

# Study of rainfall variability using Hidden Markov Model over Ghana

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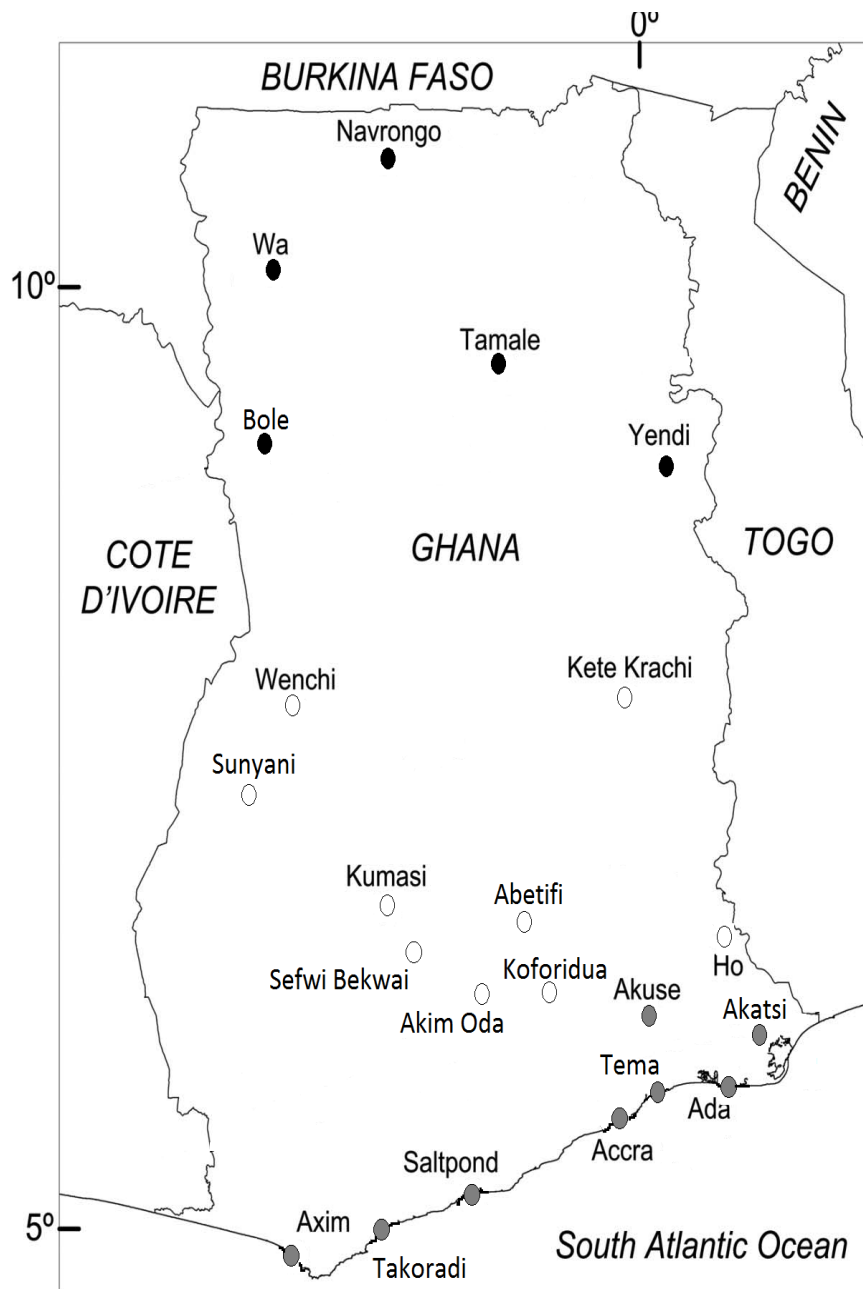
# Introduction

- The Hidden Markov Model (HMM) used in this study provides a framework for modeling daily rainfall occurrences and amounts on multi-site rainfall networks.
- The HMM fits a model to observed rainfall records by introducing a small number of discrete rainfall states.
- These states allow a diagnostic interpretation of observed rainfall variability in terms of a few rainfall patterns.

# Motivation

- The variability in rainfall particularly at the seasonal scale is extremely important for most sectors in every economy.
- The HMM allows you to *simulate* rainfall at each of the station locations to get key statistical properties (eg. rainfall probabilities, dry/wet spell lengths) which is useful for input into a crop model for agricultural planning.

# Study Area and Data



● Uni-modal Rainfall Distribution

○ Bi-modal Rainfall Distribution (2 peaks similar in magnitude)

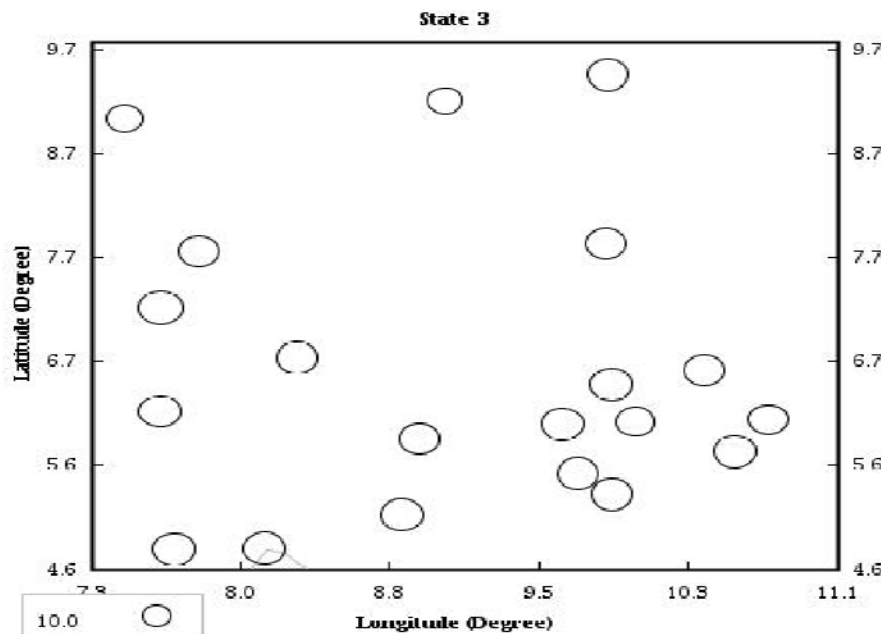
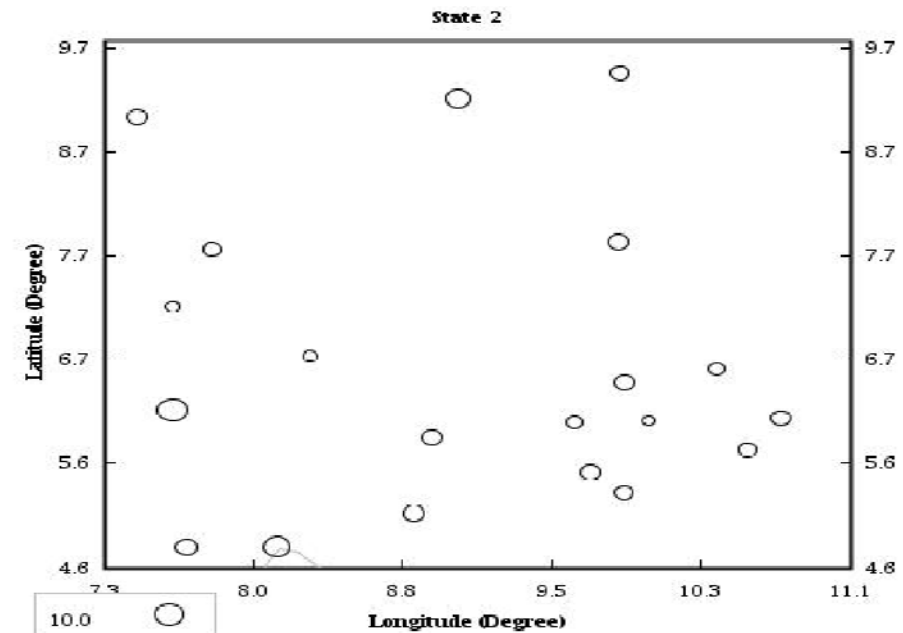
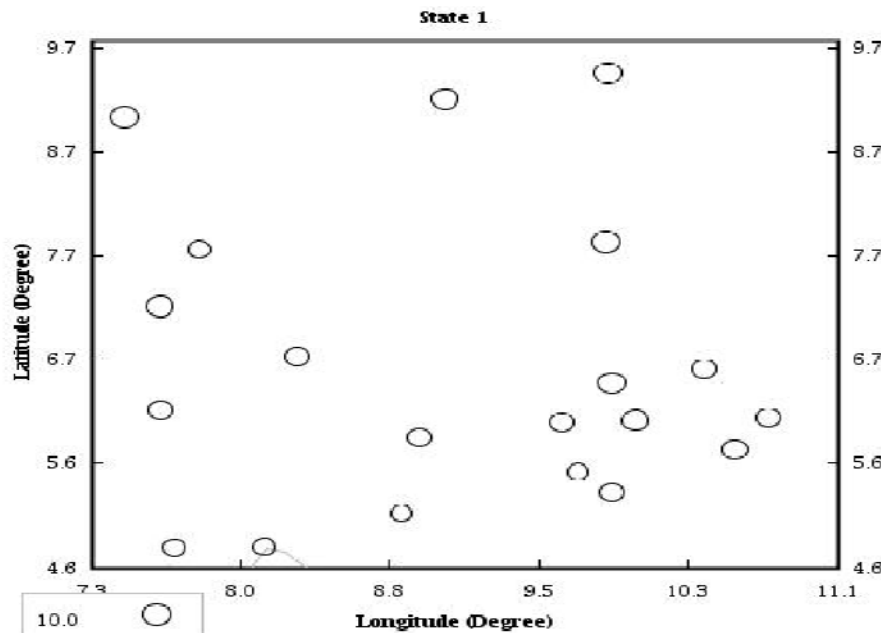
● Bi-modal Rainfall Distribution (1st peak higher)

- Daily rainfall data from Ghana Meteorological Agency
- Data period is 1981–2011
- Rain gauge data from 22 stations across Ghana
- Analysis is done according to rainfall distribution in Ghana

# Rainfall Amount over Ghana

hmm learn independent delta-exponential

Rainfall Amount (mm)



Transition probability:

First entry probabilities:

0.033, 0.967, 0.000

Conditionals probabilities:

0.670, 0.113, 0.216

0.183, 0.810, 0.007

0.412, 0.031, 0.557

Log-likelihood of the data set:  $-3.153875574679e+05$

Log-posterior of the data set:  $-3.153459737953e+05$

Per-dimension log-posterior of the data set:  $-1.400392451486e+00$

Number of free (real-valued) parameters: 248

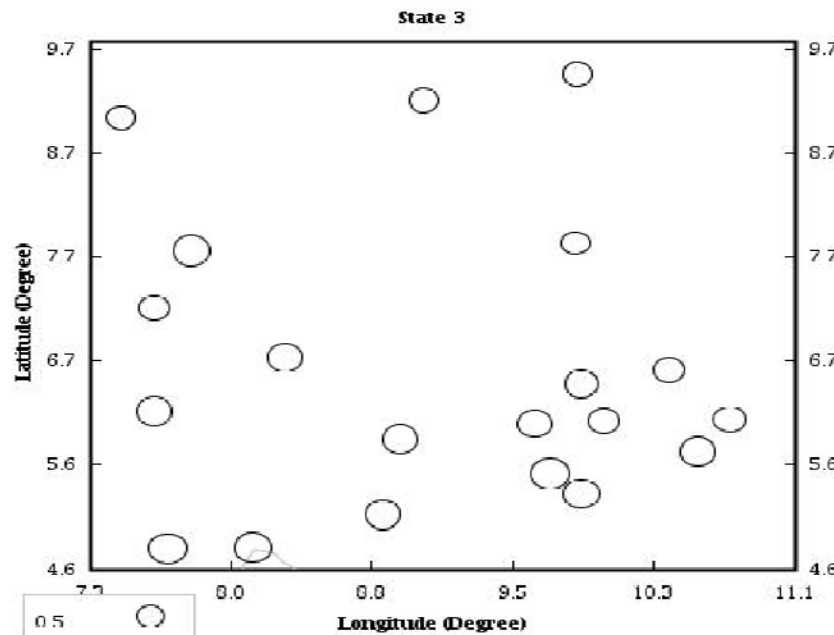
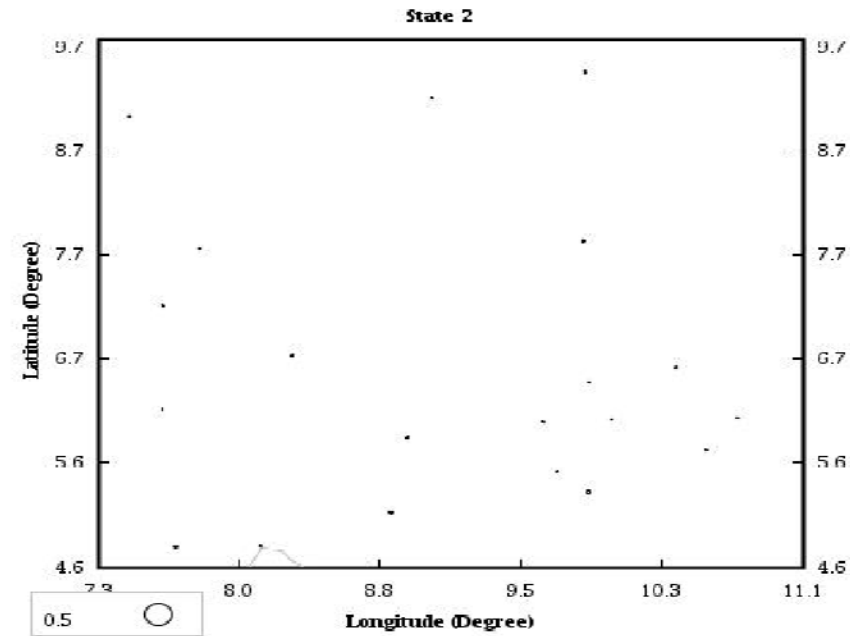
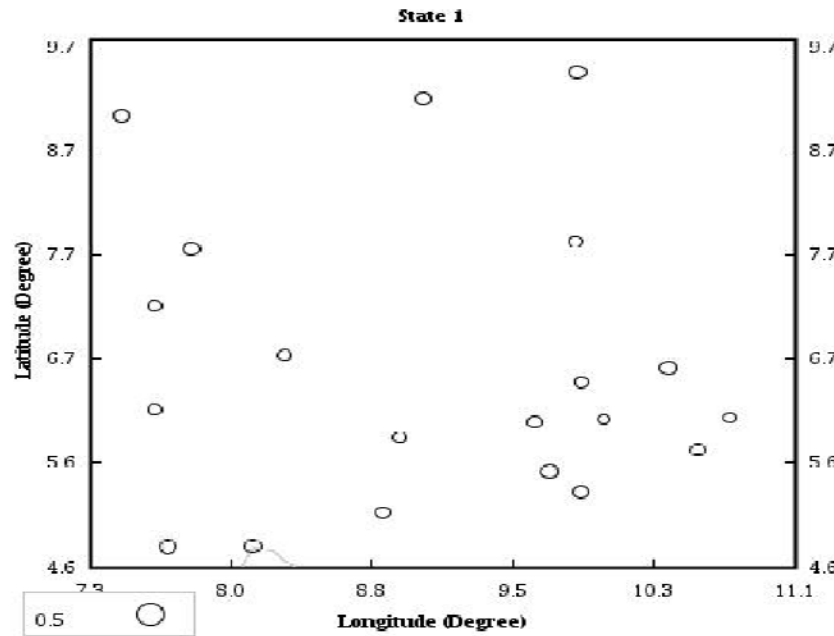
Bayes Information Criterion score:  $6.330905968293e+05$

Failure rate: 0 out of 2.

# Rainfall Probabilities over Ghana

hmm learn independent delta-exponential

### Rainfall Probabilities

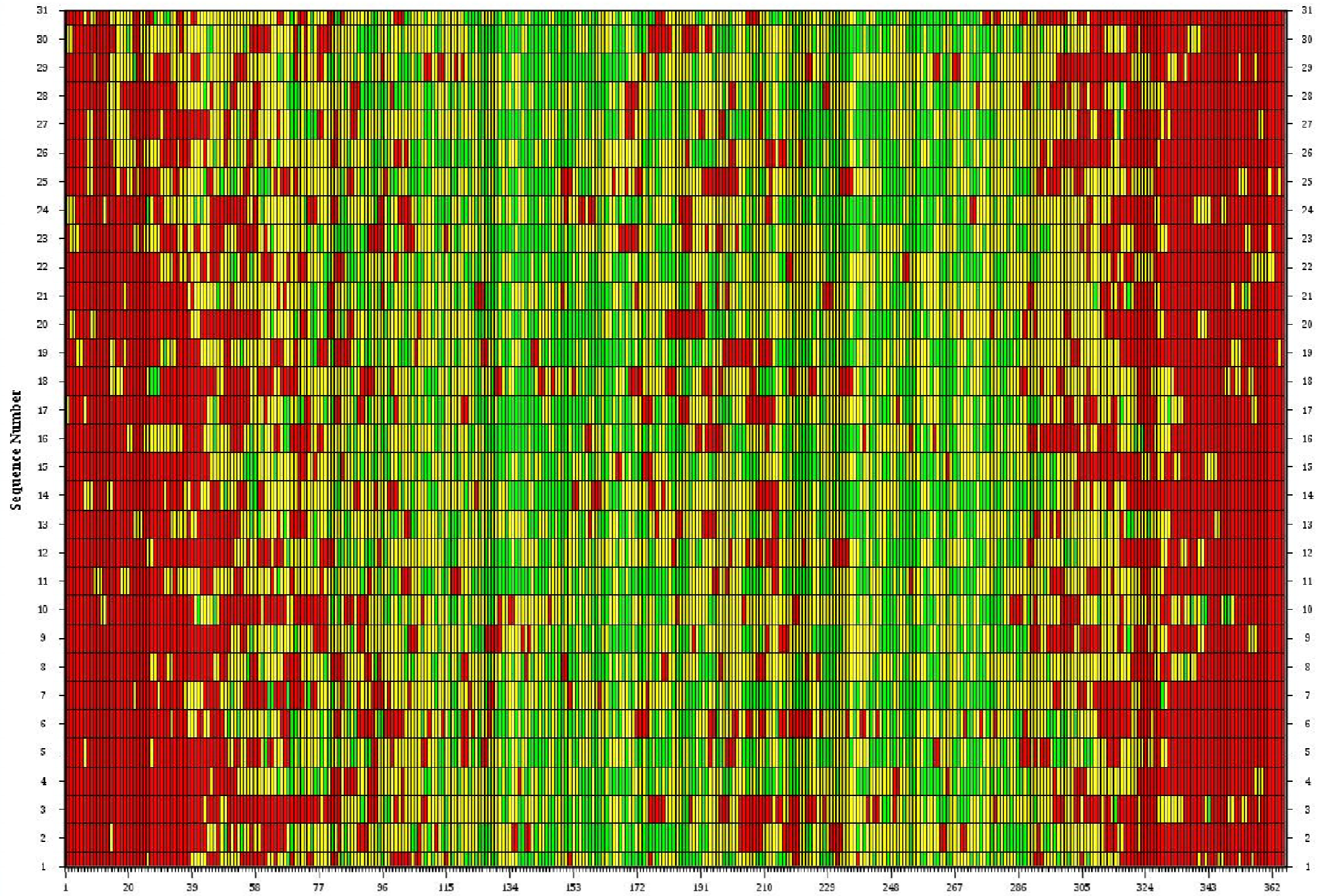


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# Probabilities

- Rainfall probabilities amount three categories are given along with the plots in earlier image.
- It is evident that the probability for Medium Rainfall is highest (0.967).

### Estimated State Sequence



State: 1 2 3

Day of Sequence





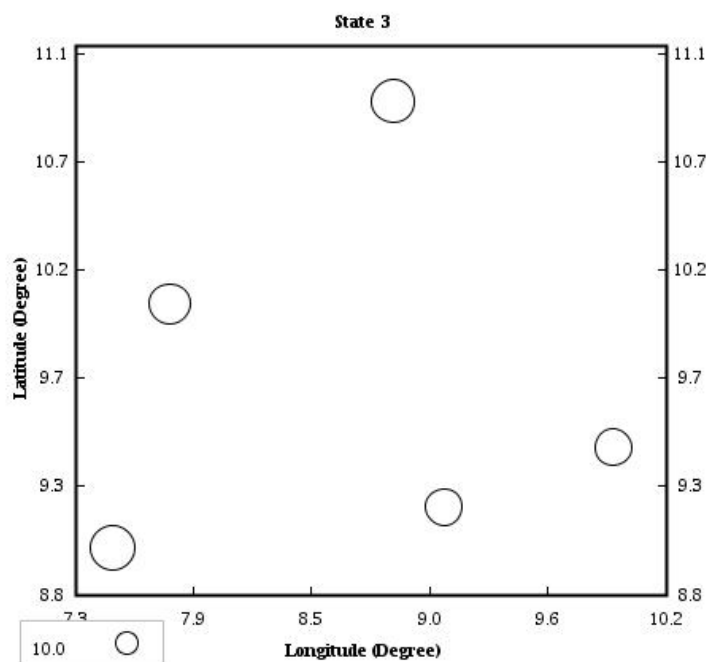
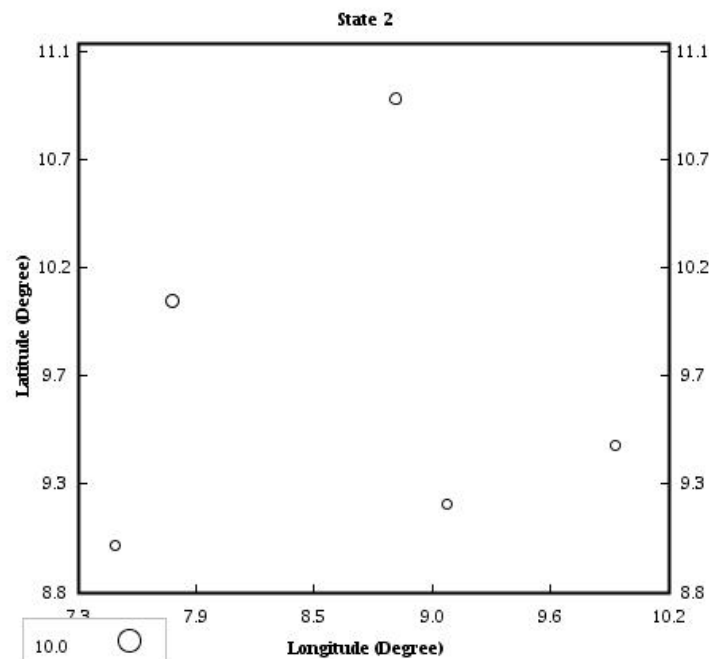
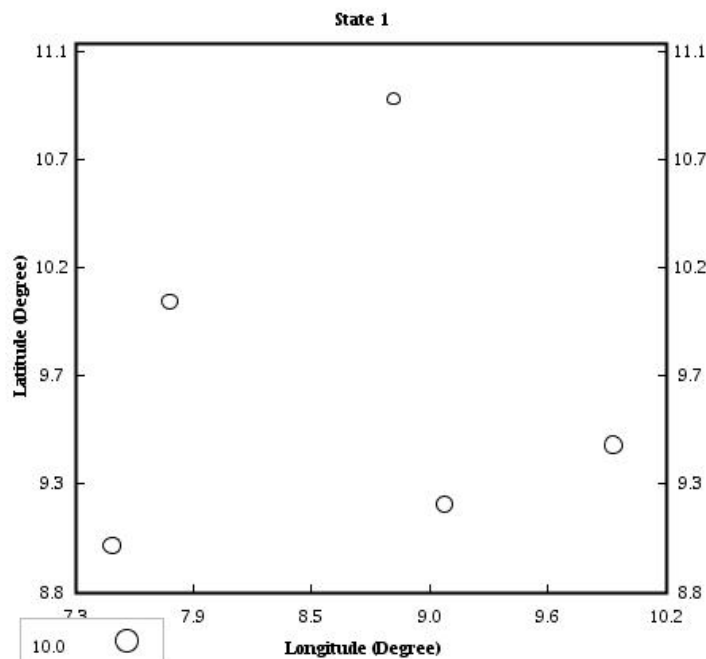
# Viterbi output

- The viterbi output is showing daily rainfall occurrence for all years.
- Red indicates scanty or no rainfall
- Yellow box is for moderate rainfall
- Where as Green box is for Very high rainfall
- Rain break spells can be identified with red boxes in the middle columns.

# Rainfall Amount over South Ghana

hmm learn independent delta-exponential

Rainfall Amount (mm)



Transition probability:

First entry probabilities:

0.062, 0.938, 0.000

Conditional probabilities:

0.660, 0.182, 0.158

0.149, 0.822, 0.029

0.527, 0.032, 0.441

Log-likelihood of the data set:  $-1.095101433414e+05$

Log-posterior of the data set:  $-1.094935096733e+05$

Per-dimension log-posterior of the data set:  $-1.219005473862e+00$

Number of free (real-valued) parameters: 104

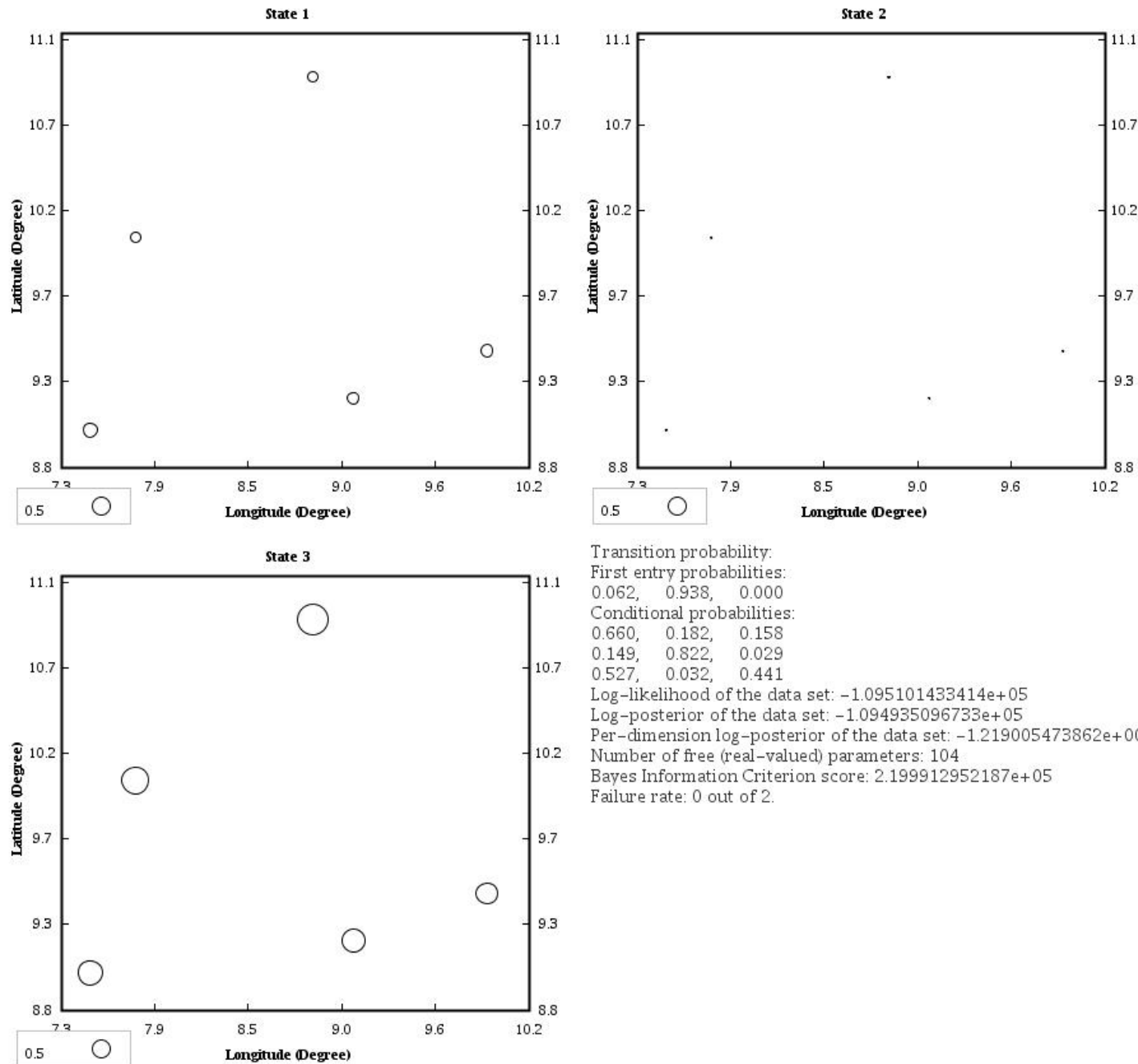
Bayes Information Criterion score:  $2.199912952187e+05$

Failure rate: 0 out of 2.

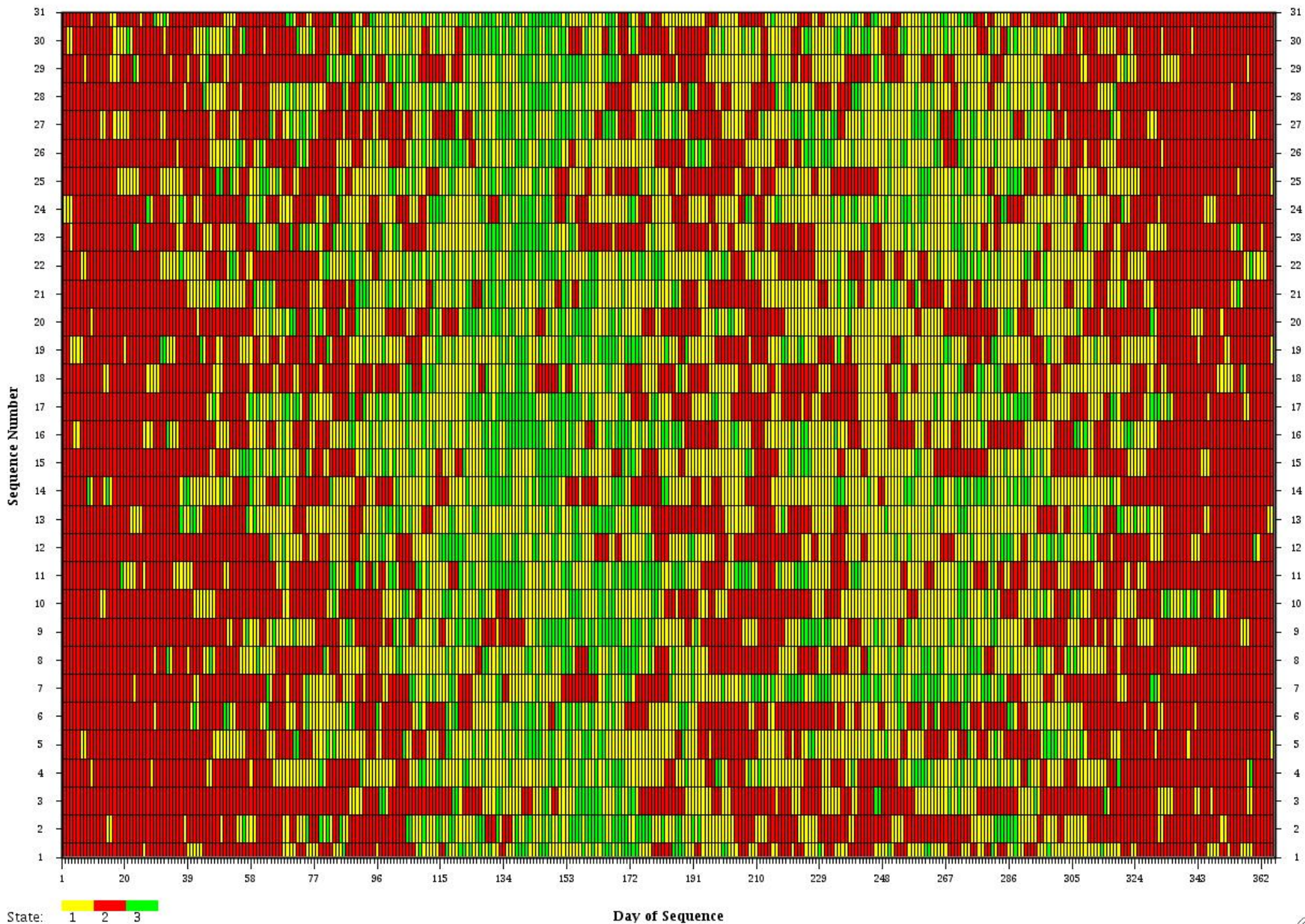
# Rainfall Probabilities over South Ghana

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## Rainfall Probabilities

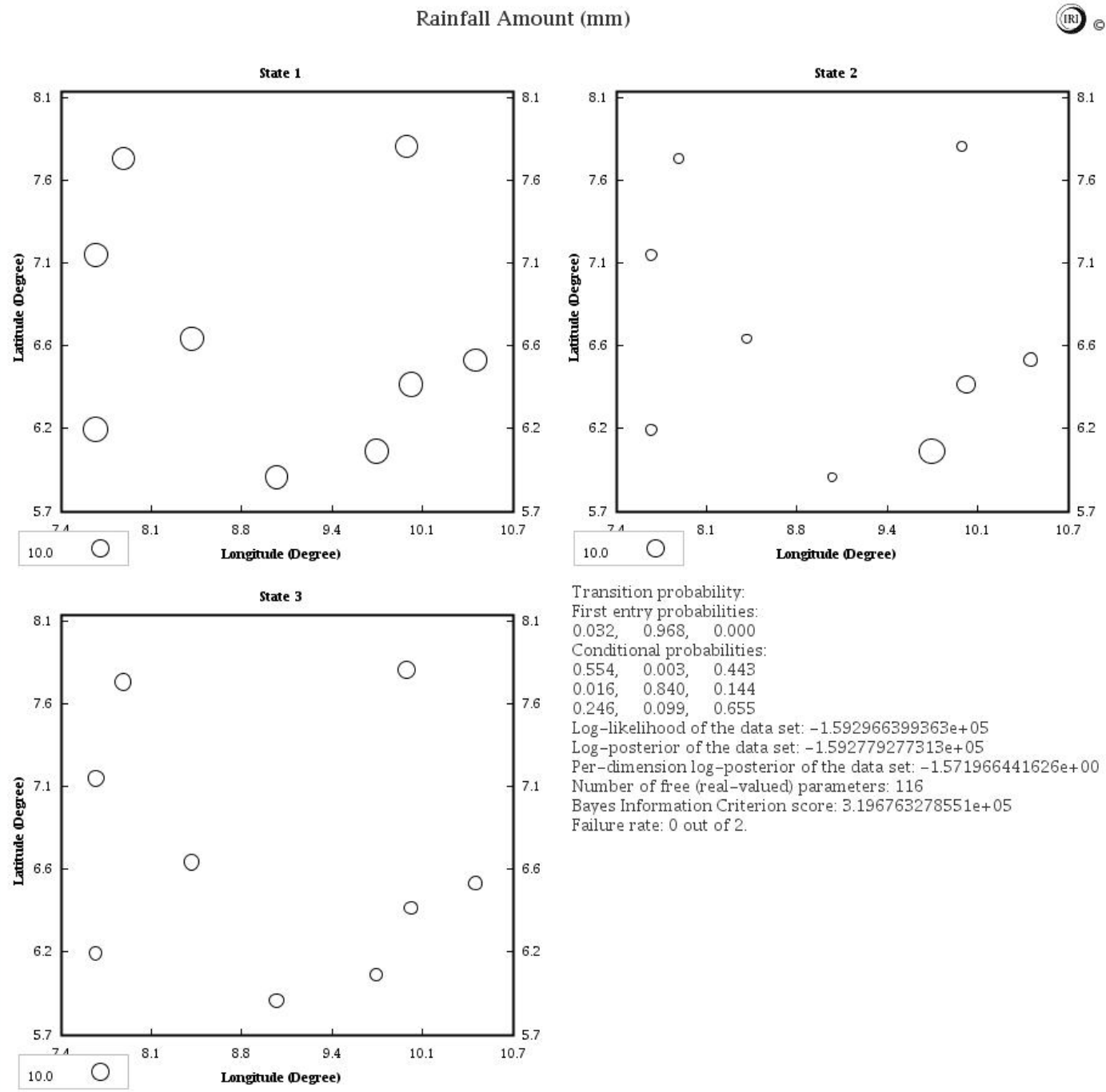


### Estimated State Sequence



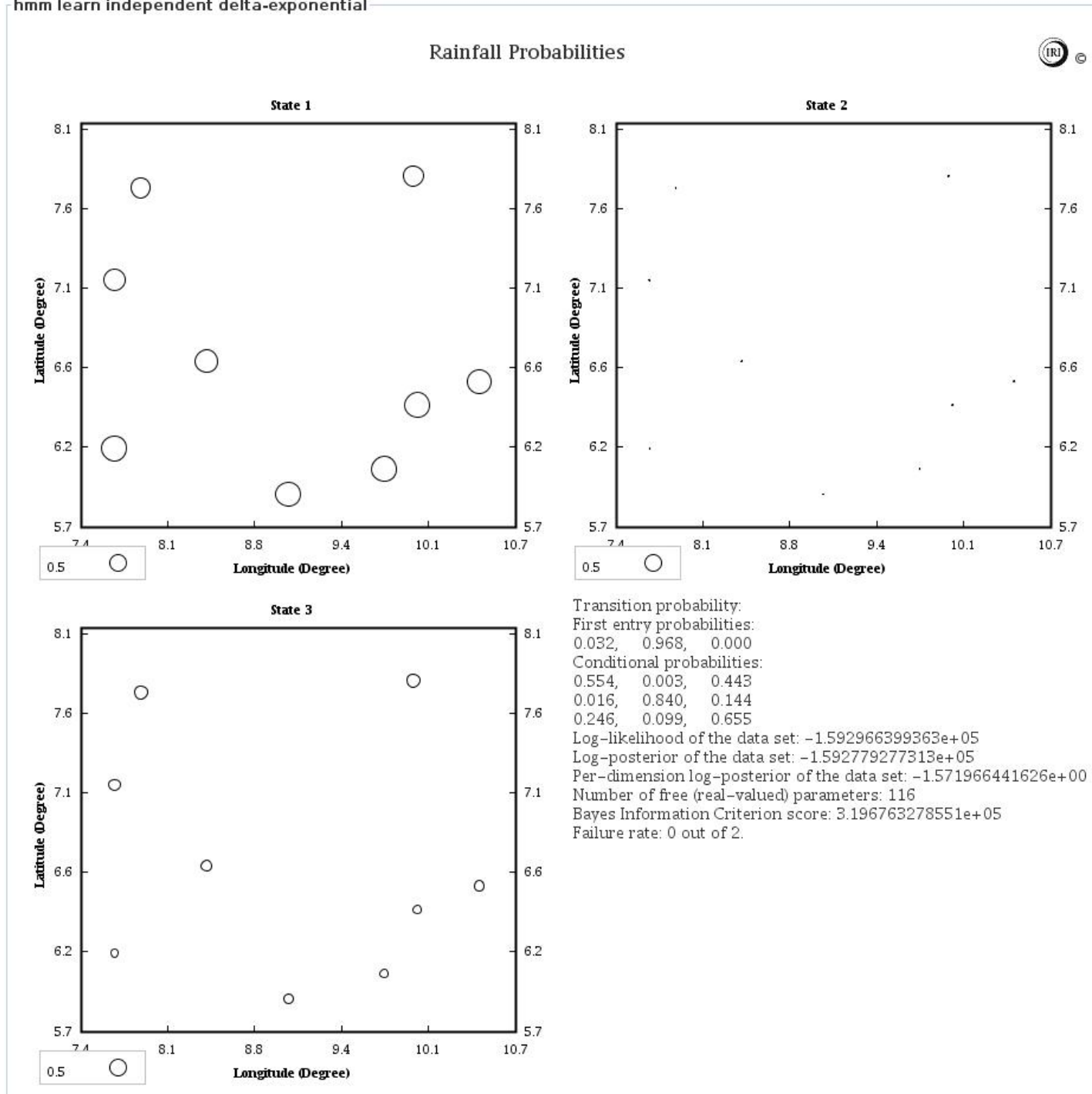
# Rainfall Amount over Mid Ghana

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# Rainfall Probabilities over Mid Ghana

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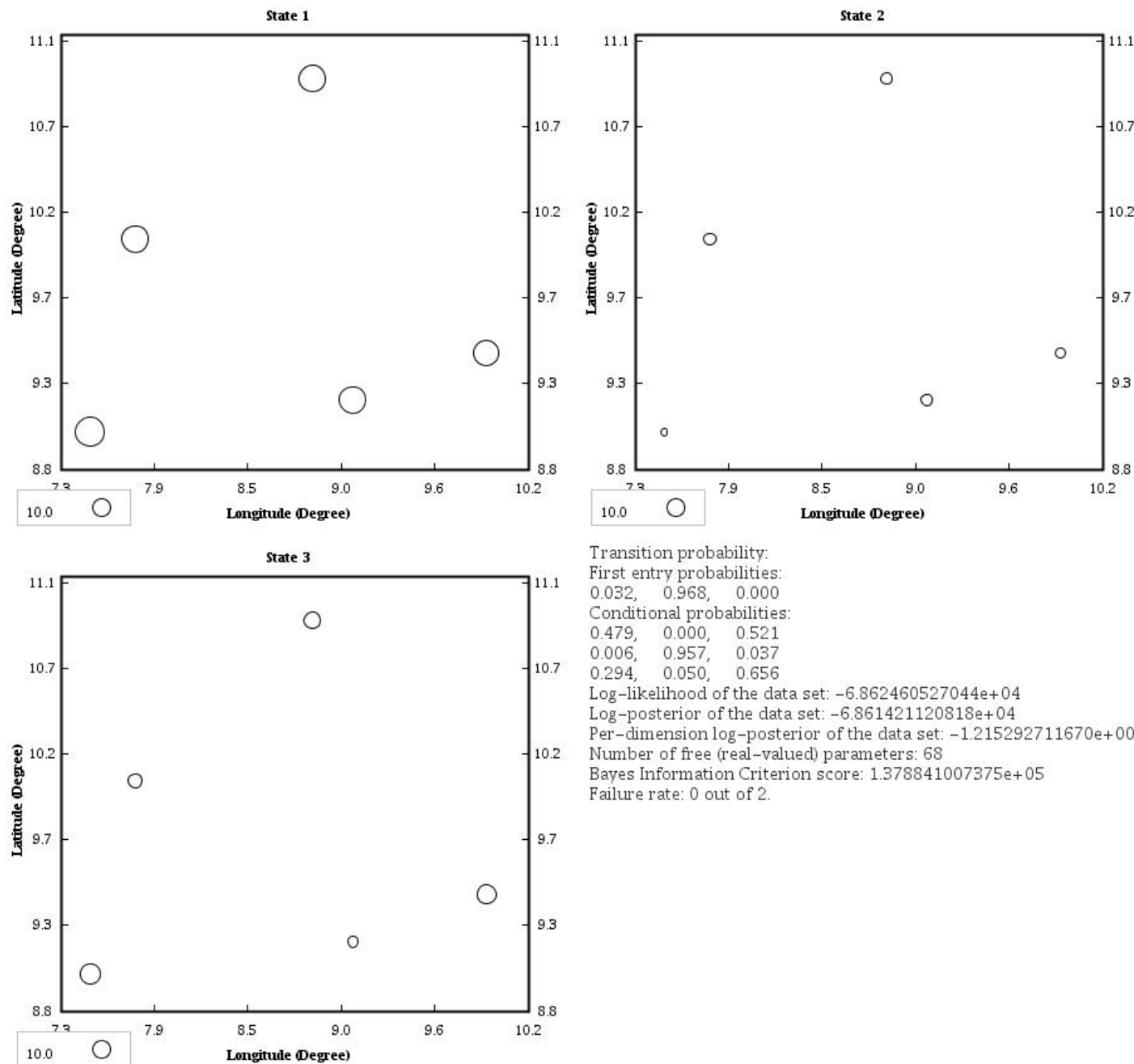
### Estimated State Sequence



# Rainfall Amount over North Ghana

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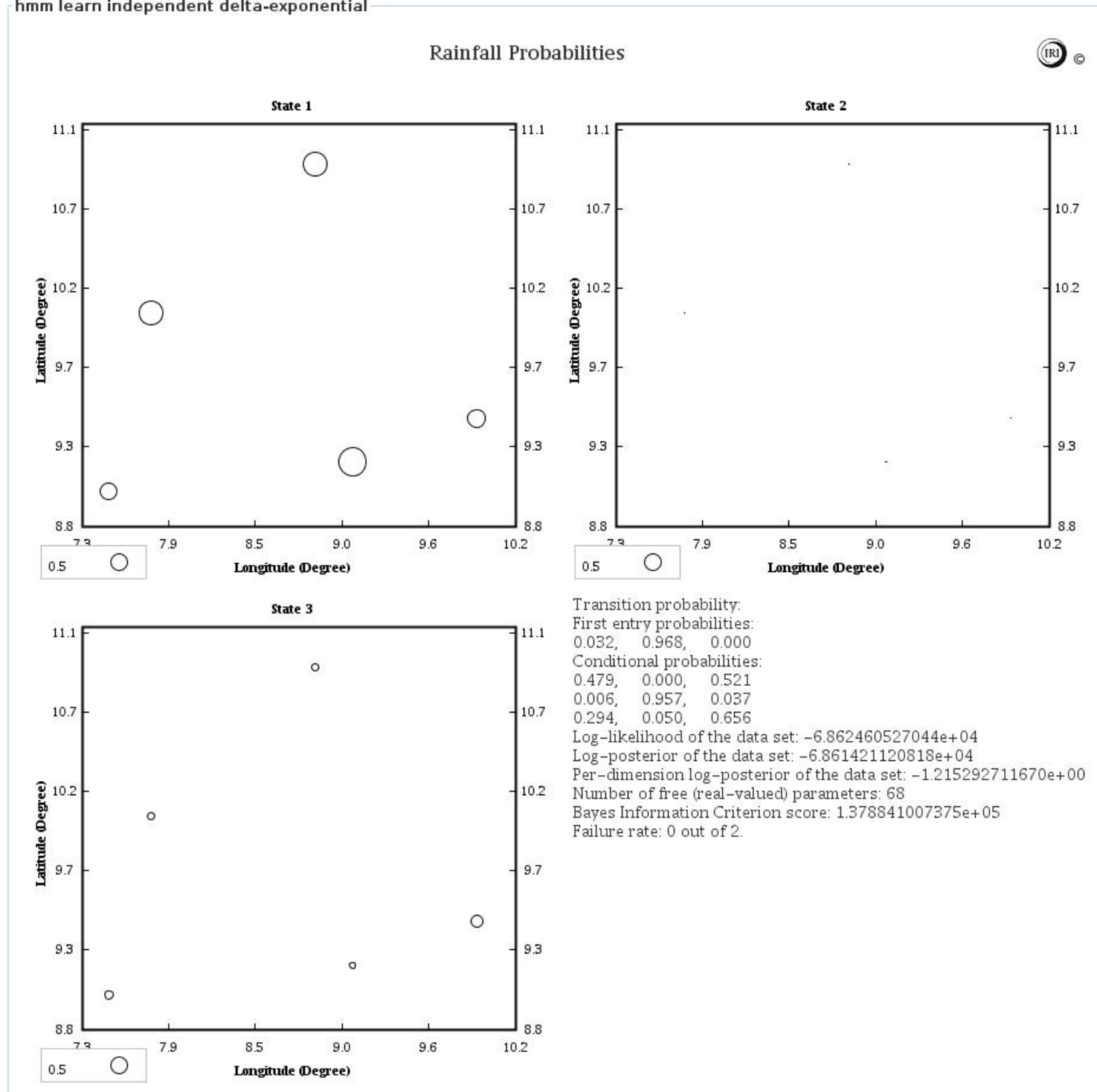
Rainfall Amount (mm)





# Rainfall Probabilities over North Ghana

hmm learn independent delta-exponential

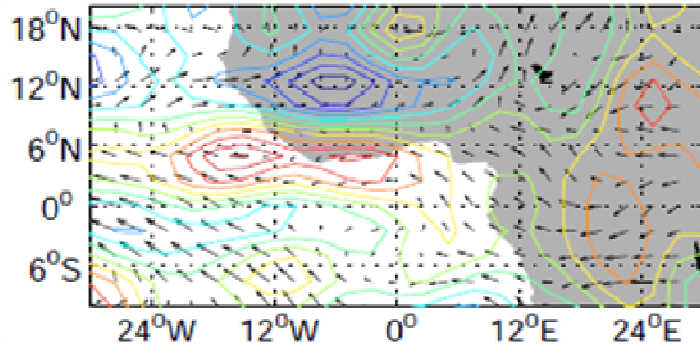


### Estimated State Sequence

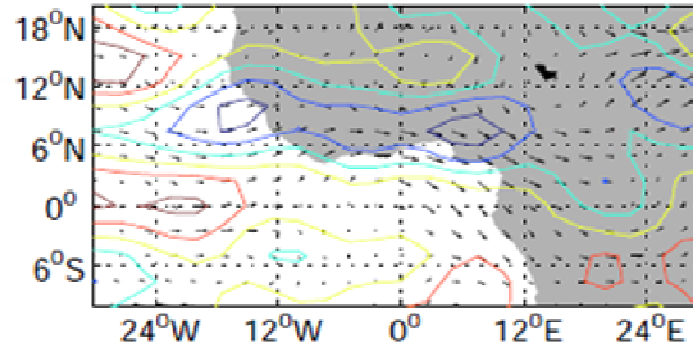


# Vertical Velocity and Wind (850 hPa)

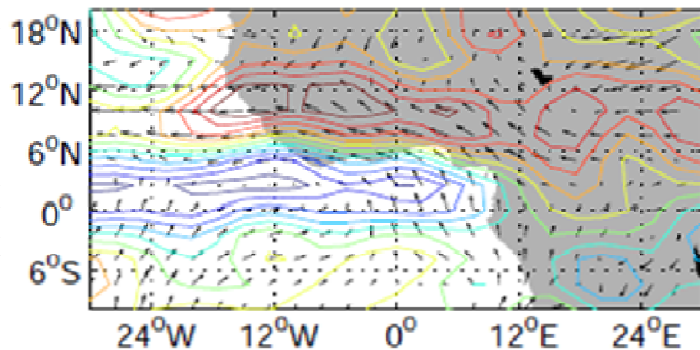
State 1 (197 days)



State 2 (503 days)



State 3 (312 days)



- Vertical velocity component is shown over the West African region along with wind speeds for each state.
- Days with high rainfall amount over the southern part agrees with state 2 where upward vertical velocity possible resulting into convection and rainfall.

# Conclusion

- High interannual variability as shown by the viterbi graphs has been known to be due to the influence of ENSO phenomenon over the country (e.g Mawunya et al, 2011).
- A number of meteorological drought is revealed over the south than the other 2 divisions

# Caveats and Future work

- Limited time for analysis
- We are still learning the HMM
- Further analysis will look into simulating rainfall using NHMM with possible rainfall predictors over Ghana
- Analysis over India rainfall

Thank you for the wonderful  
opportunity

