FAPESP-INPA-Wilson Center
The Scientific, Social, and Economic Dimensions of Development in the Amazon
Washington DC, September 25 2018

The Close Links Between the Biological Functioning of Amazonia and Climate

Paulo Artaxo
Universidade de São Paulo
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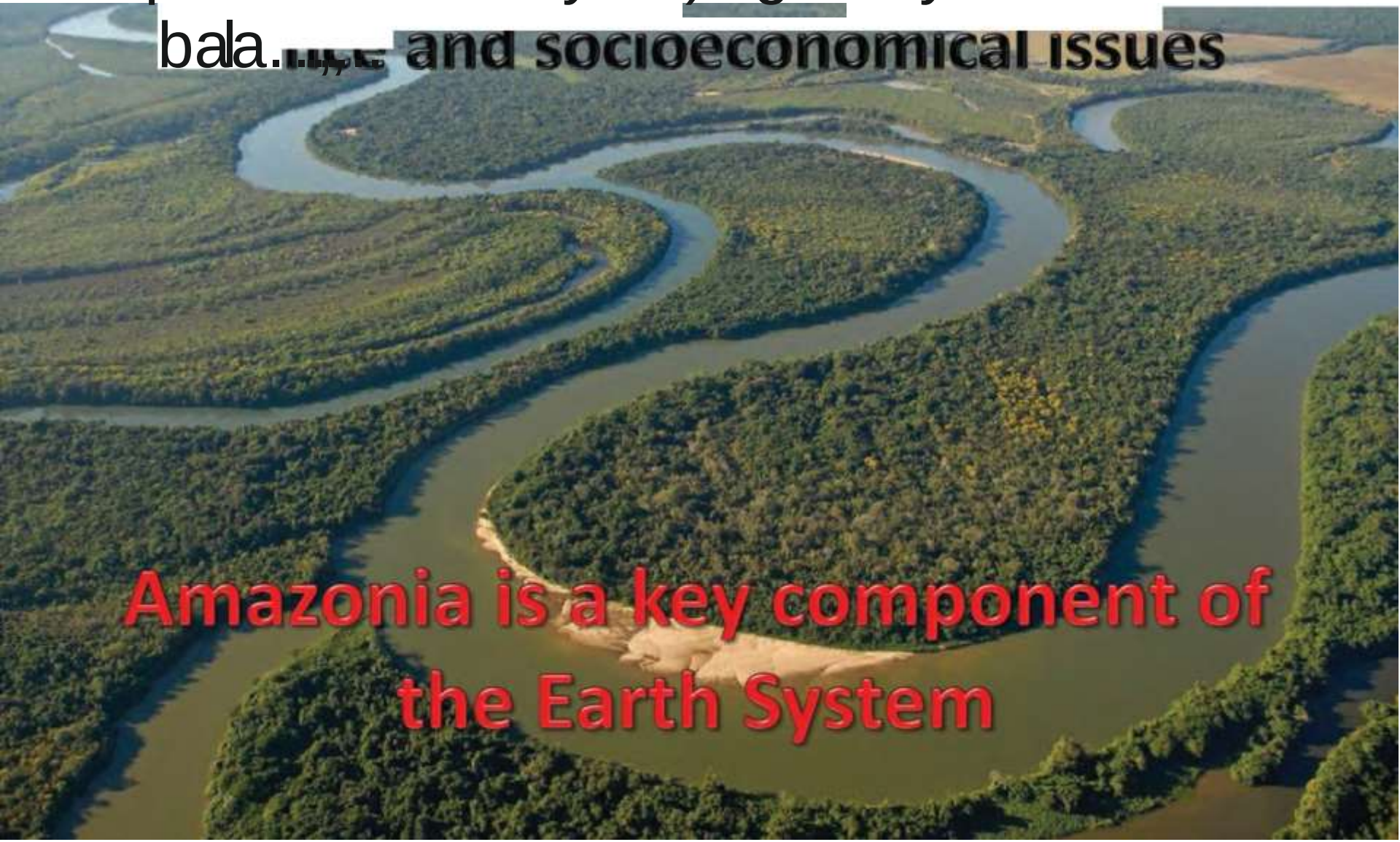
Amazonia: a unique region, with global impacts on the hydrological cycle, carbon balance and socioeconomical issues



AMAZON ECOSYSTEMS AT A GLANCE

Maintenance of global carbon cycle

- 15% of global NPP and a key carbon sink for anthropogenic CO_2
- Stores between 100 to 120 billion ton of carbon in the biomass

Climate stabilization

- Key heat source for the atmosphere
- Annual rainfall = 2400 mm

Powerful hydrology

- 18% of fresh water flow into the global oceans
- Amazon river discharge of 220,000 m^3/s

Helps to maintain cultural and ethnic diversity

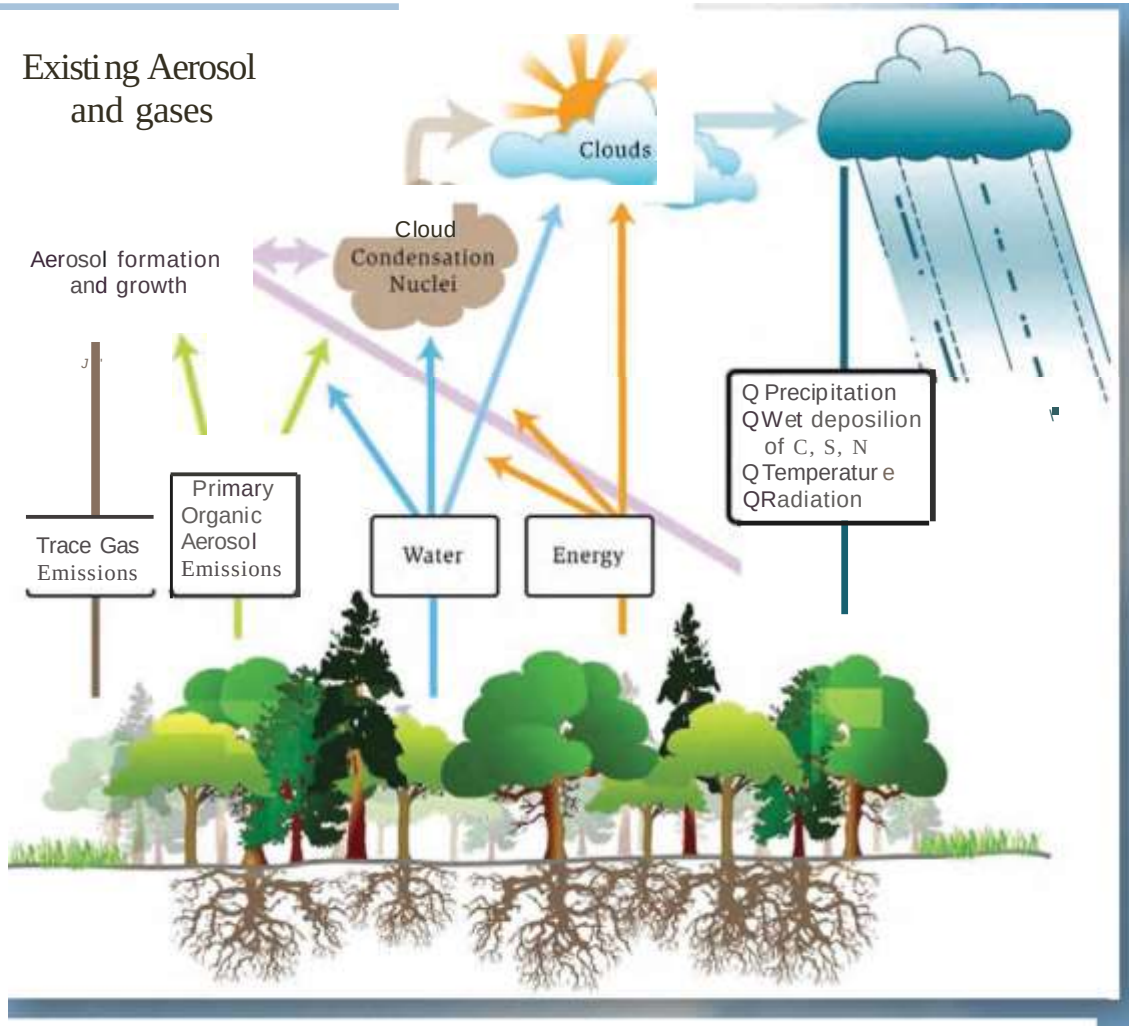
- Over 300 indigenous populations, language diversity

Biodiversity richness

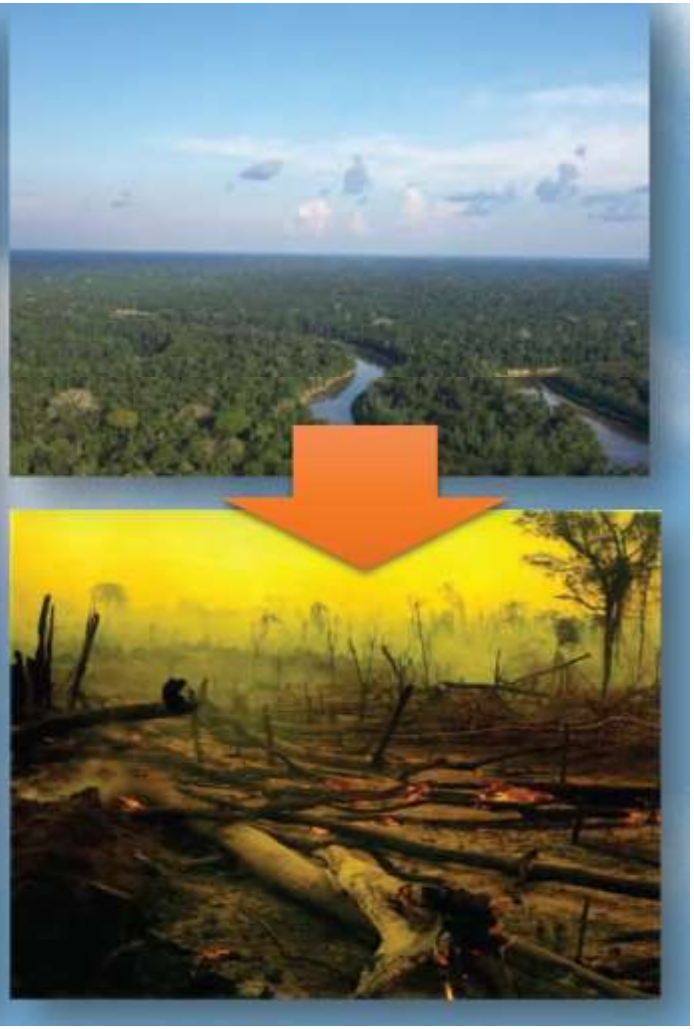
- > 10% of species

There are strong and complex links between the forest biology, and the physics and chemistry of the atmosphere

Natural System



The Transition



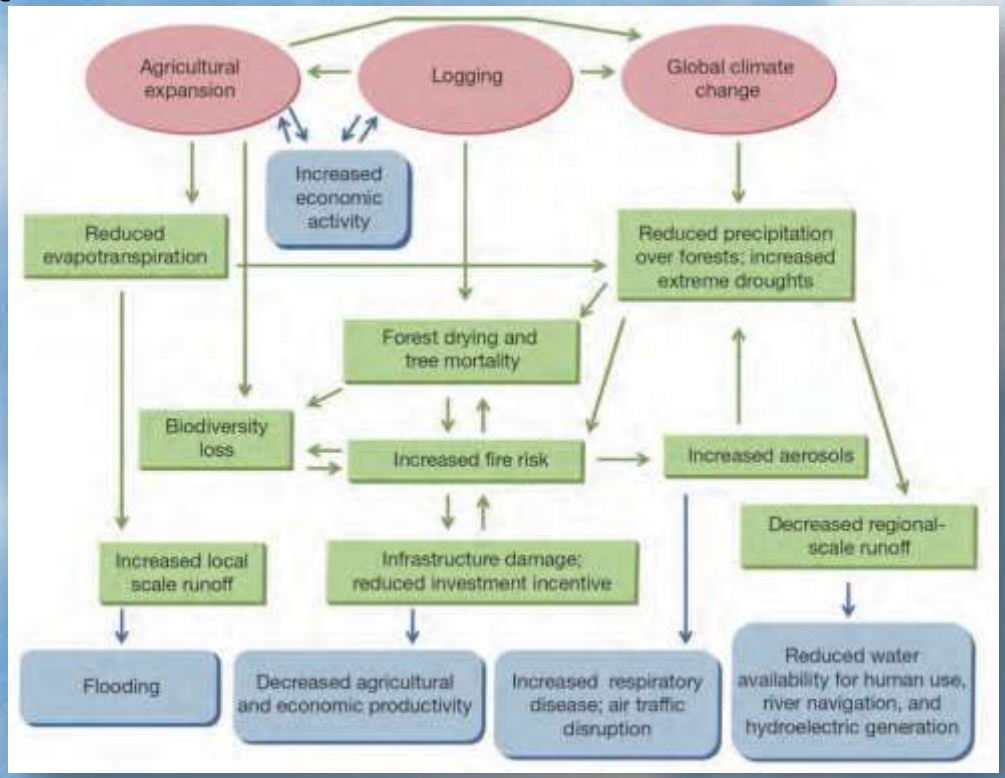
REVIEW

doi:10.1038/nature10717

The Amazon basin in transition

Eric A. Davidson[1], Alessandro C. de Araújo[2,3], Paulo Artaxo[4], Jennifer K. Balch[1,5], I. Foster Brown[1,6], Mercedes M. C. Bustamante[7], Michael T. Coe[1], Ruth S. DeFries[8], Michael Keller[9,10], Marcos Longo[11], J. William Munger[11], Wilfrid Schroeder[12], Britaldo S. Soares-Filho[13], Carlos M. Souza Jr[14] & Steven C. Wofsy[11]

$ JUHDWHU H[SDQVLRQ DQG FOLPDWH YDULDELOLW\ DUH FUHDWLQJ D QHZ HUD RI $PD]RQLDQ WUDQVLWLRQ.
(QHUJ\ ED FHD GK\G R FD \F HV FKD HV D H DUHDG\ REVHUYHG LQ $PD]RQLD.



,QWHUDFWLRQV EHWZHHQ GDQG XVH FKDQJH DQG FOLPDWH FKDQJH DUH PDMRUGLYHUV IRU FKDQJHV LQ$PD]RQLD.


But, the reality of agricultural expansion in the Amazon is one of fire and forest destruction

Deforestation

Fire…

Selective logging…

Amazonia as a Complex Nonlinear Interactive System

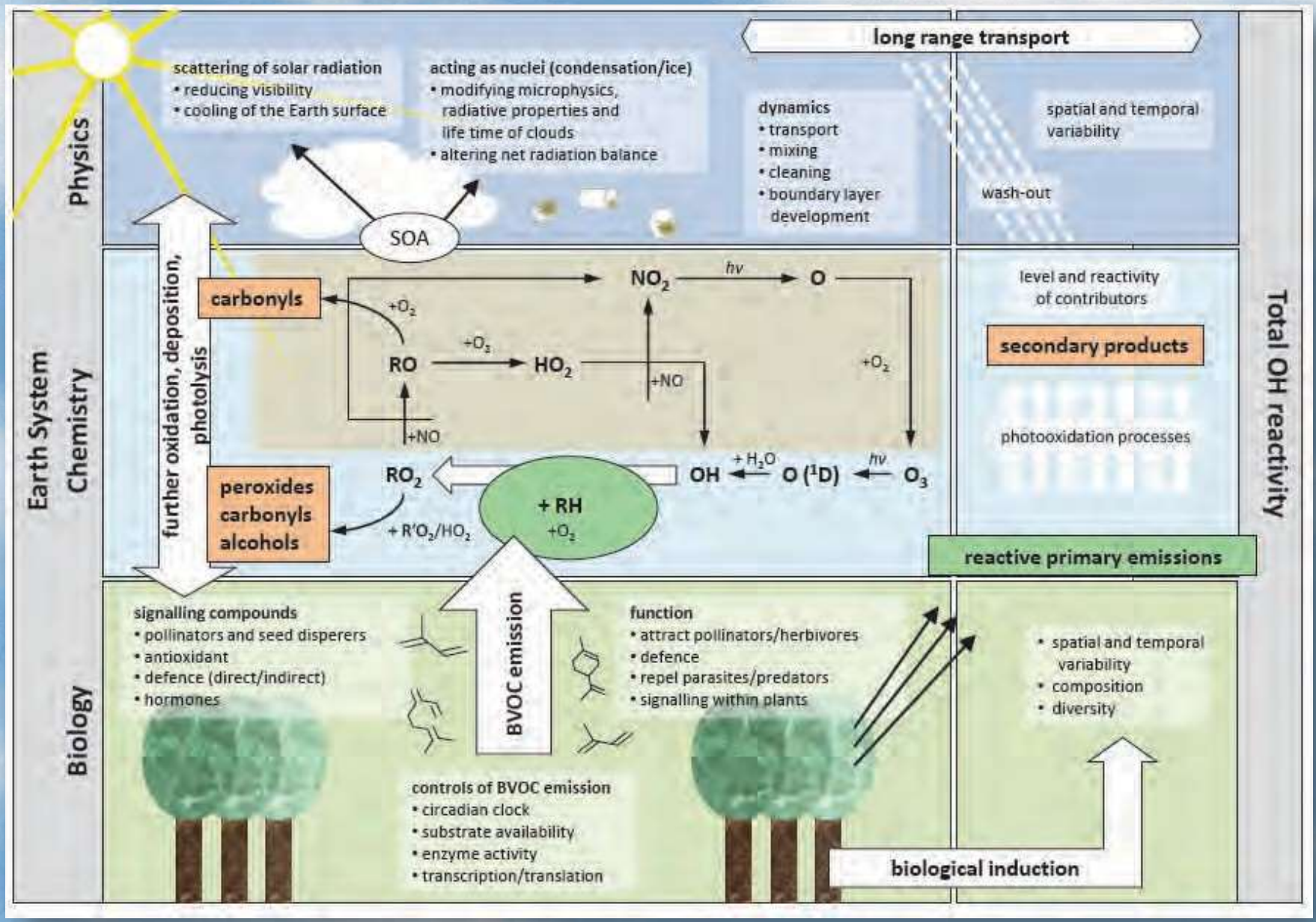


Illustration from Anke Nölscher

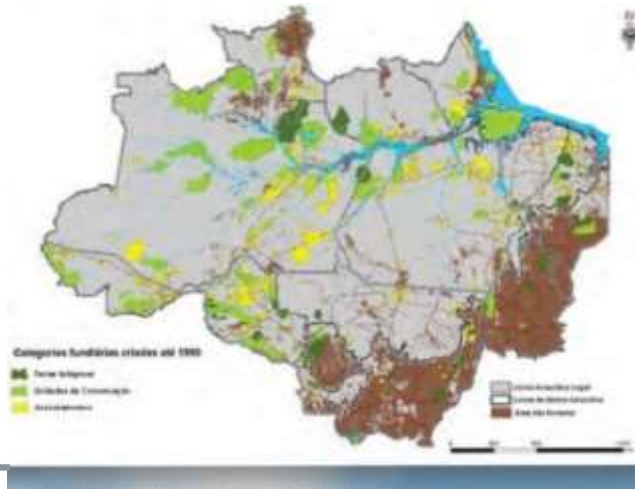
Very significant increase in protected areas 1990-2013

Protected Areas - Brazilian Amazon

1990

Indigenous Lands: 54
Area: 11 million ha

Protected Areas: 65
Area: 33 million ha



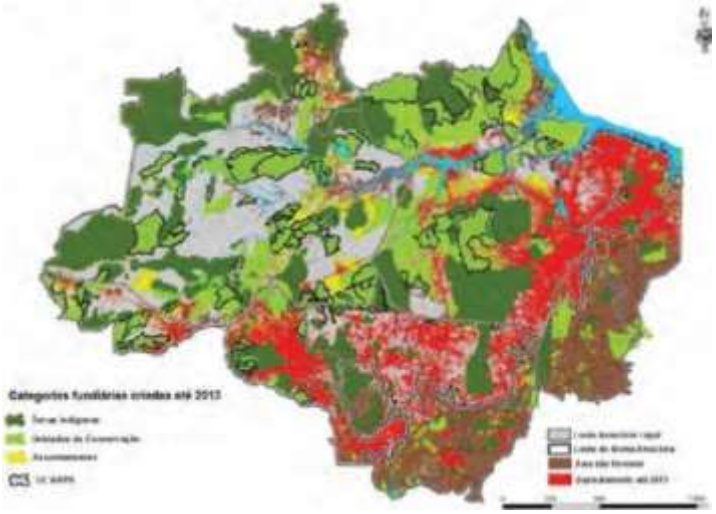
Protected Areas - Brazilian Amazon

Contribuições do INCT-MC

2013

#Indigenous Lands: 381
Area: 112 million ha

Protected Areas: 311
Area: 125 million ha



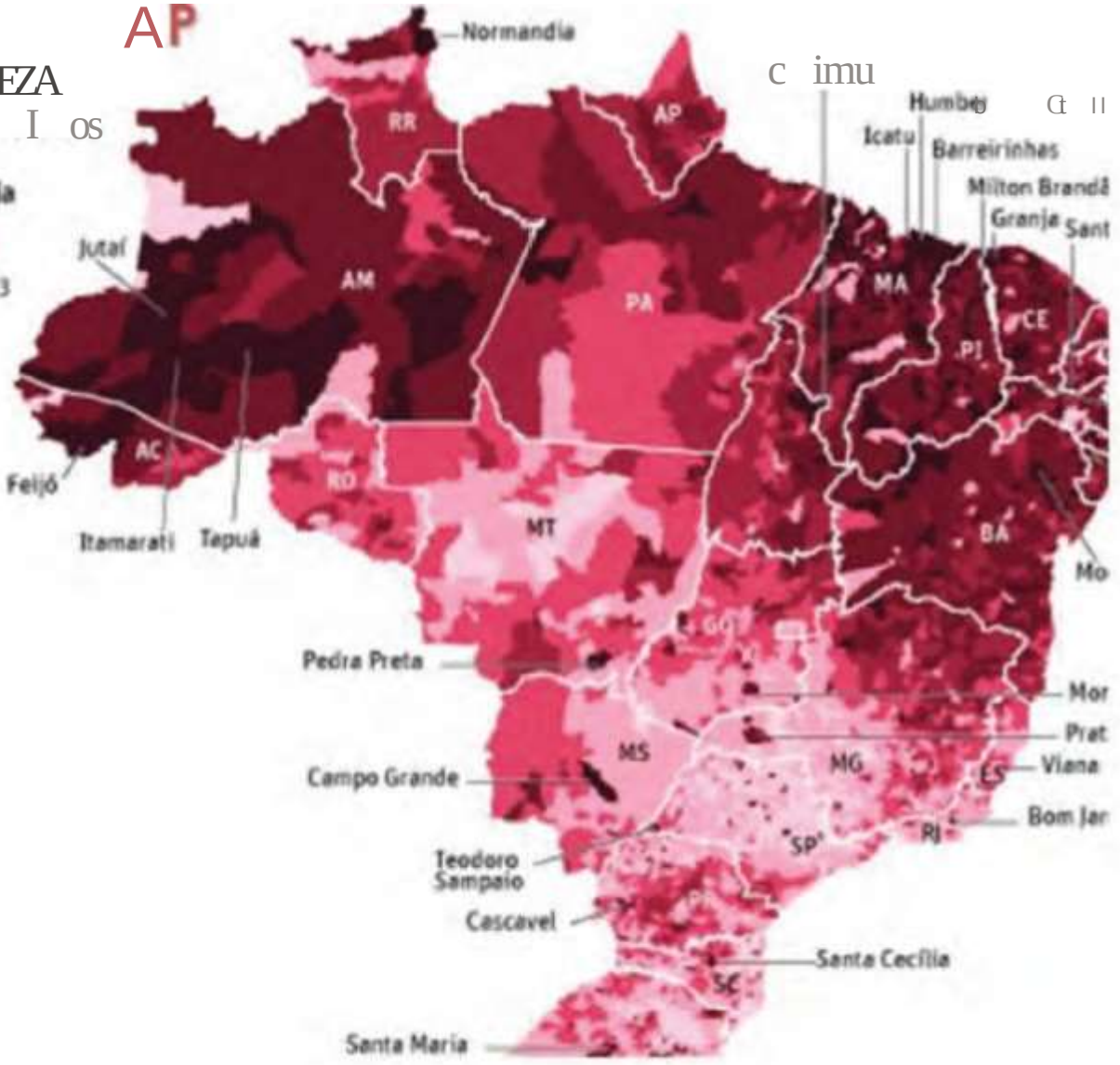
B AZI. I AP

MAPA BRASILEIRO DA POBREZA

Por munkpio e e . I os c imu

% de pessoas em situação de miséria

0 15,8 31,8 47,7 63,5 79,4 95,3



Souroe; IBGE (2014)

PROTECTED AREAS

One-third of global protected land is under intense human pressure

Kendall R. Jones,[1,2]* Oscar Venter,[3] Richard A. Fuller,[2,4] James R. Allan,[1,2] Sean L. Maxwell,[1,2] Pablo Jose Negret,[1,2] James E. M. Watson[1,2,5]

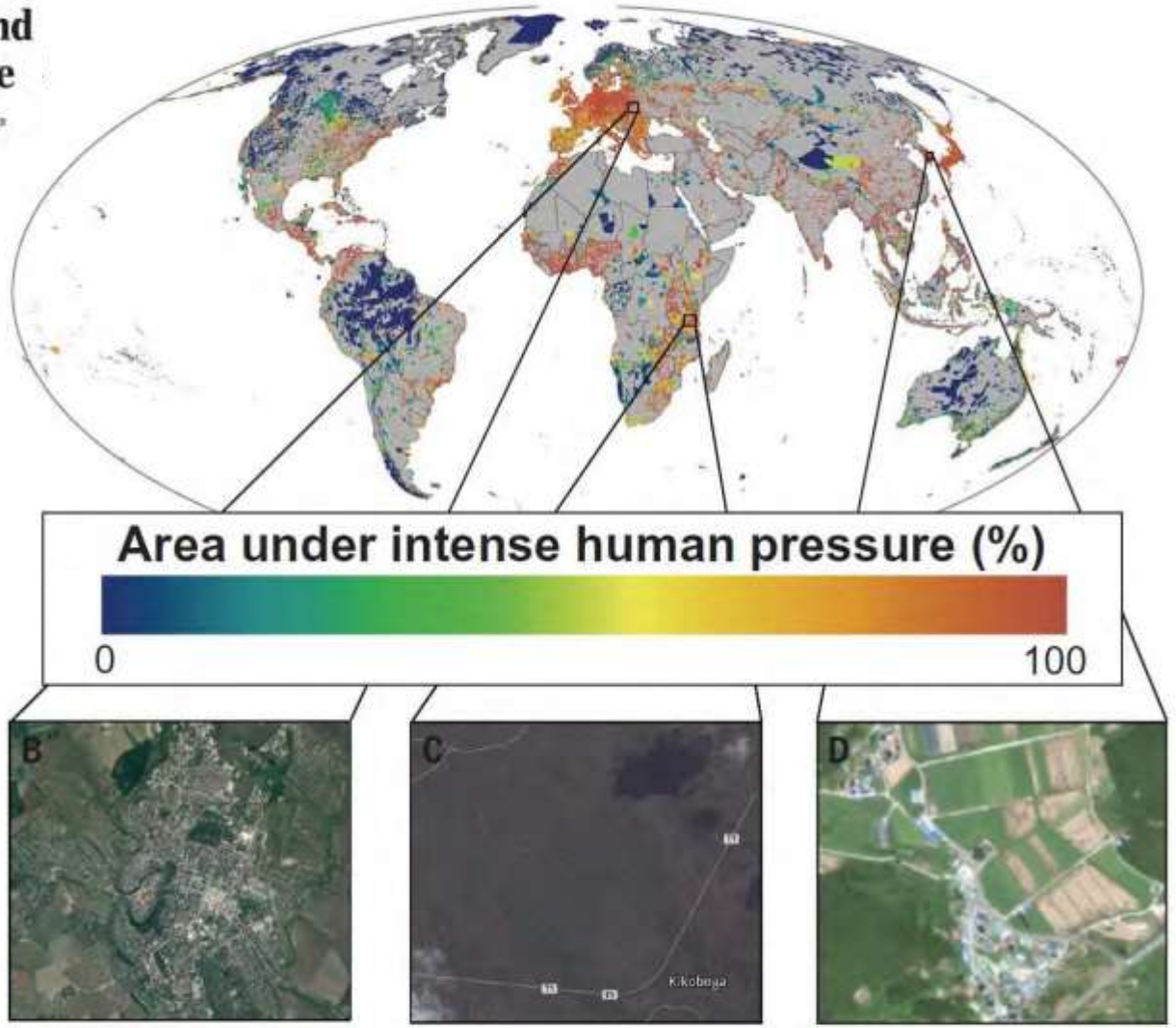
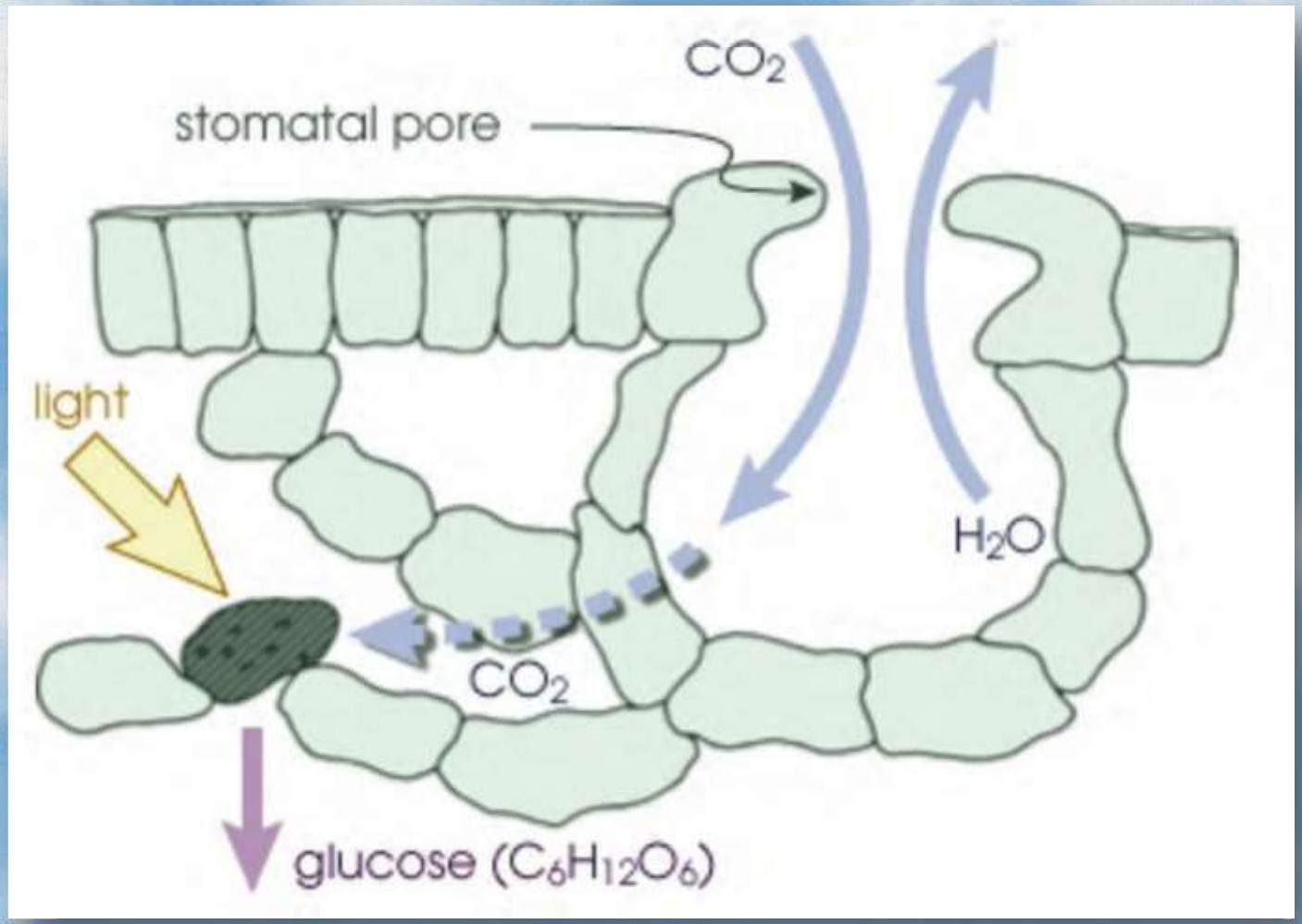


Fig. 1. Human pressure within protected areas. (**A**) Proportion of each protected area that is subject to intense human pressure, spanning from low (blue) to high (orange) levels. (**B**) Kamianets-Podilskyi, a city within Podolskie Tovtry National Park, Ukraine. (**C**) Major roads fragment habitat within Mikumi National Park, Tanzania. (**D**) Agriculture and buildings within Dadohaehaesang National Park, South Korea. [Photo credits: Google Earth]

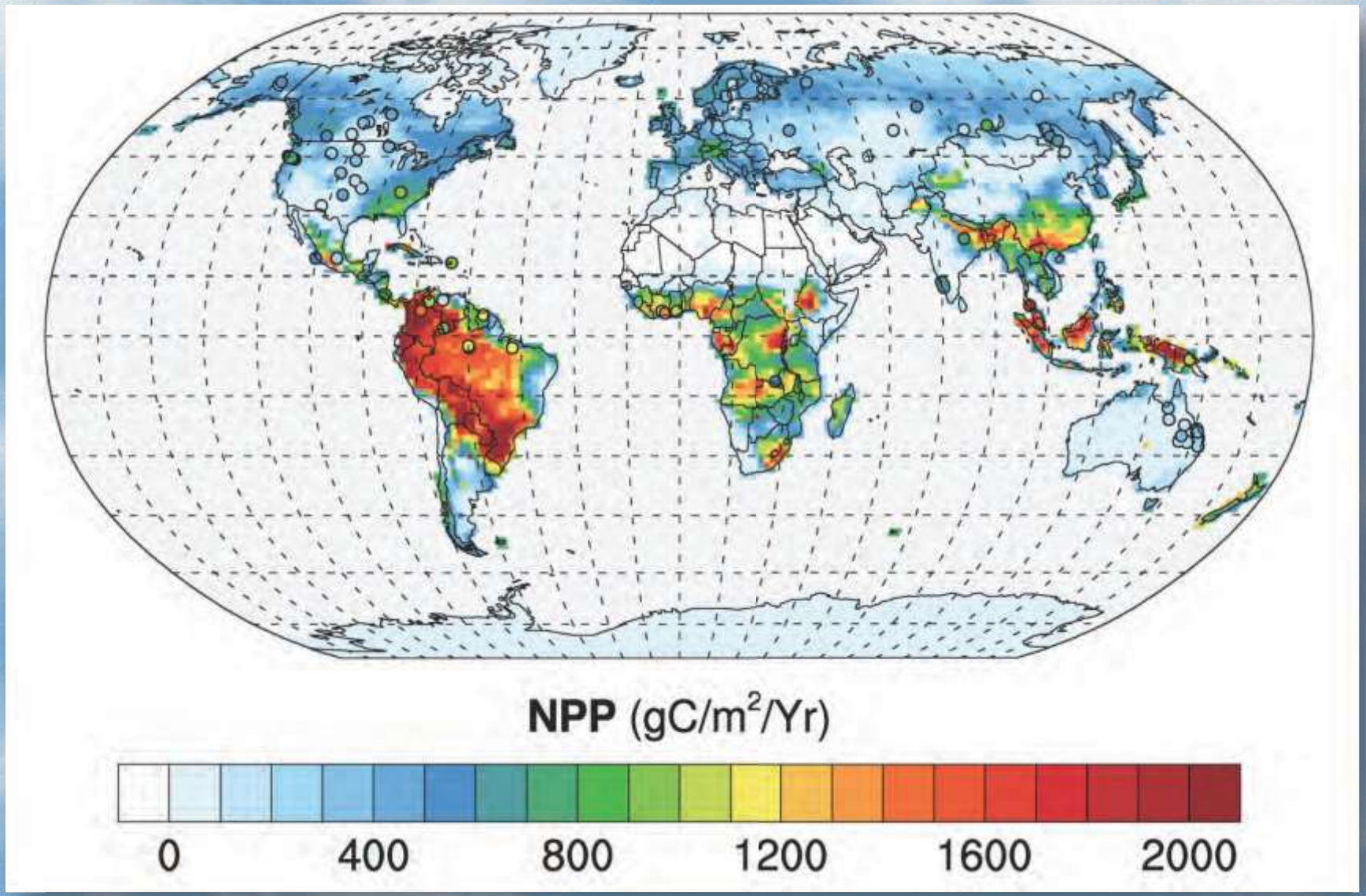
Science May 2018

Photosynthesis: where radiation meets life



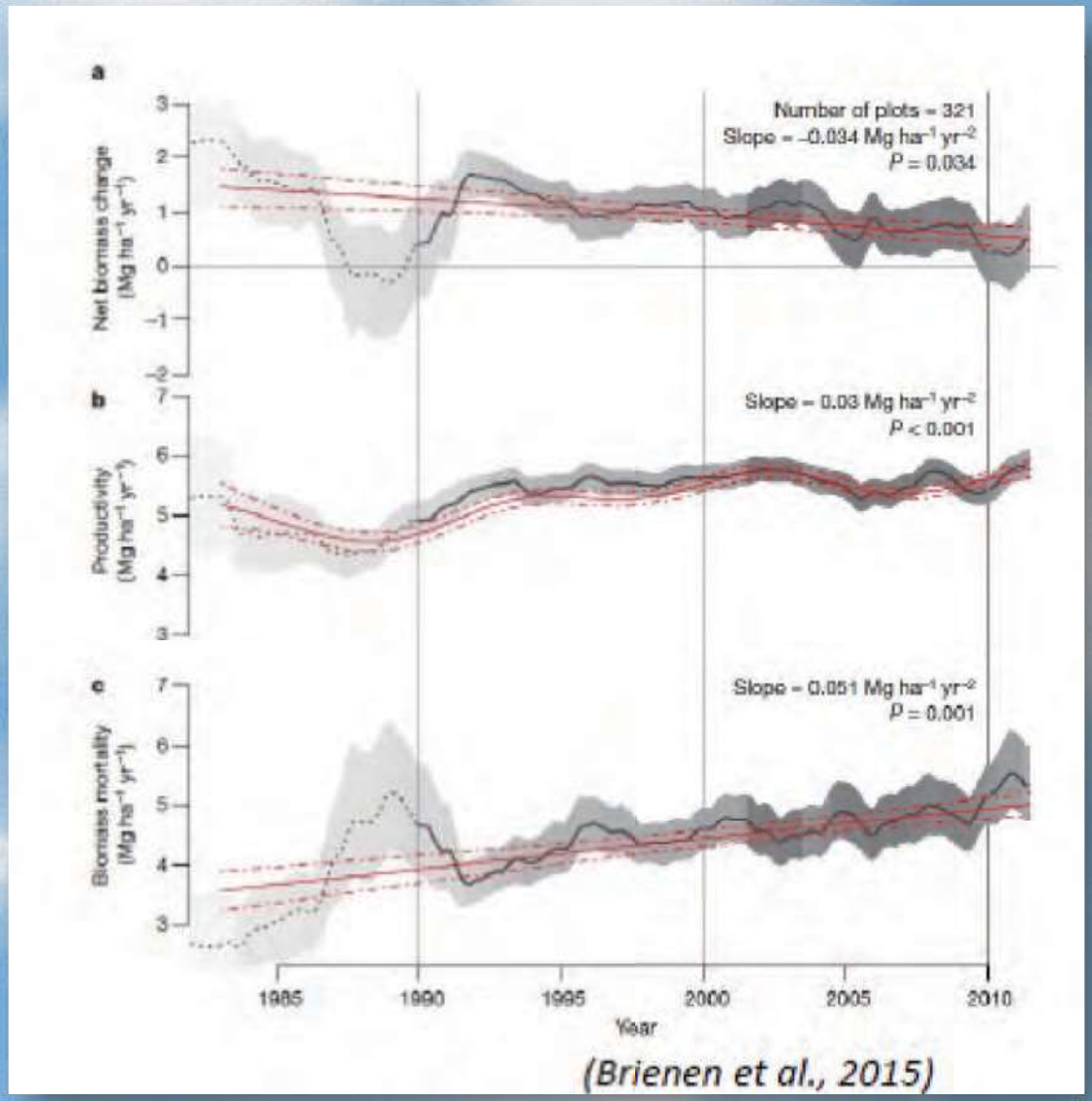
During photosynthesis, plants absorb carbon dioxide and sunlight to create fuel, glucose and other sugars for building plant structures. This process forms the foundation of the biological carbon cycle.

Global Net Primary Productivity NPP: South America is key…



Ecosystem Model Data Model Intercomparison (EMDI) project

Carbon cycling: Amazonia stores about 120 Tg C. If only a small fraction goes to or from the atmosphere, large changes in atmospheric CO2 will occurs. How tropical forests processes affects carbon, water and energy fluxes?

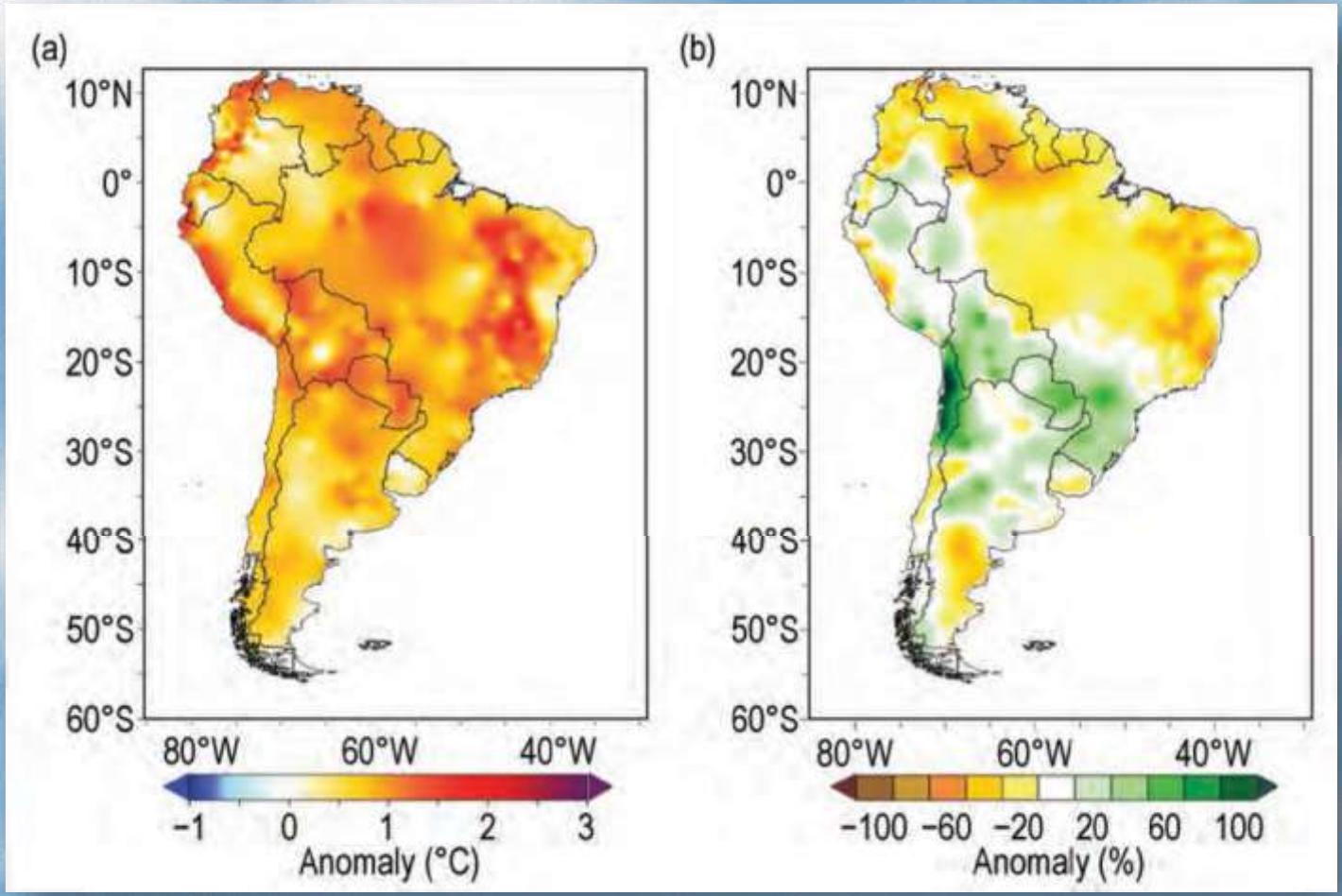


(Brienen et al., 2015)

Net carbon flux: Today: ZERO

Tree mortality: significant INCREASE

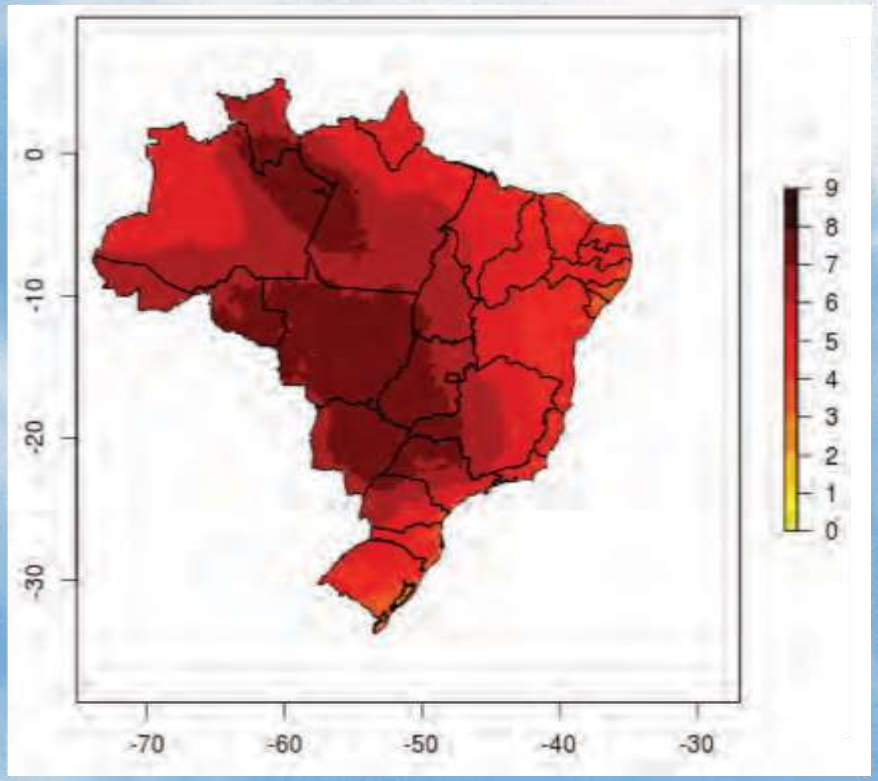
South American (a) temperature anomalies (°C) and (b) precipitation anomalies



base period: 1981–2010.

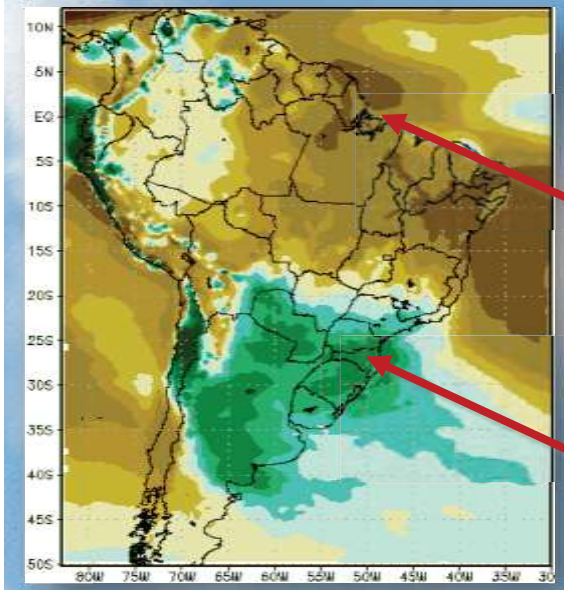
Source 2016: State of the Climate in 2015, Bull. Amer. Meteor. Soc., 97 (8), 2016.

Aumento médio de temperatura esperado para o Brasil 2071-2099



Áreas continentais se aquecem mais que áreas oceânicas

Mudança na precipitação esperada para o Brasil 2071-2100



Mudanças na chuva (%) em 2071-2100 relativo a 1961-90.

Amazonia e Nordeste do Brasil Æ deficiência de chuvas

Sudeste da America do SulÆ aumento nas chuvas

INPE, (RCP 8.5)

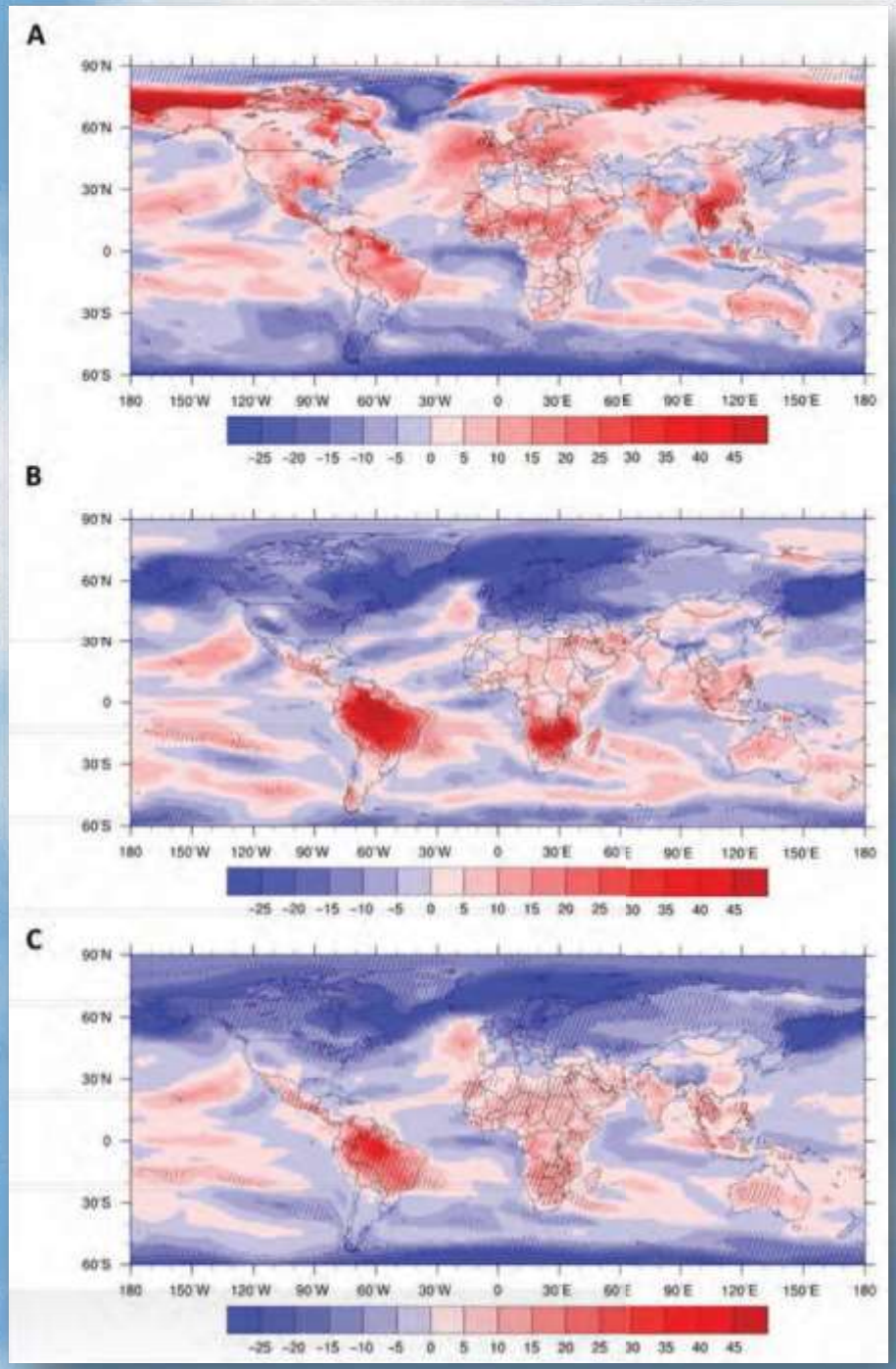
Climate models predict increasing temperature variability in poor countries

A) Boreal summer [June, July, and August (JJA)]

Relative changes of Standard Deviation of monthly temperature anomalies until the end of the 21st century. Averaged over 37 climate models

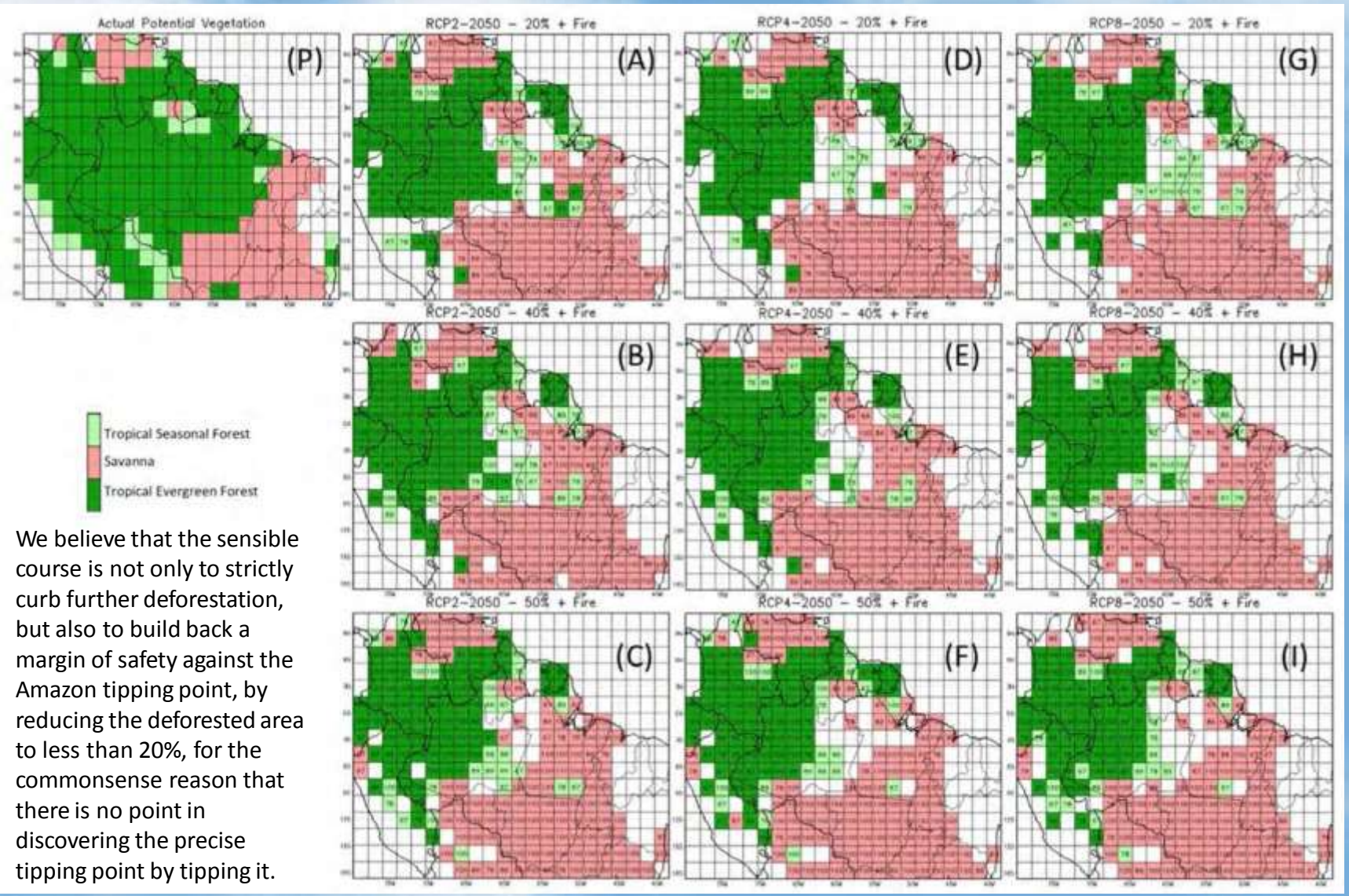
B) austral summer [December, January, and February (DJF)],

(C) the whole year



Bathiany et al., Sci. Adv. 2018;4: May 2018

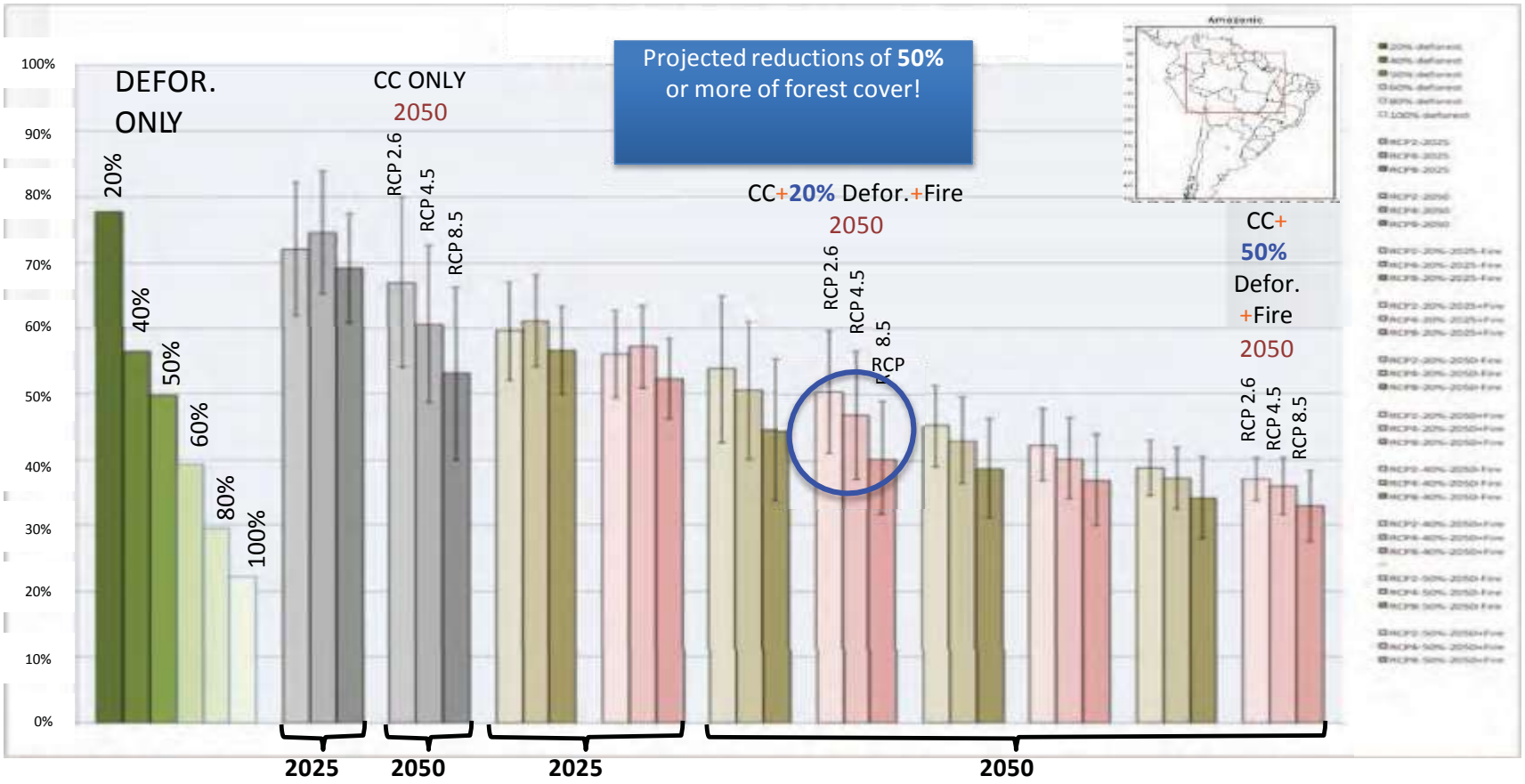
Projected distribution of natural biomes for RCP 2.4, 4.5 and 8.5. Deforestation scenarios for 20%, 40% and 50% + Fire effect



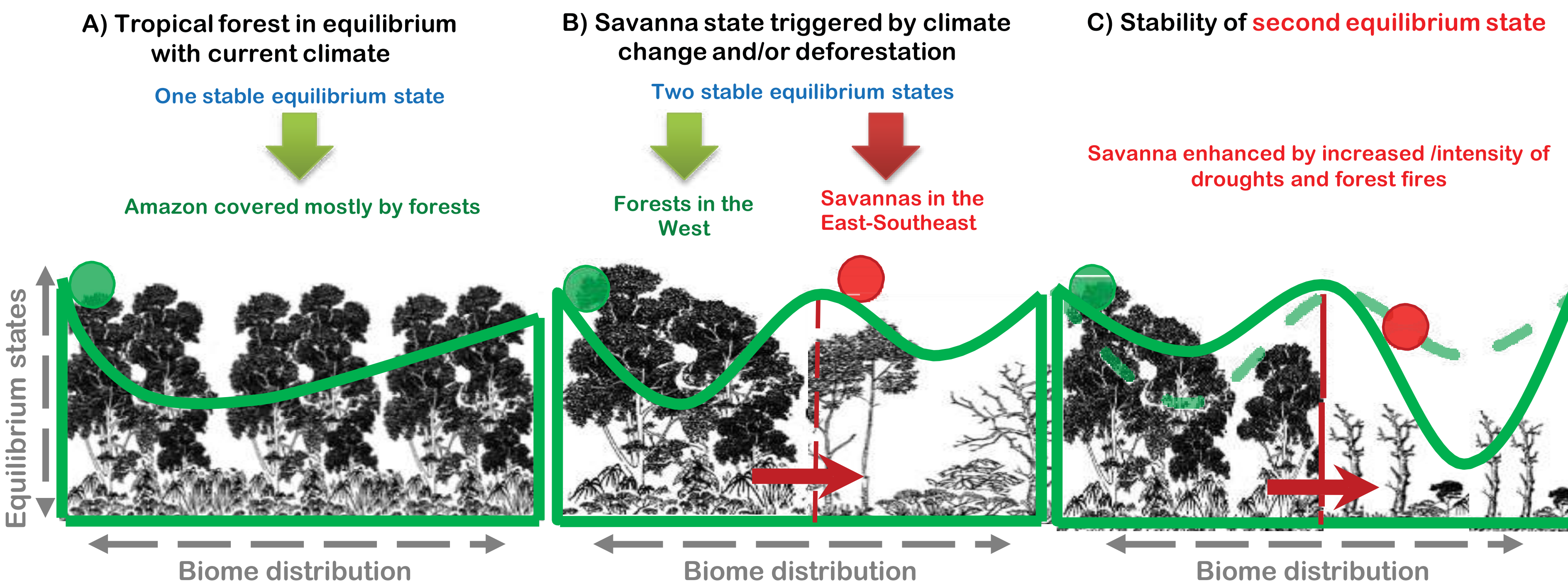
We believe that the sensible course is not only to strictly curb further deforestation, but also to build back a margin of safety against the Amazon tipping point, by reducing the deforested area to less than 20%, for the commonsense reason that there is no point in discovering the precise tipping point by tipping it.

Nobre et al., PNAS, 2016

FRACTION OF THE REMAINING FOREST AREA FOR THE ENTIRE AMAZONIA
CLIMATE CHANGE PROJECTIONS – CMIP5 – 9 EARTH SYSTEM MODELS



'TIPPING POINTS' OF FOREST-CLIMATE EQUILIBRIUM IN THE AMAZON

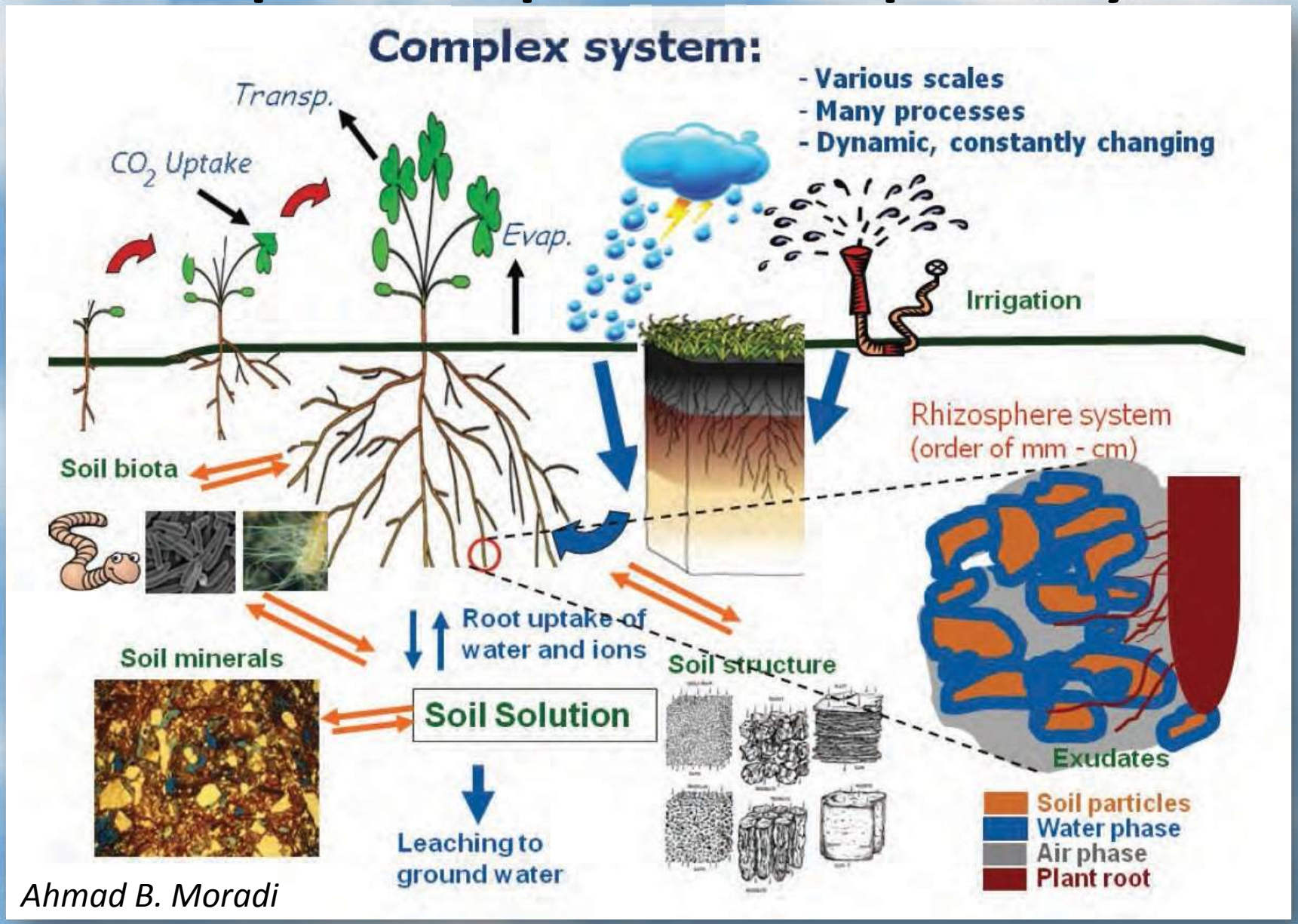


Thresholds for tipping
from state A to state B y ϰºC Amazon warming or
y ϰϬй ŽĨ ƚŽƚĂůĚĞĨŽƌĞƐƚĞĚ ĂƌĞĂ

- ➢ Kd'ƐĞƌ ĂƚŝŽŶƐ ͺd y ϲϲ ƚŽ ϲϱºC
- ➢ DĞĨŽƌĞƐƚĂƚŝŽŶ y ϲϬй
- ➢ Forest fire frequency (increasing)
- ➢ Lengthening of dry season (increasing)
- ➢ Increasing climate extremes

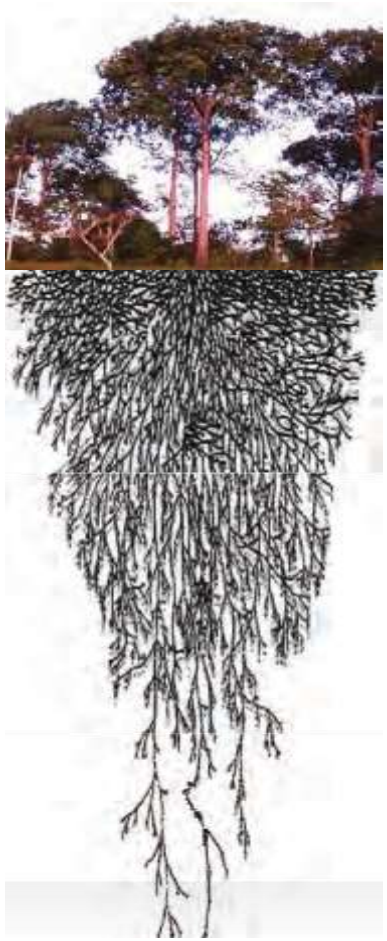
$GDSWHG IURP &DUGRVR DQG %RUPD, 2010; %RUPD, 1REUH DQG &DUGRVR, 2013, 1REUH HW DO, 2015, 2016

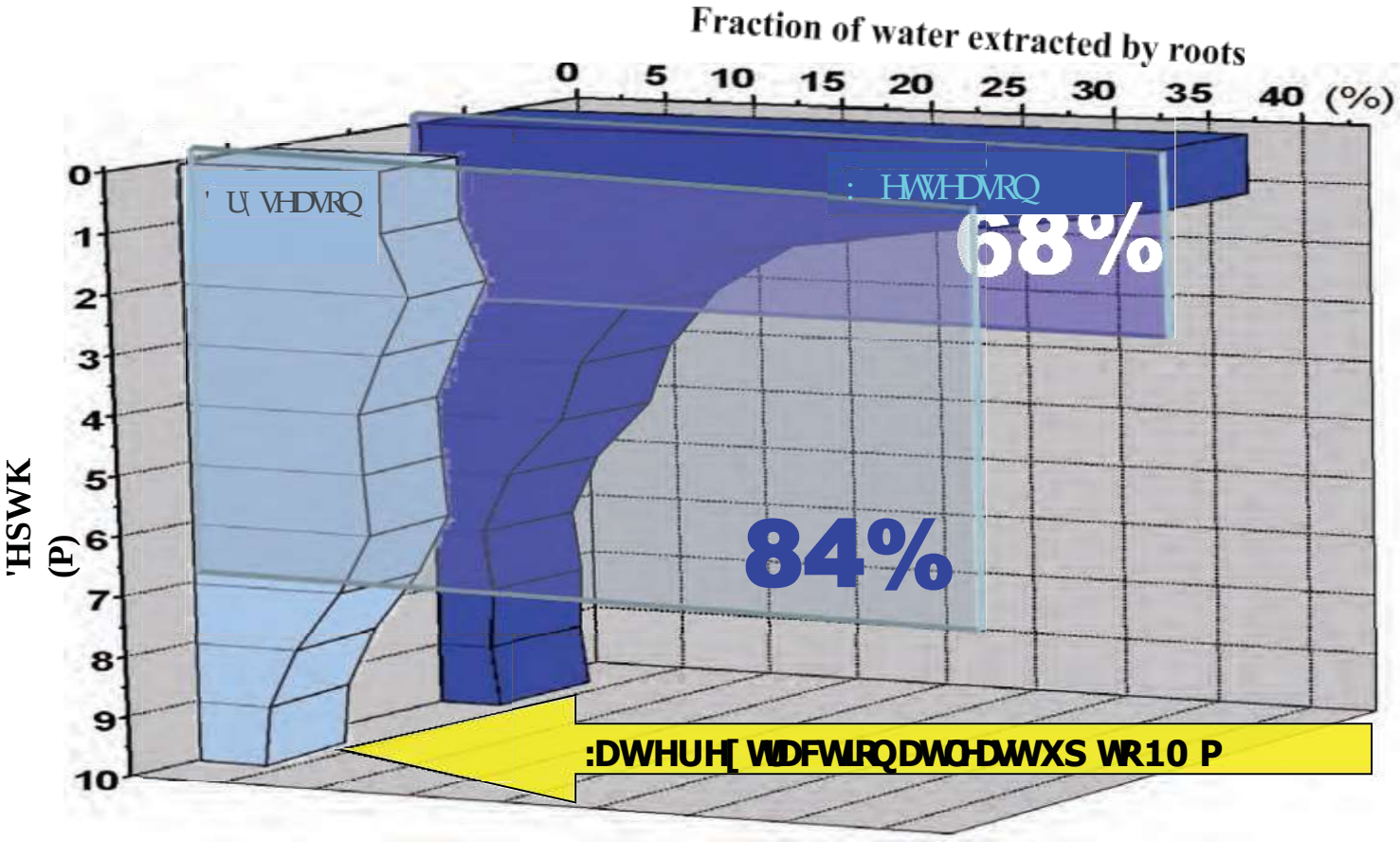
The complex soil-plant-atmosphere system



Ahmad B. Moradi

Ecological adaptation: Deep rooting in the Eastern Amazon



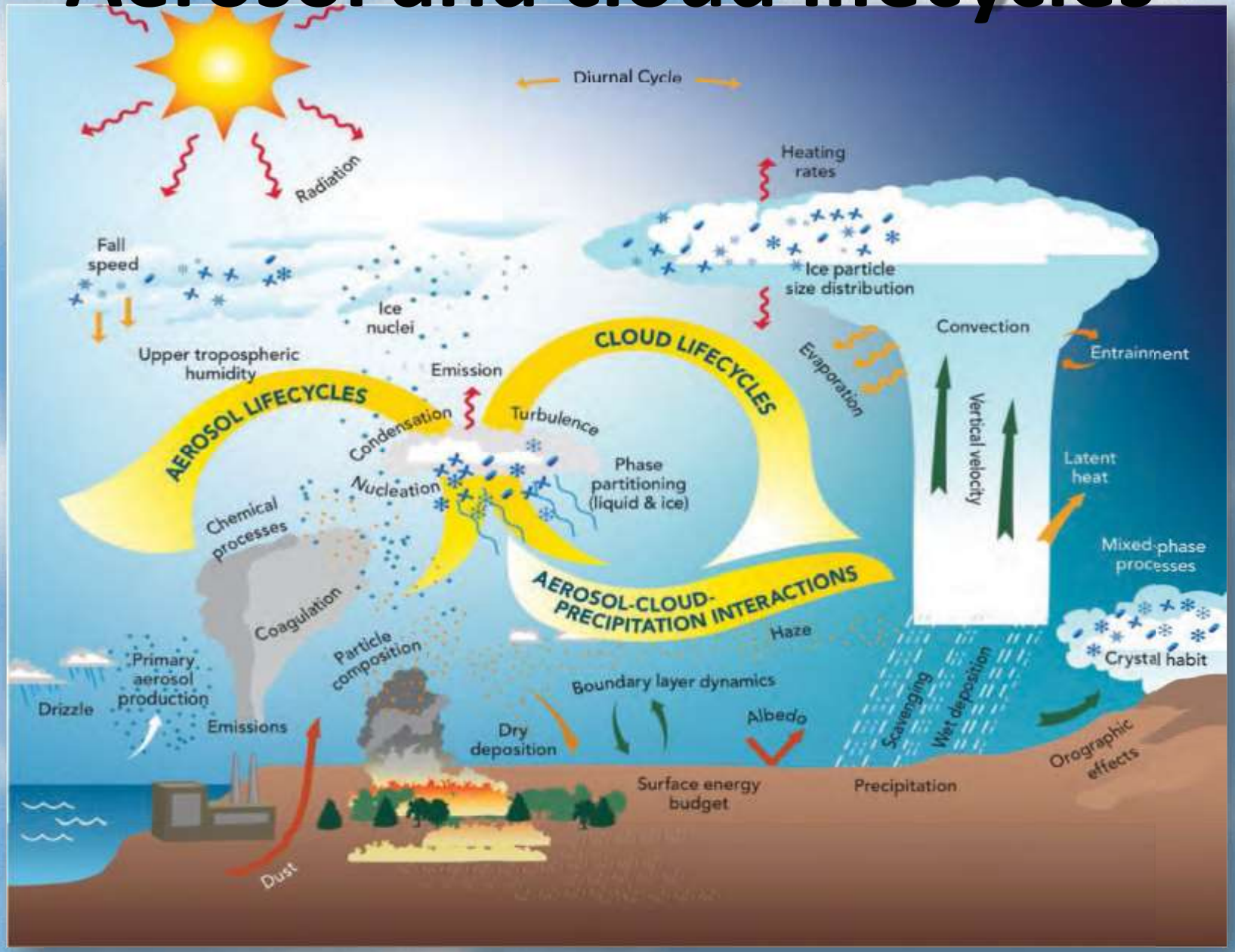


6RXUFH: %UXQR HWDO, 2005 ± 7URSLFDO IRUHWCEDLQ6DQWDUHP NP 83

Hydrological cycle critical for Amazonia

Pyrocumulus clouds

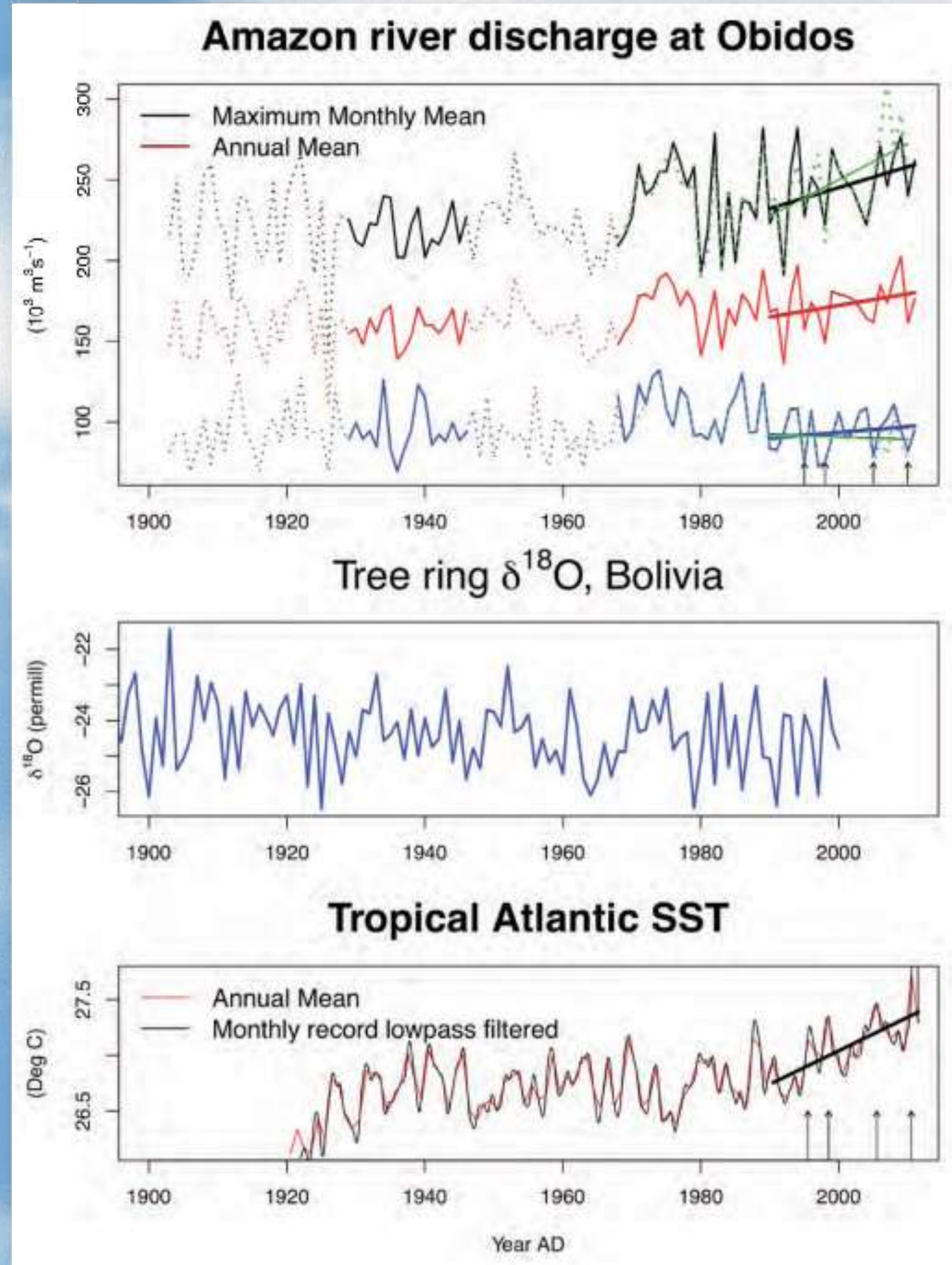
Aerosol and cloud lifecycles



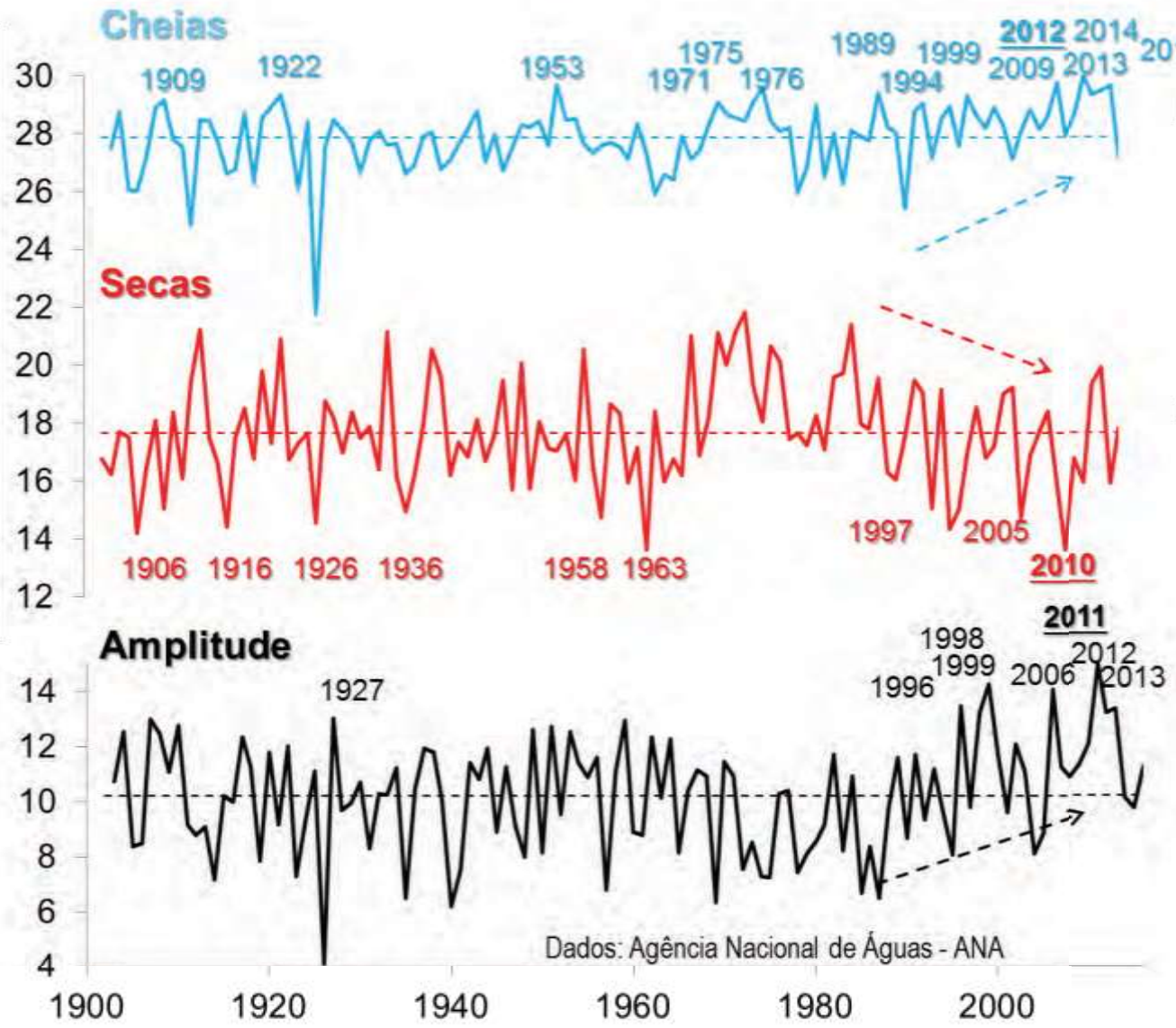

Amazonia is critical for water vapor transport over South America
What processes controls these fluxes?
Image NASA
Google

Is the Amazonian hydrological cycle intensifying?

Maximum monthly, annual mean and minimum monthly mean Amazon river discharge at Óbidos and in green maximum and minimum daily mean river ĚšĐŚĂďŐǧ ;ďω^{18}O in precipitation in Bolivia derived from tree rings (Brienen et al. 2012) and (c) tropical Atlantic sea surface temperature from Extended reconstructed sea surface temperature) (Gloor et al. 2013).



1tYHLVGHiJXD Pi[LPRV (1903-2016), P tQLPRV (1902-2016)



Méd

Média: 27,87±1,15 m

Mé

Média: 17,66±1,83 m

(

Média: 10,21±2,04 m

! $QRV FDOHQGULRV LQGLFDP FKHLDV HQWUHPDV (!29 P), VHFDV VHYHUDV (<15 P) H JUDQGHV DPSOLWXGHV DQXDLV (13 P), YDORUHV P i[LPRV HP **negrito**

-RFKHQ 6FK|QJDUW, 2017

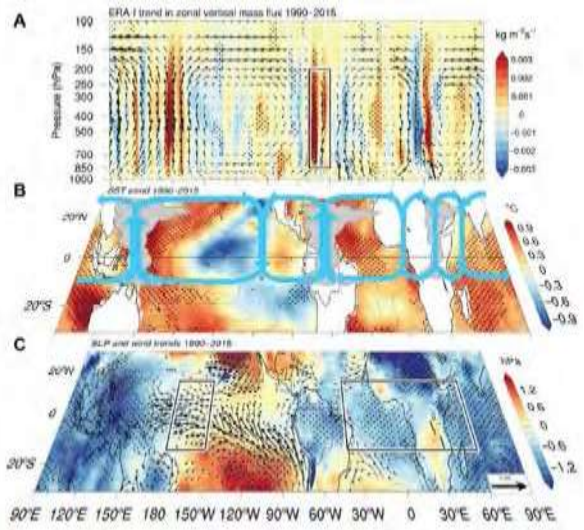
Barichivich et al., Sci. Adv. 2018;4: eaat8785

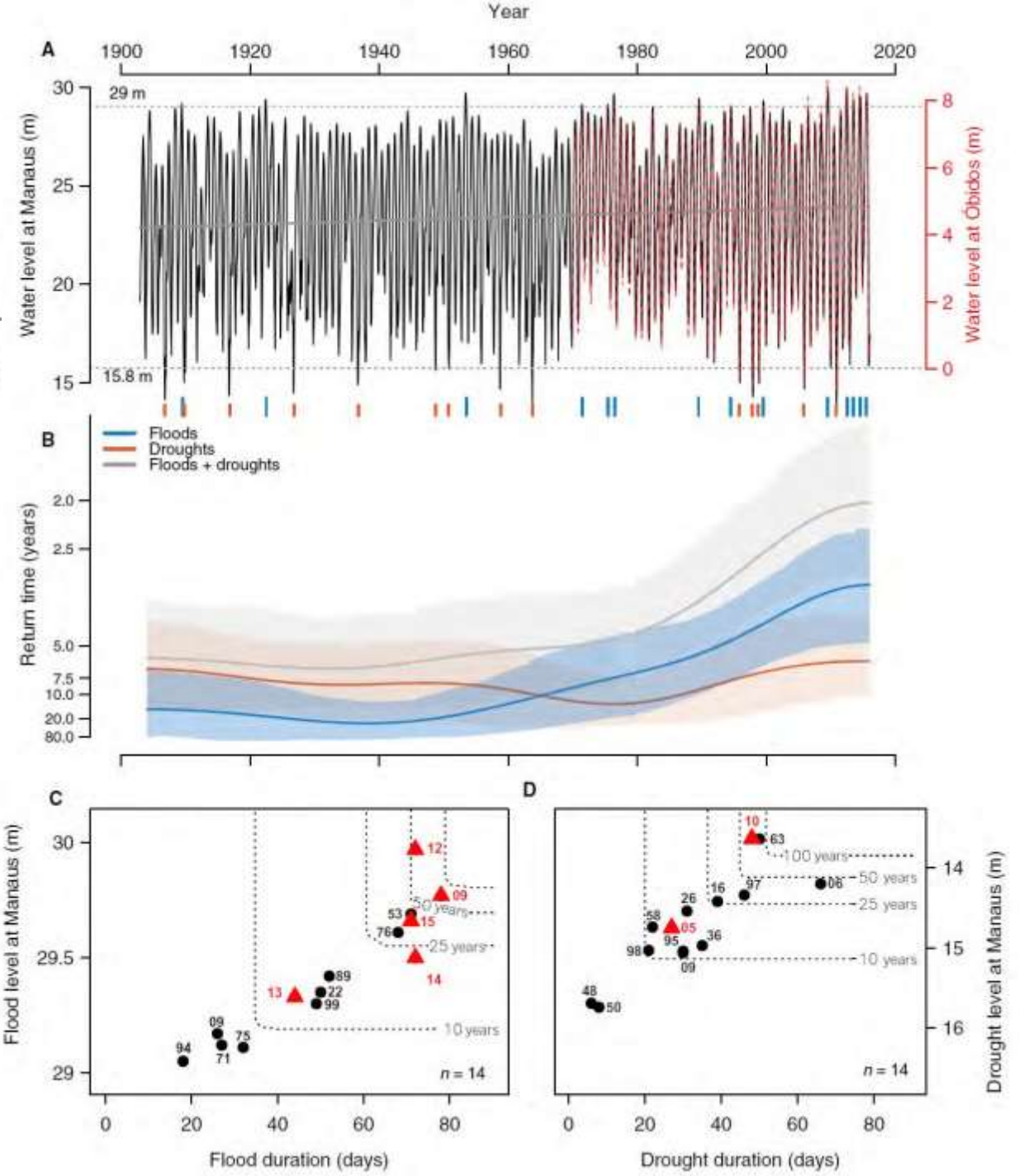
SCIENCE ADVANCES | RESEARCH ARTICLE

EARTH SCIENCE

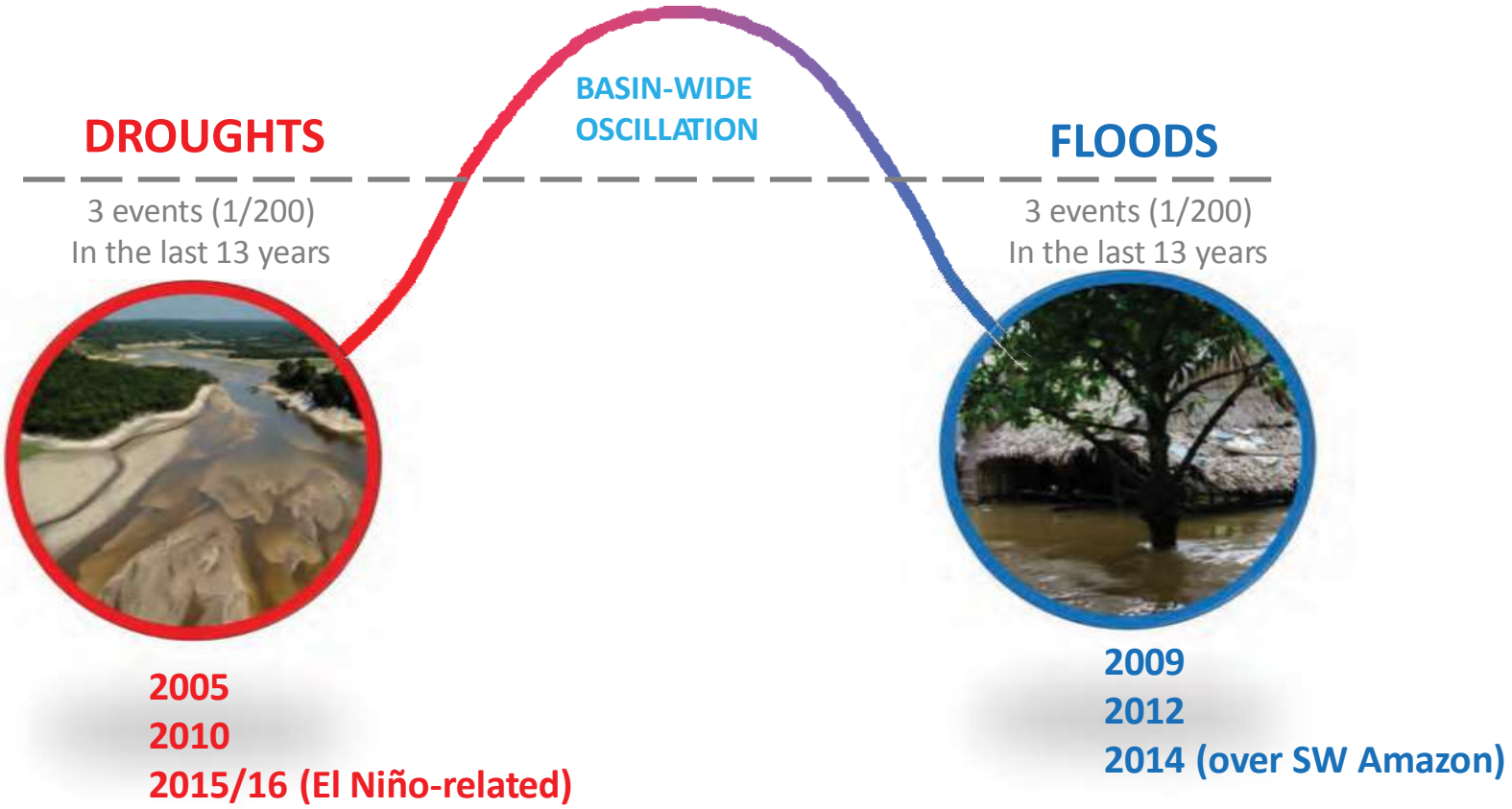
Recent intensification of Amazon flooding extremes driven by strengthened Walker circulation

Jonathan Barichivich[1,2]*, Emanuel Gloor[3], Philippe Peylin[4], Roel J. W. Brienen[3], Jochen Schöngart[5], Jhan Carlo Espinoza[6], Kanhu C. Pattnayak[3]



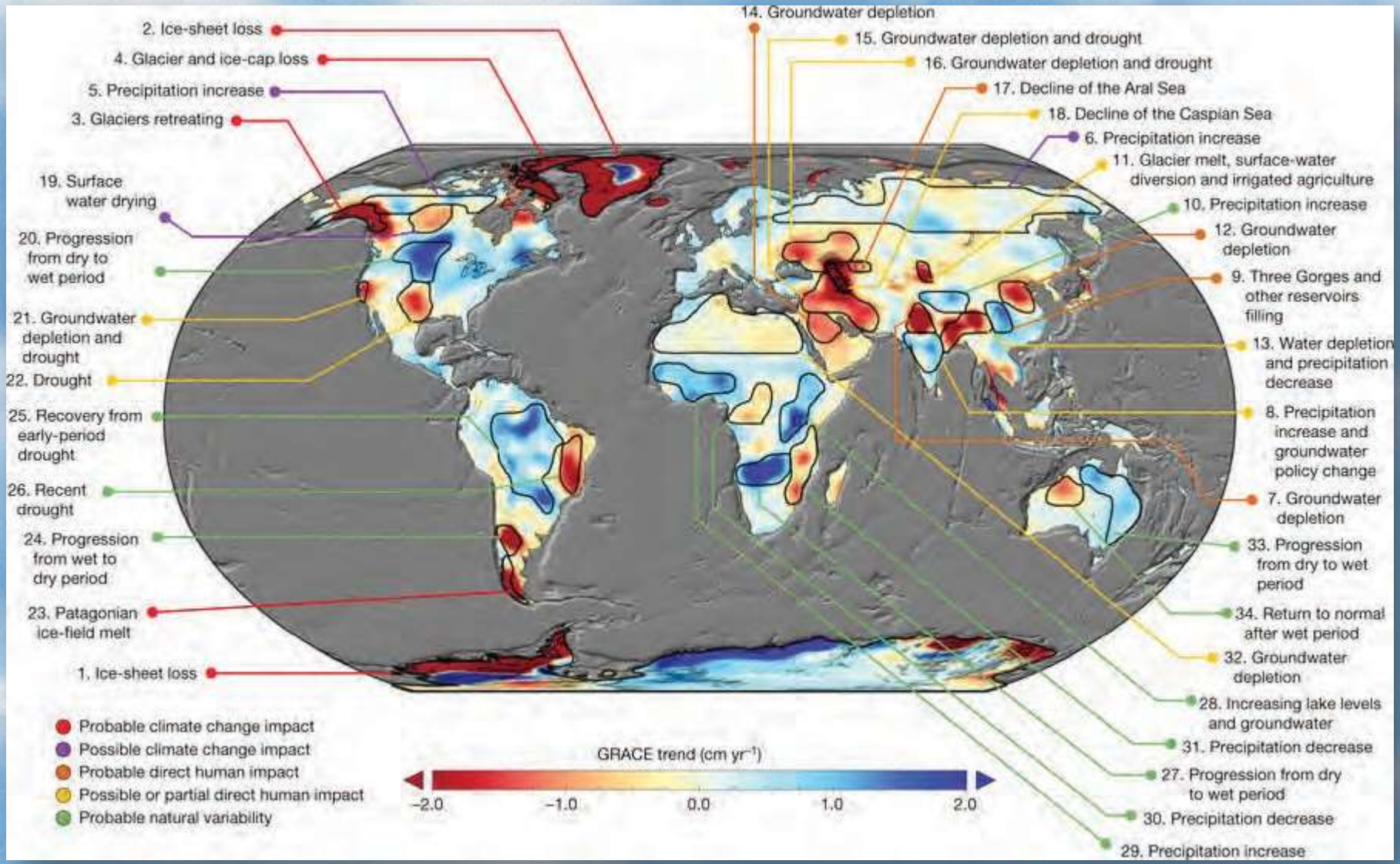


THE AMAZON CLIMATE SYSTEM HAS BEEN OSCILLATING BETWEEN TWO EXTREMES IN THE LAST 13 YEARS

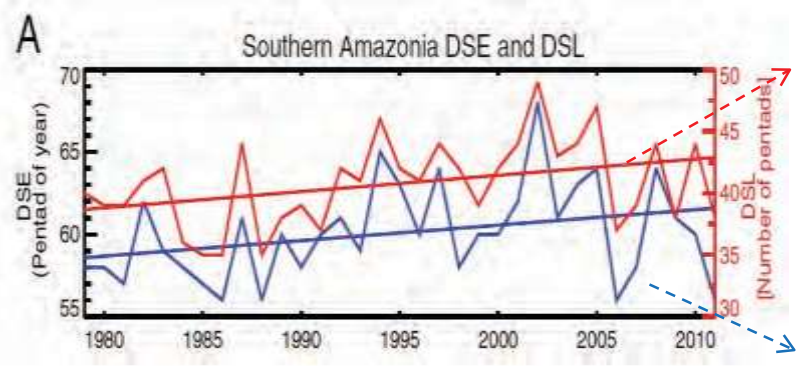


Freshwater availability is changing worldwide

Emerging trends in global freshwater availability GRACE 2002-2016 (terrestrial water storage, Nature May 2018)

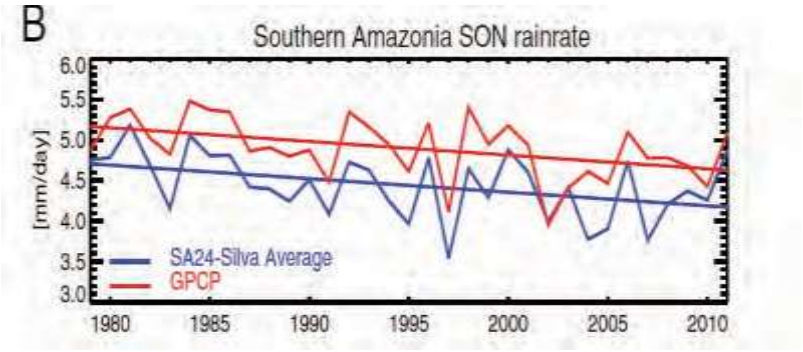


Dry season length is increasing in Amazonia



Annual time series of dry season length (DSL)

Annual time series of dry season END (DSE)

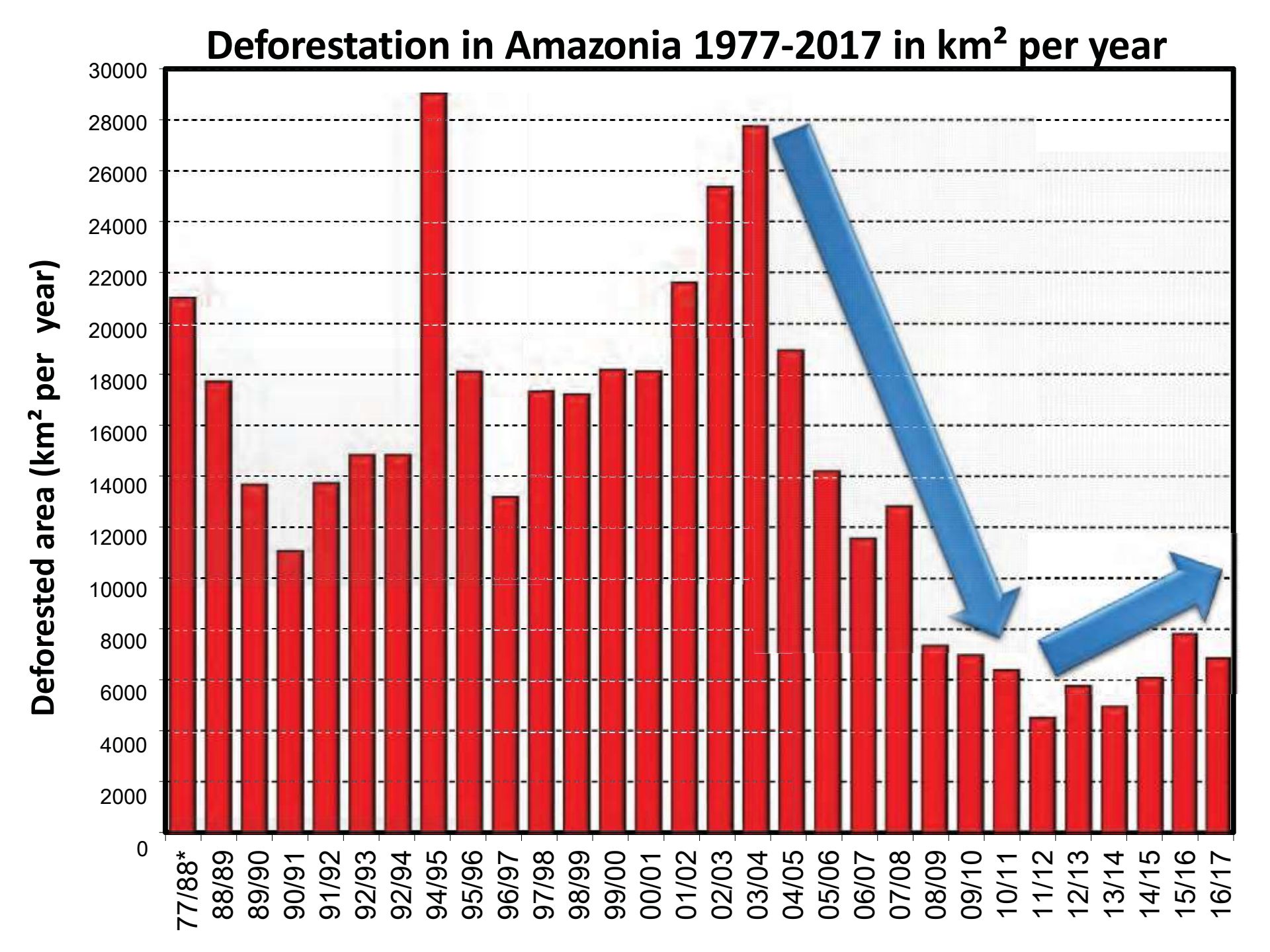


Dry season length has increased by **6.5±2.5** days/decade;

Fu et al. 2013 (PNAS)

Water vapor and global precipitation: May 2005 to May 2007

To study the effects of precipitation and how it influences other phenomena, scientists study moisture and precipitation in the atmosphere. Satellite observations cover broad areas and provide more frequent measurements that offer insights into when, where, and how much rain or snow is falling. The video, from NASA's Global


Deforestation in Amazonia 1977-2017 in km² per year
Deforested area (km² per year)
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
77/88*
88/89
89/90
90/91
91/92
92/93
92/94
94/95
95/96
96/97
97/98
98/99
99/00
00/01
01/02
02/03
03/04
04/05
05/06
06/07
07/08
08/09
09/10
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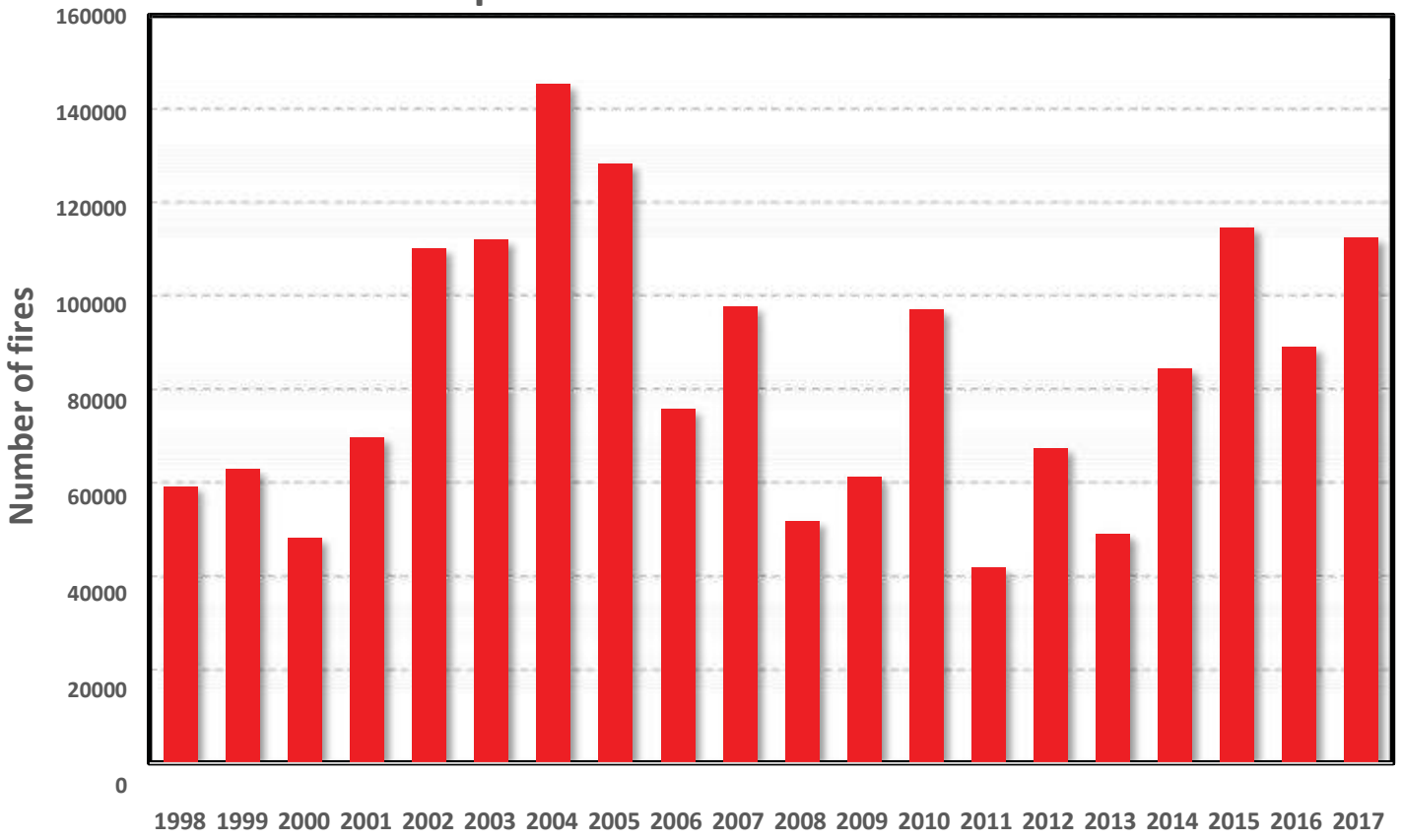
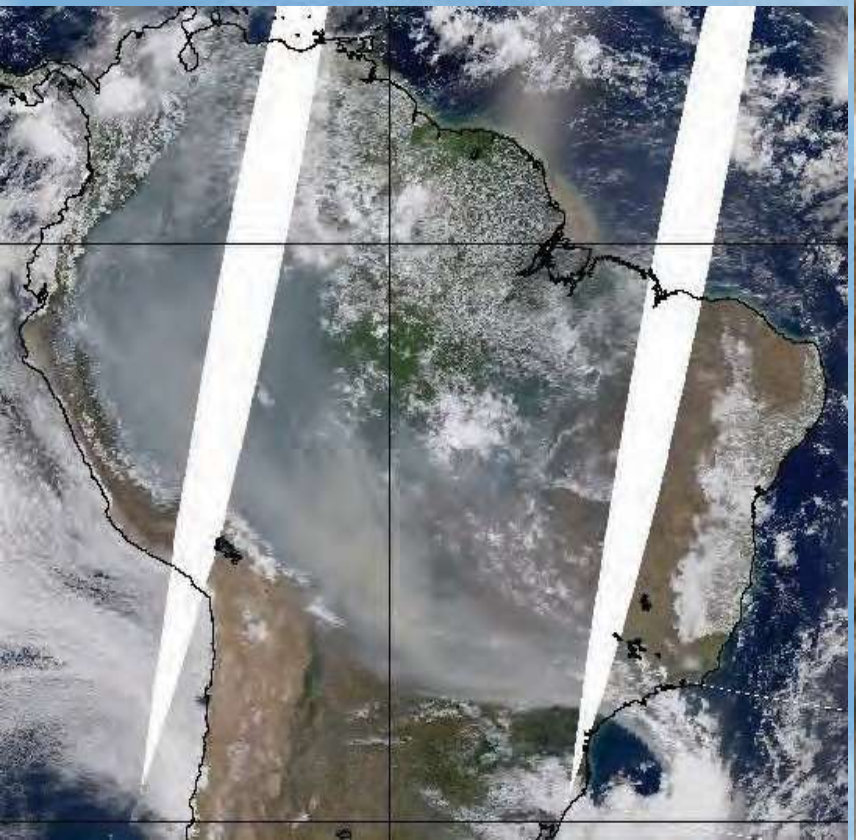
13/14
14/15
15/16
16/17

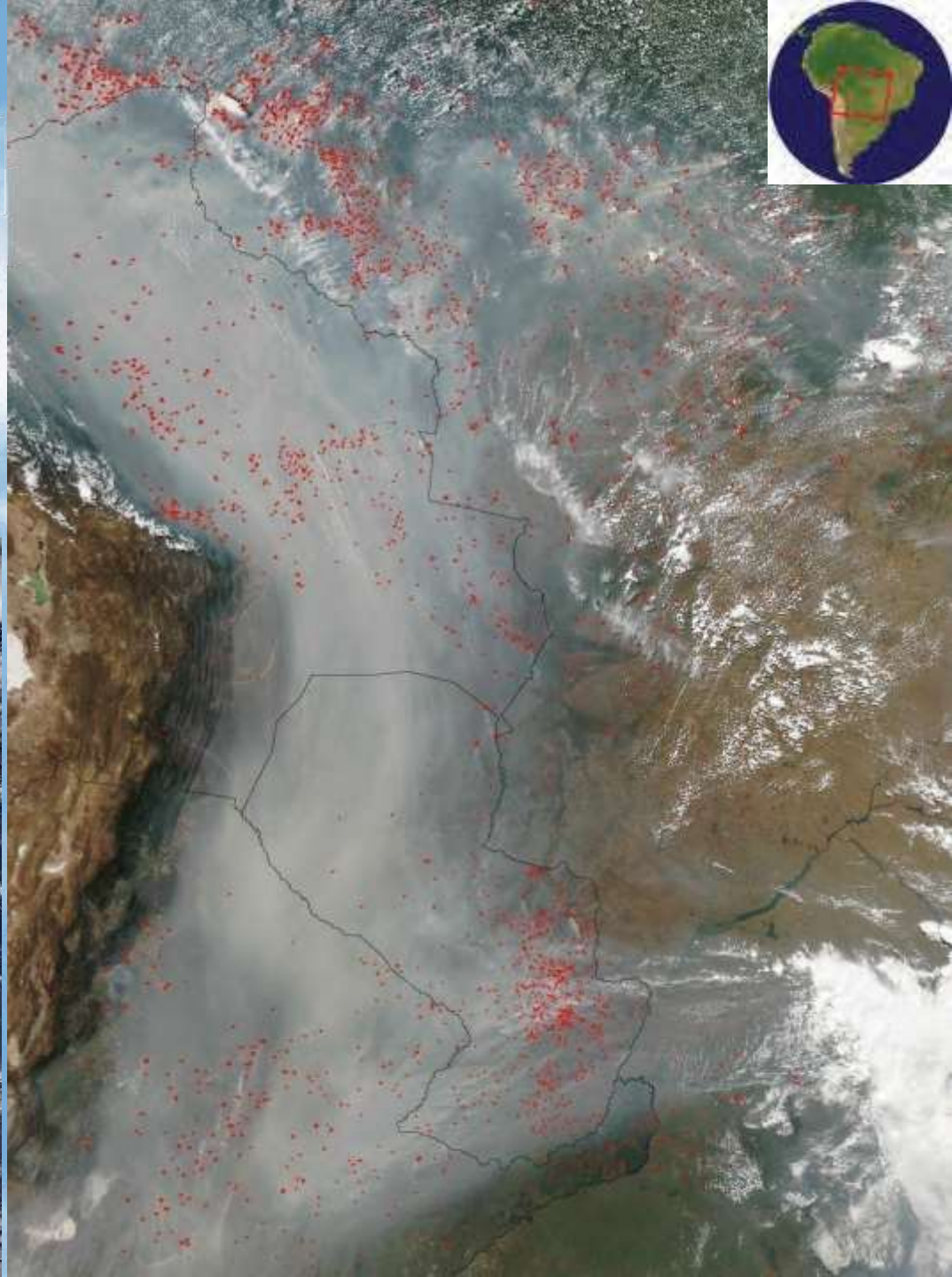
Fire spots in Amazonia 1998-2017



Large scale aerosol distribution in Amazonia

- Severe health effects on the Amazonian population (about 20 million people)
- Climatic effects, with strong effects on cloud physics and radiation balance.
- Changes in carbon uptake and ecosystem functioning

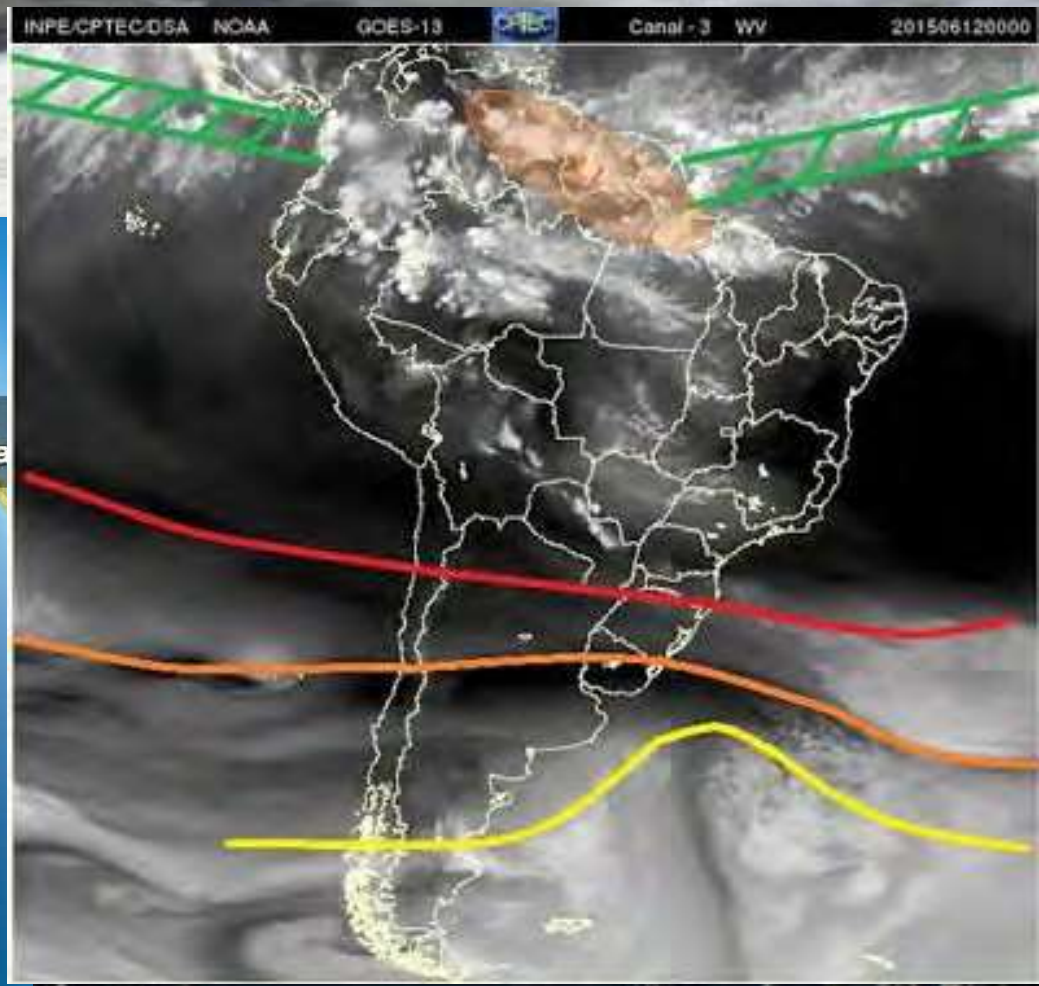




Aerosol emissions make the high variability visible – it also applies to aerosol composition and the trace gases!

All non linear processes

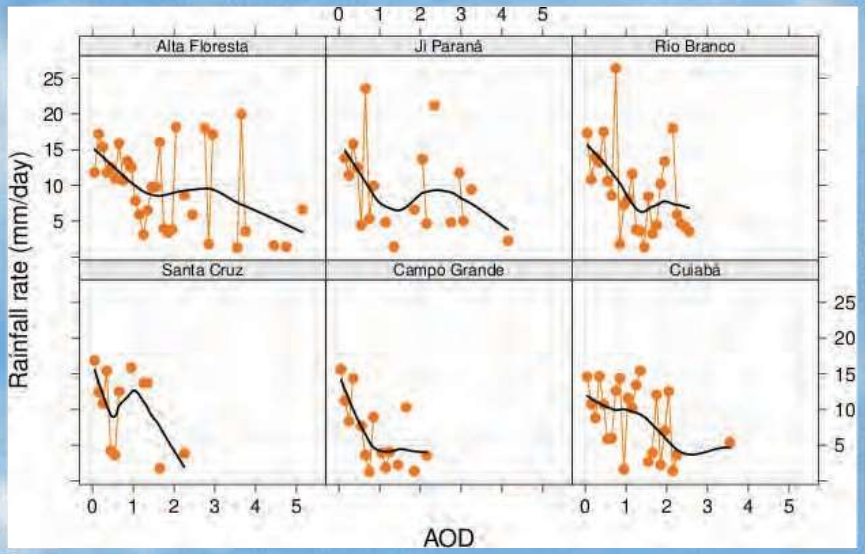
Convective clouds: Key for radiation balance and precipitation



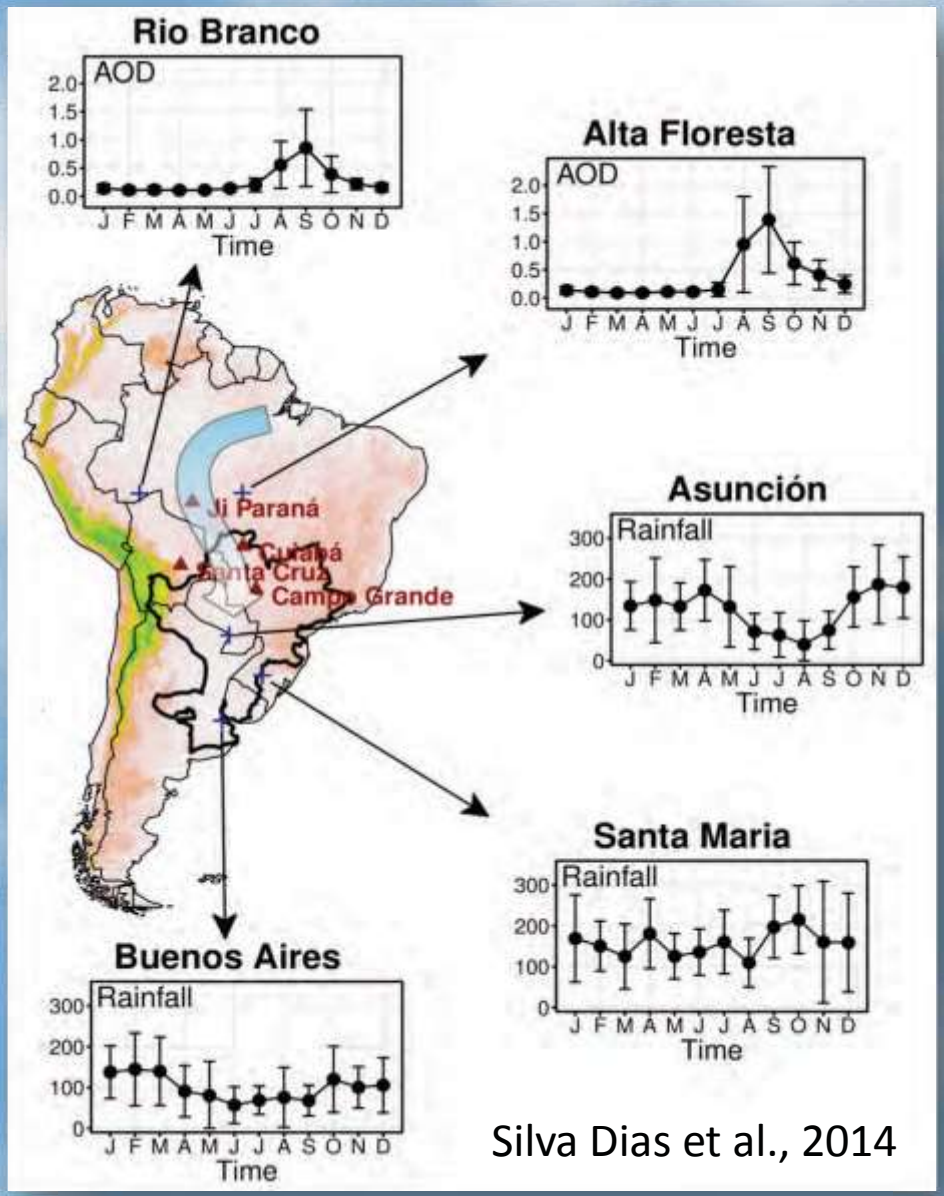
Relationship between aerosols and precipitation in the La Plata Basin

AERONET (Aerossols) + TRMM (Precipitation) + BRAMS (simulations)

Reduction in precipitation with increase in aerosols



BRAMS: Simulations with cloud microphysics confirm the measurements



Silva Dias et al., 2014

Regional dry-season climate changes due to three decades of Amazonian deforestation

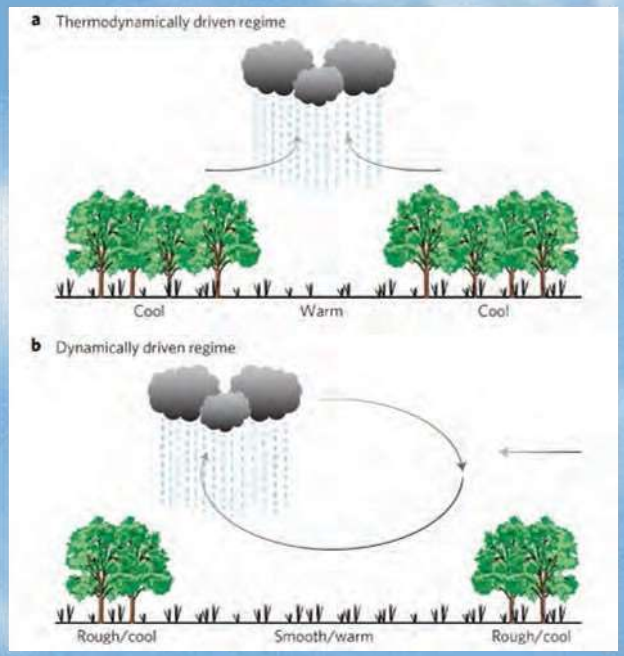
news & views

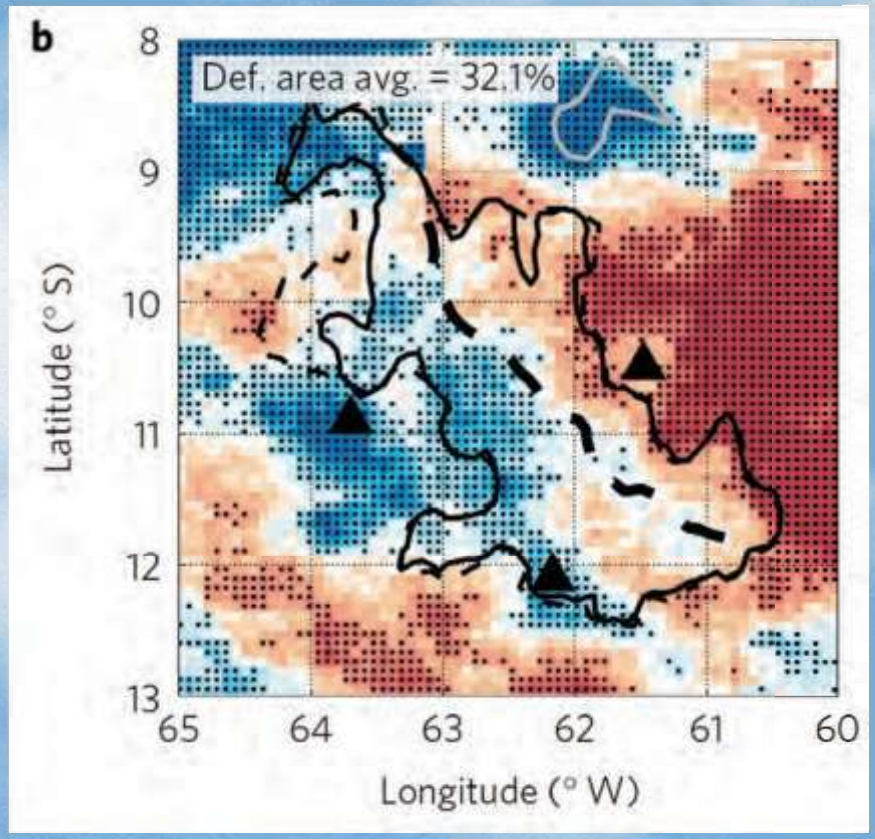
BIOSPHERE-ATMOSPHERE INTERACTIONS

Deforestation size influences rainfall

Changes to the land surface, such as land clearing and logging of forest areas, impacts moisture cycling. Now a shift from small-scale to large-scale deforestation in the southern Amazon is found to modify the mechanisms and patterns of regional precipitation.

Jeffrey Q. Chambers and Paulo Artaxo



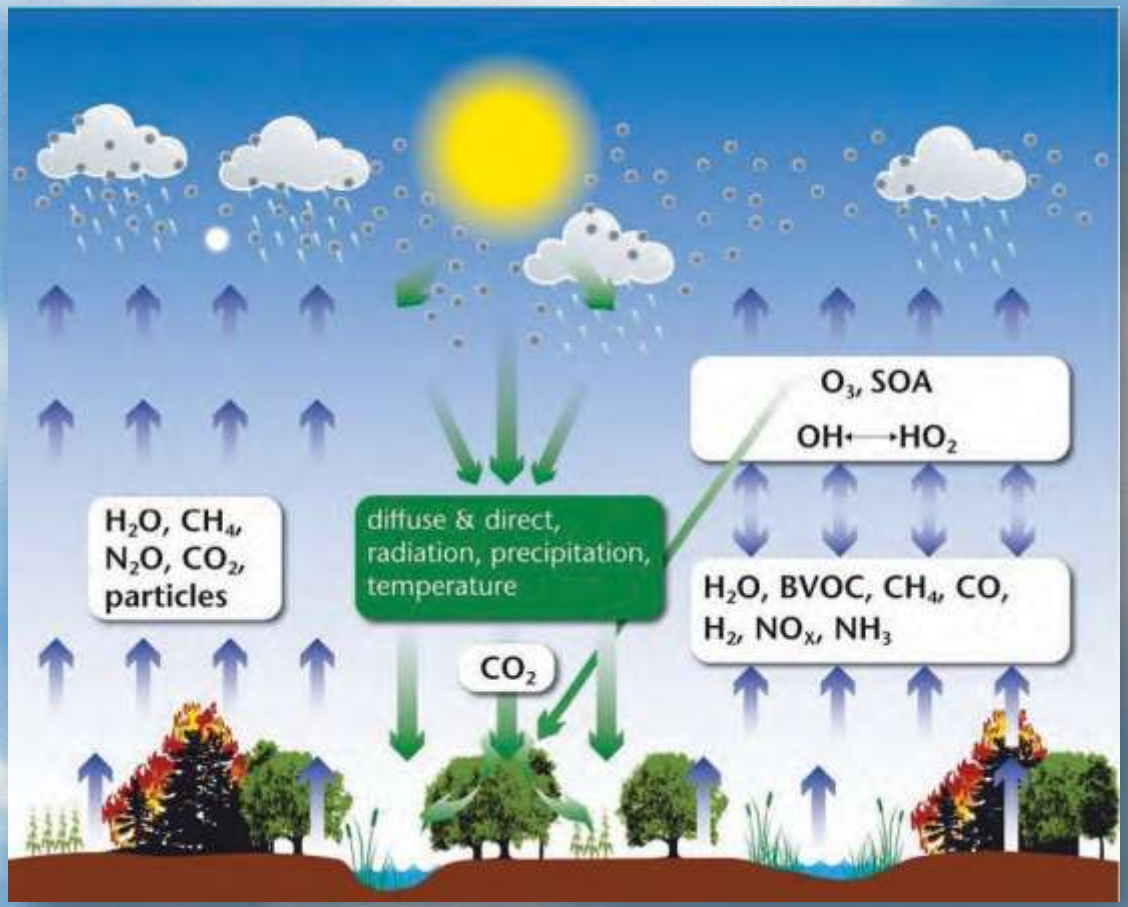


Emergence of the southeast–northwest cloud and precipitation ‘dipoles’ with increasing deforestation in Rondônia

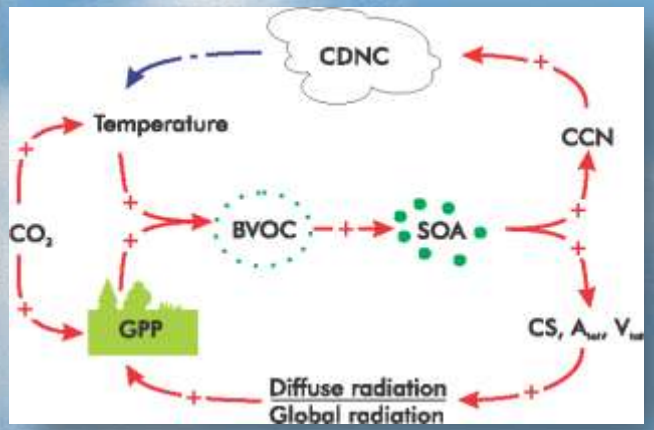
7 UDQVLWLRQLQWKH GRPLQDQWFRQWHPSRUDU\ UHJLPH ZLWKLQFUHDVLQJ YHDCHV RI GHIRUHVWDWLRQ

Jaya Khanna Nature climate change 2017

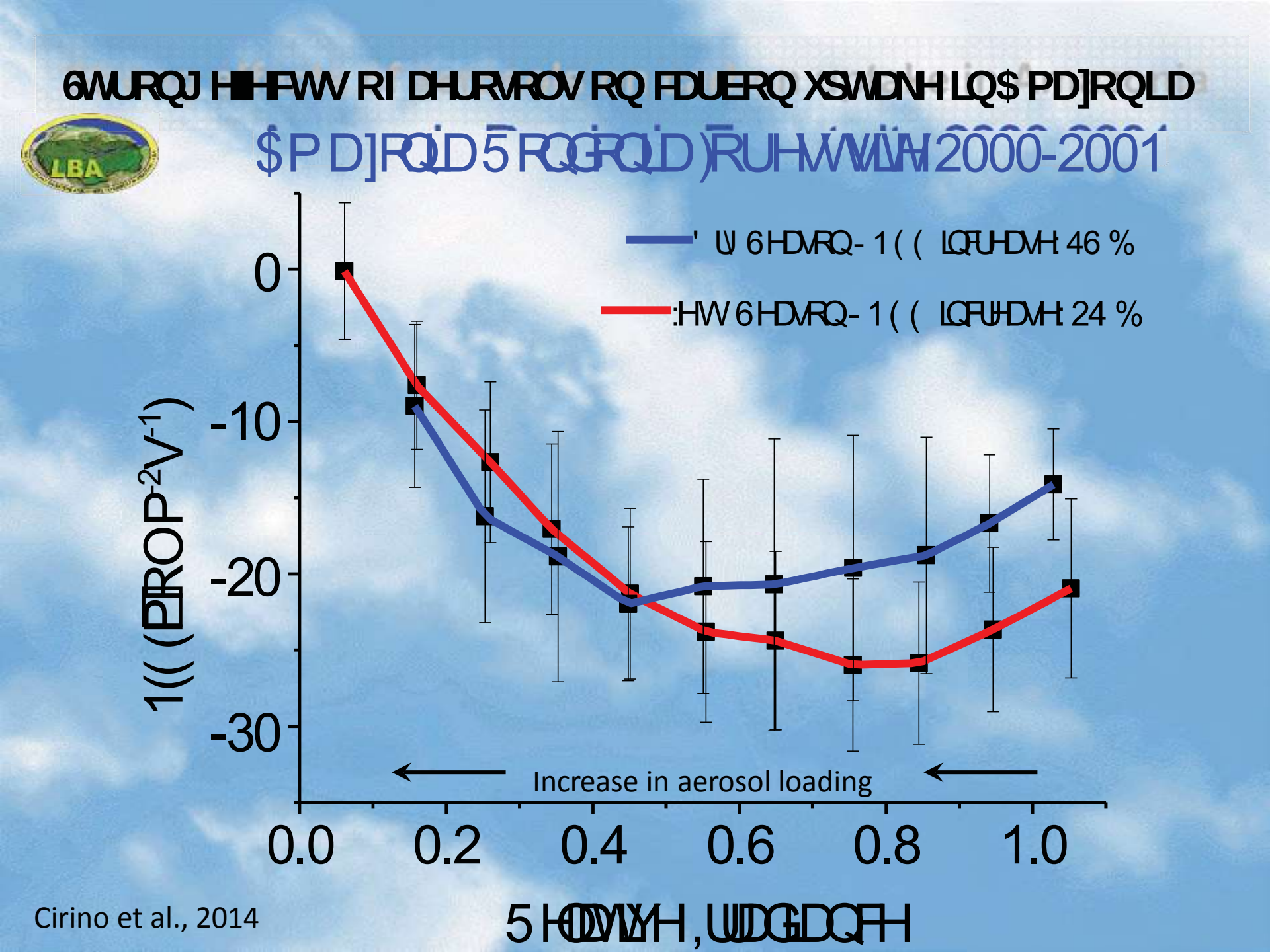
Conceptual overview of terrestrial carbon cycle – chemistry – climate interactions



Arneth et al., 2011

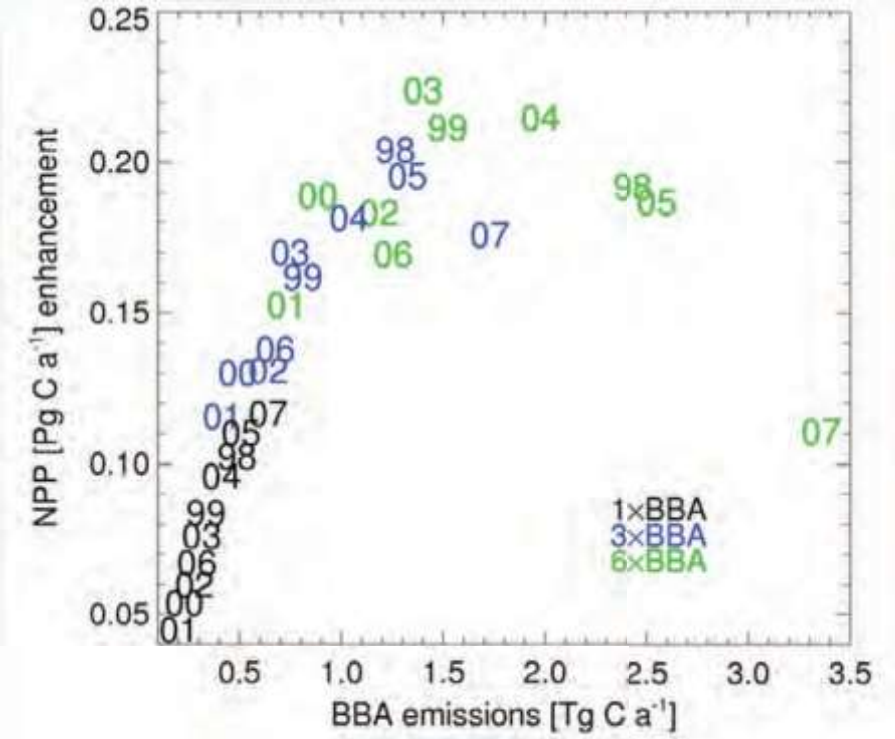


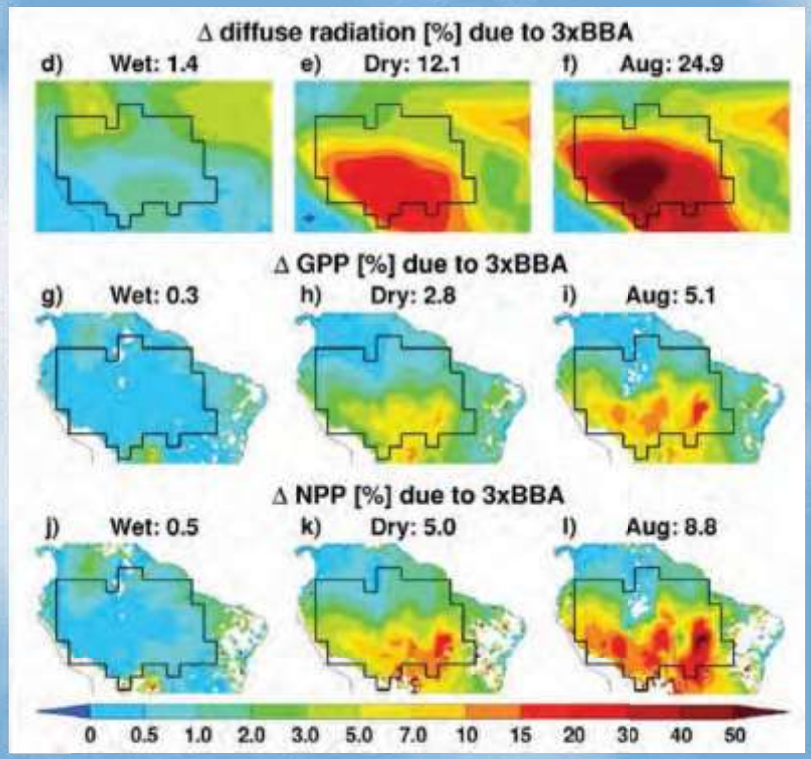
Kulmala et al, 2013


6WURQJ HIIHFWV RI DHURVROV RQ FDUERQ XSWDNH LQ$ PD]RQLD
$P D]RQLD 5RQGRQLD)RUHVWVLWH 2000-2001
' U\ 6HDVRQ - 1((LQFUHDVH 46 %
:HW 6HDVRQ - 1((LQFUHDVH 24 %
0
-10
-20
-30
1(((PROP2V-1)
Increase in aerosol loading
0.0
0.2
0.4
0.6
0.8
1.0
5HODWLYH ,UUDGLDQFH
LBA
Cirino et al., 2014

Fires increase Amazon forest productivity through increases in diffuse radiation

Rap et al., 2015





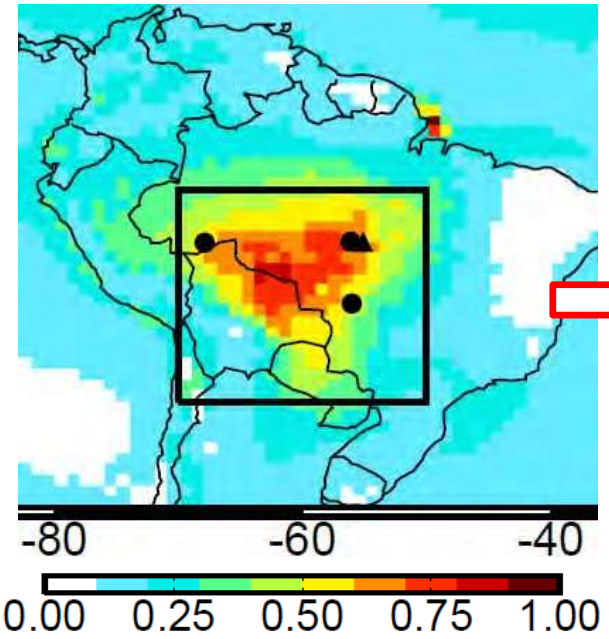
$PD]RQ EDVLQ DQQXDO PHDQ 1 3 3 HQKDQFHPHQW FDXVHG E\ %%$ DV D IXQFWLRQ RI %%$ HPLVVLRQV (EODFN VWDQGDUG %%$ HPLVVLRQV; EOXH 3 î %%$ HPLVVLRQV; DQG JUHHQ 6 î %%$ HPLVVLRQV), IRU HDFK \HDU GXULQJ

Modeled 1998–2007 mean percentage changes in (a–c) diffuse radiation, (g–i) GPP, and (j–l) NPP during the wet (defined here as December to May) season, dry (June to November) season, and August due to BBA emissions.

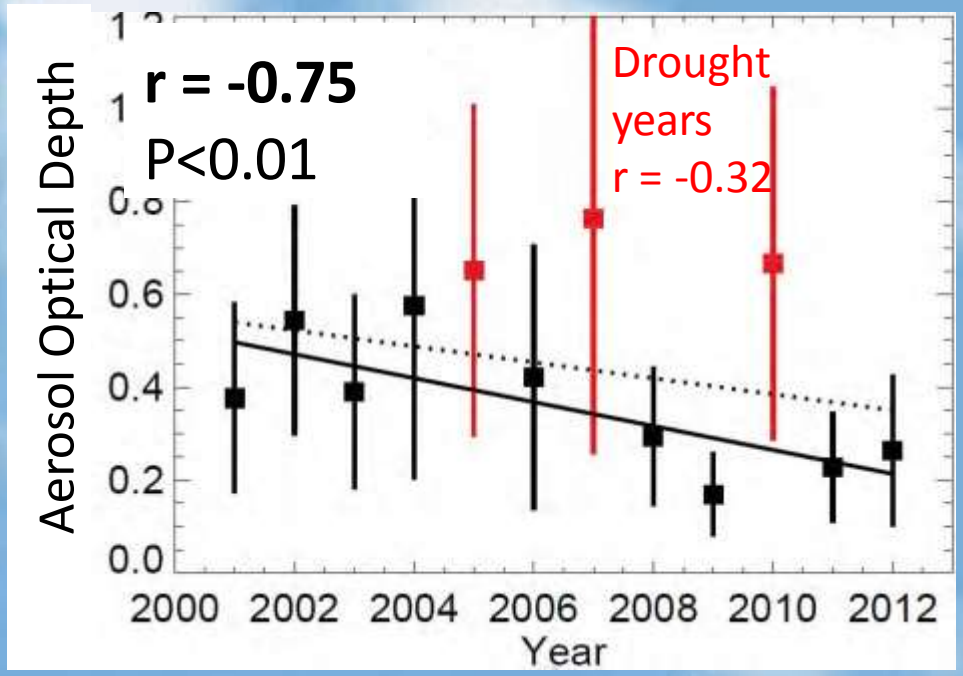
LETTERS
PUBLISHED ONLINE: 16 SEPTEMBER 2015 | DOI: 10.1038/NGEO2535
nature geoscience

Air quality and human health improvements from reductions in deforestation-related fire in Brazil

C. L. Reddington[1], E. W. Butt[1], D. A. Ridley[2], P. Artaxo[3], W. T. Morgan[4], H. Coe[4] and D. V. Spracklen[1]*



Dry season mean AOD retrieved by MODIS



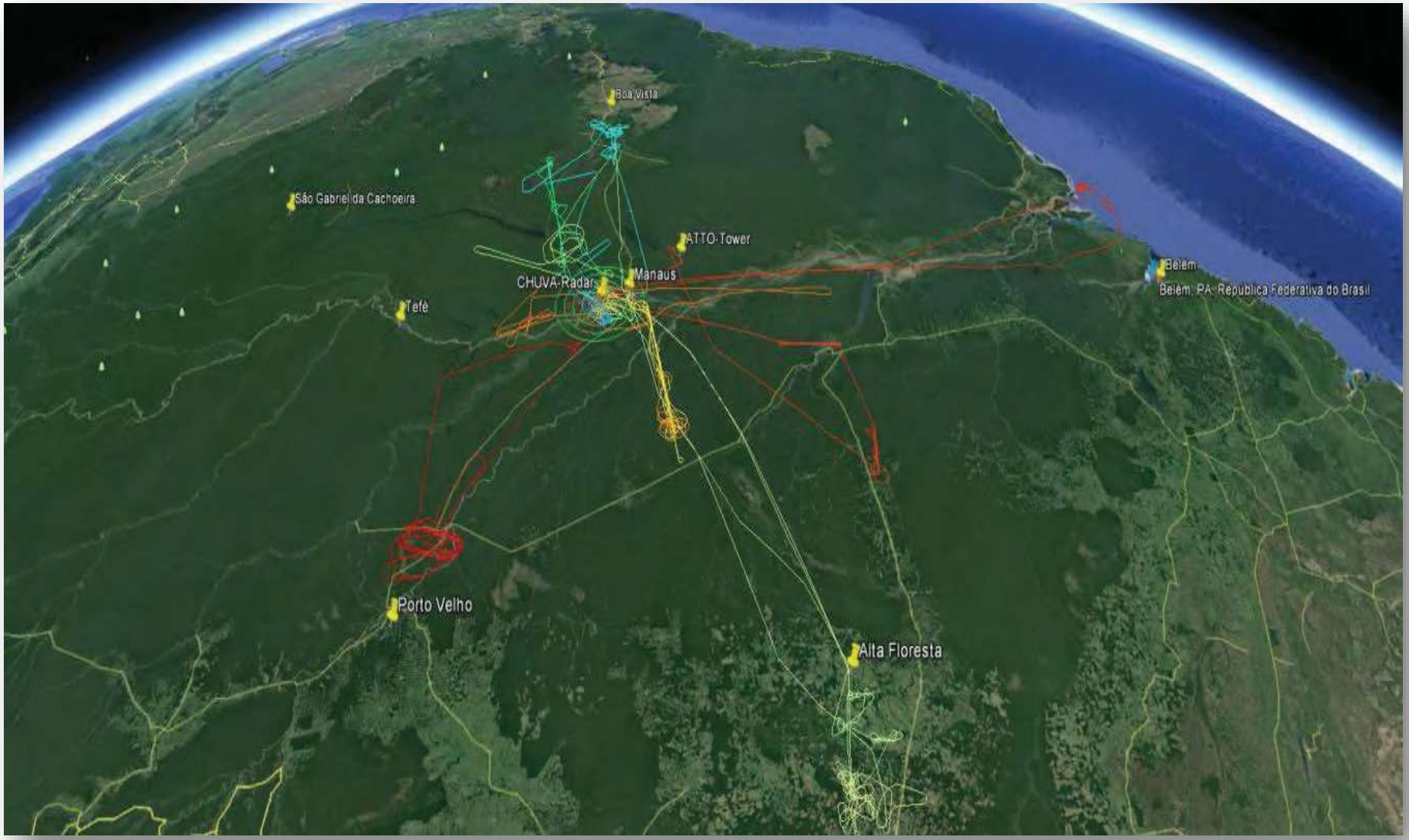
⇒Reduction in PM2.5 may be preventing roughly 1,700 premature adult deaths annually across South America.

*R$PD]RQ /DUJH VFDOH PHDVXUHPHQWV

*S +$/2 SODQH-³+LJK $OWLWXGH DQG /RQJ 5DQJH 5HVHDUFK $LUFUDIW.

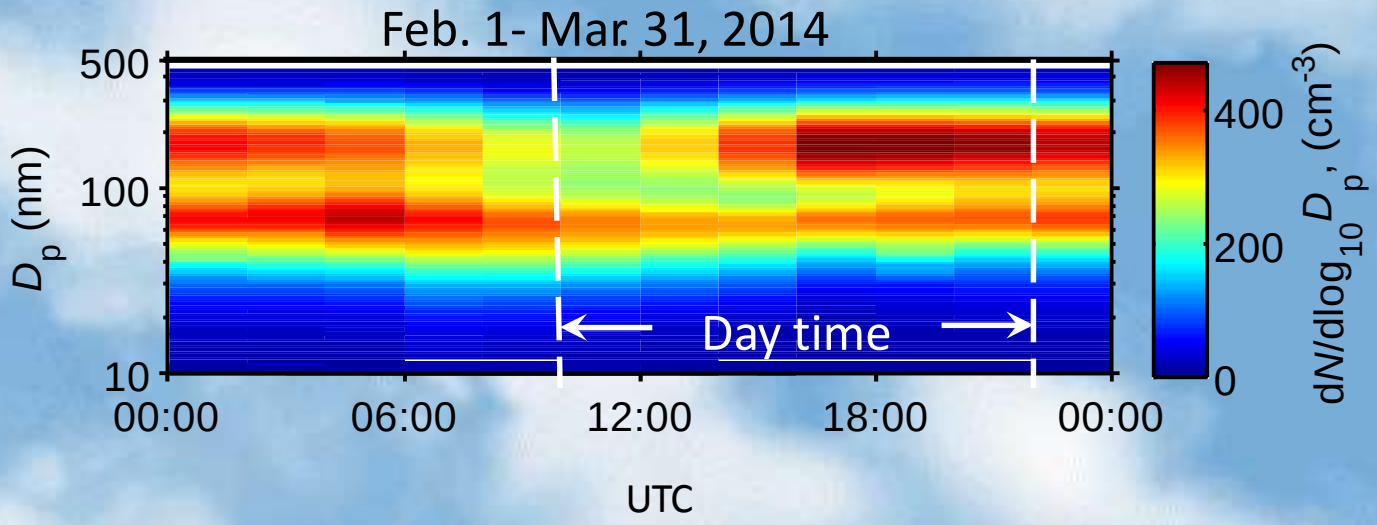
'RF(*1 SOEDQHLQ WZR FDPSDLJQV EW ZHW DQG GU\ VHDVRQV

ACRIDICON Flights G5-HALO plane dry season 2014

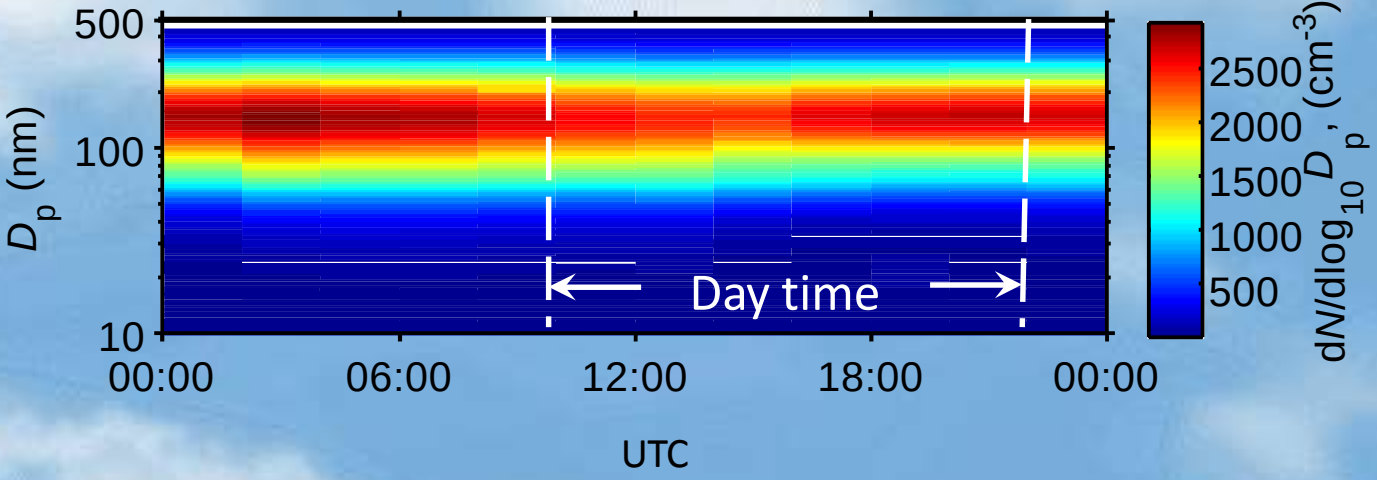


How particles are produced in Amazonia?

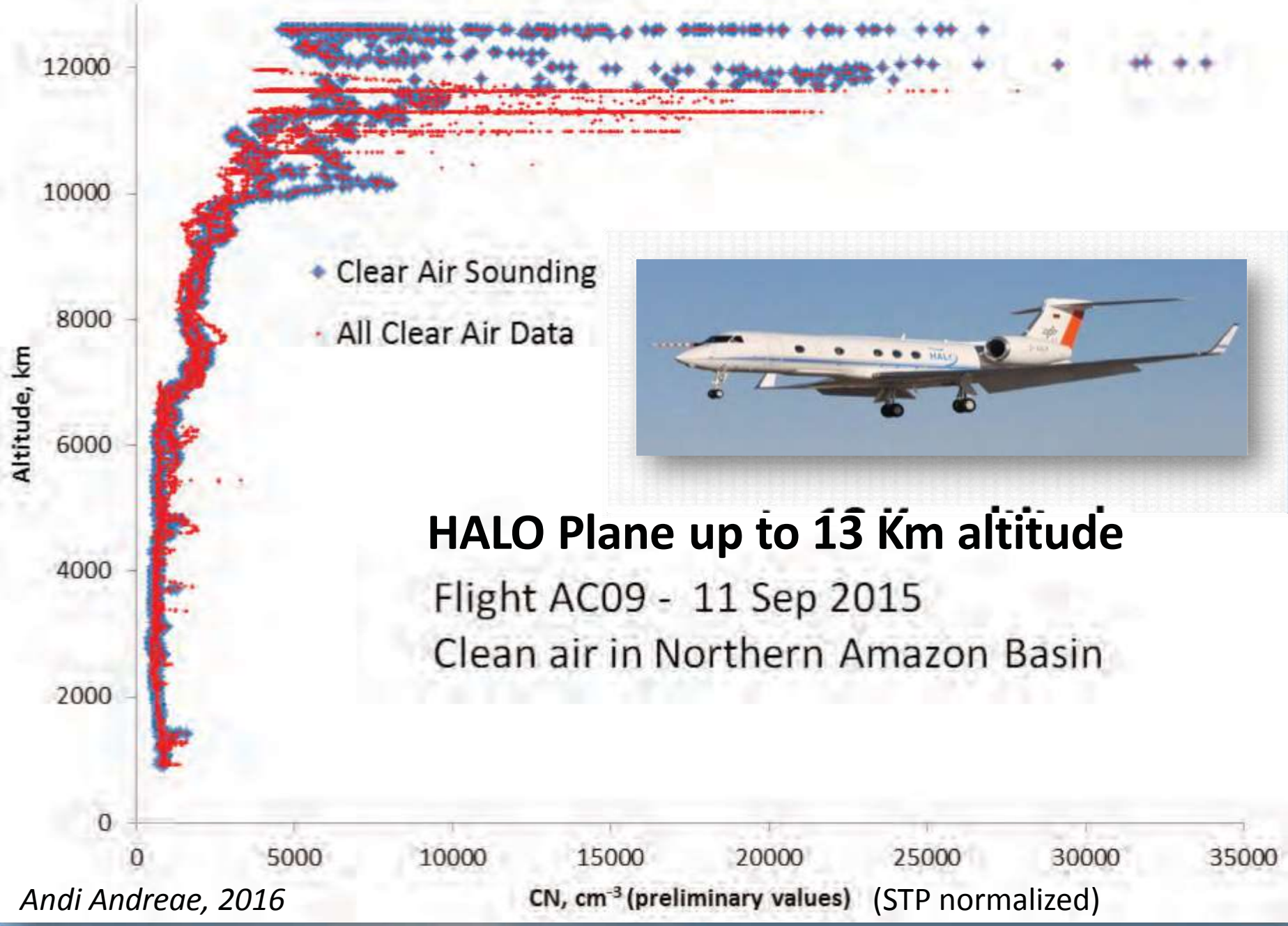
T0 site (ATTO)
(All data)
N: ~320 cm^{-3}



T0 site (ATTO)
(dry season)
N: ~3100 cm^{-3}



It rains a lot. Removal very high. How the particles are formed?

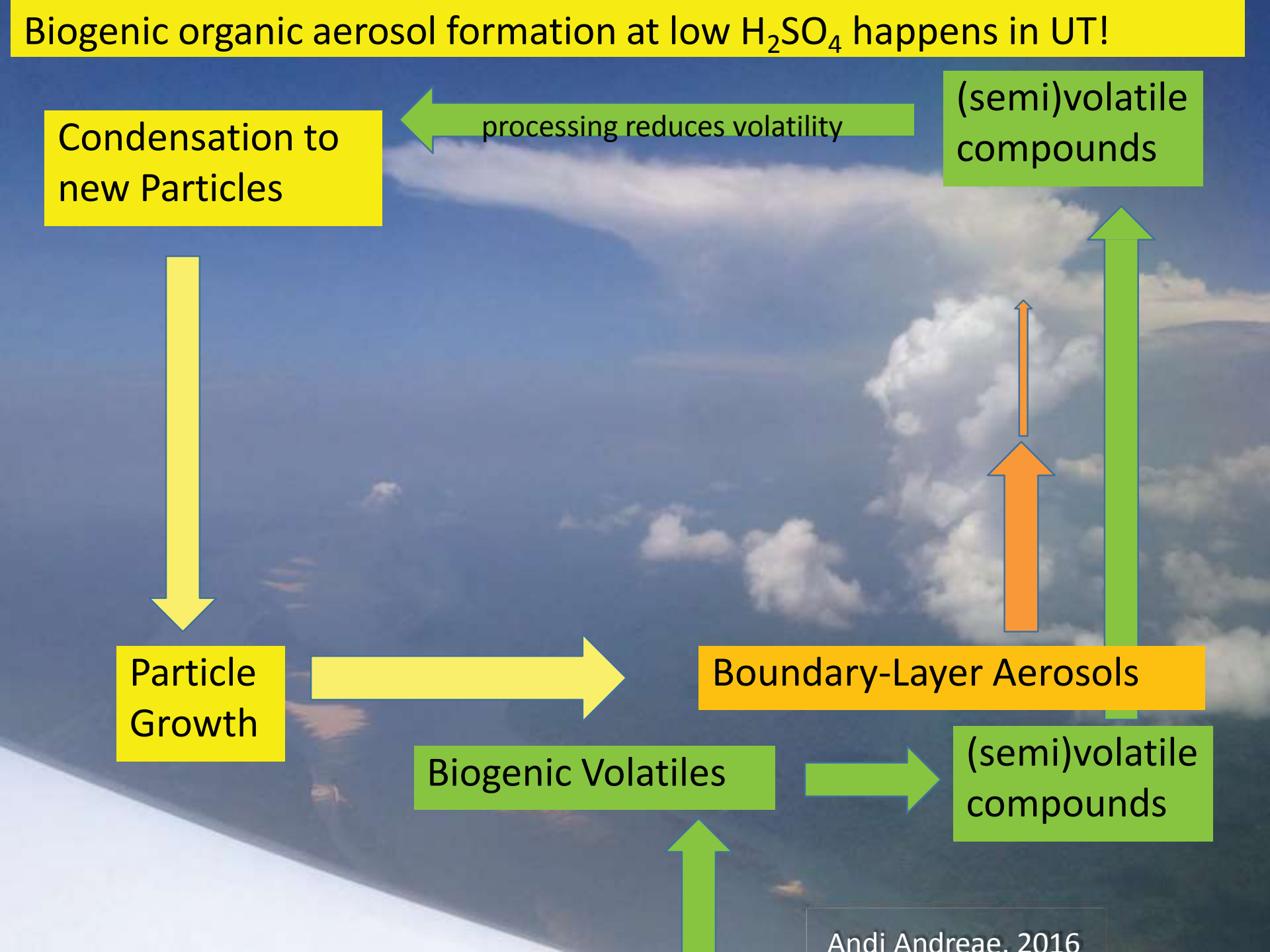


HALO Plane up to 13 Km altitude

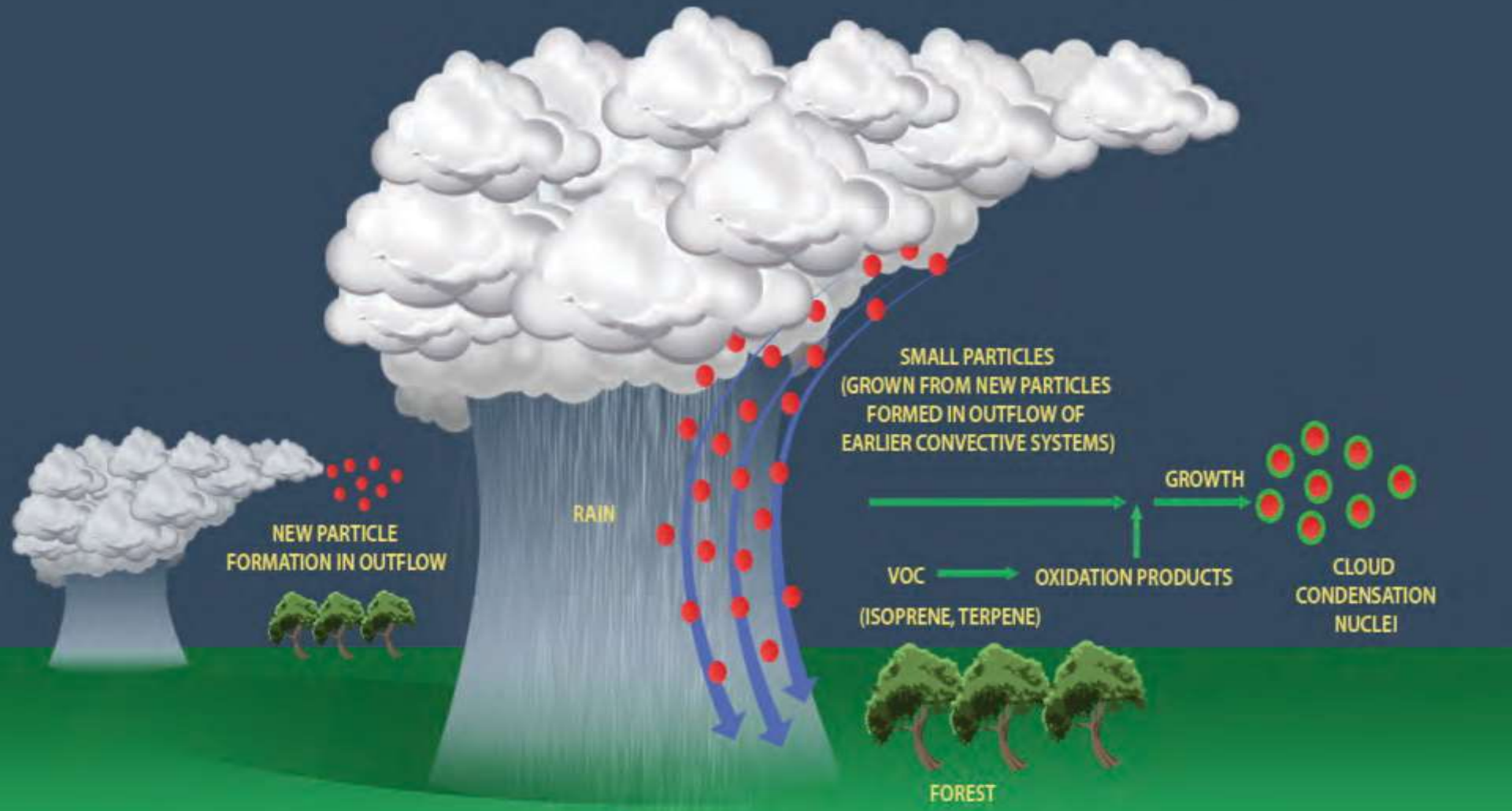
Flight AC09 - 11 Sep 2015

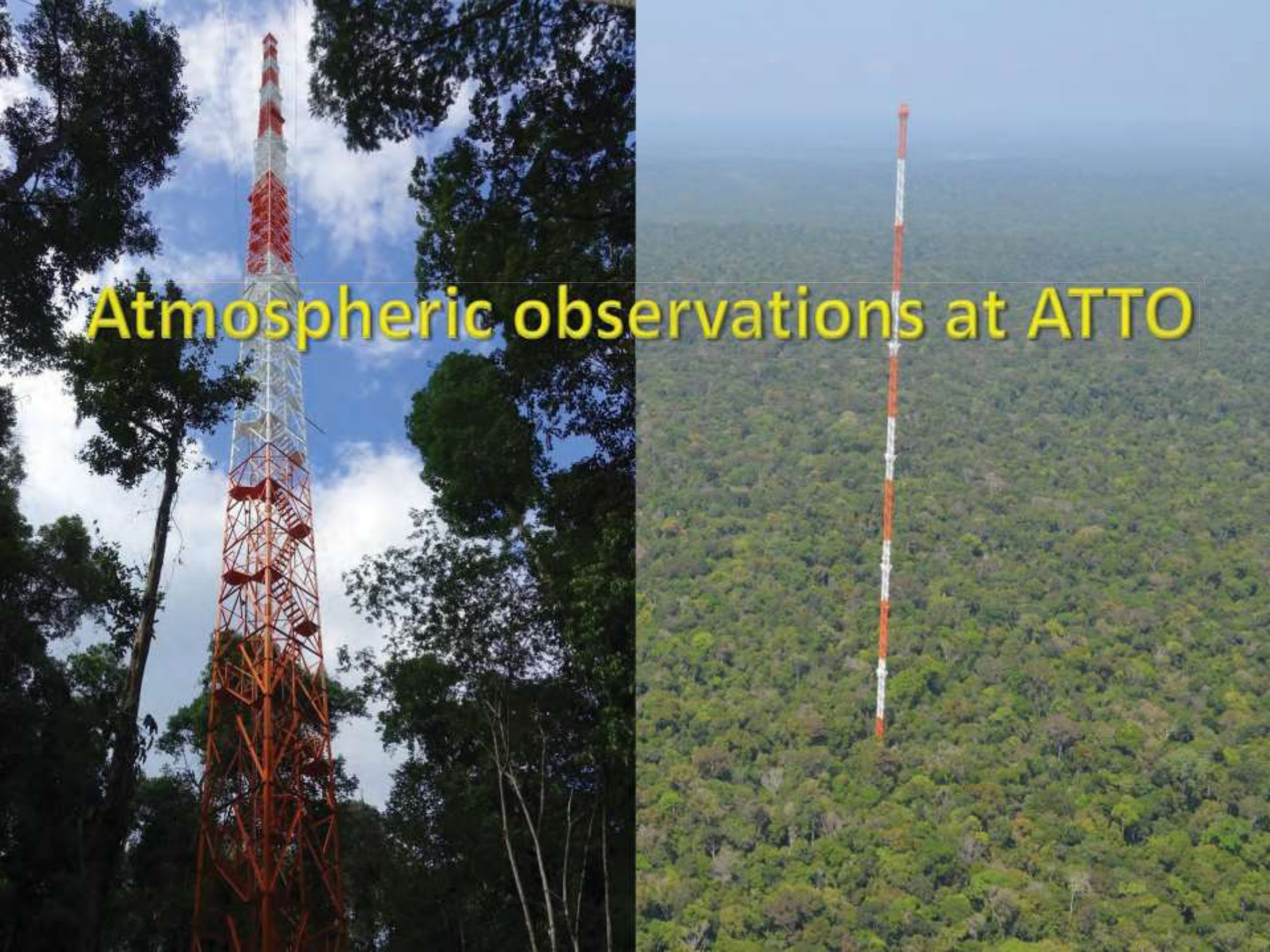
Clean air in Northern Amazon Basin

Andi Andreae, 2016

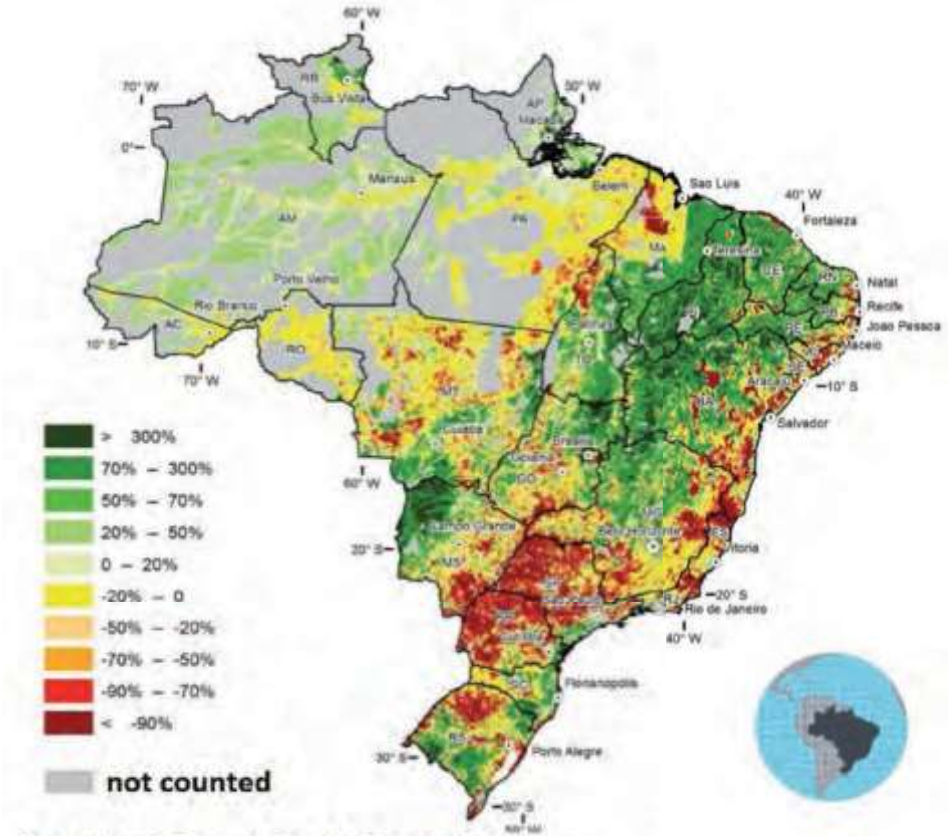

Biogenic organic aerosol formation at low H_2SO_4 happens in UT!
Condensation to new Particles
processing reduces volatility
(semi)volatile compounds
Particle Growth
Boundary-Layer Aerosols
Biogenic Volatiles
(semi)volatile compounds
Andi Andreae, 2016

Clouds as active aerosol processors in the atmosphere



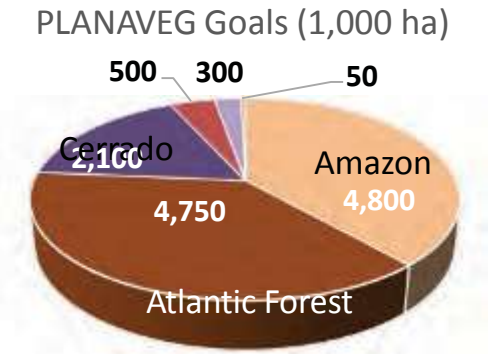

Atmospheric observations at ATTO

Brazil's NDC to the Paris Agreement calls for ecosystem restoration of 12.5 million hectares



Levels of Forest Code Compliance

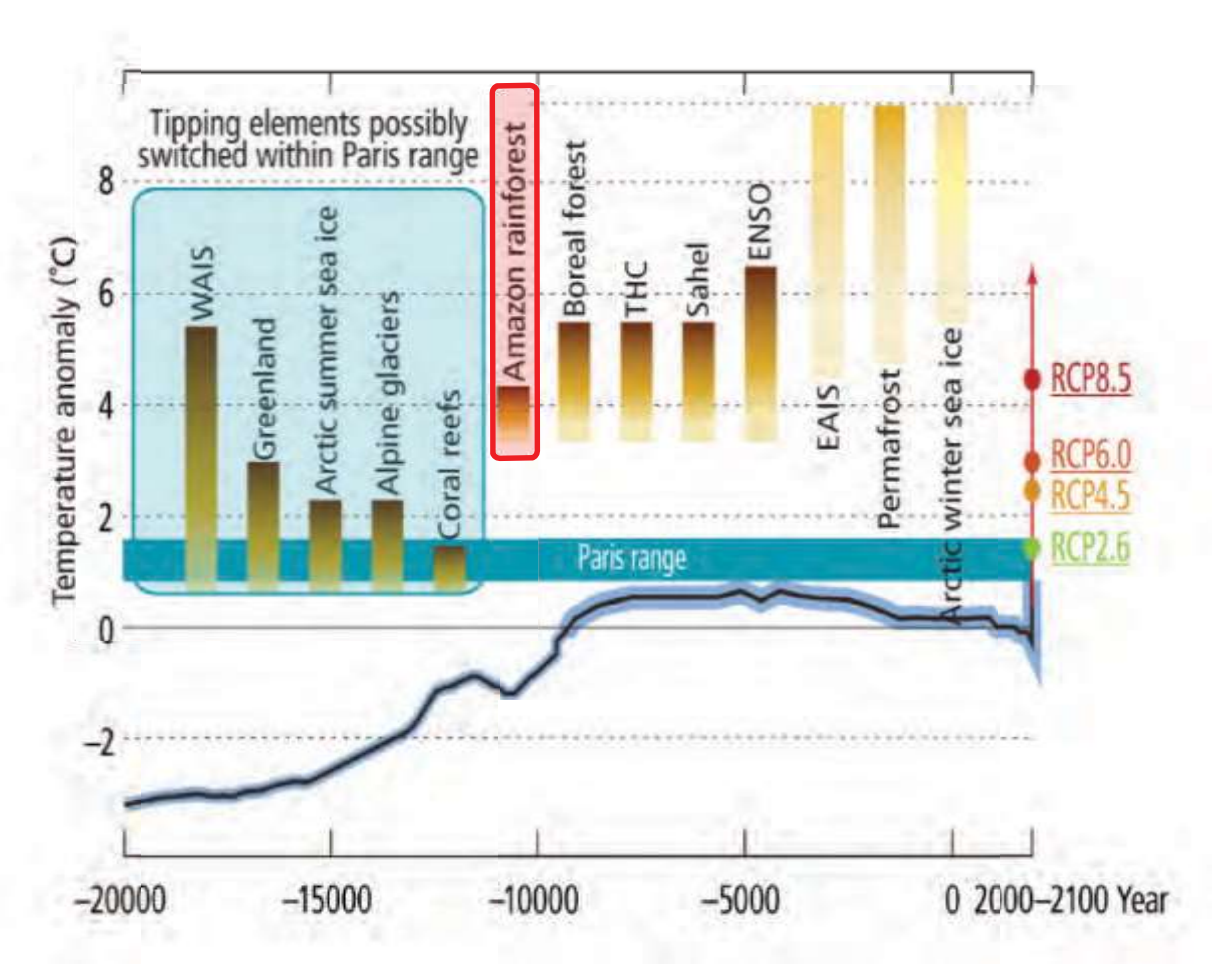
Percent difference between the remaining area of native vegetation and the area required to comply with the Forest Code



12.5 million hectares
NDC of Brazil

MMA (2017) PLANAVEG, Soares-Filho *et al.* (2014)

TIPPING POINTS & THE PARIS AGREEMENT



Schellnhuber et al. (2016). Nature Climate Change

SIX MAJOR TRANSFORMATIONS FOR GLOBAL SUSTAINABILITY

Energy

Decarbonization, efficiency
energy access

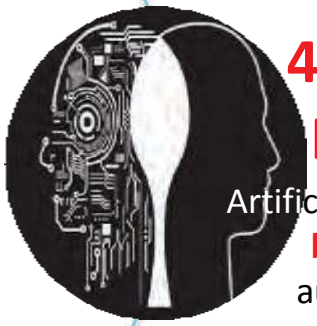
Sustainable consumption and **production**

Resource use, circular economy,
sufficiency, pollution

Food, Land Use & biosphere

Sustainable intensification, ocean,
biodiversity, forests and water,
healthy diets, nutrients

SDGs:
Prosperity
Social inclusion
Sustainability



4th Industrial Revolution

Artificial intelligence, big data,
biotech, nanotech,
autonomous systems

Cities

Housing, mobility,
sustainable infrastructure,
water, pollution

Human capacities & demography

Education, health, ageing, labor markets, gender,
inequalities

The World in 2050 Project, IIASA, 2018

Amazonia is key to global sustainability

Thanks!!!, Obrigado!!!