

Improved Lower Mekong River Basin Hydrological Decision Making Using NASA Satellite-based Earth Observation Systems

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Abstract

Better understanding of the hydrological cycle of the Lower Mekong River Basin (LMRB) and addressing the value-added information of using remote sensing data on the spatial variability of soil moisture over the Mekong Basin is the objective of this work. In this work, we present the development and assessment of the LMRB (drainage area of 495,000 km²) Soil and Water Assessment Tool (SWAT). The coupled model framework presented is part of SERVIR, a joint capacity building venture between NASA and the U.S. Agency for International Development, providing state-of-the-art, satellite-based earth monitoring, imaging and mapping data, geospatial information, predictive models, and science applications to improve environmental decision-making among multiple developing nations. The developed LMRB SWAT model enables the integration of satellite-based daily gridded precipitation, air temperature, digital elevation model, soil texture, and land cover and land use data to drive SWAT model simulations over the Lower Mekong River Basin. The LMRB SWAT model driven by remote sensing climate data was calibrated and verified with observed runoff data at the watershed outlet as well as at multiple sites along the main river course. Another LMRB SWAT model set driven by in-situ climate observations was also calibrated and verified to streamflow data. Simulated soil moisture estimates from the two models were then examined and compared to a downscaled Soil Moisture Active Passive Sensor (SMAP) 36 km radiometer products. Results from this work present a framework for improving SWAT performance by utilizing a downscaled SMAP soil moisture products used for model calibration and validation.



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Tuesday, 12 December 2017



Outline

- Introduction.
- Objectives.
- Study Area & Methods.
- SWAT Model – Data Sources, Remote Sensing Products, Calibration, Validation, and Preliminary Results.
- Summary and On going work.

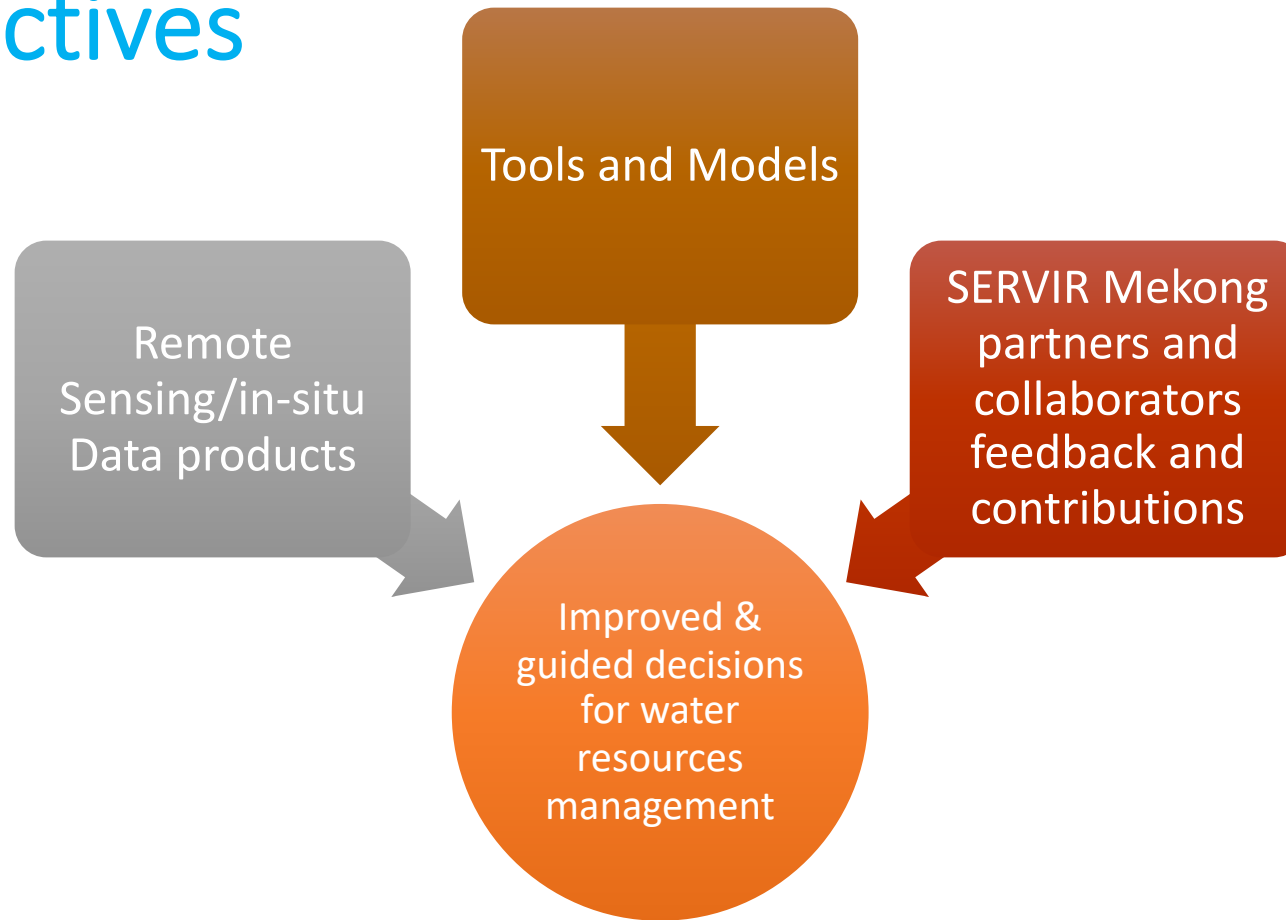


Introduction

- The coupled model framework presented in this work is part of SERVIR, a joint capacity building venture between NASA and the U.S. Agency for International Development, providing state-of-the-art, satellite-based earth monitoring, imaging and mapping data, geospatial information, predictive models, and science applications to improve environmental decision-making among multiple developing nations.
- Our developed Lower Mekong River Basin (LMRB) model enables the integration of satellite-based daily gridded precipitation, air temperature, digital elevation model, soil texture, and land cover and land use data to drive SWAT model simulations over the Lower Mekong River Basin.



Objectives



- Enhancement of the decision making activities conducted by regional stakeholders (e.g., ADPC) with regard to improved water resources management and agriculture monitoring and forecasting at the lower Mekong Basin through the use of NASA satellite dataset products.
- Provide tools and training to enable independent and operational capabilities by the SERVIR Mekong partners and collaborators.



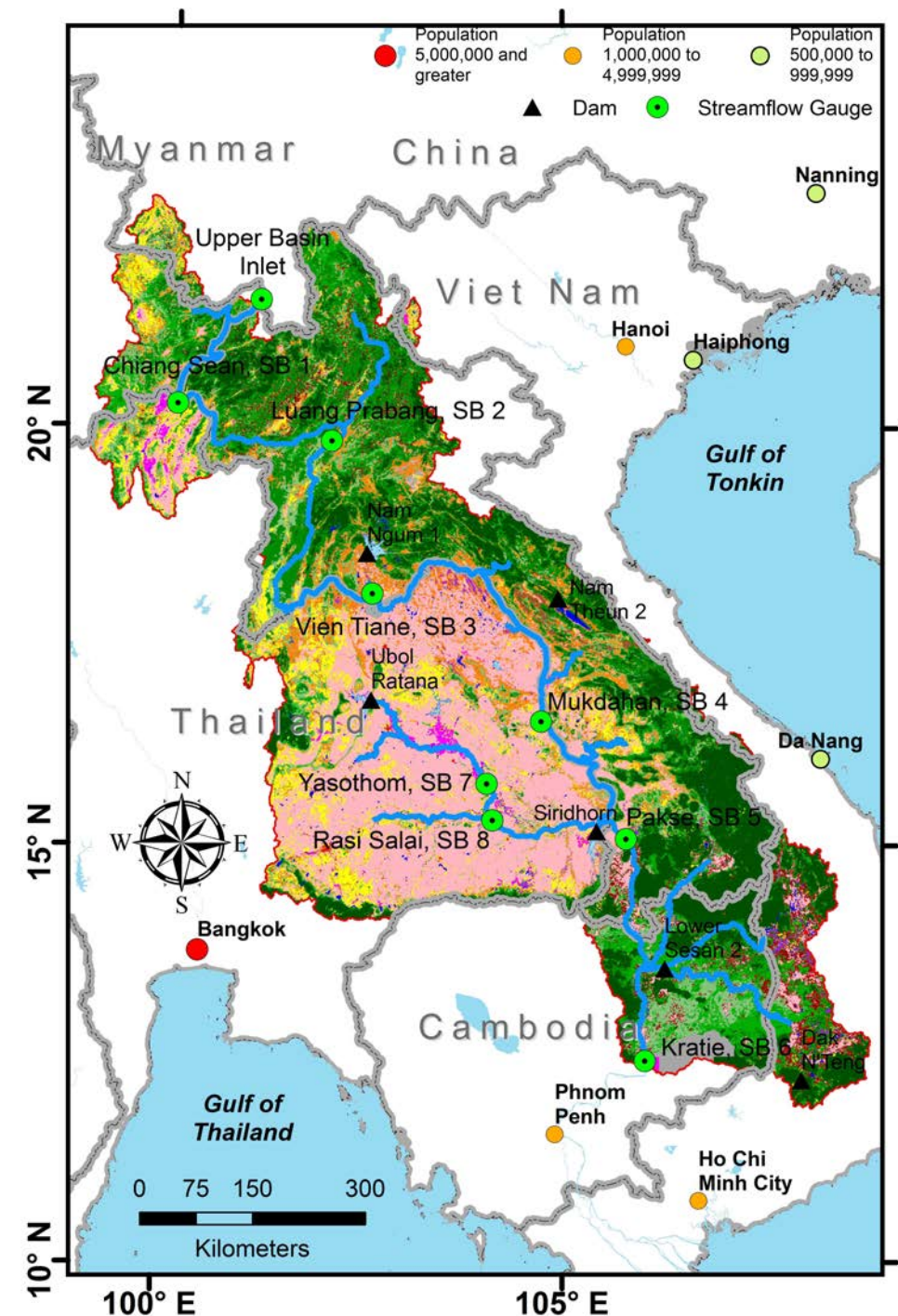
Hydrologic Decision Support system for the Lower Mekong River Basin

- The LMRB (drainage area of $\sim 495,000$ km²) SWAT Model setup closely follows MRC subbasin configuration (Rossi et al., 2009).
- A digital elevation model (DEM) with 1 arc-sec grid resolution, ASTER was adopted.
- Harmonized World Soil Database [FAO et al., 2012], version 1.2 was implemented.
- MODIS, NDVI, Landsat TM, and ETM+ data products were used to obtain lower Mekong Basin LULC map.

Rossi, et. al., 2009. Hydrologic evaluation of the lower Mekong River Basin with the soil and water assessment tool model. IAEJ 18, 1-13, <http://114.255.9.31/iaej/EN/Y2009/V18/I01-02/1>



SERVIR
MEKONG

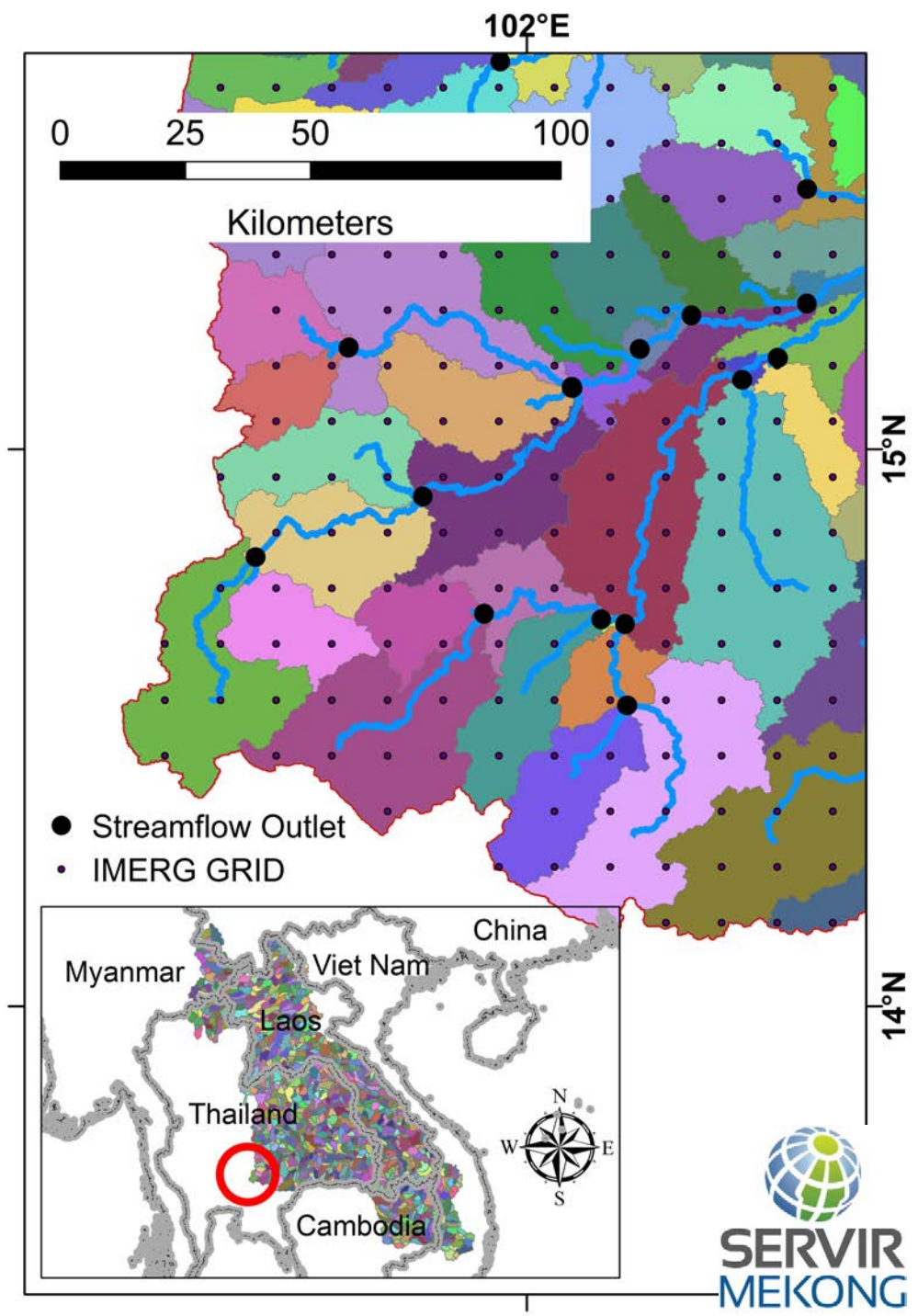
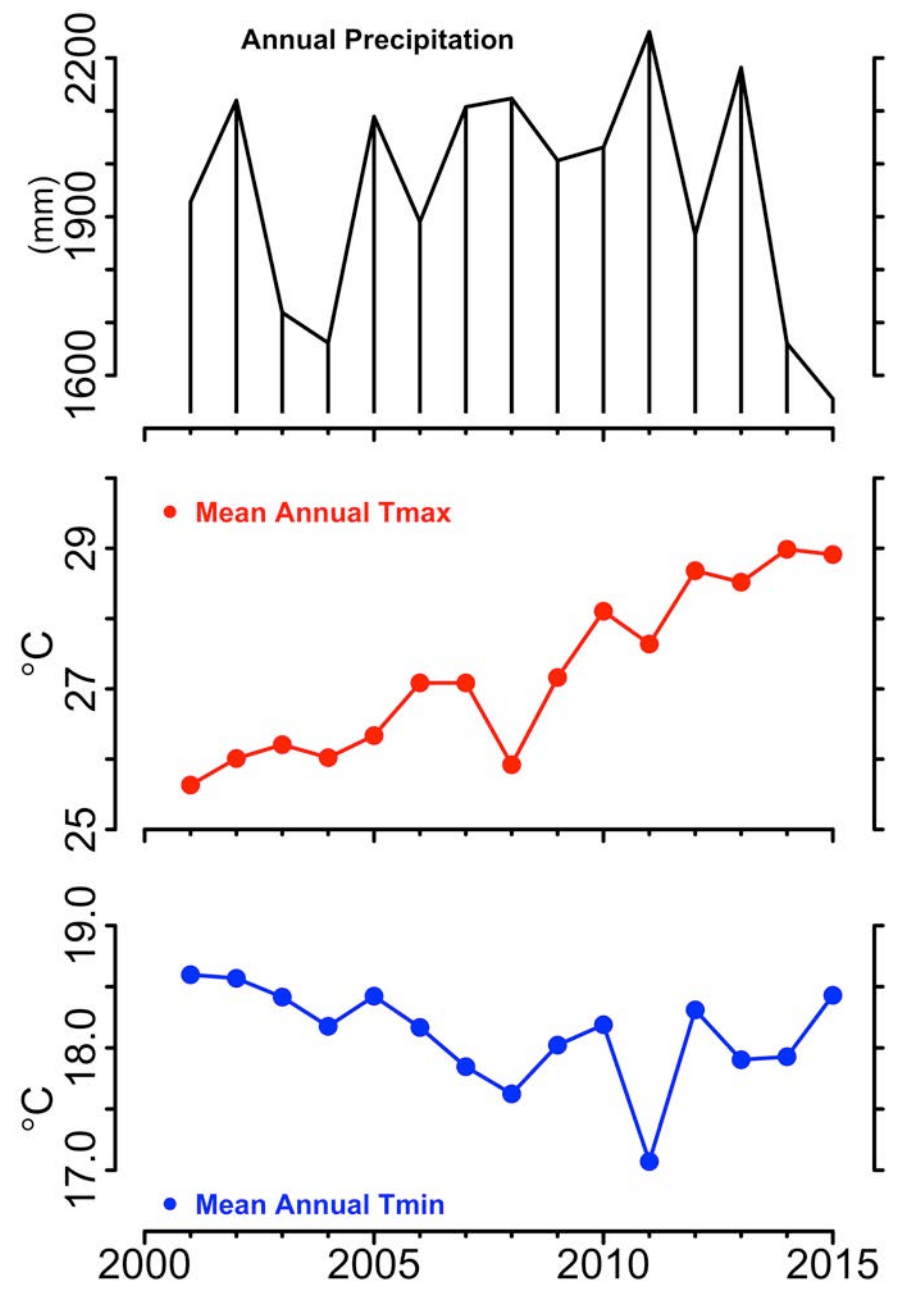




SWAT model w/ Remote Sensing Climate Input Data

Minimum and Maximum
air temperature
processed using GLDAS
Noah Land Surface Model
L4 3 hourly 0.25 x 0.25
degree V2.0

Input Precipitation Data (TRIMM & IMERG)





Remote Sensing Climate Data Retrieval/Processing Package

- R package to retrieve and analyze Remote Sensing Precipitation and air temperature data products and generate climate tables compatible with SWAT or any other Rainfall/Runoff Hydrological Model.
- Inputs are: study area DEM and shapefile, and start and end days for rain/air temperature time series data.

Package: **nasaaccess**

Type: Package

Date: 2017-Sept-19

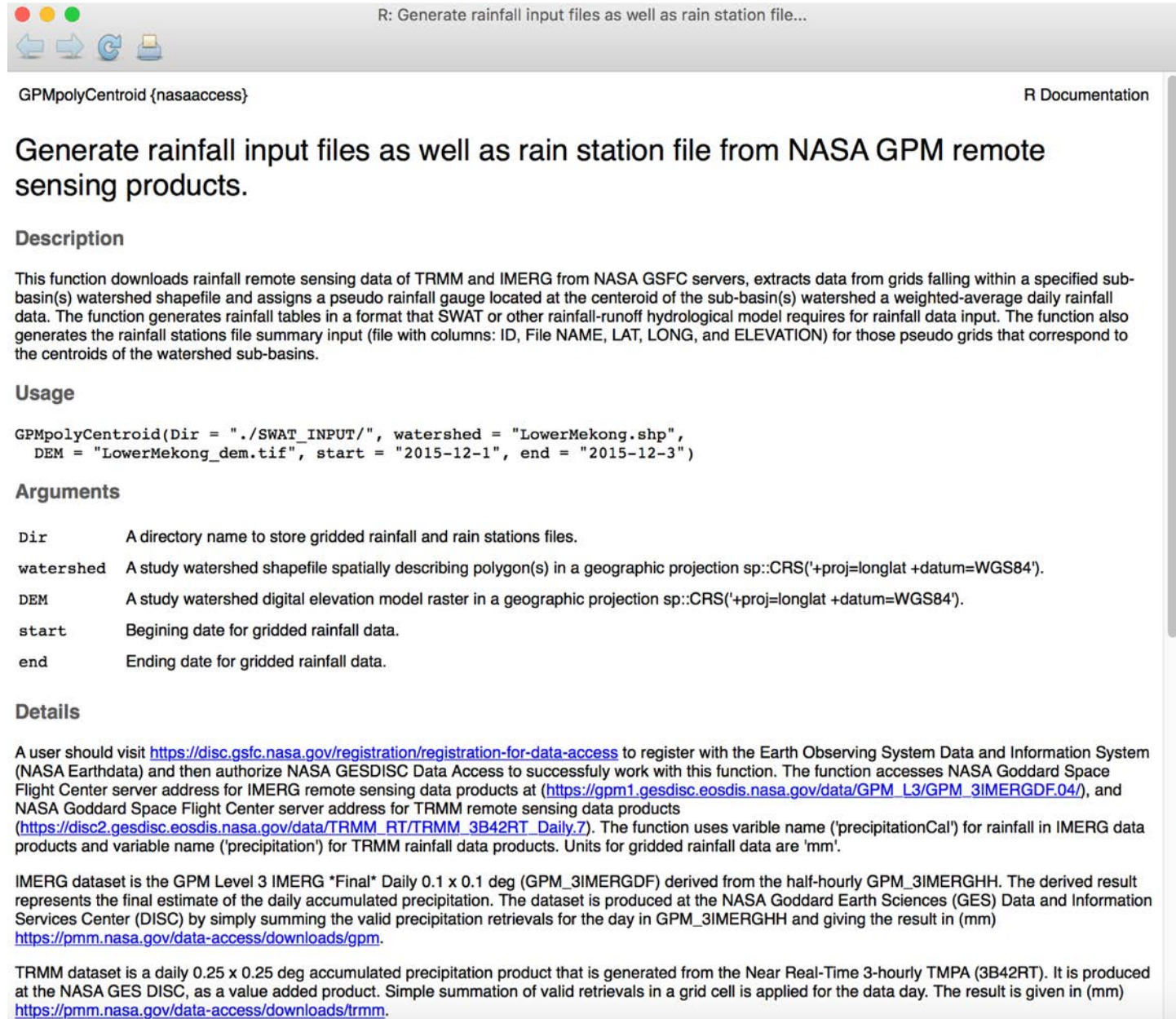
Title: The Remote Sensing data products and Hydrological model weather inputs

Version: 1.2.0

Authors@R: c(person("Ibrahim", "Mohammed", role = c("aut", "cre"), email = "ibrahim.mohammed@nasa.gov")

Author: Ibrahim Mohammed [aut,cre] Maintainer: Ibrahim Mohammed
<ibrahim.mohammed@nasa.gov>

Description: This package generates gridded ascii tables and station files needed by SWAT or any other hydrological model weather inputs.



R: Generate rainfall input files as well as rain station file...

GPMpolyCentroid {nasaaccess} R Documentation

Generate rainfall input files as well as rain station file from NASA GPM remote sensing products.

Description

This function downloads rainfall remote sensing data of TRMM and IMERG from NASA GSFC servers, extracts data from grids falling within a specified sub-basin(s) watershed shapefile and assigns a pseudo rainfall gauge located at the centroid of the sub-basin(s) watershed a weighted-average daily rainfall data. The function generates rainfall tables in a format that SWAT or other rainfall-runoff hydrological model requires for rainfall data input. The function also generates the rainfall stations file summary input (file with columns: ID, File NAME, LAT, LONG, and ELEVATION) for those pseudo grids that correspond to the centroids of the watershed sub-basins.

Usage

```
GPMpolyCentroid(Dir = "./SWAT_INPUT/", watershed = "LowerMekong.shp",  
  DEM = "LowerMekong_dem.tif", start = "2015-12-1", end = "2015-12-3")
```

Arguments

Dir	A directory name to store gridded rainfall and rain stations files.
watershed	A study watershed shapefile spatially describing polygon(s) in a geographic projection sp::CRS('+proj=longlat +datum=WGS84').
DEM	A study watershed digital elevation model raster in a geographic projection sp::CRS('+proj=longlat +datum=WGS84').
start	Beginning date for gridded rainfall data.
end	Ending date for gridded rainfall data.

Details

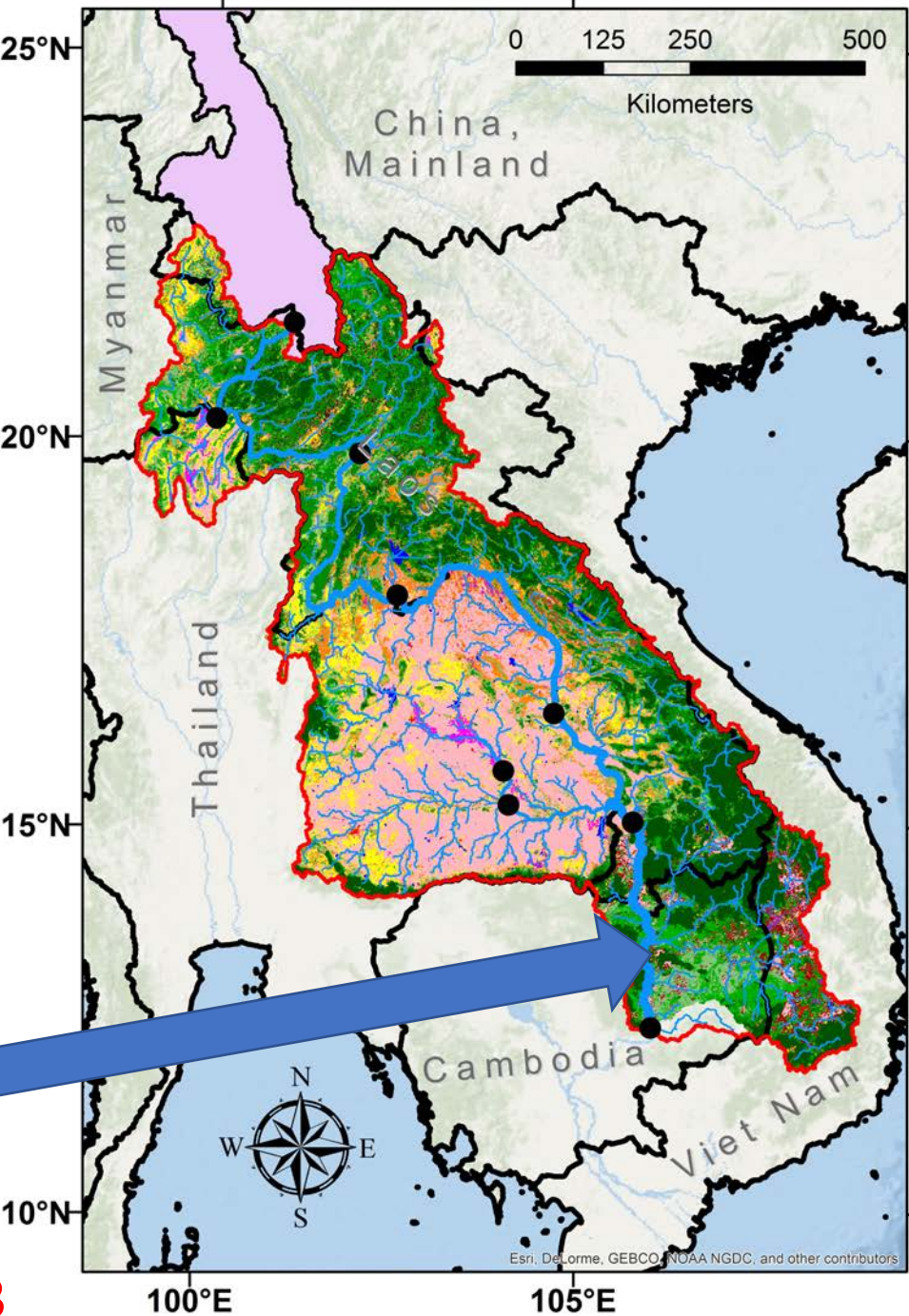
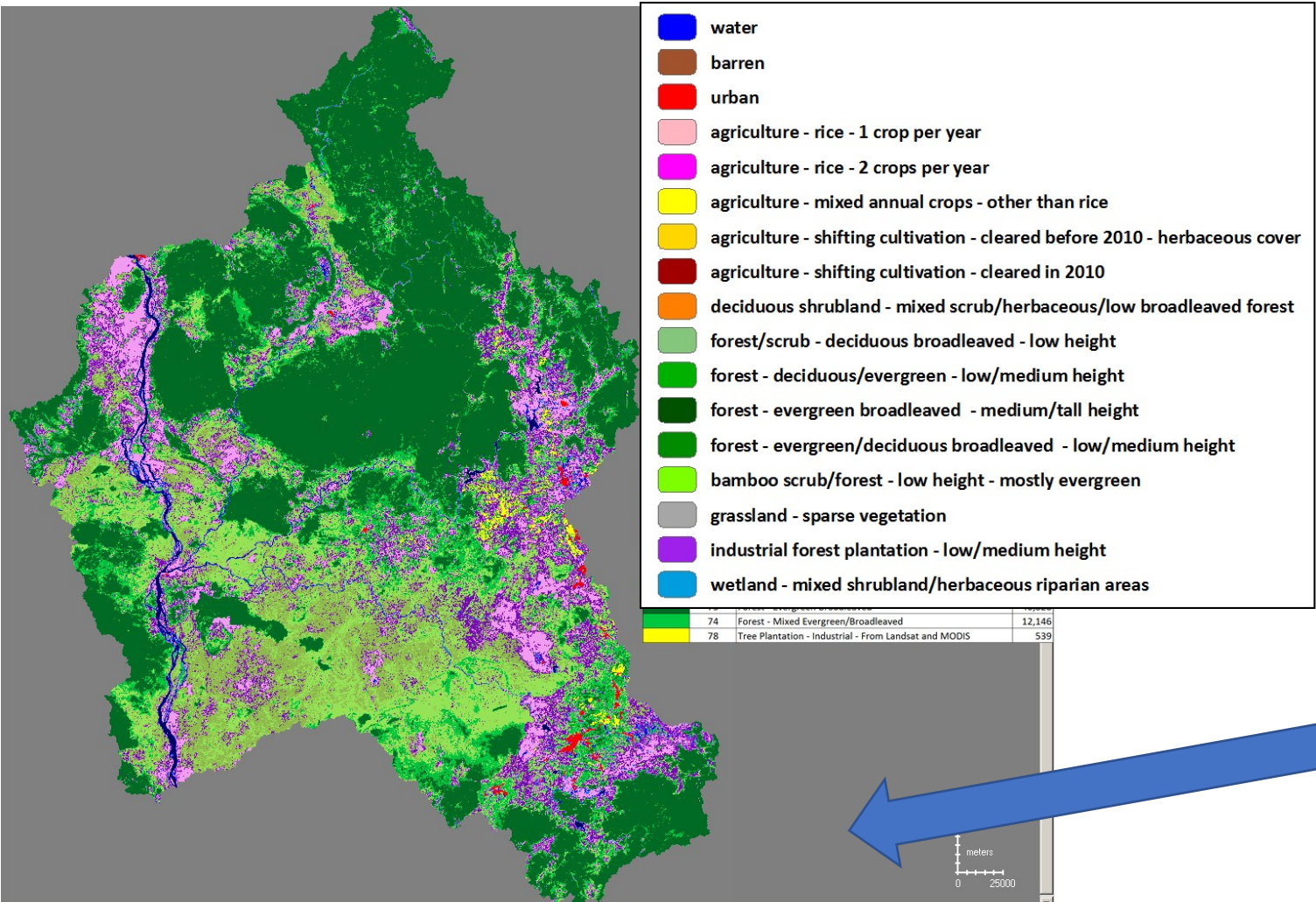
A user should visit <https://disc.gsfc.nasa.gov/registration/registration-for-data-access> to register with the Earth Observing System Data and Information System (NASA Earthdata) and then authorize NASA GESDISC Data Access to successfully work with this function. The function accesses NASA Goddard Space Flight Center server address for IMERG remote sensing data products at (https://gpm1.gesdisc.eosdis.nasa.gov/data/GPM_L3/GPM_3IMERGDF.04/), and NASA Goddard Space Flight Center server address for TRMM remote sensing data products (https://disc2.gesdisc.eosdis.nasa.gov/data/TRMM_RT/TRMM_3B42RT_Daily.7). The function uses variable name ('precipitationCal') for rainfall in IMERG data products and variable name ('precipitation') for TRMM rainfall data products. Units for gridded rainfall data are 'mm'.

IMERG dataset is the GPM Level 3 IMERG "Final" Daily 0.1 x 0.1 deg (GPM_3IMERGDF) derived from the half-hourly GPM_3IMERGHH. The derived result represents the final estimate of the daily accumulated precipitation. The dataset is produced at the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) by simply summing the valid precipitation retrievals for the day in GPM_3IMERGHH and giving the result in (mm)
<https://pmm.nasa.gov/data-access/downloads/gpm>.

TRMM dataset is a daily 0.25 x 0.25 deg accumulated precipitation product that is generated from the Near Real-Time 3-hourly TMPA (3B42RT). It is produced at the NASA GES DISC, as a value added product. Simple summation of valid retrievals in a grid cell is applied for the data day. The result is given in (mm)
<https://pmm.nasa.gov/data-access/downloads/trmm>.



Land Use and Land Cover Data





Mekong SWAT Model Parameters...

- DEM adopted: 90 meters.
- Drainage area threshold used for stream delineation: 25,349.76 Ha (253.50 km²)
- Number of HRUs: 10,096
- Sub-basins: 1,138
- Slopes: 0,2,8,20,>20
- MULTIPLE HRUs LandUse/Soil/Slope OPTION
- THRESHOLDS : 10 / 10 / 10 [%]



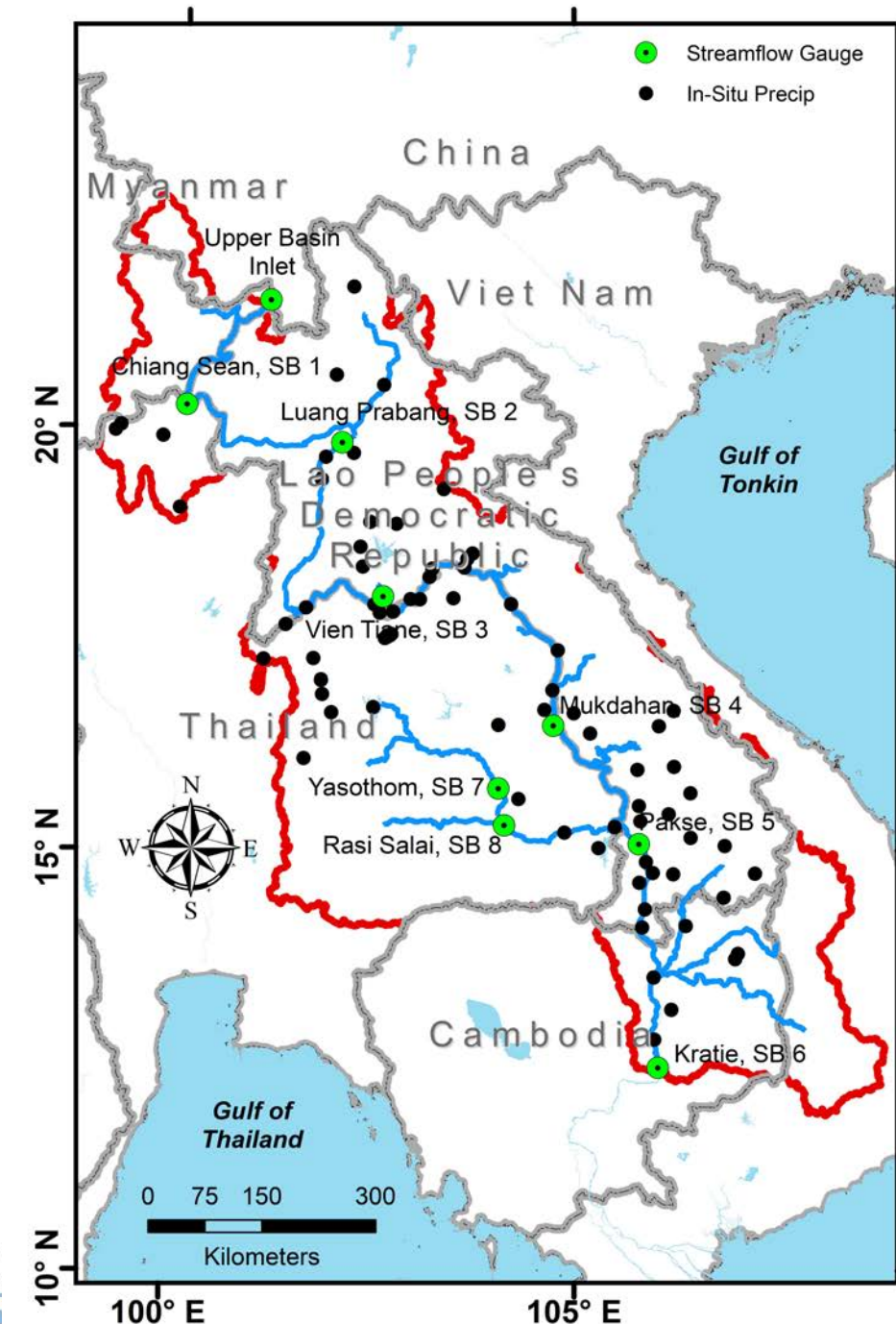
SWAT Calibration Parameters

Parameter	Description	Range
Precipitation	Correction factor	r__Precipitation(SB#s){}.pcp -0.6 0.01
High Flows		
CN2	Initial SCS runoff curve number to moisture condition II	r__CN2.mgt -10 10
AWC	Available water capacity of the soil layer	r__SOL_AWC().sol -10 10
ESCO	Soil evaporation compensation factor	v__ESCO.bsn 0.5 0.9
Base Flows		
GW_DELAY	Groundwater delay time	a__GW_DELAY.gw -30 60
REVAPMN	percolation to the deep aquifer to occur	a__REVAPMN.gw -750 750
GWQMN	Threshold depth of water in the shallow aquifer	a__GWQMN.gw -1000 1000
GW_REVAP	Groundwater "revap" coefficient	v__GW_REVAP.gw 0.02 0.1
RCHRG_DP	Deep aquifer percolation fraction	a__RCHRG_DP.gw -0.05 0.05
GWHT	Initial groundwater height	v__GWHT.gw 0.0 1.0



In-Situ Climate Data

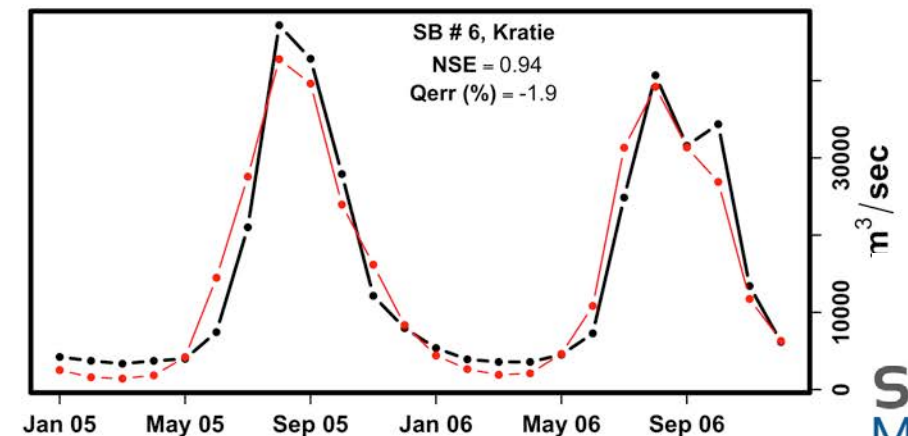
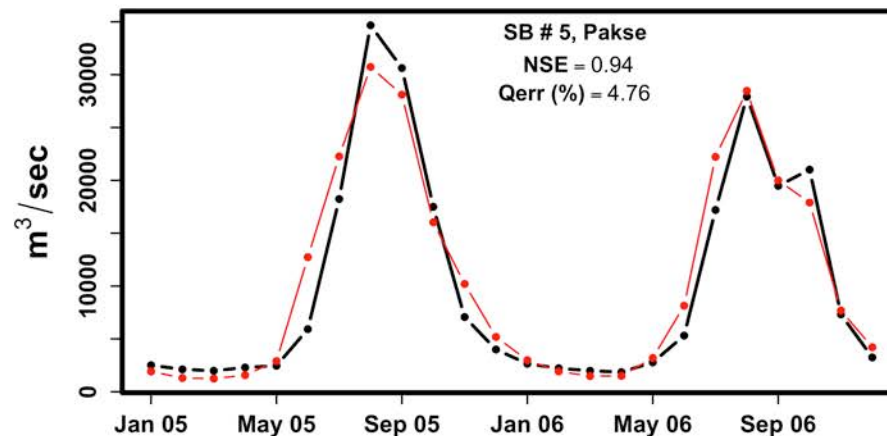
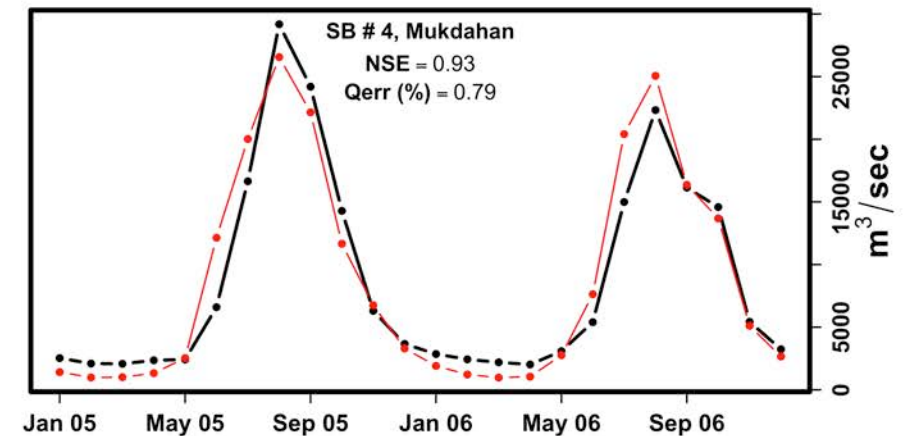
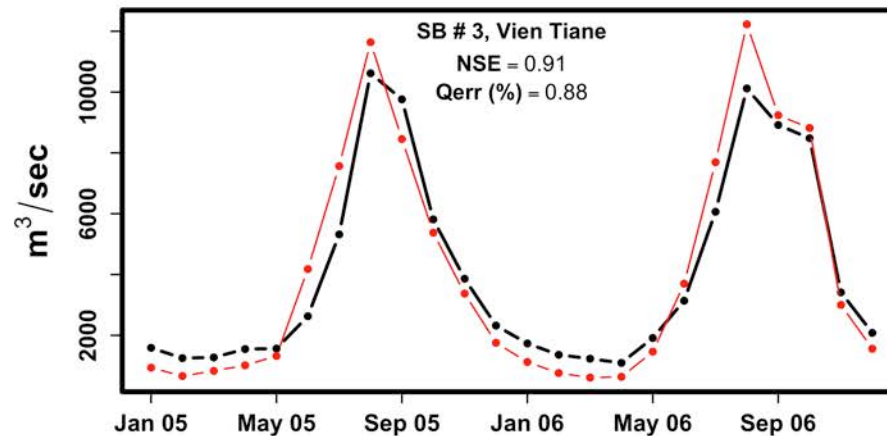
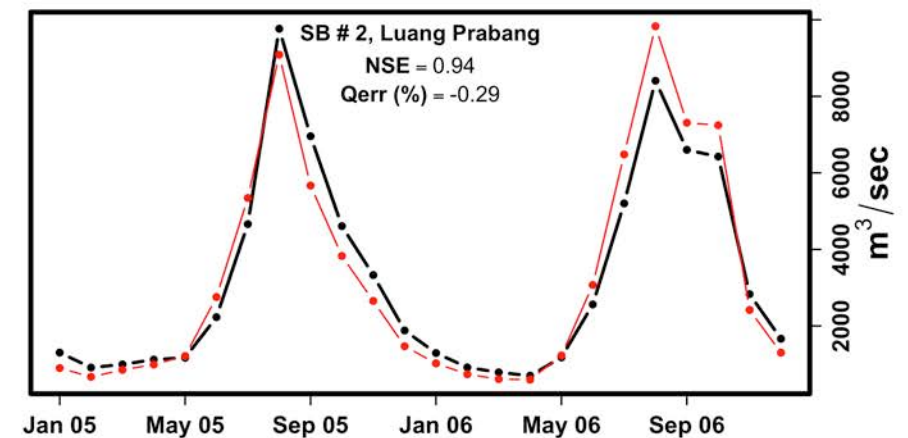
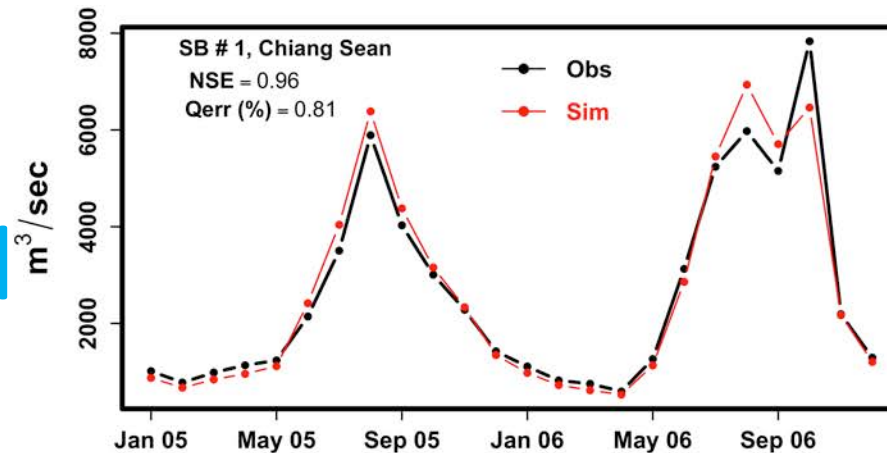
Sub-Basin	# of In-Situ Precipitation Stations
1	0
2	8
3	8
4	27
5	14
6	19
7	6
8	0



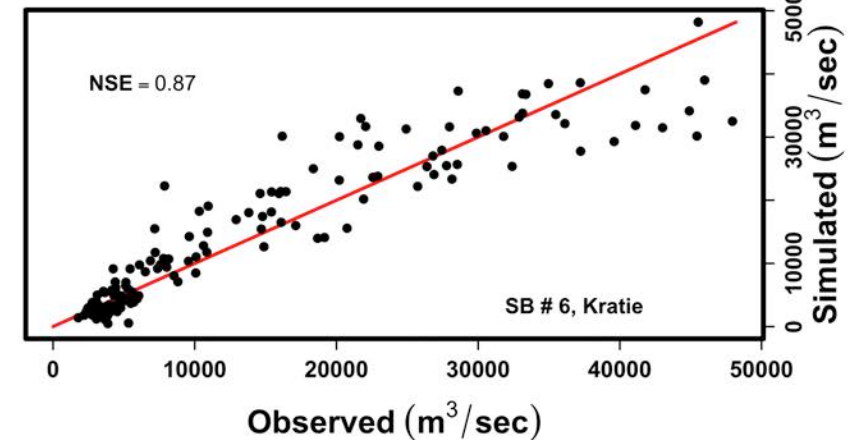
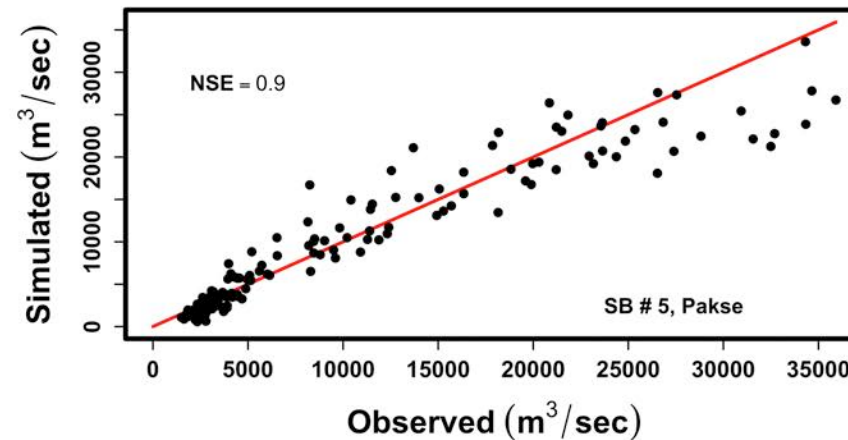
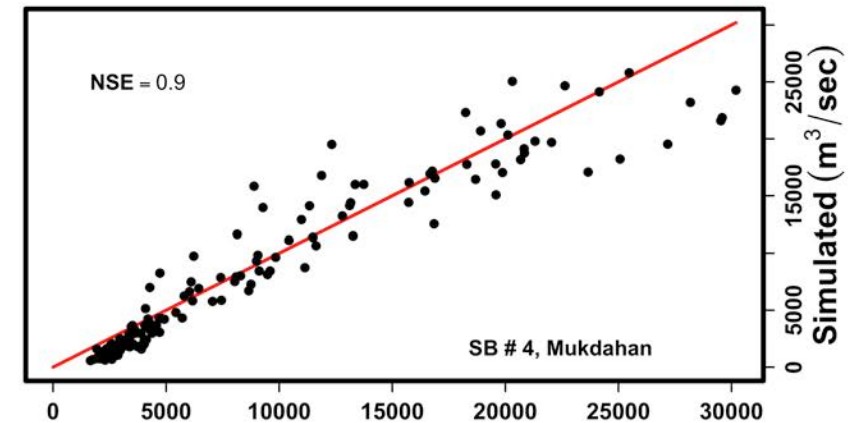
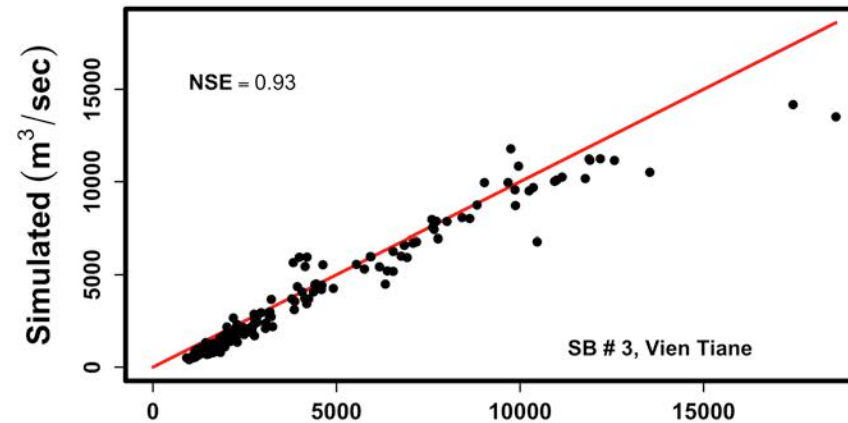
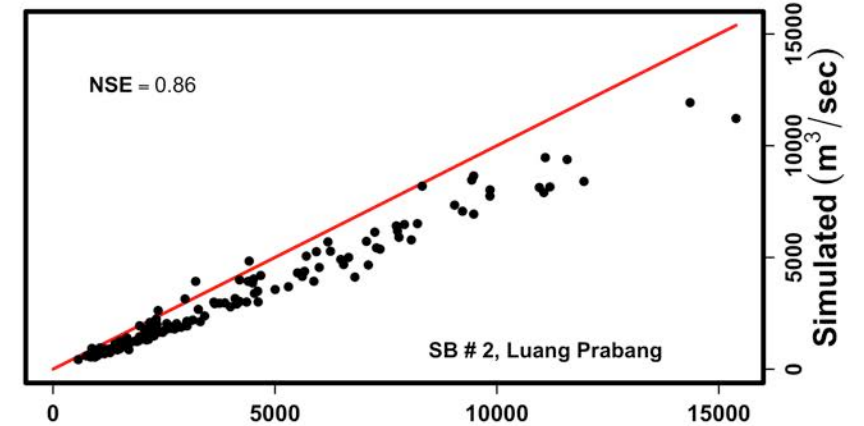
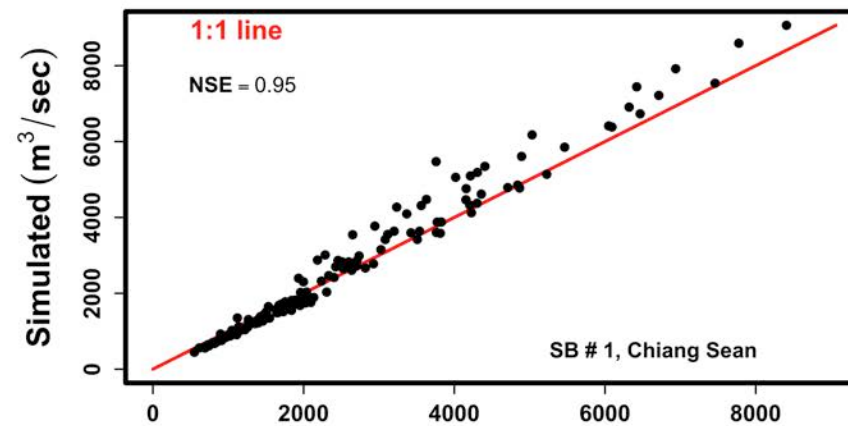


SWAT Model Streamflow Calibration

- Sequential Calibration from Upper Mekong inlet to Kratie, Cambodia



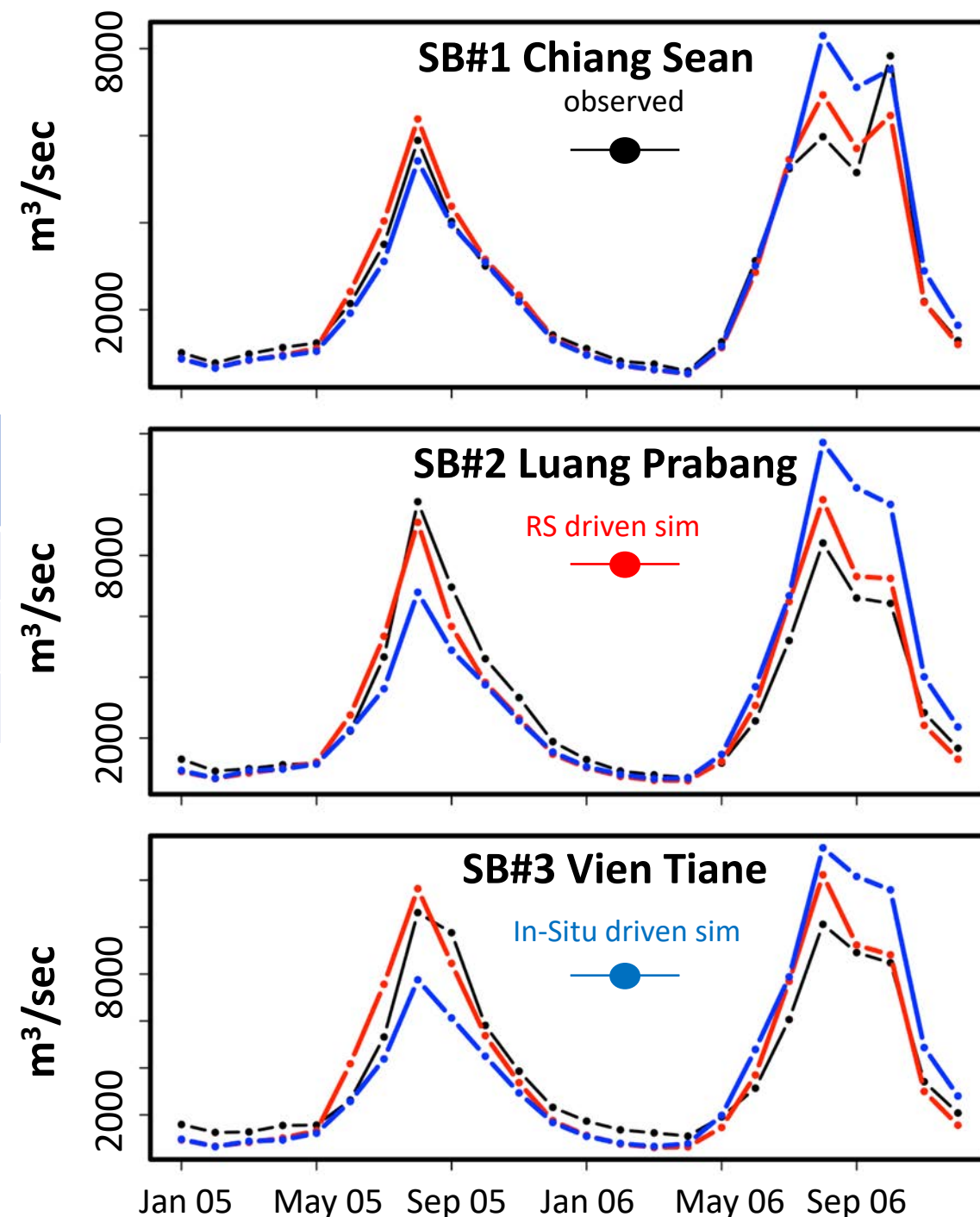
SWAT Model
verification
during 2001–
2004, and
2007–2015.

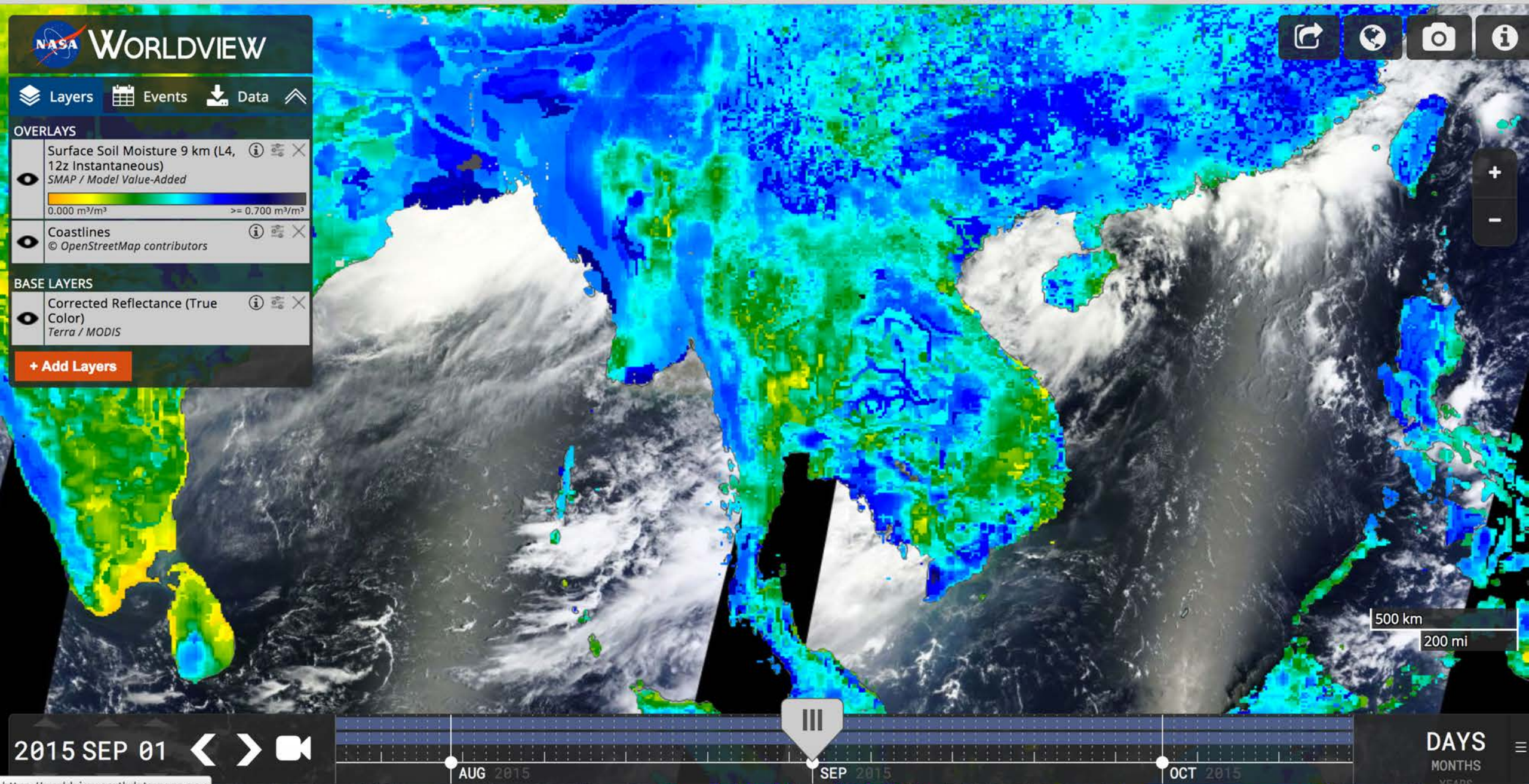


Remote Sensing and Gauge Driven SWAT models - Streamflow

Sub Basin #	NSE (RS Driven Model)	NSE (In-Situ Driven Model)
SB#1 Chiang Sean	0.96	0.89
SB#2 Luang Prabang	0.94	0.67
SB#3 Vien Tiane	0.91	0.72

Sub Basin #	Qerr % (RS Driven Model)	Qerr % (In-Situ Driven Model)
SB#1 Chiang Sean	0.81	3.76
SB#2 Luang Prabang	-0.29	7.18
SB#3 Vien Tiane	0.88	0.24

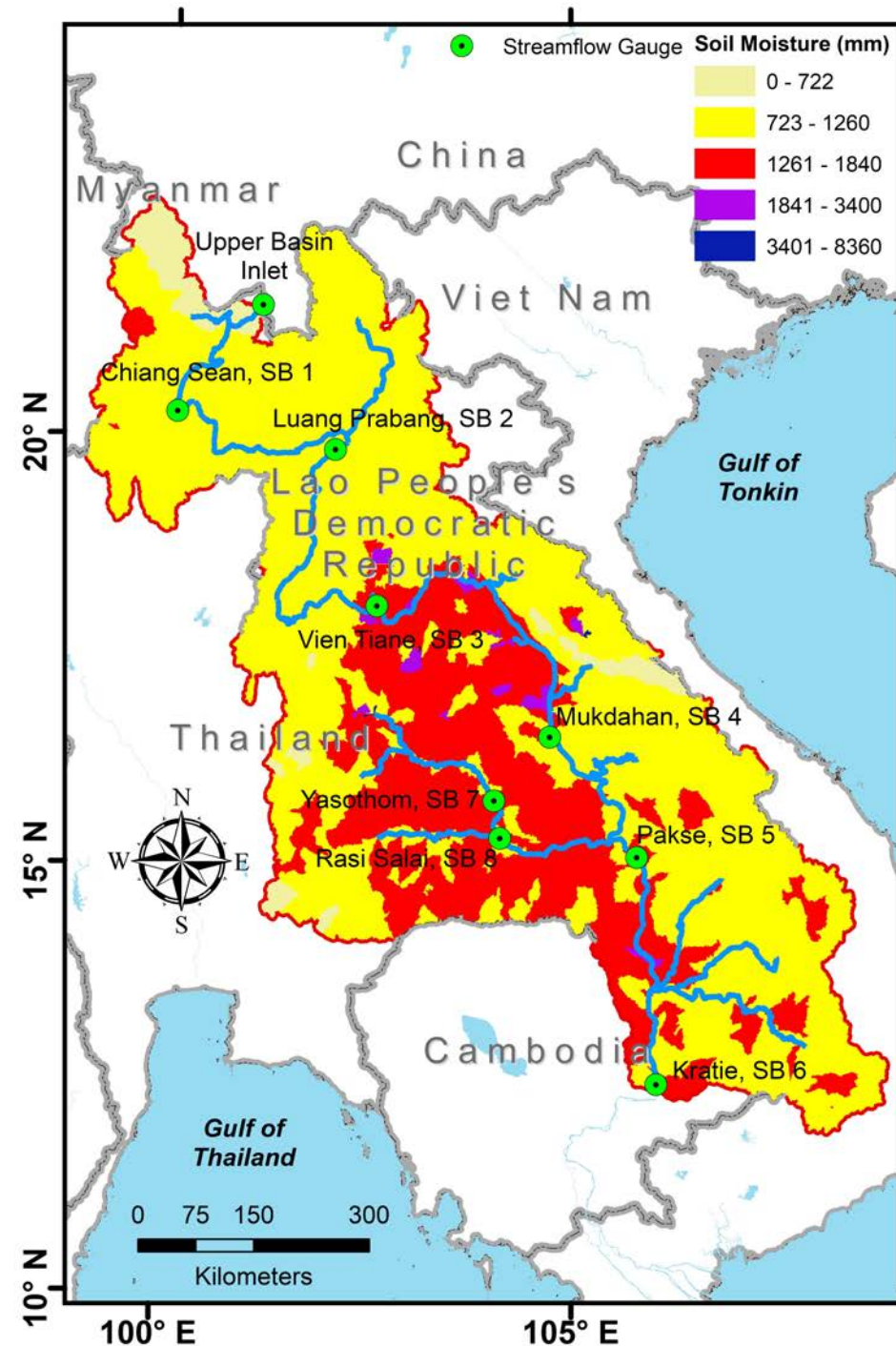




Surface Soil Moisture 9 km (L4, 12z Instantaneous, Model Value-Added) model-derived global surface soil moisture of the top 5 cm of the soil column in m³/m³ posted on a 9 km EASE-Grid 2.0.

Soil Moisture from SWAT

- **Soil water content in (mm).**
Amount of water in the soil profile at the end of 01 September 2015.
- Work is underway to evaluate SWAT soil moisture output at the top 5 cm/100 cm for better comparison with SMAP.



Summary and On going work!

- We developed the Lower Mekong River Basin (LMRB) model enabling the integration of satellite-based daily gridded precipitation, air temperature, digital elevation model, soil texture, and land cover and land use data.
- Remote sensing data showed promising modeling results when tested on the Mekong River Basin ($\sim 495,000 \text{ km}^2$ drainage area).
- We developed a tool (**nasaaccess, R package**) to retrieve and analyze Remote Sensing data for SWAT as well as other hydrological models.
- SMAP soil data give soil moisture at 5 cm (surface) or at 100 cm (root zone) while SWAT soil moisture output give soil moisture aggregated at the soil column. Work is underway to evaluate SWAT soil moisture output at the top 5 cm or at 100 cm soil depth for a better comparison.