Parameter Sensitivity to Different Observation Types in an Integrated Land Surface, Groundwater and Surface Water Simulation Model

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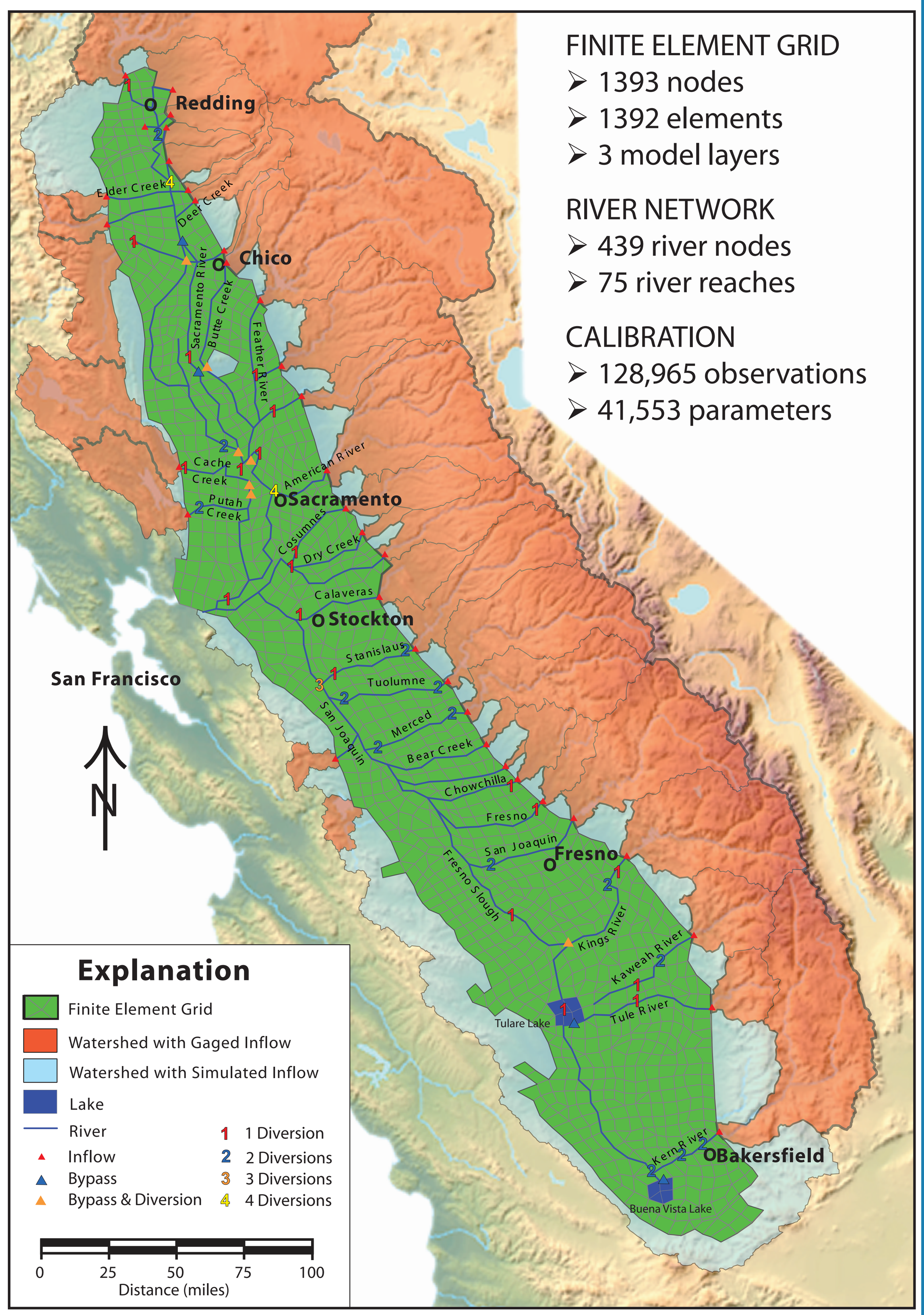
Introduction

Automated calibration of integrated hydrologic models, which simultaneously simulate several linked hydrologic processes, may provide more robust parameter estimates than automated calibration of models of a single hydrologic process owing to the direct linkage of multiple hydrologic processes. Hydrologic parameters in an integrated model are interdependent and thus more completely constrained than in a model of a single process. This interdependence greatly aids in model calibration, as each parameter is constrained by a greater number of observation types.

The sensitivities of model results to each parameter and each observation type can also be estimated, so improvement efforts can be focused on those parameters, observation types and processes with the greatest effect on simulation results. Composite scaled sensitivity (CSS) values, which summarize the sensitivity of one parameter to multiple calibration observations, can be used to show the degree to which each model parameter type is constrained by each observation type. These CSS values also indicate which types of observations to increase in order to better constrain model parameter values.

During calibration of the California Central Valley Groundwater-Surface Water Simulation Model, an integrated hydrologic model, CSS values were calculated for 41 parameter types and five observation types to determine the amount of information each observation type contained with respect to each parameter type. Observed values of stream-groundwater flow had the highest CSS value for most parameter types, indicating this type of observation provides the greatest constraints to a wide range of model parameters.

C2VSim Model Framework



FINITE ELEMENT GRID
- 1393 nodes
- 1392 elements
- 3 model layers

RIVER NETWORK
- 439 river nodes
- 75 river reaches

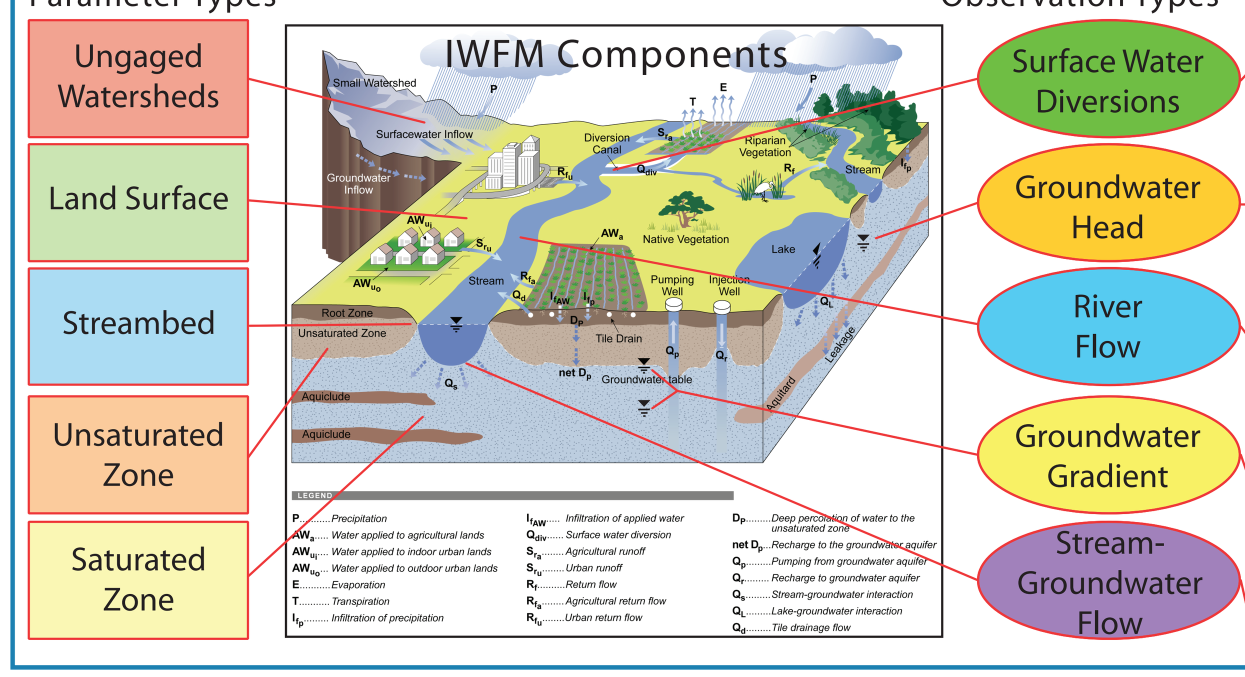
CALIBRATION
- 128,965 observations
- 41,553 parameters

Benefits of Using Parameter Estimation with an Integrated Hydrologic Model

Integrated hydrologic models are especially well suited to parameter estimation. Many flow system components (such as runoff) that are specified in stand-alone groundwater models are calculated internally in integrated models, and are thus available as calibration targets. This expands the types of observations that can be used to calibrate the model.

In addition, directly incorporating sub-models (such as runoff estimation) into the integrated model facilitates estimation of the model's sensitivity to the sub-model parameters, rather than to just the sub-model output. Incorporating multiple processes in a single model allows the model sensitivity to the parameters of each internal process to be determined, so improvements can be focused on those components with the greatest impact on model performance.

Parameter & Observation Types



Integrated Water Flow Model (IWFM)

IWFM couples a 3-D finite element groundwater flow process with1-D land surface, lake, stream flow and vertical unsaturated-zone flow processes. The land surface process simulates infiltration and runoff, agricultural and urban consumption, and recharge. The surface water flow and lake processes route flows through the stream and lake network, calculating groundwater-surface water interactions and inflows from runoff, and allocating available stream flows to meet specified surface water deliveries.

Distributed soil properties, land use and crop data, precipitation and evapotranspiration rates are used to dynamically calculate water budgets, runoff to streams and deep percolation through the unsaturated zone. Surface water diversions and groundwater pumping can each be either specified or calculated at run time to dynamically balance water supplies with water demands.

California Central Valley Groundwater-Surface Water Simulation Model (C2VSim)

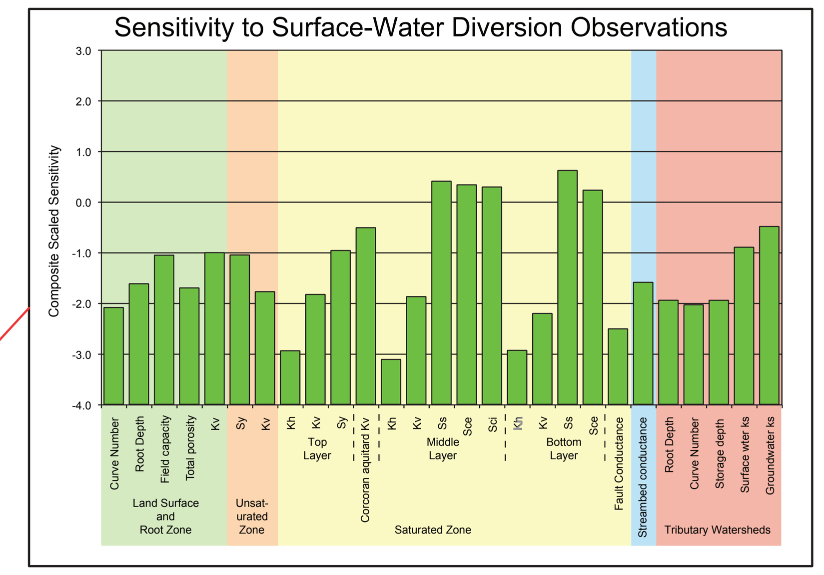
The C2VSim model (Brush et al. 2008) was developed using the Integrated Water Flow Model (IWFM) application. C2VSim simulates land-surface, groundwater and surface water flow processes in the alluvial portion of California's Central Valley, an area of approximately 20,000 mi^2, on a monthly time step from October 1921 through September 2003. The C2VSim model is currently being calibrated using the PEST parameter estimation suite.

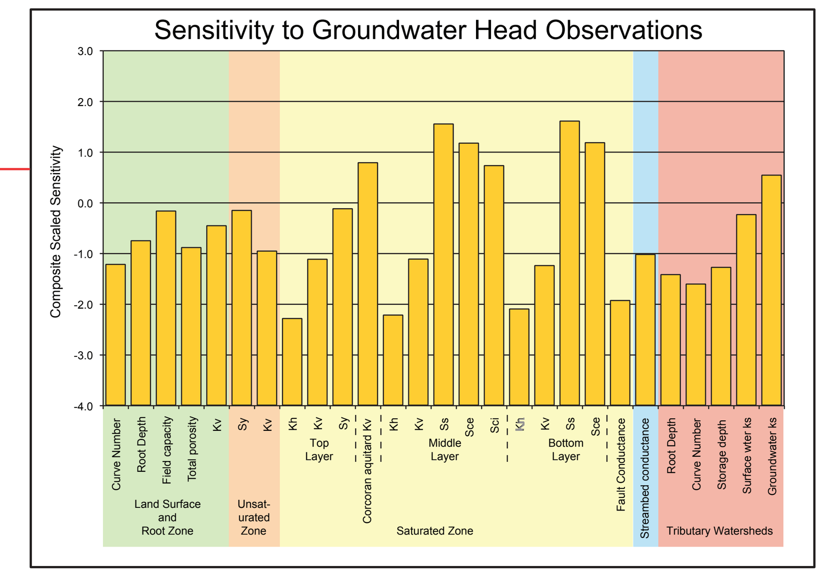
A calibrated integrated hydrologic flow model can provide robust estimates of unmeasured water resources properties. These include groundwater pumping rates, changes in groundwater storage, land surface subsidence due to groundwater withdrawals, and groundwater-surface water interaction. In addition, the model can be used to analyze proposed changes in conjunctive use projects and assess potential impacts to Central Valley streams and aquifers owing to changes in surface water flows (for example due to climate variability).

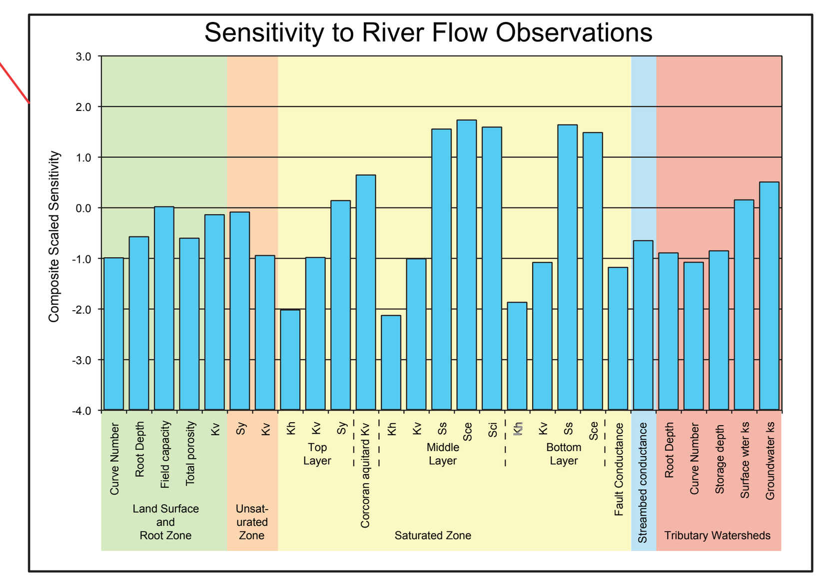
Composite Scaled Sensitivities

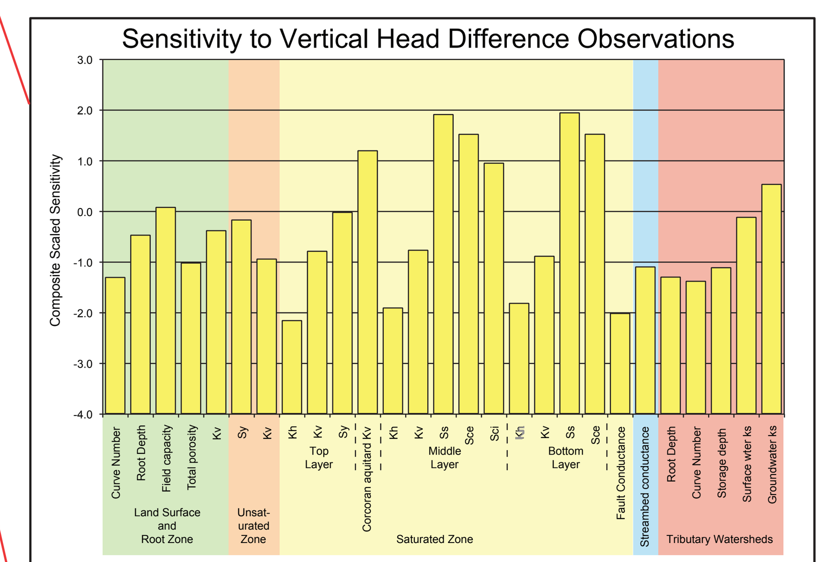
How much information does each type of observation provide towards calibrating each type of parameter? High Composite Scaled Sensitivity values reveal the most sensitive parameter types and the most informative observation types.

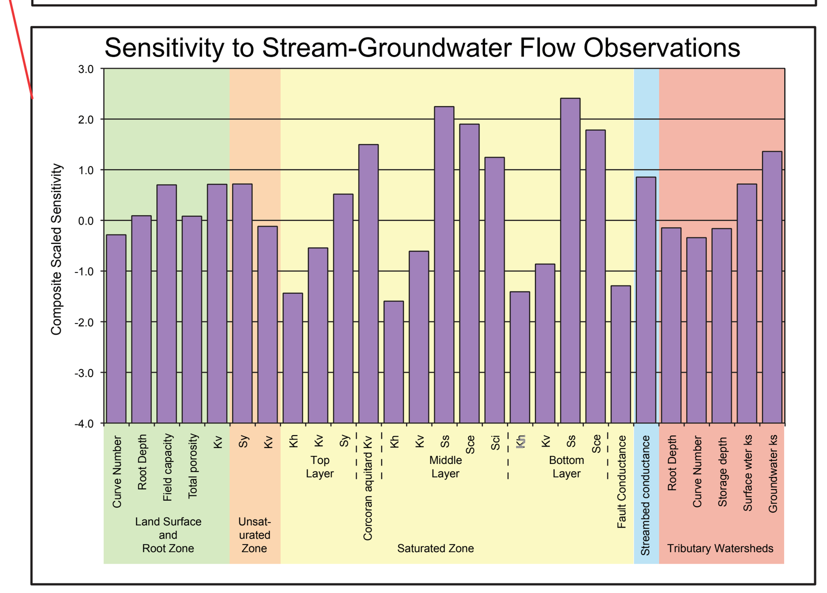
Least Informative











Most Informative

Conclusions

- Process linkages within an integrated model enhance the power of automated calibration tools by directly incorporating multiple observation types.
- Parameter estimates are most sensitive to stream-groundwater flows, a flow term that is often specified *a priori* in single-process models such as typical groundwater or surface water flow models.
- Storage parameters are the most sensitive, followed by vertical conductance parameters.
- Increasing the number of stream-groundwater and vertical head difference observations should improve parameter sensitivities.
- The current use of a uniform weight for each observation type may reduce parameter sensitivities.

Future Work

- Investigate the sensitivity of individual model parameters to each observation type and observation location.
- Increase the stream-groundwater flow observation set.
- Determine if weights for each observation will significantly increase sensitivities, and how to best calculate weights for log-transformed observations.

Acknowledgements

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IWFM source code, executables and documentation are available at no cost. Search for "IWFM" with Google or go to: http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM