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Modeling the water budget of the Upper Blue Nile basin using the JGrass-NewAge model system and satellite data

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1. Precipitation maps of UBN basin

The spatial and temporal variability of J(t) is analyzed in this section. The spatial distribution of long term mean daily and annual precipitation is presented in figure 1 a and b. SM2R-CCI shows that south and southwest part of the basin receives high precipitation while the east and northeast part of the highland receives low precipitation. Along the long term annual mean, the long term daily mean is reported.

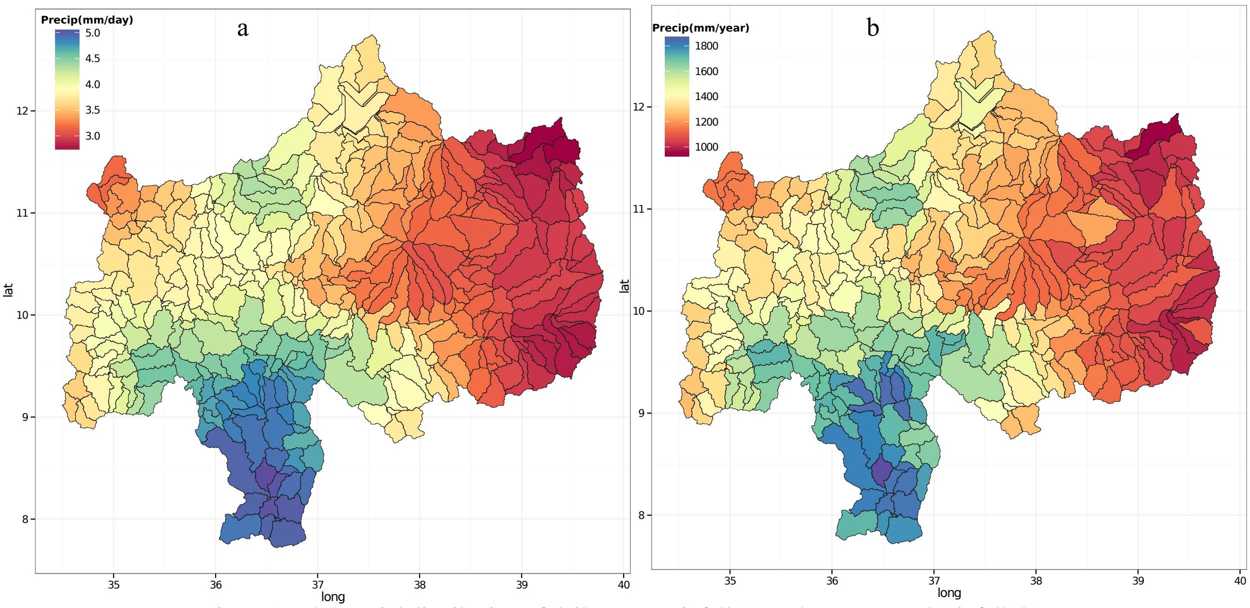

Figure 1: The spatial distribution of daily mean rainfall (a) and mean annual rainfall (b),

2. NewAge and MODIS Evapotranspiration estimation comparison

Figure 2 shows a sample of spatial and temporal estimation of MOD16 and NewAge ET for some systematically selected (selected from the four seasons) at 8-days time resolution. While the spatial pattern has some similarities, the magnitudes of ET amount between the model and MOD16 estimation is different. In all the maps, ET tends to be high in the lowlands of the basin (western part). MOD16 estimation, however, considerable underestimates ET in comparison to NewAge. Time series comparison of two ET from 2000-2009 for some selected subbasin (figure 3) shows that MOD16 highly underestimates ET. Other studies also show similar results that MOD16 considerably underestimate in comparison to some model estimations and eddy covariance flux towers data (Yilmaz et al., 2014; Knipper et al., 2016; Schaffrath and Bernhofer, 2013; Ramoelo et al., 2014).

NewAge revealed high level of temporal variability while MOD16 shows similar temporal patterns between the years. The agreement between the two estimations vary from subbasin to subbasin (figure 3). For instance, in figure 3b shows relatively better consistency while figure 3d has lower agreement between the two. The spatial distribution of the correlation and PBIAS between the model and MOD16 data is presented in figure 4a and b respectively. The NewAge estimation in the eastern part of the basin shows higher correlation with the MOD16 data, while the correlation tends to decrease systematically towards the west i.e. to the lowlands (figure 4a). Similarly, the PBIAS shows that the western part, border to the Sudan, has very high underestimation (figure 4b). The overall correlation and PBIAS between NewAge and MOD16 is 0.48± 0.15 and 14.5 ± 18.9 respectively. Based on the consistency we made, and our ability to characterize the other water budget solution with observation and GRACE, we can point out that the performance of MOD16 is low, and need to be improved in this region.

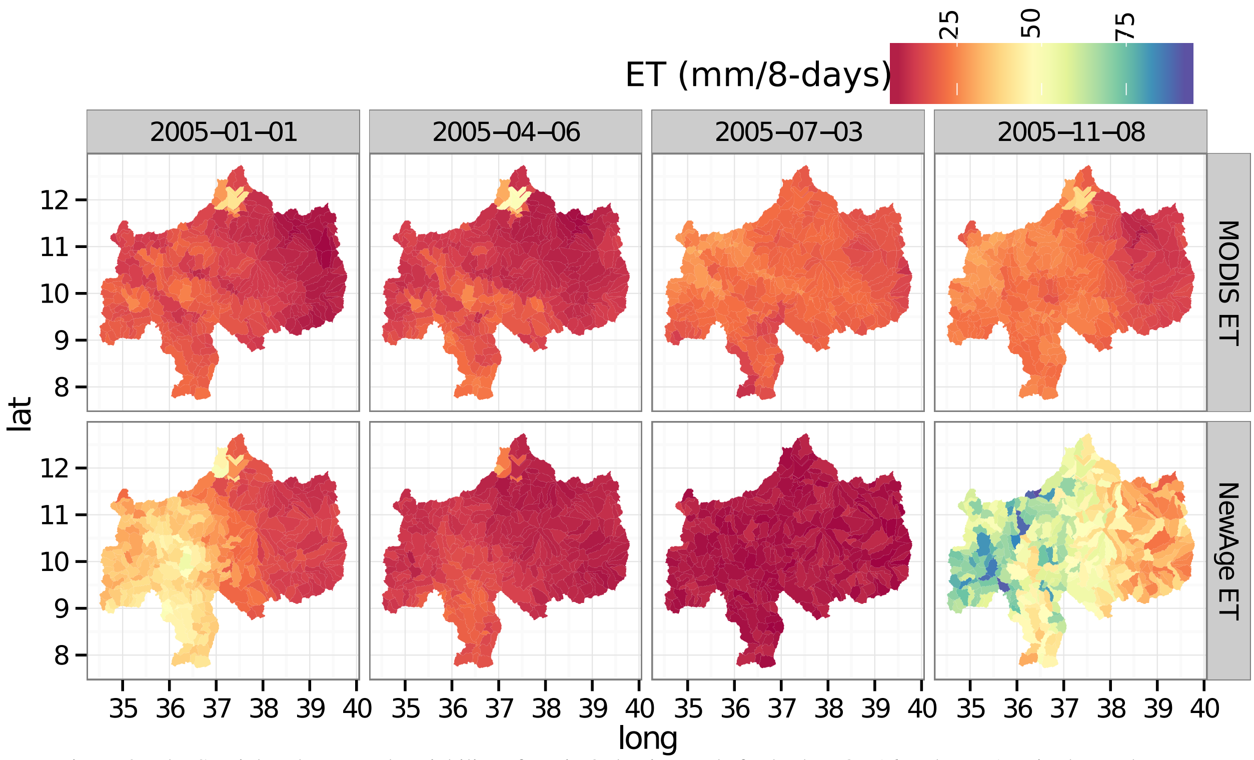

Figure 2: The Spatial and temporal variability of ET in 8-day intervals for both MOD16 and NewAge in the study area.

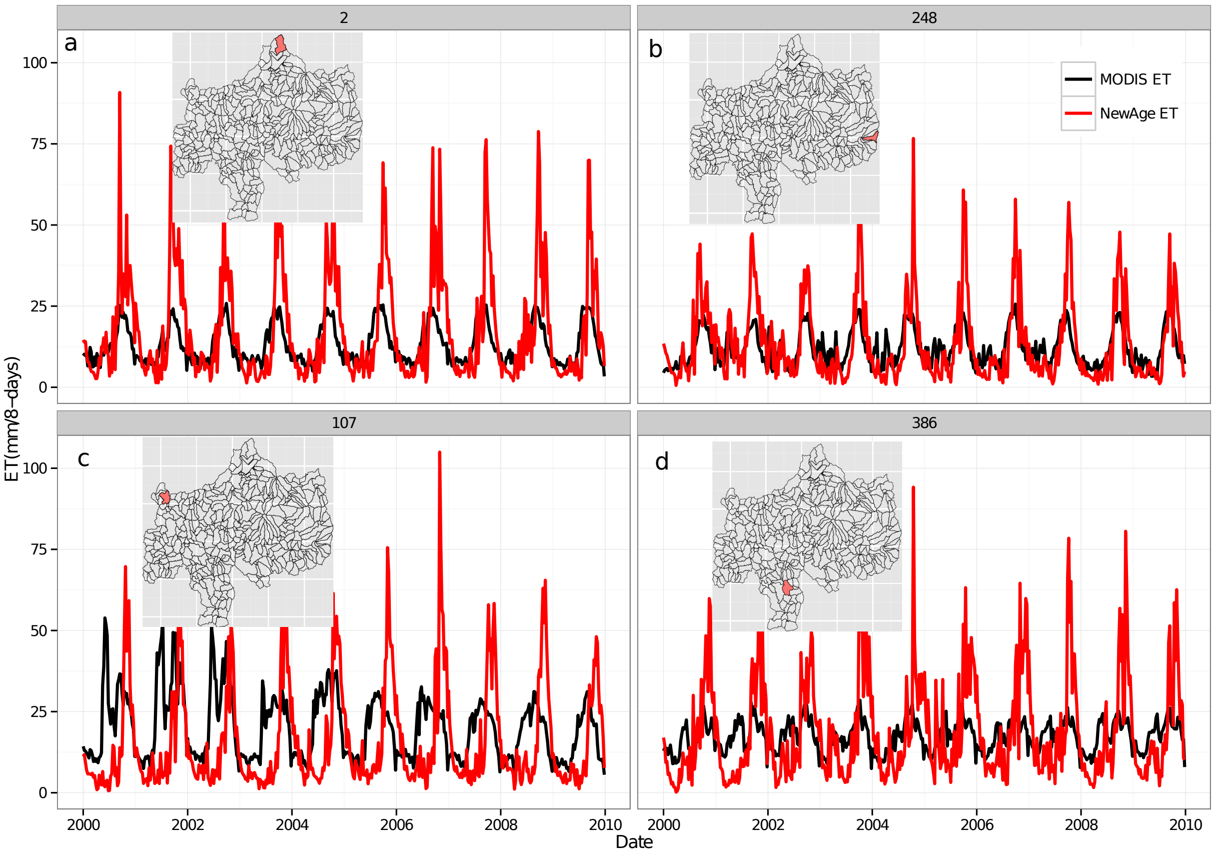

Figure 3: Time series ET estimation with NewAge and MOD16 at 8-days of time steps for four subbasin: subbasin ID2 (a), subbasin ID248 (b), subbasin ID107 (c) and subbasin ID386 (d). The location of the subbasin are indicated in the map inside the plots.

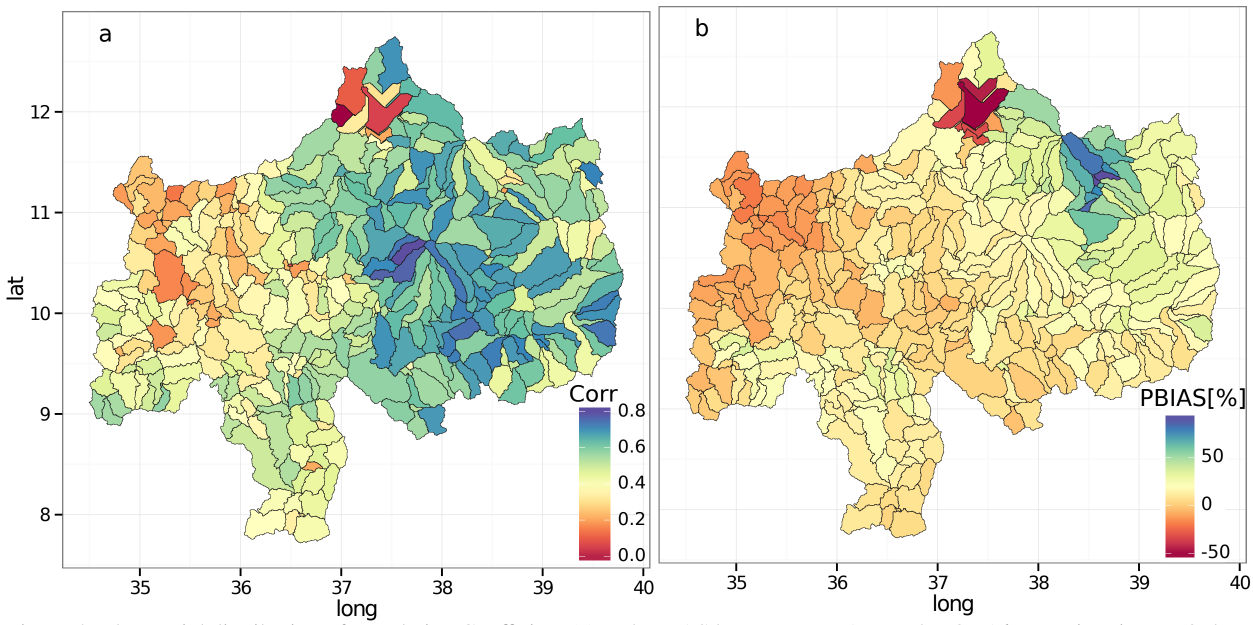

Figure 4: The spatial distribution of correlation Coefficient (a) and PBIAS between NewAge and MOD16 ET estimations at 8-days time steps.

3. NewAge simulation at each link

A sample of spatially distributed daily discharge at all the channel links is shown in figure **??**. Here, the daily discharge for the first day of May, June, July, August, September and October are presented to show the spatio-temporal dynamics of discharge.

4. NewAge and GRACE storage change maps

The spatial distribution of NewAge ds/dt and GRACE based TWSC for four months (January, April, July, and October) of 2005 is shown at figure 5. The comparison is based on the NewAge modelling at subbasin scale, and GRACE grid resolution of 1^0. Due to the possible high leakage error introduced at high spatial resolution (Swenson and Wahr, 2006), statistical comparison at subbasin level is not performed. However, focusing on maps of the sample months, some level of similar spatial and temporal pattern is revealed (figure 5).

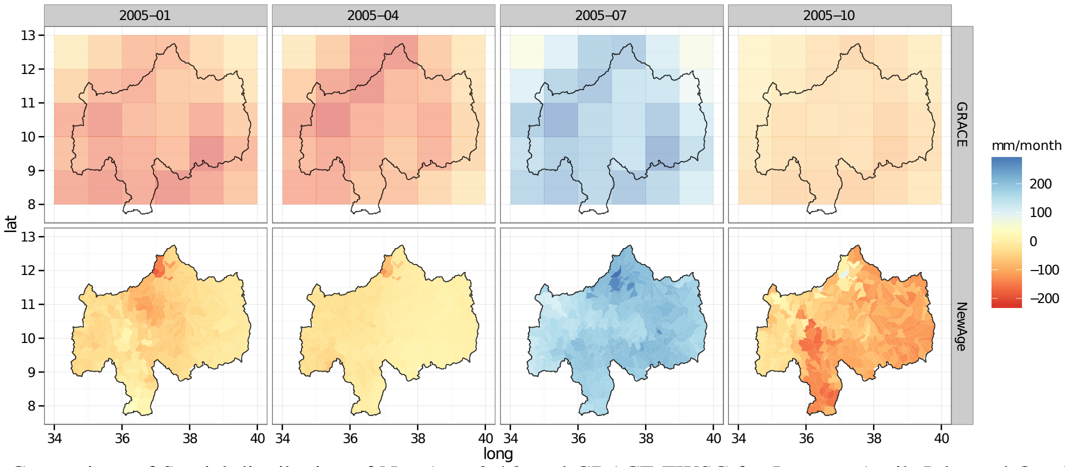

Figure 5: Comparison of Spatial distribution of NewAge ds/dt and GRACE TWSC for January, April, July, and October 2005. Note that the sptial resolution of NewAge ds/dt and GRACE is subbasin scale and 1^0 X 1^0 respectively

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