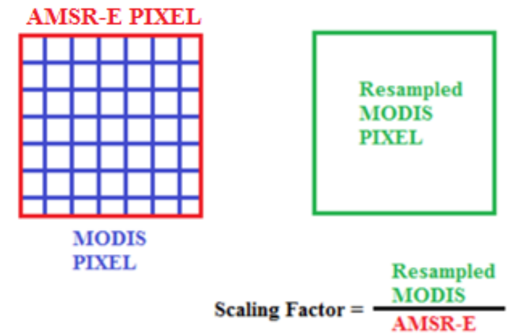
Jan 1, 2007 Day **Jan 2, 2007 Day** **Jan 1-2, 2007 Day**

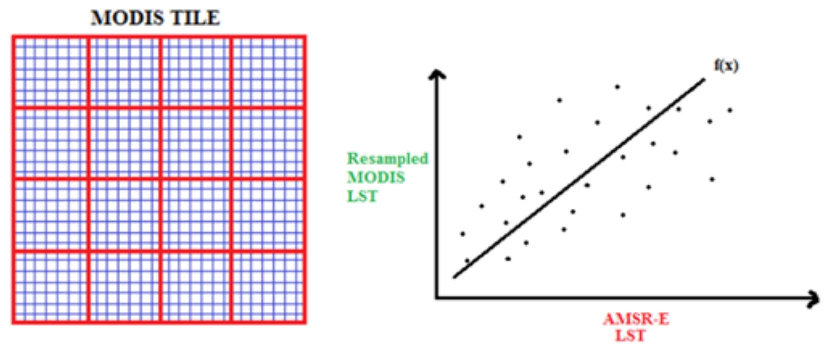
*white =
areas with coverage

Methodology

MODIS Tiles overlapping Atlantic Forest







Composite MODIS 8-day LST to 16-day intervals

Produce Interannual Climatology for each 16-day period over 14 years.

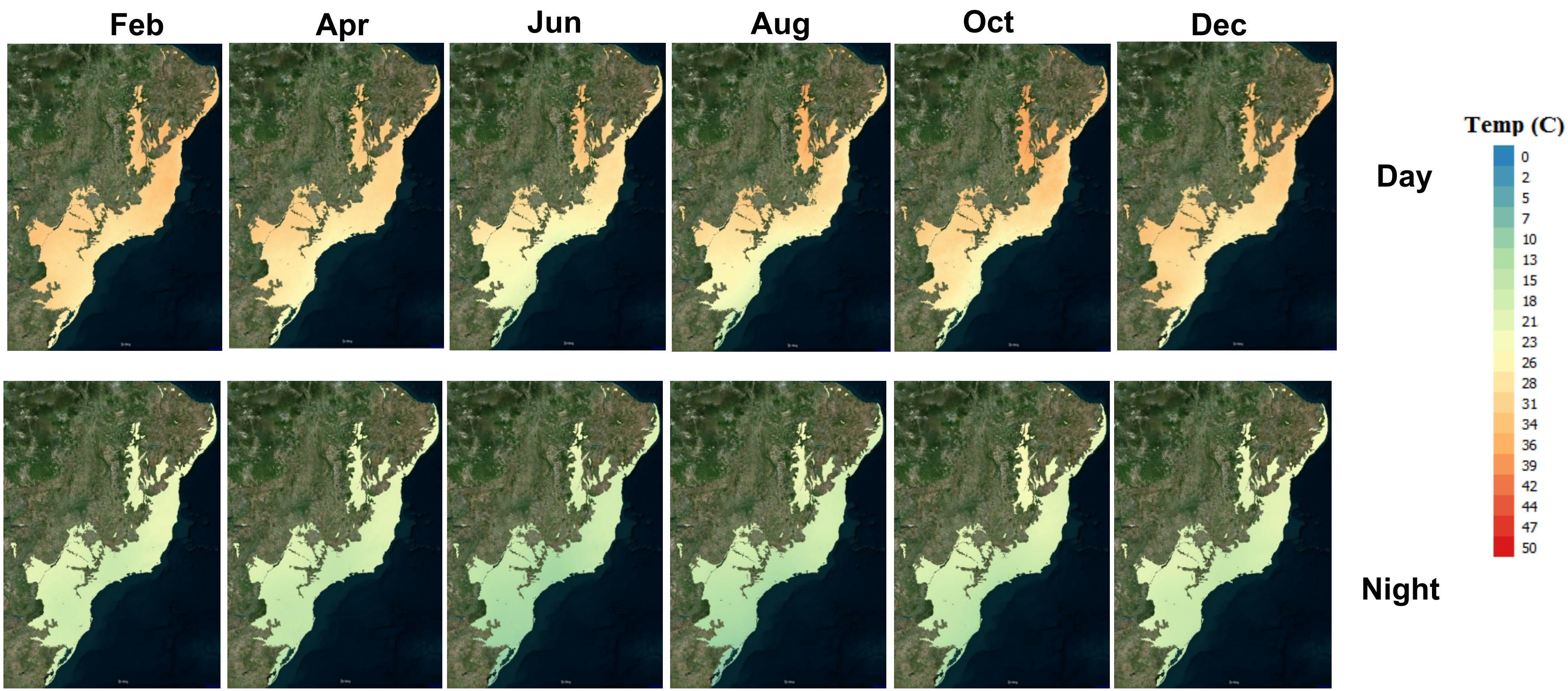
Resample MODIS Climatology LST (1km) to 25km resolution LST

Formulate a statistically-based linear relationship between the MODIS (25km) and AMSR-E (25km) LST

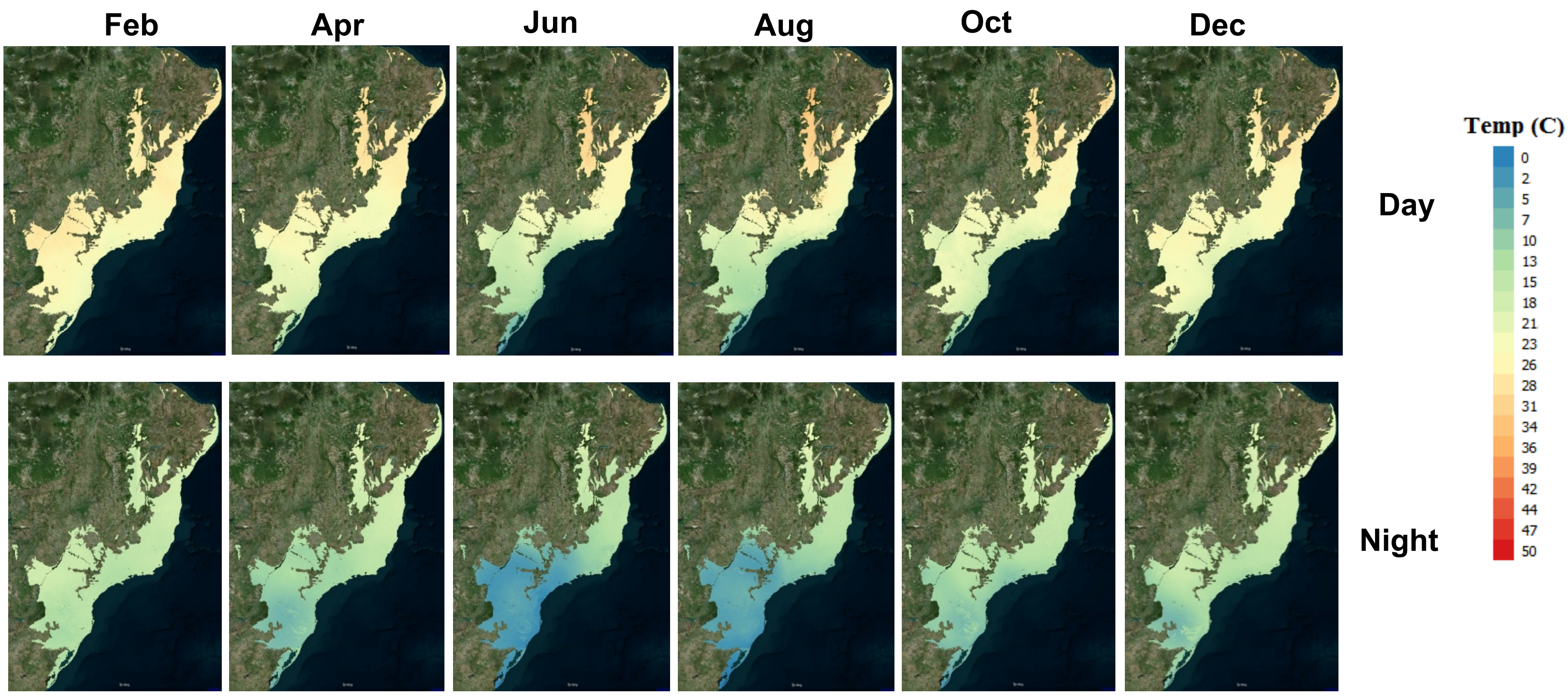
Utilize the relationship to convert 1km MODIS LST to 1km AMSR-E LST

End Product: 1km Spatial Resolution, AMSR-E LST

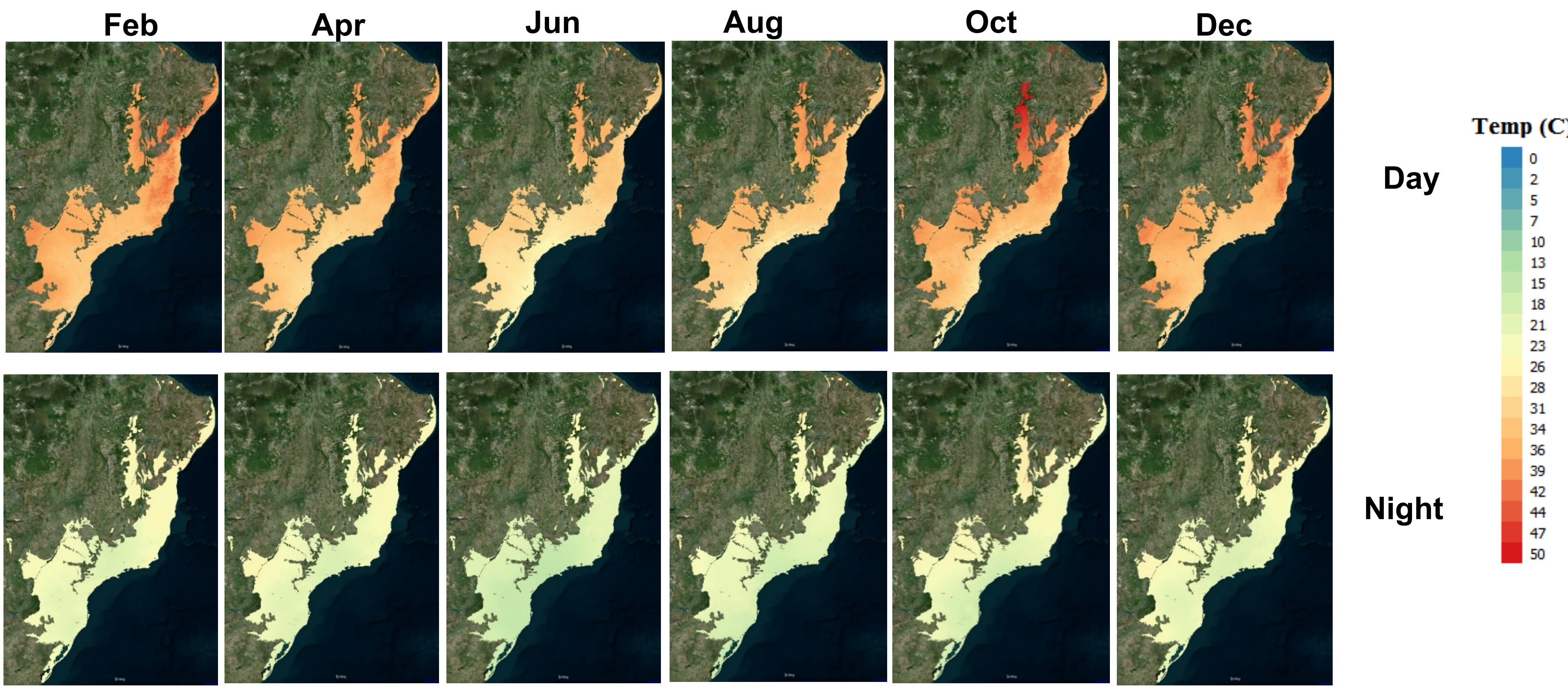
AMSR-E Climatology: LST Mean (2003-2011)



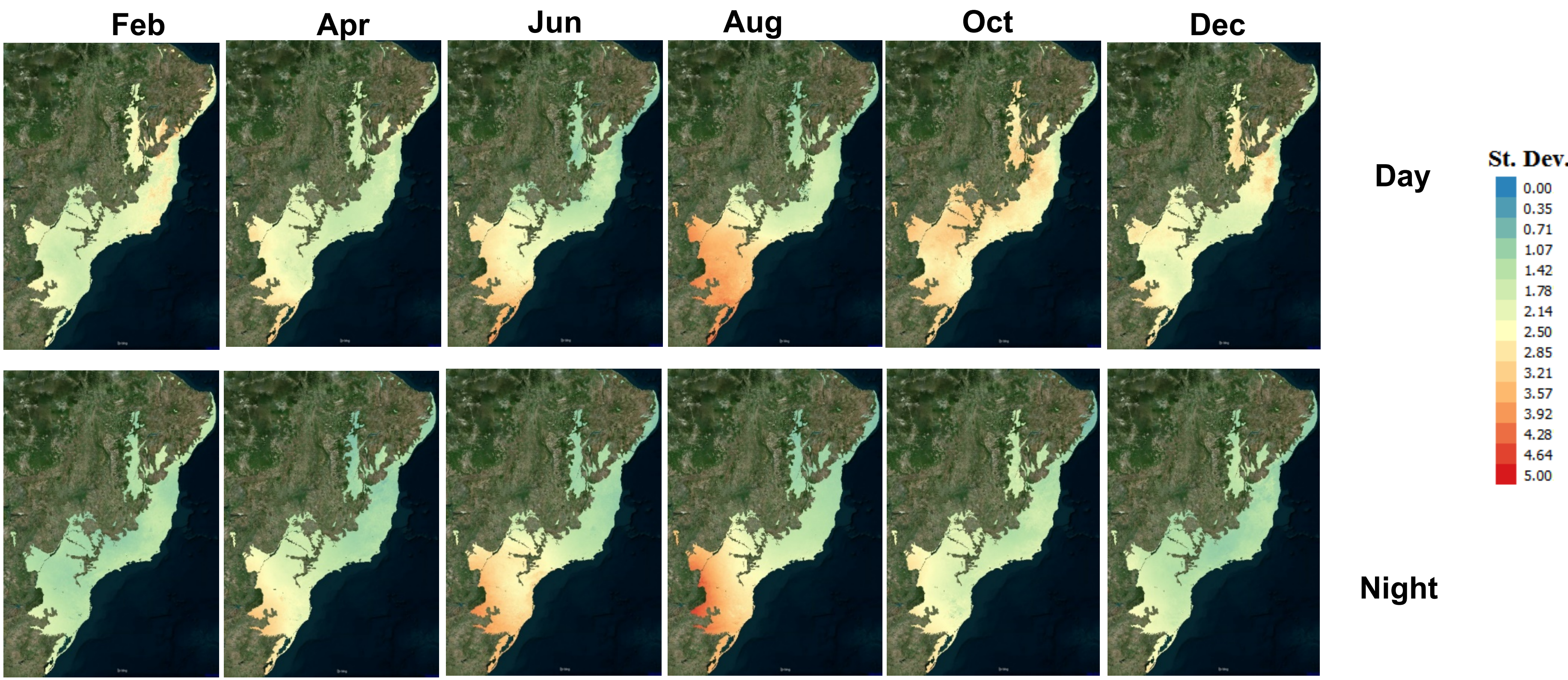
AMSR-E Climatology: LST Min (2003-2011)



AMSR-E Climatology: LST Max (2003-2011)

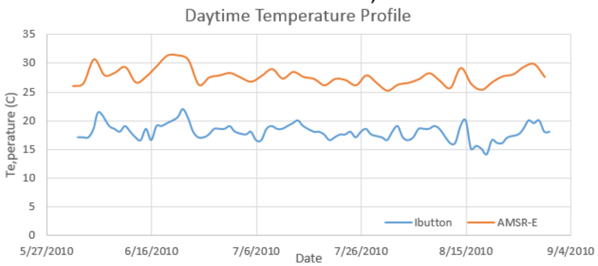


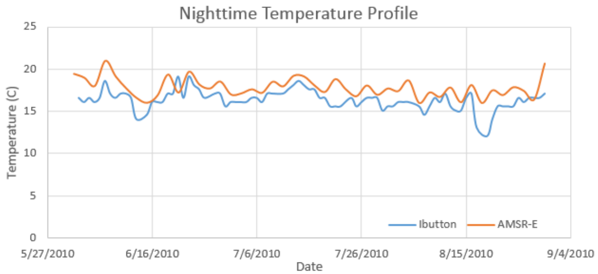
AMSR-E Climatology: LST St Dev (2003-2011)



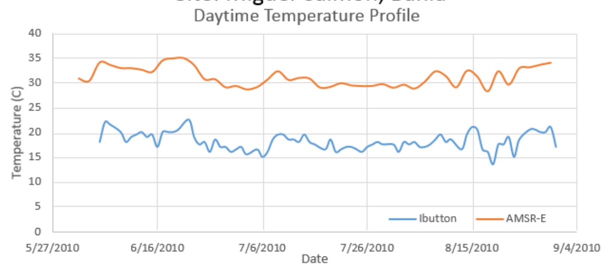
Temperature Retrieved from Data loggers and AMSR-E (1km)

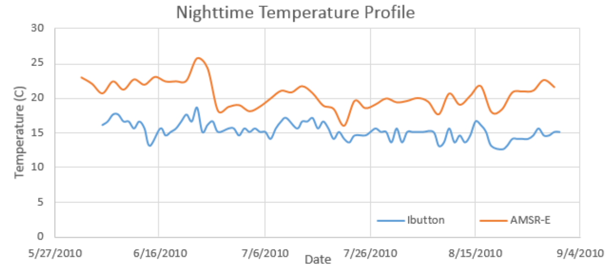
Site: Serra Bonita, Bahia



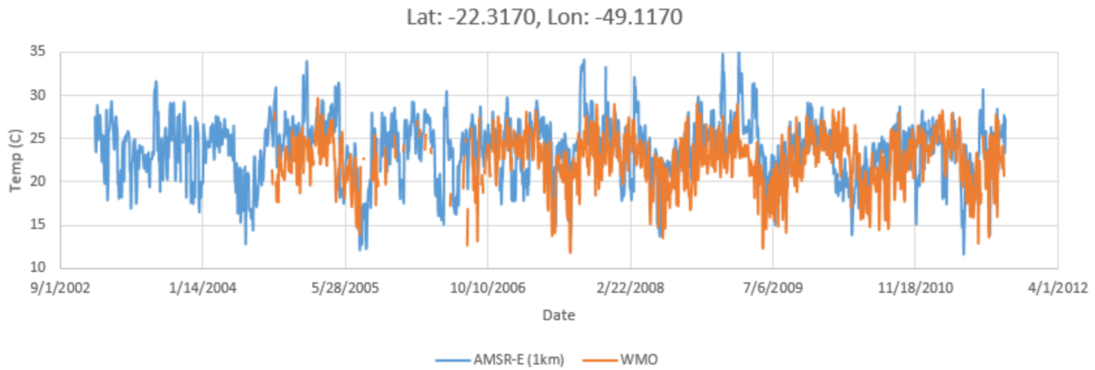


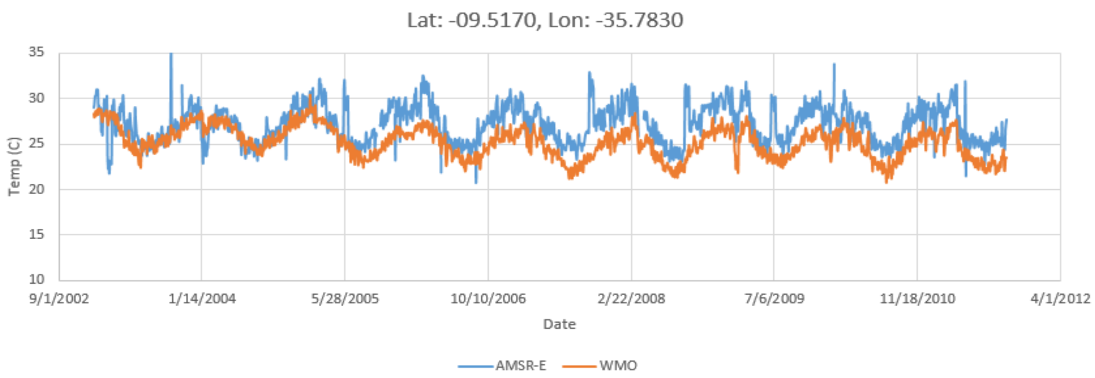
Site: Miguel Calmon, Bahia

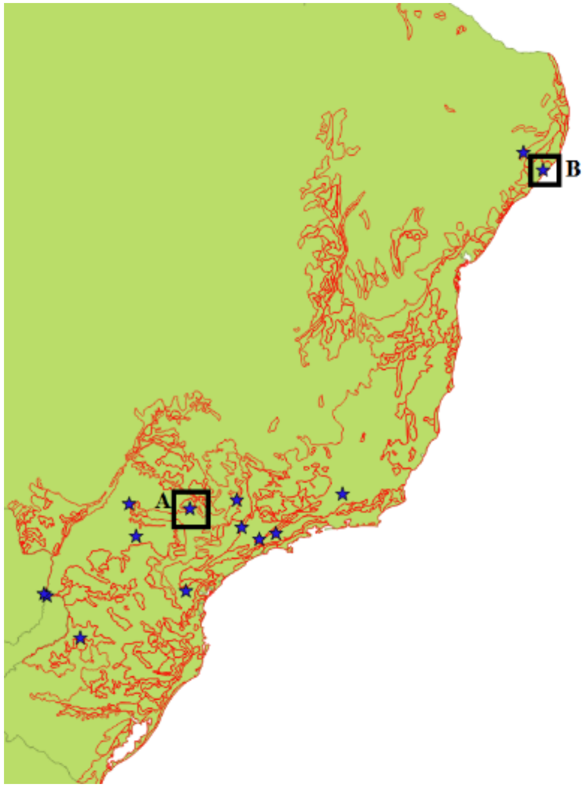




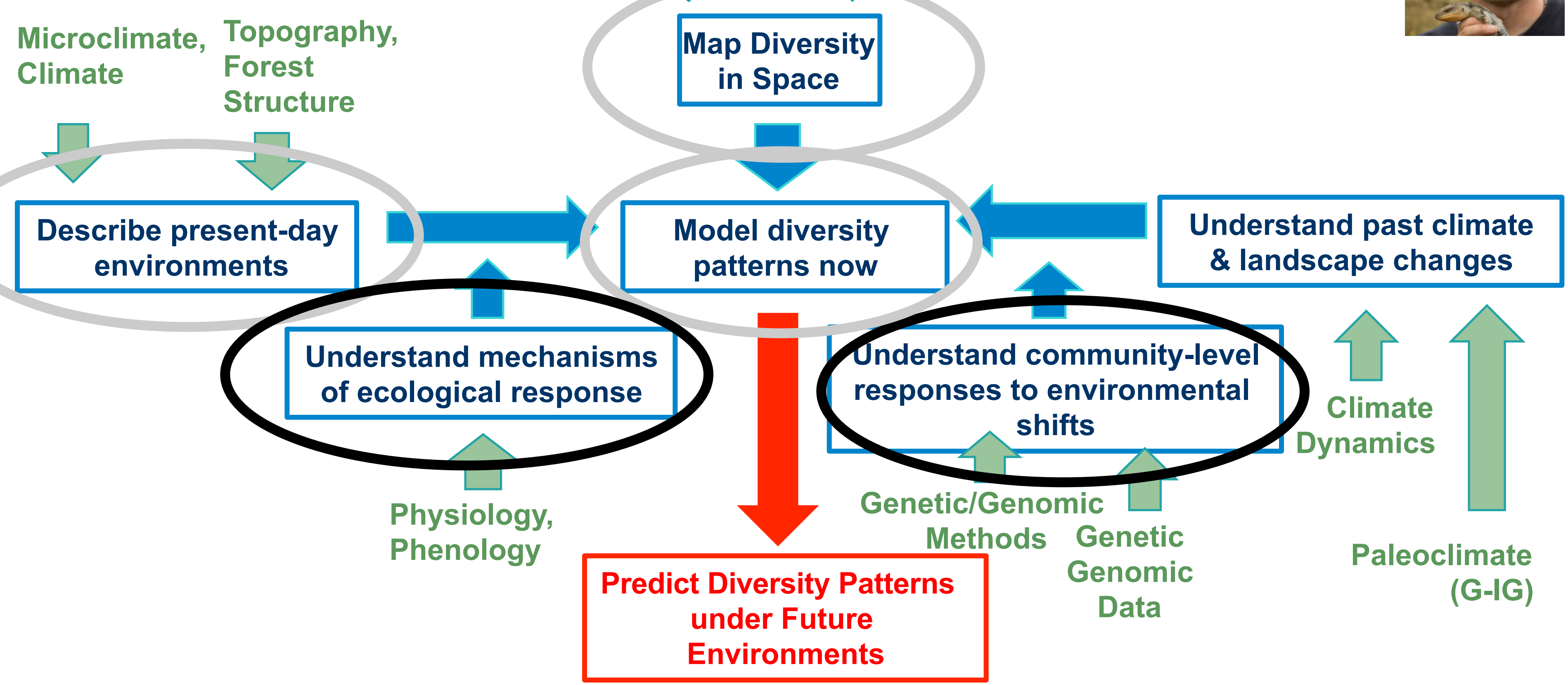
Temperature Retrieved from Weather Stations and AMSR-E (1km)







Incorporation of remote sensing components – to date

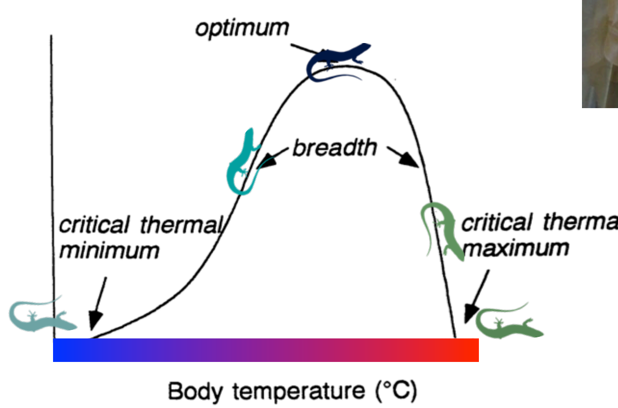


How can we incorporate remote sensing products into studies of th mechanisms of species response to climate?

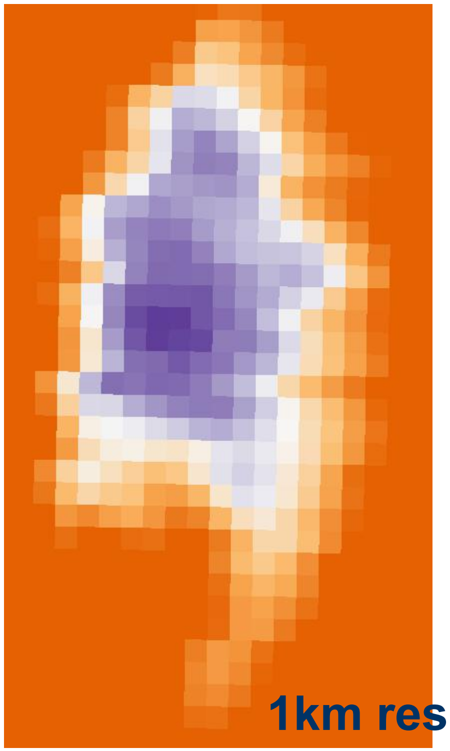
Combining remote-sensing enabled descriptions of microclimates

with

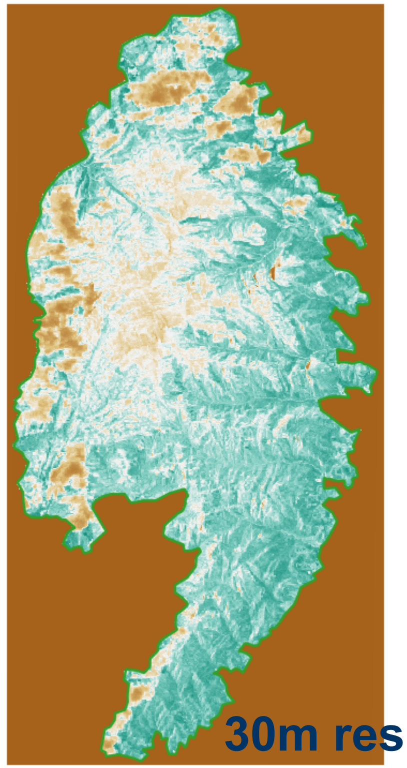
Physiological essays of target species



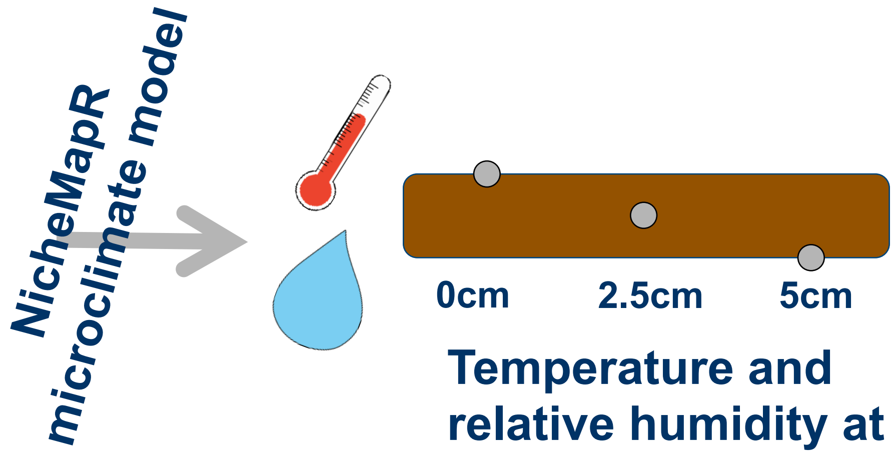
Improving characterization of present-day microenvironments for biodiversity modeling: Estimating microclimatic conditions



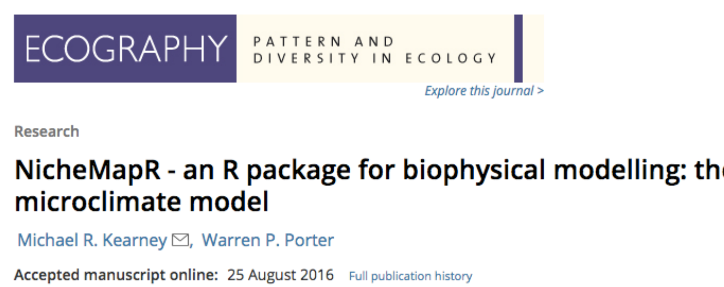
macro-climate: temp, precip, wind speed, solar radiation (New *et al* 2002)



elevation, veg, soil (DEM2; NDVI, soilgrids.org)



Temperature and relative humidity at each substrate depth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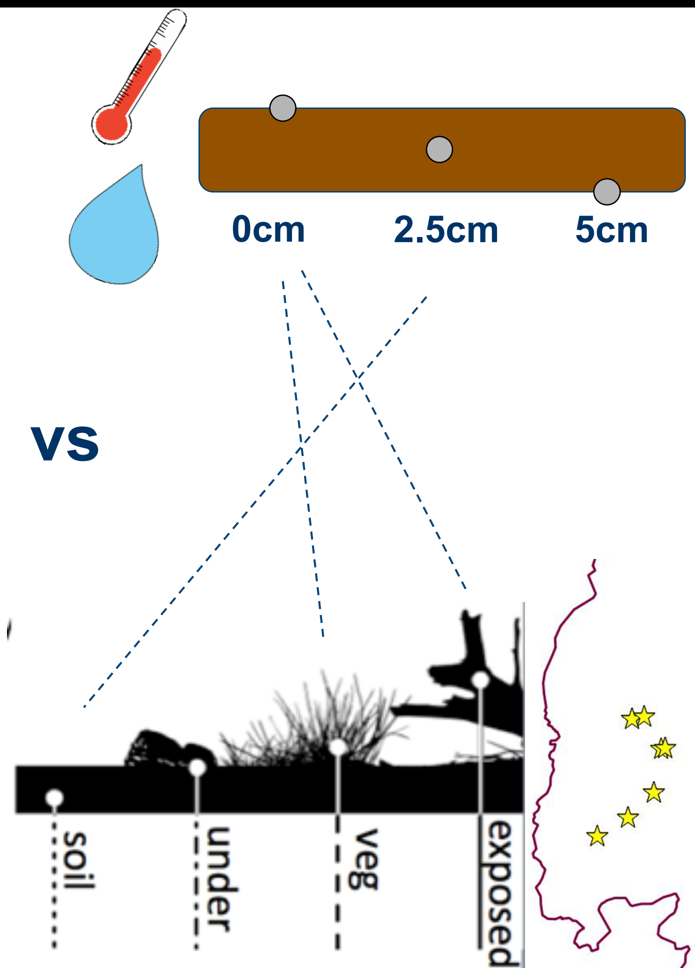
Research

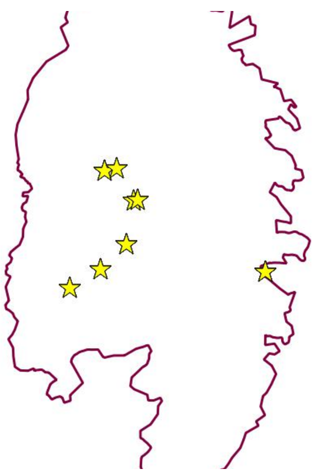
NicheMapR - an R package for biophysical modelling: the microclimate model

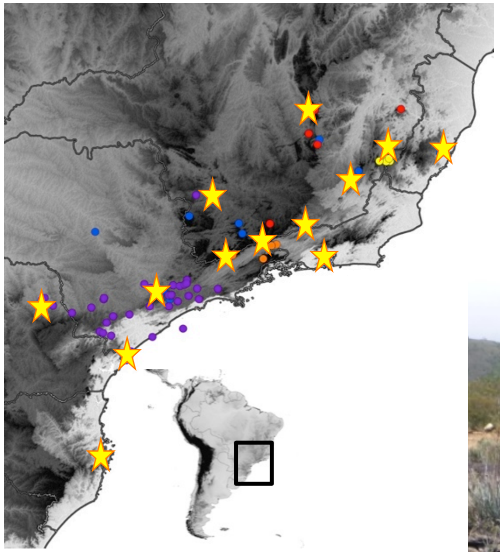
Michael R. Kearney, Warren P. Porter

Accepted manuscript online: 25 August 2016 Full publication history

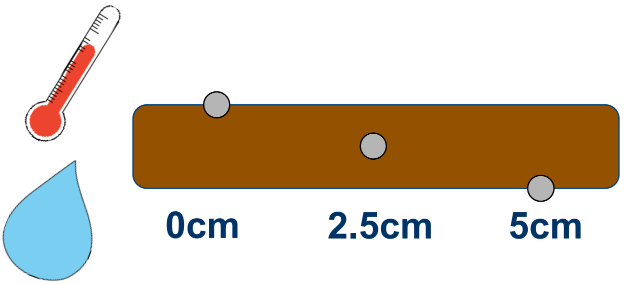
Improving characterization of present-day environments for biodiversity modeling: Validating with iButton data

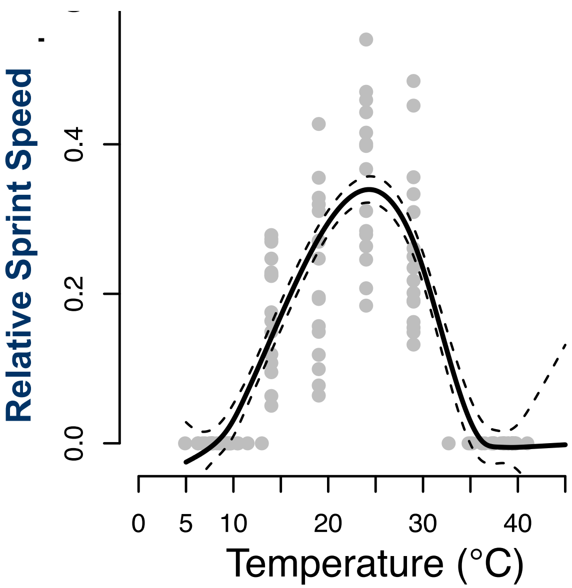




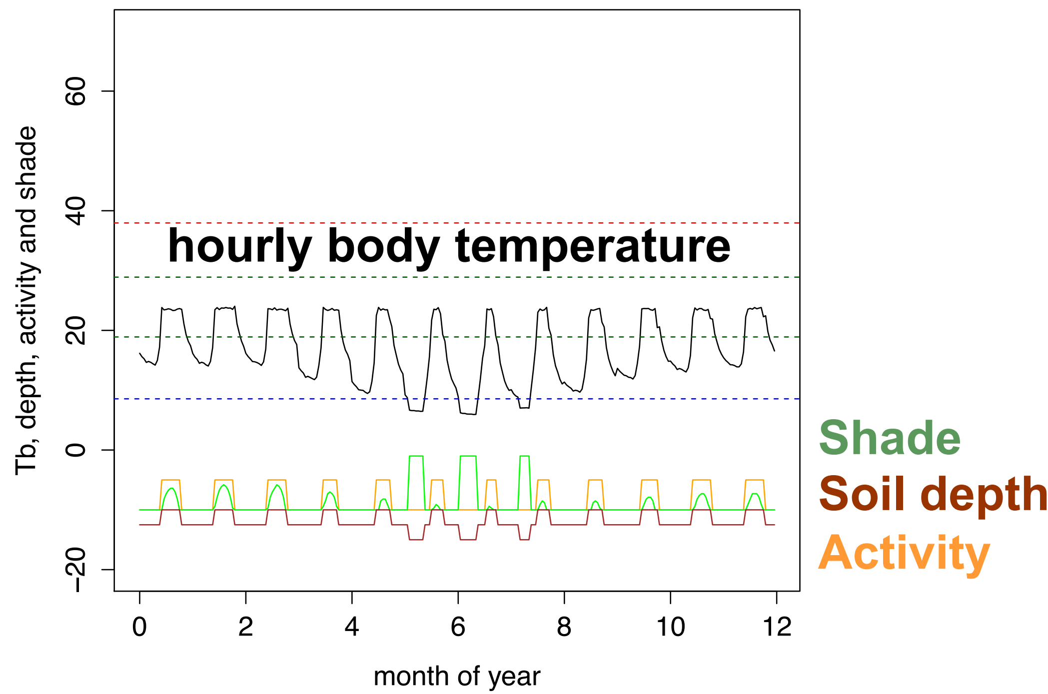


Improving characterization of present-day microenvironments for biodiversity modeling: Bringing physiology to model body temperature

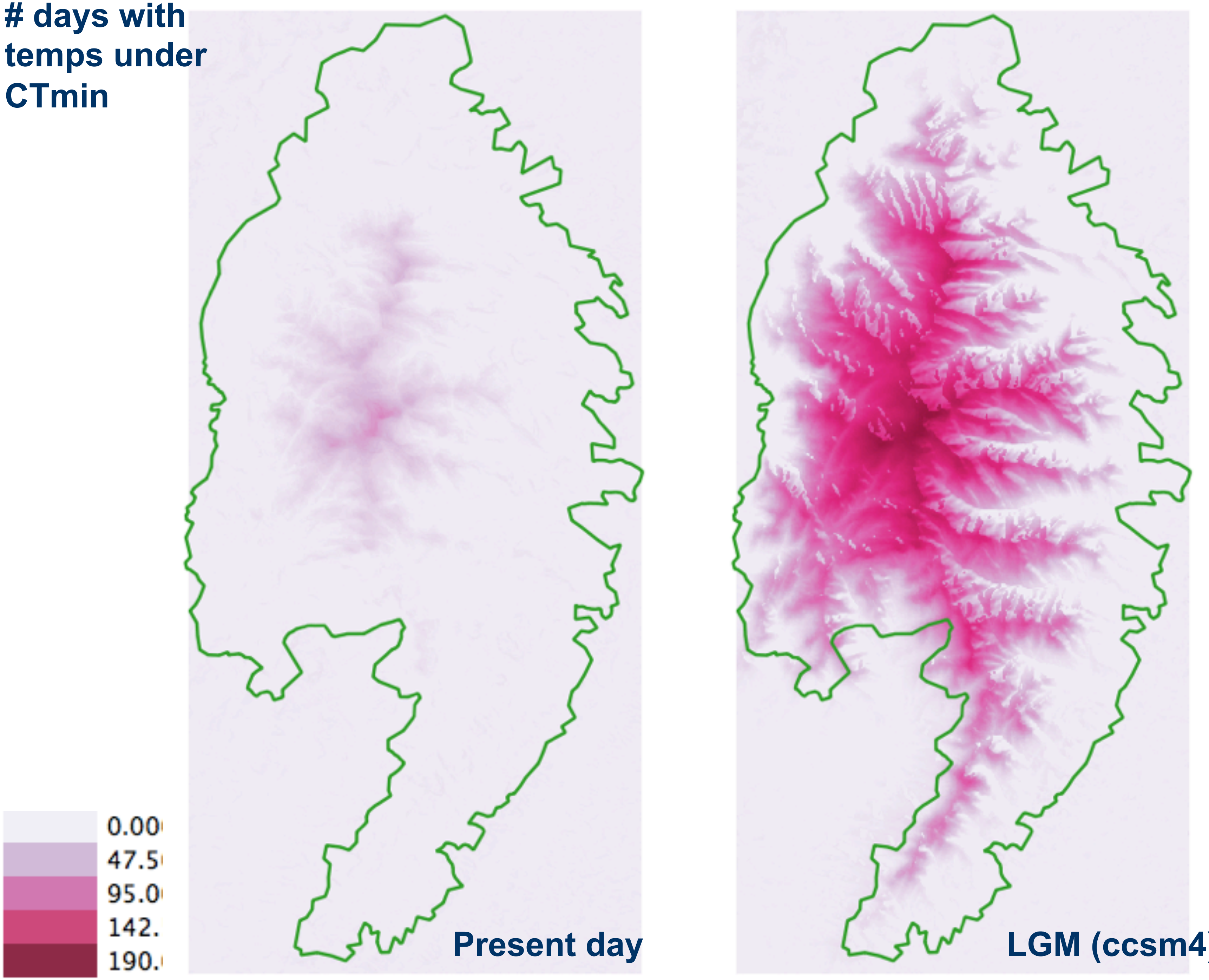




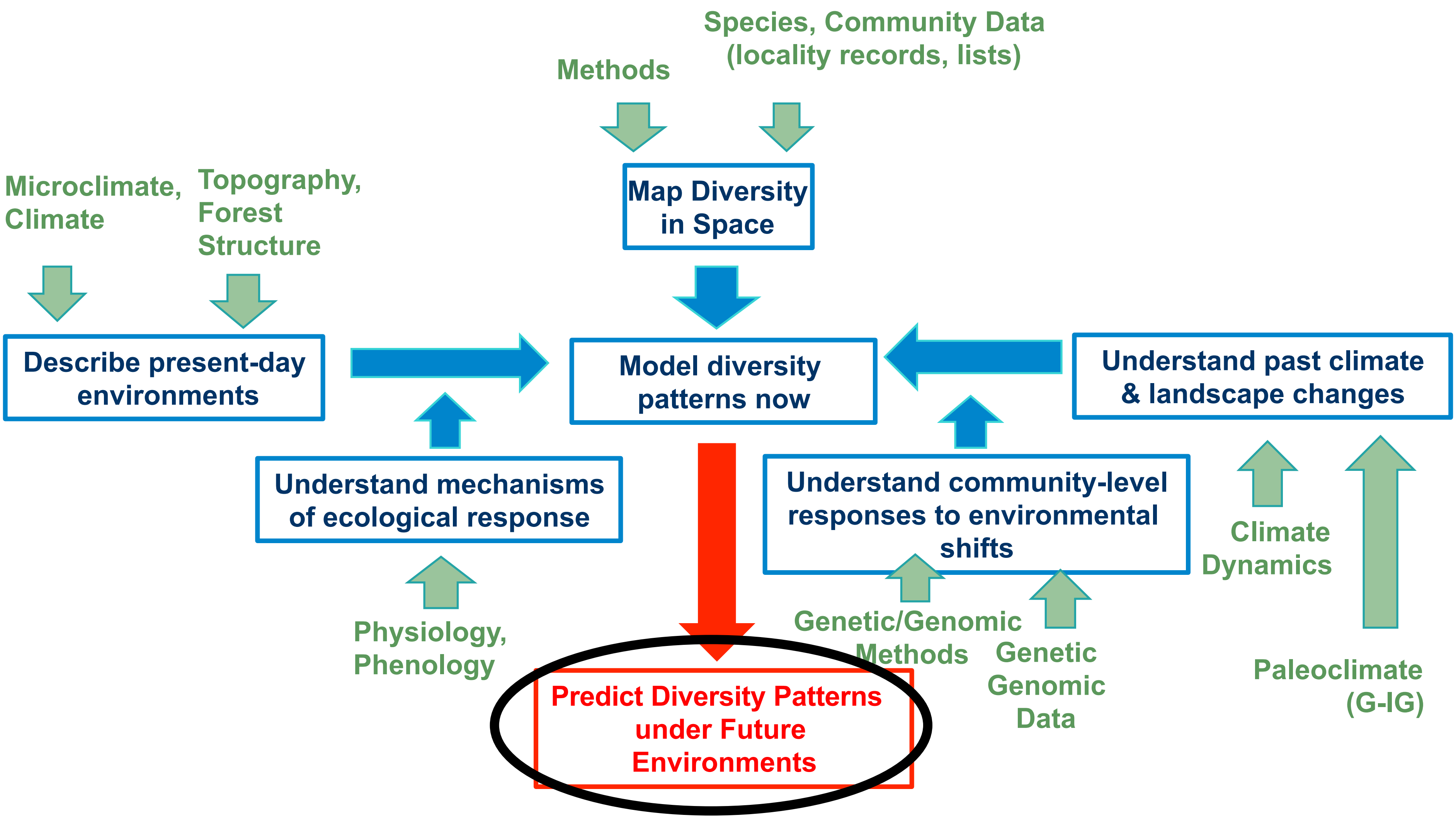
NicheMapR ectotherm model



days with temps under CTmin

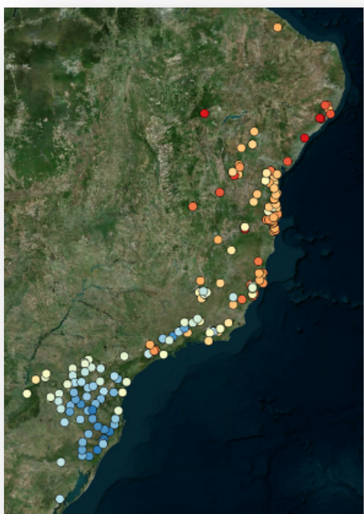


New Direction

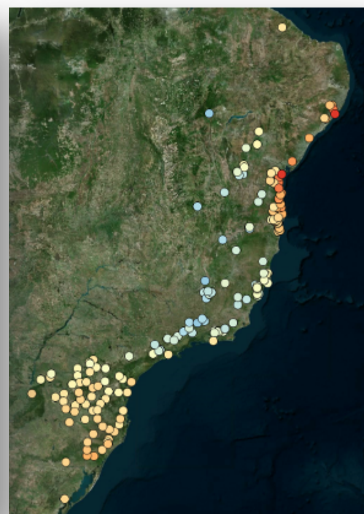


PCA CHIRPS + MODIS LST
across species with genomic-level data

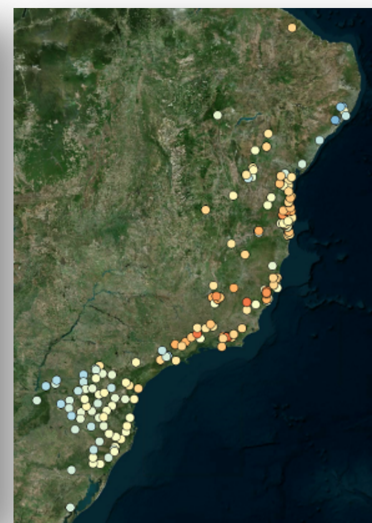
PC1



PC2



PC3



Birds
Myiothlypis leucoblephara
Myrmoderus sp.
Pyriglena sp.

Lizards,
Anolis ortonii
Anolis punctatus
Enyalius sp.
Leposoma sp.
Polychrus marmoratus

Plants
Araucaria angustifolia
Leandra sp.

New Bioclims - MERRA

- Used time-averaged hourly MERRA single-level temperature at 2 m above the displacement height.

- Created monthly maximum and minimum temperatures, which we converted to four bioclimatic temperature fields matching those available through WorldClim.

- Reanalysis of temperature provided at the native spatial resolution of MERRA. Using ancillary information on elevation and geopotential height from the Global Land One-km Base Elevation Project (GLOBE) and MERRA, the native resolution temperature fields from MERRA were downscaled to match the 1km spatial resolution of GLOBE using cubic convolution interpolation

- Used MERRA data from its inception in 1979 to 2000 to focus on the overlap with the existing WorldClim data set, which employed weather station data primarily from 1960 to 2000.

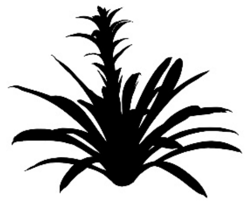
New Bioclims – AMSR-E

- Near-daily temperature minima and maxima obtained by inversion of a simplified semi-physical radiometric model that uses morning and evening brightness temperature observations. The temperature dataset provides global temperature retrievals over land for snow and ice-free non-frozen conditions for periods of no precipitation.
- Descending (morning) and ascending (evening) orbital nodes from AMSR-E's temperature retrieval provide respective minima and maxima for temperature at approximately 2 m height (Jones et al. 2010).
- We used the temperature observation from the morning and evening satellite overpasses, converted these temperatures to average monthly values, and then derived the four bioclimatic temperature fields.
- The grid resolution of the AMSR-E temperature fields is approximately 25 km; we downscaled the fields to 1 Km using cubic convolution interpolation. Downscaling followed that of the MERRA data set, except that the geopotential height was replaced by the 25-km EASE grid GLOBE DEM.
- Data generated from the 2003–2010 AMSR-E observation period.

Methods : Included groups

Tanagers

22 spp.
(CytB, Nd2, C0I, FGBI5, MBI2, Rag1)
8917 points



Bromeliaceae

Wittmackia clade 24 spp.
(ETS, g3pdh, rpb2, matk, rps, trn)
228 points

Melastomataceae

5 clades 184 spp.
25737 points

Butterflies

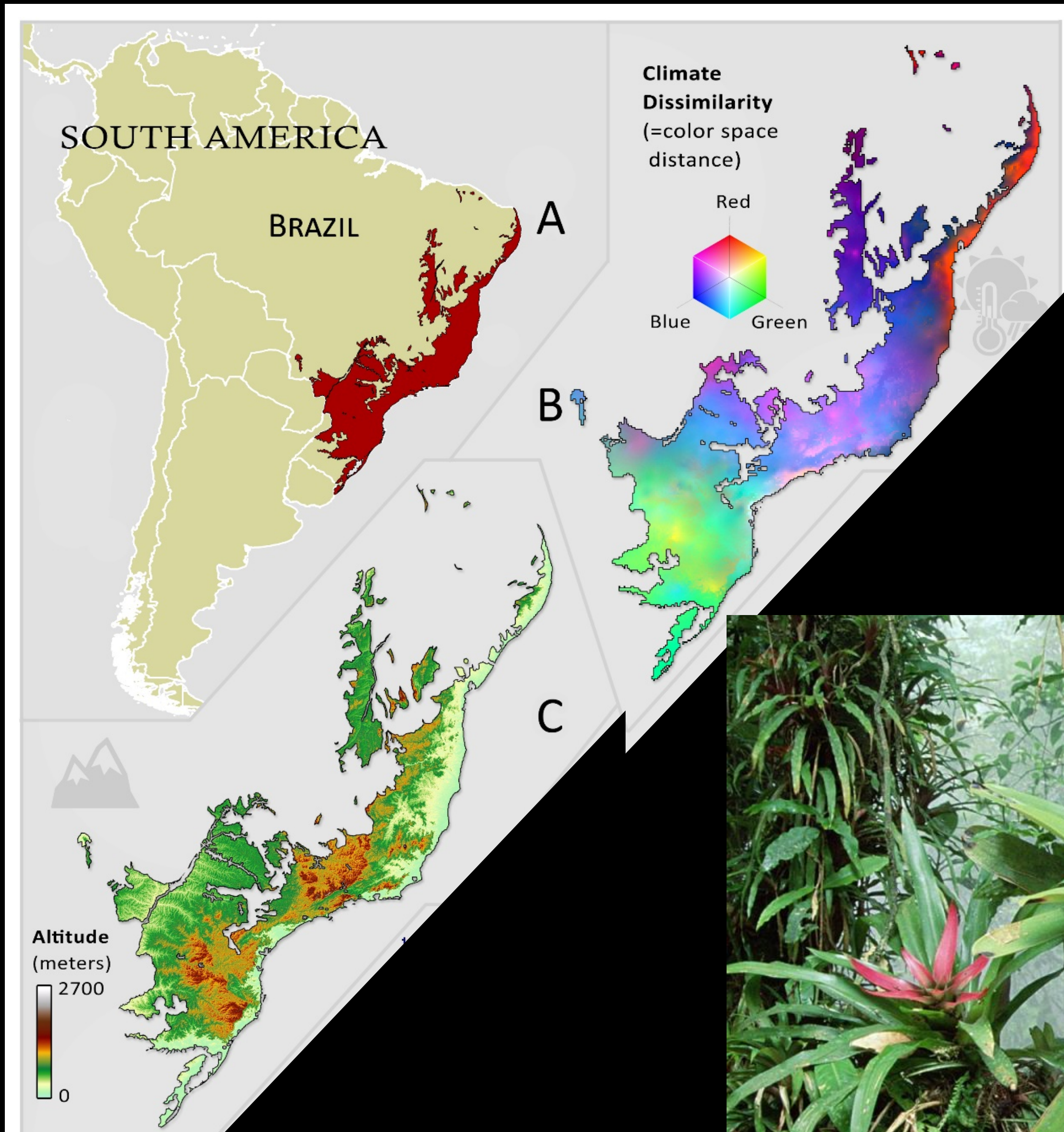
Ithomiini 8 spp.
(COI and CO2)
3269 points

Hypsiboas

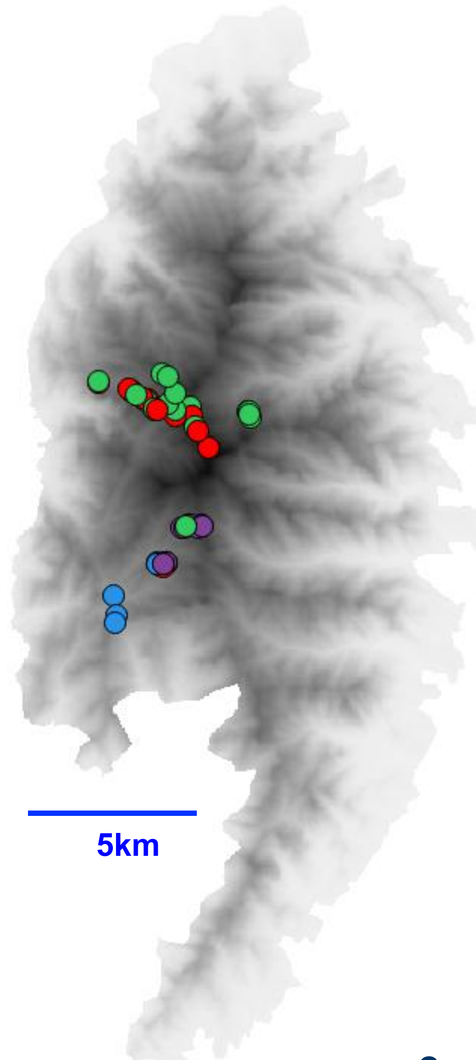
18 spp.
(COI and 16S)
227 points

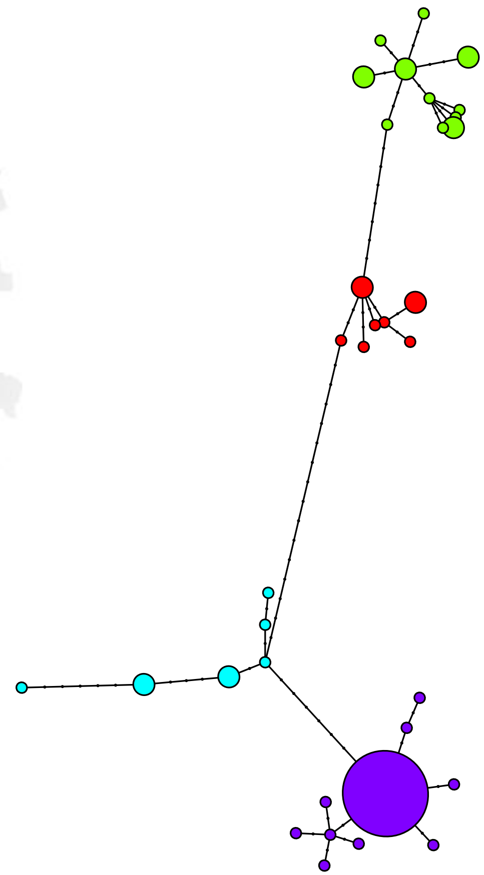
Proceratophrys

20 spp.
(COI and 16S)
690 points


SOUTH AMERICA
BRAZIL
A
Climate
Dissimilarity
(=color space
distance)
Red
Blue
Green
B
C
Altitude
(meters)
2700
0

How can we incorporate remote sensing products into studies of th mechanisms of species response to climate?

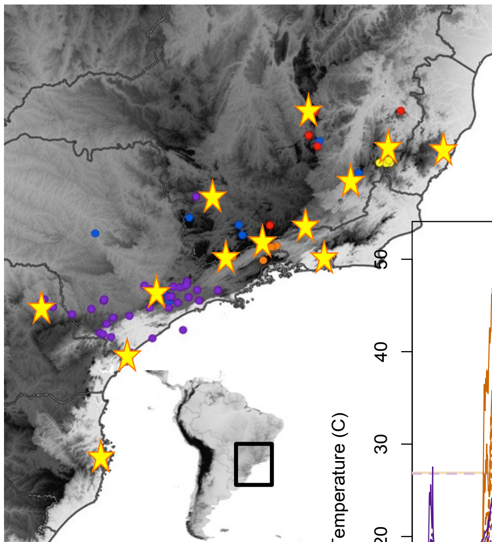


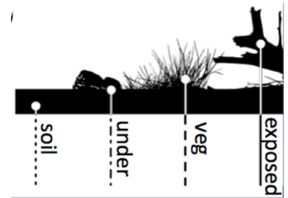


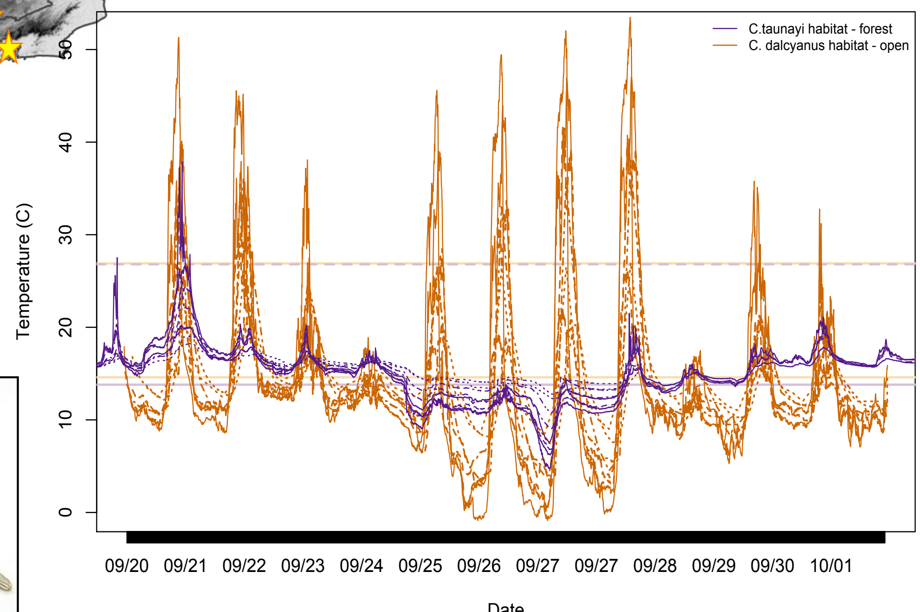
3 mtDNA genes, 50 individuals.
4.3% div in ND4 marker across <10km,
now 30k SNPs

Improving characterization of present-day microenvironments for biodiversity modeling

Characterizing microclimates with hygrobuttons is ideal – but not feasible for large spatial scales







Precise measurements, limited coverage