



Forecasting Rainfall at Short Time and Space Scales

2nd International Symposium on
QUANTITATIVE PRECIPITATION FORECASTING AND HYDROLOGY
4 - 8 June, 2006 | Boulder, Colorado, USA

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Bureau of Meteorology Research Centre
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Australia





Why do we want to do this?

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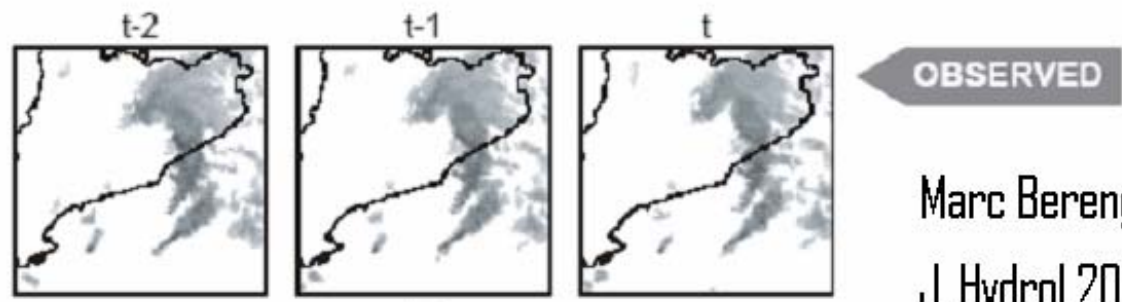


Shalan Elementary School, Heilongjiang
10 June 2005

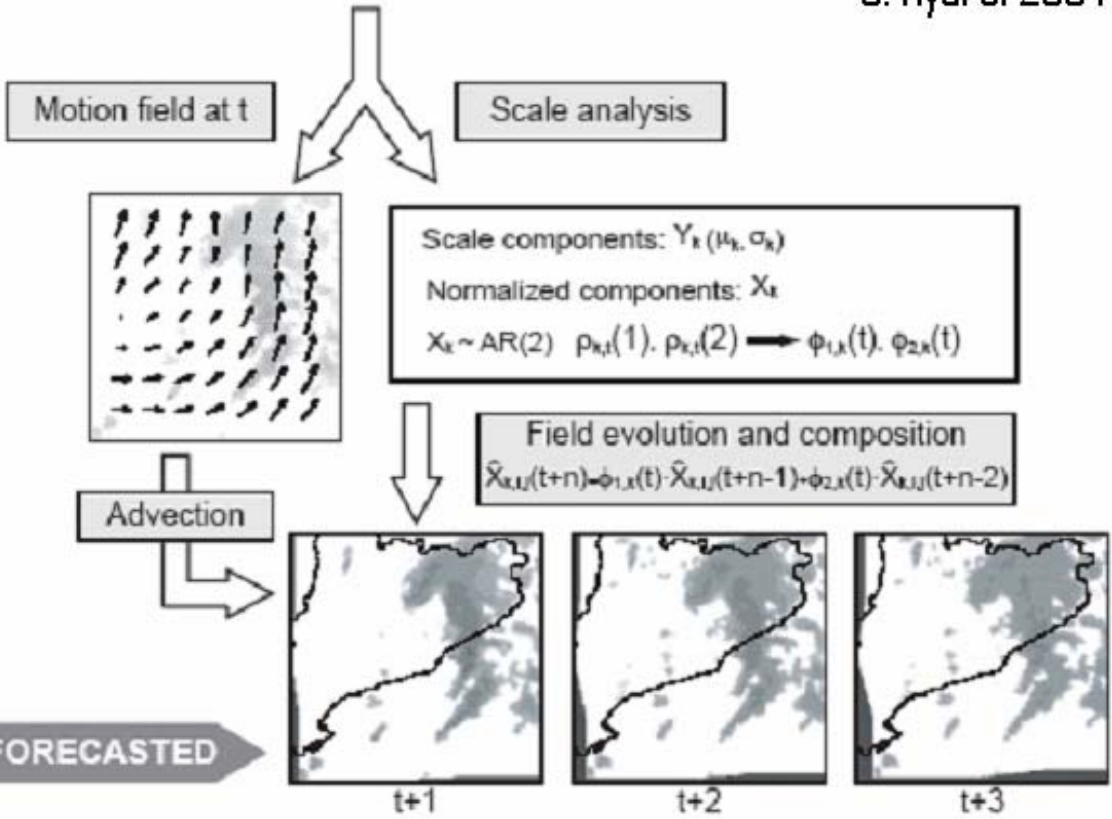




Extrapolation Forecasting



Marc Berenguer
J. Hydrol 2004

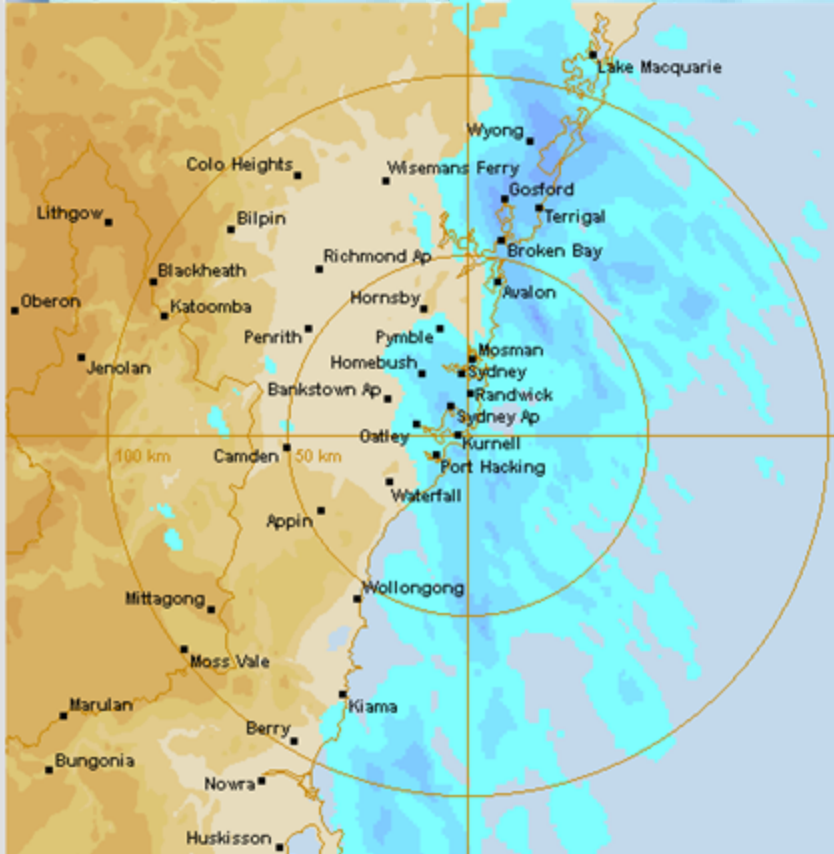




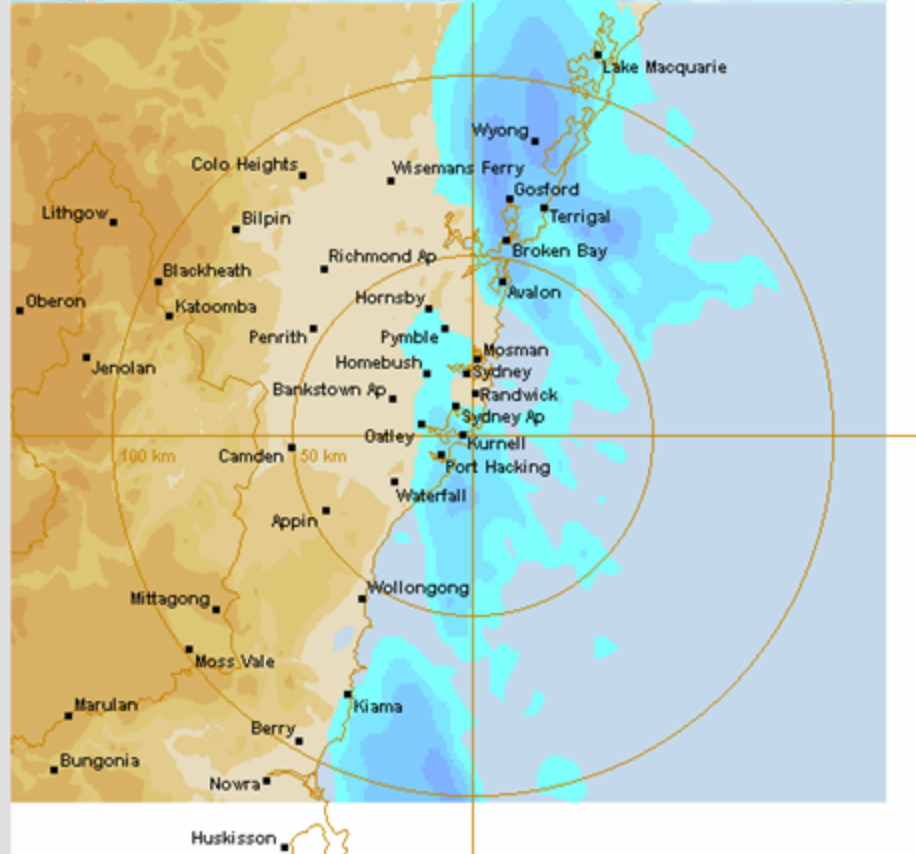
Extrapolation Forecasting

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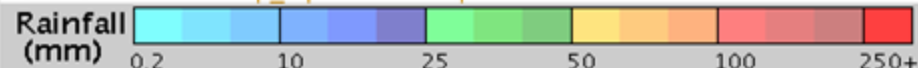
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Sydney. Rain in 1 hour to 16:25 UTC 04/06/2006 0% missing



Sydney. Rain forecast 60 mins up to 17:35 UTC 04/06/2006



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What will it take to use advection forecasts in hydrology?

First law of wing walking



- Difficult to demonstrate the use of radar products without building a more or less complete system
- Need to know the accuracy of the rainfall estimates and forecasts





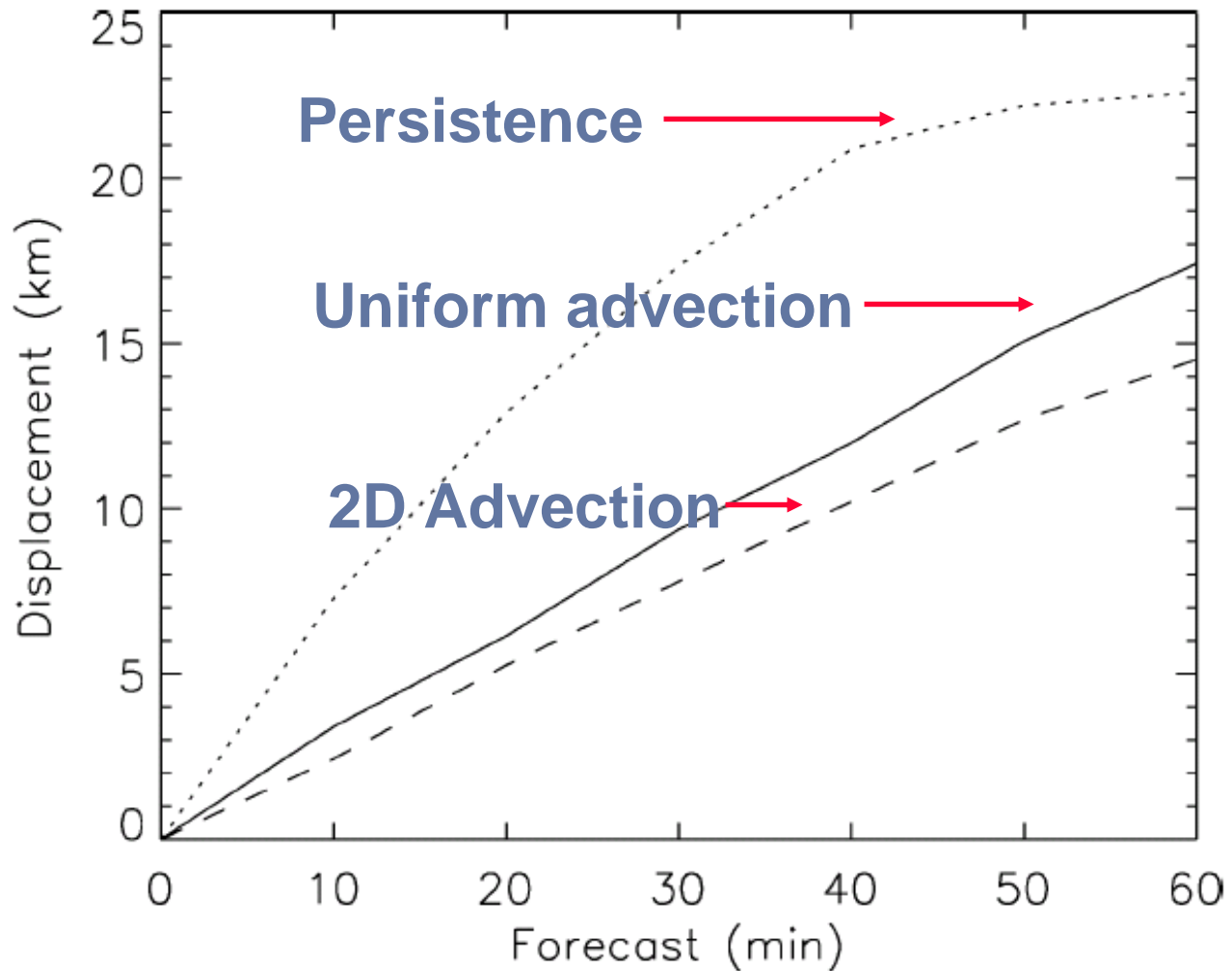
Major issues in observing and forecasting rainfall for hydrology

- Errors in location for rainfall forecasts are large relative to the scale of urban catchments
- Radar rainfall estimates and forecasts are biased at space and time scales that are large relative to urban catchments
- Hydrological models sensitive to rainfall errors



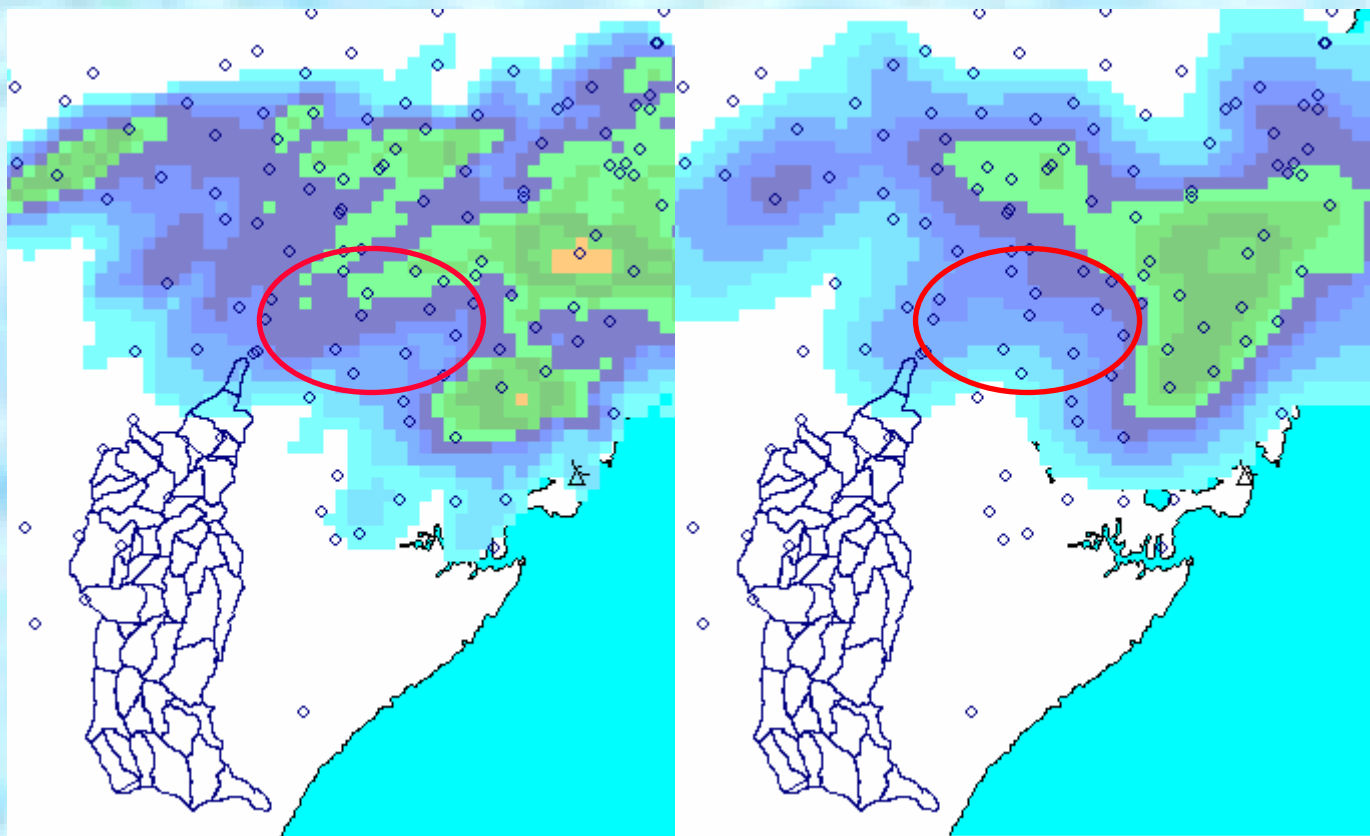


Location Errors- Ebert et al. WF 2004

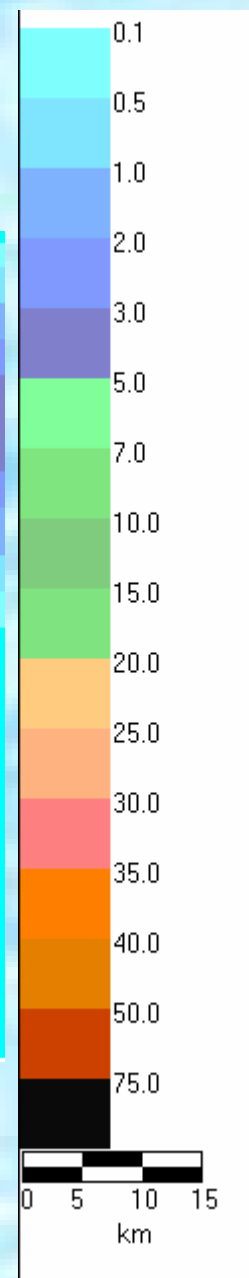




Radar Estimation Bias



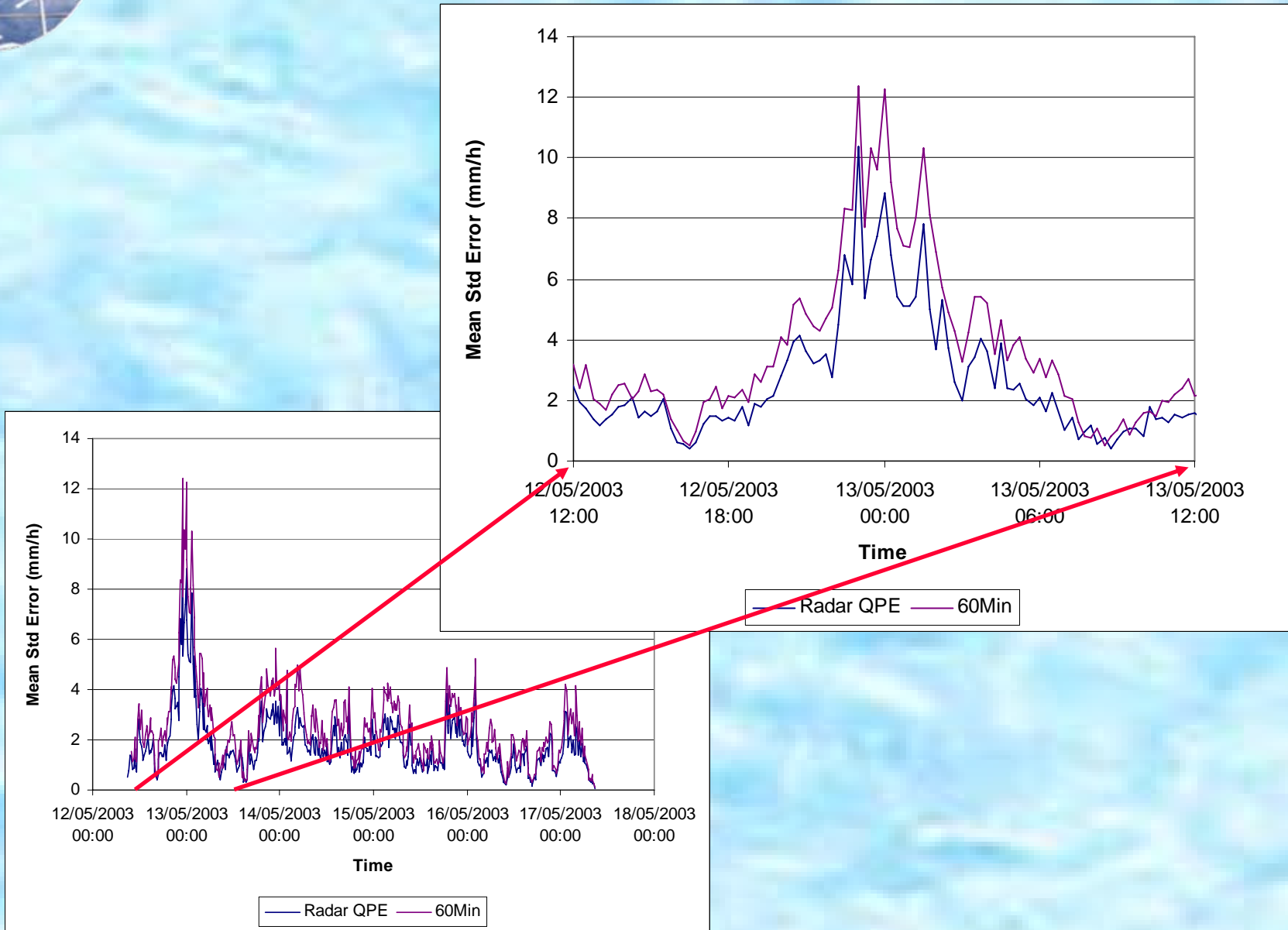
Radar
Gauge
15 minute average rainfall intensity





Radar Estimation Error

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Predictability as a Function of Scale and Situation

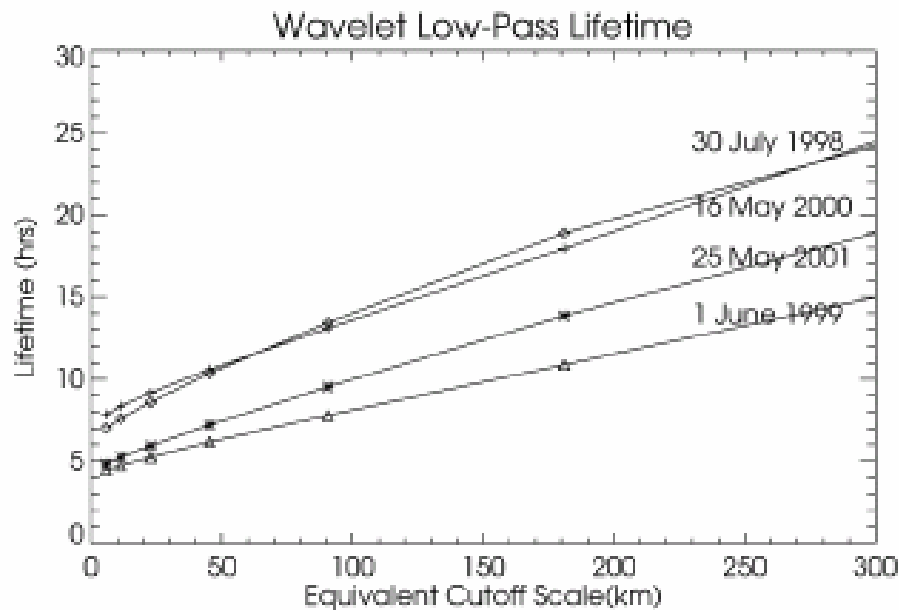


FIG. 2. Forecast lifetime as a function of low-pass cutoff scales for (top) Fourier and (bottom) wavelet filters. Results are shown for each of the four precipitation cases studied.

TURNER ET AL.

JOURNAL OF APPLIED METEOROLOGY

VOLUME 43





Can We Get Rid of Uncertainty?

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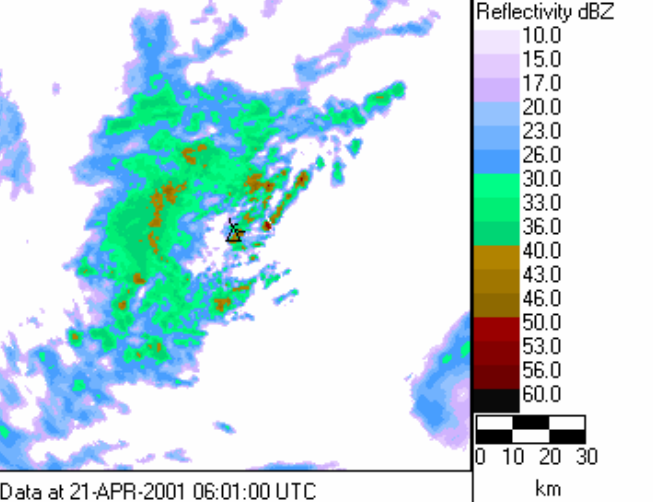


Stochastic Ensemble Forecasts

- Build space-time models of total error
- Estimate the observation error and predictability limits in real-time
- Perturb deterministic forecast with error model
- Develop a total uncertainty framework to estimate uncertainty in hydrological forecast

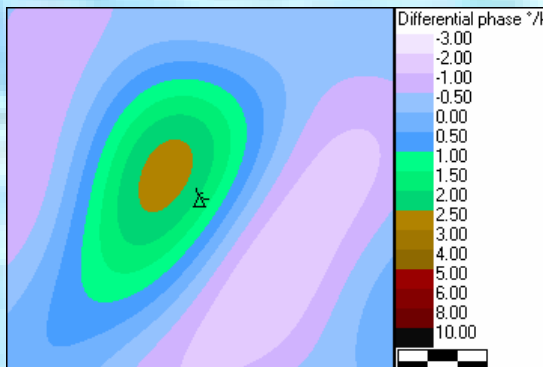


Spectral Decomposition



Data at 21-APR-2001 06:01:00 UTC

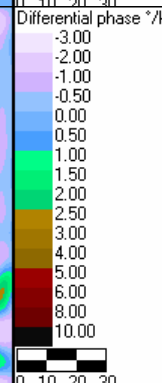
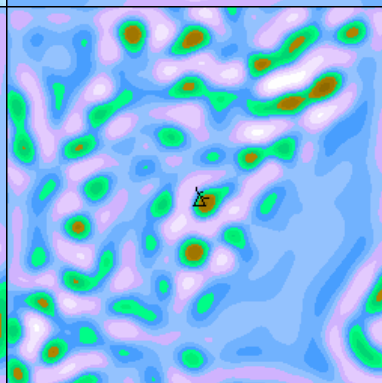
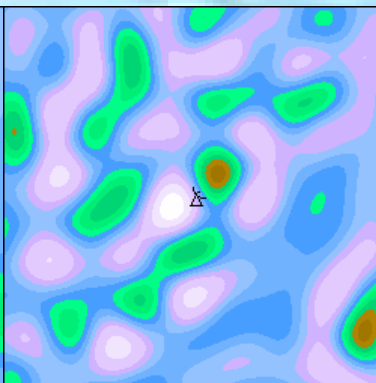
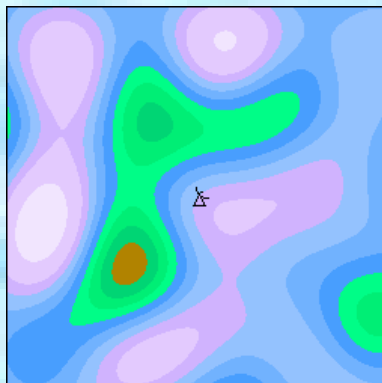
64-32 km



256-128 km

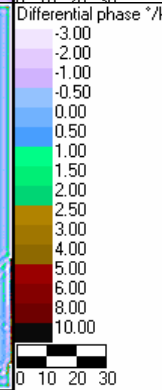
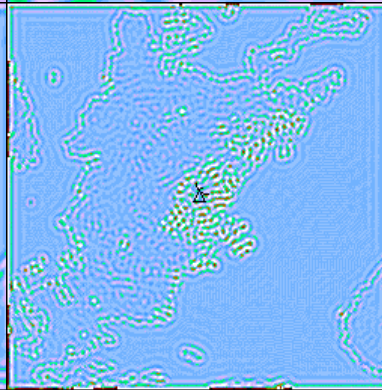
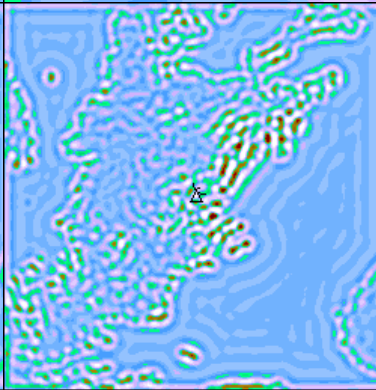
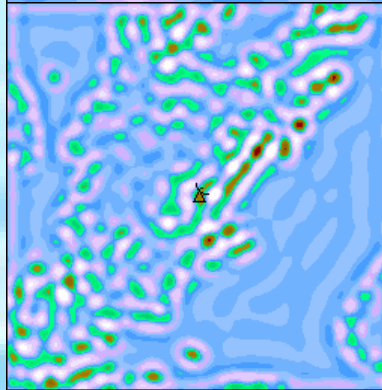
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128-64 km



32-16 km

16-8 km



4-2 km

Data at 21-APR-2001 06:01:04 UTC

Data at 21-APR-2001 06:01:05 UTC

Data at 21-APR-2001 06:01:06 UTC

8-4 km





Temporal Development Model

- The Lagrangian temporal development for each level in the cascade is forecast using an AR(2) model

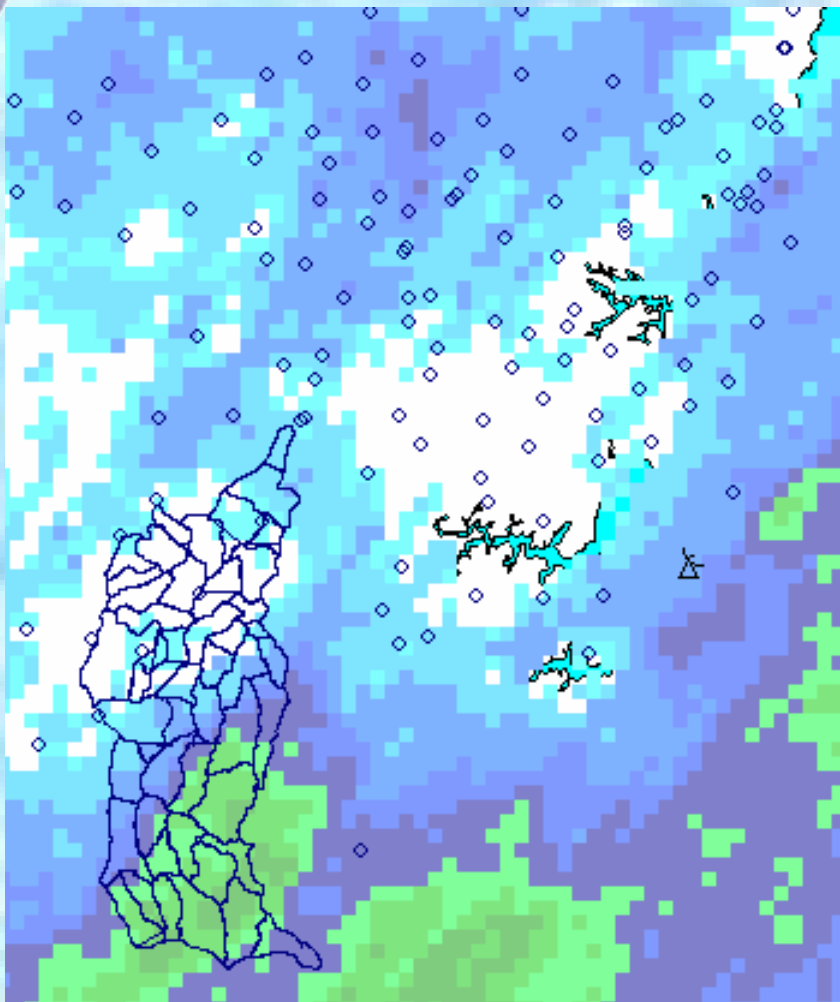
$$\hat{X}_{k,i,j}(t+n+1) = \Phi_{k,1}(t)X_{k,i,j}(t+n) + \Phi_{k,2}(t)X_{k,i,j}(t+n-1) + \varepsilon_{k,i,j}(t)$$

- AR(2) parameters are estimated at each time step for each level
- The innovation term ε is spatially correlated, temporally uncorrelated- the variance is a function of the AR(2) parameters





Ensemble Nowcasts of rainfall



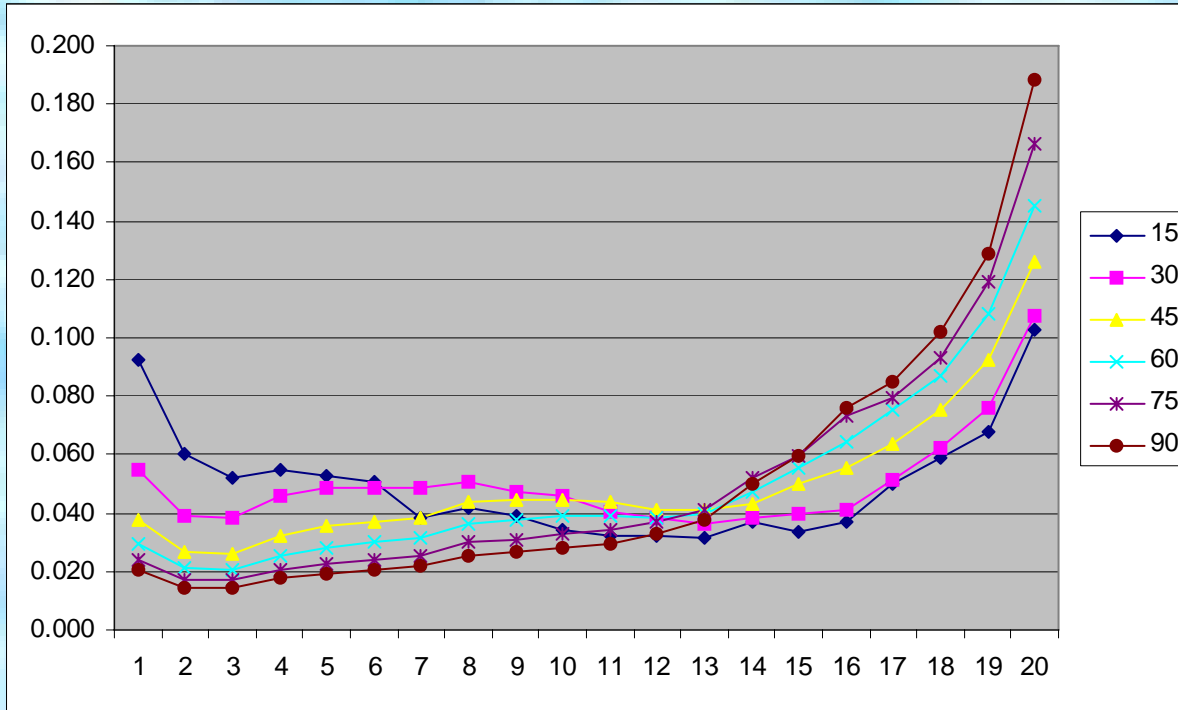
Forecast accumulations for $t+15$ to $t+30$ minutes





Verification of ensemble spread for nowcasts

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Average rainfall intensity for
0-15,15-30,30-45,45-60,60-75,75-90 minutes





Short Term Ensemble Prediction System: STEPS

- Generate a deterministic nowcast based on radar data
- Estimate the current error for the nowcast and NWP forecast over a range of spatial scales
- Merge the nowcast with the NWP forecast using weights that are a function of the forecast error at each scale
- Generate an ensemble by perturbing the deterministic blend with a stochastic component





Formulation of STEPS

■ A blend of three cascades

- Extrapolation $Y_k^e(t+t_l)$
- Noise $Y_k^n(t+t_l)$
- NWP $Y_k^m(t+t_l)$

$$Y_{k,i,j}(t+t_l) = w_k^e(t+t_l)Y_{k,i,j}^e(t+t_l) + w_k^m(t+t_l)Y_{k,i,j}^m(t+t_l) + w_k^n(t+t_l)Y_{k,i,j}^n(t+t_l)$$

- Weights assigned according to skill of extrapolation and NWP components

■ Advection velocities

- blend perturbed velocity, v_e with NWP diagnosed velocity, v_m

$$v(t+t_l) = w_2^e(t+t_l)v_e(t+t_l) + \left[1 - w_2^e(t+t_l)\right]v_m(t+t_l)$$



Forecast Skill

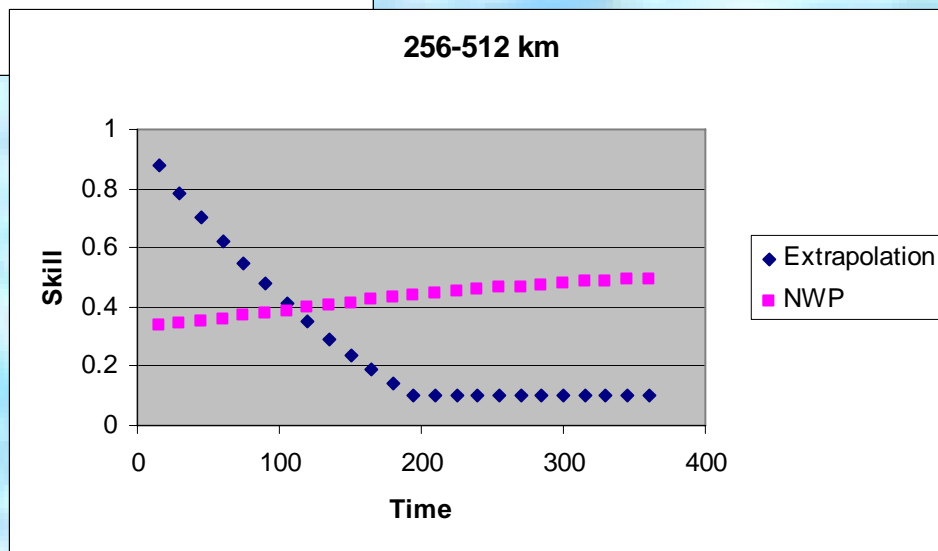
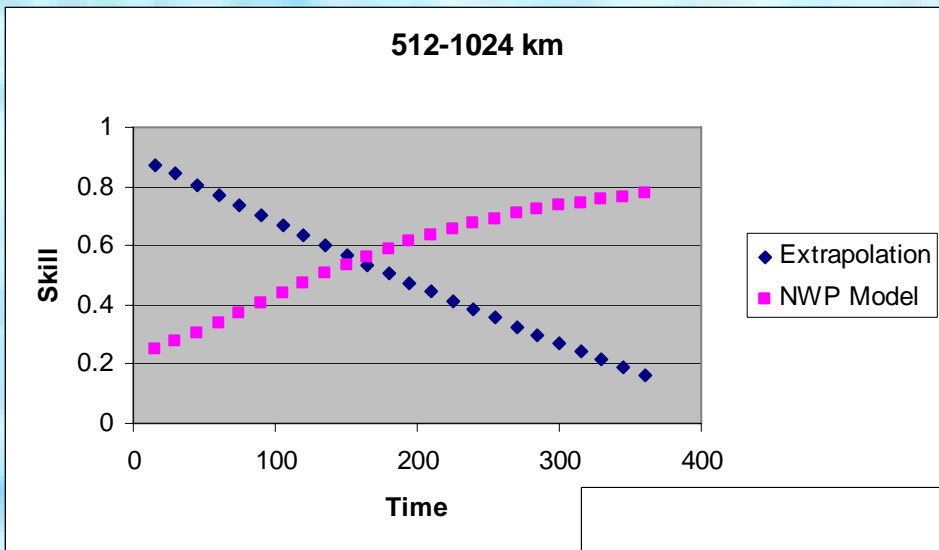
- Nowcast skill is given by the AR-2 model
- NWP skill is calculated as the correlation between the NWP cascade and radar cascades- updated in real-time but relaxing to climatology
- Blend nowcast with NWP at each scale as a function of skill





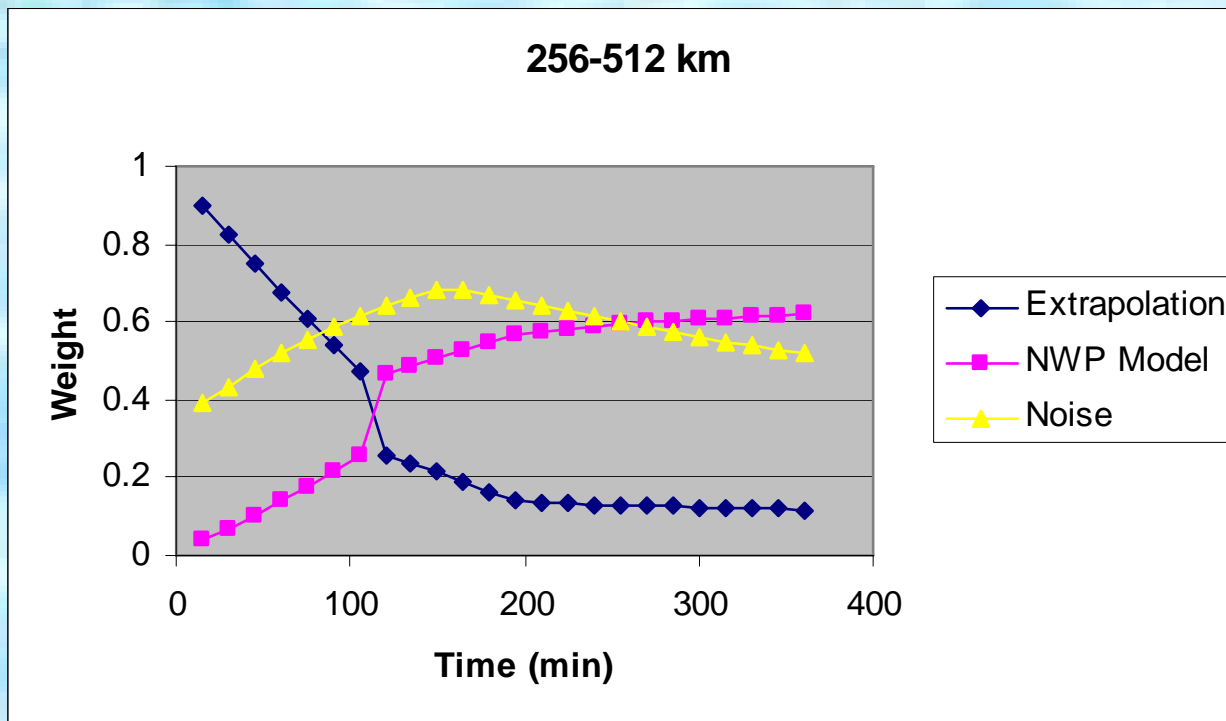
Forecast Skill

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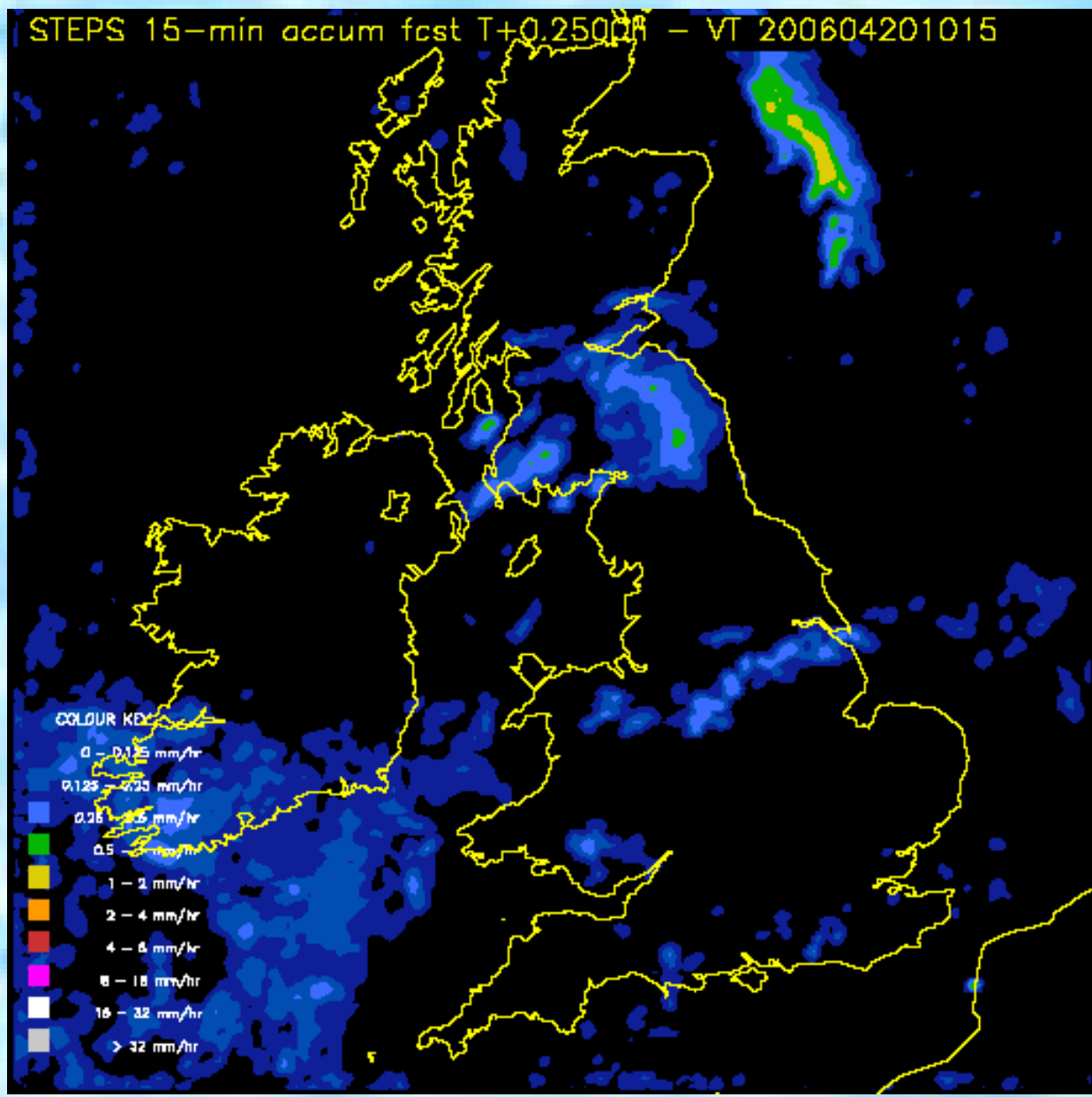


Weights



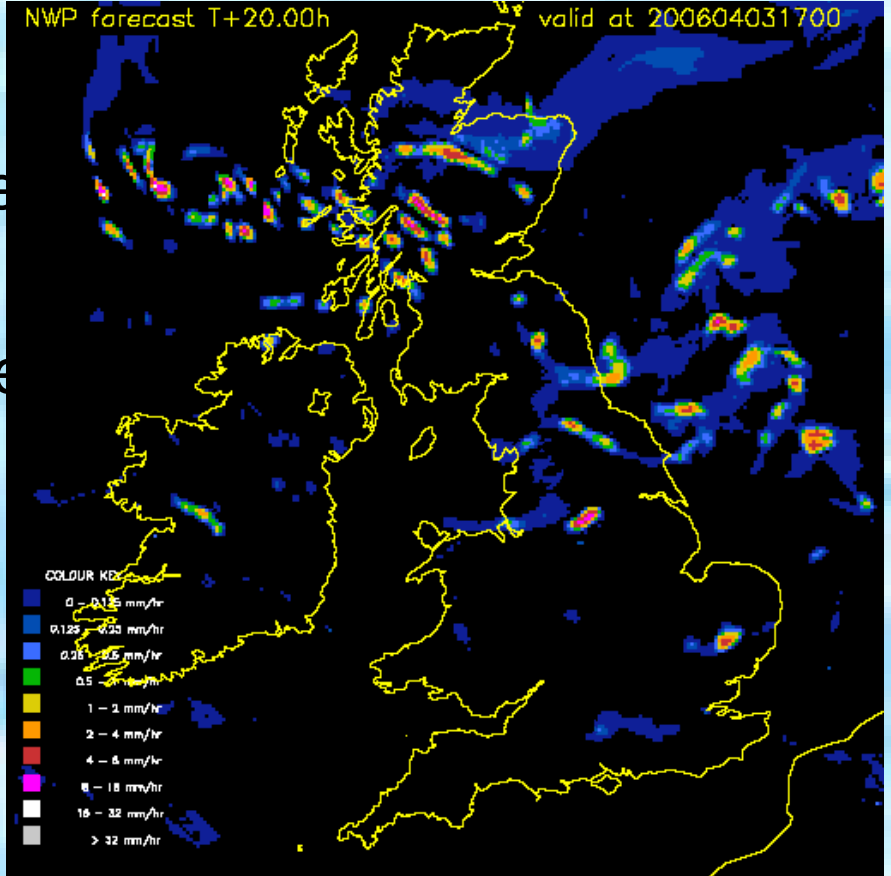
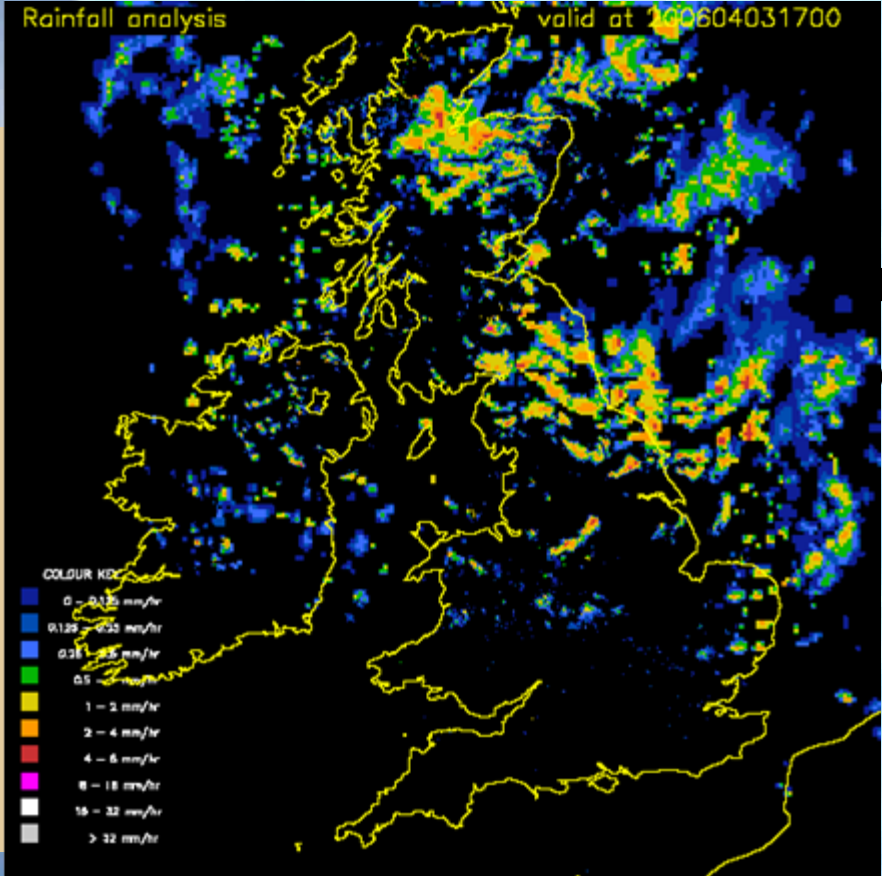


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Performance Issues: NWP

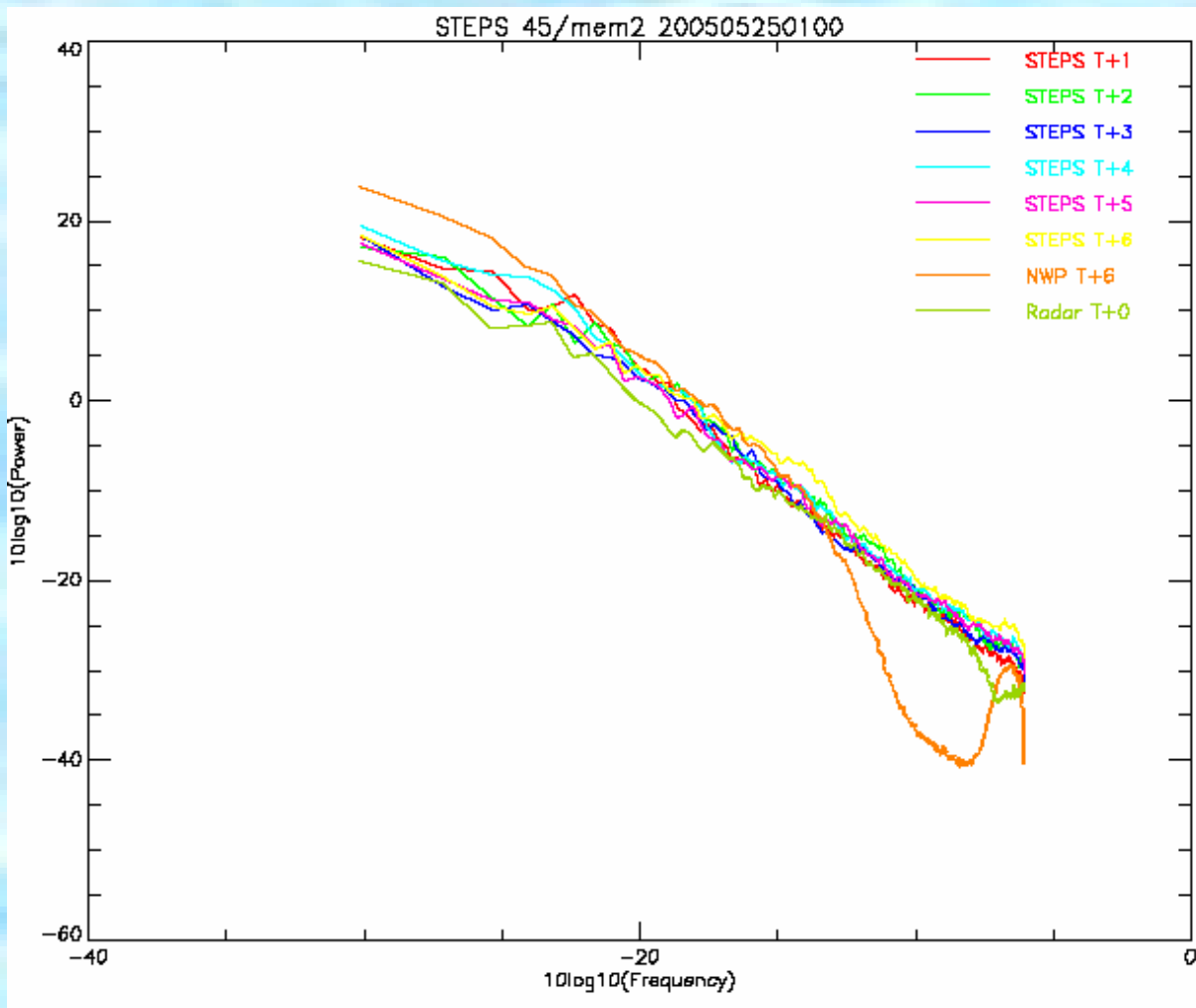


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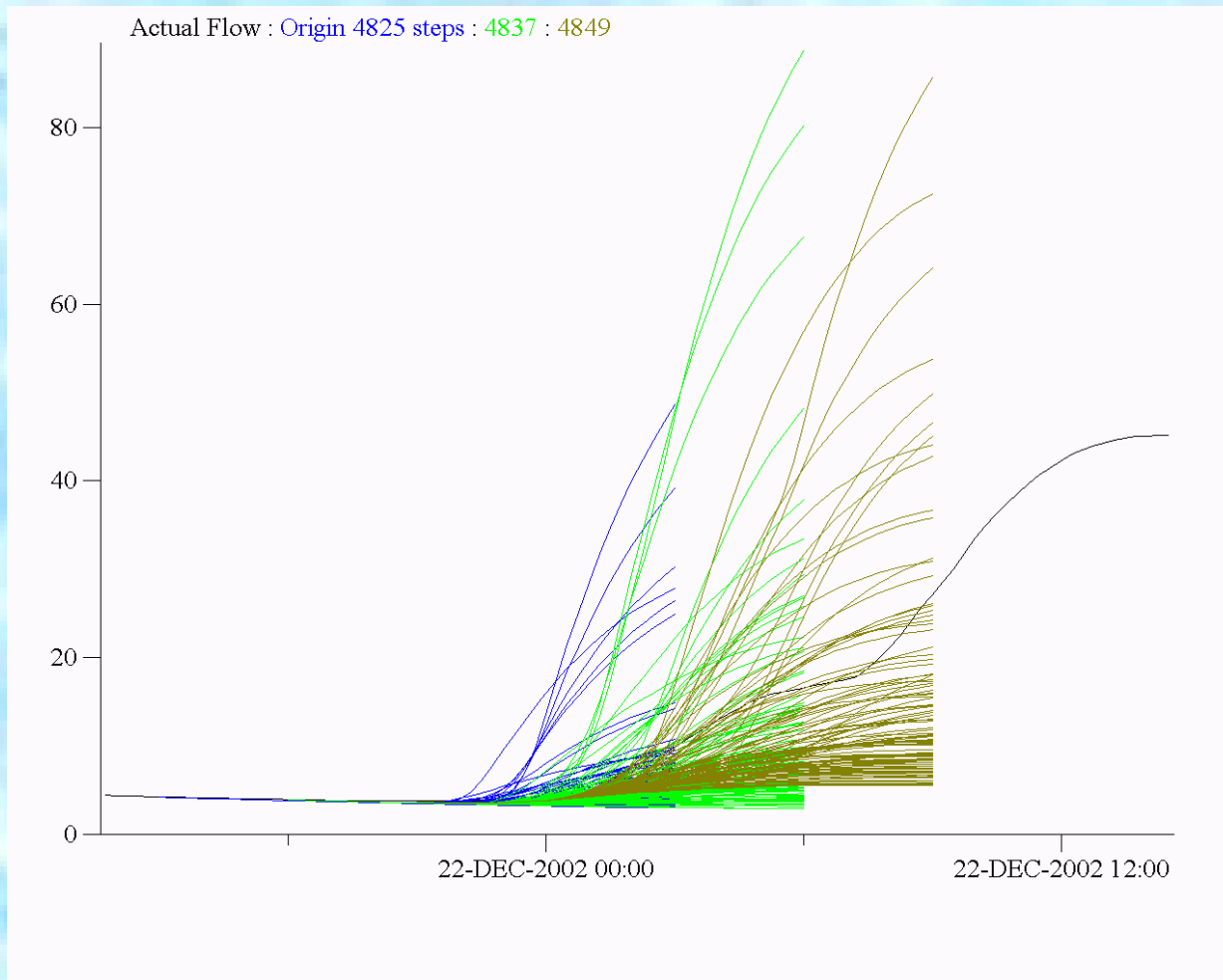


Performance Issues: NWP

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Applications: accumulation & flow forecast ensembles



courtesy of Bob Moore, Centre for Ecology and Hydrology, UK





Conclusions

- Observation error is a major source of uncertainty in rainfall nowcasts
- Observation errors and predictability limits vary significantly in time
- Ensembles are sensitive to biases in both radar observations and NWP forecasts
- Hydrological applications based on ensemble forecasts are a long way from being operational





Thank You

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