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UICCA 2

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Planning with Scant Information

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HOMOGENEOUS & NON-HOMOGENEOUS HIDDEN MARKOV DOWNSCALING MODEL FOR PROJECTION OF HYDROCLIMATE CHANGES IN TANZANIA

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Climate change poses a number of problems to water resources. The precipitation change, expressed in amount of rainfall and occurrence of wet/dry days, could cause seasonal and annual shift in the climatology of the area and bring up an extreme events intensification. Therefore, the aim of the proposed work is to develop a Statistical Downscaling Methodology on the entire Tanzania territory, where water supply by superficial and underground sources play a key role. So, Any change in hydrologic cycle could constitute a hazard and adversely affect the sustainability and also the future economic development of the area.

A Hidden Markov Model (HMM) is here used to describe annual daily rainfall occurrence at 11 gauge stations in Tanzania, in east Africa, yearly along the period 1950-1990. The model assumes that rainfall occurrence is governed by a few discrete states, with Markovian daily transitions between them. Five "hidden" rainfall states are identified. These states are able to capture the typical Tanzanian seasonality conditions; and further the occurrence and amount of precipitations proper of the different stations.

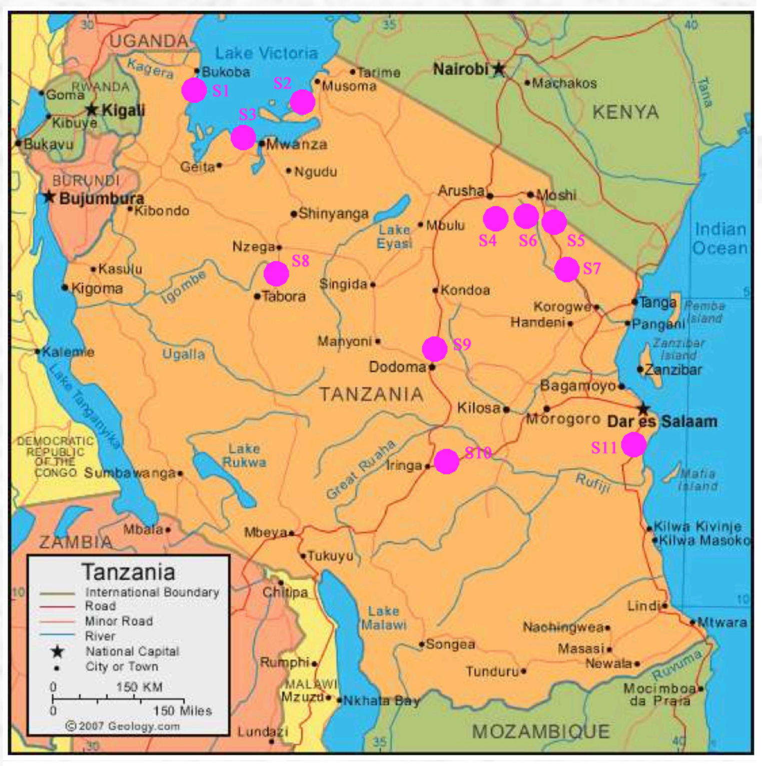
Moreover, a Non-homogeneous Hidden Markov Model (NHMM) is then applied to downscale daily precipitation occurrence at the 11 stations, using daily large scale predictors extracted from the NCAR-NCEP reanalysis General Circulation Model (GCM) dataset as: Geo Potential Height (GPH), Temperature (T), Zonal and Meridional Winds (ZW & MW) and Vertical Equator Winds from 10 to 1000 hPa (ZEW).

The calibration (1950-1980) and validation (1981-1990) tests, for different predictor combinations, evidence that a considerably betterment in fitting the historical data is obtained by using the NHMM. Then, the NHMM provides a useful diagnostic and predictive tool: (a) in understanding the statistics of daily rainfall occurrence at the station level in terms of large-scale atmospheric pattern and (b) it can be used with the goal to make future projections of the downscaled precipitation by using the GCM's simulations (for example CMIP5) under different global warming scenarios.

DATA

	ON MAP	CODE/NAME	LATITUDE	LONGITUDE
1	S1	TZ000063729 BUKOBA	-1.33N	31.82E
2	S2	TZ000063733 MUSOMA	-1.50N	33.80E
3	S3	TZ000063756 MWANZA	-2.47N	32.92E
4	S4	TZ000063789 ARUSHA	-3.33N	36.63E
5	S5	TZ000063790 MOSHI	-3.35N	37.33E
6	S6	TZ000063791 KILIMANJARO_AIRPORT	-3.42N	37.07E
7	S7	TZ000063816 SAME	-4.08N	37.72E
8	S8	TZ000063832 TABORA_AIRPORT	-5.08N	32.83E
9	S9	TZ000063862 DODOMA	-6.17N	35.77E
10	S10	TZ000063887 IRINGA	-7.63N	35.77E
11	S11	TZ000063894 DAR_ES_SALAAM_AIRPC	-6.87N	39.20E

Station location in Tanzania (data info)

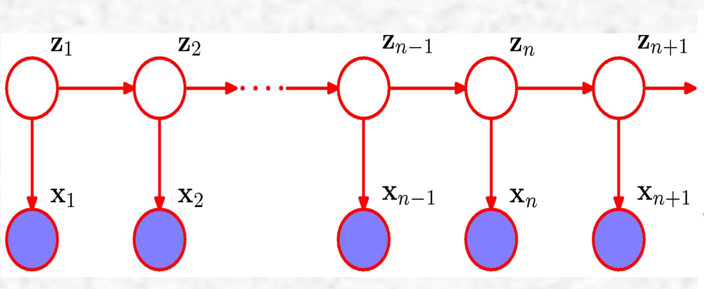


Giuseppe Faldi, 2010. "Valutazione della vulnerabilità al cambiamento climatico delle comunità costiere di Dar es Salaam (Tanzania) rispetto al fenomeno dell'intrusione salina nella falda acquifera". Dissertation. (modified)

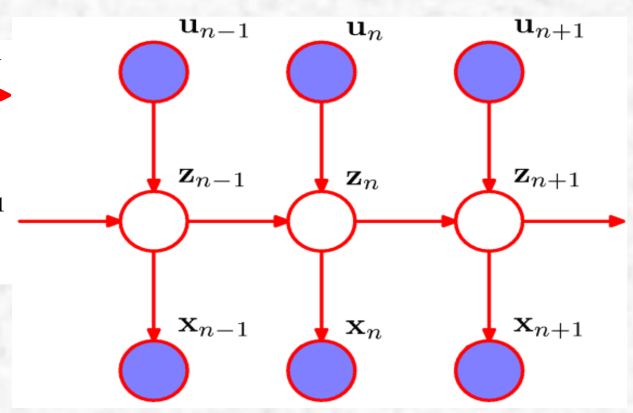
GCM data: daily large scale predictors are extracted from the NCAR-NCEP (NOAA) reanalysis General Circulation Model (GCM) dataset as: Geo Potential Height (GPH), Temperature (T), Zonal and Meridional Winds (ZW & MW)

THEORY

The **HMM** assumes that observations are generated from a mixture of distributions among which subjects move according to a hidden Markov chain, and that rainfall occurrence is governed by a few discrete states, with Markovian daily transitions between them. HMM used here follows the approach of the (Hughes and Guttorp, 1994) to model daily rainfall occurrence, while additionally modeling rainfall amounts (Robertson et al. 2004-2006). In **NHMM** the transition probabilities are allowed to vary with time, and so it generalizes the homogeneous HMM. In particular for downscaling applications, the transition probabilities between states are allowed to vary as a function of external inputs (i.e. these variables, Xk,t, can influence the evolution of the weather states sequence, Z).



Homogeneous Hidden Markov

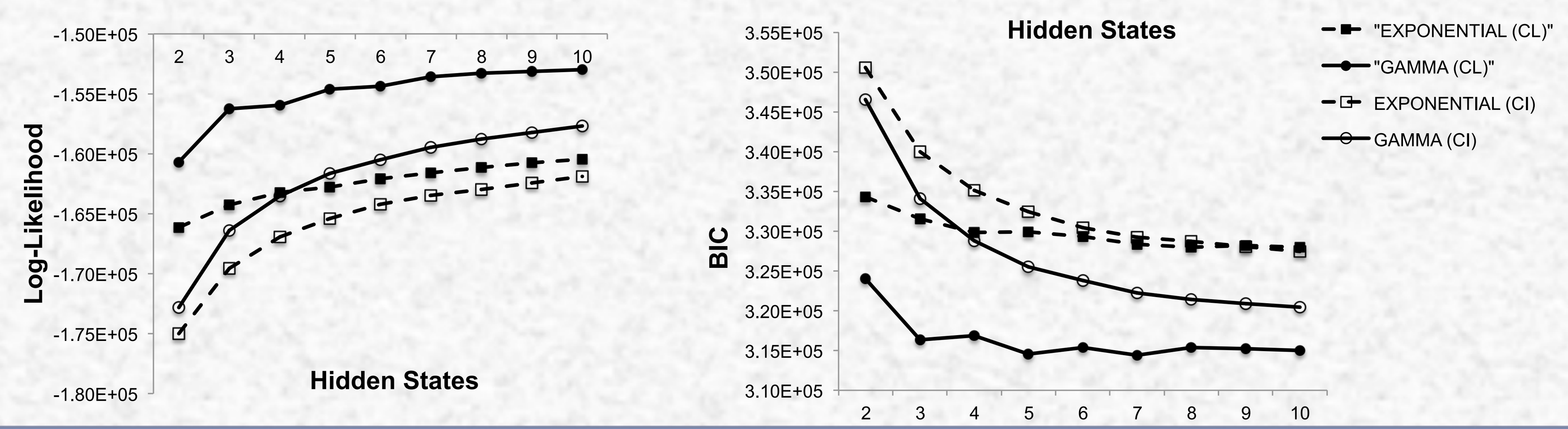


Non-Homogeneous Hidden Markov

Legend:
Zn;transition probabilities Hidden States
Un;external inputs
Xn;observed data
K;the number of Hidden States
σ and **ρ**;parameters to be estimated

CHOW LIU (CL) VS CONDITIONAL INDIPENDENCE (CI)

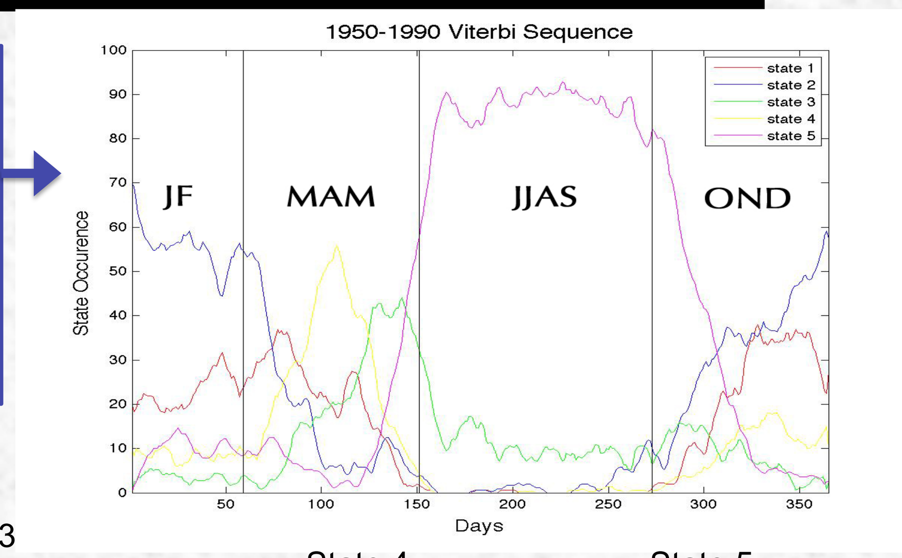
The comparison between CL and CI is made calculating, for Hidden States from 2 to 10 and for two different Density Probability Functions (Gamma and Exponential), the Bayesian Information Criterion (BIC) and the Log-Likelihood. All analysis is for the entire year 1950-1990 period running with 11 Rainfall Stations.

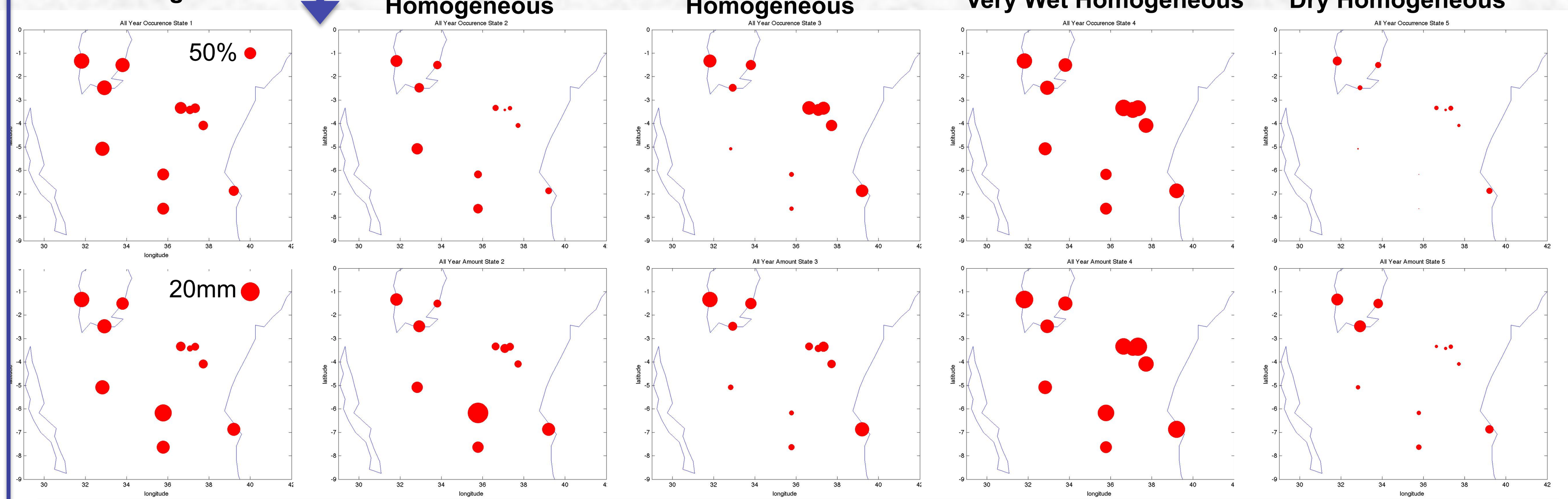


FIVE HIDDEN STATES CALCULATED ON THE ENTIRE YEAR

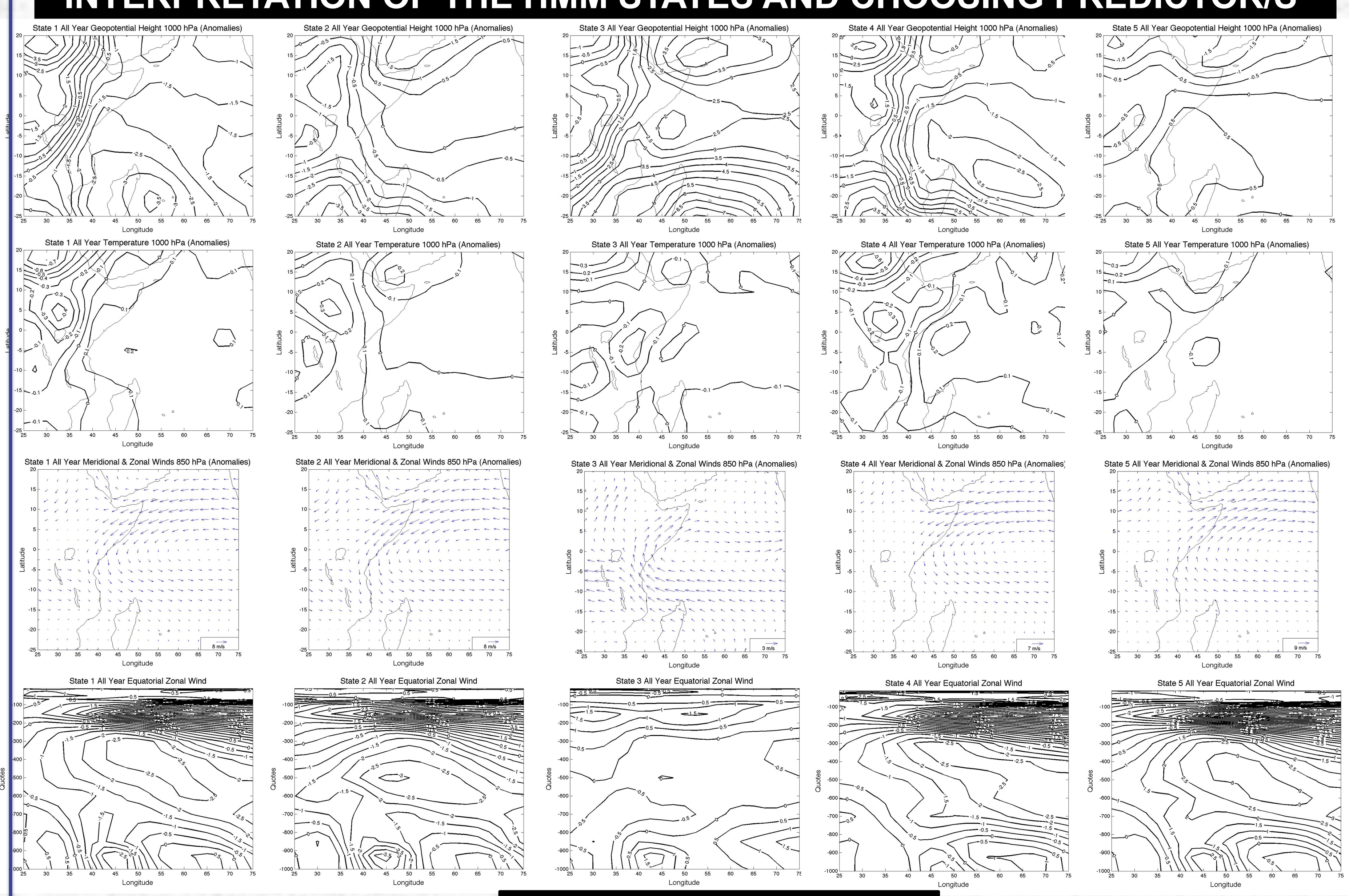
"**Occurrence**" and the mean "**Amounts**" of days receiving greater than zero rainfall calculated from the parameters of the Gamma distribution (annual period from 1950 to 1990 for 11 rainfall stations in Tanzania). The Hidden State could be physically read as a particular rainfall pattern the can sudden in the area.

The figure represent the State Occurrence during the three chosen seasons:
Mar-Apr-May (MAM)
Jun-Jul-Aug-Sep (JJAS)
Oct-Nov-Dec (OND)

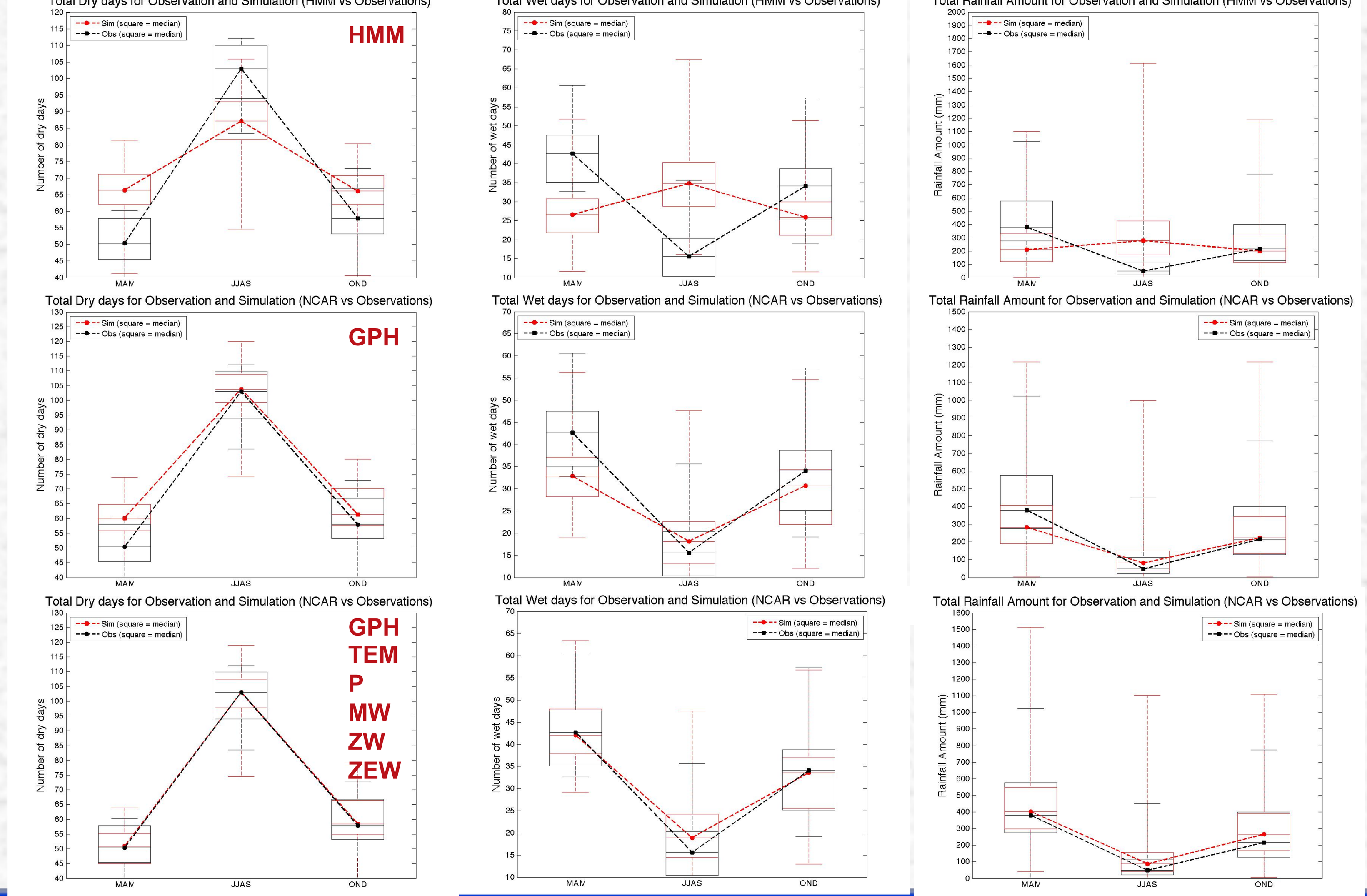




INTERPRETATION OF THE HMM STATES AND CHOOSING PREDICTOR/S



VALIDATION



The Conference is organized within the Research Project of National Interest (PRIN)
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