# Influence of uncertainty on the estimates of water balance dynamics and draught indices in the River Vistula basin

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# Water Balance models (WBM) for estimation ET

- Catchment water balance can express as:

$$\frac{\Delta S}{\Delta t} = P - R - ET \qquad \Longrightarrow R = P - ET$$

Where precipitation ($P$), runoff ($R$), actual evapotranspiration (ET), Change in water storage ($\Delta S$). Assuming negligible change in surface catchment storage in long term

- Actual Evapotranspiration ($ET$) is the key hydrological processes at catchment scales. It is difficult to measure directly.

- Budyko framework hypothesis: long enough time scales

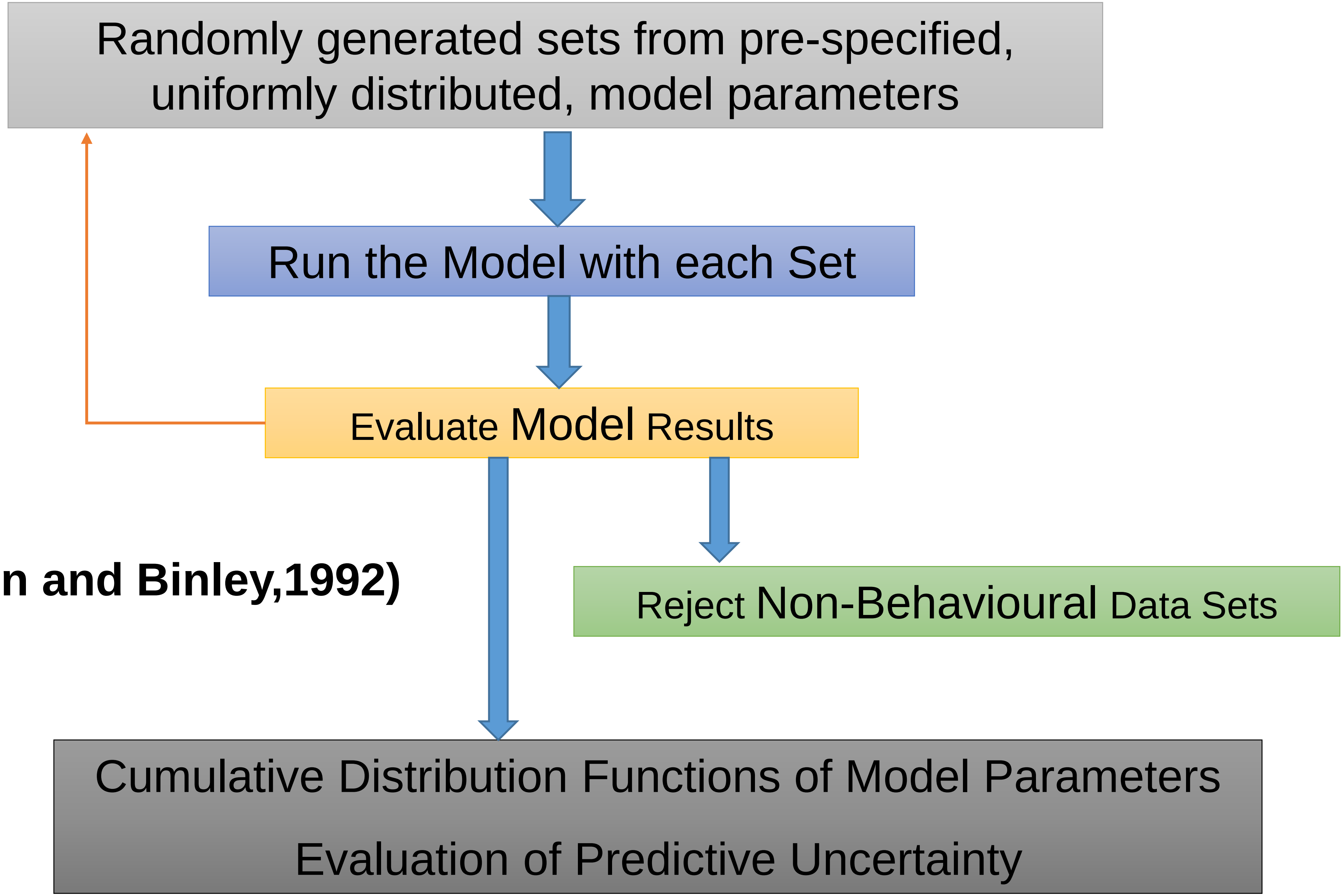
$$\text{ET} = f\ [P, ET_o] = \ \alpha P.F(\Phi) \qquad \phi = \frac{ET_o}{P} = Aridity\ index$$

$$ET_o = potential\ evapotranspiration$$

# Eight Budyko-type equations F(Φ) for estimating ET based on Φ

| Function | References |
|---|---|
| $1-\ e^{-\phi}$ | Schreber (1904) |
| $\phi\tanh(\frac{1}{\phi})$ | Ol'dekop (1911) |
| 1/$\sqrt{1+\phi^{-2}}$ | Turc (1954), Pike (1964), |
| $\phi\tanh(\frac{1}{\phi})(1-e^{-\phi})^{1/2}$ | Budyko (1948) |
| $(1+\phi^{-w})^{-1/w}$ | Generalized Turc –Pike (Milly and Dune, 2002) |
| $(1+\omega\ \phi)/(1+\omega\phi+\frac{1}{\phi})$ | Zhang et al. 2001 |
| 1+ $\phi-(1+\phi^{m})^{1/m}$ | Fu et al.(2007) |
| $1/((\frac{1}{\phi})^{n}+1)^{n}$ | Choudhury (1999) |

# Generalized Likelihood Uncertainty Estimation (GLUE)




**Source: Beven and Binley,1992)**

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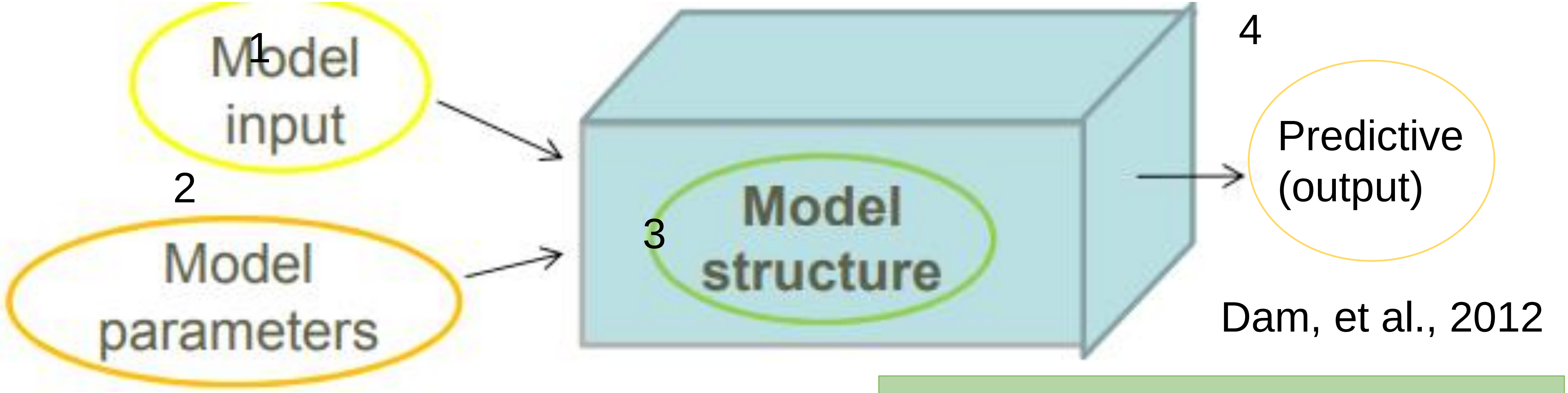
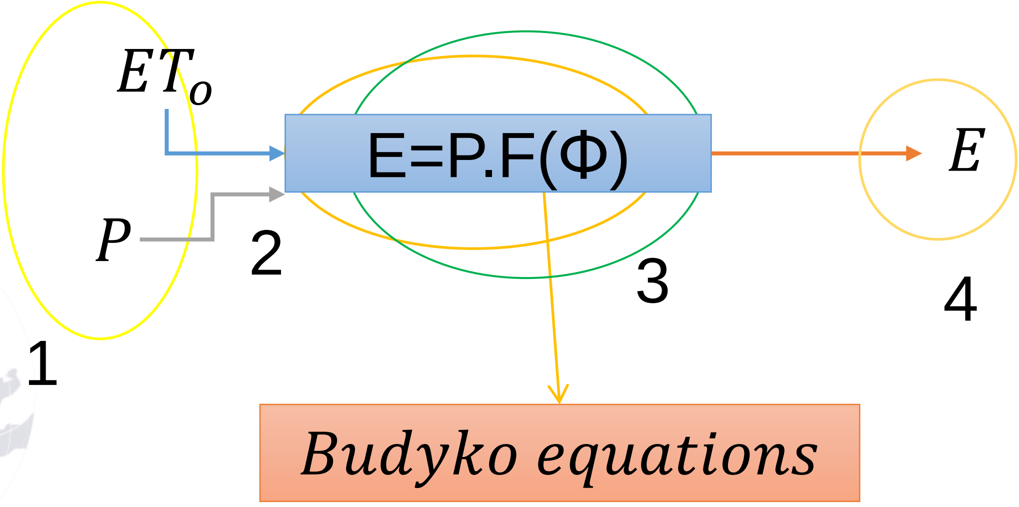
# Overview of uncertainties (U) in water balance model




Modeling in Budyko equation




U assessment methods used:

1. Input: $\alpha P$
2. Model parameters: GLUE
3. Structure: multi models
4. Predictive: Objective function

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# Structure uncertainties of drought indices

- A drought index is one that gives a quantitative estimate of drought severity.

Climate data: Precipitation and temperature

Different types of DI indices

Structural uncertainties

$ET_o$

DI =f(P, T) → $DI$

$P$

Structure uncertainties

Method of estimation ET0
1. Hargreaves Method (H)
2. Thornthwaite method (T)
3. Penman-Montieth (PM) equation

SPI
SPEI_H
SPEI_T
SPEI_PM
RDI_H
RDI_T
RDI_PM

1. SPI
2. SPEI
3. RDI

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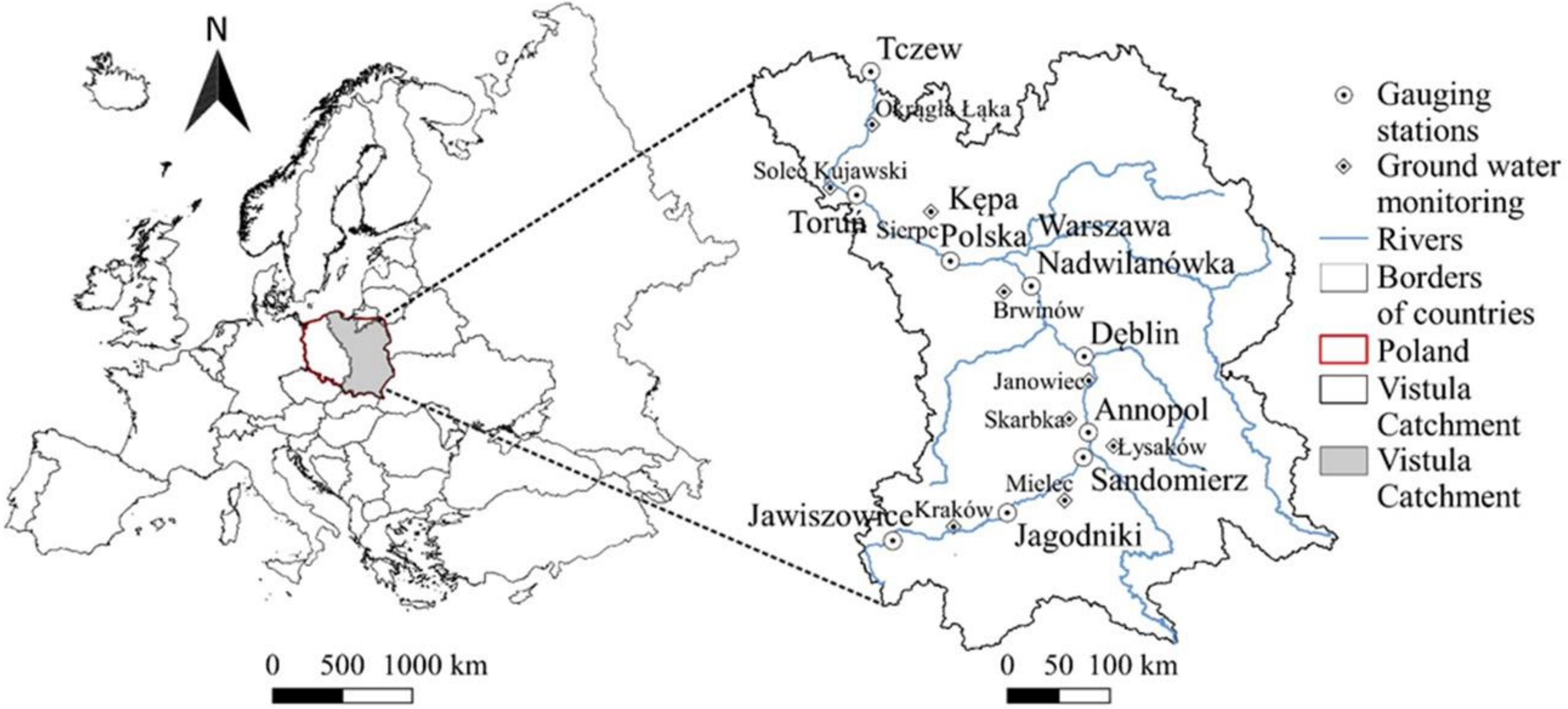
# Study area: The Vistula River basin

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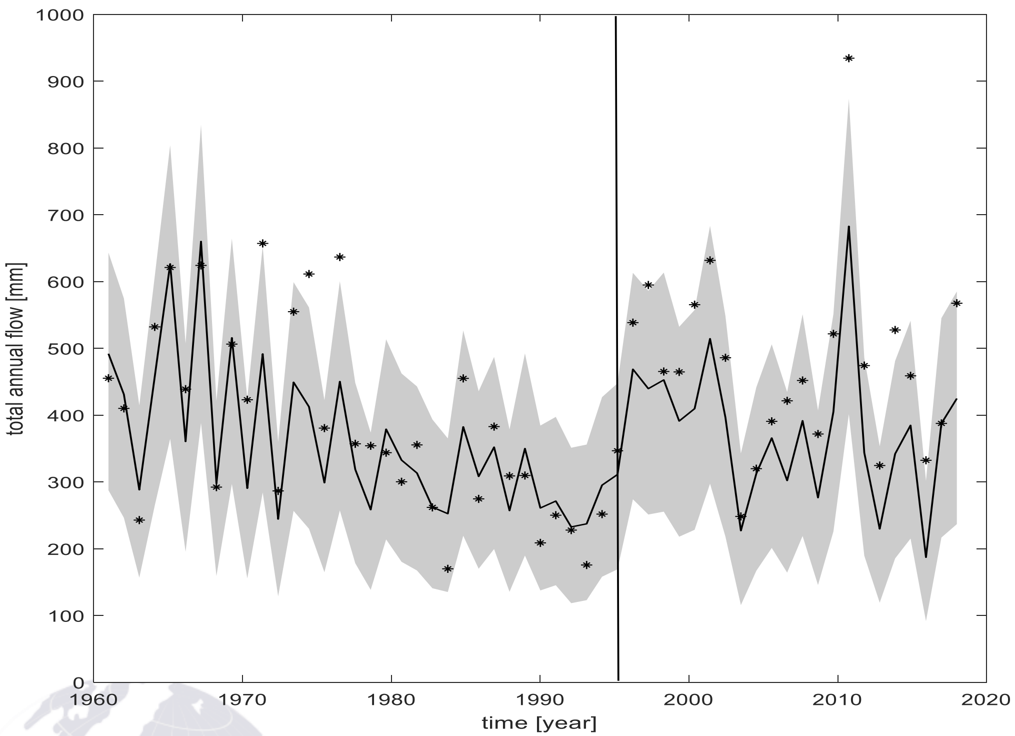
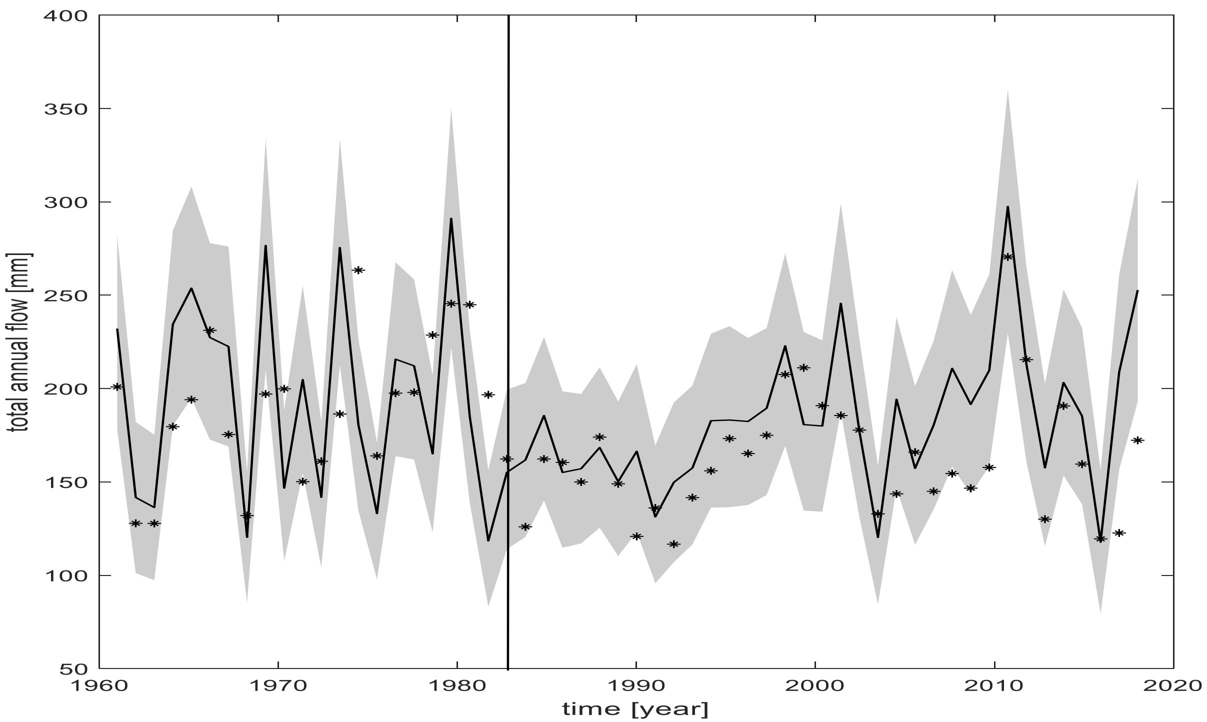
# Uncertainty in modeling Budyko equations

Calibration and validation of simulated flows at Jawiszowice gauging station




Calibration and validation of simulated flows at Tczew gauging station

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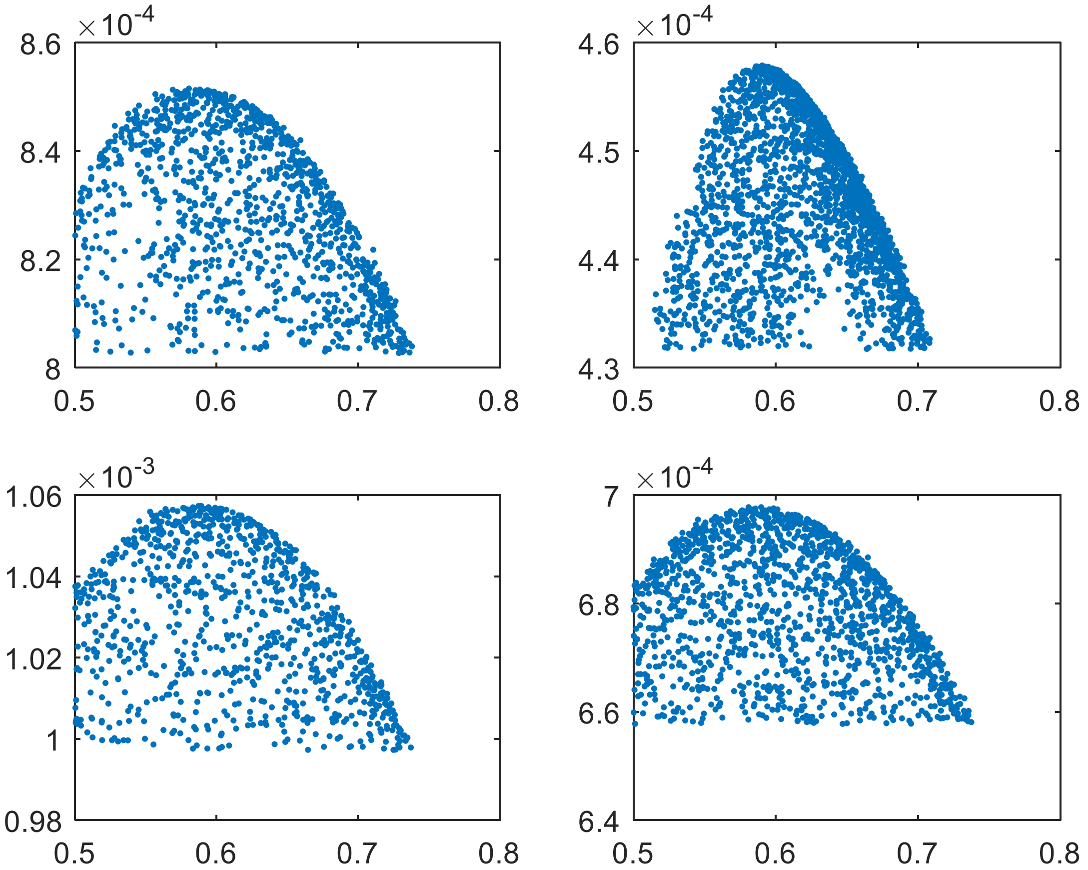
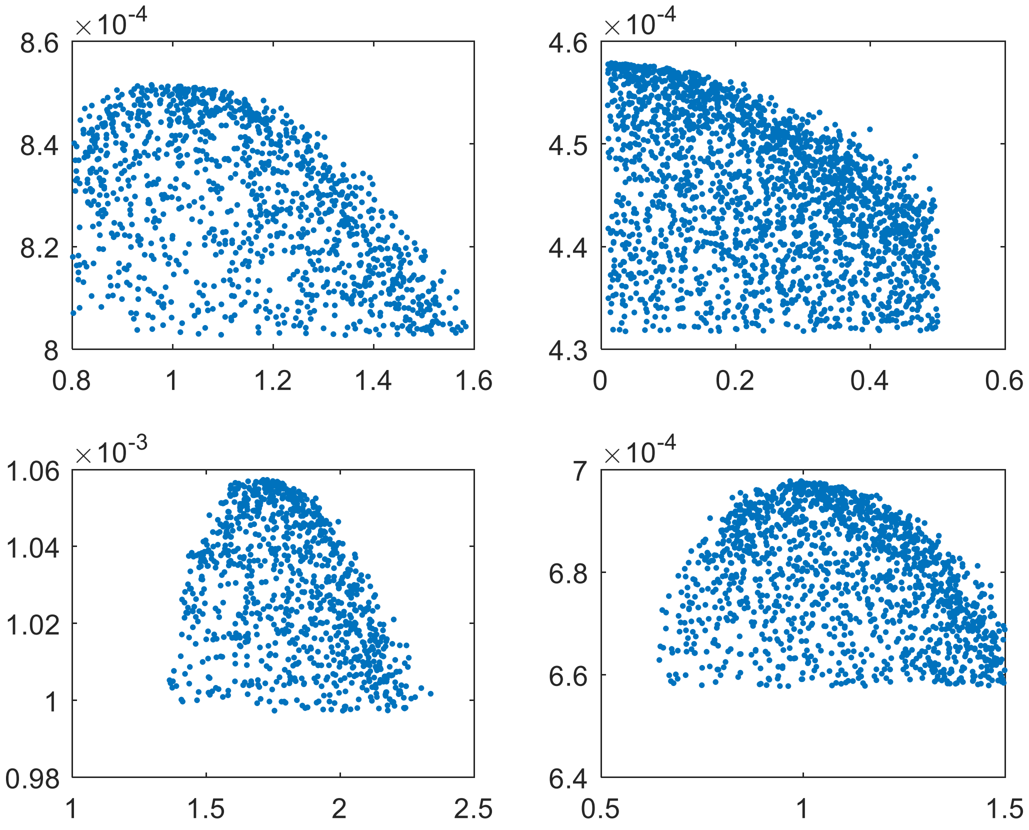
# Uncertainty in modeling Budyko equations [model parameters]




Four Budyko model parameters: Generalized Turc –Pike (Milly and Dune, 2002); Zhang et al. 2001; Fu et al.(2007); Choudhury (1999)




Effective rainfall parameter for four Budyko models

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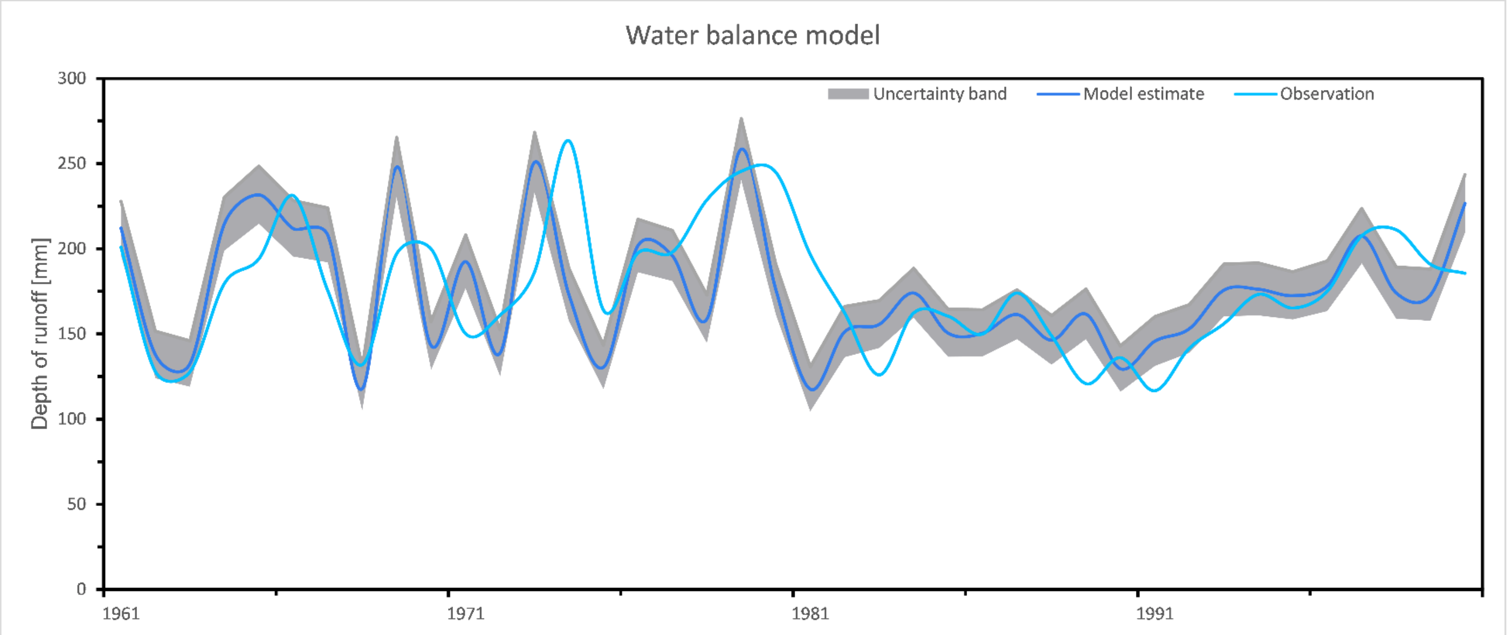
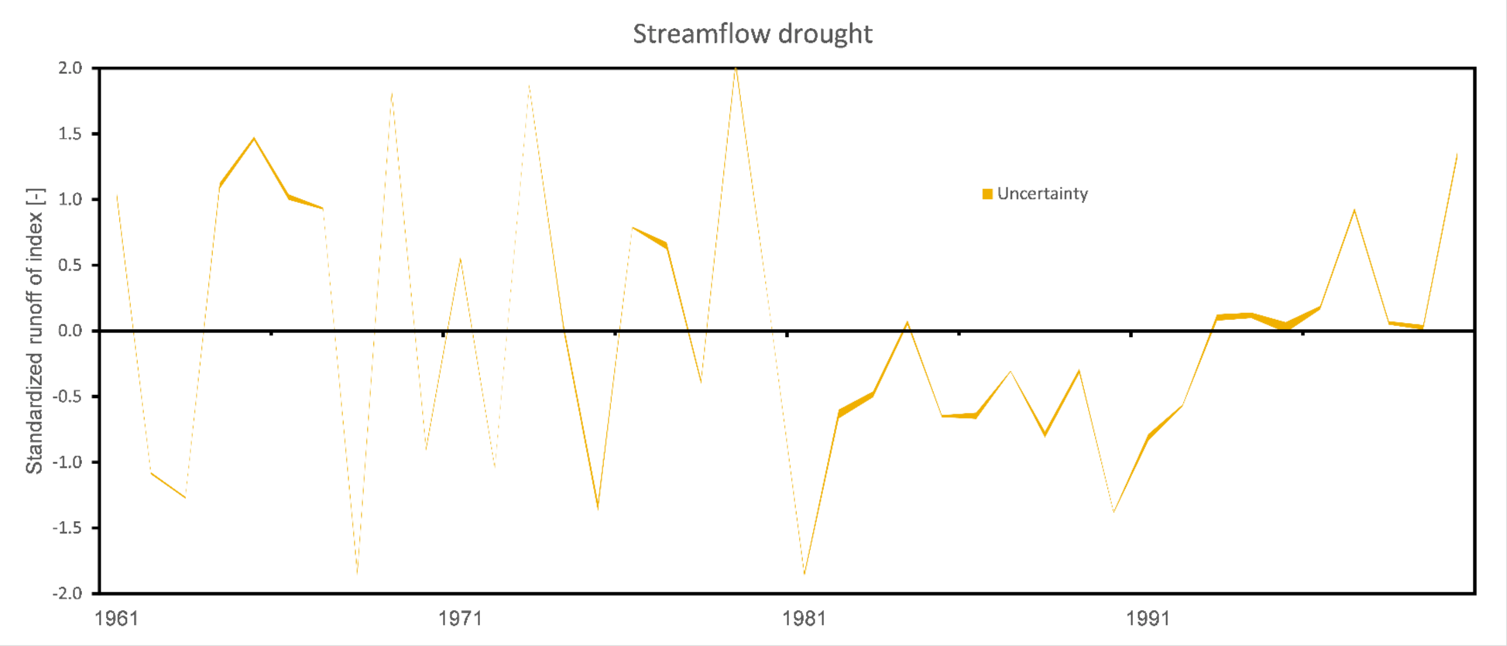
# Uncertainty in hydrological drought index

- Based on the predicted value of the flow, the SDI was calculated

- The result showed that the uncertainty reflected in the SDI is negligible, as shown in the graph below.

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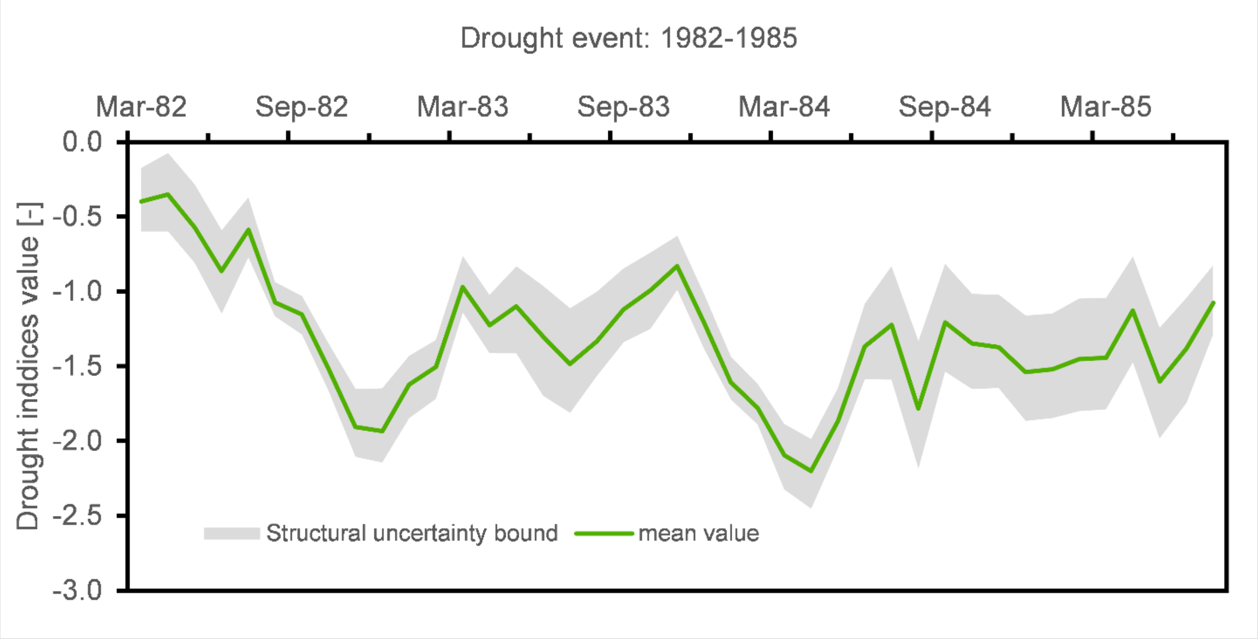
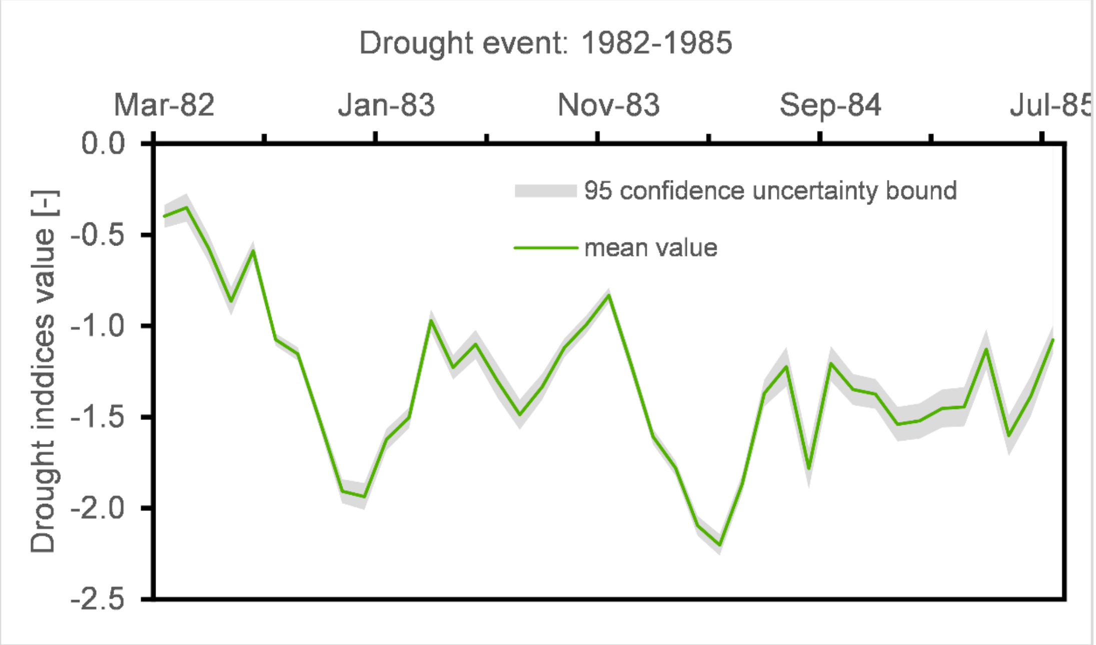
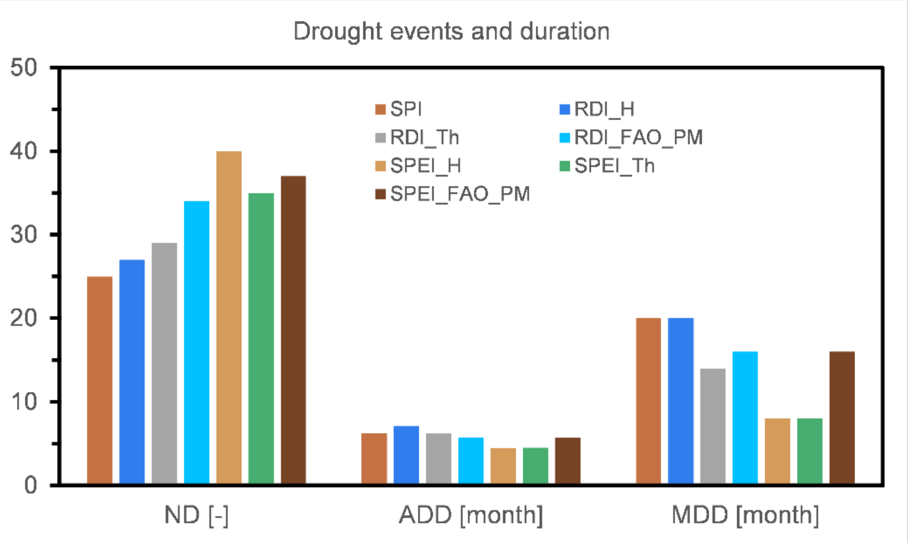
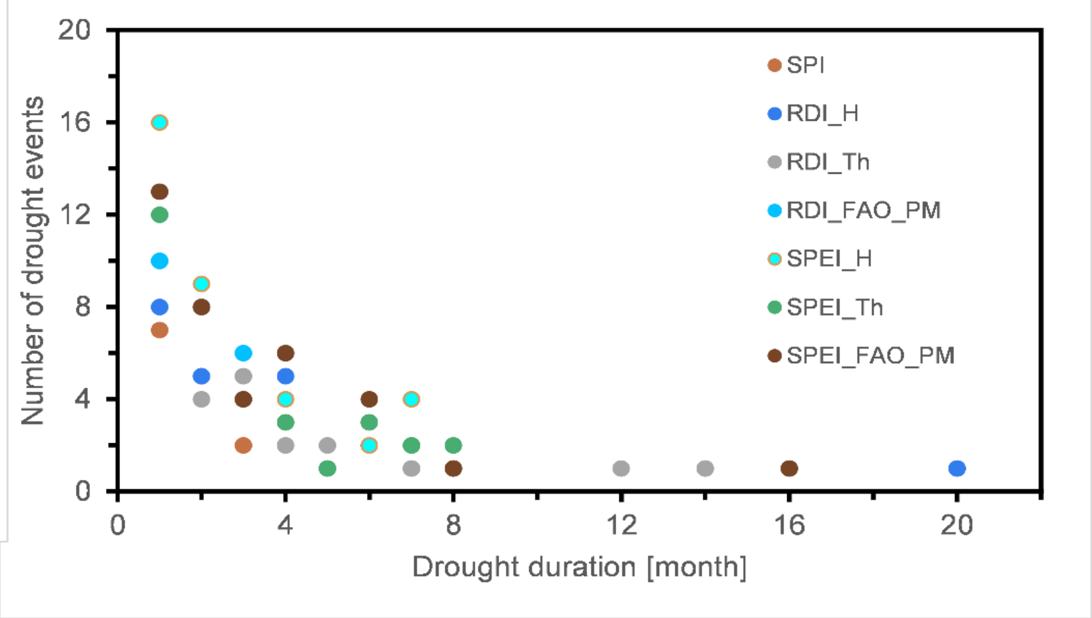
# Structural uncertainty of drought indices




ND=number of drought
ADD=average drought duration
MDD=maximum drought duration

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# Conclusions

- Uncertainty related to parameter and input error was assessed for four annual water balance models for the Vistula Basin
- The results show that the share of input and parameter/structure related errors is similar for each model and each sub-basin
- Structural uncertainty of meteorological drought indices is more considerable than hydrological drought indices.
- The modelling tools developed will be used to assess future water balance in the River Vistula basin under different water management scenarios and climate variability

# THANK YOU FOR YOUR ATTENTION!