# UT&C-BEM climate outputs

**Meteorological forcing conditions as provided by user: MeteoDataRaw**

|  |  |
| --- | --- |
| **MeteoDataRaw** |  |
| LWR\_in | incoming longwave radiation [W/m2] |
| SAB1\_in, SAB2\_in | direct incoming shortwave radiation 1 & 2 [W/m2] |
| SAD1\_in, SAD2\_in | diffuse incoming shortwave radiation 1 & 2 [W/m2] |
| T\_atm | air temperature [K] |
| windspeed\_u | wind speed[m/s] |
| pressure\_atm | atmospheric pressure [Pa] |
| rain | rainfall [mm/h] |
| rel\_humidity | relative humidity [-] |

Note SAB1, SAB2, SAD1, SAD2 are provided as outputs of the radiation partitioning code. However, if you are using your own data which is already partitioned into direct and diffuse parts you can just assign direct to either SAB1 or SAB2 and diffuse to SAD1 or SAD2. Internally, they are added to calculate total SAB and total SAD.

**Outdoor temperatures: TempVec**

|  |  |
| --- | --- |
| **TempVec** |  |
| TRoofImp | Surface temperature roof impervious area [K] |
| TRoofVeg | Surface temperature roof vegetated area [K] |
| TRoofIntImp | Interior temperature roof impervious area [K] |
| TRoofIntVeg | Interior temperature roof vegetated area [K] |
| TGroundImp | Surface temperature ground impervious area [K] |
| TGroundBare | Surface temperature ground bare area [K] |
| TGroundVeg | Surface temperature ground vegetated area [K] |
| Ttree | Surface temperature tree canopy [K] |
| TWallSun | Surface temperature sunlit wall [K] |
| TWallShade | Surface temperature shaded wall [K] |
| TWallIntSun | Interior temperature sunlit wall [K] |
| TWallIntShade | Interior temperature shaded wall [K] |
| TCanyon | Air temperature canyon [K] |
| Tatm | Air temperature atmosphere(measured) [K] |

**Air temperature and humidity at 2 m height: Results2m**

|  |  |
| --- | --- |
| **Results2m** |  |
| T2m | 2m air temperature (K) |
| q2m | 2m specific humidity (kg/kg) |
| e\_T2m | 2m vapor pressure (Pa) |
| RH\_T2m | 2m relative humidity (-) |

**Outdoor humidity: Humidity**

|  |  |
| --- | --- |
| **Humidity** |  |
| CanyonRelative | Relative humidity at canyon calculation height (-) |
| CanyonSpecific | Specific humidity at canyon calculation height (kg/kg) |
| CanyonVapourPre | Vapour pressure at canyon calculation height (Pa) |
| CanyonRelativeSat | Saturation relative humidity at canyon calculation height (-), is always 1 |
| CanyonSpecificSat | Specific humidity at saturation at canyon calculation height (kg/kg) |
| CanyonVapourPreSat | Saturation vapor pressure at canyon calculation height (Pa) |
| AtmRelative | Relative humidity at atmospheric forcing height (-) |
| AtmSpecific | Specific humidity at atmospheric forcing height (kg/kg) |
| AtmVapourPre | Vapor pressure at atmospheric forcing height (Pa) |
| AtmRelativeSat | Saturation relative humidity at atmospheric forcing height (-), is always 1 |
| AtmSpecificSat | Specific humidity at saturation at atmospheric forcing height (kg/kg) |
| AtmVapourPreSat | Saturation vapour pressure at atmospheric forcing height (Pa) |

**Building interior temperature and humidity: TempVecB**

|  |  |
| --- | --- |
| **TempVecB** |  |
| Tceiling | Building interior ceiling temperature [K] |
| Tinwallsun | Building interior sunlit wall temperature [K] |
| Tinwallshd | Building interior shaded wall temperature [K] |
| Twindows | Building window temperature [K] (currently not used in the simulations) |
| Tinground | Building interior ground/floor temperature [K] |
| Tintmass | Building interior internal heat storage element temperature [K] |
| Tbin | Building interior air temperature [K] |
| qbin | Building interior specific humidity temperature [kg/kg] |

**Building interior humidity: HumidityBuilding**

|  |  |
| --- | --- |
| **HumidityBuilding** |  |
| qbin | Specific humidity in building interior [kg/kg] |
| esatbin | Saturation vapor pressure at building interior temperature [Pa] |
| ebin | Vapor pressure in building interior [Pa] |
| RHbin | Relative humidity in building interior [-] |

**Mean radiant temperature output at defined point in canyon: MeanRadiantTemperature**

|  |  |
| --- | --- |
| **MeanRadiantTemperature** |  |
| Tmrt | Mean radiant temperature (deg C) |
| BoleanInSun | Point of Tmrt calculation is in sun or in shade |
| SWRdir\_Person | Direct shortwave radiation the person receives (W/m^2) |
| SWRdir\_in\_top | Direct shortwave radiation the person receives from the top (W/m^2) |
| SWRdir\_in\_bottom | Direct shortwave radiation the person receives from the bottom (W/m^2) |
| SWRdir\_in\_east | Direct shortwave radiation the person receives from the east (W/m^2) |
| SWRdir\_in\_south | Direct shortwave radiation the person receives from the south (W/m^2) |
| SWRdir\_in\_west | Direct shortwave radiation the person receives from the west (W/m^2) |
| SWRdir\_in\_north | Direct shortwave radiation the person receives from the north (W/m^2) |
| SWRdiff\_Person | Diffuse shortwave radiation the person receives (W/m^2) |
| LWR\_Person | Longwave radiation the person receives (W/m^2) |

**Outdoor thermal comfort, Universal thermal climate index: UTCI**

|  |  |
| --- | --- |
| **UTCI** |  |
| UTCI | Universal Thermal climate index (degC) |

**Wind speed at different heights within canyon: Wind**

|  |  |
| --- | --- |
| **Wind** |  |
| u\_Hcan | Wind speed at canyon calculation height (hdisp + canyon roughness height) (m/s) |
| u\_Zref\_und | Wind speed at undercanopy reference height (m/s) |
| u\_ZPerson | Wind speed at person height (or point which was specified by the user (m/s) |

# UT&C-BEM energy flux outputs

The energy outputs are aggregated to the urban, canyon and roof level in the function “PlanAreaEnergyBalanceCalculation.m” in the main model folder. To calculate the energy budget closure check out the mentioned script.

**Energy flux outputs per m2 of urban area: EnergyFluxUrban**

This includes all energy fluxes including canyon, building, and roof areas

|  |  |
| --- | --- |
| **EnergyFluxUrban** |  |
| SWRin\_PlanArea | Incoming shortwave radiation from the perspective of the urban plan area (W/m2) |
| SWRin\_SurfArea | Incoming shortwave radiation summed over all surfaces (W/m2) |
| SWRabs\_SurfArea | Absorbed shortwave radiation summed over all surfaces (W/m2) |
| SWRout\_SurfArea | Outgoing shortwave radiation summed over all surfaces (W/m2) |
| SWRout\_Ref\_to\_Atm | Outgoing shortwave radiation reflected to the atmosphere from the perspective of the urban plan area (W/m2) |
| SWREB\_SurfArea | Shortwave energy balance closure summed over all surfaces (W/m2) |
| SWREB\_PlanAreaUrban | Shortwave energy balance closure from the perspective of the urban plan area (W/m2) |
| LWRin\_PlanArea | Incoming longwave radiation from the perspective of the urban plan area (W/m2) |
| LWRin\_SurfArea | Incoming longwave radiation summed over all surfaces (W/m2) |
| LWRabs\_SurfArea | Absorbed longwave radiation summed over all surfaces (W/m2) |
| LWRout\_SurfArea | Outgoing longwave radiation summed over all surfaces (W/m2) |
| LWRout\_Ref\_to\_Atm | Outgoing longwave radiation reflected to the atmosphere from the perspective of the urban plan area (W/m2) |
| LWREB\_SurfArea | Longwave energy balance closure summed over all surfaces (W/m2) |
| LWREB\_PlanAreaUrban | Longwave energy balance closure from the perspective of the urban plan area (W/m2) |
| UrbanAlbedo | Urban albedo calculated from incoming and outgoing shortwave radiation (-) |
| SWRabs | Total absorbed shortwave radiation (W/m2) |
| LWRabs | Total absorbed longwave radiation (W/m2) |
| LEflux | Latent heat flux (W/m2) |
| Hflux | Sensible heat flux (W/m2) |
| GfluxGround | Conductive heat flux to the ground in the building interior (W/m2) |
| G1Building | Conductive heat flux into the building envelope (W/m2) |
| dSdtBuildEnv | Change in heat stored in the building envelope (W/m2) |
| dSdt\_Air | Change in sensible heat stored in the air (W/m2) |
| Qanth | Anthropogenic heat input (either prescribed or calculated as the energy needed for HVAC) (W/m2) |
| QanthACcondensation | Heat released due to condensation of moisture from AC (W/m2) |
| EB | Energy balance closure (W/m2) |

**Energy flux outputs per m2 of canyon area: EnergyFluxCan**

This only includes the energy fluxes in the canyon (e.g. roof energy fluxes are not included)

|  |  |
| --- | --- |
| **EnergyFluxCan** |  |
| SWRin\_SurfArea | Incoming shortwave radiation summed over all surfaces (W/m2) |
| SWRabs\_SurfArea | Absorbed shortwave radiation summed over all surfaces (W/m2) |
| SWRout\_SurfArea | Outgoing shortwave radiation summed over all surfaces (W/m2) |
| SWRout\_Ref\_to\_Atm | Outgoing shortwave radiation reflected to the atmosphere from the perspective of the canyon plan area (W/m2) |
| SWREB\_SurfArea | Shortwave energy balance closure summed over all surfaces (W/m2) |
| SWREB\_PlanAreaCanyon | Shortwave energy balance closure from the perspective of the canyon plan area (W/m2) |
| LWRin\_SurfArea | Incoming longwave radiation summed over all surfaces (W/m2) |
| LWRabs\_SurfArea | Absorbed longwave radiation summed over all surfaces (W/m2) |
| LWRout\_SurfArea | Outgoing longwave radiation summed over all surfaces (W/m2) |
| LWRout\_Ref\_to\_Atm | Outgoing longwave radiation reflected to the atmosphere from the perspective of the canyon plan area (W/m2) |
| LWREB\_SurfArea | Longwave energy balance closure summed over all surfaces (W/m2) |
| LWREB\_PlanAreaCanyon | Longwave energy balance closure from the perspective of the canyon plan area (W/m2) |
| CanAlbedo | Canyon albedo calculated from incoming and outgoing shortwave radiation (-) |
| SWRabs | Total absorbed shortwave radiation (W/m2) |
| LWRabs | Total absorbed longwave radiation (W/m2) |
| LEflux | Latent heat flux (W/m2) |
| Hflux | Sensible heat flux (W/m2) |
| Gflux | Total conductive heat flux including conductive heat flux into buildings and into the ground (W/m2) |
| dSdt\_Air | Change in sensible heat stored in the air (W/m2) |
| Qanth | Anthropogenic heat input (either prescribed or calculated as the energy needed for HVAC) (W/m2) |
| QanthACcondensation | Heat released due to condensation of moisture from AC (W/m2) |
| EB | Energy balance closure (W/m2) |

**Energy flux outputs per m2 of roof area: EnergyFluxRoof**

This only includes the energy fluxes on the roof (e.g. canyon energy fluxes are not included)

|  |  |
| --- | --- |
| **EnergyFluxRoof** |  |
| SWRin | Incoming shortwave radiation (W/m2) |
| SWRout | Outgoing shortwave radiation (W/m2) |
| LWRin | Incoming longwave radiation (W/m2) |
| LWRout | Outgoing longwave radiation (W/m2) |
| SWREB | Shortwave radiation energy budget closure (W/m2) |
| LWREB | Longwave radiation energy budget closure (W/m2) |
| RoofAlbedo | Roof albedo (-) |
| SWRabs | Total absorbed shortwave radiation (W/m2) |
| LWRabs | Total absorbed longwave radiation (W/m2) |
| LEflux | Latent heat flux (W/m2) |
| Hflux | Sensible heat flux (W/m2) |
| Gflux | Total conductive heat flux into buildings (W/m2) |
| Qanth | Anthropogenic heat released on roof (W/m2) |
| EB | Energy balance closure (W/m2) |

# Water flux outputs:

The water flux outputs are aggregated to the urban, canyon and roof level in the function “WaterBalanceComponents.m” in the main model folder. To calculate the water budget closure check out the mentioned script.

**Water flux outputs per m2 of roof area: WaterFluxRoof**

This only includes the water fluxes on the roof (e.g. canyon water fluxes are not included)

|  |  |
| --- | --- |
| **WaterFluxRoof** |  |
| Rain | Incoming rainfall (mm/time step) |
| Runoff | Runoff leaving the system (mm/time step) |
| Leakage | Leakage at the bottom of the soil column -> water leaving the system (mm/time step) |
| ET | Total evapotranspiration (mm/time step) |
| ET\_HVACexch | Exchange of water vapor between indoor and outdoor air (mm/time step) |
| AnthBuildInt | Anthropogenic moisture flux due to people/equipment in buildings (mm/time step) |
| WasteWaterAC | Anthropogenic removal of moisture from air due to condensation during air-conditioning process (mm/time step) |
| dVdt | Change in water storage in the soil due to soil moisture change (mm/time step) |
| dIdt | Change in water storage due to interception change (mm/time step) |
| IrrSurf | Irrigation flux applied at the surface of the soil (mm/time step) |
| IrrSoil | Irrigation occuring due to fixed soil moisture in some soil layers (mm/time step) |
| IrrTot | Total irritation flux (includes surface irrigation and fixed soil moisture in certain soil layers) (mm/time step) |
| Int | Intercepted or ponding water (mm) |
| WB | Water balance closure (mm/time step) |

**Water flux outputs per m2 of building (roof) area: WaterFluxBuild**

This only includes all moisture fluxes within the building (e.g. canyon and roof water fluxes are not included)

|  |  |
| --- | --- |
| **WaterFluxBuild** |  |
| dS\_ET\_dt | Change in moisture storage in the air (mm/time step) |
| ET\_HVACexch | Exchange of water vapor between indoor and outdoor air (mm/time step) |
| AnthBuildInt | Anthropogenic moisture flux due to people/equipment in buildings (mm/time step) |
| WasteWaterAC | Anthropogenic removal of moisture from air due to condensation during air-conditioning process (mm/time step) |
| WB | Water balance closure (mm/time step) |

**Water flux outputs per m2 of canyon area: WaterFluxCan**

This only includes the water fluxes in the canyon (e.g. roof water fluxes are not included)

|  |  |
| --- | --- |
| **WaterFluxCan** |  |
| Rain | Incoming rainfall (mm/time step) |
| Runoff | Runoff leaving the system (mm/time step) |
| Leakage | Leakage at the bottom of the soil column -> water leaving the system (mm/time step) |
| ET | Total evapotranspiration (mm/time step) |
| dS\_ET\_dt | Change in moisture storage in the air (mm/time step) |
| ET\_HVACexch | Exchange of water vapor between indoor and outdoor air (mm/time step) |
| AnthBuildInt | Anthropogenic moisture flux due to people/equipment in buildings (mm/time step) |
| WasteWaterAC | Anthropogenic removal of moisture from air due to condensation during air-conditioning process (mm/time step) |
| dVdt | Change in water storage in the soil due to soil moisture change (mm/time step) |
| dIdt | Change in water storage due to interception change (mm/time step) |
| IrrSurf | Irrigation flux applied at the surface of the soil (mm/time step) |
| IrrSoil | Irrigation occuring due to fixed soil moisture in some soil layers (mm/time step) |
| IrrTot | Total irritation flux (includes surface irrigation and fixed soil moisture in certain soil layers) (mm/time step) |
| Int | Intercepted or ponding water (mm) |
| WB | Water balance closure (mm/time step) |

**Water flux outputs per m2 of urban area: WaterFluxUrban**

This includes all water fluxes including canyon, building, and roof areas

|  |  |
| --- | --- |
| **WaterFluxUrban** |  |
| Rain | Incoming rainfall (mm/time step) |
| Runoff | Runoff leaving the system (mm/time step) |
| Leakage | Leakage at the bottom of the soil column -> water leaving the system (mm/time step) |
| ET | Total evapotranspiration (mm/time step) |
| ETEvaporationFromSurface | Evapotration from water intercepted on surfaces (mm/time step) |
| ETEvaporationFromSoil | Evaporation from soil (mm/time step) |
| ETTranspiration | Transpiration from plants (mm/time step) |
| ETAnthSourceBuildInt | Anthropogenic moisture flux due to people/equipment in buildings (mm/time step) |
| dS\_ET\_dt | Change in moisture storage in the air (mm/time step) |
| ET\_HVACexch | Exchange of water vapor between indoor and outdoor air (mm/time step) |
| AnthBuildInt | Anthropogenic moisture flux due to people/equipment in buildings (mm/time step) |
| WasteWaterAC | Anthropogenic removal of moisture from air due to condensation during air-conditioning process (mm/time step) |
| dVdt | Change in water storage in the soil due to soil moisture change (mm/time step) |
| dIdt | Change in water storage due to interception change (mm/time step) |
| IrrSurf | Irrigation flux applied at the surface of the soil (mm/time step) |
| IrrSoil | Irrigation occuring due to fixed soil moisture in some soil layers (mm/time step) |
| IrrTot | Total irritation flux (includes surface irrigation and fixed soil moisture in certain soil layers) (mm/time step) |
| Int | Intercepted or ponding water (mm) |
| WB | Water balance closure (mm/time step) |

# Building energy model outputs

**Building energy use for heating and cooling (including dehumidification): BEMEnergyUse**

|  |  |
| --- | --- |
| **BEMEnergyUse** |  |
| EnergyForAC | Energy consumption for AC for [total building interior] |
| EnergyForAC\_H | Energy consumption due to sensible heat load for AC for [total building interior] |
| EnergyForAC\_LE | Energy consumption for AC for [total building interior] |
| EnergyForHeating | Energy consumption for AC for [total building interior] |

The output is in Wh per total building interior and timestep

For example, 1h run time = 30 Wh for cooling and heating in that hour, but if timestep is 0.5h, it will be 15 Wh.

**Wasterheat from building interiors emitted into canyon: BEMWasteHeat**

|  |  |
| --- | --- |
| **BEMWasteHeat** |  |
| SensibleFromAC\_Can | sensible heat added to canyon air due to air conditioning energy use [W/m^2 canyon ground] |
| LatentFromAC\_Can | Latent heat added to canyon air due to air conditioning energy use (not used in the simulations) [W/m^2 canyon ground] |
| WaterFromAC\_Can | Water that is condensed and removed as runoff in sewer system [W/m^2 canyon ground] |
| SensibleFromHeat\_Can | sensible heat added to canyon air due to heating [W/m^2 canyon ground] |
| LatentFromHeat\_Can | latent heat added to canyon air due to heating [W/m^2 canyon ground] |
| SensibleFromVent\_Can | sensible heat removed or added to the canyon due to exchange of indoor to outdoor air [W/m^2 canyon ground] It can be negative for the canyon during AC as hot air is leaving for the cooler indoor air |
| LatentFromVent\_Can | latent heat removed or added to the canyon due to exchange of indoor to outdoor air [W/m^2 canyon ground] |
| BEMWasteHeat.TotAnthInput\_URB | total anthropogenic heat output to the urban area due to HVAC [W/m^2 urban] |

# Numerical solver outputs: solver

|  |  |
| --- | --- |
| **Solver** |  |
| Success | Bolean indicating convergence of solution of energy balance |
| ValuesEB | Energy balance closure for the different equations (W/m^2) |
| Tsolver | Temperatures and humidity of different canyon factes and air (K), (kg/kg) |
| YfunctionOutput | the same as ValuesEB |