The hydrological modeling with ORCHIDEE in the Amazon basin

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Introduction

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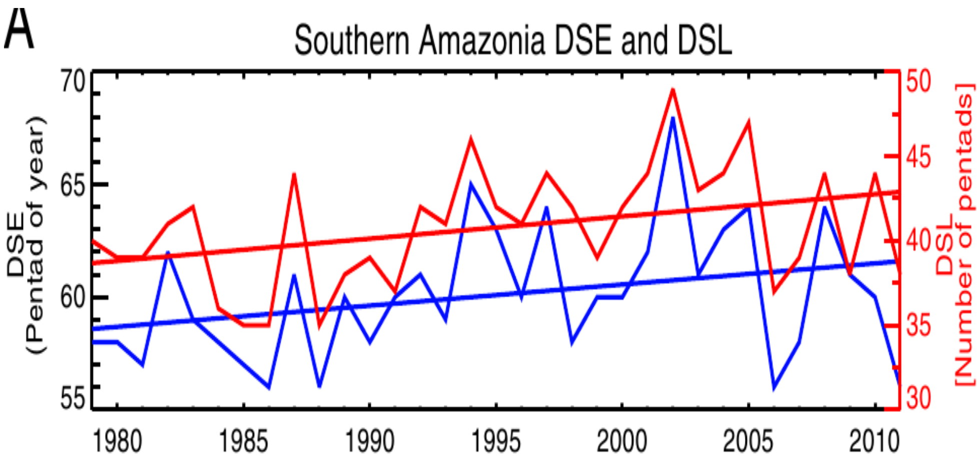
Dry-season length increases in the south since the 80's



Fu et al., PNAS, 2013

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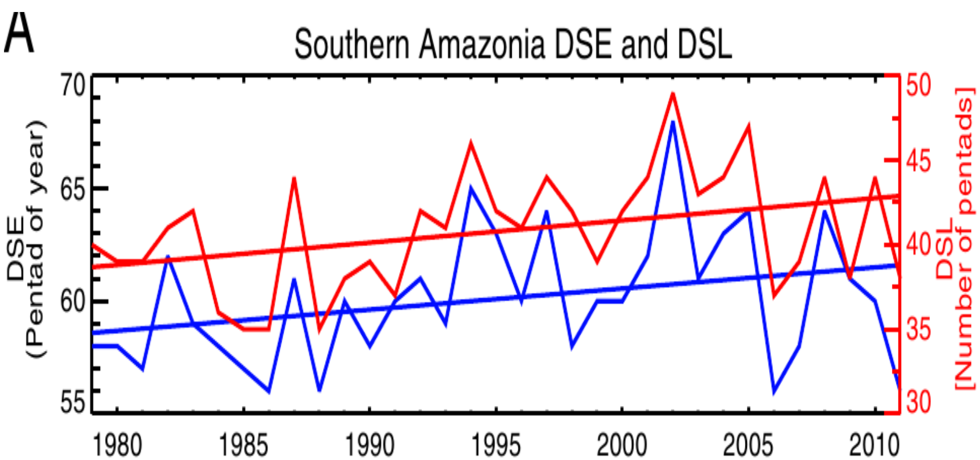

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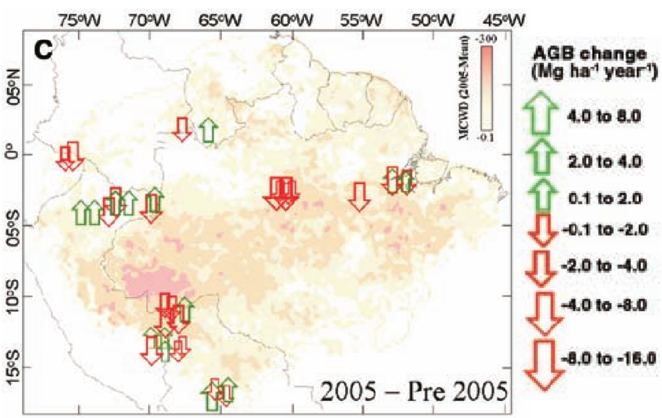
Intense 2005 drought affected aboveground biomass of forest



Phillips et al., Science, 2009

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  - How important is the use of a physically-based soil hydrology model if compared to a simple bucket model to better represent hydrological storages and fluxes?

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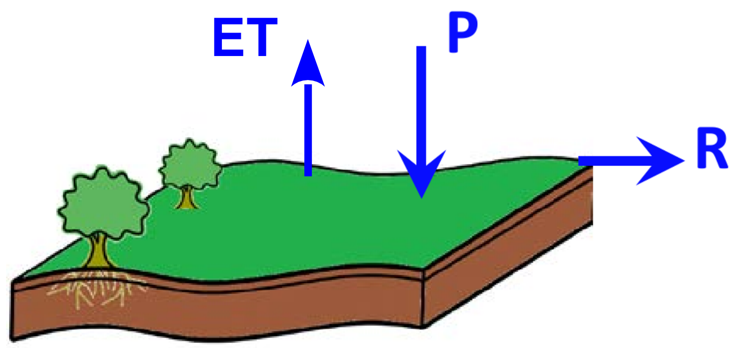
- Severe hydroclimatic (P, ET) and anthropogenic (deforestation, land-use change...) changes are already threatening the Amazon basin
- Land Surface Models (LSMs) have evolved including more physically based approach in soil hydrology representation
  - How important is the use of a physically-based soil hydrology model if compared to a simple bucket model to better represent hydrological storages and fluxes?
  - Will annual extreme flows be more severe during the middle/end of the 21st century than the present ones?

Soil hydrology schemes in ORCHIDEE

2LAY



- Conceptual description of soil moisture storage
- 2 layers for a 2-m soil
- Constant available water holding capacity (wilt. point ↔ field capa.)

- Saturation-excess (Dunne runoff, R)
- Downward flux between the 2 layers

- No drainage

Guimberteau et al.,GMD, 2014

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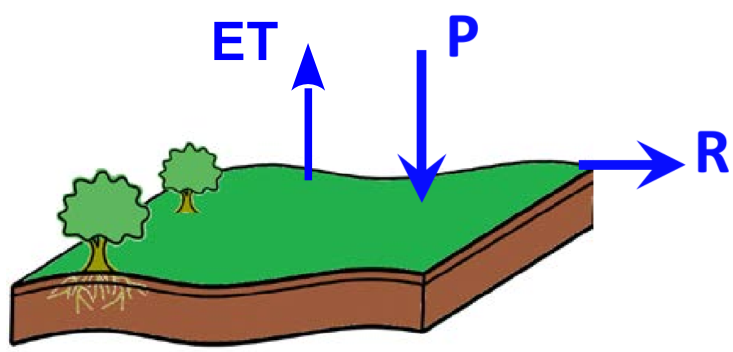

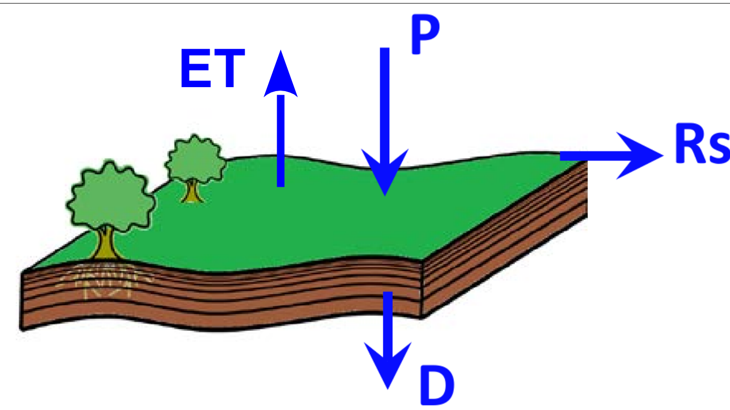

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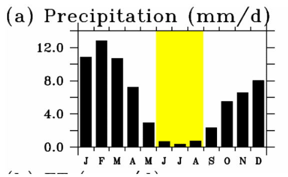
11LAY

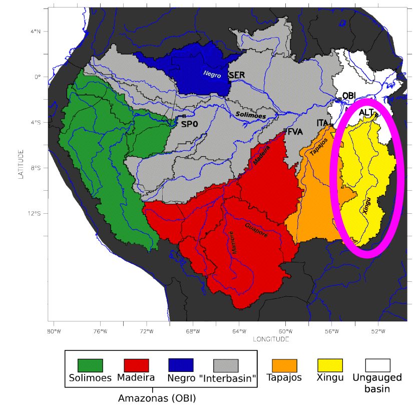
- Physically-based description of soil water fluxes
- 11 layers for a 2-m soil
- Variable water storage capacity (res. wat. content ↔ sat.) depending on soil texture heterogeneity
- Infiltration-excess (Horton runoff, Rs)
- Fluxes between layers following Richards equation & Mualem-Van Genuchten model
- Gravitational drainage, D

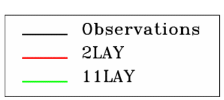
Guimberteau et al.,GMD, 2014

Dry-season ET: case study of the Xingu sub-basin



The dry season is marked in the Xingu sub-basin





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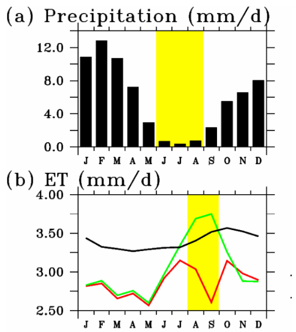

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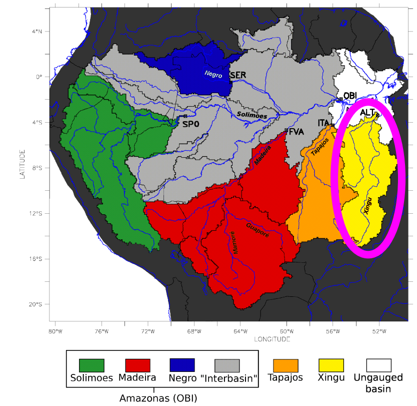

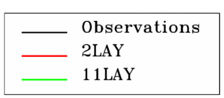

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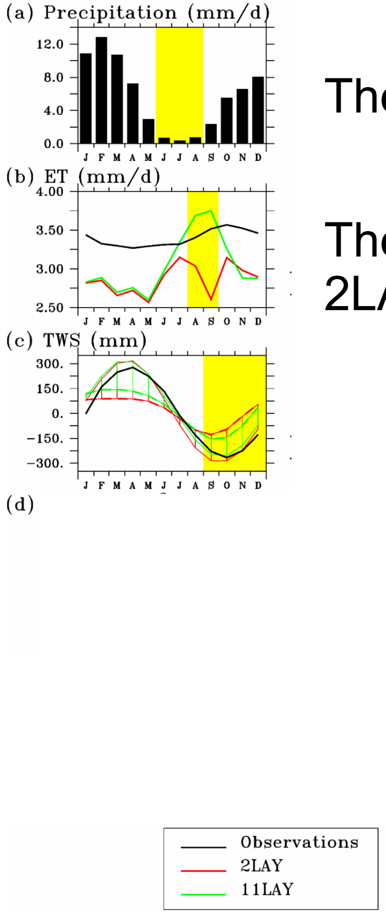

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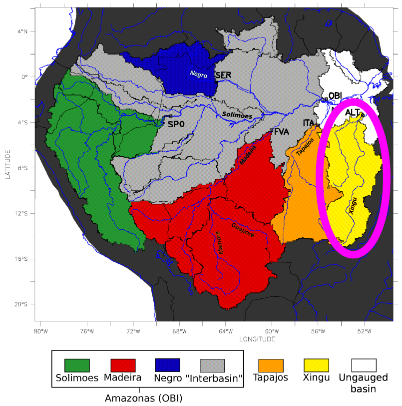

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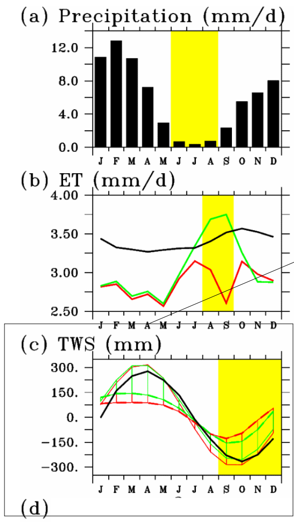

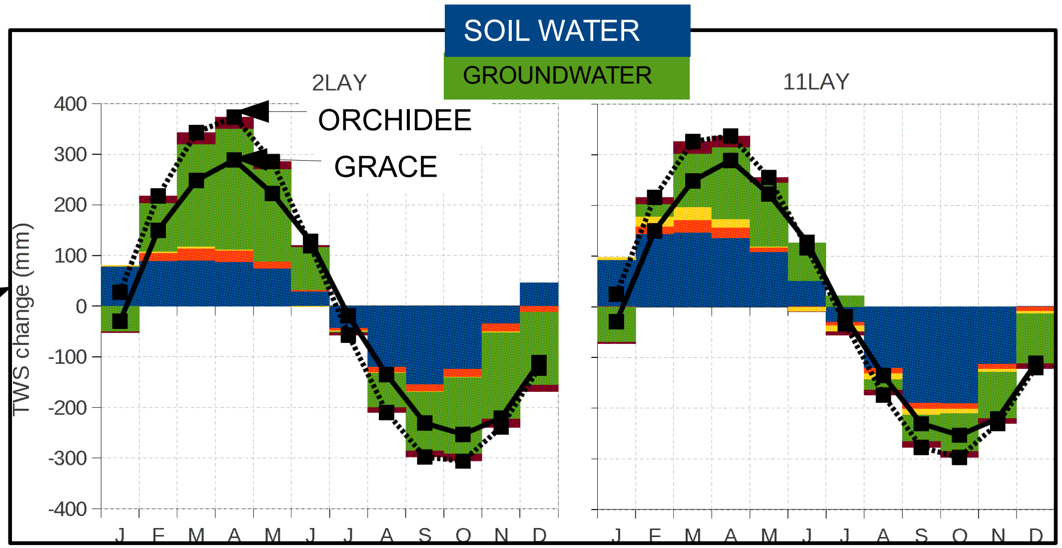

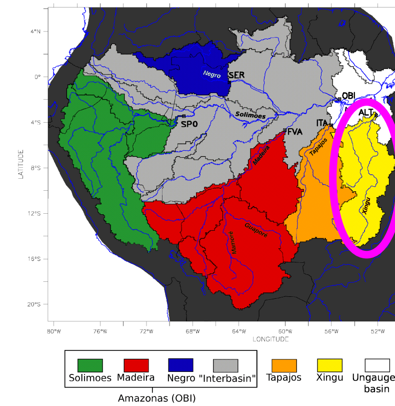

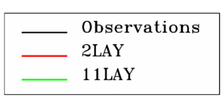

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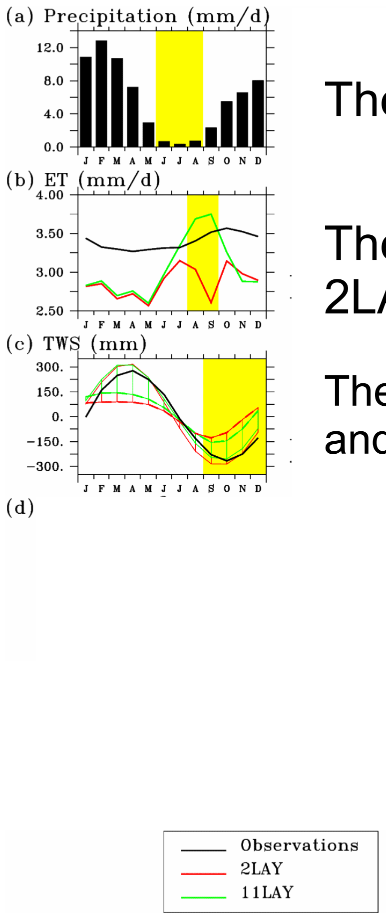

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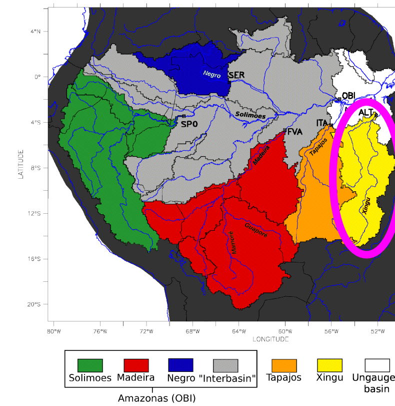

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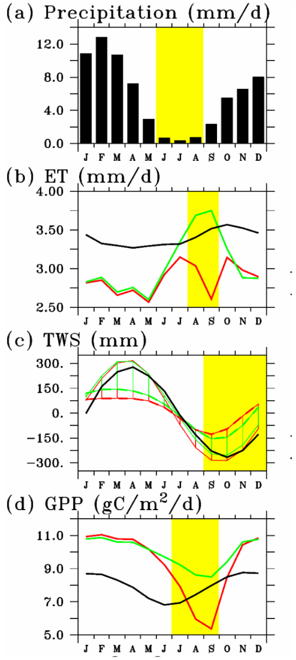

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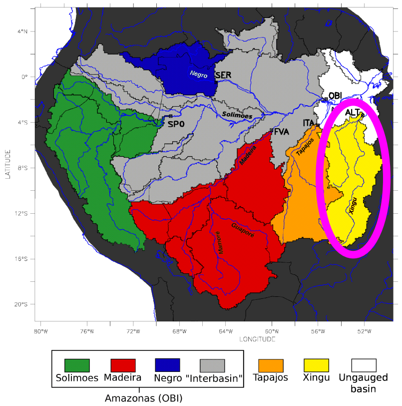

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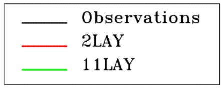

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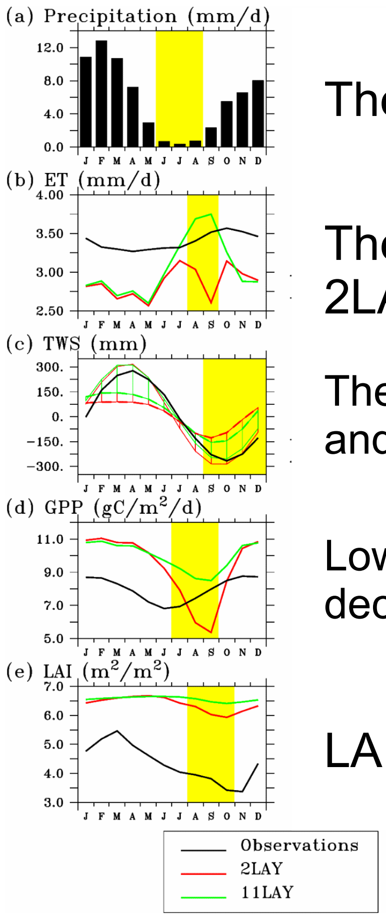

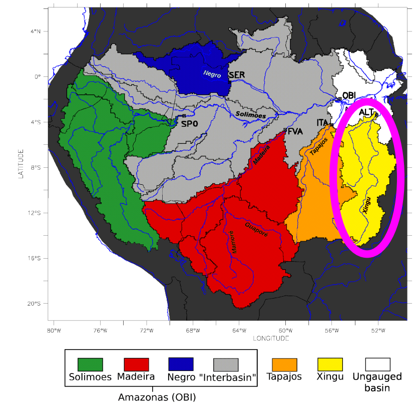

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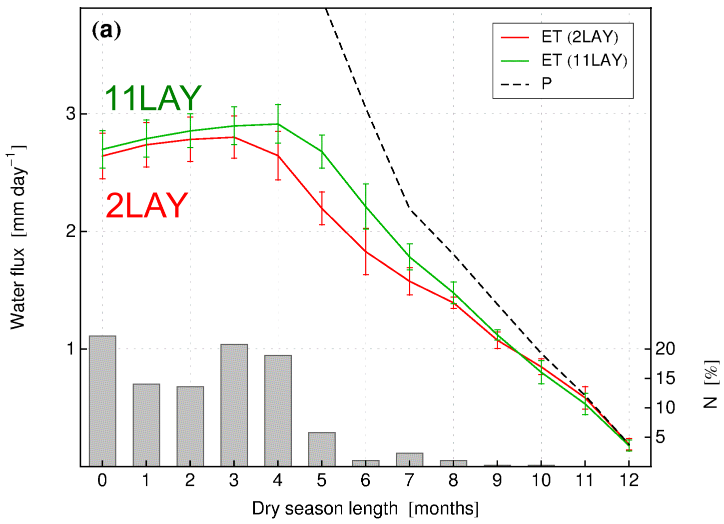
LAI variation is small between the 2 simulations

Guimberteau et al.,GMD, 2014

ET sensitivity to dry season length (DSL) over the Amazon basin

ET vs DSL



DSL definition

Mean number of months with P < 2.0 mm/d over the 29-year period

Guimberteau et al.,GMD, 2014

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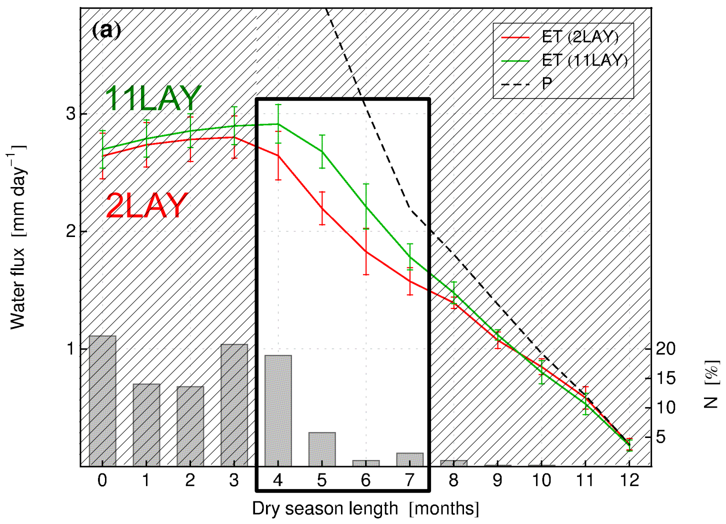

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- The impact of soil hydrology parametrization on simulated ET is high for a DSL of 4 to 7 months (30% of the total grid cells)

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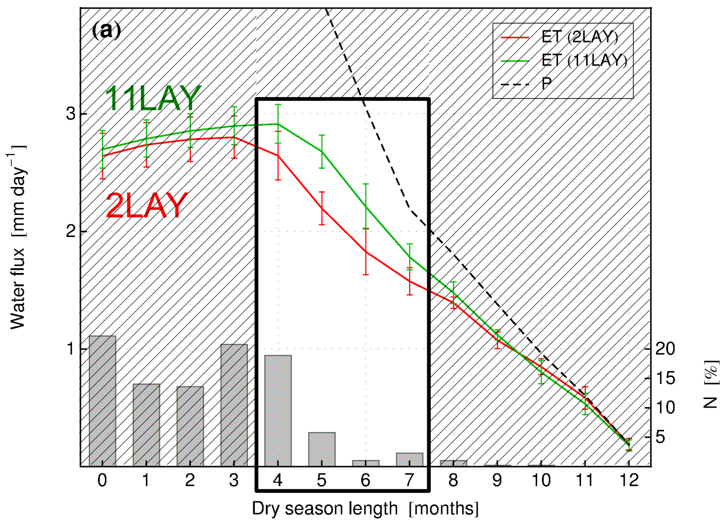
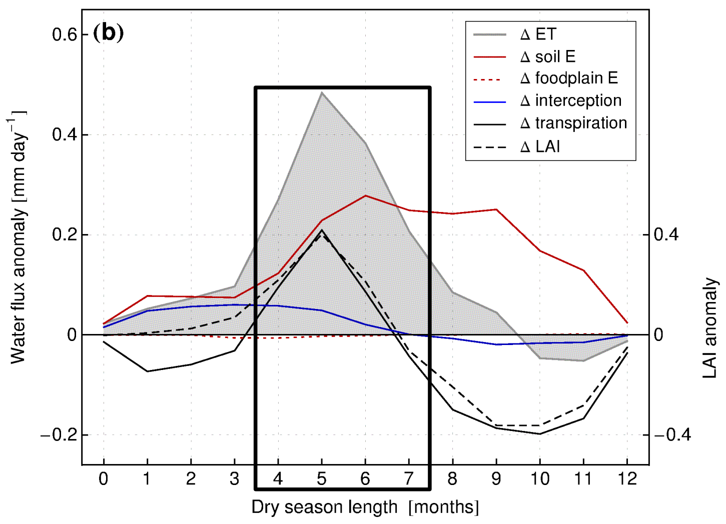


ΔET and ΔLAI vs DSL



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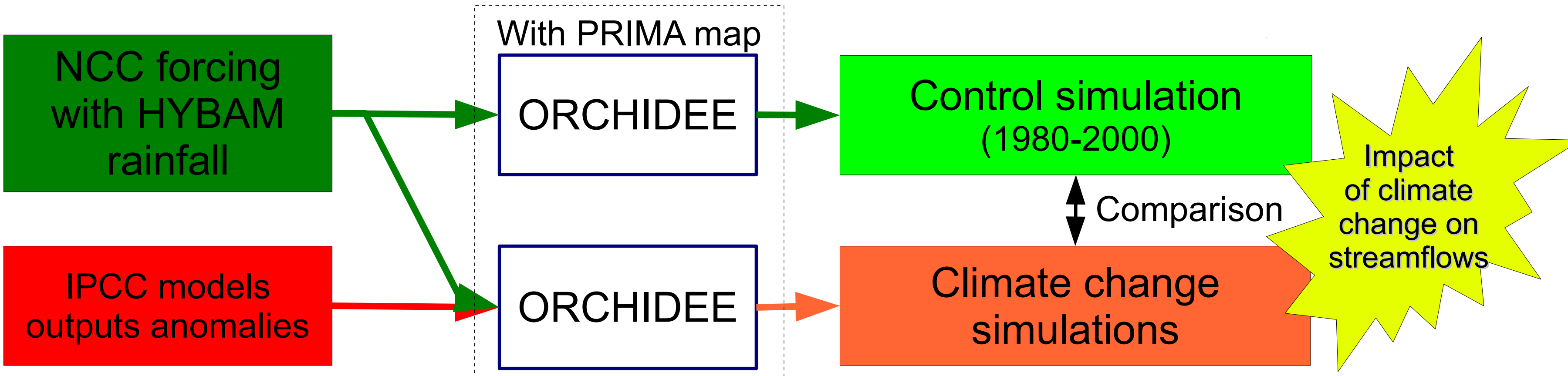
(2) A dry season length between 4 to 7 months in the Amazon basin is critical in distinguishing differences in water budget components and carbon flux dynamics simulated by the 2 soil hydrology schemes

Future changes in precipitation and impacts on extreme streamflow

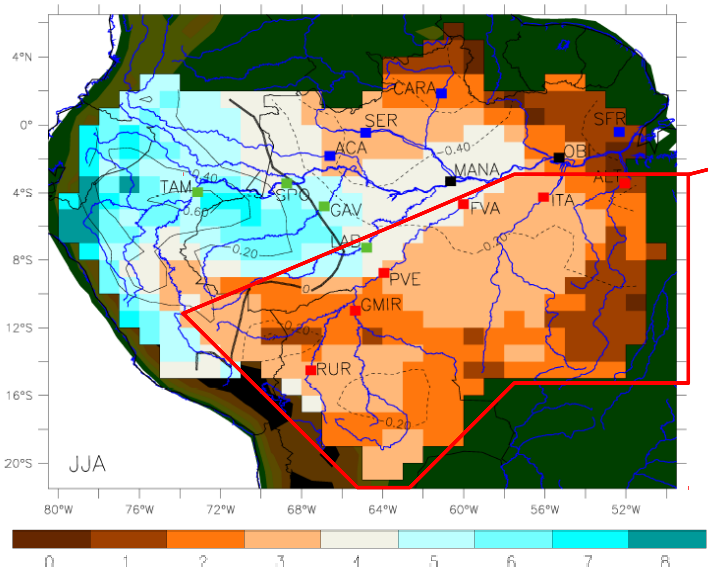
- **Delta downscaling method** approach to produce climate change forcing based on GCMs results from AR4
  - 3 scenarios: B1, A1B and A2
  - 2 periods: 2046-2065 and 2079-2098
- Climatology of future anomalies added to the NCC forcing including ORE HYBAM precipitation
  - delta method incorporates more realistic spatio-temporal patterns in precipitation
- ORCHIDEE forced by the different future climate forcings => climate change simulations



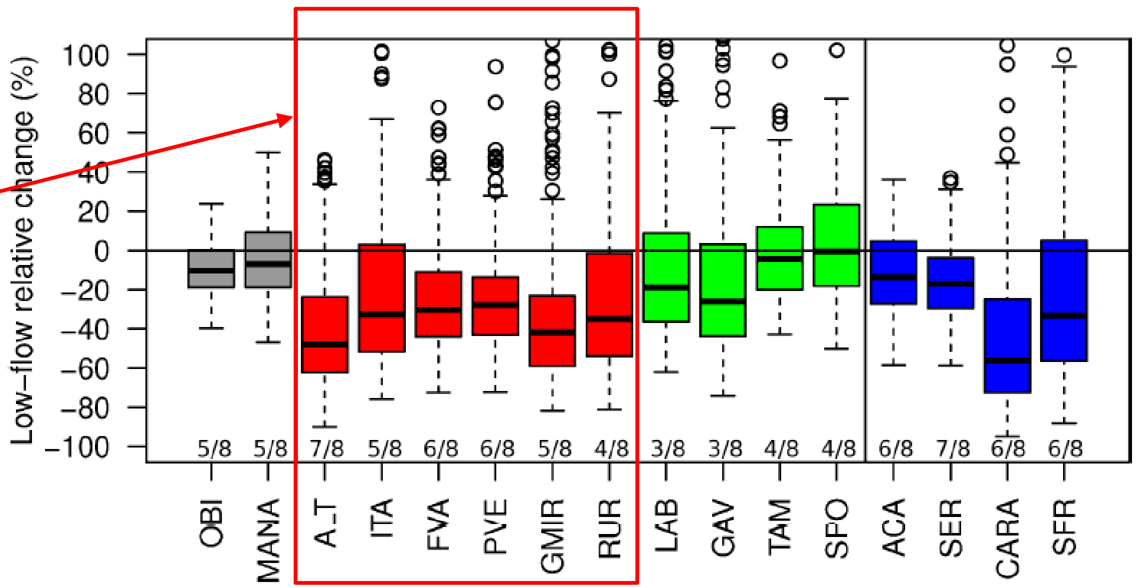
Guimberteau et al., ERL, 2013

Future changes in precipitation and impacts on extreme streamflow

Result for 2046-2065 under SRESA1B scenario



Number of GCMs out of eight that project a JJA precipitation increase



Mean relative change (%) of the **low flows** for 16 stations

- Southern sub-basins (with low runoff coefficients (R/P)) will become more responsive to precipitation change than the western sub-basins (with high runoff coefficients)
- Western and north-western sub-basins: more responsive to evaporation change

Guimberteau et al., ERL, 2013

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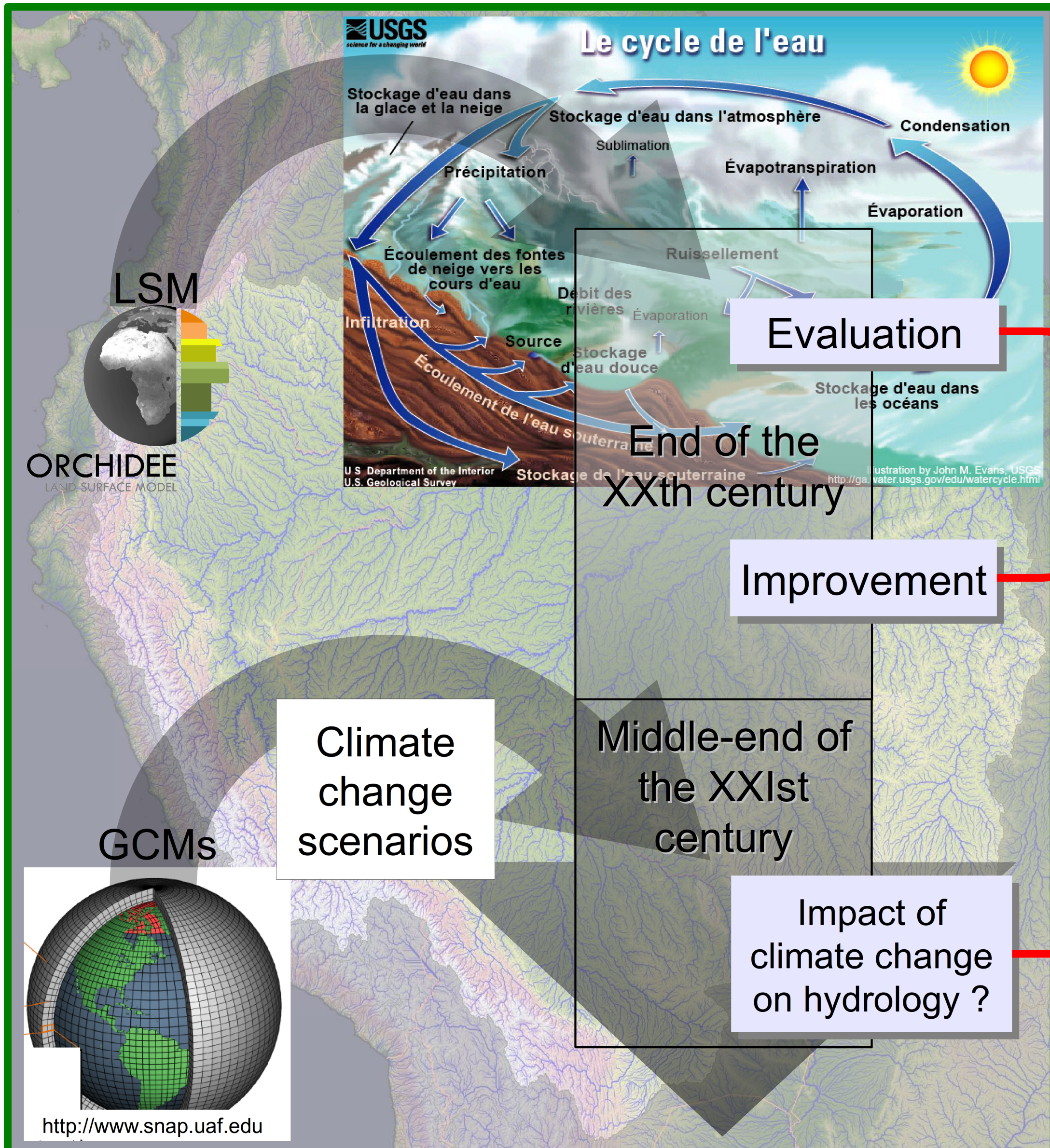
ORCHIDEE and the Amazon basin: evaluation of the model for future hydrology simulation



1

- In-situ river gauging data
- Floodplains water height from satellite products
- ET (and GPP) data products
- Total water storage variations from GRACE dataset
- Soil water profiles measurements
- FLUXNET dataset

2

- ORE HYBAM precipitation product
- Spatial distribution of flooded areas from satellite products

3

- Future change of river discharge ?
- LUC impact on hydrology ?

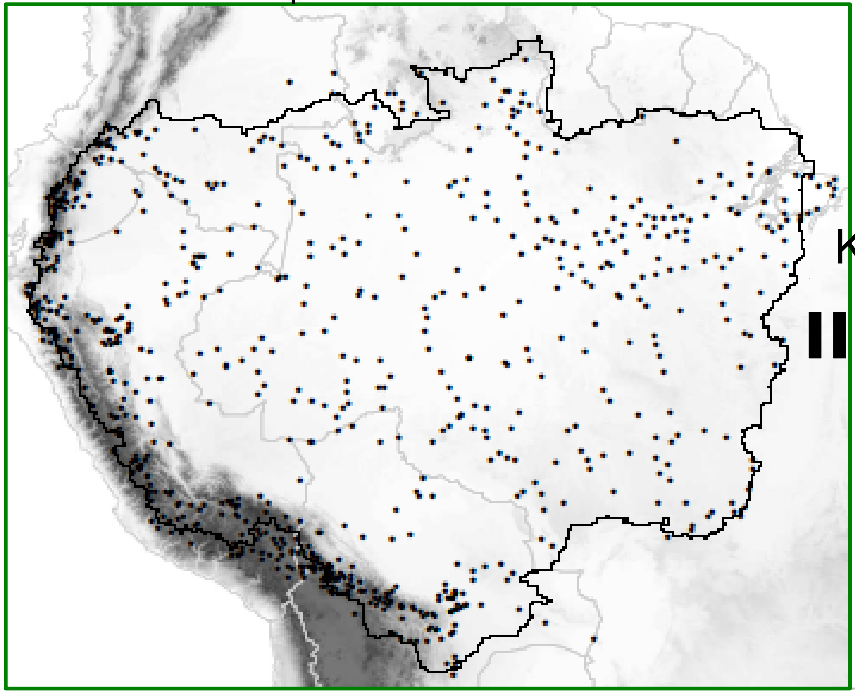
New precipitation dataset for the Amazon River basin

- ~1500 pluviometric stations from the meteorological services of Amazonian countries. 50% are selected after quality control.
- Daily data (1980-2009) interpolated over the basin (1°x1°)
- Temporal distribution of the data according to the diurnal variation of NCEP in NCC forcing (daily value spread over the 6h time-step of the forcing)

<u>ORE HYBAM</u>: Observatoire de Recherche en Environnement Hydrogéodynamique du Bassin Amazonien

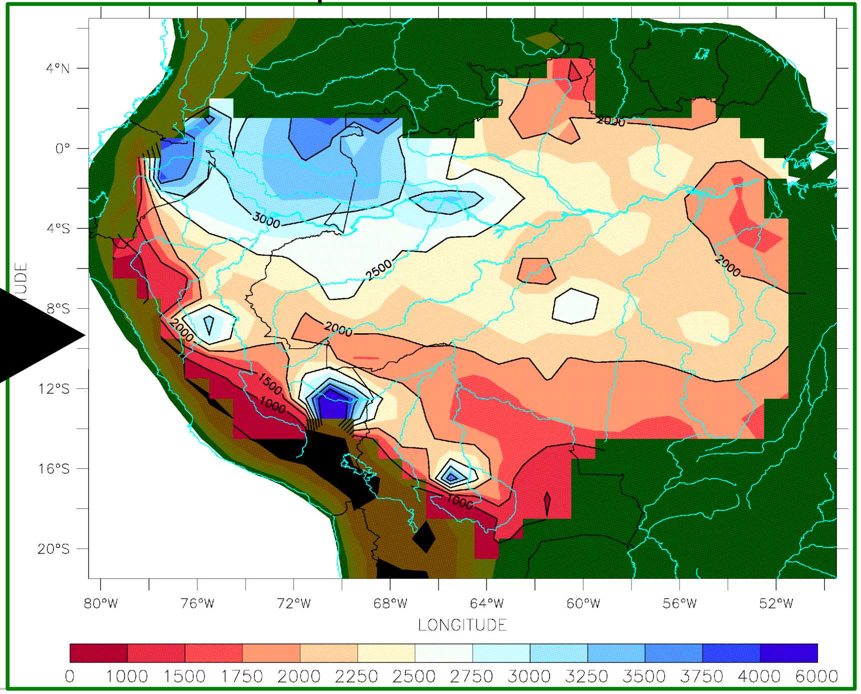
<u>NCC</u>: NCEP/NCAR Corrected by CRU (Ngo-Duc, 2005)

~750 pluviometric stations



Kriging

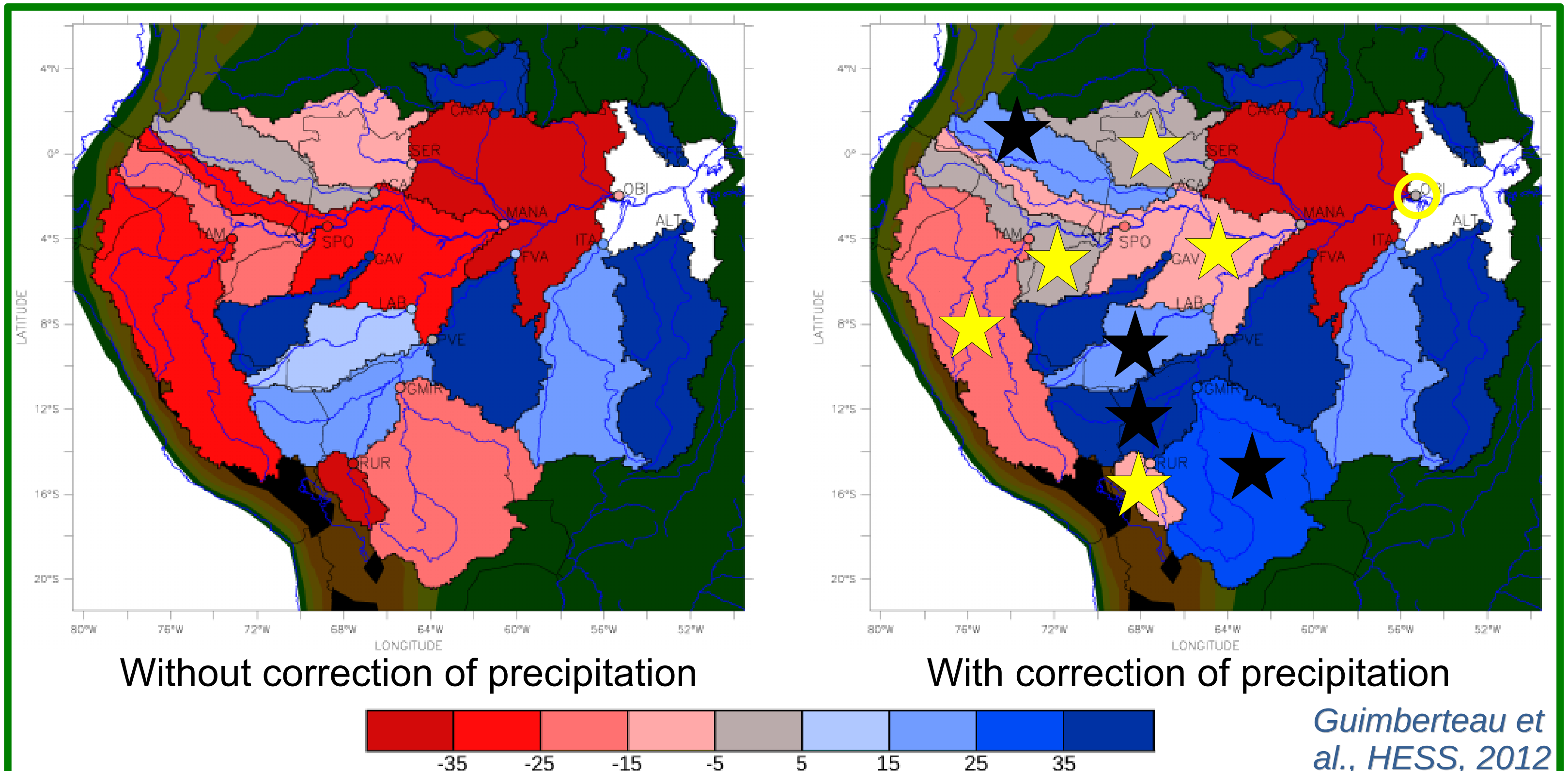
Interpolation at 1°x1°



Guimberteau et al., HESS, 2012

Simulated river discharge with ORE HYBAM precipitation

Mean annual relative bias of **runoff** (%)



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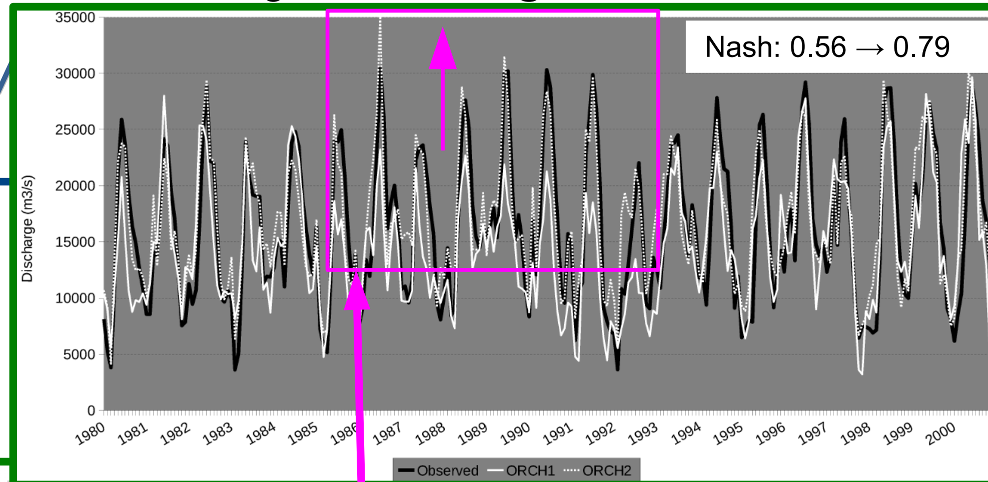
Simulated river discharge w

Negro's **discharge** at Serrinha



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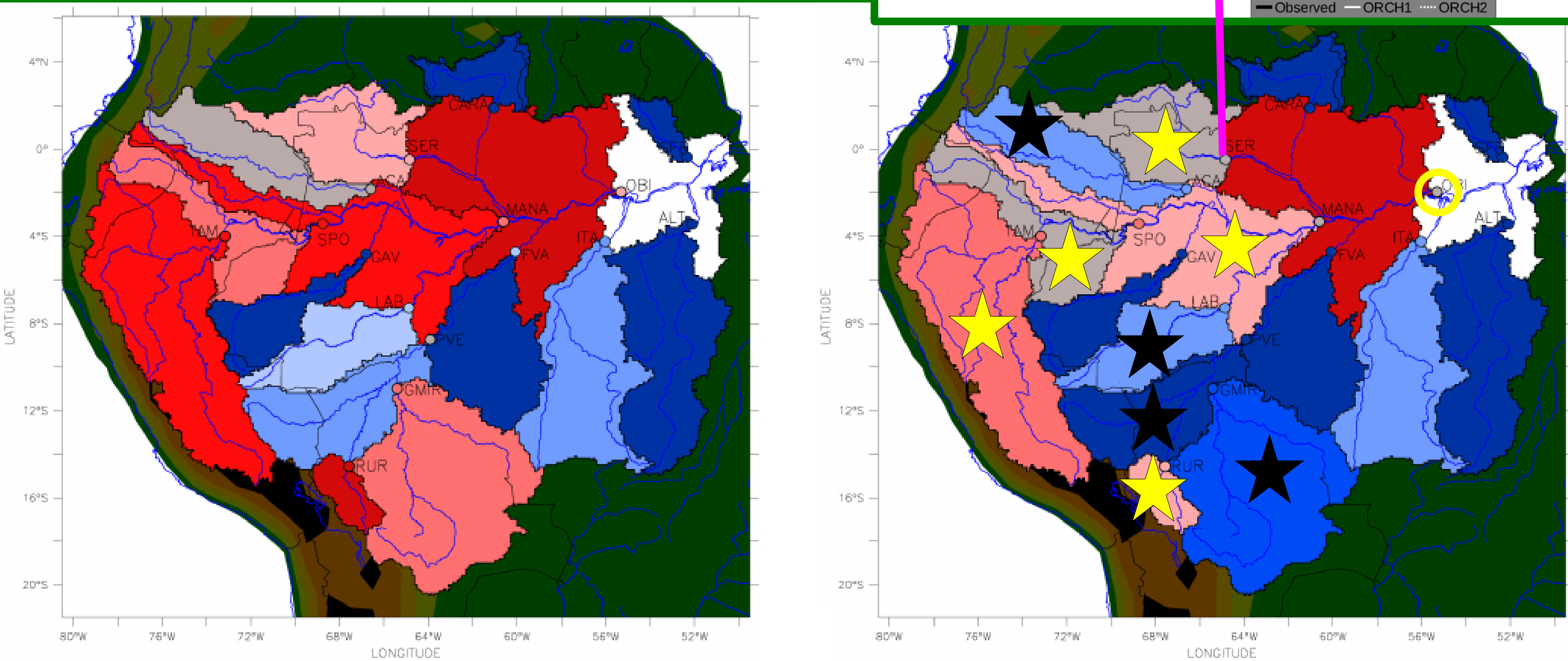
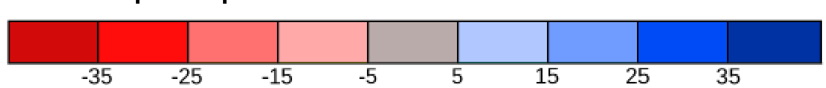


Without correction of precipitation

With correction of precipitation



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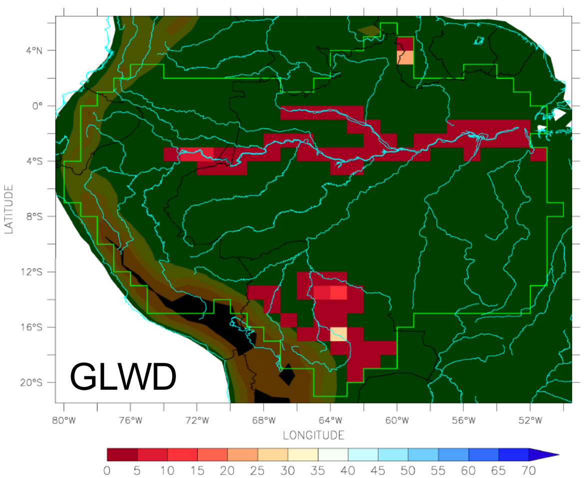
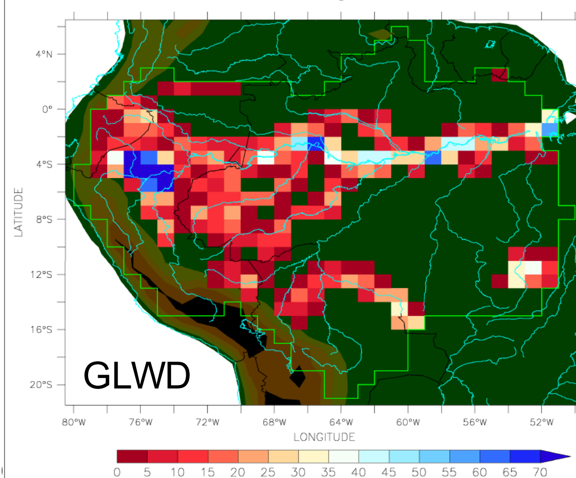
A new satellite-derived map of maximal fraction of floodplains and swamps

Floodplains



Swamps



Maximal fraction within the mesh (%)

Initially for ORCHIDEE:
GLWD (Lehner & Döll, 2004)
+ d'Orgeval & al. (2008)

Guimberteau et al., HESS, 2012

A new satellite-derived map of maximal fraction of floodplains and swamps

- Multisatellite method (Prigent & al., 2007)

  => Inundated fraction (0.25°x0.25°) at global scale (1993-2000)

- No distinction between floodplains and swamps

- Multi-temporal SAR data (Martinez & Le Toan, 2007)

  => Inundated fraction estimated for the highest water level during the 1995–96 hydrological cycle

- Distinction between floodplains and swamps

- Computation of maximal fractions of inundated areas within the mesh (1993-2000)

- For each mesh, computation of a ratio of the maximal distribution of floodplains and swamps

f^{max}

$ratio_{(FP)}$ $ratio_{(SWP)}$

$$f_{FP}^{max} = ratio_{(FP)} * f^{max}$$
$$f_{SWP}^{max} = ratio_{(SWP)} * f^{max}$$

PRIMA map

Guimberteau et al., HESS, 2012

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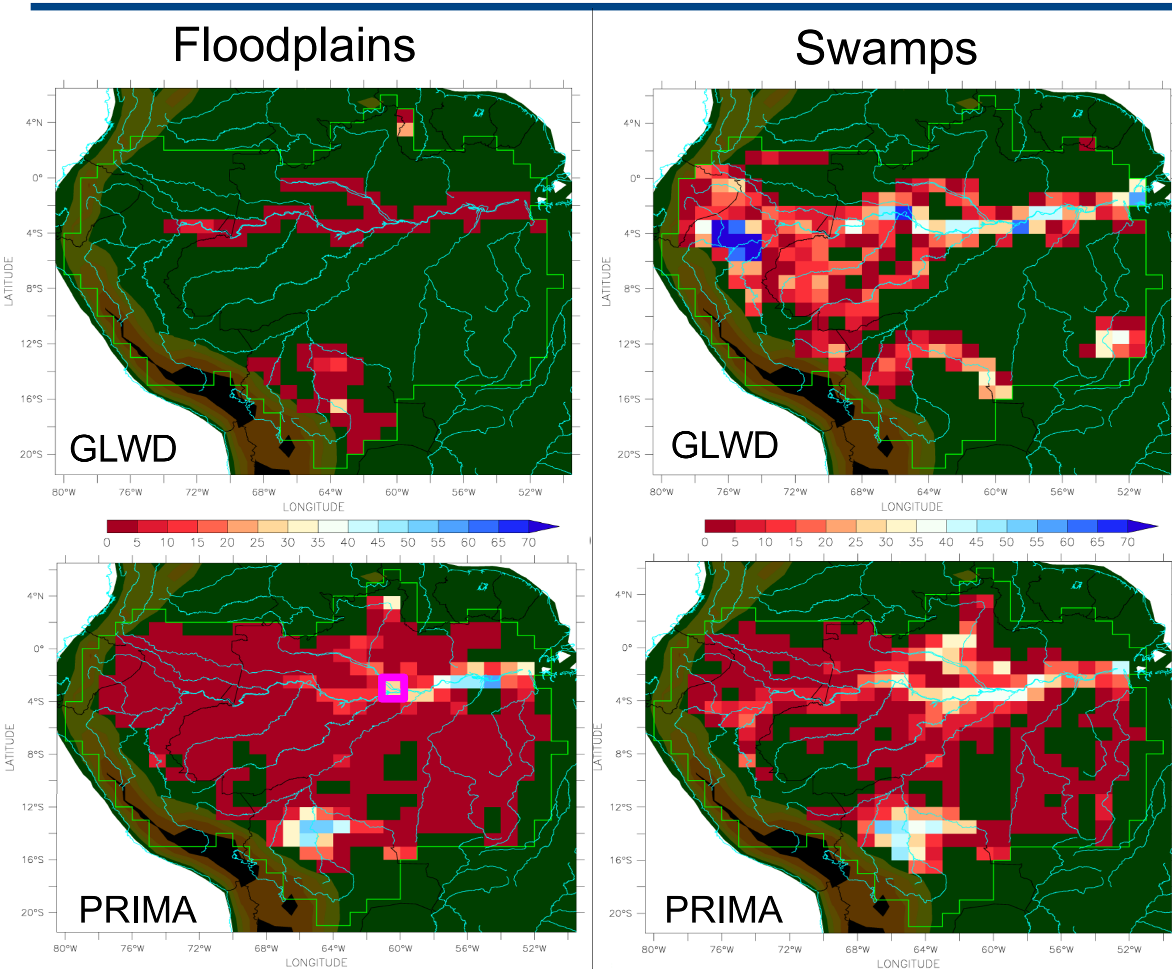

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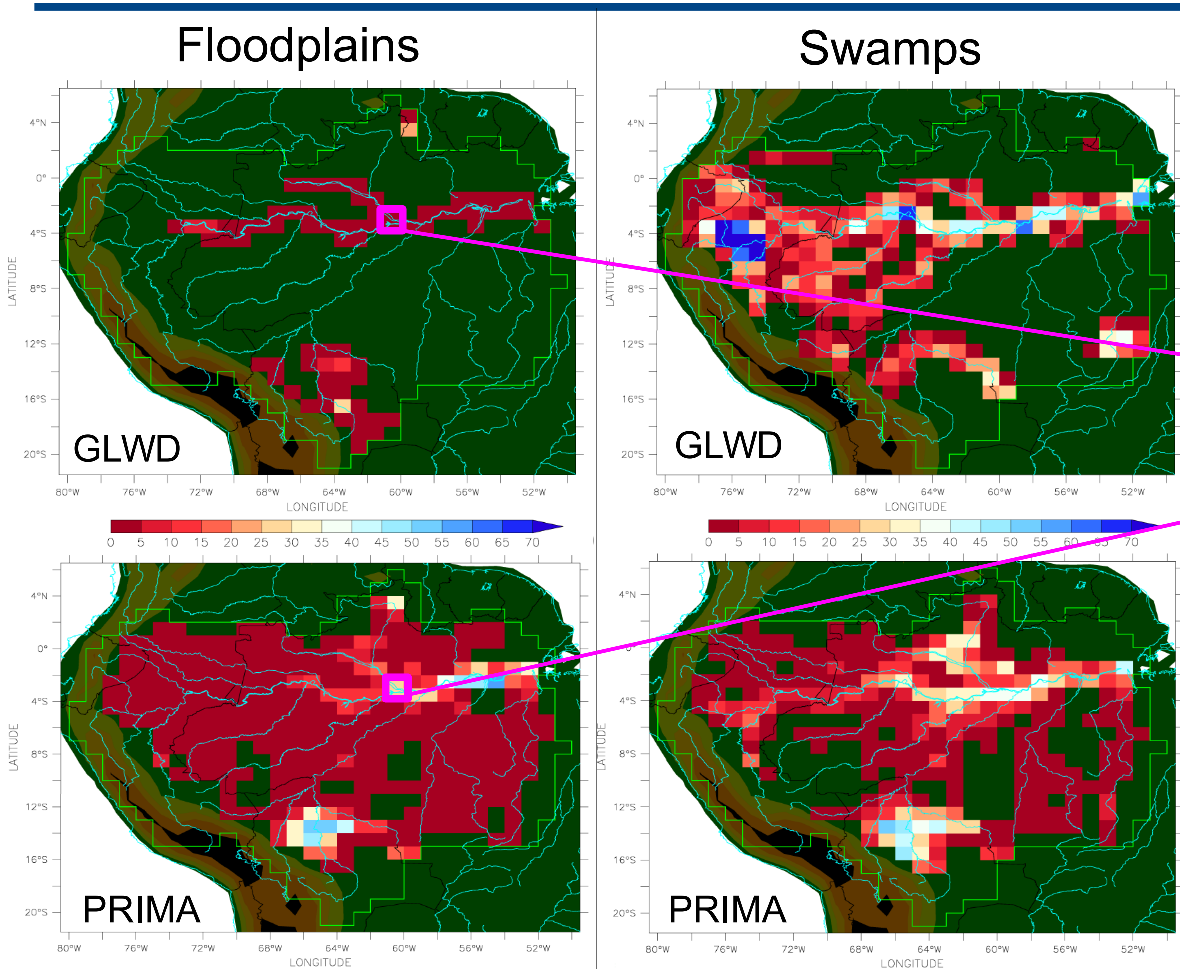

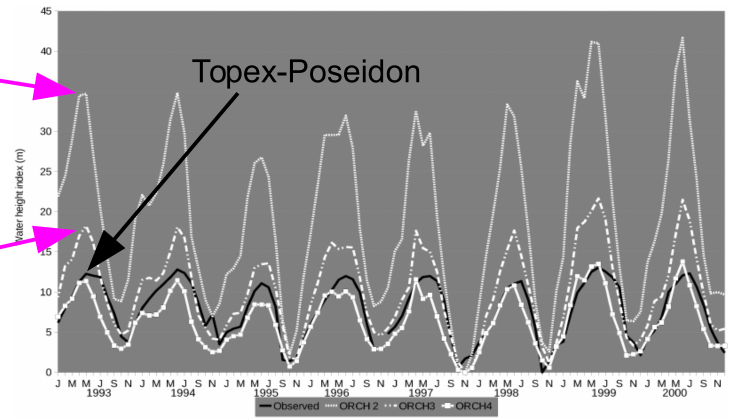

Interannual variation of **monthly water height** index (m) on the Negro

Maximal fraction within the mesh (%)

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