COUPLING TRITIUM RELEASE DATA WITH REMOTELY SENSED PRECIPITATION DATA TO ASSESS MODEL UNCERTAINTIES

Brian K. Avant, Amber R. Ignatius, Todd C. Rasmussen, Andrew J. Grundstein, Thomas L. Mote, J. Marshall Shepherd

AUTHORS: University of Georgia, Athens, Georgia, 30605.
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Abstract. An accidental tritium release (570 L, 210 TBq) from the K-Reactor at the Savannah River Site (South Carolina, USA) occurred between December 22-25, 1991. Observed tritium concentrations in rivers and streams, as well as in the coastal estuary, are used to calibrate a hydrologic flow and transport model, BASINS 4.0 (Better Assessment Science Integrating Point and Non-Point Sources) environmental analysis system and the HSPF hydrologic model.

The model is used to investigate complex hydro-meteorological and source attribution problems. Both source and meteorologic input uncertainties are evaluated with respect to model predictions.

Meteorological inputs include ground-based rain gauges supple-mented with and several NASA products including TRMM 3B42, TRMM 3B42RT, and MERRA (Modern Era Retrospective-Analysis for Research and Applications) reanalysis data.

Model parameter uncertainties are evaluated using PEST (Model-Independent Parameter Estimation and Uncertainty Analysis) and coupled to meteorologic uncertainties to provide bounding estimates of model accuracy.

HYDROLOGIC MODELING

BASINS. BASINS 4.0 (http://www.epa.gov/waterscience/basins) is an environmental analysis system that integrates geographic information system (GIS) datasets with modeling tools (Figure 1).

BASINS was designed for use by regional, state, and local agencies in performing watershed and water quality-based studies. This system makes it possible to quickly assess large amounts of point source and non-point source data in a format that is easy to use and understand.

HSPF. The U.S. EPA's Hydrological Simulation Program-FORTRAN (HSPF) is the primary watershed model included in the EPA BASINS modeling system.

HSPF is a comprehensive watershed model of hydrology and water quality, simulating land surface and subsurface hydrologic and water quality processes, linked and closely integrated with corresponding stream and reservoir processes. BASINS/HSPF is a major tool for watershed and TMDL assessments across the United States, and is widely used internationally.

HSPF is a time-continuous simulation model designed to simulate all the water quantity and water quality processes that occur in a water-shed, including sediment transport and movement of contaminants.

Although HSPF is usually classified as a spatially lumped model, it can reproduce spatial variability by dividing the basin into hydrologically homogeneous land segments, simulating runoff for each land segment independently using different meteorological input data and watershed parameters.

Using the HSPF hydrologic model in BASINS 4.0, we can calibrate a hydrologic flow and transport model with observed tritium concentrations in rivers and streams, as well as in the coastal estuary.

PEST. PEST is a nonlinear parameter estimation package utilized by HSPF to automatically calibrate the model by modifying input parameter values within user defined max/min limits through iterative runs until modeled flow matches gage flow data.

PEST uses the Gauss-Marquardt-Levenberg nonlinear parameter estimation method to best modify variable parameters for each iteration of the model. The PEST software stops iterating once the objective function, defined as the least squares of the difference between modeled and measured flow, reaches a global minimum.

Study Area. The Savannah River Site is a 310 mi^2 U.S. Department of Energy nuclear materials production facility located in the state of South Carolina (Figure 2). The site, which began operations in 1952, had five nuclear reactors (C, P, R, L, and K) plus two separations facilities (F and H) that were used to produce nuclear materials.

Data Requirements. The minimum layers needed in BASINS 4.0 to execute HSPF are Elevation, Land Use, Weather Data, and Stream Location. The National Elevation Dataset (NED) provides elevation data and the 2001 National Land Cover Dataset provides land use.

For meteorologic variables equirements, HSPF requires both precipitation and potential evaporation datasets. The surface weather station data provided by BASINS from

NOAA's National Climatic Data Center was used for default simulations.

Simulations are also run using precipitation from two different remote sensing products: NASA MERRA (Modern Era Retrospective-Analysis for Research and Applications) and Tropical Rainfall Measuring Mission (TRMM) Multi-Satellite Precipitation Analysis. MERRA outputs hourly data fields of 1/2 degrees latitude x 2/3 degrees longitude spatial resolution. TRMM MPA is ~25 km and three hourly.

Uncertainty Analysis. Tritium, a radioactive isotope of hydrogen (^{3}H or T) produced in nuclear facilities, replaces H to form titrated water, HTO. Tritium is an ideal tracer for evaluating model performance because it behaves identically to water and is readily detected at low concentrations.

An accidental discharge of tritium from the K-Reactor occurred between December 22-25, 1991. A total of 520 L of tritiated water, containing approximately 210 TBq, drained into Pen Branch, a tributary of the Savannah River, over the three-day period. The resulting plume was tracked from the site, down to the coast, and out into the coastal estuary. Figures 3-6 illustrate the data being used for model uncertainty analysis.

Possible sources of uncertainty include:

- *Conceptual uncertainty*: Usually caused by incomplete knowledge of a complex system. Evaluated using alternatives to the relationship between static and independent variables
- *Parametric uncertainty*: Often caused by lack of sufficient data. can come in two forms-
    - *Unconditional uncertainty*: parameters with values based on expert opinion or literature values. Variability in values usually result from a probability distribution of these opinions instead of ranging field measurements.
    - *Conditional uncertainty*: Calibrated or conditioned parameters that lead to an acceptable degree of agreement between model behavior and field observations.

Our strategy is to examine uncertainties that can be minimized by incorporating additional data from remotely sensed products, such as precipitation and remote sensing. We also wish to evaluate prediction uncertainties using parameter covariances, and seek strategies for minimizing source attribution errors by improving model structure.

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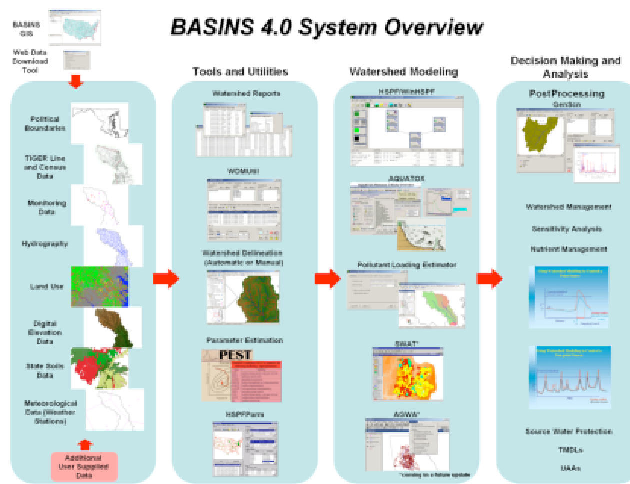

Figure 1. BASINS provides a convenient platform for conducting integrated hydrologic flow and transport modeling.

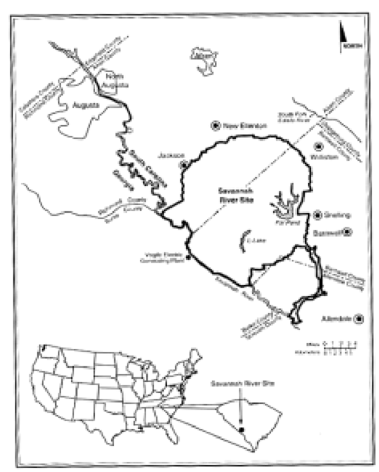

Figure 2. Savannah River Site location map.

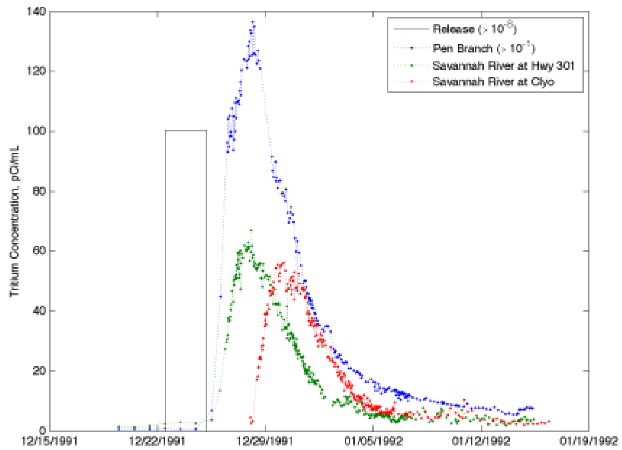

Figure 3. Observed tritium concentrations.

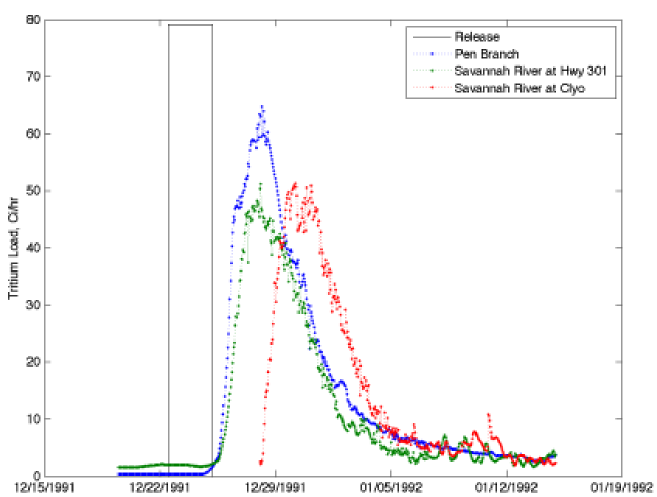

Figure 4. Observed tritium loads.

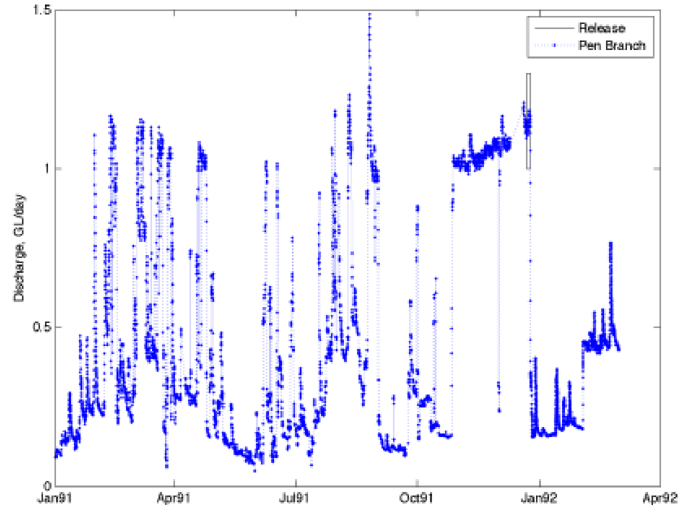

Figure 5. Discharge below K-Reactor showing natural flows in Pen Branch plus cooling water releases. Tritium release indicated by grey box.

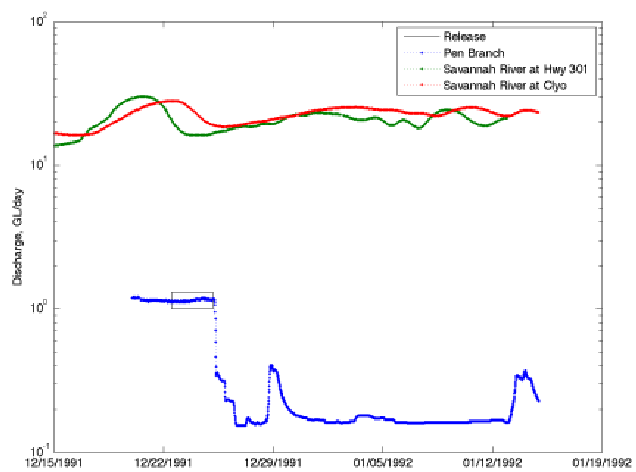

Figure 6. Stream discharge of Pen Branch and the Savannah River.