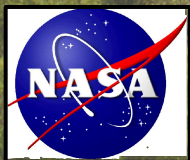# How Earth history shapes the origin and assembly of continental vertebrate biotas
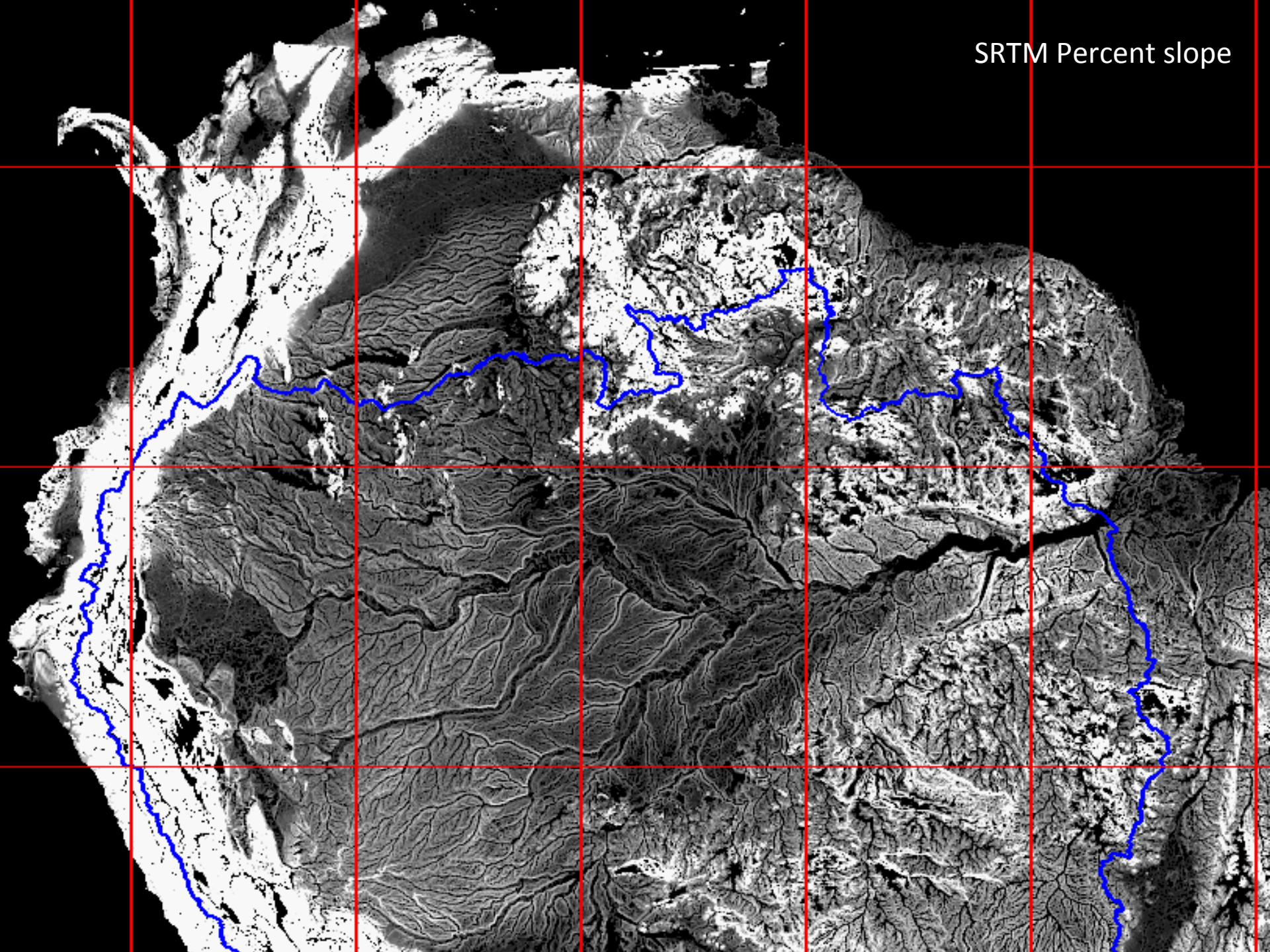
Joel Cracraft
Department of Ornithology
AMNH

Dimensions of Biodiversity US-BIOTA-São Paulo

SRTM Percent slope

Some major questions about Amazonia

● How is genetic, taxonomic, and ecological diversity distributed within Amazonia?

● What are the drivers of diversity over space and time?

● How has the Amazonian biota assembled over space and time?

● 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

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

United States

- American Museum of Natural History
- 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

Integration across disciplines
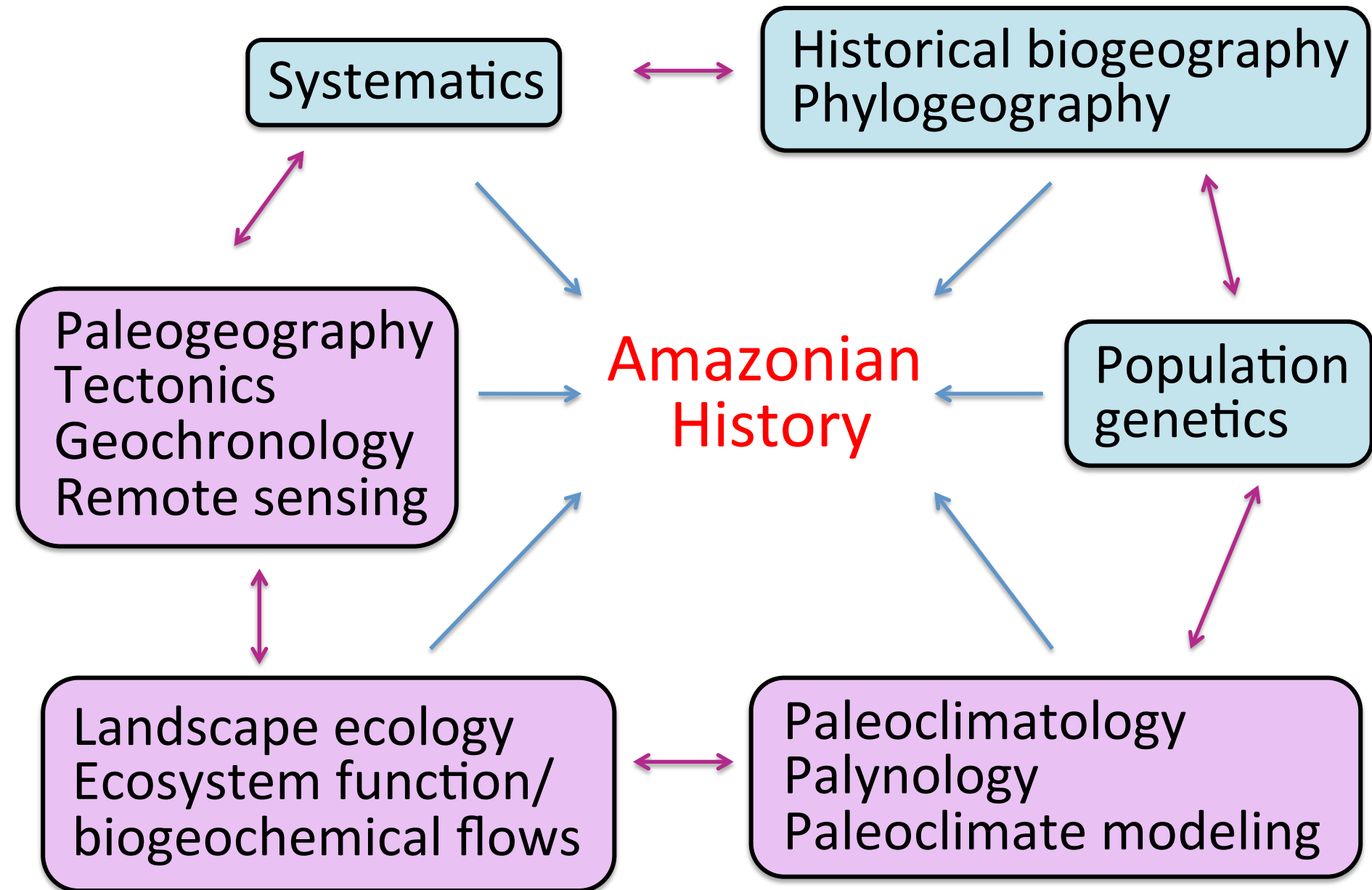
Science stories: Earth & Amazonian biotic histories

🔴 Large spatiotemporal scale: global avian diversification

🔴 Small spatiotemporal scale: speciation in birds

A global timetree and biogeography for birds

- 🔴 **Building the tree**
  - ● Phylogenomic constraint-tree for basal splits
  - ● Remainder built from 4092 bp RAG-1 & RAG-2
  - ● 230 species, 202 avian families; we eliminated 200+ taxa of songbirds

Collaborator:
Santiago Claramunt

- 🔴 **Building the time-tree**
  - ● Identified 24 clades with well-characterized fossil record represented on multiple continents
  - ● 130 fossils used to build empirical probability distributions to construct Bayesian age priors
 - ● "Validated" by reanalysis of phylogenomic dataset

- 🔴 **Biogeographic reconstructions**
  - ● 8 (5) global regions: ~paleogeographically & tectonically individuated
  - ● optimizations: parsimony (single-state transitions), ML & Bayesian

Claramunt and Cracraft *Sci. Adv*. 2015;1:e1501005

A global time-tree for birds

Most comprehensive to date

- 🔴 First "unbiased" age-estimate of Neornithes: ~91.5 Ma
  - ⚫ No deep outgroup
  - ⚫ No prior on base of Neornithes

- 🔴 Three deep stem-lineages: Paleognathae, Galloanseres, Neoaves

- 🔴 All crown-groups are ~K-Pg time in age

- 🔴 Paleogene fossils directly incorporated

- 🔴 Major result likely robust to uncertainty
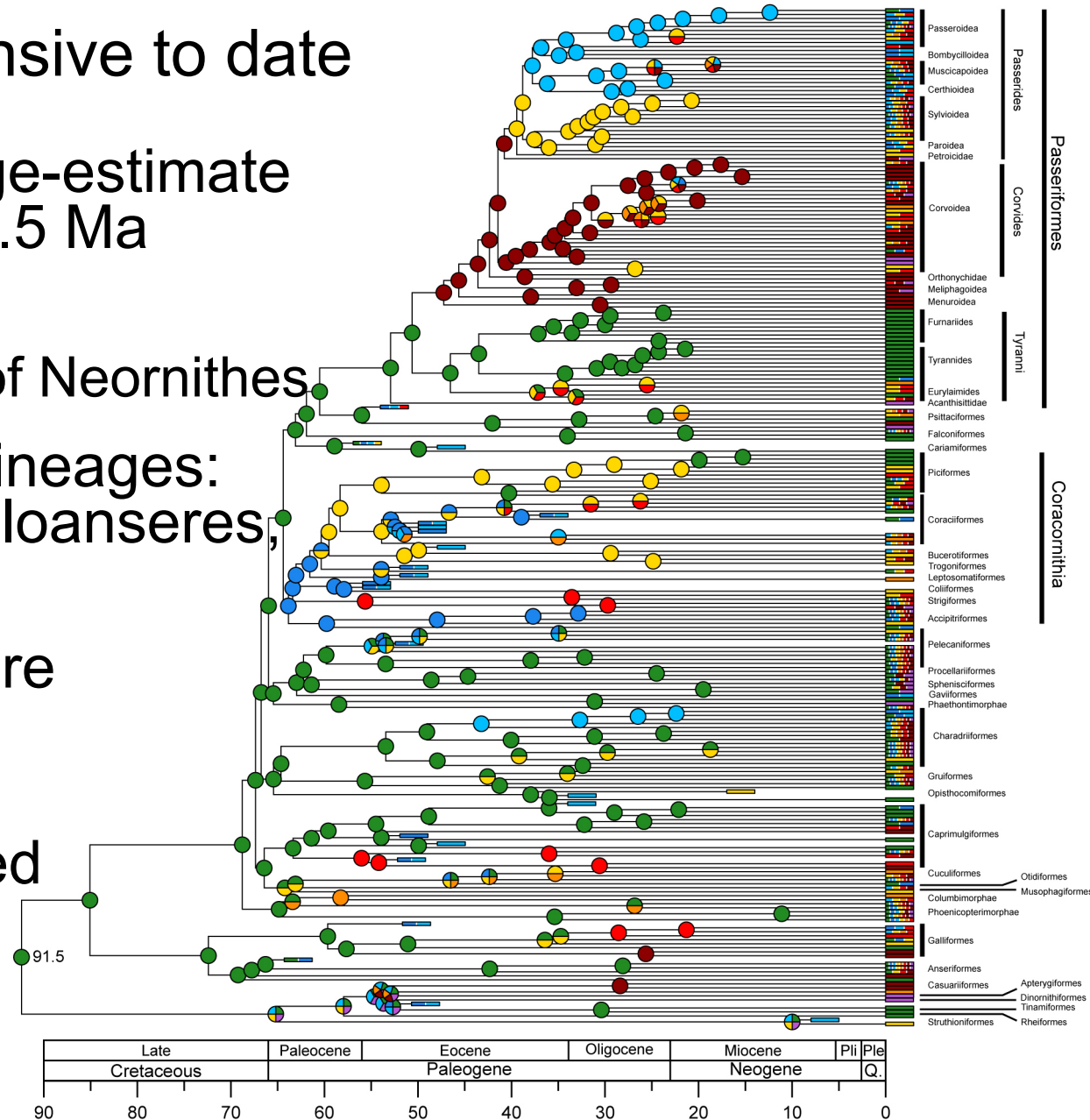
Birds had a West Gondwanan origin

Claramunt and Cracraft 2015
*Science Adv*ances:1:e1501005
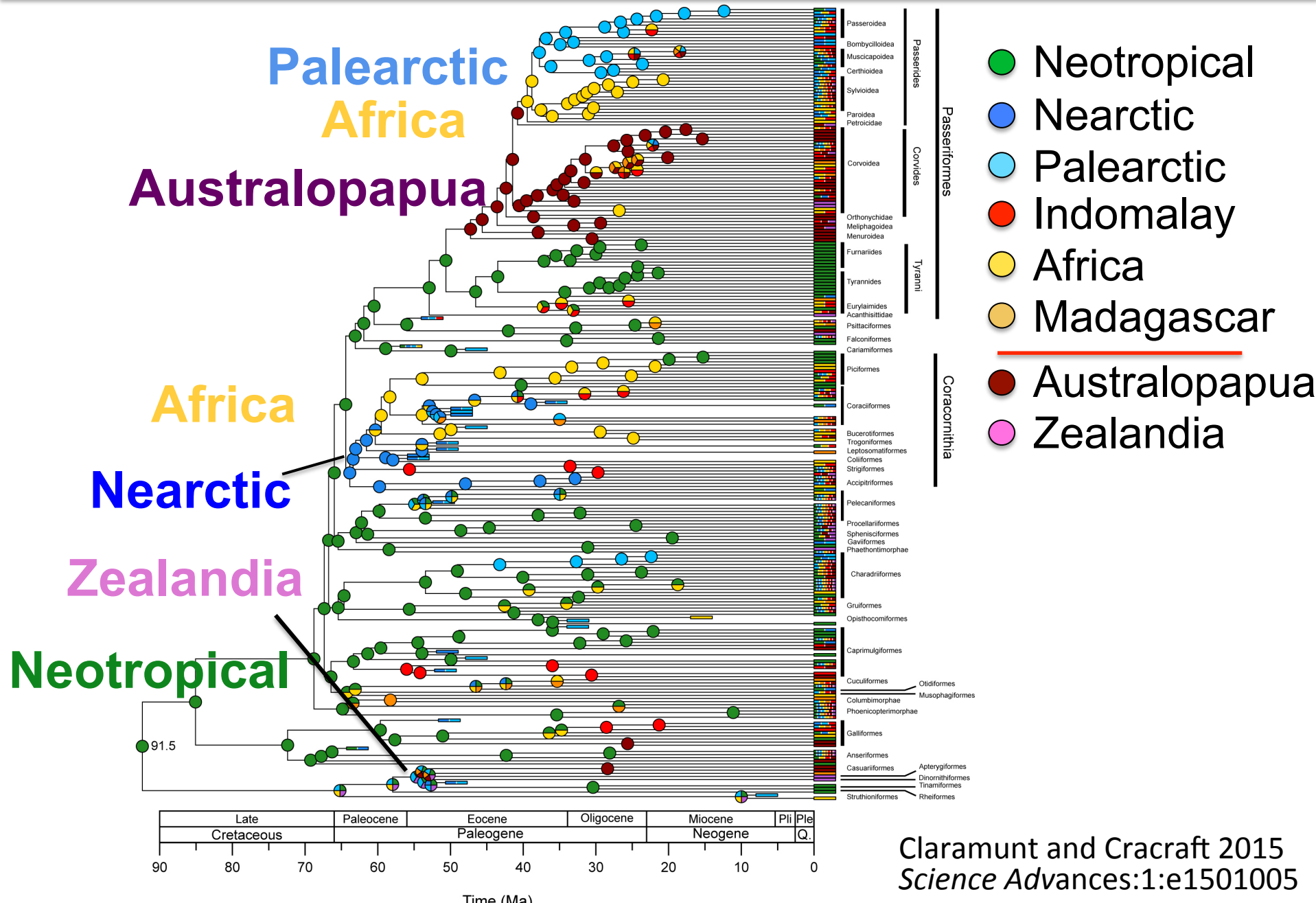
The K-Pg West Gondwanan avifauna

Palaeognathae: tinamous, ratites
Galloanseres: waterfowl, galliforms,
bony-toothed birds
Neoaves:
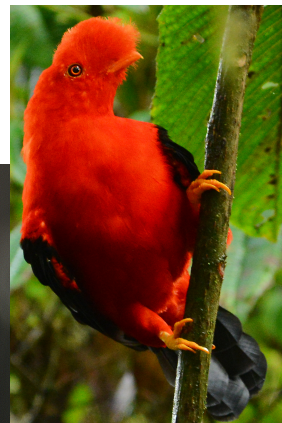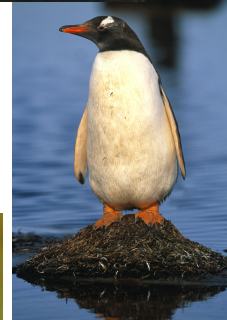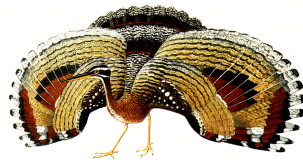flamingos + grebes

oilbirds, nightjars,
  swift + hummingbirds

hoatzins, rails, cranes,
  shorebirds

tropicbirds,
sunbittern/
Kagu

penguins, seabirds & allies

seriemas, falcons,
parrots & perching-
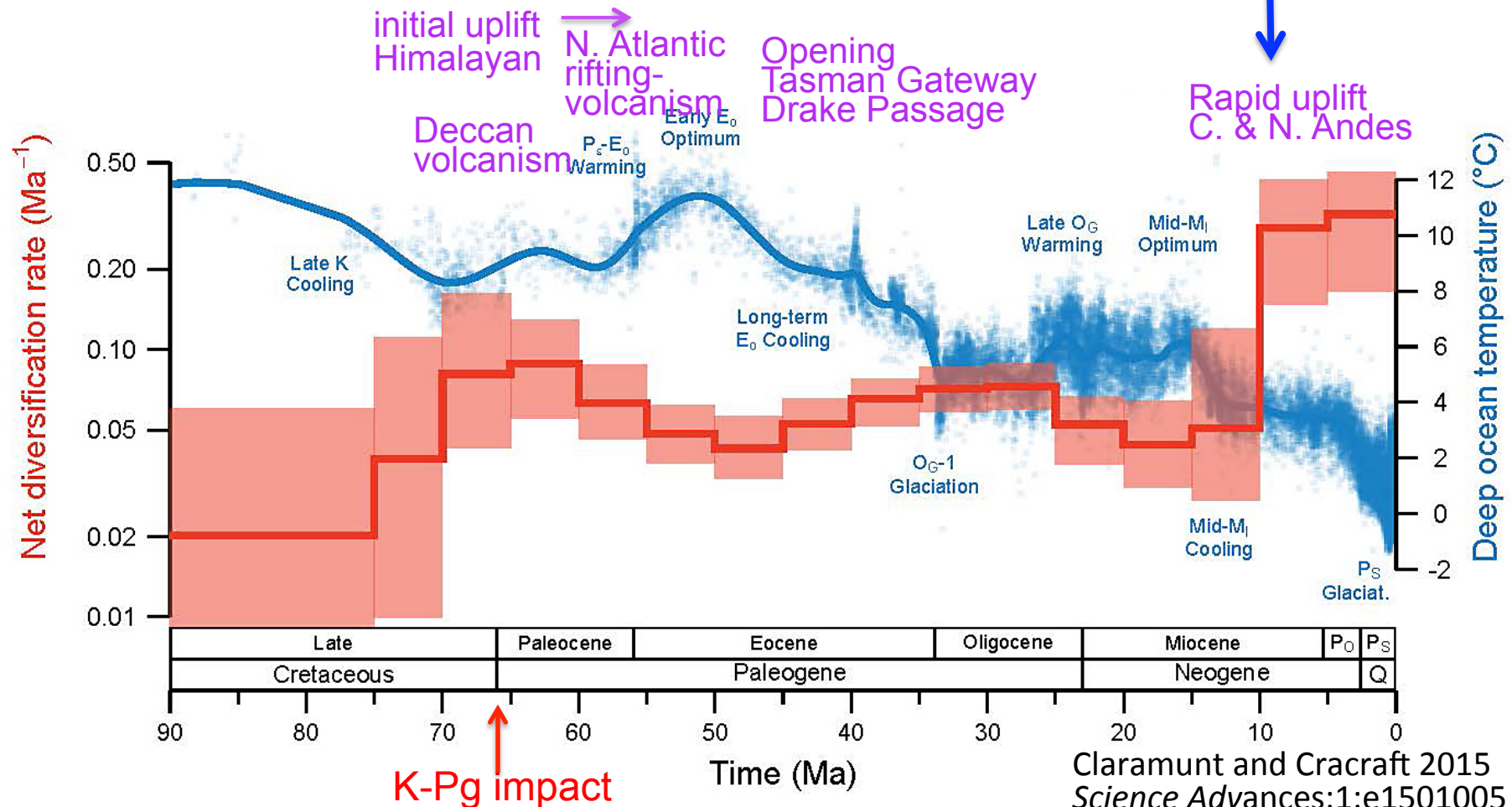birds

NOTE: these taxa only
represent stem-lineages

- Warmer, wetter periods increase biotic cosmopolitanism: S and E decline *together*
- Cool, dryer periods fragment ecosystems/biomes: S and E increase *together*
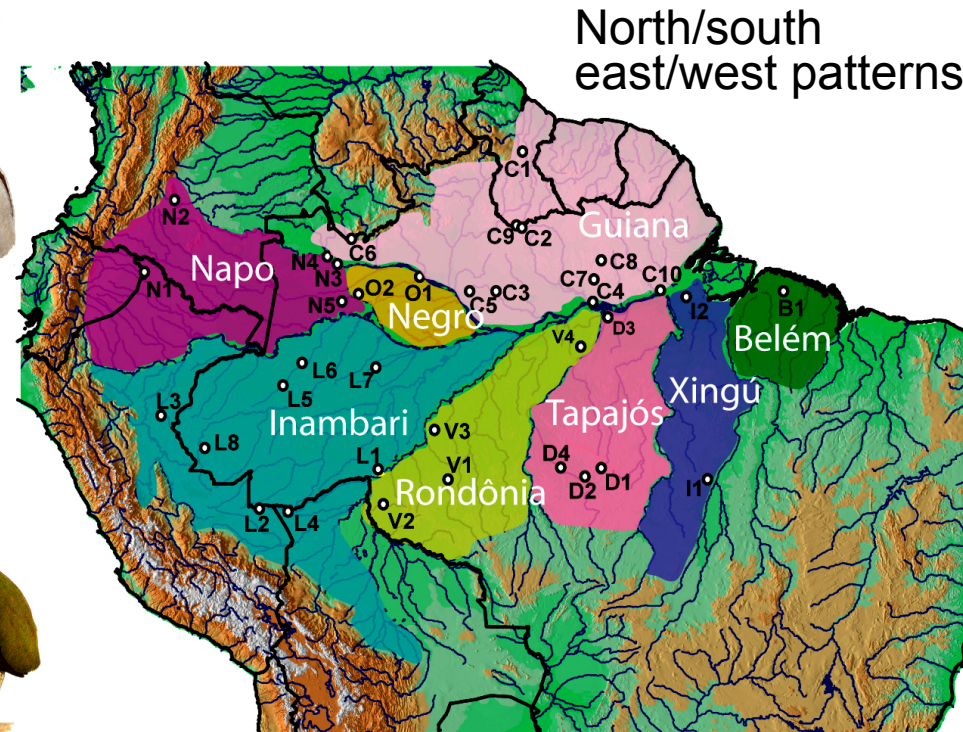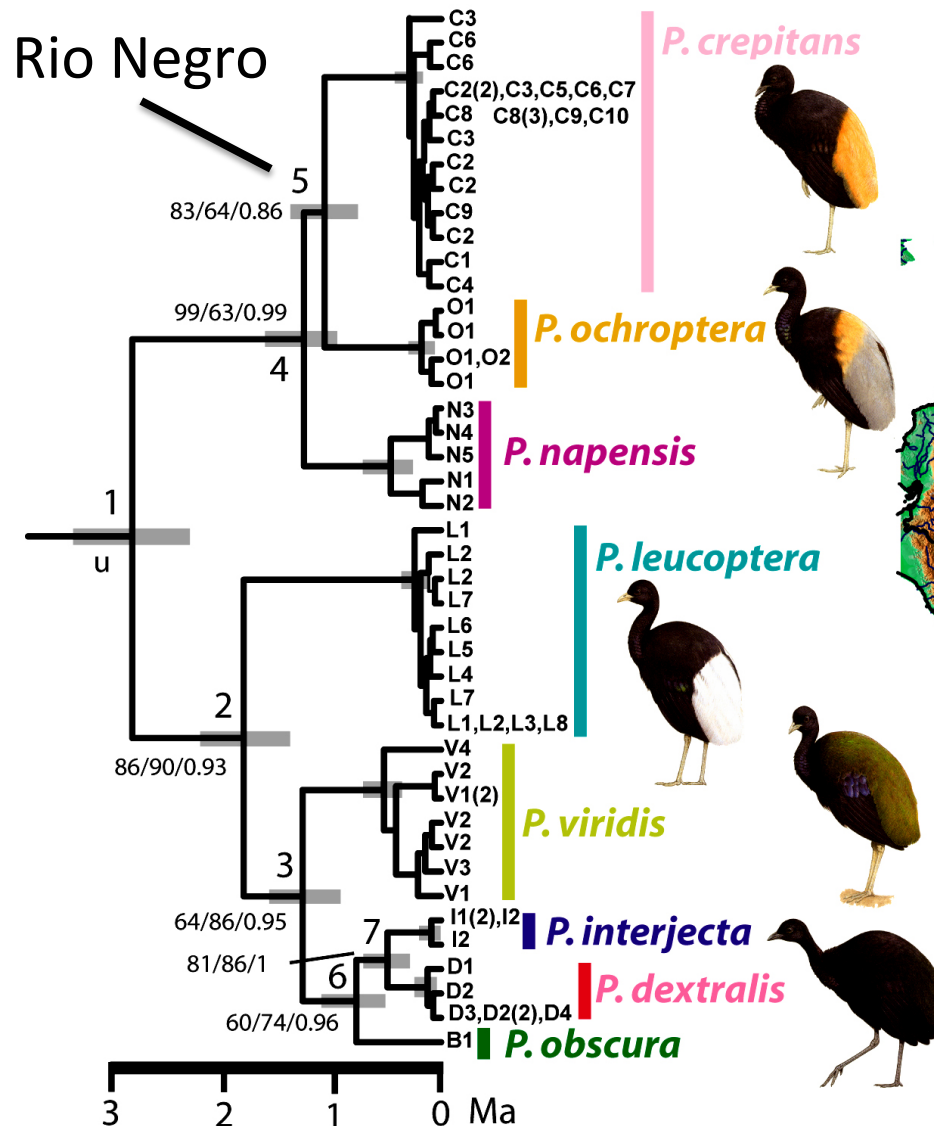- S and E correlated and causally linked

Large-scale Earth history

Tectonics causes & amplifies effects of climate change

initial uplift Himalayan

N. Atlantic rifting-volcanism

Opening Tasman Gateway Drake Passage

Deccan volcanism

Rapid uplift C. & N. Andes

P$_a$-E$_0$ Warming

Early E$_0$ Optimum

Late K Cooling

Long-term E$_0$ Cooling

Late O$_G$ Warming

Mid-M$_l$ Optimum

O$_G$-1 Glaciation

Mid-M$_l$ Cooling

P$_S$ Glaciat.

Net diversification rate (Ma^{-1})

Deep ocean temperature (°C)

| Late | Paleocene | Eocene | Oligocene | Miocene | P$_O$ | P$_S$ |
| Cretaceous | | Paleogene | | Neogene | | Q |

Time (Ma)

K-Pg impact

Claramunt and Cracraft 2015
*Science Adv*ances:1:e1501005

Small-scale biotic history: *Psophia*

Rio Negro

Small-scale
Earth history

North/south
east/west patterns

P. crepitans

P. ochroptera

P. napensis

P. leucoptera

P. viridis

P. interjecta

P. dextralis

P. obscura

83/64/0.86
99/63/0.99
86/90/0.93
64/86/0.95
81/86/1
60/74/0.96

5
4
1
u
2
3
7
6

Napo
Guiana
Negro
Belém
Xingú
Inambari
Tapajós
Rondônia

3 2 1 0 Ma

Timeline estimated by two
independent methods

Leads to a predictive
Amazonian
palaeogeography

Ribas et al. 2012. PRSL

Integrating paleogeography and remote-sensing using SRTM
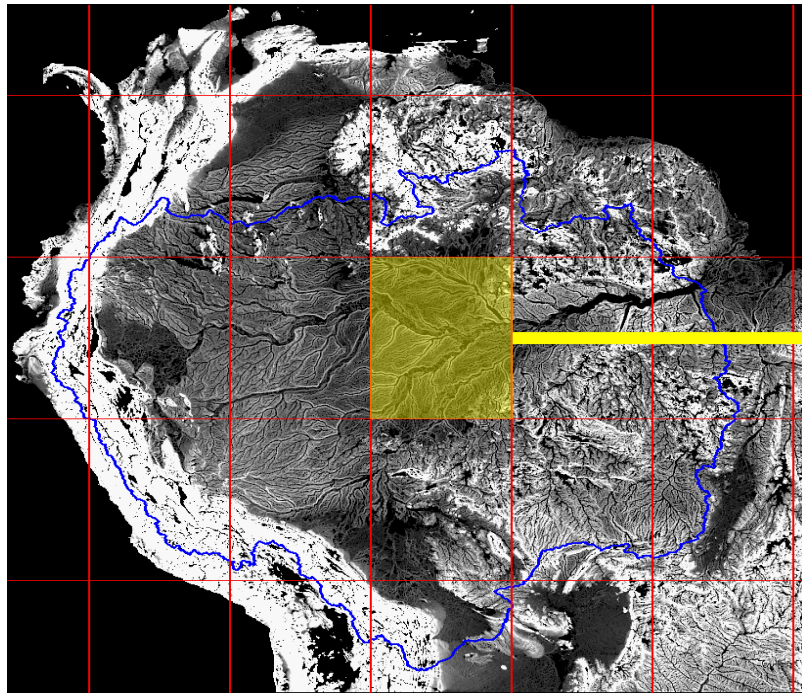
SRTM
% slope at 5 km scale
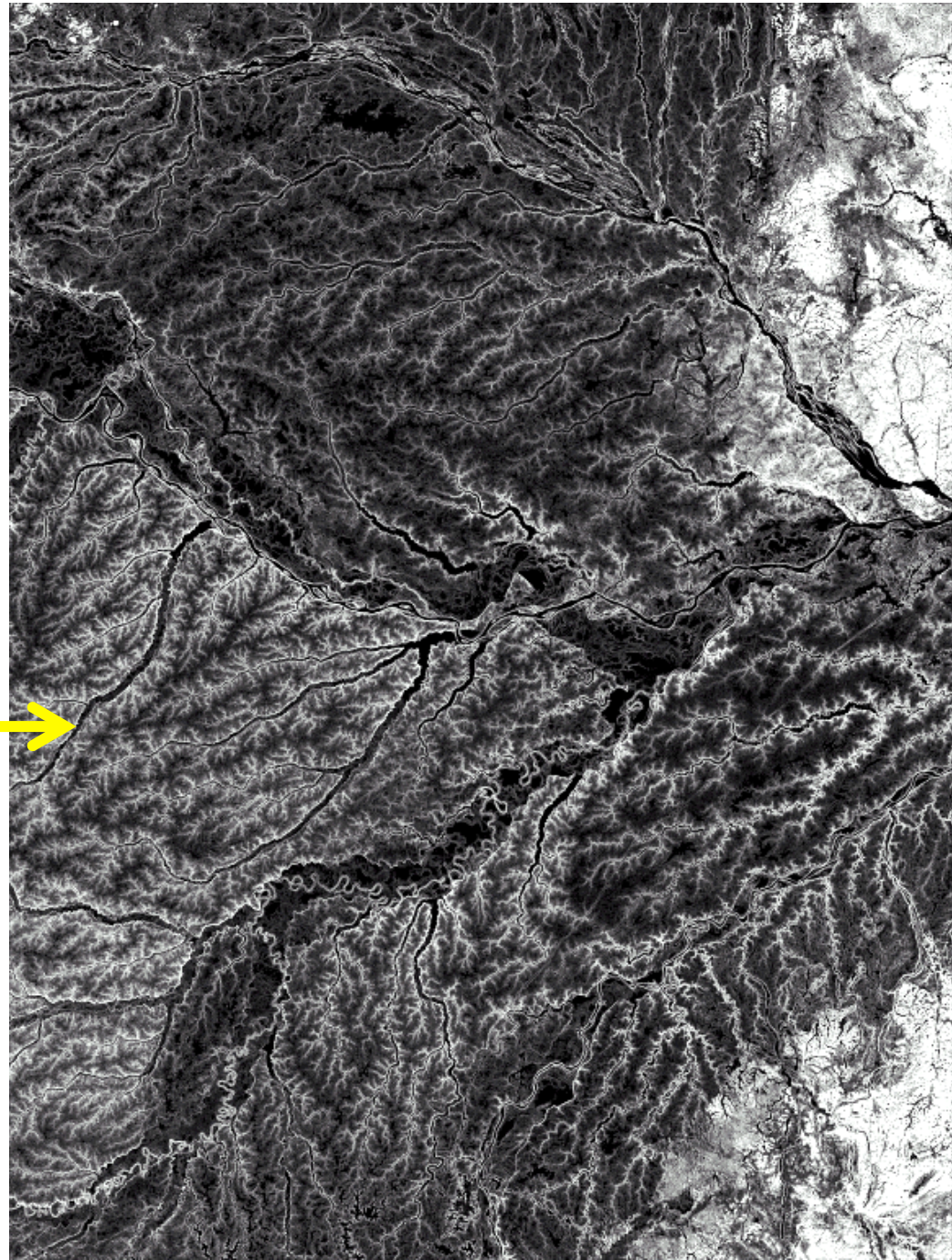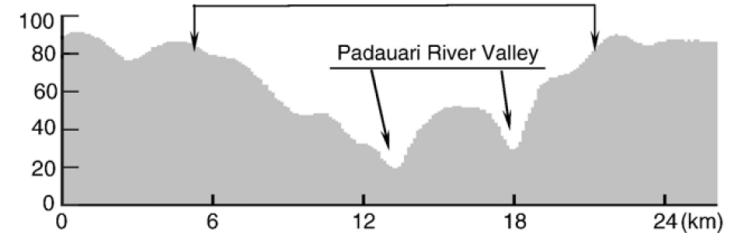
SRTM and Rio Negro paleogeography

Rio Carabinini

Rio Padauari

paleoriver
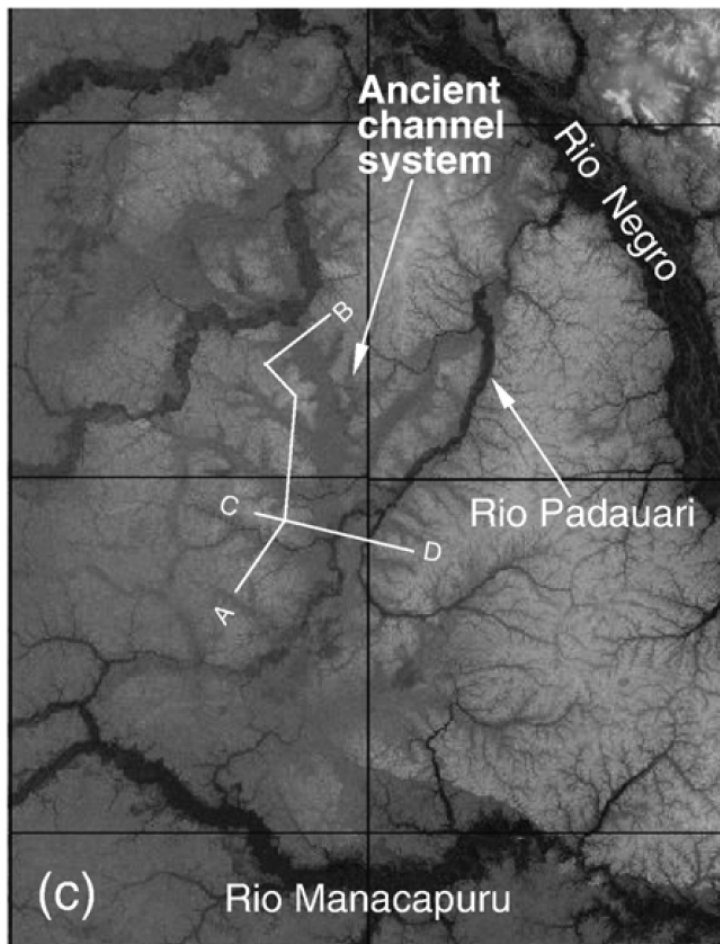
SRTM digital elevation model

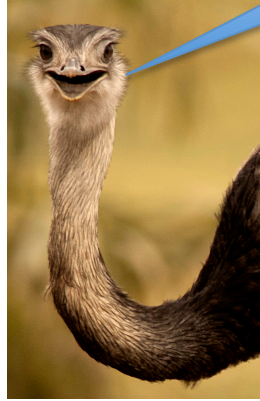Almeida-Filho & Miranda. 2007. *Remote Sensing Environ.* 110:387-392
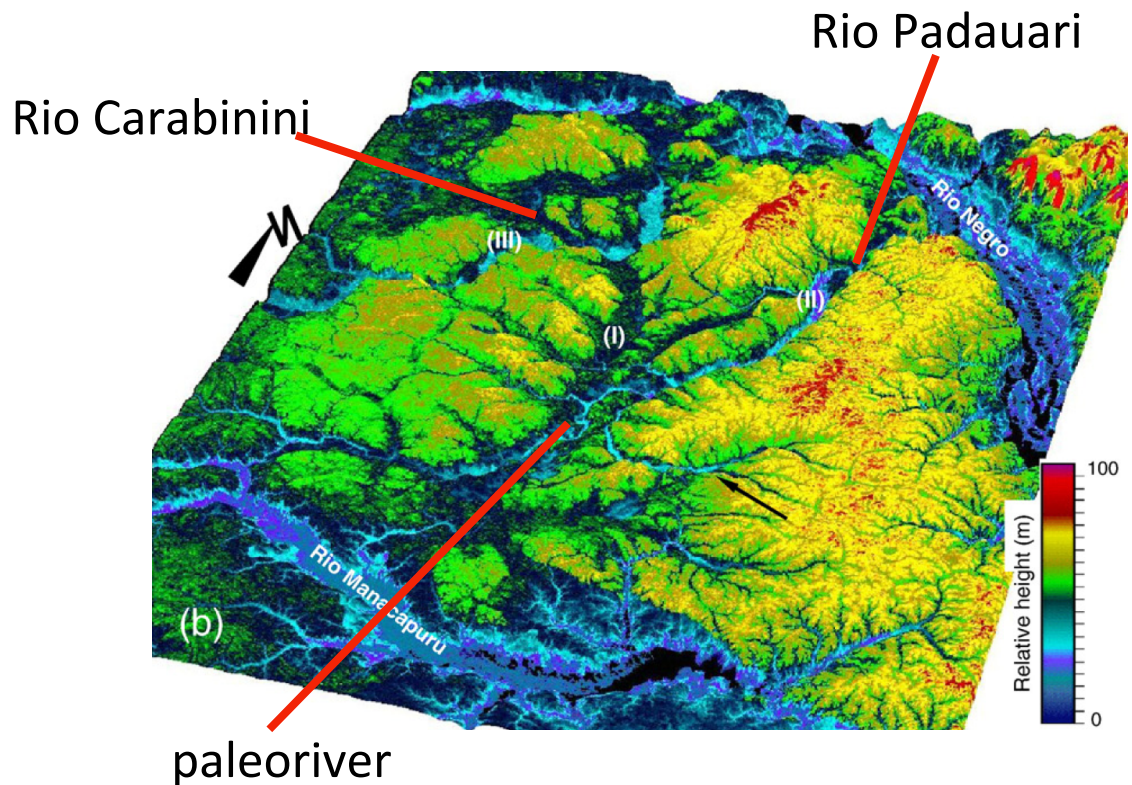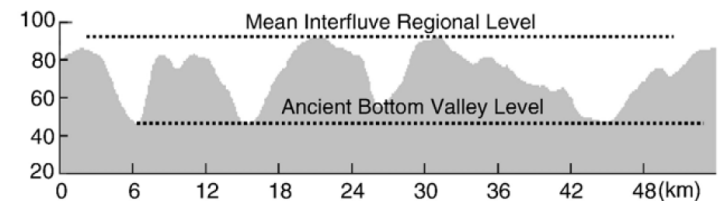
Collaborations and acknowledgments

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