

Linking water and climate change: a case for Brazil

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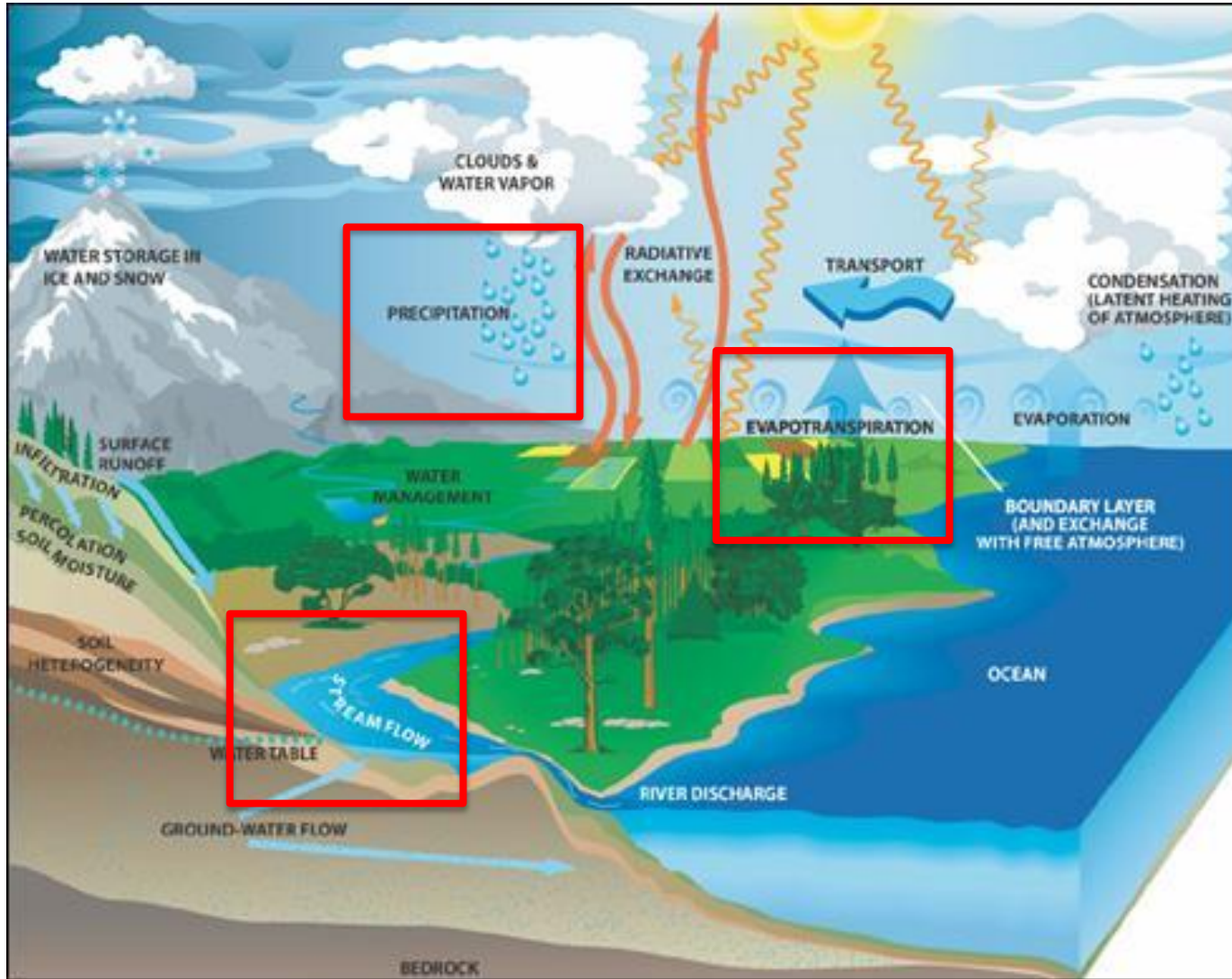
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Outline

1. Overview: The Water Cycle
2. Linking water between land and atmosphere
 - Impacts of reduced precipitation on rainfall-reliant sectors
3. A case for Brazilian hydropower: Energy sector
4. State-of-the-art modeling approach
5. Recap of the take-home message

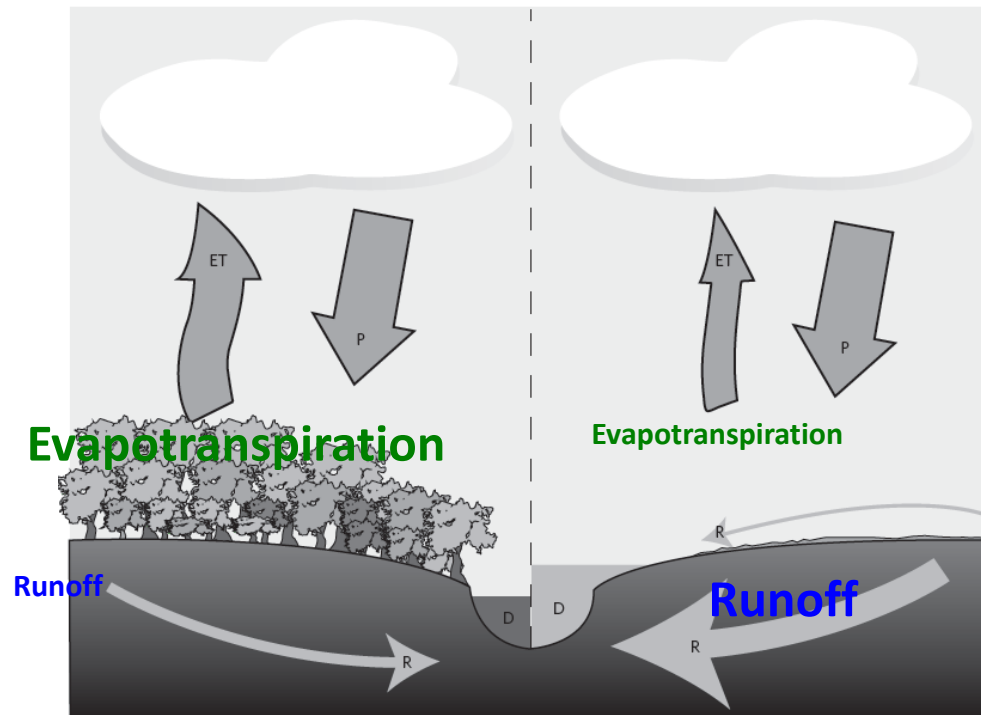
Global water cycle



Source: NASA

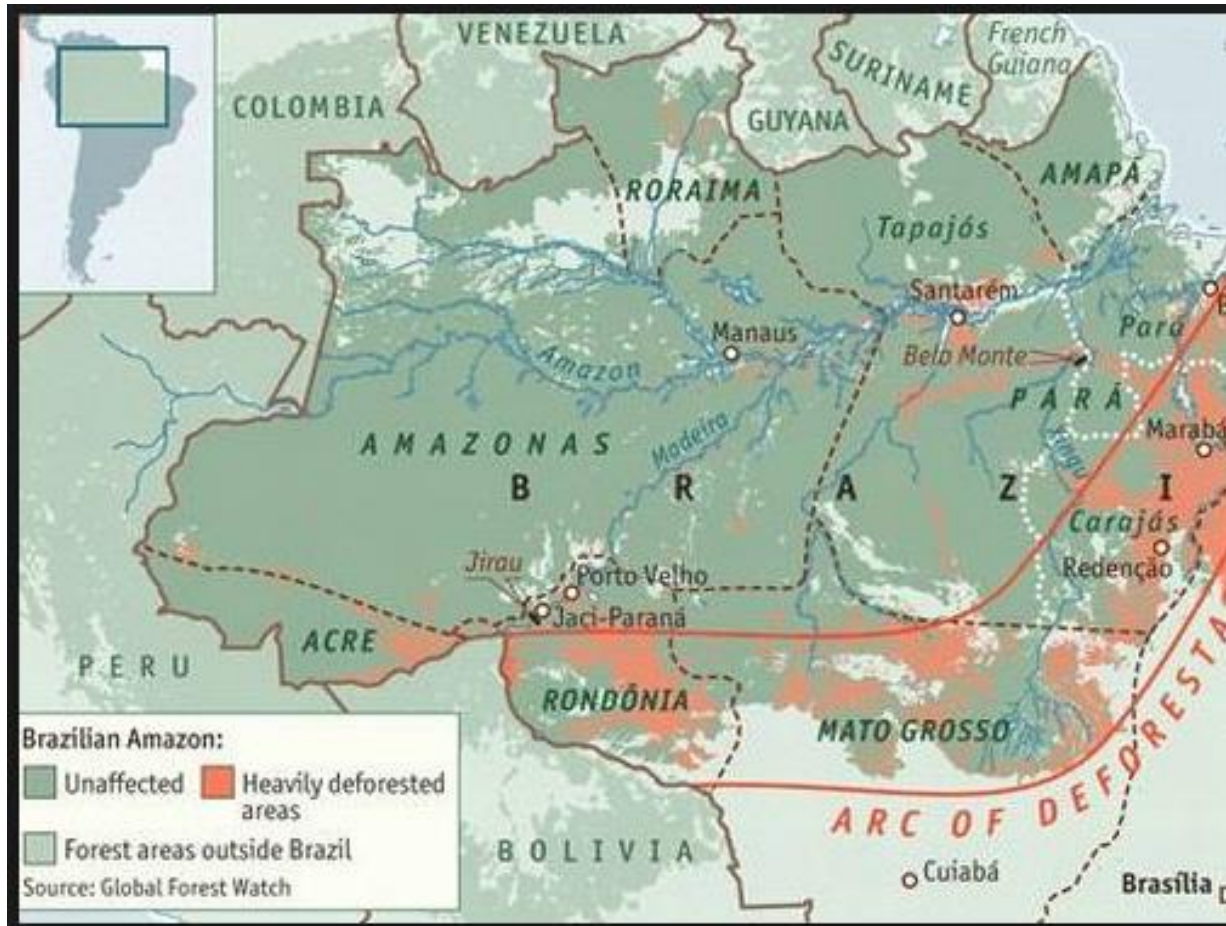
Water between land and atmosphere

- **Deforestation** (changing from trees to crops)
 - => Reduced **evapotranspiration**
 - => Increase in **runoff**



Engaging current and predicted changes: deforestation

Arc of deforestation (Current land use)



By 2050, under the business-as-usual scenario, about 40% of the Amazon is predicted to be deforested (Soares-Filho et al., 2006)

Reduced rainfall predicted due to deforestation

- **Amazonian Deforestation reduces regional Rainfall**
 - Through **evapotranspiration**, forests maintain atmospheric moisture that can return to land as rainfall
 - It may alter the regional-scale and even global-scale precipitation patterns through **the atmospheric circulation**
 - Climate models predict large-scale tropical deforestation causes reduction in regional-scale rainfall
 - If current trend of deforestation continues, 12%~21% of rainfall reduction is estimated across the Amazon basin by 2050 (Spracklen et al., 2012)

Impacts of reduced precipitation to rainfall-reliant sectors

- Threatened **Agricultural production**
 - For regions where agriculture is rain-fed, the productivity relies upon the rainfall
 - If severe droughts happen, the food security is threatened
- Threatened **hydroelectric power generation**
 - The depletion of water resources may give a challenge to a long-term stable supply of the electricity

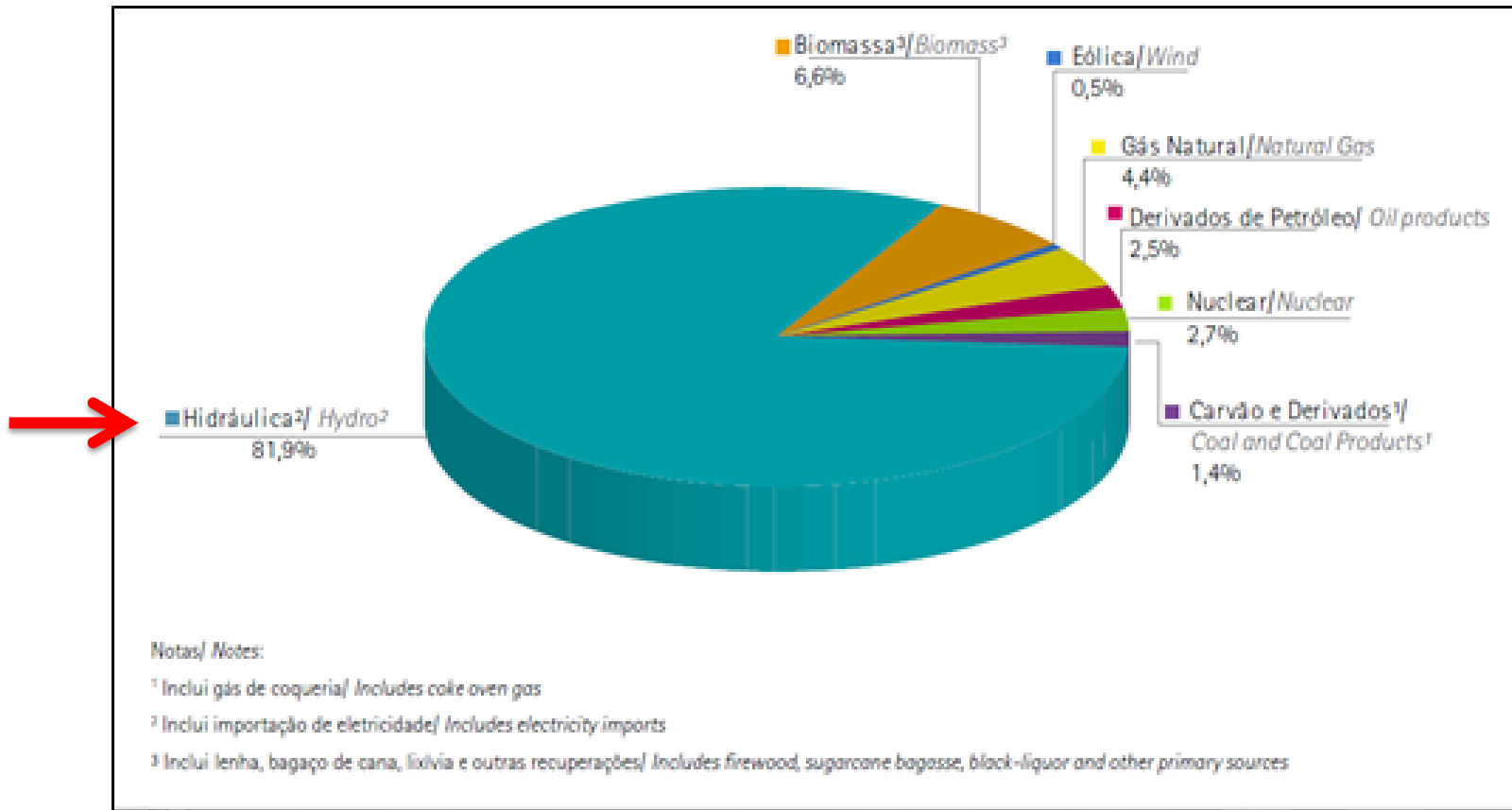
Case for Brazil



Hydroelectric dam in Brazil (Credit: Angela Linivo)

Case for Brazil

Highly dependent upon hydropower (up to 80%)

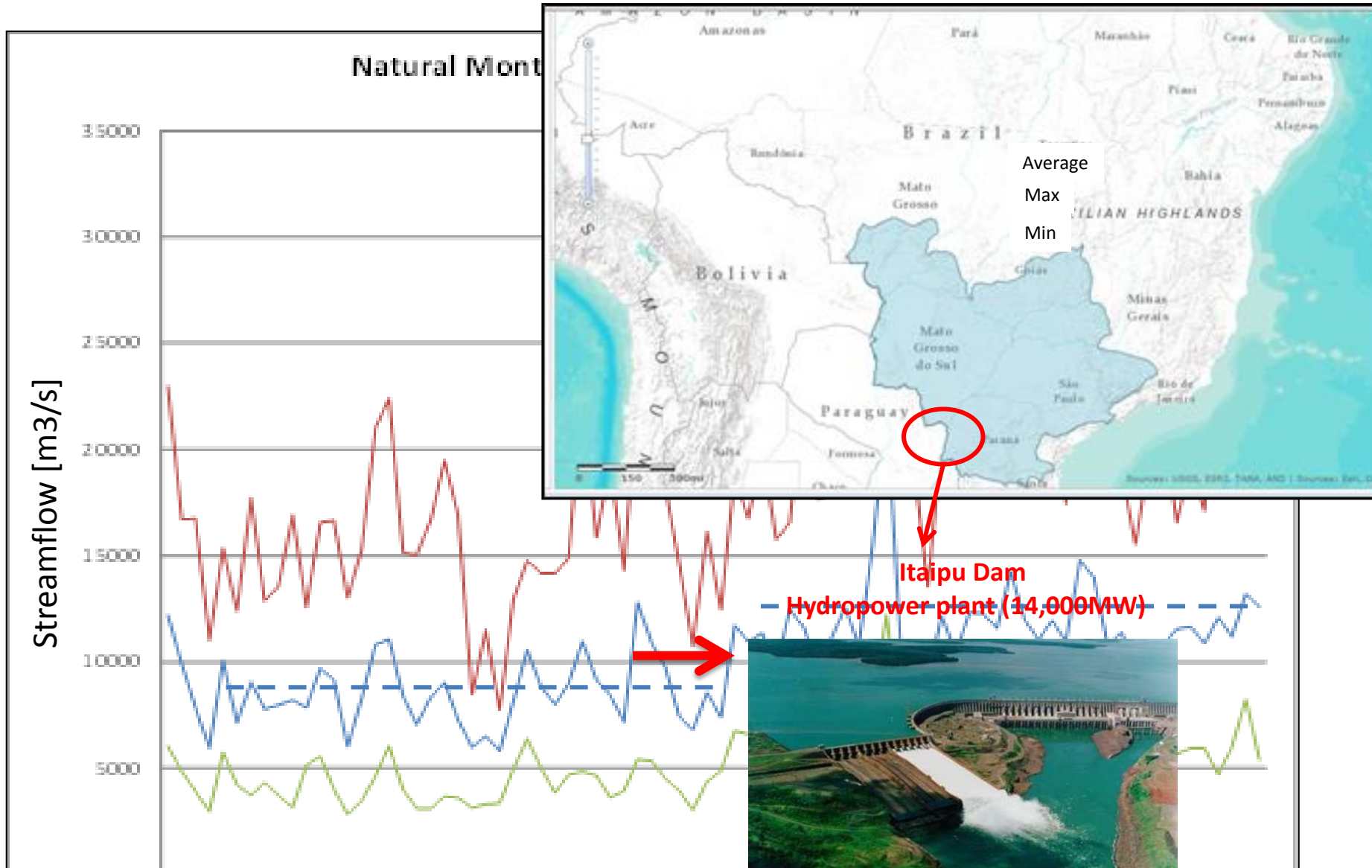


Brazilian Domestic Electricity Supply by Source – 2011 *From EPE*

Impacts of rainfall change to hydropower

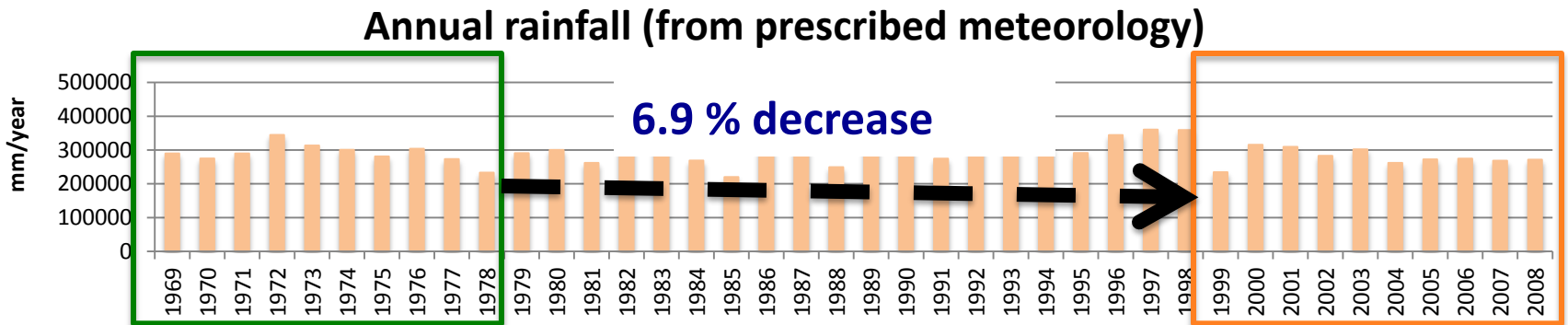
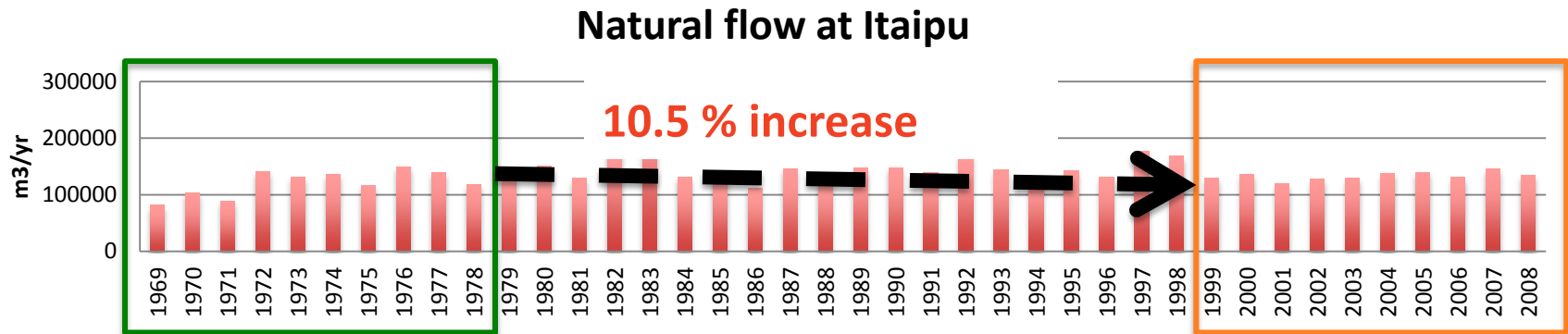
- Climate change and land-use change induce rainfall pattern change, and thus **streamflow pattern** change in rivers
 - Changes Seasonality and Brings More Irregularity
 - ⇒ Current assumption of stationary flow in energy production models are no longer valid
 - ⇒ Challenge to the market price estimation
 - Changes Maximum Flow
 - ⇒ Challenge to the energy planning such as decision of dam height

Already experiencing changes: the Parana river basin



The Parana paradox: despite the reduction in rainfall, the stream flow has increased

Parana paradox: Streamflow increase despite Rainfall reduction



Modeling framework

How can models help improve our understanding of current changes and provide future projections?

ED BRAMS
(Biosphere-regional
climate model)

PRECIPITATION,
RUNOFFS

THMB
(Terrestrial
Hydrology model)

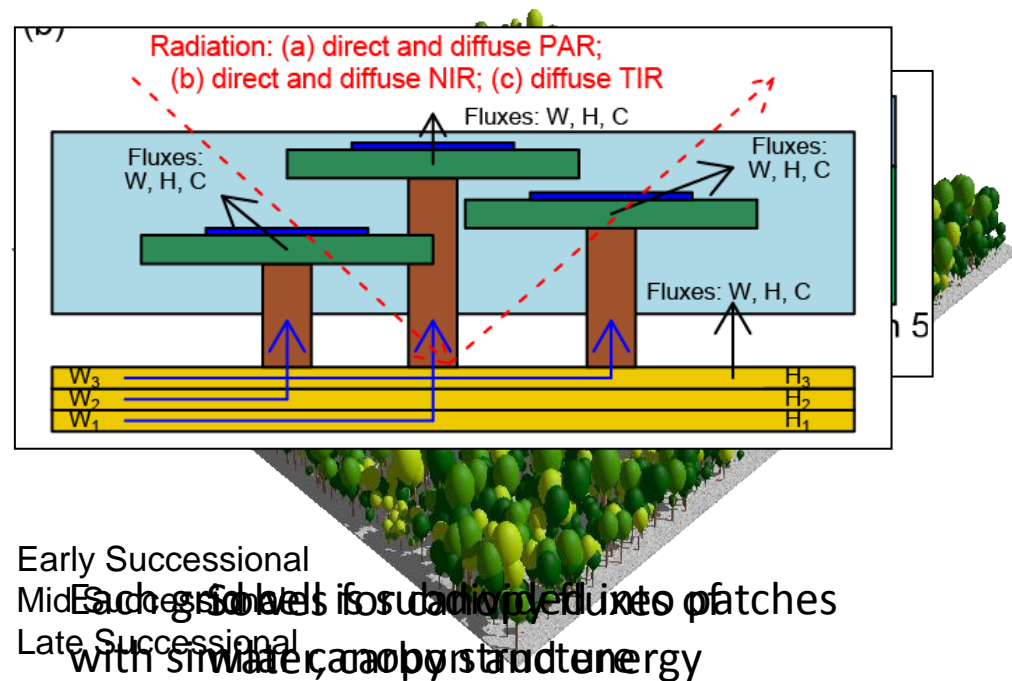
STREAMFLOW
OF RIVERS

MSUI
(Energy Simulation
Model)

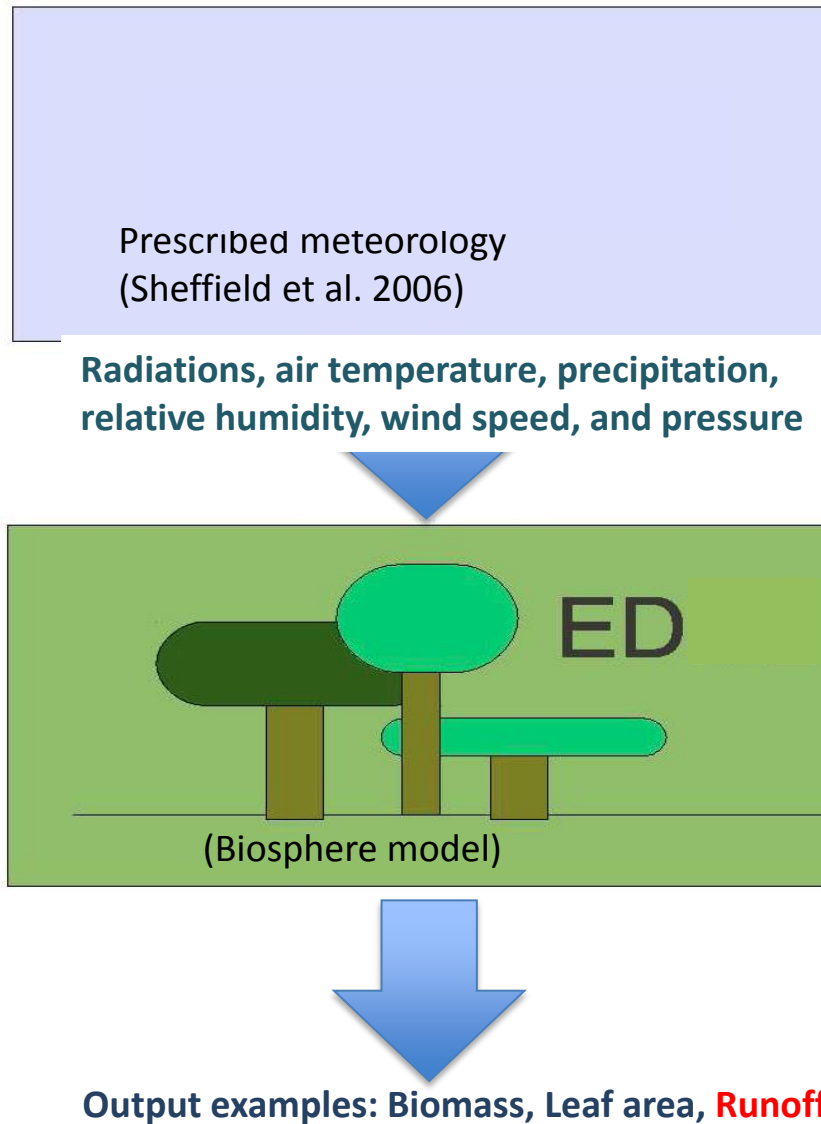


Ecosystem Demography (ED) model

- Terrestrial **Biosphere** model
- Capable of representing dynamic fine-scale **heterogeneity** in ecosystem composition, structure and function
- Has been demonstrated to be ideal for studying impacts of land use changes
- Has been evaluated against the observations in the Amazon

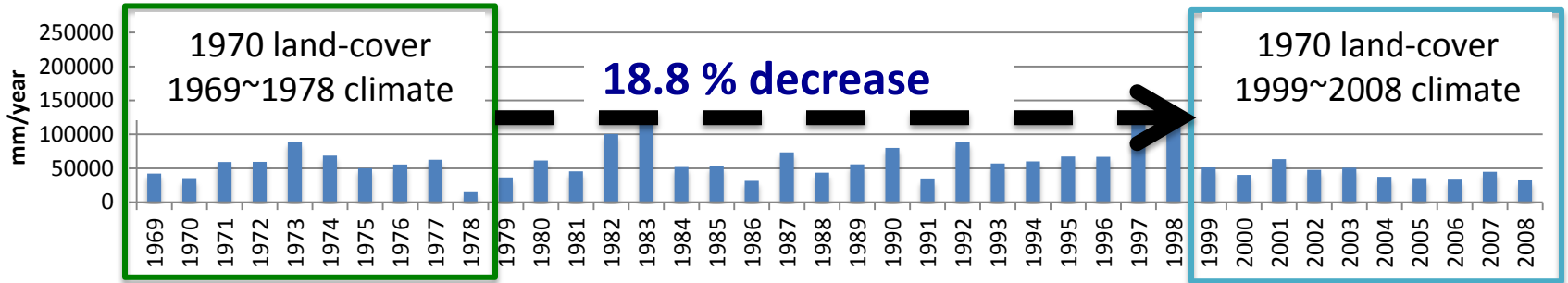


How does a biosphere model work?



Modeled runoff reproduces the natural stream flow increase

Case 1: Annual runoff with land-cover of year 1970



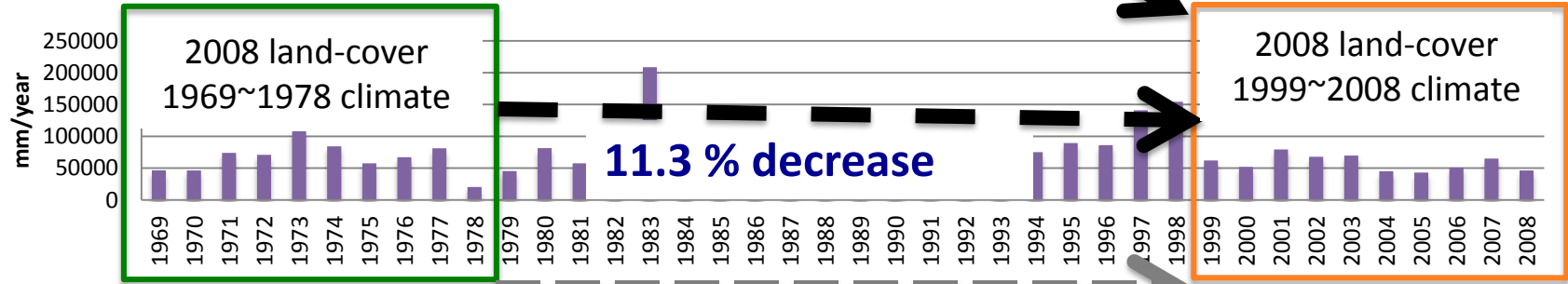
24.4 % increase

8.5 % increase

(cf) 10.5% increase
in natural stream flow

33.6 % increase

Case 2: Annual runoff with land-cover of year 2008

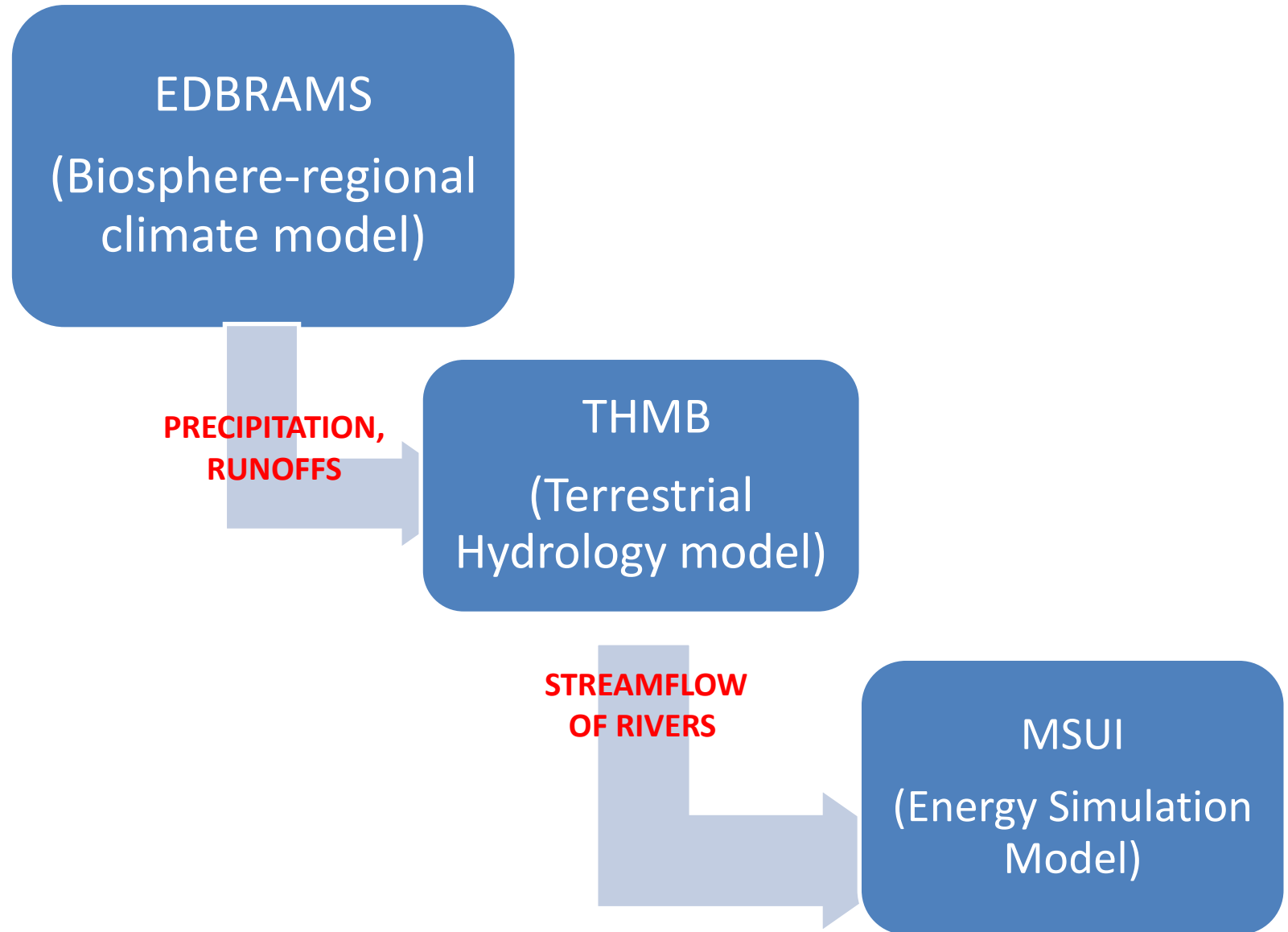


6.9% decrease in rainfall

Parana paradox result

- Our findings using the ED model
 - Model reproduces the observed phenomena!
 - The model gives an increase in the decadal average of runoff by 8.5%, from the 1970s to 2000s. This agrees well with 10.5% increase in the actual stream flow as measured at Itaipu.
 - Puzzle is solved!
 - The increase in stream flow is mainly attributed to land-cover change.

Ongoing and future work



Tapajós river basin

- In the heart of the Amazon
- More than 8 hydropower plants are planned in next 10 years



Take-home messages

- Water is very crucial in the processes of the atmosphere-land interactions
- Current and predicted deforestation alters the water cycle under anticipated climate change.
- Change in rainfall patterns will challenge the Brazilian energy sector as it heavily relies upon the hydroelectric power generation.

Thank you!



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