Institute of Earth Sciences

Faculty of Earth and Life Sciences

Natural variability versus anthropogenic change:

modelling climate and discharge characteristics of the Meuse basin during Holocene and recent periods

12th January 2007

Philip Ward

BSIK Klimaat voor Ruimte Project CS-A9:
Modelling and reconstructing precipitation and flood frequency in the Meuse catchment during the late Holocene

klimaat voor ruimte

vrije Universiteit amsterdam

Structure of Presentation

- Aims and Rationale
- Approach and Methods
- Calibration and Validation
- Preliminary Results
- Conclusions

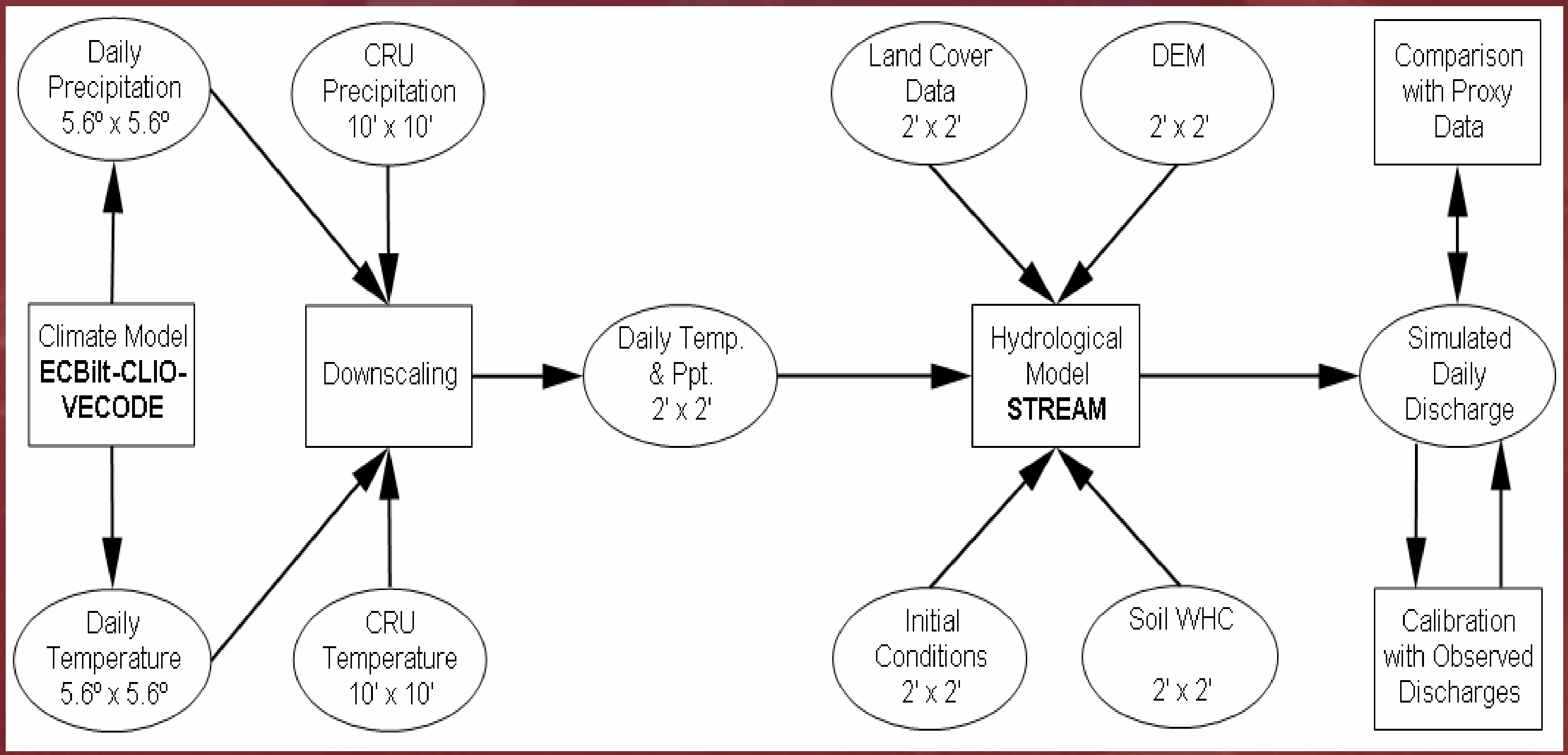
vrije Universiteit amsterdam

Aims

- Set up and validate a coupled climate-hydrological model to analyse the link between flood frequency, precipitation events and weather regimes in The Netherlands
- Analyse Meuse discharge characteristics in 4000-3000 BP (reference period) and 1000-0 BP
- Examine effects of anthropogenic changes
- Develop floodplain sedimentation module
- Examine future climate change scenarios

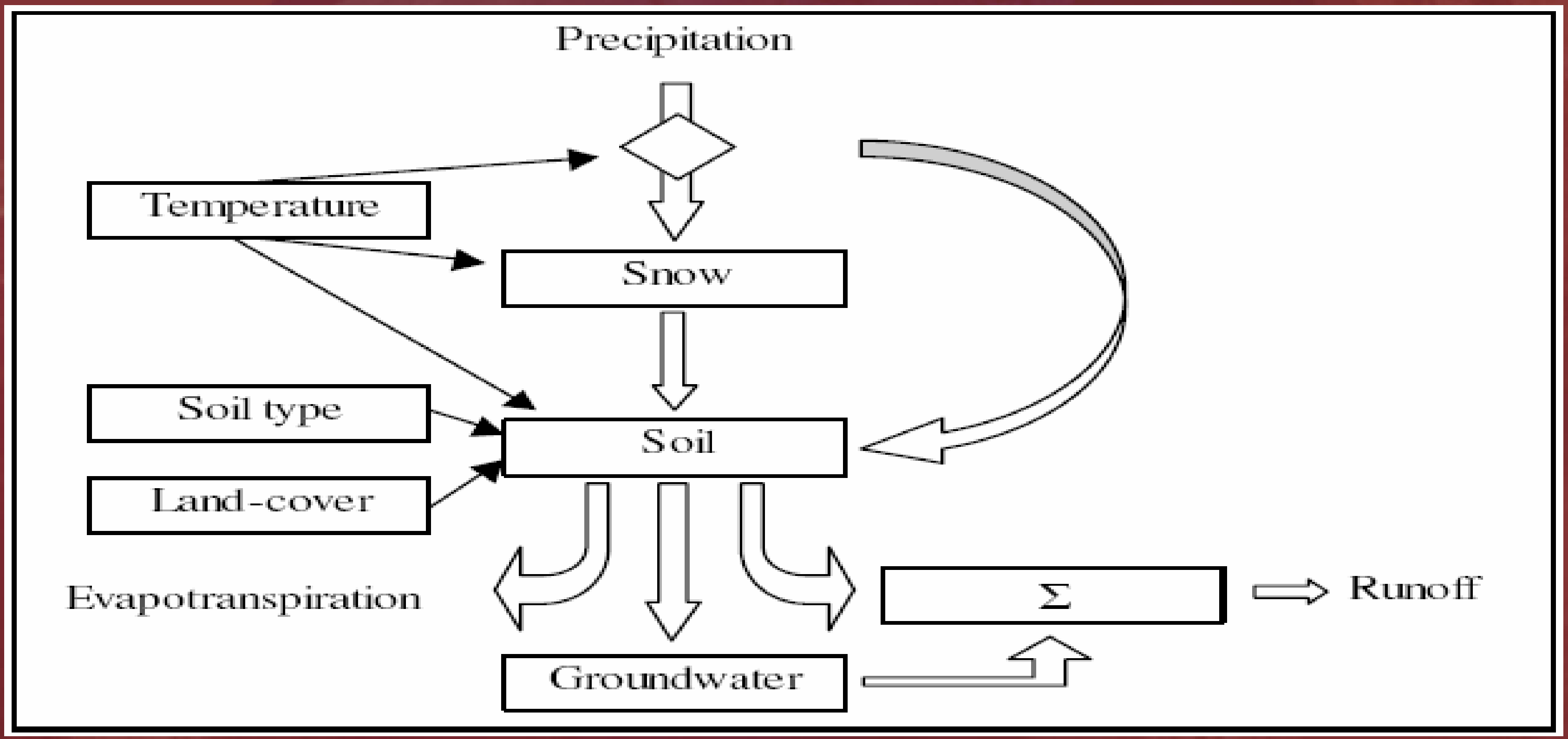
Rationale

Research Approach



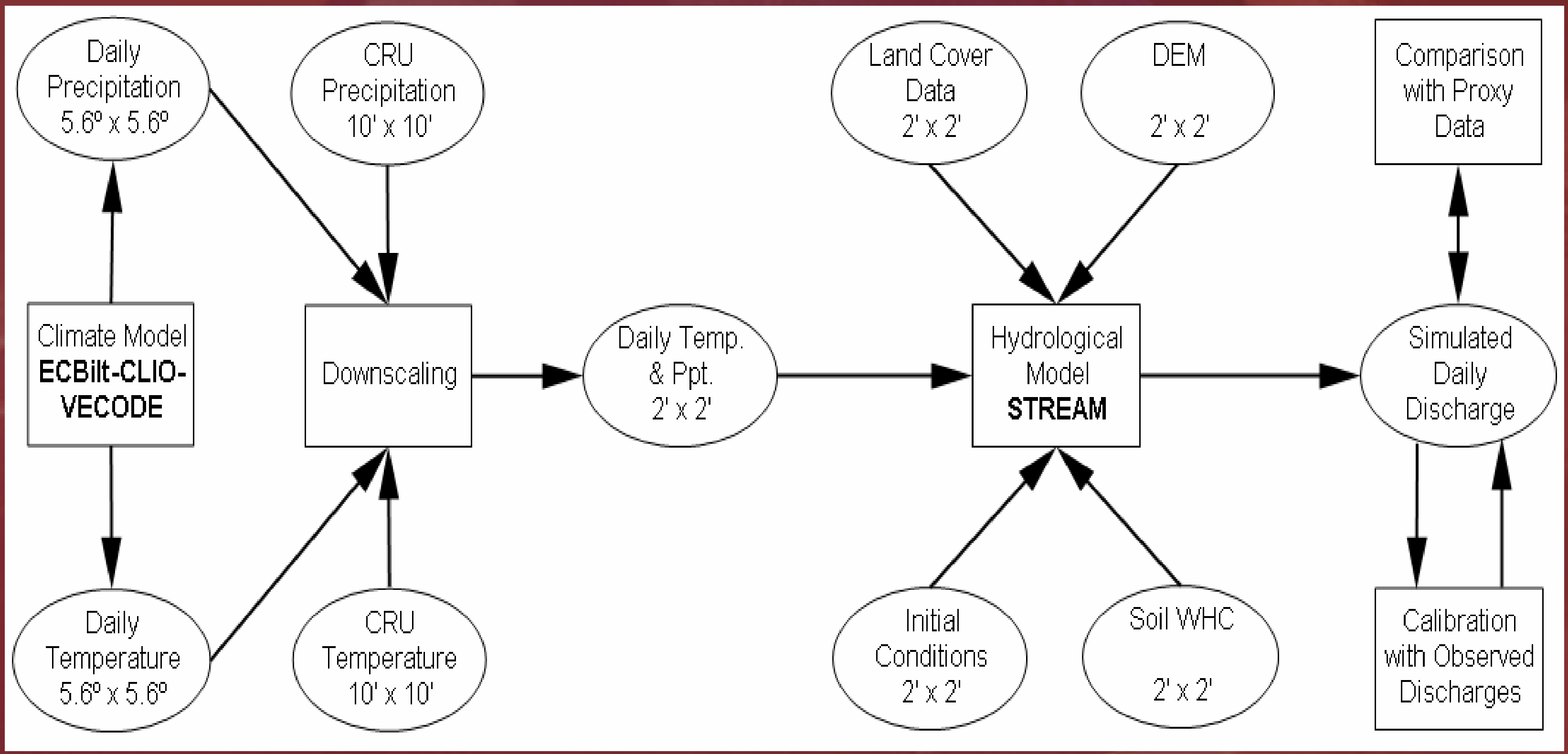
Hydrological Model - STREAM

- Raster based hydrological model (2’ x 2’)
- Calculates water balance per grid-cell



Aerts et al. (1999)

Research Approach

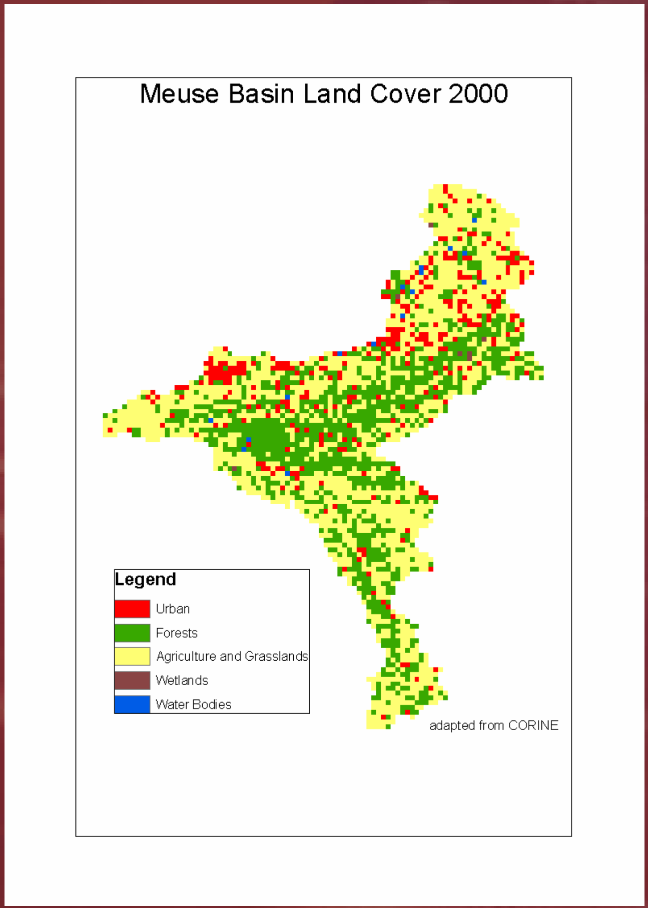


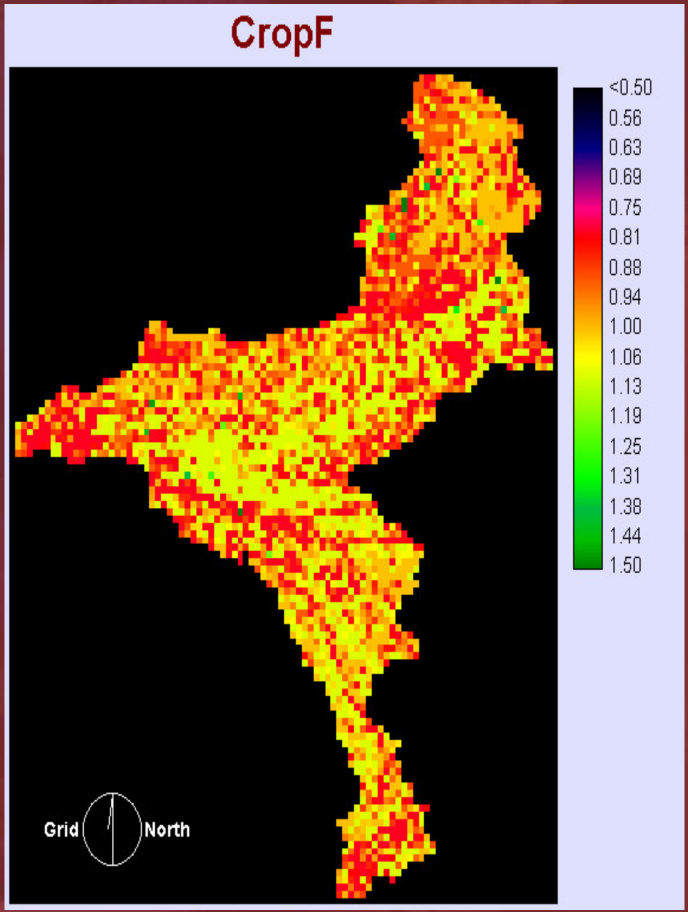
STREAM Meuse – Input Data

GIS raster database: 2’ x 2’

- Daily climate data (temperature and precipitation)
- DEM / River Routing Network
- Soil Water Holding Capacity
- Land Cover

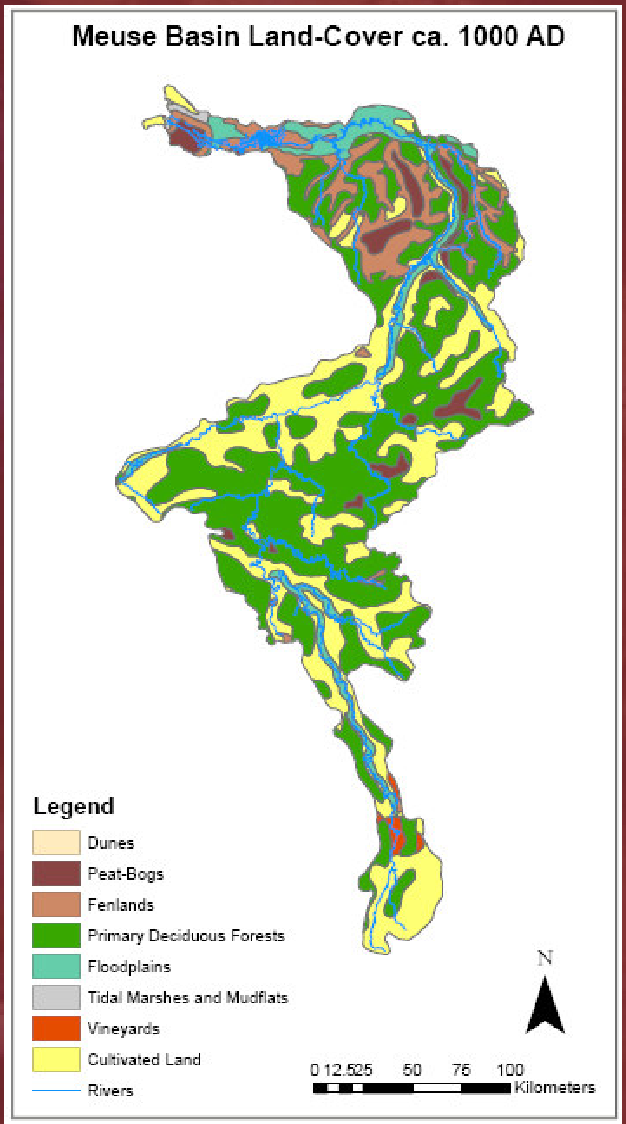
CropF (recent) - based on CORINE Land Cover





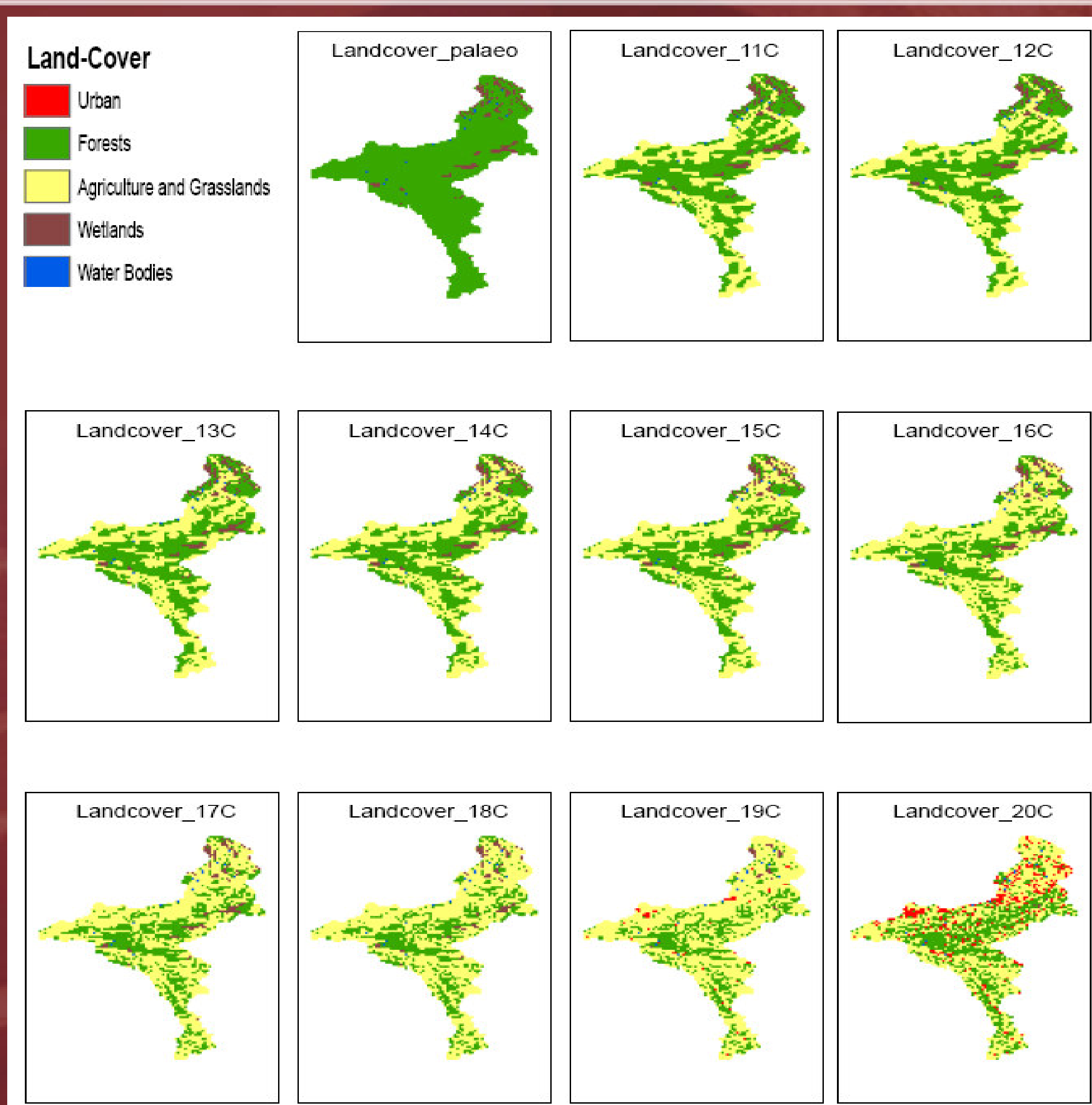
Land-Cover Maps

- Present: CORINE 250 m
- 1000AD: RWS Limburg/IWACO, 2000
- 1000-2000 AD:
  - Historical Maps
  - Historical Records
  - Pollen Analysis



vrije Universiteit amsterdam

Land-Cover Maps



STREAM Meuse: Calibration & Validation

- Parameter Estimation using modelled / observed data:
  - Discharge Borgharen
  - Discharge major tributaries
  - Basin average monthly evapotranspiration
  - Daily snow-cover at Maastricht
- Calibration: 1961-2000
- Validation: 1921-1960

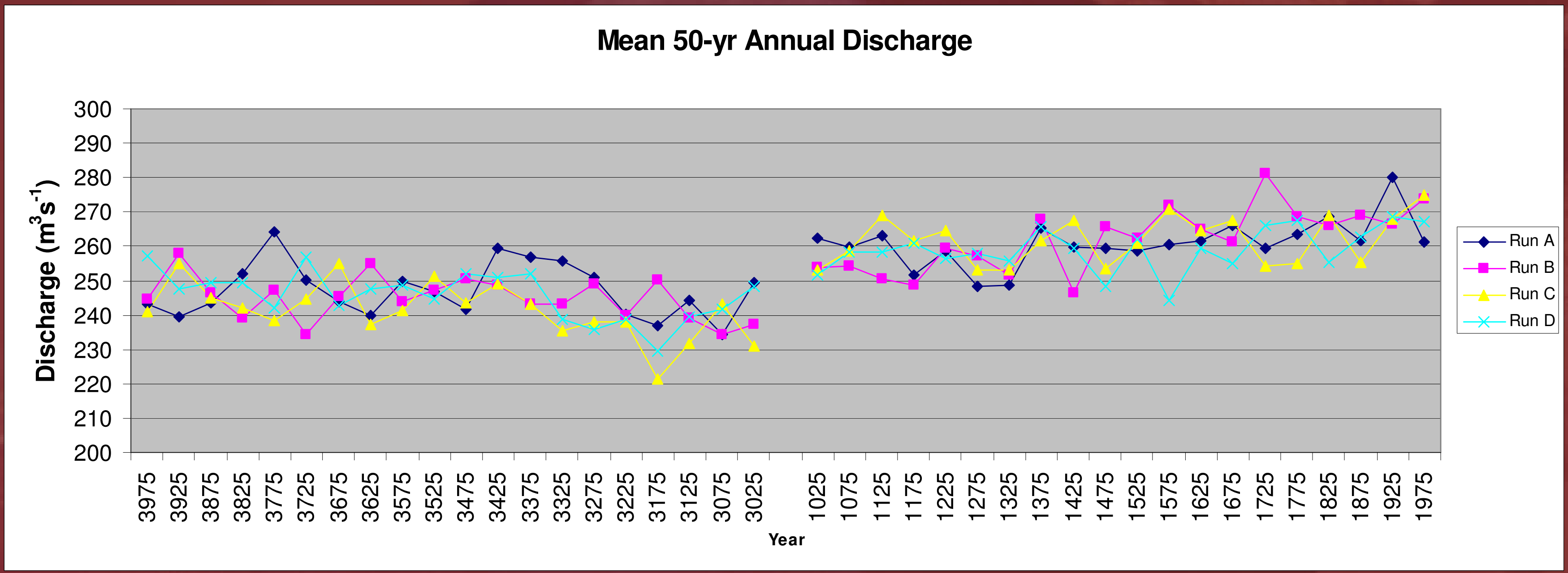
vrije Universiteit amsterdam

STREAM Meuse: Calibration & Validation

Calibration Conclusions

- Generally good agreement between modelled / observed values for annual, monthly and daily discharge characteristics
- The frequency of high and low flow events appears to be well simulated by the model
- Simulation of small tributaries (e.g. Geul) less reliable

Preliminary Results

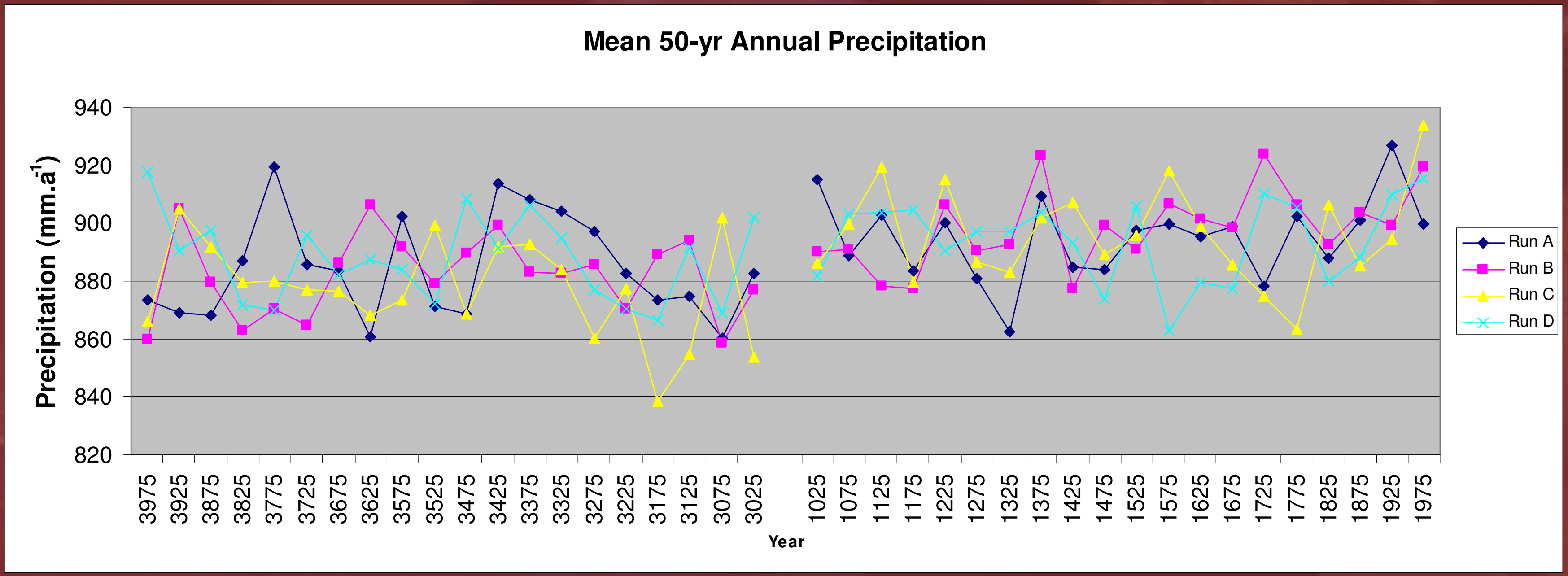


Recent mean Q > Holocene mean Q in all cases (*t-test: $p < 0.001$*)

Recent: increasing discharge (*Mann-Kendall: $p < 0.001$*)

vrije Universiteit amsterdam

Preliminary Results



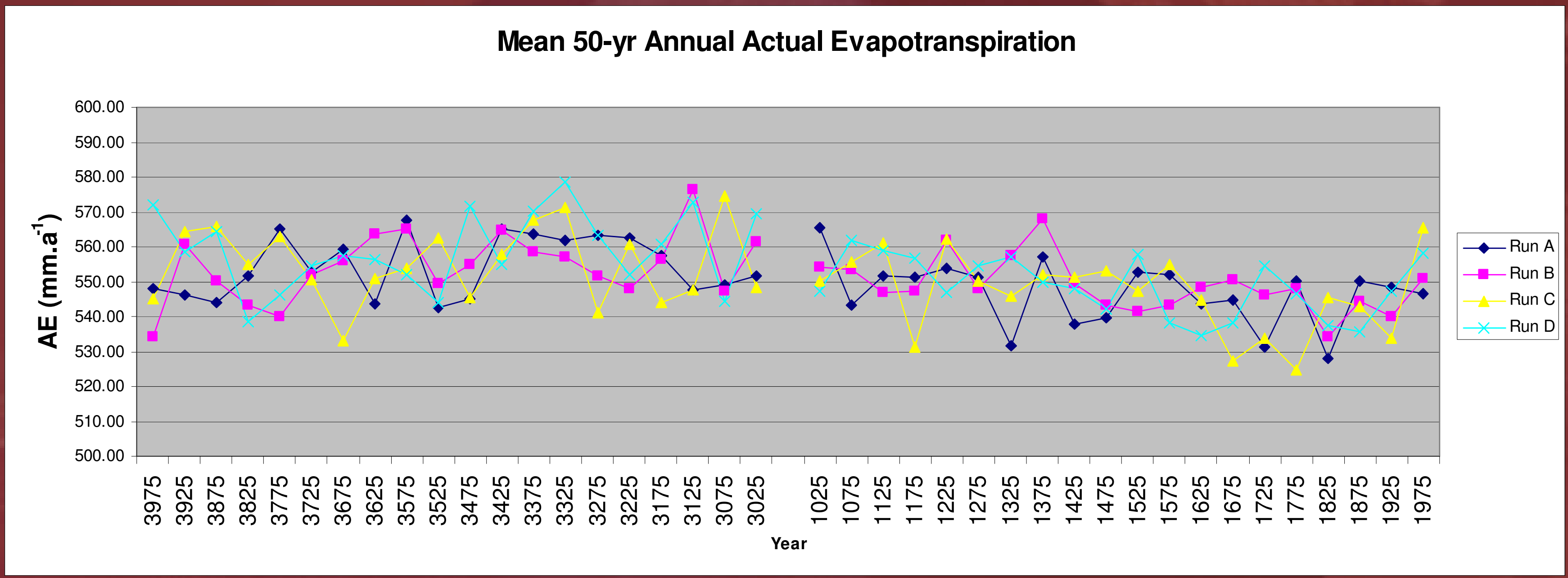
Recent mean pre > Holocene mean pre in 3 cases

(*t-test: p = (A) 0.043; (B) 0.001; (C) 0.001; (D) 0.144*)

Recent: no trend (*Mann-Kendall: p = 0.218*)

vrije Universiteit amsterdam

Preliminary Results



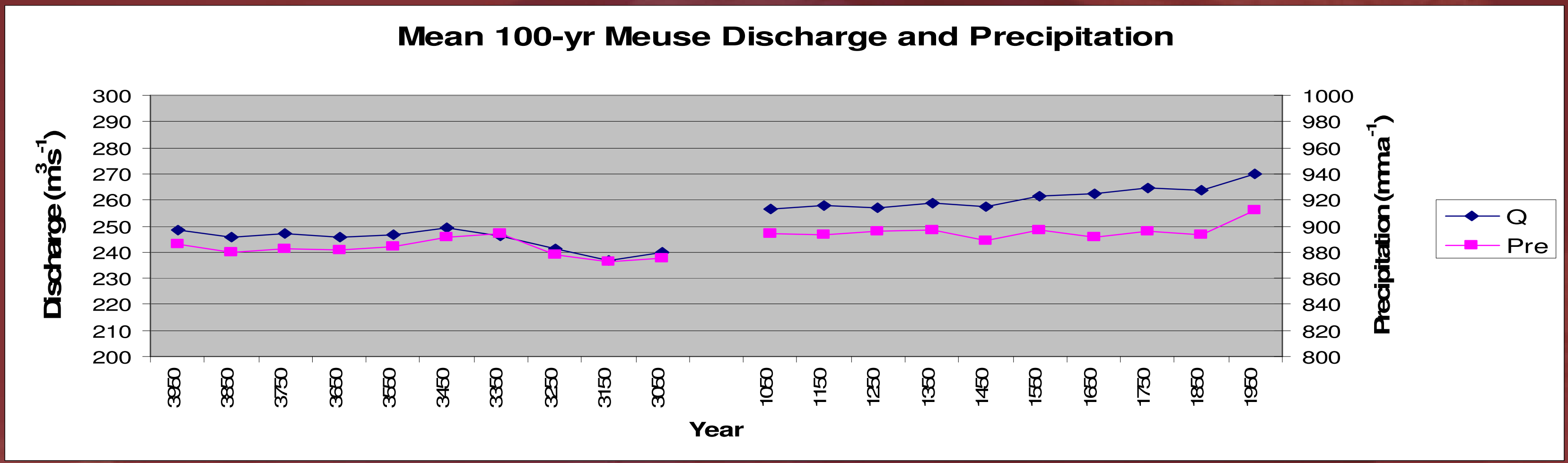
Recent mean AE < Holocene mean Q in all cases

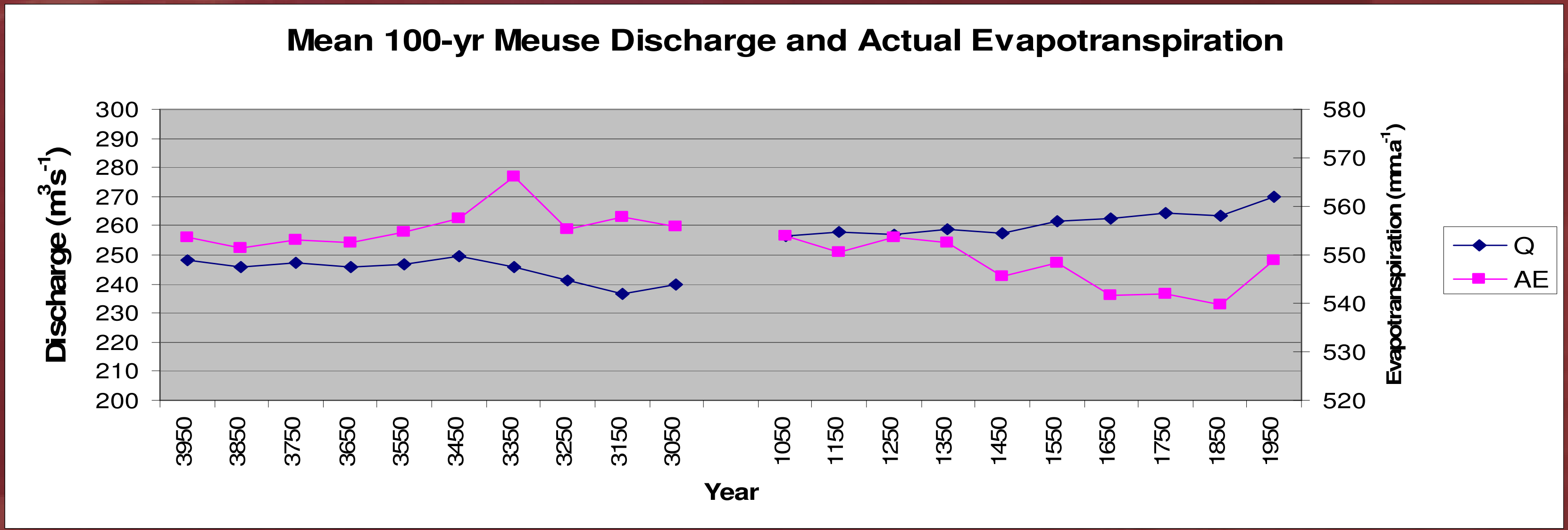
(*t-test: p = (A) 0.008; (B) 0.047; (C) 0.022; (D) 0.002*)

Recent: decreasing AE (*Mann-Kendall: p < 0.001*)

vrije Universiteit amsterdam

Preliminary Results





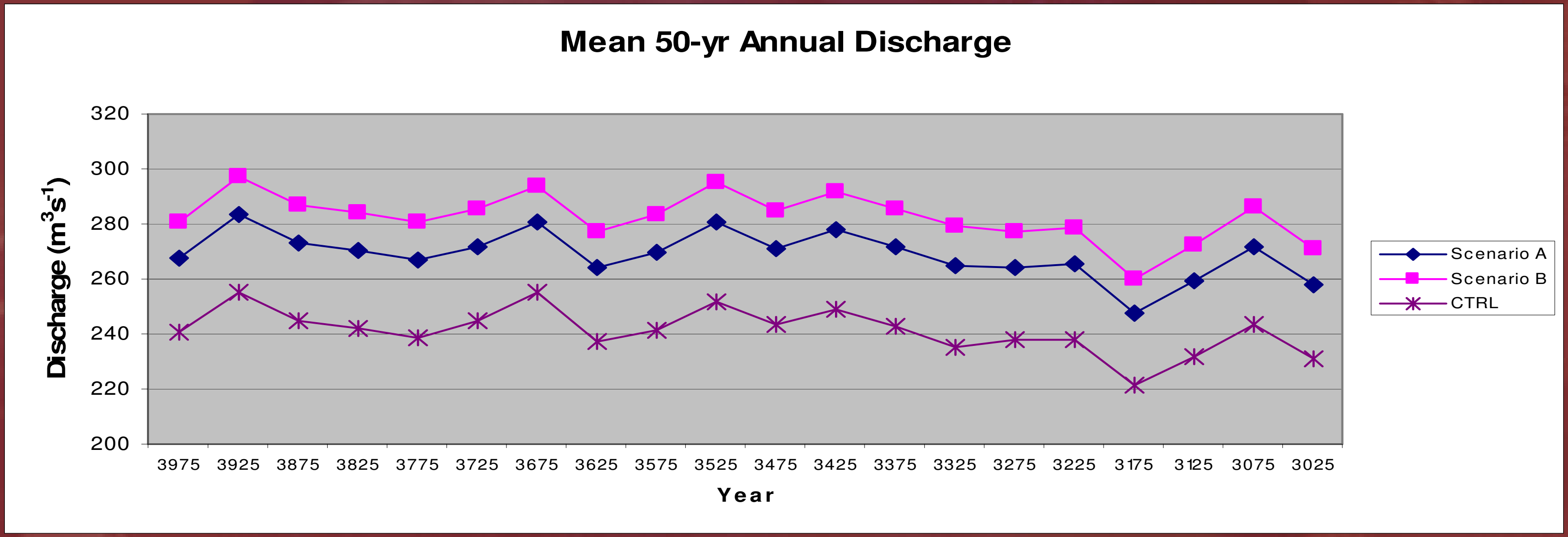
vrije Universiteit amsterdam

Deforestation scenario

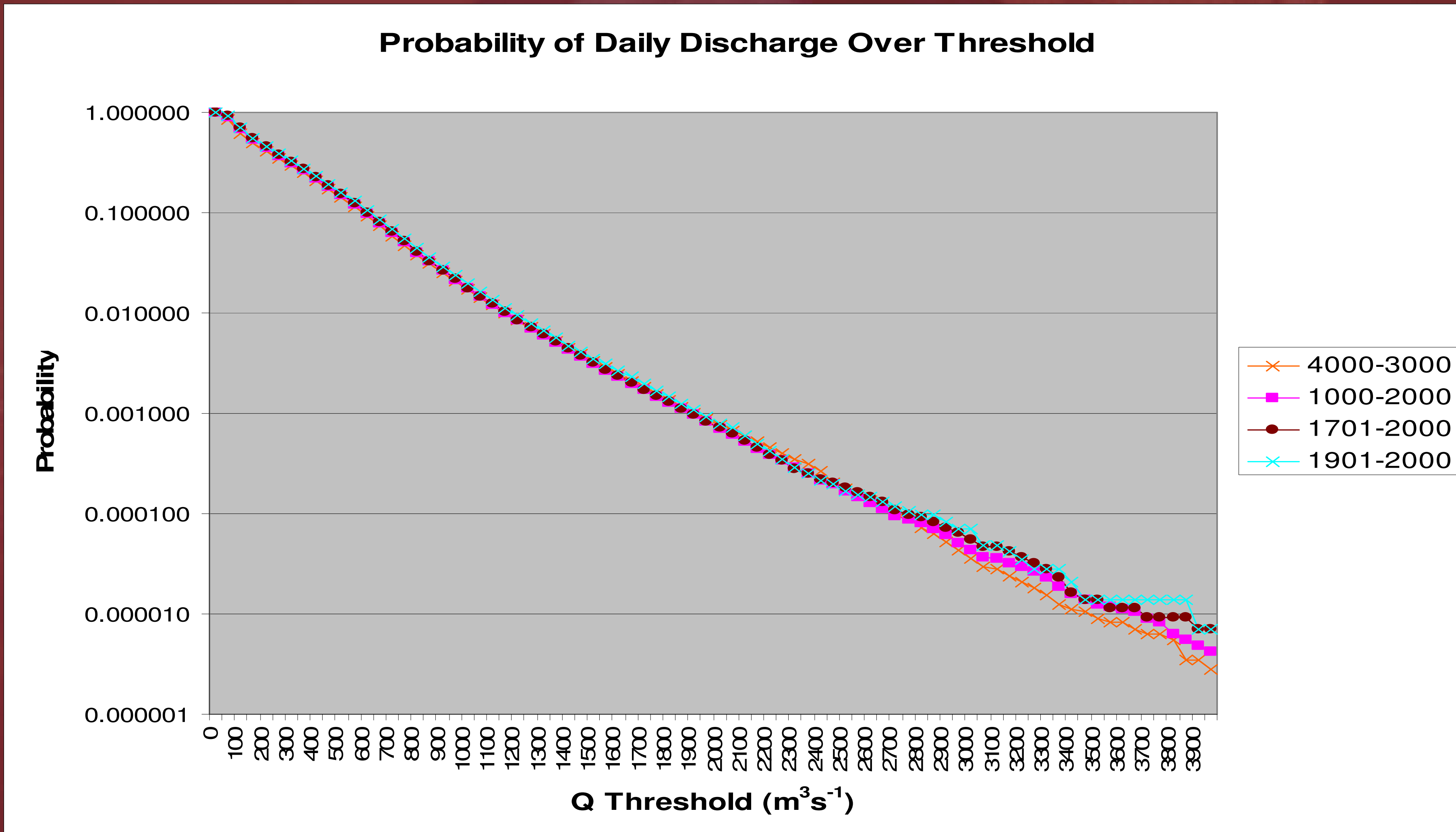
Land cover change scenarios superimposed on Holocene climatic data:

- Scenario A: 2000 AD land-use
- Scenario B: Zero forest

Deforestation scenario



Preliminary Results



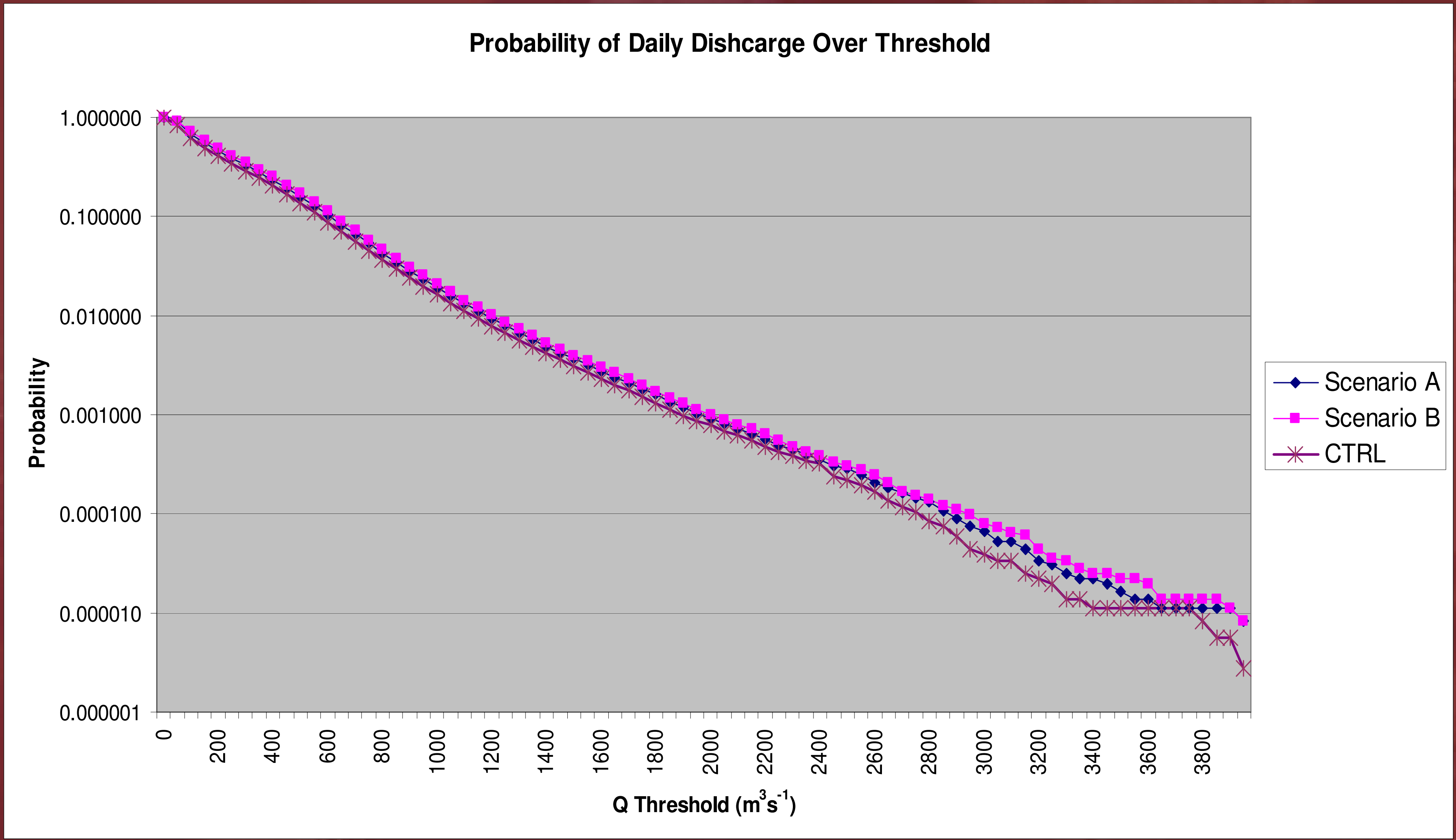
Preliminary Results

Calculated recurrence times of daily discharges over given thresholds

	Recurrence Period (yrs)	
Discharge:	> 3000 (m^3s^{-1})	> 4000 (m^3s^{-1})
3999 – 3000 BP	77	992
1001 – 2000 AD	65	665
1701 – 2000 AD	50	400
1901 – 2000 AD	40	400

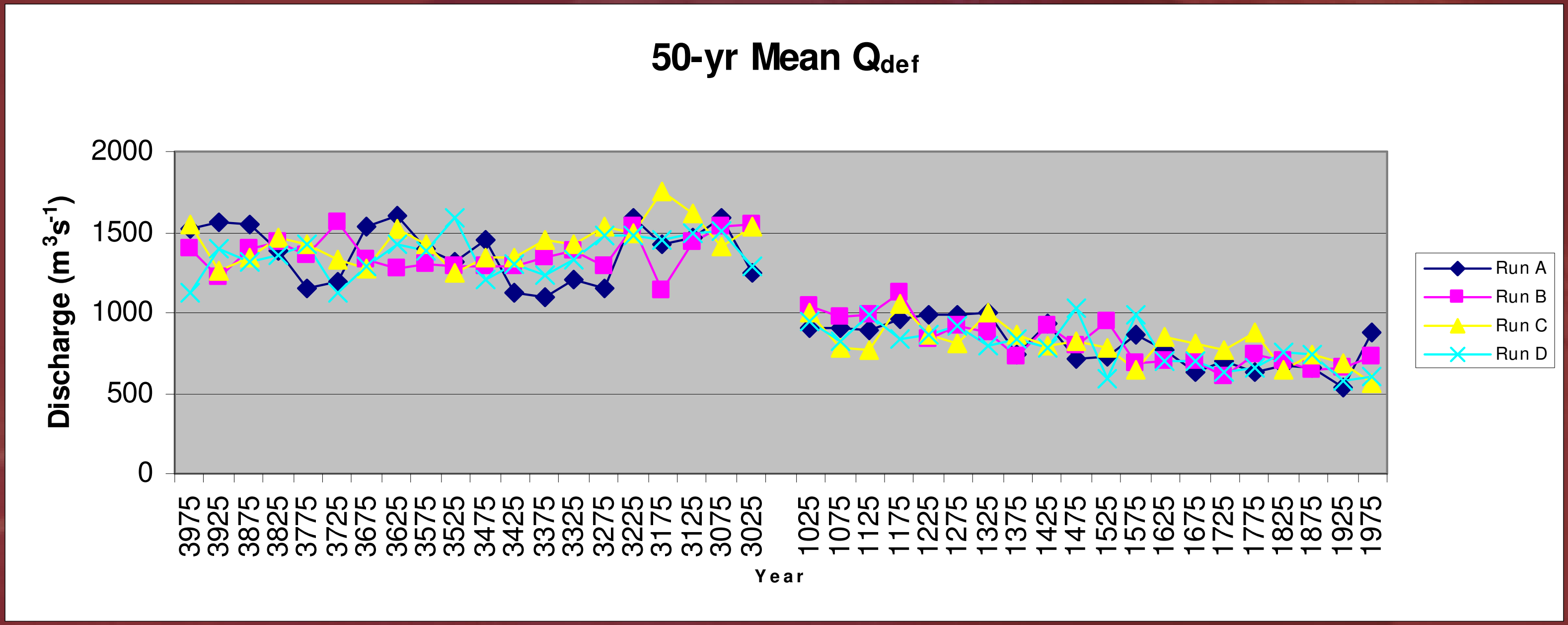
1911-2006: 2 observed discharges > 3000 m^3s^{-1} (1926 and 1993)

Deforestation scenario



vrije Universiteit amsterdam

Preliminary Results



Recent mean Q_{def} < Holocene mean Q_{def} in all cases (*t-test: $p < 0.001$*)

Recent: decreasing Q_{def} (*Mann-Kendall: $p < 0.001$*)

$Q_{def} = \sum(Q_{threshold} - Q_{day})$, if $Q_{day} < Q_{threshold}$

where,

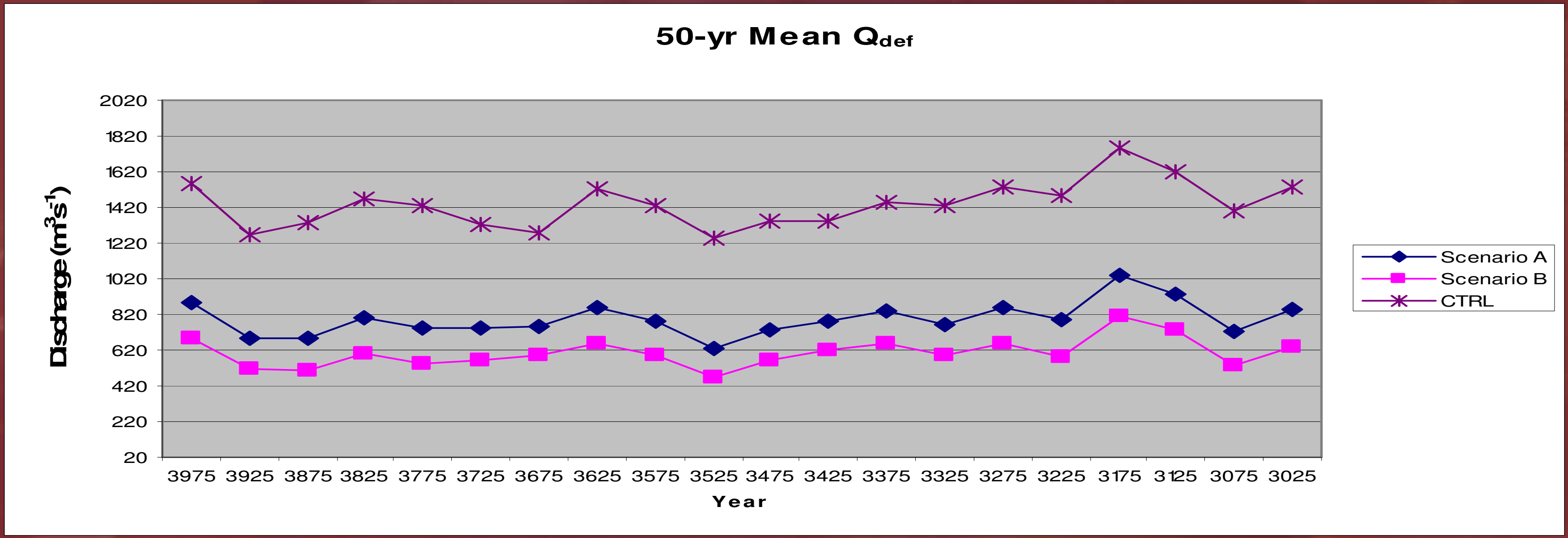
Q_{def} = discharge deficit

$Q_{threshold}$ = discharge threshold (here 60 m3s-1)

Q_{day} = discharge on a particular day

vrije Universiteit amsterdam

Deforestation scenario



Conclusions

- Mean discharge higher in 1000-2000 AD than 4000-3000 BP (dominant mechanism: decreased AE)
- AE lower due to land-use change (direct influence and resulting decrease in temperature)
- Last century: relatively large increase in mean discharge despite increased AE: enhanced precipitation of more importance in future?
- Floods more frequent in recent than in Holocene, and probably more frequent still since industrial era (reduced WHC?)
- Significant increase in flood frequency under deforestation scenarios
- Frequency and magnitude of low-flow events **lower** in recent than in Holocene (decreased AE in summer due to deforestation)