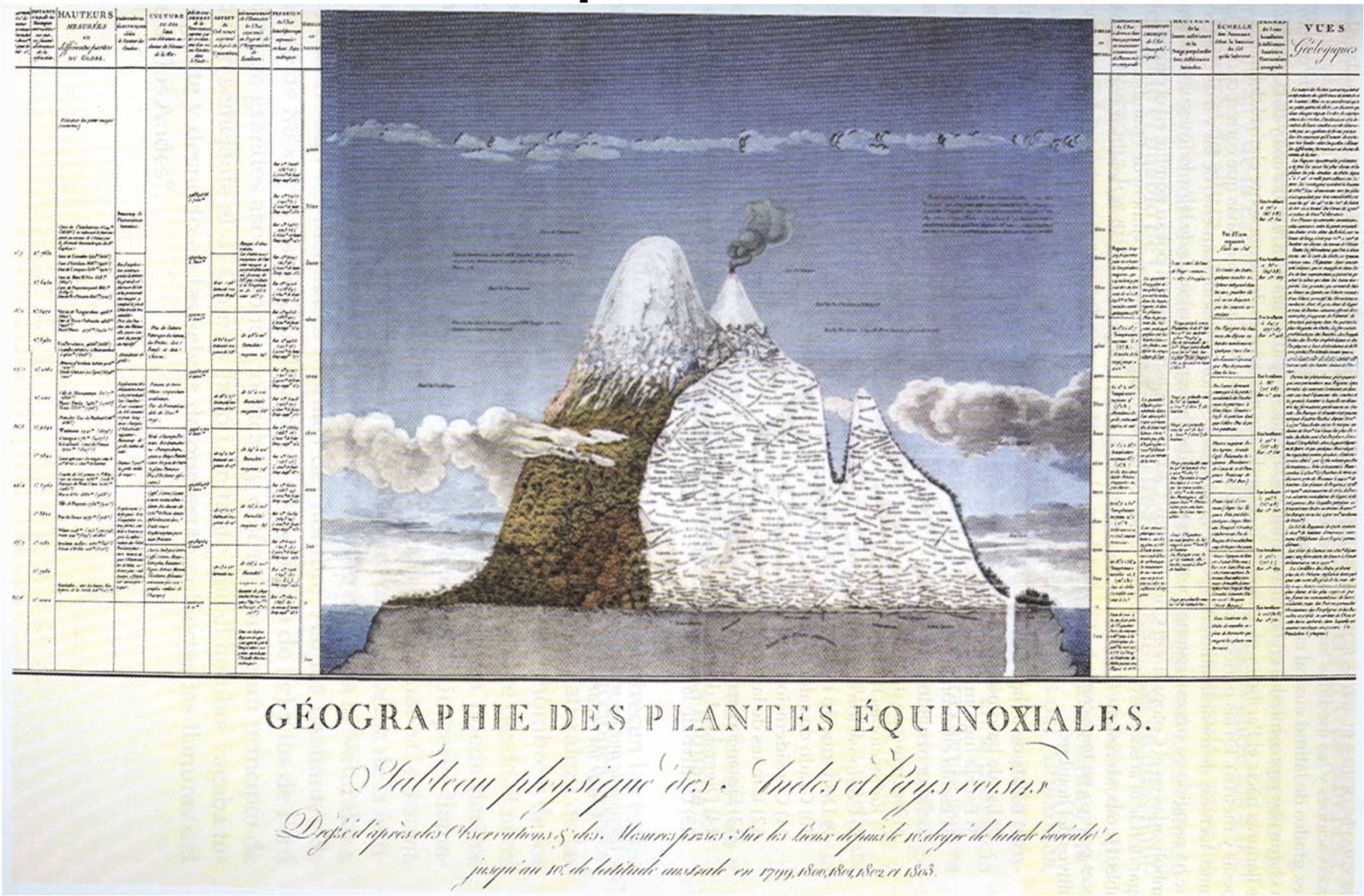
Biotic and Geophysical Diversity Across Time and Space in the Amazon and Andes

Sheri Fritz, University of Nebraska – Lincoln, USA

What are the origins of the great biodiversity of the neotropical forests?



Chimborazo, Ecuador

Von Humboldt 1817

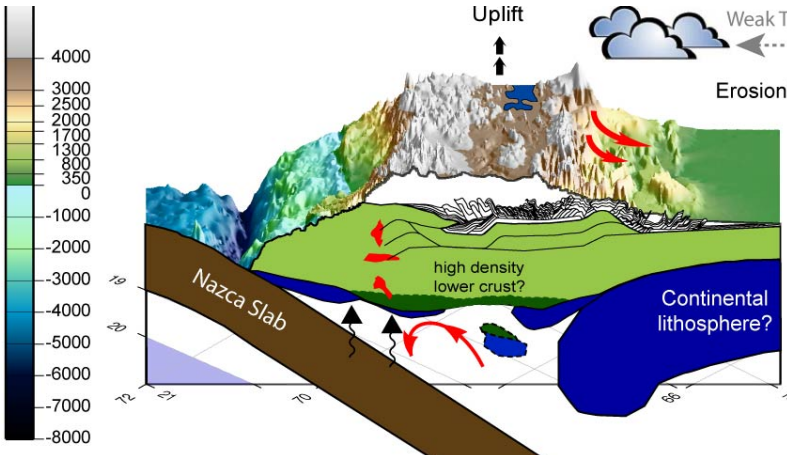
NSF Frontiers in Earth System Dynamics-Andes Amazon GeogenomicsTeam

Paul Baker
Sheri Fritz

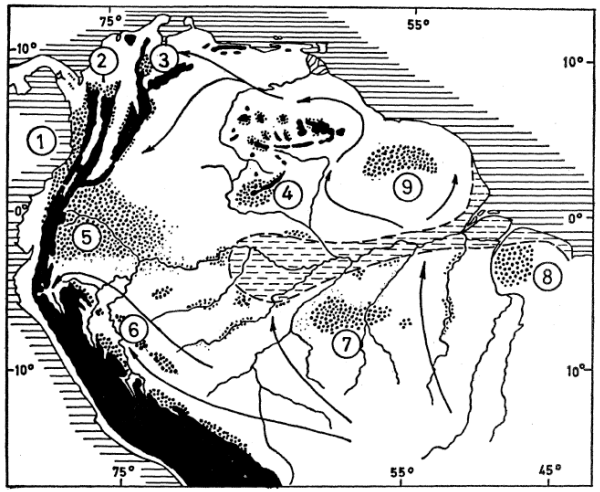
David Battisti
Chris Dick
Carmala Garzione
Brian Horton
Edgardo Latrubesse
Stefano Manzoni
Amilcare Porporato
Camila Ribas
Catherine Rigsby
Miles Silman
Cleverson Silva

Climate and paleoclimate, tectonics, geomorphology, evolutionary biology, ecology, earth system modelers

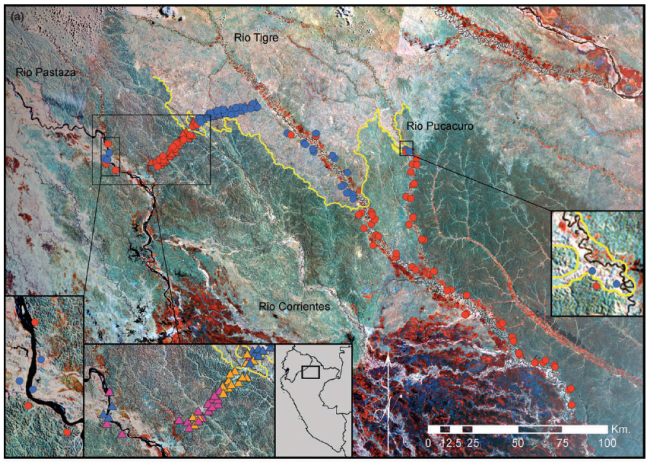
Geologic History and Speciation: Creation of New Habitat, Barriers, Corridors



Mountain Uplift



Climate Variability



Soil Heterogeneity

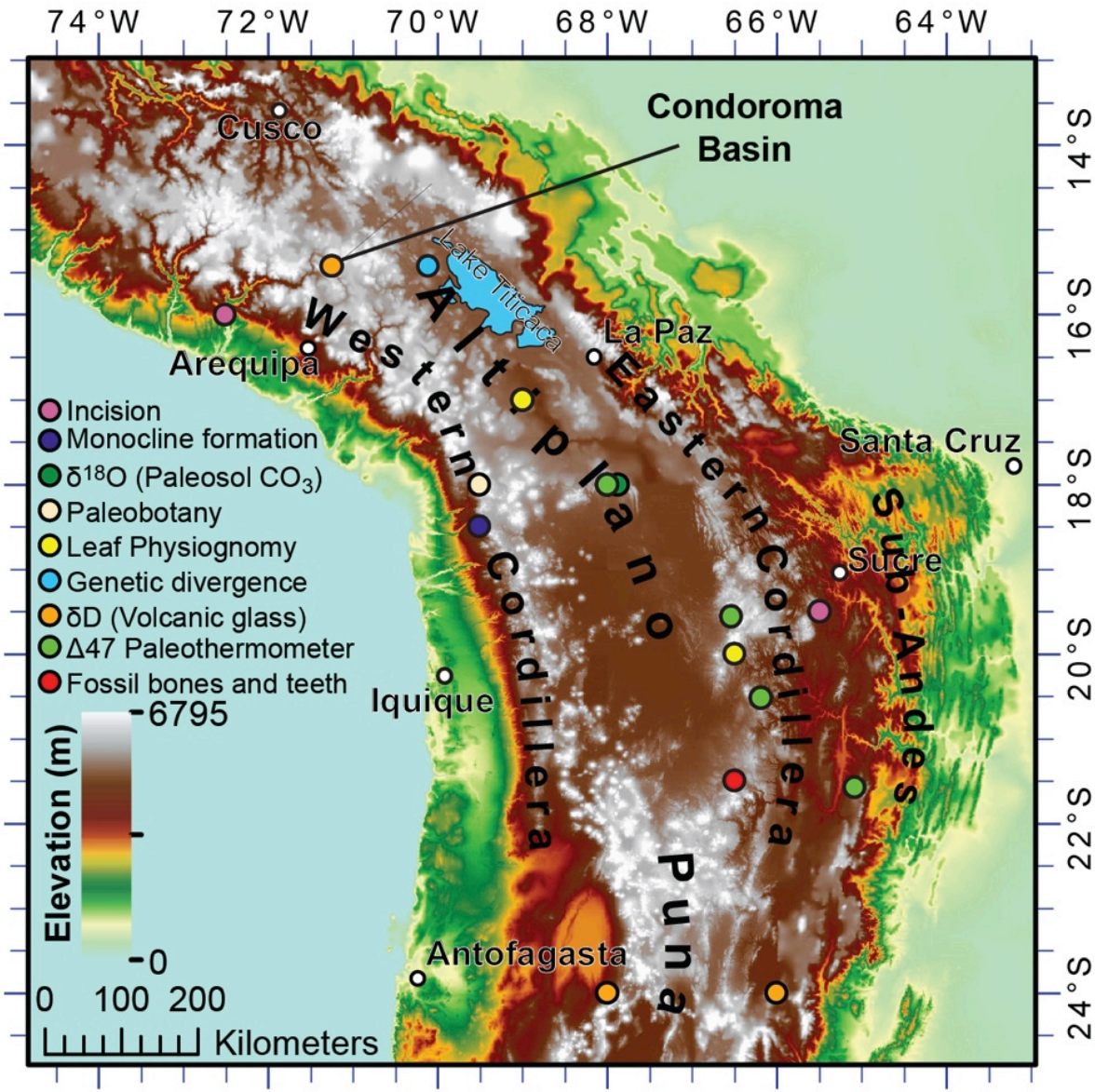
Riverine Barriers

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

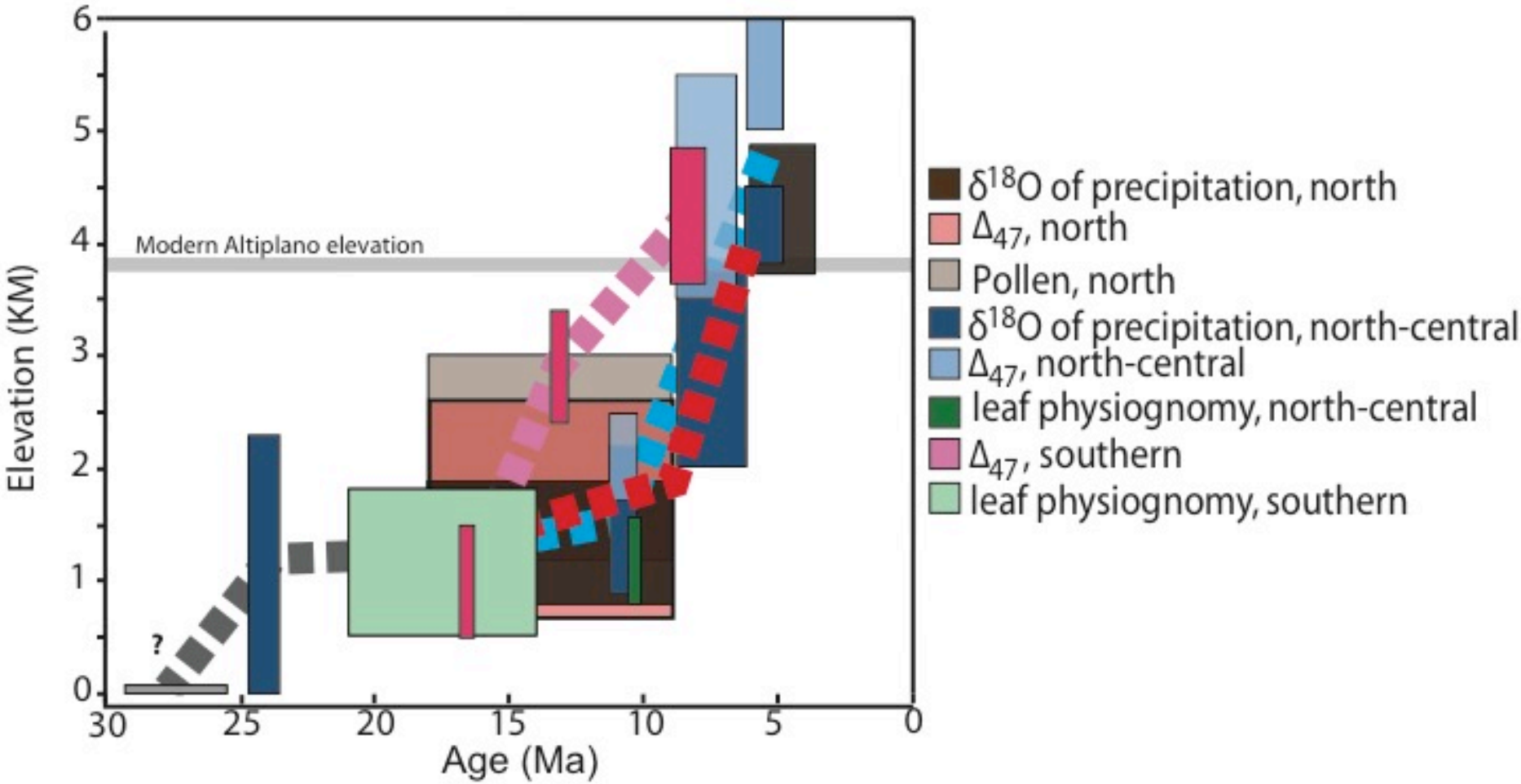
C Hoorn et al. Science 2010;330:927-931

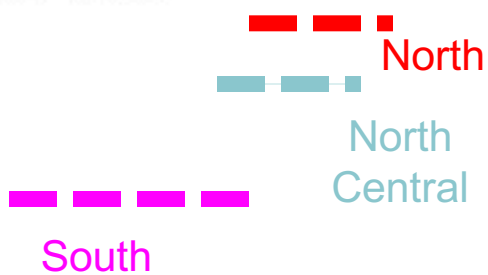
Uplift History



- **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?**

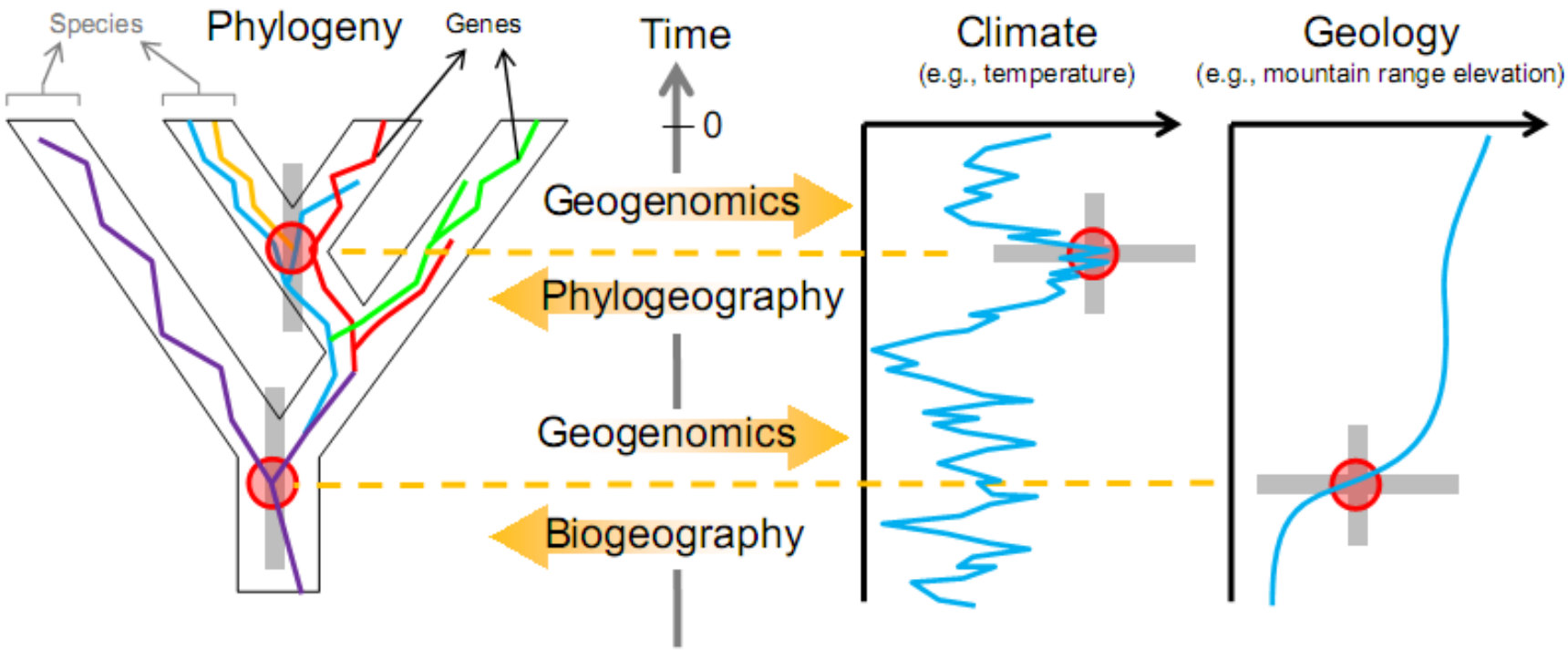
Uplift History of the Eastern Cordillera of Andes





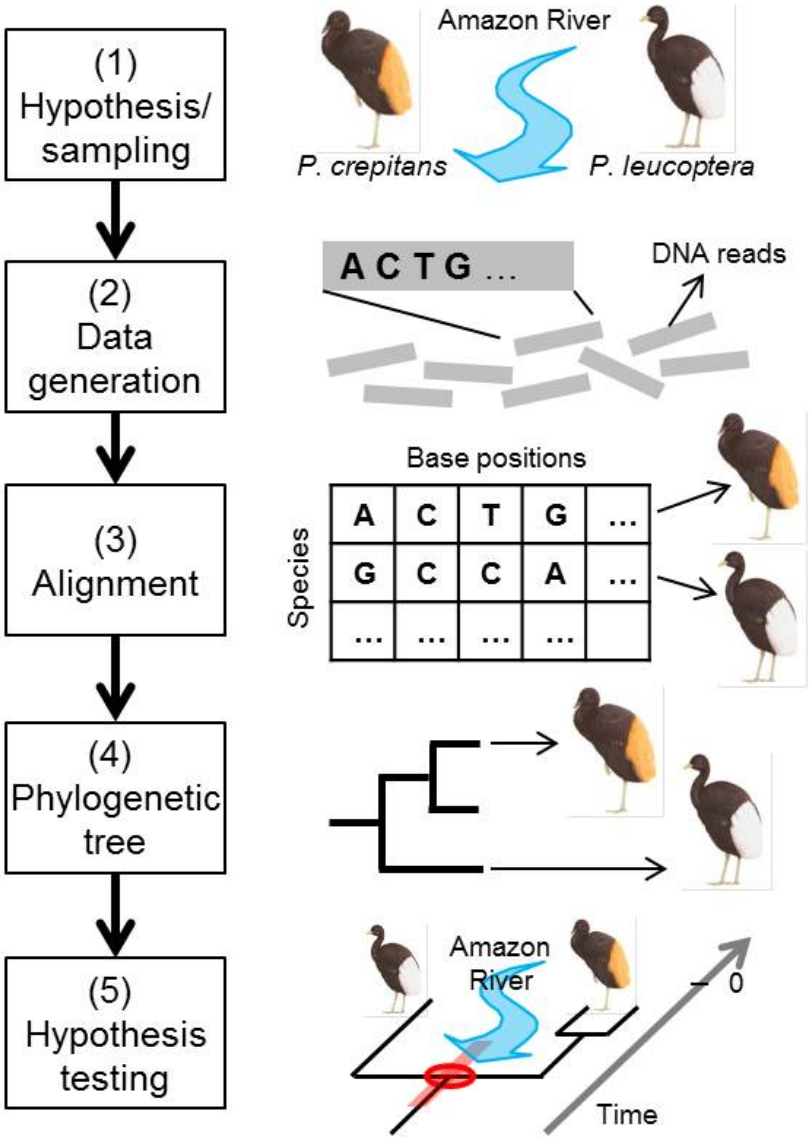
Kar et al., EPSL, 2016

Biogeography, Phylogeography, Geogenomics



Baker, Fritz et al, 2014

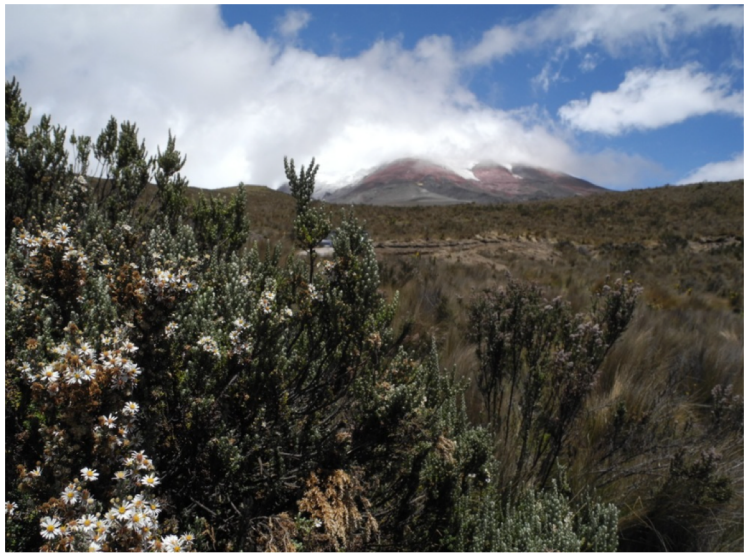
“Geo-genomics” – combining molecular genetics and geology to examine diversification



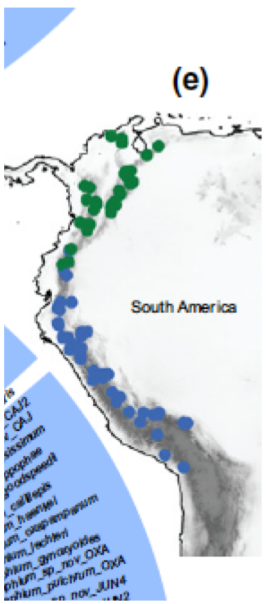
Testing geologic hypotheses with genetic data: Use divergence time of populations to constrain the age of the barrier

Baker, Fritz et al. 2014

Constraining the age of high-elevation habitat

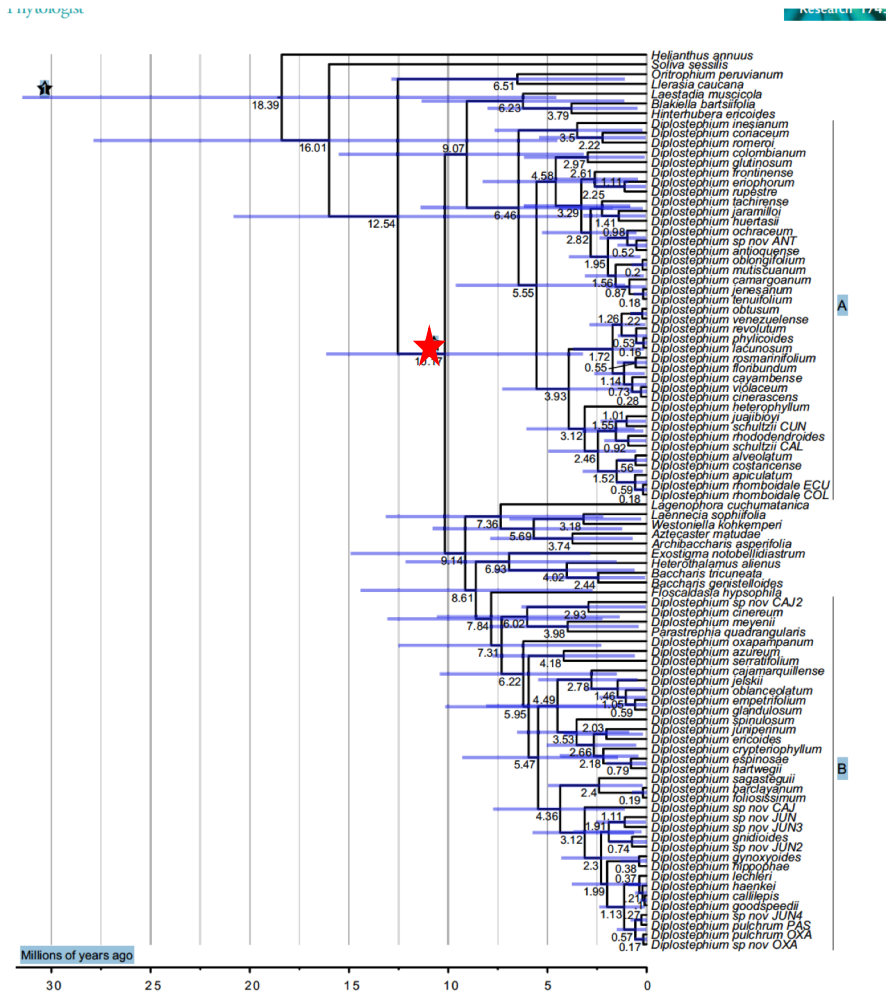


Diplostephium – South American divergence 10.17 Ma



Diplostephium
A: 6.5 Ma
B: 7.3 Ma

Vargas et al. 2017

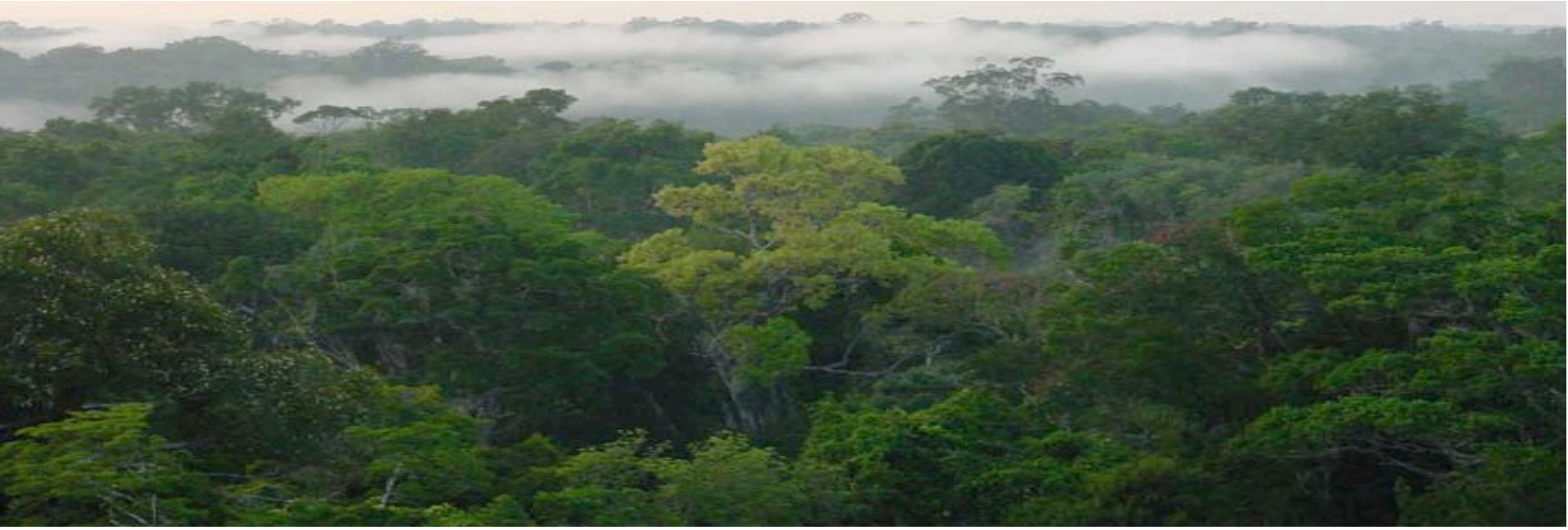


Andes-Amazon NASA-funded Team

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

Research Themes – Amazon Andes Biodiversity Group

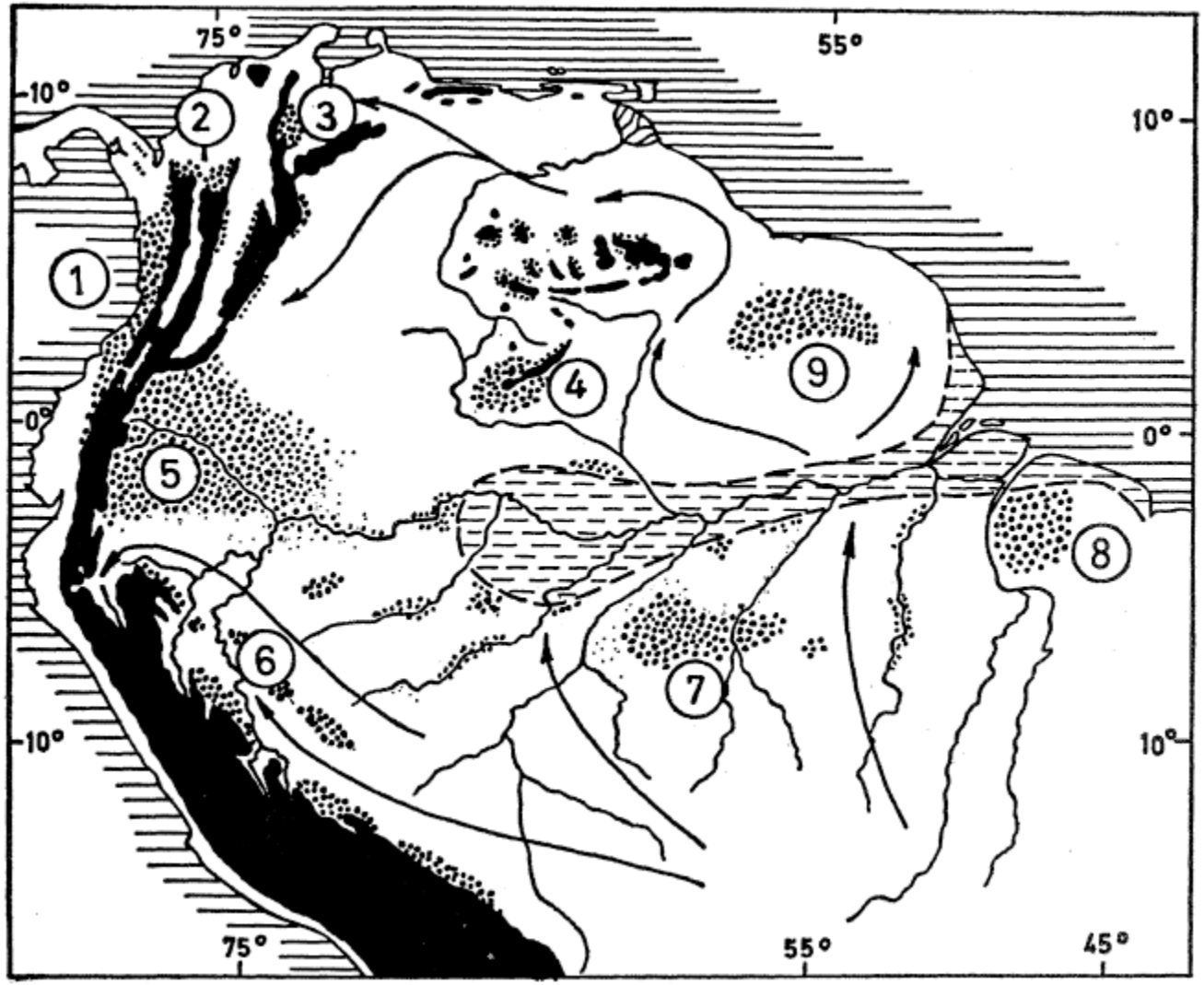


(1) Beyond Refugia – emerging paradigms of climate variation in the Quaternary

(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

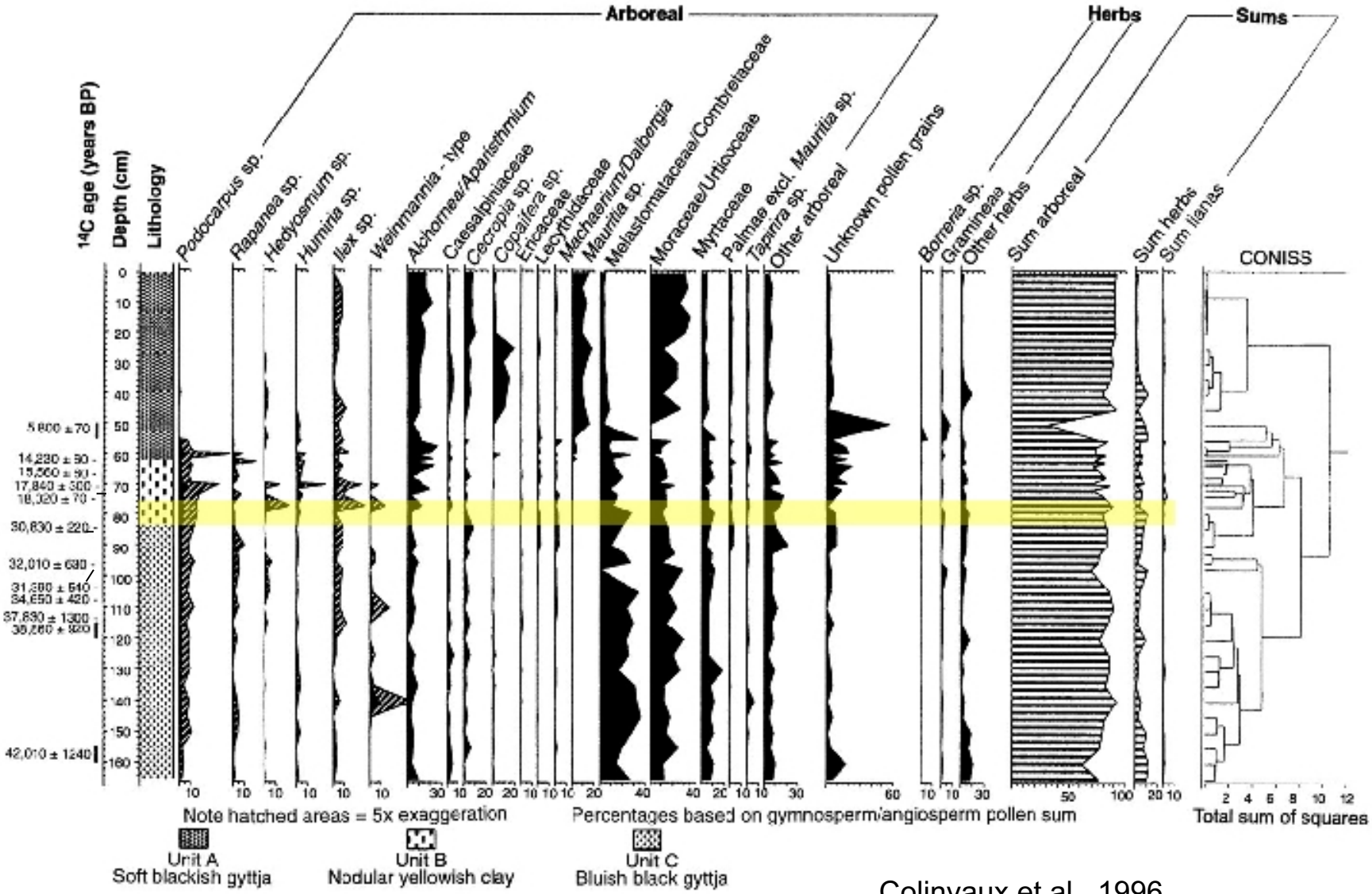
Beyond Refugia –
revisiting climate impacts on species distributions



Haffer's presumed (warm) dry forest refugia during NH ice ages

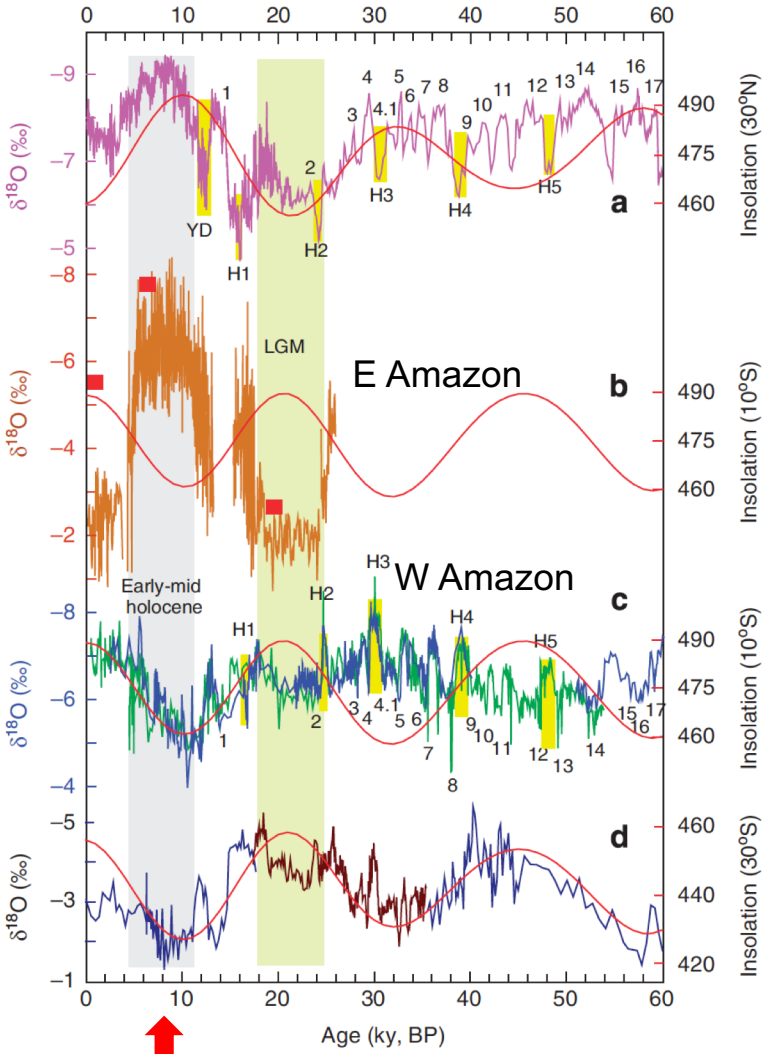
Amazon – no pollen evidence of rainforest contraction during glacial periods BUT only a few short records

Lake Pata, Brazil



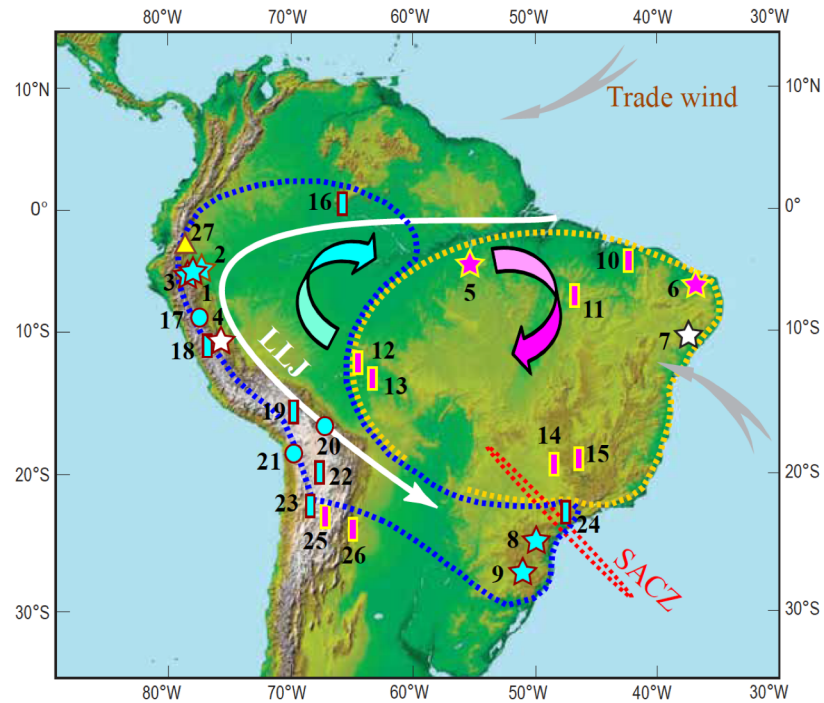
Colinvaux et al. 1996

Beyond Refugia: Climate Heterogeneity on Orbital Scales (22ka)



Wet E Amazon
Dry W Amazon

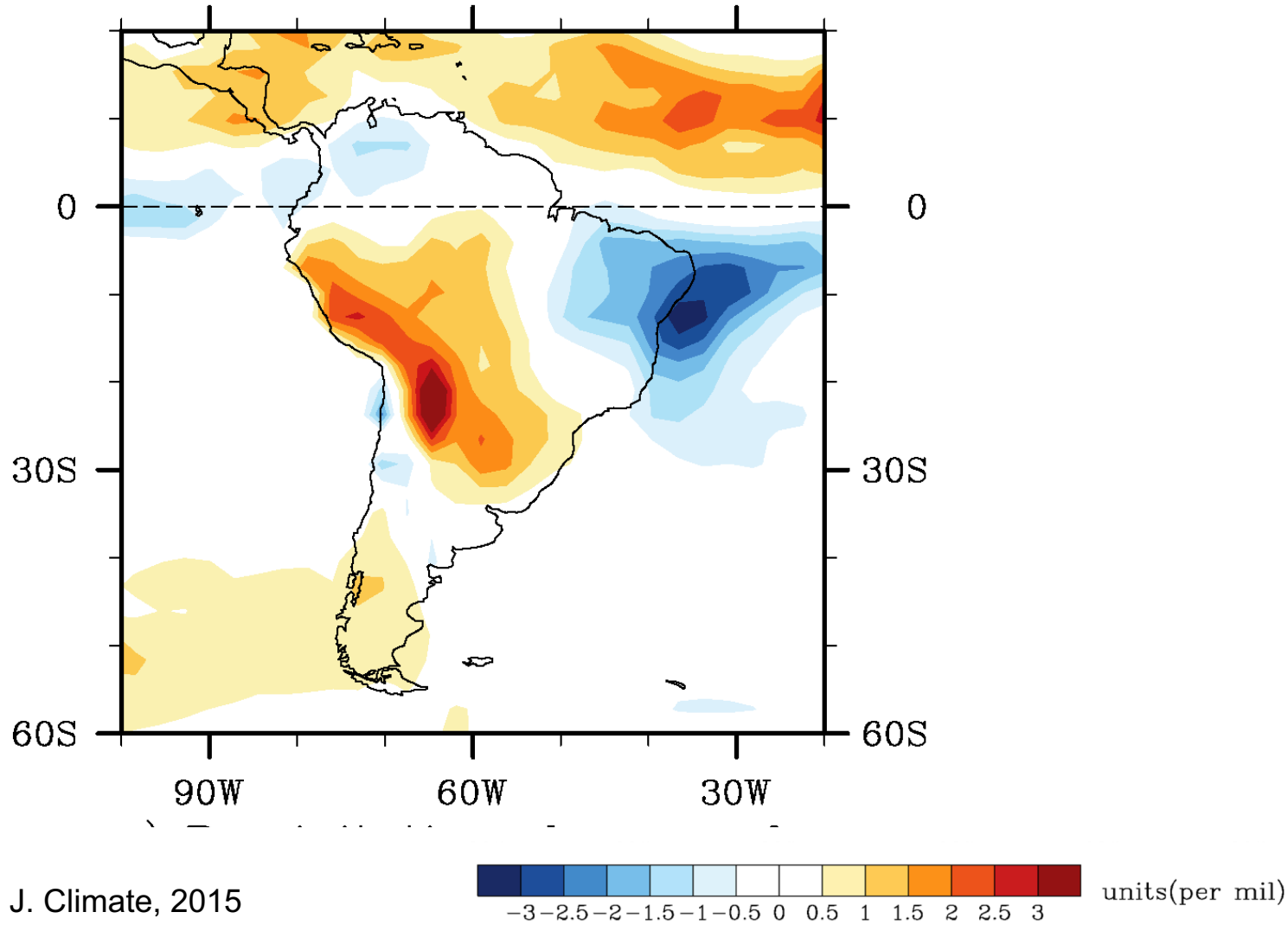
Dipole: western versus eastern Amazon -



Cheng et al. 2013

Modeling reproduces E-W Dipole on orbital (22K) time scales

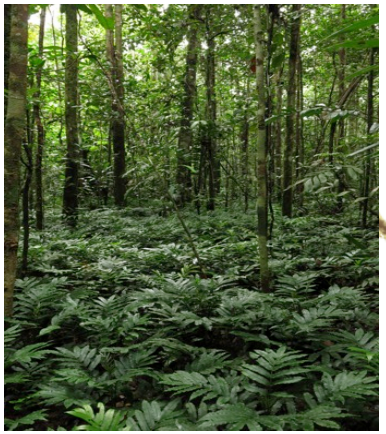
Difference in precip weighted $\delta^{18}O_p$



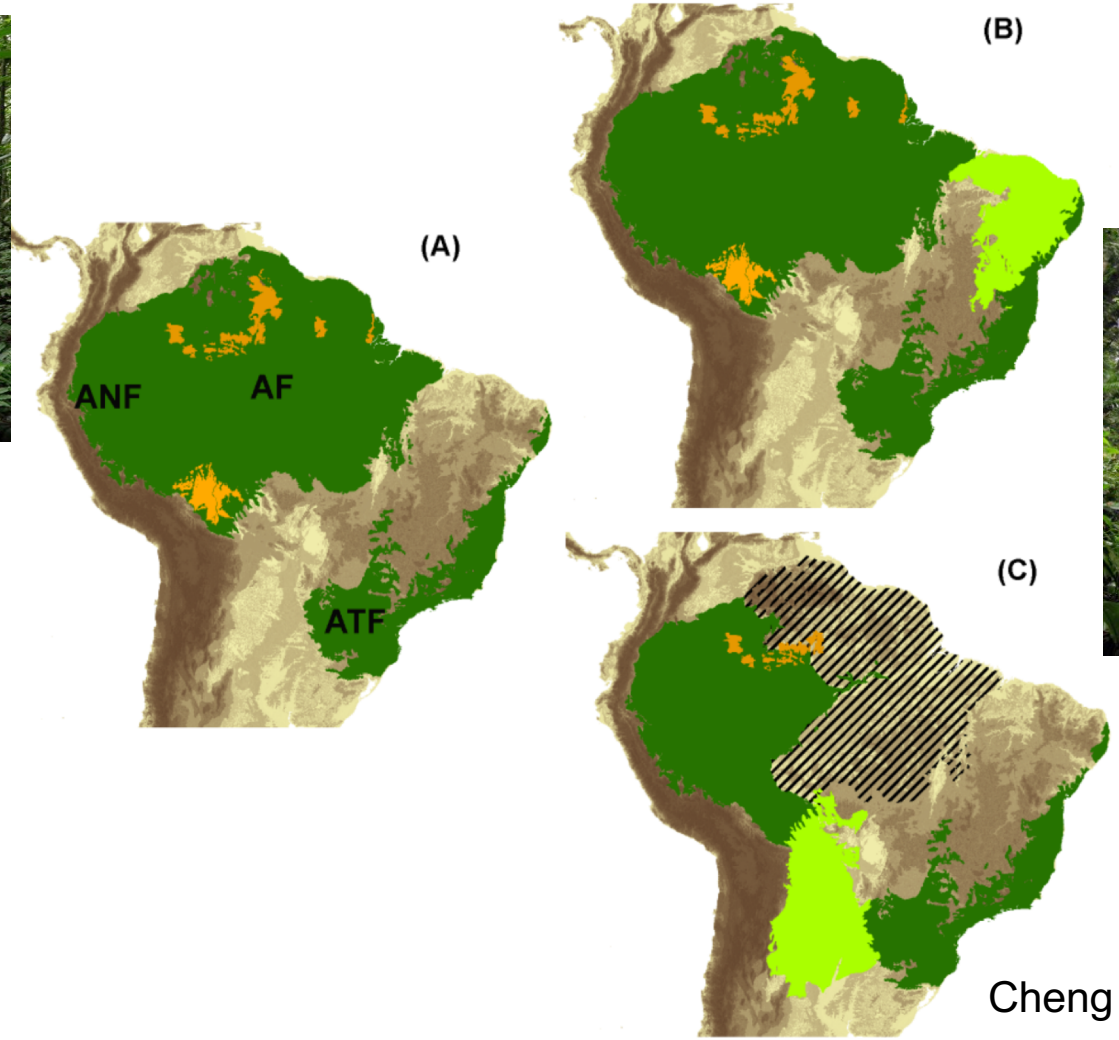
X. Liu and Battisti J. Climate, 2015

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



Amazon Forest

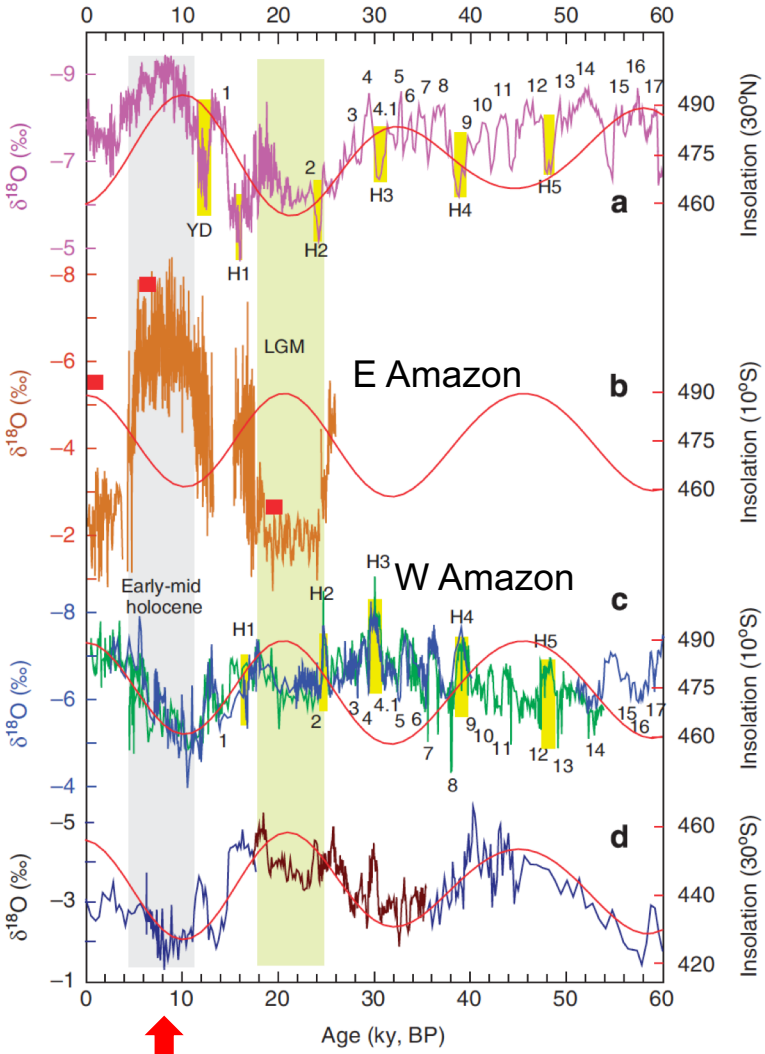


Atlantic Forest

Cheng et al. 2013

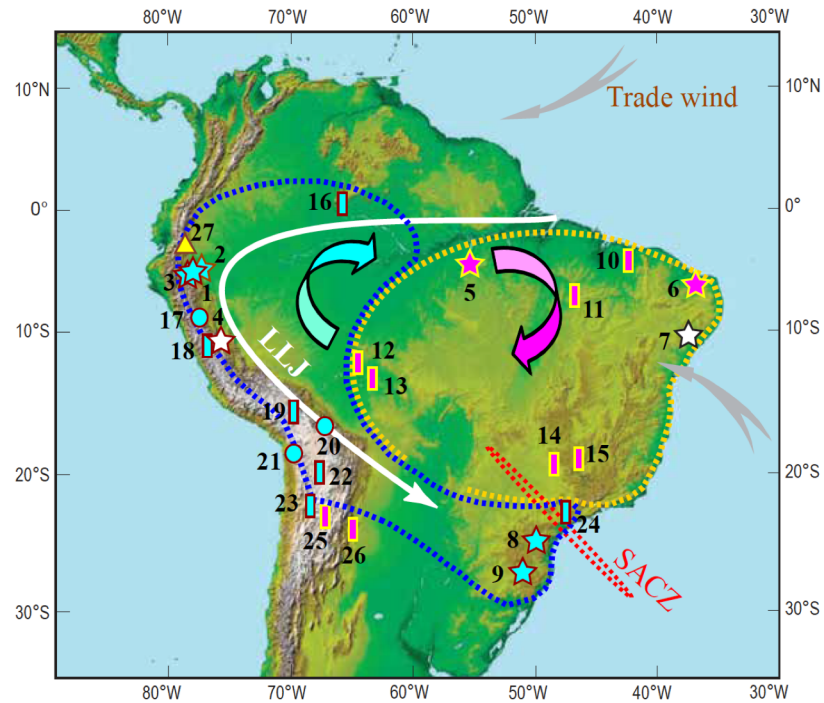
Beyond Refugia: Heinrich Events

Ice-rafted debris in N Atlantic



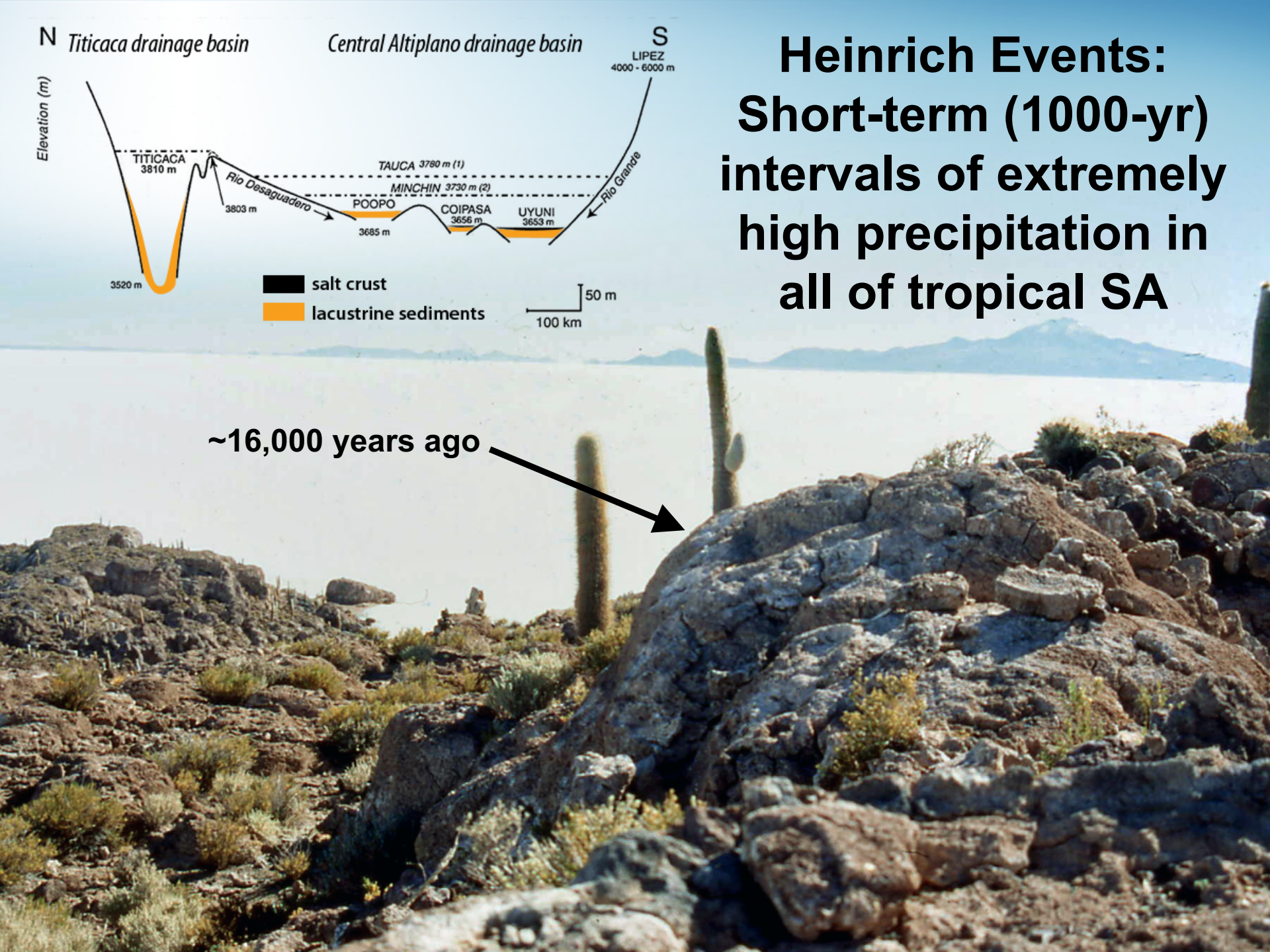
Wet E Amazon
Dry W Amazon

Dipole: western versus eastern Amazon -



Cheng et al. 2013

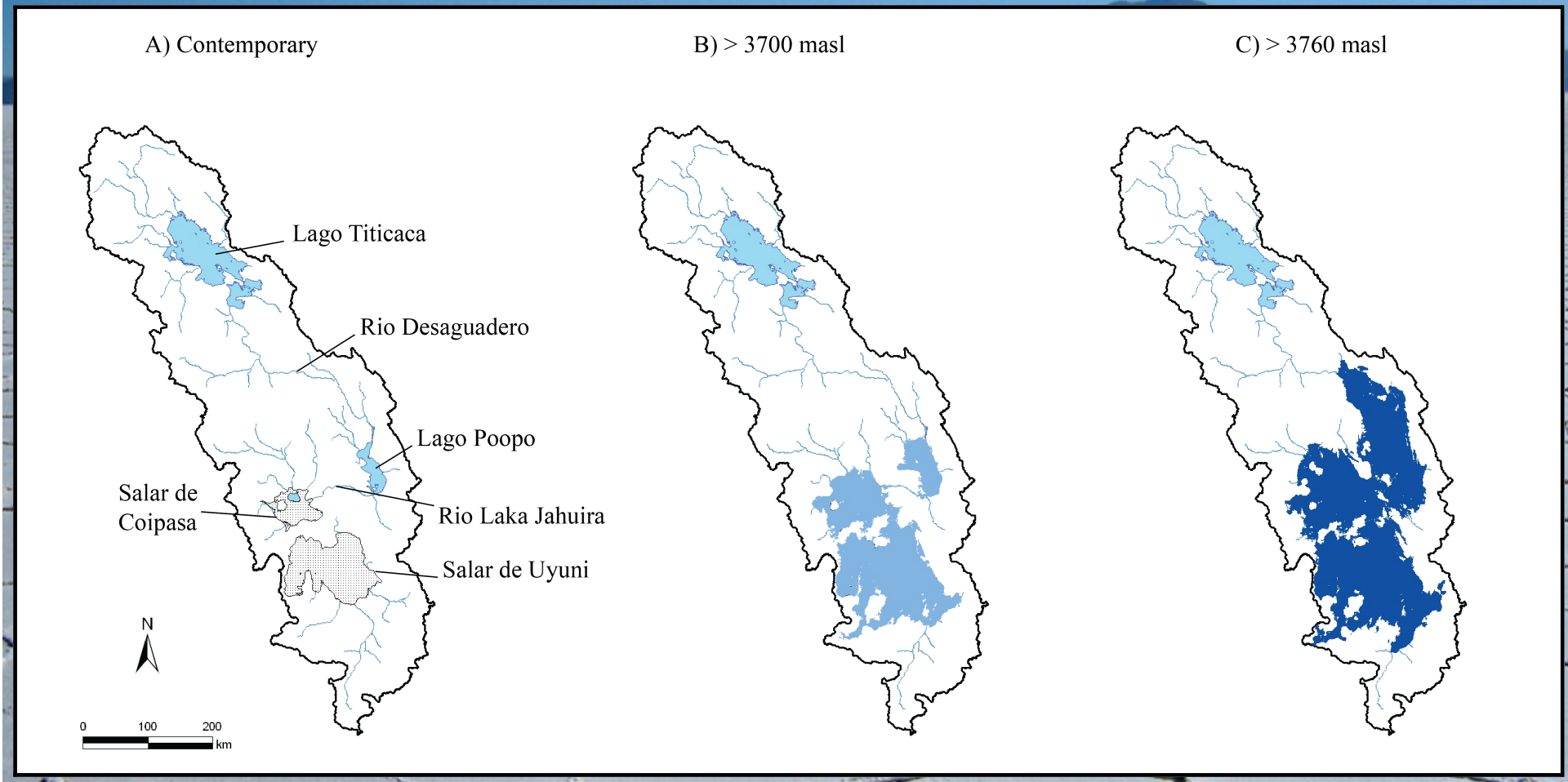
Heinrich Events: Short-term (1000-yr) intervals of extremely high precipitation in all of tropical SA



Glacial times – Heinrich events (ice-rafted debris)

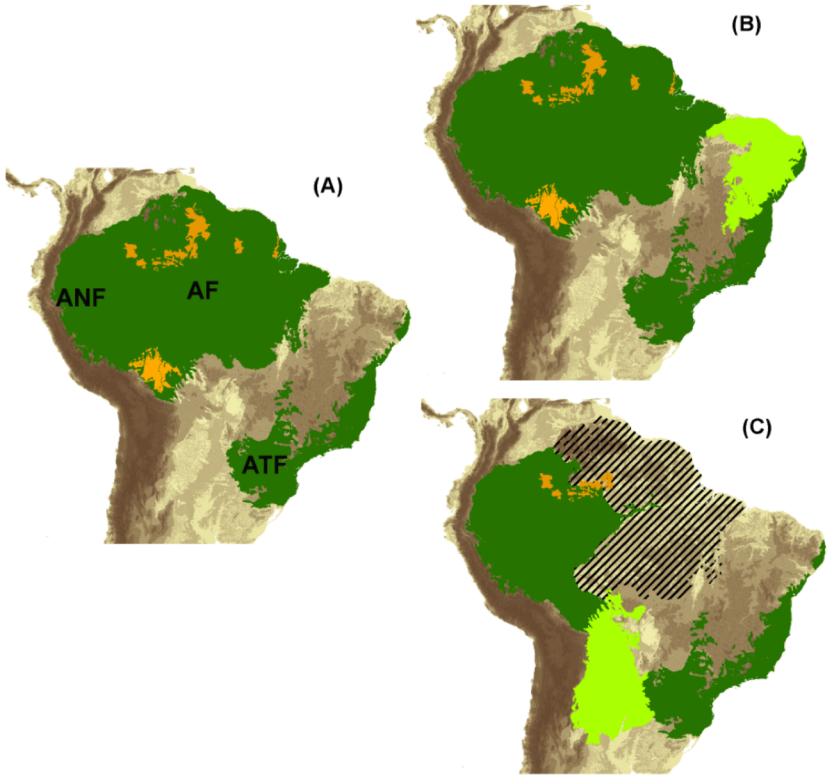
Wet throughout South American SH tropics

Today ~16 ka



Nunnery, Fritz et al. 2018

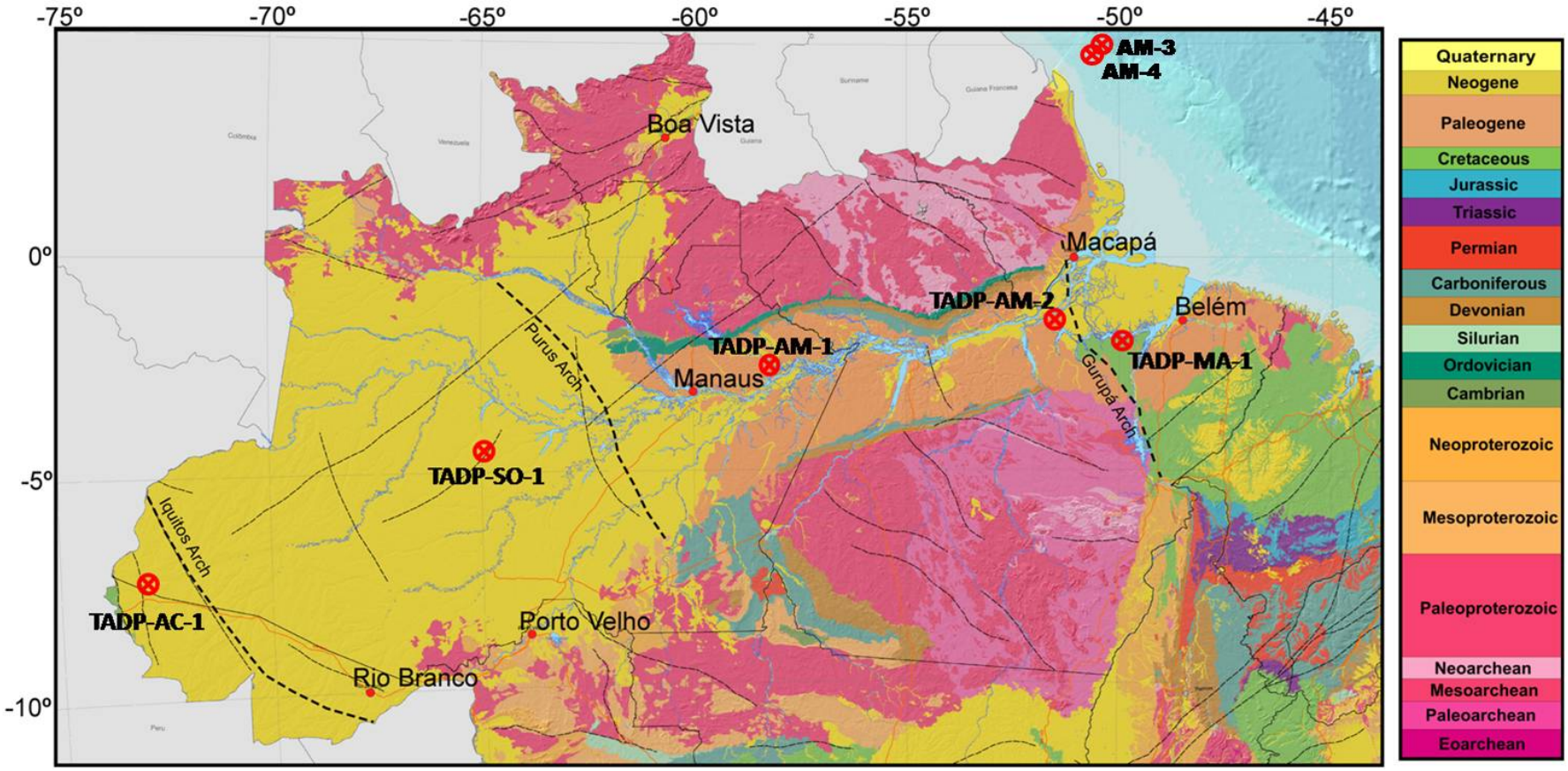
Beyond Refugia – Quaternary Climate Variation



- 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

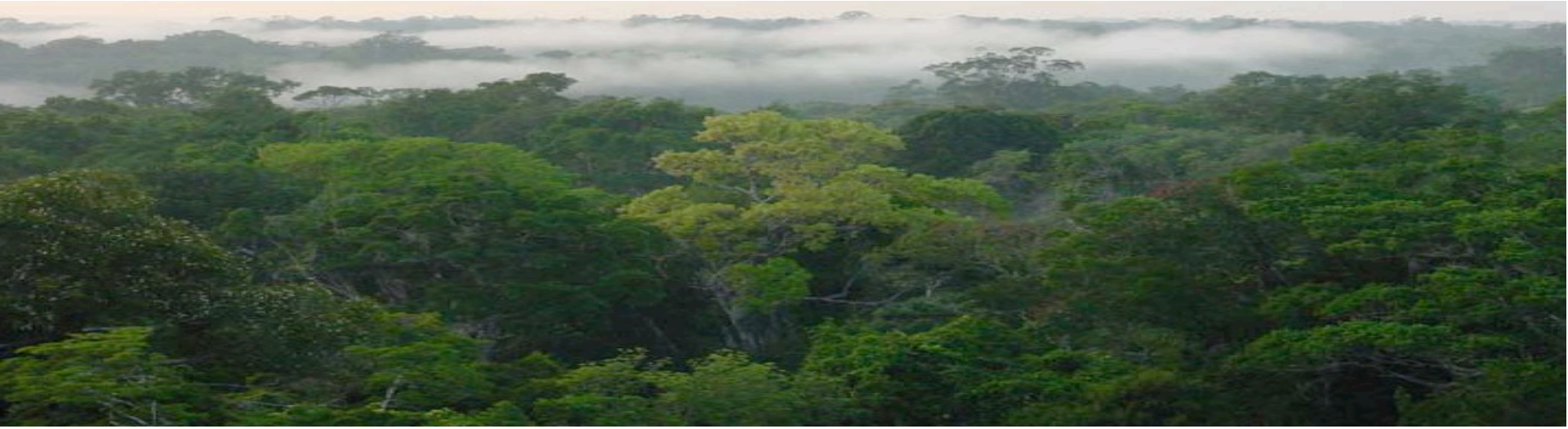
Trans-Amazon Drilling Project (TADP)

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?