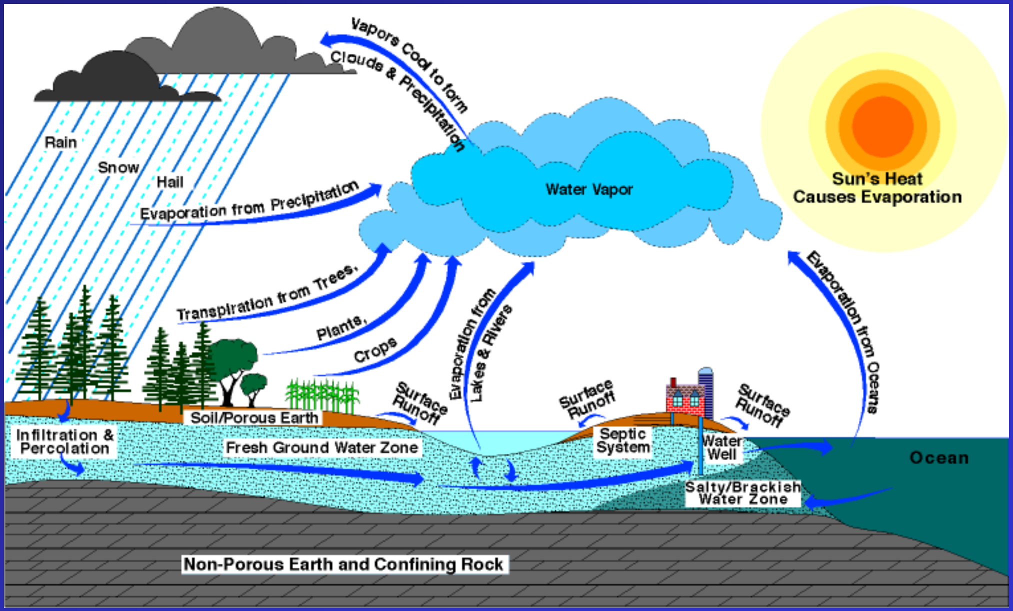
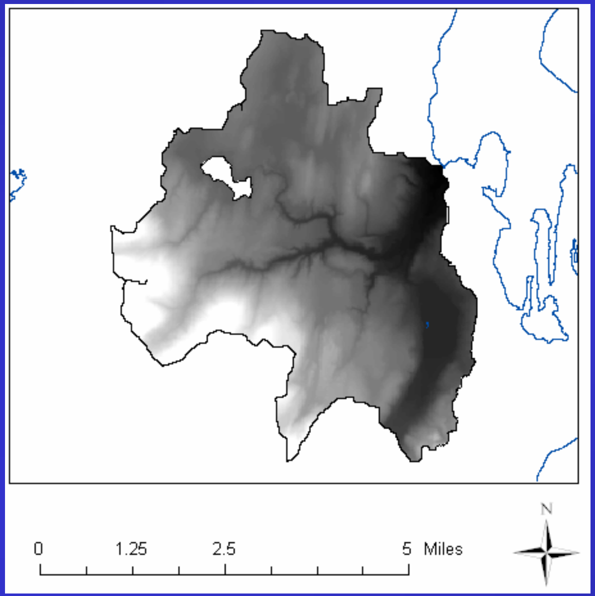
MOTIVATION & PROBLEM





DETAILED LANDSCAPE INFO. ENCAPSULATED IN GIS COVERAGES

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GIS

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MODEL INPUT FILE

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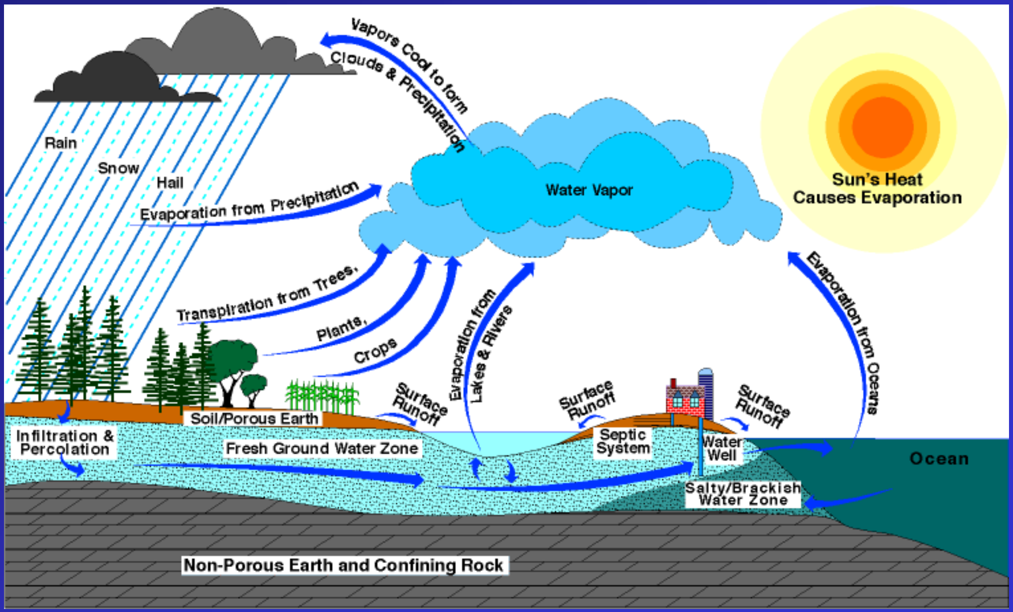
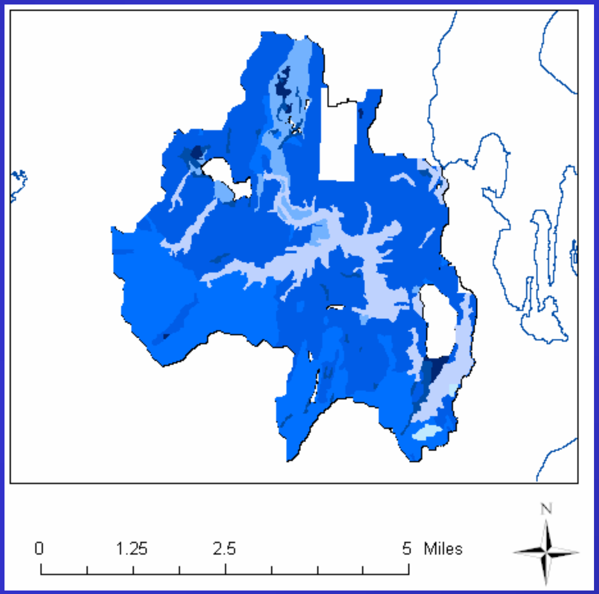
HIGHLY PARAMETERIZED MODEL

MOTIVATION & PROBLEM





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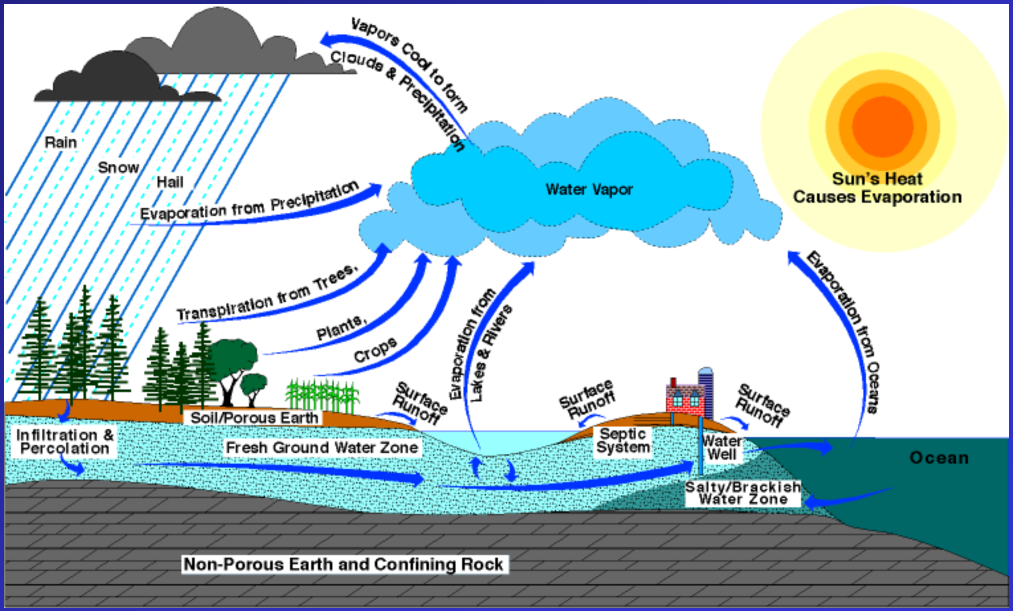

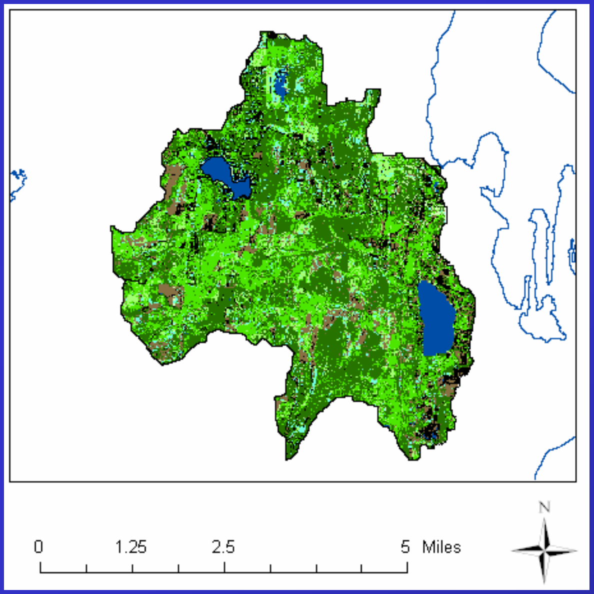

DETAILED LANDSCAPE INFO. ENCAPSULATED IN GIS COVERAGES

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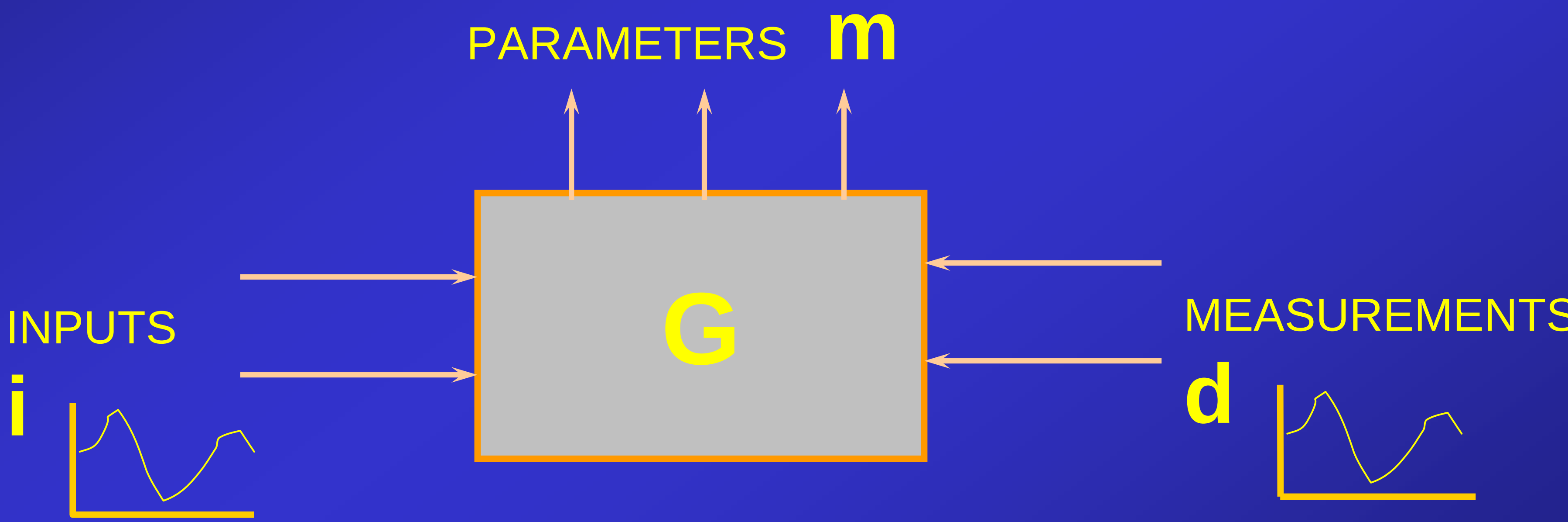
HIGHLY PARAMETERIZED MODEL

MOTIVATION & PROBLEM

- PROBLEMS ASSOCIATED WITH THE SO-CALLED "PRINCIPLE OF PARSIMONY", WHICH IS EMPLOYED IN TRADITIONAL CALIBRATION PRACTICE
  - NOT ALWAYS POSSIBLE TO KNOW AHEAD OF THE PARAMETER ESTIMATION PROCESS HOW MANY PARAMETERS CAN BE ESTIMATED
  - INDIVIDUAL PARAMETER SENSITIVITIES ARE NOT THE SOLE DETERMINER OF WHAT IS ESTIMABLE AND WHAT IS NOT
  - NOT WELL SUITED TO THE SOLUTION OF COMPLEX INVERSE PROBLEMS, SUCH AS THOSE INVOLVING SIMULTANEOUS CALIBRATION OF MULTIPLE MODELS

CONTEXT

THE INVERSE PROBLEM



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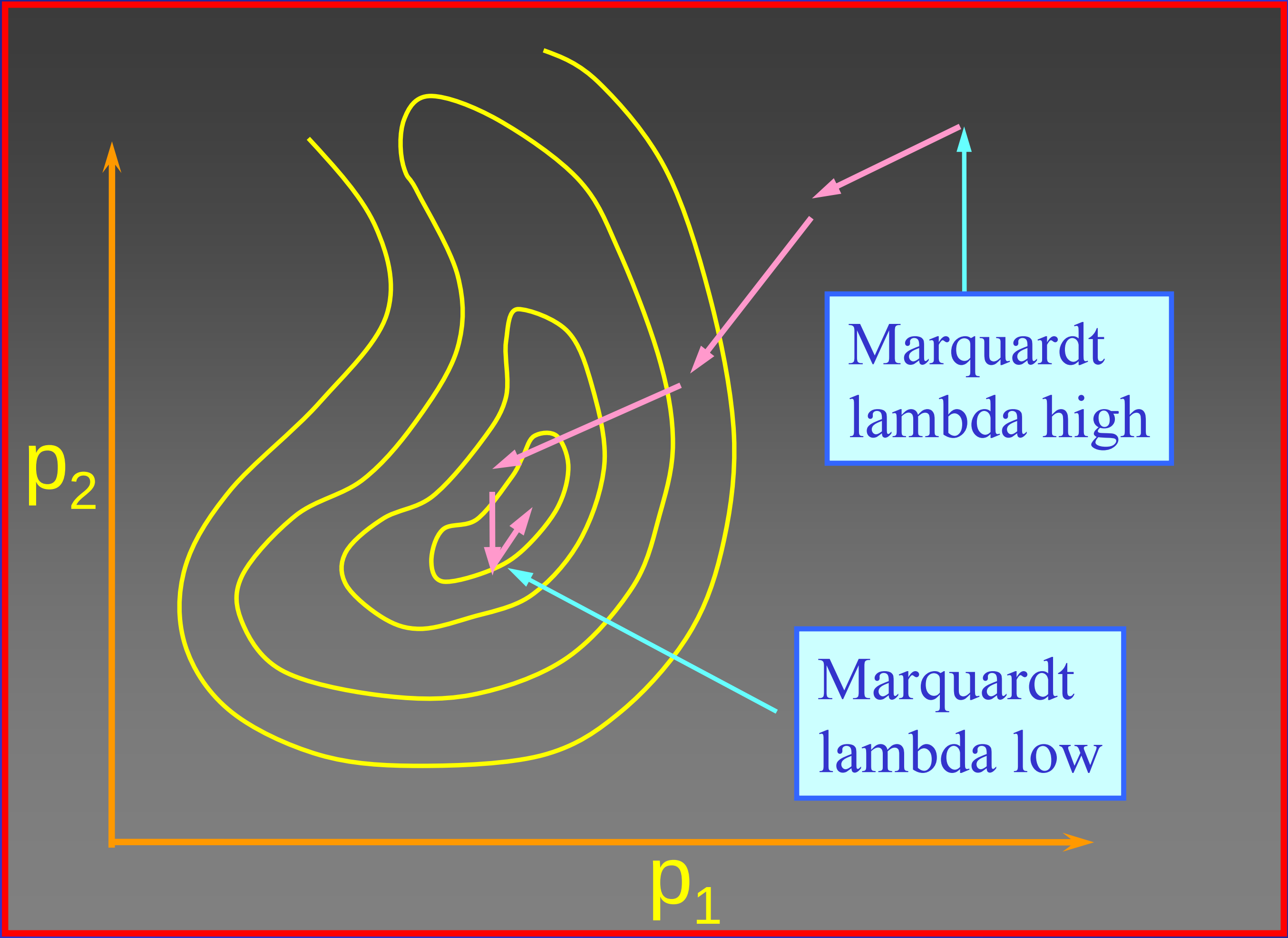
CONTEXT

- MODEL TO MEASUREMENT MISFIT QUANTIFIED USING THE LEAST SQUARES SOLUTION
  - HOMOSCEDASCITY CAN BE ACHIEVED THROUGH TRANSFORMATION
  - SERIAL CORRELATION CAN BE ADDRESSED THROUGH EMPLOYMENT OF AN ARMA MODEL
  - IT IS THE MAXIMUM LIKELIHOOD SOLUTION

CONTEXT



Skahill, B., Doherty, J., (2005). "Efficient accommodation of local minima in watershed model calibration" In revision for publication in Journal of Hydrology.

PROBLEM

- THE INVERSE PROBLEM IS ILL-POSED
  - WHICH OFTEN OCCURS AS MODEL COMPLEXITY GROWS

REGULARIZATION

- A MEASURE OR ADDITIONAL CONSTRAINT THAT IS TAKEN TO ENSURE THAT A STABLE SOLUTION IS OBTAINED TO AN OTHERWISE ILL-POSED INVERSE PROBLEM
- THE PROBLEMS OUTLINED ABOVE CAN BE OVERCOME THROUGH THE USE OF PARAMETER ESTIMATION ALGORITHMS THAT ALLOW MATHEMATICAL REGULARIZATION TO BE IMPLEMENTED AS PART OF THE PARAMETER ESTIMATION PROCESS ITSELF.

REGULARIZATION

- TRUNCATED SINGULAR VALUE DECOMPOSITION (TSVD)
- TIKHONOV REGULARIZATION

EXAMPLE - TSVD

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - v\frac{\partial C}{\partial x}$$

$$C(0,t) = C_{in}(t)$$

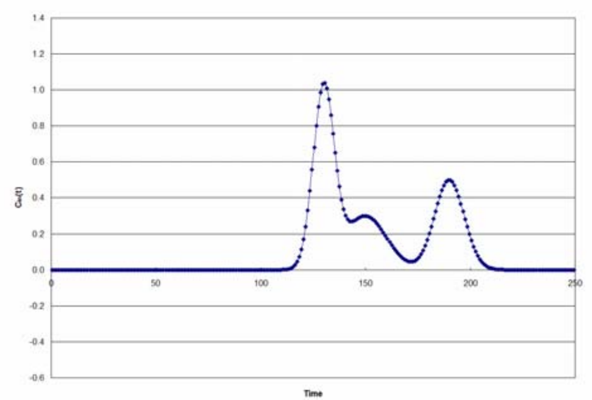
$$C(x,t) \to 0 \text{ as } x \to \infty$$

$$C(x,0) = C_0(x)$$

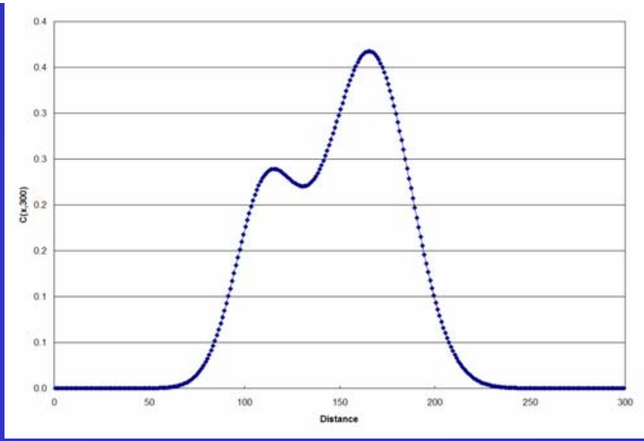
$$C(x,T) = \int_0^T C_{in}(t) f(x, T-t)\, dt,$$

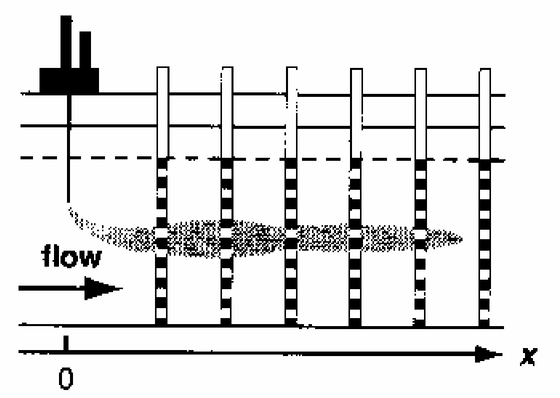
$\rightarrow$ **d = Gm**

$$f(x, T-t) = \frac{x}{2\sqrt{\pi D (T-t)^3}} \exp\left(-\frac{[x - v(T-t)]^2}{4D(T-t)}\right)$$



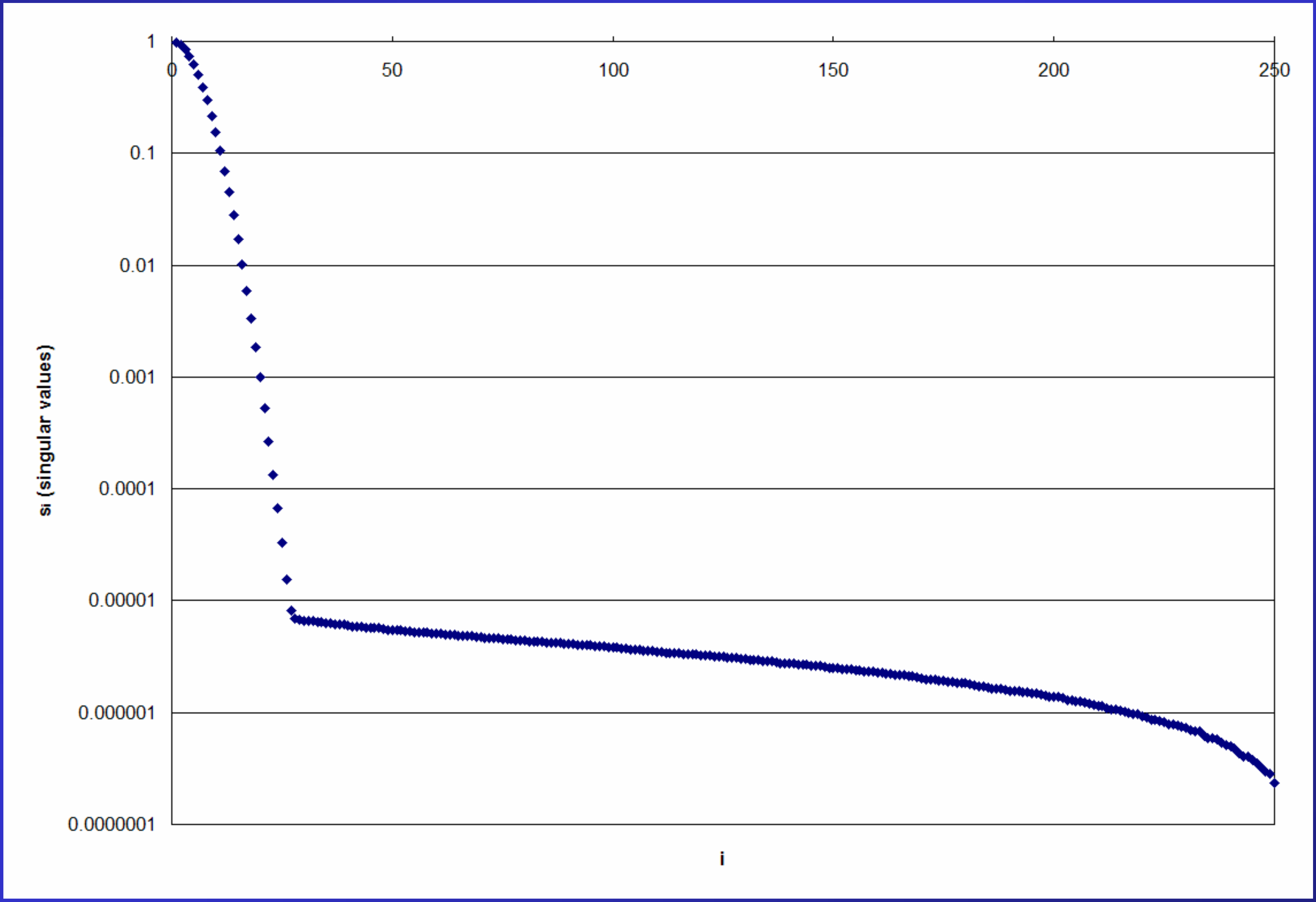
$$C_{in}(t) = \exp\left(-\frac{(t-130)^2}{2(5)^2}\right) + 0.3\exp\left(-\frac{(t-150)^2}{2(10)^2}\right) + 0.5\exp\left(-\frac{(t-190)^2}{2(7)^2}\right)$$





Skaggs, T.H., and Z.J. Kabala, Recovering the release history of a groundwater contaminant, *Water Resources Research*, 30(1), 71-79, 1994.

EXAMPLE - TSVD



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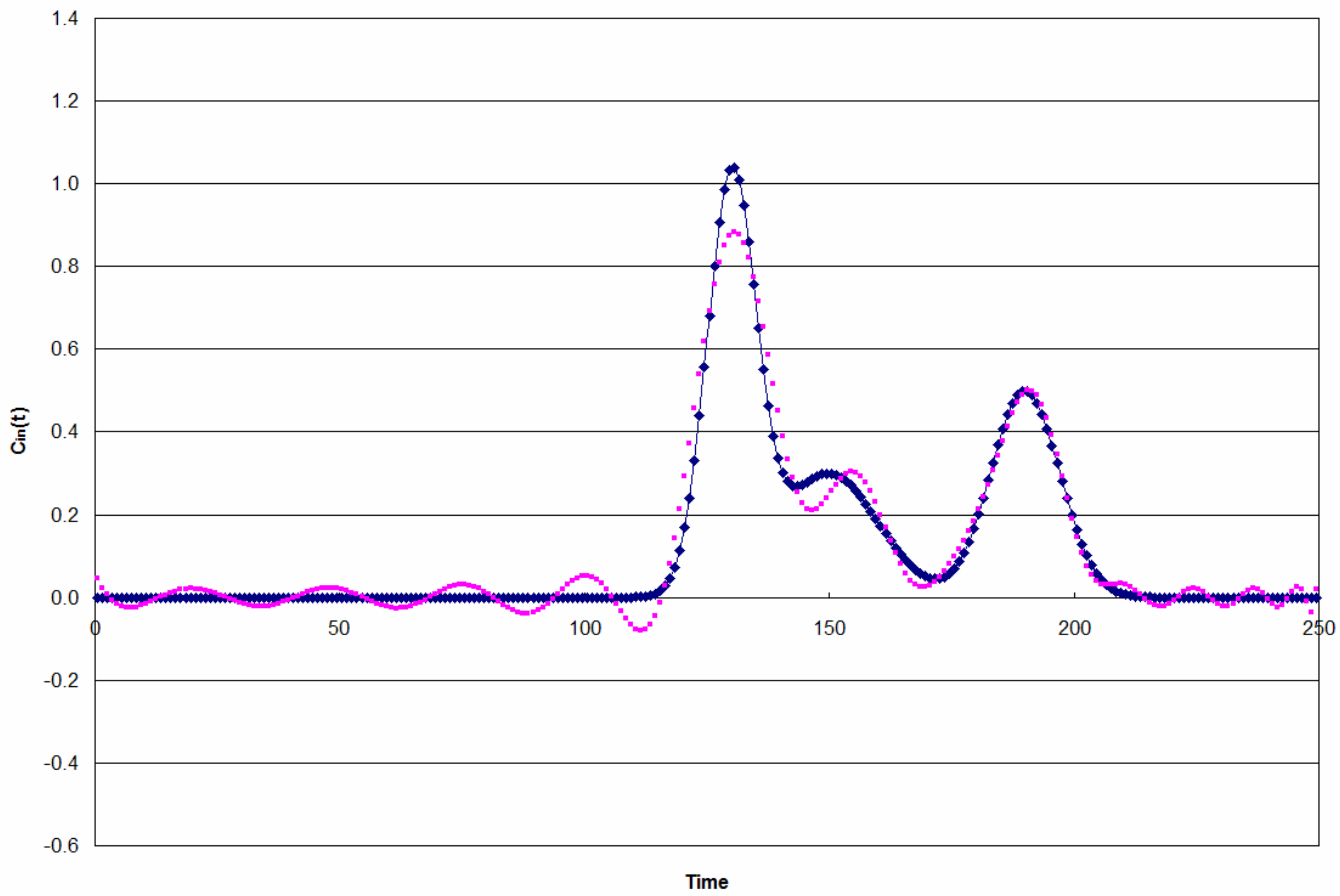
of Engineers

EXAMPLE - TSVD



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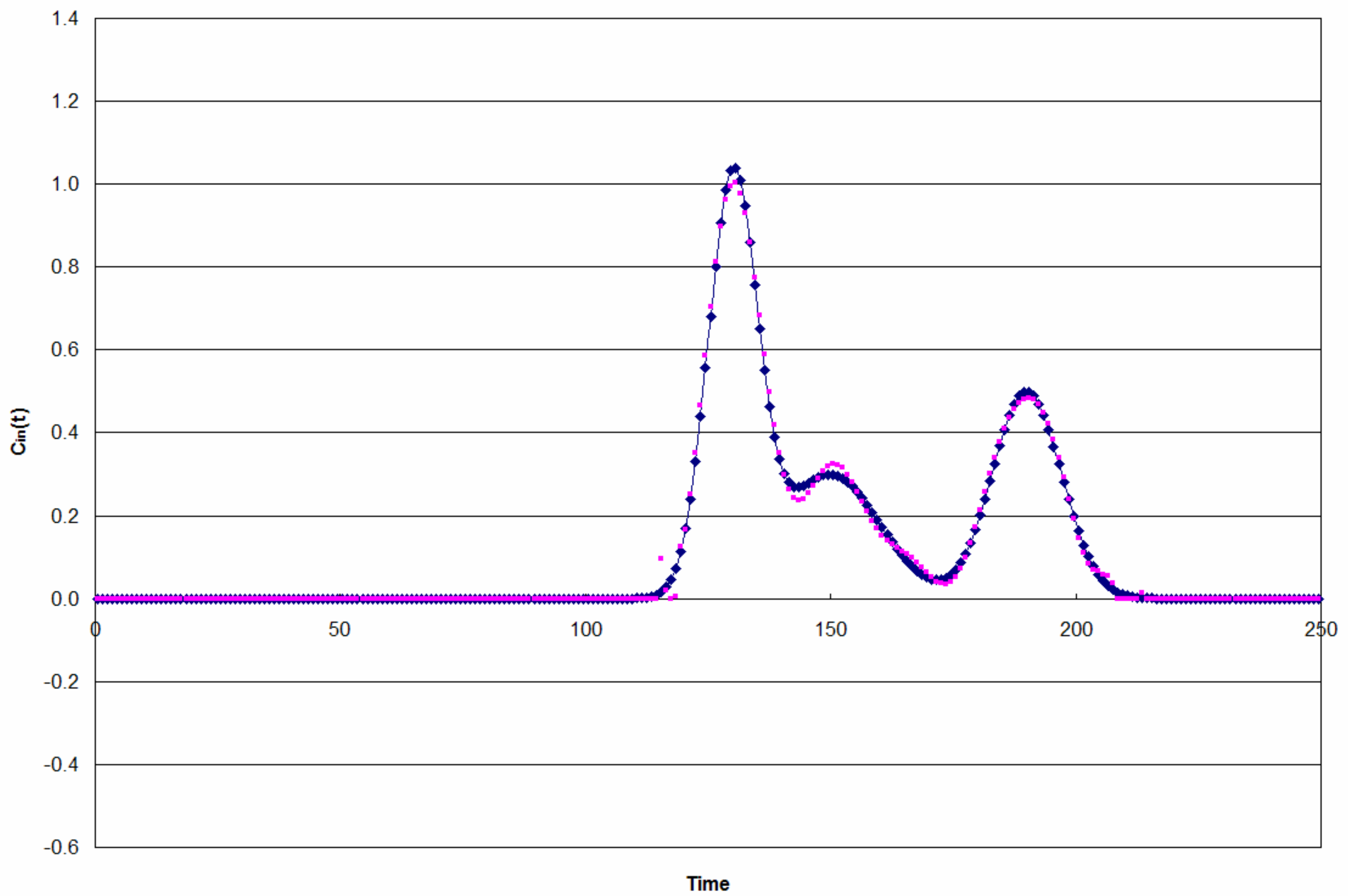
EXAMPLE - TSVD



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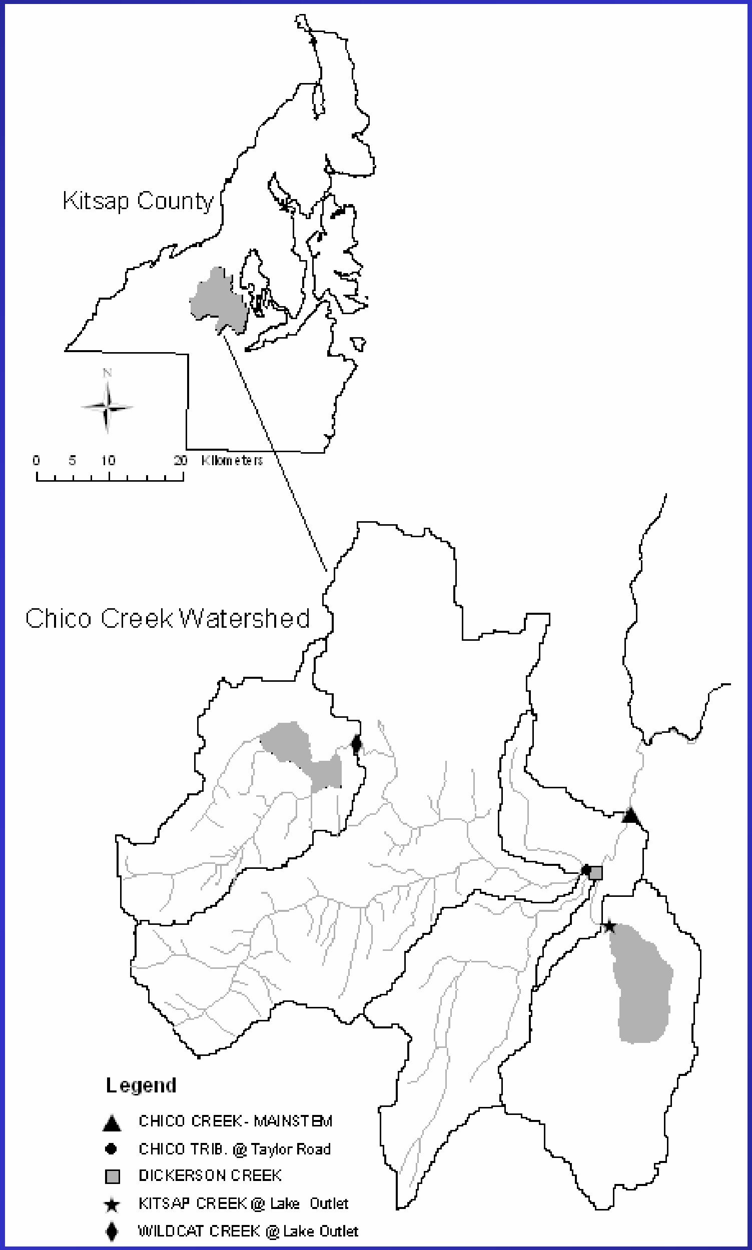
POINTS

- WITH REGULARIZATION, THERE IS A TRADE OFF BETWEEN FITTING THE DATA IN EXCHANGE FOR SOLUTION STABILITY
- TSVD CONTRASTS WITH A PRIORI PARSIMONY IN THAT WITH TSVD, THE SOLUTION SUBSPACE IS DETERMINED FROM THE INFORMATION CONTENT OF THE OBSERVATIONS
- WITH TSVD, NO ABILITY TO INSIST ON THE OBSERVANCE OF SPECIFIED PARAMETER RELATIONSHIPS IN ATTAINING STABILITY

EXAMPLE



Doherty, J., Skahill, B., (2005). "An Advanced Regularization Methodology for Use in Watershed Model Calibration" In revision for publication in Journal of Hydrology.

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EXAMPLE

- CALIBRATE EACH SUBWATERSHED MODEL INDEPENDENTLY OF THE OTHERS
- CALIBRATE ALL MODELS SIMULTANEOUSLY AGAINST RESPECTIVE GAGED FLOWS, ENSURING THAT STRICT INTER-SUBWATERSHED PARAMETER EQUALITY IS RESPECTED
- CALIBRATE EACH MODEL INDIVIDUALLY, WITH DUE RECOGNITION OF THE DESIRABILITY OF INTER-SUBWATERSHED PARAMETER SIMILARITY

EXAMPLE

Streamflow Gaging Station	Regularization	Hardwired parameter equality
Kitsap Creek	0.768	0.336
Wildcat Creek	0.918	0.879
Chico Creek (Taylor Road)	0.888	0.675
Dickerson Creek	0.936	0.879
Chico Creek (mainstream)	0.952	0.916
All gaging stations	0.917	0.846

Nash-Sutcliffe coefficients for log of daily flows based on simultaneous calibration through regularized inversion (column 2) and simultaneous calibration with hardwired parameter equality (column 3)

SUMMARY

- REGULARIZATION IS A MEASURE OR ADDITIONAL CONSTRAINT THAT IS TAKEN TO ENSURE THAT A STABLE SOLUTION IS OBTAINED TO AN OTHERWISE ILL-POSED INVERSE PROBLEM
- WITH REGULARIZATION, THERE IS A TRADE OFF BETWEEN FITTING THE DATA IN EXCHANGE FOR SOLUTION STABILITY
- REGULARIZATION ELIMINATES THE NEED FOR “PREEMPTIVE PARSIMONIZING” AHEAD OF THE CALIBRATION PROCESS
- THE RESULT IS A STABLE PROCESS THAT ALLOWS MAXIMUM RECEPTIVITY OF PARAMETERS TO BOTH “HARD INFORMATION” PROVIDED BY THE MEASUREMENT DATASET AND “SOFT DATA” EMBODIED IN A MODELER’S UNDERESTANDING OF THE AREA, ENCAPSULATED IN THE SET OF REGULARIZATION CONSTRAINTS