USE OF THE MULTI-MODEL ENSEMBLE (MME) MEAN OF GLOBAL CLIMATE MODELS (GCMs) FOR HYDRO ELECTRICITY GENERATION PLANNING IN ZAMBIA

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Hydroelectric Power and Climate Variability

• Largest source of renewable electricity globally
• Produces around 17% global electricity
• Climate variability effects on future hydroelectricity generation
• Vulnerability of Southern Africa to climate variability
• Global Climate Models (GCMs) and climate variability
• CMIP5 Representative Concentration Pathways
  - RCP2.6, RCP4.5, RCP6.0, RCP8.5
• Multi-Model Ensemble (MME) of GCMs
Climate Models – How accurate are they?

• 30 year historical climate evaluation (1970-2000) for Zambia
• 30 year mean monthly historical rainfall and temperature (Control)
• 30 year mean monthly historical rainfall and temperature (CMIP5 Modelled Data)
• Computing CMIP5 MME Mean for validation
• Validation of CMIP5 simulated climate against historical data
• Validation results
Results of validation - Rainfall
- Results of validation - Temperature

![Graph showing temperature over months of the year. The graph includes observed data, MME Mean, and ±1 SD of MME Mean, along with the ensemble spread. The temperature is measured in degrees Celsius, and the months are from January to December.]
- Bias Assessment - Rainfall
Bias Assessment - Temperature
Projected Changes in Rainfall and Temperature for Zambia

- Future Period (2035-2065); Control Period (1970-2000)
- Representative Concentration Pathway (RCP) 8.5
- Modelled rainfall and temperature data (2035-2065)
- Computation of MME mean for modelled data (2035-2065)
- Percentage changes in mean annual rainfall and temperature (control and future period)

\[
\text{- } \% \text{ Change in } R = \left( \frac{(R_{P} - R_{O})}{R_{O}} \right) \times 100 \tag{1}
\]

\[
\text{- } \% \text{ Change in } T = \left( \frac{(T_{P} - T_{O})}{T_{O}} \right) \times 100 \tag{2}
\]
Projected Monthly Rainfall Changes (2035-2065)
Projected Monthly Temperature Changes (2035-2065)
Projected Annual Rainfall Changes (2035-2065)
Projected Annual Temperature Changes (2035-2065)
- Percentage Change in Rainfall and Temperature

MME Means under RCP8.5

<table>
<thead>
<tr>
<th>Percentage Change</th>
<th>Rainfall</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
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<tr>
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<td>35</td>
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</table>

MME Mean (2035-2065) MME Mean (2070-2100)
Change in Mean Annual Water Discharge

• Projected change (2035-2065) based on control period (1970-2000)
• Mean monthly water discharge (water balance equation)
  - $Q_m = P - E \pm \Delta S$  \hspace{1cm} (3)
• 30 year monthly and annual mean water discharge and yearly water discharge (control and future period)
• Mean annual water discharge computation – $Q_A$
• Percentage change in mean annual water discharge
  - $\% \text{ Change in } Q = \left( \frac{(Q_{Ap} - Q_{Ao})}{Q_{Ao}} \right) \times 100$  \hspace{1cm} (4)
• Key Assumptions considered
- Projected changes in mean annual water discharge
Percentage variation in key climatic parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MME Mean (1970 to 2000)</th>
<th>MME Mean (2035 to 2065)</th>
<th>MME Mean (2070 to 2100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>10.4 ± 2.3</td>
<td>8.9 ± 2.3</td>
<td>5.4 ± 2.4</td>
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<tr>
<td>Temperature</td>
<td>1.5 ± 3.8</td>
<td>13.5 ± 4.9</td>
<td>24.3 ± 5.3</td>
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<tr>
<td>PET</td>
<td>4.3 ± 0.7</td>
<td>33.2 ± 1.3</td>
<td>77.9 ± 2.4</td>
</tr>
<tr>
<td>Water Discharge</td>
<td>8.7 ± 3.6</td>
<td>-7.1 ± 3.6</td>
<td>-28.5 ± 3.5</td>
</tr>
</tbody>
</table>
Effects on Future Hydro Electricity Generation

• Key resource for hydroelectricity generation is runoff
• Projected decrease in mean annual water discharge
• Zambezi River Basin highly vulnerable
• Negative effect on hydroelectricity generation under RCP8.5 scenario
• Similar findings in previous research within Zambezi Basin
Conclusions

- Expected percentage reduction in hydroelectricity generation not quantified
- Different spatial resolutions of GCMs
- Equal weighting of models
- Different Representative Concentration Pathways
- Climate model uncertainty
- Overall, Climate Models can be used for planning