# We need to ***rethink*** the radar-hail relationship.

## All about that Bayes…and hail! Bayesian models for severe hail in south-east Queensland.

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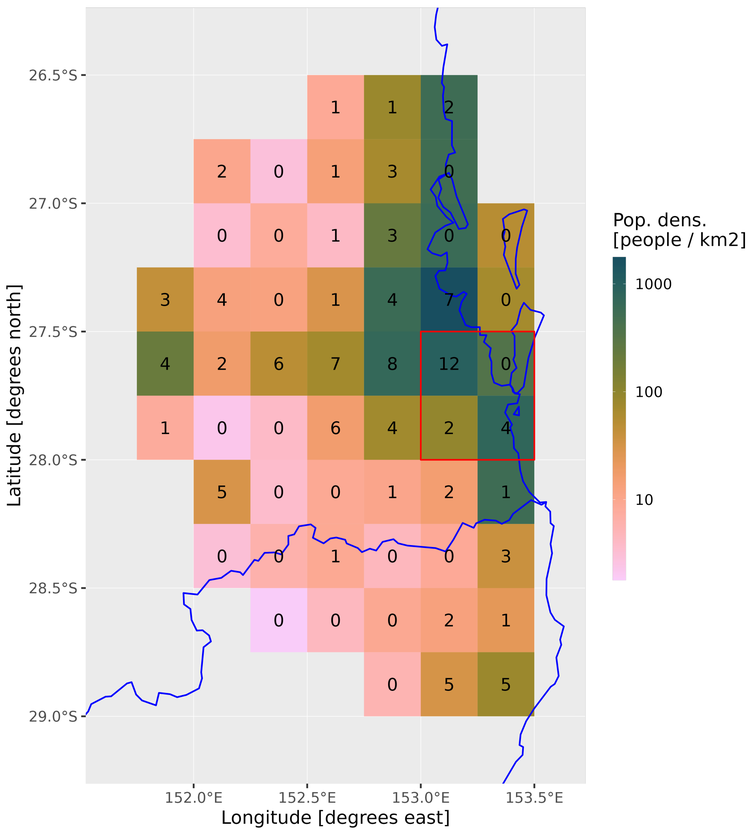
## What the hail is going on?




Hail causes **more insured losses** than bushfires and floods…**combined**[1]!

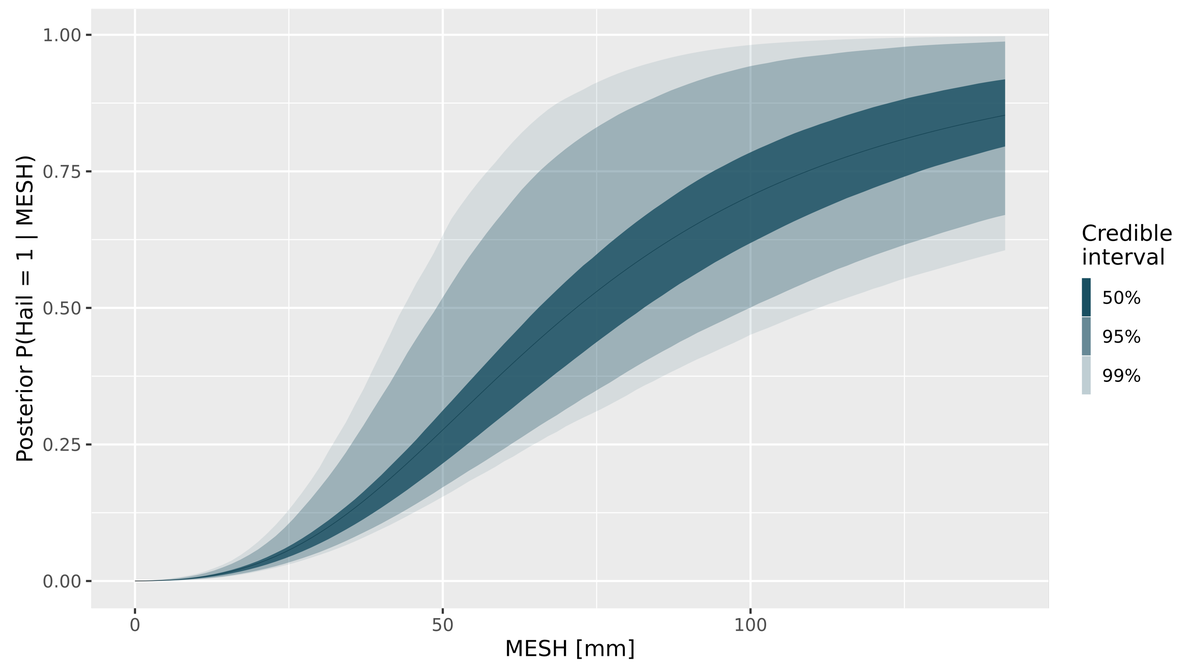
However, our understanding is **limited** by the challenges of **observing** hailstorms[2].

**Radar** products like MESH have high spatial and temporal resolution but **are challenging to connect** to hail at the surface[3, 4].

**Hail reports** (counts on figure) are truthful but spatially **biased**[5].

We take a **Bayesian** approach: combining these two imperfect observational products to **quantify the uncertainty** in our knowledge.

## To threshold or not to threshold?

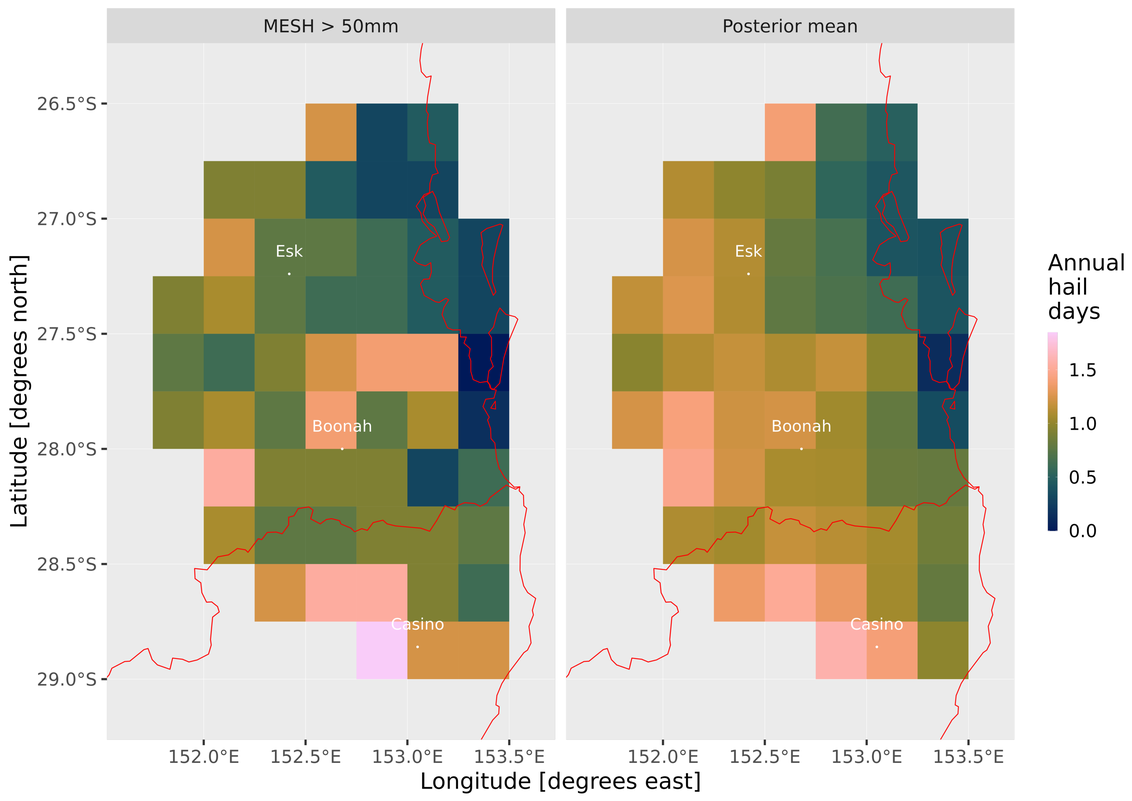



A **threshold** is commonly set on the radar product MESH to distinguish severe hail[6, 7]. However, our results suggest that this threshold:

- is not as **sharp** as anticipated or
- does not have its expected **probabilistic interpretation**.

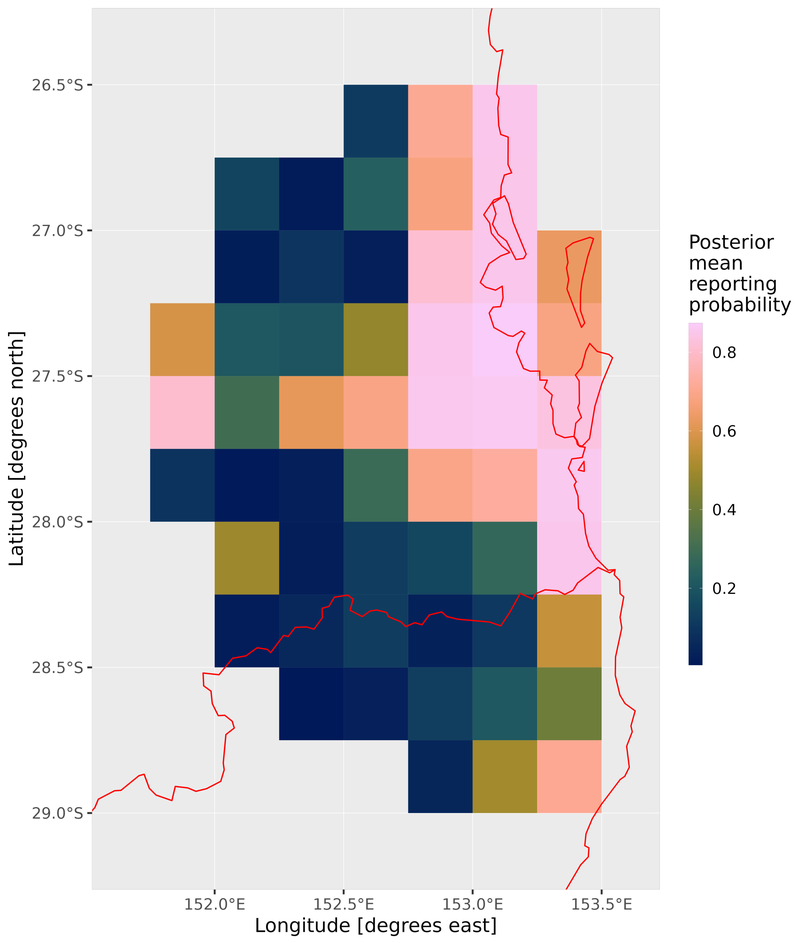
Moreover, **at values commonly used as a threshold** (e.g. 30mm)[4, 7] our model suggests the probability of hail may **only** be 10-25%.

## Keeping it (spatially) smooth.




Our method (right) not only produces a climatology **consistent with our physical understanding**[6] of the region (for example, the similar hail maximum west of Casino[7]) but is **spatially smoother** than threshold-based climatologies (left) due to the usage of **probabilities and expectations**.

## Shhh…hail is chronically under-reported!




Hail reporting rates are **highly variable** across south-east Queensland.

Reporting rates in the region are **low**. Even in the most densely populated areas, it is likely that **not all** severe hail events are reported.

Normally, when using reports, we must **ignore** areas with low reporting rates[4, 8], but our method gives us a way to use **all** reports.

## The obligatory equation.

Our approach hinges on the following equation in each spatio-temporal grid cell:

$$\underbrace{P\left(R_i^{(t)} = 1 \mid \boldsymbol{\Theta}\right)}_{\text{Reporting probability}} = \underbrace{P\left(R_i^{(t)} = 1 \mid H_i^{(t)} = 1, \boldsymbol{x}_{\mathrm{R},i}^{(t)}, \boldsymbol{\beta}_{\mathrm{R}}\right)}_{\text{Reporting rate}} \underbrace{P\left(H_i^{(t)} = 1 \mid \boldsymbol{x}_{\mathrm{H},i}^{(t)}, \boldsymbol{\beta}_{\mathrm{H}}\right)}_{\text{Hail probability}}$$

Hence, we estimate **concurrently** the probability of hail given MESH **and** the reporting rate.

## References

[1]McAneney et al. 2019. doi: 10.1080/17477891.2019.1609406
[2]Raupach et al. 2021. doi: 10.1038/s43017-020-00133-9
[3]Brook et al. 2021. doi: 10.1175/JAMC-D-20-0087.1
[4]Murillo & Homeyer 2019. doi: 10.1175/JAMC-D-18-0247.1
[5]Allen & Karoly 2014. doi: 10.1002/joc.3667
[6]Soderhlm et al. 2017. doi: 10.1002/qj.2995
[7]Warren et al. 2020. doi: 10.1002/qj.3693
[8]Bedka et al. 2018. doi: 10.1175/JAMC-D-17-0056.1