# A PROPOSAL OF ENSEMBLE PDF OF HYDROLOGICAL VARIABLES IN COLOMBIA, FROM RCM DEVELOPED FOR SOUTH AMERICA AND CARIBBEAN REGION BY THE CORDEX PROJECT

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# CONTENT

- Introduction.
- Methodology.
- An example using Annual Maximum Daily Rain (AMDR) values from RCM in Senegal.
- Expected results.

# INTRODUCTION

## -i-

- Relationships between synoptic phenomena (which have interannual scale) and river flows, precipitation cycles, temperatures, etc, have been reported for Colombia; **the ENSO is outstanding between the several synoptic phenomena.**

- Also, there is evidence about climate change is associated with both the temperature rise widespread over the territory, and the evident but spatially erratic changes of precipitation regime.

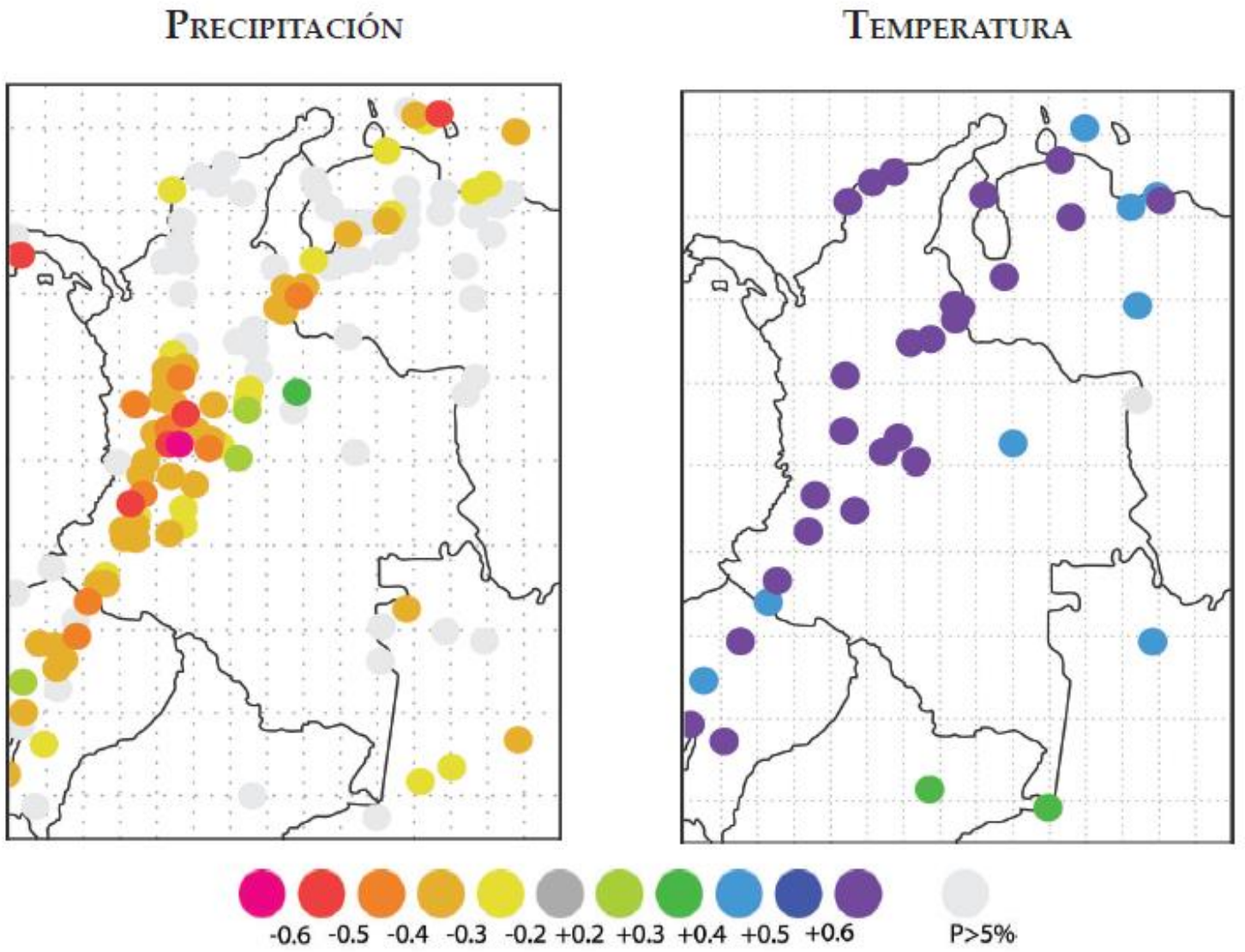
- Another studies report the impacts of climatic variability on human health, and the effects of climate change during the last century on the icecaps of Andean mountains.

# INTRODUCTION

## -ii-

Correlations between climatic annual variables in Colombia with SST in Niño 3-4 region (lag 2 months), period 1975-2000.

Orozco y Carvajal, 2008, *Incidencia de El Niño-Oscilación del Sur en la precipitación y la temperatura del aire en Colombia, utilizando el Climate Explorer*. Ingeniería y Desarrollo, 23.

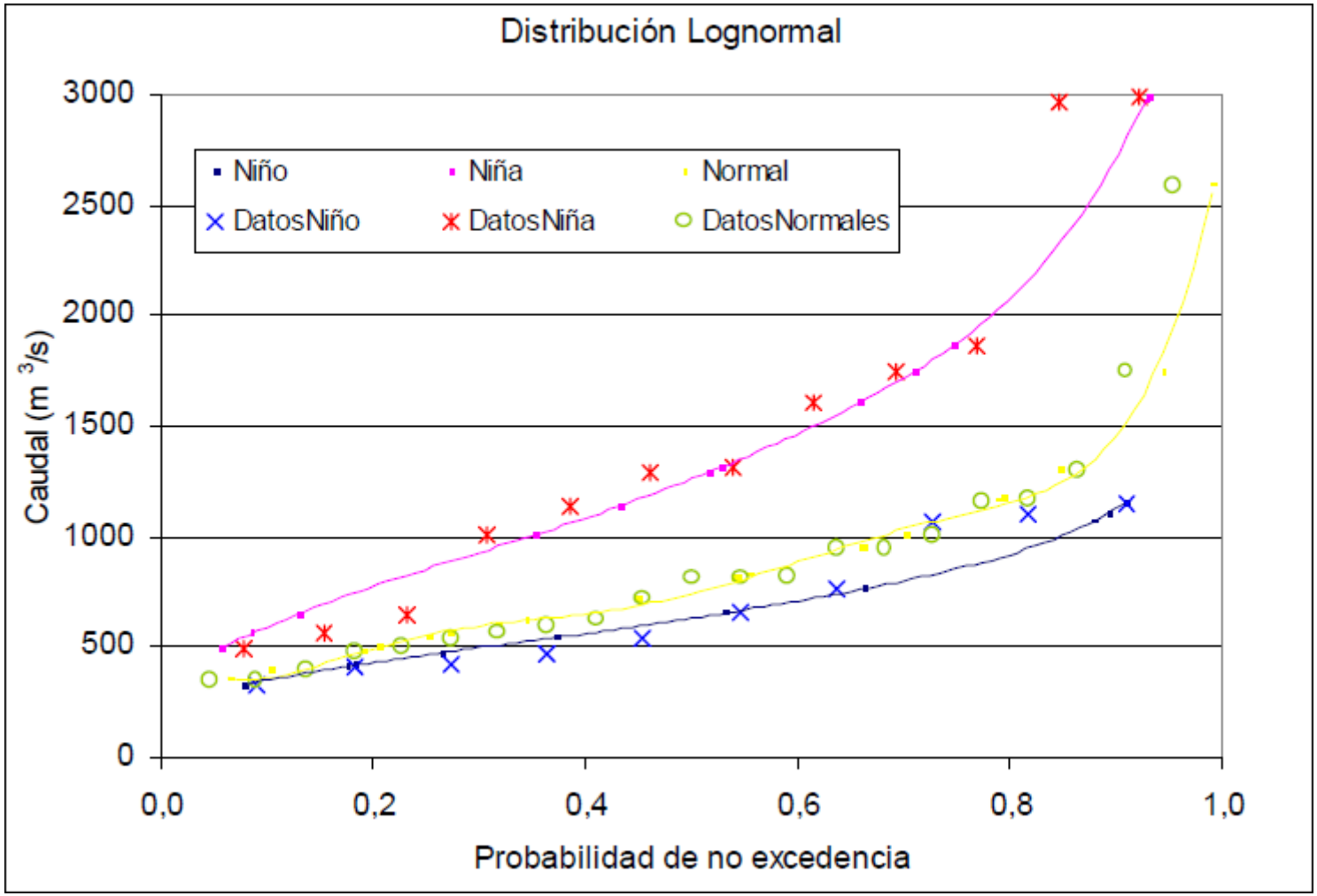


# INTRODUCTION

## -iii-

Lognormal probability density function fitted to the maximum annual flows of Negro river (Cundinamarca, Colombia), which have been differenciated between El Niño, La Niña and normal years.

Poveda, G., 2004. *La hidroclimatología de Colombia: una síntesis desde la escala inter-decadal hasta la escala diurna*. Revista Academia Colombiana de Ciencias, 28 (107), 201-222.



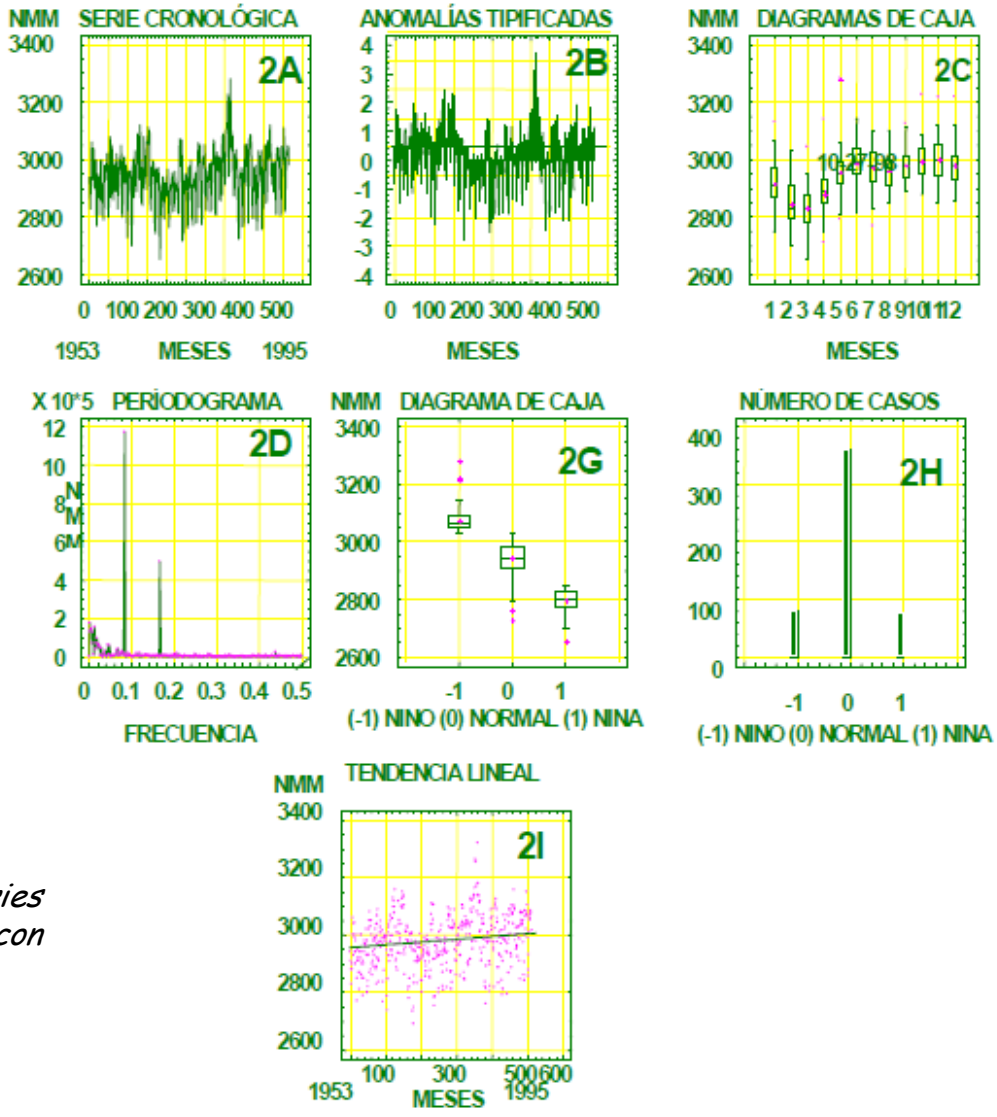
# INTRODUCTION

-iv-

The time series of mean sea level in Buenaventura (Colombian Pacific shoreline) show rising trends in the last three decades.

This feature could be useful in a early warning system related with potential signs of climate change in Colombia.

It is outstanding the difference of mean sea level discriminated in El Niño, normal and La Niña years.




Buenaventura, mean sea level. Monthly time serie.

Rangel, E. S. y Montealegre, J. E., 2003. *Análisis de series del nivel del mar en el pacífico colombiano y su relación con el cambio climático*. Meteorología Colombiana, 7, 53-66,

# METHODOLOGY

- Building a multi-model ensemble for Colombian territory is proposed, using several variables of interest, in order to improve the understanding about both the trend and impacts of global warming on Colombian water cycle.

- The proposed methodology to compute the RCM weights in the ensemble will use a comparison between the probability density function (pdf) of observed data, against the pdf of simulated data from each RCM in the observed period.

- Afterwards, non-stationary pdf will be built for each RCM; then, according to weights previously computed, the non-stationary pdf of each RCM will be combined into a single non stationary ensemble pdf. The ensemble pdf will show the trends of interest variables, not only in the mean value and/or standard deviation, but in the whole probability density function.

# AN EXAMPLE

## Annual Maximum Daily Rain (AMDR) in Senegal


- García Galiano, S. G. and Giraldo Osorio, J. D., 2010. Analysis of impacts on hydrometeorological extremes in the Senegal river basin from REMO RCM. The 2nd Lund Regional-scale Climate Modelling Workshop: Part II. *Meteorologische Zeitschrift*, 19 (4), 375-384.

- Karambiri, H., García Galiano, S. G., Giraldo, J. D., Yacouba, H., Ibrahim, B., Barbier, B. Polcher, J., 2011. Assessing the impact of climate variability and climate change on runoff in West Africa: the case of Senegal and Nakambe River basins, *Atmospheric Science Letters*. AMMA Special Issue, 12: 109-115.

- **Giraldo Osorio, J. D. and García Galiano, S. G., 2011. Building hazard maps of extreme daily rainy events from PDF ensemble, via REA method, on Senegal River Basin. *Hydrol. Earth Syst. Sci.*, 15, 3605–3615.**

- Giraldo Osorio, J. D. and García Galiano, S. G., 2012. Assessing uncertainties in the building of ensemble RCMs over Spain based on dry spell lengths probability density functions. *Climate Dynamics*. DOI 10.1007/s00382-012-1381-5.

- Giraldo Osorio, J. D. and García Galiano, S. G., 2012. Non-stationary analysis of dry spells in monsoon season of Senegal River Basin using data from Regional Climate Models (RCMs). *Journal of Hydrology*. DOI 10.1016/j.jhydrol.2012.05.029.

# AMDR IN SENEGAL

## Motivation and objectives -i-

- The Regional Climate Models (RCM) constitute a tool for simulation of plausible climate scenarios at basin scale.

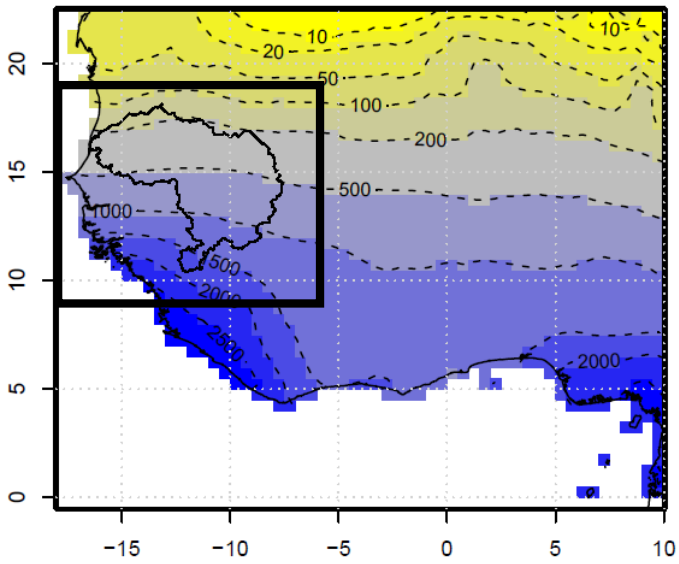
- In conjunction with Generalized Additive Models for Location, Scale and Shape (GAMLSS), it is possible to simulate the nonstationarity of the pdfs of maximum rainfall and to obtain a measure of the uncertainty of change.

- Due to the divergence in the results from RCMs, the use of ensemble techniques is needed to simulate the variability in precipitation.

- The main goal is the assessment of change in the pdfs of the Annual Maximum Daily Rainfall (AMDR) on the Senegal River Basin (West Africa), and the spatial pattern associated with change.

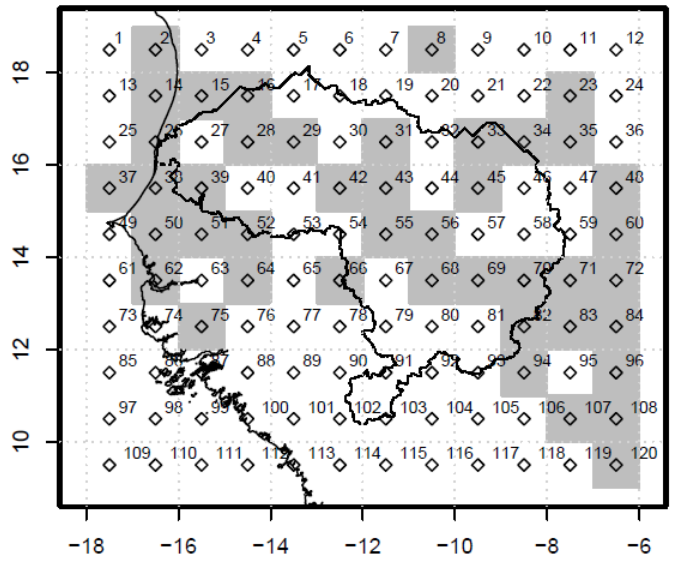
# AMDR IN SENEGAL

## Data sets -ii-




Mean yearly rainfall amount from CRU data (1961-1990) in West Africa. The black square highlights the study area of Senegal River basin.

Senegal River Basin area. The sites selected for analyses are numbered, while the IRD sites are highlighted with gray squares.




Summary of characteristics of IRD data and selected RCMs(*).

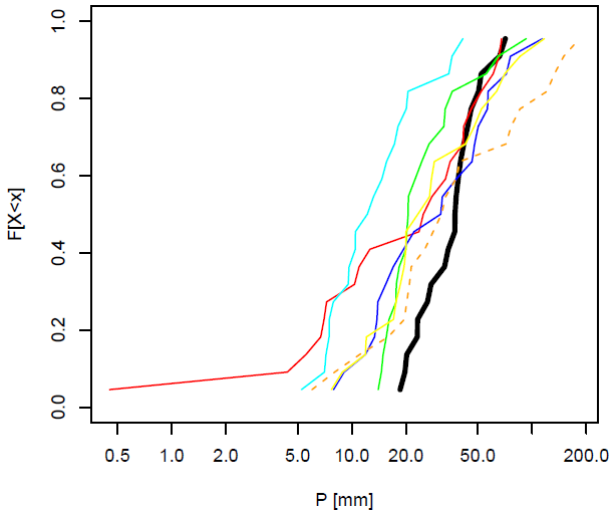
| Name | Institute | GCM | RCM | Temporal coverage |
|---|---|---|---|---|
| IRD | | | | 1970-1990 |
| GKSS/CLM | GKSS[1] | ECHAM5 | CLM | 1961-2050 |
| METO-HC/HAD | HC[2] | HadCM3Q0 | HadRM3P | 1951-2099 |
| KNMI/RACMO | KNMI[3] | ECHAM5-r3 | RACMO | 1970-2050 |
| INM/RCA | INM[4] | HadCM3Q0 | RCA | 1951-2099 |
| SMHI/RCA | SMHI[5] | HadCM3Q0 | RCA | 1951-2100 |
| MPI/REMO | MPI[6] | ECHAM5-r3 | RACMO | 1950-2050 |

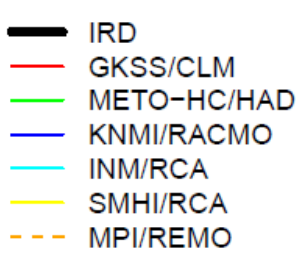
[1]Institute for Coastal Research, Germany; [2]Hadley Centre, UK; [3]Royal Netherlands Meteorological Institute; [4]National Institute of Meteorology, Spain; [5]Swedish Meteorological and Hydrological Institute; [6]Max Planck Institute, Germany.

(*) Christensen, J. H., Rummukainen, M. & Lenderink, G. (2009) Formulation of very-high-resolution regional climate model ensembles for Europe. In van der Linden, P. and J. F. B. Mitchell (Eds): ENSEMBLES: Climate change and its impacts at seasonal, decadal and centennial timescales: Summary of research and results from the ENSEMBLES project (pp. 47-58). Met Office Hadley Centre, FitzRoy Road, Exeter EX1 3PB, UK.

# AMDR IN SENEGAL

## Byas analysis –iii-



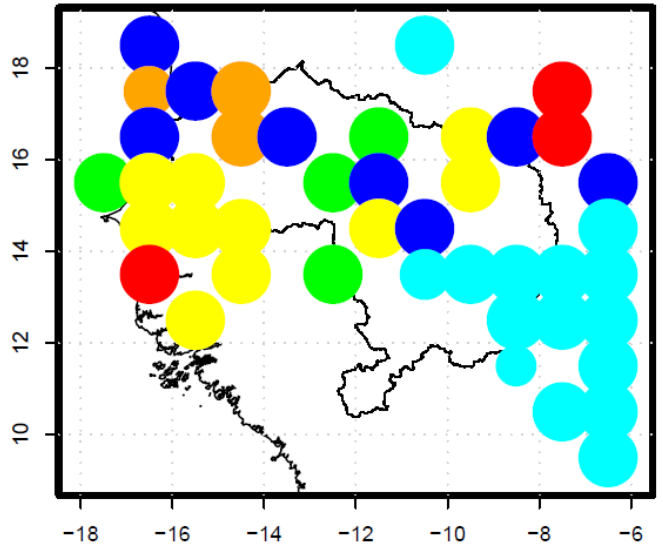



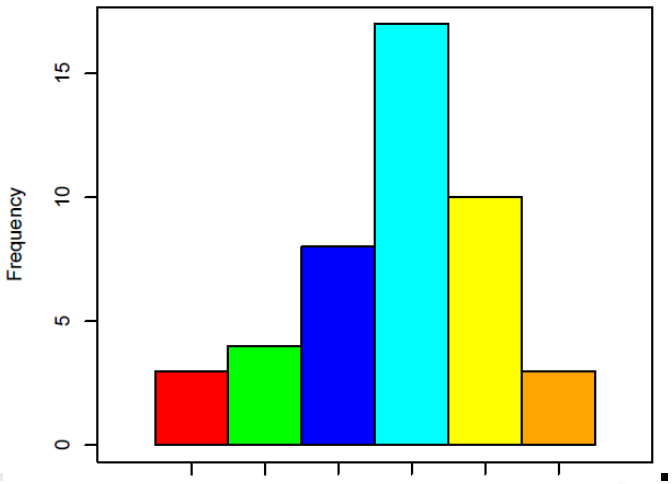

An example of bias analysis on site 28.

| | **p-value** |
|---|---|
| GKSS/CLM | 0.0845 |
| METO-HC/HAD | 0.0462 |
| KNMI/RACMO | 0.158 |
| INM/RCA | 8.36e-05 |
| SMHI/RCA | 0.23 |
| MPI/REMO | 0.412 |

If p>$\alpha$, then $H_0$ is no rejected ($H_0$: The IRD and RCM data have the same distribution).

The colours indicate the RCMs which best fit the actual AMDR cdf in each site (actual AMDR cdf from IRD time series).

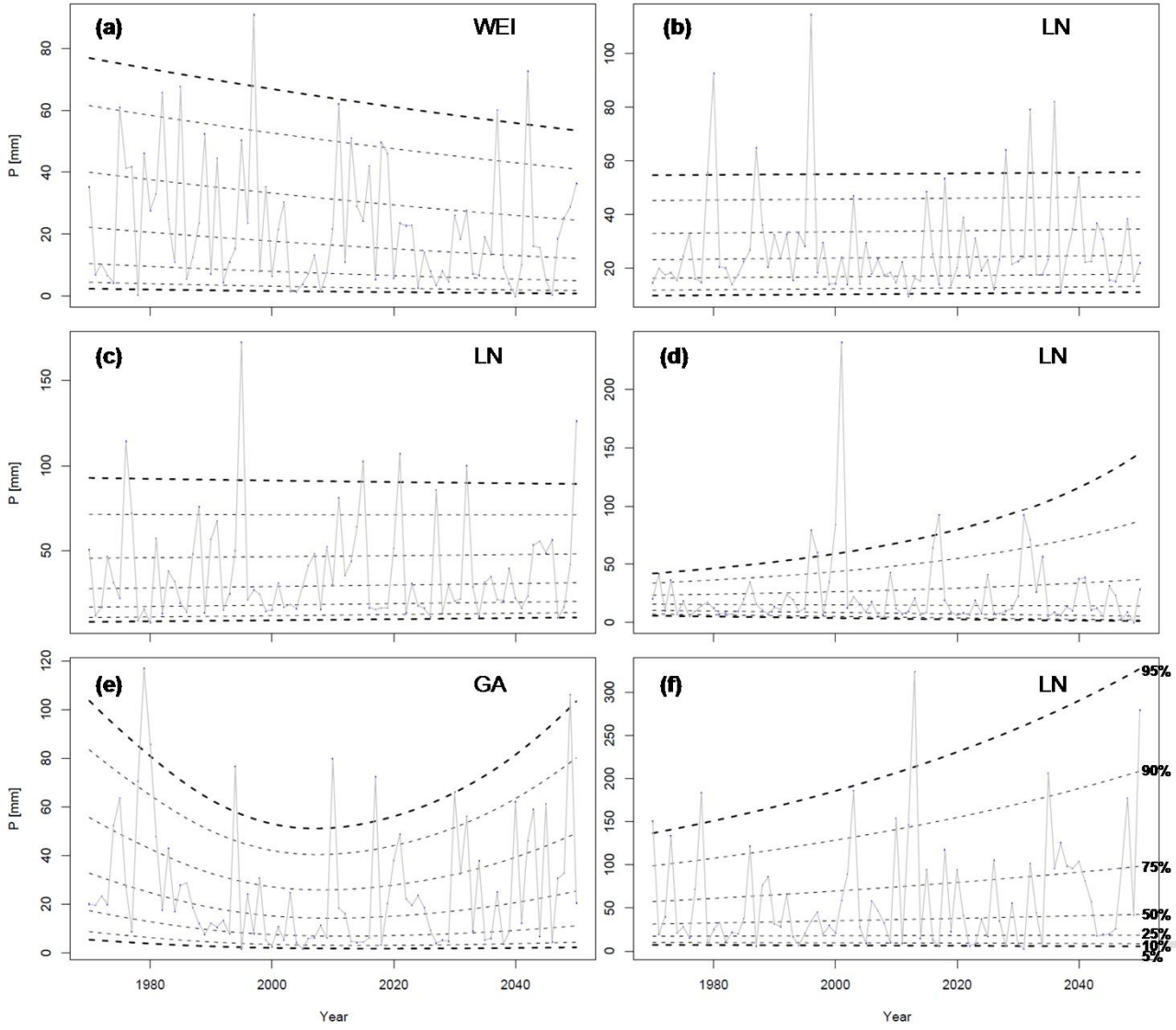



The color bars indicate the number of sites that best fit to a particular RCM

# AMDR IN SENEGAL

## GAMLSS applied to non-stationary analsysis -iv-




Example of GAMLSS analysis of AMDR for site 28 for several RCMs:
(a) GKSS/CLM
(b) METO-HC/HAD
(c) KNMI-RACMO
(d) INM-RCA
(e) SMHI/RCA
(f) MPI-M-REMO.

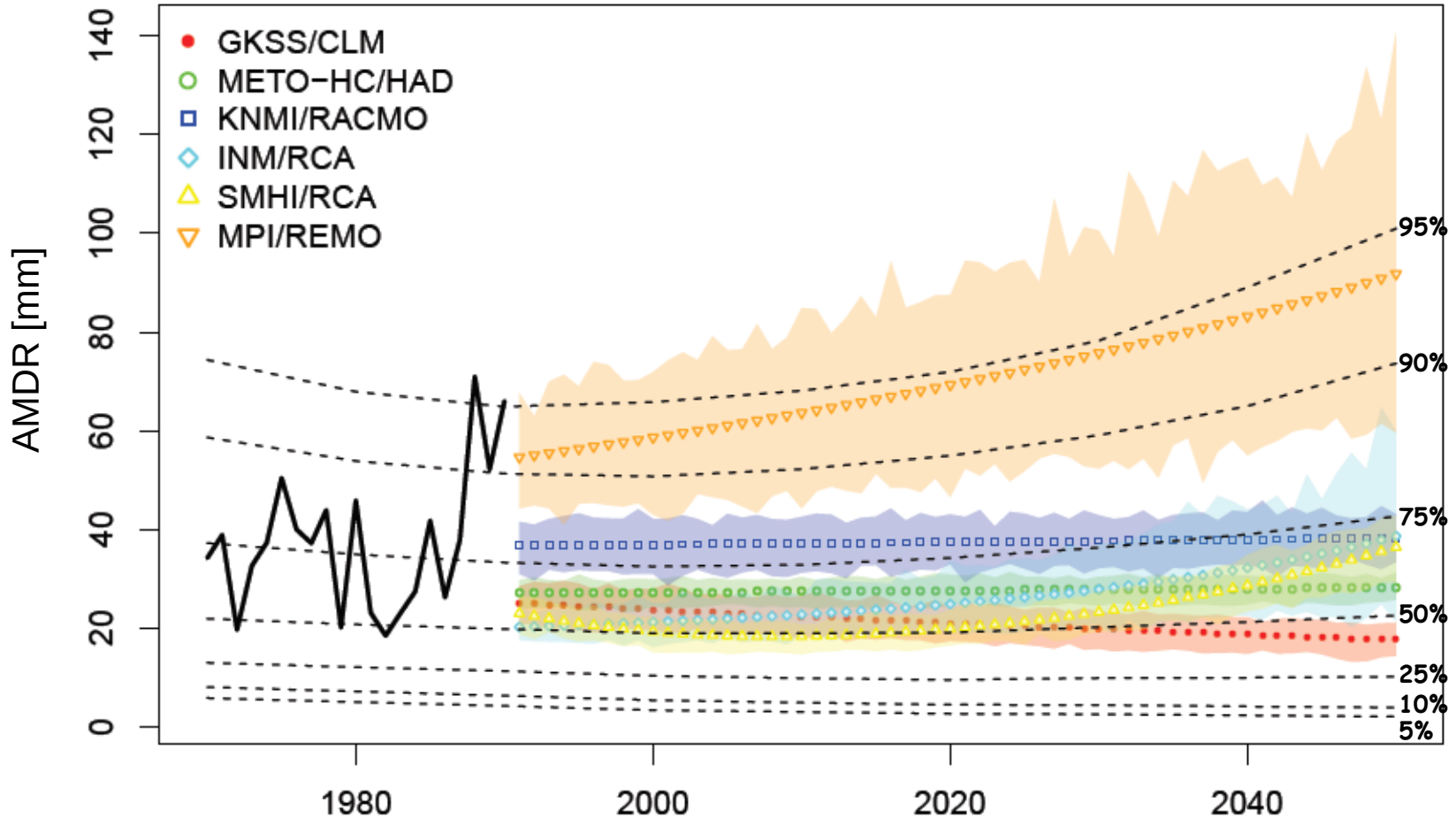
The RCM time series of AMDR is grey, and the centile curves (5 to 95 %) are represented by dashed lines.

It should be noted that the ordinate scale is automatically fixed.

The pdf used were gamma (GA), lognormal (LN) and weibull (WEI).

# AMDR IN SENEGAL

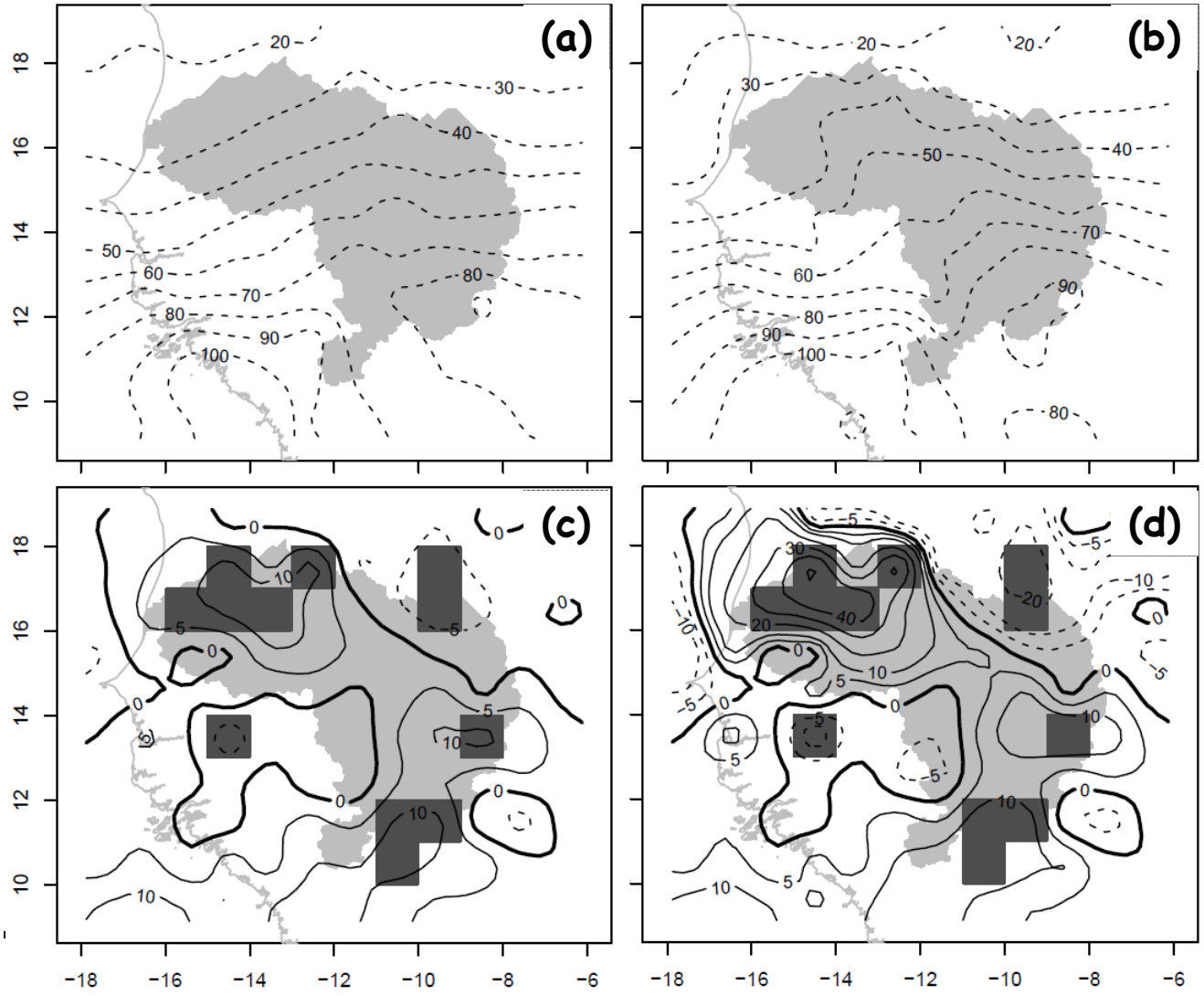
## ENSEMBLE pdf in each grid point -v-




Ensemble pdf for site 28. The dashed lines show 5 to 95% quantiles of ensemble pdf, and markers represent RCMs mean values. The colours polygons show the mean variability in the period 1991-2050, using the 95% CI computed with bootstrapping. The IRD AMDR series in 1970-1990 is presented as a solid line.

# EXPECTED RESULTS

## Maps of AMDR mean -i-




Interpolated maps from the GAMLSS analysis for mean $\mu$:

(a) Year 1990.

(b) Year 2050.

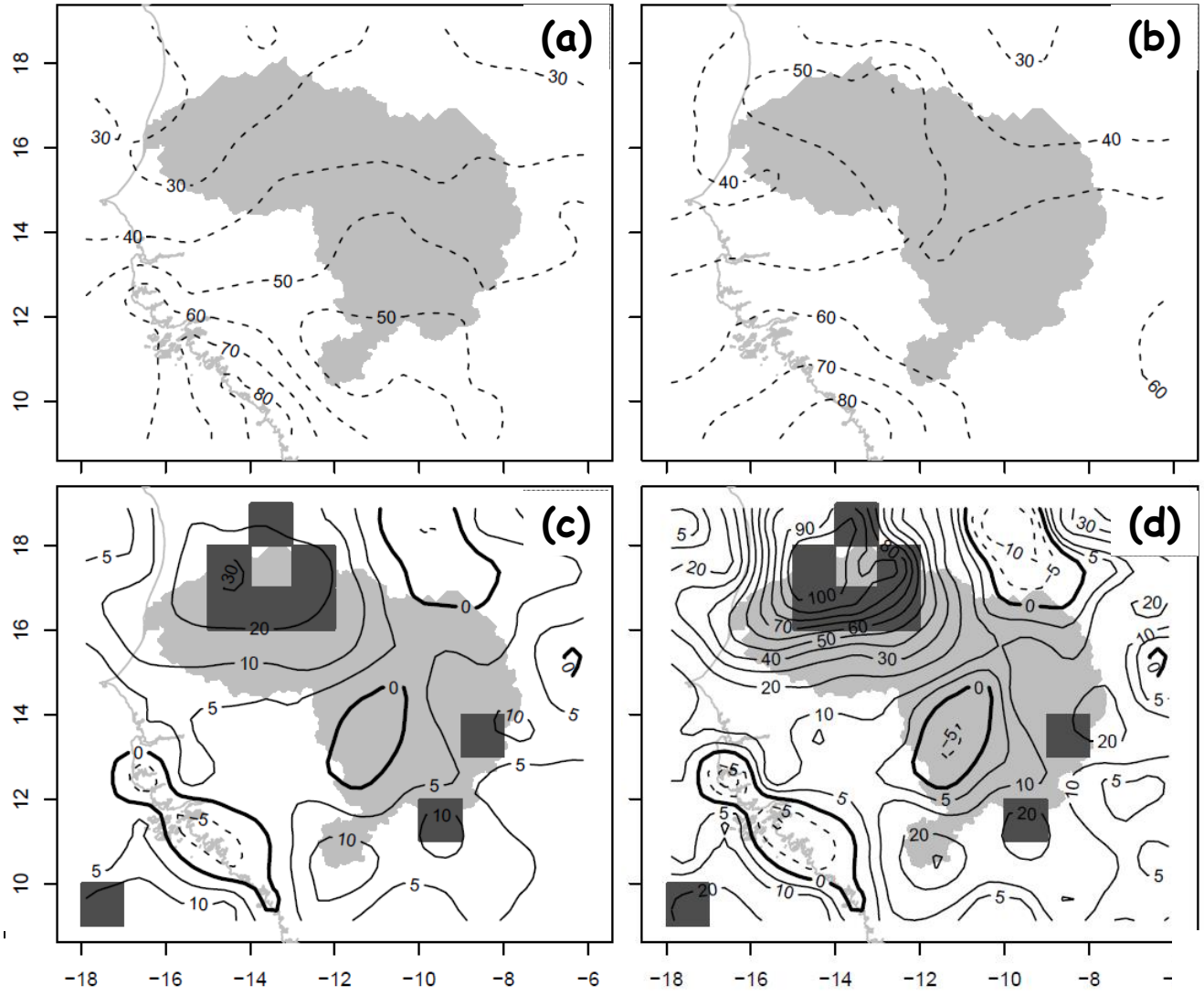
(c) Difference between the two previous maps (in mm).

(d) Percentage difference.

In the difference maps, negative values are dashed, while the confidence in projected changes is highlighted with the dark gray square.

# EXPECTED RESULTS

## Maps of AMDR standard deviation -ii-




Interpolated maps from the GAMLSS analysis for standard deviation $\sigma$:

(a) Year 1990.

(b) Year 2050.

(c) Difference between the two previous maps (in mm).

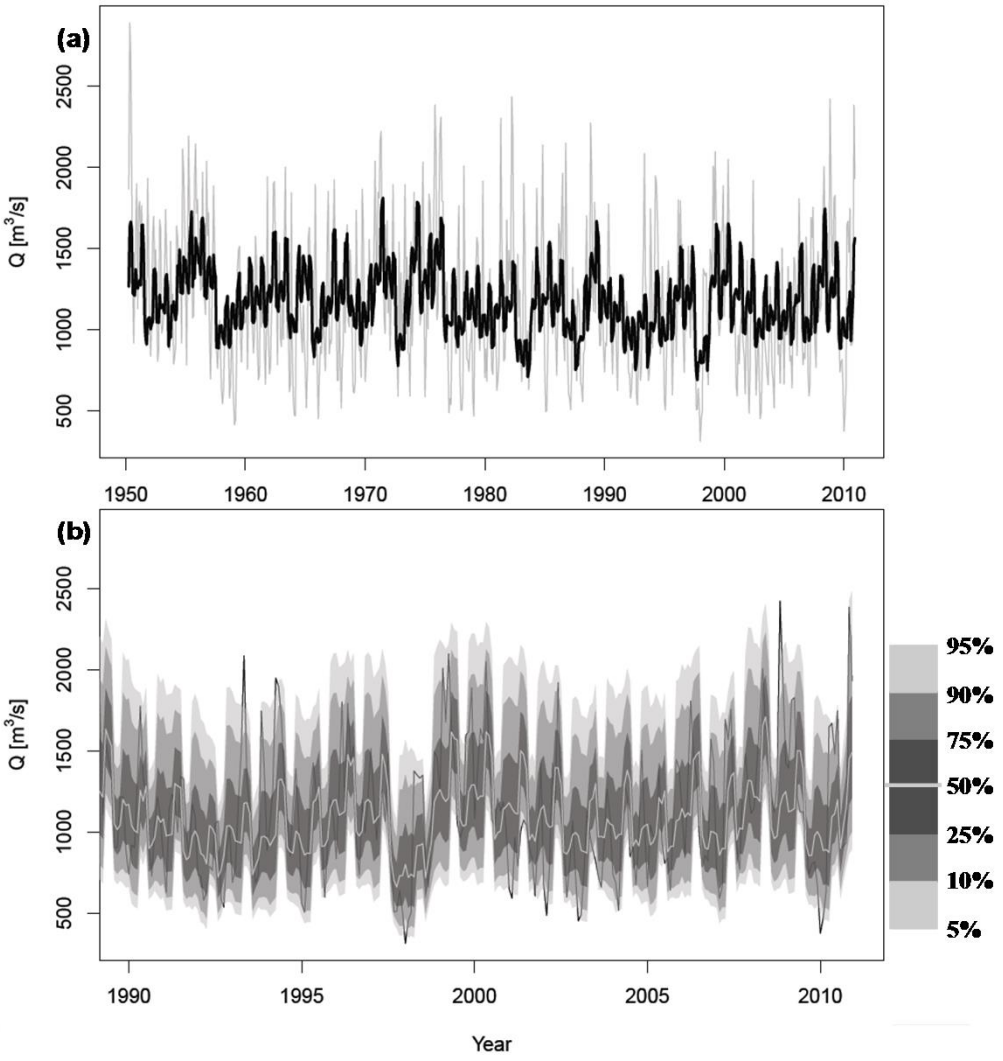
(d) Percentage difference.

In the difference maps, negative values are dashed, while the confidence in projected changes is highlighted with the dark gray square.

# EXPECTED RESULTS IN COLOMBIA

## -ii-

The ensemble pdf built in this way will be an useful tool for decision makers and water resources managers at national level, in such way that knowledge about population risk and vulnerability respect to climate change will be better, in order to design adaptation and mitigation plans to face the phenomenon of climate change.




Non-stationary pdf fitted to monthly mensual flow of Magdalena river (response variable), using the seasonal variability together with MEI as explanatory variables. (a) Flow time series (gray), together with the computed mean from the statistical model. (b) Fitted non-stationary pdf, whose quantiles are shown by gray shaded polygons.