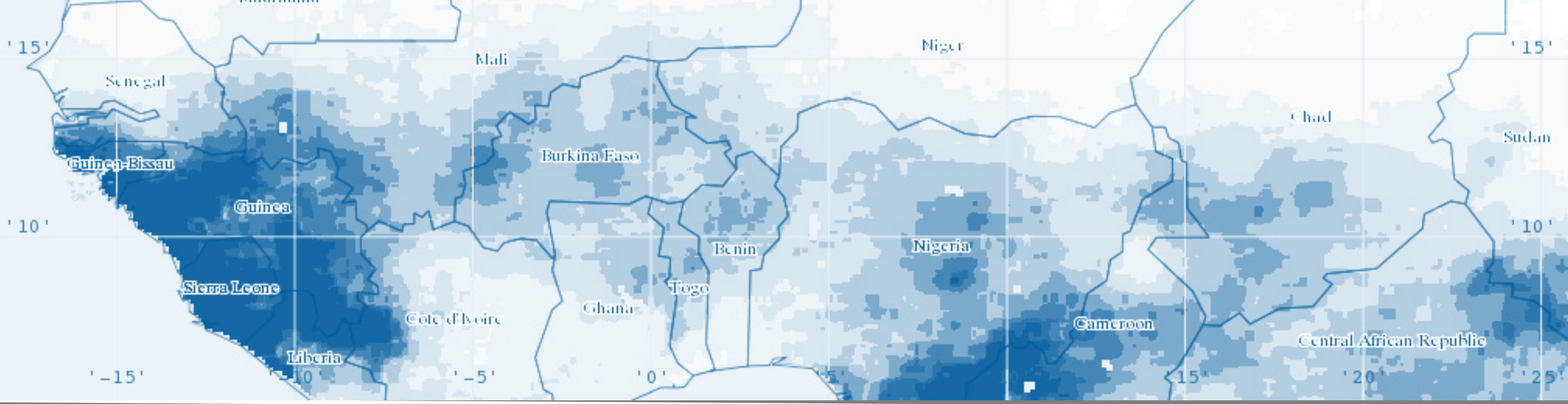

APPLICATIONS OF VIC FOR CLIMATE/ LAND COVER CHANGE IMPACTS

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VIC/BCSPP Training

Huntsville, AL

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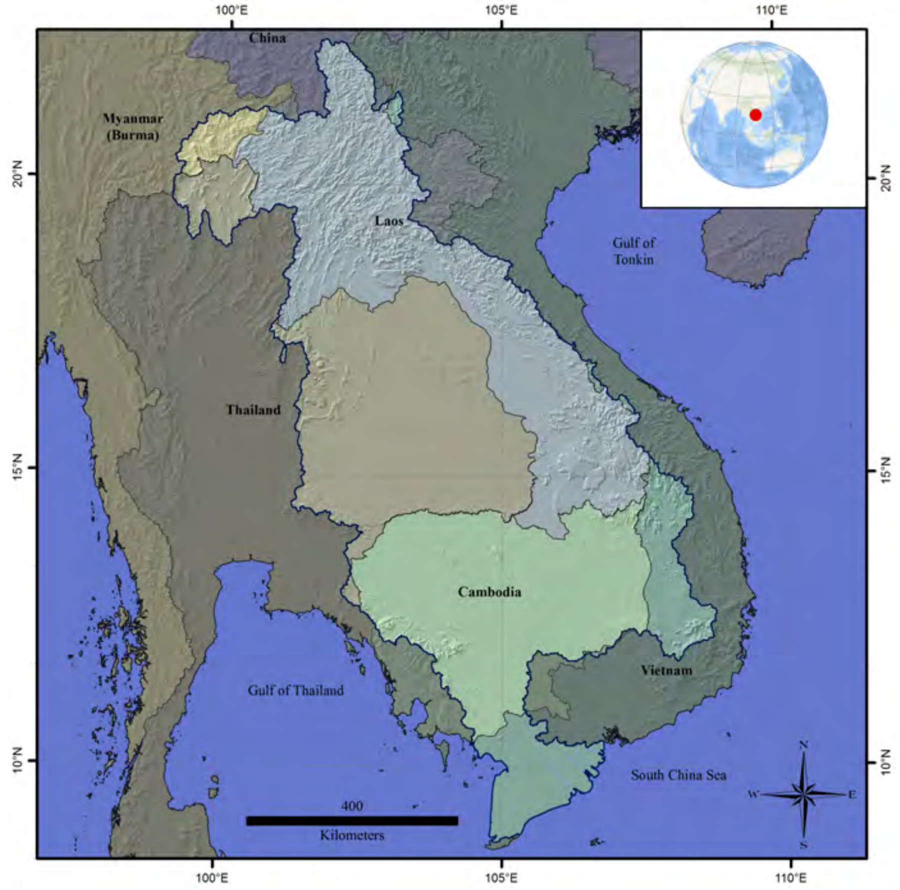
OUTLINE

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

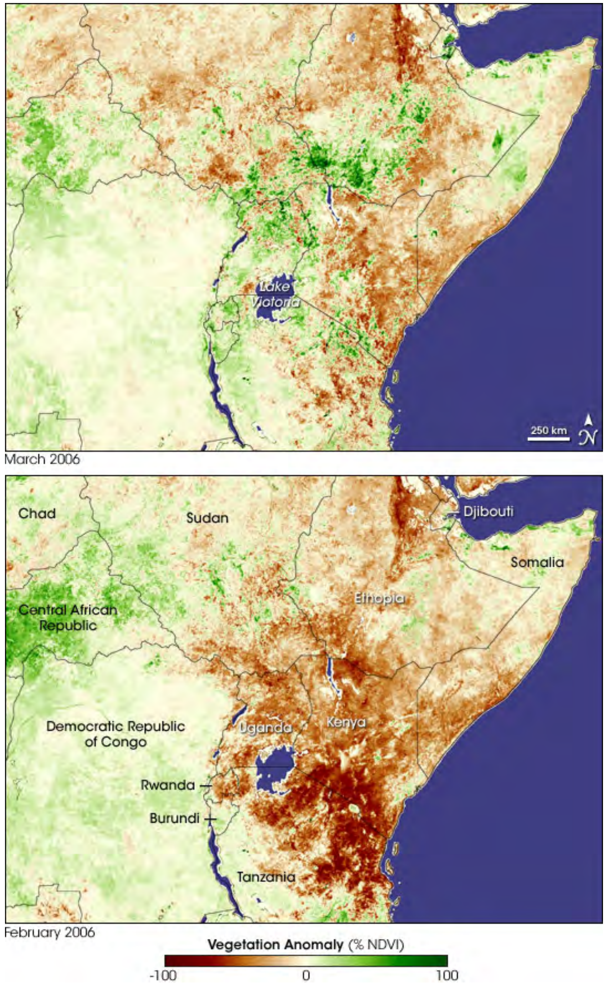
INTRODUCTION

- 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

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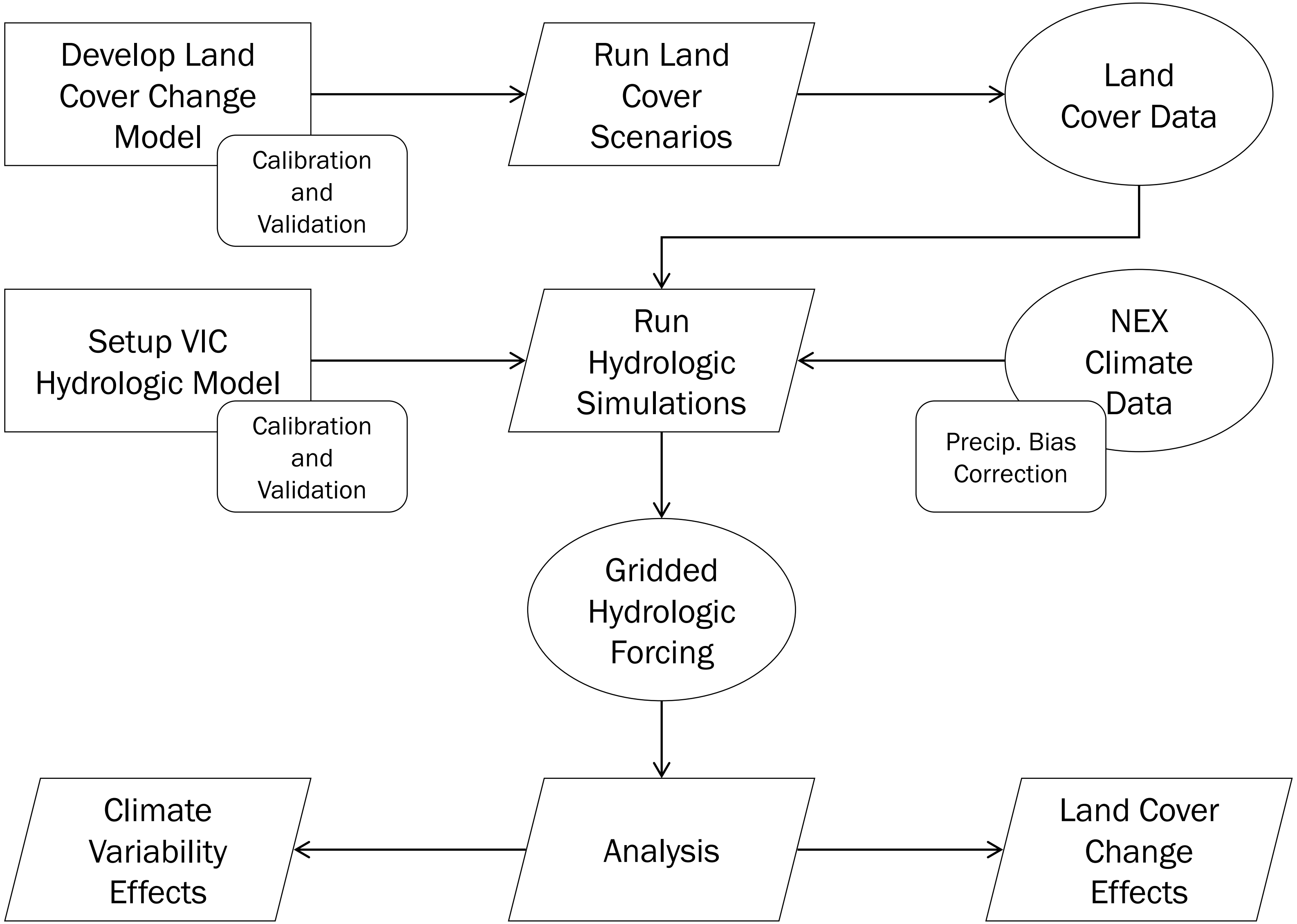
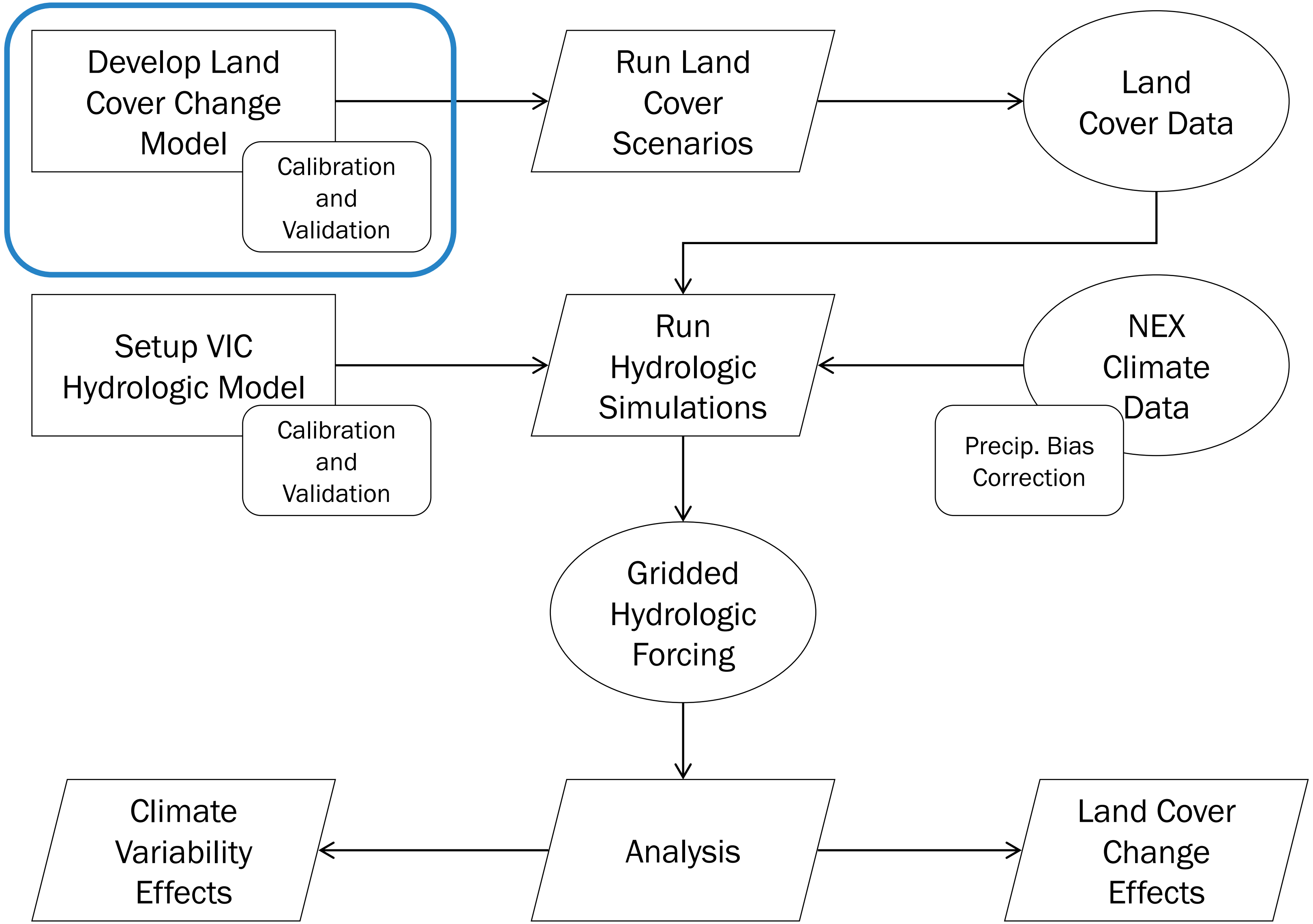
RESEARCH QUESTION

- *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

RESEARCH OUTLINE



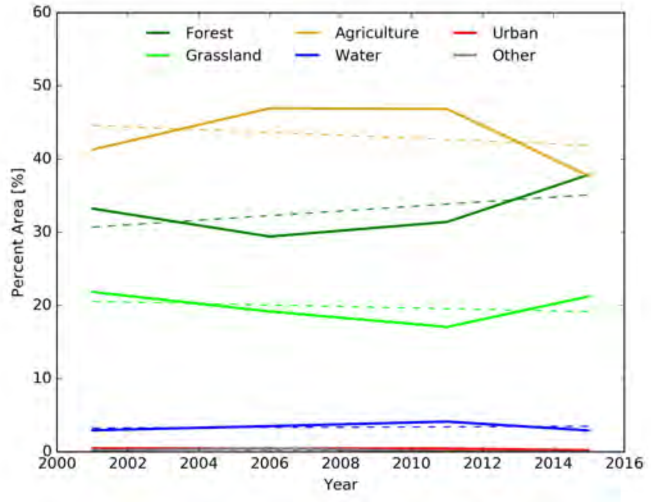
LAND COVER CHANGE MODEL



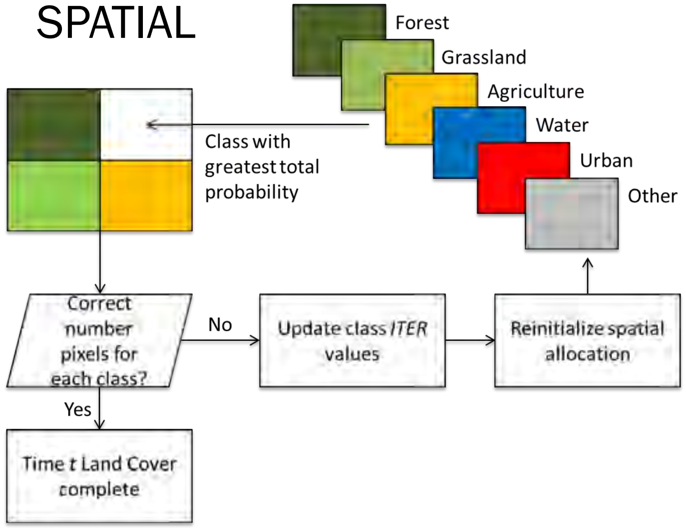
LAND COER CHANGE MODEL

- 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)

NON-SPATIAL

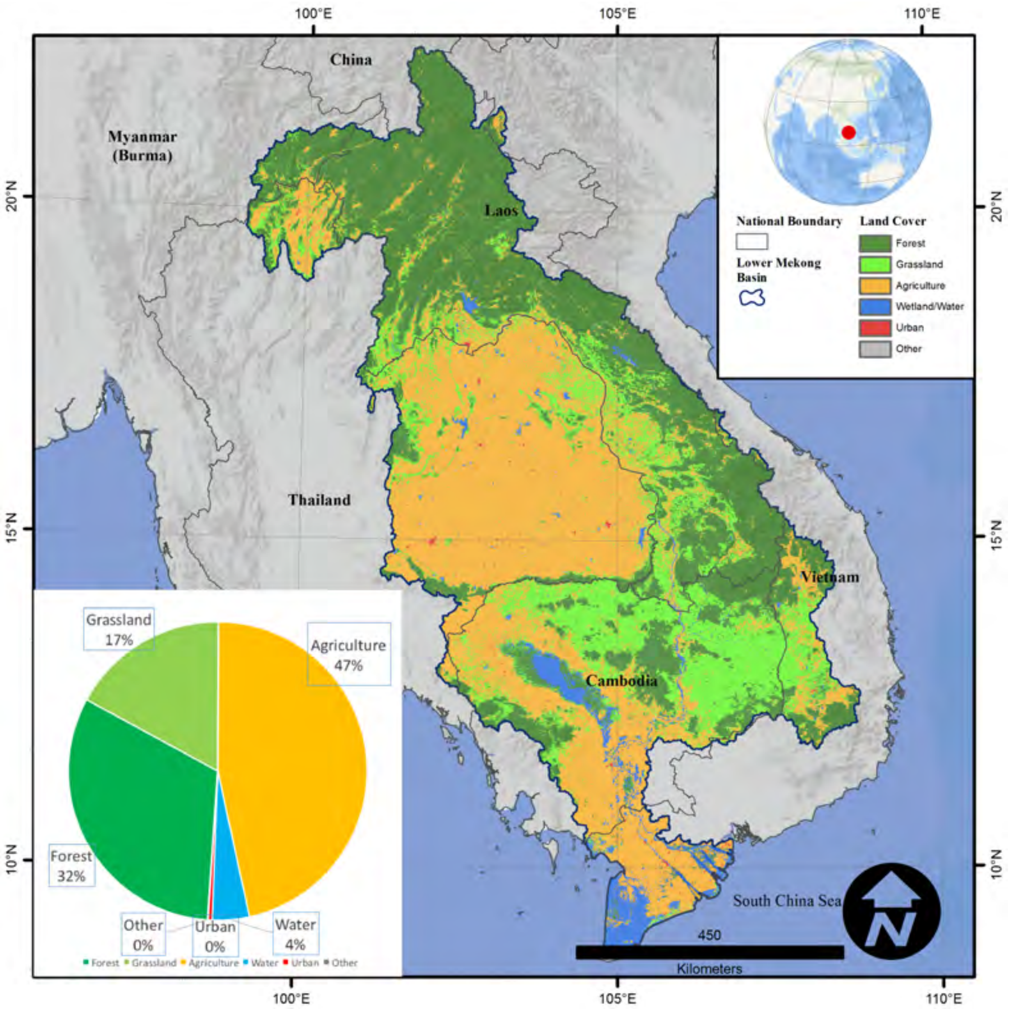


SPATIAL



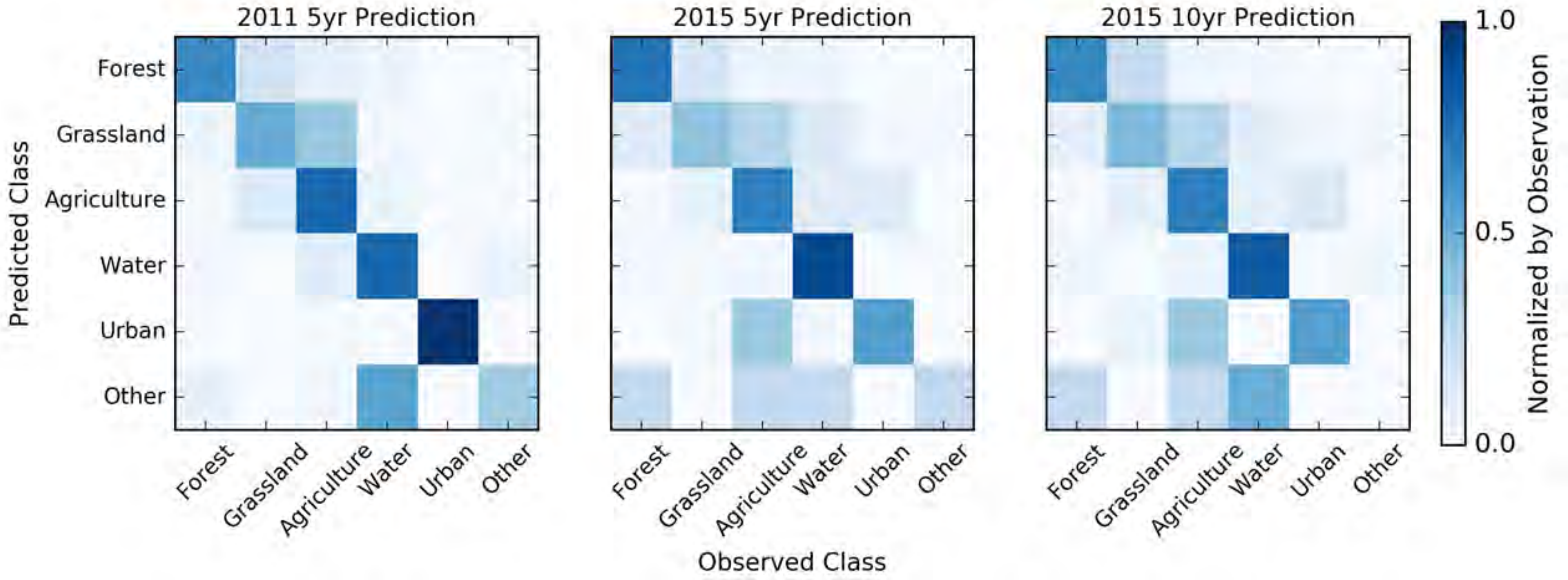
LAND COVER CHANGE MODEL

- 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



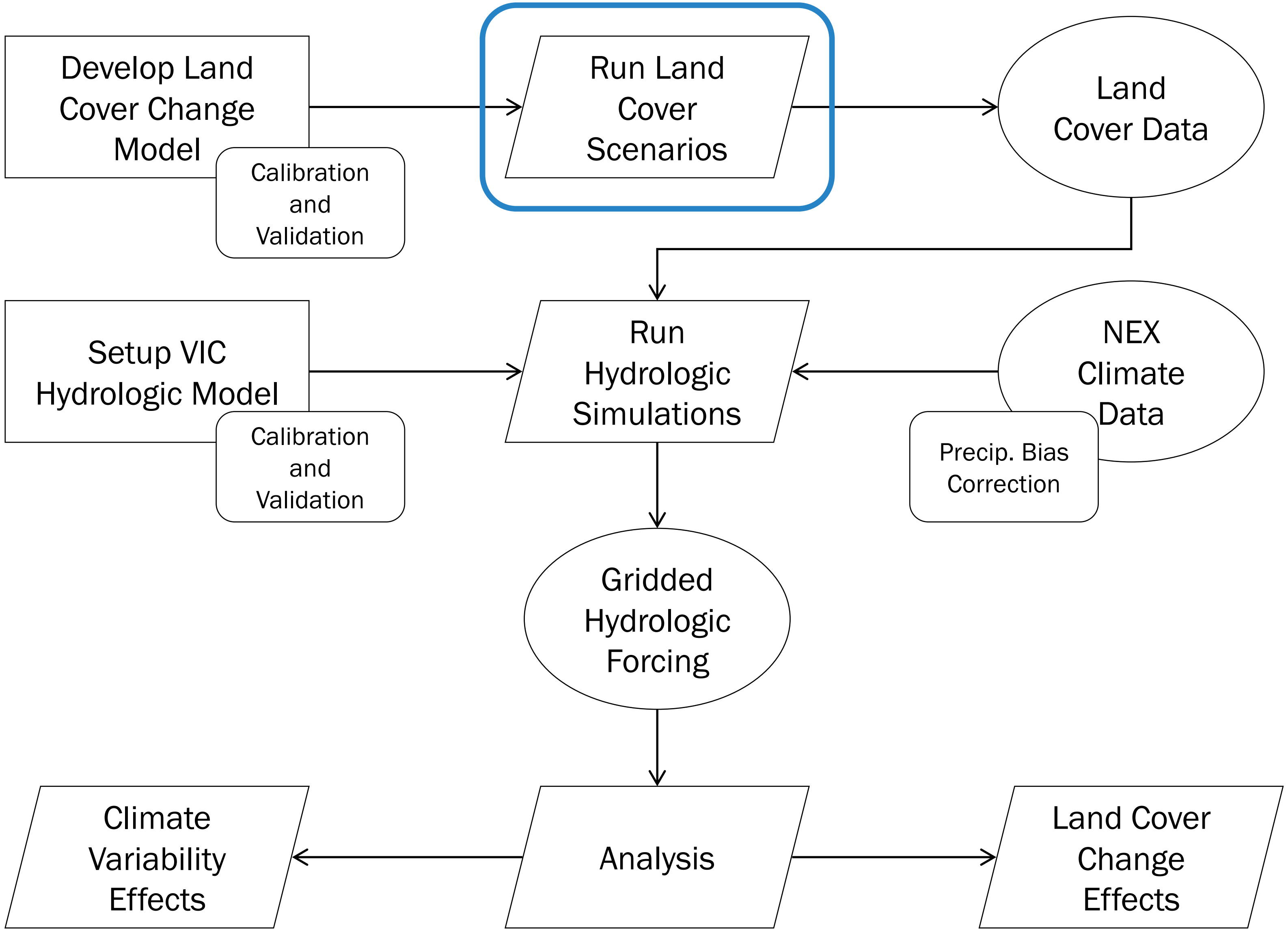
LAND COVER MODEL PERFORMANCE

- 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

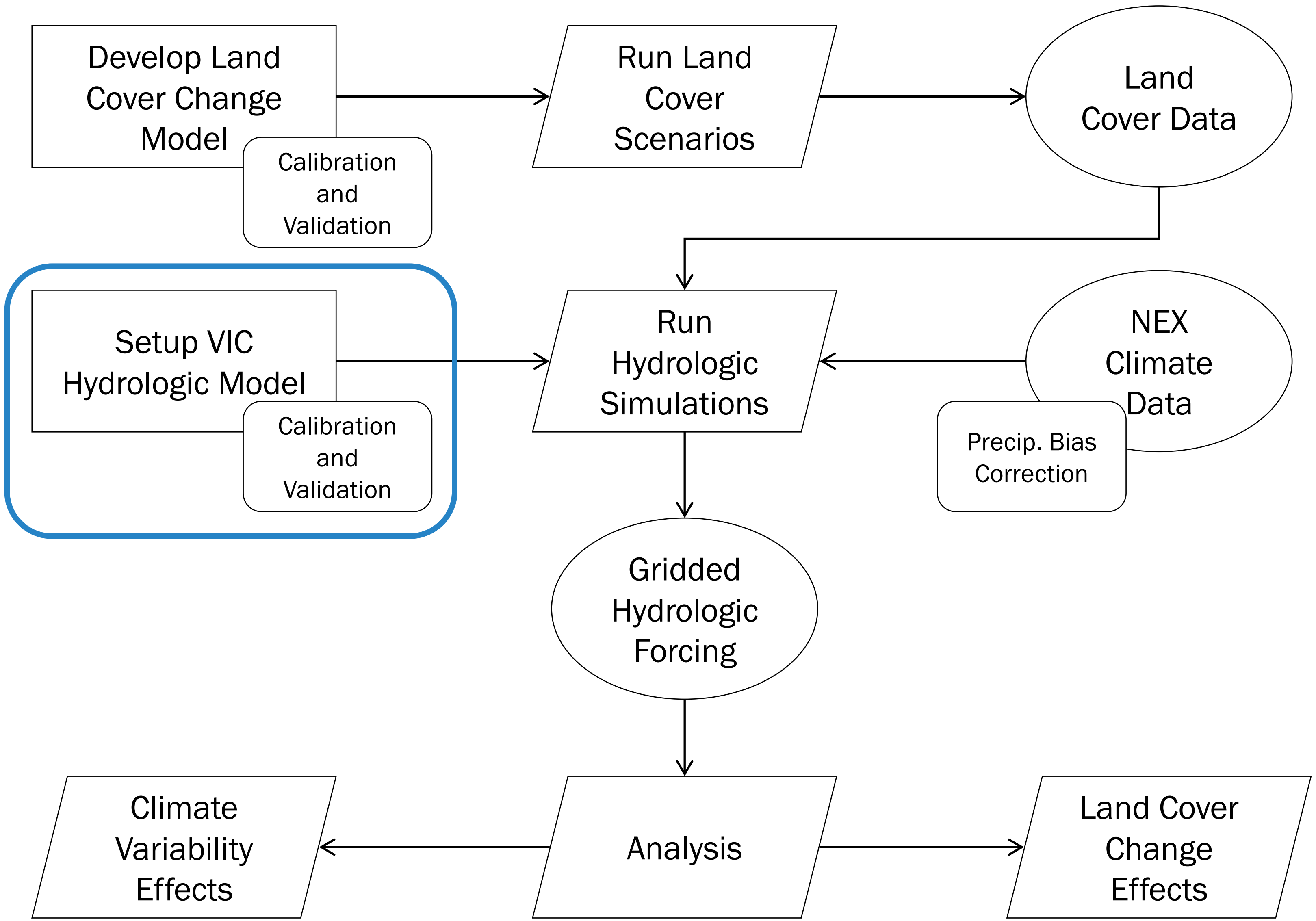
LAND COVER SIMULATIONS



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

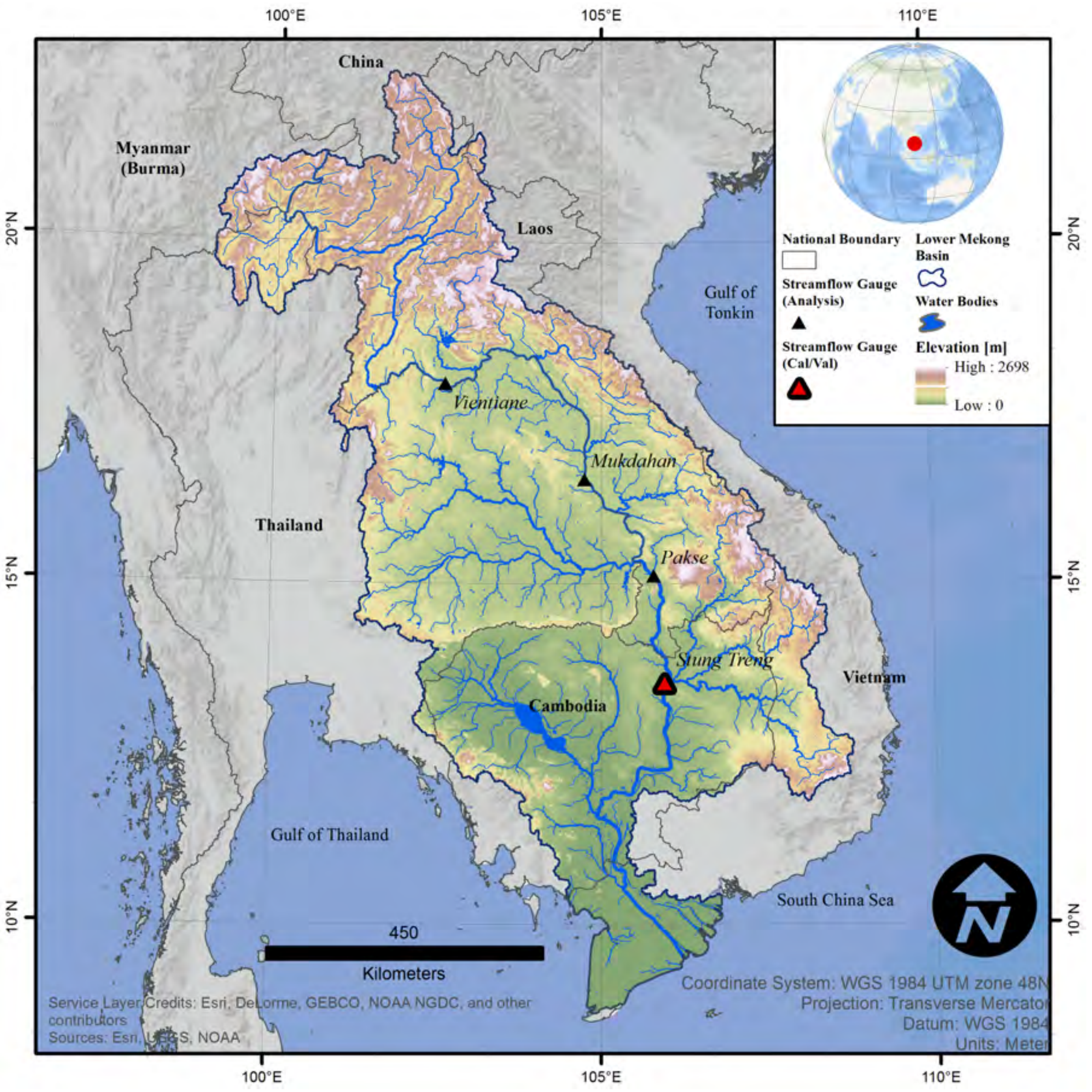
HYDROLOGIC MODEL



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]

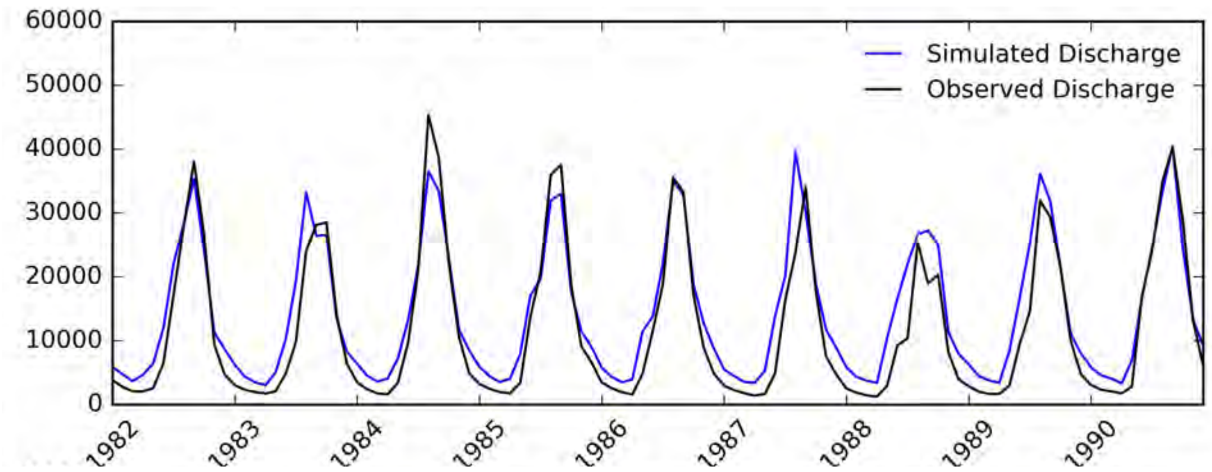
- Model was run for 1981-2010
  - Create a climatological dataset for the hydrology variables
- Calibrated/Validated model at Stung Treng station
  - Calibration period: 1981-1990
  - Validation period: 1991-2005
- Manual calibration

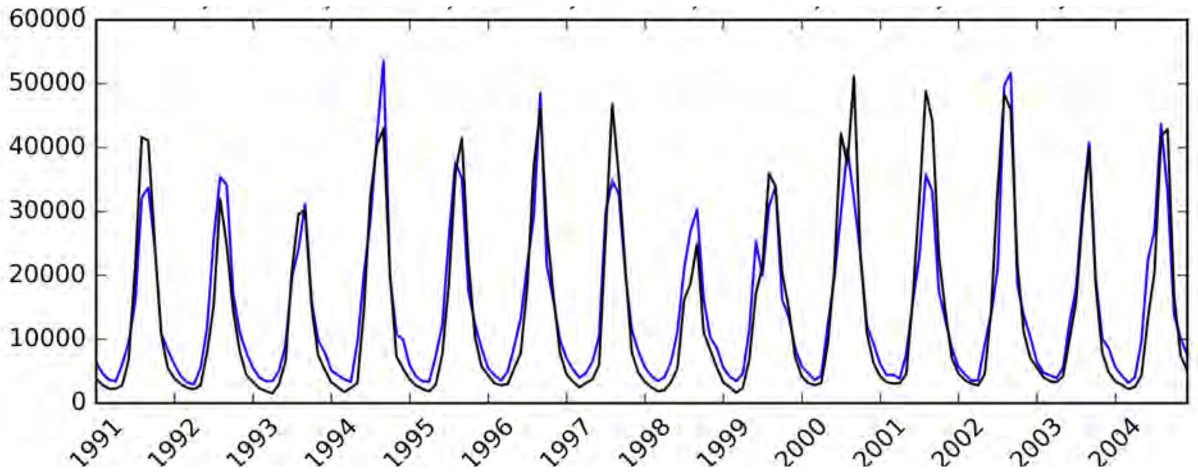


SIMULATION RESULTS

- 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*



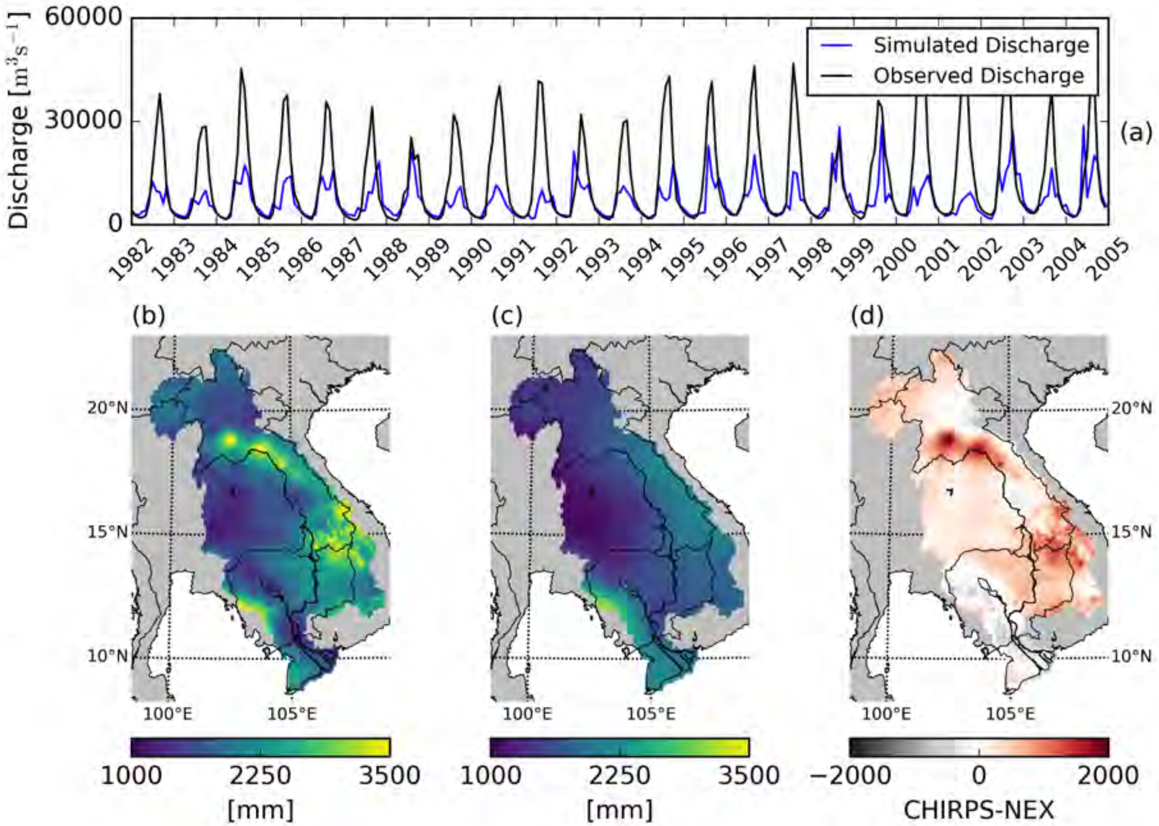


INPUT DATA UNCERTAINTY

- 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]

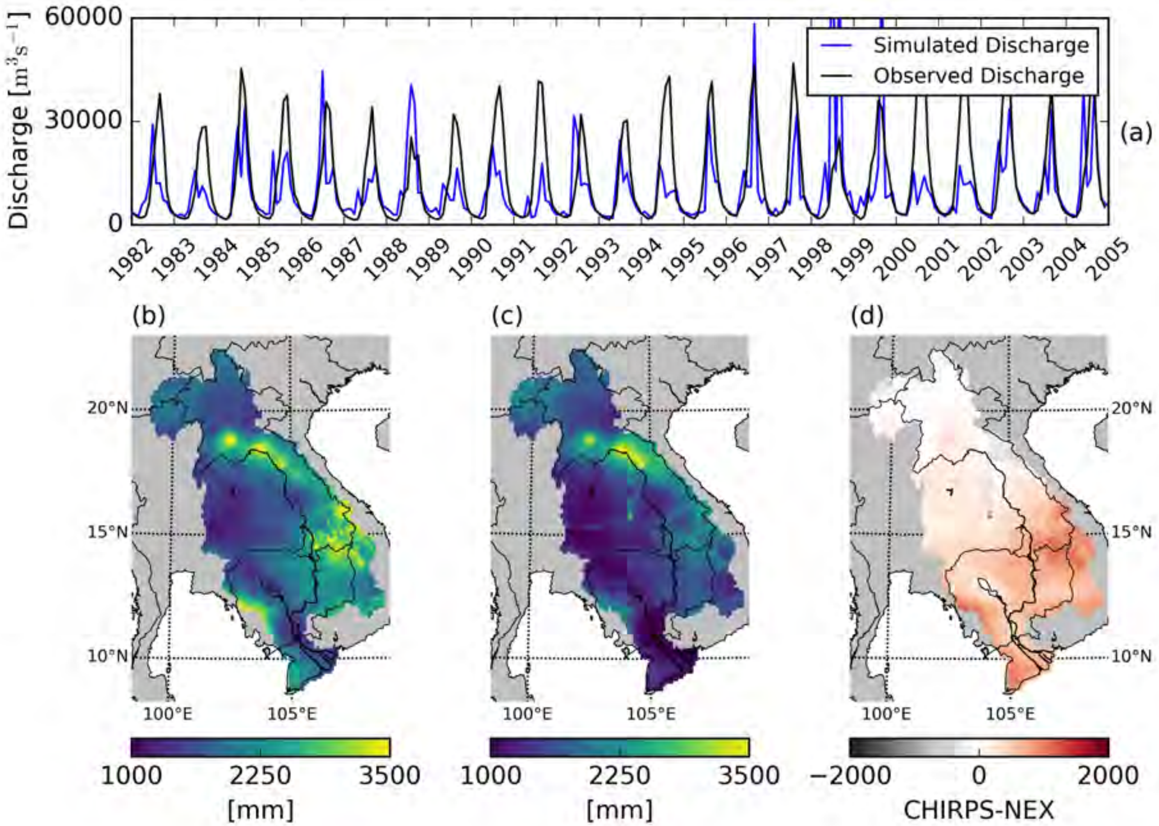


Statistic	R [-]	NSE [-]	PBIAS [%]	RSR [-]	MRE [%]
Calibration	0.67	*0.17*	*-44.28*	0.55	*44.74*
Validation	0.57	*0.11*	*-45.05*	0.55	38.56

BIAS CORRECTION OF CLIMATE PRECIPITATION

SERVIR

- 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



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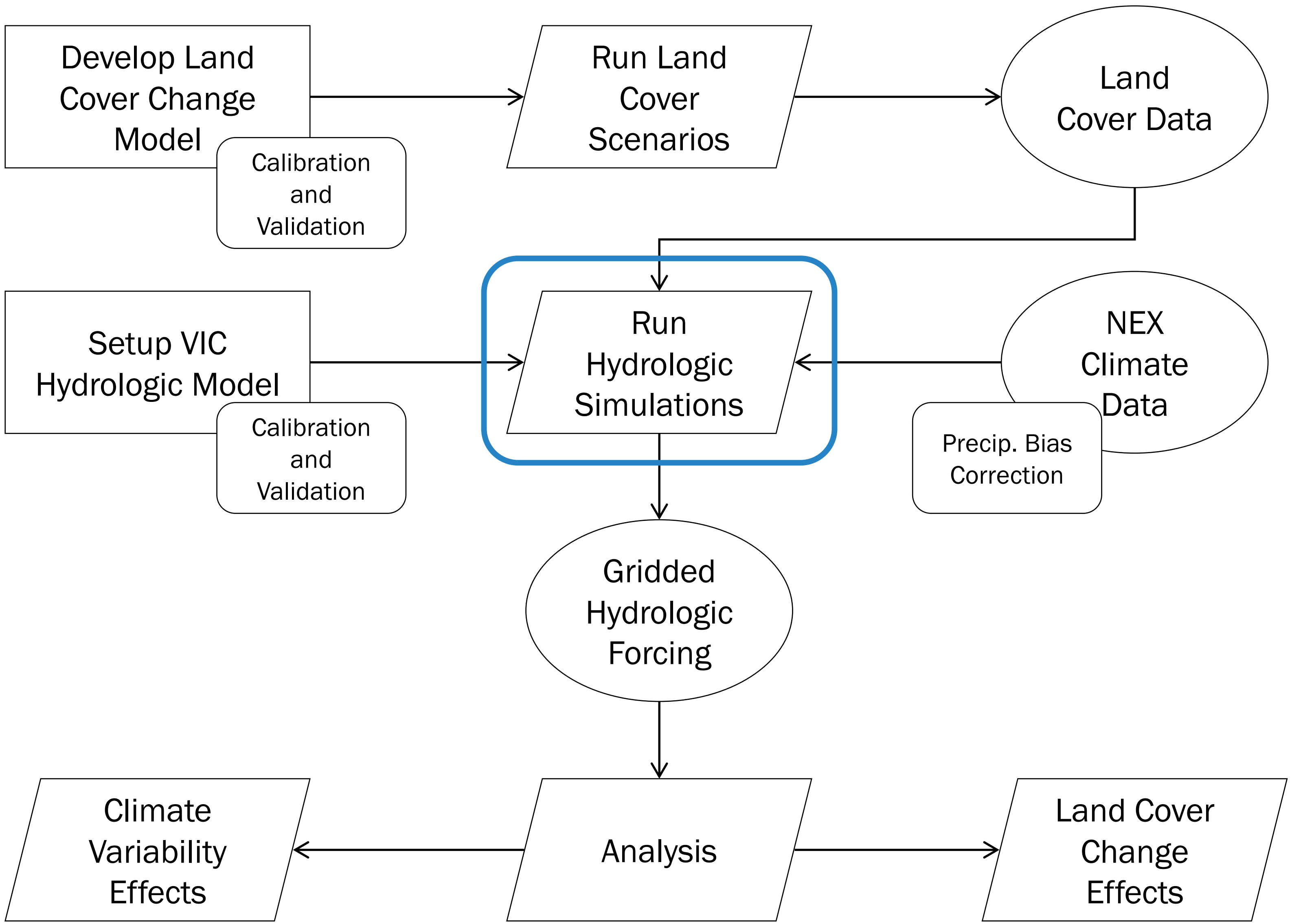
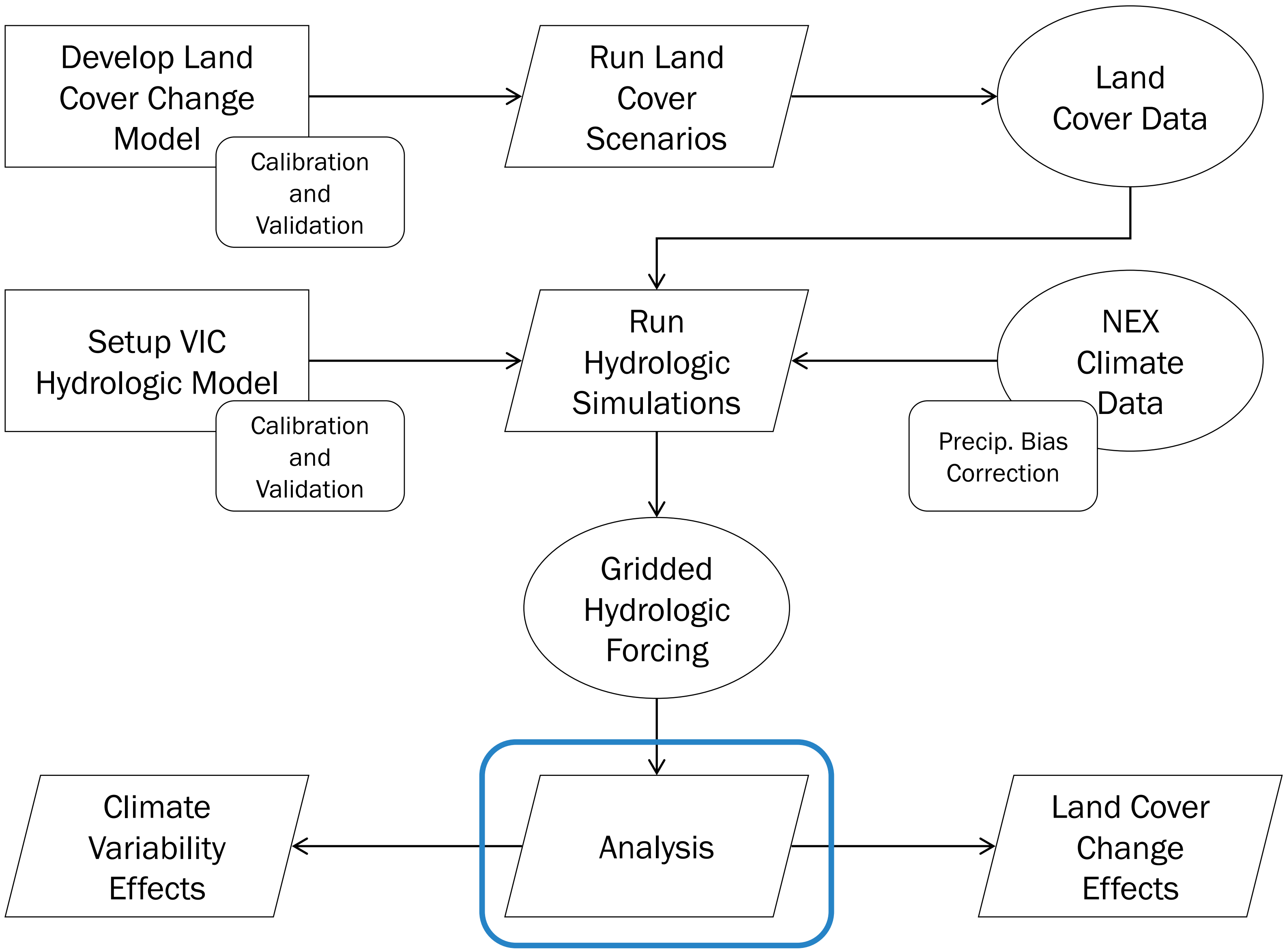
ERRORS AND UNCERTAINTIES



HYDROLOGIC SIMULATIONS

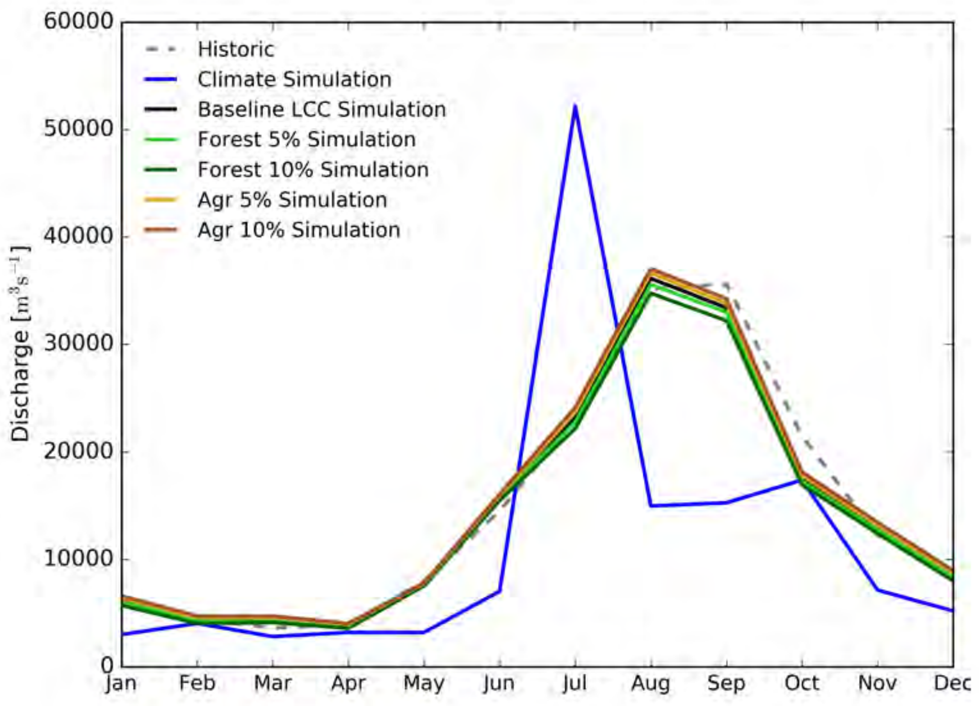
- Two sets of simulations were run for this study each changing a specific input in the hydrologic model
  1. Climate scenario: Simulation run with climate projection data. Land cover data for 2001 was kept constant
     - Both raw climate data and bias corrected data was analyzed
  2. Land cover scenario: 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%)

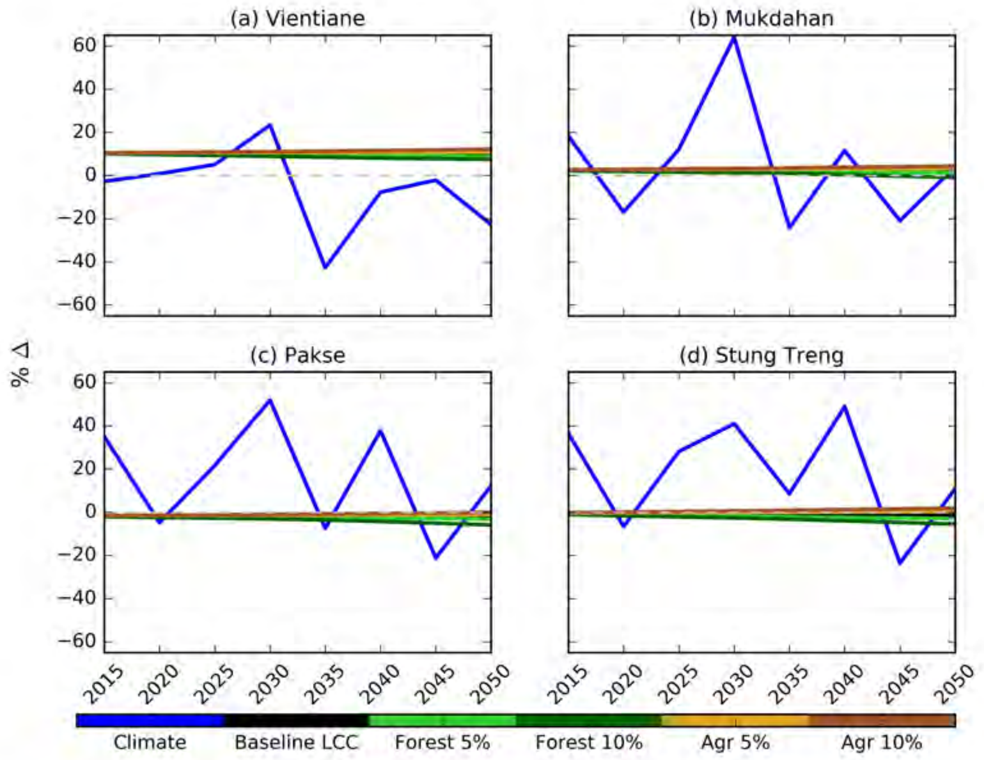
HYDROLOGIC CHANGE ANALYSIS



DISCHARGE CHANGES

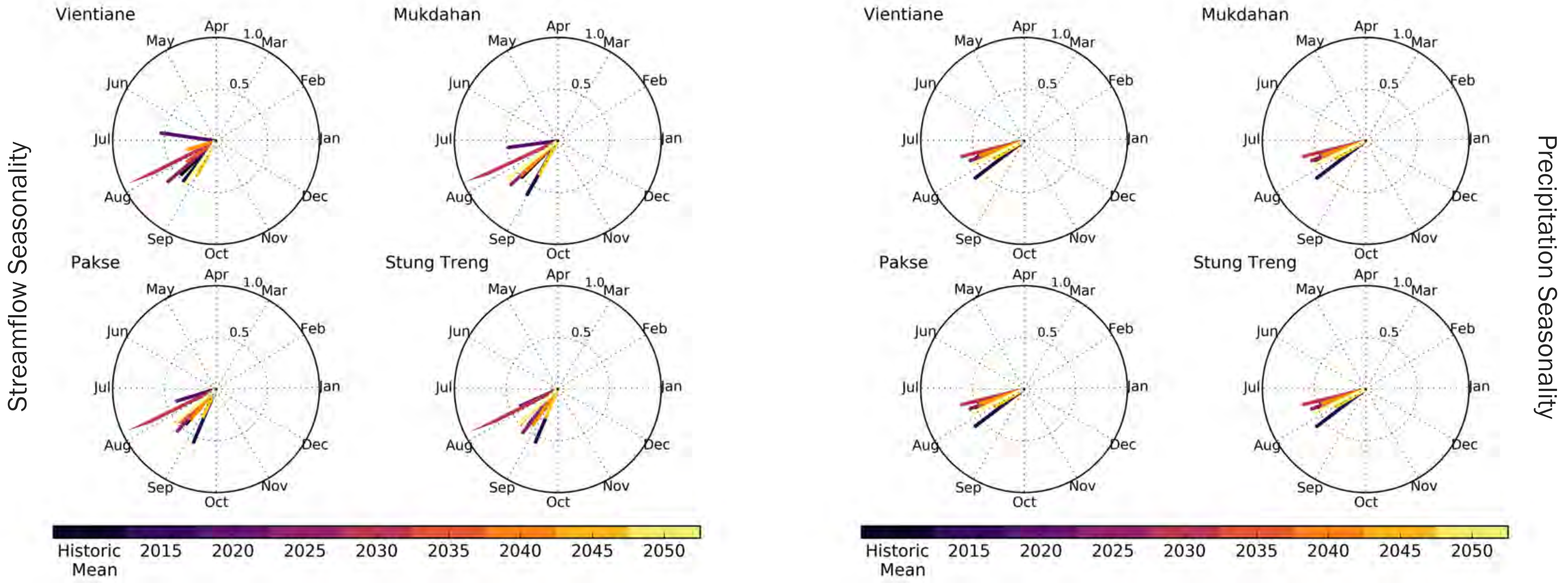
- Climate variability will make discharge inconsistent through time
- Land cover will only slightly alter discharge
  - Increase in forest results in decreases in discharge
  - Increase in agriculture results in increases in discharge





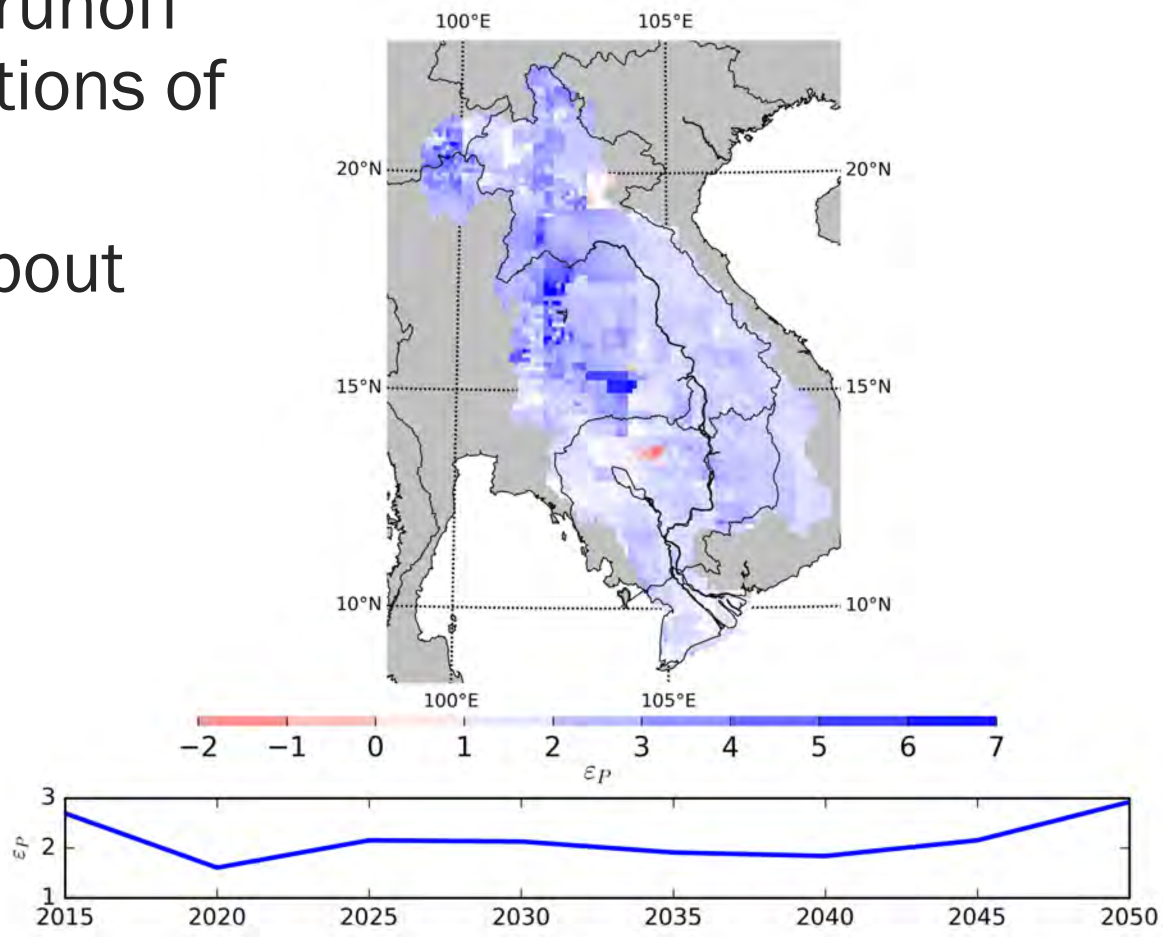
SEASONALITY

- 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



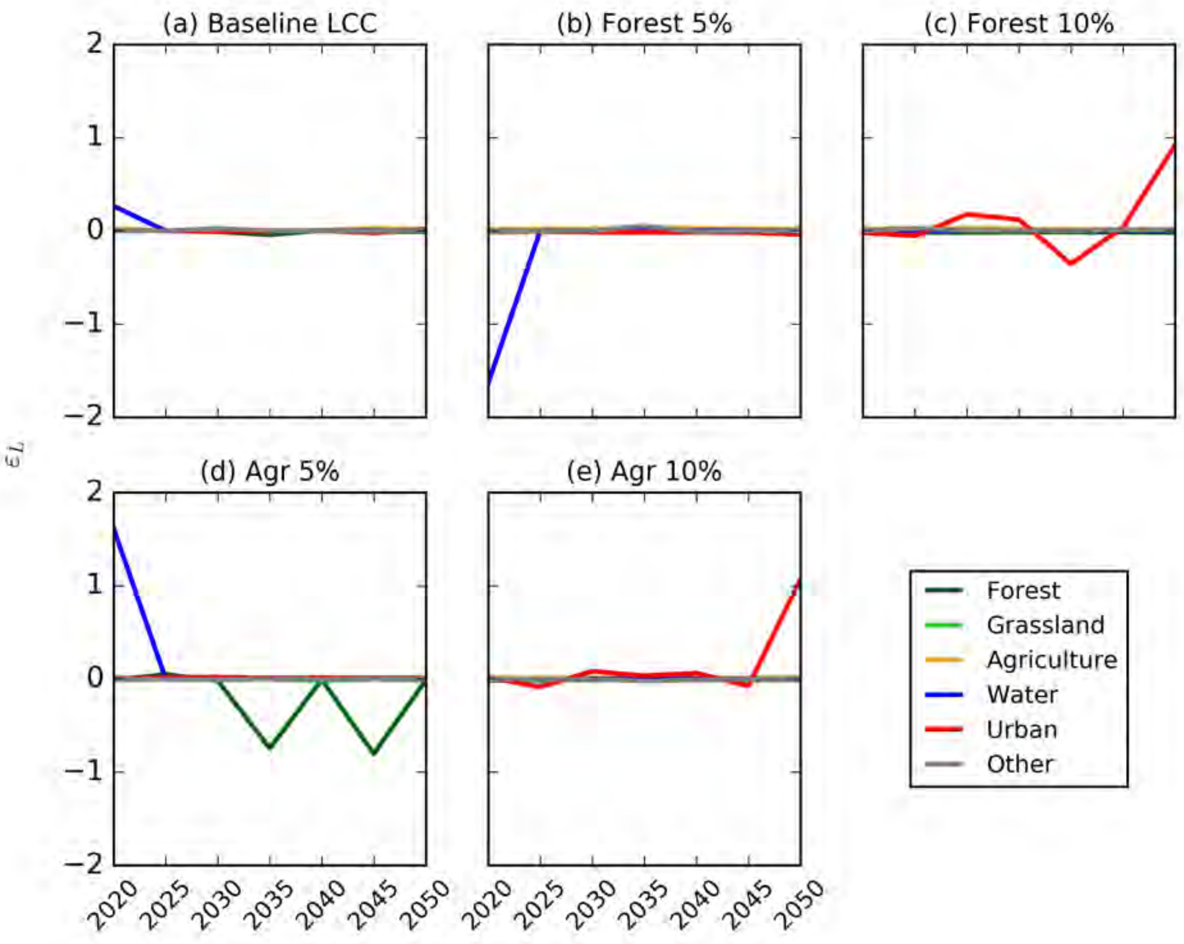
RUNOFF ELASTICITY

- 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



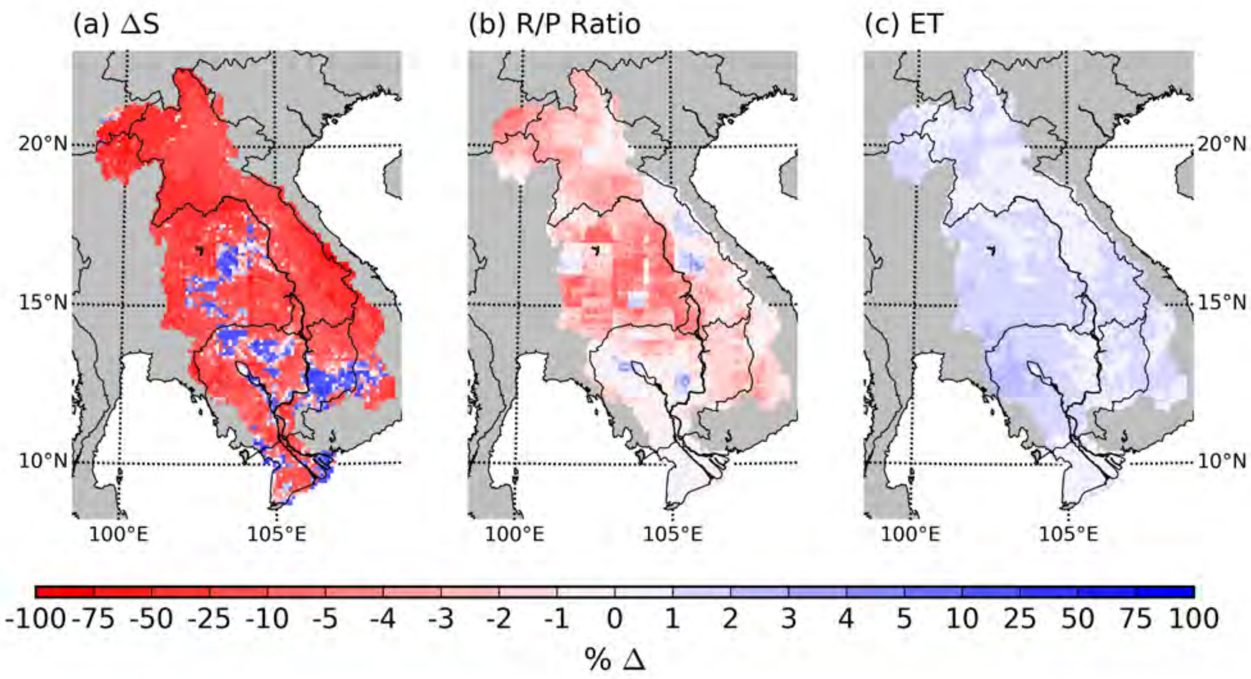
RUNOFF ELASTICITY

- 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



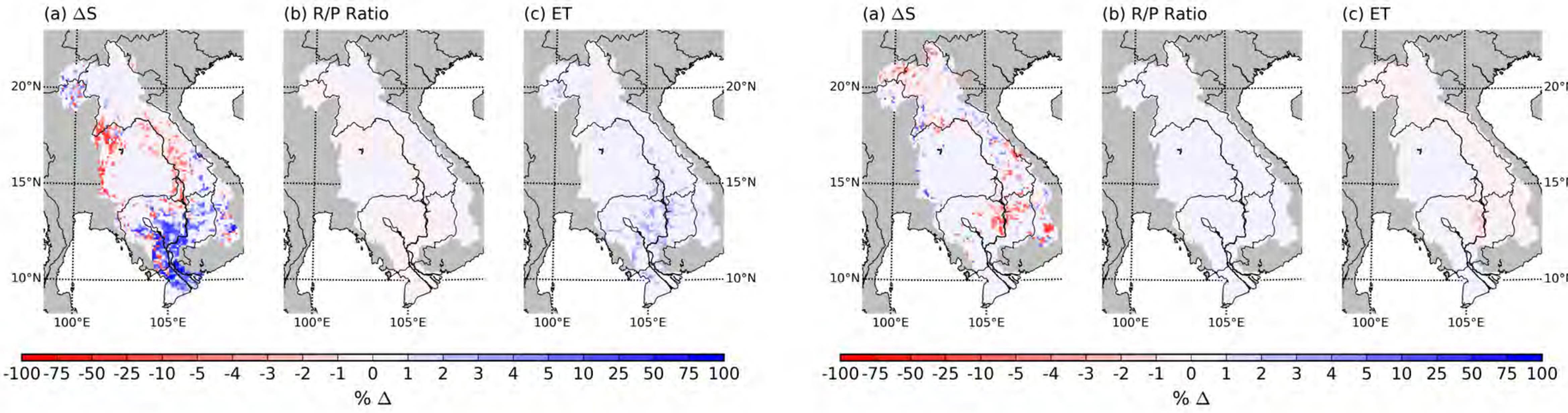
SPATIAL TRENDS

- 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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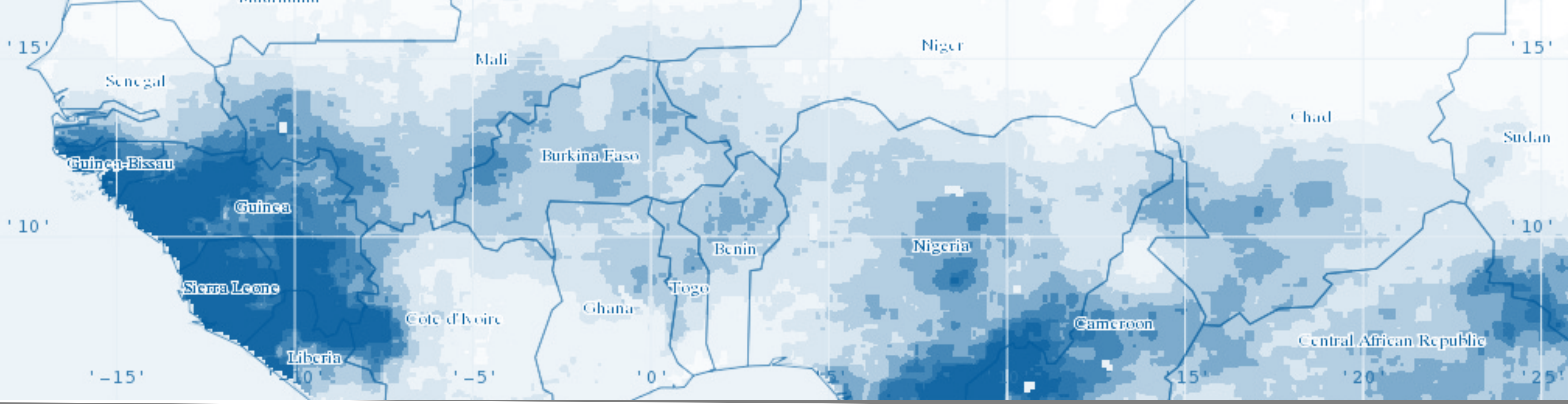

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