The Assembly and Evolution of the Amazonian Biota and its Environment

Dimensions of Biodiversity US-BIOTA-São Paulo

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www.amazoniabiodiversity.org
Scientific challenges and goals

- How is genetic, taxonomic, and ecological diversity distributed within Amazonia?
- What has been the evolutionary history of the Amazonian biota and how was it generated?
- What has been the history of the Amazonian aquatic and terrestrial environments?
- How has the Amazonian environment and its biota evolved together, and what have been the global effects of this evolutionary-ecological system over time?

Requires a new integrated approach
NSF-NASA-FAPESP project: broad-scale collaboration

**Brazil**
- Universidade de São Paulo
- Universidade Federal de Goiás
- Universidade Federal do Pará
- Universidade Estadual de Campinas
- Museu Paraense Emílio Goeldi
- Instituto Nacional de Pesquisas da Amazônia

**Argentina**
- CONICET-Instituto Superior de Entomologia, Tucumán

**Great Britain**
- University of Edinburgh

**Canada**
- University of Toronto
- City University New York
- Field Museum of Natural History
- Middle Tennessee State University
- Natural History Museum Los Angeles County
- New York Botanical Garden
- University of Michigan
- University of Colorado

**United States**
- American Museum of Natural History
- University of Michigan
- University of Colorado
Integration across disciplines

Systematics

Paleogeography
Tectonics
Geochronology
Remote sensing

Historical biogeography
Phylogeography

Population genetics

Paleoclimatology
Palynology
Paleoclimate modeling

Landscape ecology
Ecosystem function/biogeochemical flows

Amazonian History
Seasonal Maximum/Minimum Inundation from ALOS PALSAR ScanSAR

Chapman et al, 2015
**Synthetic Aperture Radar (SAR)**

- Sensor spectral **frequency** determines the surface and volume scattering contributions from the vegetation canopy and the ability to detect standing water at the surface.

**Scattering of Radar Energy**

**Flooded Vegetation VS. Non-flooded Vegetation**

- **C-band:**
  - ~6cm, 4-8GHz

- **L-band:**
  - ~23cm, 1-2GHz

[Bourgeau-Chavez et al., 2016](#)
Synthetic Aperture Radar (SAR)

- The different interactions of microwave data (PALSAR) with surface water compared to vegetation enable improved discrimination of inundated areas.

- Comparing images from multiple dates (multi-temporal) improves understanding of hydrology and helps to distinguish wetlands and wetland types.

- False color composite of multi-temporal and multi-polarized observations from ALOS PALSAR of a region of the Peruvian Amazon Basin near the Marañón River.

- Color variation is mostly driven by differences in hydrologic condition. The areas in brighter colors are sloping portions of a peat dome.
PALSAR 2 ScanSAR Coverage

Cycle_085 | 9-Oct-17 | - | 22-Oct-17
PALSAR 2 ScanSAR Coverage
PALSAR 2 ScanSAR Coverage
PALSAR 2 ScanSAR Coverage
Sentinel-1 A/B C-band SAR coverage
Pacaya-Samiria National Reserve, Peru

- Most extensive tropical flooded forest in the Peruvian Amazon
- Spans area of more than 20,000 km²
- Hosts rich biodiversity
- Home to variety of wetland types, primarily palm swamp

![Image of Pacaya-Samiria National Reserve]
ALOS2 PALSAR-2 Dual Pol ScanSAR Mosaics  

**R**: HH,  
**G**: HV,  
**B**: HH-HV

**End of Wet Season - May 2015**  
Cycle022

**End of Dry Season – Nov 2015**  
Cycle062
Multi-temporal Statistics from 20 ALOS-2 ScanSAR ensembles (Nov 2014 – Feb 2017)
Multi-temporal Statistics

- Calculated from 20 ALOS-2 ScanSAR scenes (Cycles #010 – #068; Nov 2014 – Feb 2017)

**Mean Polarization Ratio HH/HV**

**HH** more sensitive to seasonal changes inundated vegetation

**HV** useful in discriminating vegetation structure - seasonally flooded low vegetation (grasses, etc)

**Polarization Ratio (HH/HV)** potentially helpful at discriminating flooded vs. non-flooded vegetation
Multi-temporal Statistics, calculated from observations made in Jan 2015 – Dec 2017

HH Mean [PALSAR-2, L-band]

VV Mean [Sentinel-1, C-band]

HH Stdev [PALSAR-2, L-band]

VV Stdev [Sentinel-1, C-band]
Classification: Pacaya Samiria

Delineating Open Water + Flooded Low Vegetation (Permanent & Seasonal)

- **Mean HV (dB):**
  - Permanent Open Water: \(-16.5\) to \(-19.2\)
  - Intermittent Open Water / Small Tributaries: \(-16.5\) to \(-19.2\)
  - Low Vegetation Never or Rarely Flooded: \(-19.2\) to \(-22\)
  - Low Vegetation Seasonally Flooded: \(-22\) to \(-24.5\)

- **Standard Deviation HV (dB):**
  - Permanent Flooded Vegetation: \(-4.2\) to \(-6.5\)
  - Seasonally Flooded Vegetation: \(-4.2\) to \(-6.5\)
  - Rarely/Never Flooded Vegetation: \(-6.5\) to \(-9\)

*Elevation > 150m masked out*
Land Cover Classification Based on Multi-temporal PALSAR 2
Pacaya Samiria National Reserve, Peru

Regions where Height Above Nearest Drainage (HAND) index > 20m masked out in white
PALSAR Backscatter Statistics

Central Amazon
PALSAR Backscatter Statistics: Central Amazon

HH Mean

HH St Dev

HH Max – Min:
Dynamic Range in dB
Dark Blue: Open water
Light Blue: Inundated Forest
Green: Never Flooded Forest/Vegetation
Yellow: Balbina Dam region
Maroon: Seasonally submerged forest
Black: Masked areas

PALSAR Classification:
Central Amazon
PALSAR Classification:
Rio Branco Region

Dark Blue: Open water
Light Blue: Inundated Forest
Green: Never Flooded Forest/Vegetation
Yellow: Balbina Dam region
Maroon: Seasonally submerged forest
Black: Masked areas
White-sand avifauna

What can we learn about Amazonia landscape history?

Map from Vicentini 2007
## Bioclimatic Envelopes

Source, layer of representation environmental (Layer), spatial resolution (Resolution) and attribute type (Attribute) used to map bioclimatic envelopes to Amazon Basin.

<table>
<thead>
<tr>
<th>Source</th>
<th>Layer</th>
<th>Resolution</th>
<th>Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRTM (Shuttle Radar Topography Mission)</td>
<td>Elevation</td>
<td>90 m</td>
<td>Abiotic</td>
</tr>
<tr>
<td>SRTM (Shuttle Radar Topography Mission)</td>
<td>Slope</td>
<td>90 m</td>
<td>Abiotic</td>
</tr>
<tr>
<td>SRTM (Shuttle Radar Topography Mission)</td>
<td>Aspect</td>
<td>90 m</td>
<td>Abiotic</td>
</tr>
<tr>
<td>CHIRPS (Climate Hazards group InfraRed Precipitation with Station data)</td>
<td>Maximum precipitation</td>
<td>5,5 km</td>
<td>Abiotic</td>
</tr>
<tr>
<td>CHIRPS (Climate Hazards group InfraRed Precipitation with Station data)</td>
<td>Minimum precipitation</td>
<td>5,5 km</td>
<td>Abiotic</td>
</tr>
<tr>
<td>PALSAR (Phased Array type L band Synthetic Aperture Radar)</td>
<td>HH polarization</td>
<td>100 m</td>
<td>Abiotic/Biotic</td>
</tr>
<tr>
<td>MODIS (Moderate Resolution Imaging Spectroradiometer)</td>
<td>NDVI</td>
<td>250 m</td>
<td>Biotic</td>
</tr>
<tr>
<td>Avitabile et al., 2016</td>
<td>Canopy height</td>
<td>1km</td>
<td>Biotic</td>
</tr>
<tr>
<td>MODIS (Moderate Resolution Imaging Spectroradiometer)</td>
<td>Isothermality</td>
<td>1km</td>
<td>Abiotic</td>
</tr>
</tbody>
</table>
Final map of the distribution from bioclimatic envelopes in the Amazon basin with 14 classes.
Downscaled 1km AMSRE Land Surface Temperature

AMSRE LST DAY Jan. 01-02, 2003

1 km Resolution
AMSR-E 1km LST Seasonal Climatological Summary Statistics

June-July-Aug Day Mean Temperature
Dec-Jan-Feb Day Max Temperature
June-July-Aug Day St. Dev. of Temperature
Climatology Analysis over Amazon Tree Diversity Network Sites

WoldClim Temperature

CHIRPS precipitation data.
Tracking Flowering Events in the Amazon Rain Forest, A Remote Sensing Approach

Spectra of the Leaves

Spectra of the flowers
Hypothesized paleoriver postulated by phylogenetic analysis later verified by remote sensing.

Postulated paleoriver vicariance event at ~1.2 myr between *Psophia napensis* and its sister-group (*P. ochoptera* + *P. crepitans*)

Reconstructing the history of the Amazonian biota and environment

Portions of this work were carried out within the framework of the JAXA Kyoto and Carbon Initiative. ALOS PALSAR and PALSAR2 data were provided by JAXA EORC.