Towards methodical modelling:

Differences between the structure and output dynamics of multiple conceptual models

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MODELLING CHOICES

Model review

A review of 43 conceptual model structures shows the huge number of modelling choices needed to develop conceptual models (Fig. 1). We explore differences in model output dynamics of conceptualized processes across geo-climatic regions to provide systematic guidance on how to make these choices.

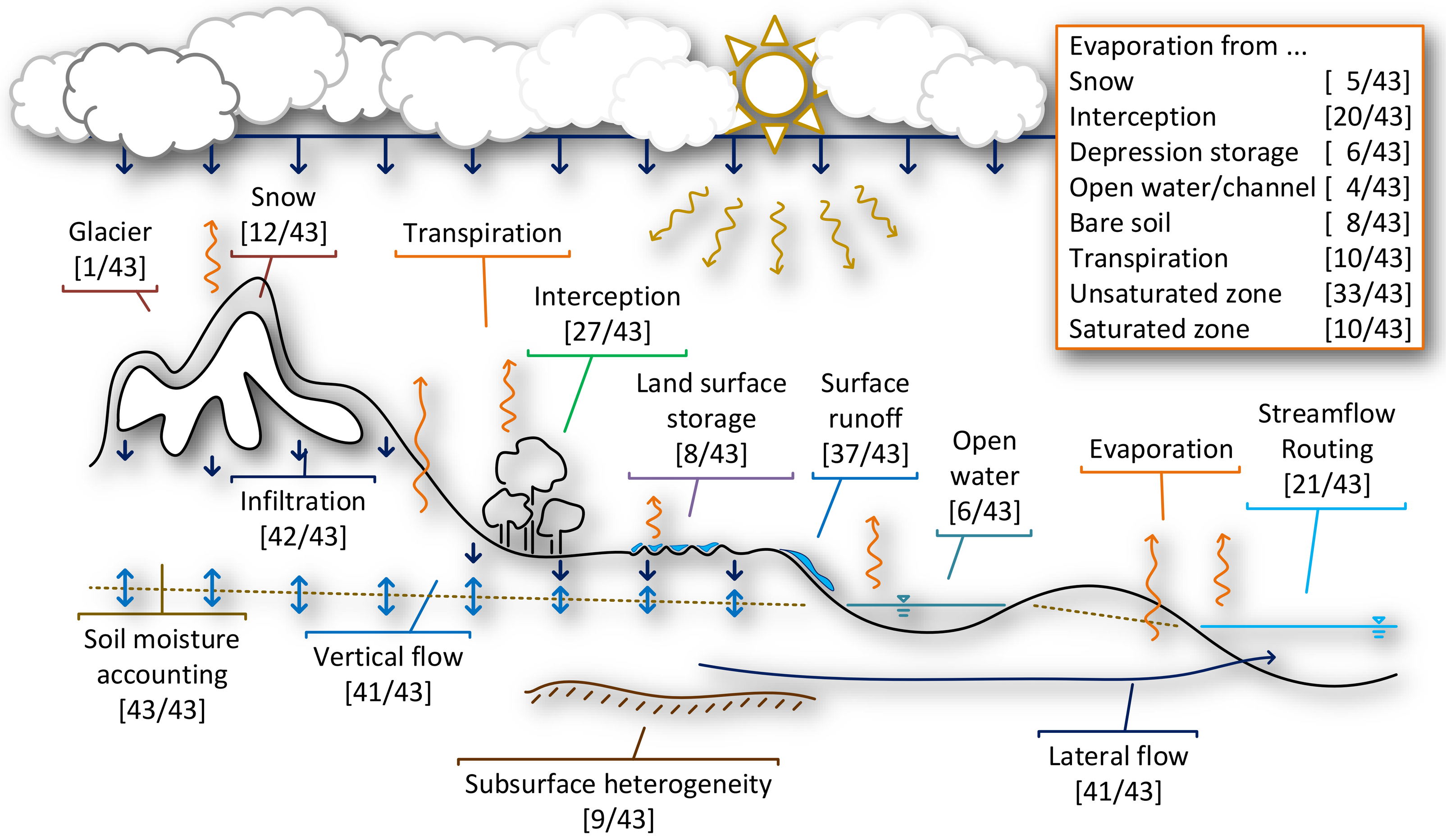


Figure 1: Simplified hydrological cycle (sub-processes not shown for clarity) with model review summary. E.g. 12 out of 43 ([12/43]) reviewed models include a snow module.

Interception differences

We find nine different interception concepts used across 27 models. We limit this preliminary study to four 1-store concepts with different underlying assumptions about required model complexity (Fig. 2).

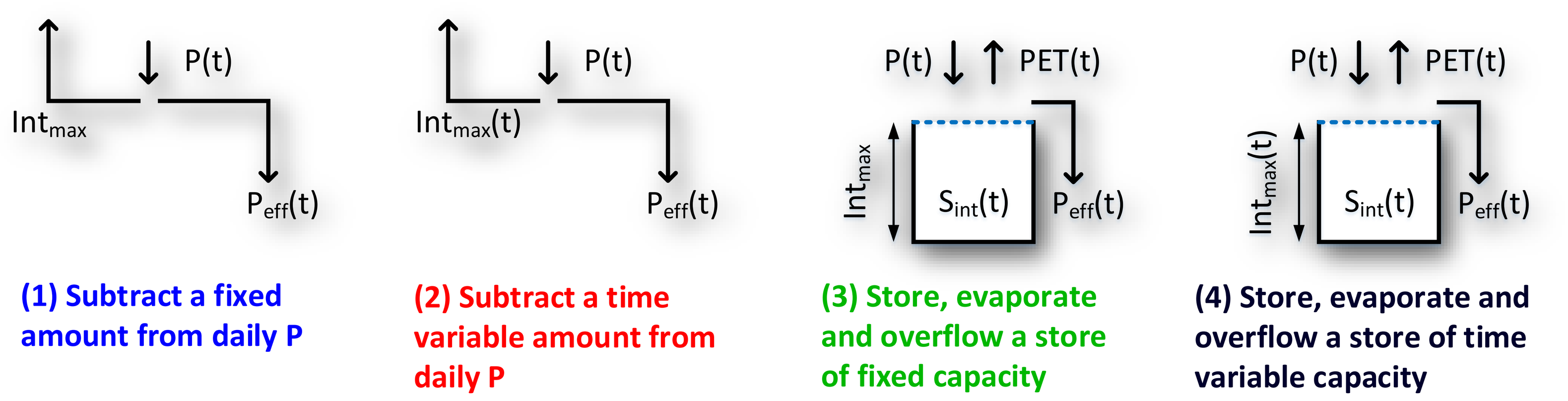


Figure 2: Four interception concepts selected from nine found in the review. We exclude multi-store concepts and bypassing mechanisms. Time variable $Int_{max}(t)$ reflects seasonal canopy capacity change.

Hypotheses

We investigate differences in dynamic behaviour with two null hypotheses:

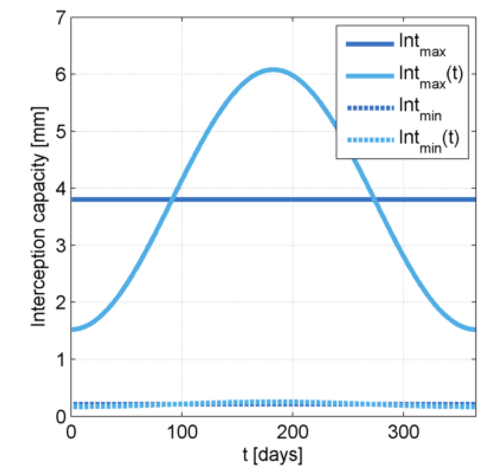
A. Concept 1 and concept 3 have the same long term water balance impact provided that long term average PET in (3) is equal to the Int_{max} term in (1);

B. Concept 1 and concept 2 have the same long term water balance impact provided that they have the same long term average interception capacity.

DYNAMIC DIFFERENCES

Experimental setup

Constant (Int_{max}) and time variable ($Int_{max}(t)$) interception capacity are set to have the same long term average value[1][2]. We create synthetic daily time series (10 year) of climatic forcing based on statistical characteristics of six representative climates[3] (Fig. 3).



Location	Climate	P pattern	P - PET peaks
Cairo	Desert	Winter >> summer	Out of phase
Rome	Warm temperate	Winter > summer	Out of phase
Vienna	Cold temperate	Summer > winter	In phase
Brasilia	Tropical	Winter >> summer	Out of phase
Moscow	Cold temperate	Even spread	-
Paramaribo	Tropical	Even spread	In phase

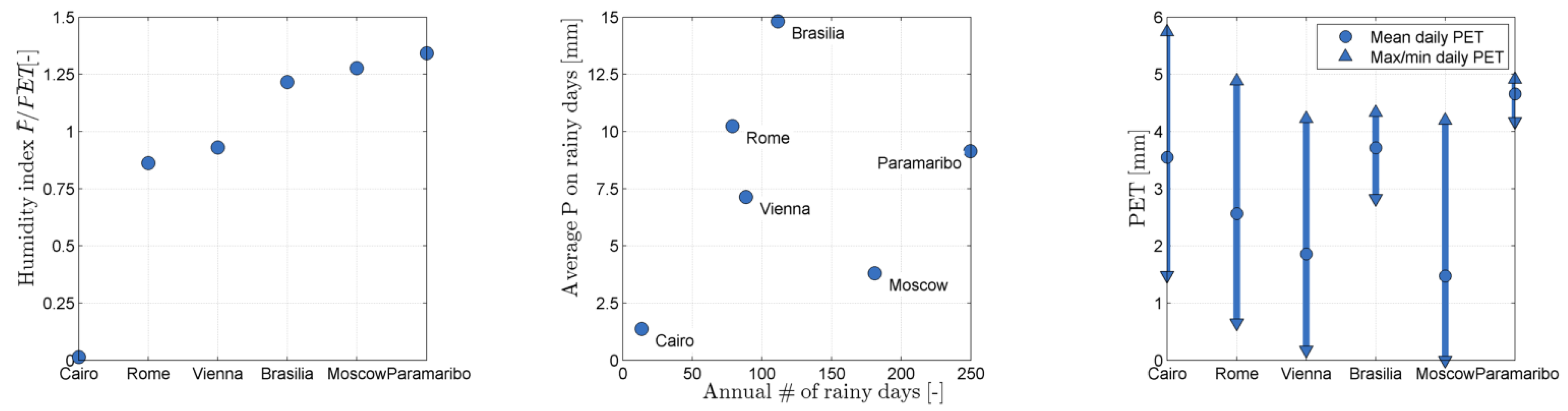


Figure 3: Experimental setup. Top-left: interception capacity; top-right and bottom row: climate forcing.

Expectations and results

Hypothesis A is likely untrue when P is strongly seasonal and out of phase with the PET peak (i.e. Brasilia). The relatively low PET rate during the wet season will lead to more P_{eff} with concept (3) compared to (1). PET rates (3) < Int_{max} (1) will have a similar effect (e.g. Moscow; Tab. 1, top).

Hypothesis A	Expected	Actual
P_{eff} from (3) ... than from (1)		
Cairo	**Similar**	**Lower**
Rome	**Higher**	**Lower**
Vienna	**Higher**	**Lower**
Brasilia	**Higher**	**Lower**
Moscow	*Higher*	*Higher*
Paramaribo	*Lower*	*Lower*

Hypothesis B	Expected	Actual
P_{eff} from (2) ... than from (1)		
Cairo	*Higher*	*Higher*
Rome	*Higher*	*Higher*
Vienna	*Similar*	*Similar*
Brasilia	*Higher*	*Higher*
Moscow	*Similar*	*Similar*
Paramaribo	*Similar*	*Similar*

Table 1: hypotheses expectations and results (*as expected*, **different**).

Hypothesis B will be untrue for cases with strong seasonality in P, out of phase with $Int_{max}(t)$ (e.g. Cairo). The relative magnitude of P and $Int_{max}(t)$ also plays a role (Tab. 1, bottom).

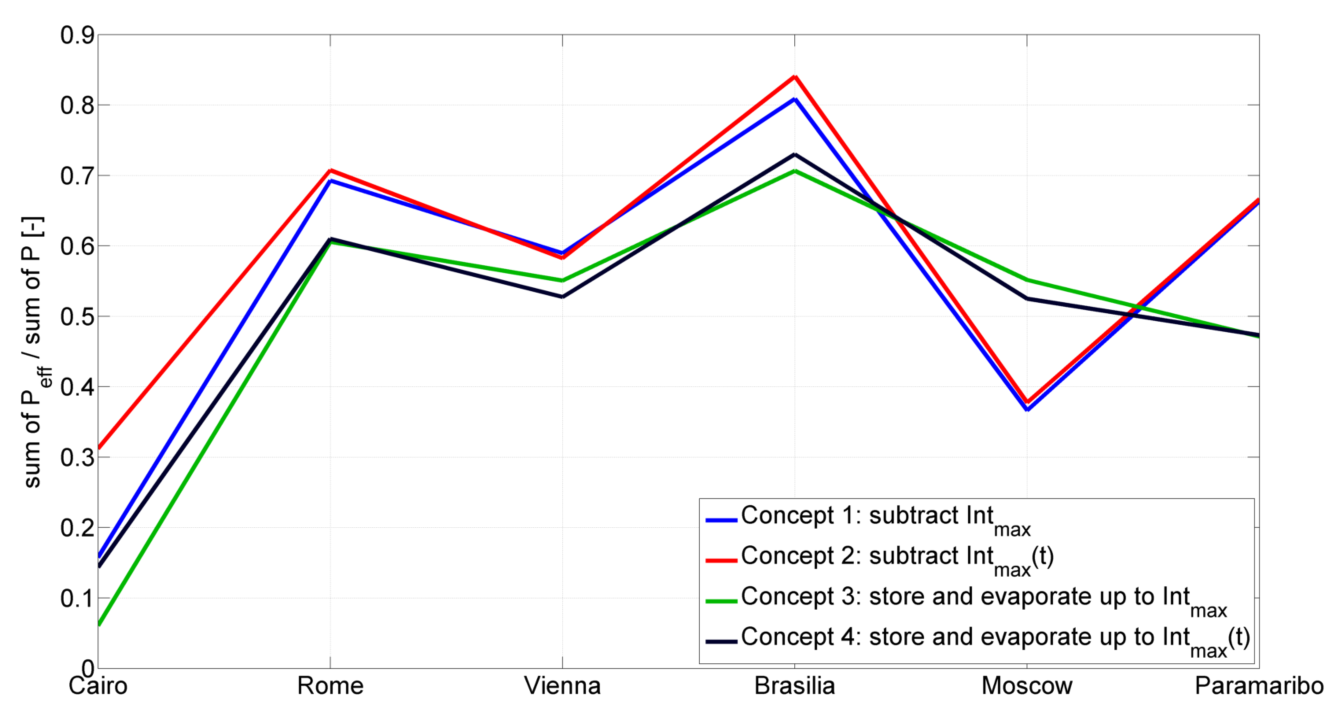


Figure 4: sums of P_{eff}/P after forcing the four interception concepts with 6 climates (experiment details in Fig. 3).

DISCUSSION & OUTLOOK

Consequences of assumptions

Hypothesis A is rejected for multiple cases, but for different reasons than expected. Two modelling assumptions play a role in explaining this: we assume that P and PET occur spread uniformly over each time step and that there is no reduction in PET on rainy days. This allows concept (3) to fill and evaporate simultaneously, leading to less store overflow and lower P_{eff} in (3) than in (1) (Fig. 5).

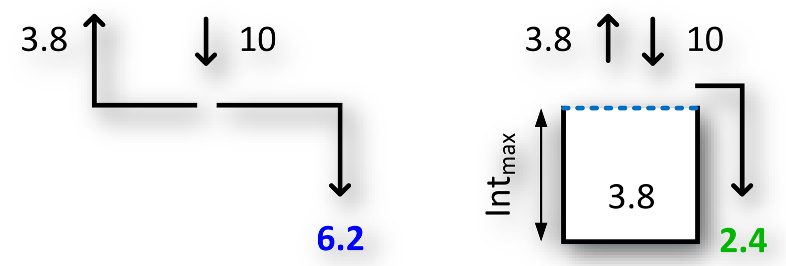


Figure 5: impact on P_{eff} of assumptions in concept 1 and (3) with P = 10, Int_{max} = PET = 3.8mm.

It is unclear if and how PET should be adjusted on rainy days. With PET = 0mm on rainy days, concept 3 and **(4)** usually produce more P_{eff} than concept 1 and (2).

An arbitrary PET reduction of 50% on rainy days makes the differences between the four concepts marginal for the non-extreme cases (Fig. 6; Cairo has strongly seasonal P, Moscow has zero PET during winter).

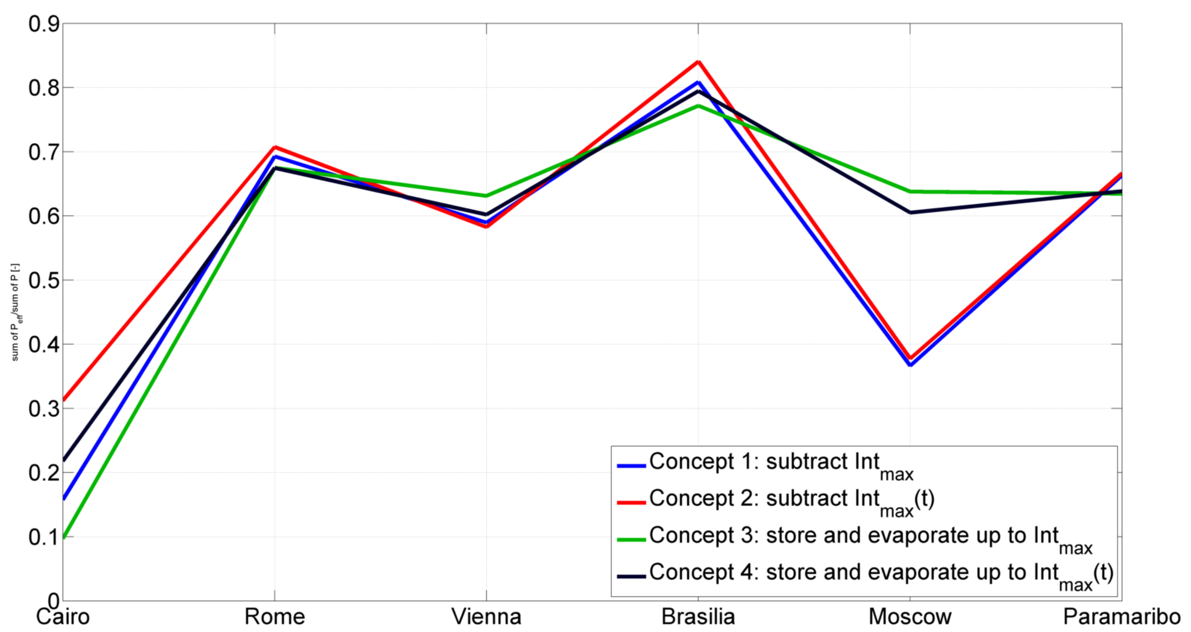


Figure 6: sums of P_{eff}/P after forcing the four interception concepts with 6 climates; assuming that PET on rainy days is 50% of normal.

This effect is reinforced when minimum capacity Int_{min} (Fig. 3) is used. The results with respect to **hypothesis B** are comparable for max and min capacities.

Conclusions

A. Modelling assumptions about PET rate during rain events can significantly influence long term canopy water balance; under adjusted PET forcing these assumptions only effect long term canopy water balance in extreme climates.

B. Seasonal variations in interception capacity, P and PET have only a marginal influence on long-term canopy water balance for most tested cases.

Thus both very simple and more complex interception models can produce a similar long term canopy water balance in many climates. However more work is needed to test the cascaded impact on other model components.

Looking forward

Similar testing of all conceptual model components (Fig. 1) will show for which cases (climatic, geographical) differences between modelling concepts and cascaded elements lead to dynamically different models.

This presentation participates in OSPP
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