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Flood Frequency Analysis Under Non-stationarity Conditions: the case of Southern Brazilian Hydroeletric Power Plants

Authors

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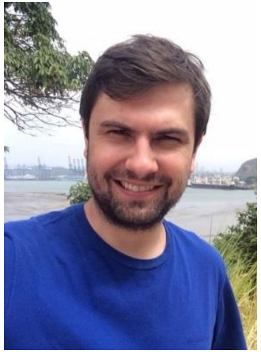
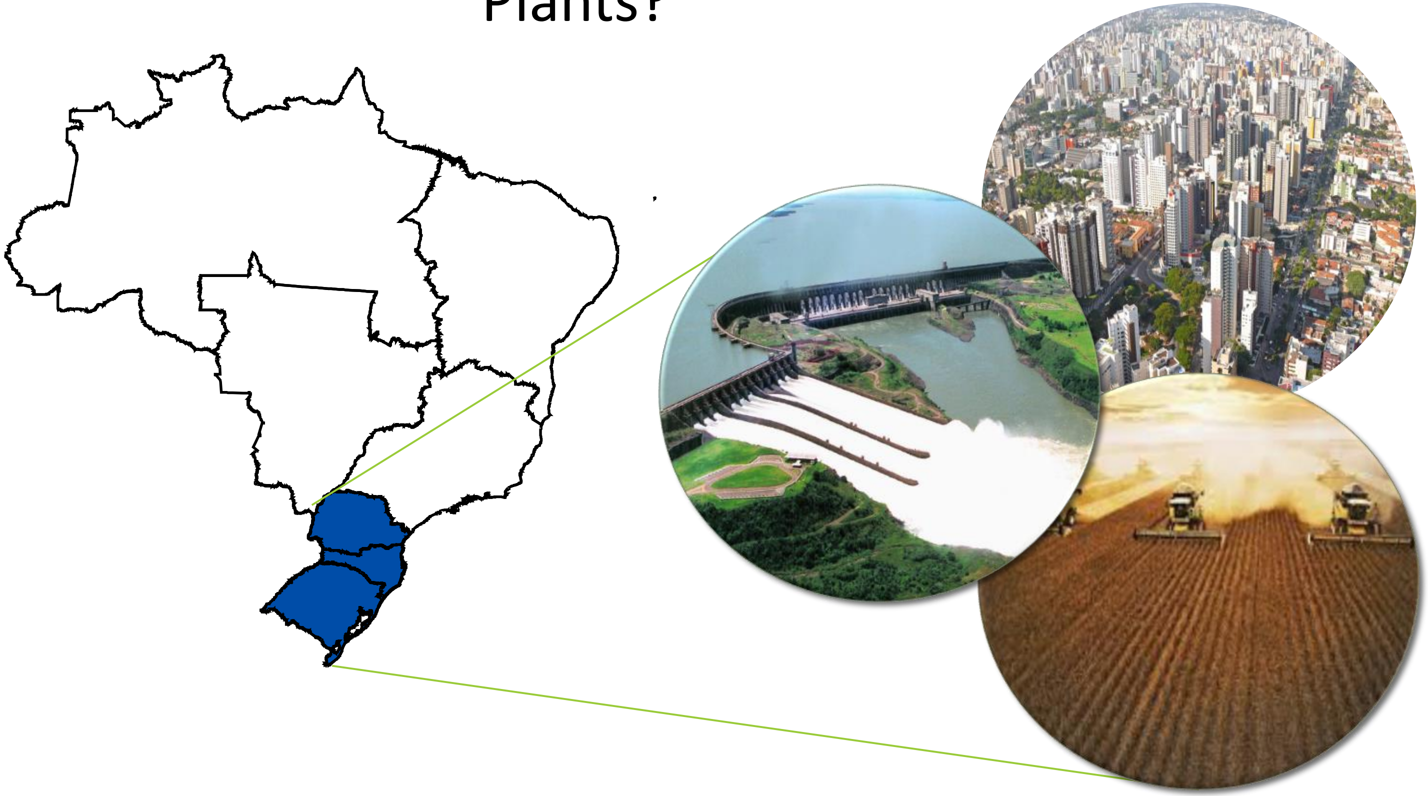


Pedro Luiz Borges Chaffe, Dr.

Nadia Bernardi Bonumá, Dr.

Justification

What are the consequences of nonstationarity in frequency analysis of high flows affluent to Southern Brazilian Hydroeletric Power Plants?



Justification

Land use and climate changes in Southern Brazil

Extreme highflows are more frequent and intense

How have we dealt with these changes in flood frequency analysis?

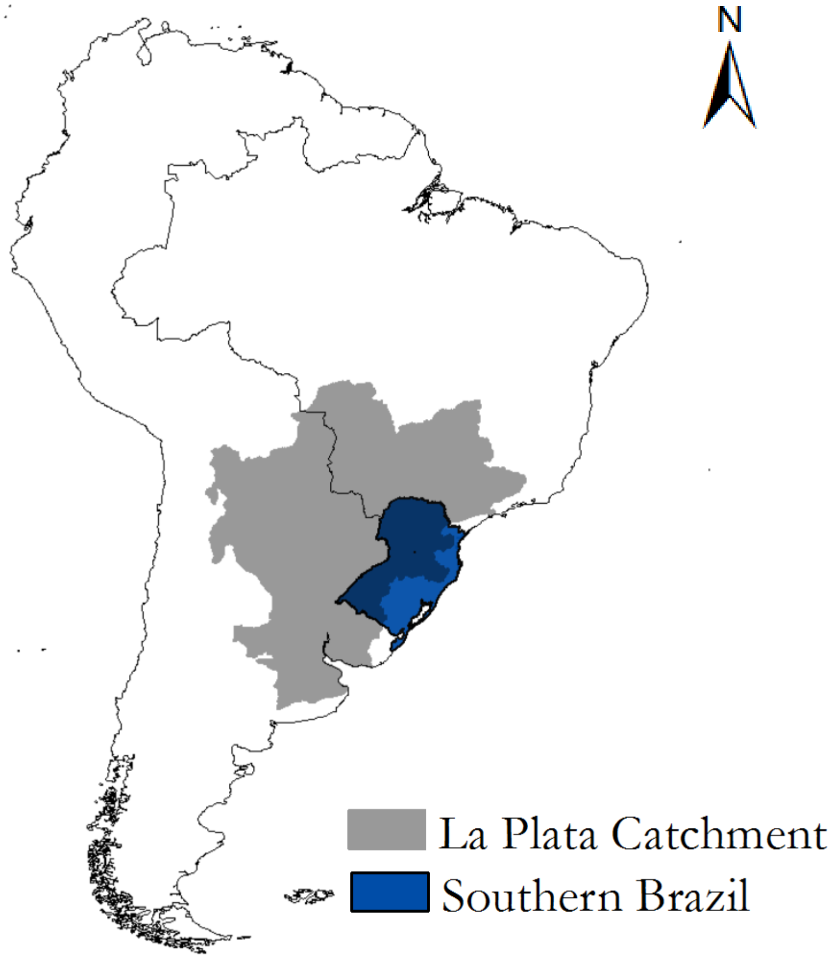
Iguazu Falls – Average Flow 1.800 m^3/s

Iguazu Falls – Record Flow – June/2014 46.000 m^3/s

MATERIAL AND METHODS

Study Area – Southern Brazil

- ✓ La Plata Basin
- ✓~ 29.000.000 inhabitants (2014)
- ✓ 575.316 km² - 6.76% of Brazil total
- ✓ 26.9 % of total installed hydroeletric power generation capacity on Brazil – 25.121 MW
- ✓ Intense industrial and agricultural activities



38 fluviometric series

Brazilian National Grid Operator (ONS)

Maximum size possible

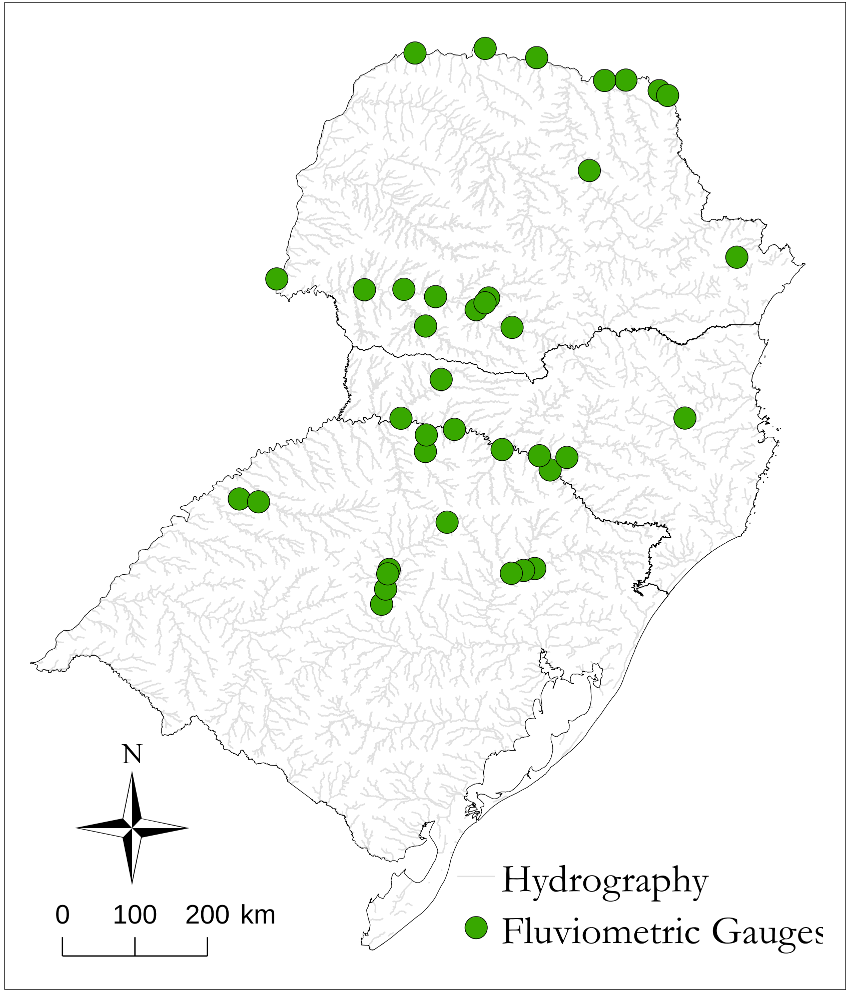
43 to 84 years

From each year of the original series

Maximum daily streamflow

Missing values

If percentage of missing values registered in the years corresponding to the 40% lower values of maximum annual daily streamflow series was ≥ 30%, the series was discarded



✓ **Vogel, Walter and Yaindl (2011)**

$$x_p = \exp[\mu_y + z_p \sigma_y]$$

LN Probability Distribution

+

$$\mu_y(t) = \bar{y} + \hat{\beta}(t - \bar{t})$$

Log-Linear Trend Model

=

$$x_p(t) = exp\left[\bar{y} + \hat{\beta}\left(t - \frac{n+1}{2}\right) + z_p s_y\right]$$

Nonstationary Frequency Model

✓ Evaluated premises

Slope Trend Model – Student's t-test

Residuals of the linear trend model

Normality – Anderson-Darling test

Independence – Durbin-Watson

Homocedasticity – Breusch-Pagan

- Level of significance $p<0.05$ was used fo all tests

Recurrence Reduction

Average time (T_f) between floods in some future year t_f associated with the flood with an average recurrence interval of T_0 in some reference year t_0.

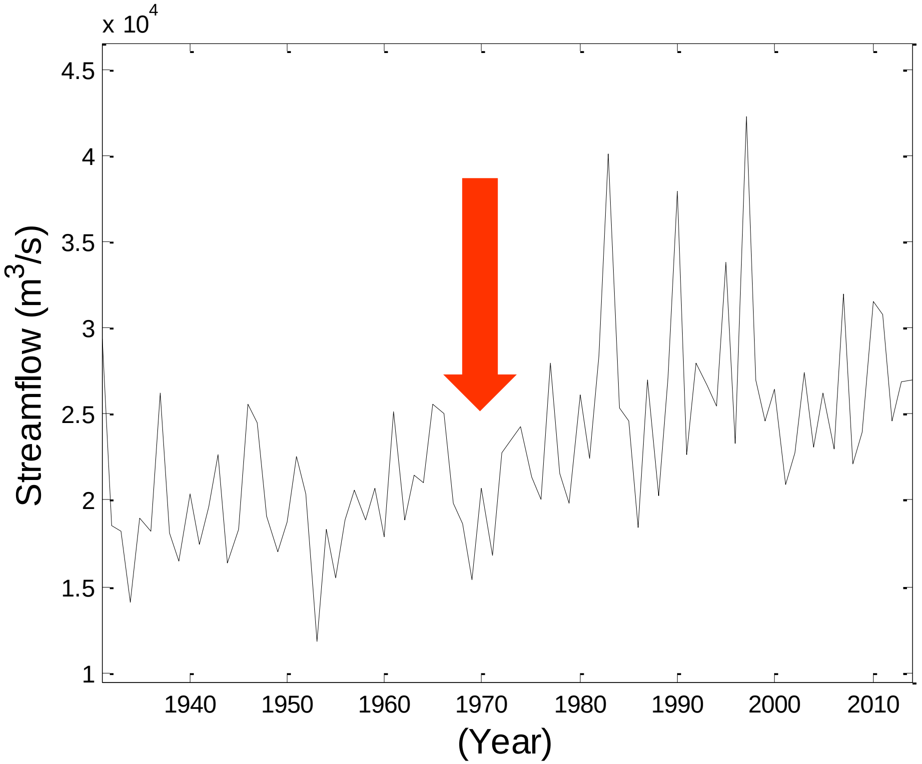
Vogel, Yiandl and Walter(2011)

We adopted a planning horizon ($tf - t_0$) equal to 10 years

RESULTS AND DISCUSSIONS

There is a different behaviour in the streamflow series after 1970

Itaipu Dam Inflow

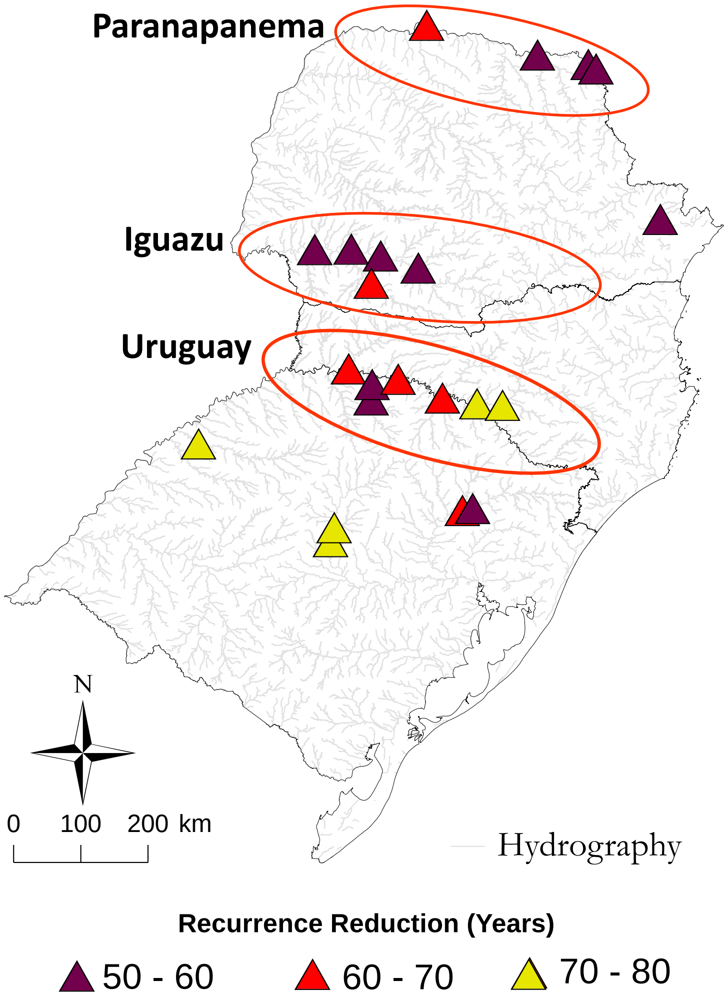


Results

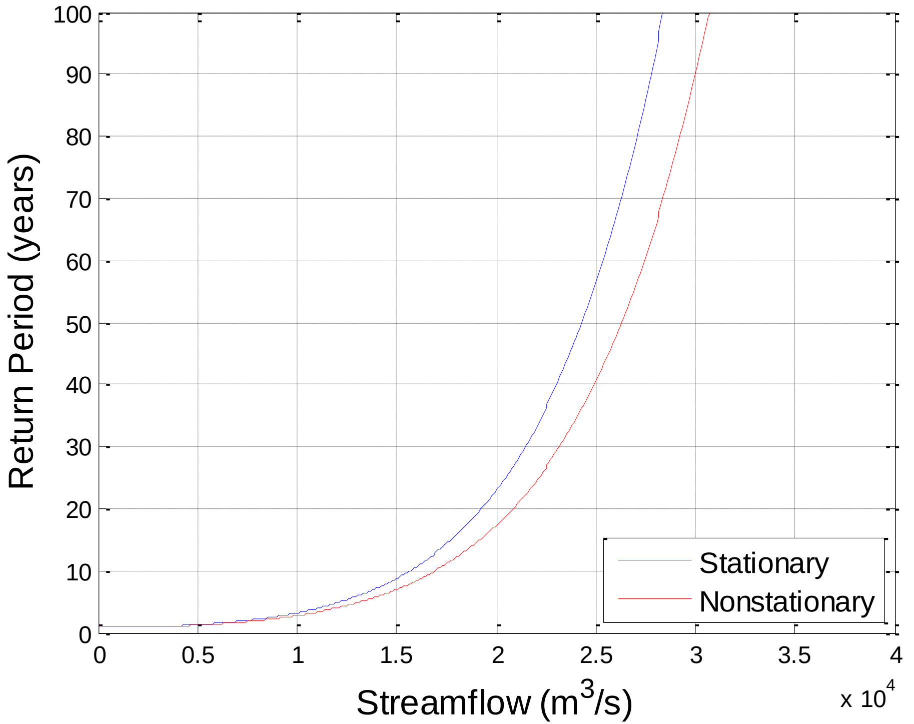
- 22 of 38 series are nonstationary

- In just a decade, the Return Period of a high flow estimated as 100 years changes from 50-77 years in nonstationary condition

- The nonstationary series are concentrated mainly in Iguazu, Paranapanema and Uruguay basins.

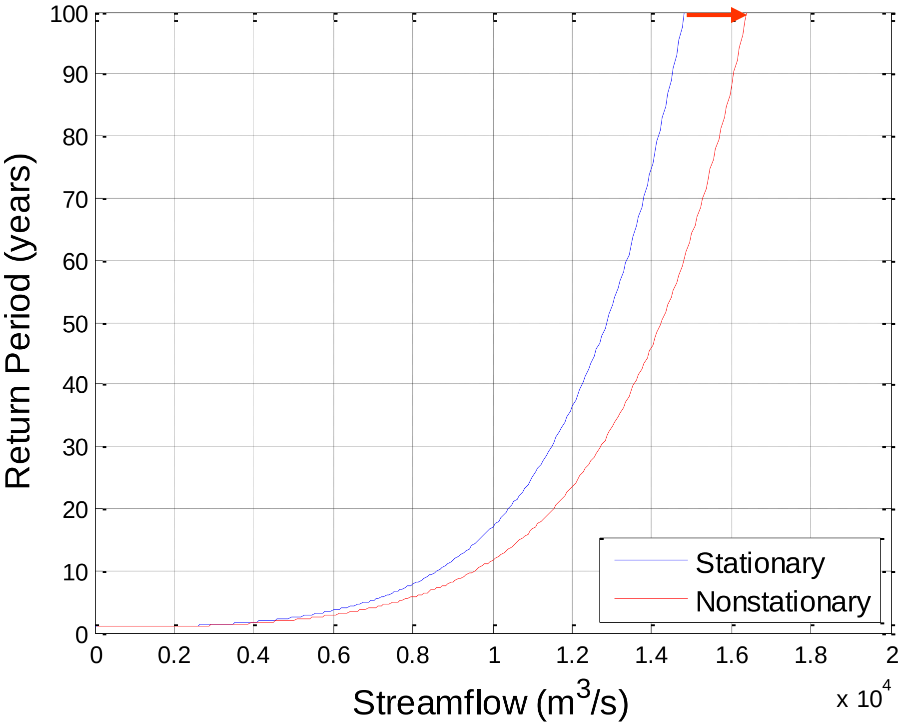


Itá
Uruguay River



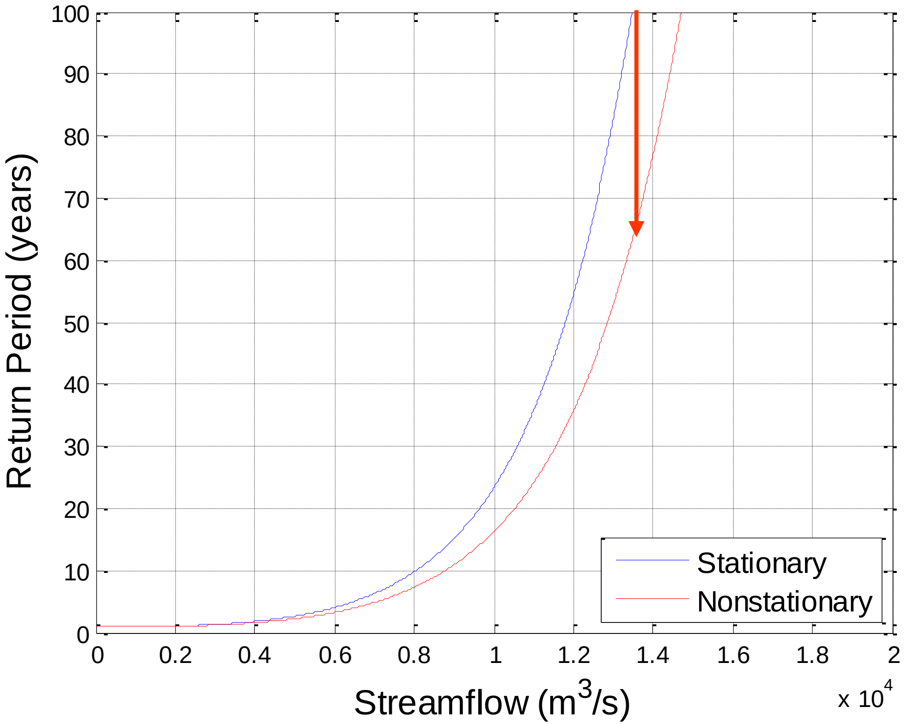
There is a significant difference between stationary and nonstationary frequency curves

Salto Osório
Iguazu River



A 100 year flood ranges from ~14.800 m³/s to ~16.400 m³/s in only ten years horizon

Taquaraçu
Paranapanema River



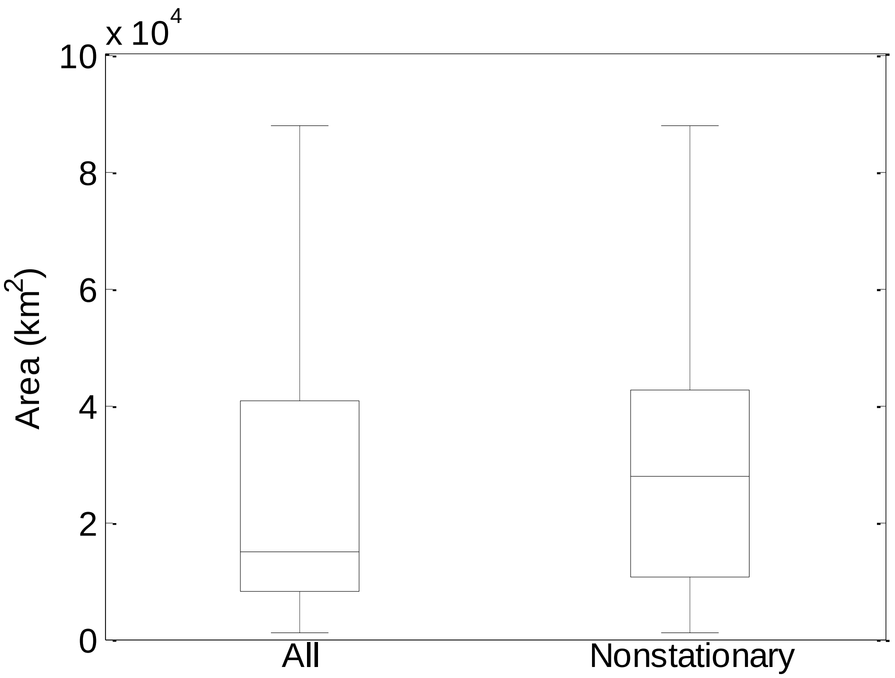
A flood estimated as 100 years in stationary model changes to ~ 65 years in nonstationary model

For a project lifetime equal to 50 years, the risk of failure changes from 40% to 54%, in just a decade.

Nonstationary, area and regularization basin

Nonstationary series are slight concentrated in basins of greater area

20 of 22 series are from gauges that have upstream regulation



Possible drivers?

Similar pattern between streamflow and precipitation series

Detzel and Mine, 2014

Changes in the El Niño-Southern Oscillation and Pacific Decadal Oscillation behaviour after 1970. There are relations between climatic indexes and presence of streamflow increase trends in Southern Brazil

Carvalho et al., 2014; Doyle and Barros, 2011; Alves, Souza Filho and Silveira, 2013; Silva, Naghettini and Portela, 2016; Silva et al., 2015

Land use change in lesser importance

Doyle and Barros, 2011

CONCLUSIONS

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- ✓ Nonstationarity are present in Southern Brazil Hydroeletric Power Plants Inflow series.
- ✓ There is a great difference between return periods and frequency curves calculated by stationary and nonstationary models.
- ✓ Due to the limited number of data, it is not possible conclude about the relation between nonstationarity, basin area and regulation.
- ✓ The most accepted drivers for changes in streamflow series are related to climatic factors.
- ✓ We need to take into account the nonstationarity approach when evaluated risks of the large hydraulic structures, since there is a significant increase for nonstationary conditions.

Thank you so much!

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