Regularized Pilot Points Method for reproducing small scale variability of hydraulic conductivity. Application to contaminant transport.

Hydrogeology Group

Andrés Alcolea, Jesús Carrera, Agustín Medina. Technical University of Catalonia. School of Civil Engineering. Barcelona. Spain

andres.alcolea@upc.edu, Tel: +34 93 4016892, Fax: +34 93 4017251.

H23E-03

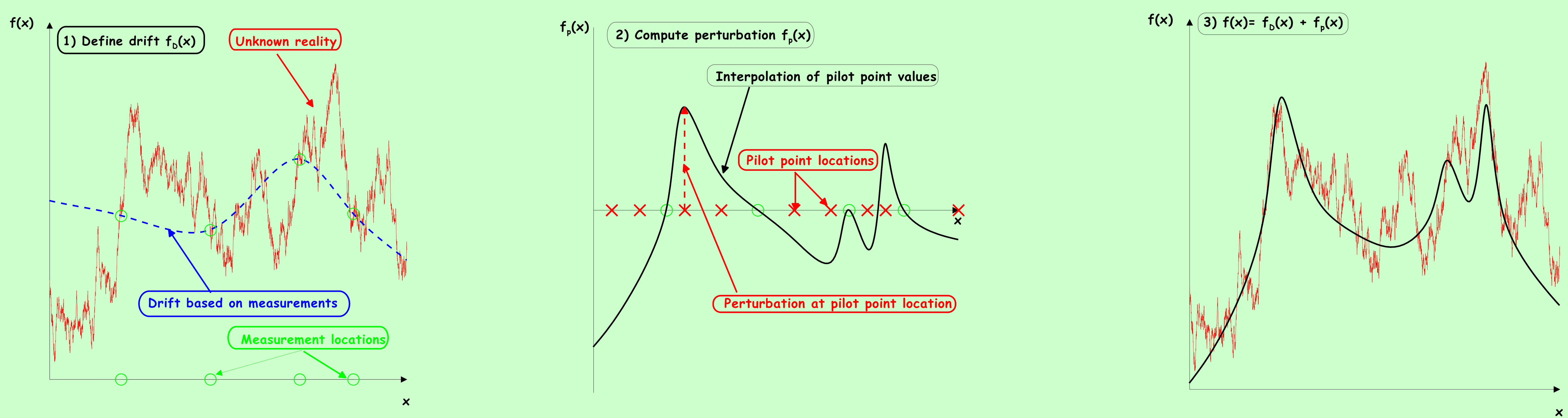
I) Motivation: Heterogeneity of K exerts a major control in contaminant transport (e.g. tailing in breakthrough curves (BTCs))

UNIVERSAL SCALING THEORY → For simplicity (modeling purposes) →

1) Large scale variability (LSV): Connectivity patterns; characterizable (inverse modeling, geology, etc.)

2) Small scale variability (SSV): High frequency fluctuations; **not characterizable**. OFTEN ~~DISREGARDED~~

II) Methodology RPPM: 1) Parameterization: the unknown field is the superposition of a drift (deterministic /stochastic) and an uncertain residual, linear combination of the model parameters (value of the field at the PP locations)



2) Computing the perturbation: Optimum set of model parameters minimize an objective function, which measures the departure of the solution from the data (in terms of state variables and **prior information of model parameters**)

$$F = F_d + \mu F_p = (\mathbf{s}-\mathbf{s}^*)^t V_s^{-1}(\mathbf{s}-\mathbf{s}^*) + \mu(\mathbf{p}-\mathbf{p}^*)^t V_p^{-1}(\mathbf{p}-\mathbf{p}^*)$$

3) Seeking the optimum weight of the plausibility term (μ): Several runs must be performed, varying the weighting factor of the plausibility term. The optimum weight maximizes the **expected likelihood** of the parameters given the data. This problem is equivalent to the minimization of the support function:

$$S = N + \ln|\underline{\underline{H}}| + N\ln\left(\frac{F}{N}\right) - \ln(\mu)$$

N: number of data

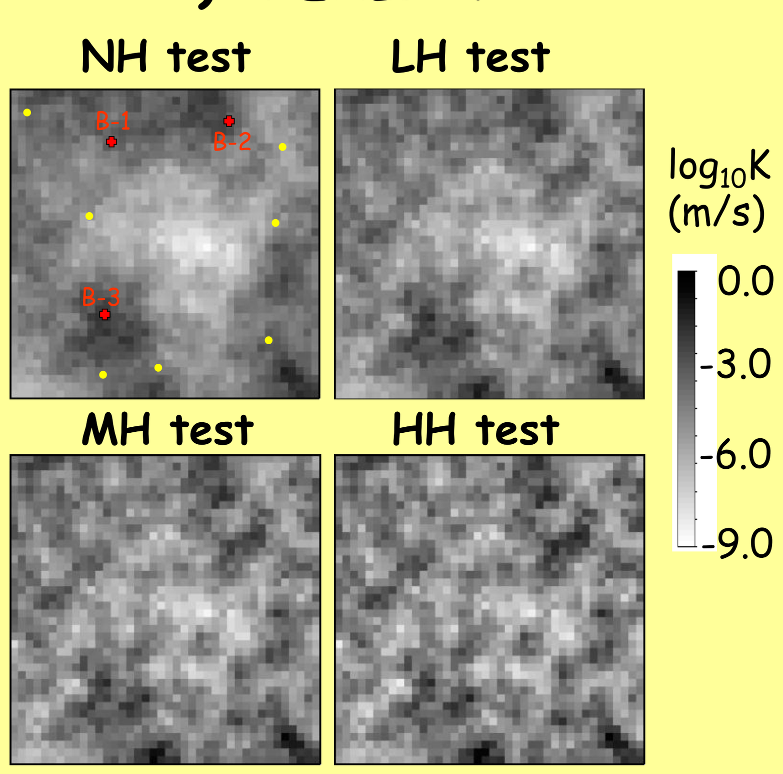
H: linear app. of Hessian

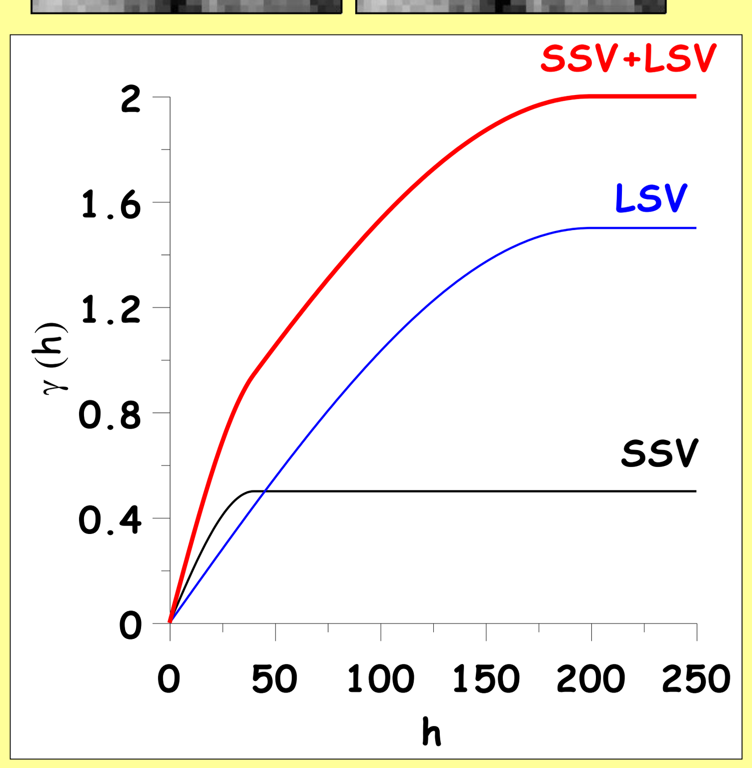
μ: weight of plausibility term

Objectives: To test 1) whether the presence of SSV impedes the characterization of LSV patterns and 2) whether including SSV allows reproducing tailing in BTCs.

III) Application: 1) Definition of synthetic tests. 2) Generation of measurements (flow and transport). 3) Calibration of log10K fields (CE and 20 CS). 4) Application of the calib. fields to a transport prediction.

1) "REALITY"



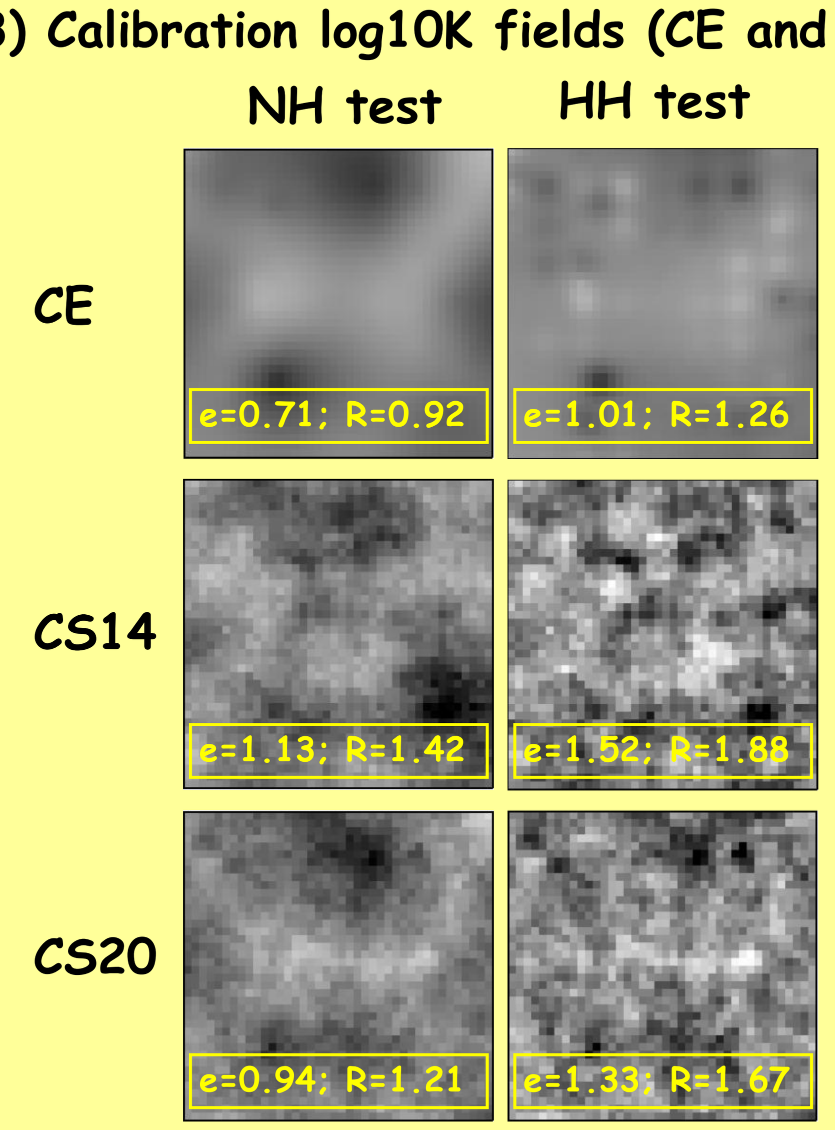


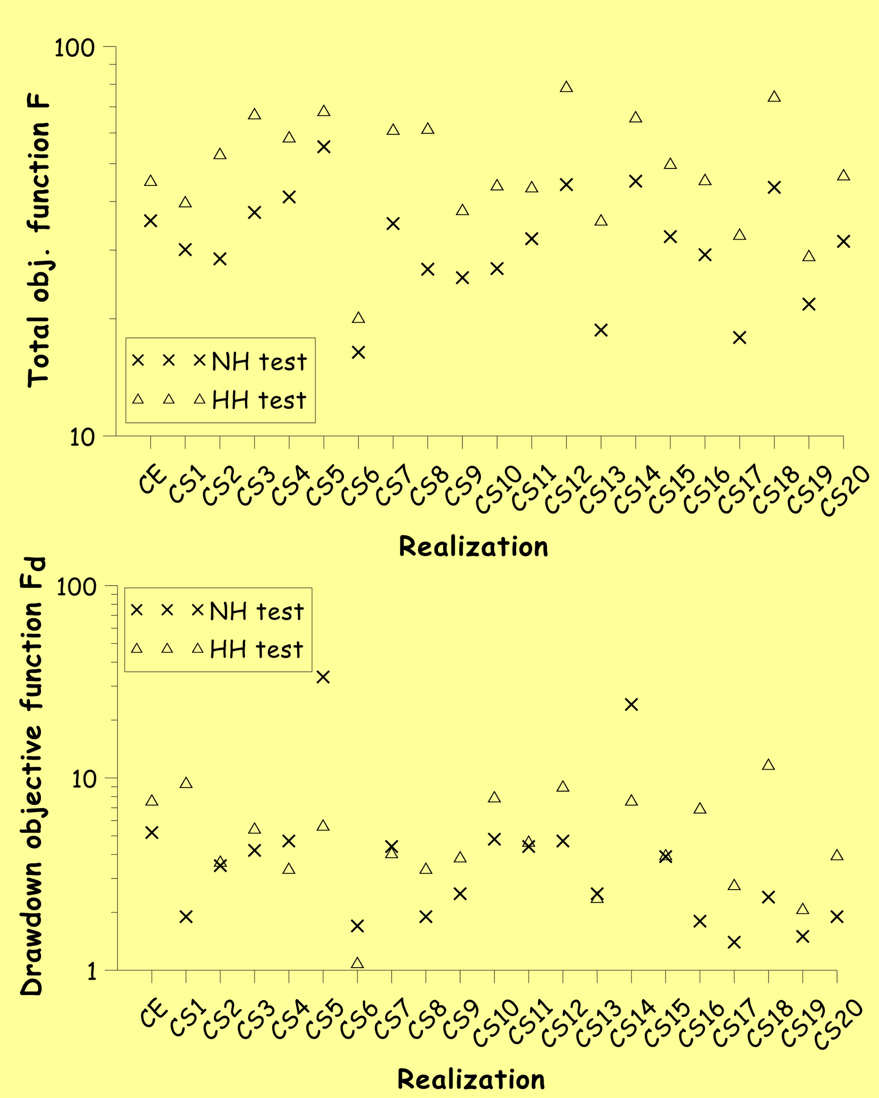
		SSV		LSV	
		a_1	S_1	a_2	S_2
NH	None	---	---	200	2.0
LH	Low	40	0.5	200	1.5
MH	Med.	40	1.0	200	1.0
HH	High	40	1.5	200	0.5

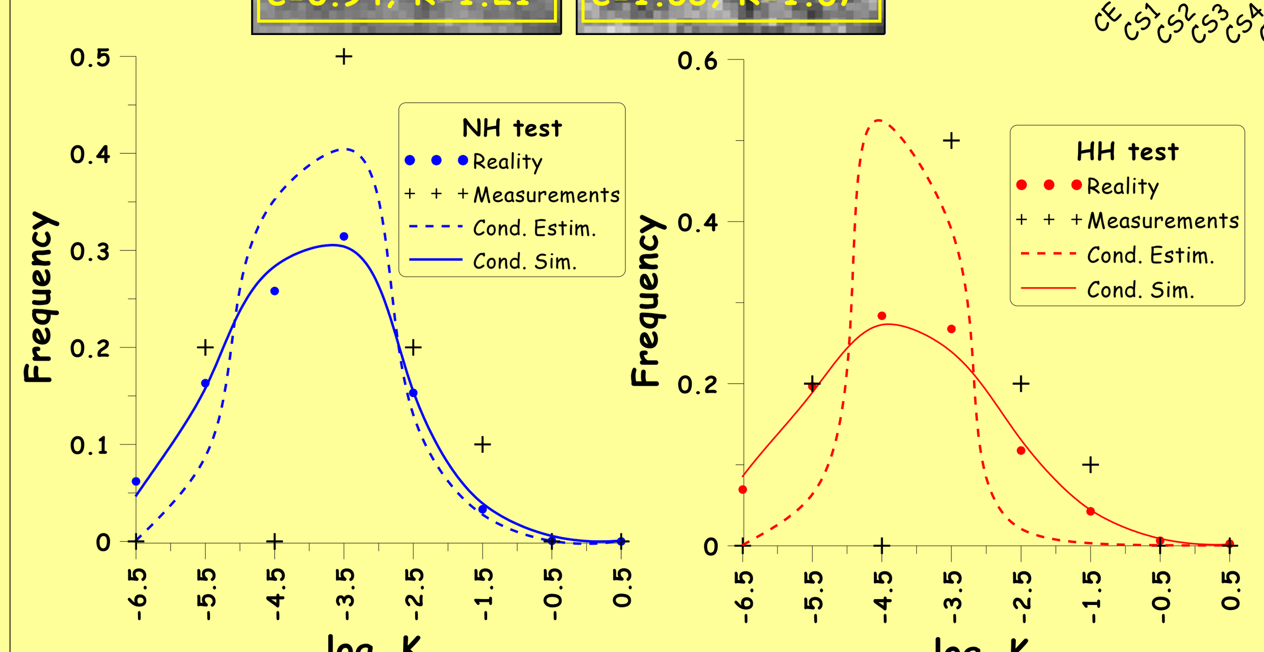
2) Calibration measurements: 10 sampling locations.

Error-free $\log_{10}K$ data and steady-state drawdown

3) Calibration log10K fields (CE and 20 CS)

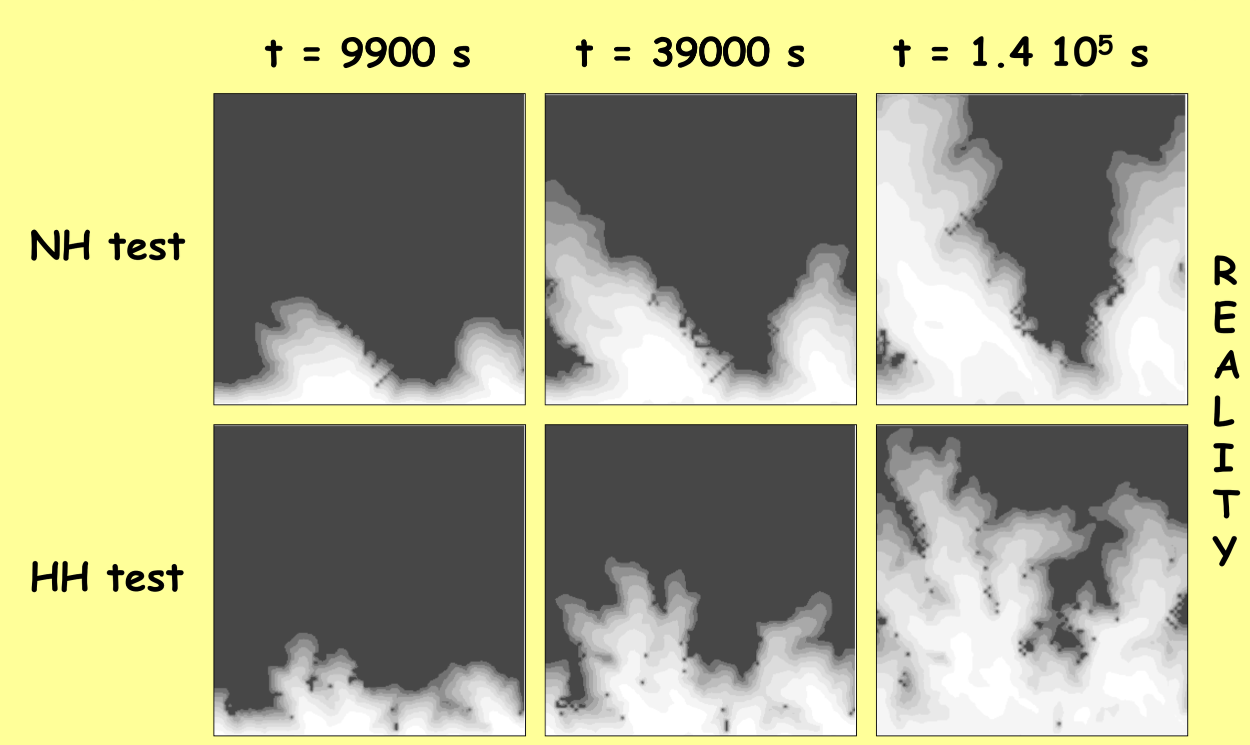




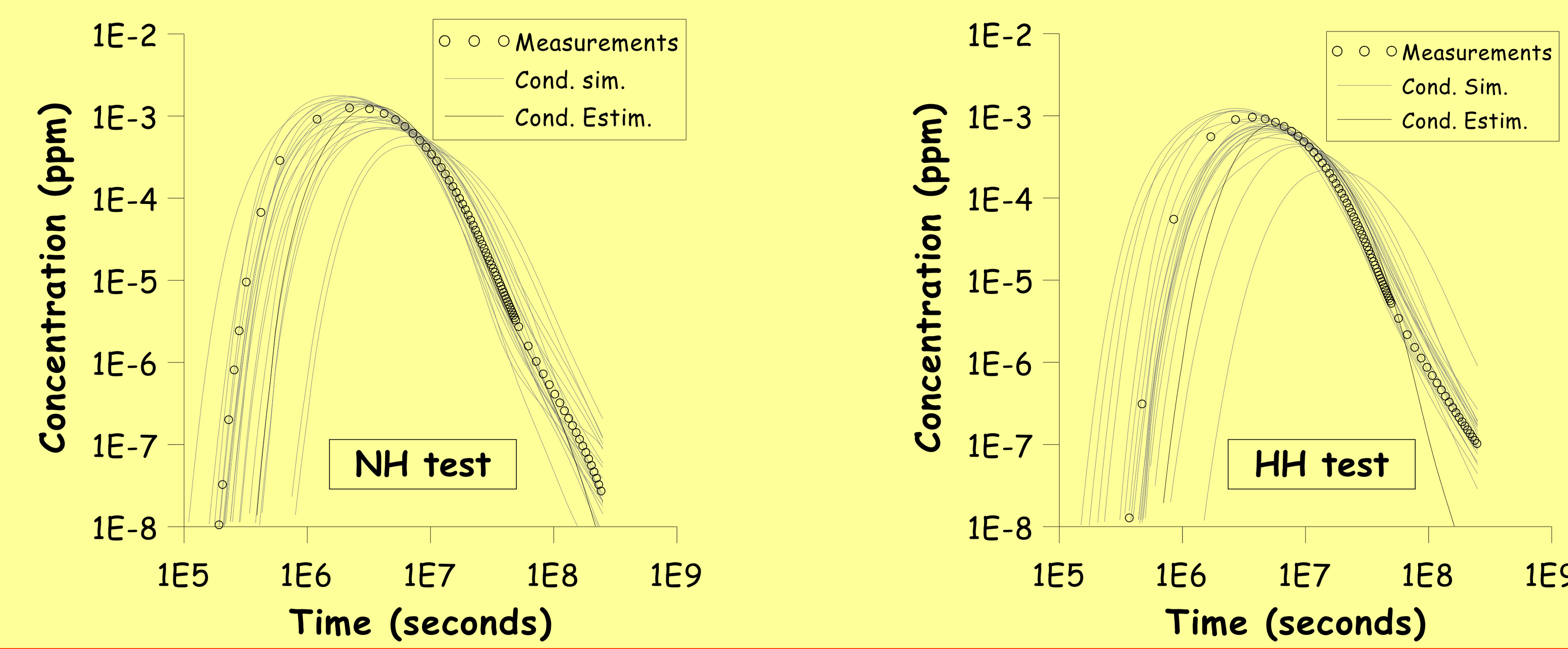


		Mean	Variance
Measurements		-3.94	1.50
NH	True	-4.60	1.57
	CE	-4.33	0.73
	CS	**-4.53**	**1.52**
HH	True	-4.71	1.71
	CE	-4.63	0.33
	CS	**-4.79**	**2.07**

4) Application of the calibrated fields to a transport prediction. Known BTCs



		Arr. Time (log10)	Peak conc. (log10)	Slope
NH	True	6.40	-2.90	-2.96
	CE	6.54	-2.88	-4.16
	CS	6.49	-2.96	**-2.91**
HH	True	6.56	-3.02	-2.29
	CE	6.76	-3.10	-5.27
	CS	6.68	-3.14	**-2.74**



Conclusions: 1) Simulated fields reproduce the statistics of the true field. Estimated fields too smooth. Not capable of reproducing SSV.

2) Simulated fields reproduce the main features of BTCs.

3) Ignoring SSV leads to simulated BTCs which reproduce peak conc. and arrival time but not the tail. Simulated fields accommodating SSV reproduce the tail as well. One does not need to characterize SSV, but to simulate its presence