Universidade de Brasília

PTARH

PROGRAMA DE PÓS-GRADUAÇÃO EM TECNOLOGIA AMBIENTAL E RECURSOS HÍDRICOS

Forecasting Inflow Persistence Using Climate-Informed Hidden Markov Models: An Application To Orós Reservoir In Brazil

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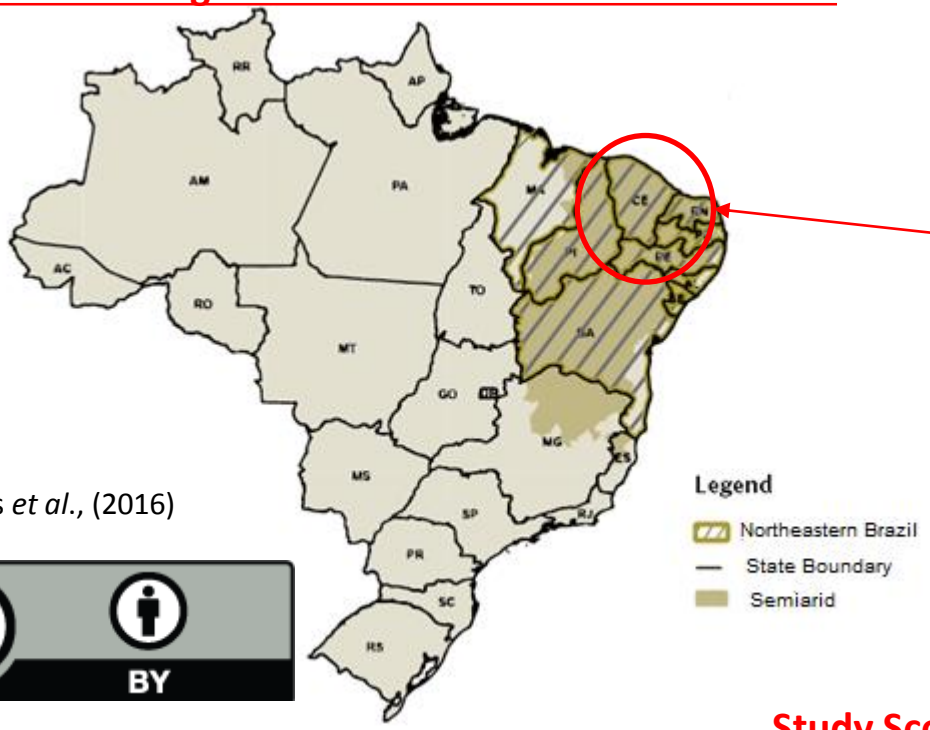
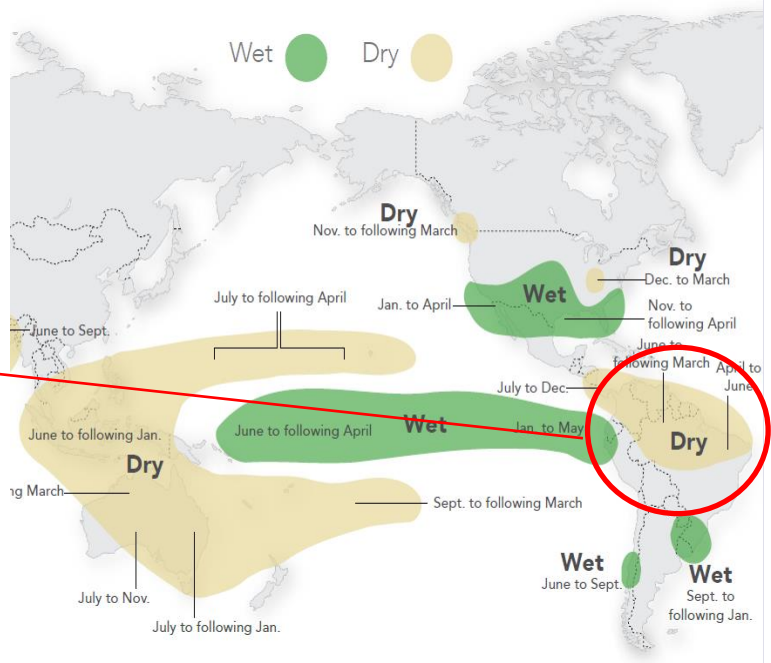
1.Introduction

Study Area - State of Ceará

- High Space-Temporal Rainfall Variability
- Two seasons: wet and dry. So, the mean annual streamflow is approximately the mean wet flow
- High Frequency of Severe Droughts
- Vulnerable region to the future climate conditions



De Nys *et al.*, (2016)



IRI (2018)

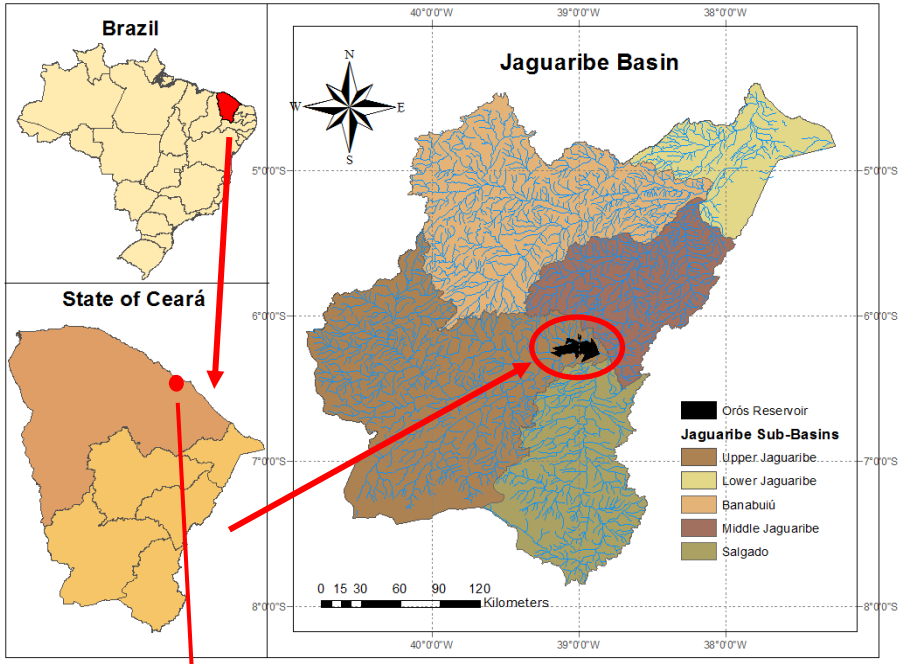
Problem

- High inflow uncertainty

Study Scope

- To improve the forecasting system using Hidden Markov Models to capture Annual Observed Hydrology Persistence
- To give some tools to local decision-makers for evaluating the best strategy to deal with extreme events like droughts

2.Data



Data Base

The Orós Reservoir Location

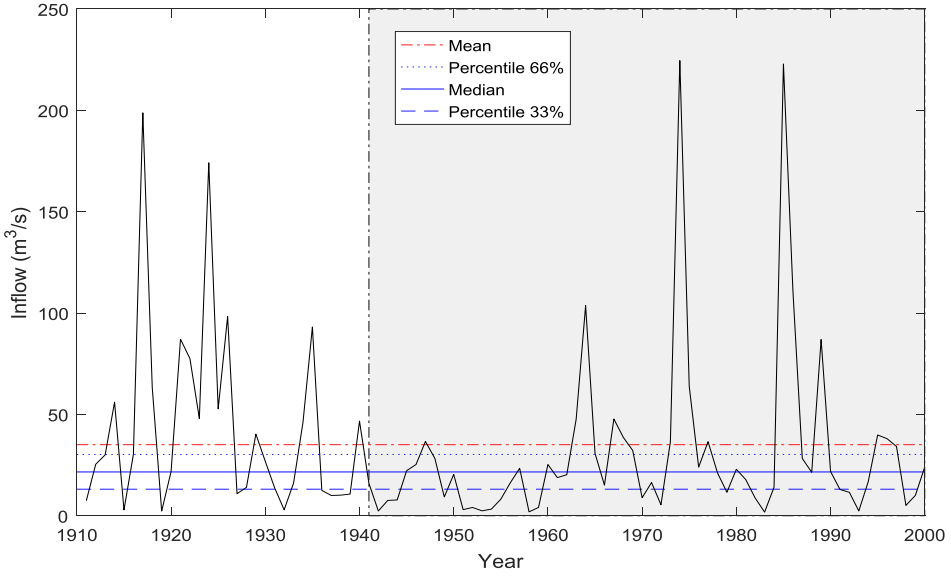
Fortaleza: state capital of Ceará

Mean annual inflow series to the Orós reservoir

- **90-year inflow time series: 1911-2000**
  - 30-year Calibration Period: 1911-1940
  - 60-year Validation Period: 1941-2000

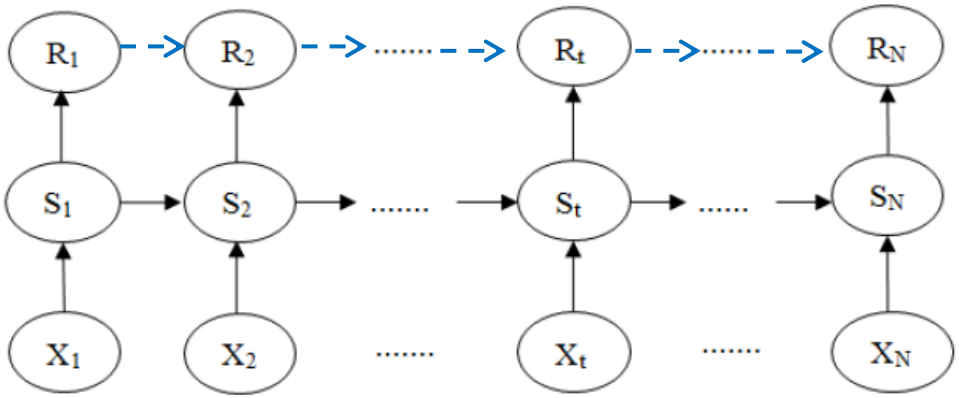
Climate information : Nino3 Climate Index

- High correlated with observed inflow



3. Hidden Markov Models (HMMs)

Autoregressive Non-Homogenous HMMs (AR-NHMMs)

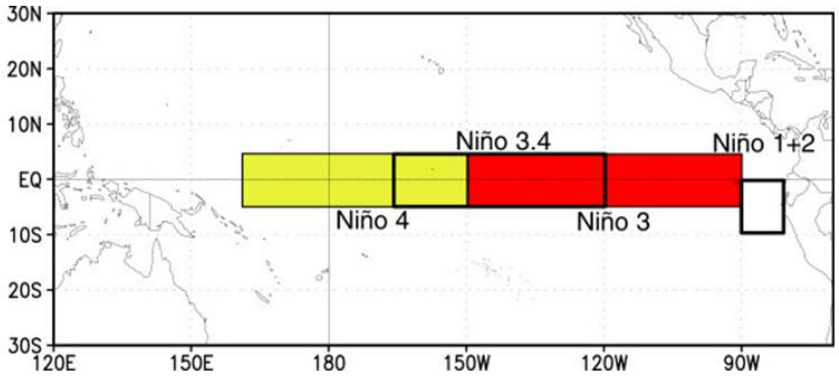


$$\gamma_{ij}(t) = \Pr(C_{s+t} = j \mid C_s = i)$$

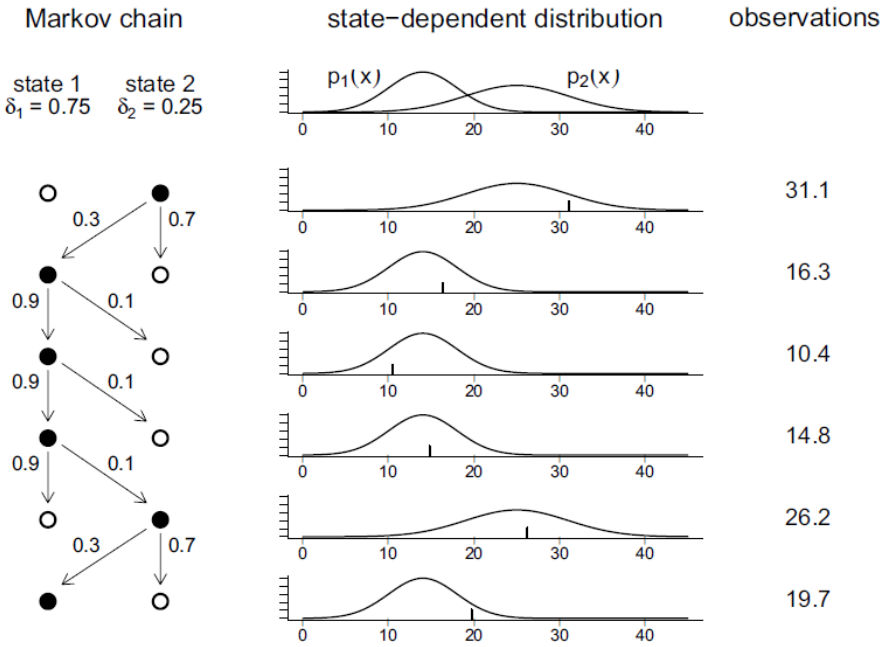
$$\mathbf{\Gamma} = \begin{pmatrix} \gamma_{11} & \cdots & \gamma_{1m} \\ \vdots & \ddots & \vdots \\ \gamma_{m1} & \cdots & \gamma_{mm} \end{pmatrix}$$

Transition probability matrix (TPM)

Hidden Markov Models (HMMs) and Non-Homogenous HMMs (NHMMs)



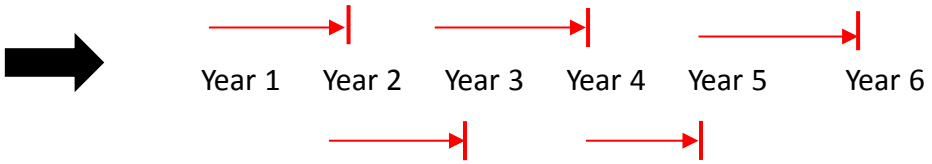
El Niño Regions (NOAA, 2018)

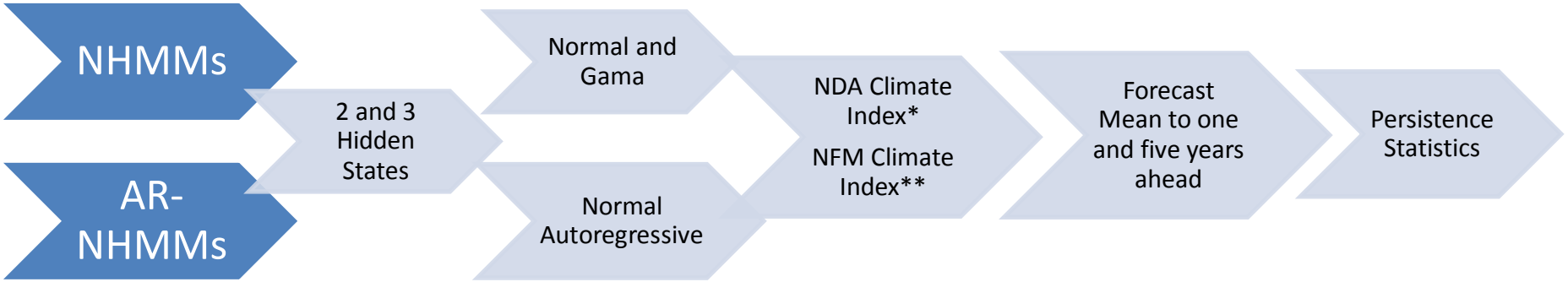


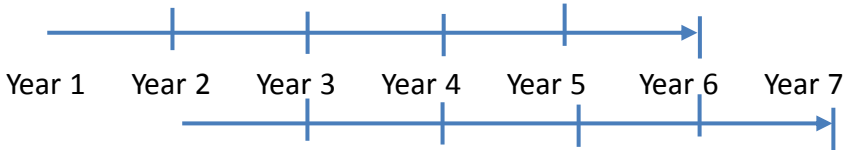
(Zucchini and MacDonald, 2009)

4.Forecasts Based on NHMMs

One year ahead forecasts





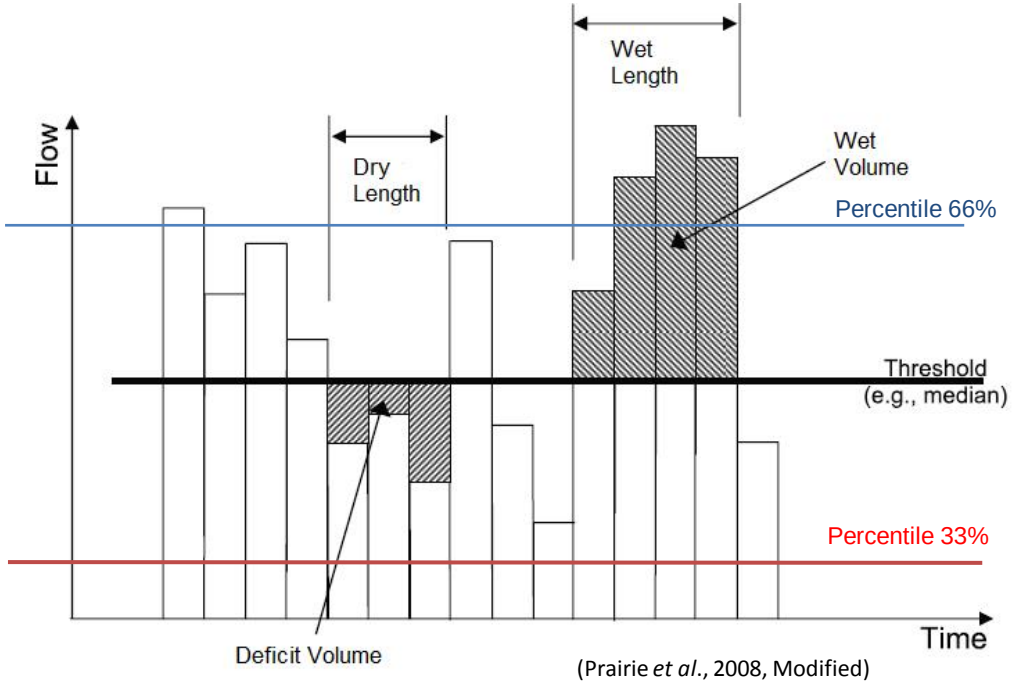


*NINO3 index for December of the previous year
**NINO3 index for February of the same year

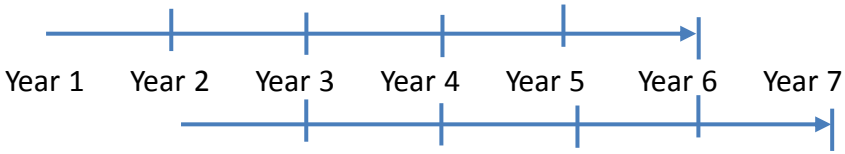
Five year ahead forecasts

4.Forecasts Based on NHMMs

Definition of Persistence statistics



(Prairie *et al.*, 2008, Modified)



T Statistic

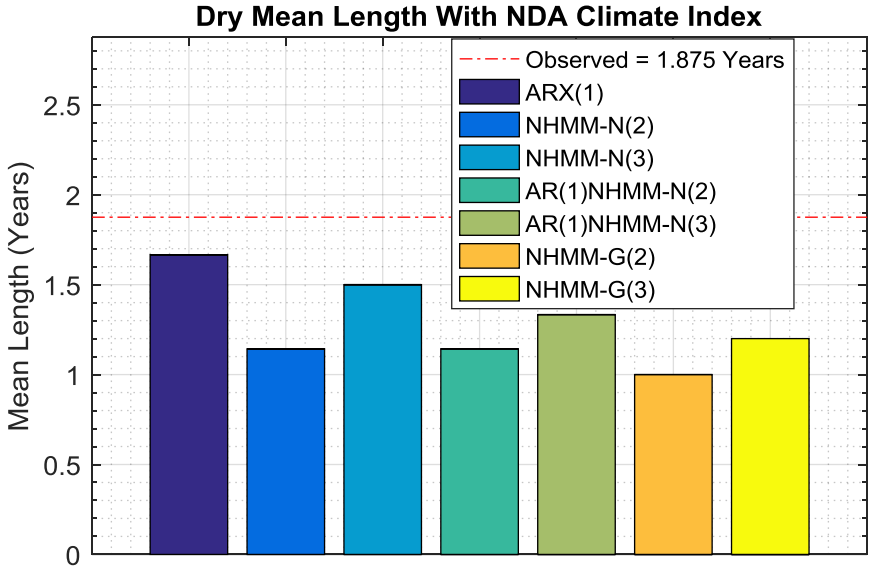
$$T = \sum_{l=2}^{6} n_c(l)$$

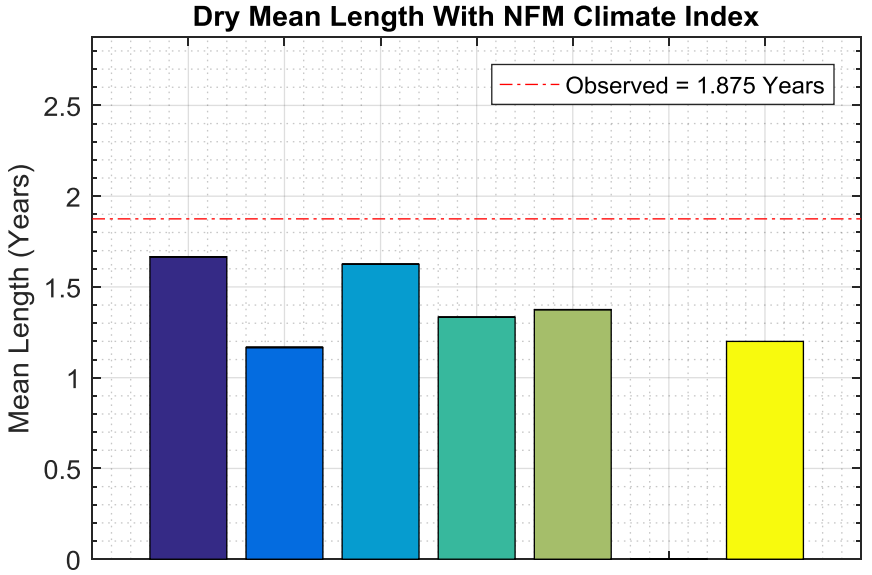
$n_c(l)$ = total number of clusters with consecutive years in the dry or wet state.

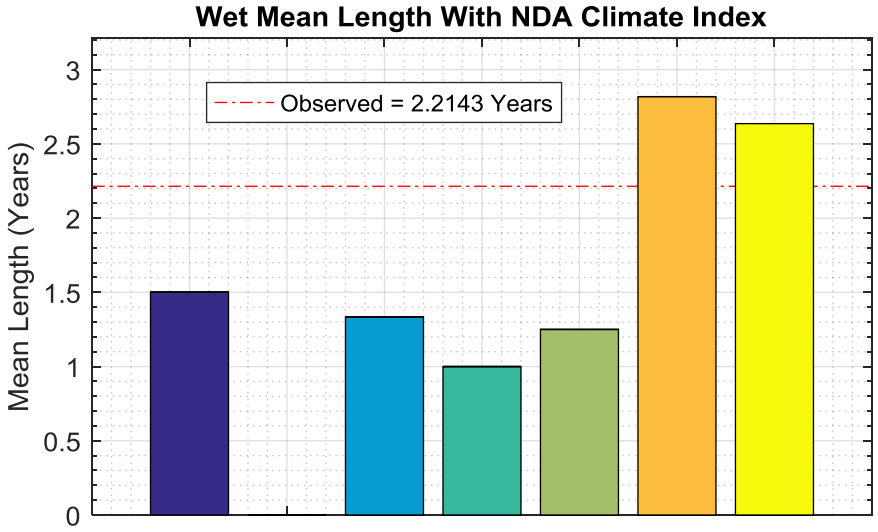
For example, if there is a series with 5 consecutive years of dry events, the value of *T* will be:

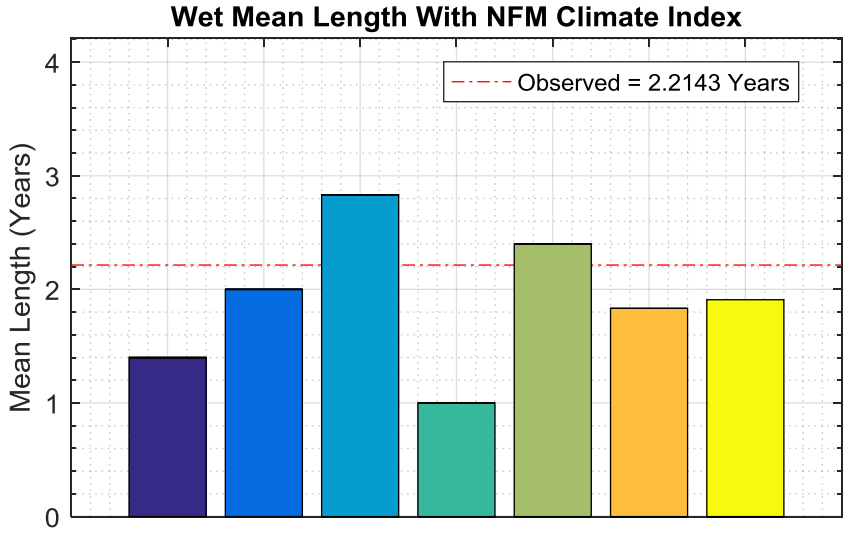
$$T = n_c(2) + n_c(3) + n_c(4) + n_c(5) + n_c(6)$$
$$= 4 + 3 + 2 + 1 + 0 = 10$$

5. Results – Mean Lengths to One Year Ahead Inflow Forecasts





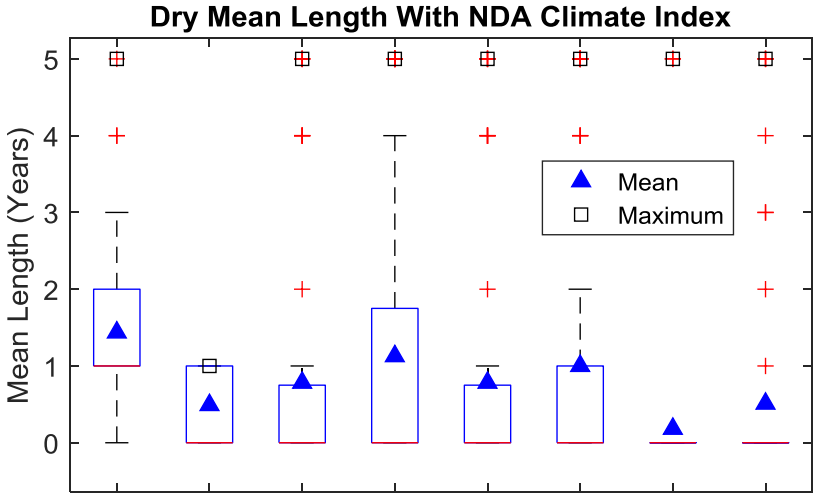


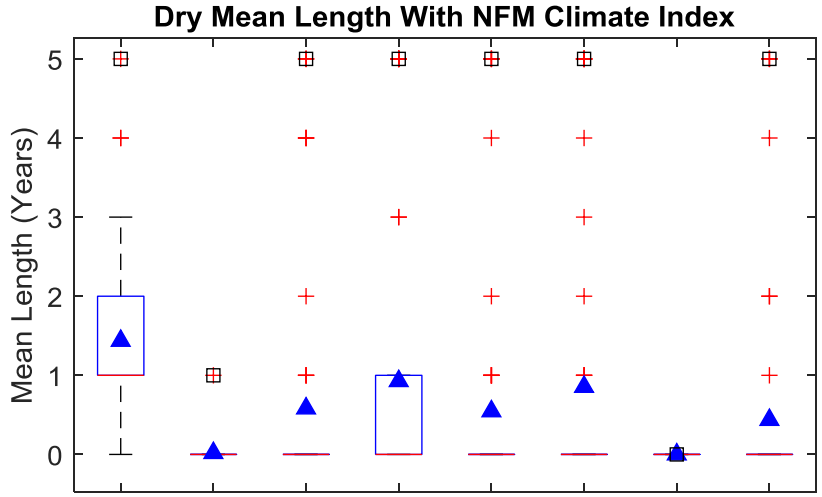


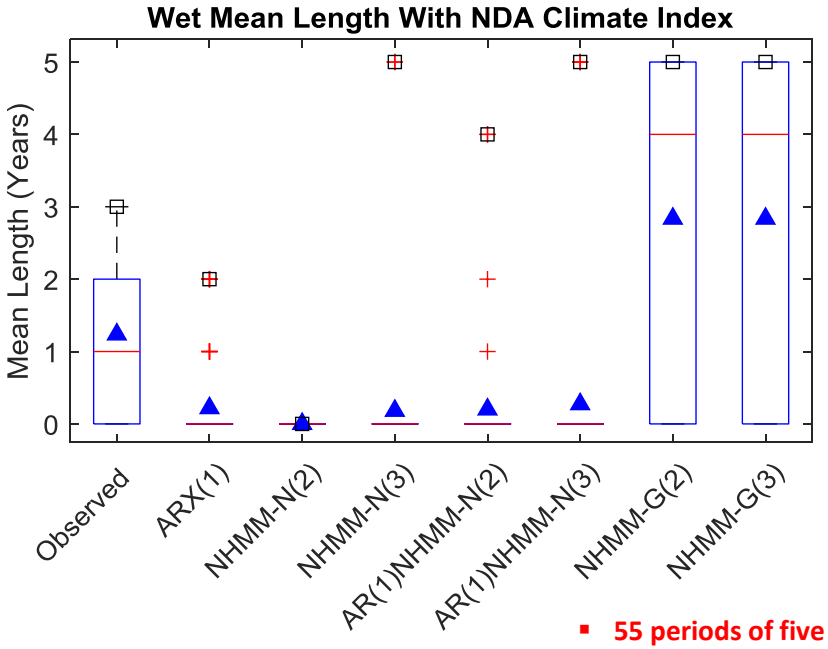
- **60 one year ahead forecasts**

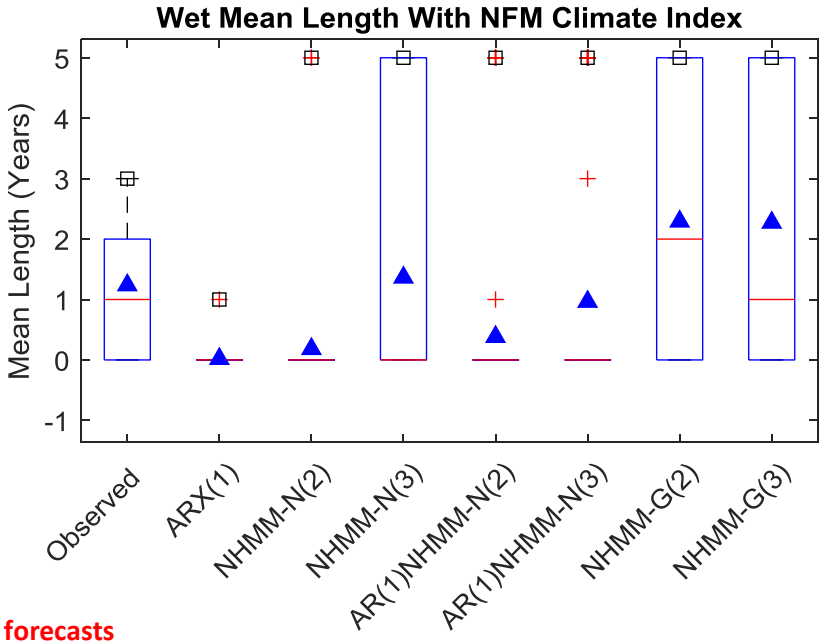
ARX1-Lag-one Autoregressive with Exogenous Variables Model

5. Results – Mean Lengths to Five Year Ahead Inflow Forecasts



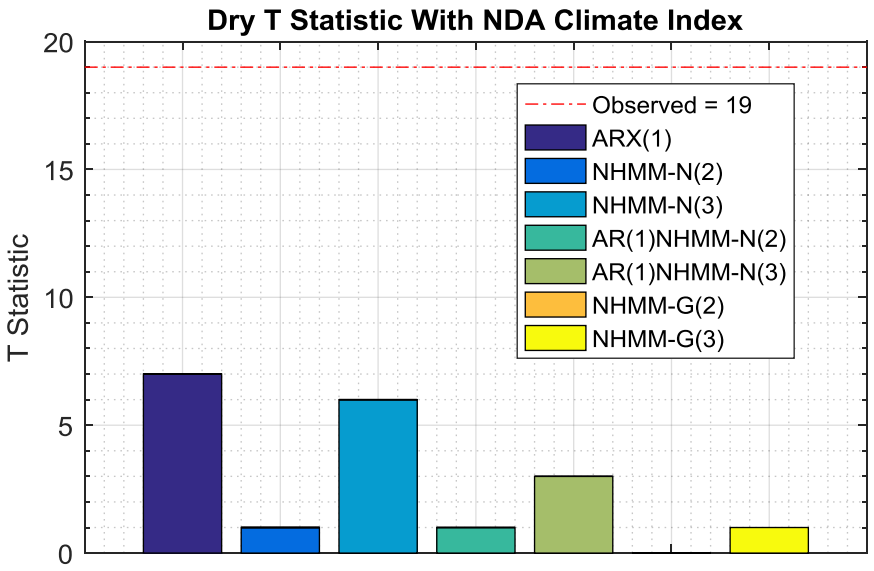


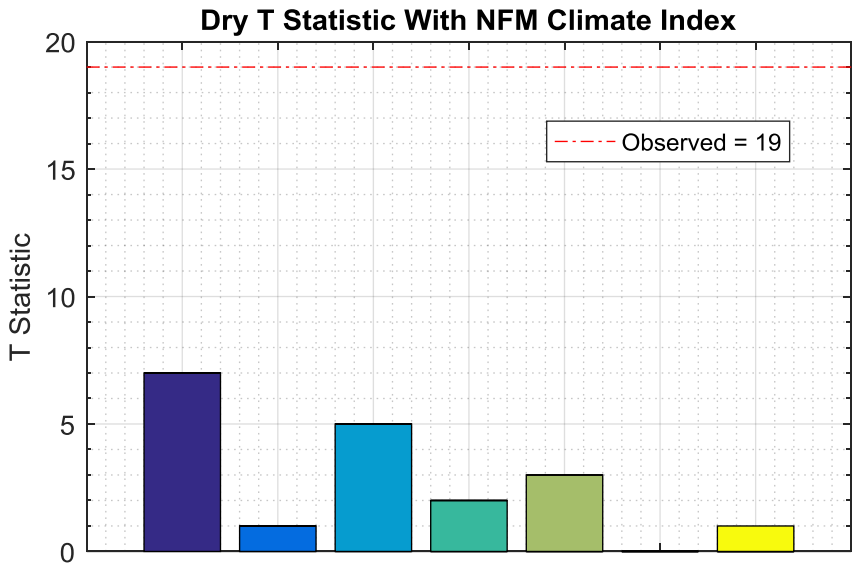


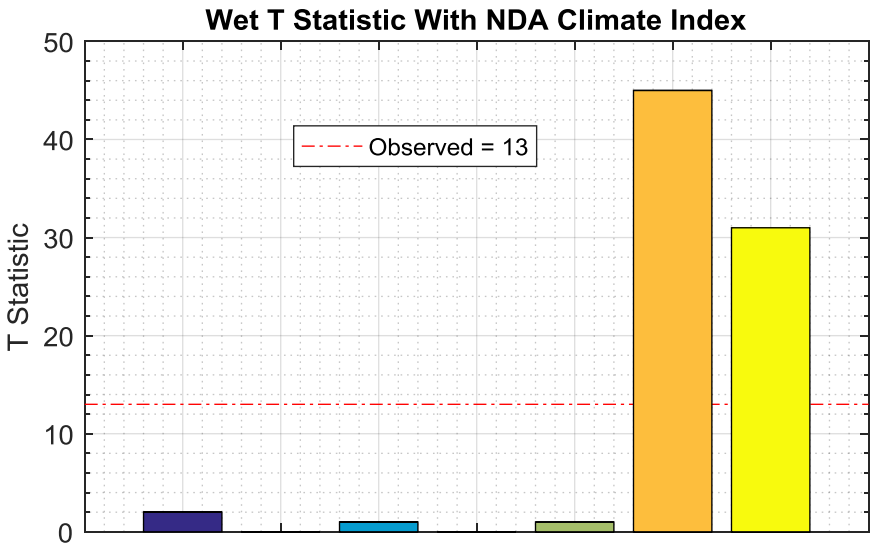


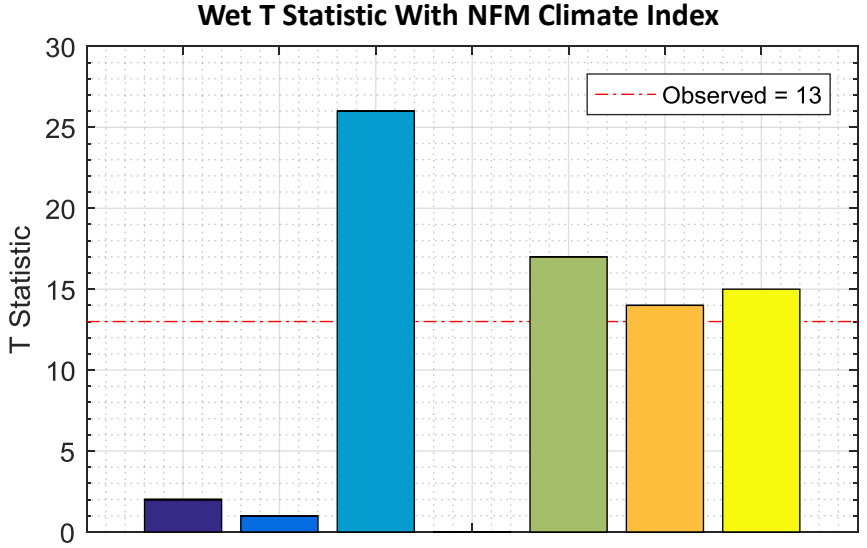
- **55 periods of five year ahead forecasts**

5. Results – T Statistic to One Year Ahead Inflow Forecasts









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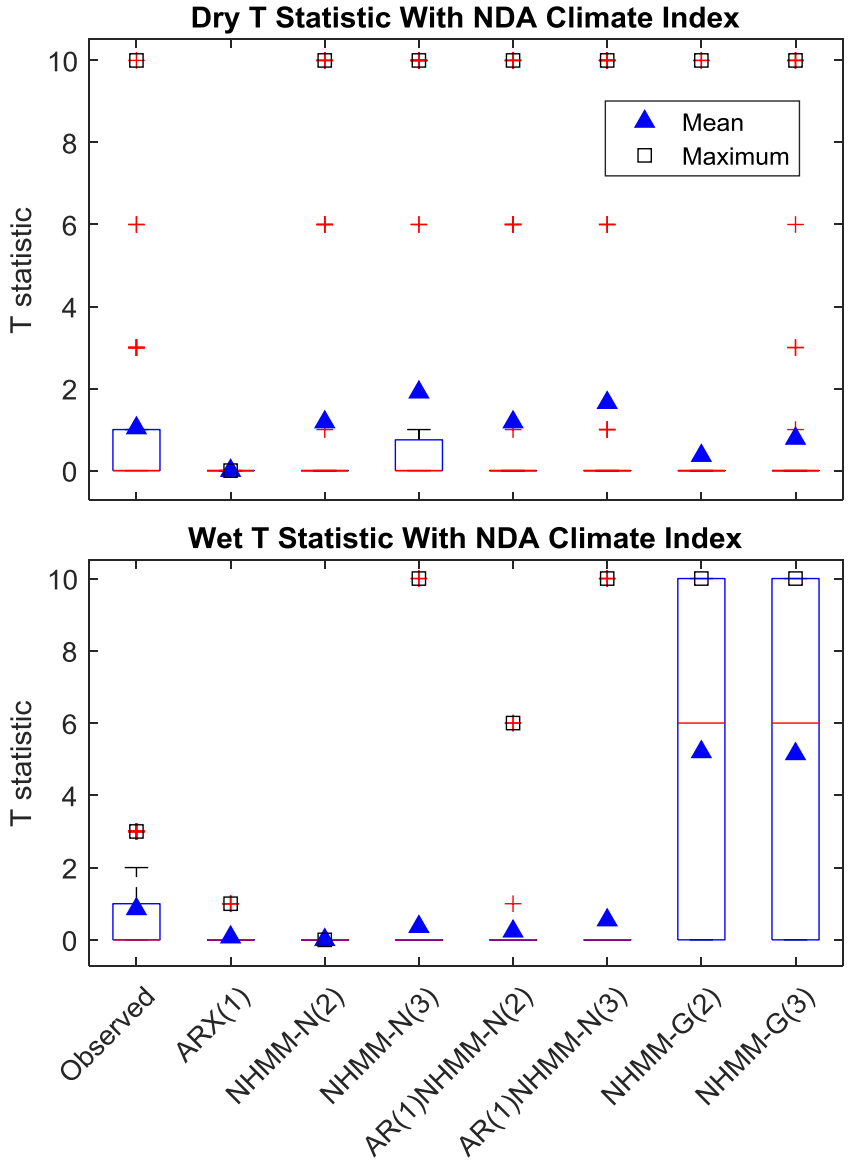

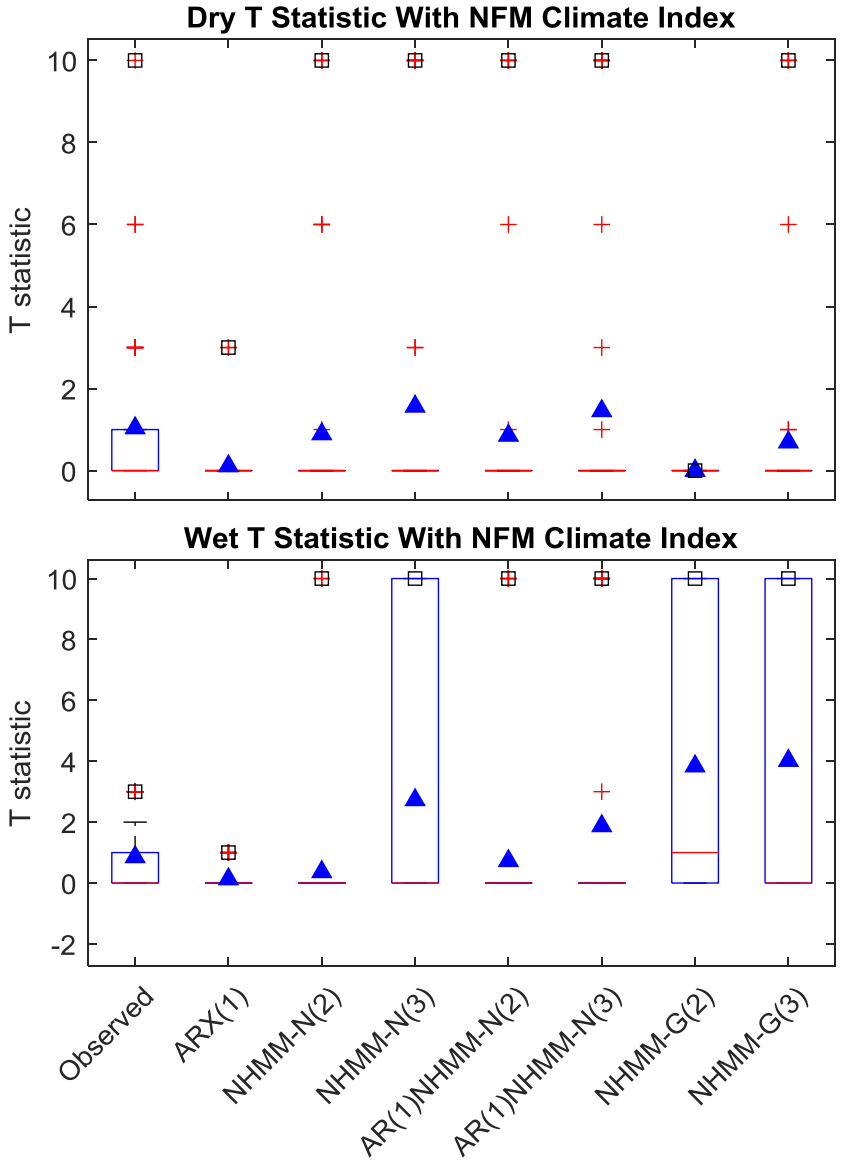

Conclusions And Future Works

- It was assessment the NHMMs and AR-NHMMs performance to forecast dry and wet periods of inflows for the Orós reservoir in the Brazil's north-eastern.
- The results are promising, it is possible to think that the NHMMs performance was similar to ARX models.
- The NHMMs with Gama state dependent distributions resulted better for calculate wet periods.
- From results, we can say that NHMMs can be used to improve the forecast system in the state of Ceará.
- The NHMMs and AR-NHMMs performance to wet periods was better with NDA climate index.
- Finally, other climate variables should be used, and also another climate influence on the observations could be tested. At present, some research works in those ways is being developed.

Thank you!!!!

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CAPES

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Data

FUNCEME

Fundação Cearense de Meteorologia e Recursos Hídricos

Governo do Estado do Ceará

IRI International Research Institute for Climate and Society

Earth Institute | Columbia University