Global Issues and Basic Research: the Future of Amazonian Forests in a Changing Climate

World-class Academic partnership

THE UNIVERSITY OF ARIZONA.

VE RI TAS HARVARD

University of São Paulo

USP

Embrapa
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Environmental photography, Jake Bryant

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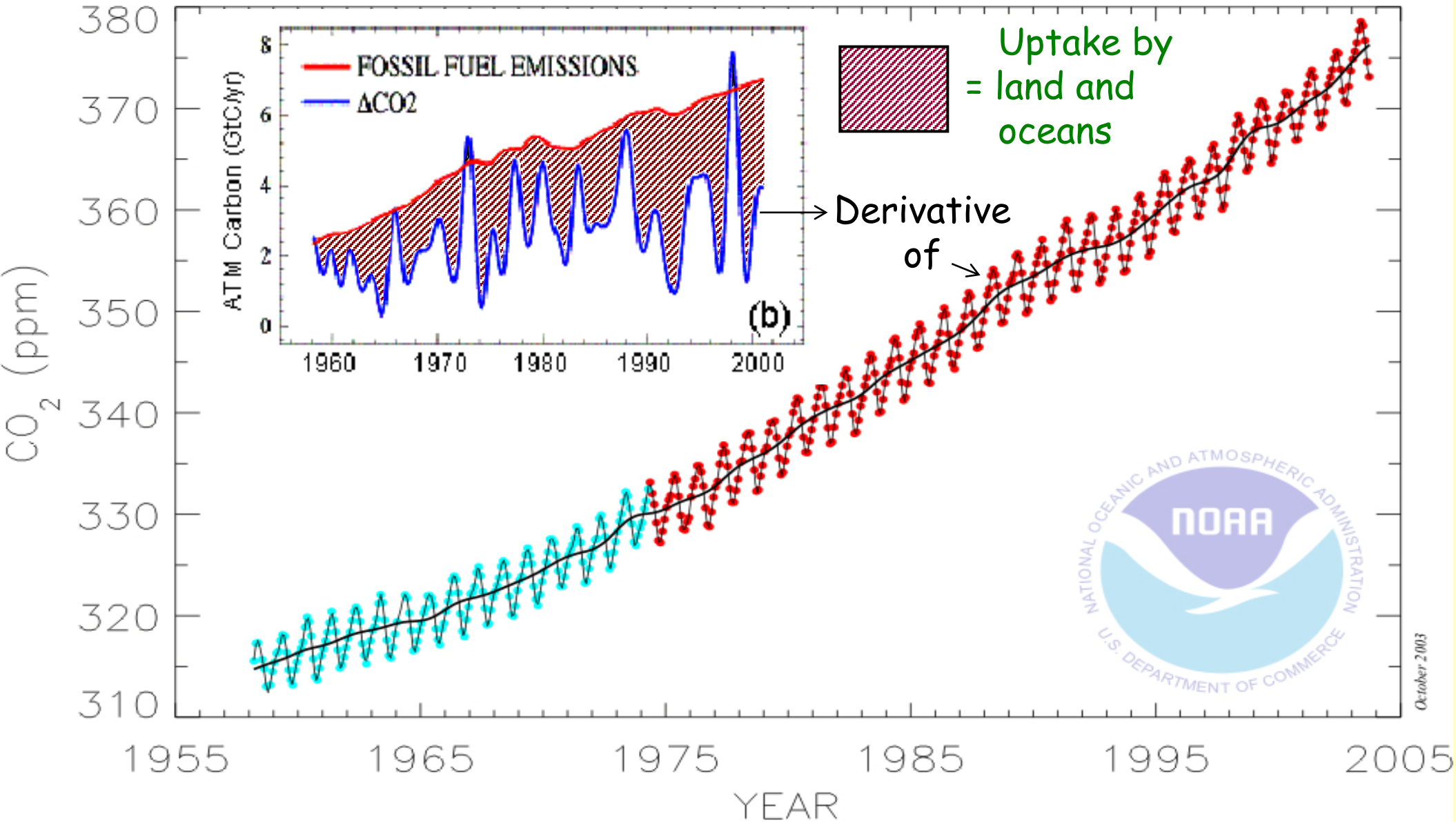
A. Problem: The sustainability of the global carbon sink

B. Three research questions for Amazon-PIRE

C. What is the "added value" of NSF-PIRE for addressing sustainability questions in the Amazon?

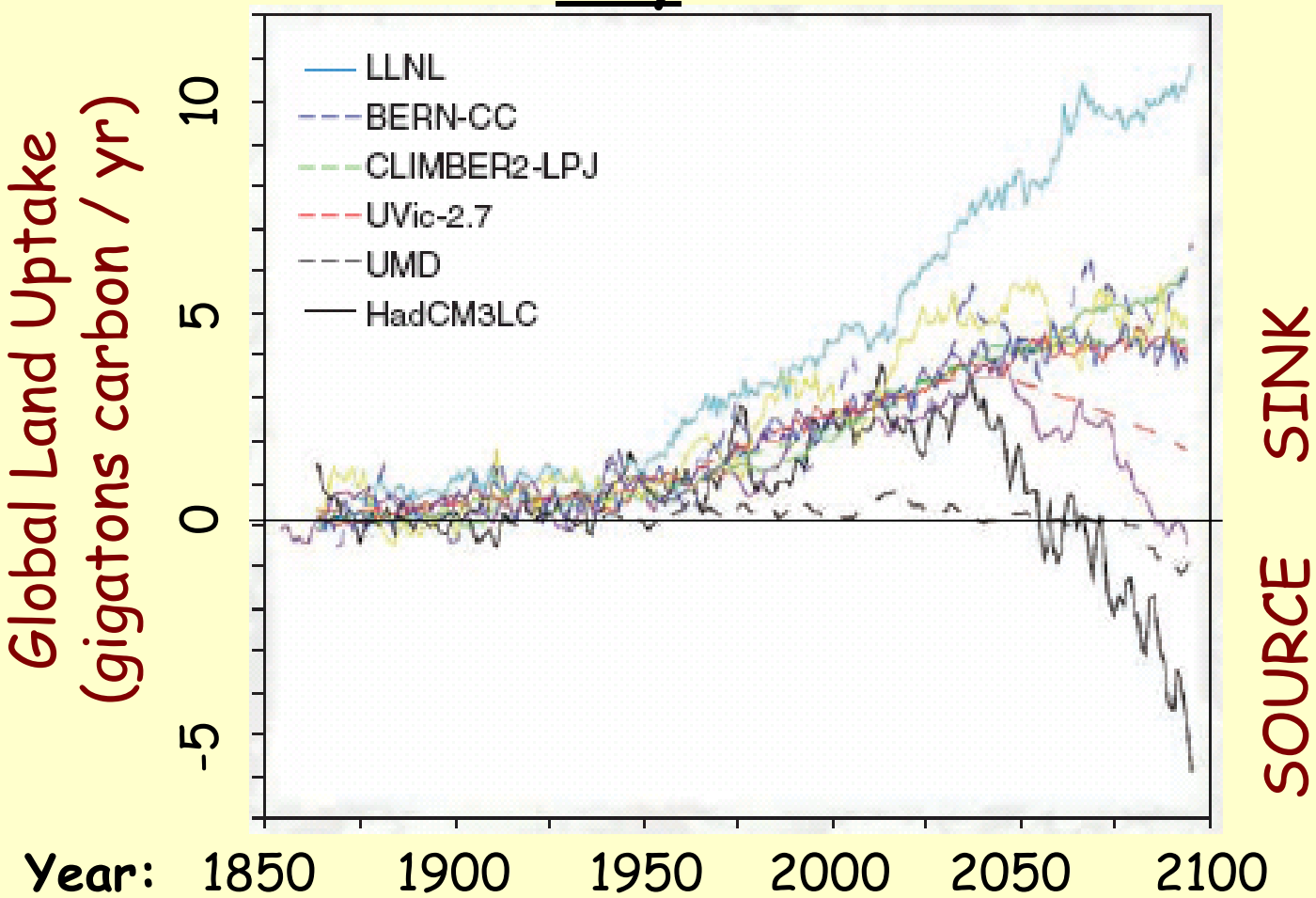
Environmental photography, Jake Bryant

Mauna Loa Monthly Mean Carbon Dioxide



How sustainable is the global terrestrial carbon sink (~2 Gt C/yr in 90s) under climate change?

Dynamic Global Vegetation Models of terrestrial carbon sink show <u>very</u> wide variation



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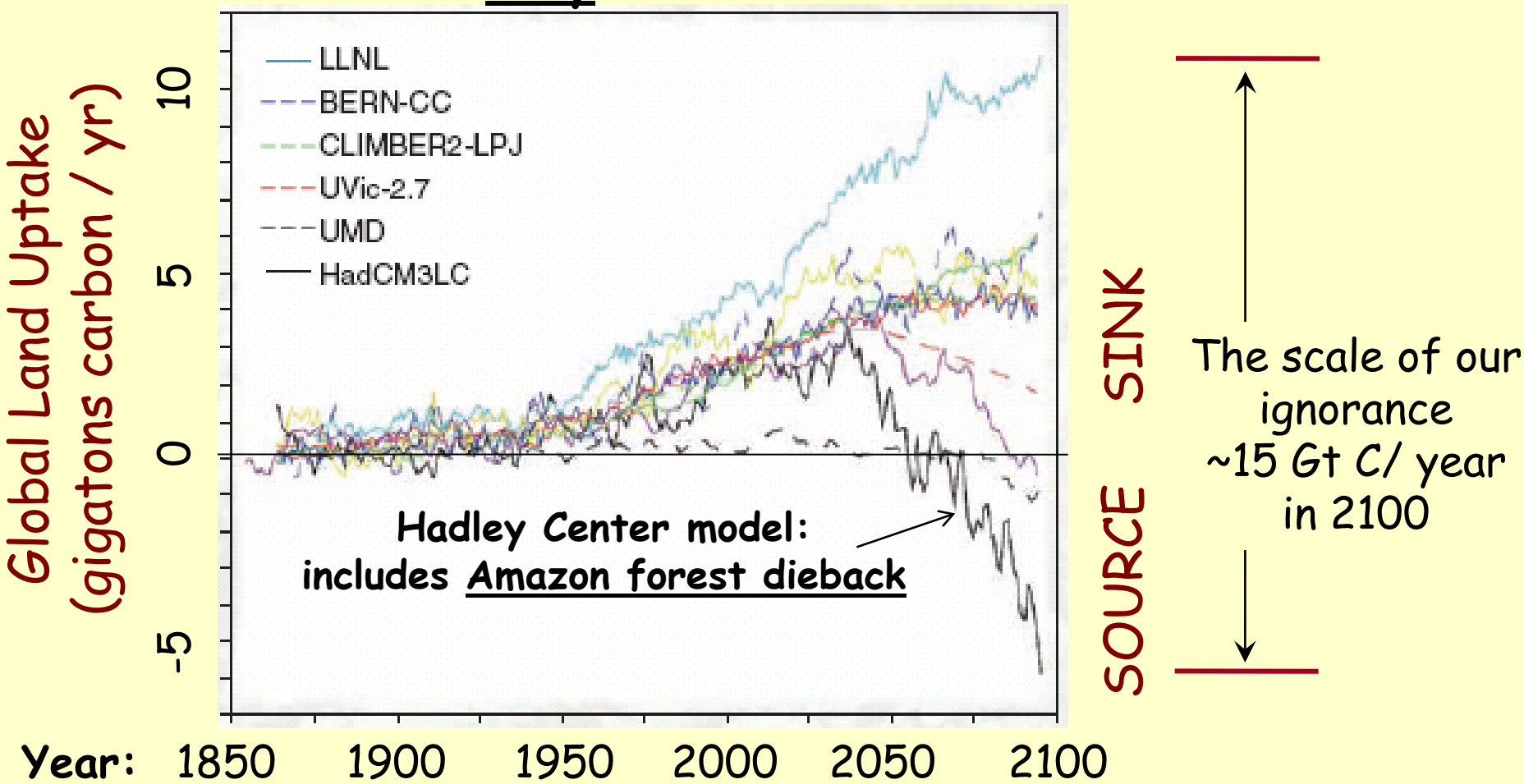

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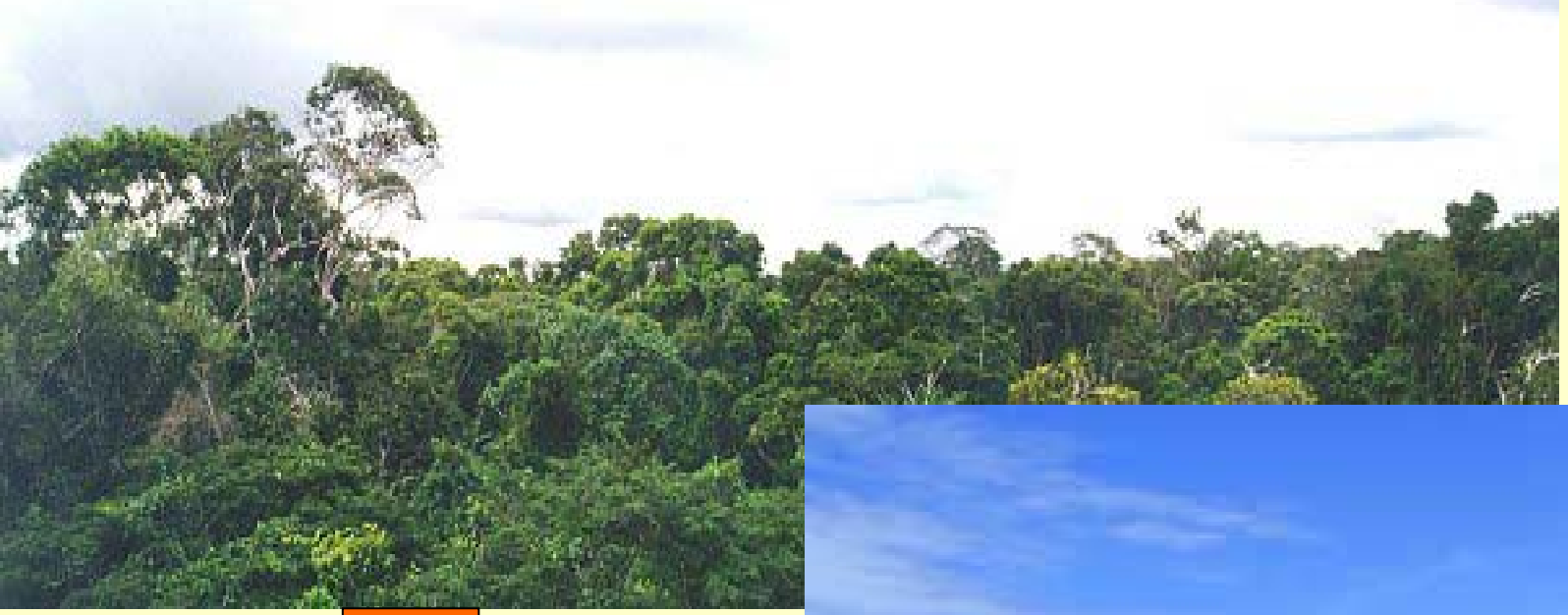
The future of Amazon forests under climate change:



??

Three research questions for Amazon PIRE

1. What is the carbon balance of Amazonian forest?
2. How do Amazonian forests respond to climatic variability?
3. What is the future of Amazon forests under climate change?

(1) What is the carbon balance of Amazonian forest?

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growth stimulation by high CO_2 (Tian et al. 1998)

(2) Observations:

Biomass plot network of ~100 plots (many ~1 ha)

→ average uptake of 0.5 tC/ha/yr

(Phillips et al., 1998; Baker et al., 2004, Phillips et al., 2009)

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PROBLEM: landscape-scale heterogeneity in old-growth forest

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(a) captures and measures the heterogeneity at the landscape scale (so that it may be accounted for); or

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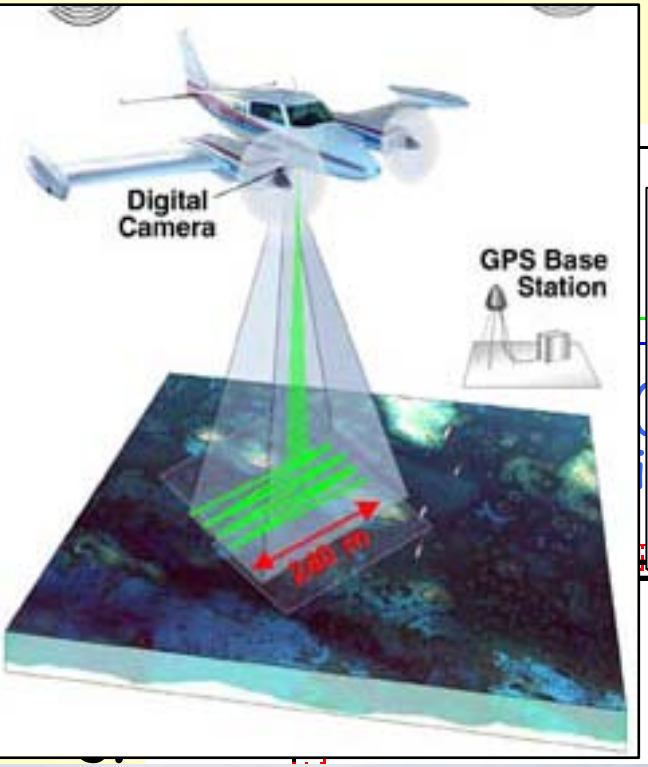

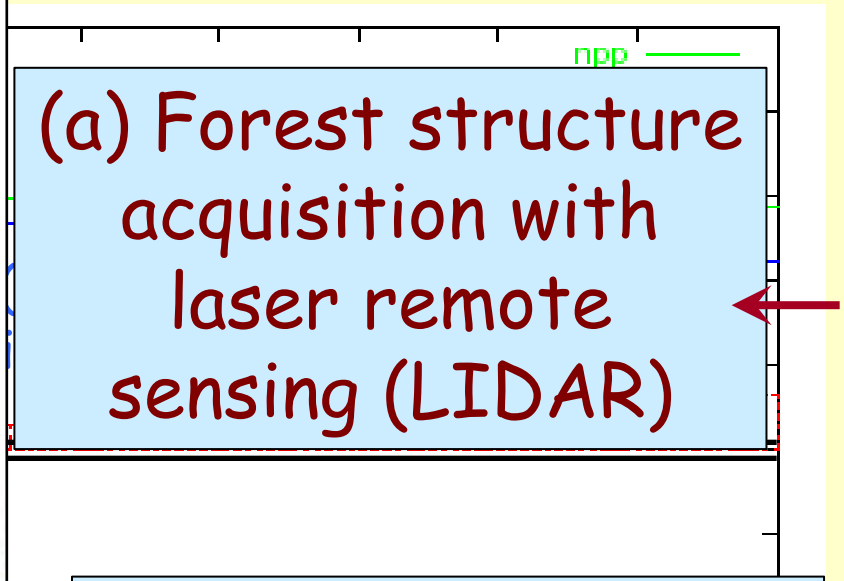

(a) Forest structure acquisition with laser remote sensing (LIDAR)

(b) Atmospheric CO_2 budgeting from aircraft profiles

Need an approach that either:

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(a) Aircraft & ground-based lasers to measure forest structure

© 2000-2008 The Evergreen State College, The Canopy Database Project and The International Canopy Network

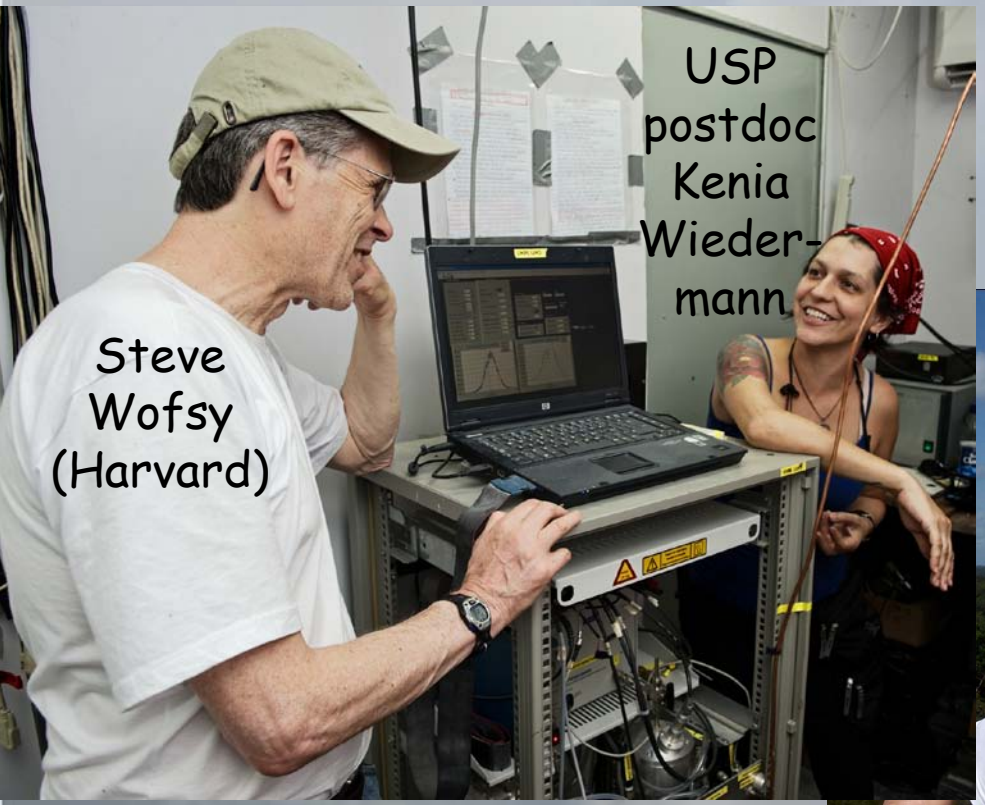
INPA Professor Flavia Costa (Brazil)

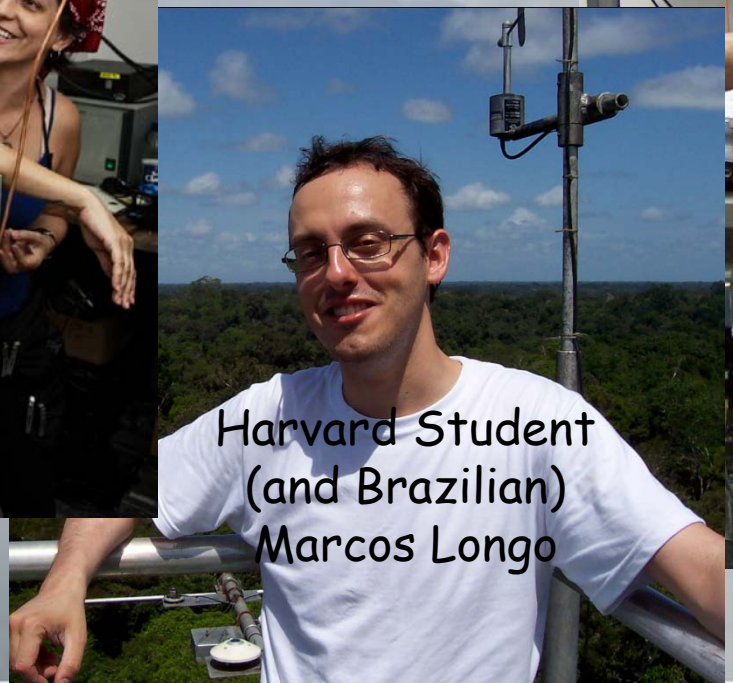
PIRE Fellow Scott Stark (UofA) INPA Student Juliana Schiet (Brazil)

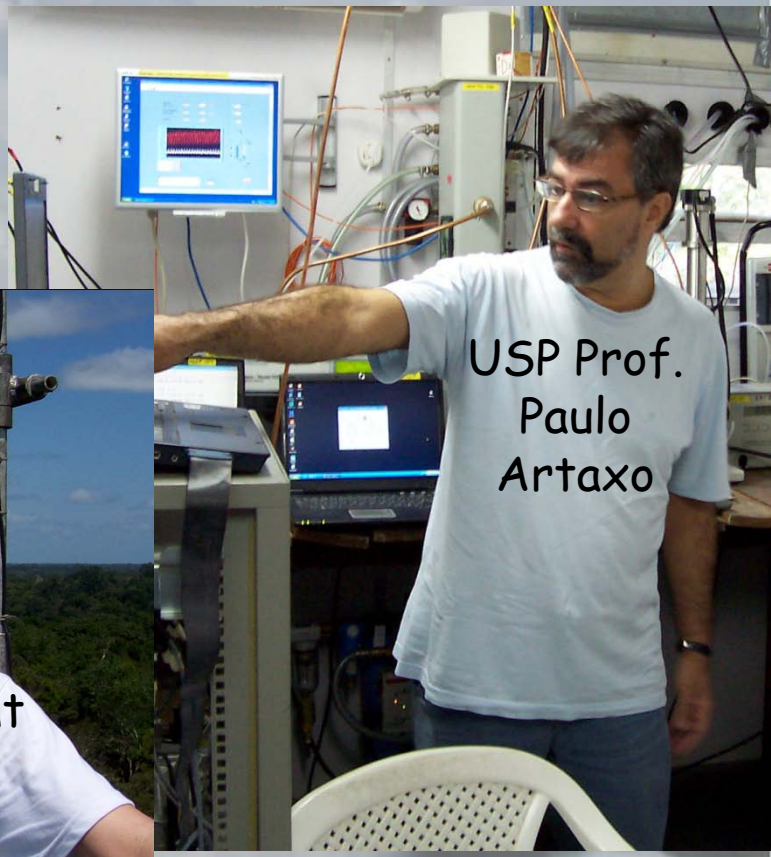
Co-funding: NSF Division of Environmental Biology (DEB), Ecosystem panel, and NASA

(b) BARCA Campaign

- **B**alanço **A**tmosférico **R**egional de **C**arbono na **A**mazônia
- Led by PIRE Co-PI Wofsy (Harvard), and Brazil Partner Artaxo (USP)







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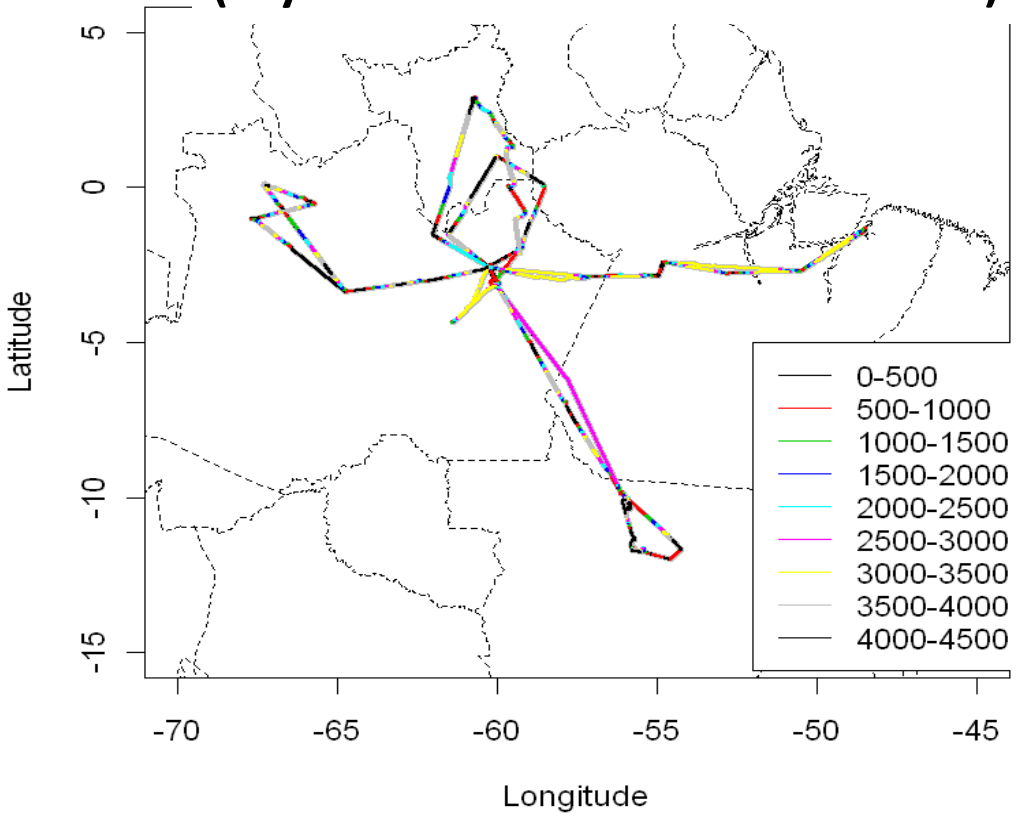
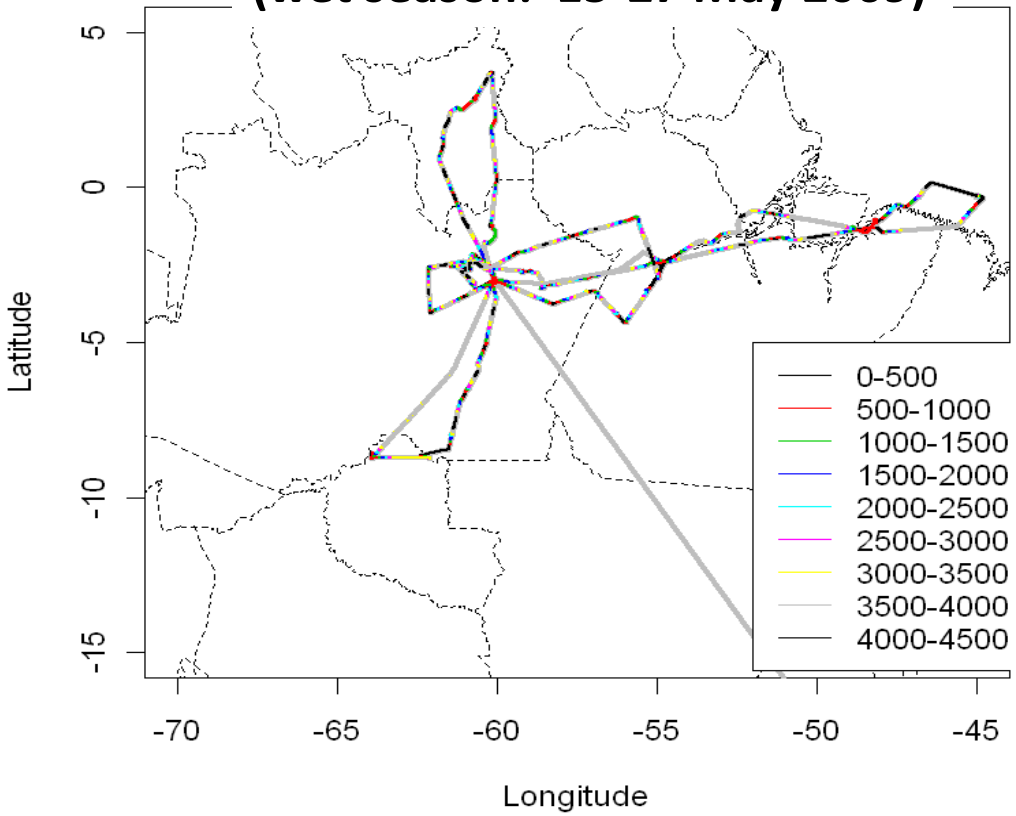
(dry season: 16-22 November 2008)



Phase B Flight Tracks
(wet season: 15-27 May 2009)



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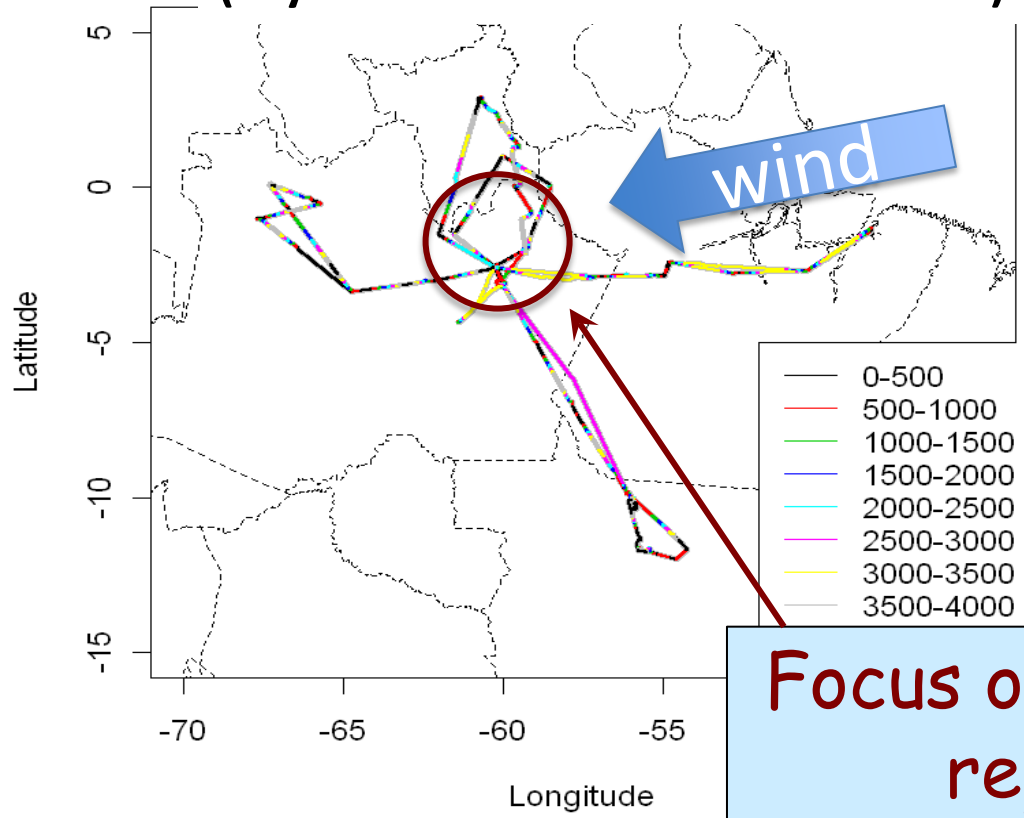

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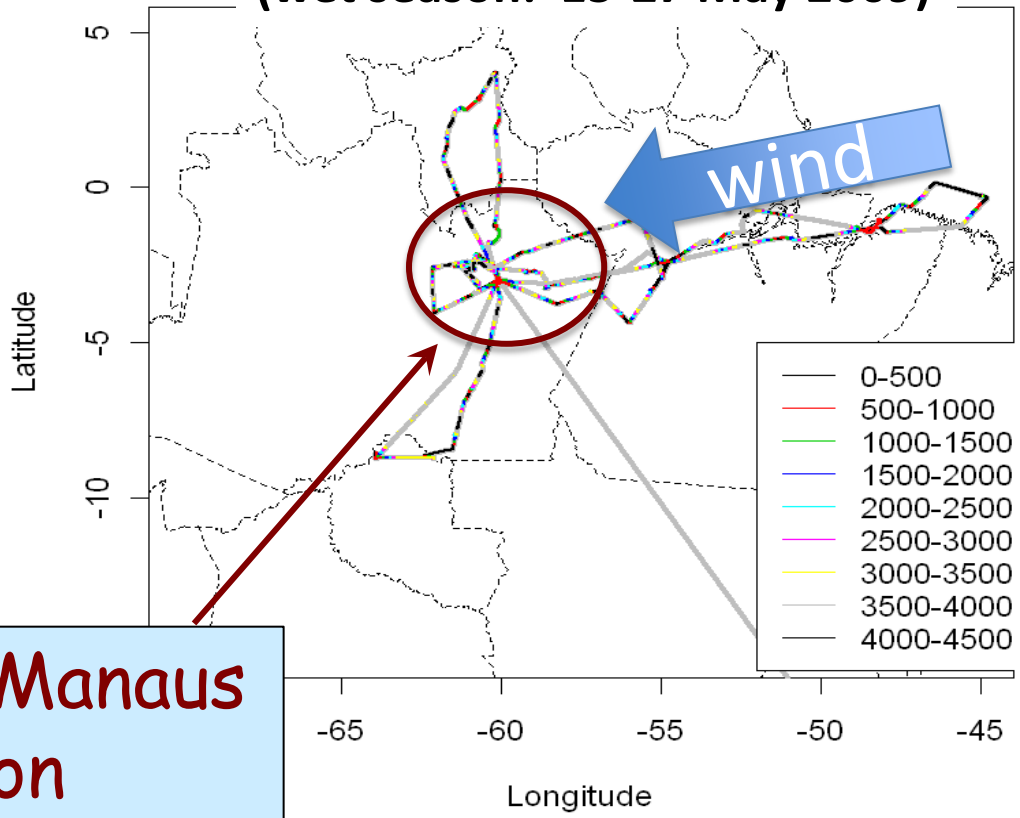
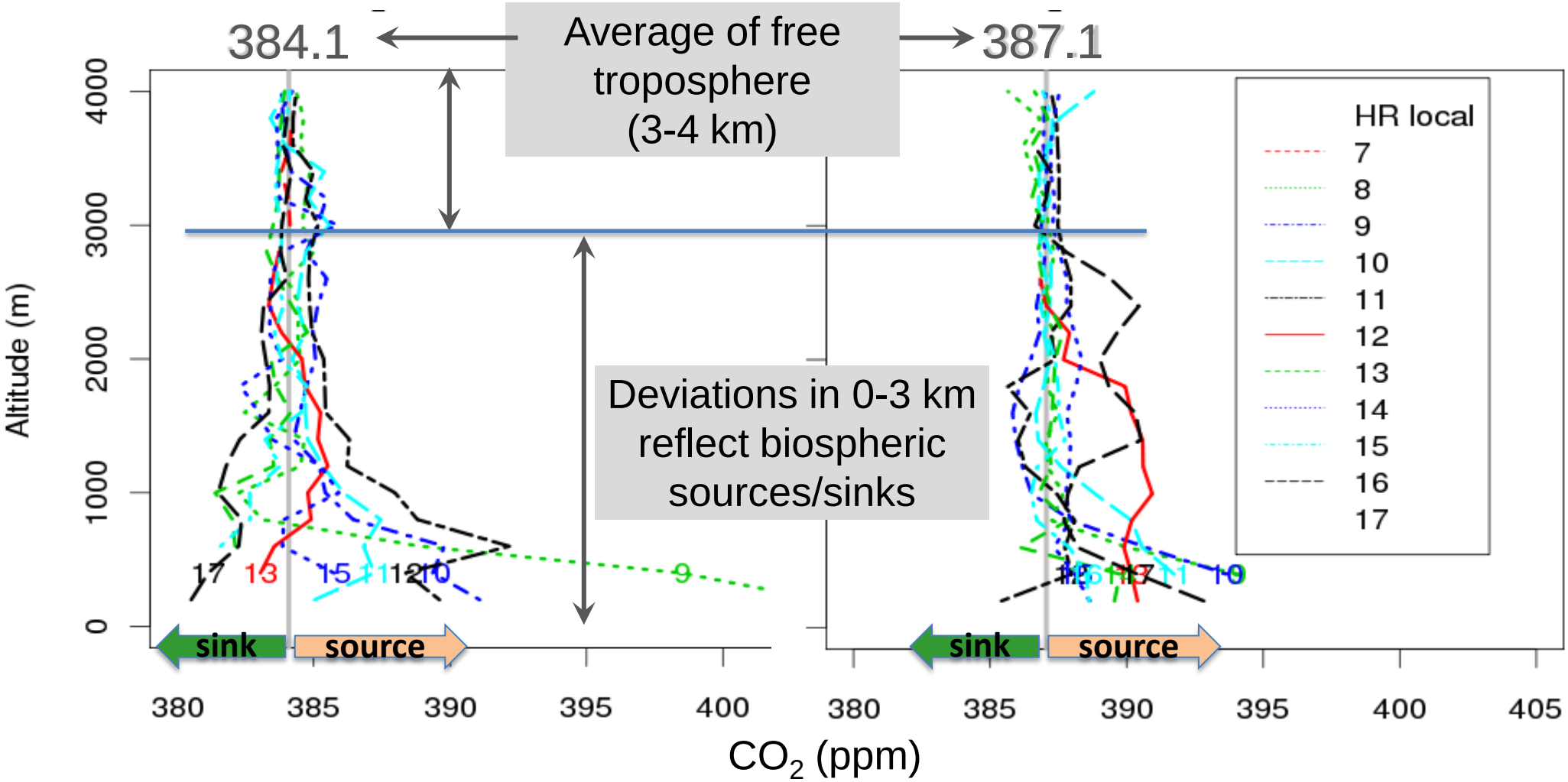


Focus on Manaus region

Manaus region CO_2 profiles (by hour of day)

A. Dry-season (16-22 November 2008)

B. Wet-season (15-27 May 2009)



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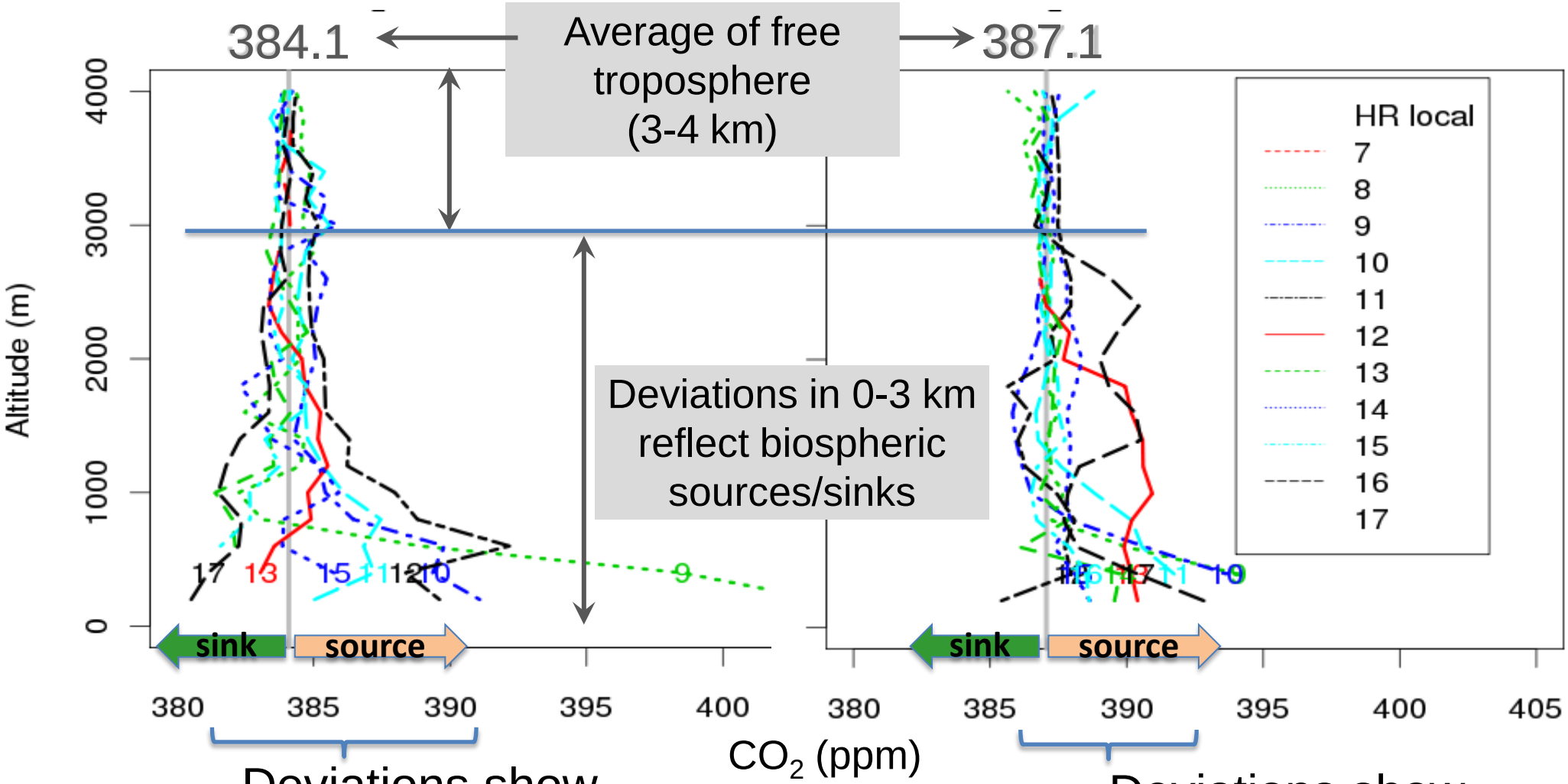
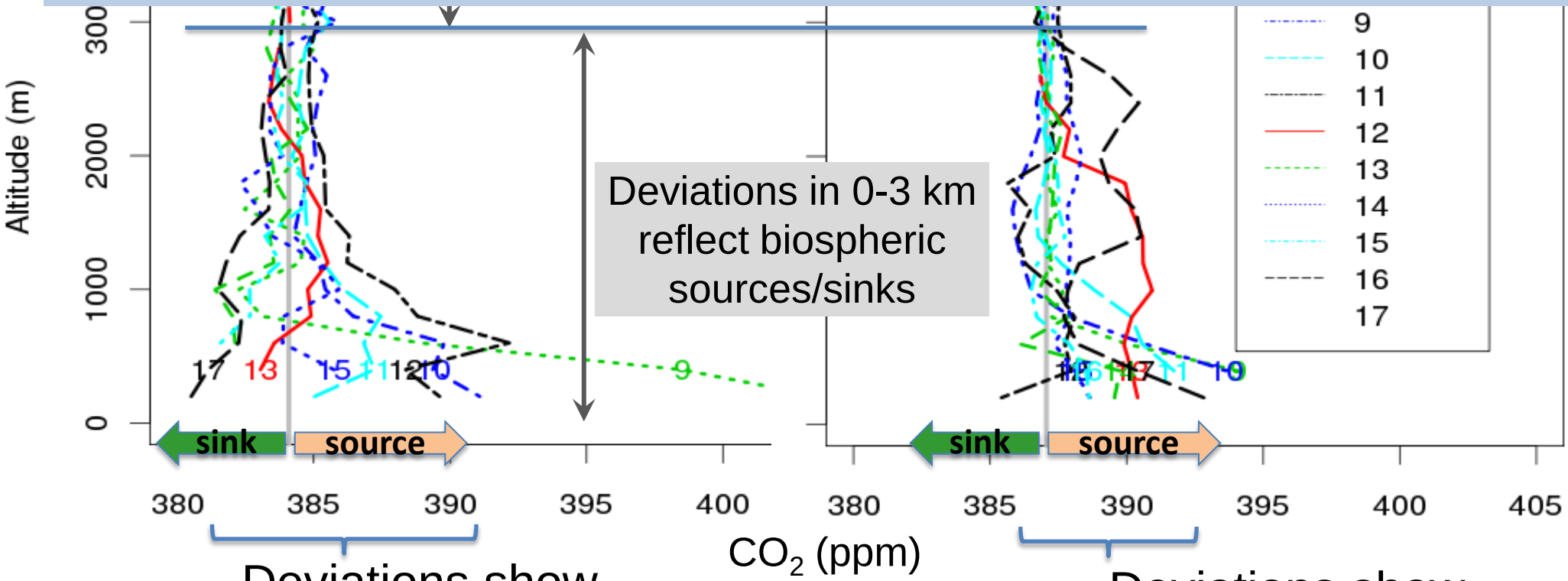


Deviations show biosphere to be neutral or a weak CO_2 source

Deviations show biosphere to be a <u>strong</u> CO_2 source

Manaus region CO_2 profiles (by hour of day)

Atmospheric measurements suggest a biospheric source of CO_2 on average in the eastern Amazon in 2008-2009
(a contrast to the network of ground-based plots which tend to show a sink for atmospheric CO_2)



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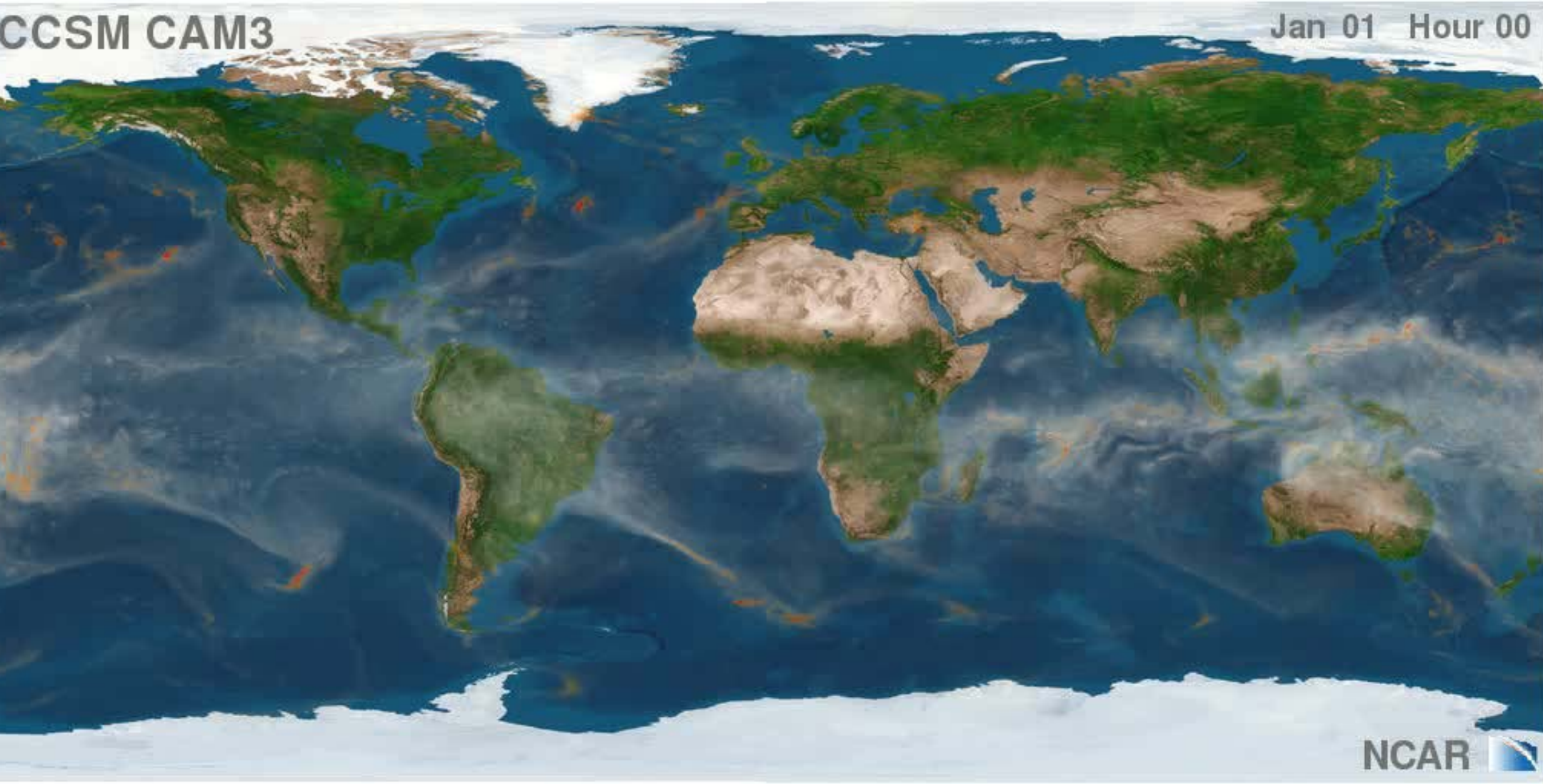
Deviations show biosphere to be a strong CO_2 source

Amazon-PIRE Question 2:

How do Amazon forests respond to climatic variability?

NCAR CCSM/CAM simulation: water vapor circulation (gray) and precipitation (orange flashes)



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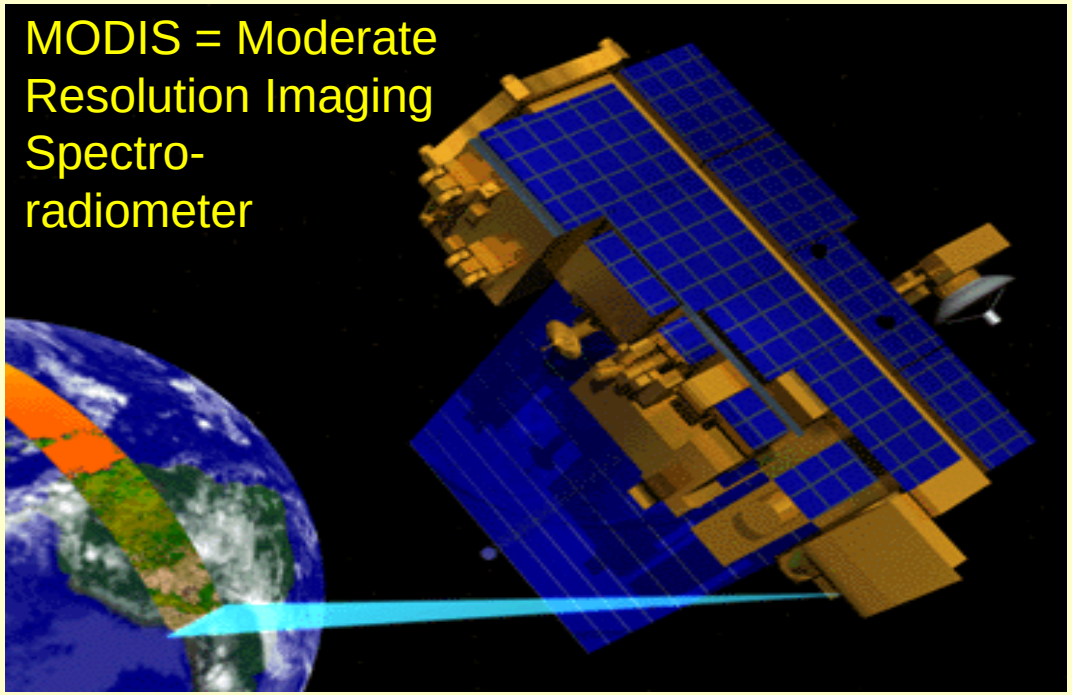
(a) Observations from Space

MODIS satellite instrument measures canopy "greenness" via Enhanced Vegetation Index (EVI)



EVI: based on reflectance in same spectral bands in which chlorophyll absorbs light (similar to NDVI, but does not saturate)

(b) Observations in the forest

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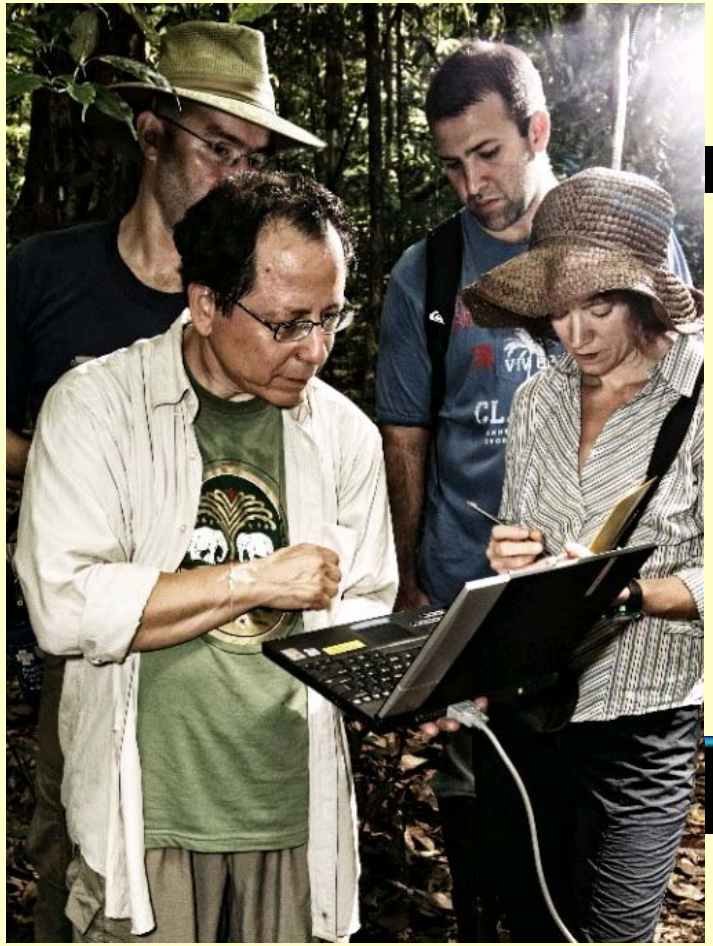
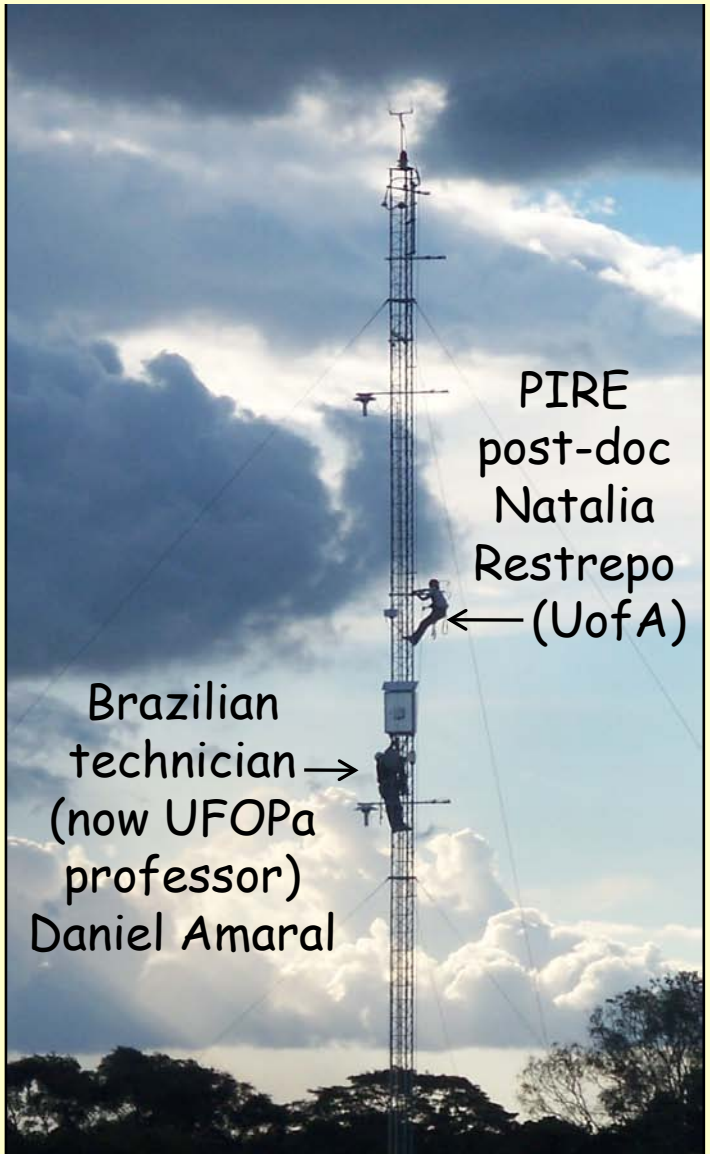


PIRE Co-PI Alfredo Huete with students in the field in Brazil (including PIRE fellow Cyndy Bresloff

(b) Observations in the forest



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26 OCTOBER 2007 VOL 318 SCIENCE

Amazon Forests Green-Up During 2005 Drought

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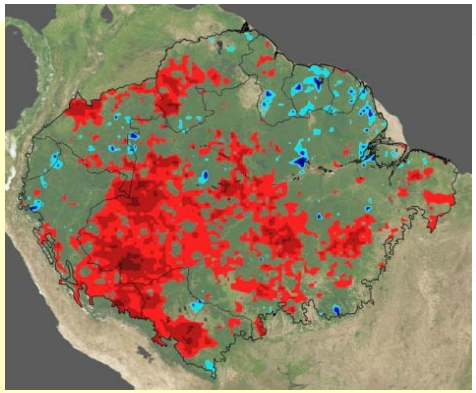
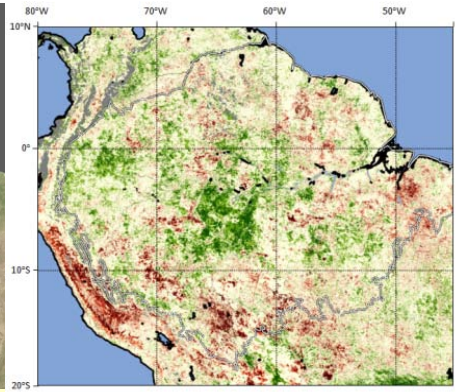


Drought map (red=drought)



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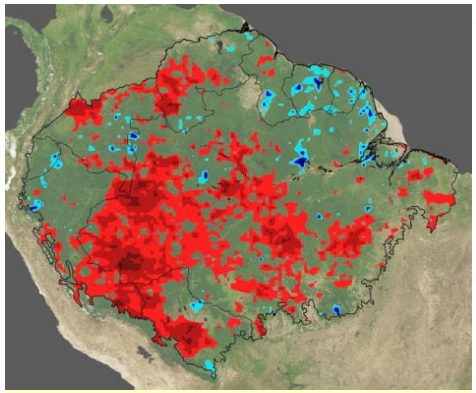

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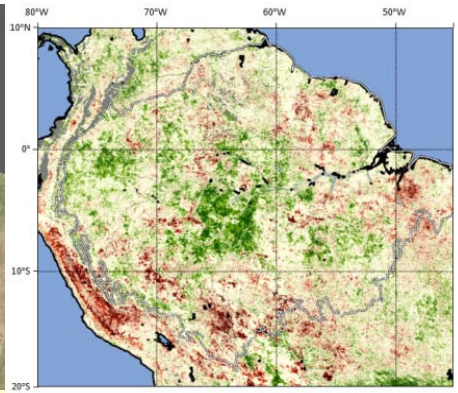

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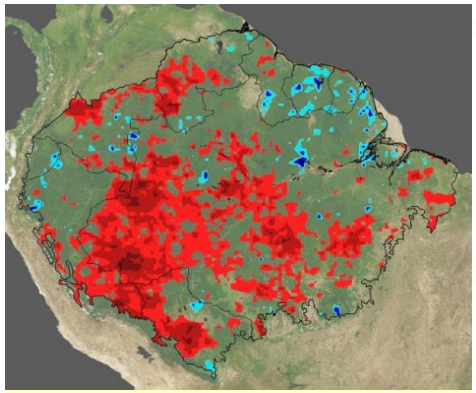

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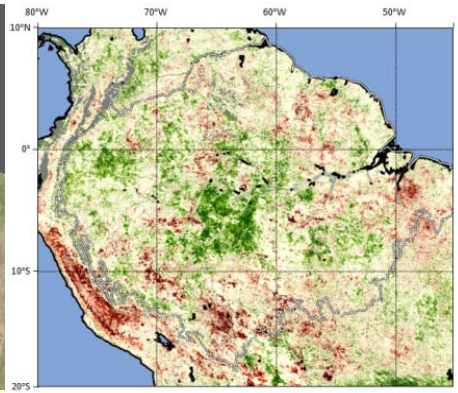

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GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L05401, 2010

Amazon forests did not green-up during the 2005 drought

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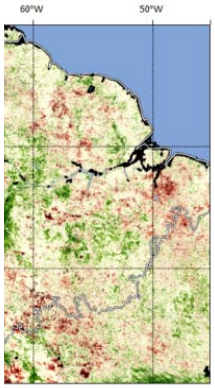

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401, 2010

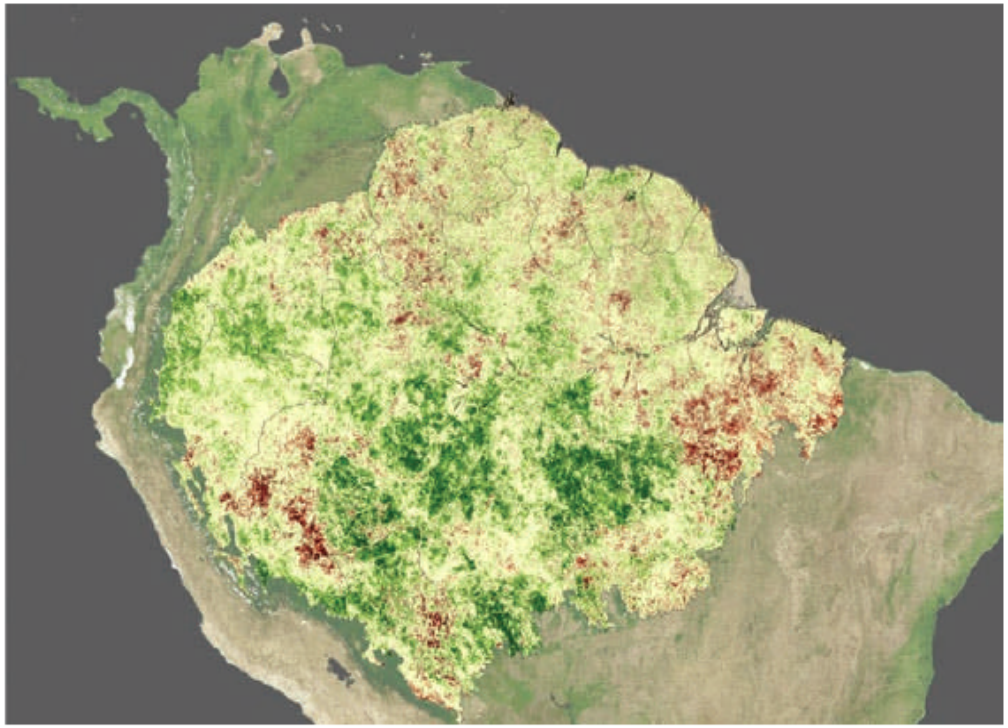
NATURE|Vol 466|22 July 2010 NEWS

Amazon drought raises research doubts

A once-in-a-century drought struck much of the Amazon rainforest in 2005, reducing rainfall by 60–75% in some areas — and giving scientists a window on to a future coloured by climate change.

The drought foreshadowed the Amazon drying that many climate modellers expect to see in a warmer world. But five years on, a spate of research, including 13 papers published on 20 July in a special issue of the journal *New Phytologist*, shows that researchers are still grappling with the impact of drought and what it could reveal about the fate of the world's largest tropical forest, a major carbon storehouse.

The debate began with a 2007 study[1] that used data gathered by NASA's Terra satellite to argue that the canopy of the Amazon rainforest grew and "greened up" during the drought — suggesting that the rainforest could be resilient to dryness, at least for short periods. The phenomenon can be attributed to fewer clouds and more sunlight. But in



K. DID AN, UNIV. ARIZONA

A controversial 2007 study found increased 'greening' in the Amazon rainforest during a drought in 2005.

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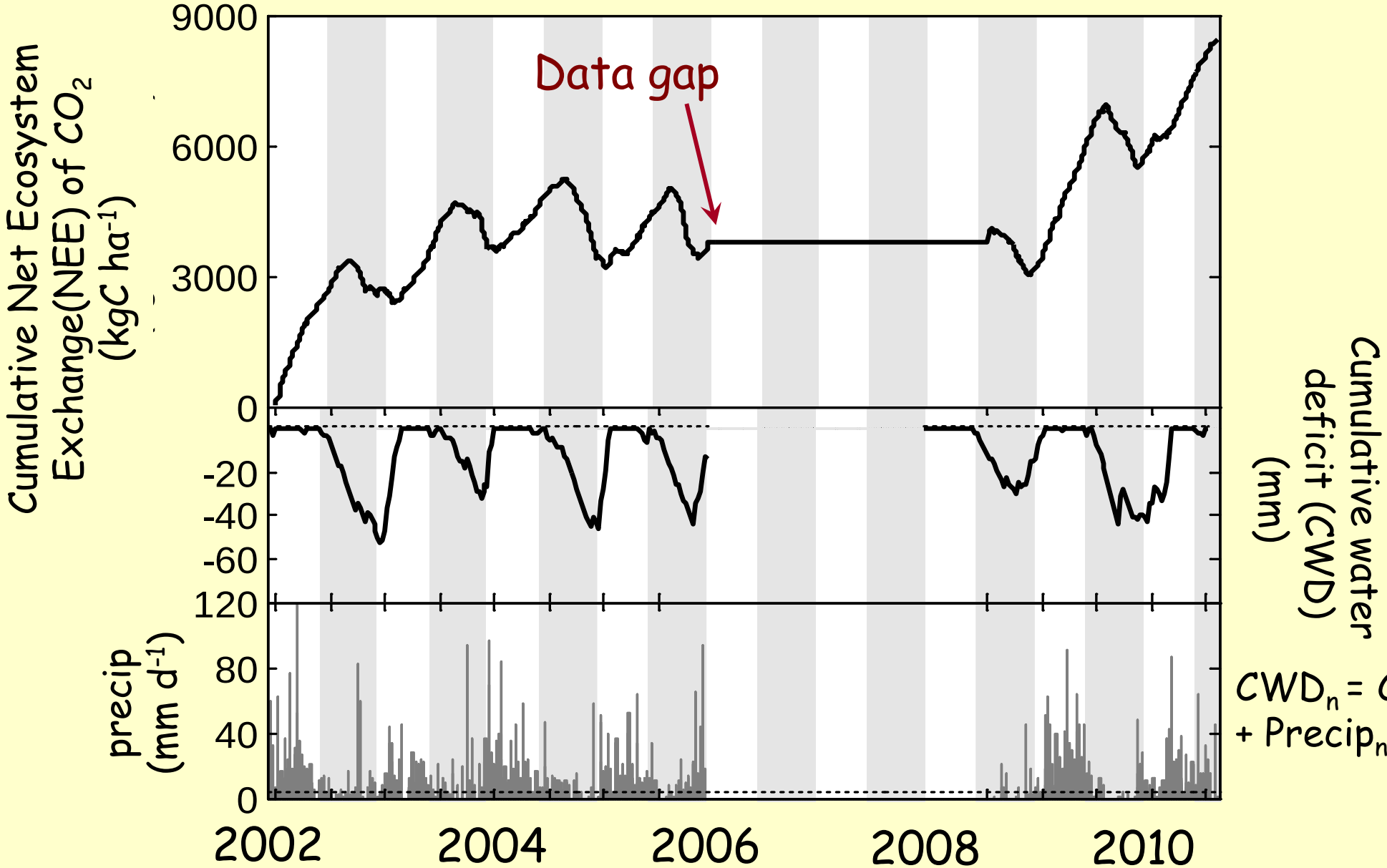
What is needed are long-term observations of <u>all three</u> of:

- Remote sensing of vegetation indices
- vegetation dynamics (from plot surveys) (as in Phillips et al.), and
- high resolution component fluxes (especially photosynthesis), from eddy flux towers

(b) Observations in the forest from PIRE tower: fluxes, to understand variation at climatically-relevant timescales



$CWD_n = CWD_{n-1} + Precip_n - ET_n$

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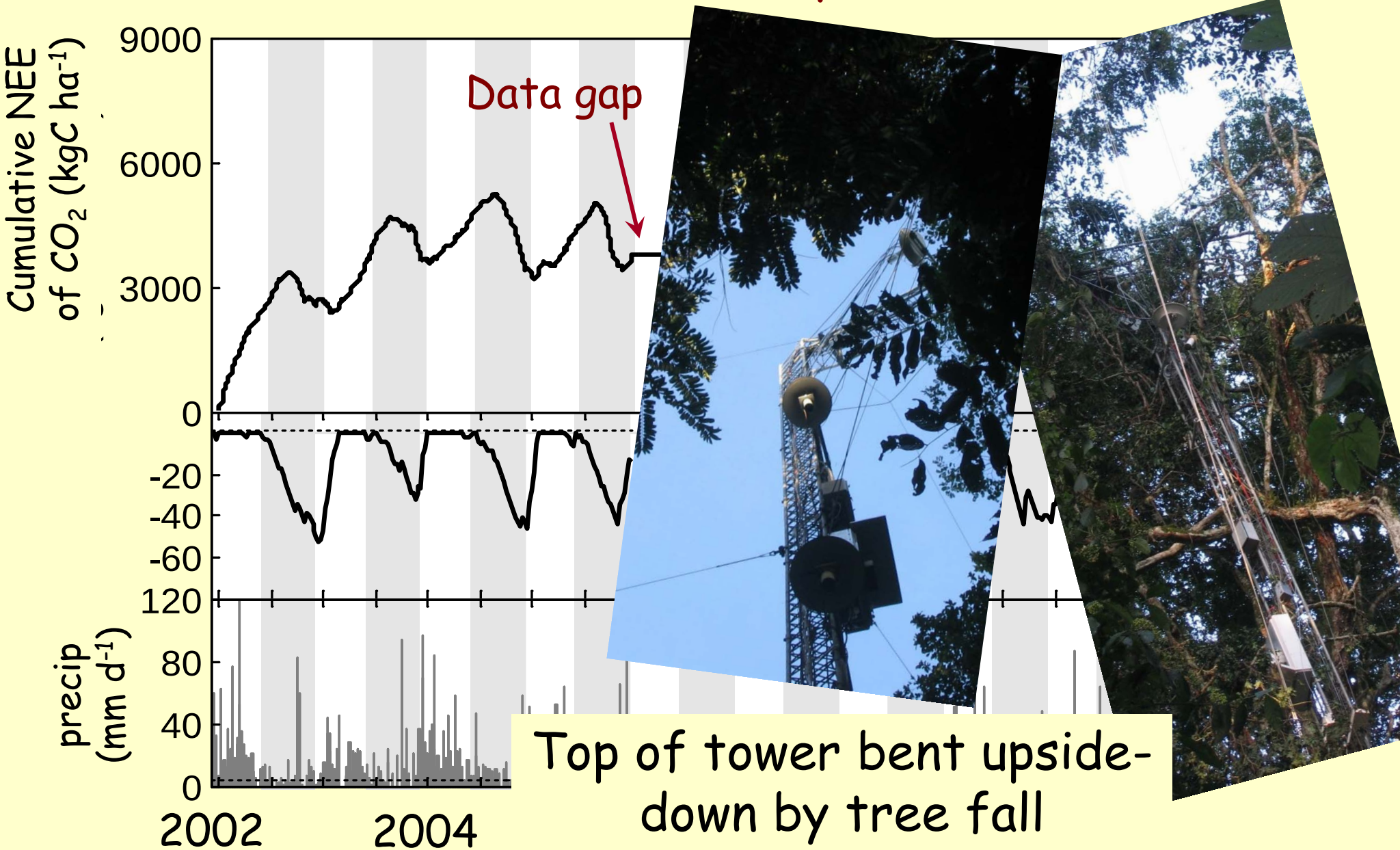
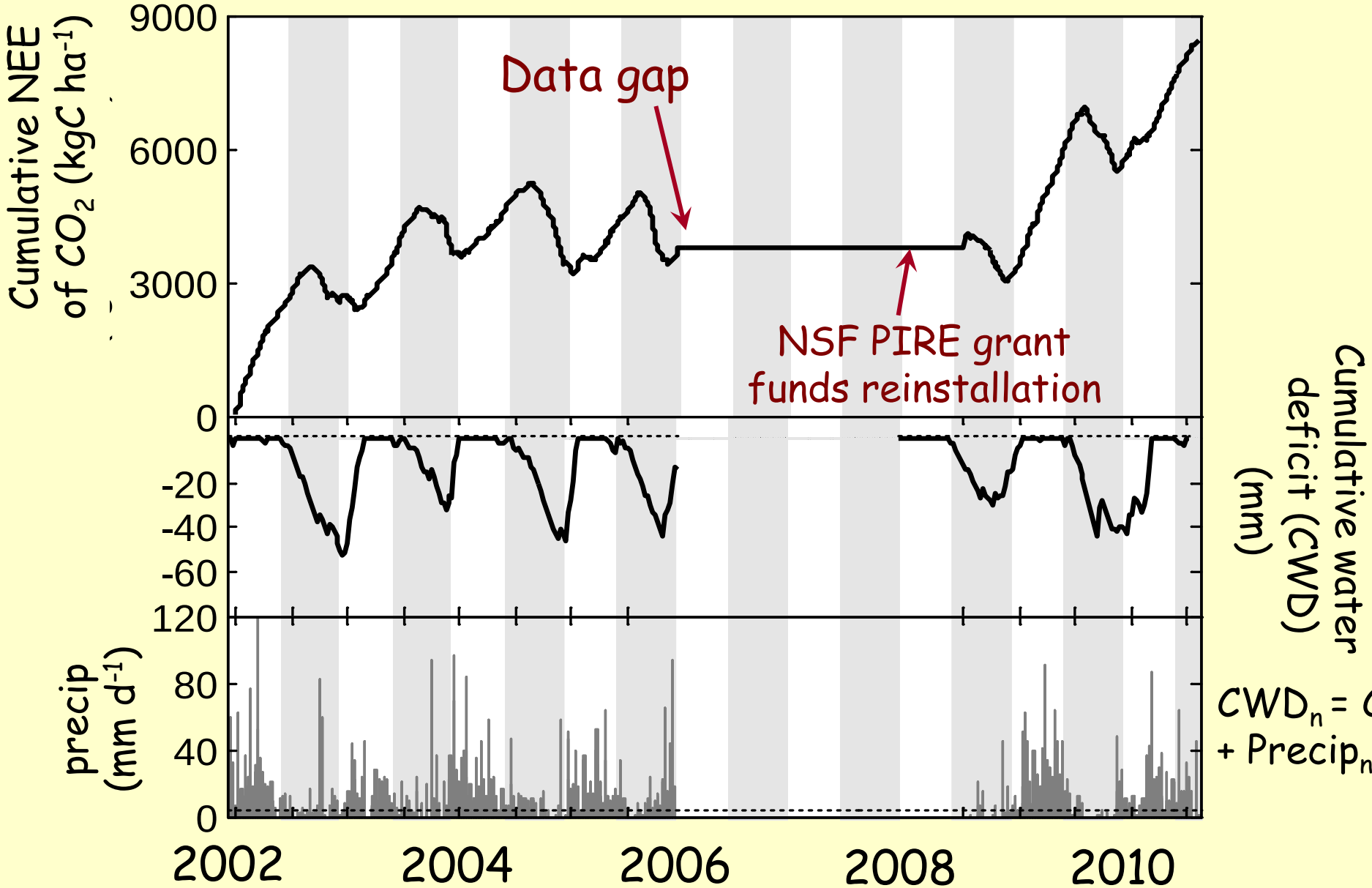


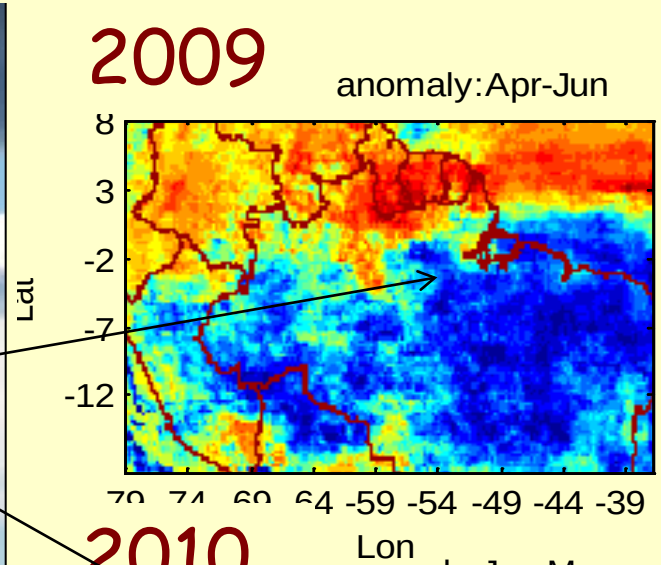
(b) Observations in the forest from PIRE tower: fluxes, to understand variation at climatically-relevant timescales

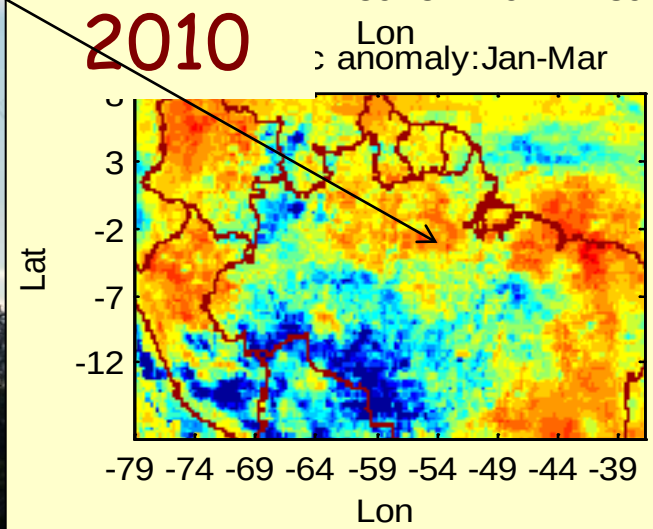


$CWD_n = CWD_{n-1} + Precip_n - ET_n$

The next test of mechanisms implicated by Saleska et al. vs. Phillips et al. apparent contrast:

Long-term observations of forest flux responses to interannual variability





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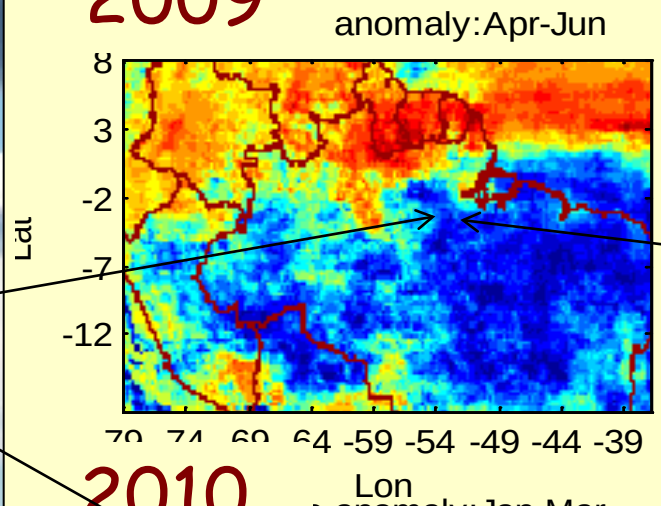
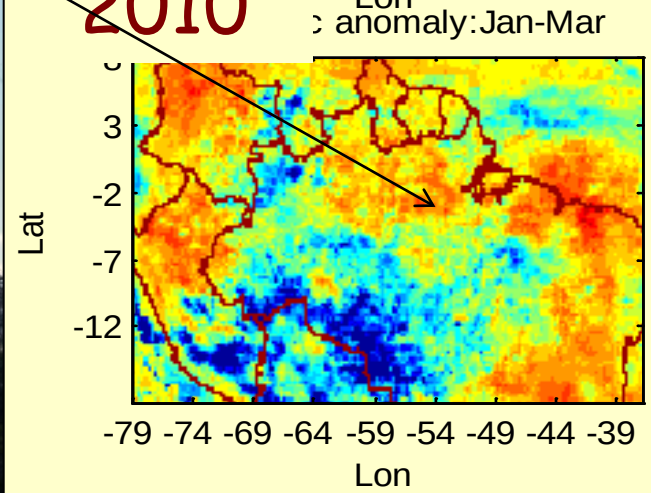
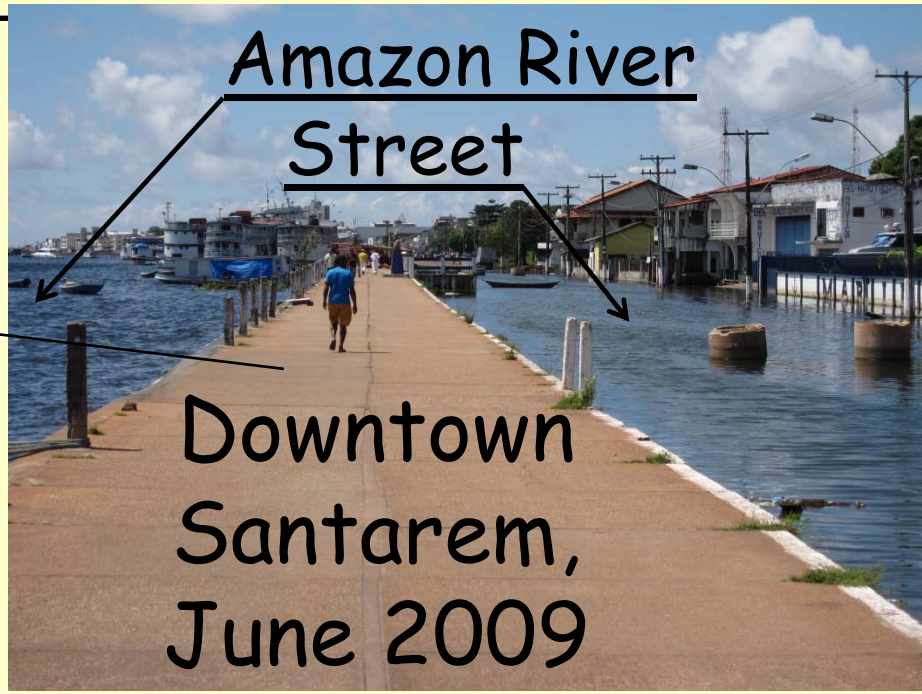
2009



2010





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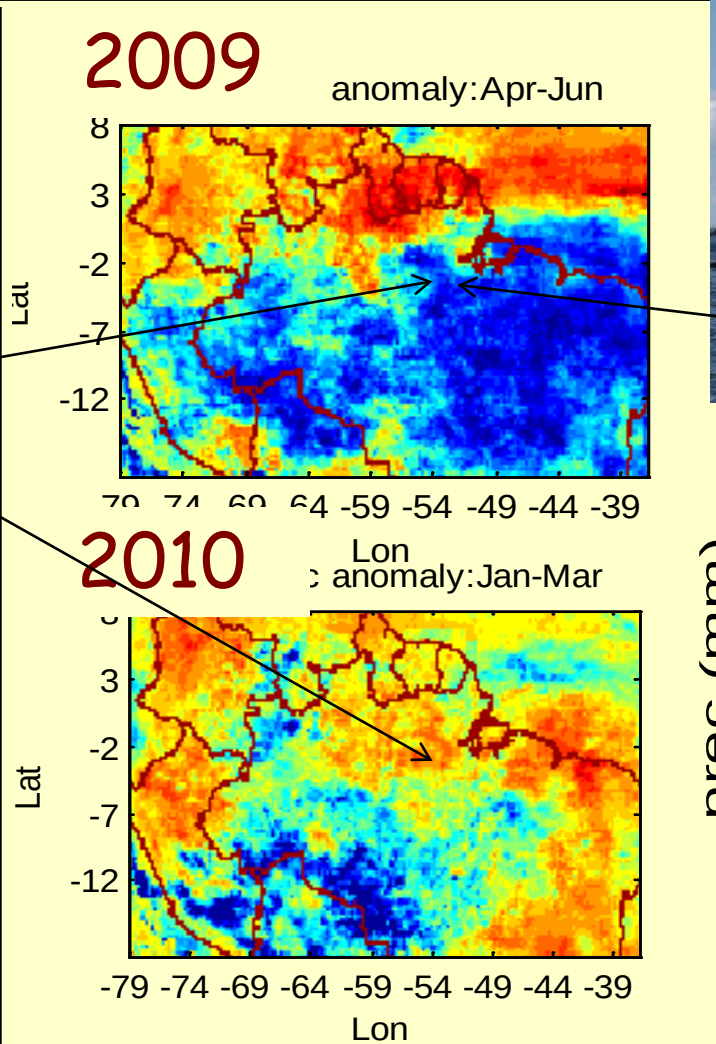
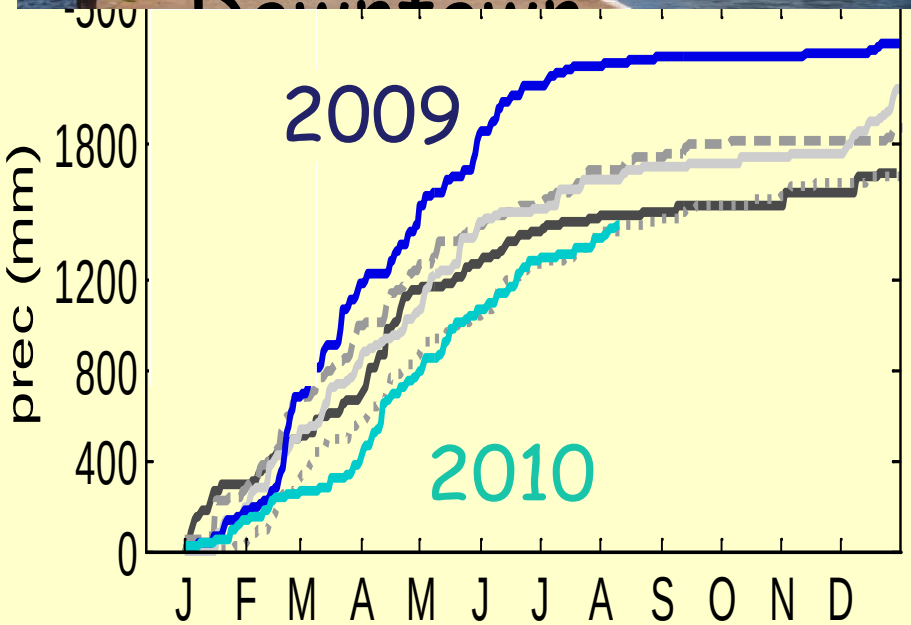
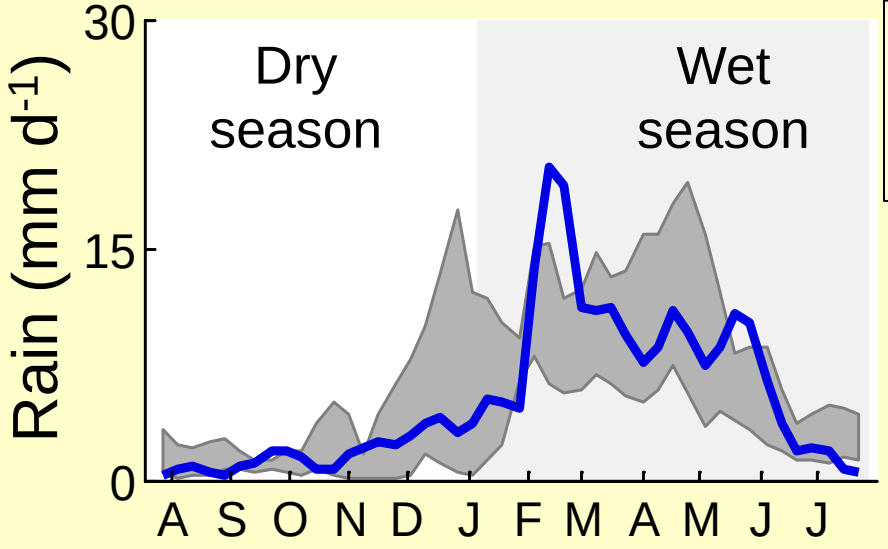




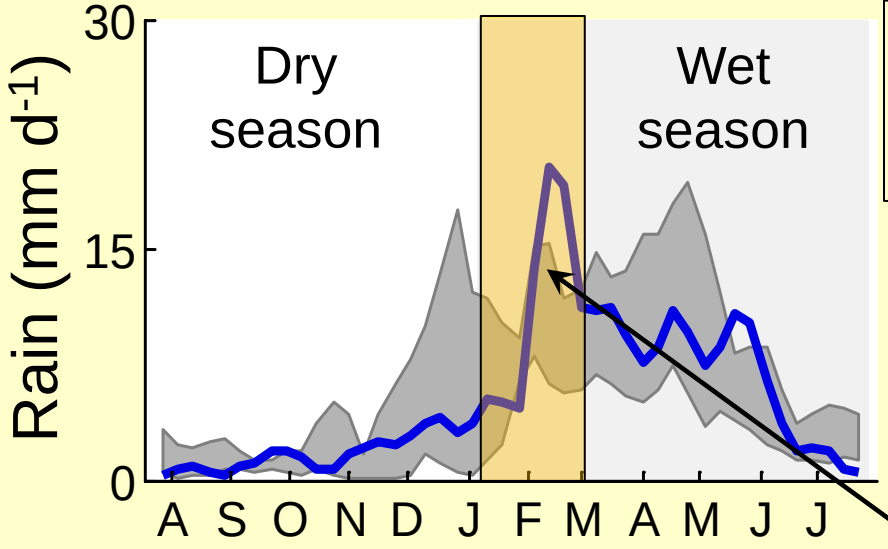
Annual cycles, August-July
Santarem PIRE Eddy Flux Tower



Range of 2002-2006

2008-2009

Annual cycles, August-July
Santarem PIRE Eddy Flux Tower



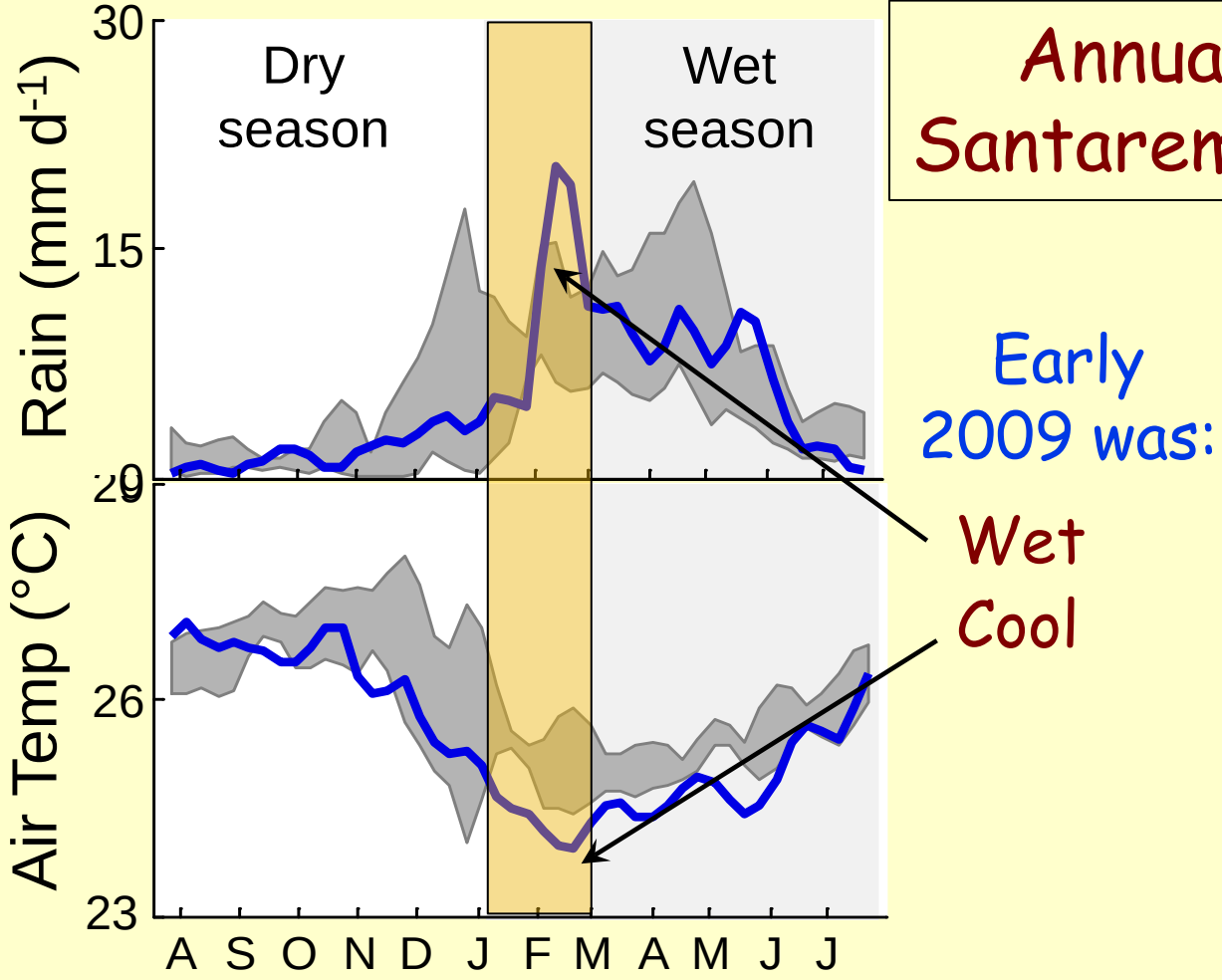
Early 2009 was:

Wet

Range of 2002-2006

2008-2009

Annual cycles, August-July
Santarem PIRE Eddy Flux Tower



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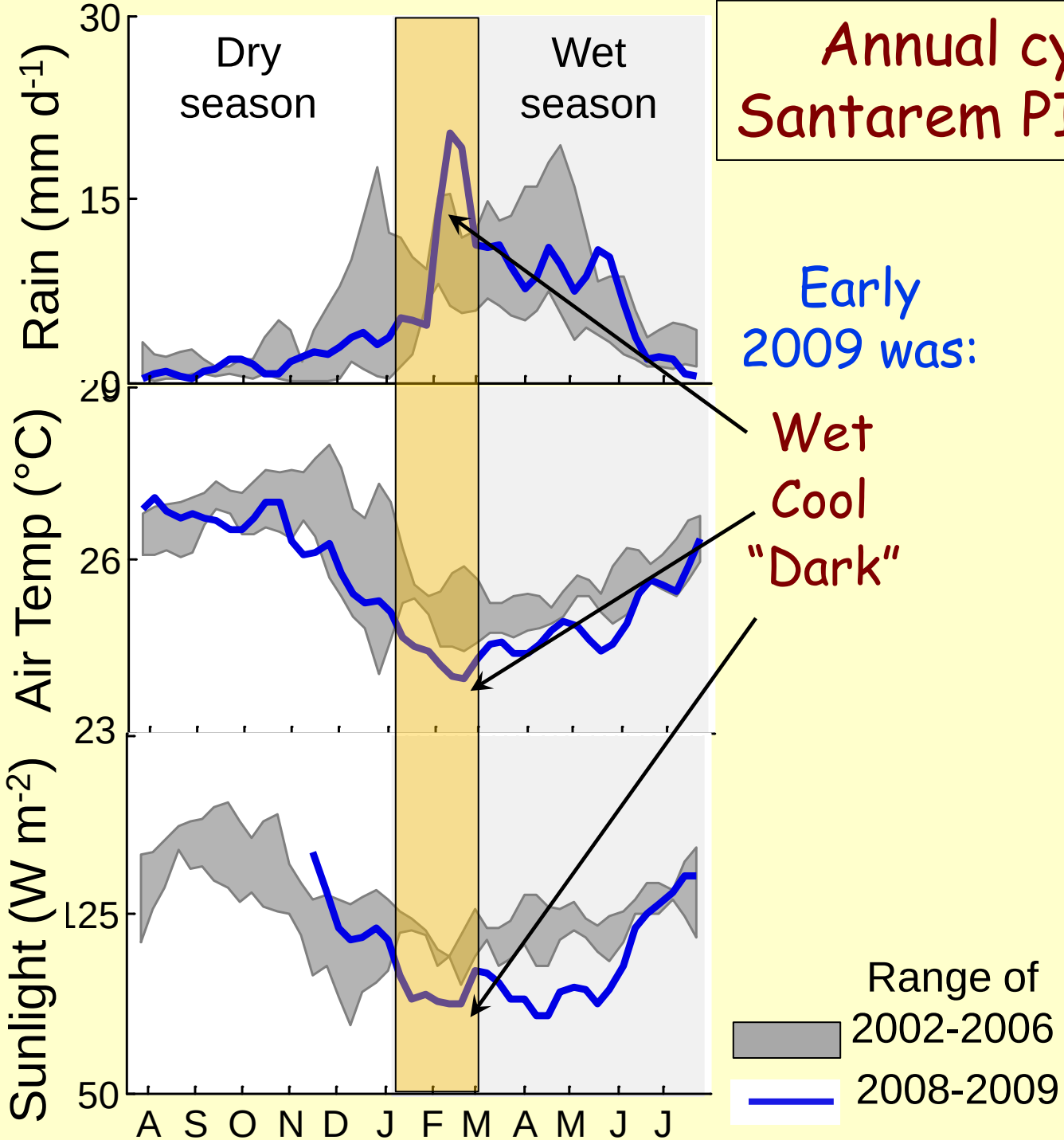

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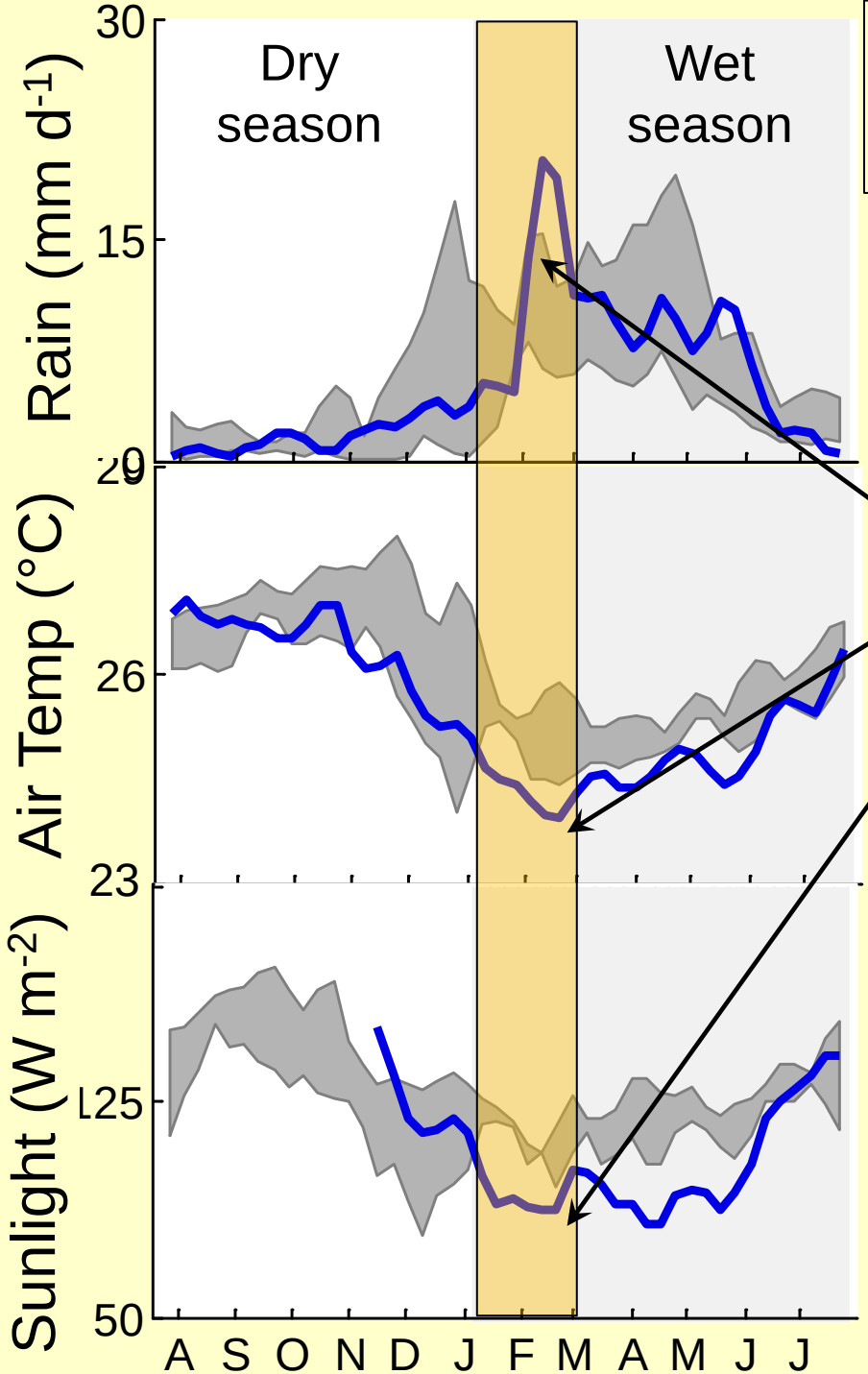


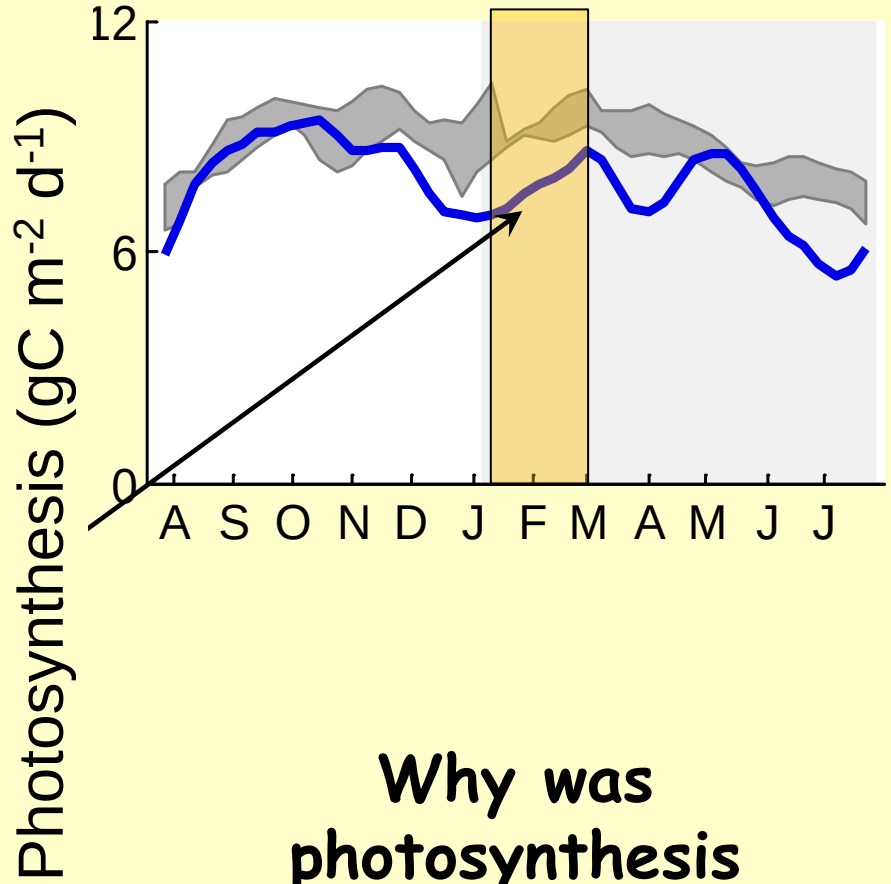
Early 2009 was:

Wet

Cool

"Dark"

With low photo-synthesis

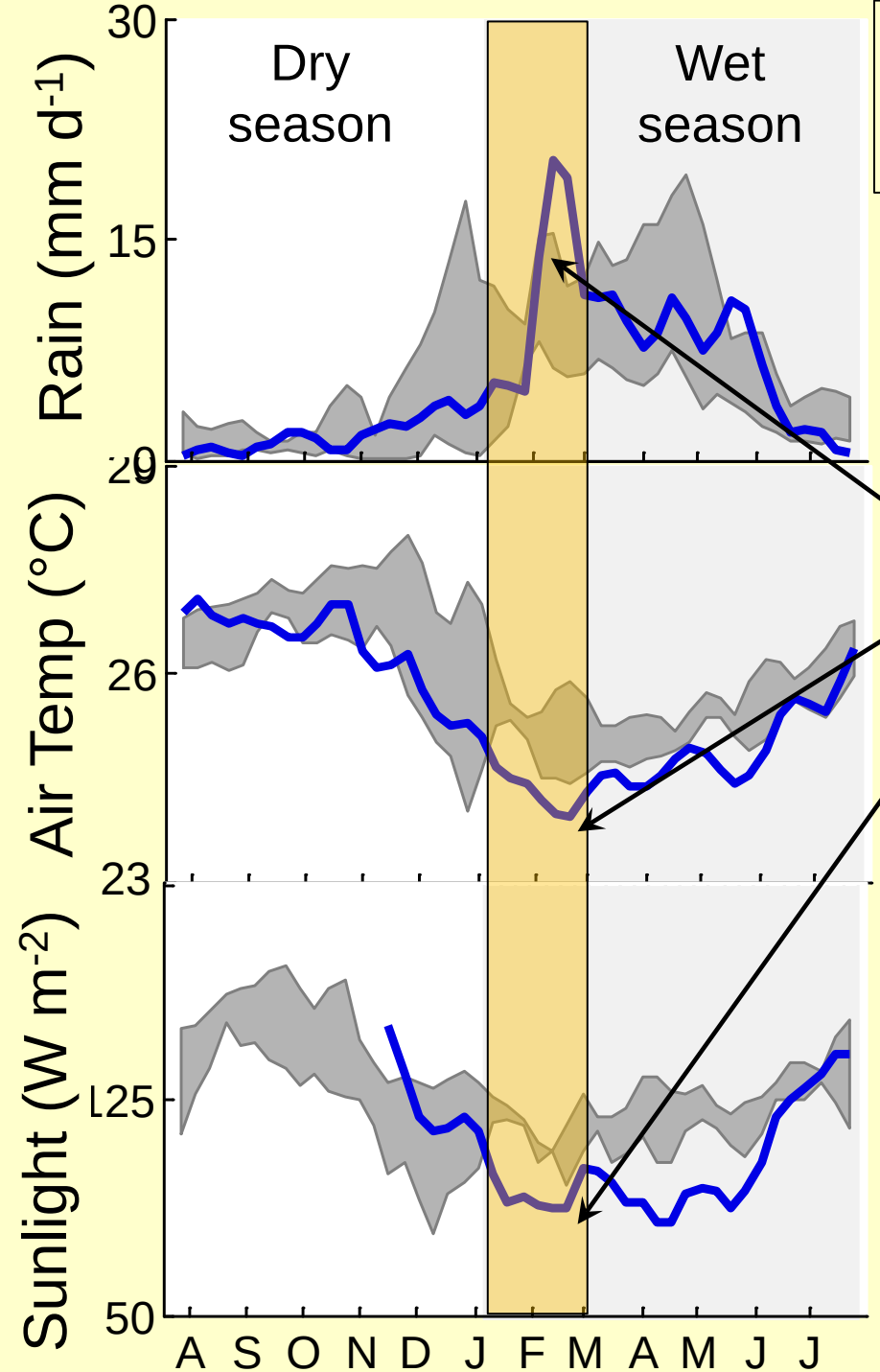


Range of 2002-2006

2008-2009

Why was photosynthesis lower during "flood"?

Annual cycles, August-July
Santarem PIRE Eddy Flux Tower



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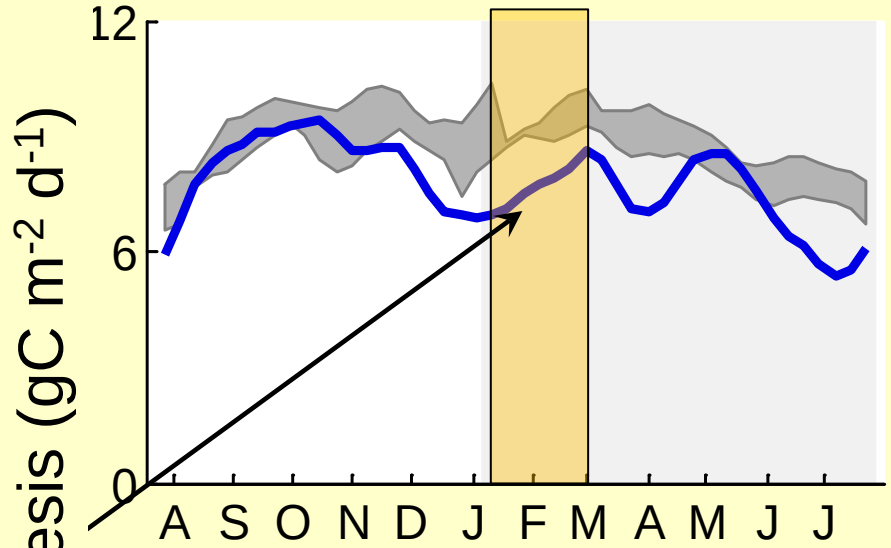
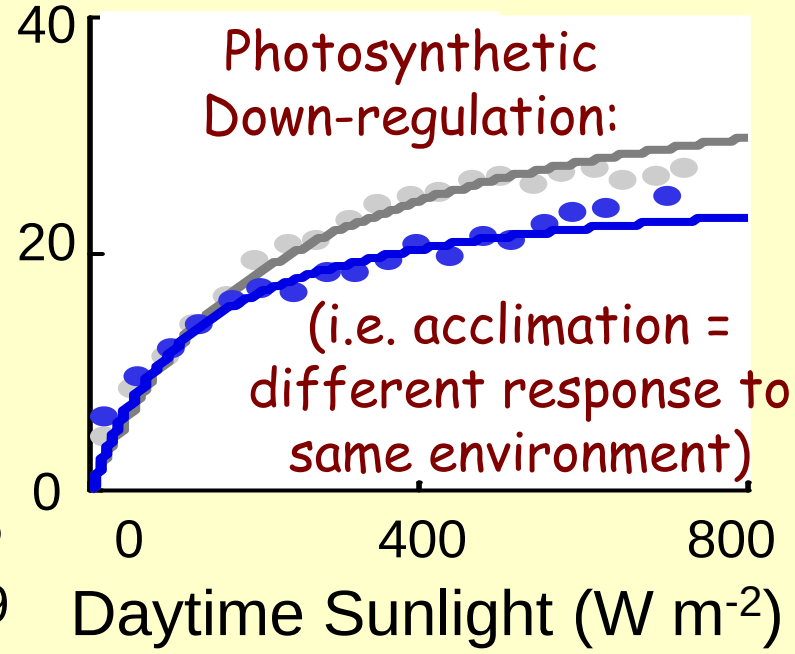




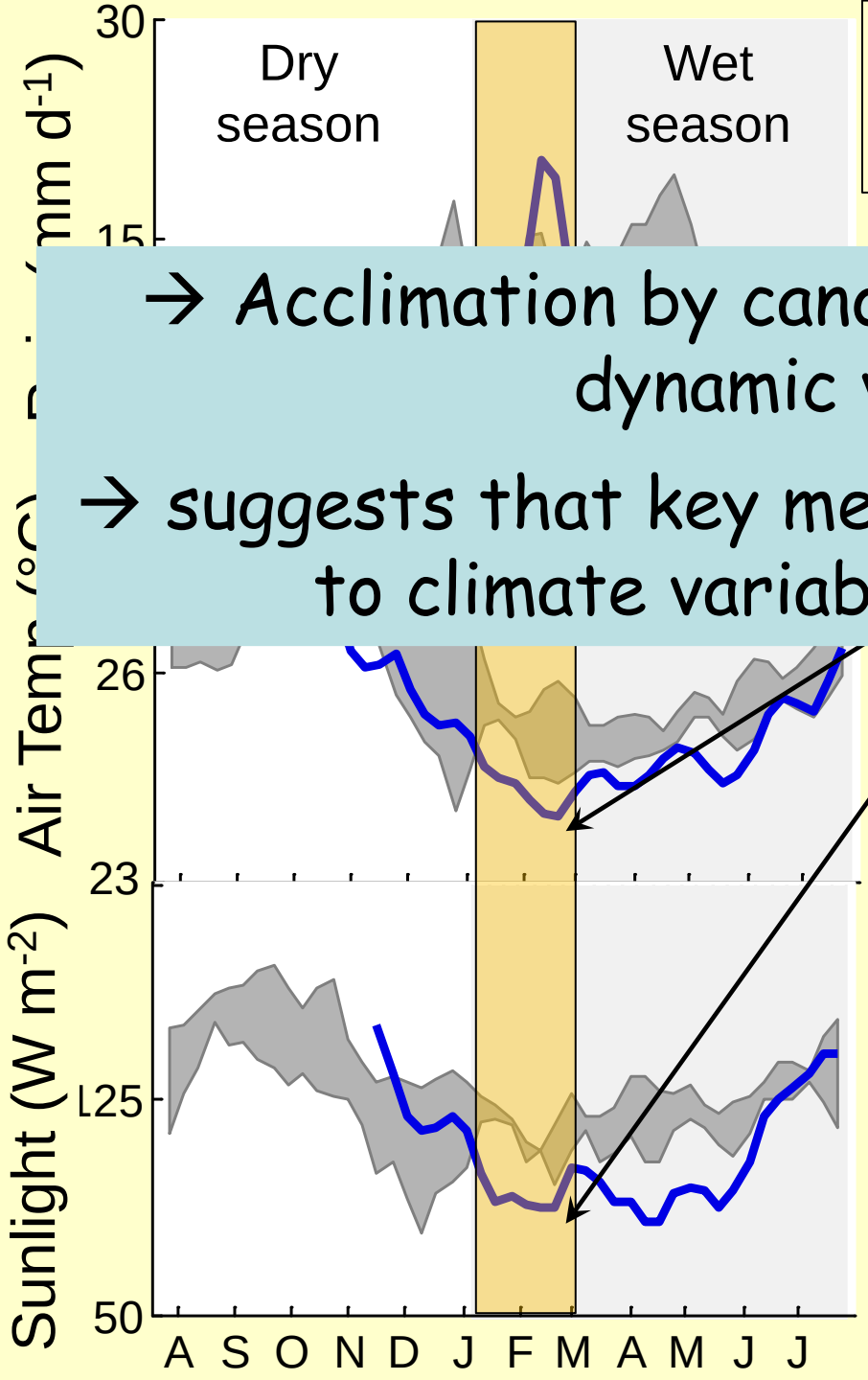
Range of 2002-2006

2008-2009

Annual cycles, August-July Santarem PIRE Eddy Flux Tower

→ Acclimation by canopy-scale photosynthesis not in dynamic vegetation models

→ suggests that key mechanisms of vegetation response to climate variability are not well-modeled



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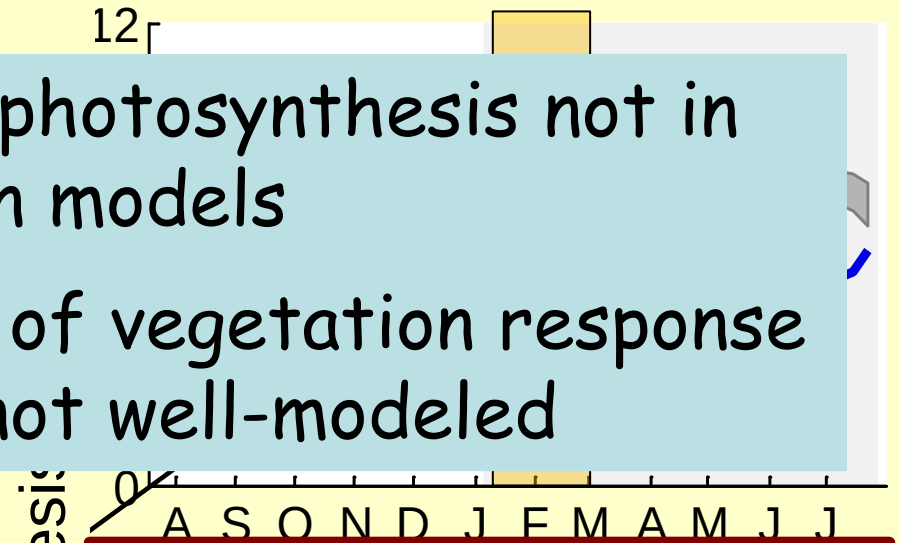
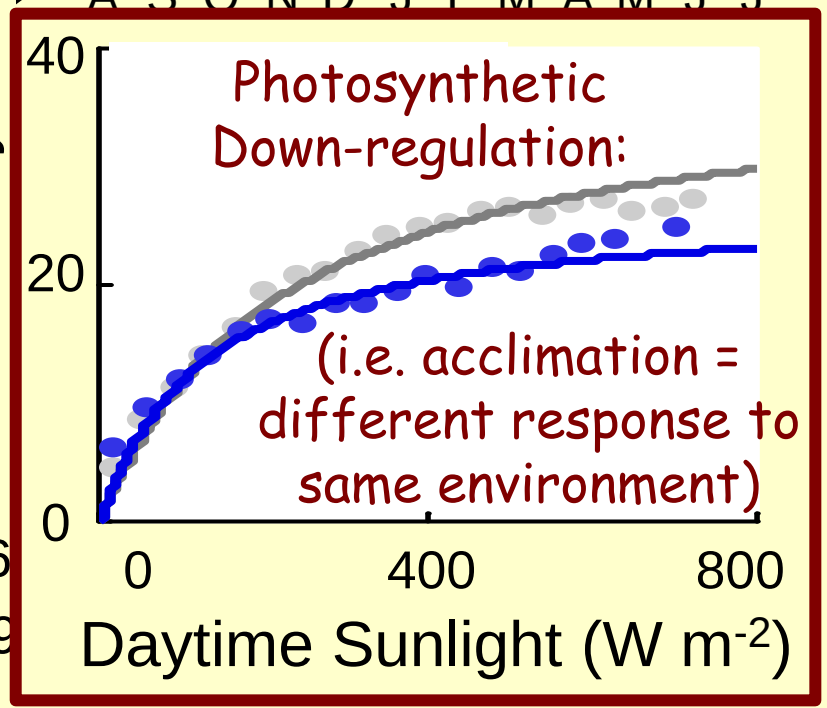




Could this explain responses to drought as well as to flood?

Could this explain responses to drought as well as to flood?

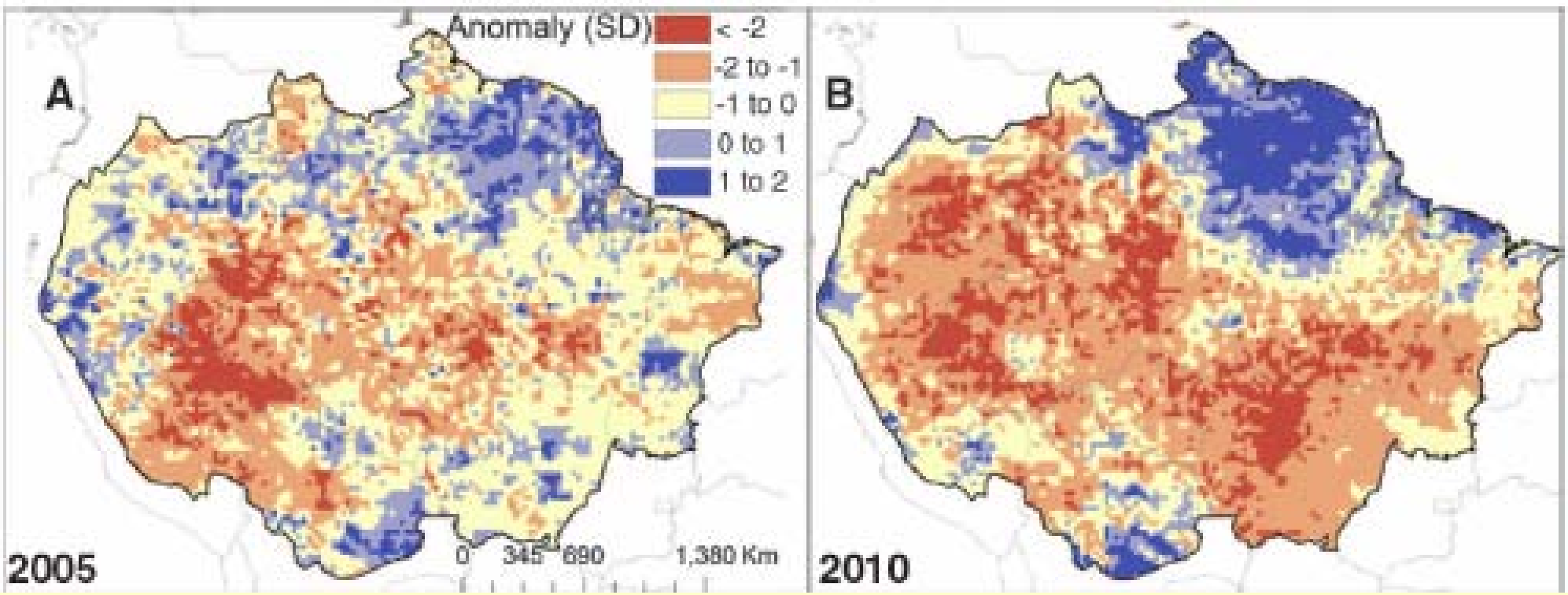
Stay tuned!!

4 FEBRUARY 2011 VOL 331 SCIENCE

BREVIA

The 2010 Amazon Drought

Simon L. Lewis,[1]*† Paulo M. Brando,[2,3]* Oliver L. Phillips,[1] Geertje M. F. van der Heijden,[4] Daniel Nepstad[2]



2005 third quarter anomaly map

TRMM satellite

2010 third quarter anomaly map

Amazon-PIRE Question 3:

What is the future of Amazon forests under climate change?

(or, how can we use new data and new insights to improve model simulations?)

Andes-Amazon Initiative -- Research Consortium

- Objective: Use four state-of-the-art terrestrial ecosystem models to predict how changes from deforestation and climate will affect the structure and functioning of Amazonian ecosystems over the coming century.

I.e. get a better answer to the question: "Are Amazon forests vulnerable to dieback?"

- Models:
  - The Ecosystem Demography model (ED)
  - Integrated Biosphere Simulator (IBIS)
  - JULES (Hadley Center, UK)
  - NCAR's Community Land Model (CLM)
- Approach: Evaluate and improve predictive capabilities of the models by testing against measurements (e.g. forest inventories, eddy flux towers, LIDAR, atmospheric CO_2)

- Harvard (**including PIRE**)
- UC Irvine
- Universidade Federal de Vicosa
- INPE (Brazilian Space Agency)
- Oxford University
- University of Arizona (**including PIRE**)
- Woods Hole Research Center

MOORE FOUNDATION

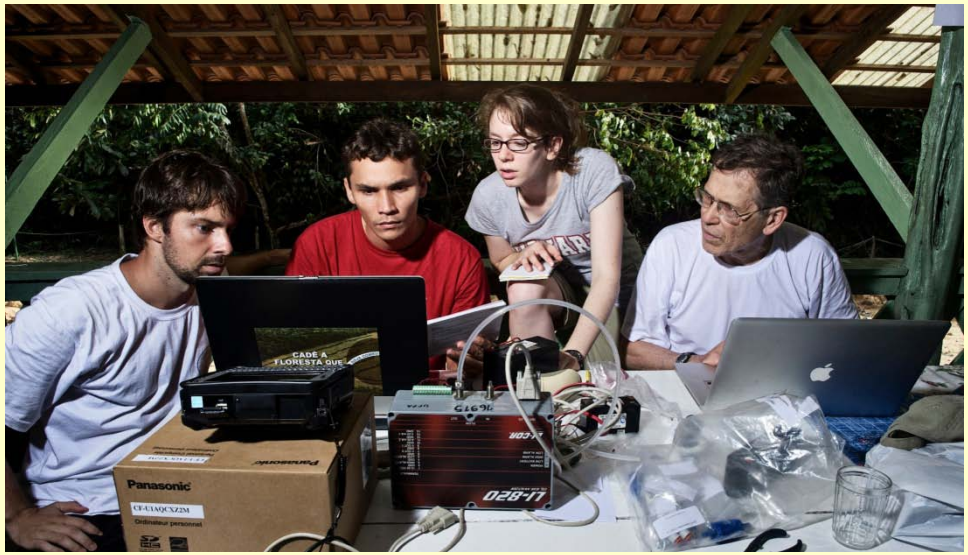
C. What is the "added value" of NSF-PIRE for addressing sustainability questions in the Amazon?

(2010 PIRE field-course video:

http://dl.dropbox.com/u/9562909/Amazon-PIRE%20for%20Scott%20Short2.m4v

C. What is the "added value" of NSF PIRE for addressing sustainability questions in the Amazon?

1. PIRE equals transformative international education



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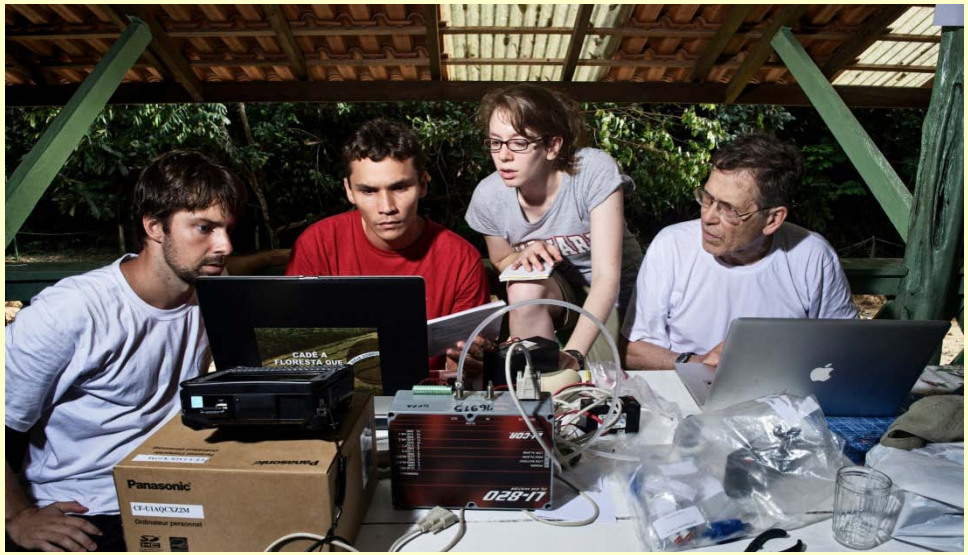

2. Sustainability science & education in the Amazon requires sustainable support for building on-the-ground collaboration. PIRE provides that -- and leverages more

3. Sustainability science research encourages natural/social science partnership to understand human dimensions

For example, coming in 2011: Ecosystem Transitions from Andean Cloud Forest to the Lowland Amazon: a Pan-American Advanced Studies Institute (PASI) on Tropical Ecology, Biogeochemistry, and Climate in Peru

For the PASI, Amazon-PIRE is recruiting social scientists to study human dimensions, e.g. impacts of carbon markets on development (through REDD, the program for Reduced Emissions from Deforestation and Degradation of forests)

Diana Liverman, Co-director, UofA Institute of Environment

Tracey Osborne, UofA Assistant Professor of Geography

Thank you!

Obrigado!

Partners

University of Arizona: Jim Shuttleworth, Alfredo Huete (PIRE Co-PI's)
Travis Huxman, Maria Teresa Velez, Kamel Didan, Francina Dominguez, Xubin Zeng, Brian Enquist, Sylvia Tesh,Tracey Osborn, Diana Liverman, Kolby Jardine, Ralph Renger (evaluation)

Post-docs: Natalia Restrepo, Luciana Alves

UofA PIRE fellows: Loren Albert, Cyndy Bresloff, Brian Chaszar, Brad Christoffersen, Joost van Haren, Chris Meehan, Rafael Rosolem, Ramon Solano, Scott Stark, Ty Taylor, Lindsey Hovland, Sarah White, Jacob Meuth, Gabe Moreno

Ginny Fitzpatrick (GK-12 fellow in UofA's BioME project) for Amazon-PIRE video

Harvard University: Steven Wofsy (PIRE Co-PI), Paul Moorcroft, Marcos Longo

Harvard PIRE fellows: Tom Powell, Matt Hayek

Brazil : Plinio B. de Camargo, Humberto da Rocha, Paulo Artaxo (U. of Sao Paulo)
Antonio Manzi, Flavia Costa, Alessandro Araujo (INPA, Manaus)
Cosme Oliveira, Rodrigo da Silva (Embrapa and Federal U. of East-Para, Santarem)
Rafael Oliveira (U. of Campinas)

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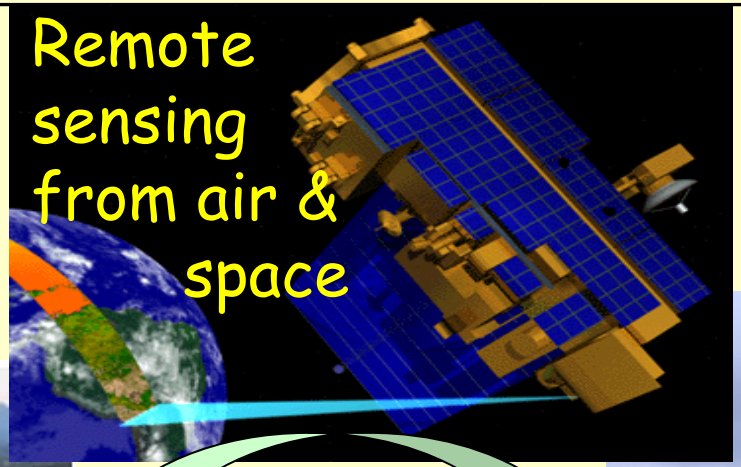
Amazon-PIRE: Carbon, water and vegetation dynamics of Amazon forests under climatic variability and change



Experiments in Biosphere 2

Model Integration

Amazon Forest Observations

International Field-based training & education