



The Abdus Salam
**International Centre
for Theoretical Physics**



Rainfall Regimes in the in Southern Mexico

An application of the Hidden Markov
Method to rainfall data stations

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*School and Workshop on Weather Regimes and Weather Types in the Tropics and Extra-tropics:
Theory and Application to Prediction of Weather and Climate,
25th October 2013*

AREA OF STUDY

Study Area:

Morelos state (Southern Mexico)

Data:

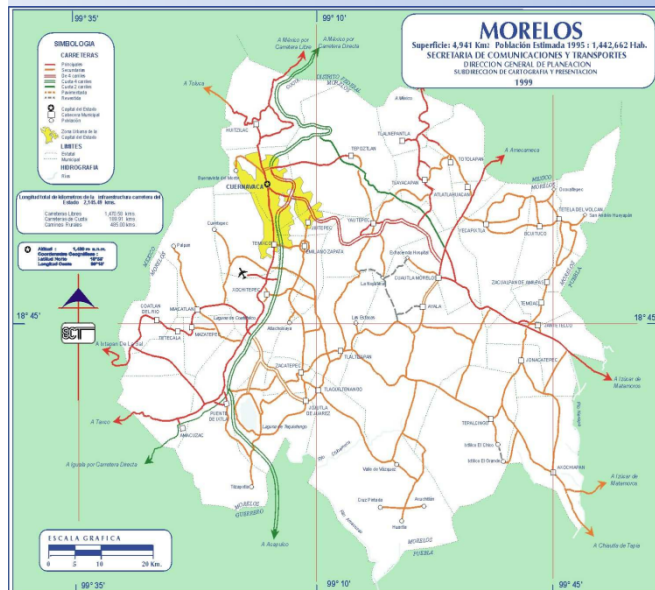
Daily rainfall

Number of stations:

7

Period:

1980-2000 (21 years)



AIMS AND GOALS

1. Identification of the Morelos rainfall regimes using HMM model in the different seasons.
2. Deeper understanding of the rainfall seasonal and intra-seasonal variability within the study area.
3. Detection of the corresponding weather pattern and comparison with results from SOM analysis.

METHODOLOGY

Application of the HMM model, using the HMMTool 2.1 program (Robertson et al.) to a subset of the available Morelos stations data.

Step 1:

Selection of the number of state during the whole year

Step 2:

Circulation pattern analysis during summer season JJA

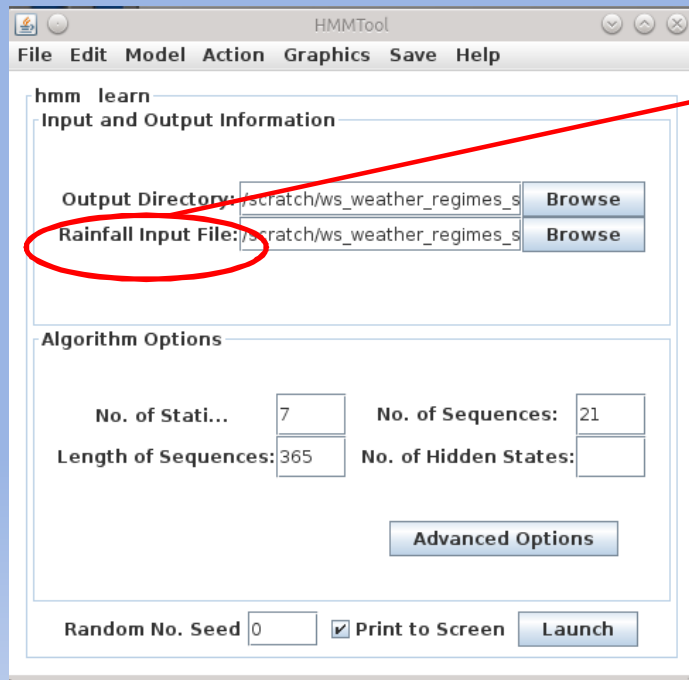
Step 3:

Conclusions and results

APPLICATION OF THE HMM

Step 1:

Selection of the optimal number of states



The screenshot shows the HMMTool application window. The 'Input and Output Information' section contains the following fields:

- Output Directory: /scratch/ws_weather_regimes_s
- Rainfall Input File: /scratch/ws_weather_regimes_s (circled in red)

The 'Algorithm Options' section contains the following fields:

- No. of Stati...: 7
- No. of Sequences: 21
- Length of Sequences: 365
- No. of Hidden States: (empty)

At the bottom, there is a 'Random No. Seed' field with the value 0, a checked 'Print to Screen' checkbox, and a 'Launch' button.

Morelos daily rainfall

APPLICATION OF THE HMM

Step 1:

Selection of the optimal number of states

HMMTool

File Edit Model Action Graphics Save Help

hmm learn

Input and Output Information

Output Directory: /scratch/ws_weather_regimes_s Browse

Rainfall Input File: /scratch/ws_weather_regimes_s Browse

Algorithm Options

No. of Stati... 7 No. of Sequences: 21

Length of Sequences: 365 No. of Hidden States:

Advanced Options

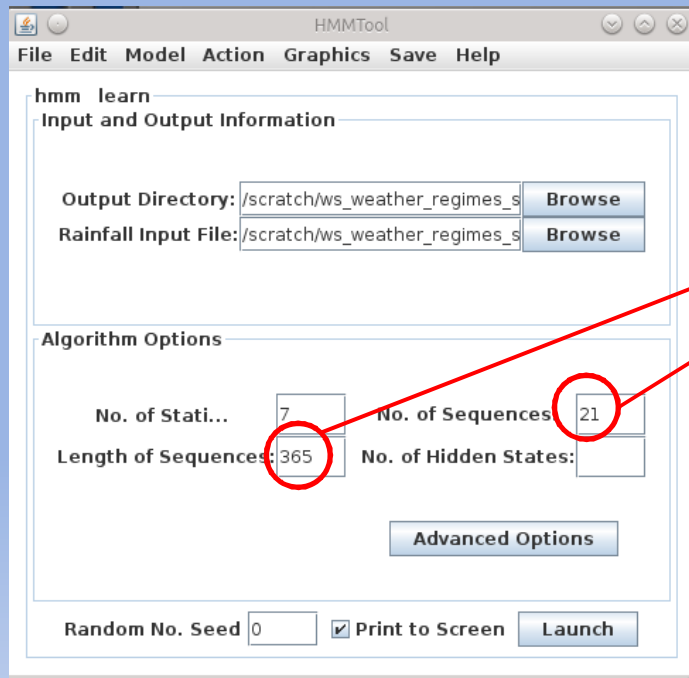
Random No. Seed 0 Print to Screen Launch

7 stations

APPLICATION OF THE HMM

Step 1:

Selection of the optimal number of states



The screenshot shows the HMMTool application window. The title bar reads "HMMTool". The menu bar includes "File", "Edit", "Model", "Action", "Graphics", "Save", and "Help". The main window is titled "hmm learn" and contains the following sections:

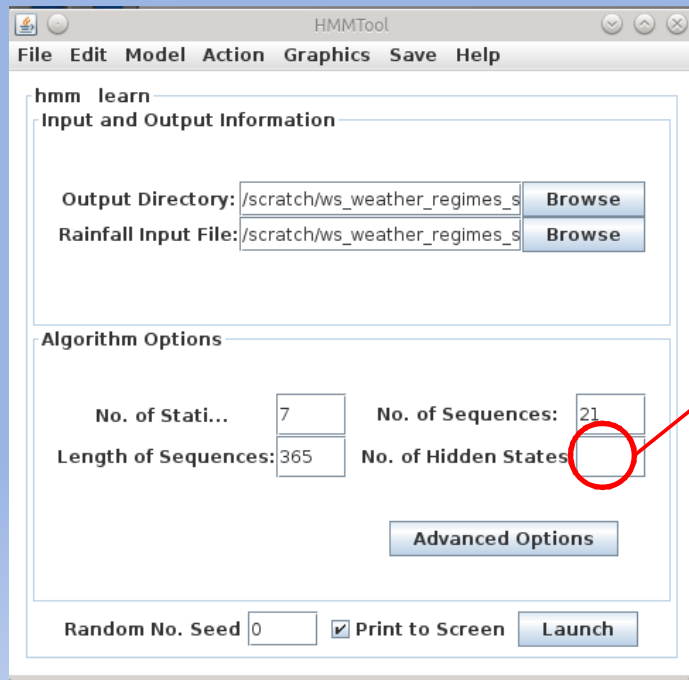
- Input and Output Information:**
 - Output Directory: /scratch/ws_weather_regimes_s (with a "Browse" button)
 - Rainfall Input File: /scratch/ws_weather_regimes_s (with a "Browse" button)
- Algorithm Options:**
 - No. of Stati...: 7 (circled in red)
 - No. of Sequences: 21 (circled in red)
 - Length of Sequences: 365 (circled in red)
 - No. of Hidden States: (empty field)
- Advanced Options:** (button)
- Random No. Seed:** 0
- Print to Screen
- Launch** (button)

21 years
From 1980 to 2000

APPLICATION OF THE HMM

Step 1:

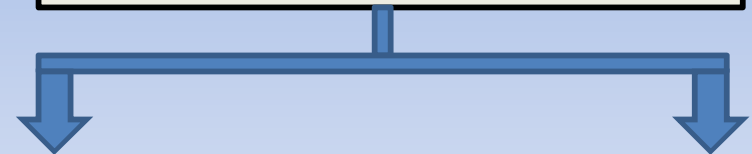
Selection of the optimal number of states



How many weather regimes ????



We want to choose the proper number of weather regimes that can describe at better the seasonal variability of rainfall in the study area.

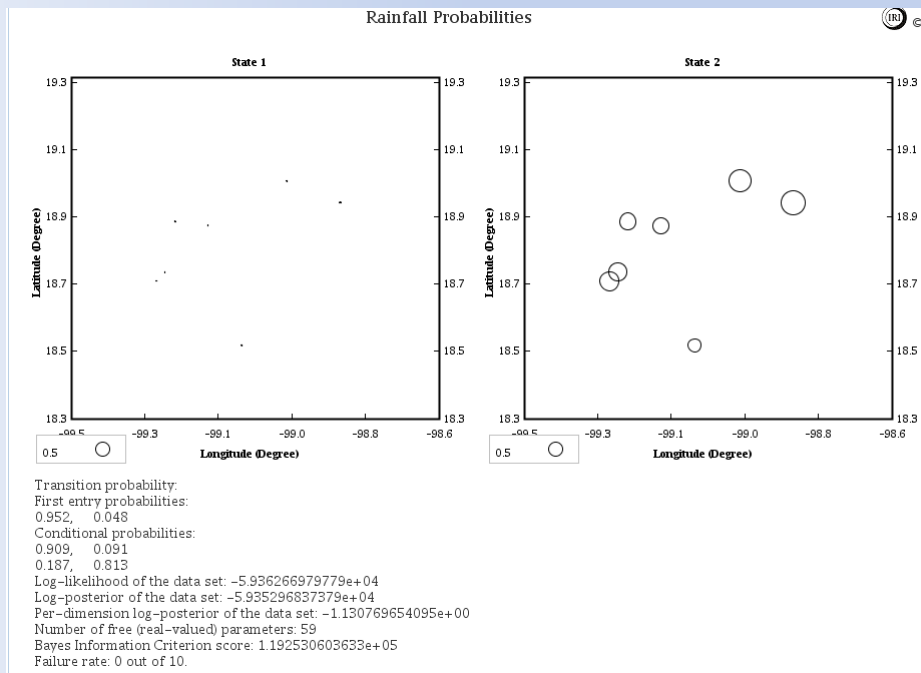


2 regimes

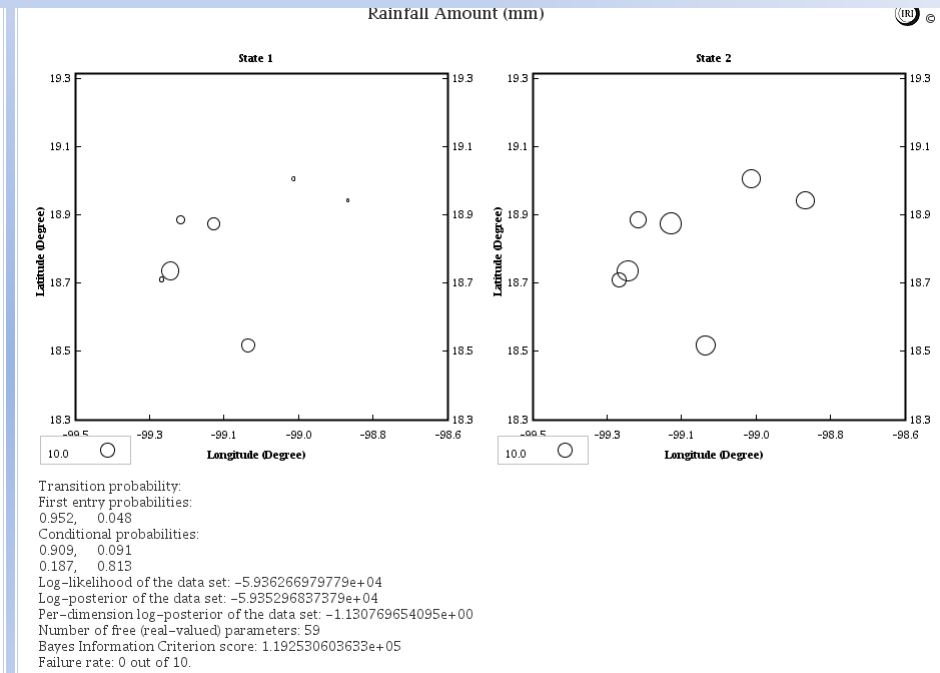
3 regimes

HMM IN THE WHOLE YEAR: 2 REGIMES

Rainfall Probabilities



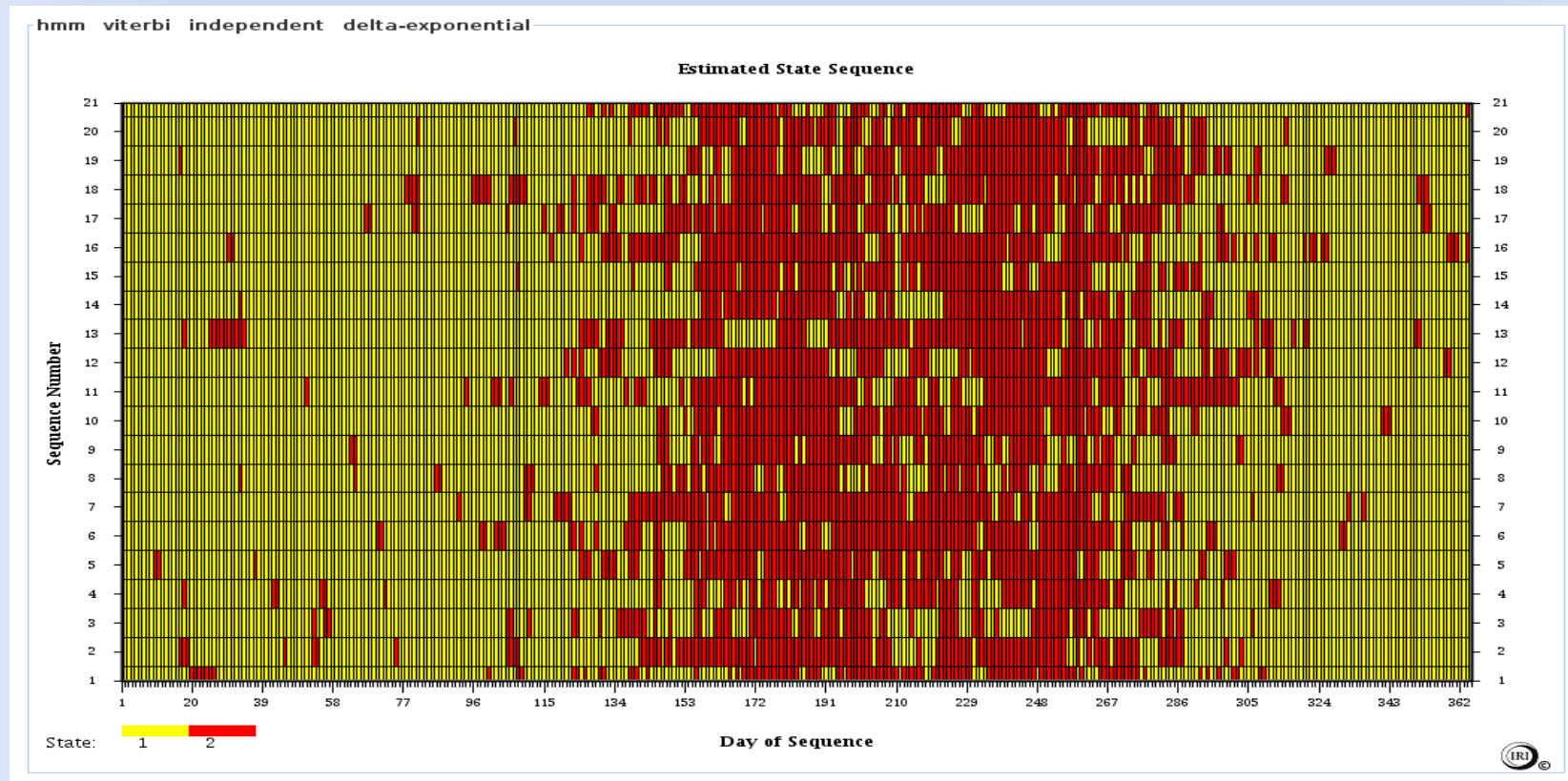
Rainfall Amounts



We have identified 2 states:

- in the **1st state** there is a **low rainfall probability** with average rainfall intensity around 5 mm/day with a certain local variability between the different station examined.
- In **2nd state** the frequency of occurrence of **rainfall is higher**, with also higher rainfall intensity with less local variability.

HMM IN THE WHOLE YEAR: 2 REGIMES



From the **Viterbi plot** it is evident that the two states identifies the **seasonal cycle**.

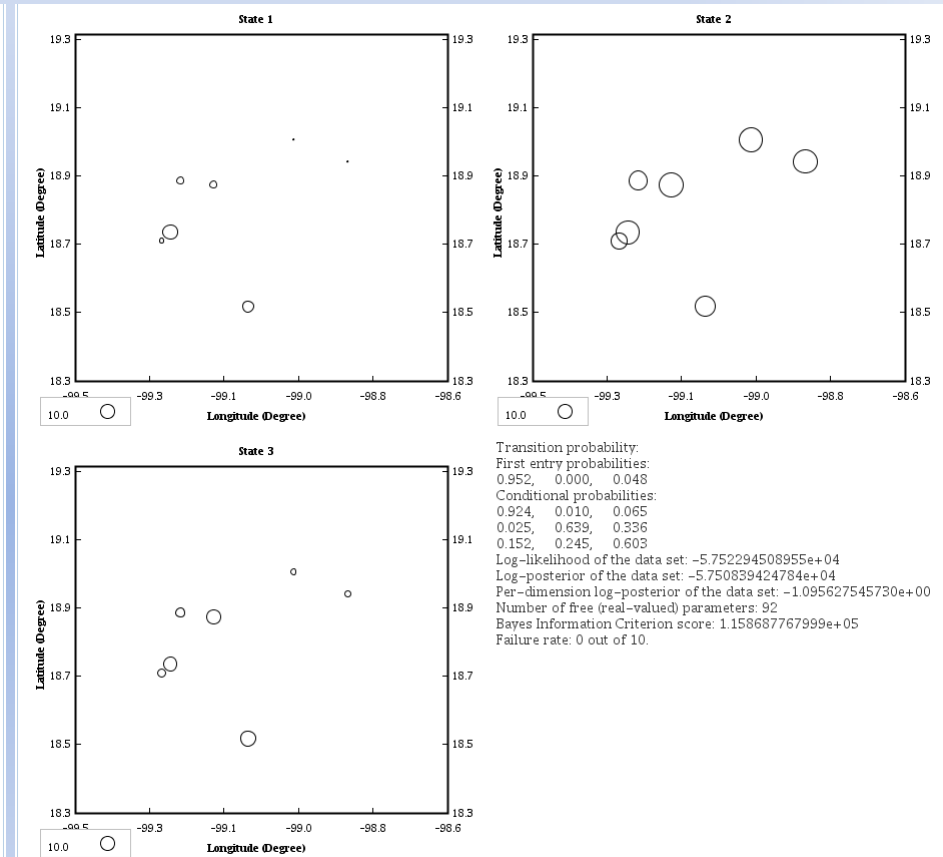
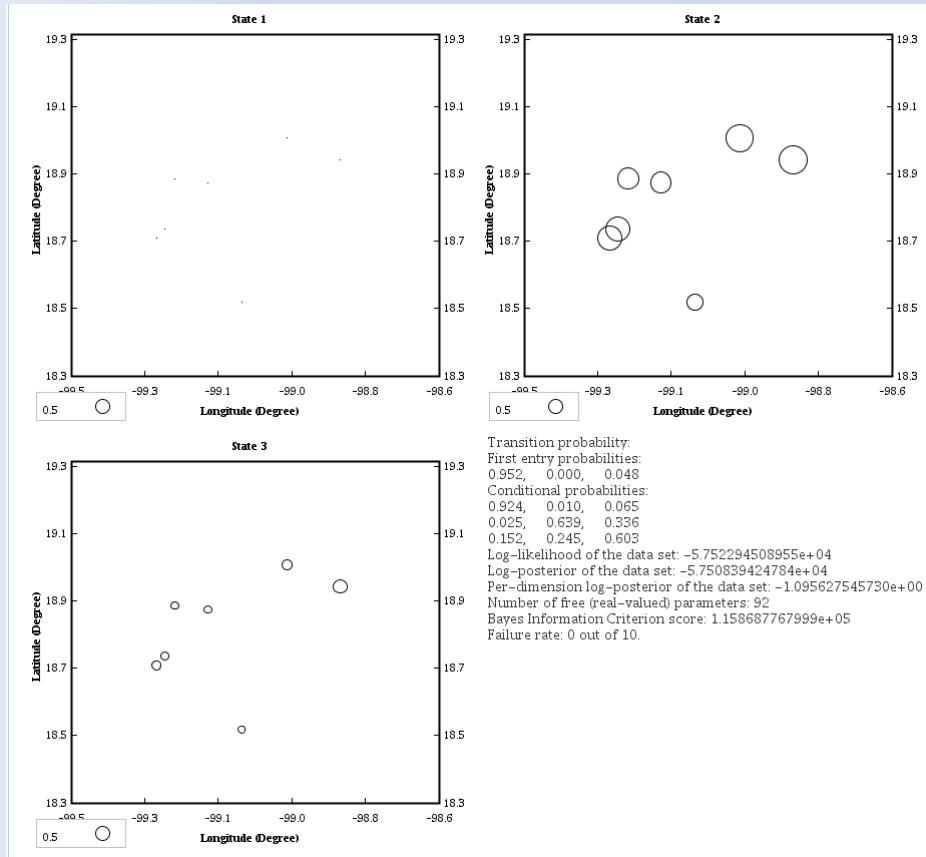
The season associated to state 2 starts around **May** and **lasts till September** and it's characterized by intense rainfall and high precipitation amounts, uniformly distributed inside the region.

The season associated to state 1 is drier than the one in state 2 and it is characterized by rare rainfall spell, less uniformly distributed inside the study area.

HMM IN THE WHOLE YEAR: 3 REGIMES

Rainfall Probabilities

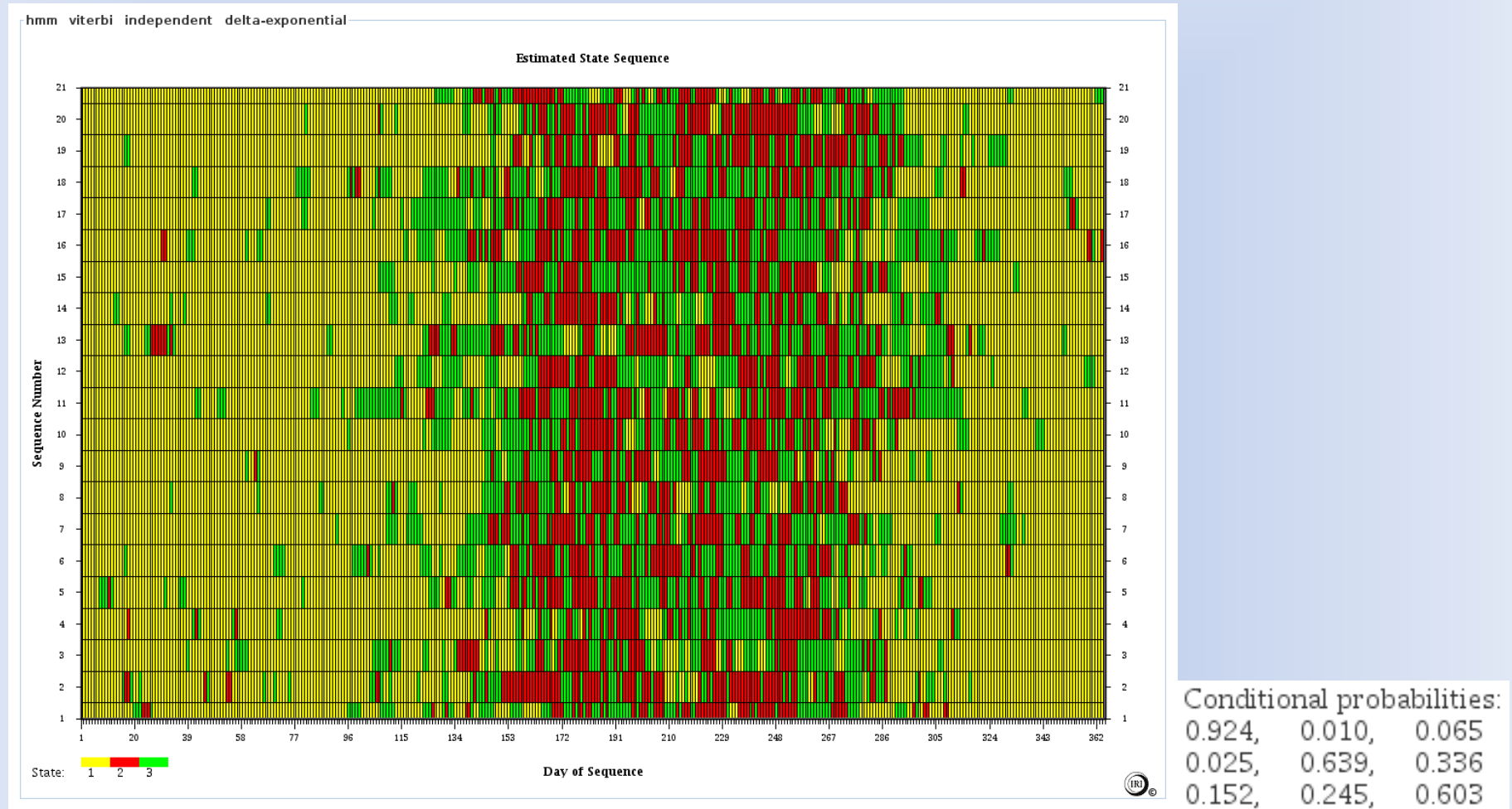
Rainfall Amounts



In the 3 states regime we noticed that:

- The first state represent the driest season, with scarce precipitation and low rainfall amounts.
- At the contrary in state 2 rainfall occurs more often and with the highest amounts.
- The state 3 has intermediate features between state 1 and 2.

HMM IN THE WHOLE YEAR: 3 REGIMES



Looking at the Viterbi table, the state 1 is associated to the winter months, while the state 2 and 3 alternate during the summer season (from April to November).

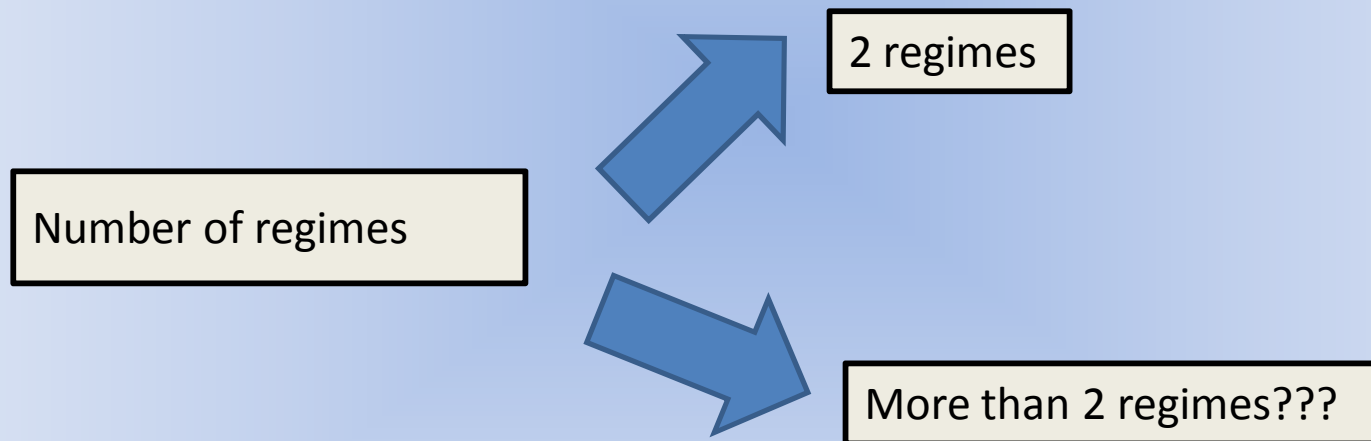
Its more likely to pass from state 2 to 3 and viceversa, than from state 1 to the others.

FIRST CONCLUSIONS...

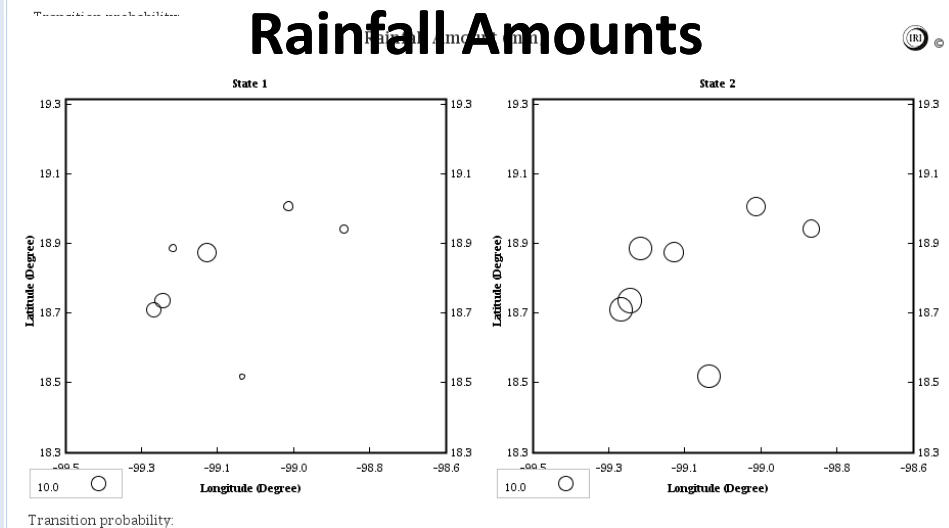
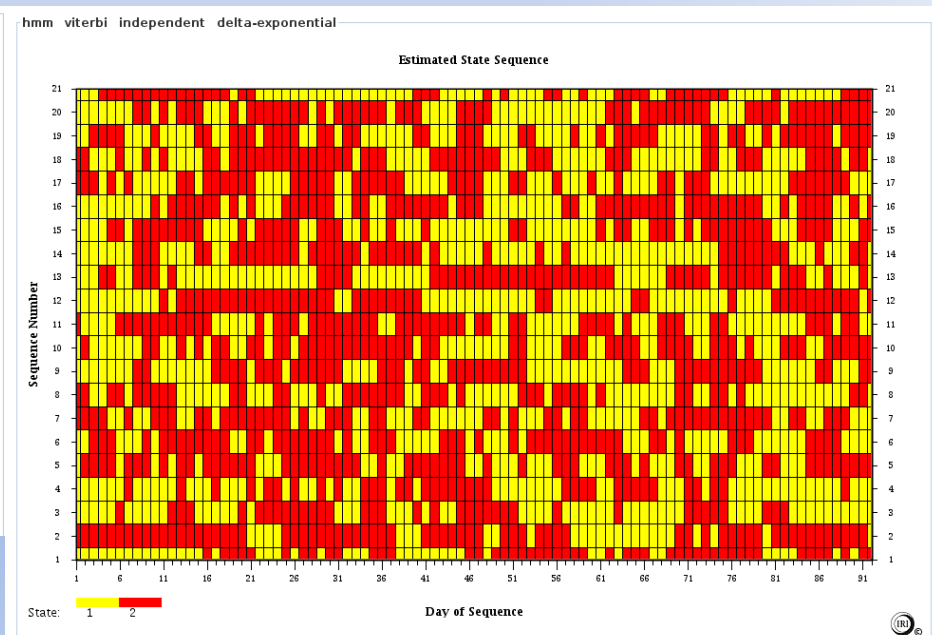
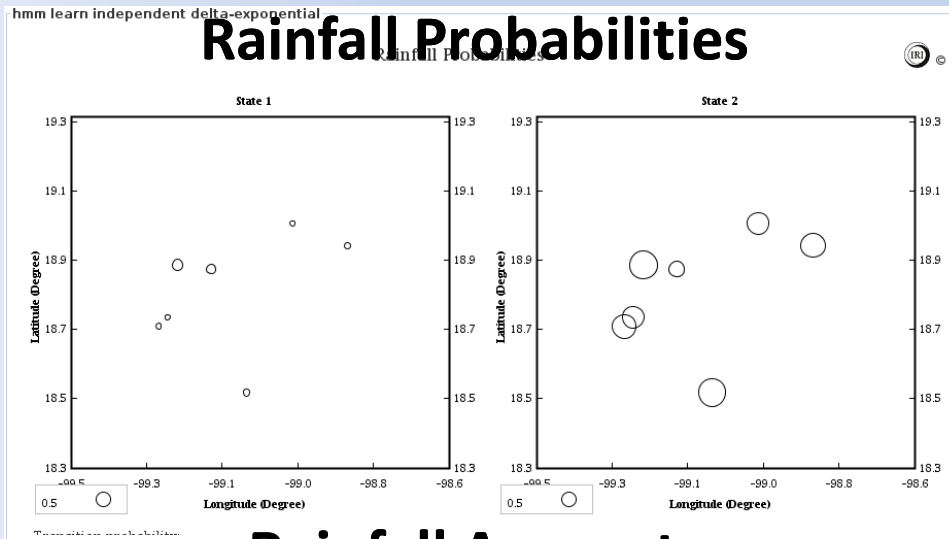
- We were able to extract the **seasonal cycle** from the rainfall data stations.
- We identify **three different regimes (dry, intermediate and wet)**
- Unfortunately, the **strong seasonal cycle overwhelms the signal of the different regimes**, making difficult the identification of the regimes in winds or geopotential height.
- **The method works, but it is not enough!**

HMM IN THE SUMMMER SEASON

Thus we tried to investigate the intraseasonal rainfall variability during summer months, to investigate if there are preferred states of circulation.



HMM IN THE SUMMER SEASON: 2 REGIMES

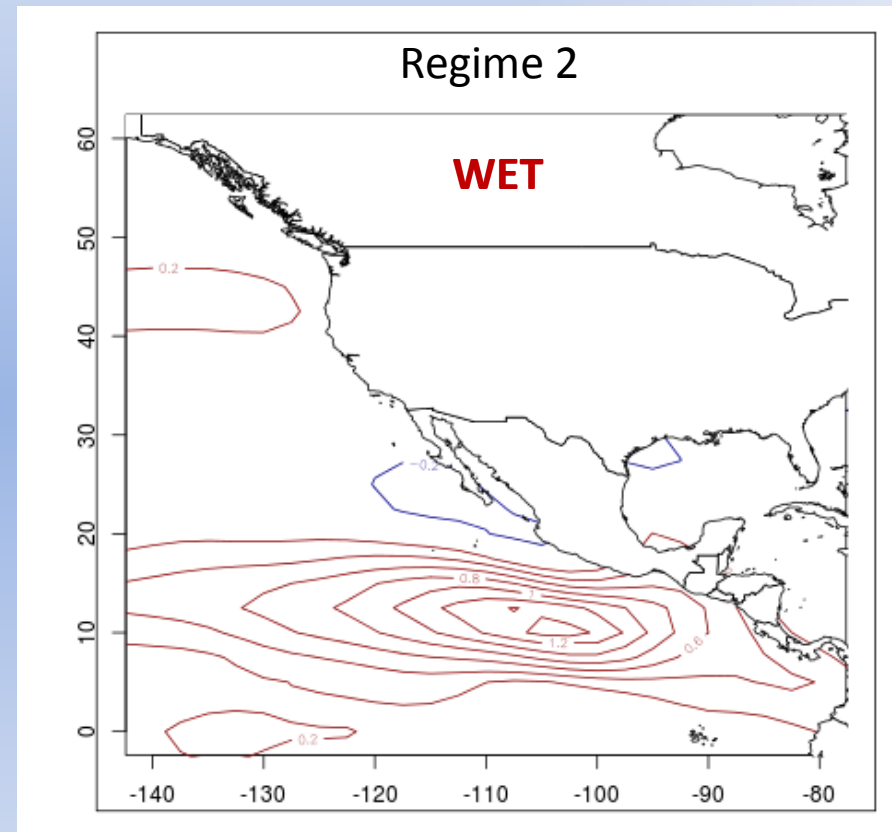
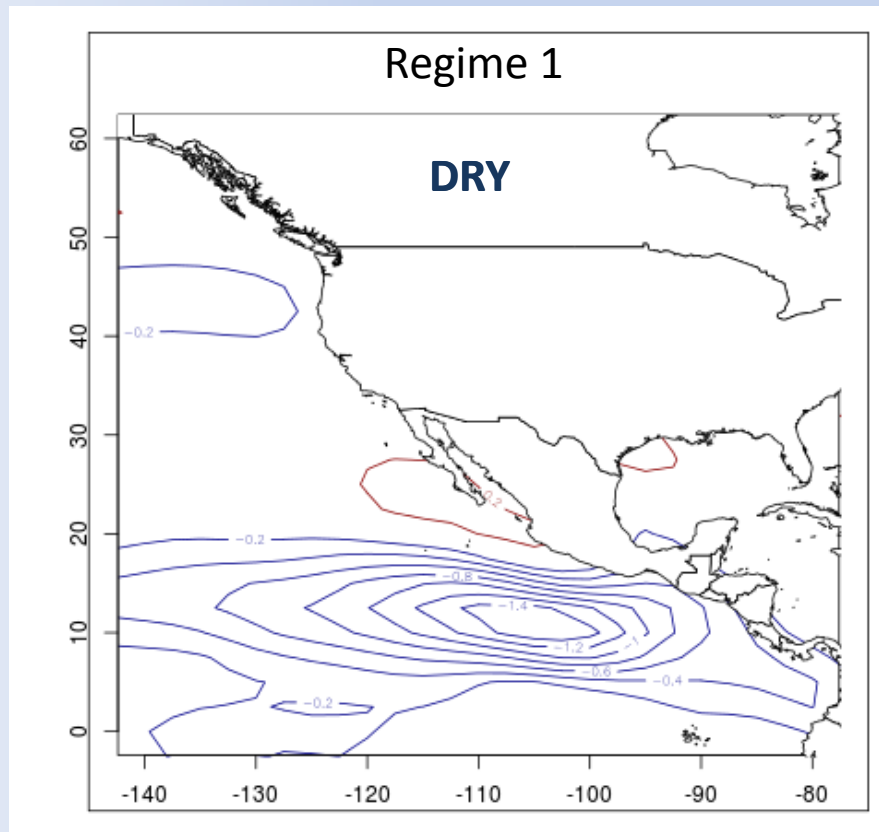


Conditional probabilities:
0.685, 0.315
0.291, 0.709

State 1: Dry
State 2: Wet

HMM IN THE SUMMER SEASON: 2 REGIMES

2-Regime Composites of 850 hPa zonal wind anomalies

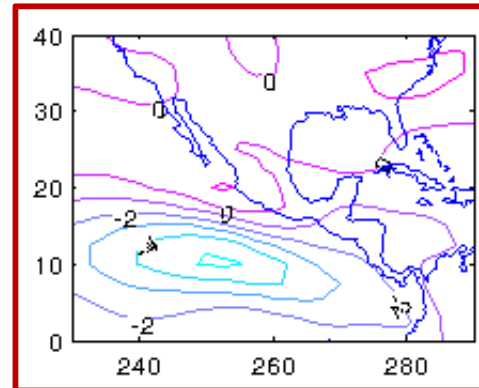
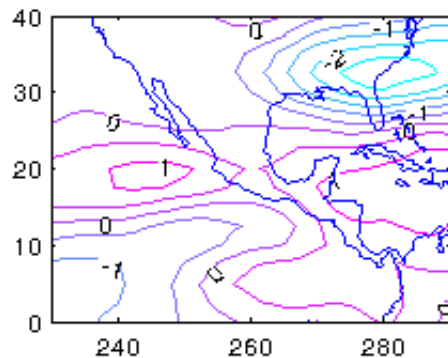
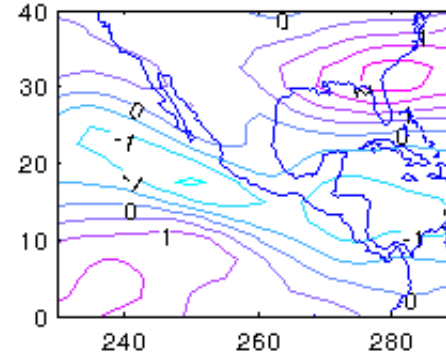
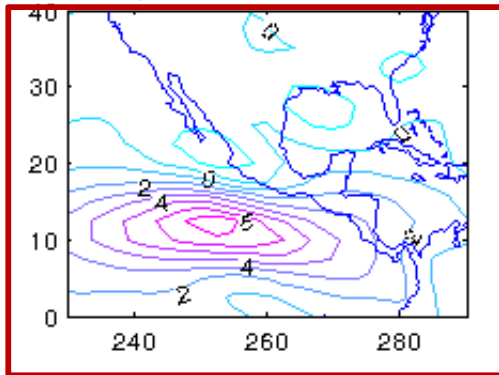


Two opposite circulation patterns associated with the two precipitation states: advection of moist air?

SOM IN THE SUMMER SEASON

Clustering of 850 hPa zonal wind

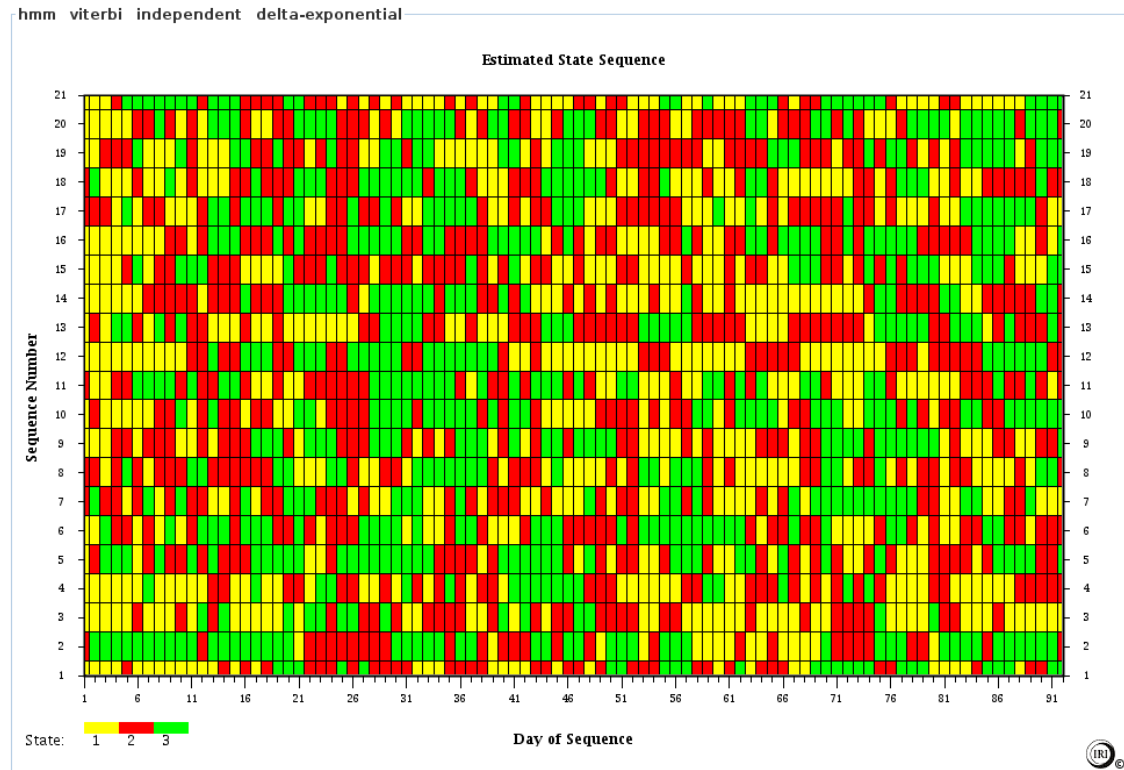
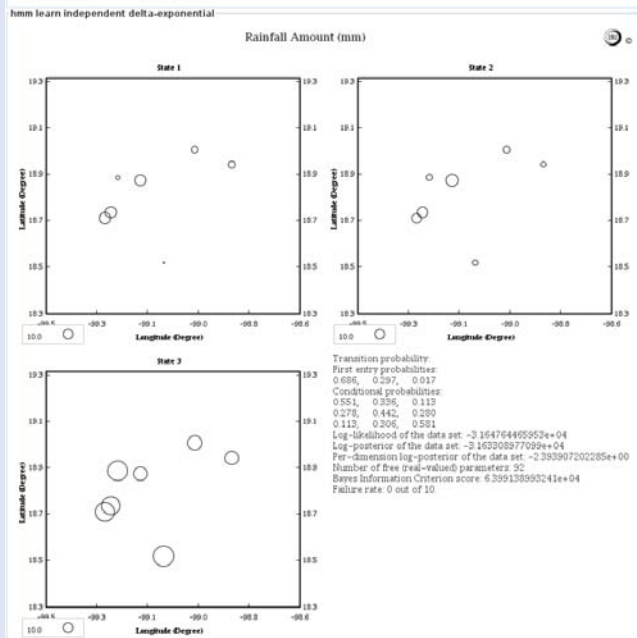
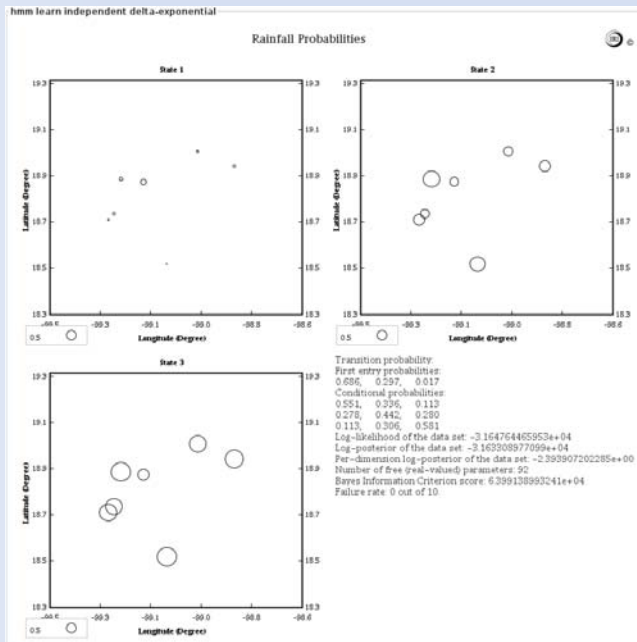
ind SOM, 2 Anomaly Patterns, 1980 2000 0 40 230 290 850 850



The 1st and the 4th patterns found with SOM look like the Dry and Wet composites obtained with HMM.

These two patterns always emerge when the number of clusters in the SOM analysis is changed.

HMM IN THE SUMMER SEASON: 3 REGIMES

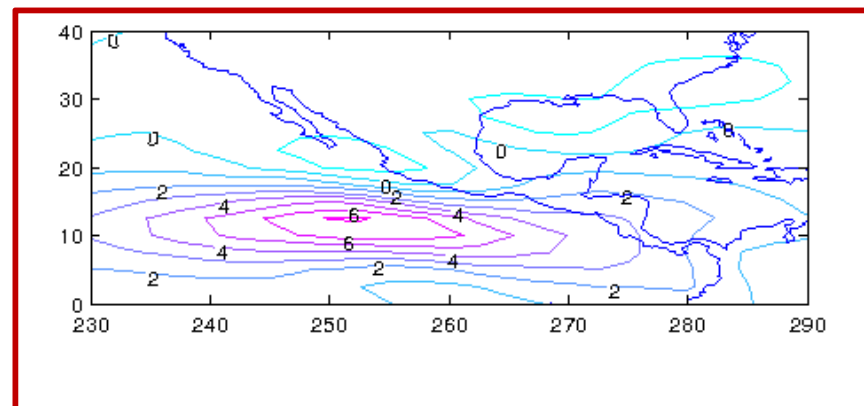
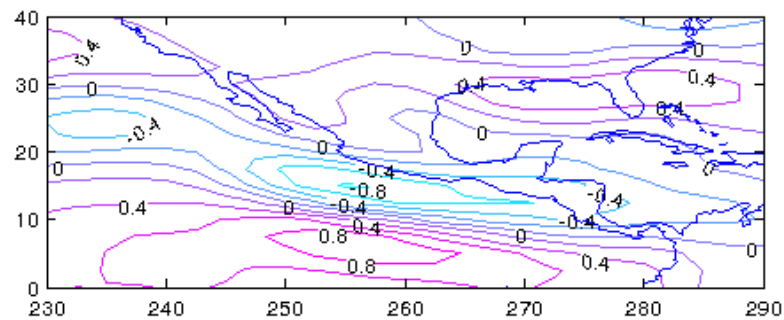
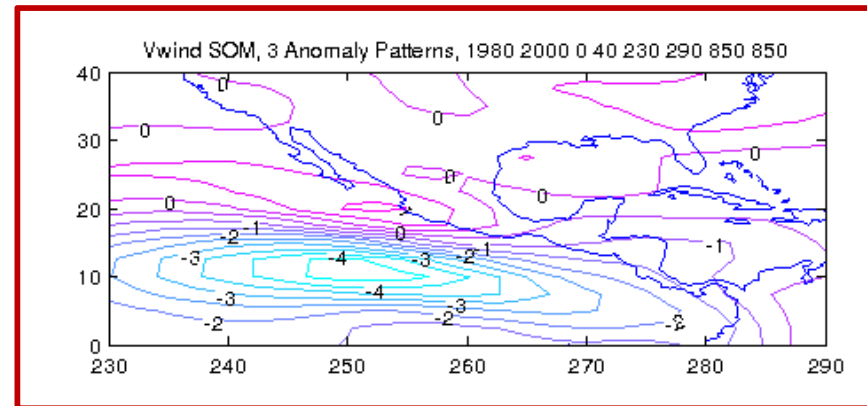


Conditional probabilities:
0.551, 0.336, 0.113
0.278, 0.442, 0.280
0.113, 0.306, 0.581

State 1: Dry
State 2: "Intermediate"
State 3: Wet

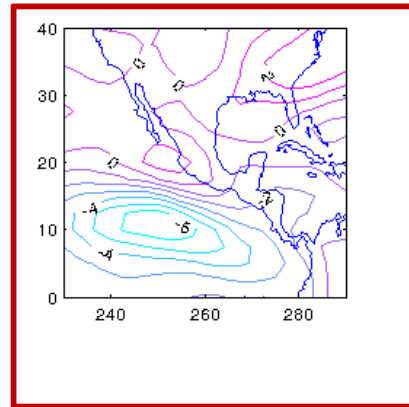
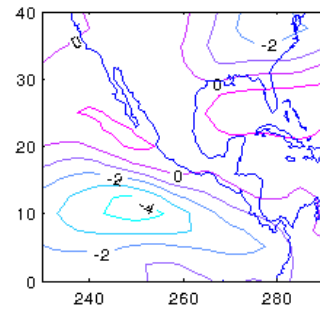
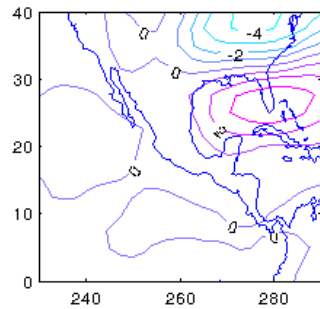
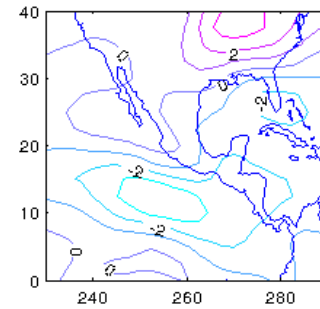
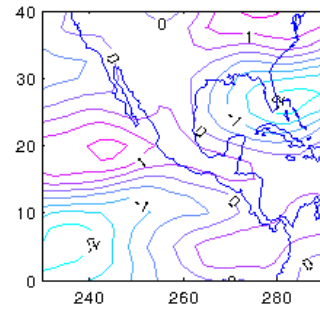
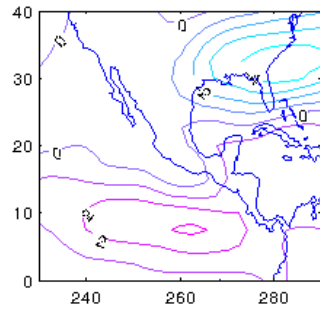
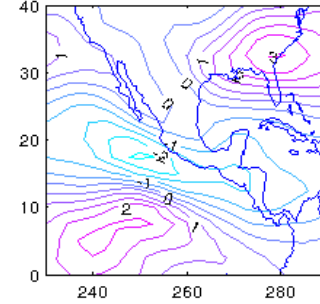
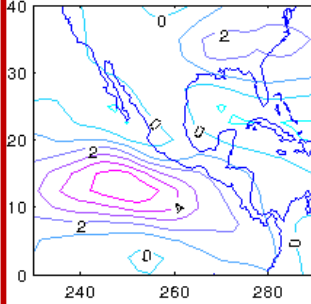
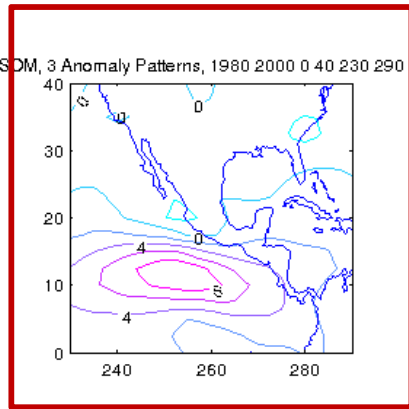
Quasi-symmetric transition matrix

SOM IN THE SUMMER SEASON: 3-CLUSTER



SOM IN THE SUMMER SEASON: 9-CLUSTER

Vwind SOM, 3 Anomaly Patterns, 1980 2000 0 40 230 290 350 850



CONCLUSIONS

- Application of the Hidden Markov Method to 21 years of rainfall data from the Morelos State in Mexico.
- Trivial identification of the seasonal cycle.
- Identification of two different regimes during the summers season, with evident wind patterns that favour/reduce moist air advection from the Pacific Ocean to Mexico.

THANK YOU FOR ATTENTION!!



*Come and visit Morelos State
(although we have never been there!)*