



Modeling of Temperature Regulation in Honeybee Hives

Matthew Burnham

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Dr. B. Wayne Bequette

Dept. of Chemical and Biological Engineering

RPI

Results from *Science* Paper

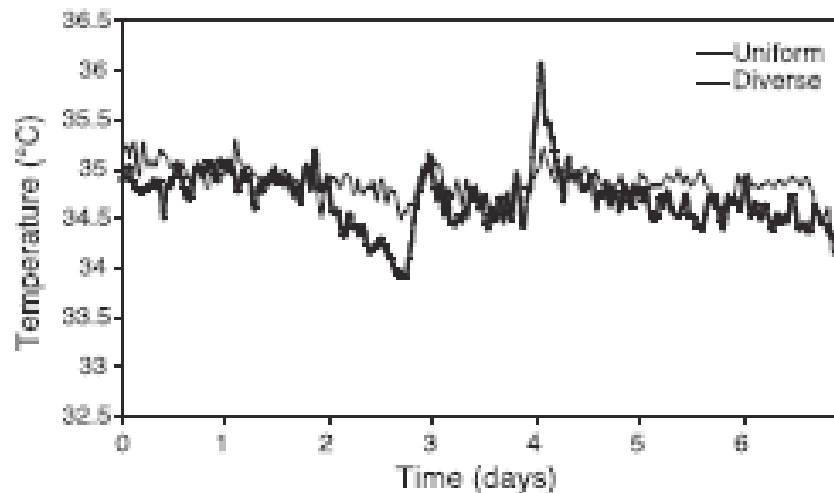


Fig. 1. Temperature variation in genetically diverse and uniform honey bee colonies. This graph shows the average hourly temperature for one representative pair of colonies in the first experimental week. Other colony pairs can be seen in Fig. S1.

- The goal of this study was to show that a hive made up of a genetically diverse population of bees was better at temperature control than a uniform population made up of one patriline.

Ref: **Julia C. Jones,^{1*} Mary R. Myerscough,² Sonia Graham,² Benjamin P. Oldroyd¹**



Modeling Equations used

Hive Energy Balance

$$\left(\dot{m}c_p\right)_H \frac{dT_H}{dt} = (UA)_{amb} (T_{amb} - T_H) - (UA)_{inner} (T_H - T) \quad (1)$$

Nest Air Energy Balance

$$\left(\dot{m}c_p\right)_{nest,air} \frac{dT}{dt} = \left(\dot{m}c_p\right)_{p,air} (T_{amb} - T) + Q_{gen} + (UA)_{inner} (T_H - T) \quad (2)$$

Also Assume:

$$\left(\dot{m}c_p\right)_{p,air} = \alpha \left(\dot{m}c_p\right)_{p,air,max}$$

$$Q_{gen} = \beta Q_{gen,max}$$

Developed by B. Wayne Bequette

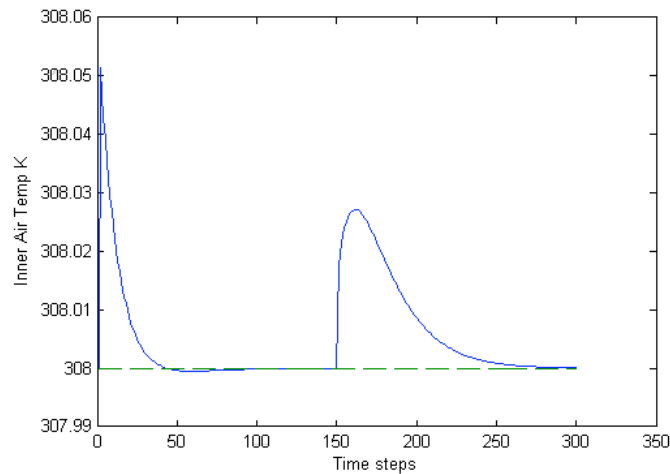
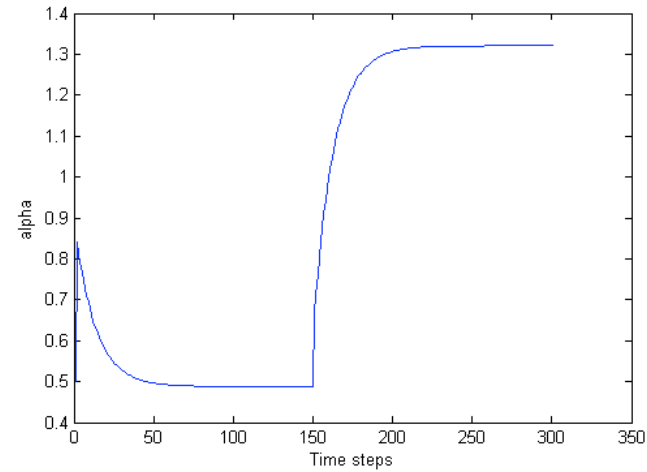
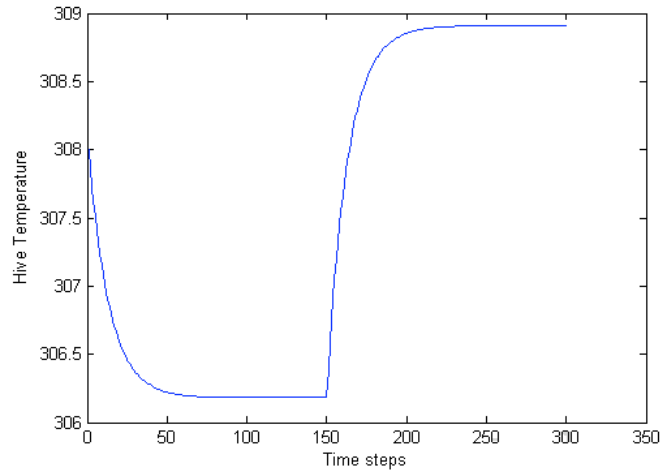


Results of these equations

- Good results
- Problem: Can not cool hive when the ambient temperature is greater then the temperature inside the hive (alpha term becomes greater than 1)



Results



As stated in previous slide, alpha can be seen to exceed one in this result where the ambient temperature rose to 309

Solution?

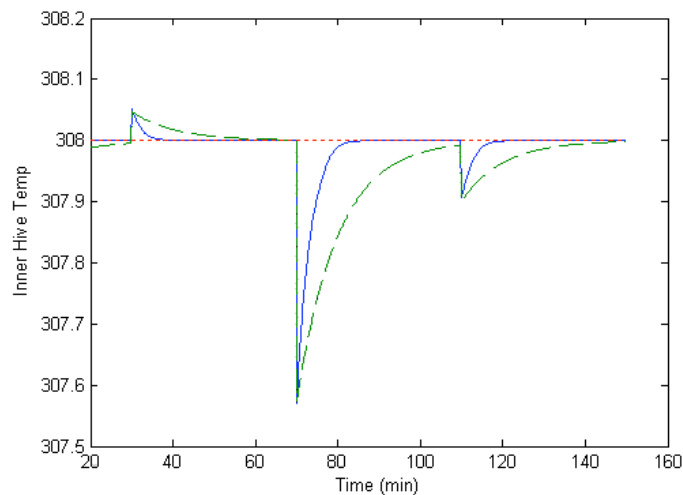
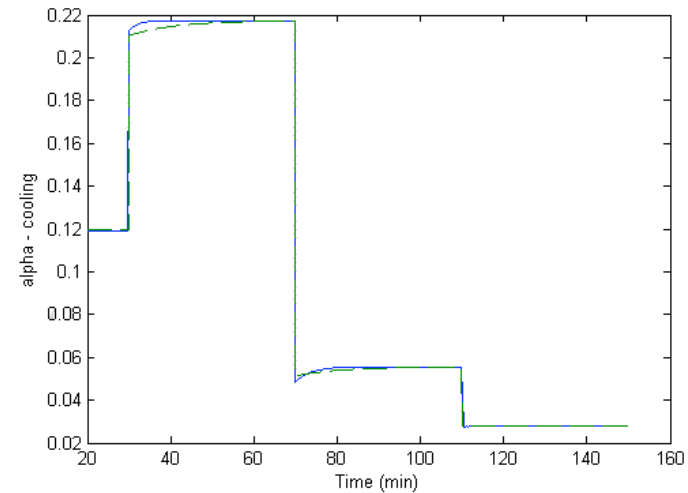
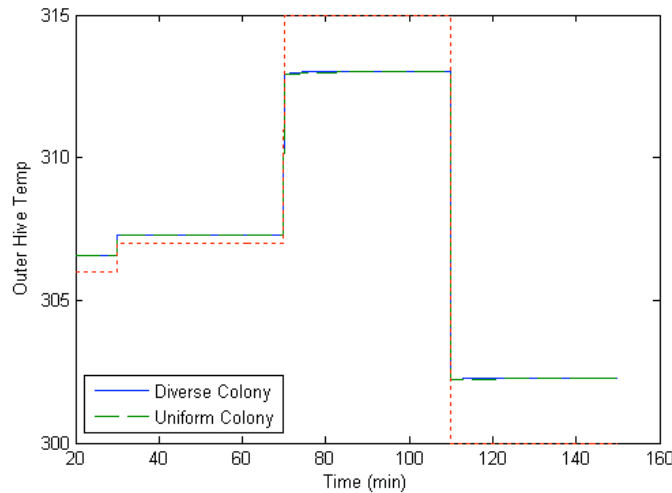
- Add evaporative cooling term to the nest air energy balance equation

$$Q_{evap} = \frac{\dot{m}^* c_{p,air} (T_{amb} - T)}{RH}$$

- Where RH is the relative humidity of the air
(Simplified assumption that evaporation rate is inversely proportional to RH)

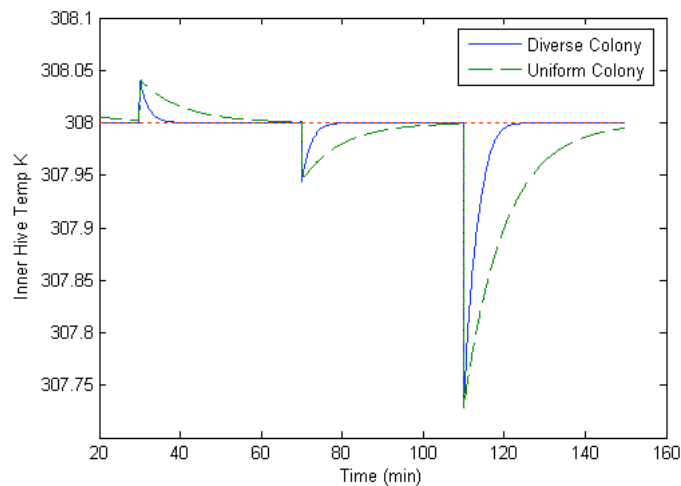
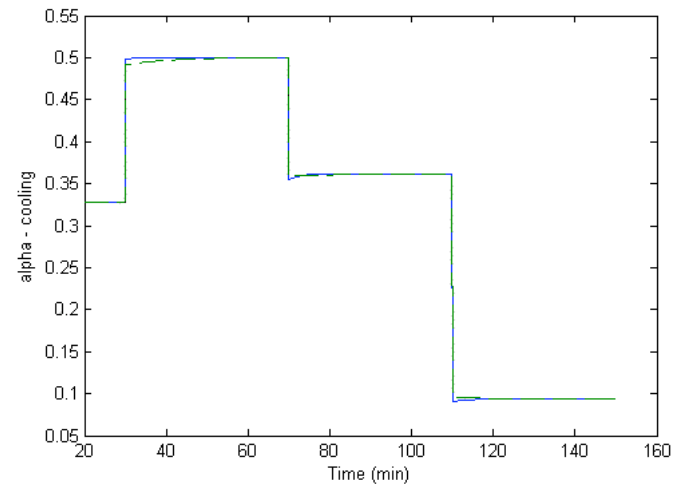
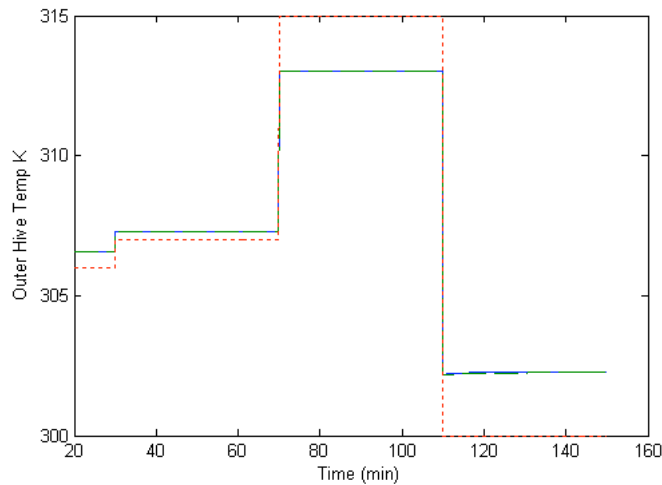
- This term cools the hive regardless of the relationship between ambient and hive temperature.

Results with Q_{evap} included



- This is using a Relative Humidity of .1
- The ambient temperature goes from 306K to 307K at 30 minutes; to 315K at 70 minutes; then down to 300K at 110 minutes

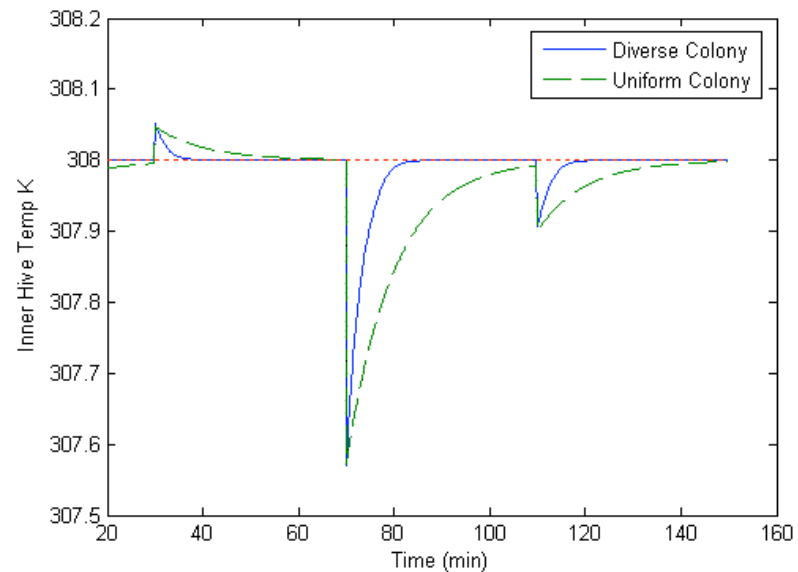
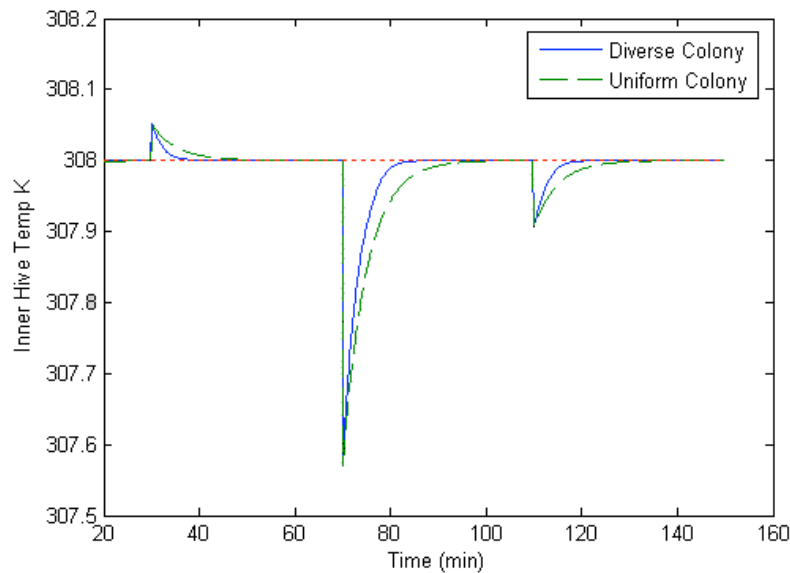
Effect of Relative Humidity



- Relative Humidity of .5 used with same Temperature switches at same times as previous
- The bees need to do more cooling since the effect of evaporative cooling drops with higher relative humidity

Effect on Patriline chosen

- Assuming that the patriline is efficiency based a patriline of high efficiency would emulate a diverse hive



The plot on the left is for a gain of .2 and the plot on the right is for a gain of .1



Results?

- The simulations ran in MATLAB emulate the results from the *Science* paper in that the genetically diverse population has better (i.e. quicker) response to temperature changes in the ambient air



Future Work

- Further parameter manipulation
- Reintroduction of “deadband” control
- Modification of the Evaporative cooling term (vapor pressure dependence)
- Adding more terms to energy equations and possibly a “bee” equation
- Research on whether diverse population is efficiency based or additive
- Development of PID controllers



Thanks

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