



Ministério da Ciência e Tecnologia



Instituto Nacional de Pesquisas Espaciais - INPE
Centro de Ciência do Sistema Terrestre - CCST

Mudanças dos Usos da Terra, Mudanças Climáticas e Extremos do Clima e as Mudanças na Distribuição da Vegetação na América do Sul.

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Workshop sobre Código Florestal
WWF-Brasil, Greenpeace e SOS Mata Atlântica

São Paulo-SP / 03 de maio de 2010

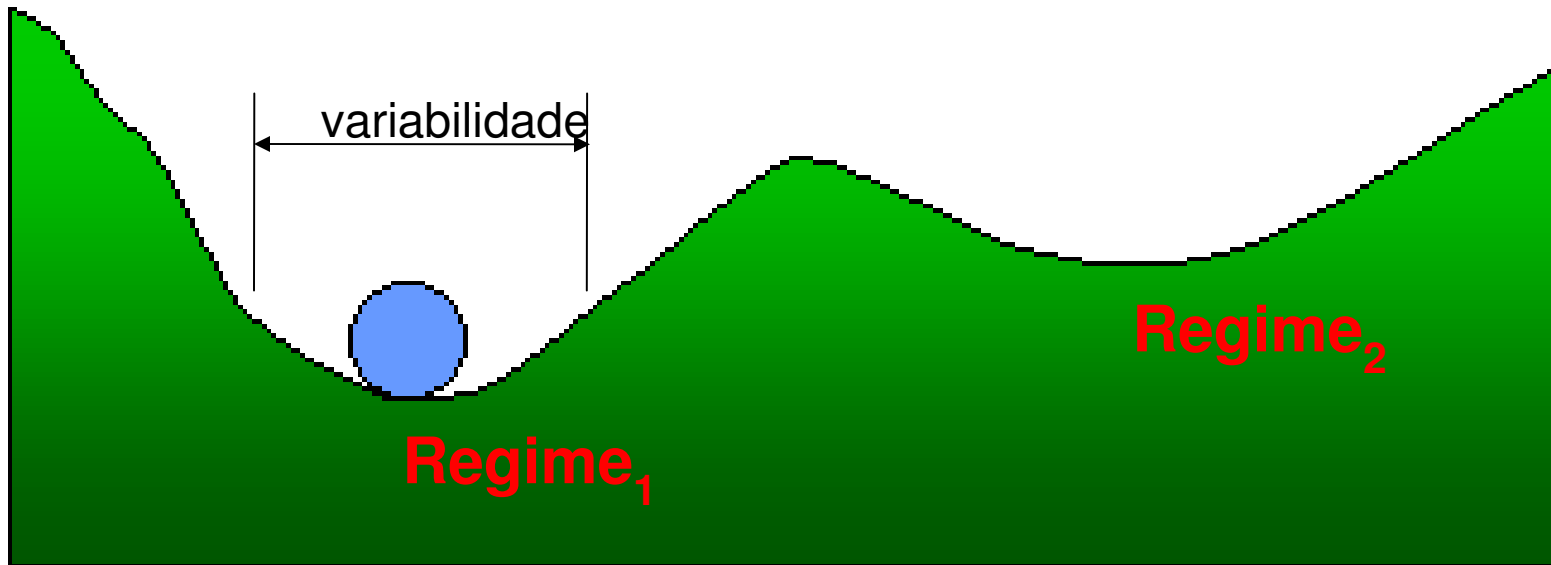
Vegetation-Climate Interactions

Climate  **Vegetation**

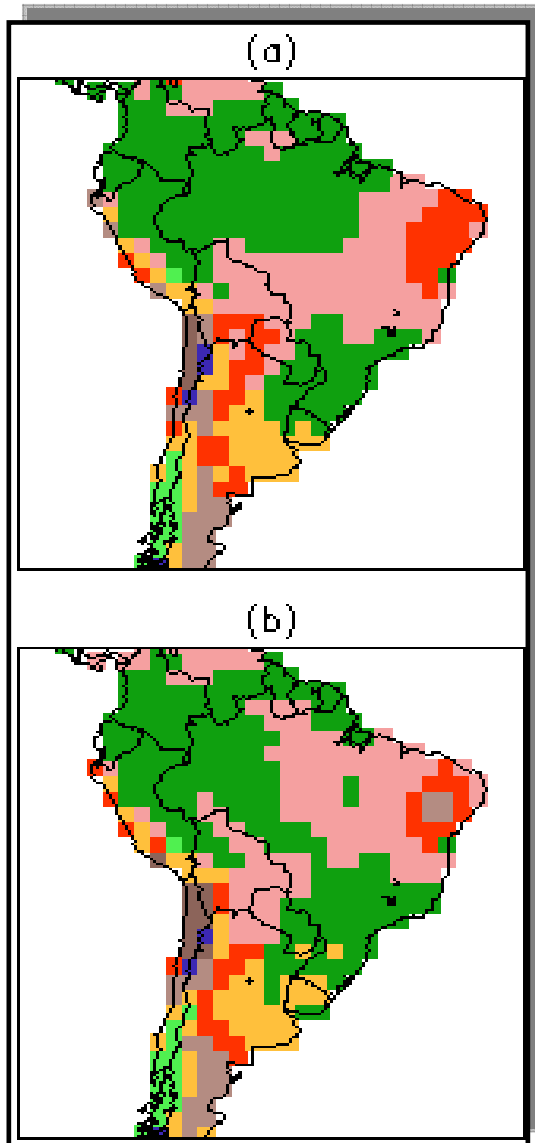


mixing

Biome-Climature Equilibrium



Two Biome-Climate Equilibrium States found for South America!

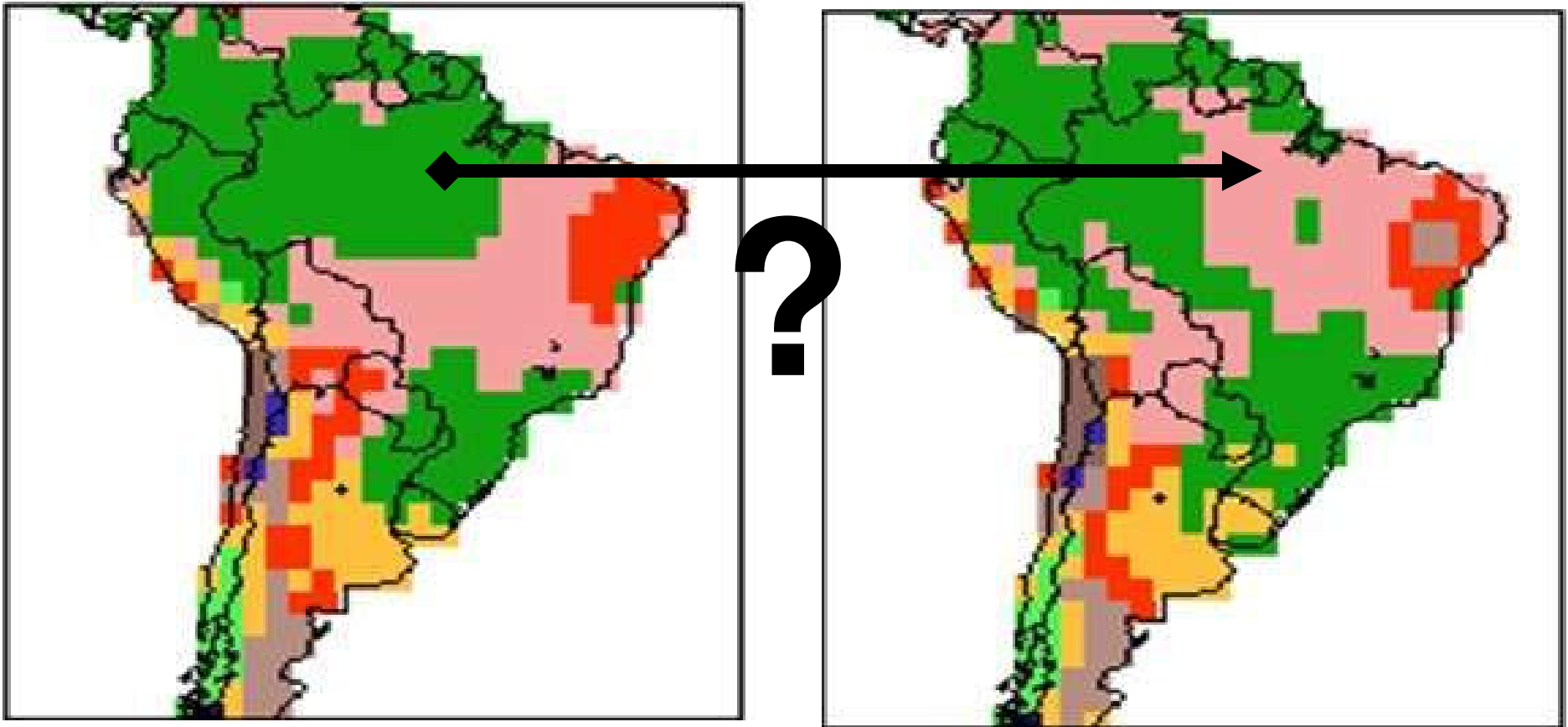


(a) First State - Biome-climate equilibrium starting from forest land cover as initial condition for the Dynamic Vegetation Model. These results are similar to current natural vegetation.

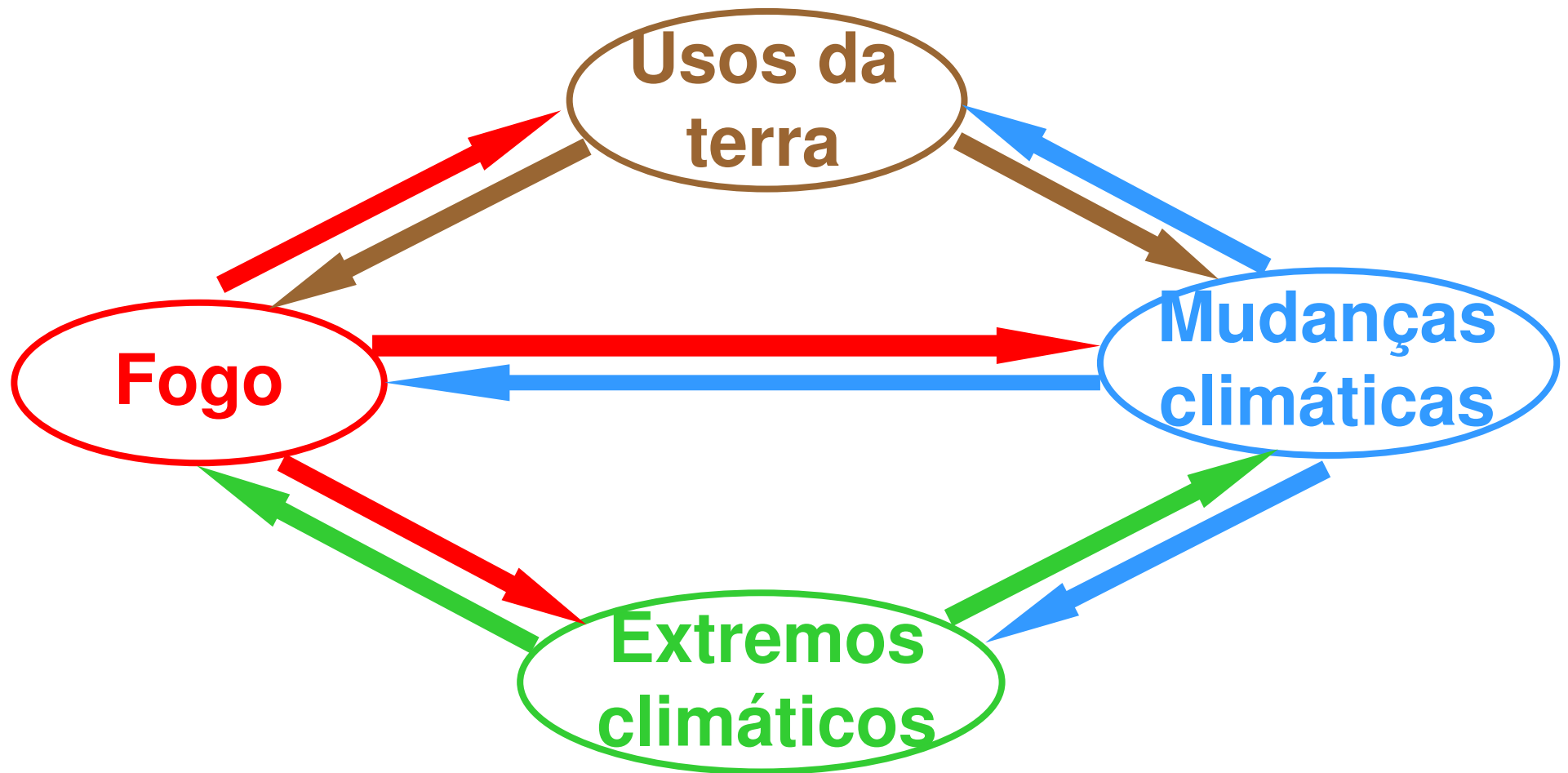
(b) Second State - Biome-climate equilibrium starting from desert land cover as Initial Condition for the Dynamic Vegetation Model

Savanização: substituição da floresta tropical por vegetação mais resistente a múltiplos estresses causados pelo aumento de temperatura, períodos de seca e fogo.

Question: What are the conditions for deforestation to induce an 'abrupt' transition to the second biome-climate stable equilibrium?



Os ecossistemas da Amazônia e do Cerrado estão sujeitos a diferentes forçantes ambientais



LAND COVER



DEFORESTATION AND BURNING AROUND THE XINGU INDIGENOUS PARK, MATO GROSSO STATE, BRAZIL, 2004.

Source: Tropical deforestation and climate change / edited by Paulo Moutinho and Stephan Schwartzman. -- IPAM - Instituto de Pesquisa Ambiental da Amazônia, 2005.

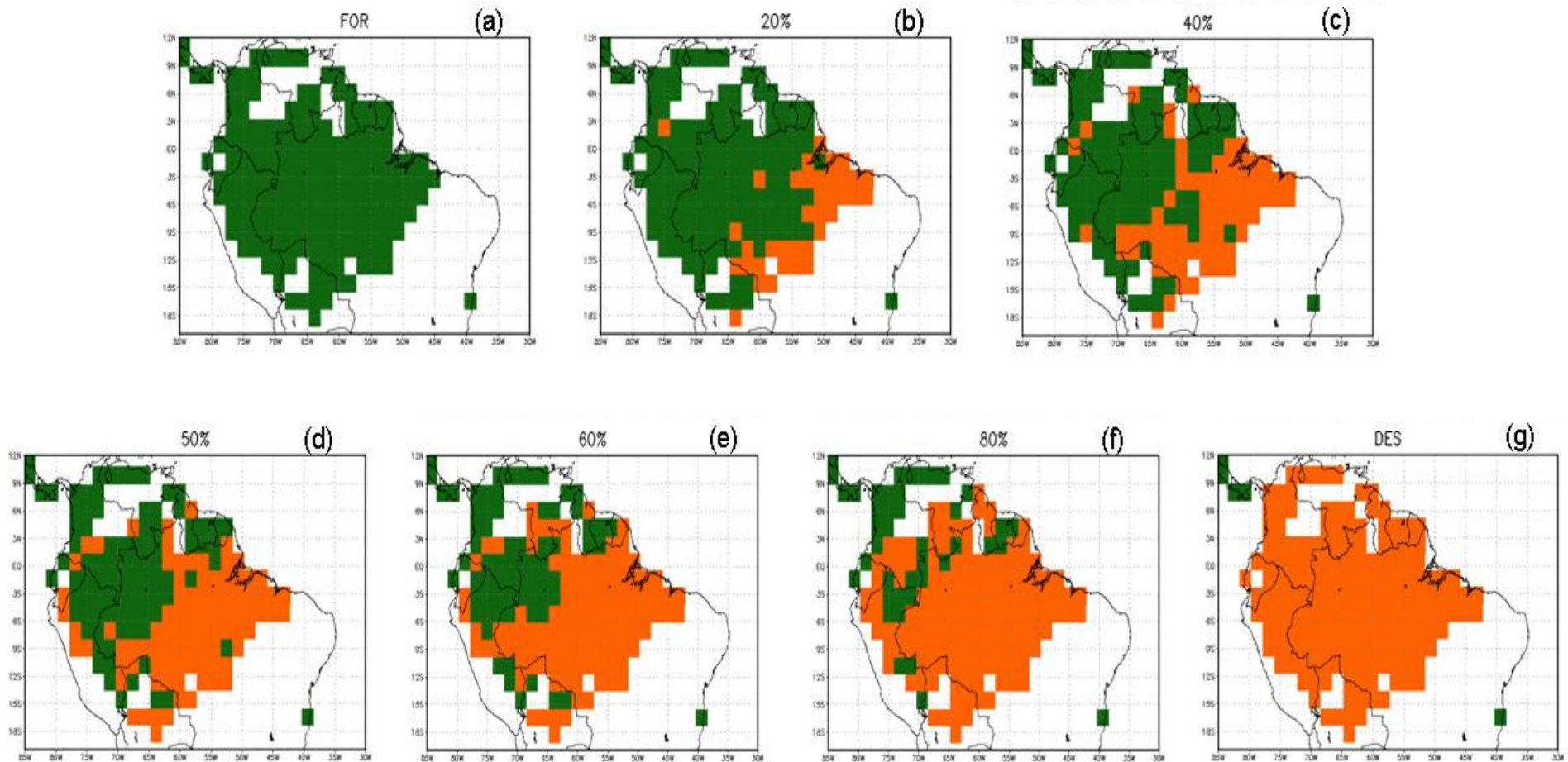
Floresta \Rightarrow Pastagem

- Redução na precipitação de 5 a 20%;
- Redução na evapotranspiração de 20 a 30%;
- Aumento de temperatura entre 0,3 e 3 °C;
- Período seco mais prolongado

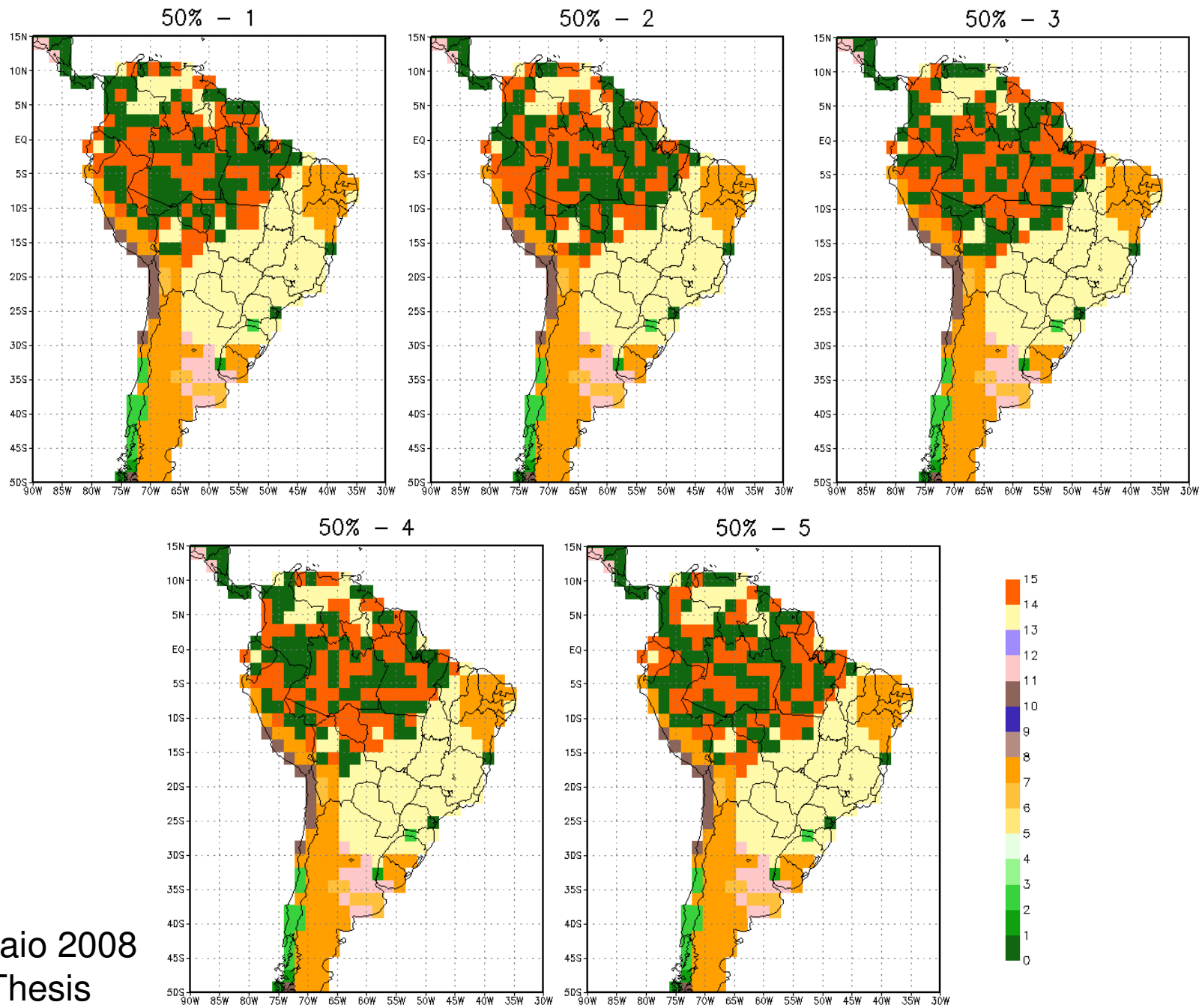
Fontes: Lean e Warrilow-1989; Nobre, et al.-1991; Henderson-Sellers et al.-1993; Lean et al.-1993, Sud et al.-1996, Lean et al.-1996, Manzi e Planton-1996, Rocha et al.-1996, Hahmann e Dickinson.-1997, Costa e Foley-2000, Rocha-2001, Werth e Avissar-2002, Voltaire e Royer-2004, Correia-2005, Sampaio et al.-2007, Costa et al.-2007.

PART I

PROJECTED DEFORESTATION SCENARIOS



Random Deforestation Scenarios (example of 50% deforestation)



Part I - Experiments:

The CPTEC model was integrated for each experiment and control for 87 months with five different initial conditions derived from five consecutive days of NCEP analyses. The results are the mean of the last 60 months (experiment – control).

1) Control case: Today land cover scenario.

2) PASTURE: Land cover change scenarios with deforested areas equal to 20%, 40%, 50%, 60%, 80% and 100% of the original extent of the Amazon forest.

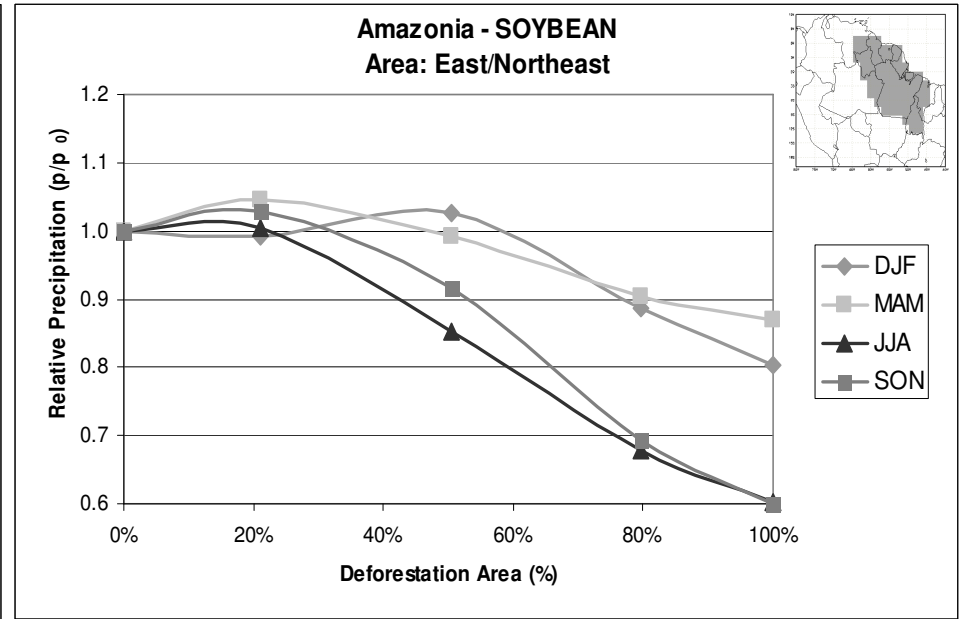
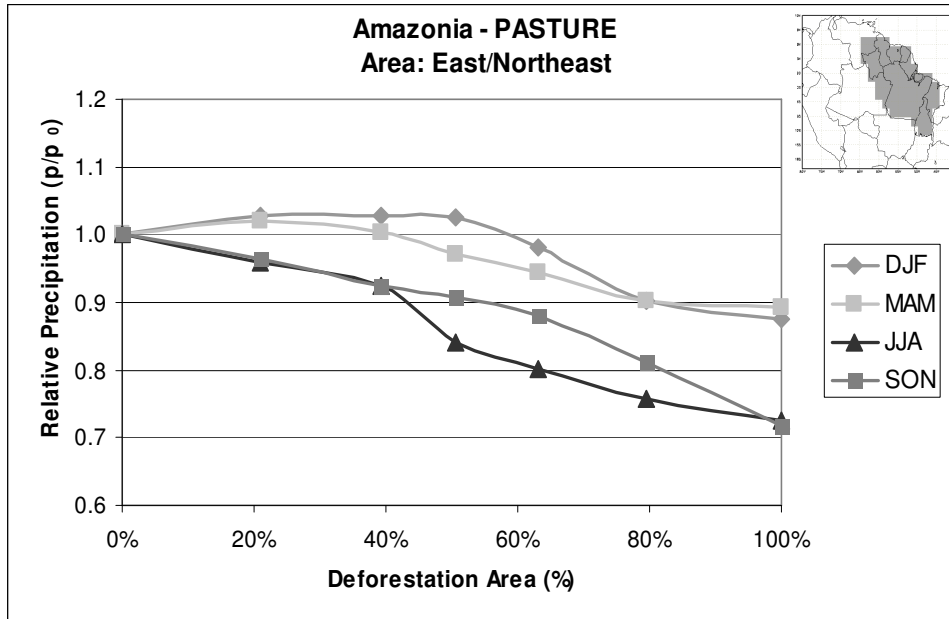
3) SOYBEAN: Land cover change scenarios with deforested areas of 20%, 50%, 80% and 100%.

For each scenario a pseudo-equilibrium between the climate and vegetation was obtained.

Precipitation

PASTURE

SOYBEAN



Relative Precipitation

Season	All Pasture	All Soybean
JJA	-27.5%	-39.8%
SON	-28.1%	-39.9%

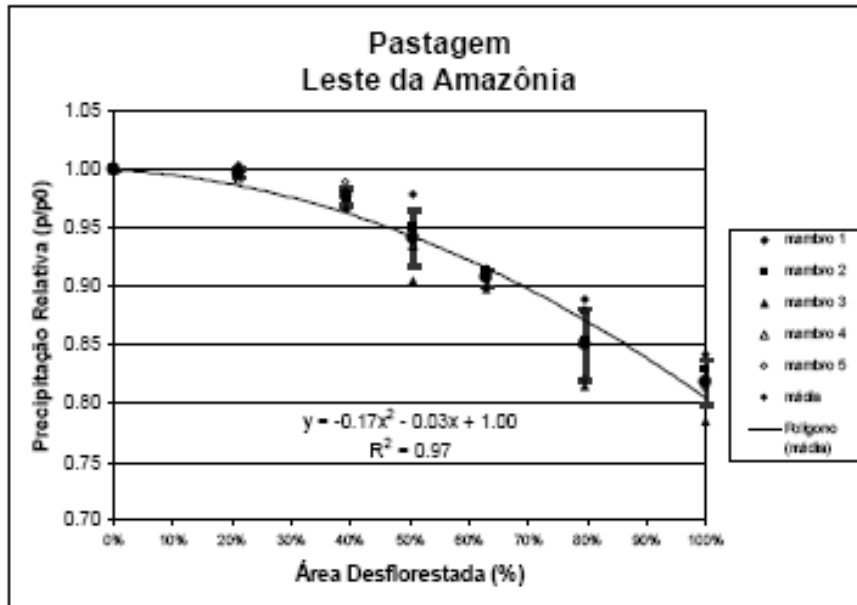
The reduction in precipitation occurs mainly during the **dry season**, and is more evident when the deforested area is larger than 40% !

all Amazonia

Season	All Pasture	All Soybean
JJA	-15.7%	-24.0%

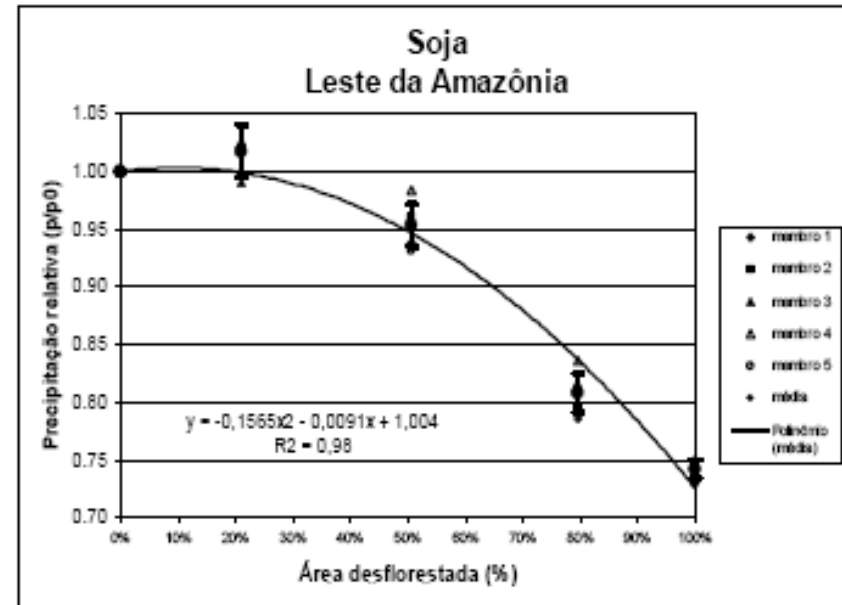
Sampaio et al., 2007
Geophys. Res. Lett., 34

PASTURE



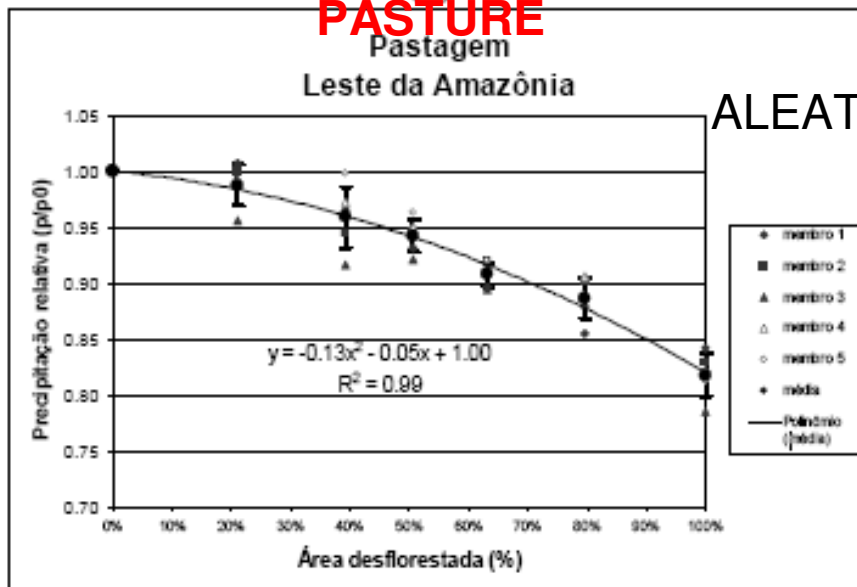
(a)

SOYBEAN



(b)

PASTURE

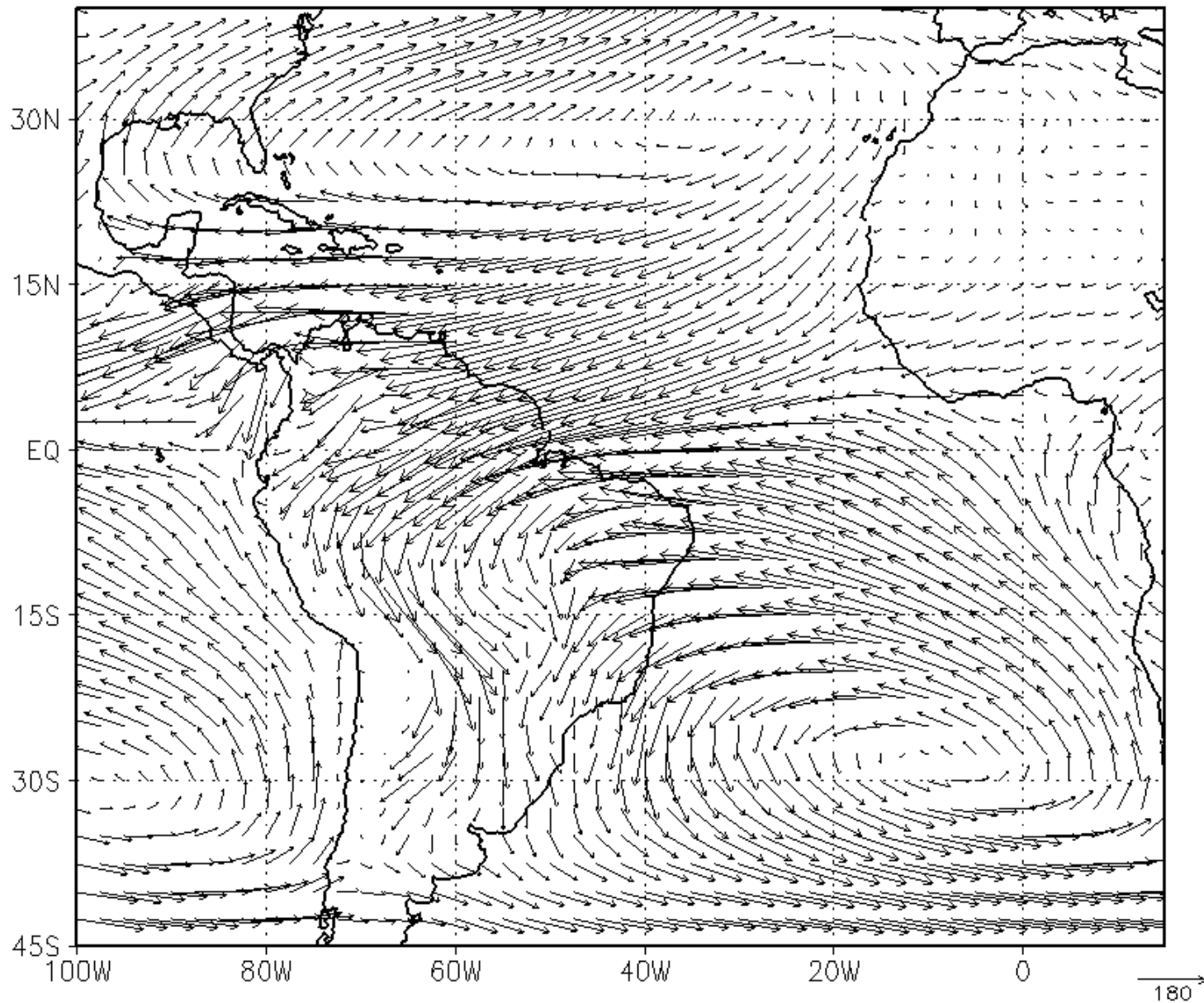


(c)

Precipitation (100% de desf.)

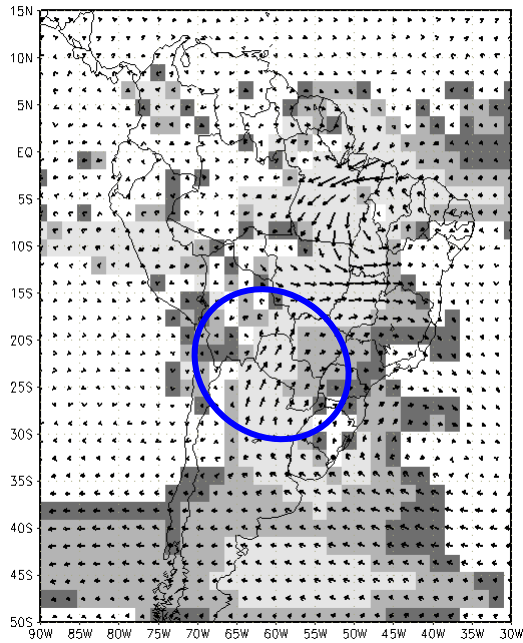
Period	All Pasture	All Soybean
Annual	-18,2%	-25,8%
ASO	-42,0%	-47,4%

decrease in precipitation
associated with pasture or
soybean expansion

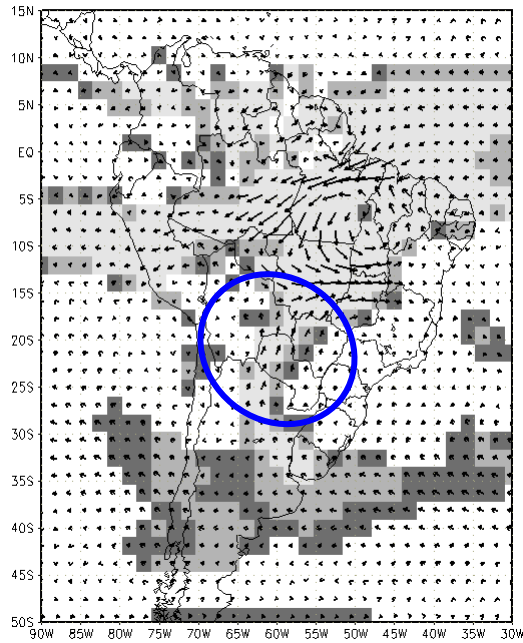


Climatologia do transporte de umidade integrado entre a superfície e 650 hPa para Dezembro a Março de 1981/82 a 2001/02.

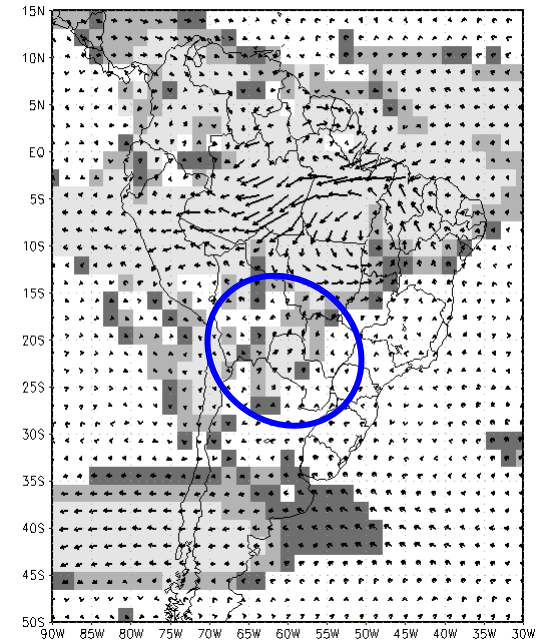
Pastagem - 20%-CONTROL
ANUAL - VIMF



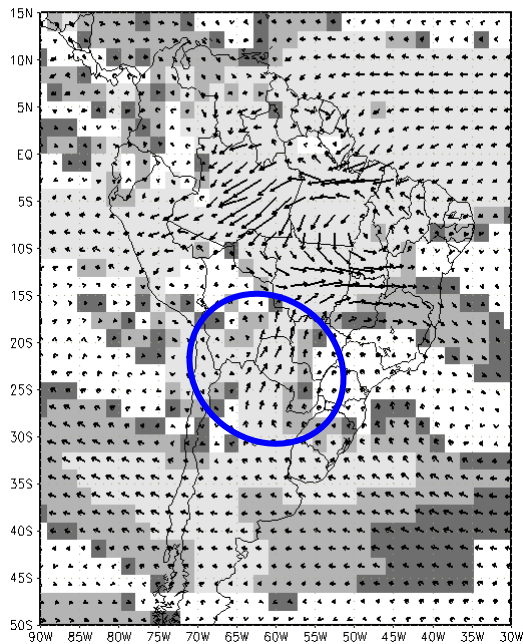
Pastagem - 40%-CONTROL
ANUAL - VIMF



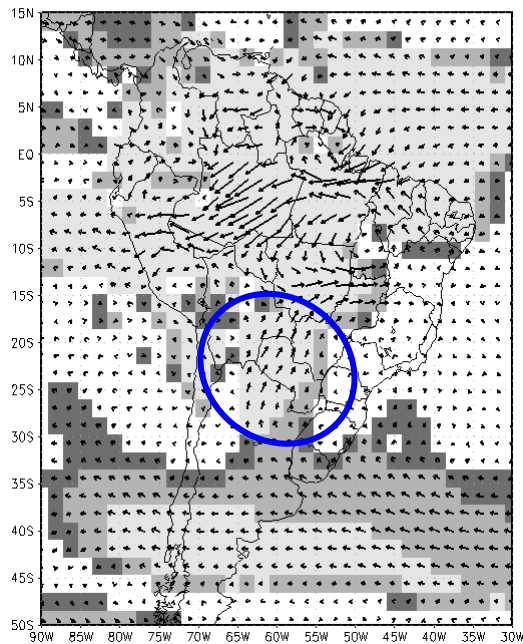
Pastagem - 50%-CONTROL
ANUAL - VIMF



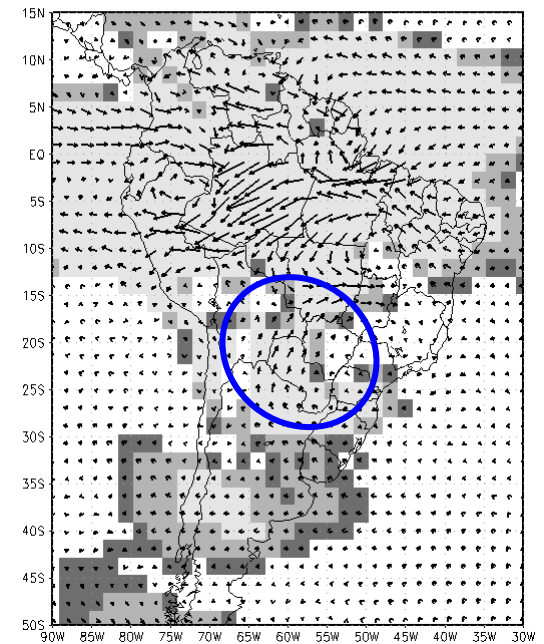
Pastagem - 60%-CONTROL
ANUAL - VIMF

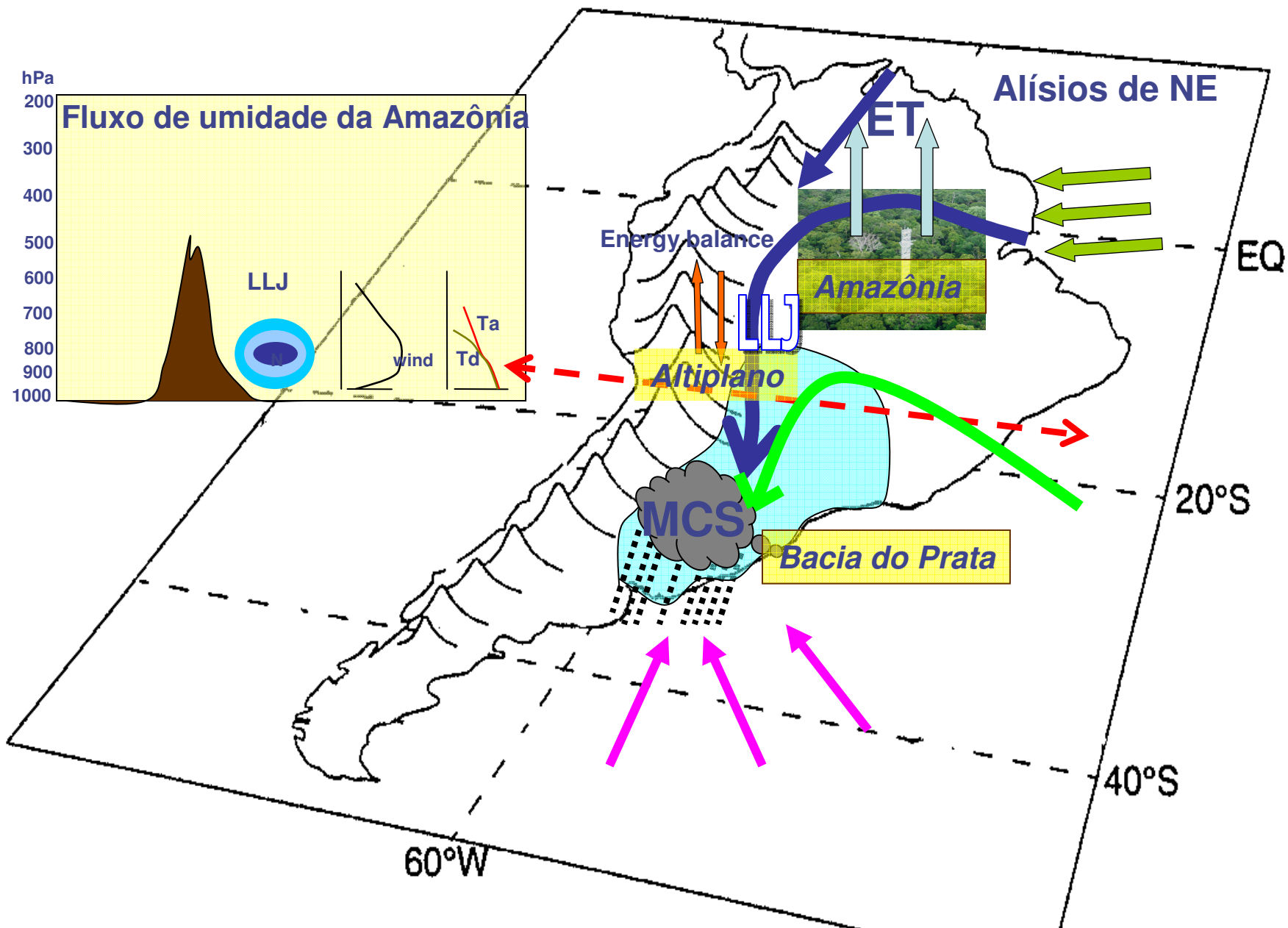


Pastagem - 80%-CONTROL
ANUAL - VIMF



Pastagem - 100%-CONTROL
ANUAL - VIMF



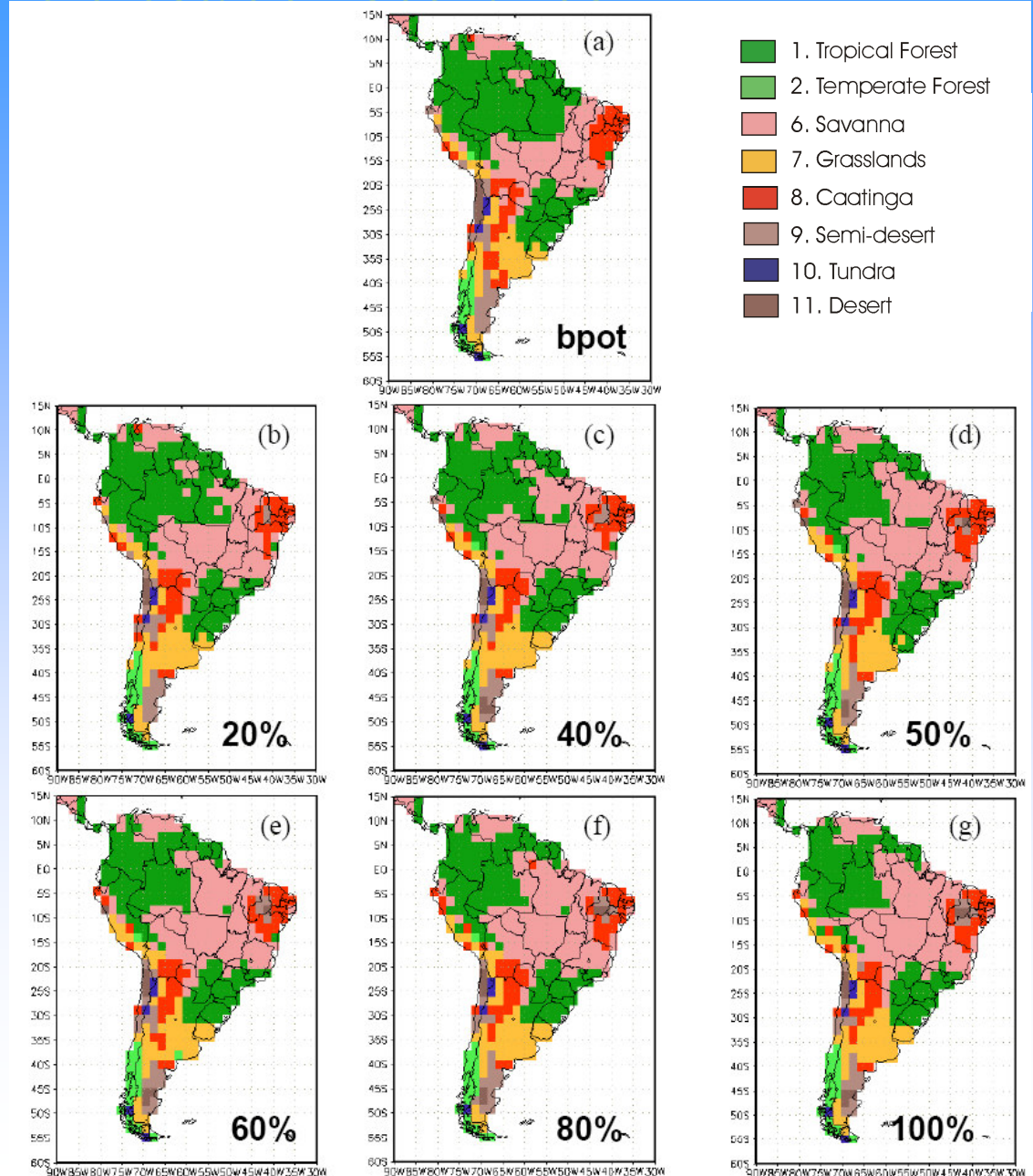


O Jato de Baixos Níveis ao leste dos Andes (SALLJ) transporta umidade atmosférica da Amazônia para o SE/S Brasil-N. Argentina (Bacia do Prata)

Searching for Multiple Biome-Climate Equilibria

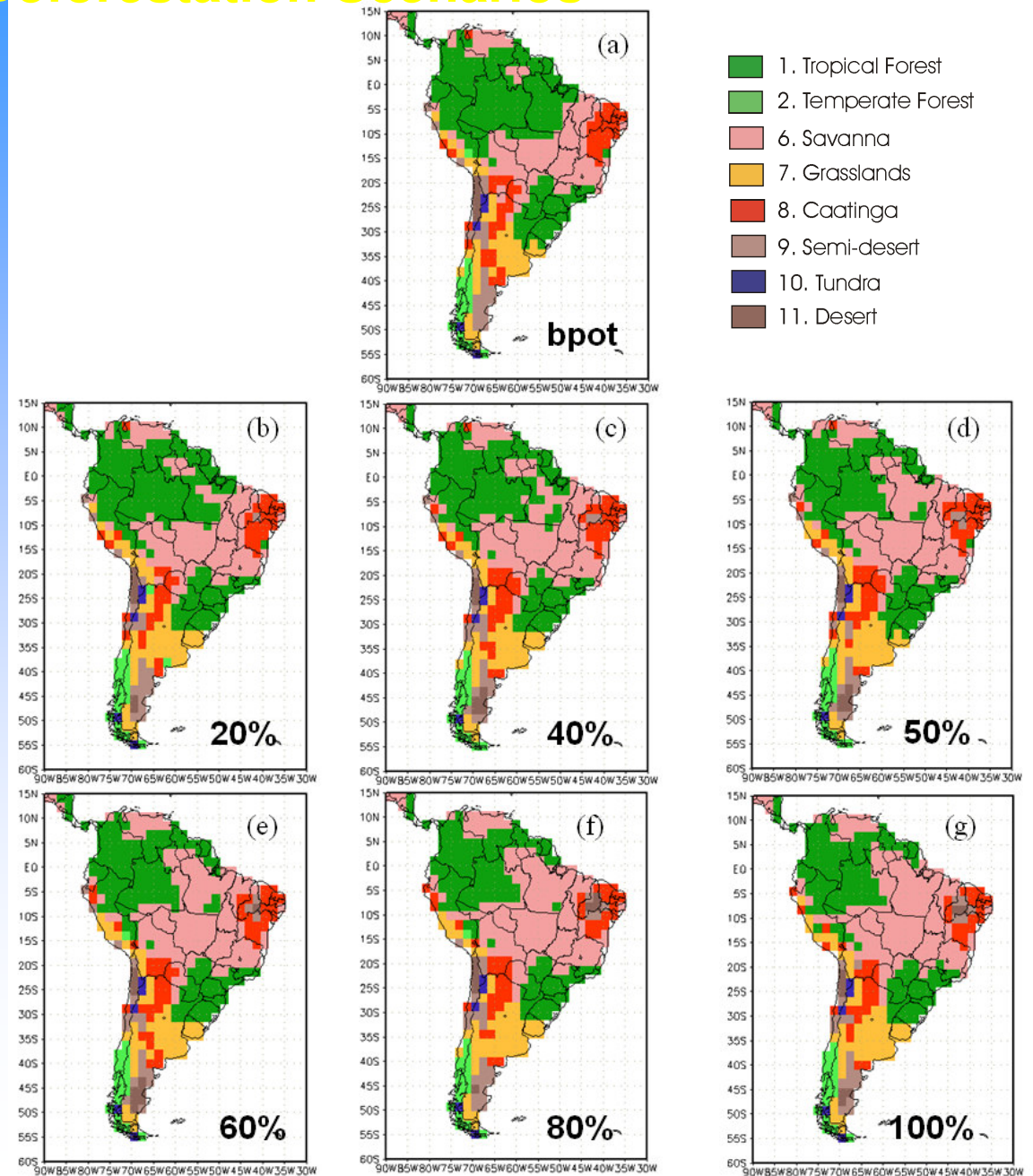
Climate from Degraded Pasture “Realistic” Deforestation Scenarios

Post-Deforestation Equilibrium Potential Biomes



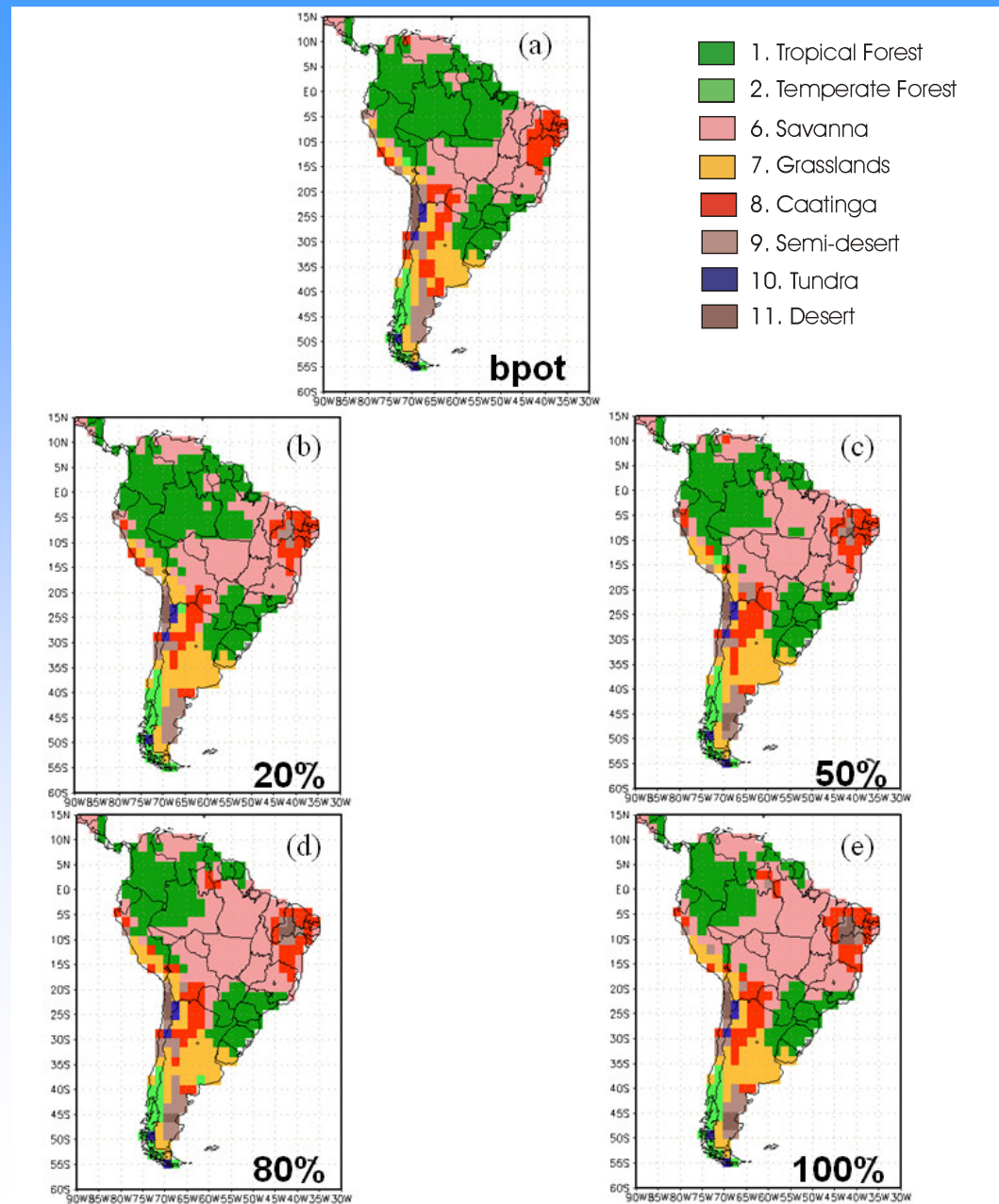
Climate from Degraded Pasture Random Deforestation Scenarios

Post-Deforestation Equilibrium Potential Biomes

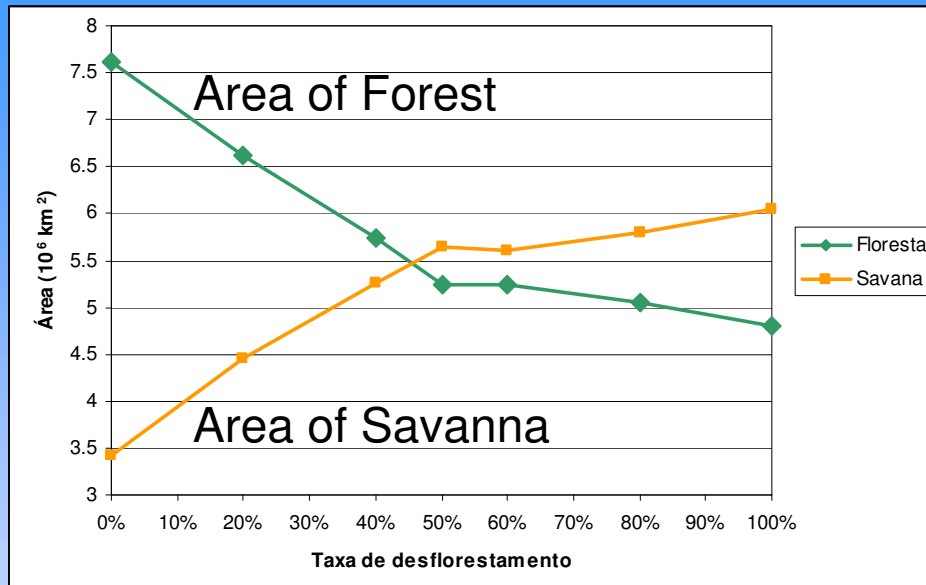


Climate from Soybean Crop "Realistic" Land Use Scenarios

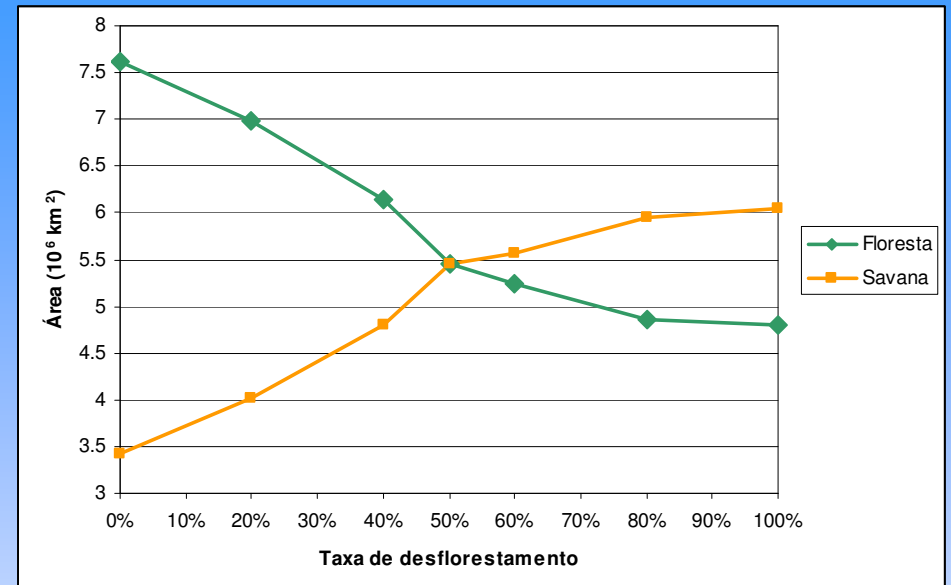
Post-Deforestation Equilibrium Potential Biomes



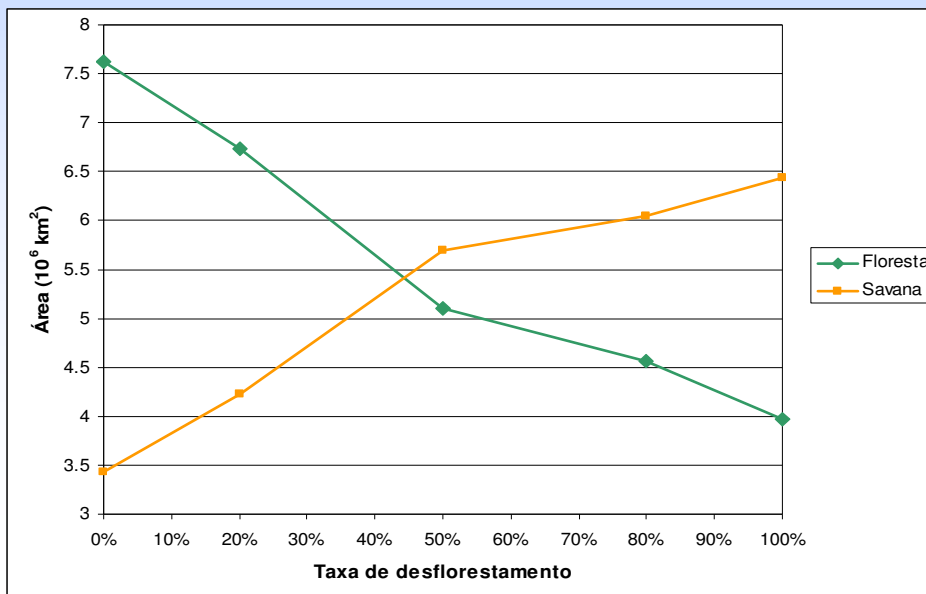
Climate from Degraded Pasture "Realistic" Deforestation Scenarios



Climate from Degraded Pasture Random Deforestation Scenarios



Climate from Soybean Crop "Realistic" Land Use Scenarios



Post-Deforestation Equilibrium Potential Biomes

PART II

CPTEC-PVM was coupled to the CPTEC AGCM

$$\begin{aligned}\text{Vegetation} &= f_1 (\text{climate variables}) \\ &= f_1 (g_0, g_5, T_c, h, s)\end{aligned}$$

g_0 = degree-days above 0 C

g_5 = degree-days above 5 C

T_c = mean temperature of the coldest month

h = aridity index

s = seasonality index

f_1 is a highly nonlinear function

**Vegetation Model
CPTEC PVM**



COUPLING

**Atmospheric
Model
CPTEC AGCM**

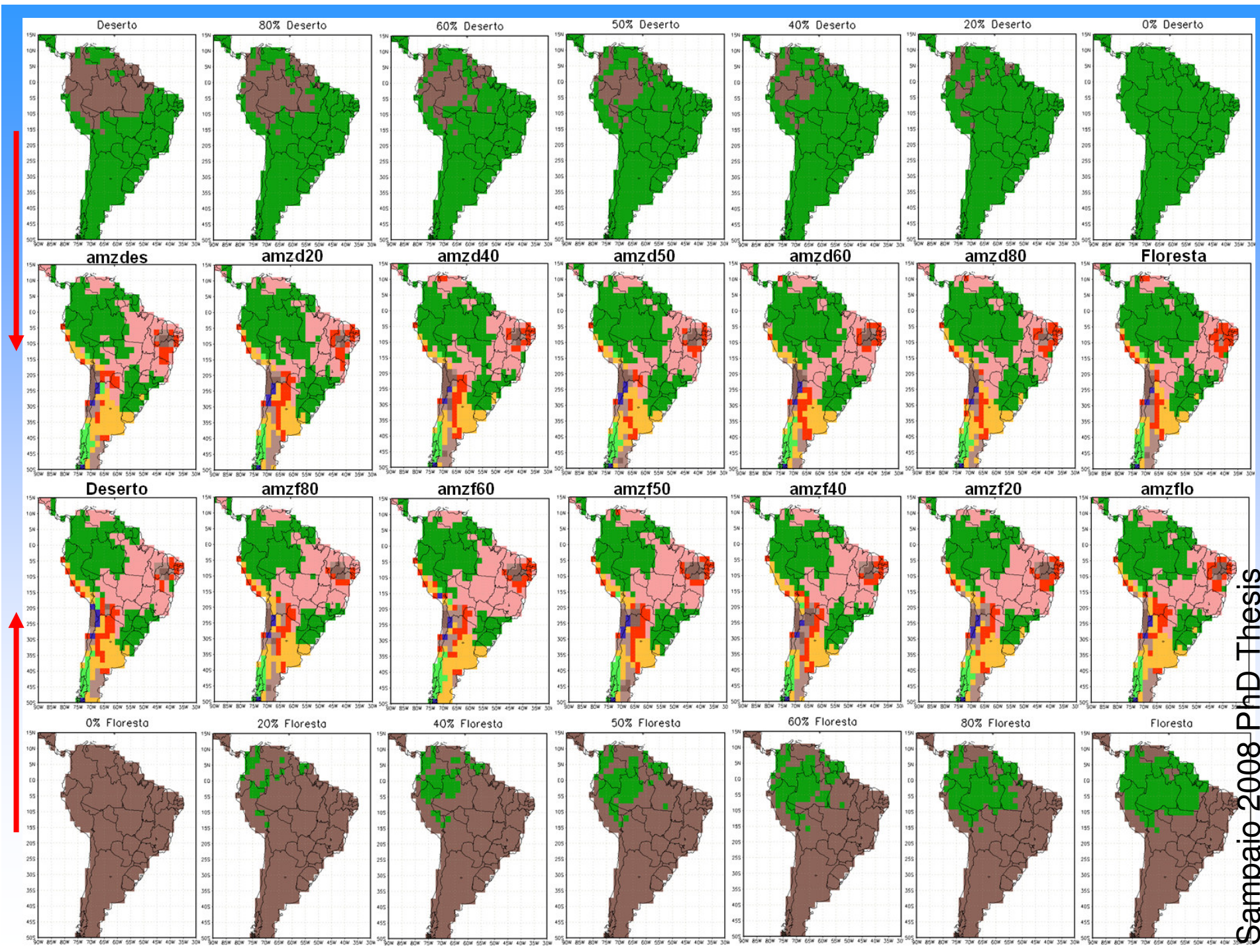
Climate = f_2 (vegetation)

= f_2 (AGCM coupled to vegetated land surface scheme)

f_2 is also a nonlinear function

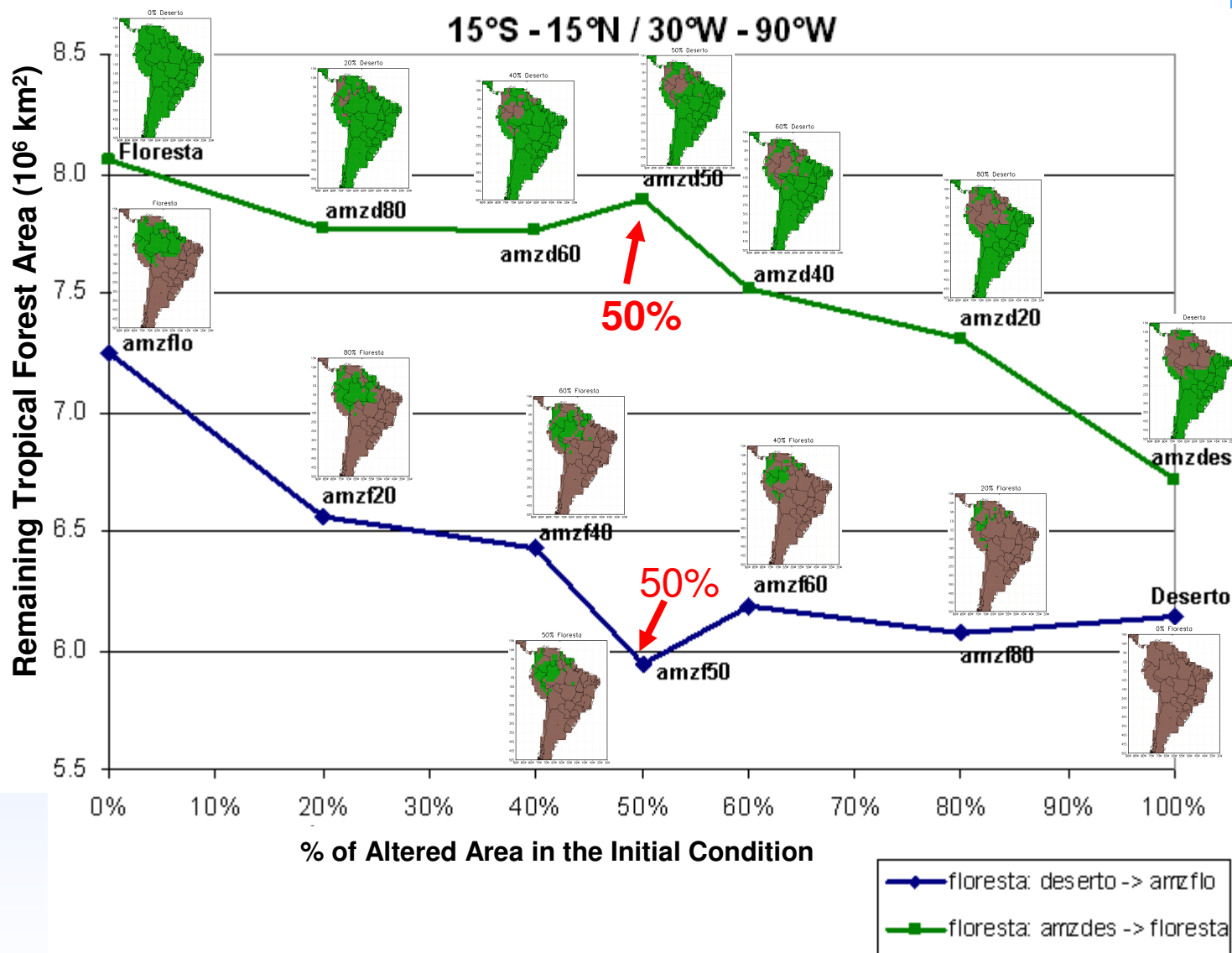
CPTEC-PVM was coupled to the CPTEC AGCM

- Control run: the present-day potential biomes (output of the PVM forced by the present-day climate) are kept unchanged during 20-year: five integrations with different initial conditions derived from five consecutive days of NCEP analyses.
- Fourteen 24-year integrations using dynamic vegetation; in these integrations, the biome distribution is updated every 6 years. Four iterations are found to be enough to reach a biosphere-atmosphere equilibrium state. The biome distribution and the climate of the last iteration are analyzed.



Tropical Forest Area

15°S - 15°N / 30°W - 90°W



These results suggest that the total deforested area of 50% is a sensitive point where there could be a change of states.

CONCLUSIONS

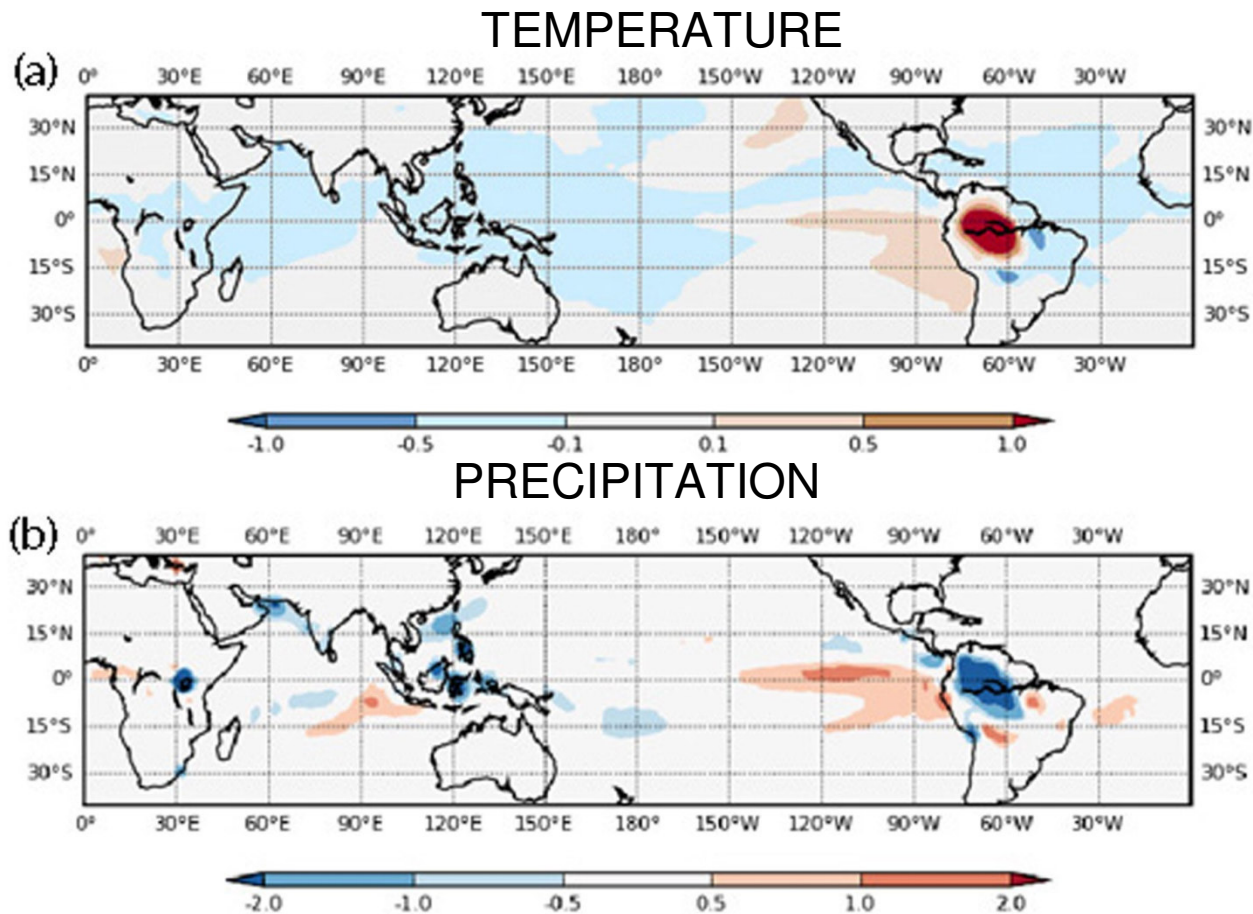
The main impacts on Amazonia climate, because of deforestation, occur over eastern and central Amazonia, and are more evident when total deforested area is larger than 40%.

The results for eastern Amazonia, where changes in land cover are expected to be larger during this century, show increase in near-surface air temperature, and decrease in evapotranspiration and precipitation, which occurs mainly during the dry season for both classes of land use conversions.

We found two biosphere-atmosphere equilibrium states for South America as in Oyama and Nobre (2003): 1) present-day potential biomes 2) a new vegetation-climate equilibrium where the eastern part of the Amazonia tropical forest are replaced by tropical savannas, and semi-desert and desert areas appear in Northeast of Brazil.

In this study, the results suggest that 50% of total deforested area in Amazonia is the threshold for transition from present day potential biomes to a new vegetation-climate equilibrium state in Amazonia.

Amazon deforestation experiment rainfall and temperature departures



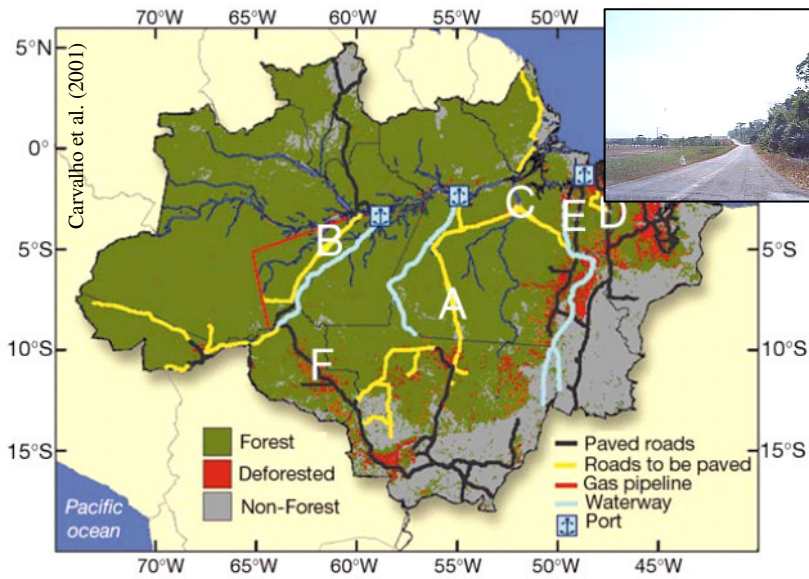
Statistically significant departures are shaded

O desflorestamento da Amazônia, aumenta a temperatura e diminui a precipitação na região. Há amplificação do fenômeno El Niño-Oscilação Sul.

Fonte: Nobre et al., 2009.

FIRE

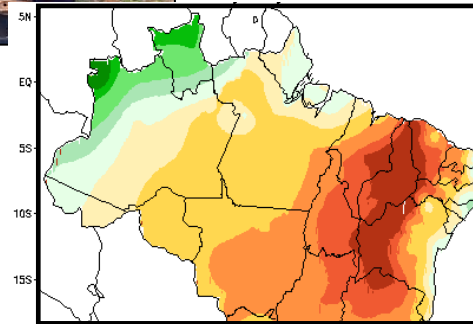




Land use



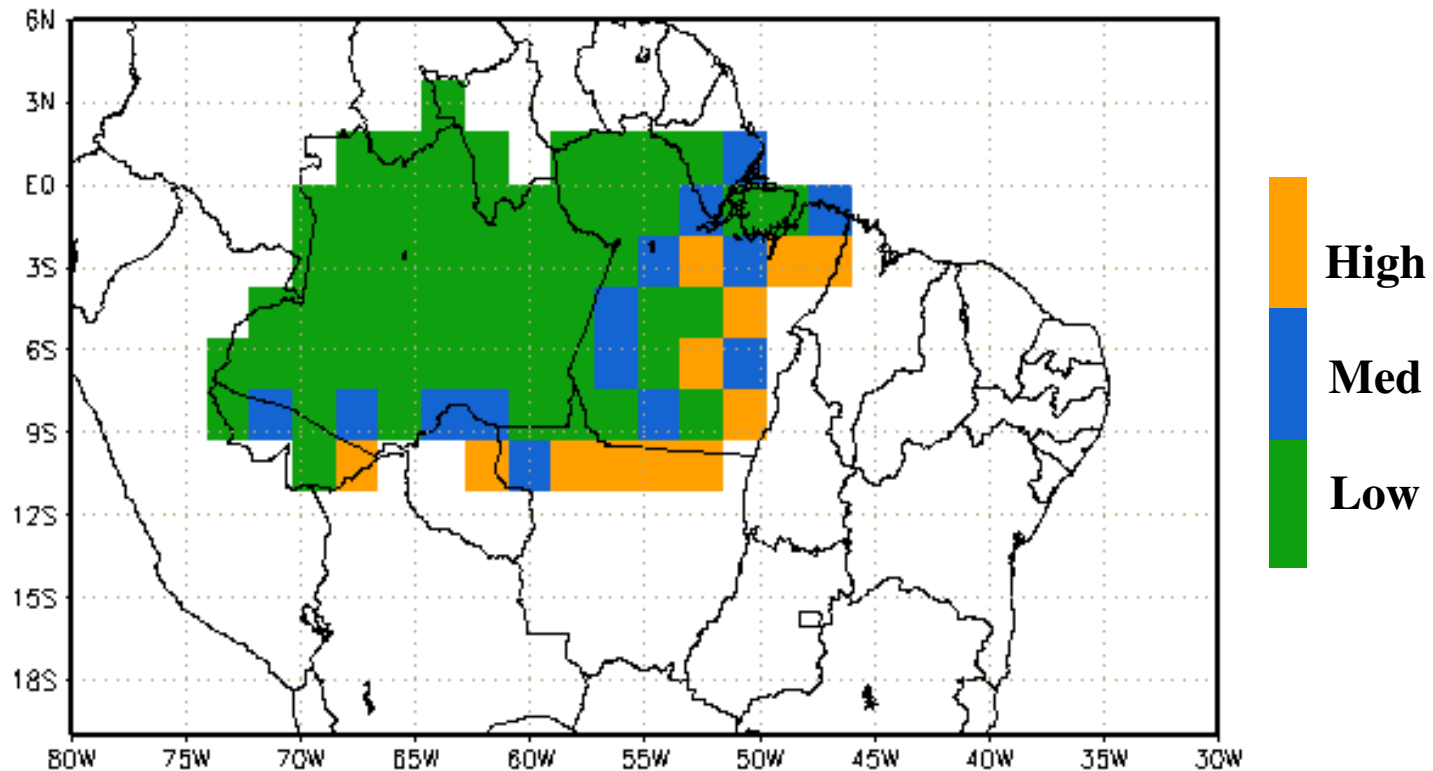
Dry season



At year-decade time scales, the majority of fires in Amazonia occur during the dry season as a result of land use

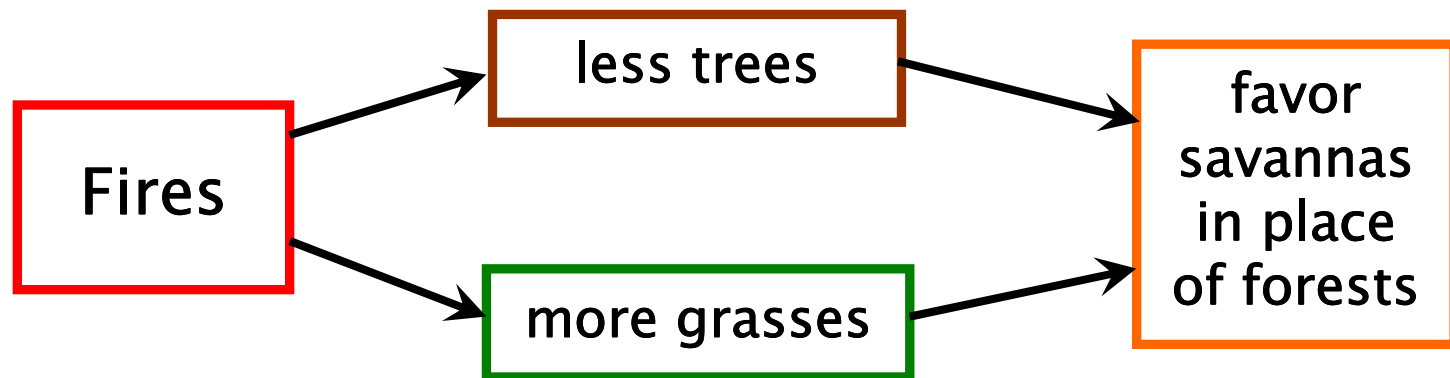


Fire activity in the areas of potential tropical forests in the Brazilian Amazon, from 1998 to 2005



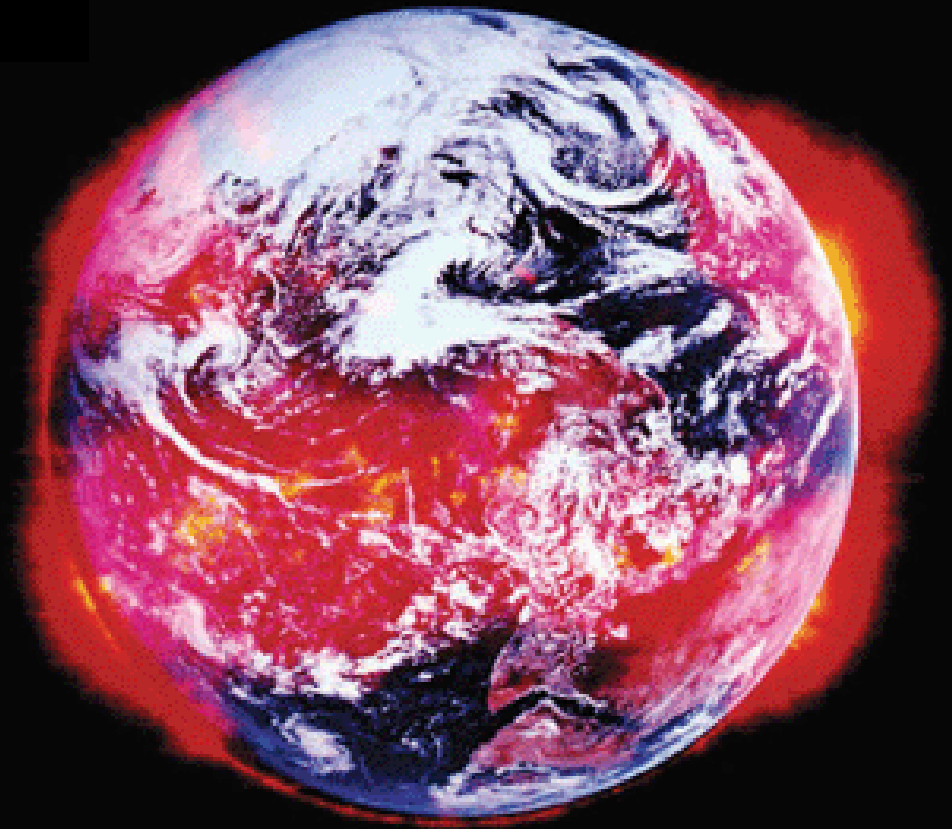
Color cells are areas of potential (not considering land use) tropical forests in the Brazilian Amazon (Oyama and Nobre 2004). Fire occurrence during 1998-2005 detected with TRMM-VIRS (Giglio et al. 2003) was classified in three levels: **Low**: active-fire detections were ≤ 50 (green), **Medium**: 50-250 (blue), and **High**: ≥ 250 (orange). Fire levels were determined based on 5% and 25% of the maximum number of detections in the study region. Medium and high fire activity coincides with areas of deforestation.

At long term, fires have also important effects on biomes distribution:



To account for fires when estimating the distribution of the natural biomes, we developed a new long-term fire parameterization based on the potential for lightning during dry-wet season transitions

CLIMATE CHANGE



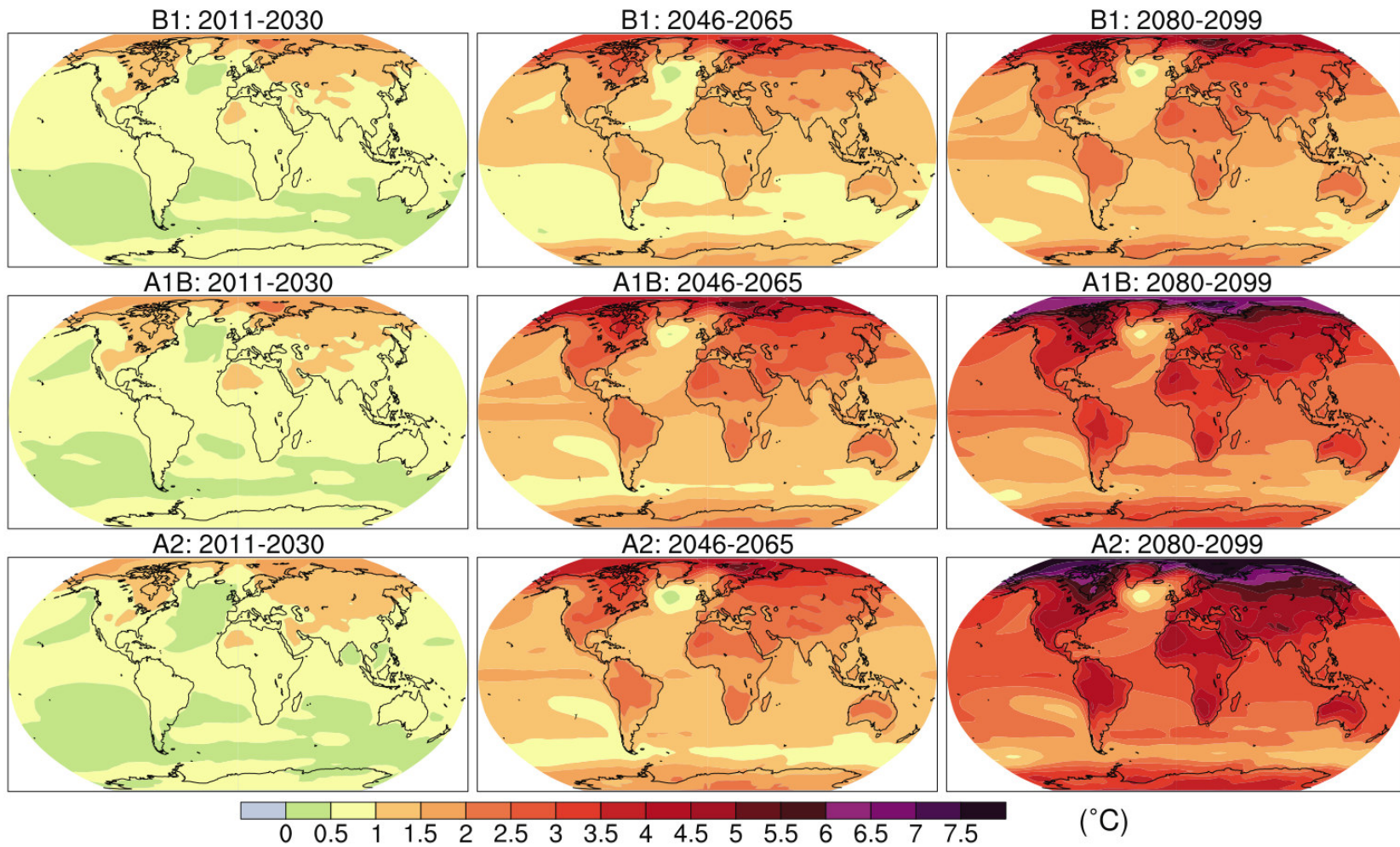


Figure 10.8

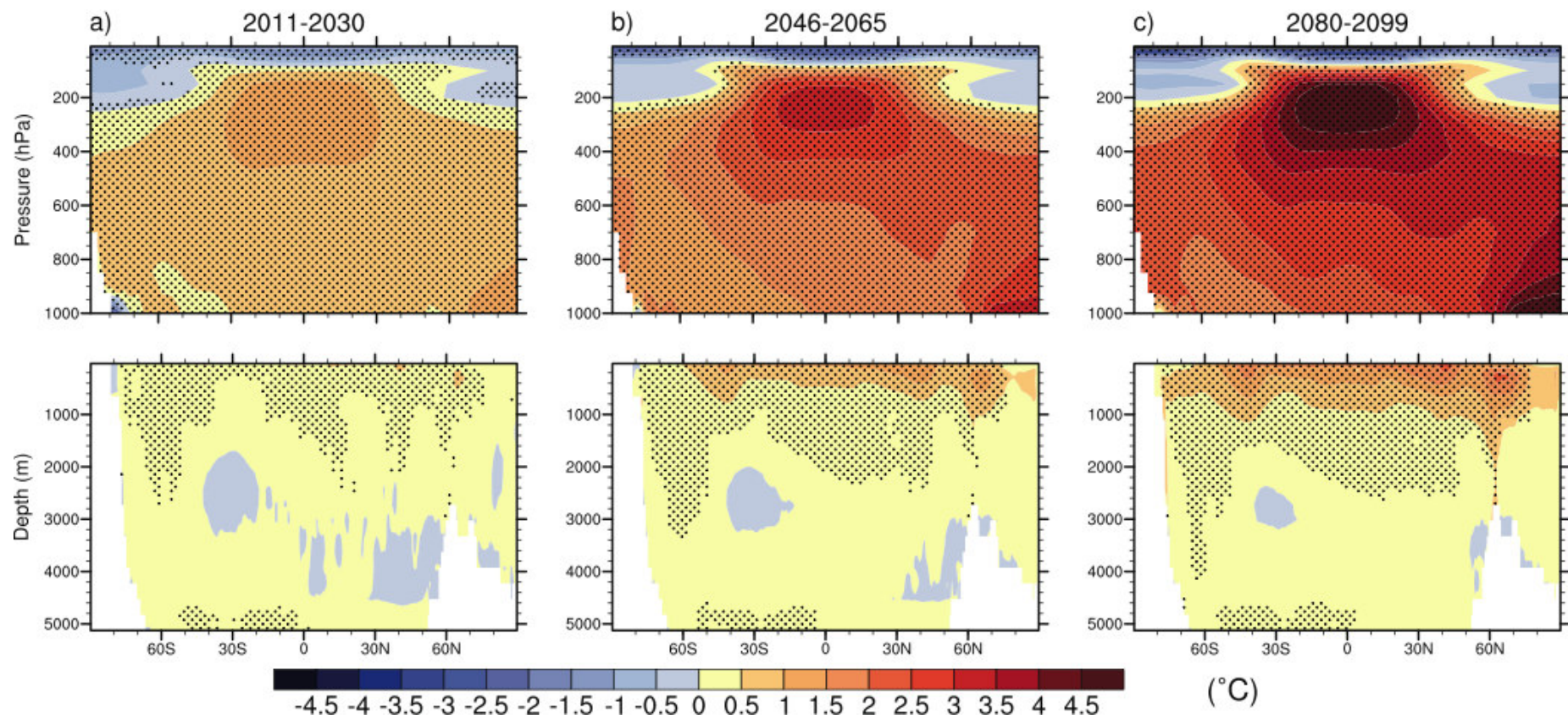


Figure 10.7

A Conexão entre Aquecimento Global e o Ciclo Hidrológico

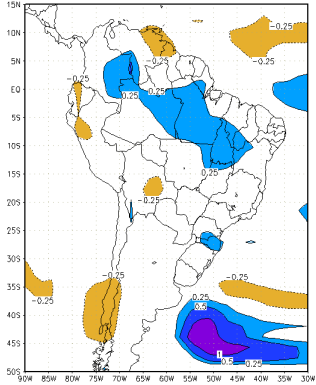


Cortesia: S. Sarooshian, U. California-Irvine

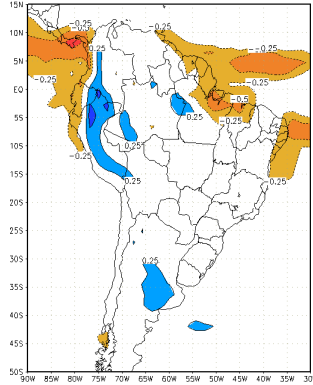
Created by: Gi-Hyeon Park

Anomalias de Precipitação (mm/dia) – 2015-2034 – A2

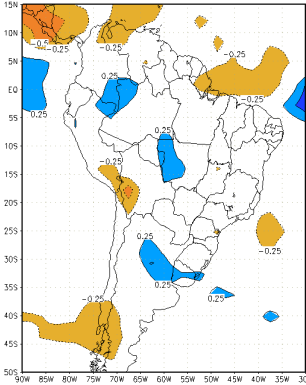
BCCR-BCM2_0 – Anom. Precipitacao(A2)
2015–2034



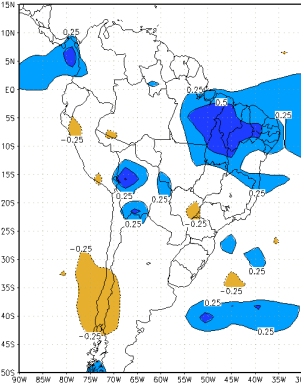
CCSM3 – Anom. Precipitacao(A2)
2015–2034



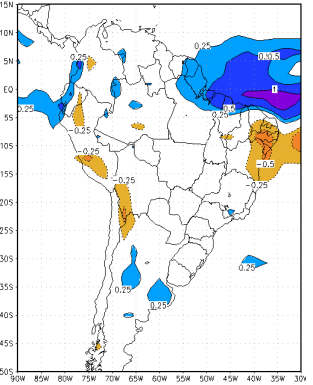
CGCM3_1_T47 – Anom. Precipitacao(A2)
2015–2034



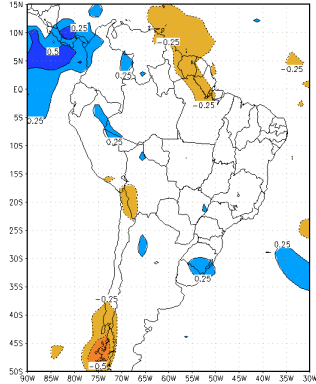
CNRM_CM3 – Anom. Precipitacao(A2)
2015–2034



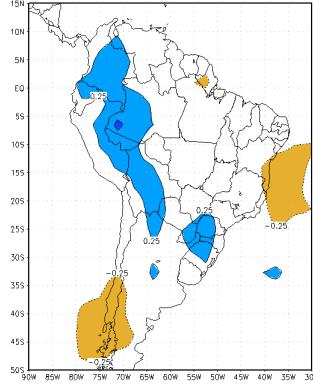
CSIRO-Mk3 – Anom. Precipitacao(A2)
2015–2034



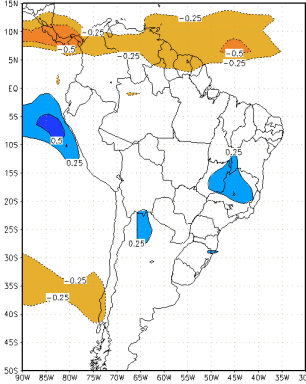
ECHAM5 – Anom. Precipitacao(A2)
2015–2034



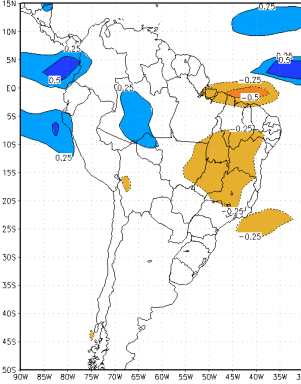
ECHO_G – Anom. Precipitacao(A2)
2015–2034



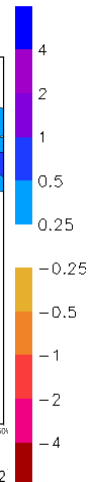
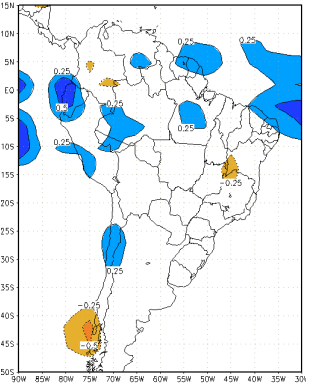
GFDL_CM2_1 – Anom. Precipitacao(A2)
2015–2034



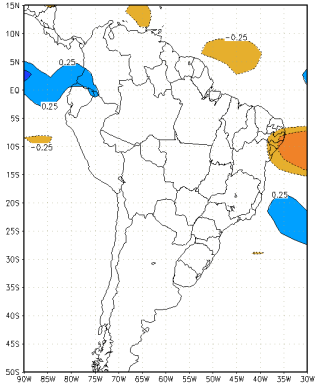
GFDL_CM2 – Anom. Precipitacao(A2)
2015–2034



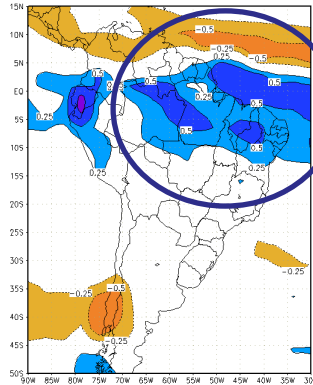
GISS_ER – Anom. Precipitacao(A2)
2015–2034



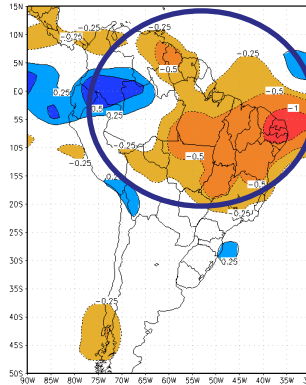
INM_CM3_0 – Anom. Precipitacao(A2)
2015–2034



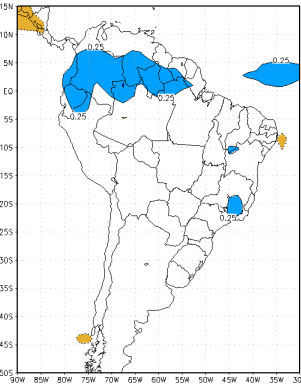
IPSL_CM4 – Anom. Precipitacao(A2)
2015–2034



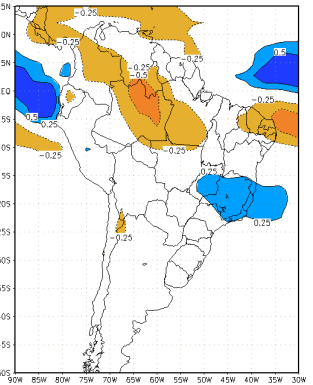
MIROC3_2_MEDRES – Anom. Precipitacao(A2)
2015–2034



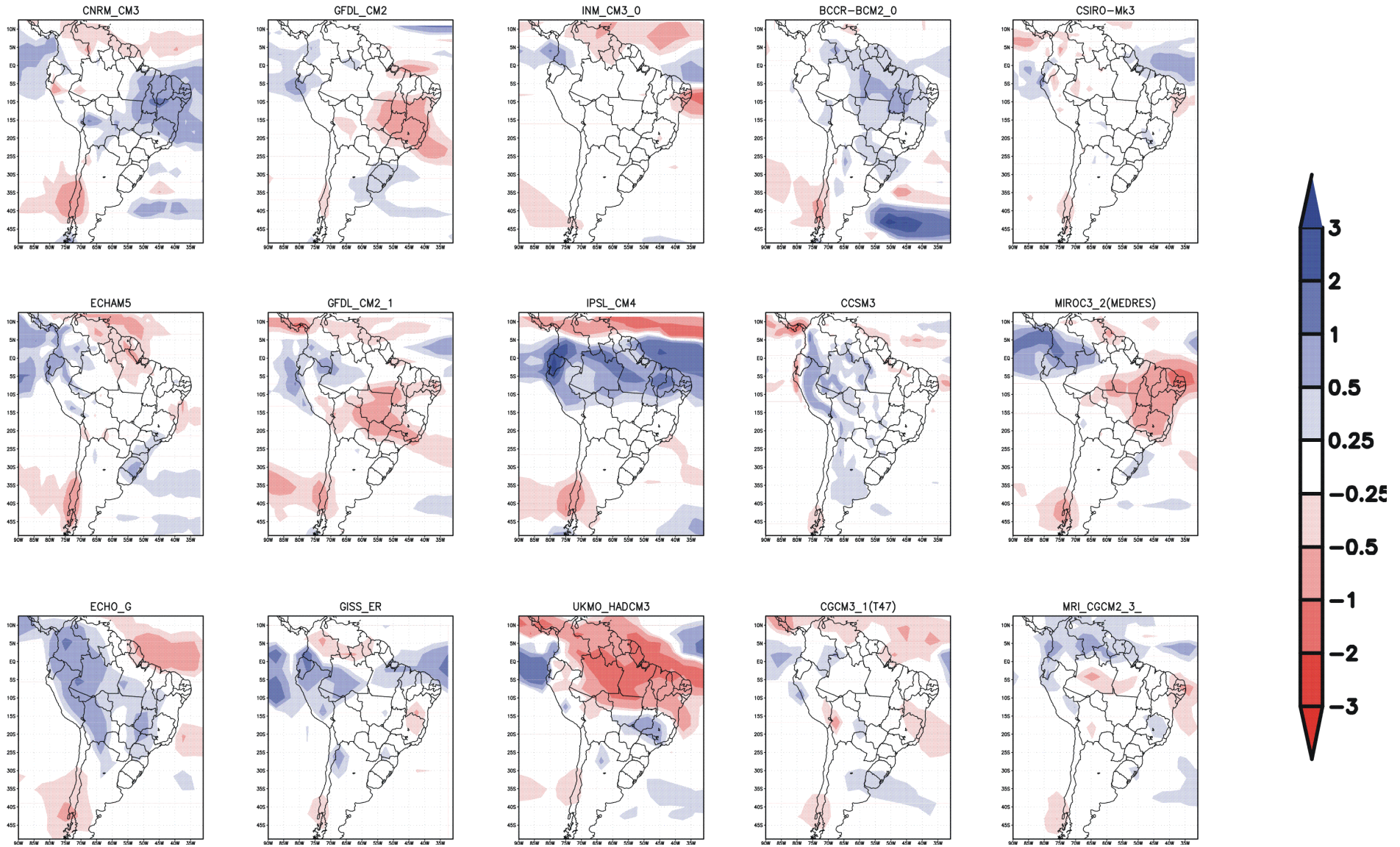
MRI_CGCM2_3_2 – Anom. Precipitacao(A2)
2015–2034



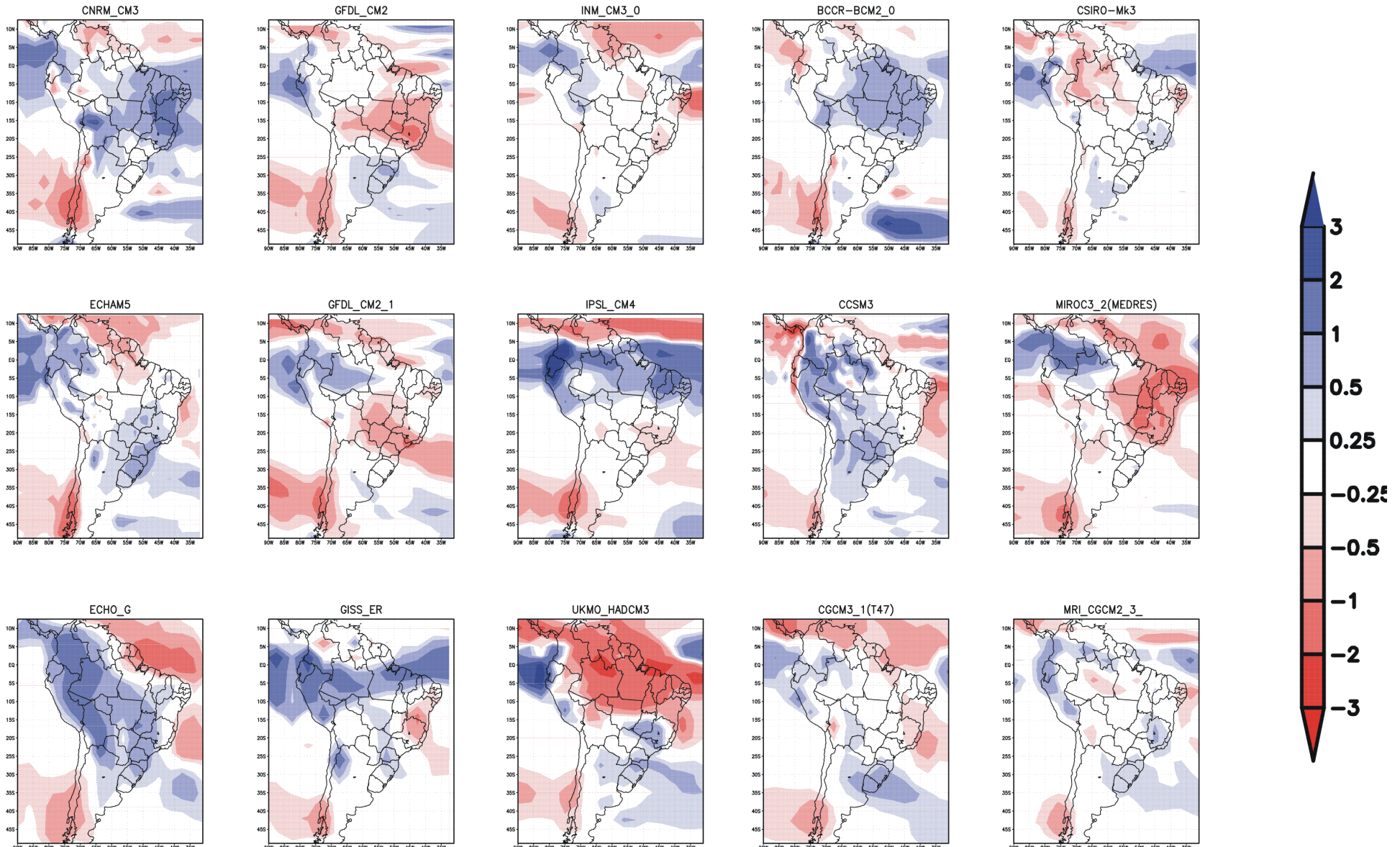
UKMO_HADCM3 – Anom. Precipitacao(A2)
2015–2034



Projeções de anomalias de precipitação (mm/dia) para América do Sul para o período de 2071-2100 (Cenário B1) em relação ao período base de 1961-1990 – Fonte: IPCC AR4



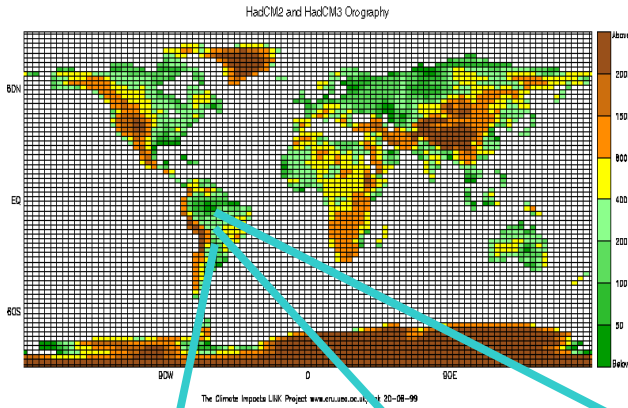
Projeções de anomalias de precipitação (mm/dia) para América do Sul para o período de 2071-2100 (Cenário A2) em relação ao período base de 1961-1990 – Fonte: IPCC AR4



PROBIO-IPCC Global models used: IPCC TAR (HadCM3)-Version 1

Downscaling

Modelos do IPCC: HadAM3



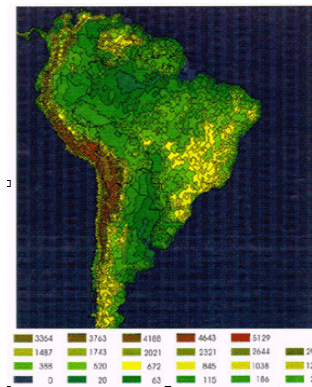
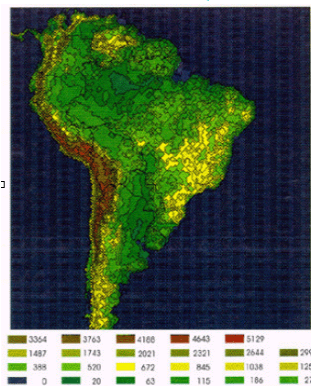
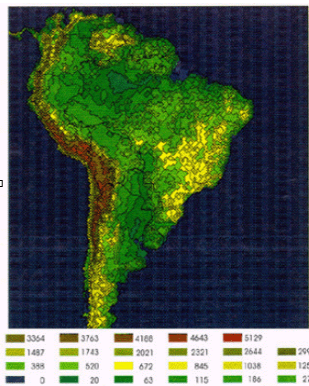
Climatology
1961-90

IPCC
Scenarios
A2, B2

Climate anomalies (future-present), from regional multimodel ensemble Time slices 2071-2100, A2, B2

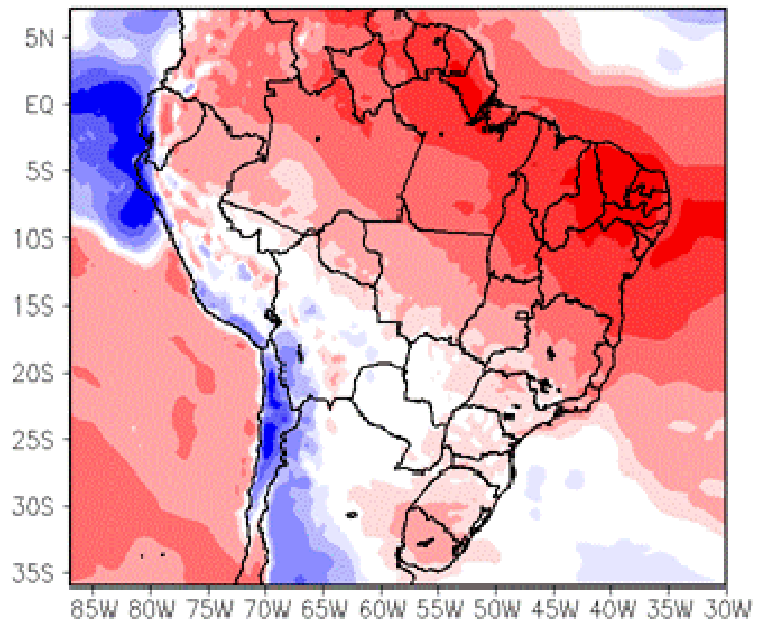
Climatology
regional model
1961-90

Regional models



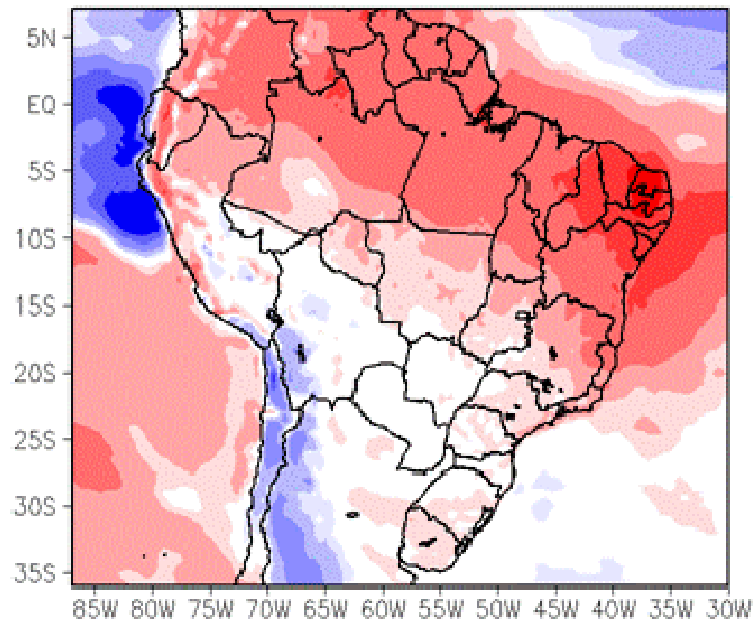
Maps of climate anomalies, and indices of extremes (Regional multimodel ensemble) 2071-2100, A2, B2

Anomalia de Precipitacao (%) Ensemble
A2 - Baseline ANUAL



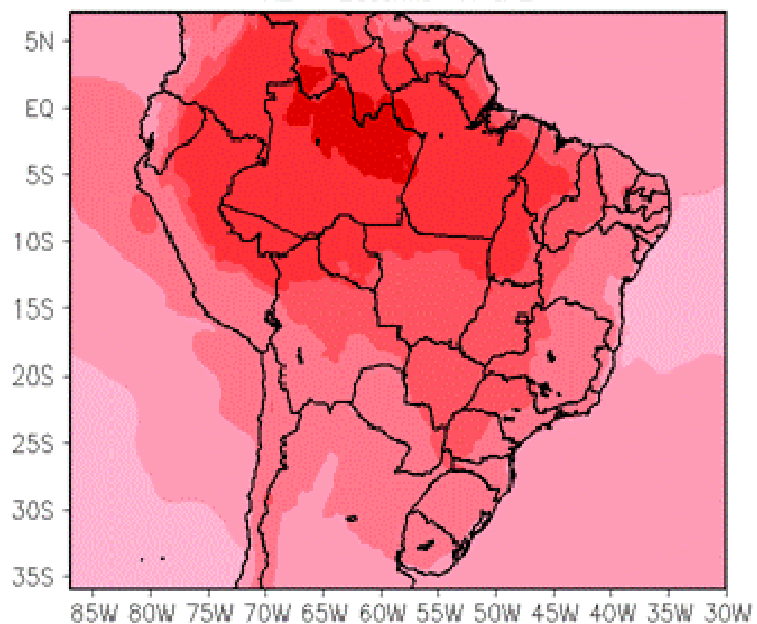
(a)

Anomalia de Precipitacao (%) Ensemble
B2 - Baseline ANUAL



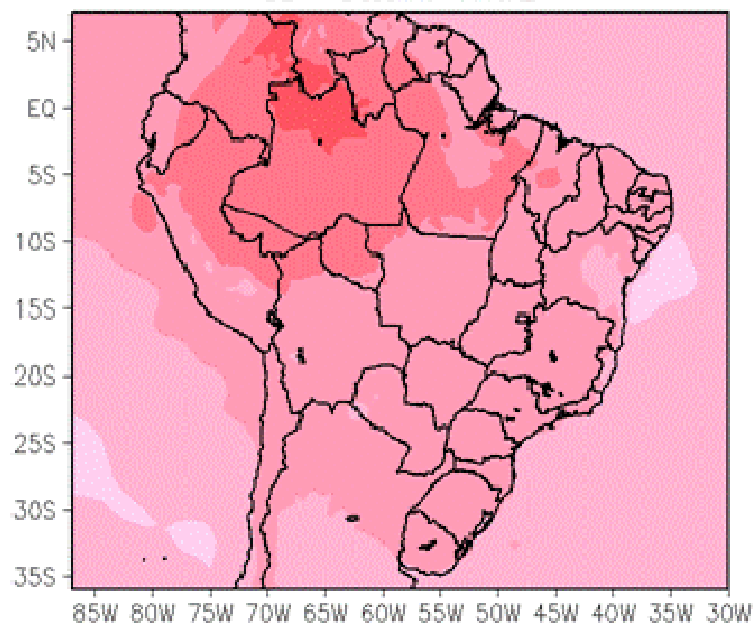
(b)

Anomalia de Temperatura (C) Ensemble
A2 - Baseline ANUAL



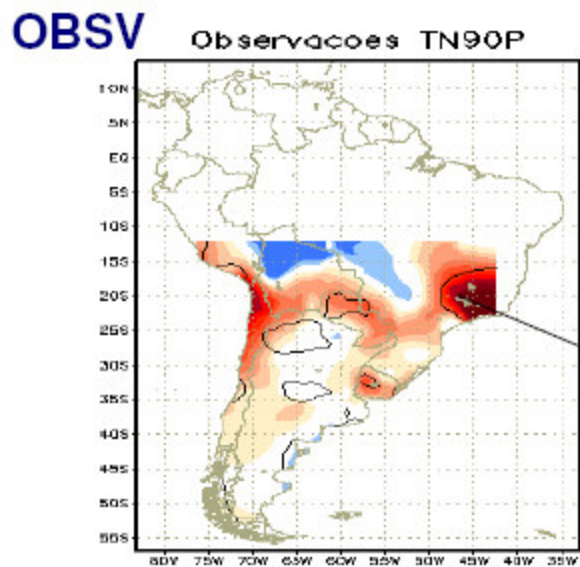
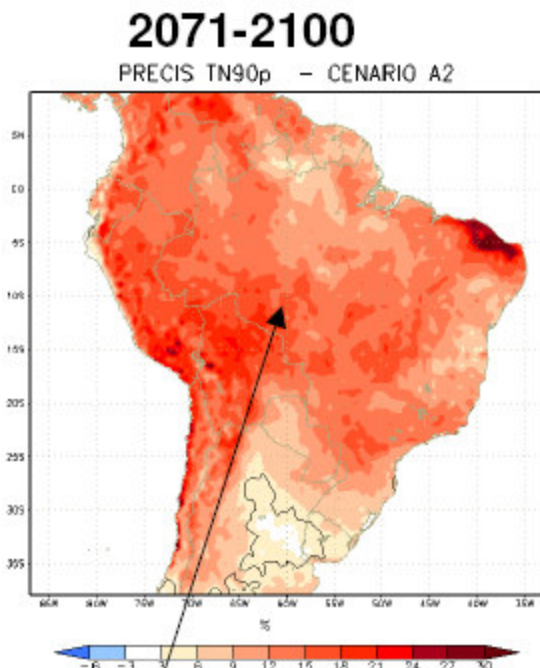
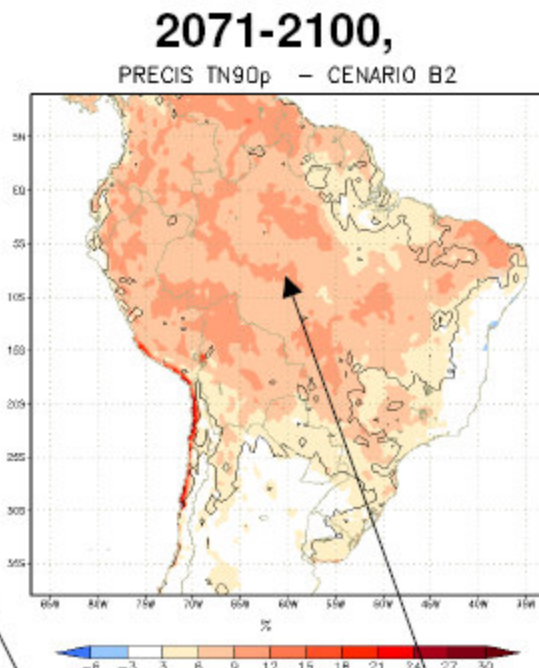
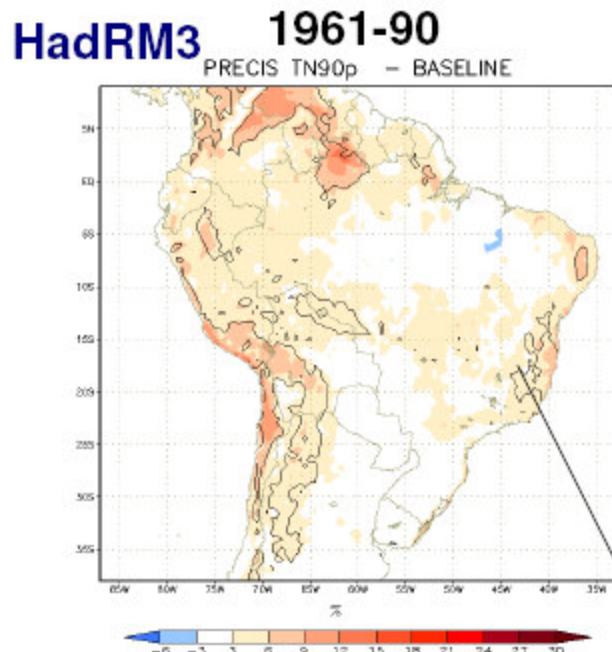
(c)

Anomalia de Temperatura (C) Ensemble
B2 - Baseline ANUAL



(d)

Índice TN90 (Noites quentes) presente (1961-90) e futuro (2071-2100)



Aumento na frequência de noites quentes até 2100

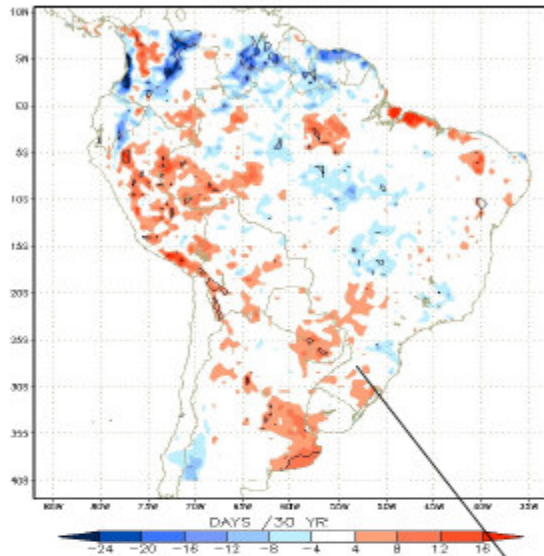
Aumento na frequência de noites quentes entre 1961-2000

Índice R10 (chuvas intensas) presente (1961-90) e futuro (2071-2100)

HadRM3

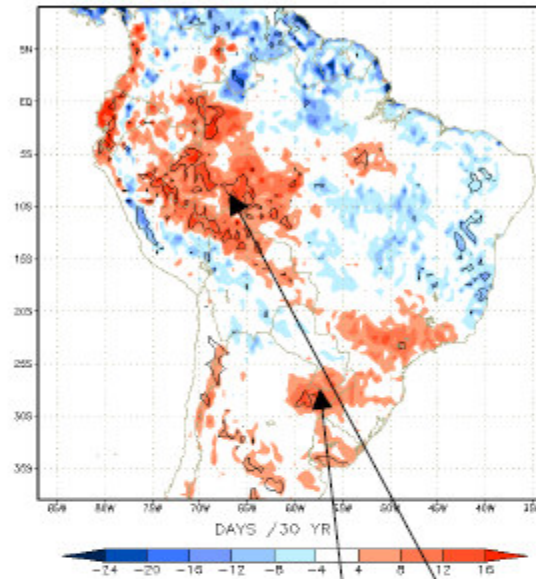
1961-90

PRECIS R10mm



2071-2100

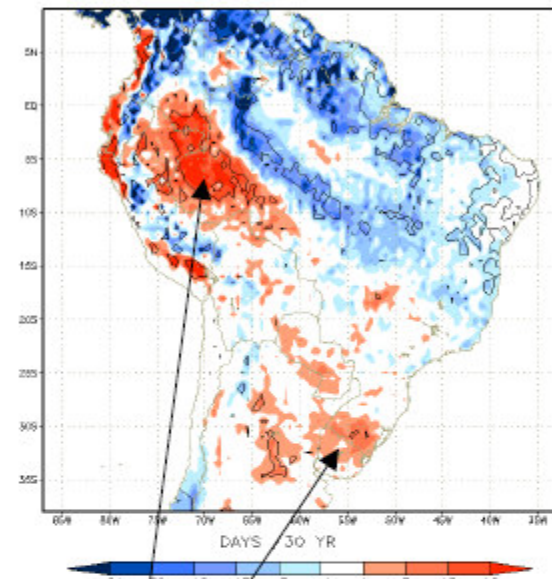
PRECIS R10mm - CENÁRIO B2



Baixas emissões

2071-2100

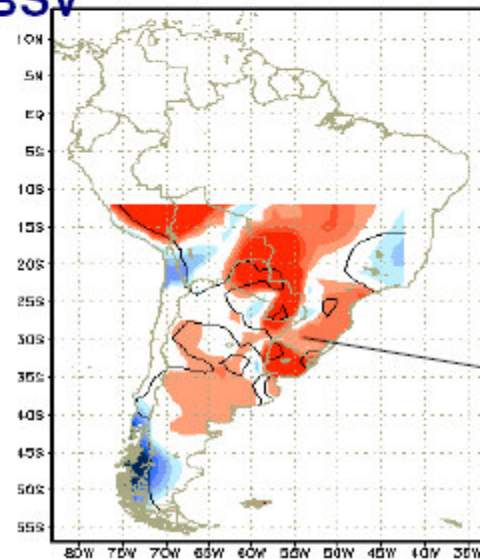
PRECIS R10mm - CENÁRIO A2



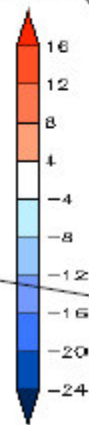
Altas emissões

OBSV

Observações R10mm



DAYS



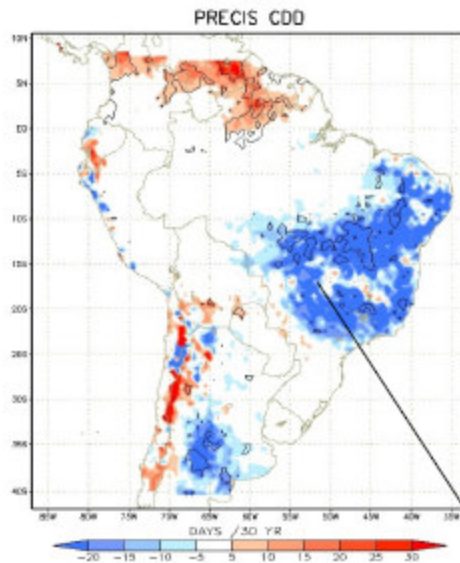
Aumento na frequência de chuvas intensas até 2100

Aumento na frequência de chuvas intensas (acima de 10 mm) entre 1961-2000

Índice CDD (dias secos consecutivos) presente (1961-90) e futuro (2071-2100)

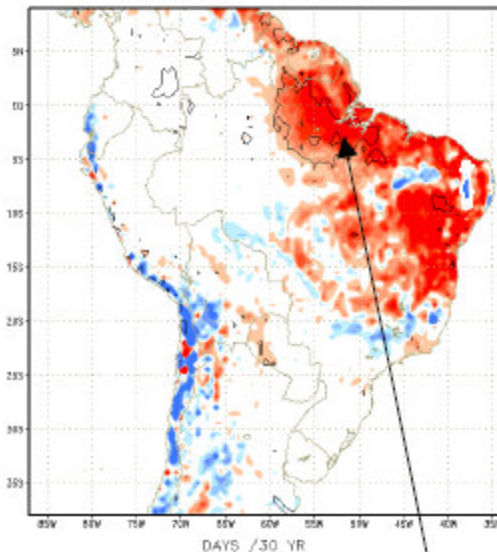
HadRM3

1961-90



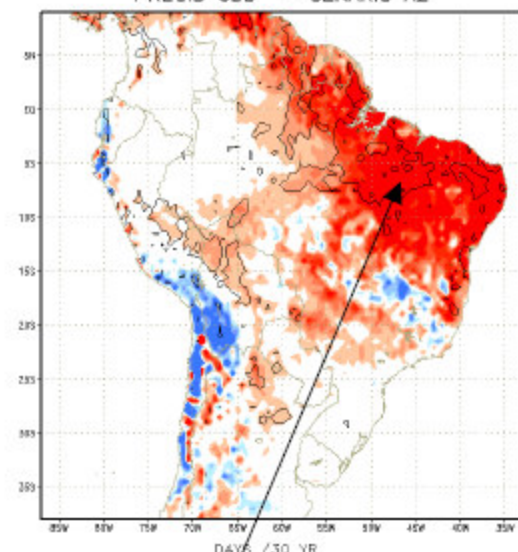
2071-2100

PRECIS CDD - CENARIO B2



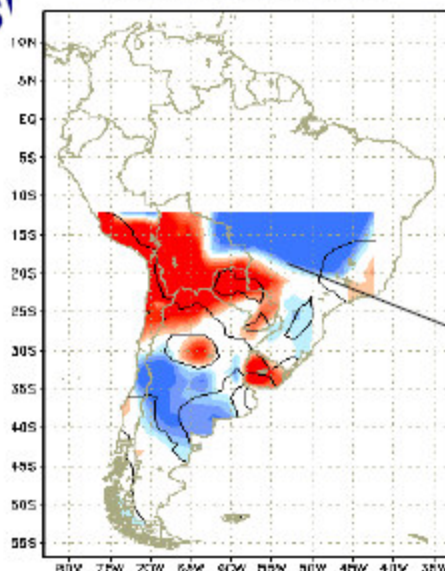
2071-2100

PRECIS CDD - CENARIO A2



OBS

Observações CDD



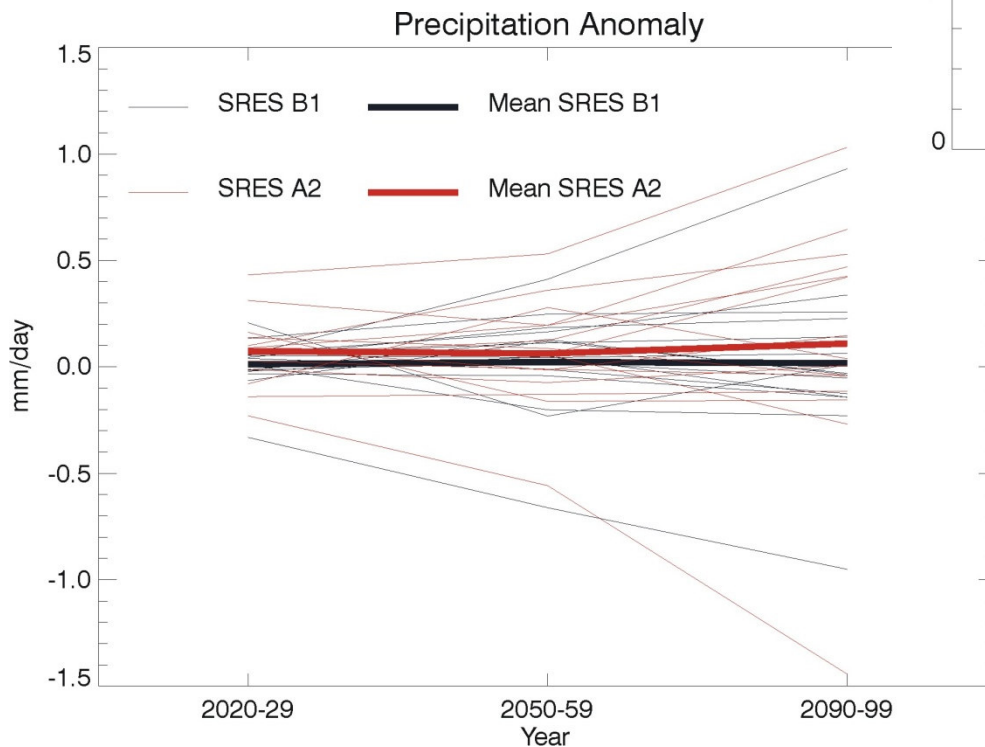
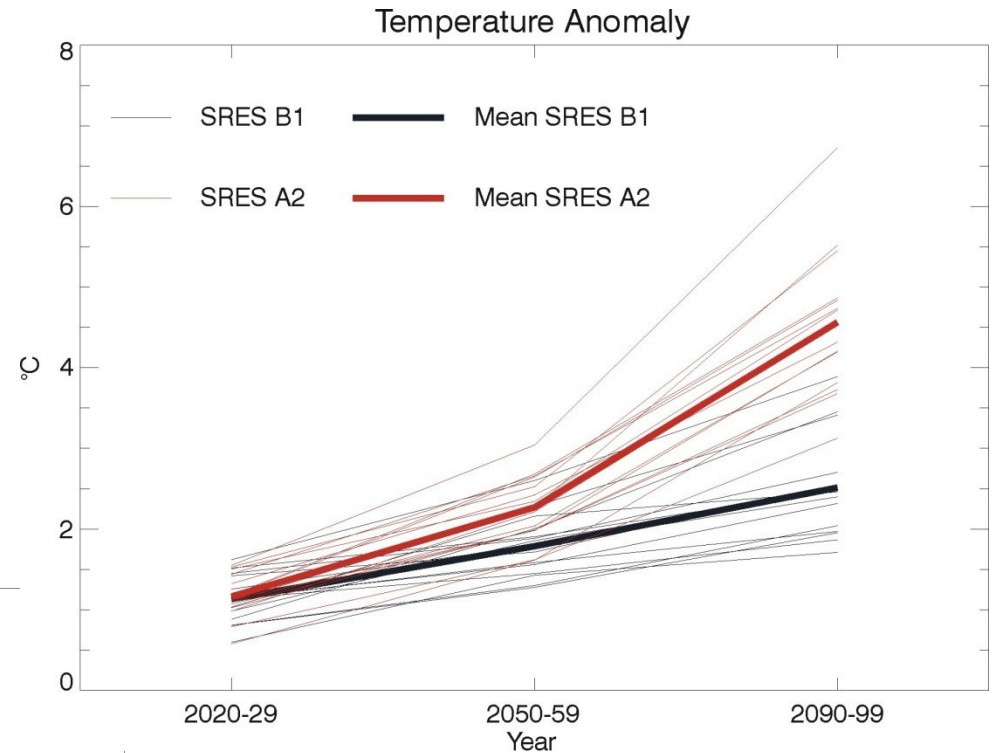
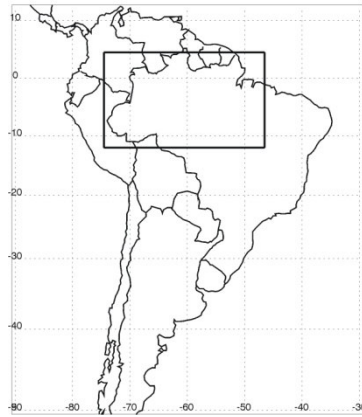
Baixas emissões

Altas emissões

Aumento na freqüência de dias secos consecutivos ate 2100

Redução na freqüência de dias secos consecutivos entre 1961-2000

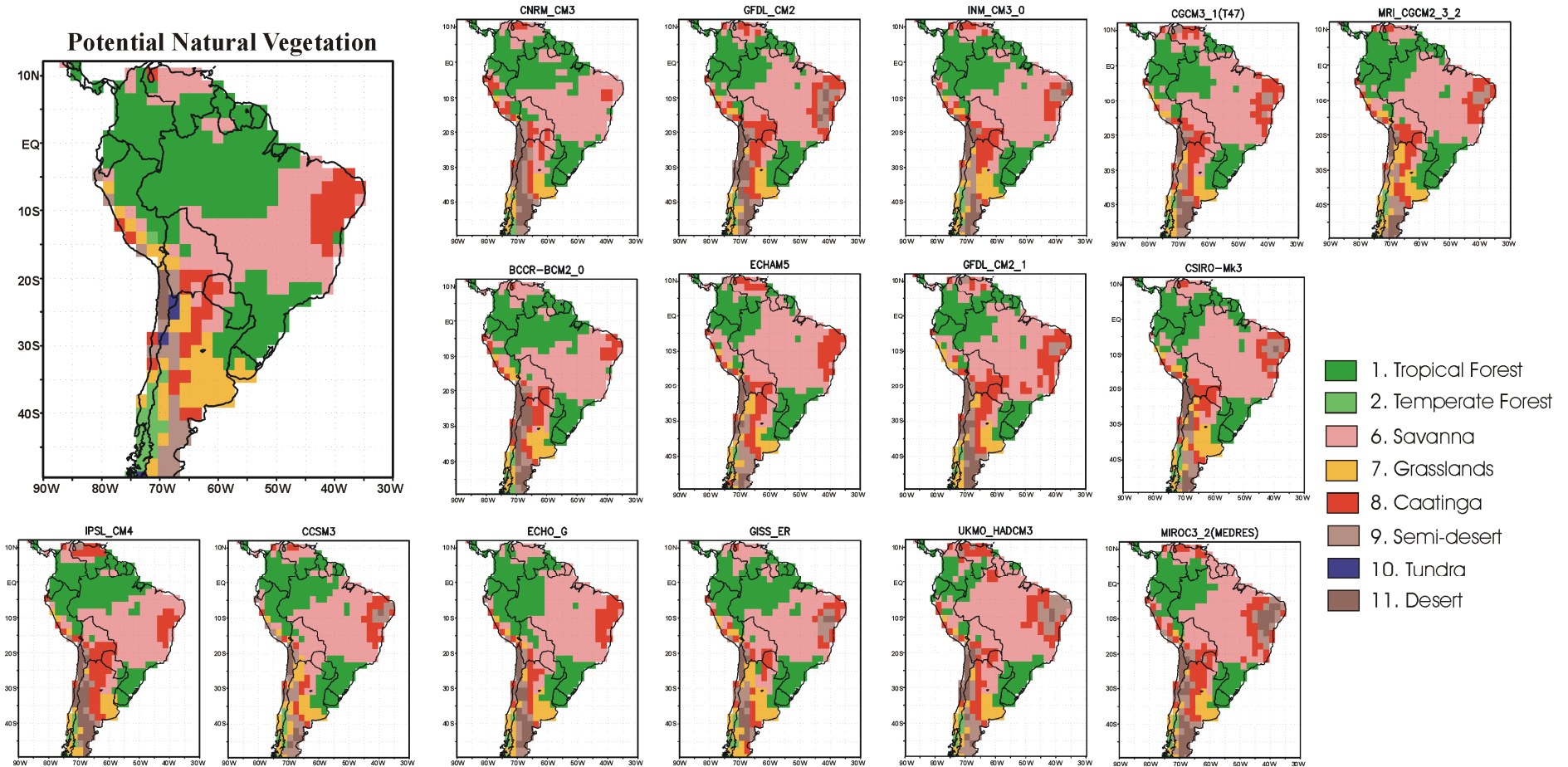
Climate Change Scenarios for Amazonia



Results from 15 AOGCMs for the SRES A2 and B1 emissions scenarios, prepared for the IPCC/AR4.

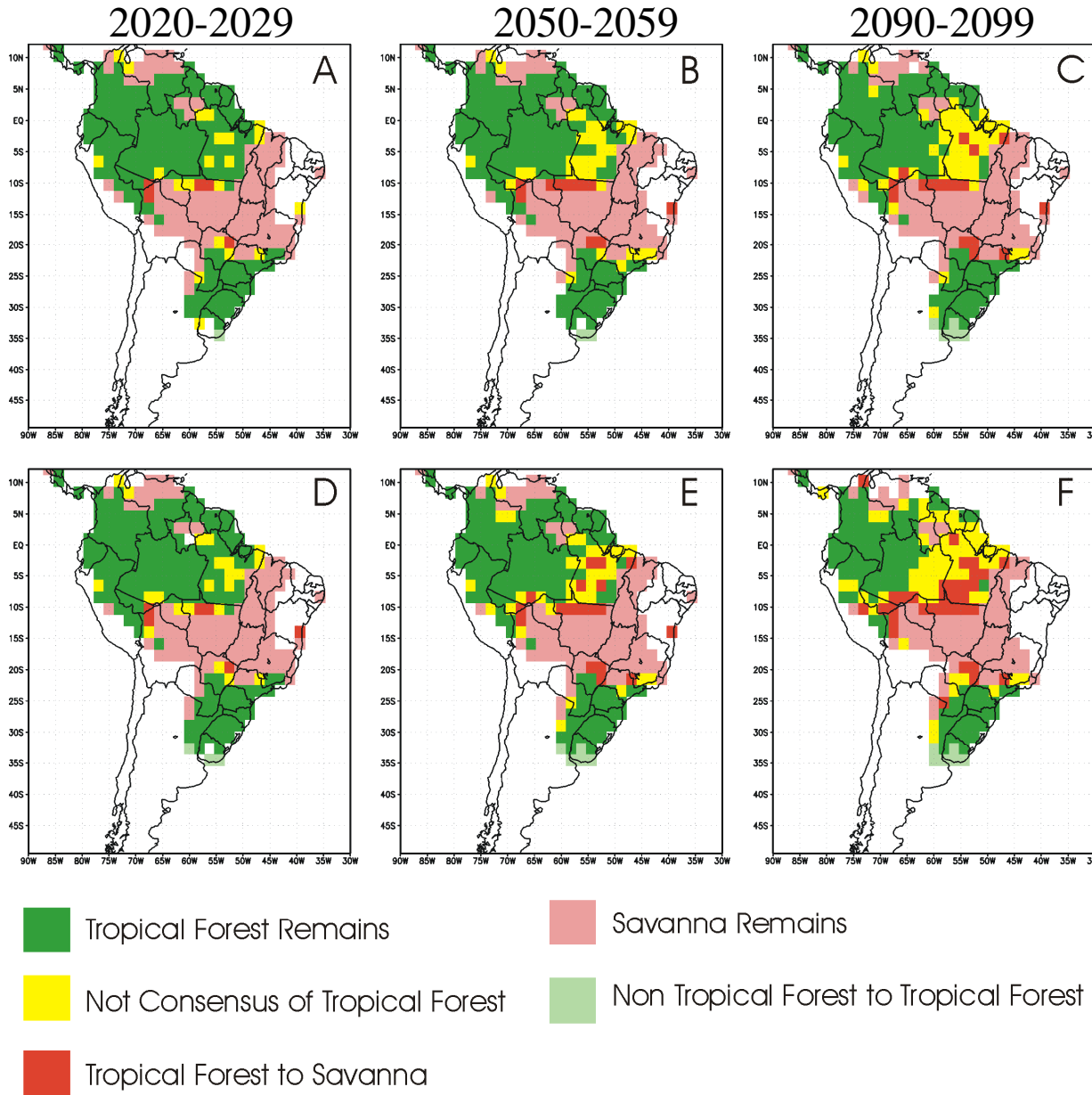
Models: BCCR-BCM2.0, CCSM3, CGCM3.1(T47), CNRM-CM3, CSIRO-MK3, ECHAM5, GFDL-CM2, GFDL-CM2.1, GISS-ER, INM-CM3, IPSL-CM4, MIROC3.2 (MEDRES), MRI-CGCM2.3.2, UKMO-HADCM3, ECHO-G

Climate Change Consequences on the Biome distribution in tropical South America

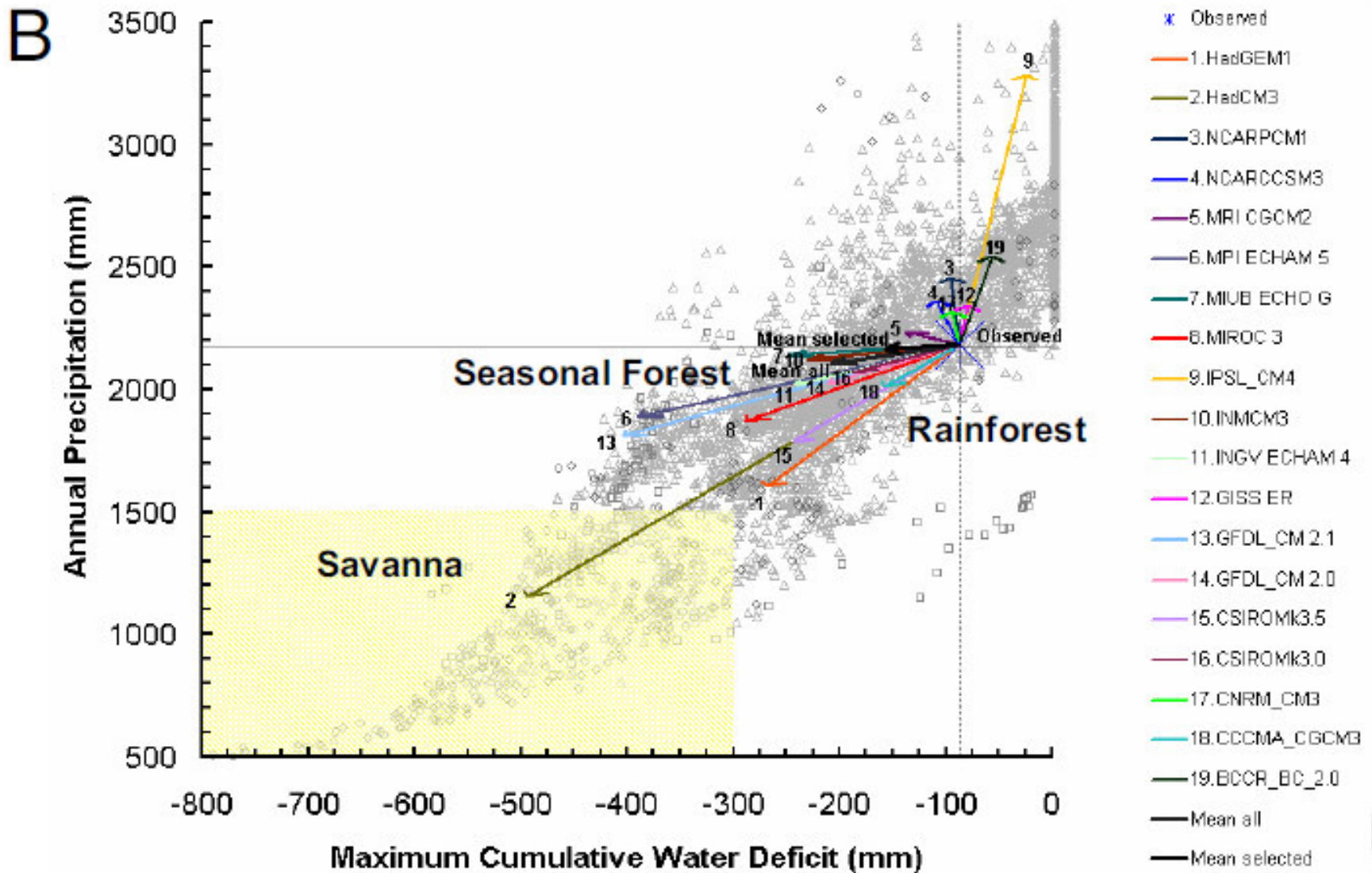


Projected distribution of natural biomes in South America for 2090-2099 from 15 AOGCMs for the A2 emissions scenarios.

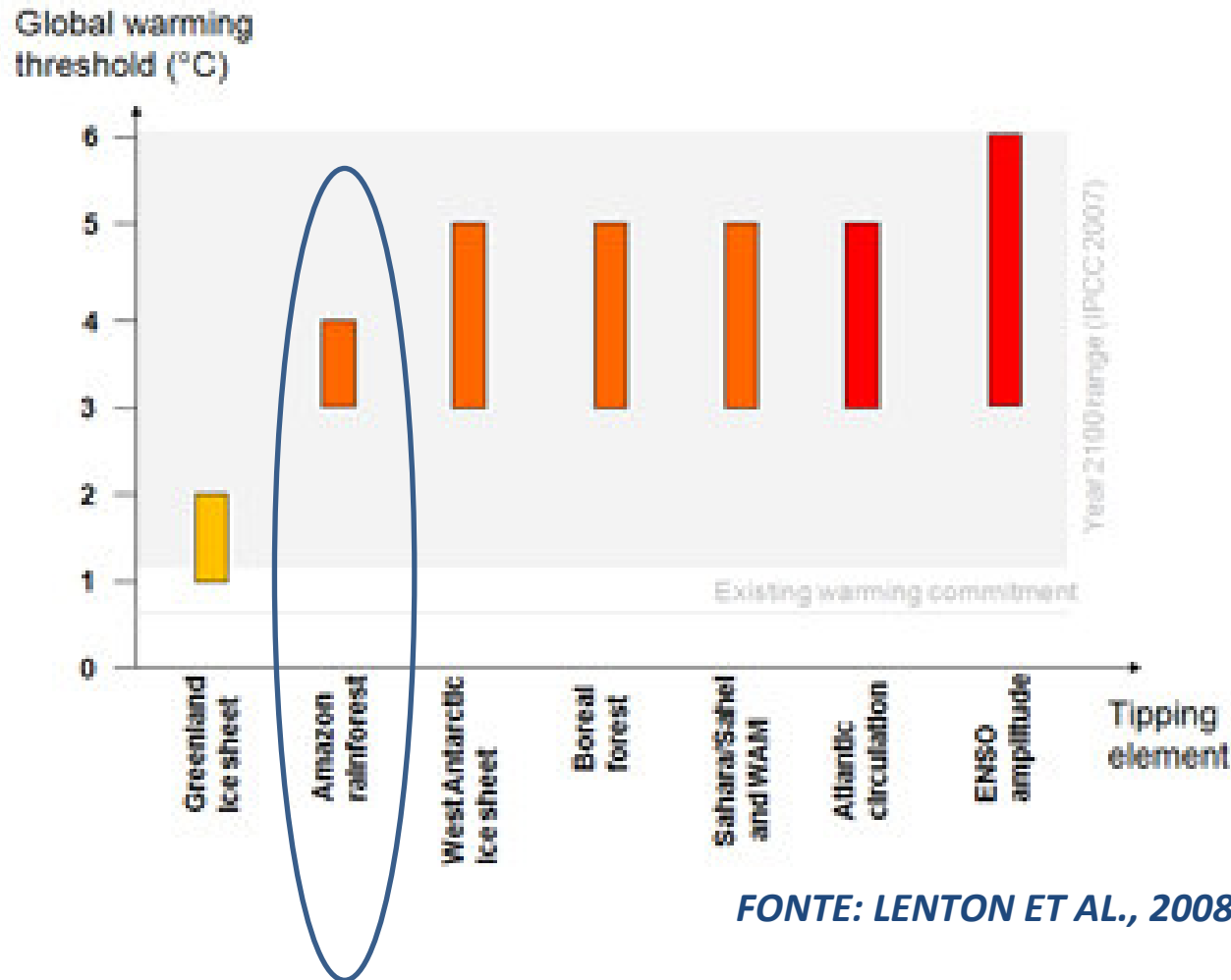
Climate Change Consequences on the Biome distribution in tropical South America



Grid points where more than 75% of the models used (> 11 models) coincide as projecting the future condition of the tropical forest and the savanna in relation with the current potential vegetation. The figure also shows the grid points where a consensus amongst the models of the future condition of the tropical forest was not found. for the periods (a) 2020-2029, (b) 2050-2059 and (c) 2090-2099 for B1 GHG emissions scenario and (d), (e) and (f) similarly for A2 GHG emissions scenario.



Our analysis concluded that, under mid-high-range emissions scenarios, there is a high probability of intensified dry seasons in E. Amazonia and a medium probability that the rainfall regime will shift sufficiently to a climate state where seasonal forest is more viable than rainforest.



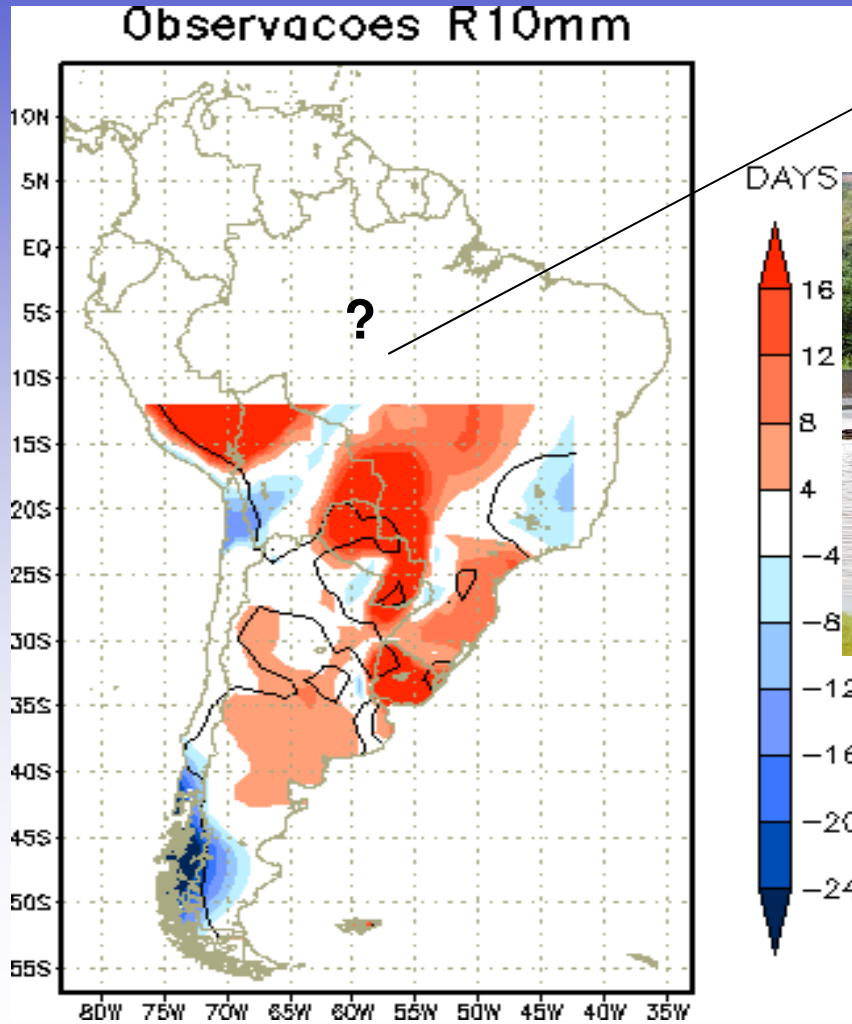
Lenton et al. (2008) e Kriegler et al. (2009) analisaram o “tipping point” de vários subsistemas do sistema climático, baseados em diferentes estudos e em opiniões de especialistas. ***Esses estudos mostraram que o limiar de temperatura entre 3°C e 4°C poderia levar a substituição da floresta tropical na Amazônia.***

CLIMATE EXTREMES



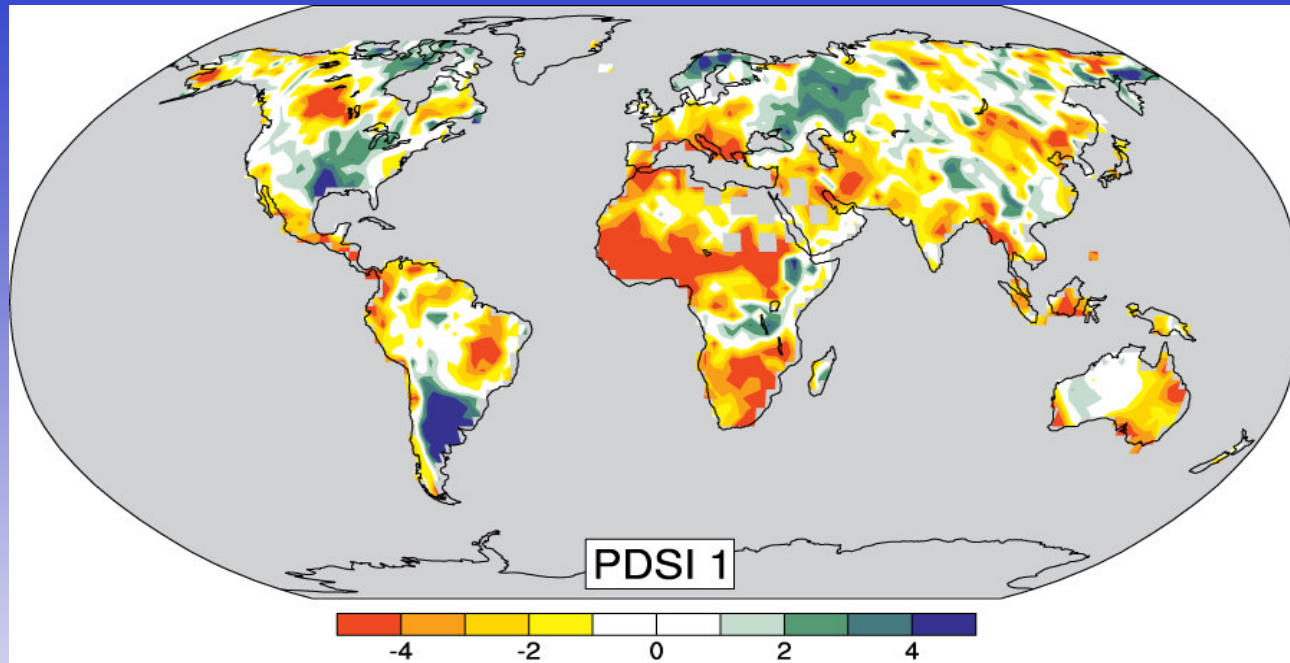
Sudeste da América do Sul: Aumento na intensidade e frequência de dias com chuva intensa (1951-2000)

Vazio de dados na Amazônia, Nordeste e partes do Centro-Oeste.

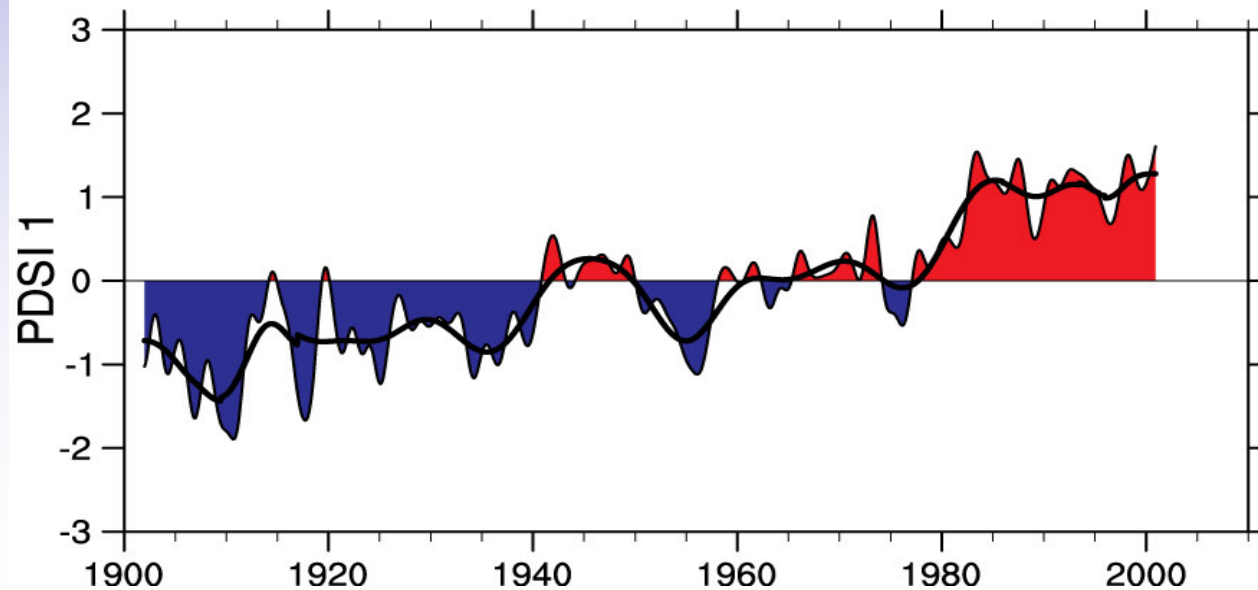


Índice R10 - Número de dias com chuva acima de 10 mm/dia

Secas estão aumentando em muitos lugares



O mais importante padrão espacial do Índice de Severidade de Seca de Palmer (PDSI) - 1900 a 2002.



Componente da série temporal responde pela maior parte da tendência do PDSI.

Desertificação - Contexto geográfico

Aridez

O Índice de Aridez, definido como a razão entre a Precipitação e a Evapotranspiração Potencial, estabelece as seguintes classes climáticas:

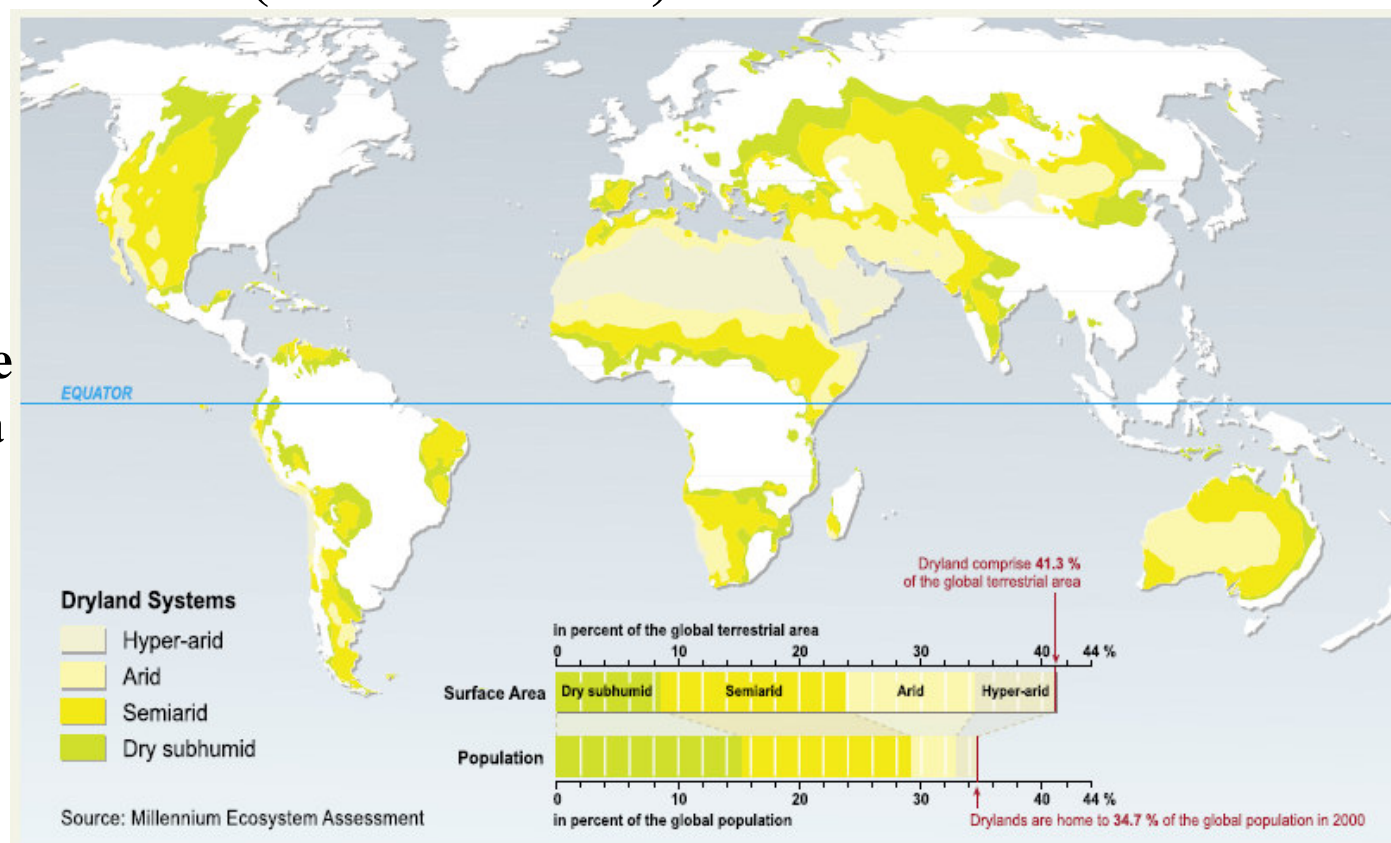
- Hiper-árido $< 0,03$
- Árido $0,03 - 0,20$
- Semi-árido $0,21 - 0,50$
- Sub-úmido seco $0,51 - 0,65$
- Sub-úmido úmido $> 0,65$

Desertificação

A Agenda 21, em seu capítulo 12, definiu a desertificação como sendo "**a degradação da terra nas regiões áridas, semi-áridas e sub-úmidas secas, resultante de vários fatores, entre eles as variações climáticas e as atividades humanas**".

Portanto, as áreas susceptíveis à desertificação e enquadradas no escopo de aplicação da Convenção das Nações Unidas para o Combate à Desertificação são aquelas de clima árido, semi-árido e sub-úmido seco (“terras secas”).

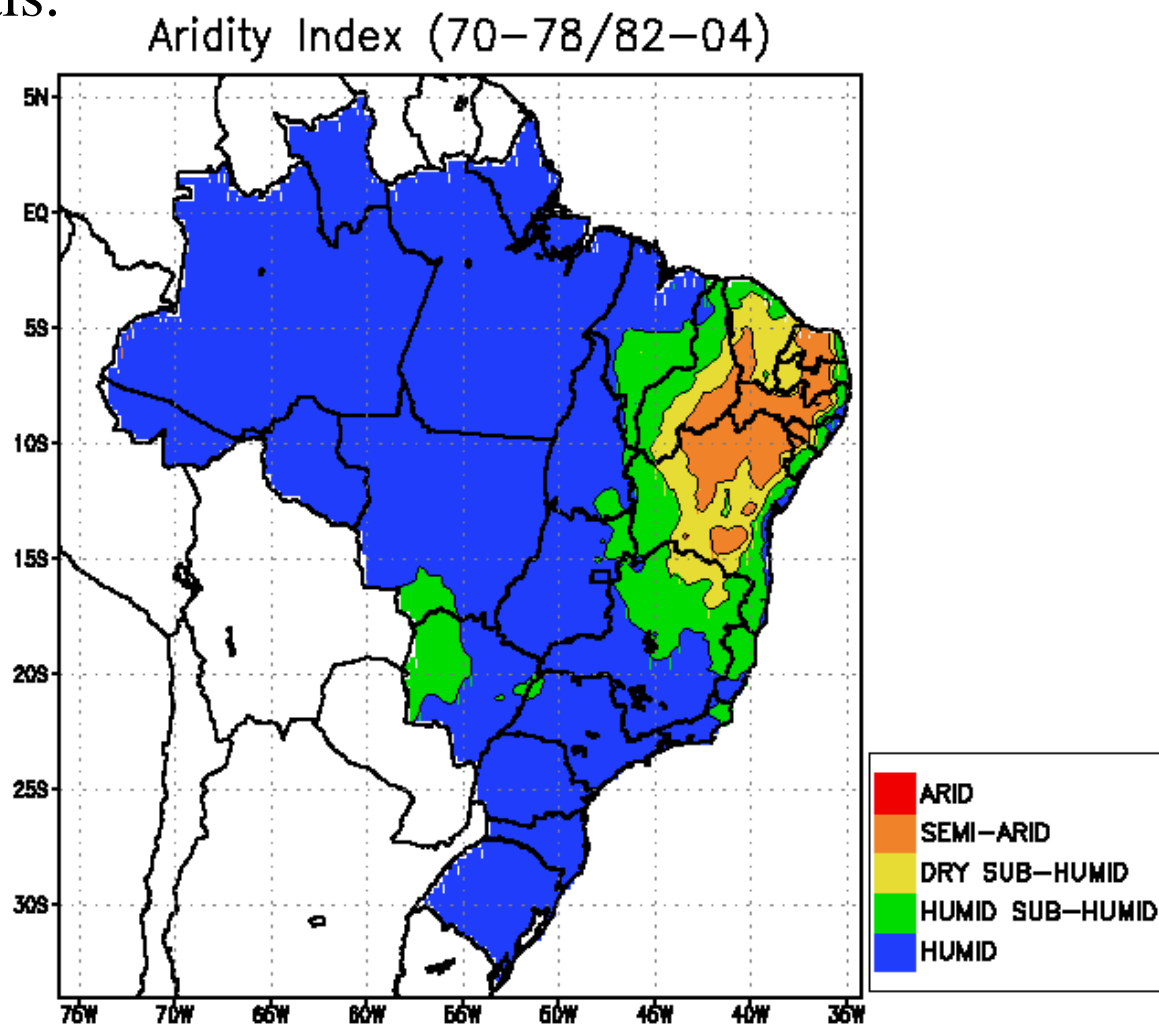
As terras “secas” abrangem 40% da superfície terrestre, e em torno de 35% da população global. Estima-se que entre 10-20% das terras secas estão afetadas pela desertificação.



† The long-term mean of the ratio of an area's mean annual precipitation to its mean annual potential evapotranspiration is the Aridity Index (AI).

Notes: The map is based on data from UNEP Geo Data Portal (<http://geodata.grid.unep.ch/>). Global area based on Digital Chart of the World data (147,573,196.6 square km); Data presented in the graph are from the MA core database for the year 2000.

De acordo com a definição da convenção, as áreas susceptíveis à desertificação estão localizadas na Região Nordeste e no Norte de Minas Gerais.



Fonte: Tomasella e Alvalá, 2010.

As causas da desertificação são várias

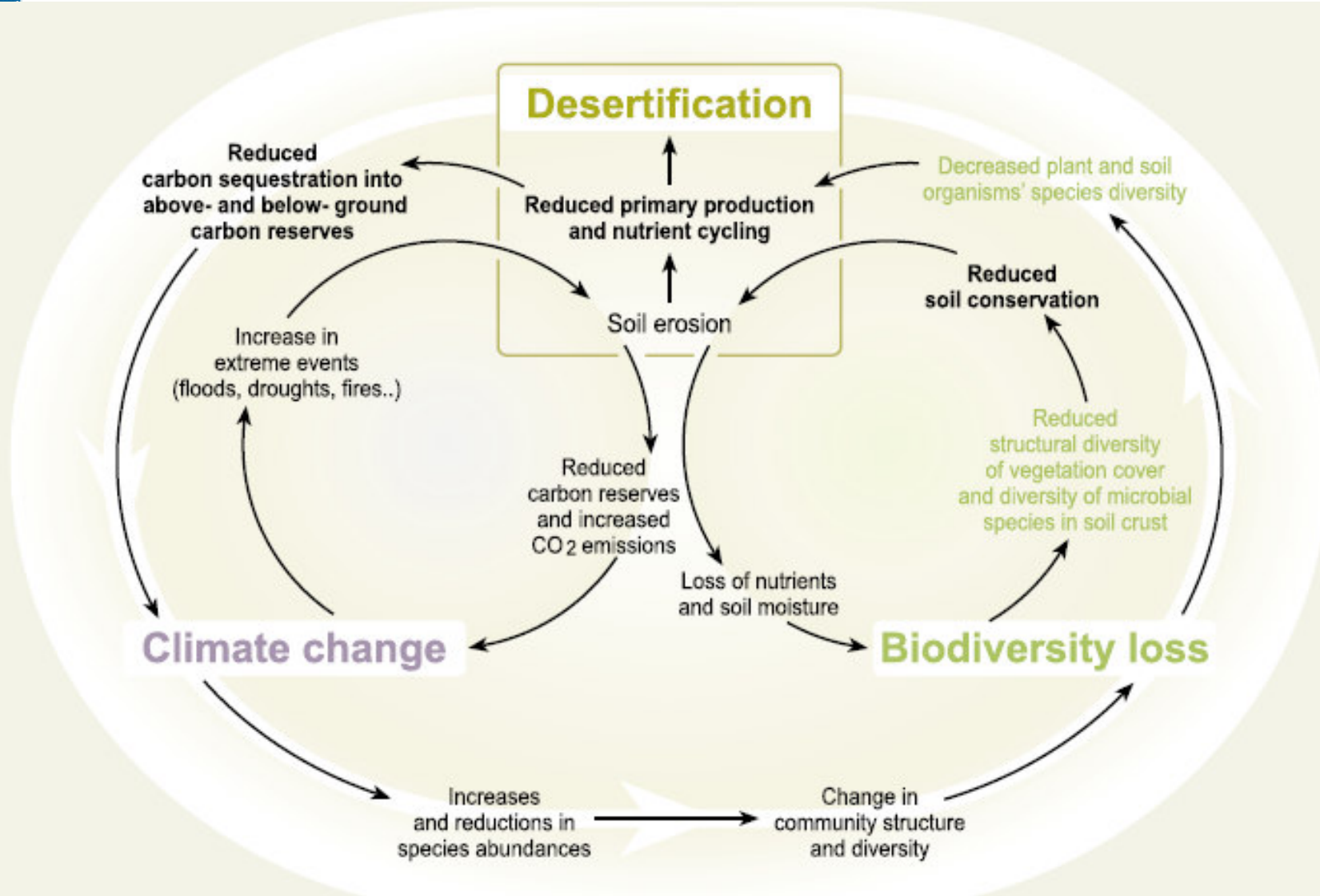
- **Mudanças climáticas**
- Mudanças no ciclo hidrológico de caráter interanual e interdecadal
- Urbanização
- Crescimento populacional
- Agricultura (desmatamento, práticas inadequada, queimadas)
- Erosão do solo

Existem inter-relações evidentes entre desertificação, mudanças climáticas e perda de biodiversidade:

A biodiversidade é responsável pelos serviços providos pelos ecossistemas de terras secas, e é afetado negativamente pela desertificação. A vegetação é responsável pela conservação do solo e por processos hidrológicos tais como infiltração, escoamento e processos físicos e químicos.

A desertificação afeta as mudanças climáticas globais pois provoca perda de solo e vegetação. Estima-se que as terras secas contêm 25% do estoque global de carbono. Portanto desertificação pode liberar uma parcela significativa desse carbono estocado: 4 % das emissões globais são atribuídas à desertificação.

O efeito da desertificação é complexo, e pouco compreendido. As mudanças climáticas afetam a biodiversidade, aumentam a evaporação e diminuem a precipitação em algumas áreas agravando a aridez. Como as plantas de ecossistemas de terras secas respondem de uma maneira diferente às mudanças climáticas, pode-se esperar mudanças na composição de espécies e sua abundância relativa nesses ecossistemas.



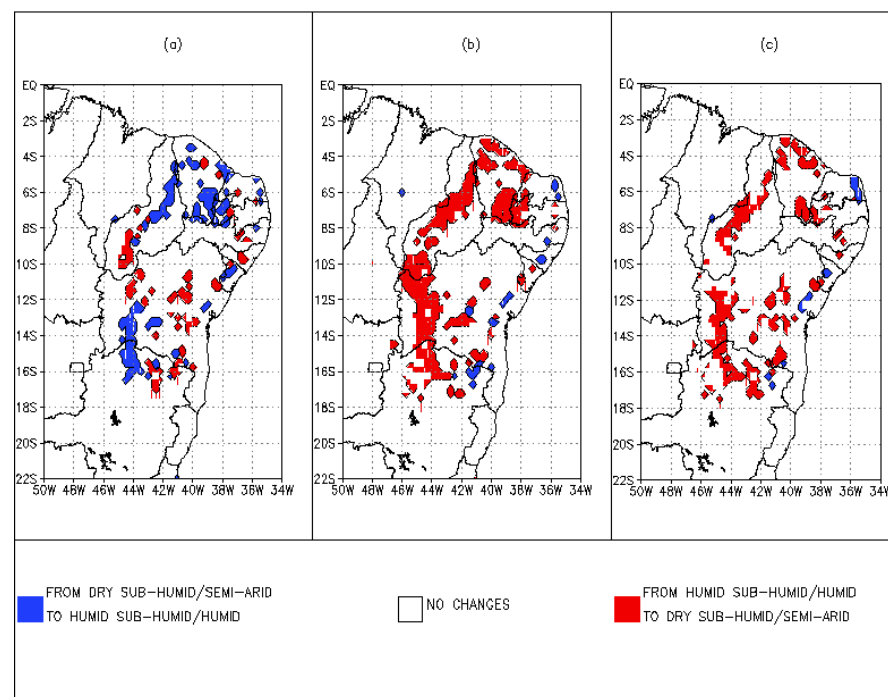
in green: major components of biodiversity involved in the linkages
bolded: major services impacted by biodiversity losses

Source: Millennium Ecosystem Assessment

No Brasil, dados históricos sugerem que as mudanças já estão ocorrendo.

(a) de 1970-1978 para 1983-1991, (b) de 1983-1991 para 1996-2004, (c) de 1970-1978 para 1996-2004.

O estudo indica uma expansão do semi-árido, o que aumenta a susceptibilidade ao processo de desertificação.





The Drought of Amazonia in 2005

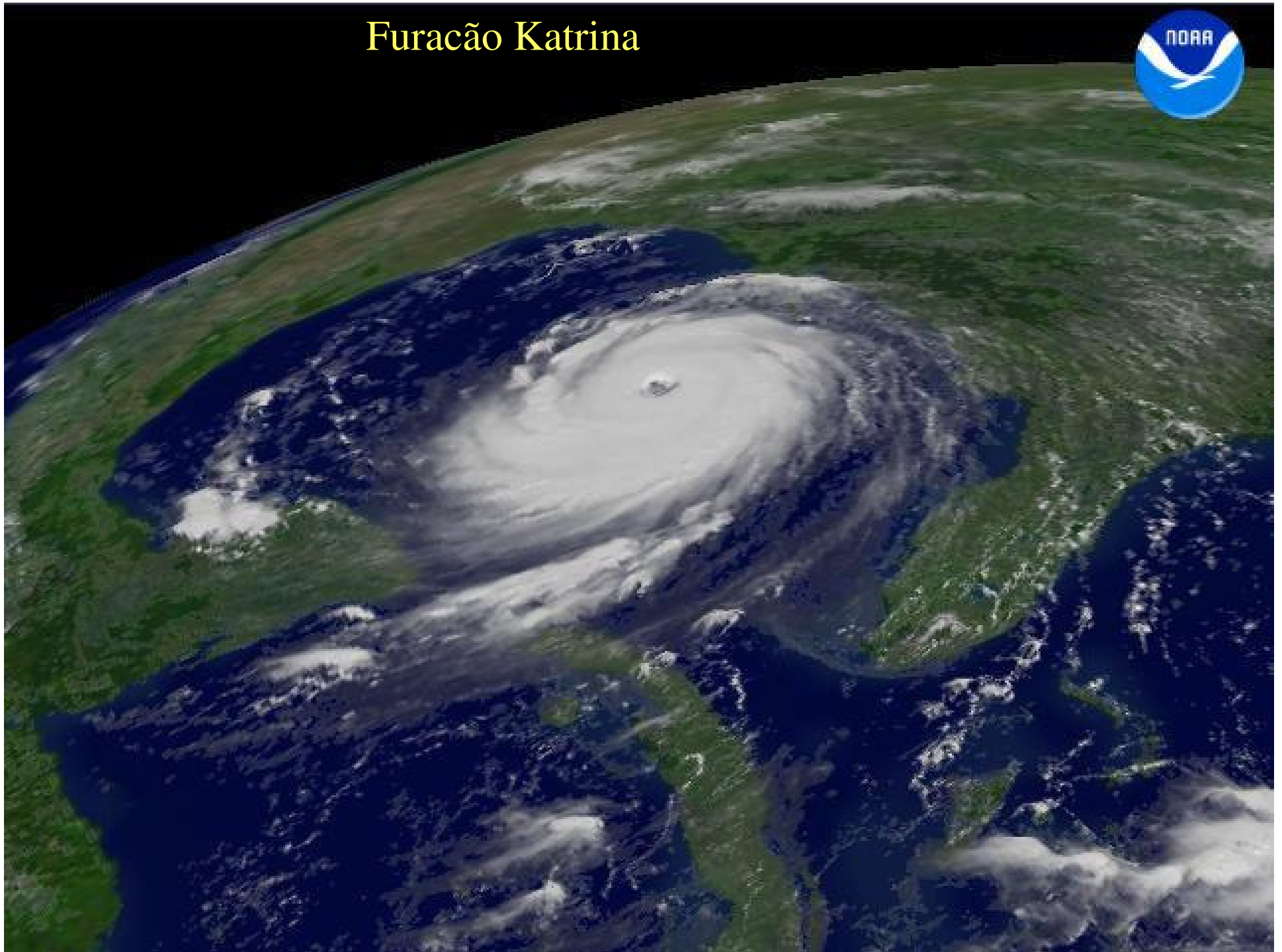
Source: Dr. Virgílio Viana

A Seca da Amazônia em 2005

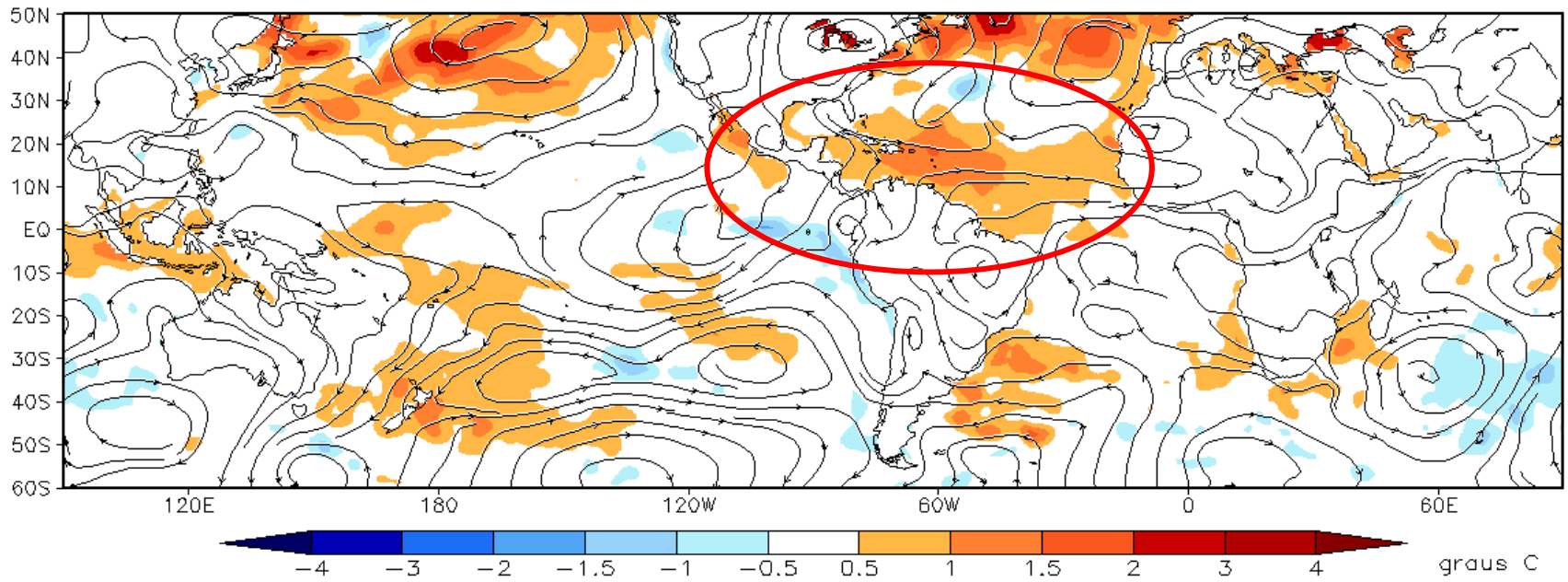
“Considerada uma das mais severas em 100 anos”



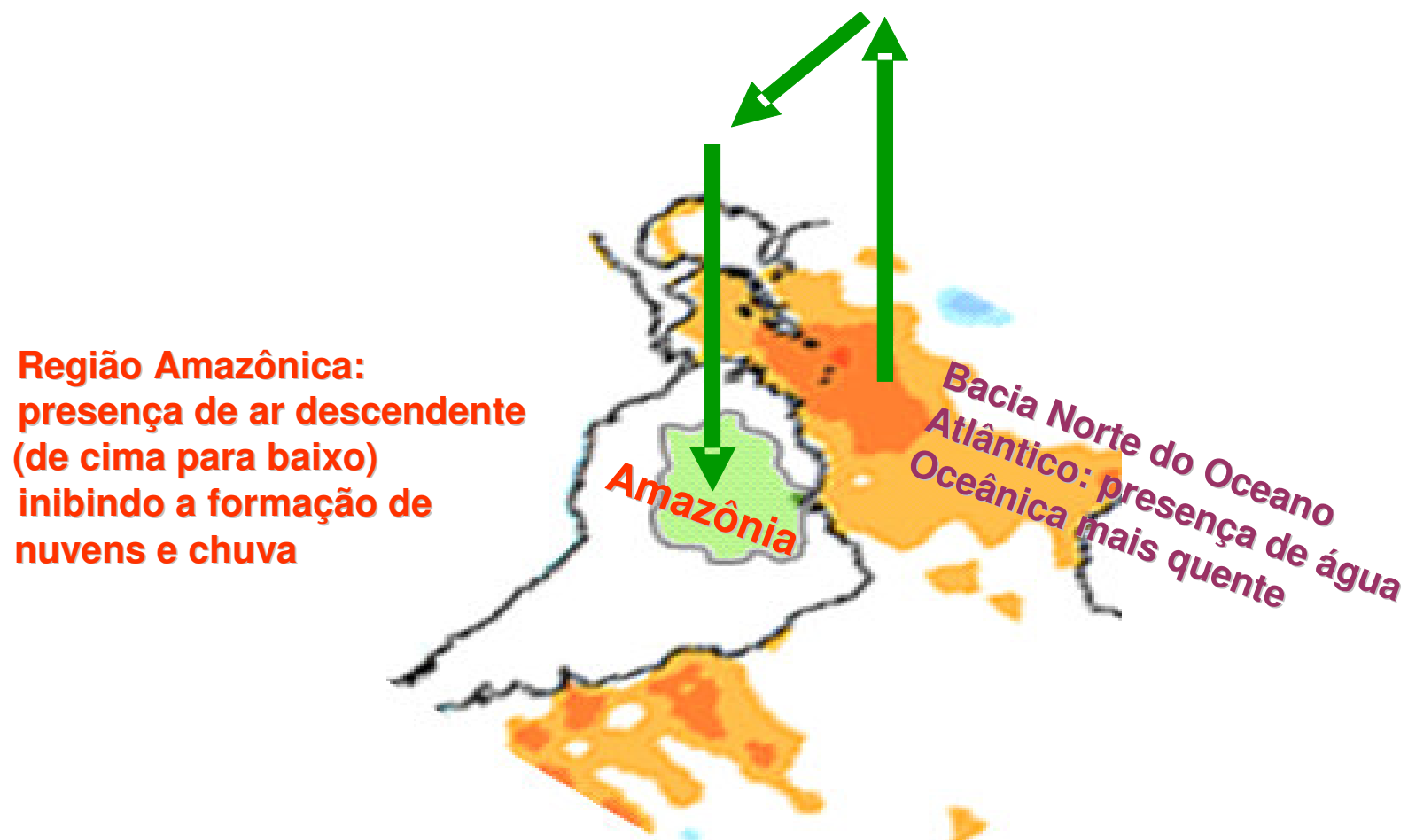
Furacão Katrina



ATSM & Anomalia de Vento 850mb SET/2005

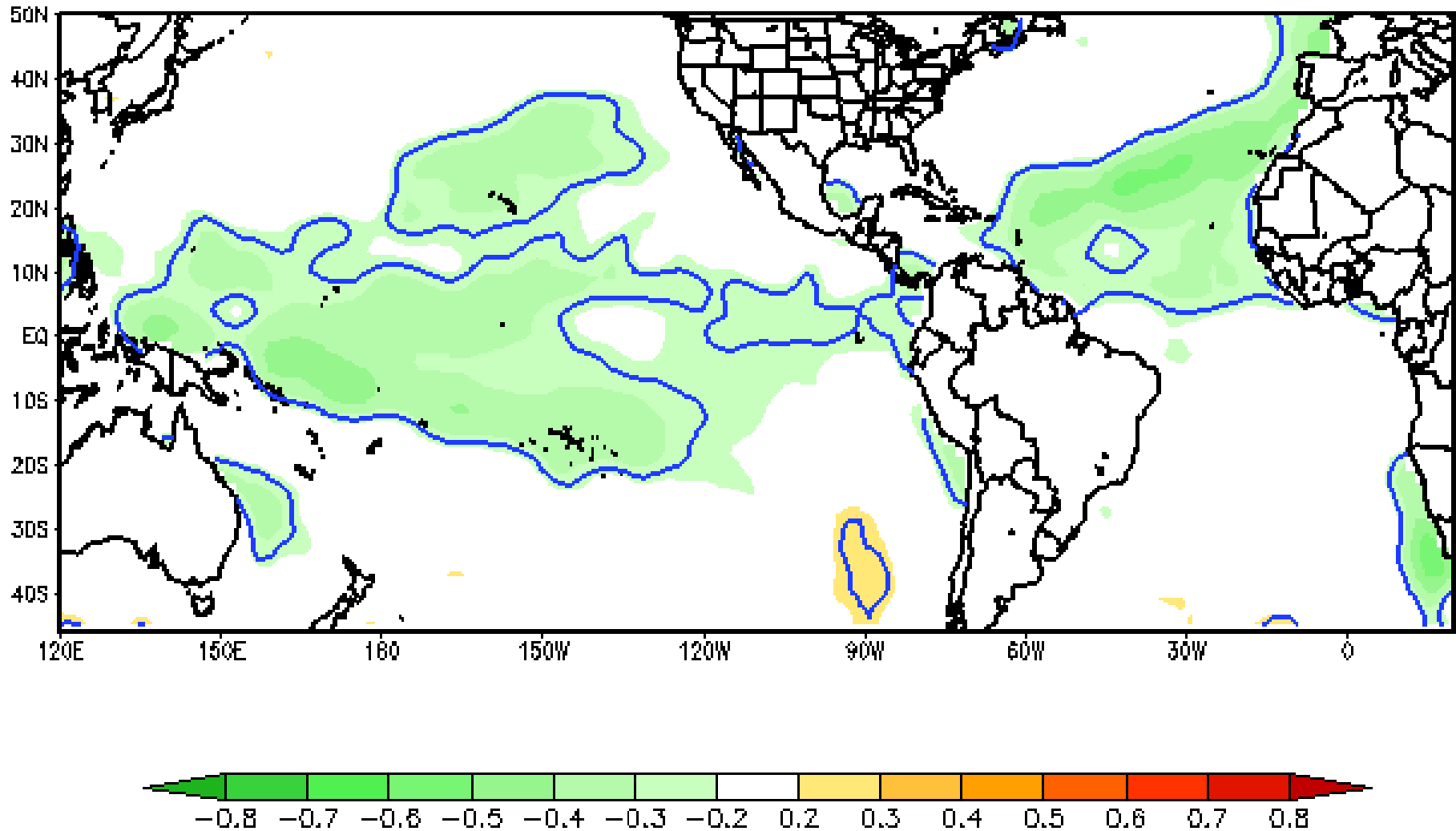


Padrão observado em Setembro 2005



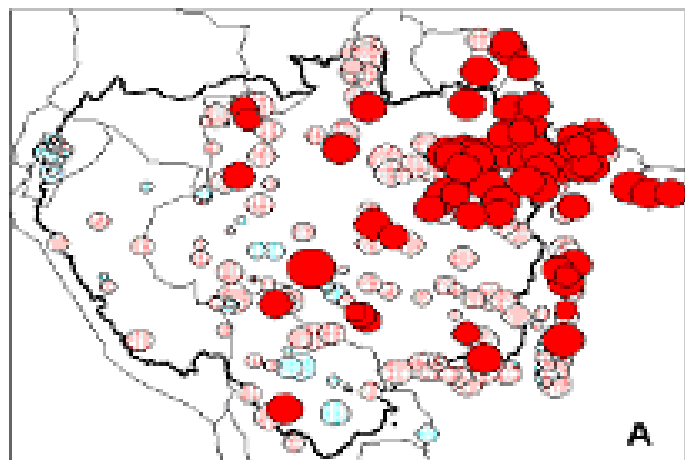
Correlation of Dec-March rainfall anomalies over Southern Amazonia (5-15°S – 50-75°W) and Global October SST anomalies

Correlation SAM Indices Versus oct SST Anomalies

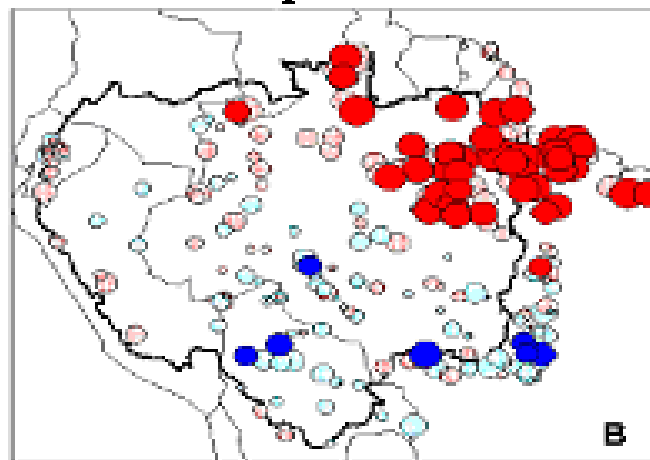


Variabilidade interanual do clima na Amazônia

El Niño

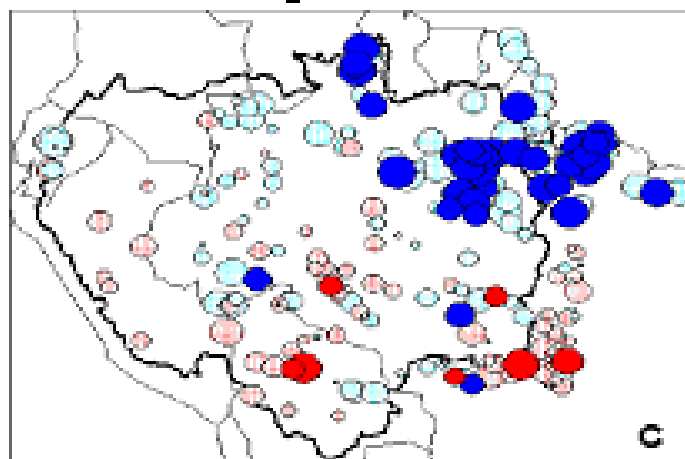


Atlântico Tropical Sul mais frio

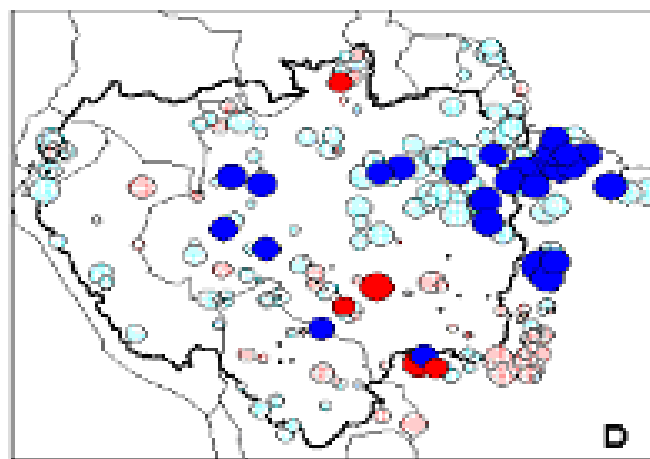


Variabilidade interanual de anomalias de chuva na Amazônia e Tocantins (Ronchail et al., 2002)

Atlântico Tropical Norte mais frio



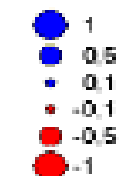
La Niña

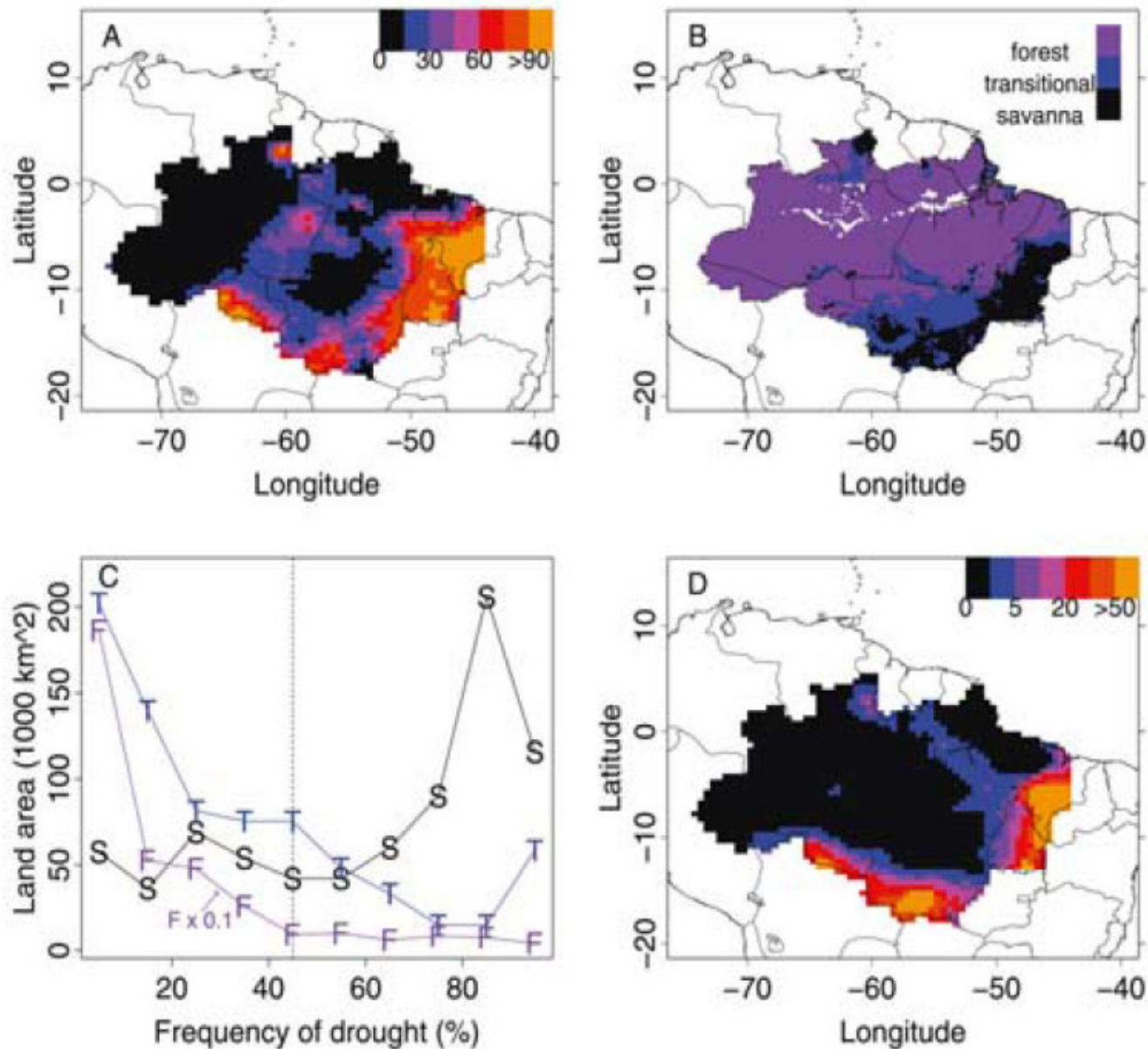


Anomalias não significantes (desvio padrão)



Anomalias significantes (desvio padrão)





(a) Observed drought frequency (% years); (b) distribution of savanna, transitional vegetation, and forest across the legal Brazilian Amazon; (c) land area (1000 km²) of vegetation types for pixels with given drought frequency (%), forest land area is multiplied by 0.1 for scaling; (d) percent attainment of the Nix [1983] criteria for savanna vegetation in the last 100 years.

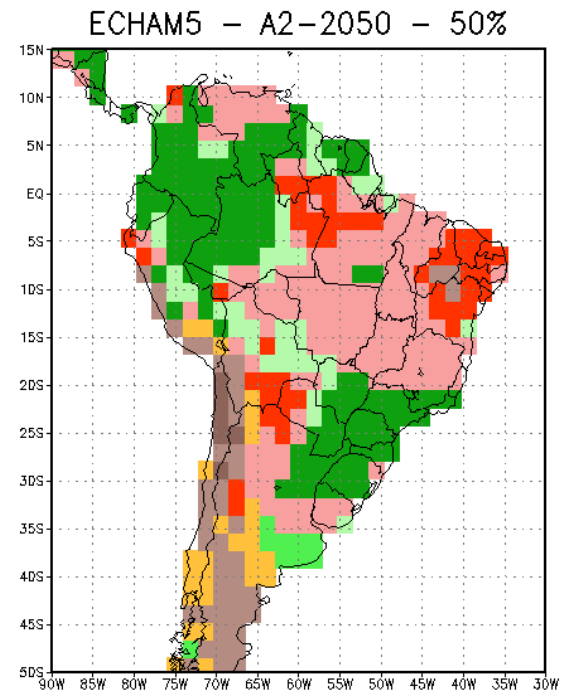
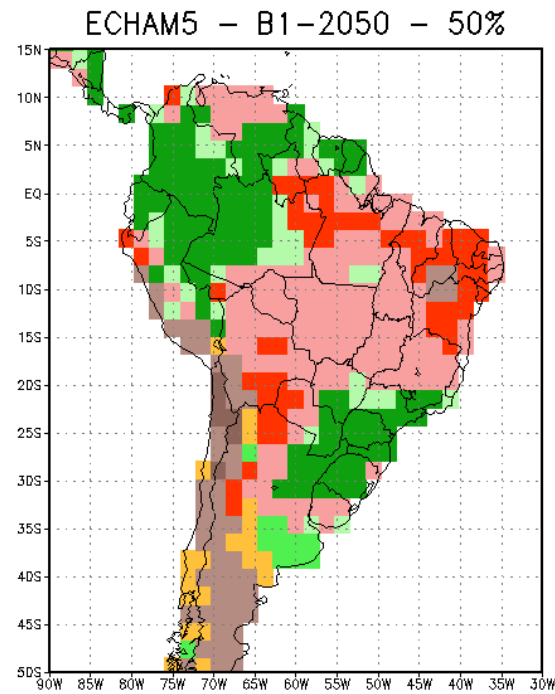
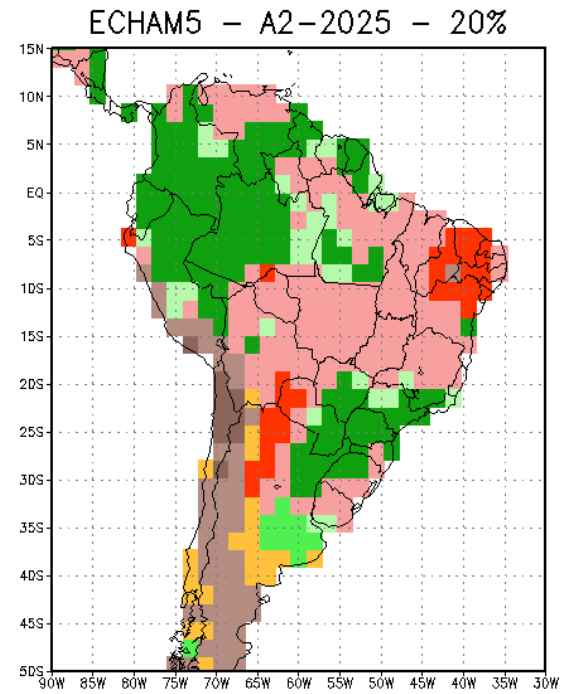
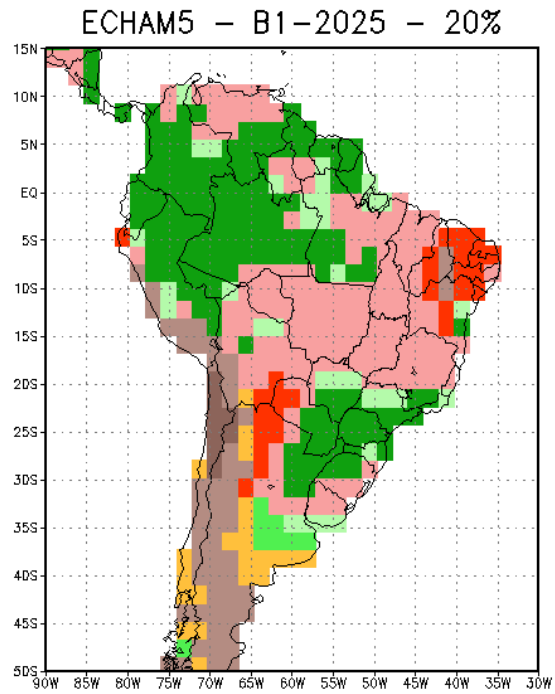
LAND COVER

+

CLIMATE CHANGE

+

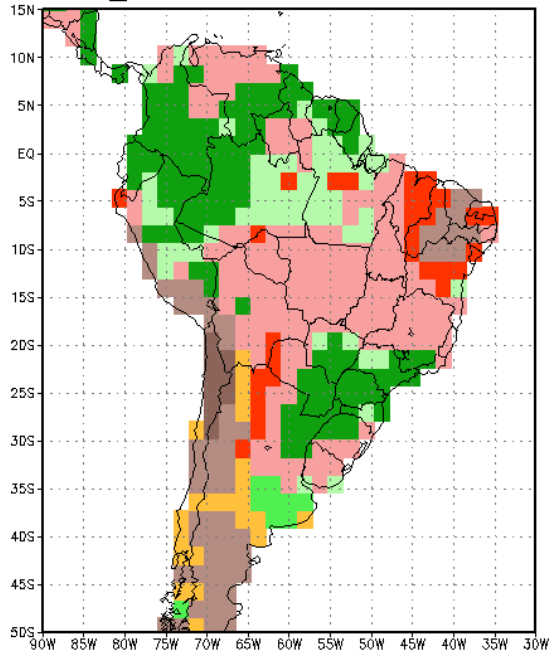
FIRE



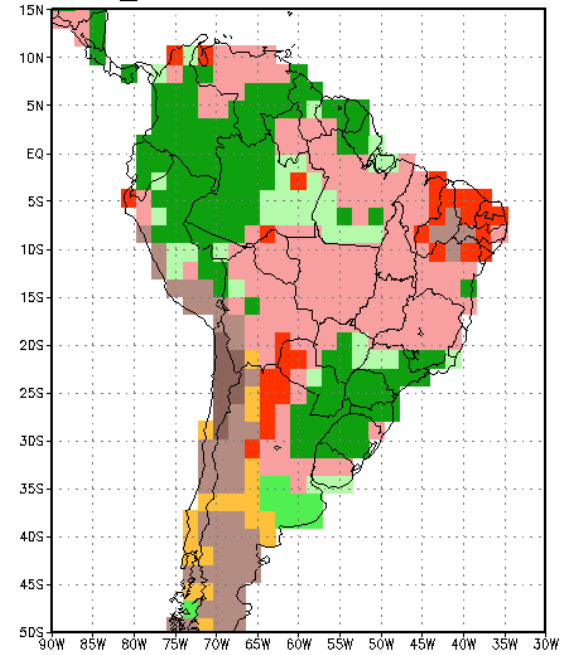
+ Fire

Nobre et al., 2010

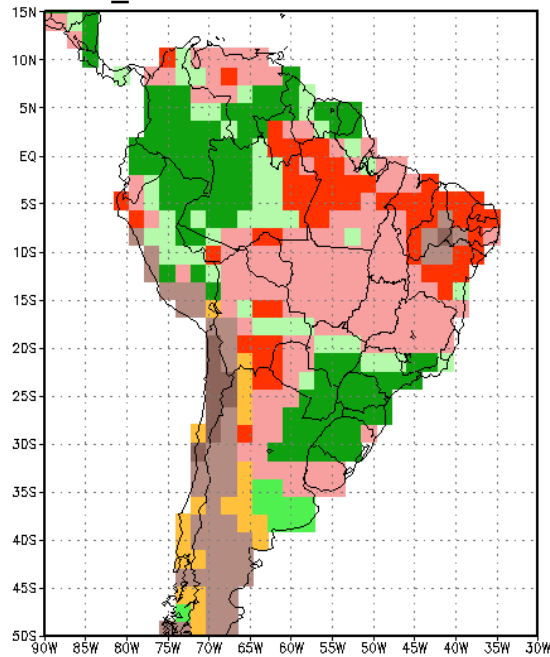
UKMO_HADCM3 - B1-2025 - 20%



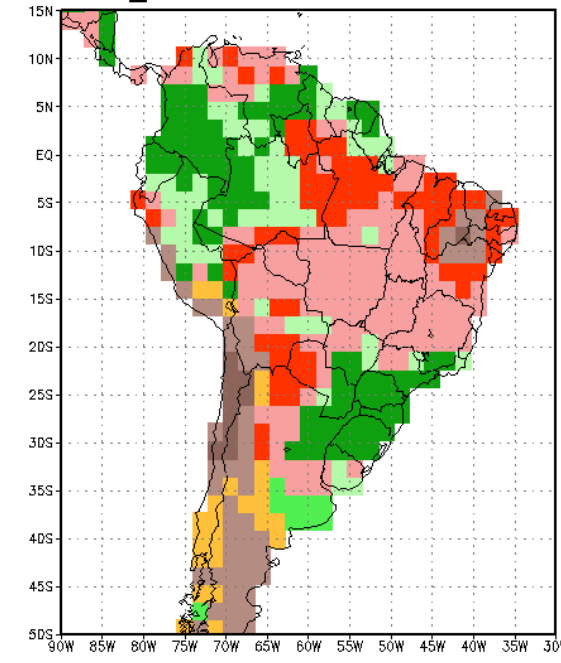
UKMO_HADCM3 - A2-2025 - 20%



UKMO_HADCM3 - B1-2050 - 50%

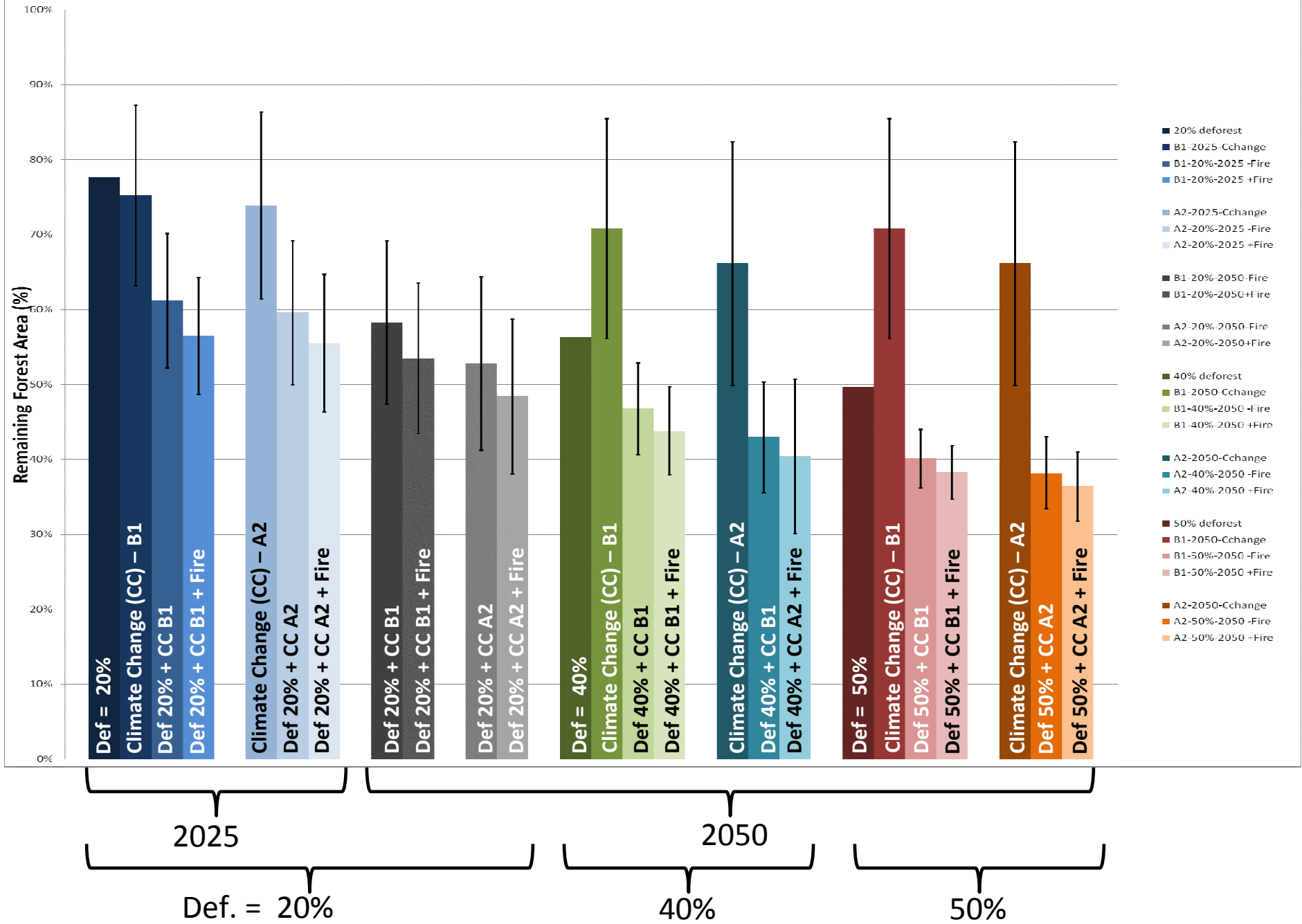


UKMO_HADCM3 - A2-2050 - 50%



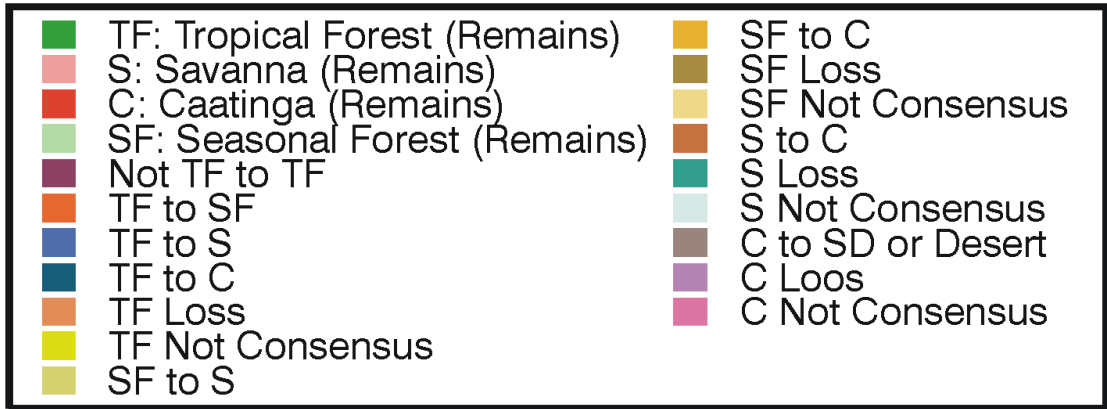
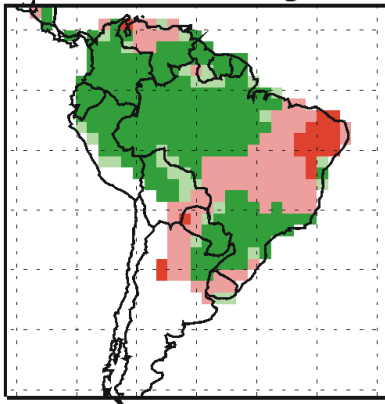
+ Fire

Amazonia

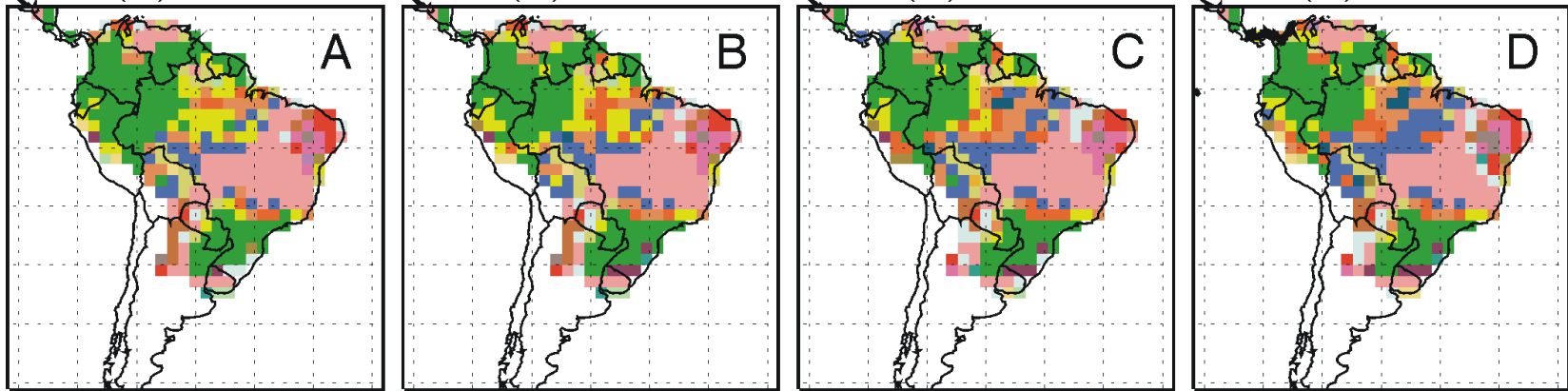


Iufire2 - Models > 75%

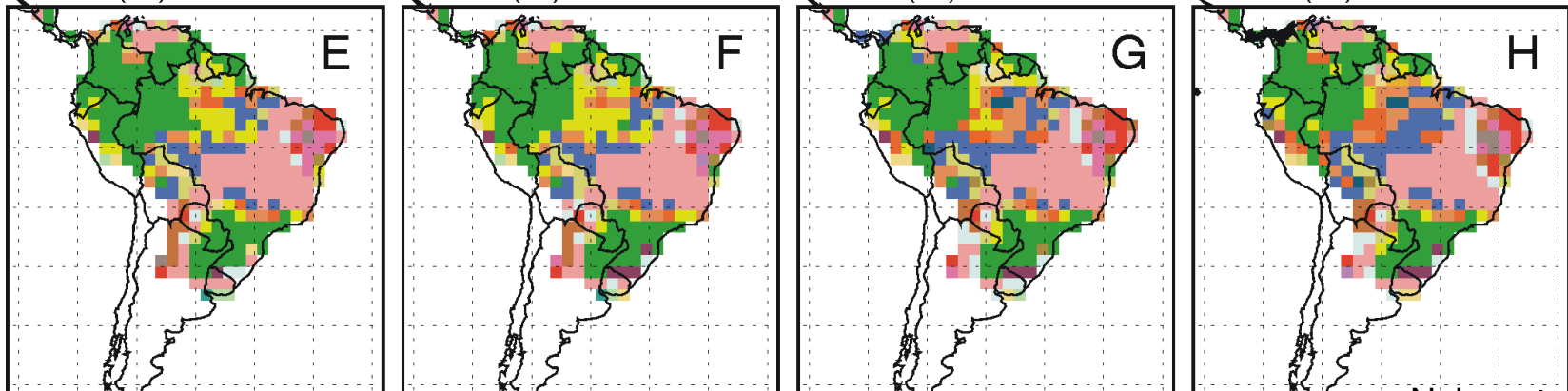
Actual Potential Vegetation



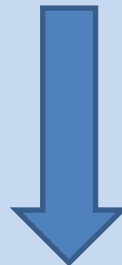
CC:2025(A2)+Desm:20%+Fire CC:2050(A2)+Desm:20%+Fire CC:2050(A2)+Desm:40%+Fire CC:2050(A2)+Desm:50%+Fire



CC:2025(B1)+Desm:20%+Fire CC:2050(B1)+Desm:20%+Fire CC:2050(B1)+Desm:40%+Fire CC:2050(B1)+Desm:50%+Fire



Mudanças Climáticas
+
Fogo
+
Efeito do Desmatamento no Clima



***Aceleração dos processos de
degradação da floresta Amazônica,
Cerrado e Caatinga***