Microclimate Temperature Modelling– a Novel Tool for Pest Management

How can EO and metrological reanalysis data be used to facilitate the use of biopesticides.

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Contents:

1 – Biopesticides for Locusts:

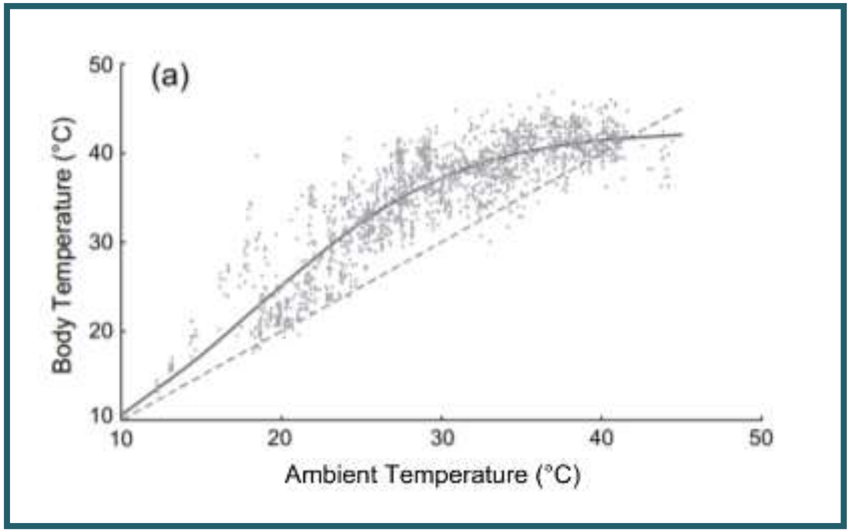
- Locust populations and their control are a serious issues to international development. Chemical biocides used as a traditional control technique.
    - In China, Locusts infest ~7 million hectares of land.
    - Last Locust plague in Western Australia, caused $55.5 million AUS of damages.
    - $6.8 million AUS worth of *Fenitrothion* used as main biocide.

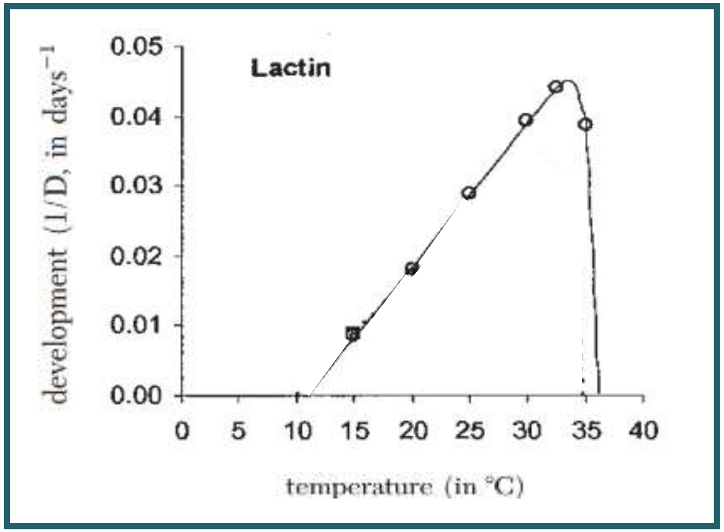
- ***'Biopesticides are biochemical pesticides that are naturally occurring substances that control pests by nontoxic mechanisms.'*** (Mazid et al, 2011).
- Metarhizium anisopliae is a natural fungal parasitoid to locust populations. But it is highly variable in efficacy – preventing widescale implementation.

1.1 – Klass et al (2007):

- A lab trial that predicts the LT90 – time to kill 90% of the locust population after biopesticide application.

1. Predict locust internal body temperature using empirical relationship.
2. Predict hourly biopesticide development using Lactin thermophile development model.



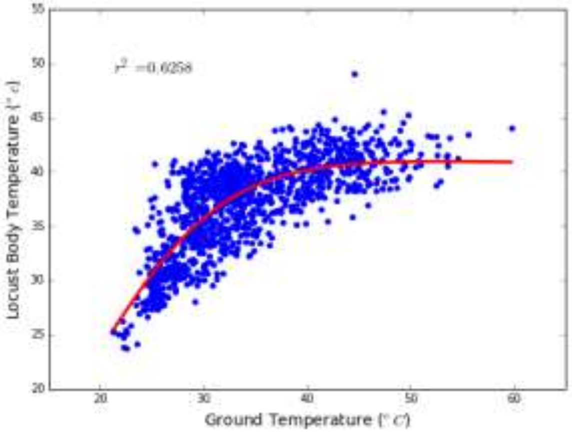


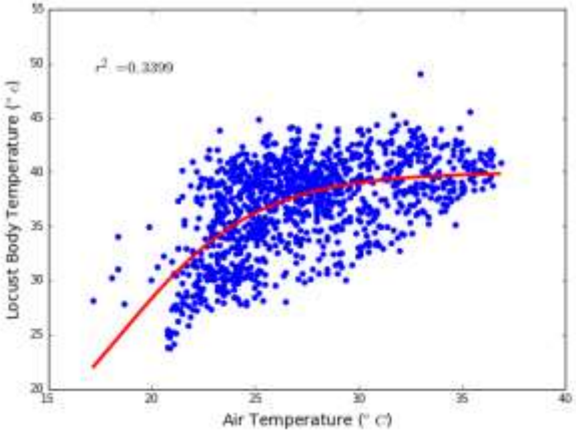
How can we predict the locust body temperature (LBT) using EO and reanalysis data?

2 – Implementation of LBT predictions

2 – Insights from the field

- From field data from 2015 & 2016, the best predictions of LBT are found when using in situ canopy temperatures.





- Within direct LST measurements and ERA5 reanalysis variables, there is no similar variable of intra canopy ambient temperature.
- Therefore, efforts were made to derive the canopy temperature.

2.1 – Predicting Canopy Temperature.

- A single source energy balance approach was taken, which is a derivate of Penman-Montieth equations. This is described in the SiriusQuality 2 crop model (Matre et al, 2006).
- Predicts ambient temperature within a 2m canopy, which is what a locust would be residing in. **This is referred to CTP.**
- Input data is hourly ECMWF ERA5 reanalysis data at 33km. Fluxes are converted from radiative units to transported system water.

$$t_c = t_a + \frac{H}{1000.\frac{\rho C_p g_a}{\lambda}}$$

$$g_a = \frac{k^2 U}{ln(\frac{3.3}{r_o})\ln(\frac{3.3}{0.1 r_o})}$$

$t_c = Canopy\ Temperature\ (^\circ C)$

$\boxed{t_a} = 2m\ Air\ Temperature (^\circ C)$

$\boxed{H} = Sensible\ Heat\ Flux\ (g\, m^{-2}\, t^{-1})$

$\rho = Density\ of\ Air\ (kg\ m^3),\ 1.225$

$C_p = Heat\, Capacity\, of\, Air\ (MJ\, kg^{-1}\, ^\circ C^{-1}),\ 0.00101$

$g_a = Canopy\ Conductance\ (m\ t^{-1})$

$\lambda = Latent\ Heat\ of\ Vaporization\ of\ Water\ (MJ\ g^{-1})$

$k = Von\ KarmenConstant,\ 0.4$

$\boxed{U} = Wind\ Speed\ (m\ s^{-1})$

$\boxed{r_o} = Surface\ Roughness\ (m)$

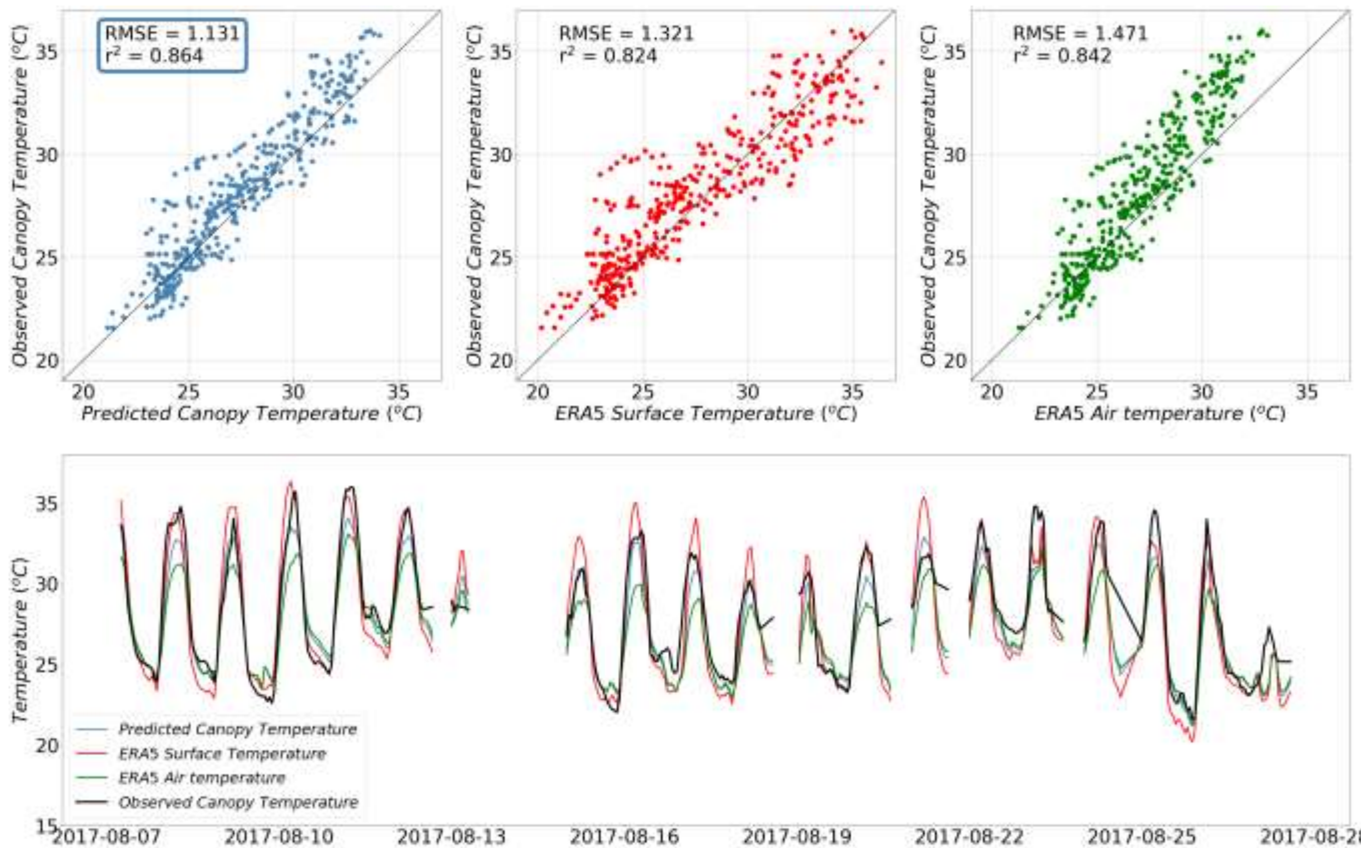
2.2 – Validation and Comparisons to Other Sources.

- **Canopy Temperature:**
  - Predictions were compared to data from campaigns in 2017 & 2018. ~40 days of data were smoothed using hourly bins.
  - Data was collected in Dongying, Eastern China.
- **LBT:**
  - The Klass LBT model was calibrated from ~1600 internal locust body temperatures, made with captured wild locusts and thermocouples.
  - Data collected in 2015 & 2016 in Dagang, China.
- **Comparison data:**
  - ERA5 surface temperature and 2m air temperature were also used to predict LBT and also directly compared to field data on canopy temperatures.

3 – Results

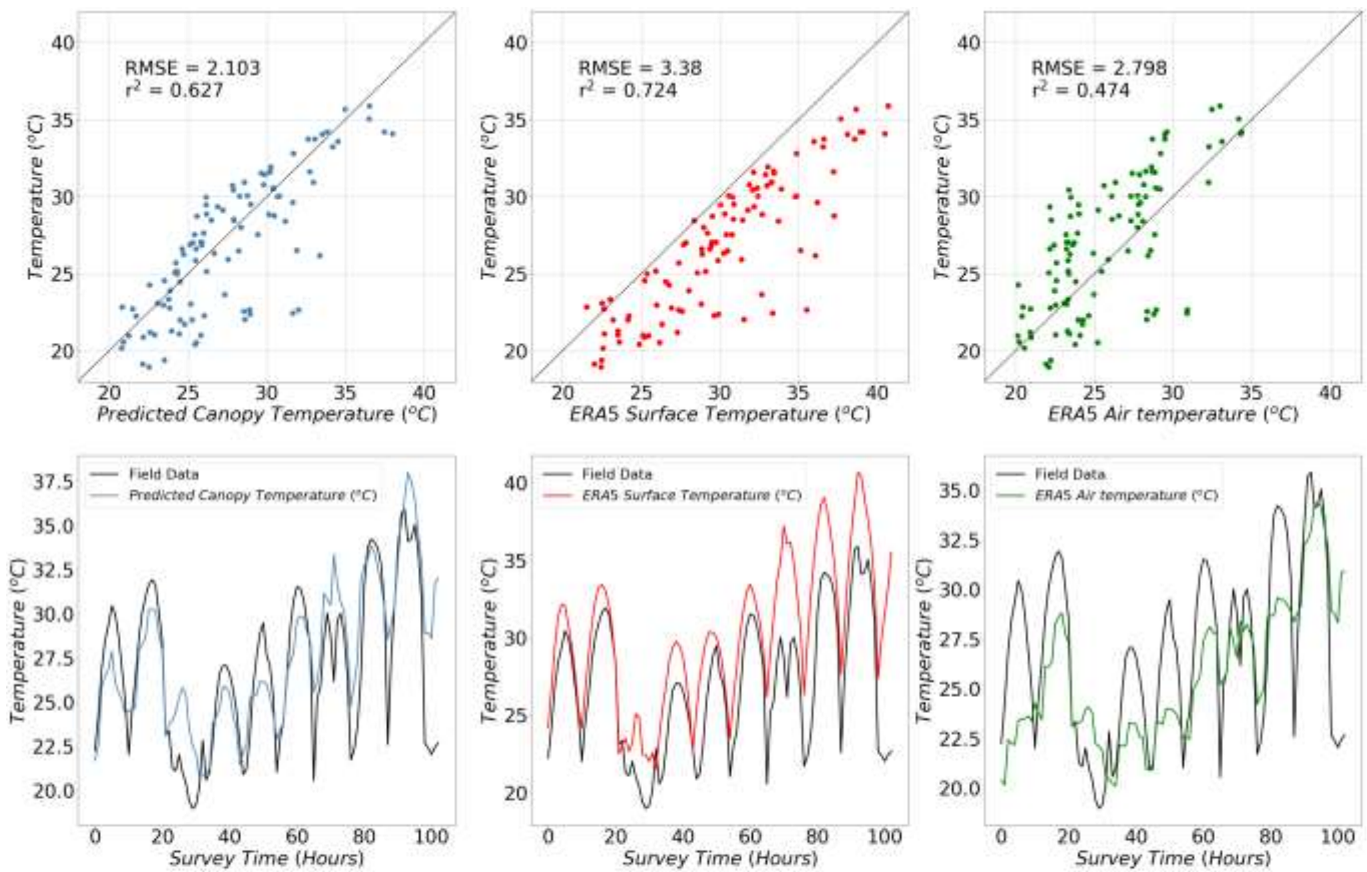
3.1 –Canopy Temperatures - 2017.

- 401 common data points.
- **CTP** represents the field data best.
- **Surface temperature** overrepresents at warmer temperatures and has a large data spread.
- **2m air temperature** nearly always underrepresents the field data.



3.1 –Canopy Temperatures - 2018.

- 103 common data points.
- **CTP** has least error, but overpredicts on the 3rd survey day.
- **Surface temperature** always overrepresents, only 4.8% of the results don't overrepresent.
- **2m air temperature** has very poor relationship.

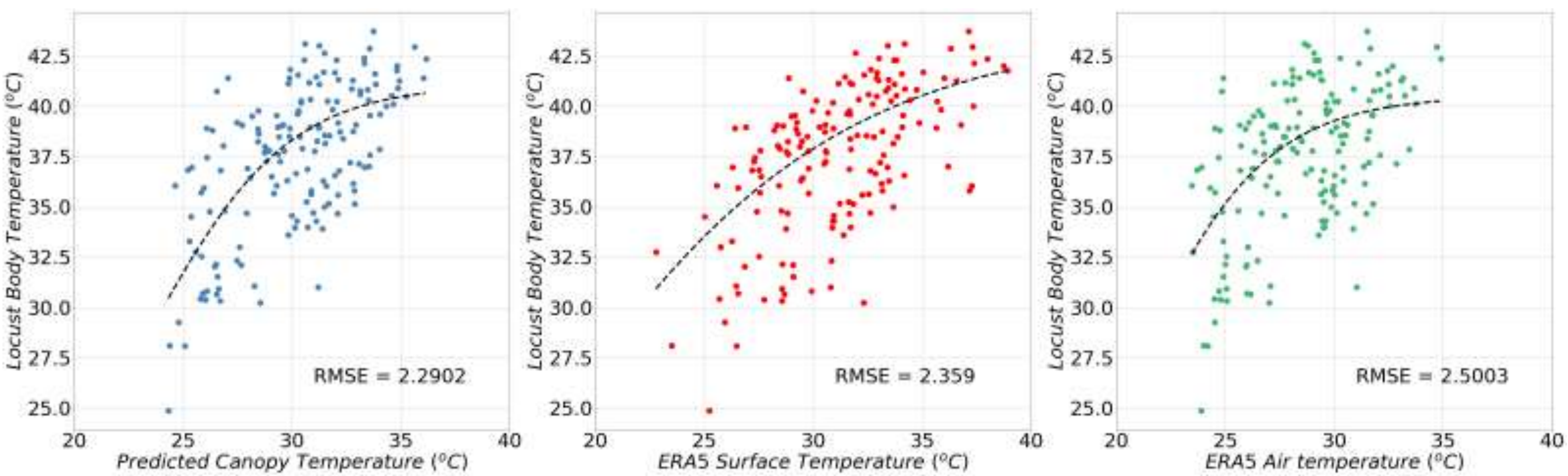


3.2 – LBT 2015 and 2016.

- Each dataset was fitted using the Klass equation to the LBT data.
- All predictions had allot of error:
    - Reflects the highly sporadic LBT data.
    - Difficult achieving standardized locust sampling technique.
- But best predictions made with CTP.

$$T_b = T_x + \frac{T_{max} - T_x}{1 + \left(\frac{T_x}{T_{infl}}\right)^s}$$

$$T_x = Temperature\ source$$
$$T_b = LBT$$



4 – Discussion and Conclusion

4 – Discussion.

- Large spatial scale (33km)
  - How will predictions vary with more mixed pixels?
  - ERA5-land product is calculated on a 9km grid.
- No measure of uncertainty or range of potential microclimate temperatures.
  - Flat standard deviation was derived in field work.
  - How does the variation change with environmental conditions?
- Incorporate into a DA scheme as a prior.
  - Bateni et al (2016) –DA scheme for partitioning LST measurements into environmental temperatures.
  - Reduces the spatial and temporal scale of data.
- Canopy temperature is a key parameter in other crop disease developments e.g. ‘*wheat stripe rust*’.

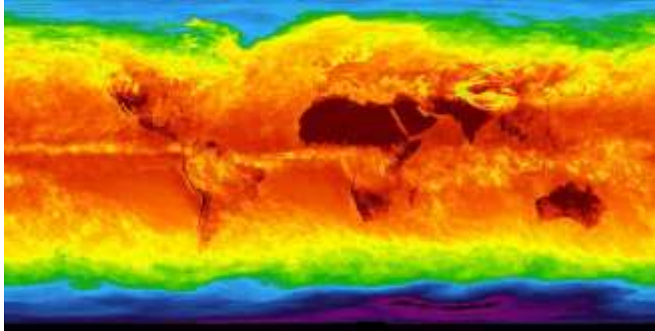
4 – Conclusion.

The SirusQuality model was implemented using ERA5 meteorological reanalysis data to calculate canopy temperature (CTP).

ERA5 surface temperature, 2m air temperature and CTP were compared to field measure canopy temperatures, and also used to predict locust body temperature (LBT), for use in biopesticide efficacy modelling.

- Canopy temperatures were best represented with the CTP.
- LBT were best predicted using CTP used as the input temperatures.

Using the SirusQuality canopy temperature model produces the best predictions of locust body temperature. This would lead to better understanding of LT90 and biopesticide efficacy in an integrated locust control scheme.



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Thanks

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