Hive Simulation

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Outline

Introduction

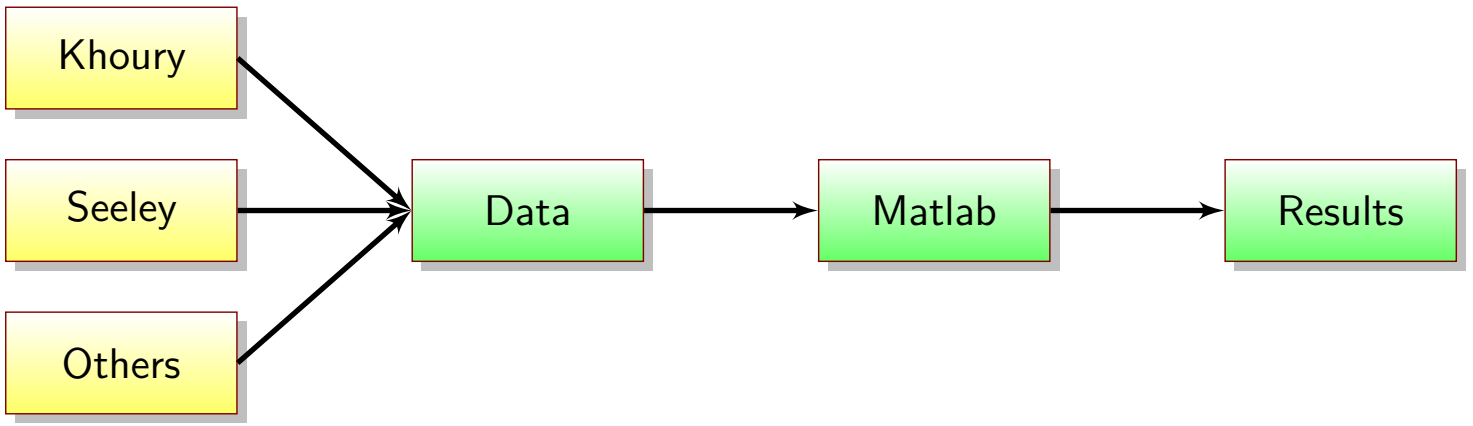


Figure 1: *Diagram of our work.*

Description of the Standard Model

It consists of four differential equations:

- Change of brood number
- Change of hive bee number
- Change of forager bee number
- Change of food

Description of the Standard Model

Let's look into one equation: **Change of brood number**

$$\frac{dB}{dt} = LS(H, f) - \phi B$$

- L is the laying rate of the queen
- S is the survival rate
- H is the amount of hive bees
- f is the amount of food
- ϕ is the adult bee emerging factor

Environmental Influences

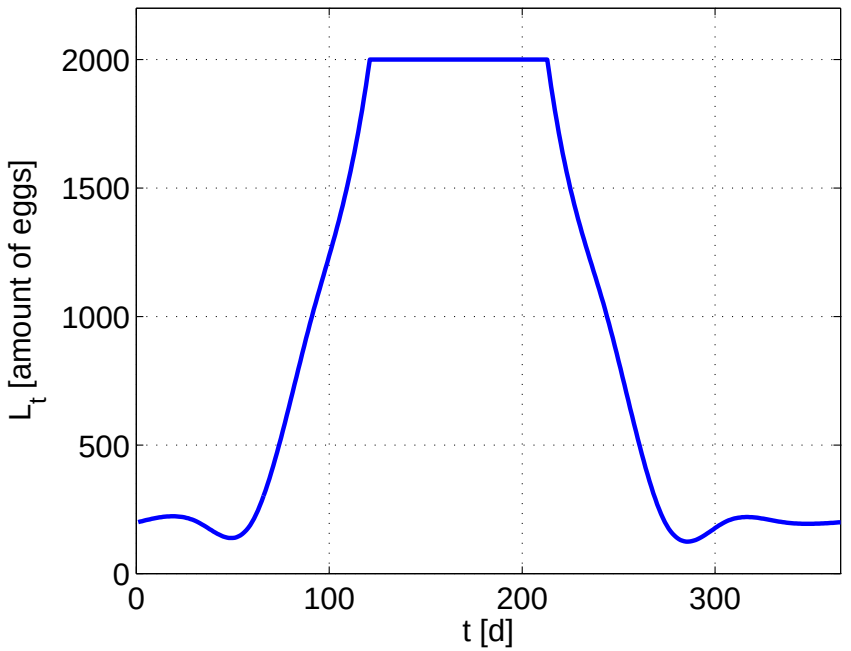


Figure 2: *The laying rate of the bee queen plotted over a year.*

Environmental Influences

Comparison between the environment dependent equation and the standard one:

- static equation: $\frac{dB}{dt} = LS(H, f) - \phi B$
- dynamic equation: $\frac{dB}{dt} = L_t S(H, f) - \phi B$

$\longrightarrow$ small changes in the formulae have significant effects (cf. Discussion).

Advanced model: Environment simulation

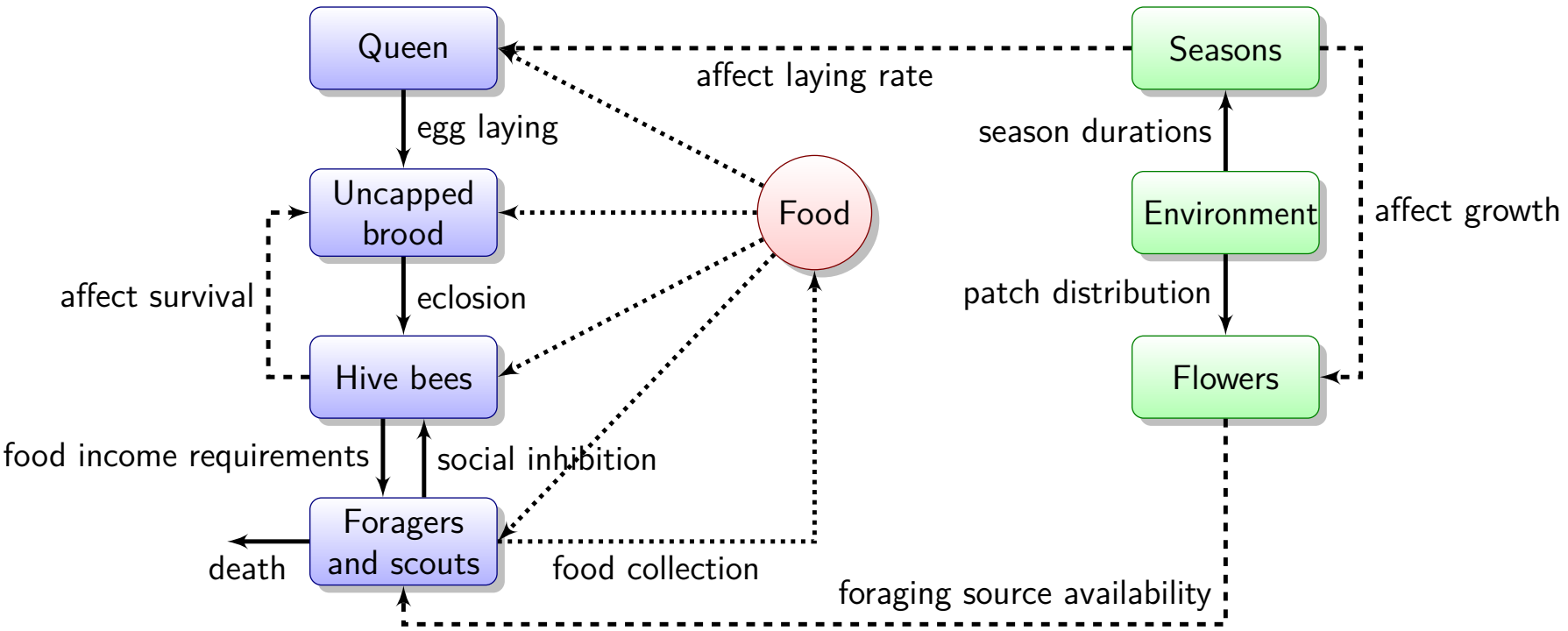


Figure 3: *Honey bee social dynamics/influences covered by our model.*

Agents: Assigning jobs

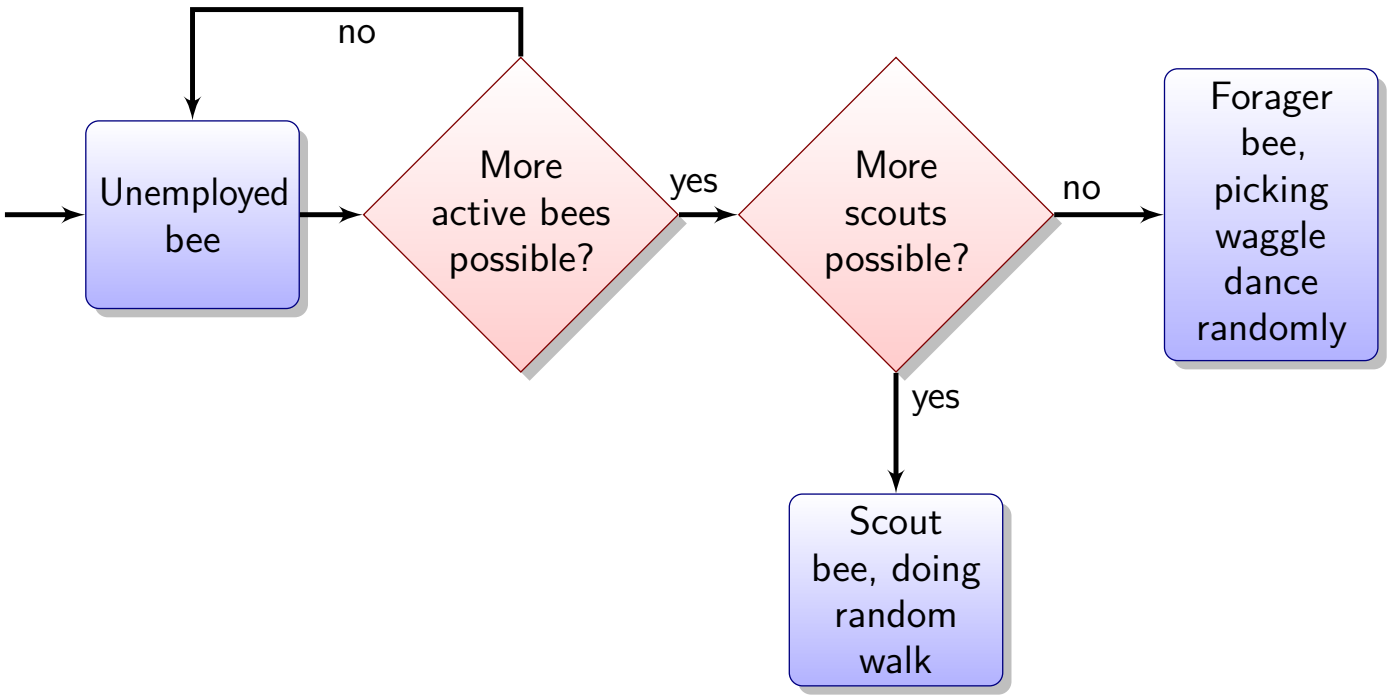


Figure 4: *Assigning jobs to unemployed bees. Scouts and foragers are possible.*

Agents: Scout bees

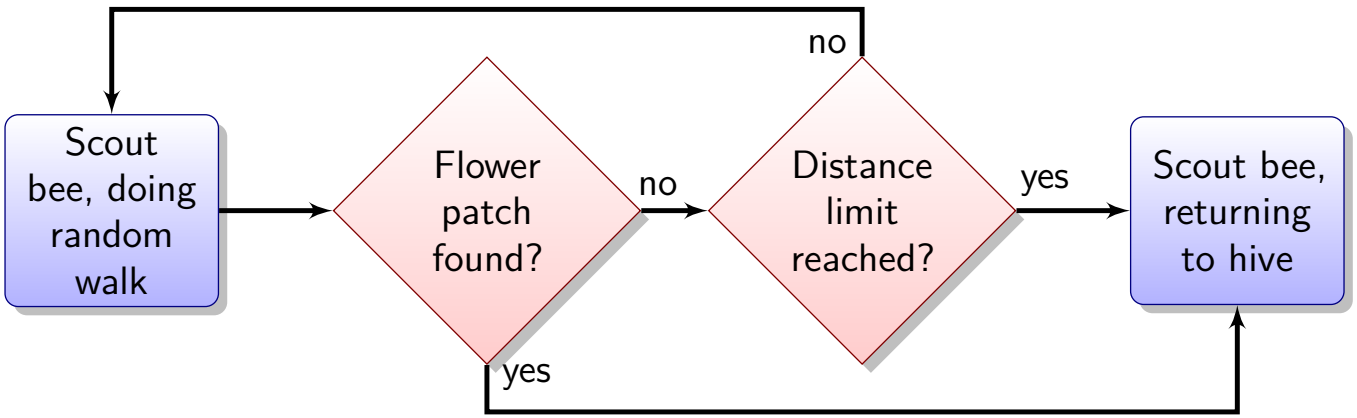


Figure 5: *Scouting behaviour until a flower patch is found or the maximum distance is reached.*

Scouts' random walk

The path a scout bee walks is recorded in a vector of x and y coordinates:

$$\begin{pmatrix} x_0 & x_1 & \dots & x_n \\ y_0 & y_1 & \dots & y_n \end{pmatrix}$$

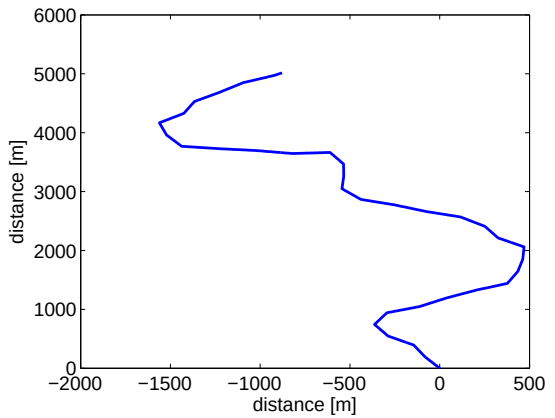


Figure 6: *Example of a random walk executed by a scout bee.*

Agents: Forager bees

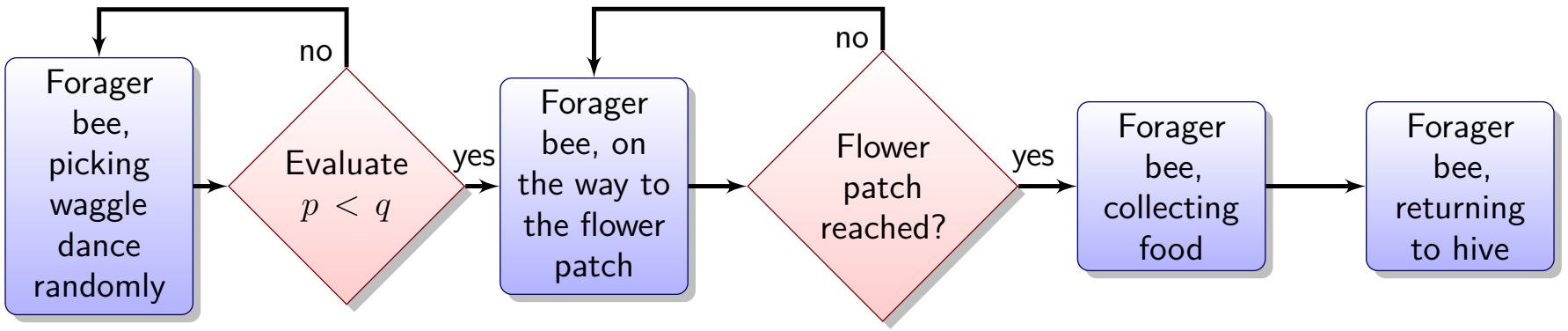


Figure 7: *Foraging behaviour.*

Path optimization

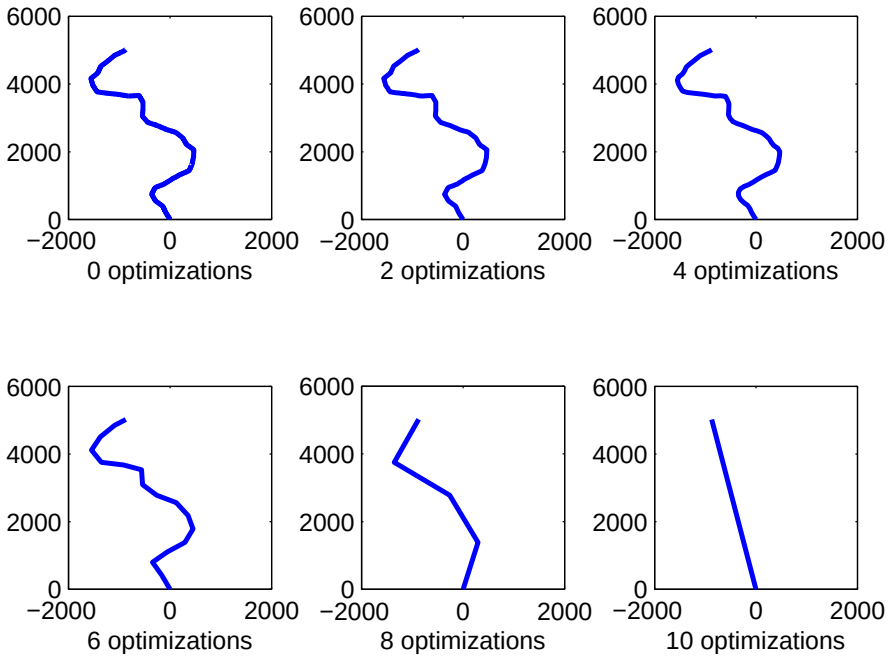


Figure 8: *Path optimization used to short cut the path to flower patches.*

Agents: Returning to the hive

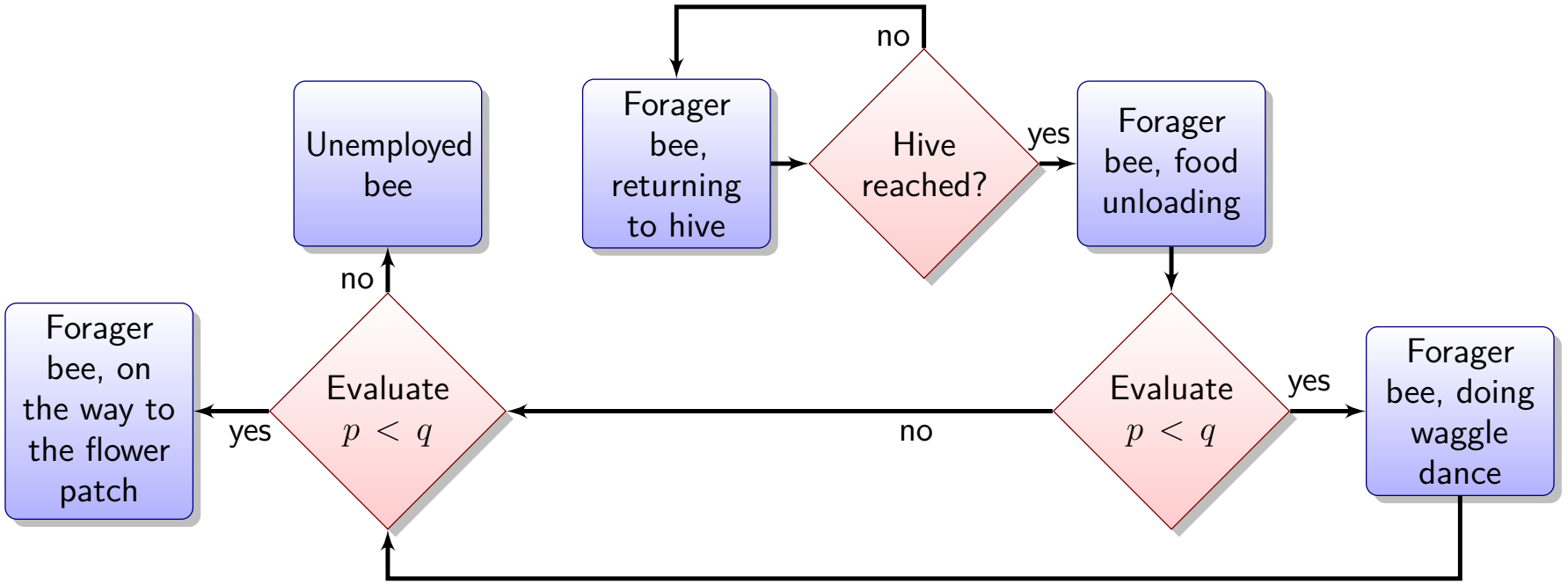


Figure 9: *Forager bee, returning from foraging.*

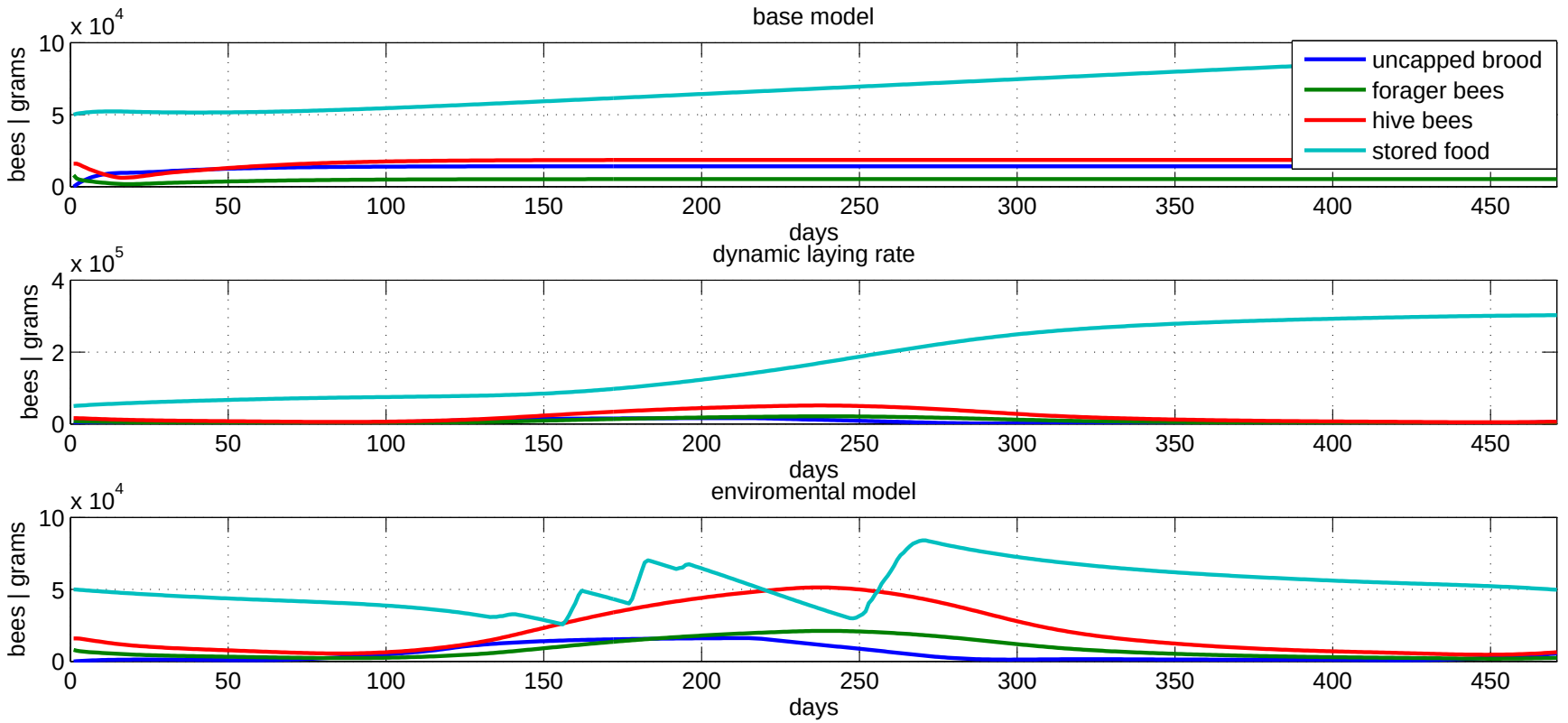
Agent based model: recorded sample clips

- Day 158, recorded sample with scouts displayed
- Day 158, recorded sample without scouts displayed
- Two different runs, not the same flower patches are being selected

Simulation results and analysis

- Evolution of the model
- Missing flower season comparison
- Critical points in the fall season

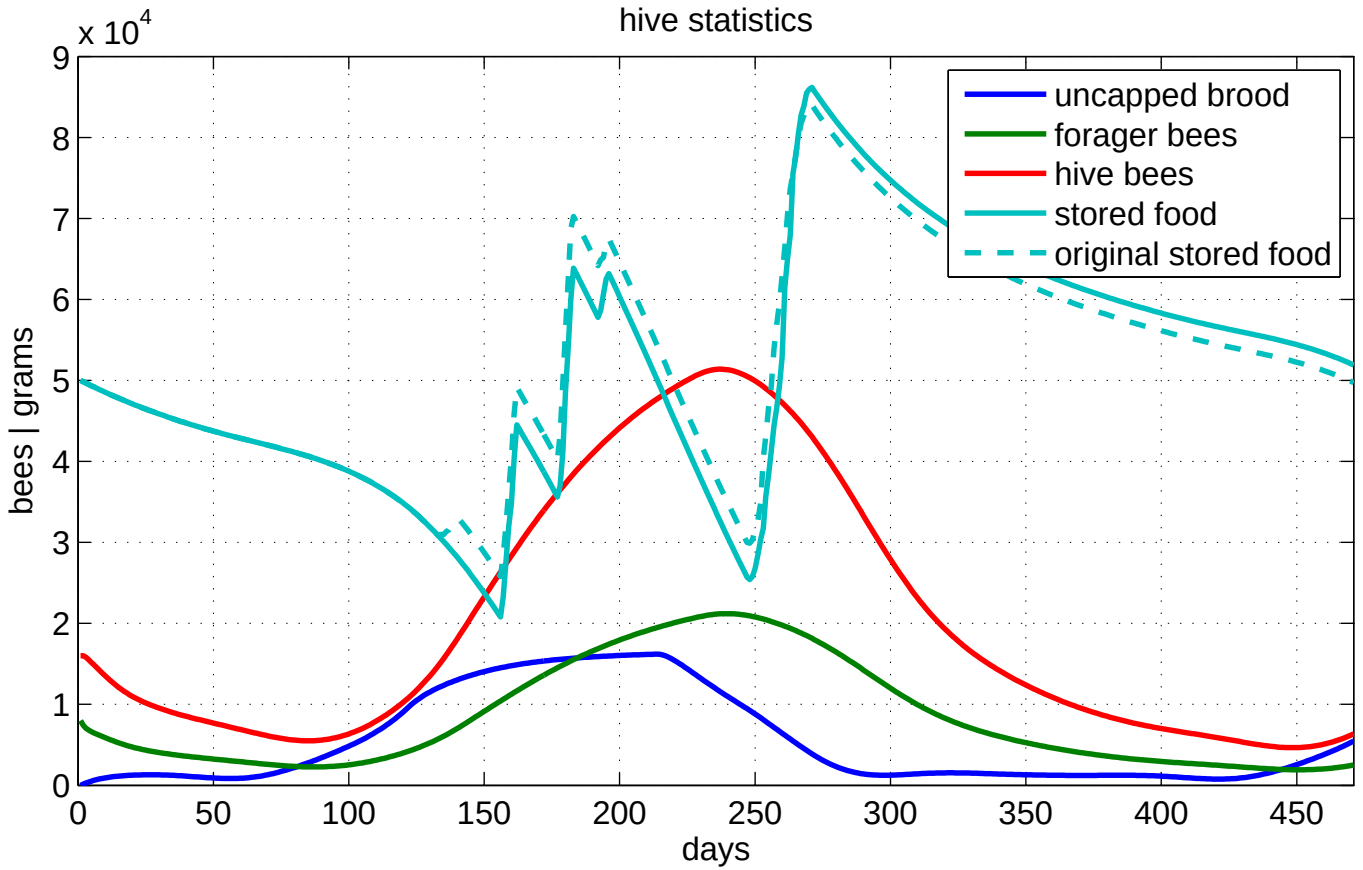
Evolution of the model



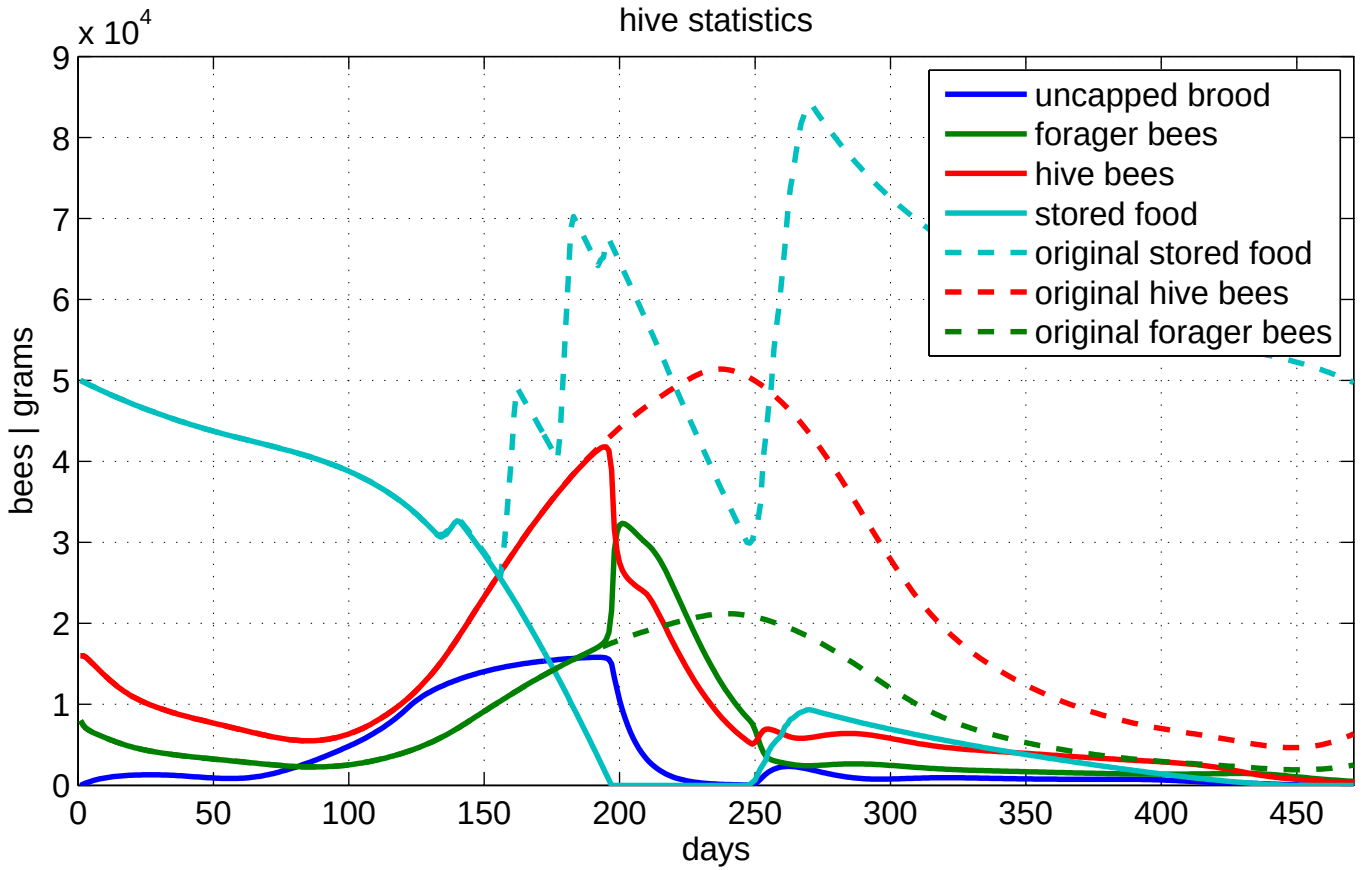
Missing flower season comparison

- Eliminate non critical seasons
- Study effects of missing season
- Observe the hives compensation measures

Spring


hive statistics
x 10^4
bees | grams
days
uncapped brood
forager bees
hive bees
stored food
original stored food
0
1
2
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
450

Summer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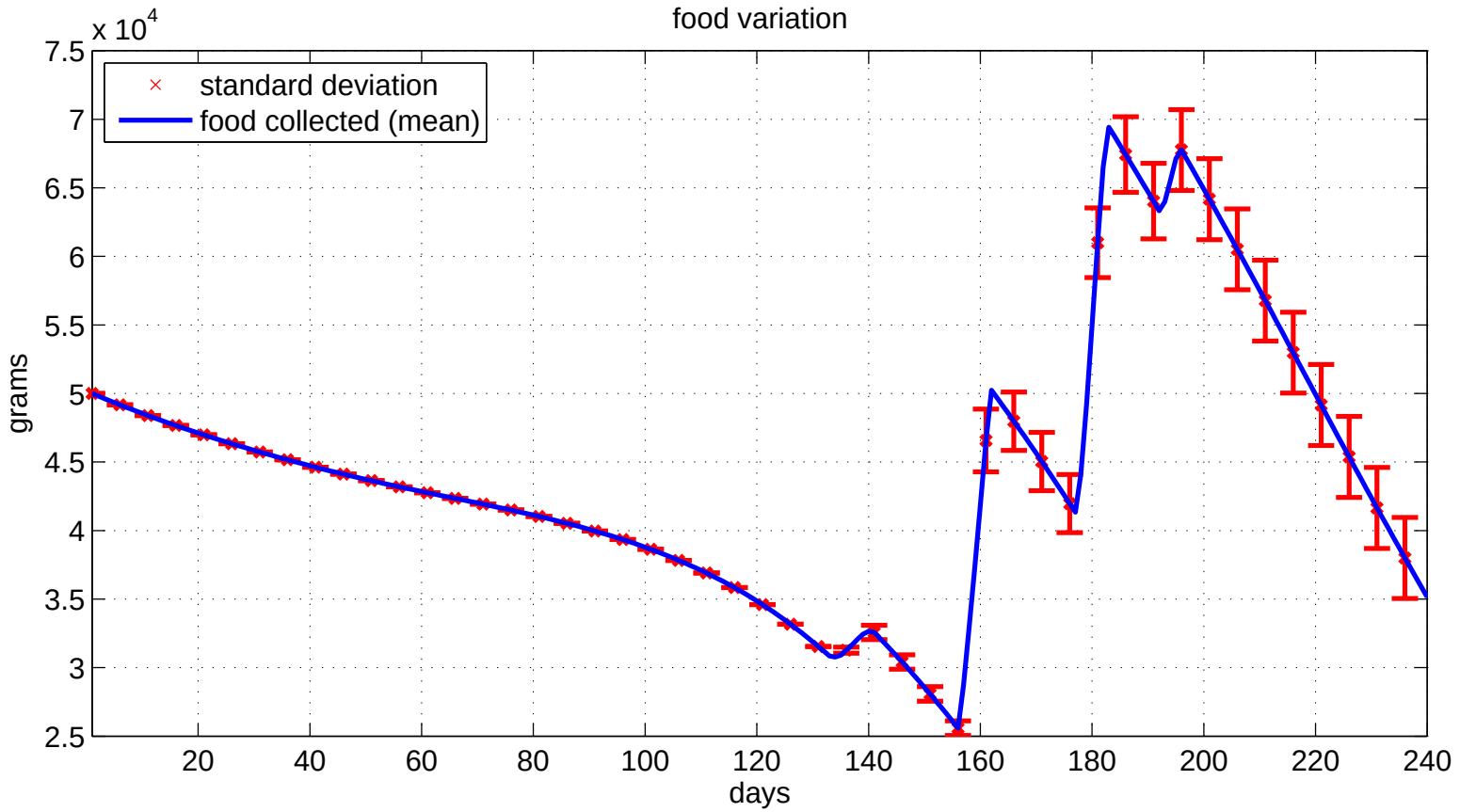
300
350
400
450

Critical points in the fall season

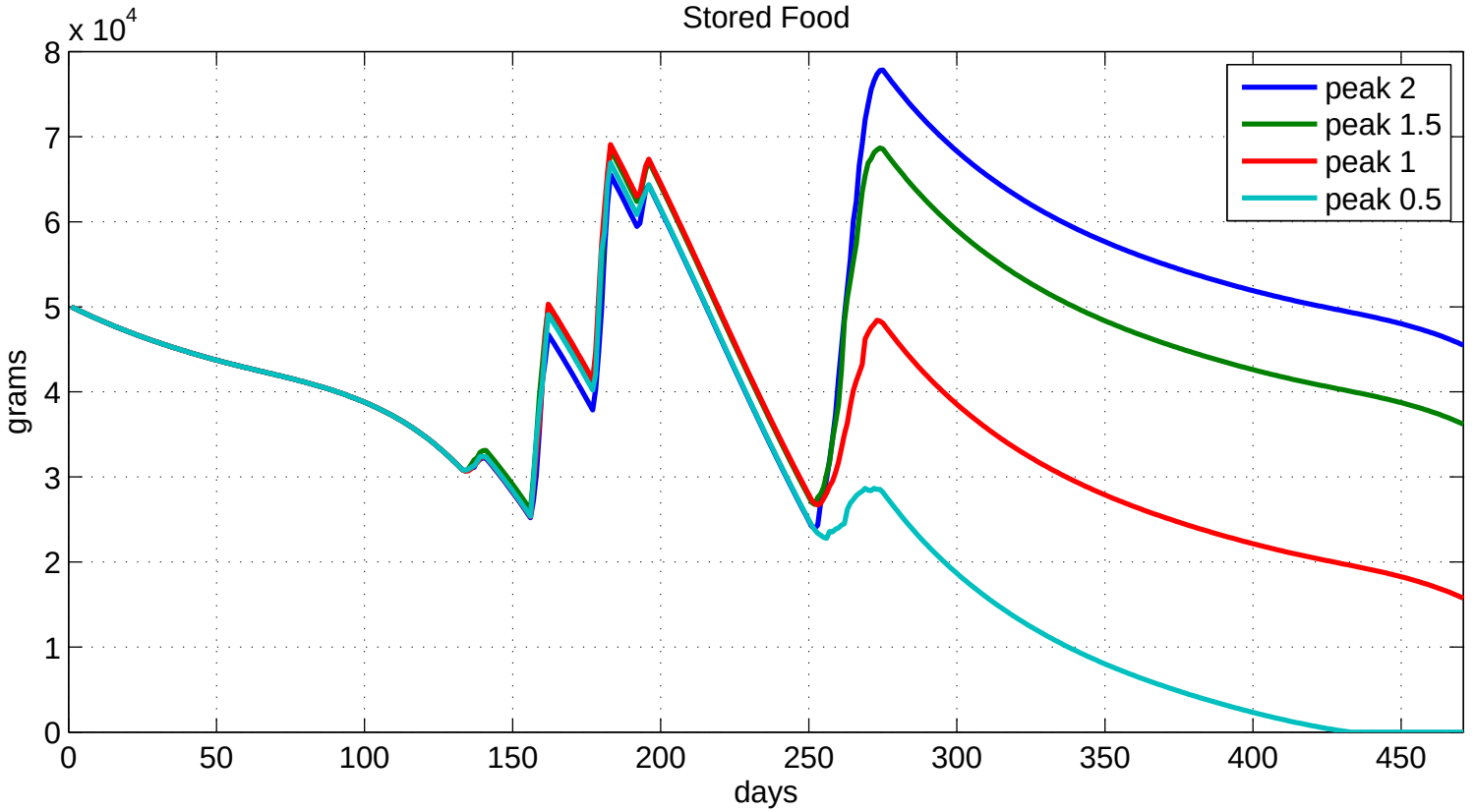
Death criteria:

- Less than 1000 bees at day 400
- Less than 20 kg of stored food at day 400

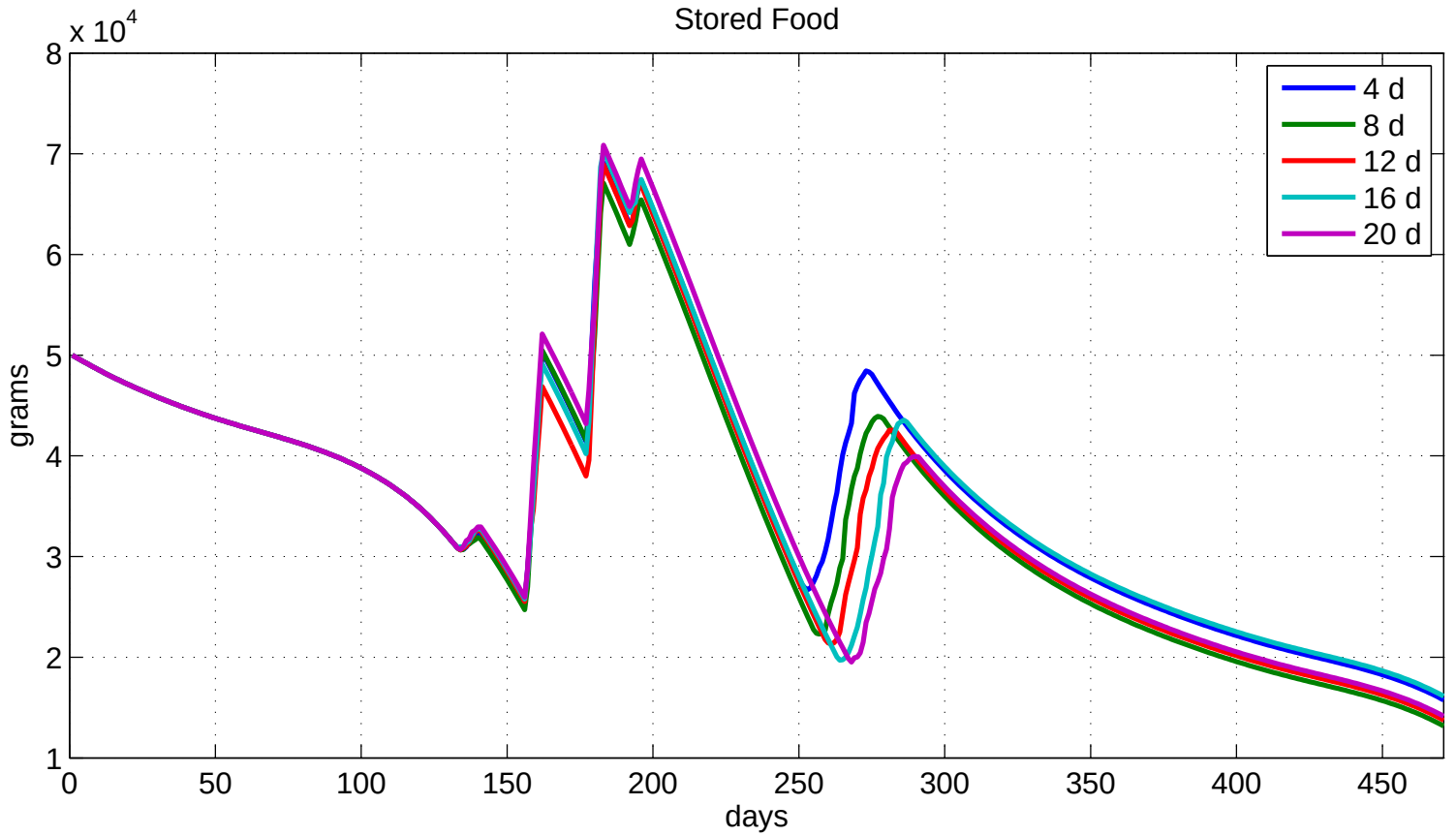
Stored food variation before fall



Peak value influence



Delay influence around breaking point



Summary

- Standard Model after *D.S. Khoury*
- Advanced Model: Environment simulation
- Complex model of assigning jobs
- Method: random walk and optimization
- Evolution of the model
- Results


Questions?