

Martin Bencsik¹, Chloe Davis¹, Adam Mcveigh², Robert Paxton³, Anja Tehel³, Dirk de Graaf⁴

¹Nottingham Trent University, Physics and Mathematics, Clifton Lane, NG11 8NS Nottingham, UK

²Harry Butler Institute, Murdoch University, Perth, Australia

³Institute for Biology, Martin Luther University Halle-Wittenberg, Hoher Weg 8, 06120 Halle (Saale), Germany

⁴Ghent University, Department of Biochemistry and Microbiology, Ghent University, Krijgslaan 281, 9000 Ghent, Belgium

Honeybee colonies presently face numerous challenges, including pests, diseases, and environmental stresses, which threaten their survival and productivity. This study explores the use of unsupervised machine learning, specifically Principal Component Analysis (PCA), to analyse hive weight data and detect colonies underperforming within a mini-apiary.

Data from eight colonies from the same apiary was collected continuously over a year, using BEEP (BEEP, NL) mass sensors. The “feature”, a seven-day long dataset comprising 15-minute interval mass measurements, was extracted, zeroed every 24 hours, and further analysed to identify deviations from the collective weight-change patterns of healthy colonies. The same protocol was applied in the UK, Belgium and Germany. The algorithm successfully flagged colonies suffering from disorders such as queenlessness, Nosema, and Varroa mite infestation, which were all corroborated by physical inspections. The method is most effective during nectar flows, where weight-change patterns provides rich information on foraging behaviour and the strength of the colony. However, it is less effective in winter, where minimal weight changes and external weather influences influences the data collected from the colonies.

Our work demonstrates the remarkable uniformity of daily weight changes in healthy colonies in the same apiary and the use of machine learning in identifying outliers. The results suggest that detection of anomalies by PCA can serve as a non-invasive monitoring method for hives within the same apiary. By eliminating the need for frequent physical inspections, this method saves beekeepers time and resources while enabling early intervention to prevent colony collapse. Future improvements, such as enhancing winter analysis by optimising the sensitivity of the algorithm in extreme weather, will further refine this promising tool for precision beekeeping.

We are presently extending the method in applying supervised machine learning to the same “feature”, in order to discriminate survivor from failing colonies, in apiaries where honeybees are not treated for varroa infestation. When the method’s specific diagnostic strengths are fully clarified, it will provide beekeepers with a quantitative mass measurement tool, providing colony status assessment without having to open the hive.

Colony Disorders revealed by automated monitoring of hive weight changes

Chloe Davis¹, Martin Bencsik¹, Adam McVeigh², Robert J. Paxton³,
Anja Tehel³, Dirk C. de Graaf⁴

1 Nottingham Trent University, Physics and Mathematics, Clifton Lane, NG11 8NS Nottingham, UK

2 Harry Butler Institute, Murdoch University, Perth, Australia

3 Institute for Biology, Martin Luther University Halle-Wittenberg, Hoher Weg 8, 06120 Halle (Saale), Germany

4 Ghent University, Department of Biochemistry and Microbiology, Ghent University, Krijgslaan 281, 9000 Ghent, Belgium



APIMONDIA 2025
Copenhagen
Denmark

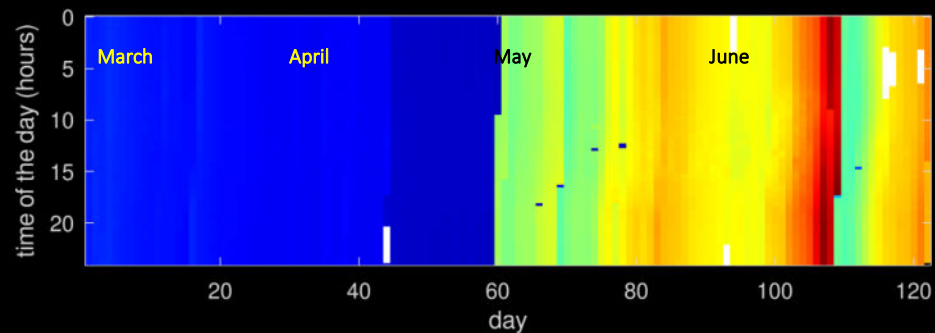


Results

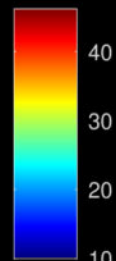
- The mass of 8 colonies **residing on the same apiary** are monitored in the UK (BEEP scales, <https://beep.nl/home-english>)
- The mass is monitored every 15 minutes.
- Here is what four months of data looks like between March and June.



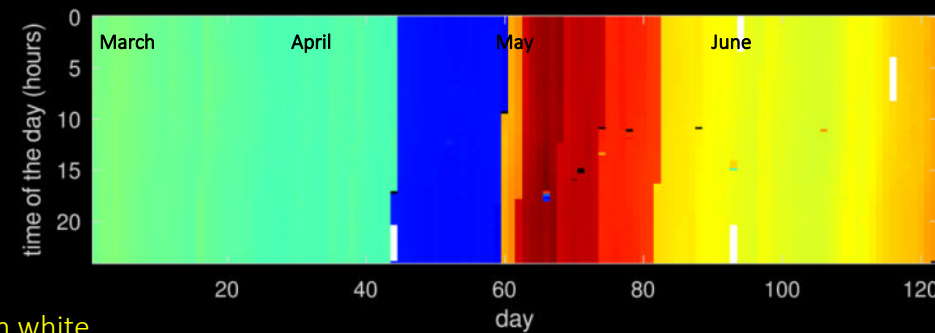
Colony NTU1 from Mar 01 2022 to Jul 01 2022



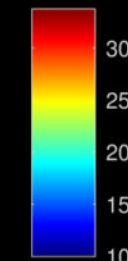
Mass (kg)



Colony NTU2 from Mar 01 2022 to Jul 01 2022

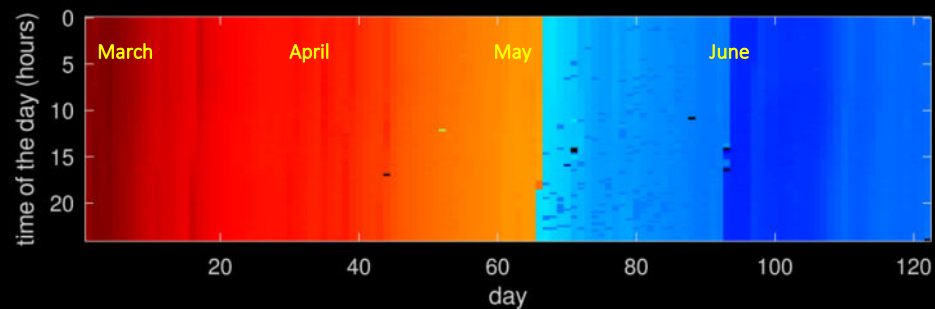


Mass (kg)

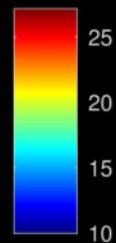


Missing data is shown in white

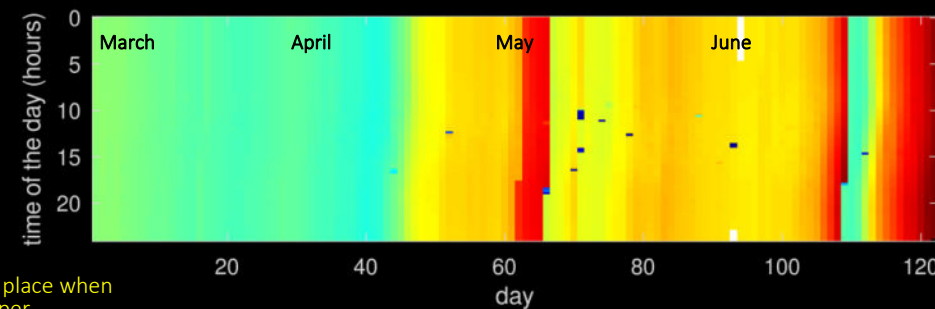
Colony NTU3 from Mar 01 2022 to Jul 01 2022



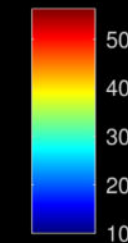
Mass (kg)



Colony NTU4 from Mar 01 2022 to Jul 01 2022

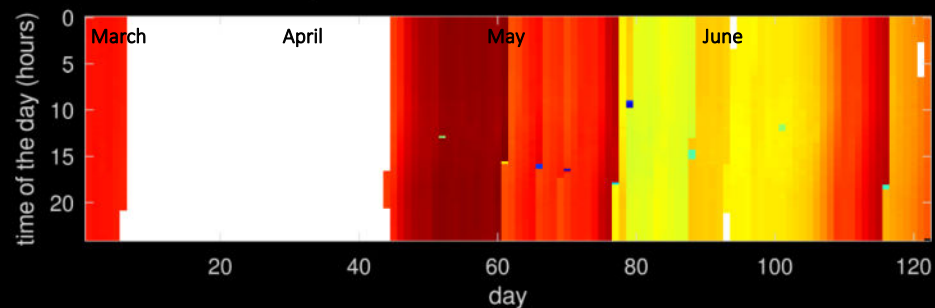


Mass (kg)

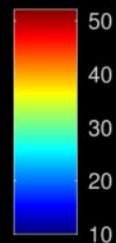


Large abrupt changes take place when updating the hardware (super removal/addition, feeding, swarming, etc.)

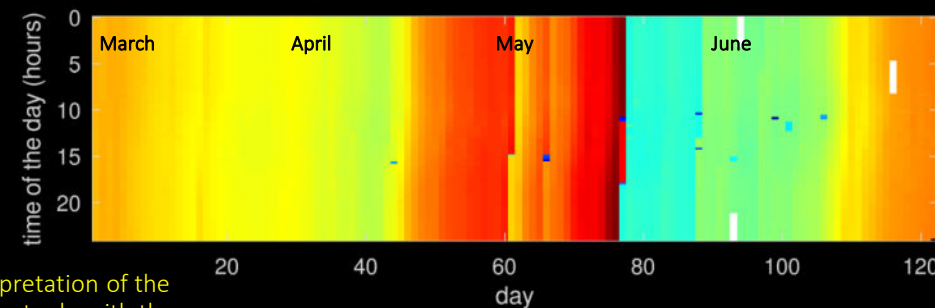
Colony NTU5 from Mar 01 2022 to Jul 01 2022



Mass (kg)



Colony NTU6 from Mar 01 2022 to Jul 01 2022

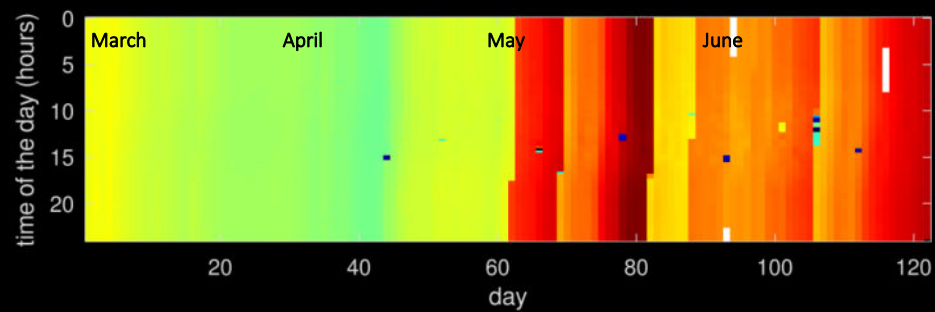


Mass (kg)

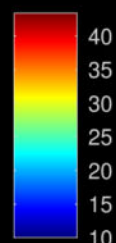


These large changes make the interpretation of the data very difficult. They have nothing to do with the colony's mass change.

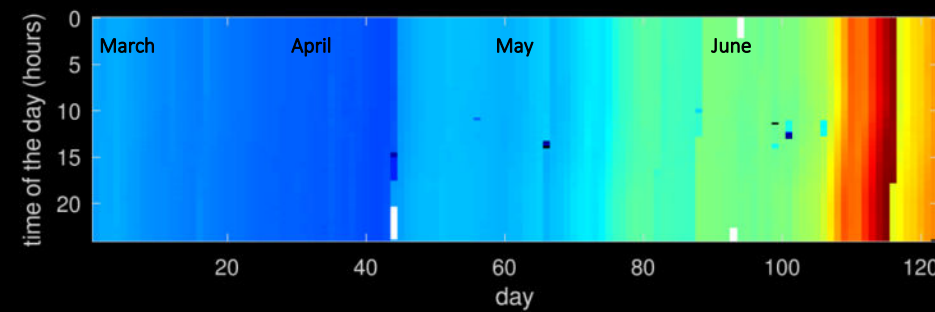
Colony NTU7 from Mar 01 2022 to Jul 01 2022



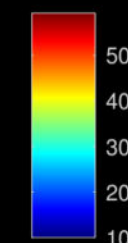
Mass (kg)



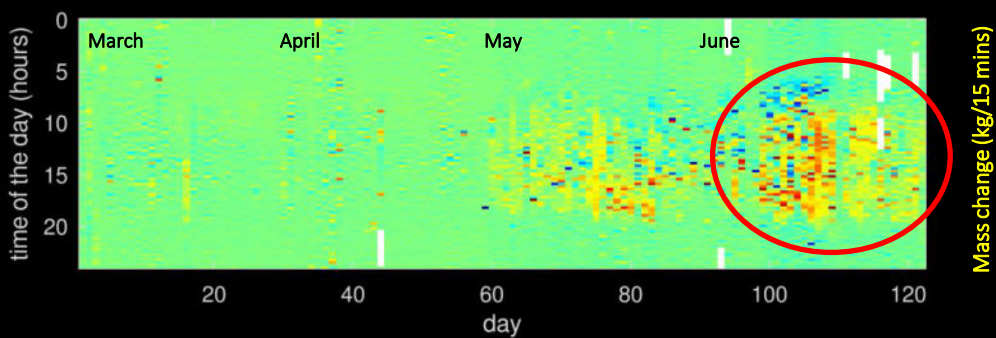
Colony NTU8 from Mar 01 2022 to Jul 01 2022



Mass (kg)



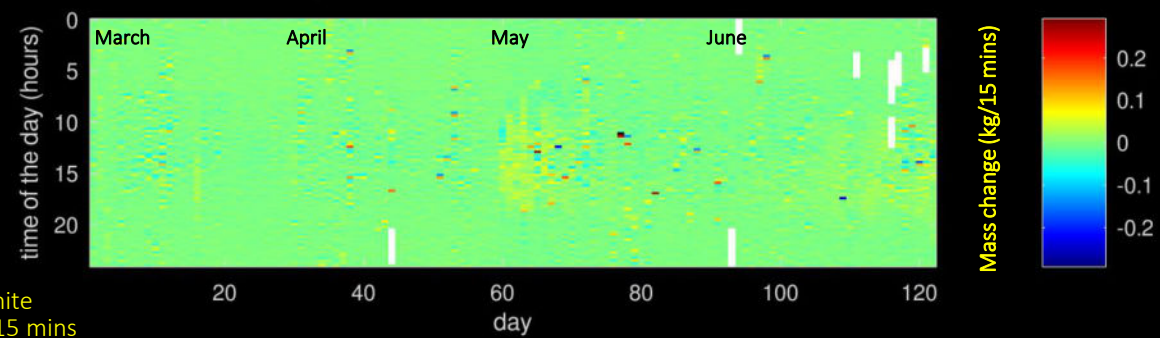
Colony NTU1 from Mar 01 2022 to Jul 01 2022



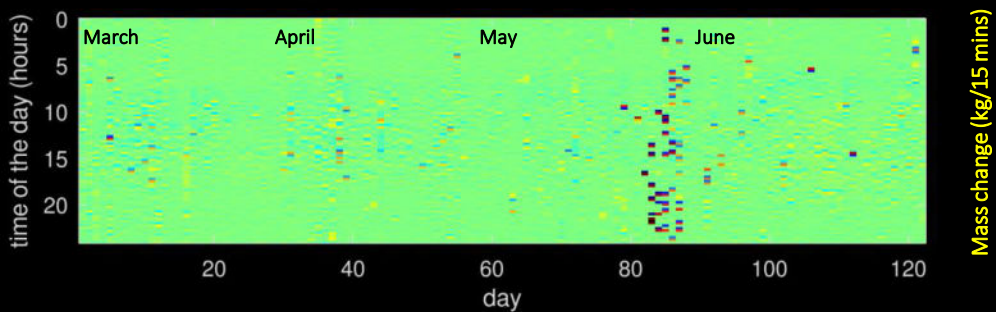
INSTANTANEOUS MASS CHANGE

Missing data is shown in white
Values greater than 300 g/15 mins
have been ignored

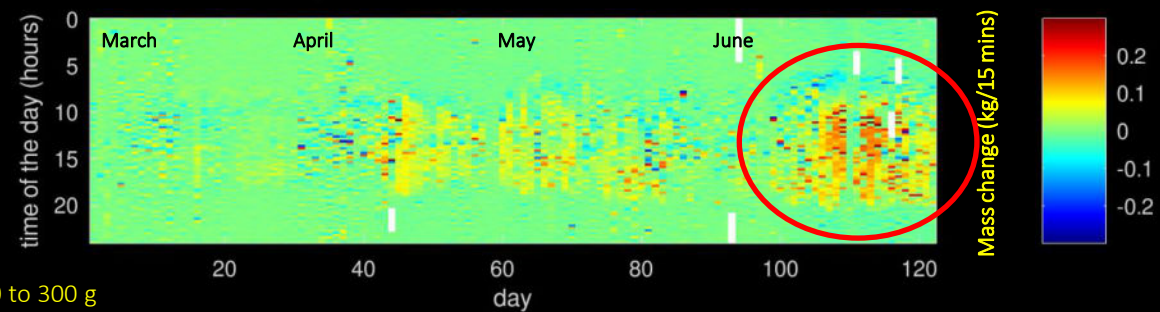
Colony NTU2 from Mar 01 2022 to Jul 01 2022



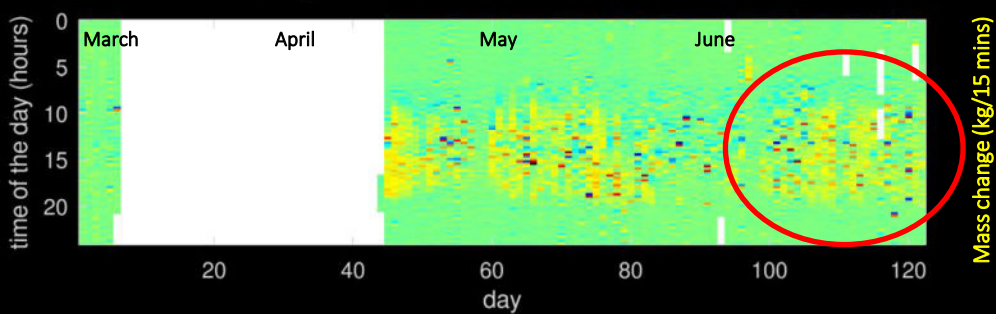
Colony NTU3 from Mar 01 2022 to Jul 01 2022



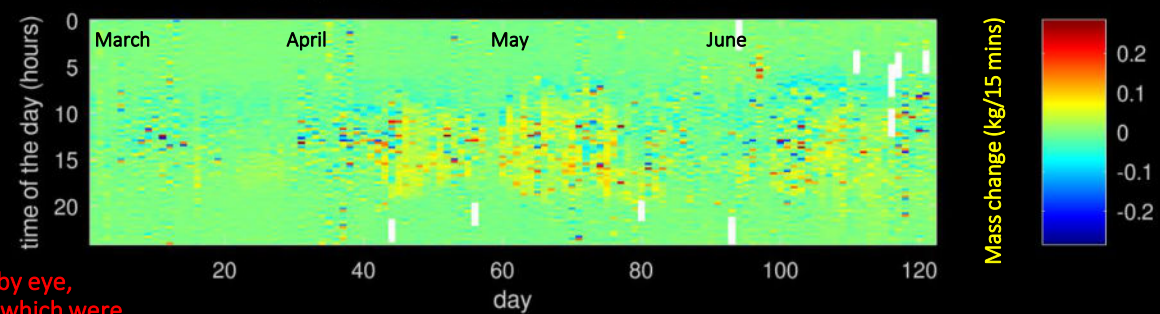
Colony NTU4 from Mar 01 2022 to Jul 01 2022



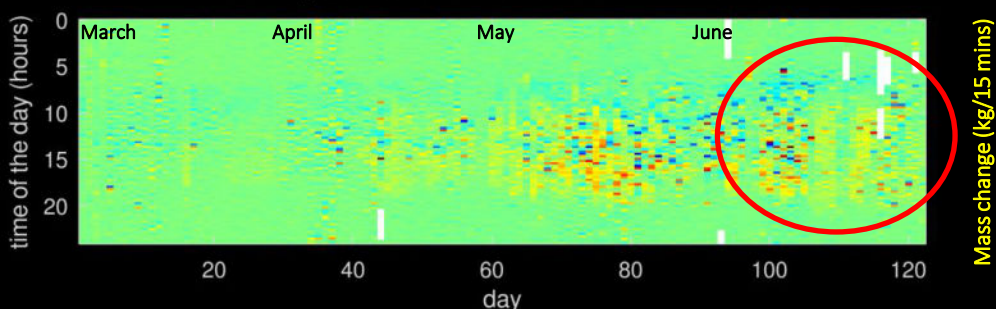
Colony NTU5 from Mar 01 2022 to Jul 01 2022



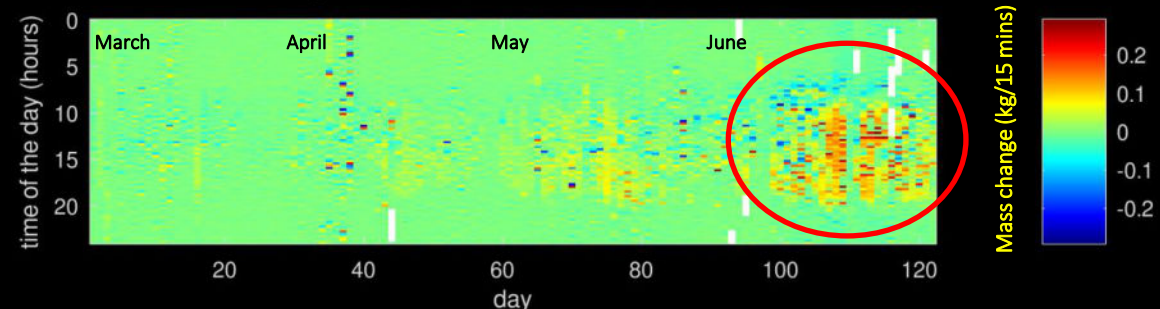
Colony NTU6 from Mar 01 2022 to Jul 01 2022



Colony NTU7 from Mar 01 2022 to Jul 01 2022

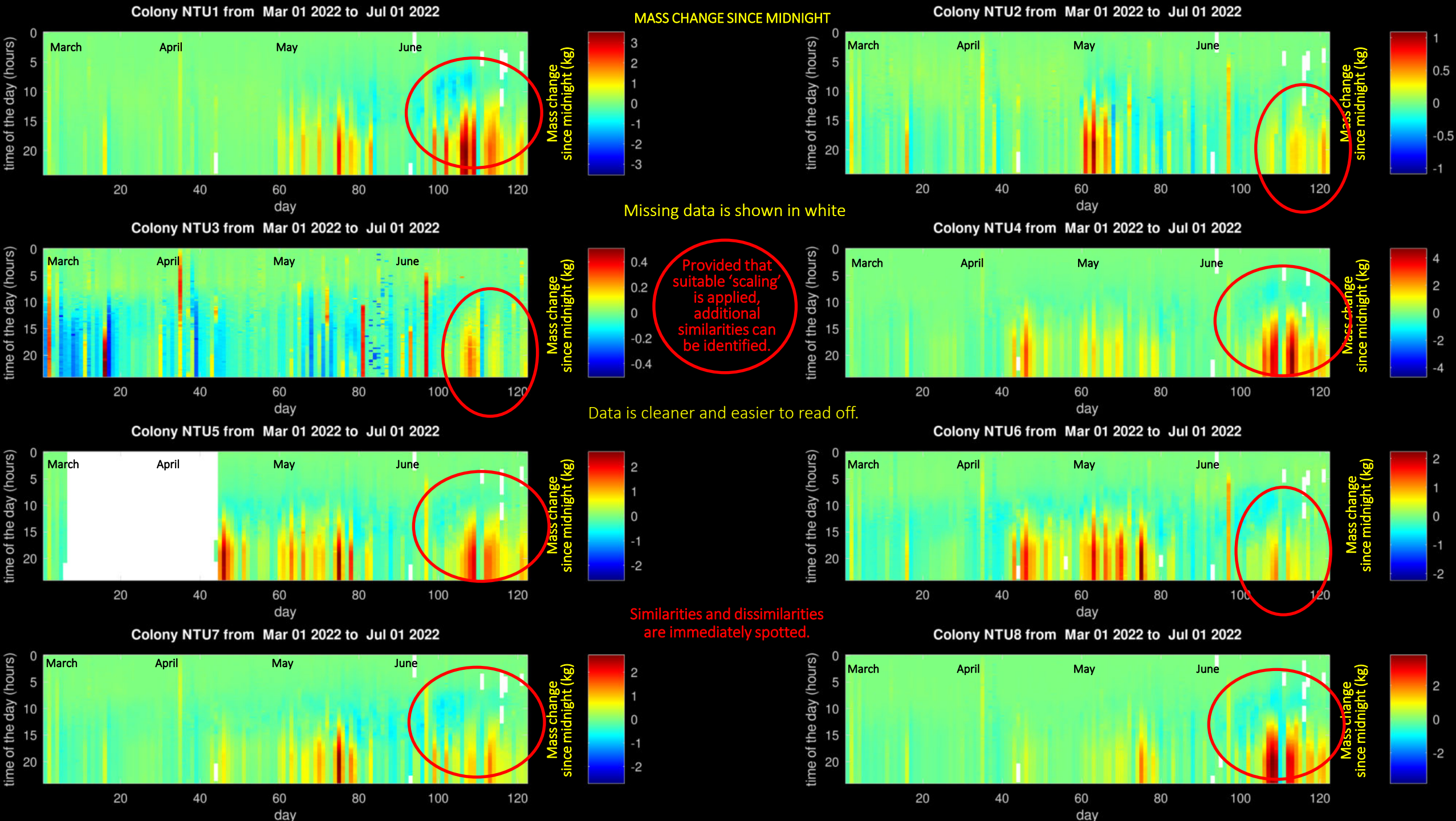


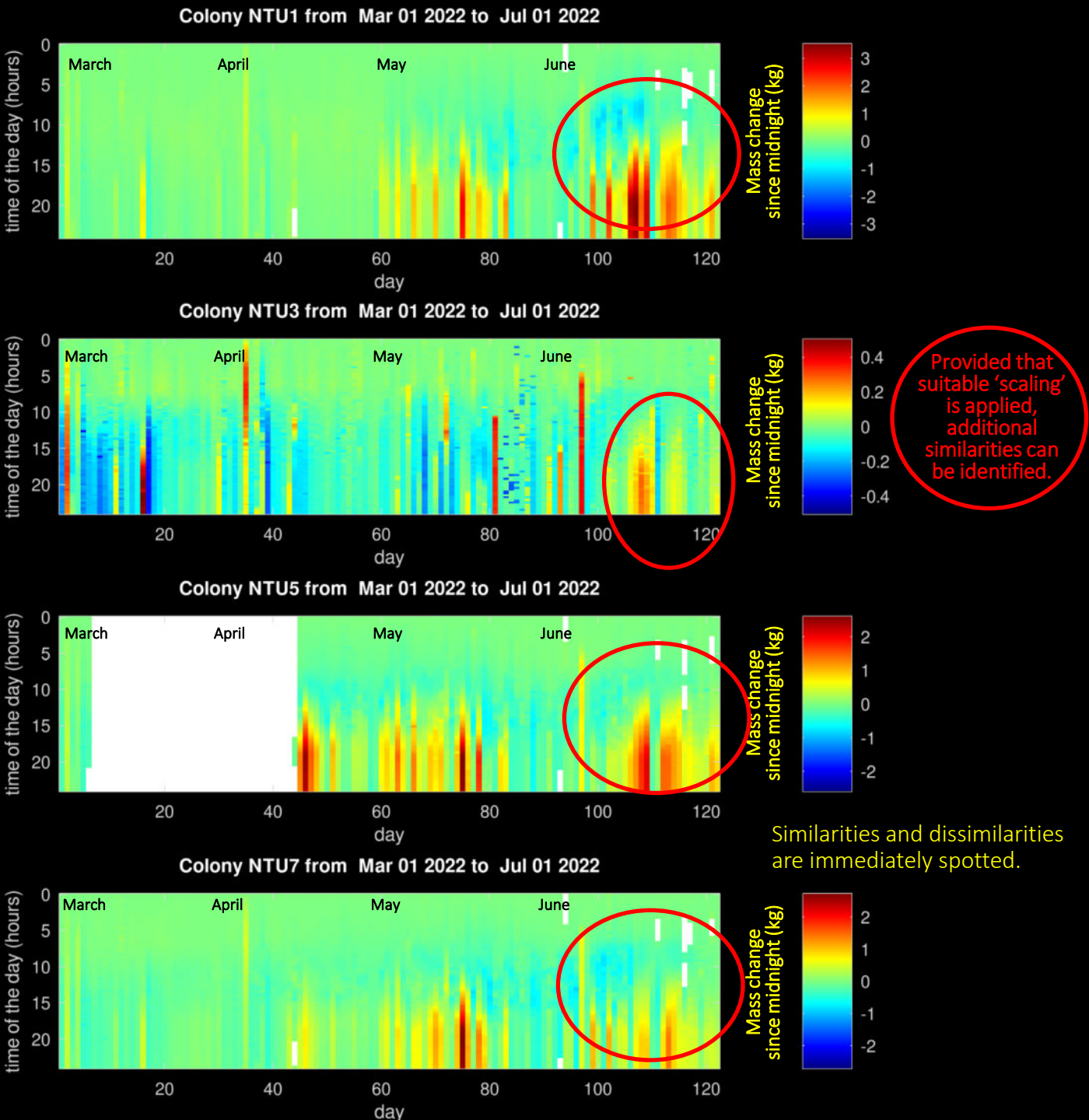
Colony NTU8 from Mar 01 2022 to Jul 01 2022



At most, within 15 mins, 200 to 300 g
change is registered by the scales.

It is now possible to identify, by eye,
similarities from hive to hive, which were
'hidden' in the previous display.





- The mass change since midnight is a high quality measurement of the mass changes.
- It exhibits very large deviations from day to day, particularly during nectar flow.
- These deviations are likely dictated by changes in the local weather and the local floral resources.
- Provided that the data is scaled appropriately, any two colonies on the same apiary exhibit REMARKABLY SIMILAR sequences of daily measurements.
- Using data sets coming from hives all residing on the same apiary allows us to compare hives and REMOVE THE LARGE DEVIATIONS DUE TO WEATHER AND THE PLANT KINGDOM.
- This way we have a method to dive into comparing the status of our colonies, provided that said 'status' is affected by the foraging strategy of the honeybees.
- The sequence of two (or more) consecutive days of "mass change since midnight" is a highly specific signature of colony status.

Hive are compared (using PCA) on the basis of their history of e.g. 7 days of daily cumulative mass data, indirectly revealing their energy consumption, ability to gather resources, colony size, etc...

-So far only unsupervised machine learning has been trialled, the comparison from hive to hive is totally automated and uses the largest deviations found in the data set, more exciting comparison can soon be made with supervised machine learning where small details are used to discriminate colonies amongst each other.

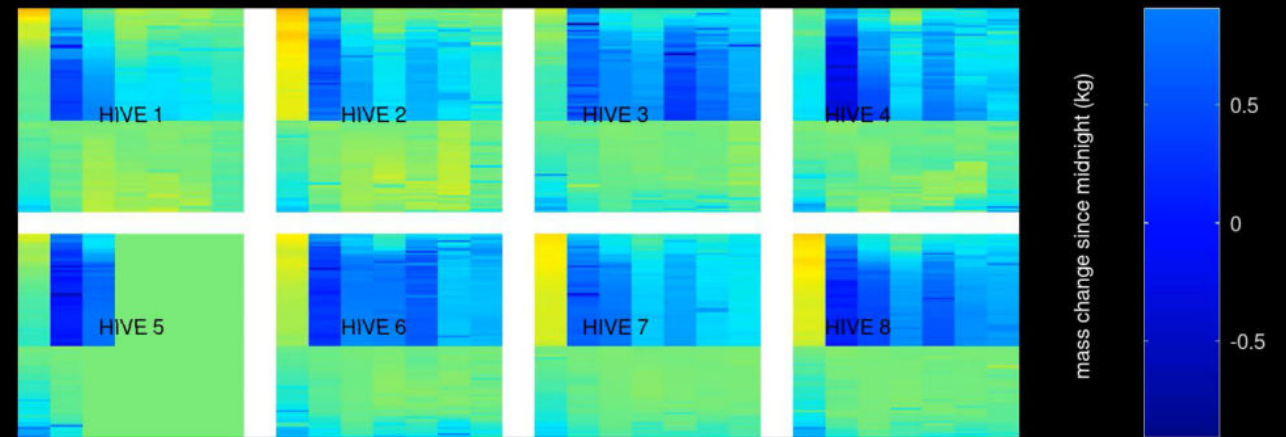
-When data is missing, the colony is clearly identified as an “outlier” (towards to the top of the bottom scrolling graph).

-When one colony, only, is **queenless**, it is also clearly identified as an “outlier” (towards to the top of the bottom scrolling graph).

-When one colony, only, has **high counts in nosema spores** (data from German apiary, not shown), it is also clearly identified as an “outlier”.

-When one colony, only, has **high varroa infestation levels** (data from Belgian apiary, not shown), it is also clearly identified as an “outlier”.

seven consecutive days of (normalised) cumulative mass change, reset to zero every day



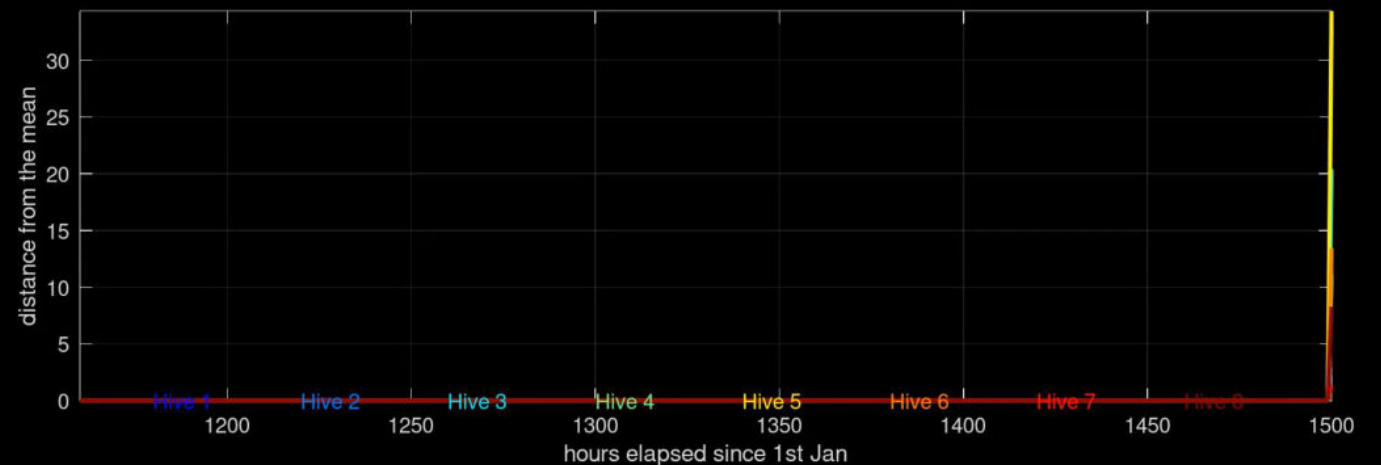
Present and Future Applications: the Better-B project.

-Using the same method, we are presently undertaking supervised machine learning on

- resilient against non-resilient colonies,
- translocated against home colonies,
- treated versus non-treated varroa resilient colonies.

-When a colony prepares for swarming, we can undertake supervised machine learning to try to pull it out from the group.

last point analysed = Fri Mar 11 11:53:00 2022

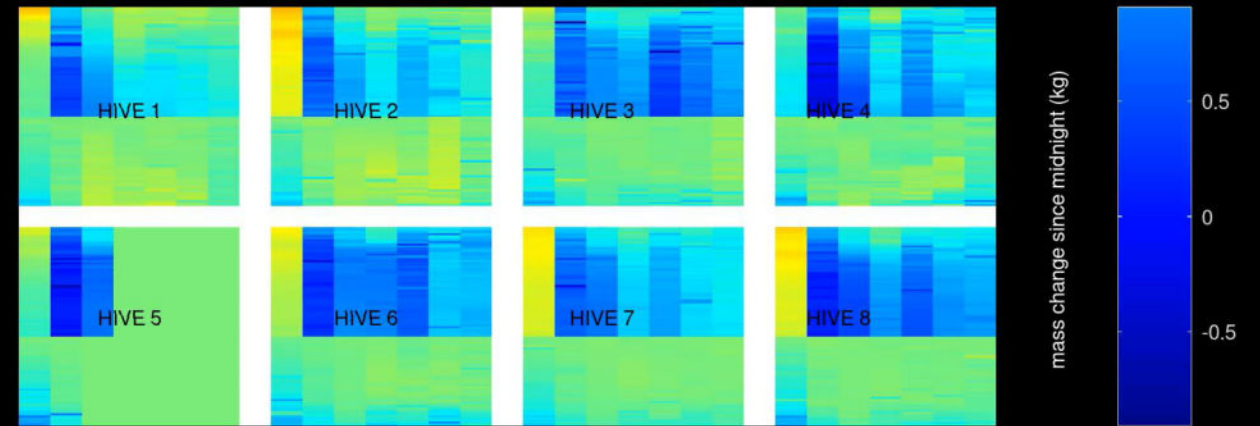


Better-B at APIMONDIA 2025

STRENGTHS

- The method will also disclose details of the timings of the hive mass changes that are revealing a disorder (Principal Axes of the PCA).
- The method is automated and does not require the monitoring, or the understanding of, either weather or floral resources.
- The method will pick up a broad variety of colony disorders, provided they affect the foraging ability of a colony. It may be possible to identify mass change patterns that are specific to a given disorder.
- The hindering, huge emphasis imposed on honeybee hive mass data measurements by
 - weather and
 - floral resources
 - is largely successfully removed.
- The method can be scaled up to much larger apiaries, where it will only become more meaningful.

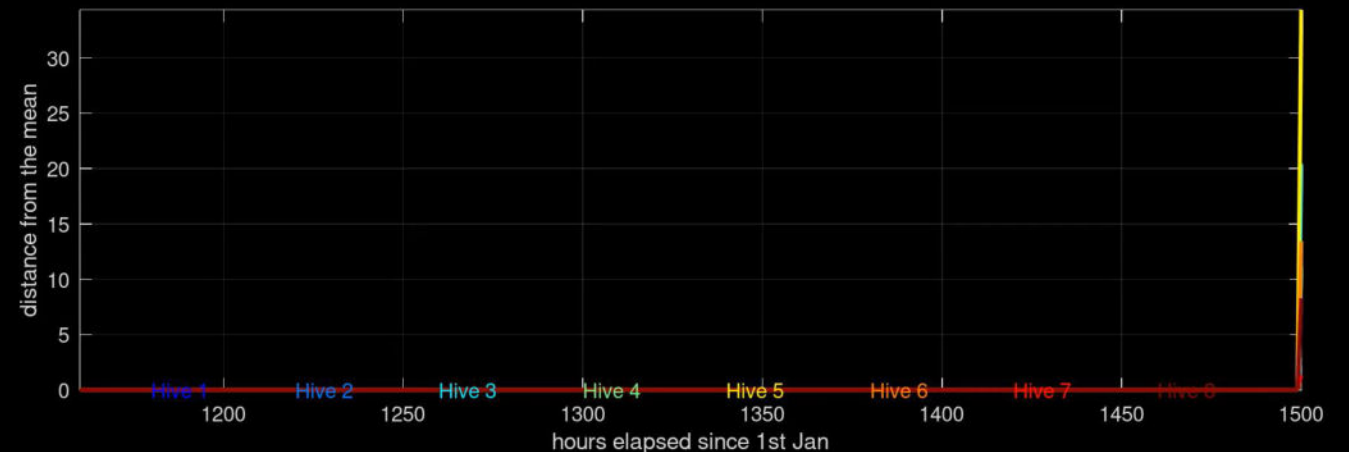
seven consecutive days of (normalised) cumulative mass change, reset to zero every day



LIMITATIONS

- The method is working well only when a few colonies (the minority) exhibit either a disorder, or performs exceptionally well.
- The method is working well during high nectar flow, otherwise a longer history of mass change is required (e.g. in the winter) in order to get a meaningful comparison.
- The method requires the simultaneous monitoring of multiple hives from the same apiary, presently an expensive exercise.
- The absence of queen, levels of nosema and varroa infestation were established by manual inspection and/or laboratory experiments, and their precise timings are difficult to establish. This makes the validation of the sensitivity challenging.

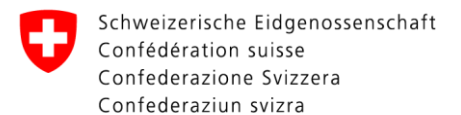
last point analysed = Fri Mar 11 11:53:00 2022





This work was supported by the Better-B project, which has received funding from the European Union, the Swiss State Secretariat for Education, Research and Innovation (SERI) and UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee.

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union, European Research Executive Agency (REA), SERI or UKRI. Neither the European Union nor the granting authorities can be held responsible for them.



Swiss Confederation