UNIVERSITAT POLITÈCNICA DE VALÈNCIA

UNIVERSIDAD DE COLIMA — EDUCACIÓN CON RESPONSABILIDAD SOCIAL

Efecto de la variabilidad climática y los embalses en régimen de caudales bajos en el valle alto del río Cauca

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7mo Congreso Nacional de Investigación en Cambio Climático

Objetivo

- Climatic variability and anthropogenic changes in land uses or river regulation by dams produce
- Changes and trends in flow series
- The probability distribution functions can change over the time
- Non- stationary statistical models could reproduce the evolution of pdf´s parameters over time

To incorporate two alteration patterns (reservoir operation and climate variability) in a non-stationary low flows frequency analysis, using the GAMLSS (Generalized Additive Models for Location, Scale and Shape) framework

Methodology

Selection of random variable and analysis

↓

Testing stationarity

↓

Potential drivers of change (covariates)

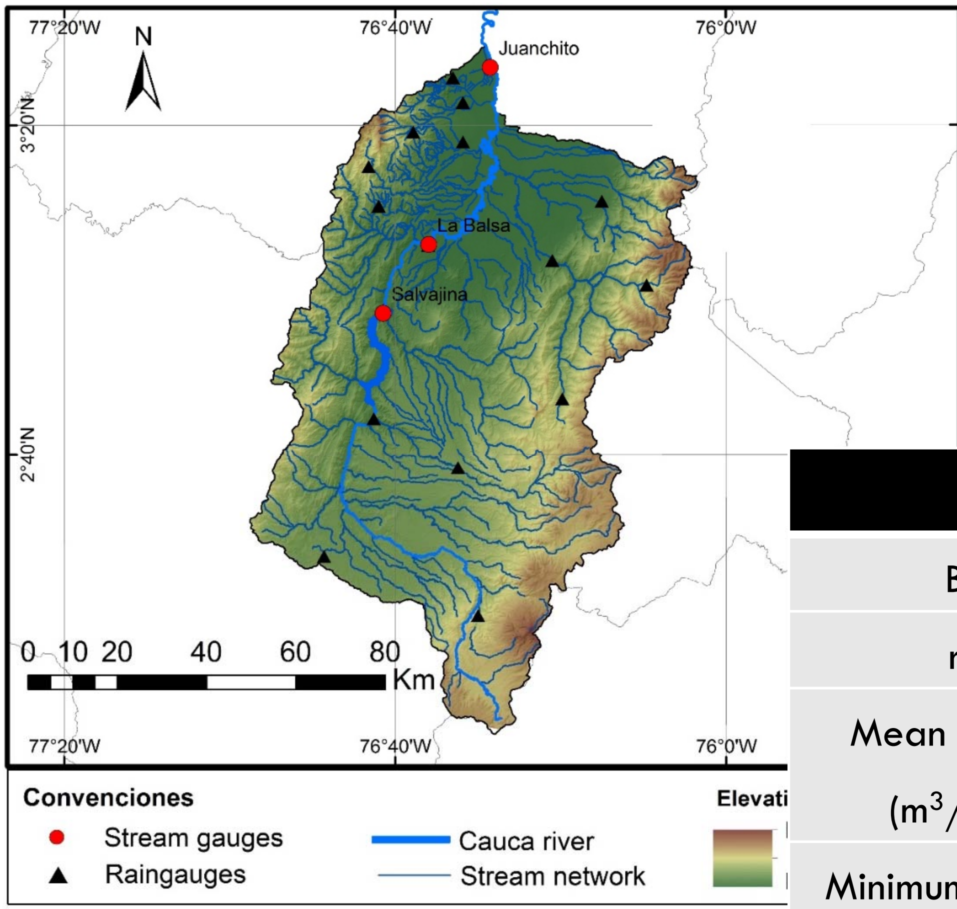
↓

Parameter estimation

↓

Model selection & exploitation

Case study



Upper Cauca River

South West of Colombia

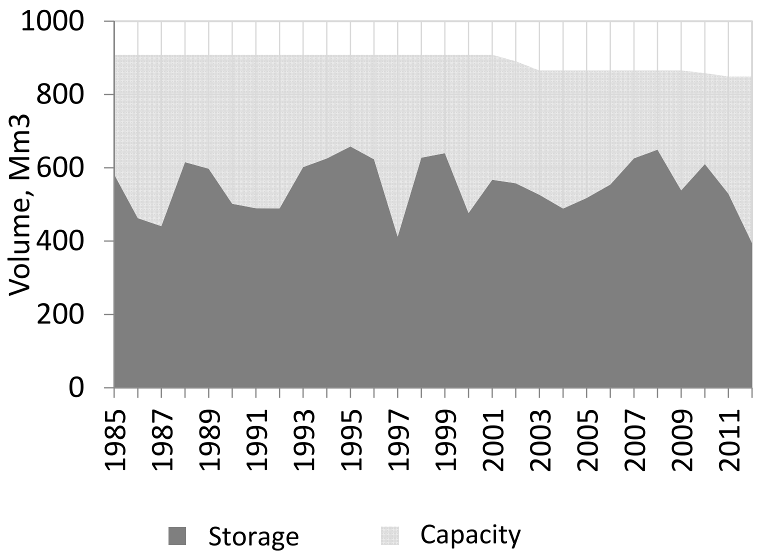
Tropical climate

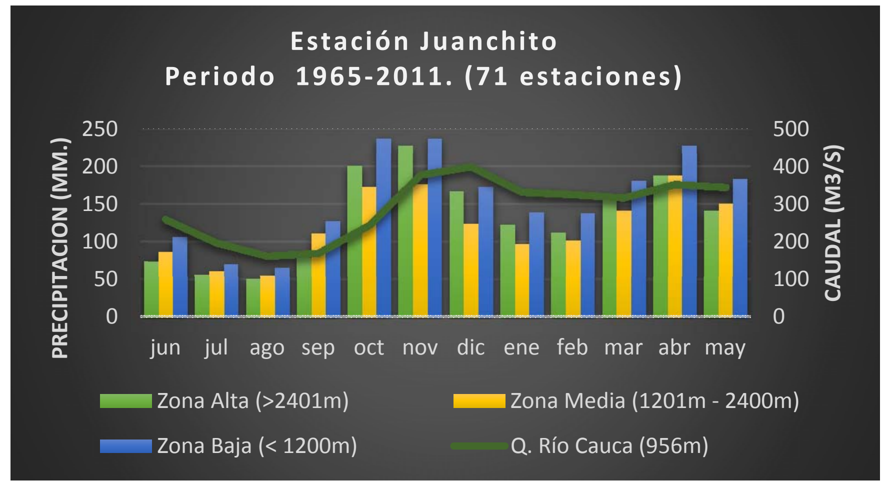
Water Supply to Cali Metropolitan Area (3 million inhabitants)

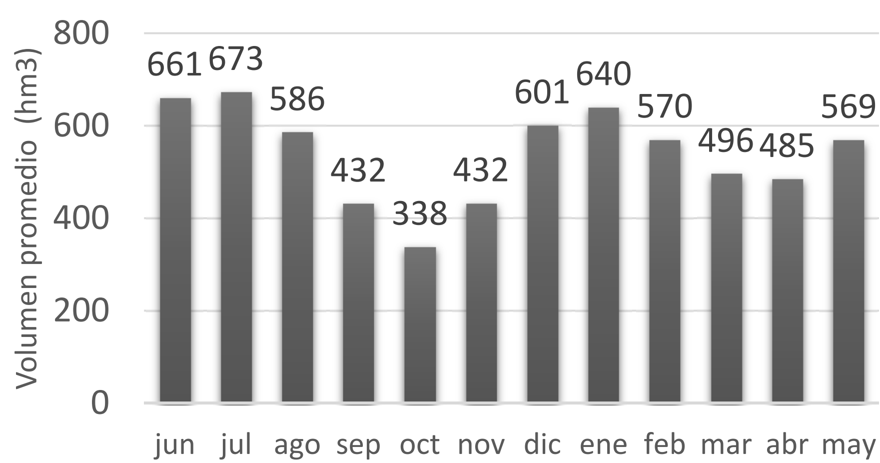
Salvajina Reservoir: 848 Hm^3

Station		Salvajina	Juanchito
Basin area (km^2)		3,652	8,556
regulated area		0%	43%
Mean flow (m^3/s)	1965-1984	143	288
	1986-2015	127	290
Minimum flow (m^3/s)	1965-1984	29	50
	1986-2015	15	86

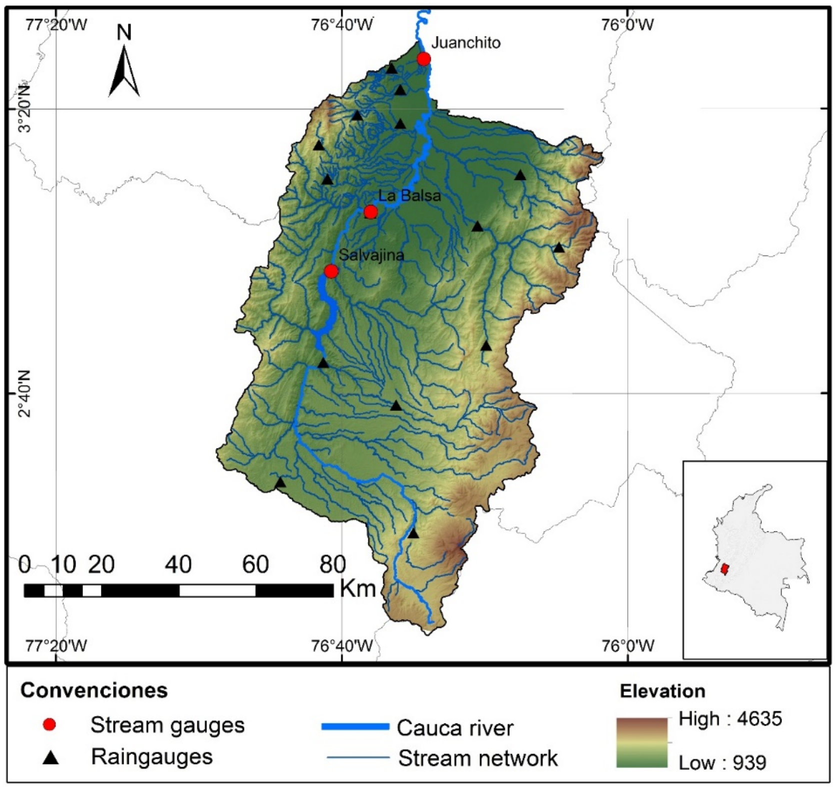
Salvajina reservoir







Case study: the problem



In Juanchito, environmental flow must be 140 m^3/s 95% of the time

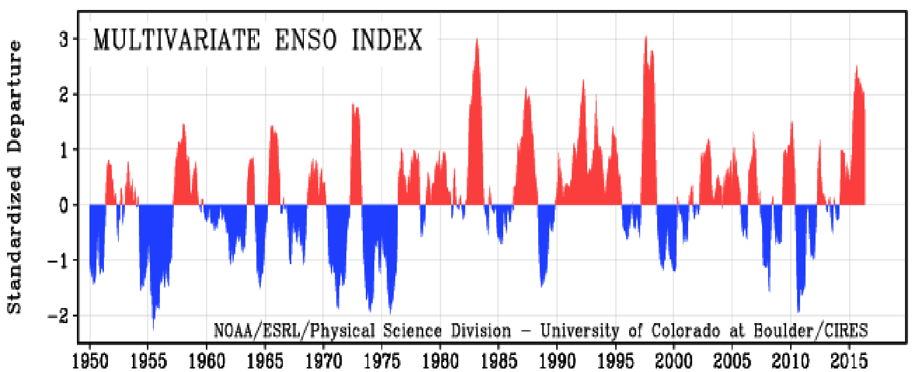
Mainly to guarantee dilution of contamination (large industrial area upstream)

In 2006-2009 there was 102 water supply cutoff due to contamination

- Annual minimum monthly discharge in m3/s: Am
- Low flow duration in days: Dmin

Climatic variability

- **EL NIÑO: droughts**, fire forests, energy failures, problems in river navigation, heat waves, …



- **LA NIÑA: floods**, land slides, diseases, pests, erosion, …

EE NOTICIAS OPINIÓN ECONOMÍA DEPORTES ENTRETENIMIENTO VIVIR MUJER

NACIONAL 21 FEB 2016 - 7:08 PM

Más de 11 hectáreas afectadas en el Valle por el fenómeno de El Niño

La ganadería y la producción de carne también preocupa a los productores del departamento.

Por: Redacción Nacional

COMPARTIDO 19

INSERTAR

Semana NACIÓN OPINIÓN ECONOMÍA VIDA MODERNA GENTE CULTURA MUNDO TECNOLOGÍA

Inundaciones en Colombia: igual a anegar Bogotá 27 veces

Así lo contempla el más reciente estudio público del Instituto Agustín Codazzi. Los departamentos de la Costa Caribe, los más afectados.

Asi se ve hoy parte del municipio de Chía, en Cundinamarca. *Foto: Foto: SEMANA.*

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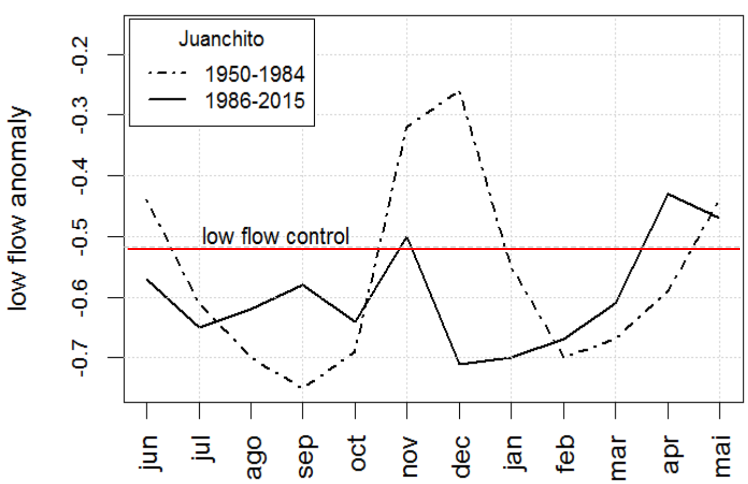
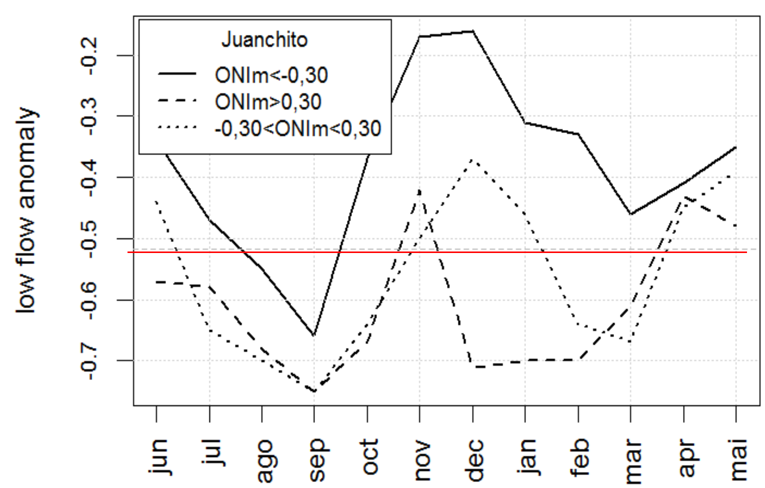
Stationarity?



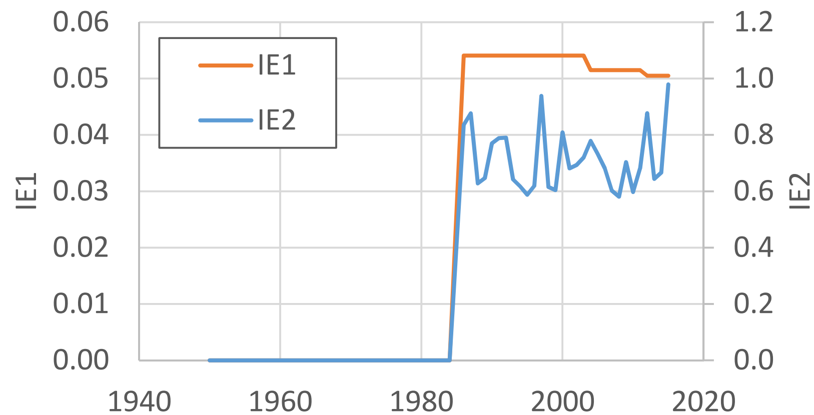


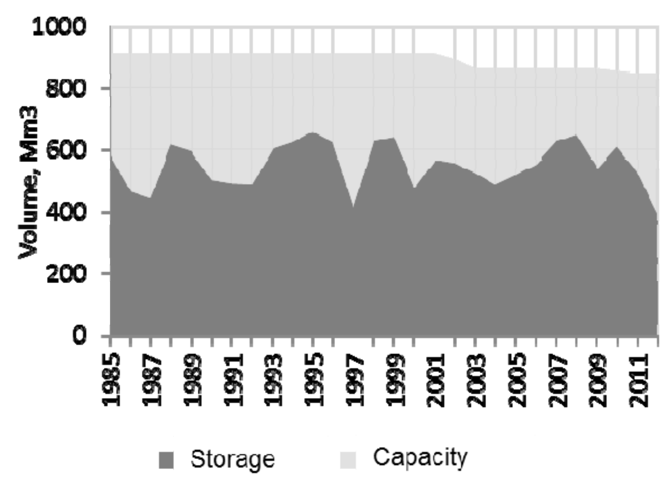
Series	Station	Period	Pettit	Mann-Kendall
Annual minimum monthly flow (m^3/s)	Salvajina	1965-2015	2000 P1	(-) P1
Annual minimum monthly flow (m^3/s)	Juanchito	1950-2015	1983 P1	(+) P1
Annual low flow duration (days)	Juanchito	1950-2015	1983 P1	(-) P1

Covariates: reservoir indices

$$IE1 = \sum_{i=1}^{N} \frac{A_{E_i}(t)}{A_T} \cdot \frac{C_E(t)}{\bar{C}(t)}$$

$$IE2 = \sum_{i=1}^{N} \frac{A_{E_i}(t)}{A_T} \cdot \frac{C_E(t)}{\overline{Vp_D}(t)}$$





$A_{E_i}(t)$: drainage area of dam in km^2,
A_T: drainage area of flow gauge station in km^2,
$\overline{Vp_D}$: average volume of water at dam in Hm^3
C_E: reservoir capacity in Hm^3
$\bar{C}$: mean annual runoff at the flow gauge station in Hm^3
n : reservoir number upstream the station

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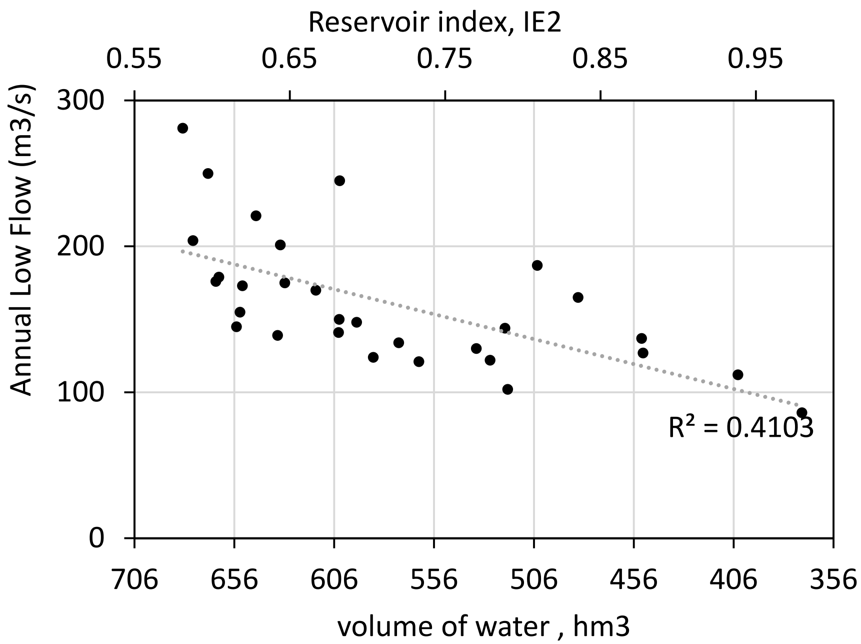
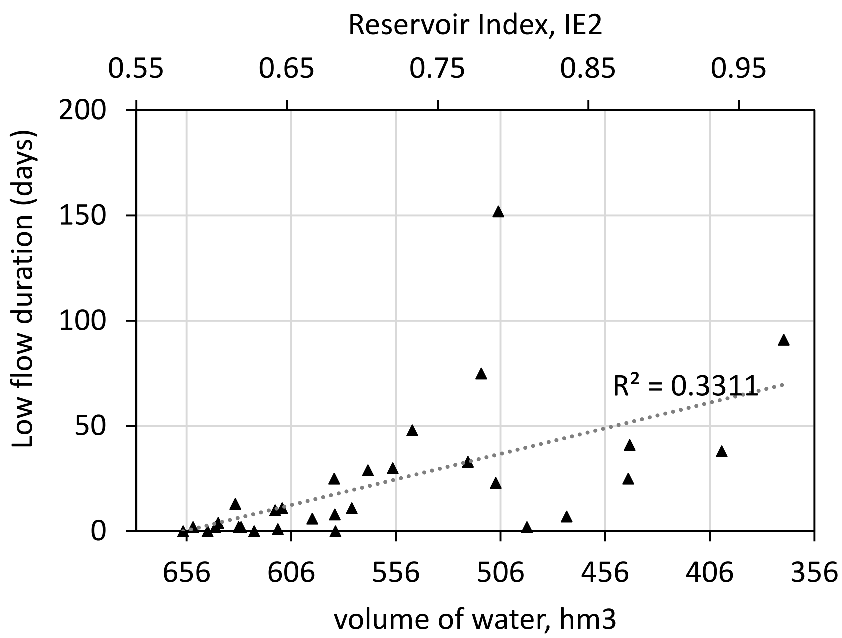
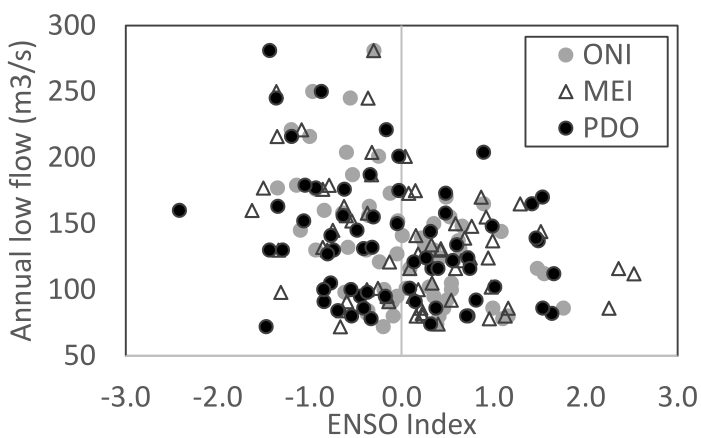
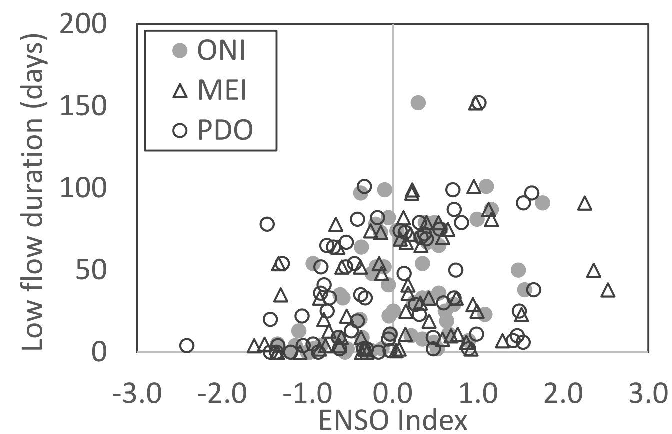
Covariates: reservoir influence

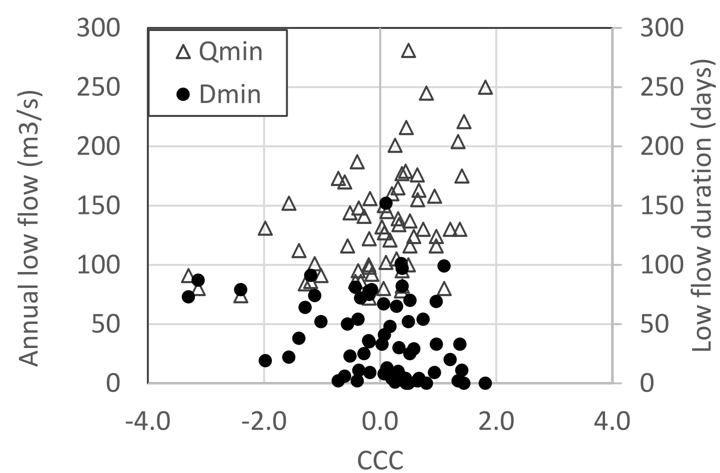




Covariates: climatic influence







GAMLSS non-stationary models

- Parametric distributions for the response variable Y
  - we used several different distributions (Gumbel, Gamma 2p, Generalized Gamma, Lognormal 2p, Weibull and Negative binomial type I)

- Distribution parameters are nonlinear function of covariates $\boldsymbol{x}_i$:

$$Y_i \sim F(y_i; \boldsymbol{\theta}_i(\boldsymbol{x}_i))$$

  - using penalized beta splines and cubic splines smoothing functions

  - potential covariates: EIs and climatic indexes

Models

Model 0	$Y_i \sim F(y_i; \theta)$	**stationary**
Model 1	$Y_i \sim F(y_i; \theta_i)$	**with covariates**

Non-stationary model selection

- Selection of the models:
  - Generalized Akaike Information Criterion (GAIC)

$$AIC = -2In(ML) + 2k$$

  - Schwarz Bayesian Criterion (SBC)

$$SBC = -2In(ML) + kIn(n)$$

- The model fit performance is evaluated by investigating the normality and independence of the (normalized quantiles) residuals
  - qq-plots and worm plots
  - Compute the first four moments of the residuals and Filliben correlation coefficient

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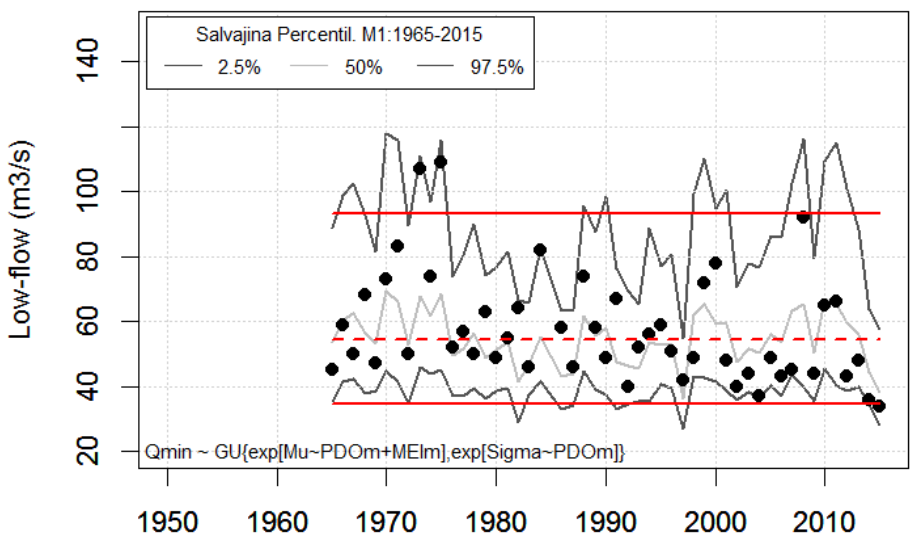
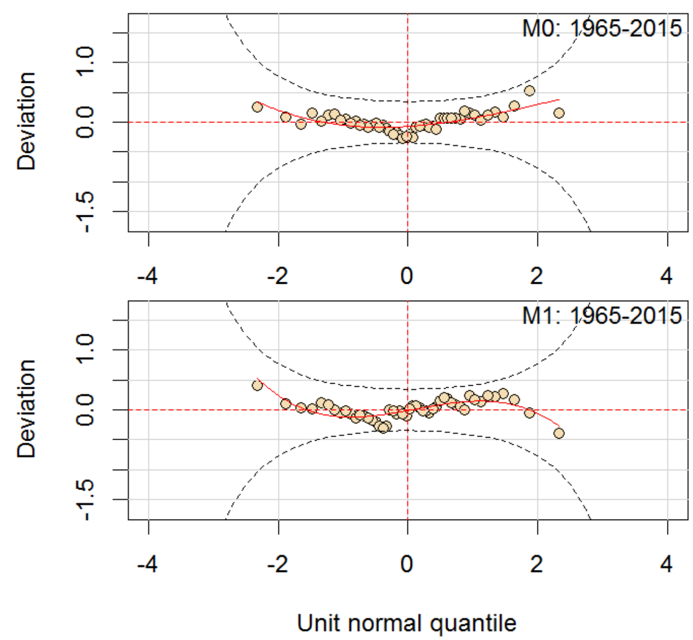
Annual Low Flow: Salvajina

- Gumbel

Model	Mu	Sigma	df	GAIC	Mean	Var.	Skew.	Kur.	Fill.
M0	1	1	2.00	412.05	8.1E-03	1.10	0.38	2.60	0.99
M1	PDO MEI	PDO	5.00	393.93	1.3E-02	1.05	0.13	2.01	0.99

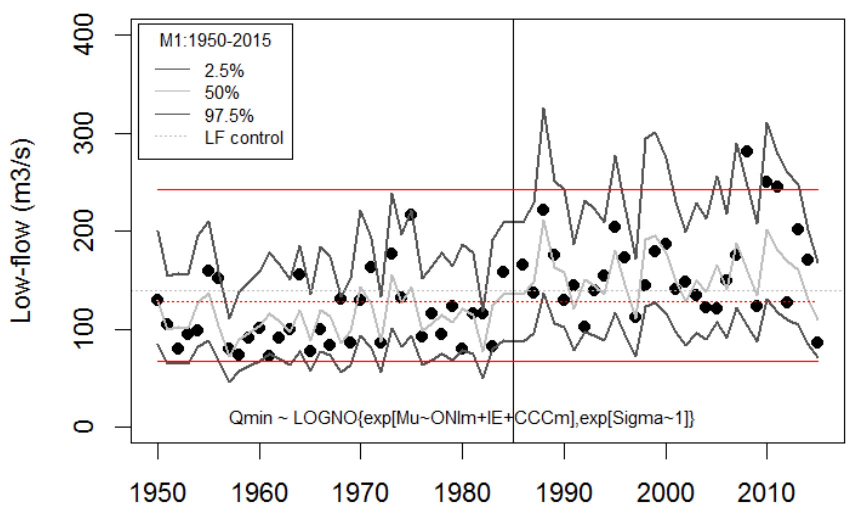


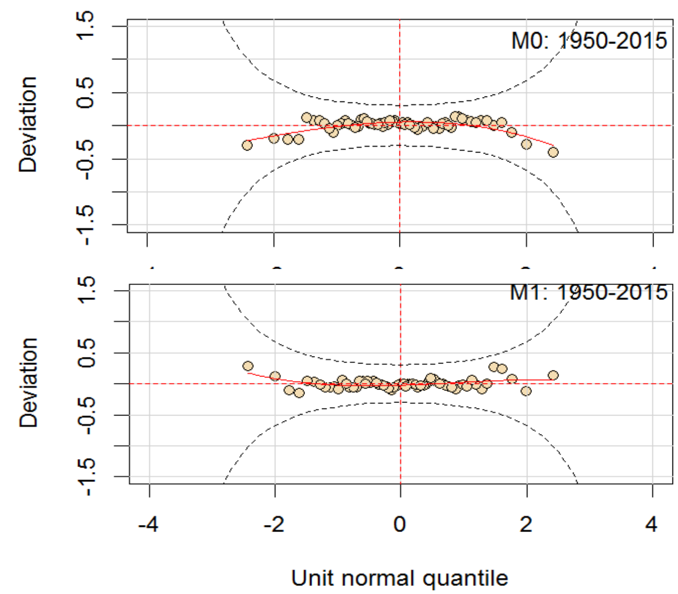


Annual Low Flow: Juanchito

- LogNormal

Model	Mu	Sigma	df	GAIC	Mean	Var.	Skew.	Kur.	Fill.
M0	1	1	2.00	675.91	-9.4E-17	1.02	0.20	2.27	0.99
M1	ONI IE CCC	1	5.00	633.99	-4.9E-16	1.02	0.12	2.64	1.00

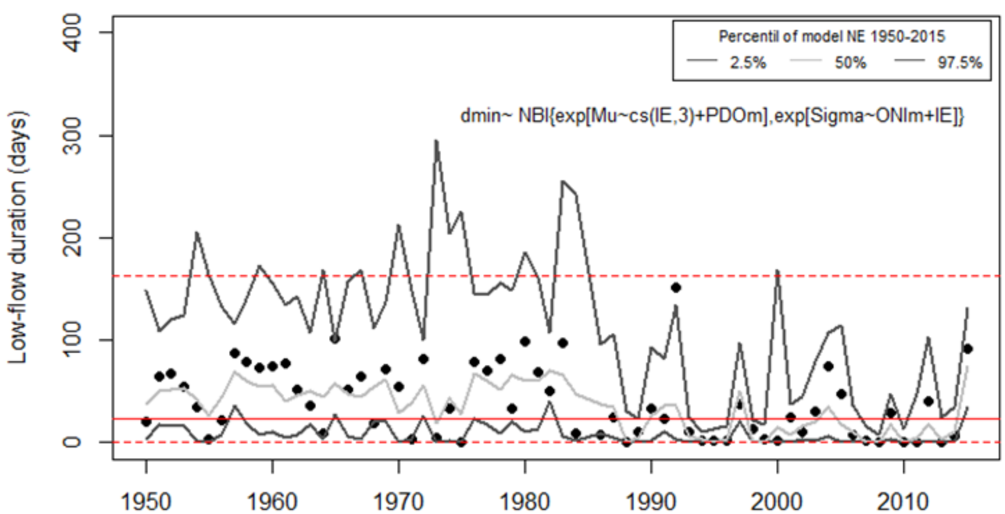


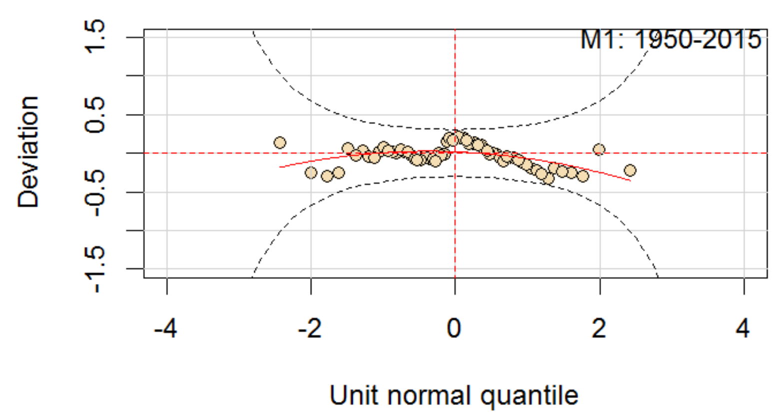


Low Flow Dration: Juanchito

Negative Binomial type I

Model	Mu	Sigma	df	GAIC	Mean	Var.	Skew.	Kur.	Fill.
M0	1	1	2.00	608.12	2.4E-02	1.02	-0.49	2.27	0.98
M1	PDO cs(IE,2.99)	ONI IE	8.99	546.92	-1.4E-03	0.91	-0.23	2.72	0.99





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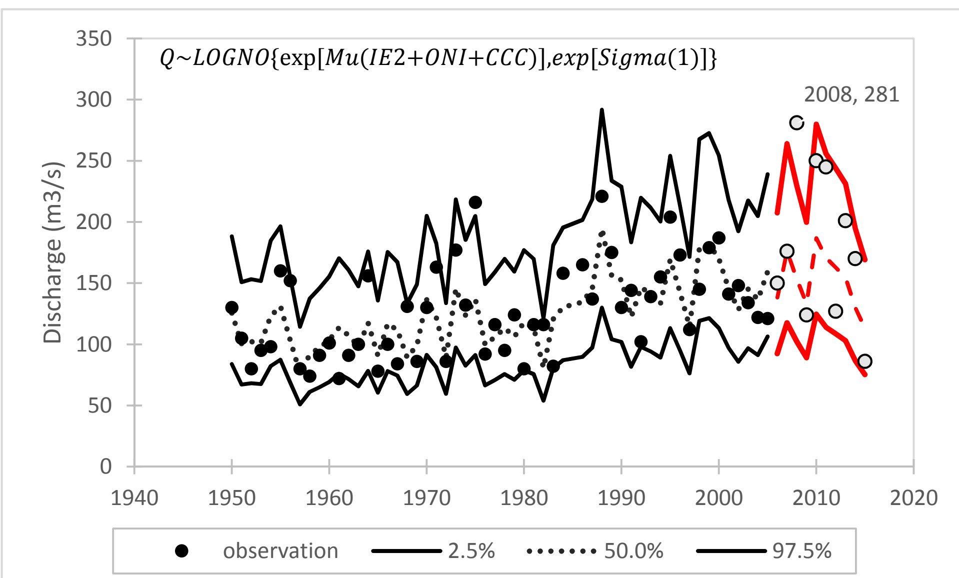
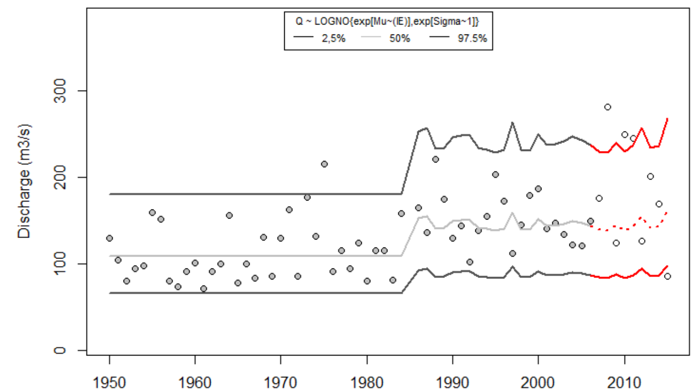
Forecasting low flows in Juanchito

Calibration period: 1951-2005

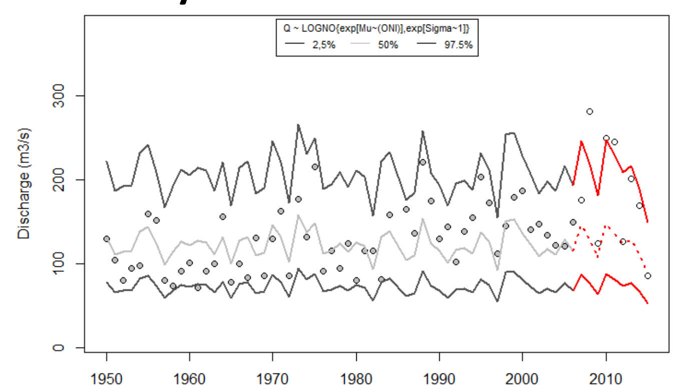
Validation period: 2006-2015 (hindcast with perfect prediction of covariates)



Only IE2



Only climate



Discussion

Stationary hypothesis have been the cornerstone in FFA

Floods are independent & identically distributed (i.i.d.)

Is it true?

Many years ago:

"Is it possible that climatic oscillations can exist alone (with no effect upon anything else) ? … So far, we are completely in the dark as the plotting of meteorological observations alone will not determine it."

Brückner, 1890

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Discussion

- And recently ...

POLICYFORUM

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1*] Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Systems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water-resource engineering. It implies that any variable (e.g., annual stream-

that has emerged from climate models (see figure, p. 574).

Why now? That anthropogenic climate change affects the water cycle (*9*) and water supply (*10*) is not a new finding. Nevertheless, sensible objections to discarding stationarity have been raised. For a time, hydroclimate had not demonstrably exited the envelope of natural variability and/or the effective range of

2011

“<u>Stationarity is dead…….and cannot be revived</u>”. “New statistical models and procedures are needed to dynamically capture the evolution of probability density functions over time”

Milly, et al., 2008

Discussion

- However, more recently

Advances in Water Resources 77 (2015) 17–36

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journal homepage: www.elsevier.com/locate/advwatres

ELSEVIER

Stationarity is undead: Uncertainty dominates the distribution of extremes

CrossMark

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“Stationarity is undead: uncertainty dominates the distribution of extremes“. ”Thus, complex non-stationary models do no not provide better .. results than the stationary models because what really matters are … the interval estimates”.

Serinaldi and Kilsby, 2015

Conclusion

- In many places it has been found clear teleconnections between flow records and
  - Dam construction and land use changes
  - Climatic variability
- Quantile uncertainty is very high, especially for floods

  => reduce uncertainty introducing more information

- Non-stationary models with external covariates using GAMLSS are very flexible and produce a reasonable interpretation of historical records and meaningful flow forecast
  - Unfortunately, currently we don’t have predictions of climate indices (with exception of ENSO)

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Muchas gracias por su atención

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