# Evaluation of Hyper-Resolution Model Derived Water Budget Components Over the Upper Blue Nile

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## Introduction

Combining remote sensing observations with global/regional hydrologic models have made it possible to estimate different water cycle components at spatial scales where in-situ measurements are sparse or unavailable. These data are critical to support water resources analysis and management.

## Objective

- Simulate the water cycle of the Blue Nile basin at high spatial (500 m) and temporal (hourly) resolution using a hyper-resolution distributed hydrologic model, Coupled Routing and Excess STorage (CREST-SVAS) and evaluate its performance in terms of evapotranspiration (ET) and Streamflow.
- Compare the performance of CREST-SVAS with different hydrologic and land surface models in terms of the ET and streamflow at different basin scales.
- Evaluate the performance of water budget estimation with respect to the observed and Gravity Recovery and Climate Experiment (GRACE) data.

## Study Area

- The Upper Blue Nile basin, the largest basin in Ethiopia (in terms of volume of discharge)
  - Drainage area: 176,000 km$^2$
- Evaluation in three sub-basins:
  - Gumara: 1,394 km$^2$
  - Gilgel: 1,664 km$^2$
  - Kessie: 65,784 km$^2$

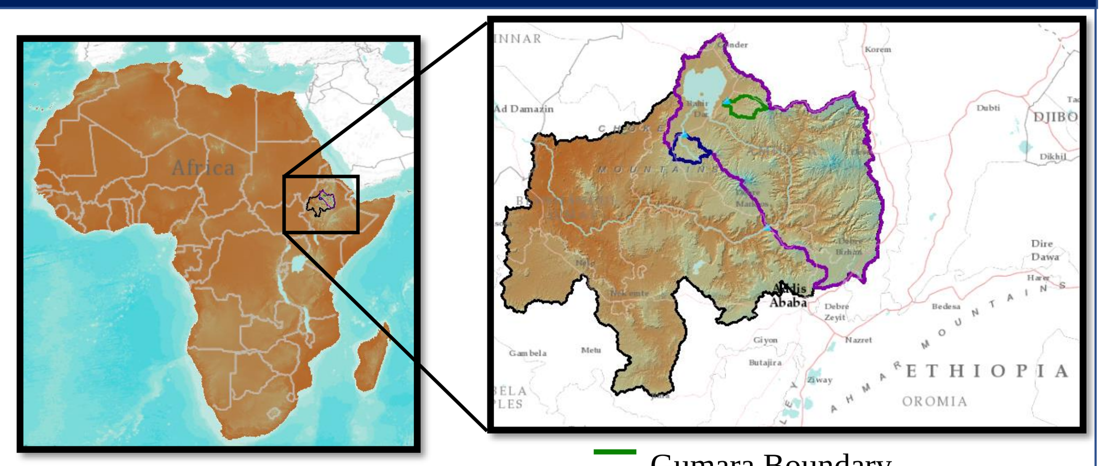


**Figure 1: Location of Upper Blue Nile basin and its three sub-basins**

## Reference Data and Model Forcings

| Variable | | Reference Data | Temporal Extent | Temporal Resolution |
|---|---|---|---|---|
| Precipitation | | Gauge observed | 1984 - 2012 | Monthly |
| ET | | GLEAM model | 1980 - 2016 (0.25° resolution) | Daily |
| Streamflow | Gumara | Gauge observed | 1980 - 2002 | Daily |
| | Gilgel | | 1980 - 2002 | |
| | Kessie | | 1980 - 2012 | |
| Terrestrial Water Storage (TWS) Anomaly | | GRACE | 2002 - 2012 | Monthly |

- HTESSEL-CaMa
- JULES
- LISFLOOD
- ORCHIDEE
- WaterGAP
- NOAH-MP
- CLMS

MERRA-2 and CHIRPS Precipitation Forcing (0.25° Resolution)

Reanalysis Era Interim and MSWEP Forcing (0.25° Resolution)

## CREST-SVAS

- **CREST-SVAS**
  - A **fully distributed** hydrological model that Strictly couples energy and water balances and imposes closed energy balance.
  - For water cycle simulation over **large** watersheds at a **fine spatiotemporal resolution** (e.g., 30 m to 1 km and hourly time).
- **Simulation properties over Blue Nile**
  - Resolution: **500 m and 3 hourly**
  - Duration: 1979 – 2014
  - Forcing Data:
    - ✓ Meteorological Forcing: **Reanalysis ERA Interim**
    - ✓ Precipitation: **MSWEP version 1**
  - Static Data:
    - ✓ Soil Texture Map: Soil Grids (3 layers, 0-2 m depth)

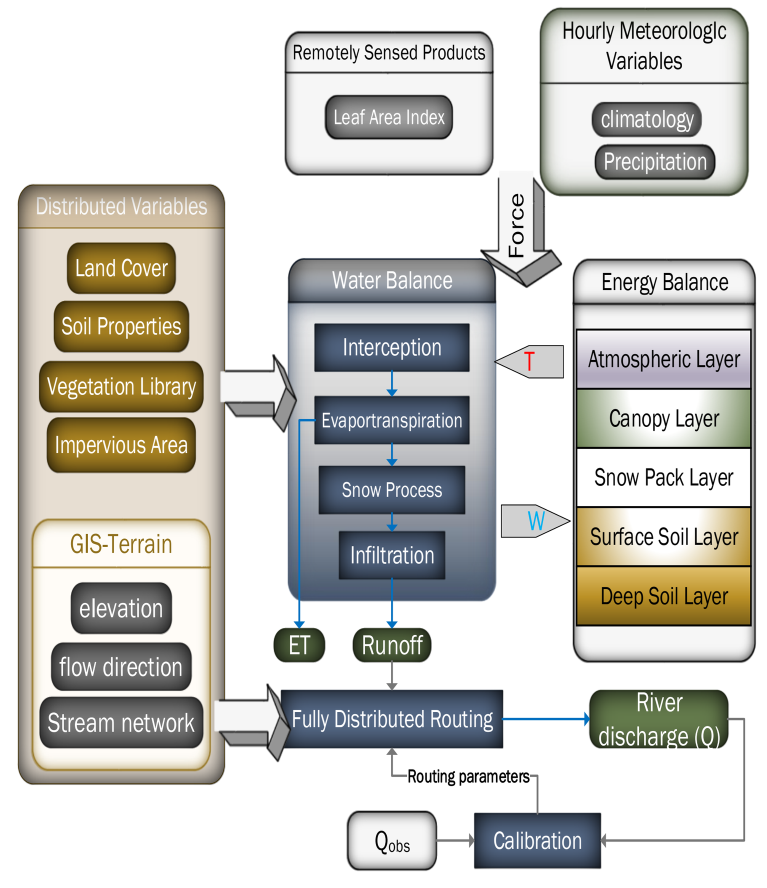


**Figure 2: CREST Framework (Shen and Anagnostou, 2017)**

## Model Validation

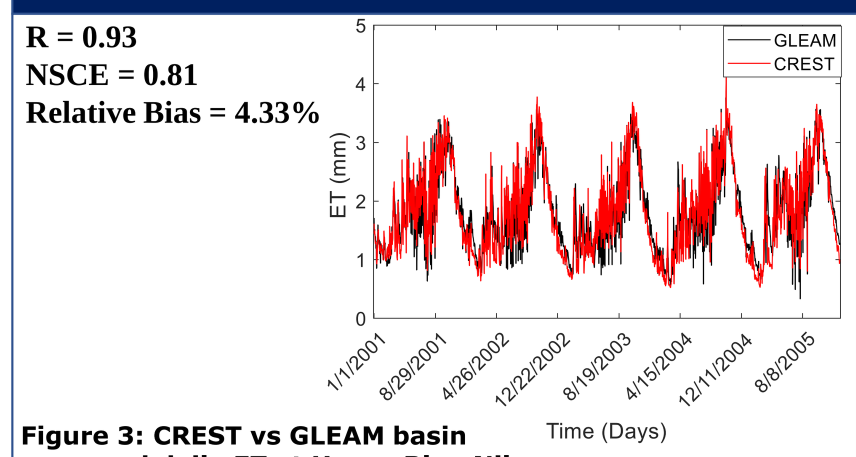


**Figure 3: CREST vs GLEAM basin averaged daily ET at Upper Blue Nile**

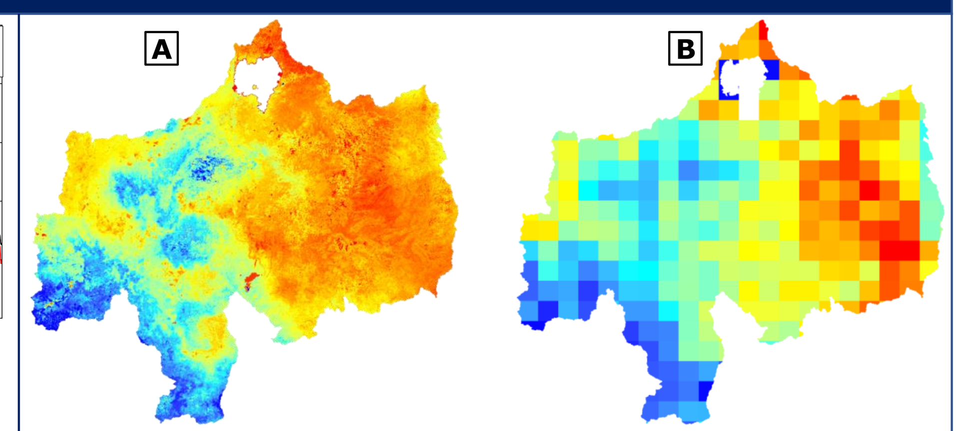

**Figure 4: ET map (A) CREST: 500 m (B) GLEAM: 27 km**

## Results: Descriptive Statistics

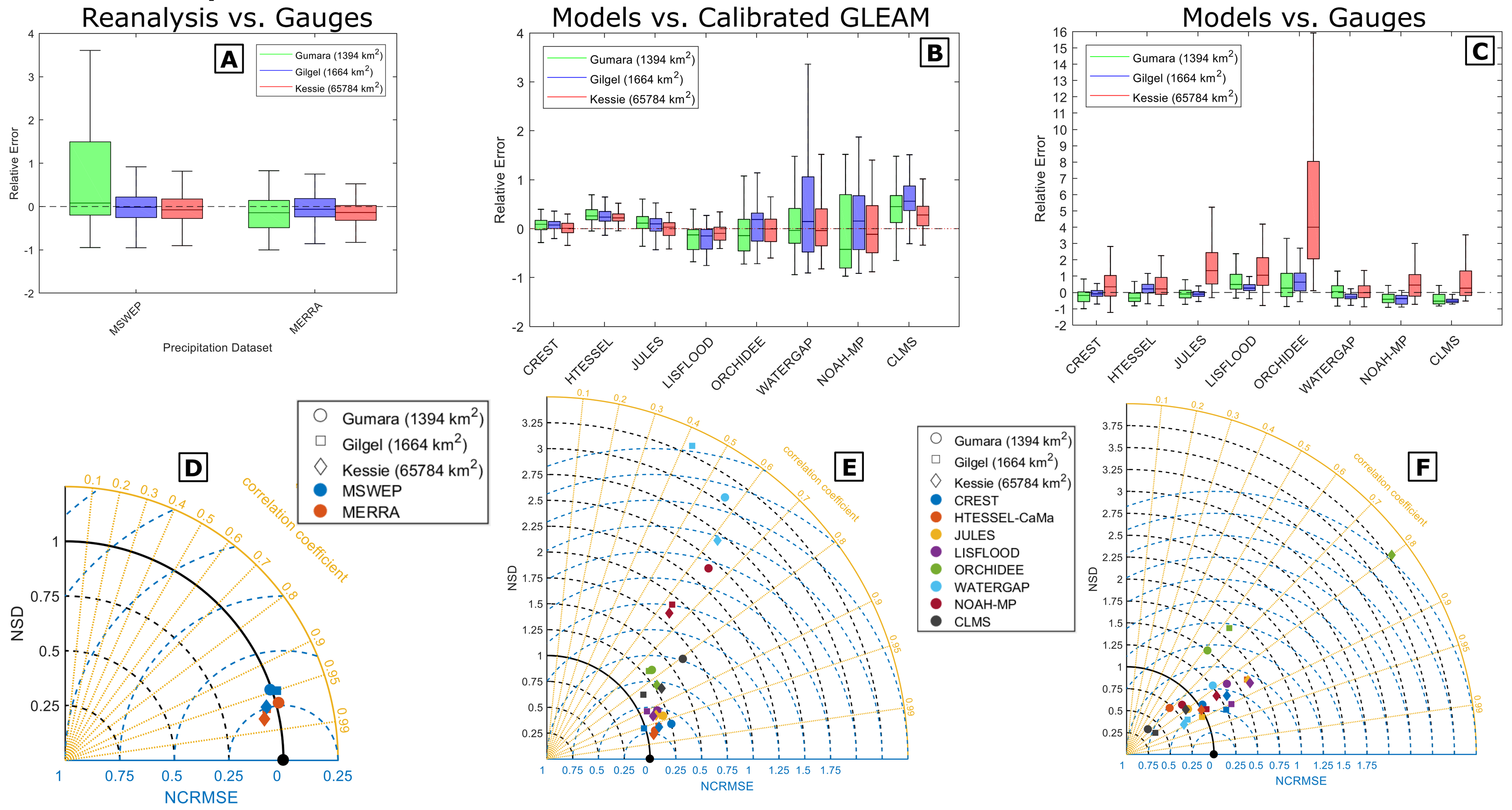


**Figure 5: Relative Error (A - C) and Normalized Taylor Diagram (D - F) of monthly basin averaged precipitation, ET, and streamflow**

## Results: Water Budget Analysis

Terrestrial water storage is an important component of the water cycle. The terrestrial water balance for a prescribed area and period can be written as, $TWS = P - ET - Q$

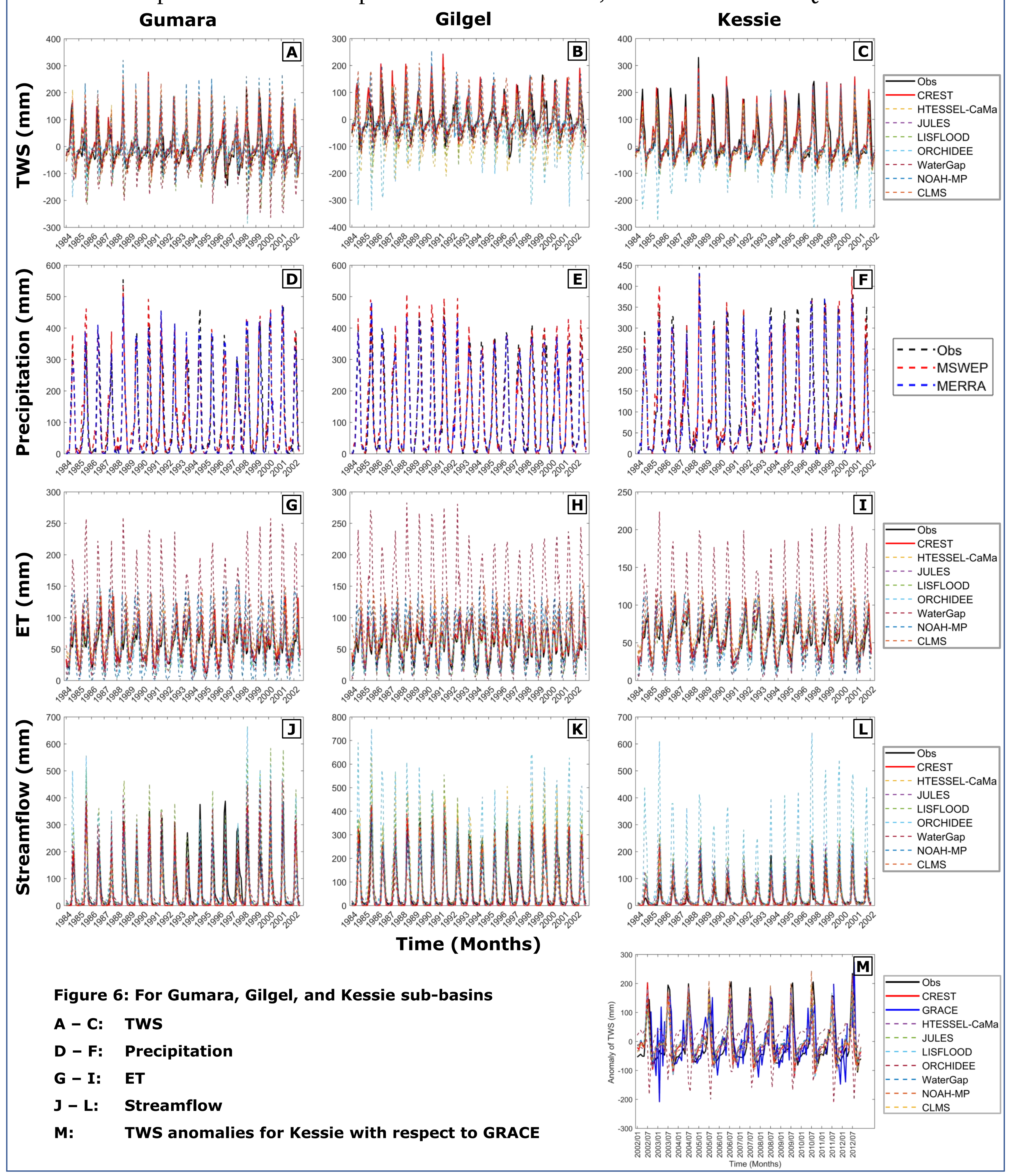


**Figure 6: For Gumara, Gilgel, and Kessie sub-basins**

- **A – C: TWS**
- **D – F: Precipitation**
- **G – I: ET**
- **J – L: Streamflow**
- **M: TWS anomalies for Kessie with respect to GRACE**

## Conclusion

- CREST and JULES perform consistently well at all three basin scales in terms of ET whereas for streamflow CREST has overestimation at Kessie. There is not any lake module in the model and Kessie is at the downstream of Lake Tana which may cause the overestimation.
- Water budget analysis indicates that the water cycle components (ET, streamflow) from CREST balance reasonably well with the observed storage change. These hyper resolution water budget components can be used as inputs in local ground water models for agricultural applications at the farm level.