The FPS in Southeastern South America: actionable regional climate information for hydrological and agricultural sectors

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With a focus on extreme rainfall events in Southeastern South America (SESA), the FPS-SESA initiative promotes inter-institutional collaboration and networking to tackle the following specific objectives: 1) to study multi-scale processes and interactions that result in extreme precipitation events; 2) to develop actionable climate information from statistical and dynamical downscaling based on co-production with the impact and user community. The Phase 2 of the FPS-SESA comprehensively addresses this second objective, for which new RCM and ESD simulations to support planned impact modeling and studies of the streamflow of the Uruguay river and crop yields in Southern Brazil. Targeted convection-permitting (CP) RCM and deep learning-based ESD simulations were performed covering 3 consecutive years from June 2018 to May 2021 in order to consider different important aspects (interannual variability) and variables for impact modeling. This period corresponds to unprecedented dry conditions (Figure 1) that, combined with high temperatures, have led to widespread crop failures, wildfires and reduced water availability. In spite of that, many extreme and localized precipitation events occurred over SESA during this period (Figure 1), making it particularly challenging to simulate and to assess the impacts of these combined events on different productive systems in the area.

Experiment Design

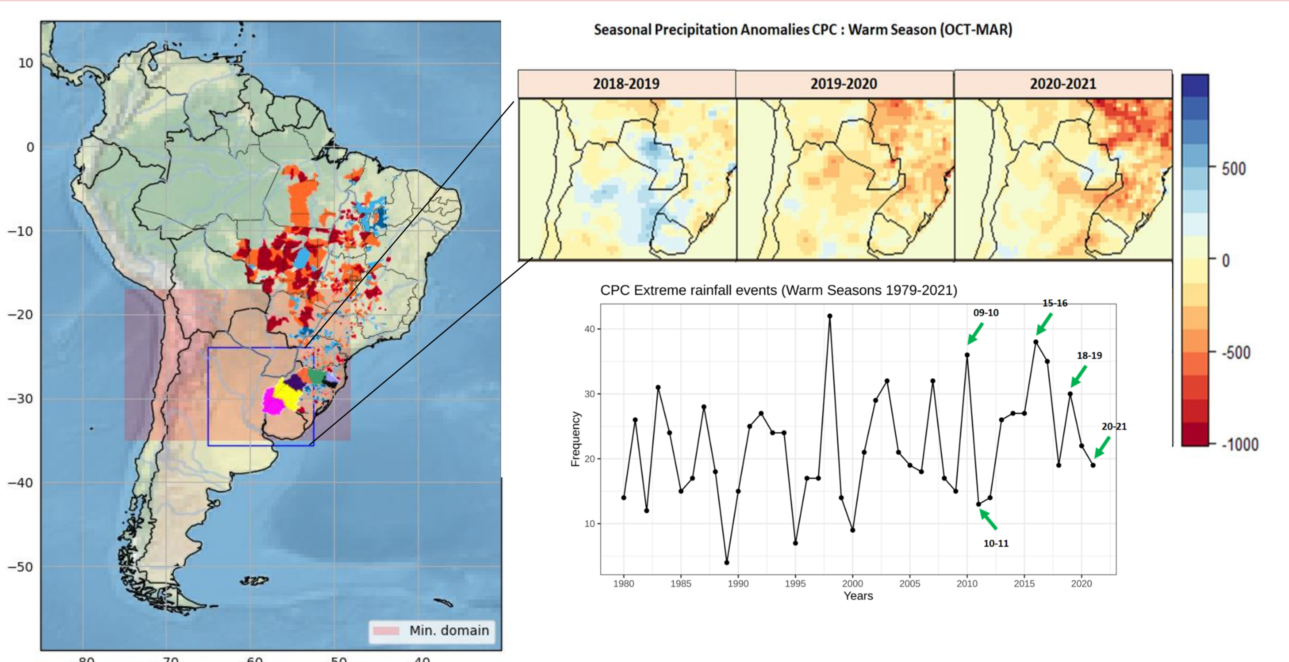

Figure1: CPM simulations domain (red rectangle), ESD simulations domain (blue square), counties with yield data over Brazil, and Uruguay river catchment sections.

CPM Simulations and Contributing Institutions

RCM	Institution	Simulations
RegCM4	University of Sao Paulo, Brazil	USP
RegCM5	ICTP, Italy	ICTP1, ICTP2
WRF433	University of Cantabria-IFCA, Spain	UCAN
WRF415	NCAR-SAAG, USA	NCAR
WRF433	CIMA-University of Buenos Aires-CONICET, Argentina	CIMA
ETA1.4.3	National Institute for Space Research, Brazil	ETA

CNN Simulations and Contributing Institutions

CNN	Loss Function
BG.S	Bernoulli Gamma wiht local predictors
BG.L	Bernoulli Gamma with spatial predictors
BLogN	Bernoulli LogNormal
BN3root	Bernoulli Normal Cube root
University of Buenos Aires-CONICET, Argentina University of Cantabria-IFCA, Spain	

***Convection-Permitting Models (CPM):** Six CP modeling systems based on WRF, RegCM and ETA RCMs
- 3-year run: June 2018-May 2021
- Horizontal resolution: 4 km
- Initial and boundary conditions: ERA5

***Empirical Statistical Downscaling (ESD):** models based on convolutional neural networks (CNN), perfect prognosis approach.
- Predictors: ERA5 mean daily fields
- Predictands: Tmax, Tmin, precipitation
- Calibration Period: 1979-2014, Test period: 2015-2021
- Different Loss Funtions were tested. Stochastic simulations were performed

The CPM and CNN simulations were used to force:

***Variable Infiltration Capacity hydrologic model:** streamflow in the Uruguay River. Contributing institution CIMA-University of Buenos Aires-CONICET, Argentina

***AgS crop growth model:** soybean and maize yield in Southern Brazil. Contributing institution EMBRAPA, Brazil.

RESULTS

95th Percentile (2018-2021)

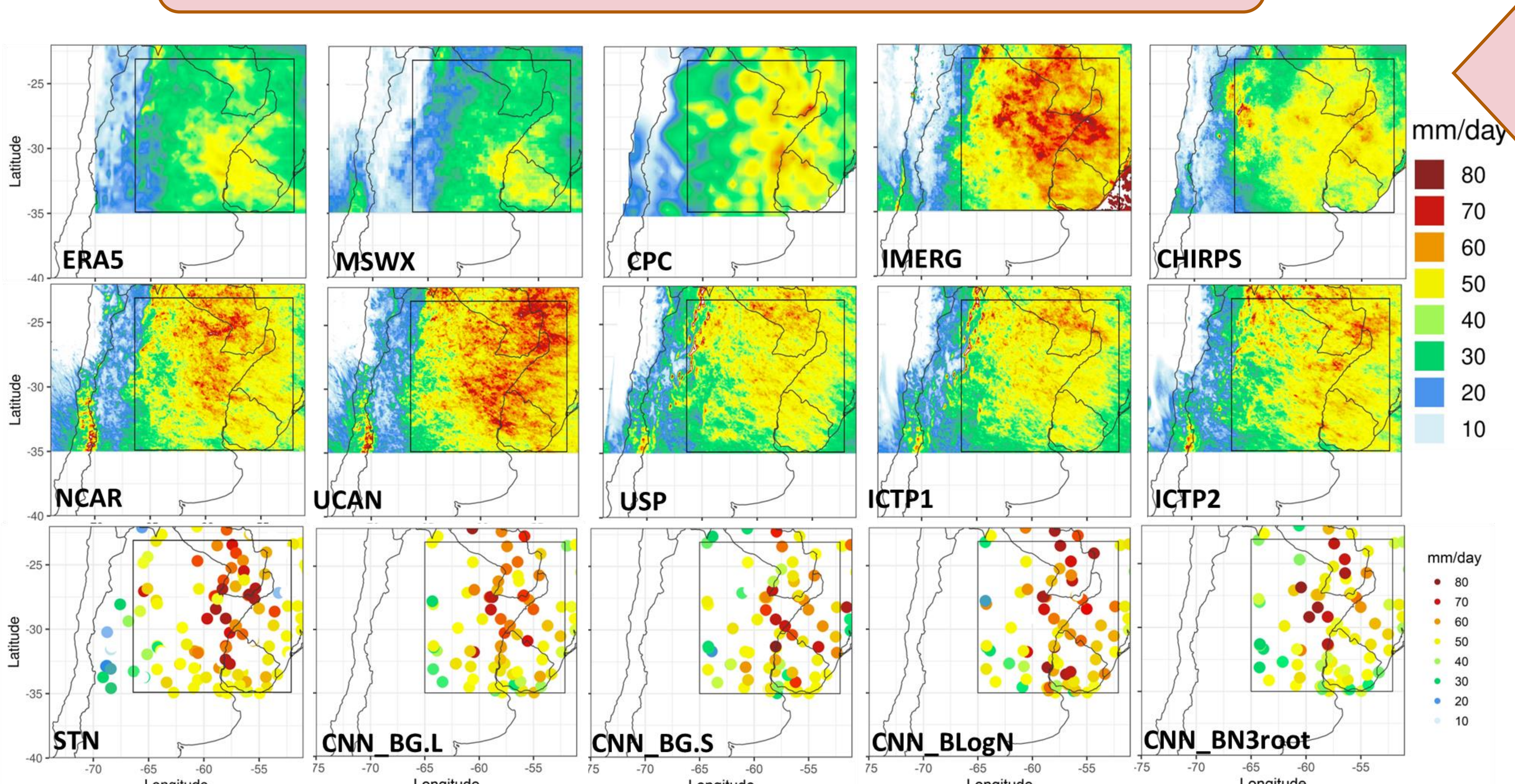

Figure 2: Daily 95th Percentile of wet days (pr>=1 mm) distribution during 2018-2021 as depicted by different observaional datasets (MSWX, CPC, IMERG, CHIRPS and Stations-STN), ERA5, CPM and CNN simulations.

- ✓ Large spread among observational datasets
- ✓ IMERG observational dataset closer to STN
- ✓ Clear added value of CPM and ESD simulations compared to ERA5
- ✓ CPM spread smaller than observations

Uruguay River Flows

Figure 4: Simulated river flows forced with by CPM simulations, ERA5 and Station Data (SMN)

- ✓ Correlations are highest at Paso de los Libres and Concordia.
- ✓ At Concordia results from simulation forced with ERA 5 follow closely simulations forced with SMN weather stations.
- ✓ Simulations from different RegCM versions: USP and ICTP_BL1 have similar behaviors while ICTP_BL2 tends to underestimate flows.
- ✓ WRF models also present different results, UCAN overestimates peaks while NCAR has lower maximum and minimum values

Correlations between streamflow simulations and observations

STATION	ERA5	NCAR	ICTP_PBL1	ICTP_PBL2	SMN	UCAN	USP
CANOAS	0.69	0.37	0.29	0.55	0.65	0.54	0.35
CONCO	0.88	0.78	0.76	0.74	0.87	0.77	0.76
GARRU	0.84	0.59	0.44	0.70	0.86	0.68	0.51
IRAI	0.76	0.51	0.26	0.62	0.76	0.61	0.33
PASOL	0.86	0.74	0.63	0.73	0.86	0.71	0.67
PELOTAS	0.72	0.37	0.26	0.67	0.86	0.50	0.28
SOBER	0.76	0.50	0.21	0.59	0.82	0.64	0.33

Interannual variability & Extreme events Location

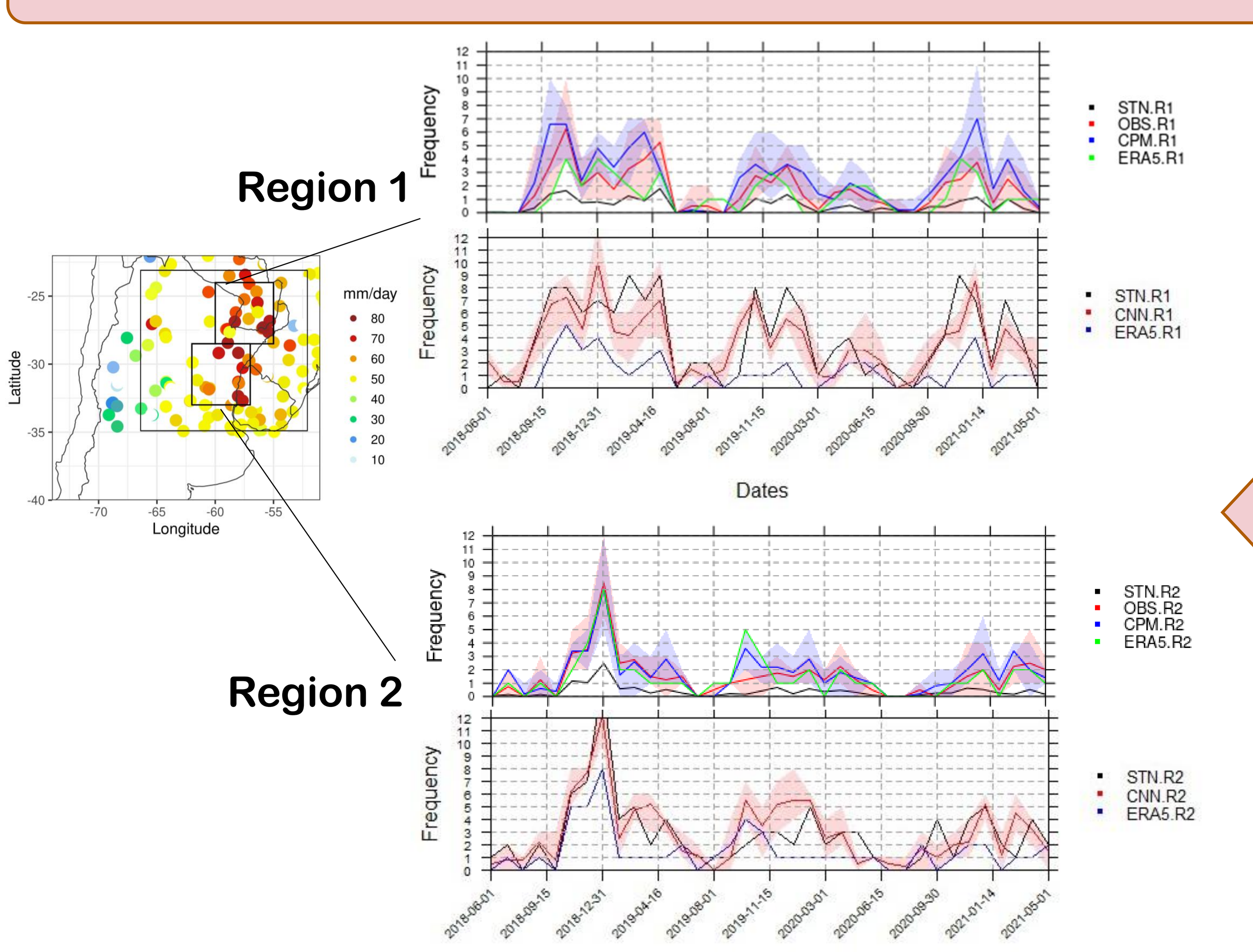

Figure 3: Monthly frequency of extreme precipitation events in two selected regions as depicted by the station data (STN) the ensemble of the gridded observational datasets (OBS), of the CPM and CNN simulations.

- ✓ The distinctive behavior of precipitation extremes over the two subregions very well captured by CPM and CNN simulations
- ✓ The interannual variability is also well reproduced by CPM and CNN simulations. Very dry years were well reproduced.
- ✓ The uncertainty is larger in the northern region of SESA.
- ✓ CPM spread is similar OBS spread

Crop Yields

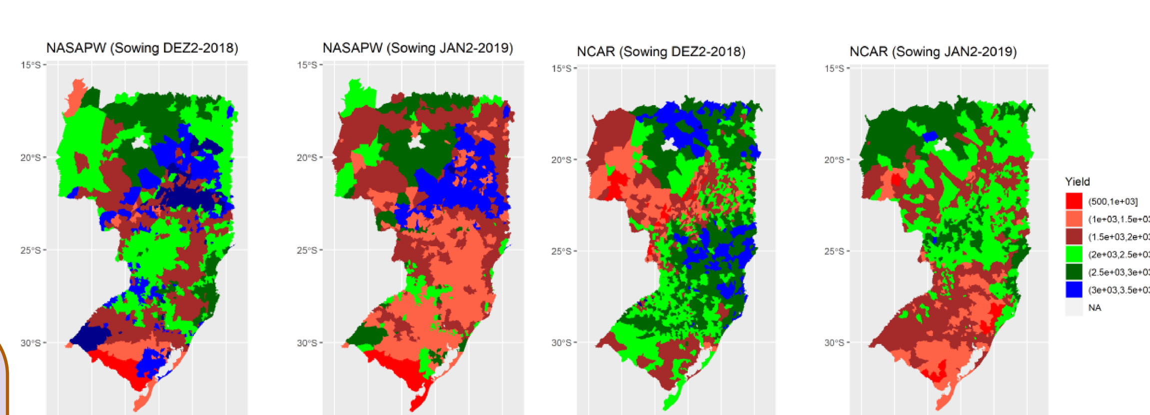

Figure 5 : Simulations of soybean yields using observational products (NASAPW) and WRF NCAR Simulations for two different sowing dates.

- ✓ Results evidenced the need to **produce multi-model simulations** to account for **different uncertainty sources.**
- ✓ **Inter-institutional collaboration** and **coordinated science** are key aspects to address these end-to-end studies.

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