STATISTICALLY DOWNSCALED CLIMATE CHANGE FOR THE SANTA RIVER BASIN, USING GLOBAL CIRCULATION MODELS (GCM) AND ITS IMPACT ON THE AVAILABILITY OF WATER RESOURCES.

Cayo RAMOS, Mg. Sc. Eng.[1] Victor CHÁVEZ [1], Katsuaki KOMAI, D. Eng.[1], Keisuke NAKAYAMA, D. Eng.,[2] Toshiyuki NAKAEGAWA, D. Eng.[2]

[1]Dept. de Recursos Hídricos , Universidad Nacional Agraria La Molina(Av. Universidad S/N, la Molina, 51-6147800, Perú)
[1]Dept. of Civil and Environmental Engineering, Kitami Institute of Technology (Koencho 165, Kitami city, 090-8507, Japan)
[2] Dept. of Civil and Environmental Engineering, Kitami Institute of Technology (Koencho 165, Kitami city, 090-8507, Japan)
[2] Senior Researcher, Meteorological Research Institute (1-1 Nagamine Tsukuba city, 305-0052, Japan)

I. Introduction

Precipitation and temperature are two important variables for the availability of water resources, especially in agriculture. The objective of this research is to determine climate projected in the near future (2020-2040) and the far future (2080-2100) for the Santa river basin. Thirteen models, GCMs, CMIP3 (11 Models) and MRI - AGCM3.1S, 3,2S, were employed for selected variables in the process of validation. The impact of climate change on the hydrology in Santa river basin was studied by comparing the statistics in actual discharge and those projected as a result of hydrological simulation with WEAP, using the best climate projection on Emissions Scenarios A1B.

II. Methods

Figure 1 shows the general procedure of the study of climate change. It involved four steps: Processes downscaling, future climate projections, determining anomalies and application of hydrological model (WEAP).

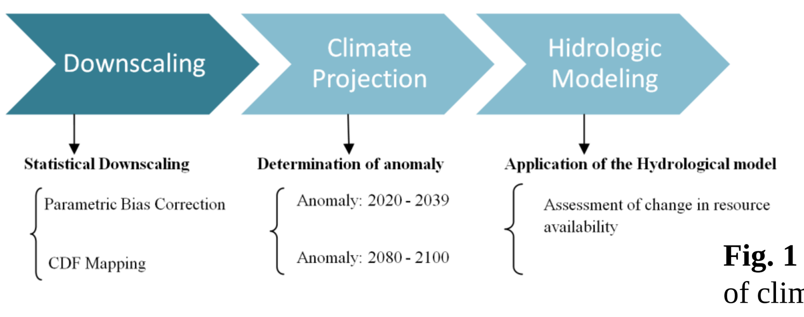


Fig. 1 Methodology for probabilistic assessment of climate change impacts on water resources.

2.1 GCMs and statistical downscaling

The equations that governing the parametric correction and CDF Mapping are :

Parametric Bias correction

$$rain_{\mathrm{mod}}' = amp_1 \times rain_{GCM}$$

$$amp_1 = \frac{\mu_{FO}}{\mu_{GCM}}$$

$$rain_{\mathrm{mod}} = amp_2 \times \left(rain_{\mathrm{mod}}' - \mu_{FO}\right) + \mu_{FO}$$

$$amp_2 = \frac{\sigma_{FO}}{amp_1 \sigma_{GCM}}$$

CDF Mapping

$$rain_{\mathrm{mod}} = amp \times rain_{GCM}$$

$$amp = \frac{rain_{PNE\_FO}}{rain_{PNE\_GCM}}$$

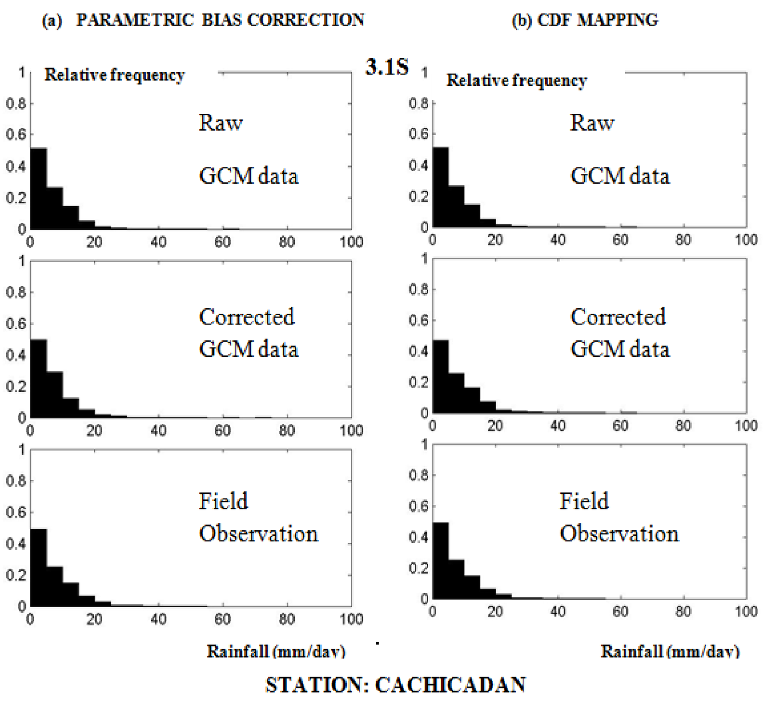


Fig 2. Probability density functions at CACHICADAN. (a) DS parametric bias correction. (b) DS CDF Mapping.

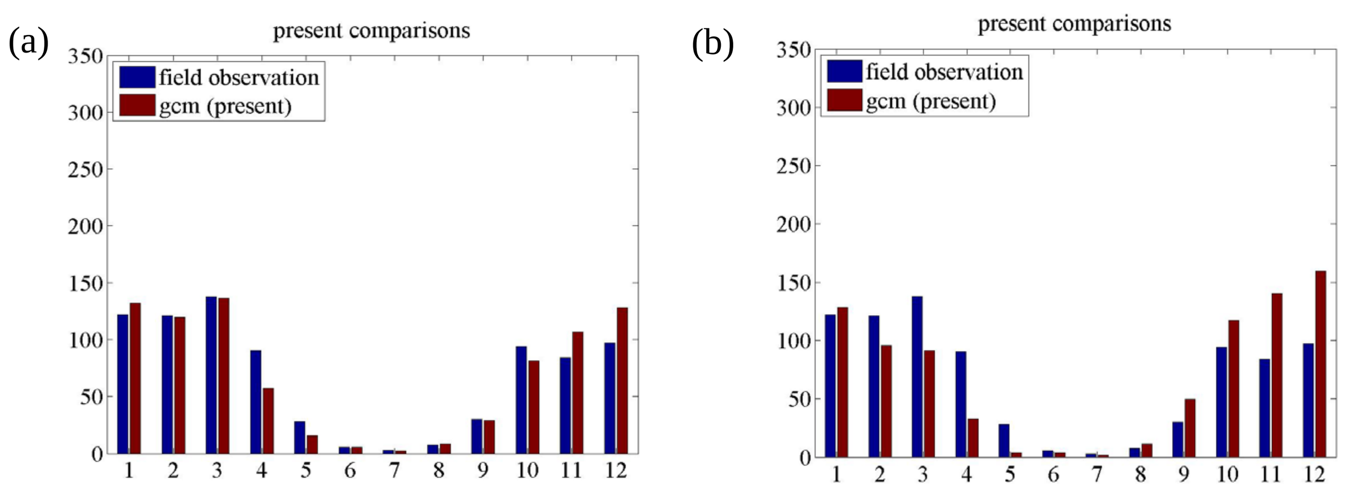


Fig 3. Twenty year-mean monthly precipitation at RECUAY. (a) MRI-AGCM 3.1S. (b) MRI-AGCM 3.2S

2.2 Hydrologic model

Water Evaluation And Planning system (WEAP) was used for simulating the future runoff data used in this analysis.

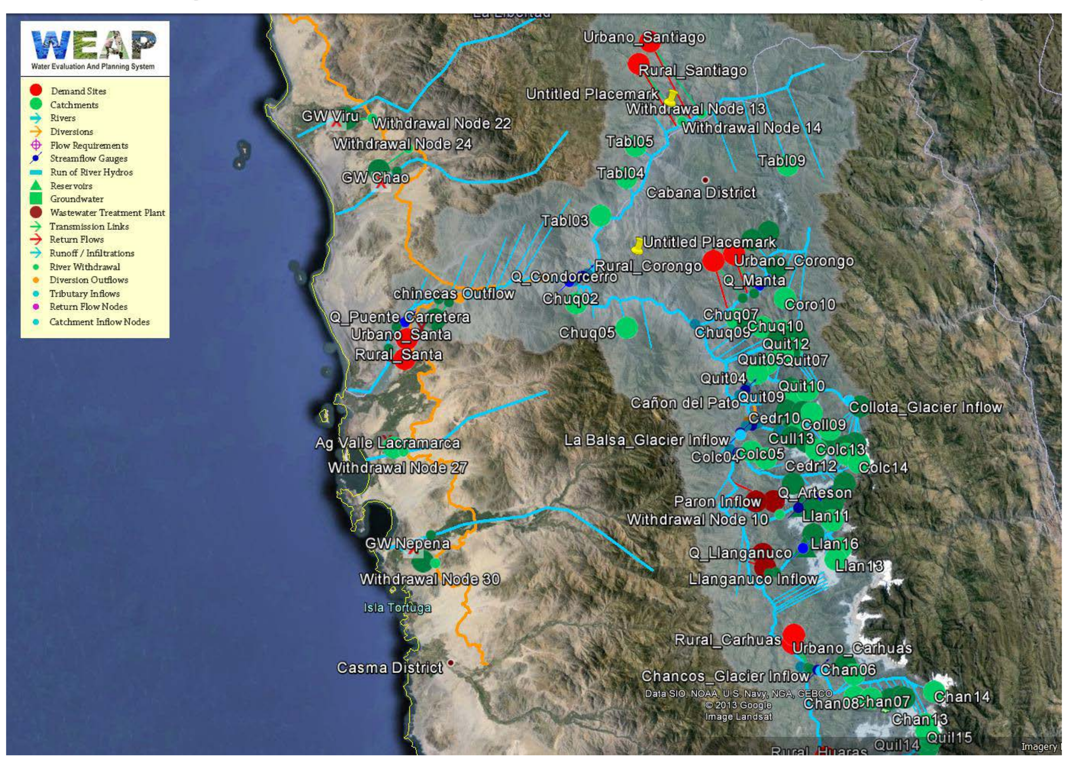


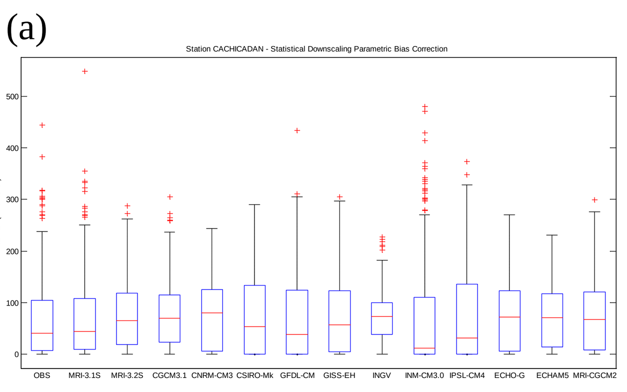
Fig 4. Schematic representation of the hydrological model WEAP.

III. Results

3.1 Statistics for validation

Figure 5(a) shows the boxplot, this diagram lets us compare all the models. The MRI-AGCM3.1S and 3.2S models showed good correspondence to field observation. For the temperature were determined the correlations daily, monthly and seasonal to have a better statistical analysis, (see Figure 5 b).

(a)



(b)

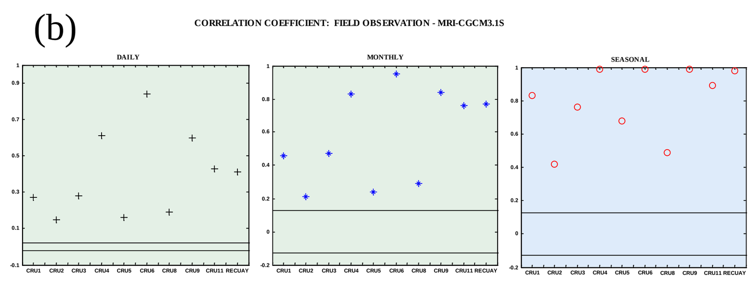


Fig. 5. (a) *Box Plot* of observed series versus the GCMs models. (b) Variation of Correlation coefficient for temperature: Field Observation vs MRI-CGCM3.1S

3.2 Analysis of annual cycle

It is important to evaluate changes in seasonal runoff so as to select the GCMs models that best represent the field observation data. Figure 6 shows the representation of the annual cycle in precipitation of different GCMs analyzed.

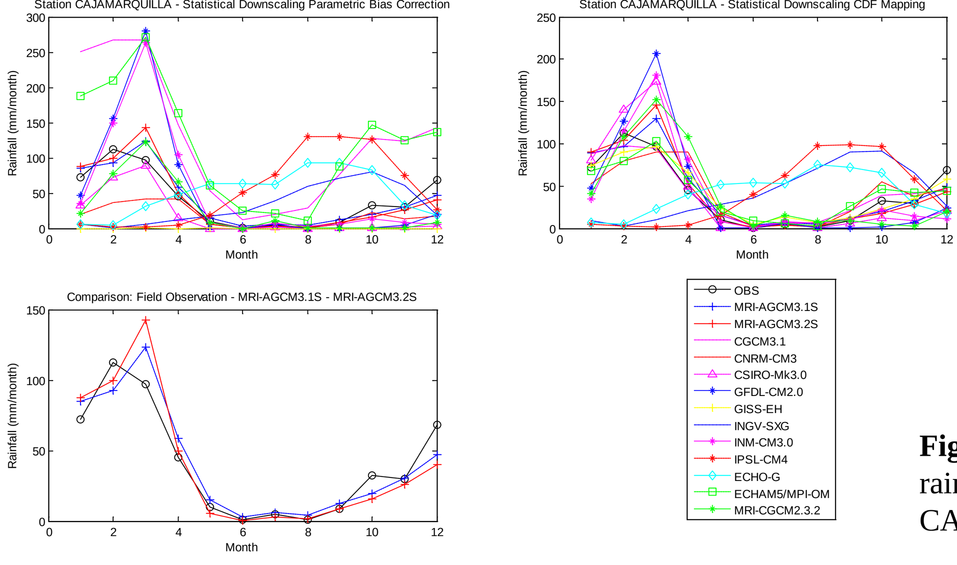


Fig 6. Seasonal variation of rainfall for the GCM models at CAJAMARQUILLA.

3.3 Analysis the Future climate scenarios, determination of anomalies in precipitation and temperature.

For the analysis of future climate the employment of the method "delta change" , for precipitation was estimated: $\Delta P\% = (F-P)/P*100$, and for temperature was calculated using the following expression: $\Delta T°C = (F-P)$.

(a)

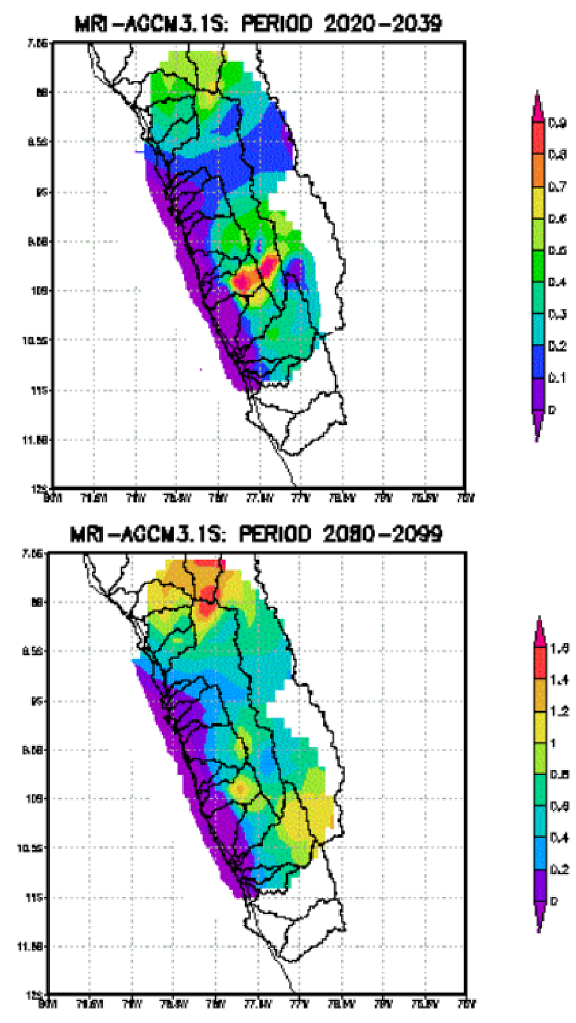


Fig 7. Projections of rainfall anomalies. Periods: Near future (2020-2039) and far future (2080-2099). The units are in mm/day.

(b)

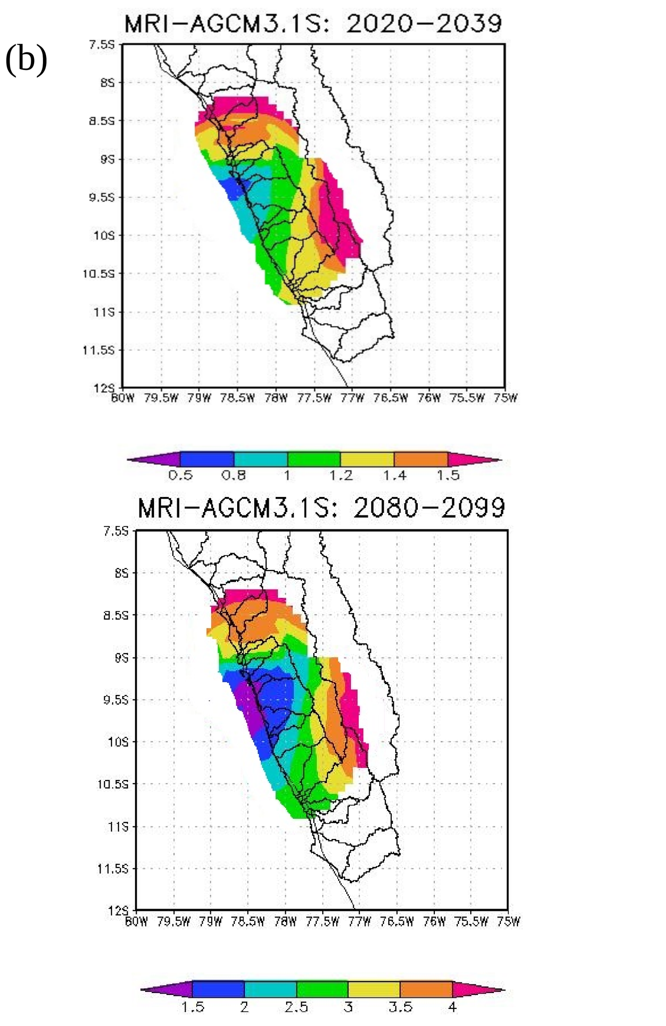


Fig 8. Projections of temperature anomalies for the A1B scenario. MRI-AGCM3.1S Model. The units are in ^{0}C

3.4 Effects of climate change on water resource availability

Climate projections simulated by hydrological model WEAP shows an increase in flow in each of the catchments studied, in peak flow of the rainy season, average flow and minimum flow in dry seasons.

The hydrological modeling shows an increase of 30% and 45% for the near future and 80% in far future.

		MRI-AGCM3.1S		MRI-AGCM3.2S	
Watershed	ΔQ%	20-39	80-99	20-39	80-99
Cedros	Q_max	29.93	93.01	36.04	99.70
	Q_mean	23.52	100.69	30.31	104.63
	Q_min	37.50	140.31	41.98	142.59
Chancos	Q_max	46.47	81.07	53.86	106.11
	Q_mean	46.18	78.82	53.86	105.66
	Q_min	34.43	63.63	40.77	82.13
Colcas	Q_max	36.07	67.30	44.59	82.97
	Q_mean	37.21	70.41	46.34	88.12
	Q_min	30.51	59.51	37.69	73.36
Tablachaca	Q_max	25.69	63.68	58.40	110.75
	Q_mean	23.86	62.57	61.22	104.57
	Q_min	16.79	39.86	38.96	66.34
Corongo	Q_max	14.81	38.16	24.85	46.33
	Q_mean	16.50	37.00	26.80	43.84
	Q_max	17.58	46.83	24.70	53.37
Llanganuco	Q_mean	51.05	100.72	57.48	130.36
	Q_min	48.32	96.98	54.17	121.75
	Q_max	40.42	75.15	45.08	95.22
Olleros	Q_mean	27.24	45.80	47.91	85.30
	Q_min	28.75	44.20	49.04	83.43
	Q_max	23.62	30.64	41.39	59.79
Pachacoto	Q_mean	14.39	39.28	46.43	81.09
	Q_min	14.56	37.73	49.86	80.10
	Q_max	13.86	33.58	50.60	76.96
Querococha	Q_mean	22.62	35.89	40.22	66.16
	Q_min	22.19	34.40	39.79	64.55
	Q_max	21.67	32.34	39.96	63.38
Quillcay	Q_mean	40.73	67.09	53.30	102.01
	Q_max	40.44	63.08	54.82	100.41
	Q_mean	29.00	45.99	40.62	70.94
Recreta	Q_min	40.25	74.01	41.84	76.93
	Q_max	68.21	106.34	90.85	115.05
	Q_mean	38.45	38.41	50.46	53.70
Condorcerro*	Q_min	48.39	120.66	61.42	148.57
	Q_max	65.61	143.39	75.26	162.71
	Q_mean	63.57	109.44	68.97	122.62

Table 1. Percentage changes in flow regimes for the Santa river watershed.

IV. Conclusions

- The MRI-AGCM3.1S and 3.2S Models, showed better correspondence to field observation in both precipitation and temperature than CMIP3 multi-models.
- Downscaling methodologies: Parametric bias correction and CDF mapping are very efficient for the variables studied in SANTA basin.
- The models indicate an increase in precipitation throughout the basin, 21% and 26% for the near future and 37% and 39% for the far future with the MRI-AGCM3.1S and 3.2S models being the strongest signal in the north and south of the basin and lower values in the central basin and coast.
- Models for temperature show signs of warming throughout the basin with an average value of 1.3 °C and 4.0 °C for midcentury and end century, respectively.
- The main hydrological impact observed, considering the changes in precipitation and temperature projected, is an increase in flow. The hydrological modeling shows an increase of 30% and 45% for the near future and 80% for the far future. This amounts to saying that a 1% increase in precipitation leads to an increase in river flow of 2.0% on average.

Contact:

Cayo Ramos Taipe
Universidad Nacional Agraria la Molina
Email: cramost@lamolina.edu.pe
Victor Chavez Mayta
Universidad Nacional Agraria la Molina
Email: vchavezmayta@gmail.com

Reference:

1. Kitoh, A., S. Kusunoki, and T. Nakaegawa, climate change projections over South America in the late 21st century with the 20 and 60 km mesh Metereological Research Institute Atmospheric general circulation model (MRI-AGCM), J. Geophys. Res., 116, DO6105, 2011, doi: 10.1029/2010JD014920.
2. IPCC, 2007. Climate Change 2007: The Scientific Basis, IPCC Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.
3. Marengo, José A. Mudanças climáticas globais e seus efeitos sobre a biodiversidade: Caracterização do clima atual e definição das alterações climáticas para o território brasileiro ao longo do século XXI / José A. Marengo –Brasília: MMA, 2006.
4. Condom T., Escobar M., Purkey D., Pouget J.C., Suarez W., Ramos C., Apaestegui J., Zapata M., Gomez J., Vergara W. Modelling the hydrologic role of glaciers within a Water Evaluation and Planning System (WEAP): a case study in the Rio Santa watershed (Peru). Hydrol. Earth Syst. Sci. Discuss., 8, 869–916, 2011, doi: 10.5194/hessd-8-869-2011.
5. Mizuta R, Oouchi K, Yoshimura H, Noda A, Katayama K, Yukimoto S, Hosaka M, Kusunoki S, Kawai H, Nakagawa M: 20-km-mesh global climate simulations using JMA-GSM model –Mean climate states–. Journal of the Meteorological Society of Japan 84: 165–185, 2006, doi:10.2151/ JMSJ.84.165.