Climate Change Impact Assessment Minas Gerais

Background

The catchment location is based in Brazil (Figure 1, Table 1). The region is in the subtropics with a distinct dry and wet season. According to the observations the dry season lasts from April to September. To estimate the climate change at four rain gauge and two temperature sites the ensemble multi-model mean of the last IPCC (AR5) assessment were considered. This consists of 39 global climate model simulations. The ensemble global multi-model mean is considered as the best estimate. The horizontal resolution of the global climate models varies between about 150 km and 400 km. Therefore, the ensemble mean does not have the resolution to resolve any differences within the catchment area and only the nearest grid point can be considered as representative of the projected changes. The chosen base line time frame is 1980-2000 and the projection time frame is 2040-2060. The twenty year mean is a suitable time period to define the climatology for the sites. This baseline time frame also matches the available surface observations with the least data missing. The chosen climate change emission pathway scenario is RCP8.8 which is defined as by having radiative imbalance of 8.5Wm-2 by 2100. This scenario is considered as a “business as usual” or worst case scenario. For projections with a time horizon of less than 50 years (to 2050s) the choice of a RCP scenario is much less important than for longer time scales (such as to 2100) as the amount of projected warming to the 2050s (considered here) is mostly dominated by model uncertainty and natural variability not emission scenario. For the choice of RCP8.5 scenario the results presented here can be considered as conservative.

Several tasks are presented:

1. A comparison of the observed mean and modelled climatology
2. Projections of monthly rainfall and mean temperature change.
3. Projections of change in consecutive dry days.
4. Scaling of the observed data by the projections of the mean change and the number of consecutive dry days.
5. Identification of importance of El Nino on the monthly rainfall.

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| --- | --- | --- | --- |
| **Station** | **Lat. (oC)** | **Lon. (oC)** | **Alt. (m)** |
| Diamantina | -18.23 | -43.64 | 1296 |
| Do Mato Dentro | -19.02 | -43.43 | 652 |
| 1843002 | -18.42 | -43.73 | 1107 |
| 1943003 | -19.25 | -43.01 | 452 |
| 1943025 | -19.22 | -43.37 | 571 |
| 1943035 | -19.22 | -43.59 | 1083 |

Table 1. Location and altitude of weather stations.

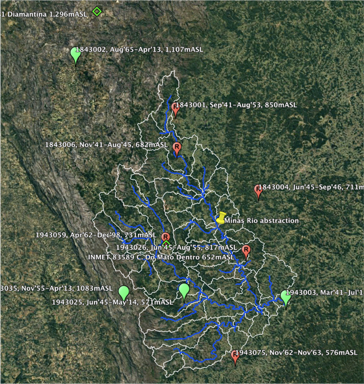
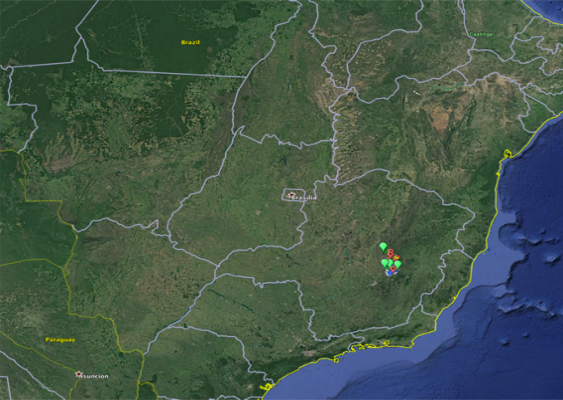


Figure 1. Location of weather stations and rain gauges

Results

1. Rainfall

The four station average and multi–model ensemble mean base line for rainfall is shown in Table 2. The model and the data both show a large seasonal cycle with a pronounced dry spell from April to September. In the annual mean the model rainfall is about 25% less than the observations suggest. This amount of difference is not untypical as climate models have lower skill in rainfall than, for example, temperature.

There is no change in the projected annual mean rainfall (Table 2. However, there is a large seasonal change in the projected rainfall. The late wet season is somewhat wetter, with a peak increase in February of +11%. The early wet season is somewhat drier. Most of the months show a decrease in rainfall with the largest decrease in the late dry season of about -20% in the transition month of September. There is therefore a clear shift in the seasonal rainfall cycle towards a wetter peak wet season and an extension of the dry season, while the annual rainfall total does not change.

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| --- | --- | --- | --- | --- |
| **Month** | **Real**  **1980-2000 (mm)** | **CMIP5**  **1980-2000 (mm)** | **CMIP5**  **2040-2060 (mm)** | **CMIP5**  **change precipitation** |
| Jan | 9.51 | 6.37 | 6.79 | +6.7% |
| Feb | 4.69 | 5.37 | 6.00 | +11.7% |
| Mar | 5.73 | 4.36 | 4.42 | +1.4% |
| Apr | 2.79 | 1.68 | 1.69 | +0.2% |
| May | 1.00 | 0.59 | 0.55 | -7.6% |
| Jun | 0.31 | 0.43 | 0.40 | -6.0% |
| Jul | 0.17 | 0.40 | 0.38 | -3.7% |
| Aug | 0.44 | 0.48 | 0.43 | -11.2% |
| Sep | 1.36 | 1.00 | 0.80 | -19.6% |
| Oct | 3.23 | 2.48 | 2.06 | -17.1% |
| Nov | 7.68 | 4.83 | 4.49 | -6.9% |
| Dec | 9.83 | 6.71 | 6.67 | -0.7% |
| Annual | 3.90 | 2.89 | 2.89 | +0.0% |

Table 2. Monthly climatology in the observations( mean of 4 rain gauges), the ensemble mean baseline and the change.

The implications are that if water availability is managed on annual basis little change due to climate change may be expected as the total annual rainfall is projected to change little. However, if water availability is managed by dry/wet or monthly then the monthly projected changes in rainfall could impact operations.

To drive the hydrological model for this projected scenario each of the observed daily mean rainfall (1980-2000) was scaled. Years with missing data were not scaled. The four sites were scaled by the same scaling factor of the projected monthly percentage changes (Table 2, Figure 2).



Figure 2. Daily mean temperature: monthly average absolute change between 1980-2000 and 2040-2060.

2.0 Temperature

The two station average and model base line daily mean temperature is shown in Table 3. The model and the data both show a distinct seasonal cycle with a July minimum and December maximum. In the annual mean the model temperature is only 0.2oC less than the observations suggest. This very small bias shows very high skill temperature. The bias in the individual months can be larger.

The projected annual mean temperature change is + 2.1oC. The warming is projected to occur in all months (Table 3, Figure 3). The largest projected change is in November (+2.7 oC) and the least in February and March (+1.8 oC).

Mean temperature influences surface evaporation and thus the surface water availability. The observed daily temperatures of the weather stations at two sites were scaled for 1980-2000.Years with missing data was not scaled. The scaling was done by adding the same projected monthly change to each of the observed time series.

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| --- | --- | --- | --- | --- |
| **Month** | **Real**  **1980-2000 (oC)** | **CMIP5**  **1980-2000 (oC)** | **CMIP5**  **2040-2060 (oC)** | **CMIP5 change temp (oC)** |
| Jan | 23.83 | 23.44 | 25.38 | **+1.9** |
| Feb | 23.99 | 23.53 | 25.34 | **+1.8** |
| Mar | 23.11 | 22.9 | 24.73 | **+1.8** |
| Apr | 21.71 | 21.42 | 23.4 | **+2.0** |
| May | 19.67 | 19.31 | 21.42 | **+2.1** |
| Jun | 18.06 | 17.57 | 19.71 | **+2.1** |
| Jul | 17.72 | 17.35 | 19.34 | **+2.0** |
| Aug | 18.88 | 18.74 | 20.78 | **+2.0** |
| Sep | 20.93 | 21.29 | 23.59 | **+2.3** |
| Oct | 22.8 | 23.16 | 25.77 | **+2.6** |
| Nov | 23.47 | 23.39 | 26.08 | **+2.7** |
| Dec | 24.04 | 23.33 | 25.54 | **+2.2** |
| Annual | 21.52 | 21.29 | 23.42 | **+2.1** |

Table 3. Daily mean temperature: monthly average absolute change between 1980-2000 and 2040-2060



Figure 3. Absolute change (oC) in every months (1=January) of the projected change (2040-2060) compared the baseline (1980-2000).

3.0 Consecutive dry days

An important parameter for management could be the number of consecutive dry days. A dry days is defined as when the total rainfall on that day is less than 1 mm. The observations suggest that average consecutive number of dry days in a year for the baseline period (1980-2000) varies between 55 days and 78 days dependent on the site (Table 4). The model ensemble mean climatology is about 72 days which is in good agreement with the observations.

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| --- | --- | --- | --- |
| **Source** | **1980-2000 (no. days)** | **2040-2060 (no. days)** | **Tuning threshold**  **(no. days)** |
| CMIP5 ensemble mean | 71.8 | 81.9 | 1.00 |
| 1843002 | 77.9 | 89.1 | 2.22 |
| 1943003 | 67.5 | 76.3 | 1.60 |
| 1943025 | 54.7 | 62.5 | 2.22 |
| 1943035 | 66.0 | 75.5 | 2.14 |

Table 4. Baseline (1980-2000), model climatology (1980-200) and projected change (2040-2060) of the average number of consecutive dry days in a year.

The climate model project an increase in the number of consecutives dry days to about 82 days or +14% (Table 4). This is consistent with a reduction of rainfall during the dry season as noted above (see 1.0). The correct change in consecutive dry days is achieved by adjusting the threshold for the definition of dry day. For example, in Table xxx for station #1843002 the average number of consecutive dry days is increased from 78 to 82 or +14% as the climate model projections suggest. This is achieved by counting all days less than 2.22 mm (the new dry day tuning threshold) as dry. This new threshold (the standard one would be 1 mm) also decreases the number of wet days by about 17%. This decrease of number of wet days is more than the climate models with a 1 mm threshold suggest (about -8% for this station). We have to make choice what is the more relevant for understanding the hydrological impact the consecutive dry or the number of wet days. Here we chose the number of consecutive dry days as a more important constraint. Dry days can occur throughout the year and are unlikely to affect the operations in the wet season. However the dry season may stress the system more. By applying the tuning threshold we are not changing the total rainfall. In the scaled time series we conserve the total rainfall by redistributing all the rainfall below the tuning threshold equally to all the wet days.

In the final step the observed data in the four stations is scaled by both the monthly rainfall projections (from 1.0) and by the projected changes consecutive dry days. In this way the new adjusted data is consisted with both the projected monthly change and the projected change in the number of consecutive dry days in the year.

4.0 El Nino

El Nino is a recurring equatorial Pacific warming pattern. It has an irregular period of 2-7 years. This phenomenon has an impact of the global mean temperature as well as regional rainfall patterns. The extent to which El Nino may change under climate change remains uncertain. In our assessment approach by applying the multi-global model mean we indirectly include the ensemble mean projected change in El Nino. It is however instructive to attempt to isolate the role of ElNino’s influence on rainfall to improve our understanding of the rainfall variability. The seasonal forecast skill of El Nino is also improving so that if there is strong control of El Nino on rainfall and thus water availability then the rainfall/water availability may itself be amenable to seasonal forecasting and thus seasonal decision making.

El Nino can be defined as the sea surface temperature anomaly for different regions in the equatorial Pacific. Nino 1.2, 3, 3.4 and 4 refer to different areas in the equatorial Pacific. Figure xx show the correlation co-efficient of these different standard ElNino indices. There is not much difference between the indices (Figure 5). Only Pearson R correlations of above about +/-0.25 are significant (p<0.05). Negative correlations are found for October and November, but correlations are mostly positive in the other months. Interestingly, for the transition month September, the month with the highest projected relative decline in rainfall, the correlation is significantly positive. This suggests that if there was a positive El Nino trend this may offset the mean projected climate change of less rainfall in this month. Diagnosing the wet and dry season separately shows the only significant correlation is found for the dry season not for the wet season. The correlation is positive so that more (less) El Nino’s would decrease (increase) the underlying climate change trend of less rainfall in the dry season.



Figure 5. Monthly correlation coefficients for the 4 rain gauge stations four El Nino indices. Significant values (p<0.05) are triangles

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| **Station** | **Metric** | **R** |
| 1843002 | nino3a | 0.26 |
| 1843002 | nino12a | 0.28 |
| 1943003 | nino4a | 0.31 |
| 1943025 | nino12a | 0.32 |
| 1943025 | nino4a | 0.34 |
| 1943003 | nino3a | 0.35 |
| 1943035 | nino4a | 0.37 |
| 1943025 | nino3a | 0.39 |
| 1943003 | nino3.4a | 0.39 |
| 1943035 | nino12a | 0.42 |
| 1943025 | nino3.4a | 0.42 |
| 1943035 | nino3.4a | 0.43 |
| 1943035 | nino3a | 0.46 |

Table 5. Seasonal correlation coefficients ranked in order for different weather stations and El Nino indices. The dry season is defined as April to September