How does the global and regional water cycle (soil moisture, precipitation, runoff, floods, drought, ground water) change as climate changes?

Key water cycle processes need to be captured at the global scale before sufficiently accurate regional downscaling simulations of the water cycle for the purpose of informing decision makers on the best approach for mitigation and adaptation become possible.
Projected precipitation changes in global climate models over regions where people live (+/- 50 latitude) mostly show low confidence (less than 66% of the models agree on the sign of the precipitation change, white region). This is especially true in northern hemisphere summer and southern hemisphere winter (red outlines). These are also regions with coherent patterns of propagating convection, a focus of Water Cycle res.

**FIGURE SPM-7.** Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}
Global Climate model areas of disagreement for precipitation:

1. Summer convection in the lee of major mountain ranges

2. Winter precipitation over mountainous regions

Hoskins says: "If the large scale is rubbish, then the detail is rubbish, too."

--New Scientist, 7 May 2008

Focus of NCAR Water System program:

1. Understanding the diurnal cycle of convection in the lee of major mountain ranges and improving the representation in climate models

2. Understanding the processes leading to winter precipitation over mountainous regions, and improving its parameterization in climate models.
“Downscaling climate models is essential. Many managers are stuck at the step of linking Global Circulation Models (GCMs) with hydrology models used in planning for utility or water supply management. Decision support systems that start with GCMs and IPCC scenarios show a large range of impacts and are not necessarily fine enough for local planning, making it difficult to use the results for planning. GCMs do not provide useful information on extreme events.”

Western Governors Roundtable on Water Resources and Climate Change, (2008)
Impact of Climate Change on Snowpack in Colorado’s Headwaters

- **Domain:** The continental-scale river basins whose headwaters reside in the Colorado region
  - South Platte
  - Arkansas
  - Rio Grande
  - Gunnison
  - Colorado River
  - Yampa/White
  - San Juan/Dolores
SWANS
Genesis & Accomplishments

Climate Change & Urban Water
Demonstrates Need for Information

Front Range & Western U.S. Adaptation Planning
Critical Info: Changes in Snowpacks; Flow Timing

Colorado Headwaters Research Program
- Atmospheric Processes
- Land Surface Processes
- Societal Applications
Natural Variability & Climate Change: Must cope with both sources of uncertainty

- Water supplies can change dramatically, and for extended periods, as a result of natural variability
- Global climate change adds further uncertainty
Risk-based decision analysis

Problem Structuring → Deterministic Analysis → Uncertainty Analysis → Evaluation of Alternatives

Goals, alternatives, information, values

Model of the decision
Sensitivity analysis to identify key variables
Represent key variables with probabilities / Evaluate robustness to uncertainty
Determine best plan under uncertainty → iterations
AwwaRF-NCAR Climate Change Primer

Develop structured process to explicitly consider CC into decision making

Work with partnering utilities from the very start

1. Inland Empire of Southern California
2. Regional Utility Alliance in California, CABY
3. Colorado Springs, CO
4. Boston, MA
5. Durham, NC
6. Palm Beach County, FL
7. New York City, NY
8. Portland, OR
Partnership Design and Decision Tools

Industry Research – AwwaRF

Utility Partners

Structured Process & Decision Tools

Project Team NCAR, consultants

Climate Research – NCAR; Universities; Federal Agencies
The Inland Empire Utility Agency

- Industry Research – AwwaRF
- WEAP, CARS, Robust Decisions
- Project Team: NCAR, RAND
- Climate Research – NCAR; Univ. Santa Clara, CEC, State
- Inland Empire Utility agency
**Critical question:** How does rainfall on a catchment translate into flow in a river?

**Critical question:** What pathways does water follow as it moves through a catchment?

**Critical question:** How does movement along these pathways impact the magnitude, timing, duration and frequency of river flows?
Planning Issues

**Critical question:** How should water be allocated to various uses in time of shortage, and still be constrained to meet other uses?

**Critical question:** How should infrastructure in the system (e.g. dams, diversion works, etc) be operated to achieve maximum benefit and/or meet regulatory requirements?

**Critical question:** How will allocation, operations and operating constraints change if new management strategies are introduced into the system?
Decision Support for Water Resources Planning and Management

Colorado’s Headwaters
Decision Support for Water Resources Planning and Management

Sacramento Basin
Decision Support for Water Resources Planning and Management

Massachusetts Water
Decision Support for Water Resources Planning and Management

Palm Beach County, FL