Supplementary information supporting the paper: Warnatzsch and Reay (2019) Assessing Climate Change Projections and Impacts on Central Malawi’s Maize Yield: The Risk of Maladaptation.

## Supplementary Tables and Figures

Table 1: Regional Climate Models (RCM) sources. All of the models other than CanRCM4\_r2 were accessed through The Earth System Grid Federation (ESGF) data index (ESGF, 2017). The CanRCM4\_r2 model was accessed through the Canadian Centre for Climate Modelling and Analysis website (CCCma, 2017).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **RCM** | **Institution** | **Lateral Boundary Conditions** | **Original Calendar** | **Reference** |
| **CCLM4-8-17\_v1** | Climate Limited-area Modelling Community (CLMcom) | CNRM-CM5 r1i1p1 | 365-days | (COSMO, 2017) |
| HadGEM2-ES r1i1p1 | 360-days |
| EC-EARTH r12i1p1 | 366-days |
| MPI-ESM-LR r1i1p1 | 366-days |
| **HIRHAM5\_v2** | Danmarks Meteorologiske Insitut (DMI) | EC-EARTH r3i1p1 | 366-days | (Christensen et al., 2007) |
| **RACMO22T\_v1** | Koninklijk Nederlands Meteorologisch Instituut (KNMI) | HadGEM2-ES r1i1p1 | 360-days | (van Meijgaard et al., 2008) |
| EC-EARTH r1i1p1 | 366-days |
| **RCA4\_v1** | Sveriges Meteorologiska och Hydrologiska Institut (SMHI) | CanESM2 r1i1p1 | 366-days | (Samuelsson et al., 2015) |
| CNRM-CM5 r1i1p1 | 366-days |
| CSIRO-MK3-6-0 r1i1p1 | 365-days |
| GFDL-ESM2M r1i1p1 | 365-days |
| IPSL-CM5A-MR r1i1p1 | 365-days |
| HadGEM2-ES r1i1p1 | 360-days |
| EC-EARTH r12i1p1 | 366-days |
| MIROC5 r1i1p1 | 365-days |
| MPI-ESM-LR r1i1p1 | 366-days |
| NORESM1-M r1i1p1 | 365-days |
| **REMO2009\_v1** | Climate Service Centre Germany (CSC) and Max Planck Institut (MPI) | EC-EARTH r12i1p1 | 366-days | (Jacob et al., 2012) |
| MPI-ESM-LR r1i1p1 | 366-days |
| **CanRCM4\_r2** | Canadian Centre for Climate Modelling and Analysis (CCCma) | CanESM2 r1i1p1 | 365-days | (Scinocca et al., 2016) |

Table 2: Observed data sources

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Dataset** | **Variable Used** | **Resolution** | **Time-Period Available** | **Source** | **Reference** |
| **Climate Research Unit (CRU) version 4.0** | Tas, TasMin, TasMax and Pr | 0.5° Monthly Land Only | 1901-2015 | Gridded Station Data | (Harris et al., 2014) |
| **University of Delaware (UDel) version 4.01** | Tas and Pr | 0.5° Monthly Land Only | 1901-2010 | Gridded Station Data | (Willmott and Matsuura, 2001) |
| **Global Precipitation Climatology Centre (GPCC) version 7** | Pr | 1.0° Monthly | 1901-2010 | Satellite and Station Data | (Schneider et al., 2015) |

Table 3: List of data sources for the 13 climate files used in the crop models. Note that all RCMs referred to in this table are listed in Table 1 and the observed data referred to in this table are from the sources listed in.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| File | Time Scale | RCP | Temperature | Evapotrasnpiration Rate | Precipitation Rate | CO­2 concentration |
| 1 | 1971-2000 | N/A | Mean of observed monthly data for minimum and maximum temperature | Calculated using methodology described in Section 2 | Observed monthly data for precipitation rates | AquaCrop Mauna Loa CO2 |
| 2 | 2020-2049 | 4.5 | Projected ensemble mean daily minimum and maximum temperature | Projected ensemble minimum precipitation rate | AquaCrop IPCC RCP 4.5 |
| 3 | Projected ensemble mean precipitation rate |
| 4 | Projected ensemble maximum precipitation rate |
| 5 | 8.5 | Projected ensemble minimum precipitation rate | AquaCrop IPCC RCP 8.5 |
| 6 | Projected ensemble mean precipitation rate |
| 7 | Projected ensemble maximum precipitation rate |
| 8 | 2040-2069 | 4.5 | Projected ensemble minimum precipitation rate | AquaCrop IPCC RCP 4.5 |
| 9 | Projected ensemble mean precipitation rate |
| 10 | Projected ensemble maximum precipitation rate |
| 11 | 8.5 | Projected ensemble minimum precipitation rate | AquaCrop IPCC RCP 8.5 |
| 12 | Projected ensemble mean precipitation rate |
| 13 | Projected ensemble maximum precipitation rate |

Table : Absolute AquaCrop output data for historic 1971-2000 climate using three different soil types

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Cultivar | Planting Date | AquaCrop Default Soil | AquaCrop Default Sandy Clay Loam Soil | Calibrated Sandy Clay Loam Soil |
| Slow-Development | **15 Nov** | 12.293 | 12.05 | 12.052 |
| **10 Dec** | 12.861 | 12.861 | 12.861 |
| **30 Dec** | 13.323 | 12.834 | 12.249 |
| Fast-Development | **15 Nov** | 7.727 | 7.384 | 7.383 |
| **10 Dec** | 7.961 | 7.961 | 7.961 |
| **30 Dec** | 8.243 | 8.243 | 8.243 |

Table : Absolute AquaCrop output data for projected climates under RCP 4.5 using three different soil types

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cultivar | Soil Type | Planting Date | 2020-2049 | | | | 2040-2069 | | |
| **Min. Rain** | **Ave. Rain** | **Max. Rain** | **Min. Rain** | | **Ave. Rain** | **Max. Rain** |
| Slow-Development | AquaCrop Default Soil | **15 Nov** | 9.781 | 12.15 | 12.229 | 8.142 | | 12.197 | 12.284 |
| **10 Dec** | 9.024 | 12.958 | 12.958 | 7.615 | | 12.324 | 12.324 |
| **30 Dec** | 4.682 | 13.699 | 13.699 | 4.324 | | 13.299 | 13.299 |
| Fast-Development | **15 Nov** | 6.162 | 7.844 | 7.947 | 5.691 | | 7.683 | 7.81 |
| **10 Dec** | 7.894 | 8.065 | 8.065 | 7.613 | | 7.901 | 7.901 |
| **30 Dec** | 8.388 | 8.388 | 8.388 | 8.093 | | 8.157 | 8.157 |
| Slow-Development | AquaCrop Default Sandy Clay Loam Soil | **15 Nov** | 5.502 | 11.985 | 12.229 | 4.628 | | 12.021 | 12.284 |
| **10 Dec** | 3.031 | 12.958 | 12.958 | 2.994 | | 12.324 | 12.324 |
| **30 Dec** | 0.995 | 13.699 | 13.699 | 1.004 | | 13.299 | 13.299 |
| Fast-Development | **15 Nov** | 1.716 | 7.611 | 7.947 | 1.431 | | 7.435 | 7.81 |
| **10 Dec** | 7.419 | 8.065 | 8.065 | 6.344 | | 7.901 | 7.901 |
| **30 Dec** | 7.391 | 8.388 | 8.388 | 6.957 | | 8.157 | 8.157 |
| Slow-Development | Calibrated Sandy Clay Loam Soil | **15 Nov** | 5.497 | 11.984 | 12.229 | 4.800 | | 12.025 | 12.284 |
| **10 Dec** | 2.683 | 12.958 | 12.958 | 2.725 | | 12.324 | 12.324 |
| **30 Dec** | 0.792 | 13.699 | 13.699 | 0.804 | | 13.299 | 13.299 |
| Fast-Development | **15 Nov** | 1.675 | 7.601 | 7.947 | 1.344 | | 7.433 | 7.810 |
| **10 Dec** | 7.410 | 8.065 | 8.065 | 6.060 | | 7.901 | 7.901 |
| **30 Dec** | 7.032 | 8.388 | 8.388 | 6.596 | | 8.157 | 8.157 |

Table : Absolute AquaCrop output data for projected climates under RCP 8.5 using three different soil types

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cultivar | Soil Type | Planting Date | 2020-2049 | | | | 2040-2069 | | |
| **Min. Rain** | **Ave. Rain** | **Max. Rain** | **Min. Rain** | | **Ave. Rain** | **Max. Rain** |
| Slow-Development | AquaCrop Default Soil | **15 Nov** | 8.337 | 12.317 | 12.423 | 4.884 | | 11.962 | 12.077 |
| **10 Dec** | 8.44 | 12.863 | 12.863 | 8.615 | | 12.186 | 12.186 |
| **30 Dec** | 5.013 | 13.324 | 13.324 | 5.191 | | 12.667 | 12.667 |
| Fast-Development | **15 Nov** | 5.604 | 7.749 | 7.891 | 4.218 | | 7.284 | 7.433 |
| **10 Dec** | 7.635 | 7.962 | 7.962 | 7.15 | | 7.527 | 7.527 |
| **30 Dec** | 8.206 | 8.244 | 8.244 | 7.775 | | 7.819 | 7.819 |
| Slow-Development | AquaCrop Default Sandy Clay Loam Soil | **15 Nov** | 3.771 | 12.112 | 12.423 | 3.548 | | 11.747 | 12.077 |
| **10 Dec** | 2.91 | 12.863 | 12.863 | 3.299 | | 12.186 | 12.186 |
| **30 Dec** | 1.112 | 13.324 | 13.324 | 1.509 | | 12.667 | 12.667 |
| Fast-Development | **15 Nov** | 1.413 | 7.448 | 7.891 | 1.107 | | 6.963 | 7.433 |
| **10 Dec** | 6.602 | 7.962 | 7.962 | 5.6 | | 7.527 | 7.527 |
| **30 Dec** | 7.249 | 8.244 | 8.244 | 7.172 | | 7.819 | 7.819 |
| Slow-Development | Calibrated Sandy Clay Loam Soil | **15 Nov** | 3.799 | 12.121 | 12.423 | 4.352 | | 11.759 | 12.077 |
| **10 Dec** | 2.816 | 12.863 | 12.863 | 3.402 | | 12.186 | 12.186 |
| **30 Dec** | 0.878 | 13.324 | 13.324 | 1.275 | | 12.667 | 12.667 |
| Fast-Development | **15 Nov** | 1.358 | 7.449 | 7.891 | 1.029 | | 6.970 | 7.433 |
| **10 Dec** | 6.473 | 7.962 | 7.962 | 5.421 | | 7.527 | 7.527 |
| **30 Dec** | 6.895 | 8.244 | 8.244 | 6.905 | | 7.819 | 7.819 |

Table : Absolute AquaCrop output data for historic (1971-2000) and projected climate under RCP 4.5 and 8.5 using the default Maize crop file and calibrated sandy clay loam soil file.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Soil Type | Planting Date | 1971-2000 | RCP | 2020-2049 | | | | 2040-2069 | | |
| **Min. Rain** | **Ave. Rain** | **Max. Rain** | **Min. Rain** | | **Ave. Rain** | **Max. Rain** |
| Calibrated Sandy Clay Loam Soil | **15 Nov** | 14.24 | 4.5 | 13.92 | 14.27 | 14.33 | 13.88 | | 14.27 | 14.33 |
| 8.5 | 13.90 | 14.25 | 14.33 | 13.72 | | 14.24 | 14.33 |
| **10 Dec** | 14.33 | 4.5 | 14.26 | 14.33 | 14.33 | 14.22 | | 14.33 | 14.33 |
| 8.5 | 14.21 | 14.33 | 14.33 | 14.18 | | 14.33 | 14.33 |
| **30 Dec** | 14.49 | 4.5 | 14.49 | 14.49 | 14.49 | 14.48 | | 14.49 | 14.49 |
| 8.5 | 14.49 | 14.49 | 14.49 | 14.49 | | 14.49 | 14.49 |

Figure 1: Change in total precipitation (mm) and water content in the effective root zone (mm) by developmental stage of the fast-development cultivar maize grown in Central Malawi for the three planting dates as compared to the baseline 1971-2000 period (red line). This data is shown for the three precipitation scenarios: minimum (palest), average (medium shade) and maximum (darkest) precipitation, for the two RPC scenarios and time periods.

Table 8: Number of days exceeding the maximum temperature threshold (32 degrees Celsius) by development stage for each cultivar

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Planting Date | Stage | Historic | RCP4.5 | | RCP8.5 | |
| **2030** | **2050** | **2030** | **2050** |
| Slow- Development Cultivar | Nov. 15 | Emergence | 8 | 6 | 8 | 8 | 7 |
| Vegetative | 1 | 0 | 2 | 1 | 10 |
| Flowering | 0 | 0 | 0 | 0 | 0 |
| Yield Formation | 0 | 0 | 0 | 0 | 0 |
| **Total** | **9** | **6** | **10** | **9** | **17** |
| Dec. 10 | Emergence | 0 | 0 | 0 | 0 | 0 |
| Vegetative | 0 | 0 | 0 | 0 | 0 |
| Flowering | 0 | 0 | 0 | 0 | 0 |
| Yield Formation | 0 | 0 | 0 | 0 | 0 |
| **Total** | **0** | **0** | **0** | **0** | **0** |
| Dec. 30 | Emergence | 0 | 0 | 0 | 0 | 0 |
| Vegetative | 0 | 0 | 0 | 0 | 0 |
| Flowering | 0 | 0 | 0 | 0 | 0 |
| Yield Formation | 0 | 0 | 0 | 0 | 0 |
| **Total** | **0** | **0** | **0** | **0** | **0** |
| Fast- Development Cultivar | Nov. 15 | Emergence | 5 | 5 | 5 | 5 | 5 |
| Vegetative | 4 | 1 | 5 | 4 | 12 |
| Flowering | 0 | 0 | 0 | 0 | 0 |
| Yield Formation | 0 | 0 | 0 | 0 | 0 |
| **Total** | **9** | **6** | **10** | **9** | **17** |
| Dec. 10 | Emergence | 0 | 0 | 0 | 0 | 0 |
| Vegetative | 0 | 0 | 0 | 0 | 0 |
| Flowering | 0 | 0 | 0 | 0 | 0 |
| Yield Formation | 0 | 0 | 0 | 0 | 0 |
| **Total** | **0** | **0** | **0** | **0** | **0** |
| Dec. 30 | Emergence | 0 | 0 | 0 | 0 | 0 |
| Vegetative | 0 | 0 | 0 | 0 | 0 |
| Flowering | 0 | 0 | 0 | 0 | 0 |
| Yield Formation | 0 | 0 | 0 | 0 | 0 |
| **Total** | **0** | **0** | **0** | **0** | **0** |

Table : Average annual precipitation rate (mm) for each RCM in 2030 (2020-2049) and 2050 (2040-2069) and a comparison to the 1971-2000 average precipitation rate of 1081.4mm

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **RCM** | **RCP 4.5** | | | | **RCP 8.5** | | | |
| **Average Annual Projected Precipitation (mm)** | | **Change from 1971-2000 Average** | | **Average Annual Projected Precipitation (mm)** | | **Change from 1971-2000 Average** | |
| **2030** | **2050** | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** |
| CCCmaCanRCM | 1117.1 | 1160.3 | 3% | 7% | 1155.9 | 1215.2 | 7% | 12% |
| CCCmaSMHI | 994.7 | 991.5 | -8% | -8% | 969.1 | 1047.6 | -10% | -3% |
| CNRM | 1104.6 | 1070.1 | 2% | -1% | 1170.0 | 1101.1 | 8% | 2% |
| CNRMSMHI | 1009.7 | 1020.2 | -7% | -6% | 1098.7 | 1083.0 | 2% | 0% |
| CSIRO | 1056.7 | 961.1 | -2% | -11% | 1117.5 | 1002.1 | 3% | -7% |
| ICHECDMI | 1001.1 | 920.5 | -7% | -15% | 943.0 | 904.9 | -13% | -16% |
| ICHECCCLM | 1010.7 | 974.3 | -7% | -10% | 932.9 | 933.0 | -14% | -14% |
| ICHECKNMI | 1063.5 | 1025.2 | -2% | -5% | 1047.0 | 1073.2 | -3% | -1% |
| ICHECMPI | 996.6 | 976.4 | -8% | -10% | 934.0 | 907.4 | -14% | -16% |
| ICHECSMHI | 1065.9 | 1077.9 | -1% | 0% | 1066.9 | 1077.4 | -1% | 0% |
| IPSL | 1089.4 | 1160.3 | 1% | 7% | 1139.6 | 1205.3 | 5% | 11% |
| MIROC | 1039.6 | 1028.0 | -4% | -5% | 1068.3 | 1034.2 | -1% | -4% |
| MOHCCCLM | 1002.0 | 986.1 | -7% | -9% | 982.5 | 990.6 | -9% | -8% |
| MOHCKNMI | 1015.5 | 1006.9 | -6% | -7% | 1045.8 | 1015.1 | -3% | -6% |
| MOHCSMHI | 1062.8 | 1096.8 | -2% | 1% | 1098.7 | 1049.4 | 2% | -3% |
| MPICCLM | 980.4 | 971.4 | -9% | -10% | 995.3 | 959.2 | -8% | -11% |
| MPIREMO | 1037.5 | 1019.9 | -4% | -6% | 1031.0 | 1021.9 | -5% | -6% |
| MPISMHI | 1080.4 | 1052.6 | 0% | -3% | 1089.9 | 1039.3 | 1% | -4% |
| NCCSMHI | 1088.3 | 1105.9 | 1% | 2% | 1121.6 | 1109.0 | 4% | 3% |
| NOAA | 1075.7 | 1114.4 | -1% | 3% | 1100.5 | 1048.2 | 2% | -3% |

## Methodology for Calculating Evapotranspiration for Central Malawi

To calculate evapotranspiration for Central Malawi, the FAO Penman Monteith (FPM) model was applied (Allen et al., 1998a).

Equation 1

Where:

* ETo is the reference evapotranspiration (mm day-1)
* Rn is the net radiation at the crop surface (MJ m2 day-1),
* G is the soil heat flux density (MJ m-2 day-1)
* T is the mean daily air temperature (°C)
* u2 is wind speed at 2 m height (m s-1)
* es is the saturation vapour pressure (kPa)
* ea is the actual vapour pressure (kPa), see Equation 10
* es – ea is the saturation vapour pressure deficit (kPa)
* Δ is the slope vapour pressure curve (kPa°C-1)
* γ is the psychrometric constant (kPa °C-1)

It is not possible to get data for all of the above variables for Central Malawi, either from observed data of the past, or from climate models used to hindcast the past or forecast future climates. Therefore, temperature-based calculation methods were applied for climatic variables with no primary data available (Allen et al., 1998b). This methodology has been tested for Malawi by Wang et al. (2011), and for South Malawi by Ngongondo et al. (2012) and deemed to be appropriate for use.

### Net Radiation at the Crop Surface

Rn is the net radiation at the crop surface (MJ m2 day-1) and can be calculated as follows:

Equation 2

Where:

* Rns is the net incoming shortwave radiation (MJm-2 day-1) and can be calculated as follows:

Equation 3

Where:

* + is the albedo or canopy reflection coefficient, which is 0.23 for the hypothetical grass reference crop
  + Rs is the fraction of the solar radiation not reflected from the surface (MJm-2 day-1) and can be calculated as follows:

Equation 4

Where:

* K­­RS is adjustment coefficient. For inland regions not influenced by large bodies of water, KRS = 0.16 ; for coastal regions, or regions where the air mass is influenced by a large nearby water body, KRS = 0.19. Since Central Malawi is highly influenced by the presence of a large water body (Lake Malawi). K­RS is considered to be 0.19 in this study.
* Tmax is the maximum air temperature (ºC)
* Tmin is the minimum air temperature (ºC)
* Ra is extra-terrestrial radiation (MJm-2 day-1) and can be calculated as follows:

Equation 5

Where:

* is the solar constant = 0.0820 MJm-2min-1
* is the inverse relative since earth-Sun (rad) which can be calculated as follows:

Equation 6

Where:

* J is the number of days in the year between 1 (1 January) and 365 or 266 (31 December). J at the middle of each month = 30.4M-15 where M is the month number
* is the sunset hour angle (rad) which can be calculated as follows:

Equation 7

Where:

* is the latitude (rad)
* is the solar declination (rad) which can be calculated as follows:

Equation 8

* Rnl is in the net outgoing longwave radiation (MJm-2 day-1) and can be calculated as follows:

Equation 9

Where:

* + is the Stefan-Boltzmann constant [4.903 x 10-9 MJ K-4 m-2 day-1
  + Tmax,K is the maximum absolute temperature during the 24-hour period [K = °C + 273.16],
  + Tmin, Kminimum absolute temperature during the 24-hour period [K = °C + 273.16],
  + ea actual vapour pressure [kPa], which can be calculated as follows:

Equation 10

Where:

* + - Tdew is the dew point temperature. Tdew is near the minimum temperature (Tmin) when the relative humidity is nearly 100%. In semi-arid regions, Tdew is estimated by subtracting 2°C from Tmin. As Central Malawi’s humidity is typically under 90%, the Tdew­ can be calculated as follows:

Equation 11 Tdew = Tmin - 2

* + Rs is the solar radiation [MJ m-2 day-1], see Equation 4.
  + Rso is the clear-sky solar radiation [MJ m-2 day-1], which can be calculated as follows:

Equation 12

Where:

* + - h is the elevation above sea level (m)
    - Ra is extra-terrestrial radiation, (MJm-2 day-1), see Equation 5.

### Soil Heat Flux Density

G is the soil heat flux density (MJ m-2 day-1)

* For daily assessment, G is assumed to be zero (0) as the soil heat flux is relatively small

Equation 13:

* For monthly assessments,

Equation 14: )

Where:

* Tmon, i-1­ is the mean air temperature of the previous month (°C)
* Tmon, i+1­ is the mean air temperature of the next month (°C)

### Mean Temperature

T is the mean daily air temperature (°C), which can be calculated as follows:

Equation 15:

Where:

* Tmax is the maximum air temperature (ºC)
* Tmin is the minimum air temperature (ºC)

### Wind Speed at 2m height

u2 is wind speed at 2 m height (m s-1). We can use a default value of 172 km day-1 which is the average value over different weather stations around the globe. This was recommended by Allen et al. (1998). To convert to the correct units for the equation above (m s-1) we can do the following:

Equation 16:

* + (<https://www.researchgate.net/publication/266523411_Comparative_study_on_estimating_reference_evapotranspiration_under_limited_climate_data_condition_in_Malawi>)

### Vapour Pressure

To calculate ETO, various vapour pressure variables are required, including the saturation vapour pressure (es), the actual vapour pressure (ea) and the slope vapour pressure curve (Δ).

* es is the saturation vapour pressure (kPa), it can be calculated as follows:

Equation 17:

Where:

* + e0(Tmax) is the vapour pressure at maximum temperature, and can be calculated as follows:

Equation 18:

Where:

* + - Tmax­ is the maximum air temperature (ºC)
  + e0(Tmin) is the vapour pressure at minimum temperature, and can be calculated as follows:

Equation 19:

Where:

* + - Tmin­ is the minimum air temperature (ºC)
* ea is the actual vapour pressure (kPa), see Equation 10
* Δ is the slope vapour pressure curve (kPa°C-1)

Equation 20:

Where:

* + T is the mean air temperature (°C), see Equation 15
  + exp[…] 2.7183 (base of natural logarithm) raised to the power […]

### Psychrometric Constant

γ is the psychrometric constant (kPa °C-1), it can be calculated as follows:

Equation 21:

Where:

* CP is the specific heat at a constant pressure, CP = 1.013 x 10-3 MJ kg-1 °C-1
* P is atmospheric pressure (kPa), which can be calculated as follows:

Equation 22:

Where:

* h is the altitude above sea level in meters (m)
  + - * For Central Malawi, the average altitude above sea level (h) is 948.1944444m (determined using data from JISAO (2014))
    - is the ratio molecular weight of water vapour / dry air, = 0.622
    - is the latent heat of vaporization, = 2.45 MJ kg-1

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