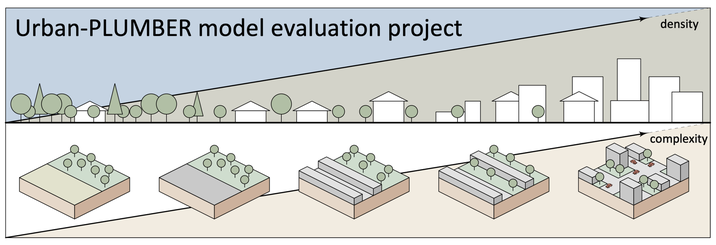
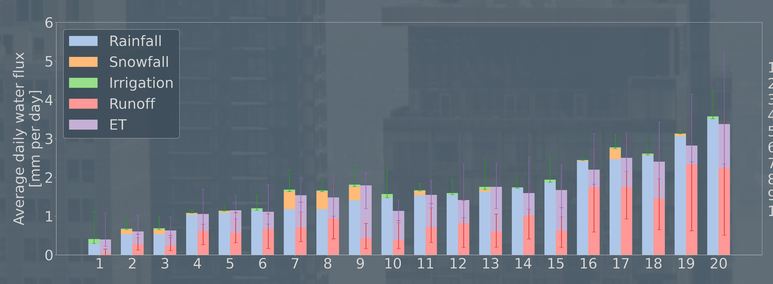
# Crucial consistency of the water balance in urban land surface models

## Multi-model comparison

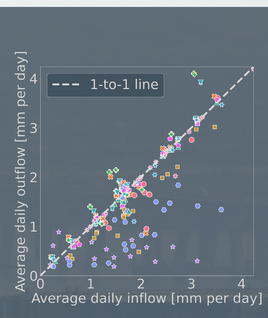



> *The energy balance is linked with the water balance through ET.*
> **A good water balance representation may help to capture the hard-to-model latent heat flux.**
> *We evaluate the water balance in 14 models based on simulations of 20 urban sites of the Urban-PLUMBER project.*




1: US-WestPhoenix
2: PL-Lipowa
3: PL-Narutowicza
4: UK-KingsCollege
5: UK-Swindon
6: GR-HECKOR
7: FI-Kunpula
8: FI-Torni
9: US-Minneapolis1
10: AU-SurreyHills
11: US-Baltimore
12: MX-Escandon
13: KR-Ochang
14: FR-Capitole
15: AU-Preston
16: JP-Yoyogi
17: CA-Sunset
18: NL-Amsterdam
19: KR-Jungnang
20: SG-TelokKurau

> *Average daily water balances for all sites.*
> *Confidence intervals indicate the full range of the model results.*
> **Model spread is as high as the fluxes and increases with average water input.**



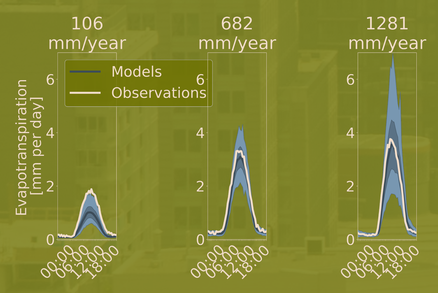

> *Average daily inflow versus outflow per model run.*
> *The marker type indicates the model.*
> *Model runs lay on the line if they close the water balance.*
> **The water balance is not closed in most model runs.**

## Urban water balance

Precipitation Irrigation

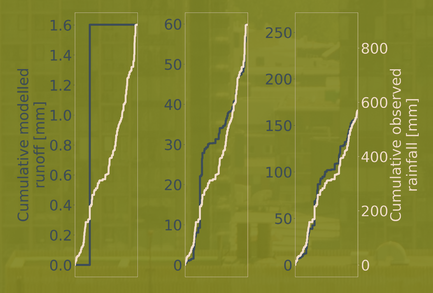
$$P + I = ET + R + \Delta S$$

## Evapotranspiration



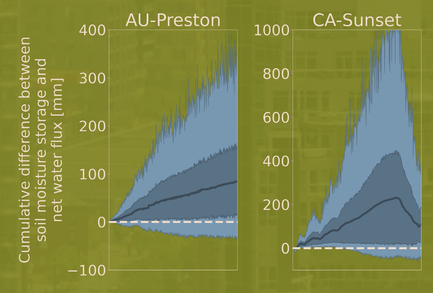

> *Daily trend of ET at three sites with increasing yearly precipitation with the median, 25-75 percentile (dark), and the full range (light) of all models.*
> **Models show an overall underestimation and diverge more at wetter sites.**

## Runoff

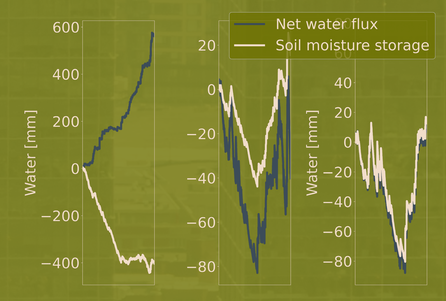



> *Cumulative runoff and precipitation over one year at one site for three models.*
> **Runoff is triggered by precipitation events of different sizes depending on the model leading to large spread in modelled cumulative runoff.**

## Storage change




> *Cumulative difference between the soil moisture storage and net water flux over a year at two sites for all models (see ET).*
> *Some of the sites show a seasonal trend.*
> **At all sites, the difference increases over time revealing a discrepancy in the models.**




> *Net water flux and soil moisture storage over a year at one site in three models.*
> **Models have the net water flux and soil moisture storage non-connected, only connected in time, or fully connected.**

$$P + I = ET + R + \Delta S$$

1. Closure of the water balance assessed by the deviation between the average daily inflow and outflow
Maximally 5% deviation +1

2. Range in the soil moisture storage and storage derived from net water flux
<250 mm +0.5 for both

3. Consistency between soil moisture storage and storage derived from net water flux expressed by $R^2$ and the index of agreement
>0.9 for both +0.5 for both

4. Difference between modelled and observed cumulative evapotranpiration
-25%-+50% +1

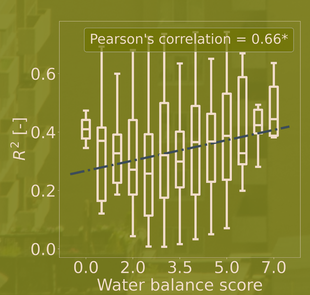
5. Similarity in the modelled and observed timescales of declining evapotranspiration
$p<0.05$ +1

6. Runoff ratio defined as cumulative runoff over cumulative precipitation
0.1-0.5 +1

7. Quick runoff response expressed by percentage of runoff in percentage of time
70% of runoff in 1% of time +1

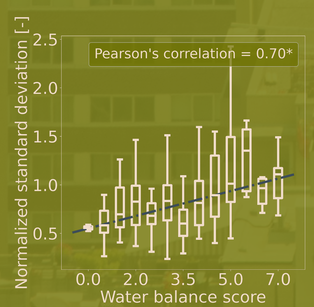
# The water balance score of a model run is based on 7 indicators.

## Higher water balance scores correlate with more accurate ET.

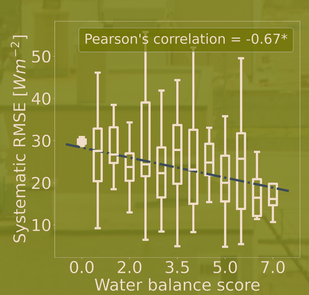



> *$R^2$ improves with a higher water balance score (closer to 1).*
> **Thus, the timing of ET is better captured.**

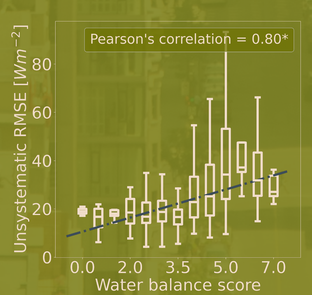
**Significant correlation*




> *The normalized standard deviation improves with a higher water balance score (closer to 1).*
> **Thus, the daily variation of ET is better captured.**




> *The systematic RMSE reduces with a higher water balance score (closer to 0).*
> **Thus, the overall drift of ET is reduced.**




> *The unsystematic RMSE rises with a higher water balance score (further from 0).*
> **Thus, the erratic error represents a larger share of the RMSE.**

## Conclusions

> **For all water fluxes, the model spread lays in the order of magnitude of the flux.**
> **Urban land surface models do not consistently reproduce a physically realistic water balance.**
> **A better water balance representation correlates with a better performance for evapotranspiration regarding the timing, daily variation, and drift.**



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