Rainfields

Quantitative Precipitation **Nowcasts**

Accumulations & Max Frequency
Learning Objectives

• Learn what QPN accumulations are.
• Learn what QPN max frequency products are.
• Learn about their constraints.
• Learn how they might be used.
Motivation (why?)

Provide a short term rainfall forecast based on recent radar.
Motivation continued…

**Constraints** – Rapid update modelling (every scan)

- No time to run a dynamical model
- NWP does not perform well at small spatial/temporal scales
QPN Definition (what)

- Quantitative Precipitation Nowcasting
- Nowcasting – forecast +1, +2 hours using advection
- Advection – use of recent motion to predict future motion

Nowcasting is a legitimate technique for:
- Thunderstorms (hour or two)
- bands of precipitation (hour or two)
- Dry lines (few hours)
- Fronts and troughs (few hours)

But mainly this is done in a qualitative sense, ie. location of features.
QPN by definition, tries to quantify.
Example
Bureau of Meteorology
Strategic Radar Enhancement Project
Nowcast Skill

Widespread rain in Sydney
QPN - Why?

Aim

– To produce a realistic Nowcast of the radar derived rainfall.

Challenges

– Radar is a composite of a wide variety of space scales that have different levels of predictability
– There are many sources of error in radar
QPN – How?

How do we overcome these challenges?

- Use **statistical models** to mimic rainfall behaviour over small spatial and temporal scales as well as produce an ensemble of predictions

  ➔ Analyse predictable rainfall elements
  ➔ Advect forward in time
  ➔ Perturb initial conditions to provide probabilistic guidance.
QPN – How?

Errors that are modelled:

– Growth and decay
– Radar observation errors (to account for Z-R errors and observing rain above ground)
– Tracking error (velocities multiplied by random number with mean of 1)
QPN - How?

- Uses last 3 scans of gauge adjusted accumulations

Differences in ensemble members are:
1. Perturbations of initial conditions
2. Perturb rain echo advection velocities
3. Scale perturbations
QPN – How?

- So let’s quickly look at the first error that is modelled – spatial growth and decay…
Predictable rainfall elements:

- Each cascade level evolves in time.
- Rate of development decreases with increasing scale.
- Hierarchy of AR(1) models used for temporal development.

"The idea of multiplicative cascade modelling is to try to capture the scale-invariant behaviour of the process…" (Flores C. 2004)
Spatial Decomposition

Use Fourier notch filters to isolate narrow bands of wavelengths in the field.
Spatial Decomposition

High Skill - Persist

128-256-512 km

64-128-256 km

32-64-128 km

Lower skill – slow decay

16-32-64 km

8-16-32 km

4-8-16 km

2-4-8 km

Little skill – fast decay
Spatial Decomposition

High Skill - Persist

Lower skill – slow decay

128-256-512 km

64-128-256 km

32-64-128 km

16-32-64 km

8-16-32 km

4-8-16 km

2-4-8 km

Decay to average areal rainfall amount → Result in smoothing over time → Decrease variance – unrealistic smoothing!!!

Little skill – fast decay
Spatial Decomposition

High Skill – Persist
Little noise added

Lower skill – slow decay
More noise added

128-256-512 km

64-128-256 km

32-64-128 km

16-32-64 km

8-16-32 km

4-8-16 km

2-4-8 km

Little skill – fast decay
Lots of noise added
Apply ONE set of decay to noise rates in all situations?

When does the predictability of even the large scales become low?
Widespread rain in Sydney
Nowcast Skill

Skill from Radar Scan 2 vs Lead Time

Large reflectivity change detected between previous scan and current scan

→ Little skill – even at large scales

→ Lots of noise added at all scales over time
**QPN Summary**

<table>
<thead>
<tr>
<th>Growth or Decay</th>
<th>Large Scale</th>
<th>Small Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>- Little skill</td>
<td>- No skill</td>
</tr>
<tr>
<td>or Decay</td>
<td>- Decay to Noise faster</td>
<td>- Decay to Noise very fast</td>
</tr>
<tr>
<td>Little Change</td>
<td>- High skill</td>
<td>- Little skill</td>
</tr>
<tr>
<td></td>
<td>- Persists, little noise added</td>
<td>- Decay to Noise faster</td>
</tr>
</tbody>
</table>

**Skill change**
- scan to scan (established rain vs growth)
- situation (scales)
QPN – Nowcast Creation

1. Decompose to scales
2. Calculate skill of each scale

Large Scale - higher skill
Smaller scales - lower skill
QPN – Nowcast Creation

3. Apply noise rate at each scale
   (high skill = small noise rate over time)
   (low skill = large noise rate over time)
QPN – Nowcast Creation

3. Apply noise rate at each scale
   (high skill = small noise rate over time)
   (low skill = large noise rate over time)
QPN – Nowcast Creation

3. Apply **noise rate** at each scale
   (high skill = small noise rate over time)
   (low skill = large noise rate over time)
QPN – Nowcast Creation

4. Perturb Motion Vectors
5. Advect forward in time applying noise rates at different scales
QPE – 6 Min Accumulation
QPE – Nowcast Example
QPN – Nowcast Example
QPN – Nowcast Example
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QPN – Nowcast Example
QPN – Nowcast Creation

1. Decompose to scales
2. Calculate skill of each scale
3. Apply noise rate at each scale
4. Perturb Motion Vectors
5. Advect forward in time applying noise rates at different scales

Repeat this process 40 times, ie 40 ensemble members….

-- Derive Probabilistic Nowcasts (later)
-- Ensemble Mean Accumulation ➔ Nowcasts
QPE – Example 2
QPN – Ensemble Mean
QPN – Ensemble Mean
QPN – Ensemble Mean
QPN – Ensemble Mean
QPN – Ensemble Mean

Ensemble mean Accumulation is used:
– no extreme forecasts
– less RMS error

Ensemble mean is used to create the QPN Max Frequency Product…
QPN Ensemble Mean

**Benefits**
- No extreme forecasts
- minimise RMS error
- Timely → every scan

**Limitations**
- No Dynamics
- Performs poorly during Growth/Decay
- No extreme forecasts
QPN – Max Frequency

• Used to assist in identifying rainfalls in the ARI spectrum

• This may assist in identifying areas for Warning

• Combines Nowcast frequencies - 30min & 1hr

• Consideration period is the near future only
QPN – Max Frequency

Constructed using:

- The QPN Ensemble Mean Accumulation
- The accumulation vs years plots

To create a QPN Max Frequency value at each pixel

39mm

1 hr QPN

Hourly Accumulation (mm)

Frequency (years)

4 yrs
QPN – Max Frequency

Then repeat for all other pixels

28mm

1 hr QPN

Hourly Accumulation (mm)

1.9 yrs

Frequency (years)
ARI Maximum Frequency 1 Hour

- 30 minute Forecast Accum → 30 minute ARI Frequency
- 1 hour Forecast Accum → 1 hour ARI Frequency
ARI Maximum Frequency 1 Hour

It could be that the past 30min rainfall *almost* exceeded 10yrs

The nowcast of 30min rainfall combined with past 30min, might exceed the 1 hour 1:10 year amount

Therefore – combine 30 minutes of past accumulated rain into the Max Frequency QPN product
QPE into ARI Max Frequency…

Incorporating QPE into a QPN Frequency:
- Add recently fallen rain to the product
QPE into ARI Max Frequency...

...whilst retaining the forecast for position and mean intensity
Other Durations (past + future) considered...

- Other products included....

QPN components are 40 member ensemble means.
Other Durations (past + future) considered…

39mm + 30 min QPE

17mm + 30 min QPN

28mm + 1 hr QPN
Other Durations (past + future) considered…

• Convert each Accum value to a Frequency (yrs)

- 39mm + 30 min QPE
- 17mm + 30 min QPN
- 28mm + 1 hr QPN

9 yrs
1 yr
1.9 yrs
Other Durations (past + future) considered…

- Record the Maximum Frequency Value (yrs) for that pixel location
- Repeat for other pixel locations

<table>
<thead>
<tr>
<th>Frequency (years)</th>
<th>Hourly Accumulation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9yrs</td>
<td>39mm</td>
</tr>
<tr>
<td>1yr</td>
<td>17mm</td>
</tr>
<tr>
<td>1.9yrs</td>
<td>28mm</td>
</tr>
</tbody>
</table>

- 30 min QPE
- 30 min QPN
- 1 hr QPN
The Max Years QPN Product
The Max Years QPN Product
The Max Years QPN Product
Forecaster Adding Value…

Frequency close to a warning threshold…

- Will current conditions persist or get worse?
- Reflectivity
- Observations
- Development triggers
- Others things to consider?

REMEMBER – QPN does NOT contain dynamics… consider development elsewhere
Suggested Thresholds for Warning

**Start Getting Nervous**

- Frequency $\geq 5$ yrs
- May consider $\geq 2$ yrs QPN
- Rapid rate of change per scan
- Is heavy rain likely to persist or intensify?

**Warning**

- Frequency $\geq 10$ yrs
- May consider $\geq 8$ yrs QPN
QPN Max Frequency

**Benefits**
- Detail of QPE
- Assist with warning area
- Extreme forecasts unlikely
- Minimise RMS error
- Best – established rain
- Timely → every scan!

**Limitations**
- No Dynamics
- Growth/Decay performs poorly
- Statistical field – not deterministic rainfall