Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
Abstraction	Groundwater abstraction at a constant rate	abstraction_1	$flux_{out} = \theta_1$	None, taken from a store with possible negative depth	$flux_{out} = \theta_1$	25
Baseflow	Linear reservoir	baseflow_1	$flux_{out} = \theta_1 * S$		$flux_{out} = \theta_1 * S$	2, 4, 6, 8, 9, 12, 13, 15, 16, 17, 18, 20, 21, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 40, 41, 43, 44, 45, 46
	Non-linear outflow from a reservoir	baseflow_2	$flux_{out} = \left(\frac{1}{\theta_1}S\right)^{\frac{1}{\theta_2}}$	$flux_{out} \leq \frac{S}{\Delta t}$ To prevent complex numbers, S = [0,∞>	$flux_{out} = min\left(\frac{S}{\Delta t}, \left(\frac{1}{\theta_1}max(S,0)\right)^{\frac{1}{\theta_2}}\right)$	9, 11
	Empirical exponential outflow from a reservoir	baseflow_3	$flux_{out} = \frac{S_{max}^{-4}}{4}S^5$	Empirical equation, so interwoven with other equations that no constraints are needed. Also implicitly assumes time step $\Delta t = 1$	$flux_{out} = \frac{S_{max}^{-4}}{4}S^5$	7
	Exponential outflow from a deficit store	baseflow_4	$flux_{out} = \theta_1 e^{-\theta_2 S}$		$flux_{out} = \theta_1 e^{-\theta_2 S}$	14
	Non-linear outflow scaled by current relative storage	baseflow_5	$flux_{out} = \theta_1\left(\frac{S}{S_{max}}\right)^{\theta_2}$	$flux_{out} \leq \frac{S}{\Delta t}$ To prevent complex numbers, S = [0,∞>	$flux_{out} = min\left(\frac{S}{\Delta t}, \theta_1\left(\frac{max(0,S)}{S_{max}}\right)^{\theta_1}\right)$	22
	Quadratic outflow from reservoir if a storage threshold is exceeded	baseflow_6	$flux_{out} = \begin{cases}\theta_1 * S^2, & if\ S > \theta_2\\ 0, & otherwise\end{cases}$	$flux_{out} \leq \frac{S}{\Delta t}$	$flux_{out} = \min\left(\theta_1 * S^2, \frac{S}{\Delta t}\right) * [1 - logisticSmoother\_S(S,\theta_2)]$	25
	Non-linear outflow from a reservoir	baseflow_7	$flux_{out} = \theta_1 S^{\theta_2}$	$flux_{out} \leq \frac{S}{\Delta t}$ To prevent complex numbers, S = [0,∞>	$flux_{out} = min\left(\frac{S}{\Delta t}, \theta_1 max(0,S)^{\theta_2}\right)$	39, 42

continued …

Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
	Exponential scaled outflow from a deficit store	baseflow_8	$flux_{out} = \theta_1\left(e^{\theta_2 S/S_{max}} - 1\right)$	$S \leq S_{max}$ $S \geq 0$	$flux_{out} = \theta_1\left(e^{\theta_2 * min\left(1, max\left(0, S/S_{max}\right)\right)} - 1\right)$	23
	Linear outflow from a reservoir if a storage threshold is exceeded	baseflow_9	$flux_{out} = \begin{cases}\theta_1(S-\theta_2), & if\ S > \theta_2\\ 0, & otherwise\end{cases}$		$flux_{out} = \theta_1 * max(0, S-\theta_2)$	20
Capillary rise	Capillary rise scaled by relative deficit in receiving store	capillary_1	$flux_{out} = \theta_1\left[1-\frac{S_1}{S_{1,max}}\right]$	$flux_{out} \leq \frac{S_2}{\Delta t}$	$flux_{out} = min\left(\theta_1\left[1-\frac{S_1}{S_{1,max}}\right], \frac{S_2}{\Delta t}\right)$	37
	Capillary rise at a constant rate	capillary_2	$flux_{out} = \begin{cases}\theta_1, if\ S \geq 0\\ 0, otherwise\end{cases}$	$flux_{out} \leq \frac{S}{\Delta t}$	$flux_{out} = min\left(\frac{S}{\Delta t}, \theta_1\right)$	13, 15
	Capillary rise if the receiving store is below a storage threshold	capillary_3	$flux_{out} = \begin{cases}\theta_1\left(1-\frac{S_1}{\theta_2}\right), & if\ S_1 < \theta\\ 0, & otherwise\end{cases}$	$flux_{out} \leq \frac{S_2}{\Delta t}$	$flux_{out} = min\left(\frac{S_2}{\Delta t}, \theta_1\left(1-\frac{S_1}{\theta_2}\right) * logisticSmoother\_S(S_1, \theta_2)\right)$	38
Depression storage	Exponential inflow rate into surface depressions	depression_1	$flux_{out} = \theta_1 * exp\left[-\theta_2\frac{S}{S_{max}-S}\right] * flux_{in}$	$flux_{out} \leq \frac{S_{max}-S}{\Delta t}$ $S \leq S_{max}$	$flux_{out} = min\left(\theta_1 * exp\left[-\theta_2\frac{S}{\max(S_{max}-S, 0)}\right] * flux_{in}, \frac{S_{max}-S}{\Delta t}\right)$	36
Evaporation	Evaporation at the potential rate	evap_1	$E_a = \begin{cases}E_p, if\ S \geq 0\\ 0, otherwise\end{cases}$	$E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(E_p, \frac{S}{\Delta t}\right)$	2, 6, 12, 13, 16, 17, 18, 23, 25, 26, 27, 33, 34, 36, 38, 39, 41, 42, 44, 45, 46
	Evaporation at scaled plant-controlled rate	evap_2	$E_a = \theta_1\frac{S}{S_{max}}$	$E_a \leq E_p$ $E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(\theta_1\frac{S}{S_{max}}, E_p, \frac{S}{\Delta t}\right)$	18, 36
	Evaporation scaled by relative storage below a wilting point and at the potential rate above wilting point	evap_3	$E_A = \begin{cases}E_p\frac{S}{\theta_1 S_{max}}, & if\ S < \theta_1 S_{max}\\ E_p, & otherwise\end{cases}$	$E_a \leq E_p$ $E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(E_p\frac{S}{\theta_1 S_{max}}, E_p, \frac{S}{\Delta t}\right)$	3, 11, 14, 21, 26, 34, 37, 42
	Scaled evaporation if storage is above the wilting point, constrained by a limitation parameter	evap_4	$E_a = E_p * max\left(0, \theta_1\frac{S-\theta_2 S_{max}}{S_{max}-\theta_2 S_{max}}\right)$	$E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(E_p * max\left(0, \theta_1\frac{S-\theta_2 S_{max}}{S_{max}-\theta_2 S_{max}}\right), \frac{S}{\Delta t}\right)$	15
	Evaporation from bare soil, scaled by relative storage	evap_5	$E_a = (1-\theta_1)\frac{S}{S_{max}}E_p$	$E_a \leq E_p$ $E_a \leq \frac{S}{\Delta t}$	$E_a = min\left((1-\theta_1)\frac{S}{S_{max}}E_p, \frac{S}{\Delta t}\right)$	4, 8, 9, 16

continued …

Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
	Transpiration from vegetation at the potential rate if storage is above a wilting point and scaled by relative storage if not	evap_6	$E_A = \begin{cases} \theta_1 * E_p, & if\ S > \theta_2 * S_{max} \\ \theta_1 \frac{S}{\theta_2 S_{max}} E_p, & otherwise \end{cases}$	$E_a \leq \theta_1 E_p$ $E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(\theta_1 E_p \frac{S}{\theta_2 S_{max}}, \theta_1 E_p, \frac{S}{\Delta t}\right)$	4, 9, 16
	Evaporation scaled by relative storage	evap_7	$E_a = \frac{S}{S_{max}} E_p$	$E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(\frac{S}{S_{max}} E_p, \frac{S}{\Delta t}\right)$	1, 3, 10, 11, 19, 22, 24, 29, 30, 31, 32, 33, 35, 45
	Transpiration from vegetation, at potential rate if soil moisture is above the wilting point, and linearly decreasing if not. Also scaled by relative storage across all stores	evap_8	$E_A = \begin{cases} \frac{S_1}{S_1 + S_2} \theta_1 E_p, & if\ S_1 > \theta_2 \\ \frac{S_1}{\theta_2} * \frac{S_1}{S_1 + S_2} \theta_1 E_p, & otherwise \end{cases}$	$E_a \leq \frac{S_1}{\Delta t}$ $E_a \geq 0$	$E_a = max\left(min\left(\frac{S_1}{S_1 + S_2} \theta_1 E_p, \frac{S_1}{\theta_2} * \frac{S_1}{S_1 + S_2} \theta_1 E_p, \frac{S_1}{\Delta t}\right), 0\right)$	8
	Evaporation from bare soil scaled by relative storage and by relative water availability across all stores	evap_9	$E_a = \frac{S_1}{S_1 + S_2} * (1 - \theta_1) \frac{S_1}{S_{max} - S_2} E_p$	$E_a \leq \frac{S_1}{\Delta t}$ $E_a \geq 0$	$E_a = max\left(min\left(\frac{S_1}{S_1 + S_2} * (1 - \theta_1) \frac{S_1}{S_{max} - S_2} E_p, \frac{S_1}{\Delta t}\right), 0\right)$	8
	Evaporation from bare soil, scaled by relative storage	evap_10	$E_a = \theta_1 \frac{S}{S_{max}} E_p$	$E_a \leq E_p$ $E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(\theta_1 \frac{S}{S_{max}} E_p, \frac{S}{\Delta t}\right)$	8
	Evaporation quadratically related to current soil moisture	evap_11	$E_a = \left(2\frac{S}{S_{max}} - \left(\frac{S}{S_{max}}\right)^2\right) E_p$	$E_a \geq 0$	$E_a = max\left(0, \left(2\frac{S}{S_{max}} - \left(\frac{S}{S_{max}}\right)^2\right) E_p\right)$	7
	Evaporation from deficit store, with exponential decline as deficit goes below a threshold	evap_12	$E_a = min\left(1, e^{2\left(1 - \frac{S}{\theta_1}\right)}\right) E_p$		$E_a = min\left(1, e^{2\left(1 - \frac{S}{\theta_1}\right)}\right) E_p$	5
	Exponentially scaled evaporation	evap_13	$E_a = \theta_1^{\theta_2} E_p$	$E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(\theta_1^{\theta_2} E_p, \frac{S}{\Delta t}\right)$	40
	Exponentially scaled evaporation that only activates if another store goes below a certain threshold	evap_14	$E_A = \begin{cases} \theta_1^{\theta_2} E_p, & if\ S_2 \leq S_{2,min} \\ 0, & otherwise \end{cases}$	$E_a \leq \frac{S_1}{\Delta t}$	$E_a = min\left(\theta_1^{\theta_2} E_p, \frac{S_1}{\Delta t}\right) * logisticSmoother\_S(S_2, S_{2,min})$	40
	Scaled evaporation if another store is below a threshold	evap_15	$E_a = \begin{cases} \frac{S_1}{S_{max}} E_p, & if\ S_2 < \theta_1 \\ 0, & otherwise \end{cases}$	$E_a \leq \frac{S_1}{\Delta t}$	$E_a = min\left(\frac{S_1}{S_{1,max}} * E_p * logisticSmoother\_S(S_2, \theta_2), \frac{S_1}{\Delta t}\right)$	41, 45

continued …

Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
	Scaled evaporation if another store is below a threshold	evap_16	$E_a = \begin{cases} \theta_1 E_p, & if\ S_2 < \theta_2 \\ 0, & otherwise \end{cases}$	$E_a \leq \frac{S_1}{\Delta t}$	$E_a = min\left(\theta_1 * E_p * logisticSmoother\_S(S_2, \theta_2), \frac{S_1}{\Delta t}\right)$	17, 25
	Scaled evaporation from a store that allows negative values	evap_17	$E_a = \frac{1}{1+e^{-\theta_1 * S}} E_p$	None, because the store is allowed to go negative	$E_a = \frac{1}{1+e^{-\theta_1 * S}} E_p$	39
	Exponentially declining evaporation from deficit store	evap_18	$E_a = \theta_1 e^{\frac{-\theta_2 S}{\theta_3}} E_p$		$E_a = \theta_1 e^{\frac{-\theta_2 S}{\theta_3}} E_p$	46
	Non-linear scaled evaporation	evap_19	$E_a = \theta_1 \left(\frac{S}{S_{max}}\right)^{\theta_2} E_p$	$E_a \leq E_p$ $E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(\theta_1 * max\left(0, \frac{S}{S_{max}}\right)^{\theta_2} E_p, E_p, \frac{S}{\Delta t}\right)$	23, 43
	Evaporation limited by a maximum evaporation rate and scaled below a wilting point	evap_20	$E_A = \begin{cases} \theta_1 \frac{S}{\theta_2 S_{max}}, & if\ S < \theta_2 S_{max} \\ E_p, & otherwise \end{cases}$	$E_a \leq E_p$ $E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(\theta_1 \frac{S}{\theta_2 S_{max}}, E_p, \frac{S}{\Delta t}\right)$	20
	Threshold-based evaporation with constant minimum rate	evap_21	$E_a = \begin{cases} E_p, & if\ S > \theta_1 \\ \frac{S}{\theta_1} E_p, & if\ \theta_2\theta_1 \geq S \geq \theta_1 \\ \theta_2 E_p & otherwise \end{cases}$	$E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(max\left(\theta_2, min\left(\frac{S}{\theta_1}, 1\right)\right) * E_p, \frac{S}{\Delta t}\right)$	28
	Threshold-based evaporation rate	evap_22	$E_a = \begin{cases} E_p, & if\ S > \theta_1 \\ \frac{S-\theta_1}{\theta_1-\theta_2} E_p, & if\ \theta_2\theta_1 \geq S \geq \theta_1 \\ 0 & otherwise \end{cases}$	$E_a \leq \frac{S}{\Delta t}$	$E_a = min\left(\frac{S}{\Delta t}, min\left(E_p, max\left(0, \frac{S-\theta_1}{\theta_2-\theta_1} E_p\right)\right)\right)$	44
Exchange	Water exchange between aquifer and channel	exchange_1	$flux_{out} = \begin{cases} \theta_1 * \left\lvert\frac{S}{\Delta t}\right\rvert + \theta_2\left(1 - exp\left[-\theta_3 * \left\lvert\frac{S}{\Delta t}\right\rvert\right]\right), & if\ S \geq 0 \\ -\left[\theta_1 * \left\lvert\frac{S}{\Delta t}\right\rvert + \theta_2\left(1 - exp\left[-\theta_3 * \left\lvert\frac{S}{\Delta t}\right\rvert\right]\right)\right], & if\ S < 0 \end{cases}$	$\begin{cases} No\ constraint \\ flux_{out} \leq flux_{in} \end{cases}$ The "channel" store in this model has 0 time delay, so the incoming flux to the channel is the maximum channel-to-groundwater flux size. Groundwater has infinite depth	$flux_{out} = \max\left(\left[\theta_1 * \left\lvert\frac{S}{\Delta t}\right\rvert + \theta_2 * \left(1 - exp\left[-\theta_3 * \left\lvert\frac{S}{\Delta t}\right\rvert\right]\right)\right] * sign(S), -flux_{in}\right)$	36
	Water exchange based on relative storages	exchange_2	$flux_{out} = \theta_1 \left(\frac{S_1}{S_{1,max}} - \frac{S_2}{S_{2,max}}\right)$		$flux_{out} = \theta_1 \left(\frac{S_1}{S_{1,max}} - \frac{S_2}{S_{2,max}}\right)$	38
	Water exchange with infinite size store based on threshold	exchange_3	$flux_{out} = \theta_1 * (S - \theta_2)$		$flux_{out} = \theta_1 * (S - \theta_2)$	36

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Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
Infiltration	Infiltration as exponentially declining based on relative storage (taken from a flux)	infiltration_1	$flux_{out} = \theta_1 * exp\left[-\theta_2 \frac{S}{S_{max}}\right]$	$flux_{out} \leq flux_{in}$	$flux_{out} = min\left(\theta_1 * exp\left[-\theta_2 \frac{S}{S_{max}}\right], flux_{in}\right)$	18, 36, 44
	Delayed infiltration as exponentially declining based on relative storage (taken from a store)	infiltration_2	$flux_{out} = \theta_1 * exp\left[-\theta_2 \frac{S_1}{S_{1,max}}\right] - flux_{used}$	$0 \leq flux_{out} \leq \frac{S_2}{\Delta t}$	$flux_{out} = \max\left(min\left(\theta_1 * exp\left[-\theta_2 \frac{S_1}{S_{1,max}}\right] - flux_{used}, \frac{S_2}{\Delta t}\right), 0\right)$	36
	Infiltration to soil moisture of liquid water stored in snow pack	infiltration_3	$flux_{out} = \begin{cases} flux_{in}, & if\ S \geq S_{max} \\ 0, & otherwise \end{cases}$		$flux_{out} = flux_{in}[1 - logisticSmoother\_S(S, S_{\max})]$	37
	Constant infiltration rate	infiltration_4	$flux_{out} = \theta_1$	$flux_{out} \leq flux_{in}$	$flux_{out} = min(flux_{in}, \theta_1)$	15, 23, 40, 44
	Maximum infiltration rate non-linearly based on relative deficit and storage	infiltration_5	$flux_{out} = \theta_1 \left(1 - \frac{S_1}{S_{1,max}}\right)\left(\frac{S_2}{S_{2,max}}\right)^{-\theta_2}$	To prevent complex numbers, S = [0,∞> To prevent numerical issues with a theoretical infinite infiltration rate, $flux_{out}$ < 10^9	$flux_{out} = min\left(10^9, \theta_1 \left(1 - \frac{S_1}{S_{1,max}}\right) max\left(0, \frac{S_2}{S_{2,max}}\right)^{-\theta_2}\right)$	23
	Infiltration rate non-linearly scaled by relative storage	infiltration_6	$flux_{out} = \theta_1 \left(\frac{S}{S_{max}}\right)^{\theta_2} flux_{in}$	$flux_{out} \leq flux_{in}$	$flux_{out} = min\left(\theta_1 * max\left(0, \frac{S}{S_{max}}\right)^{\theta_2} flux_{in}, flux_{in}\right)$	43
Interception	Interception excess when maximum capacity is reached	interception_1	$flux_{out} = \begin{cases} flux_{in}, & if\ S \geq S_{max} \\ 0, & otherwise \end{cases}$		$flux_{out} = flux_{in}[1 - logisticSmoother\_S(S, S_{\max})]$	16, 18, 22, 26, 34, 36, 39, 42, 44, 45
	Interception excess after a constant amount is intercepted	interception_2	$flux_{out} = \begin{cases} flux_{in} - \theta_1, & if\ flux_{in} \geq 0 \\ 0, & otherwise \end{cases}$	$flux_{out} \geq 0$	$flux_{out} = max(flux_{in} - \theta_1, 0)$	2, 13, 15
	Interception excess after a fraction is intercepted	interception_3	$flux_{out} = \theta_1$		$flux_{out} = \theta_1$	8
	Interception excess after a time-varying fraction is intercepted	interception_4	$flux_{out} = \left(\theta_1 + (1 - \theta_1) * \cos\left(2\pi \frac{t * \Delta t - \theta_2}{t_{max}}\right)\right) * flux_{in}$	$flux_{out} \geq 0$	$flux_{out} = max\left(0, \theta_1 + (1 - \theta_1) * \cos\left(2\pi \frac{t * \Delta t - \theta_2}{t_{max}}\right)\right) * flux_{in}$	32, 35
	Interception excess after a combined absolute amount and fraction are intercepted	interception_5	$flux_{out} = \begin{cases} \theta_1 * flux_{in} - \theta_2, & if\ flux_{in} \geq 0 \\ 0, & otherwise \end{cases}$	$flux_{out} \geq 0$	$flux_{out} = max(\theta_1 * flux_{in} - \theta_2, 0)$	23

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Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
Interflow	Interflow as a scaled fraction of an incoming flux	interflow_1	$flux_{out} = \theta_1 \frac{S}{S_{max}} * flux_{in}$		$flux_{out} = \theta_1 \frac{S}{S_{max}} * flux_{in}$	18, 36
	Non-linear interflow	interflow_2	$flux_{out} = \theta_1 S^{(1+\theta_2)}$	$flux_{out} \leq \frac{S}{\Delta t}$ To prevent complex numbers, S = [0,∞>	$flux_{out} = min\left(\theta_1 max(S,0)^{(1+\theta_2)}, max\left(\frac{S}{\Delta t},0\right)\right)$	37
	Non-linear interflow (variant)	interflow_3	$flux_{out} = \theta_1 S^{\theta_2}$	$flux_{out} \leq \frac{S}{\Delta t}$ To prevent complex numbers, S = [0,∞>	$flux_{out} = min\left(\theta_1 max(S,0)^{\theta_2}, max\left(\frac{S}{\Delta t},0\right)\right)$	10, 19, 42, 43
	Combined linear and scaled quadratic interflow	interflow_4	$flux_{out} = \theta_1 S + \theta_2 S^2$	$flux_{out} \leq \frac{S}{\Delta t}$ To prevent complex numbers, S = [0,∞>	$flux_{out} = min\left(\theta_1 max(S,0) + \theta_2 max(S,0)^2, max\left(\frac{S}{\Delta t},0\right)\right)$	45
	Linear interflow	interflow_5	$flux_{out} = \theta_1 * S$		$flux_{out} = \theta_1 * S$	28, 33, 41
	Scaled linear interflow if a storage in the receiving store exceeds a threshold	interflow_6	$flux_{out} = \begin{cases} \theta_1 * S_1 * \frac{S_2/S_{2,max} - \theta_2}{1-\theta_2}, & if\ S_2/S_{2,max} > \theta_2 \\ 0, & otherwise \end{cases}$	$\frac{S_2}{S_{2,max}} \leq 1$	$flux_{out} = \left(\theta_1 * S_1 * \frac{min\left(1, S_2/S_{2,max}\right) - \theta_2}{1-\theta_2}\right) * \left[1 - logisticSmoother\_S\left(\frac{S_2}{S_{2,max}}, \theta_2\right)\right]$	41
	Non-linear interflow if storage exceeds a threshold	interflow_7	$flux_{out} = \begin{cases} \left(\frac{S-\theta_1 S_{max}}{\theta_2}\right)^{\frac{1}{\theta_3}}, & if\ S > \theta_1 S_{max} \\ 0, & otherwise \end{cases}$	$flux_{out} \leq \frac{S-\theta_1 S_{max}}{\Delta t}$ To prevent complex numbers, S-θ1Smax = [0,∞>	$flux_{out} = min\left(max\left(0, \frac{S-\theta_1 S_{max}}{\Delta t}\right), \left(\frac{max(0, S-\theta_1 S_{max})}{\theta_2}\right)^{\frac{1}{\theta_3}}\right)$	9
	Linear interflow if storage exceeds a threshold	interflow_8	$flux_{out} = \begin{cases} \theta_1(S-\theta_2), & if\ S > \theta_2 \\ 0, & otherwise \end{cases}$		$flux_{out} = max\left(0, \theta_1(S-\theta_2)\right)$	3, 12, 27, 38
	Non-linear interflow if storage exceeds a threshold (variant)	interflow_9	$flux_{out} = \begin{cases} \left(\theta_1(S-\theta_2)\right)^{\theta_3}, & if\ S > \theta_2 \\ 0, & otherwise \end{cases}$	$flux_{out} \leq \frac{S-\theta_2}{\Delta t}$ To prevent complex numbers, S-θ2 = [0,∞>	$flux_{out} = min\left(\frac{S-\theta_2}{\Delta t}, \left(\theta_1 * max(0, S-\theta_2)\right)^{\theta_3}\right)$	4, 11, 16, 39
	Scaled linear interflow if storage exceeds a threshold	interflow_10	$flux_{out} = \begin{cases} \theta_1 \frac{(S-\theta_2)}{\theta_3}, & if\ S > \theta_2 \\ 0, & otherwise \end{cases}$		$flux_{out} = \theta_1 \frac{max(0, S-\theta_2)}{\theta_3}$	14
	Constant interflow if storage exceeds a threshold	interflow_11	$flux_{out} = \begin{cases} \theta_1, & if\ S > \theta_2 \\ 0, & otherwise \end{cases}$	$flux_{out} \leq \frac{S-\theta_2}{\Delta t}$	$flux_{out} = \min\left(\theta_1, \frac{S-\theta_2}{\Delta t}\right) * [1 - logisticSmoother\_S(S, \theta_2)]$	20

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Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
Misc	Auxiliary function to find contributing area	area_1	$A = \begin{cases} \theta_1 \left[\frac{S - S_{min}}{S_{max} - S_{min}}\right]^{\theta_2}, & if\ S > S_{min} \\ 0, & otherwise \end{cases}$	$A \leq 1$	$A = min\left(1, \theta_1 \left[\frac{S - S_{min}}{S_{max} - S_{min}}\right]^{\theta_2}\right) * [1 - logisticSmoother\_S(S, S_{min})]$	23
	General effective flow (returns flux [mm/d])	effective_1	$flux_{out} = \begin{cases} flux_{in,1} - flux_{in,2}, & if\ flux_{in,1} > flux_{in,2} \\ 0, & otherwise \end{cases}$		$flux_{out} = max(0, flux_{in,1} - flux_{in,2})$	22, 23, 25, 39, 40, 42, 43, 44, 45, 46
	Storage excess when store size changes (returns flux [mm/d])	excess_1	$flux_{out} = \frac{S - S_{max,new}}{\Delta t}$	$flux_{out} \geq 0$	$flux_{out} = max\left(\frac{S - S_{max,new}}{\Delta t}, 0\right)$	10, 19, 22, 37, 44
	Phenology-based correction factor for potential evapotranspiration (returns flux [mm/d])	phenology_1	$E_p^* = \begin{cases} 0, & if\ T(t) < \theta_1 \\ \frac{T(t) - \theta_1}{\theta_2 - \theta_1} * E_p, & if\ \theta_1 \leq T(t) < \theta_2 \\ E_p, & if\ T(t) \geq \theta_2 \end{cases}$		$E_p^* = min\left(1, max\left(0, \frac{T(t) - \theta_1}{\theta_2 - \theta_1}\right)\right) * E_p$	35
	Phenology-based maximum interception capacity (returns store size [mm])	phenology_2	$S_{max} = \theta_1 \left(1 + \theta_2 sin\left(2\pi \frac{t * \Delta t - \theta_3}{t_{max}}\right)\right)$	Assumes $0 \leq \theta_2 \leq 1$ to guarantee $S_{max} \geq 0$	$S_{max} = \theta_1 \left(1 + \theta_2 sin\left(2\pi \frac{t * \Delta t - \theta_3}{t_{max}}\right)\right)$	22
	Split flow (returns flux [mm/d])	split_1	$flux_{out} = \theta_1 * flux_{in}$		$flux_{out} = \theta_1 * flux_{in}$	5, 11, 13, 17, 21, 25, 26, 28, 29, 33, 34, 40, 41, 42, 43, 45, 46
Percolation	Percolation at a constant rate	percolation_1	$flux_{out} = \begin{cases} \theta_1, & if\ S \geq 0 \\ 0, & otherwise \end{cases}$	$flux_{out} \leq \frac{S}{\Delta t}$	$flux_{out} = min\left(\frac{S}{\Delta t}, \theta_1\right)$	37
	Percolation scaled by current relative storage	percolation_2	$flux_{out} = \theta_1 \frac{S}{S_{max}}$	$flux_{out} \leq \frac{S}{\Delta t}$	$flux_{out} = min\left(\frac{S}{\Delta t}, \theta_1 \frac{S}{S_{max}}\right)$	21, 26, 34
	Non-linear percolation (empirical)	percolation_3	$flux_{out} = \frac{S_{max}^{-4}}{4} \left(\frac{4}{9}\right)^{-4} S^5$		$flux_{out} = \frac{S_{max}^{-4}}{4} \left(\frac{4}{9}\right)^{-4} S^5$	7
	Demand-based percolation scaled by available moisture	percolation_4	$flux_{out} = \frac{S}{S_{max}} \left[\theta_1 \left\{1 + \theta_2 \left(\frac{\sum deficiencies}{\sum capacities}\right)^{\theta_3}\right\}\right]$	$flux_{out} \leq \frac{S}{\Delta t}$ To avoid erratic numerical behaviour, $flux_{out} \geq 0$	$flux_{out} = max\left(0, min\left(\frac{S}{\Delta t}, \frac{max(S,0)}{S_{max}} * \left[\theta_1 \left\{1 + \theta_2 \left(\frac{\sum deficiencies}{\sum capacities}\right)^{\theta_3}\right\}\right]\right)\right)$	33
	Non-linear percolation	percolation_5	$flux_{out} = \theta_1 \left(\frac{S}{S_{max}}\right)^{\theta_2}$	$flux_{out} \leq \frac{S}{\Delta t}$ To prevent complex numbers, S = [0,∞>	$flux_{out} = min\left(\frac{S}{\Delta t}, \theta_1 \left(\frac{max(0,S)}{S_{max}}\right)^{\theta_2}\right)$	22

continued …

Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
	Threshold-based percolation from a store that can reach negative values	percolation_6	$flux_{out} = \begin{cases} \theta_1, & if\ S \geq \theta_2 \\ \theta_1 \frac{S}{\theta_2}, & if\ 0 < S < \theta_2 \\ 0, & otherwise \end{cases}$	$flux_{out} \leq \frac{S}{\Delta t}$	$flux_{out} = min\left(\frac{S}{\Delta t}, \theta_1 min\left[1, \frac{max(0,S)}{\theta_2}\right]\right)$	39
Recharge	Recharge as scaled fraction of incoming flux	recharge_1	$flux_{out} = \theta_1 \frac{S}{S_{max}} * flux_{in}$		$flux_{out} = \theta_1 \frac{S}{S_{max}} * flux_{in}$	18, 36
	Recharge as non-linear scaling of incoming flux	recharge_2	$flux_{out} = \left(\frac{S}{S_{max}}\right)^{\theta_1} * flux_{in}$	To prevent complex numbers, S = [0,∞>	$flux_{out} = \left(\frac{max(0,S)}{S_{max}}\right)^{\theta_1} * flux_{in}$	7, 37, 45
	Linear recharge	recharge_3	$flux_{out} = \theta_1 * S$		$flux_{out} = \theta_1 * S$	19, 23, 24, 27, 30, 31, 32, 35, 38, 42
	Constant recharge from a store	recharge_4	$flux_{out} = \begin{cases} \theta_1, & if\ S \geq 0 \\ 0, & otherwise \end{cases}$	$flux_{out} \leq \frac{S}{\Delta t}$	$flux_{out} = min\left(\frac{S}{\Delta t}, \theta_1\right)$	23, 44
	Recharge to fulfil evaporation demand if the receiving store is below a threshold	recharge_5	$flux_{out} = \begin{cases} \theta_1 S_1 \left(1 - \frac{S_2}{\theta_2}\right), & if\ S_2 < \theta_2 \\ 0, & otherwise \end{cases}$		$flux_{out} = \theta_1 S_1 \left[1 - min\left(1, \frac{S_2}{\theta_2}\right)\right]$	20
	Non-linear recharge	recharge_6	$flux_{out} = \theta_1 S^{\theta_2}$	$flux_{out} \leq \frac{S}{\Delta t}$ To prevent complex numbers, S = [0,∞>	$flux_{out} = min\left(\theta_1 max(S,0)^{\theta_2}, max\left(\frac{S}{\Delta t}, 0\right)\right)$	44
	Constant recharge from a flux	recharge_7	$flux_{out} = \theta_1$	$flux_{out} \leq flux_{in}$	$flux_{out} = min(flux_{in}, \theta_1)$	45
Routing	Threshold-based non-linear routing	routing_1	$flux_{out} = \begin{cases} \theta_1 S^{\theta_2}, & if\ flux_{out} < \theta_3 S \\ \theta_3 S, & otherwise \end{cases}$	$flux_{out} \leq \frac{S}{\Delta t}$	$flux_{out} = min\left(\frac{S}{\Delta t}, \theta_1 max(S,0)^{\theta_2}, \theta_3 \frac{S}{\Delta t}\right)$	39
Saturation excess	Saturation excess from a store that has reached maximum capacity	saturation_1	$flux_{out} = \begin{cases} flux_{in}, & if\ S \geq S_{max} \\ 0, & otherwise \end{cases}$		$flux_{out} = flux_{in}\left[1 - logisticSmoother\_S(S, S_{\max})\right]$	1, 3, 4, 6, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 22, 24, 25, 30, 31, 32, 33, 35, 36, 39, 40, 41, 44, 45, 46

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Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
	Saturation excess from a store with different degrees of saturation	saturation_2	$flux_{out} = \left(1-\left(1-\frac{S}{S_{max}}\right)^{\theta_1}\right) * flux_{in}$	To prevent complex numbers, S/Smax = [0,∞>	$flux_{out} = \left(1-\left(min\left(1, max\left(0, \left(1-\frac{S}{S_{max}}\right)\right)\right)\right)^{\theta_1}\right) * flux_{in}$	2, 13, 22, 28, 29
	Saturation excess from a store with different degrees of saturation (exponential variant)	saturation_3	$flux_{out} = \left(1-\frac{1}{1+exp\left(\frac{S/S_{max}+0.5}{\theta_1}\right)}\right) * flux_{in}$		$flux_{out} = \left(1-\frac{1}{1+exp\left(\frac{S/S_{max}+0.5}{\theta_1}\right)}\right) * flux_{in}$	21, 26, 34
	Saturation excess from a store with different degrees of saturation (quadratic variant)	saturation_4	$flux_{out} = \left(1-\left(\frac{S}{S_{max}}\right)^2\right) * flux_{in}$	$0 \leq flux_{out}$	$flux_{out} = max\left(0, \left(1-\left(\frac{S}{S_{max}}\right)^2\right) * flux_{in}\right)$	7
	Deficit store: exponential saturation excess based on current storage and a threshold parameter	saturation_5	$flux_{out} = \left(1-min\left(1, \left(\frac{S}{\theta_1}\right)^{\theta_2}\right)\right) * flux_{in}$	To prevent complex numbers, S = [0,∞>	$flux_{out} = \left(1-min\left(1, \left(\frac{max(S,0)}{\theta_1}\right)^{\theta_2}\right)\right) * flux_{in}$	5
	Saturation excess from a store with different degrees of saturation (linear variant)	saturation_6	$flux_{out} = \theta_1 \frac{S}{S_{max}} * flux_{in}$		$flux_{out} = \theta_1 \frac{S}{S_{max}} * flux_{in}$	40
	Saturation excess from a store with different degrees of saturation (gamma function variant)	saturation_7	$flux_{out} = flux_{in} \begin{cases} \int_{x=\theta_5 * S+\theta_4}^{x=\infty} \frac{1}{\theta_1 \Gamma(\theta_2)} \left(\frac{x-\theta_3}{\theta_1}\right)^{\theta_2-1} e^{\left(-\frac{x-\theta_3}{\theta_1}\right)}, & x > \theta_3 \\ 0 \end{cases}$	To prevent numerical problems, S = [0,∞>	$flux_{out} = flux_{in} * integral\left(\frac{1}{\theta_1 \Gamma(\theta_2)}\left(\frac{max(x-\theta_3,0)}{\theta_1}\right)^{\theta_2-1} * e^{\left(-1*\frac{max(x-\theta_3,0)}{\theta_1}\right)}, \theta_5 * max(S,0)+\theta_4, \infty\right)$	14
	Saturation excess flow from a store with different degrees of saturation (min-max linear variant)	saturation_8	$flux_{out} = \left[\theta_1 + (\theta_2-\theta_1)\frac{S}{S_{max}}\right] * flux_{in}$	$flux_{out} \leq flux_{in}$	$flux_{out} = \left[\theta_1 + (\theta_2-\theta_1)\frac{S}{S_{max}}\right] * flux_{in}$	45
	Deficit store: saturation excess from a store that has reached maximum capacity	saturation_9	$flux_{out} = \begin{cases} flux_{in}, & if\ S = 0 \\ 0, & otherwise \end{cases}$		$flux_{out} = flux_{in} * logisticSmoother\_S(S,0)$	17, 25, 43, 46
	Saturation excess flow from a store with different degrees of saturation (min-max exponential variant)	saturation_10	$flux_{out} = min\left(\theta_1, \theta_2 + \theta_2 e^{\theta_3 S}\right) * flux_{in}$		$flux_{out} = min\left(\theta_1, \theta_2 + \theta_2 e^{\theta_3 S}\right) * flux_{in}$	39

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Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
	Saturation excess flow from a store with different degrees of saturation (min exponential variant)	saturation_11	$flux_{out} = \begin{cases} \left(\theta_1 \left[\frac{S - S_{min}}{S_{max} - S_{min}}\right]^{\theta_2}\right) flux_{in}, & if\ S > S_{min} \\ 0, & otherwise \end{cases}$	$flux_{out} \leq flux_{in}$	$flux_{out} = min\left(1, \theta_1 \left[\frac{S - S_{min}}{S_{max} - S_{min}}\right]^{\theta_2}\right) flux_{in} * [1 - logisticSmoother\_S(S, S_{min})]$	23
	Saturation excess flow from a store with different degrees of saturation (min-max linear variant)	saturation_12	$flux_{out} = \frac{\theta_1 - \theta_2}{1 - \theta_2} flux_{in}$	$flux_{out} \geq 0$	$flux_{out} = max\left(0, \frac{\theta_1 - \theta_2}{1 - \theta_2}\right) flux_{in}$	23
	Saturation excess flow from a store with different degrees of saturation (normal distribution variant)	saturation_13	$flux_{out} = flux_{in} * \int_{-\infty}^{\xi} \frac{1}{\sqrt{2\pi}} exp\left[-\frac{\xi^2}{2}\right] d\xi,\ with\ \xi = \frac{log(S/\theta_1)}{log(\theta_1/\theta_2)}$		$flux_{out} = flux_{in} * normcdf\left(\frac{log(\max(0, S)/\theta_1)}{log(\theta_1/\theta_2)}\right)$	42
	Saturation excess flow from a store with different degrees of saturation (two-part exponential variant)	saturation_14	$flux_{out} = flux_{in} \begin{cases} (0.5 - \theta_1)^{1-\theta_2} \left(\frac{S}{S_{max}}\right)^{\theta_3}, if\ \frac{S}{S_{max}} \leq 0.5 - \theta_1 \\ 1 - (0.5 - \theta_1)^{1-\theta_2} \left(1 - \frac{S}{S_{max}}\right)^{\theta_3}, otherwise \end{cases}$		$flux_{out} = \left(\begin{array}{c} \left((0.5 - \theta_1)^{1-\theta_2} max\left(0, \frac{S}{S_{max}}\right)^{\theta_3}\right) * \\ \left(\frac{S}{S_{max}} \leq 0.5 - \theta_1\right) + \\ \left(1 - (0.5 + \theta_1)^{1-\theta_2} max\left(0, 1 - \frac{S}{S_{max}}\right)^{\theta_3}\right) * \\ \frac{S}{S_{max}} > 0.5 - \theta_1 \end{array} \right) * flux_{in}$	28
Snow	Snowfall based on temperature threshold	snowfall_1	$flux_{out} = \begin{cases} flux_{in}, & if\ T \leq T_{threshold} \\ 0, & otherwise \end{cases}$		$flux_{out} = flux_{in} * [logisticSmoother\_T(T, T_{threshold}]$	6, 12, 30, 31, 32, 34, 35, 41, 43, 44, 45
	Snowfall based on a temperature threshold interval	snowfall_2	$flux_{out} = \begin{cases} flux_{in}, & if\ T \leq \theta_1 - \frac{1}{2}\theta_2 \\ flux_{in} * \frac{\theta_1 + \frac{1}{2}\theta_2 - T}{\theta_2}, & if\ \theta_1 - \frac{1}{2}\theta_2 < T < \theta_1 + \frac{1}{2}\theta_2 \\ 0, & if\ T \geq \theta_1 + \frac{1}{2}\theta_2 \end{cases}$		$flux_{out} = min\left(flux_{in}, max\left(0, flux_{in} * \frac{\theta_1 + \frac{1}{2}\theta_2 - T}{\theta_2}\right)\right)$	37
	Rainfall based on temperature threshold	rainfall_1	$flux_{out} = \begin{cases} flux_{in}, & if\ T > T_{threshold} \\ 0, & otherwise \end{cases}$		$flux_{out} = flux_{in} * [1 - logisticSmoother\_T(T, T_{threshold}]$	6, 12, 30, 31, 32, 34, 35, 41, 43, 44, 45

Process	Details	Function name	Constitutive function	Constraints	MARRMoT Code	Model
	Snowfall based on a temperature threshold interval	rainfall_2	$flux_{out} = \begin{cases} 0, \ if\ T \leq \theta_1 - \frac{1}{2}\theta_2 \\ flux_{in} * \frac{\theta_1 + \frac{1}{2}\theta_2 - T}{\theta_2}, \ if\ \theta_1 - \frac{1}{2}\theta_2 < T < \theta_1 + \frac{1}{2}\theta_2 \\ flux_{in}, \ if\ T \geq \theta_1 + \frac{1}{2}\theta_2 \end{cases}$		$flux_{out} = min\left(flux_{in}, max\left(0, flux_{in} * \frac{T - \left(\theta_1 - \frac{1}{2}\theta_2\right)}{\theta_2}\right)\right)$	37
	Refreezing of stored melted snow	refreeze_1	$flux_{out} = \begin{cases} \theta_1 * \theta_2 * (T_{threshold} - T), \ if\ T \leq T_{threshold} \\ 0, \ otherwise \end{cases}$	$flux_{out} \leq \frac{S}{\Delta t}$	$flux_{out} = min\left(\frac{S}{\Delta t}, max\left(0, \theta_1 * \theta_2 * (T_{threshold} - T)\right)\right)$	37, 44
	Snowmelt from degree-day-factor	melt_1	$flux_{out} = \begin{cases} \theta_1 * (T - T_{threshold}), \ if\ T \geq T_{threshold} \\ 0, \ otherwise \end{cases}$	$flux_{out} \leq \frac{S}{\Delta t}$	$flux_{out} = min\left(\frac{S}{\Delta t}, max\left(0, \theta_1 * (T - T_{threshold})\right)\right)$	6, 12, 30, 31, 32, 34, 35, 37, 43, 44, 45
	Snowmelt at a constant rate	melt_2	$flux_{out} = \begin{cases} \theta_1, \ if\ S \geq 0 \\ 0, \ otherwise \end{cases}$	$flux_{out} \leq \frac{S}{\Delta t}$	$flux_{out} = min\left(\frac{S}{\Delta t}, \theta_1\right)$	44
	Glacier melt provided no snow is stored on the ice layer	melt_3	$flux_{out} = \begin{cases} \theta_1 * (T - T_{threshold}), \ if\ T \geq T_{threshold}\ , S_2 = 0 \\ 0, \ otherwise \end{cases}$	$flux_{out} \leq \frac{S_1}{\Delta t}$	$flux_{out} = min\left(\frac{S_1}{\Delta t}, max\left(0, \theta_1 * \theta_2 * (T_{threshold} - T)\right)\right) * logisticSmoother\_S(S_2, 0)$	43
Soil moisture	Water rebalance to equal relative storage (2 stores)	soilmoisture_1	$flux_{out} = \begin{cases} \frac{S_2 S_{1,max} - S_1 S_{2,max}}{S_{1,max} + S_{2,max}}\ , \ if\ \frac{S_1}{S_{1,max}} < \frac{S_2}{S_{2,max}} \\ 0, \quad otherwise \end{cases}$		$flux_{out} = \left(\frac{S_2 S_{1,max} - S_1 S_{2,max}}{S_{1,max} + S_{2,max}}\right) * logisticSmoother\_S\left(\frac{S_1}{S_{1,max}}, \frac{S_2}{S_{2,max}}\right)$	33
	Water rebalance to equal relative storage (3 stores)	soilmoisture_2	$flux_{out} = \begin{cases} S_2 \frac{S_1\left(S_{2,max} + S_{3,max}\right) + S_{1,max}(S_2 + S_3)}{\left(S_{2,max} + S_{3,max}\right)\left(S_{1,max} + S_{2,max} + S_{3,max}\right)}\ , \\ if\ \frac{S_1}{S_{1,max}} < \frac{S_2 + S_3}{S_{2,max} + S_{3,max}} \\ 0, \quad otherwise \end{cases}$		$flux_{out} = \left(S_2 \frac{S_1\left(S_{2,max} + S_{3,max}\right) + S_{1,max}(S_2 + S_3)}{\left(S_{2,max} + S_{3,max}\right)\left(S_{1,max} + S_{2,max} + S_{3,max}\right)}\right) * logisticSmoother\_S\left(\frac{S_1}{S_{1,max}}, \frac{S_2 + S_3}{S_{2,max} + S_{3,max}}\right)$	33