Hail Service: Qualitative to Quantitative

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Science

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Science

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Training
Hail damage cost in Australia

Annual average insured losses and total economic costs for 2006/07-2015/16

<table>
<thead>
<tr>
<th>Type of severe weather event</th>
<th>Average insured losses (A$ 2016/17, millions)</th>
<th>Estimated total economic costs (A$ 2016/17, millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storms and hailstorms</td>
<td>$1,059m</td>
<td>$2,119-$5,297m</td>
</tr>
<tr>
<td>Tropical cyclones</td>
<td>$486m</td>
<td>$971-$2,428m</td>
</tr>
<tr>
<td>Floods</td>
<td>$248m</td>
<td>$495-$1,239m</td>
</tr>
<tr>
<td>Bushfires</td>
<td>$233m</td>
<td>$465-$1,163m</td>
</tr>
<tr>
<td>Tornadoes</td>
<td>$28m</td>
<td>$55-$138m</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>$4m</td>
<td>$8-$20m</td>
</tr>
</tbody>
</table>

Source: London Economics analysis of Insurance Council of Australia data

15% can be avoided through effective warnings as per the same report, 2016
State Severe TS warning

TOP PRIORITY FOR IMMEDIATE BROADCAST

Severe Thunderstorm Warning

for LARGE HAILSTONES, HEAVY RAINFALL and DAMAGING WINDS

For people in Northern Rivers, Mid North Coast and parts of Northern Tablelands Forecast Districts.

Issued at 4:22 pm Monday, 1 January 2018.

Severe thunderstorms are likely to produce giant hailstones, damaging winds, and heavy rainfall that may lead to flash flooding in the warning area over the next several hours. Locations which may be affected include Lismore, Grafton, Coffs Harbour, Port Macquarie, Taree, Tenterfield, Kyogle, Yamba, Mackay, Woolgoolga, Sawtell and Dorrigo.

The State Emergency Service advises that people should:

* Move your car under cover or away from trees.
* Secure or put away loose items around your house, yard and balcony.
* Keep at least 8 metres away from fallen power lines or objects that may be energised, such as fences.
* Report fallen power lines to either Ausgrid on 131 388, or Endeavour Energy on 131 003 or Essential Energy on 132 080, as shown on your power bill.
* Keep clear of creeks and storm drains.
* Don’t walk, ride your bike or drive through flood water.
* If you are trapped by flash flooding, seek refuge in the highest available place and ring 000 if you need rescue.
* Unplug computers and appliances.
* Avoid using the phone during the storm.
* Stay indoors away from windows, and keep children and pets indoors as well.
* For emergency help in floods and storms, ring the SES (NSW and ACT) on 132 500.

The next warning is due to be issued by 7:25 pm.

Warnings are also available through TV and Radio broadcasts, the Bureau's website at www.bom.gov.au or call 1300 659 218. The Bureau and State Emergency Service would appreciate warnings being broadcast regularly.
In some States: Metro STS – cell-based

This Thunderstorm is Very Dangerous

<table>
<thead>
<tr>
<th>Region</th>
<th>Qld</th>
<th>NSW</th>
<th>VIC</th>
<th>TAS</th>
<th>SA</th>
<th>WA</th>
<th>NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hail diameter (cm)</td>
<td>&gt;= 4</td>
<td>&gt;= 5</td>
<td>&gt;= 5</td>
<td>&gt;= 4</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Terminology</td>
<td>Very Large</td>
<td>Giant</td>
<td>Very Large</td>
<td>Not specified</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Large Hail formation requirements

Hailstones begin as small ice particles that grow primarily by accretion; **Larger hail** requires **abundant** (large) water droplets (strong large updraft of high liquid water content):

- Wet growth – not super cold, droplet freezes slowly
- Dry growth – super cold, droplet freezes instantly

**Long hailstone residence times**
in regions of large super-cooled liquid water content in the primary hail growth layer between -10°C to -30°C (high vertical extension)

**Minimal melting** of the fully grown hailstones on the way to the ground. (low melting layer)
Storm type: supercells better than QLCSs and pulse storms;

Life cycle: incipient cells (intense updraft) better than after cells merge into a mesoscale convective system (MCS), Persistence: 30 mins

Storm tilt: updraft/downdraft separation promotes hail growth

Updraft strength and width: increases hail generation and residence time in storm (Echo tops: taller storms can tap colder air aloft (high Z above -20°C levels) and increase hail residence time in cloud, Cell/boundary mergers: promotes stronger updraft and better chance for hail formation)

Dry air aloft (~800-500hPa): leads to evaporative cooling which promotes hail growth and size

Steep mid-level lapse rates: suggests presence of mid-level cool/dry air; promotes strong updraft

Values of WBZ height: hail is most favorable with height of 7-12 kft; less favorable if < 6 kft (air mass too cool, although small hail/graupel likely from low-top storms) and if >> 12 kft (melting)
Severe hail diagnostics

Qualitative relies on forecaster's skill
Subjective evaluation of radar features:
   TBSS, 3D storm structure (WER, BWER, high Z aloft)

The size of hail at surface can’t be determined from looking at reflectivity values in a storm alone.
Quantitative relies on science & calibration, QC

Empiric algorithms:
  - Treloar (NSW) Nomogram

Storm Top Divergence Nomogram

Warning Decision Support System-Integrated Information (WDSS-ii)
  - WDSS Maximum Estimated Size of Hail
  - WDSS Probability of Severe Hail
Radar detectability of giant hail

US definition of giant hail: >10 cm

Is a relatively rare event, accounting for <1% of hail reports in US.

Infrequent but can cause extreme damage to property and threat to exposed life.

A radar based assessment of the detectability of giant hail – Blair et all, 2011, EJSSM
568 giant hail reports over 15 yr 1995-2009
99% of storms that produced >10 cm hail were well organized supercells

>10 cm hail producing storms were characterized by median value of rotational velocities of 24 m/s, storm top divergence of 72 m/s and 50 dBZ and 60 dBZ echo heights of 13100 m and 10600 m.

VIL, Max Refl within the storm and reflectivity within the preferred hail-growth zone showed little to no skill in discriminating between 10 cm and smaller sizes.

Since 2005, only 7% of convective warnings issued by NWS accurately predicted a maximum hail size >10 cm prior to the report, with an average underestimated size error of 55 mm.
Severe hail quantitative diagnostics

Sensitive to radar calibration
Big amount of data
MESH: estimates varies between radars
MESH & POSH tabular form
No info on area impacted
Opportunity

Upgrade 4 S1 radars to Dual Pol: better quality and algorithms
The solution

Develop better algorithms and visualisation

• Particle ID based on DP – to enhance forecaster confidence
• Gridded MESH & POSH – to reduce FAR
• 256x256 km domain only - quality
• Use the GPM estimates for radar calibration bias to correct for differences between radars
• Hail swath – for impact estimate
• Add lightning density
• 3DRapic 8.0 to visualise the new products
First iteration MESH

WDSS Hail Size
First iteration: POSH

WDSS Severe Hail Probability
First iteration: MESH tracks (swath)
MESH Swath – towards impact

Possible Hail Risk Categories:

- Isolated severe TS, small hail
- Scattered Severe TS, hail
- Numerous, Severe TS, damaging-large hail,
- Widespread, Severe TS, destructive hail,
- Extremely dangerous giant hail

Need of new "small hail" service:
Large quantities of small hail (deep layer)
MESH RF3 vs Hail Size Reports

Note the scatter in hail size for the same MESH

MESH = 6cm, Hail = 2 – 11cm
Summer of 2016-2017, 5 radars

Accuracy of MESH is +- 4cm

How do we communicate this uncertainty?
Calibration in RAINFIELDS 3

Note how RAINFIELDS adjusts for the radar calibration.

WDSS does not account for differences in radar calibration.
2 day workshop: forecasters, scientists, trainers
Forecasters feedback – a list of 161 wishes!

- Products must be developed with forecaster's feedback

- Workshops are expensive but extremely useful

- Forecasters/users like deterministic estimates of hail size!

- Probabilities and uncertainties are not easy to fit in users applications

- Gridded product are more versatile
Developers went back to work
Particle ID, Radar Kriging Variance
POSH – clear intervals
Gridded MESH – colours intervals
Gridded MESH swath - colours intervals
Lightning density
Second iteration
Service contingency and consistency

Keep products and features that forecasters trust (WDSS table)
Improve TITAN
Address issues in a heterogenous network:

1° vs 2°,

S vs C,

Dual-Pol vs Single Pol,

Calibration,

lack of observation data from the field
Decreasing the lowest elevation angle from 0.5° to 0.3° will increase the range of detection by 20 km.
Conclusion:

hail nowcasting service needs tailored quantitative products
Uncertainty is inevitable in our job and probability is the language of uncertainty

We need to change our contract with the users: we give the uncertainty, they decide
Dual Pol hydrometeor classification

• Needed a mature algorithm for S-Band dual pol that is being used operationally
• Implemented the Hydrometeor Classification Algorithm
• Algorithm is used operationally by NWS
• Mark Curtis visited NCAR at Boulder, Colorado, to implement their code in RAINFIELDS 3.1
Fuzzy logic classification

• Based on $Z_h$, $Z_{DR}$, $\rho_{hv}$ with restrictions on the class depending on temperature profile from NWP

• NCAR parameters

• Classes simplified in 3D-Rapic

• Still need to develop training

<table>
<thead>
<tr>
<th>NCAR Class</th>
<th>3D-Rapic Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud</td>
<td>Clear Air</td>
</tr>
<tr>
<td>Drizzle</td>
<td>Rain</td>
</tr>
<tr>
<td>Light Rain</td>
<td>Rain</td>
</tr>
<tr>
<td>Moderate Rain</td>
<td>Rain</td>
</tr>
<tr>
<td>Heavy Rain</td>
<td>Rain</td>
</tr>
<tr>
<td>Hail</td>
<td>Hail</td>
</tr>
<tr>
<td>Rain Hail Mixture</td>
<td>Hail</td>
</tr>
<tr>
<td>Graupel Small Hail</td>
<td>Graupel</td>
</tr>
<tr>
<td>Graupel Rain</td>
<td>Graupel</td>
</tr>
<tr>
<td>Dry Snow</td>
<td>Snow</td>
</tr>
<tr>
<td>Wet Snow</td>
<td>Snow</td>
</tr>
<tr>
<td>Ice Crystals</td>
<td>Snow</td>
</tr>
<tr>
<td>Supercooled Liquid Droplets</td>
<td>&quot;Snow&quot; – grouped with the cold stuff</td>
</tr>
<tr>
<td>Flying Insects</td>
<td>Clear Air</td>
</tr>
<tr>
<td>Second Trip</td>
<td>Clutter</td>
</tr>
<tr>
<td>Ground Clutter</td>
<td>Clutter</td>
</tr>
<tr>
<td>Miscellaneous 1</td>
<td>Clutter</td>
</tr>
<tr>
<td>Miscellaneous 2</td>
<td>Clutter</td>
</tr>
</tbody>
</table>
Validation of the software
Severe Hail Index vs Hail

Rainfields 3.1 case study

Witt et al, 1998
Users consultation

Workshop – coffee table clothes on hail
Workshop hail – Buckley informal request 4.5 cm

- Radar users req: agro: Need to know in detail the areas affected by large hail that could damage crops. Possible insurance claims.

- SA: Radars used to support Detailed Severe Th'storm Warnings for major metro areas should be at least H2, with at least one radar covering the area being H1.

- QLD: Large to giant hail is common in the domains covered by Gympie, Gladstone, Brisbane, and Emerald radars. Large hail is less common but still occurs in the Warrego, Mt Isa, Cairns, and Longreach domains. Large hail (and hail period) is rare in the Mackay, Bowen, and Townsville areas, and virtually unheard of at Mornington Island, Willis Island, and Weipa areas.