



# Energy-Water-Land-Climate Nexus: Modeling Impacts from the Asset to the Regional Scale

Vincent Tidwell, Alexis Corning-Padilla

Katrina Bennett, Richard Middleton

Susan Behery

Jordan Macknick, Greg Brinkman and Measrainsey Meng



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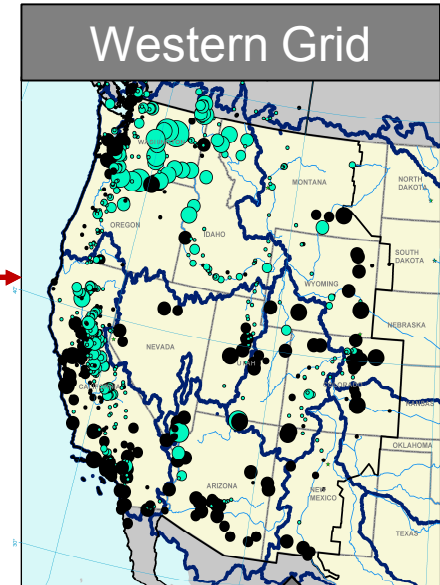
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# Objective

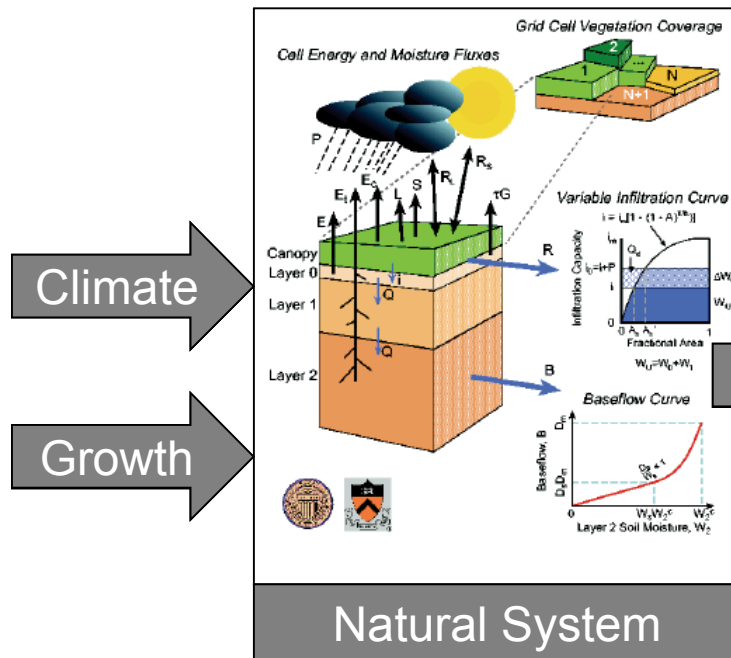
- Framework that links natural and engineered systems to evaluate climate vulnerabilities at the **asset level**:

- Multiple interacting sectors,
- Multiple forcings, and
- Multiple interacting scales.

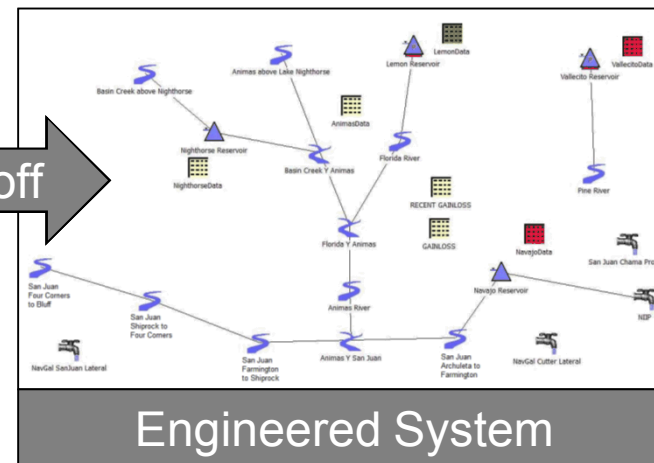
Next Speaker →



GC43C-1177  
Katrina Bennett  
Poster Thursday afternoon



Runoff →



## Deliveries

- Electric Power
- Agriculture
- Environment



# San Juan Basin

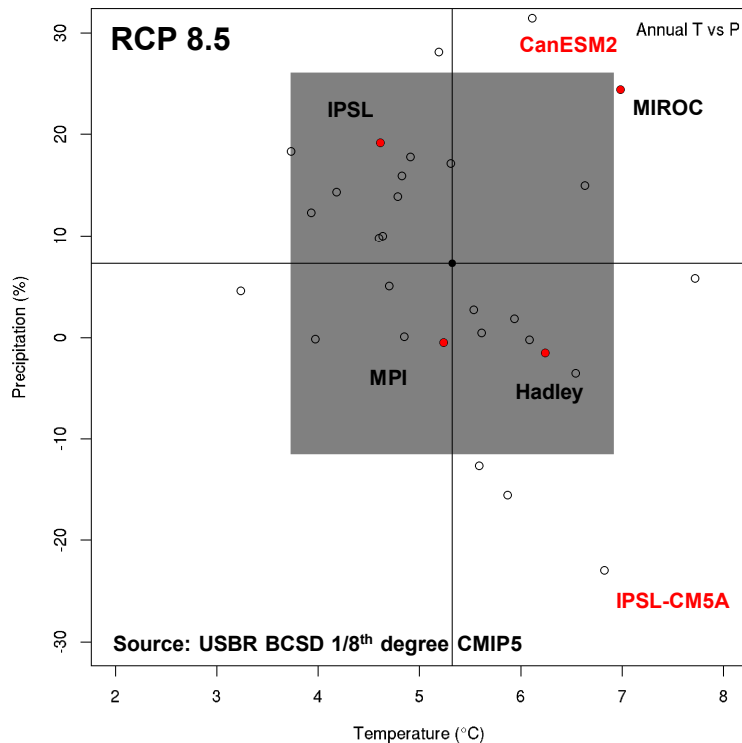


## Four Corners Region

- Colorado River basin
- Snow melt dominated system
- Water Users
  - Native American
  - Irrigation
  - Multiple power plants and limited hydropower
  - Municipalities
  - Instream flows
  - Interbasin transfers

# Model Scenarios

## 1. Six CMIP5 global climate models using scenario RCP 8.5



## 2. Climate Driven Vegetation Change (Fire, Infestation, Mortality)



## 3. Growth Scenario

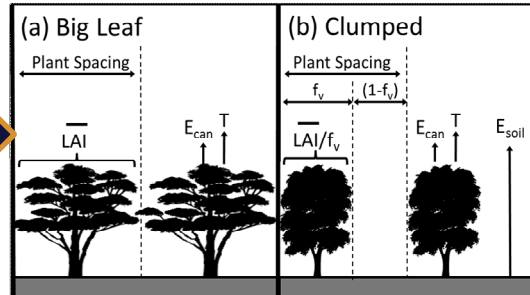


Navajo Indian Irrigation Project

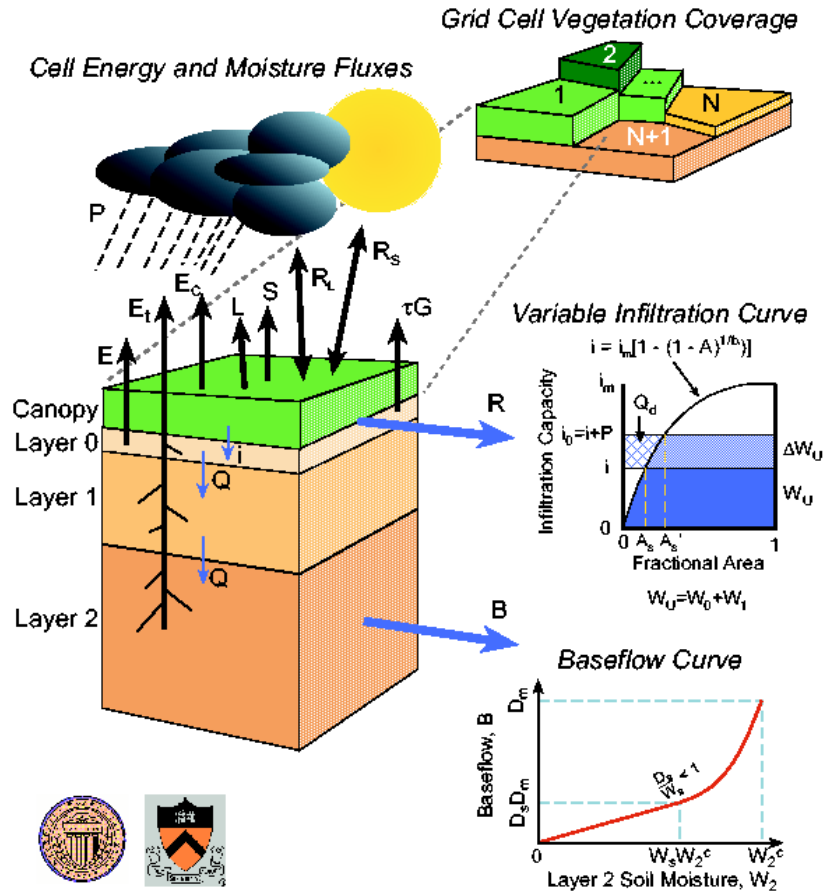
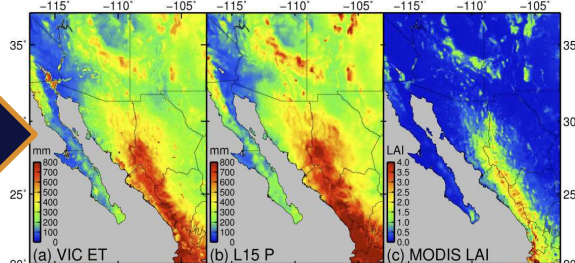
# Methods: Hydrology

- Variable Infiltration Capacity (VIC) model at 1/16<sup>th</sup> degree
- New MODIS data, including time series for each grid cell for albedo, vegetation spacing and LAI
- Downscaling using Multivariate Adaptive Constructive Analogues (MACA) data set (Abatzoglou and Brown, 2011)

VIC Version 4.2x



MODIS Veg;  
Livneh et al.  
2015

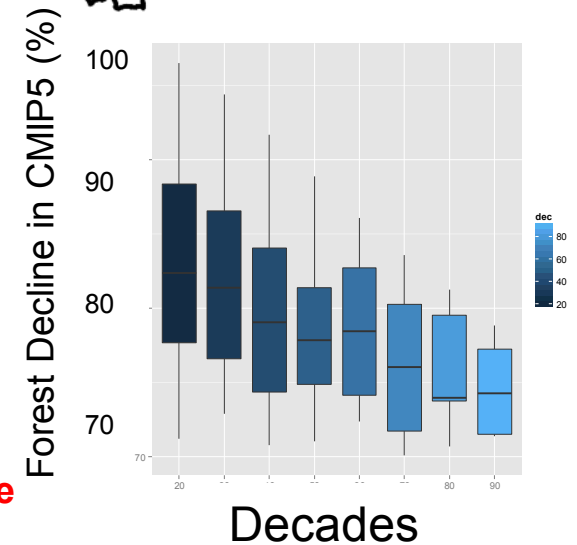
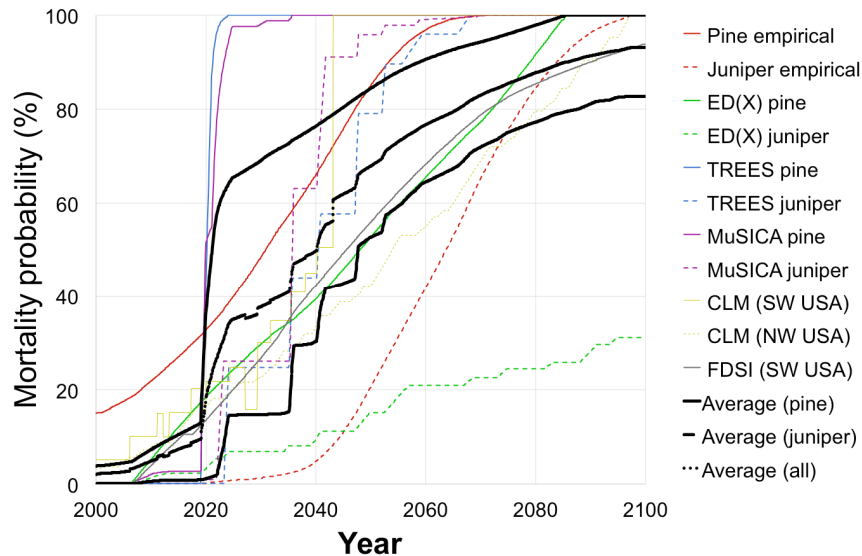
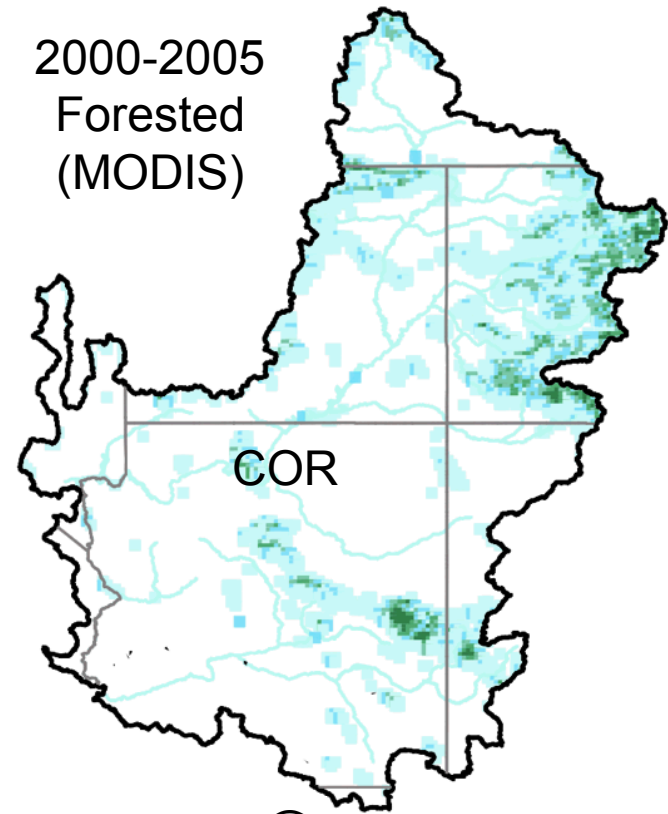
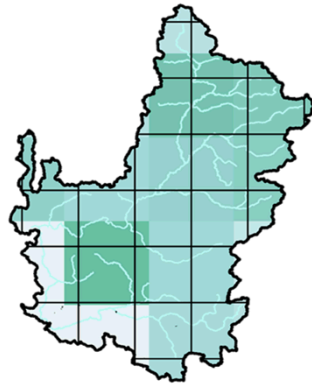


Bohn and Vivoni, 2015



# Methods: Vegetation

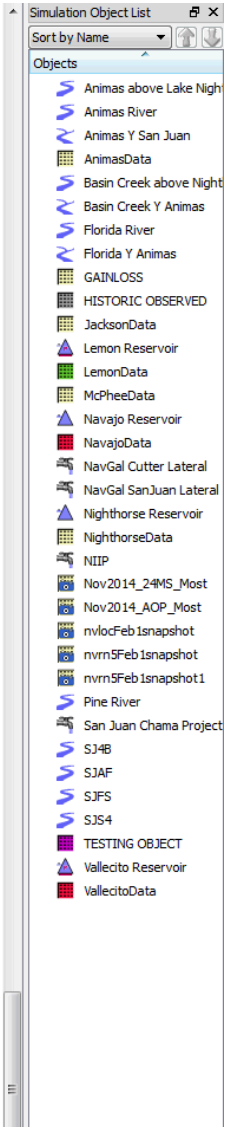
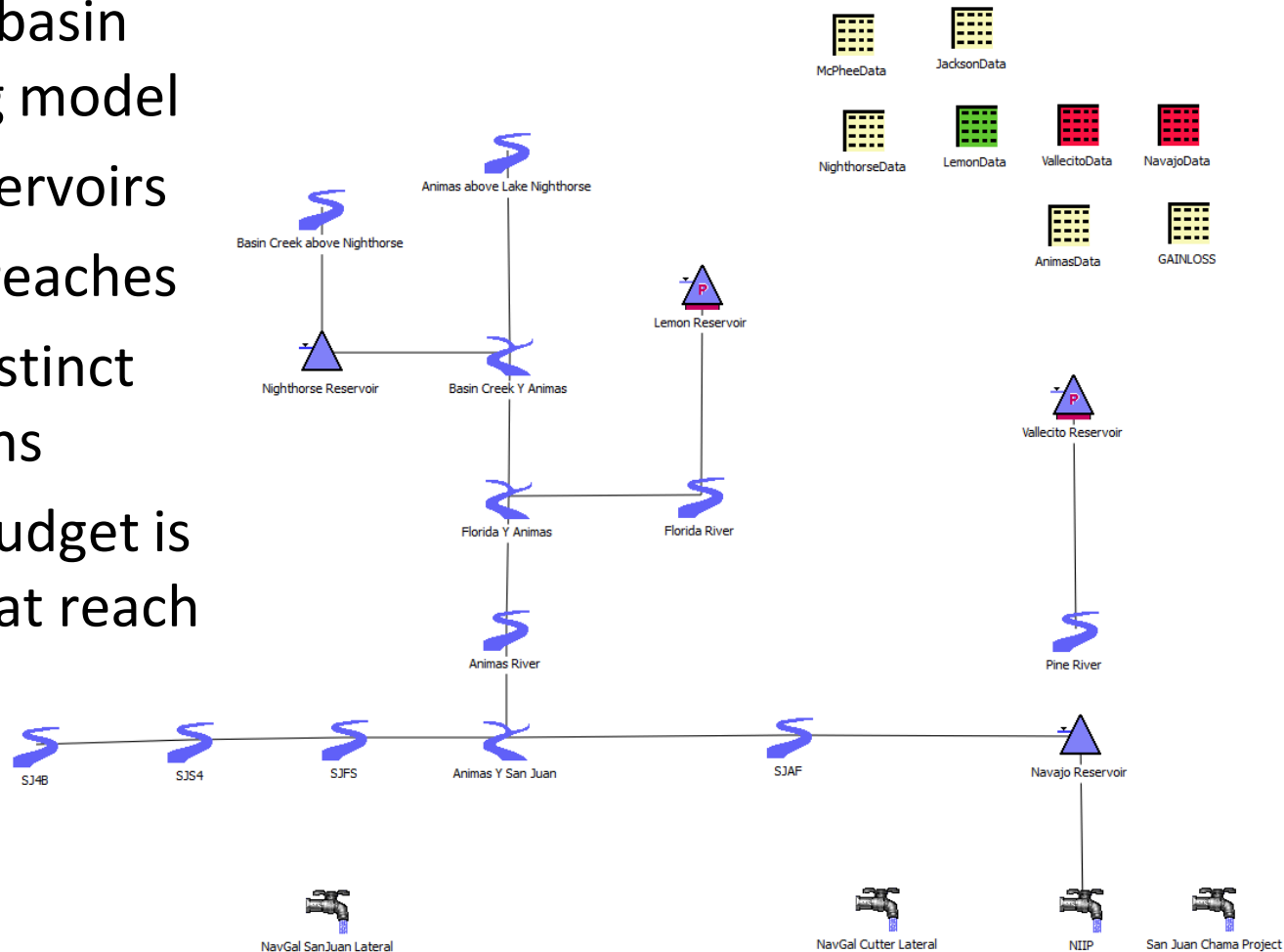
2000-2005  
Forested  
(MODIS)



**McDowell et al. Convergent predictions of massive conifer mortality due to chronic temperature rise. *Nature Climate Change*. 2015.**

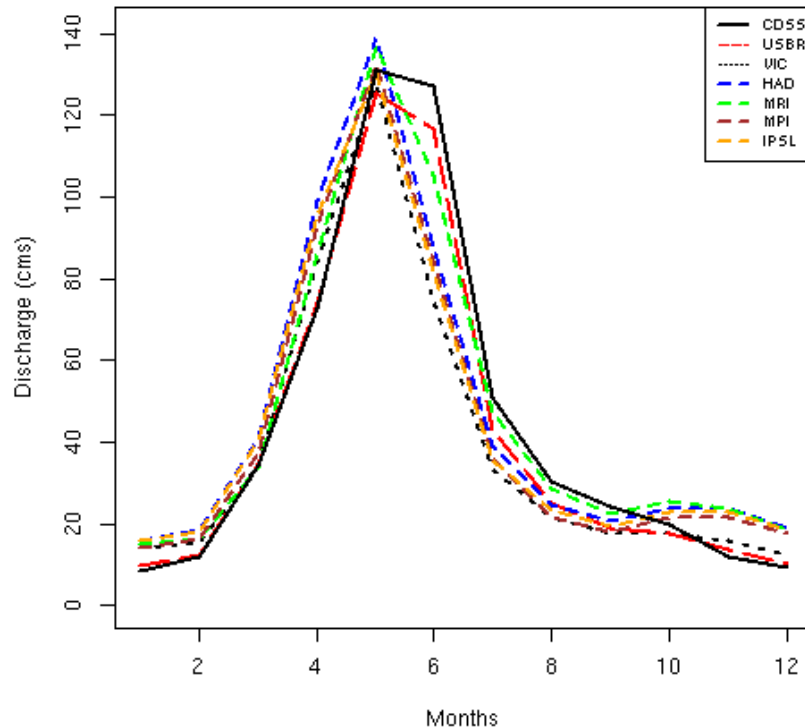
# Methods: Reservoir Routing

- RiverWare
- Current basin planning model
- Four reservoirs
- Twelve reaches
- Three distinct diversions
- Water budget is lumped at reach level



# History Matching

SJARN Monthly Average Flows (1974-2005)

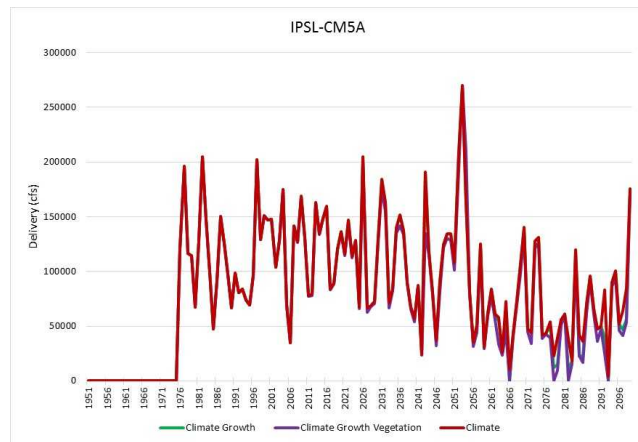
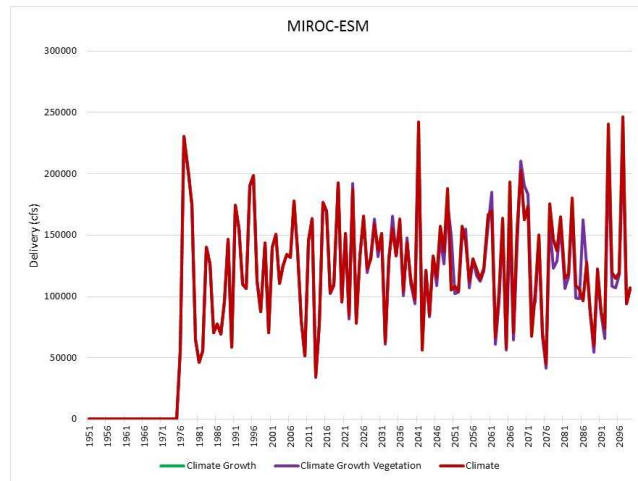


- Average monthly flows reproduced well except in June
- Calibration and validation accomplished at points just below Navajo Reservoir and the outlet to Lake Powell

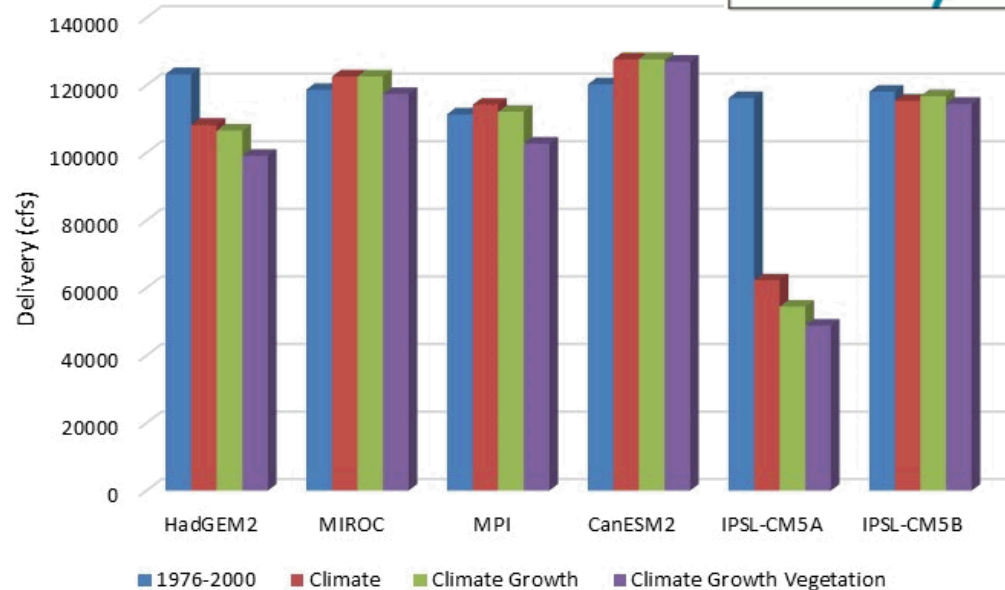
Period of Analysis	Statistic	SJARN	SJNBU
Calibration (2006-2010)	Correlation Coefficient	0.91	0.90
Calibration (2006-2010)	Nash Sutcliffe	0.78	0.76
Calibration (2006-2010)	Nash Sutcliffe Log	0.77	0.75
Validation (2001-2005)	Correlation Coefficient	0.93	0.93
Validation (2001-2005)	Nash Sutcliffe	0.83	0.59
Validation (2001-2005)	Nash Sutcliffe Log	0.77	0.43
All (2001-2010)	Correlation Coefficient	0.90	0.91
All (2001-2010)	Nash Sutcliffe	0.81	0.67
All (2001-2010)	Nash Sutcliffe Log	0.78	0.58



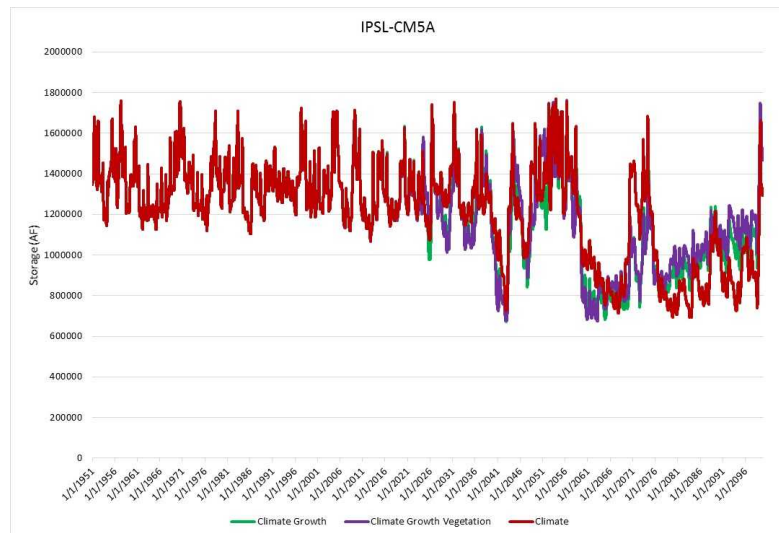
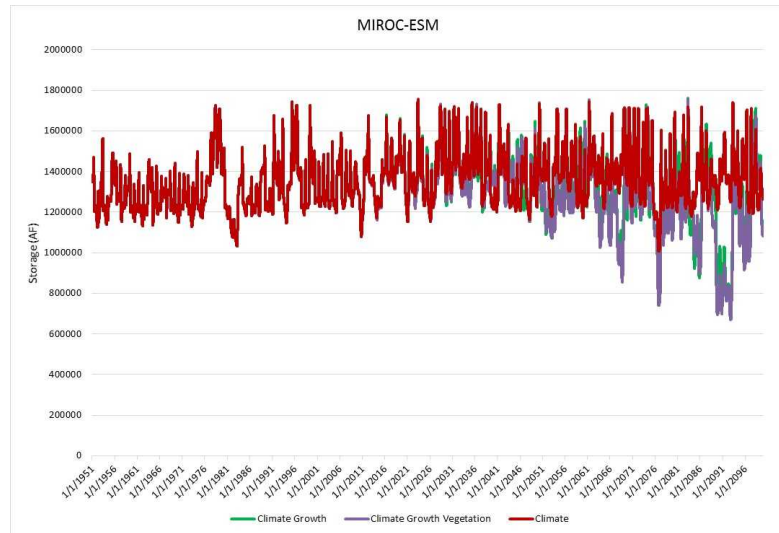
# San Juan-Chama Deliveries



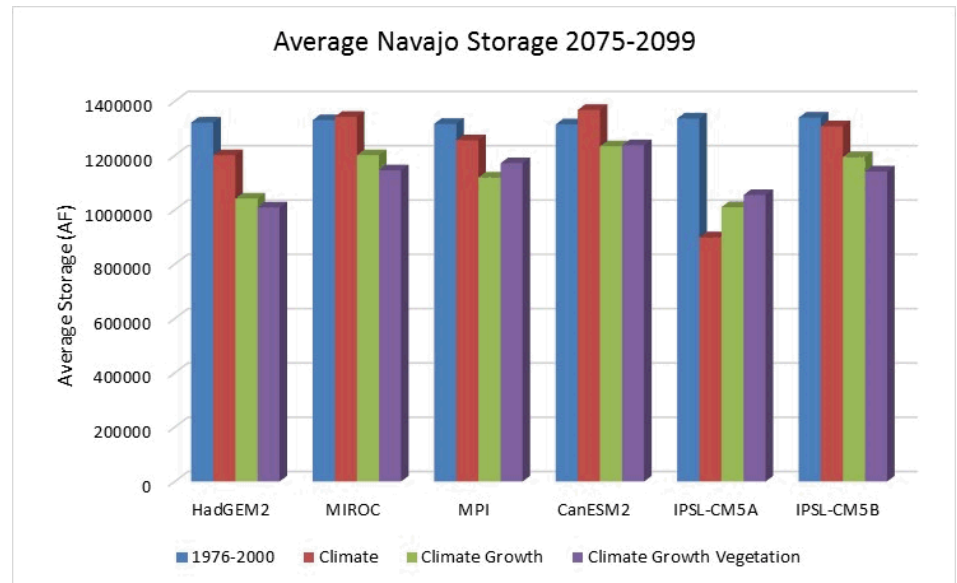
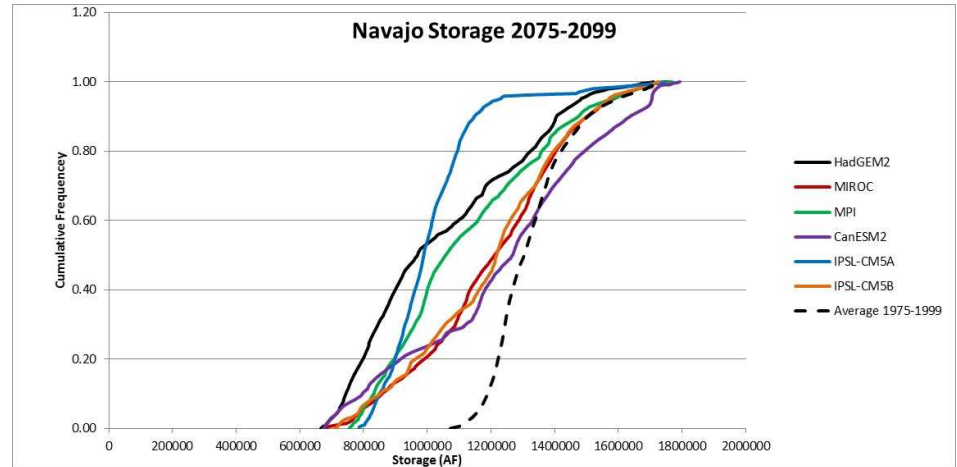
Average Deliveries 2075-2099



# Navajo Reservoir Storage

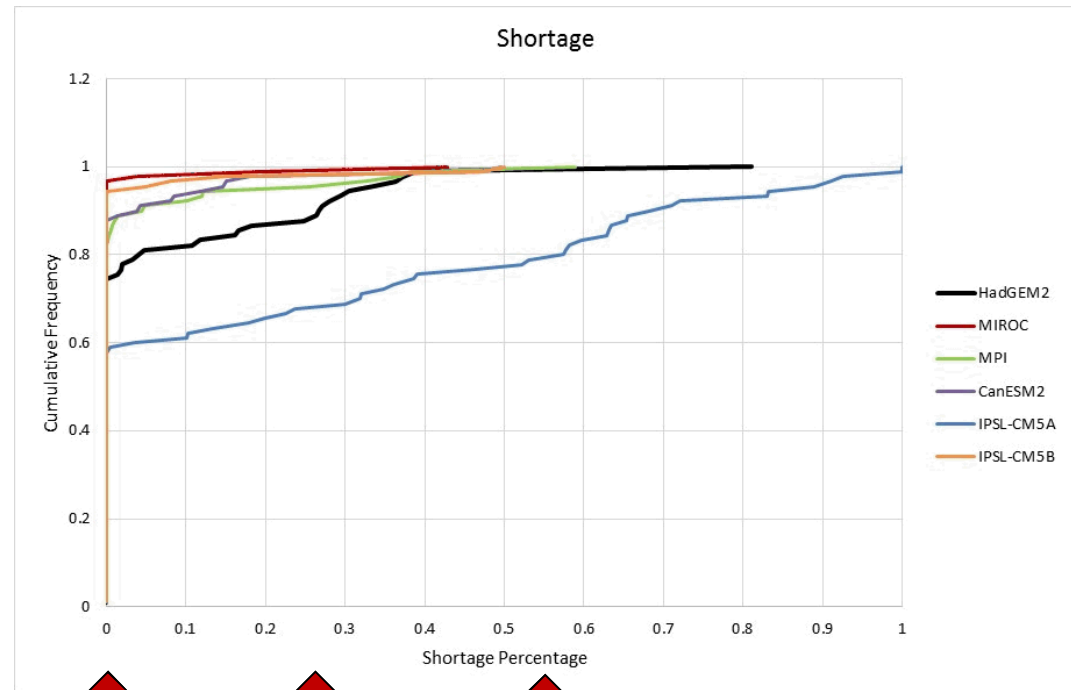
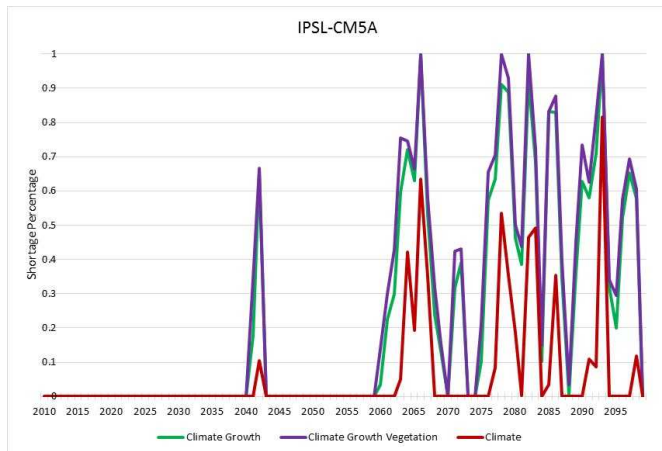
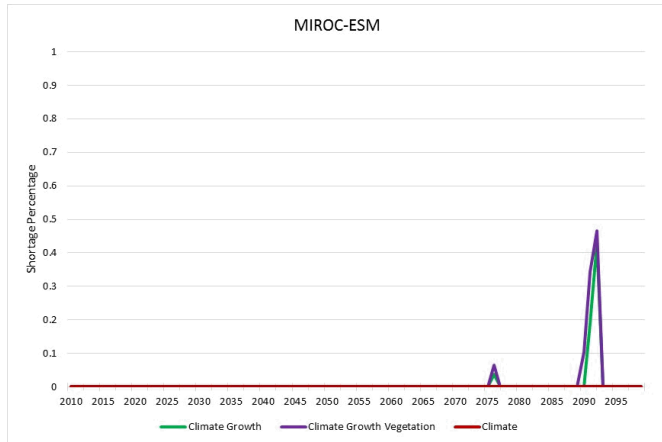


Minimum Operating Storage 662,000 AF



# Water Deliveries

- Shortage sharing used to prioritize deliveries: all share equally in times of water shortage

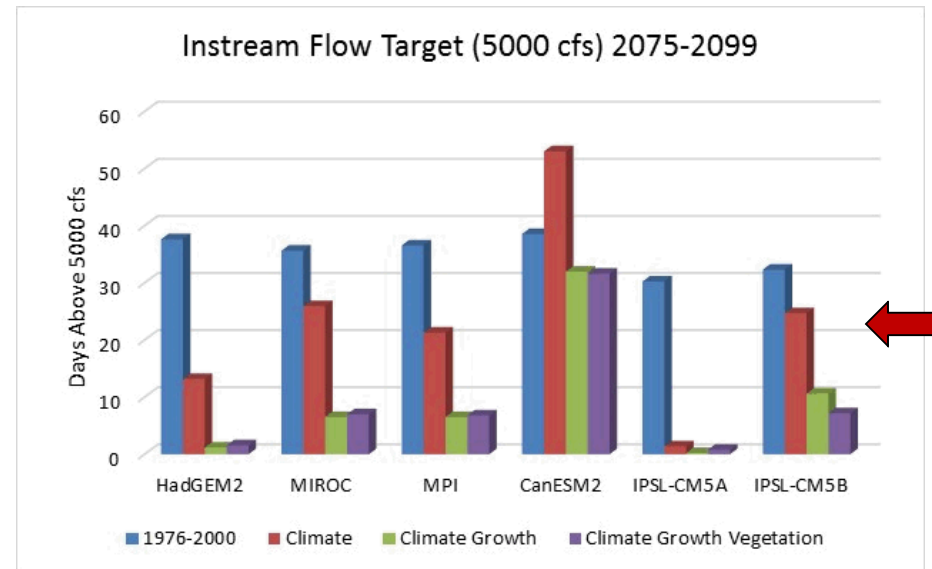
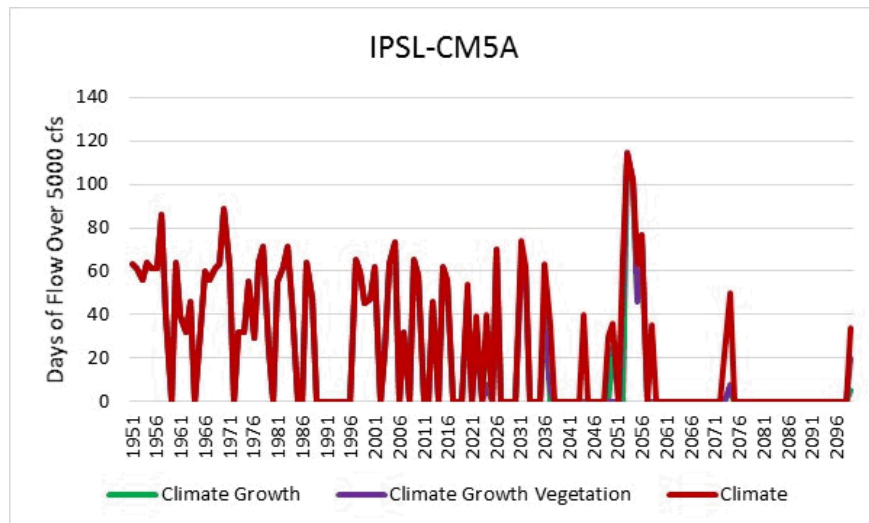
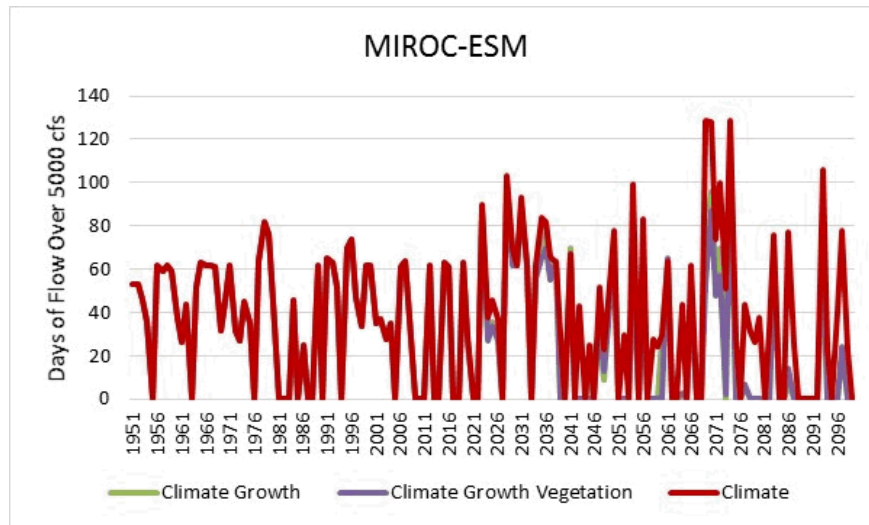


Navajo Indian Irrigation Project  
Other Farmers  
Four Corners Power Plant  
City of Farmington  
San Juan Power Plant



# Target Instream Flows

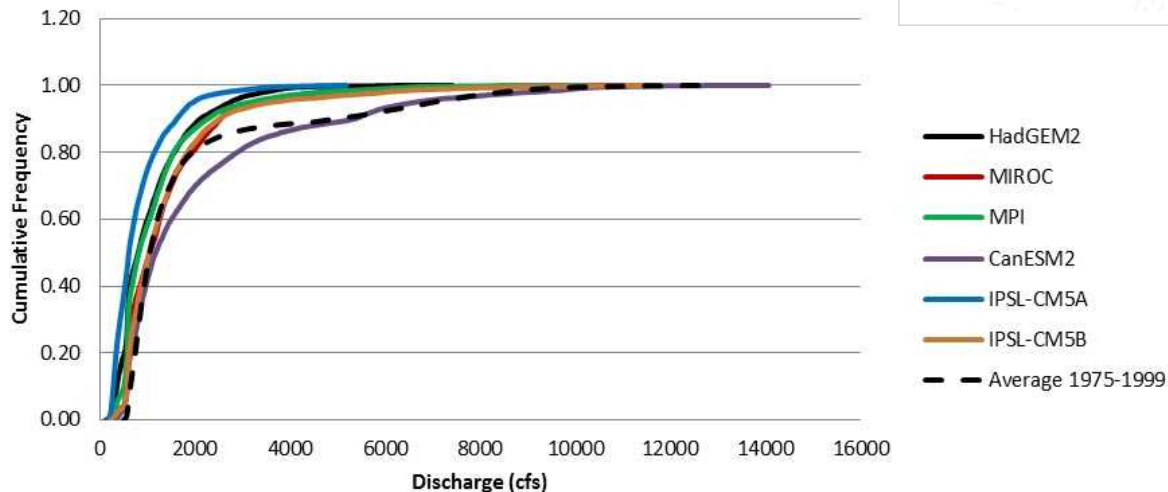
Days above 5000 cfs: March-July  
Target is 21 days per year



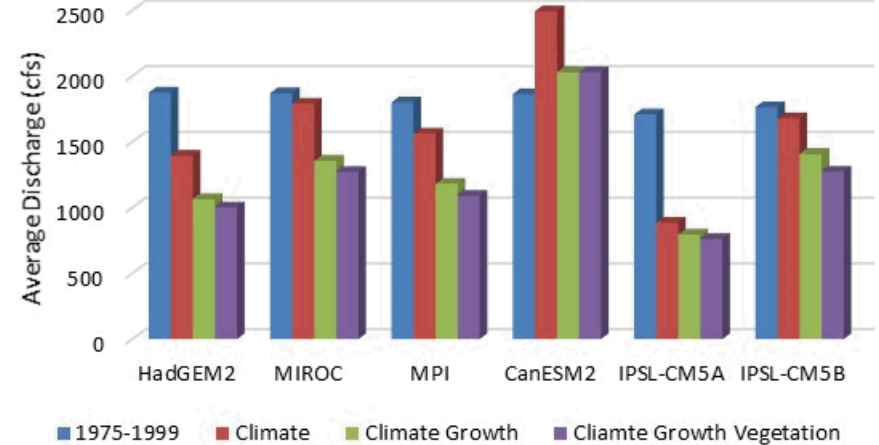
# Deliveries on Colorado River

- One of three major upper basin tributaries to Colorado River
- Supplies about 18% of average annual flow

Discharge to Lake Powell 2075-2099



Discharge to Lake Powell 2075-2099



# Summary

- ***Growth and Climate:*** Only two models yielded delivery shortages under the climate only scenario; however when combined with growth all models registered multiple shortages.
- ***Uncertainty:*** Significant differences in projected impacts were consistently evident across climate models and scenarios.
- ***Uneven Impacts:*** Impacts differ significantly by metric due to position in basin and the institutional controls dictating its operations.
- ***Non-Local Impacts:*** Local effects of climate change spilled over to other basins:
  - Lower Colorado River, and
  - San Juan- Chama diversion to Rio Grande Basin.



- Project information:
- <http://water.sandia.gov>

Vincent Tidwell

Sandia National Laboratories

[vctidwe@sandia.gov](mailto:vctidwe@sandia.gov)

(505)844-6025

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## Energy and Water in the Western and Texas Interconnects

Background Objectives Tasks Benefits/Outcomes Collaborators Links Documents Data Portal

### Water Scarcity Impacts Energy Production

In the United States the energy sector accounts for approximately 41% of daily fresh water withdrawals and 49% of total overall daily water withdrawals for the following energy-related uses:

- Hydroelectric power generation
- Thermoelectric power plant cooling and air emissions control
- Energy-resource extraction, refining, and processing

The Energy Information Administration projects the U.S. population will grow by **70 million people** between 2005 and 2030, increasing electric power demand by **50 percent** and transportation fuel demand by **30 percent**. This will require more water. Unfortunately, this growth in water demand is occurring at a time when the nation's fresh water supplies are seeing increasing stress from:

- Limitations of surface-water storage capacity
- Increasing depletion and degradation of ground water supplies
- Increasing demands for the use of surface water for in-stream ecological and environmental uses
- Uncertainty about the impact of climate variability on future water fresh surface and ground water resources

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