Wageningen Lowland Runoff Simulator

Modelstructuur en toepassingen

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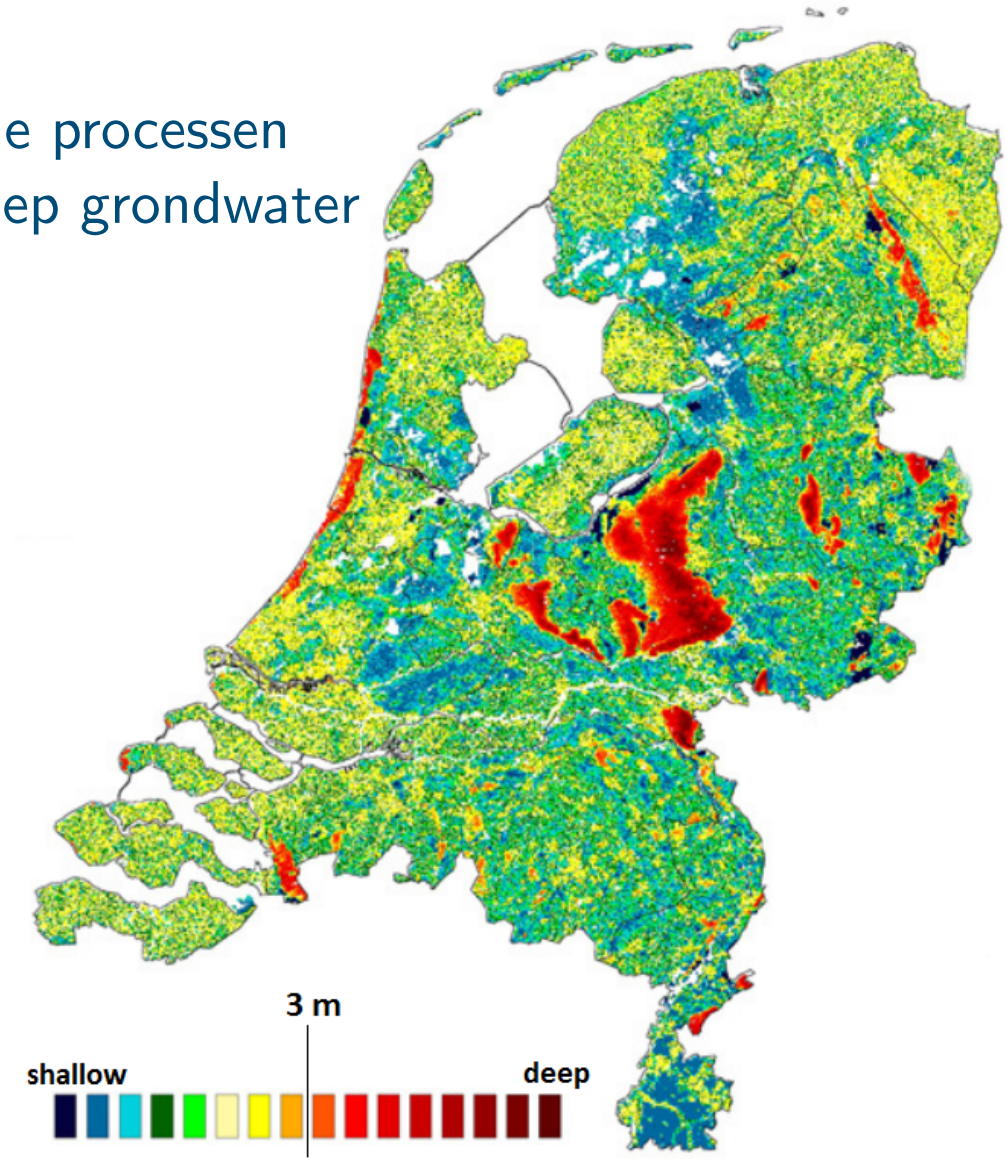
WAGENINGEN
UNIVERSITY & RESEARCH

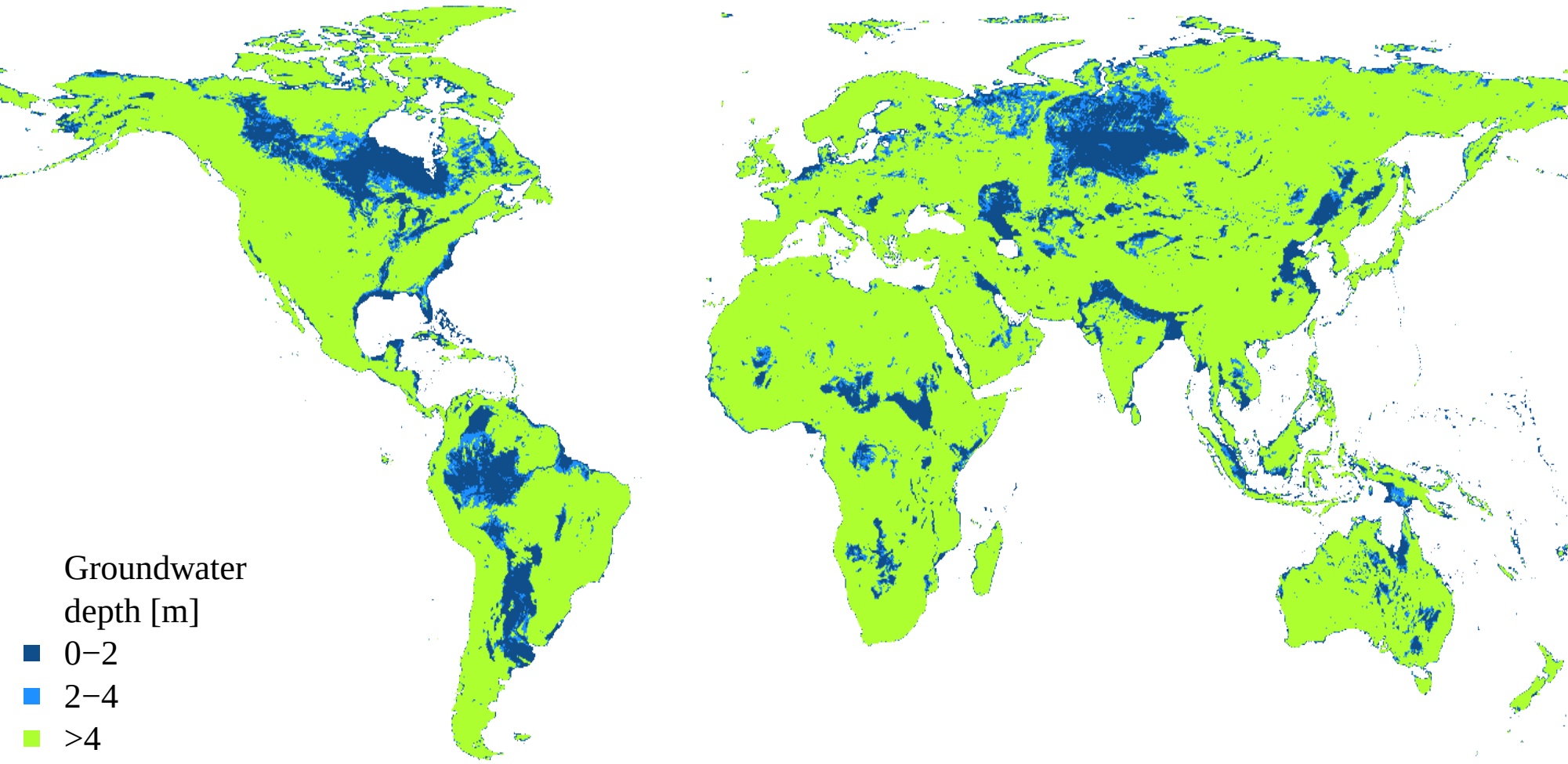
Laaglandgebieden

Gebieden waar hydrologische processen worden beïnvloed door ondiep grondwater



Witte et al., Hydrol. Earth Syst. Sci., 2012

Gebieden met ondiep grondwater wereldwijd



Based on Fan et al., Science, 2013

Doel

Voorheen:

complexe, ruimtelijk gedistribueerde modellen voor laaglandgebieden

OF

simpele, parametrische modellen voor hellende stroomgebieden

Doel

Voorheen:

complexe, ruimtelijk gedistribueerde modellen voor laaglandgebieden

OF

simpele, parametrische modellen voor hellende stroomgebieden

↓

Nu ook:

een simpel, parametrisch model voor laaglandgebieden:

Wageningen Lowland Runoff Simulator (WALRUS)

Beoogde toepassingen

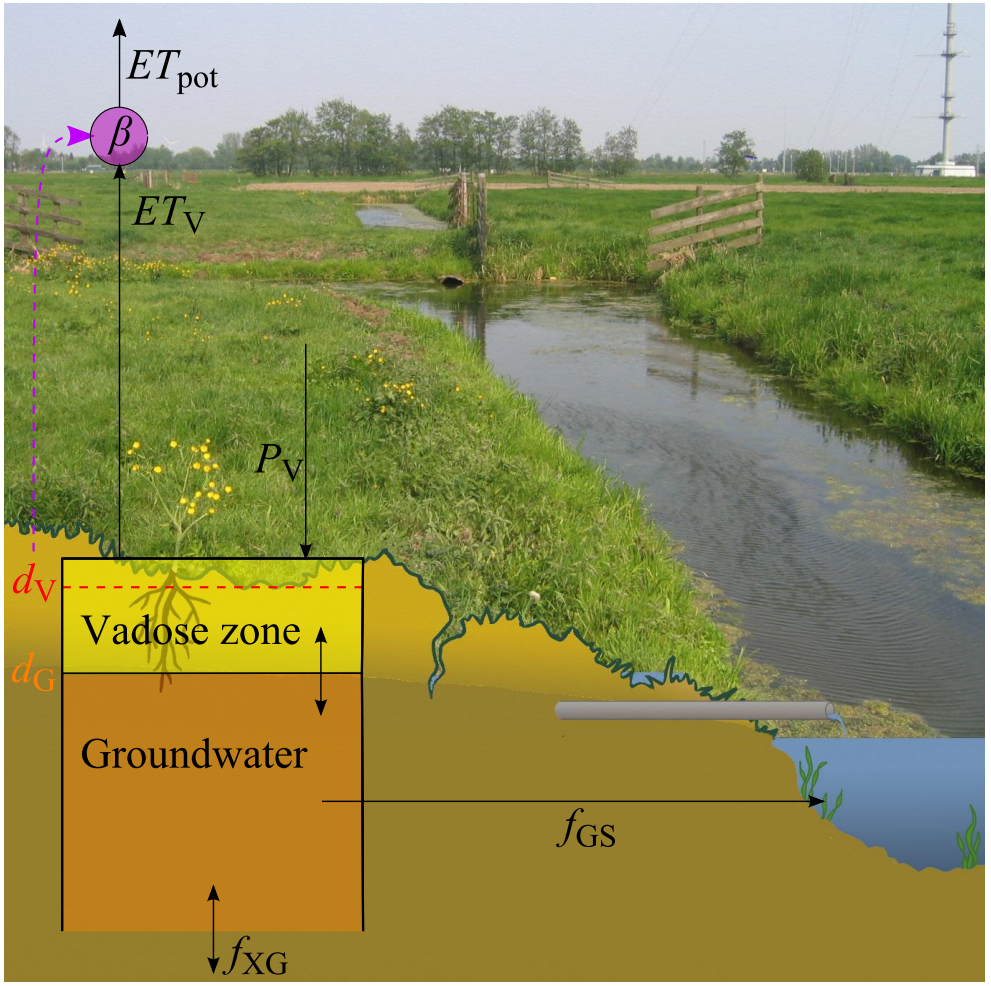
Voordelen

- Voor zowel vrij-afwaterende stroomgebieden als polders
- Snel
- Weinig parameters
- Duidelijke (kwalitatieve) relatie tussen modeltoestanden en meetbare variabelen
- Standaardopties voor initiële condities
- Open source en freeware

Mogelijke toepassingen

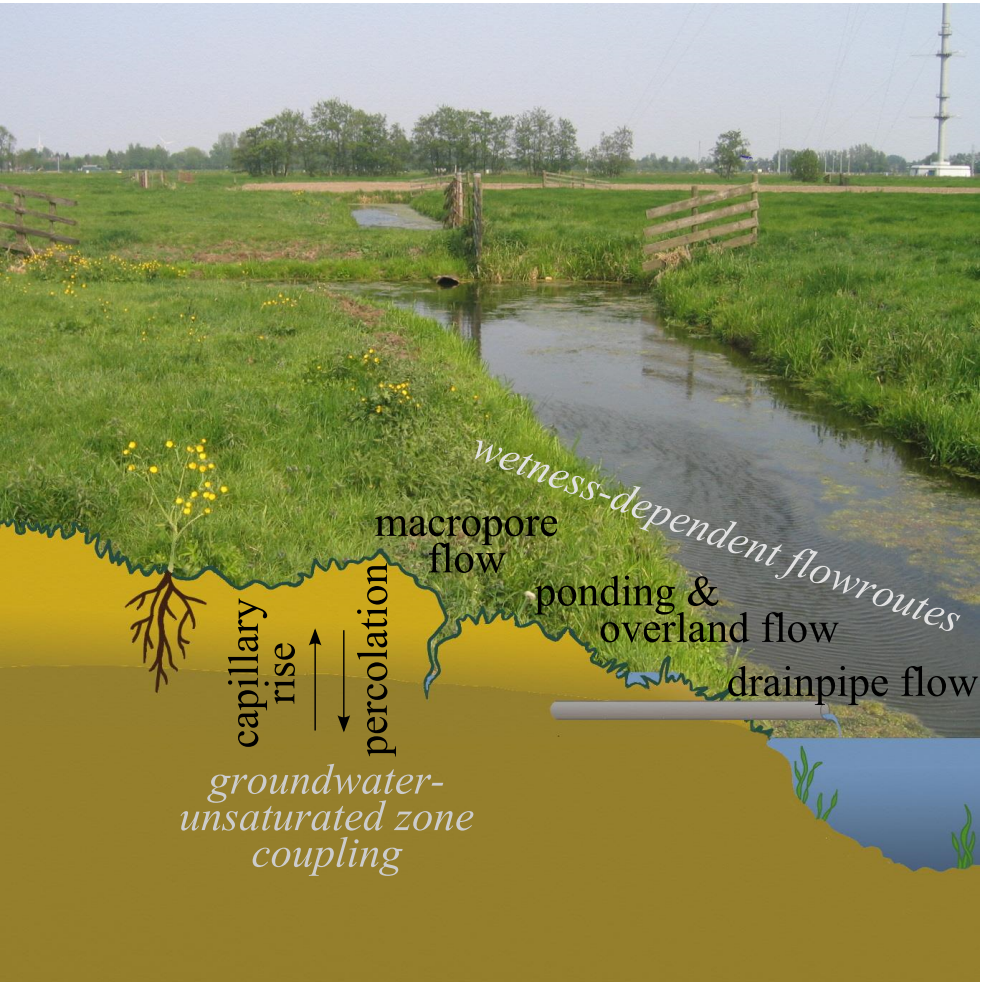
- Operationele verwachtingen
- Real-time control
- Input voor een hydraulisch model
- Risico-analyses
- Scenario-analyses
- Ontwerpen van infrastructuur
- Vullen van gaten in meetreeksen

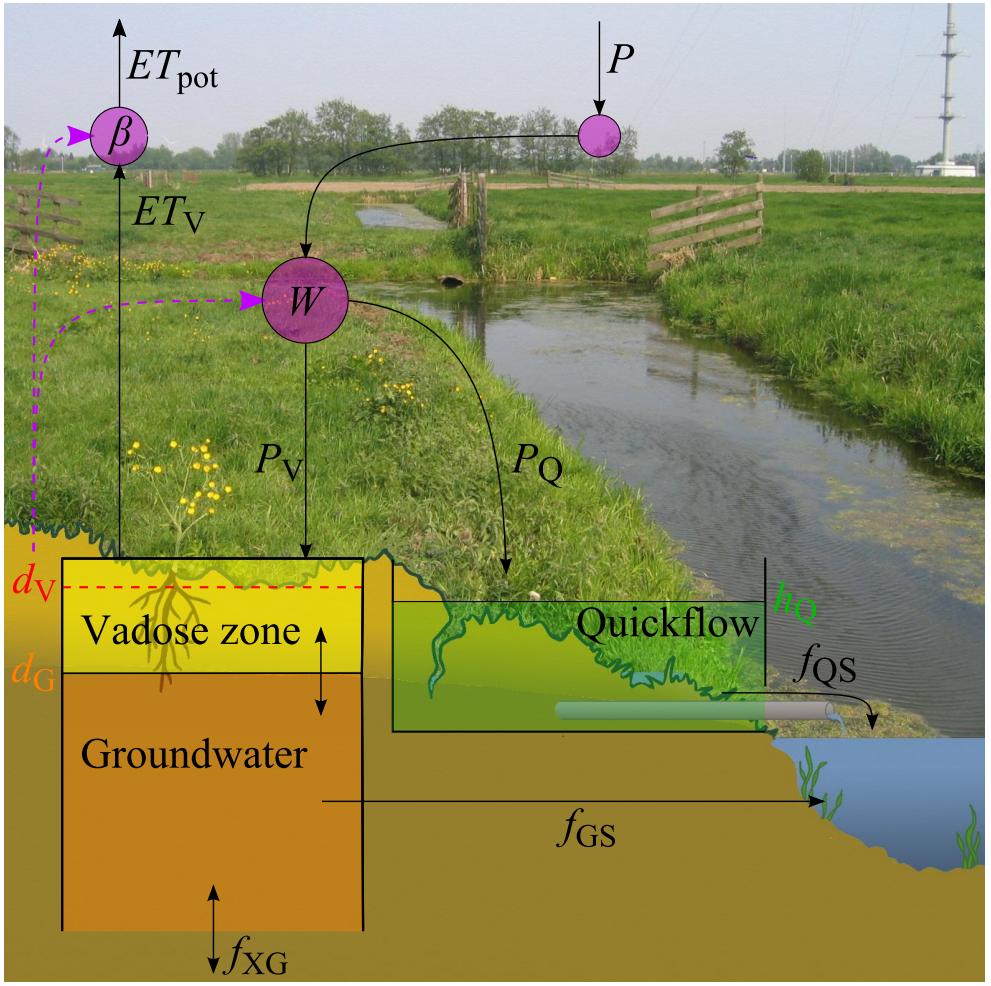
WALRUS-bijzonderheden (1)



Koppeling grondwater - onverzadigde zone

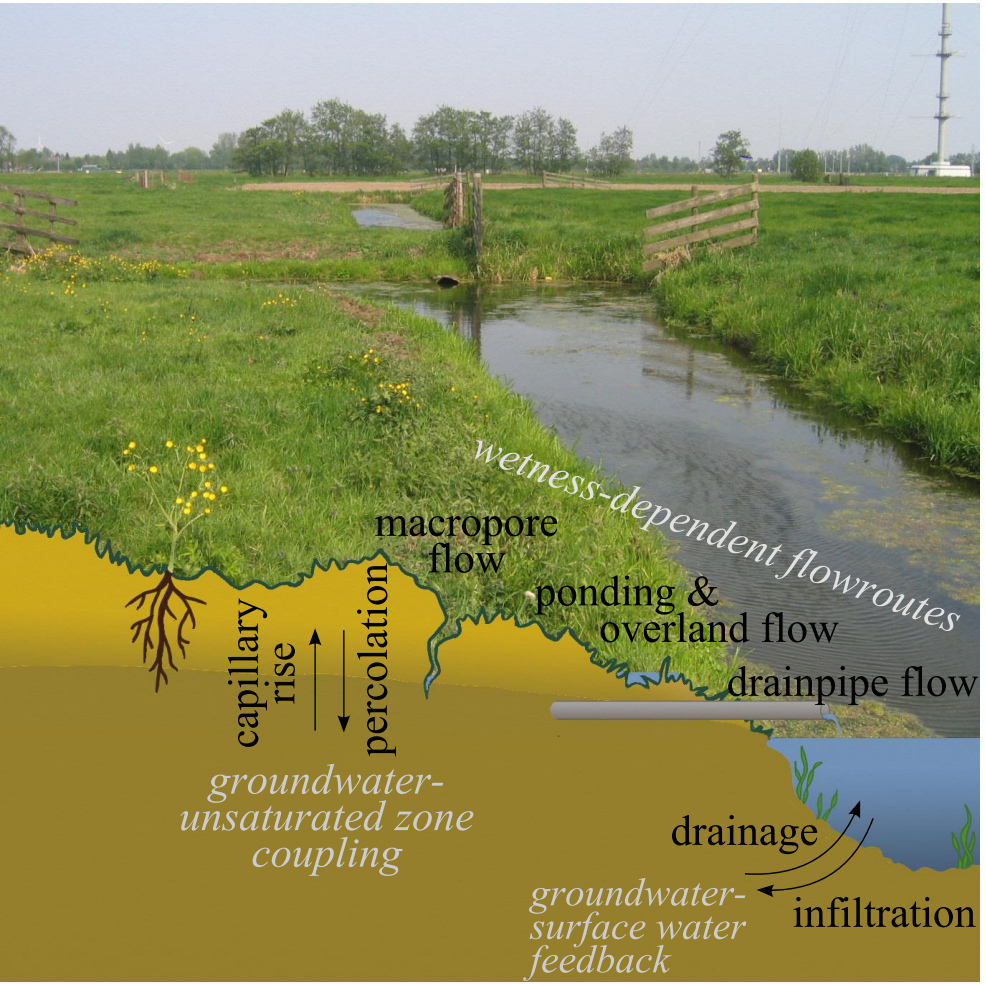
WALRUS-bijzonderheden (2)

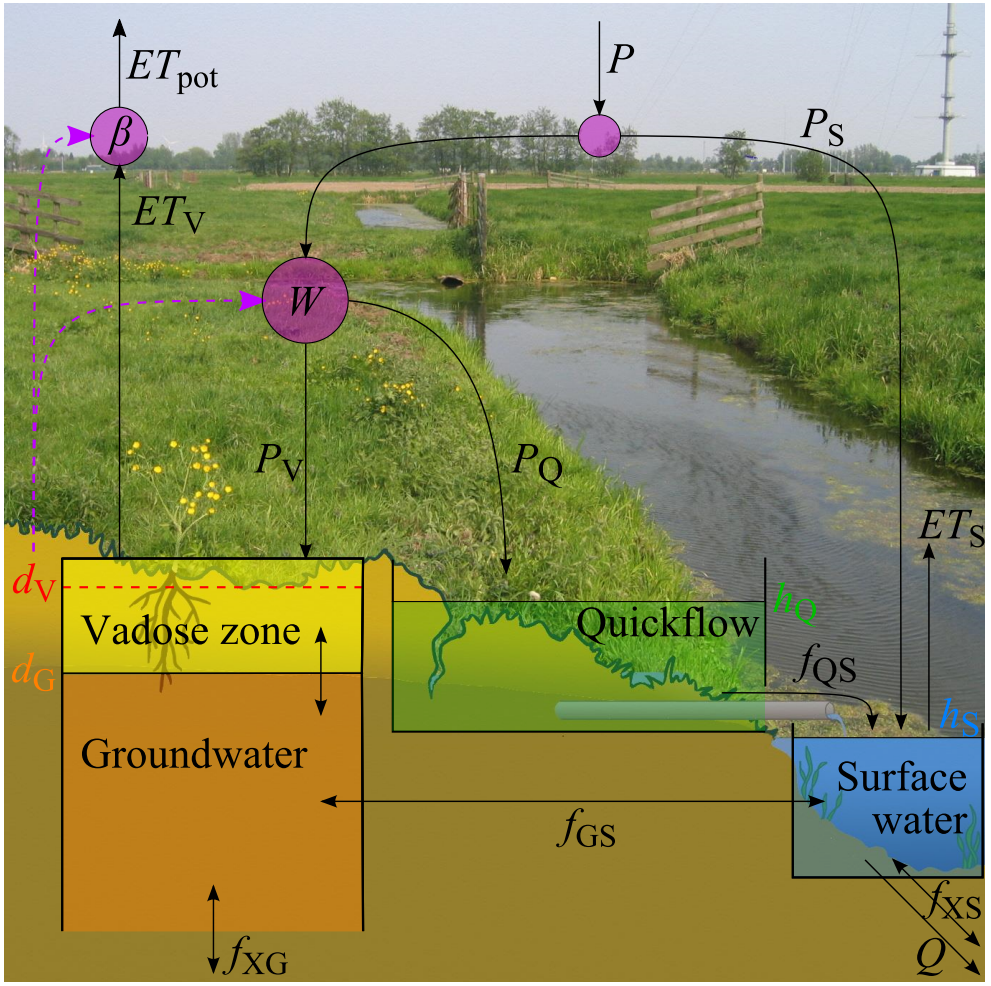




Vochttoestand-afhankelijke stroomroutes

WALRUS-bijzonderheden (3)





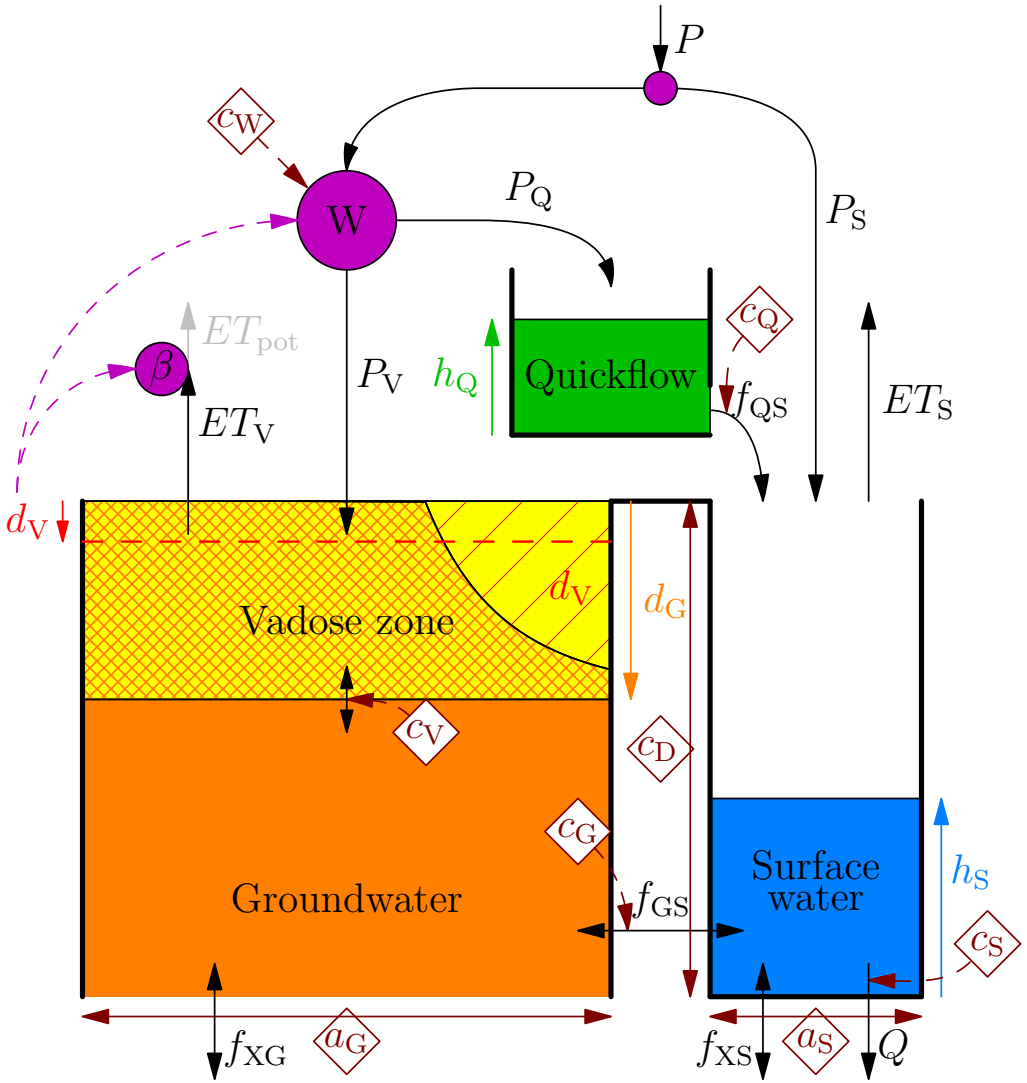
Grondwater-oppervlaktewaterterugkoppeling

Stroming tussen reservoirs

Grondwaterdrainage / infiltratie van oppervlaktewater
func(grondwaterpeil – oppervlaktewaterpeil, contactoppervlak)

Snelle stroomroutes
func(quickflow-reservoirniveau)

Afvoer
func(oppervlaktewaterpeil)
Geef $Q(h)$-relatie of gebruik default.



Benodigde data

- Neerslag
- Potentiële verdamping
- Afvoer (voor kalibratie)
- Kwel/wegzijging (indien van toepassing)
- Inlaat (indien van toepassing)
- Stuwpeil (indien van toepassing)

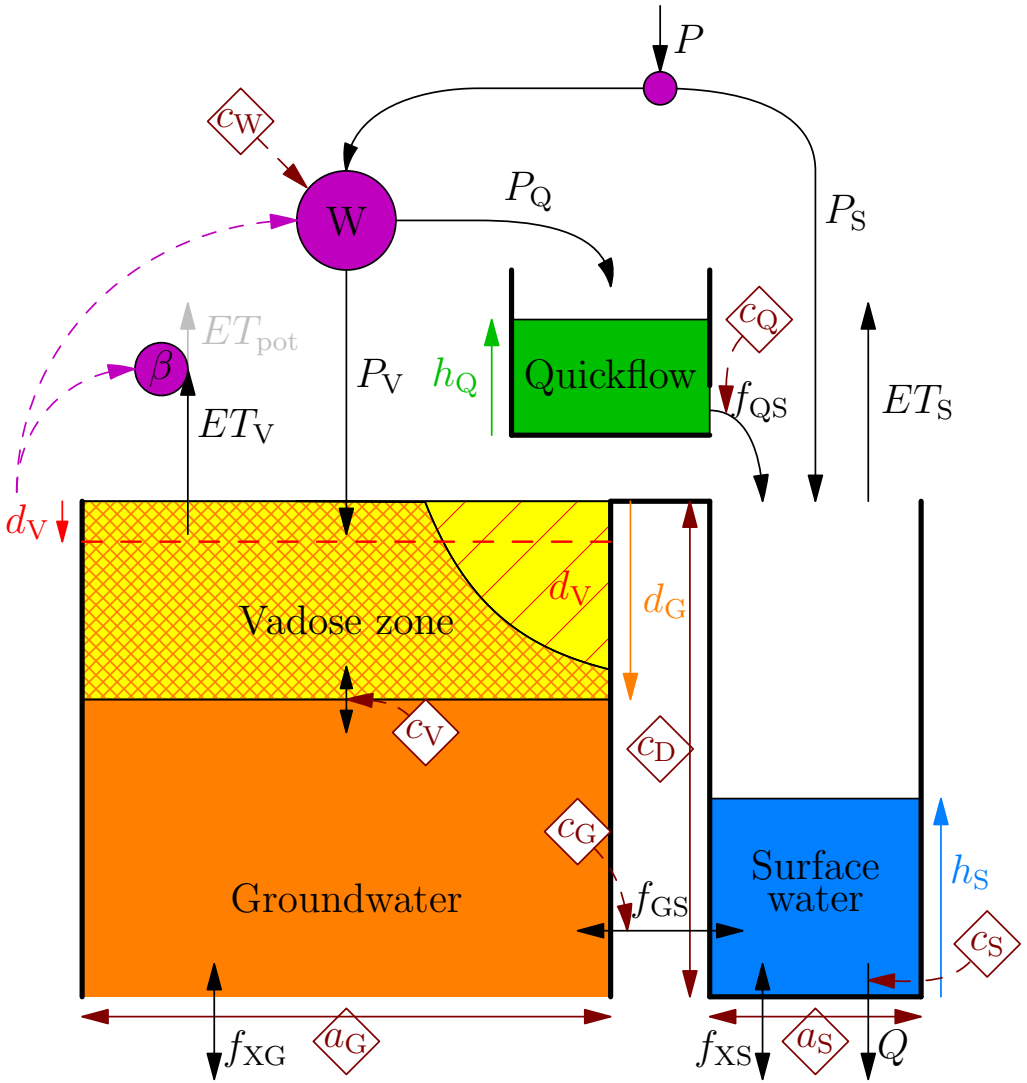
Parameters en initiële condities

Parameters

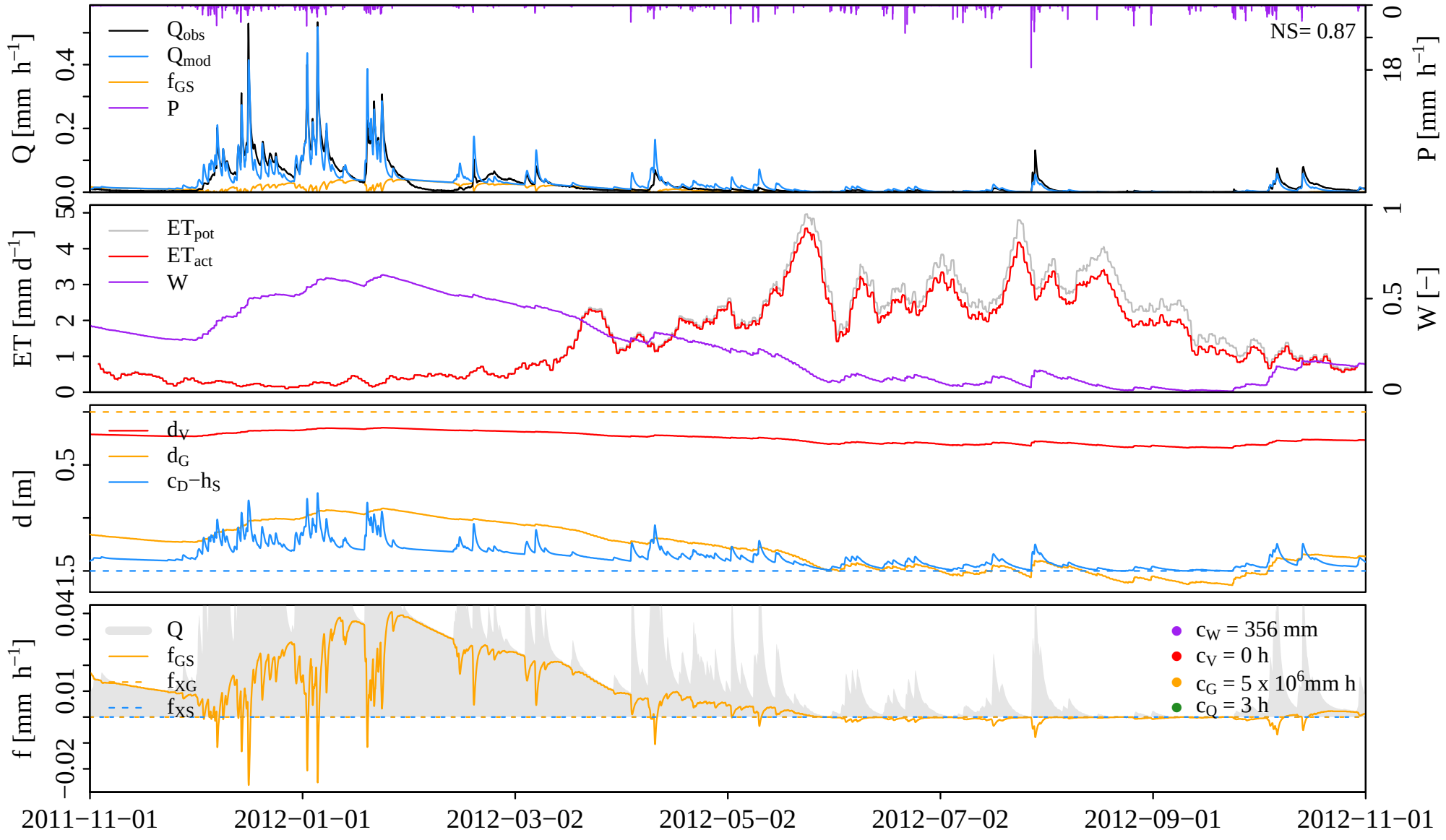
- a_S, c_D, bodemtype, (c_S): schat o.b.v. stroomgebieds-eigenschappen
- c_W, c_G, c_Q, (c_V): kalibreer

Initiële condities

- *niets gespecificeerd*: evenwicht $\rightarrow$ alle afvoer van grondwater
- G_{frac}: fractie van afvoer uit grondwater
- $d_{V,0}$, $d_{G,0}$, $h_{Q,0}$, $h_{S,0}$



Output


Q [mm h^{-1}]
Q_{obs}
Q_{mod}
f_{GS}
P
NS= 0.87
P [mm h^{-1}]
ET [mm d^{-1}]
ET_{pot}
ET_{act}
W
W [–]
d [m]
d_V
d_G
$c_D - h_S$
f [mm h^{-1}]
Q
f_{GS}
f_{XG}
f_{XS}
c_W = 356 mm
c_V = 0 h
c_G = 5 x 10^{6}mm h
c_Q = 3 h
2011−11−01
2012−01−01
2012−03−02
2012−05−02
2012−07−02
2012−09−01
2012−11−01

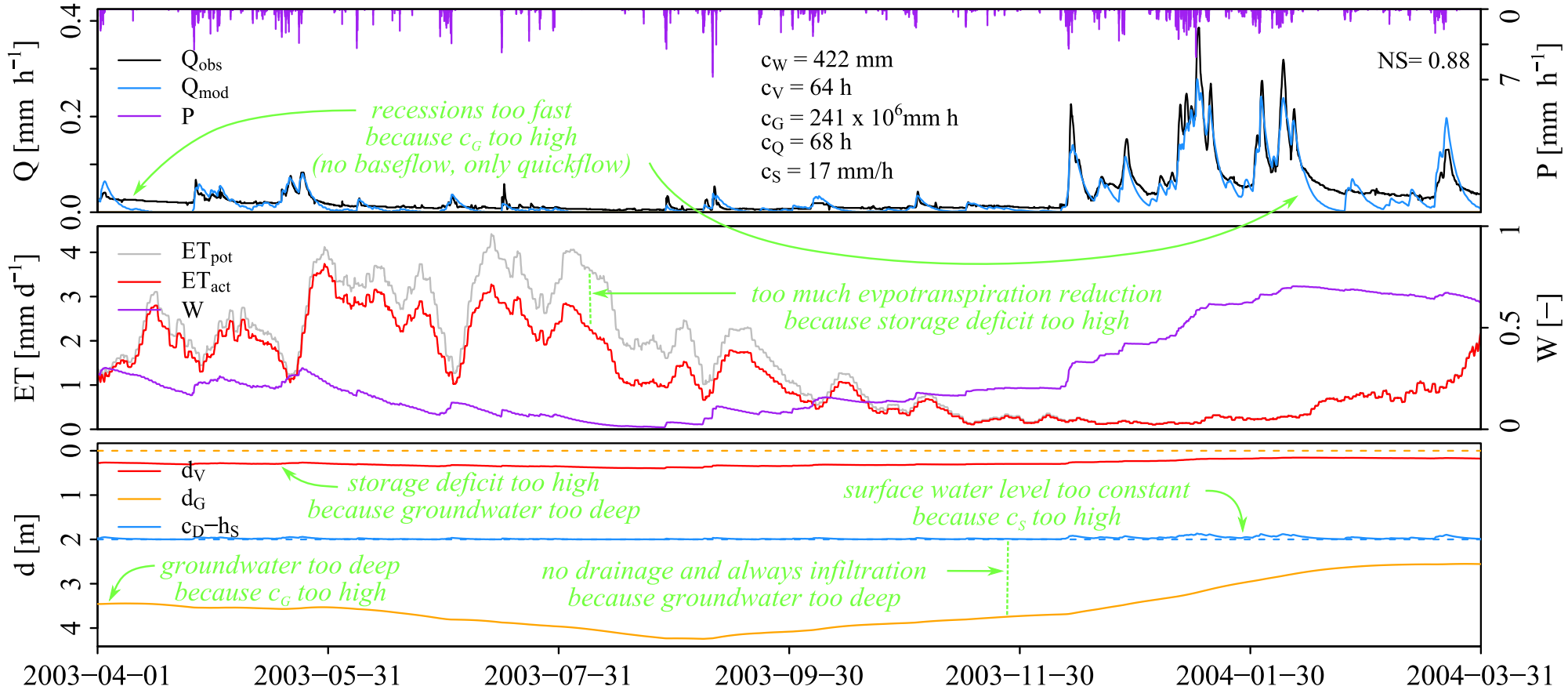
Schatten van parameters (kalibreren)

	Handmatig	Willekeurig*	Algoritmes**
Inzicht in effect parameters op alle gesimuleerde variabelen	+	−	−
Automatisch	−	+	+
Rekentijd	+	−	−
Ongevoelig voor startwaarden	+	+	−
Volledige parameterruimte afgezocht	−	+	−

* Groot aantal willekeurige parametersets (Monte Carlo), bijv. gegenereerd met Latin Hypercube Sampling

** bijv. Levenberg-Marquardt, particle swarm optimisation

Pas op voor "right for the wrong reasons"



Checklist kalibratie

Vóór simulaties, check waterbalans van observaties:

- ☐ Jaarsommen: $Q \approx P - ET_{\mathrm{pot}} + f_{\mathrm{XS}} + f_{\mathrm{XG}}$
  en $0.8 < \frac{P-Q+f_{\mathrm{XS}}+f_{\mathrm{XG}}}{ET_{\mathrm{pot}}} < 1$ (in NL)

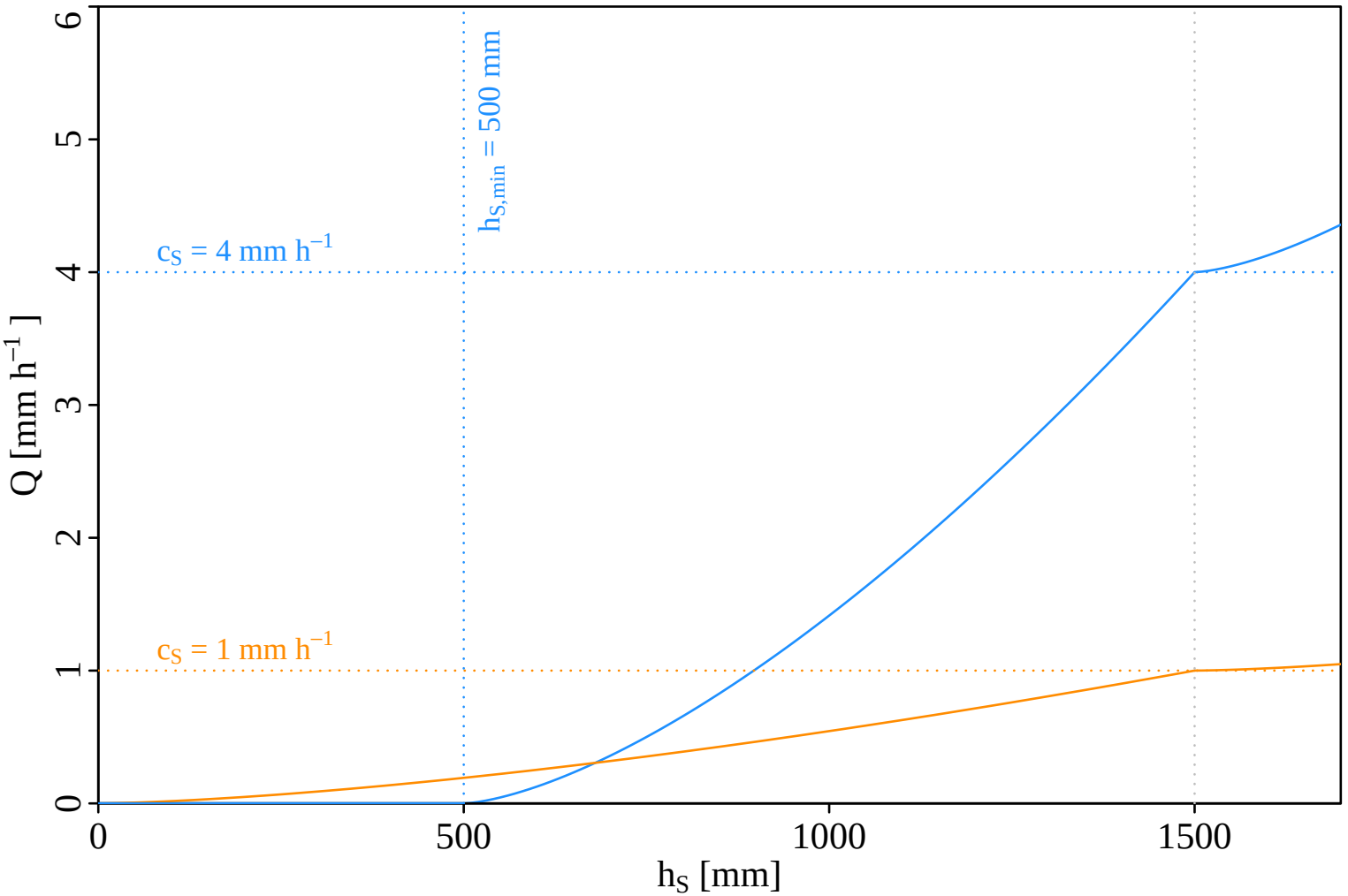
Simuleer heel jaar. Check:

- ☐ $d_{\mathrm{G,eind}} \approx d_{\mathrm{G,begin}}$
- ☐ meestal $c_{\mathrm{D}} - d_{\mathrm{G}} > h_{\mathrm{S}}$ (grondw. boven oppervlaktewater)
- ☐ $0 < W < 1$ (varieert tussen seizoenen)
- ☐ basisafvoer (f_{GS}) raakt hydrogram bij lage afvoer

Zoom evt. in op pieken. Check:

- ☐ vorm pieken correct

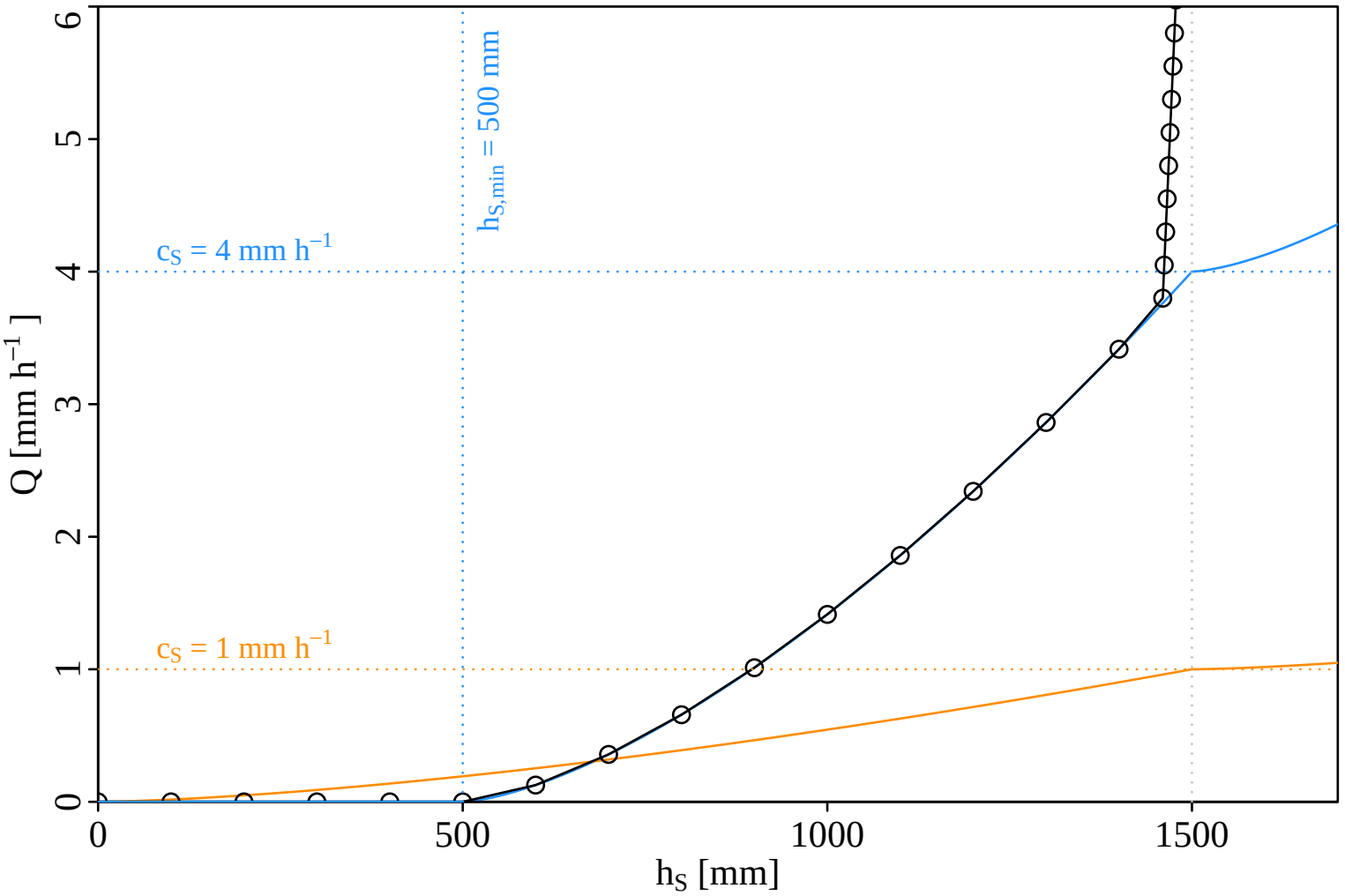
$Q(h)$-relatie



c_S lastig te schatten met automatische kalibratie.

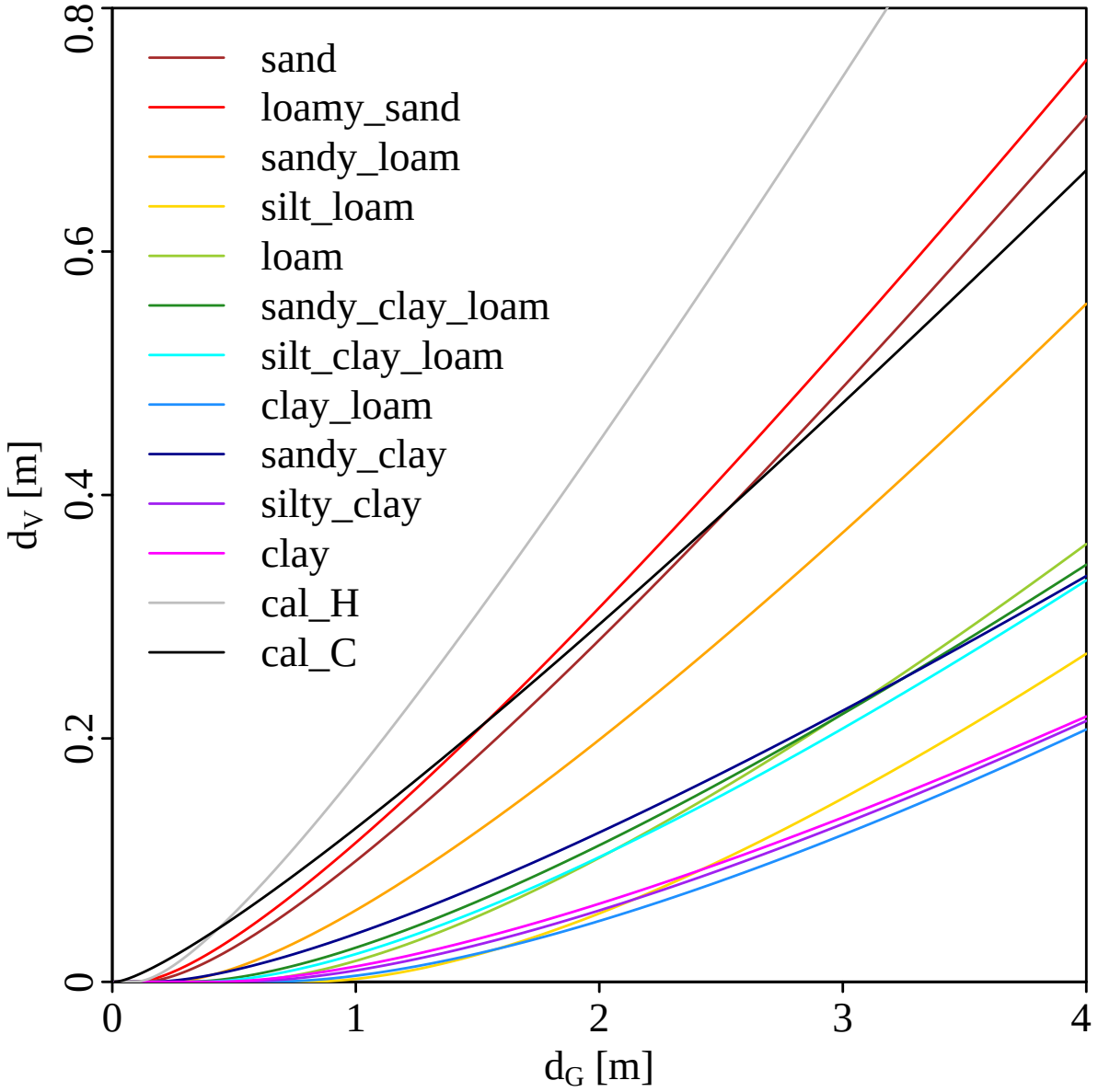
Aftopping Q als c_S te klein.

$Q(h)$-relatie



Nieuw: $Q(h)$-tabel

Bodemrelaties



- Lab versus veld (homogene kolommen / macroporiën)
- Theoretische relaties klei en silt: snel verzadigd.

WALRUS-publicaties

De Wageningen Lowland Runoff Simulator (WALRUS): een snel neerslag-afvoermodel speciaal voor laaglandstroomgebieden[1]

Claudia Brauer, Paul Torfs, Ryan Teuling en Remko Uijlenhoet[1]

De Wageningen Lowland Runoff Simulator (WALRUS) is een nieuw neerslag-afvoermodel dat het gat moet vullen tussen complexe, ruimtelijk gedistribueerde modellen die vaak gebruikt worden in laaglandstroomgebieden en simpele, ruimtelijk geïntegreerde, parametrische modellen die voornamelijk zijn ontwikkeld voor hellende stroomgebieden.

Geosci. Model Dev., 7, 2313–2332, 2014
www.geosci-model-dev.net/7/2313/2014/
doi:10.5194/gmd-7-2313-2014

Geoscientific Model Development
Open Access

The Wageningen Lowland Runoff Simulator (WALRUS): a lumped rainfall–runoff model for catchments with shallow groundwater

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Received: 2 January 2014 – Published in Geosci. Model Dev. Discuss.: 12 February 2014
Revised: 30 June 2014 – Accepted: 23 July 2014 – Published: 10 October 2014

Abstract. We present the Wageningen Lowland Runoff Simulator (WALRUS), a novel rainfall–runoff model to fill the gap between complex, spatially distributed models which are often used in lowland catchments and simple, parametric (conceptual) models which have mostly been developed for sloping catchments. WALRUS explicitly accounts for processes that are important in lowland areas, notably (1) groundwater–unsaturated zone coupling, (2) wetness-dependent flow routes, (3) groundwater–surface water feedbacks and (4) seepage and surface water supply. WALRUS consists of a coupled groundwater–vadose zone reservoir, a quickflow reservoir and a surface water reservoir. WALRUS is suitable for operational use because it is computationally efficient and numerically stable (achieved with a flexible time step approach). In the open source model code default relations have been implemented, leaving only four parameters shallow groundwater tables, exist all over the world: 13 % of the world's land surface has groundwater tables shallower than 2 m and 22 % shallower than 4 m (Fig. 1; data from Fan et al., 2013). This indicates that being able to understand and model lowland-specific hydrologic processes is beneficial for scientists and practitioners around the world.

Many types of hydrological models exist and they vary widely in their degree of complexity. The appropriate degree of complexity depends on the objectives of the model study and the catchment the model is applied to (Wagener et al., 2001). Here, we focus on models to simulate catchment runoff, or, more accurately, the changes in river discharge resulting from hydrological processes within the catchment (the terms runoff and discharge are used interchangeably in this paper). Between detailed, spatially distributed models and black box models lies the class of para-

Hydrol. Earth Syst. Sci., 18, 4007–4028, 2014
www.hydrol-earth-syst-sci.net/18/4007/2014/
doi:10.5194/hess-18-4007-2014

Hydrology and Earth System Sciences
Open Access

The Wageningen Lowland Runoff Simulator (WALRUS): application to the Hupsel Brook catchment and the Cabauw polder

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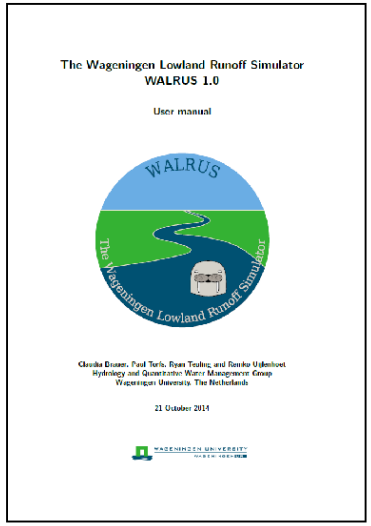
Revised: 28 August 2014 – Accepted: 6 September 2014 – Published: 10 October 2014

Abstract. The Wageningen Lowland Runoff Simulator (WALRUS) is a new parametric (conceptual) rainfall–runoff model which accounts explicitly for processes that are important in lowland areas, such as groundwater-unsaturated zone coupling, wetness-dependent flowroutes, groundwater–surface water feedbacks, and seepage and surface water supply (see companion paper by Brauer et al., 2014). Lowland catchments can be divided into slightly sloping, freely draining catchments and flat polders with controlled water levels. Here, we apply WALRUS to two contrasting Dutch catchments: the Hupsel Brook catchment and the Cabauw polder. In both catchments, WALRUS performs well: Nash–Sutcliffe efficiencies obtained after calibration on 1 year of discharge observations are 0.87 for the Hupsel Brook catchment and 0.83 for the Cabauw polder, with values of 0.74 and 0.76 for validation. The model also performs well during floods

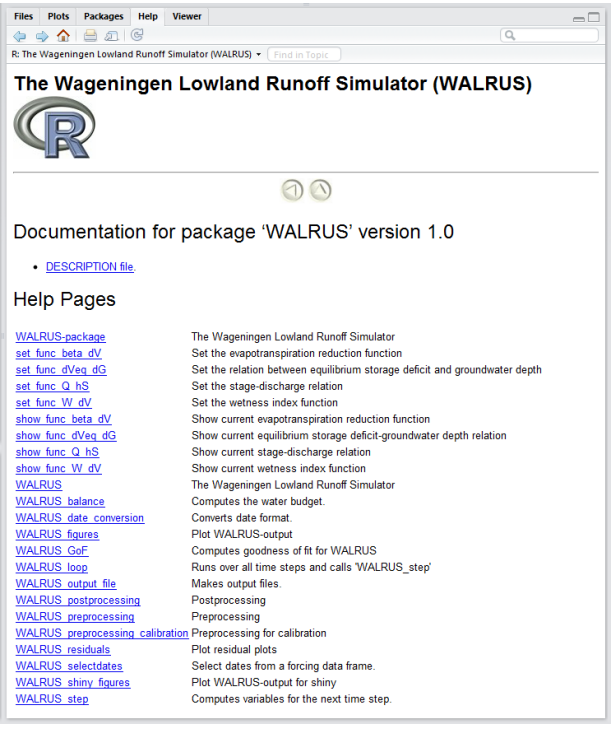
1 Introduction

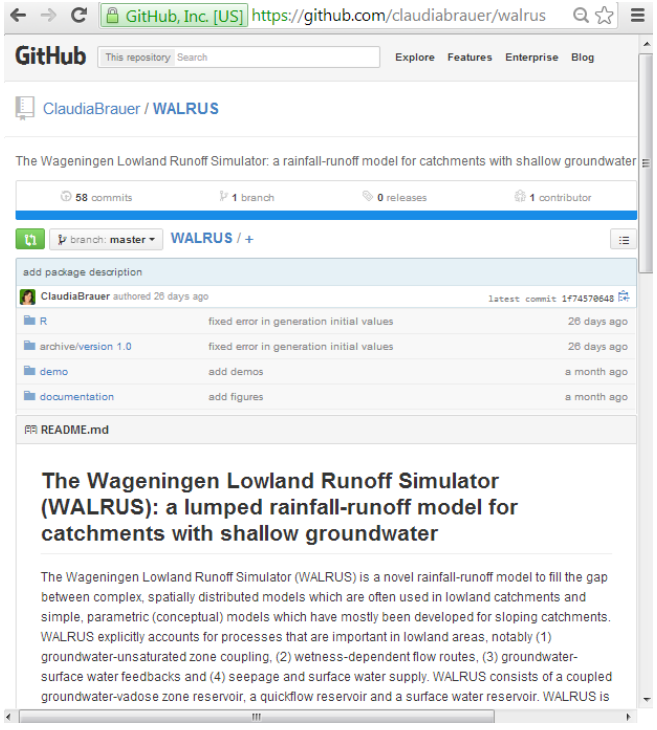
Lowlands exist all over the world (often in river deltas; Fan et al., 2013). They are generally densely populated and centres of agricultural production, economic activity and transportation. Therefore, socio-economic consequences of natural hazards are especially large in these areas. In addition, the lack of topography increases their vulnerability to flooding, climate change, and deterioration of water quality.

To mitigate natural and human disasters, hydrological models can be used by water managers as a tool for risk assessment and infrastructure design. There is growing awareness that for simulation and prediction of water and energy fluxes in lowland areas, models need to account explicitly for the dynamic groundwater table (Alley et al., 2002; Maxwell and Miller, 2005; Kollet and Maxwell, 2006; Bierkens and



Downloads

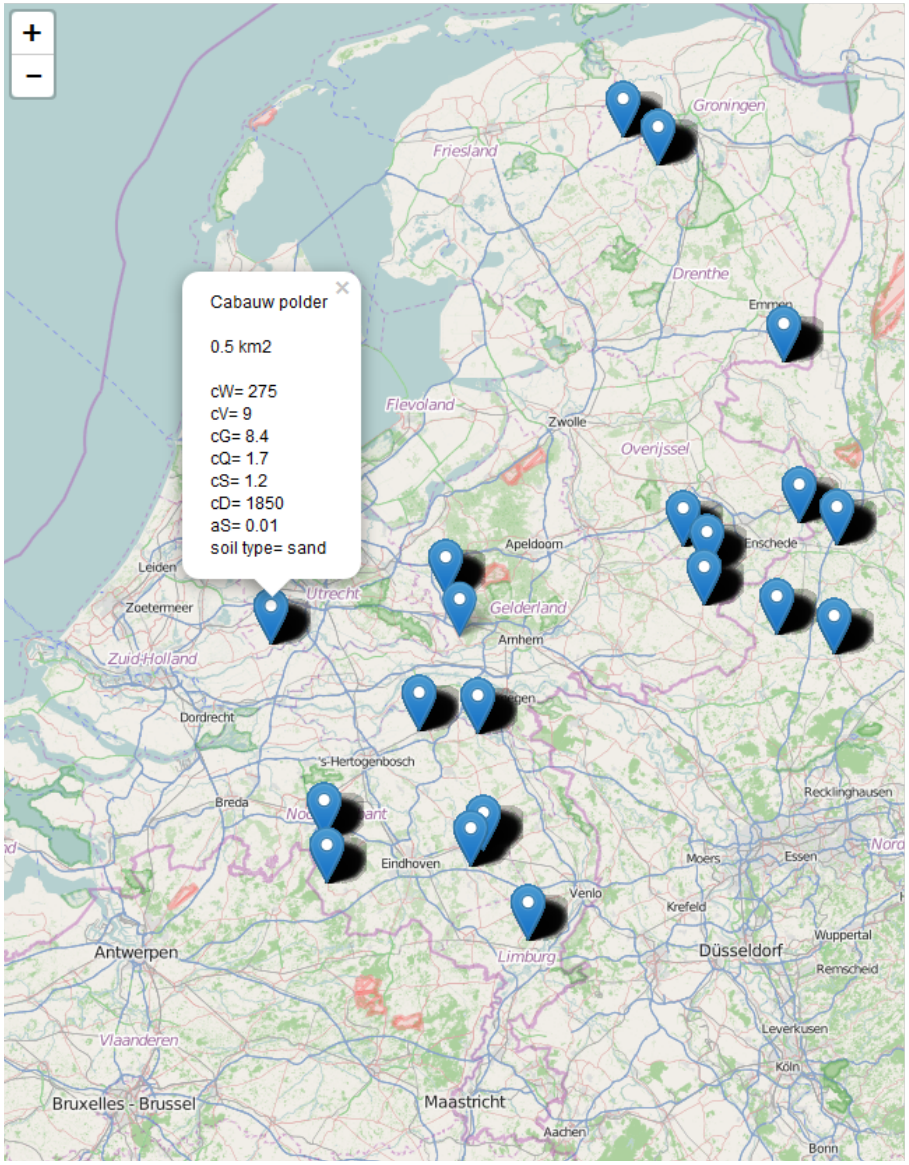




- www.github.com/ClaudiaBrauer/WALRUS
- Open source en freeware
- R-package (incl. oude versies)
- C-code (binnenkort)
- handleiding + publicaties
- ...

Toepassingen

- 5 waterschappen
- 8 adviesbureaus / zpp'ers
- 4 universiteiten / onderzoeksinstellingen (2 in buitenland)
- >40 stroomgebieden
- 34 scripties (af of bezig): 17 MSc theses, 5 MSc stages, 12 BSc theses
- $\sim$ 150 studenten in vakken
- 10 wetenschappelijke publicaties (5 extern) + 1 in review en 2 in prep.
- Stromingen-artikel



Meer informatie

- WALRUS downloads, informatie en publicaties:
  `www.github.com/ClaudiaBrauer/WALRUS`
- C.C. Brauer, A.J. Teuling, P.J.J.F. Torfs, R. Uijlenhoet (2014):
  The Wageningen Lowland Runoff Simulator (WALRUS):
  a lumped rainfall-runoff model for catchments with shallow groundwater,
  Geosci. Model Dev., 7, 2313–2332
- C.C. Brauer, P.J.J.F. Torfs, A.J. Teuling, R. Uijlenhoet (2014):
  The Wageningen Lowland Runoff Simulator (WALRUS):
  application to the Hupsel Brook catchment and Cabauw polder,
  Hydrol. Earth Syst. Sci., 18, 4007–4028
- C.C. Brauer, A. Overeem, H. Leijnse, R. Uijlenhoet (2016):
  The effect of differences between rainfall measurement techniques
  on groundwater and discharge simulations in a lowland catchment,
  Hydrol. Process., 30, 3885–3900
- C.C. Brauer (2014): PhD thesis,
  Modelling rainfall-runoff processes in lowland catchments