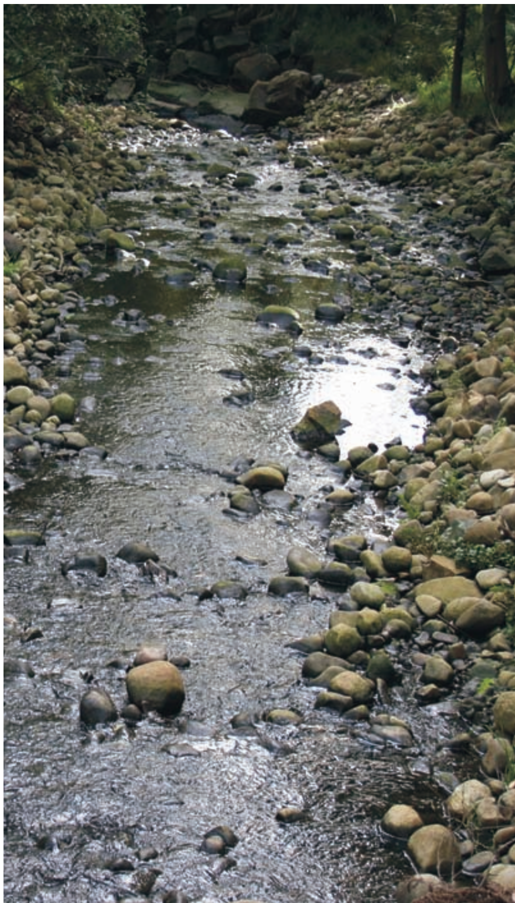


3 | Global Water Cycle

Strategic Research Questions

5.1 What are the mechanisms and processes responsible for the maintenance and variability of the water cycle; are the characteristics of the cycle changing and, if so, to what extent are human activities responsible for those changes?

5.2 How do feedback processes control the interactions between the global water cycle and other parts of the climate system (e.g., carbon cycle, energy), and how are these feedbacks changing over time?

5.3 What are the key uncertainties in seasonal to interannual predictions and long-term projections of water cycle variables, and what improvements are needed in global and regional models to reduce these uncertainties?

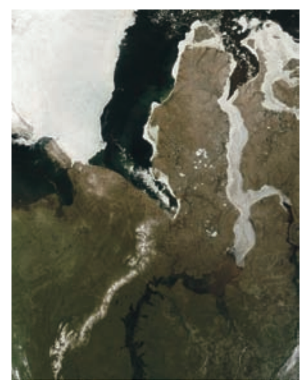
5.4 What are the consequences over a range of space and time scales of water cycle variability and change for human societies and ecosystems, and how do they interact with the Earth system to affect sediment transport and nutrient and biogeochemical cycles?

5.5 How can global water cycle information be used to inform decision processes in the context of changing water resource conditions and policies?

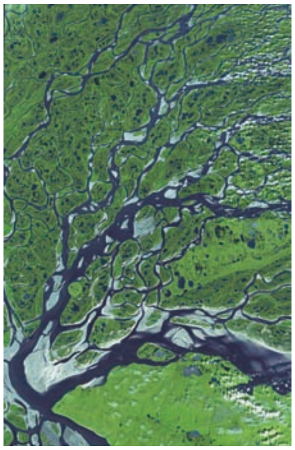
See Chapter 5 of the *Strategic Plan for the U.S. Climate Change Science Program* for detailed discussion of these research questions.

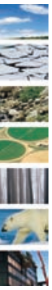
The global water (and energy) cycle plays a critical role in the functioning of the Earth system. Through complex interactions, the global water cycle integrates the physical, chemical, and biological processes that sustain ecosystems and influence climate and related global change. Inadequate understanding of the water/energy cycle is one of the key sources of uncertainty in climate prediction and climate change projections. Clouds, precipitation, and water vapor play important roles in feedbacks that are not well represented in many climate models. These processes alter surface and atmospheric heating and cooling rates, leading to adjustments in atmospheric circulation and precipitation patterns. Improved understanding of these processes will be essential to develop options for responding to the consequences of water cycle variability and change. For assessing the impacts of global and regional climate change on human societies, industrial and economic systems, and natural and managed ecosystems, water is considered a more rigid or critical constraint or limiting factor than temperature. To address these issues, the CCSP Global Water Cycle (GWC) element expends considerable effort to improve observations, data assimilation, and modeling/prediction systems that in turn deliver the information necessary for decision-support tools and assessments that provide a basis for "best practices" in the management of water resources.

The ultimate goal of water cycle research is to provide a solid foundation for decisions and investments by policymakers, managers, and individuals—be it at the Federal, state, or local level. Achieving this goal requires a program of activities that significantly improves understanding of water/energy cycle processes, incorporates this understanding in an integrated modeling/prediction framework, and tests predictions and data products in real decisionmaking contexts. In order to demonstrate techniques and their effectiveness to potential users, the GWC program also aims to expedite the transfer of science results from the research/experimental realm to operational applications.



Significant progress has been made in the understanding of cloud properties and the direct and indirect effect of aerosols on cloud and precipitation processes through field campaigns such as DOE's Cloud and Land Surface Interaction Campaign (CLASIC), and the multi-agency North American Monsoon Experiment and African Monsoon Multidisciplinary Analyses. Comprehensive satellite monitoring of water cycle parameters such as global precipitation and cloud structure in storm systems and hurricanes (with TRMM) and soil moisture and water bodies (with GRACE) as well as atmospheric profiles of temperature and humidity, and land/ocean surface parameters (Terra, Aqua) have resulted in integrated data sets and improved models of the Earth system. The incorporation of research results in models has led to better simulations of and prediction capabilities for hydroclimatic variables. Multi-model and ensemble modeling techniques developed by the NOAA Climate Prediction Program for the Americas have led to improved seasonal predictions of both the atmospheric and terrestrial hydrological cycle. Techniques have also been developed by USDA, DOI/USGS, and the DOI Bureau of Reclamation, in collaboration with NOAA, NASA, EPA, and DOE, among others, for the downscaling of seasonal precipitation forecasts to temporal scales consistent with the input requirements for agricultural management and conservation planning decision-support tools. Experimental seasonal hydrological prediction systems have been developed that use multiple climate forecast model products and empirical tools to "force" land/hydrological prediction models.



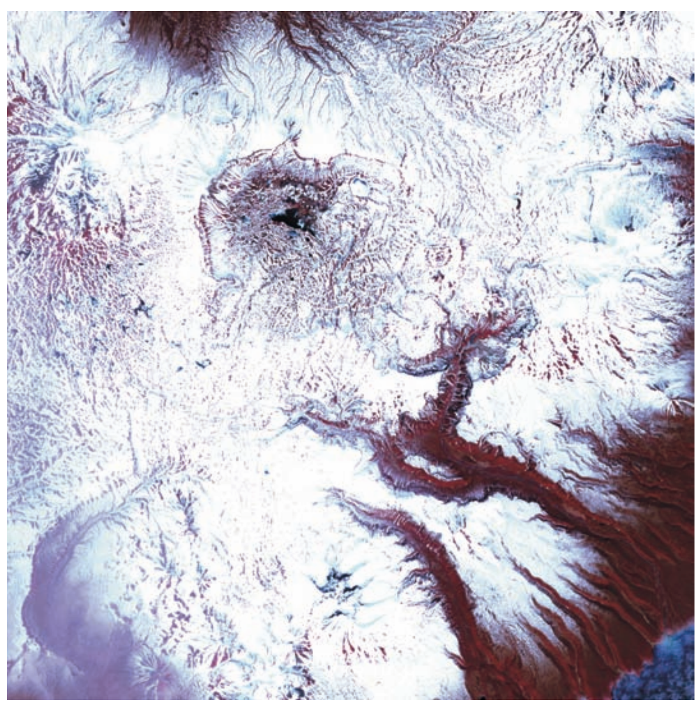


Highlights of Recent Research

Selected highlights of recent research supported by CCSP-participating agencies follow. These research results address the strategic research questions on the global water cycle identified in the *CCSP Strategic Plan*, as well as the goals of said plan.

Reducing Uncertainty in the Predictions/Projections of Climate Change, and in the Global and Regional Water/Energy Cycle.[1] An evaluation of of two modeling approaches, the multi-scale modeling framework (MMF) and the traditional Community Atmospheric Model (CAM), compared the models' simulations with observations. The evaluation showed that distributions of cloud fraction, precipitation intensity, and downwelling solar radiation flux at the surface from the MMF run were more consistent with observations than those from the CAM run (see Figure 4). This is attributed to the improved representation of convective (e.g., thunderstorm) clouds in the MMF compared to the conventional climate model.

Water Cycle over High Latitudes and Polar Regions.[2,3] Consistent with evidence of warmer temperatures, earlier spring green-up of vegetation and longer growing seasons at high latitudes, the atmospheric water cycle over polar regions shows a trend toward an earlier transition from winter to summer moisture recycling patterns during spring over North America and Europe. This conclusion is supported by findings from the Gravity Recovery and Climate Experiment (GRACE) gravity anomaly satellite, and other observations showing a thinning of the Greenland ice sheet and accelerated ice discharge. Model projections of future climate with double and triple atmospheric carbon dioxide concentrations suggest a general increase in precipitation in high-latitude river basins driven by increased transport of moisture into the basins, and higher rates of evaporation driven by rising temperature.



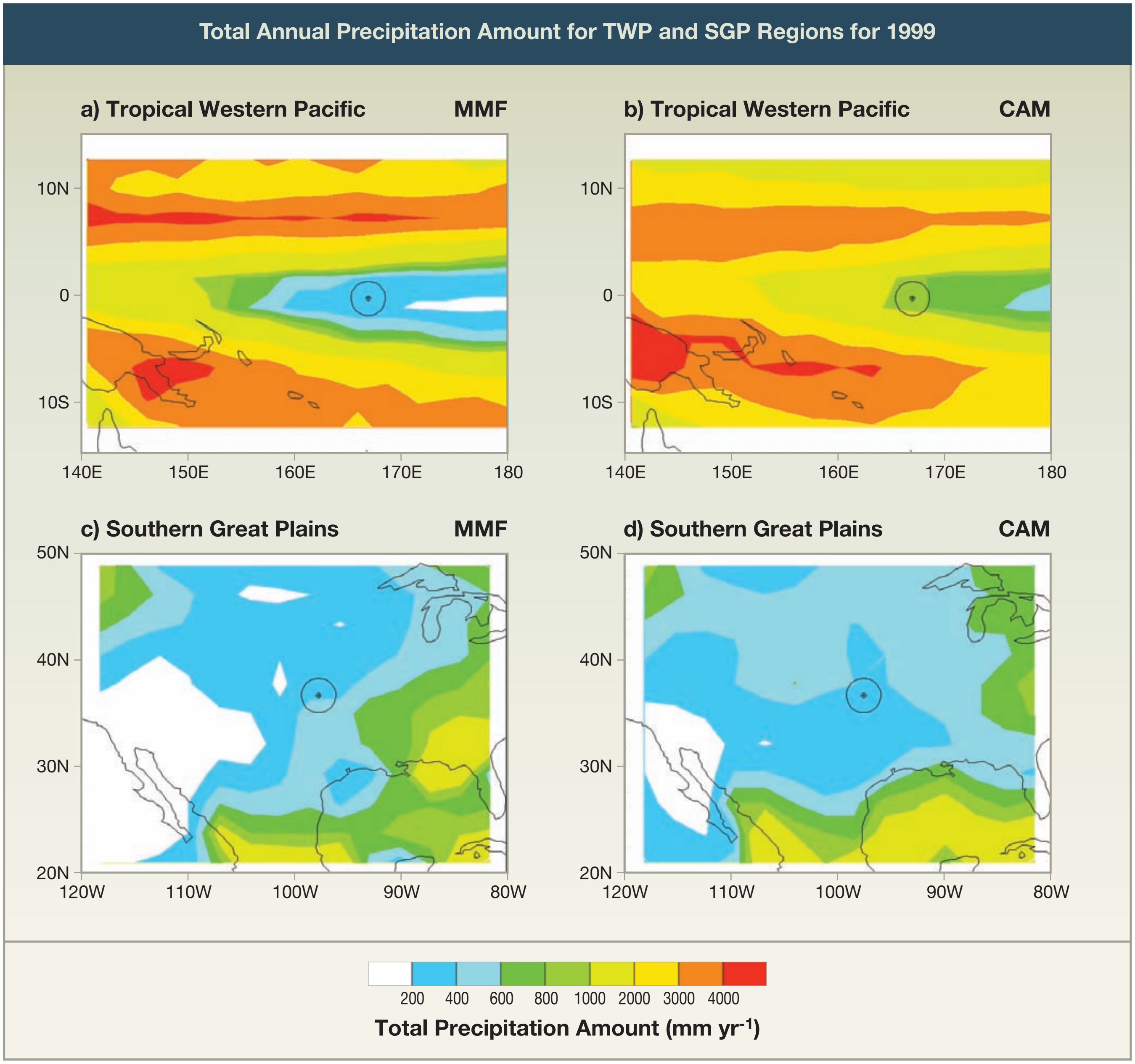
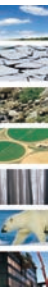
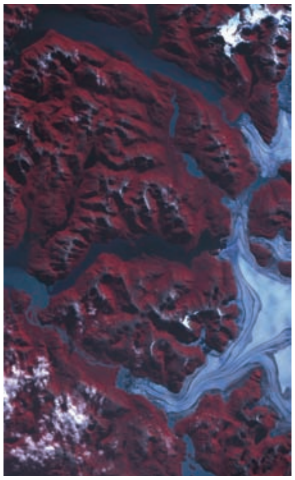


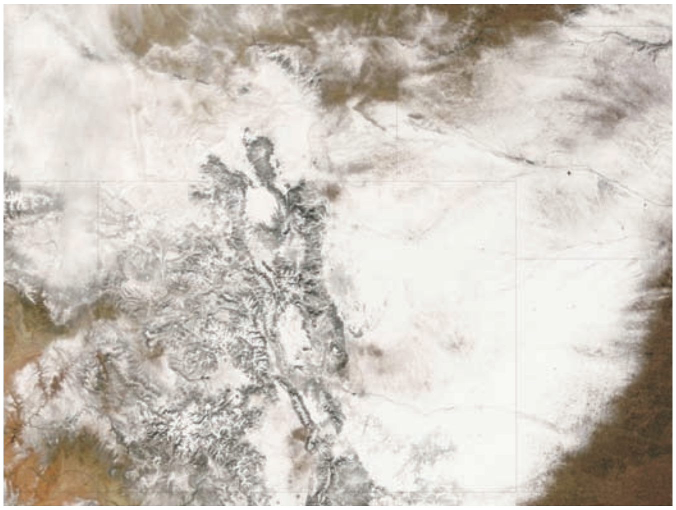
Figure 4: Total Annual Precipitation Amount for Tropical Western Pacific and Southern Great Plains Regions for 1999. Total annual precipitation amount (mm) as predicted by MMF (a,c) and CAM (b,d) for the Tropical Western Pacific (TWP) and Southern Great Plains (SGP) regions for 1999. Locations of the two Atmospheric Radiation Measurement (ARM) sites are circled. The observed precipitation amounts are 358 and 1,031 mm for the TWP and SGP sites, respectively. *Credit: M. Ovtchinnikov, T. Ackerman, and R. Marchand, DOE / Pacific Northwest National Laboratory; and M. Khairoutdinov, Colorado State University (reproduced from the* ***Journal of Climate*** *with permission from the American Meteorological Society).*



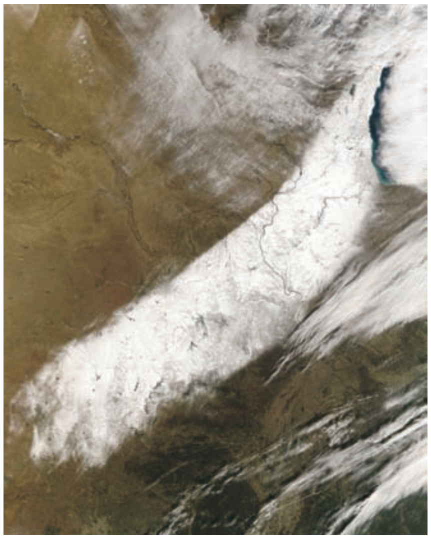


Trajectory Shifts in the Arctic and Subarctic Freshwater Cycle.[4] Manifold changes in the freshwater cycle of the high-latitude lands and oceans have been reported the past few years. A synthesis by researchers of these changes in freshwater sources and in the ocean freshwater storage illustrates the complementary and concurrent pattern and magnitude of these changes over the past 50 years. Increasing river discharge anomalies and excess net precipitation on the ocean contributed about 20,000 km^3 of freshwater to the Arctic and high-latitude North Atlantic oceans from minimal annual rates in the 1960s to maximal rates in the 1990s. Sea ice attrition provided roughly another 15,000 km^3, and glacial melt added about 2,000 km^3. The sum of inputs from these freshwater sources above the long-term average matched the amount and rate at which fresh water accumulated in the North Atlantic during much of the period from 1965 through 1995. The changes in freshwater inputs and oceanic storage occurred in conjunction with the amplifying North Atlantic Oscillation, a large-scale pattern of high and low pressure, and rising air temperatures. Freshwater may now be accumulating in the Arctic Ocean and will likely be transported southward if and when the North Atlantic Oscillation enters a new phase.

Colorado River Basin Water Management.[5] Recent studies of past climate and streamflow conditions have broadened understanding of long-term water availability in the Colorado River, revealing many periods when streamflow was lower than at any time in the past 100 years of recorded flows. Past water management decisions have been based largely on the gage record, and there has been an implicit assumption that there is a single value of the river's average annual flow—about 18.5 km^3 per year—around which interannual flow variations occur. Even though the basin experienced wet and dry periods, river flows and weather conditions were expected to return to a "normal" state, largely defined by the climate of the early and middle 20th century. However, recent reconstructions based on tree rings demonstrate that Colorado River flows occasionally shift into decade-long periods in which average flows are lower, or higher, than the supposed mean value. These reconstructions reinforce the point that the gage record covers only a small subset of the range of natural hydroclimatic variability in the river basin over several centuries. The basin's future hydrology thus may not be reasonably characterized by the gage record alone. That information, along with two important trends—a rapid increase in urban populations in the West and significant climate warming in the region—will require that water managers prepare for possible reductions in water supplies that cannot be fully averted through traditional means. Successful adjustments to these new conditions will require strong and sustained cooperation among the many entities involved in Colorado River water management and science programs.



Climate-Driven Variability and Trends in Mountain Snowpack in Western North America.[6,7] A recent study applied a regression analysis approach to snowpack and climate station data spanning the period 1960 to 2002 for the western North American region (Oregon, California, Nevada, and Colorado, among others). The study used 1 April snowwater equivalent (SWE) to represent a cumulative, simplified summary of the previous several months' weather: snow deposition, snow melting or ablation, and rain events that may either partially melt snow or be absorbed in the snowpack, increasing SWE. For most snow course locations in the West, the study found that long-term variations in spring SWE are reasonably well explained by summaries of seasonal climate at nearby stations. Day-to-day details of snow accumulation, ablation, and melt are generally of secondary importance, except where correlations between observed and climate-derived SWE are low. During the second half of the 20th century, and likely since 1916, winter and spring warming in the West have reduced spring snowpack at most locations. Increases in precipitation appear to have offset this loss in some places since mid-century, notably in the southern Sierra Nevada mountains, where large increases have occurred. Some of the interannual variability and long-term trends can be explained as a response to variability and change in North Pacific climate, especially as represented by the North Pacific Index (NPI), which responds to the oceanic variations of the El Niño Southern Oscillation and Pacific Decadal Oscillation, which are large-scale patterns of climate variations. However, NPI can only account for about half of the trends in the Pacific Northwest since mid-century (and less elsewhere or from earlier starting points), in rough agreement with modeling results. The remaining portion clearly includes the influence of the warming observed throughout the West, which is largely unrelated to the Pacific climate variability and may well represent human influences on climate. That is, even after accounting for the role of known patterns of climate variability, there is a substantial



downward trend in overall snowpack in the West that is consistent with observed warming. Even a conservative estimate (0.3°C per decade) of the likely future warming rate for the western mountains in winter would, by 2100, move the 0°C isotherm to where the 3°C isotherm now lies: Most of the western mountains would be in the transient snow zone, in which snow accumulates and melts repeatedly during the snow season. In the future, intraseasonal behavior of snowpack will likely change from a steady accumulation to alternating accumulation and loss due to warmer conditions. Simple regression-based methods currently used by water resource planners for forecasting seasonal volumetric streamflow will have to be revised or replaced by more sophisticated methods that can account for the changing role of temperature both in determining the quantity of spring snowpack (the subject of this study) and the rate at which it melts.

Vegetation, Soil Moisture, and Water Table Interactions.[8,9] The fraction of rainfall that recharges groundwater and ends up as streamflow tends to increase as the fraction of land devoted to agriculture decreases. Conversely, when the extent of cultivation increases a greater fraction of rainfall goes into evapotranspiration, potentially driving a long-term drop in groundwater levels. This is true in areas without crop irrigation. Where irrigation taps surface or groundwater, depletions may be even faster. Modeling of the coupled groundwater-surface water-soil vegetation system shows that shallow water tables can be either a sink or source of water relative to surface soil moisture, depending on the balance of infiltration versus evaporation, while deep water tables have little impact on surface fluxes. Thus, intense agriculture can amplify surface water stresses by increasing the propensity of soil moisture to decouple from a depleting water table, particularly during drought conditions.

The Effect of Irrigation on Land Surface Temperatures.[10] As seen from space, the region identified as the Umatilla Ordnance Depot in northeastern Oregon provides a striking example of temperature contrast caused by irrigation and vegetation type. Suited to hot, dry summers and an average annual precipitation of 200 mm, the native plants that grow on the depot use little water. Poplars—fast-growing commercial trees used as inexpensive lumber and pulp for paper—use large amounts of water, making them one of the most heavily irrigated crops in the Columbia River Basin. In nature, poplars grow in wetlands or along riverbanks, where they have access to water, and the commercial poplar plantation is located close to the river for the same reason. Figure 5 shows the difference in water use that distinguishes the two ecosystems.

Irrigation and Land Surface Temperature in Oregon

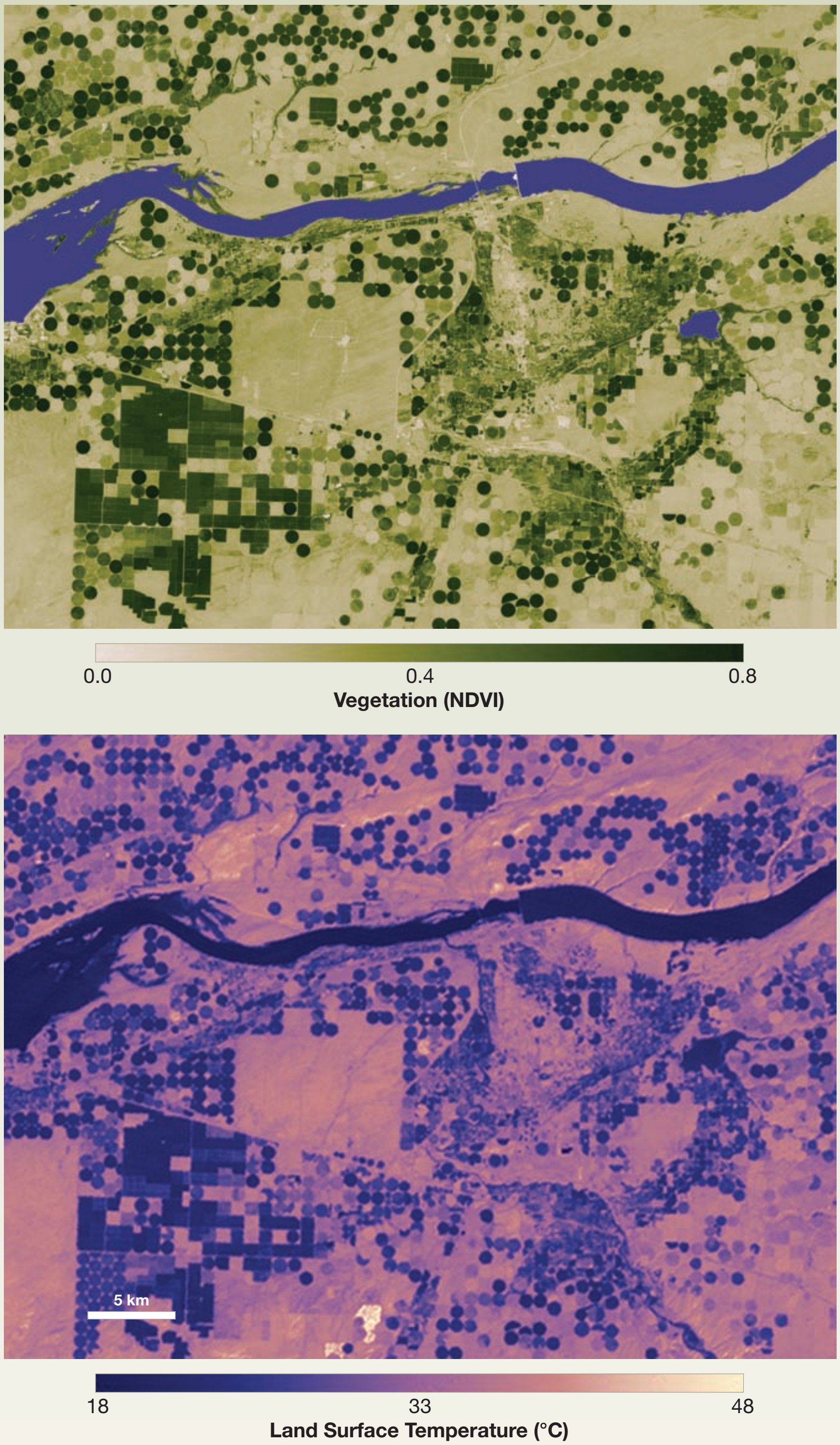
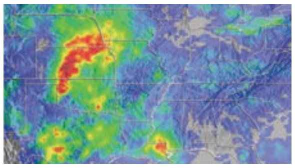


Figure 5: Irrigation and Land Surface Temperature in Oregon. The difference between poplar plantations and native vegetation is illustrated in this pair of satellite images, collected by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra satellite on 27 August 2006. The top panel depicts vegetation index, a measure of the density of plants based on the amount of photosynthesis recorded by the sensor. The availability of water causes the difference between the densely vegetated areas (dark green) and the lightly vegetated areas (light green). The contrast between irrigated and non-irrigated land is also evident in the bottom panel, which shows land surface temperatures measured by the same ASTER instrument. The coolest areas are dark blue, and the warmest pink and yellow. Irrigated crop lands are much cooler than the surrounding native vegetation. In this semi-arid region, the temperature difference is as much as 30°C (54°F), similar to the temperature difference between the Congo Rainforest and the Sahara Desert in Africa. *Credit: J. Allen, NASA / Goddard Space Flight Center (<earthobservatory.nasa.gov>), using data provided courtesy of NASA/GSFC/METI/ERSDAC/JAROS and the U.S./Japan ASTER Science Team.*

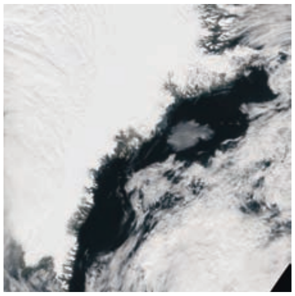


Fifty-Year High-Resolution Global Data Set of Meteorological Forcings for Land Surface and Hydrological Modeling.[11] Understanding variability of the terrestrial hydrological cycle is central to determining the potential for extreme events and its susceptibility to future change. In the absence of long-term, large-scale observations of the components of the hydrological cycle, modeling can provide consistent fields of land surface fluxes and states. To enable such an integrated analysis, researchers have created a global, 50-year, 3-hourly, 1° data set of meteorological forcings that can be used to drive models of land surface hydrology. The data set was constructed by combining a suite of global observation-based data sets with the National Centers for Environmental Prediction-National Center for Atmospheric Research reanalysis. Known systematic errors (biases) in the reanalysis precipitation and near-surface meteorology have been corrected using observation-based data sets of precipitation, air temperature, and radiation, among others. Wind induced undercatch of frozen precipitation is removed using the results of the World Meteorological Organization's Solid Precipitation Measurement Intercomparison. Precipitation is reduced in scale to 1° using statistical relationships developed with the Global Precipitation Climatology Project (GPCP) daily product. Disaggregation in time from daily to 3-hourly is accomplished similarly, using the Tropical Rainfall Measuring Mission (TRMM) 3-hourly real-time data set. Other meteorological variables (downward shortwave and longwave radiation, specific humidity, surface pressure, and wind speed) are downscaled in space while accounting for changes in elevation. The data set was evaluated against the bias-corrected forcing data set of the second Global Soil Wetness Project (GSWP2). The final product can be used to drive models of terrestrial hydrologic and ecological processes for the study of seasonal and interannual variability and for the evaluation of coupled models and other land surface prediction schemes.

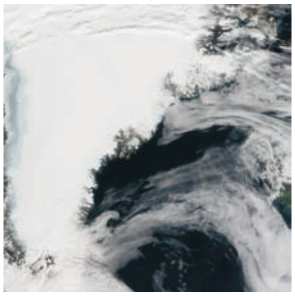
Highlights of Plans for FY 2008

The GWC research element continues to pursue important, long-term priorities. For example, insights into the formation and behavior of clouds and precipitation, including better characterizations of the phase changes of water in clouds and the phases and onset of precipitation, are emerging from field campaigns and model studies and will be promoted in continuing activities. Water vapor and cloud-radiation feedback are considered a critical part of GWC studies that need to be addressed to reduce the uncertainties associated with climate change projections. The predictability of regional precipitation is another topic of vital interest: It will be assessed and better understood by ongoing diagnostic and modeling studies that identify the connections between regional- and global-scale phenomena, land surface conditions such as soil moisture and water table fluctuations, and the interface fluxes of energy and heat between the atmosphere and the land surface-vegetation-hydrology combination. Preliminary analyses from recent studies show promise of leading to earlier (and more accurate) predictions, improved ability to assess hazards and risks of extremes such as floods and droughts, and more efficient water resource management.

In FY 2008, continuing U.S. and global observations, field campaigns and experiments, improvements to data integration and analysis systems, diagnostic and predictive model development, and applications to decision support systems will be priorities under the CCSP Global Water Cycle program. A fundamental objective is to ensure that observational capability is enhanced and improved, and that the data assimilation and modeling/prediction systems are more reliable and accurate at the point of application. Several promising results from the past years of research will be further explored with an aim to transfer this research knowledge to operational applications that provide societal benefit. Concurrently, a cohesive research strategy will be implemented to improve current deficiencies in understanding of all aspects of the regional and global water cycle. Several science questions remain to be answered, related to warnings of natural hazards and to the impact of global climate change, be it from natural or anthropogenic causes.

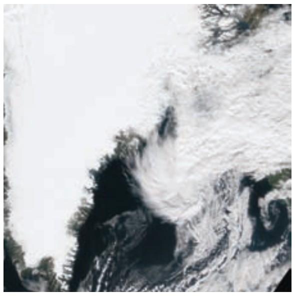


The program outlined for FY 2008 will lead to improvements in fundamental research, as well as in the planning and decisionmaking for, and management of, natural and human-made resources—a major aim of the program in addition to its fundamental research goals. A strong effort will continue to focus on major unresolved research issues that will require longer term commitments. To address both research and multi-sectoral applications needs, several initiatives will be launched in FY 2008.



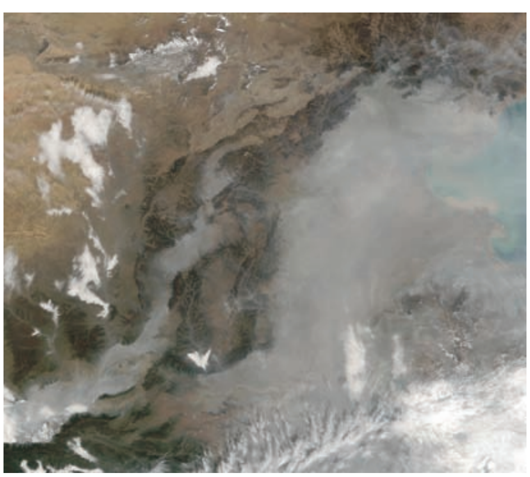
Integration of Space-Based Observations and Land Surface/Hydrology Data Assimilation Systems. The GRACE satellite has demonstrated that large-scale changes in the integrated column water content of the combined atmosphere, land surface (including rivers and reservoirs), soil moisture, and groundwater system compares remarkably well with the changes documented by the Global Land Data Assimilation System (GLDAS). In FY 2008 and beyond, further research investigations will explore whether GRACE, A-Train, and other satellite and ground-based data can be assimilated by the Land Information System (LIS), and/or provide integral closure constraints (and updated process parameterizations) to improve the output products from LIS that can potentially be linked to various decision-support tools and systems involved in the management of water resources, among others. Such an activity could represent initial components of end-to-end capabilities bridging observations, research, modeling, and applications.

This activity will address CCSP Goals 1 and 3 and Questions 5.1, 5.3, 5.4, and 5.5 of the CCSP Strategic Plan.



Integration of Observations, Research, and Modeling.[12,13] The research data from CLASIC will be analyzed in FY 2008 and beyond to address significant uncertainties in climate models particularly related to their representation of clouds and aerosols. The primary goal of CLASIC is to improve understanding of the physics of the early stages of cumulus cloud convection as it relates to land surface influences, and to translate this new understanding into improved representations of coupled surface-atmosphere processes in global and regional climate models. The data from a comprehensive array of measurements from a variety of instrument platforms will be used to characterize the synoptic-scale forcing at the DOE's Atmospheric Radiation Measurement (ARM) Climate Research Facility's (ACRF) Southern Great Plains (SGP) site and to undertake modeling studies to establish the most important relationships between land surface conditions and cumulus cloud characteristics. CLASIC was designated as the core of the Global Water Cycle Interagency Working Group CCSP FY 2007 focus area. The field campaign serves as a prototype for the CCSP focus area. The campaign featured concurrent contributions by NASA, NOAA, and USDA to extend CLASIC's temporal and spatial domain to capture the seasonal time scale and regional processes. The resulting observational framework included ground- and space-based observations, measurements from six airplanes and one helicopter, surface and subsurface hydrologic components, isotopic measurements, CO_2 fluxes, and associated modeling. Planning and operations for CLASIC and DOE's Atmospheric Science Program's Cumulus Humilis Aerosol Processing Study (CHAPS) were coordinated. Scientists from CLASIC and the North American Carbon Program (NACP) Mid-Continent Intensive (MCI) Campaign also coordinated measurement and modeling activities. These campaigns represent the cross-cutting activities of three CCSP science elements—the Global Water Cycle, Atmospheric Composition, and Global Carbon Cycle, respectively.

This activity will address CCSP Goals 1, 2, and 3 and Questions 5.1, 5.2, and 5.3 of the CCSP Strategic Plan.



Application of the ARM Mobile Facility to Study the Aerosol Indirect Effects in China. China has exceptionally high aerosol loading with diverse properties whose influence has been detected across the Pacific Rim. The rapid pace of changes in the atmospheric environment over China provides a natural test bed for identifying and quantifying the climatic effects of aerosols. Preliminary analyses of multiple satellite data sets [the Moderate Resolution Imaging Spectroradiometer (MODIS) and the TRMM Tropical Microwave Imager] indicate more complex and unique aerosol indirect effects than are found in relatively cleaner environments. Unfortunately, China is one of the least observed regions, especially in terms of aerosol and cloud properties. To this end, DOE's ARM Mobile

Facility (AMF) will be deployed from 1 January to 31 December 2008 to investigate (1) the mechanisms of the aerosol indirect effects in the region and the roles of aerosols in affecting regional climate and atmospheric circulation with a special focus on the impact of the East Asian monsoon system, and (2) effects of long-range transport of aerosols to the Pacific Rim and the western United States.

This activity will address CCSP Goals 1 and 2 and Questions 5.1 and 5.2 of the CCSP Strategic Plan.

Advanced Ensemble Multi-Model Hydrological Prediction. Efforts will continue to focus on the calibration and validation of research-mode ensemble (multi-model) forecasting techniques for surface and subsurface hydrological parameters, especially on longer seasonal time scales. The objective is to transfer improved hydrological prediction techniques for operational application on the seasonal to interannual time scale. This activity will expand on the recently developed Advanced Hydrological Prediction Service (AHPS) of NOAA's hydrological forecasting system that includes new model calibration strategies, distributed modeling approaches, ensemble forecasting, data assimilation techniques, enhanced data analysis procedures, flood forecast inundation maps, hydrological routing models and multi-sensor precipitation estimates. Data will also be ingested from USGS streamflow observations, gridded multi-sensor precipitation and SWE estimates, and others. New approaches for the remote sensing of precipitation, snow, and other inputs will be integrated into the hydrological forecast operation. AHPS is slated to be fully implemented nationwide in 2013. In parallel, CCSP researchers plan to participate in the further development of the international Hydrological Ensemble Prediction Experiment (HAPEX), which will bring the international hydrological community together with the meteorological community and demonstrate how to produce reliable hydrological ensemble forecasts that can be used with confidence by emergency management and water resources sectors to make decisions that have important consequences for the economy, and for public health and safety.

This activity will address CCSP Goals 3 and 5 and Questions 5.3 and 5.5 of the CCSP Strategic Plan.

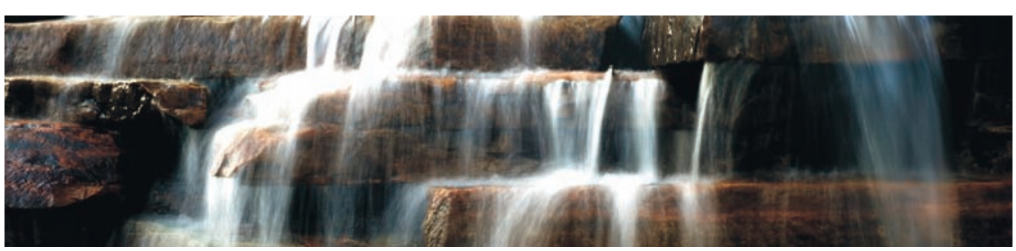
Role of Land Surface Processes in North American Hydroclimate. The feedbacks between soil moisture, vegetation, and precipitation will be investigated in observations and models with the goal of helping to understand whether land surface conditions may be a useful predictor in operational climate prediction at seasonal and sub-seasonal time scales. The behavior of snow variations and vegetation cover will be studied in order to improve land surface representations in regional climate models. The hydrologic and climatic effects of crop irrigation are not well quantified and not accurately represented in model initialization. Improvements in our understanding of the role of irrigated croplands in North American hydroclimatic regimes and their representation in models will be pursued.

This activity will address CCSP Goals 3 and 4 and Questions 5.3 and 5.4 of the CCSP Strategic Plan.

Continued Development of Tools for the Assimilation of Remote-Sensing Data into Water Quality and Sediment Transport and Erosion Models. Agricultural research activities in the area of land data assimilation systems and model analysis are focused on the efficient integration of ground-based and remote-sensing data into critical resource and conservation practice assessment models. Existing agency research projects are aimed at the sequential assimilation of surface soil moisture retrievals and vegetation indices from microwave and visible remote sensors to constrain crop growth and root-zone water balance models. In FY 2008 and beyond, this work will expand with an emphasis that includes the assimilation of remote-sensing data into distributed water quality and sediment transport and erosion models. Particular attention will be paid to development of data assimilation and modeling capabilities to quantify benefits arising from the adoption of conservation practices within agricultural watersheds.

This activity will address CCSP Goals 3 and 5 and Questions 5.3 and 5.5 of the CCSP Strategic Plan.

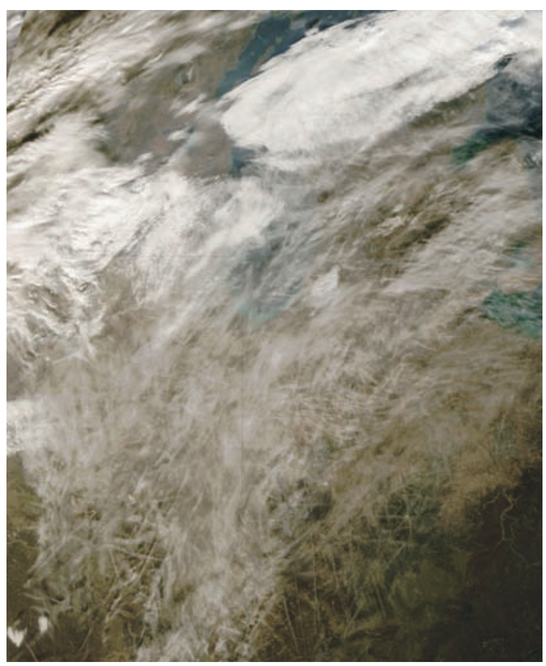
Establishing New Portals Dedicated to Specific Applications of Remote-Sensing Data with On-Line Analysis Capabilities.[14] "Giovanni," the Goddard Earth Sciences Data and Information Services Center (GES-DISC) Interactive Online Visualization and Analysis Infrastructure, was developed to provide researchers with advanced capabilities to perform data exploration and analysis with observational data from the Earth Observing System (EOS) research satellite system. Over the past decade, the central problem with data use has been the multi-step process required to search for the appropriate data files, request the files from a central archive, transfer the files to the scientist's own computing system, extract the relevant data from unfamiliar data formats, and then (finally) analyze the data to investigate the vital research question.

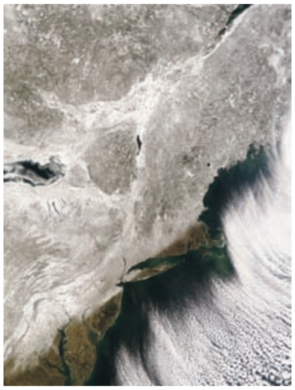


Giovanni eliminates all of the above tedious steps that precede data analysis. The result is a data exploration and analysis environment that facilitates scientific investigation with actual data, allowing rapid comprehension of regional events and increased understanding of interconnected global environmental processes. The Giovanni precursor, the TRMM Online Visualization and Analysis System (TOVAS), successfully demonstrated the basic elements of a system used entirely on the Web. The simplicity of Giovanni enables the creation of portals dedicated to specific applications of remote sensing. The first of such portals will be devoted to "precipitation data for agriculture." Release is expected in FY 2008. An A-Train Data Depot Portal and the Northern Eurasia Earth Science Partnership Initiative portal are also planned for release in the same time frame. The former is expected to be particularly useful because the A-Train, which is a formation of several NASA atmospheric observational missions in the same orbit, allows for nearly simultaneous observations. In the dedicated Giovanni interface, data from these missions will be readily available for multi-parameter comparison and analysis. In FY 2008, a specific effort under the NASA Energy and Water Cycle Study will build a portal in collaboration with the Global Change Master Directory (GCMD) for hydrological networking.

This activity will address CCSP Goals 1, 2, and 3 and Questions 5.1, 5.2, and 5.3 of the CCSP Strategic Plan.

Upper Tropospheric Water Vapor, Jet Contrails, and Implications for Climate.[15,16] Water vapor in the upper troposphere, while insignificant in the total mass of column water vapor, can have significant effects on climate through the formation of clouds (longwave forcing) or direct absorption of radiation. One study using a radiative transfer model estimated that a 10% increase in upper-tropospheric humidity (UTH) could contribute as much as 1.4 Wm^{-2} of direct radiative forcing. Supersaturation in the upper troposphere can be inferred from the presence of persistent contrails behind jet aircraft, which require humidity above that of ice saturation to form. Supersaturation is critical for understanding the process of ice cloud formation. This process, which is also affected by the presence or absence of aerosols, has implications for the radiative balance of the climate system through its effect on clouds and water vapor. Most global models of the climate system do not permit supersaturation but instead dictate full condensation of all water vapor to maintain a vapor pressure less than 100% over ice at temperatures where only ice exists (typically below -20 to -40°C). Using relative humidity (RH) data from the Atmospheric Infrared Sounder (AIRS) on the Aqua satellite, the annual mean frequency of supersaturation maximizes below the





extratropical tropopause ranges between 10 and 30% of the time. This value is similar to the annual mean potential contrail coverage frequency (which implies RH over ice greater than 100%) reported from European Centre for Medium-Range Weather Forecasts' reanalyses. While these comparisons are good, AIRS RH is not a point-wise measurement and observed supersaturation may not quantitatively define what an air parcel or a cloud/ice nucleus experiences. Further studies of supersaturated conditions from AIRS are being considered that may be able to shed some light on cloud nucleation processes when combined with other satellite sensors. In the future, an updated AIRS retrieval and cloud properties from a suite of sensors flying in formation on NASA's A-Train (such as MODIS on the EOS Aqua satellite and the Cloud Profiling Radar on CloudSat) may be useful to answer important questions about ice nucleation and its global impact, as well as to improve global models in order to examine perturbations to the Earth system. Such studies could also be useful in evaluating the potential implications of aviation on climate.

This activity will address CCSP Goals 1,2,3, and 4 and Questions 5.1, 5.2, 5.3, and 5.4 of the CCSP Strategic Plan.

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