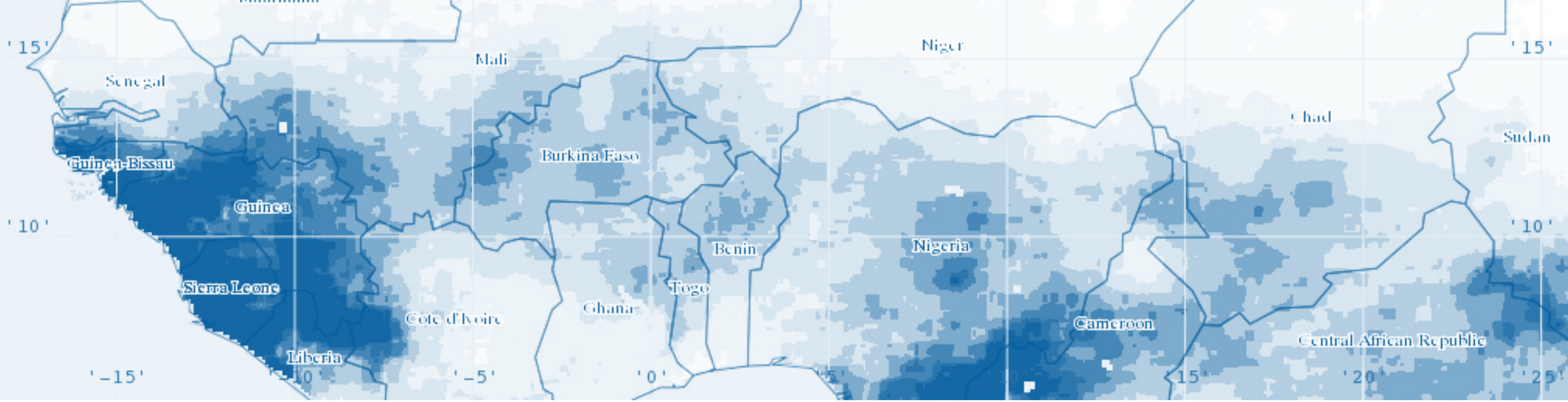

APPLICATIONS OF VIC FOR CLIMATE/ LAND COVER CHANGE IMPACTS

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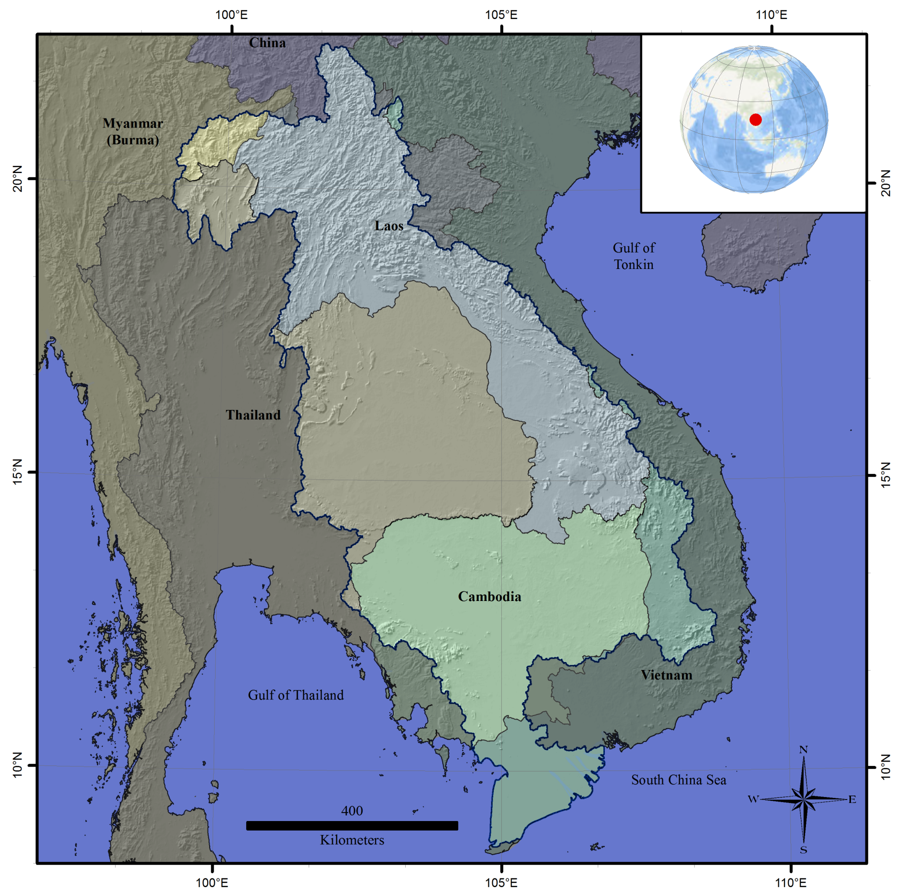
OUTLINE

- Introduction
- Research Question
- Data and Methods
  - Land Cover Change Model
  - Hydrologic Model
  - Analysis
- Results
- Conclusions

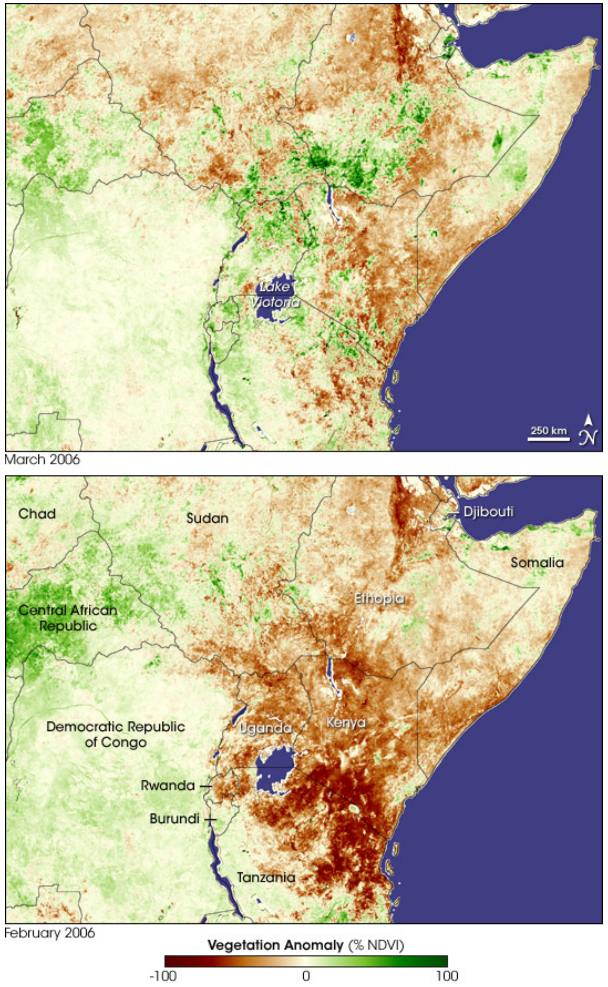
INTRODUCTION

- Study focuses on the Lower Mekong Basin (LMB)
- The LMB is an economically and ecologically important region
  - One of the largest exporters of rice and fish products [*Sakamoto et al.*, 2006; *Poulsen et al.*, 2002)
  - Within top three most biodiverse river basins in the world [*Dudgeon*, 2000]
- Natural climate variability plays an important role in water supply within the region
  - Short-term climate variability (ENSO, MJO)
  - Long-term climate variability (climate change)



INTRODUCTION

- Projections of climate change show there will be a decrease in water availability world wide which has implications for food security and ecology [*Mancosu, et al.*, 2015]
- Additional studies show there may be socioeconomic turmoil due to water wars and food security in developing regions such as the Mekong Basin [*Mainuddin et al*, 2011; *Peasrse-Smith*, 2012]



INTRODUCTION

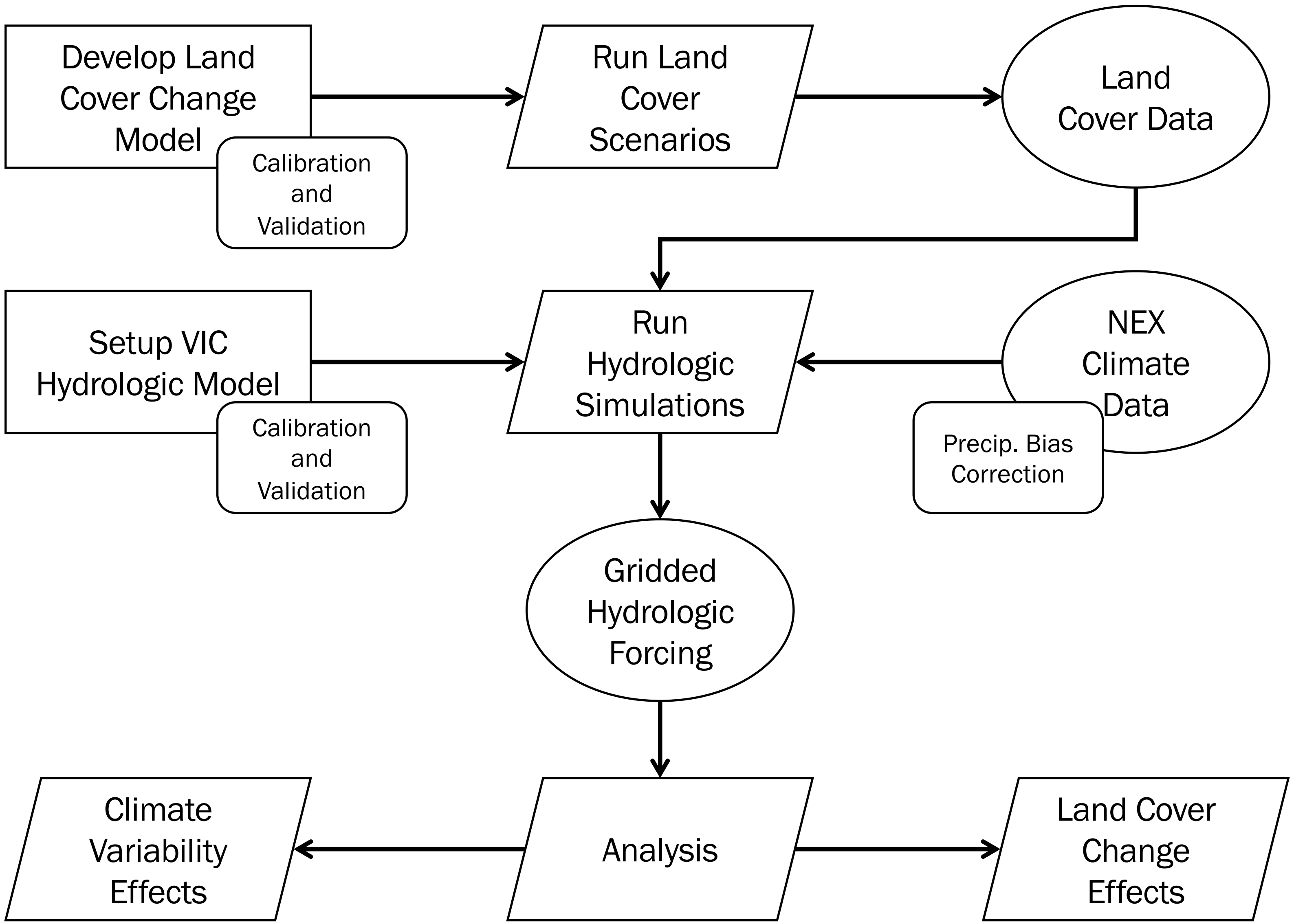
- Southeast Asia has experienced major changes in land use and land cover from 1980 – 2000 [*Fox & Vogler,* 2005]
  - Major economic reforms resulting in shift from subsistence farming to market-based agricultural production [*Rigg,* 2006]
- Changes in land cover continue to occur which have an important role within the land surface aspect of hydrology

Public domain photo

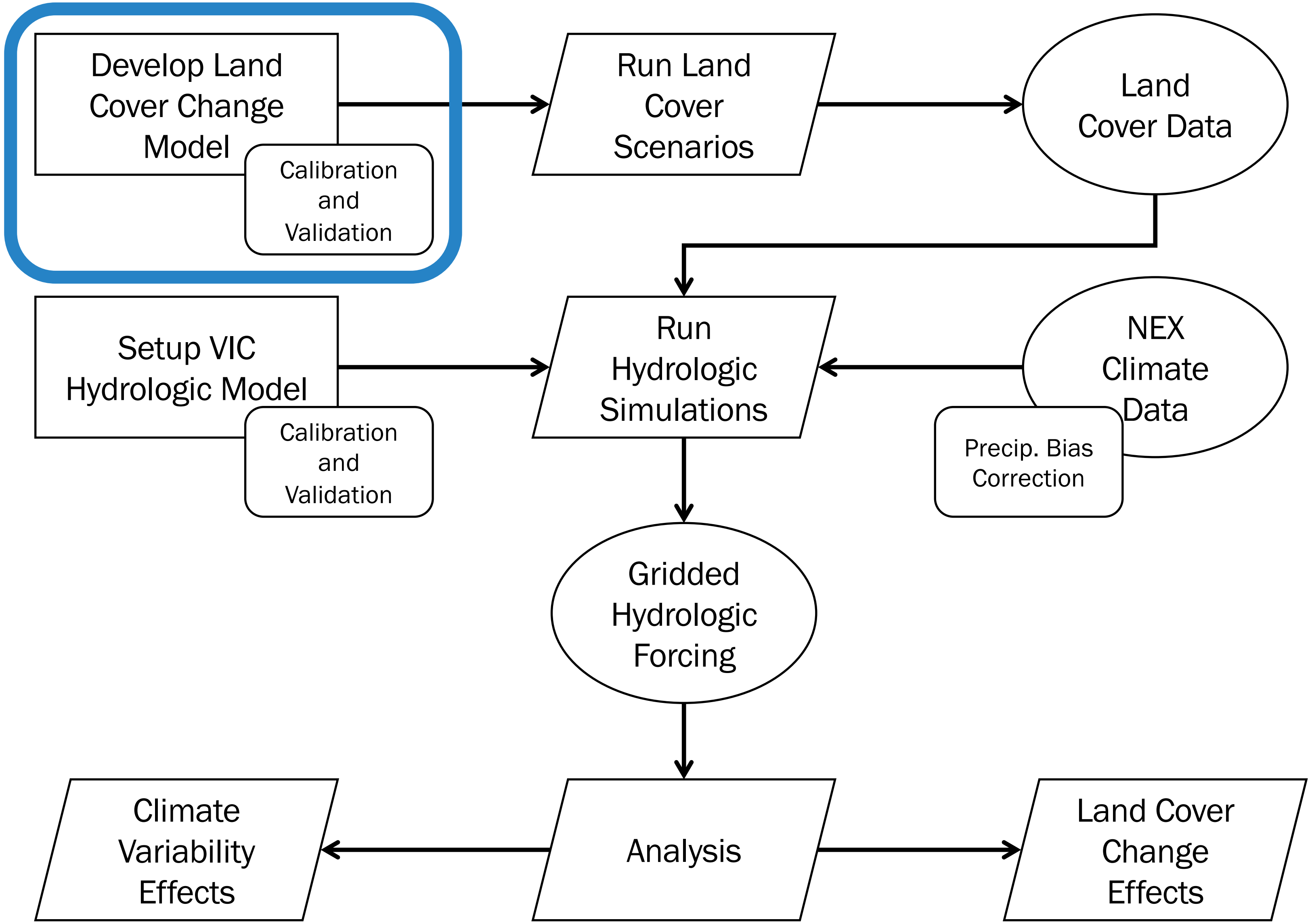
RESEARCH QUESTION

- *How will climate variability and land cover change affect the **spatial and temporal characteristics of the hydrological system** within the LMB?*
- Hypothesis:
  - Climate scenarios will result in decrease of water/streamflow with increased temperatures and changes in precipitation intensity and patterns
  - Increases in simulated agricultural land will yield increases in runoff (increases in forest land will yield decreases in runoff)
  - The system is more sensitive to climate variability than land cover change, as precipitation is a major driving force for hydrology

SERVIR

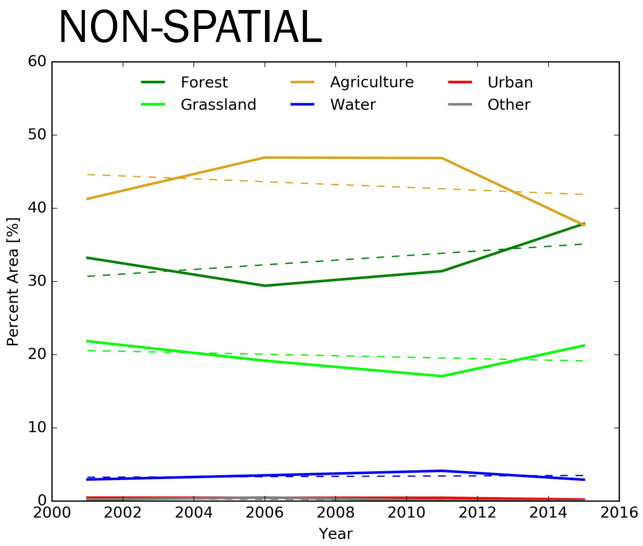

Develop Land Cover Change Model
Calibration and Validation
Run Land Cover Scenarios
Land Cover Data
Setup VIC Hydrologic Model
Calibration and Validation
Run Hydrologic Simulations
NEX Climate Data
Precip. Bias Correction
Gridded Hydrologic Forcing
Climate Variability Effects
Analysis
Land Cover Change Effects

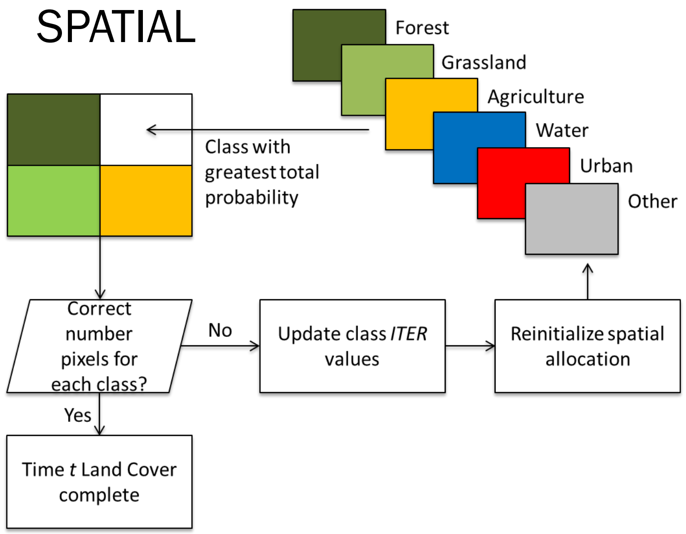
LAND COVER CHANGE MODEL



LAND COER CHANGE MODEL

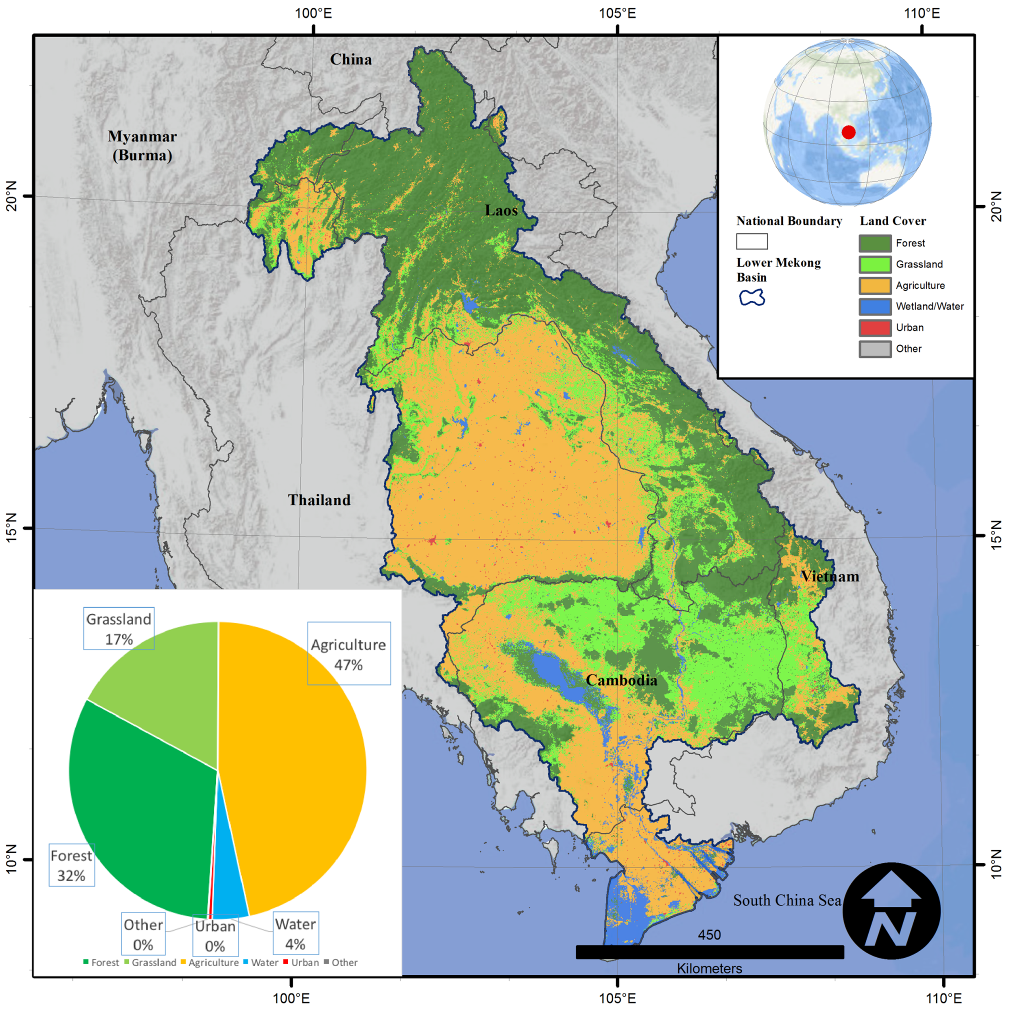
- Land cover change model is based on the CLUE-S model framework [*Verburg et al.*, 2002]
- The model contains two components to estimate land cover at a given place at a given time
  - Non-spatial component (demand for land cover type)
  - Spatial component (probability of land cover type and spatial allocation of land cover type)





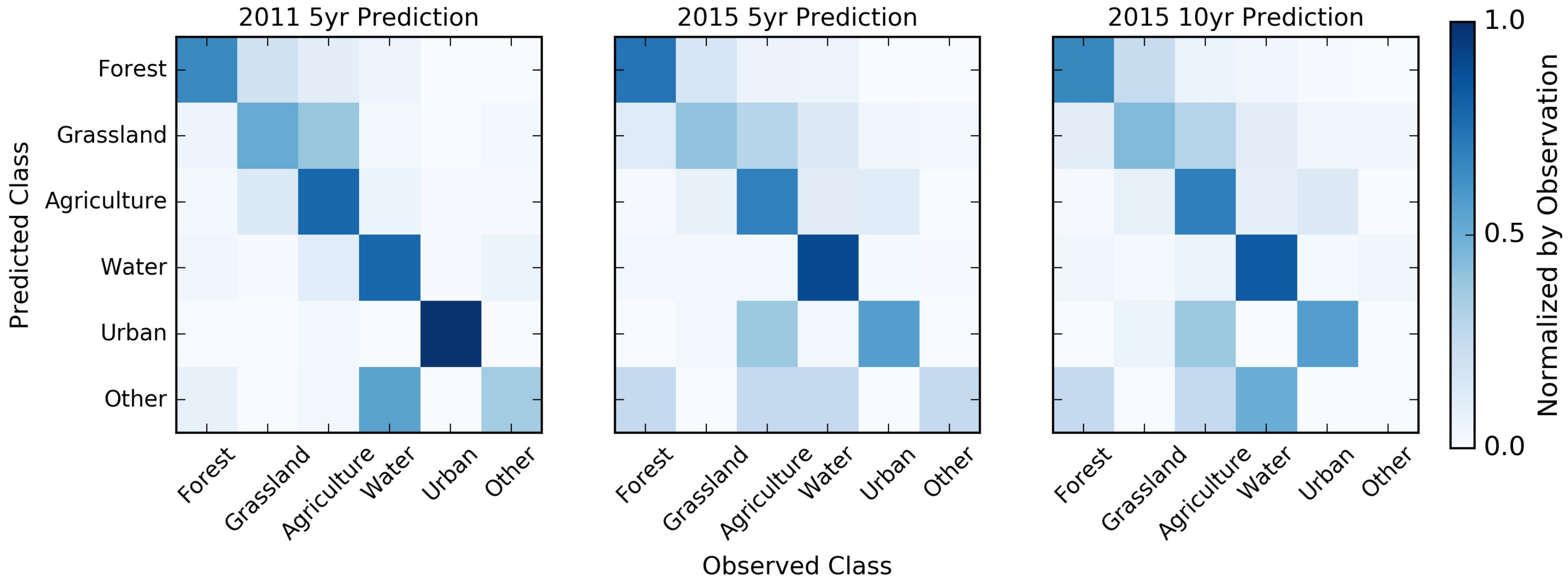
LAND COVER CHANGE MODEL

- Current model is based on six land cover classes from Intergovermental Panel on Climate Change (IPCC) land cover classification
  - Consistent with other climate modeling efforts
  - Limits the complexity of the modeling approach leading to fewer misclassifications



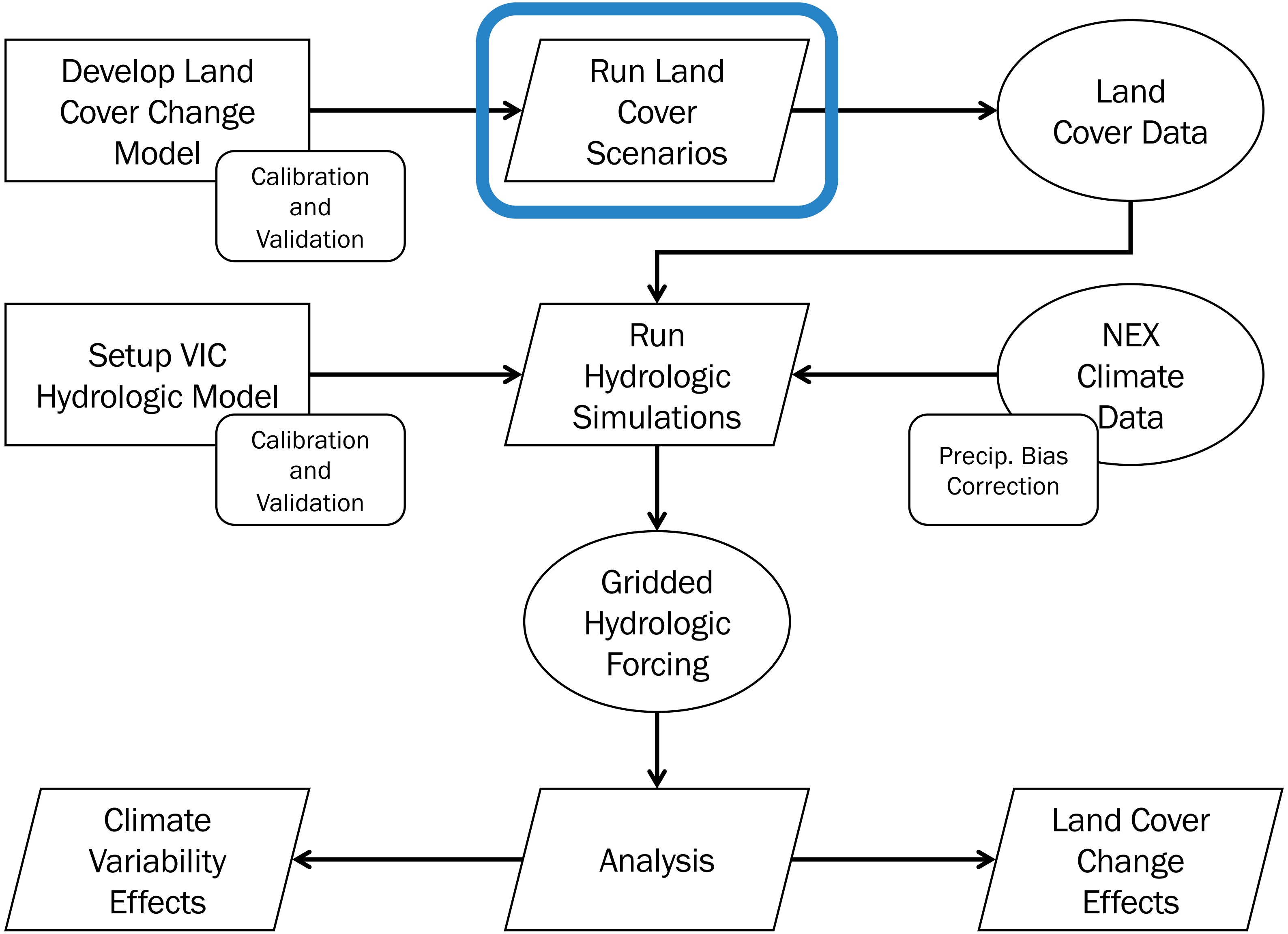
LAND COVER MODEL PERFORMANCE

- Stratified random sample to compare predicted vs observed land cover for 2011 and 2015 (n = 740)



Simulation Year	Overall Accuracy	Producer's Accuracy	User's Accuracy	Kappa Statistic
2011	71.95 %	68.00 %	70.61 %	0.64
2015 (5 yr.)	67.97 %	59.10 %	55.30 %	0.57
2015 (10 yr.)	66.08 %	53.40 %	51.32 %	0.55

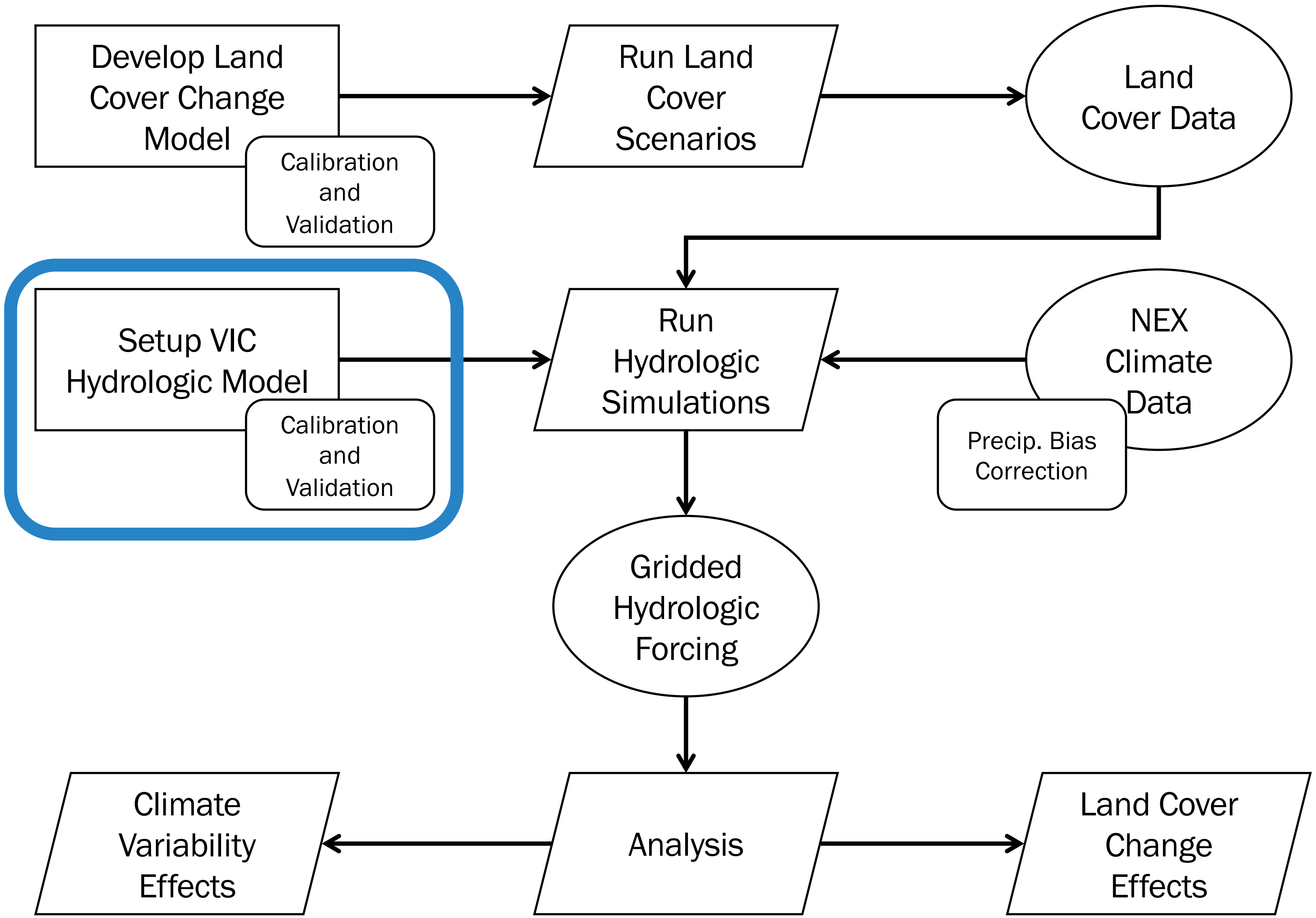
LAND COVER SIMULATIONS



LAND COVER SIMULATIONS

- Multiple land cover scenarios were simulated by altering the demand rates for individual classes
  1. Baseline scenario: all land cover demands used were from past trends
  2. Forest +5%: forest demand was set to increase by 5% each step, all other demands were from baseline
  3. Forest +10%: forest demand was set to increase by 10% each step, all other demands were from baseline
  4. Agriculture +5%: agriculture demand was set to increase by 5% each step, all other demands were from baseline
  5. Agriculture +10%: agriculture demand was set to increase by 10% each step, all other demands were from baseline

HYDROLOGIC MODEL

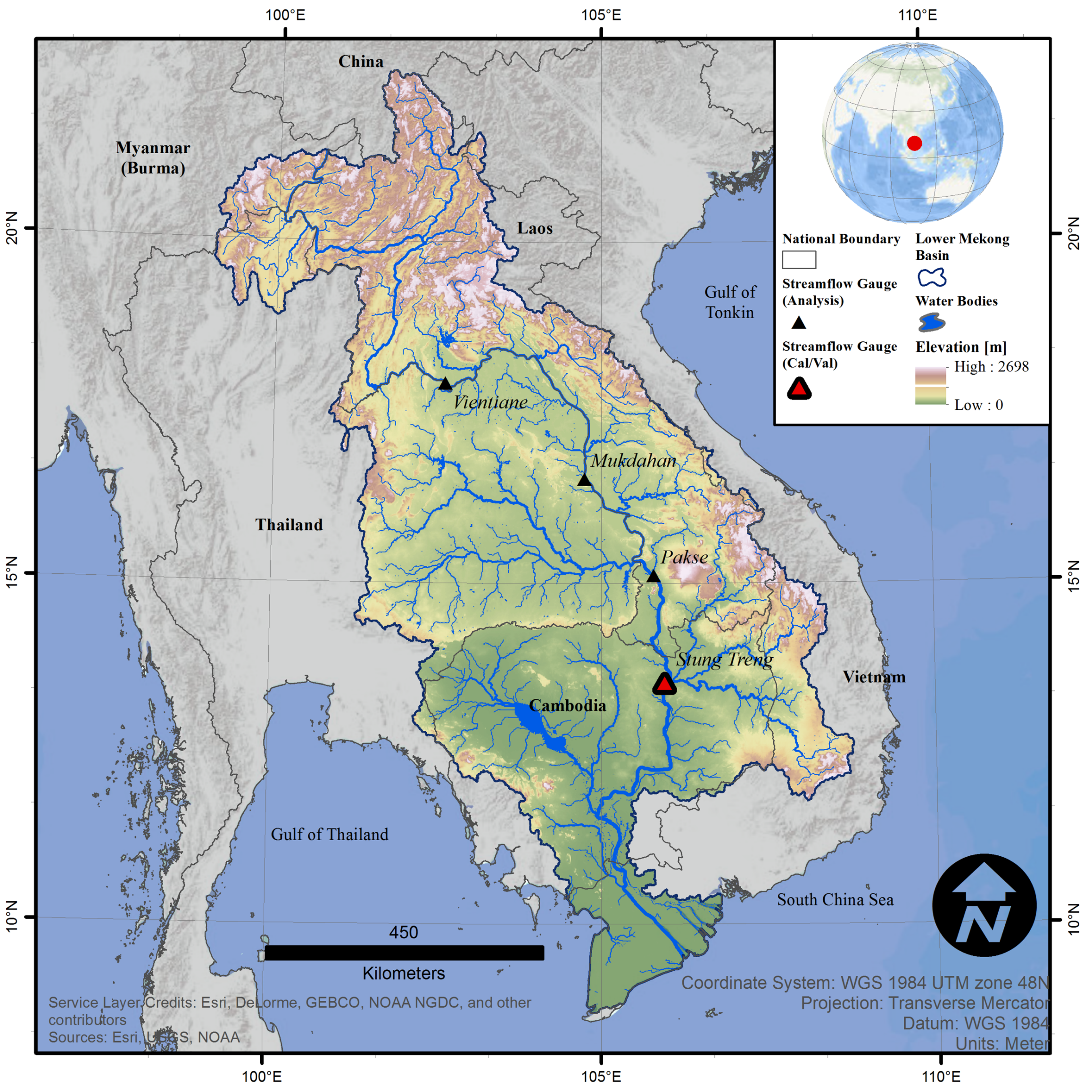


MODEL SETUP

- Simulations were run at 0.1° (~10 km) resolution for only the Lower Mekong Basin
- Data inputs are ERA-Interim Reanalysis and CHIRPS precipitation dataset
- Set one year model spin-up time and daily time step
- Used spatial variability in elevation and areal precipitation within a grid cell
  - More accurately simulates the effects of topographic variations within a grid cell
- Coupled with the streamflow routing model from *Lohmann et al.* [1996a,b]

CALIBRATION/VALIDATION

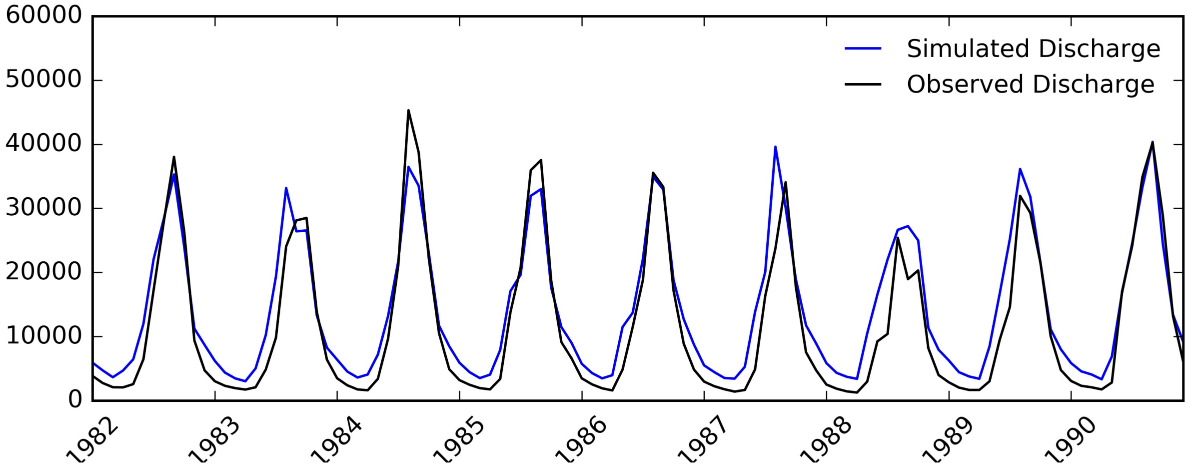
- Model was run for 1981-2010
  - Create a climatological dataset for the hydrology variables
- Calibrated/Validated model at Stung Treng station
  - Calibration period: 1981-1990
  - Validation period: 1991-2005
- Manual calibration

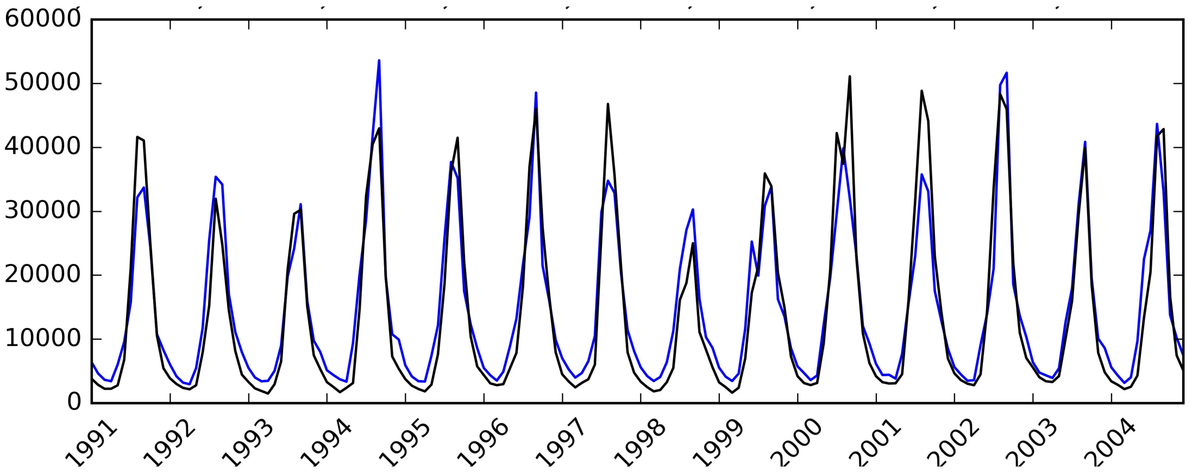


SIMULATION RESULTS

- Followed similar model accuracy guidelines as *Moriasi et al.* [2007]
- Model was found to perform very well for both periods

Statistic	R [-]	NSE [-]	PBIAS [%]	RSR [-]	MRE [%]
Calibration	0.96	**0.87**	-20.70	**0.28**	*68.13*
Validation	0.95	**0.89**	**-7.40**	**0.24**	*41.95*



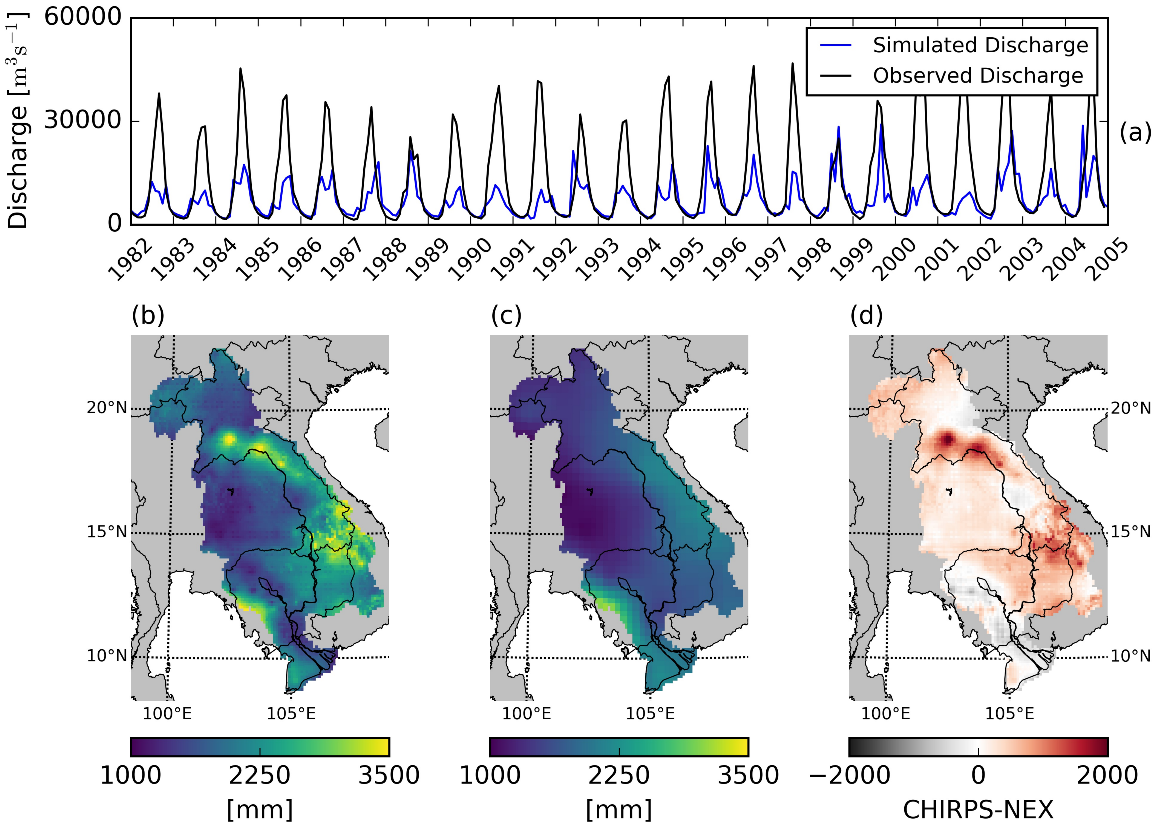


INPUT DATA UNCERTAINTY

- Model is calibrated with an observed dataset, however, a climate dataset is used to estimate the effects of climate variability on the LMB hydrology
- How much uncertainty is there when using the climate dataset as an input into the hydrologic model?
  - Simulated calibration and validations periods using the climate reanalysis dataset

INPUT DATA UNCERTAINTY

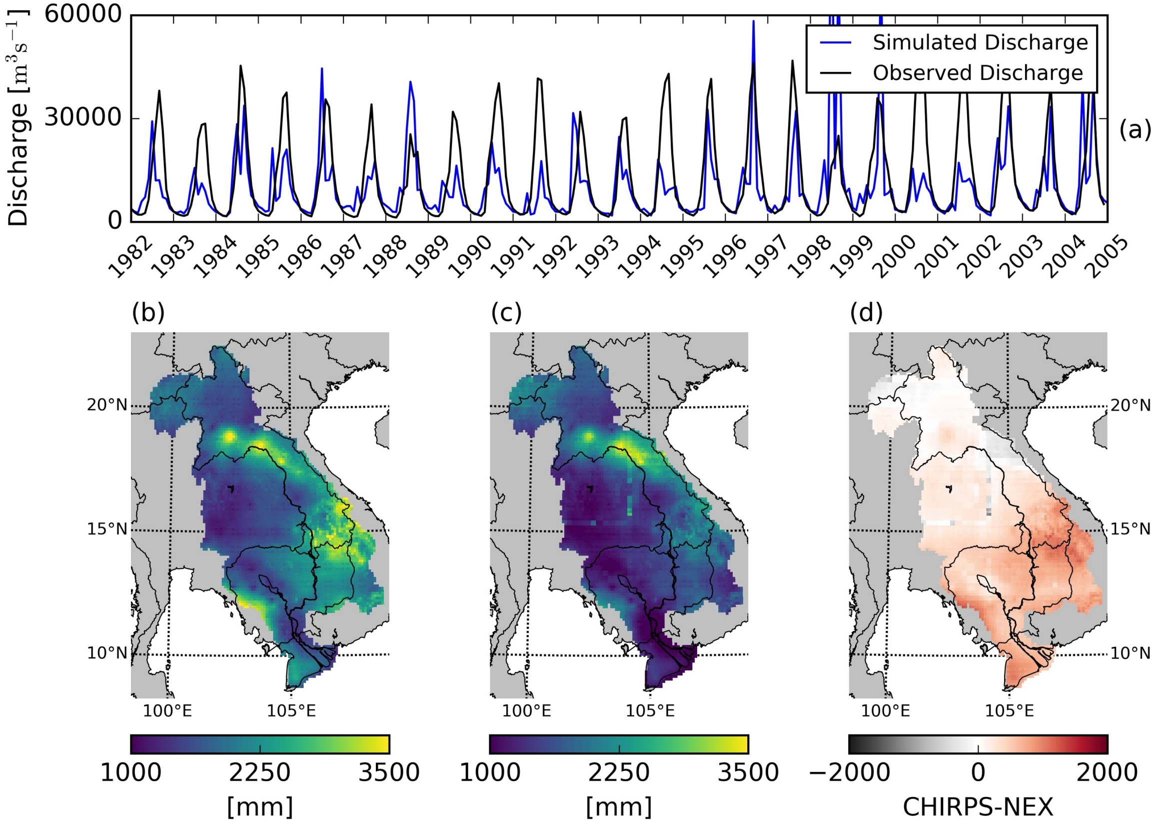
- The NEX climate reanalysis data greatly under predicts precipitation and consequently runoff
- Climate dataset is at a coarser resolution (0.25°) which fails to capture intense rainfall events [*Le et al.*, 2014]



Statistic	R [-]	NSE [-]	PBIAS [%]	RSR [-]	MRE [%]
Calibration	0.67	*0.17*	*-44.28*	0.55	*44.74*
Validation	0.57	*0.11*	*-45.05*	0.55	38.56

BIAS CORRECTION OF CLIMATE PRECIPITATION

- Used the power transformation bias correction technique [*Leander and Buishand*, 2007; *Leander et al.*, 2008]
  - Non-linear correction using an exponential form
- Slightly improved precipitation inputs
  - Results not as accurate as needed



Statistic	R [-]	NSE [-]	PBIAS [%]	RSR [-]	MRE [%]
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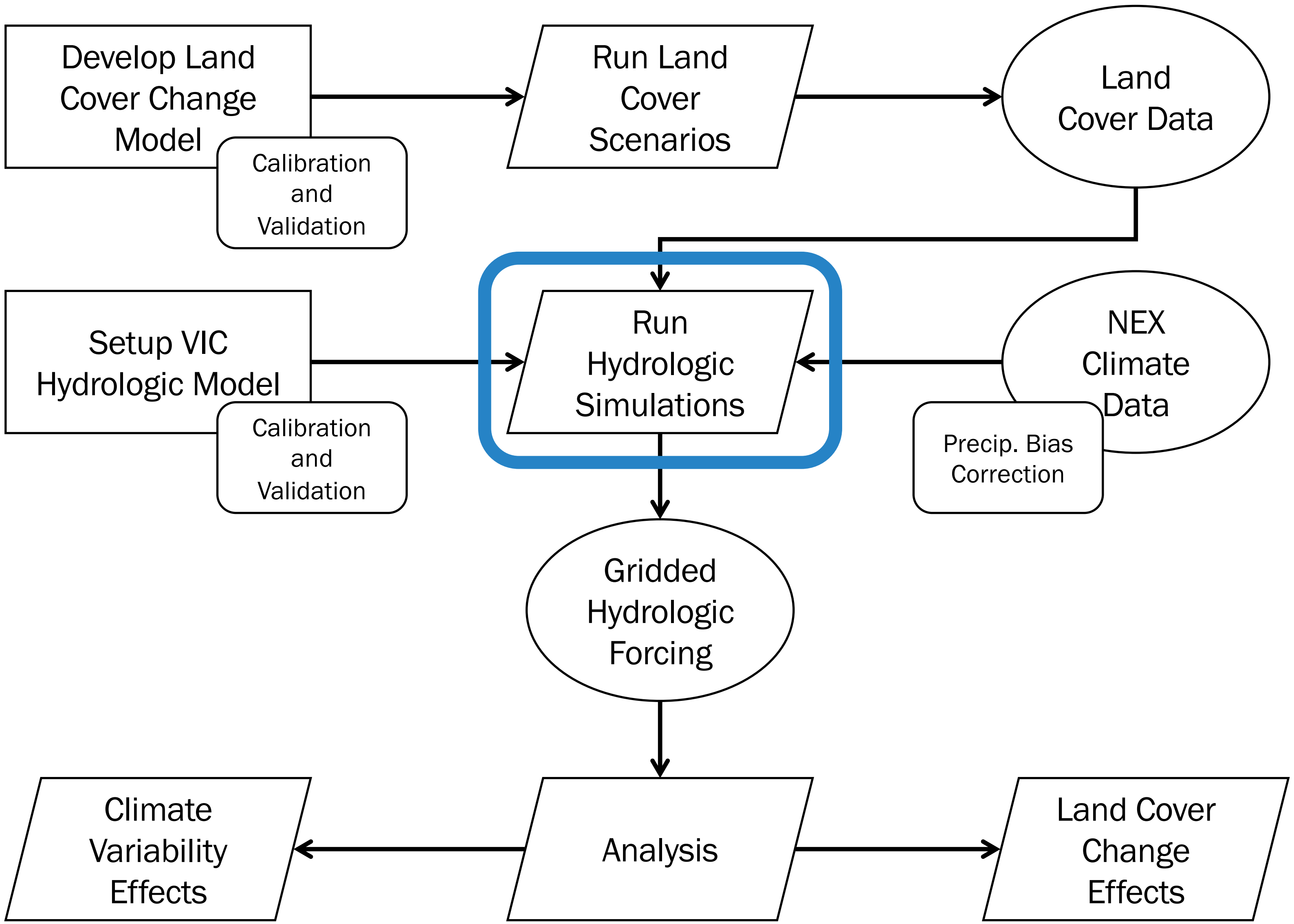
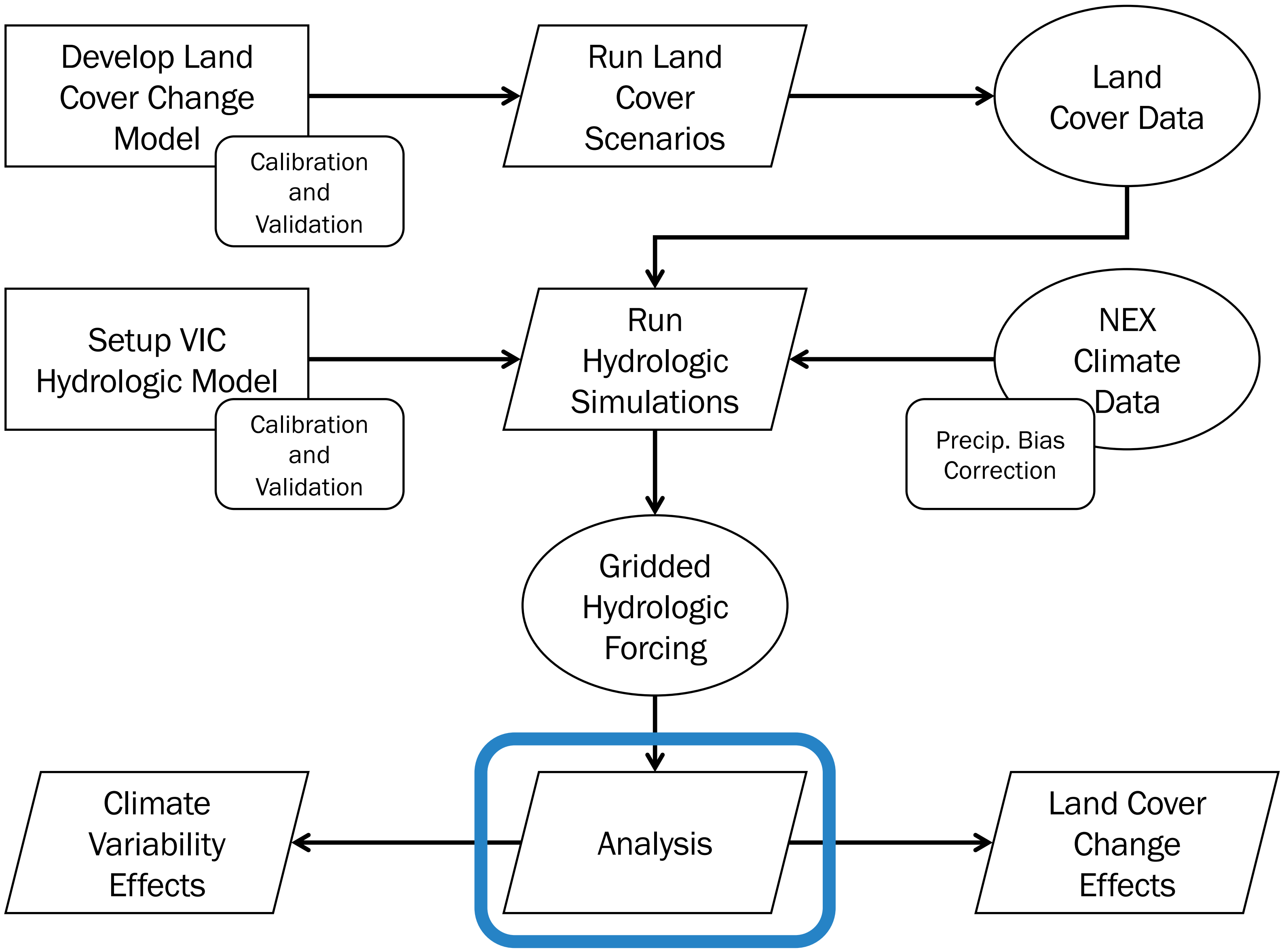
ERRORS AND UNCERTAINTIES



HYDROLOGIC SIMULATIONS

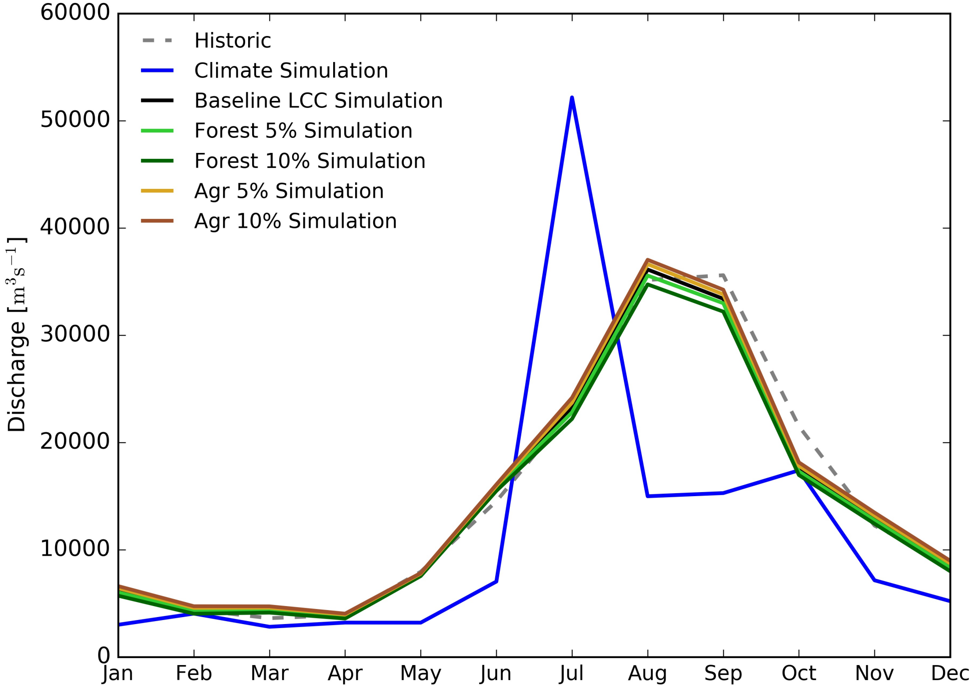
- Two sets of simulations were run for this study each changing a specific input in the hydrologic model
  1. Climate scenario: Simulation run with climate projection data. Land cover data for 2001 was kept constant
     - Both raw climate data and bias corrected data was analyzed
  2. Land cover scenario: Simulation run with land cover projection data. Metrological data for 2001 was kept constant
     - All land cover scenarios were used (baseline, forest +5%, forest +10%, agriculture +5%, and agriculture +10%)

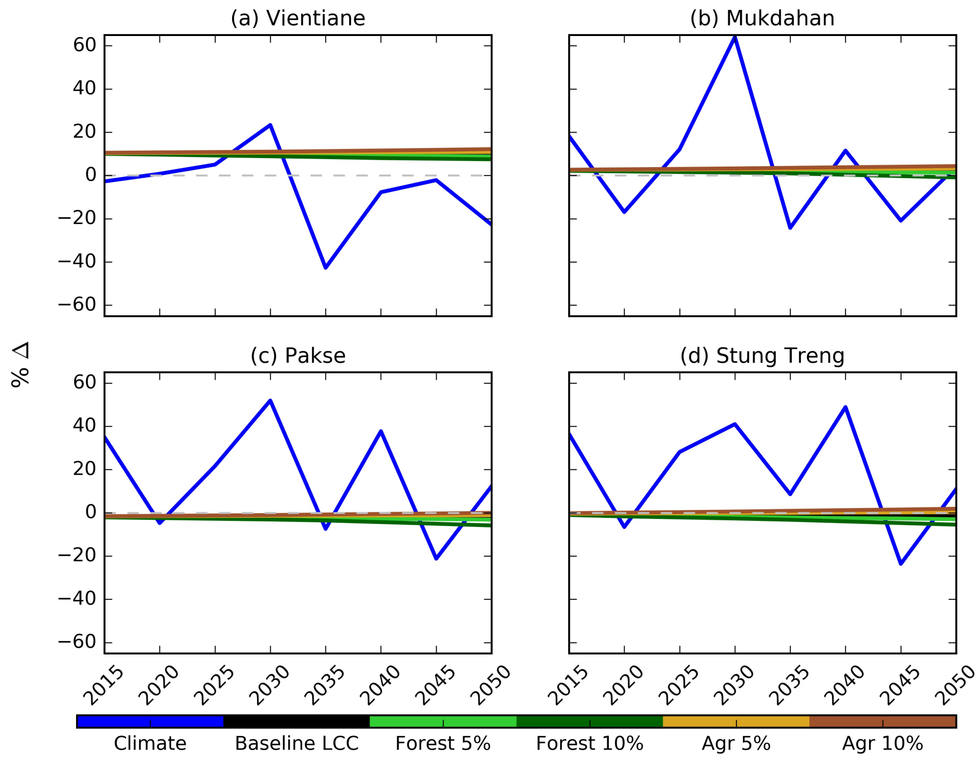
HYDROLOGIC CHANGE ANALYSIS



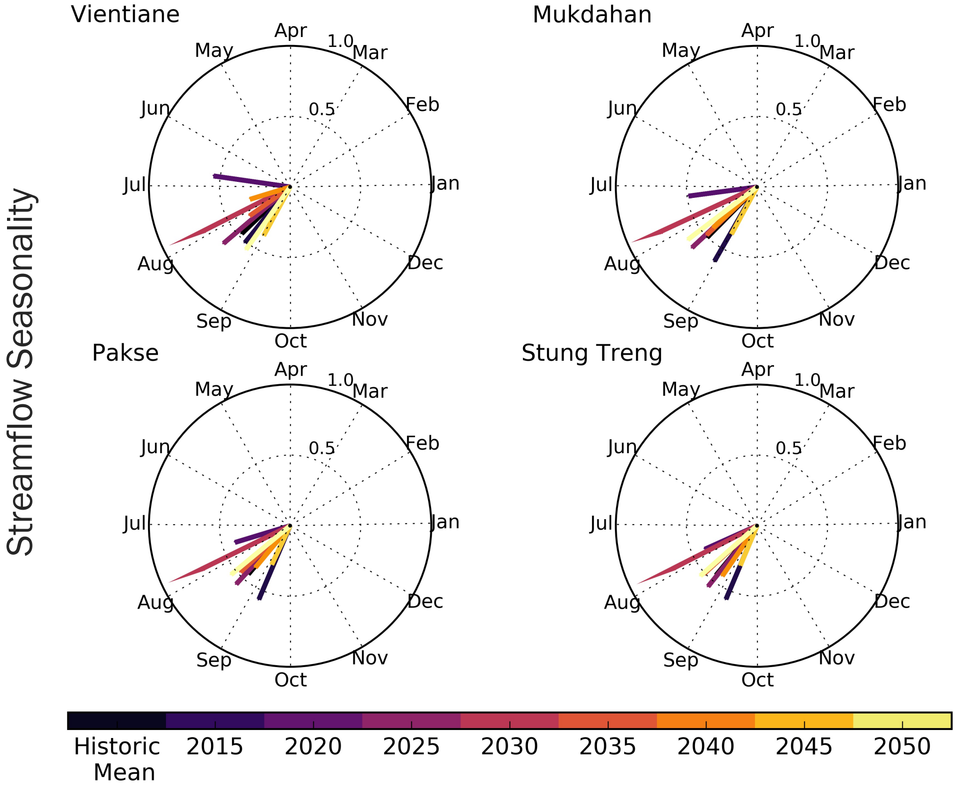
DISCHARGE CHANGES

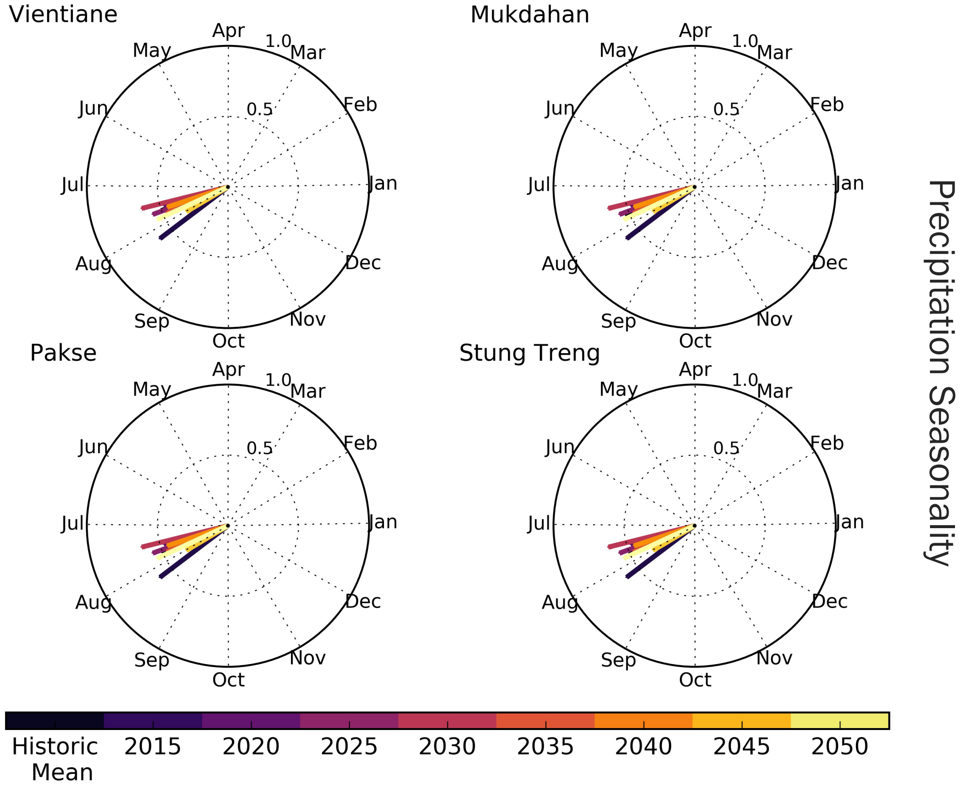
- Climate variability will make discharge inconsistent through time
- Land cover will only slightly alter discharge
  - Increase in forest results in decreases in discharge
  - Increase in agriculture results in increases in discharge





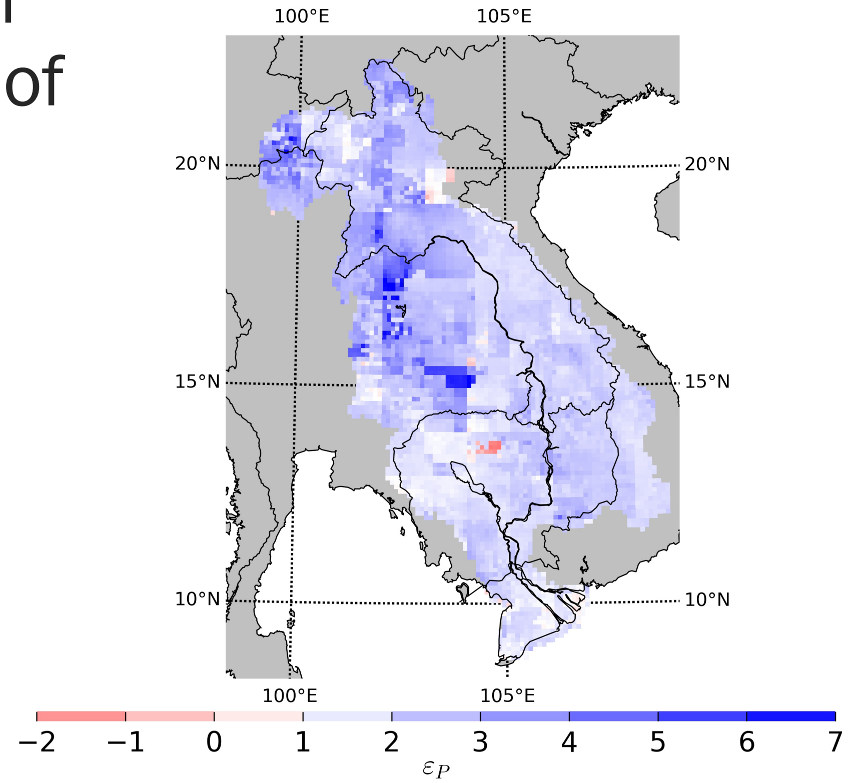
- Modeled streamflow shows greater variability in seasonality and intensity when compared to historic observations
- Precipitation seasonality shows less variability
  - Earlier dates for the peak season in both streamflow and precipitation

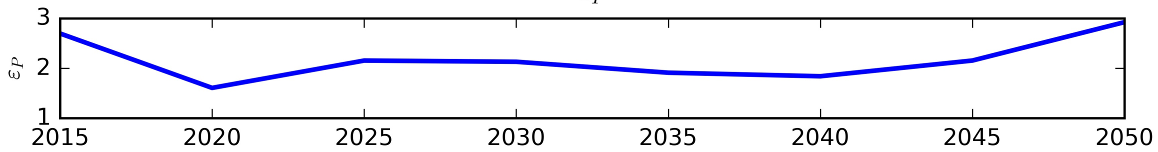




RUNOFF ELASTICITY

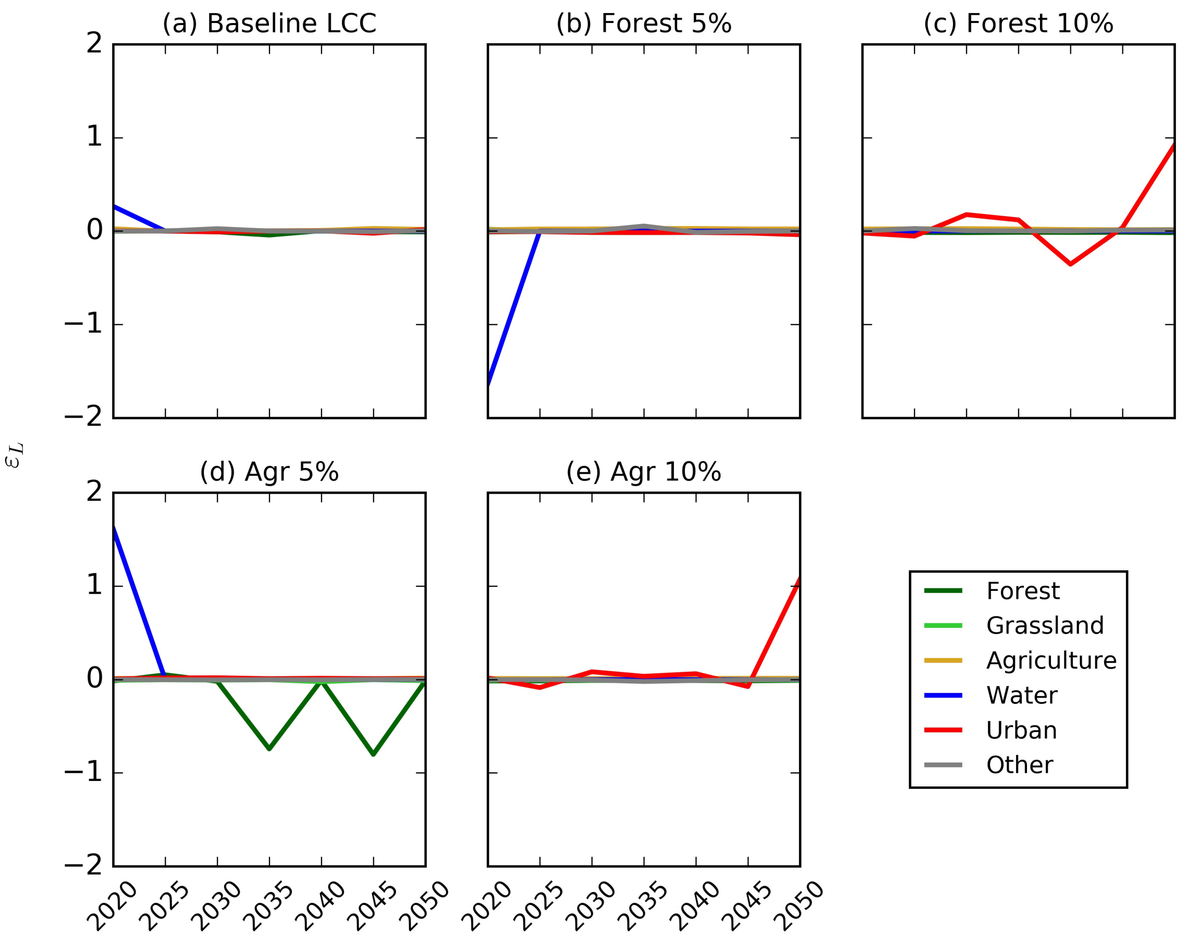
- Runoff elasticity analysis shows there will be increases in runoff with increases in precipitation throughout the basin
- There will be greater increases in runoff in the northern and western portions of the basin
- On average, runoff will increase about twice as much (~2% increase) compared to precipitation
  - Little variability throughout time





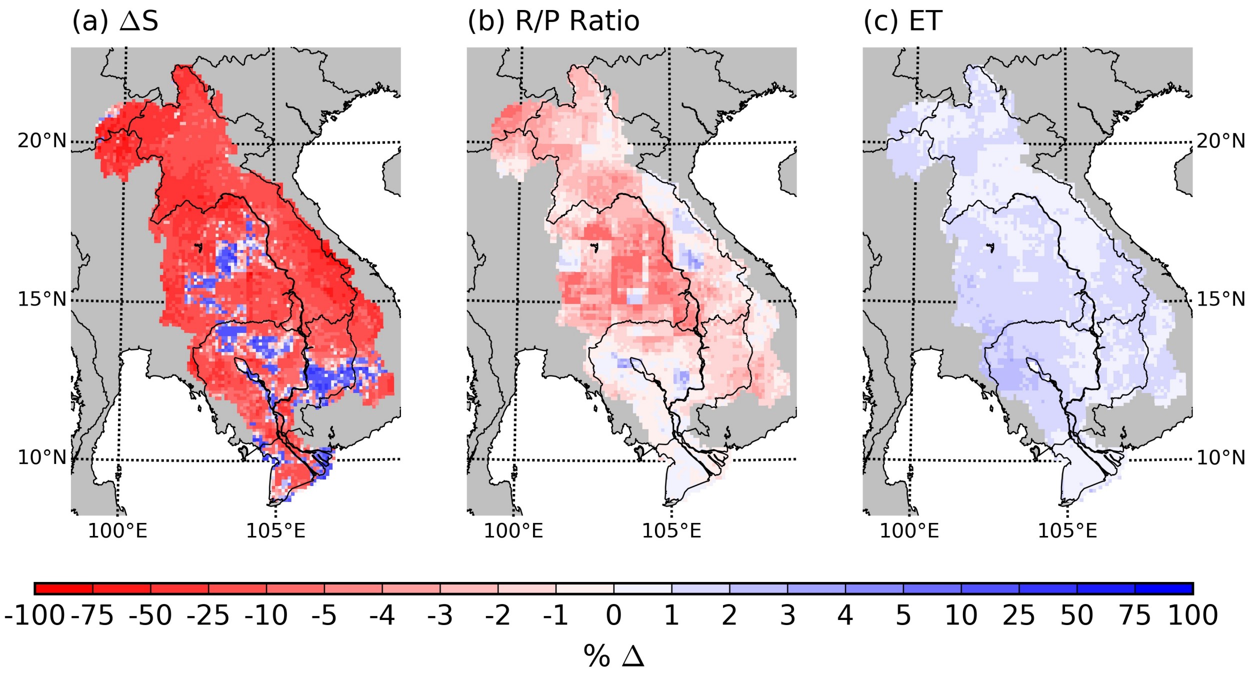
RUNOFF ELASTICITY

- Runoff will have almost no change when compared to changes in land cover classes
- Small changes occur for urban, forest, and water classes
  - These changes are so small (< 1%) that they will have minimal effects on the environment



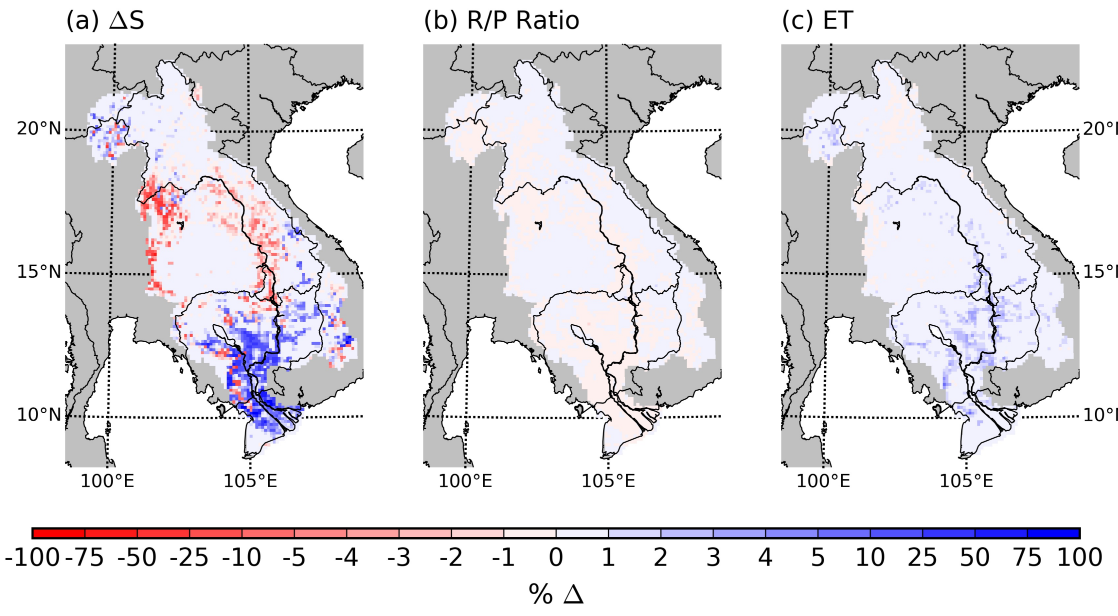
SPATIAL TRENDS

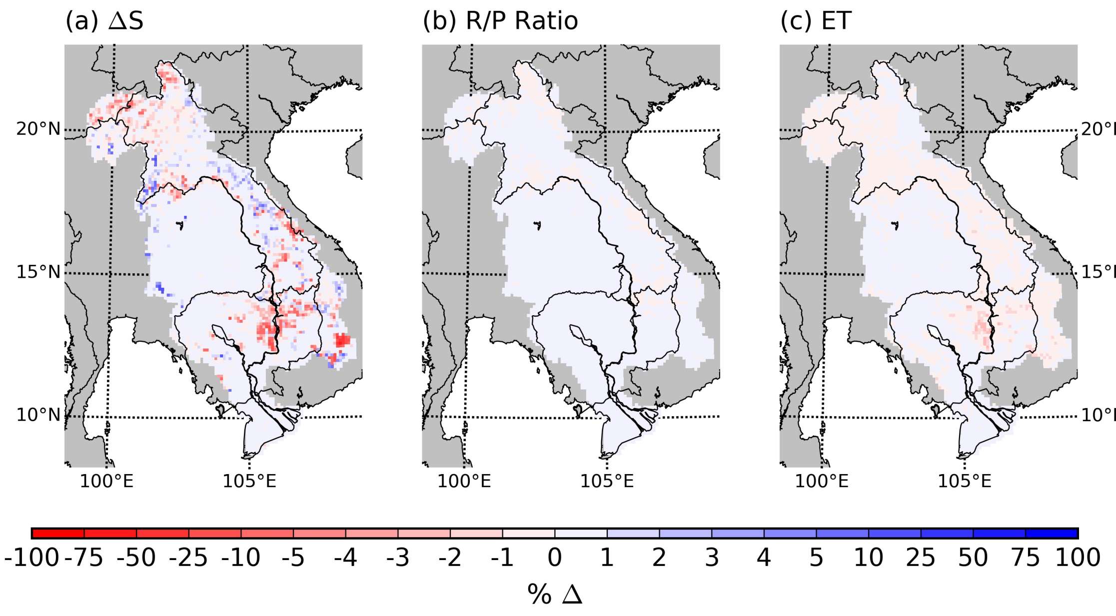
- Water storage shows a decreasing trend across the majority of the basin due to climate variability
  - Less water stored in soil and trees
- There is a decreasing trend in the runoff/precipitation (R/P) ratio
  - Lower percent of precipitation contributing to runoff
- Small increasing trend in evapotranspiration



SPATIAL TRENDS

- Small scale changes in water storage due to land cover change
  - Increase due to increases in forest, decrease due to increase in agriculture
- Little changes in evapotranspiration due to land cover change
- Almost no changes in the amount of precipitation that is converted to runoff





DECISION MAKING CONTEXT

- Study has the possibility of providing information and data can be used by water resource managers to form new policies
  - Fits into water resource framework by characterizing status as is and simulating what will happened due to changes
- Need to have extremely accurate data inputs and calibrations for accurate actionable information
- By providing this information, decision makers can have a understanding of policy changes on the effect of hydrology
  - For example: reforestation policy can lead to a decrease in streamflow
- Information from this study has too much uncertainty for accurate decision making

CONCLUSIONS

- This study was conducted to investigate the spatial and temporal changes to the LMB hydrologic system due to climate variability and land cover change
- A calibrated and validated land cover change model and hydrologic model along with a large hydrologic dataset is a result from work
- Future work will have implications for long-term water resource management
  - More accurate climate and land cover data inputs can improve results
  - Basin wide policy can be formulated to help promote development during changes in the system

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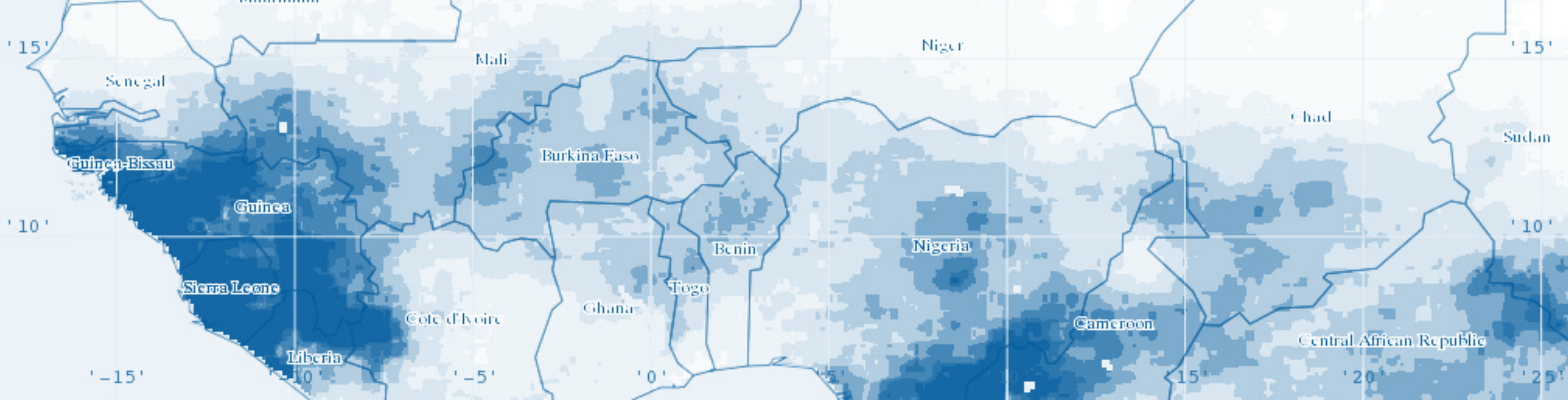

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