Pilot Points Method for the Characterization of Heterogeneous Fields: Hero or Villain?

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

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

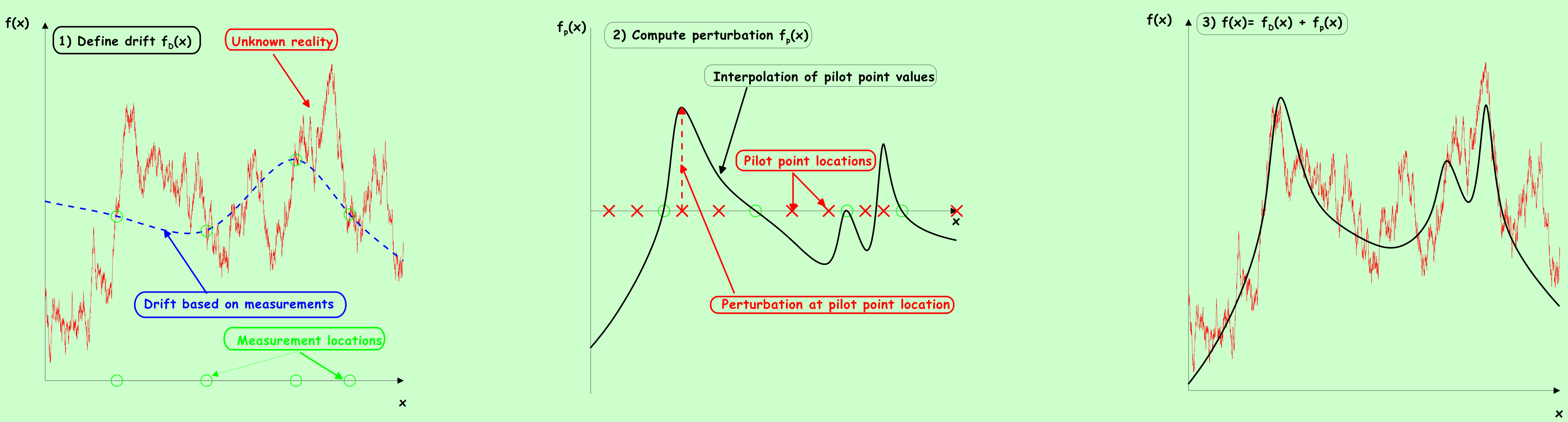
I) Motivation: Instability/Ill-posedness of the inverse problem ⇨ 1) Increasing the volume of information, including different types of data

2) Increasing the quality of the information, optimizing the observation network

3) Reducing the number of parameters; parameterization schemes, such as the Pilot Points Method (PPM)

⇧ Overparameterization

II) Methodology: The PPM consists of defining the unknown field as the superposition of 1) a drift based on a geostatistical model and 2) 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 (penalty) function, which measures the departure of the solution from the data (both in terms of state variables and **prior information of model parameters**)

"Traditional" objective function; often UNSTABLE /OVERPARAMETERIZED ➡ **FEW PILOT POINTS**

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

"Novelty": Regularization / Plausibility term

⬇

Allows accounting for a type of information which is often disregarded in the calibration process and at the same time offers **stability** to the inverse problem

⬇

Larger number of pilot points ➡ more resolution in the characterization

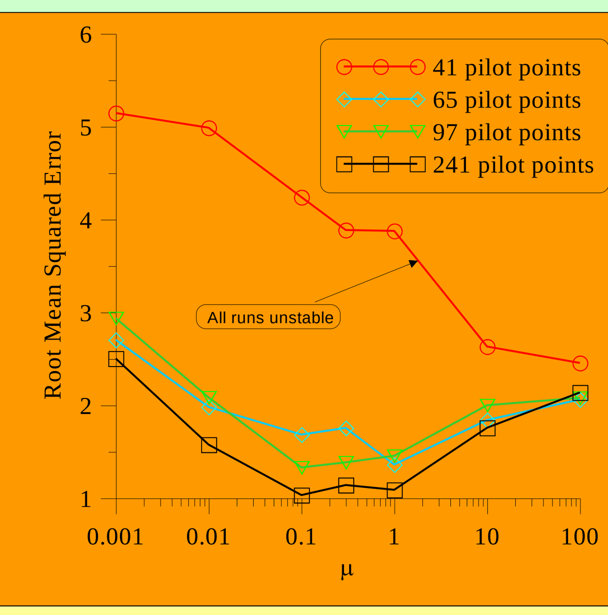
Seeking the optimum weight of the plausibility term (μ): Several runs must be performed, varying the weighting factor. The optimum weight is the one that maximizes the **expected likelihood** of the parameters given the data. This problem is equivalent to the minimization of the support function:

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

S: support function; N: number of data

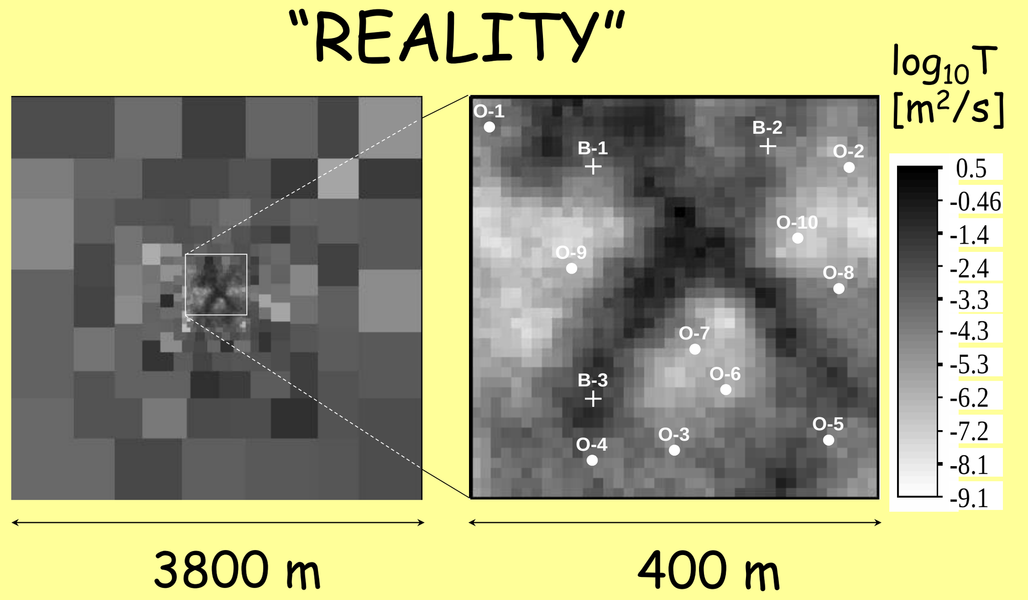
H: linear approximation of the hessian of the objective function F

μ: weight of the plausibility term



III) Application: Synthetic example. Characterization of the transmissivity field. Drawdown Data arising from three independent pumping tests at the central zone of the domain. 13 T-data in the central part

"REALITY"

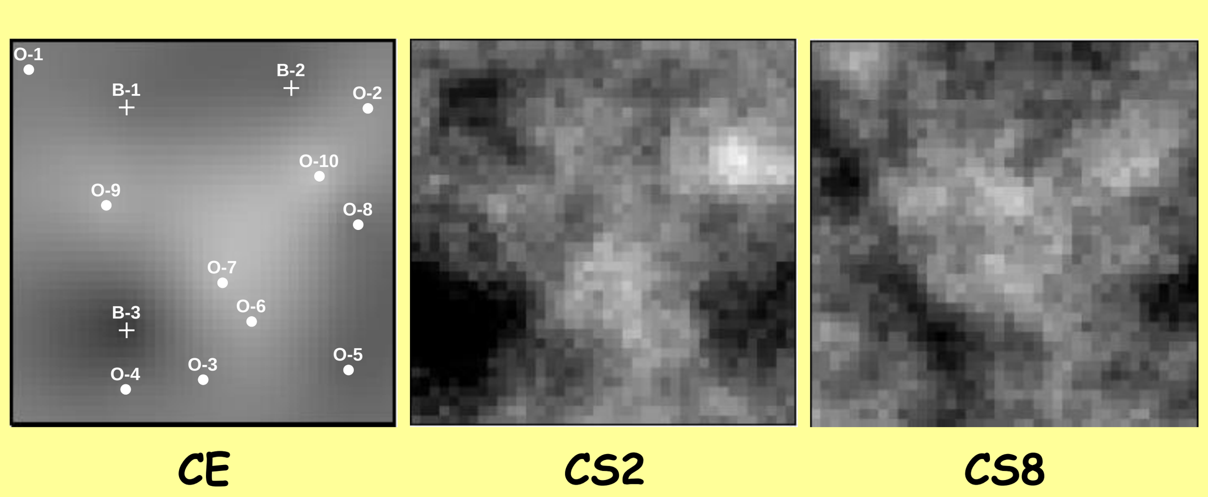


Boundary conditions: s=0 and Q=10^{-2} m³/s at B-1,B-2,B-3.

Variogram: Spherical, range =200 m, variance=2, no nugget

Storativity: Constant and known S=10^{-4}

INITIAL DRIFTS



Objectives: To test the effect of 1) the plausibility term, 2) the number of pilot points and 3) the reliability of conditional estimation vs conditional simulations (10)

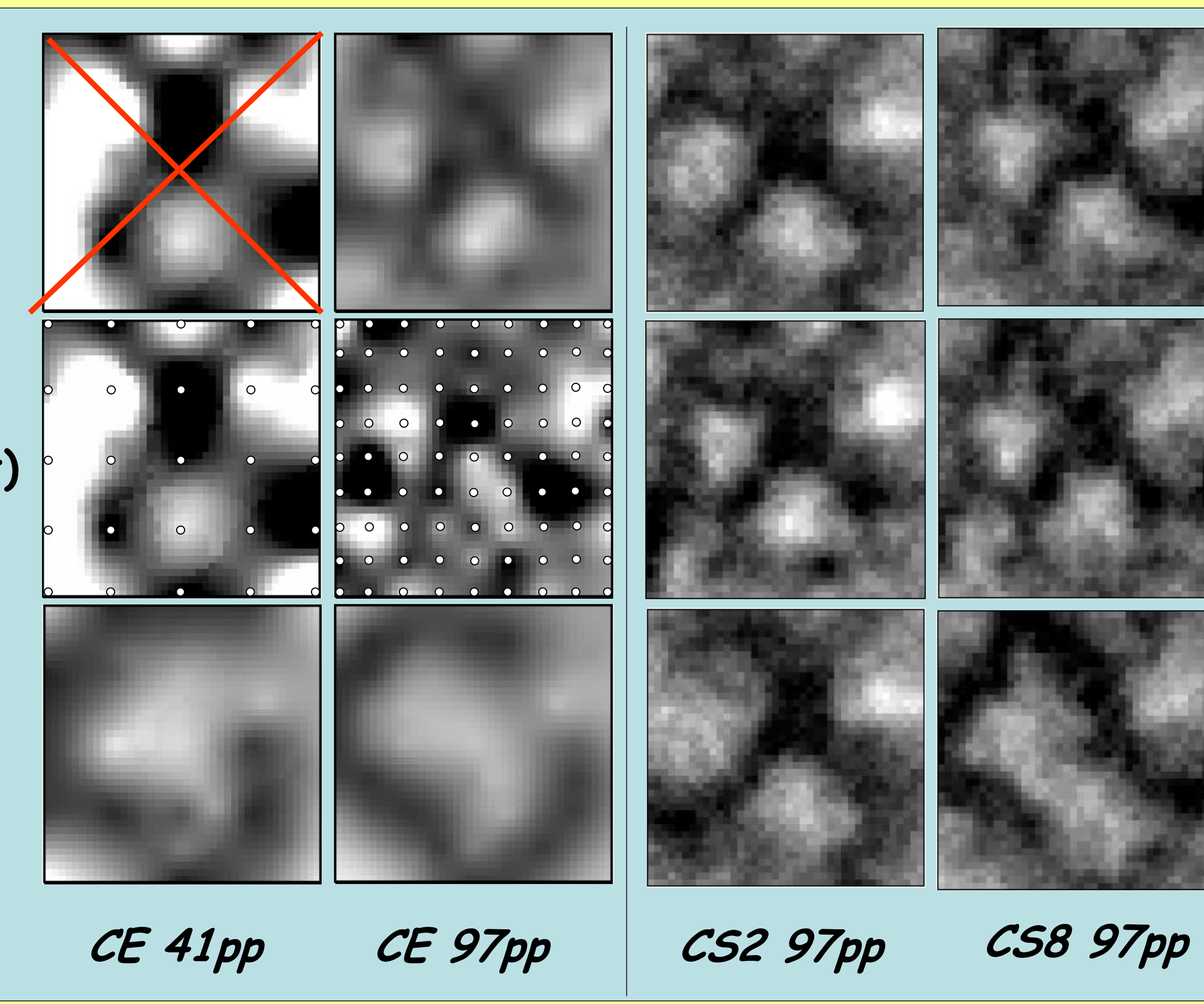
HERO; optimum weighting of the plausibility term

VILLAIN; prior information disregarded (low weight)

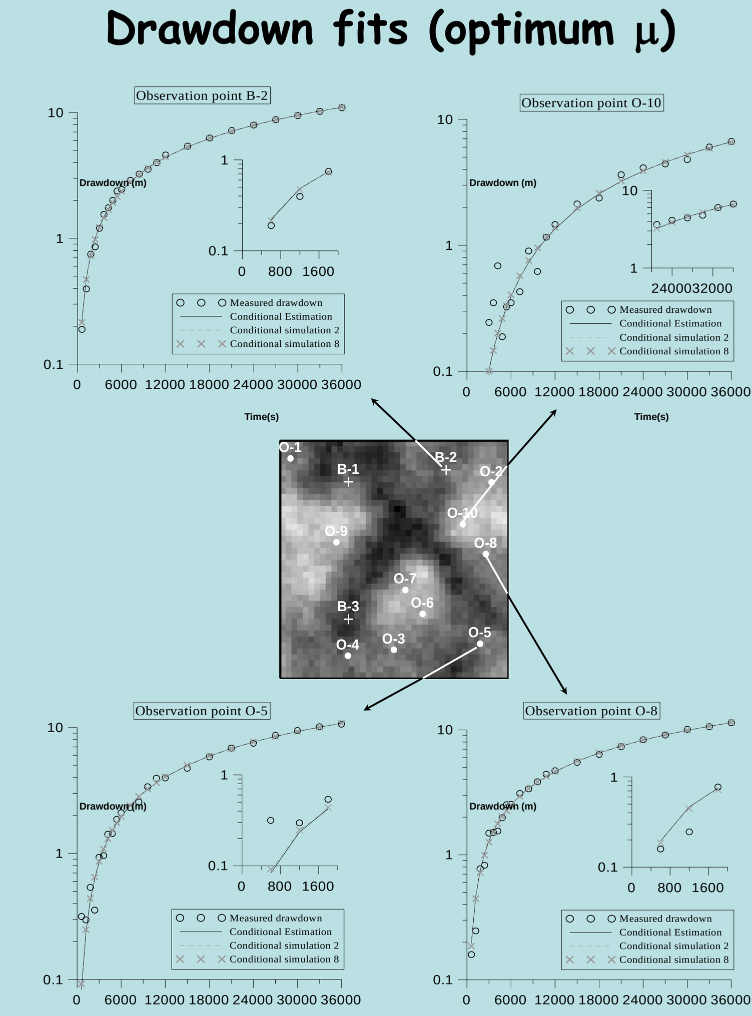
⬇ UNSTABLE

VILLAIN; too much importance to prior information

⬇ SOLUTION BIASED TOWARDS THE DRIFT



Drawdown fits (optimum μ)



Conclusions: 1) The PPM must be handled carefully !!!. The use of a plausibility term in a maximum likelihood framework is strongly recommended !!!

2) The larger is the number of pilot points, the better is the characterization of the unknown field. Contradicts the traditional usage of the PPM !!!

3) Indeed, conditional simulations resemble the "real" field better than conditional estimation. However, drawdown fits are very similar