Develop an HPC-based Hydrological Modelling Framework to Support Extreme Weather Impact Studies

Y. Xuan

College of Engineering
Swansea University, UK

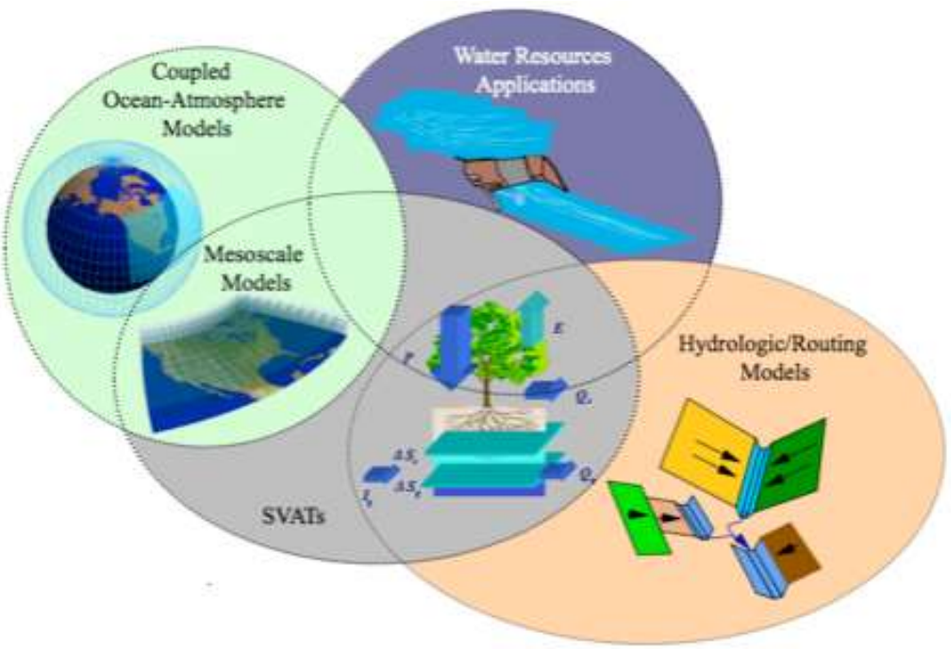
HIC2014, New York, 20th August, 2014

SWANSEA UNIVERSITY
PRIFYSGOL ABERTAWE

Knowledge Transfer Partnerships

www.swansea.ac.uk

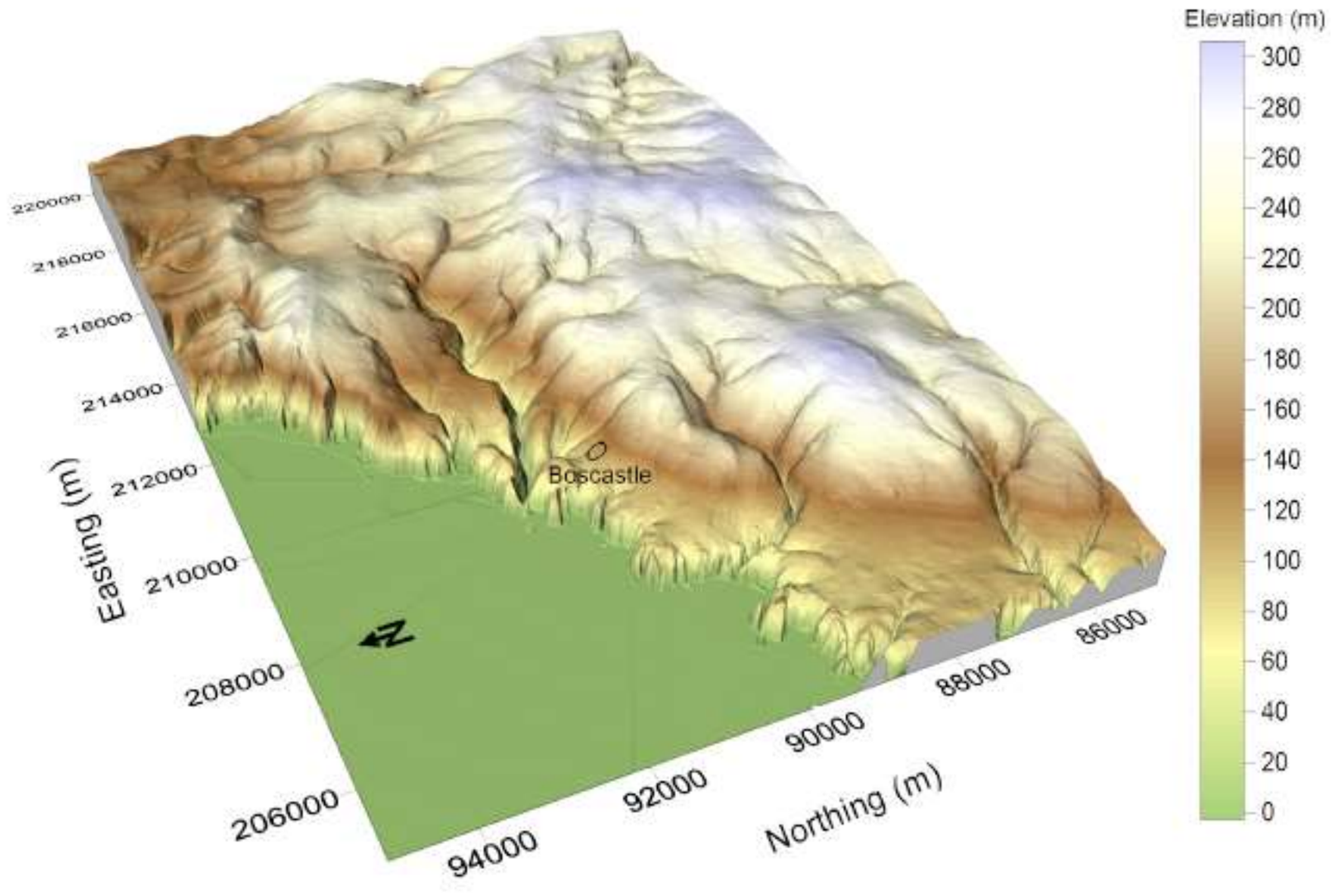
Research Areas

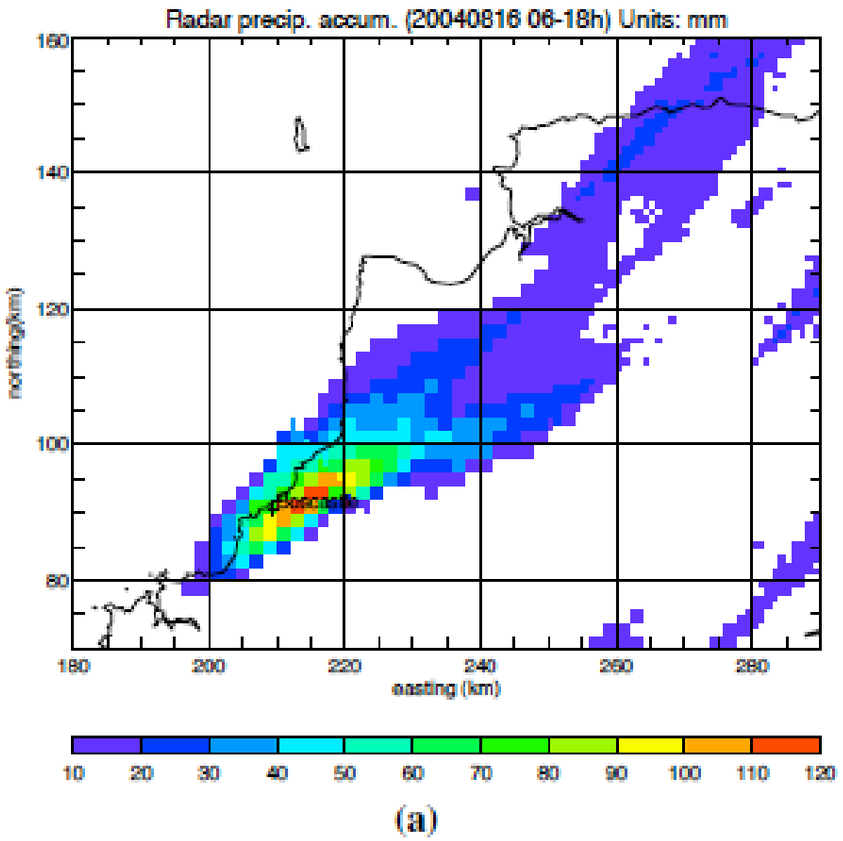


- Hydrology: Hydrological modelling.
- Water Resources & Climate Change Impact: Climate modelling & data downscaling, uncertainty analysis.
- Flood Risk Management: Flood modelling, Numerical Weather Prediction and weather radars applications, extreme storms.
- Hydroinformatics: HPC, Model integration, GIS & remote sensing, DSS.

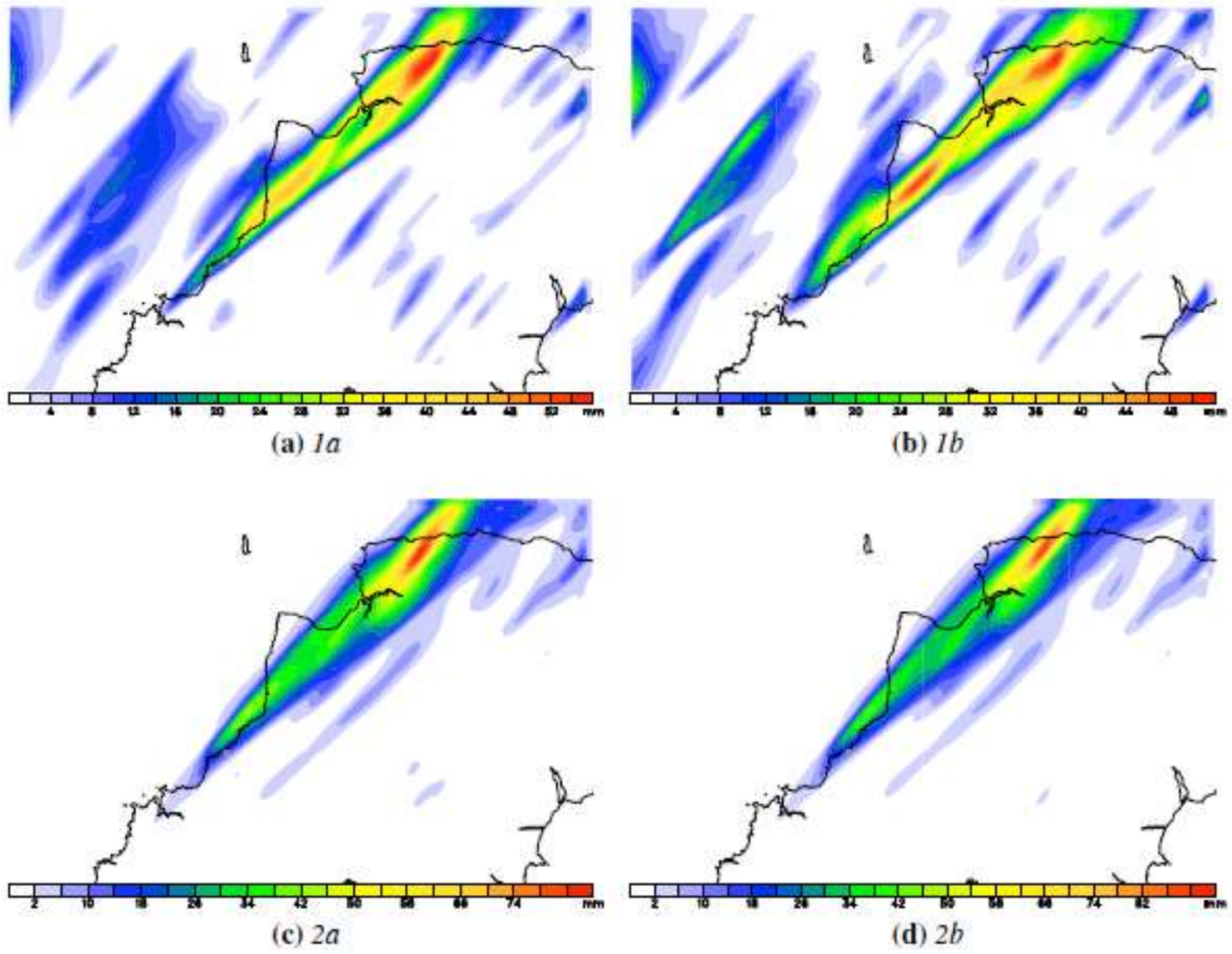
Boscastle Case: Uncertainty in high res QPFs

Image credit: EA





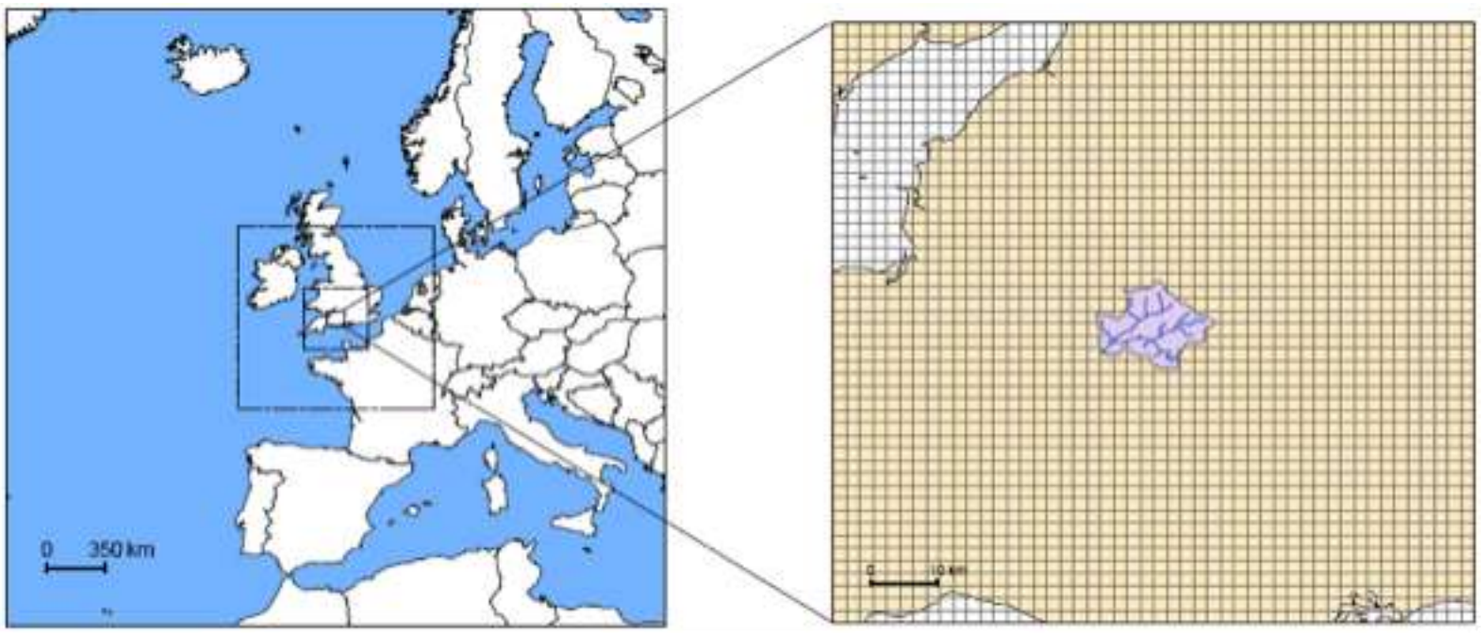
(a)



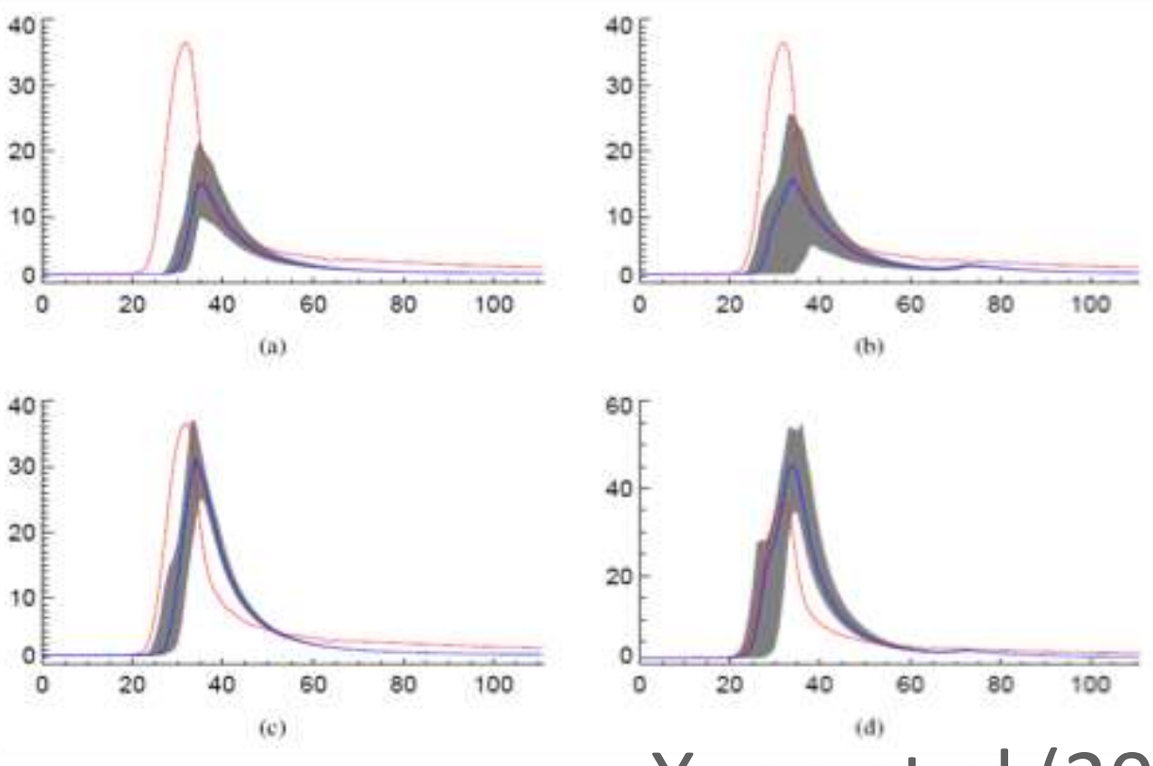
Radar

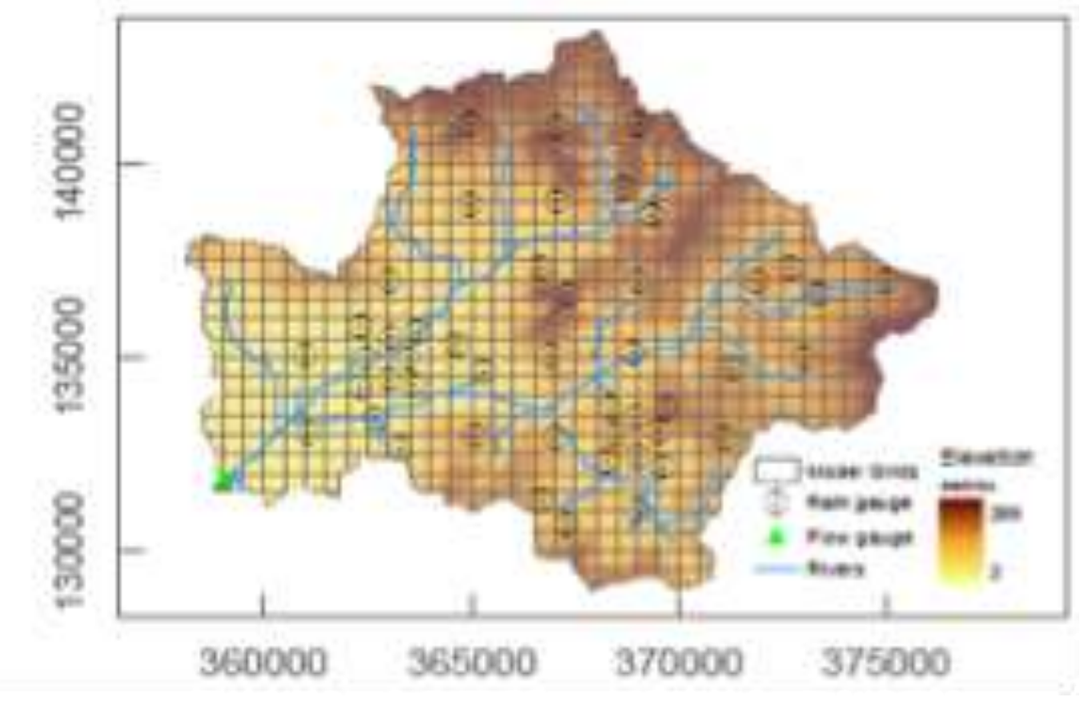
Rainfall forecast from two regional NWP models w/ different IC/LBC's (Xuan, 2007)

Model Coupling and Ensemble Flow Forecast to Address Forecast Uncertainties



High-res NWP + Distributed Hydrological model

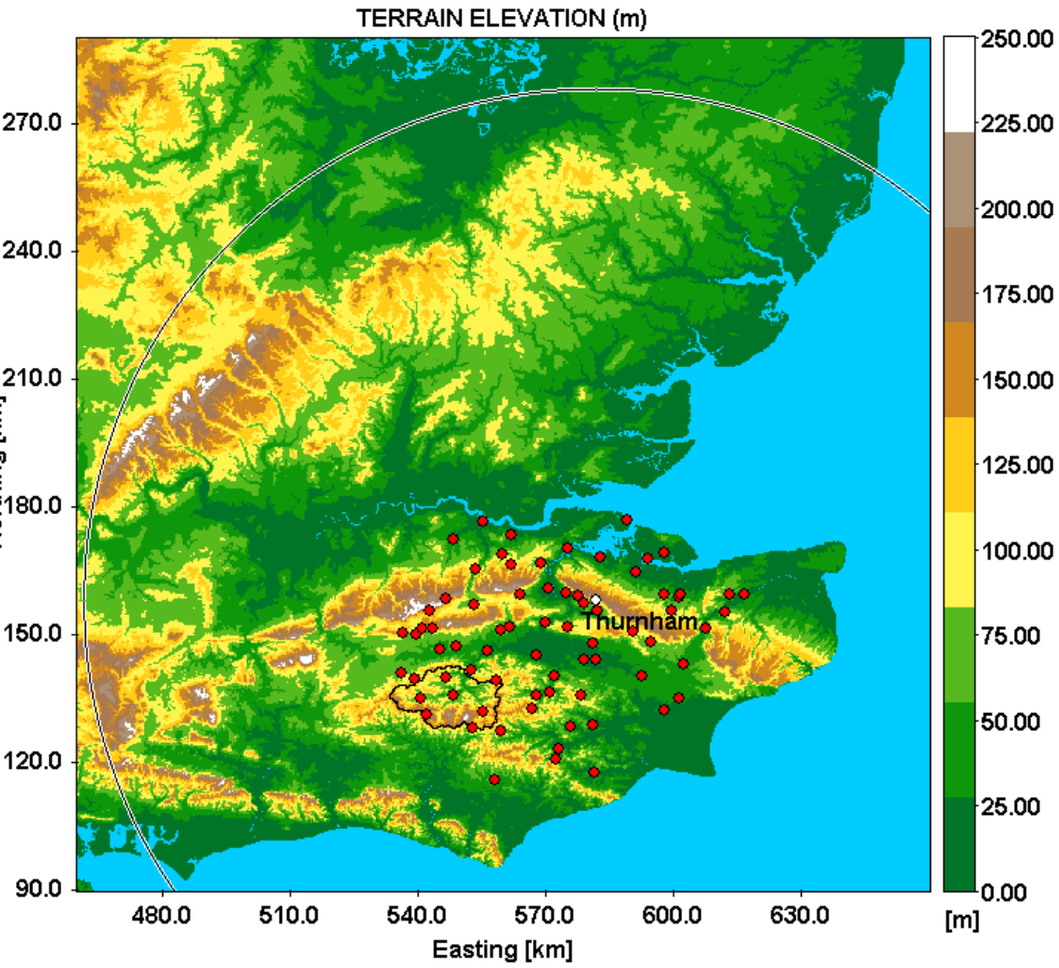


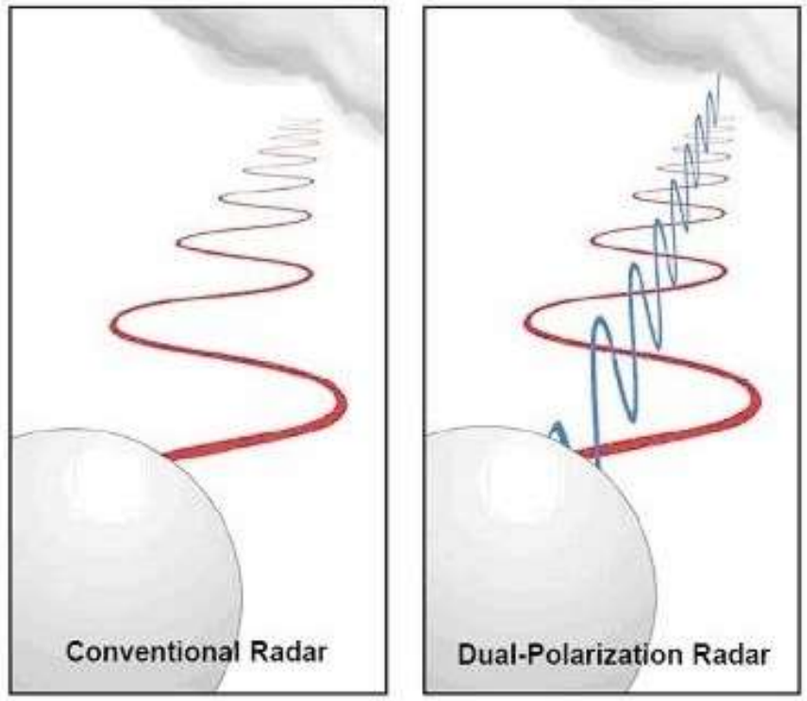


Xuan et al (2008)

Hydrological Appraisal of Thurnham Dual Polarisation Weather Radar (FRMRC 2nd Phase)

1st C-band Dual-Polarisation Radar (5.4 GHz, 5 cm wavelength)





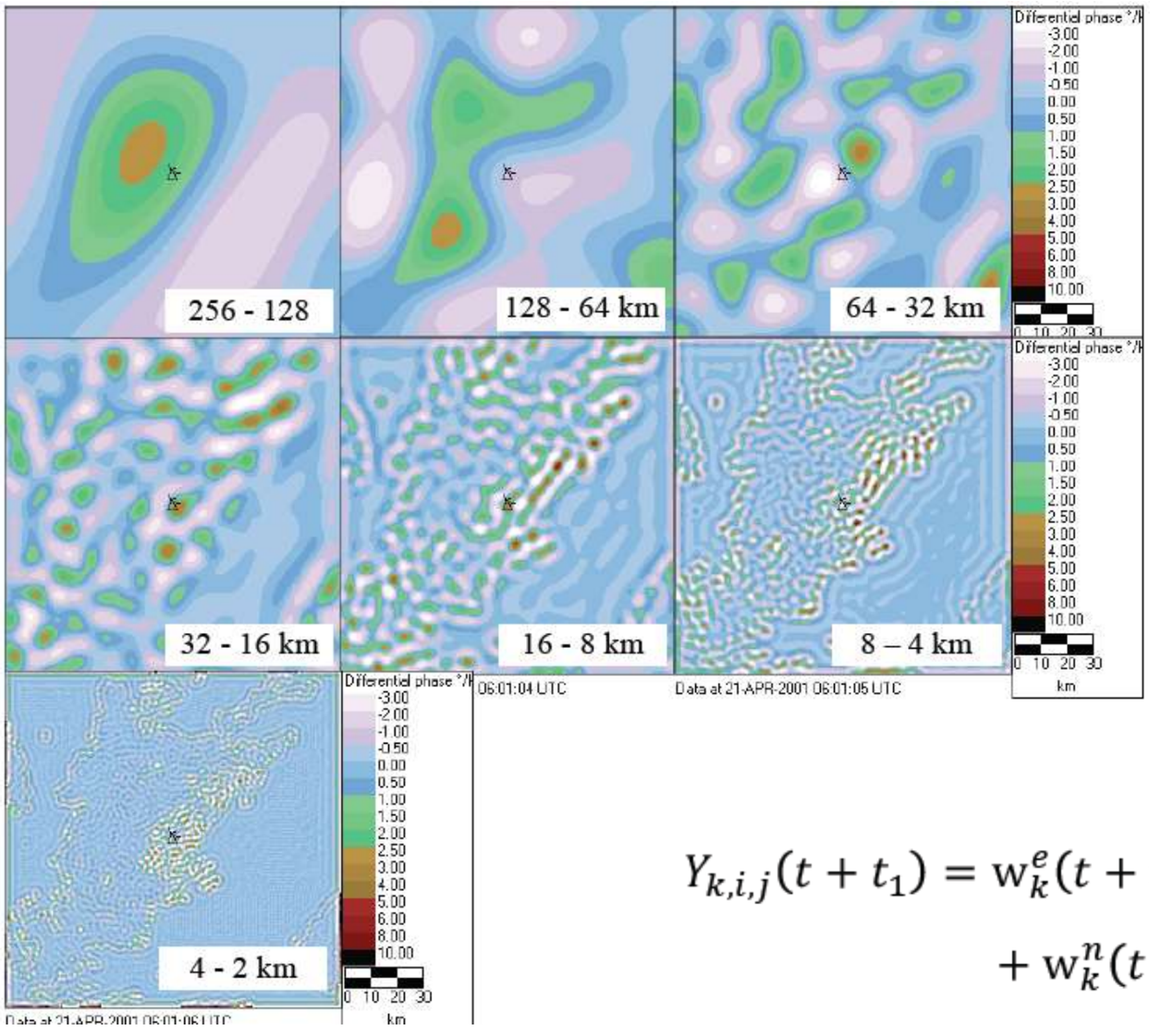
Swansea University
Prifysgol Abertawe

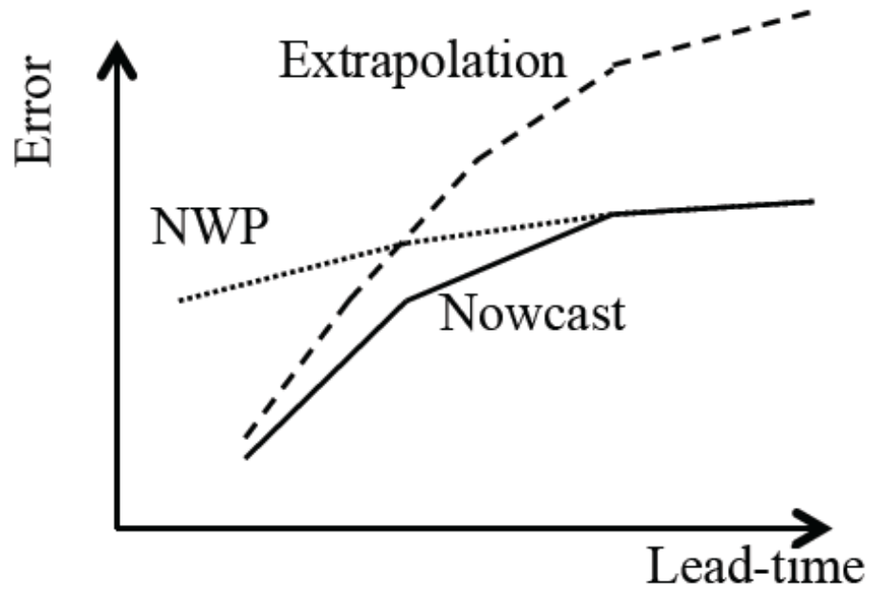
Met Office

University of BRISTOL

FRMRC flood risk management research consortium

Radar Rainfall Nowcast - the STEPS system

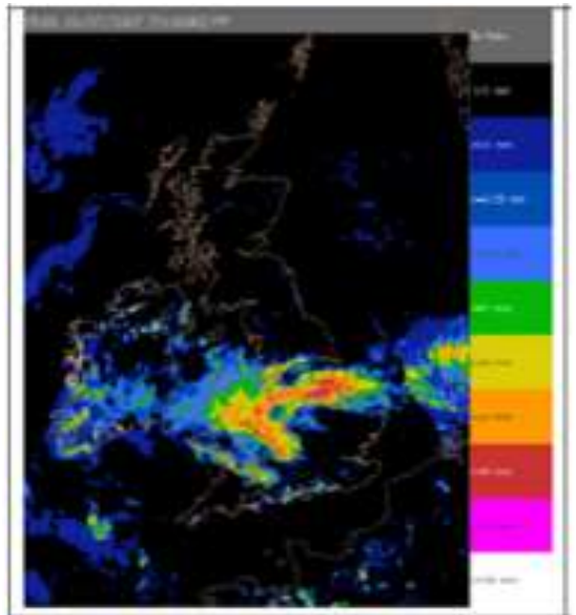




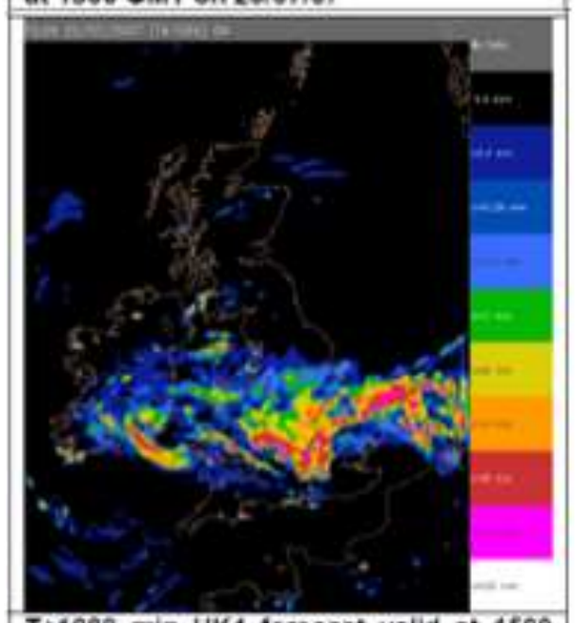
$$Y_{k,i,j}(t+t_1) = \mathrm{w}_k^e(t+t_1)Y_{k,i,j}^e(t+t_1) + \mathrm{w}_k^m(t+t_1)Y_{k,i,j}^m(t+t_1) + \mathrm{w}_k^n(t+t_1)Y_{k,i,j}^n(t+t_1)$$

Seed et al.

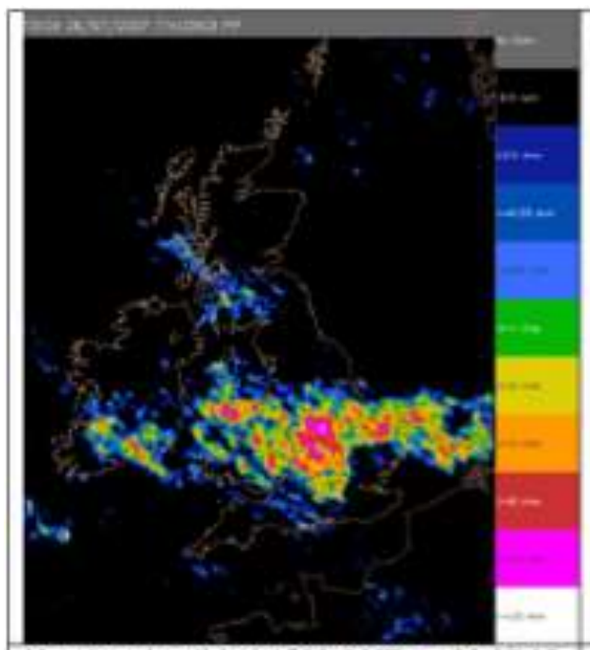
STEPS Ensemble



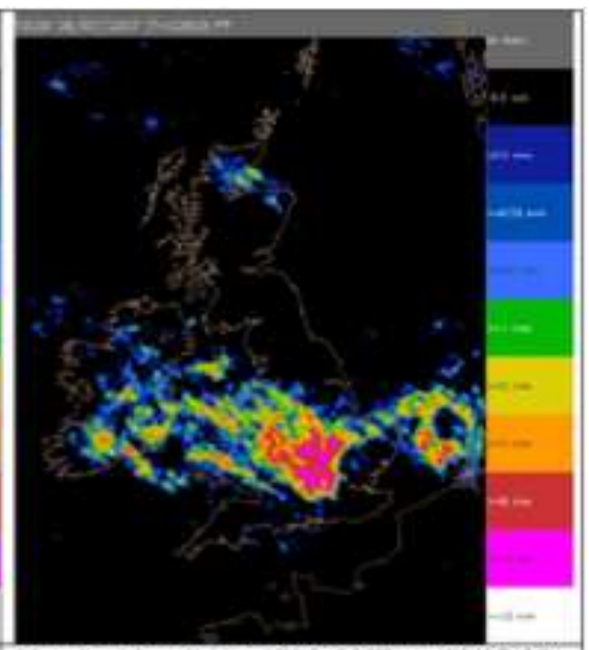
UKPP analysis of surface rain rate valid at 1500 GMT on 20/07/07



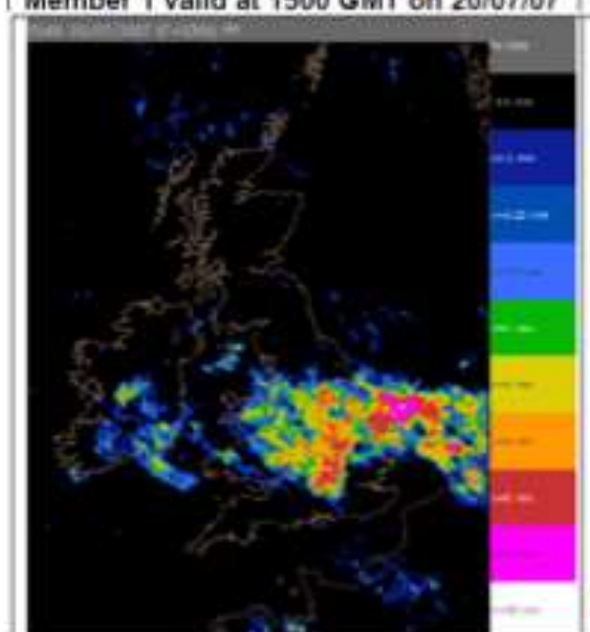
T+1080 min UK4 forecast valid at 1500 GMT on 20/07/07



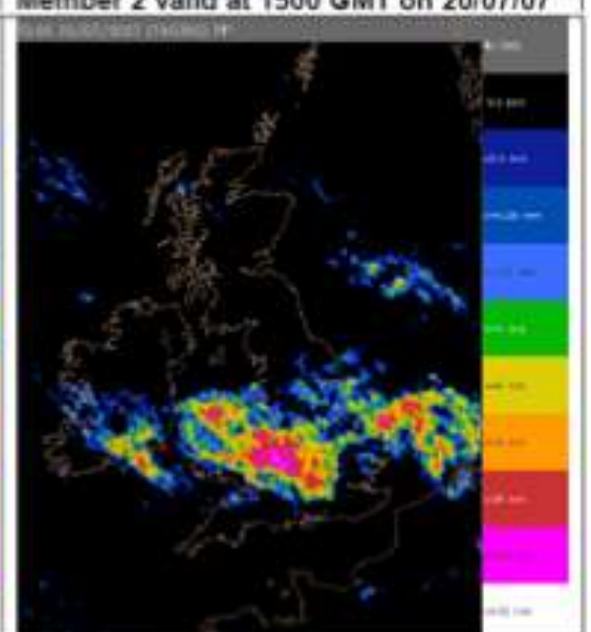
Member 1 valid at 1500 GMT on 20/07/07



Member 2 valid at 1500 GMT on 20/07/07

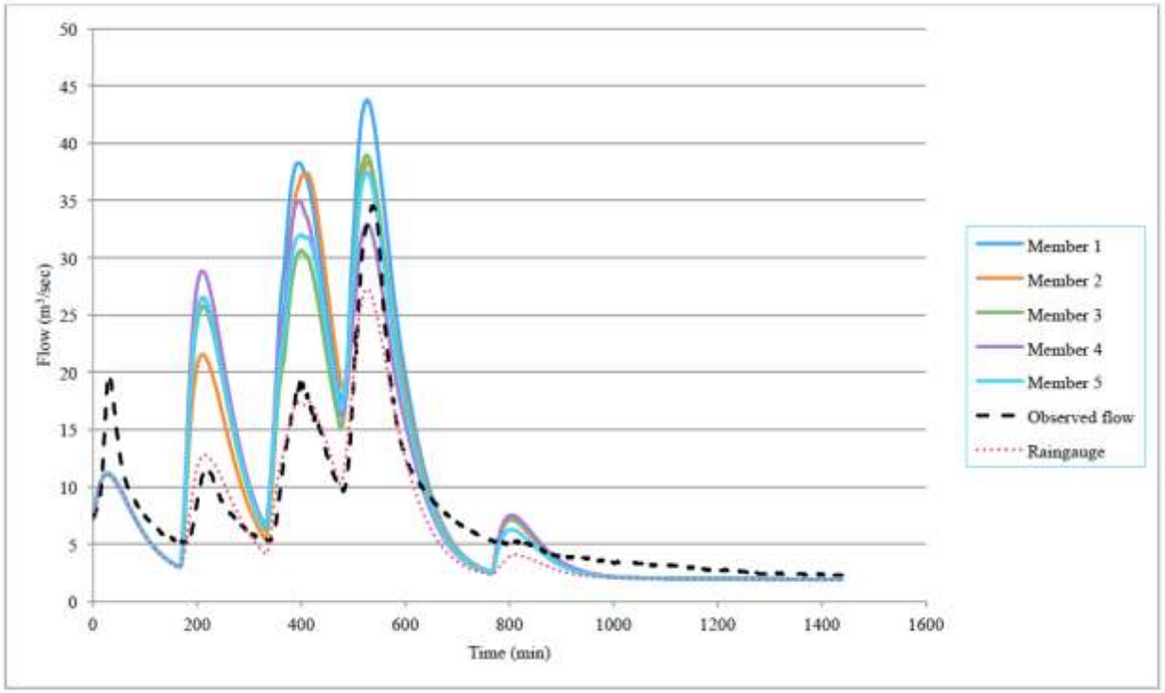


Member 3 valid at 1500 GMT on 20/07/07

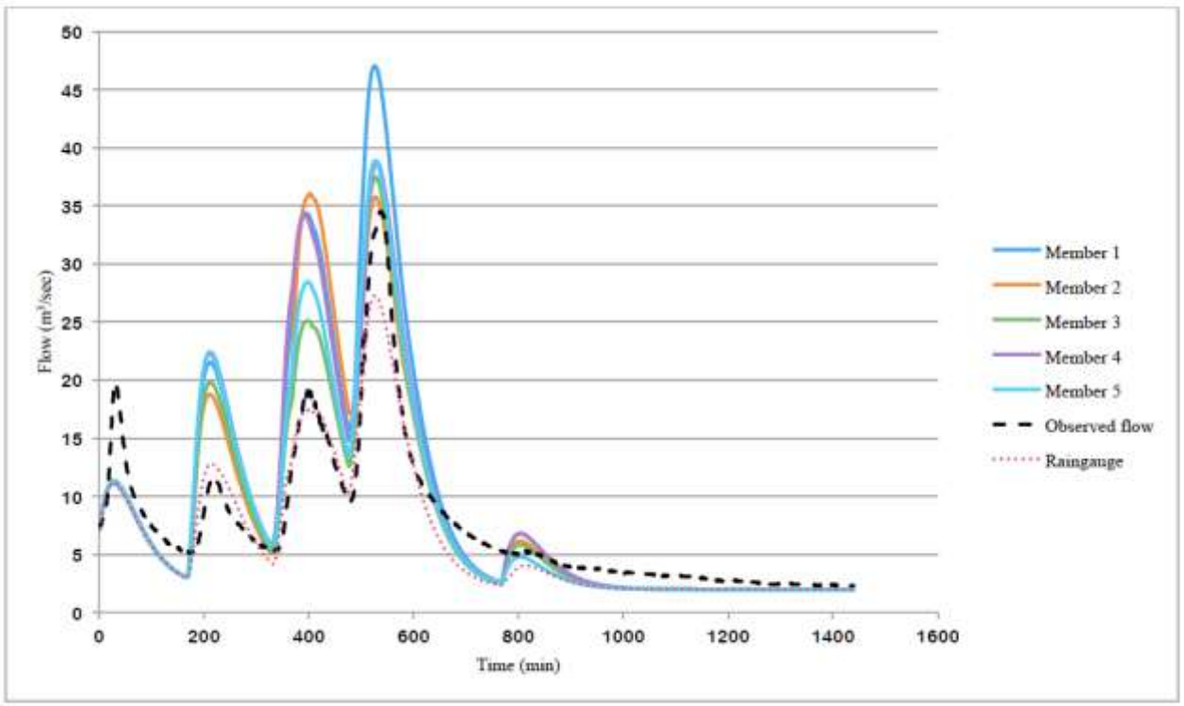


Member 4 valid at 1500 GMT on 20/07/07

Ensemble Flow Forecast



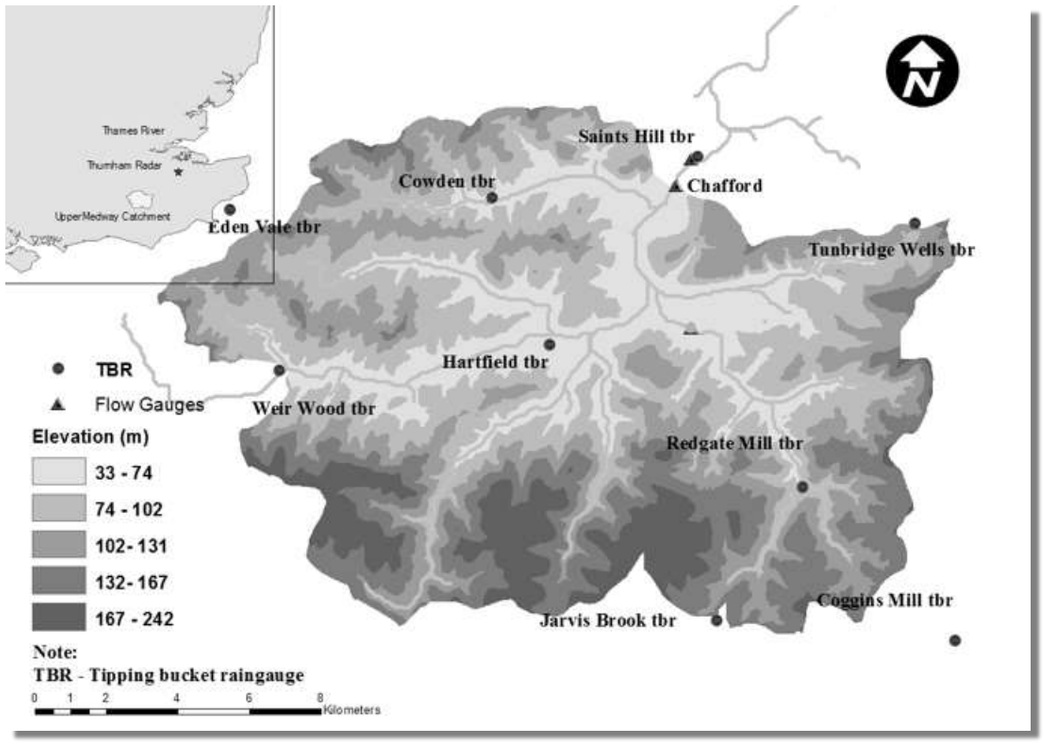
30-min lead time

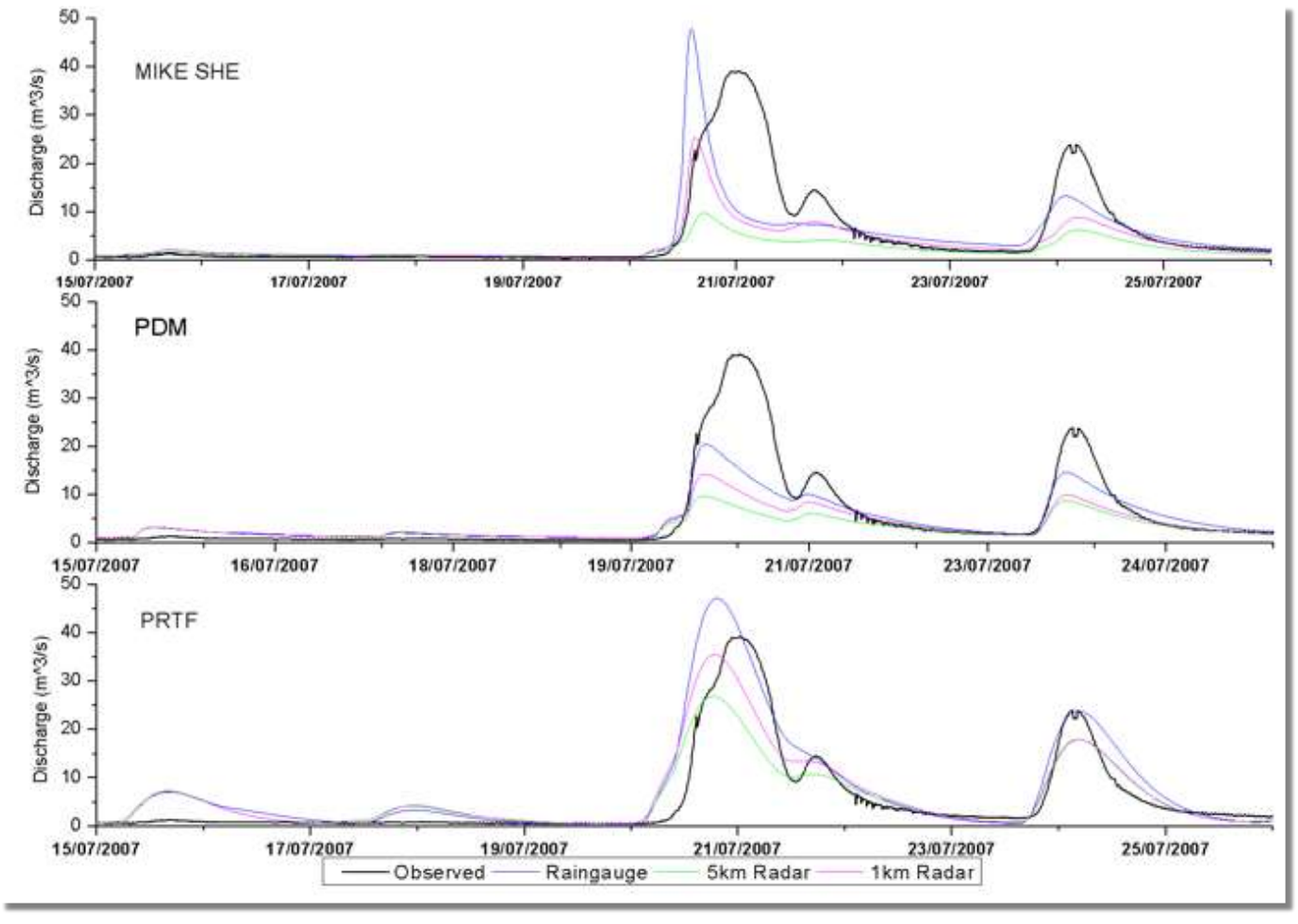


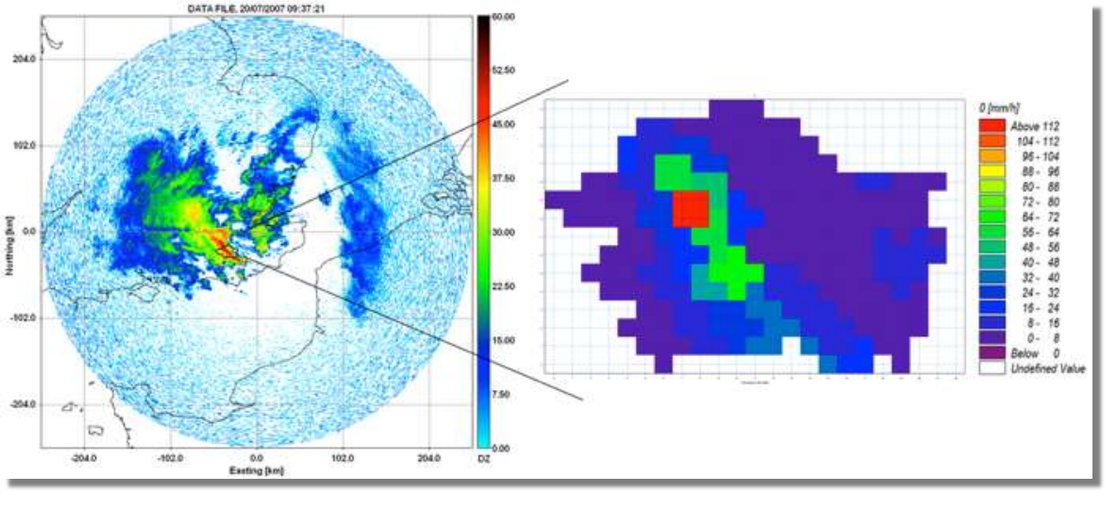
60-min lead time

Xuan et al (2014)

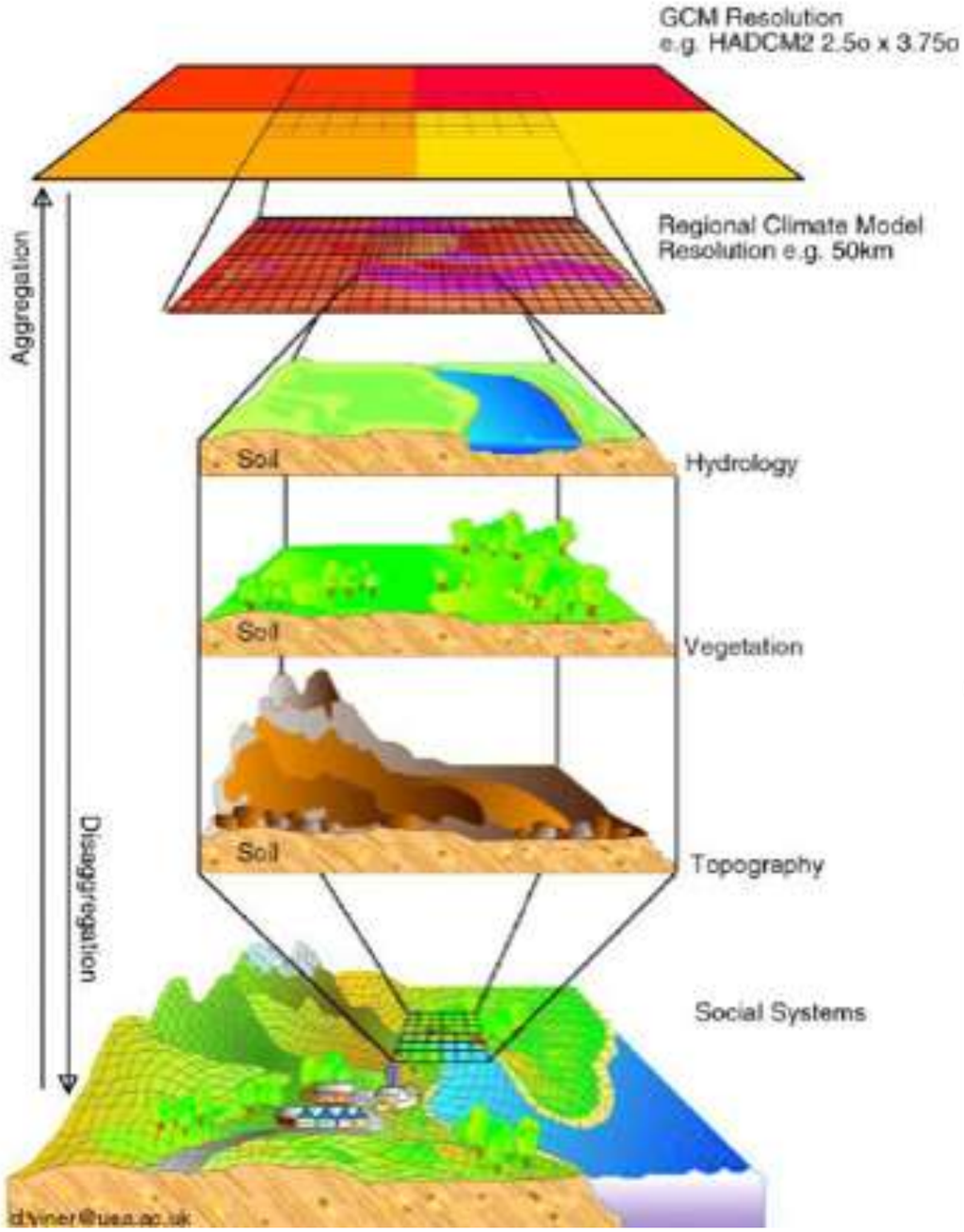
Impact of model structure and storm types on flow simulation using different hydrological models with radar rainfall inputs







Zhu, D., Y. Xuan and I. Cluckie (2014)



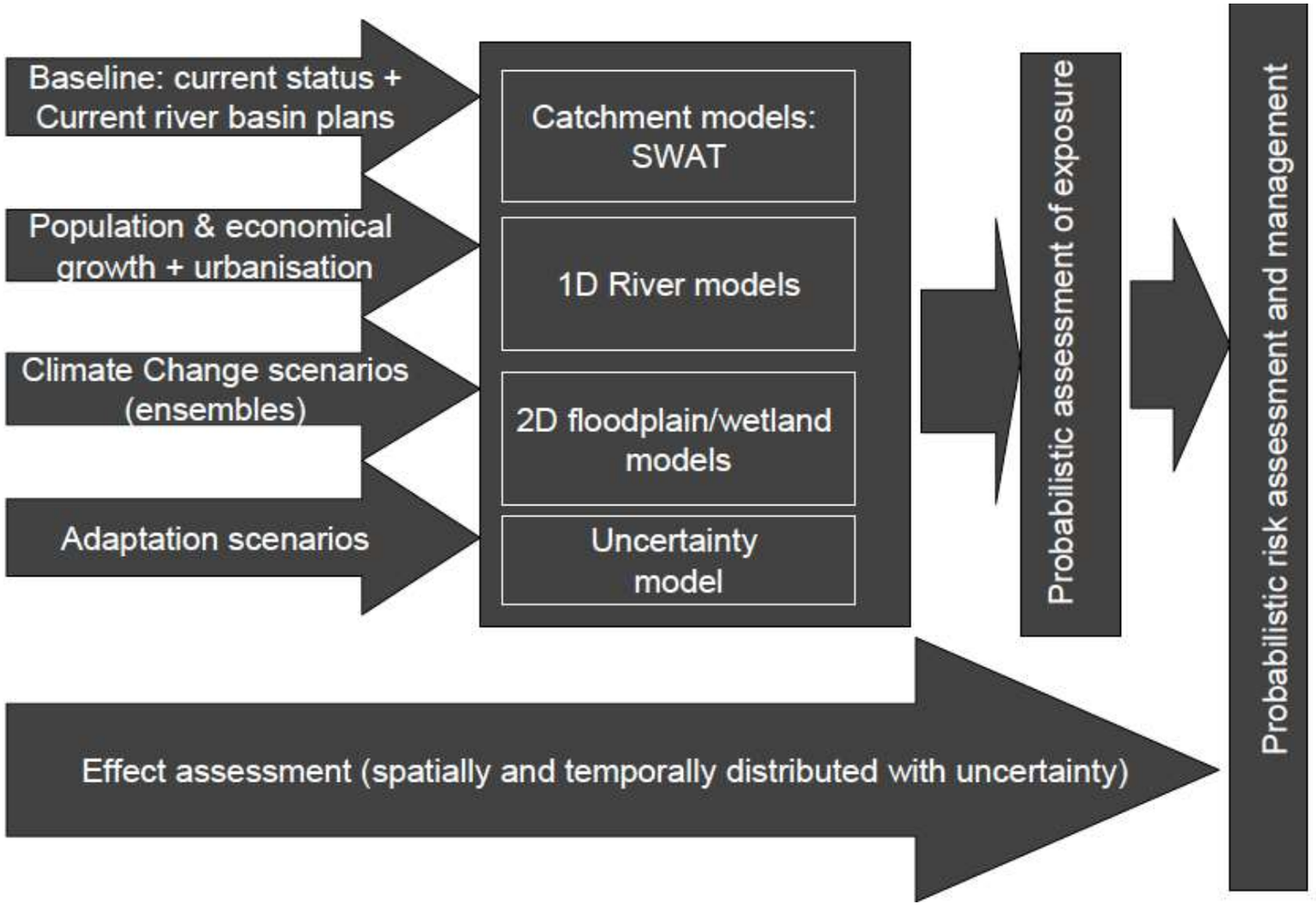
Source: CRU

Climate Change Impact, data downscaling and model coupling

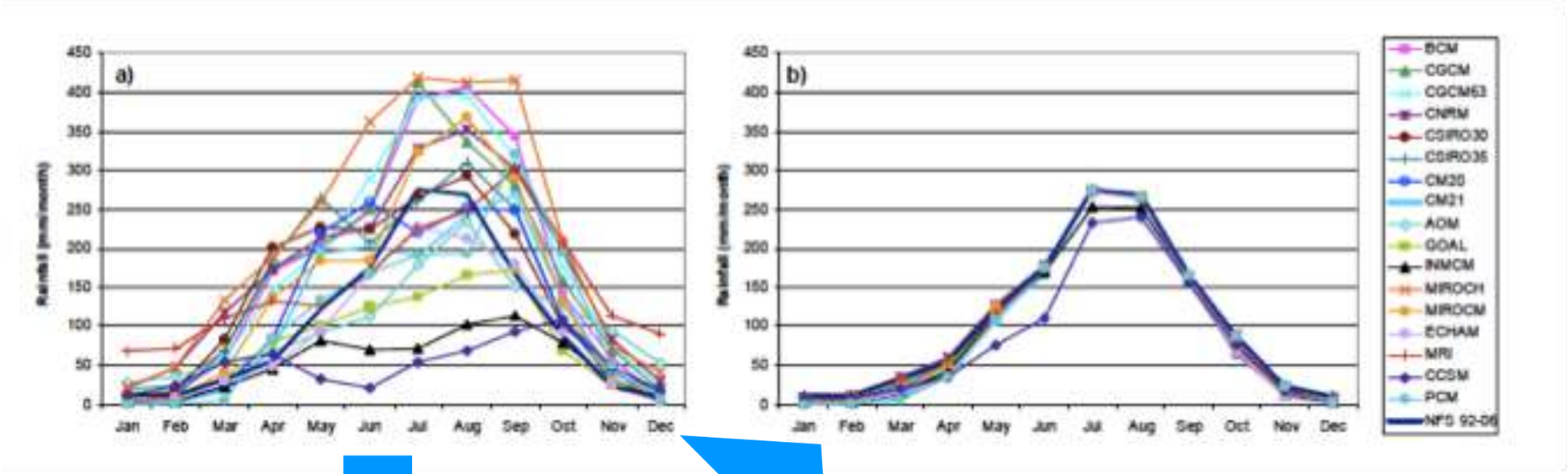
From GCM to Water Models, a downscaling/disaggregation process is needed.

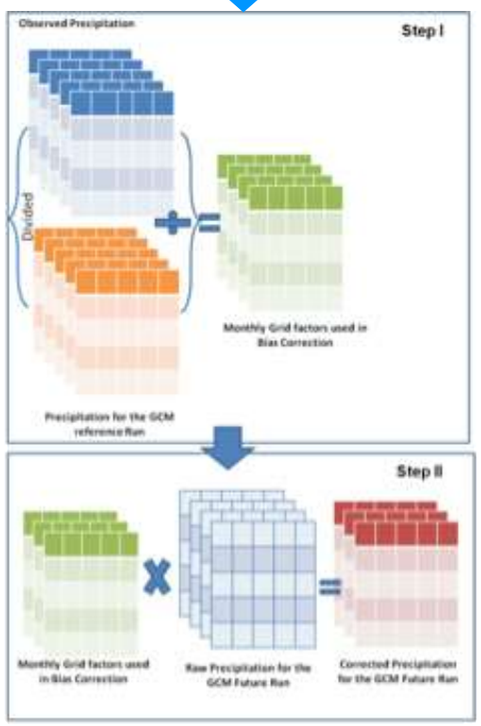
The downscaling can also be achieved using statistical method

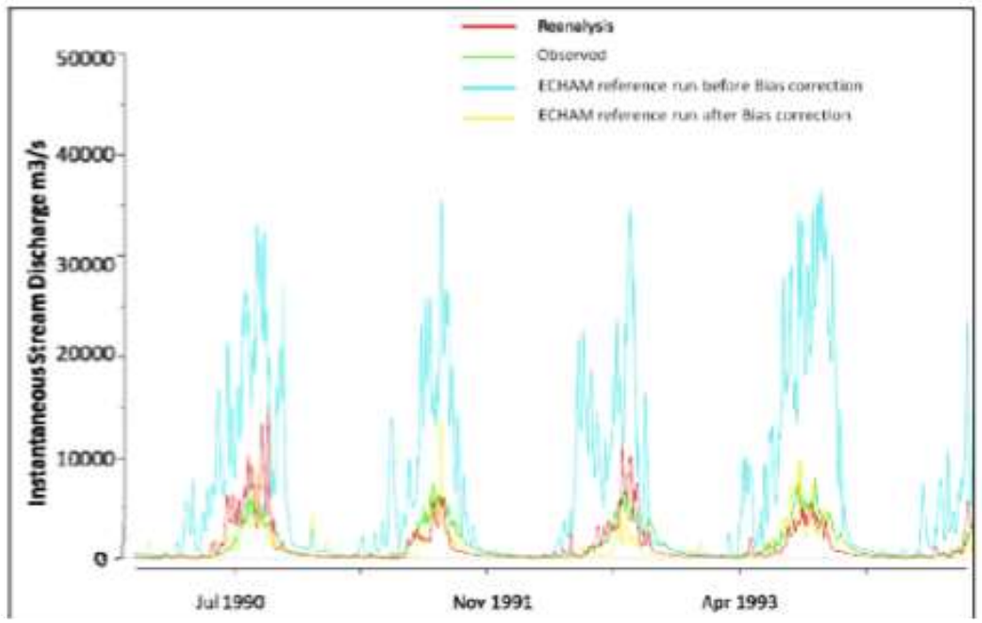
Adaptation to Climate Change Impacts on the Nile River Basin



Manipulating the Data - Bias Correction

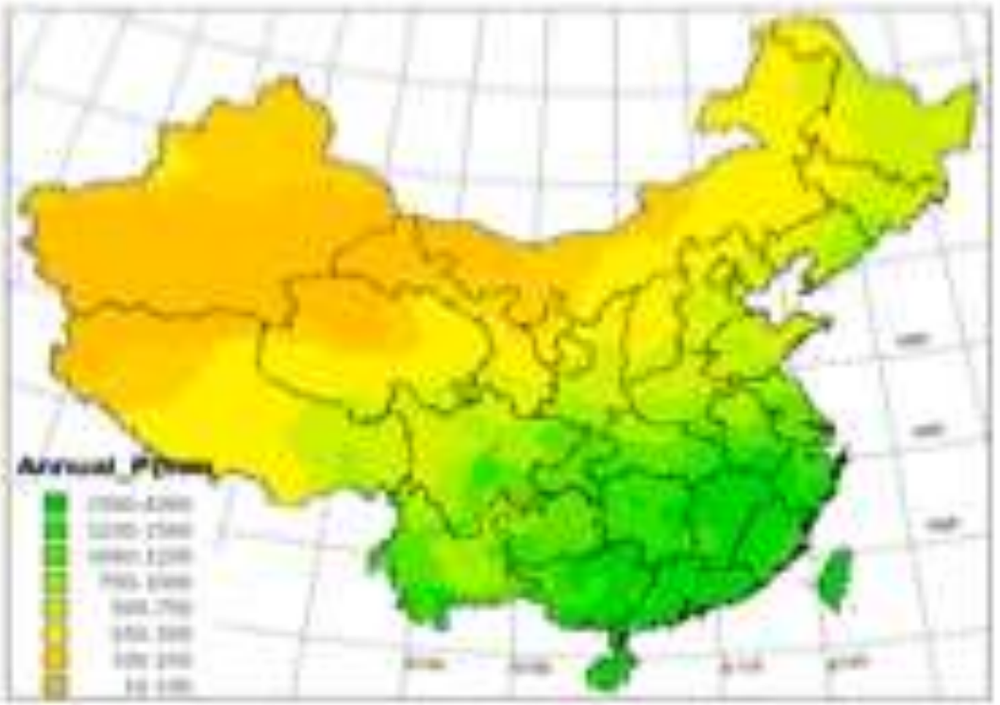


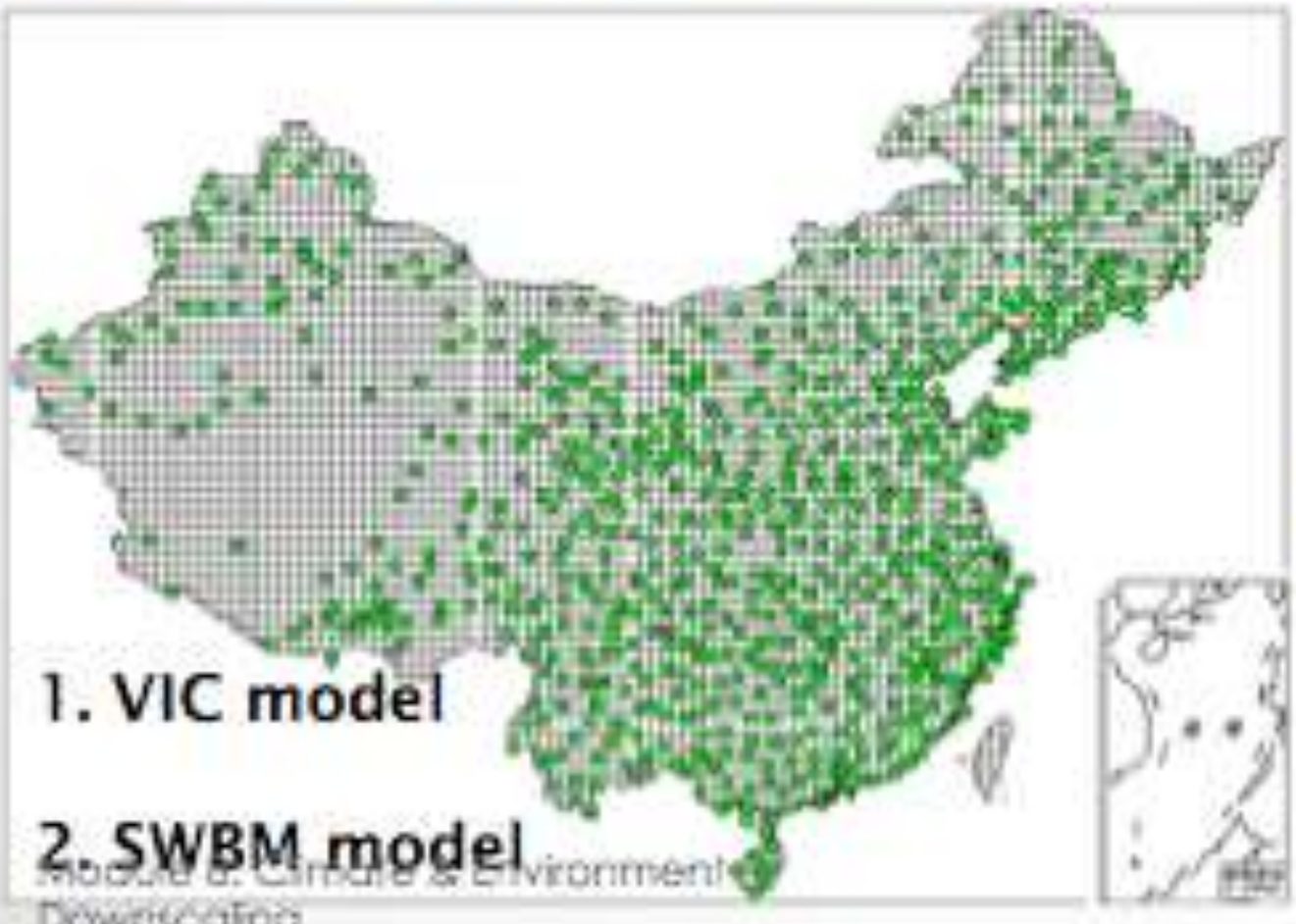


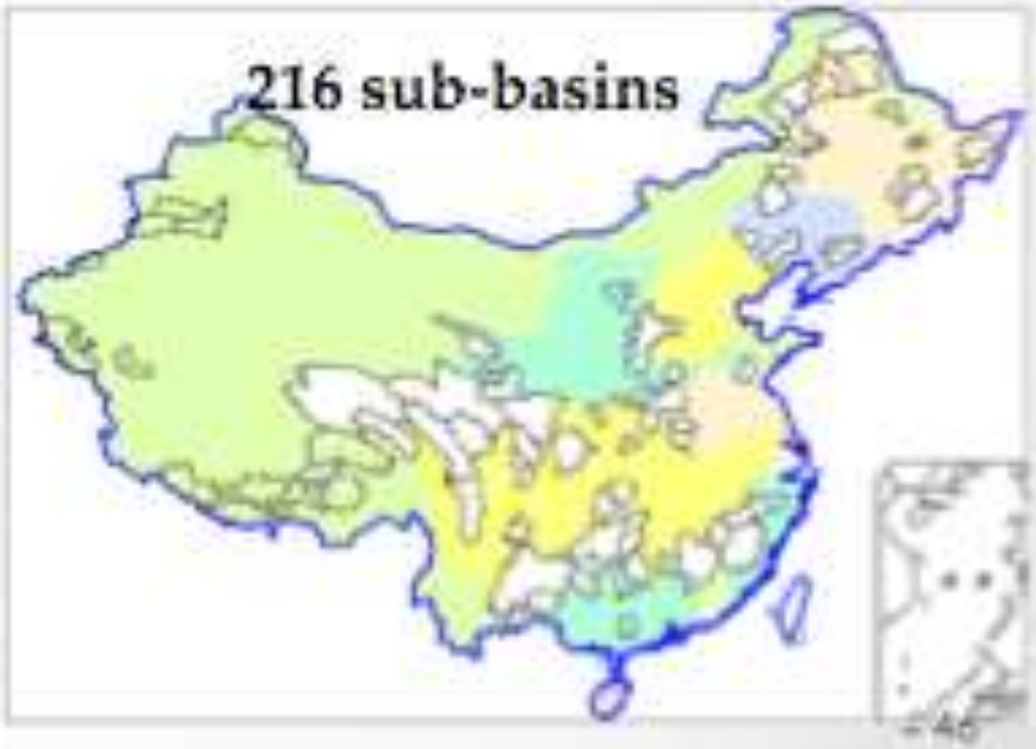


China-wide assessment model development (Wang et al, 2010)

- Study area: China-wide
- Resolution: 50×50km
- Grid cells: 4160
- Raingauges:753+2129



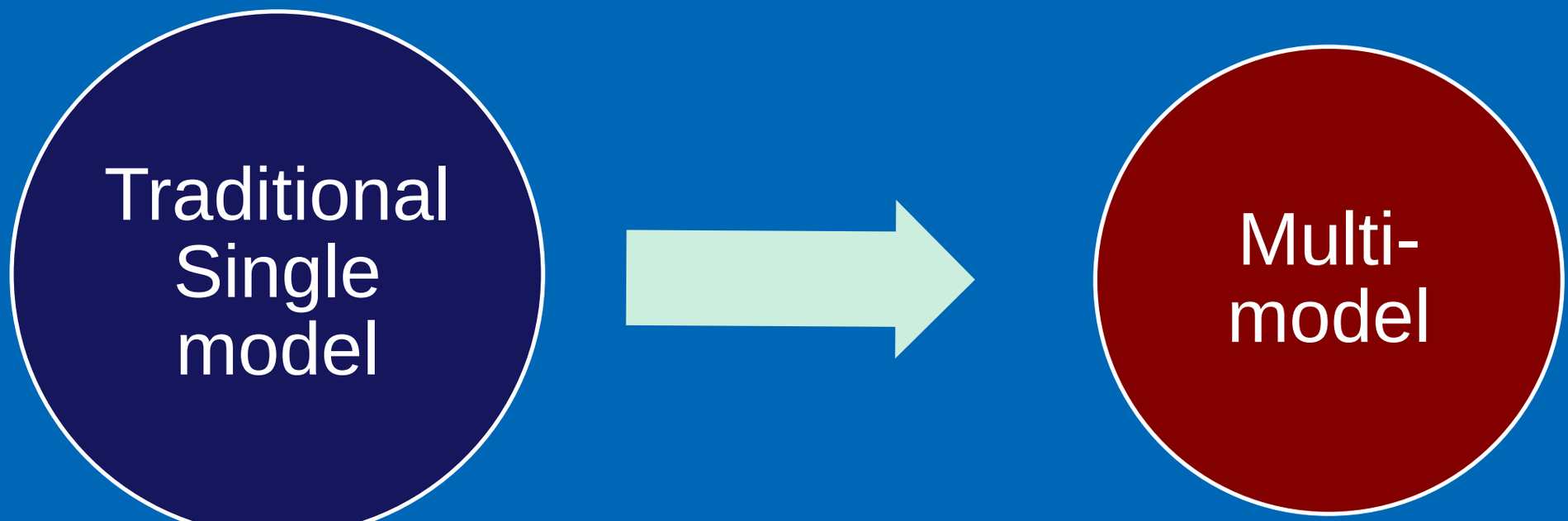




Extreme Weather Impact Studies

1) Due to climate change? More severe weather will be more likely to happen. In particular, flooding/storm surge or the opposites – droughts.
2) The study on the impacts will often follow a "change-consequence-mitigation" approach.
3) Such a mode will in turn require collaborations of multiple heterogeneous models.
4) Again, it will inherit many existing problems, such as uncertainty, scaling issues, model coupling.

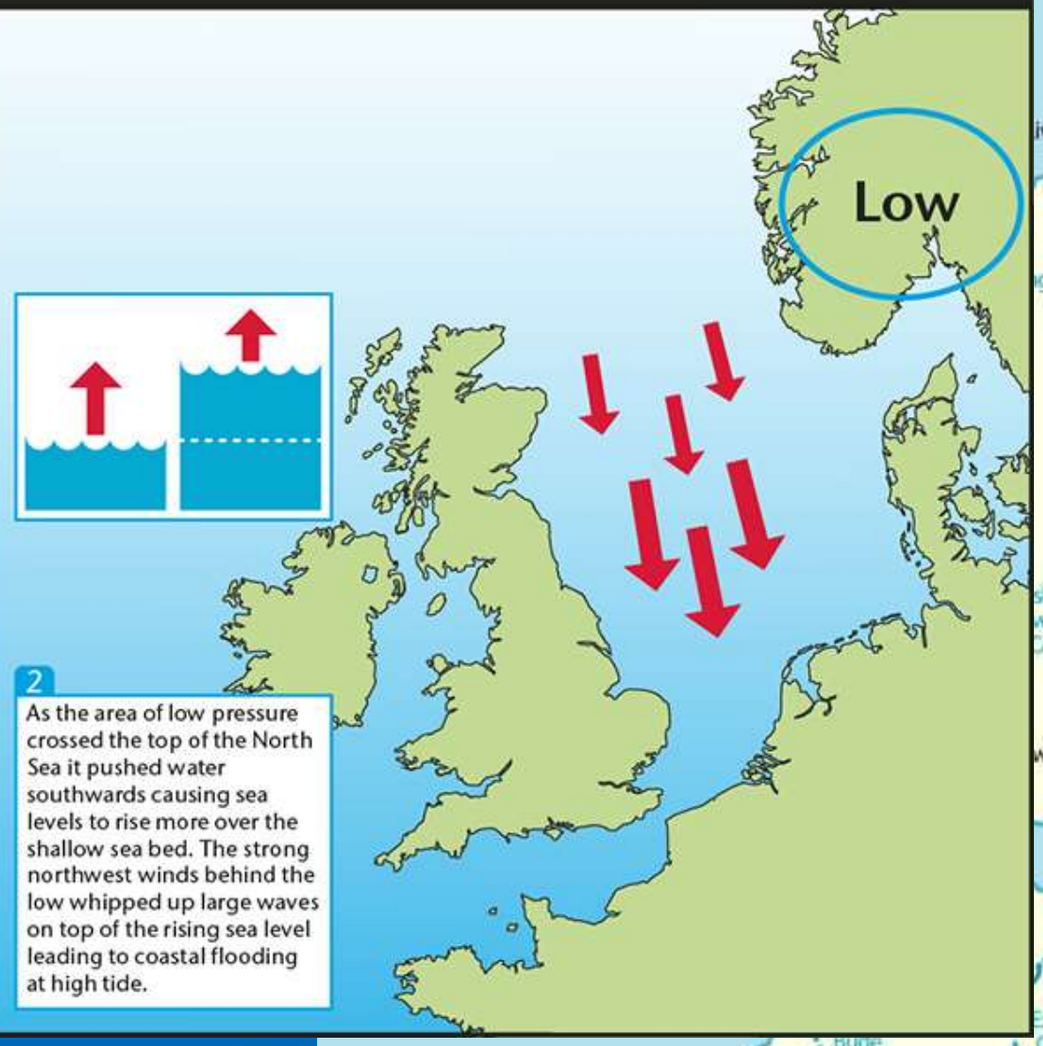
Demand of computing resources



An Example of the Complex Modeling Scenario

Met Office

What is a storm surge?



2

As the area of low pressure crossed the top of the North Sea it pushed water southwards causing sea levels to rise more over the shallow sea bed. The strong northwest winds behind the low whipped up large waves on top of the rising sea level leading to coastal flooding at high tide.

MET OFFICE
Weather data

Storm surge Model

SWANSEA
PRIFYSGOL ABERTAWE

Knowledge Transfer Partnerships

1-D Hydrodynamic Model

Thames Barrier

Chelsea

Silvertown

Southend

Sheerness

Overtopping & Failure probability model (space, time)

Teddington

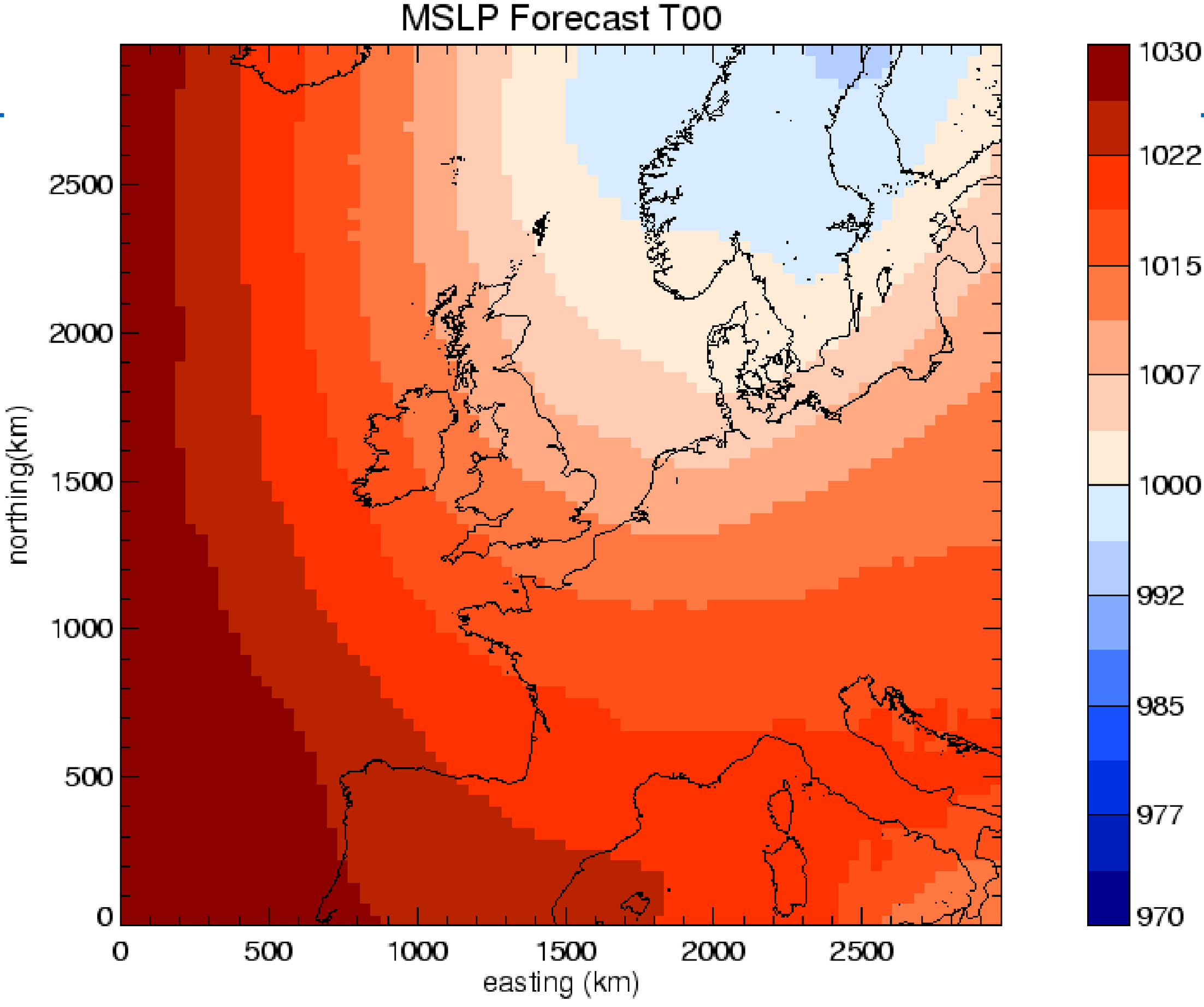
Flood inundation model for Thamesmead in real time from high tide

Coast line
Rivers
Foreshore Region
Lakes Region
Urban Region
Woodland Region

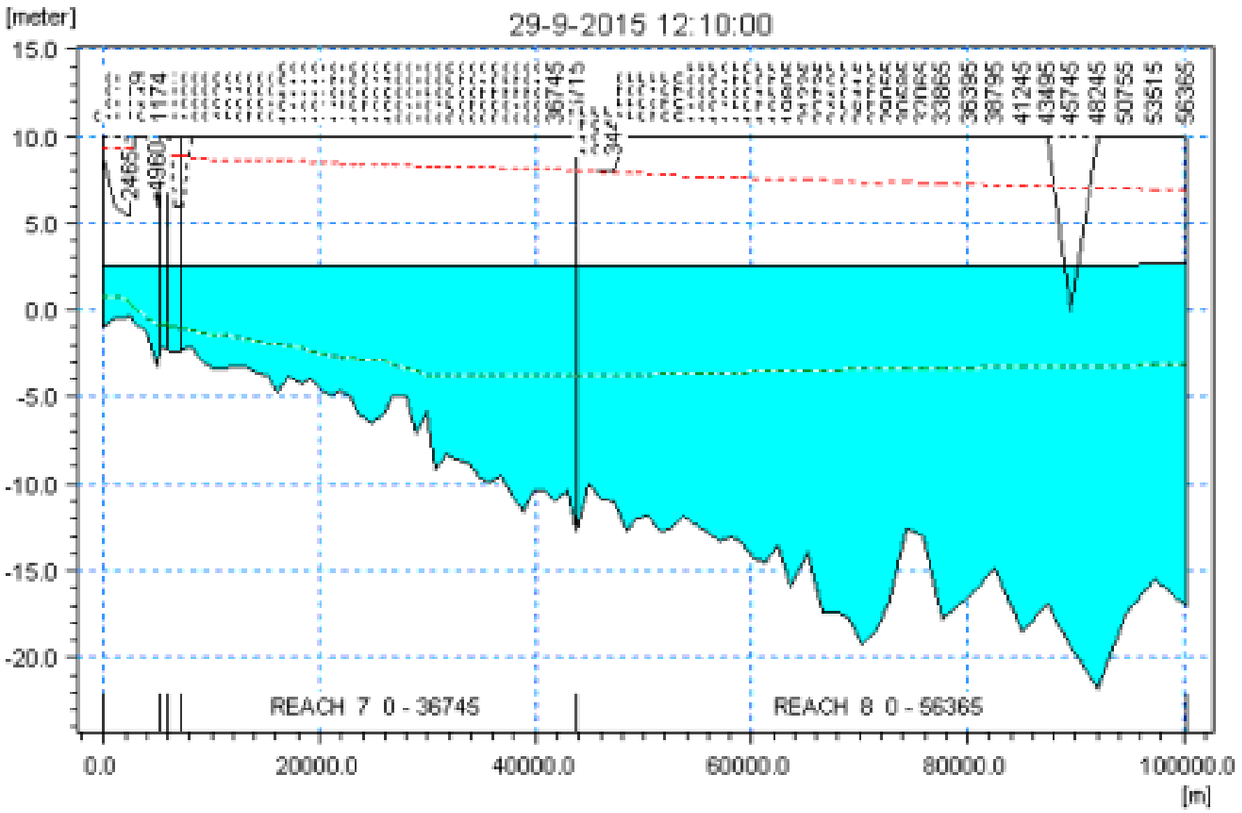
0 3,500 7,000 14,000 21,000 28,000 Kilometers

SWANSEA UNIVERSITY
PRIFYSGOL ABERTAWE

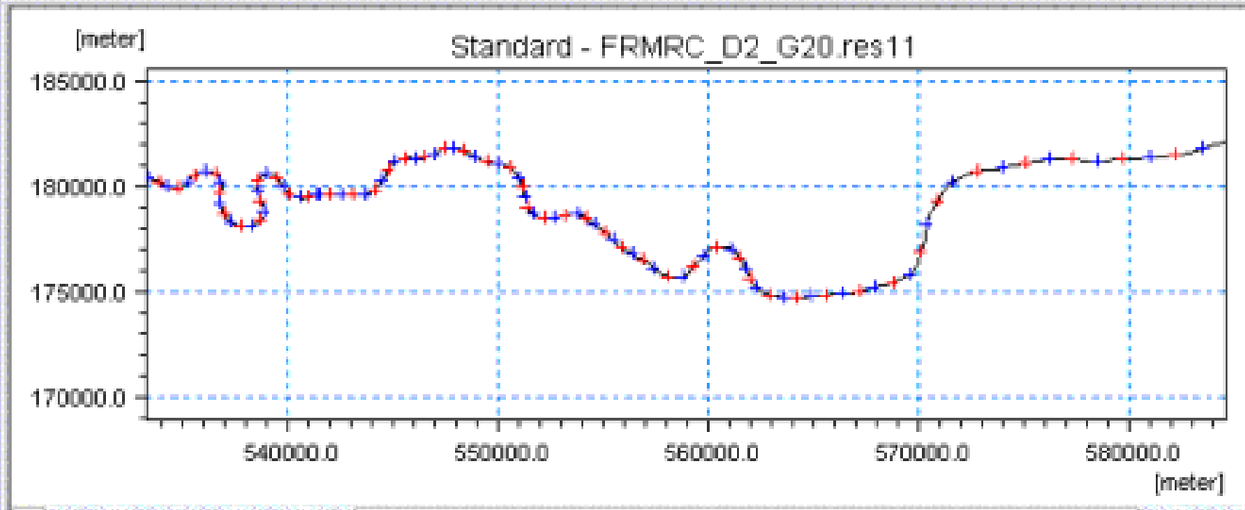
www.swansea.ac.uk


MSLP Forecast T00
northing(km)
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
easting (km)
1030
1022
1015
1007
1000
992
985
977
970

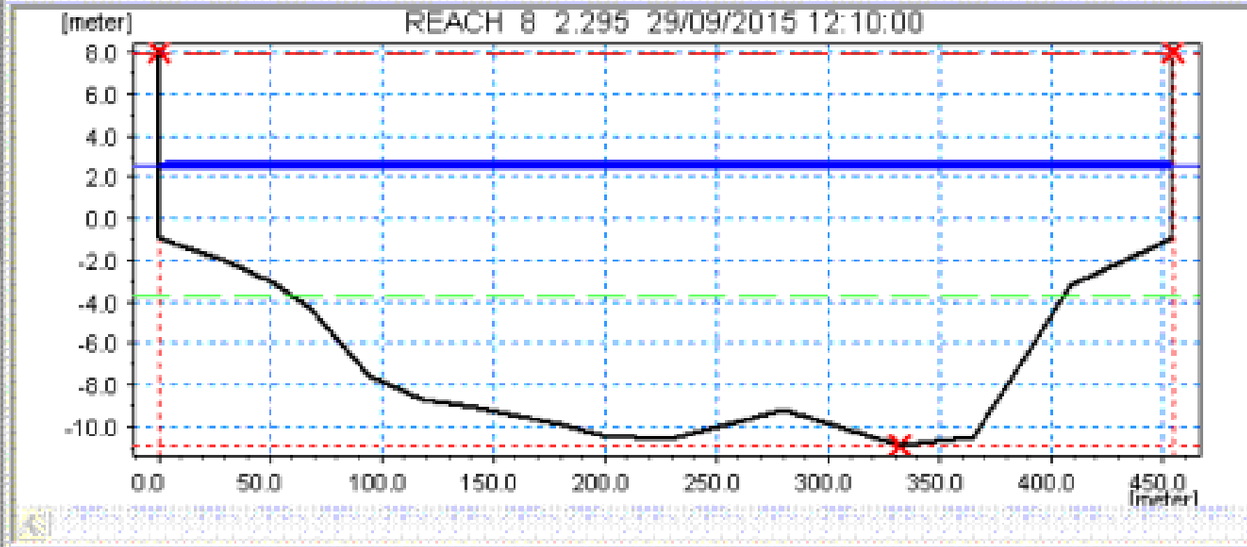
Profile Plot - FRMRC_D2_G20.res11



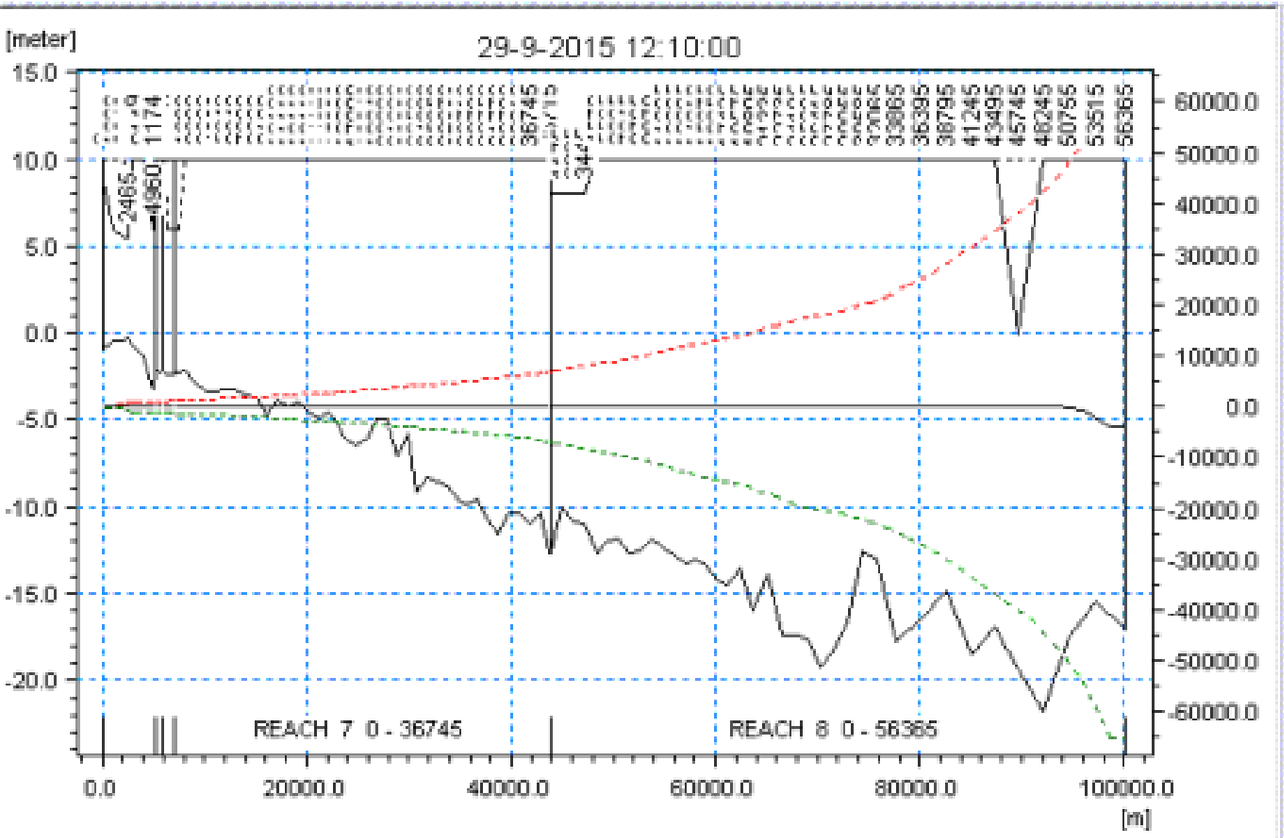
Horizontal Plan - FRMRC_D2_G20.res11



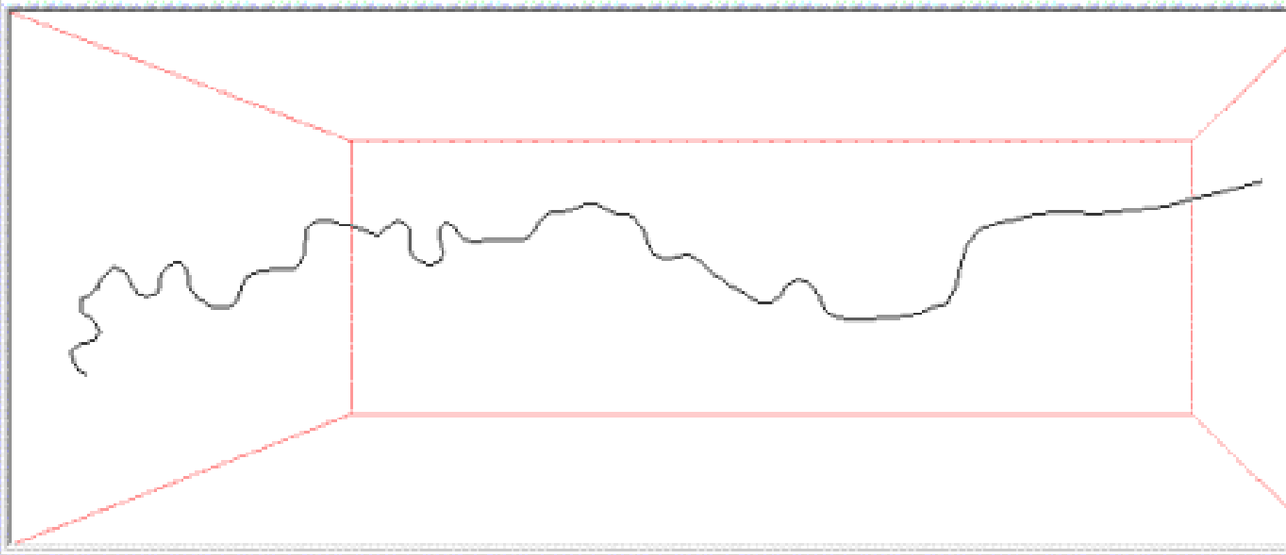
Levels in Cross section - FRMRC_D2_G20.res11



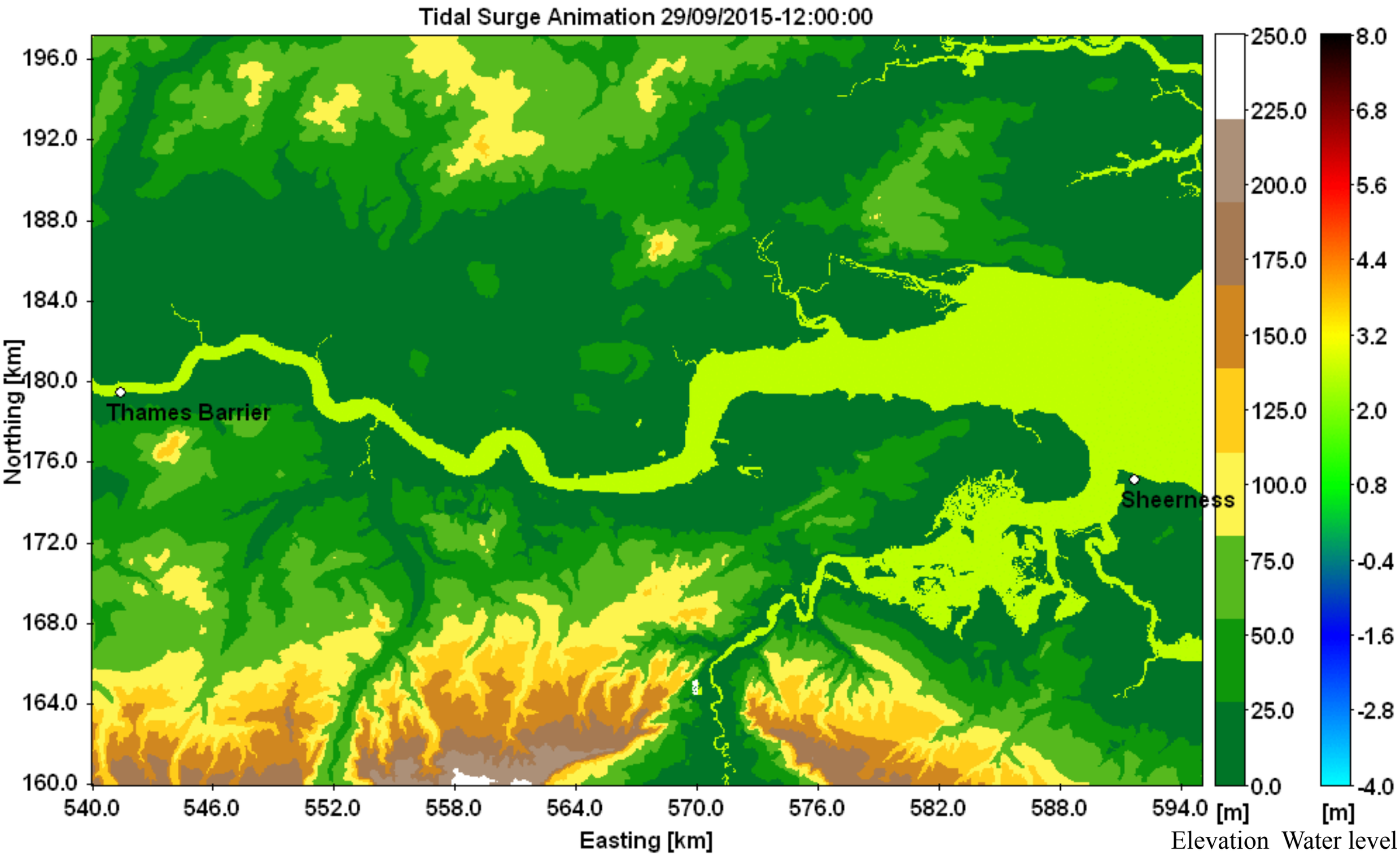
Profile Plot - FRMRC_D2_G20.res11



FRMRC_D2_G20.res11:1



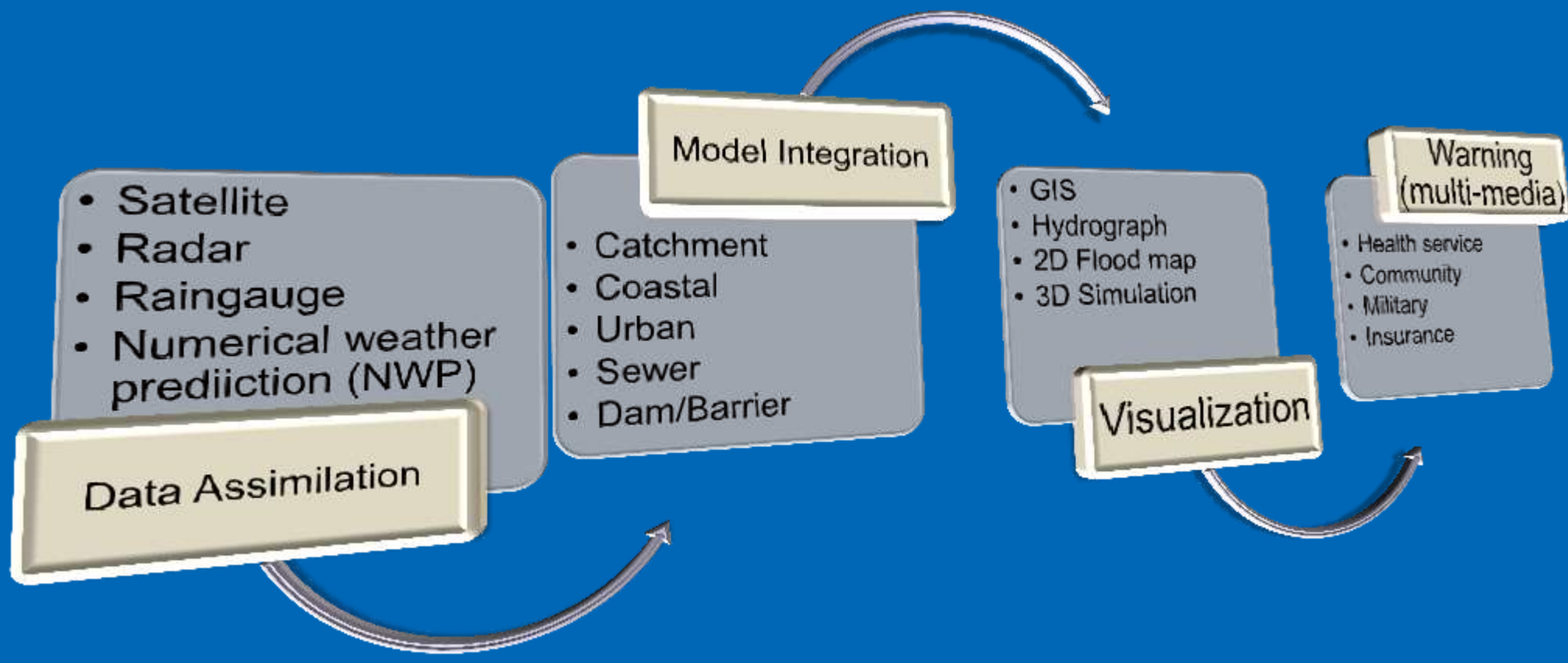
Surge up the Thames to Thames barrier



Inundation Map for Extreme Event

Inundation Map for Extreme Event

An operational chain



SWANSEA UNIVERSITY
PRIFYSGOL ABERTAWE

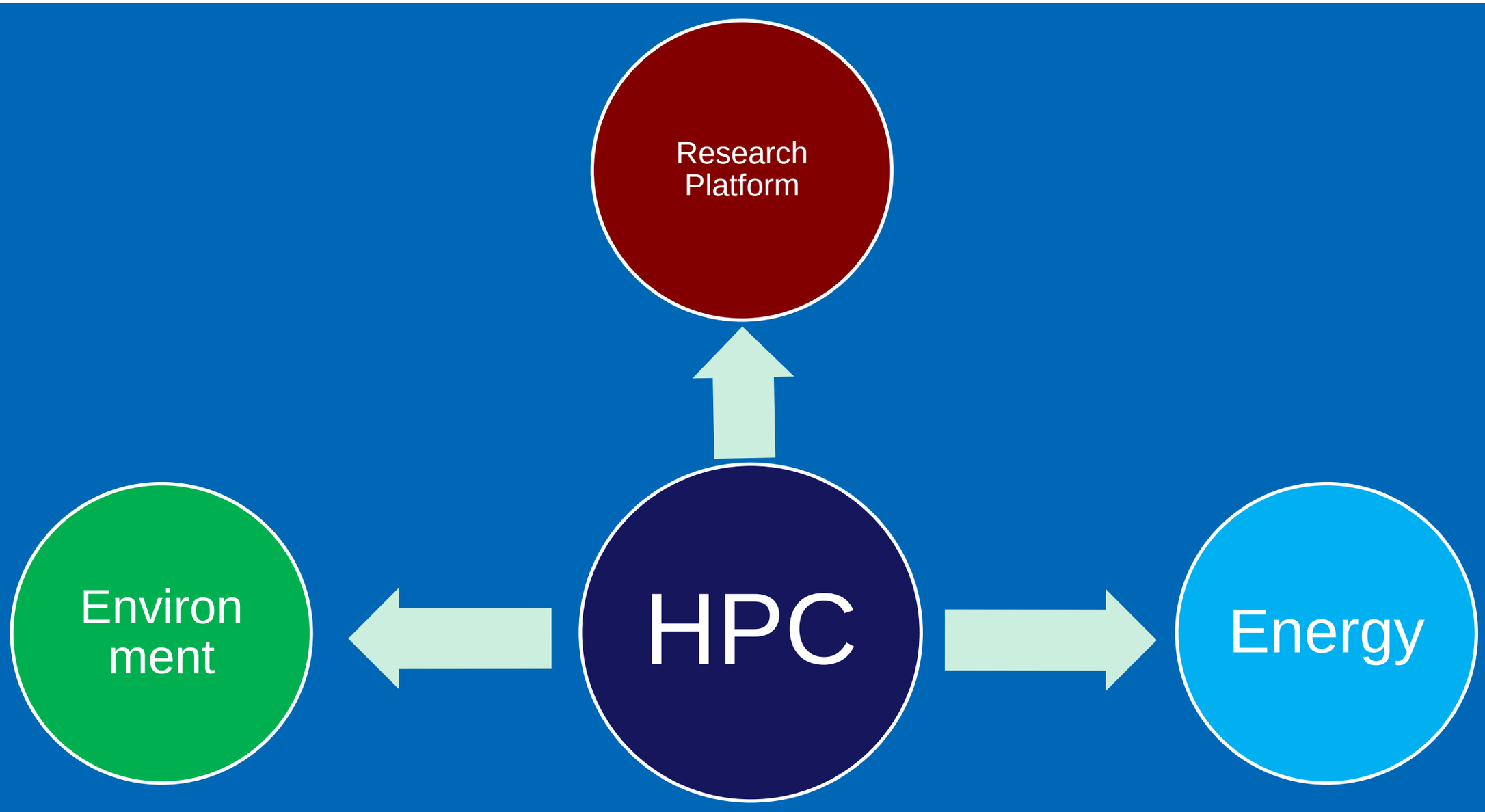
Knowledge Transfer Partnerships

www.swansea.ac.uk

Why HPC and NWP/UM

1) Intensive demand of computing resources – HPC required.
2) NWP/UM to provide weather/storm forecast – forcing field.
3) Multi-model simulation chain
4) Impact analysis and dissemination
5) Time-critical job oriented.
6) One-stop decision making service possible.
7) Big city (population, economic, political)
8) Research platform/community efforts required.

Use Case



Knowledge Transfer Partnership

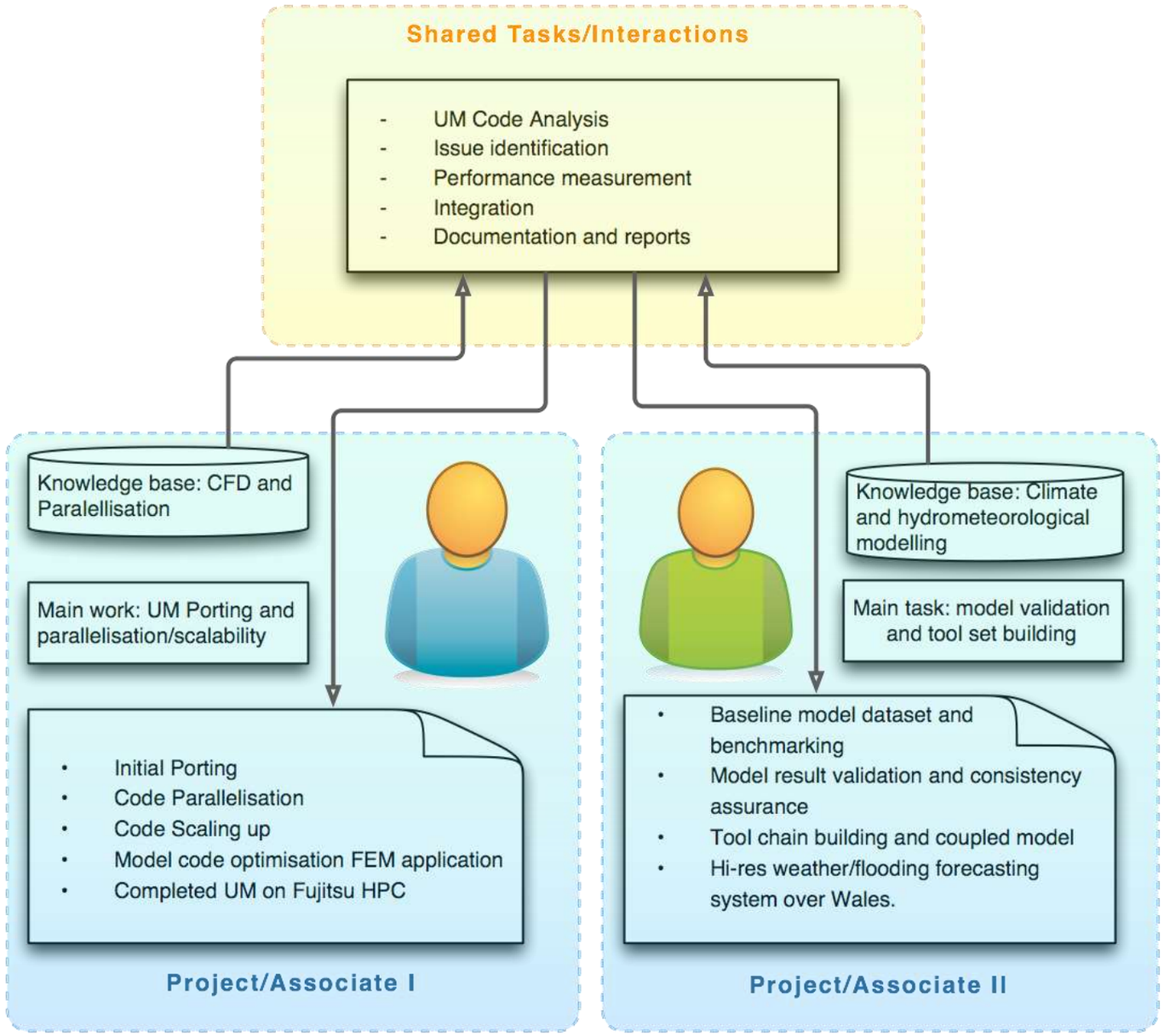
Swansea University
Prifysgol Abertawe

FUJITSU

Knowledge
Transfer
Partnerships

HPC
WALES · CYMRU

Technology Strategy Board
Driving Innovation



Key questions to be addressed

1) How models should be connected – open or closed.
2) How to maximise the computing power – parallelise the existing code.
3) Open source or not – prioritize the Open Source option but provide other option for closed/commercial software.
4) Licensing issues – GPL, LGPL, MIT, …
5) Data processing and Big Data
6) Result dissemination – using Cloud?

Acknowledgements

Met Office

Technology Strategy Board
Driving Innovation

Knowledge Transfer Partnerships

HPC WALES · CYMRU

Noddir gan
Lywodraeth Cymru
Sponsored by
Welsh Government

SWANSEA UNIVERSITY
PRIFYSGOL ABERTAWE

www.swansea.ac.uk