

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

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11:15, 30 April 2014

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



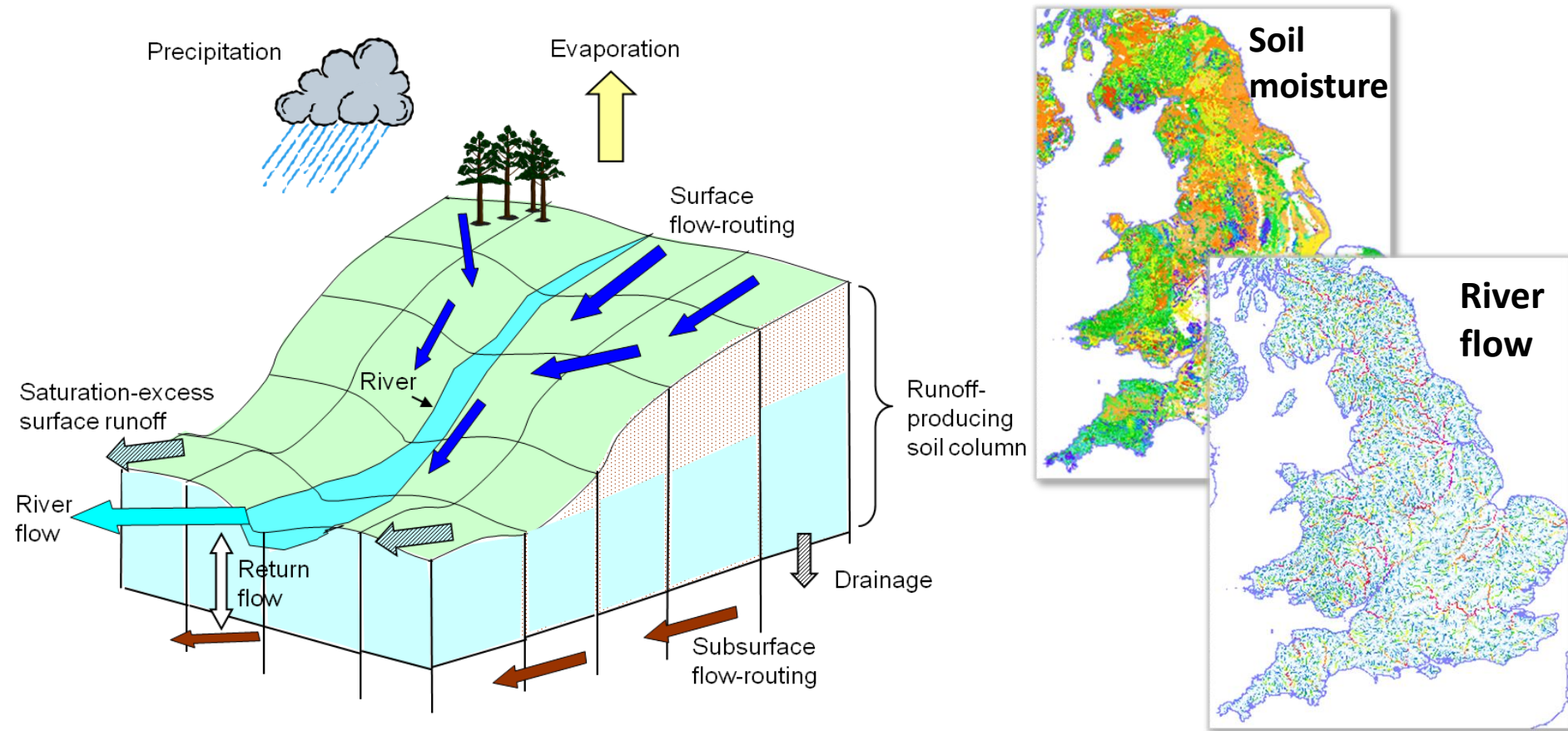
FLOODFORECASTINGCENTRE

a working partnership between



Scottish Flood Forecasting Service
Working in partnership

Grid-to-Grid (G2G) Distributed Model

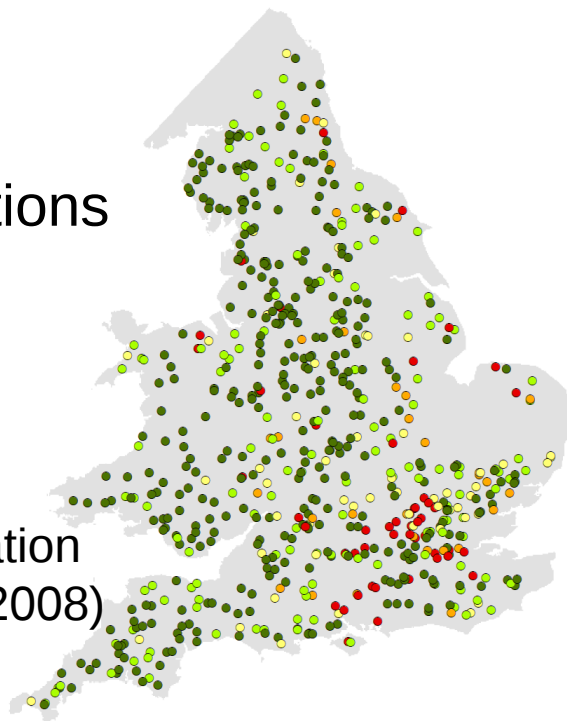


- Uses spatial datasets on **terrain, soil/geology, land-cover**
- Responds to **spatial variation of rainfall input**
- Used **operationally across Britain** at a 1km, 15 min resolution

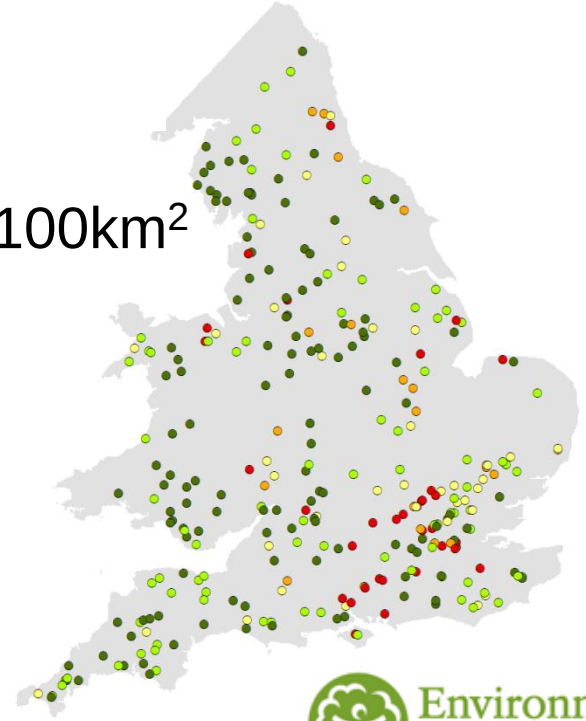
G2G for Rapid Response Catchments

- Explore use of G2G for Rapid Response Catchments
 - Typically **small area** (<100km²), **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**?

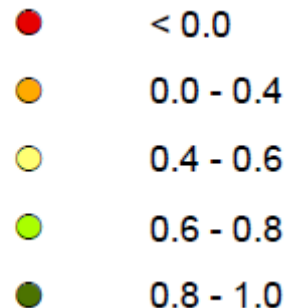
All stations



Area <100km²



R^2 Efficiency



G2G simulation
(Jan – Apr 2008)

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

Performance measures

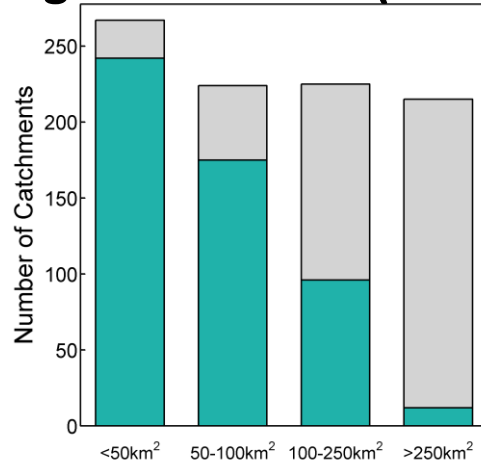
- R^2 Efficiency: perfect model is 1, negative is worse than mean flow

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

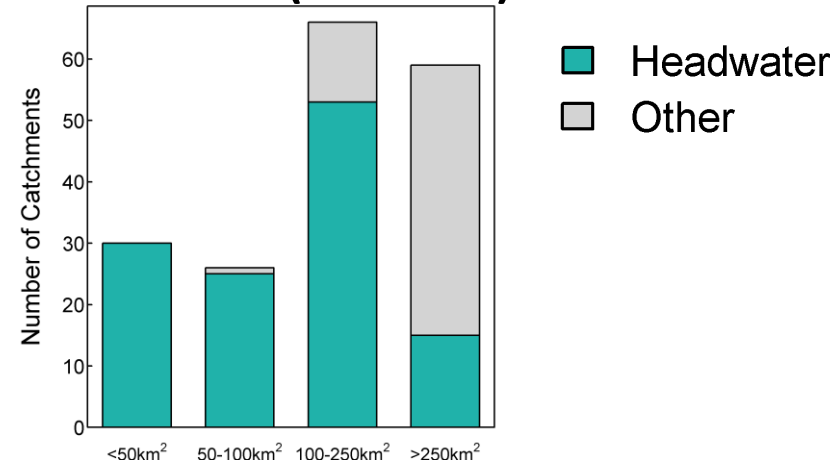
Q_t	Observed flow at time t
q_t	Modelled flow at time t
n	Number of observations
$e_t = Q_t - q_t$	Model error at time t
$\bar{Q} = \sum_{t=1}^n Q_t$	Mean of the observed flow

- 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)

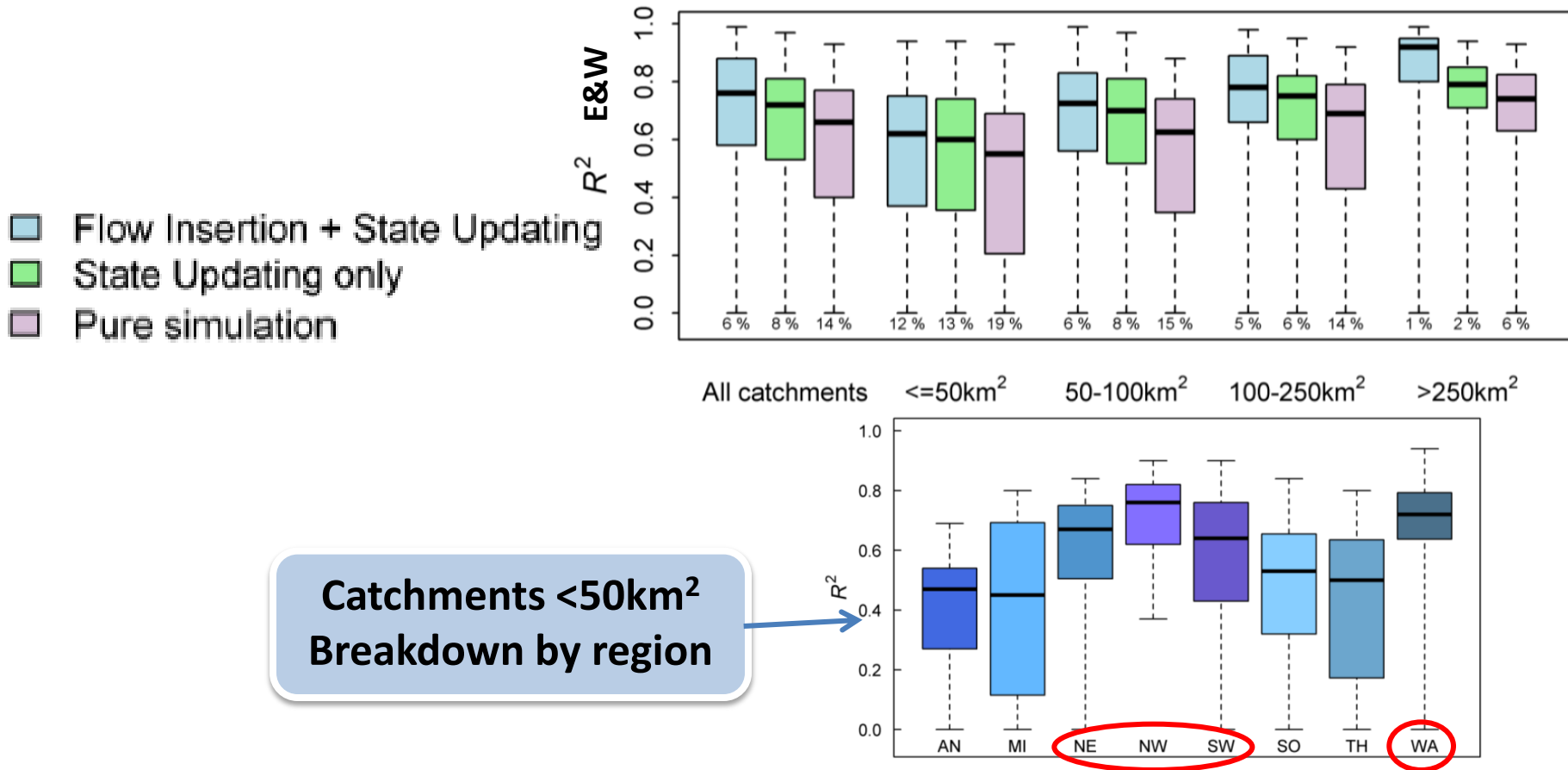


Scotland (187 sites)



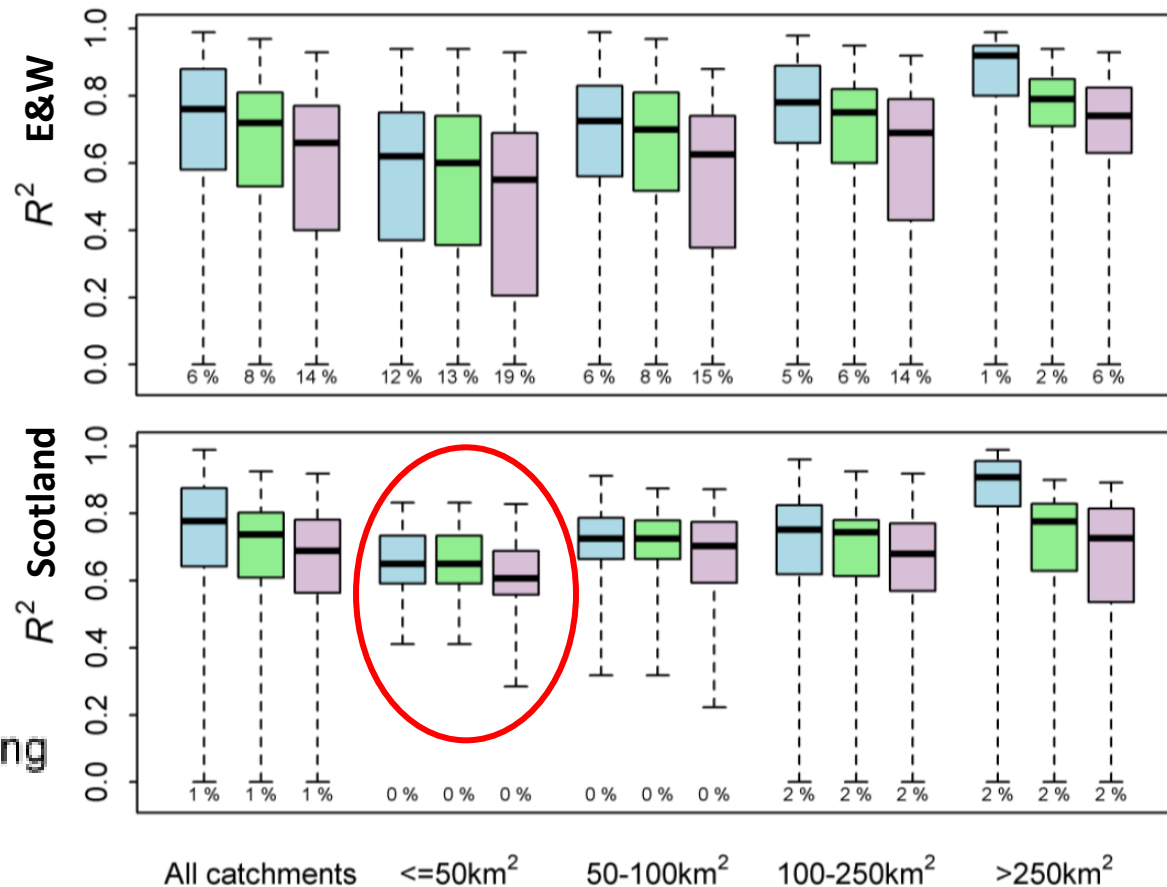
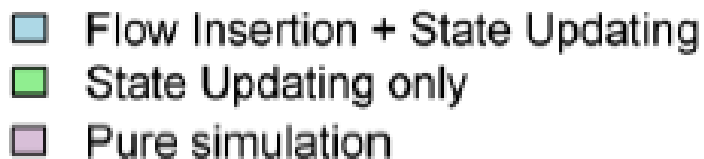
Simulation-mode assessment

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



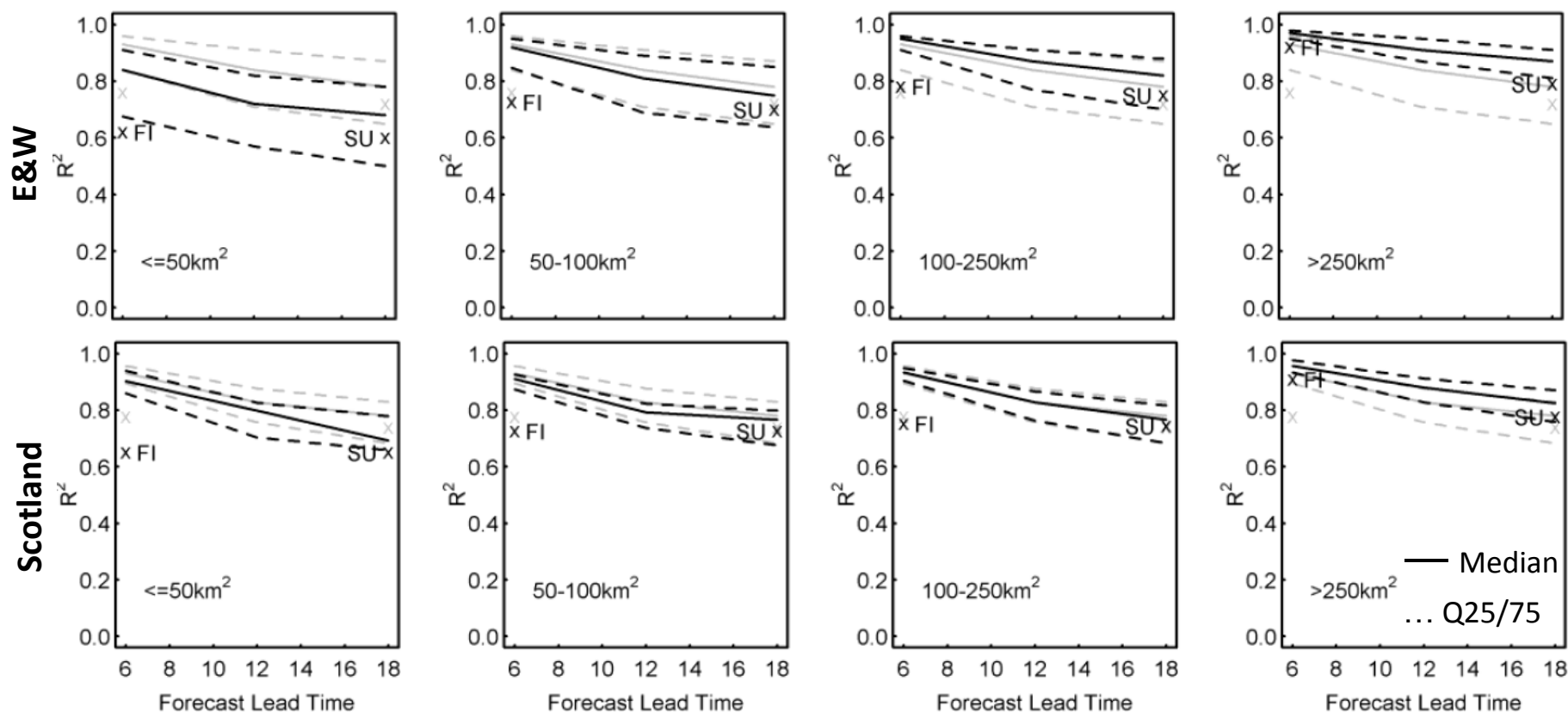
Simulation-mode assessment

- 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



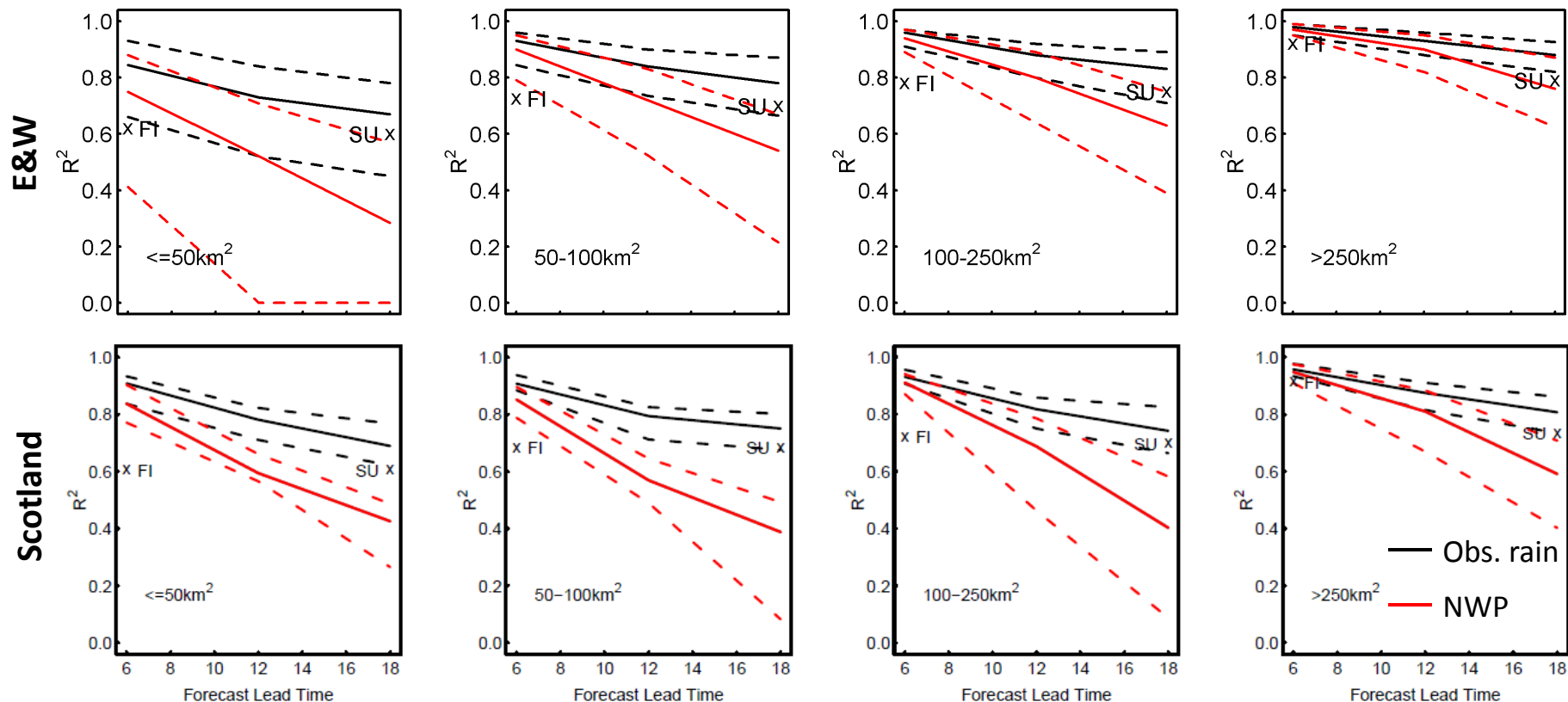
Forecast-mode: observed rain

- ARMA error-correction benefits all sites out to 12-24h
- Good simulation-mode performance for Scottish catchments < 100km² reflected in **less spread for all lead-times** and **better median R^2 for short lead-times**



Forecast-mode: UKV deterministic

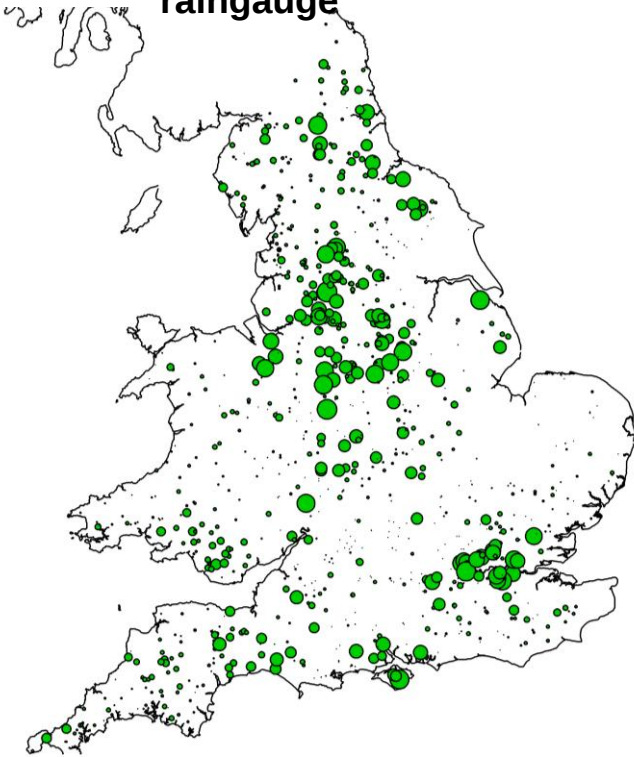
- 24h UKV (~1.5km) NWP forecasts every 6 hours (**red line**)
- Strong deterioration in NWP performance **beyond 12 hours**
- For **small catchments <50km²** Scotland performs better
- For **larger catchments England & Wales does better**



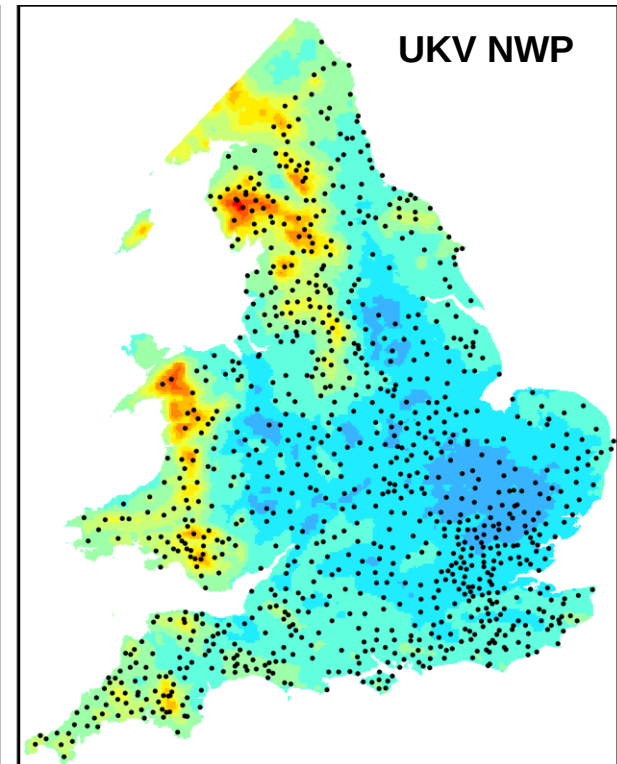
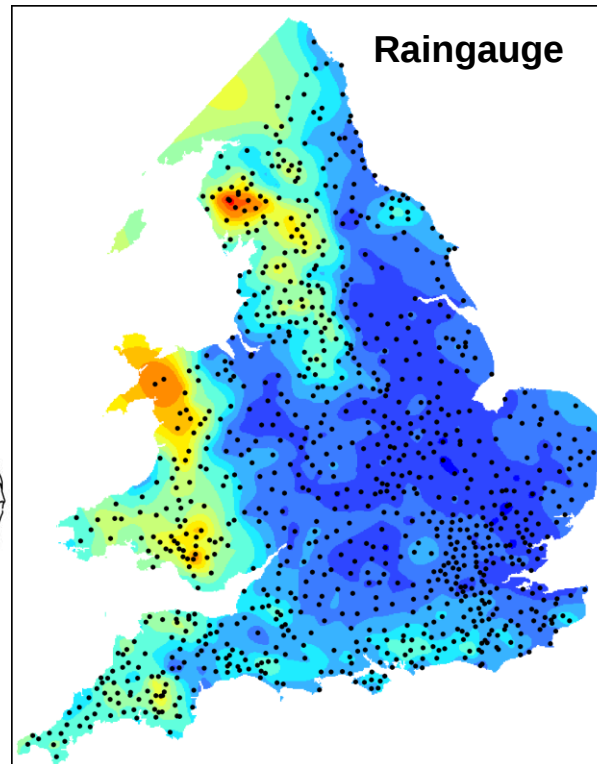
Forecast-mode: UKV deterministic

- 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

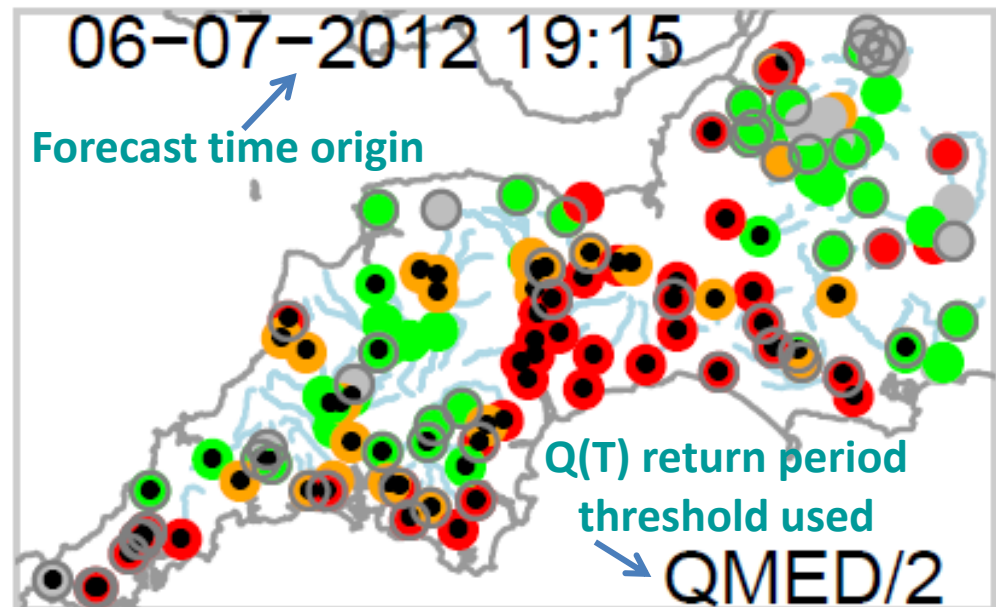
- Post-processing scheme to generate large rainfall ensembles cheaply
- Seamless combination of nowcast and deterministic NWP forecast
- Noise used to generate ensembles and downscale NWP
- 12 members (now 24), 15 minute accumulations,
7h Nowcast every 15 mins, 24h Blended ensemble every 6h



Circles denote gauging stations

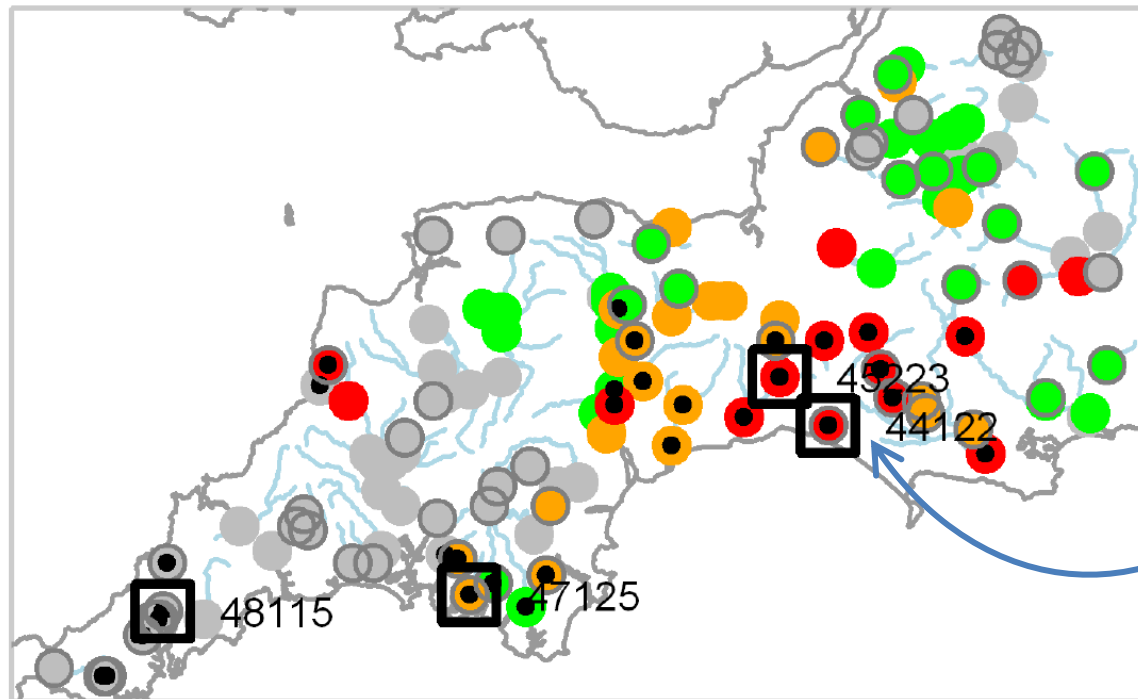
- Solid outline: area $< 50\text{km}^2$
- Observed flow exceeds threshold during forecast

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



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

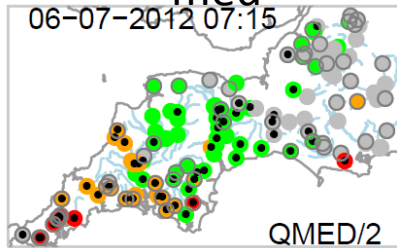
Forecast

Origin

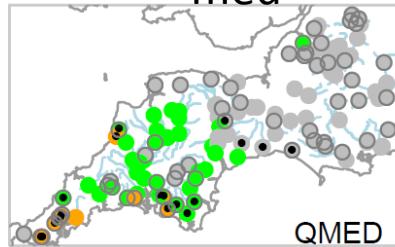
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07:15

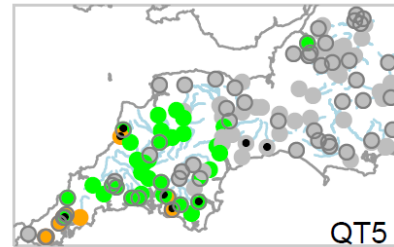
$Q_{med}/2$



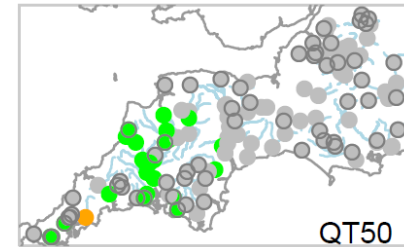
Q_{med}



$Q(5)$



$Q(50)$



Case study: 6-7 July 2012

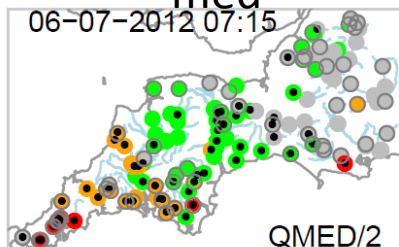
Threshold

Forecast

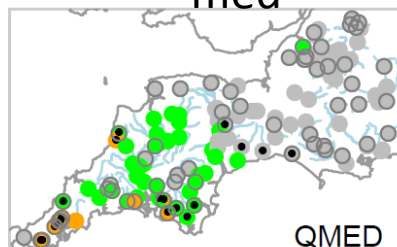
Origin

06-07-2012
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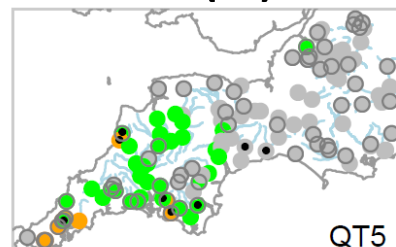
$Q_{med}/2$



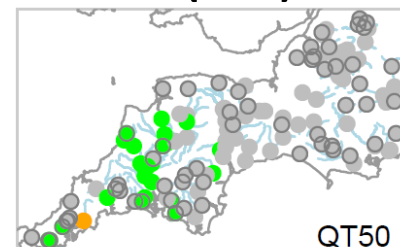
Q_{med}



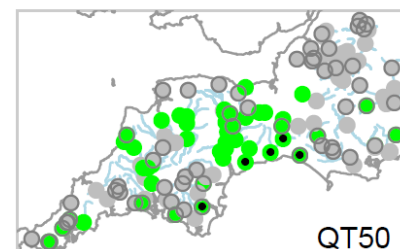
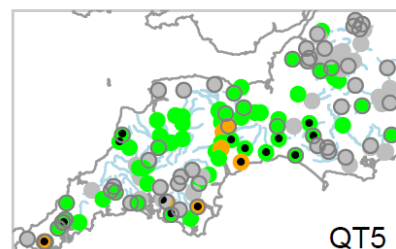
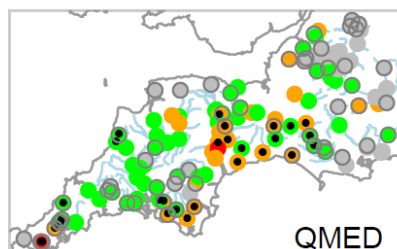
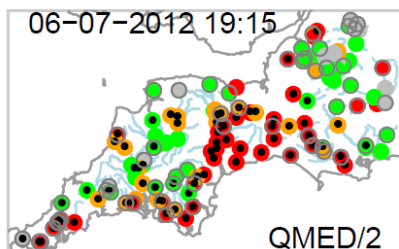
$Q(5)$



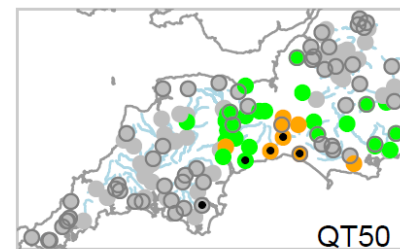
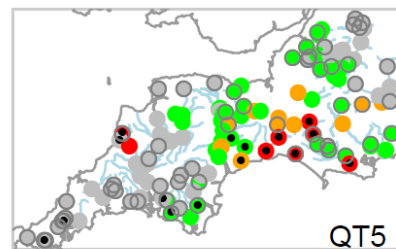
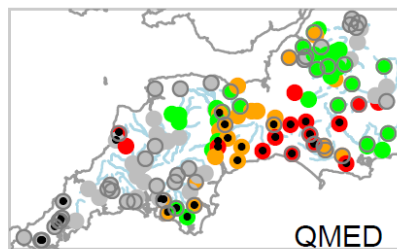
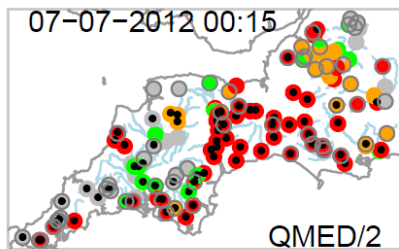
$Q(50)$



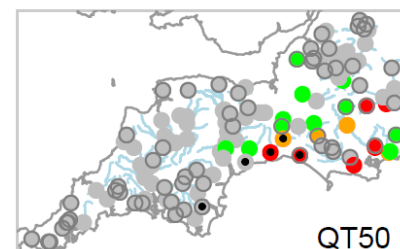
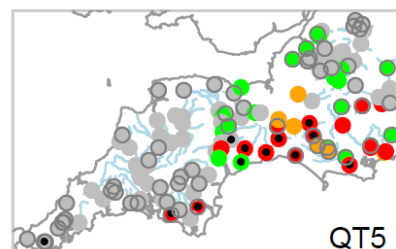
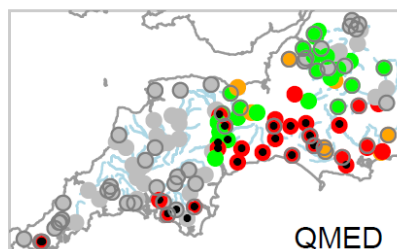
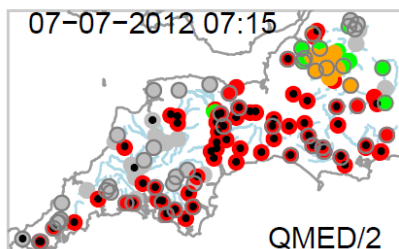
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19:15



07-07-2012
00:15



07-07-2012
07:15



Case study: 6-7 July 2012

Threshold

Forecast

Origin

06-07-2012
07:15

06-07-2012
19:15

07-07-2012
00:15

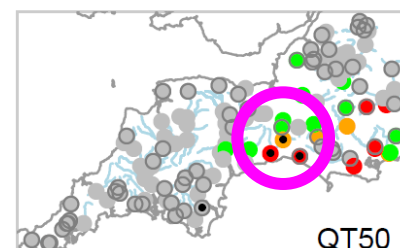
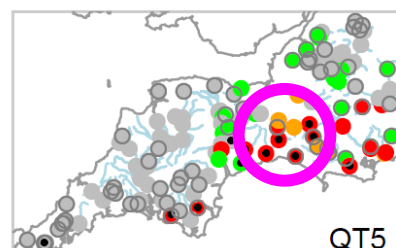
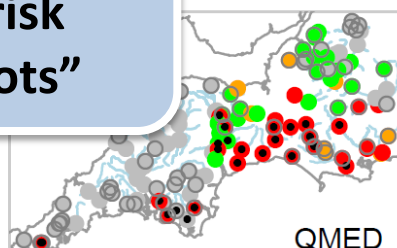
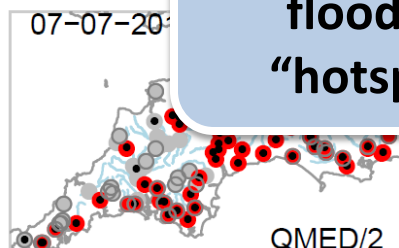
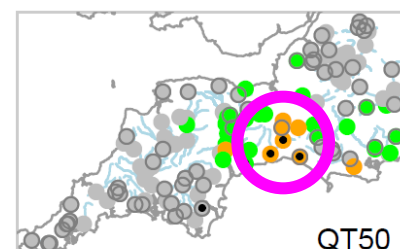
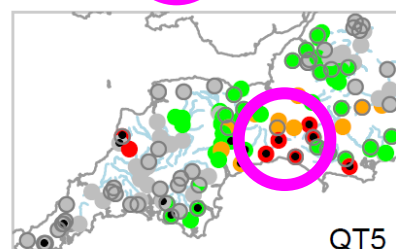
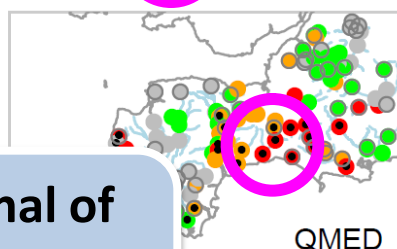
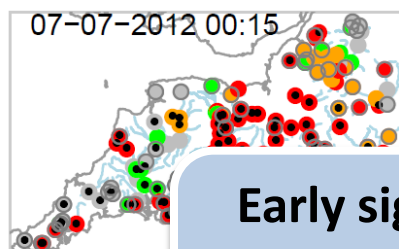
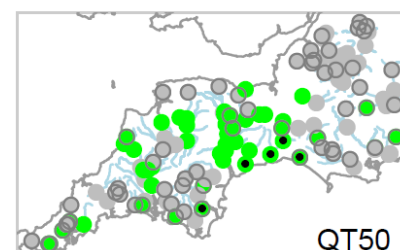
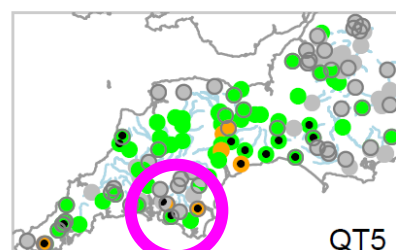
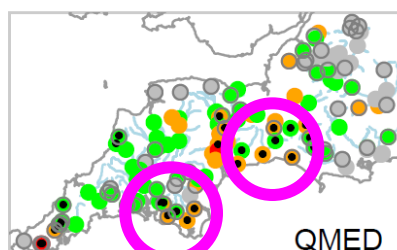
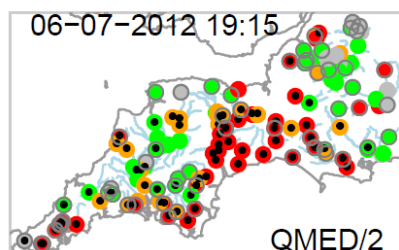
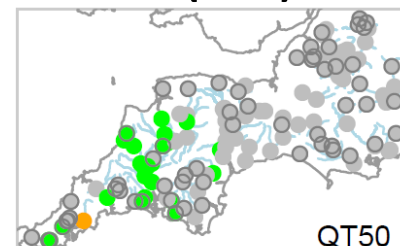
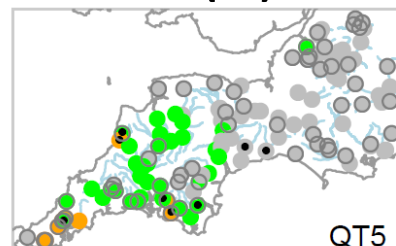
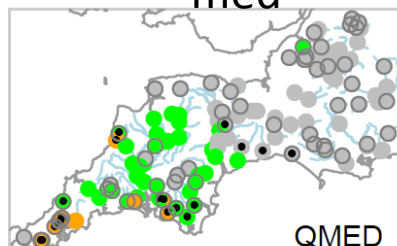
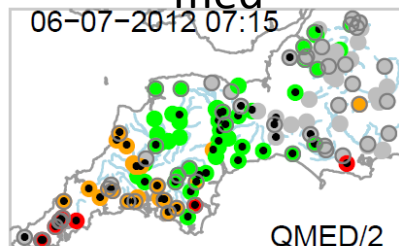
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$Q_{med}/2$

Q_{med}

$Q(5)$

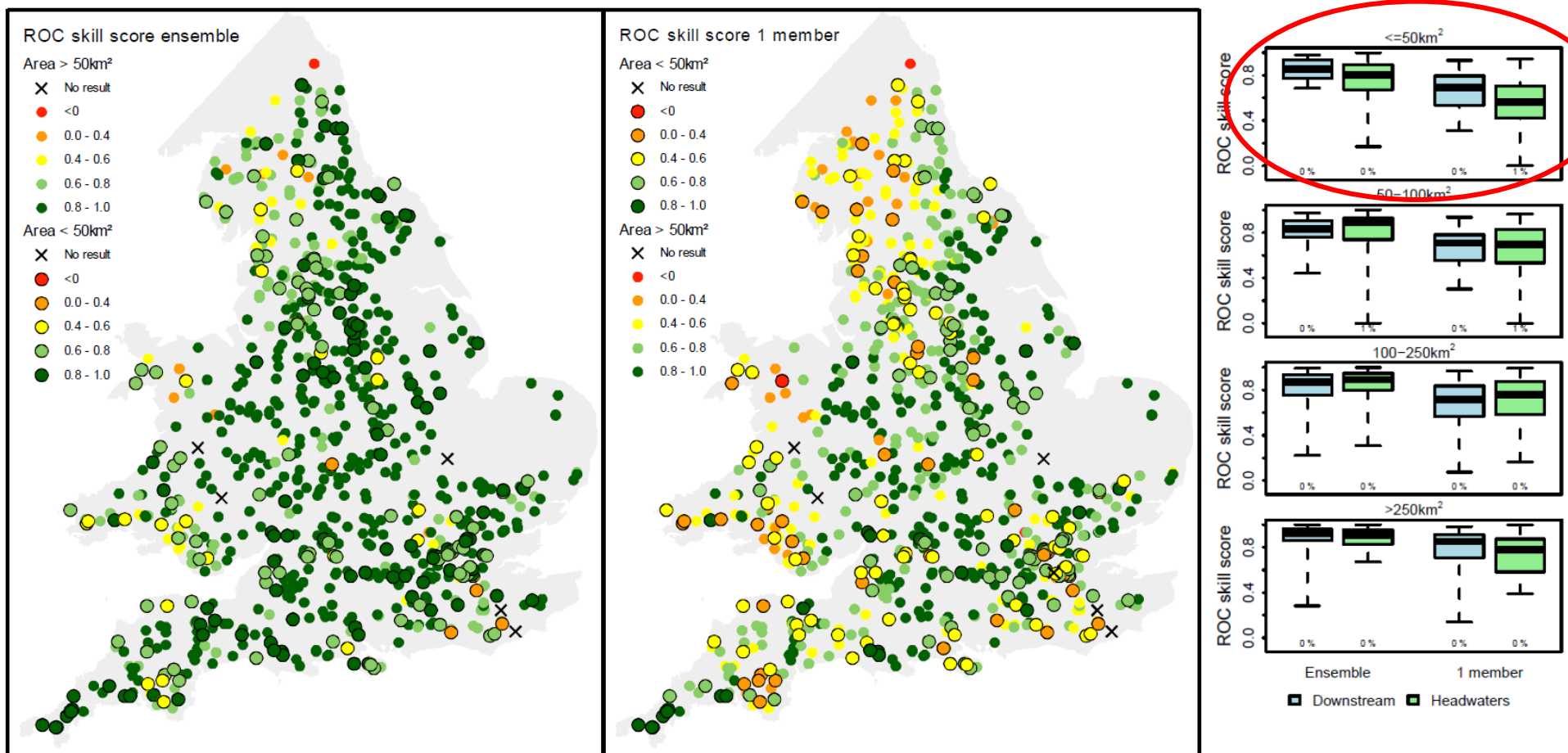
$Q(50)$



Early signal of
flood risk
"hotspots"

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)