The South Platte Basin Hydrologic Observatory

Concept

The intersection between: (1) the Rocky Mountains and developments occurring in high altitude fragile environments; (2) the metropolitan areas emerging at the interface of the mountains and the plains; (3) the irrigation occurring along rivers as they break from the mountains and snake across the Great Plains; and (4) the grasslands and the dryland farming that covers the vast amount of the Great Plains, represents a dynamic, complex, highly integrated ecosystem, stretching from Montana and North Dakota to New Mexico and Texas. Within this large area, besides tremendous increases in population in metropolitan areas, there are new energy developments, old hard rock mining concerns, new recreation developments, irrigation farms selling water to meet urban demands, new in-stream flow programs, struggling rural areas, and continued *mining* of ground water. The corresponding impacts are creating endangered and threatened species conflicts which require new knowledge to fully understand the measures needed to mitigate harmful ecosystem conditions.

Within the Rocky Mountain/Great Plains interface, water is limiting and land is plentiful, presenting natural resource managers with a number of unique problems which demand a scale of integrated science not achieved in the past. For example, water is imported into a number of the streams flowing east from the Rocky Mountains, complicating the natural systems, on both sides of the continental divide. Nitrogen is deposited in pristine watersheds that rise up high in the Rocky Mountains. Cities capture spring runoff in reservoirs to use at a steady rate over the entire year, putting water into river systems normally moving low flows in the winter. Irrigation of both urban landscapes and farm fields may be at a scale that impacts climate patterns in the region.

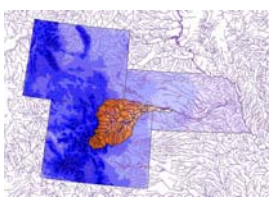
The purpose of this South Platte Basin Hydrologic Observatory proposal is to employ the "hydrologic observatory" concept to make the necessary observations in order to advance hydrologic science by studying the South Platte River Basin, as representative of many of the scientific hydrologic issues facing the Rocky Mountain/Great Plains interface watersheds.

With a detailed integration of data sets, from a wide array of study efforts, the South Platte Hydrologic Observatory will produce sound science findings to assist natural resource decision making in the region. In addition, with careful planning and efforts to correlate the South Platte findings with other rivers in the region, the findings will be able to assist decision making from Canada to Mexico.

The South Platte Hydrologic Observatory will coordinate its work with the water institutes in Montana, North and South Dakota, Wyoming, Nebraska, Kansas, Oklahoma, New Mexico and Texas, as part of an effort to extend the knowledge of the Rocky Mountain/Great Plains river system hydrology from Canada to Mexico. This water institute coordination will be organized under the auspices of the National Institutes for Water Resources.

Location

The South Platte River Basin has a drainage area of about 24,300 mi² (Dennehy, 1991) and is located in parts of three States - Colorado (79 percent of the basin), Nebraska (15 percent of the basin), and Wyoming (6 percent of the basin). The South Platte River originates in the mountains of central Colorado at the Continental Divide and flows about 450 mi northeast across the Great Plains to its confluence with the North Platte River at North Platte, Nebraska. Altitude in the basin ranges from 14,286 ft at Mt. Lincoln on the Continental Divide to 2,750 ft. at the confluence of the South Platte and North Platte Rivers.



Climate

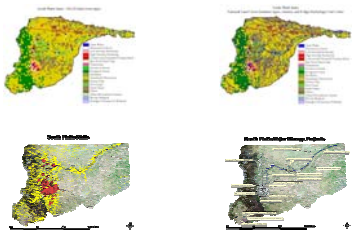
The basin has a continental-type climate modified by topography, in which there are large temperature ranges and irregular seasonal and annual precipitation. Mean temperatures increase from west to east and on the plains from north to south (Gaggiani and others, 1987). Areas along the Continental Divide average 30 in. or more of precipitation annually, which includes snowfall in excess of 300 in. In contrast, the annual precipitation on the plains east of Denver, Colorado, and in the South Park area in the southwest part of the basin, ranges from 7 to 15 in. Most of the precipitation on the plains occurs as rain, which typically falls between April and September, whereas most of the precipitation in the mountains occurs as snow, which typically falls between October and March.

Hydrology

Land Use

The three-State area of the South Platte River Basin has about 2.8 million people, over 95 percent of whom live in Colorado. The basin contains the most concentrated population density in the Rocky Mountain region, located along the Front Range urban corridor in Colorado where the mountains meet the plains. Population densities outside the urban corridor are small and centered in small towns located along the principal streams. The principal economy in the mountainous headwaters is based on tourism and recreation; the economy in the urbanized south-central region mostly is related to manufacturing, service and trade industries, and government services; and the economy of the basin downstream from Denver is based on agriculture and livestock production.

Land use and land cover in the South Platte River Basin during 1975-80 (Feagas, and others, 1983) is divided into: 41 percent rangeland, 37 percent agricultural land, 16 percent forest land, 3 percent urban or built-up land, and 3 percent other land. Rangeland is present across all areas of the basin except over the high mountain forests. Agricultural land is somewhat more restricted to the plains and the South Park area near Fairplay, Colo. Forest land occurs in a north-south band in the mountains. Urban or built-up land is present primarily in the Front Range urban corridor. The 'other land' category includes: water (110 mi²), barren lands (160 mi²), tundra (400 mi²), and perennial snow and ice (1 mi²). Barren lands primarily are areas under construction or are areas of strip mining, quarries, or gravel pits.



Science Questions

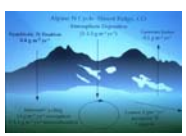
Biogeochemical and Hydrological Cycles

Hypothesis: Basin-scale transport of *N* is regulated by coupled hydrologic and biogeochemical processes occurring in terrestrial, riparian and aquatic ecosystems, involving atmospheric processes and surface water and groundwater flowpaths and interactions.

Hypothesis: Atmospheric transport driven by evapotranspiration on the plains is a dominant process responsible for basin scale dispersal of anthropogenic *N* to pristine headwaters.

Hypothesis: The importance of coupled hydrologic and biogeochemical processes in regulating *N* transport is greatest in the headwater catchments and decreases downstream as the anthropogenic inputs and degree of ecosystem *N* saturation increase.

Question: How are field-scale and regional-scale evaporation and transpiration patterns affected by soil salinization?



Hydrologic Influence on Ecosystem Functions

Question: What are the ecological consequences of dewatering secondary and tertiary streams in the South Platte watershed and how are these manifested in short term changes in ecosystem structure and longer-term effects on ecosystem function?

Question: What are the relative sensitivities of South Platte ecosystems (tundra, riparian, grassland, forests) to short- and long-term manipulations of winter and summer precipitation (increases and decreases) and what suite of organismic and ecosystem processes exhibit the same consistency of response, regardless of vegetation type?

Science Questions

Sustainability of Water Resources

Question: Sixty to eighty percent of sustainable water yield in the western US is from snowmelt runoff. Climate change scenarios suggest a decrease in annual snowfall and a forward shift in the start date of snowmelt runoff, even if annual precipitation does not change. How will changes in the amount, timing and duration of snowfall and snowmelt affect water availability?

Hypothesis: The water resource impacts of predicted climate variability and land use change will be exacerbated by increased impairment of water quality by excess *N*.

Question: How do the spatial and temporal patterns of recharge, both from precipitation and irrigation, affect the spatial and temporal patterns of return flow from the alluvial aquifer to the stream?

Question: Can groundwater storage play a larger role in the sustainability of water resources than it has in the past - is there large capacity of unused groundwater storage available in western aquifers?

Question: How are large-scale infiltration and surface runoff patterns affected by salinization (through changes in hydraulic conductivity and macrostructure associated with EC and SAR, etc.)?

Question: What are the magnitude and extent of evaporation from fallow fields or native ground fed by upflux from shallow water tables that are sustained by recharge on adjacent irrigated fields?

Question: If measures are taken to lower saline shallow water tables to reduce soil salinization and to increase crop production, to what extent will increases in evapotranspiration on irrigated land [due to increases in osmotic potential (i.e. less negative)] be offset by reductions in evaporative upflux from shallow groundwater under adjacent fallow ground?

Question: How are the long-term geomorphology and ecology of snow-melt dominated streams in semi-arid climates affected by off-season return flows generated by intensive irrigation of alluvial lands?

Fate and Transport of Chemical and Biological Contaminants

Question: What are the transport mechanisms associated with the movement of *Se* from soils to waterways and how is it impacted by long-term irrigation of lands *vs.* the irrigation of new lands (particularly on small acreage developments that are exploding across the western U.S.)?

Question: What are the comparative nature and magnitude of non point-source pollutant loading in the form of overland flow versus subsurface flow?

Question: What properties and processes affect the rate and magnitude of dissolution of salts and metals (e.g. *Se* and *Fe*) from marine-derived shale formations and their mobilization toward the river?

Surface Water/Groundwater Interactions

Recent studies suggest that bedrock groundwater may be an important component of mountain hydrologic systems. Mountain groundwater may deliver significant dissolved mass and anthropogenic contaminant loads to streams, and in some cases may escape the mountain catchment through deep circulation to become a major source of recharge to adjacent basin aquifers. Because of rapid development in many mountain areas, greater utilization of mountain water resources, and increasing pressures on basin aquifers potentially recharged by mountain groundwater, there is a growing need to improve our understanding of the occurrence, storage and flow of groundwater in mountainous terrain.

Question: What are the significant geologic controls on the infiltration, storage, and flow of groundwater in these systems?

Question: How deeply does mountain groundwater actively circulate?

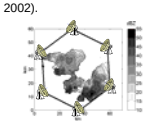
Question: Does groundwater commonly escape local catchments (failing to discharge into the local stream), and, if so, under what conditions?

Question: What are the geochemical processes controlling solute transport?

Question: What is the range and distribution of hydraulic heads, recharge rates, residence times, porosities, and permeabilities, and can these be linked to specific lithologic or geological structural features?

Precipitation Measurement Network for the South Platte Basin

We propose to develop a "network of small radar systems" that can be continuously reconfigured and redeployed to address specific science questions. For example, these radars can be configured to monitor snow at higher elevations or rainfall in mountain valleys as well as the South Platte Basin. Recent national level studies have shown that conventional long range radars such as NEXRADs will not serve this purpose and an alternative strategy is required (National Academy of Sciences Report, Weather Radar Technology beyond NEXRAD, National Academy Press, Washington DC, 2002).



In addition to the networked radar systems, a full suite of special *in situ* measurement systems such as disdrometers will be maintained.

Science Questions

Isotopes in the hydrological cycle

Isotopes of water in the hydrological cycle provide a natural tracer of a suite of physical and biological processes that characterize condensation, evaporation, recycling of water and plant water use of differential water sources (Alstad et al. 1999) and provide measures that integrate across temporal and spatial scales that can document past and current changes. Today, the isotopes of water are proving critical to unraveling the watershed recharge properties, ground water-surface water interactions, paleo-hydrogeologic interactions and articulating the linkages between the water and carbon cycle (Flanagan and Ehleringer 1998, Harvey 2001, Bowling et al. 2003, Pataki et al. 2003). Our sampling and analysis will be designed to address two central themes: First, to what degree do drought conditions, changes in climate phases of the El Nino Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) affect regional precipitation amounts, timing and isotope geochemistry? Second, how are changes in the isotopes of water manifested in ground and surface water interactions, biosphere-atmosphere interactions, records of climate in proxies records (tree rings) and the use of divergent water sources by native plants and crops in the Platte River watershed.

Existing Infrastructure, Observation and Measurement Capabilities

LTERs

Niwot Ridge LTER

An overarching theme of current research is the impact of climate change on Colorado tundra ecosystems, with a particular focus on the effects of altered snowpack and rainfall regimes. New facilities (e.g., the tundra laboratory), new research initiatives (e.g., the 100-year snow fence, the subnivean laboratory), and centralization of data management activities will assist us in meeting our research objectives.

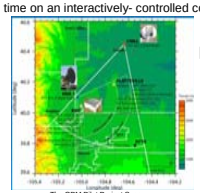
Short Grass Steppe LTER

Short Grass Steppe LTER: SGS-LTER

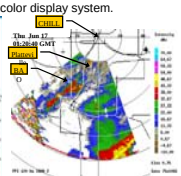
CSU-CHILL National Radar Facility

The CSU-CHILL multi-parameter radar system is available for use by the research community. The radar uses a dual transmitter / receiver design mated to a high performance antenna. This system configuration achieves isolation values of ~35 dB between the horizontal and vertical polarization channels; both the co- and cross-polar return signals are digitally processed. The radar has a variety of data collection capabilities which can be adjusted to best serve the individual investigator's interests.

The CHILL is a transportable 11 cm wavelength, pulsed Doppler weather radar with dual polarization capabilities. An 8.5 m diameter parabolic antenna produces a half-power beamwidth of 1.0 degree. Both the main beam and sidelobe radiation patterns at horizontal and vertical polarization are very well matched. The klystron-based dual transmitter systems each have a maximum output power level of ~1.0 MW. The matched dual receivers have noise power levels of ~-115 dBm. Data are available in real time on an interactively- controlled color display system.

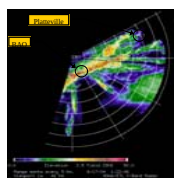


The GPM Pilot Project Scan Area Map

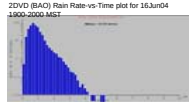


S-Band (CHILL) Radar PPI Image, 16Jun04 19:20:40 MST

2DVD (BAO) Rain Rate-vs-Time plot for 16Jun04 1900-2000 MST



X-Band (Erie-1) Radar PPI Image, 16Jun04 19:22:46 MST



2DVD (BAO) Drop Size Distribution plot for 16Jun04 1900-2000 MST

•CoAgMet

COlorado AGricultural Meteorological nETwork -- COAGMET: CoAgMet

•CoCoRaHSCoCoRaHS: Community Collaborative Rain and Hail Study

•CIRA: Cooperative Institute for Research in the Atmosphere

Cooperators and Data Sources

•The USGS Great Plains NAWQA: http://co.water.usgs.gov/nawqa/hpgw/HPGW_home.html
•South Platte NAWQA: http://co.water.usgs.gov/nawqa/spli/
•Rocky Mountain Cooperative Ecosystem Study Unit: http://www.forestry.umt.edu/research/cesu/
•Great Plains Cooperative Ecosystem Study Unit: http://greatplains.cesu.unl.edu/
•Short Grass Steppe LTER (located in the South Platte River Basin): http://www.lternet.edu/sites/sgs/
•Niwot Ridge LTER (located in the South Platte River Basin): http://www.lternet.edu/sites/nwt/
•Frasier Experimental Forest (removal of water from the forest for use in the South Platte Basin): http://www.fs.fed.us/rm/fraser/
•Loch Vale Watershed Research Project (located in the South Platte Basin): http://www.nrel.colostate.edu/projects/lvws/pages/homepage.htm
•South Platte Mapping and Analysis Program (models groundwater/surface water exchanges in the lower South Platte basin):
•Colorado State Government development of DSS for South Platte Basin:
•Tree Ring studies in South Platte Basin:
•NRCE snow survey data
•USGS, State Engineer's Office, and Denver Water flow data
•CWRRI reservoir study results
•Wildfire impact data
•Salinity data set from the Arkansas River