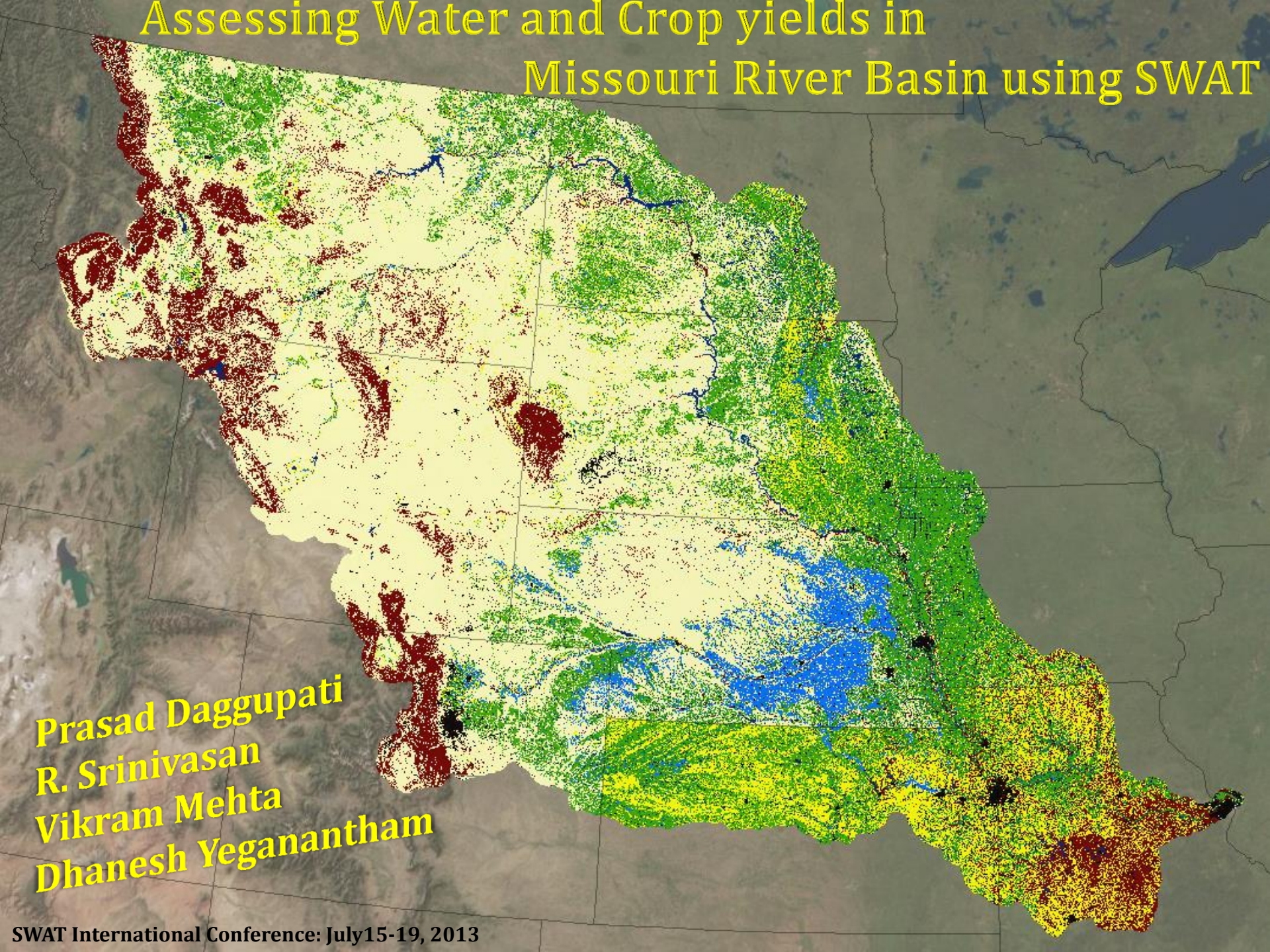
Assessing Water and Crop yields in Missouri River Basin using SWAT



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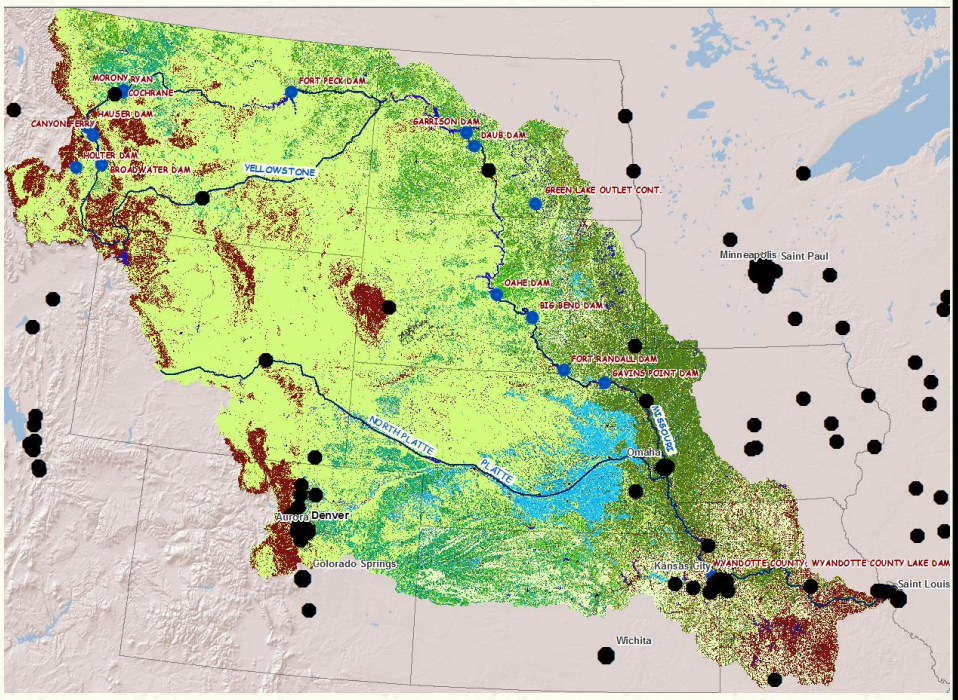
Introduction

- Missouri River Basin (MRB)
  - 500,000 square miles (~1,280,000 square km)
    - Part of 10 States
  - Basin contains
    - Sparsely-populated areas
    - Metropolitan cities
      - Kansas city, Saint Louis, Omaha, Denver
  - Cropland -117 million acres (~47.35 million ha) with 12 million acres (~4.86 million ha) irrigated
    - Very important for US food production
      - 46% of wheat
      - 22% of its grain corn
      - and 34% of its cattle

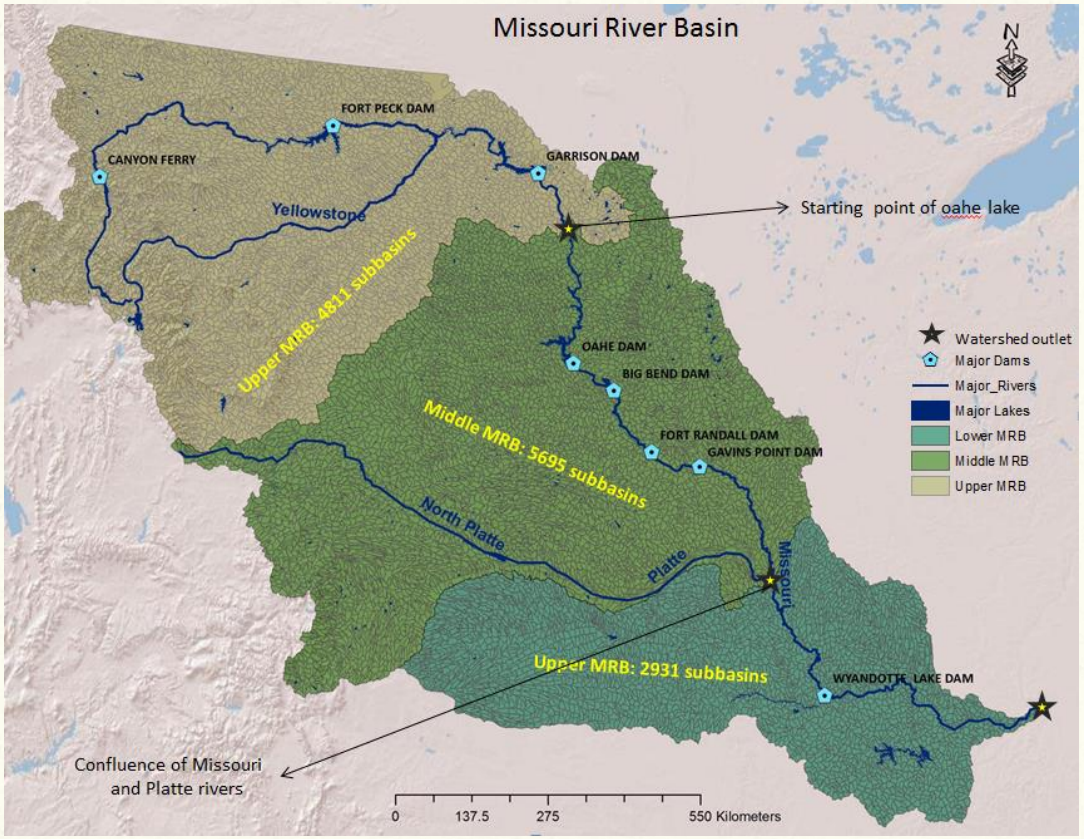


- 90% of cropland dependent on Precipitation and 10% on Irrigation
- Inhabitants of the Basin depend on the River system for
  - drinking water, irrigation and industrial needs, hydro-electricity, recreation, navigation, and fish and wildlife habitat

- Climate change and Landuse change will have dramatic impact on Crop and Water yield in MRB
- A watershed model needs to developed and calibrated
  - answer various questions related climate change and landuse change impacts
- Developing a watershed model for MRB is challenging
  - Very big basin with spatially varying hydrology and landuse
- Therefore, **Goal** is to simulate MRB using SWAT at finer resolution
  - **Objective**
    - Develop and implement a strategy to calibrate and validate SWAT model at finer resolution (HUC 12 level)for Crop and Water yields

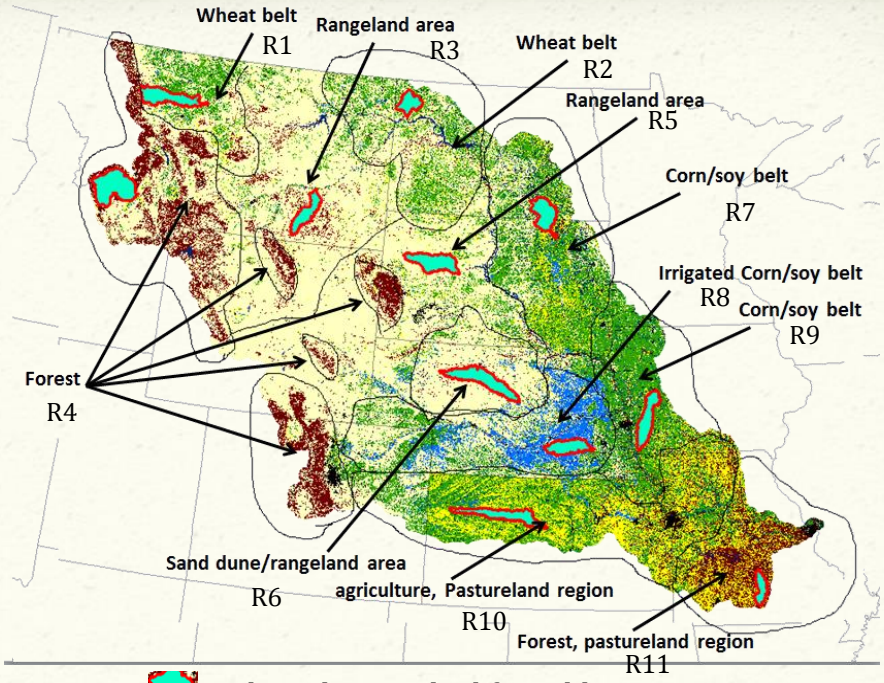
Methods

- Simulating whole MRB at finer resolution is complex and time consuming
  - Over 13,000 subbasins (Huc12's)
- Therefore, Divided MRB into 3 basins
  - Upper MRB:
    - 4811 subbasins
  - Middle MRB:
    - 5695 subbasins
  - Lower MRB:
    - 2931 subbasins
- Despite splitting into 3 basins
  - There are **spatially different landuse and hydrologic regions**



Calibration Strategy

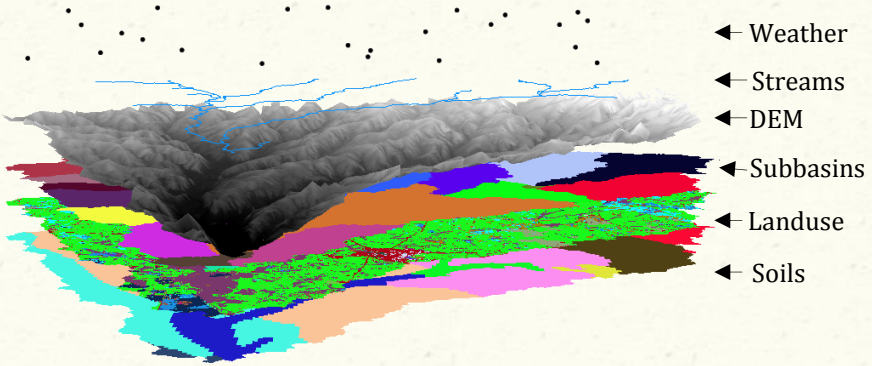
- we decided to spatially disaggregate MRB into 11regions (R1 to R11)
  - Expert opinion
    - Using landuse, soil, slope and precipitation
- Select a watershed (Huc 8 level) in each region
  - Representing region
  - Without reservoirs
- Calibrate the watershed for crop and water yields
- Transfer parameters to entire region within each Basin (UP, MI,LW basins)

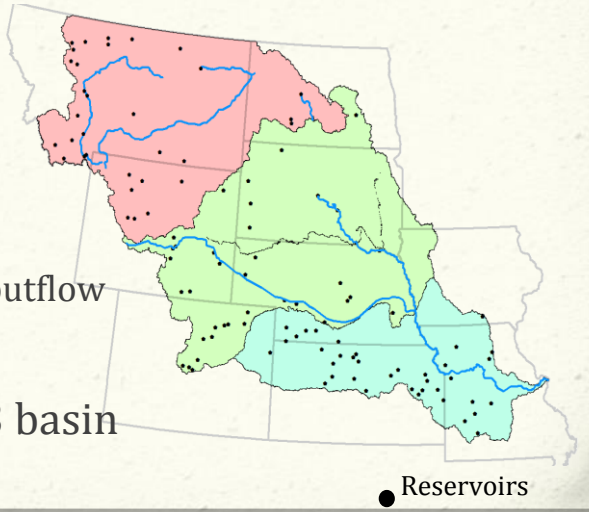


Region	UP MRB subbasins	MI MRB subbasins	LW MRB subbasins
R1	435		
R2	904		
R3	2058		
R4	1338	577	
R5		1916	
R6		553	
R7	76	944	
R8		998	539
R9		707	429
R10			1516
R11			447

Data inputs and SWAT model setup

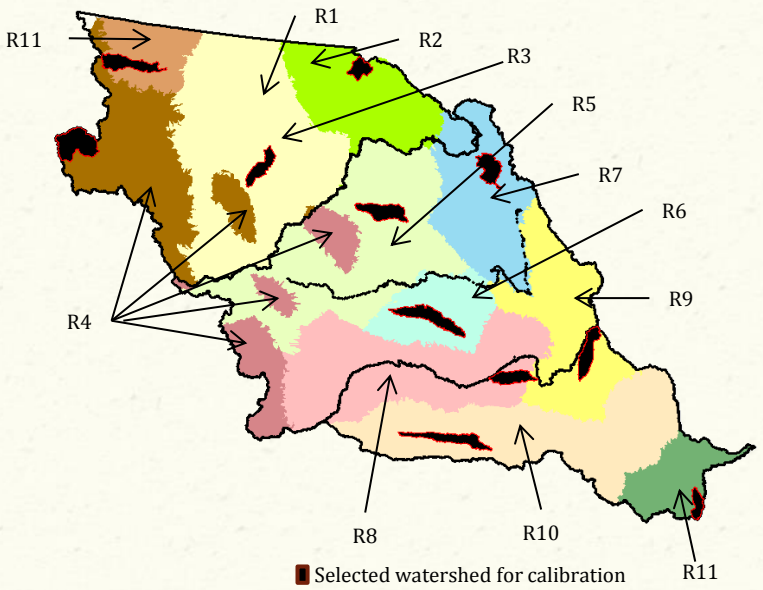
- ArcSWAT 2012 interface used
  - Rev 591 (latest)
- Watershed characterization
  - Predefined Subwatersheds and streams – **used for UP, MI and LW basin**
    - 30m DEM, 12 digit HUCs, NHD streams
  - Automatic delineation – used for delineating watersheds in each selected region
    - 30m DEM
      - Subbasin size in watersheds same as HUC12 size
- Landuse landcover
  - 30m Landuse land cover
  - with crop rotations and irrigation
    - 2010 and 2011 CDLs and MODIS irrigated land dataset
- Soils
  - STATSGO soils at 1: 250,000 scale
- Weather
  - Downscaled historical daily precipitation and temperature data from 1949 to 2010
    - Each located at 462 x 222 grid (0.125x0.125) spacing covering entire watershed
- Reservoirs
  - Lower: 37; Middle: 38; Upper: 32
  - Reservoir data from NID
    - Size, Area, volume, etc.
  - Reservoir management
    - Largest 10 reservoirs in each basin modeled using simulated daily outflow
    - Remaining reservoirs using simulated target release
      - Expert opinion
- Baseline setup finished for 11 watersheds in each region and 3 basin





Land Management practices

- For each watershed in selected region
  - **Crops**
    - planting, management practices and harvesting
      - Major emphasis given for corn, soybean, spring and winter wheat
      - Region specific heat units using heat units program
      - Auto fertilization
      - Auto irrigation in R8 (irrigation region)
      - Crop rotations also included
  - **Rangeland**
    - plant variety as grown in that region
      - Eg. Bigblue in R11 and R10
  - **Forests**
    - Evergreen forests in R4
    - Deciduous forests in R11

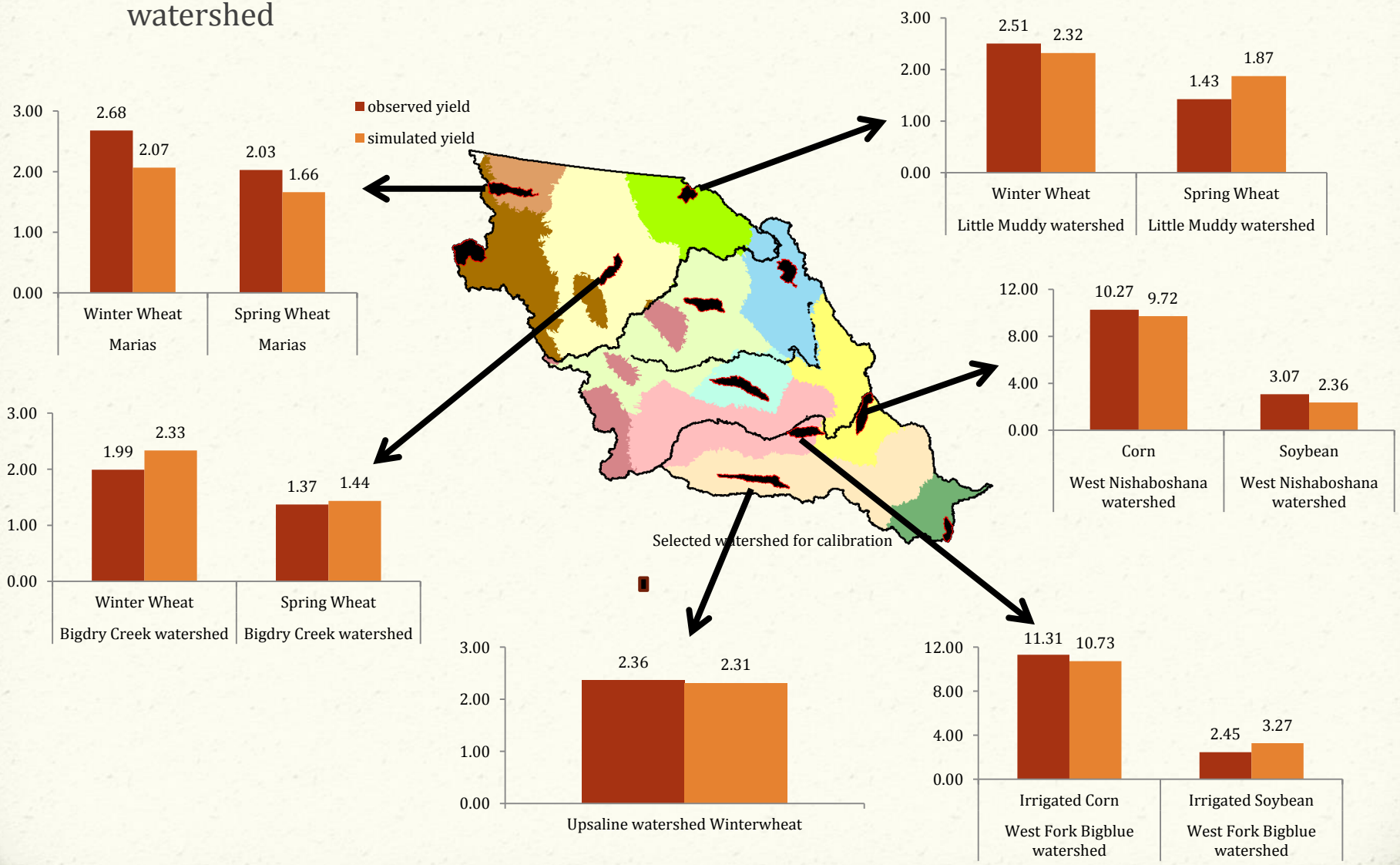


Calibration and validation

- **Crop yields** were calibrated first for each watershed
  - Manual calibration using iterative process
    - Fertilization rates (AUTO_NYR)
    - Nitrogen Stress factor (AUTO_NSTRS)
    - Application Efficiency (AUTO_EFF)
    - AUTO_WSTRS and IRR_EFF for irrigated crops
  - **Average of 2005 to 2010 simulated yields were compared with NASS generated county average in each watershed**
    - Crops compared are
      - Irrigated and Non Irrigated corn and soybean
      - Winter wheat and Spring wheat
- **Water yields** were calibrated after crop yields
  - Manual calibration of parameters to capture overall hydrology in watershed
  - SWATCUP used to automate further calibration
    - SUFI2 Algorithm
  - **Monthly** simulated and observed flow compared using statistics
    - NSE, PBIAS, r and p factor (uncertainty)
- After satisfactory calibration,
  - **crop management and hydrology parameters are transferred watershed to respective entire region**
    - Semi automated SQL scripting
- **Validation**
  - Water yields was validated at **different locations** within each basin
  - Crop yields was validated at **HUC4 level** within each basin

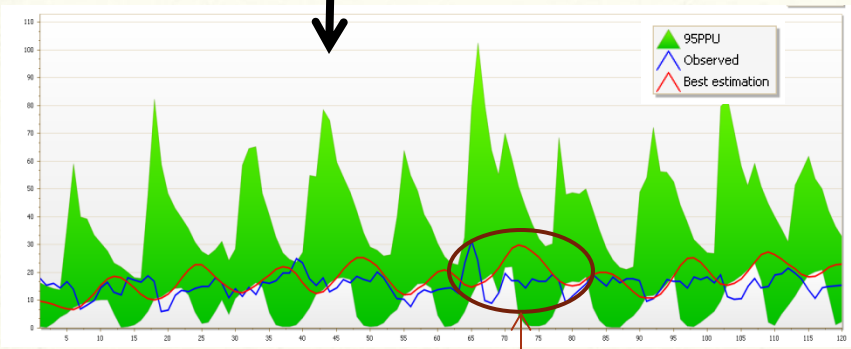
Results

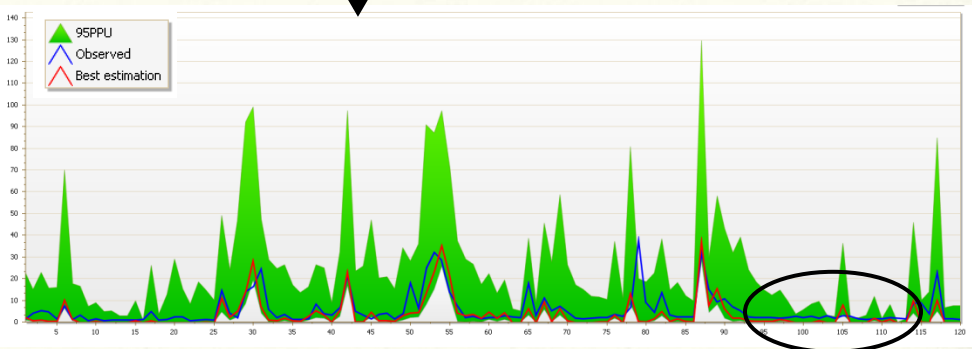
- **Crop yields calibration** for selected watersheds
  - 2005 to 2010 simulated average yield vs. NASS county average yield (observed) in each watershed



- **Water yield calibration** for each watershed representing a region

Basin	Region	Watershed	Time period	R-Square	NSE	P-factor	r-factor
UP MRB	R4	Bighole	1990 - 1999	0.74	0.70	0.77	0.88
	R3	Bigdry	1990-1999	0.60	0.57	0.91	1.99
			summer months	0.96	0.86	-	-
	R2	Little muddy	2002-2006	0.71	0.60	0.95	1.01
	R1	Marias	1990 - 1999	0.79	0.77	0.85	1.08
MI MRB	R5	Cherry	1990-1999	0.73	0.70	0.32	0.70
	R7	James	2002-2010	0.76	0.60	0.86	0.73
	R6	**Up northloop**	**1990-1999**	**0.09**	**-1.34**	**0.74**	**8.83**
LW MRB	R9	West Nishaboshana	1990-1999	0.84	0.79	0.63	0.88
	R8	**Westfork big blue**	**1980-1989**	**0.54**	**0.40**	**0.64**	**1.02**
	R10	Up saline	1990-1999	0.89	0.87	0.89	0.68
	R11	Big penny	2000-2005	0.80	0.68	0.72	0.82



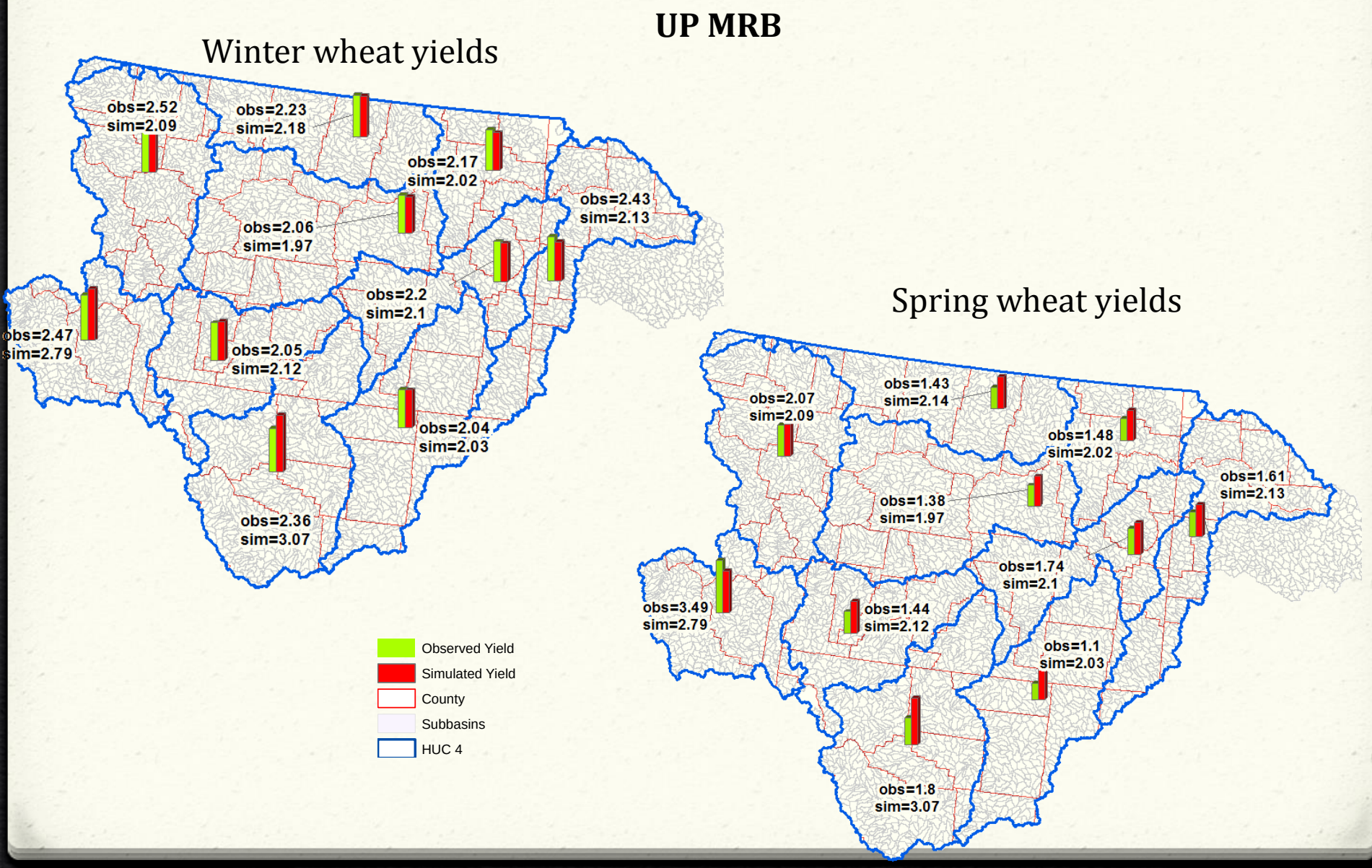


Simulated (red) peaks with precipitation events
Observed (blue) doesn't peak

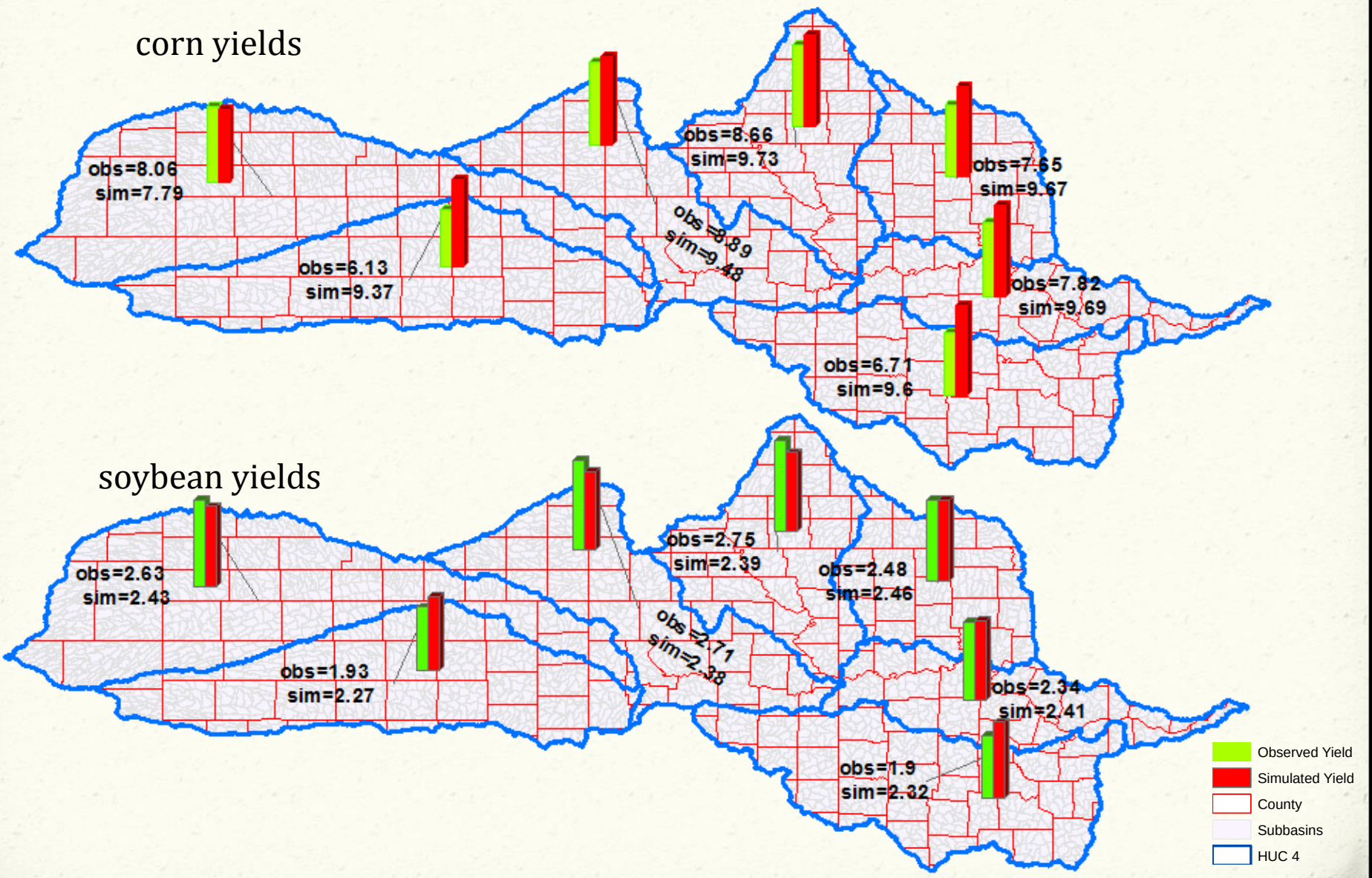
Recharge from Ogallala aquifer

Crop yield validation in UP and LW MRB at HUC 4 level

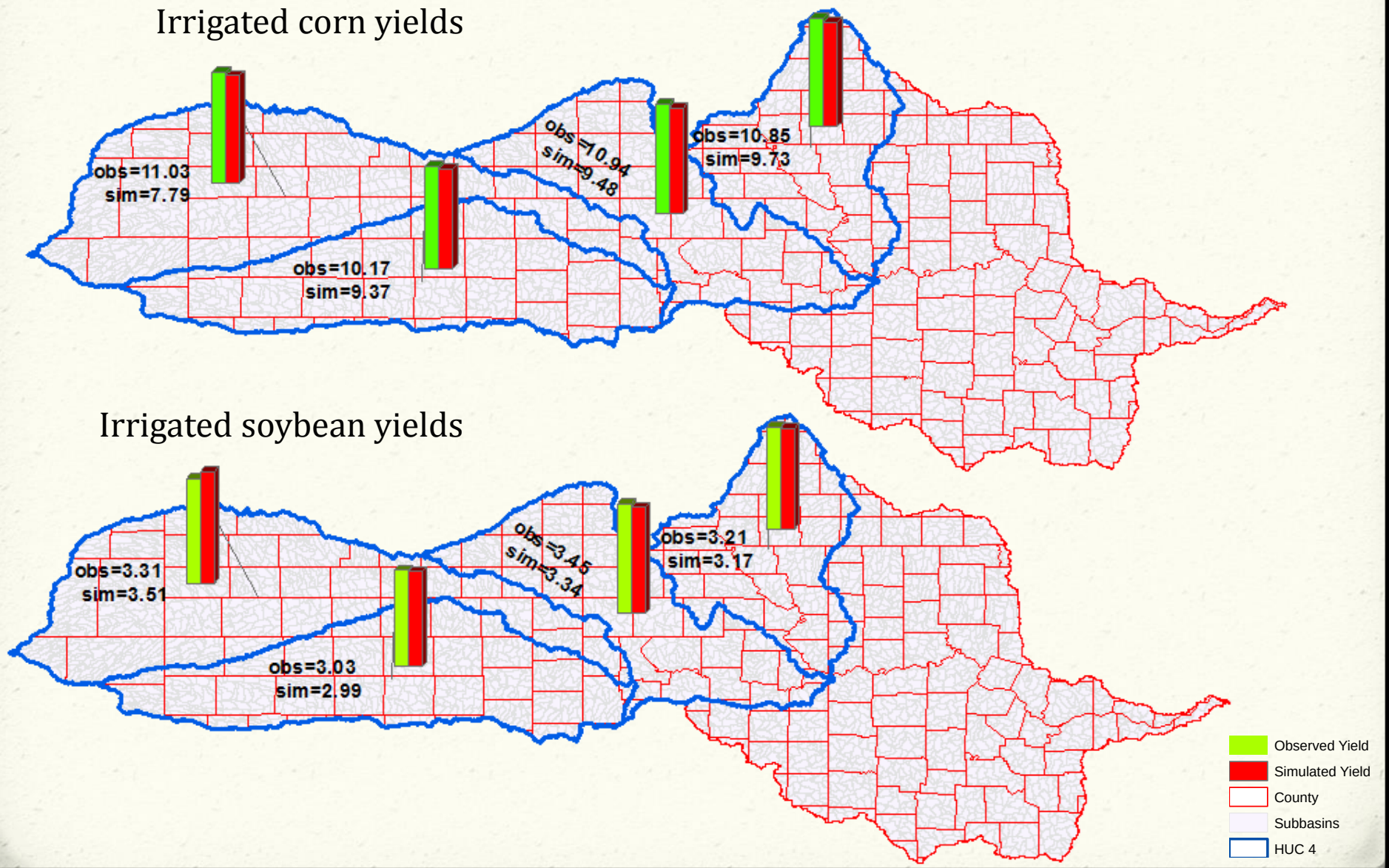
- 2005 to 2010 simulated average yield vs. NASS county average yield (observed) for each HUC 4



LW MRB

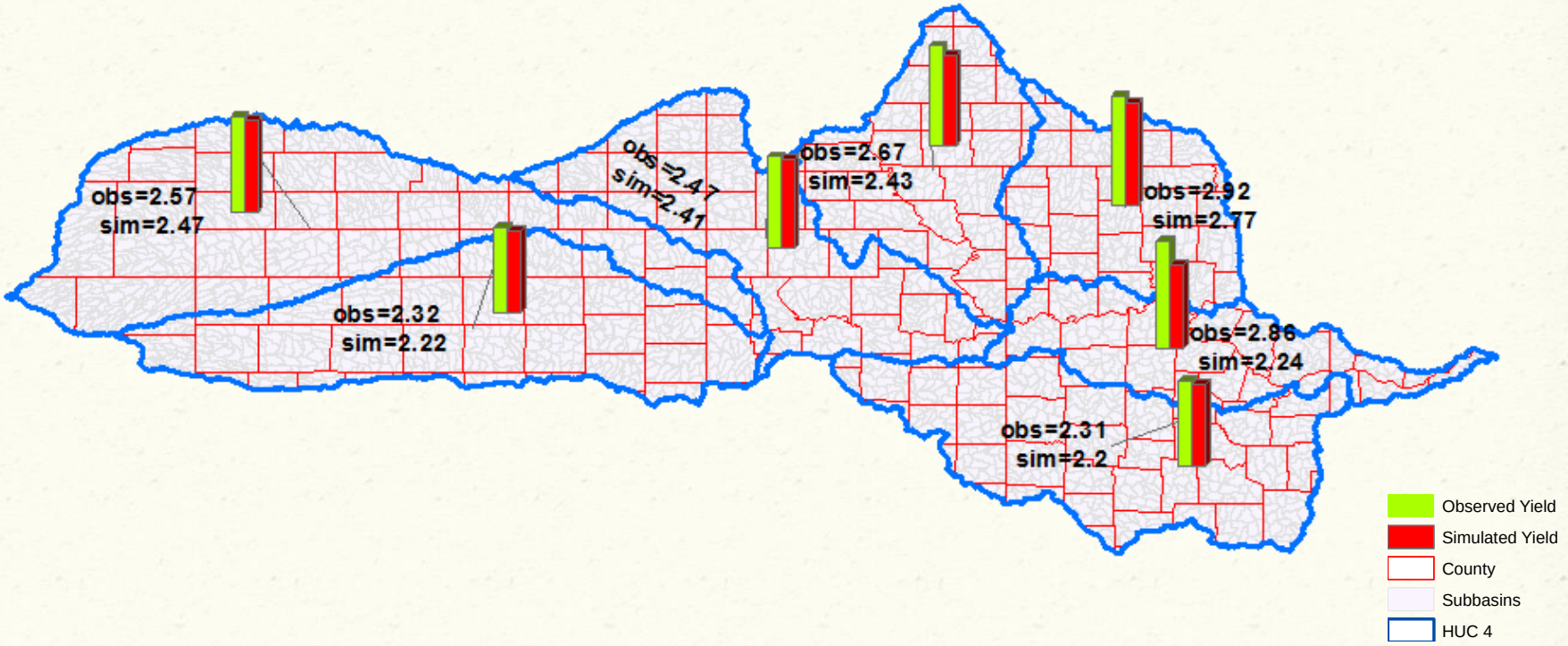

corn yields
obs=8.06
sim=7.79
obs=6.13
sim=9.37
obs=8.66
sim=9.73
obs=8.89
sim=9.48
obs=7.65
sim=9.67
obs=7.82
sim=9.69
obs=6.71
sim=9.6
soybean yields
obs=2.63
sim=2.43
obs=1.93
sim=2.27
obs=2.75
sim=2.39
obs=2.71
sim=2.38
obs=2.48
sim=2.46
obs=2.34
sim=2.41
obs=1.9
sim=2.32
Observed Yield
Simulated Yield
County
Subbasins
HUC 4

LW MRB


Irrigated corn yields
obs=11.03
sim=7.79
obs=10.17
sim=9.37
obs=10.94
sim=9.48
obs=10.85
sim=9.73
Irrigated soybean yields
obs=3.31
sim=3.51
obs=3.03
sim=2.99
obs=3.45
sim=3.34
obs=3.21
sim=3.17
Observed Yield
Simulated Yield
County
Subbasins
HUC 4

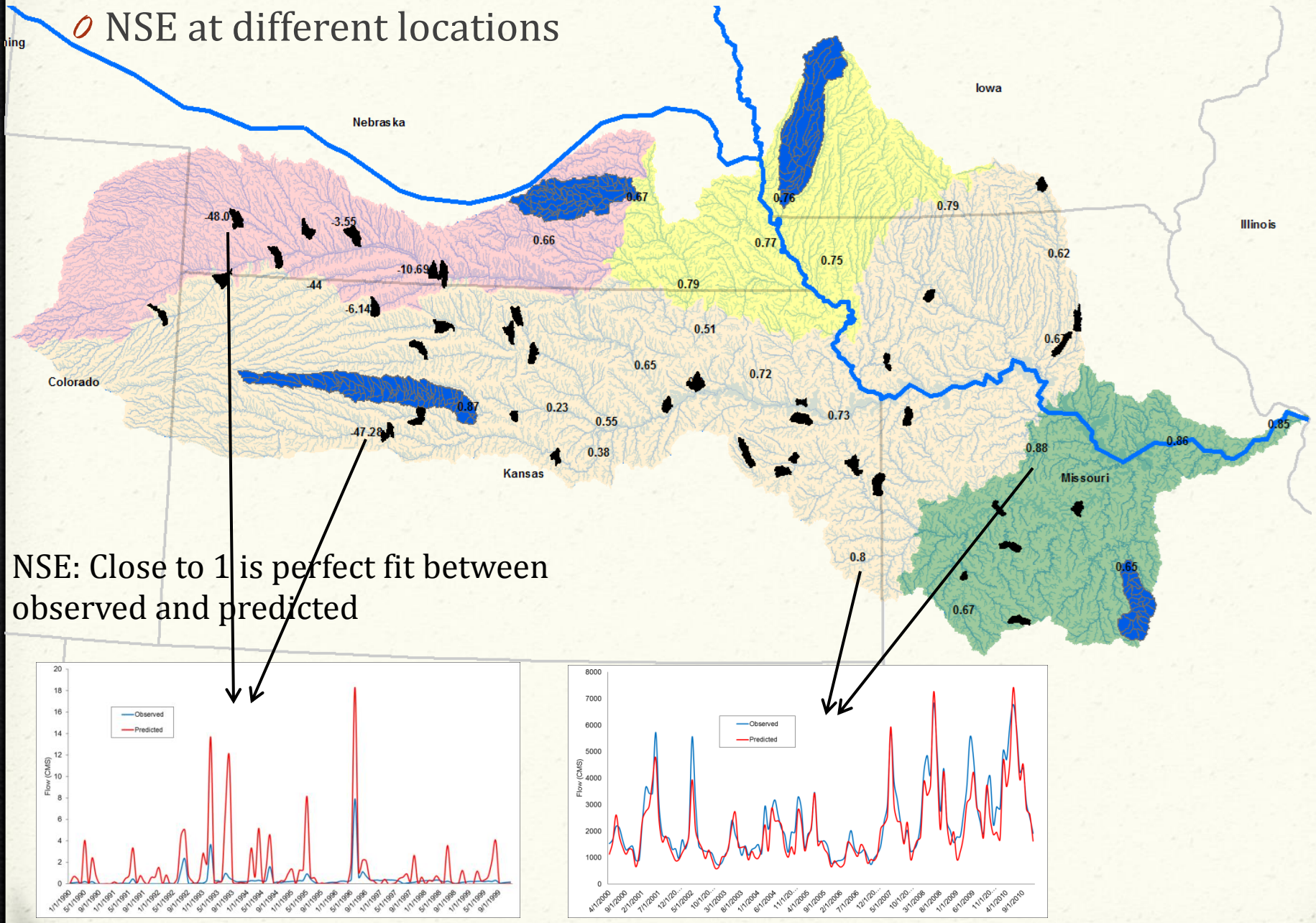
LW MRB

Continuous winter wheat yields



Water Yield validation in LW MRB

- NSE at different locations



NSE: Close to 1 is perfect fit between observed and predicted

Future work

- Validate crop yields at HUC 4 level in MI MRB
- Validate water yields at different locations in UP and MI MRB

Conclusions

- Methodology devised to calibrate Missouri River Basin (large scale watersheds)
  - Divide watershed into hydrologic regions
  - Select and calibrate a watershed in a region
    - extrapolate parameters to the region
- Crop yield calibration
  - Good for selected watersheds
  - Reasonable at HUC4 level when parameters were extrapolated
    - Corn and Spring wheat yields needs still some improvements
- Water yield calibration
  - Good for selected watersheds except for 2 watersheds due to Ogallala aquifer recharge issues
  - Reasonable during validation at different locations
    - Water abstractions and other man made changes were not captured


Thank You