Impacts of Land Use Change and atmospheric CO_2 on Gross Primary Productivity (GPP), evaporation and climate in Southern Amazon (Open data)

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This work was carried out in the scope and with the support of the project: Climate Services Through Knowledge Co-Production: A Euro-South American Initiative for Strengthening Societal Adaptation Response to Extreme Events (CLIMAX).

The project consortium includes the following institutions: Centre National de la Recherche Scientifique CNRS/Instituto Franco-Argentino sobre Estudios de Clima y sus Impactos (UMI-IFAECI) (Argentina-France); General Coordination of Earth Sciences /National Institute for Space Research (INPE) (Brazil); Institut de Recherche pour le Développement (IRD)/ Unité Mixte de Recherche (UMR 245) (France); Le Laboratoire des Sciences du Climat et de l'Environnement (LSCE) (France); Potsdam Institute for Climate Impact Research (PIK) (Germany); Technical University of Munich (TUM) (Germany) and Wageningen University and Research (WUR) Netherlands). The project is sponsored by the Collaborative Research Action (CRA) on “Climate Predictability and Inter-Regional Linkages” of the Belmont Forum, launched in 2015.

Climate variability patterns linking the South American Monsoon region, including Amazonia, with southeastern South America influence climate extremes and impact several societal sectors. More than 200 million people live in the study region, which is

also one of the largest agricultural production regions of the world and home to the world's second largest hydroelectric power plant.

The objectives of CLIMAX include better understanding the combined role of remote and local drivers on South American climate variability from sub-seasonal to decadal timescales, and its impact on the occurrence and intensity of extreme events. Special focus is given to an improved understanding of the effects of land use changes from the Amazon to the subtropics and their impact on climate.

1. EXPERIMENT DESIGN

We used four models that are classified as Dynamic Global Vegetation Models (DGVMs) (Prentice et al., 2007; Rezende et al., 2015): Integrated Model of Land Surface Processes (INLAND) (Tourigny, 2014); Lund-Potsdam-Jena managed Land model version 4 (LPJmL4) (Schaphoff et al., 2018), Lund-Potsdam-Jena General Ecosystem Simulator (LPJ-GUESS) (Smith et al. 2001, Hickler et al., 2012), and Organising Carbon and Hydrology In Dynamic Ecosystems model (ORCHIDEE) (Krinner et al., 2005).

We used three forcings with climate data (GLDAS, GSWP3, and WATCH+WFDEI), Land Use Change (LUC) data and validation data (FLUXCOM (Remote sensor+meteorological data+artificial neural network approach), FLUXCOM (eddy covariance), MODIS (Light Use Efficiency), GLEAM, and TerraClimate (Rezende et al., 2022) (Figure 1).

We conducted two sets of simulation experiments with different values of CO_2: 1) increasing CO_2 from the pre-industrial period to 2010 named **historical CO_2** (**hist CO_2**); 2) constant concentration of 278 ppm of (pre-industrial) atmospheric CO_2 named **constant CO_2 (const CO_2)**. We ran both CO_2 experiments under **Land Use Change** (**LUC**) and **Potential Natural Vegetation** (**PNV**) conditions. All combinations of CO_2 and land use change resulted in four sets of simulation experiments per climate input: 1. **LUC historical CO_2**; 2. **LUC constant CO_2**; 3. **PNV historical CO_2**; 4. **PNV constant CO_2** (Figure 1) (Rezende et al., 2022).

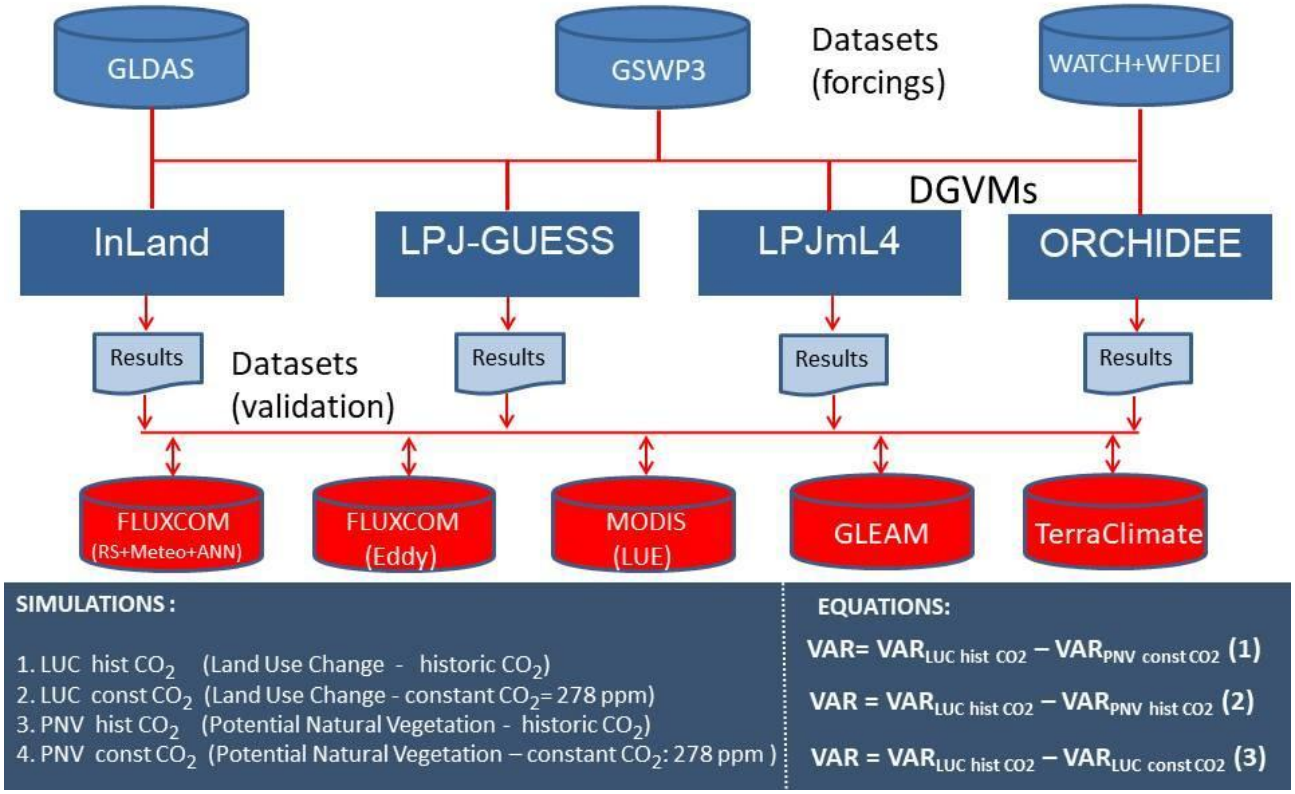

Figure 1 Diagram and scheme of experiment: atmospheric dataset used (forcings), DGVMs, DGVM results, datasets for validation, conditions of simulations, and effect-isolating equations.

2. DATA DESCRIPTION

The complete description of the data, including the climate forcing, LUC, the validation datasets, methodology, simulations, discussion and conclusion is in Rezende et al. (2022). This archive contains only the data description from the simulations (outputs) by the DGVMs.

2.1 SOFTWARE

The data were manipulated, worked, standardized, converted using the software: **Climate Data Operators (cdo) version 1.7.0**, **Grid Analysis and Display System (Grads) (**Documentation of GrADS**) version 2.0.2, and RStudio Desktop version** 1.3.1093 **(R Core Team, 2020)**, through command lines and several scripts developed for this purpose. The figures were generated with **Grads,** and **RStudio**, and some images were enhanced with **Gimp version 2.8.22**. All the software used is freeware.

2.2 PRIMARY DATA FROM SIMULATIONS

Data originating from the simulations are in monthly resolution, covering South America, with all the forcings. Despite data spanning over 1948-2010 or 1950-2010 our study focuses on the period 1981-2010.

Variables: Gross Primary Productivity (GPP) (kg m^{-2} $month^{-1}$), evaporation (mm $month^{-1}$) and transpiration (mm $month^{-1}$), and Net Primary Productivity (NPP) (kg m^{-2} $month^{-1}$) (not used in our experiment).

The naming of the files is according to the following rules:

DGVM_forcing_vegetation cover_CO2 concentration_attribute

DGVMs;
- InLand (INLAND)
- LPJ-G (LPJ-GUESS)
- LPJmL (LPJmL4)
- ORCHI (ORCHIDEE)

forcings:
- gld - GLDAS
- gsw – GSWP3
- wat – WATCH+WFDEI

vegetation cover:
- LU – Land Use Change
- PNV – Potential Natural Vegetation

CO_2 concentration:
- CO2 – historical CO2
- noCO2 – constant CO2 = 278 ppm

variables:
- E – evaporation
- Et – transpiration
- gpp – Gross Primary Productivity
- npp - Net Primary Productivity (not used in the experiment)

Example:
- inLand_gld_LU_noCO2_E.nc

2.3 SUPPLEMENTARY DATA

These interception loss data (mm month-1) were requested by a reviewer to complement the analysis and are available only for the LUC CO2 scenario and for the study region: southern Amazon (7^0S and 14^0S of latitude and 66^0W and 51^0W of longitude).

Files are named according to the following rules:

variable_season_forcing_DGVM_vegetation cover CO2 concentration_region

variable:
inter – loss by interception

season:
D – dry season
R – rainy season

forcings:
gl - GLDAS
gs – GSWP3
wa – WATCH+WFDEI

DGVMs:
in - INLAND
lg - LPJ-GUESS
lm - LPJmL4
or – ORCHIDEE

vegetation cover
L – Land Use Change
P – Potential Natural Vegetation

CO2 concentration
C – historical CO_2
N – constant CO_2 = 278 ppm

region
SA – southern Amazon

Example:
inter_D_gl_in_LC_SA.nc

2.4 PROCESSED DATA

Processed data cover all scenarios and input data sets and are restricted to the study area: southern Amazon (7^0S and 14^0S of latitude and 66^0W and 51^0W of longitude).They are in seasonal resolution with averages for January-February-March-April (JFMA) (rainy season) and averages for June-July-August-September (JJAS). Each of the files contains

the Gross Primary Productivity variables (GPP) (kg m^{-2} $month^{-1}$), evaporation (mm $month^{-1}$) and transpiration (mm $month^{-1}$), and Net Primary Productivity (NPP) (kg m^{-2} $month^{-1}$) (not used in our experiment).

Files are named according to the following rules:

season_DGVM_forcing_vegetation cover CO2 concentration_region

season
- D – dry season
- R – rainy season

DGVMs:
- in - INLAND
- lg - LPJ-GUESS
- lm - LPJmL4
- or - ORCHIDEE

forcings:
- Gl - GLDAS
- Gs – GSWP3
- Wa – WATCH+WFDEI

vegetation cover
- L – Land Use Change
- P – Potential Natural Vegetation

CO2 concentration
- C – historical CO_2
- N – constant CO_2 = 278 ppm

Example:
D_in_Gs_LN.nc

2.5 DERIVED DATA

The variable Water Use Efficiency (WUE) (kg m^{-2} mm^{-1} $month^{-1}$) results from rate: GPP / Tr (transpiration) (Eq. 1).

$$WUE = GPP / Tr \quad \text{(Eq. 1)}$$

These data refer to the study region: southern Amazon and apply to only one scenario: Land Use Change and historic CO2. Files are named naming of according to the following rules:

Variable:
WUE – Water Use Efficiency

season
D – dry season
R – rainy season

DGVMs:
in - INLAND
lg - LPJ-GUESS
lm - LPJmL4
or - ORCHIDEE

forcings:
Gl - GLDAS
Gs – GSWP3
Wa – WATCH+WFDEI

vegetation cover
L – Land Use Change
P – Potential Natural Vegetation

CO2 concentration
C – historical CO_2
N – constant CO_2 = 278 ppm

region
SA – southern Amazon

Example:
wue_D_lm_Gl_LC_SA.nc

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References

Documentation of GrADS. Center for Ocean-Land-Atmosphere Studies, Institute of Global Environment and Society, George Mason University. Archived from the original on 7 April 2015. Retrieved 14 March 2015.

Hickler T. et al., 2012. Projecting the future distribution of European potential natural vegetation zones with a generalized, tree species based dynamic vegetation model. Glob Ecol Biogeograp 21:50–63, https://doi.org/10.1111/j.1466-8238.2010.00613.x

Krinner, G.et al., 2005. A dynamic global vegetation model for studies of the coupled atmosphere-biosphere system, Global Biogeochemical Cycles, 19, GB1015, doi:10.1029/2003GB002199.

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Prentice IC (2007) Dynamic global vegetation modeling: quantifying terrestrial ecosystem responses to large-scale environmental change. In: Canadell J, Pataki D, Pitelka L (eds) Terrestrial ecosystems in a changing world. Springer, Berlin Heidelberg.

Rezende, Luiz F. C. et al., 2015. Evolution and challenges of dynamic global vegetation models for some aspects of plant physiology and elevated atmospheric CO2. Int J Biometeorol., 2015, doi: 10.1007/s00484-015-1087-6.

Rezende, Luiz F. C. et al., 2022. Impacts of Land Use Change and atmospheric CO2 on Gross Primary Productivity (GPP), evaporation and climate in Southern Amazon. Journal of Geophysical Research - Atmospheres (JGRA) - doi: 10.1029/2021JD034608. 2022.

Schaphoff, S. et al., 2018. LPJmL4 – a dynamic global vegetation model with managed land –Part 1: Model description. Geosci. Model Dev., 11, 1343–1375, 2018, https://doi.org/10.5194/gmd-11-1343-2018.

Smith B. et al (2001) Representation of vegetation dynamics in the modelling of terrestrial ecosystems: comparing two contrasting approaches within European climate space. Glob Ecol Biogeograp 10:621–637

Tourigny, E. (2014). Multi-scale fire modeling in the neotropics: coupling a land surface model to a high resolution fire spread model, considering land cover heterogeneity. Phd dissertation, Meteorology. INPE. Retrieved from http://urlib.net/sid.inpe.br/mtc-m21b/2014/05.30.00.36