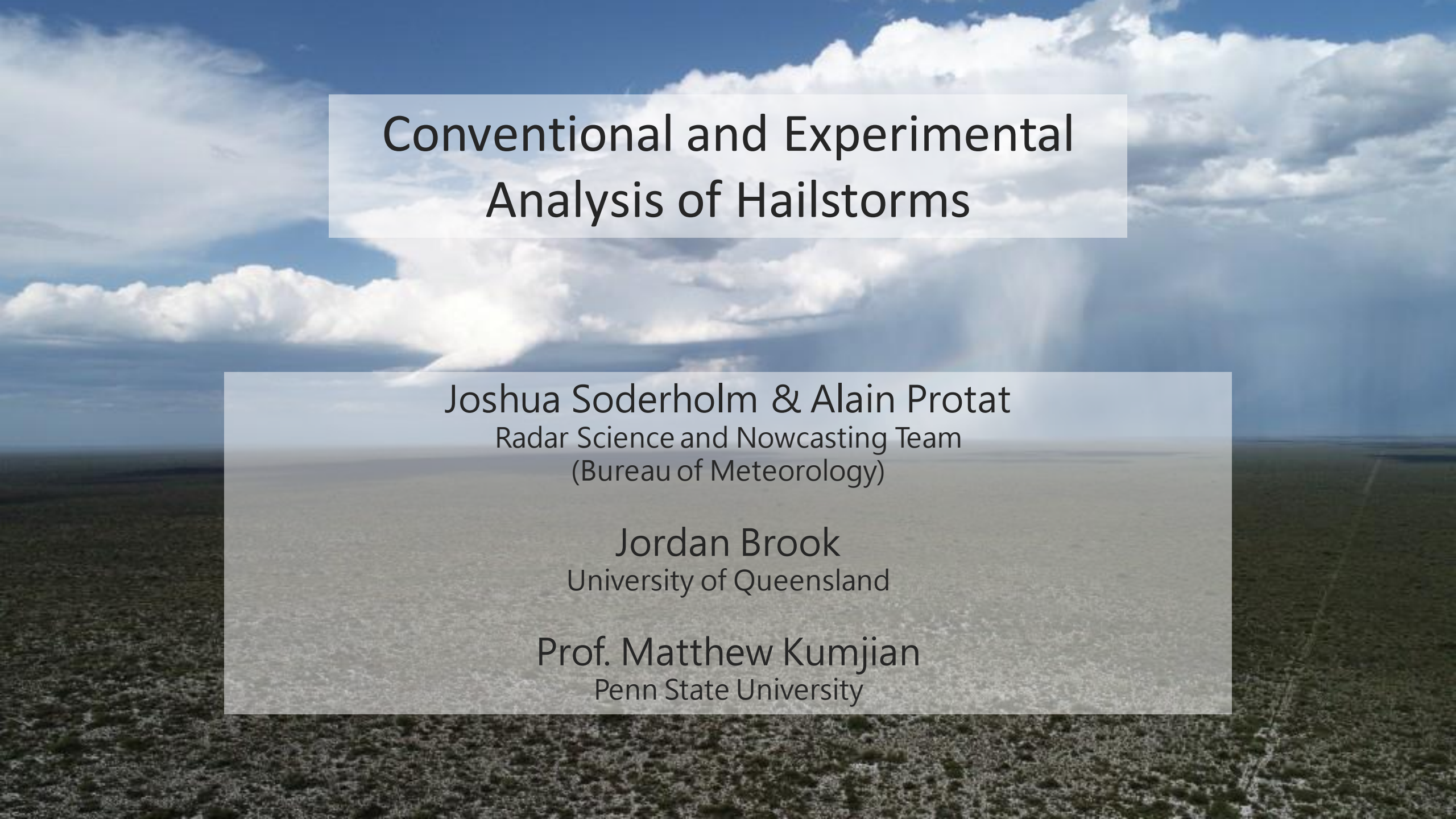

Conventional and Experimental Analysis of Hailstorms

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University of Queensland

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Recent Events
- 19 Jan 2020 (Melbourne event)
- 31 Oct 2020 (Brisbane event)

Conventional Analysis
- Introduction
- Recent Events
- Impact

Experimental Analysis
- Polarimetric and 3D wind retrievals
- Hailstone properties

Melbourne - 19th January 2020

- Favourable environment for hailstorms where a right mover interacted with the sea breeze.
- Challenging forecasting environment, especially with changes to storm motion
- Multiple reports of 5+ cm hailstones across the NE to SE suburbs (Warrandyte, Doncaster, Camberwell, Bentleigh)
- Industry wide losses $1.8B for SE Australia as of 21st July 2020

Malvern East @pjmacaulay

Bentleigh East @terkey76

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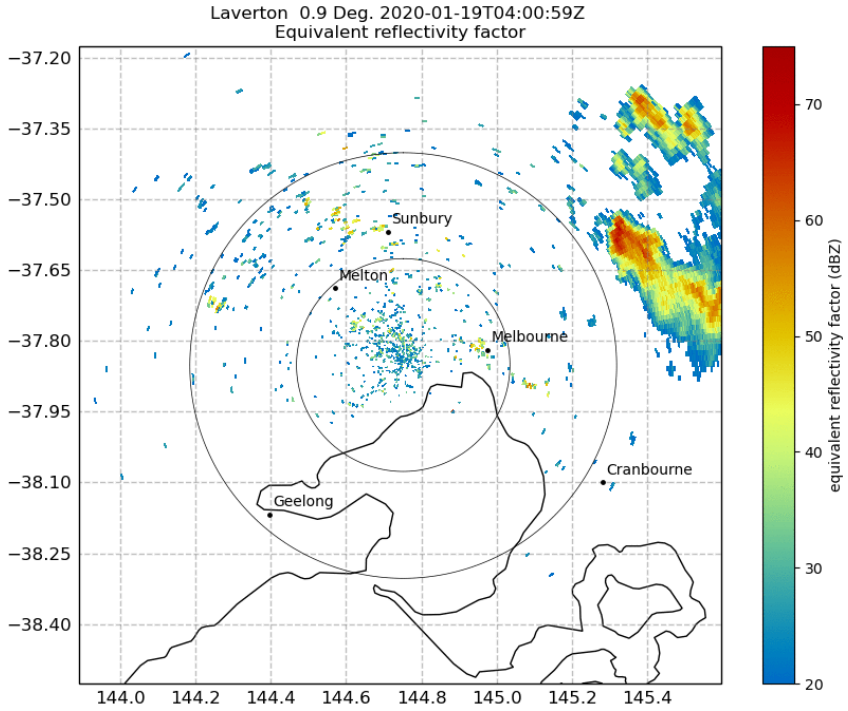
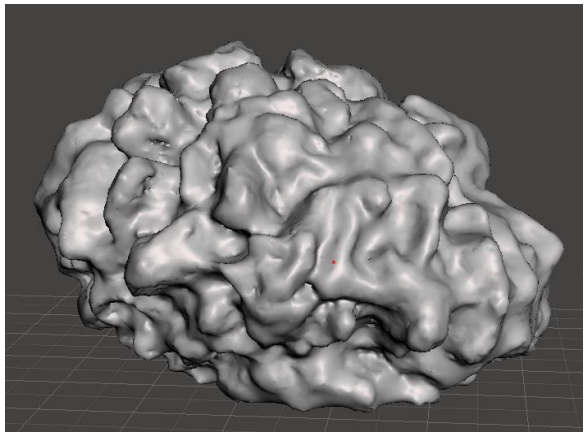
- Challenging forecasting environment, especially with changes to storm motion
- Multiple reports of 5+ cm hailstones across the NE to SE suburbs (Warrandyte, Doncaster, Camberwell, Bentleigh)
- Industry wide losses $1.8B for SE Australia as of 21st July 2020

- **Experimental Observations:**
  - Polarimetric radar ☺
  - Multi Doppler coverage ☺
  - Collaboration with IAG to assess motor bonnets
  - Aerial surveys for hailstone shape analysis
  - 43 hailstones collected for analysis



Reflectivity animation of event



3D scan of a 60mm diameter hailstone collected at Camberwell

Brisbane - 31st October 2020 🎃

- Highly favourable environment led to dozens of severe hailstorms developing between NE NSW and Wide Bay, with many training events (multiple hailstorms over the same area)
- The development of severe hailstorms was no surprise – but the size of the hail was...
- Multiple reports of 10+ cm hailstones through 4 suburbs and extreme damage to property, including concrete tile roofs
- Report of 14 cm hailstone is equal to the largest known hailstone in Australia
- Expected to result in >> $1B AUD in insured losses (GC)

Concrete tile roof damage (Wind Research Lab, UQ, 2020)

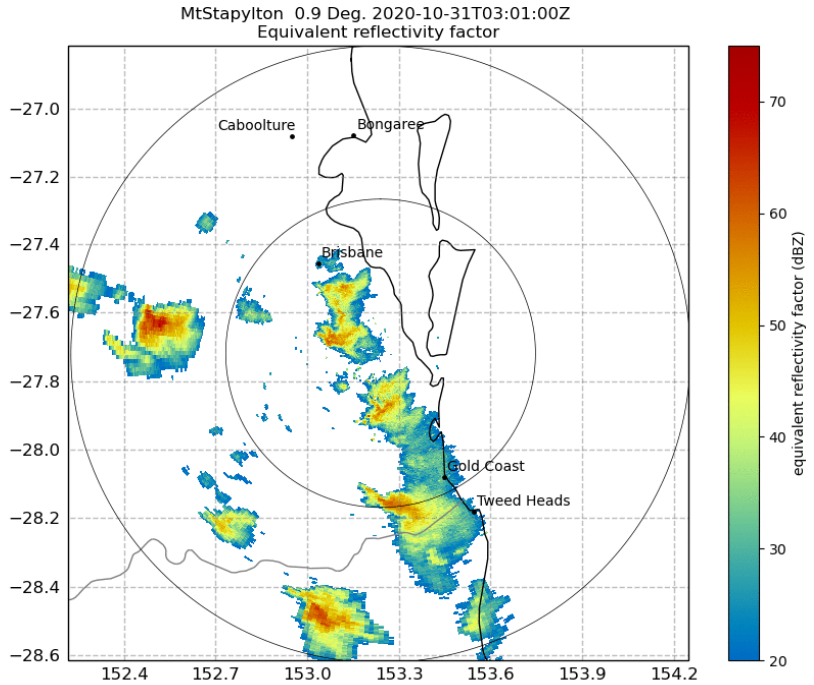
Solar Panel Damage (Wind Research Lab, UQ, 2020)

Internal ceiling perforations (ABC Brisbane, 2020)

Brisbane - 31st October 2020 🎃

- Highly favourable environment led to dozens of severe hailstorms developing between NE NSW and Wide Bay, with many training events (multiple hailstorms over the same area)
- The development of severe hailstorms was no surprise – but the size of the hail was...
- Multiple reports of 13+ cm hailstones through 4 suburbs and extreme damage to property, including concrete tile roofs
- Report of 14 cm hailstone is equal to the largest known hailstone in Australia
- Expected to result in >> $1B AUD in insured losses (GC)

- **Experimental Observations:**
  - Polarimetric radar ☺
  - Single Doppler coverage 😐
  - 136 WeatheX hail reports, 18 hail reports to BoM
  - 120 hailstones collected by UQ for analysis. Largest sample of 8+ cm D_{max} hailstones ever collected



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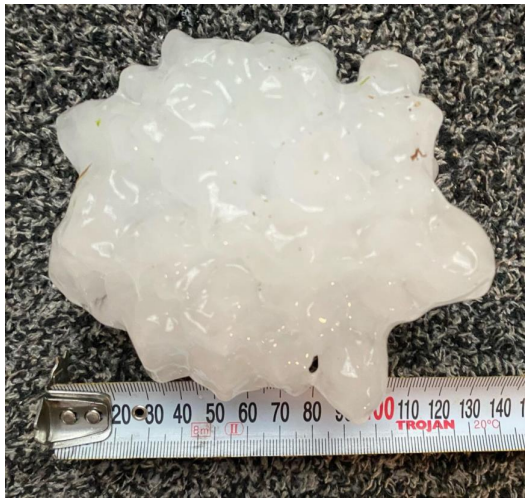
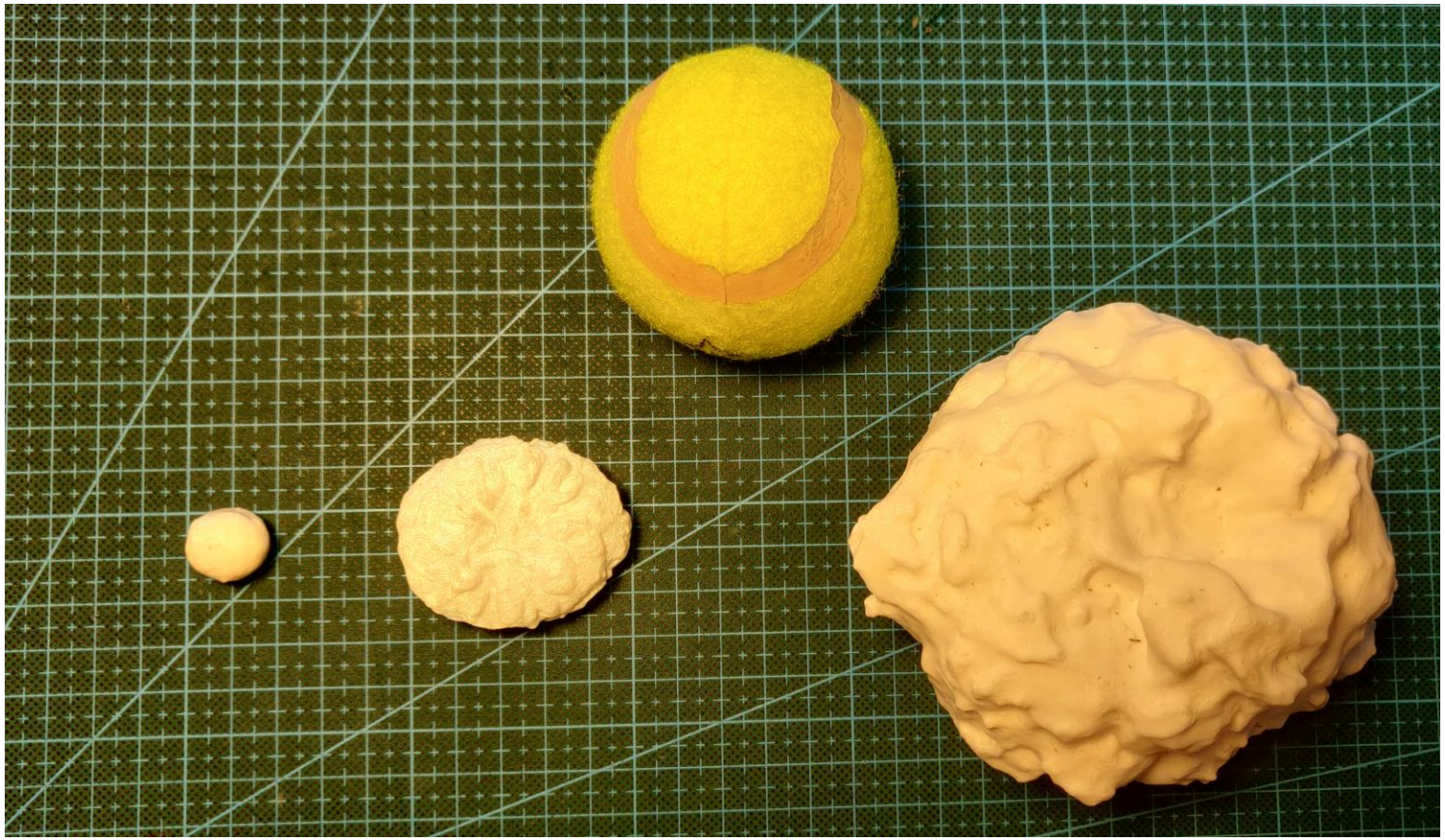


Hailstone Collected by UQ from Forestdale, QLD

Brisbane - 31st October 2020 🎃



2cm D_{max}
4 grams
Large Hail

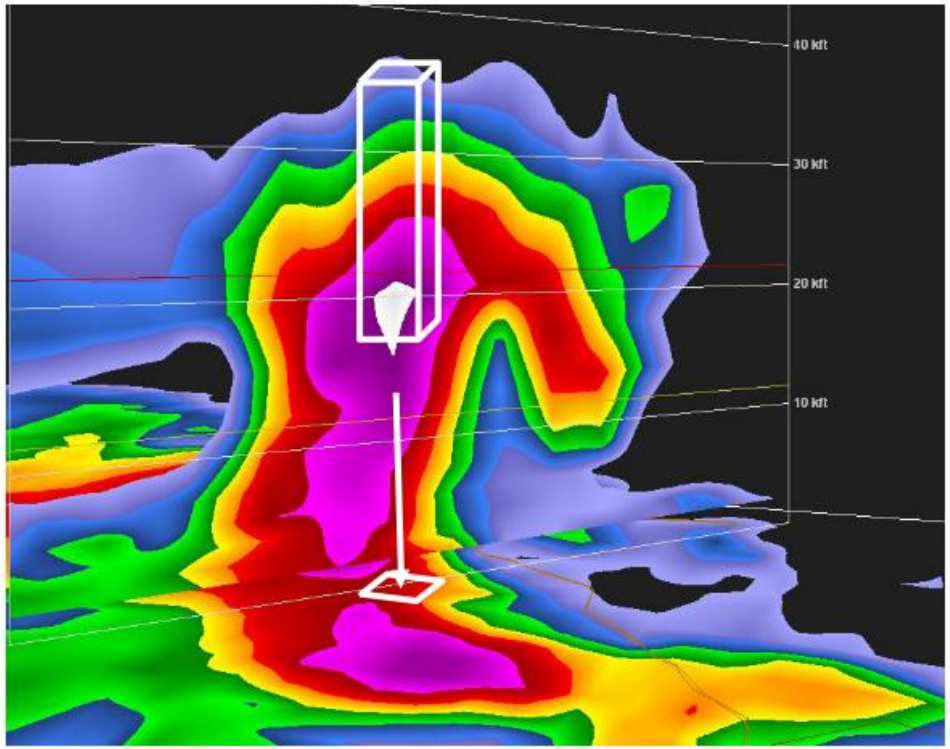
5cm D_{max}
40 grams
Giant Hail

11.5 cm D_{max}
303 grams
Argentina

13+ cm D_{max}
400-500+ grams
Brisbane

Conventional Analysis

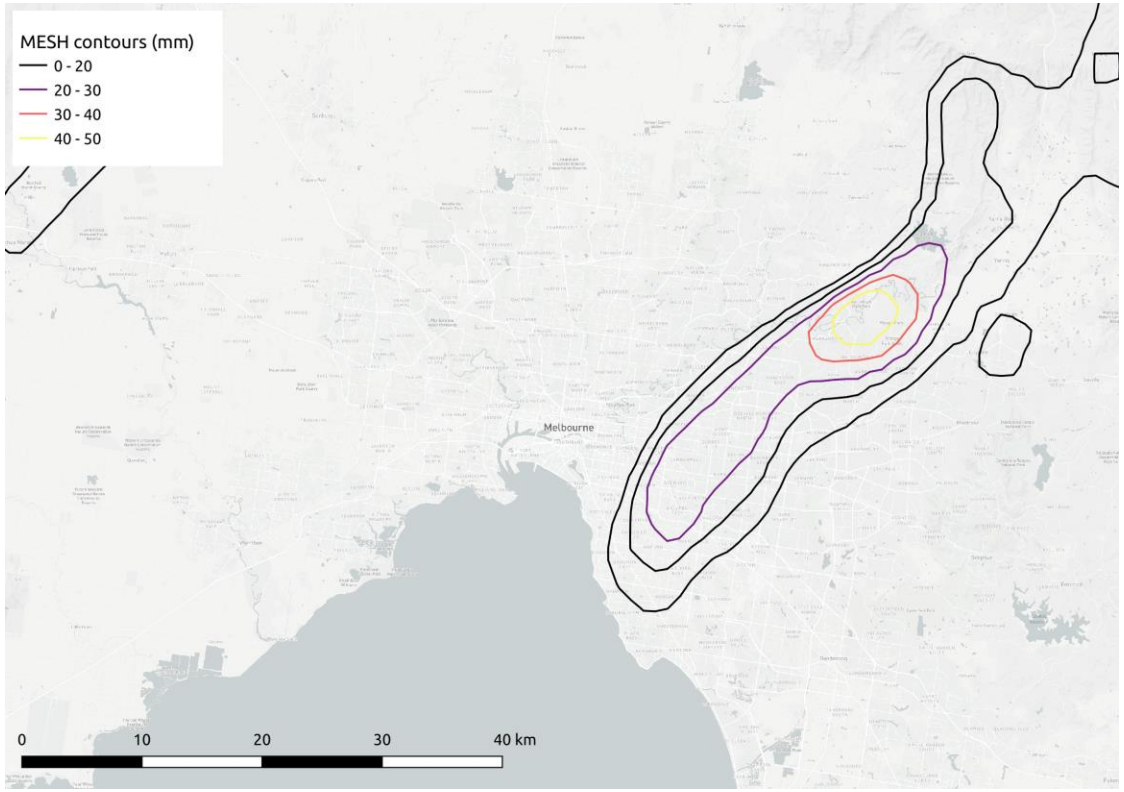
- Conventional hail detection and sizing fundamentally is the relationship between strong reflectivity above the freezing level and the severity of hail (MESH)
  - Calculated from data above the freeze level
  - Assumes a fixed hail size distribution
  - Assumes a fixed hail concentration
  - Assumes no advection (hail falls where it's detected)
- As a result, these retrievals have a high degree of uncertainly, but their widespread coverage can still be utilised effectively with caveats (Murillo and Homeyer 2020 for 6000 reports).
- Extra information from Doppler and polarimetric radar measurements not utilised in conventional analysis



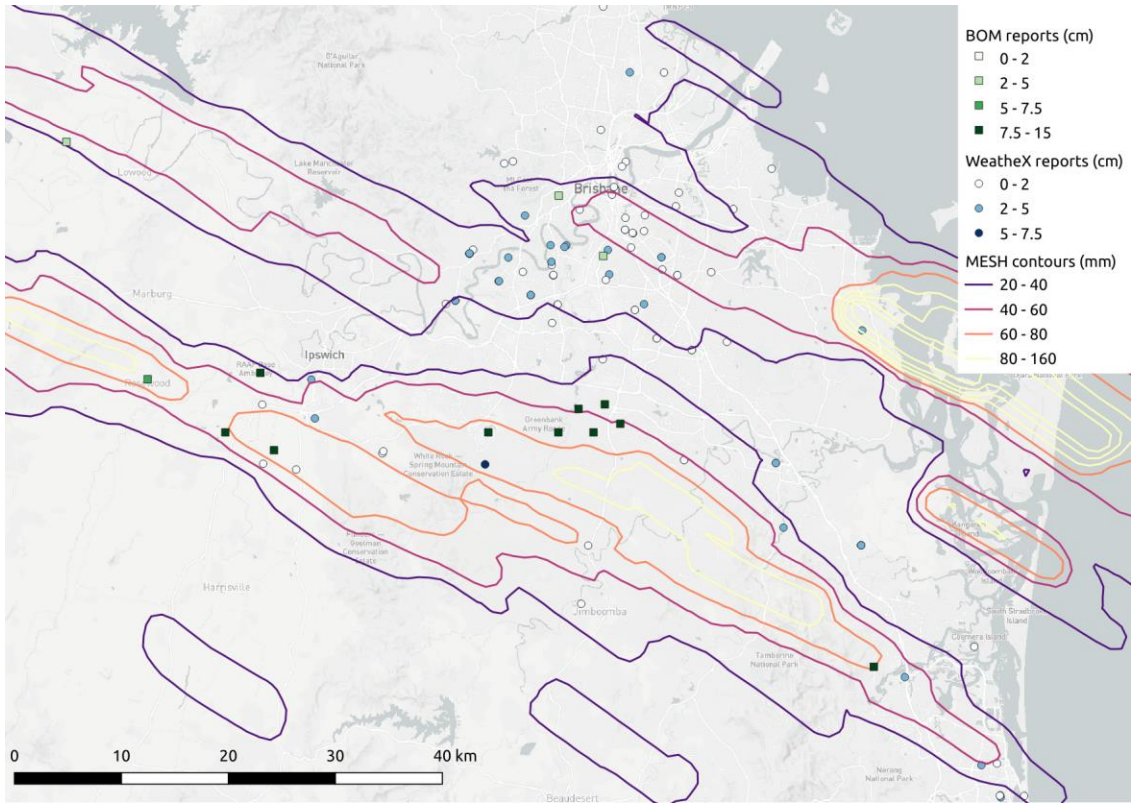
Vertical cross section of radar reflectivity through a hailstorm showing extraction of hail size using data above the freezing level

Recent Events – from the MESH perspective

- MESH is primarily used as a situational awareness tool, but can also be extended to map events and provide nowcasting using optical flow (PST)
- Applications for forecast and warning verification.



Contoured accumulated MESH for the 19th Jan 2020 Melbourne hailstorm



Contoured accumulated MESH for the 31st Oct 2020 Brisbane hailstorm. Collected reports also shown.

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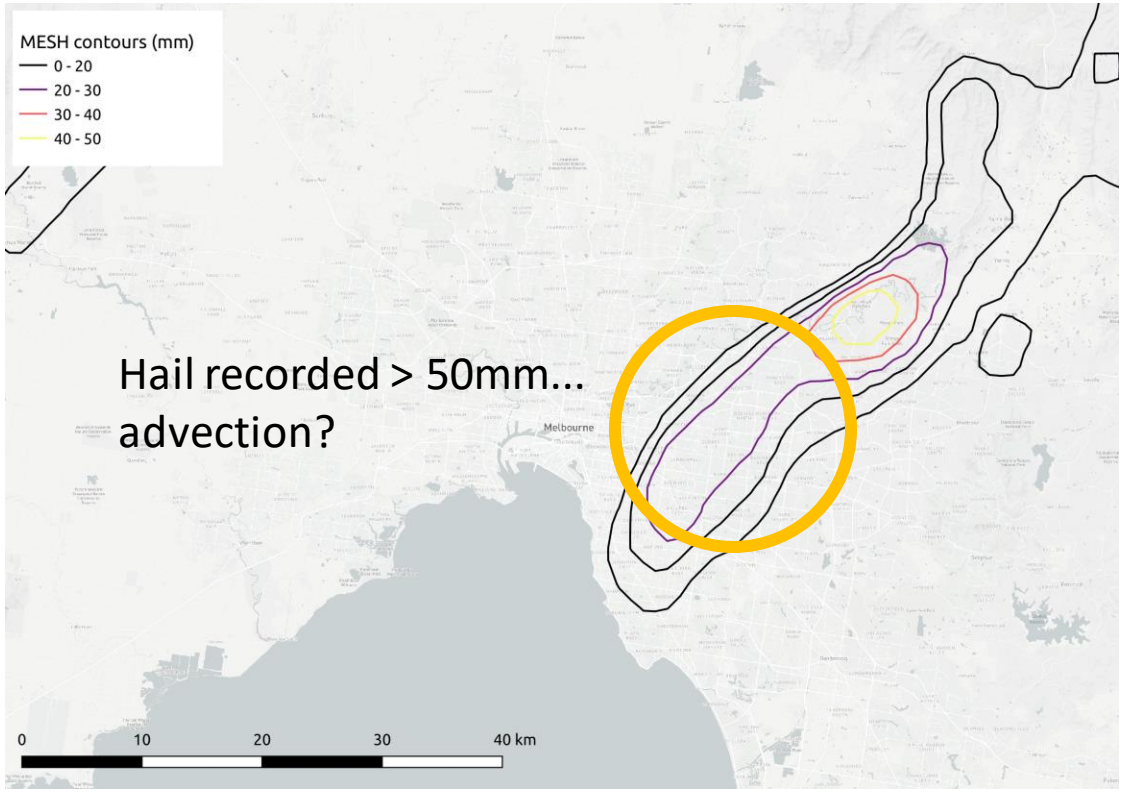

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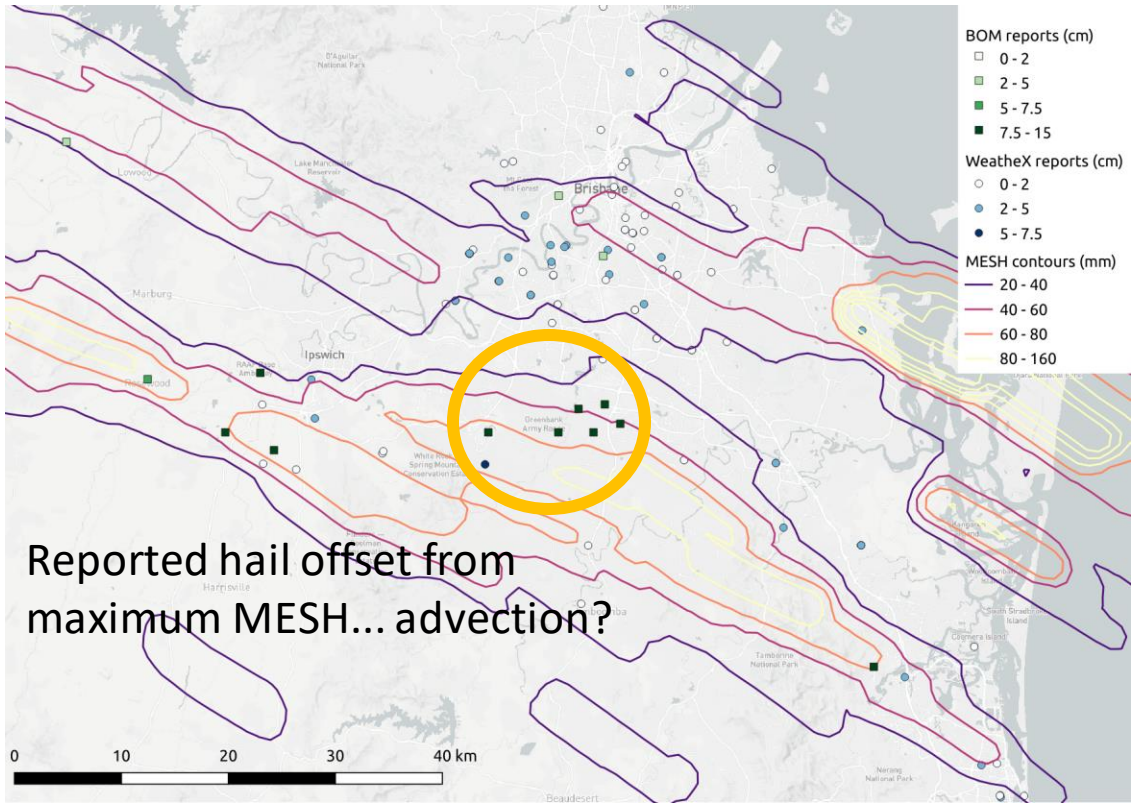


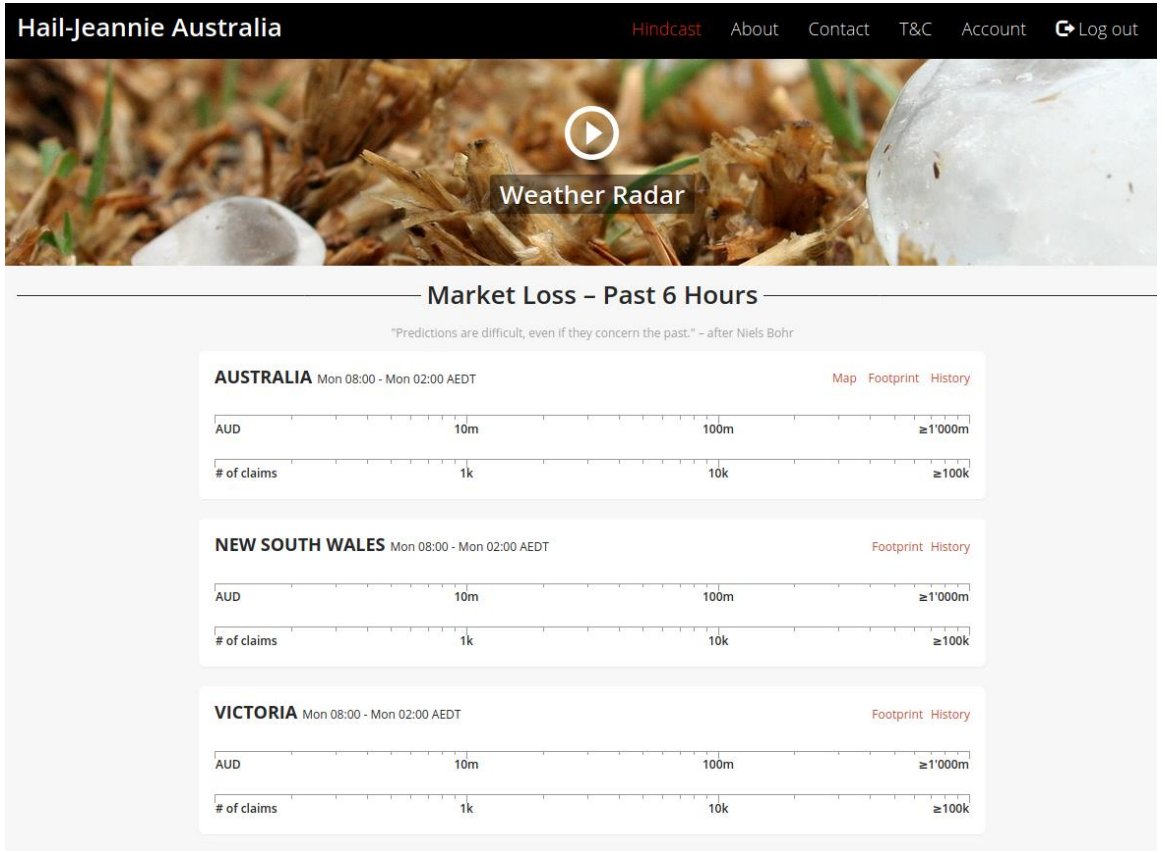
Contoured accumulated MESH for the 31st Oct 2020 Brisbane hailstorm. Collected reports also shown.

MESH for event response and loss modelling

Despite the limitations, MESH has useful skill for estimating hail impact that has significant value beyond generating warnings. This includes:

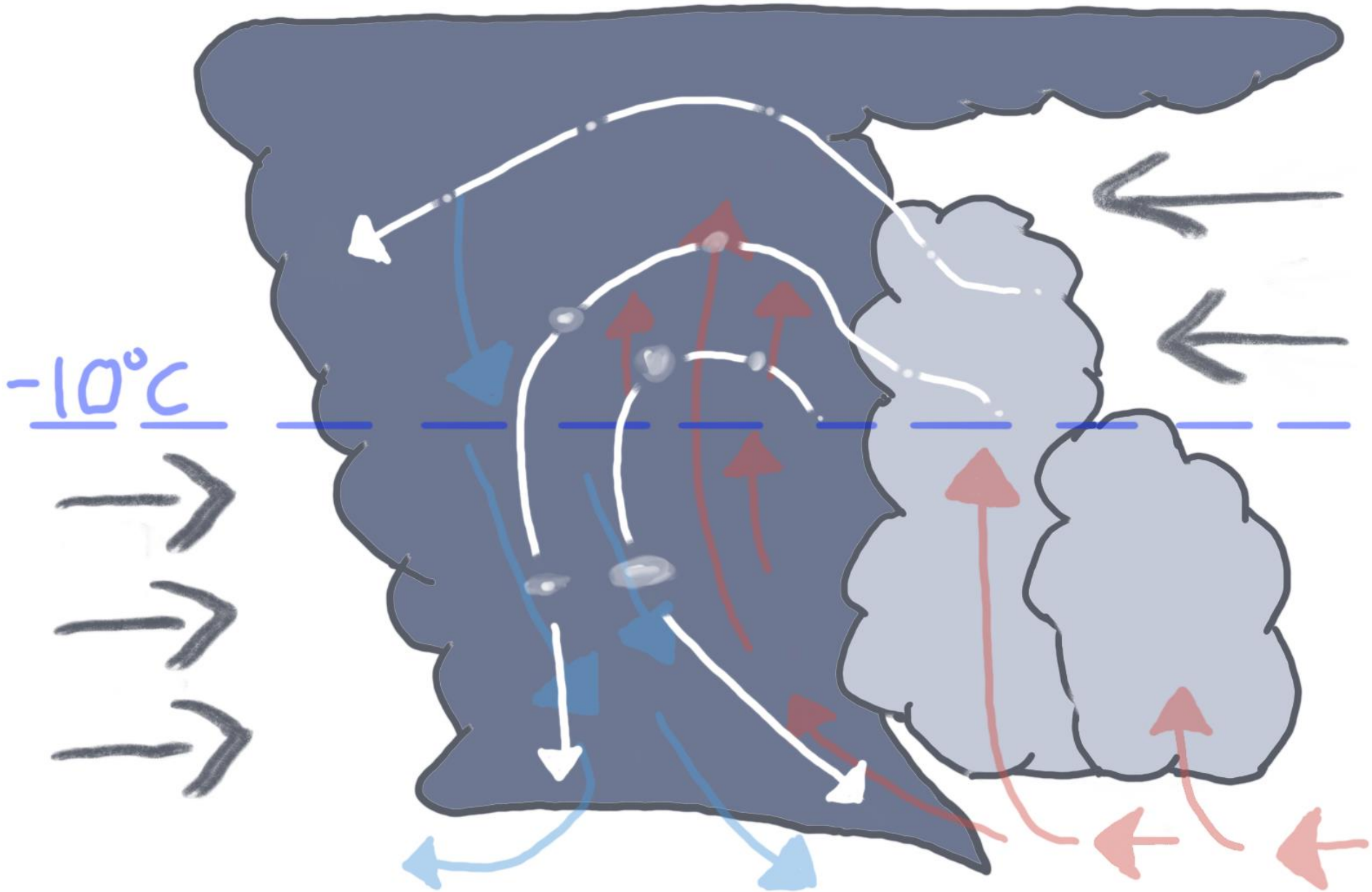
- For accelerating response and recovery
  - Impact mapping for SES
  - Energy distribution interruption
  - Insurance claim capacity and validation

- To estimate market loss
  - Motor/property loss
  - Agriculture loss
  - Solar generation loss

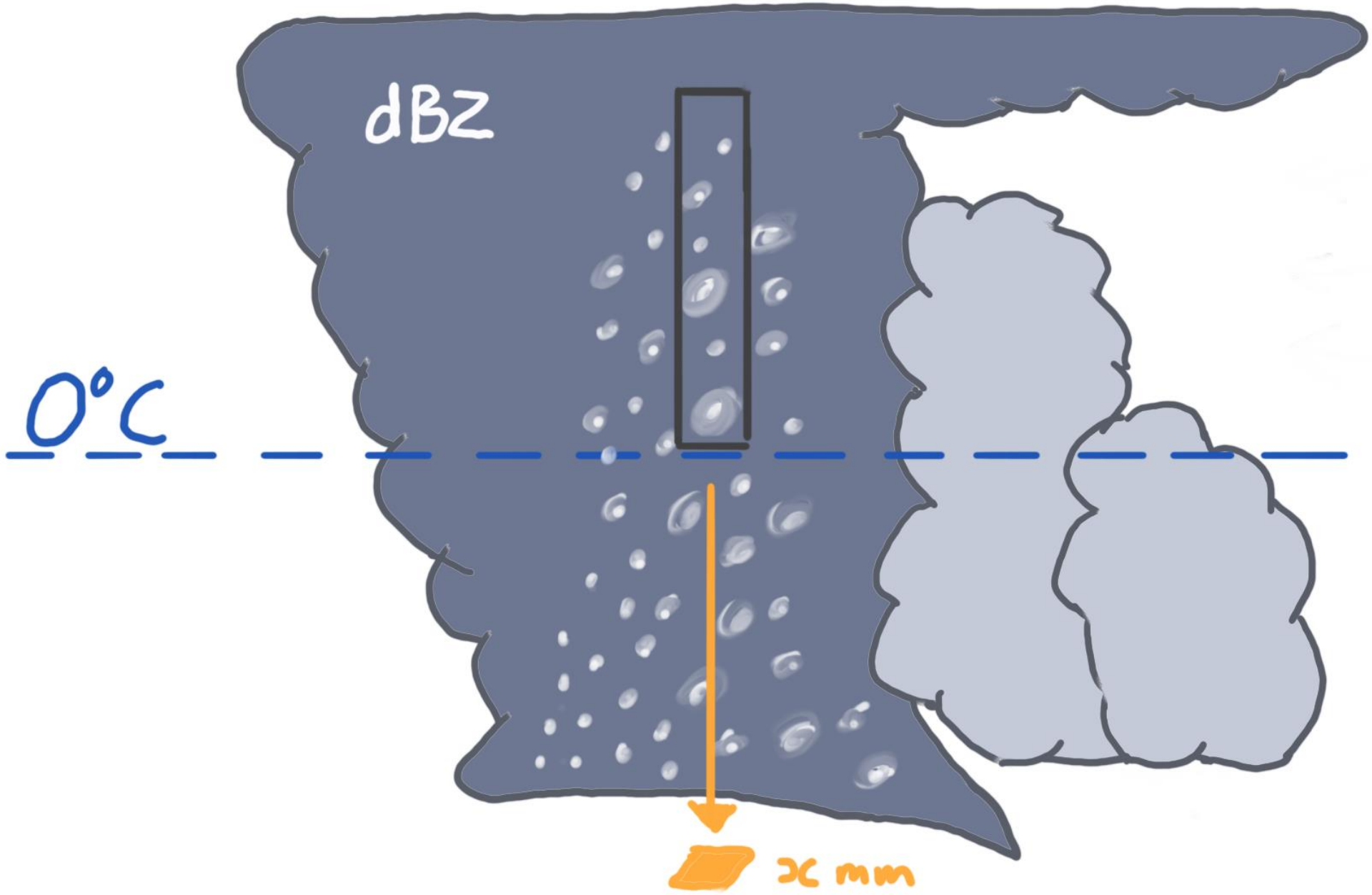


PERILS Hail-Jeannie platform for estimating hail-related insurance market loss

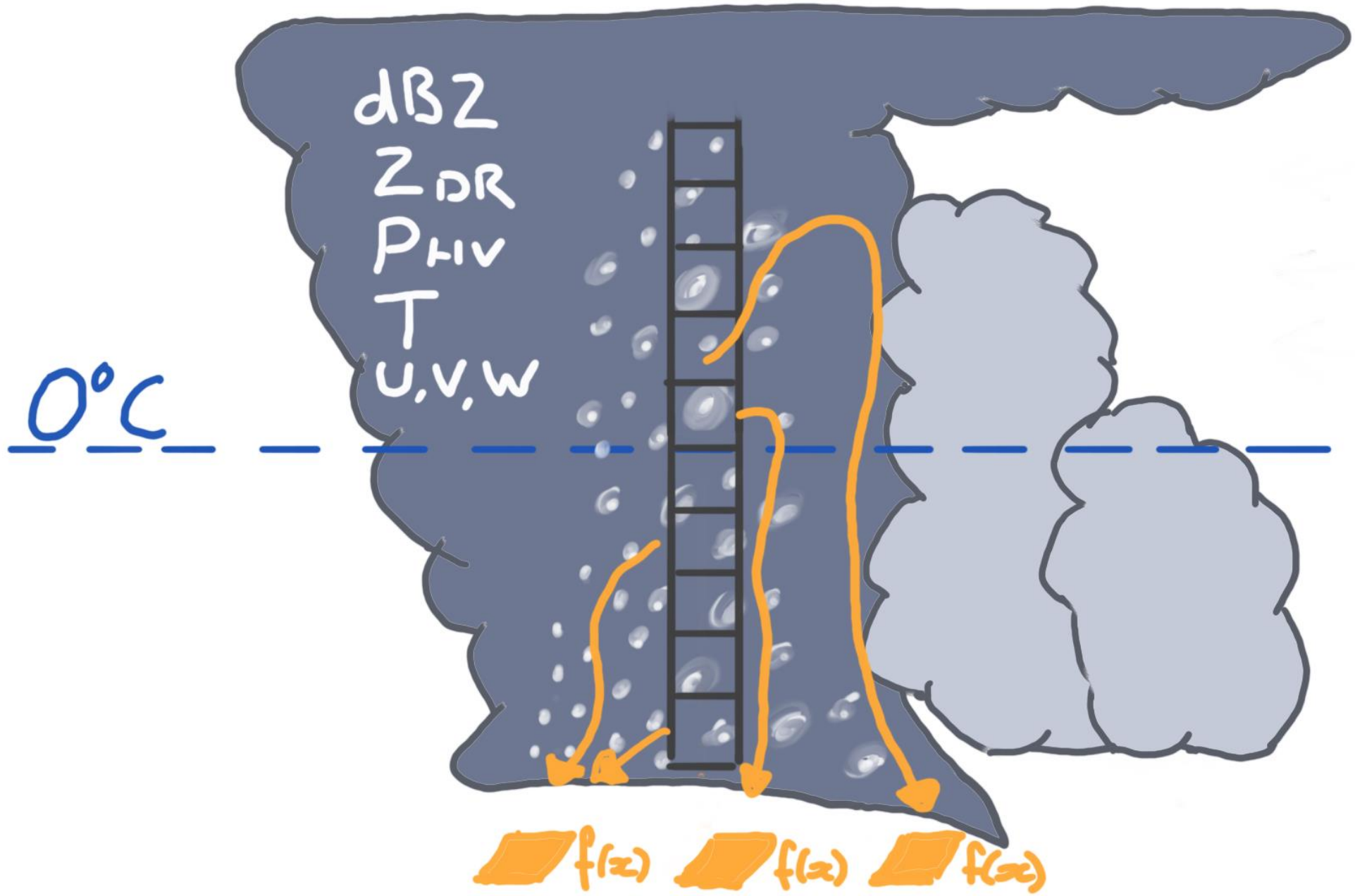
Limitations of Conventional Analysis



Limitations of Conventional Analysis



Polarimetric and 3D Wind Analysis



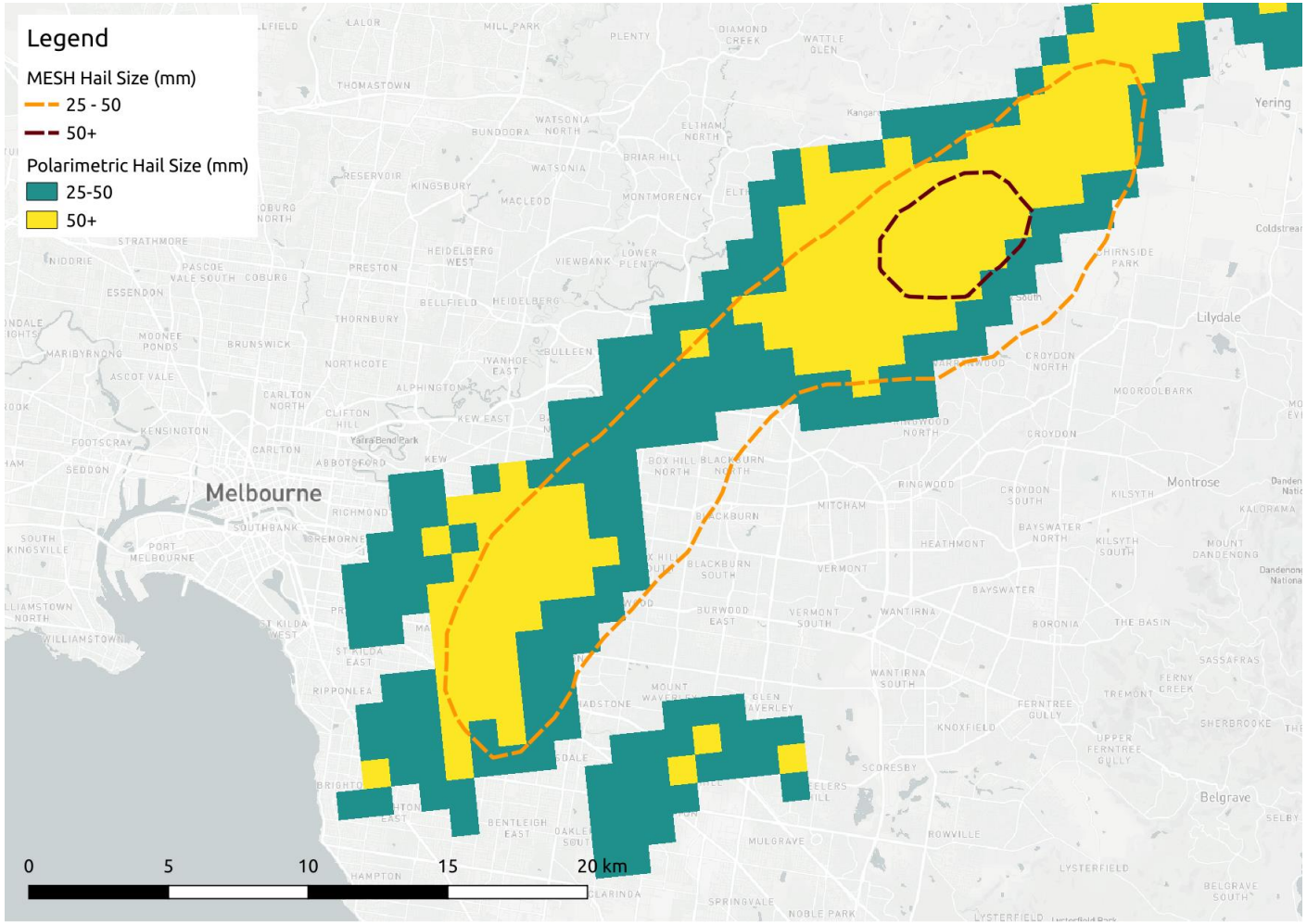
Polarimetric Analysis

Polarimetic information provides insight into precipitation shape and homogeneity, improving upon the intensity-based MESH technique

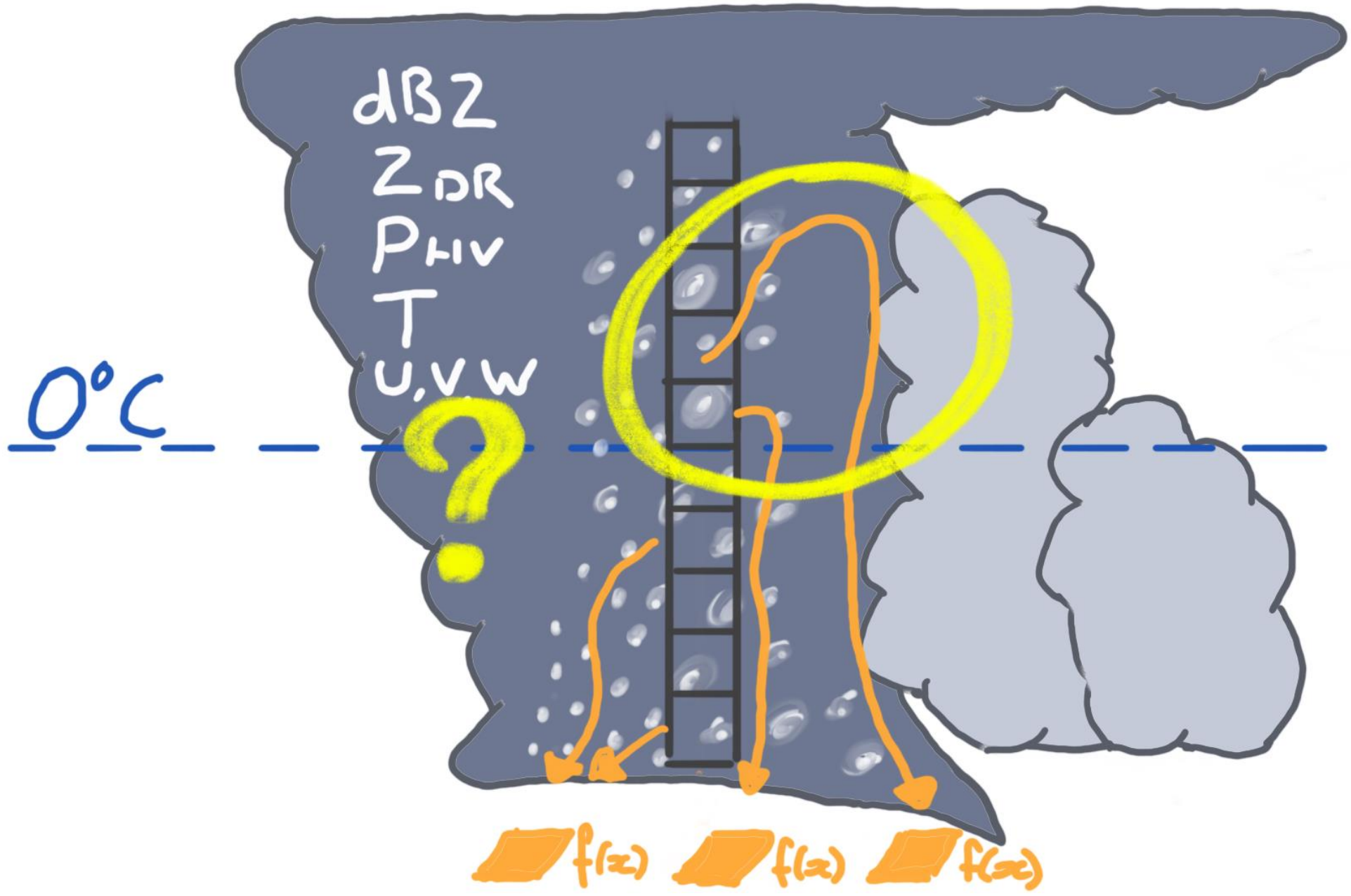
Also provides low level information, more accurately representing surface impacts

Further improvements are achived using 3D wind retreivals to model hail trajectories into the near future (Brook et al. 2020)

Evaluation: Hail size reports (growing) and insurance loss datasets (IAG)



Hail Growth



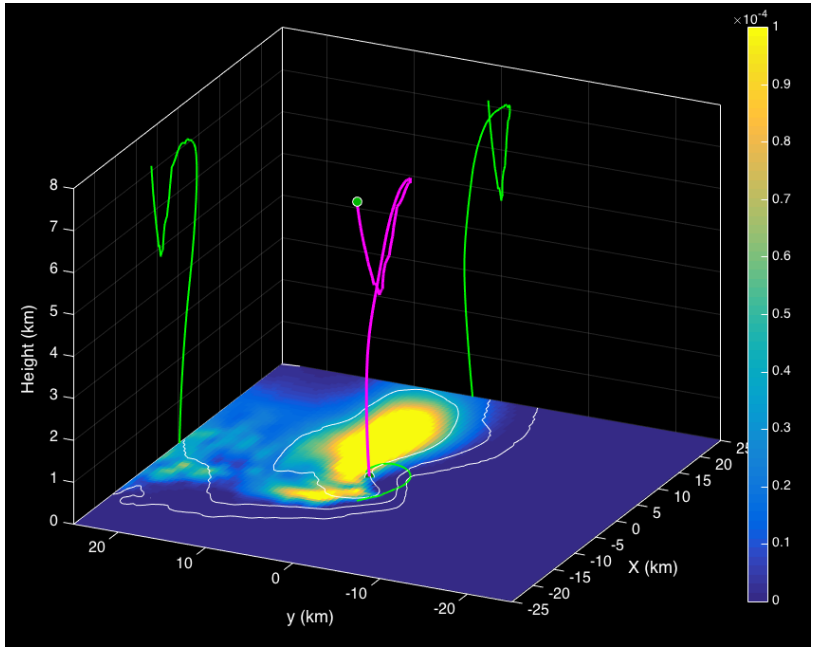
Hail Growth

Modelling hail growth and trajectories is feasible, including the simulated radar signatures, but verification is challenging.

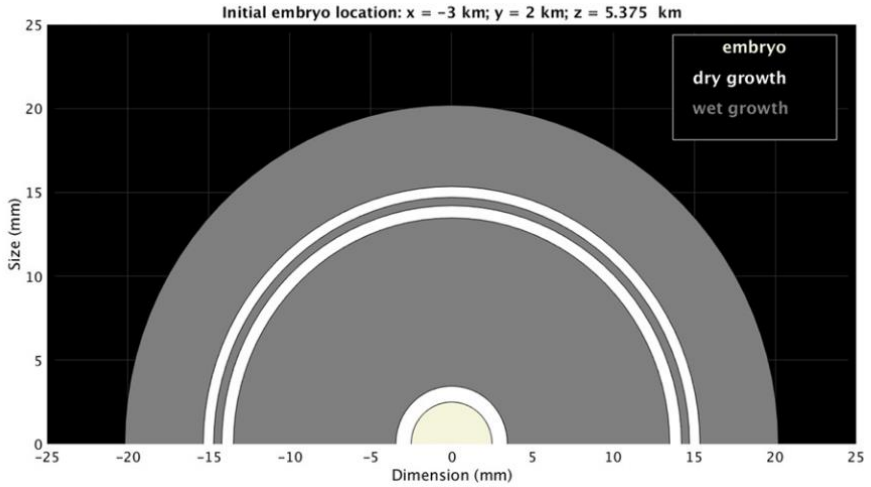
Shopping List:

1. Better understanding of relationship between shape, density and fall speed (which drive accretion, ventilation and trajectories)
2. Validation of growth regimes (which drive shape and structure)
3. Validation of hailstone trajectories

<u>Currently it's not possible to satisfy these requirements, limiting further improvements to hail analysis.</u>



Modelled Hailstone Trajectories (Kumjian et al. 2019)

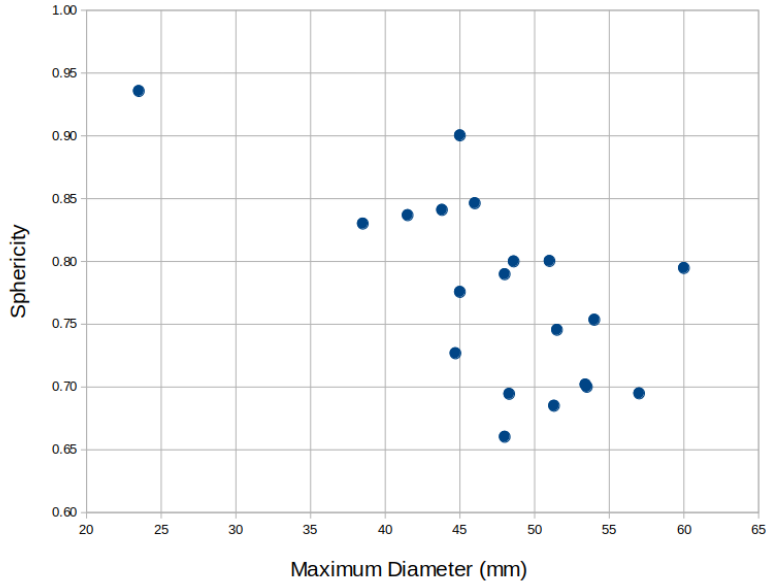


Modelled Hailstone Growth (Kumjian et al. 2020)

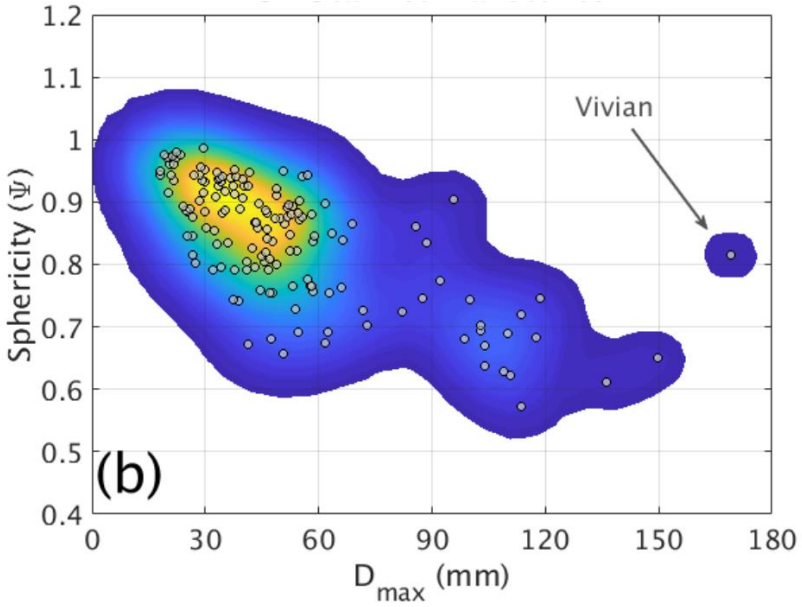
Hail Growth

Hailstone Shape

- Hailstone shape is closely related to the maximum diameter and growth regime, where it becomes increasingly oblate with increasing diameter.
- To accurately measure shape properties, 3D scans of hailstones are required



Analysis of (20) 3D scanned hailstones from the Melbourne event



Analysis of (150) 3D scanned hailstones from the US (Shedd et al. 2020)

Hail Growth

Hailstone Shape

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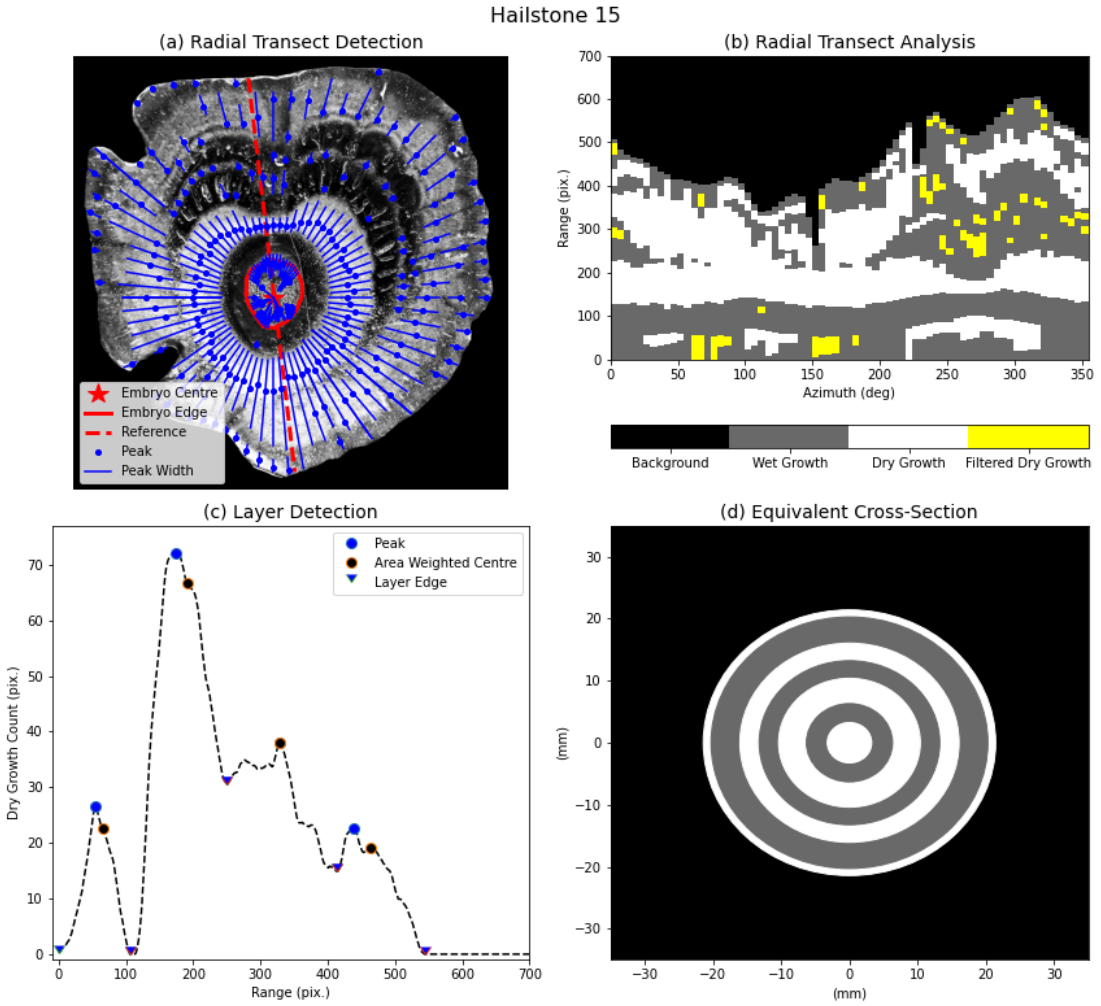
Hailstone Growth Regime

- The formation of opaque or clear ice a response to whether collected water droplets freeze near-instantaneously or not (which is a function of the accretion rate and thermodynamics)
- Growth regime drives hailstone shape, where slower-freezing clear ice leads to the growth of lobes



Measurement of hailstone cross-section growth regimes

Summary

Conventional Analysis

- Has limitations, but useful skill for assessing hail severity
- Underutilised in operations (verification, nowcasting) and in industry (event response and impact-based modelling)

Modern/Experimental Analysis

- Physically-based retrieval and modelling of hail using polarimetric and 3D wind information will significantly improve upon conventional analysis
- Predicting growth rates will further increase the accuracy of hail retrievals, and provide additional lead-time.
- Wealth of data from recent events that will provide new insight into hail growth and exceptionally giant hail.