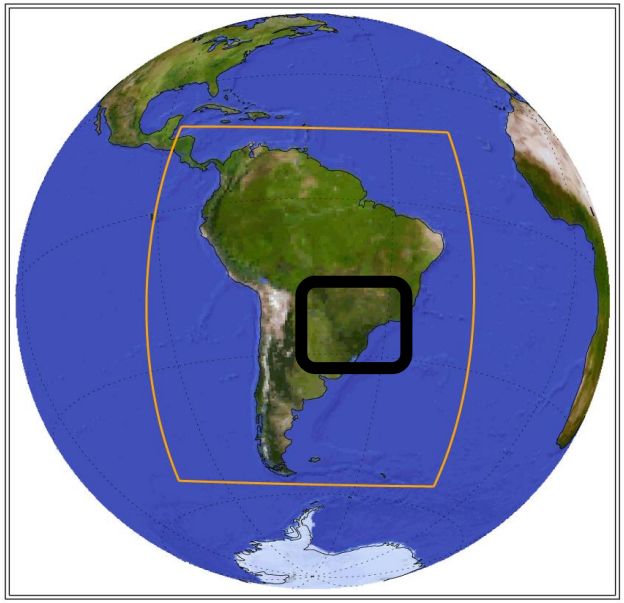
WCRP CORDEX
FLAGSHIP PILOT STUDIES

CORDEX-Flagship Pilot Study in Southeastern South America

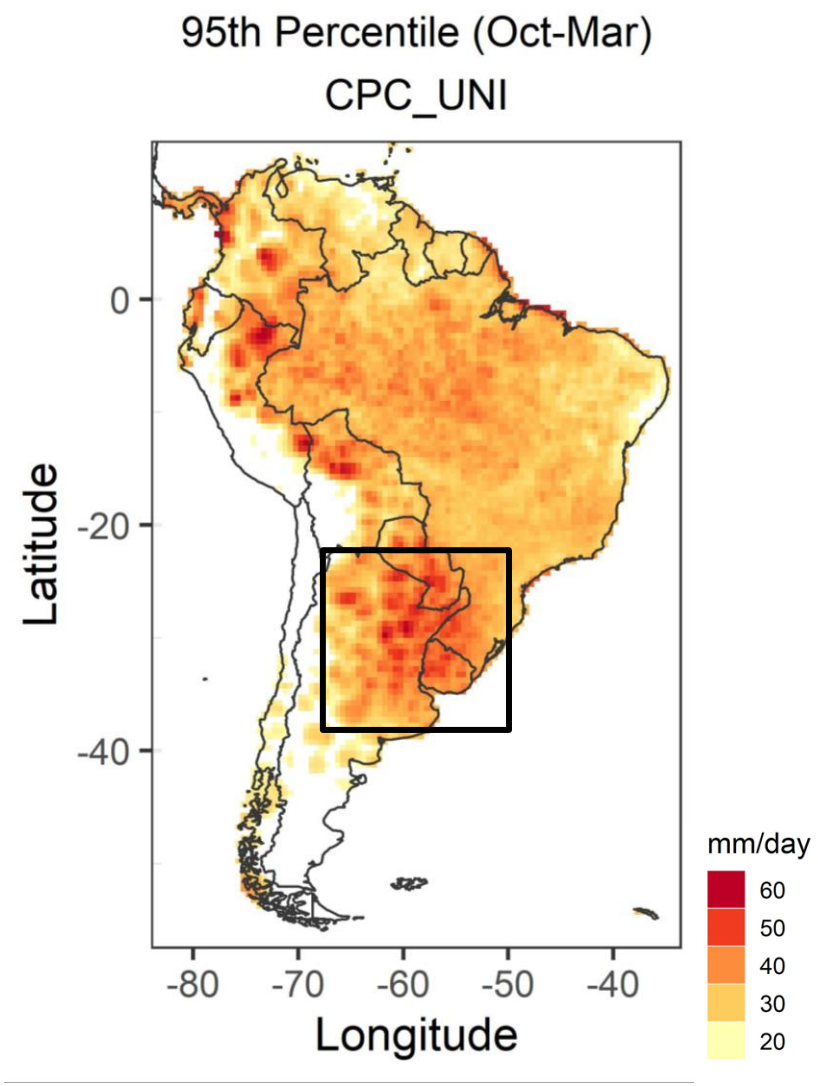
- ***FPS-SESA: Extreme precipitation events in Southeastern South America: a proposal for a better understanding and modeling***



SOUTHEASTERN SOUTH AMERICA (SESA)

http://cordexfpssesa.at.fcen.uba.ar/index.php

Motivation



- In SESA, extreme precipitation events are:

  - **typical** features.

  - becoming **more frequent** and **more intense.**

- They have large **socio-economic** and **hydrologic impacts**.

- It is **still a challenge** to better identify the factors and mechanisms that determine the location, intensity and frequency of the precipitation extremes and their large impacts.

CORDEX perspective:

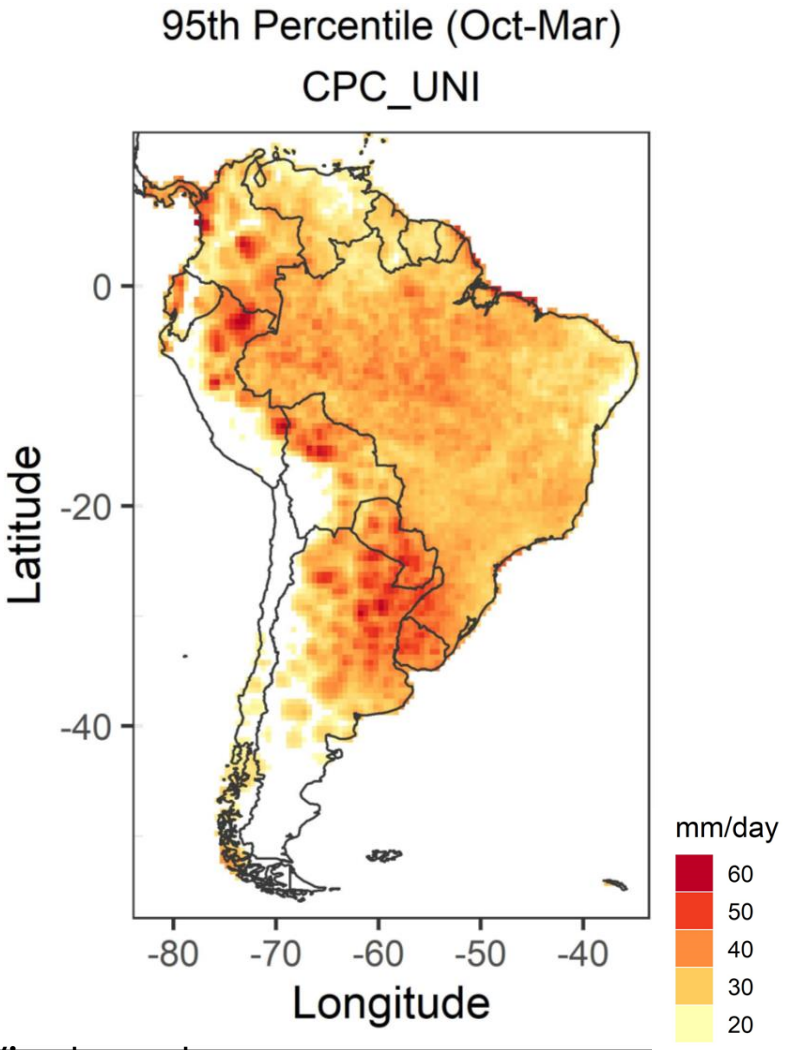
- There are **limited statistical downscaling studies** in the region.

- There is a need for developing **RCM and ESD coordinated actions**.

CORDEX-FPS-SESA

Objectives

- *to study **multi-scale processes and interactions** that result in **extreme precipitation** events;*
- *to develop actionable **climate information from statistical (ESD) and dynamical (RCM) downscaling** based on co-production with the **impact and user community***



http://cordexfpssesa.at.fcen.uba.ar/index.php

CORDEX-FPS-SESA

- **ARGENTINA :**

DCAO-University of Buenos Aires

CIMA-CONICET

- **BRAZIL :** USP – UNESP- CPTEC

INPE - EMBRAPA

- **URUGUAY:** Department of Atmospheric Sciences, University of the Republic

- **CZECHIA:** Charles University in Prague
- **SPAIN:** CSIC / University of Cantabria
- **ITALY:** ICTP

CORDEX-FPS-SESA

- **ARGENTINA :**

DCAO-University of Buenos Aires

CIMA-CONICET

- **BRAZIL :** USP – UN

INPE - EMBRAPA

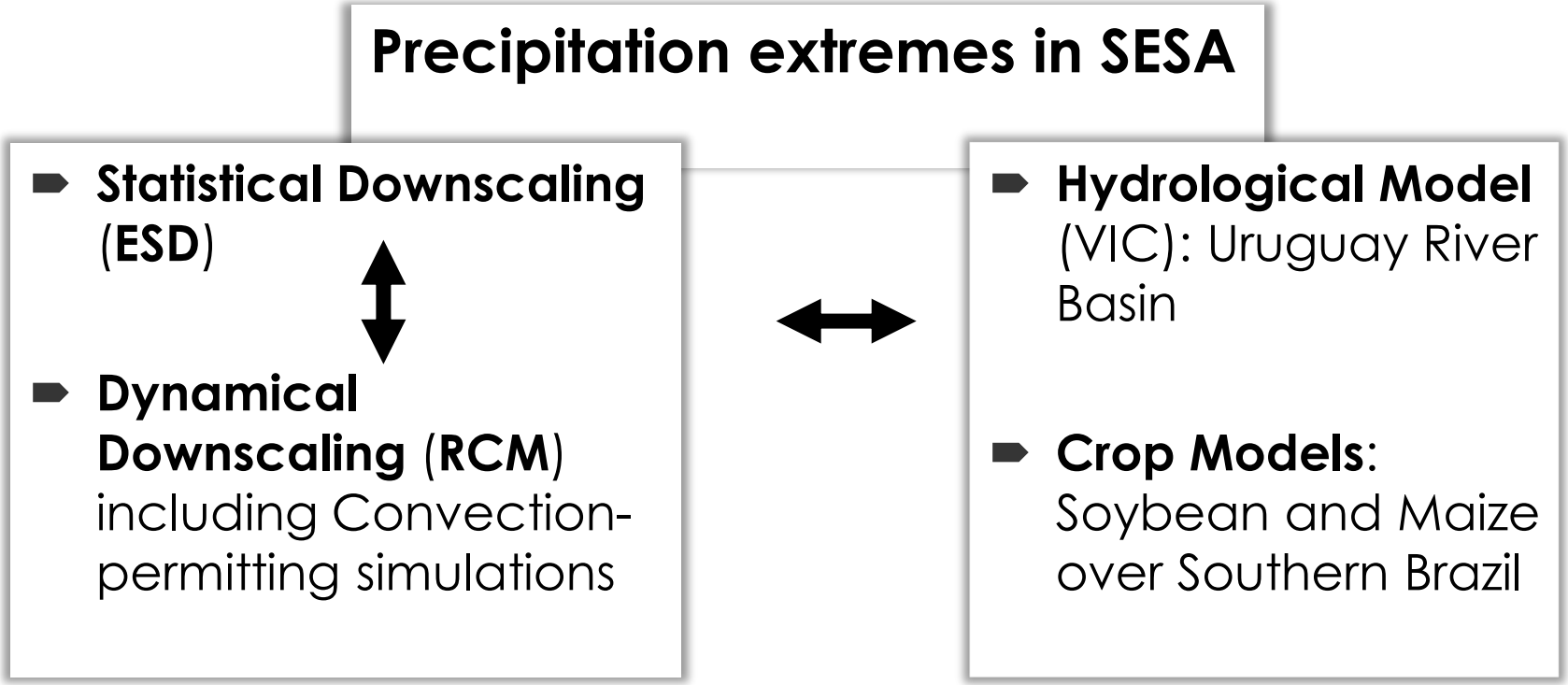
- **URUGUAY:** Departi
  Atmospheric Scien
  University of the Rep

to promote inter-institutional **collaboration** and further **networking** with focus on extreme rainfall events

- **H REPUBLIC:**
  s University in

  CSIC /
  University of
  Cantabria
- **ITALY:** ICTP

EXPERIMENTAL SETUP



EXPERIMENTAL SETUP

Precipitation extremes in SESA

- **Statistical Downscaling (ESD)**
- **Dynamical Downscaling (RCM)** including Convection-permitting simulations

- Collaboration
- Intercomparison
- Integration of ESD within the CORDEX framework

- **Hydrological Model** (VIC): Uruguay River Basin
- **Crop Models**: Soybean and Maize over Southern Brazil

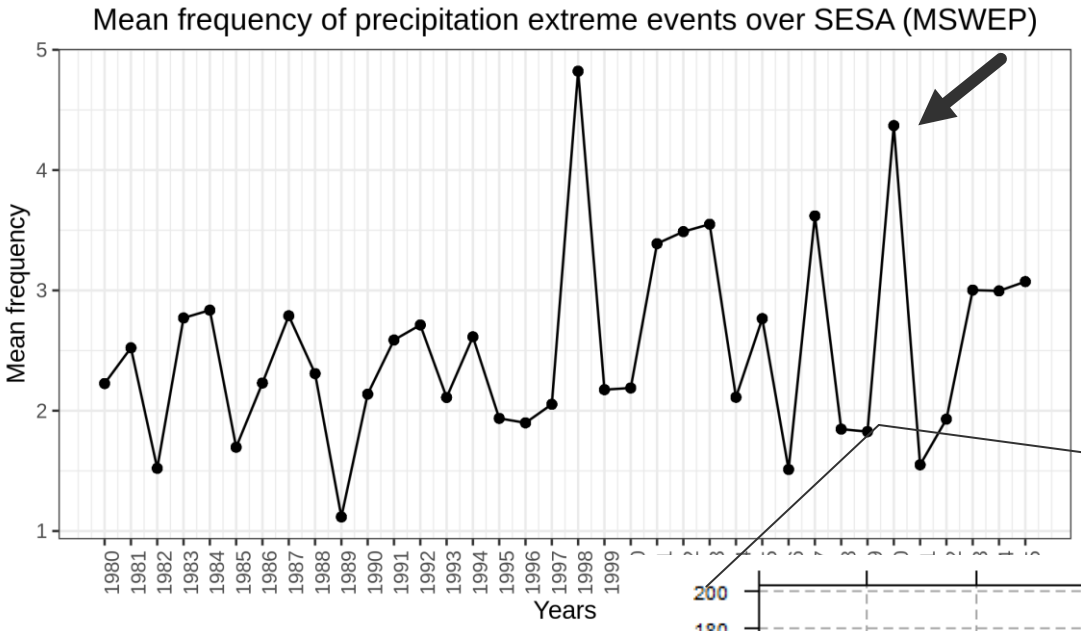
- To study the impact of extreme precipitation

EXPERIMENTAL SETUP

- **Phase I:** Simulations in the **2009-2010 warm season** (Oct-Mar) over SESA

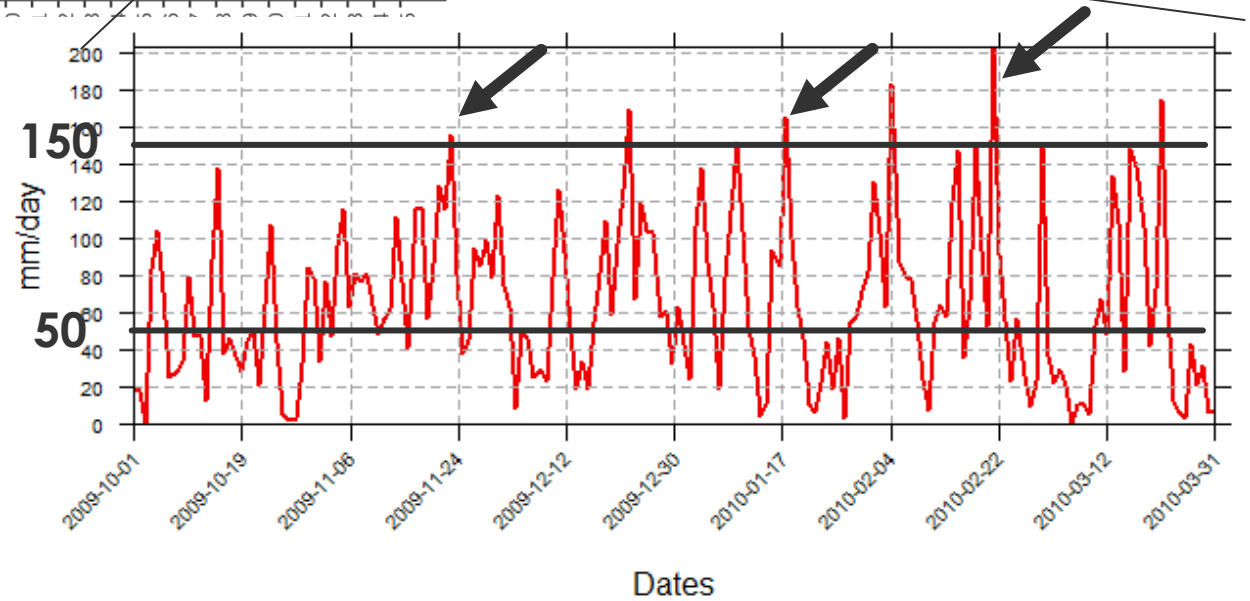
- **Phase II: 3 consecutive years** covering the period Jun 2018 to May 2021 in an extended domain.

2009-2010 Warm Season



- High number of extreme events during **2009-2010 warm season** (October to March).
- **Three case studies** within that season were selected.

Maximum Daily Precipitation in SESA Station Data
2009-10 Warm Season Selected

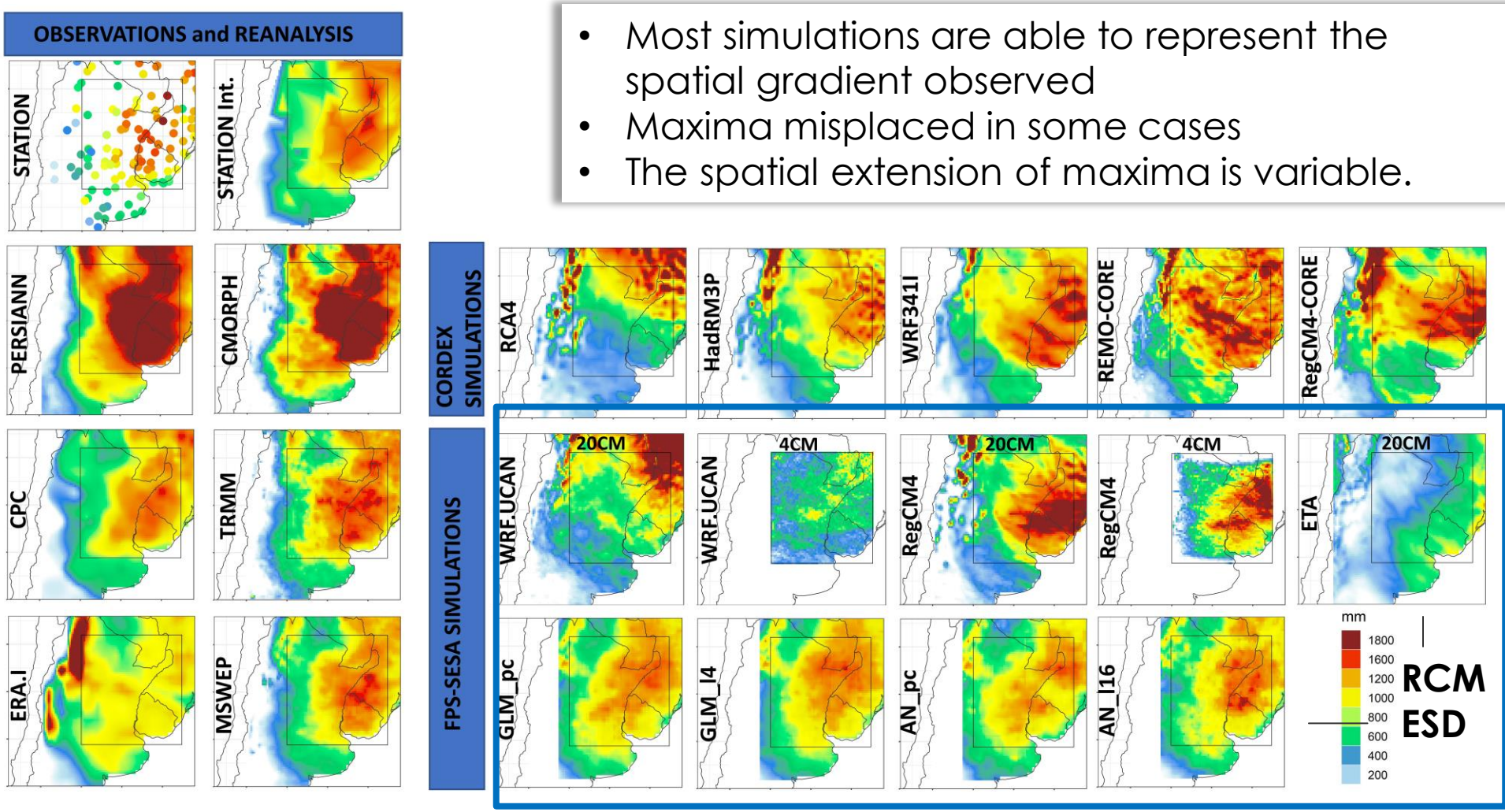


2009-2010 Warm Season

RCM	Label (model name+spatial resolution+type of simulation)	Institution
RegCM4	RegCM4.4WL RegCM4.20WL RegCM4.4CM RegCM4.20CM	University of Sao Paulo - São Paulo State University
ETA	ETA.4WL ETA.20WL ETA.4CM ETA.20CM	National Institute for Space Research-Brazil
WRF381	WRF.UCAN.4WL WRF.UCAN.20WL WRF.UCAN.4CM WRF.UCAN.20CM	University of Cantabria/CSIC
WRF391	WRF.CIMA.4WL WRF.CIMA.20WL WRF.CIMA.4CM WRF.CIMA.20CM	CIMA-University of Buenos Aires-CONICET

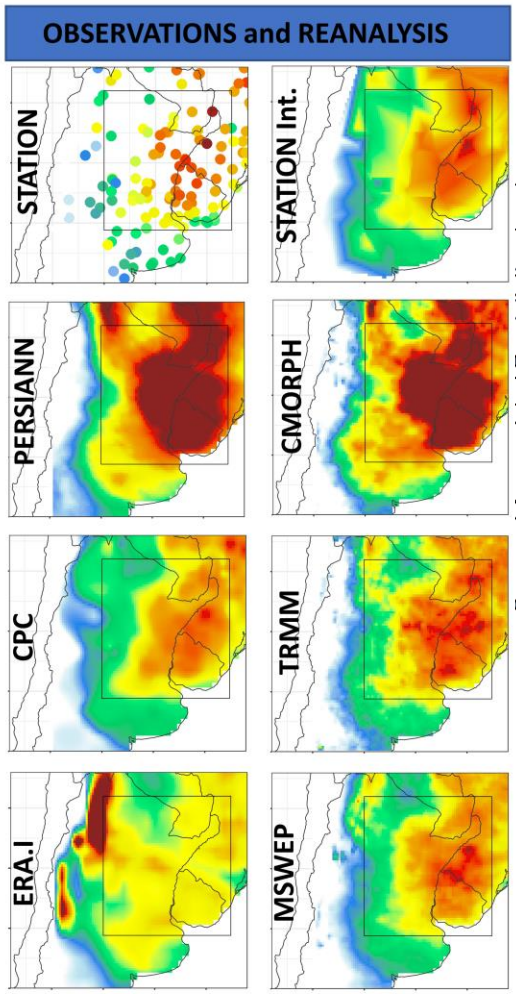
2009-2010 Seasonal Accumulated Precipitation

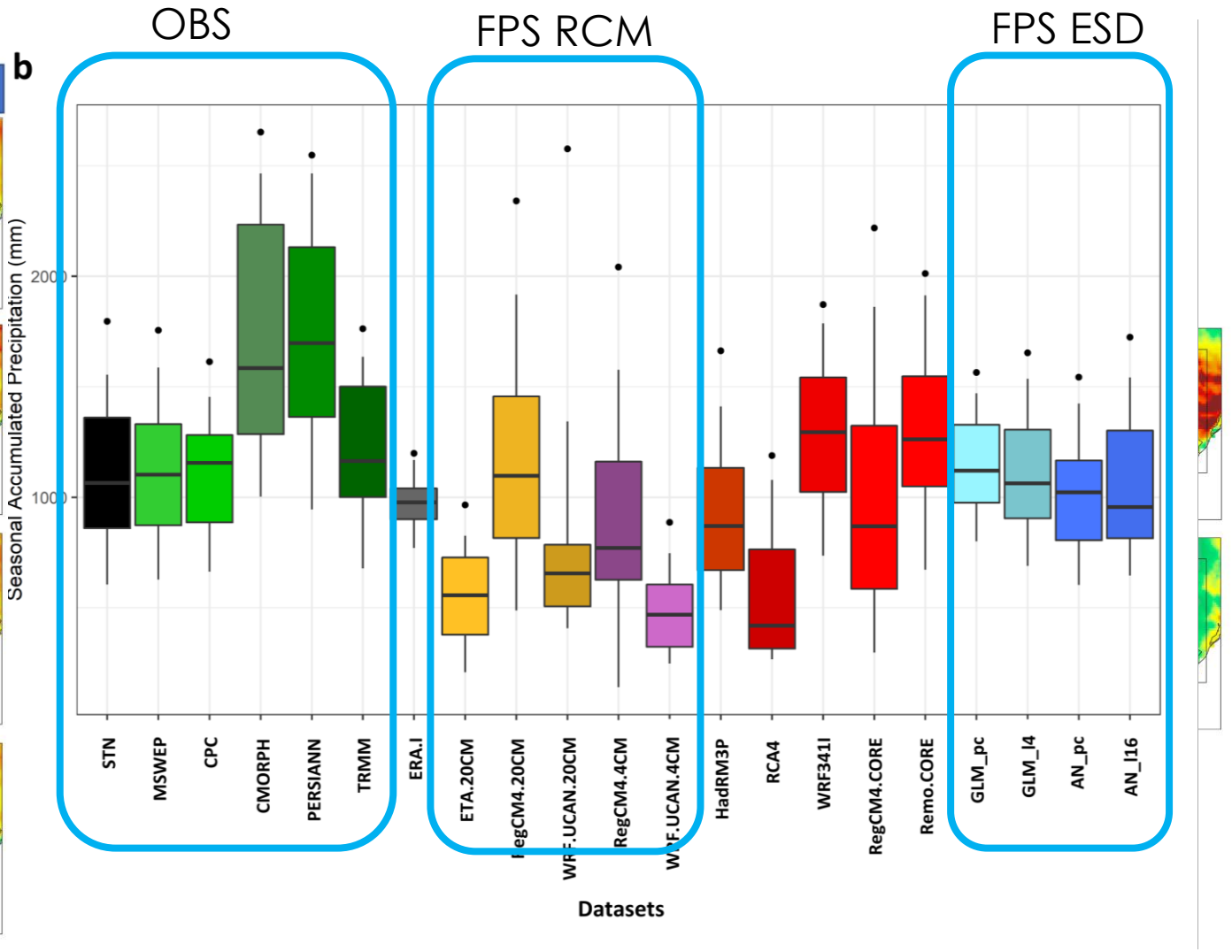
- Most simulations are able to represent the spatial gradient observed
- Maxima misplaced in some cases
- The spatial extension of maxima is variable.



Bettolli et al (2021) Clim Dyn https://doi.org/10.1007/s00382-020-05549-z

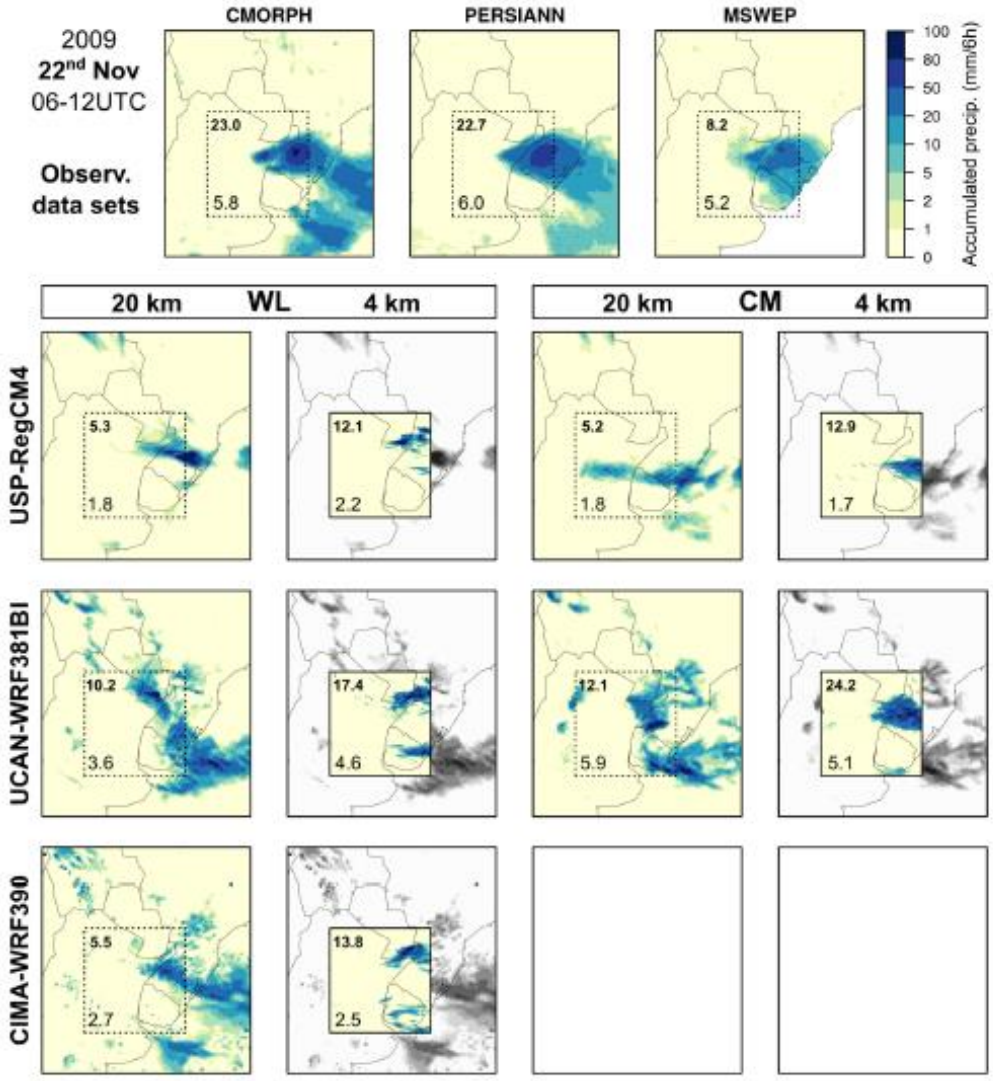
2009-2010 Warm Season





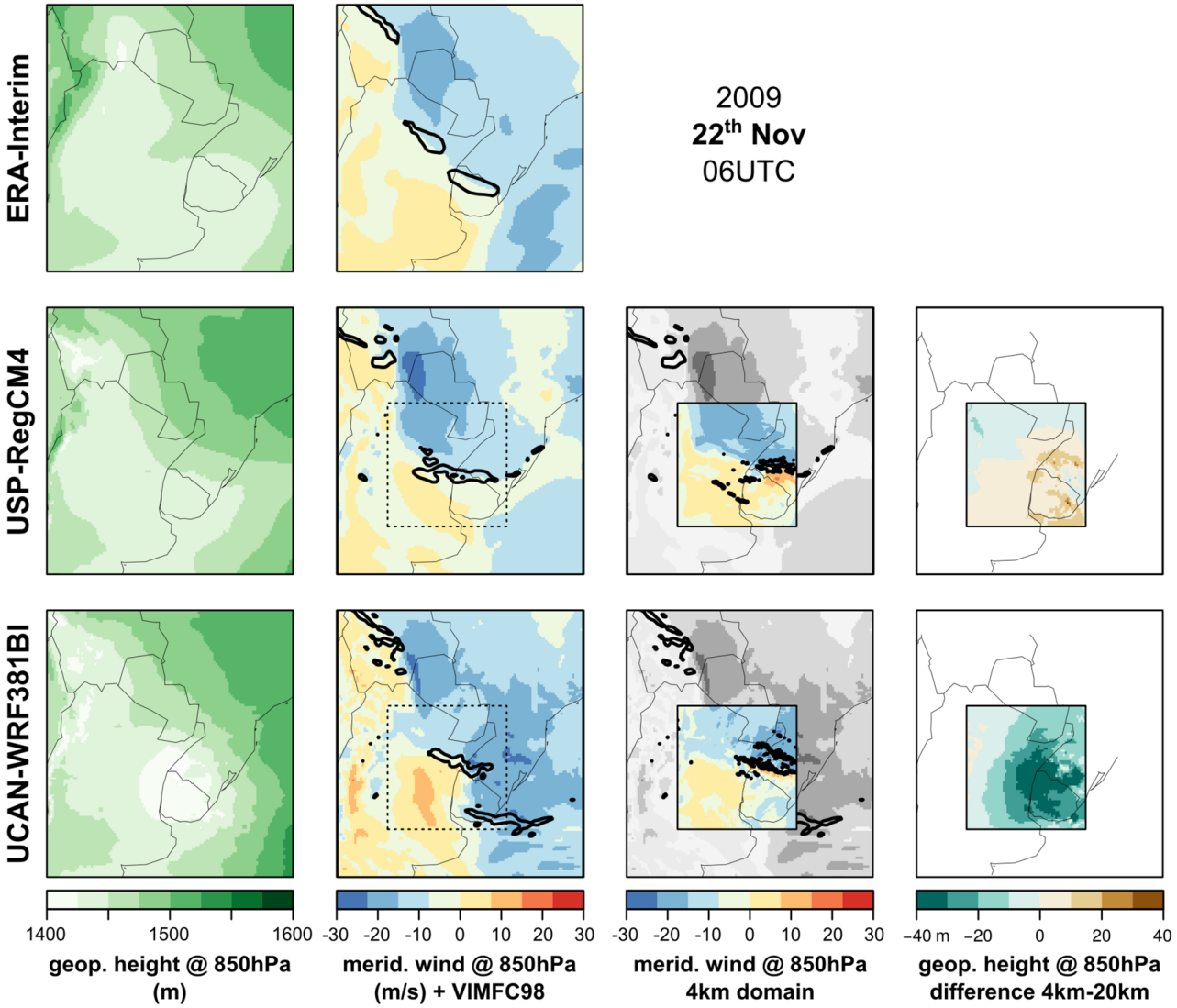
Bettolli et al (2021) Clim Dyn https://doi.org/10.1007/s00382-020-05549-z

2009-2010 Season



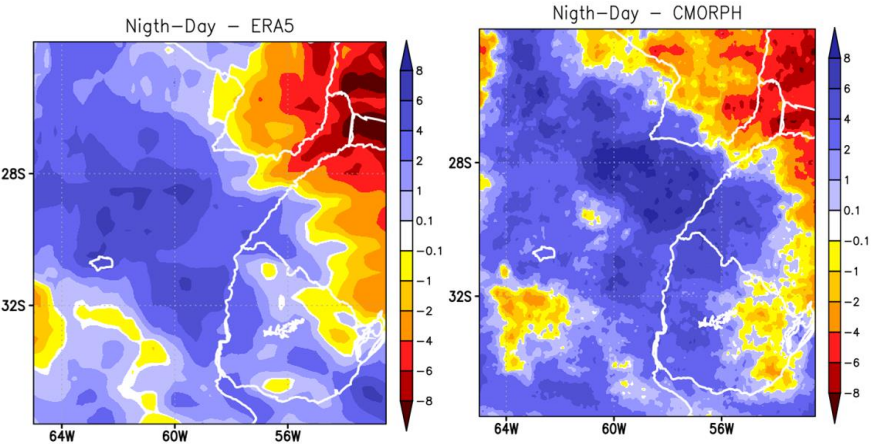
Lavin-Gullon et al (2021) Clim Dyn https://doi.org/10.1007/s00382-021-05637-8

2009-2010 Season



Lavin-Gullon et al (2021) Clim Dyn https://doi.org/10.1007/s00382-021-05637-8

Nighttime minus daytime precipitation



CMORPH **ERA5**

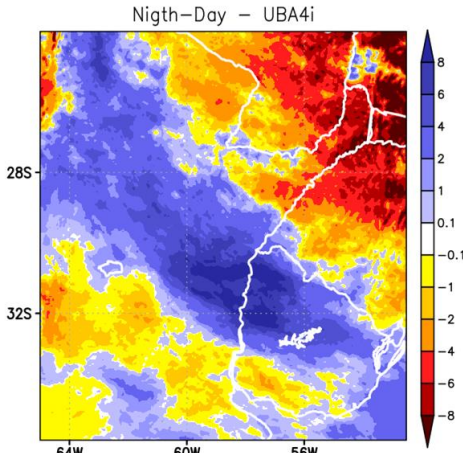
UCAN-WRF and USP-RegCM4 CP capture better the spatial pattern shown by CMORPH and ERA5;

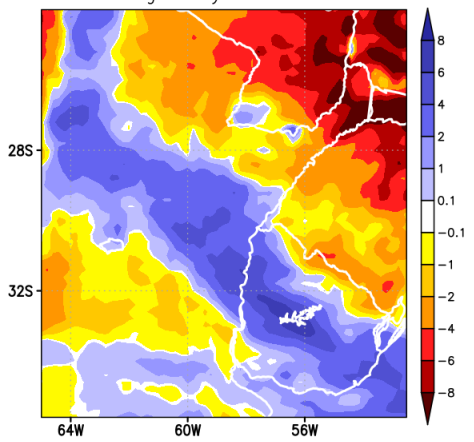
CIMA-WRF → CP and non-CP have similar spatial pattern

Courtesy of Rosmeri P da Rocha

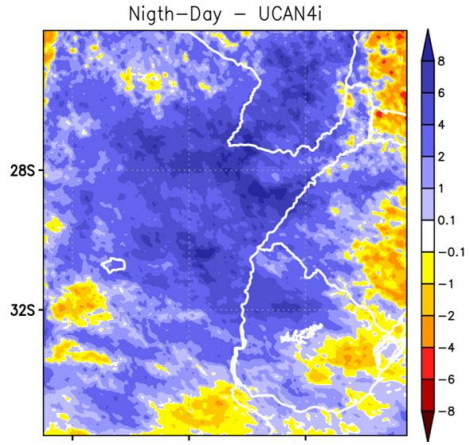
CP **non-CP**

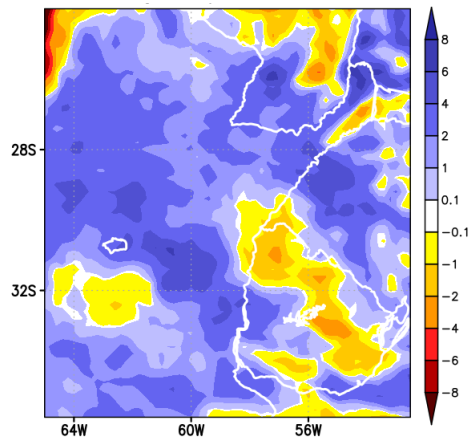
CIMA



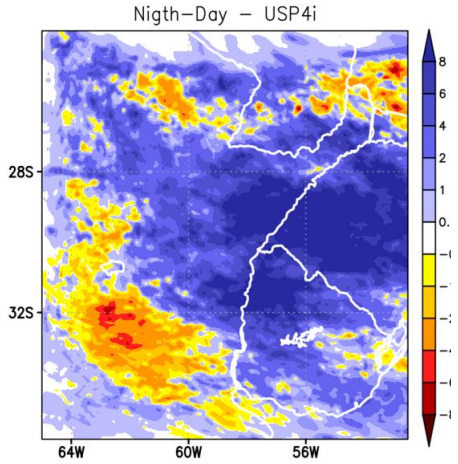


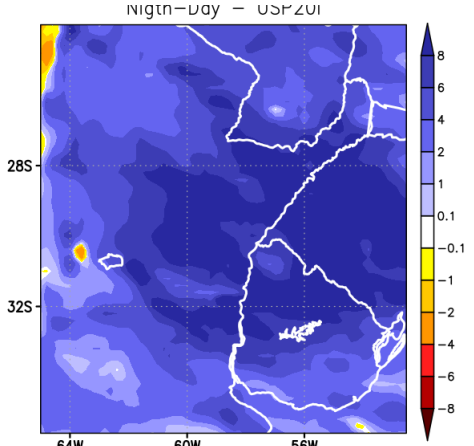
UCAN





USP



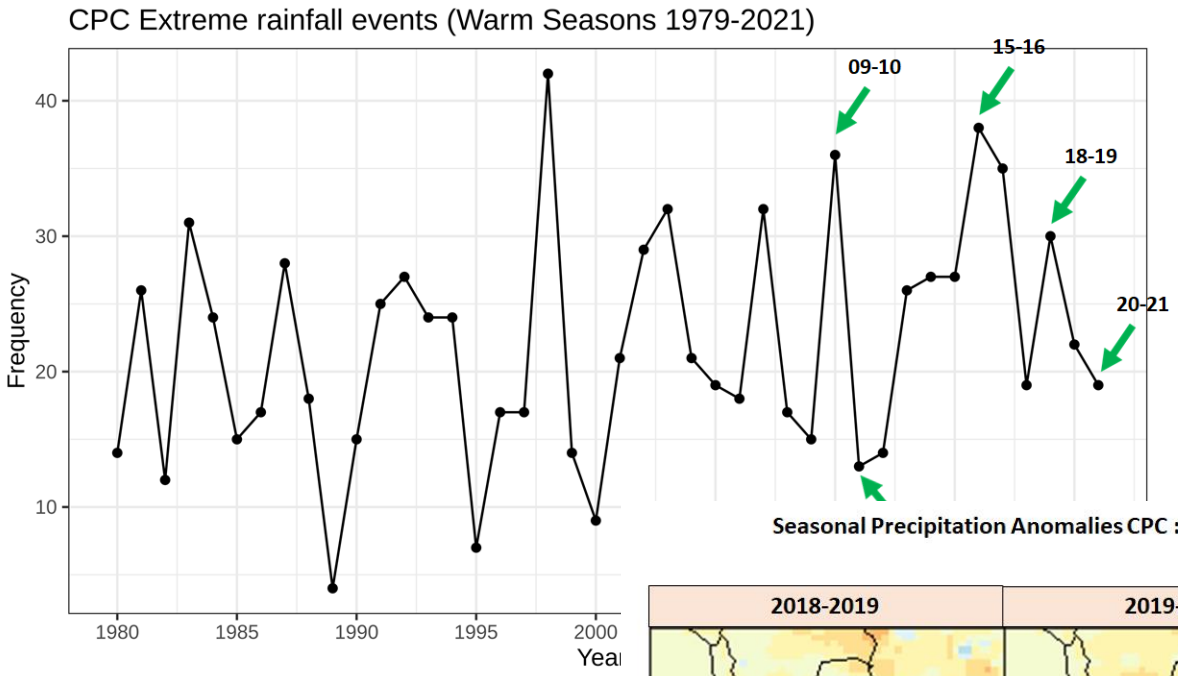


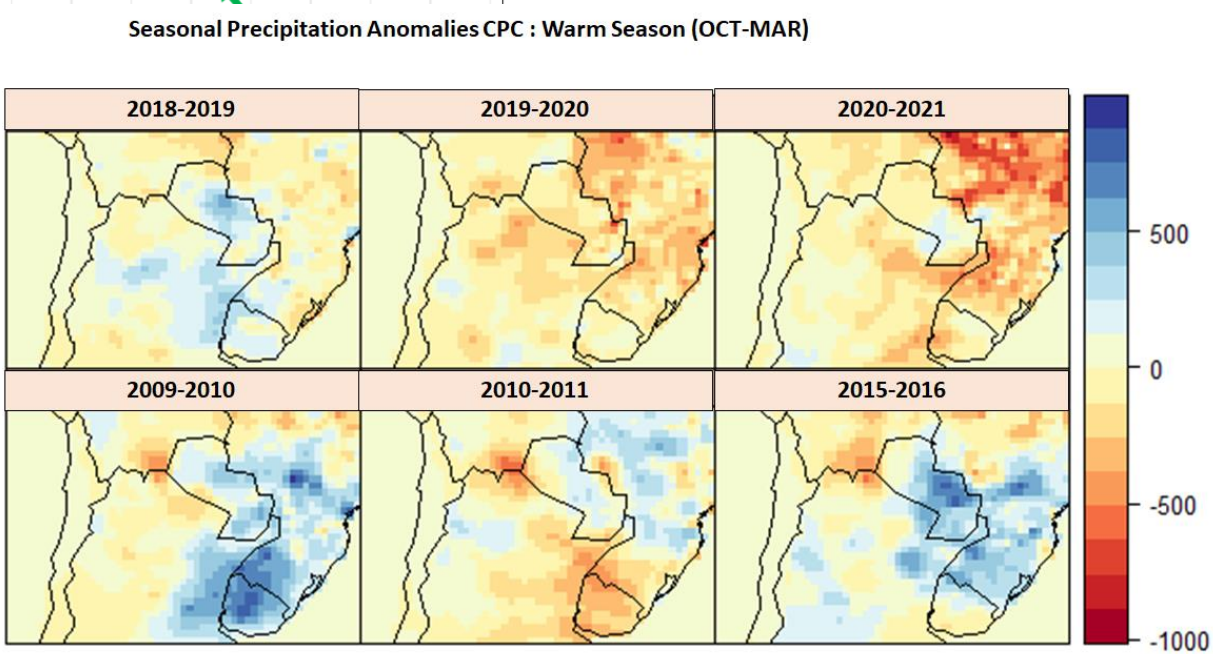
EXPERIMENTAL SETUP

- **Phase I:** Simulations in the **2009-2010 warm season** (Oct-Mar) over SESA

- **Phase II: 3 consecutive years** covering the period Jun 2018 to May 2021 in an extended domain.

EXPERIMENTAL SETUP

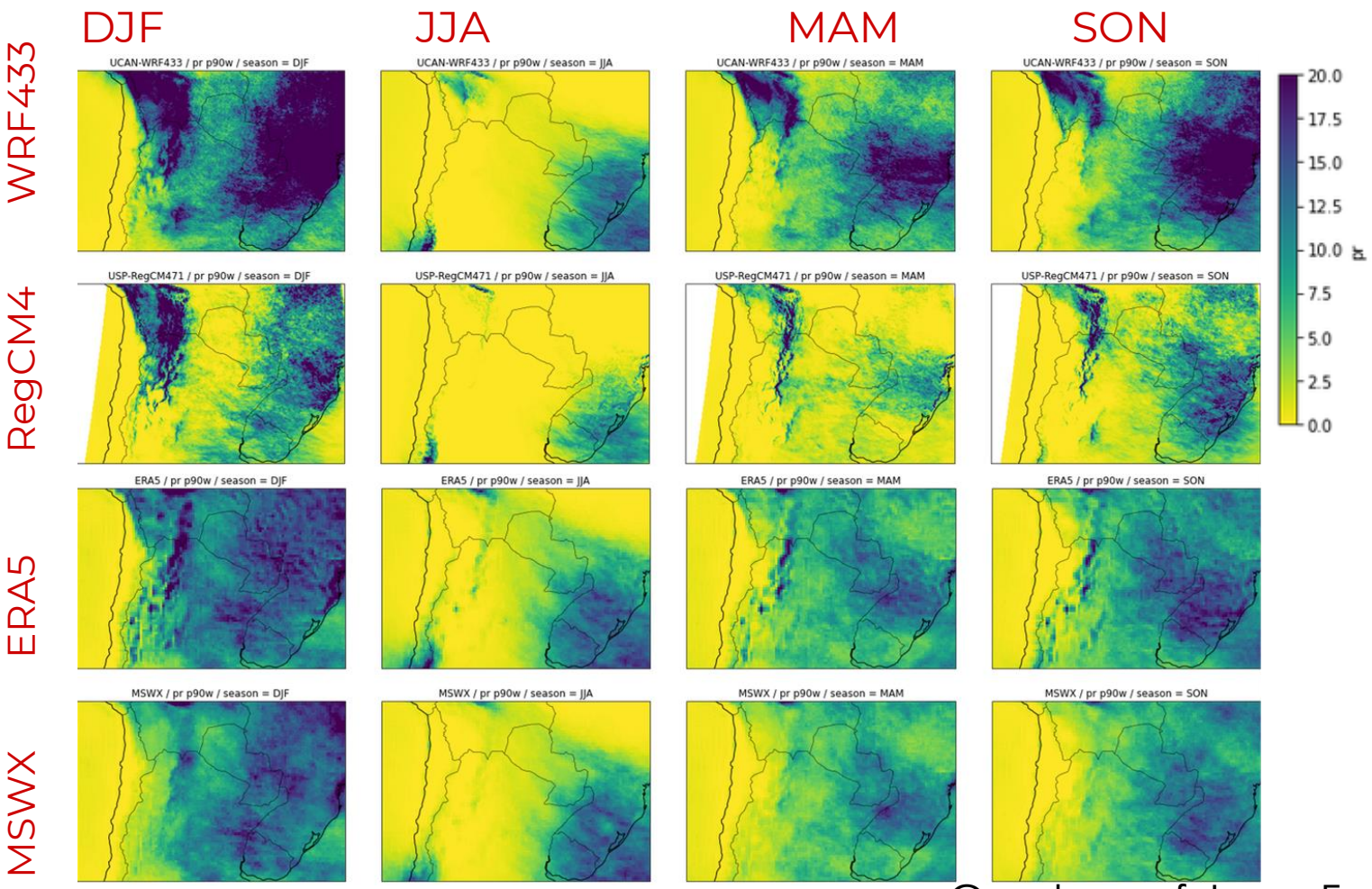




2018-2021 Period

RCM	Institution
RegCM4	University of Sao Paulo - São Paulo State University
RegCM5	ICTP, Italy
ETA	National Institute for Space Research-Brazil
WRF	University of Cantabria/CSIC
WRF	CIMA-University of Buenos Aires-CONICET
WRF	NCAR

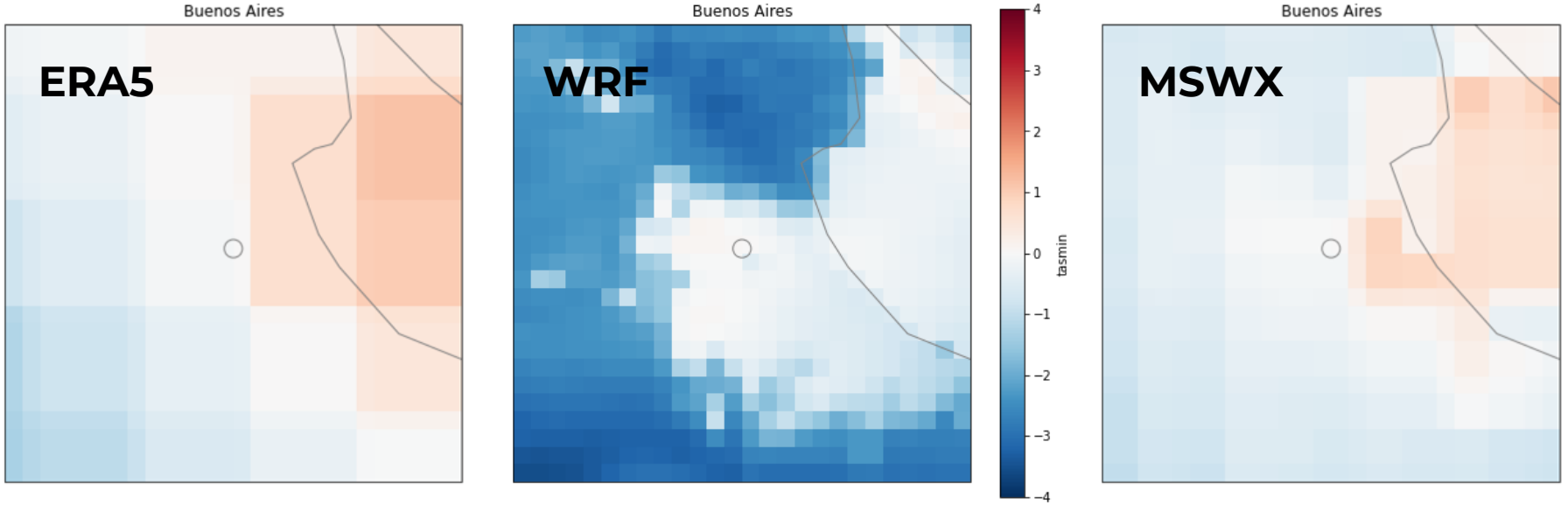
Seasonal precipitation 90th perc. (wet days)



Courtesy of Jesus Fernandez

Large-city effects

No explicit urban model was used; just "Urban and built-up" MODIS land use category



Anomaly with respect to city-centered grid point (mean of the 10 warmest nights)

Courtesy of Jesus Fernandez

Conclusions of the FPS experience so far

- Results revealed the **strengths and weaknesses** of ESD and RCM simulations in reproducing daily precipitation over Southeastern South America.
- The methods showed overall good performance in simulating daily precipitation characteristics over the region, **but no single model performed best over all validation metrics and aspects evaluated**.
- These evidenced the need to produce **multi-model and multi-method** simulations.
- **Inter-institutional collaboration** and **coordinated science are key** aspects to address these end-to-end studies.

Thanks!

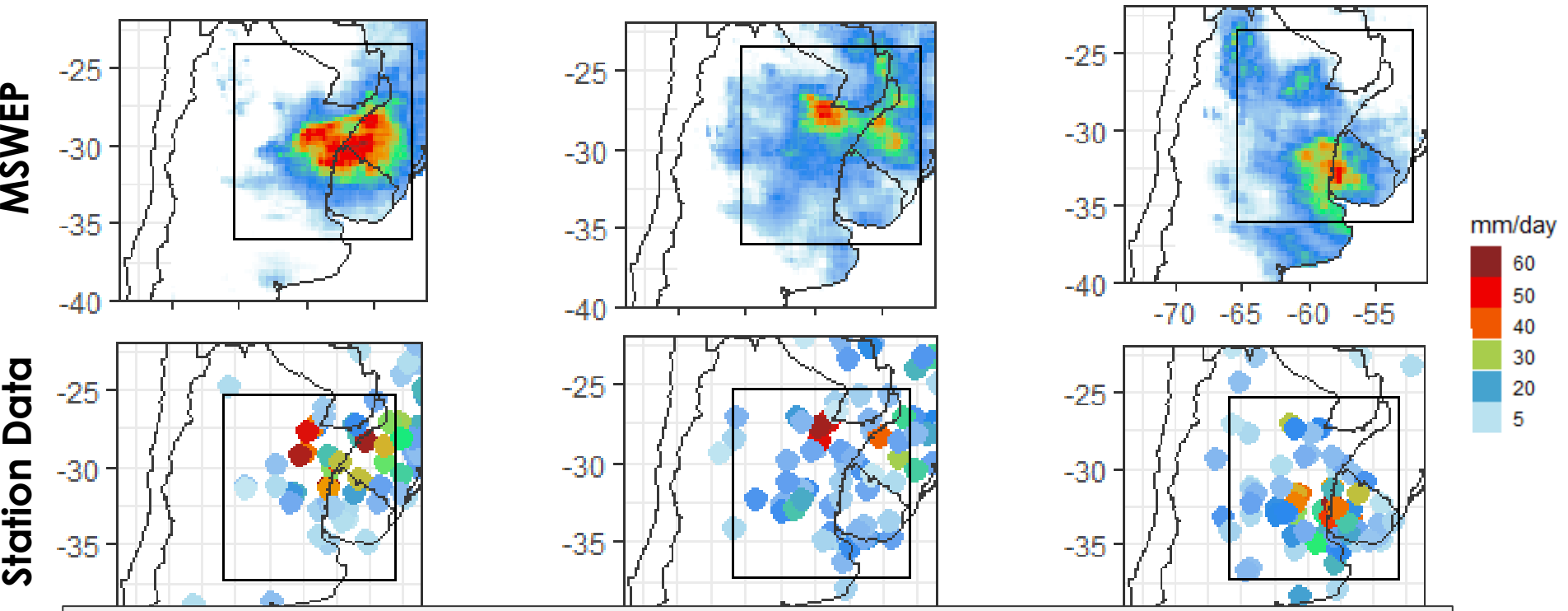
¡Muchas gracias!

bettolli@at.fcen.uba.ar

2009-2010 warm season

- **Case 1**
  3-day event: 2009-11-21 to 23
  event peak: 22-11-2009
  station max: 155 mm/day
- **Case 2**
  3-day event: 2010-01-18 to 20
  event peak: 19-01-2010
  station max: 165.4 mm/day
- **Case 3**
  3-day event: 2010-02-19 to 21
  event peak: 20-02-2010
  station max: 150 mm/day

3-day accumulated precipitation (mm/day)



The events selected have different **areal extensions and locations**

RCM simulations setup

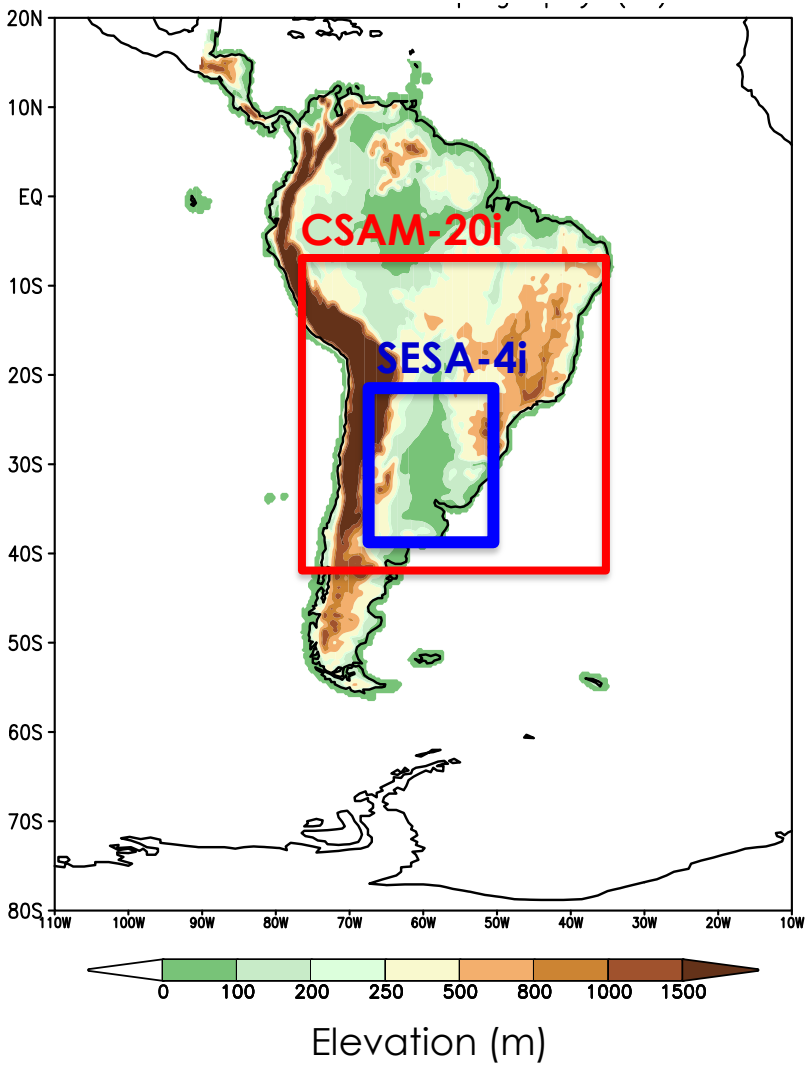
- The experimental design follows that of the FPS on Convective phenomena over Europe and Mediterranean (Coppola et al. 2019)
- **Weather Like (WL)** mode simulations starting 24 hours before the onset of each of 3 selected extreme events and run for a few days until the end of each event. **As in numerical weather prediction, these simulations benefit from an accurate initial atmospheric state**. **Climate Mode (CM)** simulations run continuously for a 6-month period starting October 1, 2009 at 00:00 UTC and ending March 31, 2010. The three extreme events occur in the CM simulations far from the initial conditions and, therefore, **this simulation mode emulates typical RCM, which is a boundary value problem.**
- Two domains and resolutions were considered: a **~20 km** horizontal grid spacing domain covering central South America (CSAM) and a **~4 km-resolution domain nested into the former focused on SESA**. The SESA domain reaches the so-called **convection-permitting resolution**, where the model dynamics explicitly develops convective cells and, therefore, the deep convection parameterization was deactivated.
- The **shallow convection parameterization was left active**.
- **One-way nesting** strategy was used and **no nudging** technique was applied inside the domain.
- For ease of comparison with observational datasets the simulations (in Mercator projections) were interpolated to the longitude-latitude grids, CSAM-20i and SESA-4i, using bilinear scheme.
- For 20-km simulations, **6-hourly ERA-interim reanalysis** data were used as boundary and

Table 2 Physical parameterizations used by each ensemble member

Parameterization scheme	CIMA-WRF390	UCAN-WRF381BI	USP-RegCM4
Radiation	RRTMG	RRTMG	CCM3
Microphysics	WDM6	WDM6	SUBEX in CSAM/WSM5 in SESA
Cumulus convection	Kain-Fritsch	Grell-Freitas	Tiedke in land/Kain-Fritsch in sea
Shallow convection	–	GRIMS	–
Land Surface	NOAH	NOAH-MP	CLM4.5
PBL	MYJ	MYNN2	Holtslag
Surface-layer	ETA-Sim	MYNN	M-O

Note that the cumulus parameterizations shown were only active in the outer (CSAM) domain. See Skamarock et al. (2008) and Giorgi et al. (2011) for further details and references for each scheme

2009-2010 warm season



RCM Simulations

- 2009-2010 season (Oct-Mar) & 3 extreme events

- **Two simulation types**

Climate mode (CM): continuous simulation (seasonal) starting at 01-10-2009 ending at 31-03-2010.

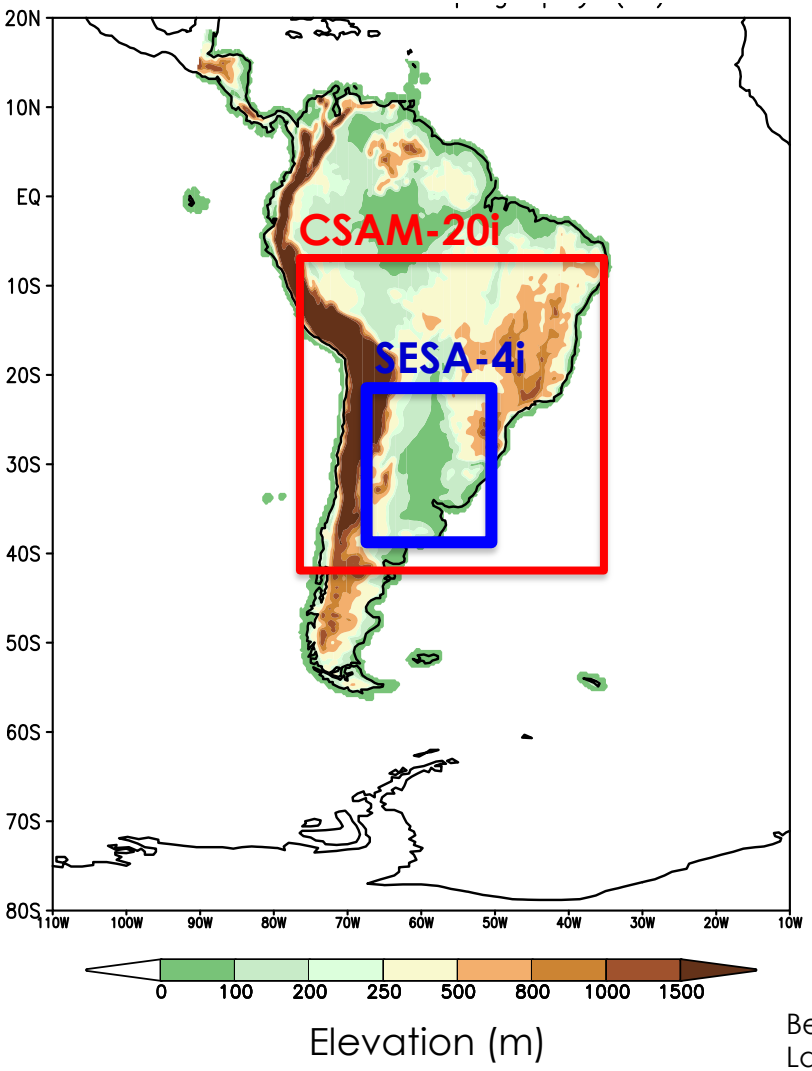
Weather like mode (WL): simulation starts ~24 hours before initial phase of each one of three extreme events;

- **Two domains**:

20 km (CSAM-20i) – convective parameterization

4 km (SESA-4i) – convection permitting

2009-2010 warm season



RCM Simulations

- **Initial and boundary conditions:**

CSAM-20i simulations were nested into ERA-Interim reanalysis;

SESA-4i simulations were nested into CSAMi-20i;

- **Models**:

RegCM4 (USP-UNESP, Brazil)

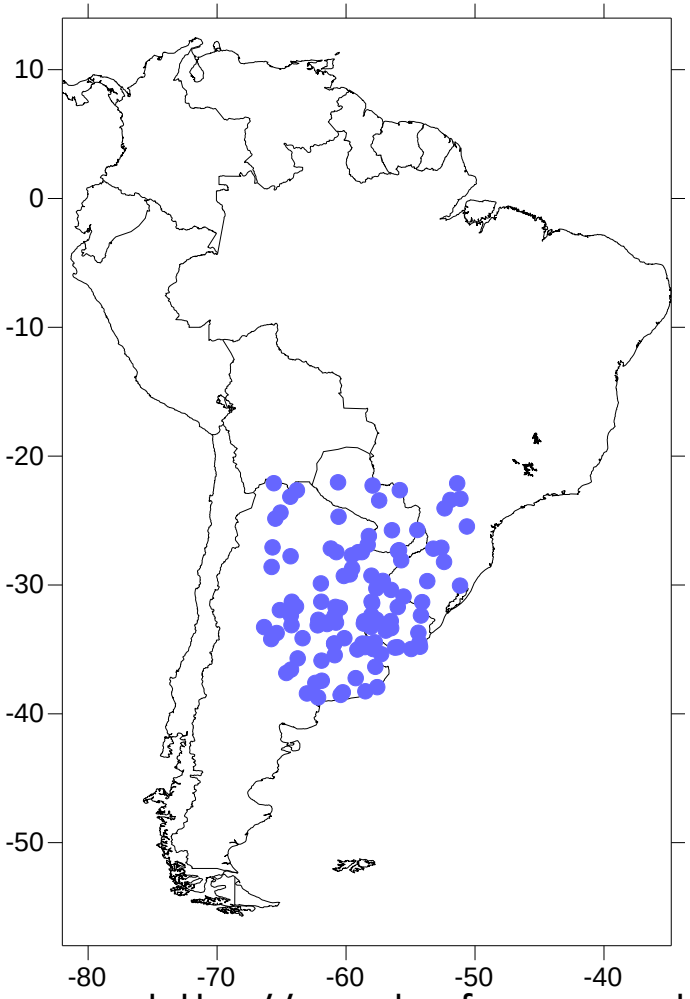
WRF391 (CIMA, Argentina)

WRF381 (IFCA/UCAN, Spain)

ETA (INPE, Brazil)

Bettolli et al 2021 Clim Dyn https://doi.org/10.1007/s00382-020-05549-z
Lavin-Guillon et al 2021 Clim Dyn https://doi.org/10.1007/s00382-021-05637-8

2009-2010 warm season

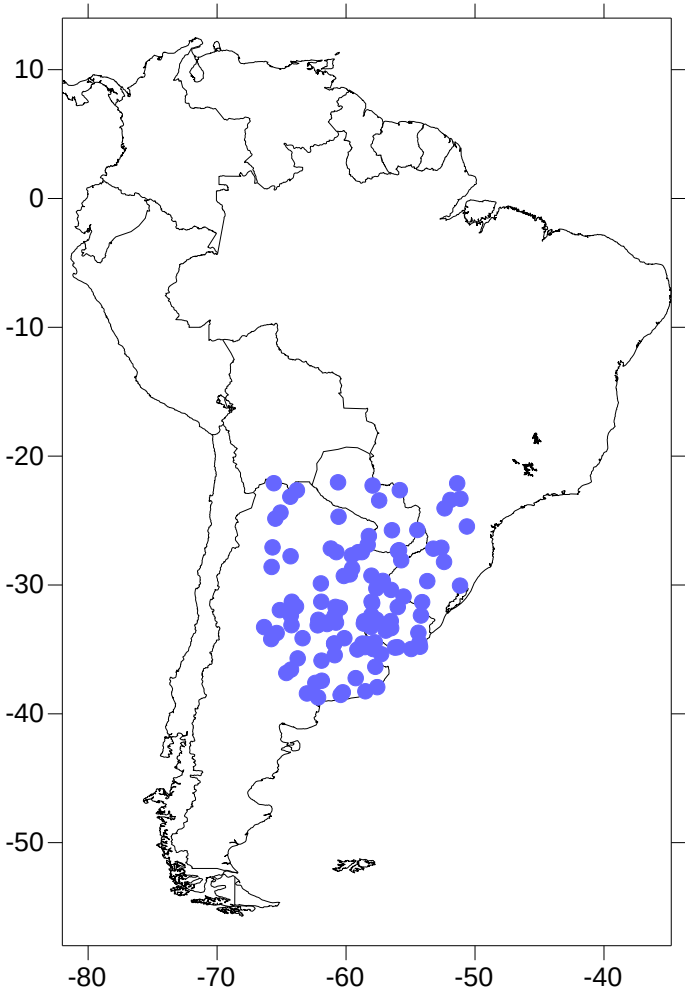


ESD Simulations

- **Approach:**
  Perfect Prognosis/MOS
- **Predictors:**
  ERA-Interim & JRA reanalysis
- **Predictands**:
  Daily Precipitation : Station Data (100) & MSWEP
- **Season:**
  October to March
- **Training and Test:**
  Cross validation k-folding strategy:
  6 folds containing 5 consecutive years in **the period 1979-2009**
  Independent Test period: 2009-2010

http://cordexfpssesa.at.fcen.uba.ar/index.php

2009-2010 warm season



ESD Simulations

Different statistical families, configurations and approaches were considered:

- **Analog Method**
- **Generalized Linear Models**
- **Generalized Linear Models conditioned on Weather Types**
- **Artificial Neural Networks**
- **Bias Adjustment Methods**

Simulations were performed in collaboration between the University of Buenos Aires and the University of Cantabria - **Climate4R**

Bettolli et al 2021 Clim Dyn https://doi.org/10.1007/s00382-020-05549-z