

# **CHOOSING MODELS IN ENVIRONMENTAL SCIENCE**

## **MODELING FOR PROBLEM SOLVING IN ES**

1. Define your goal (question, hypothesis, prediction)
2. Design or select your model
3. Implement the model
4. Evaluate the model and quantify uncertainty
5. Apply the model
6. Communicate results

## OFF-THE-SHELF MODELS

- Developed and tested by experts
- Reduces need to build from scratch



Reinventing the wheel

## MODEL SELECTION

- Is model structure **appropriate**?
- Is model performance **good enough**?
- Choose the **simplest** model that captures your processes of interest

## **MODEL SELECTION: IS IT APPROPRIATE**

- Are outputs of interest captured? (e.g., streamflow, ET, N-export)
- Is resolution appropriate?
  - space
  - time
- Does it include key mechanisms?

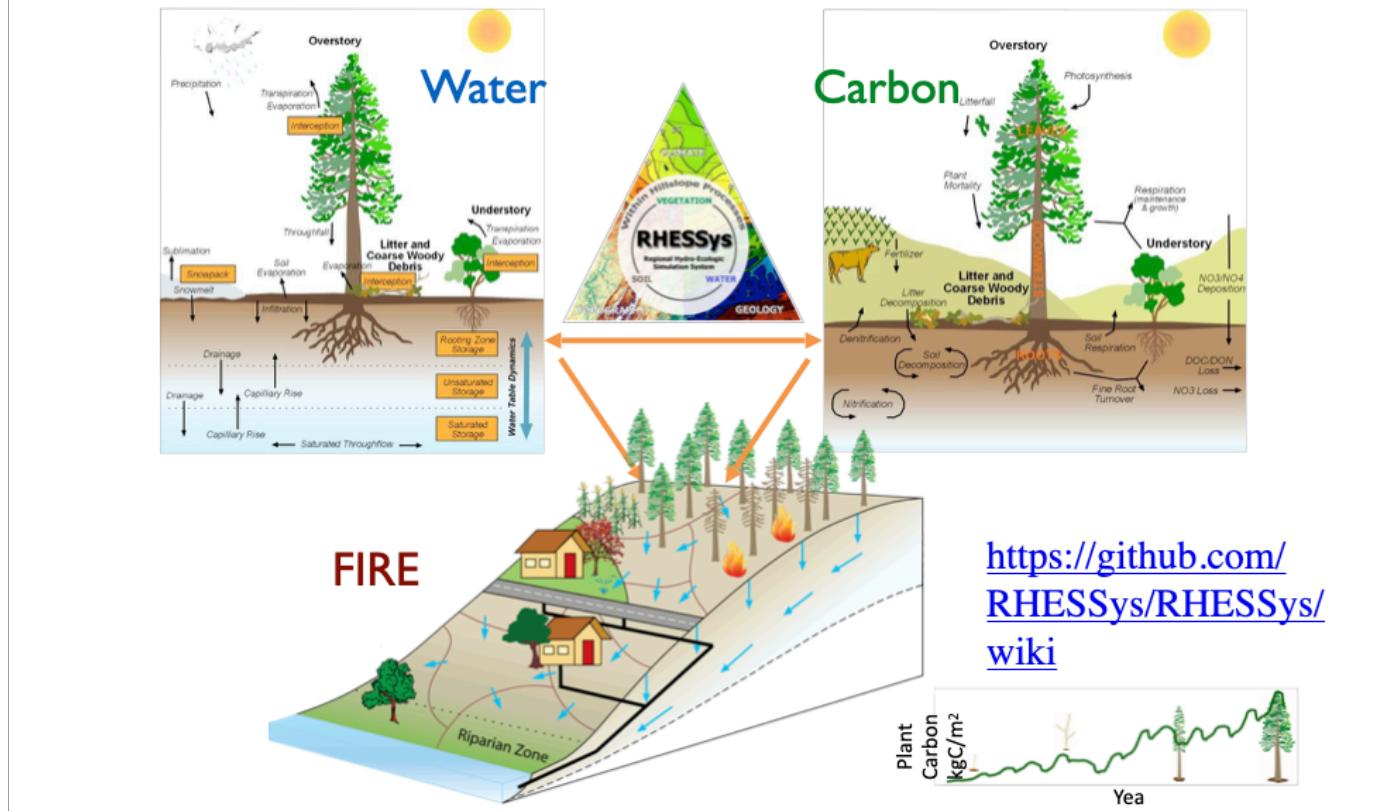
## **MODEL SELECTION: REPRESENTATION**

Example - Will a fire in the upper watershed impact ET more than a similarly sized fire lower (nearer the stream) in the watershed?

## RHESSys

- Includes evapotranspiration and links between upslope and downslope water availability to support it

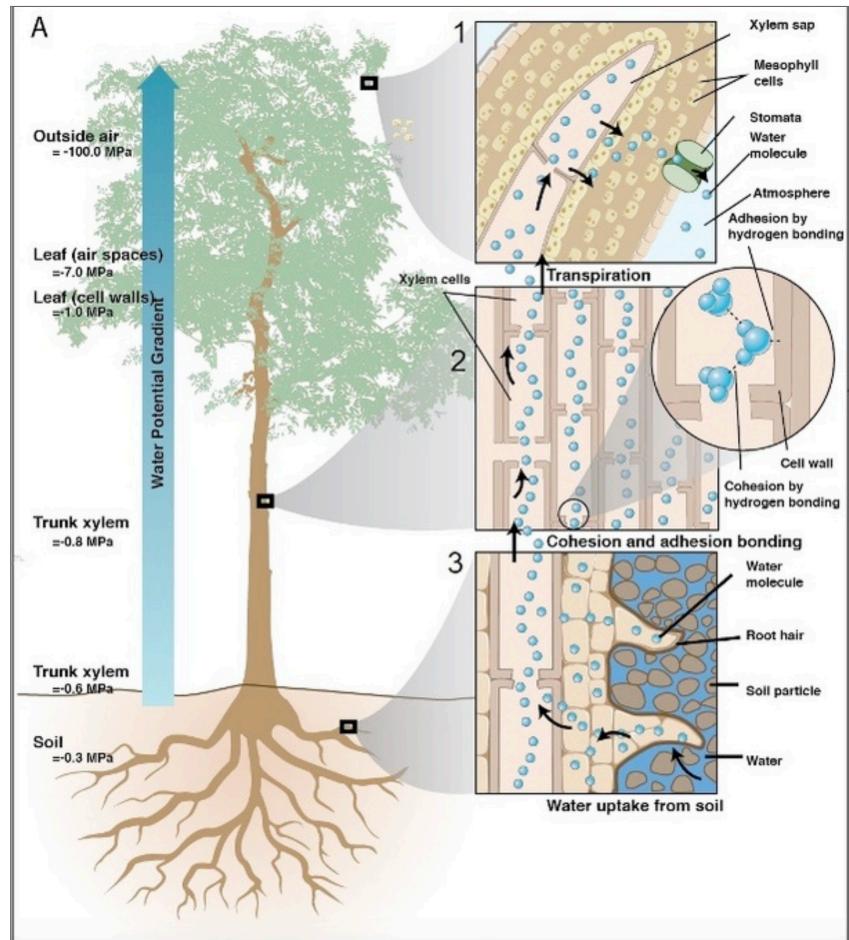
# RHESSys process model does both space-time



RHESSys

## MODEL SELECTION: REPRESENTATION

As trees age does “hardening” of the arteries - e.g reduced conductances of the xylem to water impact ET?

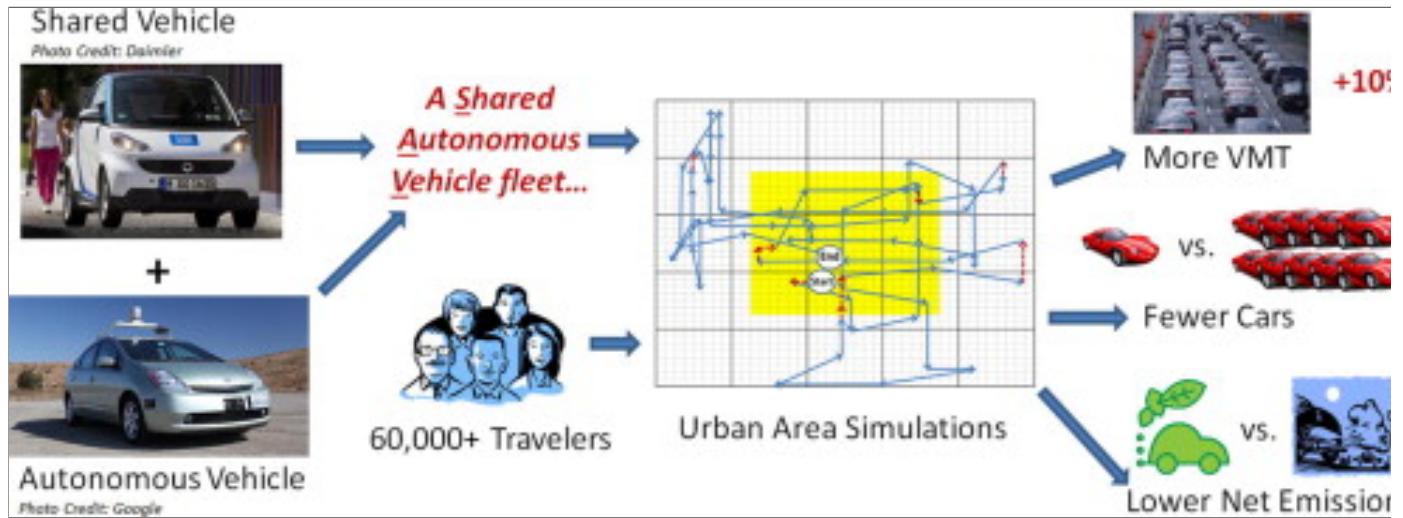


## Within Plant Hydro Model

Citation: McElrone, A. J., Choat, B., Gambetta, G. A. & Brodersen, C. R. (2013) Water Uptake and Transport in Vascular Plants. *Nature Education Knowledge* 4(5):6

## MODEL SELECTION: REPRESENTATION

Do autonomous vehicles reduce travel and environmental impacts? More precise questions - given trip demand from historic data - how many fewer cars are needed, what is the emission reduction due to more efficient cars?



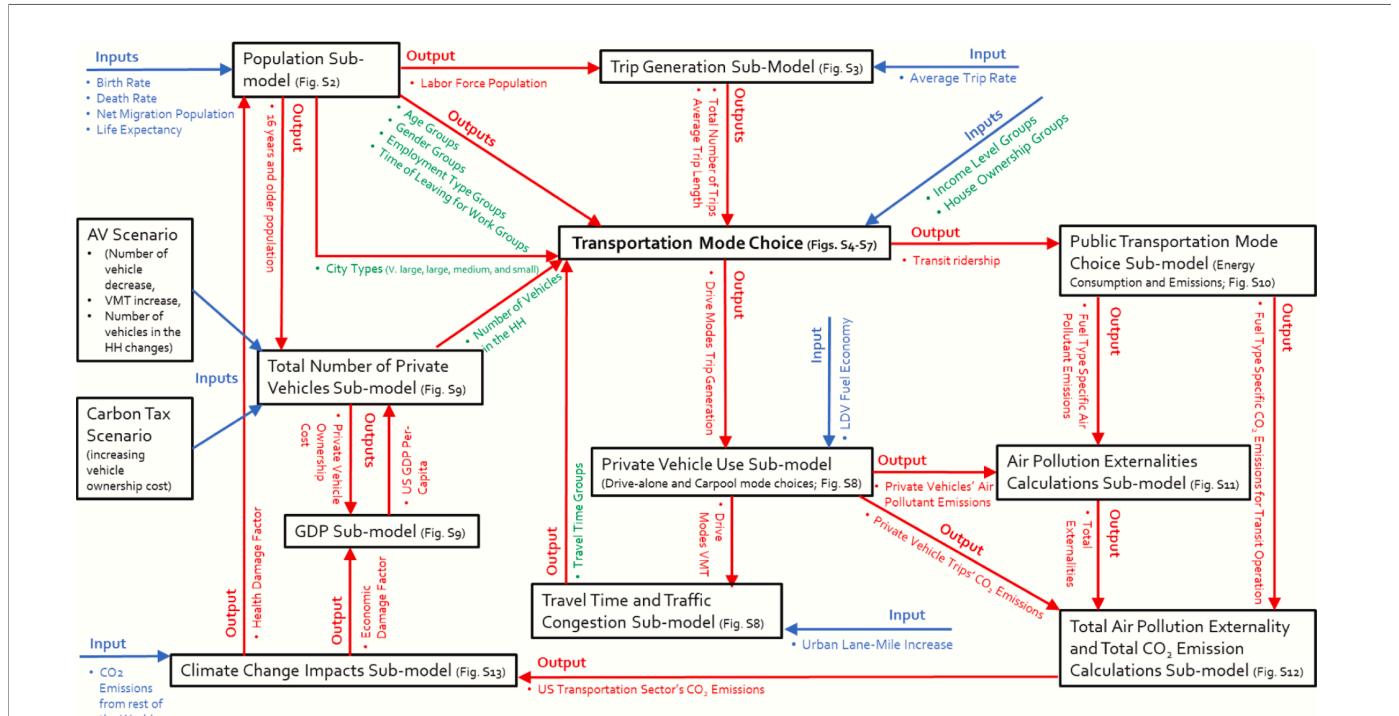
## Model Overview

Citation: Fagnant, Daniel J., and Kara M. Kockelman. "The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios."

Transportation Research Part C: Emerging Technologies 40 (2014): 1-13.

## MODEL SELECTION: A MORE COMPLEX EXAMPLE

What will the impact of autonomous vehicles be on emissions and air quality in different cities (which will likely vary in adoption)



## Overview of Model

Citation: Ercan, Tolga, Nuri C. Onat, Nowreen Keya, Omer Tatari, Naveen Eluru, and Murat Kucukvar. "Autonomous electric vehicles can reduce carbon emissions and air pollution in cities." *Transportation Research Part D: Transport and Environment* 100 (2022): 105600.

*Transport and Environment* 112 (2022): 103472.

## MODEL SELECTION: PERFORMANCE

- Does it capture outputs accurately enough?

Examples from your experience?

## **"VALIDATION" OR IS IT GOOD ENOUGH?**

- Error small relative to:
  - Model application (why do you need the estimate)
  - Simulated effect size
  - Literature/state of the art
  - Demonstrated improvement

## **VALIDATION: TYPES**

- **Reasonableness:** physical/logical checks
- **Accuracy:** comparisons to observations

## **TYPES OF COMPARISONS**

- Compare with:
  - Thought experiments
  - Physical constraints
  - Other models
  - Observed data

## THOUGHT EXPERIMENTS/ PHYSICAL CONSTRAINTS

- Conservation of mass, energy
- Expected behaviors (zero rain = zero streamflow, no cars = no emissions, more fishing with everything else the same, less fish)
- Are output physically reasonable
  - snowpack is not negative
  - reservoir storage is always positive, less than reservoir capacity
  - resulting biomass/size/height within known limits for that species
  - household expenditures more than zero, less than highest income bracket
- Are outputs consistent with known relationships

## COMPARE WITH OBSERVATIONS

What observations?

- local (ideal) - same place

But you often don't have data everywhere

- similar context - similar locations
- similar processes - same process in different locations

**Important** - even if it matches in the past, may not match in the future if something changes

Examples?

- show model works across a range of conditions

*you might not always do this yourself, build on prior model applications*

## EXAMPLES

Does the model accurately capture the behavior you are interested in - in the context you are applying it

We want to estimate how streamflow will change in the next 10 years

- **streamflow**

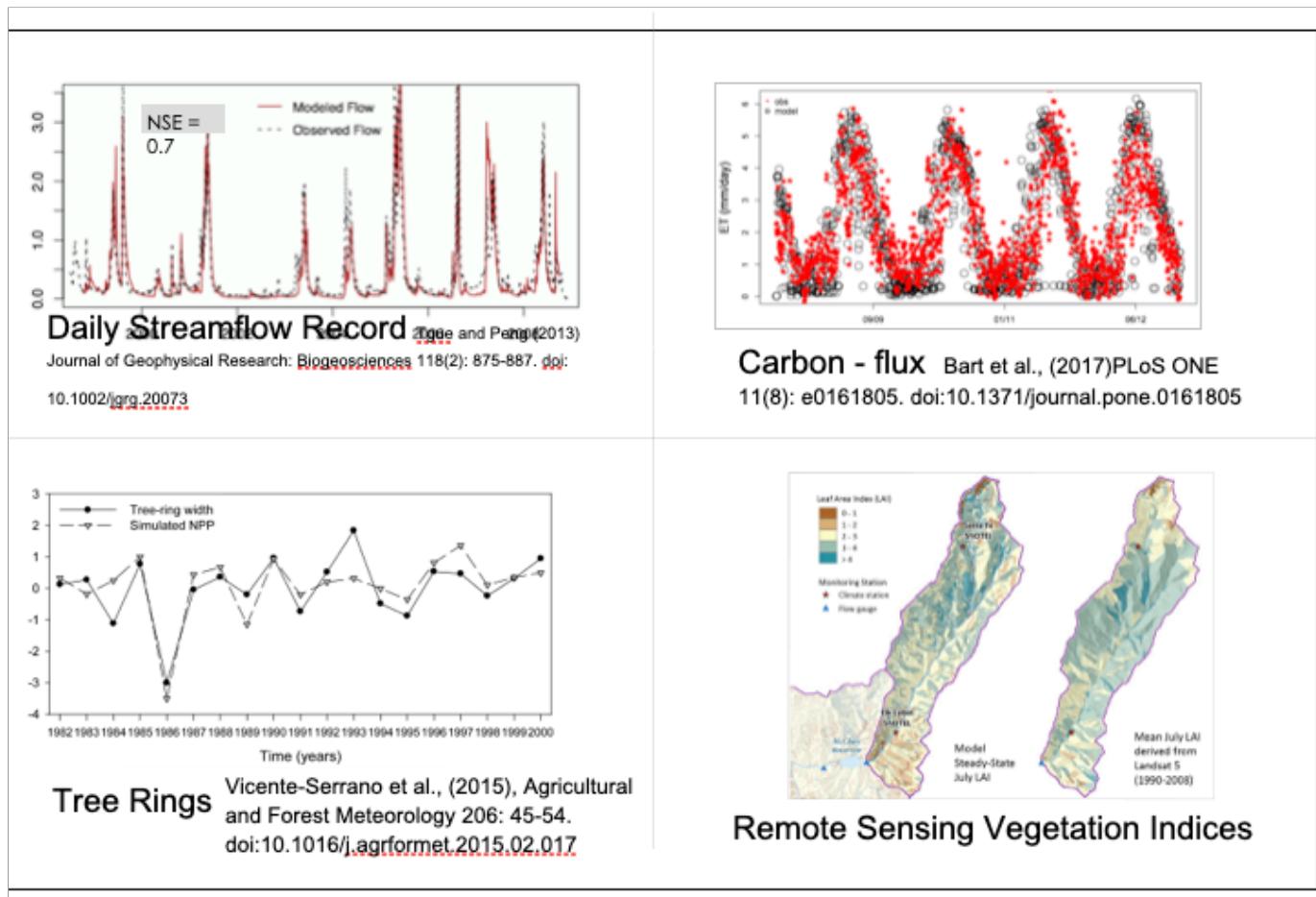
- compare to observed streamflow at gage at study site
- model applied and output compared observed streamflow from warmer, wetter, colder, drier locations
- look at how well model captures streamflow in wet and dry years

We want to estimate fish populations after a new policy is implemented that will change predation rates

- **fish population**

- compare to observed population at study site
- model applied and output compared to observed populations in warmer and colder locations; high predation or low predation locations
- look at how well model captures population growth before and after predators introduced

## EXAMPLE: RHESSYS VALIDATION



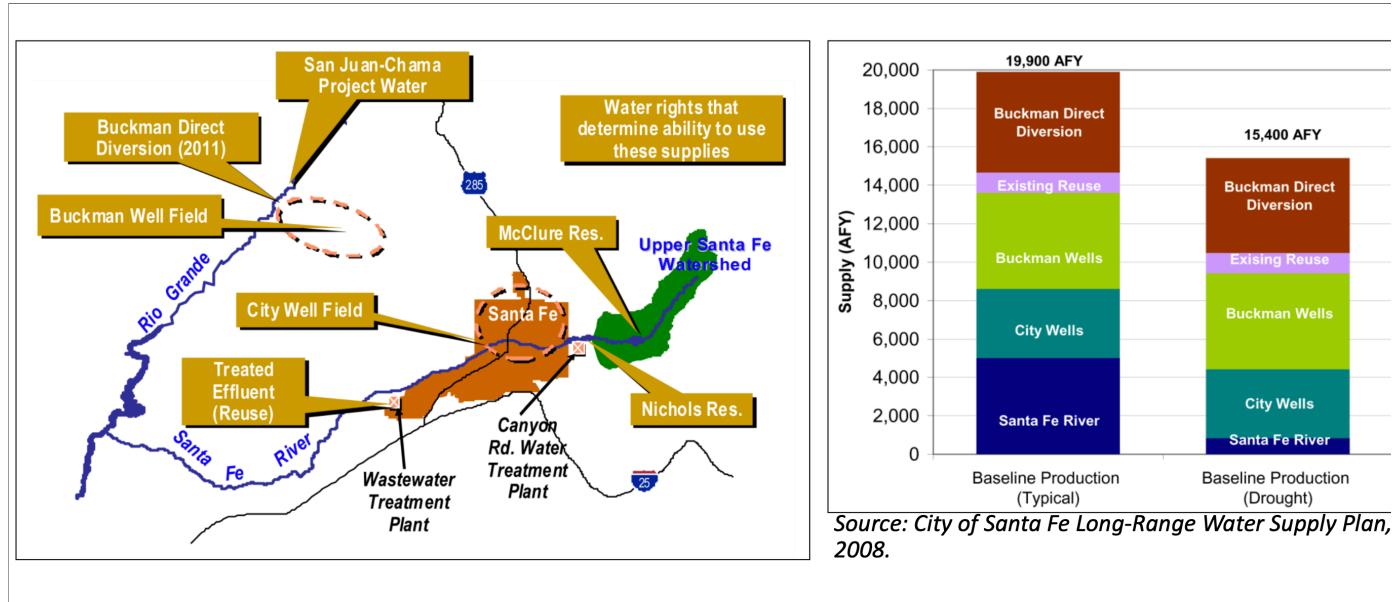
RHESSys\_pro

## EVALUATING ACCURACY

- relative to your effect size (big or small)
- relative to best available other option (other models?)

## CASE STUDY: SANTA FE WATER SUPPLY

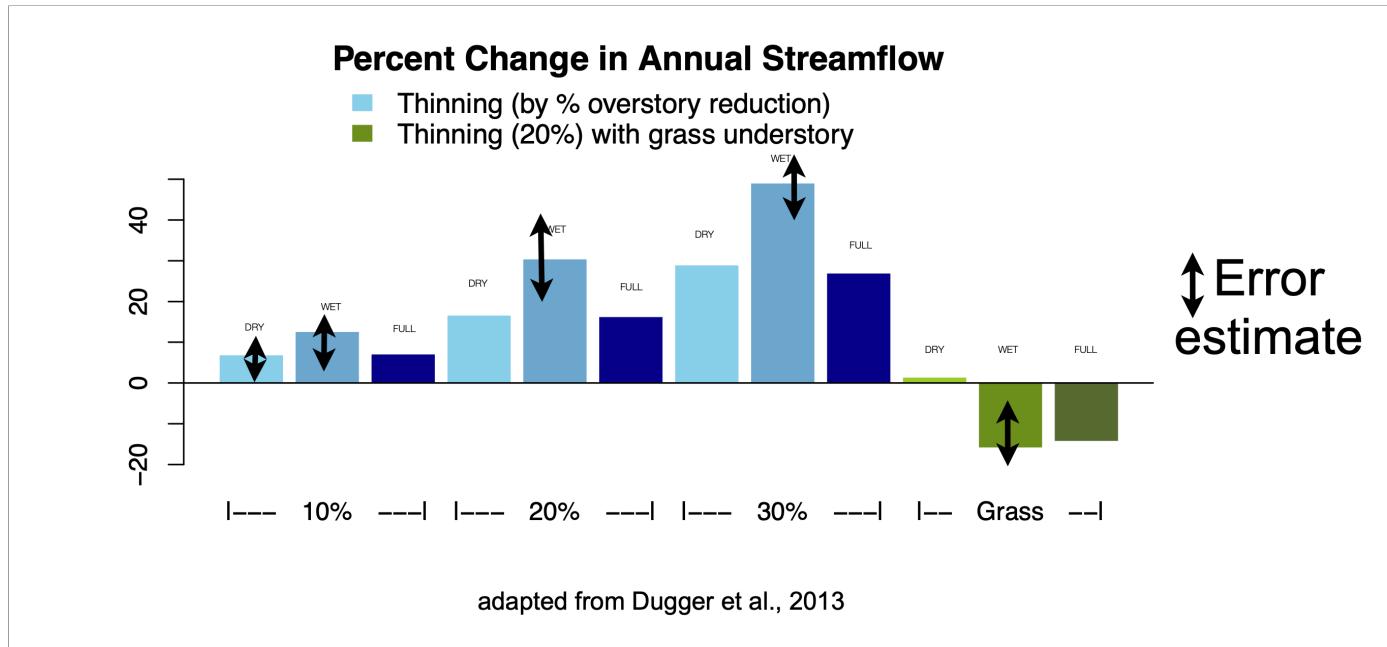
- Threshold for buying water rights under climate change uncertainty



sf

Use a model to see if we should buy water rights now or wait And if vegetation management in water supply catchment would help

## RHESSYS MODEL ESTIMATES



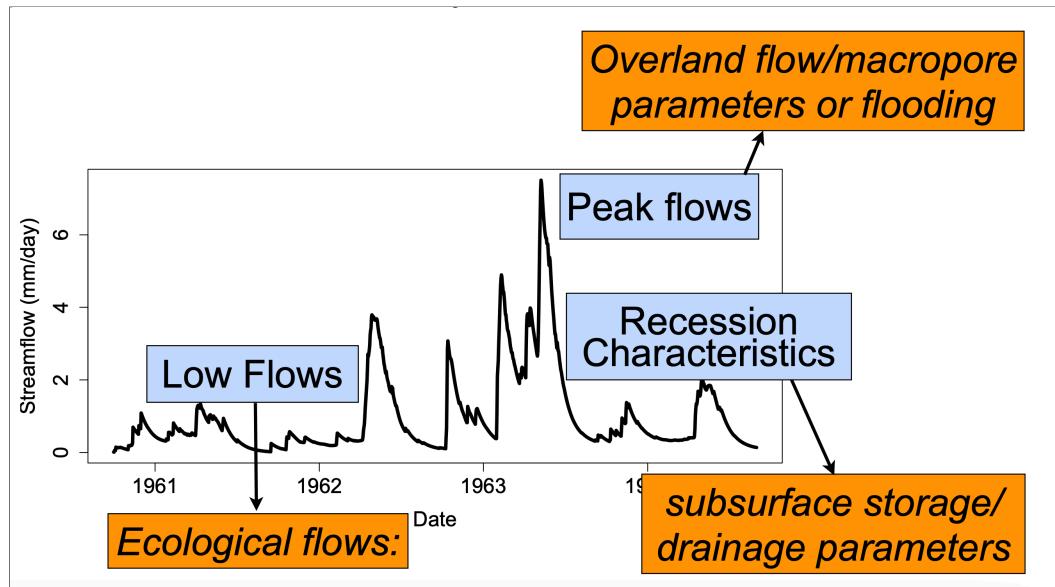
sfr

## MODEL PERFORMANCE (MEASURING ACCURACY)

- First Plot!

## PERFORMANCE OF WHAT?

Similar to sensitivity of what? Extracting what is meaningful from the model



hp

## **PERFORMANCE METRICS**

- **RMSE, Percent Error**
- what others have you used?

## STREAMFLOW DATA

Lets start by looking at some data

- **obsmm** is measured streamflow
- **strmm** is simulated streamflow from a model

Both are daily data and normalized by watershed area (mm/day)

Date information is also included

Consider some different ways you can compare models and observed Graph! (what about yearly versus daily?)

```
1 library(tidyverse)
2 library(here)
3 w8=readRDS(here("Data/w8.RDS"))
```