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MODELING AND ANALYSIS OF THE WATER CYCLE: SEASONAL AND EVENT VARIABILITY AT THE WALNUT RIVER WATERSHED

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1. INTRODUCTION

A multi-laboratory Department of Energy (DOE) team (Argonne National Laboratory, Brookhaven National Laboratory, Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory) are investigating the hydrometeorological processes at the Whitewater subbasin of the Walnut River Watershed (WRW) in Kansas. This new study is applying coupled models that simulate linked atmospheric, land surface, and hydrologic processes to resolve water cycle dynamics. An important new study element is the introduction of isotopic budget equations into mesoscale and hydrologic modeling. Two research questions have been formulated:

1) Can the predictability of the regional water balance be improved using high-resolution model simulations that are constrained and validated using new water isotope and hydrospheric water measurements?

2) Can water isotopic tracers be used to segregate different global-to-local pathways through the water cycle and predict a change in regional climate patterns?

2. SCIENTIFIC APPROACH

The WRW is within DOE's Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site and uses the Atmospheric Boundary Layer Experiments (ABLE) site to conduct coupled modeling and observational investigations toward answering the above questions. The WRW has an area of about 75 km by 100 km, which is an order of magnitude smaller than the ARM SGP site. It is a closed catchment basin amenable to computing all of the components of the hydrological budget, is sufficiently small to allow fairly good observational coverage, and contains a moderate level of ecosystem diversity.

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2.1 Multi-Scale Atmospheric, Land-Surface, and Hydrologic Model Simulations

Two coupled atmospheric-land surface models are being applied to evaluate predictability at a range of spatial resolutions. They are the Mesoscale Model version 5 (MM5) and the Regional Atmospheric Modeling System (RAMS).

Two alternative approaches (distributed, semi-distributed) are being used at the WRW for evaluating coupled and off-line surface hydrologic modeling, the influence of spatial resolution, and different parameterization schemes

An initial calibration and verification using observed precipitation (1997 to present) is being generated with the hydrologic models running off-line. Simulations will be made for a summer season, June-July-August (JJA) 2002; a winter season, December-January-February (DJF) 2002-2003; and at least one storm event during the first year. Model outputs include isotopic tracer concentrations.

One test of the atmospheric models is to compare measured and radar-derived precipitation with predicted precipitation for the different spatial scales. The Wichita National Weather Service WSR-88D radar (less than 100 km from WRW) provides precipitation estimates over the WRW. An operational network of rain gauges exists at the ARM site, including a dense 30 rain gauge network in the Whitewater subbasin of the WRW. The accuracy and precision of precipitation estimates from meteorological radars varies with the sophistication of the radar, but reasonable precipitation estimates can be made using a combination of data collected with the Wichita WSR-88D radar and the surface rain gauges.

A second test of atmospheric models is to compare the simulated cloud structure with measured cloud structure. Surface-based remote sensing techniques being refined at DOE's ARM SGP central facility in Oklahoma is being used to measure the cloud structure. Although extensive testing of model cloud and precipitation parameterizations is beyond the scope of the pilot study, it is feasible to compare modeled and measured statistics that describe cloud amount and cloud location over the ARM SGP central facility. As part of the pilot study, cloud statistics for each study case will be computed from measurements at the central facility and compared with statistics computed from model output.

Soil moisture content is a key variable in the models of the hydrological cycle, but it is measured at very few locations. A parameterization of subgrid-scale (PASS) flux model provides a means to evaluate evapotranspiration and root-zone available soil moisture. This modeling approach can provide routine, long-term estimates of both evapotranspiration and soil moisture over large regions at moderately high resolution (1 km or smaller), without the use of extensive computer resources. These data will be used to initialize the hydrologic models of the Whitewater subbasin and provide soil moisture data for evaluating hydrologic model predictions. In addition, PASS will be coupled with a mesoscale meteorological model to demonstrate the importance of adequate initialization of soil moisture conditions on variations in atmospheric water.

2.2 Isotopic Sampling, Modeling, and Analysis

Measurements of water isotopes in precipitation, lakes, streams, plants, and soils have been made for many years (e.g., Dansgaard 1964). Modeling of water isotopes in the hydrologic cycles has concentrated on adding isotope parameterizations to general circulation models (GCMs) (e.g., Jouzel et al. 1994).

Sampling for isotopic analyses during the pilot study is focused on surface and tower water vapor flux (evaporation) and liquid water (precipitation, runoff, soil and plant water) in collaboration with ongoing sampling at the SGP site.

Water vapor and precipitation samples are being collected from 3-6 sites across the study area. Surface water fluxes will track diffusion and mixing into the atmosphere and monthly to seasonal sampling will be adequate.

Streamflow samples at the Towanda gauge station in Whitewater subbasin of WRW are being collected for isotopic analyses at the same time as water vapor and precipitation sampling. Soil and plant water samples of soil pore water and plant water will be collected and analyzed on a quarterly basis at 3-4 sites representing different land use patterns in the study area.

Water isotope mass conservation is being added to the atmospheric primitive equation formulations. This has been previously done for GCMs, but the coarse resolution (200-400 km) is insufficient for understanding site scale hydrology. A generic isotope cloud physics package is being be developed with pre-existing values as placeholders to account for interactions among hydrometeors, initially water vapor, cloud water, and rainwater. This package will be upgraded as available measurements provide more realistic rate values that take into account in-cloud evaporation, condensation, autoconversion, and accretion. The new isotopic cloud physics scheme will be implemented the regional climate model, MM5. Also, an initial set of deuterium and $\delta^{18}O$ parameterizations for the surface and subsurface water transport will be implement in TOPMODEL. Isotopic validation will be based on precipitation and stream sampling data.

3. FUTURE DIRECTIONS

This initial study will allow for proof-of-concept research using high-resolution modeling and water isotopes. We envision an expanded set of studies at other sites that include different climate patterns, more complex topography, and ecosystem diversity. More advanced precipitation radar and implementation of a national isotopic monitoring network in coordination with the International Atomic Energy Association's Global Network of Isotopes in Precipitation would significantly contribute toward improved modeling and understanding of hydroclimate variability, locally and at large scales.

The pilot offers opportunities for building collaborations towards a larger U.S. Water Cycle Program with NASA, NOAA, and NSF. By building on SGP and WRW studies and data, we are rapidly moving toward a DOE implementation plan for the Interagency Water Cycle Initiative.

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References

Dansgaard, W., 1964: Stable isotopes in precipitation. *Tellus*, **16** , 436-68.

Jouzel, J., R. D. Koster, R. J. Suozzo, G. L. and Russell, 1994: Stable water isotope behavior during the last glacial maximum: A general circulation model analysis. *J. Geophys. Res.,* .**99**, 25,791-25,801.