Analysis of turbidity time series data from the Lunan Water catchment, Scotland, using Hidden Markov chains

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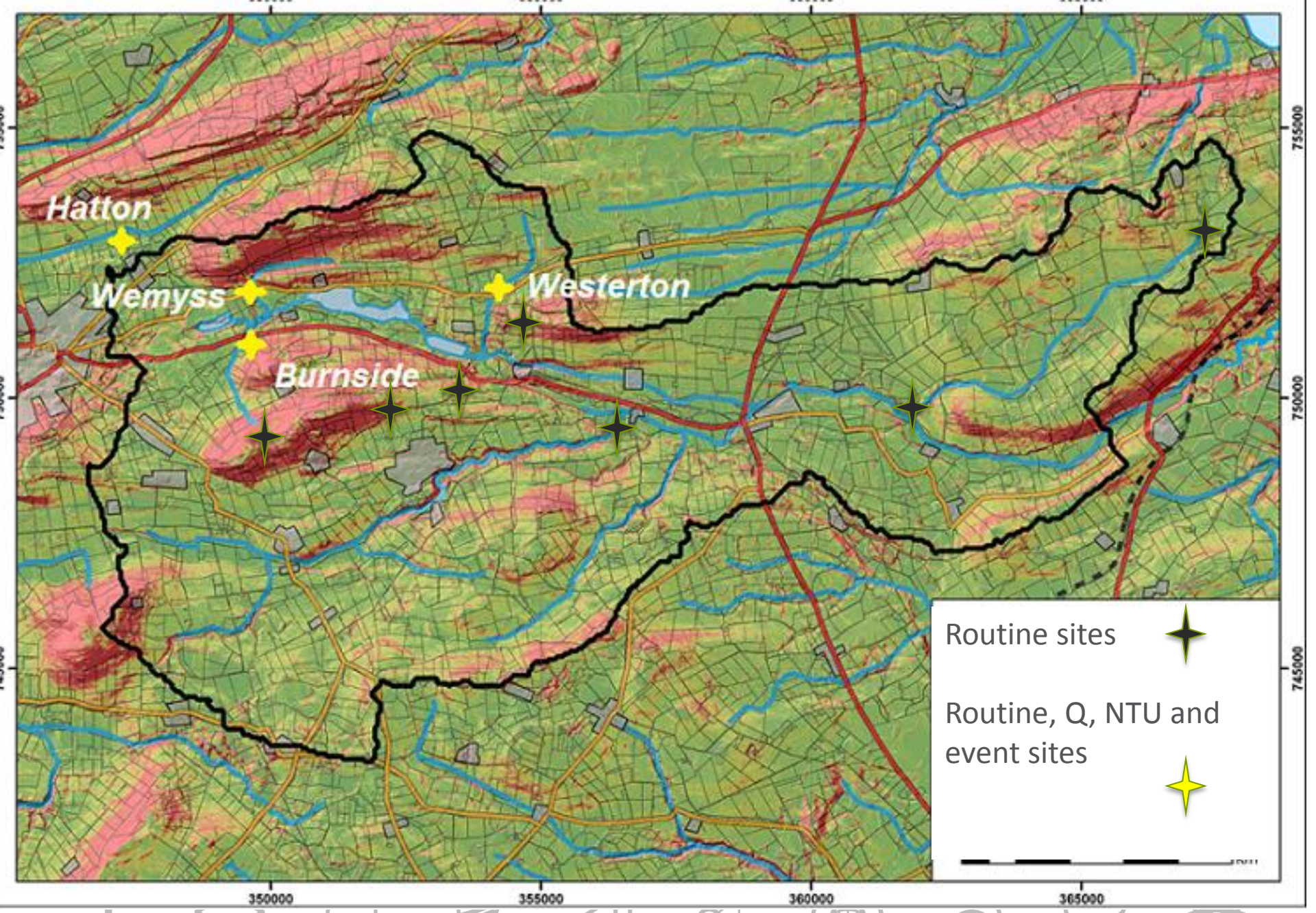
- Lunan Diffuse Pollution Monitored catchment
- Can we demonstrate the impact of WFD measures to control pollution, on water quality?

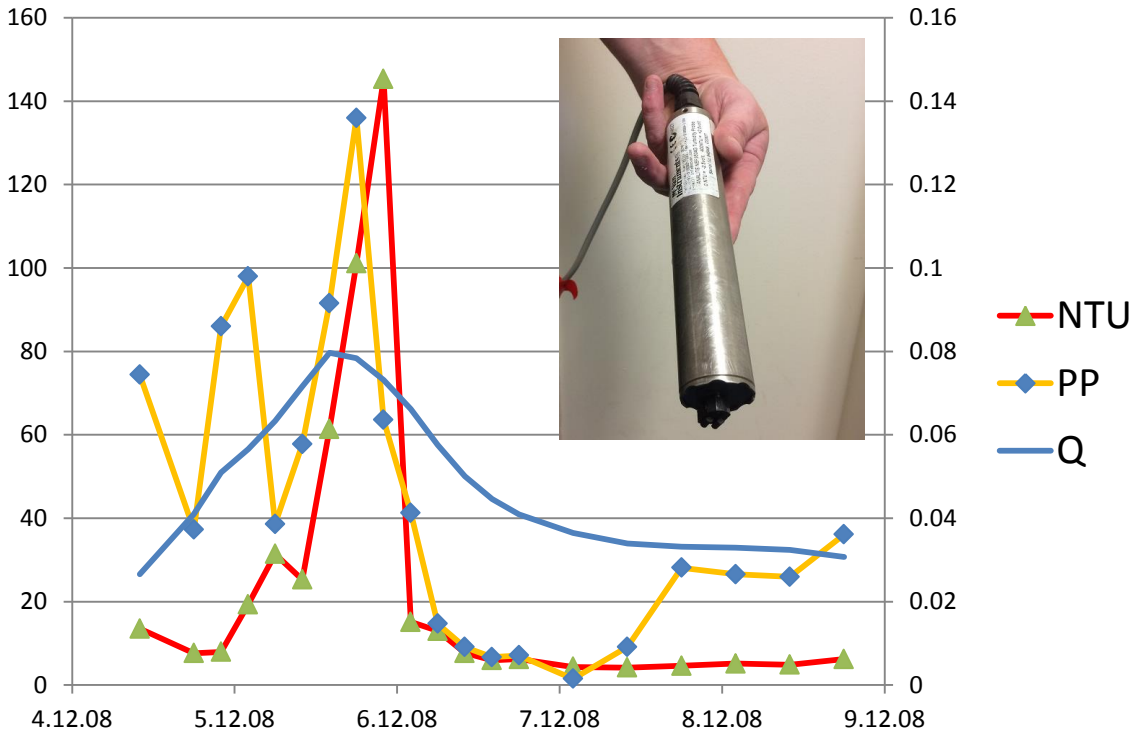
Lunan Water A=134 km²

Rescobie Loch A= 22 km²

Baldardo Burn A=3 km²


Hatton
Wemyss
Westerton
Burnside
Routine sites
Routine, Q, NTU and event sites
350000
355000
360000
365000
755000
750000
745000

Turbidity (NTU) as a surrogate water quality signal



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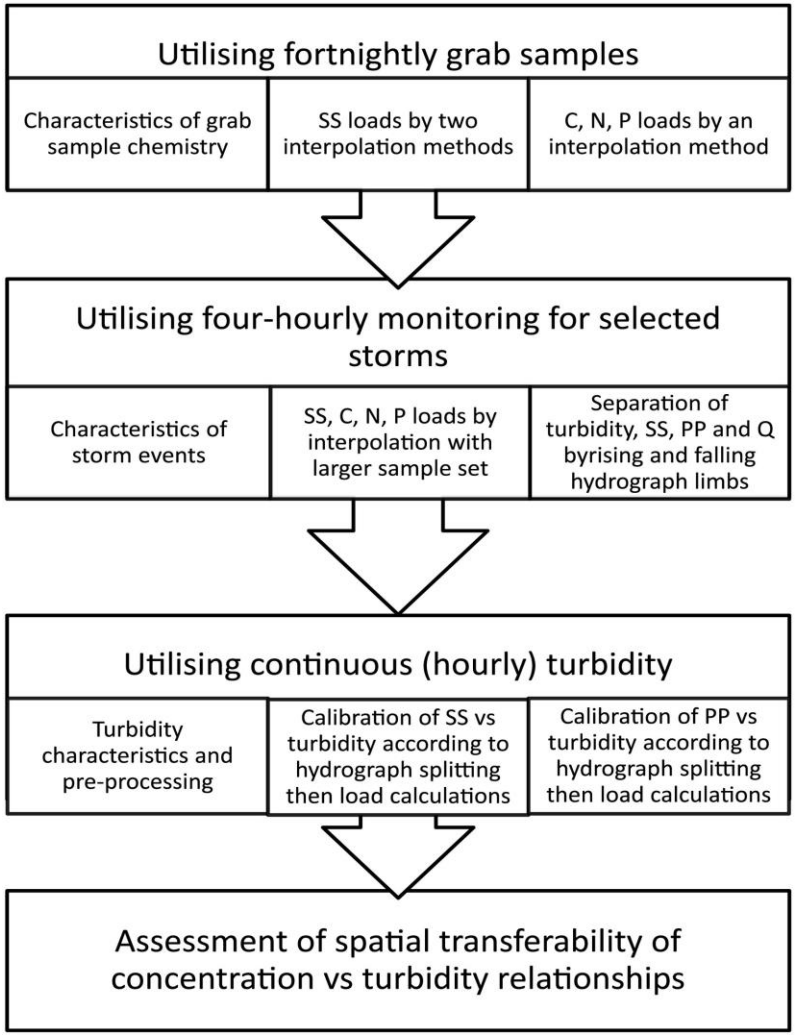
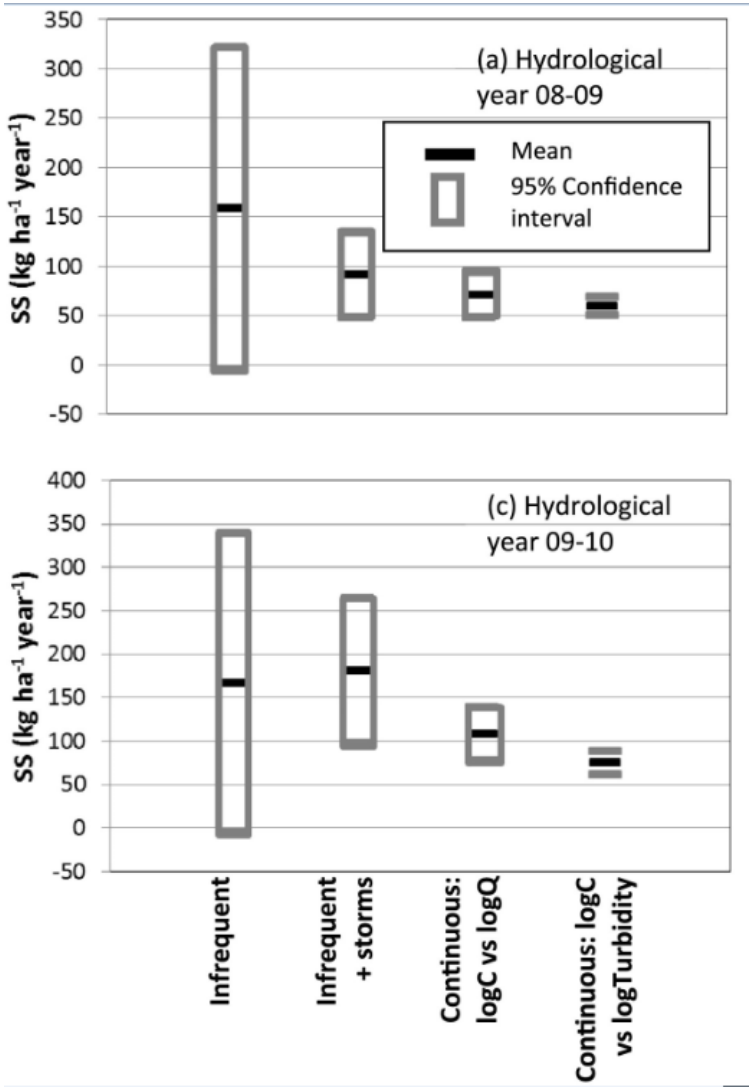
Using events and NTU to improve load estimation

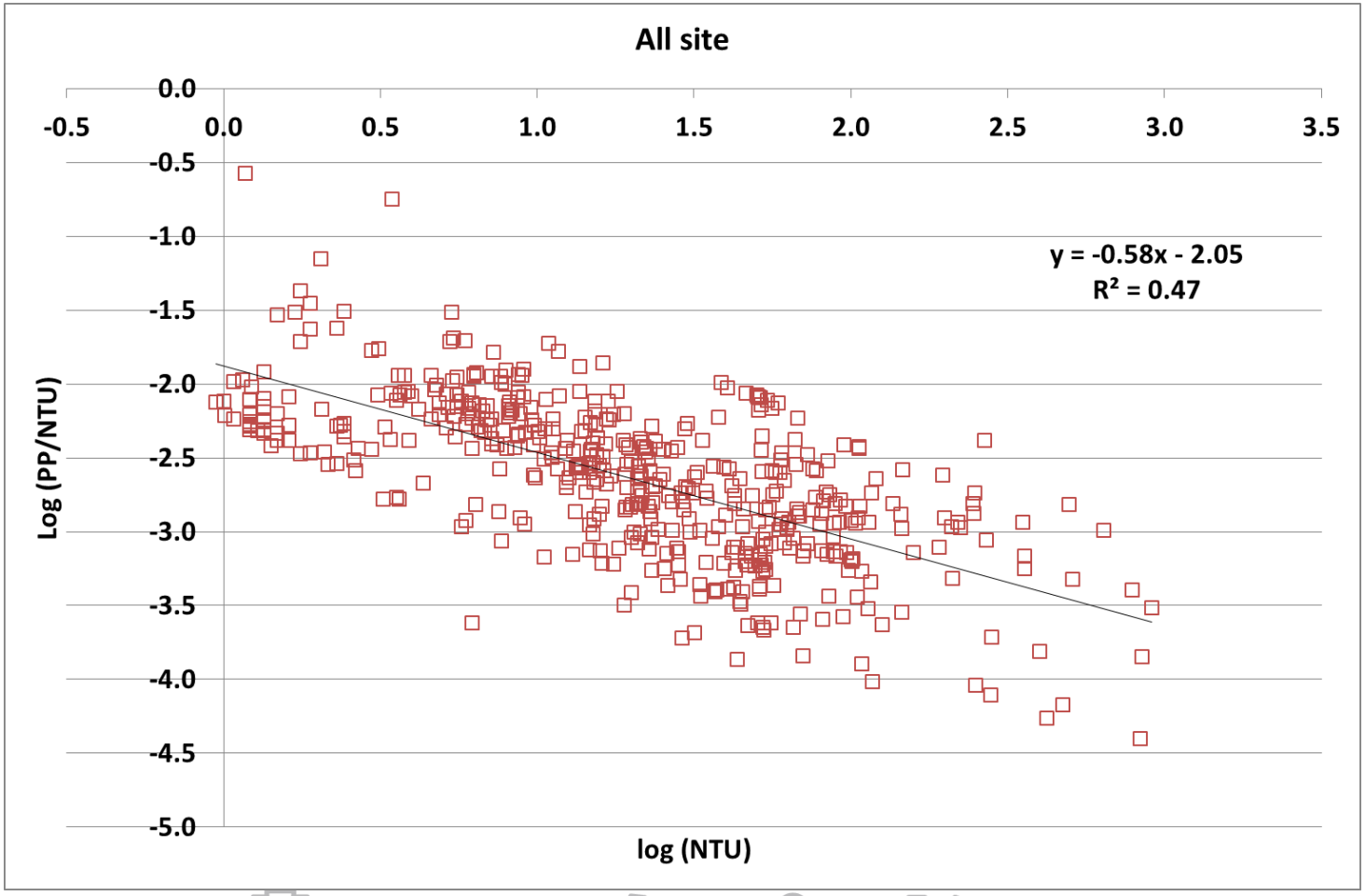




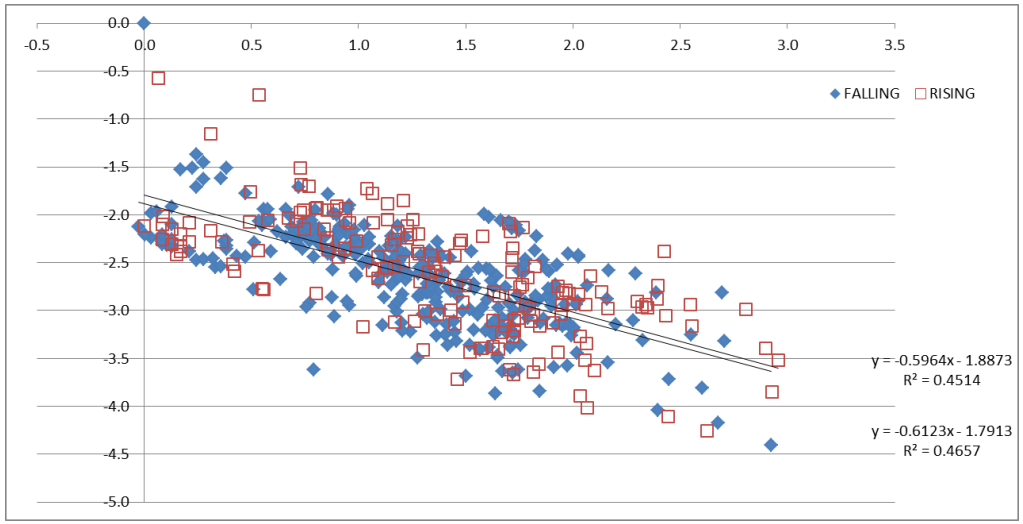
How transferable are calibrations?

- Across different events in the same stream?
- Across different seasons in the same stream?
- Across different streams in the same catchment?
- Across different catchments of similar typology?
- Across catchments of different typologies?

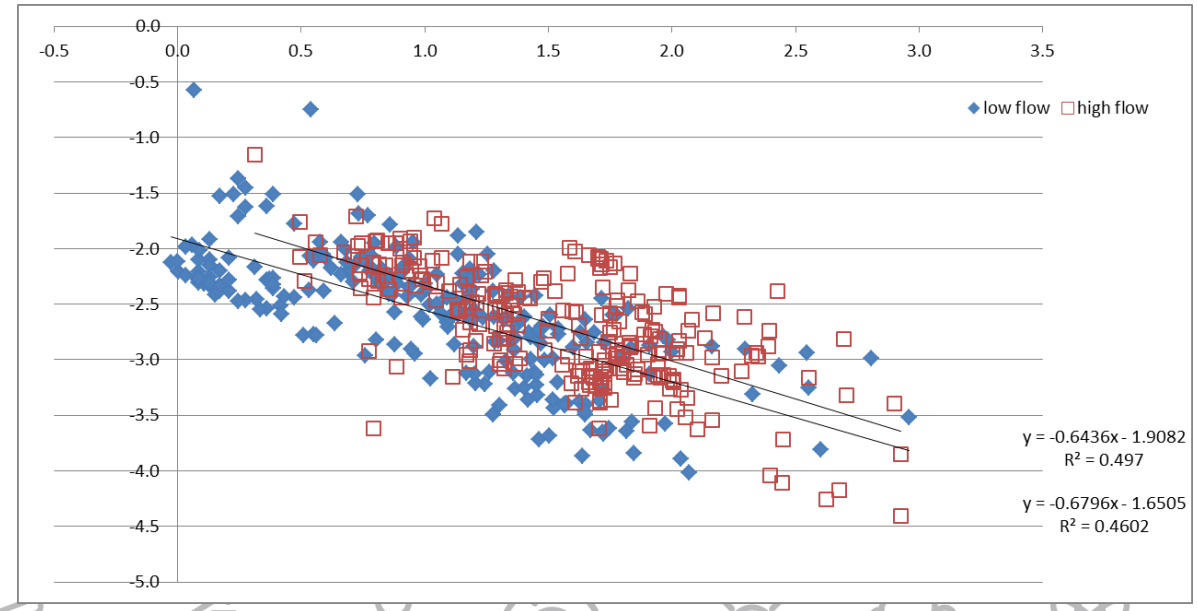
PP content of suspended material is lower for high NTU



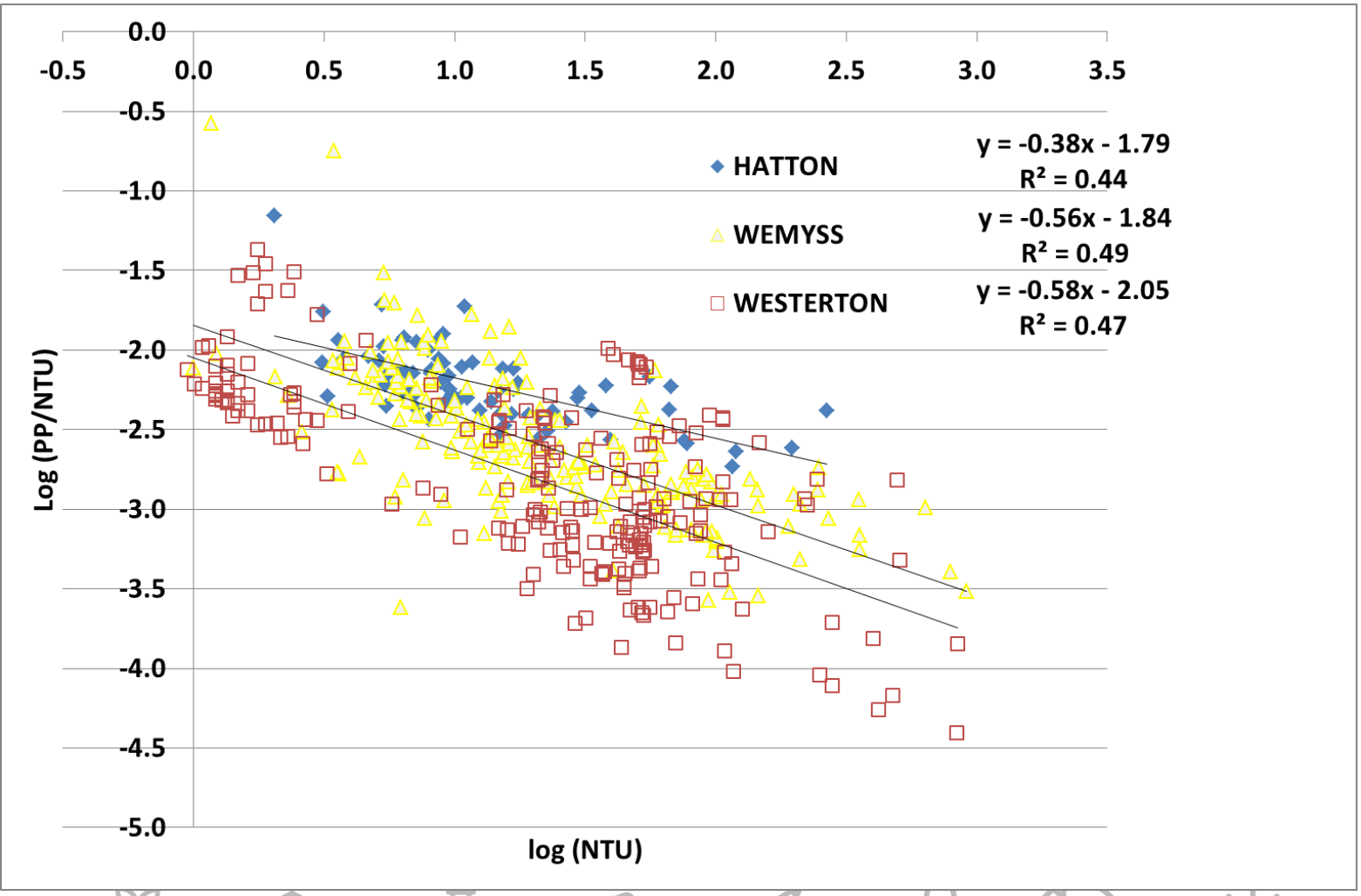
Split by hydrograph direction



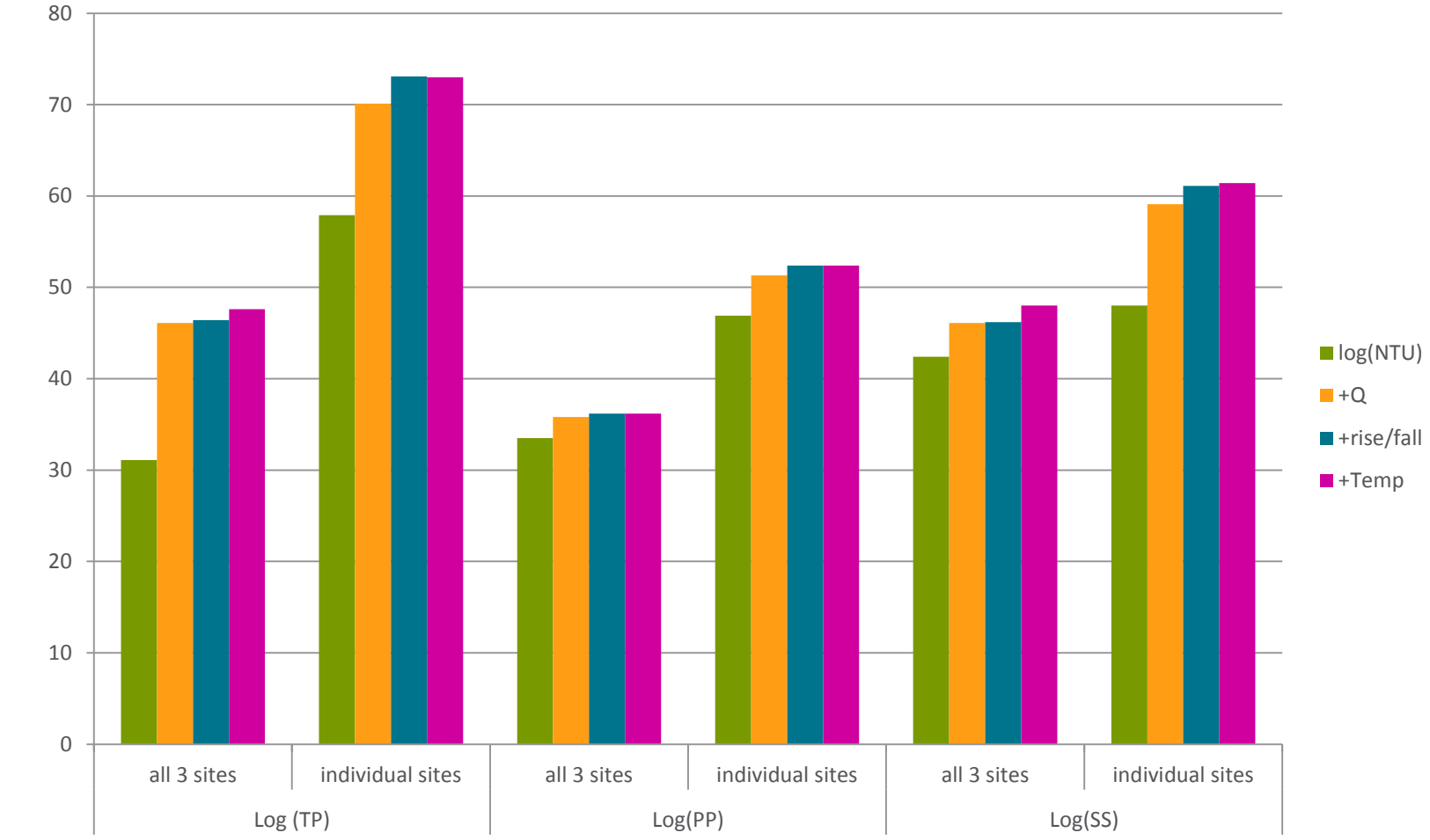
Split by high/low flow



PP content of suspended material varies across sites and during events



% variation accounted for can be improved by multiple regression



Do sources vary within events?

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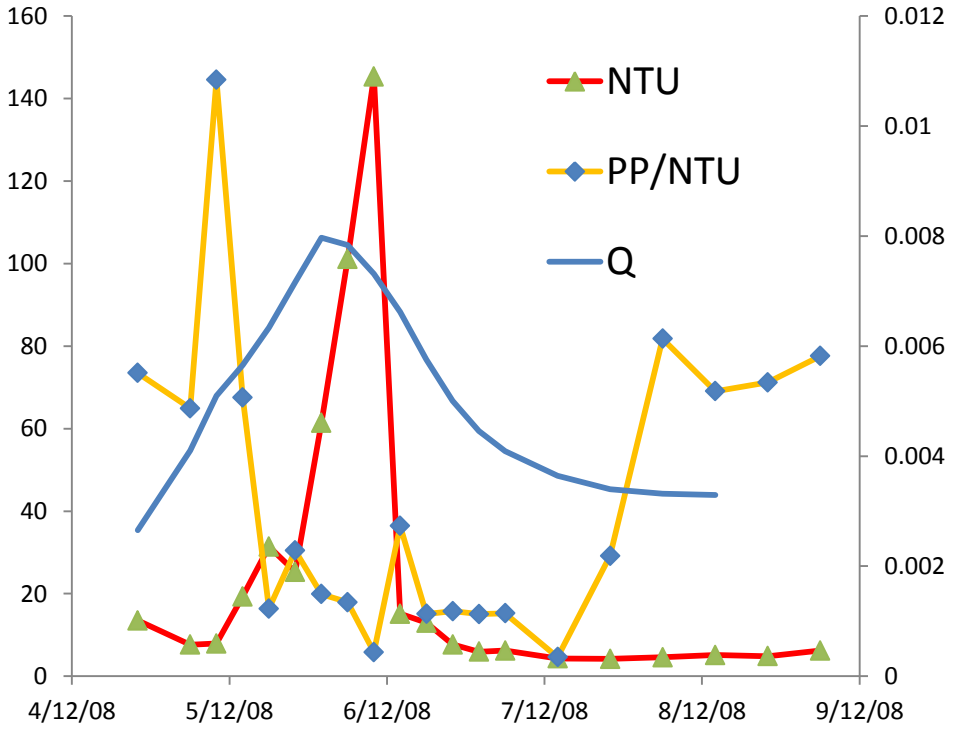
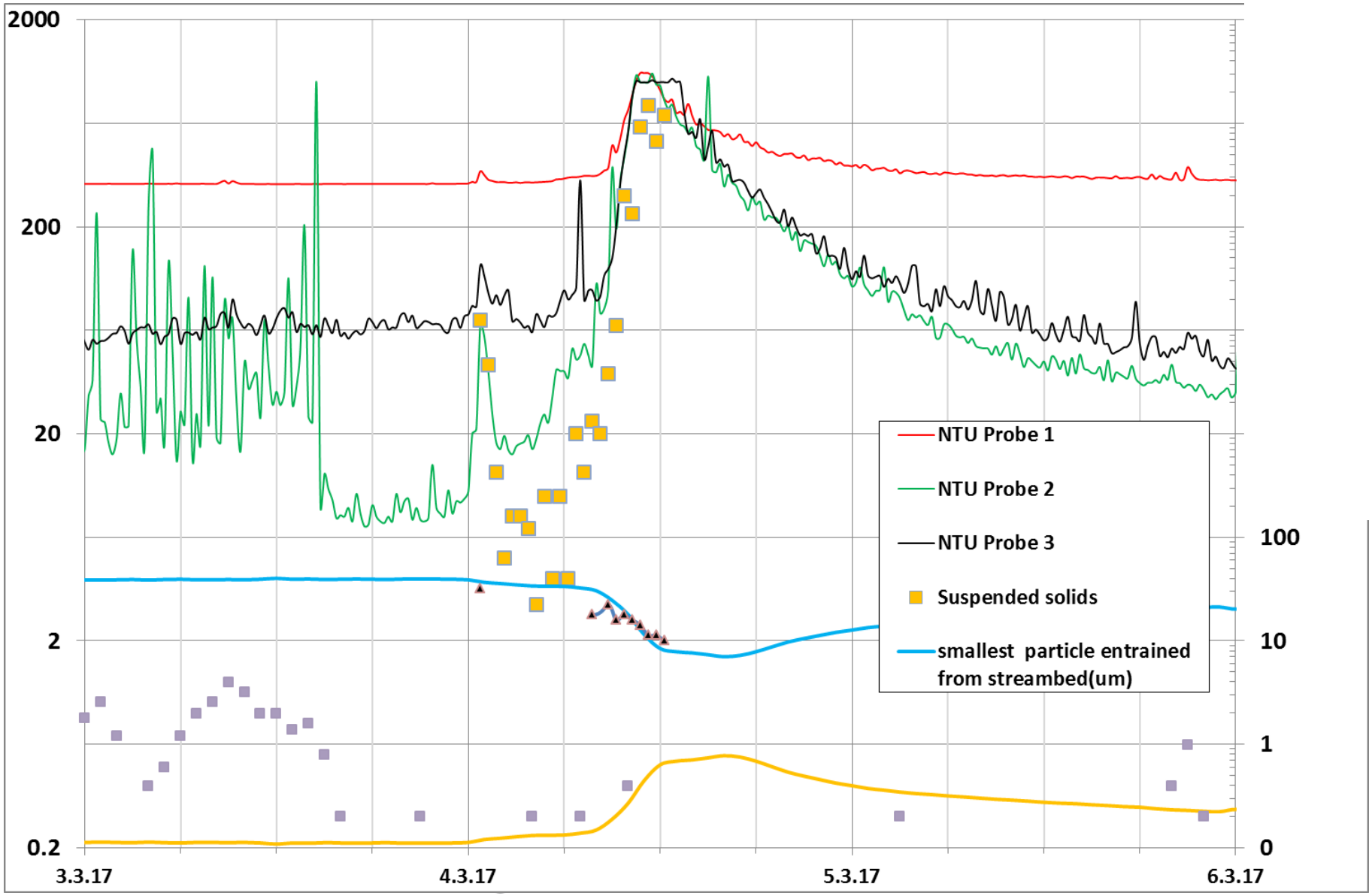


Event response of 3 “replicate” NTU probes Burnside March 2017



sources with different PP/NTU ratios

- Catchment derived and runoff dependent – eg erosion
- Catchment derived and runoff independent – eg septic tanks
- Stream derived and flow dependent – eg sediment scoured stream bed at high flow
- Stream derived and flow independent – eg stream dredging or livestock activity

Is there hidden information in the NTU trace to tell us about these sources?

Exploring the turbidity trace for hidden information

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- A. Are there hidden states of the system, perhaps dominated by different sources of particulate P or SS, which are to be found in the turbidity trace?
  - If so, we could use these hidden states to help categorise the data and make the calibrations more transferable

- B. How spatially variable is the turbidity trace for each event across a stream?
  - Would replicate traces of the turbidity tell us more about the hidden states of the system?

Hidden Markov chains - SADS and sunshine

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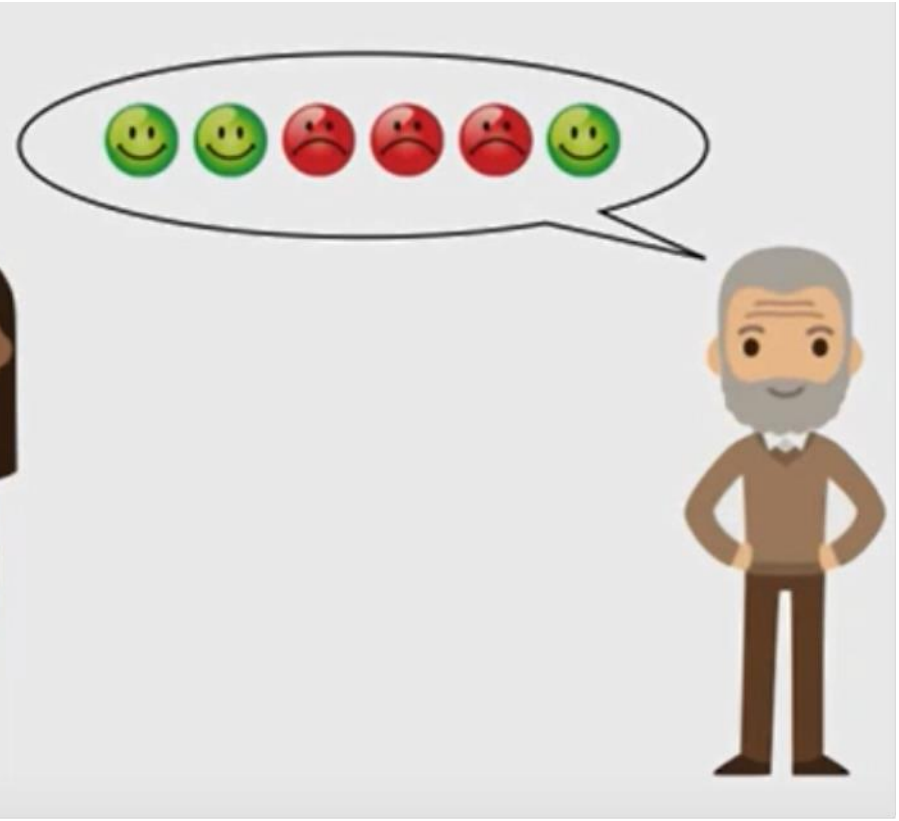
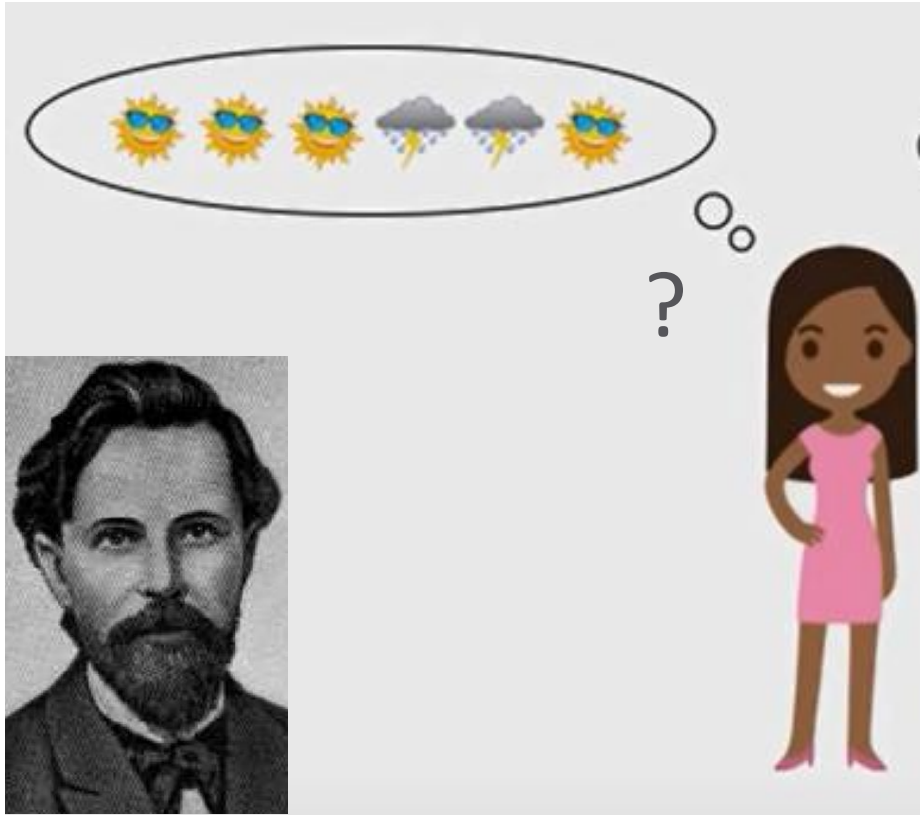
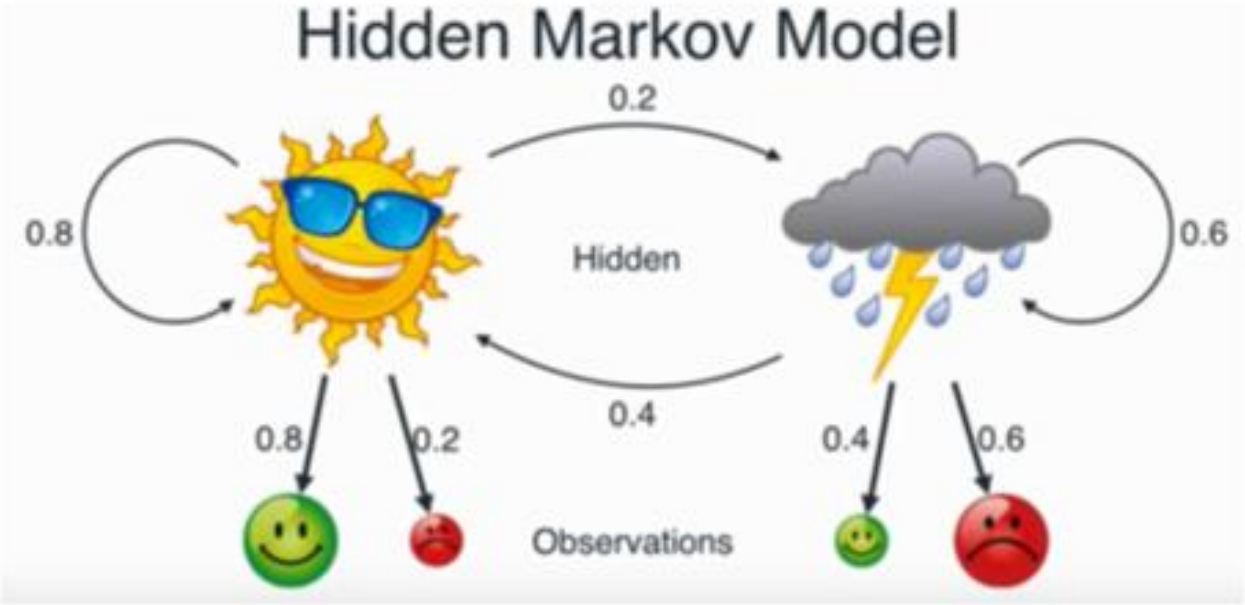
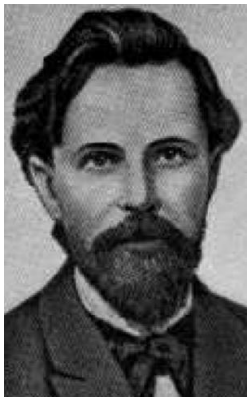
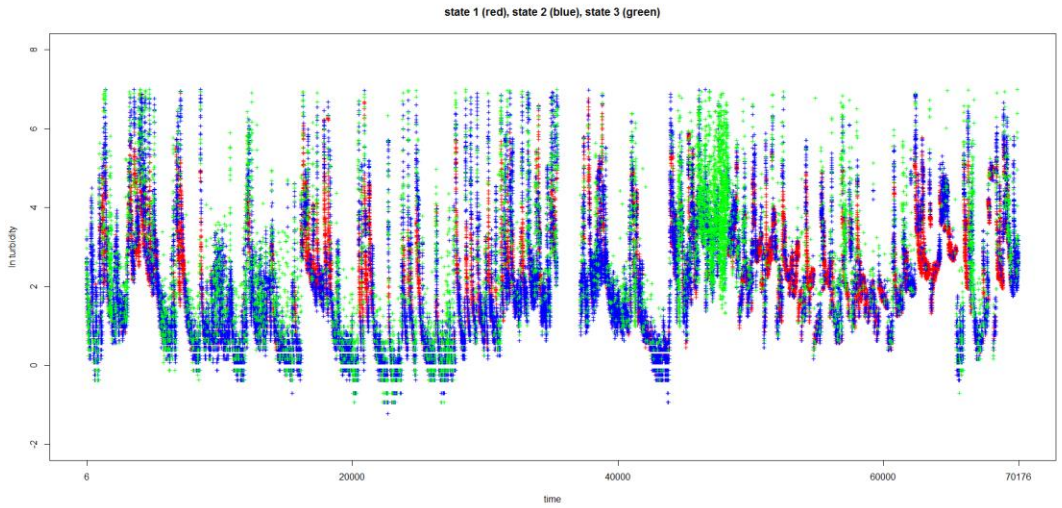





Hidden Markov Model
0.2
0.8
Hidden
0.6
0.4
0.8
0.2
0.4
0.6
Observations

Markov switching autoregressive model

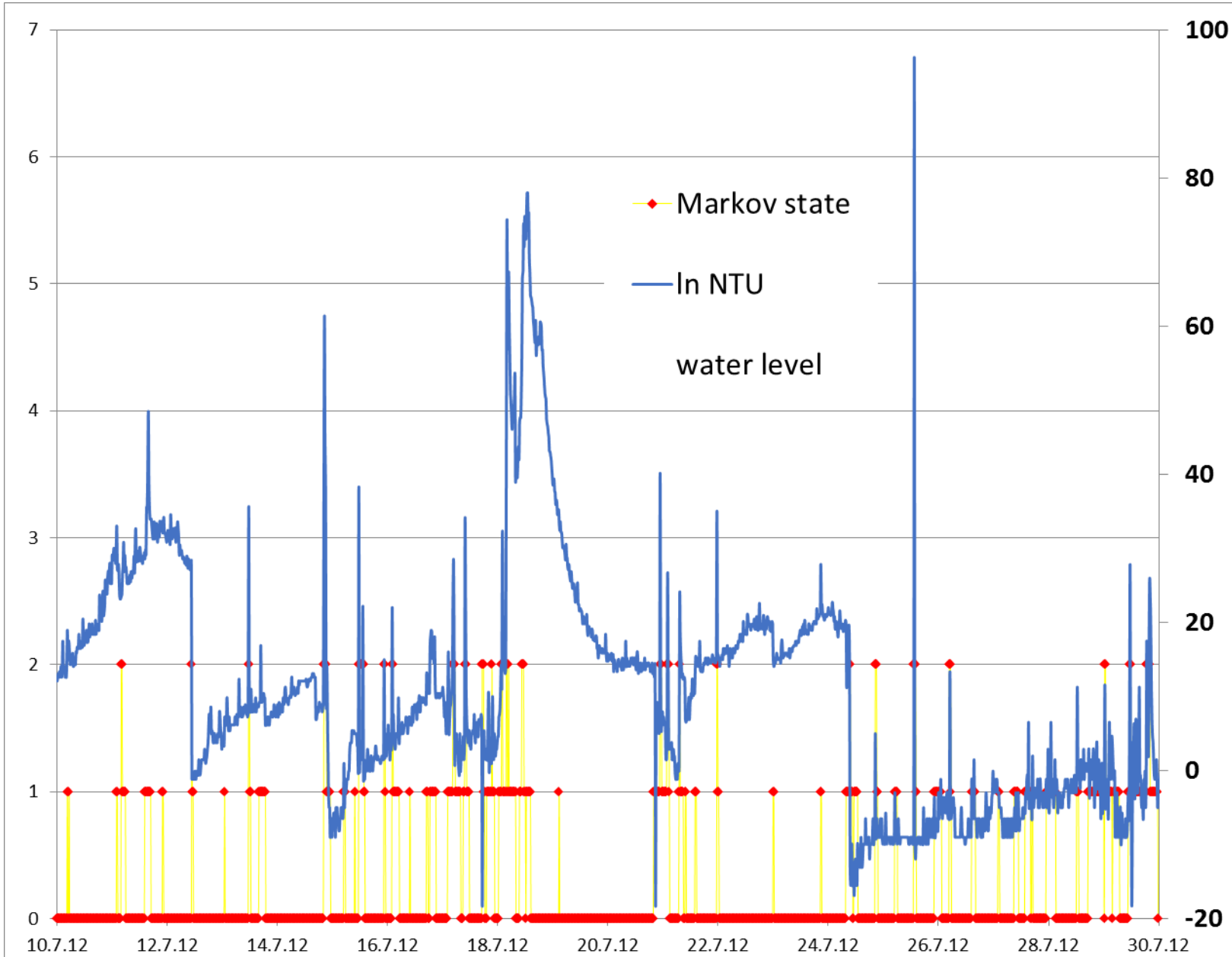


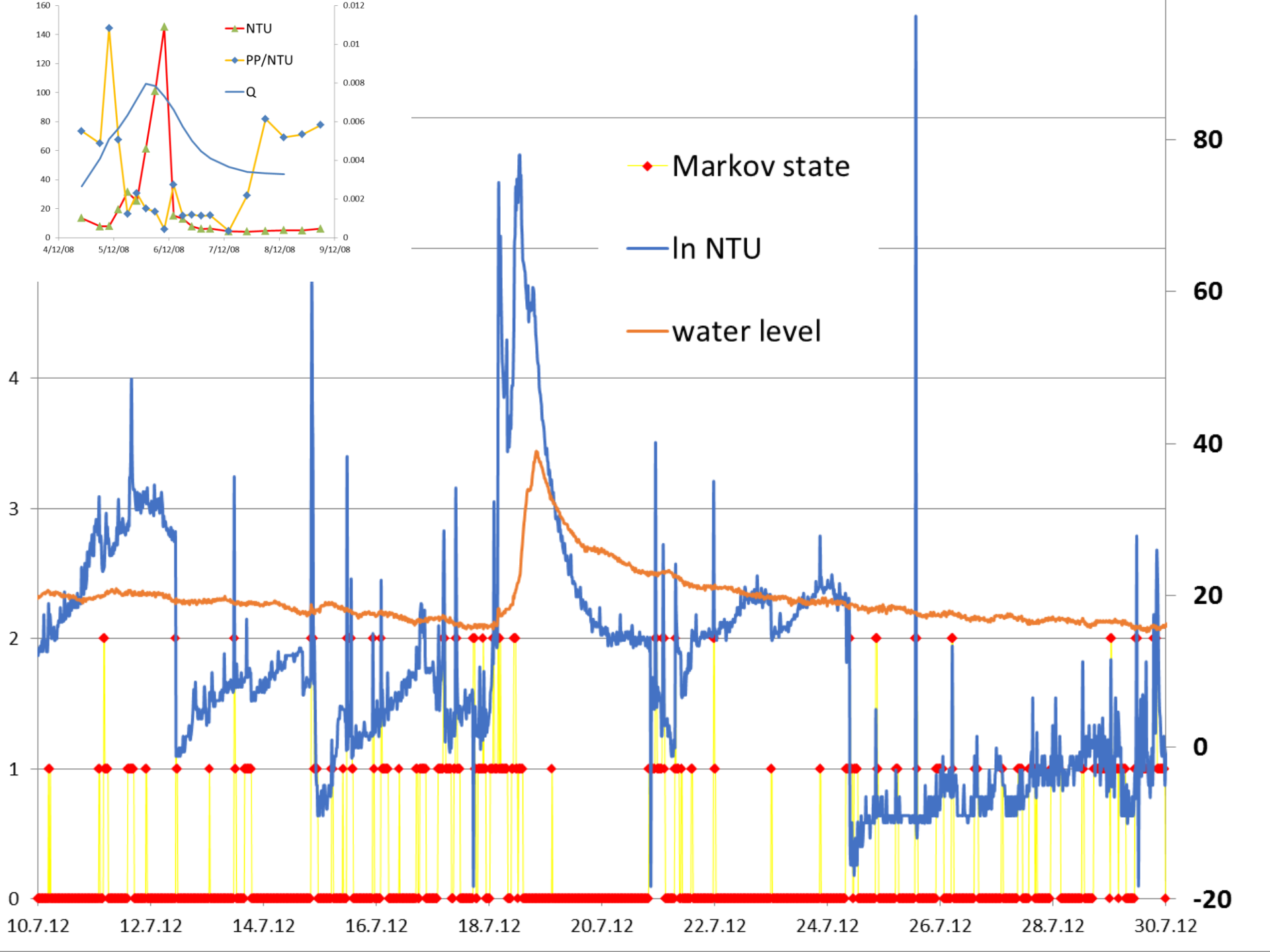


Wemyss catchment in 2011 and 2012

3 hidden states

5 time steps


Markov state
ln NTU
water level
7
6
5
4
3
2
1
0
100
80
60
40
20
0
-20
10.7.12
12.7.12
14.7.12
16.7.12
18.7.12
20.7.12
22.7.12
24.7.12
26.7.12
28.7.12
30.7.12


NTU
PP/NTU
Q
4/12/08
5/12/08
6/12/08
7/12/08
8/12/08
9/12/08
Markov state
ln NTU
water level
10.7.12
12.7.12
14.7.12
16.7.12
18.7.12
20.7.12
22.7.12
24.7.12
26.7.12
28.7.12
30.7.12

Summary

- Continuous turbidity data can be used to aid predictions of pollutant loads such as PP
- The calibrations obtained for specific events are quite good,
- These can be improved by including easily measured co-variates such as flow, temperature and hydrograph condition,
- The transferability of the calibrations declines across events at the same site and across different sites
- A principal reason for this is thought to be that the PP/NTU or PP/SS ratios for different sources vary widely (allonchthonous vs authonchthonous, flow dependent vs flow independent sources)
- Hidden Markov analysis of the different states of the turbidity trace could help distinguish these sources for different sites, and hence improve the transferability of the calibrations across sites and catchments
- ….but it's a long haul, and definitely contributes to Andy's sadness along with the weather….