Probabilistic flood forecasting for Rapid Response Catchments using a countrywide distributed hydrological model: experience from the UK

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Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

SEPA
Scottish Environment Protection Agency

Environment Agency

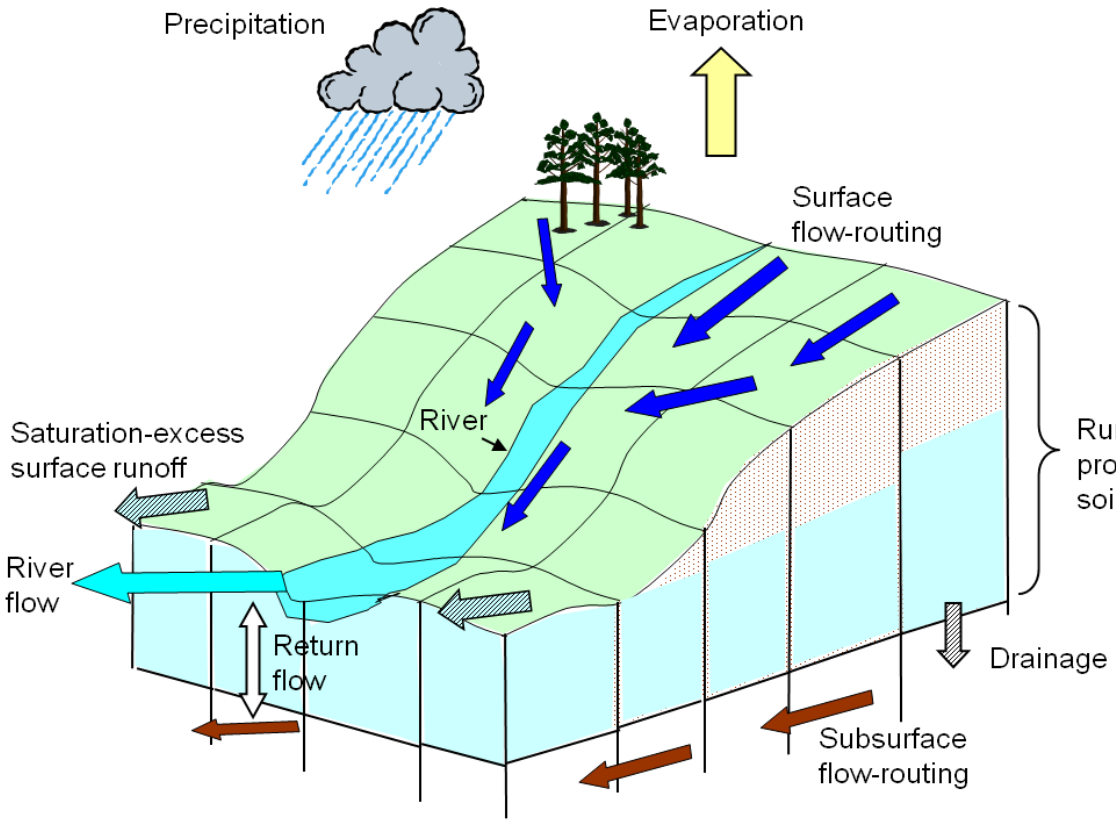
Background

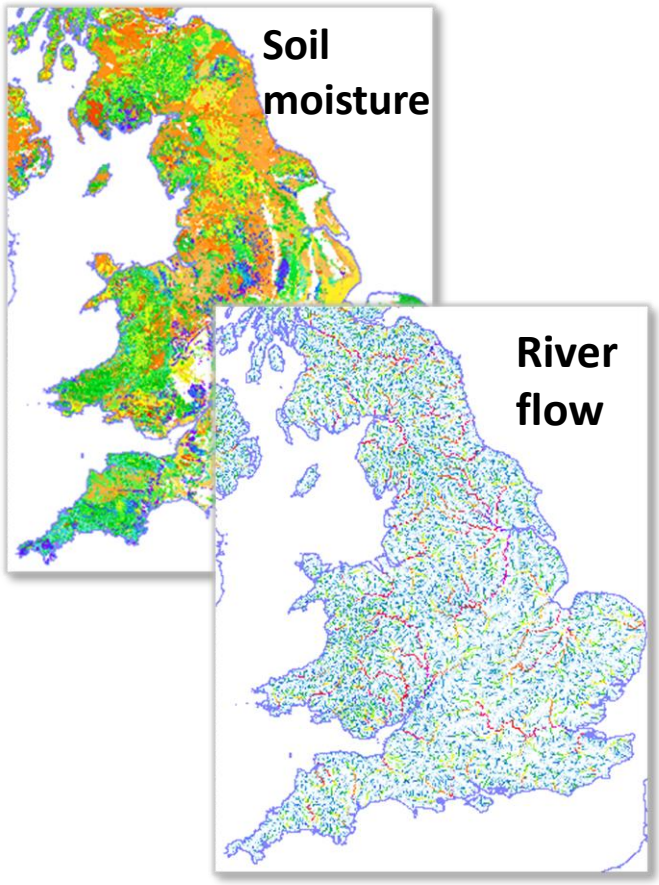
- Summer 2007 floods
  - £3 billion insurance payouts
  - 55,000 properties flooded,
    36,000 from surface water flooding
  - National infrastructure impacts
    - 140,000 homes without clean water for 17 days
    - 42,000 homes without power for 24 hours
- Pitt Review commissioned
  - Flood Forecasting Centre & Scottish Flood Forecasting Service
  - Countrywide flood forecasting using G2G distributed model

FLOODFORECASTINGCENTRE
a working partnership between Environment Agency | Met Office

Met Office | SEPA Scottish Environment Protection Agency | Scottish Flood Forecasting Service
Working in partnership

Grid-to-Grid (G2G) Distributed Model





- Uses spatial datasets on terrain, soil/geology, land-cover
- Responds to spatial variation of rainfall input
- Used operationally across Britain at a 1km, 15 min resolution

Moore *et al.*, IAHS Publ. 305 (2006)

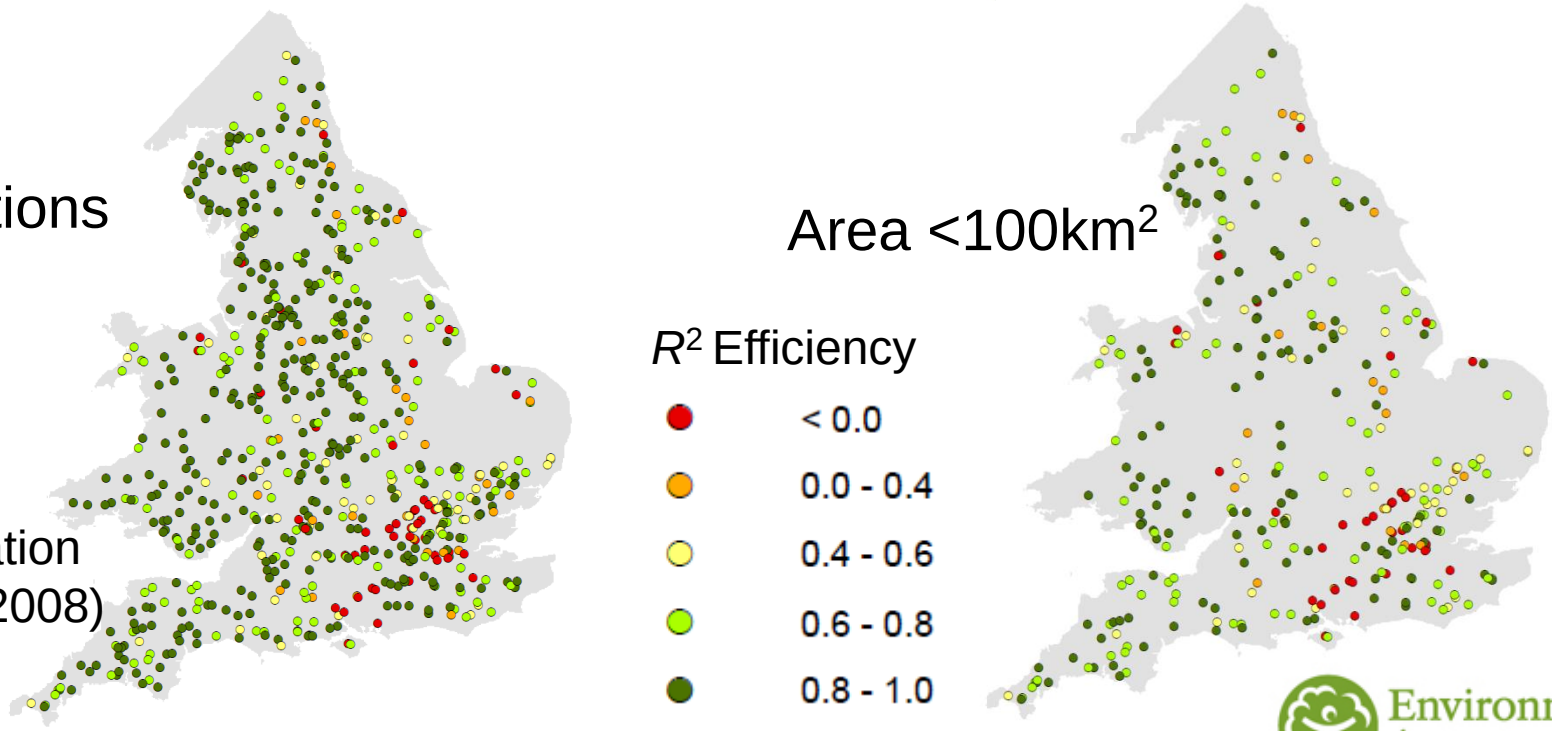
Price *et al.*; Cranston & Tavendale, Water Management (2012)

G2G for Rapid Response Catchments

- Explore use of G2G for Rapid Response Catchments
  - Typically small area (<100km^2), steep slopes & ungauged
  - Extreme floods, often due to small scale rainfall features
  - Hydro-meteorological challenge to develop warning capability
  - Value of radar/NWP *rainfall forecast ensembles*?

All stations

Area <100km^2



G2G simulation
(Jan – Apr 2008)

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G2G for Rapid Response Catchments

- Explore use of G2G for Rapid Response Catchments
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  - Hydro-meteorological challenge to develop warning capability
  - Value of radar/NWP *rainfall forecast ensembles*?
- G2G assessment methodology
  - Simulation-mode: using observed rainfall
  - Forecast-mode: foreknowledge of observed rainfall
  - Forecast-mode: use of UKV deterministic rainfall forecast
  - Forecast-mode: use of Blended Ensemble rainfall forecasts
  - Ensemble case study experience & methods of display

SEPA Scottish Environment Protection Agency

Environment Agency

Performance measures

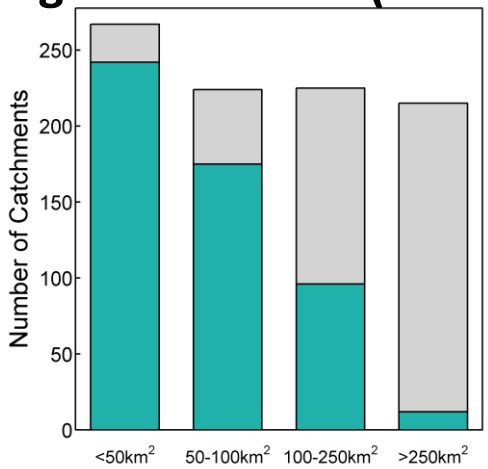
- R^2 Efficiency: perfect model is 1, negative is worse than mean flow

$$R^2 = 1 - \frac{\sum_{t=1}^{n} e_t^{\,2}}{\sum_{t=1}^{n} (Q_t - \overline{Q})^2}.$$

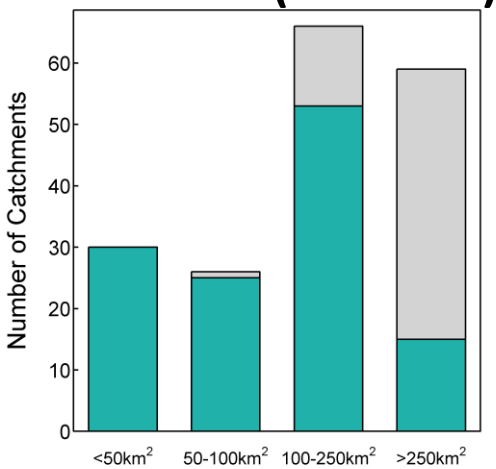
Q_t	Observed flow at time t
q_t	Modelled flow at time t
n	Number of observations
$e_t = Q_t - q_t$	Model error at time t
$\overline{Q} = \sum_{t=1}^{n} Q_t$	Mean of the observed flow

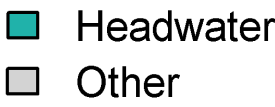
- Probability of Detection (POD), False Alarm Rate (FAR)
- Ensembles: *Relative Operating Characteristic (ROC)*, *Brier Skill Score*
- Pooled over groups of sites (e.g. catchment, region or country area)

England & Wales (932 sites)



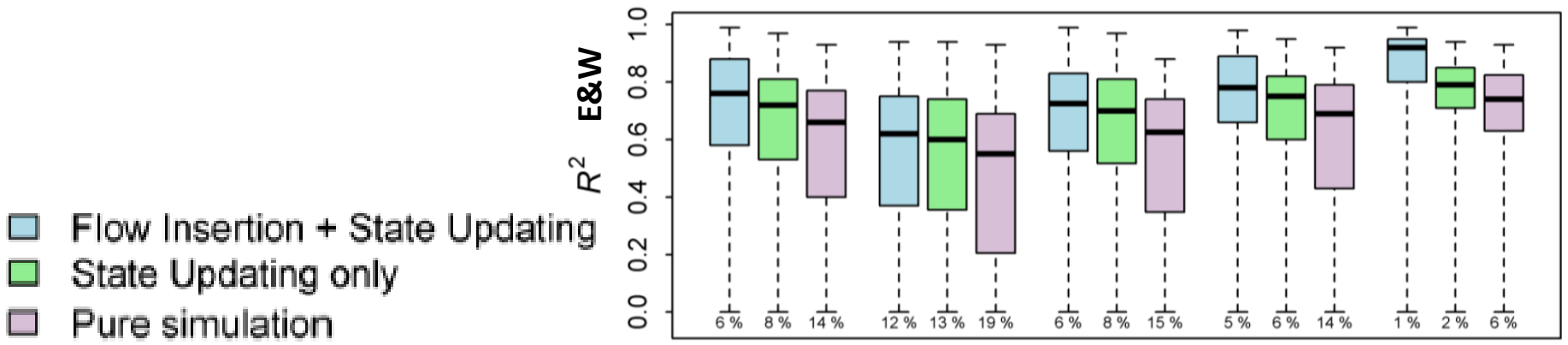
Scotland (187 sites)





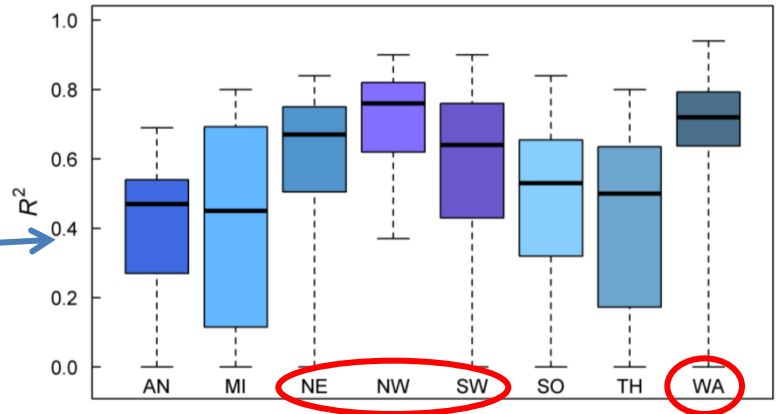
Simulation-mode assessment

- England & Wales
  - Reasonable performance for small catchments
  - Best performance in SW, NE, NW & Wales – aligned to RRC



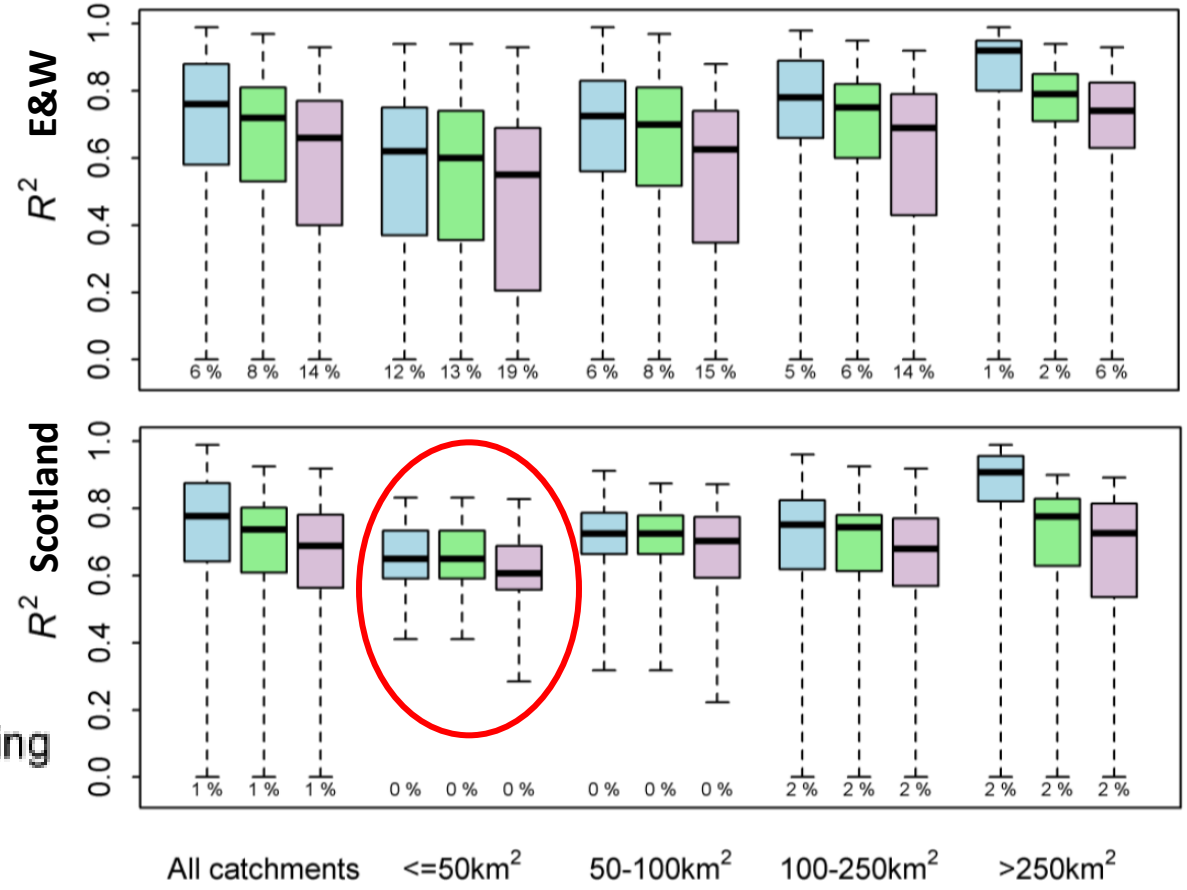
All catchments <=50km^2 50-100km^2 100-250km^2 >250km^2

Catchments <50km^2 Breakdown by region



Simulation-mode assessment

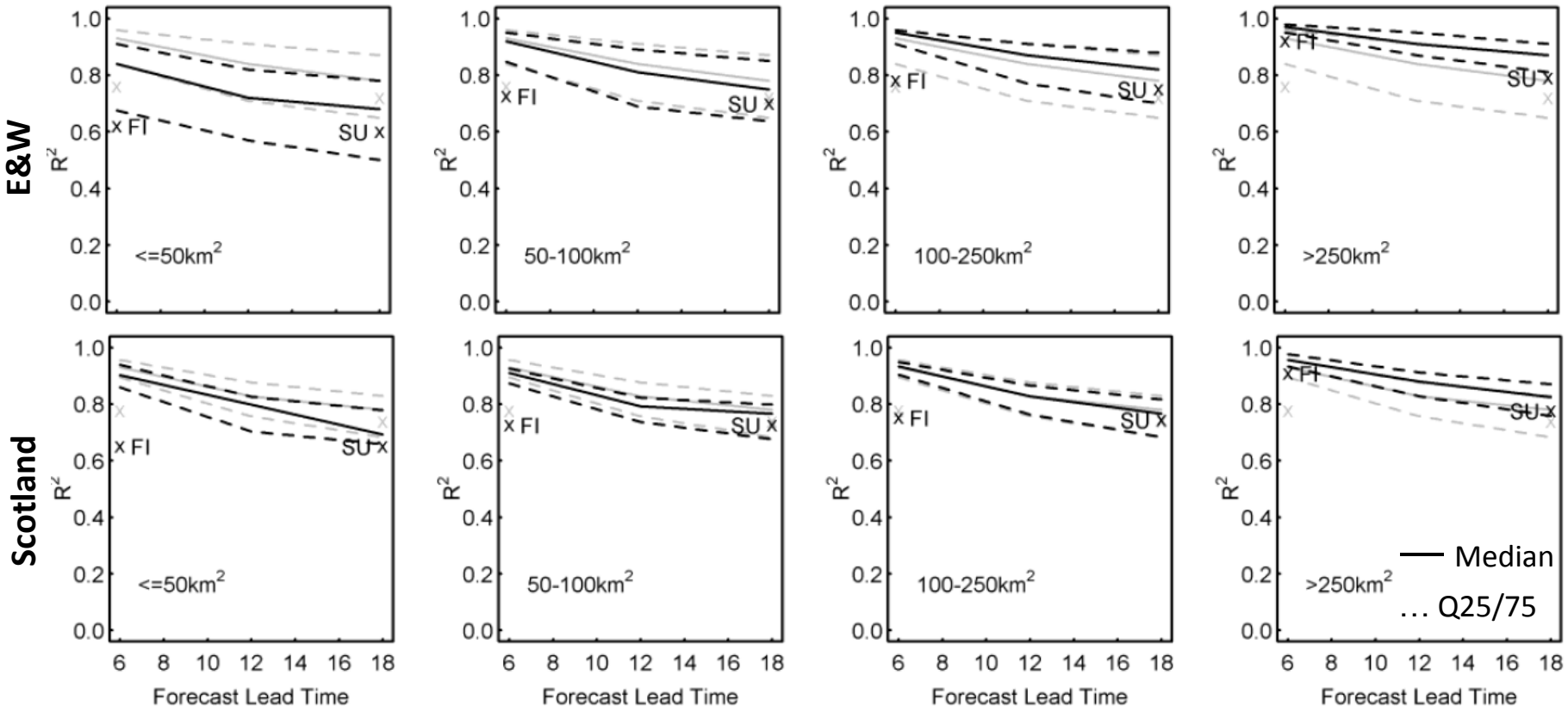
- England & Wales
  - Reasonable performance for small catchments
  - Best performance in SW, NE, NW & Wales – aligned to RRC
- Scotland
  - Performance very good for small areas
  - Similar to better performing regions of England & Wales
- G2G has utility for RRCs



Flow Insertion + State Updating
State Updating only
Pure simulation

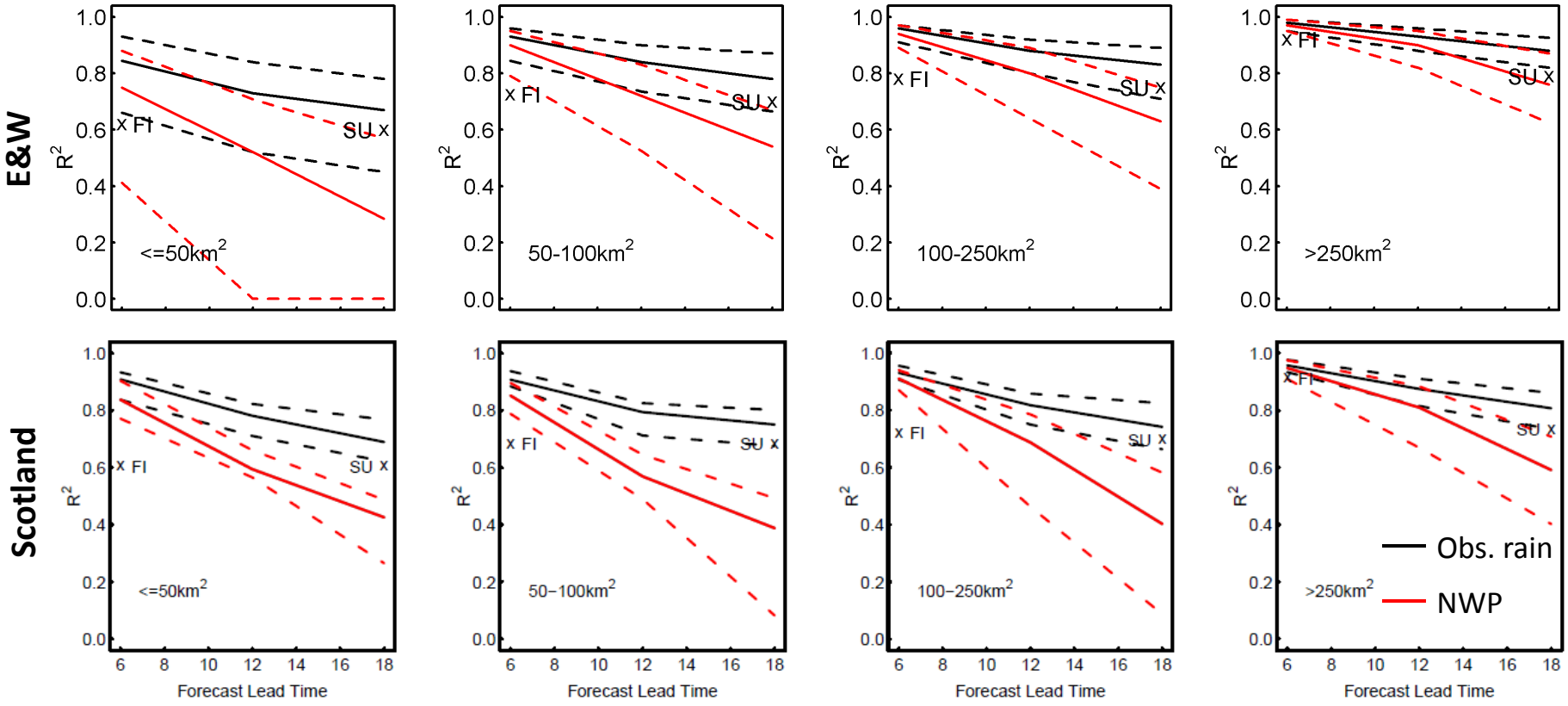
Forecast-mode: observed rain

- ARMA error-correction benefits all sites out to 12-24h
- Good simulation-mode performance for Scottish catchments < 100km^2 reflected in less spread for all lead-times and better median R^2 for short lead-times



Forecast-mode: UKV deterministic

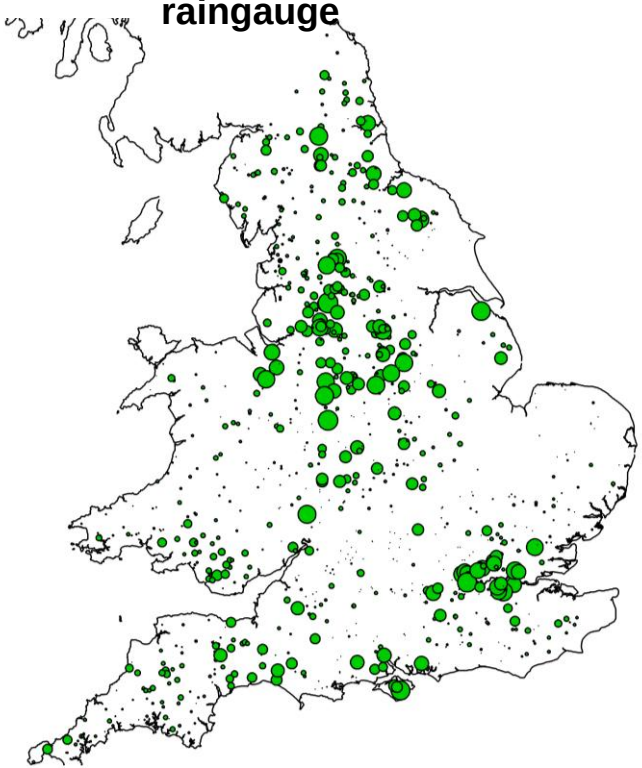
- 24h UKV (~1.5km) NWP forecasts every 6 hours (red line)
- Strong deterioration in NWP performance beyond 12 hours
- For small catchments <50km^2 Scotland performs better
- For larger catchments England & Wales does better



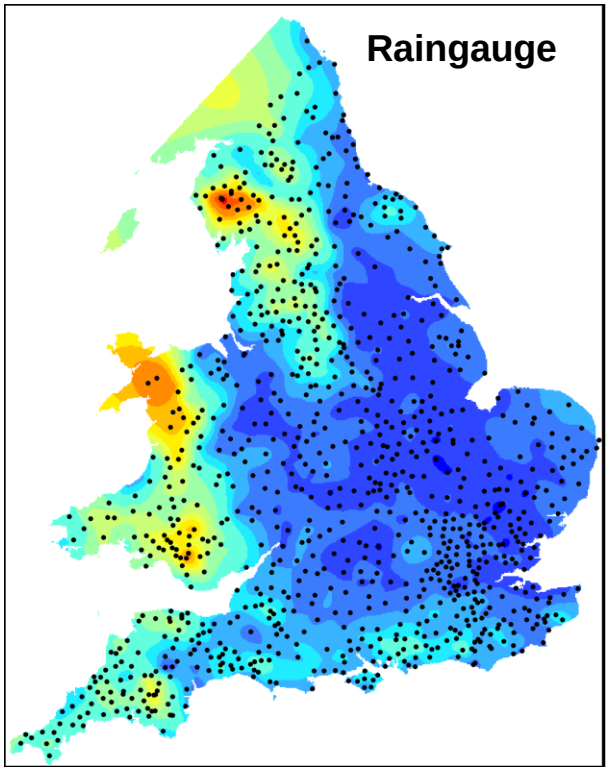
Forecast-mode: UKV deterministic

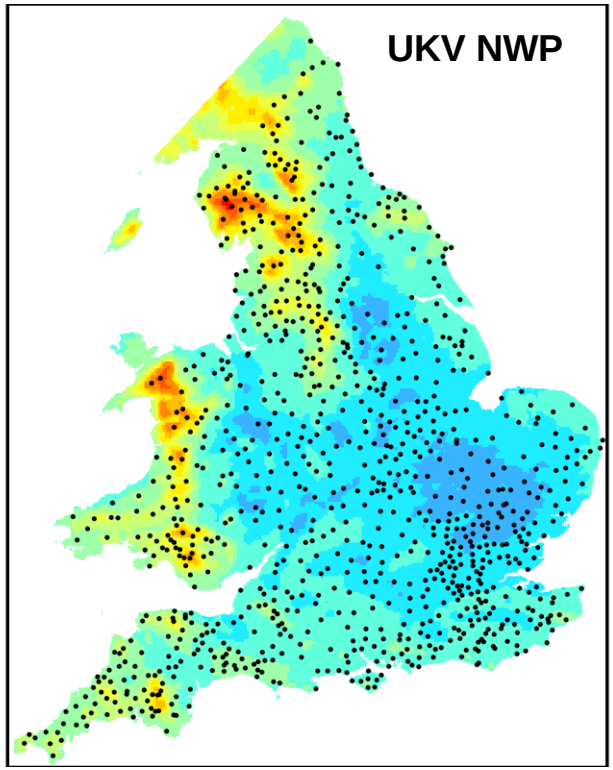
- Analysis of G2G forecasts using:
  1. Raingauge data as foreknowledge of forecast rainfall
  2. UKV deterministic NWP as forecast rainfall
- Suggests spatial biases over 2010/11 assessment period

Large circles denote NWP based forecast worse than raingauge



August 2010 – July 2011





Ensemble forecast display: region summary

- Post-processing scheme to generate large rainfall ensembles cheaply
- Seamless combination of nowcast and deterministic NWP forecast
- Noise used to generate ensembles and downscale NWP
- 12 members (now 24), 15 minute accumulations,
  7h Nowcast every 15 mins, 24h Blended ensemble every 6h

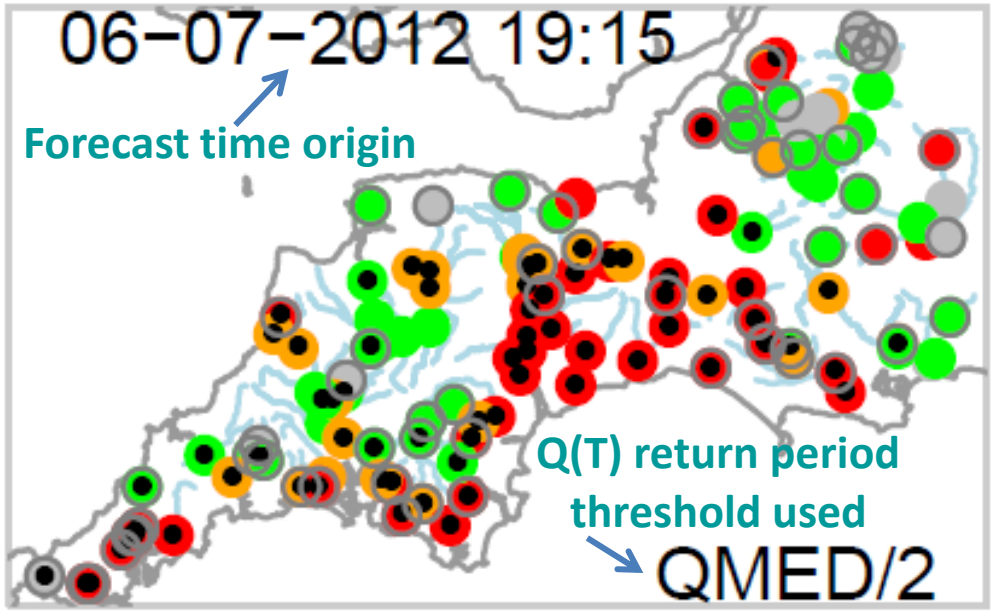
Met Office

Circles denote gauging stations

- ○ Solid outline: area <50km^2
- ● Observed flow exceeds threshold during forecast

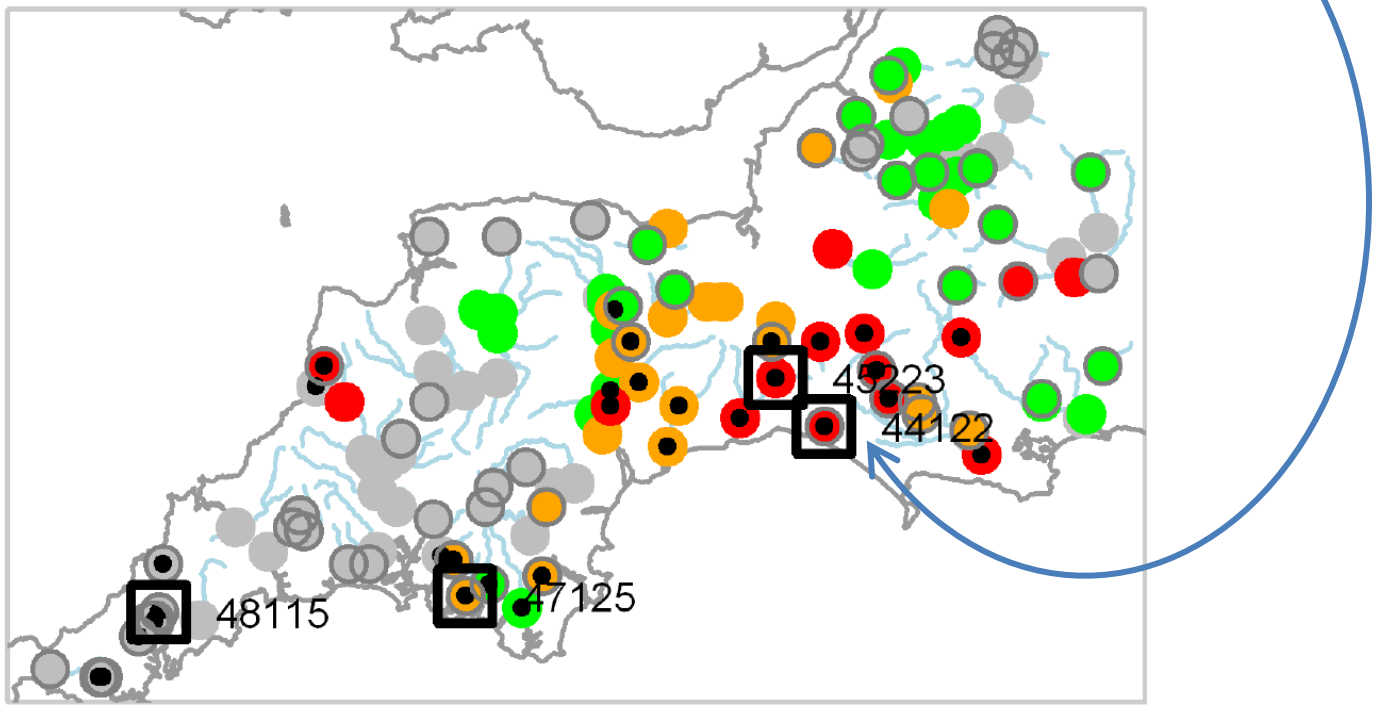
Percentage of ensembles that exceeded the Q(T) threshold at some point during forecast

0 | 0-33% | 34-66% | >67%



Case study: 6-7 July 2012

- Slow moving depression over south-west England
- >100mm recorded in 18hr ending 12:00 7 July 2012
- River Axe severely affected, and south Cornish coast
- Several flow gauges recorded new maxima



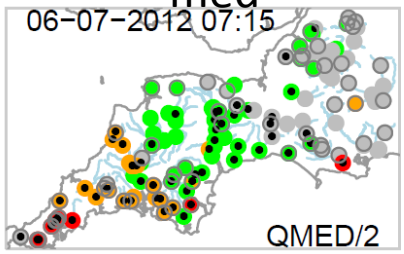
Case study: 6-7 July 2012

Threshold

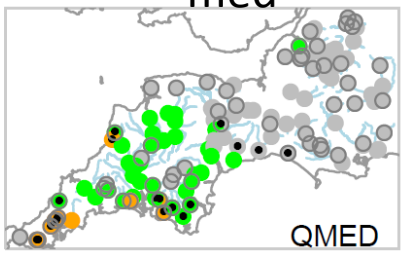
Forecast Origin

06-07-2012 07:15

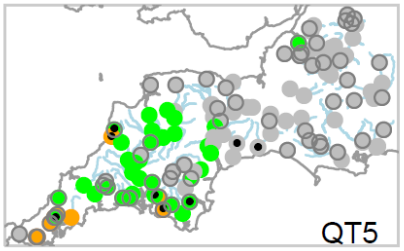
$Q_{med}/2$



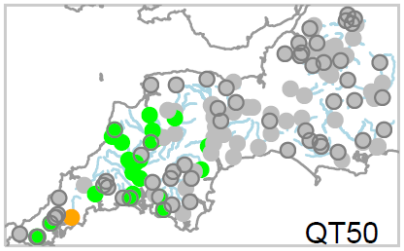
Q_{med}



Q(5)



Q(50)



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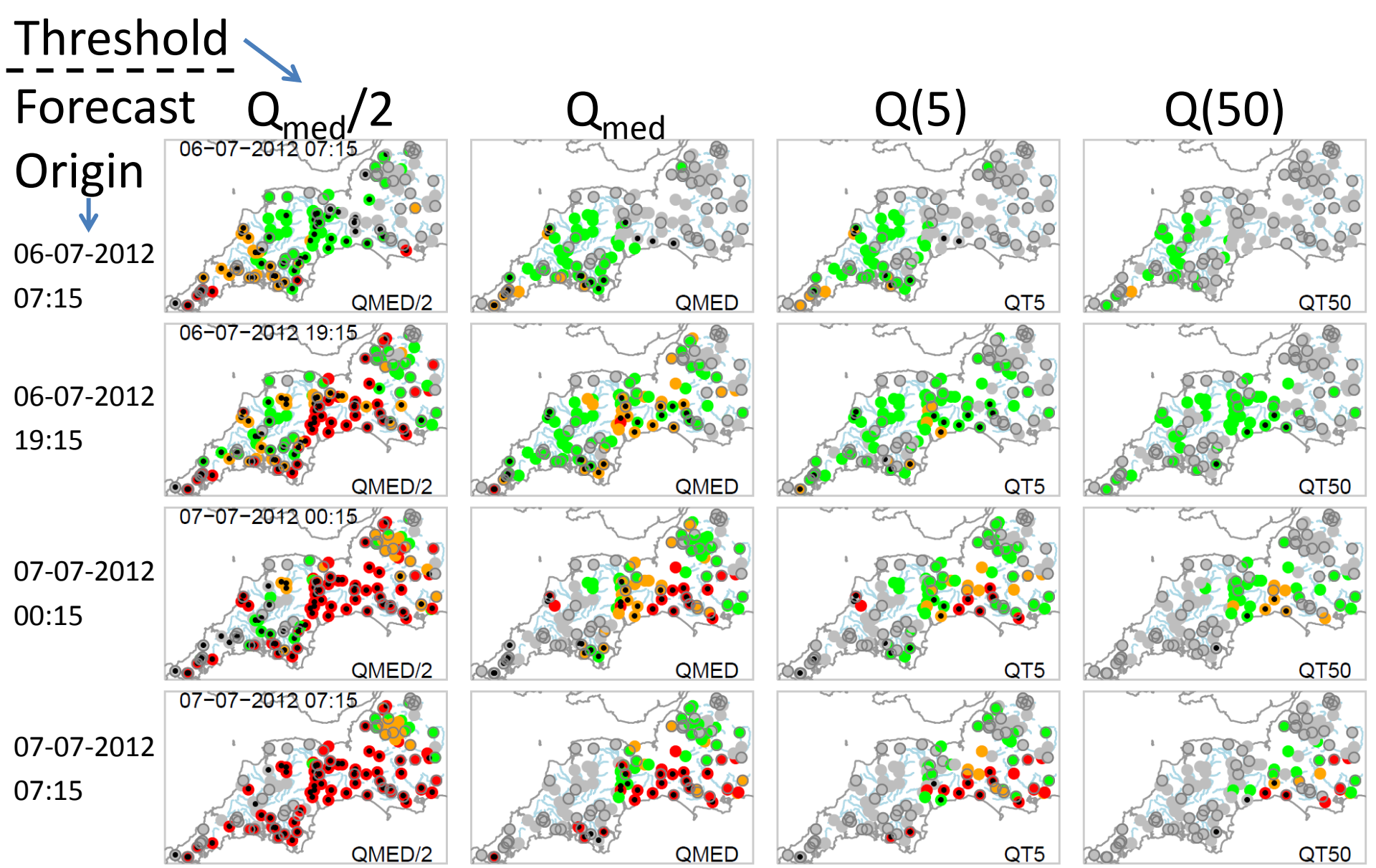

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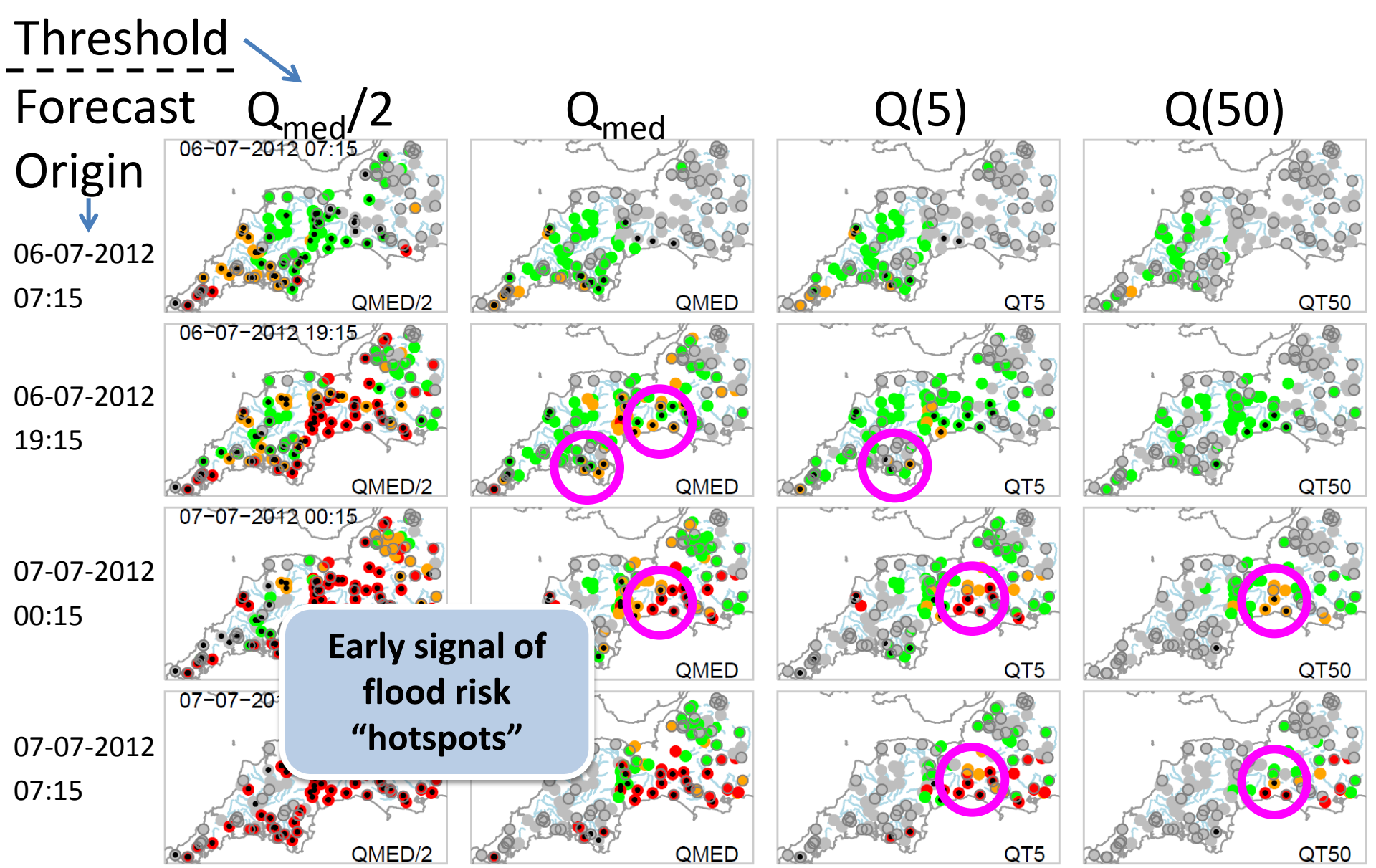
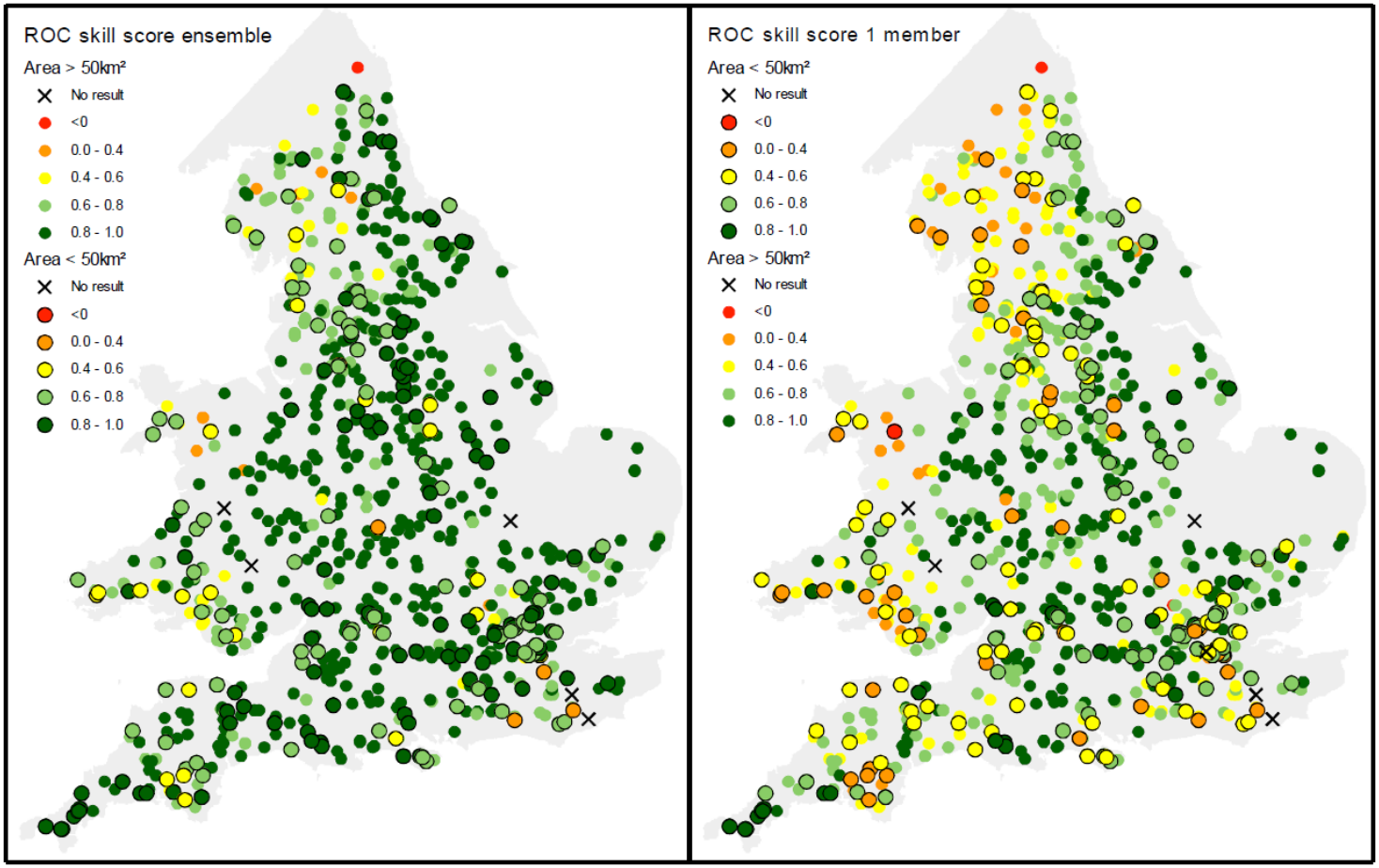
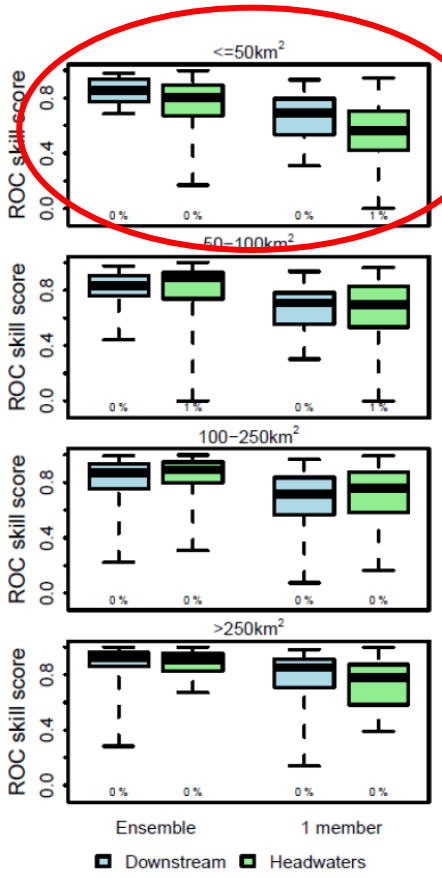


Forecast-mode: Ensembles

- England & Wales, 7 months of 24 h forecasts, 4 times a day
  - ROC score shows 12 members perform better than 1 member
  - Most benefit from using ensembles is for small catchments





Closing remarks

- Step change in flood forecasting capability across Britain
  - G2G provides fluvial forecasts “everywhere” on a 1km grid
  - Probabilistic forecasts over several days possible
- G2G has shown utility for Rapid Response Catchments
  - Uses high-res deterministic and probabilistic rainfall products
  - Case studies shows potential for early warning (possibly 12h+)
  - Ensemble rainfalls provide most benefit for small catchments
- Moving to MOGREPS-UK 2.2km NWP rainfall ensembles
- Environment Agency report to be published soon

  Evaluating G2G for use in Rapid Response Catchments: Final Report (SC110003)