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A methodology to distinguish between human interventions and impacts caused by climate change

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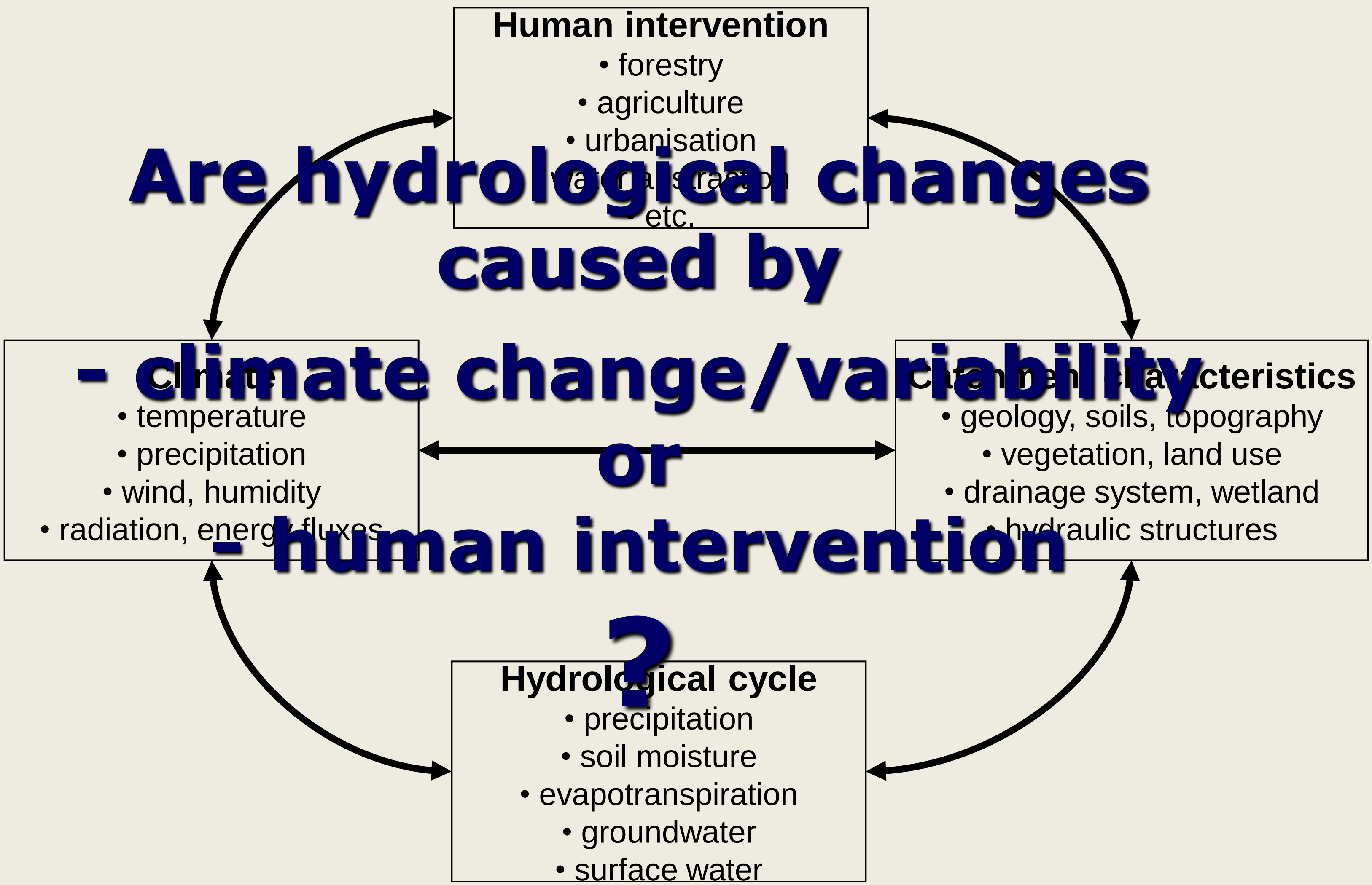
Outline

- What is the problem?
- Climate Filter
  - How to identify effect of human intervention when climate variability generates ”noise” in observed records
  - Case study from Zimbabwe
- Human Intervention Predictor
- Methodology
- Weak aspects of methodology
- Conclusions

Interactions with the hydrological system



Are hydrological changes caused by

- climate change/variability

or

- human intervention

?

Climate Filter
- idea

- Climate variability generates temporal variation in hydrological time series = ”noise” in statistical tests for detection of effects from catchment changes (human interaction)
- Hydrological models can simulate some of the climate induced temporal variability

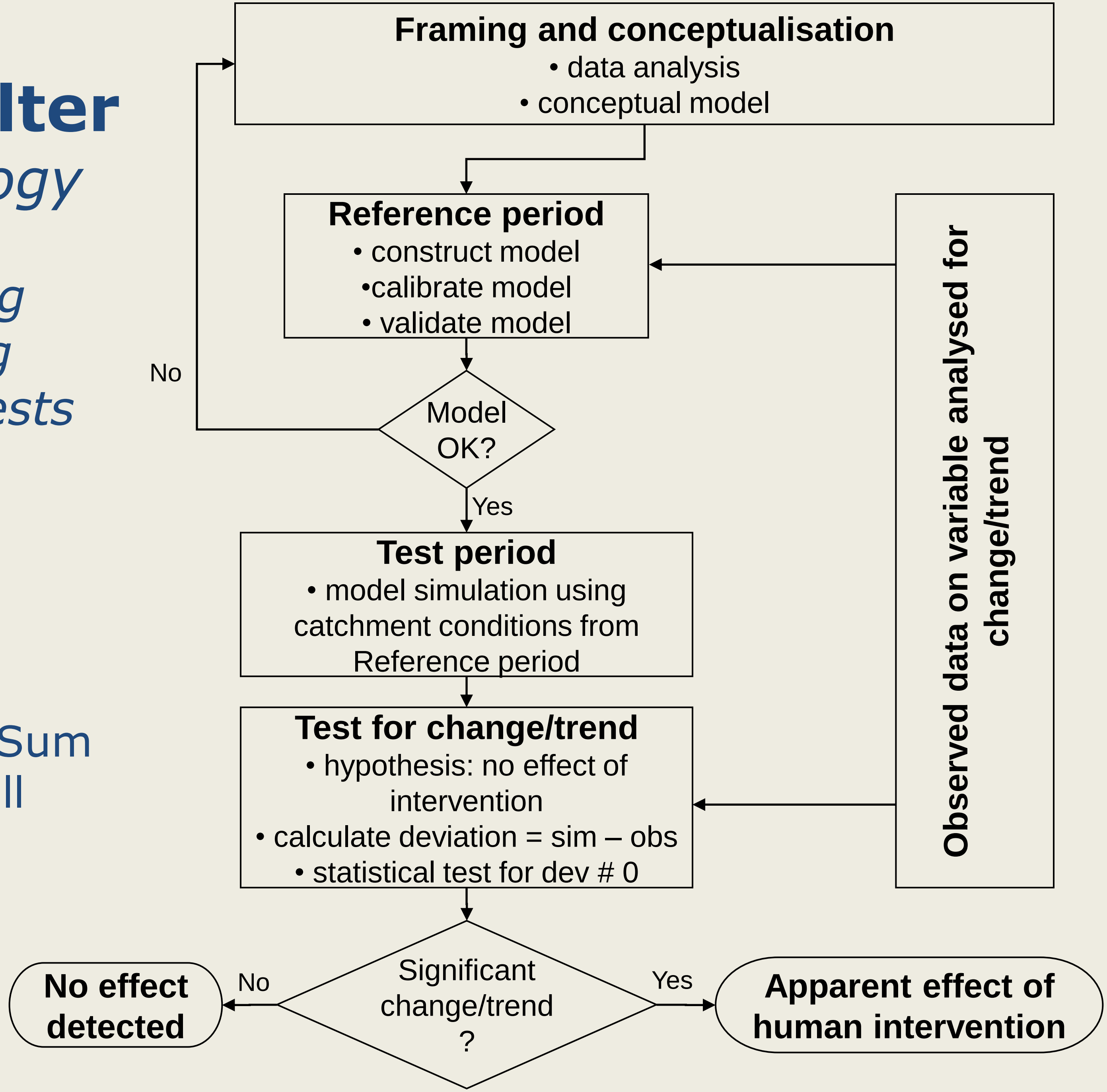
  ➔reduced ”noise”

  ➔weaker signals can be detected as statistically significant

Climate Filter

- methodology

- monitoring
- modelling
- statistical tests



Wilcoxon Rank-Sum
Mann-Kendall
Student t

Case: Illustration of Climate Filter to separate effects of climate variability and land use changes on catchment runoff in Zimbabwe

Problem

- Increased rural population and pressure on land in Zimbabwe during the past 40 years
- Large climate variability (drought periods, wet periods)
- What are the impacts on water resources ?

Reference

- Lørup JK, Refsgaard JC, Mazvimavi D (1998) Assessing the effect of land use change on catchment runoff by combined use of statistical tests and hydrological modelling: Case studies from Zimbabwe. Journal of Hydrology, 205, 147-163.

Key characteristics of selected catchments

Catchment No. and name	Area km^2	MAP[a] mm/yr	MAQ[b] mm/yr	Altitude range	Soils	Geology
C23 Nyatsime	500	800	100	1390-1600	sandy loam and sandy clay loam, some clay	Granite with dolorite intrusions
E2 Mshagashi	541	650	75	1060-1490	coarse sand to sandy loam moderately shallow	Granite
E49 Popotekwe	1010	675	80	1050-1550	coarse sand to sandy loam moderately shallow	Granite

Development of population density (persons/km^2) 1962-92 for communal lands in catchments

Catch-ment	Name of communal land	Percent of catchment	1962	1969	1982	1992	Yearly in-crease (%)
C23	Seke	53	43	64	77	97	2.7
	Chiota	35	37	52	65		2.9
E2	Mshagashi SSCF[a]	35	14	13	12	13	-0.3
E49	Chikwanda	13	24	33	41	45	2.1
	Serima	21	26	49	45	53	2.4
	Zimuto	27	25	28	42	47	2.1

Increase in population density:

C23: High population pressure, large increase

E49: Moderate population density, moderate increase

E2: Low population density, no increase

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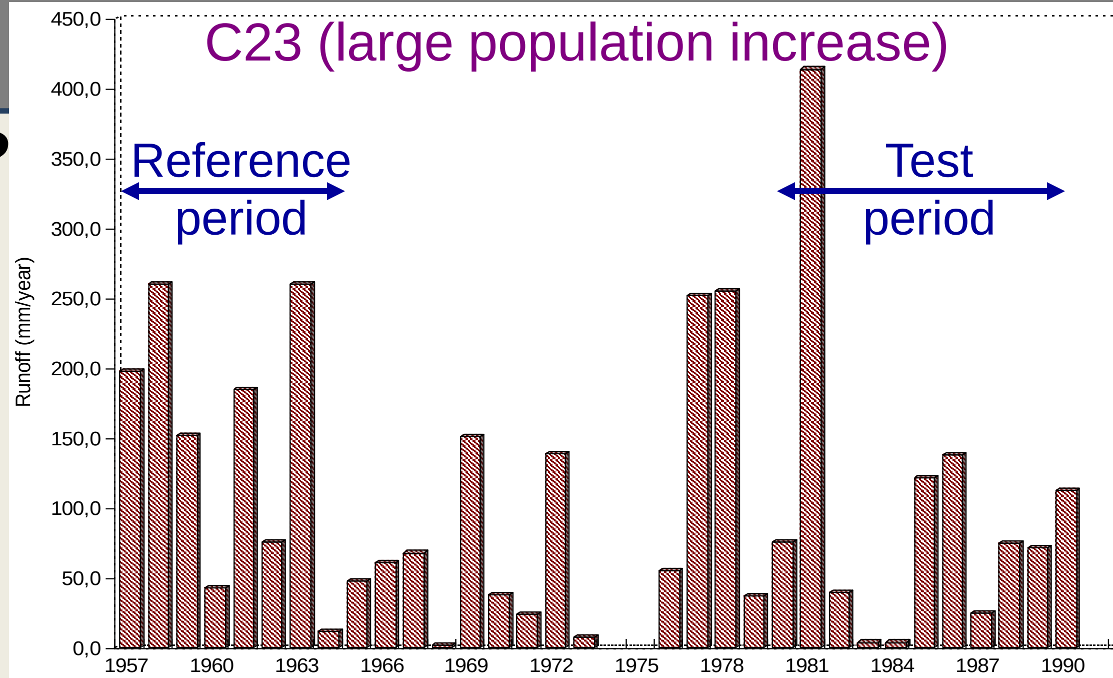
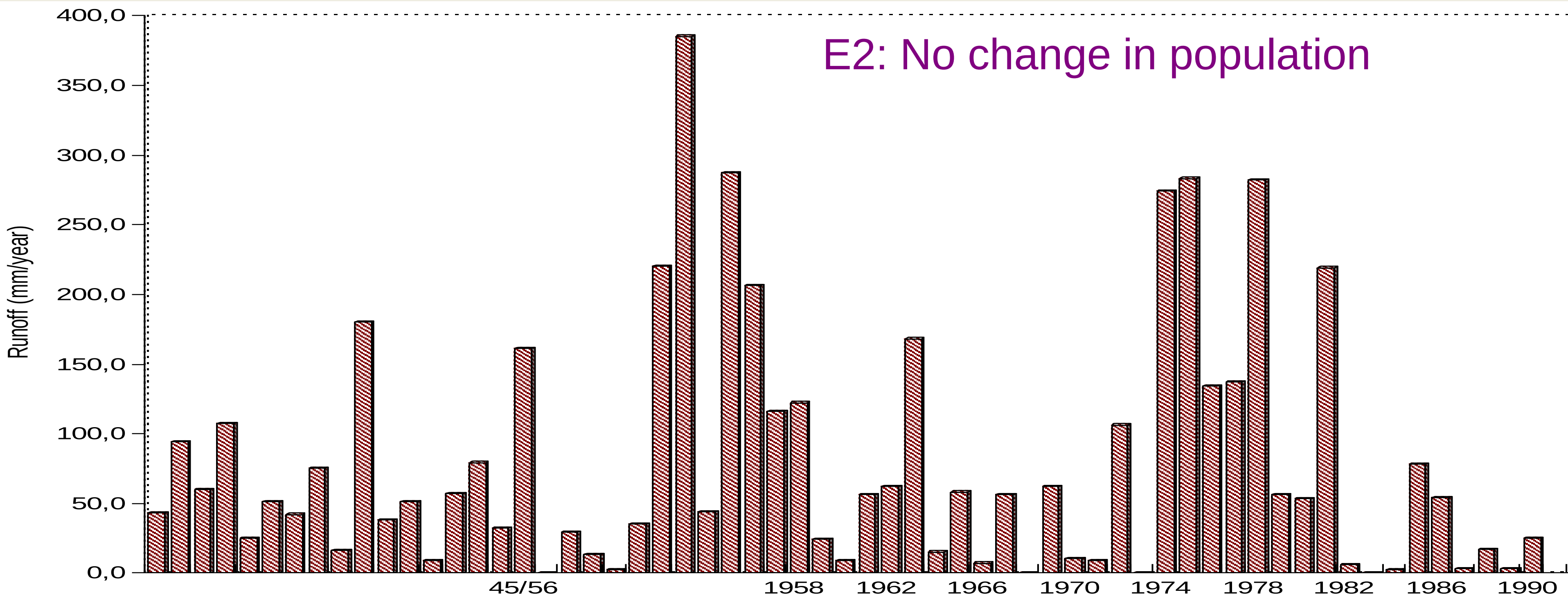
Change in runoff ?

Statistical tests

- **Wilcoxon Rank-Sum test**
- **Test for shift in mean annual runoff**





Statistical data for observed rainfall and runoff

Catchment			Rainfall (mm/yr)				Qobs (mm/yr)			
			Mean		Std. dev.		Mean		Std. dev.	
	Ref. period	Test period	Ref. period	Test period	Ref. period	Test period	Ref. period	Test period	Ref. period	Test period
C23	57-64	77-90	792	796	207	226	141	106	101	115
E2	57-65	77-90	661	650	152	218	64	62	60	88
E49	60-68	76-91[c]	649	673	168	225	69	78	64	96

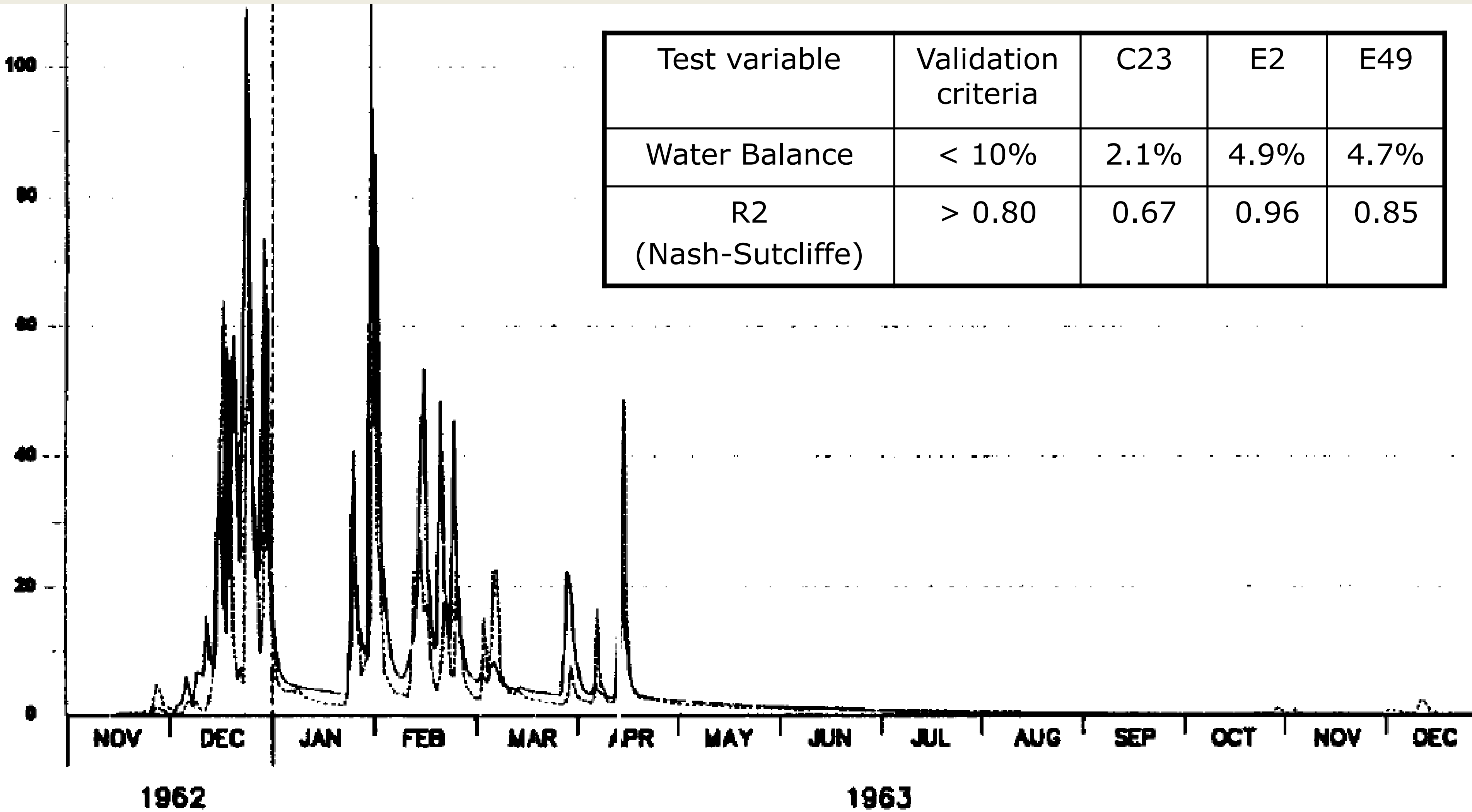
Wilcoxon Rank-Sum test

→ No statistically significant change in runoff (observed timeseries)

Rainfall-runoff modelling - NAM

- test of model performance in reference period through split-sample validation tests
- hydrographs, performance criteria

Test variable	Validation criteria	C23	E2	E49
Water Balance	< 10%	2.1%	4.9%	4.7%
R2 (Nash-Sutcliffe)	> 0.80	0.67	0.96	0.85



Climate Filter

- methodology

- monitoring
- modelling
- statistical tests

Wilcoxon Rank-Sum
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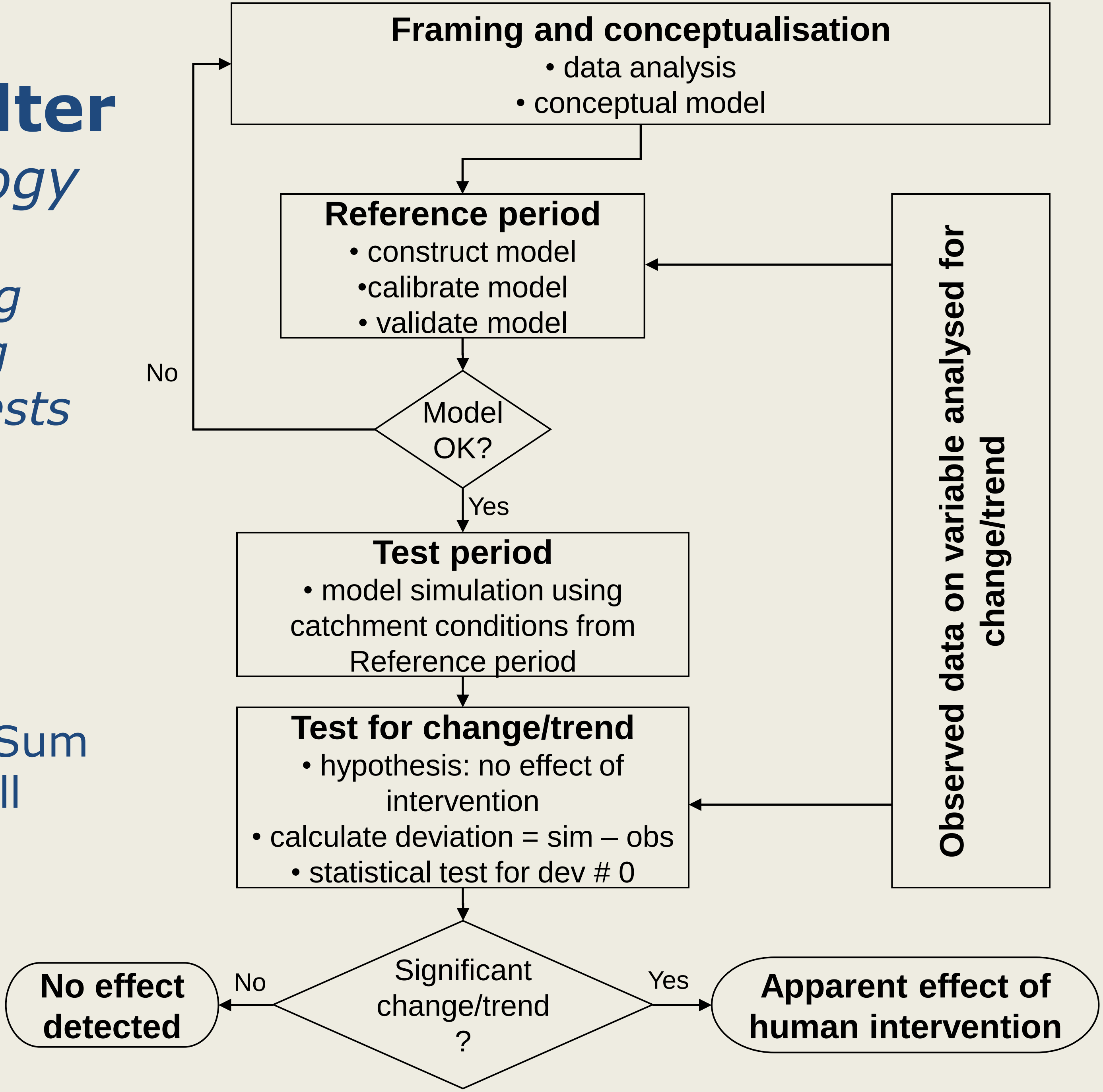
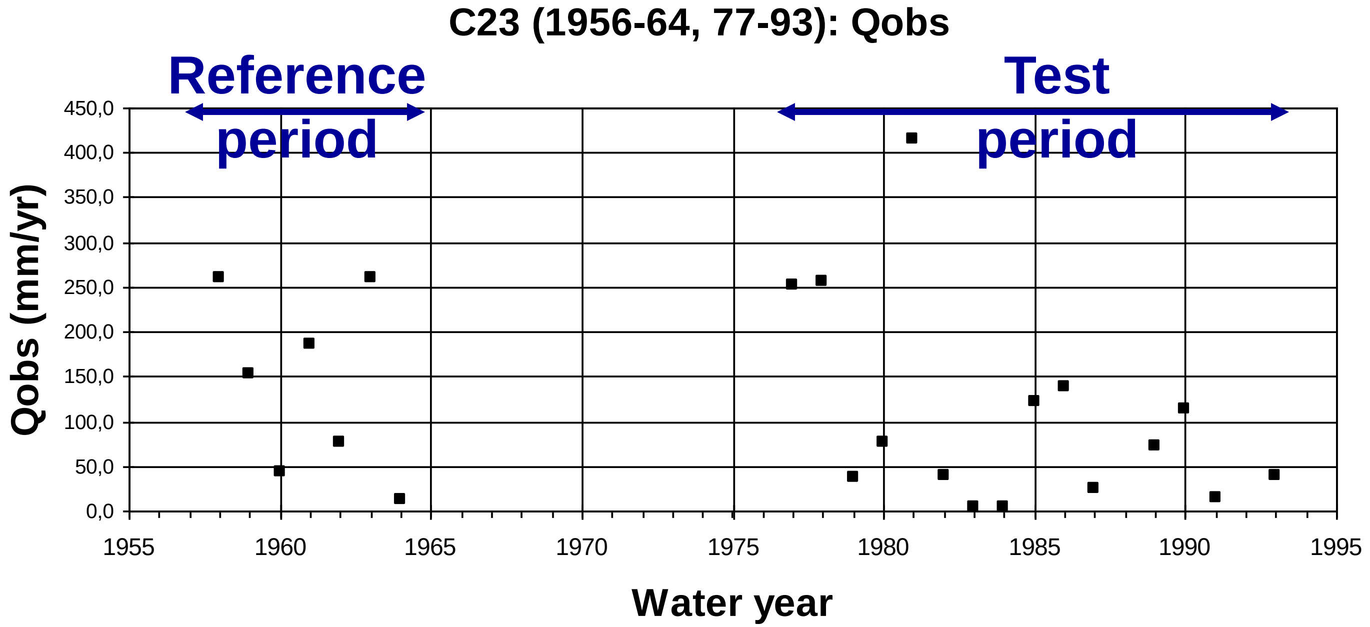
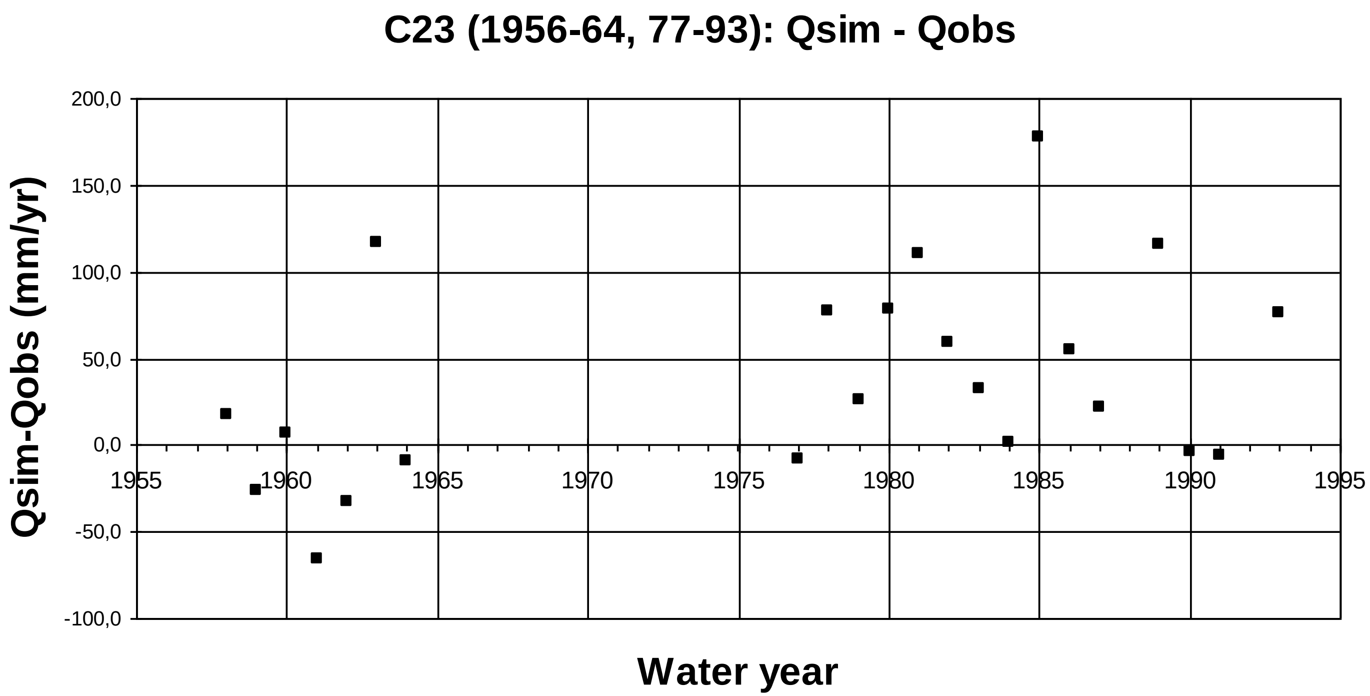




Observed runoff

Change in mean:

NOT statistically significant



Modelling

Change in mean:

STATISTICALLY SIGNIFICANT

Statistical tests for change in mean runoff

Analysing series of deviations between
- observed runoff
- simulated using NAM model calibrated for reference period

Catchment			Rainfall (mm/yr)				Qobs (mm/yr)				Qsim - Qobs (mm/yr)			
			Mean		Std. dev.		Mean		Std. dev.		Mean		Std. dev.	
	Ref. period	Test period	Ref. period	Test period	Ref. period	Test period	Ref. period	Test period	Ref. period	Test period	Ref. period	Test period	Ref. period	Test period
C23	57-64	77-90	792	796	207	226	141	106	101	115	1.3	65	57	52
E2	57-65	77-90	661	650	152	218	64	62	60	88	-1.0	4.1	13	34
E49	60-68	76-91[c]	649	673	168	225	69	78	64	96	-2.1	10	17	20

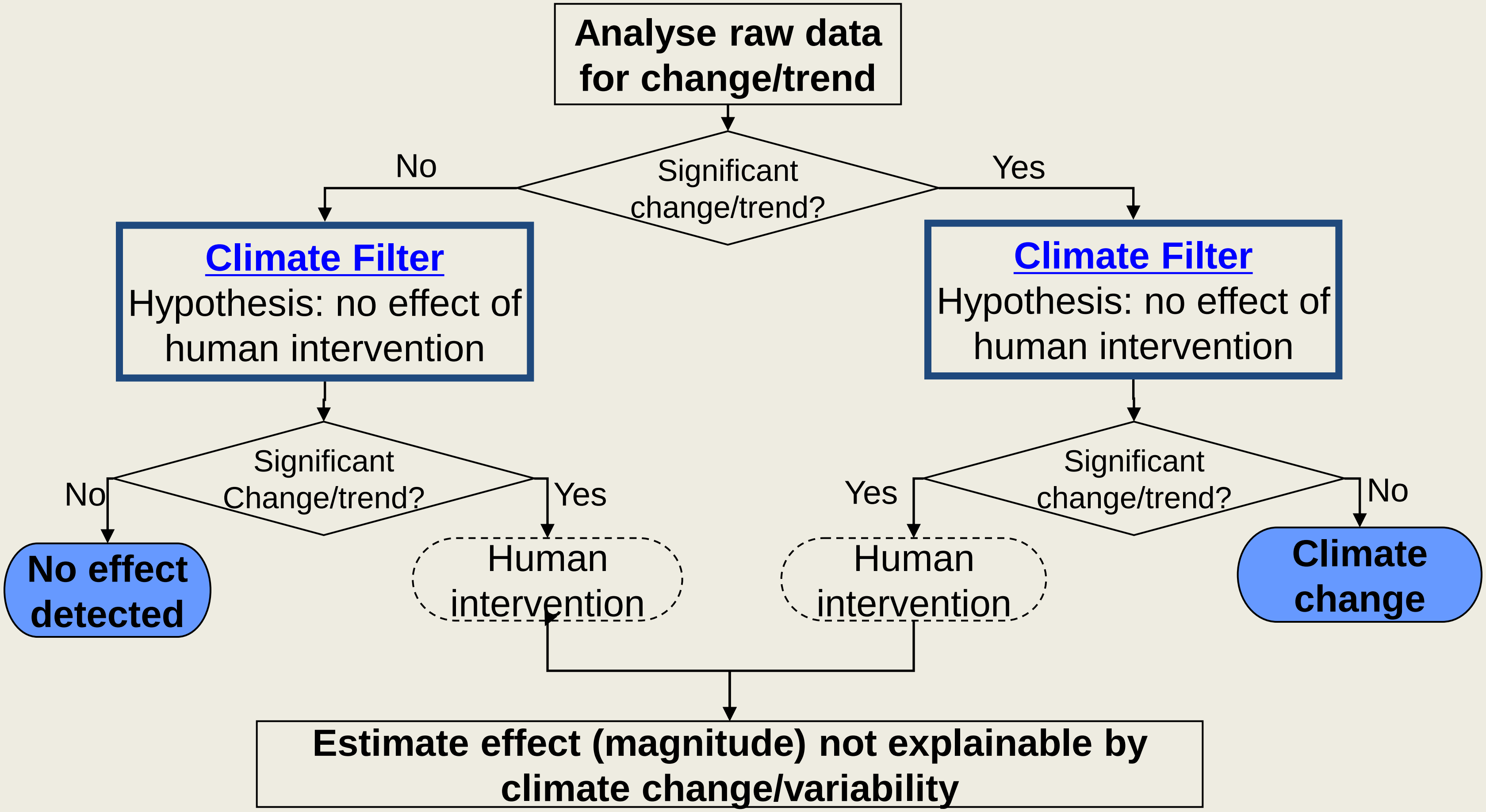
Catchment	Significance level[f] for H_0		
	Rainfall	Q_{obs}	Q_{sim} - Q_{obs}
C23	97%	40%	**1.9%**
E2	72%	32%	50%
E49	64%	82%	28%

Wilcoxon Rank-Sum test for change in mean runoff

Statistically significant

Not significant

Distinguish between human intervention and climate change



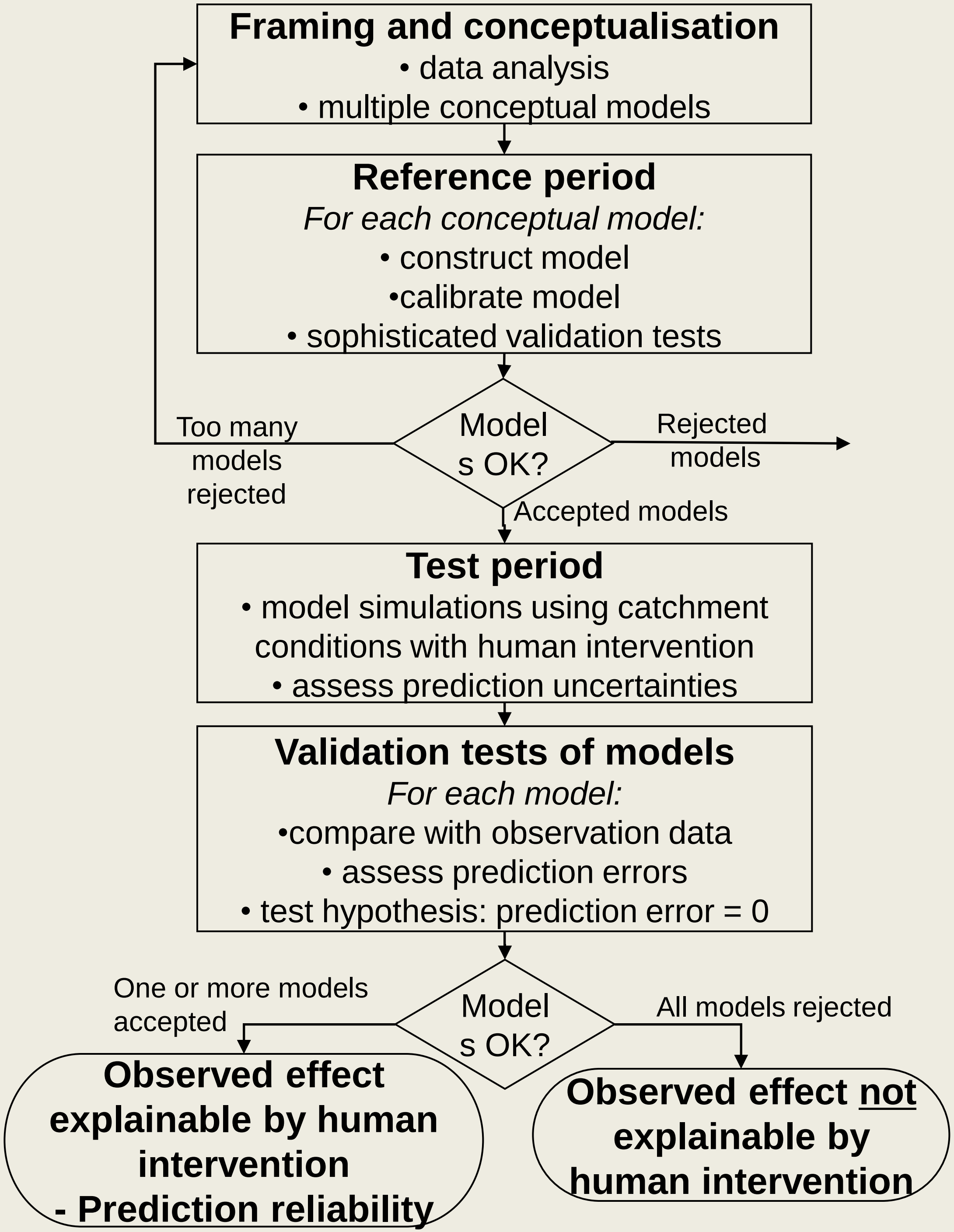
Human Intervention Predictor
- idea

- Human interventions may be simulated by hydrological models
- Due to equifinality, multiple models (model structures, parameter sets) can be accepted after validation tests in Reference period (where human intervention has not occurred yet)
- Human intervention is predicted by multiple models
  - Validation tests against field data in Test period (with human intervention) using actual climate
  - Test if prediction error can be assumed = zero
- Good match in Test period by one of the multiple models can be a ”lucky punch” ➔ need for assessment of prediction uncertainties

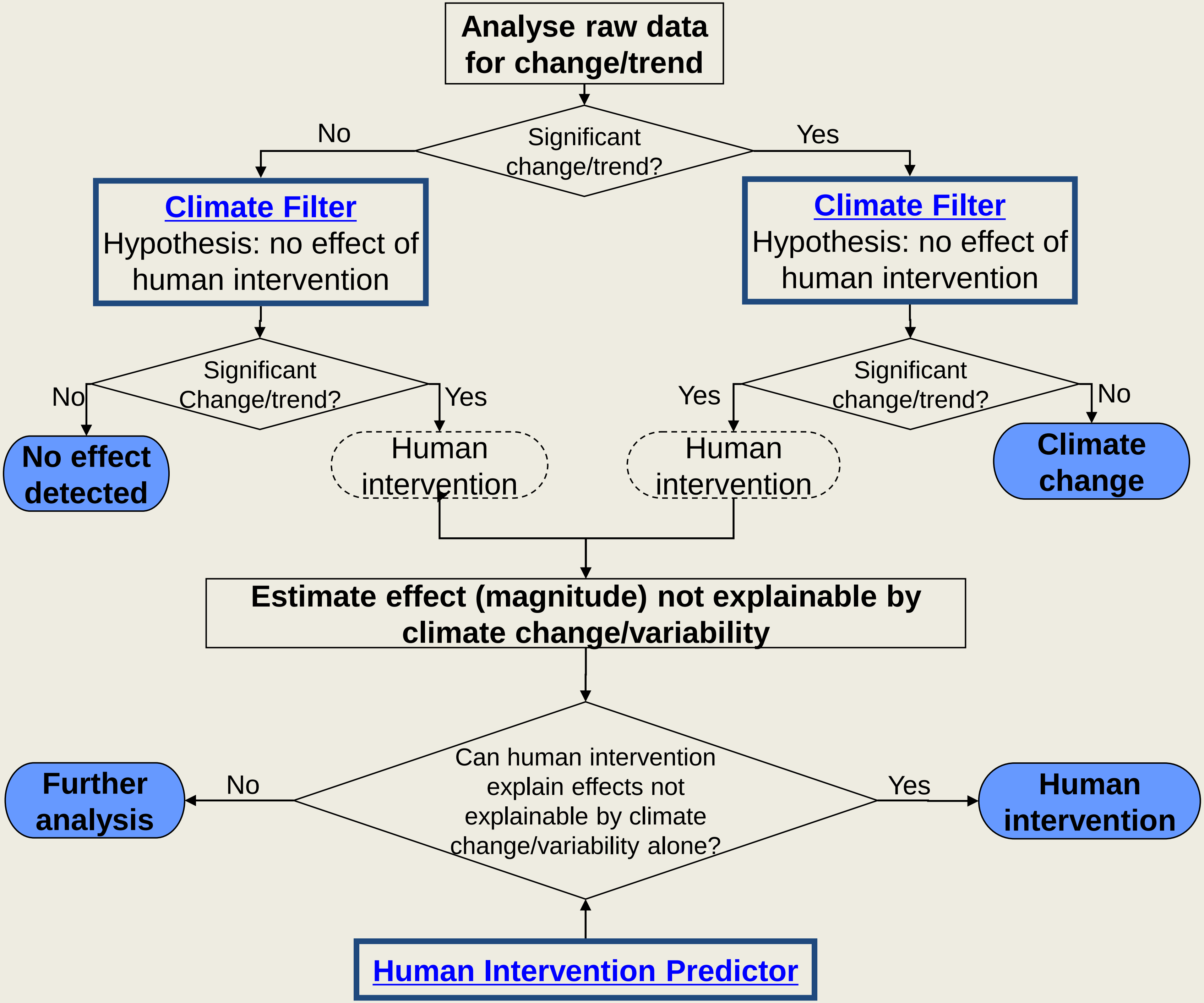
Human Intervention Predictor

- methodology

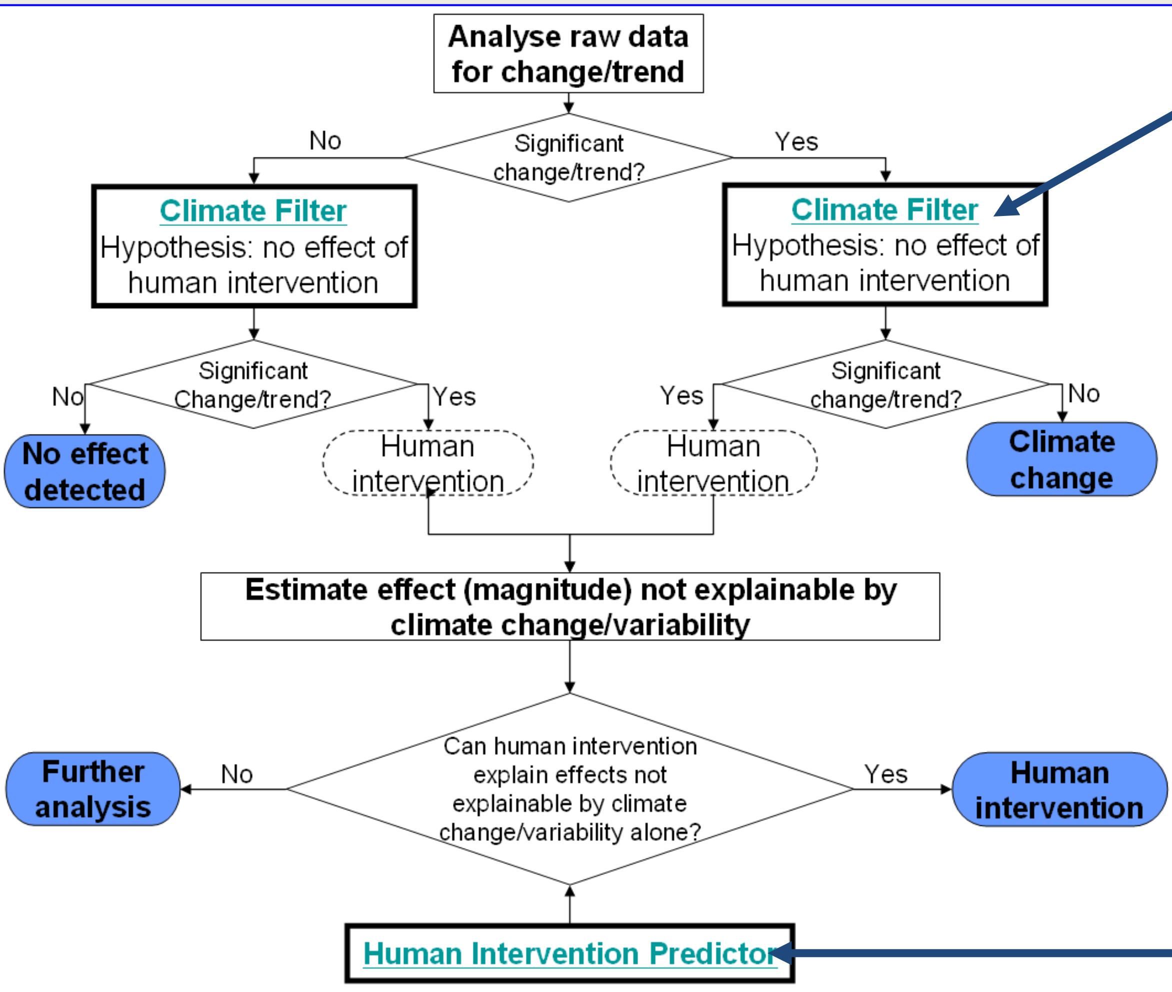
- multiple models
- validation tests
- statistical tests
-uncertainty assessments

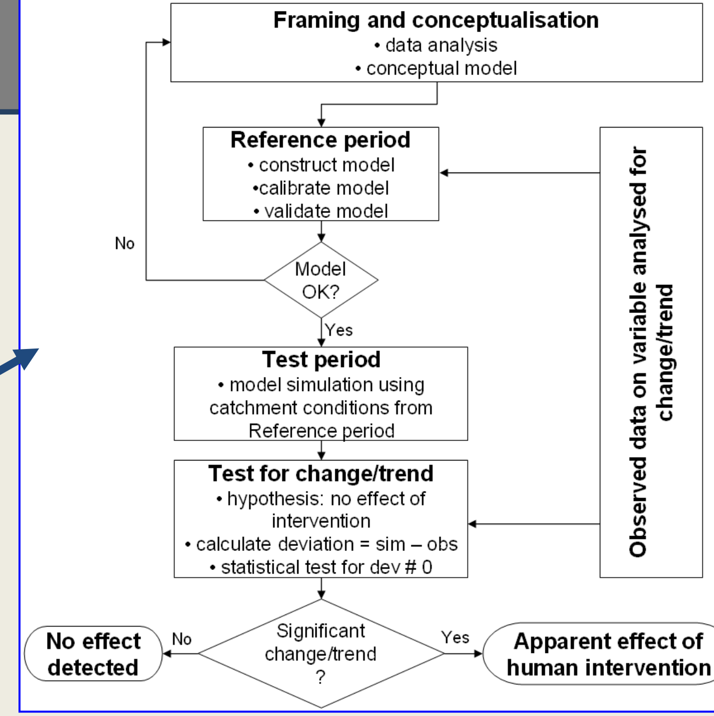


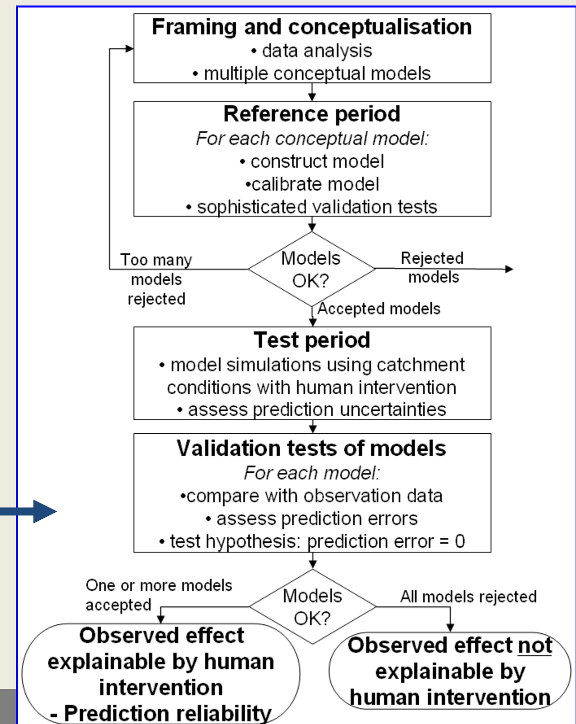
Distinguish between human intervention and climate change



Methodology





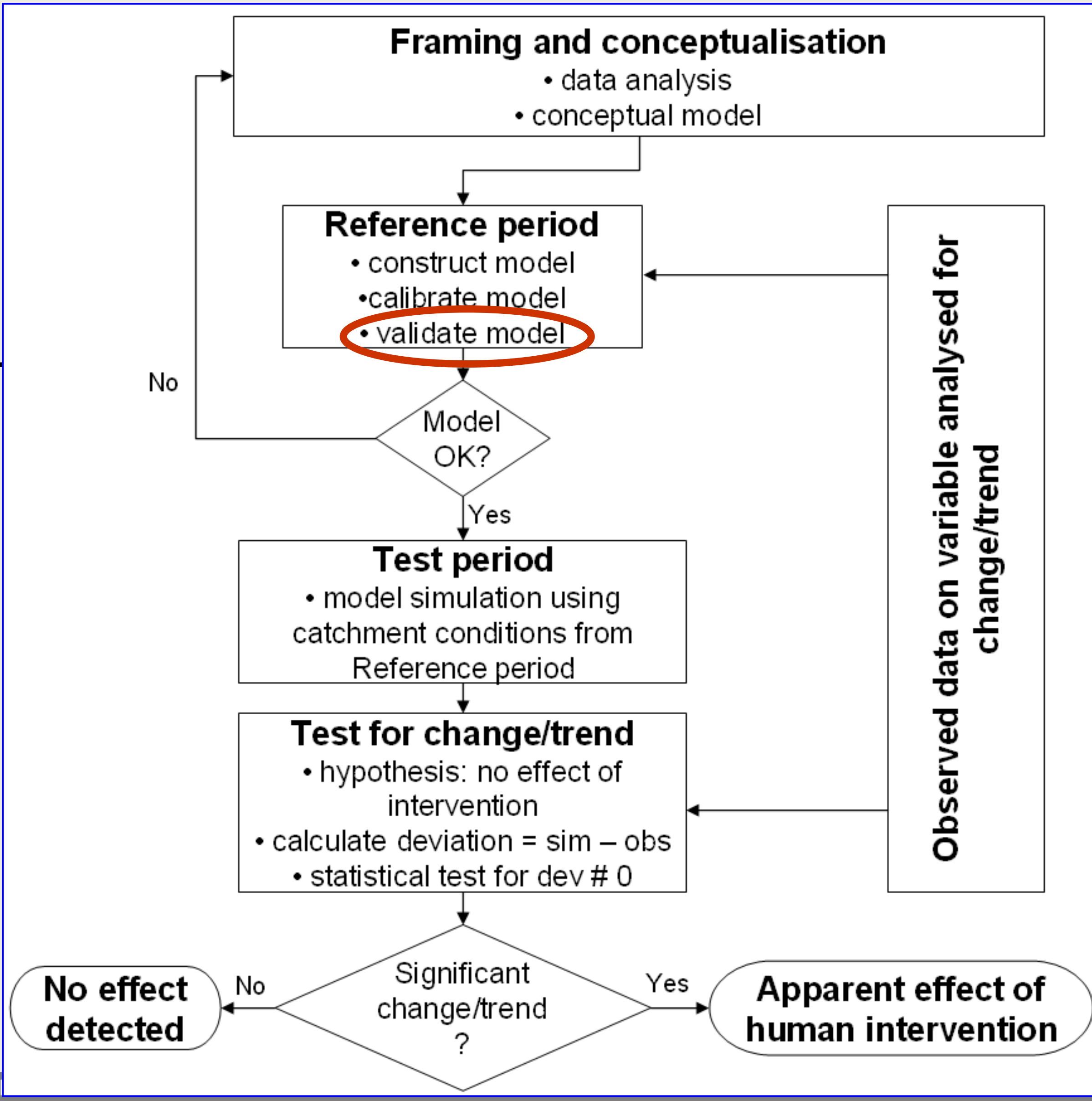


Weak aspects of methodology
- challenges (1/2)

Climate Filter

- Assumption that model from Reference period can simulate effects of climate variability/change

→ **Strong validation tests required**



Weak aspects of methodology
- challenges (2/2)

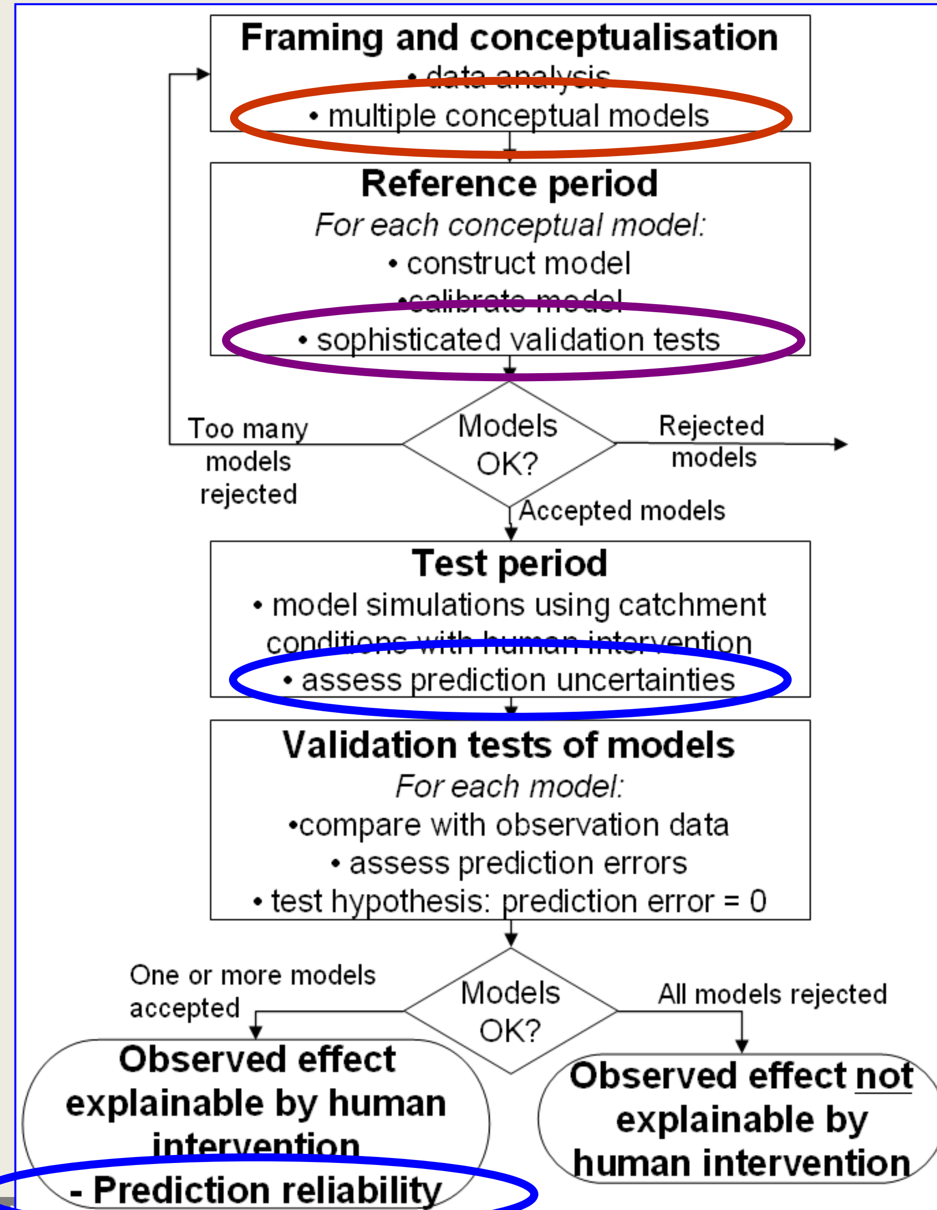
Human Intervention Predictor

- Assumption that model can simulate effects of human intervention
- Equifinality - many different models (multiple model structures, parameter sets, etc.) may pass validation tests in Reference period, but result in very different predictions in Test period

➔ **Multiple conceptual models**

➔ **Sophisticated validation tests**

➔ **Evaluate reliability of predictions - comprehensive uncertainty assessment**



Sophisticated validation schemes
- Purpose: to test the model for situations similar to its intended use

- Impacts of human interventions (e.g. land use change, water abstraction)
  - Test in another catchment(s) that have experienced similar human intervention
    - Identify catchment(s) with data before/after intervention
    - Validation tests
- Climate change impacts
  - Test in own catchment with climate variability, e.g.
    - Calibrate on dry periods
    - Validate on wet periods
  - Test on long timeseries with climate changes (incl. paleo data)
  - Test in catchments in another climate (time for place)
    - Setup on own catchment
    - Validate on catchments in another climate (requires parameter values to be identified without calibration)

Conclusions

- Both climate and human intervention influence the hydrological cycle – generally difficult to distinguish without long time series
- A good dynamic model can simulate part of the climate induced variability in hydrological time series. This can make it easier to detect impacts of human intervention (**Climate Filter**)
- A good hydrological model may be able to simulate effects of human intervention. This should always include comprehensive assessments of prediction uncertainty (**Human Intervention Predictor**)
- A methodology to distinguish between the effects of climate change/variability and human intervention should include both a Climate Filter and a Human Intervention Predictor