Abstract: Managing water resources in a sustainable manner requires at the very least an adequate characterization of hydrological fluxes (precipitation, streamflow, evapotranspiration, groundwater) and states (soil moisture) at monthly, seasonal and annual scale. In this work we present a comprehensive evaluation of water cycle components for the Upper Blue Nile basin in Ethiopia estimated from four state-of-the-art water resources reanalysis (WRR) products associated with different land surface models (LSMs), meteorological forcing and precipitation datasets. Specifically, evaluation is carried out for a dataset produced through NASA's Land Data Assimilation System (FLDAS) regional (FLDAS) scale and the latest versions (tier 2) of the global WRR product of the EU Earth2Observ project. Each product includes a multi-model ensemble output. The final ensemble output, considering all products, incorporates differences in forcing, model space/time resolutions and assimilation procedures used in each WRR product. Results from this analysis highlight the current strengths and limitations of available WRR datasets for analyzing the hydrological cycle and dynamics of East Africa region and provide unprecedented information for both developers and end users in similar hydroclimatic regimes.

1. Introduction

- Availability of multiple global water resources reanalysis (WRR) products has provided a unique opportunity to advance understanding of terrestrial hydrologic processes at regions where in situ information is sparse or nonexistent. Africa is generally characterized by sparse hydrologic observations while at the same time there is need for efficiently managing water resources to enhance food and water security in the area. Ethiopia’s hydrology plays a significant international role, being the headwaters of the Blue Nile Basin, where it contributes about 86% of the total annual flow of the Nile (Suctcliffe, 1999).

- The objectives of this study is to identify the most suitable combination of LSM and precipitation forcing to represent the hydrological cycle components for the Upper Blue Nile.

2. Methodology

- Evaluation was carried out at two basin scales, Upper Blue Nile at Elderm (177642.9 km²) and Kesaire (50418.08 km²), at monthly and annual temporal scales.
- Precipitation, evapotranspiration (ET), and streamflow were evaluated against the Ethiopian National Meteorological Agency (SNMA) deradal rainfall, remote sensing derived actual ET (Zhang et al 2014) and in-situ streamflow observations, respectively.
- For the water budget analysis the terrestrial water storage estimates were calculated using the equation adapted for watersheds: 

  \[ TWS = \int (P - ST)(Q) dt \]

and it was evaluated against the NASA Gravity Recovery and Climate Experiment (GRACE) product.

Study Area

WRR products under consideration

<table>
<thead>
<tr>
<th>WRR Models</th>
<th>Model</th>
<th>Precipitation Forcing</th>
<th>Temporal extent for the evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLDAS</td>
<td>SUIF</td>
<td>Remote sensing</td>
<td>Full extent of the study period</td>
</tr>
<tr>
<td>WRR</td>
<td>SUIF</td>
<td>Remote sensing</td>
<td>2003-2015</td>
</tr>
<tr>
<td>WRR</td>
<td>TRIP</td>
<td>Remote sensing</td>
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<tr>
<td>WRR</td>
<td>LISFLOOD</td>
<td>Remote sensing</td>
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</tr>
<tr>
<td>WRR</td>
<td>VIC</td>
<td>Remote sensing</td>
<td>2003-2015</td>
</tr>
</tbody>
</table>

- The performance of the WRR products is assessed using relative error (RE) calculated as: 

  \[ RE = \frac{SIM - OBS}{OBS} \]

3. Results

3.1 Relative Errors at Monthly Scale

![Relative Error Graph]

- Precipitation
  - 2003 2004 2005 2006 2007 2008 2009
  - 2003 2004 2005 2006 2007 2008 2009

- ET
  - 2003 2004 2005 2006 2007 2008 2009
  - 2003 2004 2005 2006 2007 2008 2009

- Streamflow
  - 2003 2004 2005 2006 2007 2008 2009
  - 2003 2004 2005 2006 2007 2008 2009

- Precipitation
  - 2003 2004 2005 2006 2007 2008 2009
  - 2003 2004 2005 2006 2007 2008 2009

4. Conclusions

- Given the close agreement of the precipitation forcing, variations in ET and streamflow parameter across the different WRR products is attributed to differences in the LSM schemes of the various models.
- WaterGAP3 and VIC best represented the observed streamflow over the Blue Nile.
- Water budget analysis showed strong variability of ATWS derived from the different WRR products, but agreement in terms of the sign.
- Precipitation seem to be the most important component in the water budget analysis for the WRR products. Relatively high mean annual precipitation results into positive ATWS and vice versa.

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