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Understanding each other's models: an introduction and a standard representation of 16 global water models to support intercomparison, improvement, and communication

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List of symbols

a soil exponent (unitless). See table S25. 51

a_i soil exponent per layer i (unitless). See table S25. 51

a_{uz} exponent for the unsaturated zone (unitless). See table S26. 52

A water abstraction (L^3 L^{-2} T^{-1}). See tables S32, S35. 58, 61

A_{act}^{gw} actual groundwater abstraction (L^3 L^{-2} T^{-1}). See table S53. 79

A_{act}^{sw} actual surface water abstraction (L^3 L^{-2} T^{-1}). See table S53. 79

$A_{act,irr}$ actual water abstraction for irrigation (L^3 L^{-2} T^{-1}). See table S43. 69

$A_{dem,dam}$ mean annual total water demand of the dam (L^3 T^{-1}). See table S37. 63

$A_{dem,5dcells}$ long term averaged water demand of 5 donwstream cells of a reservoir (L^3 T^{-1}). See table S37. 63

$A_{dem,5dcells,month}$ mean water demand of 5 downstream cells of a reservoir averaged over a specific month (L^3 T^{-1}). See table S37. 63

A_{dom} water abstraction for domestic sector (L^3 L^{-2} T^{-1}). See tables S35, S59, S60, S61, S62, S63, S64. 61, 85–91, 93, 95, 97, 98, 100

A_{dom}^{aq} water abstraction from river for domestic sector, at the origin of an aqueduct (L^3 L^{-2} T^{-1}). See table S62. 88

A_{dom}^{gw} water abstraction from groundwater storage for domestic sector (L^3 L^{-2} T^{-1}). See tables S29, S59, S60 S61, S77. 55, 85–87, 103

$A_{dom}^{gw,nrw}$ water abstraction from non-renewable groundwater storage for domestic sector (L^3 L^{-2} T^{-1}). See table S59. 85

$A_{dom}^{gw,rw}$ water abstraction from renewable groundwater storage for domestic sector (L^3 L^{-2} T^{-1}). See table S59. 85

A_{dom}^{pond} water abstraction from pond, from local reservoir, for domestic sector (L^3 L^{-2} T^{-1}). See tables S35, S62. 61, 88

A_{dom}^{re} water abstraction from reservoir for domestic sector (L^3 L^{-2} T^{-1}). See tables S62, S79. 88, 105

A_{dom}^{ri} water abstraction from river for domestic sector (L^3 L^{-2} T^{-1}). See tables S43, S62. 72, 88

A_{dom}^{sw} water abstraction from surface water bodies for domestic sector (L^3 L^{-2} T^{-1}). See tables S43, S59, S62, S63, S64, S78, S79, S80. 69, 85, 88–90, 104–106

A_{dom}^{usw} water abstraction from unlimited (unspecified) surface water source for domestic sector (L^3 L^{-2} T^{-1}). See table S62. 88

$A_{dom,cons}$ water consumption from domestic sector (L^3 L^{-2} T^{-1}). See tables S59. 86, 87, 89, 90, 92, 97, 100

$A_{dom,cons}$ domestic consumption (L^3 L^{-2} T^{-1}). See tables S60, S61, S63. 86, 87, 89, 96, 99

$A_{dom,cons}^{sw}$ domestic surface water consumption (L^3 L^{-2} T^{-1}). See table S63. 89

$A_{dom,cons}^{gw}$ domestic groundwater consumption (L^3 L^{-2} T^{-1}). See table S60. 86

$A_{dom,dem}$ water demand for domestic sector (L^3 T^{-1}). See tables S59, S60, S61, S62, S63, S78, S79. 85–89, 104, 105

$A^{sw}_{dom,loss}$ domestic surface water losses (L^3 L^{-2} T^{-1}). See table S63. 89

$A^{gw}_{dom,loss}$ domestic groundwater losses (L^3 L^{-2} T^{-1}). See table S60. 86

$A_{dom,month}$ monthly water abstraction for domestic sector (L^3 L^{-2} T^{-1}). See tables S37, S79. 63, 105

$A_{dom,rf}$ return flow from domestic sector (L^3 L^{-2} T^{-1}). See tables S60, S61, S63, S64. 86, 87, 89, 90

$A^{gw}_{dom,rf}$ return flow from domestic groundwater abstraction (L^3 L^{-2} T^{-1}). See tables S61, S60. 86, 87

$A^{sw}_{dom,rf}$ return flow from domestic surface water abstraction (L^3 L^{-2} T^{-1}). See tables S64, S63. 89, 90

$A^{re,global}_{dom}$ water abstraction from a global reservoir for domestic sector (L^3 L^{-2} T^{-1}). See tables S35, S62. 61, 88

A^{sw}_{ele} water abstraction from surface water bodies for electricity sector (L^3 L^{-2} T^{-1}). See tables S75, S76, S78, S79, S80. 101, 102, 104–106

f^{sw}_{A} abstraction surface water (L^3 L^{-2} T^{-1}). See table S59. 85, 86, 88, 89, 91–93, 95, 96, 98, 99

A_{fgw} fossil groundwater abstraction (L^3 L^{-2} T^{-1}). See table S53. 79

A_{gw} water abstraction from groundwater storage (L^3 L^{-2} T^{-1}). See tables S29, S77. 55, 103

$A_{gw,cons}$ groundwater consumption (L^3 L^{-2} T^{-1}). See table S54. 80

$A_{gw,rw}$ water abstraction from renewable groundwater storage (L^3 L^{-2} T^{-1}). See table S53. 79

$A_{hil,G}$ household, industry, and livestock demand, at the grid cell (G) (L^3 L^{-2} T^{-1}). See tables S78, S79. 104, 105

A_{ind} water abstraction for industry sector (L^3 L^{-2} T^{-1}). See tables S35, S81, S59. 61, 85, 87, 88, 90, 91, 93, 95, 97, 98, 100, 107

A^{gw}_{ind} groundwater abstraction for industry sector (L^3 L^{-2} T^{-1}). See tables S77, S69, S70. 95, 96, 103

A^{pond}_{ind} water abstraction from pond, local reservoir, for industry sector (L^3 L^{-2} T^{-1}). See tables S35, S72. 61, 98

A^{re}_{ind} water abstraction from reservoir for industry sector (L^3 L^{-2} T^{-1}). See table S79. 105

A^{ri}_{ind} water abstraction from river for industry sector (L^3 L^{-2} T^{-1}). See tables S46, S72. 72, 98

A^{sw}_{ind} surface water abstraction for industry sector (L^3 L^{-2} T^{-1}). See tables S69, S72, S73, S75. 95, 98, 99

$A_{ind,cons}$ water consumption from industry sector (L^3 L^{-2} T^{-1}). See tables S59. 86, 87, 89, 90, 92, 96, 97, 99, 100

$A^{sw}_{ind,cons}$ surface water consumption for industry sector (L^3 L^{-2} T^{-1}). See tables S73. 99

$A^{gw}_{ind,cons}$ groundwater consumption for industry sector (L^3 L^{-2} T^{-1}). See tables S70. 96

$A_{ind,dem}$ water demand abstraction for industry sector (L^3 T^{-1}). See tables S69, S78, S79. 95, 104, 105

$A_{ind,month}$ monthly water abstraction for industry sector (L^3 L^{-2} T^{-1}). See tables S37, S79. 63, 105

$A^{re,global}_{ind}$ water abstraction from a global reservoir for industry sector (L^3 L^{-2} T^{-1}). See tables S35, S72. 61, 98

A_{irr} water abstraction for irrigation sector (L^3 L^{-2} T^{-1}). See tables S1, S35, S43, S52, S59, S53, S54, S55, S56, S57, S58. 27, 61, 78, 80–85, 88, 91, 93, 95, 98, 106

A_{irr}^{aq} water abstraction from river for irrigation sector, at the origin of an aqueduct (L^3 L^{-2} T^{-1}). See table S56. 82

A_{irr}^{gw} water abstraction from groundwater storage for irrigation sector (L^3 L^{-2} T^{-1}). See tables S29, S53, S54, S55, S77. 55, 78–81, 103

$A_{irr}^{gw,nrw}$ water abstraction from non-renewable groundwater storage for irrigation sector (L^3 L^{-2} T^{-1}). See table S53. 79

$A_{irr}^{gw,rw}$ water abstraction for irrigation sector taken from renewable groundwater storage (L^3 L^{-2} T^{-1}). See table S53. 79

A_{irr}^{la} water abstraction for irrigation sector taken from lake (L^3 L^{-2} T^{-1}). See table S56. 82

$A_{irr}^{neigh,cell}$ water abstraction for irrigation sector taken from neighboring cell surplus (L^3 L^{-2} T^{-1}). See table S56. 82

A_{irr}^{pond} water abstraction for irrigation sector taken from pond, local reservoir (L^3 L^{-2} T^{-1}). See tables S35, S56. 61, 82

A_{irr}^{re} water abstraction from reservoir for irrigation sector (L^3 L^{-2} T^{-1}). See tables S56, S79. 82, 105

A_{irr}^{ri} water abstraction for irrigation from river (L^3 L^{-2} T^{-1}). See tables S46, S56. 72, 82

A_{irr}^{sw} water abstraction for irrigation sector taken from surface water (L^3 L^{-2} T^{-1}). See tables S43, S53, S56, S57, S58, S78, S79, S80. 69, 78, 79, 82–84, 104–106

A_{irr}^{usw} irrigation surface water abstraction from unlimited (unspecified) surface water source (L^3 L^{-2} T^{-1}). See table S56. 82

$A_{irr,app}$ application requirement for an irrigation system due to irrigation conveyance inefficiencies (L^3 L^{-2} T^{-1}). See tables S57, S58. 78, 83, 84

$A_{irr,cons}$ water consumption from irrigation sector (L^3 L^{-2} T^{-1}). See tables S53, S54, S56, S57. 79–83, 86, 89, 92, 96, 99

$A_{irr,cons,G}^{sw}$ irrigation surface water consumption, at the grid cell (L^3 L^{-2} T^{-1}). See tables S57, S58. 104, 105

$A_{irr,cons}^{sw}$ irrigation surface water consumption (L^3 L^{-2} T^{-1}). See tables S57, S58. 83, 84, 104, 105

$A_{irr,cons}^{gw}$ irrigation groundwater consumption (L^3 L^{-2} T^{-1}). See tables S54, S55. 80, 81

$A_{irr,dem}$ water demand for irrigation sector (L^3 T^{-1}). See tables S53, S78, S79. 79, 104, 105

$A_{irr,loss}^{sw}$ irrigation surface water losses (L^3 L^{-2} T^{-1}). See table S57. 83

$A_{irr,month}$ monthly water abstraction for irrigation sector (L^3 L^{-2} T^{-1}). See tables S37, S79. 63, 105

$A_{irr,net}$ daily net irrigation requirement. Amount of water required in the upper 50 cm soil to avoid crop water limitation (L^3 L^{-2} T^{-1}). See tables S57, S58. 78, 83, 84

$A_{irr,rf}^{gw}$ return flow from irrigation groundwater abstraction (L^3 L^{-2} T^{-1}). See table S55. 81

$A_{irr,rf}^{sw}$ return flow from irrigation surface water abstraction (L^3 L^{-2} T^{-1}). See tables S57, S58. 83, 84

$A_{irr,rf}$ return flow from irrigation sector (L^3 L^{-2} T^{-1}). See tables S57, S58. 81

$A_{irr,rf,firr}$ return flow fraction irrigated (unitless). See tables S55. 81

$A_{irr}^{re,global}$ water abstraction from a global reservoir for irrigation sector (L^3 L^{-2} T^{-1}). See tables S29, S56. 61, 82

A_{la} water abstraction from lake (L^3 L^{-2} T^{-1}). See tables S43, S78, S79. 58, 104, 105

A_{liv} water abstraction for livestock sector (L^3 L^{-2} T^{-1}). See table S35, S59. 85, 86, 88, 89, 91–93, 95, 96, 98, 99

A^{gw}_{liv} water abstraction for livestock sector taken from groundwater storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S29, S65. 55, 91

A^{sw}_{liv} water abstraction for livestock sector taken from surface water ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S43, S67, S78, S79, S80. 69, 93, 104–106

$A_{liv,cons}$ water consumption for livestock sector ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S66, S68. 92, 94

$A^{gw}_{liv,cons}$ water consumption use for livestock sector taken from groundwater ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S66. 92

$A^{sw}_{liv,cons}$ water consumption use for livestock sector taken from surface water ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S67, S68. 93, 94

$A_{liv,dem}$ water demand for livestock sector ($\mathrm{L}^3\ \mathrm{T}^{-1}$). See tables S65, S66, S67, S68, S78, S79. 91–94, 104, 105

$A^{gw}_{man,rf}$ return flow for manufacturing groundwater abstraction ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S71, S70. 96, 97

$A^{sw}_{man,rf}$ return flow for manufacturing from surface water abstraction ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S74, S73. 99, 100

A^{aq}_{man} water abstraction for manufacturing sector from river, at the origin of an aqueduct ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S72. 98

$A^{coo,c}_{man}$ manufacturing cooling water per country ($\mathrm{L}^3\ \mathrm{T}^{-1}$). See tables S70, S71, S73, S74. 96, 97, 99, 100

A^{c}_{man} water abstraction for manufacturing sector per country ($\mathrm{L}^3\ \mathrm{T}^{-1}$). See tables S69, S70, S72, S73. 95, 96, 98, 99

$A^{gw,nrw}_{man}$ water abstraction for manufacturing sector taken from non-renewable groundwater storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S69. 95

$A^{gw,rw}_{man}$ water abstraction for manufacturing sector taken from renewable groundwater storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S69. 95

A^{re}_{man} water abstraction from reservoir for manufacturing sector ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S72. 98

A^{ri}_{man} water abstraction from river for manufacturing sector ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S72. 98

A^{sw}_{man} water abstraction for manufacturing sector taken from surface water ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S43, S72, S73, S74, S78, S79, S80. 69, 98–100, 104–106

A^{usw}_{man} manufacturing surface water abstraction from unlimited (unspecified) surface water source ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S72. 98

$A^{ww,c}_{man}$ manufacturing wastewater per country ($\mathrm{L}^3\ \mathrm{T}^{-1}$). See tables S70, S71, S73, S74. 96, 97, 99, 100

$A_{man,cons}$ water consumption for manufacturing sector ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S70, S71, S73. 96, 97, 99

$A^{gw}_{man,cons}$ water consumption for manufacturing sector taken from groundwater storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S70. 96

$A^{sw}_{man,cons}$ water consumption for manufacturing sector taken from surface water ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S73. 99

$A_{man,dem}$ water demand for manufacturing sector ($\mathrm{L}^3\ \mathrm{T}^{-1}$). See tables S69, S70, S71, S72 S73. 95–99

$A^{gw}_{man,loss}$ manufacturing groundwater losses ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S70. 96

$A^{sw}_{man,loss}$ manufacturing surface water losses ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S73. 99

$A^{c}_{man,rf}$ return flow for manufacturing abstraction per country ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S71, S70. 96, 99

A^{gw}_{man} water abstraction for manufacturing sector taken from groundwater storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S29, S69, S70, S71. 55, 95–97

A_{muni} water abstraction for municipal sector (L^3 L^{-2} T^{-1}). See table S81. 107

A_{ocean} seawater abstraction (L^3 L^{-2} T^{-1}). See tables S81, S82, S83. 107–109

$A_{ocean,cons}$ seawater consumption (L^3 L^{-2} T^{-1}). See table S82. 108

$A_{ocean,rf}$ return flow from seawater abstraction (L^3 L^{-2} T^{-1}). See table S83. 109

A^{gw}_{pot} potential groundwater abstraction (L^3 L^{-2} T^{-1}). See table S53. 79

A_{re} water abstraction from local reservoir (L^3 L^{-2} T^{-1}). See tables S35, S79. 61, 105

A_{rf} return flow from water abstraction (L^3 L^{-2} T^{-1}). See table S32. 58, 61, 69

$A_{rf,nonirr}$ return flow non-irrigated areas to river (L^3 L^{-2} T^{-1}). See table S59. 87, 90, 97, 100

$A_{rf,nonirr,eva}$ return flow non-irrigated which is evaporated (L^3 L^{-2} T^{-1}). See table S59. 87, 90, 97, 100

A_{ri} water abstraction from river (L^3 L^{-2} T^{-1}). See tables S43, S80. 69, 106

$A_{sw,cons}$ surface water consumption (L^3 L^{-2} T^{-1}). See table S54. 80

A_{tot} total abstraction (L^3 L^{-2} T^{-1}). See tables S29, S53. 55, 79

$A_{tot,cons}$ total consumption (L^3 L^{-2} T^{-1}). See table S54. 80

$A^{gw}_{tot,cons}$ total consumption from groundwater (L^3 L^{-2} T^{-1}). See table S60, S66, S70. 86, 92, 96

$A^{sw}_{tot,cons}$ total consumption from surface water (L^3 L^{-2} T^{-1}). See table S63, S68, S73. 89, 99

A^{gw}_{tot} total abstraction from groundwater (L^3 L^{-2} T^{-1}). See tables S59, S65, S69. 85, 91, 95

A^{sw}_{tot} total abstraction from surface water (L^3 L^{-2} T^{-1}). See tables S62, S67, S72. 88, 93, 98

AET total amount of water from transpiration, evaporation, interception losses, and sublimation (L^3 L^{-2} T^{-1}). See tables S1, S11, S20. 27, 37, 46

b_{weir} width weir (L). See tables S34, S37. 60, 63

B area (L^2). See tables S35, S46. 61, 72

B_{calm} fraction of the calm areas (unitless). See table S21. 47

B_G area of a grid cell (L^2). See table S29, S43. 55, 69

$B_{la,global}$ global lake area (L^2). See table S32. 58

$B_{la,global,max}$ maximum global lake area (L^2). See tables S32, S49. 58, 77

$B_{la,local}$ local lake area (L^2). See table S32. 58

$B_{la,local,max}$ maximum local lake area (L^2). See tables S32, S49. 58, 77

B_{re} reservoir area (L^2). See tables S35, S38. 61, 64

$B_{re,max}$ maximum reservoir area (L^2). See table S35. 61

B_{stormy} fraction of the stormy areas (unitless). See tables S4, S21. 30, 47

$B_{we,global}$ global wetland area (L^2). See table S39. 65

$B_{we,global,max}$ maximum global wetland area (L^2). See tables S39, S49. 65, 77

$B_{we,local}$ local wetland area (L^2). See table S39. 65

$B_{we,local,max}$ maximum local wetland area (L^2). See tables S39, S49. 65, 77

c_{air} specific heat of air (unitless). See tables S2, S7, S11, S23, S24. 28, 33, 37, 49, 50

c_{ice} specific heat ice (unitless). See tables S10, S12. 36, 38

C_{bulk} bulk transfer coefficient (unitless). See table S2. 28

$C_{bulk,Eg}$ bulk coefficient for evaporation from snow-free ground (unitless). See table S11. 37

$C^{sn}_{bulk,Eg}$ bulk coefficient for evaporation from snow-covered ground (unitless). See table S11. 37

$C_{bulk,Ei}$ bulk coefficient for evaporation, from intercepted liquid water by canopy (unitless). See table S7. 33

$C^{sn}_{bulk,Ei}$ bulk coefficient for evaporation, from intercepted snow by canopy (unitless). See table S7. 33

$C_{B,red}$ area reduction factor (unitless). See tables S32, S35, S39. 58, 61, 65

C_{crop} crop coefficient (unitless). See tables S23, S24. 49, 50

C_{cropGN} crop group number (GN) is an indicator of adaptation to dry climate (unitless). See table S23. 49

$C_{dam,G}$ allocation coefficient for grid cell that can be supply by more than one dam (unitless). See table S37. 63

$C^{wu,ints}_{dom}$ domestic water use intensity ($\mathrm{L}^3\ \mathrm{capita}^{-1}\ \mathrm{T}^{-1}$). See tables S59, S62. 85, 88

$C_{dom,cons}$ domestic consumptive use coefficient (unitless). See tables S60, S61, S63, S64. 86, 87, 89, 90

$C^{techchangerate}_{ele}$ technological change rate for the electricity sector (unitless). See tables S75, S76. 101, 102

$C_{gw,Q}$ groundwater outflow coefficient or recession coefficient of groundwater zone (T^{-1}). See table S31. 57

$C^{sw}_{gw,rech}$ groundwater recharge rate below surface water bodies ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S32, S35, S39. 58, 61, 65

C_H surface exchange coefficient for sensible and latent heat fluxes between the surface and the lowest atmospheric level (unitless). See tables S23, S24. 49, 50

C_{ice} ice impedance coefficient determined from the ice content of the soil layers (unitless). See table S31. 57

$C^{w,req}_{liv}$ livestock specific animal water requirement ($\mathrm{L}^3\ \mathrm{capita}^{-1}\ \mathrm{T}^{-1}$). See table S68. 94

C_m degree-day factor ($\mathrm{L}\ \Theta^{-1}\ \mathrm{T}^{-1}$). See table S12. 38

$C_{m,season}$ seasonal degree-day factor (unitless). See table S12. 38

$C^{w,ints,2005}_{man}$ manufacturing structural water intensity of 2005 per country ($\mathrm{L}^3\ \mathrm{money}^{-1}$). See tables S69, S70, S72, S73. 95, 96, 98, 99

$C_{man,cons}$ manufacturing consumptive use coefficient (unitless). See tables S73, S70, S74, S71. 96, 97, 99, 100

$C^{tech,cr}_{man}$ technological change rate for the manufacturing sector (unitless). See tables S69, S70, S72, S73. 95, 96, 98, 99

C_{month} monthly provisional release coefficient (L^{-3} T^{-1}). See table S37. 63

C_M Manning's roughness coefficient for river bed (unitless). See table S46. 72

C_{M1} Manning coefficient 1 (unitless). See table S46. 72

C_{M2} Manning coefficient 2 (unitless). See table S46. 72

C_{M3} Manning coefficient 3 (unitless). See table S46. 72

$C_{MS,we}$ Manning-Strickler coefficient for wetlands (unitless). See table S39. 68

$C_{P,l}$ extinction coefficient for rainfall (unitless). See table S5, S4. 30, 31

$C_{P_{th}}$ throughfall coefficient (unitless). See table S5. 31

C_{PT} Priestley-Taylor coefficient: 1.26 in humid areas, 1.74 in semiarid / arid areas Kaspar [26] (unitless). See table S2. 28

$C_{ri,hydraulic}$ hydraulic radius coefficient of the river channel (L). See table S46. 72

$C_{so,F}$ reduction factor for frozen soil (unitless). See table S13. 39

$C_{so,i}$ soil matric potential coefficient (unitless). See table S28. 54

C_{su} surface drag coefficient (unitless). See tables S7, S11, S23, S24. 33, 37, 49, 50

$C_{sw,out}$ surface water outflow coefficient (T^{-1}). See tables S34, S42. 60, 68

C_{tot} total annual release coefficient (L^{-3} T^{-1}). See table S37. 63

C_{weir} coefficient friction of the reservoir weir (unitless). See tables S34, S37, S45, S46. 60, 63, 71, 72

C_{ws} reduction factor because of water stress (unitless). See table S23. 49

C_{year} yearly release coefficient (L^{-3} T^{-1}). See table S37. 63

d_0 threshold depth (L). See table S31. 57

$d_{n,i}$ layer i node depth (L). See table S13. 39

$d_{n,i+1}$ layer $i+1$ node depth (L). See table S13. 39

d^{sw}_{paddy} actual surface water depth for paddy irrigation (L). See table S57. 83

$d^{sw}_{paddy,max}$ maximal surface water depth for paddy irrigation (L) (50 mm). See table S57. 83

d_{sn} grid-average of depth of the snow cover (L). See table S13. 39

d_{so} total soil depth (L). See tables S14, S20, S25, S29, S30. 40, 46, 51, 55, 56

$d_{so,i}$ soil depth for layer index i (L). See tables S14, S24, S25, S49. 40, 50, 51, 76

$d_{so,root}$ rooting depth (L). See tables S18, S22, S49. 44, 48, 76

d_{wt} water table depth (L). See tables S29, S30, S31. 55–57

$d_{wt,i}$ depth of the layer i directly above the water table (L). See table S30. 56

D_w soil water diffusivity (L^2 T^{-1}). See table S14. 40

e vapor pressure (kPa). See tables S7, S11, S23, S24. 33, 37, 49, 50

e_{act} actual vapor pressure (kPa). See table S2. 28

e_{ca} vapor pressure in canopy air space (kPa). See tables S7, S11, S23, S24. 33, 37, 49, 50

e_{sat} saturation vapor pressure (kPa); for Mac-PDM.20 (mb). See table S2. 28

$e_{sat,dew}$ saturation vapor pressure at dew point; for Mac-PDM.20 (mb). See table S2. 28

E_{ca} evaporation, water changes from liquid to vapour, from canopy storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S1, S3, S5, S7, S9, S23, S24. 27, 29, 31, 33, 35, 46, 50

$E_{ca}^{sn,cov}$ evaporation from snow-covered canopy ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S1. 27

$E_{ca}^{sn,free}$ evaporation from snow-free canopy ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S1. 27

$E_{ca,l}$ amount of water, from rainfall, accumulated on the vegetation that changes from liquid to vapor ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S3, S7, S10. 29, 33, 36

$E_{ca,max}$ maximum amount of water accumulated on the vegetation that changes from liquid to vapor ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S7. 33

$E_{ca,s}$ amount of water, from snowfall, accumulated on the vegetation that changes from solid to vapor ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S3, S7, S9. 29, 33, 35

E_{dew} liquid dew, accumulated on the ground or snow that changes from vapor to liquid ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S8, S10. 34, 36

E_{eq} evaporation at the equilibrium ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S24. 50

$E_{floodplain}$ evaporation from floodplain, it can be wetland ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S1. 27

E_{la} evaporation from lake storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S1, S32, S33, S45, S47. 27, 58, 59, 71, 73

$E_{la,pot}$ potential evaporation from lake storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S33, S47. 59, 73

E_{lfsm} leaf and stem surface evaporation ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S9. 35

E_{osw} evaporation from open water surfaces ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S57, S58. 83, 84

E_{re} evaporation from reservoir storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S1, S35, S38, S45. 27, 61, 64, 71

$E_{re,pot}$ potential evaporation from reservoir storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S38. 64

E_{ri} evaporation from river storage ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S1, S47. 27, 73

E_{sn} sublimation, water that changes from solid (snow and ice) to vapor ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S1, S8, S9, S11, S12. 27, 34, 35, 37, 38

E_{sn}^{covgr} sublimation on snow covered ground ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S11. 37

E_{sn}^{freegr} sublimation on snow free ground ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S11. 37

$E_{sn,so}$ sublimation on soil, water that changes from solid (snow and ice) to vapor ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S10. 36

E_{sn,SG_i} sublimation in a subgrid cell Müller Schmied et al. [34] ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See tables S8, S11. 34, 37

$E_{snunderca}$ sublimation under canopy, water that changes from solid (snow and ice) to vapor (L^3 L^{-2} T^{-1}). See table S10, S11. 36, 37

E_{so} soil evaporation, water changes from liquid to vapor (L^3 L^{-2} T^{-1}). See tables S1, S8, S11, S14, S23, S24, S25. 27, 34, 37, 40, 49–51

$E_{so,i}$ soil evaporation from soil layer i (L^3 L^{-2} T^{-1}). See table S14. 40

$E_{so,ice}$ soil evaporation from ground covered with ice (L^3 L^{-2} T^{-1}). See table S1. 27

$E_{so,l}^{sn,freegr}$ soil evaporation from snow free ground (L^3 L^{-2} T^{-1}). See tables S1, S24. 27, 50

E_{we} evaporation from wetland storage (L^3 L^{-2} T^{-1}). See tables S1, S39, S41. 27, 65, 67

$ET_{so,i}$ evapotranspiration from soil layer i (L^3 L^{-2} T^{-1}). See tables S1, S14, S24. 27, 40, 50

$ET_{so,i-1}$ evapotranspiration from soil layer $i-1$ (L^3 L^{-2} T^{-1}). See table S24. 50

f fractional coverage (unitless). See tables S5, S7. 31, 33

f_a fraction of the tile which is saturated and hence has aerodynamic resistance only (unitless). This represents 1 for lake, ice or snow-covered tiles (unitless). See tables S7, S24. 33, 50

f_{ah} roughness length of the surface beneath the canopy (unitless). See table S11. 37

f_{bu} fraction of the built-up areas (unitless). See tables S18, S20, S25. 44, 46, 51

f_{B_P} fraction of the area that receives precipitation rate greater than or equal to precipitation rate (unitless). See table S6. 32

f_{ca} fraction of the vegetation or canopy class in a grid cell (unitless). See tables S4, S5, S23, S24, S50, S52. 30, 31, 49, 50, 76, 78

$f_{ca,ex}$ fraction of the exposed canopy (unitless). See table S48. 74

$f_{ca,G}$ fraction of the vegetation in a grid cell. See table S24. 50

$f_{ca,max}$ maximum fraction of vegetation type including non-biological fraction (unitless). See table S5. 31

$f_{ca,n}$ vegetation fractional coverage for the n vegetation tile. See table S1. 27

$f_{ca,sn}$ canopy wetness-snow cover fraction (unitless). See tables S7, S11. 33, 37

$f_{ca,wet}$ fractional wetted area of the canopy (unitless). See table S23. 49

$f_{cons,A}$ ratio of consumption to abstraction (unitless). See tables S54, S55, S57, S58, S60, S61, S63, S64, S70, S71, S73, S74, S82, S83. 80, 81, 83, 84, 86, 87, 89, 90, 96, 97, 99, 100, 108, 109

$f_{day,ca,wet}$ fraction of the day-time when the canopy is wet (unitless). See table S23. 49

f_{drai} drainage decay factor (L^{-1}). See table S31. 57

f_F frozen ration in the uppermost soil layer (unitless). See table S11. 37

$f_{gw,use}$ sector- and cell-specific groundwater use fraction (unitless). See tables S53, S54, S56, S57, S59, S60, S61, S62, S63, S64, S69, S70, S72, S73. 79, 80, 82, 83, 85–90, 95–100

$f_{G,sat}$ fraction of the grid area which is saturated (unitless). It is determined by the topographic characteristics and soil moisture state of a grid cell. See tables S22, S58. 48, 84

$f_{G,unsat}$ fraction of the grid area which is unsaturated (unitless). See table S21. 47

f_{h2o} fraction of the ground covered by water (unitless). See tables S21, S25. 47, 51

f_{hg} hydrogeology-related factor (unitless). See table S30. 56

f_{if} factor interflow (unitless). See table S26. 52

f_{irr} storage reduction factor due to irrigation water abstraction (unitless). See tables S29, S39, S43, S52, S53, S56. 55, 65, 69, 78, 79, 82

$f_{irr,eff}$ irrigation efficieny (unitless). See tables S56, S58. 81, 82, 84

$f_{irr,sw,eff}$ country-specific surface water irrigation efficieny (unitless). See table S56. 82

f_{la} lake area fraction of the grid cell (unitless). See table S49. 75

f_{lost} proportion lost during delivery (unitless). See tables S55, S57, S58, S60, S61, S63, S64, S70, S73, S71, S74, S83. 81, 83, 84, 86, 87, 89, 90, 96, 97, 99, 100, 109

$f_{lost,irr}$ proportion lost during delivery from irrigation sector (unitless). See tables S61. 87, 90, 97, 100

f_{LAI} interception efficiency of leaf area index (unitless). See tables S4, S9. 30, 35

f_{pg} permafrost / glacier-related factor (unitless). See table S30. 56

f_P percentage that receives a precipitation rate greater than or equal to precipitation rate over the fractions of a grid cell (unitless). See table S6. 32

$f_{Pc,G}$ fraction of the grid cell occupied by convective precipitation (unitless). See tables S5, S20. 31, 46

f_{re} fraction of the reservoir fill equal to 1 at total storage capacity (unitless). See table S37. 63

f_r relief-related factor (unitless). See table S30. 56

$f_{ri,sat}$ river channel fraction in the saturated area (unitless). See table S22. 48

$f_{root,i}$ fraction of the roots per soil layer i (unitless). See table S24. 50

f_R runoff component factor (surface, interflow, baseflow) (unitless). See table S19. 45

$f_{R_{if,max}}$ fraction of the maximum interflow or subsurface flow (unitless). See table S31. 43

$f_{R_{in,0}}$ fraction of the area for which the maximum rate of infiltration (infiltration capacity) is less than rate of the infiltration (unitless). See table S24. 50

f_{sn} fraction of the ground covered by snow (unitless). See tables S7, S8, S10, S11, S12, S25. 33, 34, 36–38, 51

$f_{so,bare}$ fraction of the bare soil in a grid cell (unitless). See tables S1, S24. 27, 50

$f_{so,bare,sat}$ fraction of the bare soil in a grid cell that is saturated (unitless). See table S24. 50

$f_{so,dep}$ soil depletion fraction (unitless). See table S23. 49

$f_{so,tex}$ soil-texture-related factor (unitless). See table S30. 56

$f_{su,gr}$ fractional area of surface ground (unitless). See table S24. 50

f_{swb} fraction of the surface water bodies (lakes, wetlands, reservoirs) (unitless). See tables S32, S43. 58, 69

$f_{S_{so,max}}$ fraction of the maximum soil moisture (unitless). See table S31. 43

$f_{w,lf}$ coverage of the water on leaf (unitless). See table S7. 33

f_{we} fraction coverage of wetland in a grid cell (unitless). See tables S20, S25, S27, S39, S40, S41. 46, 51, 53, 56, 65–67

F mass gain due to frost ($\mathrm{L}^3\ \mathrm{L}^{-2}\ \mathrm{T}^{-1}$). See table S8, S13. 34, 39

F_{so} frozen soil (Θ). See table S13. 39

g_{ca} canopy conductance ($\mathrm{M\ L\ T}^{-3}\ \Theta^{-1}$). See table S23. 49

g_{ca}^{air} water vapor conductance from the canopy air to the atmosphere ($\mathrm{M\ L\ T}^{-3}\ \Theta^{-1}$). See table S23. 49

$g_{ca}^{H_s}$ vegetation sensible heat conductance ($\mathrm{M\ L\ T}^{-3}\ \Theta^{-1}$). See table S23. 49

g_{gr}^{ca} water vapor conductance from ground to canopy air ($\mathrm{M\ L\ T}^{-3}\ \Theta^{-1}$). See table S23. 49

g_{so} soil conductance ($\mathrm{M\ L\ T}^{-3}\ \Theta^{-1}$). See table S24. 50

g_{st}^{w} water vapor leaf level stomatal conductance ($\mathrm{M\ L\ T}^{-3}\ \Theta^{-1}$). See tables S7, S23. 33, 49

$g_{st,pot}$ potential leaf level stomatal conductance, non-water stressed ($\mathrm{M\ L\ T}^{-3}\ \Theta^{-1}$). See table S23. 49

G grid cell (1). See table S49. 75

GAV gross added value per country ($\mathrm{money\ T}^{-1}$). See tables S69, S70, S72, S73. 95, 96, 98, 99

h_{of} overflow height (L). See tables S34, S37. 60, 63

h_w water height (L). See tables S34, S37. 60, 63

$h_{w,we}$ wetland water level (L). See table S42. 68

H heat ($\mathrm{M\ L}^2\ \mathrm{T}^{-2}$). See table S12. 38

H_{atm} heat flux from the overlaying atmosphere ($\mathrm{M\ L}^2\ \mathrm{T}^{-3}\ \mathrm{L}^{-2}$). See table S13. 39

H_i excess or deficit of energy needed to change the soil layer temperature to freezing temperature ($\mathrm{M\ T}^{-2}$). See table S12. 38

H_l latent heat ($\mathrm{M\ T}^{-3}$). See tables S2, S7, S8, S10, S12. 28, 33, 34, 36, 38

$H_{l,E}$ latent heat of evaporation ($\mathrm{M\ T}^{-3}$). See tables S7, S8, S9, S11, S23, S24. 28, 33, 34, 37, 49, 50

$H_{l,E_{sn}}$ latent heat of sublimation ($\mathrm{M\ T}^{-3}$). See tables S7, S11. 33, 37

H_M latent heat of melt ($\mathrm{M\ T}^{-3}$). See tables S8, S12. 34, 38

$H_{M,ice}$ latent heat of ice ($\mathrm{M\ T}^{-3}$). See table S12. 38

H_{se} sensible heat flux ($\mathrm{M\ T}^{-3}$). See tables S10,S12. 36, 38

H_{sn} snow heat content ($\mathrm{M\ T}^{-3}$). See table S12. 38

$H_{sn,i}$ snow heat content of layer i ($\mathrm{M\ T}^{-3}$). See table S12. 38

H_{so} soil heat flux density ($\mathrm{M\ T}^{-3}$). See table S2. 28

H_{soTL} reciprocal areal heat capacity of the top soil layer (M T^{-3}). See table S12. 38

$H_{so,i}$ specific heat capacity of layer i (M L^2 T^{-2}). See table S13. 39

H_{tot} total surface heat capacity (M L^2 T^{-2}). See table S12. 38

i number of element or layer or space index (unitless). See tables S8, S12, S19. 34, 38, 45

i_{GS} growing-season index (unitless). See table S7. 33

I_0 initial intercepted canopy snow load (unitless). See table S9. 35

I_{cap} interception capacity (L). See table S3. 30

j weighting parameter that varies between 0 and 1. See table S52. 78

$J_{ele,A,ints,i}$ water abstraction intensity of powerplant i. See table S75. 101

$J_{ele,cons,ints,i}$ water consumption intensity of powerplant i. See table S76. 102

$J_{ele,coo,i}$ cooling system of powerplant i. See tables S75, S76. 101, 102

$J_{ele,pt,i}$ plant type of powerplant i. See tables S75, S76. 101, 102

$J_{ele,prod,i}$ thermal electricity production of powerplant i (MWh T^{-1}). See tables S75, S76. 101, 102

k soil hydraulic conductivity (L T^{-1}). See tables S13, S14, S21, S25, S27, S28. 39, 40, 47, 51, 53, 54

k_{3so} hydraulic conductivity from the third soil layer to the deeper soil (L T^{-1}). See tables S27, S28, S30. 53, 54, 56

k_{aq} hydraulic conductivity of the layer containing the water table (unitless). See table S30. 56

k_{bot} hydraulic conductivity of the bottom soil with free gravitational drainage (L T^{-1}). See table S31. 56, 57

k_j hydraulic conductivity at the interface j (unitless). See table S25. 51

k_b recession coefficient of the saturated/groundwater storage, producing baseflow /groundwater runoff (T^{-1}). See table S31. 57

k_0 recession coefficient of the unsaturated zone storage, upper outlet for fast interflow (T^{-1}). See table S26. 52

k_1 recession coefficient of the unsaturated zone reservoir, lower outlet for slow interflow (T^{-1}). See table S26. 52

k_{uz} recession coefficient of the unsaturated zone reservoir to the saturated/groundwater reservoir (groundwater recharge / percolation) (T^{-1}). See table S30. 56

k_{sat} effective saturated hydraulic conductivity (unitless). See tables S13, S25, S28. 39, 51, 54

k_{sat}^{gw} saturated hydraulic conductivity for groundwater (unitless). See table S31. 57

k_{th} thermal conductivity (unitless). See table S13. 39

K_f generatio ratio for interflow (unitless). See table S26. 52

K_{ff} generatio ratio for overflow of the uppermost layer, i.e. the Horton runoff (unitless). See table S22. 48

l_G distance between centers of neighboring grid cells (L). See table S46. 72

$l_{G,ri}$ distance between centers of neighboring grid cells, in river flow direction (L). See table S42. 68

l_{ri} length of river sections (L). See tables S45, S46. 25, 71, 72

$l_{ri,hom}$ length of homogeneous rivers segments (L). See table S46. 72

LAI leaf area index (L L^{-1}). See tables S4, S5, S6, S7, S9, S49. 30–33, 35, 74–77

LAI_{max} maximum leaf area index (L L^{-1}). See table S7. 33

LAI_{min} minimum leaf area index (L L^{-1}). See table S7. 33

LAI_{month} leaf area index of monthly vegetation (unitless). See table S7. 33

LC land cover (unitless). See table S19. 45

M snowmelt, water that changes from solid to liquid (L^3 L^{-2}T^{-1}). See tables S8, S11, S12, S14, S20, S21, S25, S39. 34, 37, 38, 40, 46, 47, 51, 65

M_{ca} snowmelt on canopy (L^3 L^{-2} T^{-1}). See table S9. 35

M_i snowmelt of layer i (L^3 L^{-2}T^{-1}). See table S12. 38

M_{in} flow of liquid water into layer i from the layer above (L^3 L^{-2} T^{-1}). See table S8. 34

M_{out} flow of liquid water out of layer i to the layer below (L^3 L^{-2} T^{-1}). See table S8. 34

M_{pot} potential snowmelt, amount of water that could change from solid to liquid independent of snow storage state (L^3 L^{-2}T^{-1}). See tables S8, S12. 34, 38

M_{SG_i} snowmelt in a subgrid cell Müller Schmied et al. [34] (L^3 L^{-2} T^{-1}). See table S8. 34

M_t snowmelt at the time t (L^3 L^{-2}T^{-1}). See table S12. 38

$M_{underca}$ snowmelt under canopy (L^3 L^{-2} T^{-1}). See table S10. 36

n linear reservoir cascade index (unitless). See table S46. 72

NR net radiation flux (M L^{-2} T^{-3}). See tables S2, S10, S12. 28, 36, 38

NR_n net radiation at crop surface (M J L^{-2} T^{-1}). See table S2. 28

P_{conv} relative amount of convective precipitation (L^3 L^{-2} T^{-1}). See table S21. 47

P_{dr} drip, dripping of water at the edge of the canopy (L^3 L^{-2} T^{-1}). See tables S5, S9. 31, 35

$P_{dr,l}$ dripping of rain at the edge of the canopy(L^3 L^{-2} T^{-1}). See table S5. 31

$P_{dr,s}$ dripping of snow at the edge of the canopy (L^3 L^{-2} T^{-1}). See tables S5, S9. 31, 35

P_{eff} effective precipitation reaching the soil surface (L^3 L^{-2} T^{-1}). See table S57. 83

P_{gr} total precipitation falls directly to the ground (snow or soil surface) (L^3 L^{-2} T^{-1}). See table S6. 32

$P_{gr,l}$ rainfall falls directly to the ground (L^3 L^{-2} T^{-1}). See table S6. 32

$P_{gr,l,calm}$ rainfall falling to the ground in calm areas (L^3 L^{-2} T^{-1}). See table S4. 30

$P_{gr,l,stormy}$ rainfall falling to the ground in stormy areas (L^3 L^{-2} T^{-1}). See table S4. 30

$P_{gr,s}$ snowfall falls directly to the ground (L^3 L^{-2} T^{-1}). See tables S6, S10. 32, 36

$P_{gr,s,calm}$ snowfall falling to the ground in calm areas (L^3 L^{-2} T^{-1}). See table S4. 30

$P_{gr,s,stormy}$ snowfall falling to the ground in stormy areas (L^3 L^{-2} T^{-1}). See table S4. 30

P_{int} precipitation intercepted by canopy (L^3 L^{-2} T^{-1}). See tables S4, S7, S3. 29–31, 33

$P_{int,l}$ interception of rainfall by canopy (L^3 L^{-2} T^{-1}). See tables S3, S4, S5, S10. 29–31, 36

$P_{int,l,calm}$ interception of rainfall by canopy in calm areas (L^3 L^{-2} T^{-1}). See table S4. 30

$P_{int,l,stormy}$ interception of rainfall by canopy in stormy areas (L^3 L^{-2} T^{-1}). See table S4. 30

$P_{int,max}$ calibration parameter of the canopy storage (L). See table S49. 76

$P_{int,s}$ interception of snowfall by canopy (L^3 L^{-2} T^{-1}). See tables S3, S4, S5, S9. 29–31, 35

$P_{int,s,calm}$ interception of snowfall by canopy in calm areas (L^3 L^{-2} T^{-1}). See table S4. 30

$P_{int,s,stormy}$ interception of snowfall by canopy in stormy areas (L^3 L^{-2} T^{-1}). See table S4. 30

P_{ra} rainfall (L^3 L^{-2} T^{-1}). See tables S4, S5, S6, S8, S9, S12, S20, S25, S39. 30–32, 34, 38, 46, 51, 65

$P_{mean,G}$ grid cell average precipitation (L^3 L^{-2} T^{-1}). See tables S5, S6. 31, 32

P_{sn} snowfall (L^3 L^{-2} T^{-1}). See tables S4, S5, S6, S9, S12. 30–32, 34, 35

$P_{s,ca}$ snowfall that is affected by the canopy interception and dripping (L^3 L^{-2} T^{-1}). See table S8. 34

P_{s,SG_i} snowfall in a subgrid (SG) cell Müller Schmied et al. [34] (L^3 L^{-2} T^{-1}). See table S8. 34

P_{th} throughfall, total precipitation falls to the ground through canopy spaces (L^3 L^{-2} T^{-1}). See tables S3, S5, S8, S9, S12, S14, S20, S21, S22, S25, S30. 29, 31, 34, 35, 38, 40, 46–48, 51, 56

$P_{th,l}$ rainfall falls to the ground through canopy spaces (L^3 L^{-2} T^{-1}). See tables S3, S5. 29, 31

$P_{th,s}$ snowfall falls to the ground through canopy spaces (L^3 L^{-2} T^{-1}). See tables S3, S5. 29, 31

P_{tot} total precipitation which includes rainfall and snowfall (L^3 L^{-2} T^{-1}). See tables S3, S4, S5, S7, S8, S9, S10, S20, S21, S25, S32, S33, S35, S38, S39, S47. 29–31, 33–36, 40, 46, 47, 51, 58, 59, 61, 64, 65, 73

PAR photosynthetically active radiation. It is assumed to be 50% of shortwave incoming solar radiation (M L^2 T^{-3}). See table S2. 28

PET total amount of water from transpiration, evaporation, interception losses, and sublimation that would occur if a sufficient water source were available (L^3 L^{-2} T^{-1}). See tables S2, S7, S11, S23, S24, S33, S38, S41, S47, S52, S57. 28, 33, 37, 49, 50, 59, 64, 67, 73, 78, 83

PET' overall PET flux reduced by canopy evaporation and evaporation from open-surface-bodies (L^3 L^{-2} T^{-1}). See table S24. 50

PET_{ows} total amount of water from transpiration, evaporation from the impervious areas, defined here as open water storage (L^3 L^{-2} T^{-1}). See tables S20, S24. 46, 50

PFT plant functional type (unitless). See tables S48, S49. 74, 75

POP population within the gridcell. See tables S59, S62. 85, 88

$POP_{liv,t}$ livestock type specific animal population within the gridcell. See table S68. 94

POP_u urban population within the gridcell. See tables S69, S70, S71, S72, S73, S74. 95–100

POP_u^c urban population of a country. See tables S69, S70, S71, S72, S73, S74. 95–100

q specific humidity of near-surface air (M M^{-1}). See tables S2, S7, S11, S23, S24. 28, 33, 37, 49, 50

q_{gr} specific humidity at ground surface (M M^{-1}). See tables S2, S23. 28, 49

q_{sat}^{ca} saturated specific humidity at canopy temperature (M M^{-1}). See tables S7, S11, S23, S24. 33, 37, 49, 50

q_{sat}^{gr} saturated specific humidity at ground surface (M M^{-1}). See tables S2, S11, S24. 28, 37, 50

$q_{sat}^{gr,sn}$ saturated specific humidity at ground surface with snow (M M^{-1}). See table S11. 37

q_{sat}^{sn} saturated specific humidity at snow (M M^{-1}). See table S7. 33

q_{so} relative humidity of the soil pore space (M M^{-1}). See table S24. 50

q_{su} relative humidity at the near-surface (M M^{-1}) dimensions. See table S11. 37

Q_{ef} environmental flow (L^3 T^{-1}). See tables S35, S56, S62, S72, S75. 61

Q_i vertical water flux from soil layer above, including infiltration in the upper layer and percolation and capillary rise in all layers (L^3 T^{-1}). See table S14. 40

Q_{i-1} vertical water flux to soil layer below, including infiltration in the upper layer and percolation and capillary rise in all layers (L^3 T^{-1}). See table S14. 40

$Q_{in,so}$ soil moisture flux (L^3 T^{-1}). See table S13. 39

$Q_{in,surf}$ surface moisture flux remaining after surface runoff has been removed (L^3 T^{-1}). See table S25. 51

Q_{iu} inflow upstream of a grid cell (L^3 T^{-1}). See tables S32, S35, S43, S45, S46, S54, S55, S56, S57, S59, S60, S61, S62, S63, S65, S66, S67, S68, S69, S70, S71, S72, S73. 58, 61, 69, 71, 72, 80–83, 85–89, 91–99

$Q_{iu,la}$ mean total annual inflow in a lake (L^3 T^{-1}). See tables S34, S43. 60, 69

$Q_{iu,mean}$ mean annual inflow in a reservoir (L^3 T^{-1}). See table S37. 63

$Q_{iu,re}$ inflow reservoir (L^3 T^{-1}). See tables S35, S37, S43. 61, 63, 69

$Q_{iu,tot,re}$ mean total annual inflow in a reservoir (L^3 T^{-1}). See table S37. 63

$Q_{iu,we,up}$ inflow from the wetland of an upstream grid cell (L^3 T^{-1}). See tables S39, S40, S45. 65, 66, 71

Q_{la} outflow from a lake (L^3 T^{-1}). See tables S32, S34, S43. 58, 60, 61

$Q_{la,global}$ outflow from a global lake (L^3 T^{-1}). See tables S32, S34, S39. 58, 60, 65

$Q_{la,local}$ outflow from a local lake (L^3 T^{-1}). See tables S32, S34, S39. 58, 60, 65

Q_{mean} outflow mean (L^3 T^{-1}). See table S35. 61

Q_{od} outflow downstream of a grid cell (L^3). See table S43. 69

$Q_{rv,up}$ outflow from rivulet storage of upstream grid cells (L^3 T^{-1}). See tables S40, S45. 66, 71

Q_{pf} preferential flow (L^3 T^{-1}). See tables S21, S29, S30. 47, 55, 56

Q_{re} outflow from a local reservoir that flows directly into the river channel of the cell (L^3 T^{-1}). See tables S35, S37, S39, S43, S46. 61, 63, 65, 69, 72

$Q^{irr}_{re,de}$ outflow from a irrigation reservoir driven by water demand in downstream cells (L^{3}T^{-1}). See table S37. 63

$Q_{re,global}$ outflow from a global reservoir (L^3 T^{-1}). See table S37. 63

$Q^{irr}_{re,global}$ outflow from a global reservoir designed for irrigation (L^3 T^{-1}). See table S37. 63

$Q^{non-irr}_{re,global}$ outflow from a global reservoir designed for other purposes than irrigation (L^3 T^{-1}). See table S37. 63

$Q^{purpose}_{re,global}$ outflow from a global reservoir for irrigation or others purposes (L^3 T^{-1}). See table S37. 63

$Q_{re,mean}$ long-term mean outflow from a reservoir (L^3 T^{-1}). See table S37. 63

$Q_{re,min}$ minimum outflow from reservoir (L^3 T^{-1}). See table S37. 63

$Q_{re,nd}$ non-damaging outflow from reservoir (L^3 T^{-1}). See table S37. 63

$Q_{re,norm}$ normal outflow from reservoir (L^3 T^{-1}). See table S37. 63

$Q_{re,local}$ outflow from a local reservoir (L^3 T^{-1}). See tables S43, S37, S46. 61, 63, 72

Q_{ri} streamflow (L^3). See tables S35, S43, S45, S46. 61, 69, 71, 72

$Q_{ri,in}$ streamflow inflow (L^3 T^{-1}). See tables S32, S35, S46. 58, 61, 72

$Q_{ri,n}$ outflow of river storage cascade n (L^3 T^{-1}). See table S43. 69

$Q_{ri,n-1}$ outflow of prior river storage cascade $n-1$ (L^3 T^{-1}). See table S43. 69

$Q_{ri,out}$ streamflow outflow (L^3 T^{-1}). See tables S32, S35, S46. 58, 61, 72

$Q_{ri,up}$ streamflow from the upstream grid cell (L^3 T^{-1}). See tables S40, S45. 66, 71

Q_{we} outflow from wetland (L^3 T^{-1}). See tables S39, S42. 65, 68

$Q_{we,global}$ outflow from a global wetland (L^3 T^{-1}). See tables S39, S42, S43. 65, 68, 69

$Q_{we,local}$ outflow from a local wetland (L^3 T^{-1}). See tables S32, S35, S39, S42. 58, 61, 65, 68

r_b bulk canopy resistance (T L^{-1}) . See tables S7, S11, S23. 33, 37, 49

r_{ca} vegetation or canopy aerodynamic resistance (T L^{-1}; for Mac-PDM.20 cms^{-1}). See tables S2, S7, S11, S23. 28, 33, 37, 49

$r_{ca,dry}$ aerodynamic resistance of the dry leaves (T L^{-1}). See table S23. 49

$r_{floodplain}$ floodplain resistance (unitless). See tables S11, S24. 37, 50

r_o architectural resistance (T L^{-1}). See tables S7, S23. 33, 49

r_{sn} snow resistance (unitless). See tables S7, S11, S23, S24. 33, 37, 49, 50

r_{so} bare soil resistance (T L^{-1}). See tables S11, S24. 37, 50

r_{tot} total resistance to water vapor transfer from the canopy to the canopy air (T L^{-1}) . See table S7. 33

r_w aerodynamic resistance (T L^{-1}; for Mac-PDM.20 cms^{-1}). See tables S2, S7, S23. 28, 33, 49

r_{wca} aerodynamic resistance under canopy air space (T L^{-1}). See tables S11, S24. 50

R_0 runoff 0 (L^3 L^{-2} T^{-1}). See table S20. 46

R_1 runoff 1 (L^3 L^{-2} T^{-1}). See table S20. 46

R_2 runoff 2 (L^3 L^{-2} T^{-1}). See table S20. 46

R_{bu} immediate runoff in urban areas (L^3 L^{-2} T^{-1}). See table S18. 44

R_{cr} capillary rise (L^3 L^{-2} T^{-1}). See tables S14, S26, S28, S29, S30. 40, 52, 54–56

$R_{cr,max}$ maximum capillary rise in a cell fraction, depending on height of ground water table and relative elevation of grid (L^3 L^{-2} T^{-1}). See table S28. 54

R_G total runoff of a grid (G) cell, a lag process between runoff generation and river routing for each grid cell (L^3 L^{-2} T^{-1}). See table S19, S44. 45, 70

$R_{gl,we,la}$ liquid runoff from glaciers, wetlands, and lakes / is this a part of saturation excess flow? (M L^{-2} T^{-1}). See table S20. 46

R_{gw} groundwater runoff, outflow of the groundwater storage (L^3 L^{-2} T^{-1}). See tables S14, S29, S30, S31, S32, S43, S54, S55, S56, S57, S59, S60, S61, S62, S63, S65, S66, S67, S68, S69, S70, S71, S72, S73. 40, 43, 44, 55–58, 69, 80–83, 85–89, 91–99

R_{gw}^{ri} groundwater runoff which recharges rivers (L^3 L^{-2} T^{-1}). See table S43. 69

$R_{gw,max}$ Maximum drainage when the water table depth is at the surface (L^3 L^{-2} T^{-1}). See table S31. 57

$R_{gw,rout}$ groundwater routing parameter for Mac-PDM.20 (unitless). See table S31. 57

$R_{gw,up}$ groundwater runoff from the upstream grid cell (L^3 L^{-2} T^{-1}). See tables S40, S45. 66, 71

R_{gwr} groundwater recharge (L^3 L^{-2} T^{-1}). See tables S14, S20, S29, S30, S54. 40, 43, 46, 55, 56

R_{gwr}^{swb} groundwater recharge below surface water bodies (L^3 L^{-2} T^{-1}). See tables S32, S35, S39. 58, 61, 65

$R_{gwr,i}$ groundwater recharge in layer i (L^3 L^{-2} T^{-1}). See table S14. 40

$R_{gwr,i-1}$ groundwater recharge in layer $i-1$ (L^3 L^{-2} T^{-1}). See table S14. 40

$R_{gwr,max}$ maximum groundwater recharge (L^3 L^{-2} T^{-1}). See tables S30, S39. 56, 65

$R_{gwr,min}$ minimum groundwater recharge (L^3 L^{-2} T^{-1}). See table S27. 56

R_G^n runoff concentration in a grid (G) cell, of a time step n, represents the lag process between runoff generation and river routing, for each grid cell. The runoff generated for each grid cell is routed to the corner of each cell and a concentration time is determined before it enters into the river storage (L^3 L^{-2} T^{-1}). See table S19. 45

R_G^1 runoff concentration in a grid cell of the first time step (L^3 L^{-2} T^{-1}). See table S44. 70

R_{ho} hortonian overland flow or infiltration excess overland flow occurs when precipitation exceeds the infiltration capacity of the soil. The water excess runs off over the ground surface because soil cannot absorb it (L^3 L^{-2} T^{-1}). See tables S20, S21, S25. 46, 47, 51

$R_{ho,calm}$ hortonian overland flow in calm areas (L^3 L^{-2} T^{-1}). See table S21. 47

$R_{ho,stormy}$ hortonian overland flow in stormy areas (L^3 L^{-2} T^{-1}). See table S21. 47

R_{if} interflow or subsurface flow, outflow of the soil storage that discharges into river, lake, and wetland storages. It doesn't reach the groundwater storage (L^3 L^{-2} T^{-1}). See tables S14, S17, S20, S26, S43. 40, 43, 46, 52, 69

$R_{if,fast}$ fast interflow from the unsaturated storage (L^3 L^{-2} T^{-1}). This does not flow from the soil storage. See tables S17, S18, S26. 43, 44, 52

$R_{if,max}$ maximum subsurface flow (L^3 L^{-2} T^{-1}). See table S31. 43

$R_{if,slow}$ slow interflow from the unsaturated storage (L^3 L^{-2} T^{-1}). This does not flow from the soil storage. See tables S17, S18, S26. 43, 44, 52

R_{in} infiltration (L^3 L^{-2} T^{-1}). See tables S8, S10, S14, S20, S18, S21, S25, S27, S57. 34, 36, 40, 44, 46, 47, 51, 53, 83

$R_{in,0}$ corresponding point infiltration capacity (L^3 L^{-2} T^{-1}). See tables S20, S24. 46, 50

$R_{in,BL}$ infiltration from the base layer (BL) (L^3 L^{-2} T^{-1}). See table S30. 56

$R_{in,cum}$ cumulative infiltration (L^3 L^{-2} T^{-1}). See table S25. 51

$R_{in,i}$ infiltration in layer i (L^3 L^{-2} T^{-1}). See tables S8, S14, S20, S25. 34, 40, 46, 51

$R_{in,i-1}$ infiltration in layer $i-1$ (L^3 L^{-2} T^{-1}). See tables S8, S25. 34, 51

$R_{in,L}$ infiltration from layer (L) (L^3 L^{-2} T^{-1}). See table S26. 52

$R_{in,max}$ infiltration capacity or the maximum rate of infiltration (L^3 L^{-2} T^{-1}). See tables S20, S21, S24, S25. 46, 47, 50, 51

$R_{in,over-so}$ infiltration over soil covered cell fraction (L^3 L^{-2} T^{-1}). See table S25. 51

$R_{in,pot}$ potential infiltration (L^3 L^{-2} T^{-1}). See table S25. 51

$R_{in,r}$ re-infiltration (L^3 L^{-2} T^{-1}). See table S14. 40

$R_{in,sat}$ infiltration at saturation level (L^3 L^{-2} T^{-1}). See table S26. 52

$R_{in,TL}$ infiltration from the top soil layer (TL) (L^3 L^{-2} T^{-1}). See table S20. 46

R_{of} runoff induced by the over saturation at the surface / is this similar to saturation excess flow (L^3 L^{-2} T^{-1}). See table S20, S56. 46, 82

R_{pe} percolation or drainage, infiltrated water into the soil that runs off toward the groundwater storage (L^3 L^{-2} T^{-1}). See tables S14, S18, S25, S26, S27, S29, S30, S39. 40, 51–53, 55, 56, 65

$R_{pe,h2osfc}$ bottom drainage from the surface water store (L^3 L^{-2} T^{-1}). See table S25. 51

R_s water that leaves the surface layer (topsoil layer) e.g. as overland flow / fast runoff in ISIMIP2b (L^3 L^{-2} T^{-1}). See table S16. 41, 42

R_{sat} saturation excess overland flow occurs when the soil is saturated or filled with water, and any additional precipitation or irrigation causes runoff. (L^3 L^{-2} T^{-1}). See tables S20, S18, S22, S25. 44, 46, 48, 51

R_{sb} sum of water that flows out from subsurface layer(s) including the groundwater layer (if present). Equals groundwater runoff in case of a groundwater layer below only one soil layer in ISIMIP2b (L^3 L^{-2} T^{-1}). See table S17. 41, 43

R_{sn} snow runoff, melted water that runs off on the ground surface covered with snow (L^3 L^{-2} T^{-1}). See table S12. 38

$R_{snwcp,ice}$ ice runoff from snow-capped surfaces / is this a part of saturation excess flow (M L^{-2} T^{-1}). See table S20. 46

$R_{sof,i}$ infiltration from soil layer i (L^3 L^{-2} T^{-1}). See table S14. 40

$R_{sof,i-1}$ infiltration from soil layer $i-1$ (L^3 L^{-2} T^{-1}). See table S8. 40

R_{su} surface runoff or overland flow, water excess that runs off over the ground surface as Hortonian overland flow and (rainfall rate dependent) / or Saturation excess overland flow (soil saturated or filled with water) (L^3 L^{-2} T^{-1}). See tables S14, S16, S18, S20, S22, S25, S32, S43, S44, S46. 40, 42, 44, 46, 48, 51, 58, 69, 70, 72, 85

$R_{su,ice}$ ice water runoff at the land model resolution / is this the water that runs off over the ground surface covered with ice / part of saturation excess flow (M L^{-2} T^{-1}). See table S20. 46

$R_{su,l}$ liquid water runoff at the land model resolution / is this the saturation excess flow (M L^{-2} T^{-1}). See tables S20, S43. 46, 69

$R_{su_{LC,R}}$ runoff generated for each cell that is routed towards the corner of each cell, with a concentration time, depending on land cover class, slope, and runoff component (surface, interflow, or baseflow). Runoff generated for a grid cell is then calculated using a triangular-weighting-function (L^3 L^{-2} T^{-1}). See tables S19, S44. 45, 70

R_{tot} total runoff from land includes surface runoff, subsurface runoff, and groundwater recharge (L^3 L^{-2} T^{-1}). See tables S14, S20, S18, S30, S35, S37, S43, S46. 40, 44, 46, 56, 61, 63, 69, 72

$R_{tot,ISIMIP2b}$ total runoff ISIMIP2b, it includes surface runoff and subsurface runoff (L^3 L^{-2} T^{-1}). See table S15. 41

s_{ri} river bed slope (L L^{-1}). See table S46. 72

$s_{vp,sat}$ slope of saturated vapour pressure (M L^{-1} T^{-2} Θ^{-1}). See table S2. 28

$s_{we,mean}$ mean slope within wetland (L). See table S42. 68

S_{buf} storage buffer (L^3 L^{-2} T^{-1}). See table S57. 83

S_{ca} canopy compartment that retains water from precipitation and loses water through throughfall, stemflow and interception loss (evaporation) (L^3 L^{-2}). See tables S3, S4, S5, S7, S20, S23, S26. 29–31, 33, 46, 49, 52

$S_{ca,dif}$ the difference between the canopy storage capacity and the water stored on the canopy (L^3 L^{-2}). See table S5. 31

$S_{ca,int}$ canopy compartment that retains water after precipitation is intercepted by canopy (L^3 L^{-2}). See table S5. 31

$S_{ca,l}$ canopy compartment that retains rainfall and loses water through throughfall, stemflow and evaporation (L^3 L^{-2}). See tables S3, S4, S5. 29–31

$S_{ca,max}$ maximum value of canopy storage compartment (L^3 L^{-2}). See tables S4, S5, S7, S20, S23, S49, S51. 30, 31, 33, 46, 49, 75, 77

$S_{ca,min}$ minimum value of canopy storage compartment (L^3 L^{-2}). See table S49. 75

$S_{ca,p}$ interception storage parameter (unitless). See tableS49. 75

$S_{ca,s}$ canopy compartment that retains snowfall and loses water through throughfall, stemflow and sublimation (L^3 L^{-2}). See tables S3, S4, S5. 29–31

S_{cons} conservative storage limit (unitless). See table S37. 63

S_f storage of the fast response reservoir (L^3 T^{-1}). See table S22, S26. 48, 52

S_{flood} flood storage limit (unitless). See table S37. 63

S_{ftr} specified threshold of the fast response reservoir (L^3 T^{-1}). See table S22. 48

S_{gw} groundwater storage (L^3 L^{-2}). See tables S29, S31, S53. 55, 57, 79

$S_{gw,nrw}$ groundwater storage non-renewable (L^3 L^{-2}). See table S29. 55

$S_{gw,rw}$ groundwater storage renewable (L^3 L^{-2}). See tables S29, S31, S53, S59, S69. 55, 57, 79, 85, 95

S_i storage of i element = overland, baseflow, river or wetland (unitless). See table S52. 78

S_{ice} ice storage (L^3 L^{-2}). See table S12. 38

$S_{ice,sn,i+1}$ solid water stored in the upper snow layer $(i+1)$, i is the snow layer index (L^3 L^{-2}). See table S11. 37

S_{la} lake storage (L^3 L^{-2}). See tables S32, S33, S34, S47. 58–60, 73

$S_{la,global}$ global lake storage (L^3 L^{-2}). See tables S32, S34. 58, 60

$S_{la,global,max}$ maximum global lake storage (L^3 L^{-2}). See tables S32, S49. 58, 77

$S_{la,local}$ local lake storage (L^3 L^{-2}). See tables S32, S34. 58, 60

$S_{la,local,max}$ maximum local lake storage (L^3 L^{-2}). See tables S32, S34, S49. 58, 60, 77

$S_{la,max}$ maximum amount of water in the lake storage (L^3 L^{-2}). See table S34. 60

$S_{l,sn,i+1}$ liquid water stored in the upper snow layer $(i+1)$, i is snow layer index (L^3 L^{-2}). See table S11. 37

S_{norm} normal storage limit (unitless). See table S37. 63

S_{paddy} storage of flooded paddy rice (L^3 L^{-2}). See table S22. 82

S_{pon} ponding storage (sealed areas) (L^3 L^{-2}). See table S20, S24. 46, 50

$S_{pon,max}$ maximum ponding zone storage (L). See tables S20, S24. 46, 50

S_{re} reservoir storage (L^3 L^{-2}). See tables S35, S37, S38. 61, 63, 64

$S_{re,act}$ actual reservoir storage (L^3). See table S35. 61

$S_{re,C}$ reservoir storage capacity (L^3). See tables S35, S37, S49. 61, 63, 77

$S_{re,global}$ global reservoir storage (L^3 L^{-2}). See tables S35, S43. 63, 69

$S_{re,global}^{purpose}$ global reservoir storage for irrigation or others purposes (L^3 L^{-2}). See table S37. 63

$S_{re,local}$ local reservoir storage (L^3 L^{-2}). See table S37. 63

$S_{re,max}$ maximum water amount of reservoir storage (L^3 L^{-2}). See tables S35, S37. 61, 63

$S_{re,tot}$ total reservoir storage capacity (L^3). See table S37. 63

S_{ri} river storage (L^3 L^{-2}). See tables S43, S45, S46. 69, 71, 72

$S_{ri,n}$ state of the n^{th} cascade in the river storage (L^3 L^{-2}). See tables S43, S46, S56. 69, 72, 82

S_{rv} rivulet storage that collects water of small creeks, streams. (L^3 L^{-2}). See tables S19, S44. 45, 70

S_{rz} root zone water storage (L^3 L^{-2}). See tables S7, S18, S24. 33, 44, 50

$S_{rz,max}$ maximum root zone water storage or root zone storage capacity (L^3 L^{-2}). See tables S7, S18, S24, S51. 33, 44, 50, 77

S_{sn} snow storage, compartment that accumulates snow below freezing temperature and loses snow by melting and sublimation (L^3 L^{-2}). See tables S8, S11, S12. 34, 37, 38

S_{soc} compartment that accumulates snow on canopy below freezing temperature and loses snow by melting and sublimation (L^3 L^{-2}). See tables S9, S10. 35, 36

$S_{sn,i}$ snow storage of layer i (L^3 L^{-2}). See table S12. 38

$S_{sn,i}$ number of snow layers i (unitless). See tables S8,S12. 34, 38

$S_{sn,ice}$ frozen water content in snow storage (L^3 L^{-2}). See table S8. 34

$S_{sn,l}$ liquid water content in snow storage (L^3 L^{-2}). See tables S8, S12. 34, 38

S_{sn,SG_i} subcompartment that accumulates snow in subgrid cells below freezing temperature and loses snow by melting and sublimation Müller Schmied et al. [34] (L^3 L^{-2}). See table S12. 38

S_{suc} compartment that accumulates snow under canopy below freezing temperature and loses snow by melting and sublimation (L^3 L^{-2}). See table S10. 36

S_{so} soil water storage compartment (L^3 L^{-2}). See tables S14, S20, S18, S22, S23, S24, S27, S30, S49, S57. 28, 40, 44, 46, 48–50, 56, 77, 83

$S_{so,3L}$ soil moisture or soil water content for the third layer (3L) (L^3). See table S27. 43

$S_{so,a,i}$ simulated actual soil moisture content of layer i (L^3 L^{-3}). See tables S52, S56. 78

$S_{so,crit}$ critical volumetric soil moisture concentration that corresponds to a critical water suction potential (L^3 L^{-2}). See tables S23, S24, S57. 49, 50, 83

$S_{so,cur}$ current soil water content or current soil moisture (L^3 L^{-2}). See table S52. 78

S_{so,F_i} frozen soil water or frozen soil moisture at layer index i (L^3 L^{-2}). See tables S14, S29. 40, 55

$S_{so,FC}$ soil water content at field capacity (FC) (L^3 L^{-2}). See tables S2, S20, S23, S24, S25, S30, S57. 28, 46, 49–51, 53, 56, 78, 83

$S_{so,FL}$ soil water content in first layer (FL) (L^3 L^{-2}). See table S24. 50

$S_{so,i}$ soil storage in layer i (L^3 L^{-2}). See tables S14, S24, S25. 40, 50, 51

$S_{so,ini}$ initial soil water content or soil moisture (L^3 L^{-2}). See table S25. 51

$S_{so,l,i}$ liquid soil storage in layer i (L^3 L^{-2}). See table S14. 40

$S_{so,max}$ maximum soil storage (L^3 L^{-2}). See tables S20, S23, S24, S30. 46, 49, 50, 56

$S_{so,max,i}$ maximum soil moisture content of layer i (L^3 L^{-3}) See table S25. 51, 76

$S_{so,pot}$ potential soil water content or soil moisture (L^3 L^{-2}). See table S25. 51

$S_{so,max,3L}$ maximum soil moisture or soil water content of the third soil layer (3L) (L). See tables S17, S30. 43, 56

$S_{so,r,i}$ residual soil moisture content of layer i ($\mathrm{L}^3\ \mathrm{L}^{-3}$) See tables S24, S25. 50, 51

$S_{so,ready}$ ready available soil water content ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See table S57. 78, 83

$S_{so,rel}$ relative soil water content or soil moisture ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See tables S21, S23, S24, S25. 47, 49–51

$S_{so,sat,FL}$ soil water content at saturation in first layer ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See table S25. 51

$S_{so,SG}$ subgrid soil storage ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See table S20. 46

$S_{so,SG,min}$ minimum subgrid soil moisture storage ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See table S20. 46

$S_{so,SG,max}$ maximum subgrid soil moisture storage ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See table S20. 46

$S_{so,sat}$ soil water content at saturation (SAT) ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See tables S21, S25, S26, S28, S30, S57. 47, 51–54, 56, 78

$S_{so,sat,p}$ soil water content at saturation parameter (unitless). See tables S49, S50. 75, 76

$S_{so,t,i}$ target soil moisture content of layer i ($\mathrm{L}^3\ \mathrm{L}^{-3}$). See tables S52, S56. 78

$S_{so,T2L}$ volumetric soil moisture content or soil storage for the top two layers (T2L) (L^3). See tables S20, S57. 46, 83

$S_{so,TL}$ total available water capacity for the top soil layer ($\mathrm{L}^3\ \mathrm{L}^{-1}\ \mathrm{L}^{-2}$). See tables S18, S22, S49. 44, 48, 76

$S_{so,tot}$ total soil water content or total soil moisture ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See tables S20, S21, S23, S24, S25, S26, S28, S30. 46, 47, 49–52, 54, 56

$S_{so,uF}$ unfrozen soil water or unfrozen soil moisture ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See table S14. 39

S_{so,uF_i} unfrozen soil water or unfrozen soil moisture at layer index i ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See tables S14, S29. 40, 55

$S_{so,uF_{i,gw}}$ unfrozen soil water or unfrozen soil moisture at the layer i that has groundwater table ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See table S30. 56

$S_{so,w,i}$ soil moisture limit above which the actual transpiration is equated with the PET at layer i ($\mathrm{L}^3\ \mathrm{L}^{-3}$). See table S24. 50

$S_{so,WP}$ soil water content at wilting point (WP) ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See tables S20, S21, S23, S25, S26, S30, S52, S57. 46, 47, 49, 51, 52, 56, 78, 83

$S_{so,F}$ frozen soil water or frozen soil moisture ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See table S14. 39

S_{uz} unsaturated zone storage ($\mathrm{L}^3\ \mathrm{L}^{-2}$), with two possible outflows: fast interflow and slow interflow. See tables S26, S30. 52, 56

$S_{uz,thr}$ threshold for the unsaturated zone storage (L) which triggers fast interflow. See table S26. 52

$S_{w,first}$ the water storage at the beginning of the year ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See table S37. 63

S_{we} wetland storage, compartment filled by precipitation or inflow and emptied by evapo(transpi)ration, outflow and groundwater recharge ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See tables S39, S42, S56. 65, 68, 82

$S_{we,global}$ global wetland storage ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See tables S39, S42. 65, 68

$S_{we,global,max}$ maximum global wetland storage ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See tables S39, S49. 65, 77

$S_{we,local}$ local wetland storage ($\mathrm{L}^3\ \mathrm{L}^{-2}$). See tables S39, S42. 65, 68

$S_{we,local,max}$ maximum local wetland storage (L^3 L^{-2}). See tables S39, S42, S49. 65, 68, 77

S_y specific yield depending on soil properties and water table location (M L^{-1}). See table S29. 55

SAI exposed stem area index (unitless). See tables S4, S6. 30, 32

SR incoming solar radiation (M T^{-3}). See table S2. 28

SWE snow water equivalent (L^3 L^{-2} T^{-1}). See tables S10, S13. 36, 39

t time (T). See tables S3, S7, S8, S9, S10, S11, S13, S14, S19, S25, S29, S31, S32, S34, S35, S39, S43, S44, S46. 29, 33–37, 39, 40, 45, 46, 51, 55, 57, 58, 60, 61, 65, 69, 70, 72

t_{ret} topographic index of the retention time (L). See tables S43, S45, S46. 69, 71, 72

$t_{ri,fast}$ property of the fast reservoir (25 T L^{-1}). See table S43. 69

$t_{ri,slow}$ property of the slow reservoir (3 T L^{-1}). See table S43. 69

$t_{ri,stream}$ property of the stream reservoir (0.24 T L^{-1}). See tables S43, S45, S46. 69, 71, 72

t_{we} lag time for outflow computation of the wetland storage (T). See table S42. 68

t_{day} day of year (L). See table S12. 38

t_{year} number of days in the actual year (L). See tables S2, S12. 28, 38

tri_x triangular function (unitless). See table S19. 45

T transpiration, water evaporated by plants through their stomata (L^3 L^{-2} T^{-1}). See tables S1, S14, S23, S25, S52. 27, 40, 49, 51, 78

T_{act} actual transpiration, the initial water evaporated by plants through their stomata (L^3 L^{-2} T^{-1}). See table S23. 49

$T_{ca}^{sn,cov}$ transpiration of snow-covered canopy (L^3 L^{-2} T^{-1}). See table S23. 49

$T_{ca}^{sn,free}$ transpiration of snow-free canopy (L^3 L^{-2} T^{-1}). See table S23. 49

T_i water removed by transpiration in each layer i (L^3 L^{-2} T^{-1}). See table S14. 40

T_{max} maximum transpiration (L^3 L^{-2} T^{-1}). See table S23. 49

T_{pot} potential transpiration, water evaporated by plants through their stomata, if a sufficient water source is available (L^3 L^{-2} T^{-1}). See table S23. 49

$U_{ca,sn}$ canopy snow unloading from wind speed and above-freezing temperatures (L^3 L^{-2} T^{-1}). See table S9. 35

v flow velocity (L T^{-1}). See tables S45, S46. 71, 72

v_{mean} mean flow velocity (L T^{-1}). See table S46. 72

W wind speed (L T^{-1}). See tables S2, S7, S11, S23, S24. 28, 33, 37, 49, 50

W_2 wind speed at 2m height (L T^{-1}). See tables S2, S23, S24. 28, 49, 50

w_{sfc} balance of surface water (M). See table S25. 51

X irrigation efficiency (unitless). See tables S54, S55, S57. 80, 81, 83

X_{conv} conveyance efficiency (unitless). See table S57. 83

X_{dom} water use efficiency of the domestic sector (unitless). See tables S60, S63. 86, 89

X_{et} evaporation efficiency (unitless). See table S2. 28

X_{ind} water use efficiency of the industrial sector (unitless). See tables S70, S73. 96, 99

z gravitational potential (M L^{-1} T^{-2}). See table S13. 39

Z vertical coordinate (L). See table S28. 54

Z_{cr} matric head induced by capillary action (L). See table S28. 54

α empirical parameter (unitless). See tables S13, S24, S25, S46, S52. 39, 50, 51, 72, 78

β empirical shape parameter. It needs to be fitted during the calibration processes (unitless). See tables S13, S18, S21, S24, S25, S31, S46. 39, 44, 47, 50, 51, 57, 72

γ psychrometric constant. See tables S2, S7, S11, S23, S24. 28, 33, 37, 49, 50

Λ_{rz} root zone soil moisture stress parameter (unitless). See table S7. 33

Γ gamma function (unitless). See tables S31, S46. 57, 72

δ time variation (unitless). See tables S3, S8, S9, S10, S11, S12, S13, S14, S20, S24, S25, S28, S29, S30, S32, S35, S39, S43, S44, S45, S46. 29, 34–36, 38–40, 46, 50, 51, 54–56, 58, 61, 65, 69–72

Δt time step (T). See tables S4, S5, S7, S8, S9, S10, S11, S12, S13, S20, S25, S30, S34, S35, S37, S43, S45, S46, S53, S59, S69. 30, 31, 33–39, 46, 51, 53, 56, 60, 63, 71, 72, 78, 79, 85, 95

ϵ_c empirical constant (17.8), found by calibration [25] (unitless). See table S2. 28

ζ_{sn} snow layer thickness of layer j (L^3 L^{-2}). See table S12. 38

$\zeta_{so,i}$ soil layer thickness of layer i (L). See table S13, S52. 39, 78

η parameter (unitless). See table S31. 57

θ air temperature (Θ). Note: in the equations, air temperature is in Kelvin degrees. See tables S2, S7, S8, S9, S10, S11, S12, S25. 28, 33–36, 38, 51

$\theta_{day,max}$ daily maximum air temperature (Θ). See table S2. 28

$\theta_{day,mean}$ daily mean air temperature (Θ). See table S2. 28

$\theta_{day,min}$ daily minimum air temperature (Θ). See table S2. 28

θ_f triple point temperature for water Θ). See table S12. 38

θ_{freeze} freezing temperature (Θ). See table S12. 38

θ_{min} minimum air temperature (Θ). See table S7. 33

$\theta_{,month}$ mean monthly air temperature (Θ). See table S2. 28

θ_M air temperature above 0 (Θ). See tables S8, S12. 34, 38

θ_{sn} snow temperature (Θ). See table S12. 38

$\theta_{sn,i}$ snow temperature of layer i (Θ). See table S12. 38

θ_{so} soil temperature (Θ). See tables S12, S23, S25. 38, 49, 51

$\theta_{so,i}$ soil temperature of soil layer i (Θ). See table S13. 39

$\theta_{so,i+1}$ soil temperature of soil layer $i+1$ (Θ). See table S13. 39

θ_{su} temperature of the surface layer (Θ). See table S10. 36

θ_{SG_i} mean air temperature in a subgrid cell Müller Schmied et al. [34] (Θ). See tables S8, S12, S13. 34, 38, 39

θ_{veg} vegetation temperature (Θ). See table S23. 49

ι storage parameter, defined as the hydraulic retention time of a single linear reservoir segment of length l_{ri}. It can be calculated as the average travel time of water through a single river segment (unitless). See table S46. 72

κ calibration constant (2.3×10^3) that approximately compensates for the differences in advection or in vapour transfer effect [25] (unitless). See tables S2. 28

κ_{gw} retention time for water in the groundwater storage (L). See table S30. 57

κ_{ol} retention time for water in the overland flow storage (L). See table S44. 45

κ_{ri} retention time for water in the river flow storage (L). See tables S43, S46. 69, 72

λ water distribution uniformity scalar, depending on the irrigation system. See table S57. 78

ν decay coefficient (T). See table S13. 39

$\Pi_{R_{in}}$ infiltration shape parameter (unitless). See tables S20, S24. 46, 50

ρ_{air} density of atmospheric air (M L^{-3}). See tables S2, S7, S11, S23, S24. 28, 33, 37, 49, 50

ρ_{ice} intrinsic density of ice (M L^{-3}). See table S12. 38

$\rho_{sn,i}$ snow density of layer i (M L^{-3}). See table S12. 38

ρ_w density water (M L^{-3}). See tables S8, S9, S10, S11. 34, 36, 37, 78

σ subgrid topographical variability (unitless). See table S20. 46

τ time constant (T). See table S25. 51

υ scale parameter (unitless). See tables S31, S24. 50, 57

ϕ_{so} soil porosity (L^3). See tables S13, S20, S22. 39, 46, 78

χ constant, energy needed to melt ice (M L^{-2} T^{-2} L^{-3}). See table S12. 38

χ_f energy of fusion (M L^2 T^{-3} L^{-2}). See table S12. 38

χ_M energy flux given to the pack because of liquid water refreezing or removed from the pack during melt (M L^{-2} T^{-2} L^{-3}). See tables S8, S10. 34, 36

χ_{rs} energy flux advected to the snowpack by rain or snow (M L^{-2} T^{-2} L^{-3}). See tables S10, S12. 36, 38

χ_{to} total energy (M L^2 T^{-2} L^{-2}). See table S12. 38

Ψ matric potential(M L^{-1} T^{-2}). See table S13. 39

Ψ_i soil matric potential of layer i (M L^{-1} T^{-2}). See table S28. 54

Ψ_{jwt} matric potential of the layer directly above the water table (M L^{-1} T^{-2}). See table S30. 56

Ψ_{sat} saturated soil matric potential (M L^{-1} T^{-2}). See table S13. 39

$\Psi_{sat,i}$ saturated soil matric potential of layer i (M L^{-1} T^{-2}). See table S28. 54

Ψ_{wt} matric potential at the water table (i.e. 0) (M L^{-1} T^{-2}). See table S30. 56

Table S1. Actual evapotranspiration (AET)

Model	Equation
CLM4.5	$AET = E_{ca} + E_{so} + T$
CLM5.0	$AET = E_{ca} + E_{so} + T$
CWatM	$AET = E_{ca} + E_{la} + E_{re} + E_{ri} + E_{sn} + E_{so} + T$
DBH	$AET = E_{ca} + E_{so} + T$
H08	$AET = E_{so}$
JULES-W1	$AET = E_{ca} + E_{sn} + E_{so} + T$
LPJmL	$AET = E_{ca} + E_{la} + E_{re} + E_{ri} + E_{sn} + E_{so} + T$
Mac-PDM.20	$AET = E_{ca} + E_{so}$
MATSIRO	$AET = E_{ca}^{sn,cov} + E_{ca}^{sn,free} + E_{sn} + E_{so,ice} + E_{so,l}^{sn,freegr}$
mHM	$AET = E_{ca} + ET_{so,i}$
MPI-HM	$AET = A_{irr} + E_{so} + E_{we} + T$
ORCHIDEE	$AET = E_{ca} + E_{floodplain} + E_{sn} + E_{so}$
PCR-GLOBWB	$AET = E_{ca} + E_{la} + E_{re} + E_{ri} + E_{so}$
VIC	$AET = \sum_{n=1}^{N} f_{ca,n} \times (E_{ca} + T) + f_{so,bare} \times E_{so}$
	for: $\sum_{n=1}^{N+1} f_{ca,n} = 1$ see details [28]; [29]; [20]
WaterGAP2	$AET = E_{ca} + E_{la} + E_{re} + E_{sn} + E_{so} + E_{we}$
WAYS	$AET = E_{so}$

Table S2. Potential evapotranspiration (PET)

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$PET = \frac{0.408 \times s_{vp,sat} \times (NR_n - H_{so}) + \gamma \times \frac{900}{\theta} \times W_2 \times (e_{sat} + e_{act})}{s_{vp,sat} + \gamma \times (1 + 0.34 \times W_2)}$
DBH	not represented
H08	$PET = \begin{cases} \rho_{air} \times r_w \times (q_{sat}^{gr} - q_{gr}), & \text{snow present} \\ \rho_{air} \times r_w \times (q_{sat}^{gr} - q_{gr}) \times \frac{(1+zeta \times X_{et})}{(1+zeta)}, & \text{snow absence} \end{cases}$ Where zeta is ζ in Milly [31]. And $X_{et} = \begin{cases} 1.0, & 0.75 \times S_{so,FC} < S_{so} \\ \frac{W \times S_{so}}{0.75 \times S_{so,FC}}, & 0.75 \times S_{so,FC} > S_{so} \end{cases}$
JULES-W1	$PET = \frac{0.408 \times s_{vp,sat} \times (NR_n - H_{so}) + \gamma \times \frac{900}{\theta} \times W_2 \times (e_{sat} + e_{act})}{s_{vp,sat} + \gamma \times (1 + 0.34 \times W_2)}$
LPJmL	$PET = \frac{s_{vp,sat}}{(s_{vp,sat} + \gamma \times \theta)} \times \frac{2 \times PAR}{H_{l,E}}$
Mac-PDM.20	$PET = \frac{s_{vp,sat} \times (NR_n - H_{so}) + \gamma \times c_{air} \times (e_{sat} - e_{sat,dew}) \times r_w}{(597.3 - (\theta - 273.15) \times 0.564) \times (s_{vp,sat} + \gamma \times (1 + \frac{r_w}{r_{ca}}))}$
MATSIRO	$PET = \frac{0.408 \times s_{vp,sat} \times (NR_n - H_{so}) + \gamma \times \frac{900}{\theta} \times W_2 \times (e_{sat} + e_{act})}{s_{vp,sat} + \gamma \times (1 + 0.34 \times W_2)}$ (used only in crop growth scheme)
mHM	$PET = \kappa \times SR \times ((\theta_{day,mean} - 273.15) + \epsilon_c) \times \sqrt{\theta_{day,max} - \theta_{day,min}})$. See [25]
MPI-HM	$PET = \frac{0.408 \times s_{vp,sat} \times (NR_n - H_{so}) + \gamma \times \frac{900}{\theta} \times W_2 \times (e_{sat} + e_{act})}{s_{vp,sat} + \gamma \times (1 + 0.34 \times W_2)}$
ORCHIDEE	$PET = \rho_{air} \times C_{bulk} \times W \times (q_{sat}^{gr} - q)$. See [33]; [31]
PCR-GLOBWB	$PET = 1 \times 0.165 \times 216.7 \times t_{year} \times \frac{e_{sat}}{(\theta_{,month} - 273.15) + 273.3}$
VIC	$PET = \frac{0.408 \times s_{vp,sat} \times (NR_n - H_{so}) + \rho_{air} \times c_{air} \times \frac{(e_{sat}+e_{act})}{r_w}}{s_{vp,sat} + \gamma}$
WaterGAP2	$PET = C_{PT} \times \frac{s_{vp,sat}}{s_{vp,sat} + \gamma} \times NR$ $C_{PT} = \begin{cases} 1.26, & \text{G = humid} \\ 1.74, & \text{G = arid or semi-arid} \end{cases}$ $s_{vp,sat} = \frac{4098 \times 0.6108 \times \exp(\frac{17.27 \times (\theta - 273.15)}{\theta - 35.85})}{(\theta - 35.85)^2}$ $\gamma = \frac{0.0016286 \times 101.3}{H_l}$ $H_l = \begin{cases} 2.501 + 0.334(\text{MJ kg}^{-1}), & \theta < 273.15 \\ 2.501 - 0.002361(\text{MJ kg}^{-1}) \times (\theta - 273.15), & \theta \geq 273.15 \end{cases}$. See [13]
WAYS	$PET = \frac{0.408 \times s_{vp,sat} \times (NR_n - H_{so}) + \gamma \times \frac{900}{\theta} \times W_2 \times (e_{sat} + e_{act})}{s_{vp,sat} + \gamma \times (1 + 0.34 \times W_2)}$

Table S3. Canopy storage (S_{ca})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	$\frac{\delta S_{ca}}{\delta t} = P_{int} - (P_{th,l} + P_{th,s}) - E_{ca}$	P_{int}	$P_{th,l}$ $P_{th,s}$ E_{ca}
CLM5.0	$\frac{\delta S_{ca}}{\delta t} = P_{int} - (P_{th,l} + P_{th,s}) - E_{ca}$	P_{int}	$P_{th,l}$ $P_{th,s}$ E_{ca}
CWatM	$\frac{\delta S_{ca}}{\delta t} = P_{tot} - P_{th} - E_{ca}$	P_{tot}	E_{ca} P_{th}
DBH	$\frac{\delta S_{ca}}{\delta t} = P_{tot} - P_{th} - E_{ca}$	P_{tot}	E_{ca} P_{th}
H08	not represented		
JULES-W1	$\frac{\delta S_{ca}}{\delta t} = P_{tot} - P_{th} - E_{ca}$	P_{tot}	E_{ca} P_{th}
LPJmL	$\frac{\delta S_{ca}}{\delta t} = P_{tot} - P_{th} - E_{ca}$	P_{tot}	E_{ca} P_{th}
Mac-PDM.20	not represented (all water intercepted is assumed to evaporate)		
MATSIRO	$\frac{\delta S_{ca}}{\delta t} = \frac{\delta S_{ca,l}}{\delta t} + \frac{\delta S_{ca,s}}{\delta t}$ $\frac{\delta S_{ca,l}}{\delta t} = P_{int,l} - P_{th,l} - E_{ca,l}$ $\frac{\delta S_{ca,s}}{\delta t} = P_{int,s} - P_{th,s} - E_{ca,s}$	$P_{int,l}$ $P_{int,s}$	$E_{ca,l}$ $E_{ca,s}$ $P_{th,l}$ $P_{th,s}$
mHM	$\frac{\delta S_{ca}}{\delta t} = P_{tot} - P_{th} - E_{ca}$	P_{tot}	E_{ca} P_{th}
MPI-HM	not represented		
ORCHIDEE	$\frac{\delta S_{ca}}{\delta t} = P_{tot} - P_{th} - E_{ca}$	P_{tot}	E_{ca} P_{th}
PCR-GLOBWB	$\frac{\delta S_{ca}}{\delta t} = P_{tot} - P_{th} - E_{ca}$	P_{tot}	E_{ca} P_{th}
VIC	$\frac{\delta S_{ca}}{\delta t} = P_{tot} - P_{th} - E_{ca}$ See [28]	P_{tot}	E_{ca} P_{th}
WaterGAP2	$\frac{\delta S_{ca}}{\delta t} = P_{tot} - P_{th} - E_{ca}$	P_{tot}	E_{ca} P_{th}
WAYS	$\frac{\delta S_{ca}}{\delta t} = P_{tot} - P_{th} - E_{ca}$	P_{tot}	E_{ca} P_{th}

Table S4. Precipitation intercepted by canopy storage (P_{int})

Model	Equation
CLM4.5	$P_{int} = 0.25 \times (P_{ra} + P_{sn}) \times \Big(1 - exp\Big(-0.5 \times (LAI + SAI)\Big)\Big)$ 0.25 = scales interception from point to grid cell
CLM5.0	$P_{int} = 0.25 \times (P_{ra} + P_{sn}) \times \Big(1 - exp\Big(-0.5 \times (LAI + SAI)\Big)\Big)$ 0.25 = scales interception from point to grid cell
CWatM	$P_{int} = min(P_{tot}, S_{ca,max})$ $S_{ca,max}$ from Global Land Cover Characteristics database version 2.0 varying every 10 days depending on land use class
DBH	$P_{int} = P_{tot} \times \Big(f_{ca} + f_{ca} \times \exp \frac{C_{P,l} \times LAI}{f_{ca}}\Big)$
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	$P_{int} = I_{cap} \times (1.0 - \exp(-0.5 \times P_{tot}))$
MATSIRO	$P_{int,l} = (B_{stormy} \times P_{int,l,stormy}) + \Big((1 - B_{stormy}) \times P_{int,l,calm}\Big)$ $P_{int,s} = (B_{stormy} \times P_{int,s,stormy}) + \Big((1 - B_{stormy}) \times P_{int,s,calm}\Big)$ $P_{int,l,stormy} = min\Bigg(f_{LAI} \times \Big(P_{gr,l,calm} + \frac{P_{gr,l,stormy}}{B_{stormy}}\Big), \frac{S_{ca,max} - S_{ca,l}}{\Delta t}\Bigg)$ $P_{int,l,calm} = min\Big(f_{LAI} \times P_{gr,l,calm}, \frac{S_{ca,max} - S_{ca,l}}{\Delta t}\Big)$ $P_{int,s,stormy} = min\Bigg(f_{LAI} \times \Big(P_{gr,s,calm} + \frac{P_{gr,s,stormy}}{B_{stormy}}\Big), \frac{S_{ca,max} - S_{ca,s}}{\Delta t}\Bigg)$ $P_{int,s,calm} = min\Big(f_{LAI} \times P_{gr,s,calm}, \frac{S_{ca,max} - S_{ca,s}}{\Delta t}\Big)$
mHM	$P_{int} = min(P_{tot}, S_{ca,max})$
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$P_{int} = P_{tot} - (S_{ca,max} - S_{ca})$
WAYS	$P_{int,l} = P_{ra} - (S_{ca,max} - S_{ca})$

Table S5. Throughfall (P_{th})

Model	Equation
CLM4.5	$P_{th,l} = \frac{S_{ca,int} - S_{ca,max}}{\Delta t} \times \frac{P_{ra}}{P_{ra} + P_{sn}} \geq 0$ $P_{th,s} = \frac{S_{ca,int} - S_{ca,max}}{\Delta t} \times \frac{P_{sn}}{P_{ra} + P_{sn}} \geq 0$ $S_{ca,int} = S_{ca} + P_{int} \times \Delta t \geq 0$
CLM5.0	$P_{th,l} = \frac{S_{ca,int} - S_{ca,max}}{\Delta t} \times \frac{P_{ra}}{P_{ra} + P_{sn}} \geq 0$ $P_{th,s} = \frac{S_{ca,int} - S_{ca,max}}{\Delta t} \times \frac{P_{sn}}{P_{ra} + P_{sn}} \geq 0$ $S_{ca,int} = S_{ca} + P_{int} \times \Delta t \geq 0$
CWatM	$P_{th} = P_{tot} + S_{ca} - E_{ca}$
DBH	$P_{th} = P_{tot} \times \left(1 - f_{ca} + \left(f_{ca} \times exp^{\frac{-C_{P,l} \times LAI}{f_{ca}}}\right)\right)$
H08	not represented
Jules-W1	$P_{th} = P_{tot} \times \left(\left(1 - \frac{S_{ca}}{S_{ca,max}}\right)^{\frac{f_{Pc,G} \times S_{ca,max}}{P_{tot} \times \Delta t}}\right) + \left(P_{tot} \times \frac{S_{ca}}{S_{ca,max}}\right)$. See [5]
LPJmL	$P_{th} = P_{tot} - E_{ca}$
Mac-PDM.20	not represented
MATSIRO	$P_{th} = P_{dr} + (P_{tot} - P_{int})$ $P_{int} = P_{int,l} + P_{int,s}$ $P_{dr} = P_{dr,l} + P_{dr,s}$ $P_{dr,l} = 1.14 \times 10^{-11} \times exp\left(3.7 \times 10^{3} \times S_{ca,l}\right)$ $P_{dr,s} = 1.14 \times 10^{-11} \times exp\left(3.7 \times 10^{3} \times S_{ca,s}\right)$
mHM	$P_{th} = max\Big(0, P_{tot} - (S_{ca,max} - S_{ca})\Big)$
MPI-HM	not represented
ORCHIDEE	$P_{th} = (P_{tot} \times (f_{ca,max} \times (1 - exp(-LAI)))) \times C_{P_{th}}$
PCR-GLOBWB	$P_{th} = \begin{cases} P_{tot}, & S_{ca} \geq S_{ca,max} \\ 0, & S_{ca} < S_{ca,max} \end{cases}$
VIC	$P_{th} = P_{mean,G} \times exp\Big(\frac{-f \times S_{ca,dif}}{P_{mean,G}}\Big)$ $S_{ca,dif} = \frac{S_{ca,max} - S_{ca}}{\Delta t}$
WaterGAP2	$P_{th} = \begin{cases} 0, & P_{tot} < (S_{ca,max} - S_{ca}) \\ P_{tot} - (S_{ca,max} - S_{ca}), & \text{other} \end{cases}$
WAYS	$P_{th} = max\Big(0, P_{tot} - (S_{ca,max} - S_{ca})\Big)$

Table S6. Precipitation falls directly to the ground (P_{gr})

Model	Equation
CLM4.5	$P_{gr,l} = P_{ra} \times (1 - 0.25 \times (1 - exp(-0.5 \times (LAI + SAI))))$ $P_{gr,s} = P_{sn} \times (1 - 0.25 \times (1 - exp(-0.5 \times (LAI + SAI))))$
CLM5.0	$P_{gr,l} = P_{ra} \times (1 - 0.25 \times (1 - exp(-0.5 \times (LAI + SAI))))$ $P_{gr,s} = P_{sn} \times (1 - 0.25 \times (1 - exp(-0.5 \times (LAI + SAI))))$
CWatM	not represented
DBH	not represented
H08	no canopy compartment, rainfall and snowfall fall directly to the ground. $P_{gr} = P_{ra} + P_{sn}$
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	computed same as table S5
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	$P_{gr} = -\left(\frac{P_{mean,G}}{f_{B_P}}\right) \times \ln(f_P);\ for\ 0 < f_P \leq 1$. See details [29]
WaterGAP2	not represented
WAYS	not represented

Table S7. Canopy evaporation (E_{ca})

Model	Equation
CLM4.5	$E_{ca} = -\rho_{air} \times \left(\frac{g_{st}^{w} + q}{r_{tot}}\right)$
CLM5.0	$E_{ca} = -\rho_{air} \times \left(\frac{g_{st}^{w} + q}{r_{tot}}\right)$
CWatM	$E_{ca} = PET \times \left(\frac{S_{ca}}{S_{ca,max}}\right)^{\frac{2}{3}}$ where: $S_{ca,max}$ = LAI LAI is varying every 10 days depending on land use class
DBH	$E_{ca} = \frac{1}{H_{l,E}} \times \left(\frac{e_{ca} - e}{r_b}\right) \times \left(\frac{\rho_{air} \times c_{air}}{\gamma}\right) \times f_{ca,sn}$
H08	not represented
Jules-W1	$E_{ca} = f_a \times PET$. See [4]
LPJmL	$E_{ca} = min\{PET, S_{ca}\}$
Mac-PDM.20	$E_{ca} = P_{int}$ (all intercepted precipitation is assumed to evaporate)
MATSIRO	$E_{ca} = (E_{ca,l} + E_{ca,s})$; where: ${E_{ca,l}}^{t+1} = (1 - f_{sn}) \times f_{w,lf} \times H_{l,E} \times \rho_{air} \times C_{bulk,Ei} \times W \times \left({q_{sat}^{ca}}^{t+1} - q\right)$; ${E_{ca,s}}^{t+1} = (1 - f_{sn}) \times f_{w,lf} \times H_{l,E_{sn}} \times \rho_{air} \times C_{bulk,Ei}^{sn} \times W \times \left({q_{sat}^{sn}}^{t+1} - q\right)$; $H_l = \begin{cases} H_{l,E}, & \theta < 273.15 \\ H_{l,E_{sn}}, & \theta > 273.15 \end{cases}$
mHM	$E_{ca} = \begin{cases} PET \times \left(\frac{S_{ca}}{S_{ca,max}}\right)^{\frac{2}{3}}, & S_{ca,max} > 0 \\ 0, & S_{ca,max} = 0 \end{cases}$
MPI-HM	not represented
ORCHIDEE	$E_{ca} = (q_{sat}^{ca} - q) \times W \times C_{su} \times (1 - r_{sn}) \times r_{ca}$
PCR-GLOBWB	$E_{ca} = PET$
VIC	$E_{ca,max} = PET \times \left(\frac{S_{ca}}{S_{ca,max}}\right)^{\frac{2}{3}} \times \frac{r_w}{(r_w + r_o)}$ $S_{ca,max}$ = $0.2 \times LAI_{month}$ $E_{ca} = E_{ca,max} \times f$ $f = min\left(1, \frac{S_{ca} + P_{tot} \times \Delta t}{E_{ca,max} \times \Delta t}\right)$. See [28]
WaterGAP2	$E_{ca} = PET \times \left(\frac{S_{ca}}{S_{ca,max}}\right)^{\frac{2}{3}}$ where: $S_{ca,max} = 0.3\text{mm} \times LAI$ LAI is calculated based on simple growth model and based on land cover characteristics, see [34].
WAYS	$E_{ca} = PET \times \left(\frac{S_{ca}}{S_{ca,max}}\right)^{\frac{2}{3}}$ where: $S_{ca,max} = 0.3\text{mm} \times LAI$ The leaf area index (LAI) is seasonal varying which is determined by the growing-season index (i_{GS}), day length (t) and the current root zone water storage (S_{rz}), see [54]. $LAI = LAI_{min} + i_{GS} \times (LAI_{max} - LAI_{min})$x $i_{GS} = f(\theta_{min}) \times f(t) \times f(S_{rz})$ $f(\theta_{min}) = \begin{cases} 0, & \theta_{min} \leq 271.15 \\ \frac{\theta_{min} - 271.15}{278.15 - 271.15}, & 271.15 < \theta_{min} < 278.15; \\ 1, & \theta_{min} \geq 278.15 \end{cases}$ $f(t) = \begin{cases} 0, & t \leq 36000 \\ \frac{t - 36000}{39600 - 36000}, & 36000 < t < 39600 \\ 1, & t \geq 39600 \end{cases}$ $\frac{S_{rz} \times (S_{rz,max} + \Lambda_{rz})}{S_{rz,max} \times (S_{rz} + \Lambda_{rz})}$ The root zone soil moisture stress parameter Λ_{rz} is fixed at 0.07.

Table S8. Snow storage (S_{sn})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	$\frac{\delta S_{sn,ice}}{\delta t} = \begin{cases} f_{sn} \times (P_{sn} + (F - E_{sn})) - M, & i = S_{sn,i} + 1 \\ -M, & i = S_{sn,i} + 2, ..., 0 \end{cases}$ $\frac{\delta S_{sn,l}}{\delta t} = \begin{cases} (f_{sn} \times (P_{ra} + (E_{dew} - E_{so})) - M_{out}) + M, & i = S_{sn,i} + 1 \\ (M_{in} - M_{out}) + M, & i = S_{sn,i} + 2, ..., 0 \end{cases}$	P_{sn} P_{ra} E_{dew} F	E_{sn} M M_{out}
CLM5.0	$\frac{\delta S_{sn,ice}}{\delta t} = \begin{cases} f_{sn} \times (P_{sn} + (F - E_{sn})) - M, & i = S_{sn,i} + 1 \\ -M, & i = S_{sn,i} + 2, ..., 0 \end{cases}$ $\frac{\delta S_{sn,l}}{\delta t} = \begin{cases} (f_{sn} \times (P_{ra} + (E_{dew} - E_{so})) - M_{out}) + M, & i = S_{sn,i} + 1 \\ (M_{in} - M_{out}) + M, & i = S_{sn,i} + 2, ..., 0 \end{cases}$	P_{sn} P_{ra} E_{dew} F	E_{sn} M M_{out}
CWatM	$\frac{\delta S_{sn}}{\delta t} = P_{sn} - M - E_{sn}$ $P_{sn} = \begin{cases} P_{tot}, & \theta < 273.15 \\ 0, & \theta \geq 273.15 \end{cases}$	P_{sn}	M E_{sn}
DBH	$\frac{\delta S_{sn}}{\delta t} = P_{tot} - E_{sn} - R_{in}$	P_{tot}	E_{sn} R_{in}
H08	$\frac{\delta S_{sn}}{\delta t} = P_{sn} - M - E_{sn}$	P_{sn}	M E_{sn}
JULES-W1	$\frac{\delta S_{sn}}{\delta t} = P_{tot} - M - E_{sn}$	P_{tot} for $\theta < 273.15$	M E_{sn}
LPJmL	$\frac{\delta S_{sn}}{\delta t} = \begin{cases} S_{sn} - P_{th} - M - E_{sn}, & \theta < 273.15 \\ S_{sn} - M - E_{sn}, & \theta > 273.15 \end{cases}$	P_{th}	M E_{sn}
Mac-PDM.20	$\frac{\delta S_{sn}}{\delta t} = P_{sn} - M$ $P_{sn} = \begin{cases} P_{tot}, & \theta < \theta_M \\ 0, & \theta \geq \theta_M \end{cases}$	P_{sn}	M
MATSIRO	$\frac{\delta S_{sn}}{\delta t} = P_{s,ca} - E_{sn} - M + F$	$P_{s,ca}$ F	E_{sn} M
mHM	$\frac{\delta S_{sn}}{\delta t} = P_{sn} - M$ $P_{sn} = \begin{cases} P_{tot}, & \theta < \theta_M \\ 0, & \theta \geq \theta_M \end{cases}$	P_{sn}	M
MPI-HM	$\frac{\delta S_{sn}}{\delta t} = \frac{\delta S_{sn,ice}}{\delta t} + \frac{\delta S_{sn,l}}{\delta t}$ $\frac{\delta S_{sn,ice}}{\delta t} = P_{sn} - M + F$ $\frac{\delta S_{sn,l}}{\delta t} = M_{pot} - M - F$ $F = \begin{cases} S_{sn,l}, & \theta < 273.15 \\ 0, & \theta \geq 273.15 \end{cases}$	P_{sn} F	M
ORCHIDEE	$\frac{\delta S_{sn,i}}{\delta t} = \begin{cases} P_{sn} + P_{ra} - R_{in,i} - M_{,i} - E_{sn}, & i = 1 \\ R_{in,i-1} - R_{in,i} - M_i, & i = 2,3 \end{cases}$ See [53]	P_{sn} P_{ra}	$R_{in,i}$ M E_{sn}
PCR-GLOBWB	$\frac{\delta S_{sn}}{\delta t} = P_{sn} - M$	P_{sn}	M
VIC	$\frac{\delta S_{sn,l}}{\delta t} = P_{ra} + \left(\frac{H_l}{\rho_w \times H_{l,E}} - \frac{\chi_M}{\rho_w \times H_M}\right) \times \Delta t$ $\frac{\delta S_{sn,ice}}{\delta t} = P_{sn} + \left(\frac{H_l}{\rho_w \times H_{l,E}} + \frac{\chi_M}{\rho_w \times H_M}\right) \times \Delta t$. See [2]	P_{ra} P_{sn}	H_l $H_{l,E}$ χ_M H_M
WaterGAP2	$\frac{\delta S_{sn}}{\delta t} = \frac{1}{100} \times \sum_{i=1}^{100} (P_{s,SG_i} - M_{SG_i} - E_{sn,SG_i})$ $P_{s,SG_i} = \begin{cases} P_{tot}, & \theta_{SG_i} < 273.15 \\ 0, & other \end{cases}$	P_{sn}	M_s E_{sn}
WAYS	$\frac{\delta S_{sn}}{\delta t} = P_{sn} - M$	P_{sn}	M

Table S9. Snow held on the canopy (S_{soc})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	Interception by vegetation does not distinguish between liquid and solid phases		
CLM5.0	$\frac{\delta S_{soc}}{\delta t} = P_{int,s} - (P_{dr,s} - U_{ca,sn}) \times \Delta t - E_{lfsm} \times \Delta t$	$P_{int,s}$	E_{lfsm} $U_{ca,sn}$ $P_{dr,s}$
CWatM	not represented		
DBH	$\frac{\delta S_{soc}}{\delta t} = P_{tot} - P_{th} - P_{dr} - E_{ca}$ for ambient temperature lower than the freezing temperature, precipitation is retreated as snow.	P_{tot}	P_{th} P_{dr} E_{ca}
H08	not represented		
JULES-W1	$\frac{\delta S_{soc}}{\delta t} = \left(0.7 \times ((4.4 \times LAI) - I_0) \times \left(1 - exp^{\frac{-P_{tot}}{4.4 \times LAI}}\right)\right) - E_{sn} - M_{ca} - 0.4 \times M_{ca}$. See [5]	P_{tot} for $\theta < 273.15$; I_0	M_{ca} E_{sn}
LPJmL	not represented		
Mac-PDM.20	not represented		
MATSIRO	$\frac{\delta S_{soc}}{\delta t} = P_{int,s} - P_{dr,s} - E_{ca,s}$	$P_{int,s}$	$P_{dr,s}$ $E_{ca,s}$
mHM	not represented		
MPI-HM	not represented		
ORCHIDEE	not represented		
PCR-GLOBWB	not represented		
VIC	$\frac{\delta S_{soc}}{\delta t} = f_{LAI} \times P_{sn}$. $f_{LAI} = 0.6$ See [2], [48]	P_{sn}	
WaterGAP2	not represented		
WAYS	not represented		

Table S10. Snow under canopy (S_{suc})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	see table S8		
CLM5.0	$\frac{\delta S_{suc}}{\delta t} = f_{sn} \times (P_{int,l} + E_{dew} - E_{ca,l}) \times \Delta t$	$P_{int,l}$ E_{dew}	$E_{ca,l}$
CWatM	not represented		
DBH	$\frac{\delta S_{suc}}{\delta t} = P_{gr,s} - E_{sn,so} - R_{in}$	$P_{gr,s}$	$E_{sn,so}$ R_{in}
H08	not represented		
JULES-W1	$\frac{\delta S_{suc}}{\delta t} = P_{tot} - \frac{S_{soc}}{\delta t} - M_{underca} - E_{snunderca}$	P_{tot} for $\theta < 273.15$	$M_{underca}$ $E_{snunderca}$
LPJmL	not represented		
Mac-PDM.20	not represented		
MATSIRO	see table S8		
mHM	not represented		
MPI-HM	not represented		
ORCHIDEE	see table S8		
PCR-GLOBWB	not represented		
VIC	$\rho_w \times c_{ice} \times \frac{\delta S_{suc} \times \theta_{su}}{\Delta t} = H_l + H_{se} + NR + \chi_M + \chi_{rs}$. See [2]	P_{tot}	SWE
WaterGAP2	not represented		
WAYS	not represented		

Table S11. Sublimation (E_{sn})

Model	Equation
CLM4.5	$E_{sn} = E_{so} - max\left(E_{so} \times \frac{S_{l,sn,i+1}}{S_{ice,sn,i+1} + S_{l,sn,i+1}}, 0\right)$ for $E_{so} \geq 0$
CLM5.0	$E_{sn} = min\left(AET, \frac{S_{sn}}{\Delta t}\right)$
CWatM	$E_{sn} = min(M, E_{so})$
DBH	$E_{sn} = \frac{1}{H_{l,E}} \times \left(\frac{e_{ca} - e}{r_b}\right) \times \left(\frac{\rho_{air} \times c_{air}}{\gamma}\right) \times f_{ca,sn} \times \frac{H_{l,E}}{H_{l,E} + H_{l,E_{sn}}}$
H08	$E_{sn} = PET$
JULES-W1	$E_{sn} = \frac{\rho_{air}}{r_{so} + r_{ca}} \times (q_{sat}^{ca} - q)$
	$E_{snunderca} = \frac{\rho_{air}}{f_{ah} + r_{ca}} \times (q_{sat}^{gr} - q)$. See [17]; [47]
LPJmL	$E_{sn} = \begin{cases} 0.1 \text{ (mm day}^{-1}), & S_{sn} \geq 0.1 \text{ (mm)} \\ 0 \text{ (mm day}^{-1}), & S_{sn} < 0.1 \text{ (mm)} \end{cases}$
Mac-PDM.20	not represented
MATSIRO	$E_{sn}^{freegr\,t+1} = (1 - f_{sn}) \times f_F \times H_{l,E_{sn}} \times \rho_{air} \times C_{bulk,Eg} \times W \times \left(q_{su} \times q_{sat}^{gr}{}^{t+1} - q\right)$
	$E_{sn}^{covgr\,t+1} = f_{sn} \times H_{l,E_{sn}} \times \rho_{air} \times C_{bulk,Eg}^{sn} \times W \times \left(q_{sat}^{gr,sn\,t+1} - q\right)$
mHM	not represented
MPI-HM	not represented
ORCHIDEE	$E_{sn} = (q_{sat}^{ca} - q) \times W \times C_{su} \times (1 - r_{floodplain}) \times r_{sn}$
PCR-GLOBWB	not represented
VIC	$E_{sn} = \frac{H_{l,E}}{\rho_w \times H_{l,E_{sn}}}$. See [2]
WaterGAP2	$E_{sn,SG_i} = PET$ see [42]
WAYS	not represented

Table S12. Snowmelt (M)

Model	Equation
CLM4.5	$M = \frac{H_i \times \Delta t}{H_M}$ for $i = S_{sn,i} + 1, ..., 0$
CLM5.0	$M = min\left(S_{ice}, \frac{\chi}{H_M}\right)$
CWatM	$M = C_m \times C_{m,season} \times (1 + 0.01 \times P_{ra}) \times (\theta_{SG_i} - \theta_M) \times \Delta t - E_{sn};$ See[45] for 10 elevation zones per grid. $M_{glacier} = C_{m glacier} \times C_{m,season glacier} \times (\theta_{SG_i} - \theta_M)$ for 3 elevation zones per grid
DBH	$M = \theta_{freeze} \times (H_{tot} + \delta H_{tot}) - (\theta_{so} \times H_{tot} + \theta \times \delta H_{tot})$
H08	$M = \frac{\chi_f}{H_{M,ice}}$ with $H_{M,ice} = 0.333 \times 10^6$
JULES-W1	$M = \frac{min\left(S_{sn}, \frac{\theta - \theta_M}{H_M \times H_{soTL}}\right)}{\Delta t}$ for $\theta > \theta_M$; $M \times \Delta t \leq S_{sn}$; $H_M \times M \times \Delta t \leq \frac{\theta - \theta_M}{H_{soTL}}$ for details see [22]
LPJmL	$M = \begin{cases} \frac{H}{0.3\chi^9}, & \theta > 273.15 \\ R_{sn} = P_{th}, & S_{sn} > 20.000 \text{ (mm)} \end{cases}$
Mac-PDM.20	$M = \begin{cases} min\,(S_{sn}, C_m \times (\theta - 273.15\ )), & \theta > 273.15 \\ 0, & \theta \leq 273.15 \end{cases}$
MATSIRO	$M = \sum_{i=1}^{N} M_t$ for $k = 1, N$ for $k = 1$(starting from top layer) for $S_{sn(1)} \neq 0\ and\ \theta_M < \theta_{sn1}$ $H_{sn} = H_{sn2} - H_{sn1} - \frac{c_{ice} \times S_{sn1} \times (\theta_M - \theta_{sn1})}{\Delta t}$ $M = min\left(\frac{S_{sn1}}{\Delta t}, \frac{H_{sn}}{H_M}\right)$ $M_1 = f_{sn} \times M$ $H_{sn} = H_{sn} - (M \times H_M)$ $for\ 2 \leq k \leq N$ $\theta_{sn,k} = \theta_{sn,k} + \frac{H_{sn}}{c_{ice} \times S_{sn,k}} \times \Delta t$ $H_{sn} = max\left(\frac{c_{ice} \times S_{sn,k} \times (\theta_{sn,k} - \theta_M)}{\Delta t}, 0\right)$ $M = min\left(\frac{S_{sn,i}}{\Delta t}, \frac{H_{sn}}{H_M}\right)$ $M_i = f_{sn} \times M$
mHM	$M = min\,(S_{sn}, (\theta - \theta_M) \times C_m)$ where $\theta > \theta_M$
MPI-HM	$M_{pot} = max\left(0, \left(\sin\left(\pi \times \frac{t_{day}}{t_{year}}\right) \times 8.3 + 0.7\right) \times (\theta - \theta_{freeze})\right)$ $M = M_{pot} + max\,(0, S_{sn,l} - 0.06 \times S_{sn})$
ORCHIDEE	$M_i = S_{sn,i} - \frac{1.9 \times 10^6 \times \frac{\rho_{sn,i}}{\rho_{ice}} \times \zeta_{sn} \times (\theta_{sn,i} - \theta_f) - H_{sn,i}}{H_{M,ice}}$. See [53]
PCR-GLOBWB	$M = min\,(S_{sn}, (\theta - \theta_M) \times C_m)$ where $\theta > \theta_M$
VIC	$\chi_{to} = (NR + H_{se} + H_l + \chi_{rs}) \times \Delta t$. See [2]
WaterGAP2	$M = \begin{cases} C_m \times (\theta_{SG_i} - 273.15\ ), & \theta_{SG_i} > 273.15\ , S_{sn,SG_i} > 0\ mm \\ 0, & \text{other} \end{cases}$ C_m = landcover specific degree-day factor, see [34]
WAYS	$M = \begin{cases} min\,(S_{sn}, C_m \times (\theta - 273.15\ )), & \theta > 273.15 \\ 0, & \theta \leq 273.15 \end{cases}$

Table S13. Frozen soil (F_{so})

Model	Equation
CLM4.5	$\frac{H_{so,i}\times\zeta_{so,i}}{\Delta t}\times(\theta_{so,i}{}^{n+1}-\theta_{so,i}{}^{n}) = H_{atm}{}^{n}+\frac{\delta H_{atm}}{\delta\theta_{so,i}}\times(\theta_{so,i}{}^{n+1}-\theta_{so,i})-\alpha\times\frac{k_{th}\times(\theta_{so,i}{}^{n}-\theta_{so,i+1}{}^{n})}{d_{n,i+1}-d_{n,i}}-(1-\alpha)\times\frac{k_{th}\times(\theta_{so,i}{}^{n+1}-\theta_{so,i+1}{}^{n+1})}{d_{n,i+1}-d_{n,i}}$ Where the superscripts n and n + 1 indicate values at the beginning and end of the time step, respectively. See [37]
CLM5.0	$\frac{H_{so,i}\times\zeta_{so,i}}{\Delta t}\times(\theta_{so,i}{}^{n+1}-\theta_{so,i}{}^{n}) = H_{atm}{}^{n}+\frac{\delta H_{atm}}{\delta\theta_{so,i}}\times(\theta_{so,i}{}^{n+1}-\theta_{so,i})-\alpha\times\frac{k_{th}\times(\theta_{so,i}{}^{n}-\theta_{so,i+1}{}^{n})}{d_{n,i+1}-d_{n,i}}-(1-\alpha)\times\frac{k_{th}\times(\theta_{so,i}{}^{n+1}-\theta_{so,i+1}{}^{n+1})}{d_{n,i+1}-d_{n,i}}$ See Oleson et al. [37]
CWatM	$\frac{\delta F_{so}}{\delta t} = -(1-\nu)\times F-\theta_{SG_i}\times exp(-0.04\times\nu\times\frac{d_{sn}}{SWE}); F_t = F_{t-1}+\frac{\delta F_{so}}{\delta t}\times\Delta t$. See [32]
DBH	not represented
H08	not represented. When a surface is snow-covered, soil moisture does not change through precipitation or evaporation.
JULES-W1	not represented
LPJ-ML	not represented
Mac-PDM.20	not represented
MATSIRO	$Q_{in,so} = k\times\big(\frac{\delta\Psi}{\delta z}-1\big)$ $k = C_{so,F}\times k_{sat}\times\big(\frac{S_{so,uF}}{\phi_{so}-S_{so,F}}\big)^{2\times\beta+3}$ $\Psi = \Psi_{sat}\times\big(\frac{S_{so,uF}}{\phi_{so}-S_{so,F}}\big)^{-\beta}$ $C_{so,F} = \big(1-\frac{S_{so,F}}{S_{so,uF}+S_{so,F}}\big)^{\alpha}$. See [44] α is unity. k and Ψ are calculated after the formula in Clapp and Hornberger [10]. For more detail, see [49].
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	The motivation for development of the frozen soil algorithm is to represent the effects of seasonally frozen ground on surface hydrologic response and the surface energy balance, at a level of complexity consistent with the previously developed VIC algorithms. In this spirit, the VIC soil moisture transport scheme was retained, and the thermal and moisture fluxes are solved separately. At each time step, thermal fluxes through the soil column are solved prior to the prediction of soil layer ice content. Subsequently, moisture fluxes are computed using the updated ice contents. Finally, soil thermal properties for the next time step are estimated from the revised distribution of soil moisture and ice. See for details: Section 2.1 in Cherkauer and Lettenmaier [8]
WaterGAP2	not represented
WAYS	not represented

Table S14. Soil storage (S_{so})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	$\frac{\delta d_{so} \delta S_{so,l,i}}{\delta t} = Q_i - Q_{i-1} - T_i$	Q_i	Q_{i-1} T_i
CLM5.0	$\frac{\delta d_{so} \delta S_{so,l,i}}{\delta t} = Q_i - Q_{i-1} - T_i$	Q_i	Q_{i-1} T_i
CWatM	$\frac{\delta S_{so}}{\delta t} = R_{cr} + R_{in} - R_{gwr} - R_{if} - E_{so} - T$	R_{cr} R_{in}	E_{so} R_{gwr} R_{if} T
DBH	$\frac{\delta S_{so,i}}{\delta t} = \begin{cases} R_{in,i} - E_{so,i} - R_{gwr,i}, & \text{i = 0 (top layer)} \\ R_{gwr,i-1} - R_{gwr,i} - T_i, & i > 0 \end{cases}$	$R_{in,i}$ $R_{gwr,i-1}$	$E_{so,i}$ $R_{gwr,i}$ T_i
H08	$\frac{\delta S_{so,i}}{\delta t} = M + P_{th} - E_{so} - R_{in}$	M P_{th}	E_{so} R_{in}
JULES-W1	$\frac{\delta S_{so}}{\delta t} = M + P_{th} - E_{so} - R_{if} - R_{su}$	M P_{th}	E_{so} R_{if} R_{su}
LPJmL	$\frac{\delta S_{so}}{\delta t} = (R_{if} + R_{in}) - R_{gwr} - R_{if} - E_{so} - T$	R_{if} R_{in}	E_{so} R_{gwr} T
Mac-PDM.20M	$\frac{\delta S_{so}}{\delta t} = M + P_{tot} - E_{so} - R_{su}$	P_{tot} M	E_{so} R_{su}
MATSIRO	$\frac{\delta S_{so}}{\delta t} = \sum_{n=1,13} [(S_{so,F_i} + S_{so,uF_i}) \times d_{so}]$		
mHM	$\frac{\delta S_{so,i}}{\delta t} = \begin{cases} R_{in,i} - ET_{so,i} - R_{sof,i}, & \text{i = 0 (top soil layer)} \\ R_{sof,i-1} - ET_{so,i} - R_{sof,i}, & i > 0 \end{cases}$	$R_{in,i}$	$ET_{so,i}$ $R_{sof,i}$
MPI-HM	$\frac{\delta S_{so}}{\delta t} = R_{in} - R_{pe} - E_{so} - T$	R_{in}	E_{so} R_{pe} T
ORCHIDEE	$\frac{\delta S_{so}}{\delta t} = R_{in} + R_{in,r} - R_{su} - E_{so}$	R_{in} $R_{in,r}$	E_{so} R_{su}
PCR-GLOBWB	$\frac{\delta S_{so}}{\delta t} = R_{in} - R_{gwr} - R_{if} - E_{so} - T$	R_{in}	E_{so} R_{gwr} R_{if} T
VIC	$\frac{\delta S_{so}}{\delta t} = \frac{\delta}{\delta d_{so}} \times \left(D_w \times \frac{\delta S_{so}}{\delta d_{so}} \right) + \frac{\delta k}{\delta d_{so}}$ for the top two soil layers: $\frac{\delta S_{so}}{\delta t} \times d_{so,i} = R_{in} - E_{so} - T - k \times d_{so,i} - D_w \times d_{so,i}$ for details see Gao et al. [20]; Liang et al. [29] for lower soil layer: $\frac{\delta S_{so3}}{\delta t} \times (d_{so,3} - d_{so,2}) = k_{d_{so,2}} + D_{w,2} - T - R_{gw}$	$D_{w d_{so,1}}$ $k_{d_{so,1}}$ R_{in}	$k_{d_{so,1}}$ $D_{w d_{so,2}}$ E_{so} T R_{gw}
WaterGAP2	$\frac{\delta S_{so}}{\delta t} = R_{in} - R_{tot} - E_{so}$	R_{in}	R_{tot} E_{so}
WAYS	$\frac{\delta S_{so}}{\delta t} = M + P_{th} - E_{so} - R_{tot}$	M P_{th}	E_{so} R_{tot}

Table S15. Total runoff in ISIMIP2b $(R_{tot,ISIMIP2b})$

Model	Equation
CLM4.5	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
CLM5.0	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
CWatM	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
DBH	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
H08	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
JULES-W1	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
LPJmL	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
Mac-PDM.20	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
MATSIRO	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
mHM	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
MPI-HM	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
ORCHIDEE	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
PCR-GLOBWB	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
VIC	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
WaterGAP2	$R_{tot,ISIMIP2b} = R_s + R_{sb}$
WAYS	$R_{tot,ISIMIP2b} = R_s + R_{sb}$

Table S16. Surface runoff in ISIMIP2b (R_s)

Model	Equation
CLM4.5	$R_s = R_{su}$
CLM5.0	$R_s = R_{su}$
CWatM	$R_s = R_{su}$
DBH	$R_s = R_{su}$
H08	$R_s = R_{su}$
JULES-W1	$R_s = R_{su}$
LPJmL	$R_s = R_{su}$
Mac-PDM.20	$R_s = R_{su}$
MATSIRO	$R_s = R_{su}$
mHM	$R_s = R_{su}$
MPI-HM	$R_s = R_{su}$
ORCHIDEE	$R_s = R_{su}$
PCR-GLOBWB	$R_s = R_{su}$
VIC	$R_s = R_{su}$
WaterGAP2	$R_s = R_{su}$
WAYS	$R_s = R_{su}$

Table S17. Subsurface runoff in ISIMIP2b (R_{sb})

Model	Equation
CLM4.5	$R_{sb} = R_{gw}$
CLM5.0	$R_{sb} = R_{gw}$
CWatM	$R_{sb} = R_{if} + gw$
DBH	not represented
H08	$R_{sb} = R_{gw}$
JULES-W1	$R_{sb} = R_{if}$
LPJmL	$R_{sb} = R_{if}$
Mac-PDM.20	$R_{sb} = R_{gw}$
MATSIRO	$R_{sb} = R_{gw}$
mHM	$R_{sb} = R_{if,fast} + R_{if,slow} + R_{gw}$
MPI-HM	$R_{sb} = R_{gwr}$
ORCHIDEE	$R_{sb} = R_{gw}$
PCR-GLOBWB	$R_{sb} = R_{if}$
VIC	$R_{sb} = \begin{cases} \frac{R_{if,max} \times f_{R_{if,max}}}{f_{S_{so,max}} \times S_{so,max,3L}} \times S_{so,3L}, & 0 \leq S_{so,3L} \leq f_{S_{so,max}} \times S_{so,max,3L} \\ \frac{R_{if,max} \times f_{R_{if,max}}}{f_{S_{so,max}} \times S_{so,max,3L}} \times S_{so,3L} + \left(R_{if,max} - \frac{R_{if,max} \times f_{R_{if,max}}}{f_{S_{so,max}}}\right) \times \left(S_{so,3L} - \frac{f_{S_{so,max}} \times S_{so,max,3L}}{S_{so,max,3L} - f_{S_{so,max}} \times S_{so,max,3L}}\right)^2, \\ S_{so,3L} \geq f_{S_{so,max}} \times S_{so,max,3L} \end{cases}$
WaterGAP2	$R_{sb} = R_{gw}$
WAYS	$R_{sb} = R_{if} + R_{gw}$

Table S18. Total runoff from land (R_{tot})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	not represented
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	$R_{tot} = R_{su} + R_{if,fast} + R_{if,slow} + R_{gw}$
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$R_{tot} = R_{in} \times \left(\frac{S_{so}}{S_{so,max}}\right)^{\gamma} + R_{bu} + R_{sat}$ with $S_{so,max} = S_{so,TL} \times d_{so,root}$ and $R_{bu} = 0.5 \times R_{in} \times f_{bu}$, R_{in} is reduced by R_{bu} before calculating R_{tot}, γ is the calibration parameter according to [3, 34].
WAYS	$R_{tot} = \left(1 - \left(1 - \frac{S_{rz}}{(1+\beta) \times S_{rz,max}}\right)\right)^{\beta} \times R_{in}$

Table S19. Runoff concentration in a grid cell (R_G^n)

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$R_G^n = \sum\limits_{LC} \times \sum\limits_{f_R} \times \sum\limits_{i}^{max} \times tri_x \times R_{su_{LC,R}} \times (t-i+1)$; for "i" runs from 1 to maximum number of days. $tri_x = \int\limits_{i-1}^{i} \times \frac{2}{max} - \lvert u? - \frac{max}{2} \rvert \times \frac{4}{max^2} du$
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	$R_G = \frac{S_{rv}}{\kappa_{ol}}$
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	not represented
WAYS	not represented

Table S20. Surface runoff (R_{su})

Model	Equation
CLM4.5	$R_{su,l} = R_{gl,we,la} + R_{su,l} + R_{if}$ $R_{su,ice} = R_{snwcp,ice}$
CLM5.0	$R_{su,l} = R_{gl,we,la} + R_{su,l} + R_{if}$ $R_{su,ice} = R_{snwcp,ice}$
CWatM	$R_{su} = R_{ho} + R_{if} + R_{of}$
DBH	$R_{su} = R_{ho} + R_{sat}$
H08	$R_{su} = \begin{cases} \frac{(S_{so,tot} - d_{so} \times 1000 \times (S_{so,FC} - S_{so,WP}))}{t}, & \frac{S_{so,tot}}{d_{so} \times 1000 \times (S_{so,FC} - S_{so,WP})} \geq 1 \\ 0, & \frac{S_{so,tot}}{d_{so} \times 1000 \times (S_{so,FC} - S_{so,WP})} < 1 \end{cases}$
JULES-W1	$R_{su} = \begin{cases} \left(P_{ra} \times \frac{S_{ca}}{S_{ca,max}} \times exp\left(-\frac{f_{Pc,G} \times S_{ca,max} \times R_{in}}{P_{ra} \times S_{ca}}\right)\right) + \left(P_{ra} \times \left(1 - \frac{S_{ca}}{S_{ca,max}}\right) \times exp\left(-\frac{f_{Pc,G} \times S_{ca,max}}{P_{ra} \times \Delta t}\right)\right) \\ for\ R_{in} \times \delta P_{th} \leq S_{ca} \\ P_{ra} \times exp\left(-\frac{f_{Pc,G}(R_{in} \times \delta P_{th} + S_{ca,max} - S_{ca})}{P_{ra} \times \Delta t}\right) \\ for\ R_{in} \times \delta P_{th} > S_{ca} \end{cases}$
LPJmL	$R_{su} = P_{tot} - R_{in,TL}$
Mac-PDM.20	$R_{su} = \begin{cases} P_{ra} - AET, & S_{so,FC} < S_{so,tot} \\ 0, & S_{so,tot} \leq S_{so,FC} \end{cases}$ Runoff is generated from excess rainfall (rainfall minus evaporation) when the soil water content exceeds the capacity of the soil (field capacity).
MATSIRO	$R_{su} = R_{ho} + R_{sat} + R_{of}$
mHM	$R_{su} = f_{bu} \times R_{in,i} - \frac{S_{pon}}{S_{pon,max}}(PET_{ows} - E_{ca})$ occurs only on the fraction of the impervious/sealed land cover class, at the top soil layer: $i = 0$
MPI-HM	$R_{su} = 1 - f_{we} \times \begin{cases} P_{ra} + M + (S_{so} - S_{so,max}), & S_{so,SG,max} \leq S_{so,SG} + P_{ra} + M \\ P_{ra} + M - \max(0, S_{so,SG,min} - S_{so}) - R_0, & S_{so,SG,min} \leq S_{so,SG} + P_{ra} + M \leq S_{so,SG} + P_{ra} + M \\ 0, & S_{so,SG} + P_{ra} + M \leq S_{so,SG,min} \end{cases}$ $R_0 = \frac{S_{so,SG,max} - S_{so,SG,min}}{1 + \sigma} \times (R_1 - R_2)$ $R_1 = \min\left(1, \left(\frac{S_{so,SG,max} - S_{so,SG}}{S_{so,SG,max} - S_{so,SG,min}}\right)^{1+\sigma}\right)$ $R_2 = \max\left(\frac{0, S_{so,SG,max} - S_{so,SG} - P_{ra} - M}{S_{so,SG,max} - S_{so,SG,min}}\right)^{1+\sigma}$ $S_{so,SG} = \begin{cases} S_{so,SG,max} - (S_{so,SG,max} - S_{so,SG,min}) \times \left(1 - \frac{S_{so} - S_{so,SG,min}}{S_{so,max} - S_{so,SG,min}}\right)^{\frac{1}{1+\sigma}}, & S_{so} > S_{so,SG,min} \\ S_{so}, & S_{so} \leq S_{so,SG,min} \end{cases}$
ORCHIDEE	$R_{su} = P_{th} - R_{in}$
PCR-GLOBWB	$R_{su} = R_{ho} + R_{if}$
VIC	Since the top thin soil layer has a very small water holding capacity, the direct runoff (surface runoff) within each time step is calculated for the entire upper layer (layer 1 and layer 2) as (Liang et al. [29]; Gao et al. [20]): $R_{su} = \begin{cases} P_{tot} - d_{so2} \times (\phi_{so} - S_{so,T2L}) + d_{so2} \times \phi_{so} \times \left(1 - \frac{R_{in,0} + P_{tot}}{R_{in,max}}\right)^{1+\Pi_{R_{in}}}, & P_{tot} + R_{in,0} \leq R_{in,max} \\ P_{tot} - d_{so2} \times (\phi_{so} - S_{so,T2L}), & P_{tot} + R_{in,0} \geq R_{in,max} \end{cases}$
WaterGAP2	$R_{su} = R_{tot} - R_{gwr}$
WAYS	$R_{su} = R_{tot} - R_{gwr}$

Table S21. Hortonian overland flow (R_{ho})

Model	Equation
CLM4.5	$R_{ho} = \max\left(R_{in} - (1 - f_{h2o})\, R_{in,max}, 0\right)$
CLM5.0	$R_{ho} = \max\left(R_{in} - (1 - f_{h2o})\, R_{in,max}, 0\right)$
CWatM	$R_{ho} = M + P_{th} - Q_{pf} - R_{in}$ Preferential flow, that bypass the soil matrix $Q_{pf} = (P_{th} + M) \times \left(\frac{S_{so,rel}}{S_{so,sat}}\right)^{\beta}$
DBH	$R_{ho} = \int\limits_{0}^{f_{G,unsat}} P_{th} \times P_{conv} - k$
H08	not represented
JULES-W1	not represented
LPJmL	it is taken into account when surface runoff is computed, but not separately considered.
Mac-PDM.20	not represented
MATSIRO	$R_{ho} = B_{stormy} \times R_{ho,stormy} + (1 - B_{calm}) \times R_{ho,calm})$
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$R_{ho} = 1 - \frac{S_{so,sat} - S_{so,tot}}{S_{so,tot} - S_{so,WP}} \times P_{tot}$ $R_{ho} = max(R_{in} - (1 - f_{h2o}) \times R_{in,max}, 0)$
VIC	not represented
WaterGAP2	not represented
WAYS	not represented

Table S22. Saturation excess overland flow (R_{sat})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	not represented
DBH	$R_{sat} = \int_{0}^{f_{G,sat}} P_{th}$
H08	not represented
JULES-W1	any saturation excess is moved to the soil layer below (the move of excess water to upper soil layers due to saturation is restricted. The excess saturation water is forced down to lower layers, and if the bottom soil layer becomes super-saturated, then the excess water is added to the interflow (Best et al. [5]).
LPJmL	$R_{sat} = R_{su}$
Mac-PDM.20	$R_{sat} = R_{su}$
MATSIRO	$R_{sat} = f_{G,sat} \times f_{ri,sat} \times P_{th}$
mHM	not represented
MPI-HM	implicitly included in surface runoff computation
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	same as Table S20.
WaterGAP2	$R_{sat} = \begin{cases} S_{so} - S_{so,max}, & S_{so} > S_{so,max} \\ 0, & \text{other cases} \end{cases}$ with $S_{so,max} = d_{so,root} \times S_{so,TL}$
WAYS	$R_{sat} = \frac{max(0, S_f - S_{ftr})}{K_{ff}}$ The Overflow of the uppermost layer is only active when the storage of the fast response reservoir exceeds the specified threshold S_{ftr}

Table S23. Transpiration (T)

Model	Equation
CLM4.5	$T = -r_{ca,dry} \times \rho_{air} \left(g_{ca}^{air} \times q + g_{gr}^{ca} \times q_{gr} - \left(g_{ca}^{air} + g_{gr}^{ca} \right) \times \left(q_{sat}^{ca} + \frac{\delta q_{sat}^{ca}}{\delta \theta_{veg}} \Delta \theta_{veg} \right) \right) \times \frac{g_{ca}^{H_s}}{g_{ca}^{air} + g_{st}^{w} + g_{gr}^{ca}}$
CLM5.0	$T = -r_{ca,dry} \times \rho_{air} \left(g_{ca}^{air} \times q + g_{gr}^{ca} \times q_{gr} - \left(g_{ca}^{air} + g_{gr}^{ca} \right) \times \left(q_{sat}^{ca} + \frac{\delta q_{sat}^{ca}}{\delta \theta_{veg}} \Delta \theta_{veg} \right) \right) \times \frac{g_{ca}^{H_s}}{g_{ca}^{air} + g_{st}^{w} + g_{gr}^{ca}}$
CWatM	$T_{act} = C_{ws} \times (T_{pot} - E_{so})$ $C_{ws} = \frac{S_{so,tot1sol} - S_{so,WP1sol}}{S_{so,crit1sol} - S_{so,WP1sol}}$ $S_{so,crit1sol} = (1 - f_{so,dep}) \times (S_{so,FC1sol} - S_{so,WP1sol}) + S_{so,WP1sol}$ $f_{so,dep} = \frac{1}{0.76 + 1.5 \times T_{max}} - 0.1 \times (5 \times C_{cropGN})$
DBH	$T = \frac{1}{H_{l,E}} \times \frac{e_{ca} - e}{\frac{1}{g_{ca}} + 2 \times r_b} \times \frac{\rho_{air} \times c_{air}}{\gamma} \times (1 - f_{ca,wet})$
H08	Transpiration is not explicitly computed, but is considered in the parameter snow-free albedo, taken from the GSWP2 standard monthly land use data set and included plant phenological aspects.
JULES-W1	$T = PET \times f_{ca} \times \frac{g_{ca}}{g_{ca} + C_H \times W_2}$
LPJmL	$T = min \left(T_{max} \times S_{so,rel}, (1 - f_{day,ca,wet}) \times PET \times \frac{1.391}{1 + \frac{g_{st,pot}}{3.26}} \right)$ $(1 - f_{day,ca,wet})$ is remaining day time canopy available energy.
MaC-PDM.20	Transpiration is not modeled separately, see Table S24.
MATSIRO	$T = T_{ca}^{sn,free} + T_{ca}^{sn,cov}$
mHM	Transpiration is not modeled separately, see Table S24, where the Feddes equation based on the PET concept is used.
MPI-HM	$T = f_{ca} \times PET \times \min \left(1, \max \left(0, \frac{S_{so} - S_{so,WP}}{0.75 \times S_{so,max} - S_{so,WP}} \right) \right)$
ORCHIDEE	$T = (q_{sat}^{ca} - q) \times W \times C_{su} \times (1 - r_{sn}) \times r_{ca})$
PCR-GLOBWB	$T = min(C_{crop} \times PET, \theta_{so})$
VIC	$T = \left(1 - \left(\frac{S_{ca}}{S_{ca,max}} \right)^{\frac{2}{3}} \right) \times PET \times \frac{r_w}{r_w + r_o + r_{ca}}$ See details in: Blondin [6]; Ducoudré et al. [16]
WaterGAP2	Transpiration is not modeled separately, see Table S24.
WAYS	Transpiration is not modeled separately, see Table S24.

Table S24. Evaporation from soil (E_{so})

Model	Equation
CLM4.5	$E_{so} = -\frac{\rho_{air}(q - q_{sat}^{gr})}{r_{so}}$
CLM5.0	$E_{so} = -\frac{\rho_{air}(q - q_{sat}^{gr})}{r_{so}}$
CWatM	$E_{so} = C_{crop} \times PET$
DBH	$E_{so} = \frac{1}{H_{l,E}} \times \frac{q_{so} \times (e_{ca} - e)}{r_{so} + r_{wca}} \times \frac{\rho_{air} \times c_{air}}{\gamma} \times (1 - f_{su,gr})$
H08	$E_{so} = \alpha \times PET$ where: $\begin{cases} \alpha = 1, & S_{so,tot} \geq S_{so,crit} \\ \alpha = \frac{S_{so,tot}}{S_{so,crit}}, & S_{so,tot} < S_{so,crit} \end{cases}$ $S_{so,crit} = 0.75 \times S_{so,FC}$ (fixed at 150 [kgm^{-2}]. For detail see [40].
JULES-W1	$E_{so} = PET \times (1 - f_a) \times \frac{(1 - f_{ca}) \times g_{so}}{(1 - f_{ca}) \times g_{so} + C_H \times W_2}$ $g_{so} = \frac{1}{100} \times \left(\frac{S_{so,FL}}{S_{so,crit}}\right)^2$
LPJmL	$E_{so} = E_{eq} \times \alpha \times S_{so,rel} \times (1 - f_{ca,G})$
Mac-PDM.20	E_{so} is assumed to occur at the PET rate until $S_{so,FC}$ is reached, below which the ratio of E_{so} to PET declines linearly to zero: $\frac{E_{so}}{PET} = 1, \quad S_{so} \geq S_{so,FC}$ $\frac{E_{so}}{PET} = \frac{S_{so}}{S_{so,FC}}, \quad S_{so} \leq S_{so,FC}$
MATSIRO	$E_{so} = E_{so,l}^{sn,freegr}$
mHM	$ET_{so,i} = \begin{cases} \alpha \times f_{root,i} \times PET', & \text{for } i = 0 \text{ (first layer)} \\ \alpha \times f_{root,i} \times \left(PET' - \sum_{l=0}^{i-1} ET_{so,i-1}\right), & \text{for } i > 0 \end{cases}$ $PET' = PET - E_{ca} - \frac{S_{pon}}{S_{pon,max}}(PET_{ows} - E_{ca})$ $\alpha = \begin{cases} 0, & \frac{S_{so,i}}{d_{so,i}} \leq S_{so,r,i} \\ \frac{\frac{S_{so,i}}{d_{so,i}} - S_{so,r,i}}{S_{so,w,i} - S_{so,r,i}}, & S_{so,r,i} < \frac{S_{so,i}}{d_{so,i}} \leq S_{so,w,i} \\ 1, & S_{so,w,i} < \frac{S_{so,i}}{d_{so,i}} \end{cases}$
MPI-HM	$E_{so} = f_{so,bare} \times PET \times \min\left(1, \max\left(0, \frac{S_{so} - 0.05 \times S_{so,max}}{S_{so,max} - 0.05 \times S_{so,max}}\right)\right)$
ORCHIDEE	$E_{so} = (q_{sat}^{ca} - q) \times W \times C_{su} \times (1 - r_{floodplain}) \times (1 - r_{sn}) \times r_{so}$
PCR-GLOBWB	$E_{so} = C_{crop} \times PET$
VIC	The bare soil evaporation only occurs on the top thin layer. When the surface soil is saturated, it evaporates at the potential evaporation rate. When the top soil layer is not saturated, its evaporation rate (E1) is calculated using the Arno formulation by Franchini and Pacciani [19]. $E_{so} = PET \times \left(\int_{i=0}^{f_{so,bare,sat}} \delta f_{R_{in,0}} + \int_{f_{so,bare,sat}}^{1} \times \frac{R_{in,0}}{R_{in,max}\left(1 - (1 - f_{R_{in,0}})^{\frac{1}{\Pi_{R_{in}}}}\right)} \delta f_{R_{in,0}}\right)$
WaterGAP2	$E_{so} = min\left(PET - E_{ca},\ (PET_{,max} - E_{ca}) \times \frac{S_{so}}{S_{so,max}}\right)$ $PET_{,max} = 15\ (\text{mm day}^{-1})$ Note: Evaporation and transpiration are calculated together.
WAYS	$E_{so} = (PET - E_{ca}) \times min\left(1, \frac{S_{rz}}{\upsilon \times S_{rz,max} \times (1 + \beta)}\right)$ the scale parameter υ is set to 0.5, and the shape parameter β need to be fitted during the calibration processes. Note: Evaporation and transpiration are calculated together.

Table S25. Infiltration (R_{in})

Model	Equation
CLM4.5	$R_{in} = R_{in,over-so} + R_{pe,h2osfc}$ $R_{in,over-so} = (1 - f_{h2o})Q_{in,surf} - R_{ho} - (1 - f_{sn} - f_{h2o})E_{so}$ $R_{pe,h2osfc} = min\left(f_{h2o}R_{in,max}, \frac{w_{sfc}}{\Delta t}\right)$
CLM5.0	$R_{in} = R_{in,over-so} + R_{pe,h2osfc}$ $R_{in,over-so} = (1 - f_{h2o})Q_{in,surf} - R_{ho} - (1 - f_{sn} - f_{h2o})E_{so}$ $R_{pe,h2osfc} = min\left(f_{h2o}R_{in,max}, \frac{w_{sfc}}{\Delta t}\right)$
CWatM	$R_{in,pot} = \frac{S_{so,sat}}{\beta+1} - \frac{S_{so,sat}}{\beta+1} \times \left(1-(1-\alpha)^{\frac{\beta+1}{\beta}}\right)$ $\alpha = 1-(1-\frac{S_{so,rel}}{S_{so,sat}})^{\beta}$ $R_{in} = min\,(P_{tot}, R_{in,pot})$ The infiltration capacity of the soil is estimated using the Xinanjiang (also known as VIC/ARNO) model β = shape parameter of the Xinanjiang model
DBH	$R_{in} = k_{sat} \times \left(1 + \frac{(S_{so,sat} - S_{so,ini}) \times S_{so,pot}}{R_{in,cum}}\right)$
H08	$R_{in} = \frac{S_{so,FC}}{t} \times \frac{S_{so,tot}}{S_{so,FC}}^{\tau}$. See [21] t = 100 [days] = 86400 × 100 [s]; τ is set at 2.
JULES-W1	$R_{in} = k \times \left(\frac{\delta T}{\delta d_{so}} + 1\right); k = k_{sat}\left(\frac{\theta}{\theta_{so}}\right)^{2\times a+3}$
LPJmL	$R_{in} = P_{tot} \times \sqrt{1 - \frac{S_{so,tot} - S_{so,WP}}{S_{so,sat,FL} - S_{so,WP}}}$ i = top layer
Mac-PDM.20	$R_{in} = P_{tot} - R_{sat}$
MATSIRO	$R_{in} = P_{th} - R_{ho} - R_{sat}$
mHM	$R_{in,i} = \begin{cases} P_{th} + M - R_{su}, & \text{i = 0 (top soil layer)} \\ R_{in,i-1} - \left(\frac{\frac{S_{so,i}}{d_{so,i}} - S_{so,r,i}}{S_{so,max,i} - S_{so,r,i}}\right)^{a_i}, & i > 0 \end{cases}$
MPI-HM	$R_{in} = (P_{ra} + M) \times (1 - f_{we}) - R_{su}$
ORCHIDEE	$R_{in,j} = \frac{k_{j,j} + k_{sat,j}}{2}$
PCR-GLOBWB	$R_{in} = min(P_{ra} + M, k_{sat})$
VIC	for there is no vegetation coverage: $R_{in} = P_{ra} - R_{pe}$ for there is vegetation coverage: $R_{in} = P_{th} - R_{pe}$ See [20]; [29].
WaterGAP2	$R_{in} = M + P_{th} - (0.5 \times (M + P_{th}) \times f_{bu})$
WAYS	$R_{in} = M + P_{th}$

Table S26. Interflow (R_{if})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$R_{if} = f_{if} \times R_{pe}$
DBH	not represented
H08	not represented
JULES-W1	$R_{if} = \begin{cases} 0, & S_{so,tot} < S_{so,WP} \\ R_{in,sat} \times S_{ca} \times \frac{S_{so,tot} - S_{so,WP}}{R_{in,sat} - S_{so,WP}}, & S_{so,WP} \leq S_{so,tot} < S_{so,sat} \\ R_{in,sat}, & S_{so,tot} > S_{so,sat} \end{cases}$
LPJmL	$R_{if} = R_{in,L}\sqrt{1 - \frac{S_{so,tot} - S_{so,WP}}{S_{so,sat} - S_{so,WP}}}$
Mac-PDM.20	not represented
MATSIRO	not included in the version used in ISIMIP2b
mHM	$R_{if,fast} = \begin{cases} k_0 \times (S_{uz} - S_{uz,thr}), & S_{uz} > S_{uz,thr} \\ 0, & S_{uz} \leq S_{uz,thr} \end{cases}$ $R_{if,slow} = k_1 \times (S_{uz})^{1+a_{uz}}$ Interflow originates from the unsaturated zone storage, a bucket below the soil storage.
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$R_{if} = R_{pe} - R_{cr}$ for $R_{pe} > R_{cr}$
VIC	not represented
WaterGAP2	not represented
WAYS	$R_{if} = \frac{S_f}{K_f}$ K_f needs to be fitted.

Table S27. Percolation (R_{pe})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$R_{pe} = (1 - f_{we}) \times min(R_{in}, k_{3so})$ Unsaturated conductivity using Van Genuchten equation for each soil layer
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	$R_{pe} = (S_{so,sat} - S_{so,FC}) \times \left[1 - exp\left(\frac{-\Delta t}{\frac{S_{so,FC}}{k}}\right)\right]$
Mac-PDM.20	not represented
MATSIRO	not explicitly represented
mHM	not represented (defined as groundwater recharge, see Table S30)
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	not represented
WAYS	not explicitly represented

Table S28. Capillary rise (R_{cr})

Model	Equation
CLM4.5	Represented through the concept of soil matrix potential: $\Psi_i = \Psi_{sat,i}\left(\frac{S_{so,tot}}{S_{so,sat}}\right)^{C_{so,i}} \geq -1\times10^8$
CLM5.0	Represented through the concept of soil matrix potential: $\Psi_i = \Psi_{sat,i}\left(\frac{S_{so,tot}}{S_{so,sat}}\right)^{C_{so,i}} \geq -1\times10^8$
CWatM	$R_{cr} = 0.5\times\sqrt{k_{3so}\times k_{sat}}\times R_{cr,max}$ $R_{cr,max}$: cell fraction, depending on height of ground water table and relative elevation of grid
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	$R_{cr} = k\times\left(\frac{\delta Z_{cr}}{\delta Z}-1\right)$
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$R_{cr} = 0.5\times\sqrt{k_{3so}\times k_{sat}}\times R_{cr,max}$ $R_{cr,max}$: cell fraction, depending on height of ground water table and relative elevation of grid
VIC	not represented
WaterGAP2	not represented
WAYS	not represented

Table S29. Groundwater storage (S_{gw})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	Only represented indirectly through changes in the water table depth (unconfined aquifer) $\Delta d_{wt} = \frac{(R_{gwr} - R_{gw})}{S_y} \Delta t$	R_{gwr}	R_{gw}
CLM5.0	Only represented indirectly through changes in the water table depth (unconfined aquifer) $\Delta d_{wt} = \frac{(R_{gwr} - R_{gw})}{S_y} \Delta t$	R_{gwr}	R_{gw}
CWatM	$\frac{\delta S_{gw}}{\delta t} = Q_{pf} + R_{pe} - R_{cr} - R_{gw} - A^{gw}_{irr} - A^{gw}_{dom} - A^{gw}_{man} - A^{gw}_{liv}$	R_{pe} Q_{pf}	R_{cr} R_{gw} A^{gw}_{irr} A^{gw}_{dom} A^{gw}_{man} A^{gw}_{liv}
DBH	not represented		
H08	$\frac{\delta S_{gw}}{\delta t} = S_{gw,rw} - S_{gw,nrw}$ $S_{gw,rw} = R_{gwr} - R_{gw} - \frac{A_{tot}}{B_G}$	R_{gwr}	R_{gw} A_{tot}
JULES-W1	not represented		
LPJmL	not represented		
Mac-PDM.20	$\frac{\delta S_{gw}}{\delta t} = R_{gwr} - R_{gw}$	R_{gwr}	R_{gw}
MATSIRO	$\frac{\delta S_{gw}}{\delta t} = \sum_{n=1,13} \Big((S_{so,F_i} + S_{so,uF_i}) \times d_{so} \Big)$ It explicitly diagnoses groundwater table depth and calculate water flux between groundwater storage and unsaturated soil based on the condition of the soil layer that has groundwater table. Groundwater pumping and baseflow are used instead of root uptake and interflow.		
mHM	no water table depth or confined aquifers are considered: $\frac{\delta S_{gw}}{\delta t} = R_{gwr} - R_{gw}$	R_{gwr}	R_{gw}
MPI-HM	very simple representation, no water table depth or confined aquifers are considered $\frac{\delta S_{gw}}{\delta t} = R_{gwr} - R_{gw} - f_{irr} \times S_{gw}$	R_{gwr}	R_{gw}
ORCHIDEE	not represented		
PCR-GLOBWB	$\frac{\delta S_{gw}}{\delta t} = R_{pe} - R_{cr} - R_{gw} - A^{gw}_{irr} - A^{gw}_{dom} - A^{gw}_{man} - A^{gw}_{liv}$	R_{pe}	R_{cr} R_{gw} A^{gw}_{irr} A^{gw}_{dom} A^{gw}_{man} A^{gw}_{liv}
VIC	not represented		
WaterGAP2	$\frac{\delta S_{gw}}{\delta t} = R_{gwr} - R_{gw} - A_{gw}$	R_{gwr}	R_{gw} A_{gw}
WAYS	$\frac{\delta S_{gw}}{\delta t} = R_{gwr} - R_{gw}$	R_{gwr}	R_{gw}

Table S30. Groundwater recharge (R_{gwr})

Model	Equation
CLM4.5	$R_{gwr} = -k_{aq}\frac{(\Psi_{wt} - \Psi_{jwt})}{(d_{wt} - d_{wt,i})}$
CLM5.0	$R_{gwr} = -k_{aq}\frac{(\Psi_{wt} - \Psi_{jwt})}{(d_{wt} - d_{wt,i})}$
CWatM	$R_{gwr} = R_{pe} + Q_{pf} - R_{cr}$
DBH	$R_{gwr} = k_{3so} \times (\frac{\delta S_{so,max,3L}}{\delta d_{so,3}} + 1)$
H08	$R_{gwr} = min(R_{gwr,max}, f_r \times f_{so,tex} \times f_{hg} \times f_{pg} \times R_{tot})$. See [11]
JULES-W1	$R_{gwr} = k_{bot}$. See [4] and [5].
LPJmL	$R_{gwr} = R_{in,BL}\sqrt{1 - \frac{S_{so,tot} - S_{so,WP}}{S_{so,sat} - S_{so,WP}}}$
Mac-PDM.20	$R_{gwr} = S_{so} - S_{so,FC}$
MATSIRO	$R_{gwr} = \frac{\delta S_{so,uF_{i,gw}}}{\Delta t}$
mHM	$R_{gwr} = k_{uz}S_{uz}$
MPI-HM	$R_{gwr} = (1 - f_{we}) \times R_{gwr,min} \times \frac{S_{so}}{S_{so,max}} + (R_{gwr,max} - R_{gwr,min}) \times \left(\text{min}\left(1, \text{max}\left(0, \frac{S_{so} - 0.90 \times S_{so,max}}{S_{so,max} - 0.90 \times S_{so,max}}\right)\right)^{1.5}\right)$ if $S_{so} > 0.05 \times S_{so,max}$
ORCHIDEE	$R_{gwr} = max(0, 1 - \frac{S_{so}}{S_{somax}}) \times R_{gw}$ See [15]
PCR-GLOBWB	$R_{gwr} = R_{pe} - R_{cr}$
VIC	not represented
WaterGAP2	$R_{gwr} = \begin{cases} 0 & \text{(semi)arid grid cell, sandy texture and } P_{th} \leq 12.5(\text{mm day}^{-1}) \\ min(R_{gwr,max}, f_r \times f_{so,tex} \times f_{hg} \times f_{pg} \times R_{tot}) & \text{other cases} \end{cases}$ where $R_{gwr,max}$ is set to 7, 4.5, 2.5 mm d^{-1} for sandy, loamy, and clayey soils. See [11]
WAYS	$R_{gwr} = min(R_{gwr,max}, f_r \times f_{so,tex} \times f_{hg} \times f_{pg} \times R_{tot})$. See [11]

Table S31. Groundwater runoff (R_{gw})

Model	Equation
CLM4.5	$R_{gw} = C_{ice} \times R_{gw,max} \exp\left(-f_{drai} d_{wt}\right)$
CLM5.0	$R_{gw} = C_{ice} \times R_{gw,max} \exp\left(-f_{drai} d_{wt}\right)$
CWatM	$R_{gw} = C_{gw,Q} \times S_{gw}$
DBH	not represented
H08	$R_{gw} = \dfrac{S_{gwmax}}{t} \times \left(\dfrac{S_{gw,rw}}{S_{gwmax}}\right)^{\eta}$ where η = 2 and t = 100 days.
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	$R_{gw} = R_{gw,rout} \times (S_{gw}/100)^3$
MATSIRO	$R_{gw} = \dfrac{k_{sat}^{gw} \times \upsilon^{\beta}}{\Gamma_{\beta}} \left(d_0 \times \left(\dfrac{(\beta-1)!}{\upsilon^{\beta}} - e^{(-\upsilon \times d_0)} \times \sum_{n=0}^{\beta-1} \dfrac{(\beta-1)!}{n!} \times \dfrac{{d_0}^{n}}{\upsilon^{\beta-n}} \right) - \left(\dfrac{\beta!}{\upsilon^{\beta+1}} - e^{(-\upsilon \times d_0)} \times \sum_{n=0}^{\beta} \dfrac{\beta!}{n!} \times \dfrac{{d_0}^{n}}{\upsilon^{\beta-n+1}} \right) \right)$. See [27]; [55]
mHM	$R_{gw} = k_b S_{gw}$
MPI-HM	$R_{gw} = \dfrac{S_{gw}}{\kappa_{gw}}$
ORCHIDEE	$R_{gw} = k_{bot}$
PCR-GLOBWB	$R_{gw} = C_{gw,Q} \times S_{gw}$
VIC	not represented
WaterGAP2	$R_{gw} = \begin{cases} 0, & S_{gw} \leq 0 \\ C_{gw,Q} \times S_{gw}, & S_{gw} > 0 \end{cases}$ where $C_{gw,Q} = 0.01 d^{-1}$
WAYS	$R_{gw} = C_{gw,Q} \times S_{gw}$ $where\, C_{gw,Q} = 0.01 d^{-1}$

Table S32. Lake storage (S_{la})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	virtual storage, i.e. P-E automatically balanced by lake runoff term		
CLM5.0	virtual storage, i.e. P-E automatically balanced by lake runoff term		
CWatM	it has two types of lakes: "global lakes" are lakes that receive inflow not only from the grid cell itself and "local lakes" receive inflow from the grid cell itself. $\frac{\delta S_{la}}{\delta t} = Q_{ri,in} - Q_{ri,out}$	$Q_{ri,in}$	$Q_{ri,out}$
DBH	not represented		
H08	not represented		
JULES-W1	not represented		
LPJmL	$\frac{\delta S_{la}}{\delta t} = P_{tot} + Q_{iu} - Q_{la} - E_{la} - A$	P_{tot}, Q_{iu}	E_{la}, A
Mac-PDM.20	not represented		
MATSIRO	Lake storage is a part of river storage. Not explicitly included in the version used for ISIMIP2b.		
mHM	not represented		
MPI-HM	Lake storage is part of the wetland storage.		
ORCHIDEE	not represented		
PCR-GLOBWB	Lake storage is a part of river storage.		
VIC	not represented		
WaterGAP2	WaterGAP2 has two types of representations of lakes. Local lakes receive water only from the grid cell itself, while global lakes receive water from grid cell itself and the inflow from upstream cells. $\frac{\delta S_{la,local}}{\delta t} = (R_{su} \times f_{swb}) + R_{gw} + A_{rf} + B_{la,local} \times (P_{tot} - E_{la}) - R_{gwr}^{swb} - A_{la} - Q_{la,local}$ $B_{la,local} = C_{B,red} \times B_{la,local,max}$ $C_{B,red} = 1 - (\frac{\lvert S_{la,local} - S_{la,local,max}\rvert}{2S_{la,local,max}})^{3.32}$ $R_{gwr}^{swb} = \begin{cases} 0, & \text{humid cell} \\ C_{gw,rech}^{sw} \times C_{B,red} \times B_{la,local}, & \text{arid and semi-arid cells} \end{cases}$ $\frac{\delta S_{la,global}}{\delta t} = Q_{iu} + A_{rf} + Q_{we,local} + B_{la,global} \times (P_{tot} - E_{la}) - R_{gwr}^{swb} - A_{la} - Q_{la,global}$ $B_{la,global} = C_{B,red} \times B_{la,global,max}$ $C_{B,red} = 1 - (\frac{\lvert S_{la,global} - S_{la,global,max}\rvert}{2S_{la,global,max}})^{3.32}$ $R_{gwr}^{swb} = \begin{cases} 0, & \text{humid cell} \\ C_{gw,rech}^{sw} \times C_{B,red} \times B_{la,global}, & \text{arid and semi-arid cells} \end{cases}$	R_{su}, R_{gw}, P_{tot}, Q_{iu}, $Q_{we,local}$, A_{rf}	R_{gwr}^{swb}, A_{la}, $Q_{la,local}$, $Q_{la,global}$, E_{la}
WAYS	not represented		

Table S33. Evaporation from lake (E_{la})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$E_{la} = min(S_{la}, E_{la,pot} - min(P_{tot}, E_{la,pot})$
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	E_{la} = min(S_{la}, $E_{la,pot}$)
Mac-PDM.20	E_{la} = $P_{tot} - PET$
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	E_{la} = PET
VIC	not represented
WaterGAP2	$E_{la} = PET$ with albedo = 0.08
WAYS	not represented

Table S34. Outflow from lake (Q_{la})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	Modified Puls approach (Chow et al. [9]; Maniak [30]). Routing, reservoirs and lakes are done in sub steps of a day. $\frac{S_{la1}+S_{la2}}{\Delta t} = \frac{Q_{iu,la1}+Q_{iu,la2}}{2} - \frac{Q_{la1}+Q_{la2}}{2}$ for: $1 =$ first time step (t); 2 = second time step $(t+\Delta t)$
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	for $S_{la} \geq S_{la,max}, Q_{la} = (S_{la,max} - S_{la}),$ else $Q_{la} = 0$
Mac-PDM.20	not represented
MATSIRO	not included in the version used for ISIMIP2b
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$Q_{la} = 1.7 \times C_{weir} \times max(h_w - h_{of})^{1.5} \times b_{weir}$
VIC	not represented
WaterGAP2	$Q_{la,local} = C_{sw,out} \times S_{la,local} \times (\frac{S_{la,local}}{S_{la,local,max}})^{1.5}$ $Q_{la,global} = C_{sw,out} \times S_{la,global}$ for $C_{sw,out} = 0.01d^{-1}$
WAYS	not represented

Table S35. Reservoir storage (S_{re})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	not represented		
CLM5.0	not represented		
CWatM	$\frac{\delta S_{re}}{\delta t} = Q_{ri,in} - Q_{ri,out}$	$Q_{ri,in}$	$Q_{ri,out}$
DBH	not represented		
H08	$\frac{\delta S_{relocal}}{\delta t} = R_{tot} \times B_{re} - A_{re} - Q_{re}$ $\frac{\delta S_{reglobal}}{\delta t} = Q_{ri,in} - Q_{ri,out}$	R_{tot} $Q_{ri,in}$	A_{re} R_{tot} $Q_{ri,out}$
JULES-W1	not represented		
LPJmL	$\frac{\delta S_{re}}{\delta t} = P_{tot} + Q_{iu} - Q_{la} - E_{re} - A$	P_{tot} Q_{iu}	Q_{la} E_{re} A
Mac-PDM.20	not represented		
MATSIRO	$\frac{\delta S_{re}}{\delta t} = S_{reglobal} + S_{relocal}$ $\frac{\delta S_{relocal}}{\delta t} = R_{tot} - \frac{Q_{re,local}}{B} - A_{dom}^{pond} - A_{ind}^{pond} - A_{irr}^{pond}$ $\frac{\delta S_{reglobal}}{\delta t} = \frac{Q_{iu} + Q_{re,local} - Q_{re}}{B} - A_{dom}^{re,global} - A_{ind}^{re,global} - A_{irr}^{re,global}$	$Q_{iu,re}$	Q_{re} A_{dom} A_{irr} A_{ind}
mHM	not represented		
MPI-HM	not represented		
ORCHIDEE	not represented		
PCR-GLOBWB	$\frac{\delta S_{re}}{\delta t} = \begin{cases} Q_{ri} = Q_{mean} for\ S_{re} > 0.7 \times S_{re,C} \\ Q_{ri} = max\left(Q_{mean} \times \frac{S_{re,C} - S_{re,act}}{S_{re,act} - 0.3 \times S_{re,C}}, Q_{ef}\right) for\ 0.3 > S_{re} > 0.7 \times S_{re,C} \\ Q_{ef} for\ 0.3 < S_{re} \end{cases}$		
VIC	not represented		
WaterGAP2	$\frac{\delta S_{re}}{\delta t} = Q_{iu} + A_{rf} + Q_{we,local} + B_{re} \times (P_{tot} - E_{re}) - R_{gwr}^{swb} - A_{re} - Q_{re}$ for $B_{re} = C_{B,red} \times B_{re,max}$ for $C_{B,red} = 1 - \left(\frac{\lvert S_{re} - S_{re,max} \rvert}{S_{re,max}}\right)^{2.814}$ for $R_{gwr}^{swb} = \begin{cases} 0 & \text{for humid cell} \\ C_{gw,rech}^{sw} \times C_{B,red} \times B_{re} & \text{for arid and semi-arid cells} \end{cases}$	Q_{iu}, $Q_{we,local}$, P_{tot}, A_{rf}	E_{re}, R_{gwr}^{swb}, B_{re}, Q_{re}, A_{re}
WAYS	not represented		

Table S36. Inflow from upstream surface water bodies for reservoir storage

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	sum of inflows of water from neighboring upstream grid cells routed with kinematic wave approach
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	sum of inflows of water from neighboring upstream grid cells routed with kinematic wave approach
VIC	not represented
WaterGAP2	not represented
WAYS	not represented

Table S37. Outflow from reservoir (Q_{re})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$Q_{re} = \begin{cases} min(Q_{re,min},\ \frac{1}{\Delta t} \times f_{re} \times S_{re,C}, & f_{re} \leq 2 \times S_{cons} \\ Q_{re,min} + (Q_{re,norm} - Q_{re,min}) \times \left(\frac{f_{re} - 2 \times S_{cons}}{S_{norm} - 2 \times S_{cons}}\right), & S_{norm} \geq f_{re} > 2 \times S_{cons} \\ Q_{re,norm} + \frac{f_{re} - S_{norm}}{S_{flood} - S_{norm}} \times max\Big((Q_{iu,re} - Q_{re,norm}), (Q_{re,nd} - Q_{re,norm})\Big), & S_{flood} \geq f_{re} > S_{norm} \\ max(\frac{f_{re} - S_{flood}}{\Delta t} \times S_{re,C},\ Q_{re,nd}), & f_{re} > S_{flood} \end{cases}$
DBH	not represented
H08	Non-irrigation dam $Q_{re} = Q_{iu,mean}$ Irrigation reservoir dam $Q_{re} = \begin{cases} C_{year} \times C_{month} \\ \frac{S_{re,C}}{0.5}^2 \times C_{year} \times C_{month} + \Big(1 - (\frac{S_{re,C}}{0.5}^2)\Big) \end{cases}$ for: $S_{re,C} = \begin{cases} \frac{Q_{iu,mean}}{2} \times \left(1 + \frac{\sum C_{dam,G} \times (A_{irr,month} + A_{ind,month} + A_{dom,month})}{A_{dem,dam}}\right), & A_{dem,dam} \geq 0.5 \times Q_{iu,mean} \\ Q_{iu,mean} + \sum C_{dam,G} \times (A_{irr,month} + A_{ind,month} + A_{dom,month}) - A_{dem,dam}, & A_{dem,dam} < 0.5 \times Q_{iu,mean} \end{cases}$ $\sum C_{dam,G}$ = for an area downstream of the dam up to 10 grid cells; $C_{tot} = C_{month} \times Q_{iu,tot,re}$; $C_{month} = \dfrac{S_{w,first}}{0.85 \times S_{re,tot}}$; $S_{re,C} = \dfrac{S_{re,tot}}{C_{tot}}$
LPJmL	for $S_{re} \geq S_{re,max}, Q_{re} = (S_{re,max} - S_{re}),\ else\ Q_{re} = 0$
Mac-PDM.20	not represented
MATSIRO	$Q_{re} = Q_{re,global} + Q_{re,local}$ $Q_{re,local} = \dfrac{max(S_{re,local} + R_{tot} \times \Delta t - S_{re,global}, 0)}{\Delta t}$ $Q_{re,global} = \begin{cases} Q^{purpose}_{re,global} + \frac{S^{purpose}_{re,global} - S_{re,global}}{\Delta t}, & S^{purpose}_{re,global} + (Q_{re,local} - Q^{purpose}_{re,global}) \times \Delta t > S_{re,global} \\ Q^{purpose}_{re,global} + \frac{S_{re,global}}{\Delta t}, & S^{purpose}_{re,global} + (Q_{re,local} - Q^{purpose}_{re,global}) \times \Delta t < 0 \\ Q^{purpose}_{re,global}, & \text{else} \end{cases}$ $Q^{purpose}_{re,global} = Q^{irr}_{re,global}$ or $Q^{non-irr}_{re,global}$
mHM	not represented
MPI-HM	not represented
PCR-GLOBWB	$Q_{re} = 1.7 \times C_{weir} \times max(h_w - h_{of})^{1.5} \times b_{weir}$
WaterGAP2	irrigation reservoir type: $Q_{re} = \begin{cases} Q^{irr}_{re,de}, & \frac{S_{re,max}}{Q_{re,mean}} \geq 0.5 \\ 4 \times (\frac{S_{re,max}}{Q_{re,mean}})^2 \times Q^{irr}_{re,de} + (1 - 4 \times (\frac{S_{re,max}}{Q_{re,mean}})^2 \times Q_{iu,re}), & \frac{S_{re,max}}{Q_{re,mean}} < 0.5 \end{cases}$ with $Q^{irr}_{re,de} = \begin{cases} C_{year} \times \frac{Q_{re,mean}}{2} \times (1 + \frac{A_{dem,5dcells,month}}{A_{dem,5dcells}}), & A_{dem,5dcells} \geq \frac{Q_{re,mean}}{2} \\ C_{year} \times Q_{re,mean} + A_{dem,5dcells,month} - A_{dem,5dcells}, & A_{dem,5dcells} < \frac{Q_{re,mean}}{2} \end{cases}$ non-irrigation reservoir type: $Q_{re} = \begin{cases} C_{year} \times Q_{re,mean}, & \frac{S_{re,max}}{Q_{re,mean}} \geq 0.5 \\ 4 \times (\frac{S_{re,max}}{Q_{re,mean}})^2 \times C_{year} \times Q_{re,mean} + (1 - 4 \times (\frac{S_{re,max}}{Q_{re,mean}})^2 \times Q_{iu,re}), & \frac{S_{re,max}}{Q_{re,mean}} < 0.5 \end{cases}$ both reservoir types: $C_{year} = \begin{cases} 0.1, & \text{filling phase for } S_{re} < (S_{re,max} \times 0.1) \\ \frac{S_{re}}{S_{re,max} \times 0.85}, & \text{not filling phase} \end{cases}$ and $Q_{re} = \begin{cases} Q_{re}, & S_{re} \geq S_{re,max} \times 0.85 \times 0.1 \\ Q_{re} \times 0.1, & S_{re} < S_{re,max} \times 0.85 \times 0.1 \end{cases}$ For details on the calculation of reservoir outflow please see [23] and [14]
WAYS	not represented

Table S38. Evaporation from reservoir (E_{re})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$E_{re} = min(S_{re}, E_{re,pot} - min(P_{tot}, E_{re,pot}) \times B_{re}$
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	$E_{re} = min(S_{re}, E_{re,pot})$
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$E_{re} = PET$
VIC	not represented
WaterGAP2	$E_{re} = PET$ with albedo = 0.08
WAYS	not represented

Table S39. Wetland storage (S_{we})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	not represented		
CLM5.0	not represented		
CWatM	not represented		
DBH	not represented		
H08	not represented		
JULES-W1	not represented		
LPJmL	not represented		
Mac-PDM.20	not represented		
MATSIRO	not represented		
mHM	not represented		
MPI-HM	$\frac{\delta S_{we}}{\delta t} = f_{we} \times \left(P_{ra} + M - \frac{R_{gwr,max}}{10}\right) - E_{we} + Q_{iu,we,up} - Q_{we} - f_{irr} \times S_{we}$	$Q_{iu,we,up}$, P_{ra}, M	R_{pe}, E_{we}, Q_{we}
ORCHIDEE	not represented		
PCR-GLOBWB	not represented		
VIC	not represented		
WaterGAP2	WaterGAP2 has two types of representations of wetlands. Global wetlands are wetlands that receive inflow from the grid cell itself and the upstream grid cells, while local wetlands receive inflow only from the grid cell where have been identified. $\frac{\delta S_{we,local}}{\delta t} = Q_{la,local} + B_{we,local} \times (P_{tot} - E_{we}) - R^{swb}_{gwr} - Q_{we,local}$ for $B_{we,local} = C_{B,red} \times B_{we,local,max}$ for $C_{B,red} = 1 - \left(\frac{\lvert S_{we,local} - S_{we,local,max}\rvert}{S_{we,local,max}}\right)^{3.32}$ for $R^{swb}_{gwr} = \begin{cases} 0, & \text{for humid cell} \\ C^{sw}_{gw,rech} \times C_{B,red} \times B_{we,local}, & \text{for arid and semi-arid cells} \end{cases}$ $\frac{\delta S_{we,global}}{\delta t} = Q_{la,global} + Q_{re} + B_{we,global} \times (P_{tot} - E_{we}) - R^{swb}_{gwr} - Q_{we,global}$ for $B_{we,global} = C_{B,red} \times B_{we,global,max}$ for $C_{B,red} = 1 - \left(\frac{\lvert S_{we,global} - S_{we,global,max}\rvert}{S_{we,global,max}}\right)^{3.32}$ for $R^{swb}_{gwr} = \begin{cases} 0, & \text{for humid cell} \\ C^{sw}_{gw,rech} \times C_{B,red} \times B_{we,global}, & \text{for arid and semi-arid cells} \end{cases}$	$Q_{la,local}$, P_{tot}, $Q_{la,global}$, Q_{re}	E_{we}, R^{swb}_{gwr}, $Q_{we,local}$, $Q_{we,global}$
WAYS	not represented		

Table S40. Inflow from upstream grid cell for wetland storage ($Q_{iu,we,up}$)

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	not represented
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-Hm	$Q_{iu,we,up} = {f_{we}}^2 \times (Q_{rv,up} + R_{gw,up} + Q_{ri,up})$
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	not represented
WAYS	not represented

Table S41. Evaporation from wetland (E_{we})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	not represented
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	$E_{we} = PET \times f_{we}$
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$E_{we} = PET$ with albedo = 0.08
WAYS	not represented

Table S42. Outflow from wetland (Q_{we})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	not represented
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-Hm	$Q_{we} = \frac{S_{we}}{t_{we}}$ for $t_{we} = \frac{l_{G,ri}}{C_{MS,we} \times h_{w,we}^{\frac{2}{3}} \times s_{we,mean}^{\frac{1}{2}}}$
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$Q_{we,local} = C_{sw,out} \times S_{we,local} \times (\frac{S_{we,local}}{S_{we,local,max}})^{2.5}$ $Q_{we,global} = C_{sw,out} \times S_{we,global}$ with $C_{sw,out} = 0.01d^{-1}$
WAYS	not represented

Table S43. River storage (S_{ri})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	$\frac{\delta S_{ri}}{\delta t} = Q_{iu} - Q_{ri} + R_{su,l}$	Q_{ri}	Q_{iu}
CLM5.0	$\frac{\delta S_{ri}}{\delta t} = Q_{iu} - Q_{ri} + R_{su,l}$	Q_{ri}	Q_{iu}
CWatM	$\frac{\delta S_{ri}}{\delta t} = R_{if} + R_{gw} + R_{su} + Q_{iu} - Q_{od} - A^{sw}_{dom} - A^{sw}_{irr} - A^{sw}_{liv} - A^{sw}_{man}$		
DBH	not represented		
H08	$\frac{\delta S_{ri}}{\delta t} = Q_{ri} - Q_{iu}$; $Q_{iu}$is modified if a reservoir is present. See [36]	Q_{ri}	Q_{iu}
JULES-W1	not represented		
LPJmL	$\frac{\delta S_{ri}}{\delta t} = Q_{iu} - Q_{iu,la} - Q_{ri} - A_{act,irr}$	Q_{iu}	$Q_{iu,la}$, Q_{ri}, $A_{act,irr}$
Mac-PDM.20	not represented		
MATSIRO	at a grid without reservoir $\frac{\delta S_{ri}}{\delta t} = Q_{iu,re} - Q_{re}$ for $Q_{iu,re} = \frac{Q_{iu} + R_{tot}}{B_G}$ at a grid with reservoir $\frac{\delta S_{ri}}{\delta t} = \frac{\delta S_{re,global}}{\delta t}$	$Q_{iu,re}$, Q_{iu}, R_{tot}	Q_{re}
mHM	$\frac{\delta S_{ri}}{\delta t} = R_{tot} + Q_{iu} - Q_{ri}$	Q_{iu}	Q_{ri}
MPI-HM	$\frac{\delta S_{ri,n}}{\delta t} = Q_{ri,n-1} - Q_{ri,n} - f_{irr} \times S_{ri,n}$ for n = [1,...,5] and $Q_{ri0} = Q_{iu}$ $Q_{ri,n} = \frac{S_{ri,n}}{\kappa_{ri}}$for n = [1,...,5]	Q_{iu}	Q_{ri}
ORCHIDEE	$\frac{\delta S_{ri,fast,i+1}}{\delta t} = S_{ri,fast,i} + R_{su} - \frac{S_{ri,fast,i}}{t_{ret} \times t_{ri,fast}}$ $\frac{\delta S_{ri,slow,i+1}}{\delta t} = S_{ri,slow,i} + R_{gw} - \frac{S_{ri,slow,i}}{t_{ret} \times t_{ri,slow}}$ $\frac{\delta S_{ri,stream,i+1}}{\delta t} = S_{ri,stream,i} + \frac{S_{ri,fast,i}}{t_{ret} \times t_{ri,fast}} + \frac{S_{ri,slow,i}}{t_{ret} \times t_{ri,slow}} - \frac{S_{ri,stream,i}}{t_{ret} \times t_{ri,stream}}$	R_{su}, R_{gw}	
PCR-GLOBWB	$\frac{\delta S_{ri}}{\delta t} = R_{if} + R_{gw} + R_{su} + Q_{iu} - Q_{od} - A^{sw}_{dom} - A^{sw}_{irr} - A^{sw}_{liv} - A^{sw}_{man}$	R_{if}, R_{gw}, R_{su}, Q_{iu}	Q_{od}, A^{sw}_{dom}, A^{sw}_{irr}, A^{sw}_{liv}, A^{sw}_{man}
VIC	not represented		
WaterGAP2	$\frac{\delta S_{ri}}{\delta t} = Q_{iu} + R_{su} \times (1 - f_{swb}) + R^{ri}_{gw} + A_{rf} - A_{ri} - Q_{ri}$ with $R^{ri}_{gw} = \begin{cases} R_{gw} & \text{arid and semi-arid cells} \\ R_{gw} \times (1 - f_{swb}) & \text{humid cells} \end{cases}$	$Q_{we,global}$, R_{su}, R^{ri}_{gw}	A_{ri}, Q_{ri}
WAYS	not represented		

Table S44. Rivulet storage (S_{rv})

Model	Equation	Water Flux	
		Inflows	Outflows
CLM4.5	not represented		
CLM5.0	not represented		
CWatM	$\frac{\delta S_{rv}}{\delta t} = R_{su_{LC,R}} - R_G^1$	$R_{su_{LC,R}}$	R_G^1
DBH	not represented		
H08	not represented		
JULES-W1	not represented		
LPJmL	not represented		
Mac-PDM.20	not represented		
MATSIRO	not represented		
mHM	not represented		
MPI-HM	$\frac{\delta S_{rv}}{\delta t} = R_{su} - R_G$	R_{su}	R_G
ORCHIDEE	not represented		
PCR-GLOBWB	not represented		
VIC	not represented		
Water-GAP2	not represented		
WAYS	not represented		

Table S45. Inflow from upstream surface water bodies (Q_{iu})

Model	Equation
CLM4.5	sum of inflows of water from neighboring upstream grid cells
CLM5.0	sum of inflows of water from neighboring upstream grid cells
CWatM	sum of inflows of water from neighboring upstream grid cells, lakes and reservoirs.Kinematic wave approach.
DBH	not represented
H08	$Q_{iuG} = v \times S_{riG-1}$ for v = 0.5
JULES-W1	not represented
LPJmL	$Q_{iu} = Q_{ri} - E_{la} - E_{re}$
Mac-PDM.20	not represented
MATSIRO	$Q_{iu} = \sum\limits_{upstreamG} \times Q_{ri}{}^{upstreamG}$
mHM	sum of inflows of water from neighboring upstream grid cells
MPI-HM	$Q_{iu} = R_{gw,up} + Q_{rv,up} + Q_{ri,up} - Q_{iu,we,up}$
ORCHIDEE	$Q_{iu} = \sum \frac{S_{ri,stream,upper}}{t_{ret} \times t_{ri,stream}}$
PCR-GLOBWB	$Q_{iu} = \frac{\delta Q_{ri}}{\delta l_{ri}} + C_{weir} \times C_{weir} \times Q_{ri}{}^{(C_{weir}-1)} \times \frac{\delta Q_{ri}}{\Delta t}$
VIC	not represented
WaterGAP2	inflow from upstream grid cells is routed through global lakes see Table S32.
WAYS	not represented

Table S46. Streamflow (Q_{ri})

Model	Equation
CLM4.5	$Q_{ri} = \frac{v}{l_G} \times S_{ri}$
CLM5.0	$Q_{ri} = \frac{{C_{ri,hydraulic}}^{\frac{2}{3}} \times s_{ri}}{C_M}$
CWatM	$\frac{\Delta t}{l_{ri}} \times {Q_{ri}}_{i+1}^{t+1} + \alpha \times ({Q_{ri}}_{i+1}^{t+1})^{\beta} = \frac{\Delta t}{l_{ri}} \times {Q_{ri}}_{i}^{t+1} + \alpha \times ({Q_{ri}}_{i+1}^{t})^{\beta} + \Delta t \times (\frac{{Q_{ri}}_{i+1}^{t+1} + {Q_{ri}}_{i+1}^{t}}{2})$ For each cell and for each time step using an iterative approach given in Chow et al. [9]. The coefficients can be calculated using Manning's equation.
DBH	not represented
H08	$Q_{ri} = \sum R_{su} + Q_{iu}$ When a dam is present, outflow from dam is used, see Table 35.
JULES-W1	not represented
LPJmL	$Q_{ri,out} = Q_{ri,in} \times \frac{1}{\iota \times \Gamma \times n} \times \frac{t}{\iota}^{(n-1)} \times e^{\frac{-t}{\iota}}$ for: $n = \frac{l_{ri}}{l_{ri,hom}}$; $\iota = \frac{l_{ri,hom}}{v_{mean}}$; Γ = gamma function which allows for non-integer values of "n".
Mac-PDM.20	not represented
MATSIRO	at a grid without reservoir $Q_{ri,t} = (Q_{iu} + {R_{tot}}^*) - \frac{S_{ri,(t+\Delta t)} - S_{ri,t}}{\Delta t} \times B - (A_{irr}^{ri} + A_{dom}^{ri} + A_{ind}^{ri}) \times B$ A part of R_{tot} flows into a pond and is stored in the pond, then R_{tot} becomes ${R_{tot}}^*$ which = $Q_{re,local}$ at a grid with reservoir $Q_{ri} = Q_{re} - (A_{irr}^{ri} + A_{dom}^{ri} + A_{ind}^{ri}) \times B$
mHM	${Q_{ri}}_{i+1}^{t+1} = C_{M1} \times {Q_{ri}}_{i}^{t+1} + C_{M2} \times {Q_{ri}}_{i}^{t} + C_{M3} \times {Q_{ri}}_{i+1}^{t}$ for each cell i and for each time step t using an iterative approach given in Chow et al. [9]. The coefficients $C_{M1} - C_{M3}$ are fully derived in Thober et al. [50].
MPI-HM	$Q_{ri} = \frac{S_{ri,n}}{\kappa_{ri}}$ for n = 5
ORCHIDEE	$Q_{ri} = \frac{S_{ri,stream,i}}{t_{ret} \times t_{ri,stream}}$
PCR-GLOBWB	$Q_{ri} = \frac{\delta Q_{ri}}{\delta l_{ri}} + C_{weir} \times C_{weir} \times {Q_{ri}}^{(C_{weir}-1)} \times \frac{\delta Q_{ri}}{\Delta t}$
VIC	not represented
WaterGAP2	$Q_{ri} = \frac{v}{l_{ri}} \times S_{ri}$ for $v = {C_M}^{-1} \times {C_{ri,hydraulic}}^{\frac{2}{3}} \times {s_{ri}}^{\frac{1}{2}}$ for details see Verzano et al. [52]
WAYS	not represented

Table S47. Evaporation from river (E_{ri})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$E_{ri} = E_{la,pot} - min(P_{tot}, E_{la,pot})$
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	$E_{ri} = E_{la} = min(S_{la}, E_{la,pot})$
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$E_{ri} = PET$
VIC	not represented
WaterGAP2	not represented
WAYS	not represented

Table S48. Minimum and Maximum values of each water storage Part I

Water Storage	CLM4.5		CLM5.0		CWatM		DBH	
	Min	Max	Min	Max	Min	Max	Min	Max
Canopy storage	0	depends on vegetation characteristics (> 20 PFT) and state (LAI)	0	depends on vegetation characteristics (> 20 PFT) and state (LAI)	0	specific to each land cover class and time of the year	0	$(2 \times 10^{-4}$and $5 \times 10^{-4}) \times LAI$
Snow storage	0	no upper limit	0	no upper limit	0	no upper limit	$\begin{cases} 0, & \text{for canopy} \\ 0.002m, & \text{for ground surface} \end{cases}$	$\begin{cases} 10^{-4} \times LAI \times f_{ca,ex}, & \text{for canopy} \\ \text{no limit}, & \text{for ground surface} \end{cases}$
Soil storage	0	100%	0	100%	0	(saturated soil layer water content - residual soil layer water content) x soil layer depth	0	100%, absolute capacity is determined by soil properties
Groundwater storage	0	no upper limit	0	4800mm	0	no upper limit	not represented	not represented
Lake storage	0	the storage is forced constant (any imbalance between P and ET is compensated by an artificial runoff term, keeping lake depth at a constant value)	0	the storage is forced constant (any imbalance between P and ET is compensated by an artificial runoff term, keeping lake depth at a constant value)	0	no upper limit	not represented	not represented
Wetland storage	not represented	not represented	not represented	not represented	not represented	not represented	not represented	not represented
Reservoir storage	not represented	not represented	not represented	not represented	0	defined for each reservoir, cannot be exceed because of included non damaging outflow function	0	Reservoir storage capacity
River storage	not represented	not represented	not represented	not represented	0	no upper limit	0	∞

Table S49. Minimum and Maximum values of each water storage Part II

Water Storage	H08		JULES-W1		LPJmL		MATSIRO
	Min	Max	Min	Max	Min	Max	
Canopy storage	not represented	not represented	$S_{ca,min}$ = 0.5	$S_{ca,max} = S_{ca,min} + 0.05 \times LAI$ Minimum LAI permitted in calculation of the albedo in snow-free conditions is set to 0.5 m2/m2, maximum LAI value ranges between 1 and 5 depending on the plant functional type (PFT). [5]	0	$S_{ca,p}$ specific to each PFT, respectively, tropical and temperate trees 0.02, boreal trees 0.06, grasses 0.01. Canopy water storage is assumed to be the product of daily precipita2on, leaf area index, and a PFTand CFT-specific parameter that approximates the leaf form of the PFTs and the precipita2on regime (rainfall intensity) where they typically grow. The parameter is tabulated in Gerten et al. (2004).	not represented
Snow storage	0	no upper limit	0	no upper limit	0 mm	20000 mm	not represented
Soil storage	wilting point	field capacity	Depends on the soil type per grid cell. Defined per grid cell (0.5 degrees). Volumetric soil moisture content at the wilting point (m3 water per m3 soil) i.e. the point at which soil moisture stress completely prevents transpiration, ranges between 0 (for ice covered regions) and 0.263. The configuration uses soil data from the Harmonized World Soil Database	Depends on the soil type per grid cell. Defined per grid cell (0.5 degrees). The volumetric soil moisture content at saturation (m3 water per m3 soil) ranges between 0 (for ice covered regions) and 0.458. The configuration uses soil data from the Harmonized World Soil Database. [35]	0	$S_{so,sat,p}$ specific to soil type clay=0.468; silty clay=0.468; sandy clay=0.406; clay loam=0.465; silty clay loam=0.464; sandy clay loam=0.404; loam=0.439; silt loam=0.476; sandy loam=0.434; silt=0.476; loamy sand=0.421; sand=0.339; rock and ice=0.006.	Soil storage is constrained by soil layer thickness and porosity
Groundwater storage	0	no upper limit	not represented	not represented	not represented	not represented	not represented
Lake storage	not represented	not represented	not represented	not represented	0	$f_{la} \times 5 \times G \times 1000$	not represented
Wetland storage	not represented	not represented	not represented	not represented	not represented	not represented	not represented
Reservoir storage	0	dam capacity	not represented	not represented	0	Reservoir dependent, this is an input to the model	Reservoir storage cannot exceed storage capacity specified in GRanD data
River storage	no limit	no limit	not represented	not represented	0	no upper limit	not represented

Table S50. Minimum and Maximum values of each water storage Part III

Water Storage	Mac-PDM.20		mHM		MPI-HM		ORCHIDEE		PCR-GLOBWB	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Canopy storage	not represented	not represented	0	$P_{int,max} = 0.15 - 0.4mm$	0	no upper limit	0	$0.02 \times LAI \times f_{ca}$	0	no upper limit
Snow storage	0	no upper limit	0	no upper limit	0	no upper limit	0	no upper limit	0	no upper limit
Soil storage	0	no upper limit	0	$\sum_{i=1}^{N} S_{so,max,i} d_{so,i}$, where $N = 6$ is number of soil layers	0	$S_{so,max} = S_{so,TL} \times d_{so,root}$	0	$S_{so,sat,p}$ specific to soil type (m^3 m^{-3}) clay=0.3; silty clay=0.36; sandy clay=0.38; clay loam=0.41; silty clay loam=0.43; sandy clay loam=0.39; loam=0.43; silt loam=0.45; sandy loam=0.41; silt=0.46; loamy sand=0.41; sand=0.43.	0	porosity * layer depth
Groundwater storage	0	no upper limit	0	no upper limit	0	no upper limit	not represented	not represented	0	no upper limit
Lake storage	not represented	not represented	not represented	not represented	0	no upper limit	not represented	not represented	0	no upper limit
Wetland storage	not represented	not represented	not represented	not represented	0	no upper limit	not represented	not represented	0	no upper limit
Reservoir storage	not represented	not represented	not represented	not represented			not represented	not represented	0	design capacity of reservoir
River storage	not represented	not represented	0	no upper limit		not represented	0	no upper limit	0	no upper limit

Table S51. Minimum and Maximum values of each water storage Part IV

Water Storage	VIC		WaterGAP2		WAYS	
	Min	Max	Min	Max	Min	Max
Canopy storage	0	no upper limit	0	$S_{ca,max} = 0.3 \times LAI$	0	f(LAI_{max})
Snow storage	0	no upper limit	0	1000 mm	0	no upper limit
Soil storage	0	porosity * layer depth	0	$S_{so,max}$	0	$S_{rz,max}$
Groundwater storage	0	no value	no limit	no limit	0	no upper limit
Lake storage	0	no upper limit	$-S_{la,local,max}$ $-S_{la,global,max}$	$S_{la,local,max} = B_{la,local,max} \times 5m$ $S_{la,global,max} = B_{la,global,max} \times 5m$		not represented
Wetland storage	0	no upper limit	0	$S_{we,local,max} = B_{we,local,max} \times 2m$ $S_{we,global,max} = B_{we,global,max} \times 2m$		not represented
Reservoir storage	0	design capacity of reservoir	0	$S_{re,C} \times 0.85$		not represented
River storage	0	no value	0	no limit	0	no upper limit

Table S52. Irrigation water demand (A_{irr})

Model	Equation
CLM4.5	$A_{irr} = j \times S_{so,sat} + (1-j) \times S_{so,WP} - S_{so,cur}$
CLM5.0	$A_{irr} = j \times S_{so,sat} + (1-j) \times S_{so,WP} - S_{so,cur}$
CWatM	$A_{irr} = A_{irr}^{gw} + A_{irr}^{sw}$
DBH	not represented
H08	$A_{irr} = A_{irr}^{gw} + A_{irr}^{sw}$
JULES-W1	not represented
LPJmL	$A_{irr} = A_{irr,net} + A_{irr,app}$ $A_{irr,net} = max(0, S_{so,FC} - S_{so,ready})$ $A_{irr,app} = max(0, (S_{so,sat} - S_{so,FC}) \times \lambda - S_{so,ready})$, see [41]
Mac-PDM.20	not represented
MATSIRO	$A_{irr} = \frac{\rho_w}{\Delta t} \times \sum_{i=1}^{3} max[(S_{so,t,i} - S_{so,a,i}), 0] \times \zeta_{so,i}$ $S_{so,t,i} = \alpha \times \phi_{so}$ α is set at 1 for rice and 0.75 for the other crops, see [38].
mHM	not represented
MPI-HM	$A_{irr} = \left(T \times \frac{f_{ca} - f_{irr}}{f_{ca}} + PET \times f_{irr}\right) - T$ $f_{irr} = 1 - \frac{A_{irr}}{\sum S_i}$; for i $= baseflow, river, wetland$
ORCHIDEE	not represented
PCR-GLOBWB	$A_{irr} = A_{irr}^{gw} + A_{irr}^{sw}$
VIC	not represented
WaterGAP2	$A_{irr} = A_{irr}^{gw} + A_{irr}^{sw}$
WAYS	not represented

Table S53. Irrigation groundwater abstraction (A_{irr}^{gw})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A_{pot}^{gw} = A_{tot} - A_{act}^{sw}$ $A_{act}^{gw} = min(S_{gw} - A_{pot}^{gw})$ $A_{fgw} = A_{pot}^{gw} - A_{act}^{gw}$
DBH	not represented
H08	$A_{irr}^{gw} = A_{irr}^{gw,rw} + A_{irr}^{gw,nrw}$ $A_{irr}^{gw,rw} = min(f_{gw,use} \times A_{irr,dem} \times \frac{S_{gw,rw}}{\Delta t})$ $A_{irr}^{gw,nrw} = f_{gw,use} \times A_{irr,dem} - A_{gw,rw}$
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	Given the amount of water requirement for irrigation, water is firstly taken from local river flow (potentially regulated by global reservoir), then from local reservoir (same cell or upstream cell). Then, rest of water requirement unmet is taken from groundwater resource. Here MATSIRO assumes unlimited groundwater resource. $A_{irr}^{gw} = A_{irr,dem} - A_{irr}^{sw}$
mHM	not represented
MPI-HM	$A_{irr}^{gw} = f_{irr} \times S_{gw}$
ORCHIDEE	not represented
PCR-GLOBWB	$A_{pot}^{gw} = A_{tot} - A_{act}^{sw}$ $A_{act}^{gw} = min(S_{gw} - A_{pot}^{gw})$ $A_{fgw} = A_{pot}^{gw} - A_{act}^{gw}$
VIC	not represented
WaterGAP2	$A_{irr}^{gw} = \frac{A_{irr,cons}}{0.7} \times f_{gw,use}$ $A_{irr,cons}$ is calculated with a Global Irrigation Model, see [34] and [12].
WAYS	not represented

Table S54. Irrigation groundwater consumption $(A^{gw}_{irr,cons})$

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A_{gw,cons} = A_{tot,cons} - A_{sw,cons}$
DBH	not represented
H08	$A^{gw}_{irr,cons} = f_{cons,A} \times A^{gw}_{irr}$
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	Theoretically speaking, $A^{gw}_{irr,cons} = X \times A^{gw}_{irr}$ where X is overall irrigation efficiency (which does not consider combinations of irrigation system type and water sources.)
mHM	not represented
MPI-HM	no water losses are computed
ORCHIDEE	not represented
PCR-GLOBWB	$A^{gw}_{irr,cons} = \dfrac{R_{gw}}{R_{gw} + Q_{iu}} \times A_{irr} \times X$
VIC	not represented
WaterGAP2	$A^{gw}_{irr,cons} = A_{irr,cons} \times f_{gw,use}$ $A_{irr,cons}$ is calculated with a Global Irrigation Model, see [34] and [12].
WAYS	not represented

Table S55. Return flow from irrigation groundwater abstraction ($A^{gw}_{irr,rf}$)

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A_{irr,rf} = f_{irr,eff} \times A_{irr}$, See [12] $A_{irr,rf,firr} = A_{irr} - A_{irr,cons}$
DBH	not represented
H08	$A^{gw}_{irr,rf} = (1 - f_{lost}) \times (1 - f_{cons,A}) \times A^{gw}_{irr}$ [24]
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	In MATSIRO, return flow is implicitly accounted for. MATSIRO estimates potential irrigation water amount to keep soil moisture at the target level of 0.75. Irrigation water added, added as sprinkler irrigation, can percolate into deeper layers, ultimately recharging groundwater, or contribute to local runoff depending on the rate of consumptive use by crops and soil wetness conditions.
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{gw}_{irr,rf} = \frac{R_{gw}}{R_{gw} + Q_{iu}} \times A_{irr} \times (1 - X)$
VIC	not represented
WaterGAP2	$A^{gw}_{irr,rf} = A^{gw}_{irr} - A^{gw}_{irr,cons}$
WAYS	not represented

Table S56. Irrigation surface water abstraction (A^{sw}_{irr})

Model	Equation
CLM4.5	$A^{sw}_{irr} = A_{irr}$
CLM5.0	$A^{sw}_{irr} = A_{irr}$
CWatM	$A^{sw}_{irr} = \frac{A_{irr,cons}}{f_{irr,eff}}$ $f_{irr,eff}$: see [46]. It also simulates overflow of the flooded topsoil for paddy rice land use. This saturation excess it is not controlled by soil hydraulic properties, but by human intervention. $R_{of} = max(0, S_{paddy} - 0.05\text{ m})$; S_{paddy} = the storage of flooded paddy rice (only for paddy rice land use)
DBH	not represented
H08	$A^{sw}_{irr} = A^{aq}_{irr} + A^{re}_{irr} + A^{ri}_{irr} + A^{usw}_{irr}$
JULES-W1	not represented
LPJmL	$A^{sw}_{irr} = A^{la}_{irr} + A^{neigh,cell}_{irr} + A^{re}_{irr} + A^{ri}_{irr}$
Mac-PDM.20	not represented
MATSIRO	Given the amount of water requirement for this sector, water is firstly taken from local river flow (potentially regulated by global reservoir), then from local reservoir (same cell or upstream cell). $A^{sw}_{irr} = A^{pond}_{irr} + A^{re,global}_{irr} + A^{ri}_{irr}$
mHM	not represented
MPI-HM	$A^{sw}_{irr} = \sum_{n=1}^{5}(f_{irr} \times S_{ri,n}) + f_{irr} \times S_{we}$
ORCHIDEE	not represented
PCR-GLOBWB	$A^{sw}_{irr} = \frac{Q_{iu}}{R_{gw} + Q_{iu}} \times A_{irr}$
VIC	not represented
WaterGAP2	$A^{sw}_{irr} = \frac{A_{irr,cons}}{f_{irr,sw,eff}} \times (1 - f_{gw,use})$ $A_{irr,cons}$ is calculated with a Global Irrigation Model, see [34] and [12].
WAYS	not represented

Table S57. Irrigation surface water consumption ($A^{sw}_{irr,cons}$)

Model	Equation
CLM4.5	$A^{sw}_{irr,cons} = A^{sw}_{irr} - A^{sw}_{irr,rf}$
CLM5.0	$A^{sw}_{irr,cons} = A^{sw}_{irr} - A^{sw}_{irr,rf}$
CWatM	For paddy irrigation: $A_{irr,cons} = (d^{sw}_{paddy,max} - ({d^{sw}_{paddy}}^{t-1} - {P_{eff}}^{t}))$ ${d^{sw}_{paddy}}^{t} = {d^{sw}_{paddy}}^{t-1} + {P_{eff}}^{t} + A_{irr} + R_{in} - {E_{osw}}^{d,t}$ For non paddy: $A_{irr,cons} = \begin{cases} S_{so,T2L} - S_{so,ready} & (S_{so,ready} < S_{so,crit}) \\ 0 & (S_{so,ready} \geq S_{so,crit}) \end{cases}$ $S_{so,T2L} = S_{so,FC} - S_{so,WP}$ $S_{so,ready} = S_{so} - S_{so,WP}$ $S_{so,crit} = (1-p) \times S_{so,T2L} + S_{so,WP}$ $p = \frac{1}{(0.76 + 1.5 \times PET)} - 0.4 + \frac{(PET - 0.6)}{4}$, see [51].
DBH	not represented
H08	$A^{sw}_{irr} = A^{sw}_{irr,cons} + A^{sw}_{irr,loss} + A^{sw}_{irr,rf}$ $A^{sw}_{irr,cons} = f_{cons,A} \times A^{sw}_{irr}$ $A^{sw}_{irr,loss} = f_{lost} \times (1 - f_{cons,A}) \times A^{sw}_{irr}$
JULES-W1	not represented
LPJmL	$A^{sw}_{irr,cons} = \frac{A_{irr,net} + A_{irr,app} - S_{buf}}{X_{conv}}$, $X_{conv} = 0.95$, see [7] and Table S52.
Mac-PDM.20	not represented
MATSIRO	Theoretically speaking, $A^{sw}_{irr,cons} = X \times A^{sw}_{irr}$
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{sw}_{irr,cons} = \frac{Q_{iu}}{R_{gw} + Q_{iu}} \times A_{irr}$
VIC	not represented
WaterGAP2	$A^{sw}_{irr,cons} = A_{irr,cons} \times (1 - f_{gw,use})$ $A_{irr,cons}$ is calculated with a Global Irrigation Model, see [34] and [12].
WAYS	not represented

Table S58. Return flow from irrigation surface water abstraction $(A^{sw}_{irr,rf})$

Model	Equation
CLM4.5	$A^{sw}_{irr,rf} = f_{G,sat} \times A^{sw}_{irr}$
CLM5.0	$A^{sw}_{irr,rf} = f_{G,sat} \times A^{sw}_{irr}$
CWatM	$A^{sw}_{irr,rf} = f_{irr,eff} \times A_{irr}$, See [12]
DBH	not represented
H08	$A^{sw}_{irr,rf} = (1 - f_{lost}) \times (1 - f_{cons,A}) \times A^{sw}_{irr}$. See [12], [24]
JULES-W1	not represented
LPJmL	$A^{sw}_{irr,rf} = A^{sw}_{irr,cons} - A_{irr,net} - A_{irr,app}$ Where: $E_{osw} = (-A_{irr,net} - A_{irr,app}) \times 0.5$
Mac-PDM.20	not represented
MATSIRO	Return flow from irrigation using surface water is not separately estimated in MATSIRO; this component is a part of the return flow from the total water use within a grid cell.
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$A^{sw}_{irr,rf} = A^{sw}_{irr} - A^{sw}_{irr,cons}$
WAYS	not represented

Table S59. Equations for domestic groundwater abstraction (A^{gw}_{dom})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A^{gw}_{tot} = (1 - f^{sw}_{A}) \times (A_{irr} + A_{ind} + A_{dom} + A_{liv})$ CWatm only calculates total abstraction from groundwater or surface. $f^{sw}_{A} = \frac{R_{su}}{R_{su}+R_{gw}}$
DBH	not represented
H08	$A^{gw}_{dom} = A^{gw,rw}_{dom} + A^{gw,nrw}_{dom}$ $A^{gw,rw}_{dom} = min(f_{gw,use} \times A_{dom,dem} \times \dfrac{S_{gw,rw}}{\Delta t})$ $A^{gw,nrw}_{dom} = f_{gw,use} \times A_{dom,dem} - A^{gw,rw}_{dom}$
JULES-W1	not represented
LPJmL	prescribed data offered by ISIMIP2b framework
Mac-PDM.20	not represented
MATSIRO	Given the amount of water requirement from the domestic sector, water is firstly taken from local river flow (potentially regulated by g $A^{gw}_{dom} = A_{dom,dem} - A^{sw}_{dom}$
where $A_{dom,dem}$ is domestic sectoral water requirement.	
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{gw}_{dom} = \dfrac{R_{gw}}{R_{gw} + Q_{iu}} \times A_{dom,dem}$
VIC	not represented
WaterGAP2	$A^{gw}_{dom} = A_{dom} \times f_{gw,use}$ $A_{dom} = C^{wu,ints}_{dom} \times POP$ for $C^{wu,ints}_{dom}$ see [18].
WAYS	not represented

Table S60. Equations for domestic groundwater consumption ($A^{gw}_{dom,cons}$)

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A^{gw}_{tot,cons} = (1 - f^{sw}_{A}) \times (A_{irr,cons} + A_{ind,cons} + A_{dom,cons} + A_{liv})$
DBH	not represented
H08	$A^{gw}_{dom} = A^{gw}_{dom,cons} + A^{gw}_{dom,loss} + A^{gw}_{dom,rf}$ $A^{gw}_{dom,cons} = f_{cons,A} \times A^{gw}_{dom}$ $A^{gw}_{dom,loss} = f_{lost} \times (1 - f_{cons,A}) \times A^{gw}_{dom}$
JULES-W1	not represented
LPJmL	prescribed data offered by ISIMIP2b
Mac-PDM.20	not represented
MATSIRO	only 10 % of domestic water use is assumed to be consumptively used. Theoretically speaking: $A^{gw}_{dom,cons} = X_{dom} \times A^{gw}_{dom}$
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{gw}_{dom,cons} = \frac{R_{gw}}{R_{gw} + Q_{iu}} \times \frac{A_{dom,cons}}{A_{dom,dem}}$
VIC	not represented
WaterGAP2	$A^{gw}_{dom,cons} = A_{dom,cons} \times f_{gw,use}$ $A_{dom,cons} = \begin{cases} A_{dom} \times C_{dom,cons}, & year < 2000 \\ A_{dom} - A_{dom,rf}, & year \geq 2000 \end{cases}$ Starting with 2000 $A_{dom,cons}$ is based on return flow data, see [18].
WAYS	not represented

Table S61. Equations for return flow from domestic groundwater abstraction ($A^{gw}_{dom,rf}$)

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	It computes only total return flow from non-irrigated water abstractions. $A_{rf,nonirr} = (1 - f_{lost}) \times (A_{ind} + A_{dom} - (A_{ind,cons} + A_{dom,cons}))$ $A_{rf,nonirr,eva} = f_{lost} \times (A_{ind} + A_{dom} - (A_{ind,cons} + A_{dom,cons}))$
DBH	not represented
H08	$A^{gw}_{dom,rf} = (1 - f_{lost}) \times (1 - f_{cons,A}) \times A^{gw}_{dom}$, see [24]
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	90 % of domestic water use is implicitly assumed to have returned to the original source (groundwater; see [39]).
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{gw}_{dom,rf} = \dfrac{R_{gw}}{R_{gw} + Q_{iu}} \times \dfrac{A_{dom,dem} - A_{dom,cons}}{A_{dom,dem}}$
VIC	not represented
WaterGAP2	$A^{gw}_{dom,rf} = A_{dom,rf} \times f_{gw,use}$ $A_{dom,rf} = \begin{cases} A_{dom} - (A_{dom} \times C_{dom,cons}) & year < 2000 \\ A_{dom,rf} & year \geq 2000 \end{cases}$ Starting with 2000 $A_{dom,rf}$ is based on wastewater volume data, see [18].
WAYS	not represented

Table S62. Equations for domestic surface water abstraction (A^{sw}_{dom})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A^{sw}_{tot} = f^{sw}_{A} \times (A_{irr} + A_{ind} + A_{dom} + A_{liv})$
DBH	not represented
H08	$A^{sw}_{dom} = A^{aq}_{dom} + A^{re}_{dom} + A^{ri}_{dom} + A^{usw}_{dom}$
JULES-W1	not represented
LPJmL	prescribed data offered by ISIMIP2b
Mac-PDM.20	not represented
MATSIRO	Given the amount of water requirement for this sector, water is firstly taken from local river flow (potentially regulated by global reservoir), then from local reservoir (same cell or upstream cell). $A^{sw}_{dom} = A^{pond}_{dom} + A^{re,global}_{dom} + A^{ri}_{dom}$
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{sw}_{dom} = \dfrac{Q_{iu}}{R_{gw} + Q_{iu}} \times A_{dom,dem}$
VIC	not represented
WaterGAP2	$A^{sw}_{dom} = A_{dom} \times (1 - f_{gw,use})$ $A_{dom} = C^{wu,ints}_{dom} \times POP$ for $C^{wu,ints}_{dom}$ see [18].
WAYS	not represented

Table S63. Equations for domestic surface water consumption ($A^{sw}_{dom,cons}$)

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A^{sw}_{tot,cons} = f^{sw}_{A} \times (A_{irr,cons} + A_{ind,cons} + A_{dom,cons} + A_{liv})$
DBH	not represented
H08	$A^{sw}_{dom} = A^{sw}_{dom,cons} + A^{sw}_{dom,loss} + A^{sw}_{dom,rf}$ $A^{sw}_{dom,cons} = f_{cons,A} \times A^{sw}_{dom}$, see [12] $A^{sw}_{dom,loss} = f_{lost} \times (1 - f_{cons,A}) \times A^{sw}_{dom}$
JULES-W1	not represented
LPJmL	prescribed data offered by ISIMIP2b
Mac-PDM.20	not represented
MATSIRO	only 10 % of domestic water use, from surface water bodies, is assumed to be consumptively used. Theoretically speaking: $A^{sw}_{dom,cons} = X_{dom} \times A^{sw}_{dom}$
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{sw}_{dom,cons} = \frac{Q_{iu}}{R_{gw} + Q_{iu}} \times \frac{A_{dom,cons}}{A_{dom,dem}}$
VIC	not represented
WaterGAP2	$A^{sw}_{dom,cons} = A_{dom,cons} \times (1 - f_{gw,use})$ for $A_{dom,cons} = \begin{cases} A_{dom} \times C_{dom,cons}, & year < 2000 \\ A_{dom} - A_{dom,rf}, & year \geq 2000 \end{cases}$ Starting with 2000 $A_{dom,cons}$ is based on return flow data, for details see [18].
WAYS	not represented

Table S64. Equations for return flow from domestic surface water abstraction $(A^{sw}_{dom,rf})$

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A_{rf,nonirr} = (1 - f_{lost}) \times (A_{ind} + A_{dom} - (A_{ind,cons} + A_{dom,cons}))$ $A_{rf,nonirr,eva} = f_{lost} \times (A_{ind} + A_{dom} - (A_{ind,cons} + A_{dom,cons}))$
DBH	not represented
H08	$A^{sw}_{dom,rf} = (1 - f_{lost}) \times (1 - f_{cons,A}) \times A^{sw}_{dom}$ [24]; [12]
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	90 % of domestic water use, from surface water bodies, is implicitly assumed to have returned to the original source (surface water; [39]).
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$A^{sw}_{dom,rf} = A_{dom,rf} \times (1 - f_{gw,use})$ $A_{dom,rf} = \begin{cases} A_{dom} - (A_{dom} \times C_{dom,cons}) & year < 2000 \\ A_{dom,rf} & year \geq 2000 \end{cases}$ Starting with 2000 $A_{dom,rf}$ is based on wastewater volume data, for details see [18].
WAYS	not represented

Table S65. Equations for livestock groundwater abstraction (A_{liv}^{gw})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A_{tot}^{gw} = (1 - f_A^{sw}) \times (A_{irr} + A_{ind} + A_{dom} + A_{liv})$
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A_{liv}^{gw} = \dfrac{R_{gw}}{R_{gw} + Q_{iu}} \times A_{liv,dem}$
VIC	not represented
WaterGAP2	water used in the livestock sector is solely abstracted from surface water bodies
WAYS	not represented

Table S66. Equations for livestock groundwater consumption ($A^{gw}_{liv,cons}$)

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A^{gw}_{tot,cons} = (1 - f^{sw}_{A}) \times (A_{irr,cons} + A_{ind,cons} + A_{dom,cons} + A_{liv}))$ no duifference between withdrawal and consumption for livestock
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{gw}_{liv,cons} = \frac{R_{gw}}{R_{gw} + Q_{iu}} \times \frac{A_{liv,cons}}{A_{liv,dem}}$
VIC	not represented
WaterGAP2	not represented

Table S67. Equations for livestock surface water abstraction (A_{liv}^{sw})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A_{tot}^{sw} = f_A^{sw} \times (A_{irr} + A_{ind} + A_{dom} + A_{liv})$
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A_{liv}^{sw} = \frac{Q_{iu}}{R_{gw}+Q_{iu}} \times A_{liv,dem}$
VIC	not represented
WaterGAP2	$A_{liv}^{sw} = A_{liv,cons}^{sw}$
WAYS	not represented

Table S68. Equations for livestock surface water consumption $(A^{sw}_{liv,cons})$

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	same as Table S67
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{sw}_{liv,cons} = \frac{Q_{iu}}{R_{gw}+Q_{iu}} \times \frac{A_{liv,cons}}{A_{liv,dem}}$
VIC	not represented
WaterGAP2	$A^{sw}_{liv,cons} = \sum_{i=1}^{10} POP_{liv,t} \times C^{w,req}_{liv}$ for 10 livestock types [1], [34].
WAYS	not represented

Table S69. Equations for manufacturing groundwater abstraction (A^{gw}_{man})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A^{gw}_{tot} = (1 - f^{sw}_{A}) \times (A_{irr} + A_{ind} + A_{dom} + A_{liv}))$
DBH	not represented
H08	$A^{gw}_{man} = A^{gw,rw}_{man} + A^{gw,nrw}_{man}$ Where: $A^{gw,rw}_{man} = min(f_{gw,use} \times A_{man,dem} \times \frac{S_{gw,rw}}{\Delta t})$ $A^{gw,nrw}_{man} = f_{gw,use} \times A_{man,dem} - A^{gw,rw}_{man}$
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	combines manufacturing sector and electricity sector and calls this sector industrial sector. Given the amount of water requirement for the industrial sector, water is firstly taken from local river flow (potentially regulated by global reservoir), then from local reservoir (same cell or upstream cell). Then, rest of water requirement unmet is taken from groundwater resource. Here, here MATSIRO assumes unlimited groundwater resource. $A^{gw}_{ind} = A_{ind,dem} - A^{sw}_{ind}$ where $A_{ind,dem}$ is water requirement of the industrial sector.
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{gw}_{man} = \frac{R_{gw}}{R_{gw} + Q_{iu}} \times A_{man,dem}$
VIC	not represented
WaterGAP2	$A^{gw}_{man} = A^{c}_{man} \times \frac{POP_u}{POP^c_u} \times f_{gw,use}$ $A^{c}_{man} = C^{w,ints,2005}_{man} \times GAV \times C^{tech,cr}_{man}$
WAYS	not represented

Table S70. Equations for manufacturing groundwater consumption ($A^{gw}_{man,cons}$)

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A^{gw}_{tot,cons} = (1 - f^{sw}_{A}) \times (A_{irr,cons} + A_{ind,cons} + A_{dom,cons} + A_{liv}))$
DBH	not represented
H08	$A^{gw}_{man} = A^{gw}_{man,cons} + A^{gw}_{man,loss} + A^{gw}_{man,rf}$ $A^{gw}_{man,cons} = f_{cons,A} \times A^{gw}_{man}$ [43] $A^{gw}_{man,loss} = f_{lost} \times (1 - f_{cons,A}) \times A^{gw}_{man}$
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	10 % of domestic water use is assumed to be consumptively used. Theoretically speaking: $A^{gw}_{ind,cons} = X_{ind} \times A^{gw}_{ind}$ where X_{ind} is overall water use efficiency of the industrial sector.
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{gw}_{man,cons} = \frac{R_{gw}}{R_{gw} + Q_{iu}} \times \frac{A_{man,cons}}{A_{man,dem}}$
VIC	not represented
WaterGAP2	$A^{gw}_{man,cons} = (A^{c}_{man} - A^{c}_{man,rf}) \times \frac{POP_{u}}{POP^{c}_{u}} \times f_{gw,use}$ $A^{c}_{man} = C^{w,ints,2005}_{man} \times GAV \times C^{tech,cr}_{man}$ $A^{c}_{man,rf} = \begin{cases} A^{c}_{man} \times C_{man,cons} & year < 2000 \\ A^{coo,c}_{man} + A^{ww,c}_{man} & year \geq 2000 \end{cases}$ For details on manufacturing cooling and waste water see [18].
WAYS	not represented

Table S71. Equations for return flow from manufacturing groundwater abstraction $(A^{gw}_{man,rf})$

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A_{rf,nonirr} = (1 - f_{lost}) \times (A_{ind} + A_{dom} - (A_{ind,cons} + A_{dom,cons}))$ $A_{rf,nonirr,eva} = f_{lost} \times (A_{ind} + A_{dom} - (A_{ind,cons} + A_{dom,cons}))$
DBH	not represented
H08	$A^{gw}_{man,rf} = (1 - f_{lost}) \times (1 - f_{cons,A}) \times A^{gw}_{man}$
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	90 % of domestic water use is implicitly assumed to have returned to the original source (groundwater; [39]).
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{gw}_{man,rf} = \dfrac{R_{gw}}{R_{gw} + Q_{iu}} \times \dfrac{A_{man,dem} - A_{man,cons}}{A_{man,dem}}$
VIC	not represented
WaterGAP2	$A^{gw}_{man,rf} = \begin{cases} A^{gw}_{man} \times C_{man,cons}, & year < 2000 \\ (A^{coo,c}_{man} + A^{ww,c}_{man}) \times \frac{POP_u}{POP^c_u} \times f_{gw,use}, & year \geq 2000 \end{cases}$ For details on manufacturing cooling and waste water see [18].
WAYS	not represented

Table S72. Equations for manufacturing surface water abstraction (A^{sw}_{man})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A^{sw}_{tot} = f^{sw}_{A} \times (A_{irr} + A_{ind} + A_{dom} + A_{liv})$
DBH	not used for ISIMIP2b
H08	$A^{sw}_{man} = A^{aq}_{man} + A^{re}_{man} + A^{ri}_{man} + A^{usw}_{man}$
JULES-W1	not represented
LPJmL	prescribed data offered by ISIMIP2b
Mac-PDM.20	not represented
MATSIRO	combines manufacturing sector and electricity sector and calls this sector industrial sector. Given the amount of water requirement for this sector, water is firstly taken from local river flow (potentially regulated by global reservoir), then from local reservoir (same cell or upstream cell). $A^{sw}_{ind} = A^{pond}_{ind} + A^{re,global}_{ind} + A^{ri}_{ind}$
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{sw}_{man} = \dfrac{Q_{iu}}{R_{gw} + Q_{iu}} \times A_{man,dem}$
VIC	not represented
WaterGAP2	$A^{sw}_{man} = A^{c}_{man} \times \dfrac{POP_u}{POP^c_u} \times (1 - f_{gw,use})$ $A^{c}_{man} = C^{w,ints,2005}_{man} \times GAV \times C^{tech,cr}_{man}$
WAYS	not represented

Table S73. Equations for manufacturing surface water consumption $(A^{sw}_{tot,cons})$

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A^{sw}_{tot,cons} = f^{sw}_{A} \times (A_{irr,cons} + A_{ind,cons} + A_{dom,cons} + A_{liv})$
DBH	not represented
H08	$A^{sw}_{man} = A^{sw}_{man,cons} + A^{sw}_{man,loss} + A^{sw}_{man,rf}$ $A^{sw}_{man,cons} = f_{cons,A} \times A^{sw}_{man}$ [12] $A^{sw}_{man,loss} = f_{lost} \times (1 - f_{cons,A}) \times A^{sw}_{man}$
JULES-W1	See [12]
LPJmL	prescribed data offered by ISIMIP2b
Mac-PDM.20	not represented
MATSIRO	only 10 % of domestic water use is assumed to be consumptively used. Theoretically speaking: $A^{sw}_{ind,cons} = X_{ind} \times A^{sw}_{ind}$
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A^{sw}_{man,cons} = \dfrac{Q_{iu}}{R_{gw} + Q_{iu}} \times \dfrac{A_{man,cons}}{A_{man,dem}}$
VIC	not represented
WaterGAP2	$A^{sw}_{man,cons} = (A^{c}_{man} - A^{c}_{man,rf}) \times \dfrac{POP_u}{POP^{c}_{u}} \times (1 - f_{gw,use})$ $A^{c}_{man} = C^{w,ints,2005}_{man} \times GAV \times C^{tech,cr}_{man}$ $A^{c}_{man,rf} = \begin{cases} A^{c}_{man} \times C_{man,cons} & year < 2000 \\ A^{coo,c}_{man} + A^{ww,c}_{man} & year \geq 2000 \end{cases}$ For details on manufacturing cooling and waste water see [18].
WAYS	not represented

Table S74. Equations for return flow from manufacturing surface water abstraction $(A^{sw}_{man,rf})$

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	$A_{rf,nonirr} = (1 - f_{lost}) \times (A_{ind} + A_{dom} - (A_{ind,cons} + A_{dom,cons}))$ $A_{rf,nonirr,eva} = f_{lost} \times (A_{ind} + A_{dom} - (A_{ind,cons} + A_{dom,cons}))$
DBH	not represented
H08	$A^{sw}_{man,rf} = (1 - f_{lost}) \times (1 - f_{cons,A}) \times A^{sw}_{man}$. See [24]
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	90 % of domestic water use is implicitly assumed to have returned to the original source (surface water; [39]).
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$A^{sw}_{man,rf} = \begin{cases} A^{sw}_{man} \times C_{man,cons} & year < 2000 \\ (A^{coo,c}_{man} + A^{ww,c}_{man}) \times \frac{POP_u}{POP^c_u} \times (1 - f_{gw,use}) & year \geq 2000 \end{cases}$ For details on manufacturing cooling and waste water see [18].
WAYS	not represented

Table S75. Equations for electricity surface water abstraction (A_{ele}^{sw})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	It combines manufacturing and electricity sector in industry sector.
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	represented in table S72. It combines manufacturing and electricity sector in industry sector.
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$A_{ele}^{sw} = \sum_{i=1}^{n} J_{ele,prod,i} \times J_{ele,A,ints,i}(J_{ele,coo,i}, J_{ele,pt,i}) \times C_{ele}^{techchangerate}$
WAYS	not represented

Table S76. Equations for electricity surface water consumption

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	not represented
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$A_{ele}^{sw} = \sum_{i=1}^{n} J_{ele,prod,i} \times J_{ele,cons,ints,i}(J_{ele,coo,i}, J_{ele,pt,i}) \times C_{ele}^{techchangerate}$
WAYS	not represented

Table S77. Groundwater abstraction (A_{gw})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	It calculates the water abstraction in total from all users and afterwards it distributes the total withdrawal to different sources: surface water, sustainable groundwater (available groundwater), unsustainable groundwater (fossil groundwater), human water use sectors (domestic, livestock, irrigation, industry).
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	$A_{gw} = A^{gw}_{irr} - A^{gw}_{dom} - A^{gw}_{ind}$
mHM	not represented
MPI-HM	$A_{gw} = A^{gw}_{irr}$
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$A_{gw} = A^{gw}_{irr} - A^{gw}_{dom} - A^{gw}_{ind}$
WAYS	not represented

Table S78. Total lake abstraction (A_{la})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	It calculates the water abstraction in total from all users and afterwards it distributes the total withdrawal to different sources: surface water, sustainable groundwater (available groundwater), unsustainable groundwater (fossil groundwater), human water use sectors (domestic, livestock, irrigation, industry).
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	$A_{la} = (A^{sw}_{irr,cons,G} + A_{hil,G}) + (A^{sw}_{irr,cons downstream} + A_{hil,G downstream})$
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	$A_{la} = A^{sw}_{irr}$
ORCHIDEE	not represented
PCR-GLOBWB	$A_{la} = A_{dom,dem} + A_{ind,dem} + A_{irr,dem} + A_{liv,dem}$
VIC	not represented
WaterGAP2	$A_{la} = A^{sw}_{dom} + A^{sw}_{ele} + A^{sw}_{irr} + A^{sw}_{liv} + A^{sw}_{man}$ The net surface water abstraction is satisfied in WaterGAP2 in following order 1. River, 2. global lakes and reservoirs and 3. local lakes
WAYS	not represented

Table S79. Total reservoir abstraction (A_{re})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	It calculates the water abstraction in total from all users and afterwards it distributes the total withdrawal to different sources: surface water, sustainable groundwater (available groundwater), unsustainable groundwater (fossil groundwater), human water use sectors (domestic, livestock, irrigation, industry).
DBH	not used for ISIMIP2b
H08	$A_{re} = A_{dom,month} + A_{ind,month} + A_{irr,month}$
JULES-W1	not represented
LPJmL	$A_{re} = (A^{sw}_{irr,cons,G} + A_{hil,G}) + (A^{sw}_{irr,consdownstream} + A_{hil,Gdownstream})$
Mac-PDM.20	not represented
MATSIRO	$A_{re} = A^{re}_{dom} + A^{re}_{ind} + A^{re}_{irr}$
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	$A_{la} = A_{dom,dem} + A_{ind,dem} + A_{irr,dem} + A_{liv,dem}$
VIC	not represented
WaterGAP2	$A_{re} = A^{sw}_{dom} + A^{sw}_{ele} + A^{sw}_{irr} + A^{sw}_{liv} + A^{sw}_{man}$
	The net surface water abstraction is satisfied in WaterGAP2 in following order 1. River, 2. global lakes and reservoirs and 3. local lakes
WAYS	not represented

Table S80. Total river abstraction (A_{ri})

Model	Equation
CLM4.5	not represented
CLM5.0	$A_{ri} = A_{irr}$
CWatM	It calculates the water abstraction in total from all users and afterwards it distributes the total withdrawal to different sources: surface water, sustainable groundwater (available groundwater), unsustainable groundwater (fossil groundwater), human water use sectors (domestic, livestock, irrigation, industry).
DBH	not represented
H08	not represented
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	combined with lake abstraction
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	$A_{ri} = A^{sw}_{dom} + A^{sw}_{ele} + A^{sw}_{irr} + A^{sw}_{liv} + A^{sw}_{man}$ The net surface water abstraction is satisfied in WaterGAP2 in following order 1. River, 2. global lakes and reservoirs and 3. local lakes
WAYS	not represented

Table S81. Seawater abstraction (A_{ocean})

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	not represented
DBH	not represented
H08	To have the potential to use desalination three conditions must be met: 1) GDP > 14000 USD person / year in terms of purchasing power parity (PPP) 2) humidity index below 8% 3) within 3 grid cells of the seashore It is assumed that seawater desalination is not used for irrigation and all demand for municipal and industrial water is abstracted by desalination if available. Therefore: $A_{ocean} = A_{ind} + A_{muni}$
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	not represented
WAYS	not represented

Table S82. Seawater consumption $(A_{ocean,cons})$

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	not represented
DBH	not represented
H08	Desalination is not used for irrigation. $A_{ocean,cons} = f_{cons,A} \times A_{ocean}$ Where $f_{cons,A}$ is the ratio of consumption to withdrawal and is equal to 0.1 and 0.15 for industrial and municipal water use, respectively.
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	not represented
WAYS	not represented

Table S83. Return flow from seawater abstraction $(A_{ocean,rf})$

Model	Equation
CLM4.5	not represented
CLM5.0	not represented
CWatM	not represented
DBH	not represented
H08	Desalination is never used for irrigation. $A_{ocean,rf} = (1 - f_{lost}) \times (1 - f_{cons,A}) \times A_{ocean}$ Where, $f_{cons,A}$ is the ratio of consumption to withdrawal (-) and f_{lost} is the proportion lost during delivery (-). The fist factor is set to 0.1 for industrial use and 0.15 for municipal use, the second factor is set to 0.
JULES-W1	not represented
LPJmL	not represented
Mac-PDM.20	not represented
MATSIRO	not represented
mHM	not represented
MPI-HM	not represented
ORCHIDEE	not represented
PCR-GLOBWB	not represented
VIC	not represented
WaterGAP2	not represented
WAYS	not represented

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Global Water Models

Global water models (GWMs) were developed from the earliest land surface models (LSMs) created by Thornthwaite and Mather (1957), Manabe (1969), Freeze and Harlan (1969), and Deardorff (1978). These first land surface models simulated the terrestrial water cycle by considering vegetation processes, evaporation, soil moisture, and snow cover. Later on, during the 1980s, the first global hydrological model (GHMs) is developed, with a spatial resolution of 0.5°x0.5°, accompanied by its essential inputs, calibration and validation datasets, and modeling application studies, thereby, emphasizing the necessity of global-scale hydrology (Vörösmarty et al., 1989). Dooge (1982) identified the two major challenges of global hydrology, scaling and parameterization, and concluded that a global scale model requires prudent simplification (Dooge, 1986). Eagleson (1986) underlined the necessity of global-scale hydrology.

In the 1990s, LSMs were intensively improved (Sellers et al., 1997), other GHMs were developed (Yates, 1997; Arnell, 1999), experiments on parameterization were done (Federer et al., 1996), and a global hydrological data compendium was made publicly available for model calibration and validation (Vörösmarty et al., 1996). Furthermore, Vörösmarty et al., 1997 assessed globally the impact of hydraulic engineering (i.e., on dams and reservoirs) on the river systems. This decade is remarkable through the community's progress toward a global-scale capability.

In the 2000s, other studies appeared on the hydrological calibration (Nijssen et al., 2001; Döll et al., 2003), human impact schemes (Alcamo et al., 2003; de Rosnay et al., 2003), and vegetation dynamics, including CO2 fertilization effects (Gerten et al., 2007). Ultimately, over the years, many global water models have been developed and improved and many studies have been done to assess freshwater resources on the global scale (Bierkens, 2015). Global water models impose uncertainties from forcing data, model parameters, processes included or excluded, and numerical algorithms used. Additionally, each modeling group has a different model development concept and purpose. Therefore, many models combined in an ensemble approach collect many uncertainties and structural differences. It is recommended to evaluate GWMs for historical periods before making future projections, in order to validate their performance and reduce uncertainties (Krysanova et al., 2018; Do et al., 2020).

In the end, Arheimer et al., 2020 showed that the catchment models can be applied at a global scale because of the new global datasets, increased computational capacity, new methods to estimate parameters, and collaboration. GWMs may even become a part of the Earth System Models used to simulate the water cycle at a high resolution, including human water demand and use (Wood et al., 2011; Bierkens, 2015).

Evaluation of 16 global water models analyzed in the present study

Zaherpour et al. (2018) proved that the models simulate better the monthly runoff in the wetter equatorial and northern hydrobelts than in drier southern hydrobelts. They also showed that GWMs overestimated mean and extreme monthly runoff.

Veldkamp et al. (2018) identified that mean, high and low flows are improved by considering water abstractions and reservoir operations. However, these are also influenced by uncertainties regarding water abstraction sources, return flow sinks, and the timing of these issues. Masaki et al. (2017) reported that different simulated outflows from reservoirs depend on dam operation algorithms, with similar concepts in some cases, and on the simulated river inflows. Zhao et al. (2017) highlighted the influence of the routing scheme on streamflow timing and magnitude and recommended inclusion of floodplain storage and backwater effects in models.

Wartenburger et al. (2018) demonstrated the importance of actual (simulated) land evapotranspiration in global water cycle and concluded that model results are affected by the methods used to estimate evapotranspiration, number of soil layers, model structure, and uncertainties in the climate input datasets. Wartenburger et al. (2018) recommended improving the simulation of low runoff and the magnitude and timing of seasonal cycles, investigating methods to calibrate models, testing models with different parameter values, and examining the interconnected uncertainties (e.g., perturbed parameter ensembles: Gosling, 2013).

Scanlon et al. (2019) pointed out that some GWMs agree better with GRACE than others. They concluded that GWMs underestimated GRACE-derived seasonal water storages amplitudes in tropical and (semi-)arid basins and overestimated them in northern high-latitude basins. They suggested to increase the number of soil layers in the models, improve the simulation of snow physics by including processes that delay snowmelt, improve evapotranspiration schemes, and add surface water and groundwater storage compartments to some models.

GWMs were evaluated for a specific case: the 2003 European heatwave and drought (Schewe et al., 2019). They found that most of the models overestimate the impacts on water resources and hydropower in some river basins. They also underlined the need to further evaluate and improve the models for extreme conditions and to consider all optimistic and pessimistic results in an ensemble as hypotheses.

GWMs were also applied to model projections of climate change on irrigation water requirements (Wada et al., 2013), on regional and global water scarcity (Schewe et al., 2014), on hydrological drought (Prudhomme et al., 2014), and on soil moisture drought (agricultural drought, Grillakis, 2019). The first two studies, Wada et al. (2013) and Schewe et al. (2014), concluded that hydrological model uncertainty is higher than climate model uncertainty and explained the high variation of projected impacts of climate change on the irrigation sector and river discharge through the differences existent in the model structures.

Prudhomme et al. (2014) underlined that models project little or even no increase in drought frequency if they include the active response of vegetation to CO_2 and to climate change in their structure. Generally, it is also recommended to include this process in models because elevated CO_2 concentrations cause physiological and structural effects on plants and indirectly influence runoff and evapotranspiration over a geographical area. The physiological effect reduces the opening of leaf stomata because less water is needed to assimilate carbon, leading to decreased transpiration and, indirectly, increased runoff. The structural effect or fertilization effect causes an increase in plant growth and leads to increased transpiration per unit area and, indirectly, a decreased runoff (Gerten et al., 2004). However, Singh et al. (2020) demonstrated that increased leaf area under elevated CO_2 concentrations (structural effect) might counterbalance the increased water use efficiency (physiological effect).

Reinecke et al. (2021) highlighted less severe decreases of groundwater recharge, and even increases in some regions, when the CO2 fertilization effect (active vegetation) is considered.

In summary, GWMs can be apply to assess the large-scale impacts of climate change and human activity on freshwater systems, in addition to some model shortcomings (Hattermann et al., 2017). Gosling et al. (2017) underlined that the global and regional water models share many similarities regarding runoff simulation results and their conceptual approach to model development, although the GWM results vary more than regional water results.

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Definitions used by 16 global water models

Table S84. Glossary with variables used in the study

Symbol	Dimension (L = length; T = time)	Variable: with synonyms	Definition
A	L^3 L^{-2} T^{-1}	water abstraction: water withdrawal	amount of water extracted, from surface water or groundwater, by humans for various economic sectors. It represents the sum of the water consumed by humans (water consumption), evaporative and percorative loss, and water returned to the groundwater or surface water, being the part of the water not consumed.
A_{pot}	L^3 L^{-2} T^{-1}	potential water abstraction: potential water withdrawal	amount of water extracted by humans considering unlimited water supply.
A_{act}	L^3 L^{-2} T^{-1}	actual water abstraction: actual water withdrawal	amount of water extracted by humans considering water availability.
A_{cons}	L^3 L^{-2} T^{-1}	water consumption: water use	part of water extracted that evapotranspirates during use of purpose.
A_{dom}	L^3 L^{-2} T^{-1}	domestic water abstraction: domestic water withdrawal	amount of water extracted by humans for households and small businesses.
A_{ele}	L^3 L^{-2} T^{-1}	electricity water abstraction: electricity water withdrawal	amount of water extracted by humans to cool thermal and nuclear power plants, which are using the heat, obtain by burning of fossil fuels, gas, biomass or through nuclear energy, to produce electricity.
A_{irr}	L^3 L^{-2} T^{-1}	irrigation water abstraction: irrigation water withdrawal	amount of water extracted by humans for use in agricultural irrigation.
A_{ind}	L^3 L^{-2} T^{-1}	industrial water abstraction: industrial water withdrawal	amount of water extracted by humans for use in industrial sector, in some models this sector includes manufacturing and electricity sectors.

A_{liv}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	livestock water abstraction: livestock water withdrawal	amount of water extracted by humans for livestock production.
A_{man}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	manufacturing water abstraction: manufacturing water withdrawal	amount of water extracted by humans in factories, for producing goods.
A_{rf}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	return flow from water abstraction: return flow from water withdrawal	part of water extracted by humans that returns into the soil, groundwater, lake, reservoir, river and ocean.
A^{oc}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	seawater abstraction: seawater withdrawal	seawater or saline and brackish water extracted by humans to be used for various economic sectors, for example, for domestic and manufacturing sectors or for electricity production.
E_{so}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	evaporation from soil: evaporation from bare soil	amount of water that changes from liquid to vapor from the bare soil (not through vegetation).
E_{ca}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	canopy evaporation: evaporation of the water intercepted by canopy, interception loss	amount of water accumulated on the vegetation that changes from liquid to vapor.
E_{la}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	evaporation from lake	water that changes from liquid to vapor from a lake.
E_{re}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	evaporation from reservoir	water that changes from liquid to vapor from a reservoir.
E_{ri}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	evaporation from river	water that changes from liquid to vapor from a river.
E_{sn}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	sublimation: evaporation from snow	water that changes from solid (snow and ice) to vapor.
AET	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	actual evapotranspiration: total evapotranspiration	total amount of water from transpiration, evaporation, interception losses, and sublimation, considering water availability.
PET	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	potential evapotranspiration	total amount of water from transpiration, evaporation, interception losses, and sublimation, considering unlimited water source.
E_{we}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	evaporation from wetland	water which changes from liquid to vapor above a wetland.
M	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	snowmelt	water that changes from solid to liquid.
P_{de}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	dew	atmospheric water condensing directly on the land surface
P_{dr}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	drip	water spill from canopy to the ground when the water exceeds the canopy interception capacity (through dripping).
P_{ra}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	rainfall	liquid precipitation that falls in a given area and in a given time, provided as climate input data in ISIMIP2.
P_{sn}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	snowfall	solid precipitation, combined in small ice crystals, that falls in a given area and in a given time, provided as climate input data in ISIMIP2.
P_{sf}	$\mathrm{L}^{3}\,\mathrm{L}^{-2}\,\mathrm{T}^{-1}$	stemflow	water spill to the ground through canopy, which flows along twigs, branches and stems.

P_{th}	$L^3 L^{-2} T^{-1}$	throughfall	water spill to the ground through canopy spaces.
P_{tot}	$L^3 L^{-2} T^{-1}$	total precipitation: precipitation	liquid or solid water resulting from the condensation or freezing of water vapor and falling to the ground under gravity.
Q_{iu}	$L^3 T^{-1}$	inflow from upstream surface water bodies	water from upstream, which can be a river, a lake, a wetland, a reservoir.
Q_{ib}	$L^3 T^{-1}$	inter-basin water transfer: trans-basin diversion	anthropogenic transport of water from one river basin, where it is available, to another basin where water is less available or could be utilized for other purposes. This could be an output at a location and input to another.
Q_{la}	$L^3 T^{-1}$	outflow from lake	water that flows out of a lake to a river, wetland or reservoir.
Q_{re}	$L^3 T^{-1}$	outflow from reservoir	water that flows out of a reservoir, a lake which is made by humans, to a river.
Q_{ri}	$L^3 T^{-1}$	streamflow: outflow, flow, river discharge	volumetric flow rate of water through a river cross-section. The streamflow is transfer through a channel to the ocean or to an inland sink.
Q_{we}	$L^3 T^{-1}$	outflow from wetland	water that flows out of a wetland to a river.
R_{cr}	$L^3 L^{-2} T^{-1}$	capillary rise	water rising from roundwater to soil under the influence of capillary forces.
R_{ct}	$L^3 L^{-2} T^{-1}$	channel transmission losses	water from river storage which recharges the groundwater storage.
R_{gw}	$L^3 L^{-2} T^{-1}$	groundwater runoff	water that leaves the groundwater storage to a river, lake or wetland.
R_{gwr}	$L^3 L^{-2} T^{-1}$	groundwater recharge	water leaving the last soil layer(s) and reaching the groundwater storage. In some models, this variable describes *seepage*.
R_{ho}	$L^3 L^{-2} T^{-1}$	Hortonian overland flow: infiltration excess overland flow, flooding excess overland flow, unsaturated overland flow	water that runs off over the soil surface because the rainfall intensity exceeds the infiltration capacity.
R_{in}	$L^3 L^{-2} T^{-1}$	infiltration	water from rainfall or throughfall or snowmelt or irrigation which flows through the soil surface into the root zone, under the effect of gravity.
R_{if}	$L^3 L^{-2} T^{-1}$	interflow: subsurface storm flow, subsurface runoff	water that runs-off laterally from the soil.
R_{pe}	$L^3 L^{-2} T^{-1}$	percolation	amount of water that penetrates in the soil layers, beyond the root zone of plants
R_{sat}	$L^3 L^{-2} T^{-1}$	saturation excess overland flow: saturation overland flow, saturation excess runoff, Dunne runoff	water that runs off over the soil surface because the soil is saturated.
R_{su}	$L^3 L^{-2} T^{-1}$	surface runoff: overland flow, fast runoff, flood	water that runs-off over the soil surface as Hortonian overland flow and / or saturation excess overland flow.

		runoff, surface flow, surface or direct runoff	
R_{tot}	$L^3 L^{-2} T^{-1}$	total runoff	total amount of water that runs-off the grid-cell, either over the soil surface, or from the subsurface (lateral flow). In some studies, the streamflow is converted to runoff by dividing the streamflow values with the area upstream of the gauging station (for example, the area upstream of station according to the DDM30‘ river network Döll and Lehner, 2002).
S_{ca}	$L^3 L^{-2}$	canopy storage	compartment that retains water from precipitation and loses water through throughfall, stemflow and interception loss (evaporation).
S_{gl}	$L^3 L^{-2}$	glacier storage	compartment which retains water from rainfall, snowfall, and loses water through sublimation, glacier melt, runoff from liquid precipitation.
S_{gw}	$L^3 L^{-2}$	groundwater storage	compartment, beneath the soil water compartment, that receives water from seepage, groundwater recharge, and loses water through capillary rise, groundwater runoff, and abstraction for human water use. Hydrologically, it includes saturated zone or phreatic zone.
S_{la}	$L^3 L^{-2}$	lake storage	compartment that fills with water through fluxes above and beyond the ground and stores water for a residence time. It loses water through discharge to other storages, evaporation, groundwater recharge, and water abstraction for human water use.
S_{so}	$L^3 L^{-2}$	soil storage	compartment that keeps and loses water from flows above and beyond the ground’s surface. Hydrologically, it includes unsaturated zone.
S_{re}	$L^3 L^{-2}$	reservoir storage	compartment that fills with water behind dams through fluxes above and beyond the ground and stores water for a residence time. It loses water through discharge to other storages, evaporation, groundwater recharge, and water abstraction for human water use.
S_{ri}	$L^3 L^{-2}$	river storage	compartment filled with water through fluxes above and beyond the ground. It loses water through river discharge, evaporation, channel transmission losses and water abstraction for human water use.
S_{sn}	$L^3 L^{-2}$	snow storage	compartment that accumulates snow below freezing temperature and loses snow by melting and sublimation.
S_{soc}	$L^3 L^{-2}$	snow held on the canopy	snow compartment that accumulates snow on the vegetation.
S_{suc}	$L^3 L^{-2}$	snow under the canopy	amount of snow accumulated under the canopy or on the soil
S_{sw}	$L^3 L^{-2}$	surface water bodies: surface water	surface water bodies can include river, lake, wetland, and reservoir.
S_{we}	$L^3 L^{-2}$	wetland storage	compartment, as a transition area between the terrestrial and aquatic systems, filled by precipitation or inflow and emptied by evapo(transpi)ration, outflow and groundwater recharge.
T	$L^3 L^{-2} T^{-1}$	transpiration	water evaporated by plants through their stomata.

Note: In the ISIMIP2b, the word “prescribed” has two meanings: (i) data which are simulated by other models and provided by the ISIMIP2b framework as input (https://www.isimip.org/gettingstarted/details/38/); (ii) data obtained from satellite observations, other datasets, or maps. Prescribed data highlight some limitations of the models or underline the lack of some processes that were intentionally or non-intentional removed from the model structure, according to the purpose of the model development or other priorities such as time.

Examples of how different model equations can be between GWMs

Different equations used by GWMs led to different model results, for example, different evapotranspiration methods led to significant differences in runoff estimation (Gosling and Arnell, 2011b; Kingston et al., 2009). The equations include parameters that are used to calibrate GWMs. The application of different parameter values can lead to different results between models (as can the employment of different model structures). As examples, we present how global water models simulate the groundwater recharge and the maximum value of canopy storage differently.

Groundwater recharge (Table S30) is computed by 14 models. JULES-W1 and LPJmL do not include in their structure groundwater storage and seepage (the water that seeps from the last soil layer), which was reported as groundwater recharge and groundwater runoff for ISIMIP2b. CLM4.5 and CLM5.0 use the same approach to compute groundwater recharge, by using the concept of soil matrix potential and considering the hydraulic conductivity of the layer containing the water table. CWatM and PCR-GLOBWB use the same approach by reducing percolation with capillary rise, but CWatM also considers preferential flow as inflow. DBH estimates it depending on potential soil water content multiplied by the soil depth layer and maximized by soil hydraulic conductivity. Three models (H08, WaterGAP2, and WAYS) consider it as being the minimum value between maximum groundwater recharge and total runoff from land, weighted by a relief-related factor, a soil texture-related factor, a hydrogeology-related factor, and a permafrost- and/or glacier-related factor (Döll and Fiedler, 2008). Further, WaterGAP2 sets (semi-)arid grid cells, sandy texture, and grid cells with throughfall equal or below 12.5 (mm day^{-1}) to 0. MATSIRO estimated groundwater recharge as being the variation of unfrozen soil moisture over time. MPI-HM equals groundwater recharge to percolation. ORCHIDEE estimates it depending on relative soil water content, but it is capped down to 0 and maximized by groundwater runoff.

Maximum value of canopy storage (Table S7). Another example is that the models estimate differently the maximum value of canopy storage and leaf area index (LAI) values. WaterGAP2 and WAYS estimate the maximum value of canopy storage by multiplying 0.3 mm with LAI. Further, WAYS estimates seasonal LAI depending on the growing-season index, day length, and the actual root zone water storage. The root zone soil moisture stress parameter is fixed at 0.07, while WaterGAP2 estimates LAI based on a simple growth model and based on land cover characteristics (Table S7). VIC multiplies 0.2 mm by the monthly LAI. Additional, VIC takes into account aerodynamic and architectural resistances. CWatM equals maximum value of canopy storage with LAI that varies every 10 days depending on land use classes.

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Table S85. Downscaled and bias-adjusted output from CMIP5 Global Climate Models (GCMs) used by the ISIMIP2b Impact Models[1] with a spatial resolution of 0.5°x 0.5° and a daily temporal resolution

GCM output used[2]	Models
IPSL-CM5A-LR	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
HadGEM2-ES	CLM4.5, CLM5.0, CWatM, H08, JULES-W1, LPJmL, MATSIRO, mHM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
GFDL-ESM2M	CLM4.5, CLM5.0, CWatM, H08, JULES-W1, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, ORCHIDEE-DGVM, PCR-GLOBWB, WaterGAP2, WAYS
MIROC5	CLM4.5, CLM5.0, CWatM, H08, JULES-W1, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS

Notes:
1. Source data: https://www.isimip.org/gettingstarted/availability-input-data-isimip2b/, 2. EartH2Observe, WFDEI and ERA-Interim data Merged and Bias-corrected for ISIMIP (EWEMBI), http://dataservices.gfz-potsdam.de/pik/showshort.php?id=escidoc:1809891. Data source of the bias-corrected atmospheric data is ISIMIP project.
2. Data source of the original data: CMIP5 (Coupled Model Intercomparison Project Phase 5)
Reference: Lange, S. (2016): EartH2Observe, WFDEI and ERA-Interim data Merged and Bias-corrected for ISIMIP (EWEMBI). GFZ Data Services. http://doi.org/10.5880/pik.2016.004

Table S86. Climate variables used as input for the ISIMIP2b Impact Models[1] with a spatial resolution of 0.5°x 0.5° and a time span between 1661 – 2299

Variable name	Symbol (unit)	Temporal resolution	Models
snowfall	prsn (kg m^{-2} s^{-1})	3 hourly	MATSIRO
		daily	H08
total precipitation	pr (kg m^{-2} s^{-1})	daily	CLM4.5, CLM5.0, DBH, JULES-W1, H08, LPJmL, Mac-PDM.20, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
near surface wind speed	sfcWind (m s^{-1})	daily	CLM4.5, CWatM,DBH, H08, JULES-W1, Mac-PDM.20, ORCHIDEE
eastward wind	ua (m s^{-1})	daily	CLM5.0, ORCHIDEE
westward wind	va (m s^{-1})	daily	CLM5.0, ORCHIDEE
surface air pressure	ps (Pa)	daily	CLM5.0, CWatM, DBH, H08, JULES-W1, ORCHIDEE
		3 hourly	MATSIRO, ORCHIDEE
near surface specific humidity	huss (kg kg^{-1})	daily	CLM4.5, CWatM, H08, JULES-W1, H08
relative humidity	rhs (%)	daily	CLM5.0, CWatM, DBH, JULES-W1, Mac-PDM.20
		3 hourly	MATSIRO
mean temperature	tas (K)	daily	DBH, CWatM,JULES-W1, H08, LPJmL, Mac-PDM.20, mHM, MPI-HM, PCR-GLOBWB, WaterGAP2, CLM4.5, CLM5.0, JULES-W1, PCR-GLOBWB,
		3 hourly	MATSIRO
maximum temperature	tasmax (K)	daily	DBH, CWatM, JULES-W1, mHM, ORCHIDEE , PCR-GLOBWB
minimum temperature	tasmin (K)	daily	DBH, CWatM, JULES-W1, mHM, ORCHIDEE, PCR-GLOBWB
shortwave downwelling radiation	rsds (W m^{-2})	daily	CLM4.5, CLM5.0, CWatM, DBH, JULES-W1, H08, LPJmL[2], Mac-PDM.20, ORCHIDEE, WaterGAP2
		3 hourly	MATSIRO
longwave downwelling radiation	rlds (W m^{-2})	daily	CLM4.5, CLM5.0, CWatM, DBH, JULES-W1, H08, Mac-PDM.20, ORCHIDEE, WaterGAP2
		3 hourly	MATSIRO

Note:
1: Data source of the bias-corrected atmospheric data: ISIMIP project and Lange, 2016; Data source of the original data: CMIP5 (Coupled Model Intercomparison Project Phase 5)
2: LPJmL: Long wave net radiation derived from longwave downwelling radiation and mean temperature.
3: *Climate forcings* are used by climate community to point out the natural and human-made factors that affect the Earth's climate (IPCC, 2012). Natural factors include the Sun's energy, regular changes in the Earth's orbital cycle, and large volcanic eruptions, while human-made factors are greenhouse gas emissions and land use changes. The global hydrological community and vegetation community consider *climate forcings* as climate input data or climate variables for their models.

Reference: Lange, S. (2016): EartH2Observe, WFDEI and ERA-Interim data Merged and Bias-corrected for ISIMIP (EWEMBI). GFZ Data Services. http://doi.org/10.5880/pik.2016.004

Table S87. CO_2 concentrations and Land use datasets

Dataset	Variable name / short description	Symbol	Data source	Time Span	Spatial Resolution	Temporal Resolution	Models
Atmospheric CO_2 concentrations	CO_2 concentrations / Values are constant for 1661 – 1860, following observations from 1861 –2005, and correspond to RCP 2.6 and 6.0 from 2006 – 2299	CO_2		1661 – 2299	0.5°x0.5°	annual constant	CLM4.5, CLM5.0, DBH, JULES-W1. LPJmL, ORCHIDEE, PCR-GLOBWB H08
MIRCA2000	irrigated and rainfed crop areas / around the year 2000	LU	Portmann et al., 2000	1998 – 2002	0.5°x0.5° / 5‘x5‘	monthly	H08, ORCHIDEE, MPI-HM
Historical, gridded land use	Land use / 5 Rainfed crop land, irrigated crop land, pastures and total crop land (the sum of rainfed and irrigated)	LUH	HYDE 3.2, Klein Goldewijk, 2017	10 000 BCE – 2015 CE	0.5°x0.5°	2000 - 2015 CE: annual 1700 - 2000 CE: 10 years	CLM4.5, CLM5.0, CWatM, H08LPJmL, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB
Future land-use patterns	Land use and land cover / 6 land-use types: rain-fed crop land, irrigated crop-land, rain-fed bioenergy, irrigated bio-energy, pastures, natural vegetation and urban areas	LULC	MAgPIE land-use model according to the SSP2 shared-socio-economic pathway and RCP 2.6 / RCP 6.0.	2006 – 2100	0.5°x0.5°	annual	JULES-W1, MPI-HM

Note: 1. https://www.isimip.org/gettingstarted/details/30/

Reference:

1. Klein Goldewijk, Dr. ir. C.G.M. (Utrecht University) (2017): Anthropogenic land-use estimates for the Holocene; HYDE 3.2. DANS. https://doi.org/10.17026/dans-25g-gez3
2. Portmann, F. T., Siebert, S. & Döll, P. (2010): MIRCA2000 – Global monthly irrigated and rainfed crop areas around the year 2000: A new high-resolution data set for agricultural and hydrological modeling, Global Biogeochemical Cycles, 24, GB 1011, doi:10.1029/2008GB003435.

Table S88. Other input date sets used by the ISIMIP2b Impact models

Dataset	Data source	Spatial Resolution	Temporal resolution / details / Time span	Models
soil type[1]	ISIMIP2b	0.5°x05°	static	CLM4.5, CLM5.0, DBH, JULES-W1, LPJmL, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2[4]
plant functional types (PFT) parameters	Samanta et. al., 2014	0.5°x05°	static	JULES-W1
topographical information (subgrid slope distribution)	Hagemann and Gates, 2003	1kmx1km	static	MPI-HM
River-routing network	DDM30[2] (Döll and Lehner, 2002)	30'x30' (0.5°x05°)	static	CLM4.5, CLM5.0, CWatM, H08, LPJmL, MPI-HM, PCR-GLOBWB[5], WaterGAP2
	TRIP model			MATSIRO
	Simulated Topological Network (STN-30p) (Vörösmarty et al., 2000)			ORCHIDEE
	HydroSHEDS[Lehner et al., 2006]			mHM
crop parameters		0.5°x05°	static	H08
Albedo	2012	0.5°x05°	static	H08, CWatM[6],
Land-sea mask	ISIMIP2b	0.5°x05°	static	CLM5.0, DBH, CWatM, Mac-PDM.20, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
GRanD	Lehner et al., 2011	6862 dams and their associated reservoirs, total storage capacity of 6197 km^3	static	CWatM[7], H08, LPJmL, MATSIRO, PCR-GLOBWB, WaterGAP2[8]
Water abstraction for domestic and industrial uses consistent with SSP2 and RCP 6.0	ISIMIP2b[3], multi-model averages of PCR, WaterGAP, H08	0.5°x05°	available until 2050, the values are kept static from 2050 onwards	LPJmL
Global Lakes and Wetlands Database (GLWD)	Lehner and Döll, 2004; Lehner et al., 2011	1:1 to 1:3 million resolution	static	MPI-HM, PCR-GLOBWB, WaterGAP2
Regarding soil data — we use the SoilGrids250 from ISRIC:	Hengl et al., 2017	0.002°x0.002°	static	mHM

Note: 1. H08 does not require soil type. In addition to estimate subgrid slope distribution, information about permafrost, slope, geology etc. are required (see Hanasaki et al., 2018). 2. DDM30 = the 30' global drainage direction map (Döll and Lehner, 2002). 3. For modelling groups that do not have their own representation, ISIMIP2b provides files containing the multi-model mean from WaterGAP2, PCR-GLOBWB and H08 scenarios for domestic and industrial uses under SSP2 from the Water Futures and Solutions Project (WFaS; Wada et al., 2016). 4. Soil data from WISE Available Water Capacity (Batjes, 2012). 5. PCR-GLOBWB combines DDM30 with GLWD. 6. Muller et al., 2012. 7. CWatm: HydroLakes database (Messager et al., 2016; Lehner et al., 2011) 8. WaterGAP2 uses a pre-published and adjusted version of GRanD, see https://www.arcgis.com/home/item.html?id=d966db9c7b2949ac8380458d7020adf9.

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Table S89. Natural Vegetation datasets used by the ISIMIP2b impact models

Dataset	Data source	Time Span	Spatial Resolution	Models
Land Surface Parameter set 2 (LSP2)	Hagemann, 2002	2001	0.5°x0.5°	LPJmL, MPI-HM
MODIS	NASA		0.5°x0.5°	CLM5.0, WaterGAP2[1]
Global Land Cover for Simple Biosphere 2 Model	FAO	April 1992 – March 1993	1kmx1km	DBH
Global Land Cover Map (GlobCover)	European Space Agency GlobCover Portal (ESA)[4]	2009	0.5°x0.5°	Mac-PDM.20, mHM, PCR-GLOBWB

Note: 1. WaterGAP2 uses The International Geosphere–Biosphere Programme (IGBP) classification based on MODIS data for the year 2004.

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http://due.esrin.esa.int/page_globcover.php

Table S90. Socio-economic datasets with a spatial resolution of 0.5°x0.5° and 5'x5' and an annual temporal resolution

Dataset name	Variable name / details	Symbol (unit)	Data source	Time Span	Models
Historical, country-level population	population	pop (number people)	Hyde 3.2 (Klein Goldewijk et al., 2010; Klein Goldewijk, 2011)	1861 – 2009	PCR-GLOBWB WaterGAP2
Historical, gridded population	population	pop (number people)	Hyde 3.2 (Klein Goldewijk et al., 2010; Klein Goldewijk, 2011)	1861 – 2005	PCR-GLOBWB WaterGAP2
Future, country-level population	country-level population, urban population and age structure (in five-year age bands) / based on SSP2	pop (number people)	IIASA (population & age structure) and NCAR (urbanshare)	2006 – 2099	PCR-GLOBWB WaterGAP2
Future, gridded population	population / based on SSP2 population / based on all SSPs	pop (number people)	Samir and Lutz, 2014[3] Jones and O'Neill ,2016	2006 – 2099 2006 – 2100	PCR-GLOBWB WaterGAP2
Historical, country-level Gross Domestic Product (GDP)[1]	Gross Domestic Product	GDP (per capita and PPP $)	Geiger and Frieler, 2018	1861 – 2005	PCR-GLOBWB WaterGAP2
Future, gridded Gross Domestic Product (GDP)[2]	Gross Domestic Product	GDP (per capita and PPP $)	Murakamiaan and Yamagata, 2016	2006-2099	PCR-GLOBWB WaterGAP2
Future, country-level Gross Domestic Product (GDP)	Gross Domestic Product	GDP (per capita and PPP $)	Geiger and Frieler, 2017; Geiger and Frieler, 2018	2006-2100	PCR-GLOBWB WaterGAP2

Note: 1. National income (GDP / capita) and GDP time series (2005 PPP $, purchasing power parities (PPP) conversion factor, local currency unit to international dollar) from 1850-2009 from Penn World Tables 8.1 extrapolated with per capita growth rates from the Maddison project, and extended by Penn World Tables 9.0 and World Development Indicators. Interpolated between 2006-2009 to match with OECD SSP2 projections starting in 2010. 2. All dataset: 1980 – 2100, by 10 years. The data in 1980–2010 are estimated by downscaling actual populations and GDPs by country, while those in 2020–2100 are estimated by downscaling projected populations and GDPs under three shared socioeconomic pathways (SSP): SSP1; SSP2; and SSP3, by country. 3. https://www.isimip.org/gettingstarted/details/32/

References:

1. Geiger, T., Frieler, K. (2017): Continuous national Gross Domestic Product (GDP) time series for 195 countries: past observations (1850-2005) harmonized with future projections according the Shared Socio-economic Pathways (2006-2100). GFZ Data Services. http://doi.org/10.5880/pik.2017.003

2. Geiger, T., Frieler, K. (2018): Continuous national Gross Domestic Product (GDP) time series for 195 countries: past observations (1850-2005) harmonized with future projections according the Shared Socio-economic Pathways (2006-2100) (Version 2.0) [Data set]. GFZ Data Services. https://doi.org/10.5880/pik.2018.010

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Table S91. Hydrological output data of the ISIMIP2b global water models1 with a spatial resolution of 0.5°x 0.5°

Hydrological variable	ISIMIP2b protocol Symbol (Units) / Temporal resolution	Models
Runoff	qtot (kg m^{-2} s^{-1}) / daily	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, Mac-PDM.20, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
Surface runoff	qs (kg m^{-2} s^{-1}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, Mac-PDM.20, MATSIRO, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2. WAYS
Subsurface runoff	qsb (kg m^{-2} s^{-1}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, Mac-PDM.20, MATSIRO, mHM, MPI-HM, ORCHIDEE, ORCHIDEE-DGVM, PCR-GLOBWB, WaterGAP2, WAYS
Groundwater recharge	qr (kg m^{-2} s^{-1}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
Groundwater runoff	qg (kg m^{-2} s^{-1}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
Discharge (gridded)	dis (m^{3} s-^{1})	CLM4.5, CLM5.0, CWatM, DBH, H08, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Monthly maximum of daily discharge	maxdis (m^{3} s-^{1}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Monthly minimum of daily discharge	mindis (m^{3} s-^{1}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Evapotranspiration	evap (kg m^{-2} s^{-1}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, Mac-PDM.20, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
Potential Evapotranspiration	potevap (kg m^{-2} s^{-1}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, Mac-PDM.20, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
Soil moisture	soilmoist (kg m^{-2}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, Mac-PDM.20, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Soil moisture, root zone	rootmoist (kg m^{-2}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, Mac-PDM.20, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
Frozen soil moisture for each layer	soilmoistfroz (kg m^{-2}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Temperature of Soil	tsl (K)	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Snow depth	snd (m) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Snow water equivalent	swe (kg m^{-2}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Total water storage	tws (kg m^{-2}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, JULES-W1, LPJmL, MATSIRO, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Canopy water storage	canopystor / monthly	CLM4.5, CLM5.0, CWatM, DBH, JULES-W1, LPJmL, MATSIRO, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
Glacier storage	glacierstor / monthly	CLM4.5, CLM5.0, CWatM
Groundwater storage	groundwstor / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, mHM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Lake storage	lakestor / monthly	CLM4.5, CLM5.0, CWatM, MATSIRO, WaterGAP2
Wetland storage	wetlandstor / monthly	CLM4.5, CLM5.0, CWatM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Reservoir storage	reservoirstor / monthly	CWatM, DBH, H08, LPJmL, MATSIRO, PCR-GLOBWB, WaterGAP2
Annual maximum daily thaw depth	thawdepth (m) / monthly	CLM4.5, CLM5.0, CWatM, DBH, LPJmL, MATSIRO, ORCHIDEE,
River storage	riverstor / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, LPJmL, MATSIRO, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2
Rainfall	rainf (kg m^{-2} s^{-1}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
Snowfall	snowf (kg m^{-2} s^{-1}) / monthly	CLM4.5, CLM5.0, CWatM, DBH, H08, JULES-W1, LPJmL, Mac-PDM.20, MATSIRO, mHM, MPI-HM, ORCHIDEE, PCR-GLOBWB, WaterGAP2, WAYS
Leaf Area Index	lai (-) / monthly	CLM45, ORCHIDEE, WAYS

Table S92. Water management variables of the ISMIP2b global water models[1] with a spatial resolution of 0.5°x0.5° and a monthly temporal resolution

Output variable	ISIMIP2b protocol Symbol (Units) / Temporal resolution	Models
Irrigation water demand (=potential irrigation water Withdrawal)	pirrww (kg m^{-2} s^{-1})	CLM4.5, CLM5.0, CWatM, DBH, H08, LPJmL, MATSIRO, MPI-HM, PCR-GLOBWB, WaterGAP2
Actual irrigation water withdrawal	airrww (kg m^{-2} s^{-1})	CLM4.5, CLM5.0, CWatM, DBH, H08, LPJmL, MATSIRO, MPI-HM, PCR-GLOBWB
Potential irrigation water consumption	pirruse (kg m^{-2} s^{-1})	CLM4.5, CLM5.0, CWatM, DBH, H08, LPJmL, MATSIRO, MPI-HM, PCR-GLOBWB, WaterGAP2
Actual irrigation water consumption	airruse (kg m^{-2} s^{-1})	CLM4.5, CLM5.0, CWatM, DBH, H08, LPJmL, MATSIRO, MPI-HM, PCR-GLOBWB
Actual green water consumption on irrigated cropland	airrusegreen (kg m^{-2} s^{-1})	CLM4.5, CLM5.0, CWatM, DBH, H08, LPJmL, MATSIRO, PCR-GLOBWB
Potential green water consumption on irrigated cropland	pirrusegreen (kg m^{-2} s^{-1})	CLM4.5, CLM5.0, CWatM, DBH, H08, LPJmL, MATSIRO, PCR-GLOBWB
Actual green water consumption on rainfed cropland	arainfusegreen (kg m^{-2} s^{-1})	CLM4.5, CLM5.0, CWatM, DBH, H08, LPJmL, MATSIRO, PCR-GLOBWB
Actual domestic water withdrawal	adomww (kg m^{-2} s^{-1})	CWatM, H08, MATSIRO, PCR-GLOBWB
Actual domestic water consumption	adomuse (kg m^{-2} s^{-1})	CWatM, H08, MATSIRO, PCR-GLOBWB
Actual manufacturing water withdrawal	amanww (kg m^{-2} s^{-1})	CWatM, H08, MATSIRO, PCR-GLOBWB
Actual Manufacturing water consumption	amanuse (kg m^{-2} s^{-1})	CWatM, H08, MATSIRO, PCR-GLOBWB
Actual electricity water withdrawal	aelecww (kg m^{-2} s^{-1})	CWatM, H08, PCR-GLOBWB
Actual electricity water consumption	aelecuse (kg m^{-2} s^{-1})	CWatM, H08, PCR-GLOBWB
Actual livestock water withdrawal	aliveww (kg m^{-2} s^{-1})	CWatM, H08, PCR-GLOBWB
Actual livestock water consumption	aliveuse (kg m^{-2} s^{-1})	CWatM, H08, PCR-GLOBWB
Total (all sectors) actual water consumption	atotuse (kg m^{-2} s^{-1})	CWatM, H08, PCR-GLOBWB, WaterGAP2
Total (all sectors) actual water withdrawal	atotww (kg m^{-2} s^{-1})	CWatM, H08, PCR-GLOBWB, WaterGAP2
Total (all sectors) water demand (=potential water withdrawal)	ptotww (kg m^{-2} s^{-1})	CWatM, H08, PCR-GLOBWB, WaterGAP2
Total (all sectors) potential water consumption	ptotuse (kg m^{-2} s^{-1})	CWatM, H08, PCR-GLOBWB, WaterGAP2
Actual industrial water consumption	ainduse (kg m^{-2} s^{-1})	CWatM, PCR-GLOBWB
Potential domestic water consumption	pdomuse (kg m^{-2} s^{-1})	H08
Potential manufacturing water consumption	pmanuse (kg m^{-2} s^{-1})	H08
Actual industrial water withdrawal	aindww (kg m^{-2} s-^{1})	PCR-GLOBWB

https://www.isimip.org/protocol/

Table S93. Human water use sectors included in the Global Water Models – Part I

Model	Irrigation											Livestock											Domestic										
	Water withdrawal (source)					Return flow (destination)						Water withdrawal (source)					Return flow (destination)						Water withdrawal (source)					Return flow (destination)					
	G	L	R_e	R_i	O	S	G	L	R_e	R_i	O	G	L	R_e	R_i	O	S	G	L	R_e	R_i	O	G	L	R_e	R_i	O	S	G	L	R_e	R_i	O
CLM4.5				✓		✓	✓			✓																							
CLM5.0				✓		✓	✓			✓																							
CWatM	✓	✓	✓	✓		✓	✓			✓		✓	✓	✓	✓								✓	✓	✓	✓						✓	
H08	✓			✓	✓	✓	✓																✓	✓		✓	✓					✓	
LPJmL		✓		✓		✓				✓																							
MATSIRO	✓		✓	✓		✓	✓																✓		✓	✓						✓	
MPI-HM[1]	✓	✓		✓																													
PCR-GLOBWB	✓	✓	✓	✓		✓	✓					✓	✓	✓	✓			✓					✓	✓	✓	✓			✓				
WaterGAP2	✓	✓	✓	✓			✓	✓	✓	✓			✓	✓	✓								✓	✓	✓	✓				✓	✓	✓	

Legend: G = groundwater; L = lake; O = ocean; R_e = reservoir; R_i = river; S = soil; **Bold** = LSMs; *Italic* = GHMs; Underline = DGVMs.

Note: 1: MPI-HM extracts water from the wetland storage, which includes the water stored in lakes.

Table S94. Human water use sectors included in the Global Water Models – Part II

Model	Manufacturing											Electricity											Desalination											
	Water withdrawal (source)						Return flow (destination)					Water withdrawal (source)						Return flow (destination)					Water withdrawal (source)						Return flow (destination)					
	G	L	R_e	R_i	O	S	G	L	R_e	R_i	O	G	L	R_e	R_i	O	S	G	L	R_e	R_i	O	G	L	R_e	R_i	O	S	G	L	R_e	R_i	O	ISW
CWatM	✓	✓	✓	✓						✓																								
H08	✓		✓	✓						✓																	✓						✓	
MATSIRO	✓		✓	✓						✓																								
PCR-GLOBWB	✓	✓	✓	✓			✓																											
WaterGAP2	✓	✓	✓	✓				✓	✓	✓																								

Legend: G = groundwater; ISW = inland saline water; L = lake; O = ocean; R_e = reservoir; R_i = river; S = soil; **Bold** = LSMs; *Italic* = GHMs; Underline = DGVMs. CWatM and PCR-GLOBWB did not compute desalination for ISIMIP2b.

MATSIRO, PCR-GLOBWB, and CWatM combine manufacturing and electricity in industry sector.

Desalination

H08 computes seawater abstraction, consumption, and return flows for ISIMIP2b (Tables S81–S83) (Hanasaki et al., 2018). Seawater abstraction represents the sum of seawater abstraction for the municipal and industry sectors. Three conditions must be met in order to use desalination: i) GDP > USD 14,000 person year^{-1} in terms of purchasing power parity (PPP); ii) humidity index below 8%; iii) within three grid cells of the seashore. It is assumed that seawater desalination is not used for irrigation and that all demand for municipal and industrial water is abstracted by desalination if available. In the context that desalination is not used for irrigation, seawater consumption represents seawater abstraction weighted by the ratio of consumption to withdrawal, which is equal to 0.1 and 0.15 for industrial and municipal water use. Return flow from seawater abstraction represents seawater abstraction weighted by the non-used fraction (0.1 and 0.15 for industrial and municipal water use) and proportion lost during delivery (set to zero).

H08 used the canal (aqueduct) scheme for ISIMIP2b.

Table S95. Potential future research in global hydrological modeling – Part I

Model	Input data	Output data	Temporal resolution	Spatial resolution	Calibration	Canopy storage	Soil storage	Snow storage	Glacier storage
CLM4.5	✓	✓			✓	✓	✓		
CLM5.0	✓	✓			✓	✓	✓		
CWatM		✓			✓				
DBH	✓	✓			✓				
H08	✓			✓	✓				
JULES-W1		✓			✓				
LPJmL	✓	✓		✓					
Mac-PDM.20									
MATSIRO	✓	✓							
mHM								✓	✓
MPI-HM				✓		✓			
ORCHIDEE					✓				
PCR-GLOBWB	✓		✓	✓			✓	✓	
VIC									
WaterGAP2	✓	✓							
WAYS									

Legend: Bold = LSMs, *Italic* = GHMs, Underline = DGVMs.

Table S96. Potential future research in global hydrological modeling – Part II

Model	Groundwater storage	River storage	Runoff scheme	Lakes storage	Reservoir storage	Wetland storage	Water use model
CLM4.5	✓	✓	✓	✓	✓	✓	✓
CLM5.0	✓	✓	✓	✓	✓	✓	✓
CWatM							
DBH				✓		✓	✓
H08							
JULES-W1		✓	✓				
LPJmL							
Mac-PDM.20							✓
MATSIRO	✓						✓
mHM	✓			✓	✓	✓	✓
MPI-HM					✓		
ORCHIDEE							
PCR-GLOBWB	✓		✓		✓		
VIC	✓				✓		✓
WaterGAP2	✓						✓
WAYS							✓

Legend: Bold = LSMs, *Italic* = GHMs, Underline = DGVMs.

We synthesized some challenges in water modelling by reviewing articles published by the climate, global hydrological, and vegetation communities. We classified these according to the 23 unsolved problems in hydrology (UPH) identified by Blöschl et al., 2019 (Table S97), to harmonize the efforts of the global and catchment hydrological communities. Briefly, these challenges can be overcome through innovative and creative collaboration among communities and investment in technical infrastructure. In the end, hydrology is an *inexact* science influenced by *aleatory* (random) and *epistemic* (lack of knowledge) uncertainties (Beven, 2018).

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Beven, K. (2018). On hypothesis testing in hydrology: Why falsification of models is still a really good idea. Wiley Interdisciplinary Reviews:Water,5(3), e1278.
Blöschl G, et al.: Twenty-three Unsolved Problems in Hydrology (UPH) – A community perspective. Hydrological Sciences Journal 64(1):1141–1158. https://doi.org/10.1080/02626667.2019.1620507, 2019.

Table S97 Challenges of global hydrological modelling overlapping with unsolved problems in hydrology

	Challenges of hydrological modelling
Time variability and change (Blöschl et al., 2019)	**Challenges of simulating terrestrial water cycle on the global scale, identified through the present study**
1. Is the hydrological cycle regionally accelerating/decelerating under climate and environmental change, and are there tipping points (irreversible changes)? 2. How will cold region runoff and groundwater change in a warmer climate (e.g. with glacier melt and permafrost thaw)? 3. What are the mechanisms by which climate change and water use alter ephemeral rivers and groundwater in (semi-) arid regions?	**a.** couple the climate and hydrological models, having climate feedback from the hydrological models (Ning et al., 2019); **b.** add glacial meltwater runoff (Schewe et al., 2019; Huss and Hock, 2018, Zekollari et al., 2019; Cáceres et al., 2020); **c.** couple the climate, lands use, hydrology, and human components including their feedbacks and interactions (Nazemi &Wheater, 2015; Pokhrel et al., 2016; Wada et al., 2017; Thiery et al., 2017; 2020 a and b); **d.** land-use dynamics scheme (Sood and Smakhtin, 2015)
Measurements and data (Blöschl et al., 2019)	**Challenges of simulating terrestrial water cycle on the global scale, identified through the present study**
16. How can we use innovative technologies to measure surface and subsurface properties, states, and fluxes at a range of spatial and temporal scales? 18. How can we extract information from available data on human and water systems in order to inform the building process of socio-hydrological models and conceptualizations?	**e.** perform the GWMs at a high resolution of 1 km than 55 km (Wood et al., 2011; Bierkens 2015; Beven et al., 2015; Wada et al., 2016; Burek et al., 2020); **f.** improve the quality of the input data, GRACE products (Murray et al., 2012; Scanlon et al., 2019); **g.** make single-model sensitivity analyses (Gosling and Arnell, 2011; Müller Schmied et al. 2014; Pianosi et al., 2015; Cuntz et al., 2016); **h.** make multi-parameterization of the single models or model compartments; **j.** improve the simulation of the human impact on freshwater resources (Bierkens, 2015; Nazemi&Wheater, 2015; Döll et al., 2016; Wada et al., 2017; Masaki et al., 2017; Veldkamp et al., 2018); **i.** distinguish between the groundwater source and surface water source for water abstractions and identify how the return flows recharge groundwater (Döll et al., 2016; Veldkamp et al., 2018; Scanlon et al., 2019).
Modelling methods (Blöschl et al., 2019)	**Challenges of simulating terrestrial water cycle on the global scale, identified through the present study**
19. How can hydrological models be adapted to be able to extrapolate to changing conditions, including changing vegetation dynamics? 20. How can we disentangle and reduce model structural/parameter/input uncertainty in hydrological prediction?	**k.** understand different model biases (errors) and their influence on the simulations identify and explain the strengths and weaknesses of individual models (fire community: Rabin et al., 2017); **l.** assess the influence of the models' structure on simulations, go deep into equations, to improve the equations, and to create new equations; **m.** improve the processes representation of the models, for example, incorporation of a dynamic groundwater scheme (Pokhrel et al., 2016; Scanlon et al., 2018, 2019); **n.** add other processes in the models such as transmission losses, capillary rise, evaporation from small ephemeral ponds, dynamic response of vegetation to the climate change and CO_2 concentrations; improve the capture of the spatial pattern, intra and inter-annual variabilities; explain the reasons for different output results and use several types of data (e. g., GRACE, GPS, well observations, MODIS, Envisat) for multi-criteria validation (of the models' outputs), model calibration (models' parameters), data assimilation (Döll et al., 2003; Döll et al., 2015; Döll et al., 2016; Vanderkelen et al., 2020); **o.** improve parameterizations by using parameter transfer method, multiscale parameter regionalization (Samaniego et al., 2010), or by using stepwise parameter estimation (Arheimer et al., 2020); **p.** add floodplain storage and wetland evaporation; to develop or open new data sets on "interbasin transfers, regional water distribution network, river cross-sectional dimensions, and hydrogeological subsurface properties" (Bierkens, 2015, page 4942); **q.** weight individual models based upon their performance (Zaherpour et al., 2019) **r.** identify hidden parameters in the code (Mendoza et al., 2015)
Interfaces with society (Blöschl et al., 2019)	**Challenges of simulating terrestrial water cycle on the global scale, identified through the present study**
21. How can the (un)certainty in hydrological predictions be communicated to decision makers and the general public? 22. What are the synergies and tradeoffs between societal goals related to water management (e.g. water–environment–energy–food–health)? 23. What is the role of water in migration, urbanisation and the dynamics of human civilisations, and what are the implications for contemporary water management?	**s.** evaluate the models' performance, for example, following the steps proposed by Krysanova et al., 2018 or to create new feasible steps for GWMs taking into account their shortcomings (Zaherpour et al., 2018 and 2019) or evaluating them for several scales and gauge stations (Samaniego et al., 2017); **t.** compare with the outputs of the high-resolution continental scale models (for example, Parflow) (Scanlon et al., 2018); **u.** complement the global studies with regional studies (Gosling et al., 2011; Gosling et al., 2017; Hatterman et al., 2017); **v.** connect the GWMs with socio-economic and energy models (Calvin et al., 2013; Burek et al., 2020); **x.** identify and explain the strengths and weaknesses of multi-model ensembles, individual model compartments (Clark et al., 2011; Niu et al., 2011; Essery et al., 2013);

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