What are the origins of the great biodiversity of the neotropical forests?
Climate and paleoclimate, tectonics, geomorphology, evolutionary biology, ecology, earth system modelers
Geologic History and Speciation: Creation of New Habitat, Barriers, Corridors

Mountain Uplift

Climate Variability

Soil Heterogeneity

Riverine Barriers
Poorly constrained aspects of the evolution of tropical South America:

- Timing of uplift of the Andes in different parts of range (N-S, E vs W)
- How did trans-continental drainage of Amazon River develop through time?
- Presence and extent of any marine incursions or mega-wetlands (Pebas)
- Climate history
- History of forest composition and diversity
- What is the timing of uplift of different parts of the Andean range from N to S?
- When did the Western Cordillera attain sufficient elevation to generate high-elevation topography?
Uplift History of the Eastern Cordillera of Andes

Kar et al., EPSL, 2016
Biogeography, Phylogeography, Geogenomics

Baker, Fritz et al, 2014
“Geo-genomics” – combining molecular genetics and geology to examine diversification

1. Hypothesis/sampling
2. Data generation
3. Alignment
4. Phylogenetic tree
5. Hypothesis testing

Testing geologic hypotheses with genetic data: Use divergence time of populations to constrain the age of the barrier

Baker, Fritz et al. 2014
Constraining the age of high-elevation habitat

*Diplostephium* – South American divergence 10.17 Ma

Diplostephium

A: 6.5 Ma
B: 7.3 Ma

Vargas et al. 2017
Andes-Amazon NASA-funded Team

Sheri Fritz – paleoclimate, limnology
Greg Asner – remote sensing
Paul Baker – geology
David Battisti – climate dynamics
Chris Dick – evolutionary biology
Robin Martin – biogeochemistry

Ivan Pirates – evolutionary biology
Oscar Vargas – evolutionary biology
Alex Wheatley – geology
Xavier Benito – limnology
(1) Beyond Refugia – emerging paradigms of climate variation in the Quaternary

(2) Modeling mountain uplift, habitat variation, and speciation through geologic time and across space in a complex terrain

(3) Fine-scale spatial variation in climate, topography, substrates and implications for biotic distributions and speciation
Haffer’s presumed (warm) dry forest refugia during NH ice ages
Amazon – no pollen evidence of rainforest contraction during glacial periods BUT only a few short records

Lake Pata, Brazil

Colinvaux et al. 1996
Beyond Refugia: Climate Heterogeneity on Orbital Scales (22ka)

Dipole: western versus eastern Amazon -

Cheng et al. 2013
Modeling reproduces E-W Dipole on orbital (22K) time scales

Difference in precip weighted $\delta^{18}O_p$
Prediction: Rainforest connections

Wet west (C) leads to connection of Atlantic forest and Amazon forest to the south; wet east (B) leads to a connection to the east

[Image: Maps showing forest connections]
Beyond Refugia: Heinrich Events
Ice-rafted debris in N Atlantic

Dipole: western versus eastern Amazon -

E Amazon
W Amazon

Wet E Amazon
Dry W Amazon

Cheng et al. 2013
Heinrich Events: Short-term (1000-yr) intervals of extremely high precipitation in all of tropical SA ~16,000 years ago
Glacial times – Heinrich events (ice-rafted debris)

Wet throughout South American SH tropics

Today

~16 ka

A) Contemporary

B) > 3700 masl

C) > 3760 masl

Nunnery, Fritz et al. 2018
Beyond Refugia – Quaternary Climate Variation

- Spatial variability in precipitation on orbital scales – E to W anti-phasing across tropical South America
- Wet Heinrich events throughout SH tropics of South America
- Massive hydrologic variation on multiple time scales
- Biotic impacts largely unknown
Trans-Amazon Drilling Project (TADP)

ICDP-IODP

PIs: Paul Baker, Sheri Fritz, Cleverson Silva, Andrea Marzoli
>30 scientists from 12 countries in Europe and the Americas
Trans-Amazon Drilling Project

- What is the history of assembly of the tropical forest and its diversity in different parts of the lowland Amazon?
- What is the climate history of the lowland Amazon?
- When did trans-Amazon fluvial drainage begin, and how did it develop?
- How did Andean uplift affect climate, nutrients, and vegetation in the lowlands?