IWAS Brazil ÁGUA-DF

WG I – Climate in Central Brazil

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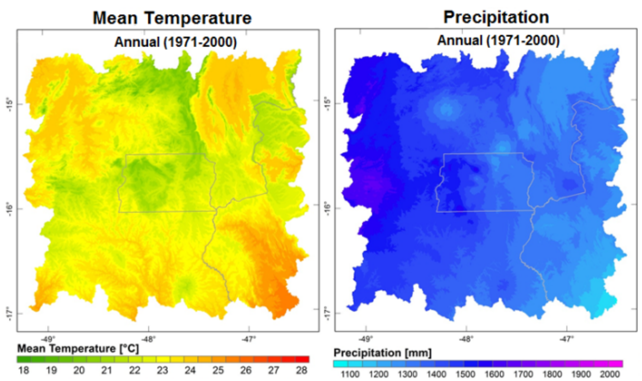
Final Workshop - Project IWAS ÁGUA DF
Integrated Water Resources Management in Distrito Federal – DF
June 4-6, 2013

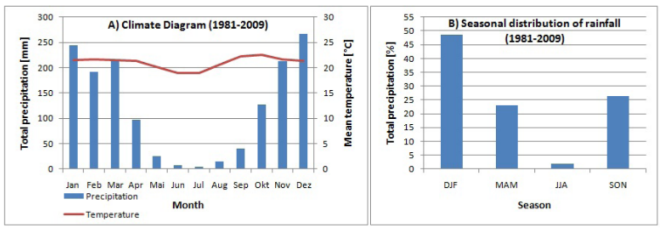
Funded by
Patrocinado por
Federal Ministry of Education and Research

1 Introduction

Current Climate

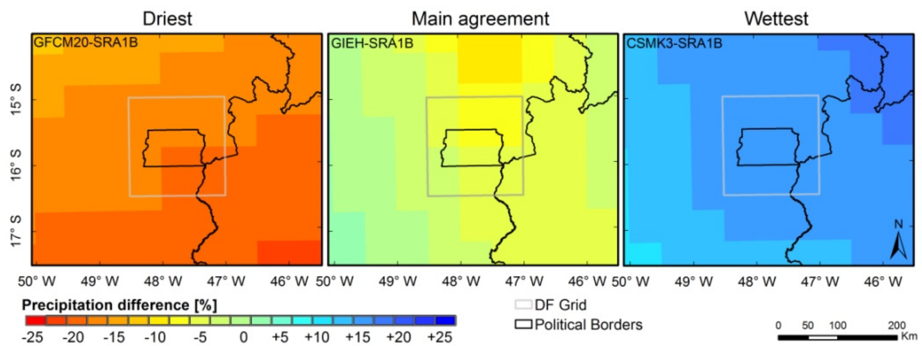
- **Assess the regional climate patterns**
  - Climatology
  - Spatial Distribution
  - Trend Analysis

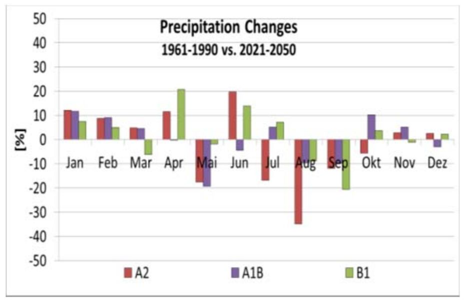




Future Scenarios

- **Develop regional climate change scenarios**
  - GCMs analysis
  - Downscaling





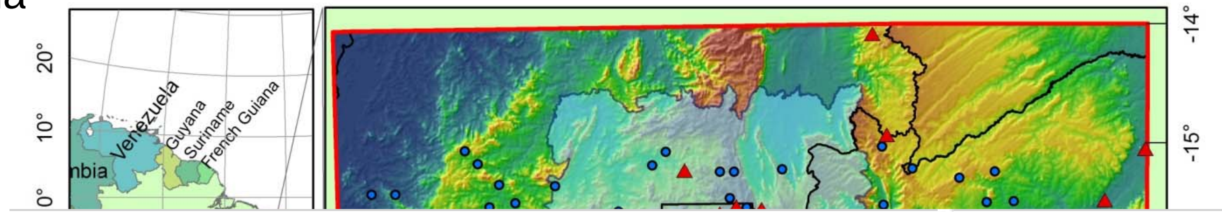
2 Current Climate

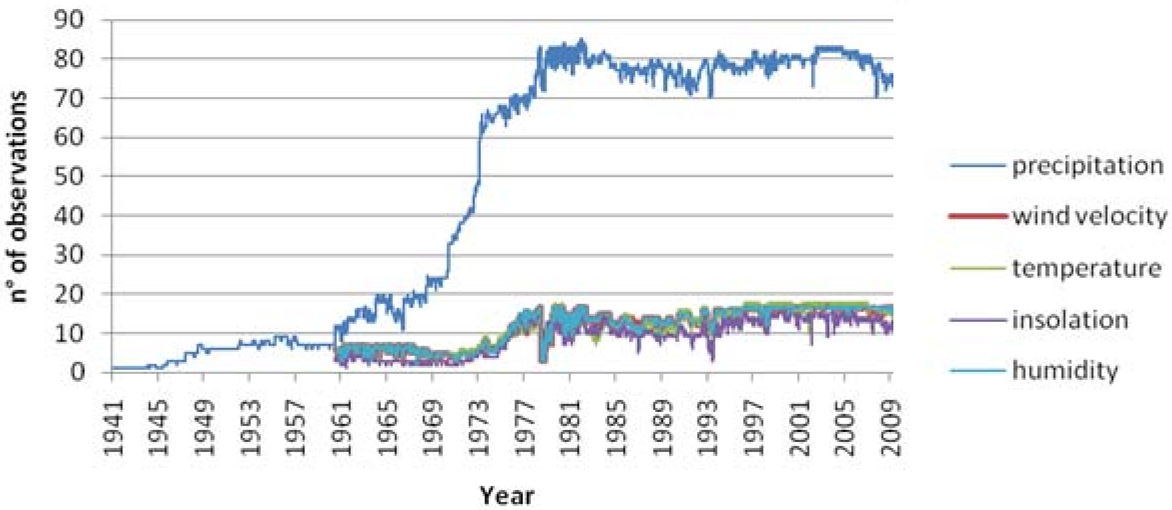
- **Assess the current climate**
  - Better understanding of regional climate patterns;
  - Provide good quality data to other WGs;
  - Calibrate and test impact models;
  - Reference.
- **Tasks**
  1. Assimilation of all relevant data
  2. Homogeneity tests
  3. Spatial distribution
  4. Trend analysis
  5. Regional climate patterns

2 Current Climate

1. Data Assimilation

- Latitude -14°, -18°; Longitude -44°, -51°
- Temperature, precipitation, wind vel., rel. humidity and sunshine duration
- INMET (SIM), ANA (HIDROWEB), CAESB and EMBRAPA
- Quality control
- More tha





2 Current Climate

✓ **Data Assimilation**

2. **Homogeneity tests and homogenization of time-series**
   - ABBE, Buishand, Alexandersson, steady-state conditions, CRADDOCK, double sum analysis, quotient criteria, and difference in limits.

Table1: Status of the CLIMA-DF database after homogeneity test

	Status			
Climate variable	Homogeneous	Inhomogeneous	Insufficient Data*	TOTAL
Mean surface air temperature	**4**	**1**	*32*	37
Precipitation	**55**	**5**	97	157
Global Radiation	5	0	12	17
Relative Humidity	12	0	5	17
Wind Speed	12	0	5	17

2 Current Climate

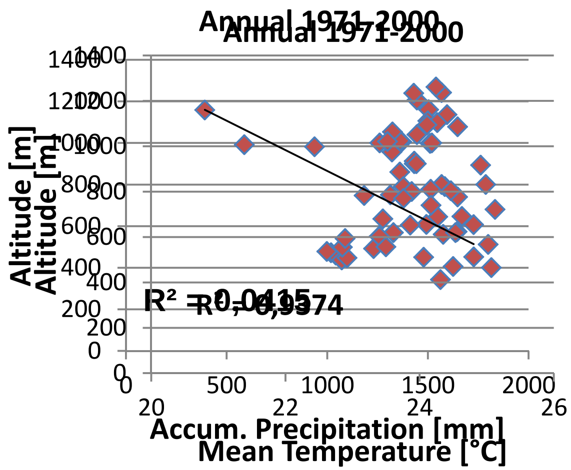
- ✓ **Data Assimilation**
- ✓ **Homogeneity tests and homogenization of time-series**

3. **Spatial distribution**
   - Climatology (i.e., 1971-2000 and 2001-2010)
     - Mean temperature and precipitation
     - fill gaps methods: Differenzenkriterium and Quotientenkriterium (Bernhofer, 2004)
     - 30-Year Normal Period (WMO, 1989)
   - Interpolation method
     - State-of-the-art (COST Action719, 2008): “THE USE OF GEOGRAPHIC INFORMATION SYSTEMS IN CLIMATOLOGY AND METEOROLOGY”
     - Deterministic Methods: Nearest Neighbour, IDW;
     - Probabilistic Methods: Linear regression models, Ordinary kriging;
     - Combined methods: Universal kriging, residual kriging;

2 Current Climate

3. Spatial distribution

- Interpolation method
- Independent validation (correlation coeff., MSE, Nash – Sutcliffe)
- Borges et al. 2013a



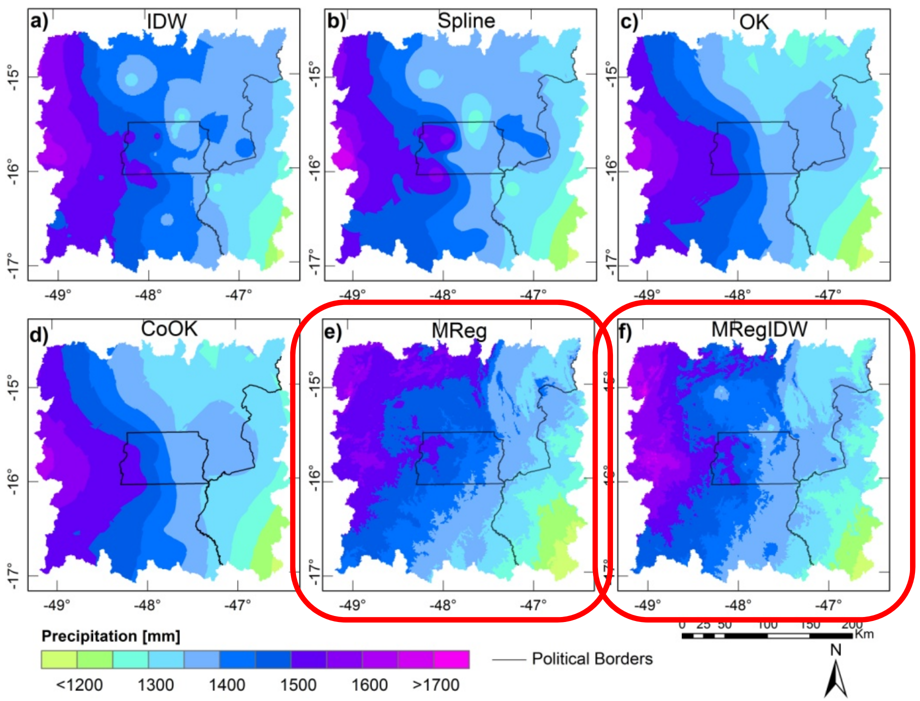


Figure: Comparison between different interpolation methods

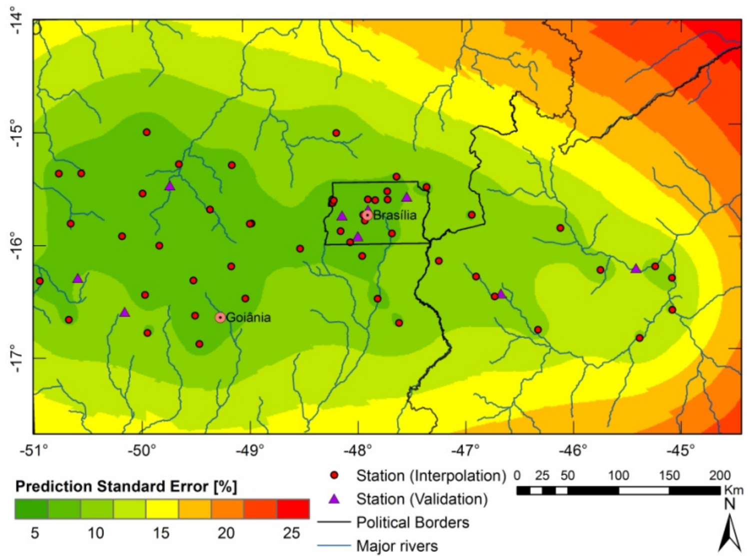
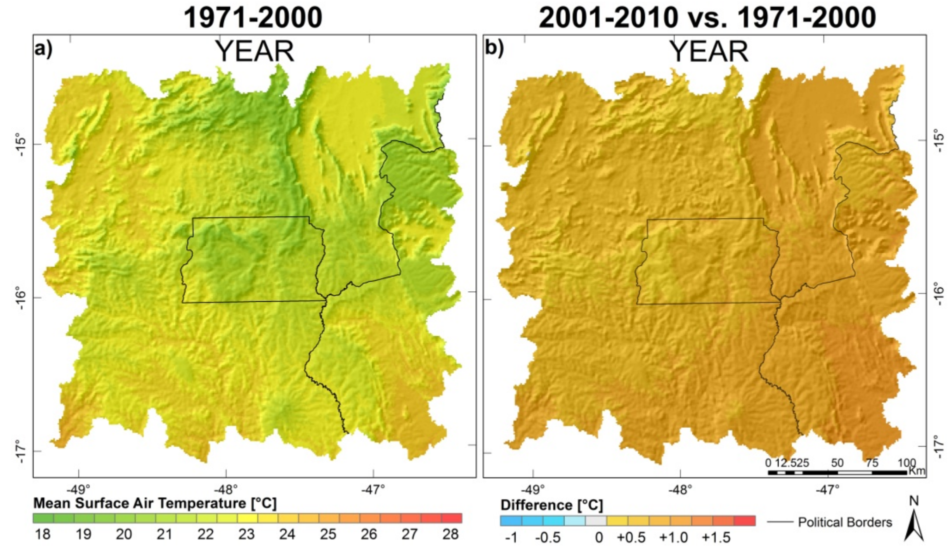


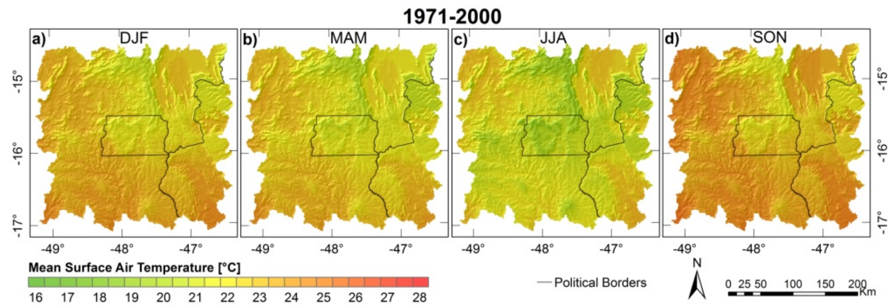
Figure: Uncertainties of interpolation demonstrated by prediction standard error [%]

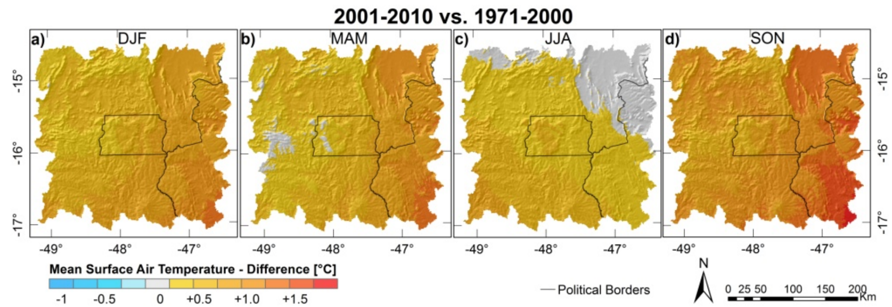
2 Current Climate

3. Spatial distribution

- Temperature
  - Annual
  - Seasonal
  - Difference (2001-2010 vs. 1971-2000)



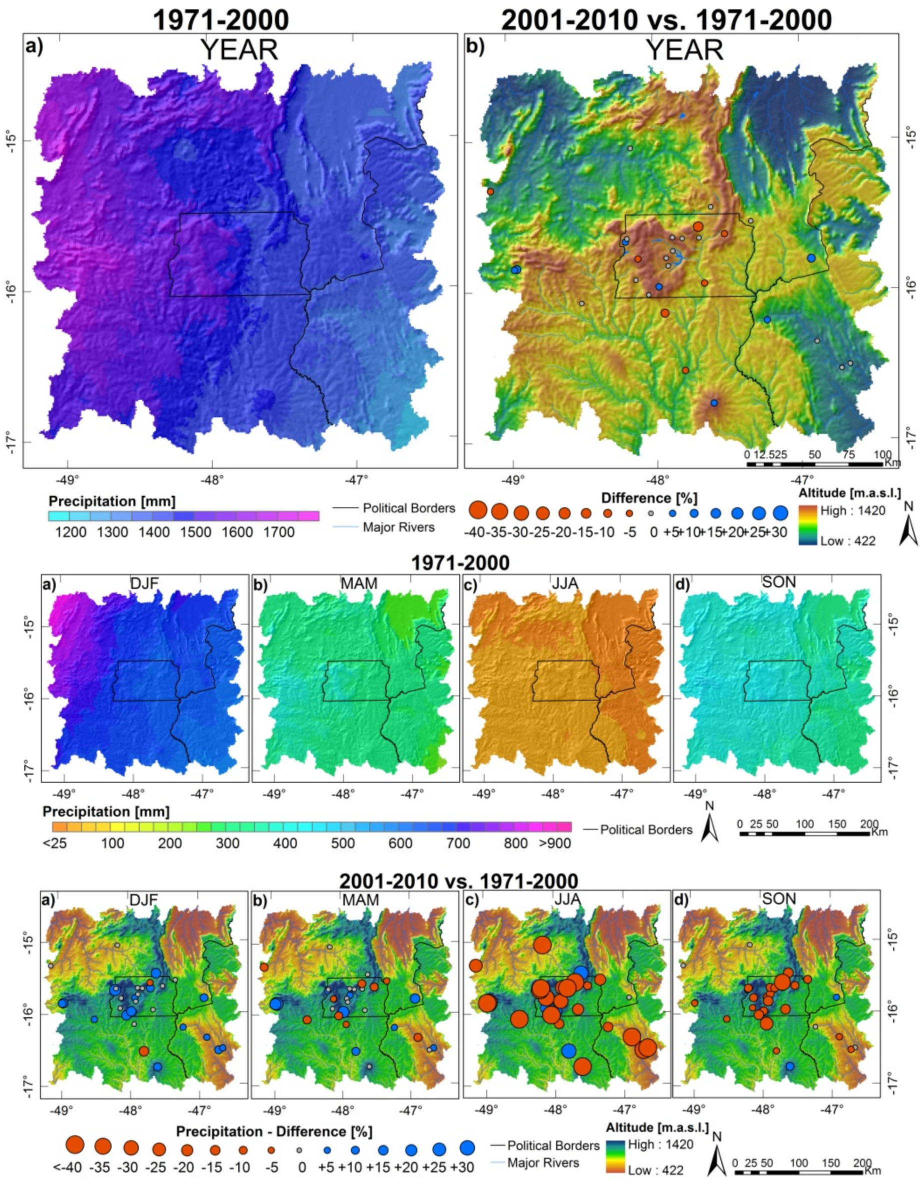




2 Current Climate

3. Spatial distribution

- Precipitation
  - Annual
  - Seasonal
  - Difference (2001-2010 vs. 1971-2000)



2 Current Climate

- ✓ **Data Assimilation**
- ✓ **Homogeneity tests and homogenization of time-series**
- ✓ **Spatial distribution**

4. **Trend analysis**
   - Linear trend: Rapp, 2000
   - Significance level (SIG) of trends: Mann-Kendall;
   - Borges et al. 2013b

2 Current Climate

4. Trend analysis

- Temperature
  - Significant increase in mean temperature

Table: Trend analysis of seasonal and annual mean surface air temperature for the period 1971-2010.

Station ID	DJF		MAM		JJA		SON		Annual	
	Abs [°C]	SIG [%]	Abs [°C]	SIG [%]	Abs [°C]	SIG [%]	Abs [°C]	SIG [%]	Abs [°C]	SIG [%]
01547004	+0.7	>99	+0.8	>99	+0.7	>95.4	+1.5	>99.7	+1.1	>99.7
01547016	+1.6	>99.9	+0.8	>95.4	+0.7	>95.4	+2.1	>99.99	+1.3	>99.99
01548014	+1.1	>99.9	+1.3	>99.9	+1.0	>99	+1.9	>99.99	+1.3	>99.99
01550003	+1.0	>99	+0.9	>95.4	+0.8	>90	+1.7	>99.9	+1.1	>99.9
01649013	+1.0	>99.7	+1.2	>99.7	+1.5	>99.7	+1.9	>99.99	+1.6	>99.7

SIG level: >86.6% = significant; >95.4%=very significant; >99.7%=highly significant and NS=not significant (after Schönwiese 2000).

2 Current Climate

4. Trend analysis

- Precipitation
    - Significant increase in the rainy season
    - Significant decrease in the dry season

Table: Trend analysis of seasonal and annual precipitation for the period 1971-2010.

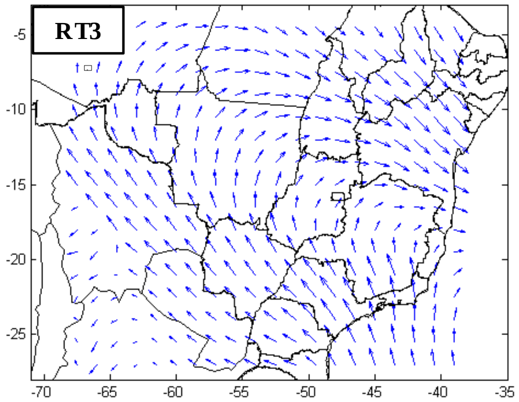
	DJF			MAM			JJA			SON			Annual		
Station ID	Abs[mm]	Rel[%]	SIG [%]	Abs[mm]	Rel[%]	SIG [%]	Abs[mm]	Rel[%]	SIG [%]	Abs[mm]	Rel[%]	SIG [%]	Abs[mm]	Rel[%]	SIG [%]
01546000	46.12	7.64	NS	-37.39	-14.16	NS	-18.46	-106.91	>95.4	-145.93	-43.47	>90	-155.66	-12.76	NS
01546005**	105.49	14.62	NS	74.33	21.07	NS	1.65	8.34	NS	38.29	10.01	NS	219.76	14.88	>68.3
01547002	140.96	23.74	>90	-26.05	-8.41	NS	1.9	8.24	>68.3	-128.95	-36.86	>68.3	-12.14	-0.95	NS
01547003**	-37.18	-5.14	NS	-57.63	-17.54	NS	-6.59	-35.42	NS	-30.37	-8.57	NS	-131.77	-9.25	NS
01547004	-68.87	-10.41	NS	71.67	19.56	>68.3	-8.53	-24.03	NS	-62.22	-14.14	NS	-67.96	-4.52	NS
01547008	-43.78	-7.47	NS	39.79	12.01	NS	-8.37	-35.54	NS	-118.34	-28.76	>68.3	-130.71	-9.67	NS
01547009	-73.03	-12.2	NS	46.24	13.99	NS	3.52	13.33	NS	-82.02	-20.63	>68.3	-105.29	-7.78	NS
01547010	-4.09	-0.58	NS	-61.93	-16.12	NS	-5.01	-18.27	NS	-101.76	-23.41	NS	-172.79	-11.17	>68.3
01547011	91.04	14.99	>80	3.39	1.05	NS	-5.39	-18.11	>68.3	-47.76	-12.89	NS	41.28	3.1	NS
01547012	-9.68	-1.56	NS	-13.85	-4.67	NS	-3.43	-13.99	NS	-99.3	-25.03	>68.3	-126.27	-9.43	NS
01547013	56.85	9.39	NS	-44.41	-14.33	NS	-5.21	-21.79	>86.6	-62.19	-16.99	NS	-54.96	-4.21	NS
01547014*	83.93	12.73	NS	120.19	33.34	>68.3	17.24	64.6	NS	-65.16	-15.41	NS	156.19	10.63	NS
01547015*	-75.36	-11.45	NS	-46.85	-13.53	NS	-10.28	-38.53	NS	-61.29	-16.14	NS	-193.77	-13.73	>68.3
01547016**	-236.11	-36.27	>90	-40.45	-14.15	NS	-8.09	-33.14	>68.3	-132.74	-38.62	>86.6	-417.39	-31.98	>95.4
01548000**	49.5	6.78	NS	-44.84	-12.2	NS	-16.81	-68.95	>86.6	-31.31	-7.64	NS	-43.48	-2.84	NS
01548001**	-102.37	-15.94	NS	-24.22	-8.12	NS	-25.62	-169.83	>99	-8.21	-2.3	NS	-160.41	-12.23	>68.3
01548003	133.46	16.93	>68.3	103.54	26.96	>86.6	-13.5	-50.23	NS	-65.04	-15.23	NS	158.46	9.74	>68.3
01548004	156.75	19.2	>80	110.65	27.69	>95	-13.3	-45.98	NS	-33.01	-7.59	NS	221.09	13.16	>86.6
01548005	149.28	20.55	>80	-49.33	-13.26	NS	-11.06	-33.79	NS	-52.76	-11.42	NS	36.13	2.27	NS
01548006	15.28	2.2	NS	-70.28	-19.43	>68.3	-10.45	-37.22	NS	-60.86	-14.39	NS	-126.31	-8.38	NS
01548007	52.03	7.34	NS	-30.98	-8.2	NS	-38.58	-118.08	>90	-62.95	-15.25	NS	-80.48	-5.25	NS
01548014	199.14	28.29	>86.6	65.62	17.29	NS	9.04	29.68	NS	-26.74	-6.12	NS	247.06	15.93	NS
01549000	22.12	2.97	NS	-102.64	-36.49	>90	-13.34	-73.14	>86.6	-115	-29.06	>95.4	-208.85	-14.52	>80
01549001	-28.27	-3.65	NS	-61.91	-19.16	>80	0.48	2.13	NS	-24.64	-6.19	NS	-114.33	-7.53	NS
01549002	11.25	1.36	NS	-84.57	-23.29	>80	-17.39	-74.67	>95	-108.02	-26.55	>86.6	-198.73	-12.25	>80
01549003	90.67	10.32	>68.3	-101.09	-26.9	>86.6	-21.43	-80.54	>95.4	-108.09	-25.29	>86.6	-139.94	-8.19	NS
01549004**	-11.38	-1.25	NS	-74.78	-20.06	>68.3	-20.12	-93.43	>95	-33.58	-8.12	NS	-139.86	-8.13	NS
01549009	87.1	11.24	>68.3	-37.63	-11.17	NS	-10.39	-43.24	>68.3	-52.59	-13.02	NS	-13.51	-0.88	NS
01550000**	-44.67	-5.46	NS	-43.63	-13.83	NS	-16.47	-76.78	>80	-28.71	-7.77	NS	-133.47	-8.75	>68.3
01550001**	-129.95	-13.4	NS	-145.61	-41.29	>95.4	-10.12	-53.28	>86.6	21.07	5.19	NS	-264.6	-15.15	>68.3
01550002**	33.43	4.21	NS	28.07	8.66	NS	-0.15	-1.11	NS	87.87	25.38	>80	149.22	10.1	>68.3
01550003	123.89	13.1	NS	-48.67	-12.54	NS	0.53	2.13	NS	-17.84	-4.07	NS	57.92	3.22	NS
01645000	113.98	21.38	>80	43.74	21.78	>68.3	-9.22	-77.17	>95.4	-150.02	-52.46	>95.4	-1.53	-0.15	NS
01645002	-90.18	-18.01	NS	-47.4	-23.47	NS	-8.47	-65.87	>99.99	-174.1	-62.59	>99	-320.15	-32.22	>90
01645003	67.75	12.46	>68.3	-42.26	-20.61	NS	-2.44	-17.29	NS	-61.7	-21.58	NS	-38.64	-3.69	NS
01645005	-28.47	-5.18	NS	-19.81	-9.24	NS	-16.71	-83.52	>95.4	-59.41	-19.99	NS	-124.4	-11.5	NS
01645007	-2.26	-0.42	NS	-20.54	-10.59	NS	-4.63	-34.32	>95.4	-132.8	-41.08	>80	-160.23	-14.97	NS
01645009	96.25	18.42	>68.3	-1.18	-0.59	NS	-6.76	-55.65	NS	-70.14	-25.2	NS	18.16	1.79	NS
01646000	147.86	25.52	>80	-5.78	-2.81	NS	1.48	7.66	NS	31.92	10.2	NS	175.48	15.7	>68.3
01646001	53.09	8.42	>68.3	-55.26	-18.64	NS	-11.89	-58.59	>86.6	-28.92	-8.32	NS	-42.98	-3.32	NS
01646003	104.65	16.46	NS	-28.72	-9.82	NS	-11.67	-47.27	>80	-35.85	-11.1	NS	28.4	2.23	NS
01646004**	79.69	13	NS	17.36	6.01	NS	-14.74	-85.72	>68.3	-56.01	-17.18	NS	26.3	2.11	NS
01647001	150.44	22.33	NS	-4.87	-1.67	NS	-2.42	-11.76	NS	69.58	19.01	NS	212.73	15.73	NS
01647002**	285.21	39.86	>95.4	30.26	8.78	NS	-12.07	-53.17	NS	176.26	46.37	>95.4	479.66	32.78	>95.4
01647003**	-58.13	-8.11	NS	-23.98	-6.6	NS	-9.7	-32.3	NS	-37.83	-10.12	NS	-129.64	-8.74	NS
01647008**	-17.36	-2.69	NS	-47.75	-15.35	NS	-5.87	-28.23	>68.3	18.05	5.58	NS	-52.92	-4.07	NS
01648001	57.63	8.33	NS	-64.7	-17.68	NS	-15.04	-56.42	>90	-49.93	-12.44	NS	-72.03	-4.85	NS
01649000*	149.81	22.41	>86.6	-8.21	-2.54	NS	-16.96	-75.62	>86.6	-72.51	-19.18	NS	52.13	3.74	NS
01649001**	-55.52	-7.25	NS	18.58	5.16	NS	-14.3	-54.69	>68.3	-13.63	-3.47	NS	-64.88	-4.2	NS
01649004**	-5.91	-0.82	NS	-24.04	-6.64	NS	-20.99	-94.81	NS	40.43	10.08	NS	-10.51	-0.7	NS
01649006	17.61	3.6	NS	-165.33	-54.84	>99	-12.13	-72.08	>90	-164.27	-45.23	>95.4	-324.11	-27.69	>99
01649007**	35.65	3.86	NS	-54.89	-14.92	>68.3	-17.53	-84.15	>99	44.39	9.69	NS	7.63	0.43	NS
01649009**	120.11	15.22	NS	-98.92	-25.03	>68.3	-11.22	-44.14	>80	-186.17	-44.74	>95.4	-176.19	-10.84	>68.3
01649010	16.41	2.53	NS	-36.49	-12.26	NS	-3.38	-15.91	>68.3	-93.03	-25.09	NS	-116.48	-8.7	NS
01649012**	-267.02	-37.03	>95.4	-182.65	-53.57	>95.4	-23.18	-87.08	>86.6	-76.03	-24.61	>86.6	-548.89	-39.27	>99
01649013	48.79	6.52	NS	28.32	7	NS	-21.89	-70.25	>80	-60.03	-13.95	>68.3	-4.81	-0.3	NS
01650000**	103.5	13.86	>68.3	-80.4	-24.19	NS	-12.79	-52.69	>68.3	22.42	6.37	NS	32.72	2.25	NS
01650001**	-326.6	-39.77	>90	-233.62	-63.73	>99	-17.4	-73.38	>95.4	-170.42	-48.27	>95.4	-748.03	-47.81	>99.9
01650002**	53.23	6.19	NS	-63.91	-18.92	NS	-17.49	-74.13	>95.4	-48.63	-12.94	NS	-76.8	-4.81	NS
01650003**	-53.61	-7.47	NS	-13.27	-3.8	NS	-6.78	-26.92	>68.3	-47.26	-11.87	NS	-120.92	-8.11	NS

2 Current Climate

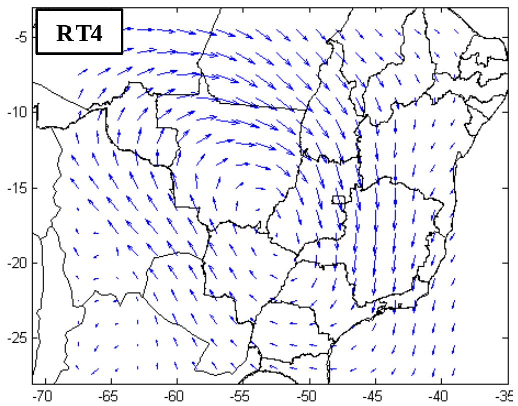
5. Regional Climate Patterns

- Relationship of wind at 850hPa with Precipitation
- Anunciação et al. 2013

ZCN+
9,5% days
20% extreme
43% persistence



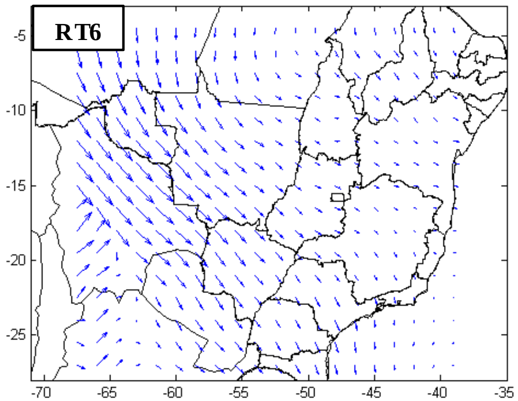
(a)



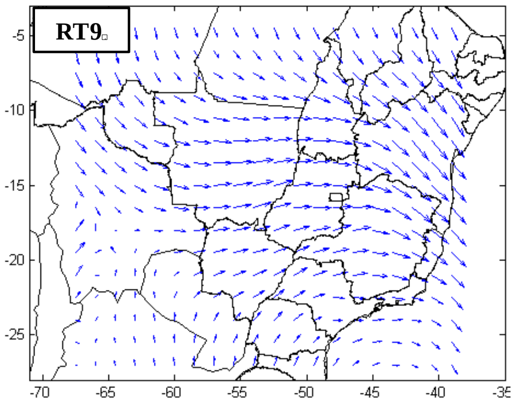
(b)

ZC
15%
14%
48%

ZCS
14%
12,6%
38%



(c)



(d)

ZCN-
13,4%
8,3%
55%

3 Future Scenarios

1. GCMs analysis

- Demand of impact assessments to future climate conditions

1. Differences between the projections of the GCMs;
2. Growing number of climate models;
3. Desire to limit the number of models;
4. Urcertainties.

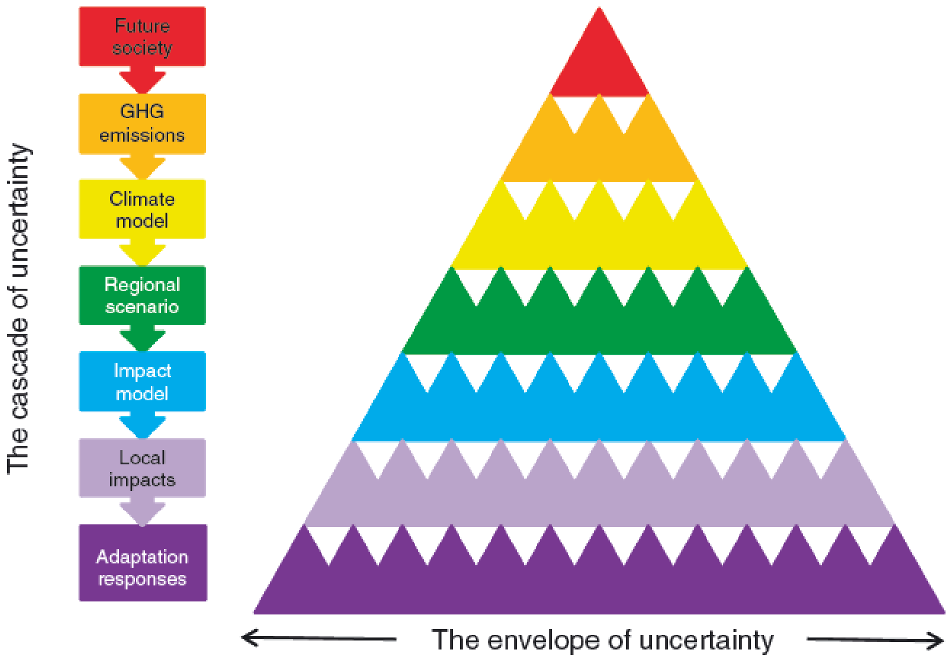


Figure: Cascade of uncertainty proceeds
Surce: Wilby and Dessai, 2010.

3 Future Scenarios

1. GCMs analysis

- GCMs used in the IPCC AR4 (CMIP3);
- SRES scenarios and 20th Century runs;
- Representative Climate Futures;
- Define climate futures:
  - Temperature: “lowest”, “main agreement” e “highe
  - Precipitation: “driest”, “main agreement” e “wettes
- Illustrate the spatial distribution of climate futures

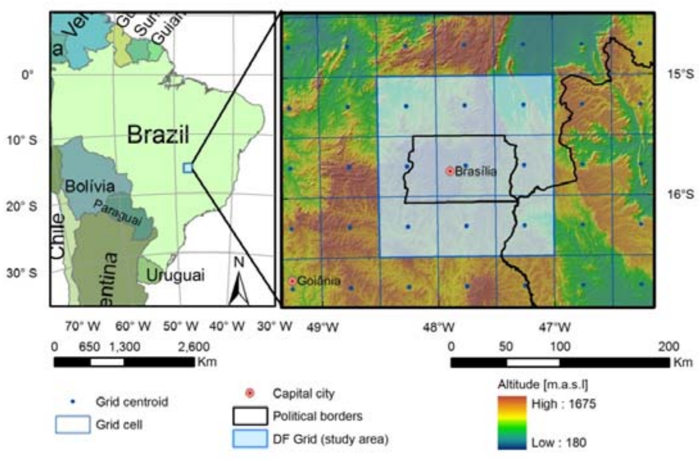


Figure: Spatial distribution of GCMs interpolated grids (0.5° x 0.5°) and their centroids, and area of study DF Grid (right).

Table: Description of the GCMs used

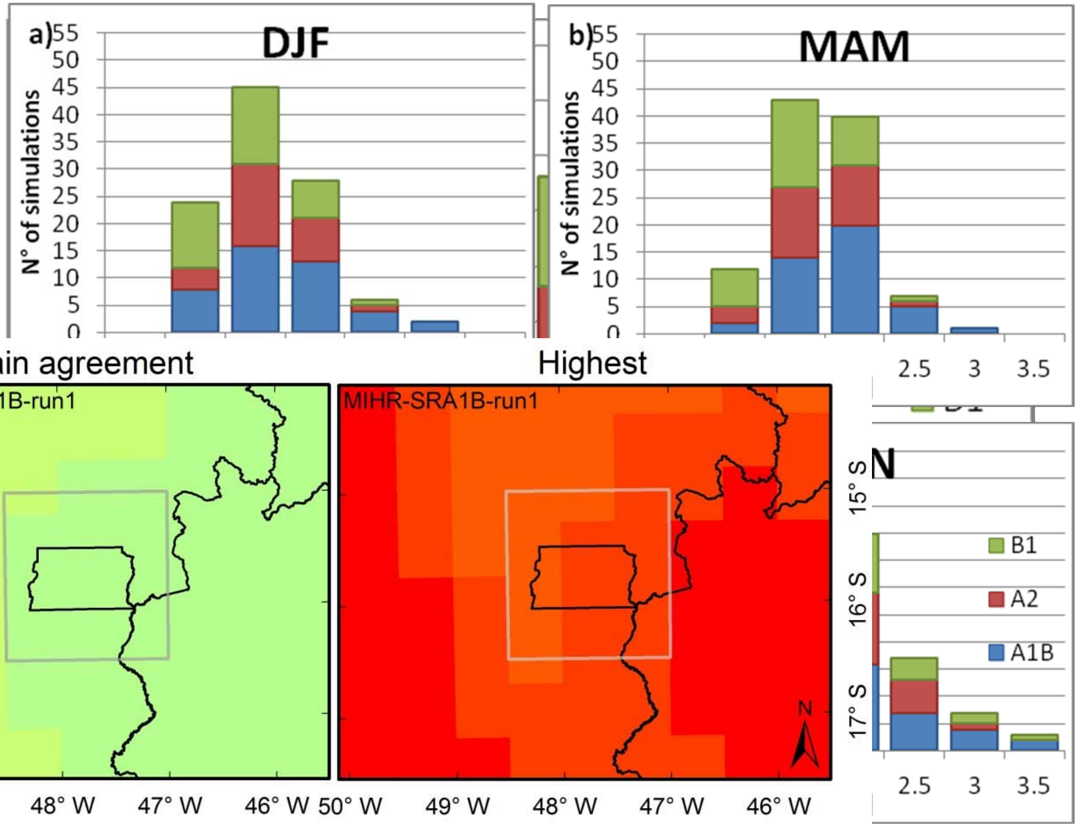
Model (Acronym)	Model (CERA)	Centre	Resolution (Lon x Lat)
BCM2.0	BCM2	Bjerknes Centre for Climate Research, Norway	1.9° x 1.9°
CGCM3-MR	CGMR	Canadian Center for Climate Modeling and Analysis, Canada	2.5° x 2.5°
CGCM3-HR	CGHR		1.9° x 1.9°
CM3	CNCM3	Centre National de Recherches Meteorologiques, France	1.9° x 1.9°
Mk3.0	CSMK3	Australia's Commonwealth Scientific and Industrial Research Organisation, Australia	1.9° x 1.9°
ECHO-G	ECHOG	Meteorological Institute, University of Bonn, Germany. Meteorological Research Institute of KMA, Korea	3.75° x 3.75°
FGOALS-g1.0	FGOALS	Institute of Atmospheric Physics, China	2.8° x 2.8°
CM2.0	GFCM20	Geophysical Fluid Dynamics Laboratory, USA	2.5° x 2.0°
CM2.1	GFCM21		
AOM	GIAOM	Goddard Institute for Space Studies, USA	4° x 3°
E-H	GIEH		5° x 4°
E-R	GIER		
HadCM3	HADCM3	UK Met. Office, UK	3.75° x 2.75°
HadGEM1	HADGEM1		1.875° x 1.25°
CM3.0	INCM3	Institute for Numerical Mathematics, Russia	5° x 4°
CM4	IPCM4	Institute Pierre Simon Laplace, France	2.5° x 3.75°
MIROC3.2-hires	MIHR	National Institute for Environmental Studies, Japan	1.125° x 1.125°
MIROC3.2-medres	MIMR		2.8° x 2.8°
ECHAM5-OM	MPEH5	Max-Planck-Institut for Meteorology, Germany	1.9° x 1.9°
CGCM2.3.2	MRCGCM	Meteorological Research Institute, Japan	2.8° x 2.8°
CCSM3	NCCCSM	National Centre for Atmospheric Research, USA	1.4° x 1.4°
PCM	NCPCM		2.8° x 2.8°

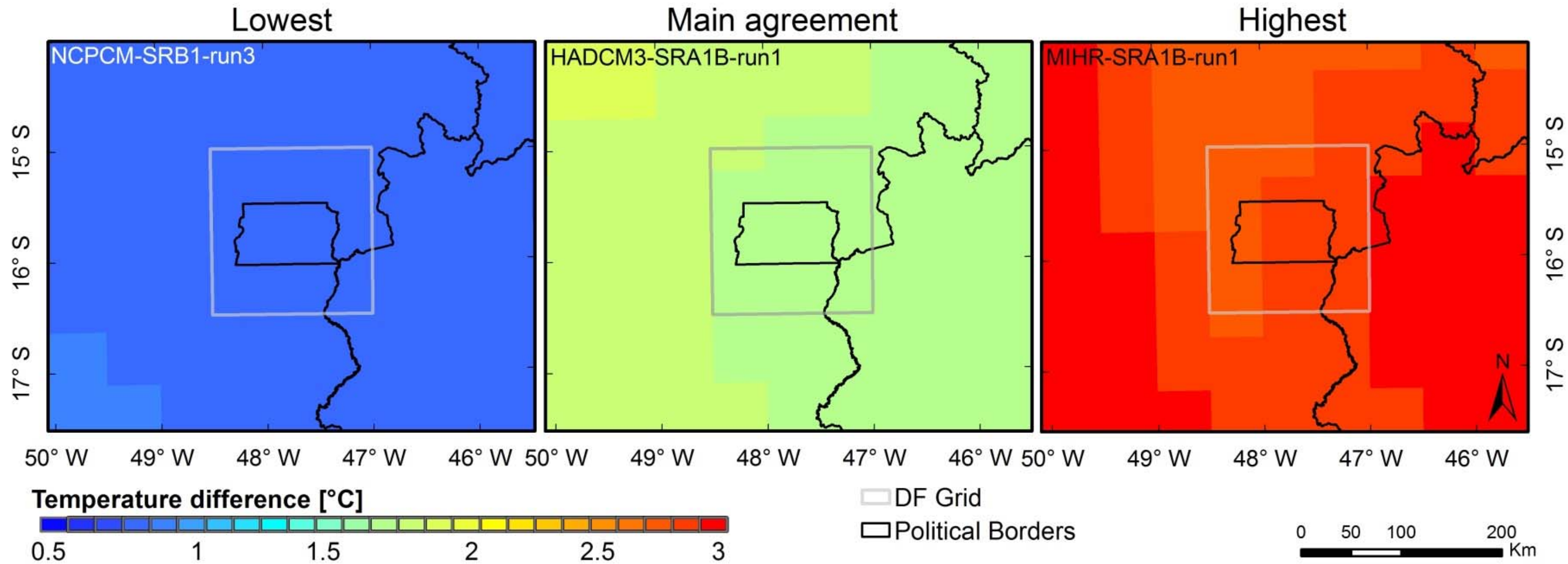
3 Future Scenarios

1. GCMs analysis

- Mean temperature difference [°C] (2021-2050 vs. 1961-1990)

- “lowest” change: warming from 0.6 to 1°C (9.7% of simulations);





...mpared to the climatological normal (i.e., 1961-1990). In green, the simulations of B1 ... the simulations of scenario A1B (moderate) ... and in blue the ... a) December, January and February – DJF; b) March, April and May – MAM; c) June, July and August – JJA; d) September, October and November – SON.

Figure: Illustration of the GCMs outputs according to the ... mean surface temperature [°C] for the period 2021-2050, compared to the climatological normal (1961-1990). Simulations are representative of climates "lowest" (MRCGCM-SRB1), "main agreement" (MPEH5-SRA1B) and "highest" (MIHR-SRA1B).

3 Future Scenarios

1. GCMs analysis

- Precipitation difference [%] (2021-2050 vs. 1961-1990)

- "driest": decrease from -15.1 to -30% (2% of simulations);
- "main agreement": decrease from -0.1 to -5% (33% of simulations);
- "wettest": increase from +5.1 a +15% (15% of simulations);
- Sign of change: 58% of the simulations agree to some decrease.

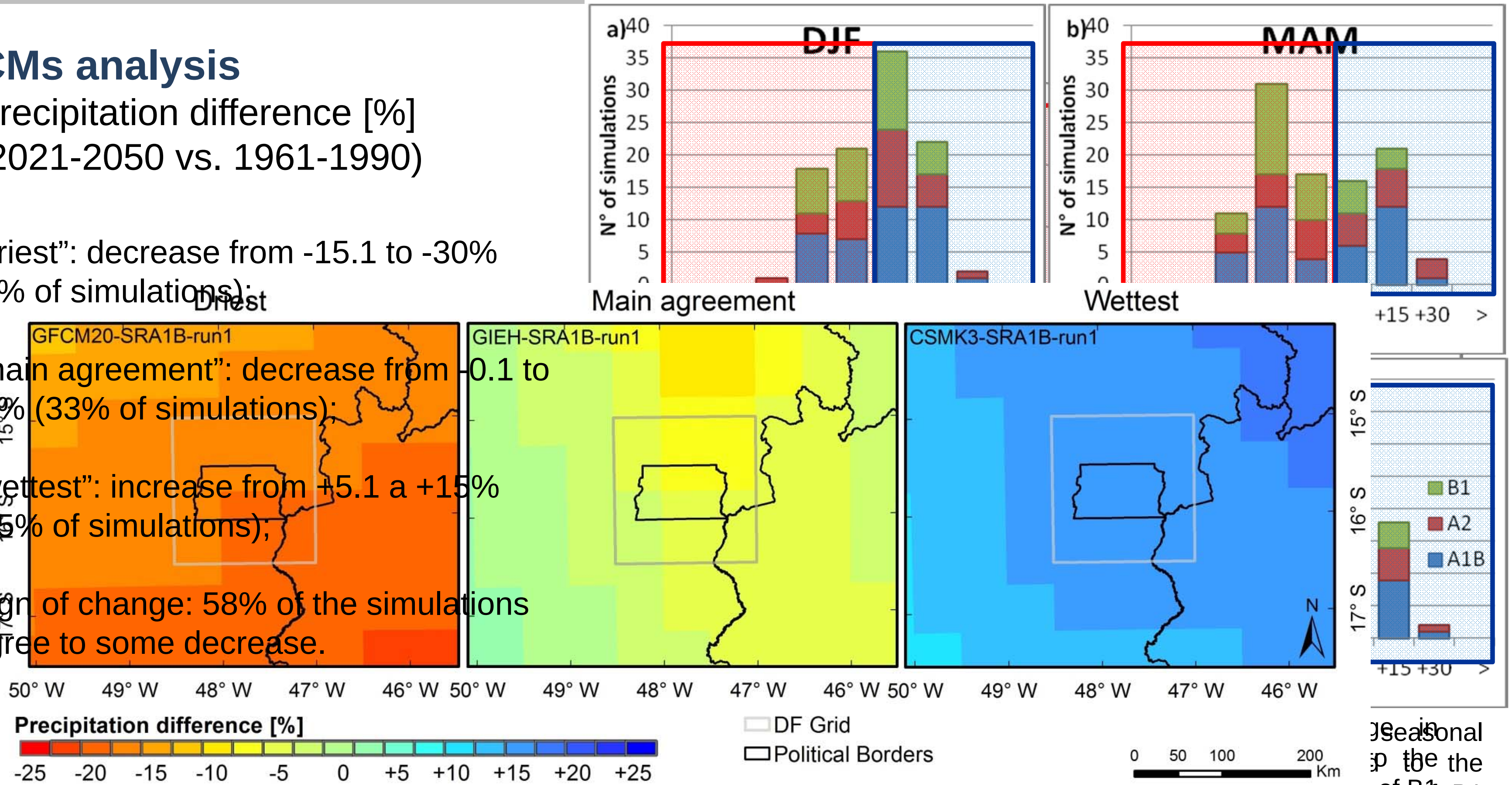


Figure: Illustration of the GCMs outputs according to the differences in annual precipitation [%] for the period 2021-2050, compared to the climatological normal (1961-1990). Simulations are representative to climate futures "driest" (GFCM20-SRA1B), "main agreement" (GIEH-SRA1B) and "wettest" (CSMK3-SRA1B).

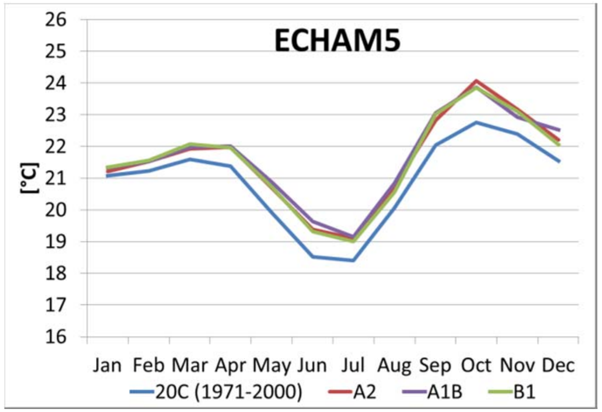
... seasonal ... to the climatological normal (i.e., 1961-1990). In green, the simulations of B1 scenario (optimistic); in red the simulations A2 (pessimistic) and in blue the simulations of scenario A1B (moderate). ... December, January and February – DJF; b) March, April and May – MAM; c) June, July and August – JJA; d) September, October and November – SON.

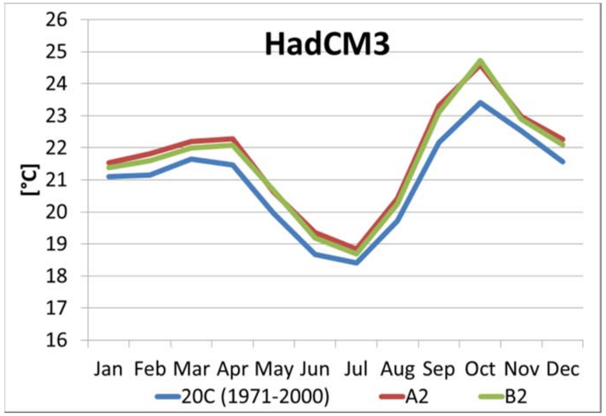
3 Future Scenarios

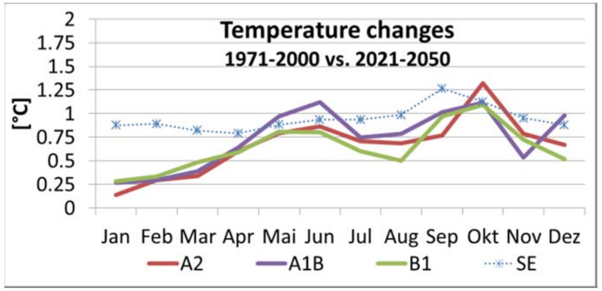
2. Statistical Downscaling - SDSM

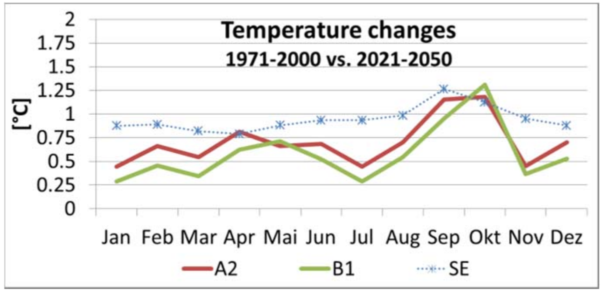
- Brasília-INMET station

Mean Temperature (**2021-2050**)







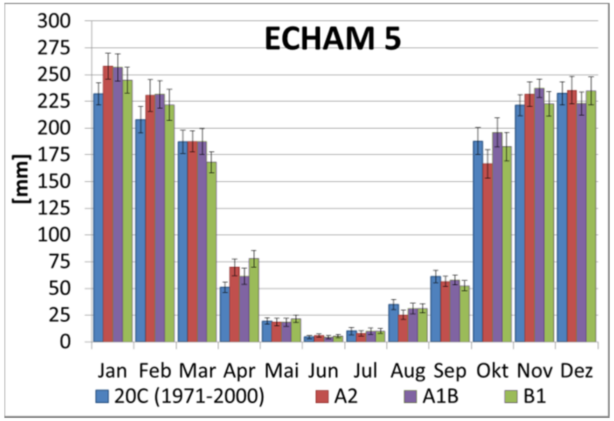


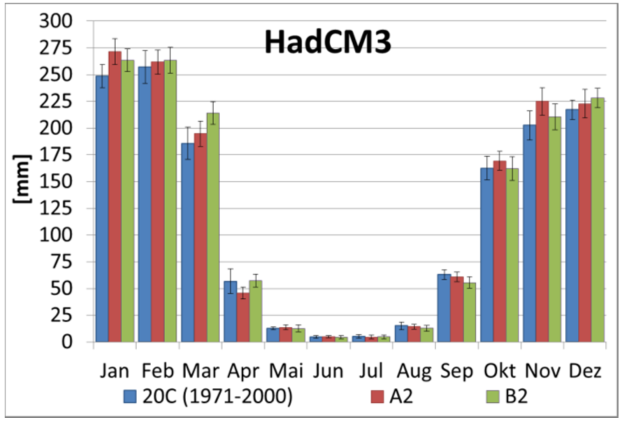
3 Future Scenarios

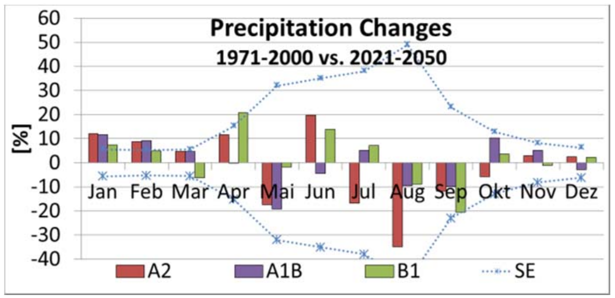
2. Statistical Downscaling - SDSM

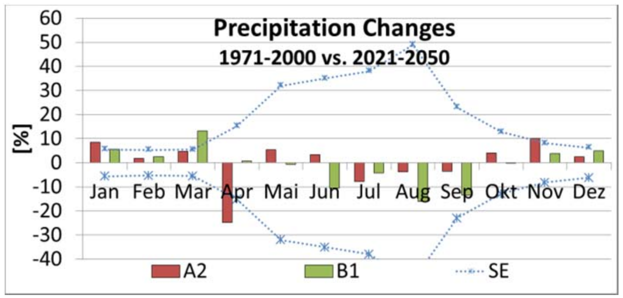
- Brasília-INMET station

Precipitation (**2021-2050**)









4 Conclusions

- **Consistent Database;**
- **Knowledge of regional climate patterns, as well as spatial and temporal distribution of climatic variables;**
- **Robust assessment of future climate scenarios;**
- **Temperature:**
  - Already under increasing temperature;
  - Scenarios indicate regional warming of at least 0,6°C, and more likely 1.5°C, for 2021-2050 period.

- **Precipitation:**
  - Already affected;
  - Scenarios indicate anomalies in the annual distribution of rainfall;
  - Wetter summers and dryer winters;

- **Analysis on frequency of extreme events is needed;**
- **Include other climatic variables (humidity, wind velocity and global radiation);**
- **MPI for GCMs and new generation (CMIP5).**
- **Cooperation**
  - 5 publications;
  - 1 Book chapter;
  - 4 Workshops;
  - Very high potential for further cooperation.

IWAS Brazil ÁGUA-DF

TECHNISCHE UNIVERSITÄT DRESDEN

WG I – Climate in Central Brazil

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Andrea Malheiros Ramos - INMET
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Funded by
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