RainGain 2nd National Observers Group (NOG) Meeting, UK

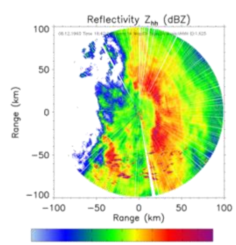
London, 16th April 2013

THE RAINGAIN PROJECT

Advanced observation and rainfall prediction for urban pluvial flood management

(Sep 2011 – Jul 2015)

Objective: to improve fine-scale measurement and prediction of rainfall and to enhance urban pluvial flood prediction in order to enable urban water managers to adequately cope with intense storms, so that the vulnerability of populations and critical infrastructure can be reduced.



Project Partners

1) TU Delft (NL)
2) Zuid-Holland Province (NL)
3) Gemeentewerken Rotterdam (NL)
4) KU Leuven (B)
5) Aquafin NV (B)
6) Ecole des Ponts ParisTech (F)
7) Marne-la-Vallée (F)
8) Seine-St.-Denis (F)
9) Météo France (F)
10) Imperial College London (UK)
11) Met Office (UK)
12) Local Government Flood Forum (UK)
13) Véolia (F)

AGENDA FOR THE DAY

- **09:35 – 11:15: Surface water flood risk management in UK:**
  - Andy Johnston – Local Government Information Unit/Local Government Flood Forum
  - Andy Lane – UK National Flood Forecasting Centre
  - Alex Nickson – Greater London Authority
  - David Stewart – Torbay Council
- ***11:15 – 11:30: Coffee break***
- **11:30 – 12:30: Surface water flood risk management in RainGain partner countries:**
  - Daniel Goedbloed – Province Holland Zuid, The Netherlands
  - Natalija Stancic & Philippe Bompard, Conseil Général de la Seine-Saint-Denis/ Val-de-Marne , France
  - Johan van Assel – Aquafin NV, Belgium
- ***12:30 – 13:15: Lunch***
- **13:15 – 14:15: Progress to date and next steps for RainGain project – UK project partners:**
  - Cedo Maksimovic & Susana Ochoa – Imperial College London
  - Jacqueline Sugier, Timothy Darlington & Lipen Wang – UK Met Office
  - Laurie Thraves & Andy Johnston – Local Government Flood Forum
- **14:15 – 15:15: Break-out session (over coffee):**

  'Way forward for the implementation of surface water flood forecasting and warning systems and for enhancing the resilience of local communities to surface water flooding'

PROGRESS TO DATE AND NEXT STEPS FOR RAINGAIN PROJECT - UK PROJECT PARTNERS:

- Introduction by Prof. Cedo Maksimovic
- Imperial College London - Susana Ochoa
- The UK Met Office - Jacqueline Sugier, Timothy Darlington & Li-Pen Wang
- Local Government Flood Forum - Laurie Thraves

Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
INTERREG IVB

INTRODUCTION

- Urban pluvial flooding: challenges and needs
- The RainGain project: tackling the challenges

Prof. Čedo Maksimović

Investing in Opportunities
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INTERREG IVB

URBAN PLUVIAL FLOODING

Extreme rainfall events exceed the capacity of the drainage system

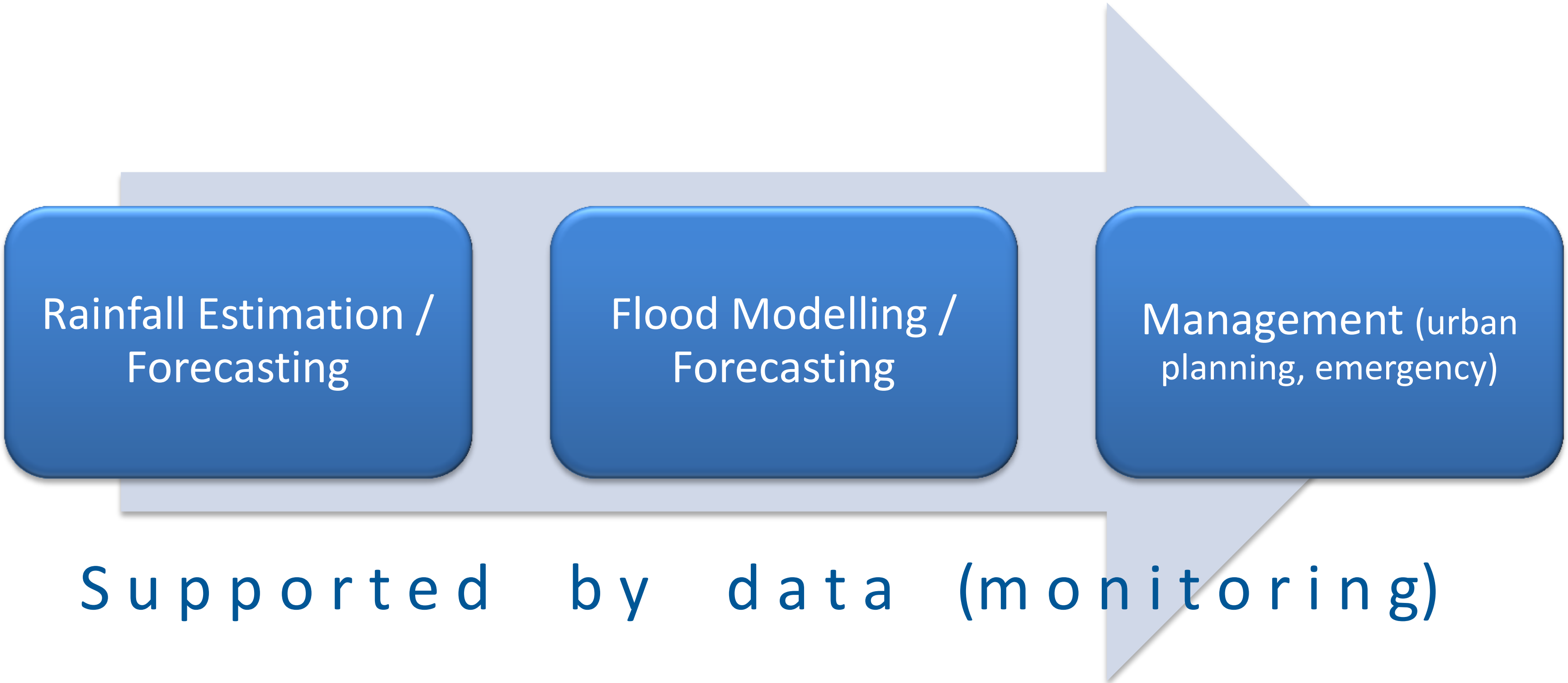
URBAN PLUVIAL FLOODING

- Insufficient capacity of sewer system

- Surface flow (overland system)

- Dynamic interactions between the two systems
- It’s localised and happens quickly – “flash floods”

Model Assembly for Pluvial Flood Modelling, Forecasting and Management



Same “framework” as other types of flooding, but for urban pluvial flooding each step is a bit more complex

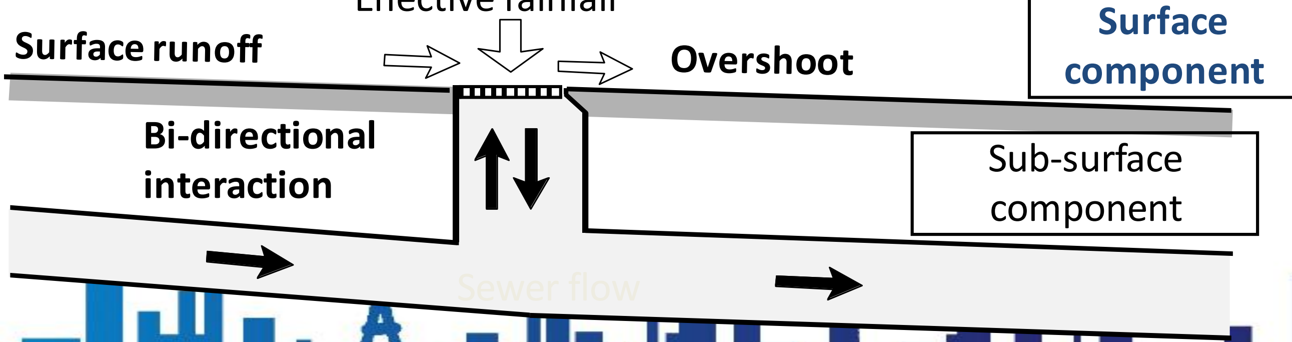
Rainfall Estimation / Forecasting → Flood Modelling / Forecasting → Management (urban planning, emergency)

- The rainfall events which generate pluvial flooding are often associated with **thunderstorms of small spatial scale** (~ 10 km), whose magnitude and spatial distribution are **difficult to monitor and predict** (also: <u>lead time vs. accuracy</u>)

- Rainfall estimates/forecasts with fine spatial and temporal resolution required

Rainfall Estimation / Forecasting → **Flood Modelling / Forecasting** → Management (urban planning, emergency)

- Urban "jungle" is complex
- Interaction of sewer and overland systems
- Since flooding is localised, models must have fine spatio-temporal resolution
- Model detail vs. Runtime



Rainfall Estimation / Forecasting → **Flood Modelling / Forecasting** → Management (urban planning, emergency)

- Urban catchments **change** constantly
- Complete **flood records** for calibration and verification are seldom available
- High **uncertainty in boundary conditions**
- High **operational uncertainty** (blockages, pipe burst, pump failure, change in geometry of roads and other channels, etc.)
- **Individual sources of uncertainty are magnified by small scale**

Rainfall Estimation / Forecasting → Flood Modelling / Forecasting → **Management (urban planning, emergency)**

- **Uncertainty** in modelling and forecasting **hinders decision making**
- **Low awareness**
- Given rapid onset and short forecasting lead-times, the **public become the principal responders**, but they are not so willing to respond

- **Lack of coordination** between stakeholders involved
- **Budgetary cuts**

- …

Tackling the Challenges

Rainfall Estimation / Forecasting

Flood Modelling / Forecasting

Management (urban planning, emergency)

Three pilot locations have been adopted

- Cranbrook catchment (London Borough of Redbridge)
- Purley Area (London Borough of Croydon)
- Torquay City Centre (Torbay, Devon)

Over to my UK colleagues for more details about the progress to date and next steps…

IMPERIAL COLLEGE LONDON

Susana Ochoa

IMPLEMENTATION OF PILOT LOCATIONS

- Cranbrook catchment (London Borough of Redbridge)
- Purley Area (London Borough of Croydon)
- Torquay City Centre (Torbay, Devon)

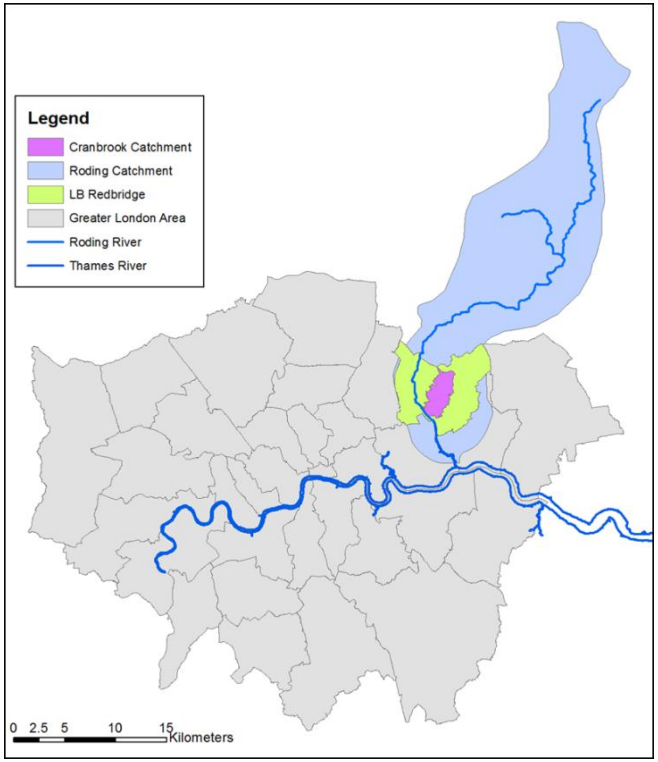
ACTIVITIES TO DATE

- Data collection & processing
- Implementation of monitoring systems
- Understanding of flooding mechanisms and flood risk management objectives

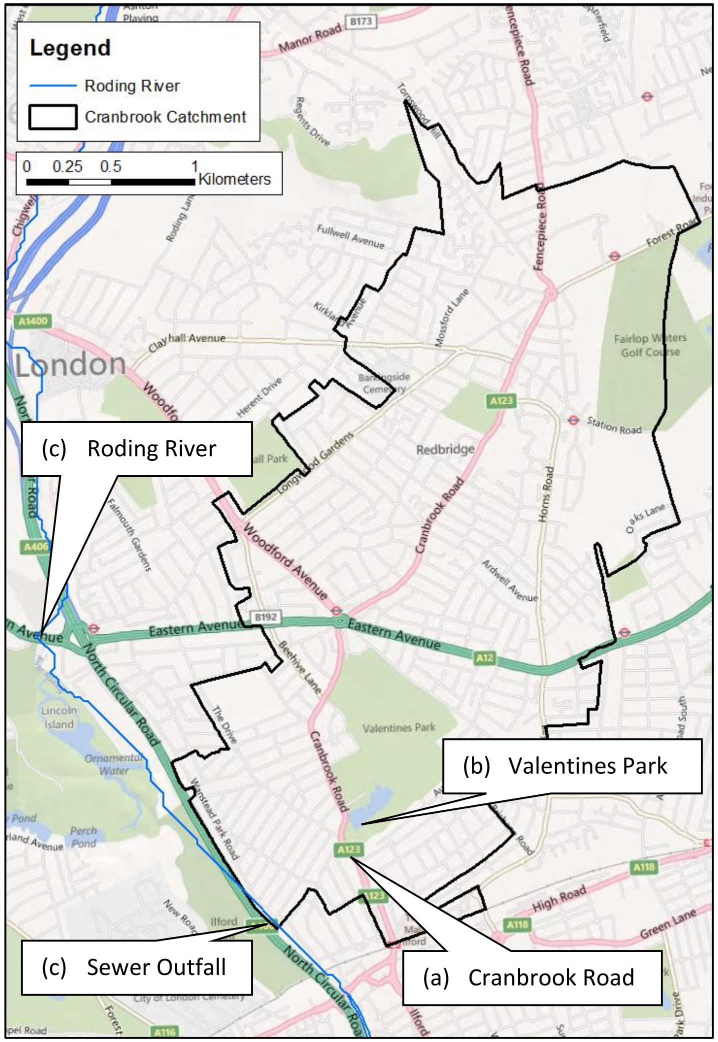
Cranbrook Catchment,

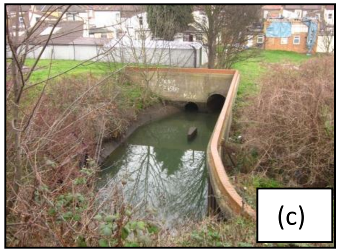
London Borough of Redbridge

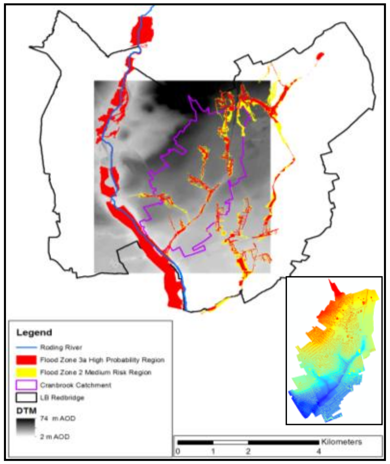
- **Area:** aprox. 900 ha
- **Cran Brook:** 5.75km (5.69km culverted)
- Predominantly urban catchment
- Sub-catchment of Roding River catchment
- Has experienced **severe fluvial, surface and coincidental flooding** in the past. Most recent events in October 2000 and February 2009
- **Aims/Expectations:** improved modelling & forecasting of surface flooding to support both urban planning and emergency management



Location and Environmental Setting

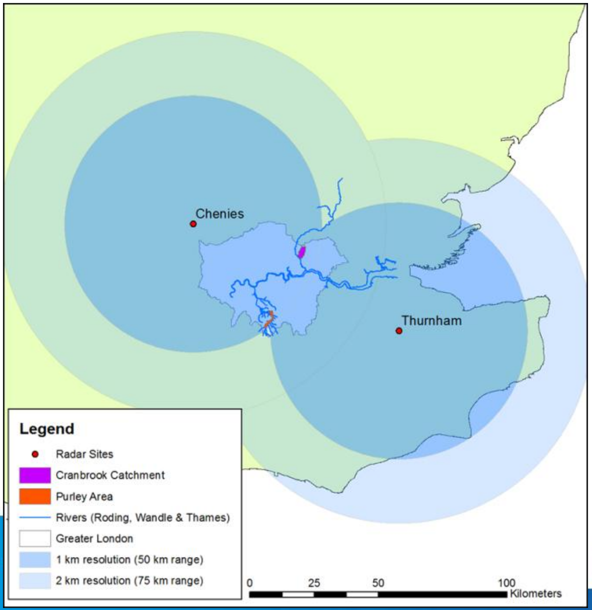




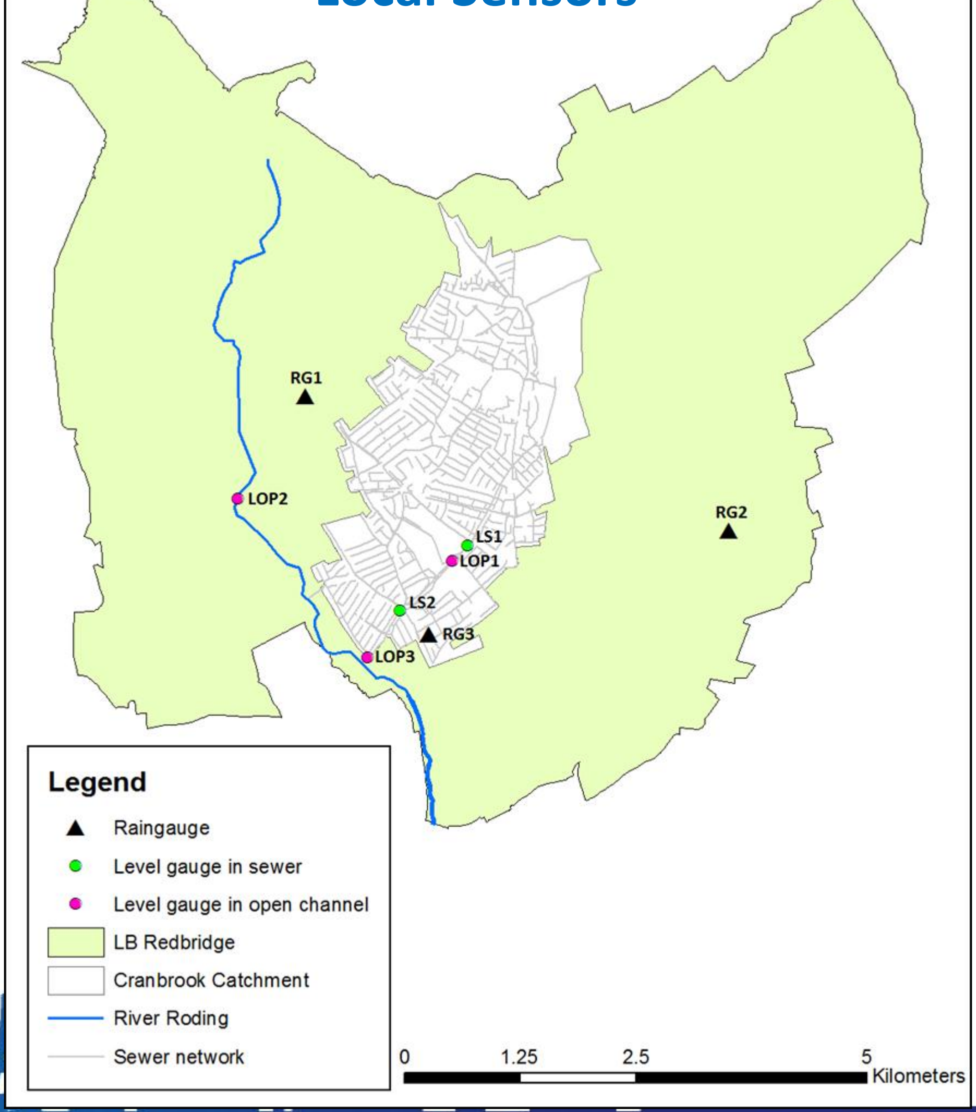


Monitoring System

Met Office C-band radars



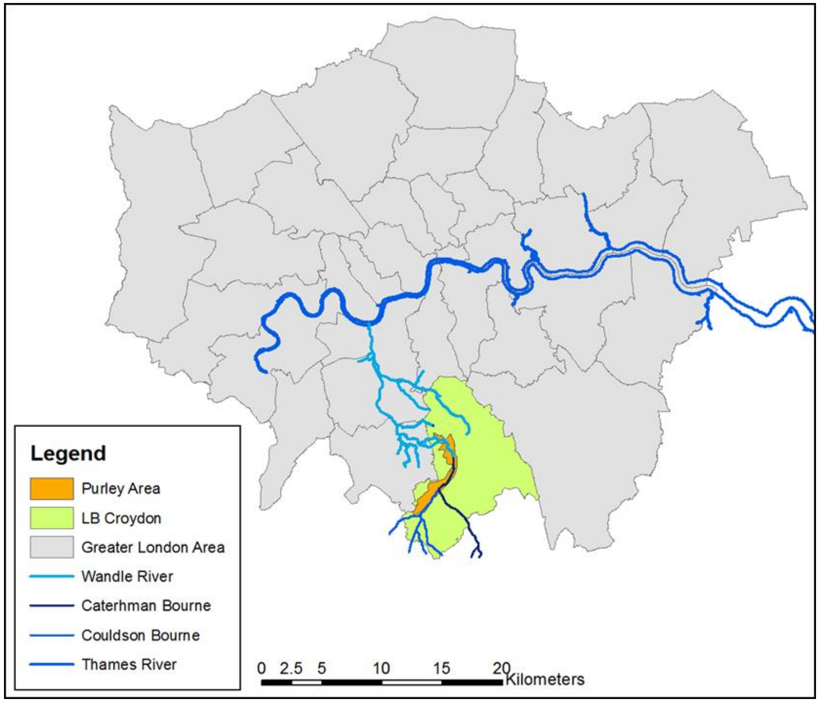
Local Sensors



Purley Area,

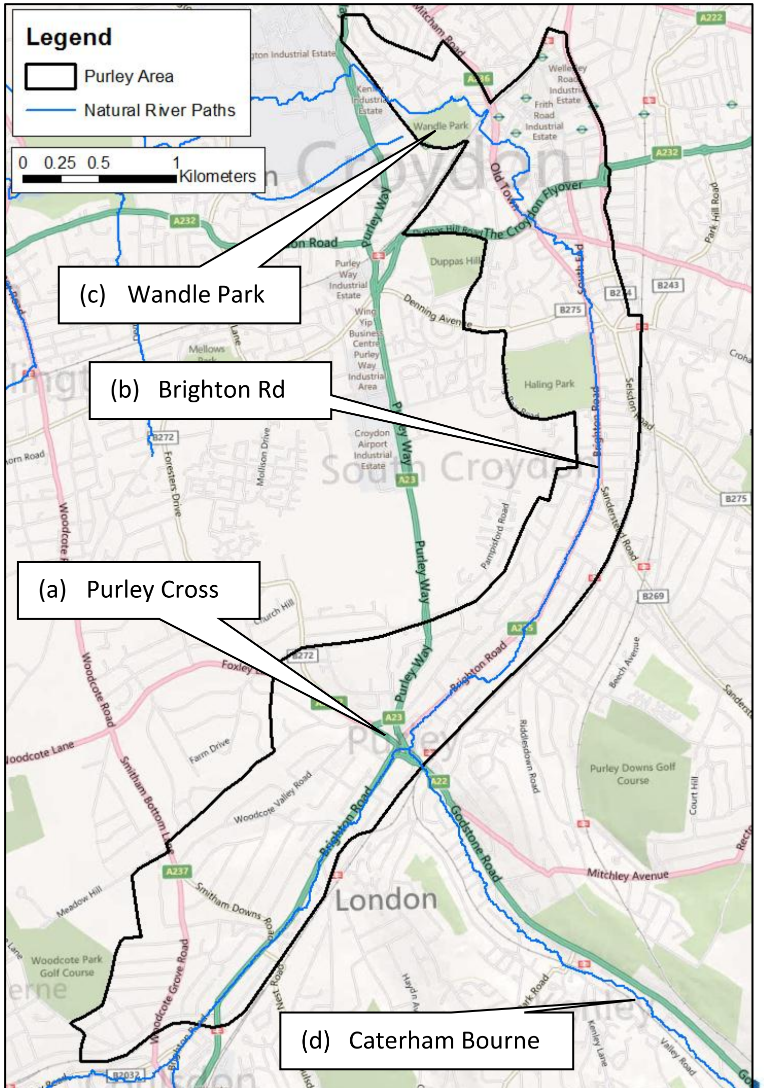
London Borough of Croydon

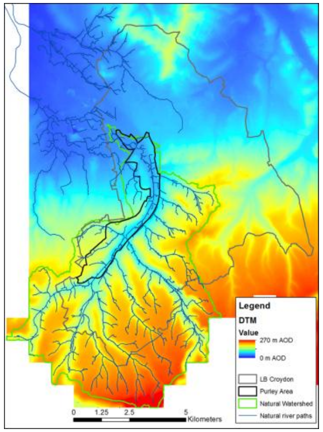
- Croydon is ranked the **4th** settlement in England **most susceptible** to surface water flooding (Defra)
- **Purley area:** highest risk of surface flooding within the Borough (SWMP)
- Stretches along depression of former pathway of River Wandle, now culverted
- **Area:** Approx. 6.5 km^2
- Highly urbanised, high density of receptors, slopes drain to natural depression



- **Aims/Expectations:** improved modelling & forecasting of surface flooding to support both urban planning and emergency management

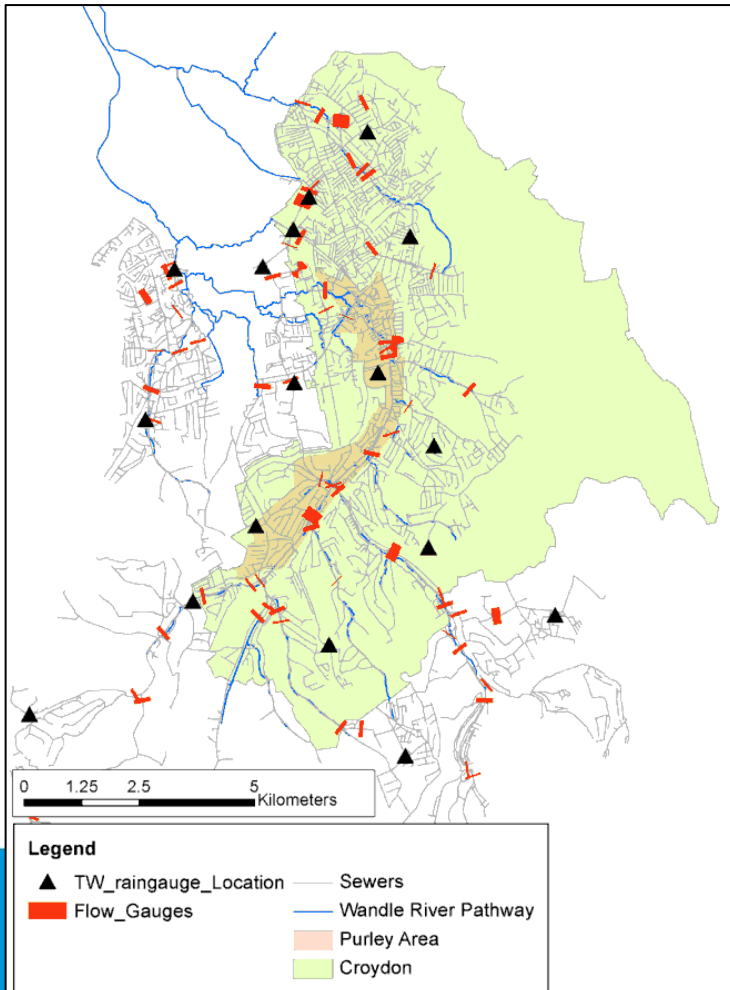
Location and Environmental Setting



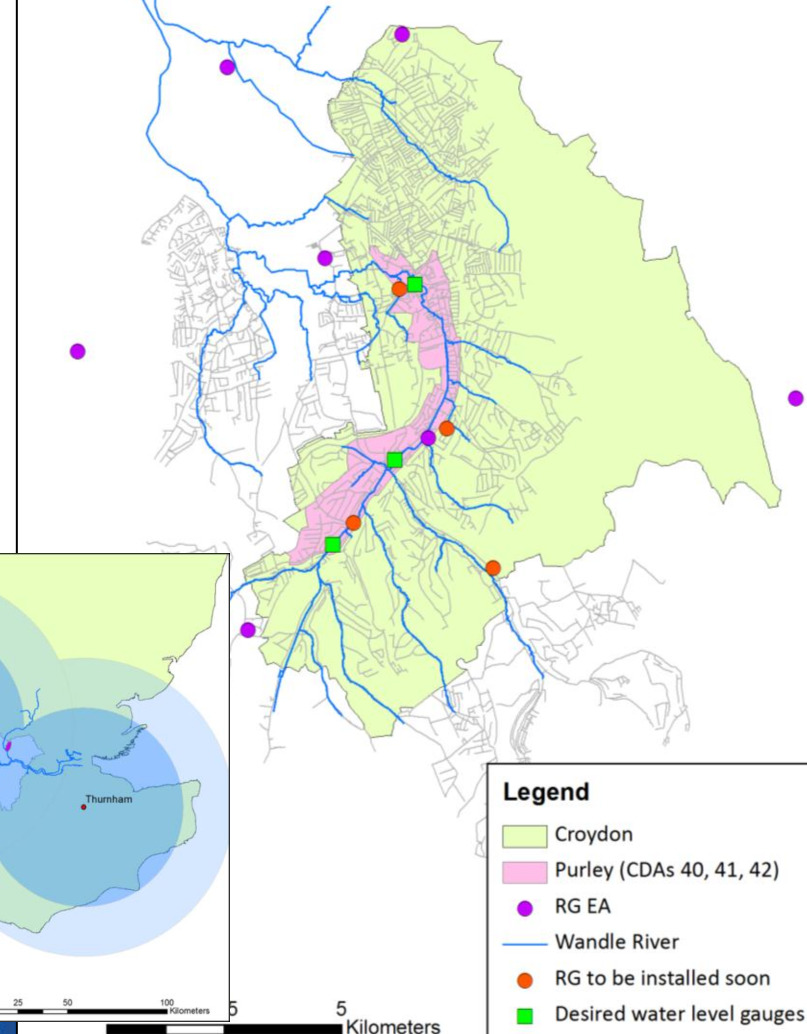


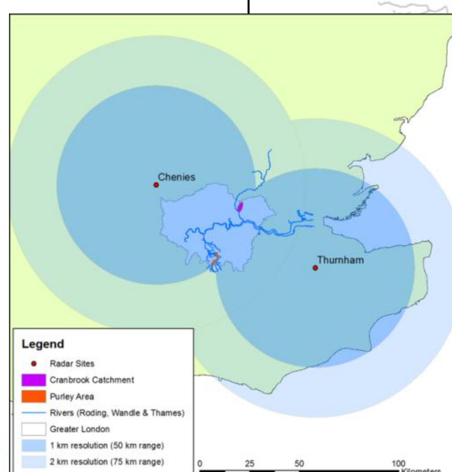
Monitoring System

Medium term flow survey data provided by Thames Water



Existing and envisaged sensors

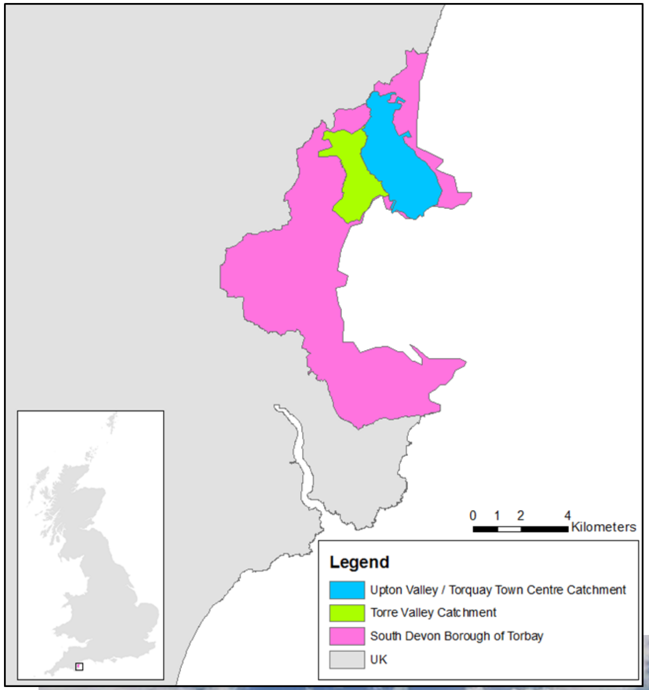


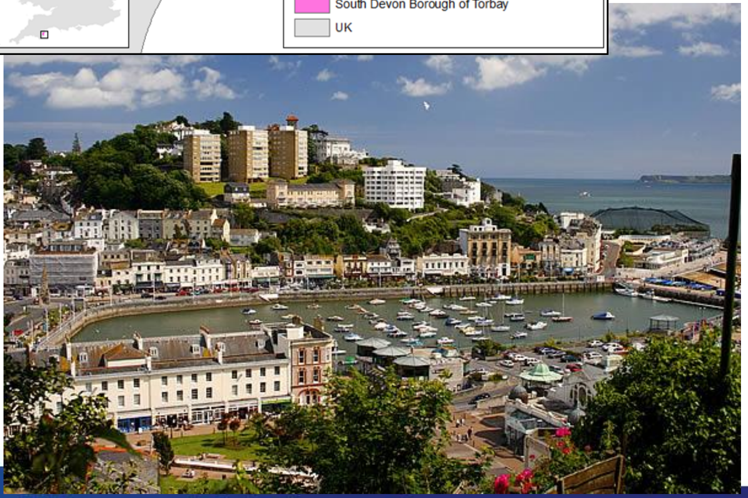


Torquay Town Centre,

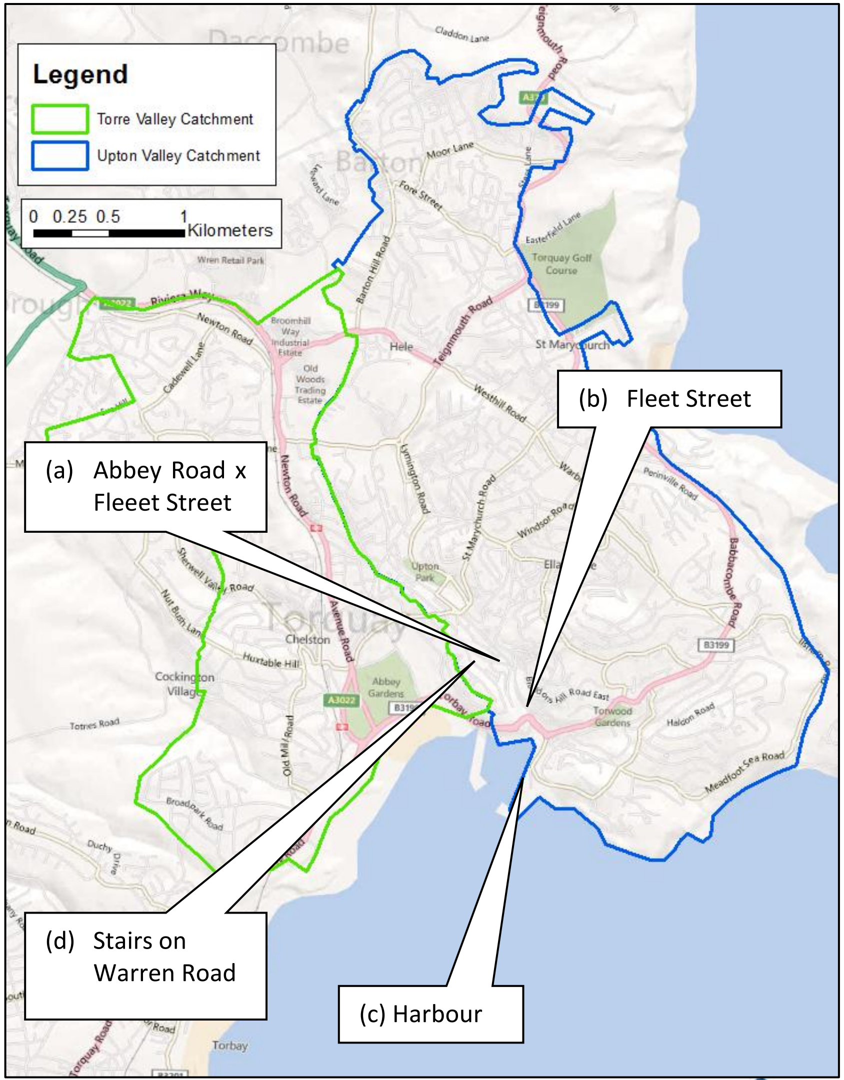
South Devon Borough of Torbay

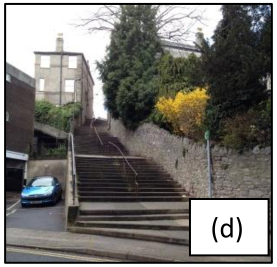
- "British Riviera" – tourist place
- Highly urbanised, high density of receptors
- Severe pluvial flooding in the last few years: October 1999, May 1999, October 2004, August 2007
- Tides may generate back water effects
- **Area:** 14.6 km^2
- **Aims/expectations:** mainly flood forecasting, RT control, many control elements!

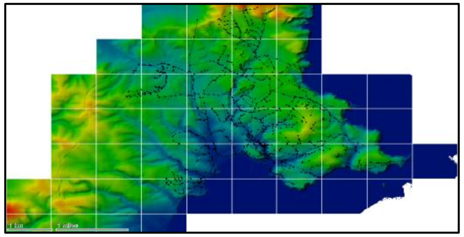




Location and Environmental Setting

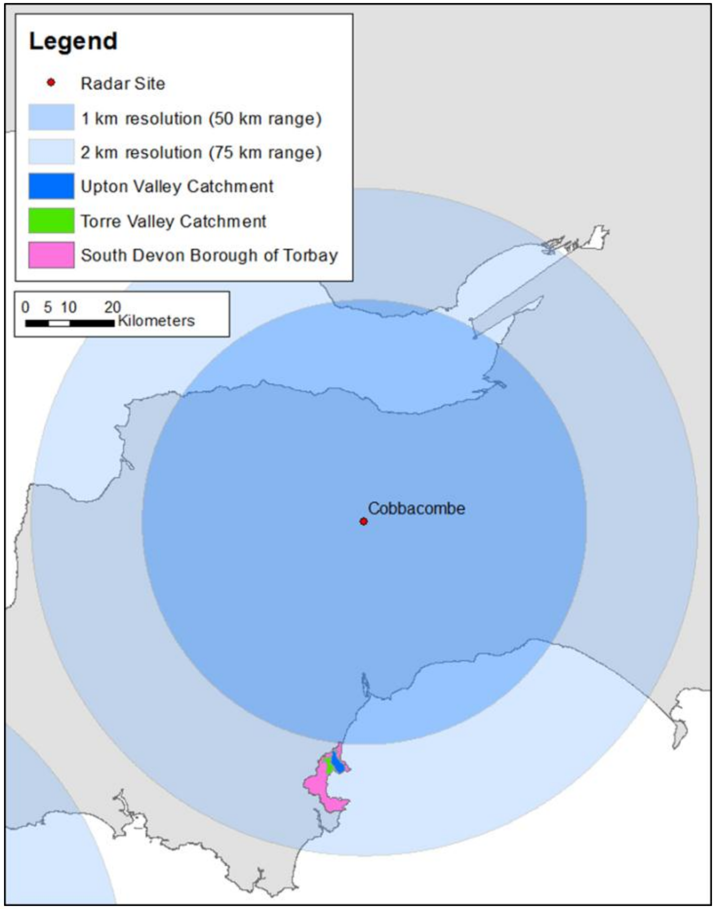




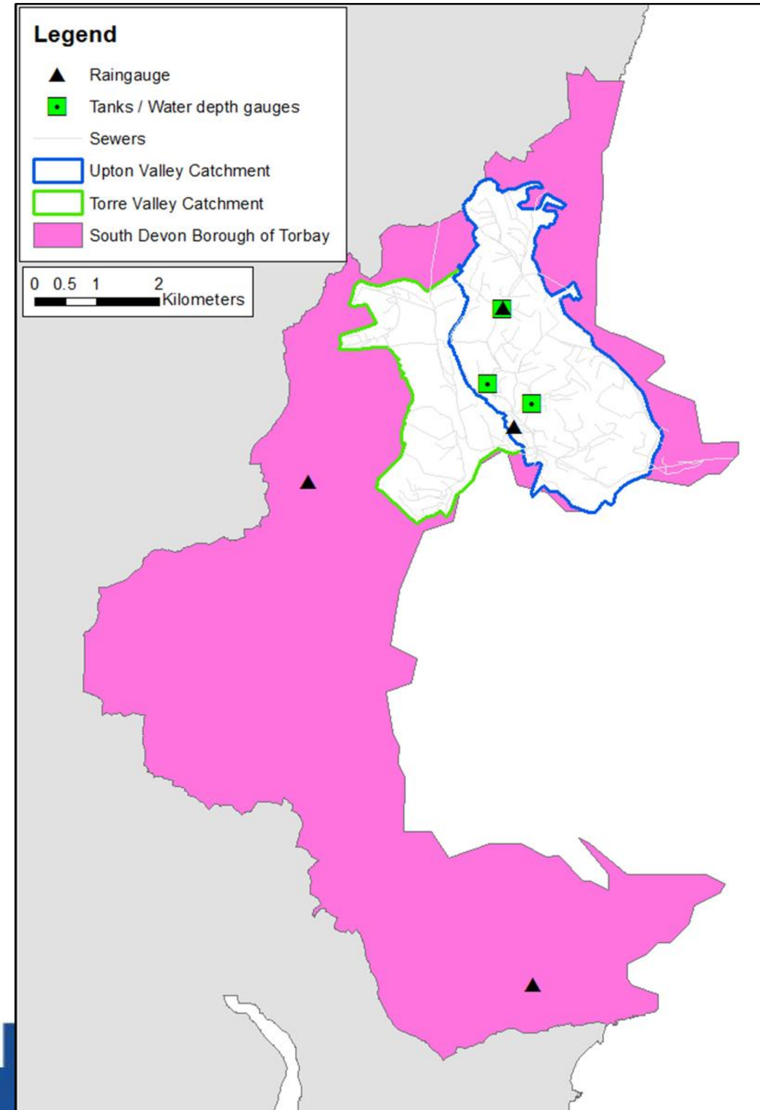


Monitoring System

Met Office C-band Radar

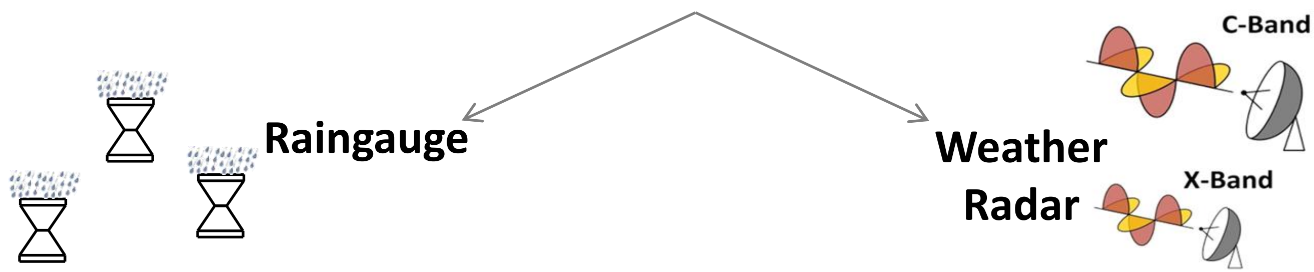


Local monitoring system



Rainfall Estimation / Forecasting → Flood Modelling / Forecasting → Management (urban planning, emergency)

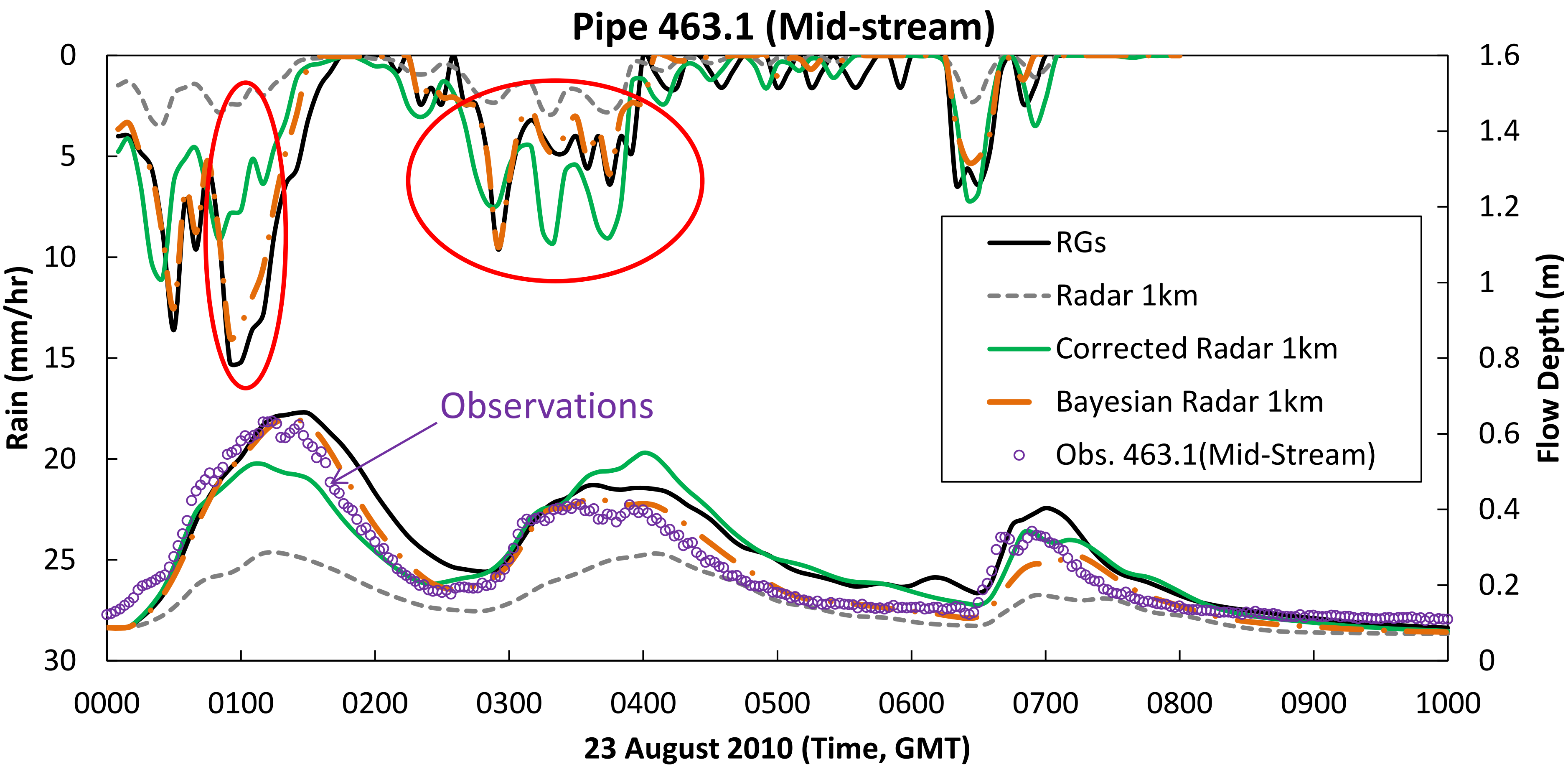
Review and testing of gauge-based adjustment techniques to improve radar rainfall estimates for urban hydrological applications



	RAINGAUGE	RADAR
Accuracy		
Coverage, spatial characterisation of rainfall field		

Further processing of radar rainfall estimates can improve its applicability to urban hydrological applications

Simulation of flow depths can be largely improved using radar rainfall estimates "locally" adjusted with the co-located raingauge measurements



Better calibration results could be achieved when using adjusted rainfall inputs, as these can better capture the spatial structure and accuracy of rainfall fields

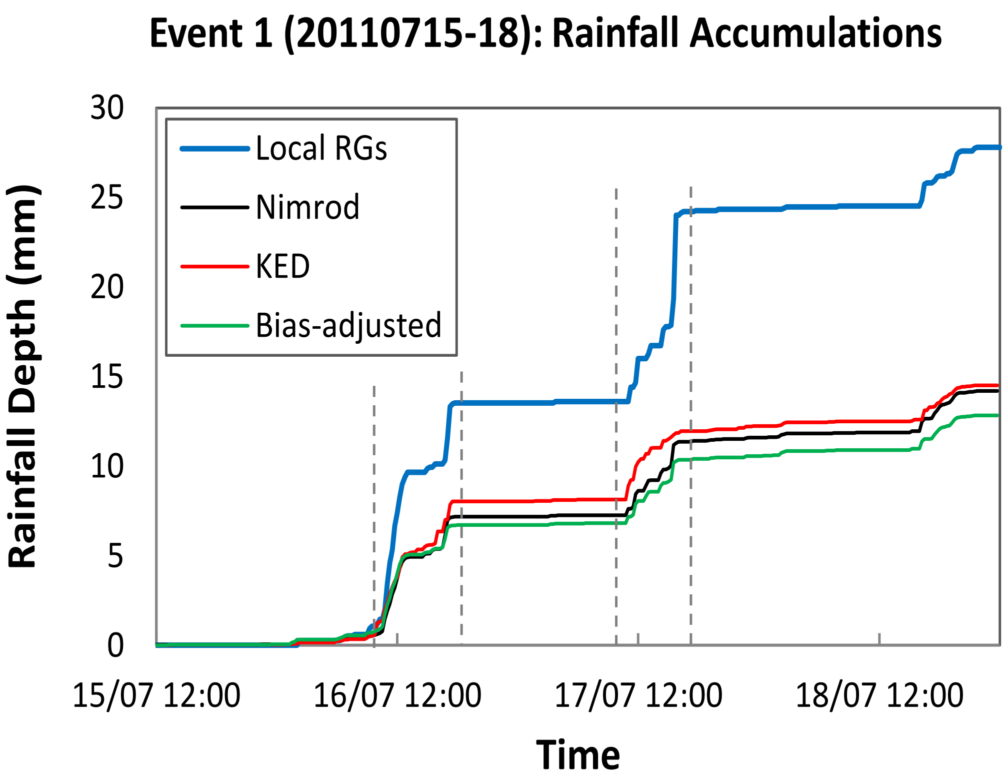
	MEAN RELATIVE DIFFERENCE IN PEAK FLOW	
INPUT	EVENT 1	EVENT 2
RG	30.57%	40.56%
NIMROD	28.27%	36.96%
MERGED	24.91%	29.75%
BK	25.35%	27.69%

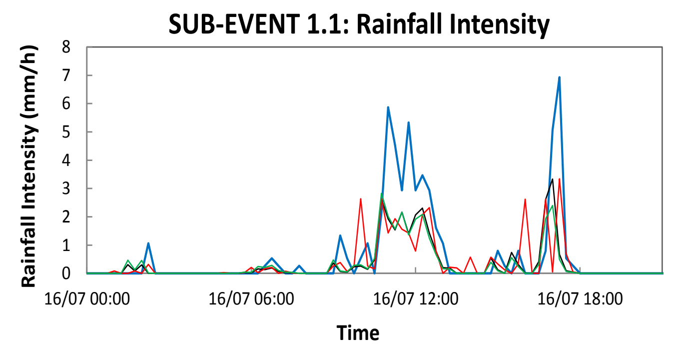
	MEAN RELATIVE DIFFERENCE IN PEAK DEPTH	
INPUT	EVENT 1	EVENT 2
RG	90.96%	76.29%
NIMROD	46.21%	24.76%
MERGED	32.34%	21.12%
BK	31.88%	22.30%

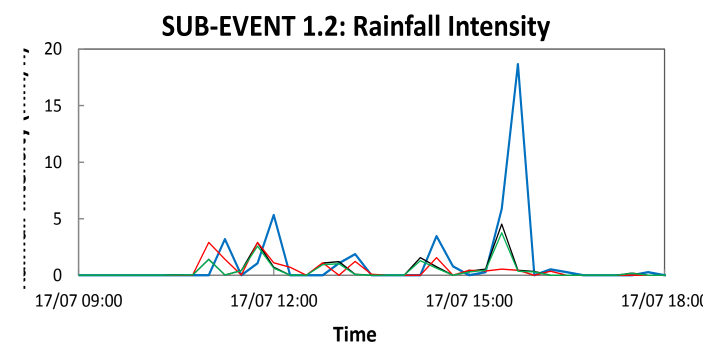
	MEAN R^2 - FLOW	
INPUT	EVENT 1	EVENT 2
RG	69.43%	69.72%
NIMROD	66.58%	66.75%
MERGED	70.08%	70.30%
BK	69.94%	70.19%

	MEAN R^2 - DEPTH	
INPUT	EVENT 1	EVENT 2
RG	70.54%	70.15%
NIMROD	70.29%	65.62%
MERGED	74.84%	71.30%
BK	74.60%	71.67%

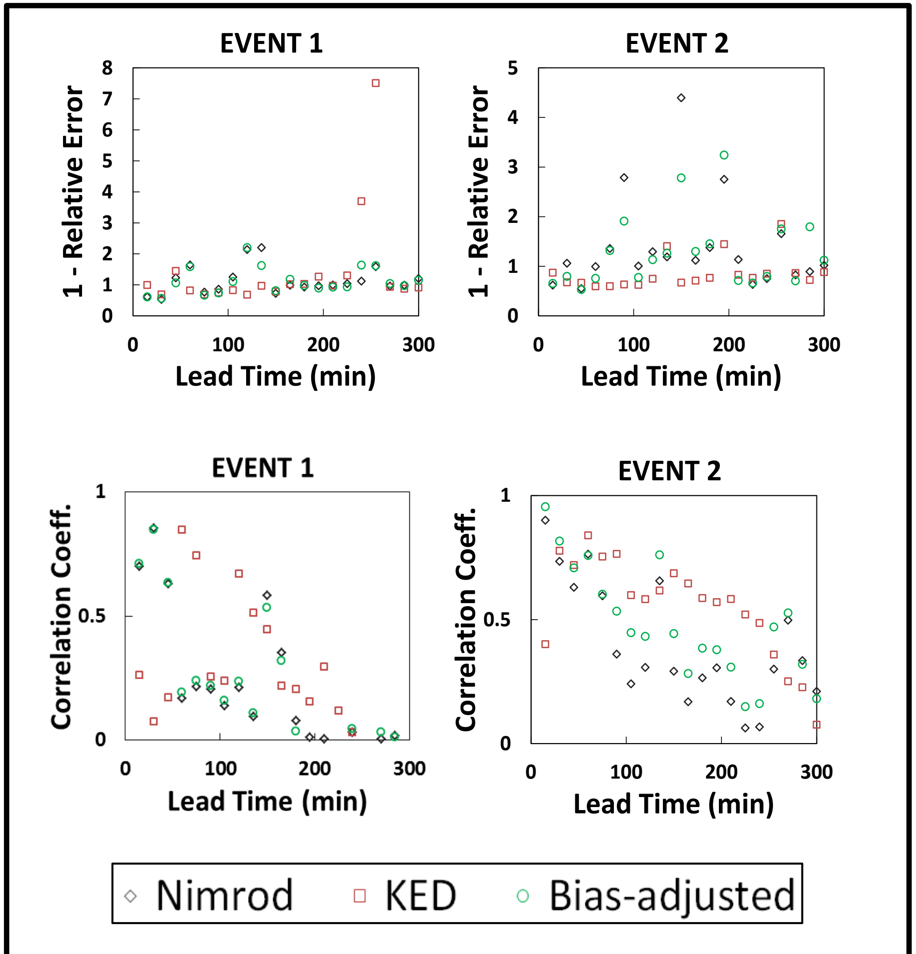
Adjustments were done at too large scales and no improvements were achieved at the local scale of urban catchments – spatial variability needs to be considered!

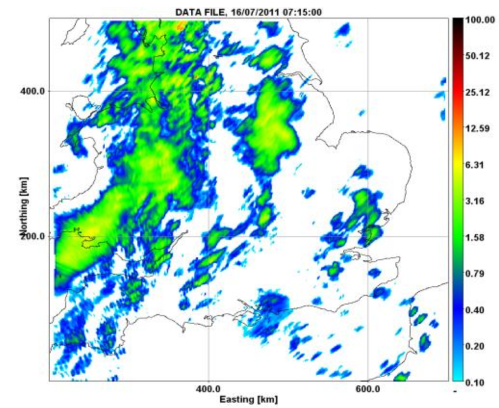




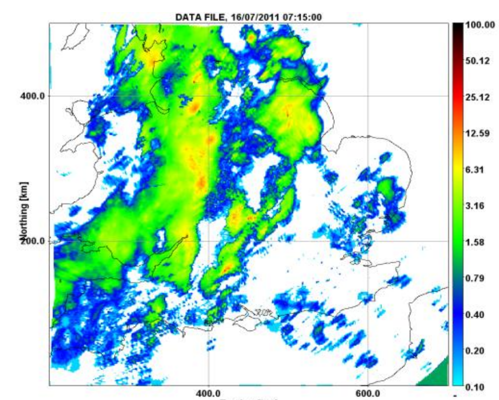


Adjusted radar rainfall estimates may lose their temporal correlation and may not be suitable for further rainfall nowcasting uses





Nimrod Forecasts

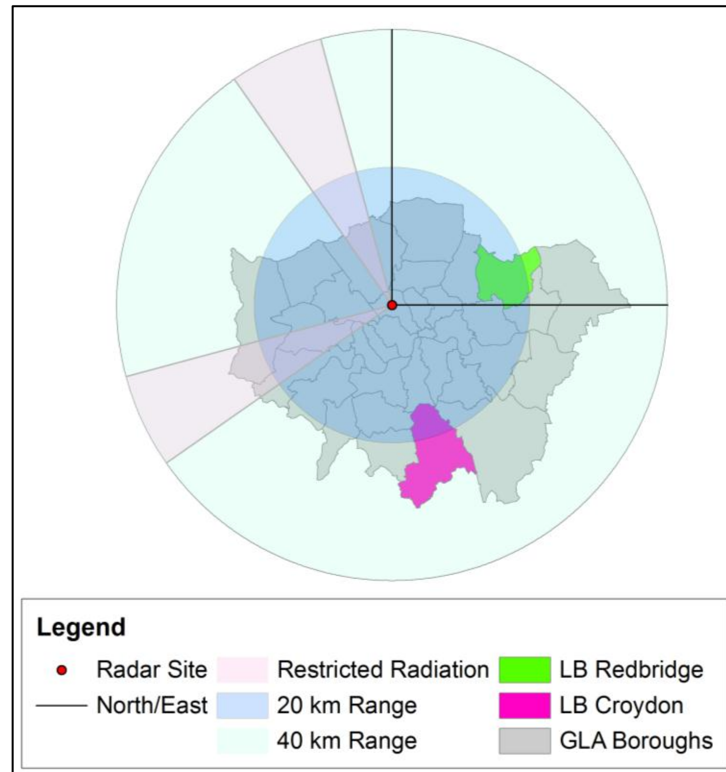


KED Forecasts

Rainfall Estimation / Forecasting → Flood Modelling / Forecasting → Management (urban planning, emergency)

Installation of X-band radar in London (April 2013 – September 2013)

- Smaller wavelength makes X band radar more sensitive and able of detecting smaller particles (e.g. drizzle, light snow, cloud formation).
- Because it is closer to the ground, it may be able to provide better rainfall estimates for London
- The performance of this radar and the benefits it can provide will be assessed in the RainGain project



Rainfall Estimation / Forecasting → Flood Modelling / Forecasting → Management (urban planning, emergency)

Installation of X-band radar in London (April 2013 – September 2013)

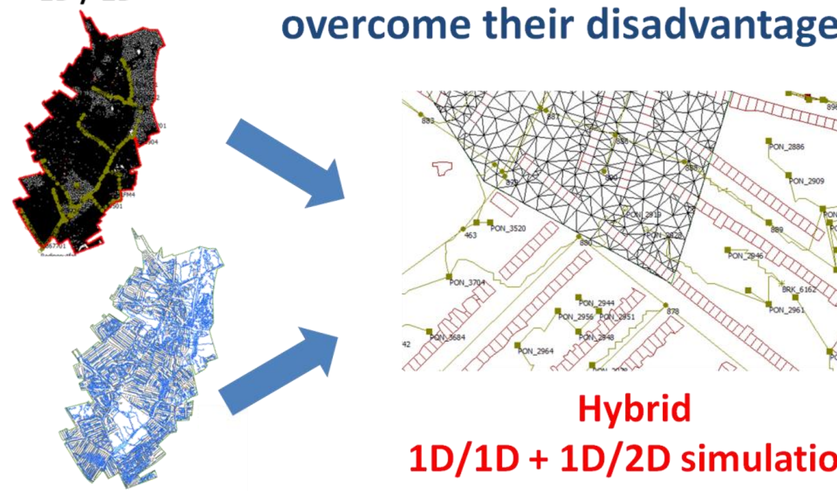
A website for displaying real time and historical data collected with the X-band radar is under development

Rainfall Estimation / Forecasting → **Flood Modelling / Forecasting** → Management (urban planning, emergency)

- Improved calibration of dual-drainage models based on monitoring data and improved rainfall estimates

To combine their advantages and overcome their disadvantages…

1D / 2D



1D / 1D

Hybrid
1D/1D + 1D/2D simulation

- Overall uncertainty analysis and risk-based model calibration
- Analysis and definition of local pluvial flood triggers (for translating rainfall alerts into flooding for a given area)

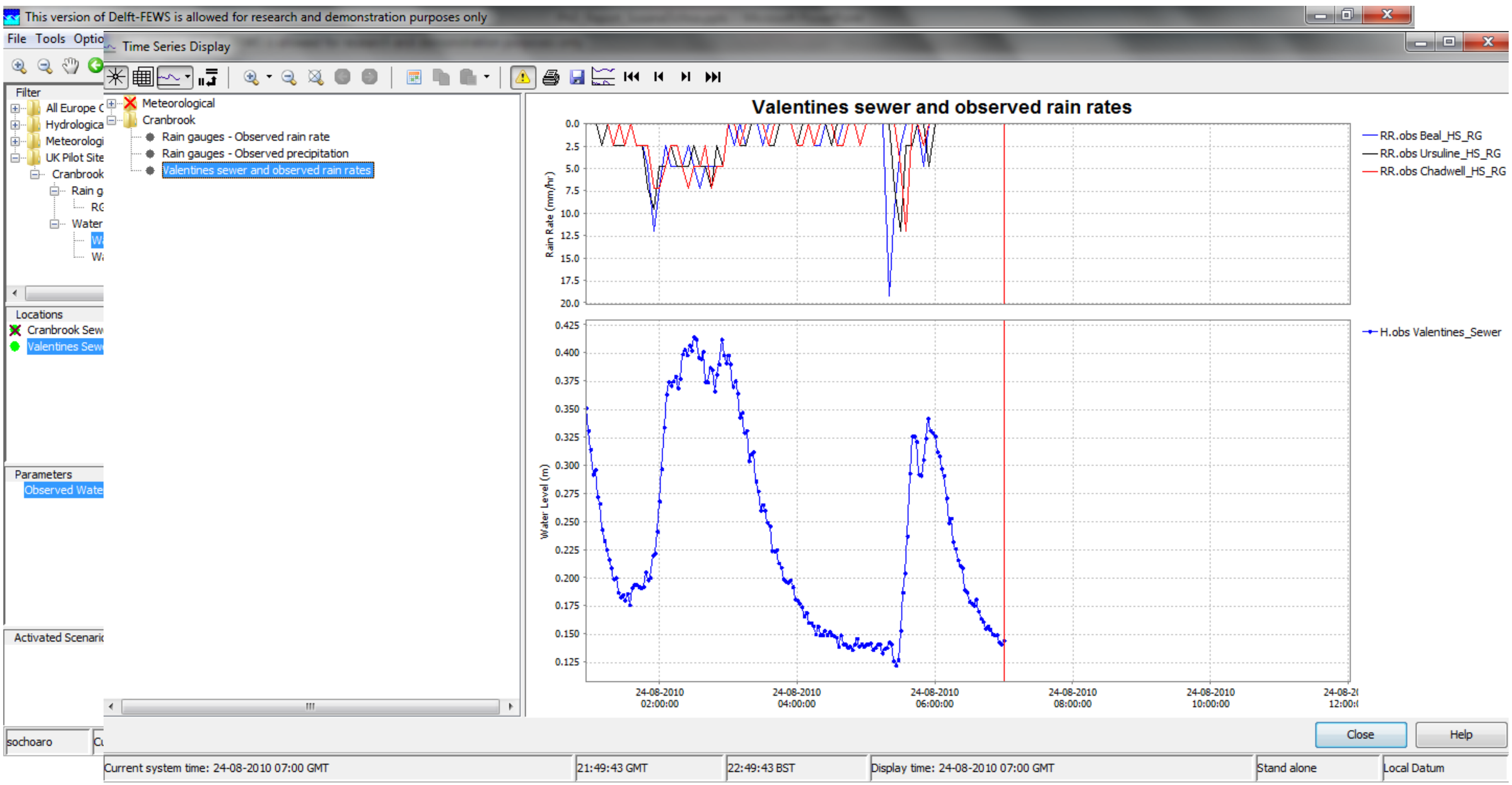
- Models of different levels of complexity will be implemented, calibrated and benchmarked

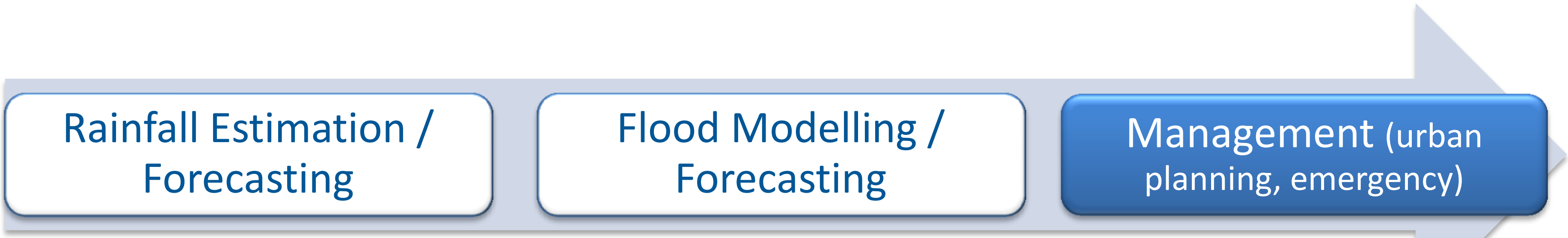
Rainfall Estimation / Forecasting

Flood Modelling / Forecasting

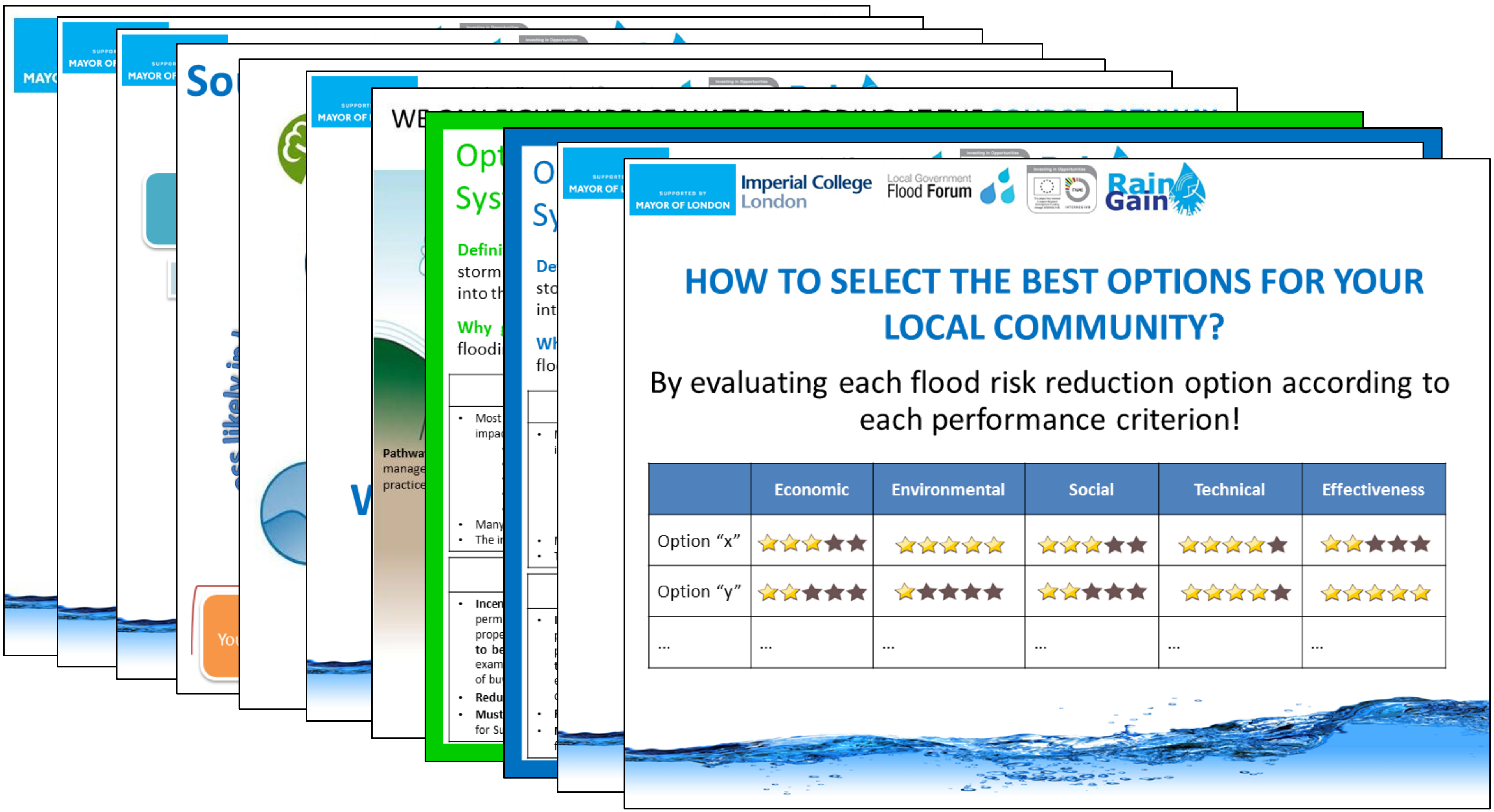
Management (urban planning, emergency)

Implementation of pilot platform for urban pluvial flood forecasting





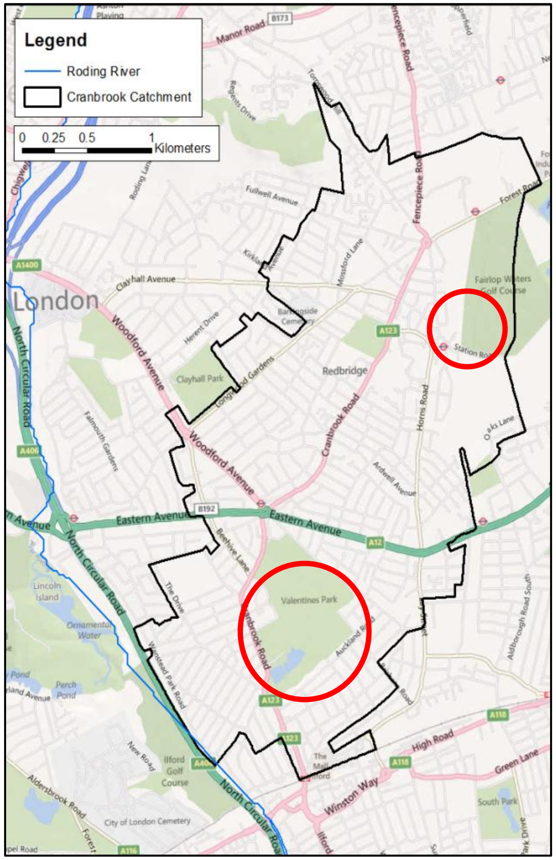
Workshop pack for participatory management of local surface water flood risk



Rainfall Estimation / Forecasting → Flood Modelling / Forecasting → **Management** (urban planning, emergency)

Collaboration with WPS in modelling for reduction of flood risk in Redbridge

1. **Storage at Fairlop Gravel Extraction Site**, including day-lighting of a portion of the Cran Brook and remediation of the current extraction site
2. **Increase storage potential at Valentine's Park**:
   - Increasing weir level at downstream end of park lake
   - Restoration of open channel section and surrounding floodplain area
   - Reduce peak points currently diverted around lake



Rainfall Estimation / Forecasting

Flood Modelling / Forecasting

Management (urban planning, emergency)

Continuous communication and discussion with end users to ensure optimum use of the tools developed throughout the project

THE UK MET OFFICE

Jacqueline Sugier & Timothy Darlington

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INTERREG IVB

Met Office

Upgrading the UK weather radar network

Dr Jacqueline Sugier, Tim Darlington, Radar R&D, Observations, Met Office

RAINGAIN NOG2 meeting, London, April 2013

UK Radar Network

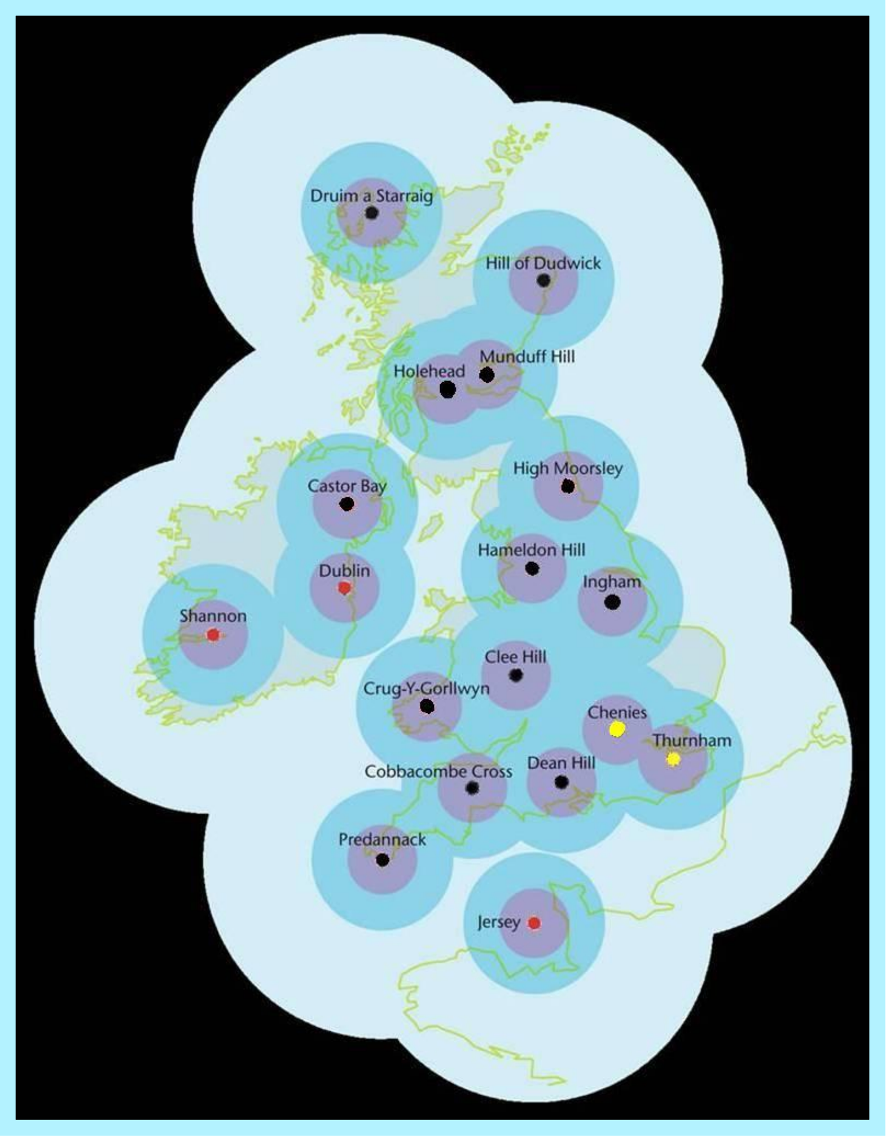
Status February 2013

UK radar network is comprised of 15 radars:

- Doppler radars
- 2 radars with dual polarisation capability (yellow dots).

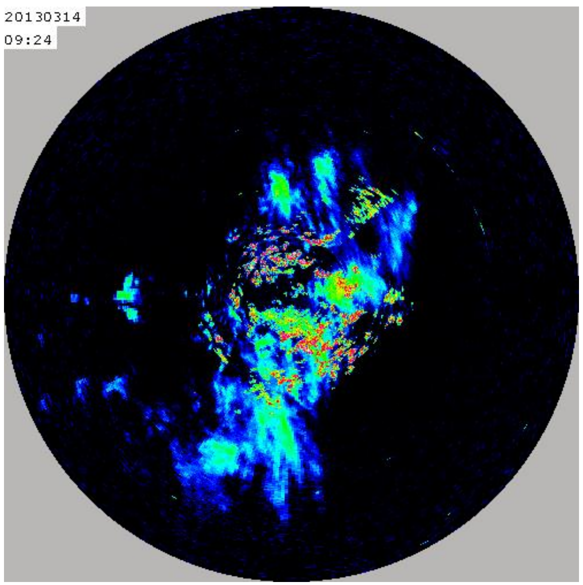
All UK radars are capable of:

- Detecting and monitoring precipitation up to 255km from the radar
- Collecting data at up to 75m x 1° resolution



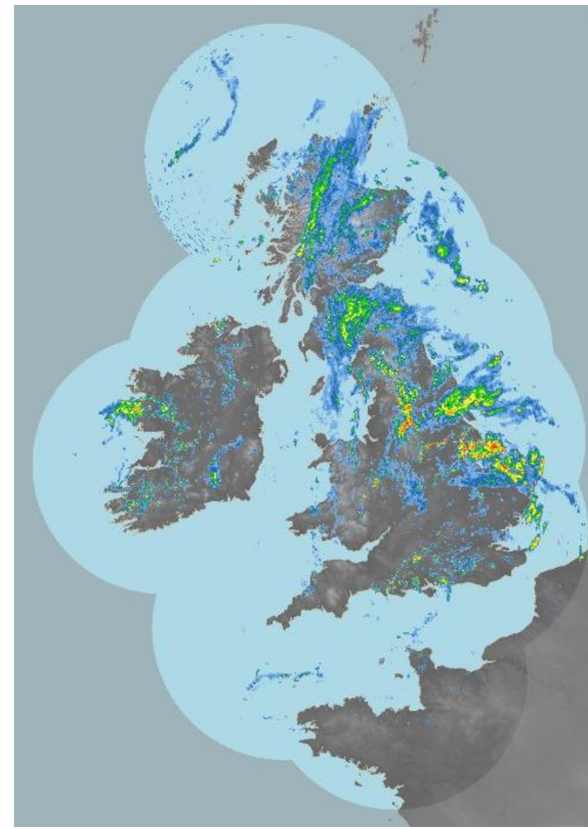
Operational radar products

Operational products are generated around the clock every 5 mins.



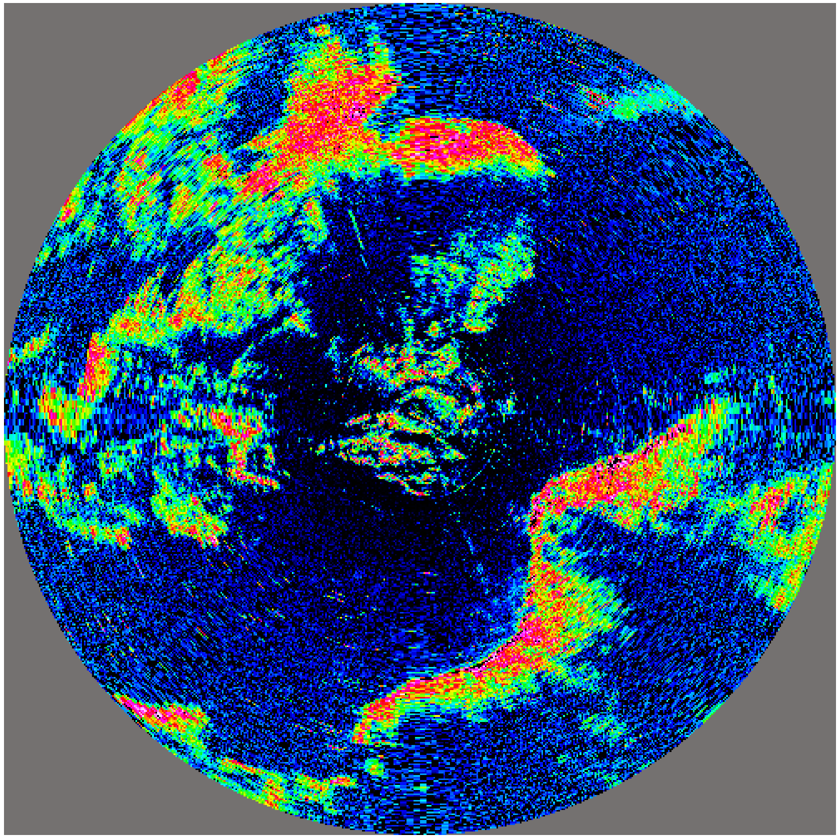
Rainfall products
derived from radar reflectivity

Rainfall products are generated at 5km, 1km, and 500m resolution.



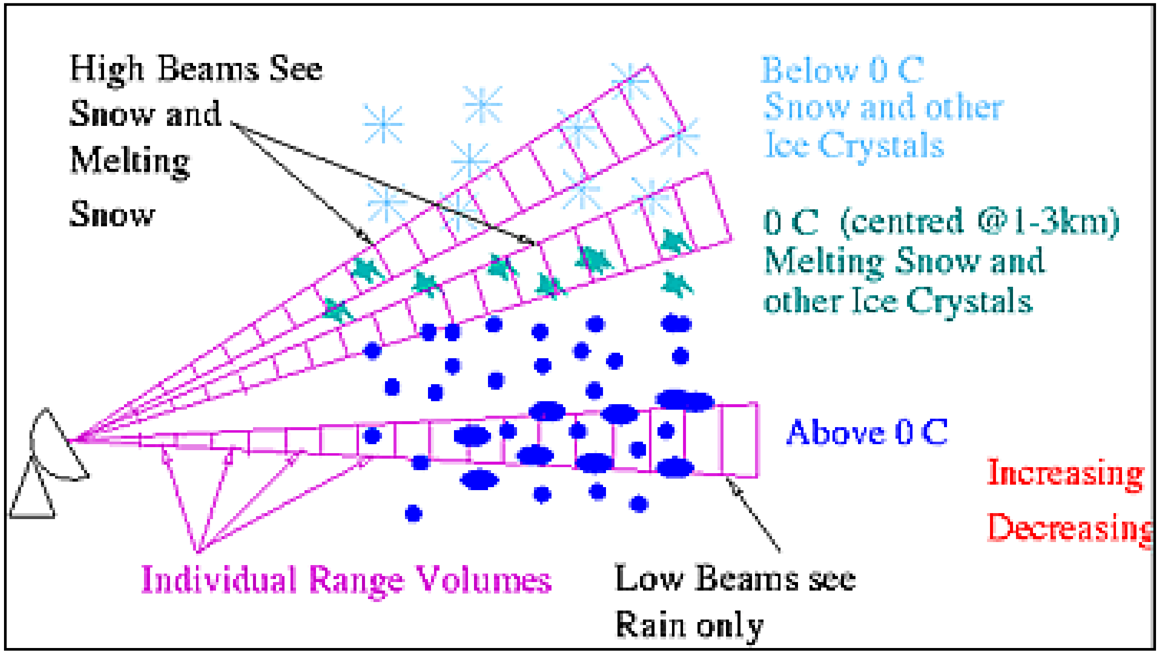
What weather radar sees

- Ground clutter (trees, building, hills…)
- Planes, ship,
- Wet Hail
- Rain
- Wet snow
- Insects, bird (clear air echoes)
- Dry Hail
- Dry snow



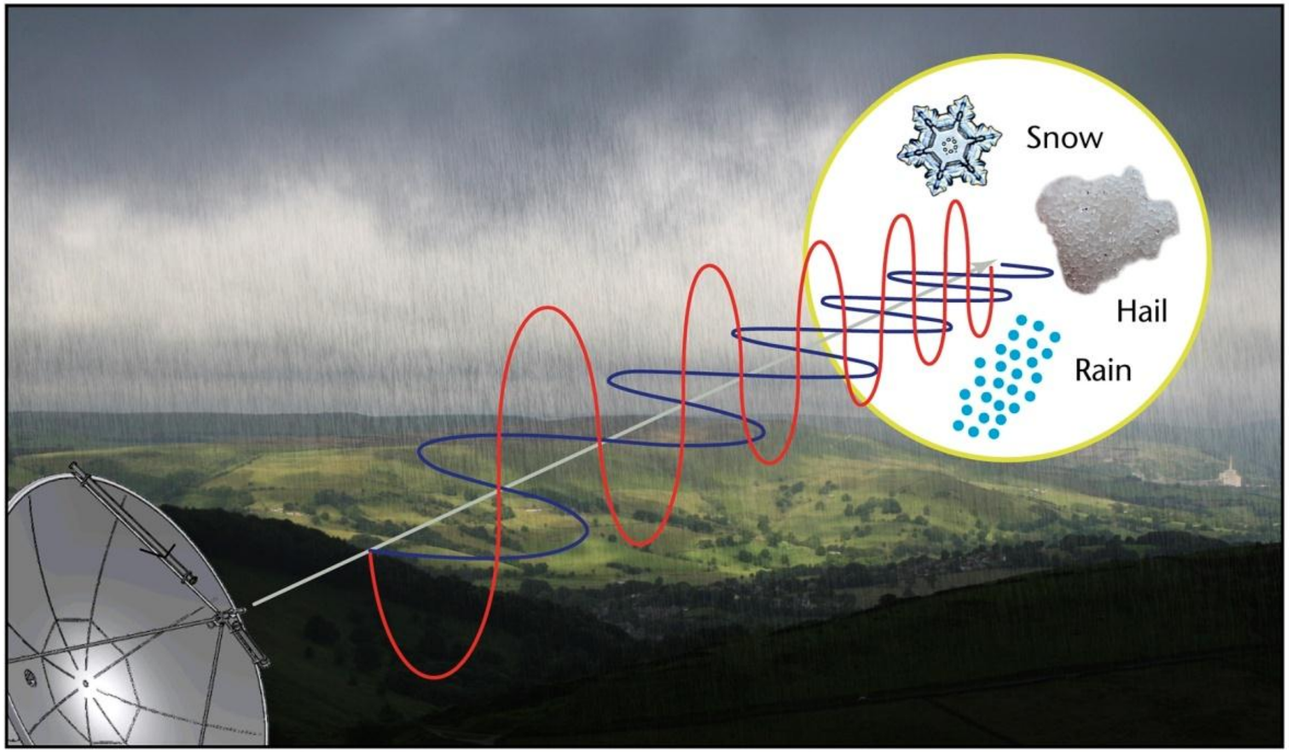
What weather radar sees

Schematic diagram representing the hydrometeor diversity within the radar sampling volume (courtesy of STFC Chilbolton Observatory)



Conversion from the radar measured signal to rainrate requires the knowledge of the liquid water content and the drop-size distribution within the radar sampling volume which may vary in time and space – No simple relationship can therefore provide accurate results every time.

Network upgrade to Dual polarisation



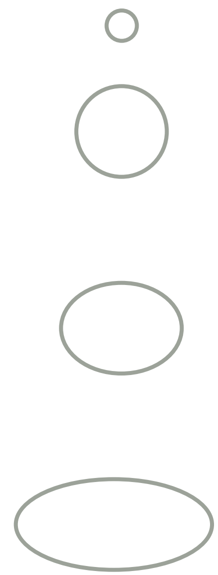
Dual polarisation radars transmit and receive signals in both vertical and horizontal polarisations. Small differences between the two signals tell us about the shape of the target and its composition (ice or water).

Differential reflectivity, ZDR
provide mean particle shape

- The bigger the drop the more oblate it becomes.
- The shape of the raindrop affects how it reflects the vertically and horizontally polarised radar beam.
- ZDR is the ratio between the received power measured in the horizontal (H) and vertical (V) plan:

ZDR = 10* log10(ZH / ZV)

Raindrop size against ZDR



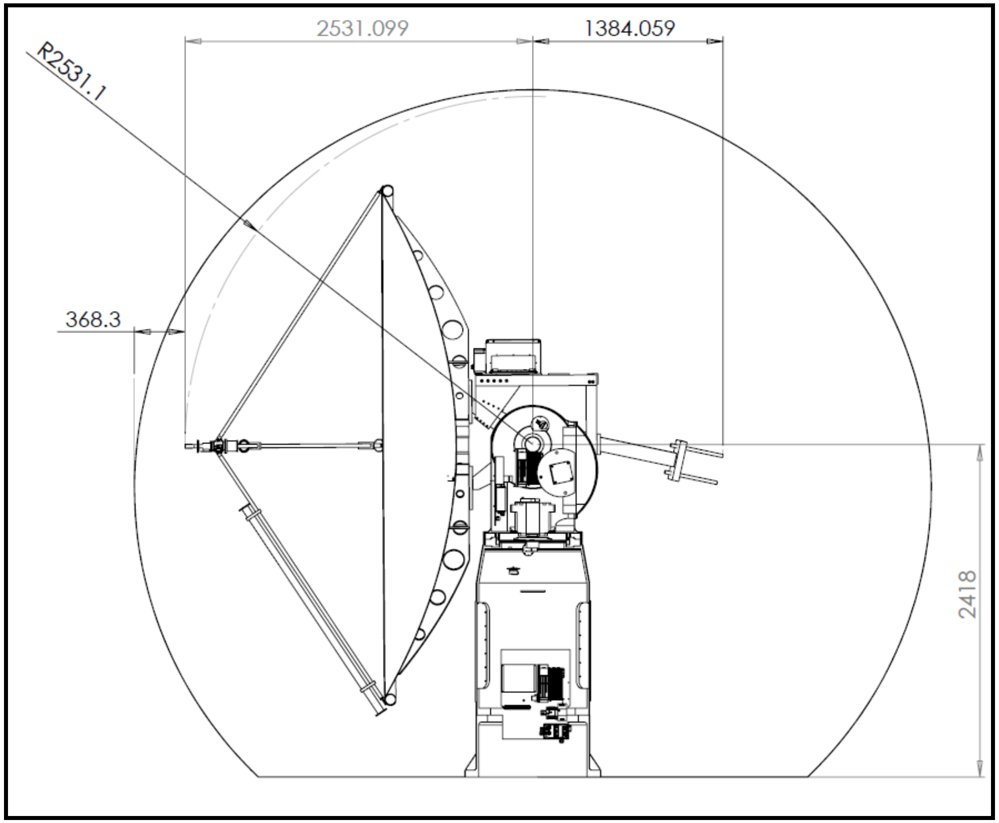
Small drops (1mm)
ZDR ~ 0dB

~ 3 mm ZDR ~ 1.5dB

Large raindrop > 6mm
ZDR ~ 6 dB;

Weather Radar Network Renewal Design

Radar systems and software have been developed in partnership with academia and industry to create a bespoke and fully customisable radar system and network



University of Essex

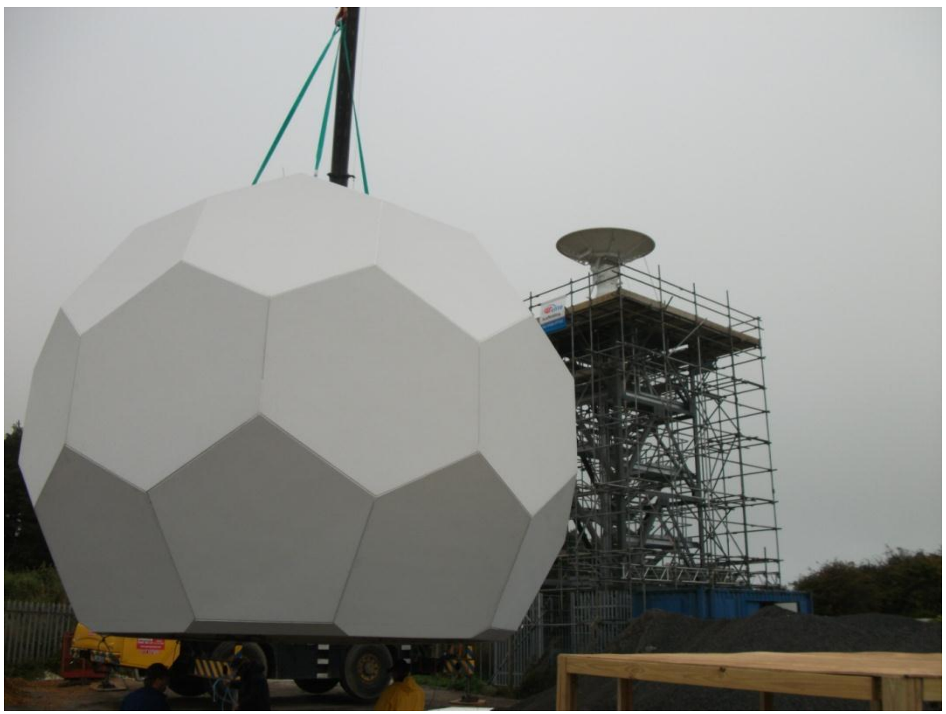
Pascall

Science & Technology Facilities Council

Rutherford Appleton Laboratory

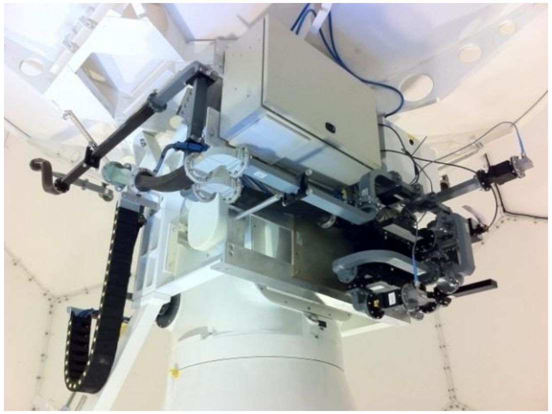
Renewal on the ground

- Replacement of the receiver, antenna, radome and waveguide system, and refurbishment of the pedestal.



Weather Radar Network Renewal Implementation

- Doppler capability rolled-out to all but 1 UK radar.
- Dual polarisation design is running at 2 Ops sites (Chenies – NW London; and Thurnham – Kent) and 1 R&D site (Wardon Hill – Dorset).



- Upgrade to a 3rd and 4th operational sites are underway (Castor Bay-NI; and Predannack - Cornwall). 5 installations planned for FY 13/14.
- Completion late FY 15/16

Benefits of dual polarisation

Met Office

Our goal: Deliver optimum radar products to improve short-range forecast particularly of severe weather.

Great opportunity:

- Dual polarisation Signal Processing (Cyclops D4) and receiver was developed in-house – we have complete control over the signal processing.

Radar reflectivity
Rainfall
Radial wind
Radar refractivity

→

NWP (DA, STEPS, UKPP, VER)

FSD

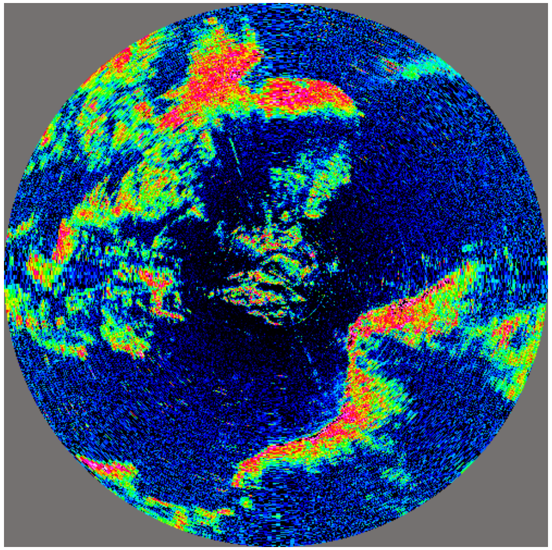
EA, FFC

Working with our academic partners, our research focus on optimising the radar product accuracy.

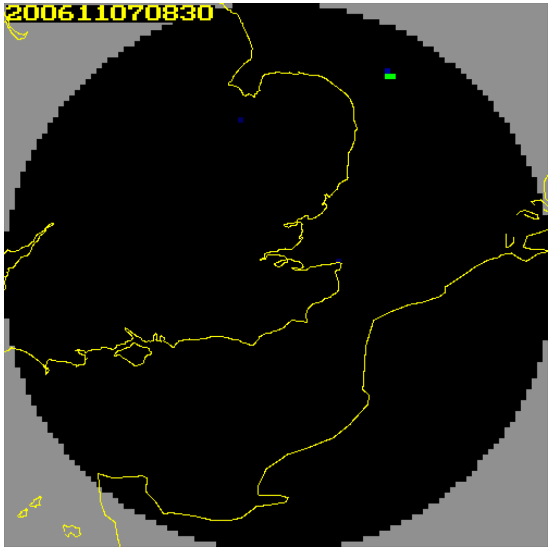
Spurious echoes identification

Problem: A major limitation to assimilating radar products into NWP and hydrological models is the presence of non-precipitation echoes in the data.

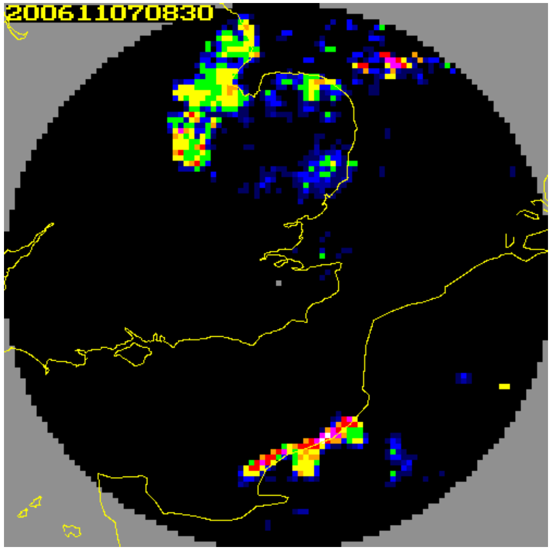
Raw Reflectivity (dBZ)



Rainfall estimate using DP



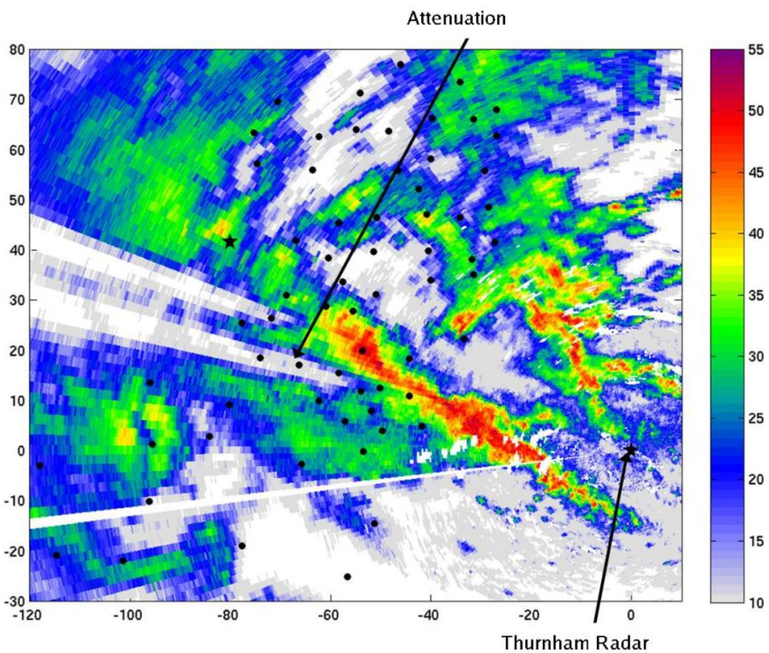
Rainfall estimate without DP



Characteristics of weather radars microwave frequencies

Higher frequency: more severe Attenuation during critical events

Severe attenuation of the radar return is a major problem in intense rainfall, particularly during event likely to cause floods.



From Delrieu et al, 2000: Quantification of Path-Integrated Attenuation for X-band and C-band Weather Radar Systems Operating in the Mediterranean Heavy Rainfall

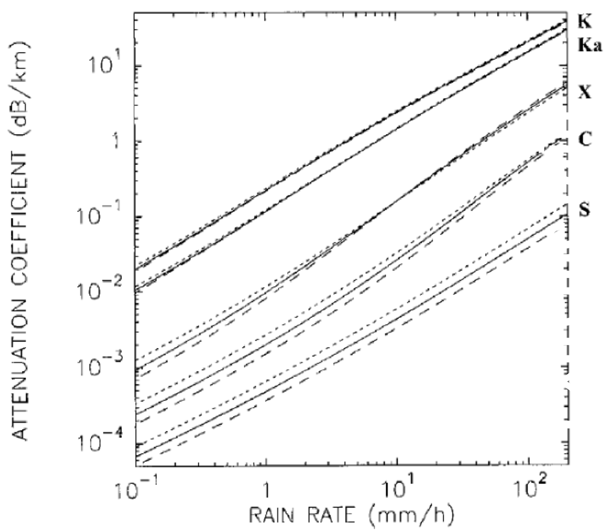
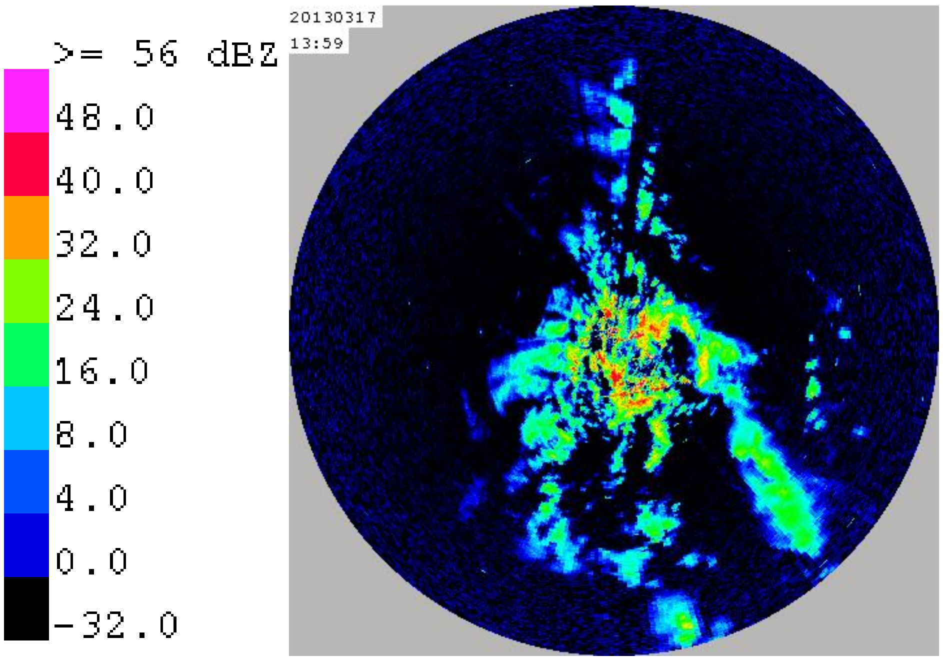


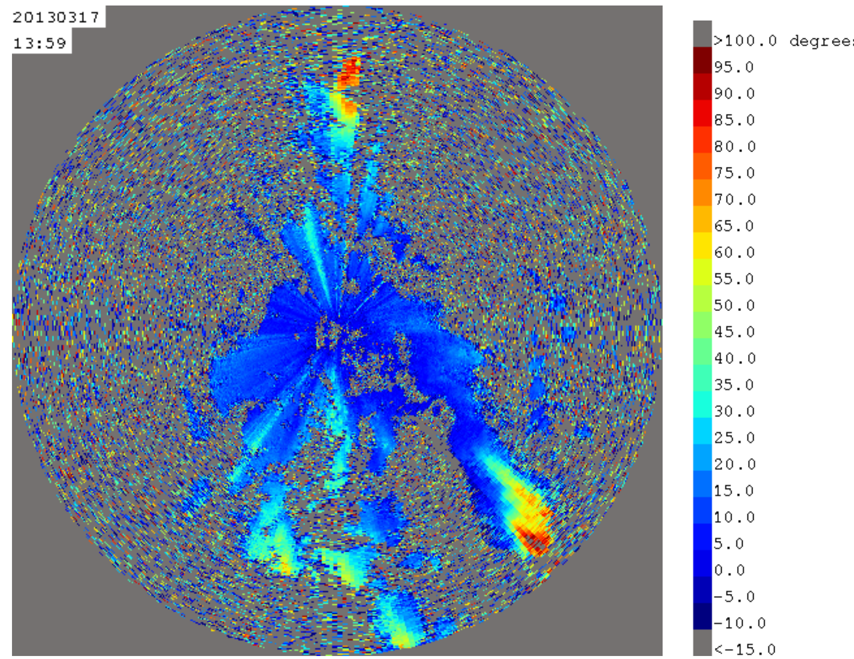
FIG. 3. Some examples of k–R relationships established using Mie theory (spherical rain drops) for the K- (0.86 cm), Ka- (1.15 cm), X- (3.2 cm), C- (5.6 cm), and S-band (10 cm) wavelengths and the Cévennes DSD model (see Table 1) for raindrop temperatures T = 0°C (dotted line), T = 10°C (continuous line), and T = 20°C (dashed line).

Example of Differential Phase, ϕ_{DP} Chenies – 17 Mar 2013

Reflectivity, dBZ



Differential Phase Shift, degree



As rain becomes heavier raindrop become oblate. The horizontally polarised wave will be more affected by more water than the vertically polarized wave.

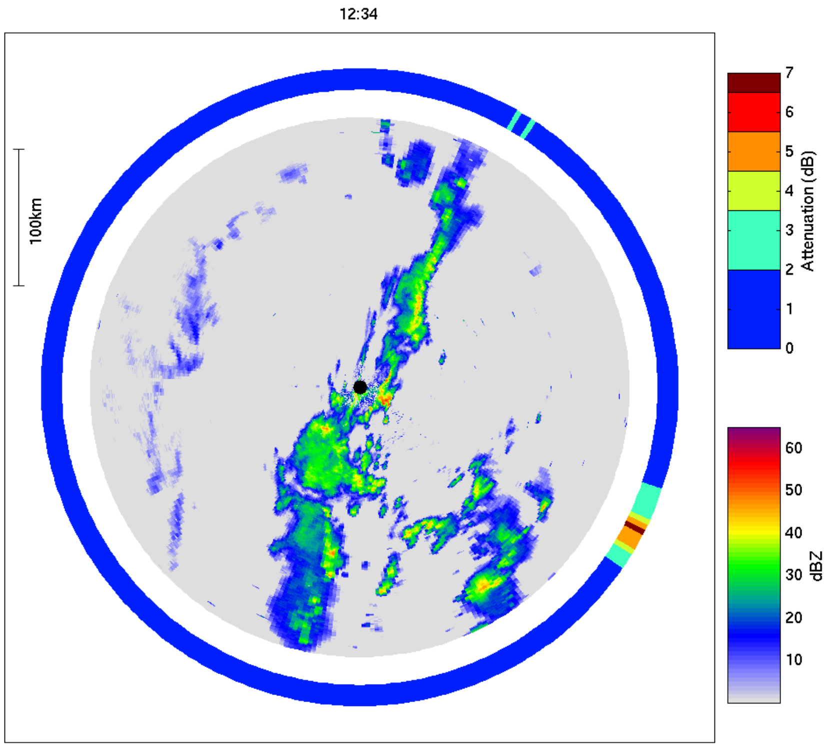
$$\phi_{DP} = \phi_H - \phi_V$$

ϕ_{DP} Indicates the relative delay between the Horizontal and Vertical wave
→ Increase in differential phase related to attenuation of the radar signal.

Passive emissions

Dept. of Meteorology

- Attenuators are emitters (Prevost 1818).
- Radar signal Attenuating storms emit at the radar frequency.
- Emission can be expressed as the total attenuation along the path of the radar beam.
- Radar receiver is sensitive enough to act as a radiometer and measure emissions (transmitter switched off)



Our goal: to bring new emission techniques combined with dual polarisation parameter into operational use for improving the identification and correction of attenuation of the radar return caused by rain and wet radome.

Improved QPE accuracy during heavy rainfall

Problem: Severe attenuation of the radar reflectivity in heavy rainfall cause severe under estimation of rainfall.

KPD is a phase parameter immune to the error related radar calibration or reduction of the reflectivity factor caused by partial beam blockage, attenuation by precipitation or wet radome.

KDP is also less sensitive than reflectivity to changes in the DSD.

New opportunity: use R=f(KDP) instead of R=f(Z). KDP can be used to identify area of heavy rain and derive rainfall estimate without using the reflectivity.

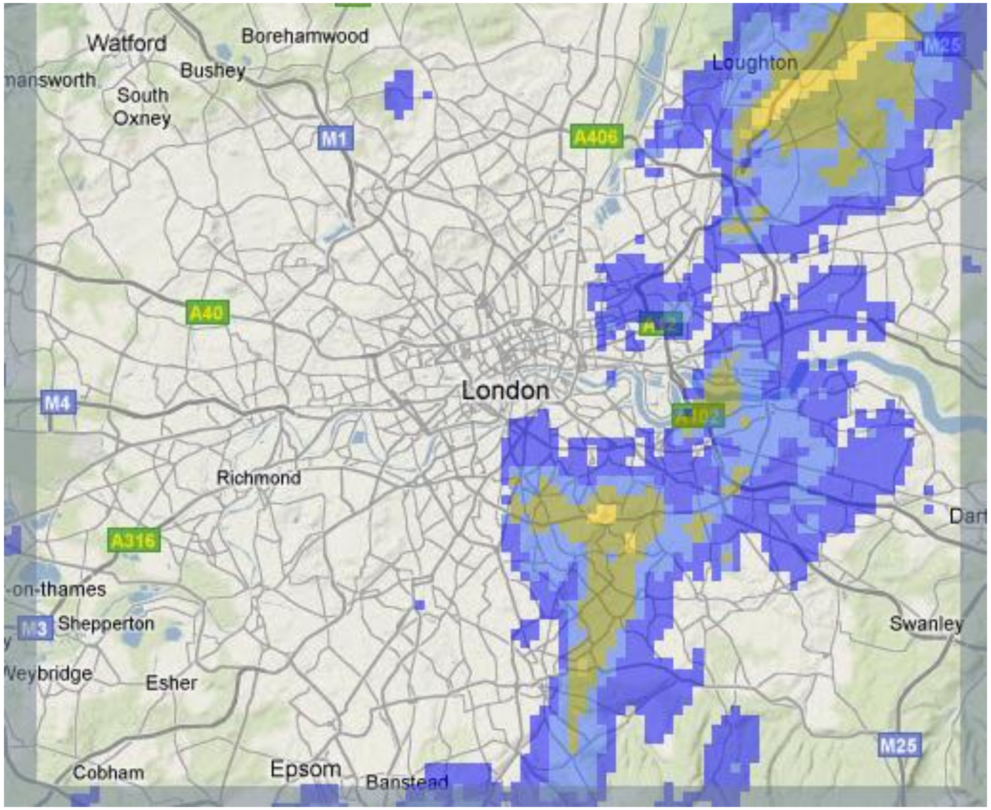
Over to Tim for further development carried out as part of the RAINGAIN project....

High resolution rainrate products

Tim Darlington, Met Office

This project has received European Regional Development Funding through INTERREG IV B.

High-resolution processing



500m data on Invent

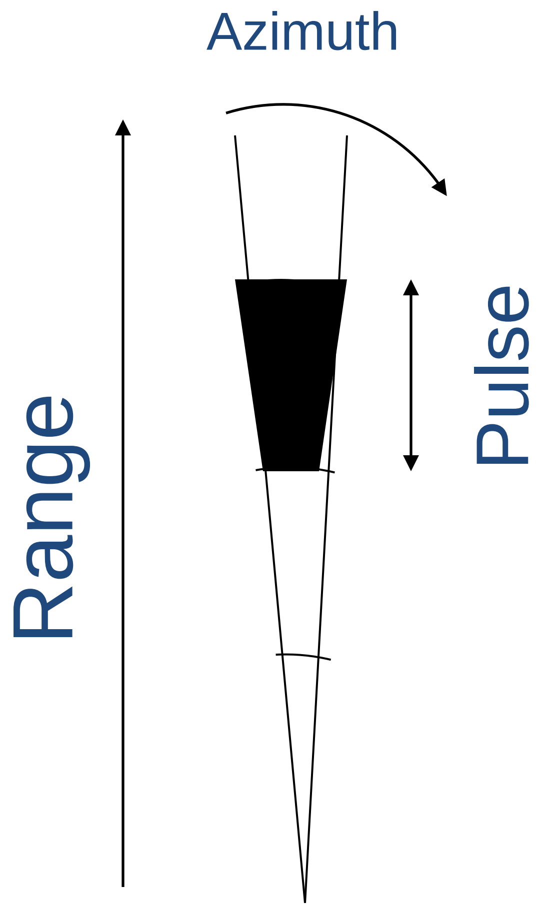
- Can we refine resolution of the rainfall estimates for urban catchments? (While maintaining /improving quality)
- **Our goal: 100 m or better resolution over central London by 2014**

Signal processing techniques

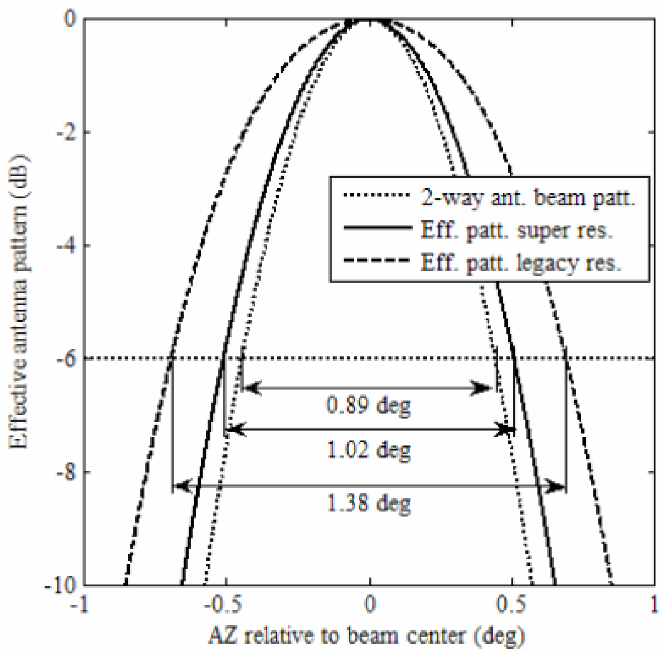
- Higher resolution comes at a price : Can’t get something for nothing
  - Degradation of quality / detection efficiency
- Recover with signal processing

Fine scale resolution – limiting factors

- Weather radar measurements are collected in polar coordinates i.e. range gates per degrees
- Range gate resolution is limited by the transmitted pulse length
- The angular resolution is mostly limited by the beam width of the antenna at the transmission wavelength



Azimuth Improvements



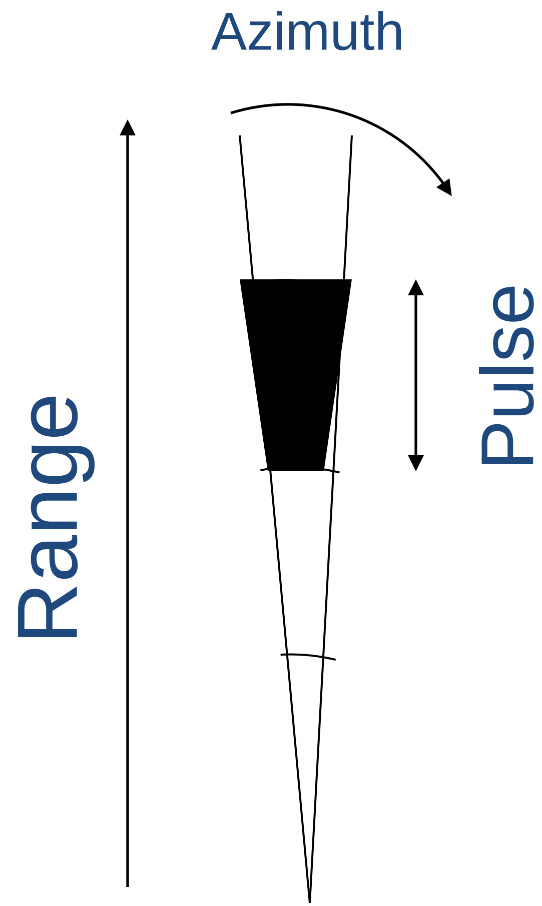
Effective antenna patterns corresponding to legacy- and super-resolution processing for a Gaussian intrinsic antenna beam pattern with a two-way 6-dB beam width of 0.89 deg. *

- Based on work in the US
- Beam width usually degraded by scanning motion of antenna
- ~30% improvement in azimuth resolution
- Downside: increased measurement error – can be compensated for…. work in progress

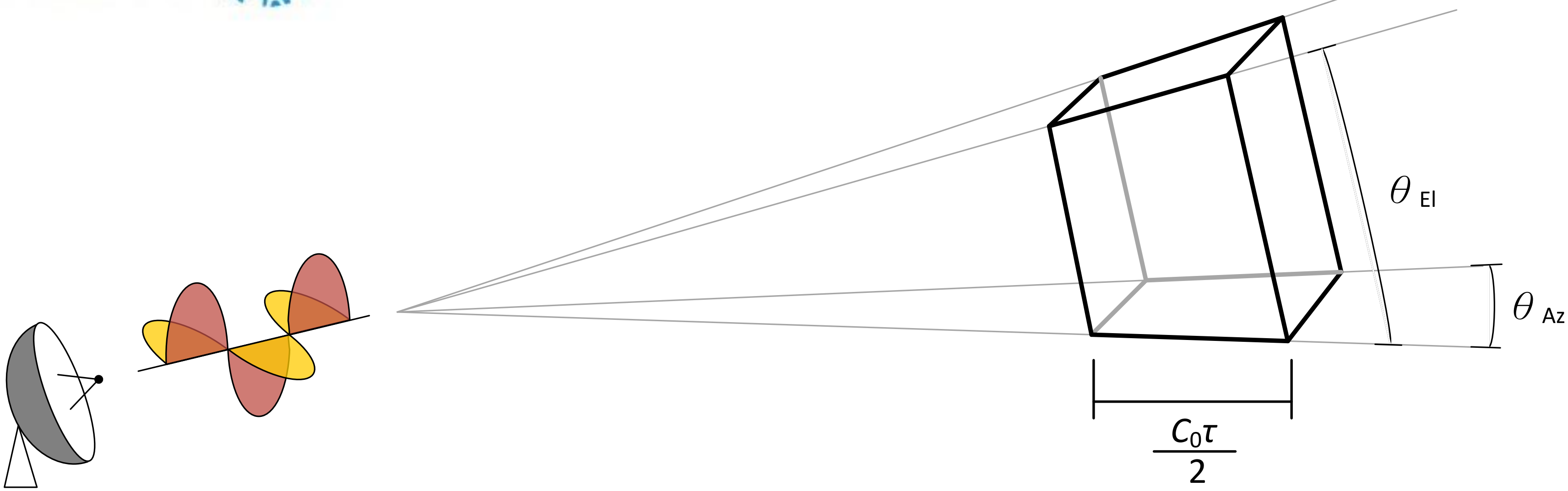
* **Design considerations for improved tornado detection using super-resolution data on the NEXRAD network**
Sebastian Torres, Christopher Curtis

Range Improvement

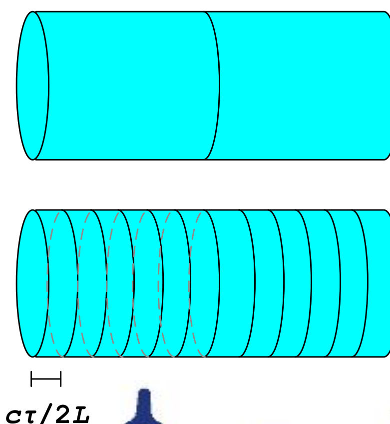
- Range resolution governed by pulse length – use shorter pulse:
  - Degrades detection ability / quality
  - Use signal processing to recover
- Apply signal processing to longer pulse – "RETRO"



Range Oversampling



Resolution Cell Volume:
two separate objects that lie within the same resolution cell cannot be distinguished by radar



High resolution products

- Development of high resolution products has started

- Currently using a mix of conventional and high resolution input data

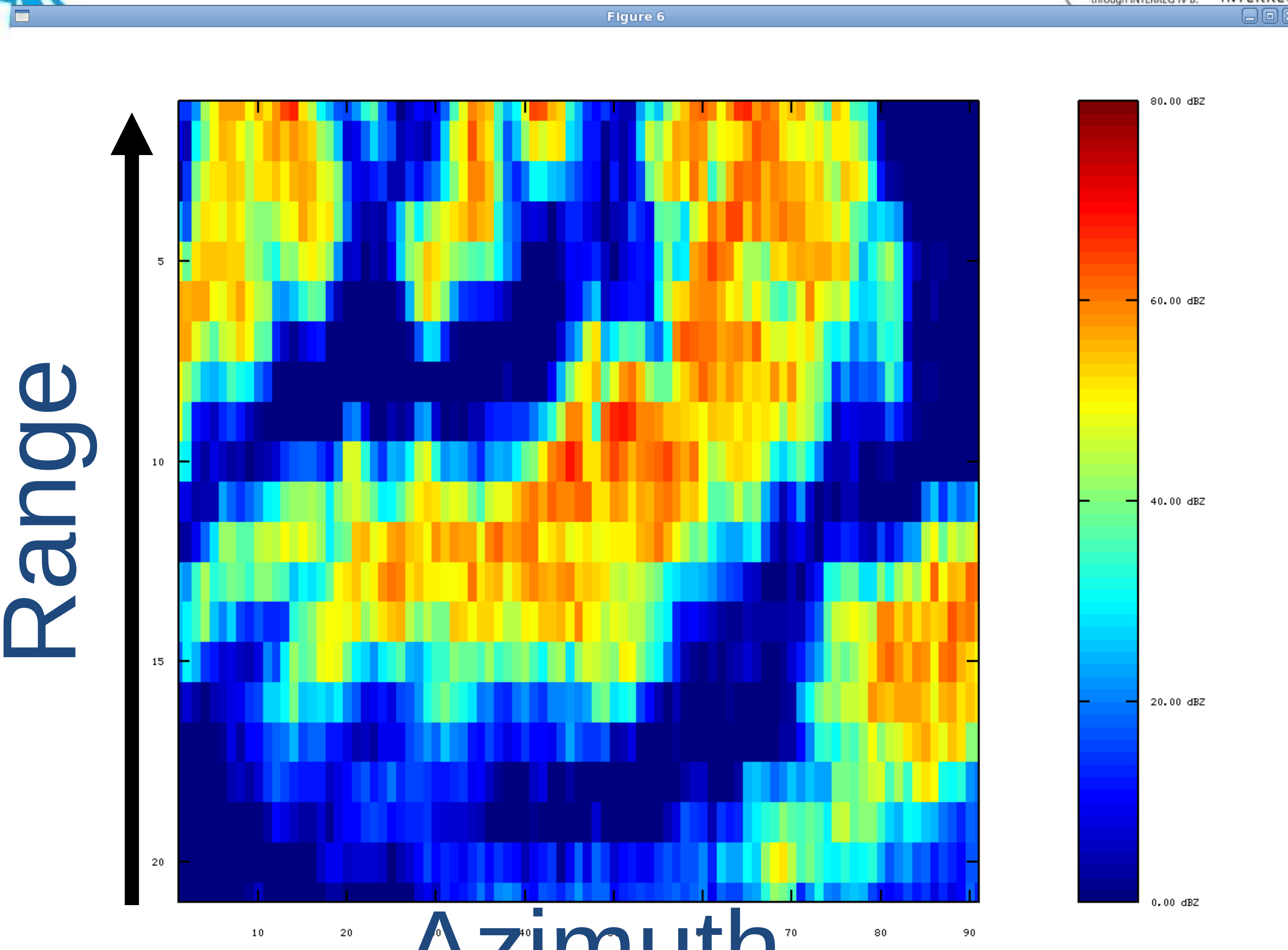
300m x 1 degree Input Data

Polar

Data

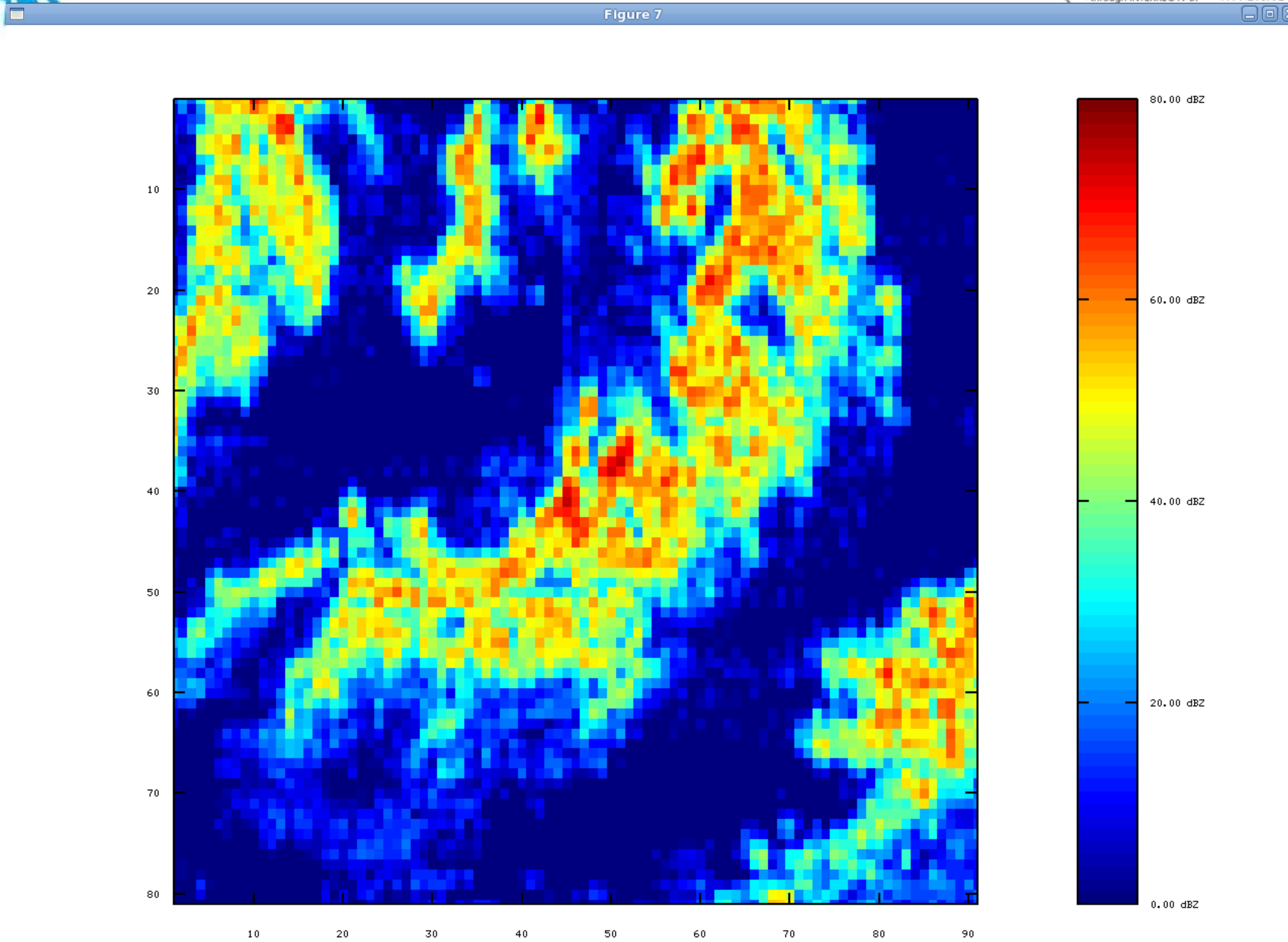
Plot

Range



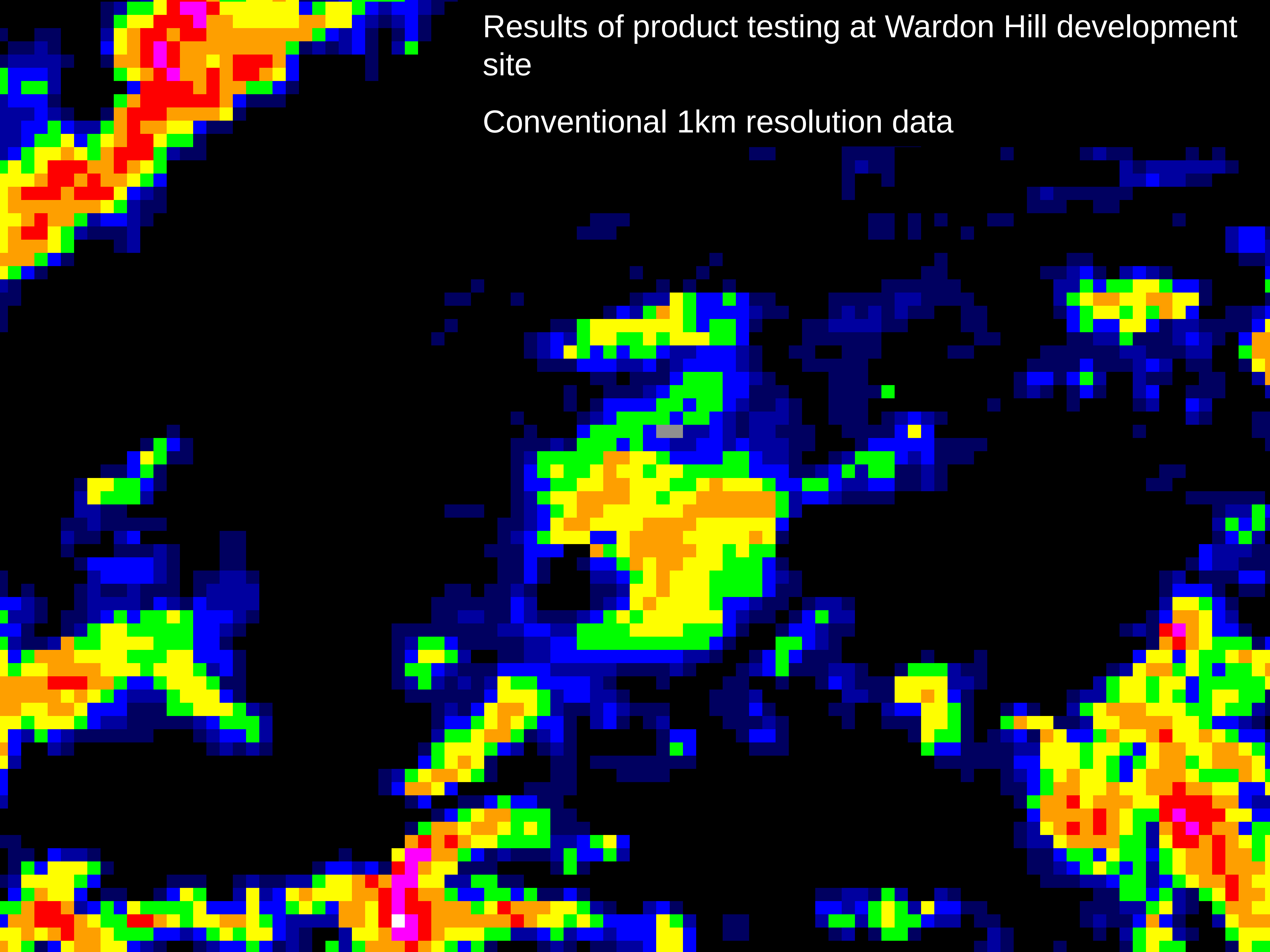
Azimuth

75m sharpened input data



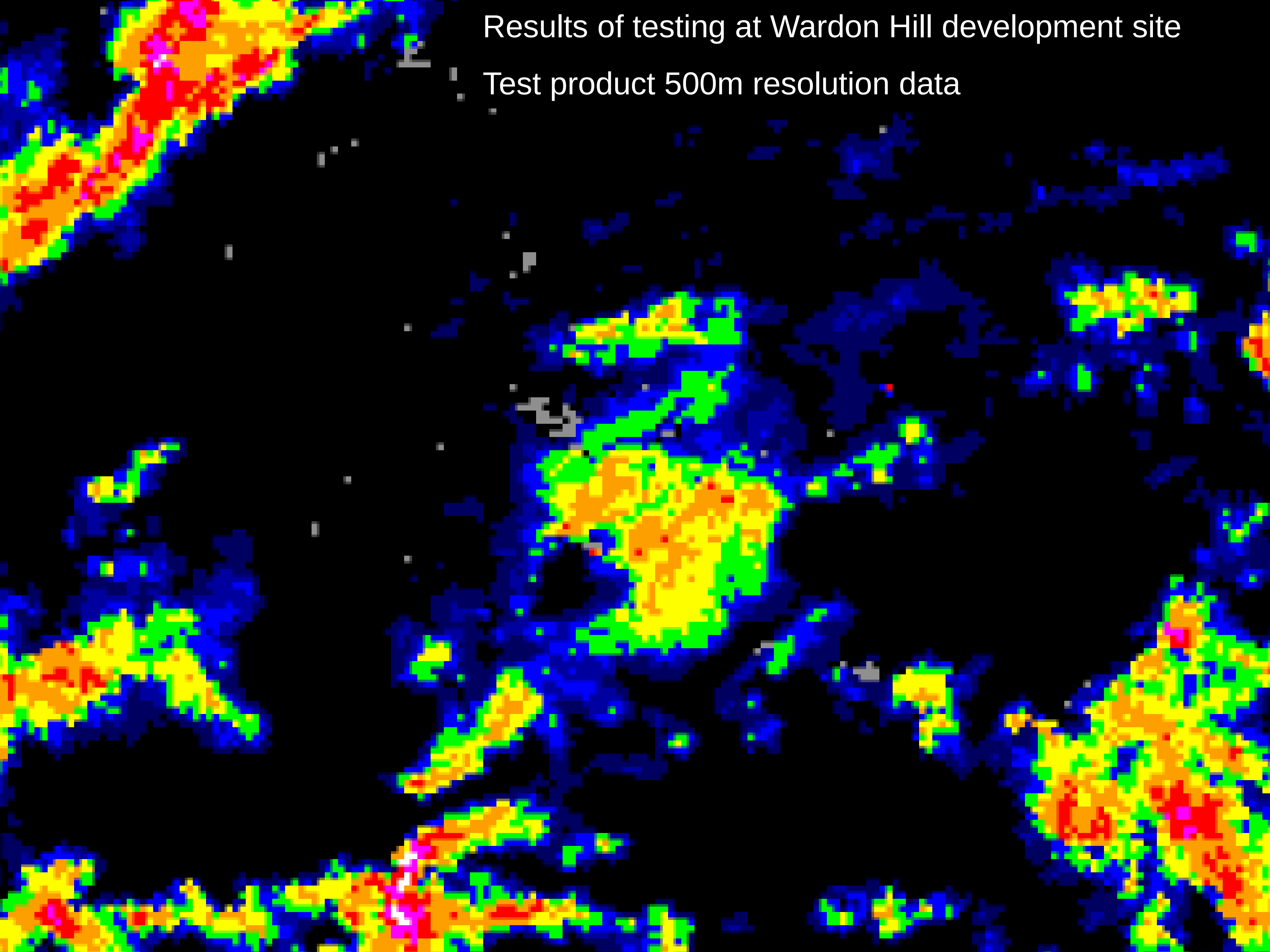
Results of product testing at Wardon Hill development site

Conventional 1km resolution data



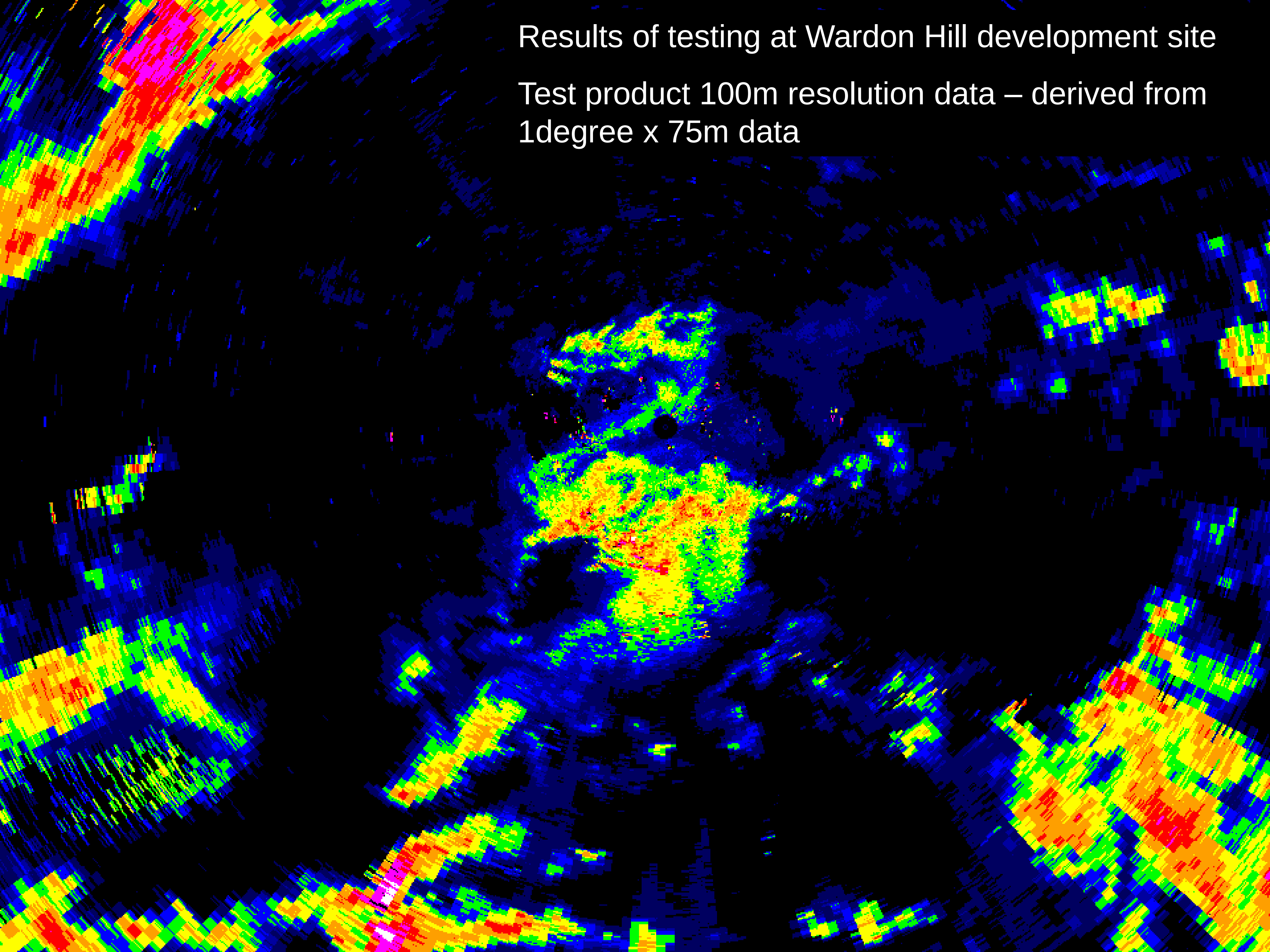
Results of testing at Wardon Hill development site

Test product 500m resolution data



Results of testing at Wardon Hill development site

Test product 100m resolution data – derived from 1degree x 75m data



Range oversampling benefits

- Oversample based processing for
  - reduced measurement variance
  - Or faster scans
- Deconvolution for higher resolution
  - Computationally intensive (Real-time?)
  - Can lead to bias in results

Future work

- Trial starting in May
- High resolution composite data over London
- Comparison against gauges
- Evaluate both DSP techniques