# DARE WP1.1 A tool for urban flood delineation using Synthetic Aperture Radar.

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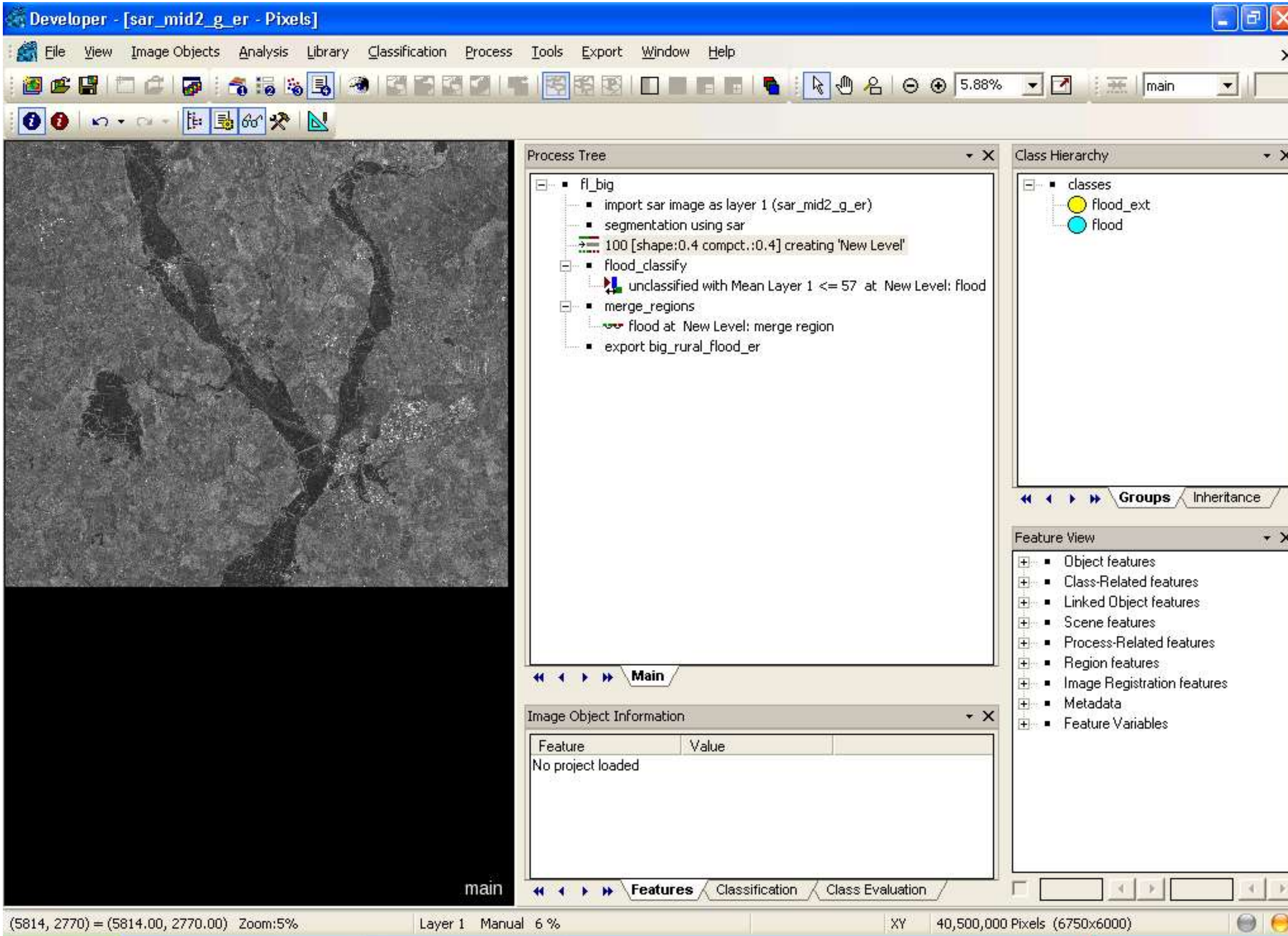
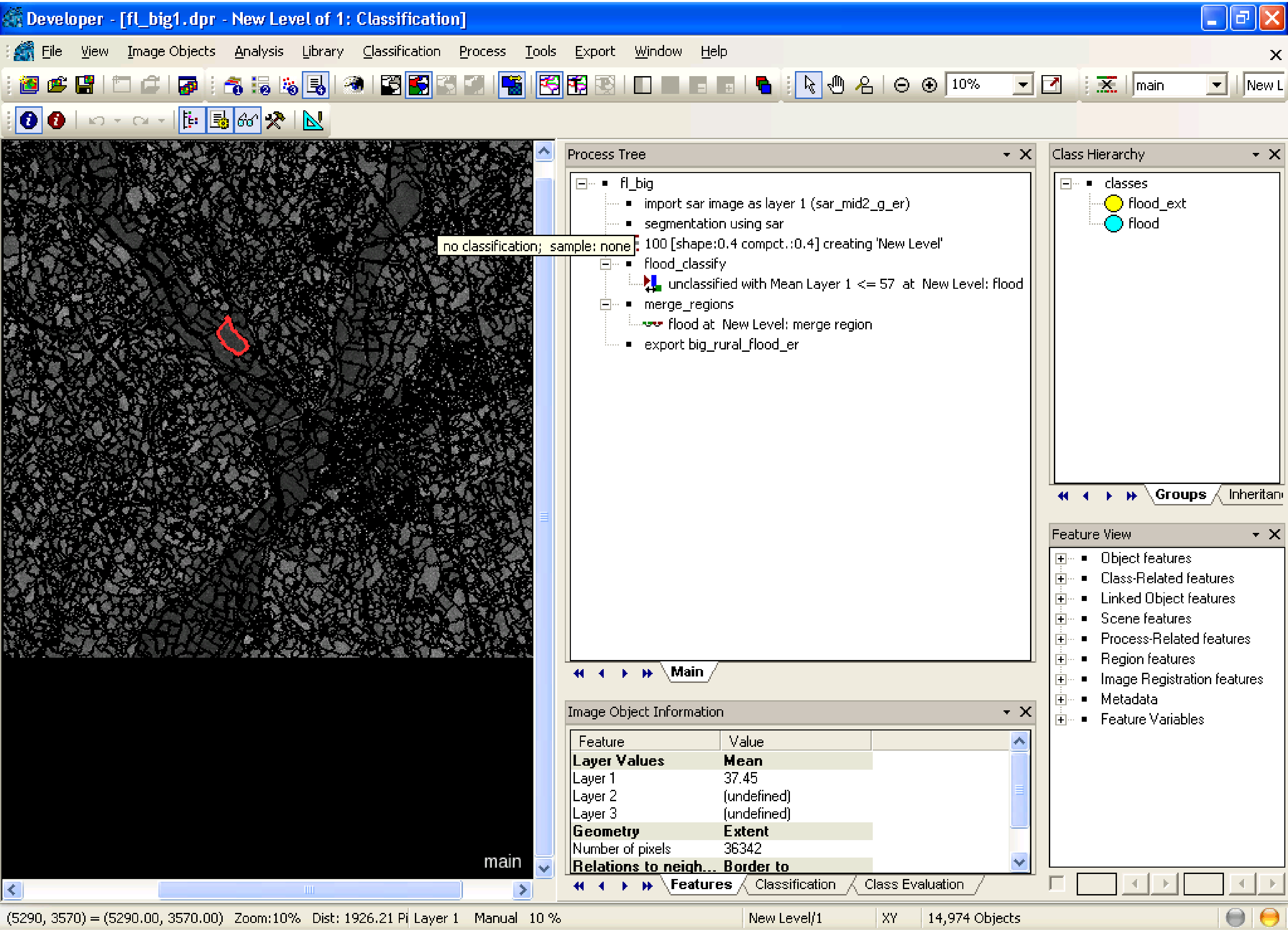
- High resolution SAR sensors now commonly used in natural disasters such as flooding (synoptic, all-weather, day/night)
- Sensors have resolutions as high as 1m
- Flood water generally appears dark in SAR image

# Uses of flood extents derived from SAR images.

- Damage assessment and mitigation.
- Flood relief management
  - several systems to extract the flood extent from a SAR image developed
  - tend to work well in rural areas and poorly in urban areas.
- Improved flood forecasting using data assimilation.

# Flood extent delineation algorithm.




Developer - [fl_big1.dpr - New Level of 1: Classification]
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segmentation using sar
100 [shape:0.4 compct.:0.4] creating 'New Level'
flood_classify
unclassified with Mean Layer 1 <= 57 at New Level: flood
merge_regions
flood at New Level: merge region
export big_rural_flood_er
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flood_ext
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Feature View
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Scene features
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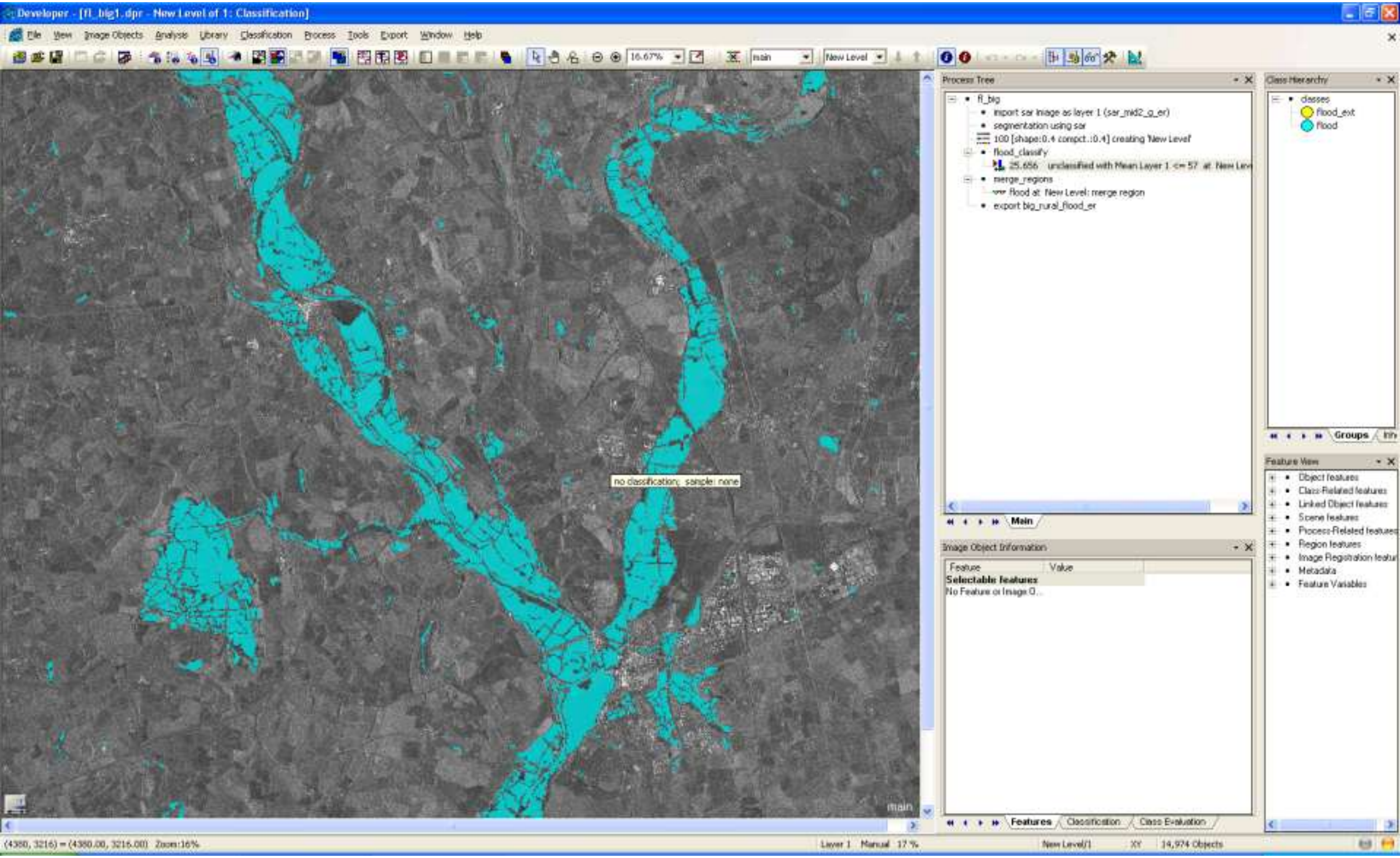
New Level/1
XY
14,974 Objects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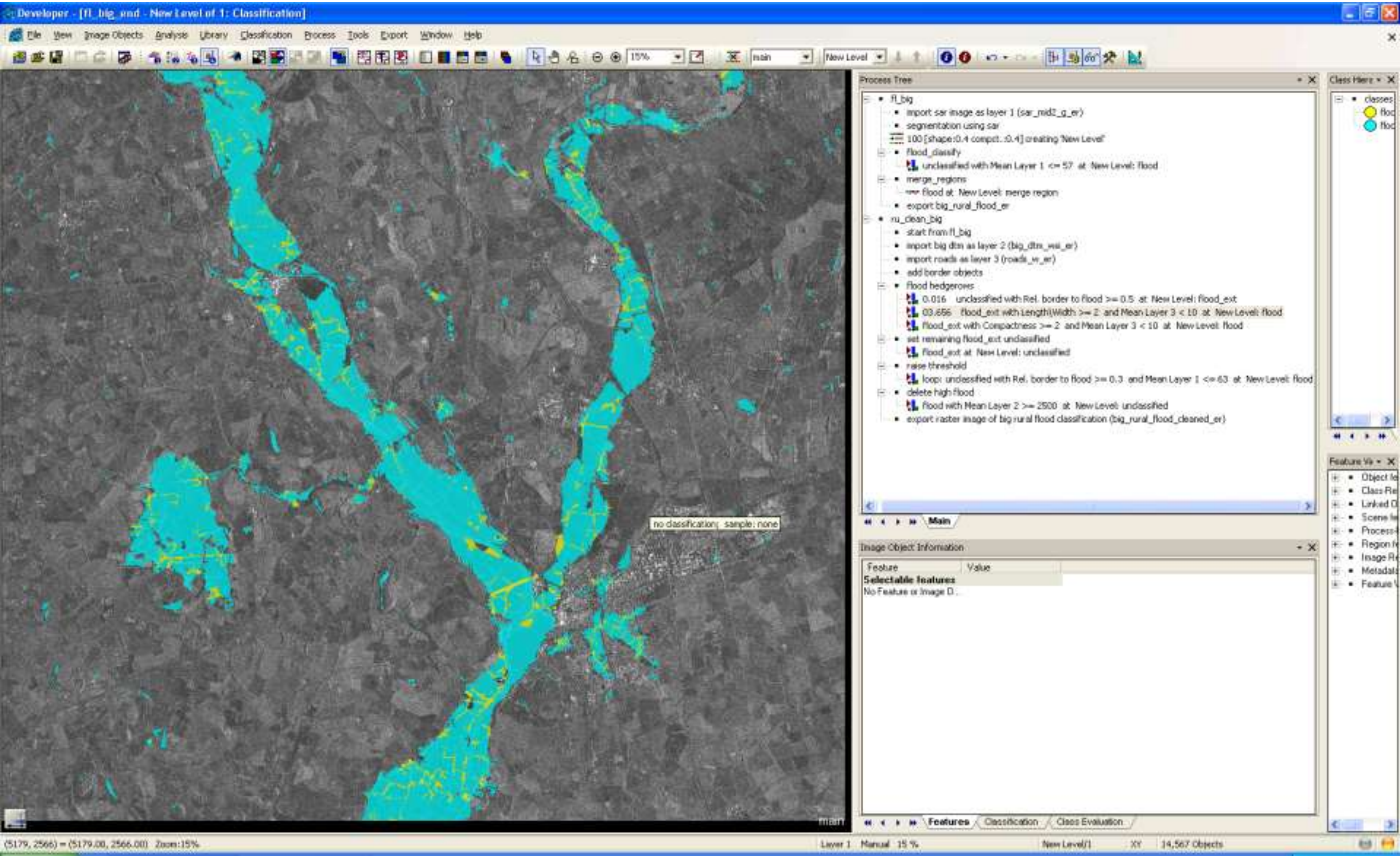
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merge_regions
flood at New Level: merge region
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ru_clean_big
start from fl_big
import big dtm as layer 2 (big_dtm_wsi_er)
import roads as layer 3 (roads_w_er)
add border objects
flood hedgerows
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03.656 flood_ext with Length\Width >= 2 and Mean Layer 3 < 10 at New Level: flood
flood_ext with Compactness >= 2 and Mean Layer 3 < 10 at New Level: flood
set remaining flood_ext unclassified
flood_ext at New Level: unclassified
raise threshold
loop: unclassified with Rel. border to flood >= 0.3 and Mean Layer 1 <= 63 at New Level: flood
delete high flood
flood with Mean Layer 2 >= 2500 at New Level: unclassified
export raster image of big rural flood classification (big_rural_flood_cleaned_er)
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Classification
Class Evaluation
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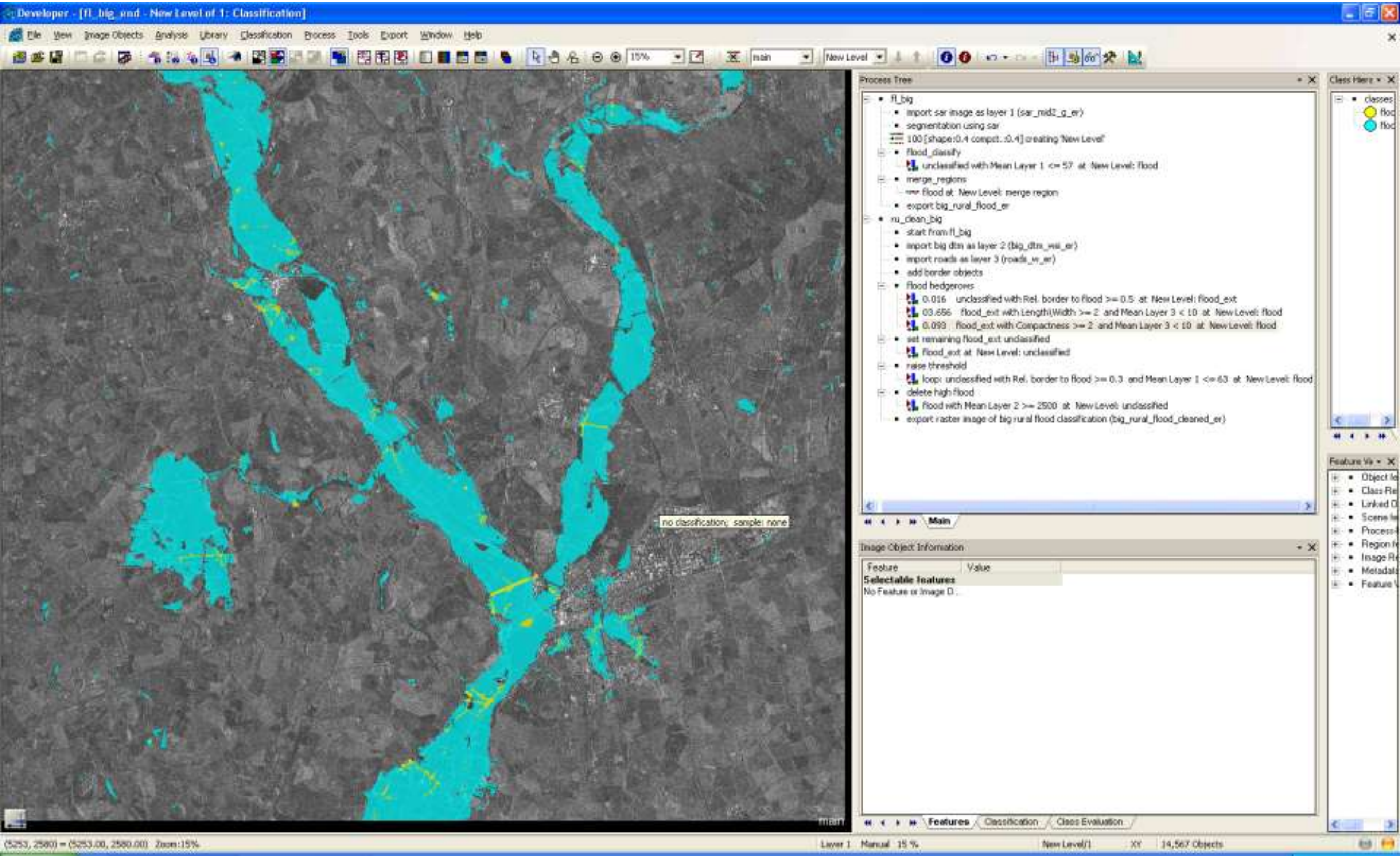
New Level/1
XY
14,567 Objects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set remaining flood_ext unclassified
flood_ext at New Level: unclassified
raise threshold
loop: unclassified with Rel. border to flood >= 0.3 and Mean Layer 1 <= 63 at New Level: flood
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Class Evaluation
Class Hierarchy
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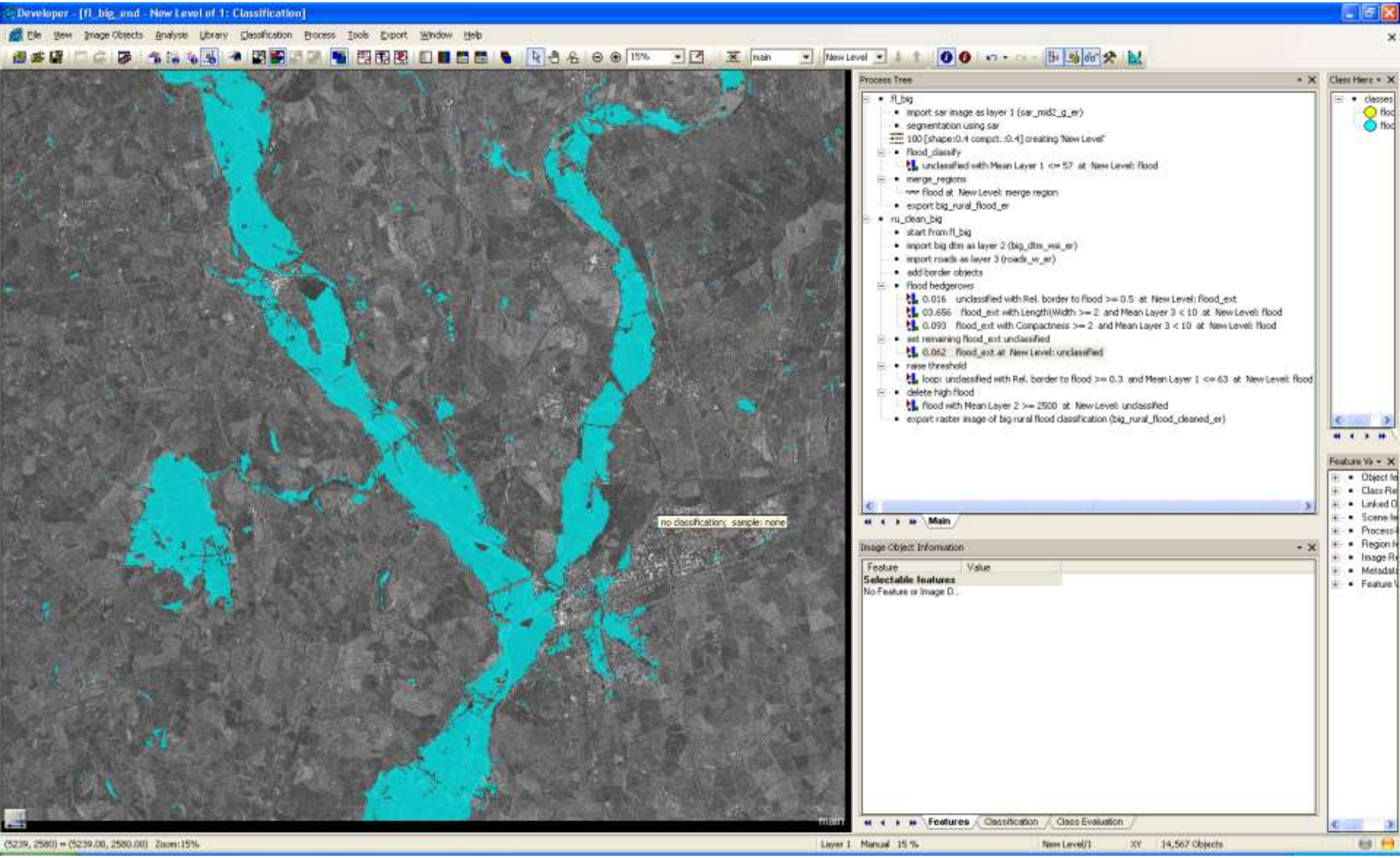
(5253, 2580) = (5253.00, 2580.00) Zoom:15%
Layer 1 Manual 15 %
New Level/1
XY
14,567 Objects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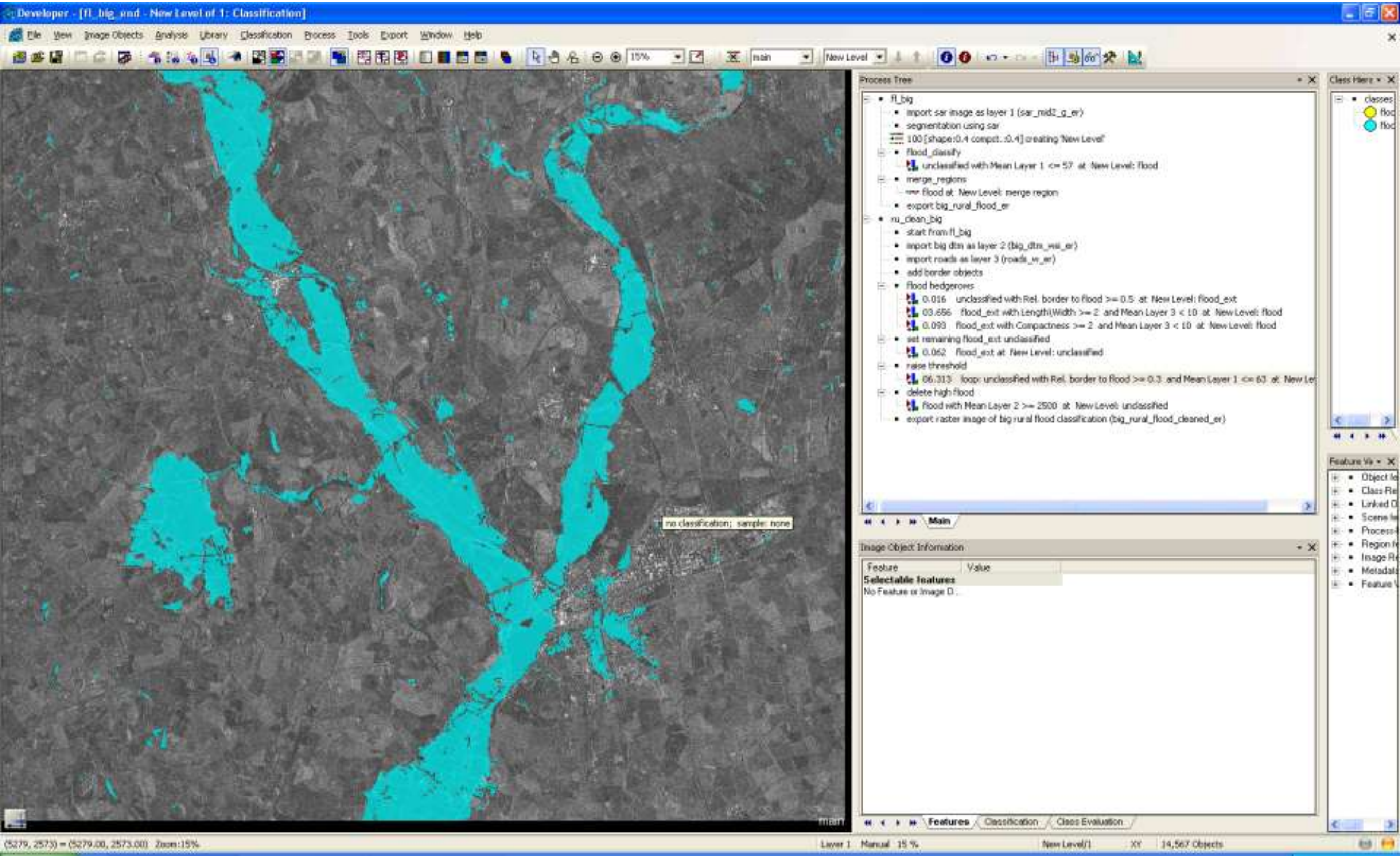
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export raster image of big rural flood classification (big_rural_flood_cleaned_er)
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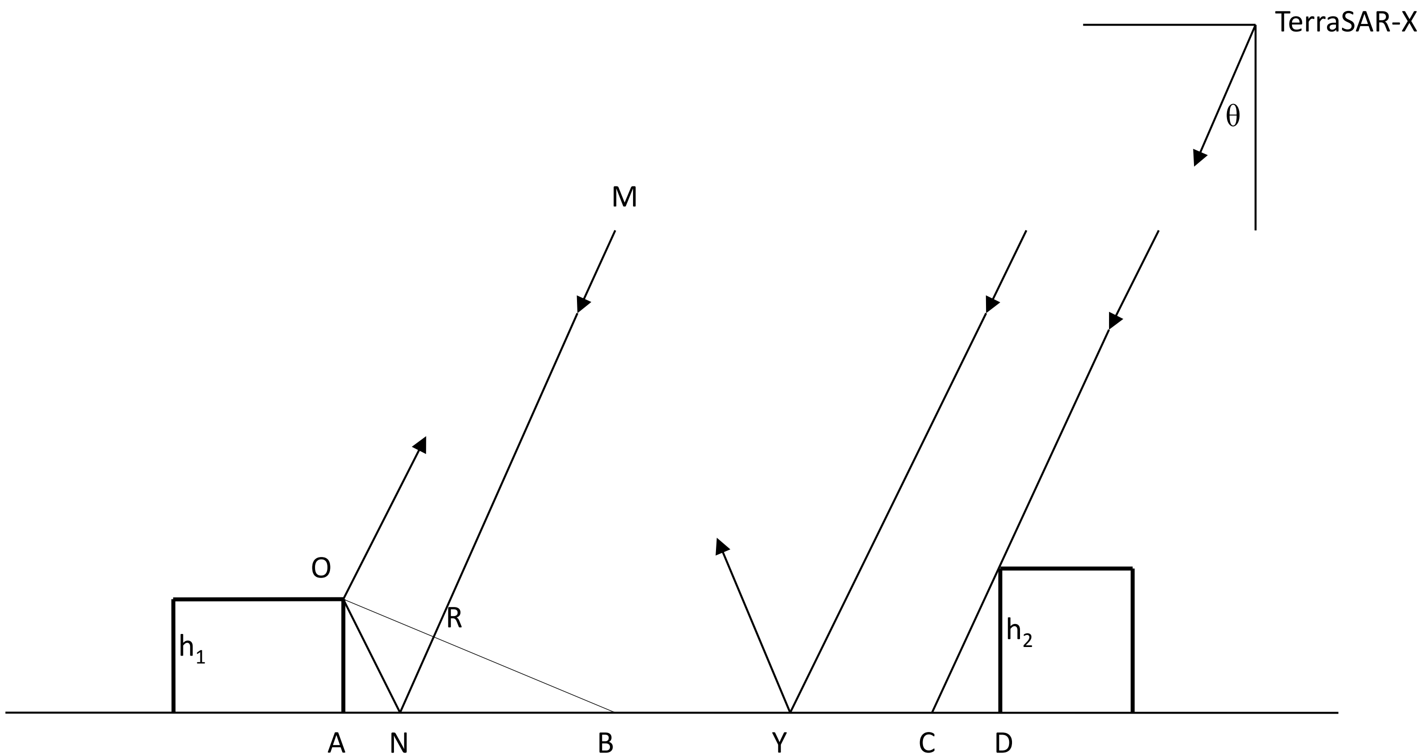
Classification
Class Evaluation
(5279, 2573) = (5279.00, 2573.00) Zoom:15%
Layer 1 Manual 15 %
New Level/1
XY
14,567 Objects

*TerraSAR-X image of Tewkesbury flooding on 25th July 2007 showing urban areas (3m resolution, dark areas are water).*




*Layover (AB) and shadow (CD) in a flooded street between adjacent buildings.*

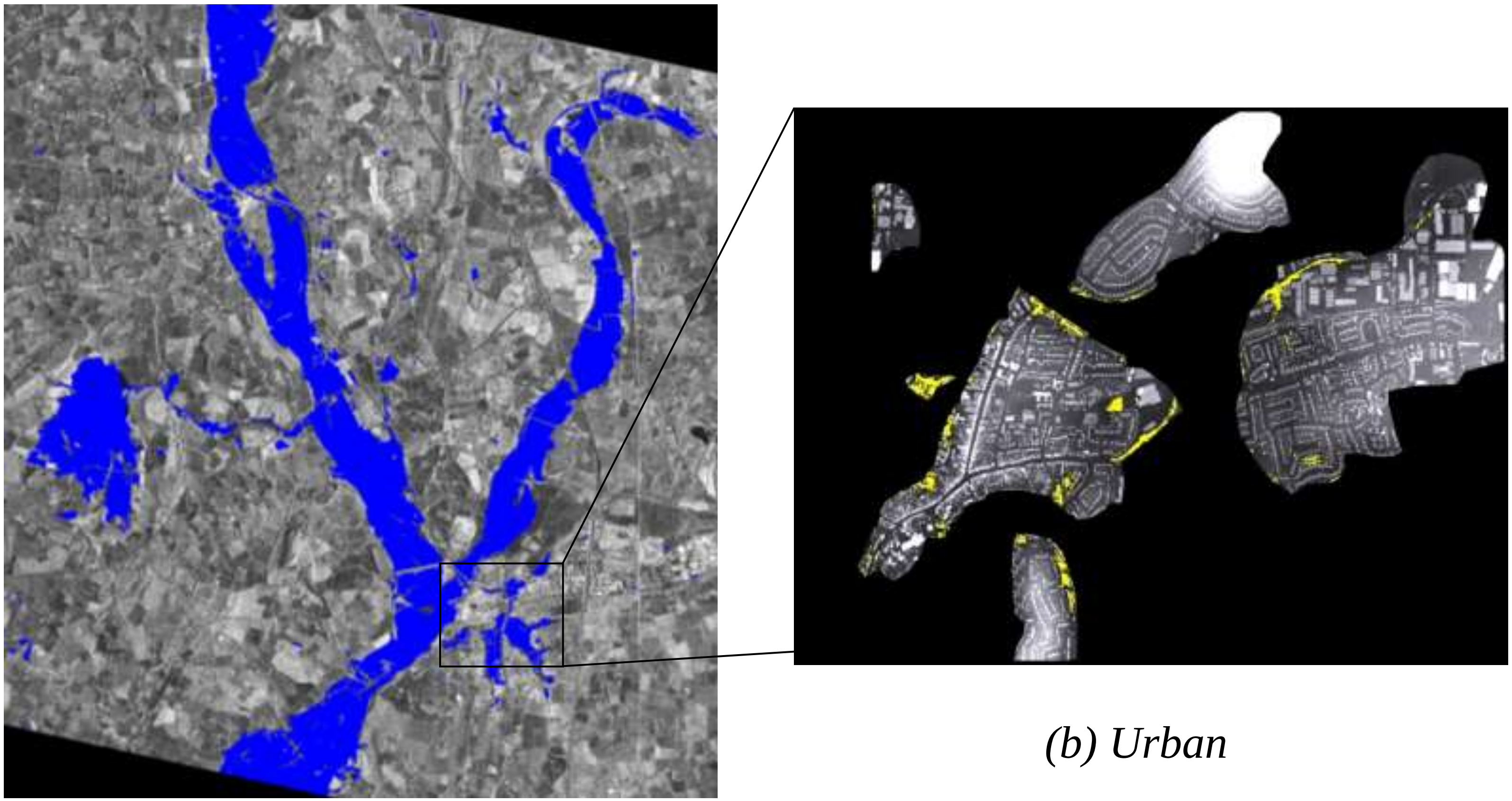
*LiDAR DSM of Tewkesbury (2m resolution).*

*Regions unseen by TerraSAR-X in LiDAR DSM due to combined shadow and layover (satellite looking West).*

# Urban flood detection

- guided by rural flood detection
  - use local waterline heights in the rural areas
  - flooding in urban areas should not be at a substantially higher level than in nearby rural areas.
  - group low backscatter/low height pixels using region-growing
  - regions of shadow and layover masked out.

# Flood extent detected automatically in near real-time

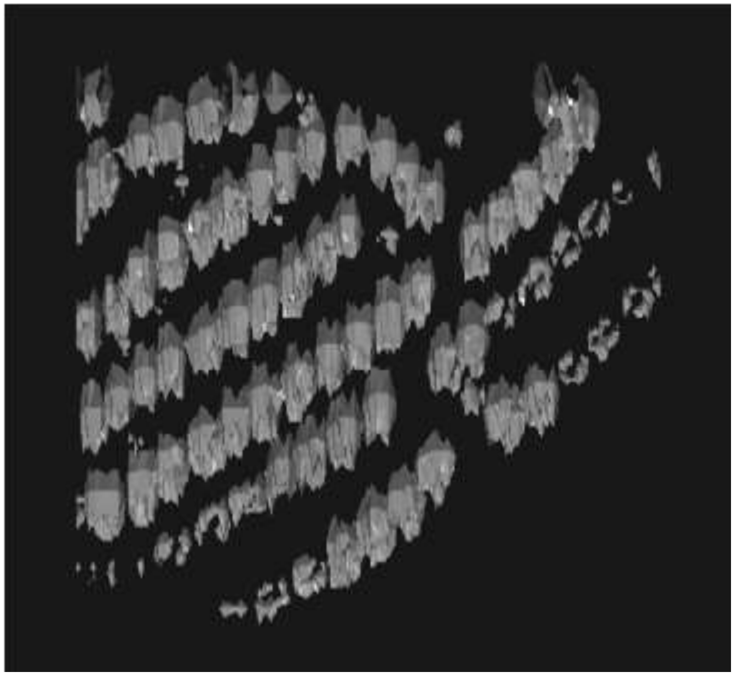


*(b) Urban*

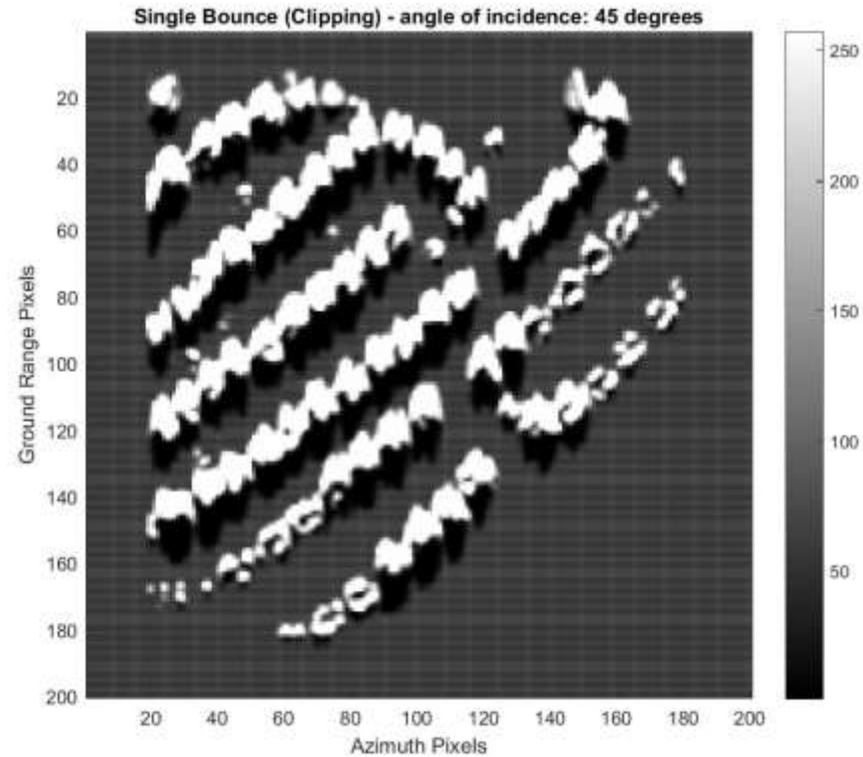
*(a) Rural*

# SAR simulator: RaySAR

- To date used SETES SAR simulator, not publicly available
- Number of SAR simulators are open-source
- A first step in WP1.1 has been investigation of simulators
- Should not be too computer-intensive
- Selected RaySAR, based on POV-Ray
- POV-Ray is ray-tracer developed for use with incoherent visible light
- RaySAR extends POV-Ray to cope with coherent SAR ray-tracing
- RaySAR can model layover and shadow
- Processing time ~ minutes/scene



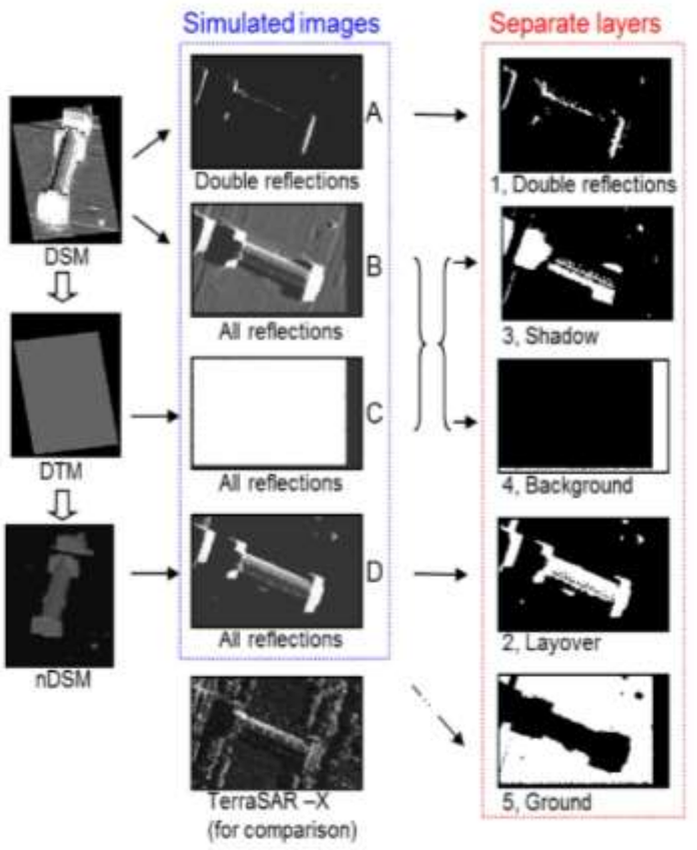
(a) *POV-Ray image of LiDAR DEM containing houses (viewed from North, incidence angle 45º)*




(b) *RaySAR single-bounce image showing shadow (illuminated from North, incidence angle 45º)*

# Detection of layover and shadow

- Get LiDAR DSM of study area.
- Create normalised DSM (nDSM) by subtracting DTM from DSM.
- Create simulated ground-range-projected SAR images for DSM, DTM and nDSM.
- Layover is where backscatter > 0 in nDSM SAR image.
- Shadow is where backscatter = 0 in DSM SAR image and backscatter > 0 in DTM SAR image.
- To test, check if get same shadow/layover map from RaySAR as from SETES for Tewkesbury.



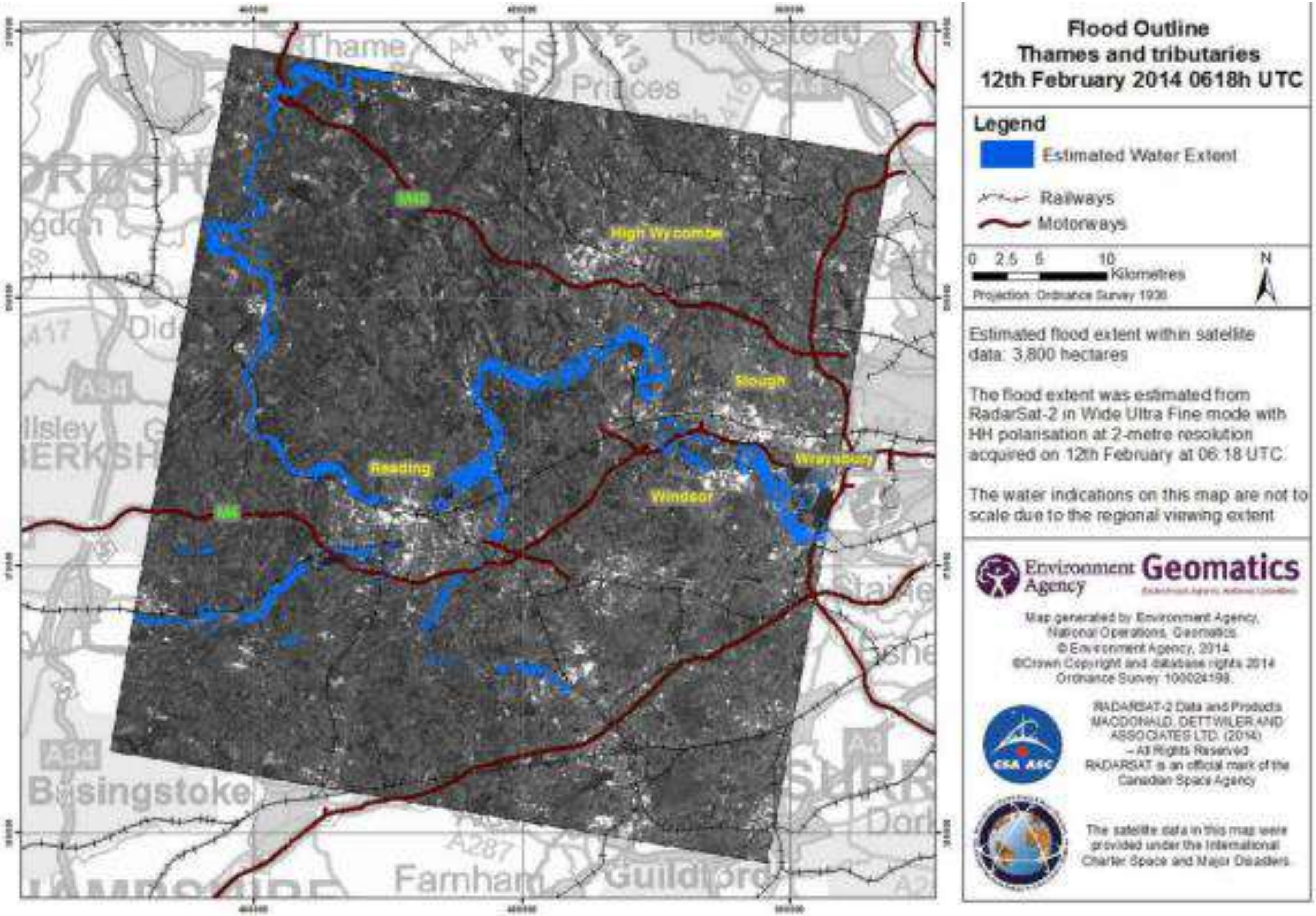

*DEMs, simulated images (looking West), and separate layers (after Tao, 2015).*

# Thames flooding west of London in early 2014

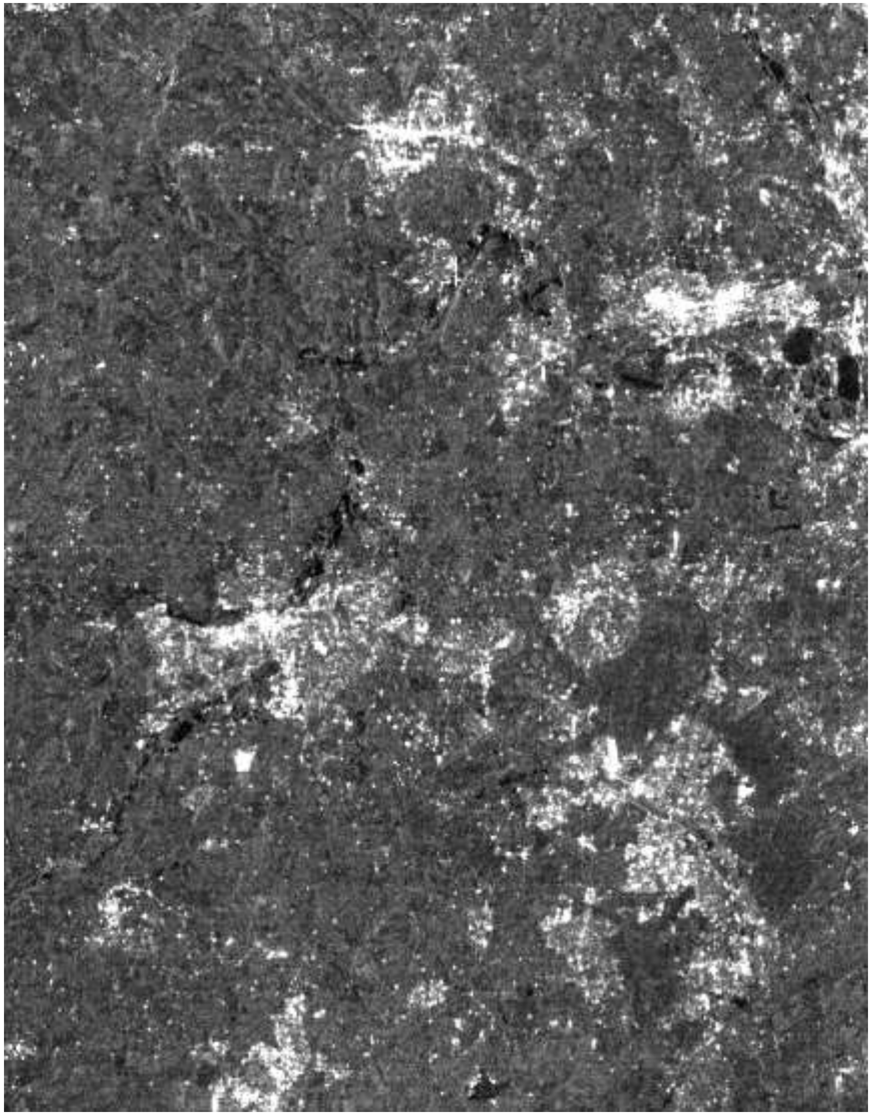
- Substantial urban areas flooded (Jan and Feb)

- CSK constellation uniquely useful for flood monitoring (12-hour revisit interval).

- Five CSK images acquired under CORSAIR project –
  - 04/01/2014 (pre-flood),
  - 10/01/2014 (first peak),
  - 12/02/2014 (1 day after second, higher, peak),
  - 13/02/2014 (when EA acquired aerial photography),
  - 14/02/2014.

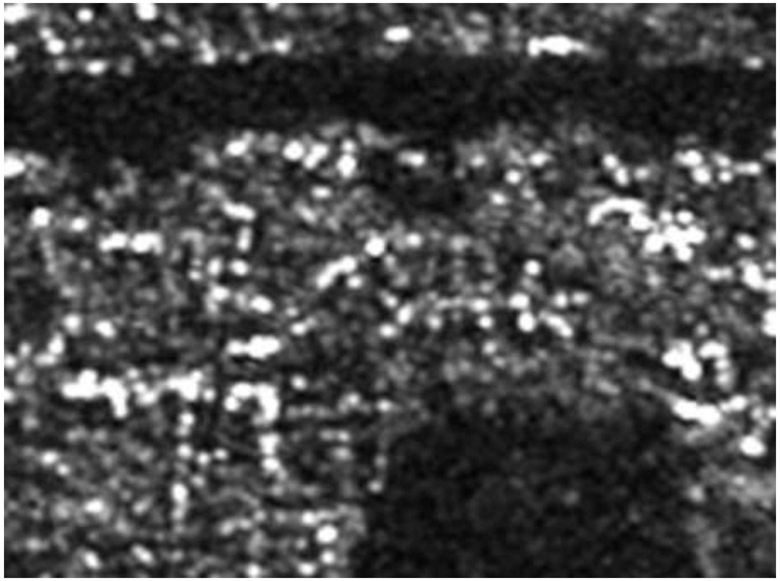



*EA flood outlines for 12/02/2014*



*CSK image of Thames flood west of London on 12/02/2014*

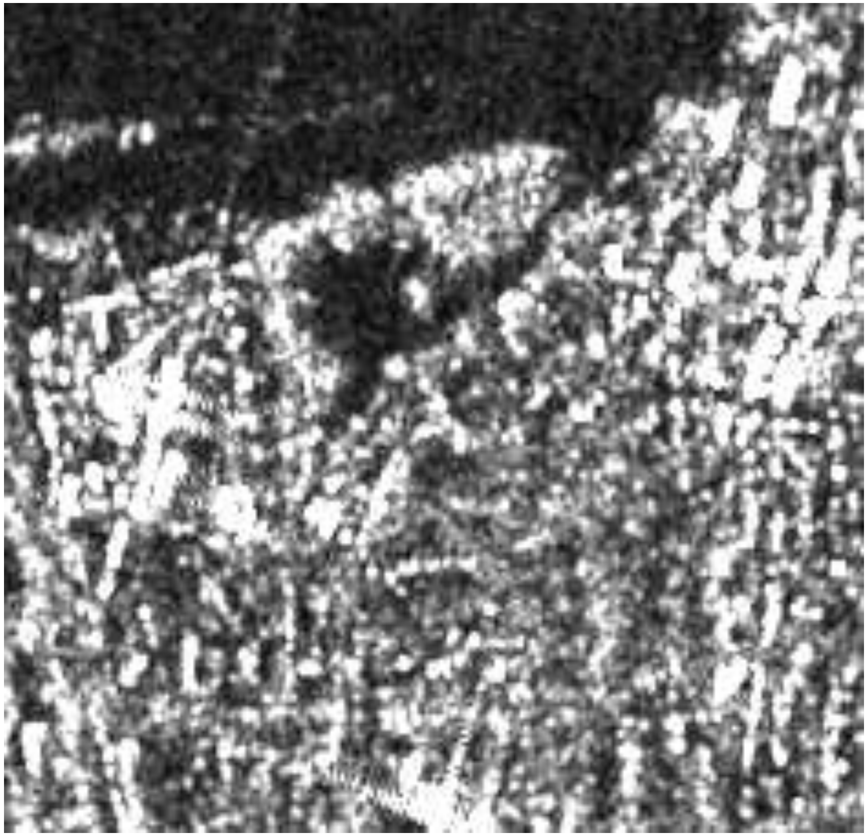
*Press photo*
*(12/02/2104)*



*CSK 3m resolution image*
*(12/02/2014)*

*Flooding in Wraysbury*

*EA aerial photo (13/02/2014)*

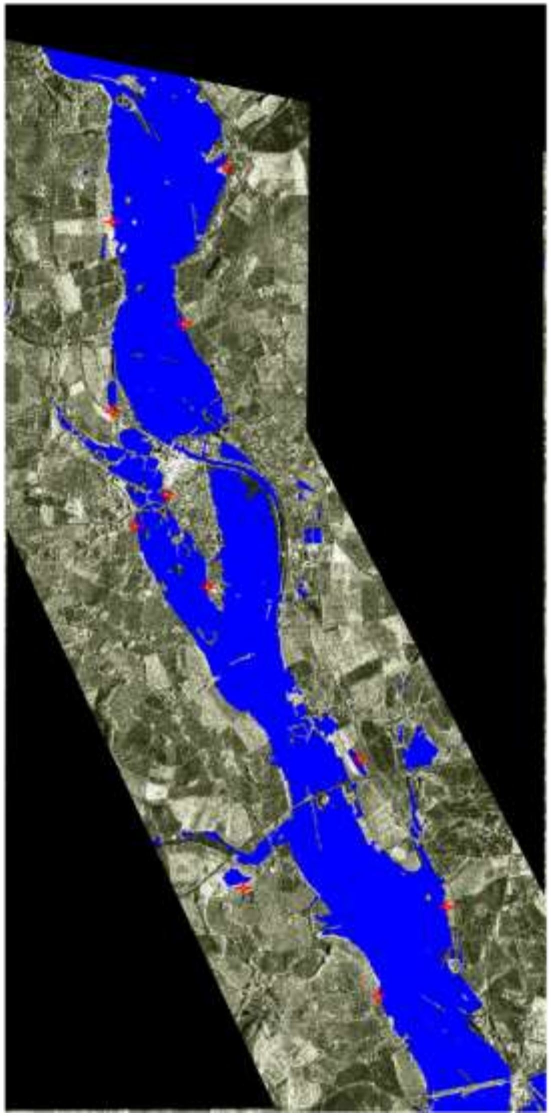


*CSK image (12/02/2014)*

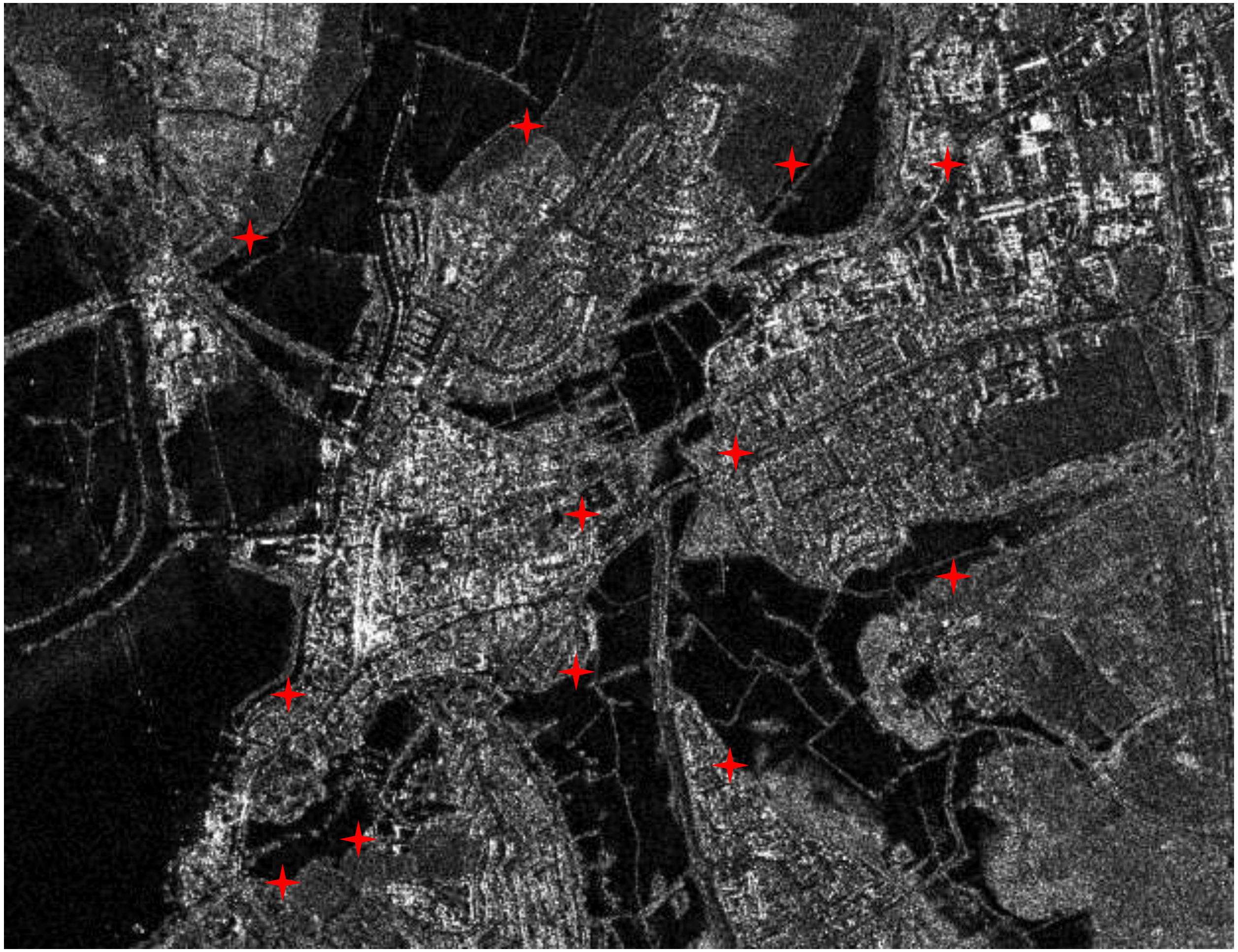
*Flooding in Wargrave*

# How to get water levels from flood extents ……

- flood extents can provide observations for assimilation into a flood forecasting model
- water levels can be estimated along the boundaries of a flood extent by intersecting them with the floodplain DTM
- river gauges provide very accurate water levels, but gauge only every 20 km or so – much more spatial information in waterline
- select a subset of waterline levels for assimilation because adjacent levels will be strongly correlated.
- select candidate waterline points in rural areas of low slope and vegetation, so that levels can be measured as accurately as possible.



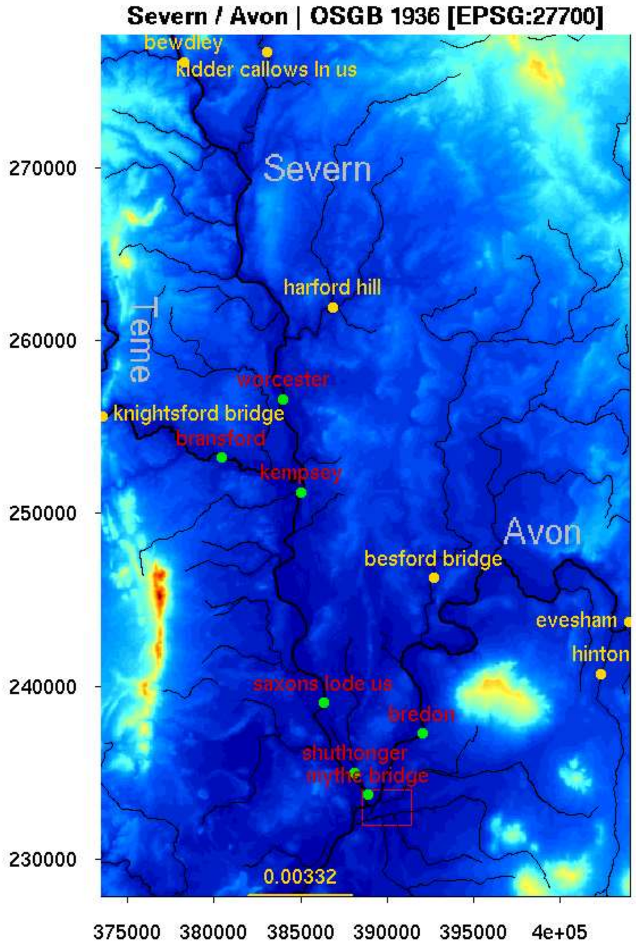
*Candidate waterline points (red) remaining after thinning in rural region .*



*Candidate waterline points (red) remaining after thinning in urban region .*

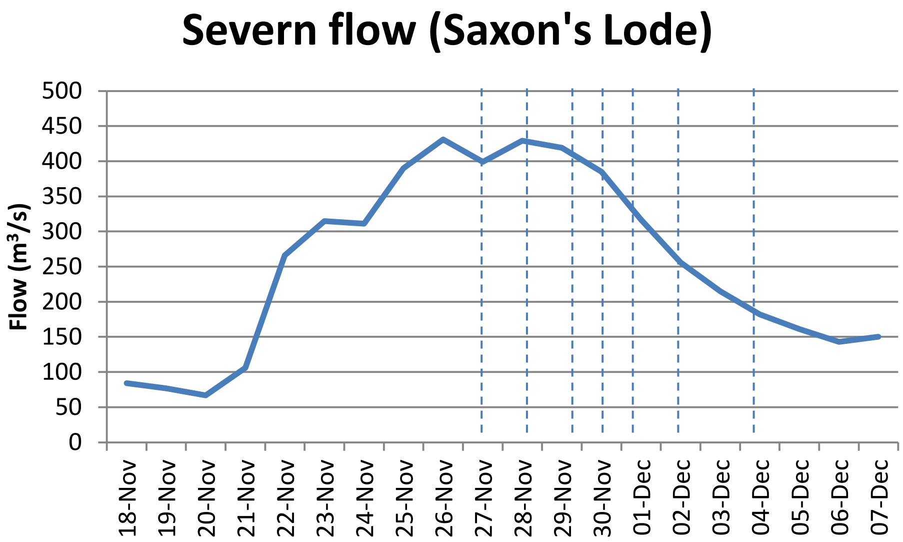
# Satellite-supported flood forecast in river networks: a real case study (links to WP1.2).

- Aim: Improve a flood inundation model using a real sequence of SAR images.
- WLOs assimilated into a model of a river network, to update the model state, and to simultaneously estimate river discharge and model parameters, including river depths and channel friction.
- Study based on a real event on Lower Severn and Avon rivers in November 2012.

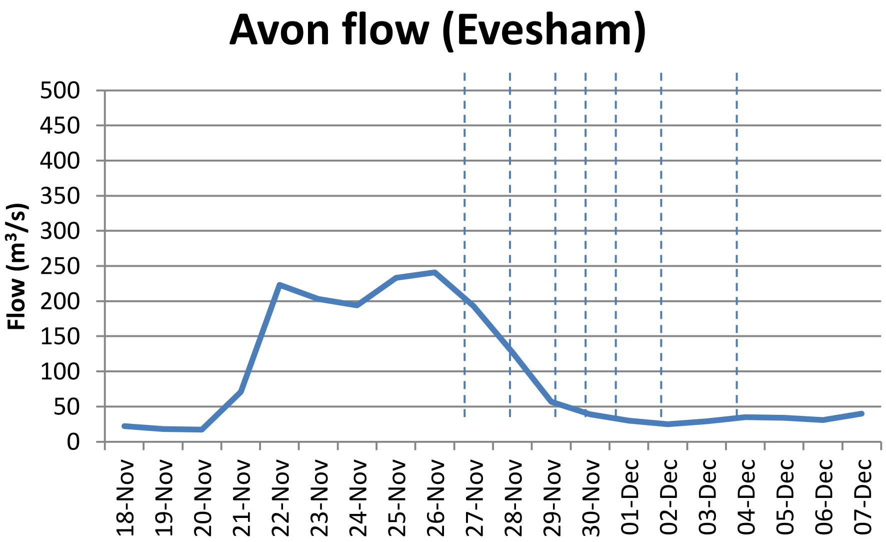


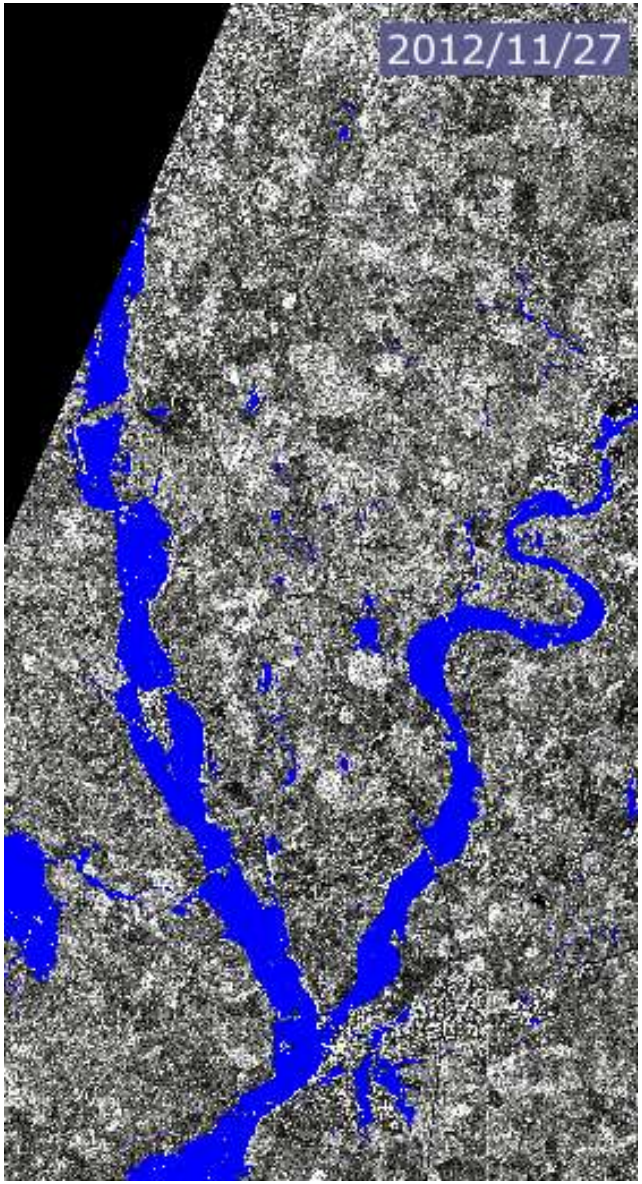

*Flood inundation study area*

# Event of 23 November – 4 December 2012



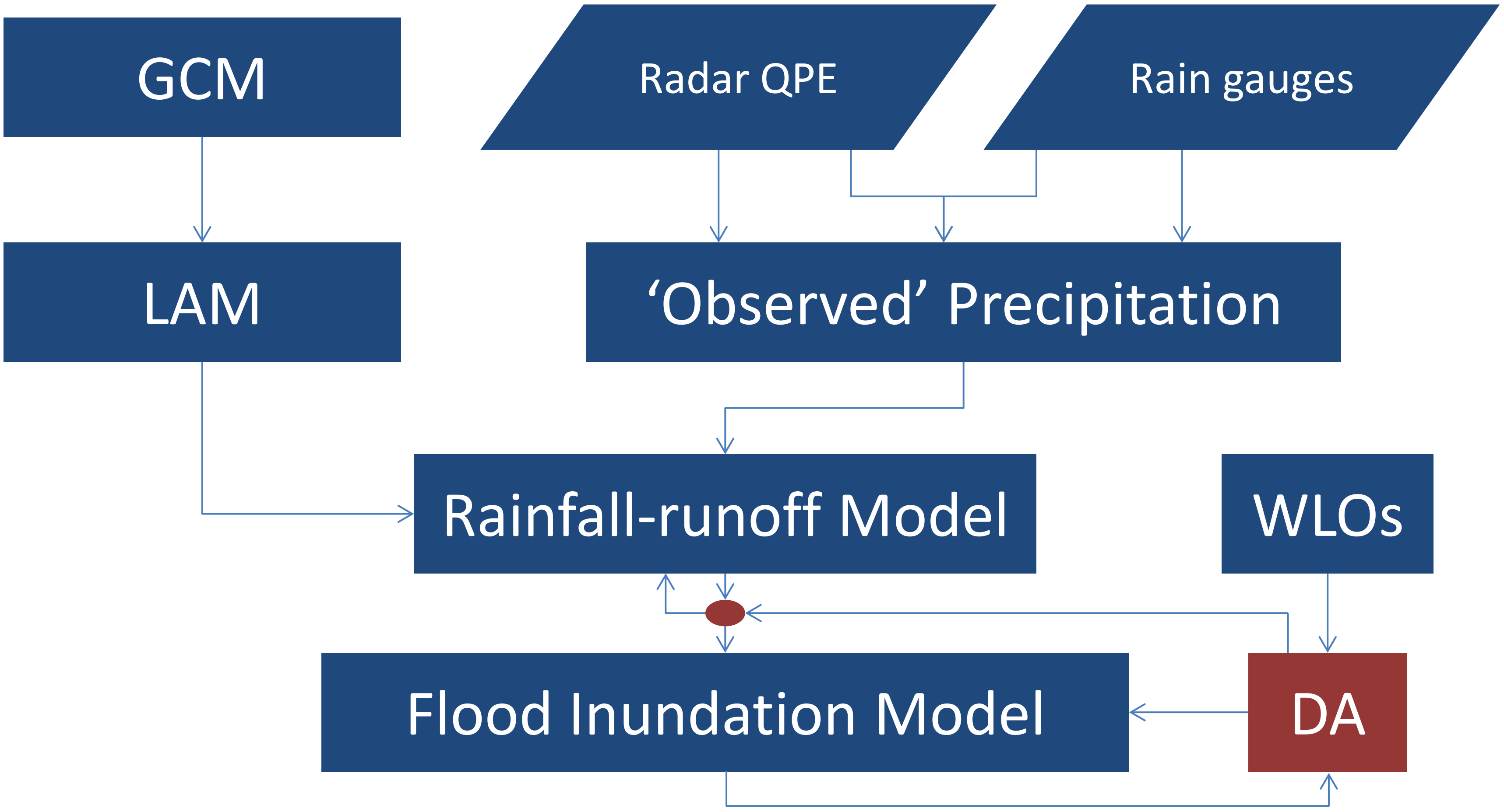






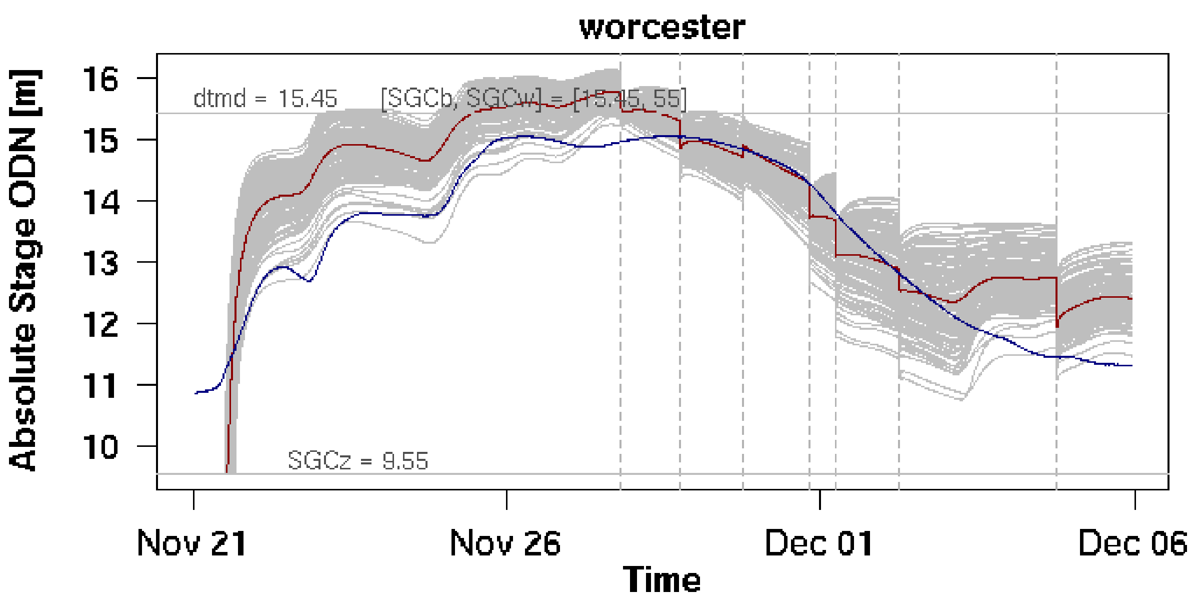

*Daily COSMO-SkyMed images of flood of 23/11/12 – 4/12/12,*
*with flood extents (blue) overlain in model domain.*

# Flood modelling cascade and assimilation system

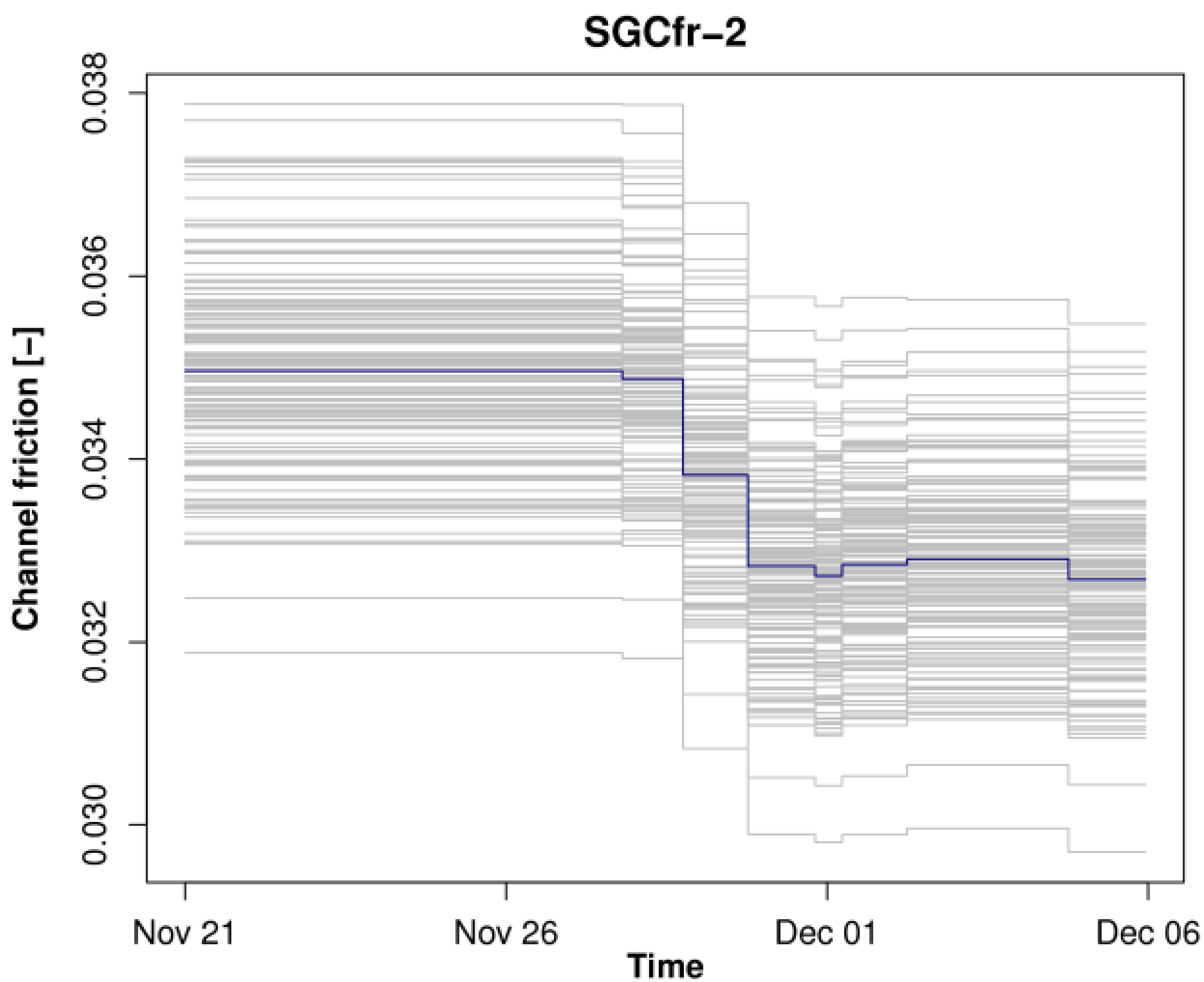


# Data assimilation

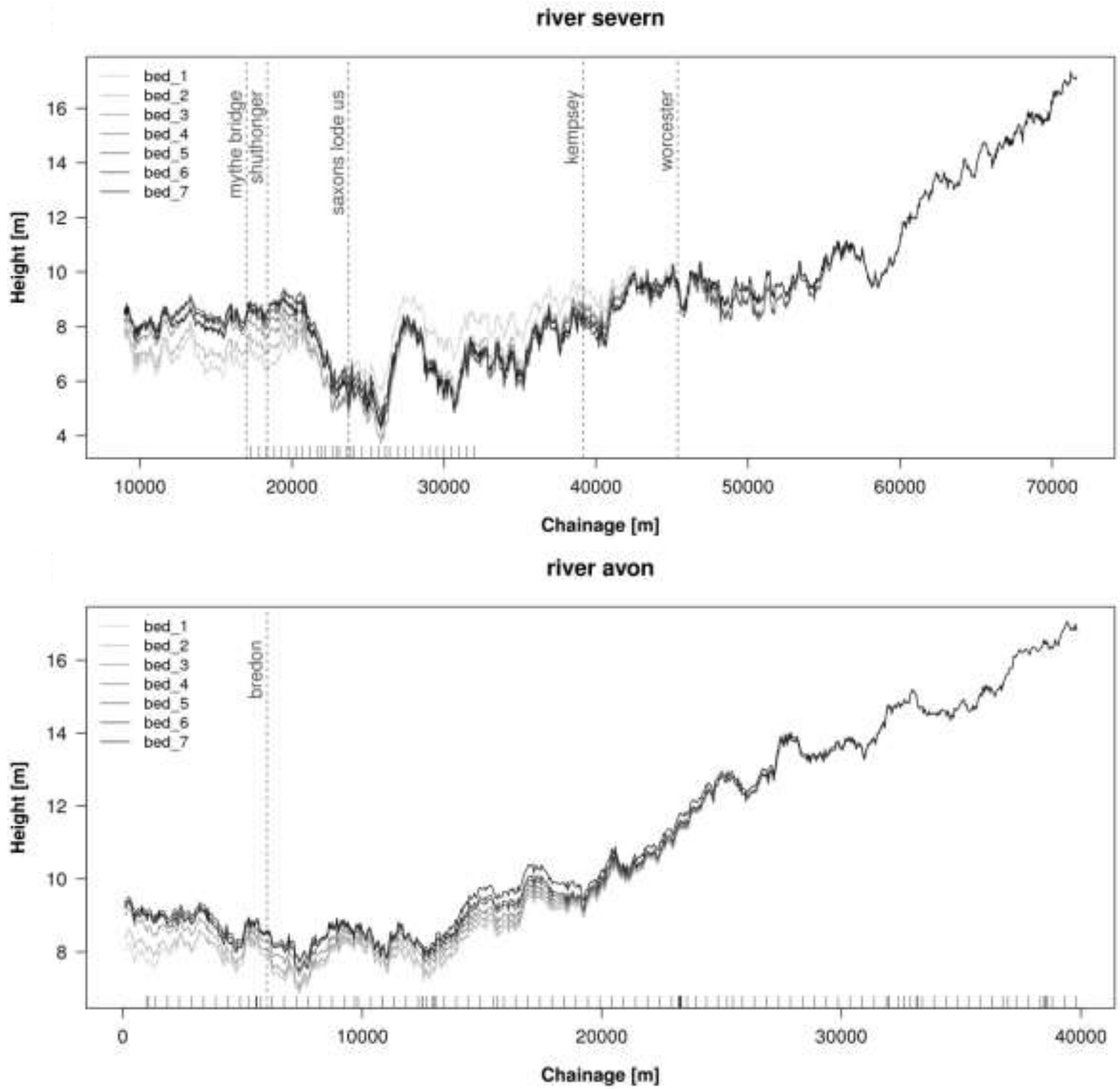
- Data assimilation method was local Ensemble Kalman filter
  - only WLOs within a certain distance of a model water level were used in its correction
  - weight of observations was reduced as their distance from the particular model point increases




*Time series of water levels predicted by the filter at Worcester on the Severn.*




*Evolution of the estimation of channel friction in the assimilation.*




*Evolution of the estimate of river depths during seven sequential assimilation steps for the Severn (top), and the Avon (bottom).*

# WP1.1 link to WP3.1 (technology translation)

- PDRA will be employed as technology translator
- Example of work = developing SAR urban flood delineator to be stand-alone
- Market research study