

Hydraulic models in unsatfit

from [unsatfit](#) document: <https://sekika.github.io/unsatfit/model.html>

See also [this paper](#) and [models in SWRC Fit](#). WRF = water retention function, HCF = hydraulic conductivity function, CH = common H.

1. Basic unimodal models

1.1. Brooks and Corey (BC) model

- Brooks and Corey (1964)
- Name: bc, BC
- WRF parameters: qs, qr, hb, l
- `get_init() = get_init_bc():` returns hb, l
- `get_wrf() = get_wrf_bc():` returns full WRF parameters
- HCF: [General HCF](#)
- Parameters which only appears in HCF: Ks, p, q, r
- Full parameters: qs, qr, hb, l, Ks, p, q, r
- Bound: b_qs, b_qr, b_hb, b_lambda, b_ks, b_p, b_q, b_r

1.2. van Genuchten (VG) model

- van Genuchten (1980)
- Name: vg, VG
- WRF parameters: qs, qr, a, m, q
- Converted parameter: $n = q/(1-m)$ i.e. $m = 1-q/n$
- Note that in unsatfit, m is used as a variable instead of n, because the bound of m, $0 < m < 1$ is easier to handle than the bound of n, $n > q$, as unsatfit can make q as a variable.
- `get_init() = get_init_vg():` returns a, m where $q=1$
- `get_wrf() = get_wrf_vg():` returns full WRF parameters where $q=1$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: Ks, p, r
- Full parameters: qs, qr, a, m, Ks, p, q, r
- Bound: b_qs, b_qr, b_a, b_m, b_ks, b_p, b_q, b_r

Modified van Genuchten model

- Vogel et al. (2000)
 - Name: mvg, MVG, Modified VG
 - WRF parameters: qs, qr, a, m, hs, q
 - Converted parameter: $n = q/(1-m)$ i.e. $m = 1-q/n$
 - $hs = 2$ cm for $1 < n < 2$ in Vogel et al., (2000)
 - HCF: [General HCF](#)
 - Parameters which only appears in HCF: Ks, p, r
 - Full parameters: qs, qr, a, m, hs, Ks, p, q, r
 - Bound: b_qs, b_qr, b_a, b_m, b_hs, b_ks, b_p, b_q, b_r
- In general, modified model can be made by calling `modified_model(hs)` after `set_model()`

1.3. Kosugi (KO) model

- Kosugi (1996)
- Name: ln, KO
- WRF parameters: qs, qr, hm, sigma
- `get_init() = get_init_ln():` returns hm, sigma
- `get_wrf() = get_wrf_ln():` returns full WRF parameters
- HCF: [General HCF](#)
- Parameters which only appears in HCF: Ks, p, q, r
- Full parameters: qs, qr, hm, sigma, Ks, p, q, r
- Bound: b_qs, b_qr, b_hm, b_sigma, b_ks, b_p, b_q, b_r

1.4. Fredlund and Xing (FX) model

- Fredlund and Xing (1994)
- Name: fx, FX
- WRF parameters: qs, qr, a, m, n
- `get_init() = get_init_fx():` returns a, m, n
- `get_wrf() = get_wrf_fx():` returns full WRF parameters
- HCF: not provided
- Bound: b_qs, b_qr, b_fxa, b_fxm, b_fxn

2. Bimodal models

2.1. dual-BC model

- Seki et al. (2022)
- Name: bc2f, DB, dual-BC
- WRF parameters: qs, qr, w1, hb1, l1, hb2, l2
- `get_init() = get_init_bc2f():` returns w1, hb1, l1, hb2, l2
- `get_wrf() = get_wrf_bc2f():` returns full WRF parameters where $qr=0$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: Ks, p, q, r
- Full parameters: qs, qr, w1, hb1, l1, hb2, l2, Ks, p, q, r
- Bound: b_qs, b_qr, b_w1, b_hb, b_lambda1, b_hb2, b_lambda2, b_ks, b_p, b_q, b_r

2.1.1. dual-BC-CH model

- Seki et al. (2022)
- Name: bc2, DBC, DBCH, dual-BC-CH
- WRF parameters: qs, qr, hb, hc, l1, l2
- Converted parameter: $w1 = 1/(1+(hc/hb)^(12-l1))$
- `get_init() = get_init_bc2():` returns hb, hc, l1, l2
- `get_wrf() = get_wrf_bc2():` returns full WRF parameters where $qr=0$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: Ks, p, q, r
- Full parameters: qs, qr, hb, hc, l1, l2, Ks, p, q, r
- Bound: b_qs, b_qr, b_hb, b_hc, b_lambda1, b_lambda2, b_ks, b_p, b_q, b_r

2.2. dual-VG model

- Priesack and Durner (2006), equation corrected at Seki et al. (2022)
- Name: vg2, DV, dual-VG
- WRF parameters: qs, qr, w1, a1, m1, a2, m2, q
- Converted parameter: $n1 = q/(1-m1)$, $n2 = q/(1-m2)$
- `get_init() = get_init_vg2():` returns w1, a1, m1, a2, m2 where $q=1$
- `get_wrf() = get_wrf_vg2():` returns full WRF parameters where $qr=0$, $q=1$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: Ks, p, r
- Full parameters: qs, qr, w1, a1, m1, a2, m2, Ks, p, q, r
- Bound: b_qs, b_qr, b_w1, b_a1, b_m, b_a2, b_m, b_ks, b_p, b_q, b_r

2.2.1. dual-VG-CH model

- Priesack and Durner (2006), equation corrected at Seki et al. (2022)
- Name: vg2ch, DVC, DVCH, dual-VG-CH

- WRF parameters: $q_s, q_r, w_1, a_1, m_1, m_2, q$
- Converted parameter: $n_1 = q/(1-m_1), n_2 = q/(1-m_2)$
- `get_init() = get_init_vg2ch()`: returns w_1, a_1, m_1, m_2 where $q=1$
- `get_wrf() = get_wrf_vg2ch()`: returns full WRF parameters where $q_r=0, q=1$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: K_s, p, r
- Full parameters: $q_s, q_r, w_1, a_1, m_1, m_2, K_s, p, q, r$
- Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{a_1}, b_m, b_{m_1}, b_{m_2}, b_{K_s}, b_p, b_q, b_r$

2.3.dual-KO model

- Seki (2007), Seki et al. (2022)
- Name: $\ln 2, DK, \text{dual-KO}$
- WRF parameters: $q_s, q_r, w_1, hm_1, \sigma_1, hm_2, \sigma_2$
- `get_init() = get_init_ln2()`: returns $w_1, hm_1, \sigma_1, hm_2, \sigma_2$
- `get_wrf() = get_wrf_ln2()`: returns full WRF parameters where $q_r=0$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: K_s, p, q, r
- Full parameters: $q_s, q_r, w_1, hm_1, \sigma_1, hm_2, \sigma_2, K_s, p, q, r$
- Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{hm_1}, b_{\sigma_1}, b_{hm_2}, b_{\sigma_2}, b_{K_s}, b_p, b_q, b_r$

2.4.dual-KO-CH model

- Seki et al. (2022)
- Name: $\ln 2ch, DKC, DKCH, \text{dual-KO-CH}$
- WRF parameters: $q_s, q_r, w_1, hm_1, \sigma_1, \sigma_2$
- `get_init() = get_init_ln2ch()`: returns $w_1, hm_1, \sigma_1, \sigma_2$
- `get_wrf() = get_wrf_ln2ch()`: returns full WRF parameters where $q_r=0$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: K_s, p, q, r
- Full parameters: $q_s, q_r, w_1, hm_1, \sigma_1, \sigma_2, K_s, p, q, r$
- Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{hm_1}, b_{\sigma_1}, b_{\sigma_2}, b_{K_s}, b_p, b_q, b_r$

2.5.VG1BC2 model

- Seki et al. (2022)
- Name: $vgbc, VGBC, VG1BC2, VB$
- WRF parameters: $q_s, q_r, w_1, a_1, m_1, hb_2, l_2, q$
- Converted parameter: $n_1 = q/(1-m_1)$
- `get_init() = get_init_vgbc`: returns w_1, a_1, m_1, hb_2, l_2 where $q=1$
- `get_wrf() = get_wrf_vgbc`: returns full WRF parameters where $q_r=0, q=1$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: K_s, p, r
- Full parameters: $q_s, q_r, w_1, a_1, m_1, hb_2, l_2, K_s, p, q, r$
- Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{a_1}, b_m, b_{hb_2}, b_{\lambda_2}, b_{K_s}, b_p, b_q, b_r$
- HCF variation: $r=1$ and independent p
- Name: $vgbcp2, VGBCIP, VG1BC2-IP, VB-IP$
- Parameters which only appears in HCF: K_s, p_1, p_2

2.6.VG1BC2-CH model

- Seki et al. (2022)
- Name: $vgbcch, VGBCCH, VG1BC2-CH, VBC$
- WRF parameters: $q_s, q_r, w_1, a_1, m_1, l_2, q$
- Converted parameter: $n_1 = q/(1-m_1)$
- `get_init() = get_init_vgbcch()`: returns w_1, a_1, m_1, l_2 where $q=1$
- `get_wrf() = get_wrf_vgbcch()`: returns full WRF parameters where $q_r=0, q=1$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: K_s, p, r
- Full parameters: $q_s, q_r, w_1, a_1, m_1, l_2, K_s, p, q, r$
- Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{a_1}, b_m, b_{\lambda_2}, b_{K_s}, b_p, b_q, b_r$
- HCF variation: $r=1$ and independent p
- Name: $vgbcchp2, VGBCCHIP, VG1BC2CH-IP, VBC-IP$
- Parameters which only appears in HCF: K_s, p_1, p_2

2.7.KO1BC2 model

- Seki et al. (2022)
- Name: $kobc, KOBC, KO1BC2, KB$
- WRF parameters: $q_s, q_r, w_1, hm_1, \sigma_1, hb_2, l_2$
- `get_init() = get_init_kobc()`: returns $w_1, hm_1, \sigma_1, hb_2, l_2$
- `get_wrf() = get_wrf_kobc()`: returns full WRF parameters with $q_r=0$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: K_s, p, q, r
- Full parameters: $q_s, q_r, w_1, hm_1, \sigma_1, hb_2, l_2, K_s, p, q, r$
- Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{hm_1}, b_{\sigma_1}, b_{hb_2}, b_{\lambda_2}, b_{K_s}, b_p, b_q, b_r$
- HCF variation: $r=1$ and independent p
- Name: $kobcp2, KOBCIP, KO1BC2-IP, KB-IP$
- Parameters which only appears in HCF: K_s, p_1, p_2, q

2.8.KO1BC2-CH model

- Seki et al. (2022)
- Name: $kobcch, KOBCCH, KO1BC2-CH, KBC$
- WRF parameters: $q_s, q_r, w_1, hm, \sigma_1, l_2$
- `get_init() = get_init_kobcch()`: returns w_1, hm, σ_1, l_2
- `get_wrf() = get_wrf_kobcch()`: returns full WRF parameters with $q_r=0$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: K_s, p, q, r
- Full parameters: $q_s, q_r, w_1, hm, \sigma_1, l_2, K_s, p, q, r$
- Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{hm_1}, b_{\sigma_1}, b_{\lambda_2}, b_{K_s}, b_p, b_q, b_r$
- HCF variation: $r=1$ and independent p
- Name: $kobcch2, KOBCCHIP, KO1BC2-CH-IP, KBC-IP$
- Parameters which only appears in HCF: K_s, p_1, p_2, q
- Full parameters: $q_s, q_r, w_1, hm, \sigma_1, l_2, K_s, p_1, p_2, q$

3.Giving pressure head of zero water content

3.1.Peters model (Kosugi type)

- Peters (2013)
- Name: $pk, PK, \text{Peters-KO}, PE, \text{Peters}$

- WRF parameters: $q_s, q_r, w_1, h_m, \sigma_1, h_e$
- $q_r=0$ by definition. $\theta=0$ at $h=h_e$.
- `get_init() = get_init_pk(he)`: returns w_1, h_m, σ_1
- `get_wrf() = get_wrf_pk(he)`: returns full WRF parameters with $q_r=0$
- HCF: Peters (2013)
- Parameters which only appears in HCF: K_s, p, a, ω
- Full parameters: $q_s, q_r, w_1, h_m, \sigma_1, h_e, K_s, p, a, \omega$
- Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{h_m}, b_{\sigma_1}, b_{h_e}, b_{K_s}, b_p, b_a, b_{\omega}$

3.2. Fayer and Simmons model (van Genuchten type)

- Fayer and Simmons (1995)
- Name: `vgfs, VGFS, Fayer-VG`
- WRF parameters: $q_s, q_r, q_a, a, m, h_e, q$
- $q_r=0$ by definition. $\theta=0$ at $h=h_e$.
- $q=1$ should be provided. Otherwise not calculated.
- Converted parameter: $n = q/(1-m)$ i.e. $m = 1 - q/n$
- `get_init() = get_init_vgfs(he)`: returns q_a, a, m where $q=1$
- `get_wrf() = get_wrf_vgfs(he)`: returns full WRF parameters with $q_r=0, q=1$
- HCF: [General HCF](#)
- Parameters which only appears in HCF: K_s, p, r
- WRF parameters: $q_s, q_r, q_a, a, m, h_e, K_s, p, q, r$
- Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{a_1}, b_m, b_{h_e}, b_{K_s}, b_p, b_q, b_r$

4. Trimodal models

See Seki et al. (2026) for detail. Available from version 6.0.

4.1. tri-VG model

- Seki et al. (2022)
- Name: `vg3, TV, tri-VG`
- WRF parameters: $q_s, q_r, w_1, a_1, m_1, ww_2, a_2, m_2, a_3, m_3, q$
- Converted parameter: $w_2 = (1-w_1) * ww_2$ (w_2 was transformed to make the bound independent of w_1), $n_1 = q/(1-m_1)$, $n_2 = q/(1-m_2)$, $n_3 = q/(1-m_3)$
- `get_init() = get_init_vg3(a1=0)`: without input parameter, returns $w_1, \alpha_1, m_1, ww_2, \alpha_2, m_2, \alpha_3, m_3$ where $q=1$. When $a_1>0$, a_1 is fixed and not in return parameter.
- `sort_param() = sort_param_vg3()`: Sort parameters of tri-VG model in the reverse order of α , and convert ww_2 to w_2
- HCF: [General HCF](#)
- Parameters which only appears in HCF: K_s, p, r
- Full parameters: $q_s, q_r, w_1, a_1, m_1, ww_2, a_2, m_2, a_3, m_3, K_s, p, q, r$
- Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{a_1}, b_m, b_{w_1}, b_{a_2}, b_m, b_{a_2}, b_m, b_{K_s}, b_p, b_q, b_r$

4.2. BC1VG2 VG3 model

- Seki et al. (2022)
- Name: `BCV, BC1VG2VG3`
- WRF parameters: $q_s, q_r, w_1, hb_1, l_1, ww_2, a_2, m_2, a_3, m_3, q$
- Converted parameter: $w_2 = (1-w_1) * ww_2$ (w_2 was transformed to make the bound independent of w_1), $n_2 = q/(1-m_2)$, $n_3 =$

- $q/(1-m_3)$
 - `get_init() = get_init_bvv(hb1=0)`: without input parameter, returns $w_1, hb_1, l_1, ww_2, \alpha_2, m_2, \alpha_3, m_3$ where $q=1$. When $hb_1>0$, hb_1 is fixed and not in return parameter.
 - HCF: [General HCF](#)
 - Parameters which only appears in HCF: K_s, p, r
 - Full parameters: $q_s, q_r, w_1, hb_1, l_1, ww_2, a_2, m_2, a_3, m_3, K_s, p, q, r$
 - Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{hb_1}, b_{\lambda}, b_{w_1}, b_{a_2}, b_m, b_{a_2}, b_m, b_{K_s}, b_p, b_q, b_r$
- ### 4.3. VVP model
- Seki et al. (2026)
 - Name: `VVP, tri-PDI`
 - WRF parameters: $q_s, q_r, w_1, a_1, m_1, ww_2, a_2, m_2, h_e, q$
 - Converted parameter: $w_2 = (1-w_1) * ww_2$ (w_2 was transformed to make the bound independent of w_1), $n_2 = q/(1-m_2)$
 - $q_r=0$ by definition. $\theta=0$ at $h=h_e$.
 - `get_init() = get_init_vvp(he)`: returns $w_1, a_1, m_1, ww_2, a_2, m_2$ where $q=1$
 - HCF: Seki et al. (2026)
 - Parameters which only appears in HCF: K_s, p, r, a
 - Full parameters: $q_s, q_r, w_1, a_1, m_1, ww_2, a_2, m_2, h_e, K_s, p, q, r, a$
 - Bound: $b_{q_s}, b_{q_r}, b_{w_1}, b_{a_1}, b_m, b_{w_1}, b_{a_2}, b_m, b_{h_e}, b_{K_s}, b_p, b_q, b_r, b_a$