# 8th International Workshop on Monsoons (IWM-8)


# Projected lifecycle of the South American monsoon using statistical downscaling with CMIP6 - GCMs

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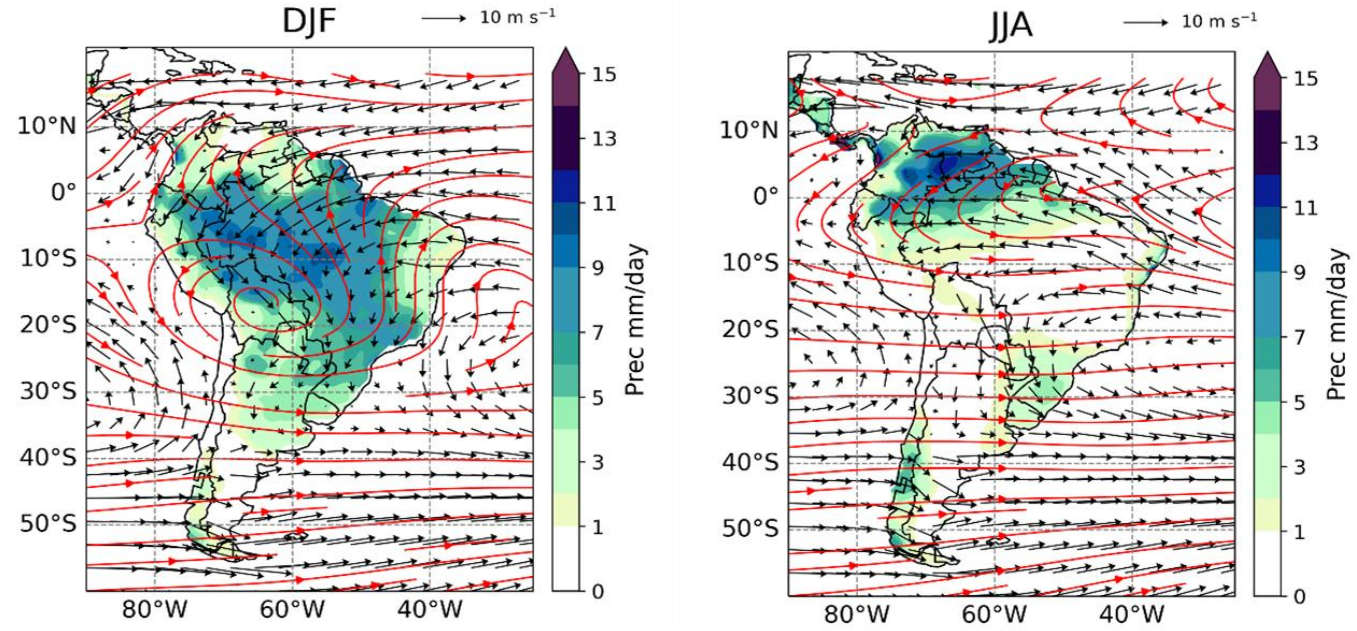
# Introduction

## Features of the South American Monsoon (SAM)

### Climatology: Precipitation and Circulation

**Observed Data**




Mean precipitation (mm day$^{-1}$) from CPC, wind vector (m s$^{-1}$) at 850 hPa, and streamlines (solid red lines) at 200 hPa from ERA5 in summer (DJF) and winter (JJA) for the 1993-2016 period.


**A New Look into the South America Precipitation Regimes: Observation and Forecast**

by Glauber W. S. Ferreira and Michelle S. Reboita *

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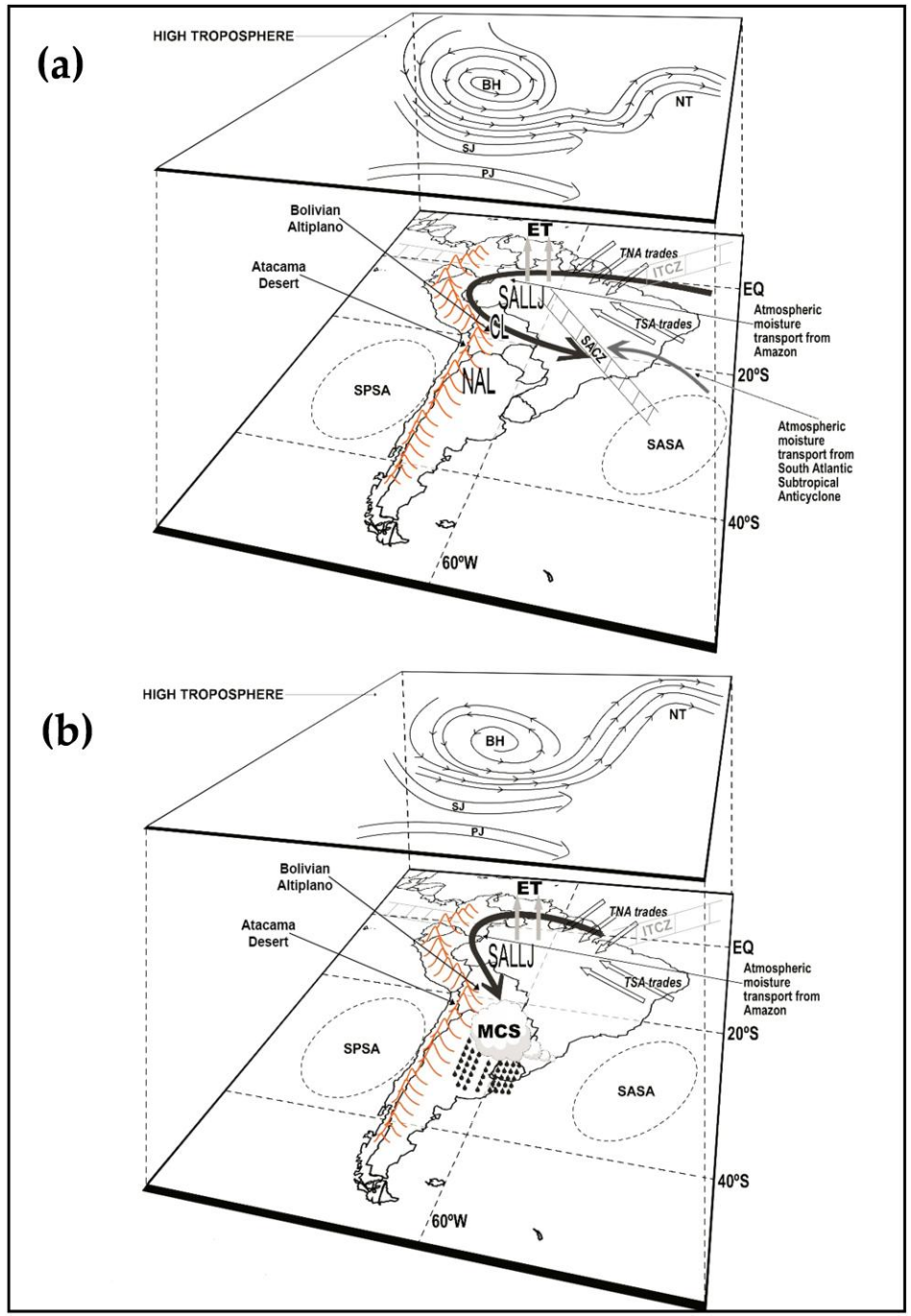
* Author to whom correspondence should be addressed.

*Atmosphere* **2022**, *13*(6), 873; https://doi.org/10.3390/atmos13060873


Schematic sketch of important atmospheric circulation features over the South American region, considering events with (a) and without (b) SACZ. SALLJ = South American Low-Level Jet East of the Andes; TNA trades = Tropical North Atlantic trade winds; TSA trades = Tropical South Atlantic trade winds; ET = evapotranspiration from Amazon forests; MCS = Mesoscale Convective System; ITCZ = Intertropical Convergence Zone; SPSA = South Pacific Subtropical Anti-cyclone; SASA = South Atlantic Subtropical Anticyclone; CL = Chaco Low; NAL = Northwestern Argentinean Low; NT = Northeast Trough; BH = Bolivian High; SJ = Subtropical Jet; PJ = Polar Jet.

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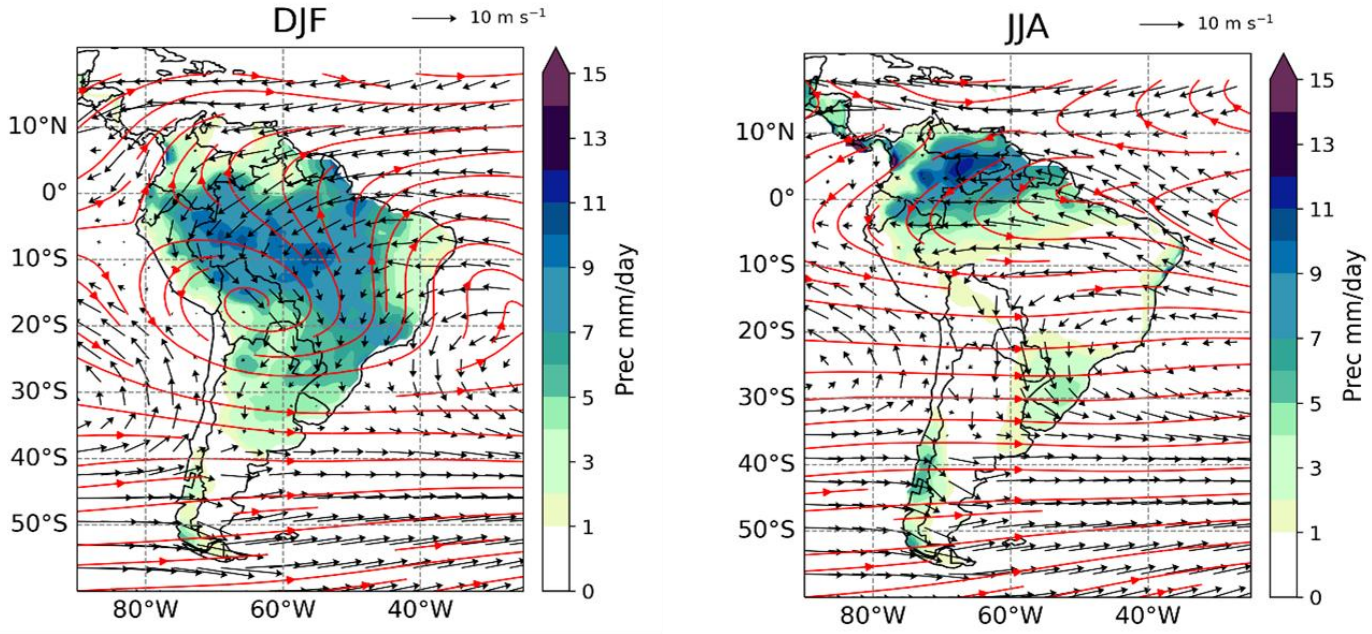


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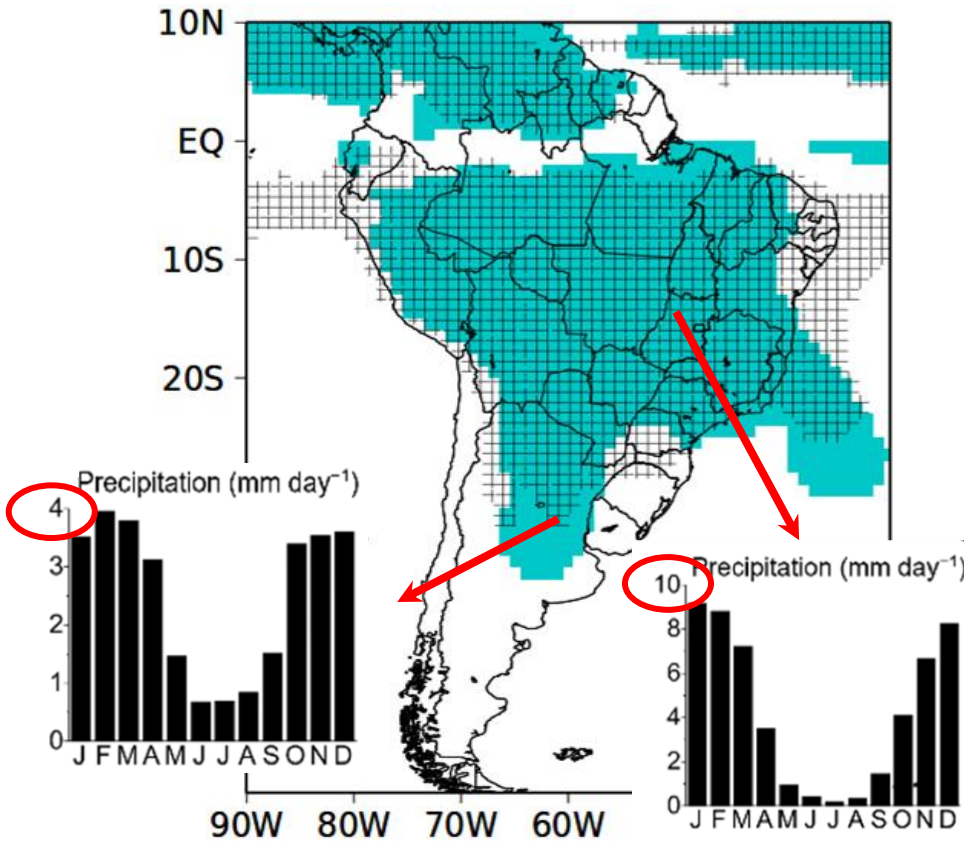
### SAM area




SAM area calculated following Wang et al. (2012)'s methodology and GPCP precipitation.

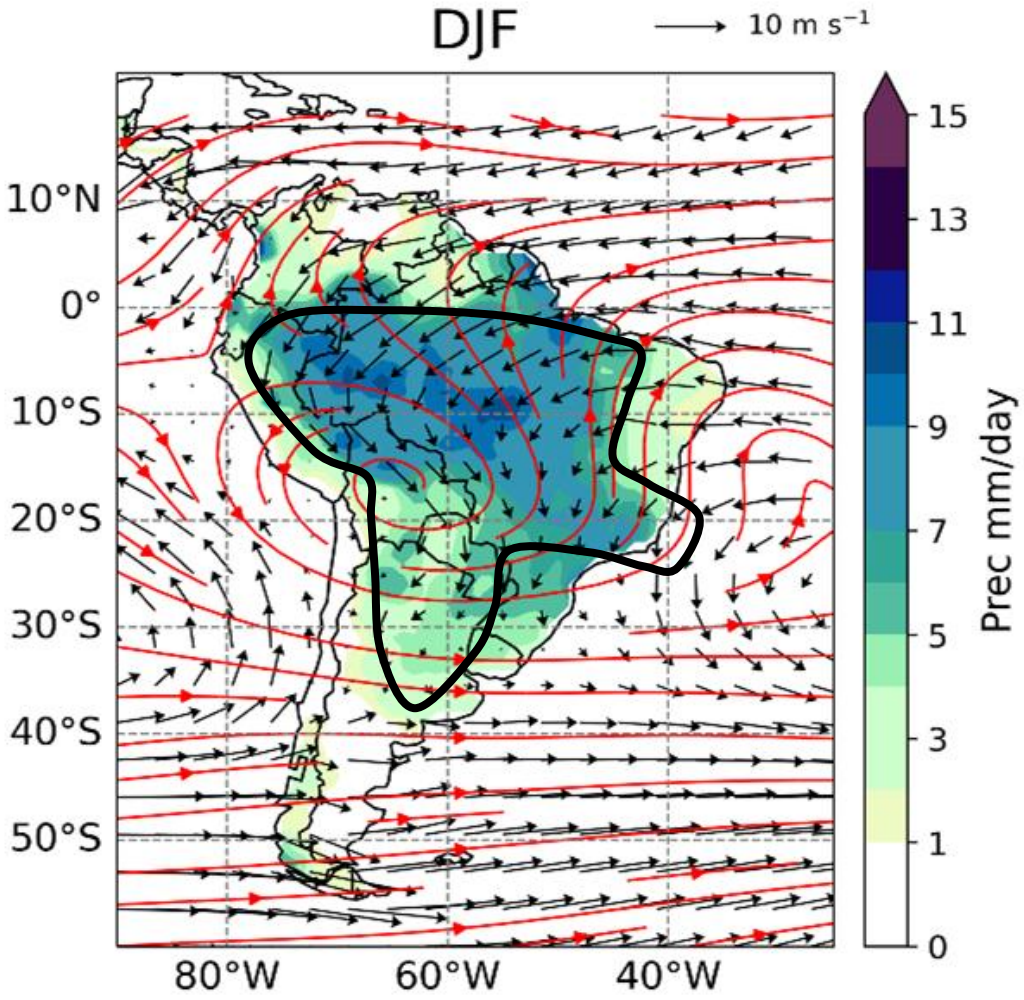
Climate Change Impacts on the South American Monsoon System and Its Surface–Atmosphere Processes Through RegCM4 CORDEX-CORE Projections

Thales Alves Teodoro, Michelle Simões Reboita, Marta Llopart, Rosmeri Porfírio da Rocha & Moetasim Ashfaq

*Earth Systems and Environment* **5**, 825–847 (2021) | Cite this article

# Introduction

## Features of the South American Monsoon (SAM)




When is the **onset** of the rainy season?

When is the **demise** of the rainy season?

What is its **length**?

**Main features of SAM lifecycle** { onset, demise, length

# Objective

To compare the **SAM lifecycle**

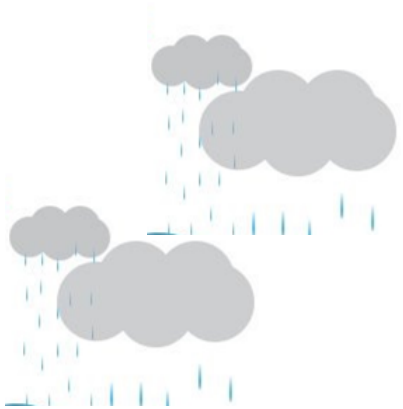
in projections of **eight** global climate models (**GCMs**) of

the Coupled Model Intercomparison Project Phase 6 (**CMIP6)** between

(a) the **original GCM outputs** (downloaded from ESGF) and

(b) after applying the **statistical downscaling** (SD) technique.

**lifecycle** { onset, demise, length



# Methodology

## 1. GCMs Selection

**Method**: ranking technique (Rupp et al., 2013)

**Models**

CMCC-CM2-SR5
CMCC-ESM2
EC-Earth3
GFDL-ESM4
IPSL-CM6A-LR
MIROC6
MPI-ESM1-2-LR
MRI-ESM2-0

## 2. Statistical Downscaling

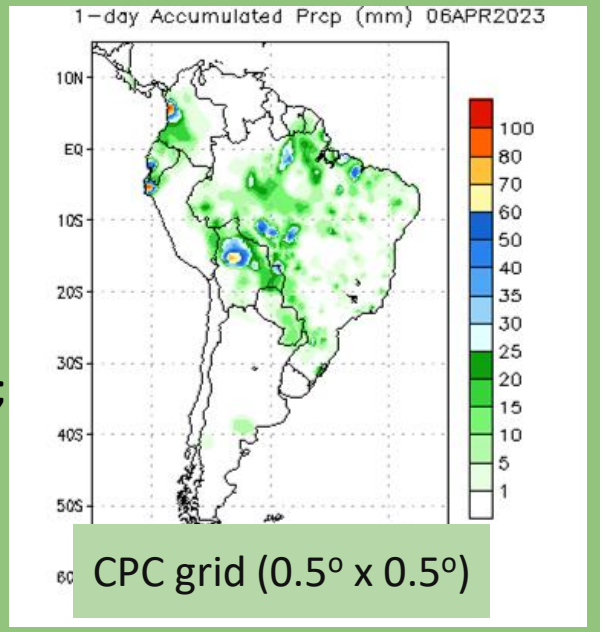
GCMs interpolated to the reference dataset grid

↓

**SD method**: Quantile Delta Mapping (QDM; Cannon et al., 2015)

↓

calibration: 1995-2014

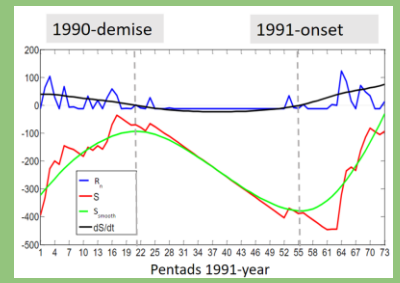



CPC grid (0.5º x 0.5º)

## 3. SAM Lifecycle

**Method**: modified method of Liebmann and Marengo (2001) by Bombardi and Carvalho (2008).

Data: precipitation pentads




Applied in CPC and individual models (hist and SSPs 2-45 e 5-85)
→ CMIP6 original
→ CMIP6 SD

# Results Part I: Validation

# Results

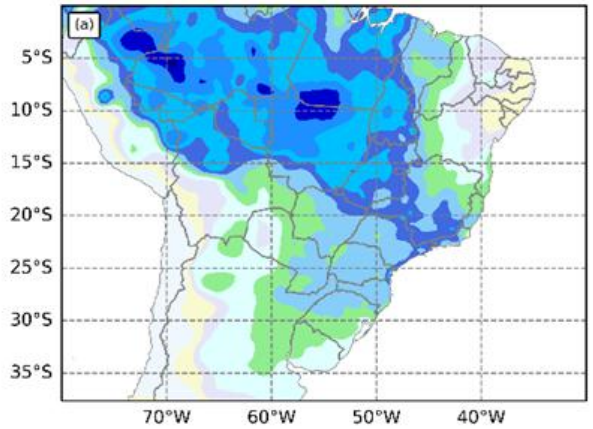
## SD and Validation

Precipitation climatology of the rainy period (October - March)
Historical Period: 1995-2014

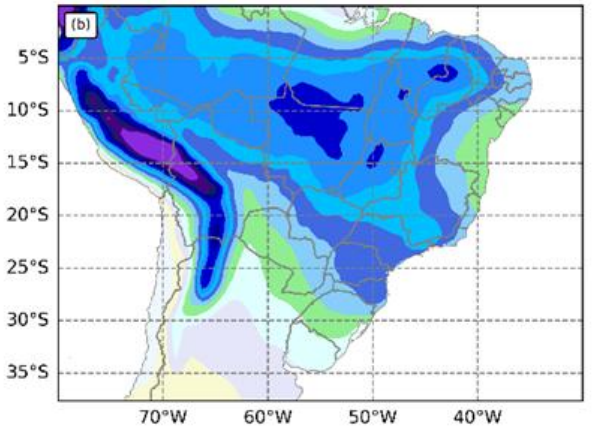
Averages

Differences

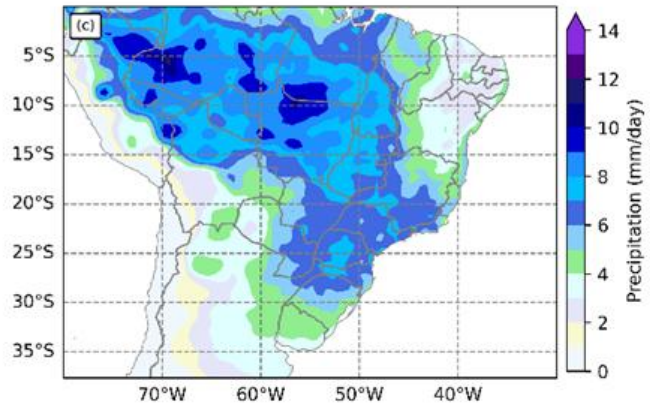
**CPC**



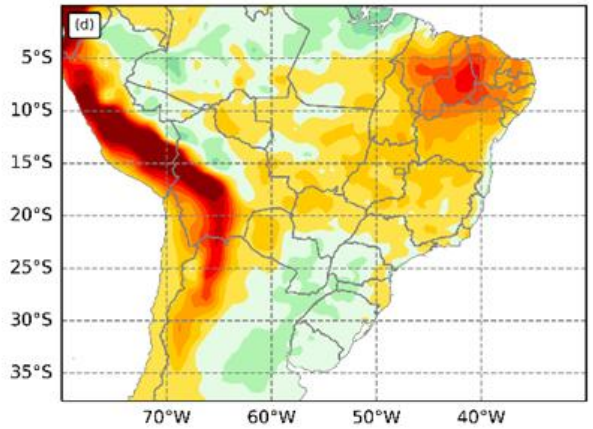

**CMIP6**



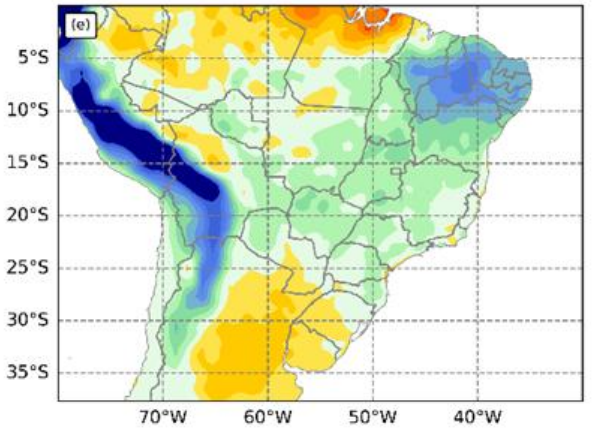

**CMIP6-SD**



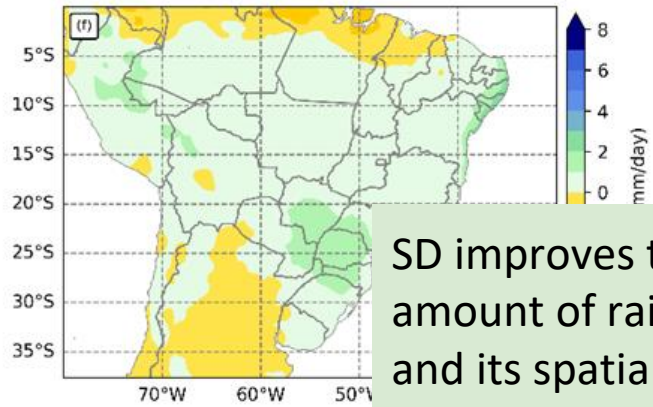

**CMIP6-SD - CMIP6**




**CMIP6 - CPC**




**CMIP6-SD - CPC**



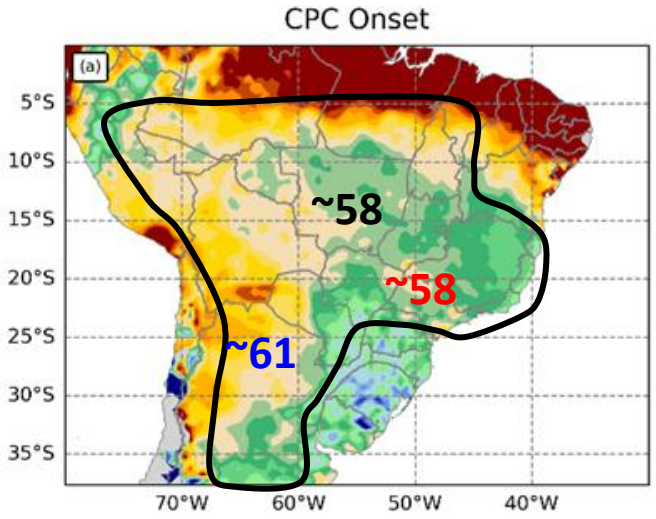

SD improves the amount of rainfall and its spatial distribution

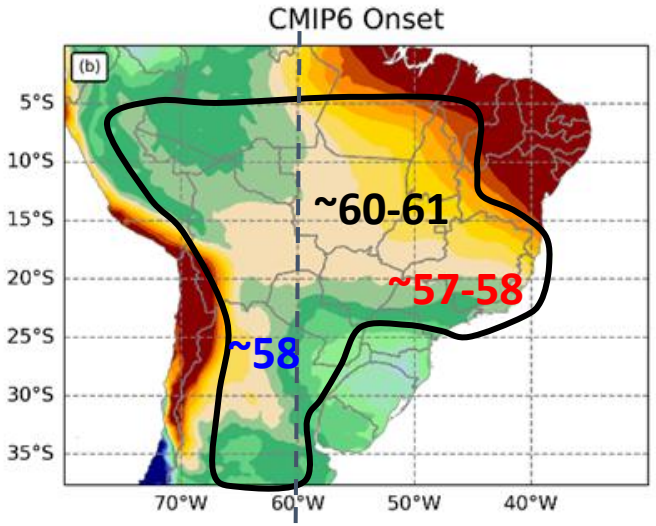
# Results

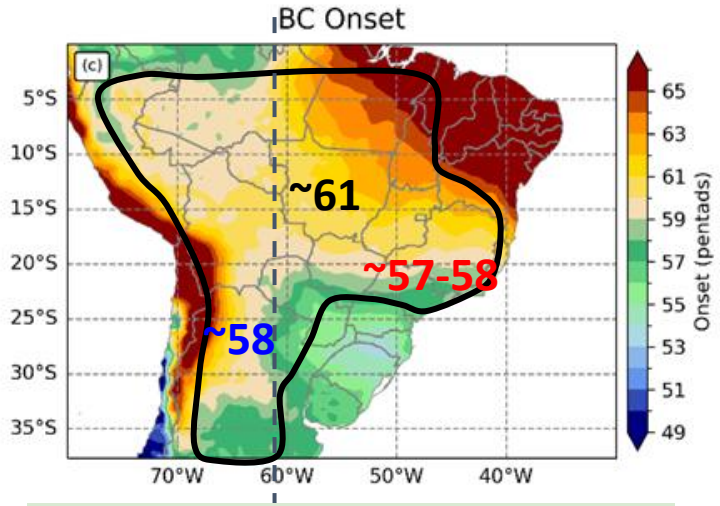
## SD and Validation

Monsoon Lifecycle: **Onset**
Historical Period: 1995-2014

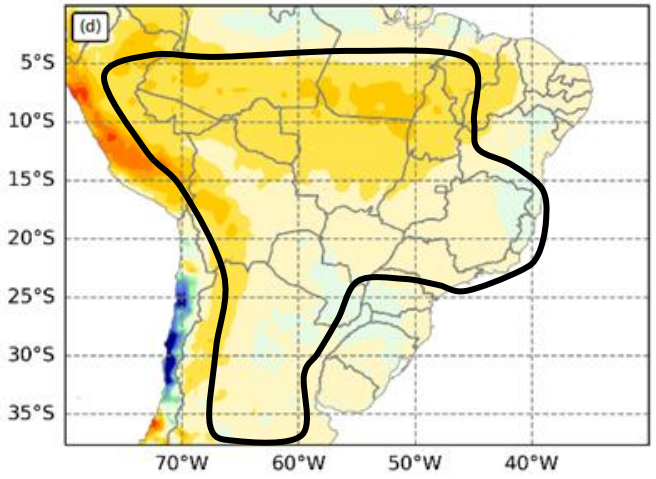
| Pentads | Dates |
|---|---|
| 58 | 13-17 Oct |
| 59 | 18-22 Oct |
| 60 | 23-27 Oct |
| 61 | 28-01 Oct |

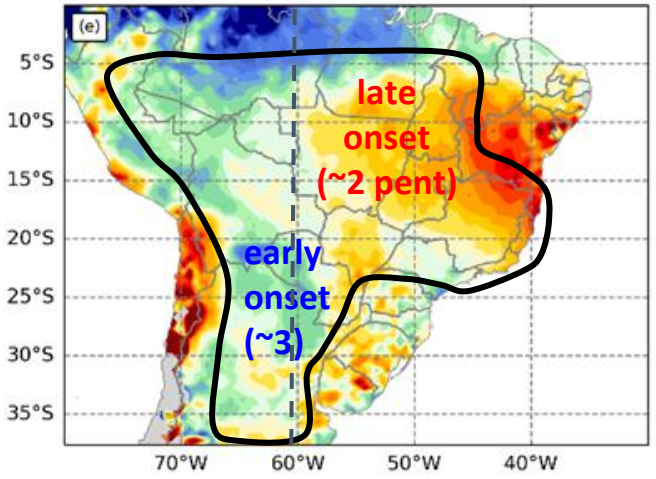


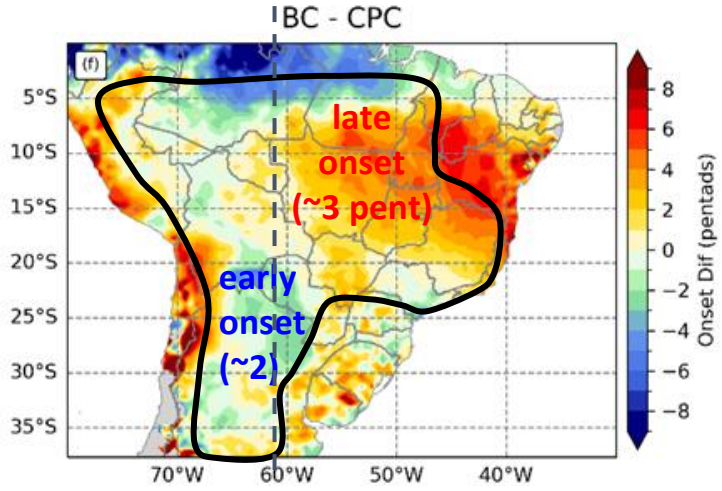




SD improves the SAM onset west 60°W



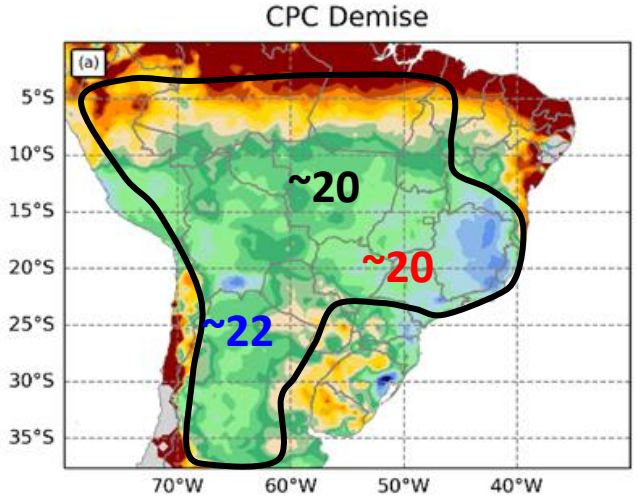



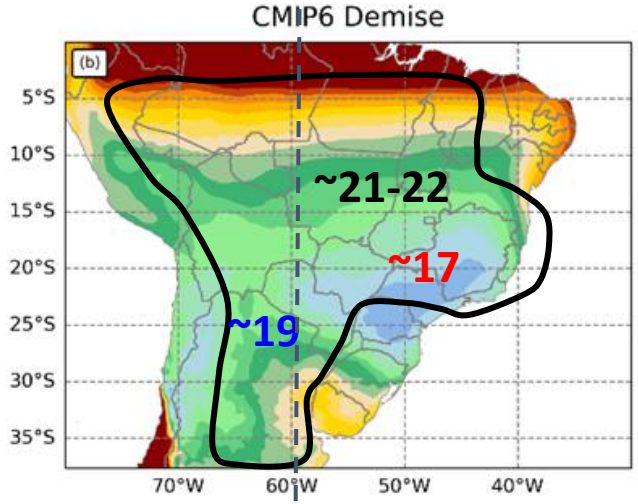
# Results

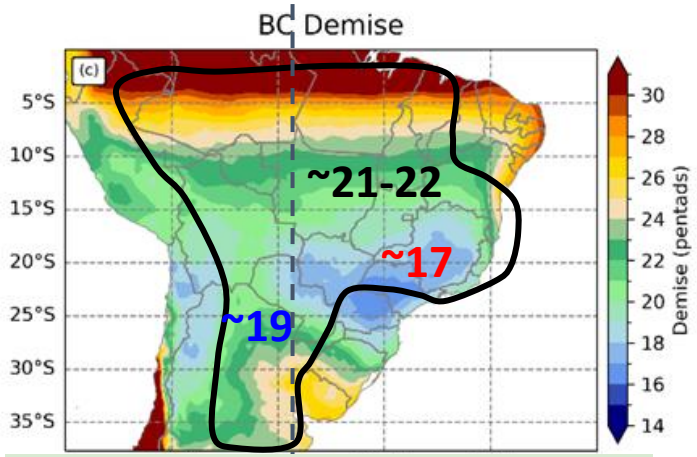
## SD and Validation

Monsoon Lifecycle: **Demise**
Historical Period: 1995-2014

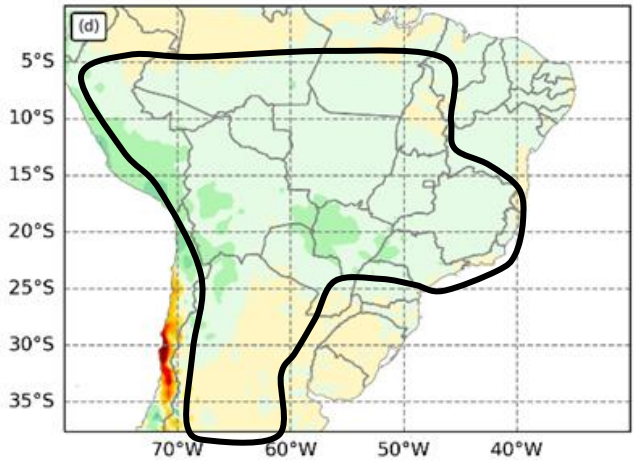
| Pentads | Dates |
|---|---|
| 17 | 22-26 Mar |
| 18 | 27-31 Mar |
| 19 | 01-05 Apr |
| 20 | 05-10 Apr |
| 21 | 11-15 Apr |
| 22 | 16-20 Apr |

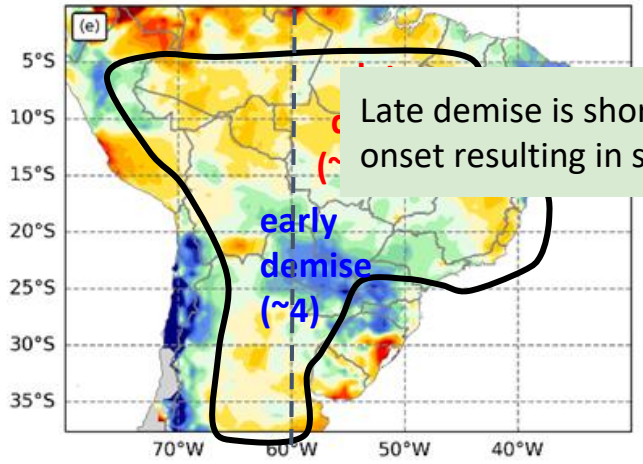


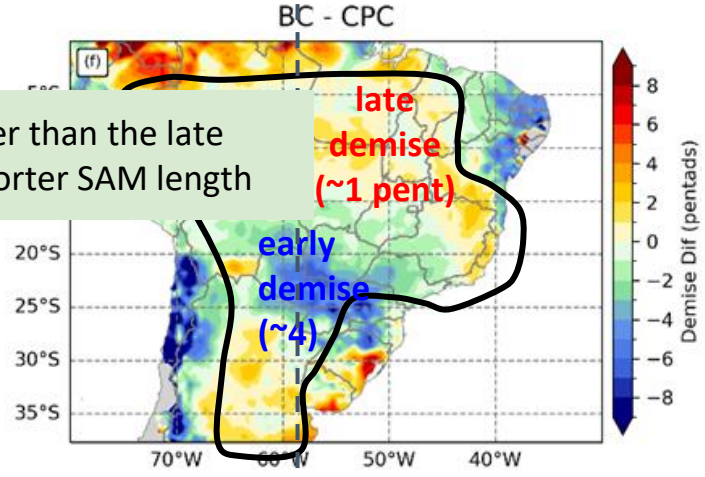




SD slightly improves the SAM demise west 60°W in the Amazon region



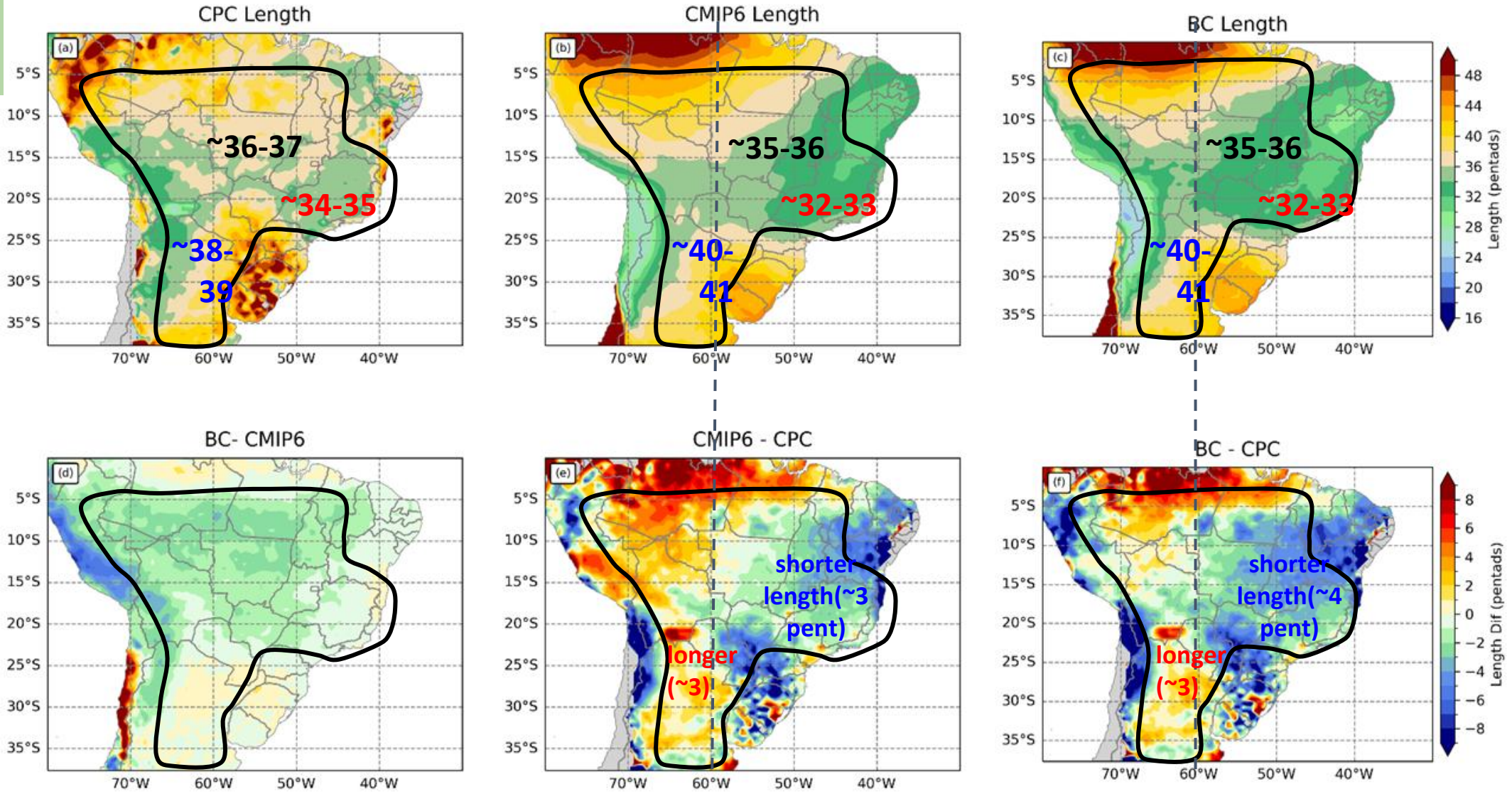

Late demise is shorter than the late onset resulting in shorter SAM length



# Results

## SD and Validation

Monsoon Lifecycle: **Length**
Historical Period: 1995-2014



# Conclusions Part I

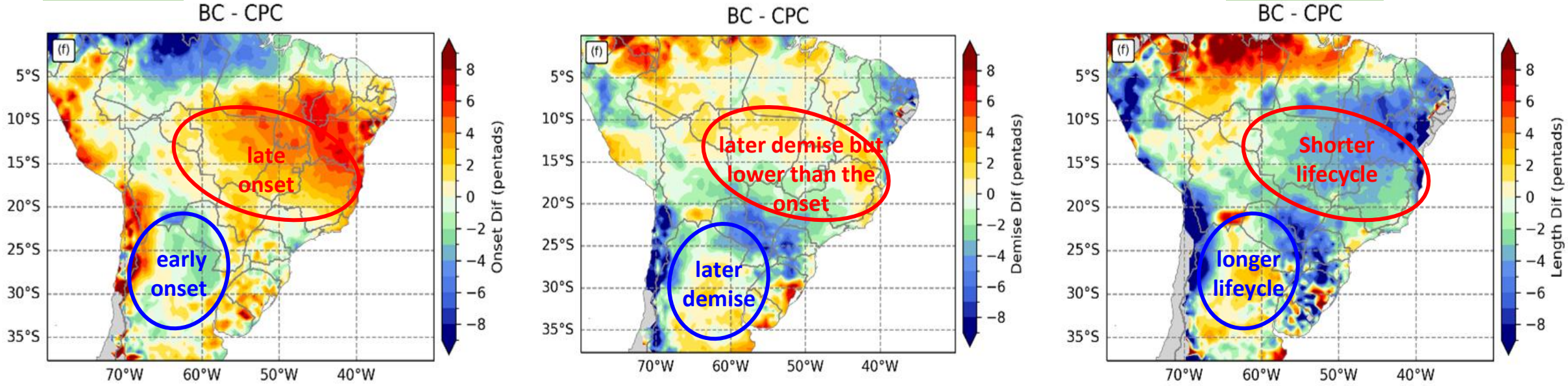
CMIP6 SD improves the seasonal amount and spatial distribution of rainfall compared to the original CMIP6 output.
In terms of the SAM lifecycle SD improves:

**Onset** - the representation of onset west 60ºW

**Demise** - the representation of demise west Amazonia

**Length**

CMIP6 SD - CPC



# Results Part II: Climate Projections

# Results: prec

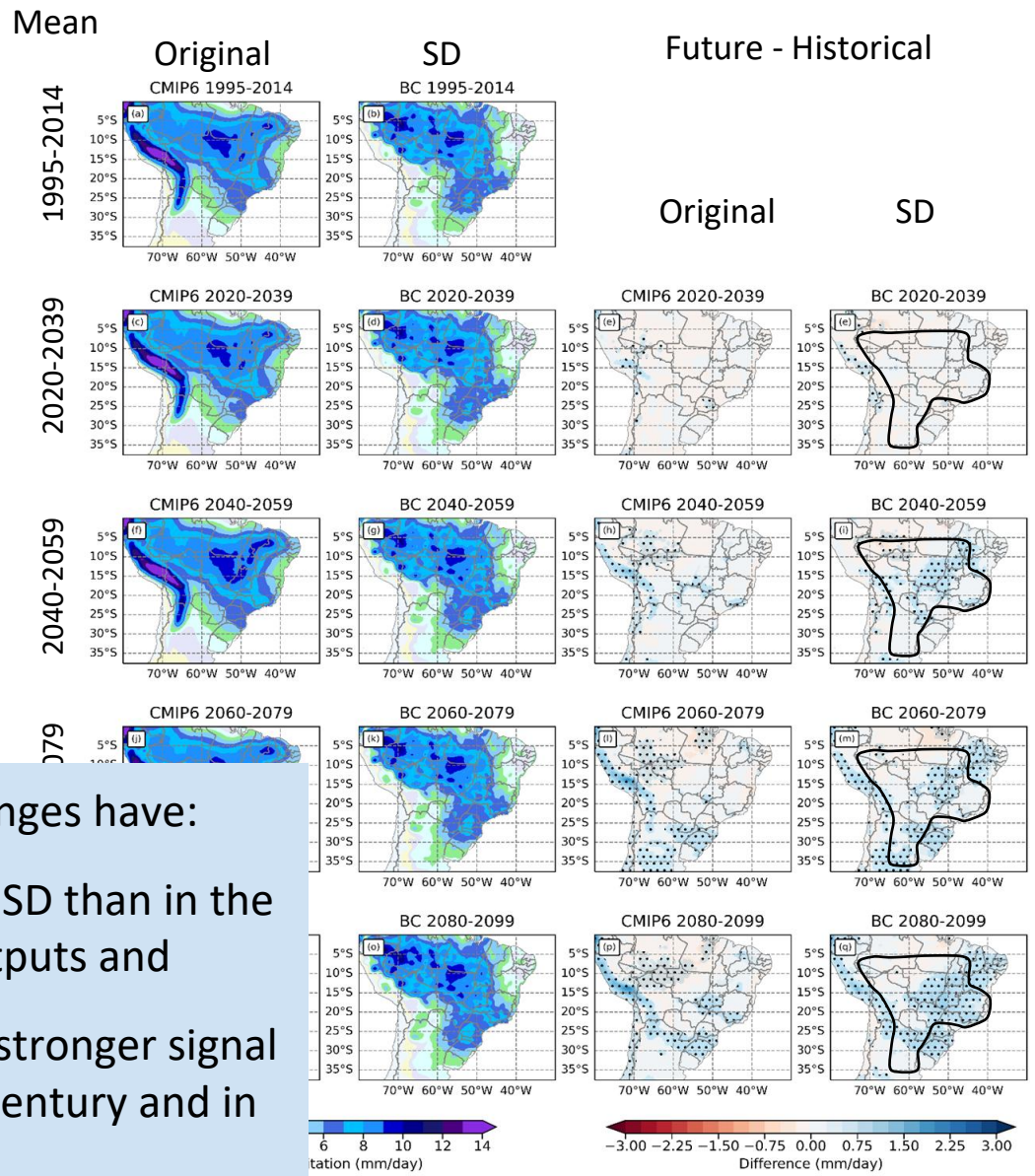
In climate change studies we are interested in the signal projected by models. Here we analyse the scenarios SSP2-4.5 and SSP5-8.5.

The projected changes have:

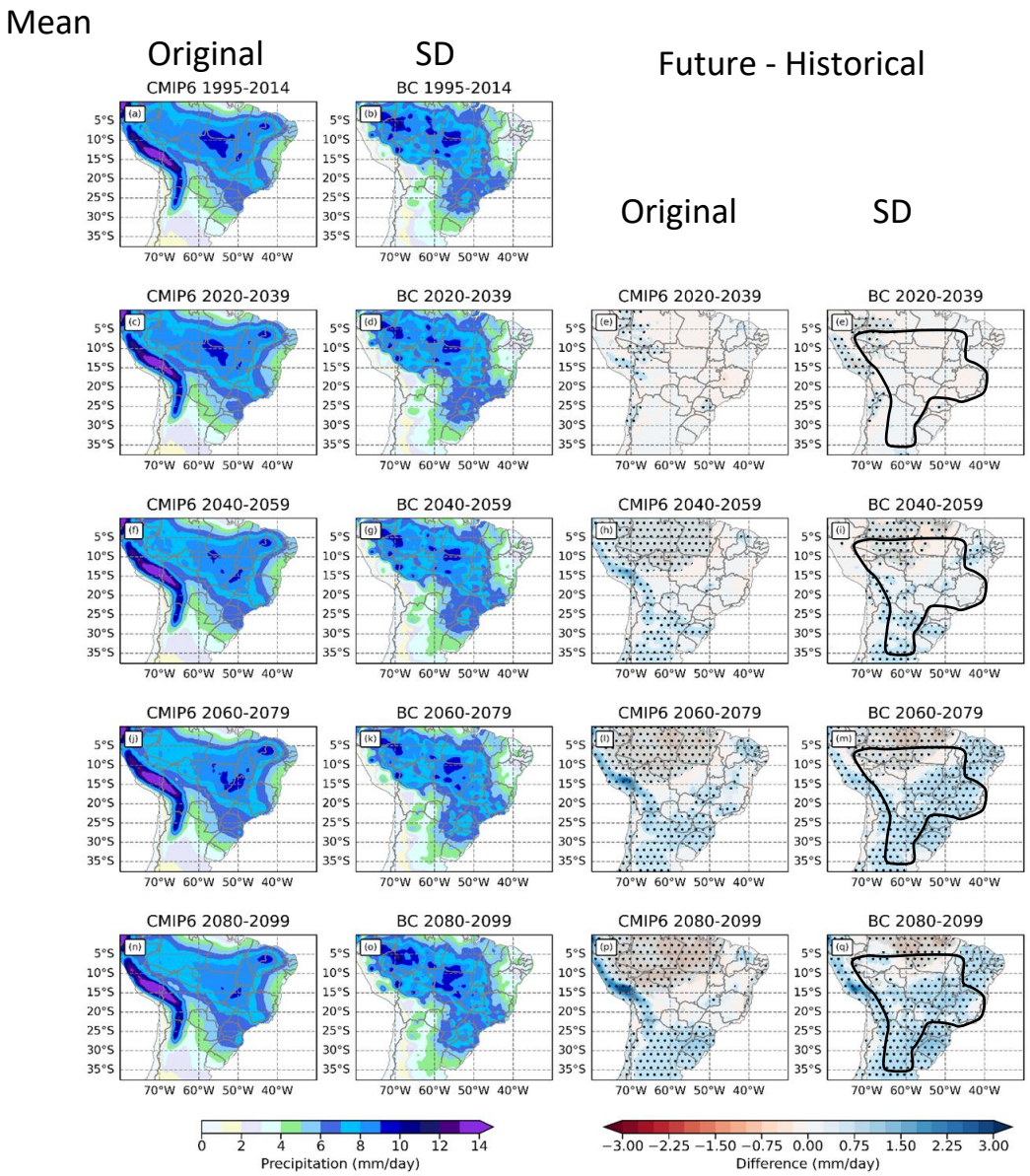
-stronger signal in SD than in the CMIP6 original outputs and

-in both datasets, stronger signal at the end of the century and in SSP5-8.5 scenario

Scenario SSP2-4.5




Scenario SSP5-8.5



# Results: onset

Scenario SSP2-4.5

Scenario SSP5-8.5

Mean

original SD Future - Historical

1995-2014

CMIP6 1995-2014 BC 1995-2014

2020-2039

CMIP6 2020-2039 BC 2020-2039 CMIP6 2020-2039 BC 2020-2039

2040-2059

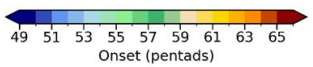
CMIP6 2040-2059 BC 2040-2059 CMIP6 2040-2059 BC 2040-2059

2060-2069

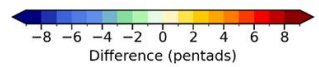
CMIP6 2060-2079 BC 2060-2079 CMIP6 2060-2079 BC 2060-2079

2070-2099

CMIP6 2080-2099 BC 2080-2099 CMIP6 2080-2099 BC 2080-2099






Projections indicate a late onset.

# Results: demise

Scenario SSP2-4.5

Scenario SSP5-8.5

Mean

original SD Future - Historical

original SD

1995-2014

2020-2039

2040-2059

2060-2069

2070-2099

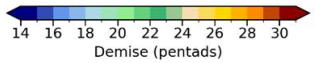
CMIP6 1995-2014 BC 1995-2014

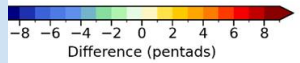
CMIP6 2020-2039 BC 2020-2039 CMIP6 2020-2039 BC 2020-2039

CMIP6 2040-2059 BC 2040-2059 CMIP6 2040-2059 BC 2040-2059

CMIP6 2060-2079 BC 2060-2079 CMIP6 2060-2079 BC 2060-2079

CMIP6 2080-2099 BC 2080-2099 CMIP6 2080-2099 BC 2080-2099




Projections indicate a late demise, but shorter than that of the onset.

# Results: length

Scenario SSP2-4.5

Scenario SSP5-8.5

Mean

original SD Future - Historical

original SD

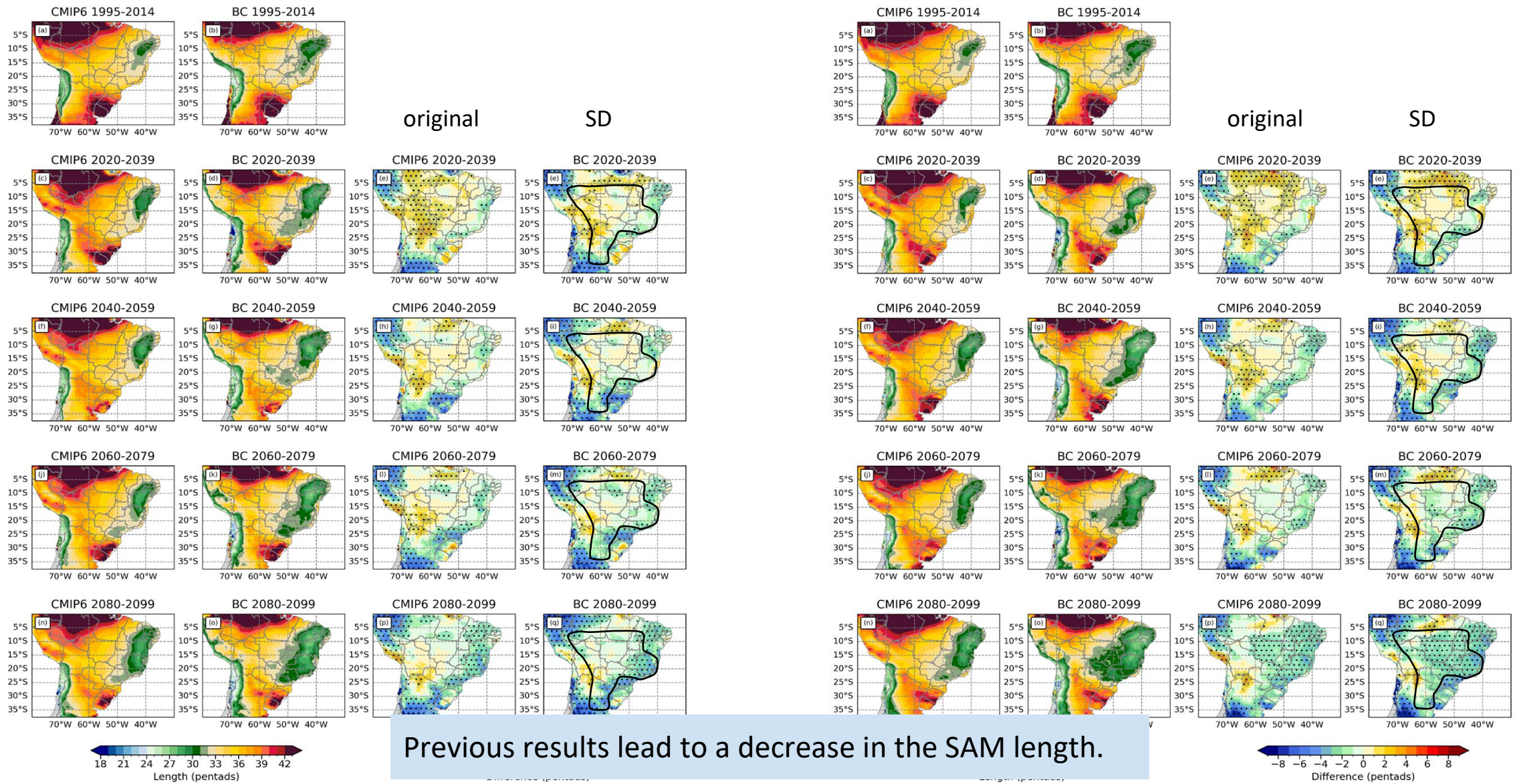
1995-2014

2020-2039

2040-2059

2060-2069

2070-2099




Previous results lead to a decrease in the SAM length.

# General Conclusions

Although CMIP6-SD improves the amount and the spatial representation of the precipitation across South America, there is no huge improvements in the spatial pattern of the monsoon lifecycle when compared to the original CMIP6 models.

The projected changes for precipitation:

-stronger signal in SD than in the CMIP6 original outputs and

-in both datasets, stronger signal at the end of the century and in SSP5-8.5 scenario: dry conditions in Amazonia and wet in most parts of South America.

Projected SAM Lifecycle at the end of the century (2070-2099):

→late onset
→late demise (but shorter compared to the onset)
→shorter lifecycle

**SAM length** is projected to **decrease** but the **amount of precipitation** is projected to **increase**. It indicates that the rainfall will be more concentrated in shorter periods.

So, monsoon areas will be more vulnerable to floods in future scenarios.

atmosphere

*Article*

# South American Monsoon Lifecycle Projected by Statistical Downscaling with CMIP6-GCMs

**Michelle Simões Reboita [1,*], Glauber Willian de Souza Ferreira [1], João Gabriel Martins Ribeiro [1], Rosmeri Porfírio da Rocha [2] and Vadlamudi Brahmananda Rao [3]**

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The full article can be accessed at Atmosphere, vol. 14(9), 1380, 2023.

*Thanks for your attention!*