STORM HAZARDS TESTBED

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Australian Government
Bureau of Meteorology

Earth Systems and Climate Change Hub
National Environmental Science Programme

The University Of Queensland
AUSTRALIA

GUY CARPENTER

ROAMES™ FUGRO

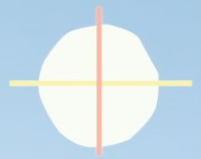
Argonne NATIONAL LABORATORY

1. Weather Radars & Hazard Detection
2. Storm Hazards Testbed
3. Platform
4. Climatology Applications

Weather Radar & Hazard Detection

Weather Radars

Rain



Hail

- Buckland Park
- Mt Stapylton
- Melbourne
- Terry Hills

With dual-pol technology, a radar uses both horizontally (H) and vertically (V) polarized beams, instead of only H

1. Ratio of returned H and V gives a measure of target shape and orientation **(Z_{dr})**
   - Tumbling hail vs oblate large rain drops
2. Correlation between H and V returns gives a measure of homogeneity **(ρ_{hv})**
   - rain vs rain and hail
   - tornadic debris
3. Phase shift between H and V gives a measure of liquid water content **(θ_{dp})**
   - Sensitive to rain (no change for hail)

Large Hail Detection

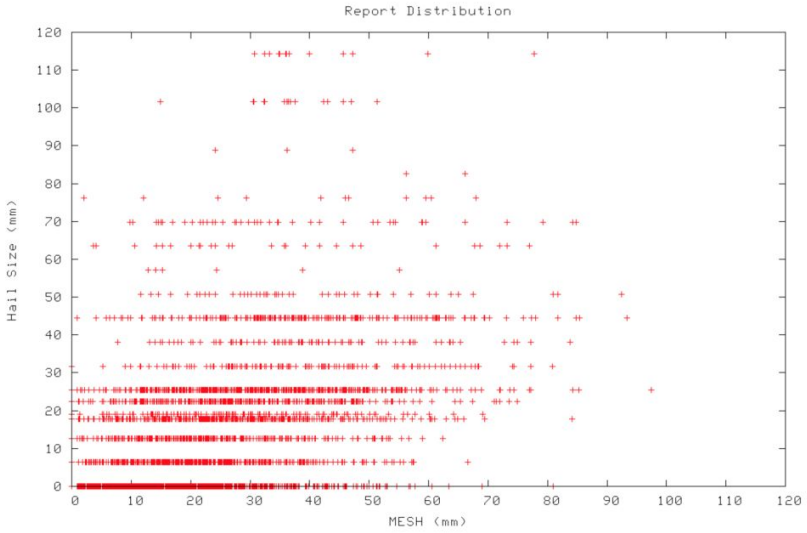
Single Pol

Maximum Estimated Size of Hail (MESH)

Regrided reflectivity data is vertically integrated and weighted according to 0 °C and -20 °C heights.

Poor verification - some use for severe vs nonsevere

Applied across forecasting and industry



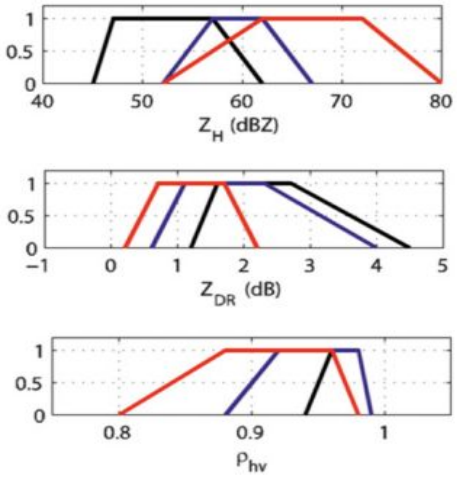
Reports vs MESH from SHAVE (Wilson et al. 2009)

Dual Pol

Hail Size Discrimination Algorithms (HSDA)

Applies physical relationship between dual-pol moments, temperature profile and hail distributions

- Applied to the rain/hail PID region
- Membership functions for three hail size categories (< 20 , 20 - 50, > 50 mm)
- Significant improvement over MESH (POD and FAR) (Ortega et al. 2016)
- Sensitive to ZDR quality :-)



Red: > 50 mm
Blue: 20-50 mm
Black: < 20 mm

Membership functions for near surface (melting) hail (Ryzhkov et al. 2013)

Large Hail Detection

No one-to-one relationship between Z and hail size

Hail size has a distribution

Different distributions have the same Z

- Sparse Giant hail (50 dBZ)
- Heavy rain and small hail (50 dBZ)

Hail size distribution changes with height

- Melting
- Sorting

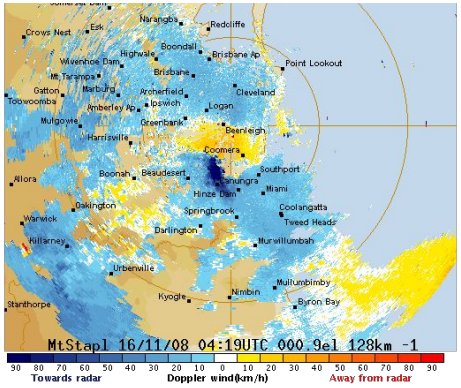
Large hail approaches the radar wavelength - Change from Rayleigh to Mie scattering - no linear relationship between hail size and scattered Z

Dual Pol can help!

Damaging Wind Detection

Doppler Wind

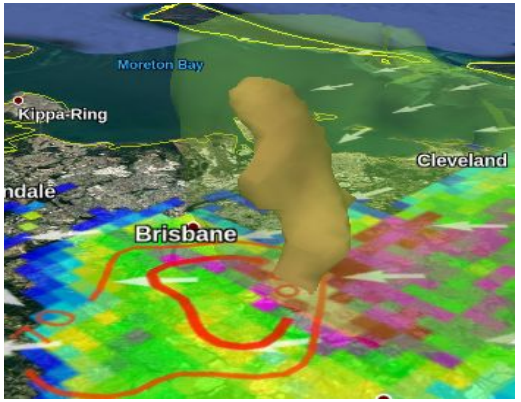
- Many BoM radars measure Doppler Wind (radial component of wind field)
- Lowest tilt of 3D scans surveys approximately 200-400 m ASL (within 80 km)
- Quantification difficult due to perspective of radial wind
- *Relationship between gust speed and feeder lockouts (Darveniza et al. 2007)*



27 -11-2014 Hailstorm

Wind Retrieval Algorithms

- Robust statistical algorithm to retrieve 2D wind field from single Doppler (Xu 2006)
- Variation technique to retrieve 3D wind field from multi Doppler (Protat 1999)
- Limited by small wind events (< 3 km in diameter), radar range (resolution), radar beam height, coverage, cold pool depth



27 -11-2014 Hailstorm showing
> 90 km/h gusts over the Archerfield area

Storm Hazards Testbed

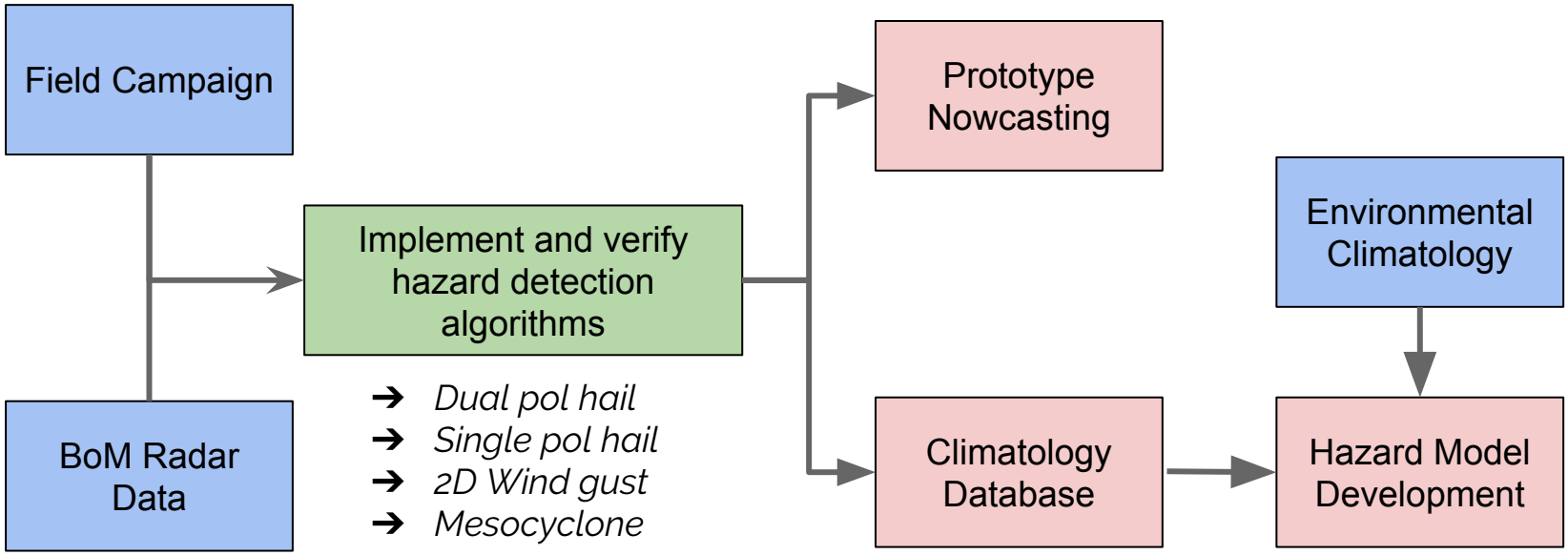
Testbed Aims & Objectives

Deliver hail and wind detection tools for the Australian radar network using the latest operational and research technology

1. Implement, calibrate (adapt) and verify radar-derived hazard algorithms
   a. Single pol hail
   b. Dual pol hail
   c. 2D wind retrievals
   d. Mesocyclone detection
2. Implement algorithms within a prototype real-time nowcasting platform
3. Apply algorithms to produce a radar-derived hazard climatology across the national radar network
   a. 20 year hailstorm frequency (single pol hail)
   b. 10-15 year windstorm & mesocyclone frequency (2D wind retrievals)

Roadmap

Linking the science of thunderstorms to hazard detection and modelling.



4 year Research Program

- 2-3 year data collection (field and citizen science)
- Full time research scientist
- 2 PhD and 4 honours projects

Algorithms

- **Dual pol hail**
  - *Implement Gary Wen's clustering PID and NCAR fuzzy-logic HCA to identify rain/hail regions (X and S band)*
  - *Apply HSDA algorithm to S band and provide verification*
  - *Explore application of combining HSDA, ZDR columns and BWER detection to improve nowcasting lead-time (research)*
  - *Integrate into real-time nowcasting testbed (Amazon platform)*
- *Single pol hail*
  - *Verification of MESH in an Australian context + Z correction (clutter/TRMM)*
  - *Explore improvements relating to hail core tilt*
- *2D Wind gust*
  - *Single Doppler retrieval (Xu 2006) and multi Doppler variation technique (Protat et al. 1999)*
  - *Explore application of boundary layer wind model calibration using AWS and in situ measurements*
- *Mesocyclone*
  - *QC of Doppler noise (mostly dual-PRF; Altube et al. 2016)*
  - *Miller et al. 2003*

Now for the observations...

Field Campaign

BoM & Mt Stapylton Dual-pol

UQ-XPOL Deployment Team

2 min volumes (16 tilts)

http://radar.uqhail.com

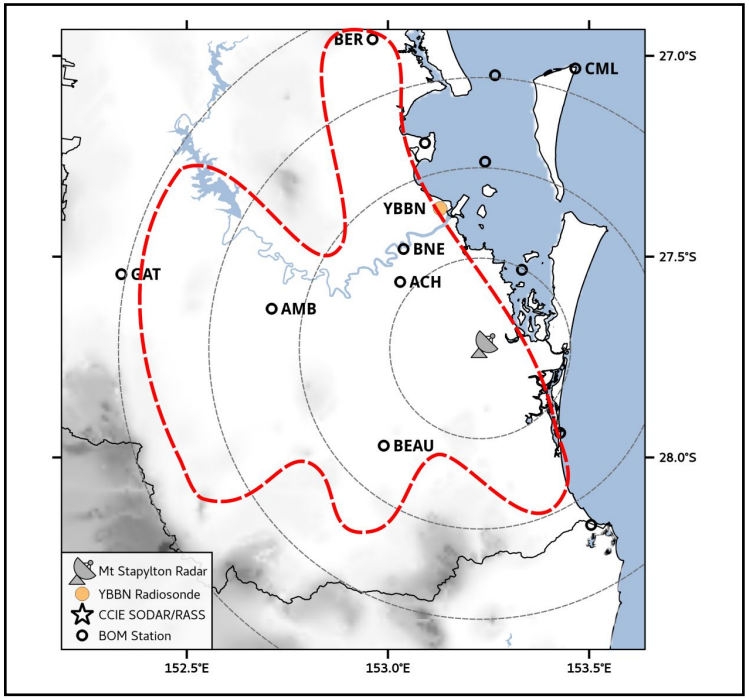
In Situ Deployment Teams (2)

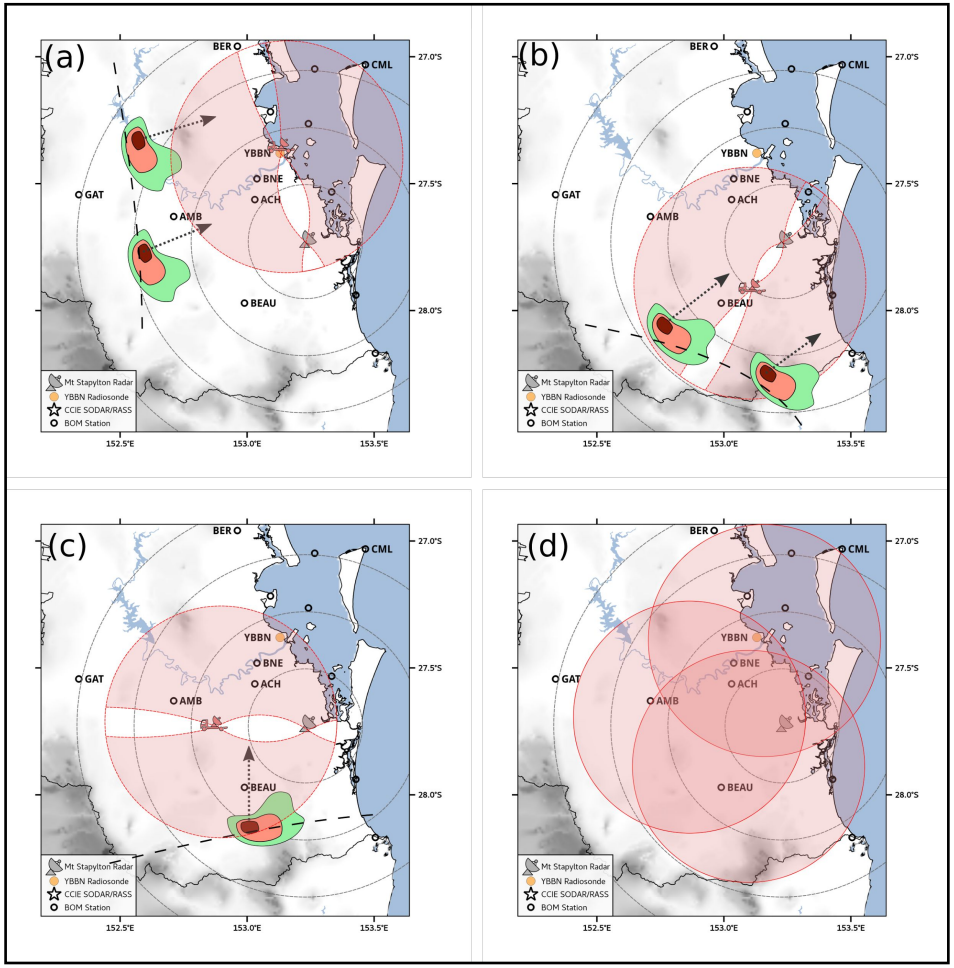
World first mobile field campaign targeting hazard verification

Verifying radar-derived hail size through dual-frequency (UQXPOL and Mt Staplyton), dual-pol observations and surface hail disdrometers.

Verifying radar-derived near-surface winds through surface observations and high resolution mobile radar.

Field Campaign

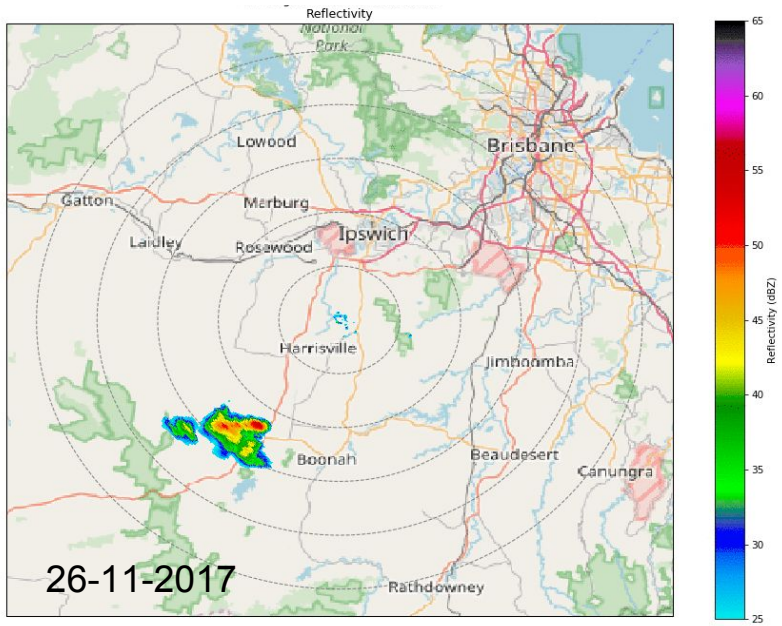




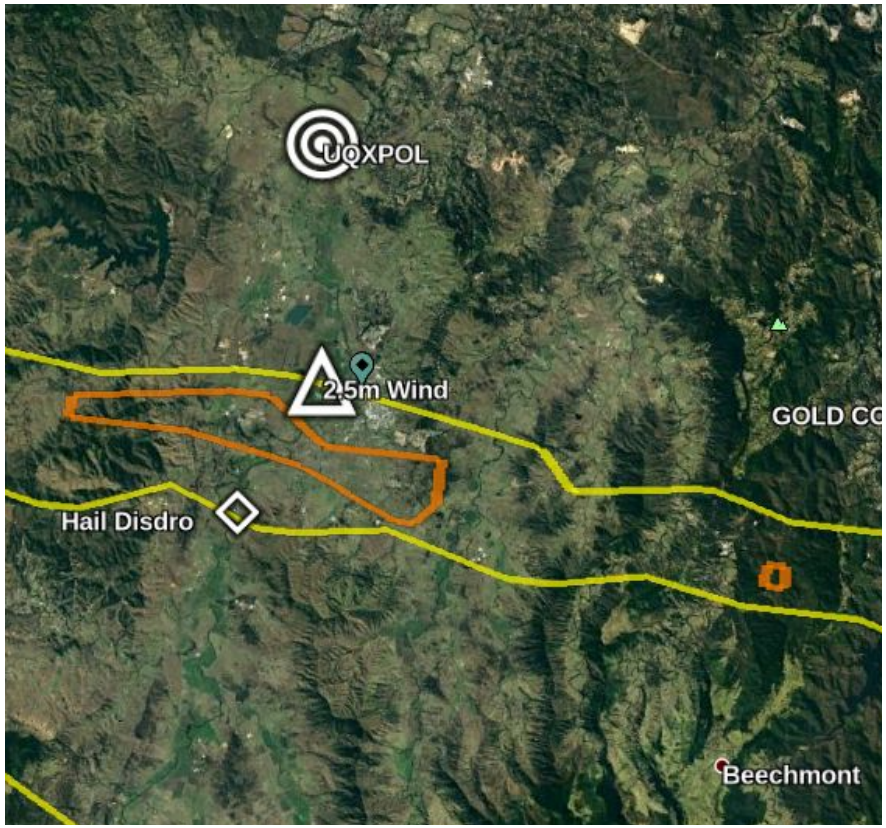
1. Surface measurements of hail size (mobile disdrometers) and the evolution of the hail core aloft using dual-polarised radar moments (fixed and mobile radar)
2. Observations of surface gusts (mobile towers) and the evolution of cold pool structure aloft using Doppler radar moments (fixed and mobile radar)
3. Upper air data of pre storm environment from Brisbane Airport, mobile soundings and surface stations to characterise preconditioning processes.

Field Campaign - Oct 2017

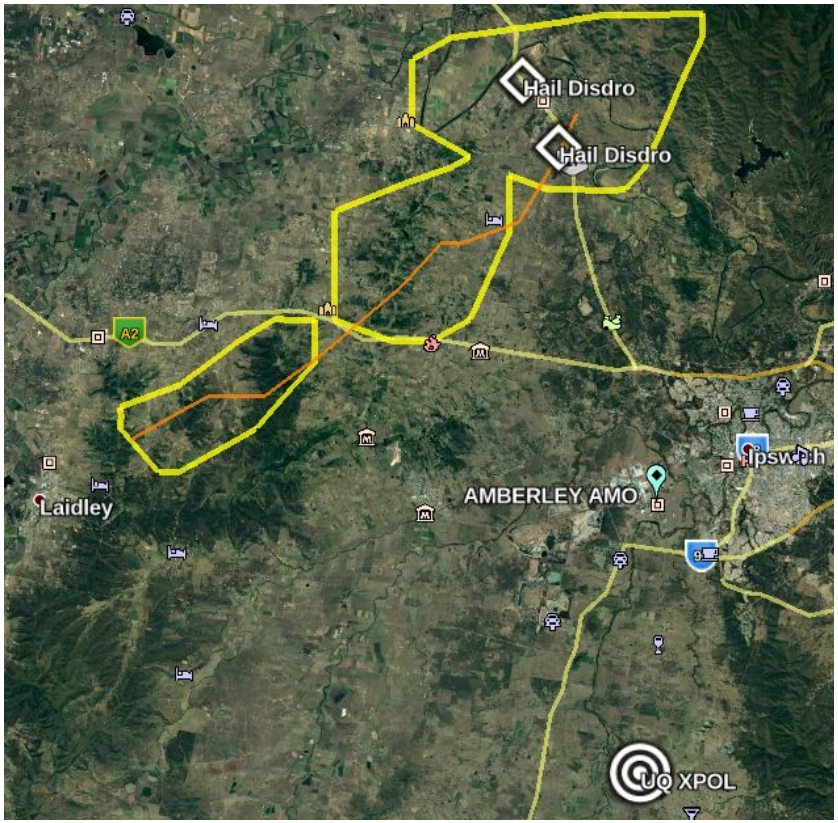
- 5 Operation days (3 full deployment)
  - UQXPOL, radiosondes & in situ
- 3 successful disdrometer deployments
  - 2 have sampled 1-2 cm hail
  - 1 has sampled 2-4 cm hail
- 1 wind tower deployment
- 64 hail size reports across social media and uqhail.com (another 20 from Tues)



Field Campaign - Oct 2017

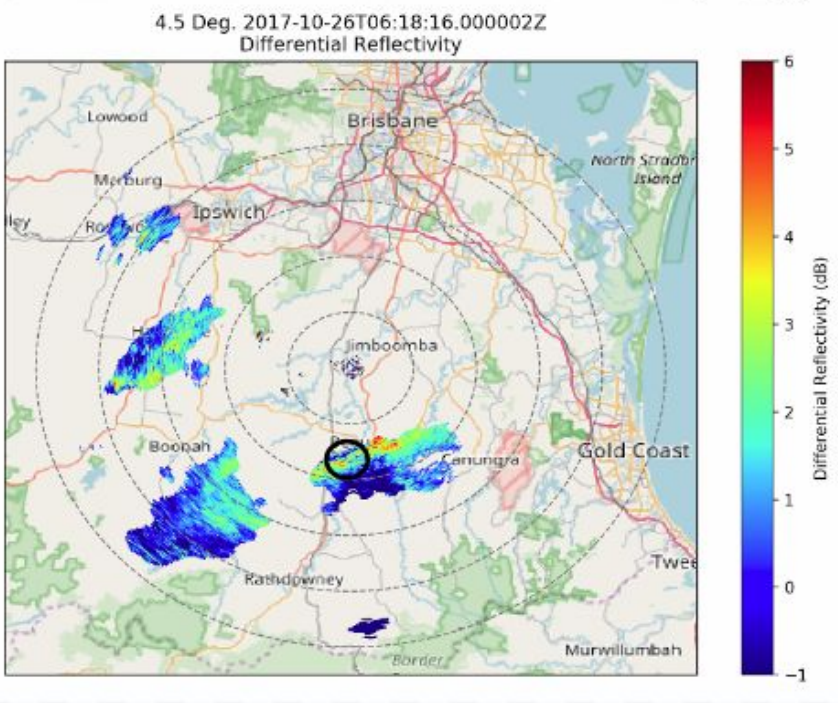


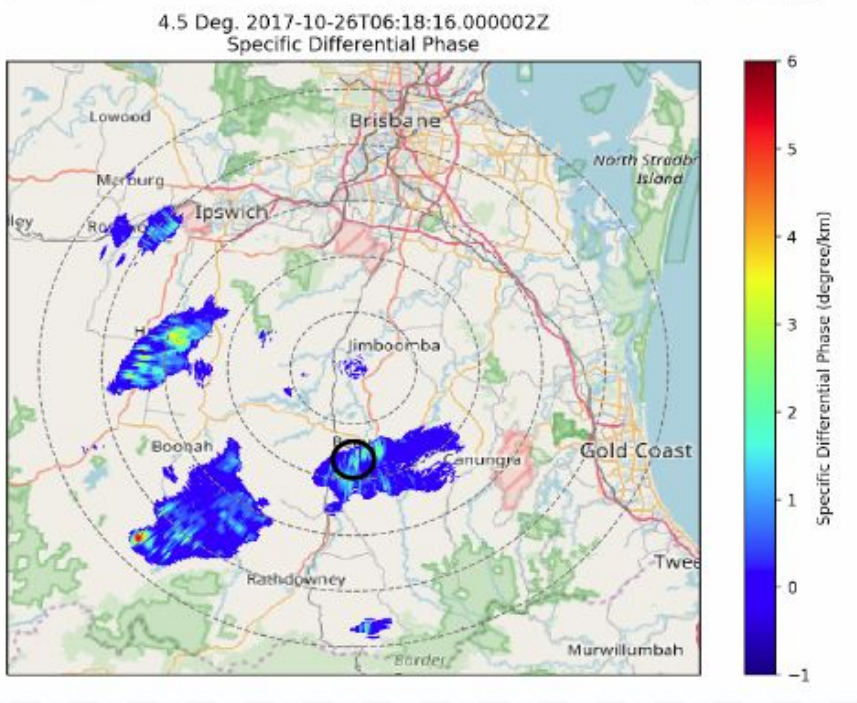
Deployment sites for 26-10-2016 showing UQ-XPOL (target), 2.5 m wind tower (triangle) and hail disdrometer (diamond). Mt Stapylton derived hail contours (MESH) at 15 mm (yellow) and 30 mm (orange) shown.



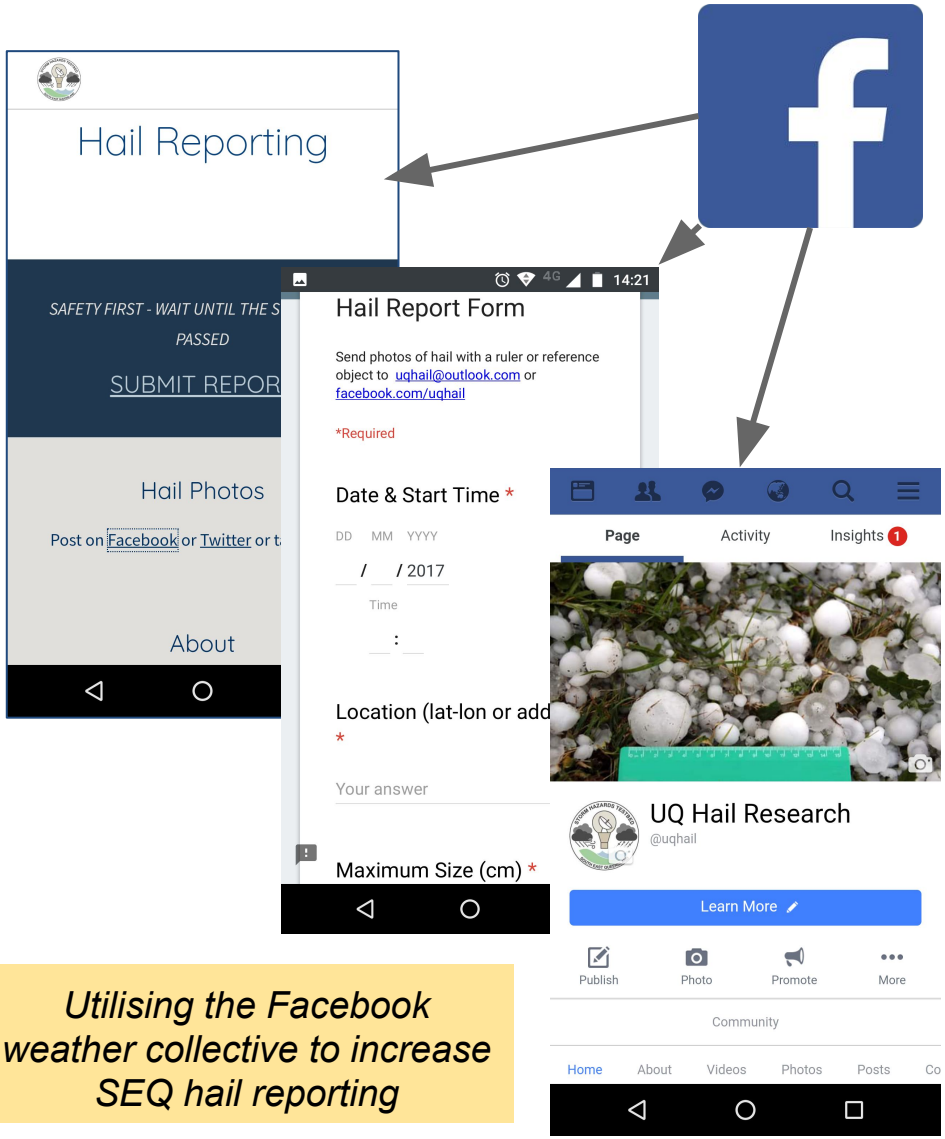
Deployment sites for 29-10-2016 showing UQ-XPOL (target) and hail disdrometers (diamonds). Mt Stapylton derived hail contours (MESH) at 15 mm (yellow) shown.

Field Campaign - Oct 2017





Engagement



Utilising the Facebook weather collective to increase SEQ hail reporting

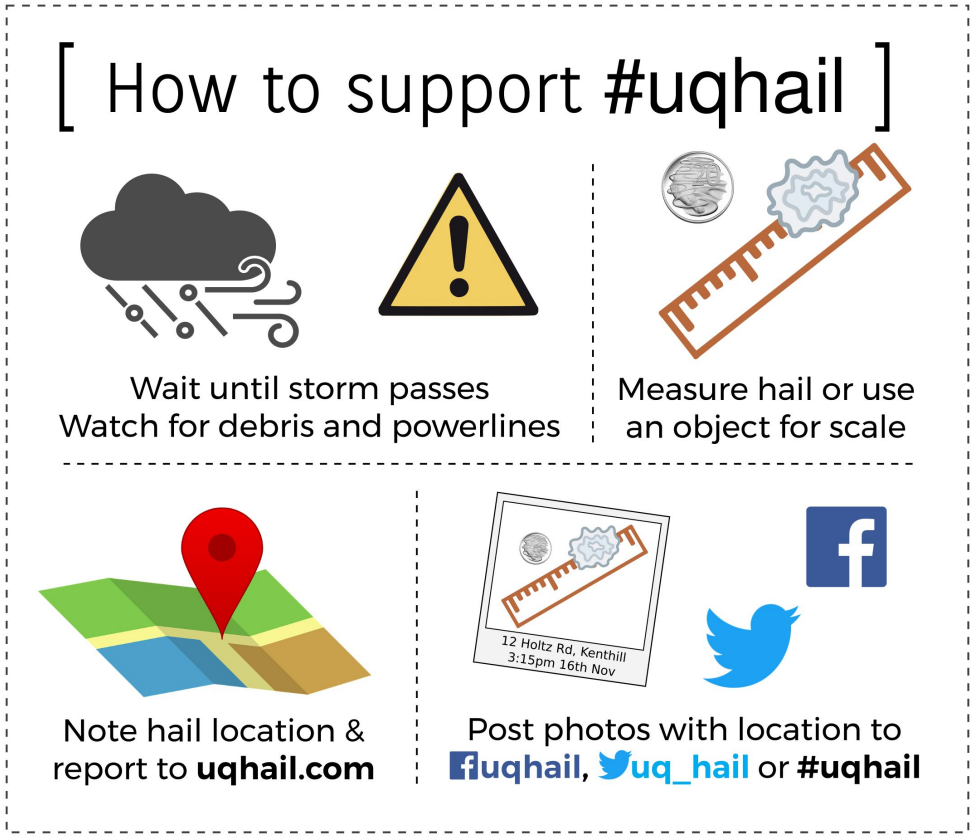
QRO Engagement

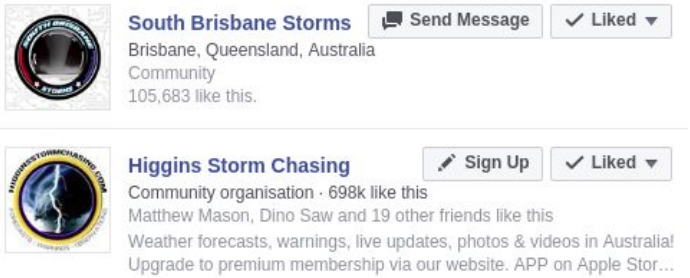
- ➔ Forecaster briefings
- ➔ Adaptive radiosonde releases
- ➔ Staff supporting research team
- ➔ Collaboration on outputs

UQ

- ➔ Volunteers from undergraduate, postgrad, research staff, academics
- ➔ Collaboration across meteorology (AORG) and wind engineering (WIRL)

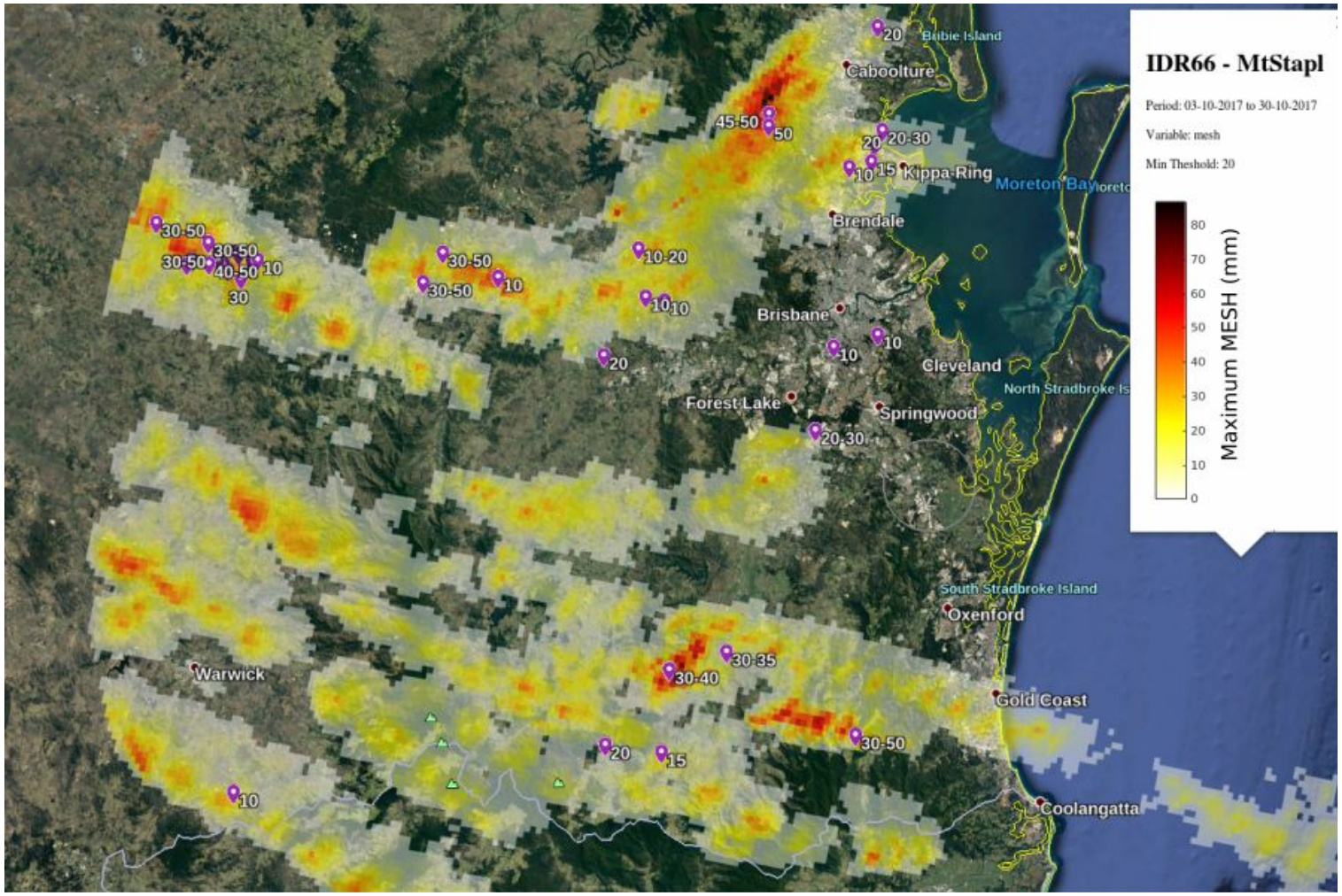
Citizen Science





- Print, radio, TV, online news (ABC, channel 7)
- BoM Twitter (more professional)
- Local Government Facebook
- Facebook Weather Groups

Citizen Science - October 2017



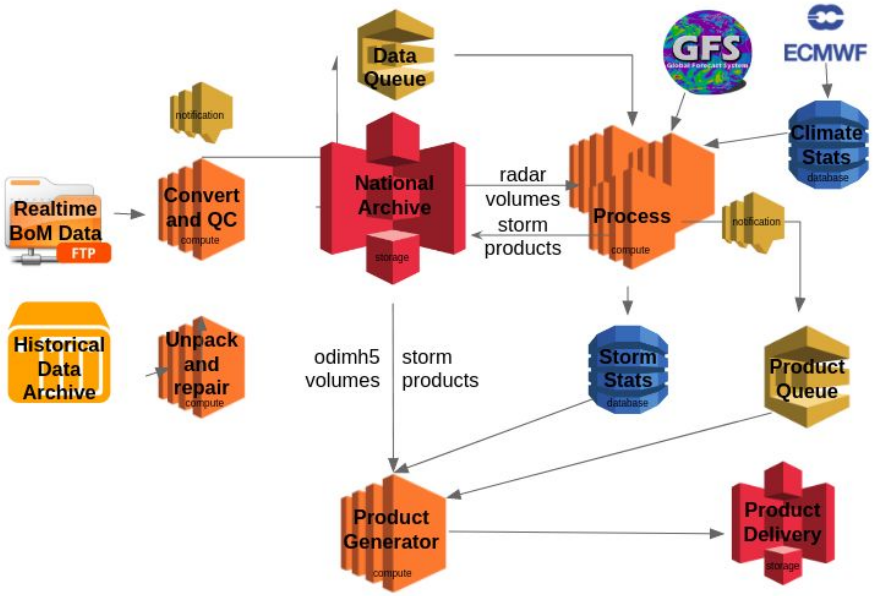
Maximum value of MESH (mm) during October 2017 derived from Mt Stapylton radar. Public hail reports collated by the uqhail citizen science initiative. Location shown with a purple marker and hail size labelled (mm).

Platform

Prototyping Platform

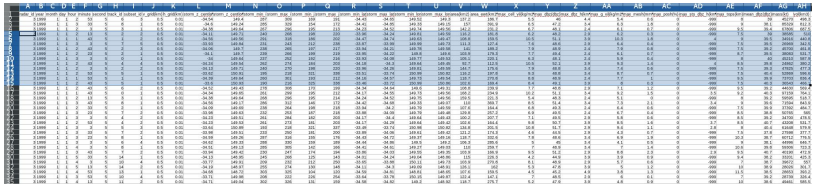
- One platform for nowcasting and climatological (decades of data) processing
  - One database
  - One compute pipeline
  - One storage point
- Complete automation and scalable from one radar to > 700 years of historical data (30 TB).
- Capable of handling the diversity of Australian radars
- Modular/objective - easy to add new capabilities

Amazon Web Services Pipeline



Outputs

Spreadsheets (with a few 100k rows)

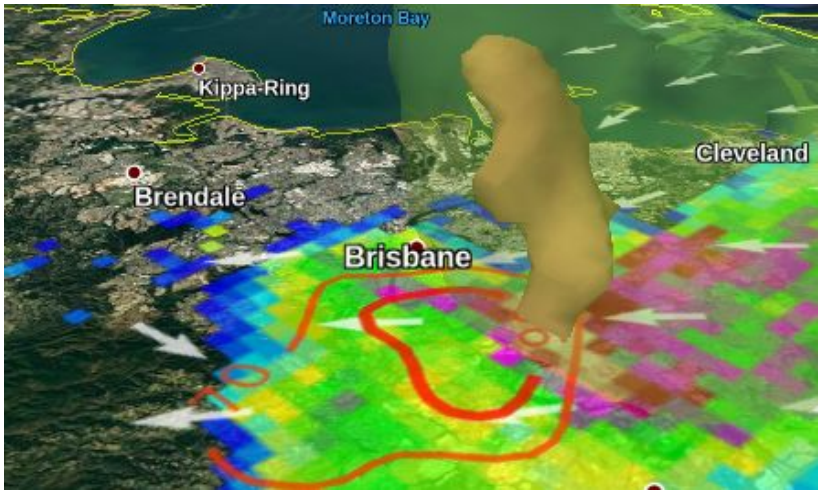


Data Service

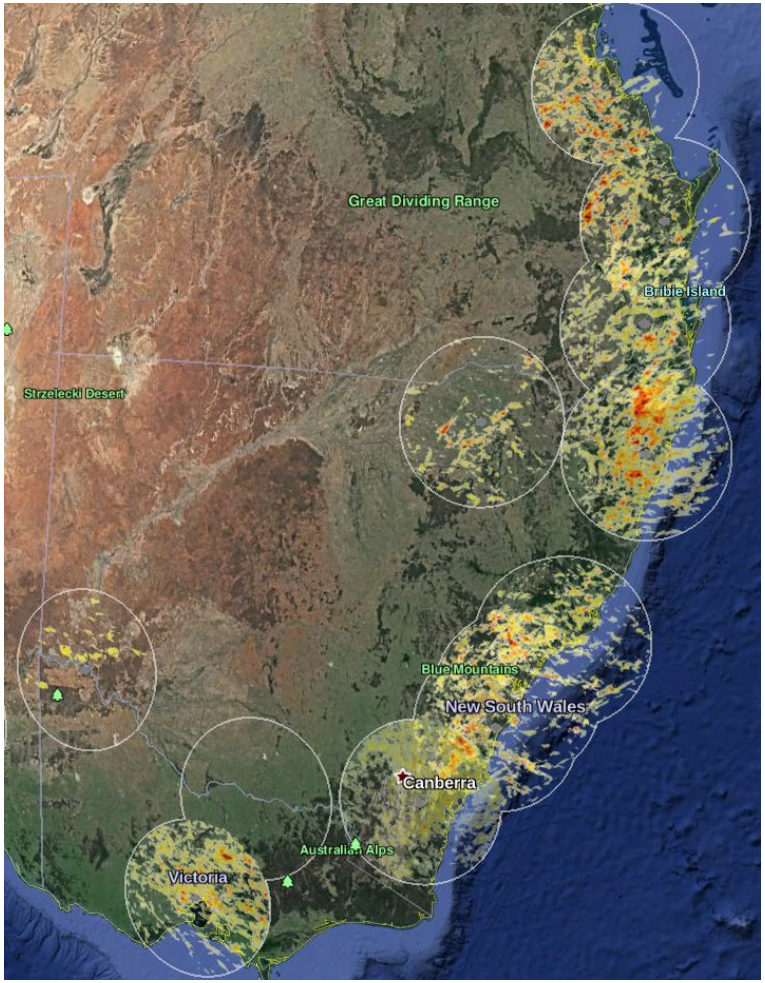
```
#Connect to the s3 radar bucket containing data
conn = S3Connection(anon = True)
bucket = conn.get_bucket('roames-wxradar-archive')

#Create the query string for the bucket knowing
#how ROAMES stores their radar data in s3 (odimh5_archive/ID/yyyy/mm/dd/)
my_pref = "odimh5_archive/" + site + datetime_t.strftime('/%Y/%m/%d')
```

Case & Real-time Visualisation



Climatology Visualisation

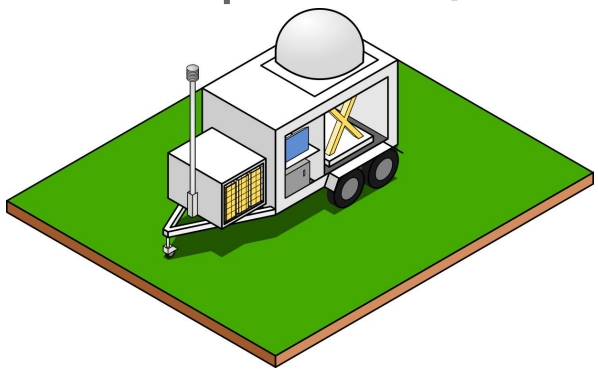


Real-time: PyART + Amazon

SNS
-Location
-Offsets

4G

Dual Pol data (tilts -1.5G/hr)



UQ-XPOL startup triggers Amazon Docker image in EC2

radar.uqhail.com

- In situ teams (tablet or mobile phone)
- Bureau of Meteorology
- Industry Partners
- Media
- UQ staff and students
- Public (Facebook etc)

Real-time Public 2 minute dual pol data from a mobile radar :-)

Climatology

Advantages

Radar provide a direct measurement of thunderstorm intensity, structure and dynamics. Limited by outages, range and attenuation.

- Hail/tops/density/size spatial analysis
- Storm track length/duration/direcion

Report-based climatologies are biased towards locales, time of day, reference objects. Inconsistent.

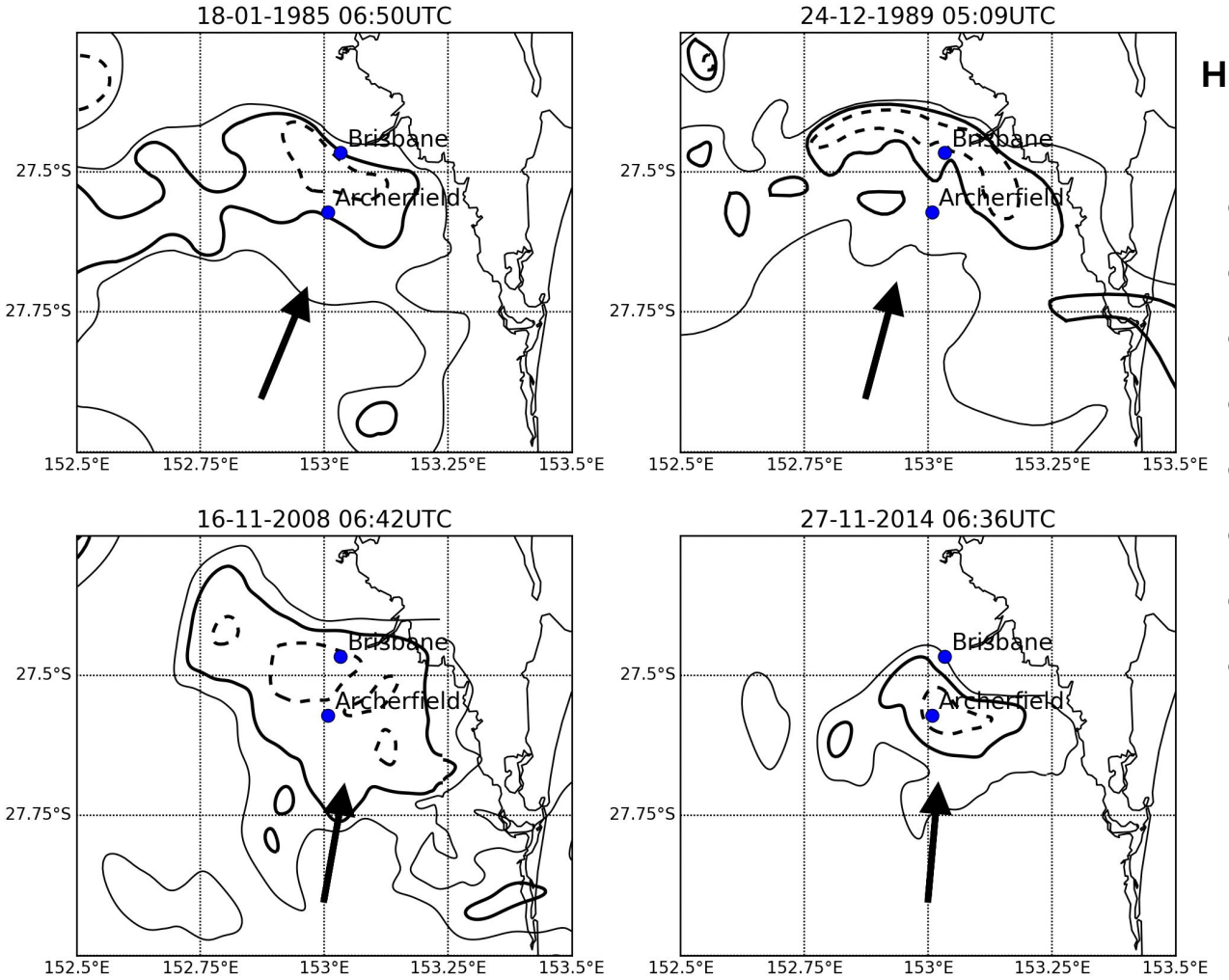
Reanalysis climatologies capture the environment, not the convection. Finescale variability limitations.

- 768 years of radar data across (27 TB)
- Some sites > 20 year record
- Issues with diversity, outages and moving radars!

- Hail - Improve and expand long-term climatologies through QC and MESH verification
- Mesocyclone Climatology (supercell frequency - high impact weather)
- Straightline wind Climatology

Hazard model development

Changes in Technology



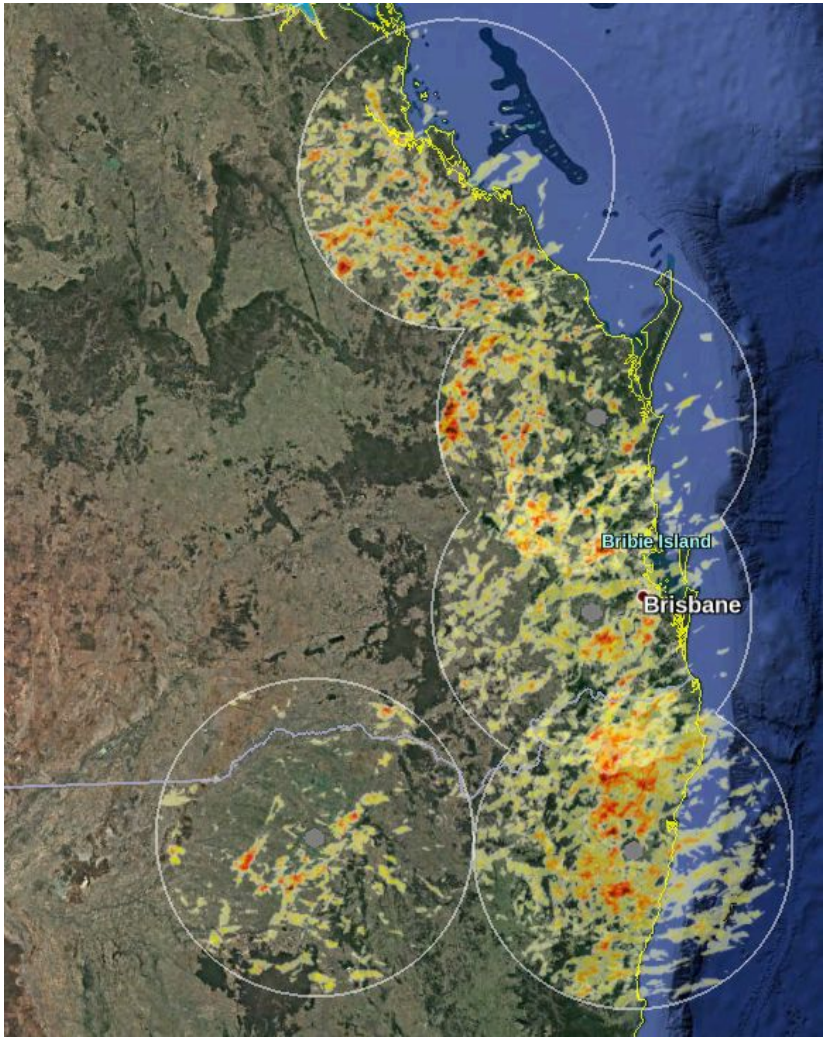
History of SEQ Weather Radars

- Eagle Farm - 277 (WWII)
- UQ Physics (1970s) - S
- Eagle Farm - WF44-C
- Brisbane AP - WF100-C
- Marburg - WSR74-S
- Mt Stapylton 1500-S
- CP2 S & X dual-pol
- Mt Stapylton 1500-S dual-pol

High impact thunderstorm cases shown with contoured reflectivity (30dBZ thin line, 40 dBZ bold line, 50 dBZ dash bold line)

Applications

- Ground truth for long-term environmental climatologies (e.g., calibrating parameters)
- Finescale hazard modelling (Risk)
- Distribution network management
  - Clearance vs Risk
  - Maintenance cycle
  - Assessment of new corridors
- Develop an understanding thunderstorm drivers
  - local (e.g., terrin, sea breeze)
  - synoptic (e.g., fronts, wind regimes)
  - climate scale (ENSO forcing)
- More to come!



Annual Hailstorm frequency (MESH > 20mm)

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Questions?