Improving forecasts of thunderstorm asthma by including low level moisture and optimising economic value

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1. How do we forecast thunderstorm asthma?

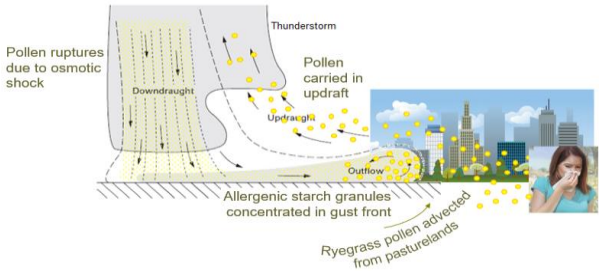

Fig. 1. Hypothesised mechanism for thunderstorm asthma.

- First-ever early warning service for epidemic thunderstorm asthma (ETSA) created following the deadly 21 Nov 2016 event.
- Based on risk matrix combining predicted
  - grass pollen concentration
  - likelihood of severe thunderstorms with damaging winds (Fig. 1)
- Moderately skilful (Bannister *et al.*, *BAMS*, 2021), but can it be improved?

2. Moisture enhances ETSA predictability

- Of TS indices tested, daily max mixing ratio in the lowest 1km of atmosphere was most skilful at predicting ETSA events (Brown *et al.*, *WAF*, 2022).
- Official forecasts of 2m max mixing ratio also useful (Fig. 2).

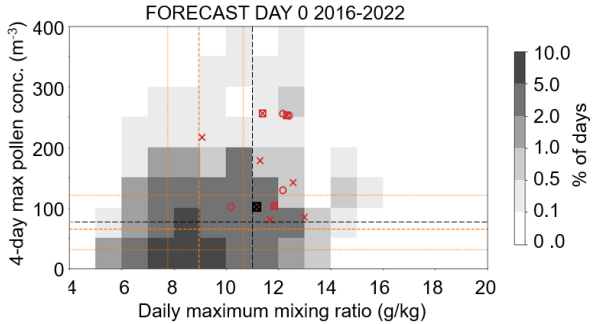

Fig. 2. Joint frequency of grass pollen concentration and max mixing ratio. Red symbols indicate days with enhanced asthma presentations at Melbourne area public hospitals. Black symbol indicates conditions on 21 Nov 2016.

3. Fixed Risk Multicategory (FIRM) score

- FIRM optimises forecasts based on economic value. For ETSA, misses are much more serious than false alarms.
- FIRM is consistent with forecast directives based on fixed risk thresholds (Taggart *et al.*, *QJRMS*, 2022).
- Specify:
  - risk parameter α such that cost/loss ratio = 1-α
  - optional weights w_i for relative importance of forecasting on the correct side of each category threshold (Low, Mod, High)
- Generate a scoring matrix S:

S =

	Observed: Low	Mod	High
Low	0	αw_1	$\alpha(w_1+w_2)$
Mod	$(1-\alpha)w_1$	0	αw_2
High	$(1-\alpha)(w_1+w_2)$	$(1-\alpha)w_2$	0

- Multiply S by the fraction of forecasts in each contingency table cell and sum to get FIRM.

4. Optimizing thresholds for ETSA forecasting

- High ETSA risk triggers the Department of Health to take action to protect.
- Minimise 2-category FIRM score (Low-Mod, High) to find the max mixing ratio threshold that best trades off costly missed events and less costly false alarms.

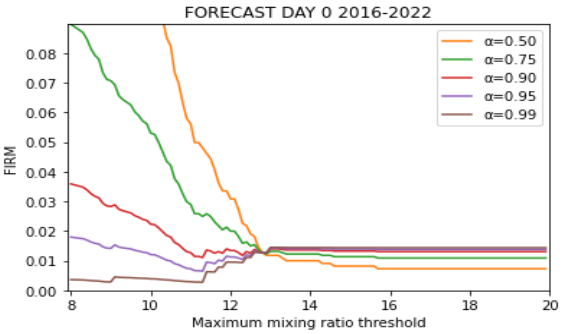

Fig. 3. FIRM vs max mixing ratio threshold for different values of α. For α of 0.9 to 0.95 (missed events 10 to 20 times more costly than false alarms) optimum threshold is 11 g/kg.

5. Revised ETSA risk forecast matrix

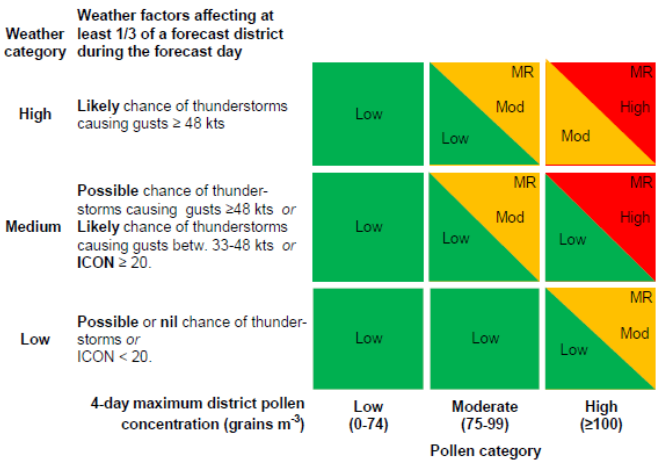

Fig. 4. Revised ETSA risk matrix based on grass pollen concentration, likelihood of severe thunderstorms with damaging winds, and daily maximum mixing ratio. Triangular cells with "MR" require daily max mixing ratio ≥ 11 g/kg.

6. Performance of new ETSA matrix

- New ETSA risk matrix better distinguishes days with thunderstorm asthma near Melbourne 2017-2022.
- More science needed to guide forecast improvements.

Original matrix (current)

Forecast ETSA risk	Obs ETSA: No	Yes
Low	508	5
Mod	34	3
High	2	0

Revised matrix (new)

Forecast ETSA risk	Obs ETSA: No	Yes
Low	488	2
Mod	45	4
High	11	2

7. Key points

- **Low level moisture adds useful information for predicting epidemic thunderstorm asthma.**
- **The FIRM score is useful in optimizing max mixing ratio threshold in a revised ETSA risk matrix.**

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