Report for Marielle

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This document is supposed to give a compact overview of the current results that lead to the questions we now face.

Data preprocessing

Until now we only dealt with the bird ider (as it had the longest time series). We decided for the following preprocessing:

We aggregated each 30 second interval to one data point. The time series we examine now includes:

- Step length/ speed(m/s)
- Turning angle
- Height first difference

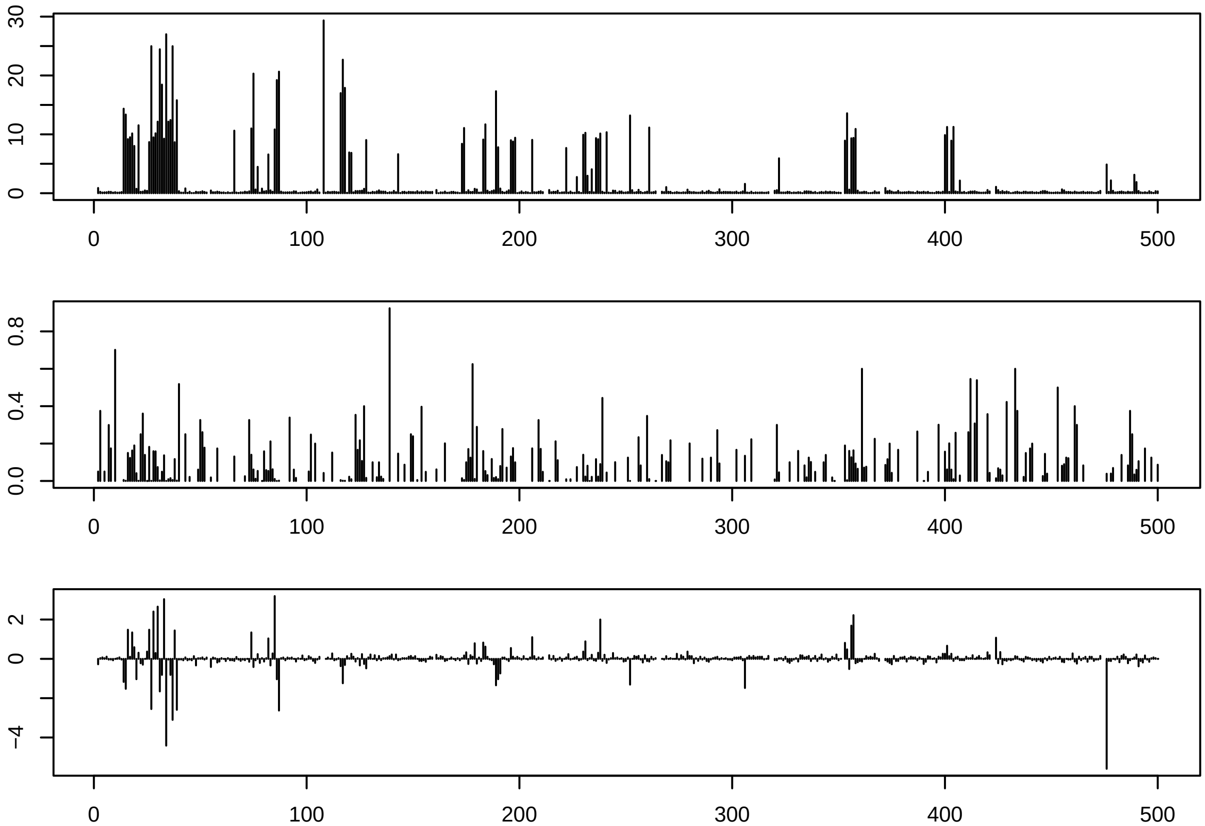
Therefore we first computed Step length and turning angle on a 1 Hz basis within each interval. For Step length we just computed the average as a summary statistic.

For the turning angle we observed that the soaring behaviour stands out by a more or less constant (slightly fluctuating) turning angle within the 30 second interval. However the turning direction is sometimes right and sometimes left which is not of interest for detecting this behaviour. Therefore for turning angle we computed the absolute value of the mean in each time interval. Afterwards it is scaled by a factor of $1/\pi$ so we can model it using the Beta-distribution.

For the first difference of the height we also computed this within each interval and then computed the average.

We had to exclude some outliers, especially for height first difference, namely data points that showed an average height first difference above 20 m/s and below -110 m/s. This already leads to the first question: Is this resonable for the animal?

Afterwards the three time series looked like this:



One can observe that there are large Step lengths in combination with small turning angles and mostly downward movement, medium Step lengths in combination with turning angles around 0.15 and upward movement as well as barely any step length in combination with different turning angles and basically no vertical movement.

3 state HMM

This made a 3 state HMM look reasonable with states:

- State 1: Soaring
- State 2: Gliding/ flying
- State 3: Resting

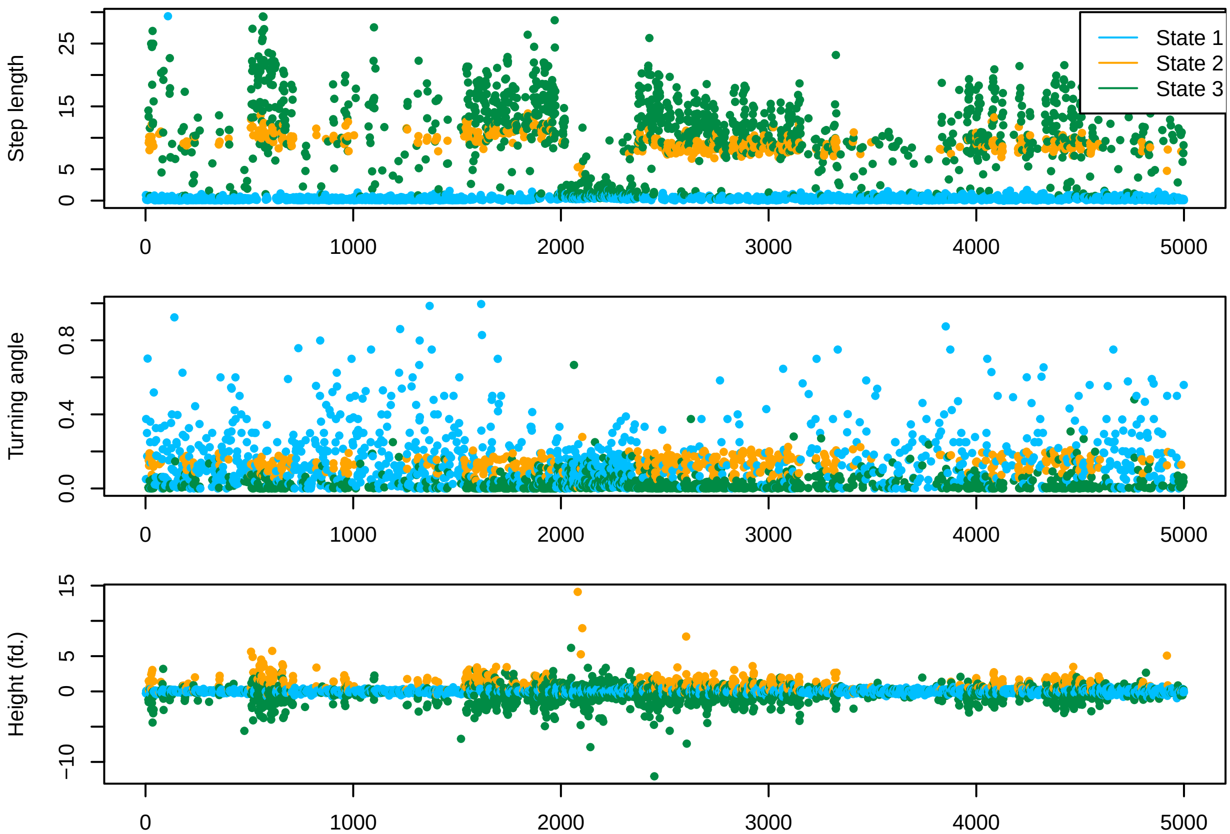
We formulated this model without covariates and fitted it to the first 5000 observations (which is a one way trans-himalayan migration). Which results in the transition probabilities and stationary distribution:

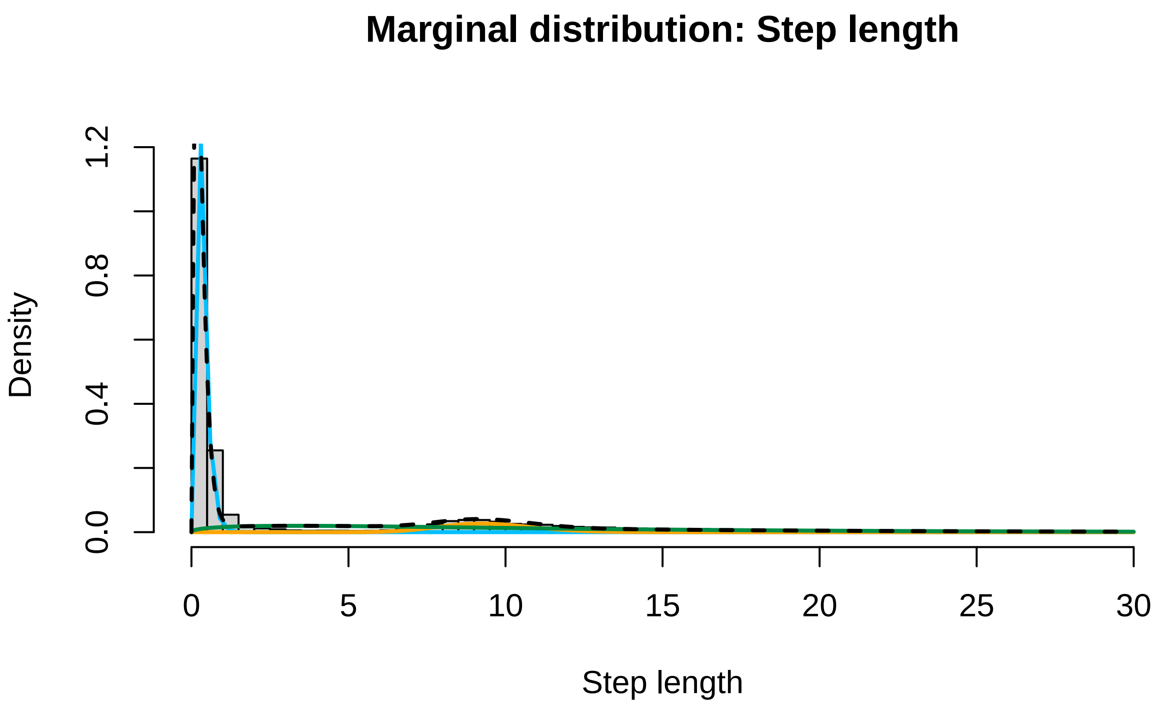
Transition probability matrix:

```
##            [,1]       [,2]      [,3]
## [1,] 0.86800355 0.01962751 0.1123689
## [2,] 0.07021677 0.31375198 0.6160312
## [3,] 0.25451582 0.19366838 0.5518158
```

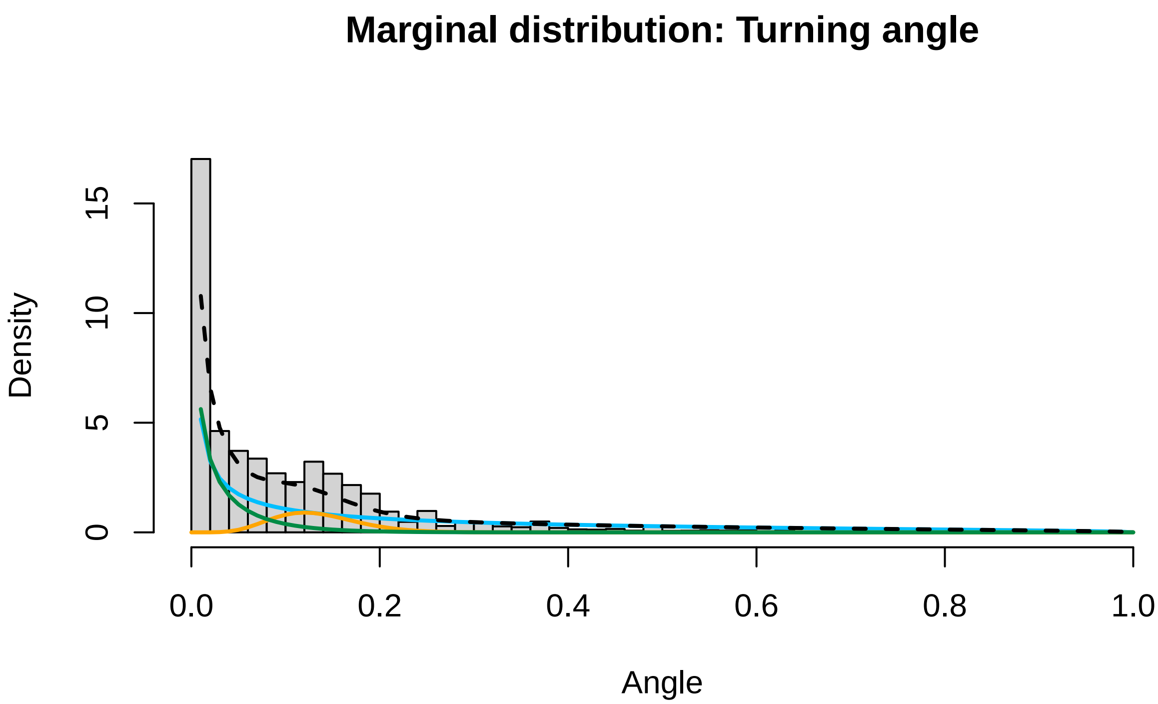
Stationary state distribution:

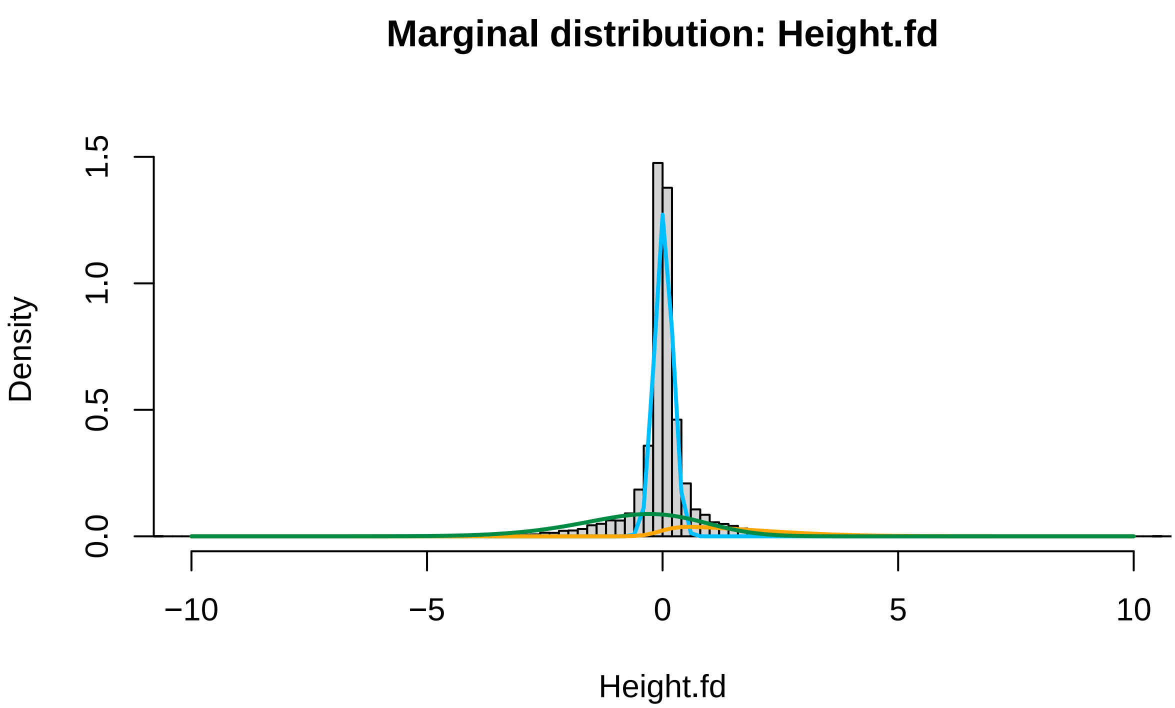
```
## [1] 0.61118746 0.09921031 0.28960223
```



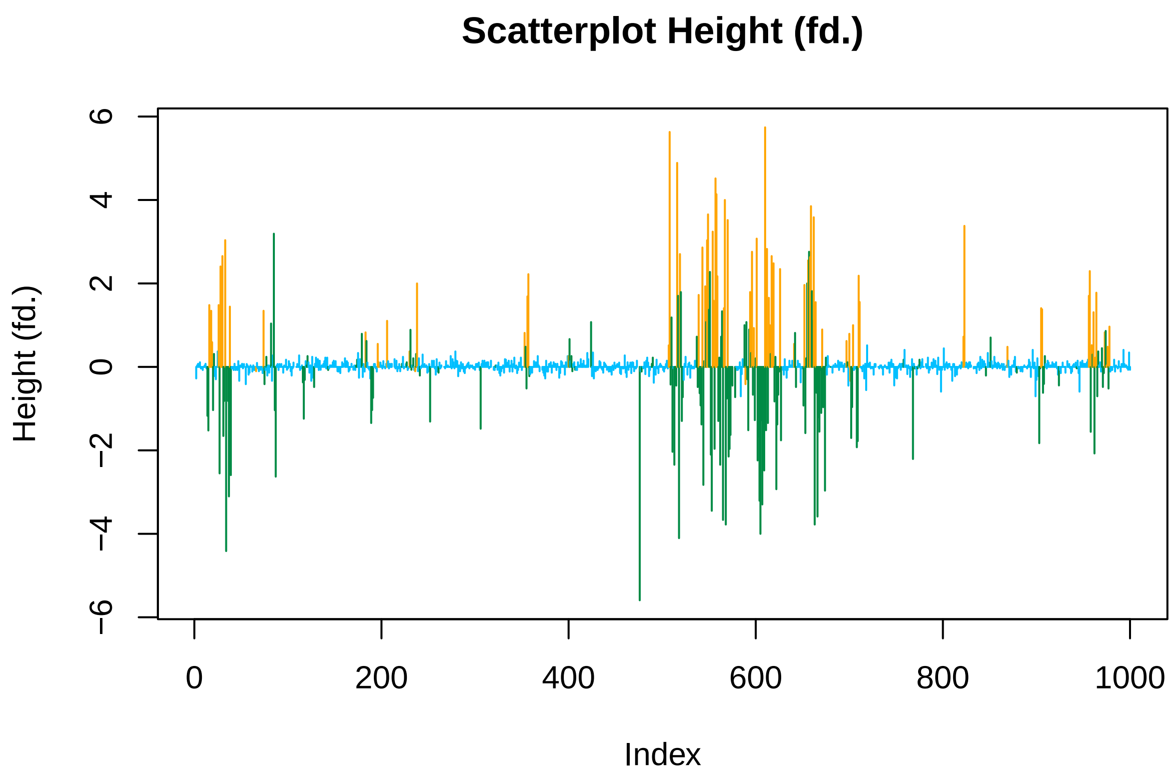


Here we can observe a lack of fit as the model overestimates how often step lenghts of 2-6 meters should appear.





So overall this model already looks promising. However the distinction between soaring and gliding is not as clear as we hoped. This is observable in the marginal plot above as well as in the scatterplot:



The model often also decodes upward movement as state 2 which should reflect only gliding. Therefore we looked into four state models.

4 state HMMs

4 state Model without covariates

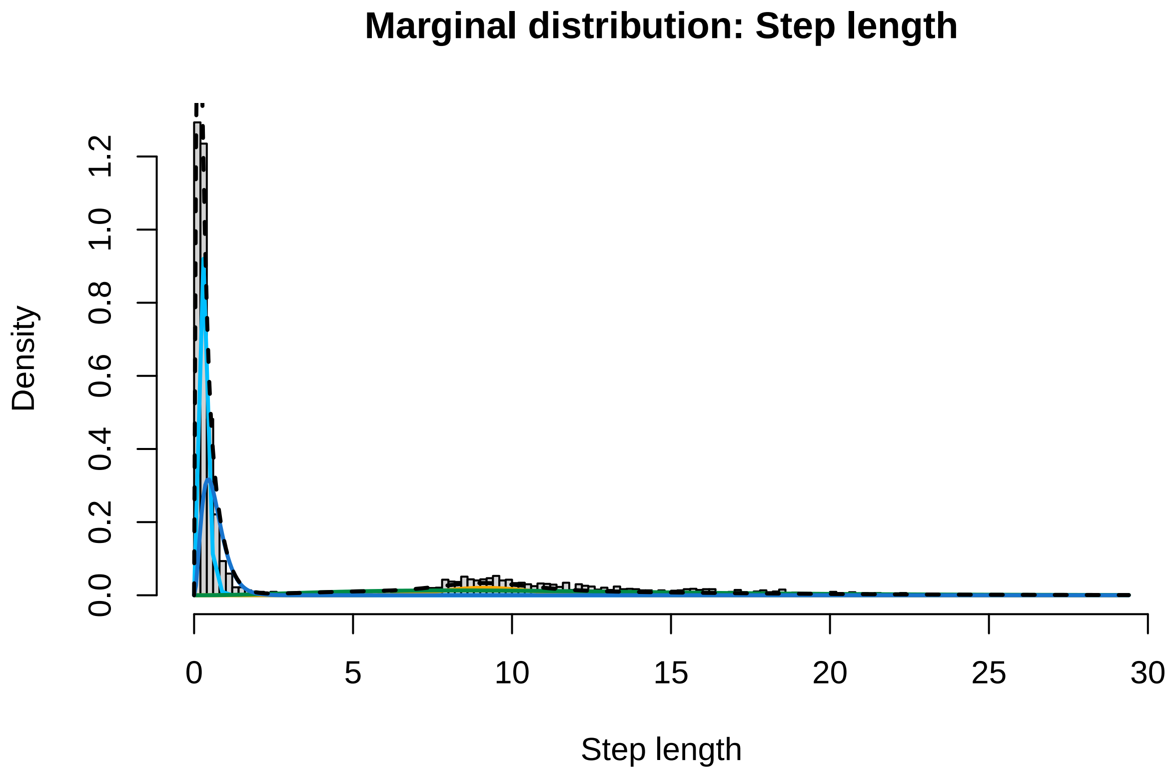
First we fitted a four state HMM without covariates with the aim at finding a model that better seperates states 2 and 3. This yielded the following results:

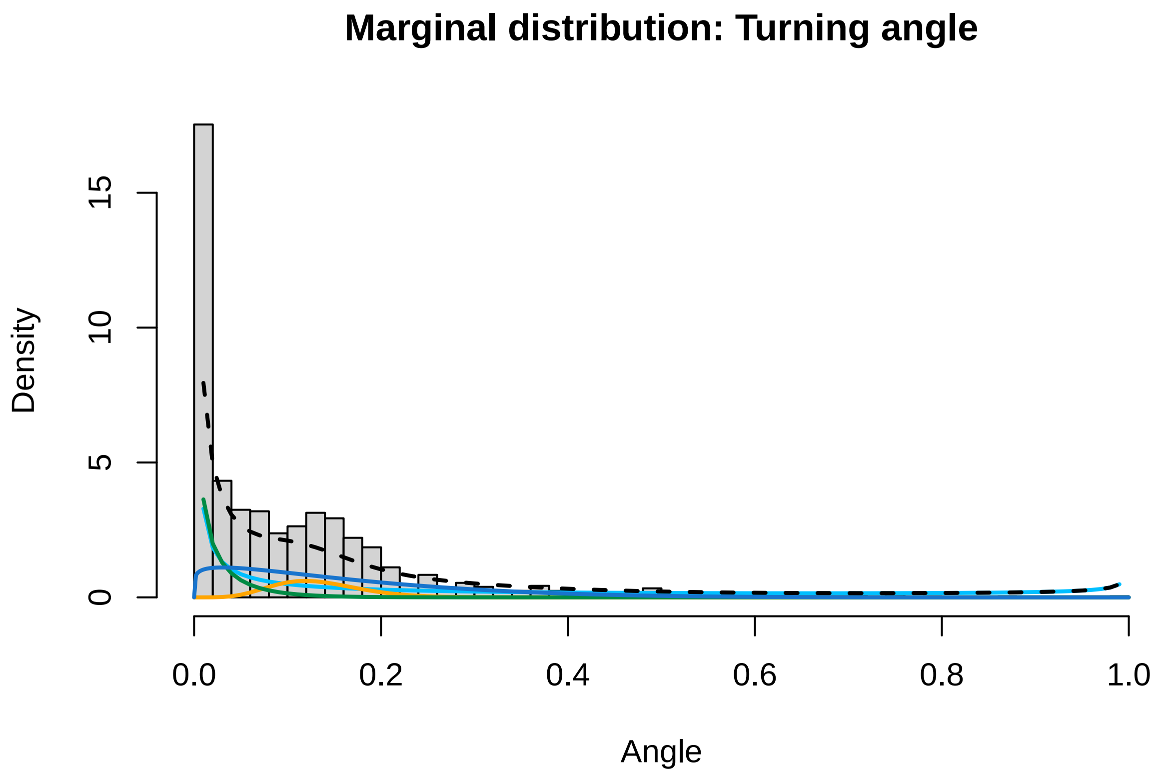
Transition probability matrix:

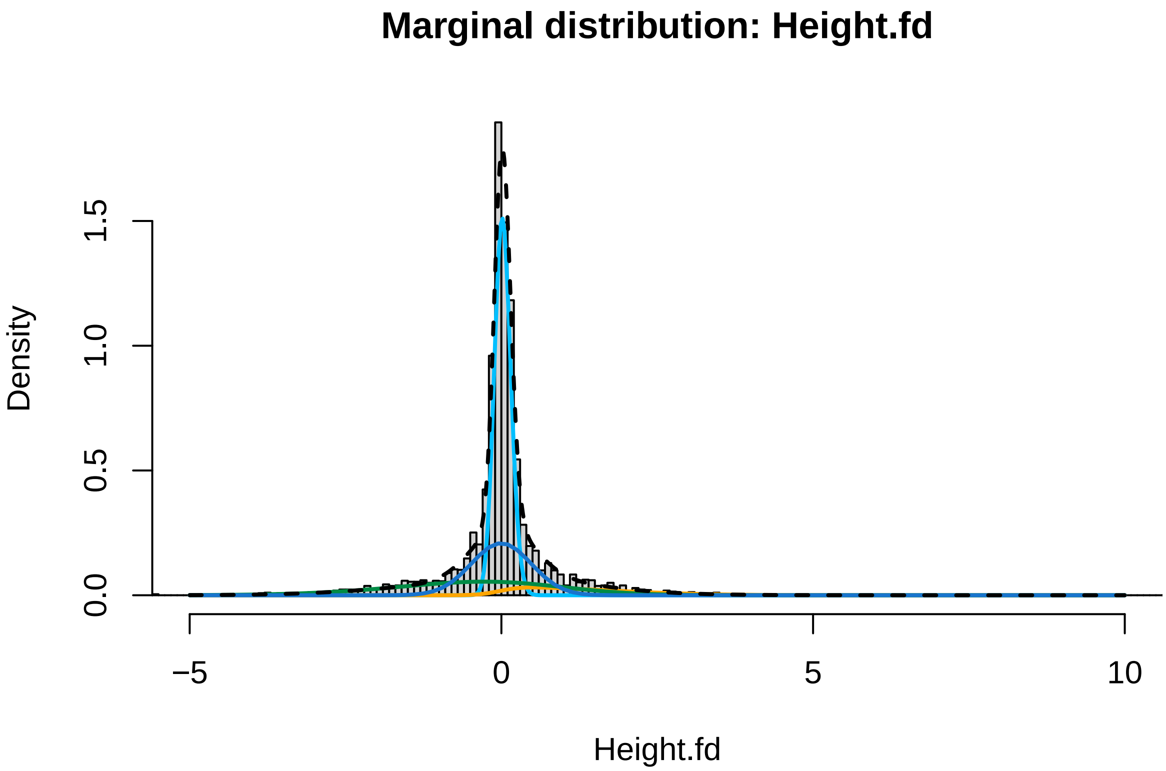
```
##            [,1]       [,2]       [,3]       [,4]
## [1,] 0.79509498 0.02349971 0.07368018 0.10772513
## [2,] 0.09183038 0.27718824 0.54369743 0.08728395
## [3,] 0.20992394 0.17018923 0.43522963 0.18465720
## [4,] 0.22848433 0.03012788 0.11230147 0.62908632
```

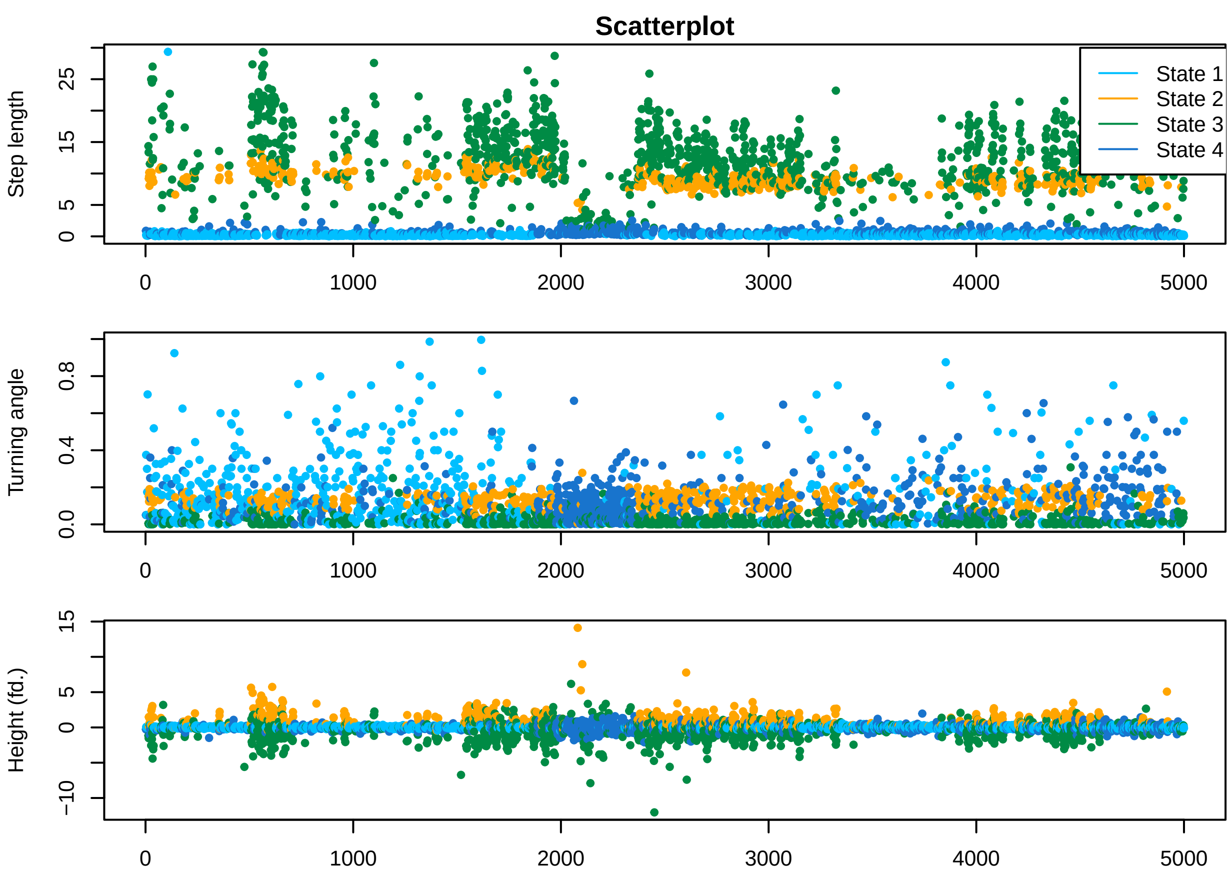
Stationary state distribution:

```
## [1] 0.49752575 0.06943857 0.18172651 0.25130917
```


Marginal distribution: Step length
Density
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
5
10
15
20
25
30
Step length


Marginal distribution: Turning angle
Density
0
5
10
15
0.0
0.2
0.4
0.6
0.8
1.0
Angle

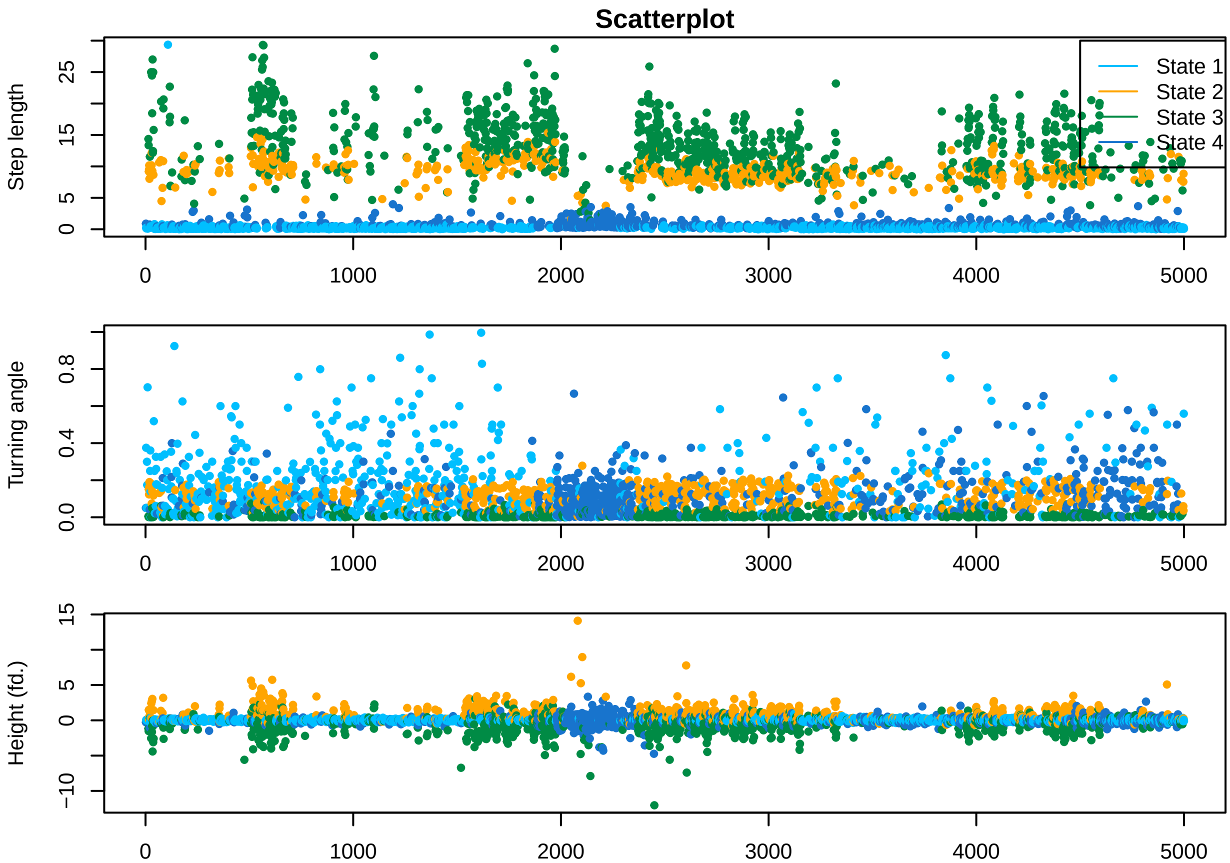




Here states 1 to 3 are basically characterised by the same characteristics as in the three state HMM. The new fourth state we interpreted as some kind of resting behaviour as well but distinctly more active then the resting behaviour captured in state 1 as the step length is longer, there is less variability in the turning angles and more vertical movement. Introducing this fourth state leads to a clearer distincion between soaring and gliding.

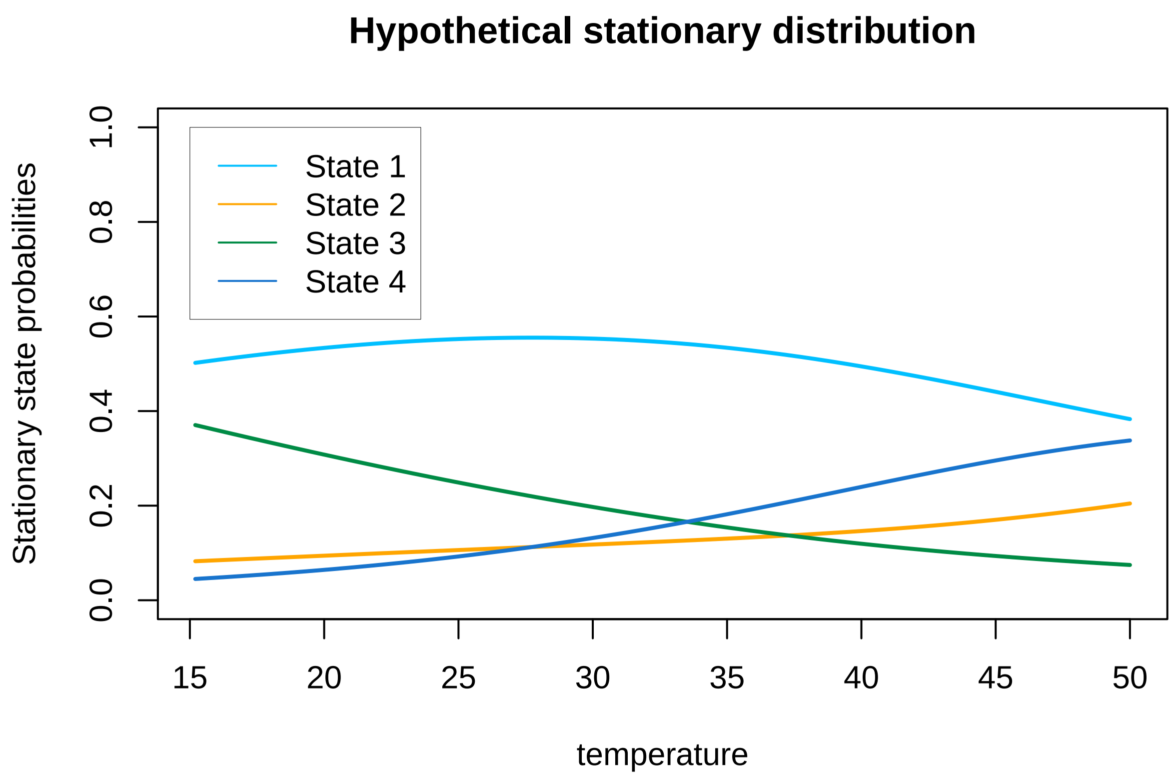
4 state Models with covariates

Temperature Now that we got that far we started introducing covariates into the state switching process by expressing the transition probabilities as functions of those covariates. We started by introducing a dependency on the temperature.

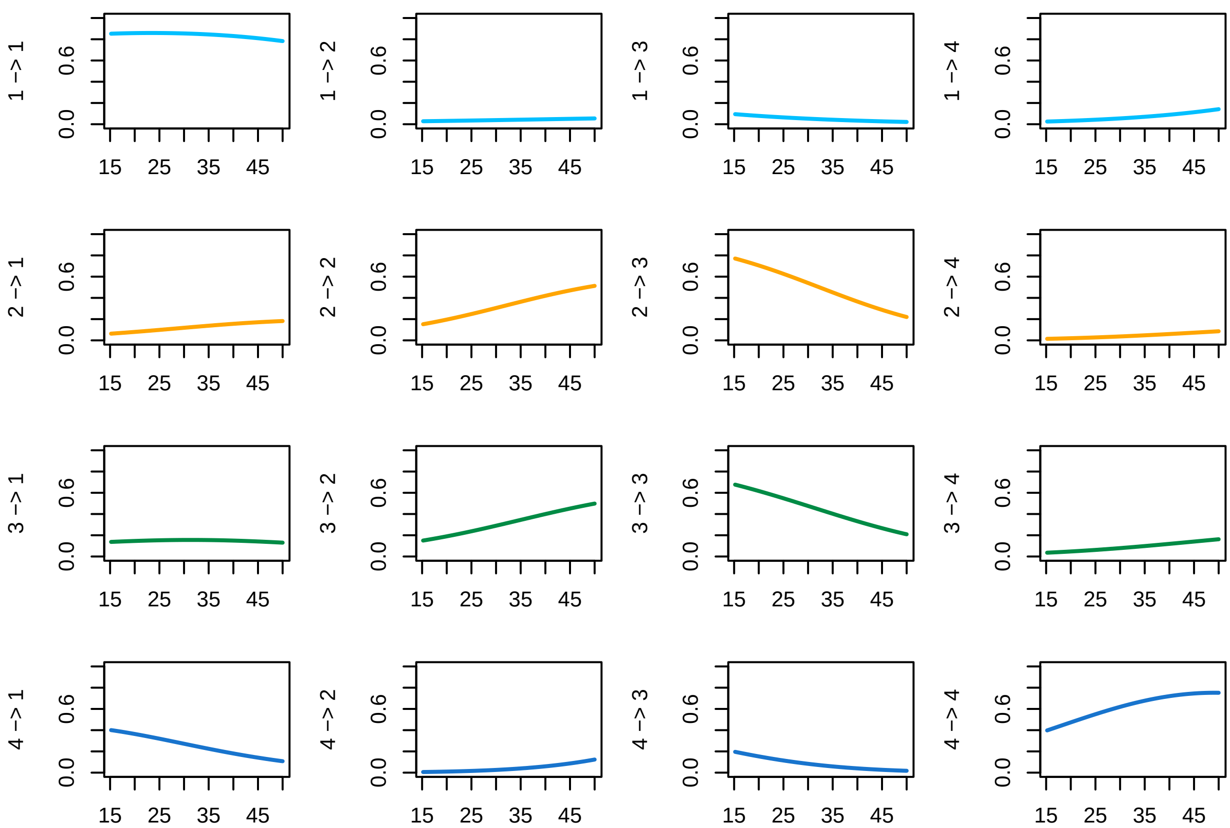


This model seperates states 2 and 3 even better. Overall however the decoded states have not changed much.

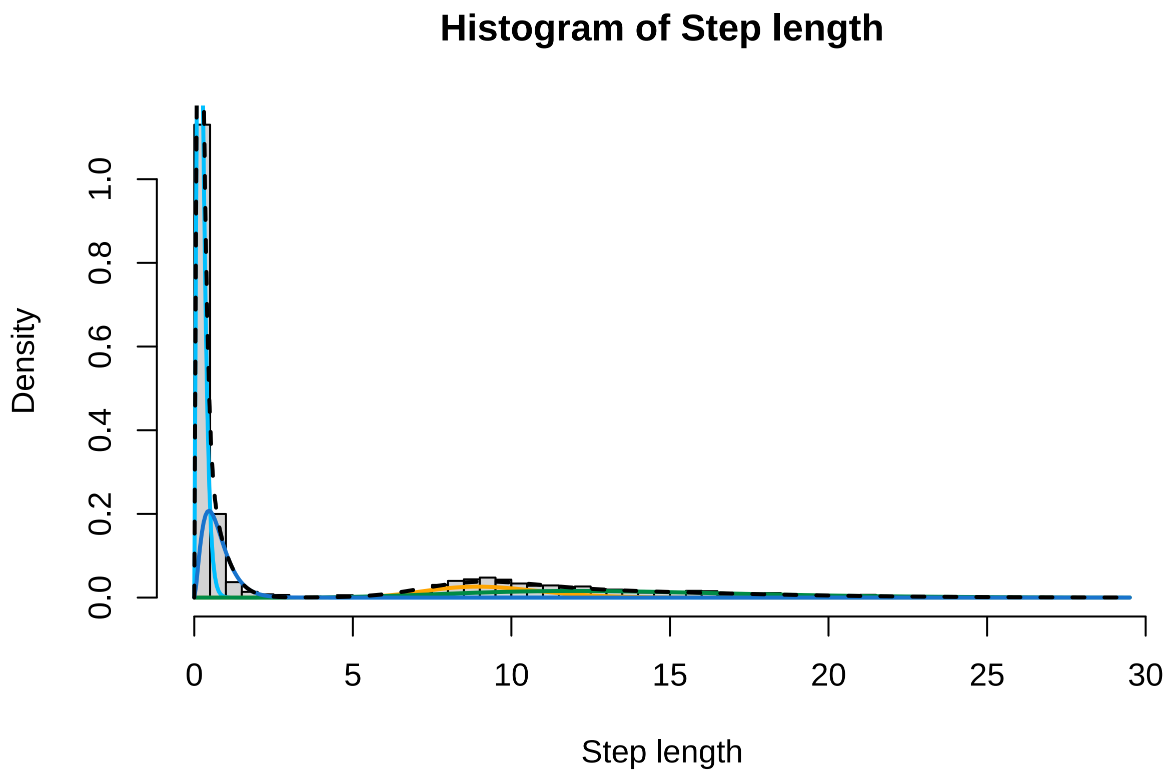
We can now look at the hypothetical stationary state distribution depending on the external temperature:

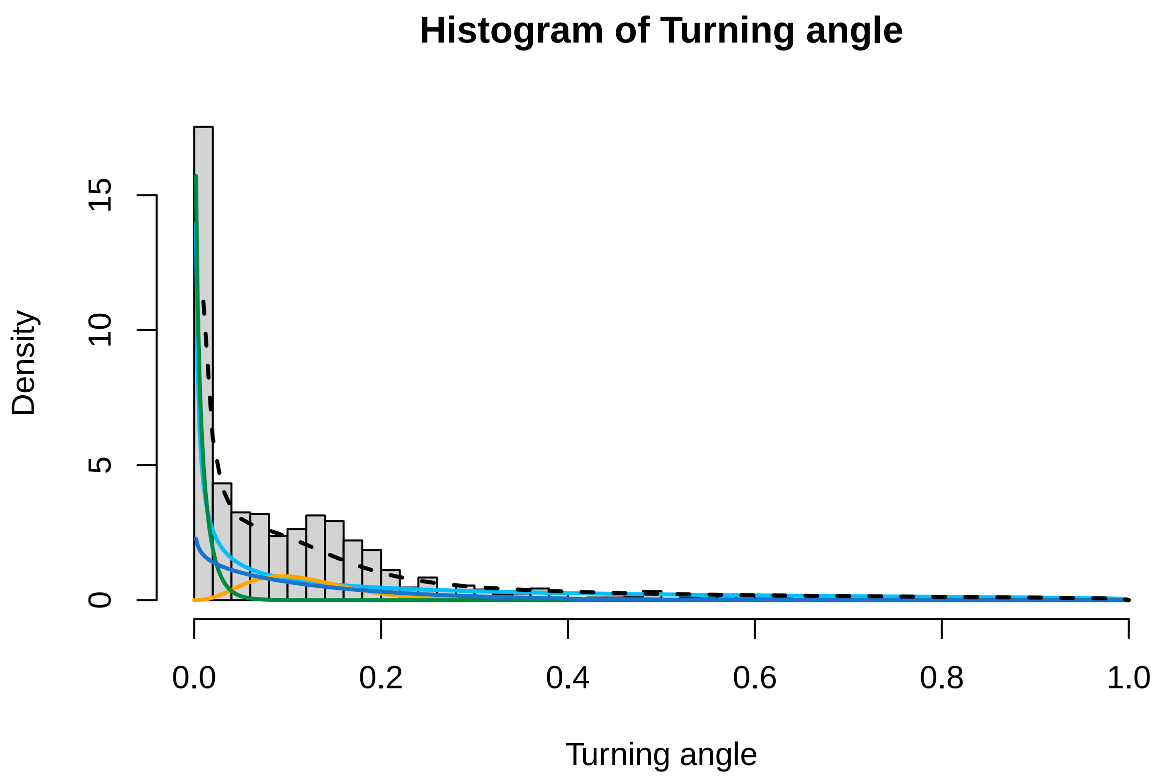


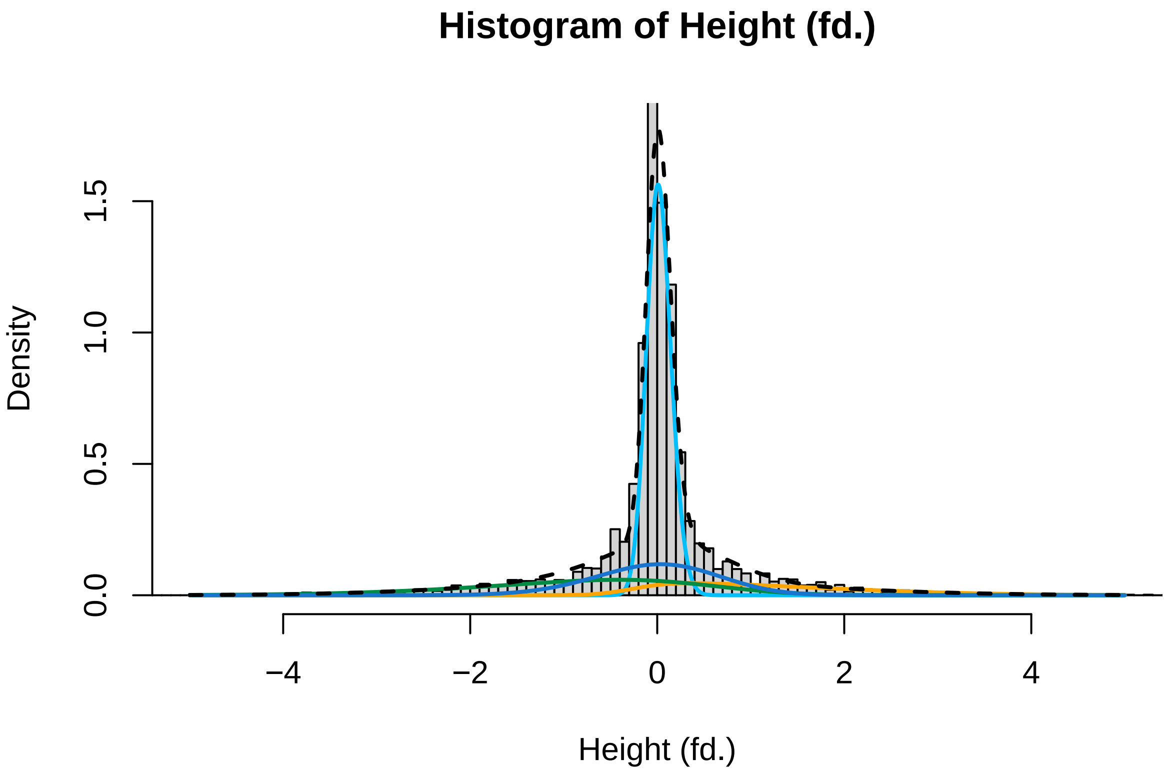
Also we can look at the transition probabilities depending on the temperature:



As the transition probabilities depend on the temperature we cannot plot the component distributions against the histogram using the stationary distribution. However we can replace the stationary distribution by the relative frequency of the decoded states in this case. This way we still optain the following plots:







Especially here we can see that this model better seperates downwards and upwards movement when looking at the orange and green distributions for states 2 and 3 respectively.