Rainfields

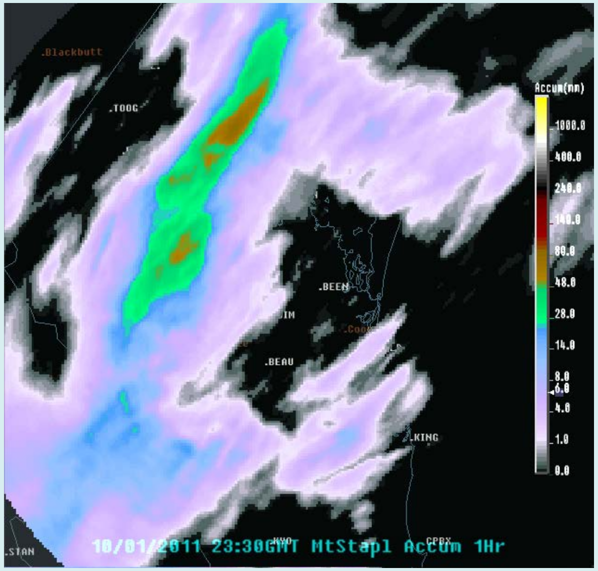
Quantitative Precipitation **Nowcasts**

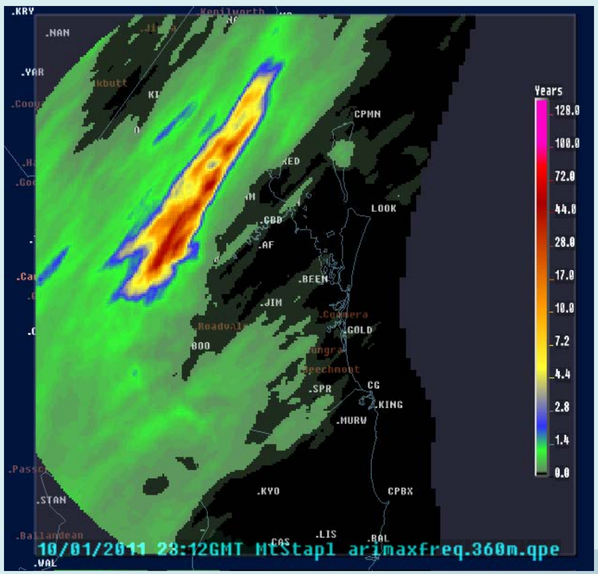
Accumulations & Max Frequency

Learning Objectives

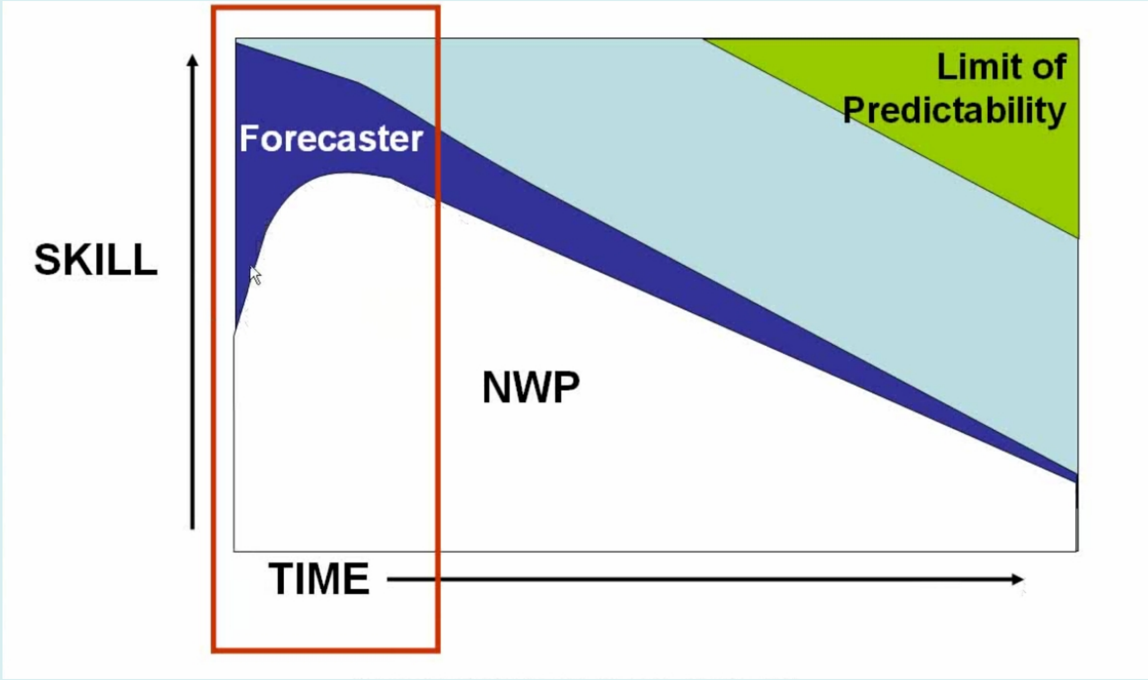
- Learn what QPN accumulations are.
- Learn what QPN max frequency products are.
- Learn about their constraints.
- Learn how they might be used.

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

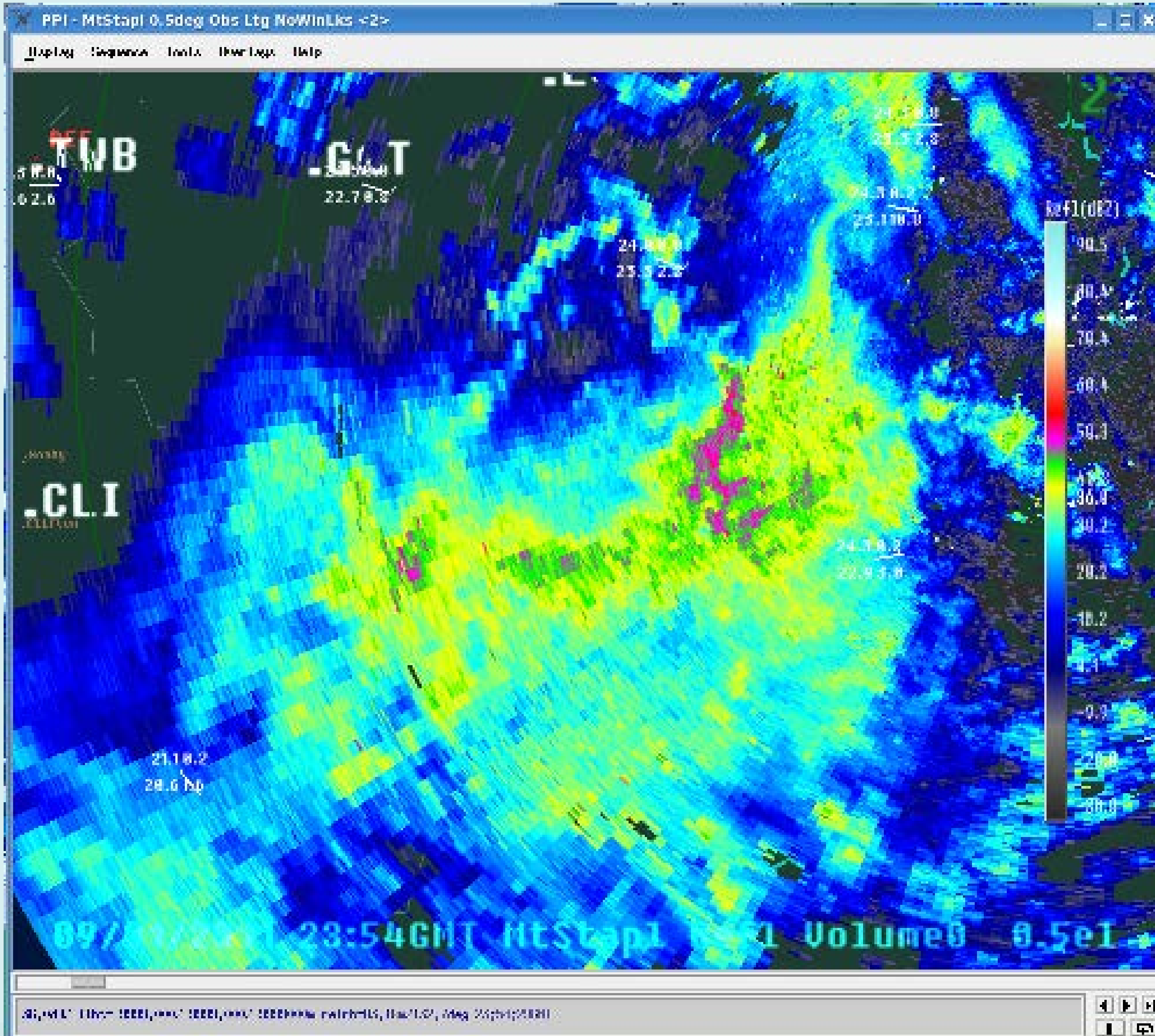
Nowcasting is a legitimate technique for:

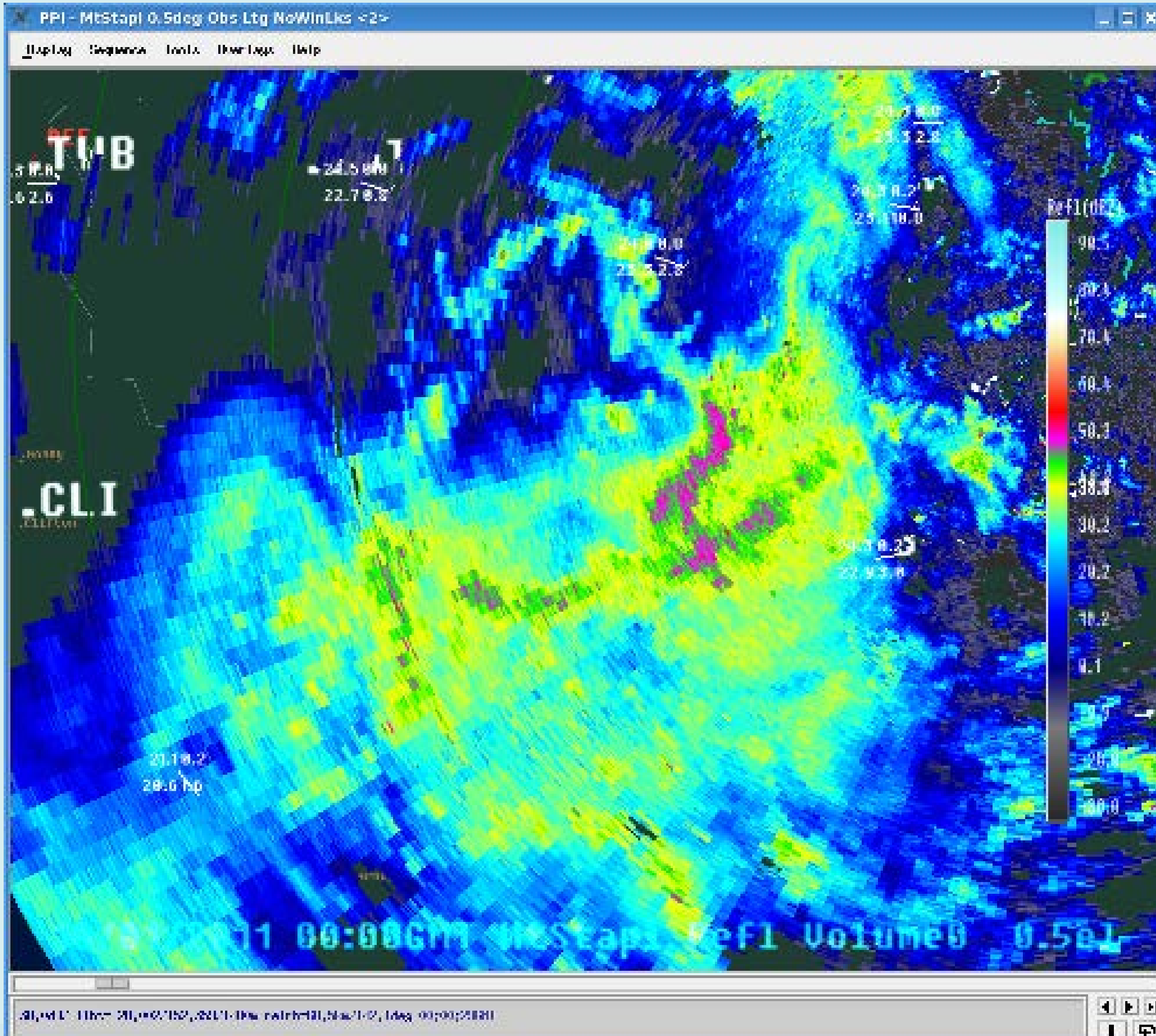
- Thunderstorms (hour or two)
- bands of precipitation (hour or two)
- Dry lines (few hours)
- Fronts and troughs (few hours)

But mainly this is done in a qualitative sense, ie. location of features.

QPN by definition, tries to *quantify*.

Example

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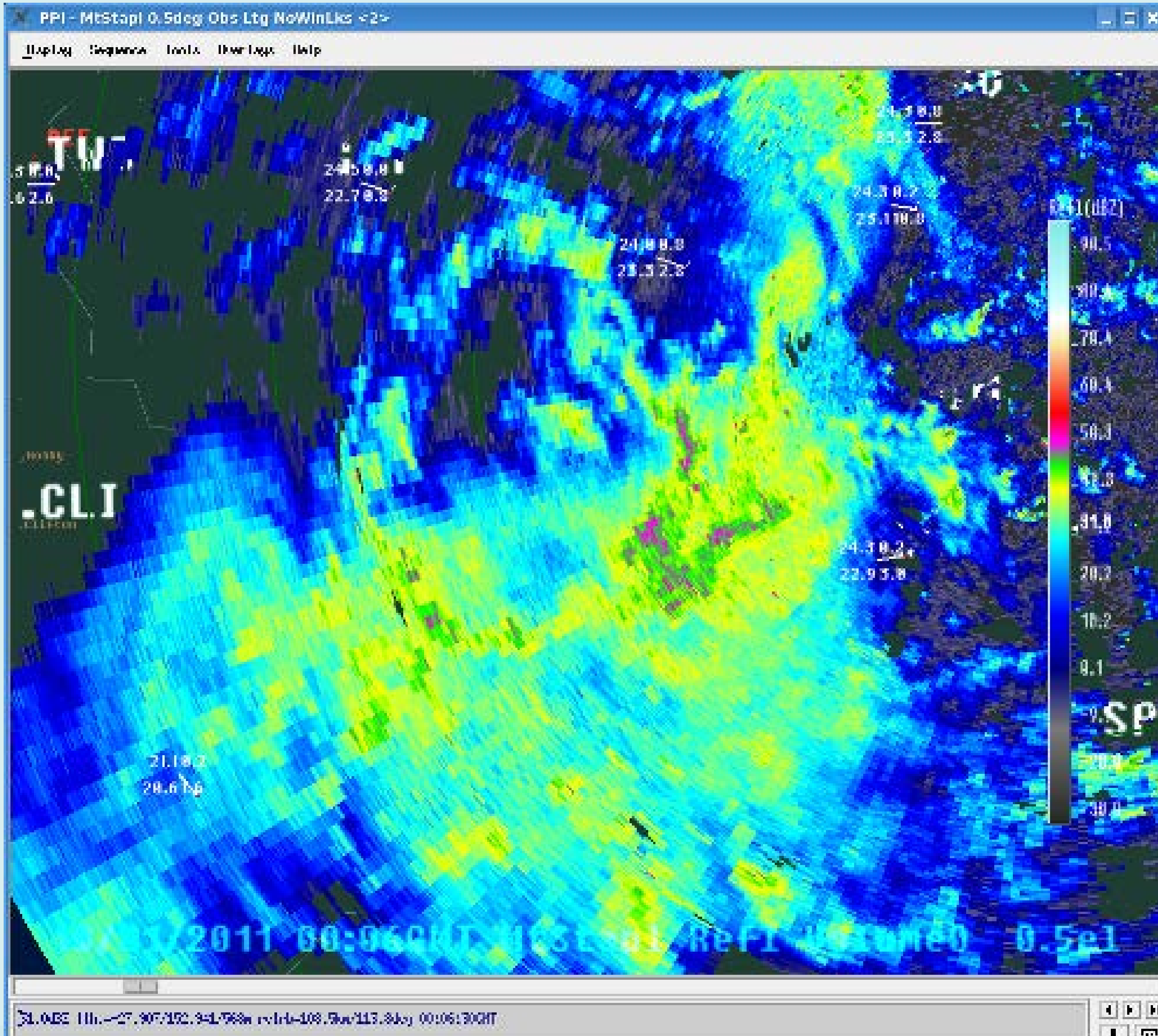
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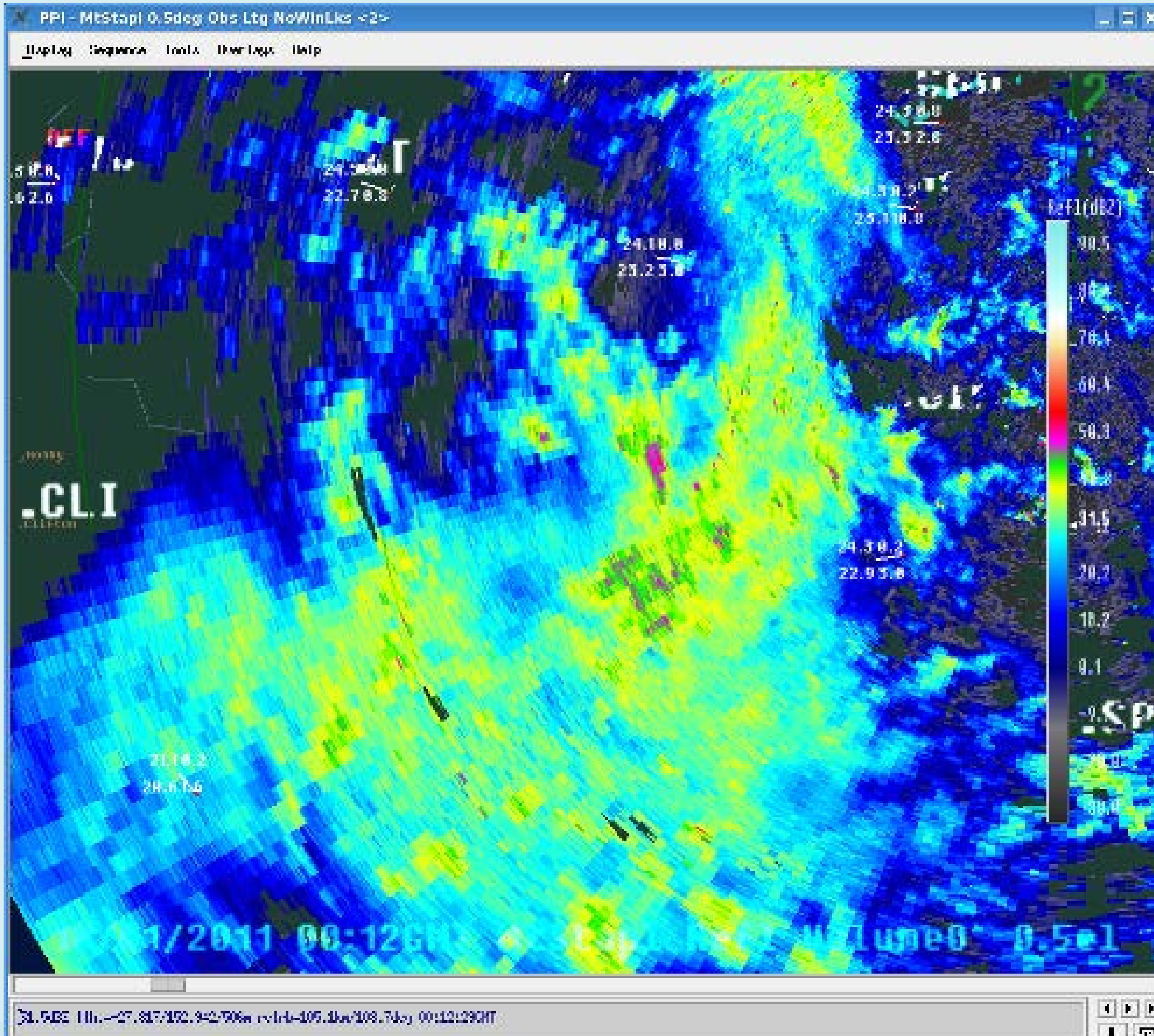
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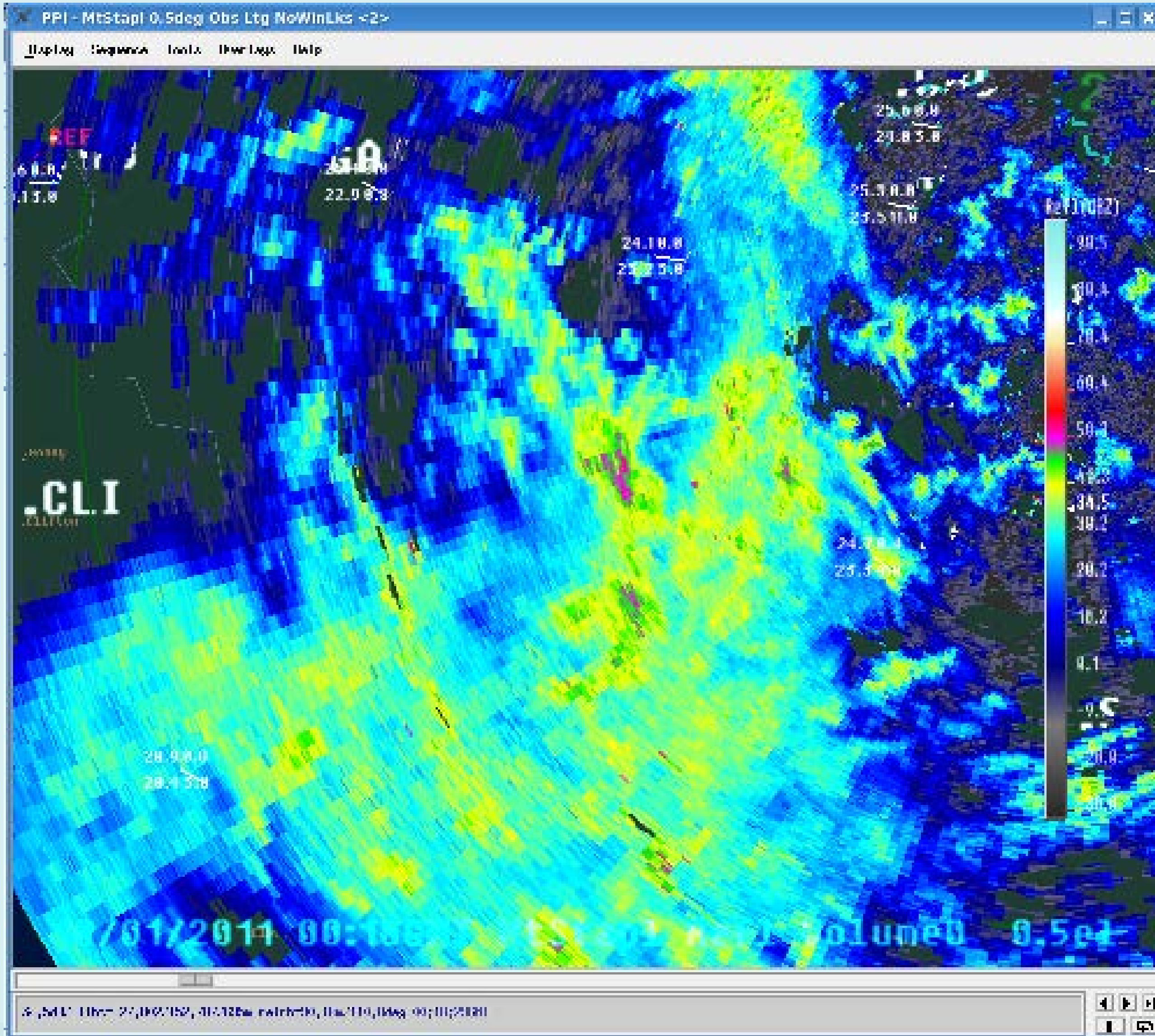
Refl(dBZ)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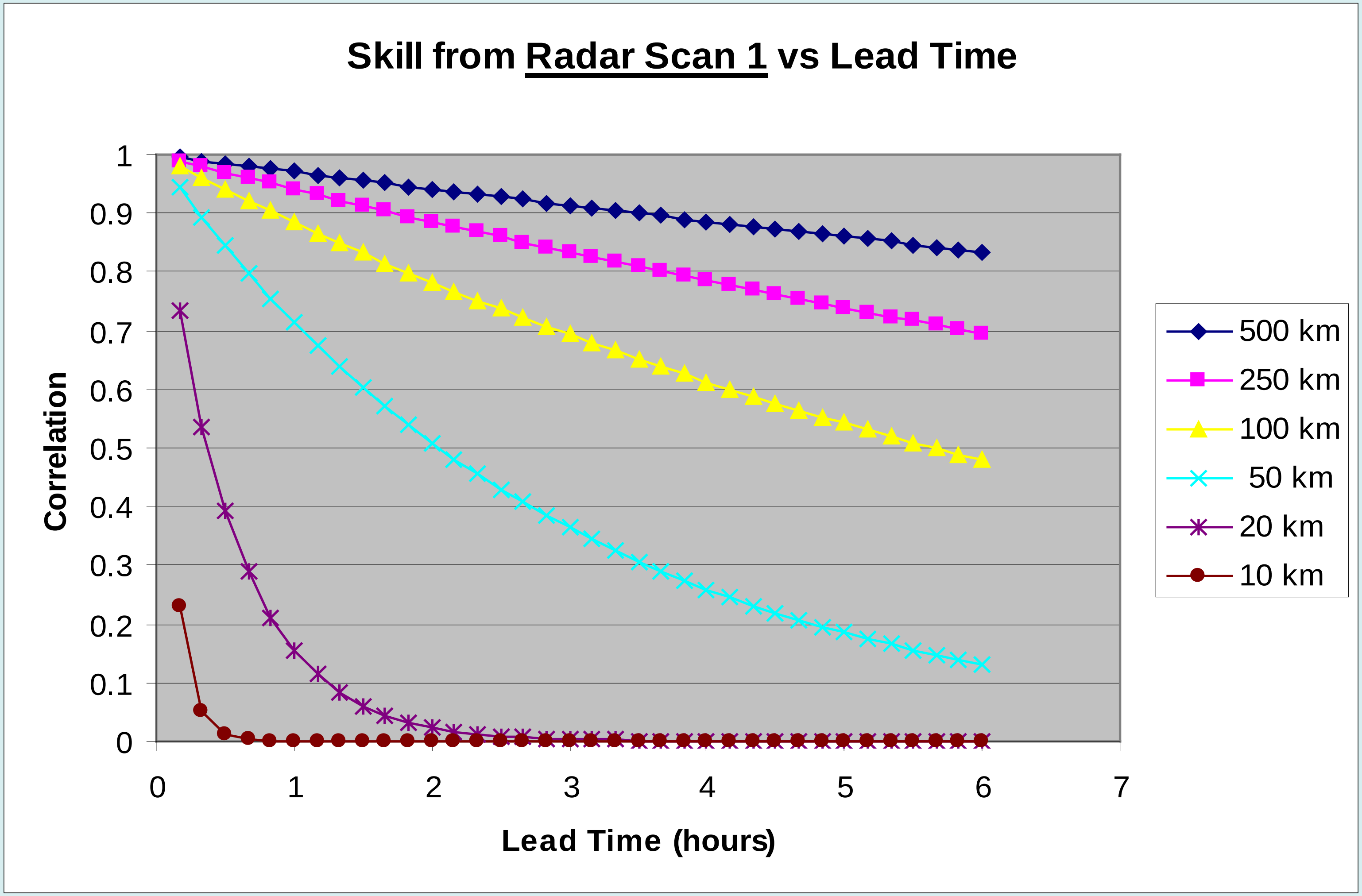
Nowcast Skill



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…

Scale Decomposition

Predictable rainfall elements:

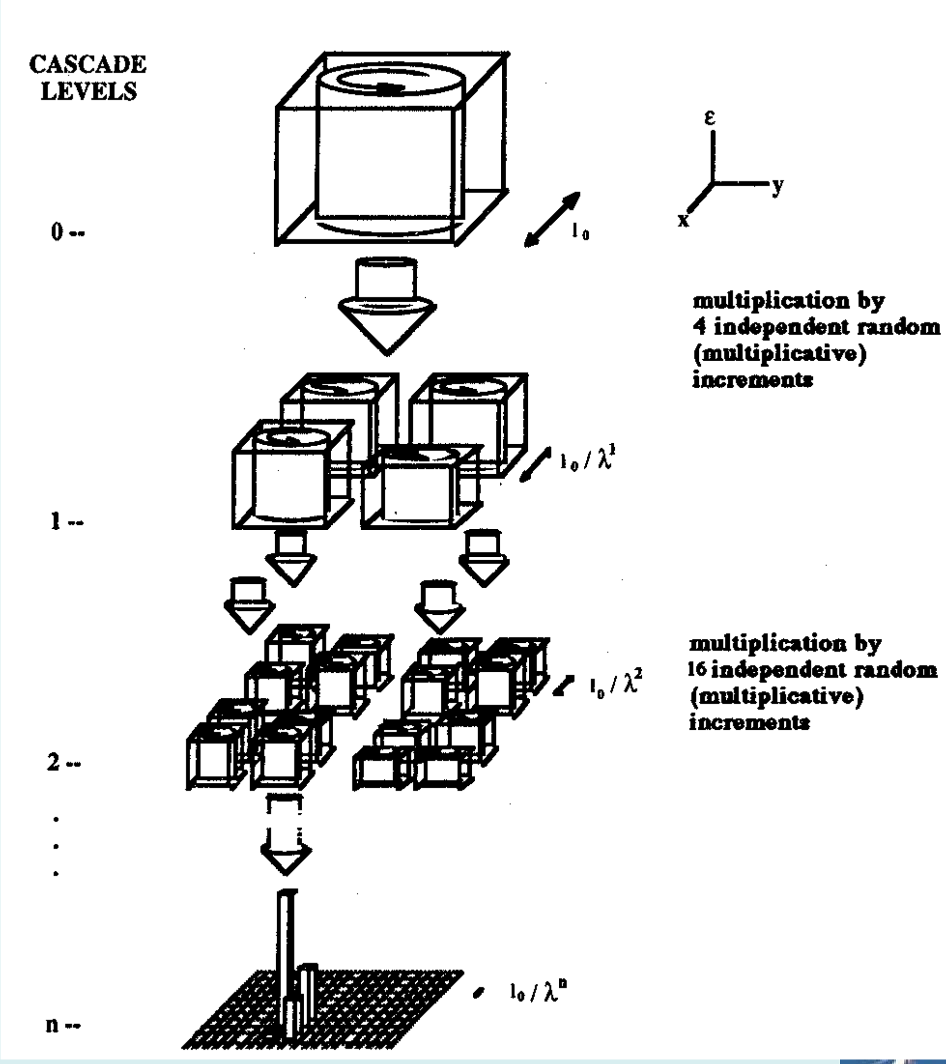
- Each cascade level evolves in time

Rate of development decreases with increasing scale

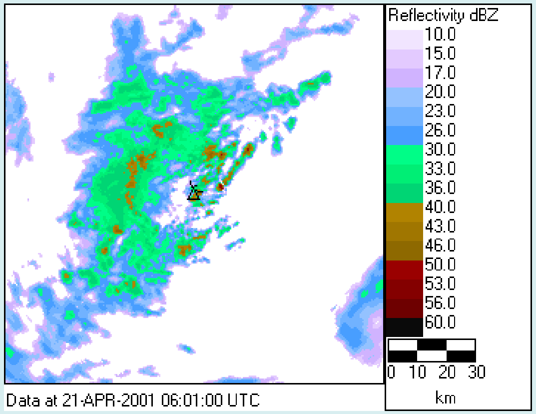
Hierarchy of AR(1) models used for temporal development

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

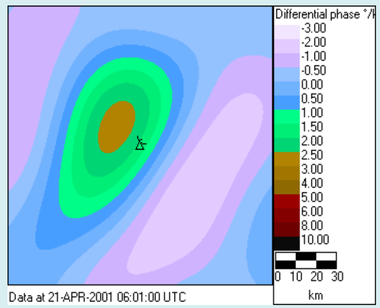
Multiplicative cascade model for Turbulence



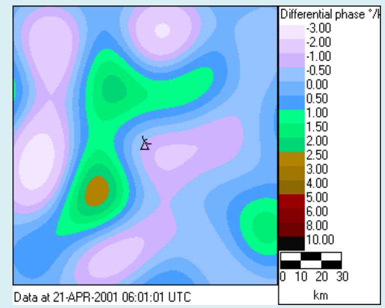
Spatial Decomposition



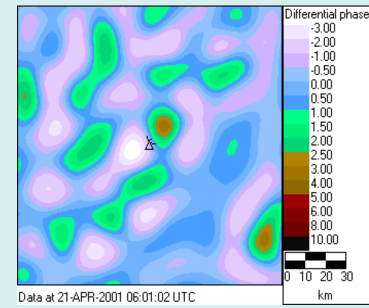
128-256-512 km



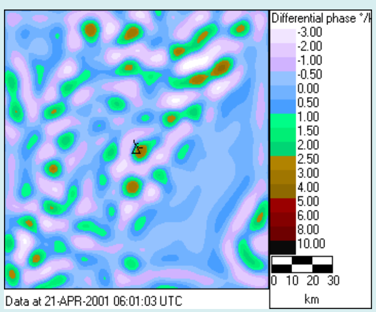
64-128-256 km



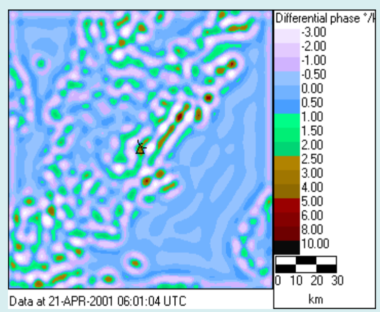
32-64-128 km



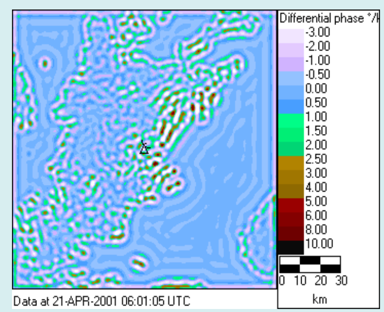
16-32-64 km



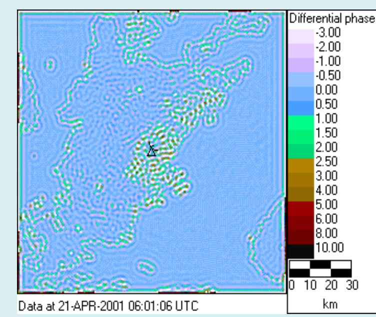
8-16-32 km



4-8-16 km

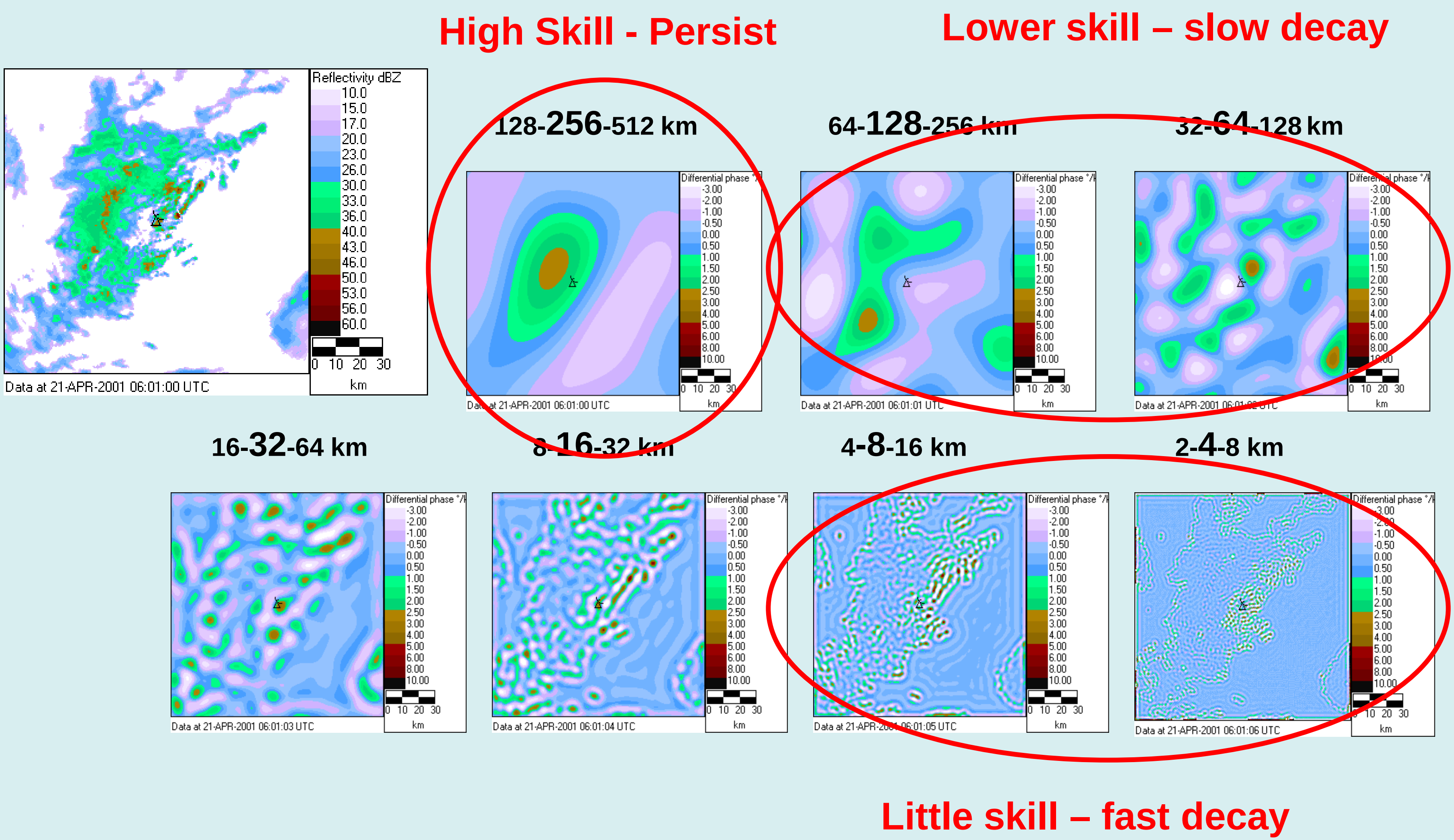


2-4-8 km



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

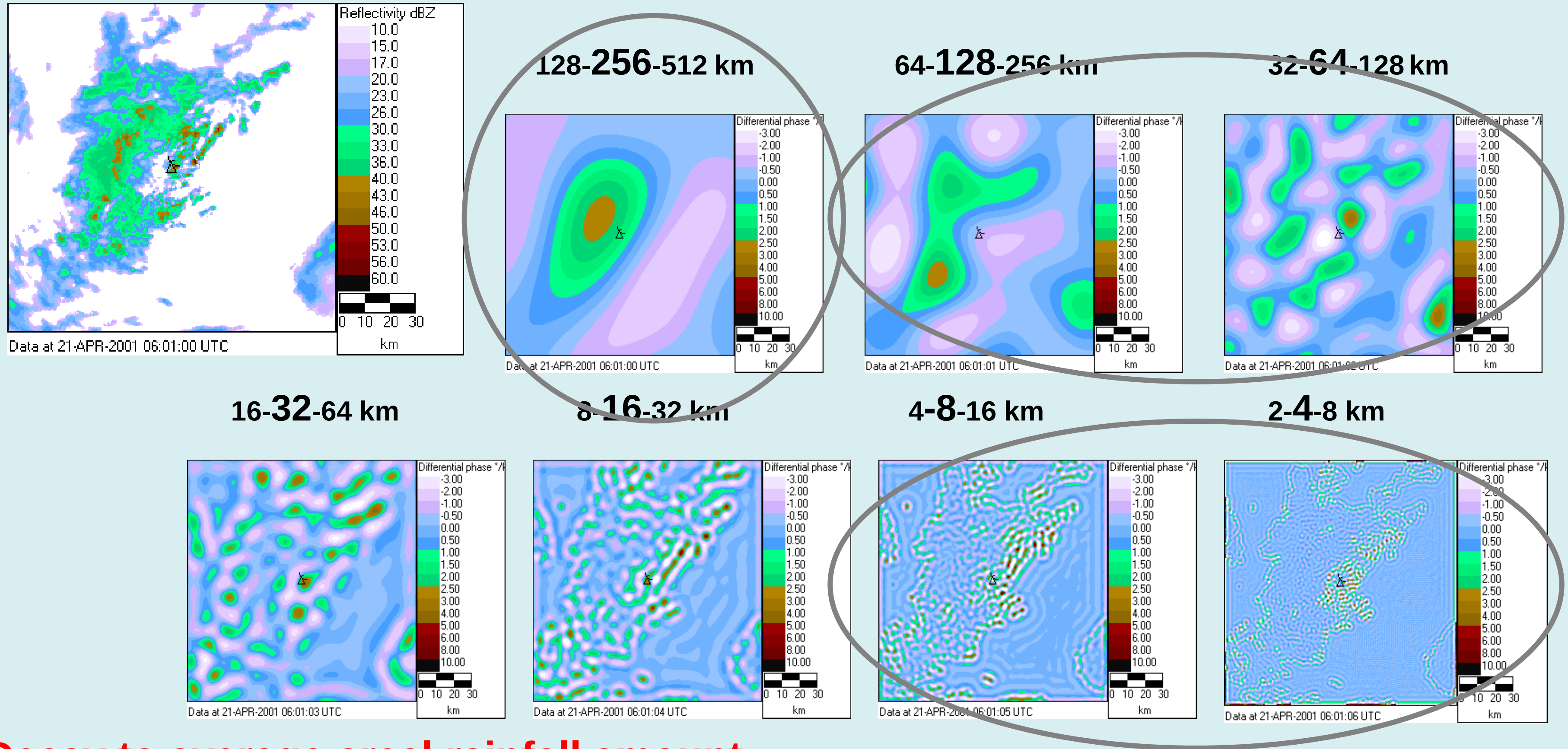
Spatial Decomposition



Spatial Decomposition

High Skill - Persist

Lower skill – slow decay



Decay to average areal rainfall amount

→ Result in smoothing over time

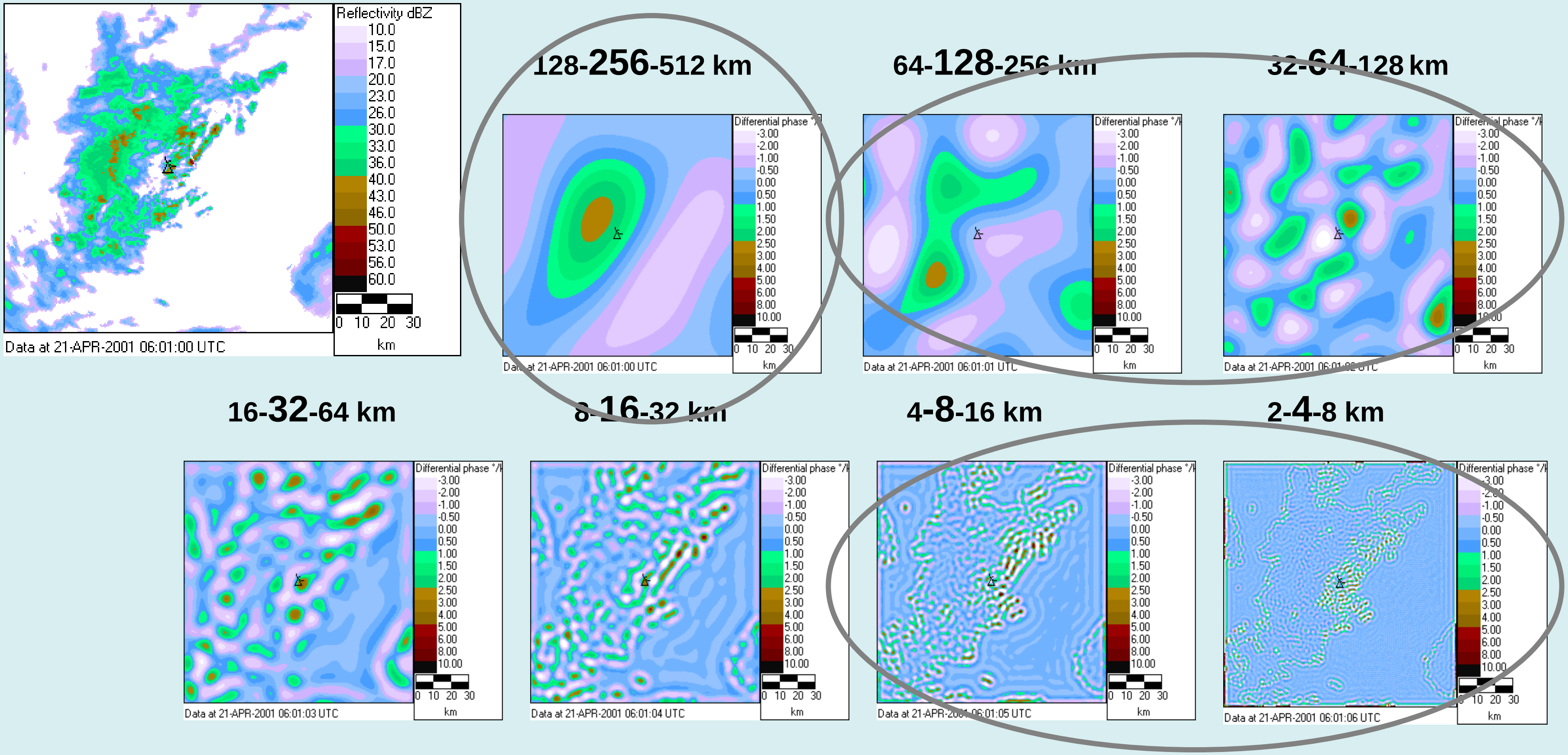
→ Decrease variance – unrealistic smoothing!!!

Little skill – fast decay

Spatial Decomposition

High Skill – Persist
Little noise added

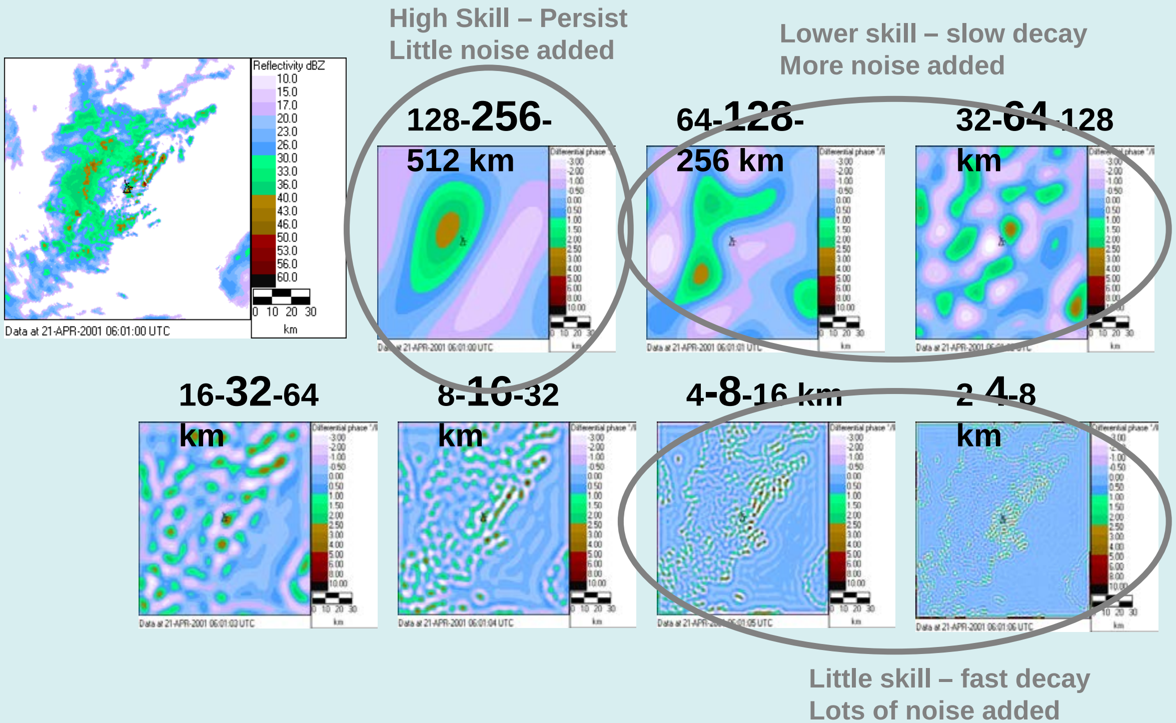
Lower skill – slow decay
More noise added



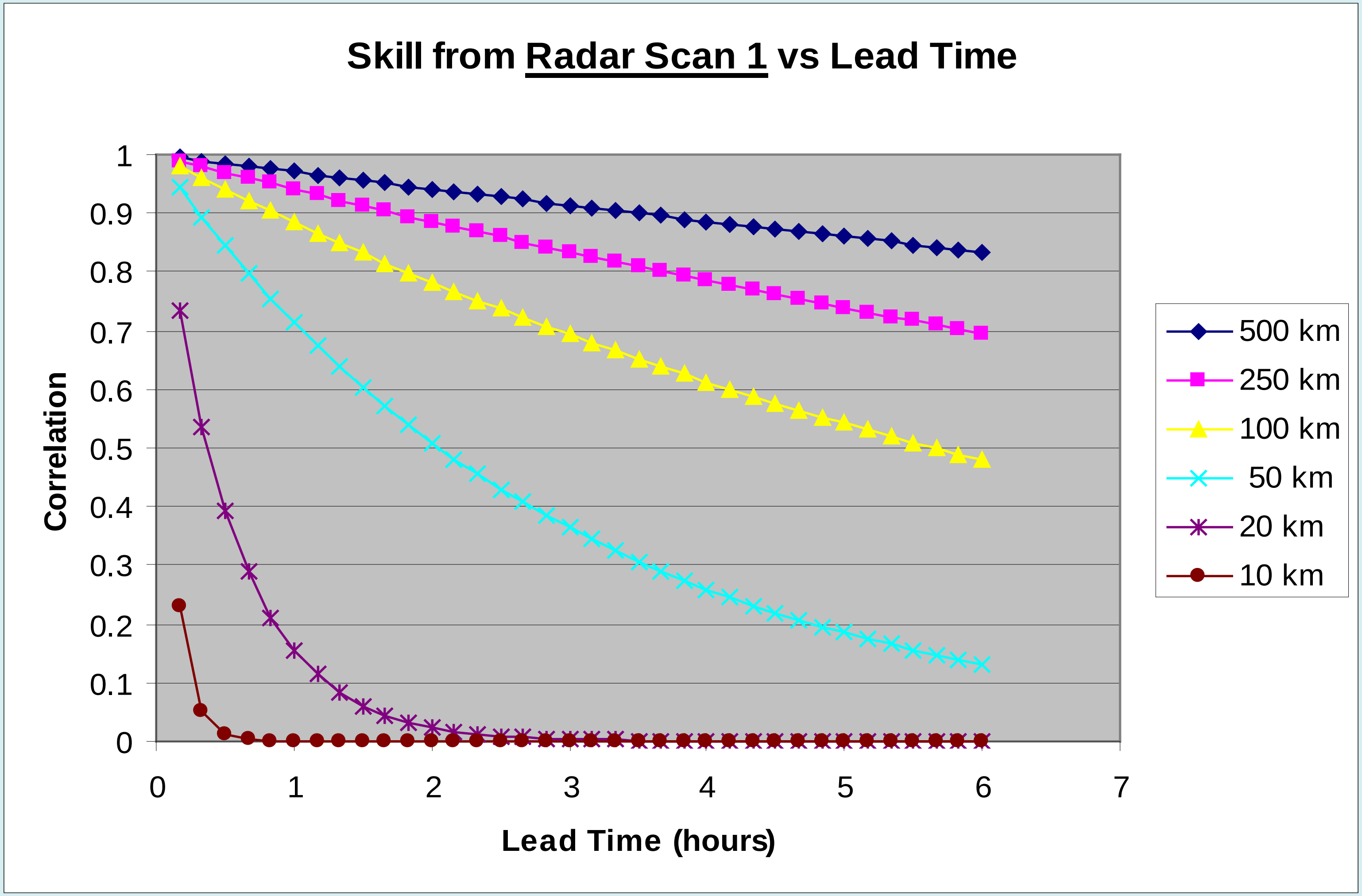
Little skill – fast decay
Lots of noise added

Apply ONE set of decay to noise rates in all situations?

When does the predictability of even the large scales become low?

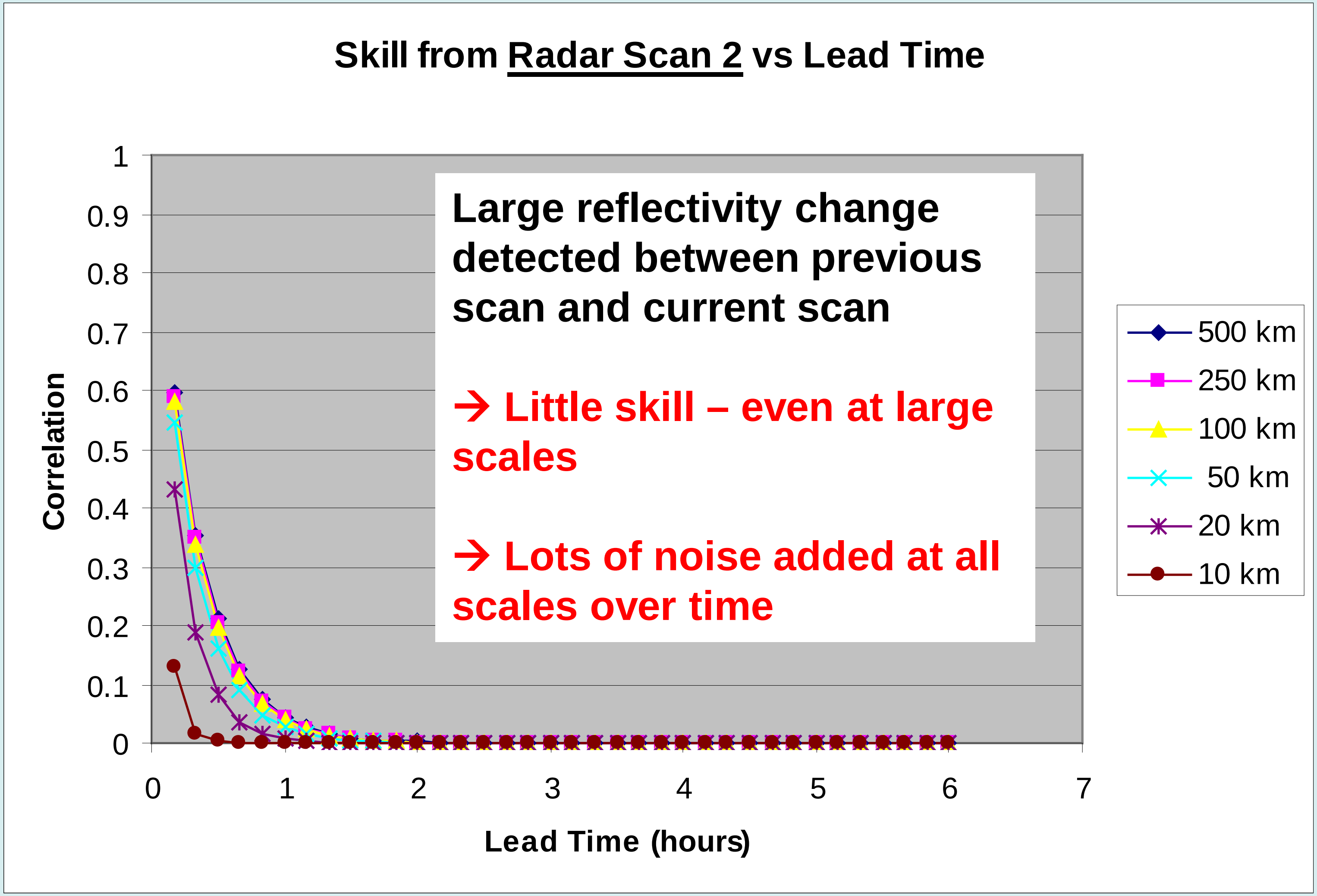


Nowcast Skill



Widespread rain in Sydney

Nowcast Skill



QPN Summary

	Large Scale	Small Scale
Growth or Decay	- Little skill - Decay to Noise faster	- No skill - Decay to Noise very fast
Little Change	- High skill - Persists, little noise added	- Little skill - Decay to Noise faster

Skill change

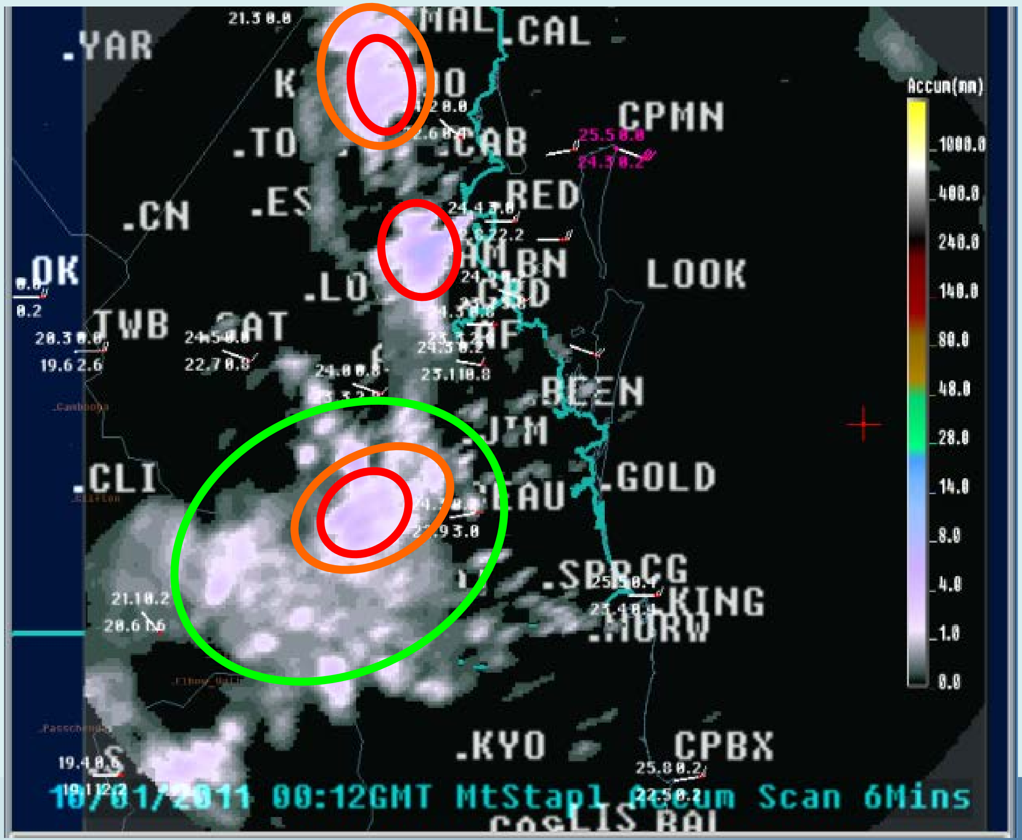
- scan to scan (established rain vs growth)

- situation (scales)

QPN – Nowcast Creation

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

Large Scale - higher skill



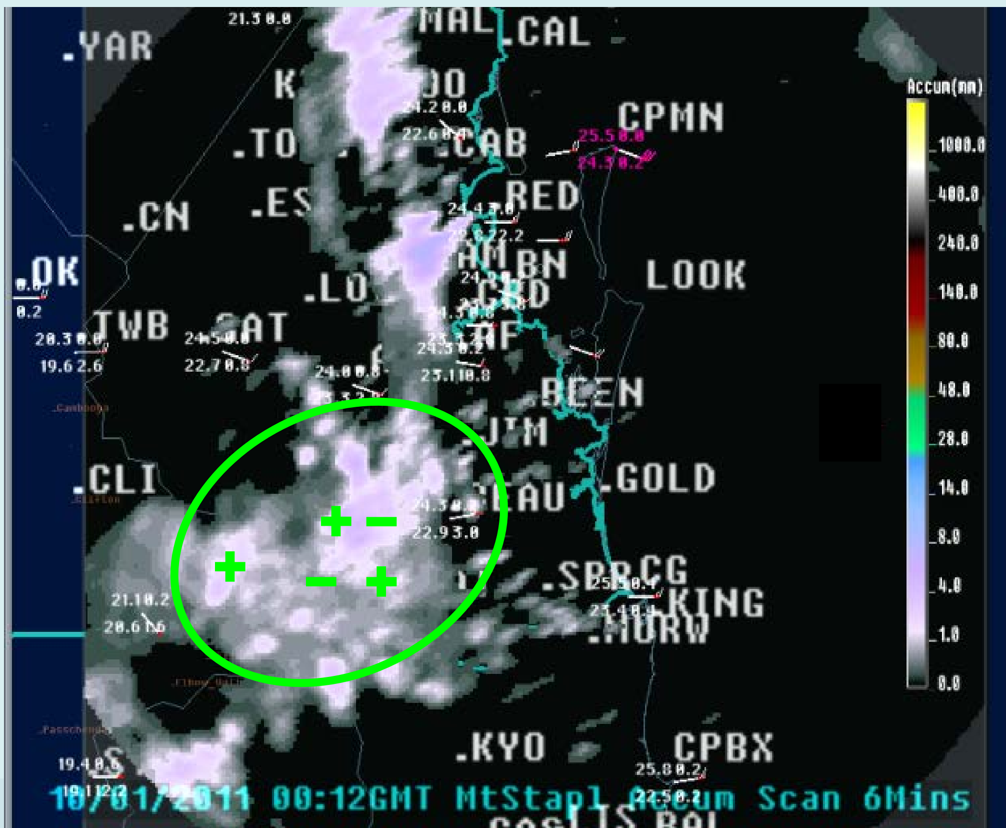
Smaller scales - lower skill

QPN – Nowcast Creation

3. Apply noise rate at each scale

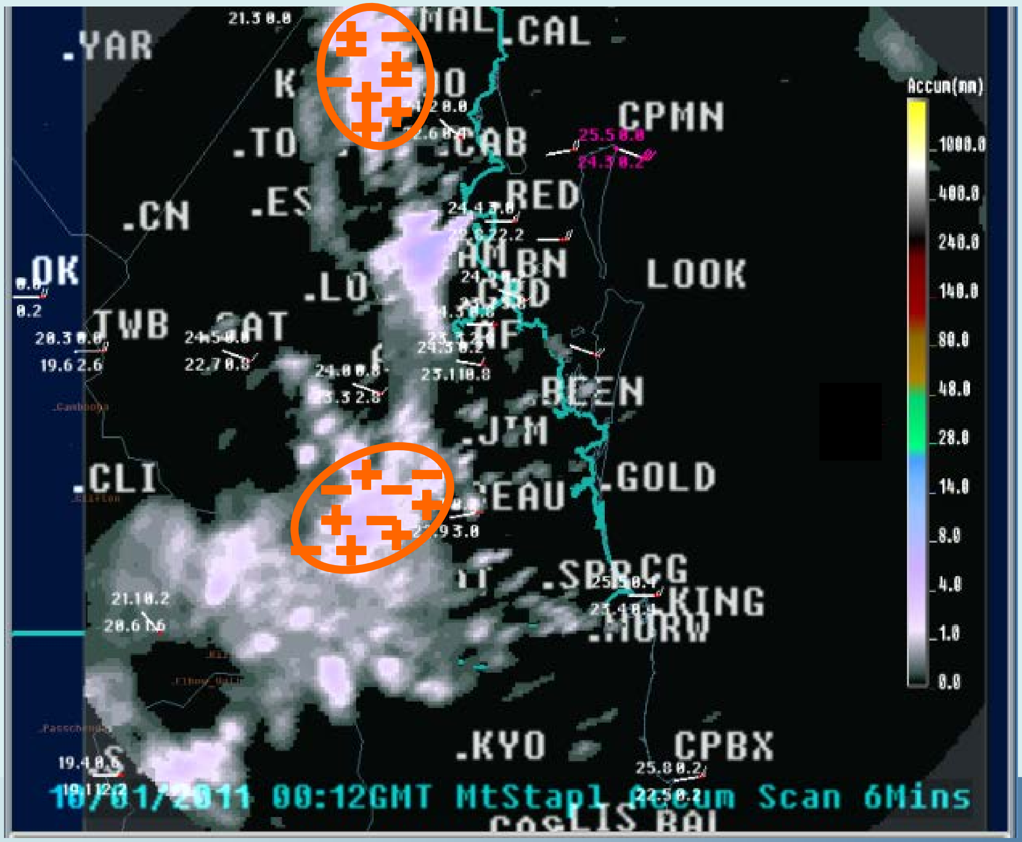
   (high skill = small noise rate over time)

   (low skill = large noise rate over time)



QPN – Nowcast Creation

3. Apply <u>noise rate</u> at each scale
   (high skill = small noise <u>rate</u> over time)
   (low skill = large noise <u>rate</u> over time)

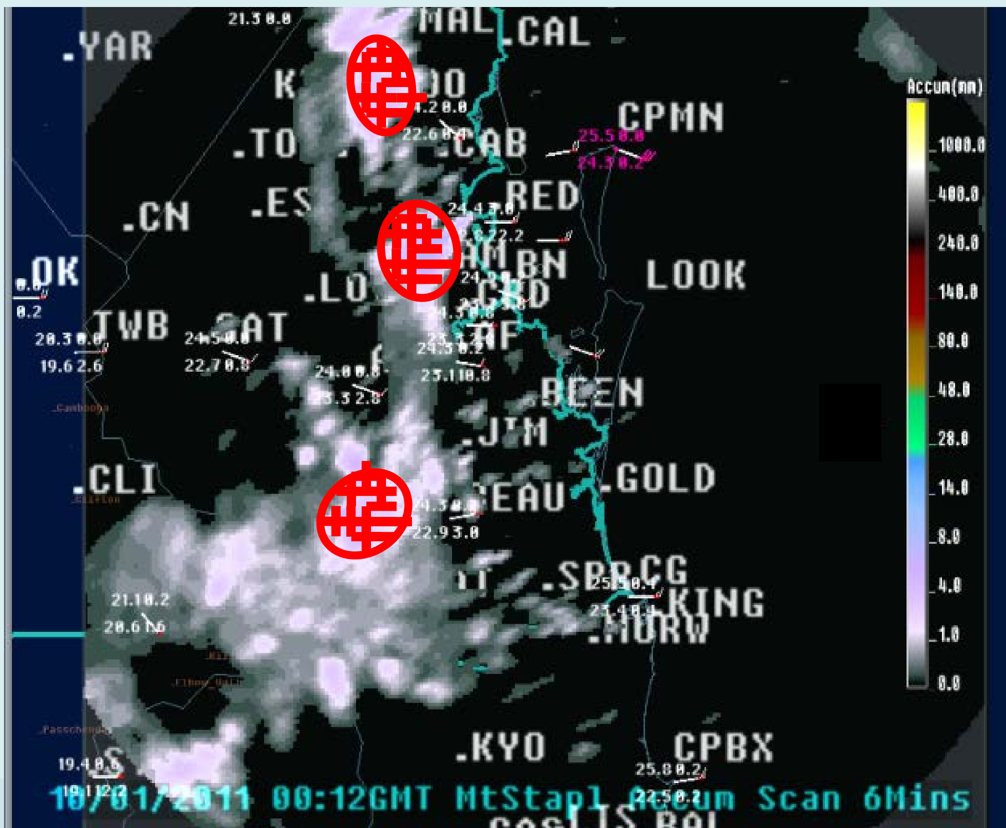


QPN – Nowcast Creation

3. Apply noise rate at each scale

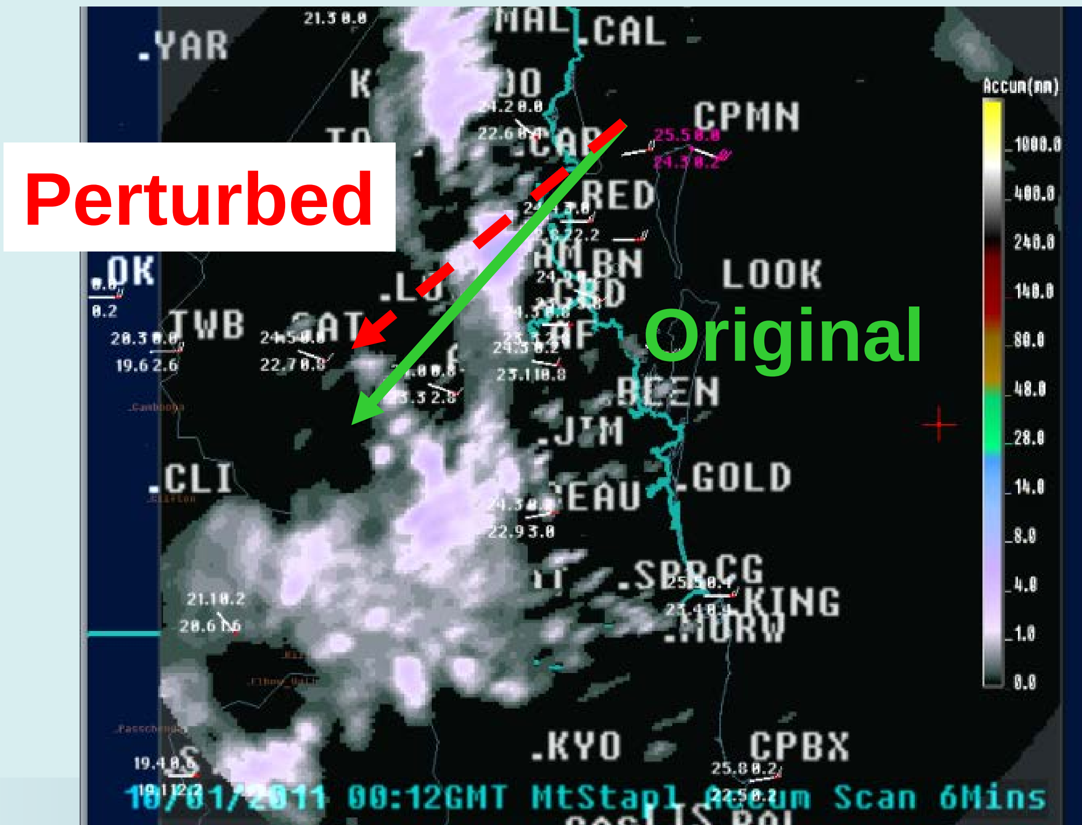
   (high skill = small noise rate over time)

   (low skill = large noise rate over time)

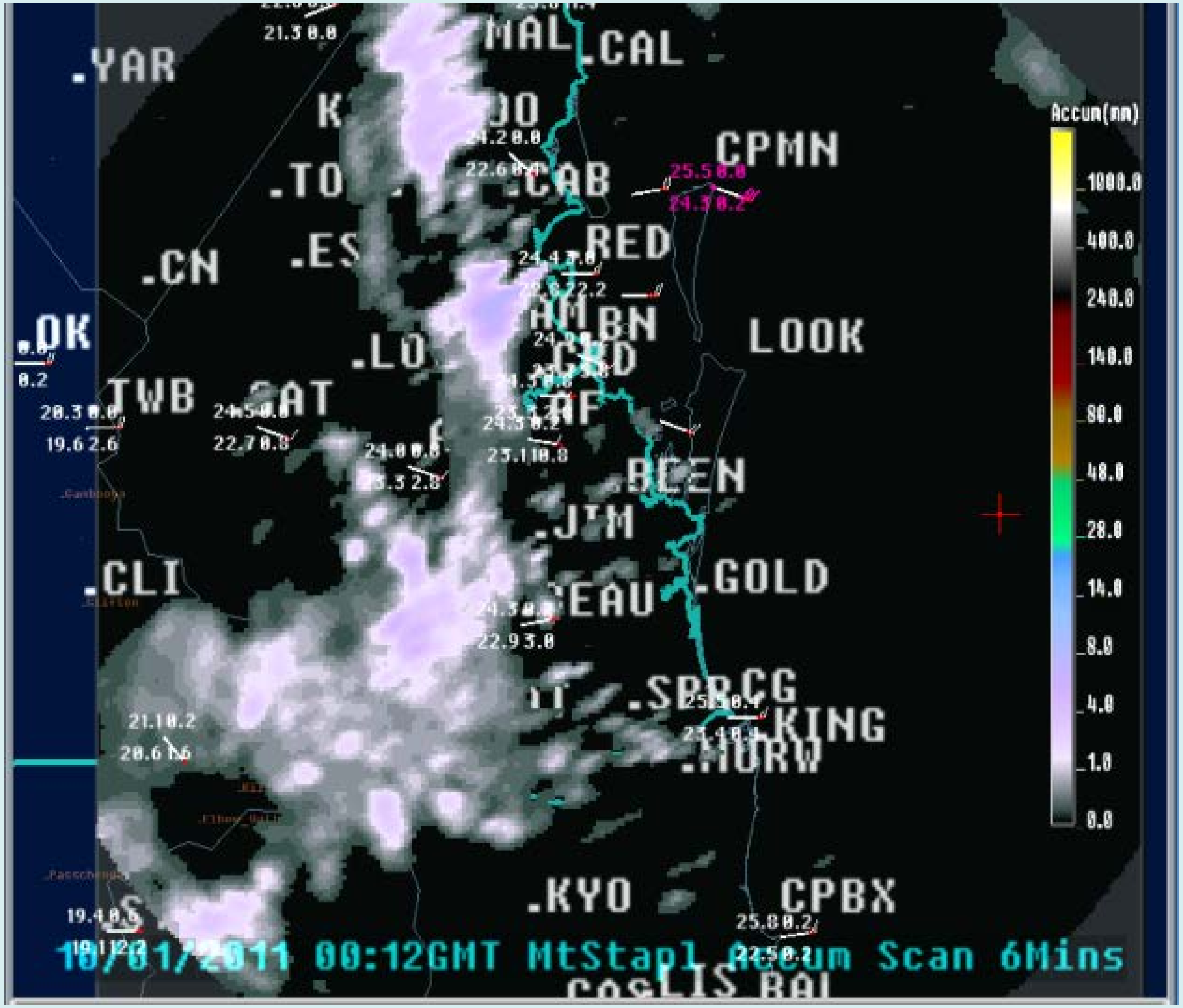


QPN – Nowcast Creation

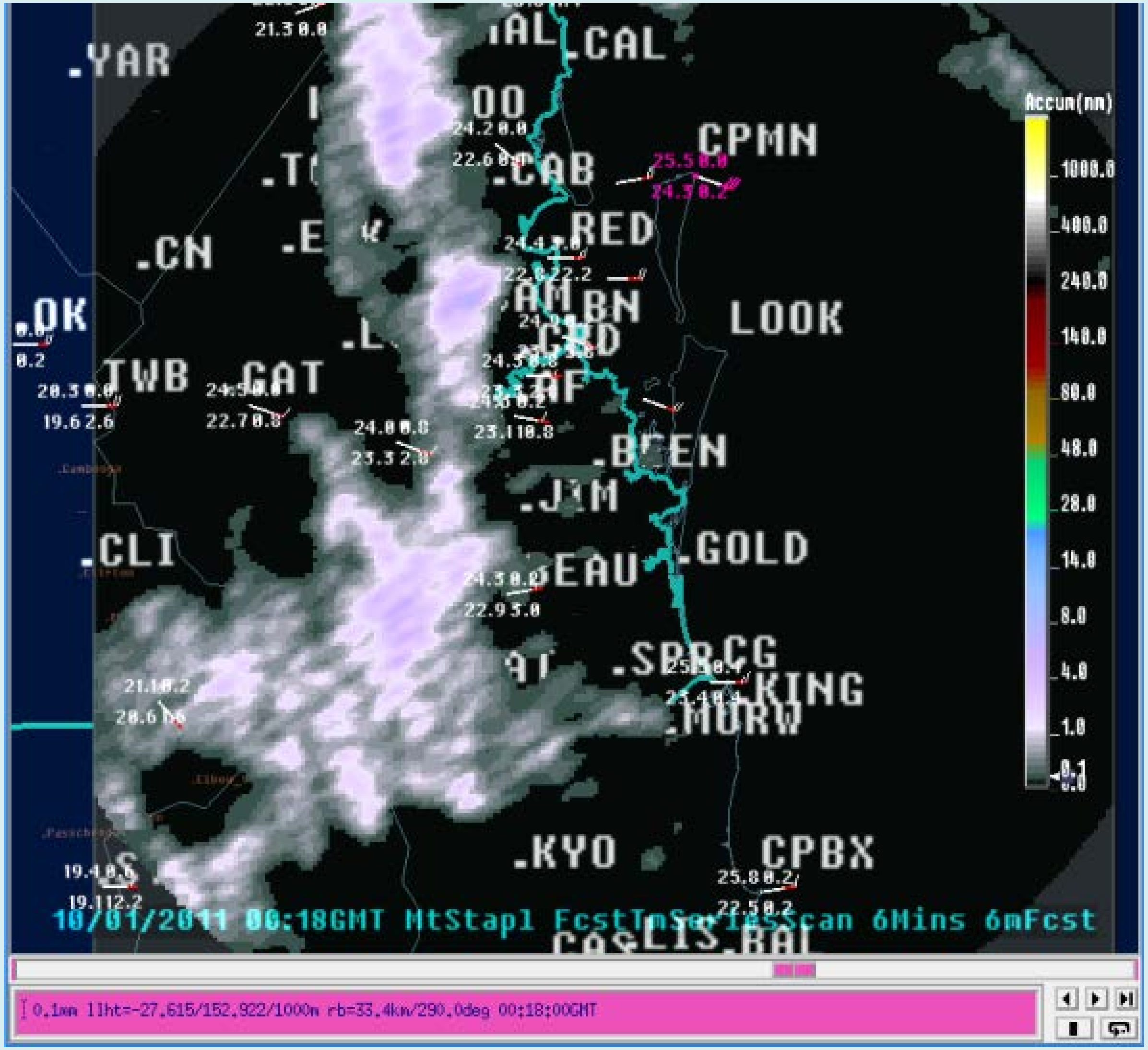
4. Perturb Motion Vectors
5. Advect forward in time applying noise rates at different scales



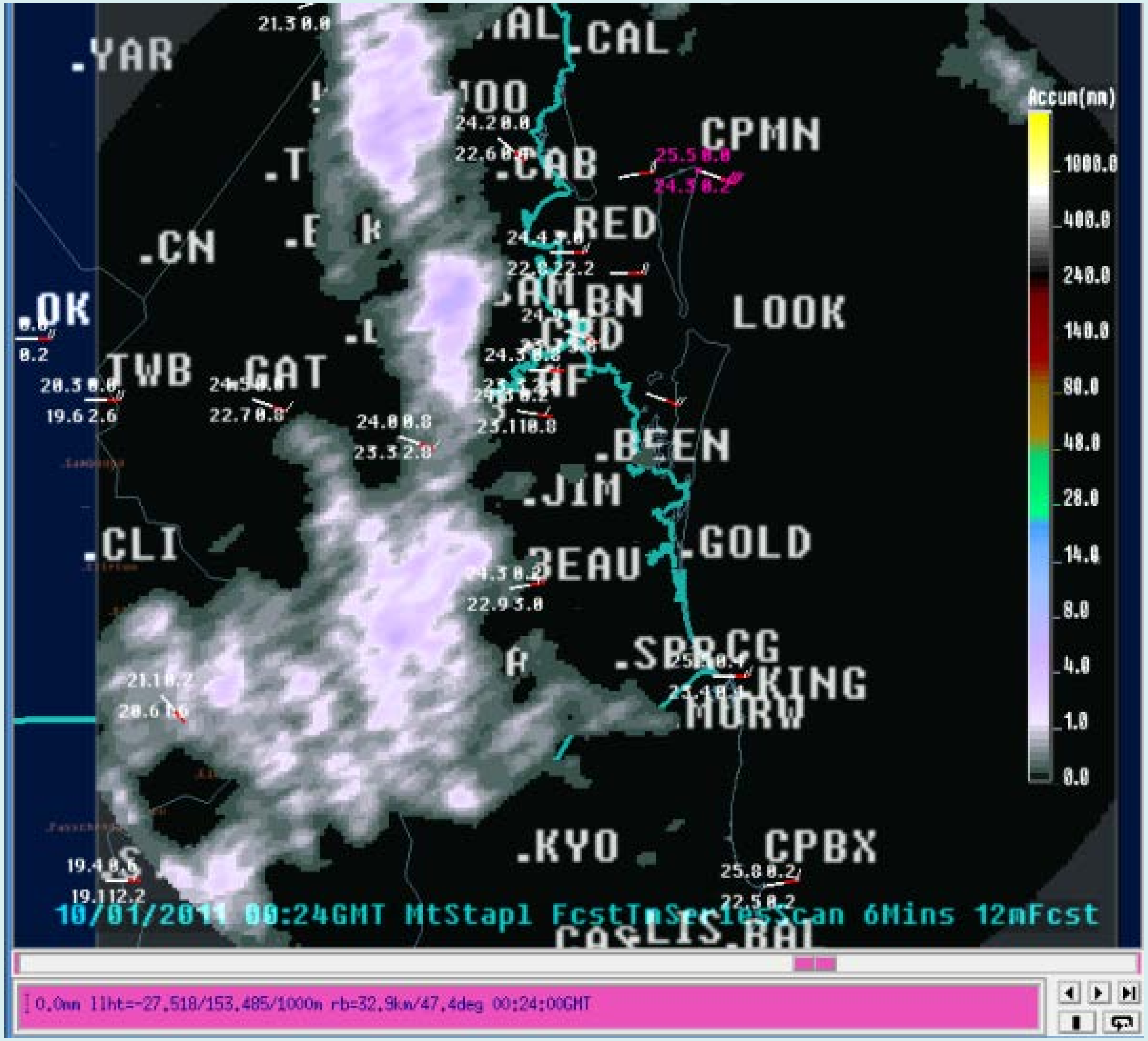
QPE – 6 Min Accumulation



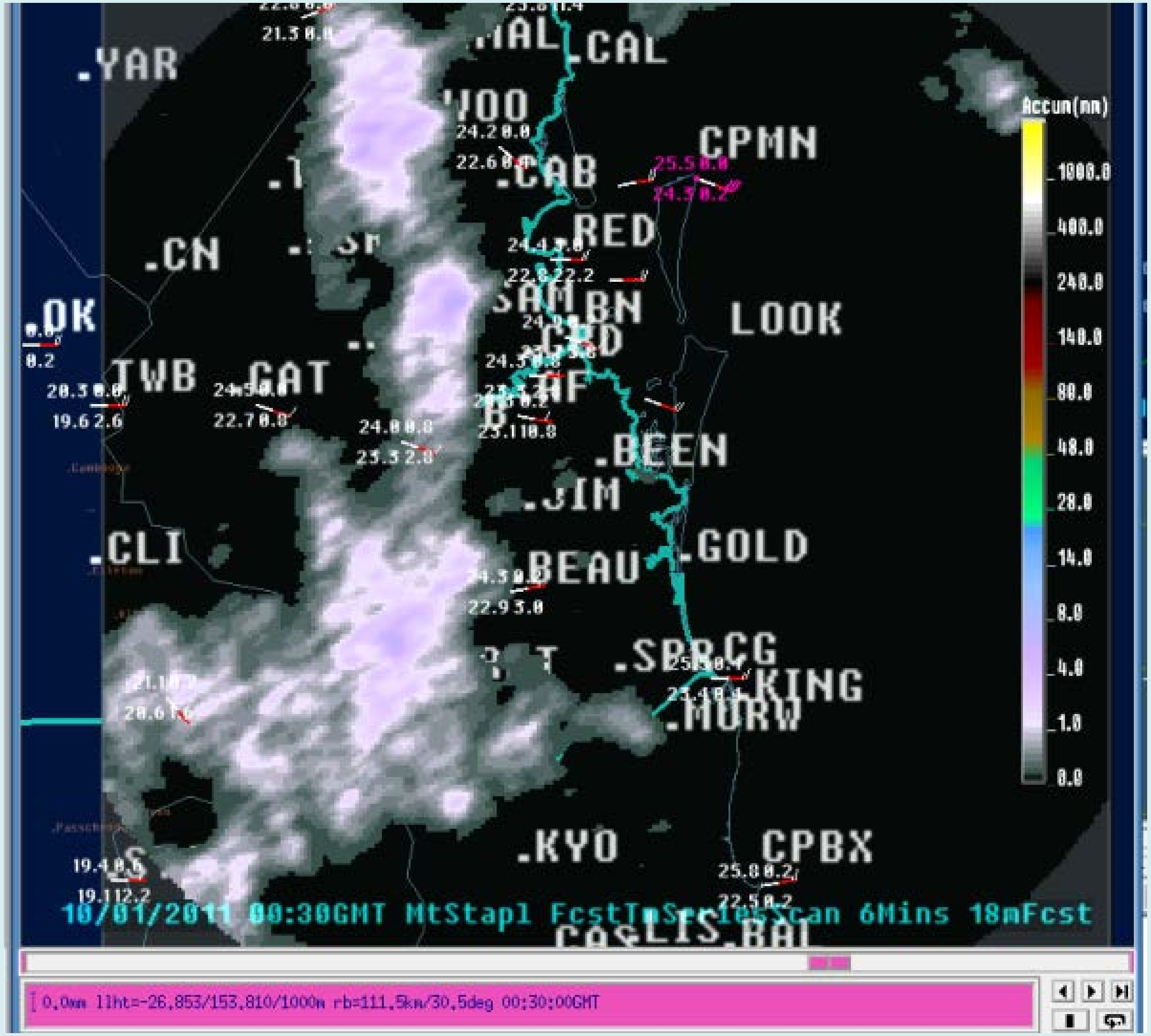
QPE – Nowcast Example



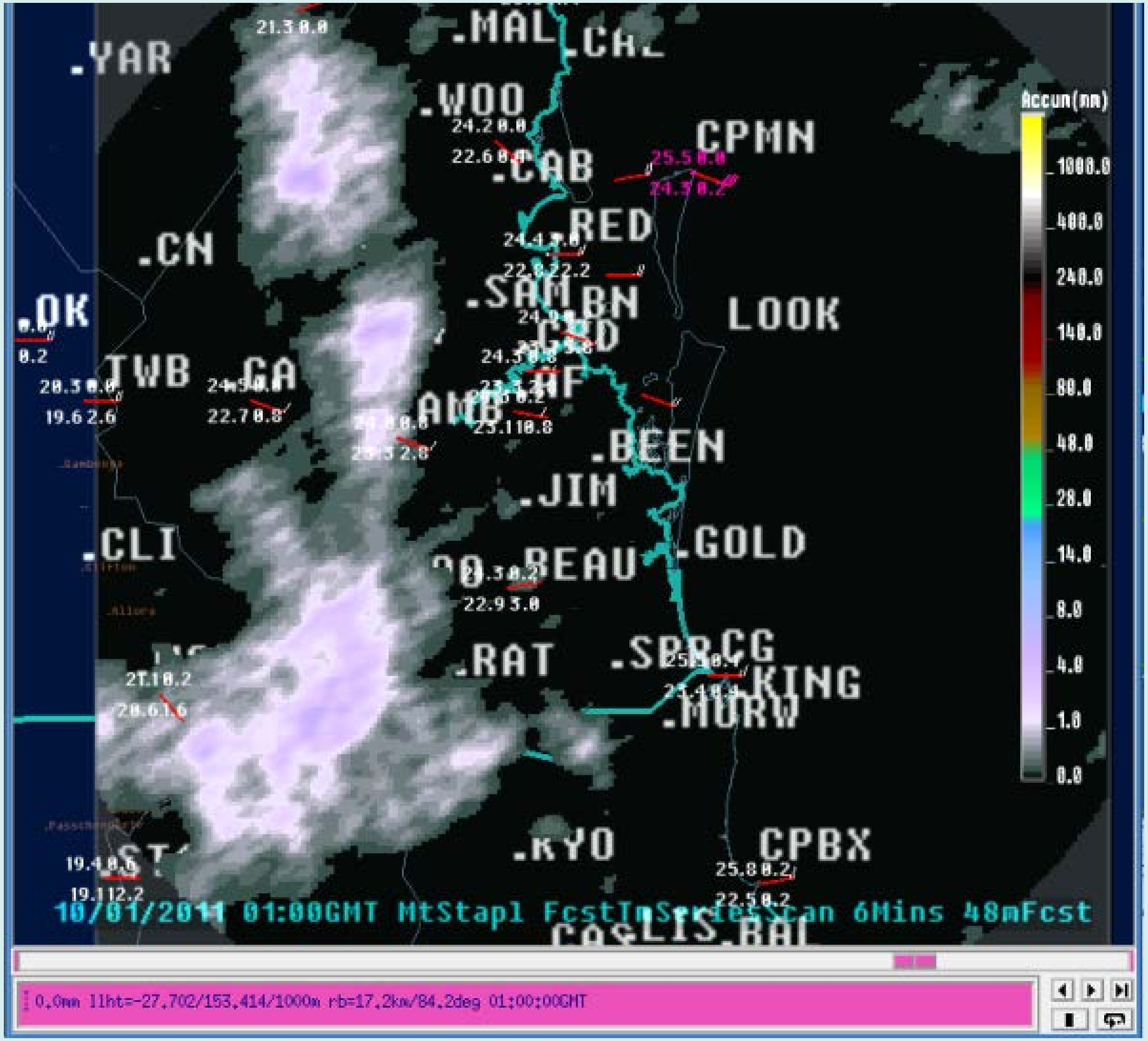
QPN – Nowcast Example



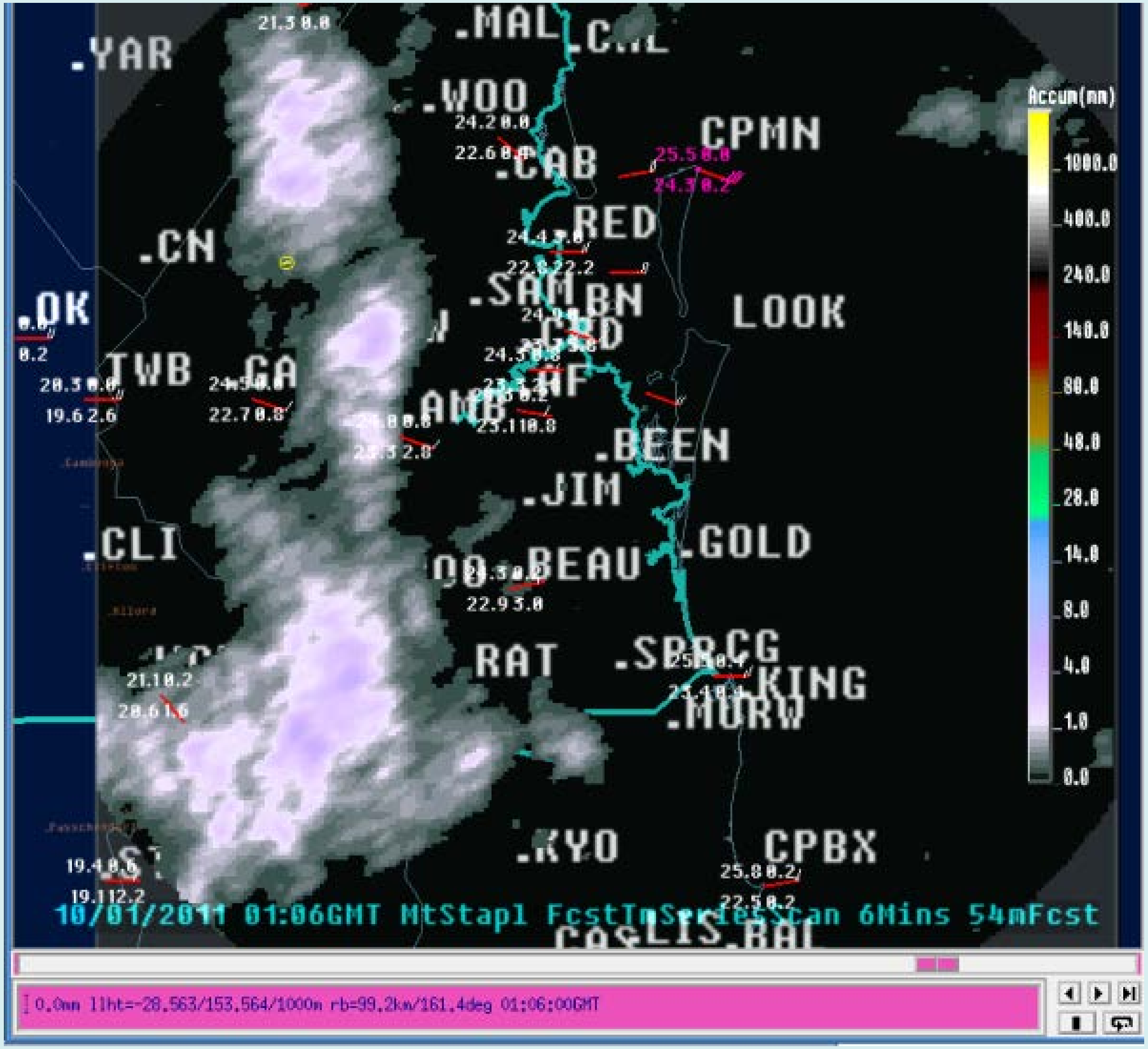
QPN – Nowcast Example



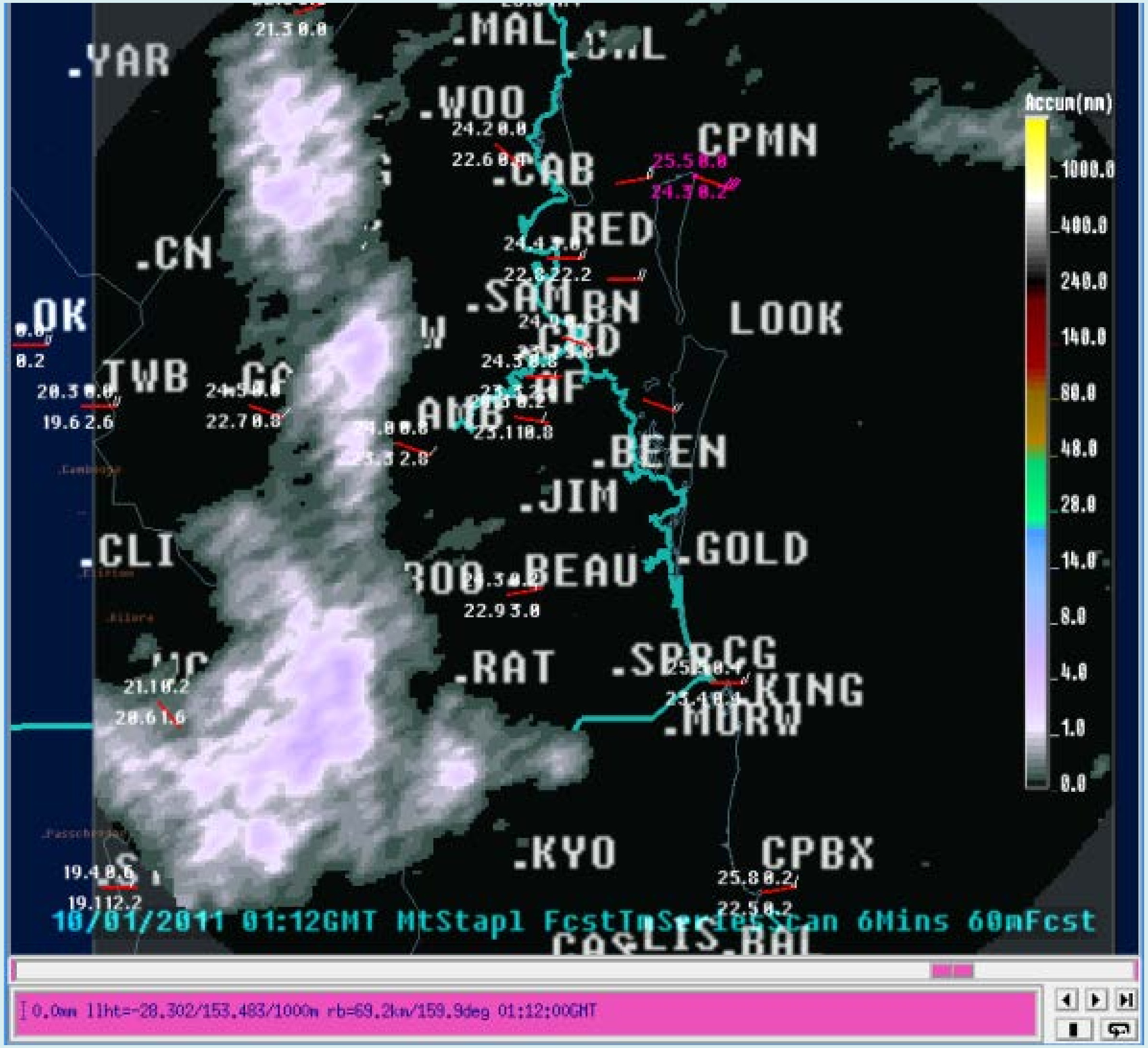
QPN – Nowcast Example



QPN – Nowcast Example



QPN – Nowcast Example



QPN – Nowcast Example

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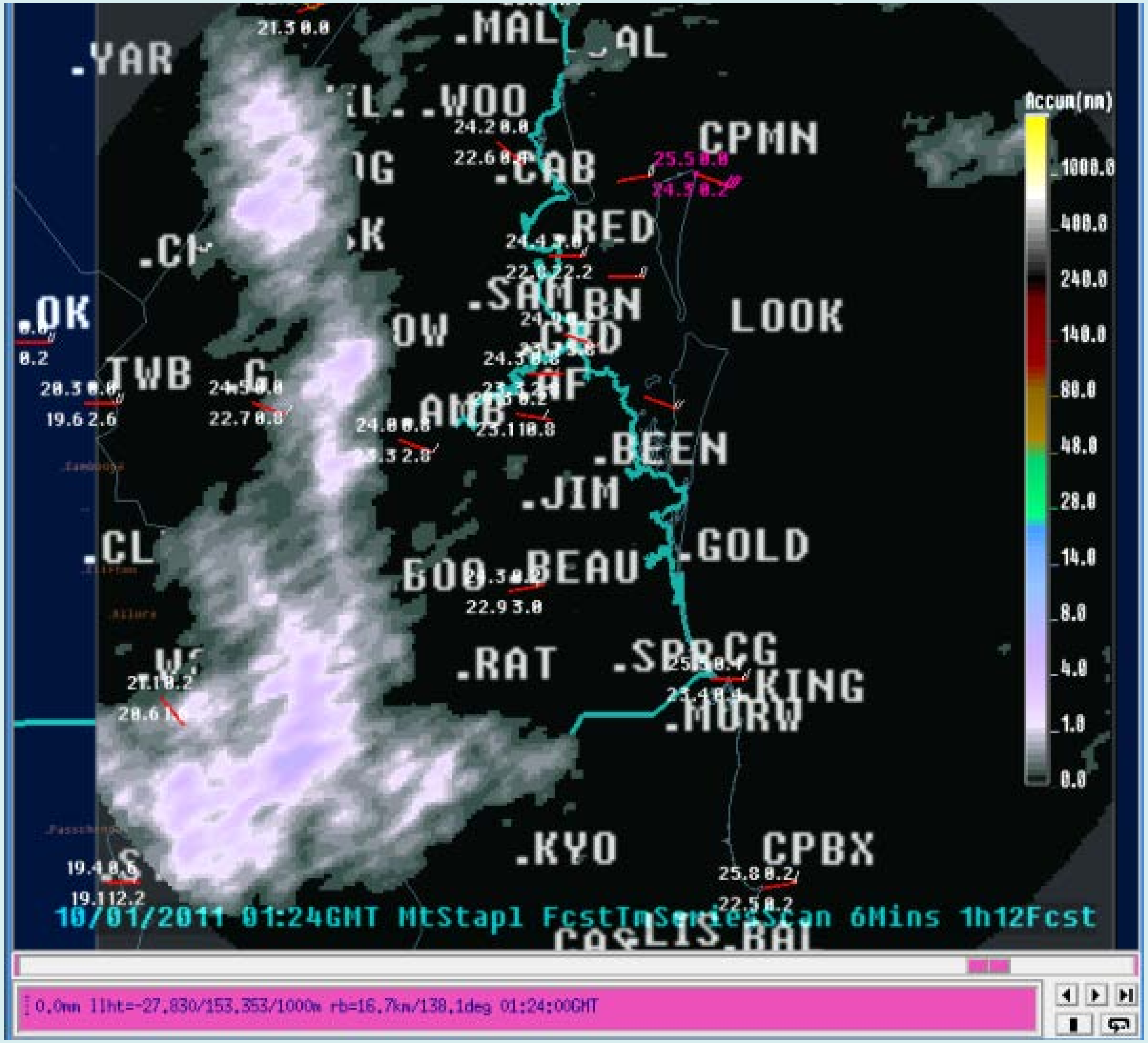


QPN – Nowcast Creation

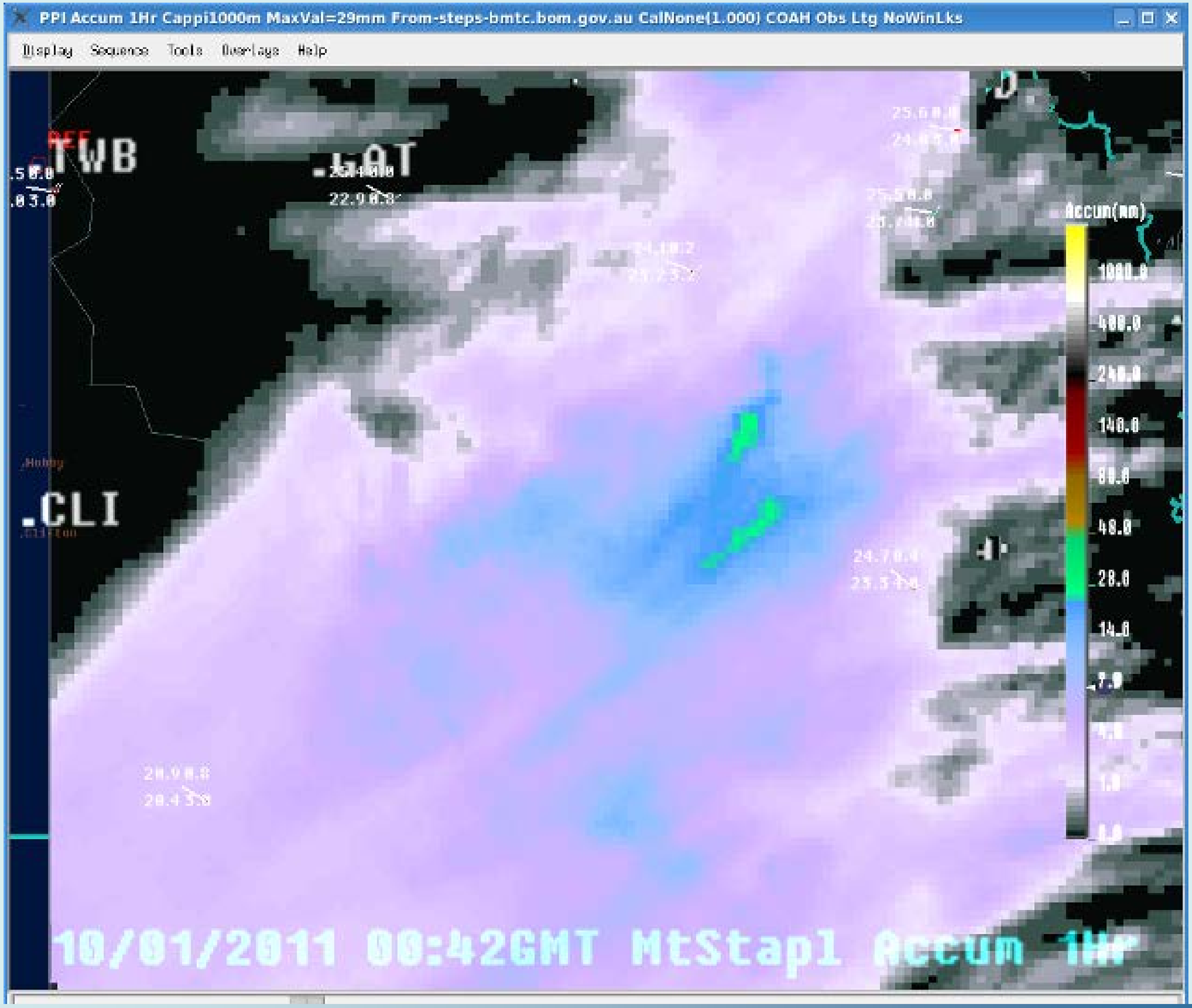
1. Decompose to scales
2. Calculate skill of each scale
3. Apply noise rate at each scale
4. Perturb Motion Vectors
5. Advect forward in time applying noise rates at different scales

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

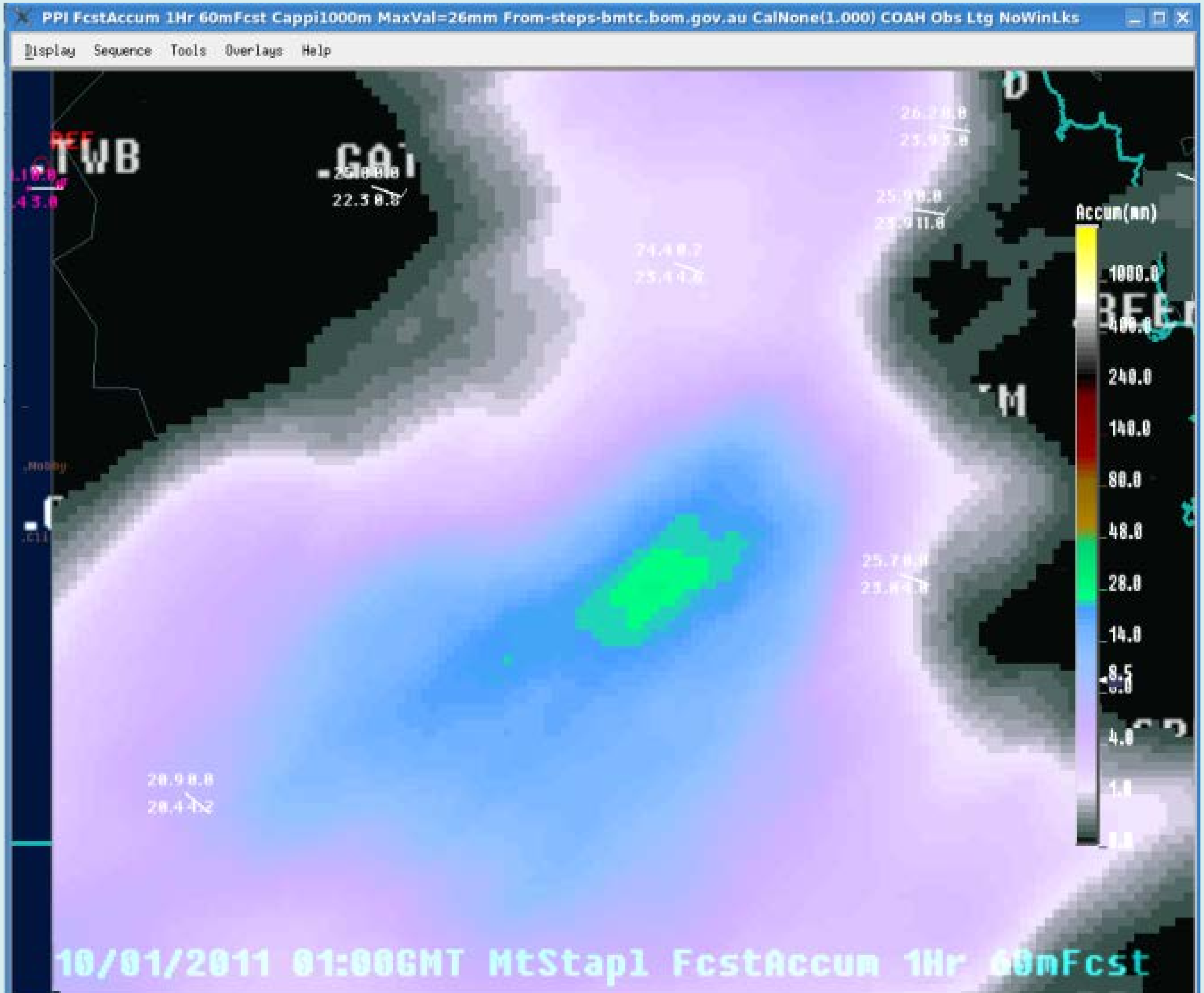
-- Derive Probabilistic Nowcasts (later)

-- Ensemble Mean Accumulation →Nowcasts

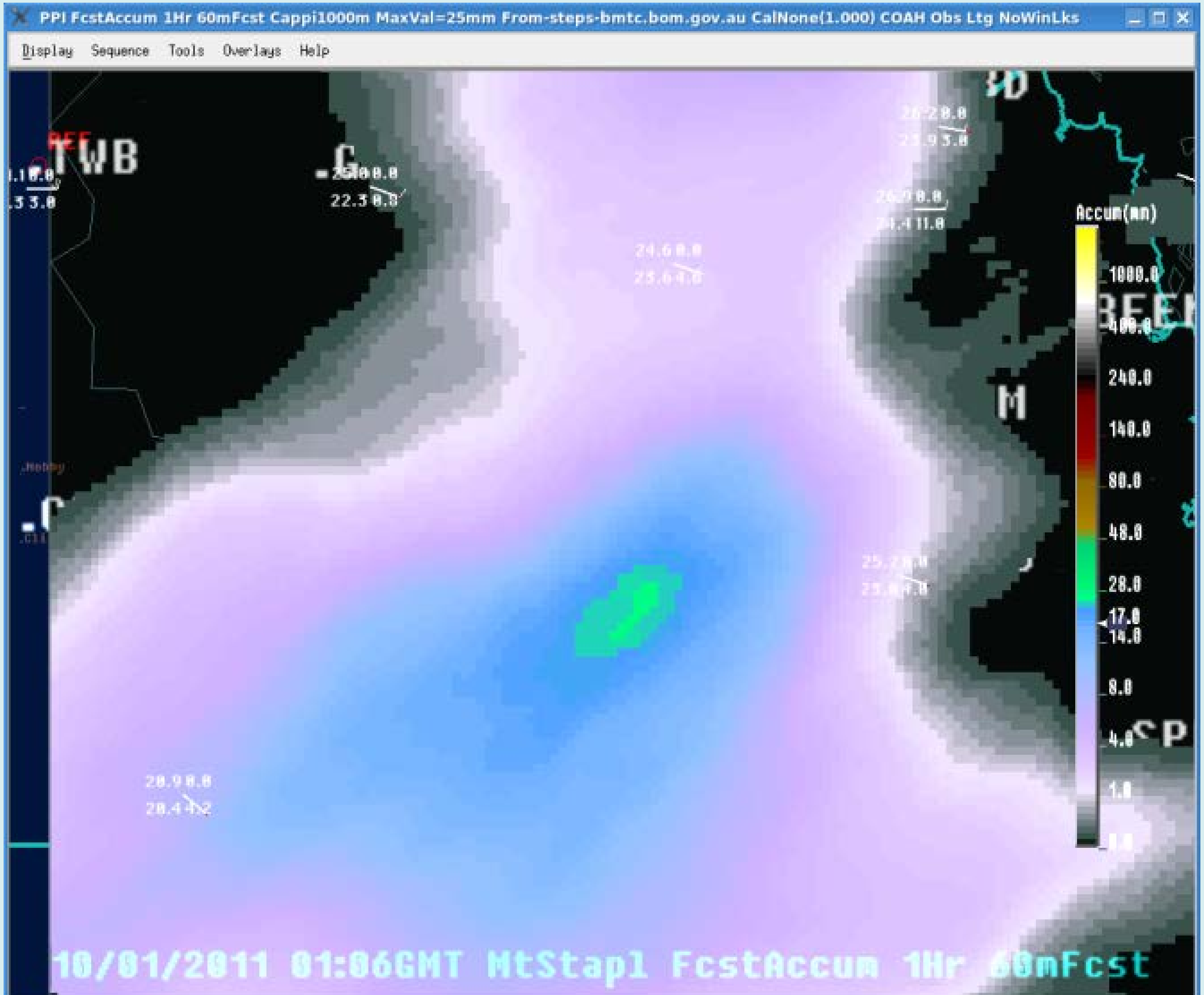
QPE – Example 2



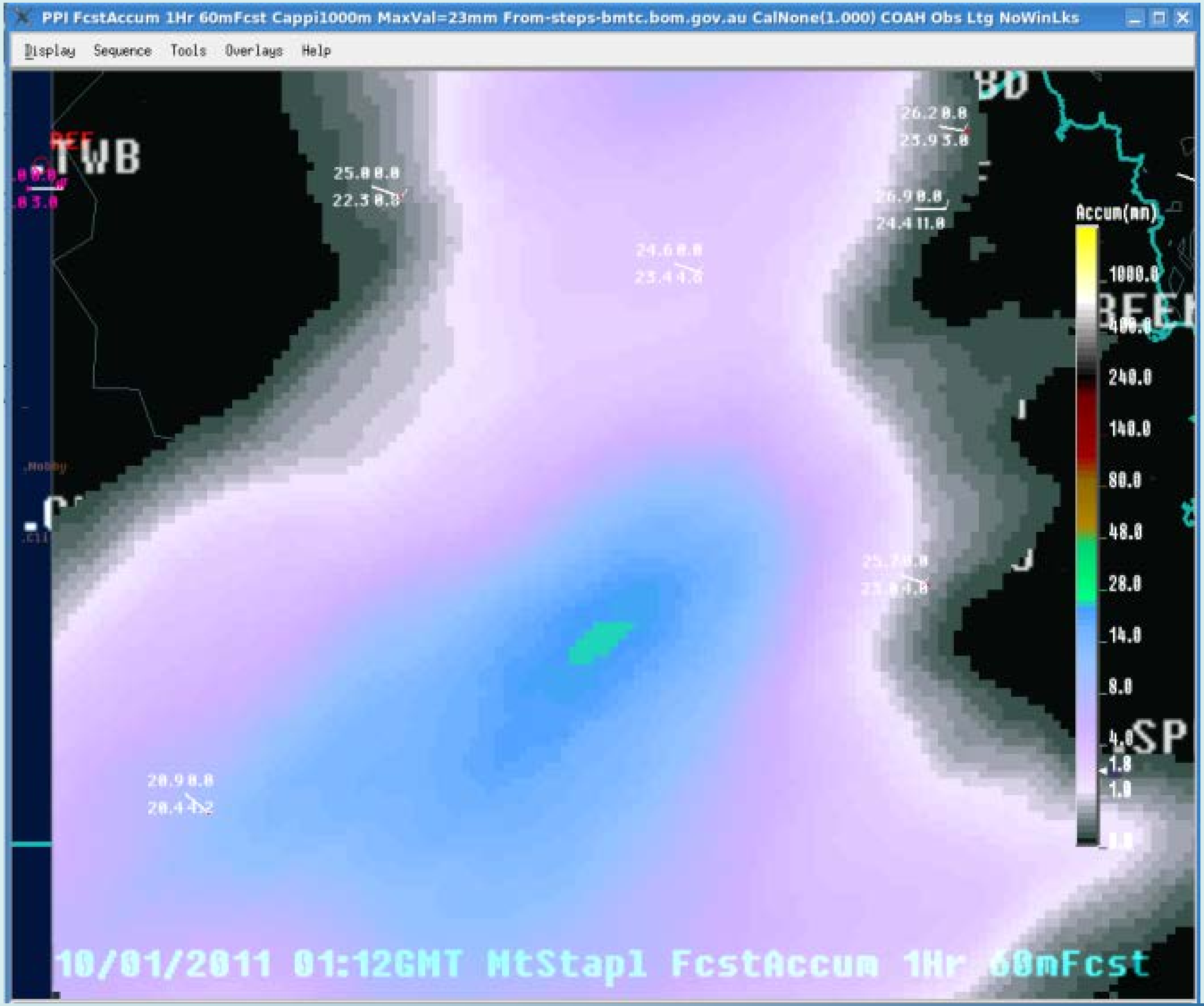
QPN – Ensemble Mean



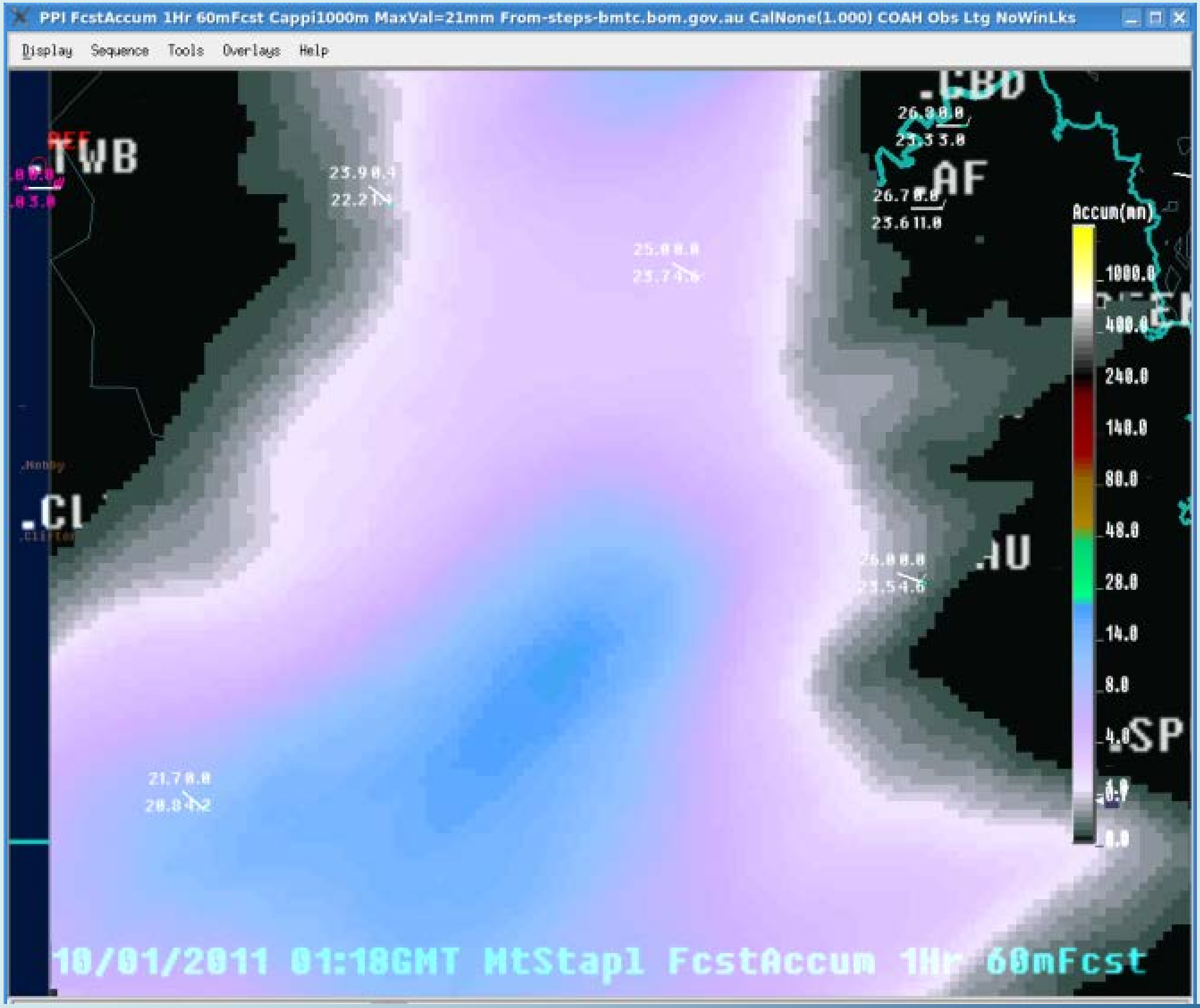
QPN – Ensemble Mean



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

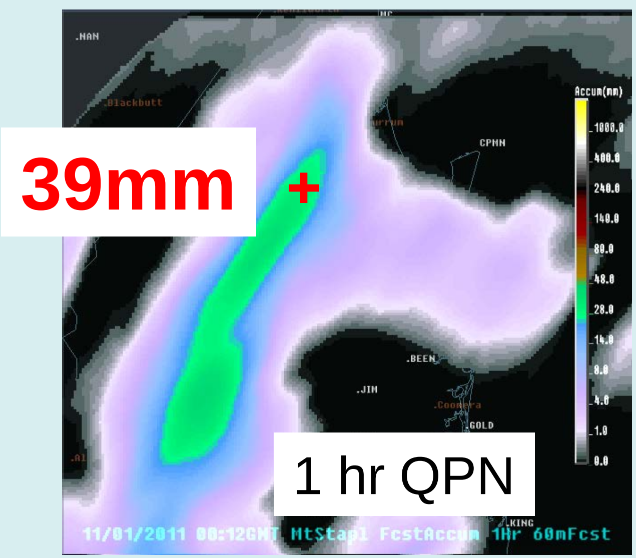
- Used to assist in identifying rainfalls in the ARI spectrum
- This may assist in identifying areas for Warning
- Combines Nowcast frequencies - 30min & 1hr
- Consideration period is the near future only

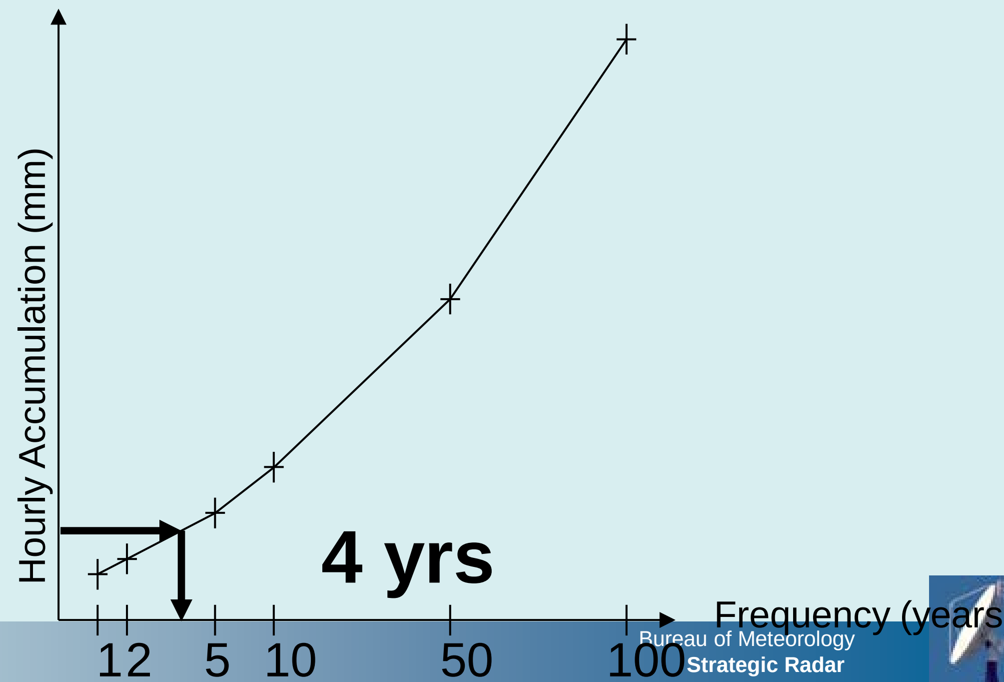
QPN – Max Frequency

Constructed using :

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

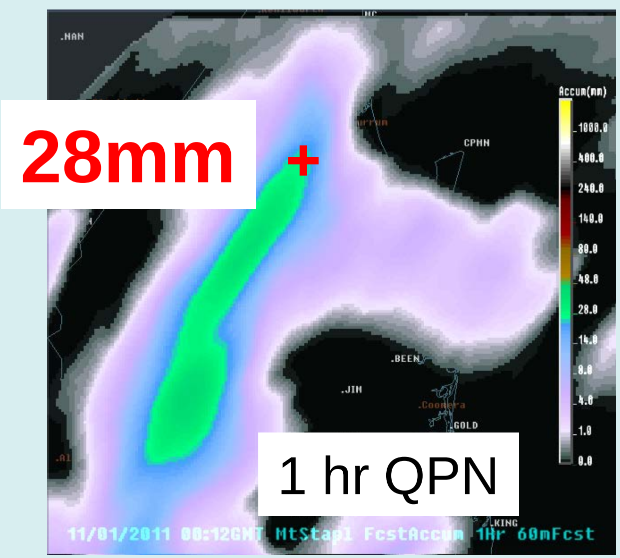
To create a QPN Max Frequency value at each pixel

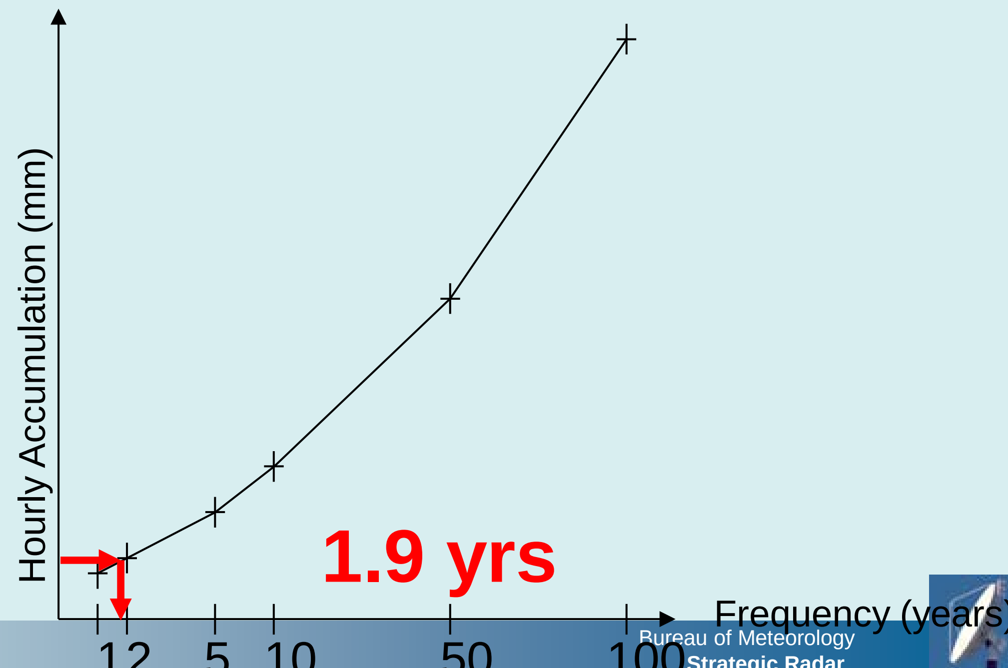




QPN – Max Frequency

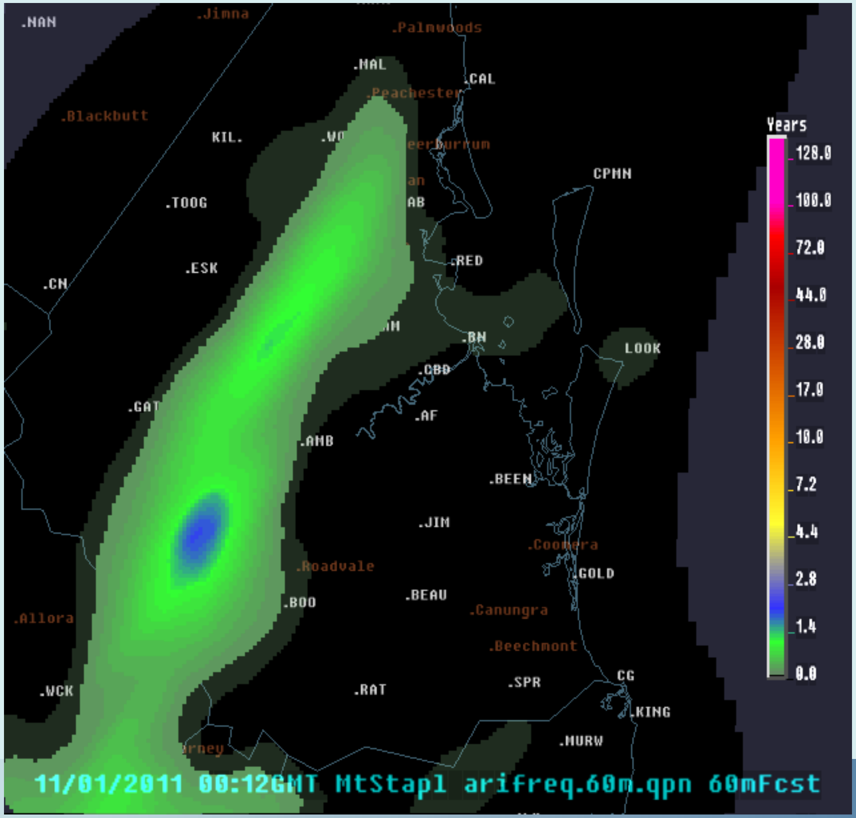
Then repeat for all other pixels



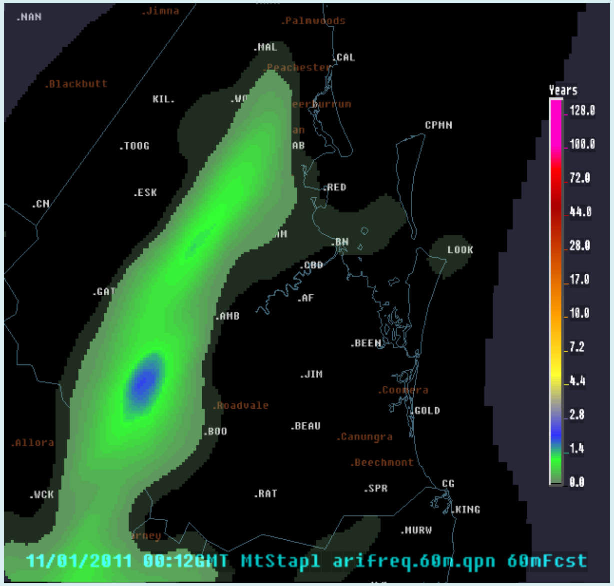


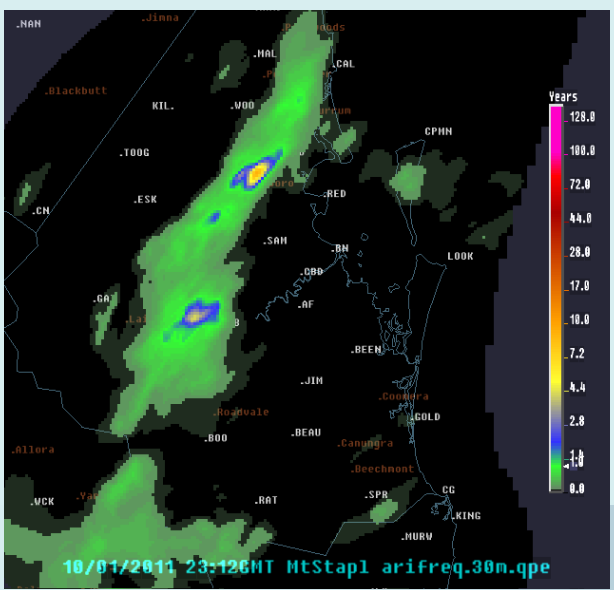
ARI Maximum Frequency 1 Hour

- 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

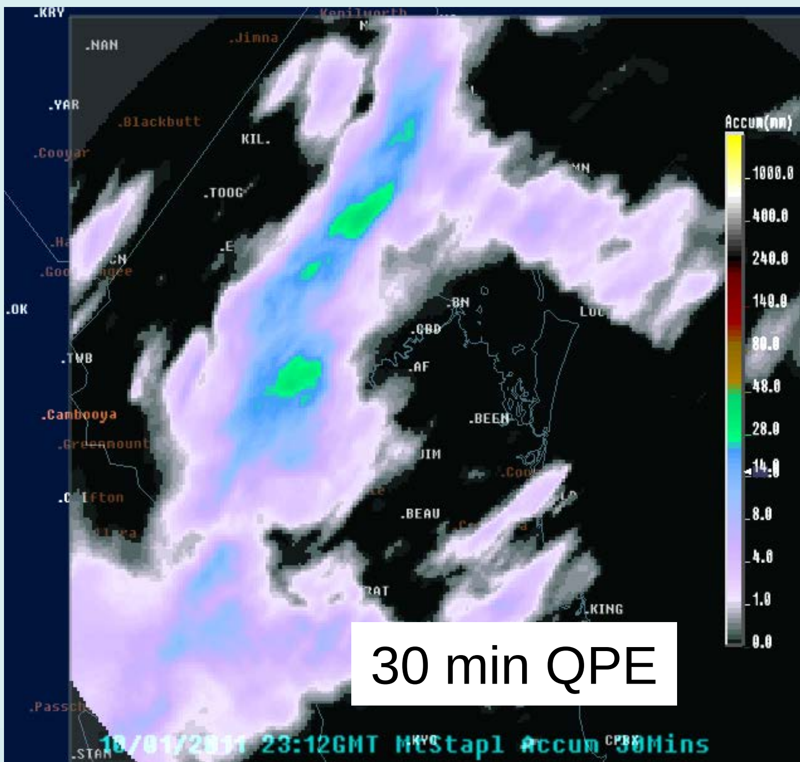
The nowcast of 30min rainfall combined with past 30min, might exceed the 1 hour 1:10 year amount

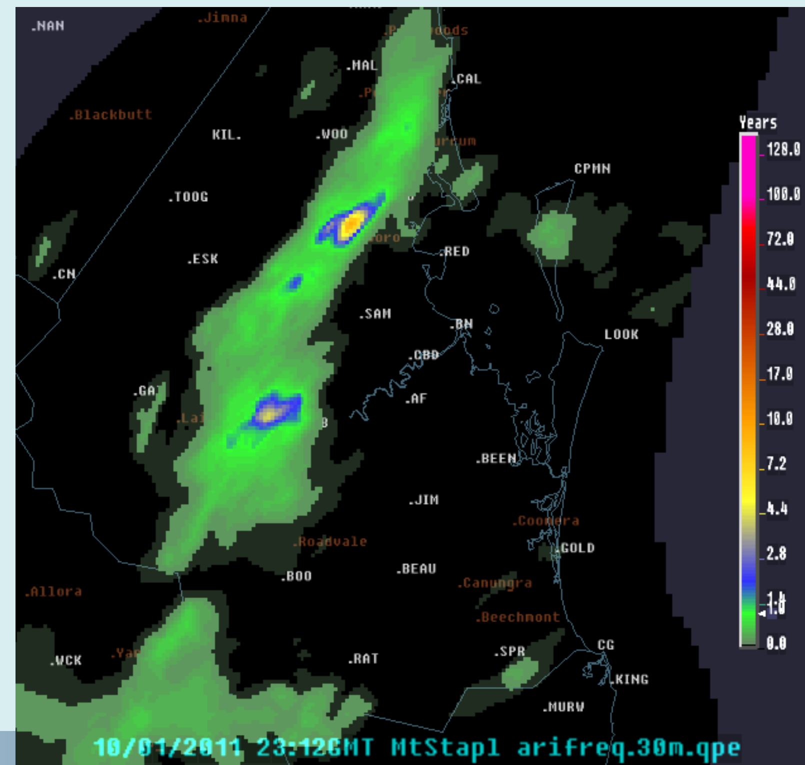
Therefore – combine 30 minutes of past accumulated rain into the Max Frequency QPN product

QPE into ARI Max Frequency…

Incorporating QPE into a QPN Frequency:

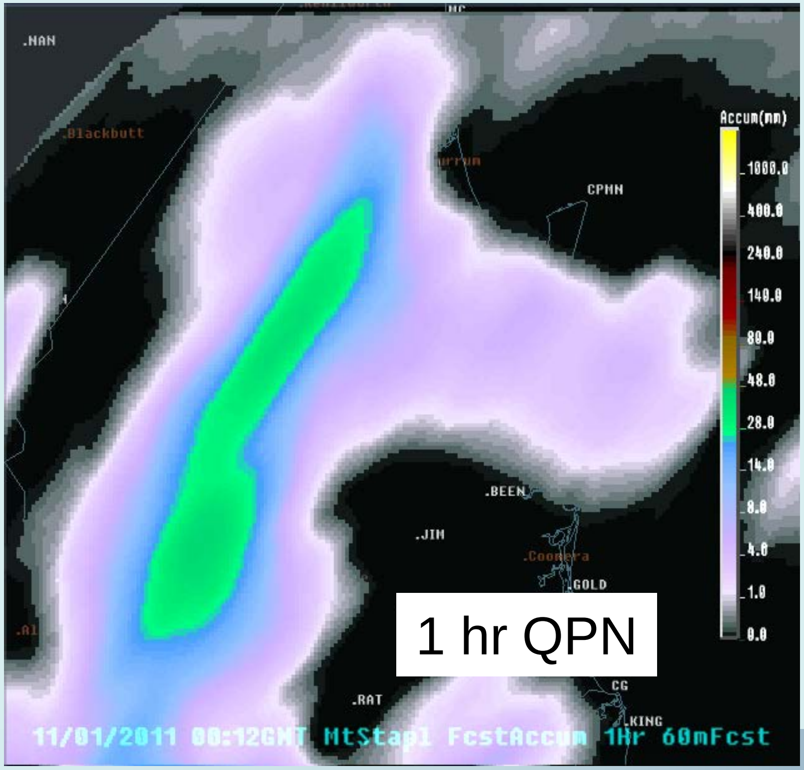
- Add recently fallen rain to the product

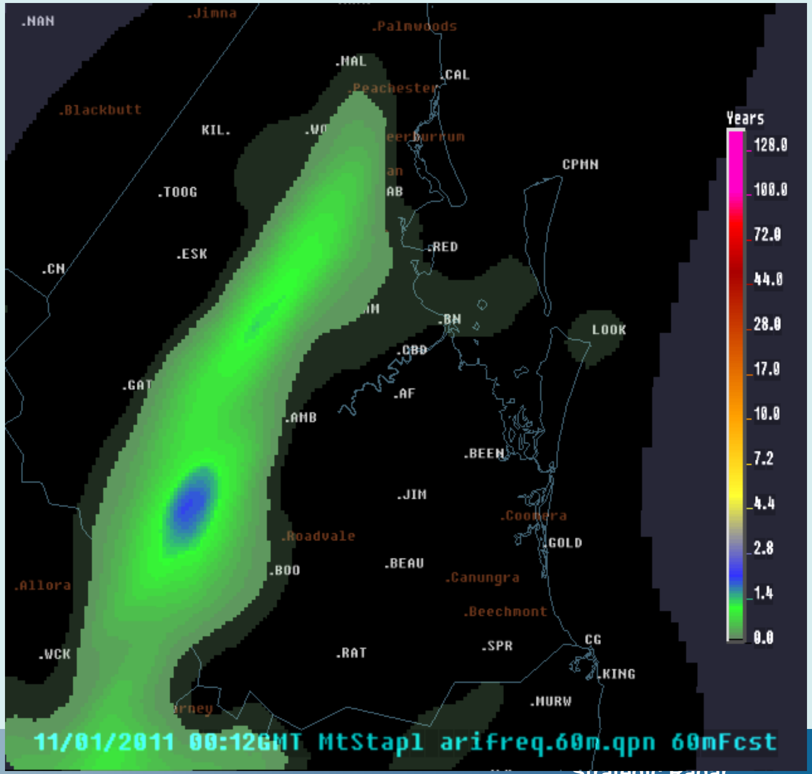




QPE into ARI Max Frequency…

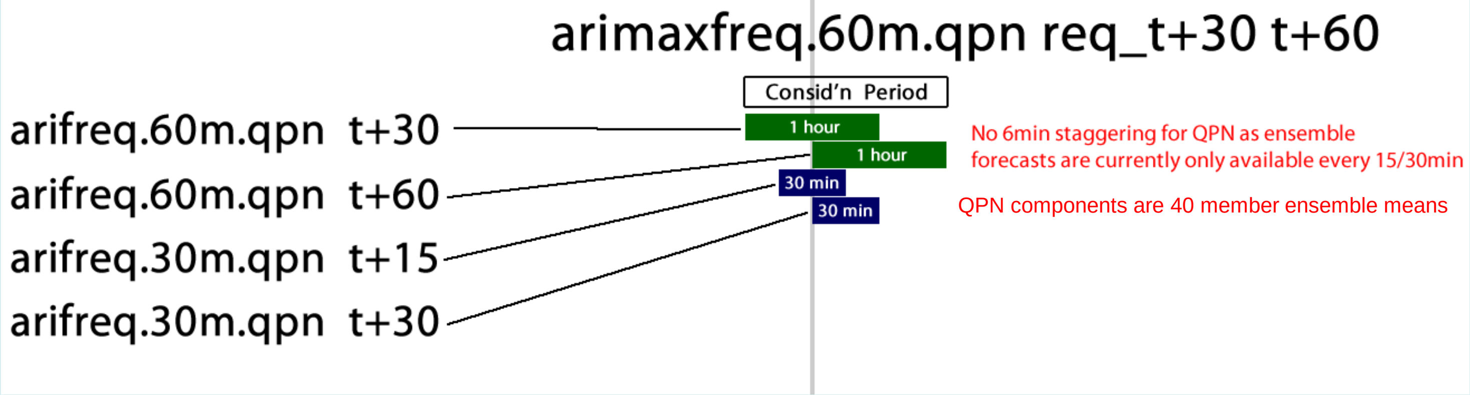
…whilst retaining the forecast for position and mean intensity



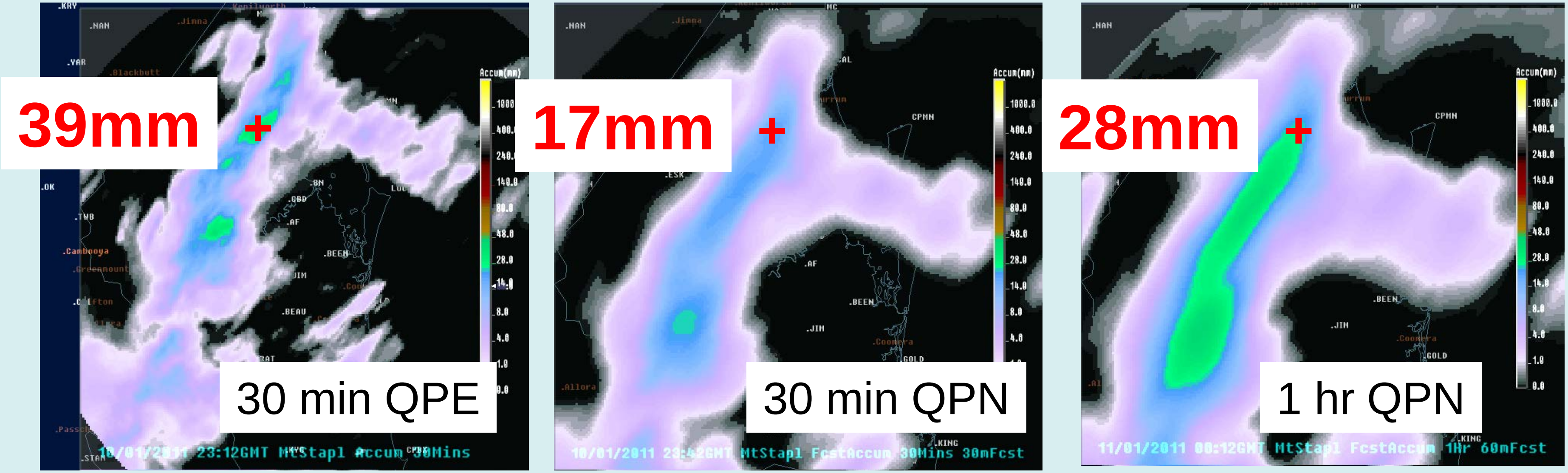


Other Durations (past + future) considered…

- Other products included….



Other Durations (past + future) considered…



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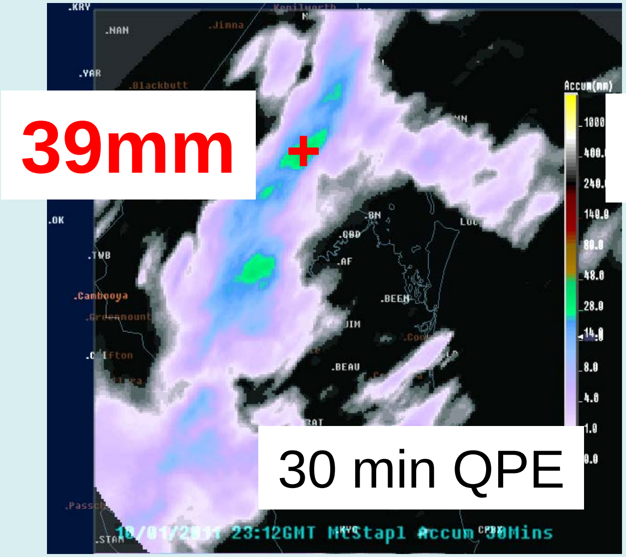
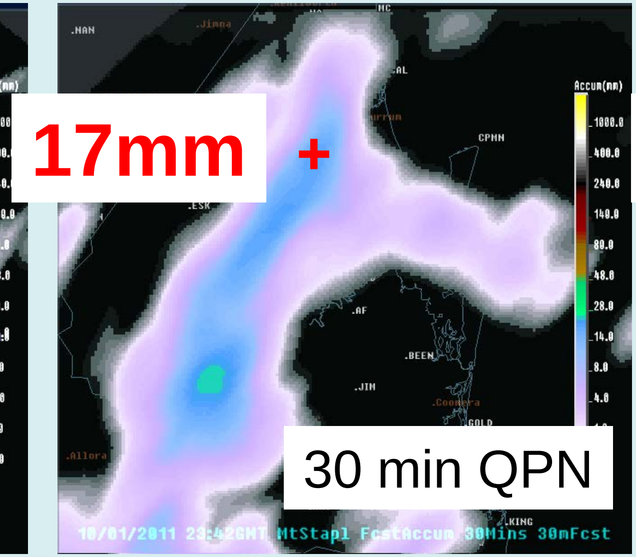
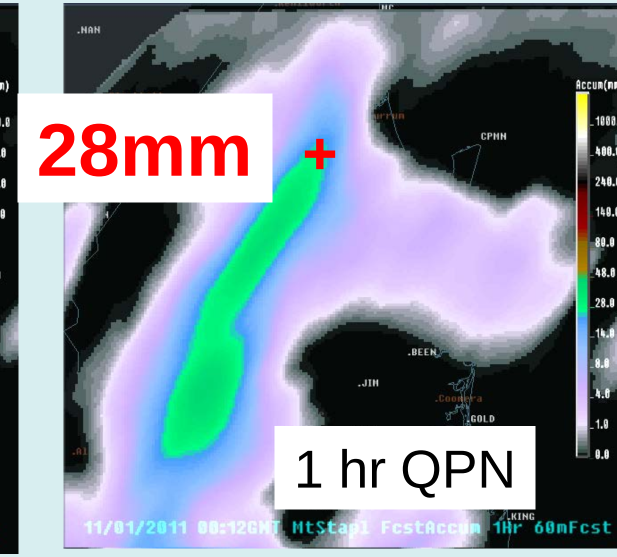


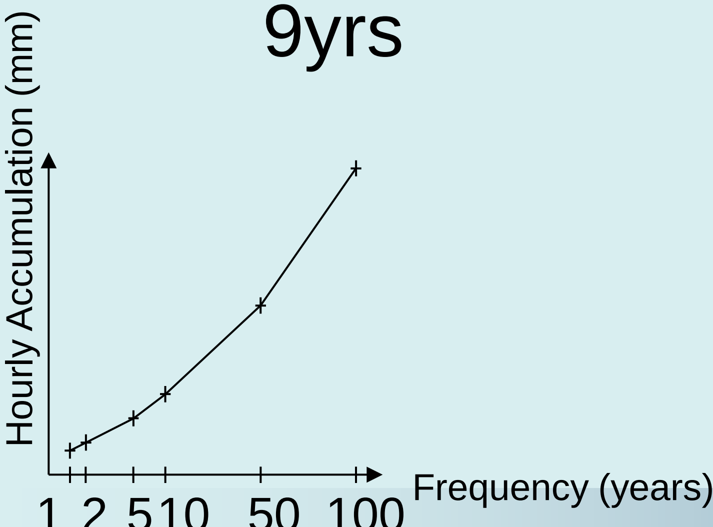




9yrs

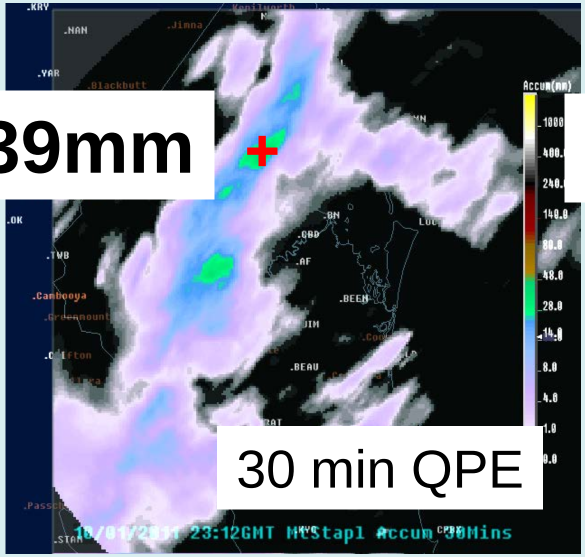
1yr

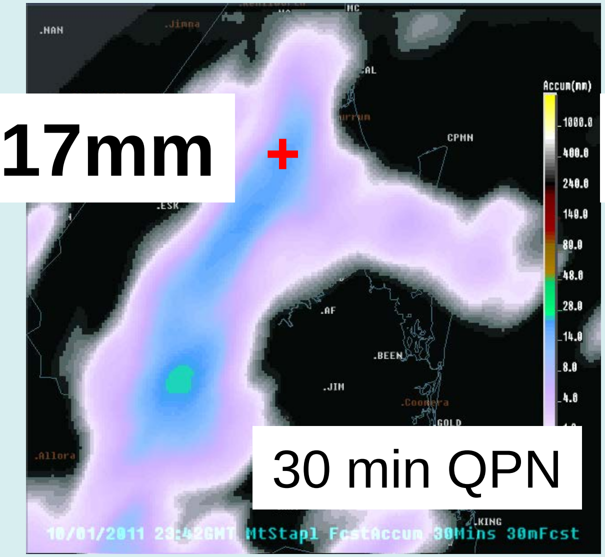
1.9yrs

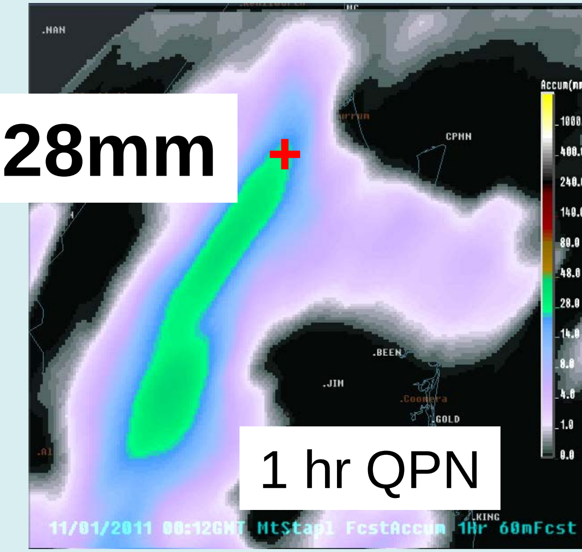


- **Convert each Accum value to a Frequency (yrs)**

Other Durations (past + future) considered...



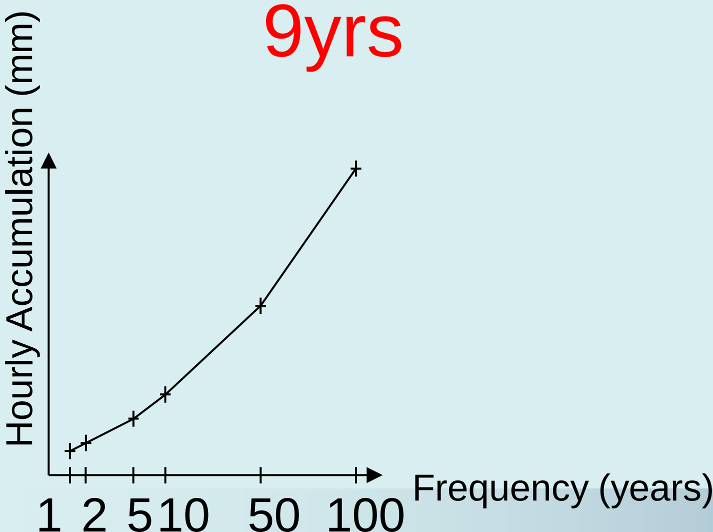




9yrs

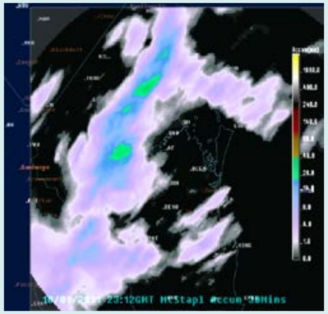
1yr

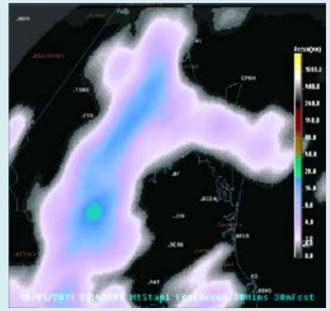
1.9yrs

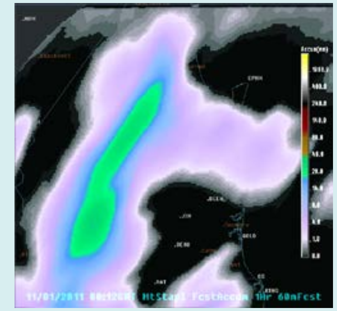


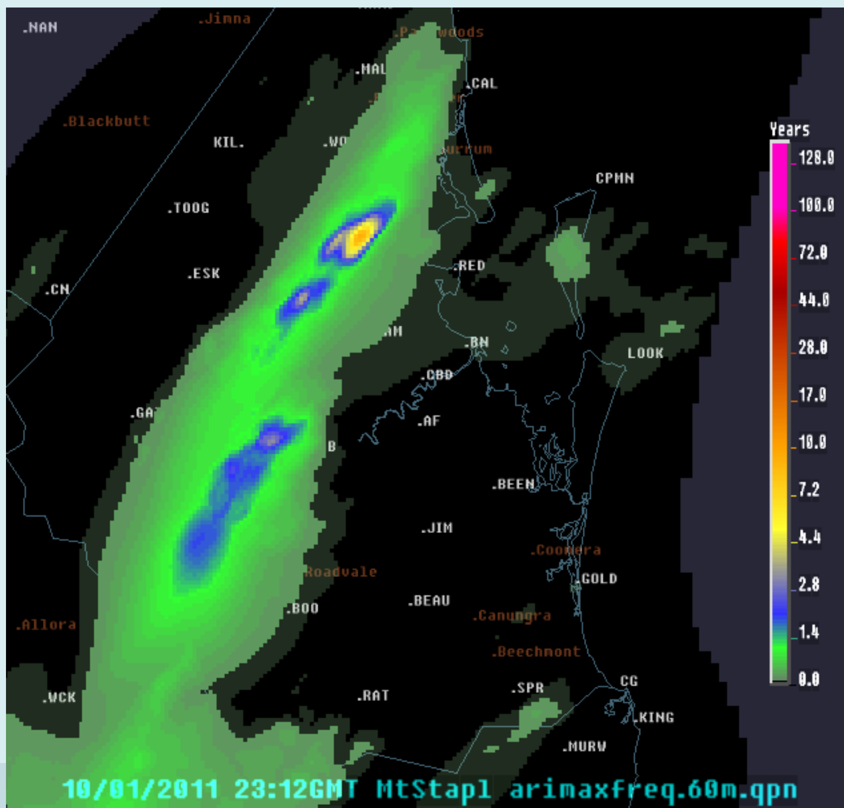
- **Record the Maximum Frequency Value (yrs) for that pixel location**
- **Repeat for other pixel locations**

The Max Years QPN Product

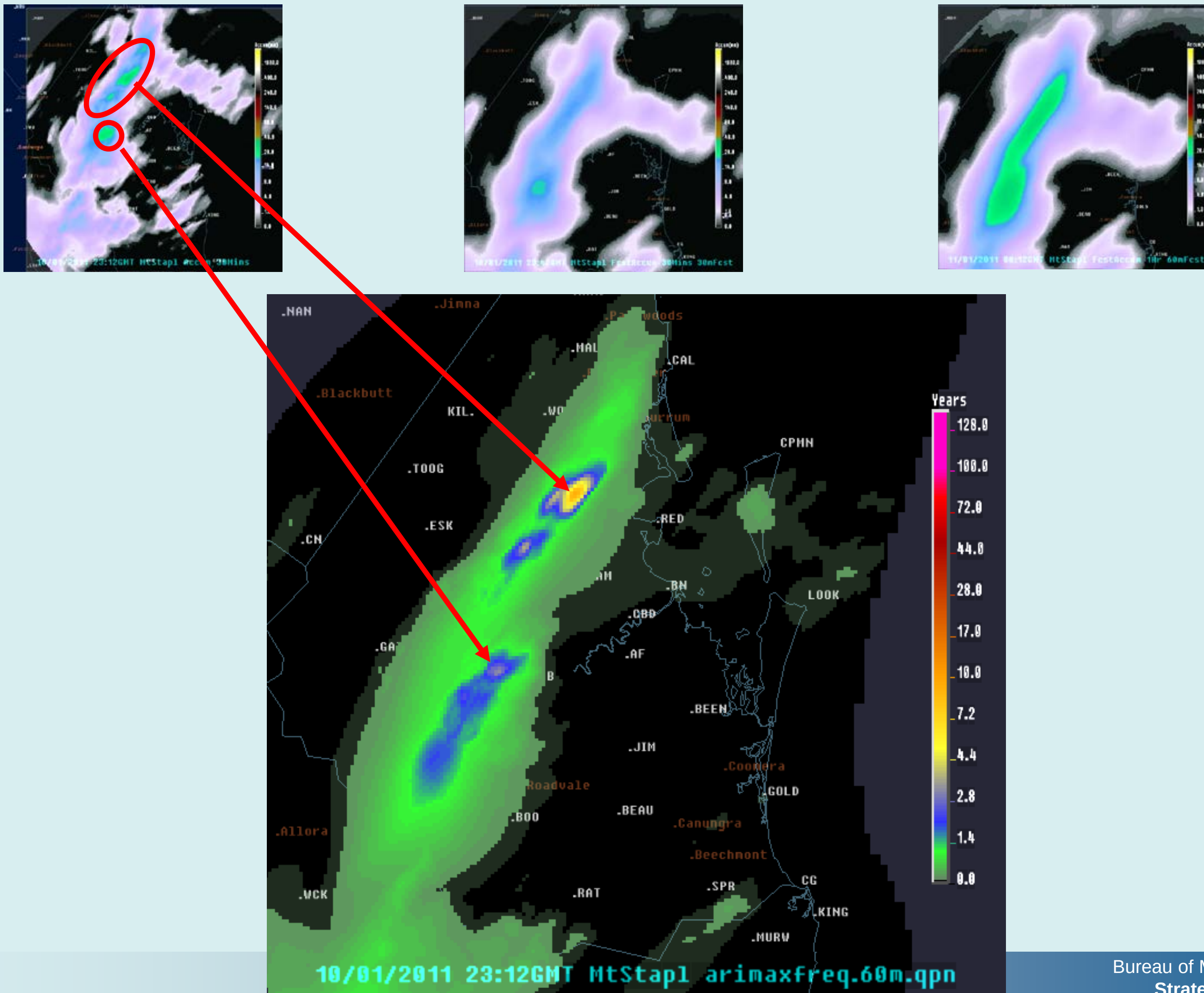




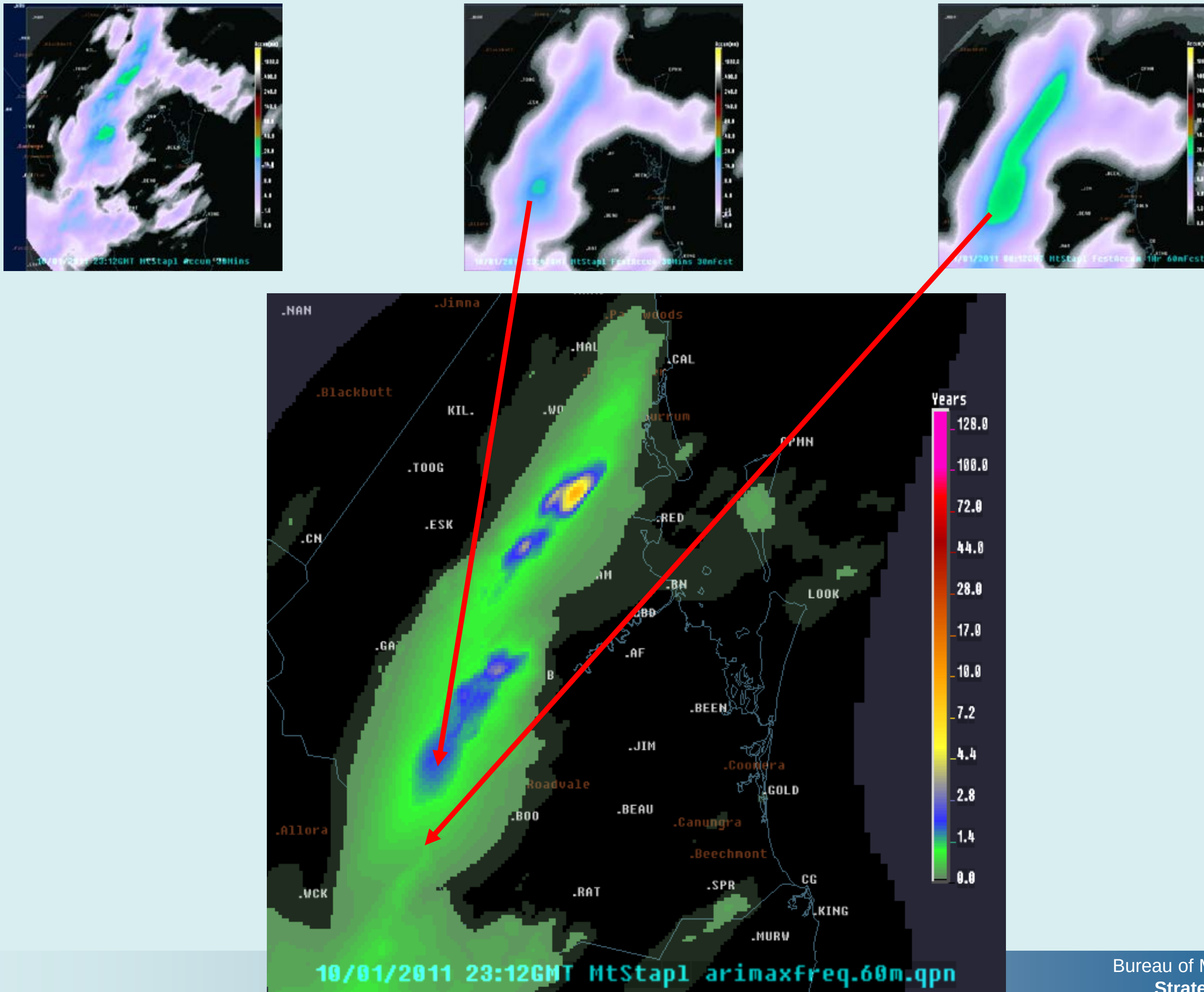




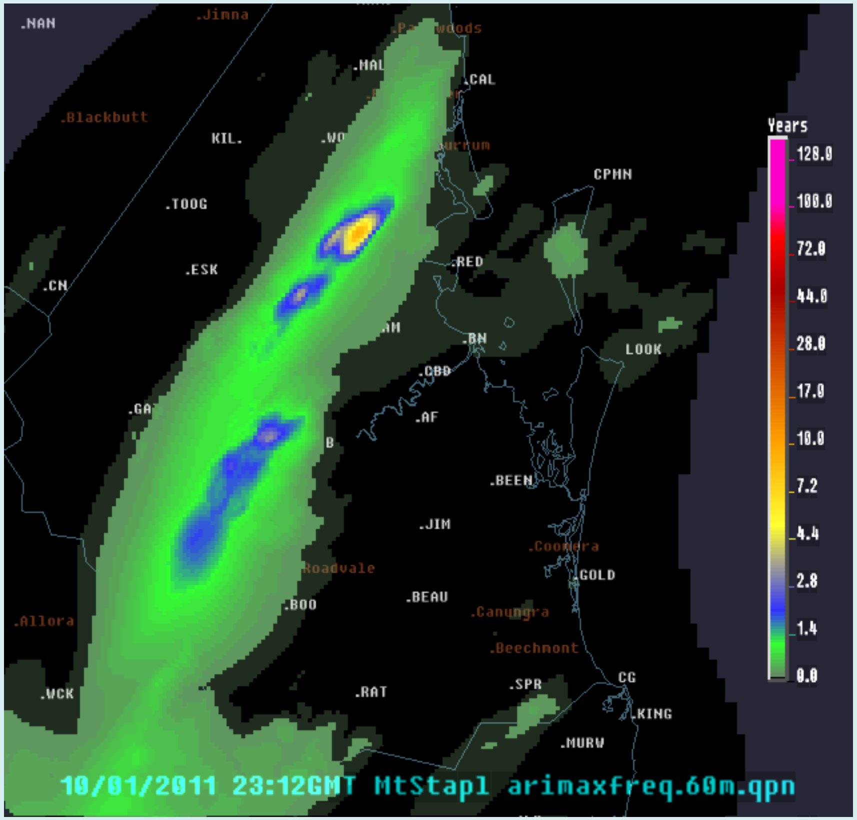
The Max Years QPN Product



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 ≥ 5 yrs

May consider ≥ 2 yrs QPN

Rapid rate of change per scan

Is heavy rain likely to persist or intensify?

Warning

Frequency ≥ 10 yrs

May consider ≥ 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