Recent developments in countrywide flood forecasting using the G2G distributed hydrological model

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BHS Meeting: Hydrology for Flood Risk Management
21 November 2013

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Background

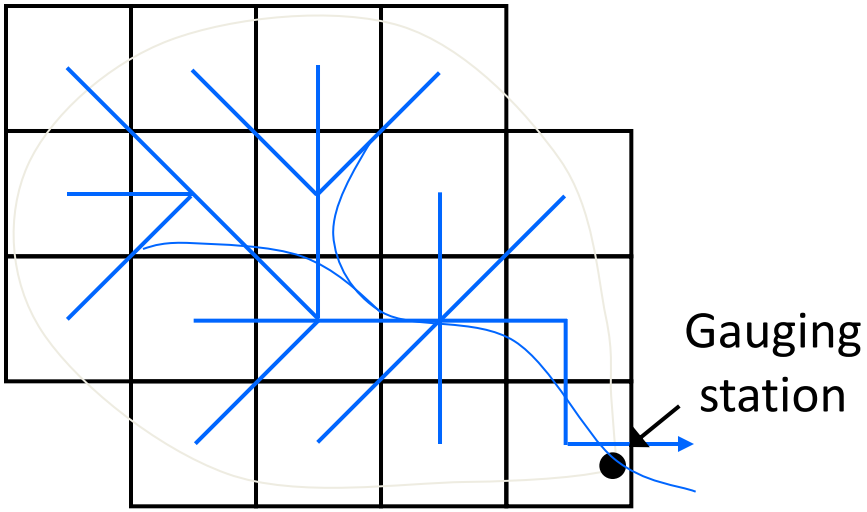
- Summer 2007 floods
  - £3 billion insurance payouts
  - 55,000 properties flooded,
    36,000 from surface water flooding
  - National infrastructure impacts
    - 140,000 homes without clean water for 17 days
    - 42,000 homes without power for 24 hours
- Pitt Review commissioned
  - Flood Forecasting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

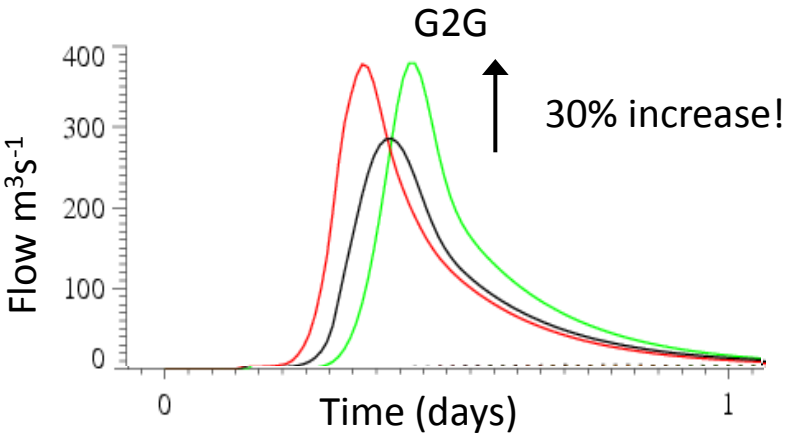
FLOODFORECASTINGCENTRE
a working partnership between Environment Agency | Met Office

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

Distributed Hydrological Modelling (G2G)

Grid-to-Grid (G2G) Model





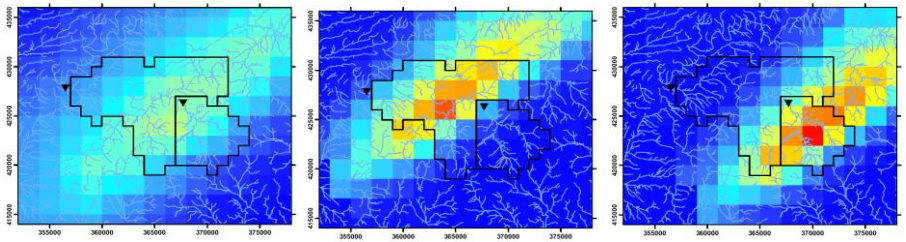
Catchment-wide storm

Lower catchment storm

Upper catchment storm

Benefits

- One model for large regions (UK)
- Flow estimates in each grid (1km^2)
- Realistic response to different storm intensities and extent



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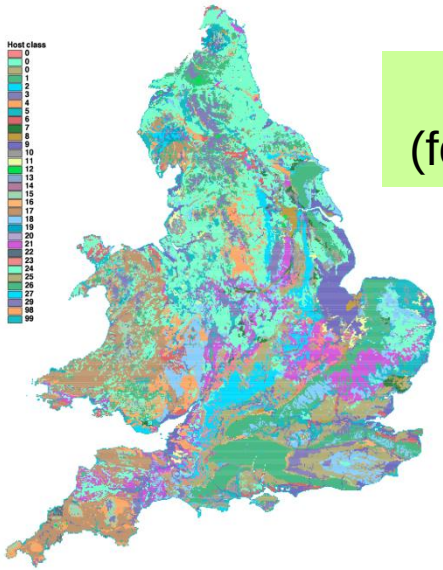
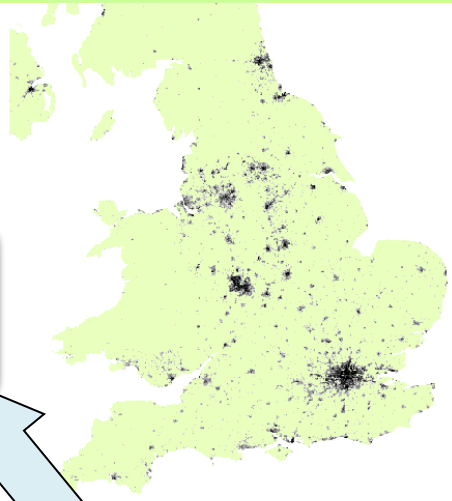
Moore *et al.*, IAHS Publ. 305 (2006); Cole & Moore, JoH (2009)

Factors affecting G2G runoff production



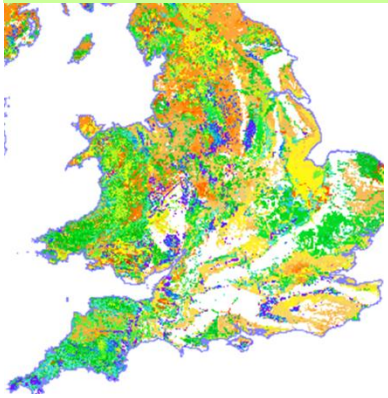
Soil properties
(for each HOST class)

Urban/Suburban coverage
- Increase runoff (by decreasing soil depth)



G2G Runoff Production

Soil Moisture Deficit
(modelled)

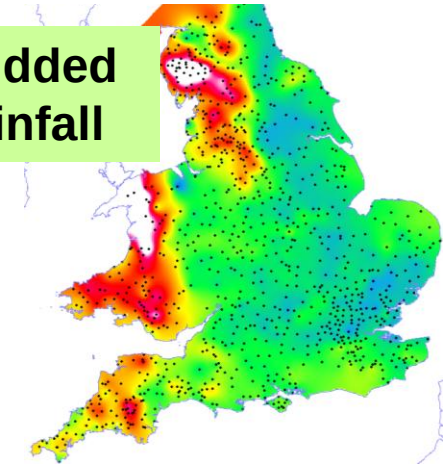


Terrain/slope

Steep slopes → Shallow storage

Shallow slopes → Deep storage

Gridded rainfall

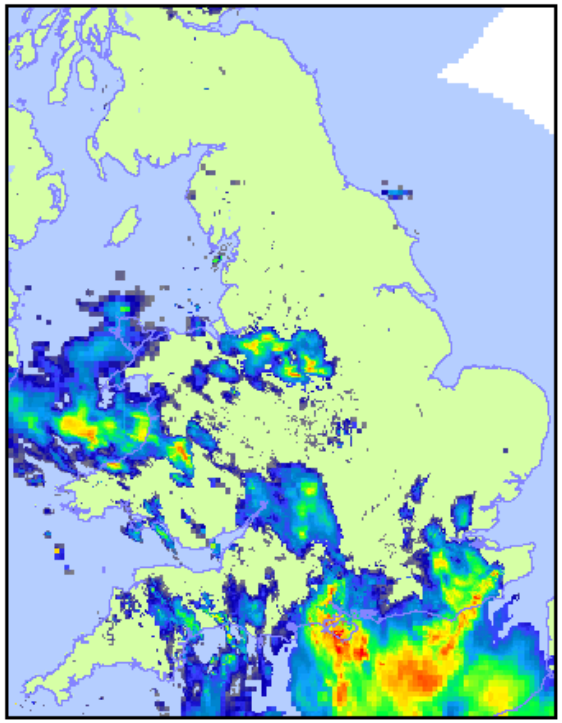


G2G national application for FFC & SFFS

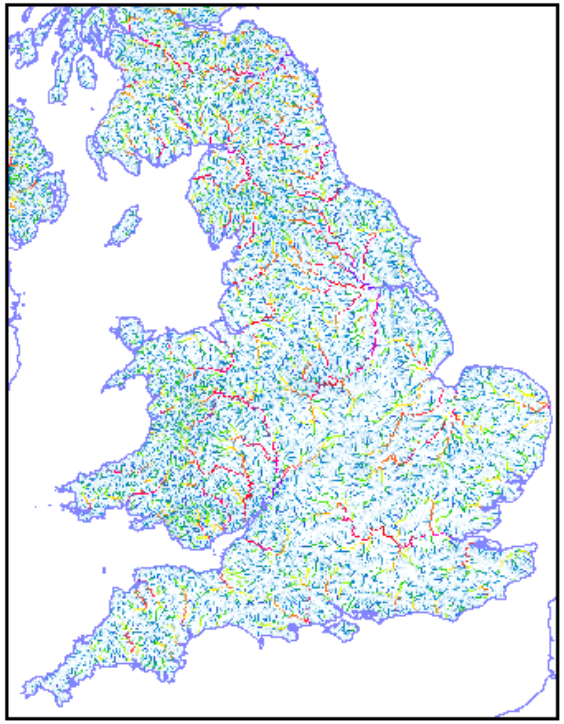
G2G runs 24/7 within FEWS across England, Wales & Scotland

Operates at a 15 minute time-step on a 1km grid, out to 5 days

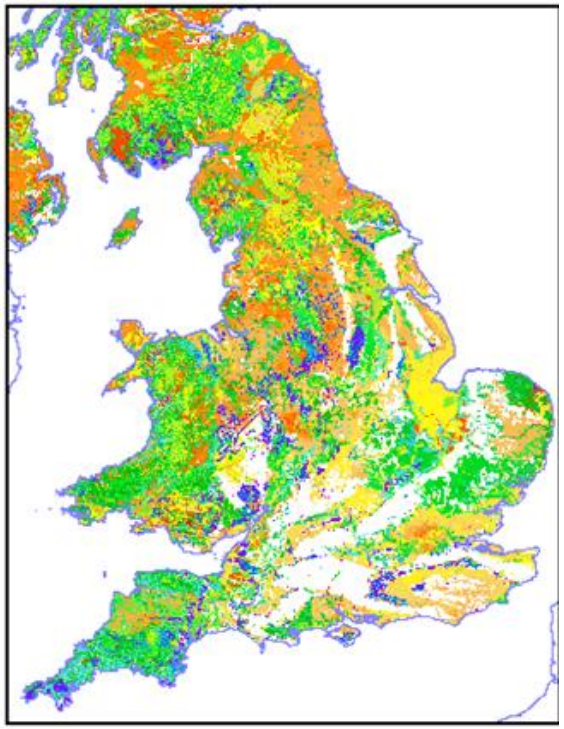
Forecasts river flow, surface runoff and soil moisture



Raingauge-adjusted radar rainfall (HyradK)



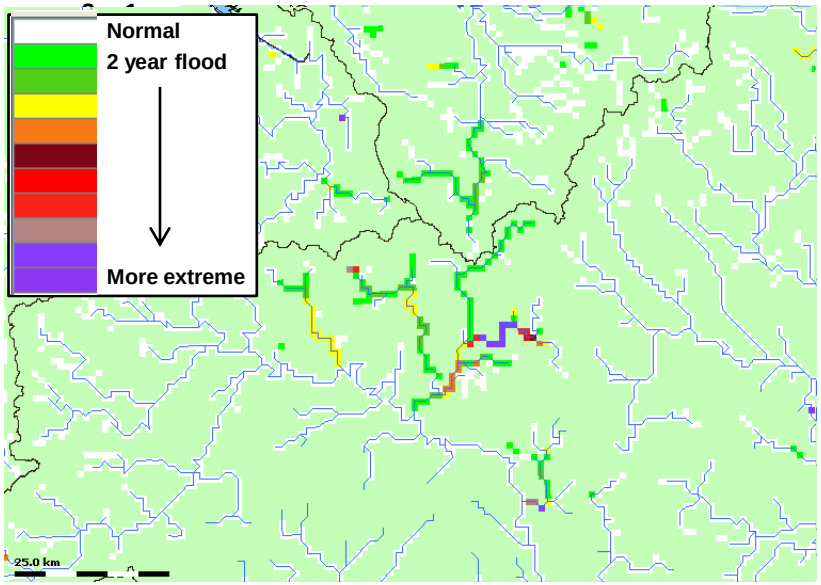
River flow



Soil moisture

Price *et al.;* Cranston and Tavendale, Proc. ICE – Water Management (2012)

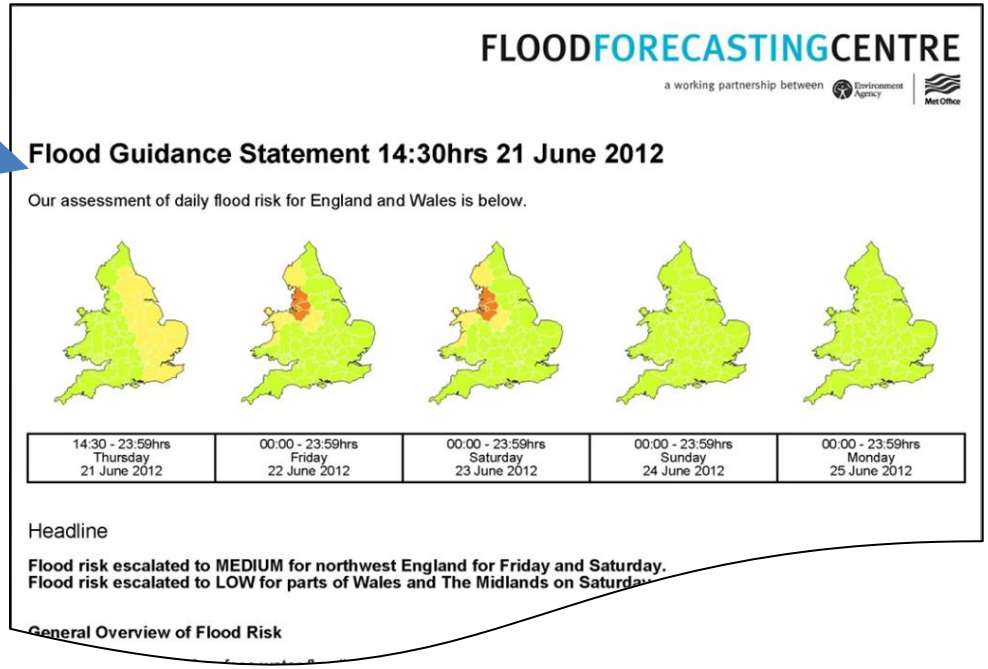
Flood Guidance Statement (FGS)



1km maps

G2G flow outputs converted to flood return periods using Q(T) maps

- G2G forecasts inform Flood Guidance Statement
- Daily flood risk assessment for emergency responders (10:30)
- Updated during events
- Information presented at county level out to 5 days



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a working partnership between Environment Agency | Met Office

Flood Guidance Statement 14:30hrs 21 June 2012

Our assessment of daily flood risk for England and Wales is below.

14:30 - 23:59hrs Thursday 21 June 2012	00:00 - 23:59hrs Friday 22 June 2012	00:00 - 23:59hrs Saturday 23 June 2012	00:00 - 23:59hrs Sunday 24 June 2012	00:00 - 23:59hrs Monday 25 June 2012

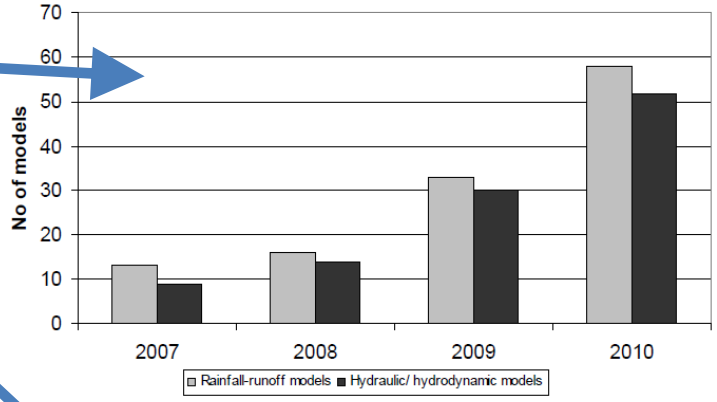
Headline

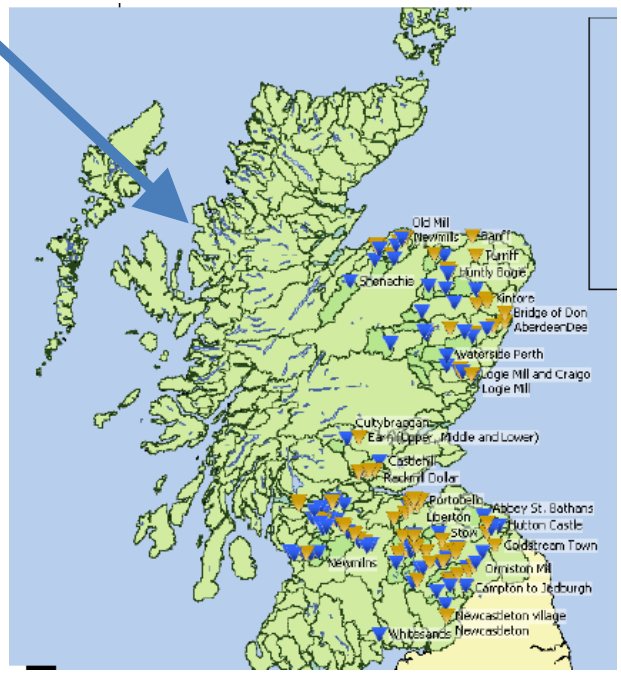
Flood risk escalated to MEDIUM for northwest England for Friday and Saturday.
Flood risk escalated to LOW for parts of Wales and The Midlands on Saturday

General Overview of Flood Risk

G2G for Scotland

- Recent improvement in local forecasting model coverage
- **BUT** still large areas of Scotland **without** a flood forecasting capability
- Flood Risk Management (Scotland) Act 2009
- Created joint Met Office and SEPA **Scottish Flood Forecasting Service**
- G2G applied to give **first national picture of flood risk**
- **Snowmelt** module needed





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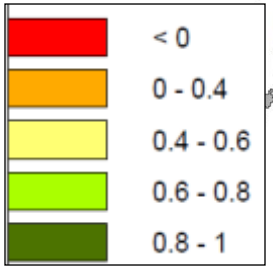
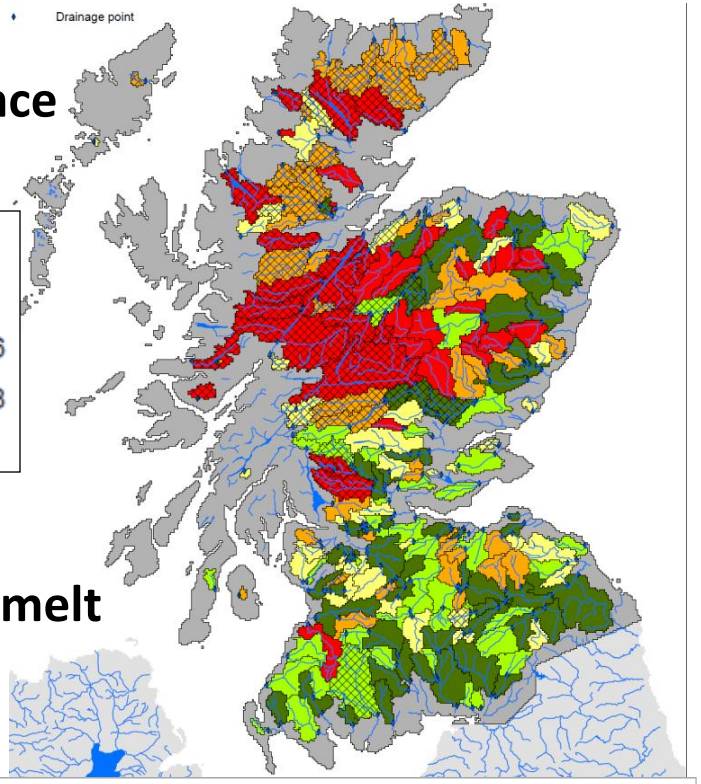
Cranston and Tavendale, Proc. ICE – Water Management (2012)

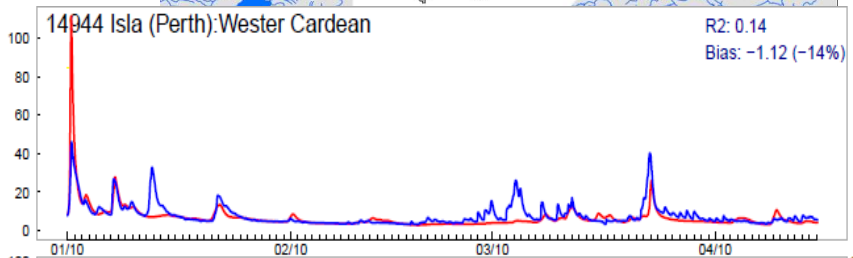
G2G for Scotland – Snowmelt modelling

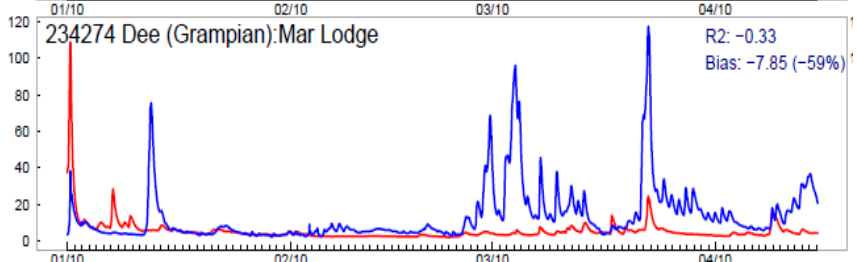
Model Performance (R^2)





No Snowmelt

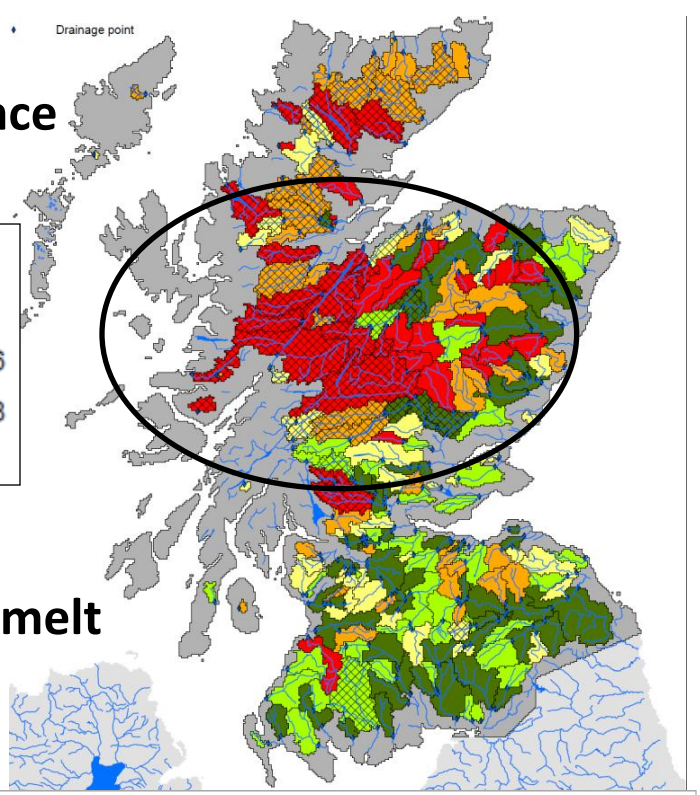




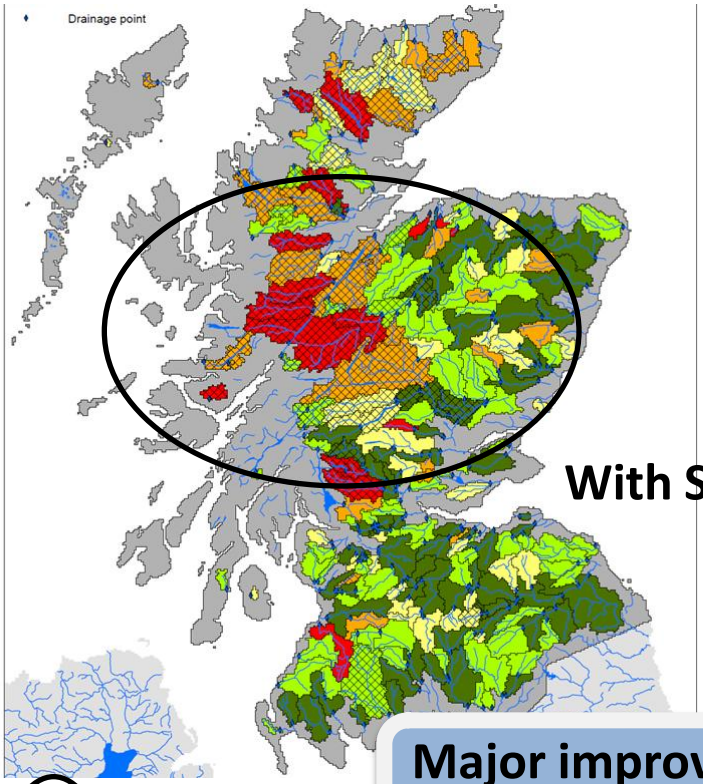
G2G for Scotland – Snowmelt modelling

Model Performance (R^2)

< 0
0 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1

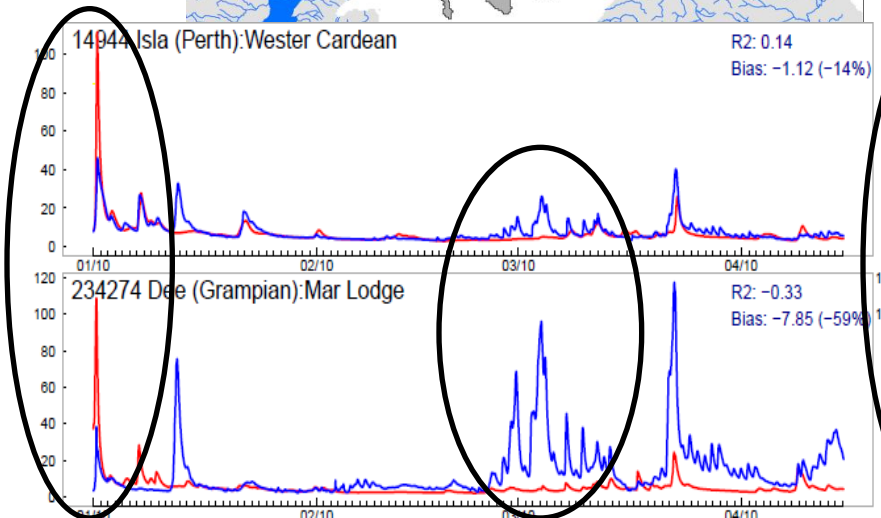


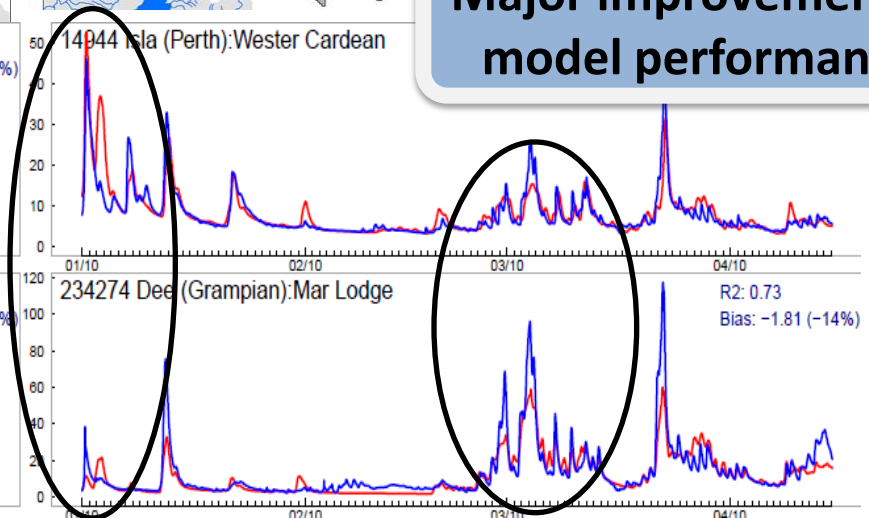
No Snowmelt



With Snowmelt

Major improvement in model performance

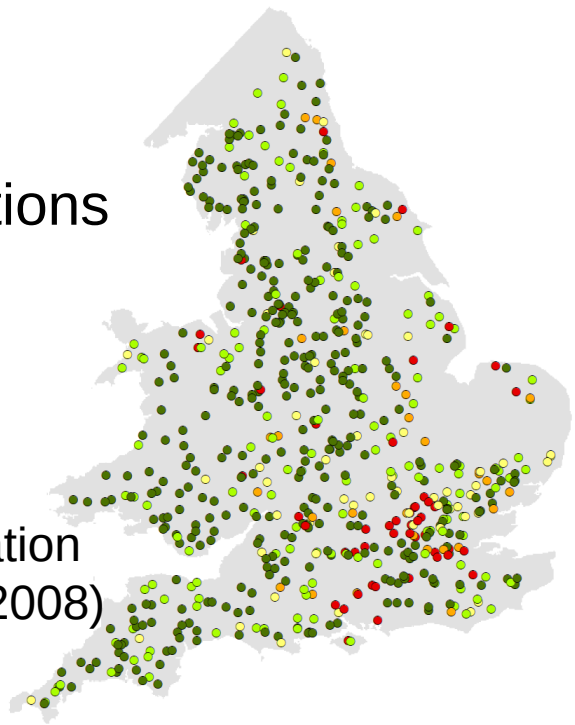




G2G for Rapid Response Catchments

- Explore use of G2G for Rapid Response Catchments
  - typically small area (<100km^2) & ungauged
  - need to develop forecast/warning capability
  - Value of radar/NWP *rainfall forecast ensembles*?
  - Case study experience & methods of display

All stations

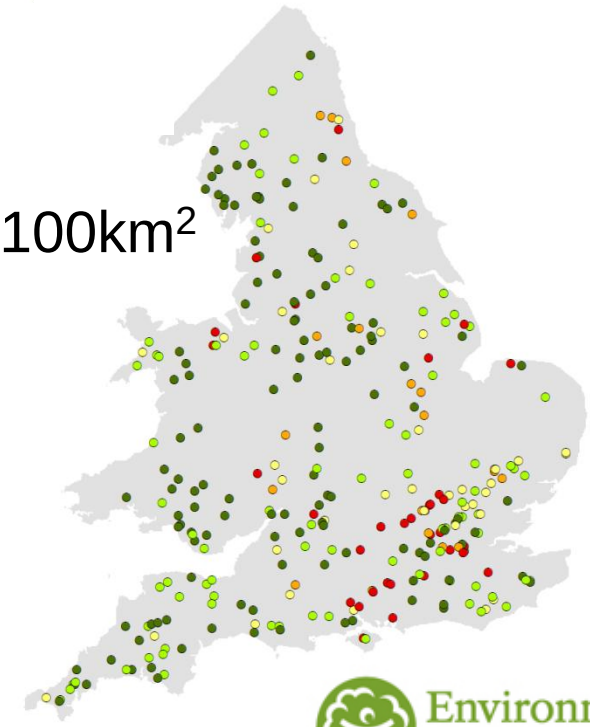


G2G simulation
(Jan – Apr 2008)

R^2 Efficiency

- < 0.0
- 0.0 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0

Area <100km^2



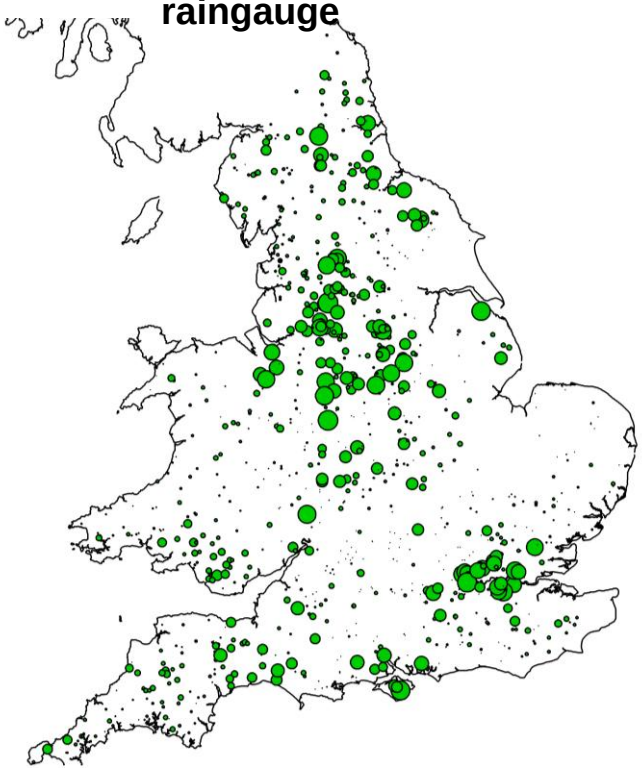
SEPA
Scottish Environment Protection Agency

Environment Agency

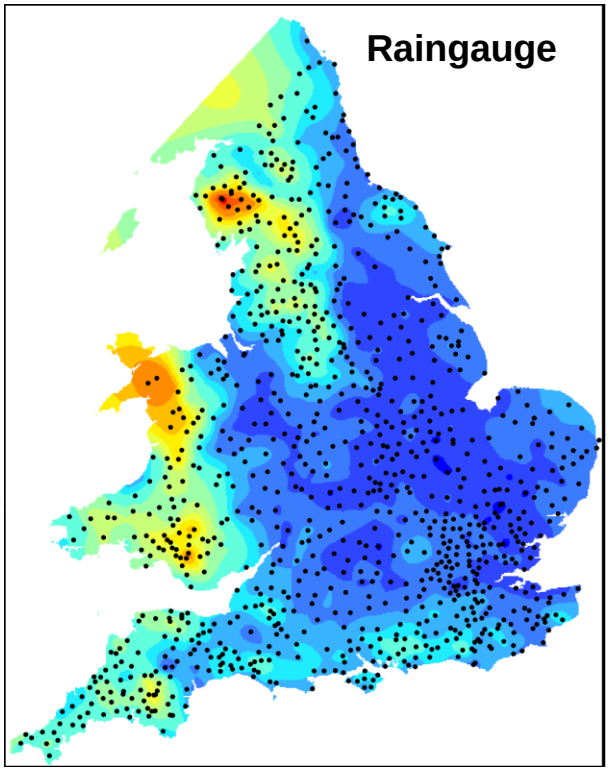
G2G for Rapid Response Catchments

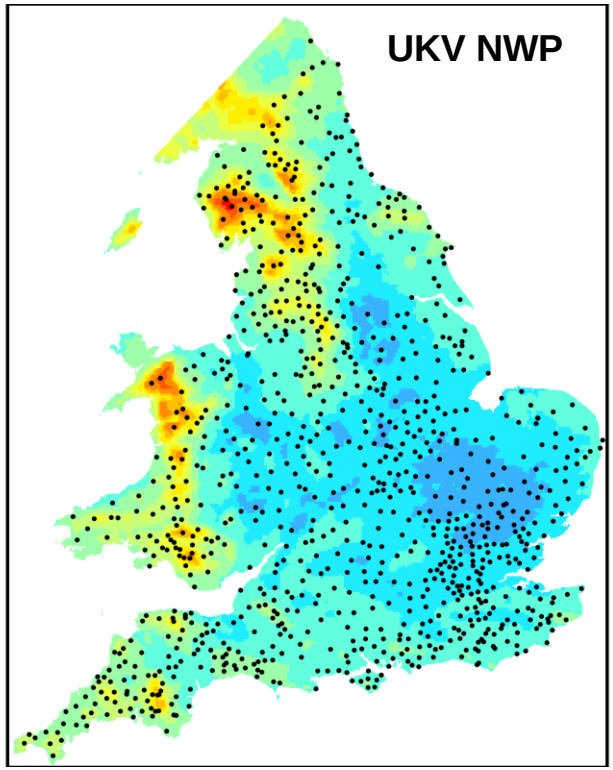
- Analysis of G2G forecasts using:
  - Raingauge data as foreknowledge of forecast rainfall data
  - UKV deterministic NWP as forecast rainfall data
- Suggests spatial biases over 2010/11 assessment period

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

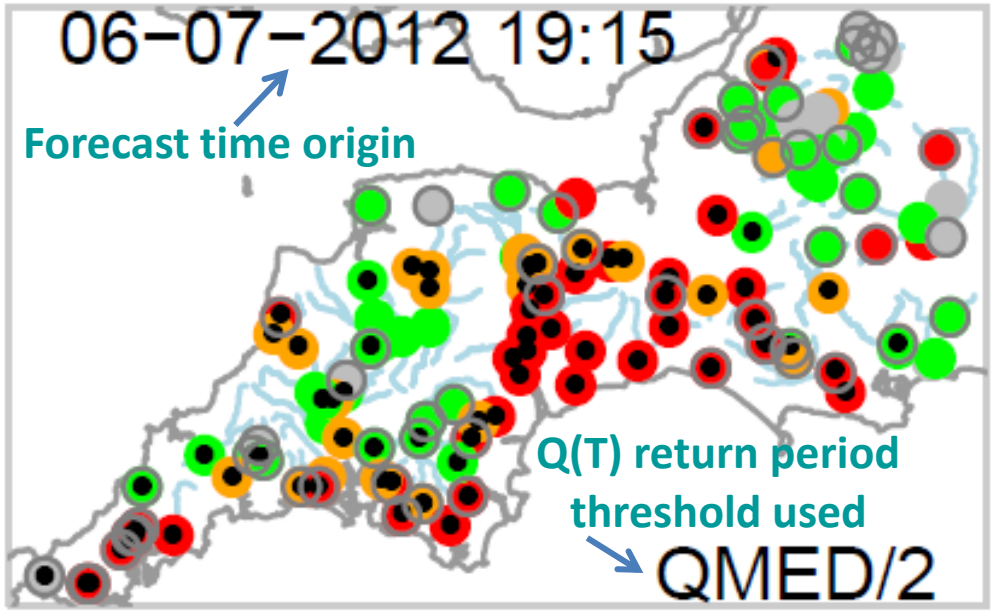
Met Office

Circles denote gauging stations

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

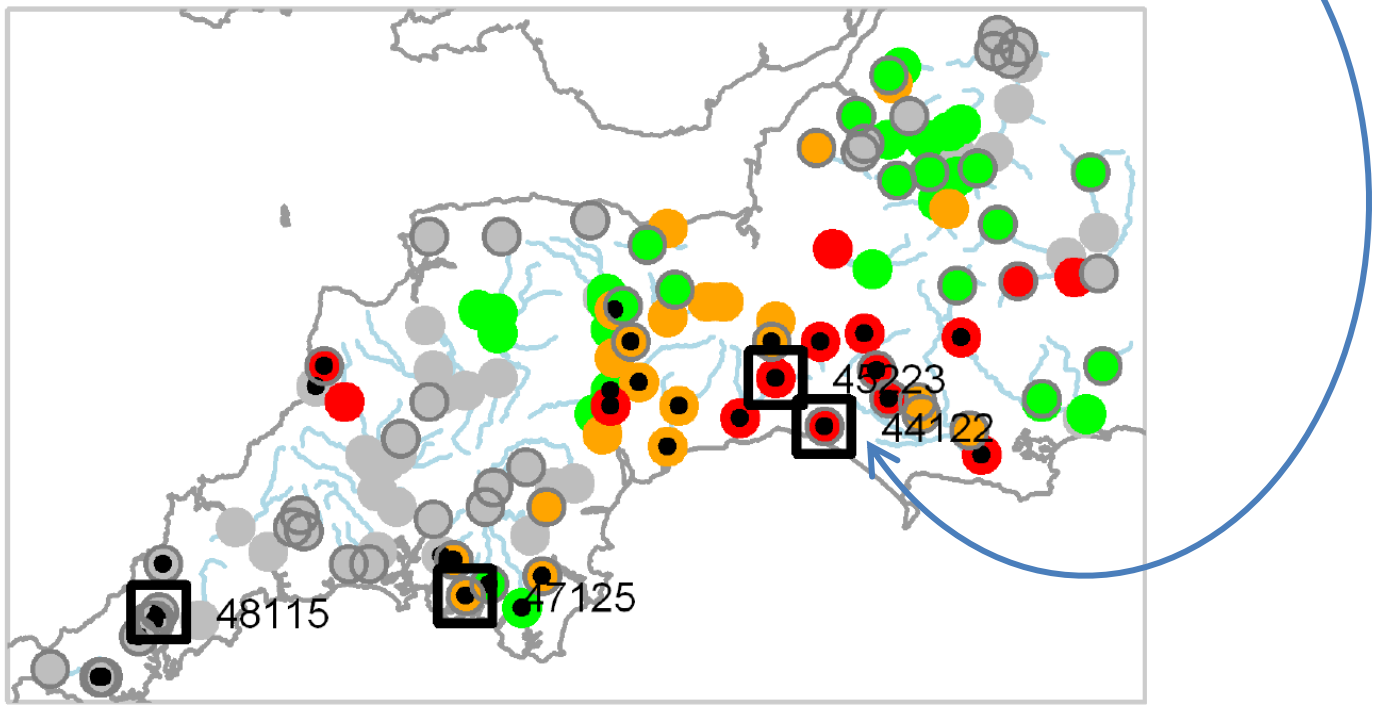
Percentage of ensembles that exceeded the Q(T) threshold at some point during forecast

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



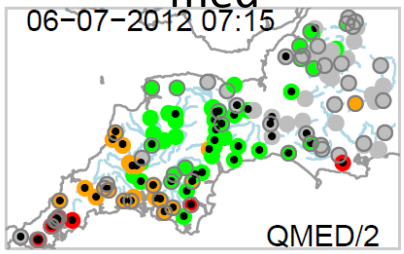
Case study: 6-7 July 2012

Threshold

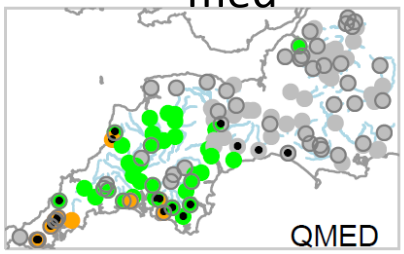
Forecast Origin

06-07-2012 07:15

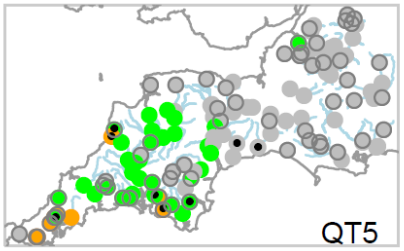
$Q_{med}/2$



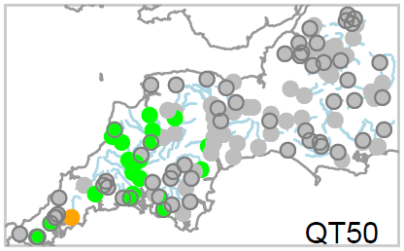
Q_{med}



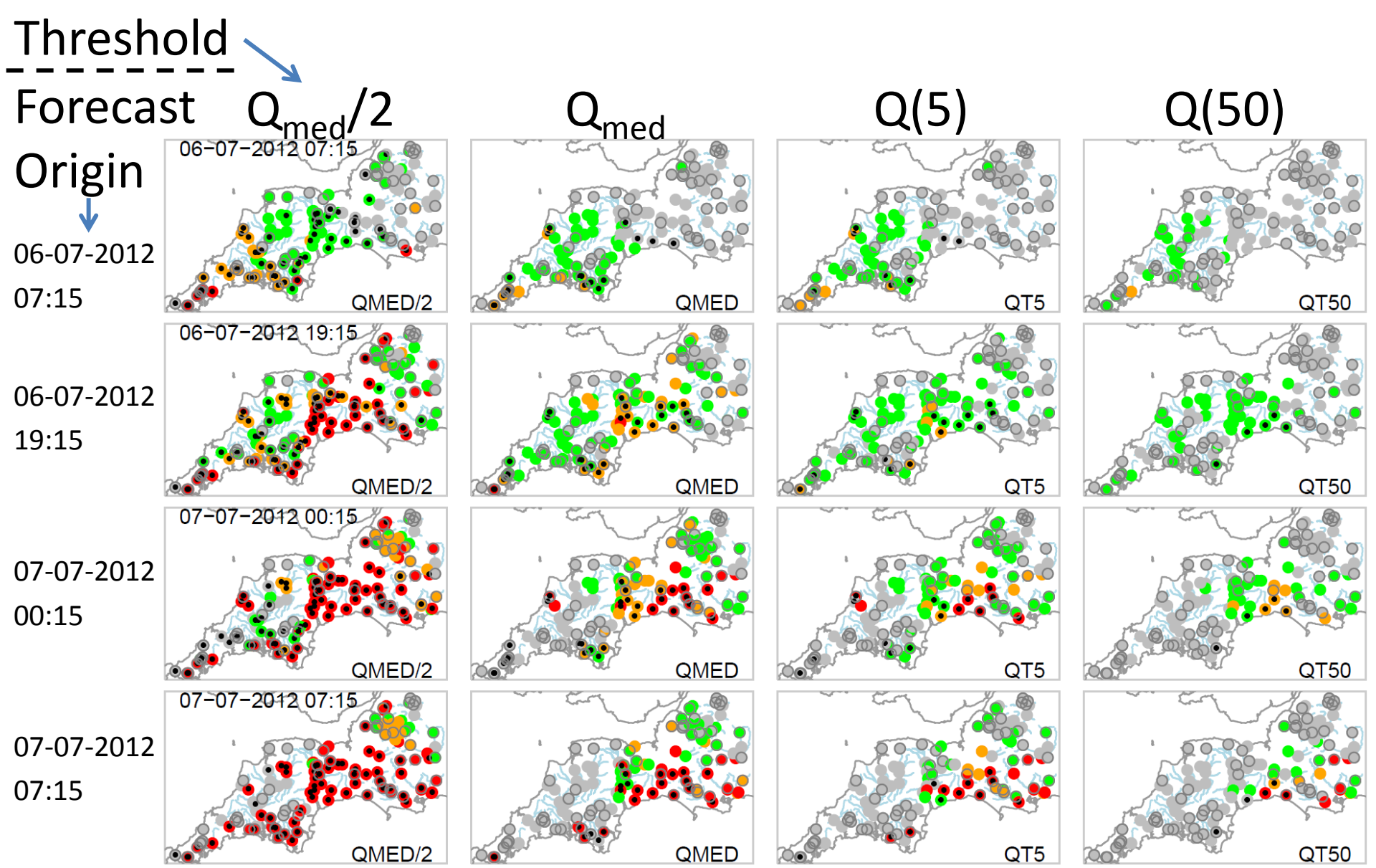
Q(5)



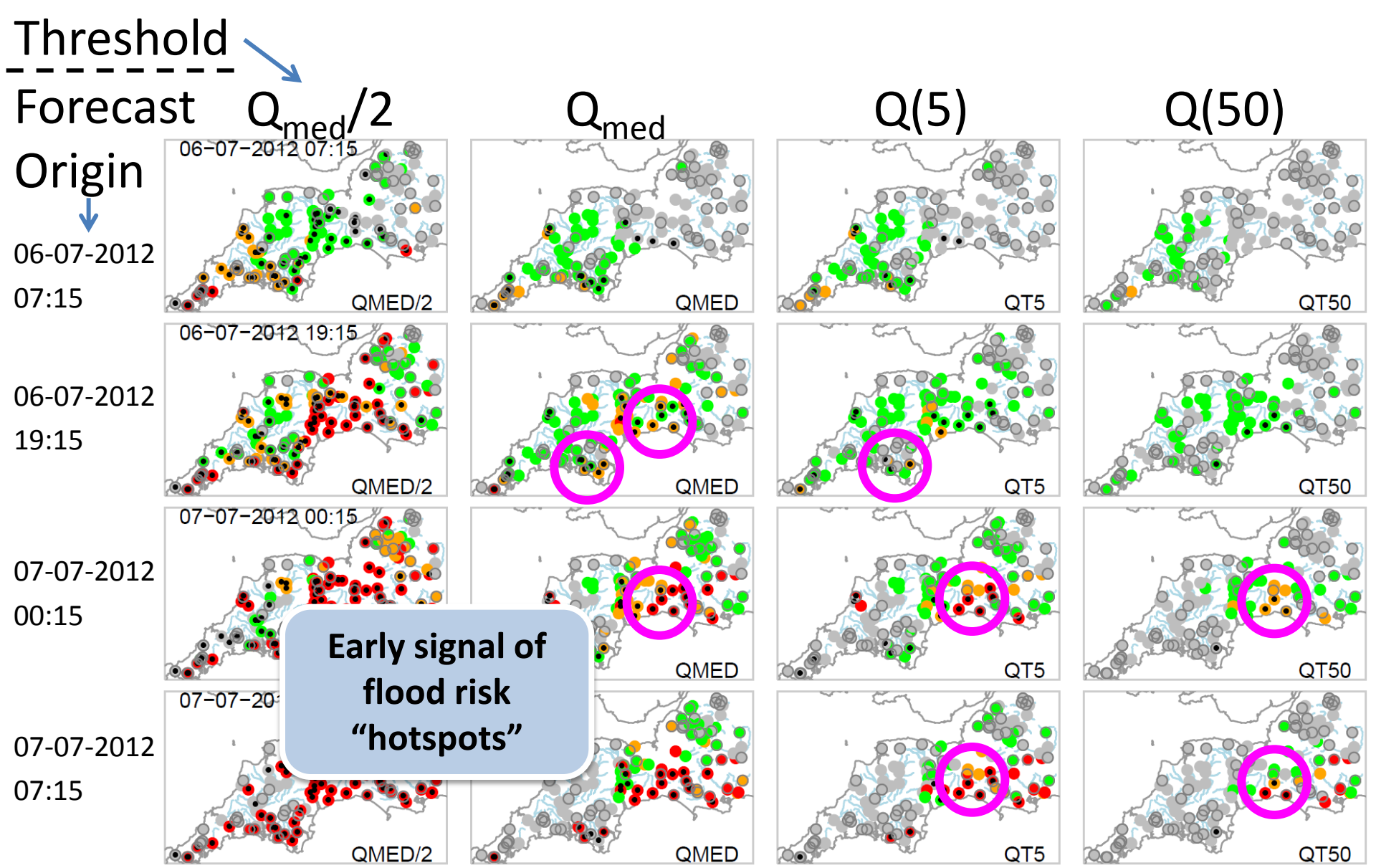
Q(50)



Case study: 6-7 July 2012



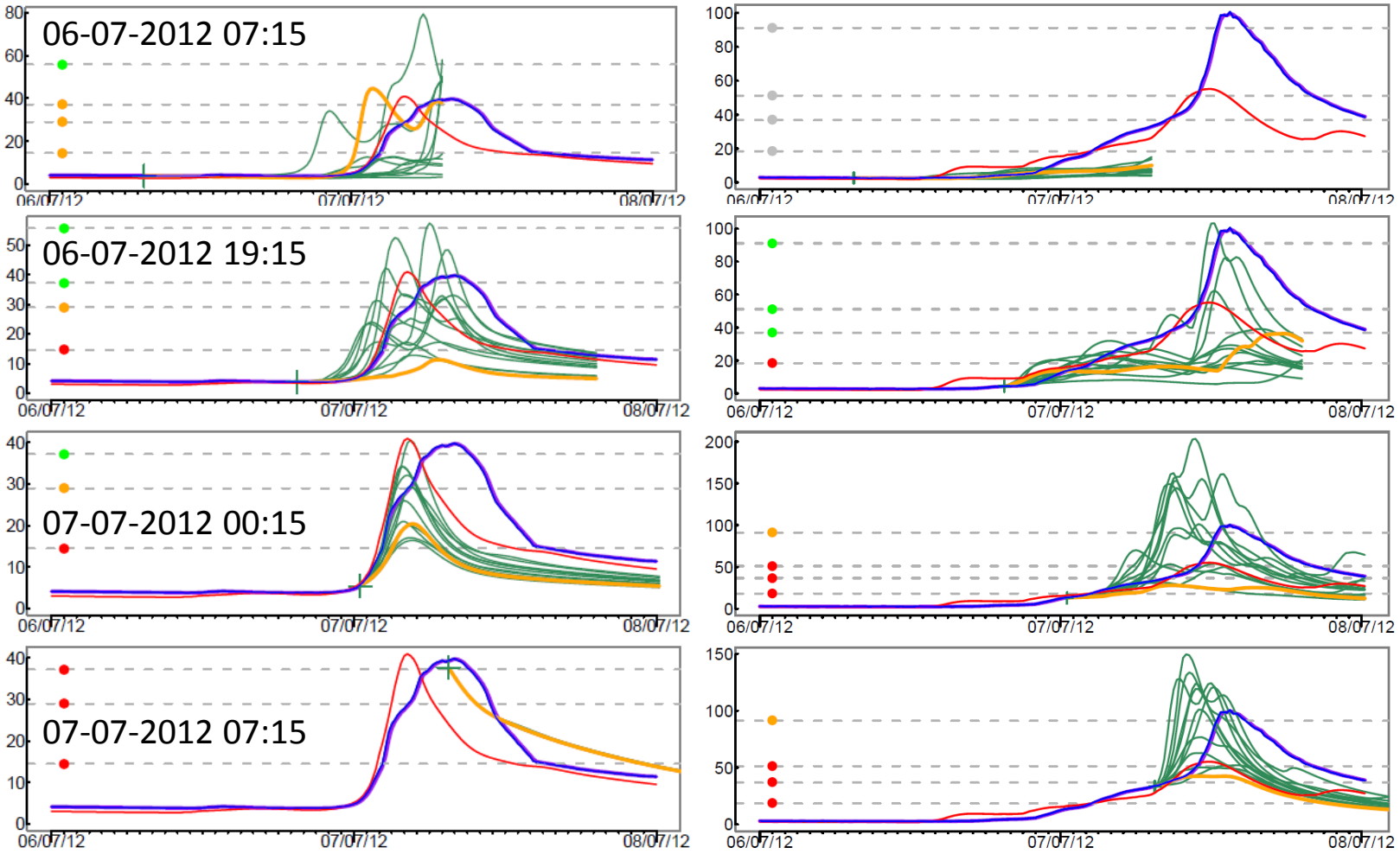
Case study: 6-7 July 2012



Case study: 6-7 July 2012

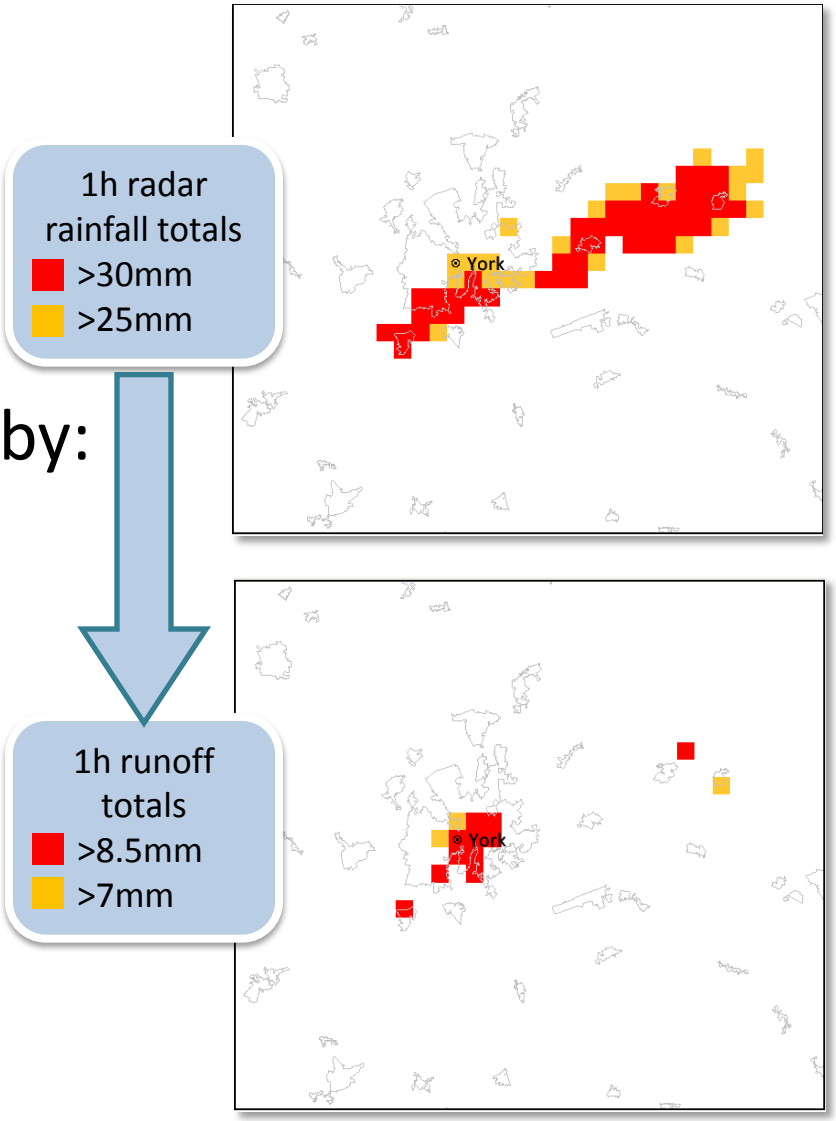
- Strong signal at least 12 hours before

Yealm at Puslinch (55km^2) | Axe at Chard Junction (85km^2)



G2G alerts for surface water flooding

- Extreme Rainfall Alerts (ERA)
  - National rainfall-threshold based method
  - Based on FEH 30 year return period rainfalls "averaged" across 8 UK cities
- G2G runoff production affected by:
  - Rainfall amount **plus**
  - Urban/suburban coverage
  - Soil and geology properties
  - Antecedent soil moisture conditions
- Prototype runoff threshold exceedances seem **more targeted**



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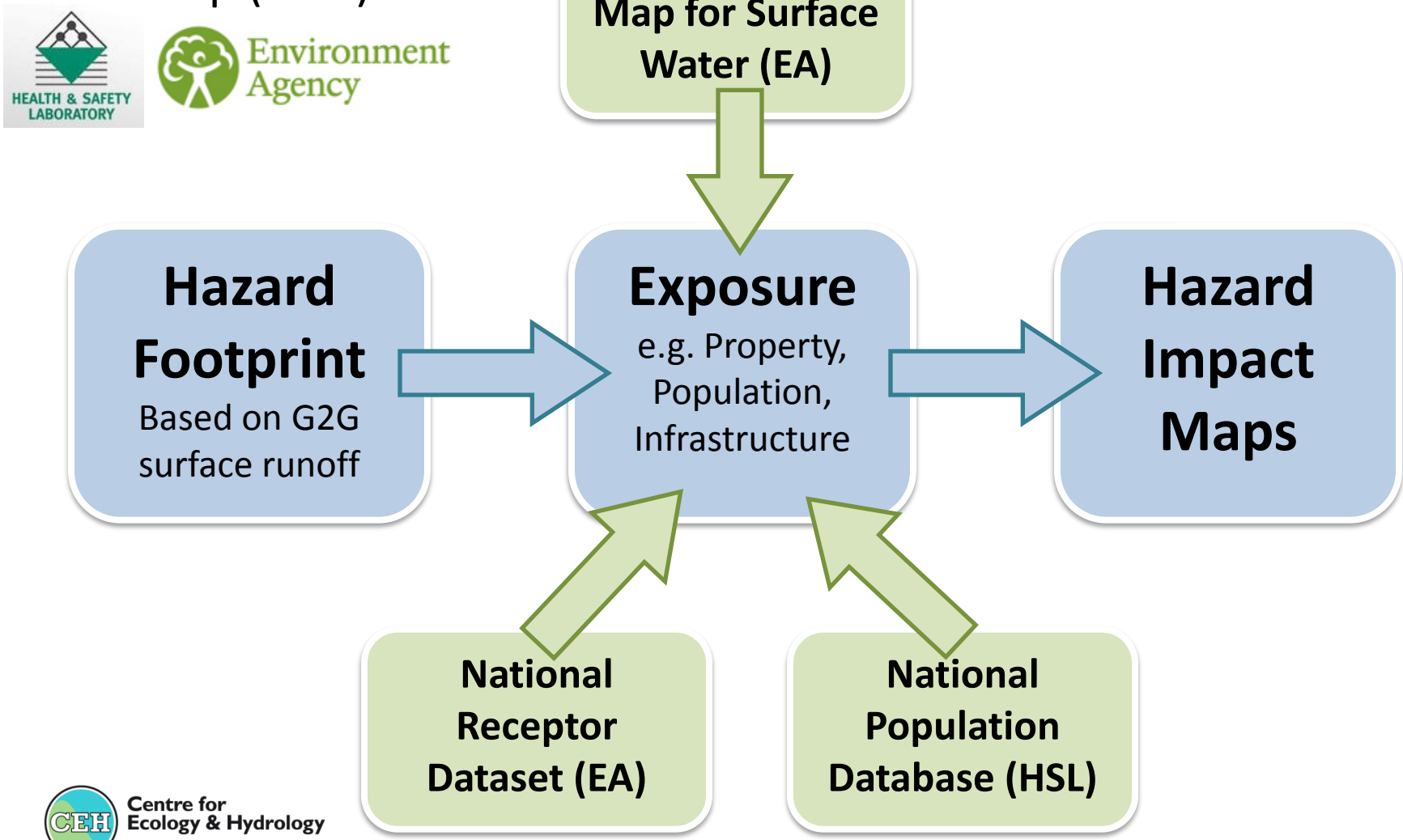
Cole *et al.*, ICFR 2013, Exeter (2013)

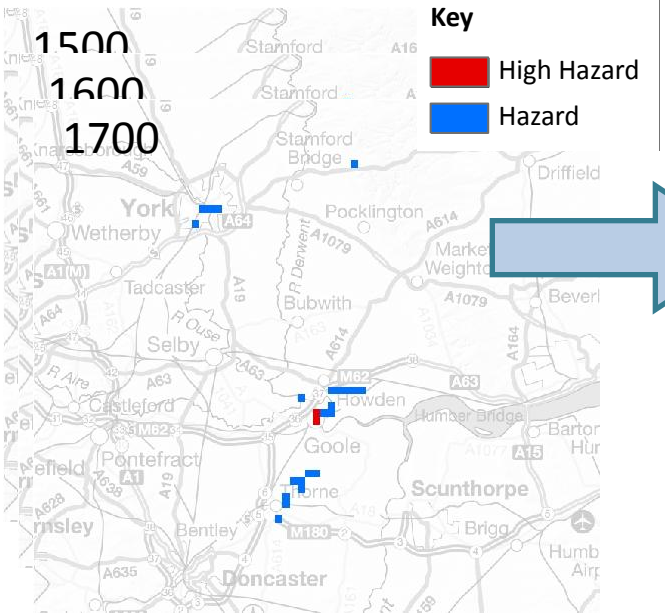
Real-time SWF impact modelling approach

Natural Hazards Partnership (NHP)

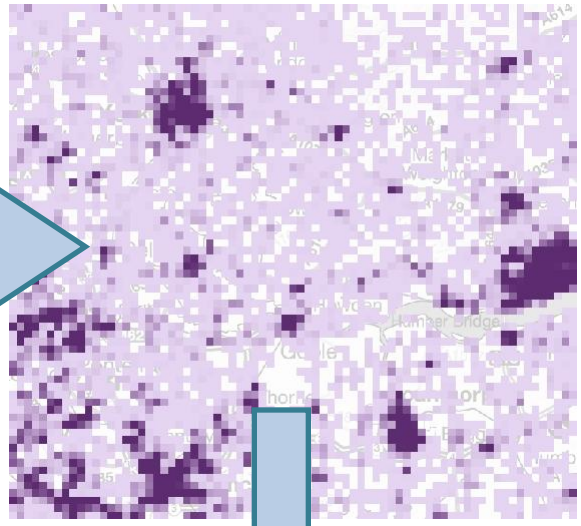


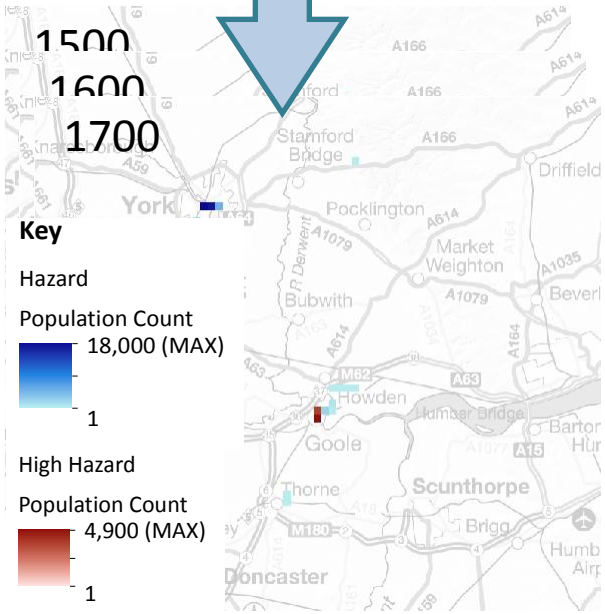
SWF Population impacts

G2G Hazard footprint

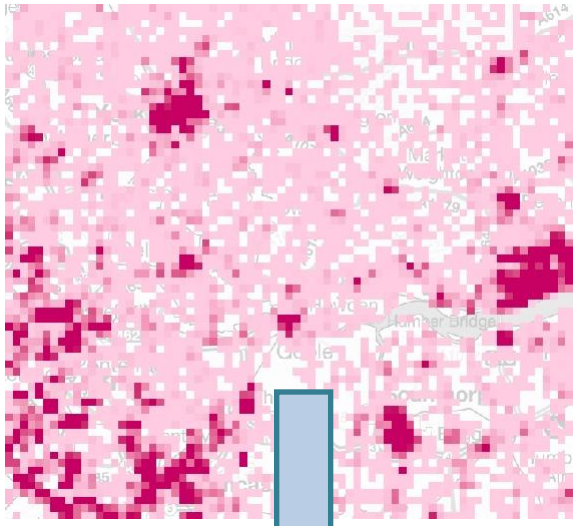


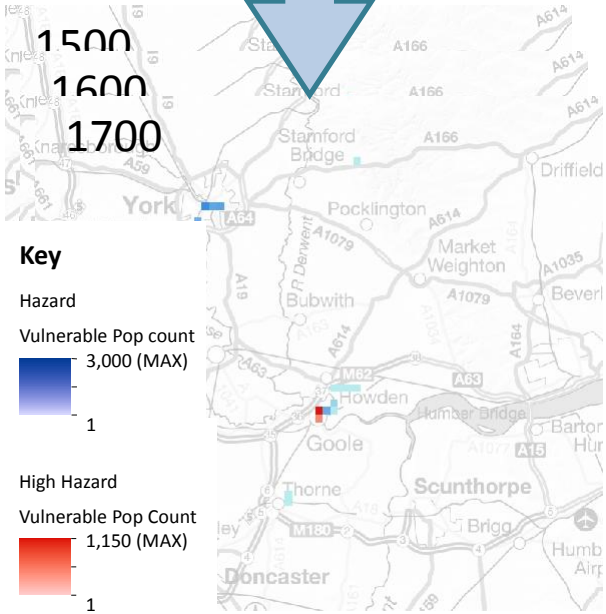
Population





Vulnerable Pop.





Hazard impact maps

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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+)
- Real-time mapping of surface water flooding impacts
  - Aim to move from static to dynamic maps of hazard and impact
  - Presentation of results, local, regional and national (with HSL)
- Moving to MOGREPS-UK 2.2km NWP rainfall ensembles