DARE: Data Assimilation for the Resilient City

EPSRC Senior Fellowship in Digital Technology for LWEC (DT/LWEC)

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Vulnerable city
DEFRA London Climate Change Risk Assessment (2012)
- Flooding
- Heat stress
- Water availability

But not just London!

Solutions from maths and digital technology

8th August 2015 night time ASTER TIR image for Greater London
Vision: Revolution in model predictive skill

Observations

Model state

Data Assimilation

Updated state and parameters

Improved Forecast
DARE programme

WP1: DA for urban flood inundation modelling

WP2: Understanding natural variability of urban observations

WP3: Technology Translation and Knowledge Exchange

WP4: DT/LWEC network
Pilot projects

- £75k available – expect to fund 3x £25k projects
- research, knowledge exchange or science outreach activities
- application of digital technologies to help the human and natural environments be more resilient and adaptable to climate change.
- Anything considered! (Some workshop activities to help with ideas)
- Must have a concrete deliverable

Eligibility:
- UoR has to obey EPSRC rules
- Early career
- Business
- Overseas

Application: 1 page case for support; 1 page budget; (letter of support)

Deadline: January 15
Rest of the talk

• Introduction to data assimilation
• Introduction to flood modelling

Sanita Vetra-Carvalho

• Observations & Practical Assimilation
The Ensemble Kalman Filter (EnKF)

Construct an ensemble \( \{x_i^f\}, (i = 1, \ldots, N) \) : 

\[
P^f = P_e^f = \left( x^f - \overline{x^f} \right) \left( x^f - \overline{x^f} \right)^T,
\]

\[
P^f H^T = \left( x^f - \overline{x^f} \right) \left( H \left( x^f \right) - H \left( \overline{x^f} \right) \right)^T,
\]

\[
H P^f H^T = \left( H \left( x^f \right) - H \left( \overline{x^f} \right) \right) \left( H \left( x^f \right) - H \left( \overline{x^f} \right) \right)^T.
\]

Use these in the standard KF equation to update the best estimate (ensemble mean):

\[
\overline{x^a} = \overline{x^f} + P^f H^T \left( H P^f H^T + R \right)^{-1} \left( y^o - H \left( \overline{x^f} \right) \right).
\]
Inundation Forecasting

- Shallow water modelling
- Must be able to deal with
  - Shocks
  - Complex topography (may change with time!)
  - Sources
  - Outflow B.C.s
  - Sinks (infiltration)
  - Wetting and drying

- [Urban areas harder - sewer network, buildings]
- Movie made with Clawpack (open source finite volume code by LeVeque et al)
Inundation Forecasting

Uncertainty in inputs leads to uncertainty in inundation forecast.
WP1.1 Delineation of urban floods using SAR
Example: Satellite observations of flood extent

TerraSAR-X image of Tewkesbury flooding on 25th July 2007, showing detail in urban areas (dark areas are water) (© DLR 2007).
TerraSAR-X image of the lower Severn July 2007 flood, with derived flood extent (blue) overlain (© DLR 2007).
SAR shadow (Mason et al 2014)

Tewkesbury lidar height map (DTM)

Regions unseen (black) in TerraSAR-X image due to shadow and layover
Results: Feb 2014 Thames Flood

CosmoSkyMed images obtained under CORSAIR

150m x 150 m Blackett Close, Staines

EA 2m DSM of the same area

CSK image (Blackett Close in red box)
Flood detection

(a) Predicted flood extent in Blackett Close validation area (light grey = flooded in SAR and aerial photo, dark grey = flooded in aerial photo only), and (b) extract from SAR image.

78% flood detection rate
Network activities and plans

• Website (blog etc) [http://research.reading.ac.uk/dare/](http://research.reading.ac.uk/dare/)
  – Blog contributors welcomed

• DARE workshop Henley
  – Workshop meeting report to be published in peer reviewed literature

• Adjoint workshop training course (July 2018)
  – 1 day Data Assimilation tutorial as part of wider international workshop (Portugal)

• Pilot project (call launched at this workshop)

• WhyWhatNow? summaries