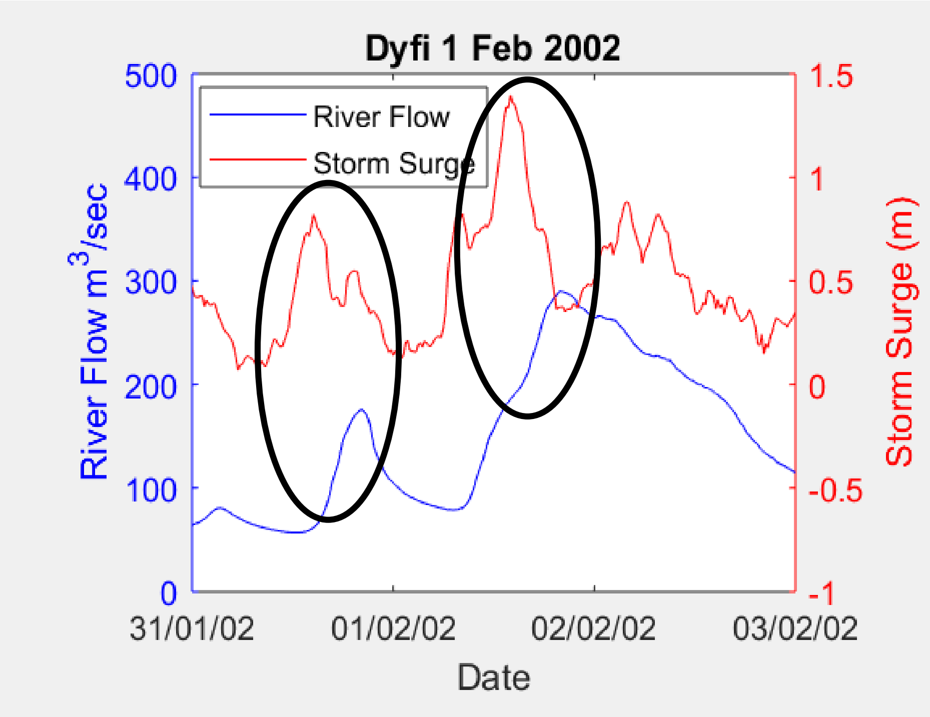
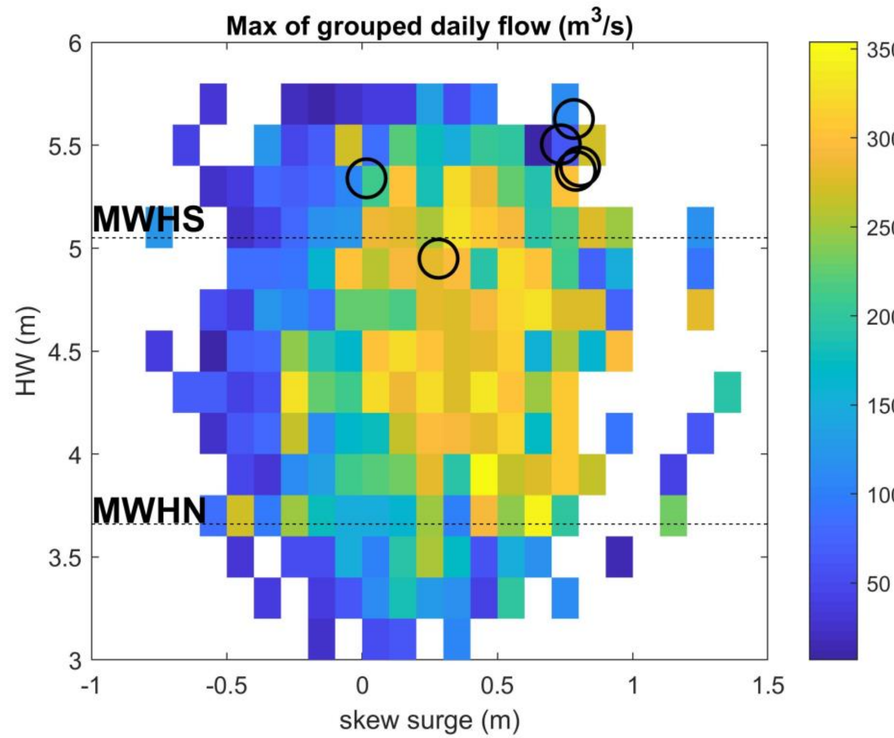
Modelling estuary combination hazard

Lisa Harrison, Mariam Elnahrawi, Peter Robins, Matt Lewis*, Tom Coulthard, David Cooper, Davey Jones, Shelagh Malham, Jim Freer, Gemma Coxon, Nick Barcock, Sue Mason

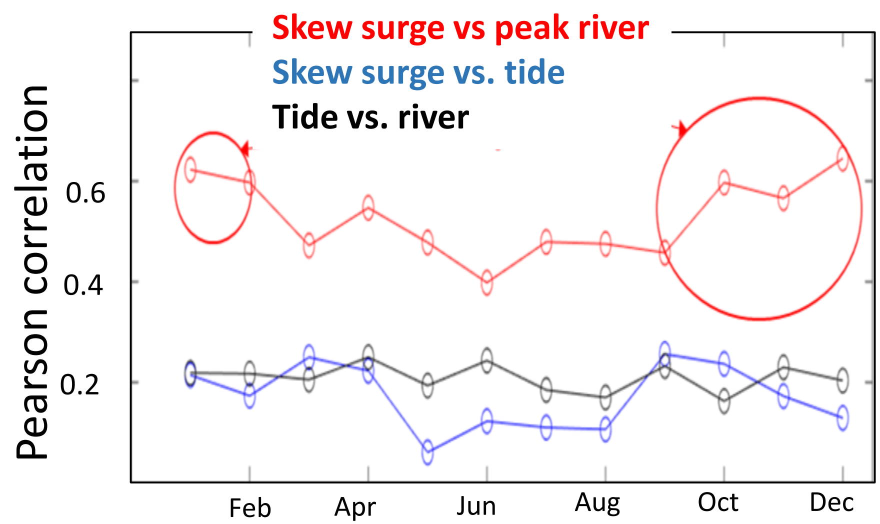
***m.j.lewis@bangor.ac.uk**

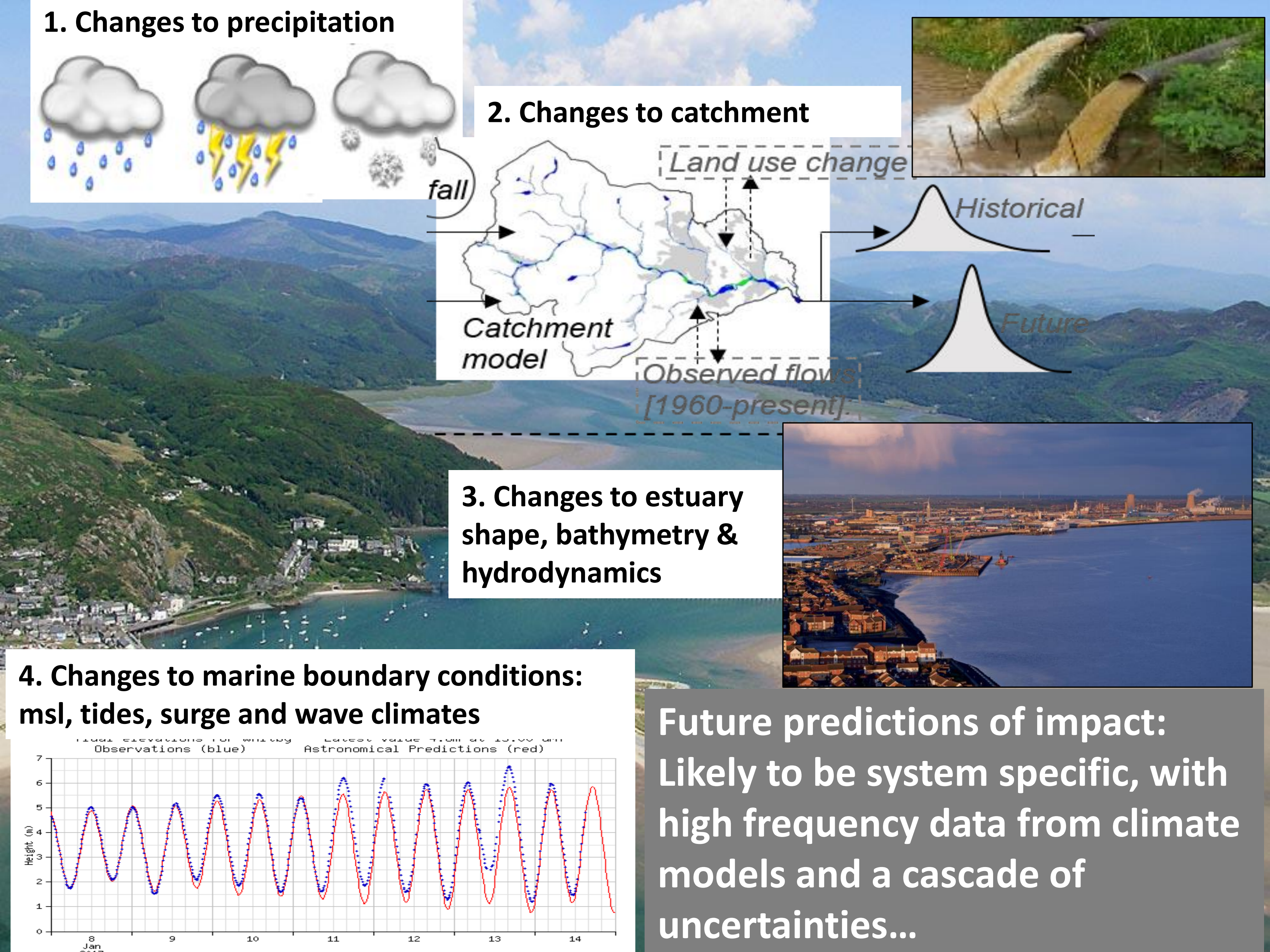
- Terrestrial and marine processes meet at estuaries
- Understanding how estuaries respond in future is crucial
- 40% of world population “near” coast, with majority of major cities on estuaries.
- In UK, ~20 million live/work close to estuaries crucial for trade and industry





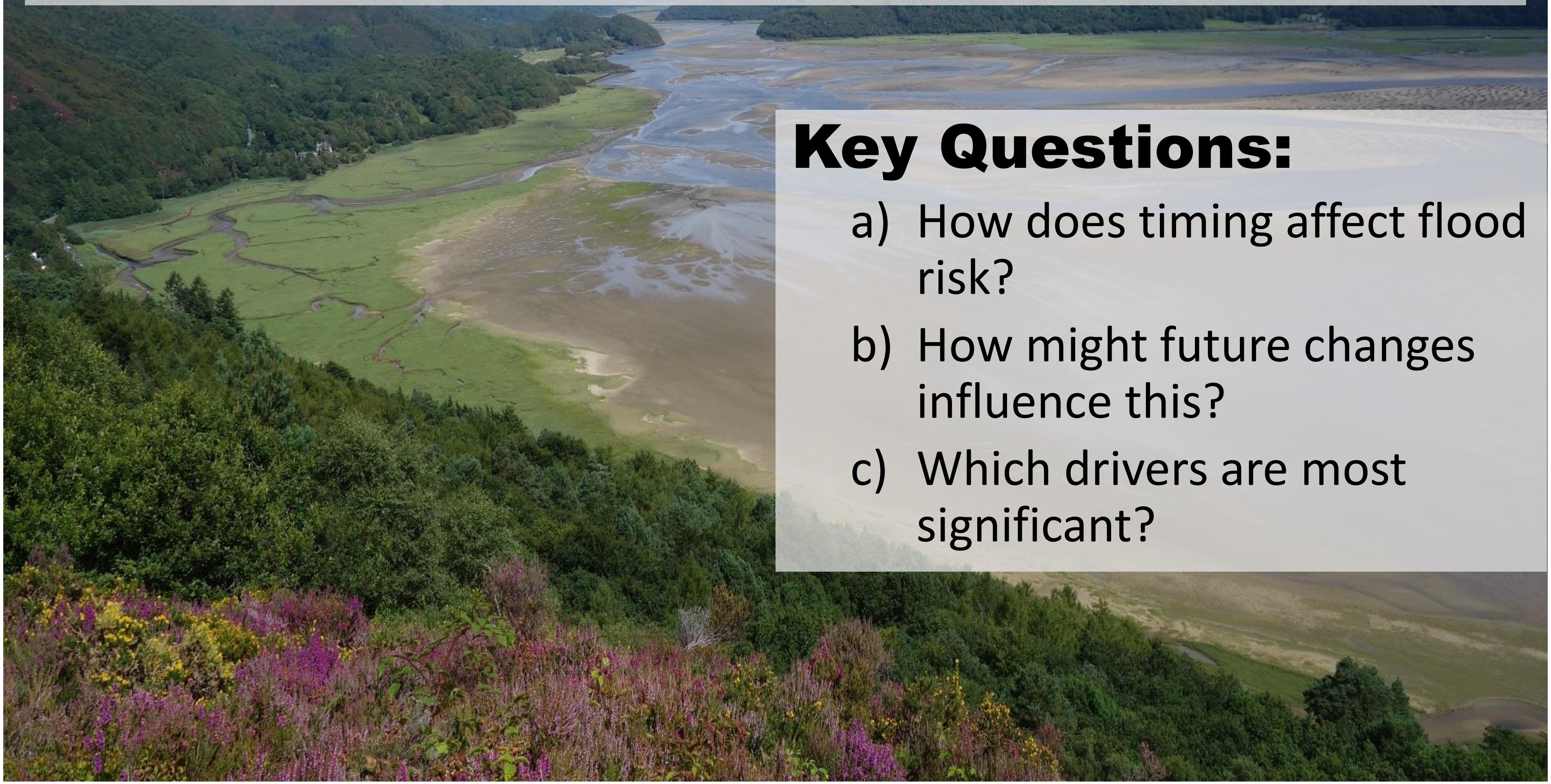
- Combination estuary hazard from tide, surge and river flow.
- Concern this may increase in future….




1. Changes to precipitation
fall
2. Changes to catchment
Land use change
Catchment model
Observed flows [1960-present]
Historical
Future
3. Changes to estuary shape, bathymetry & hydrodynamics
4. Changes to marine boundary conditions: msl, tides, surge and wave climates
Observations (blue)
Astronomical Predictions (red)
Height (m)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Jan
Future predictions of impact: Likely to be system specific, with high frequency data from climate models and a cascade of uncertainties…

Deterministic inundation model with probabilistic model at open boundary is typically used for flood risk:

- **good for estimating maximum water levels, <u>but not for location and timing</u>**
- **Multiple runs required, with much uncertainty**
- **Poor representation of climate change**



Key Questions:

a) How does timing affect flood risk?

b) How might future changes influence this?

c) Which drivers are most significant?

- Contrasting estuaries:

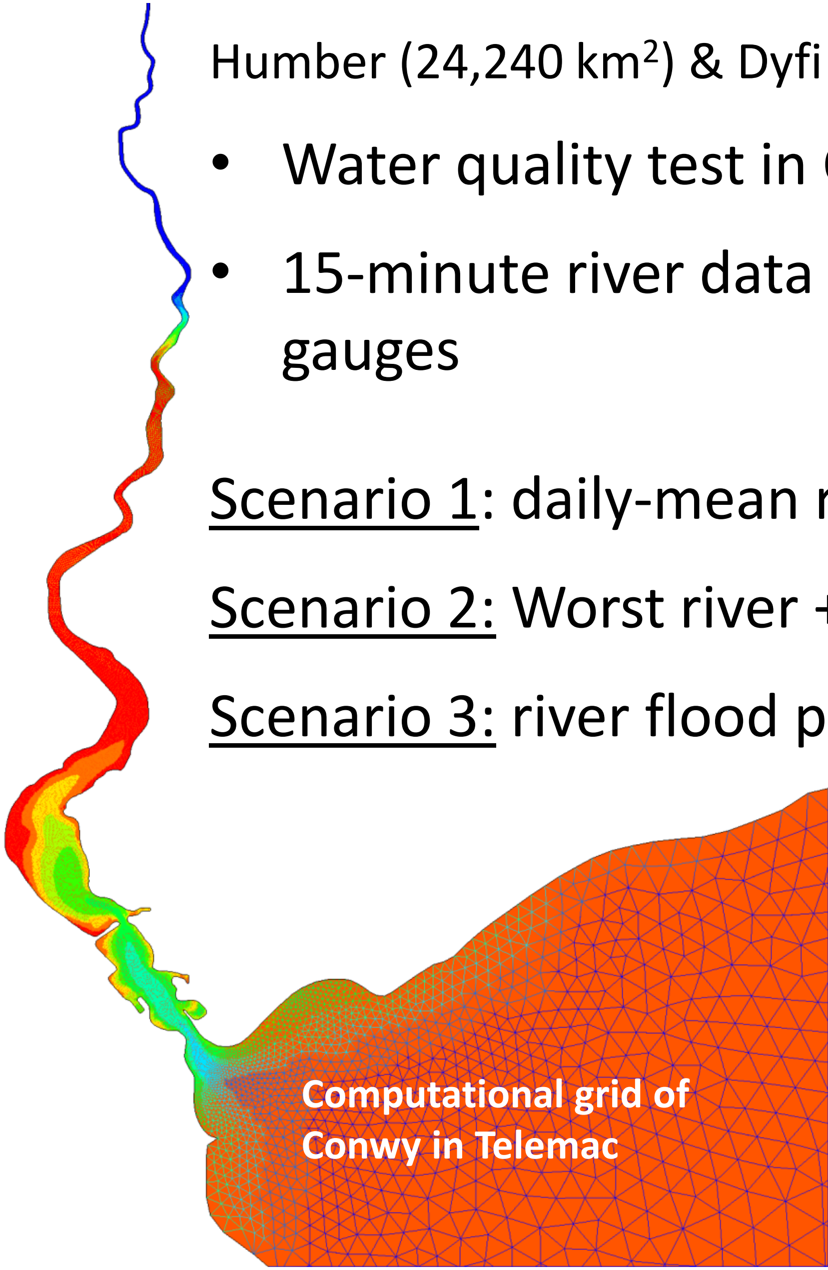
Humber (24,240 km^2) & Dyfi (470 km^2)

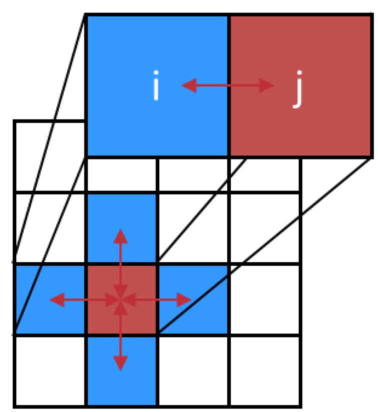
- Water quality test in Conwy
- 15-minute river data & nearest tide gauges

Scenario 1: daily-mean river + worst surge

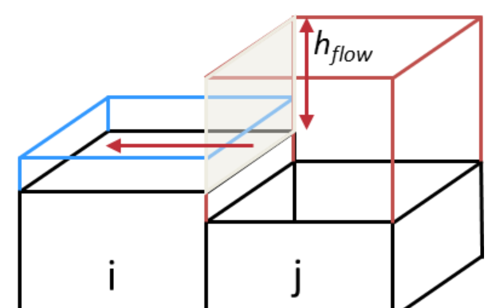
Scenario 2: Worst river + worst surge

Scenario 3: river flood phase ± 12 hrs of surge

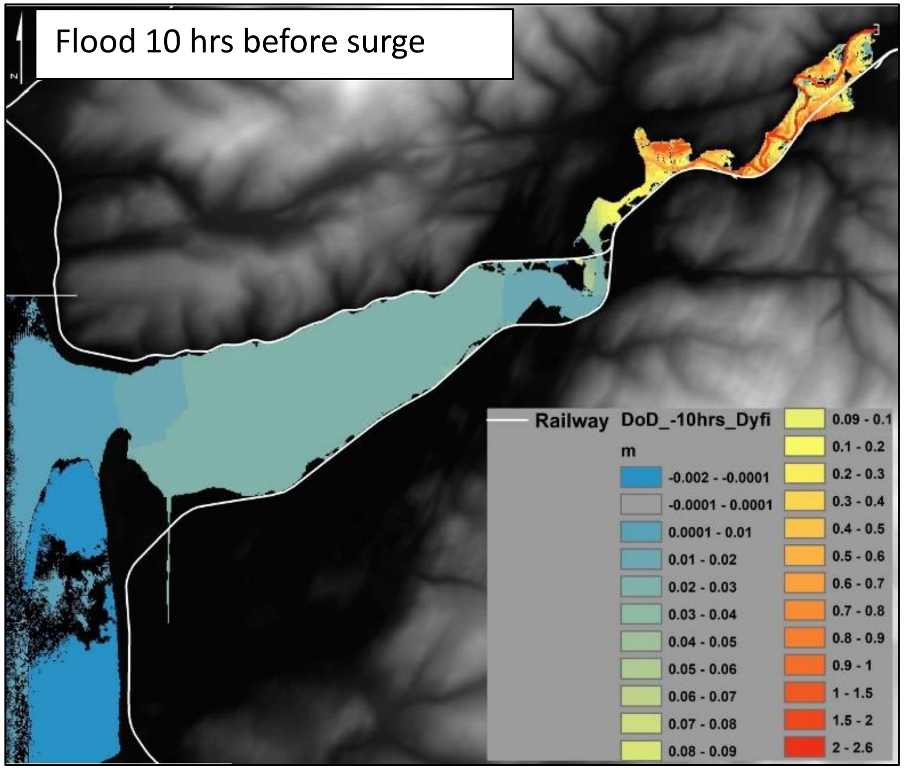


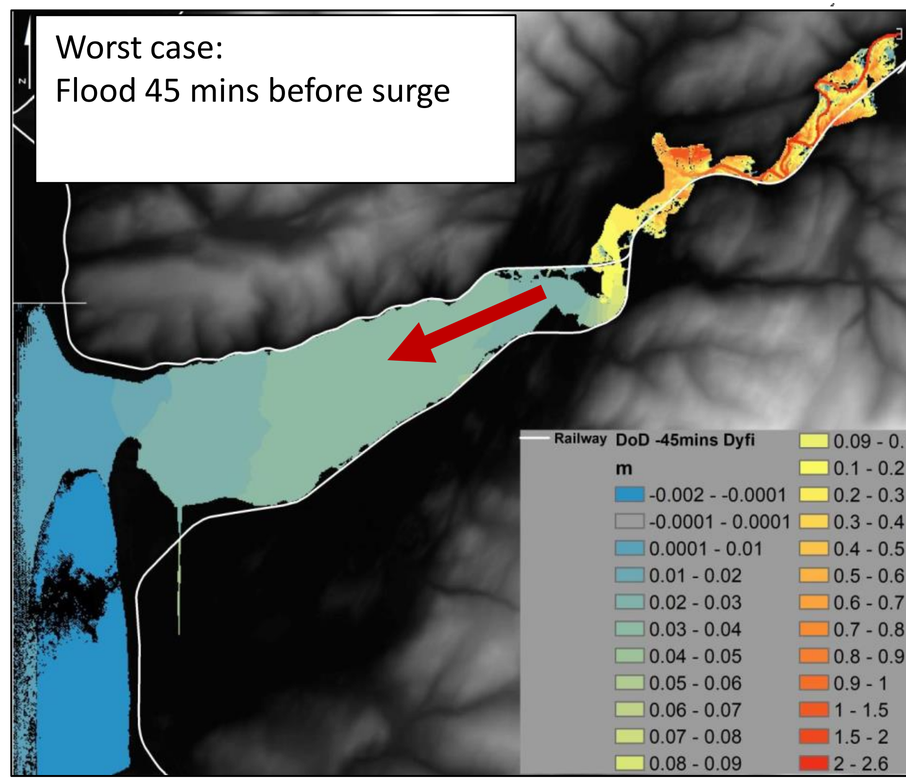


Representation of flow between cells in LISFLOOD-FP



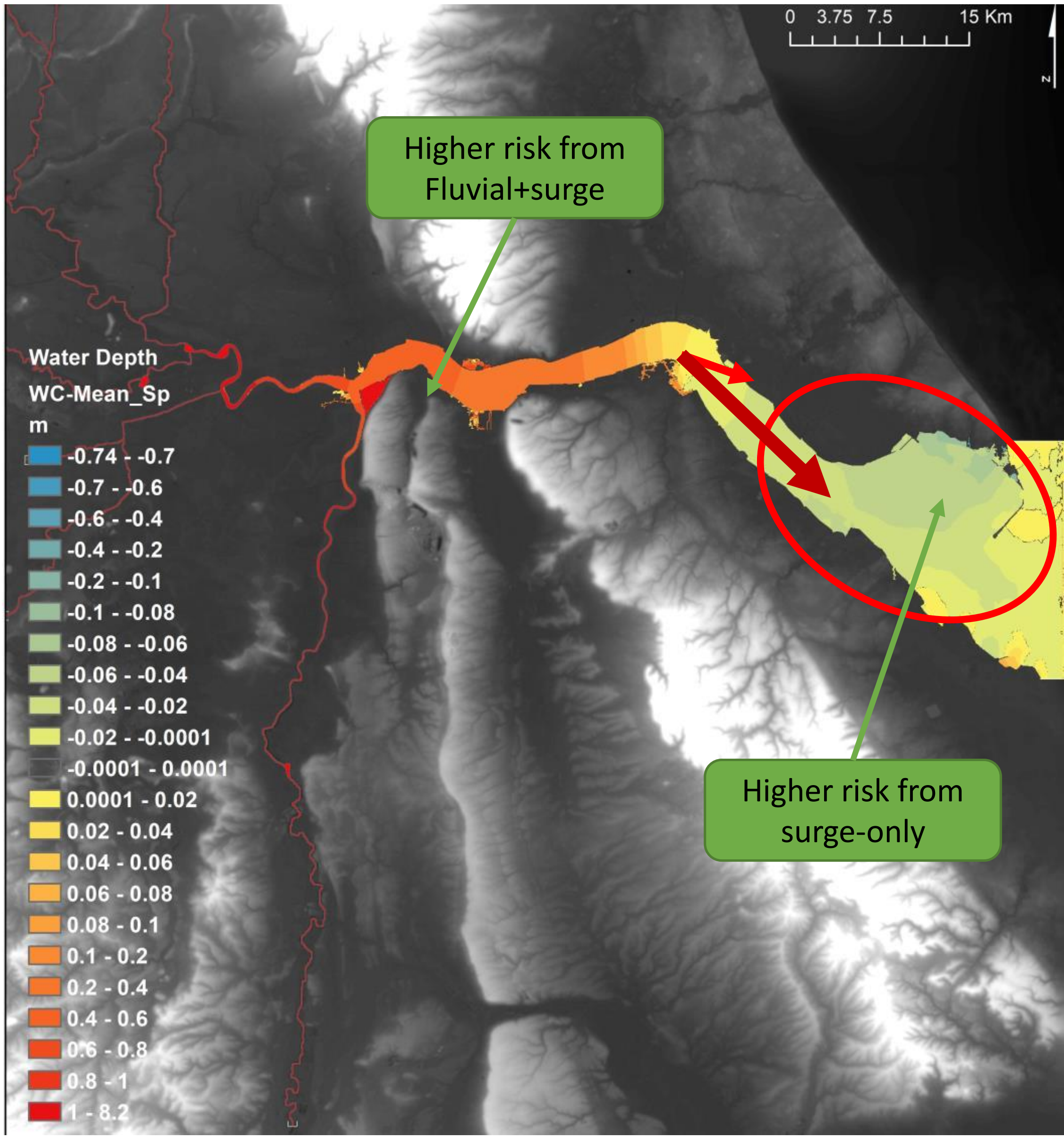
Dyfi Estuary Results





- SLR largest driver of inundation extent, with tipping point of 0.75m SLR
- Increased fluvial flood volume (up to 40%) least important (as confined to upper estuary).
- **Phasing** of drivers important (river floods last <1 day)
- **Future changes to the magnitude, and shape, of rivers important to resolve.**

Humber Estuary Results

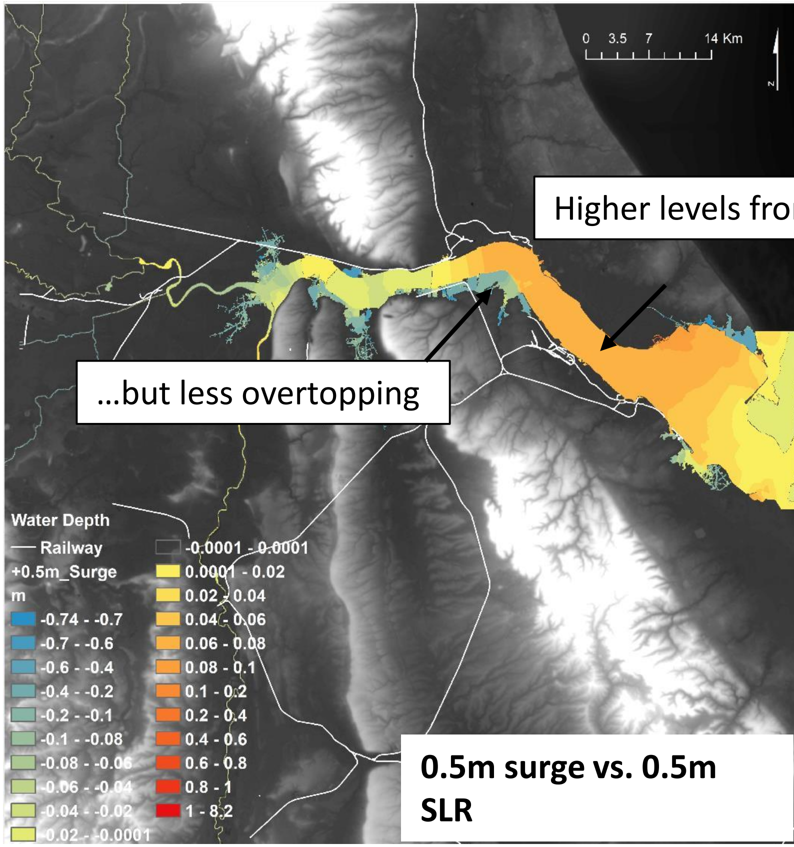


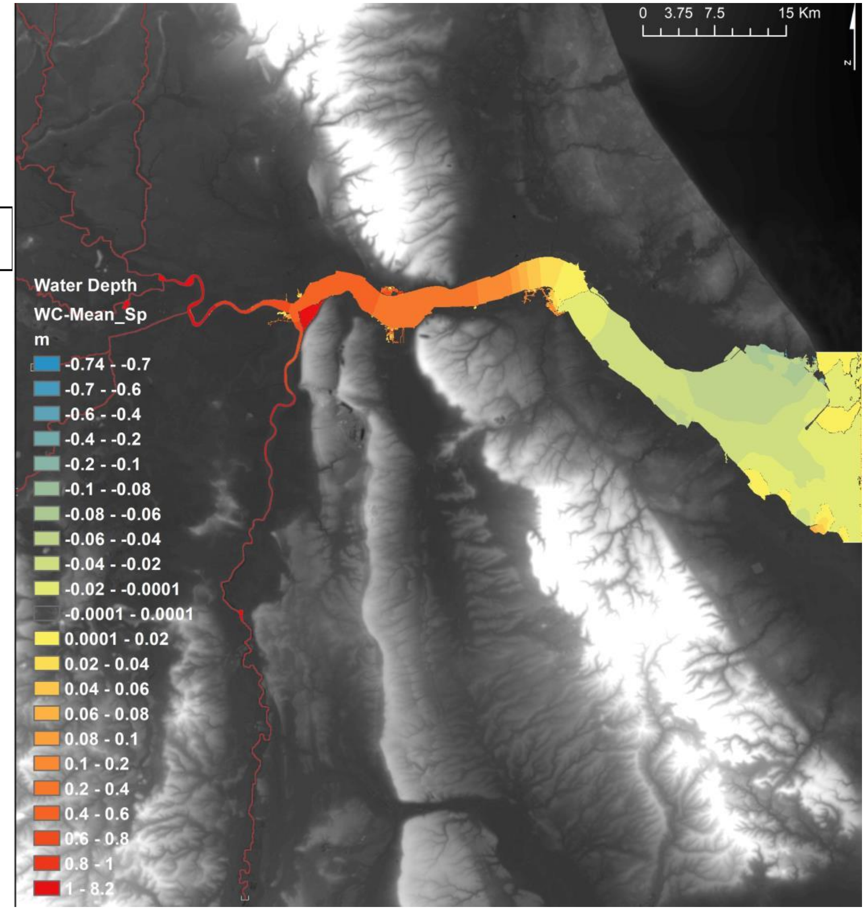
- SLR largest inundation driver, with the tipping point of 1m SLR

- Fluvial-surge phasing had little impact:

slow response system (river floods last >2 days, spanning several tides)

- **Magnitude, rather than timing, of fluvial events important**



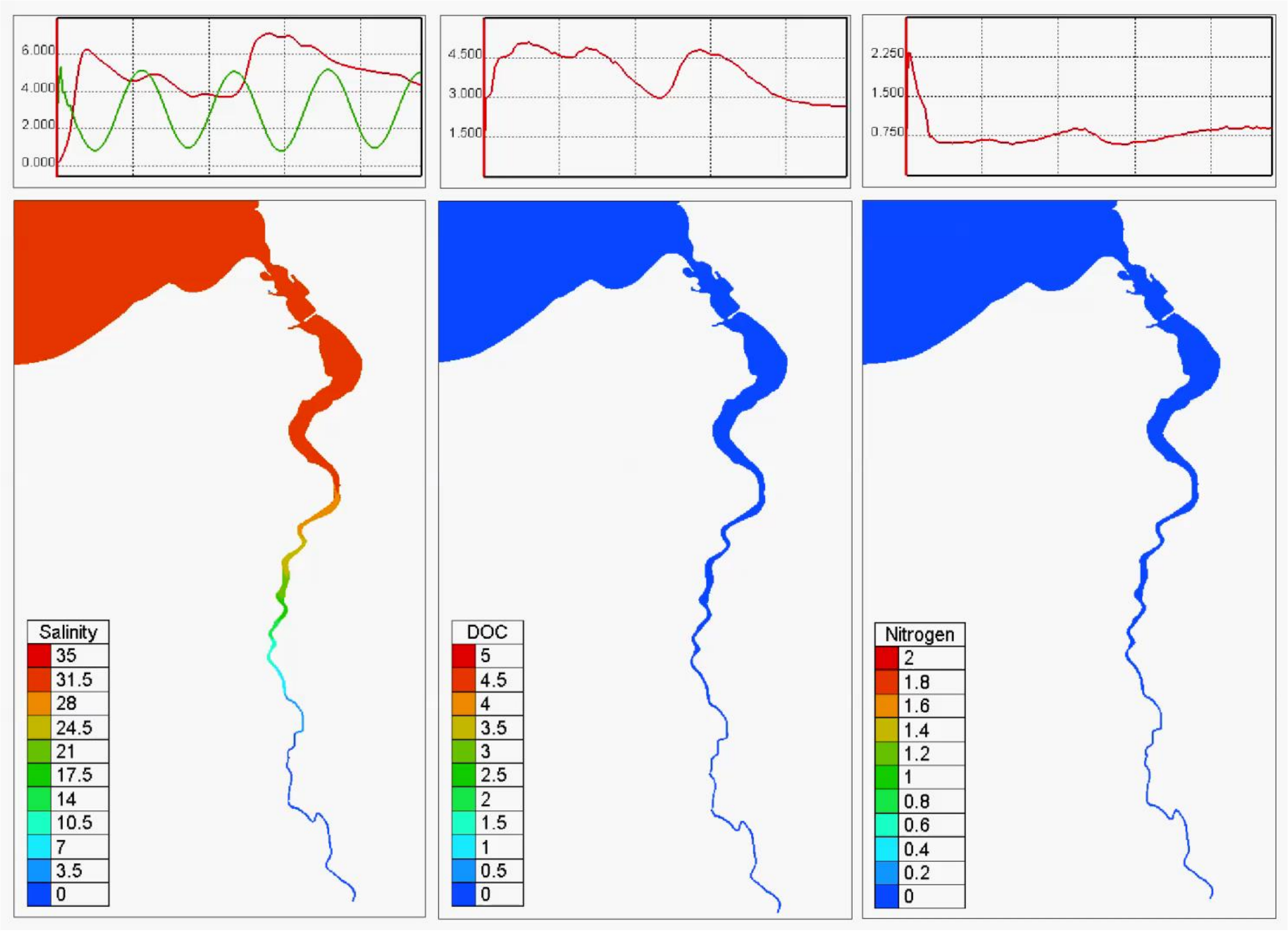


Longer-duration surges result in higher maximum water depths in outer estuary, perhaps as the narrow mouth constricts marine inflow

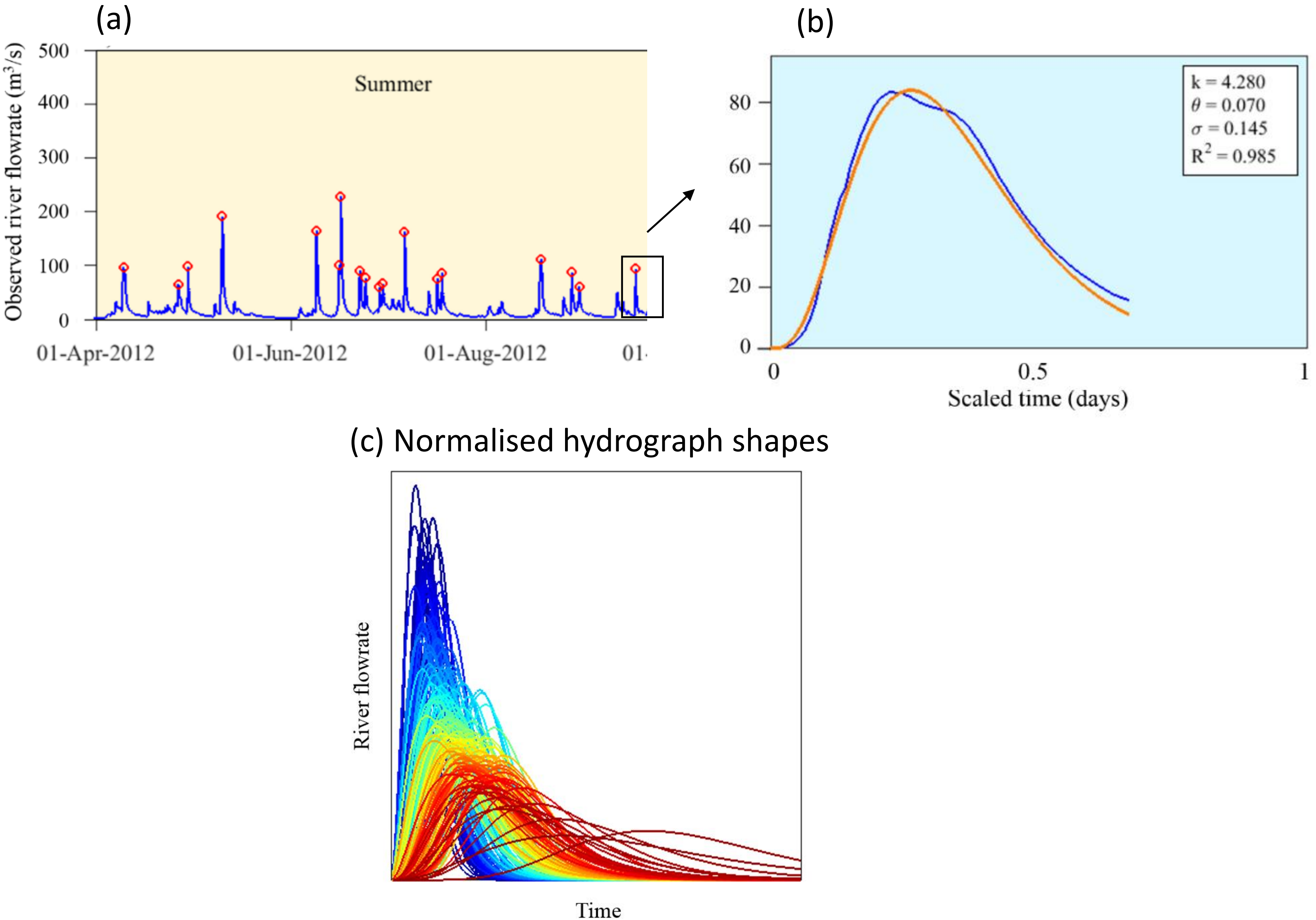
Surge volume rather than just maximum surge height is important for both estuaries.

Fluvial extremes appear to reduce the marine extremes in the outer estuary

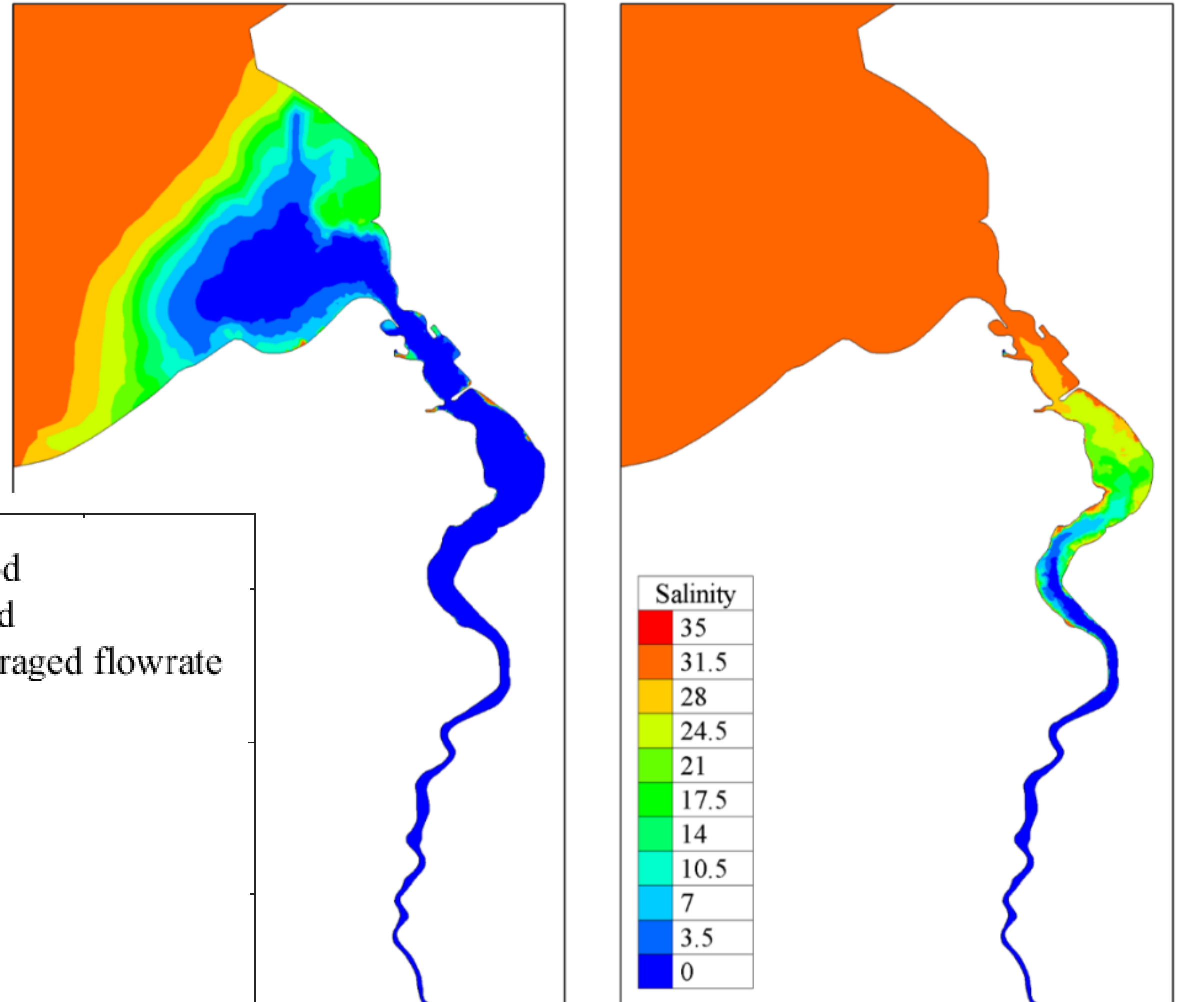
Rivers prevent some surge entering the estuary, likely because of reduced pressure gradient (head) driven flow of the storm tide into the estuary

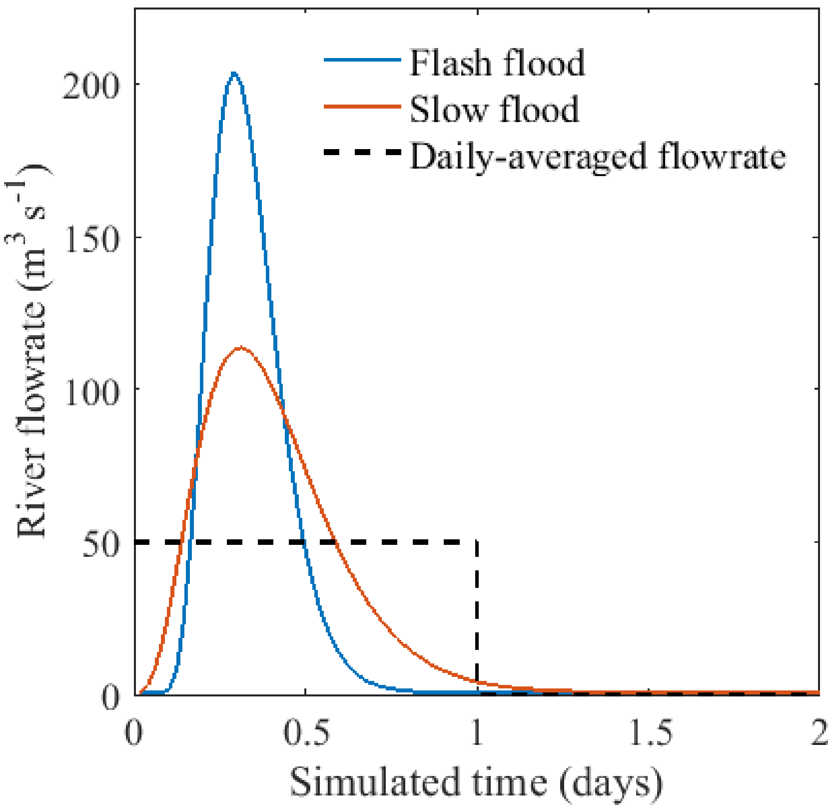


Tidal elevation and river flow boundary forcing's for 21-Oct-2014
conservative tracers in TELEMAC V7.1; wetting and drying; *dt* 1s (15min result outputs)
0.03 Manning friction (constant); bathy from LiDAR and boat surveys; TPXO tides;


(a)
Summer
Observed river flowrate (m3/s)
500
400
300
200
100
0
01-Apr-2012
01-Jun-2012
01-Aug-2012
(b)
k = 4.280
θ = 0.070
σ = 0.145
R2 = 0.985
80
60
40
20
0
0
0.5
1
Scaled time (days)
(c) Normalised hydrograph shapes
River flowrate
Time

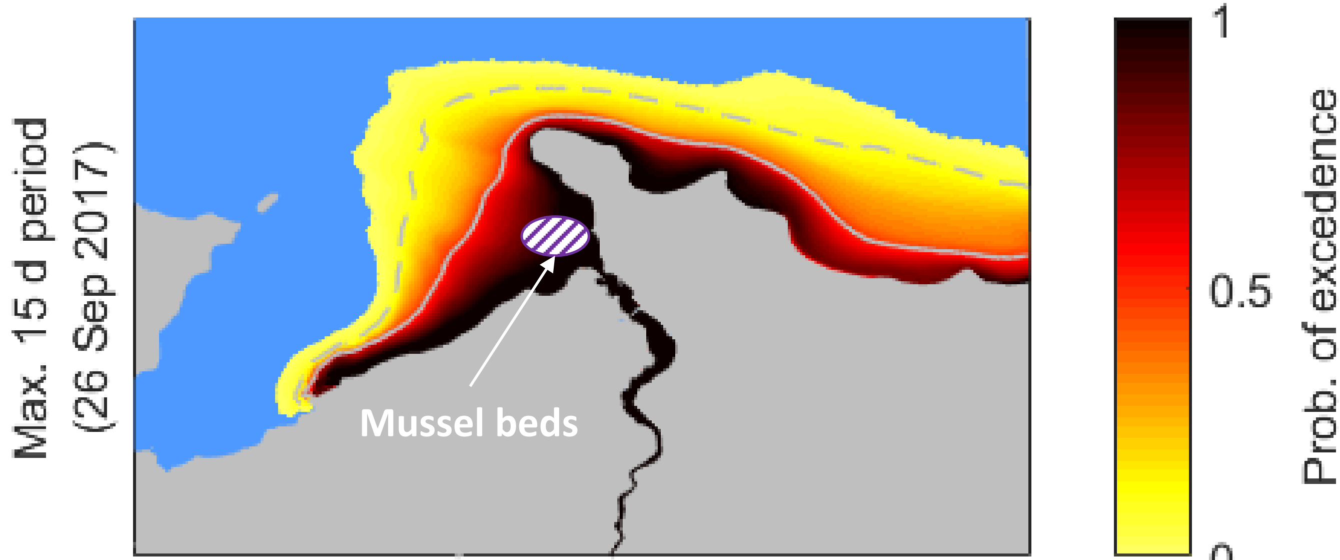
a) Run 1: Flash (15-min forcing)   b) Run 1: Flash (daily forcing)

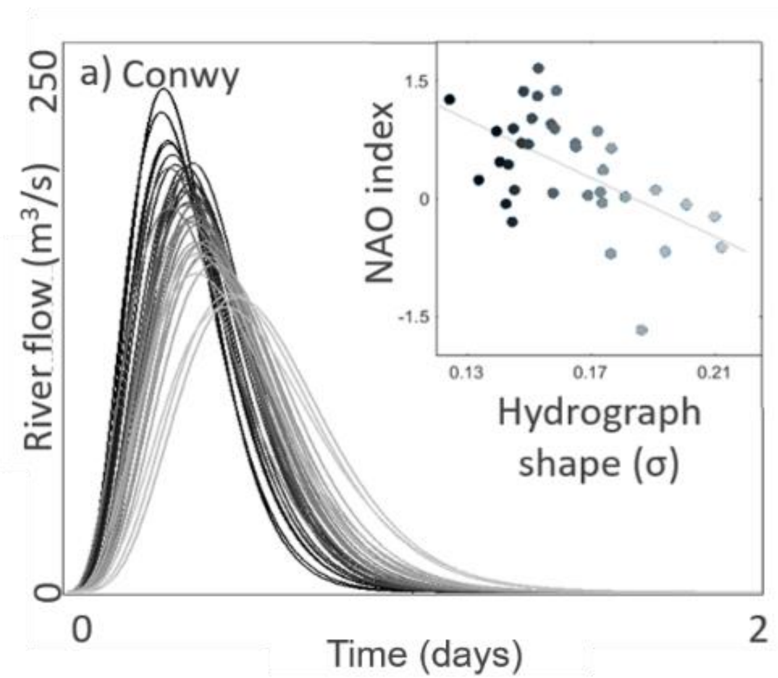


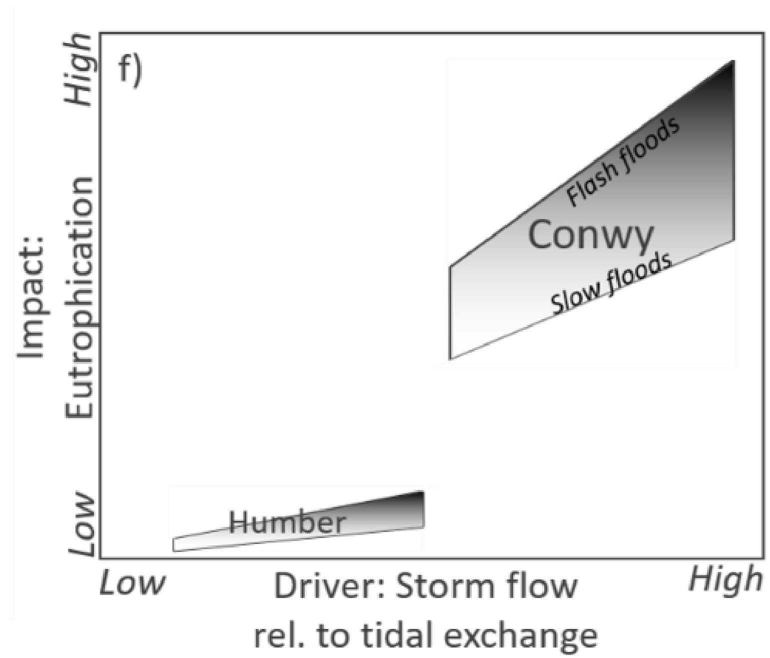


Future impact modelling need to resolve sub-daily river flow for smaller estuaries, including changes to hydrograph shapes (rainfall, land-use, etc)

Virus dispersal – Risk Maps







Conclusions

1. **Tides, surges and river extremes, can co-occur <u>and interact</u> generating a combination estuary hazard**
    - ***Region between the fluvial and marine flooding processes found, with increased water-levels upstream and reduced downstream***
2. **Larger estuaries with slow response catchments appear most vulnerable in outer estuary**
    - ***Shape of storm surge appears important***
3. **Small estuaries with quick response catchments appear most vulnerable in the inner estuary**
    - ***Sub-daily future river flows, including catchment variability/change, <u>need for both flooding and water quality future impact assessment</u>***