

# It is Normal Not to be Gaussian

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# Disjunctive Kriging: The Untold Story

*Unpublished*

# Disjunctive Kriging: The Untold Story

To be or not to be  
multiGaussian?

The danger of parsimony

**EXCLUSIVE MONICA LEWINSKY'S**  
**\$12 MILLION TELL-ALL BOOK**  
■ She got pregnant during their affair - secret abortion & lies

*Her ultimate revenge on Bill!*

**NATIONAL ENQUIRER**

**THE TRUTH EXPOSED!**  
**95 lb star collapses**  
**Angie's DEADLY LIVER DAMAGE!**  
- FRIENDS FEAR  
**Pregnancy & wedding heartbreak**

**ORGAN TRANSPLANT BOMBSHELL**

**Sally Struthers LONELY LIFE AS A HOARDER**  
STORY BEHIND DUI ARREST

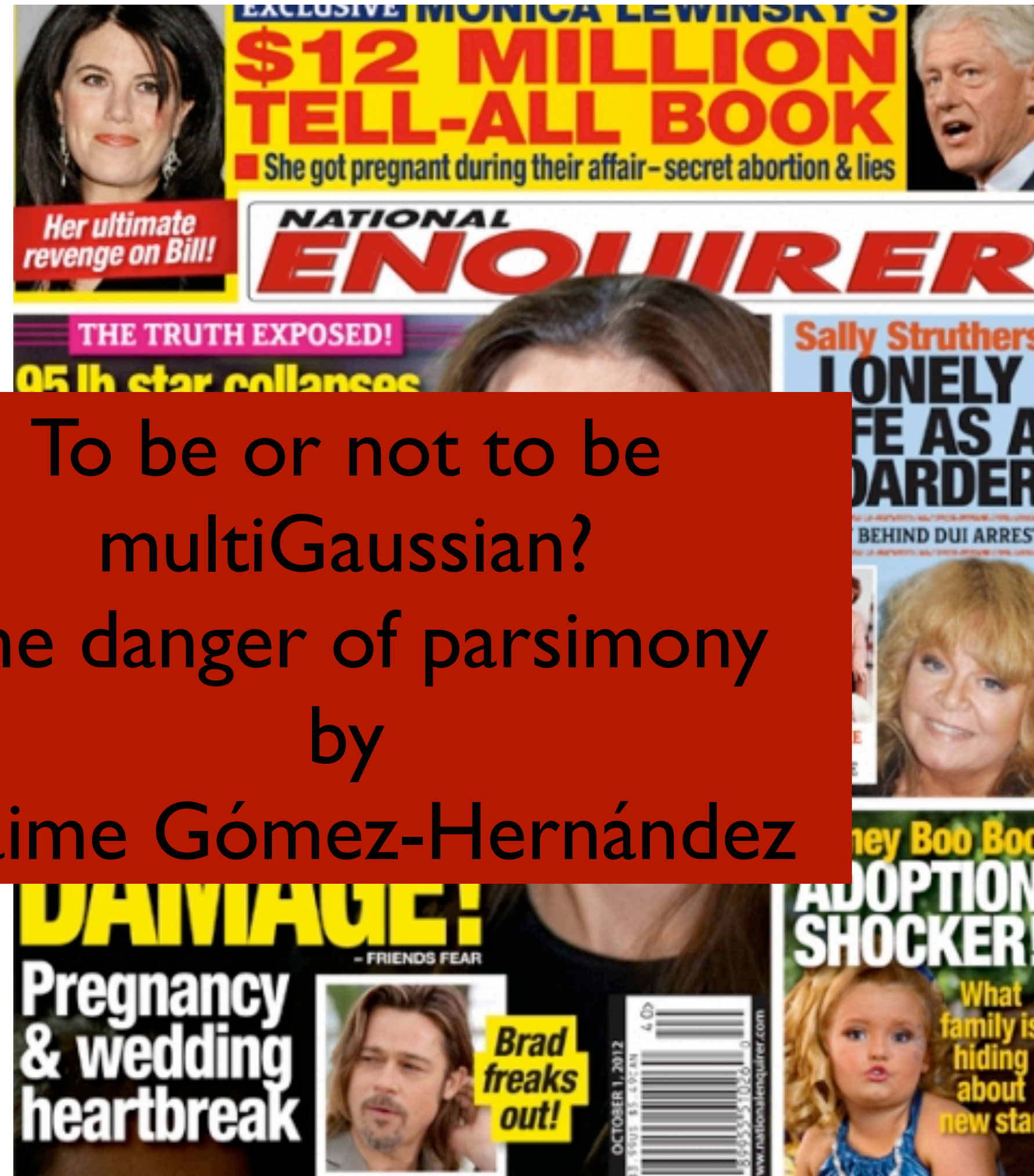
**'ALL IN THE FAMILY' EXCLUSIVE**

**Honey Boo Boo ADOPTION SHOCKER!**  
What family is hiding about new star

**Brad freaks out!**

OCTOBER 1, 2012  
\$3.99 US \$4.99 CAN  
www.nationalenquirer.com





To be or not to be  
multiGaussian?  
The danger of parsimony  
by  
J. Jaime Gómez-Hernández

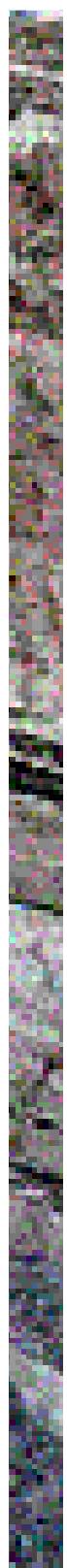
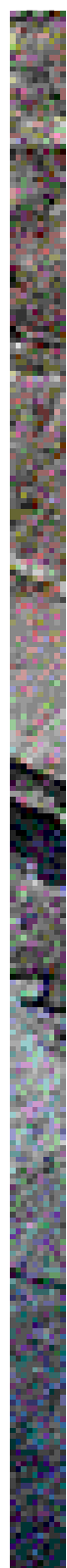
To be or not to be  
multiGaussian?  
A reflection on stochastic  
hydrogeology

Advances in Water Resources, 1998  
(136 cites)

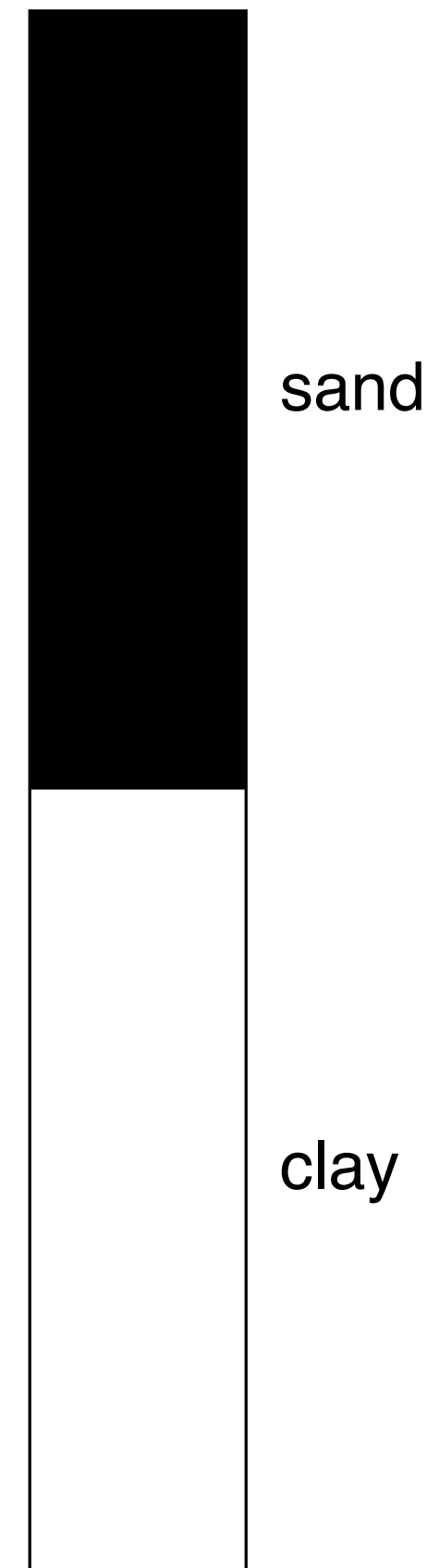
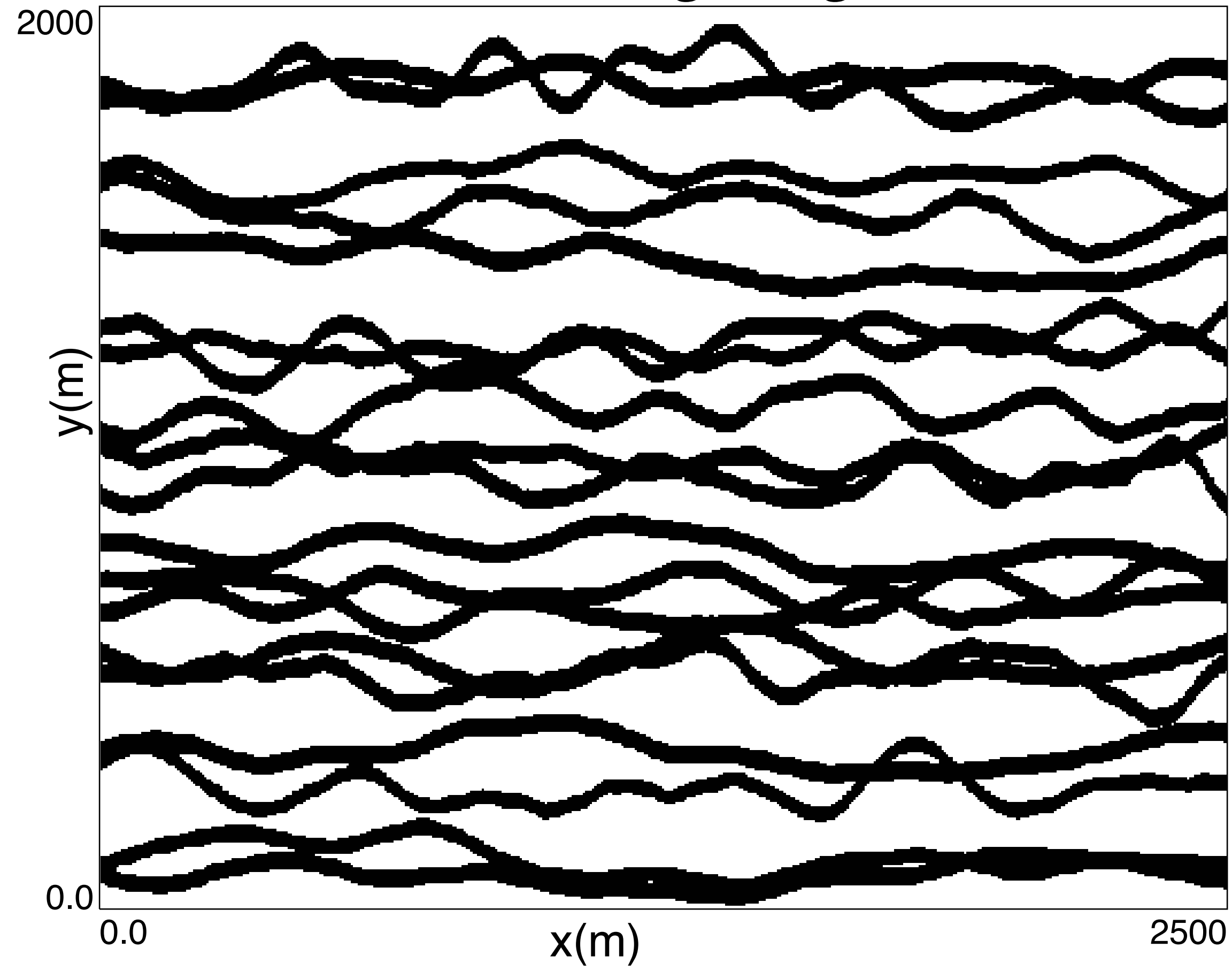




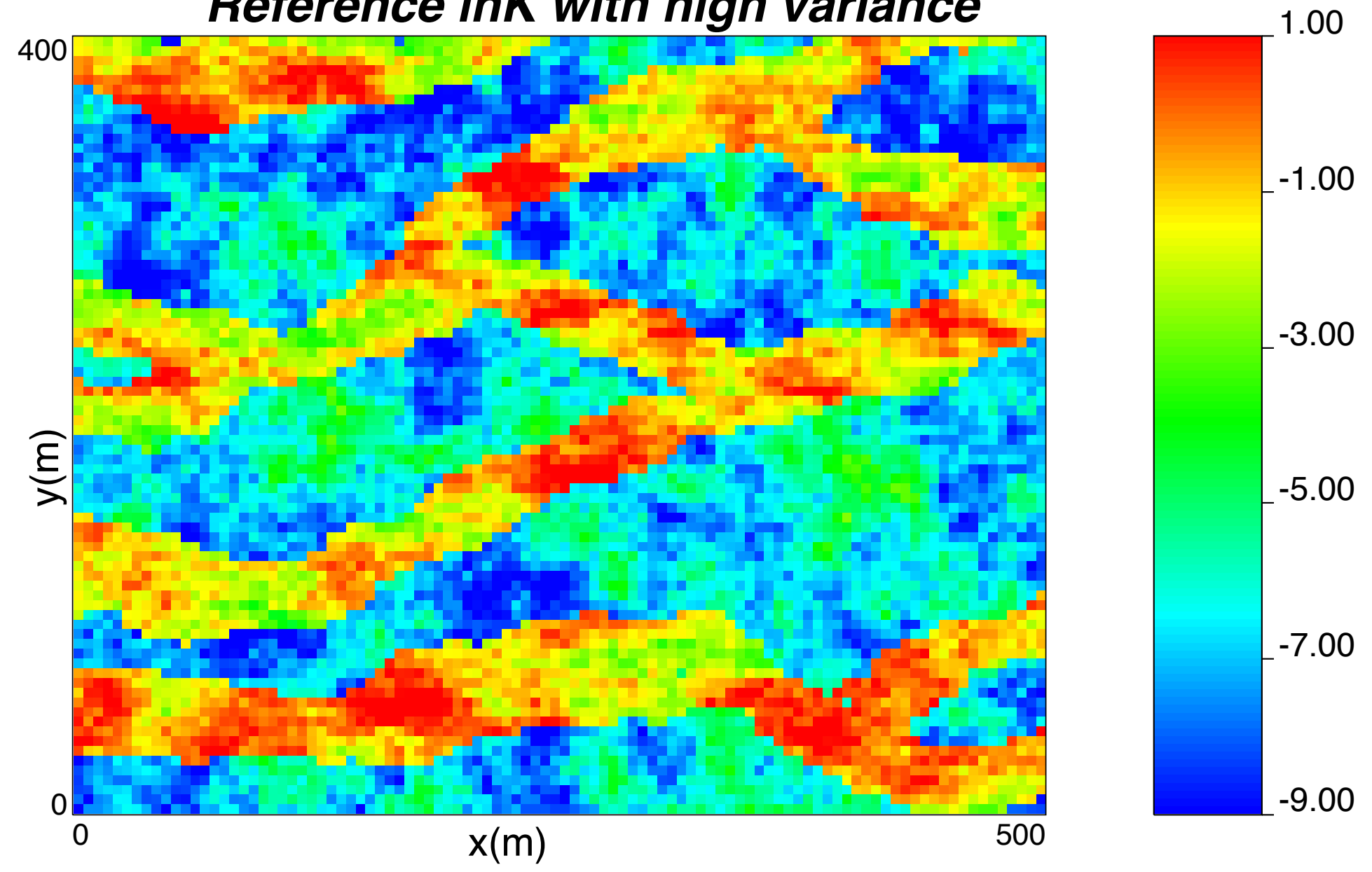


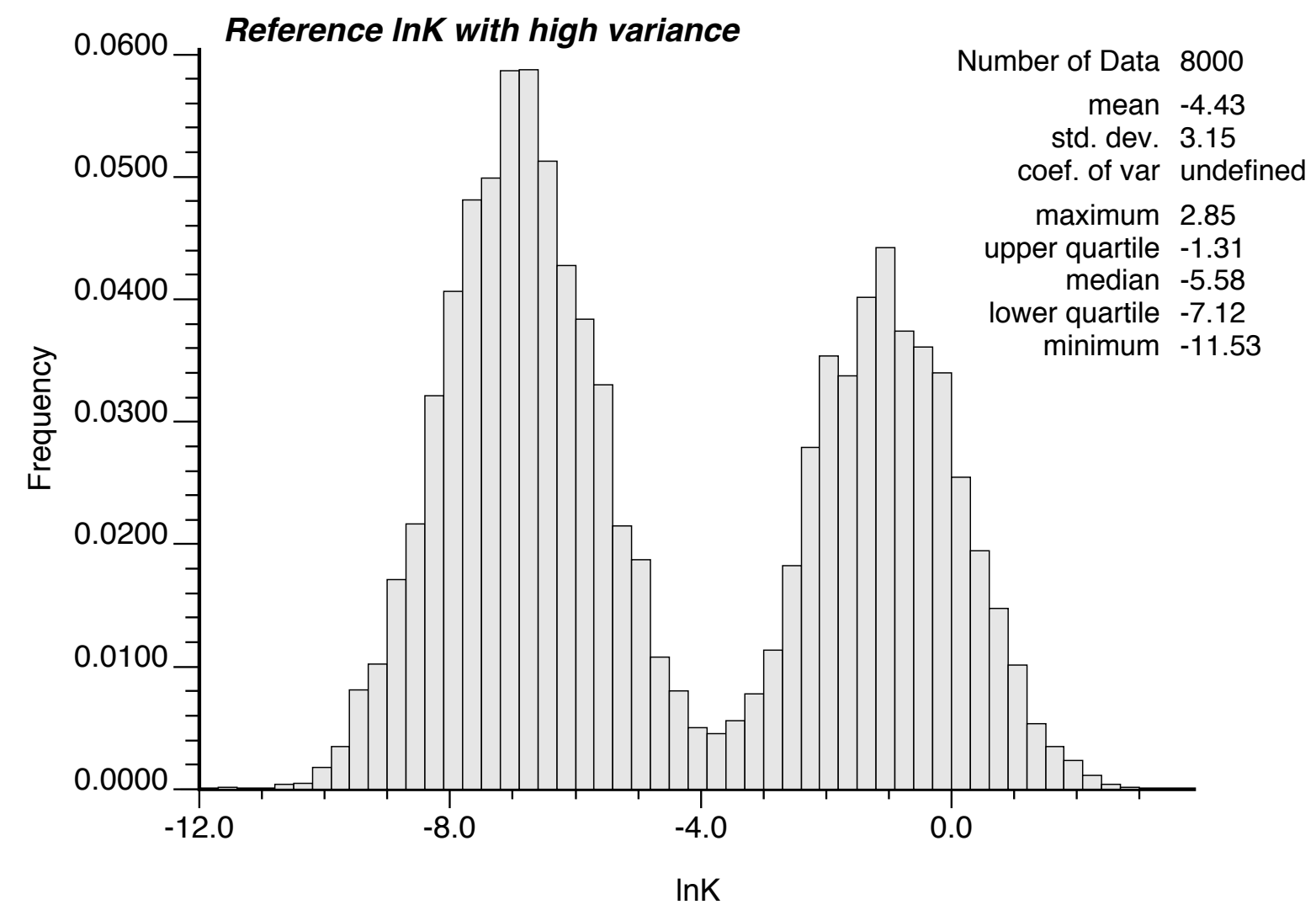
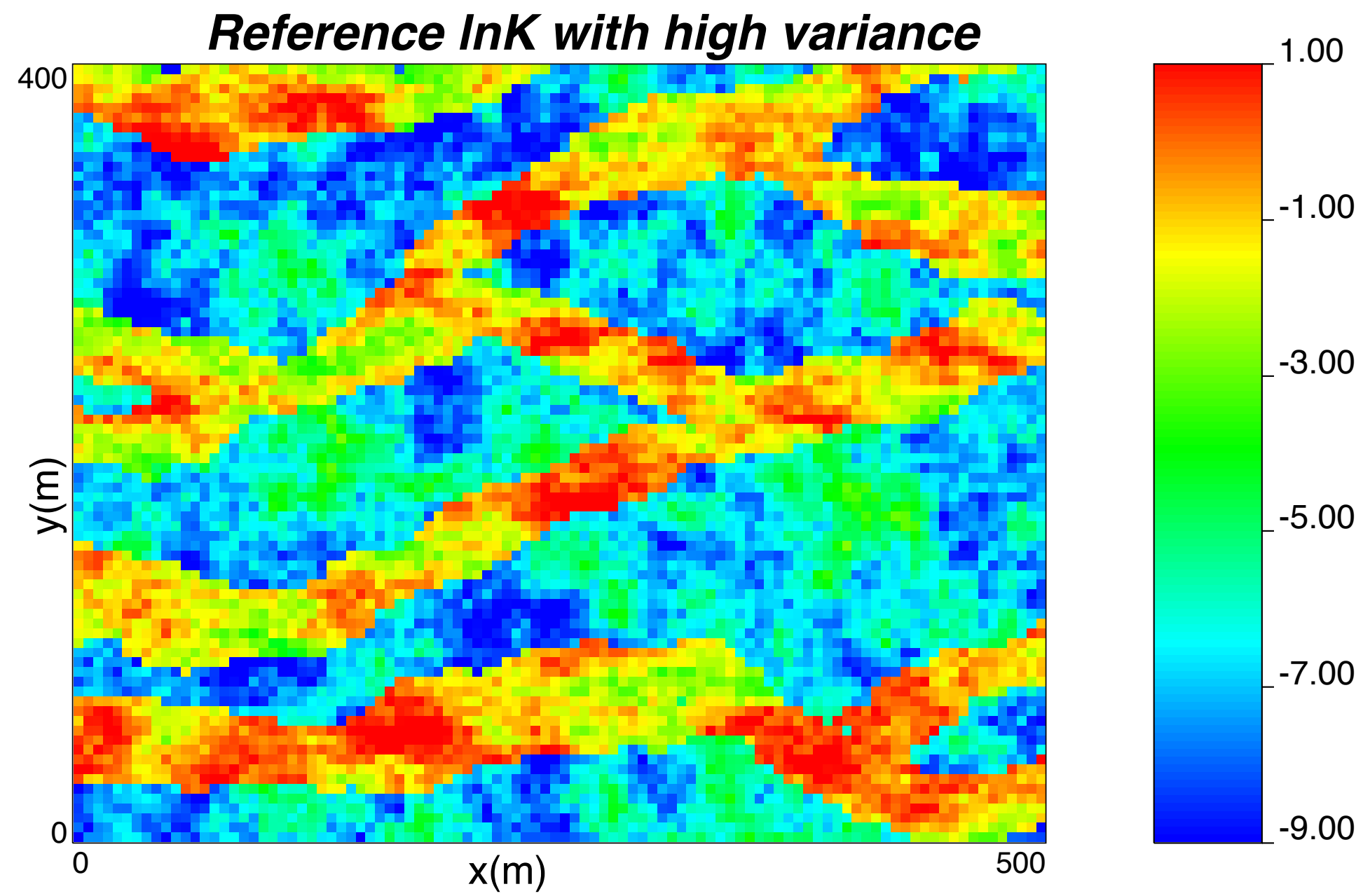


# *Training image*

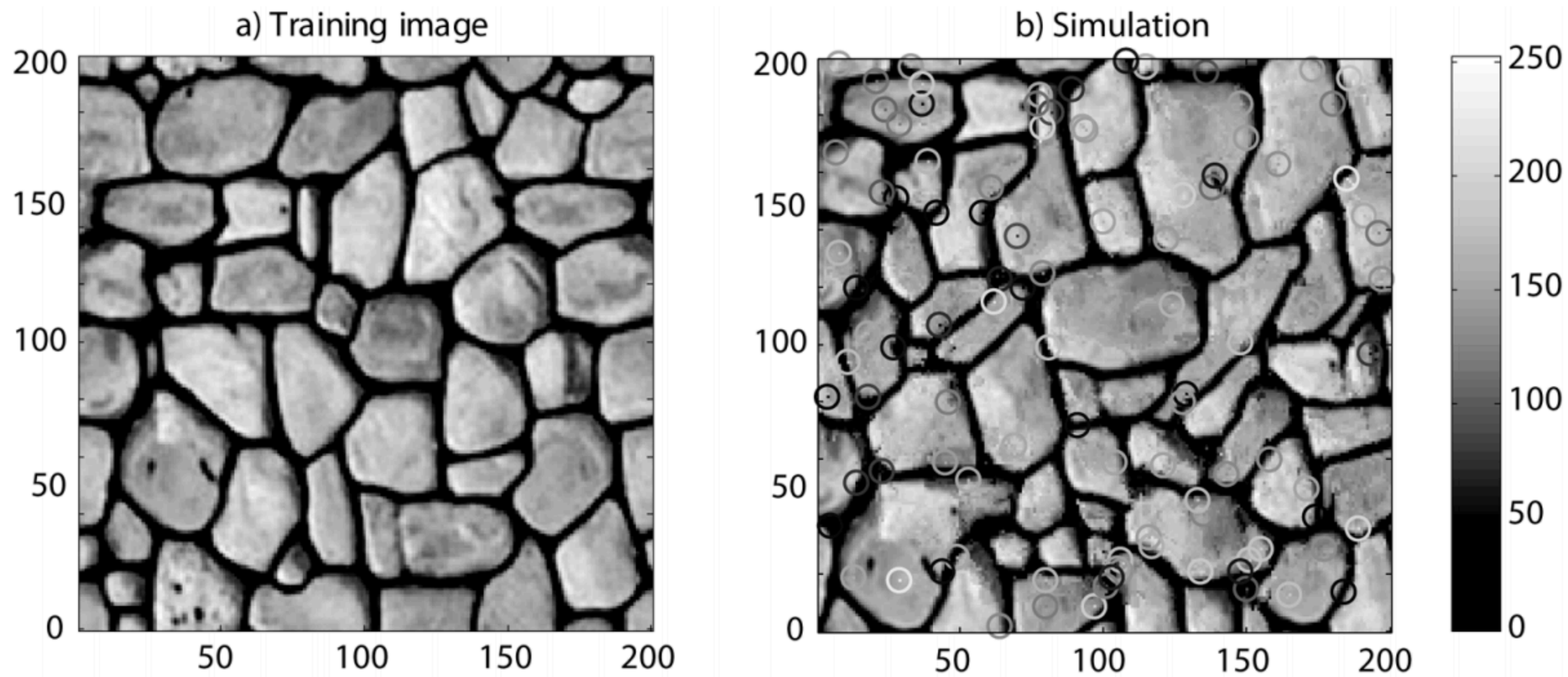


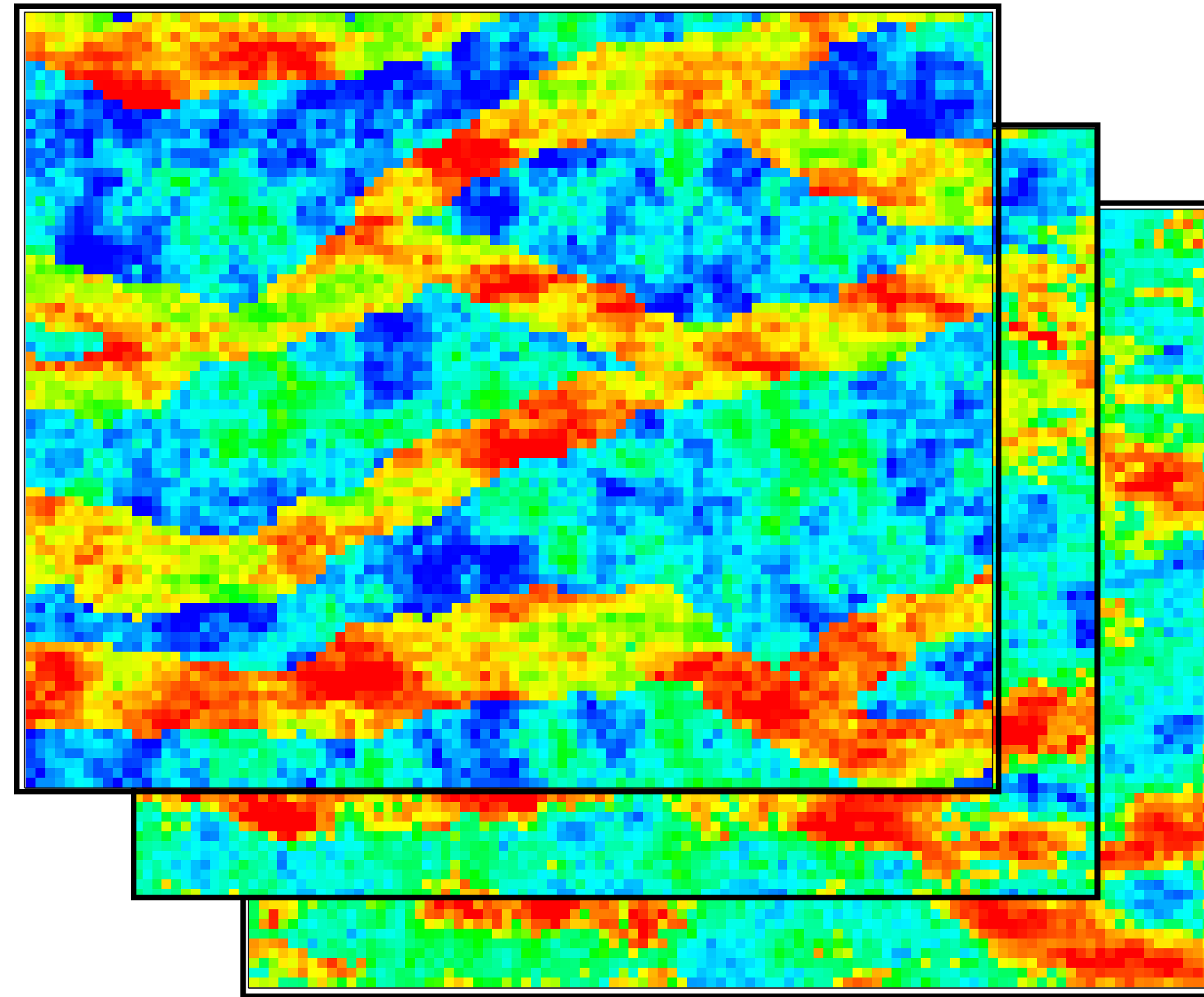
***Reference InK with high variance***



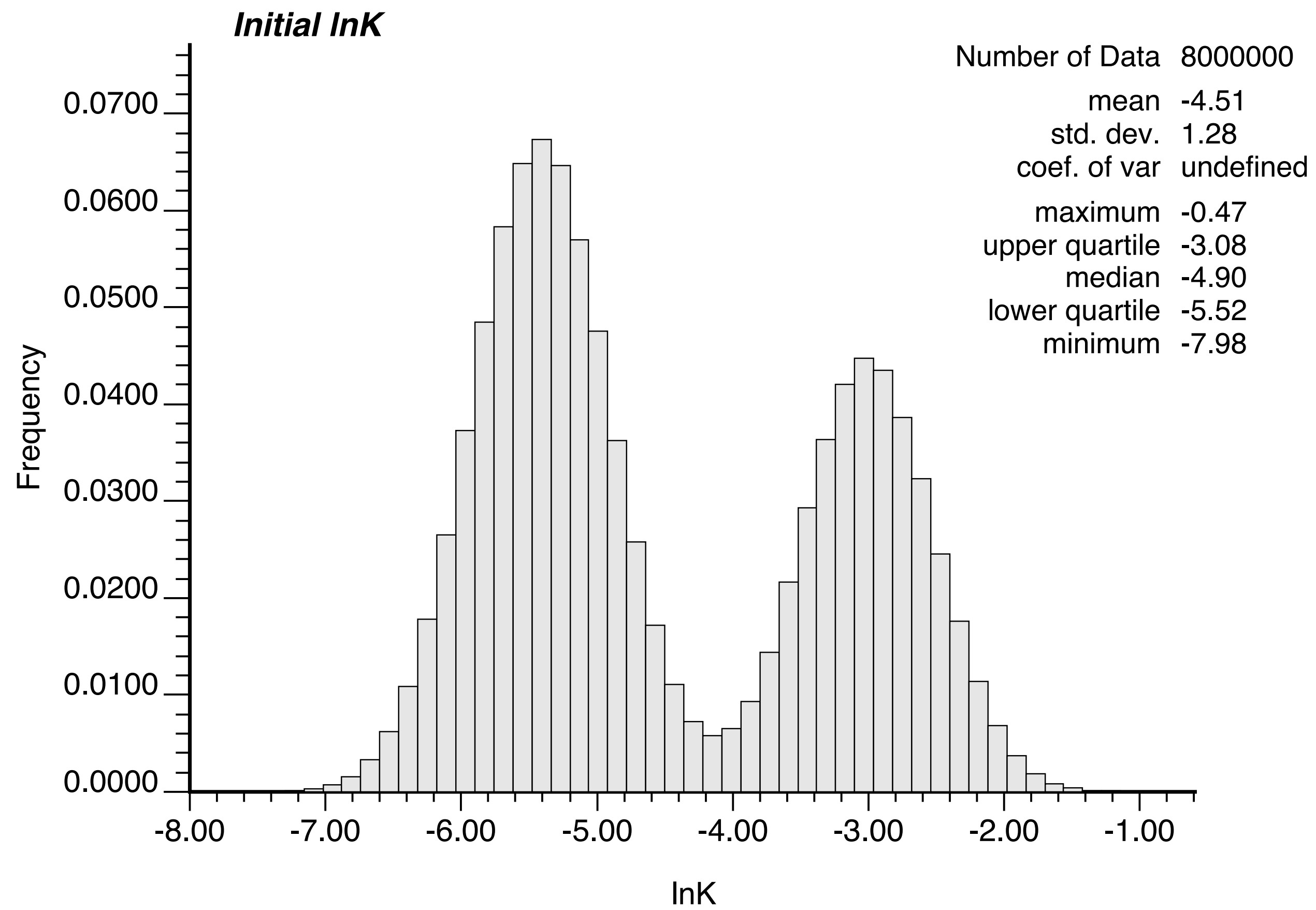


# MARIETHOZ ET AL.: PERFORMING MULTIPLE-POINTS SIMULATIONS

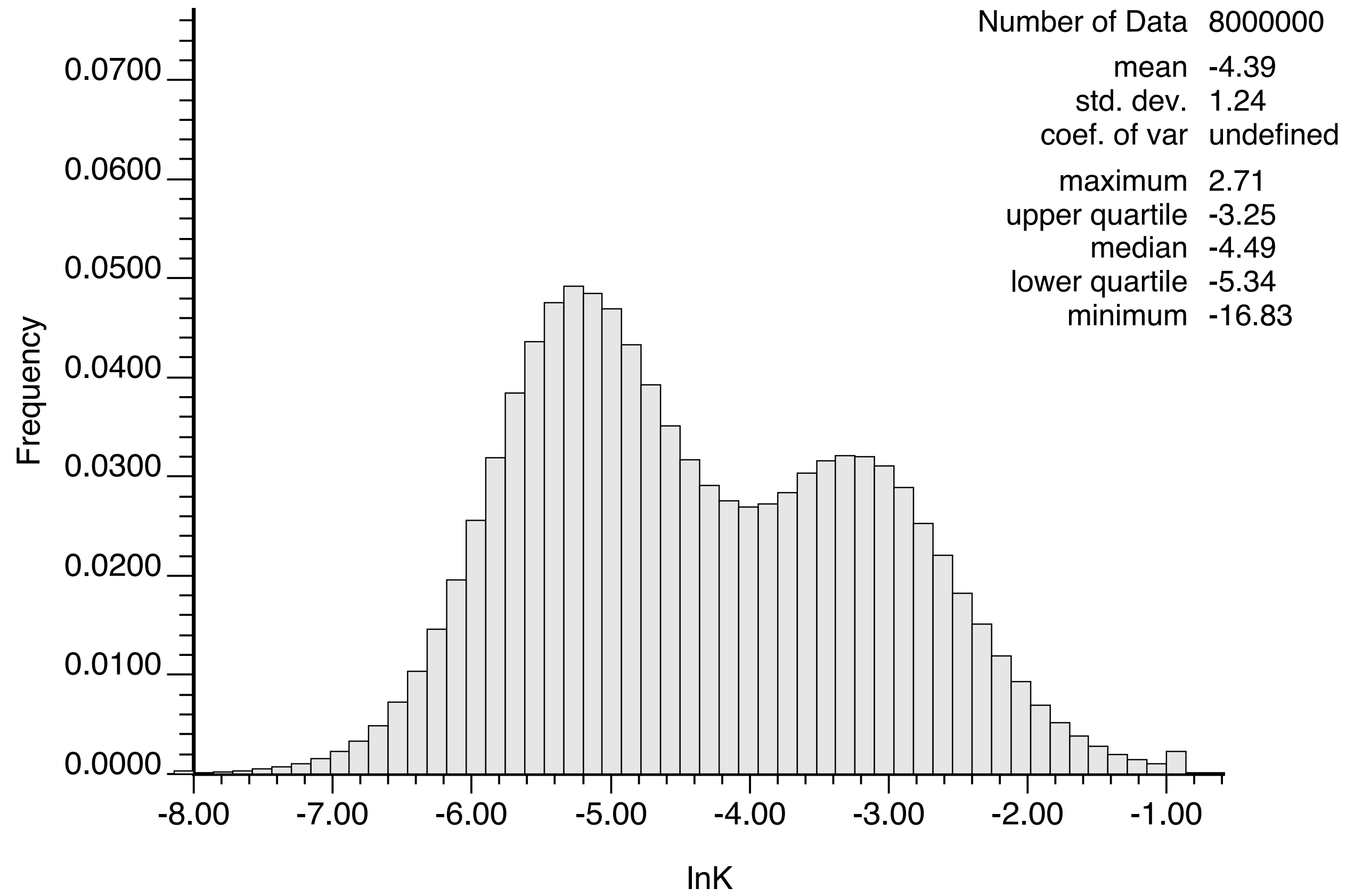




Ensemble Kalman Filter  
with non-Gaussian prior ensemble







## The standard EnKF

$$\mathbf{x}_t = F_t(\mathbf{x}_{t-1})$$

## Transformation functions

$$\mathbf{y}_t = \Phi_t(\mathbf{x}_t)$$

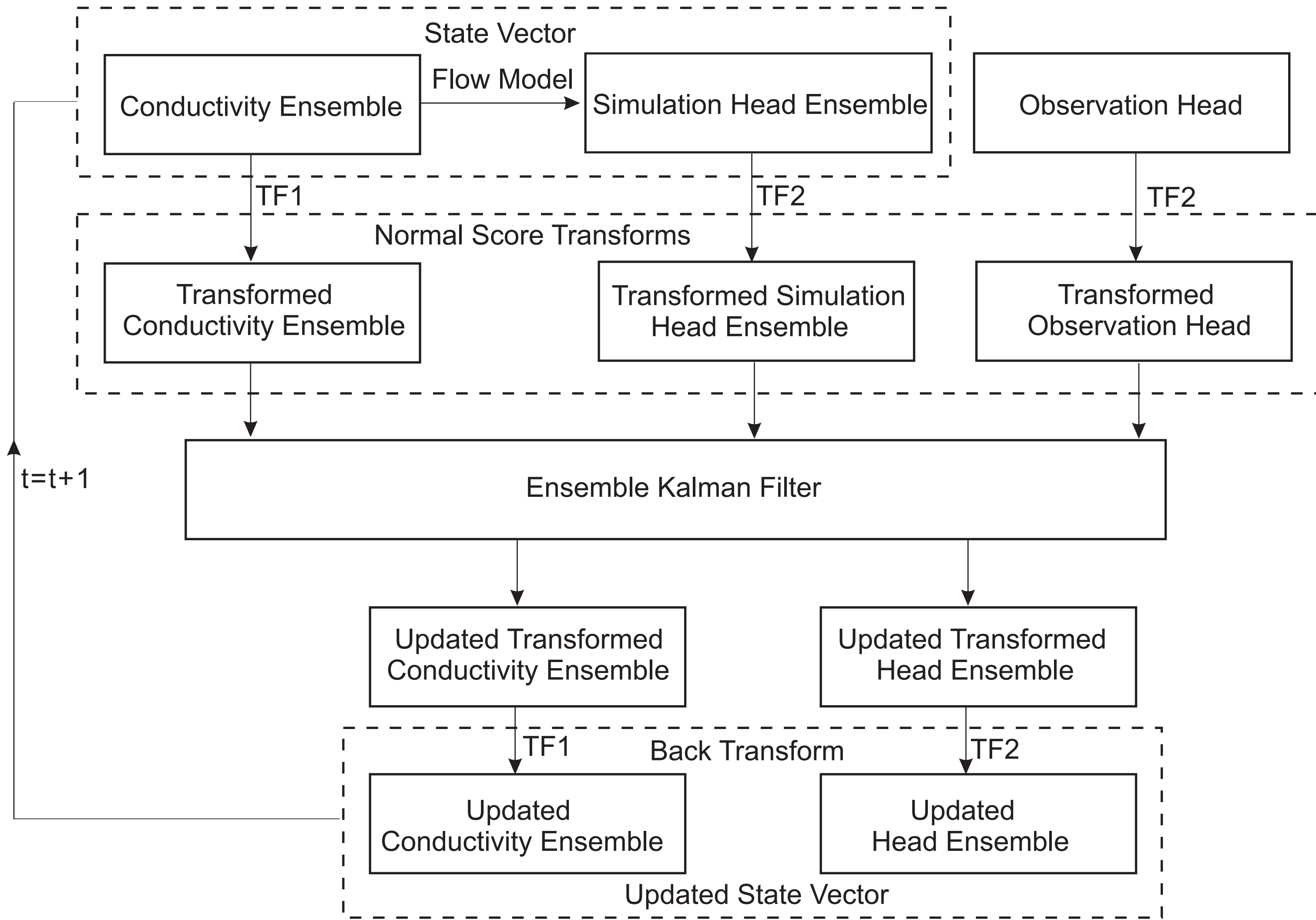
$$\mathbf{y}_{t-1} = \Phi_{t-1}(\mathbf{x}_{t-1})$$

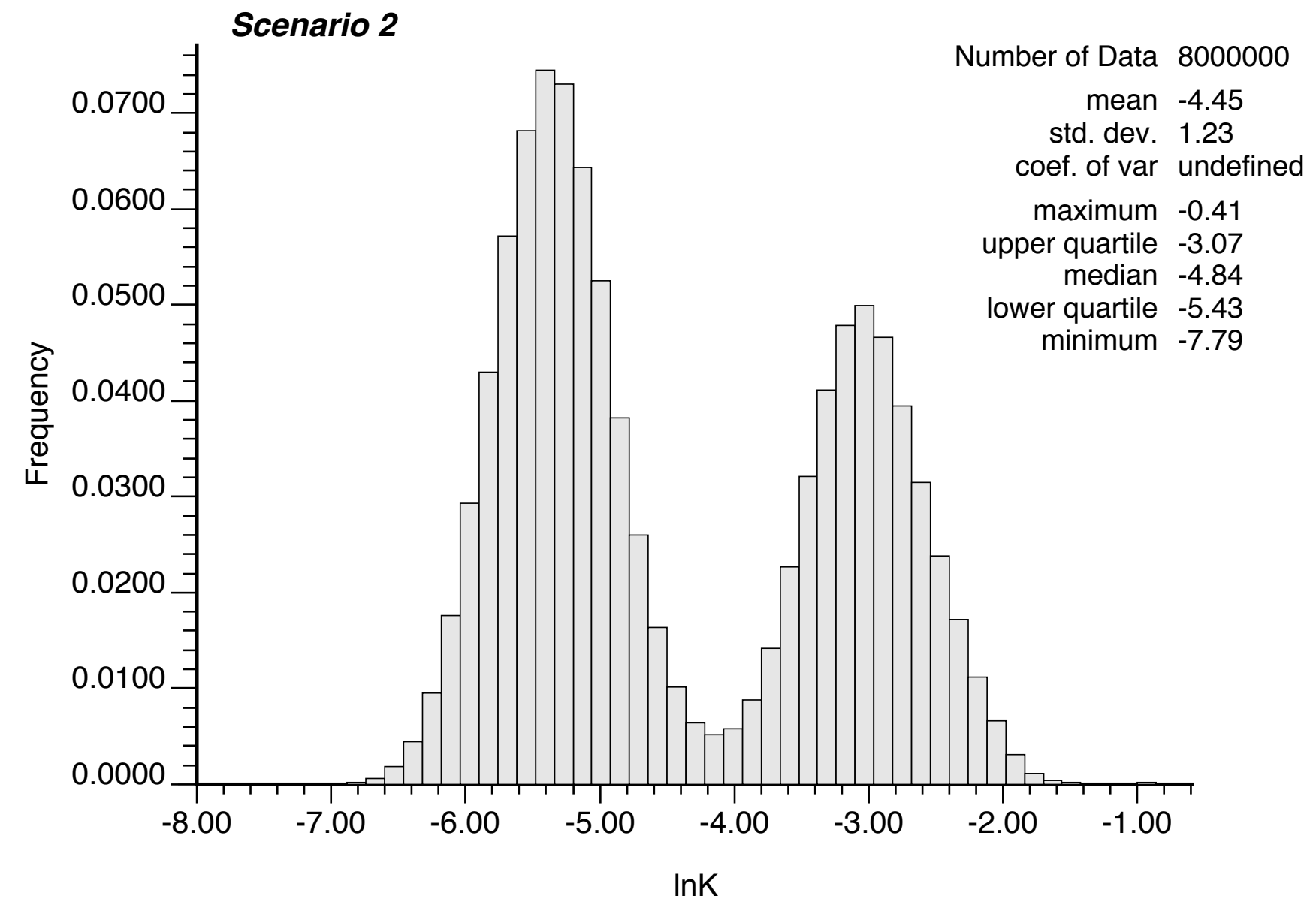
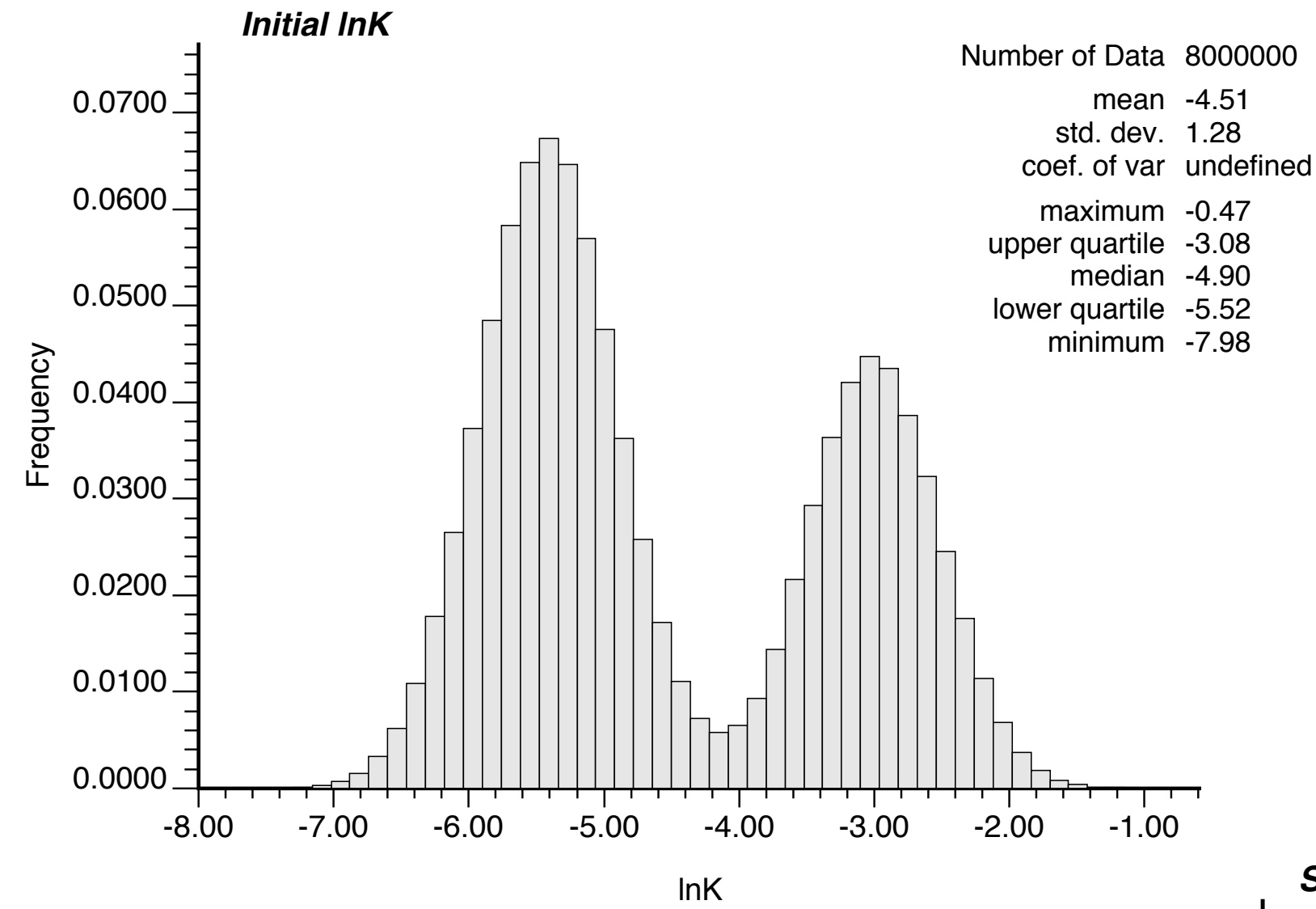
## The NS-EnKF

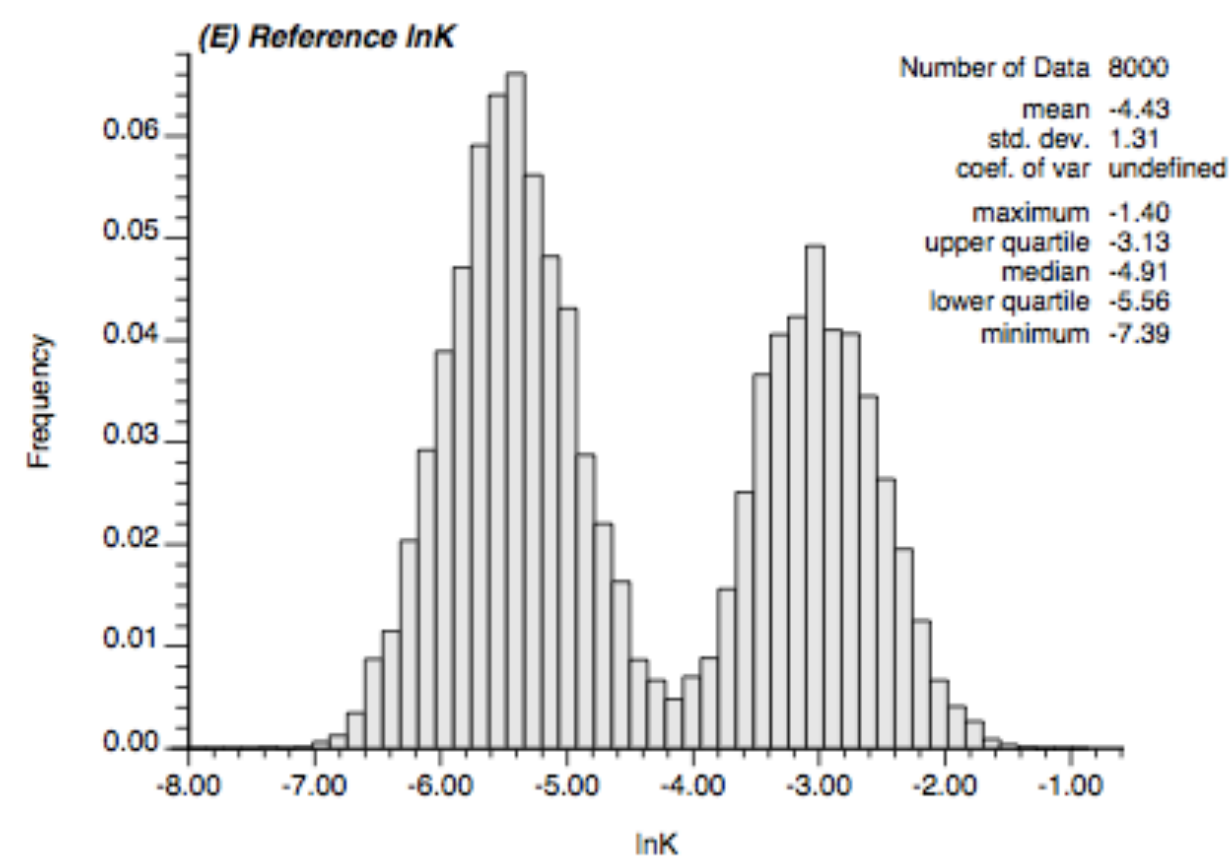
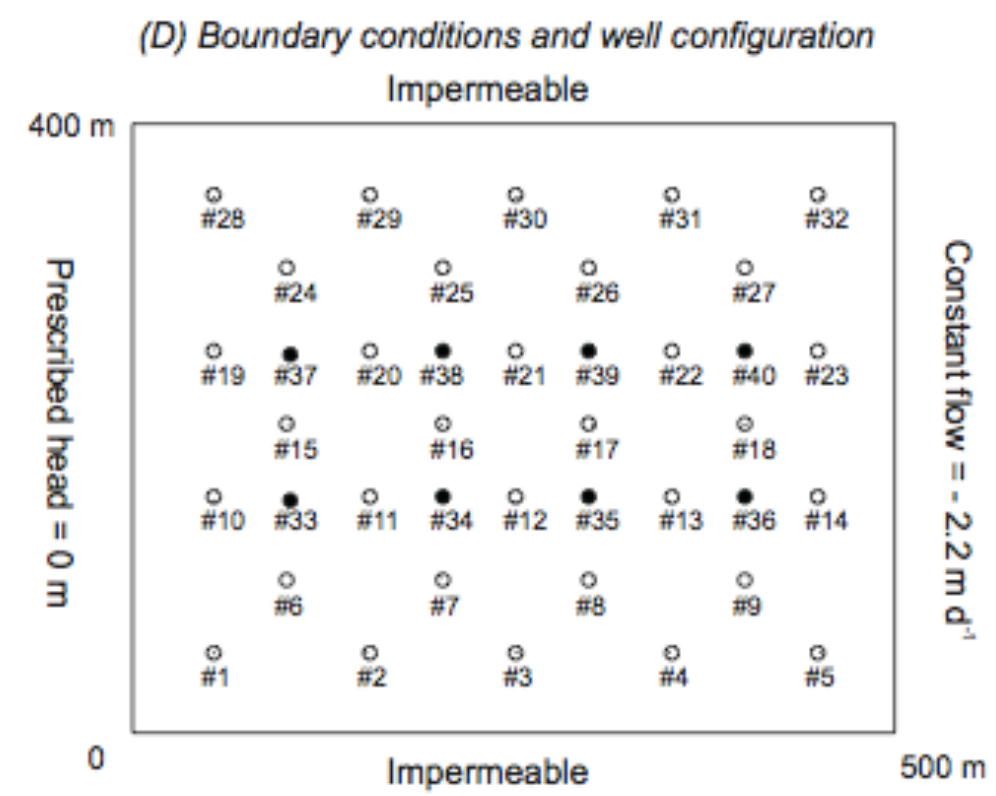
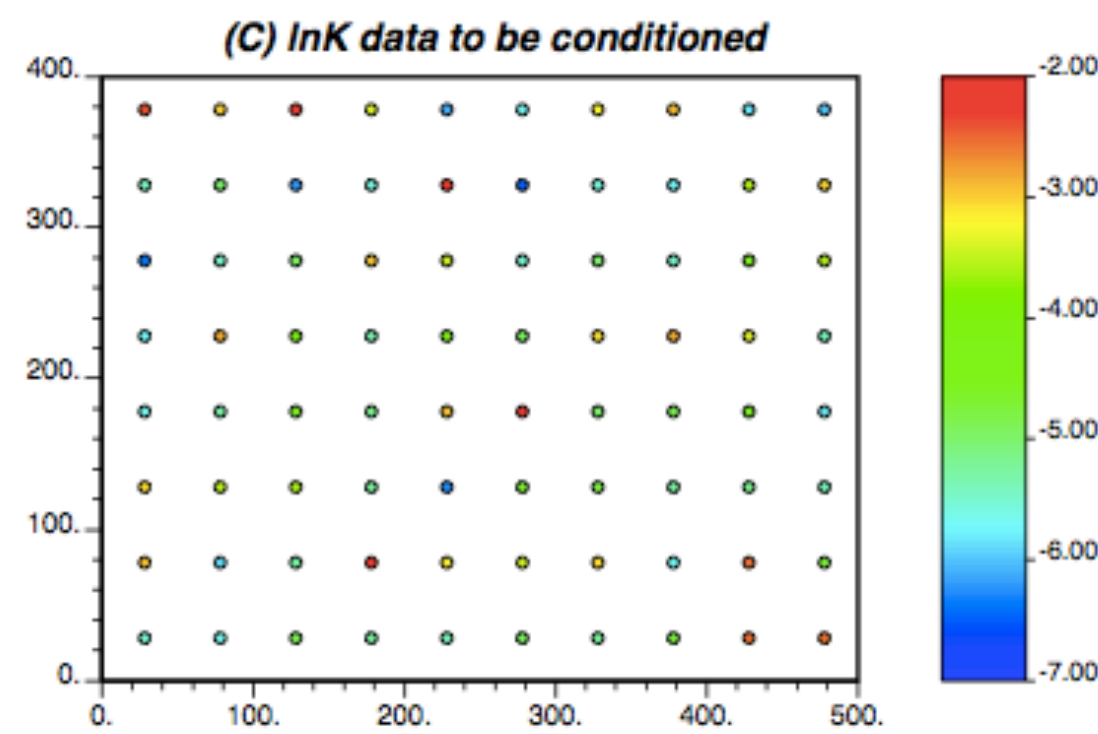
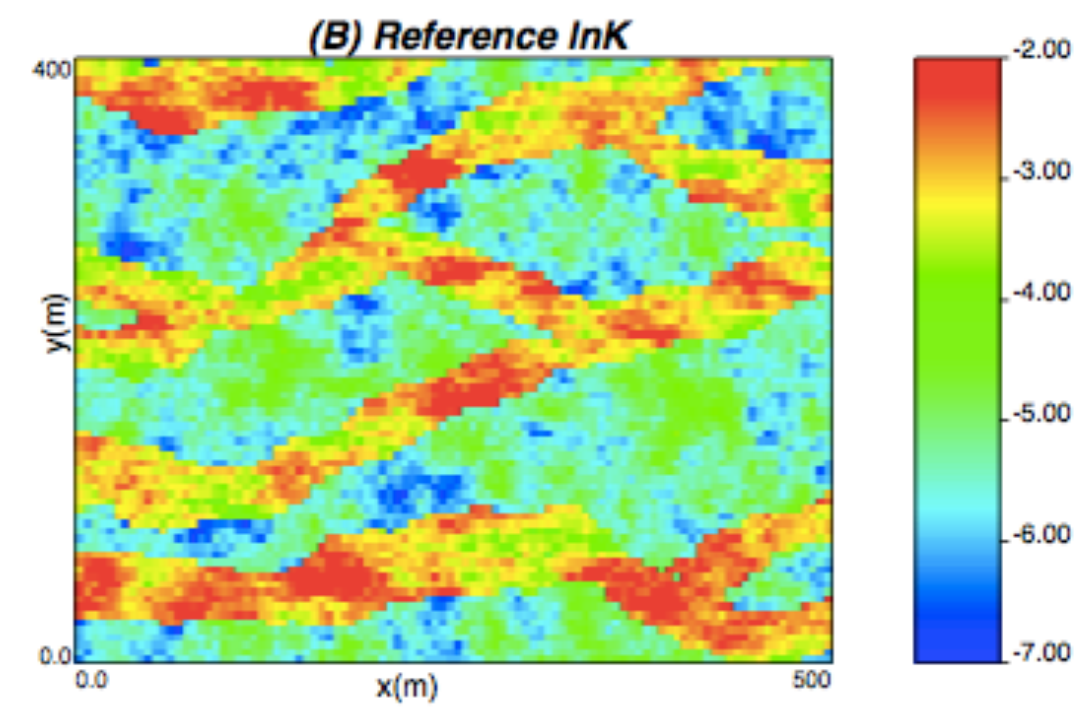
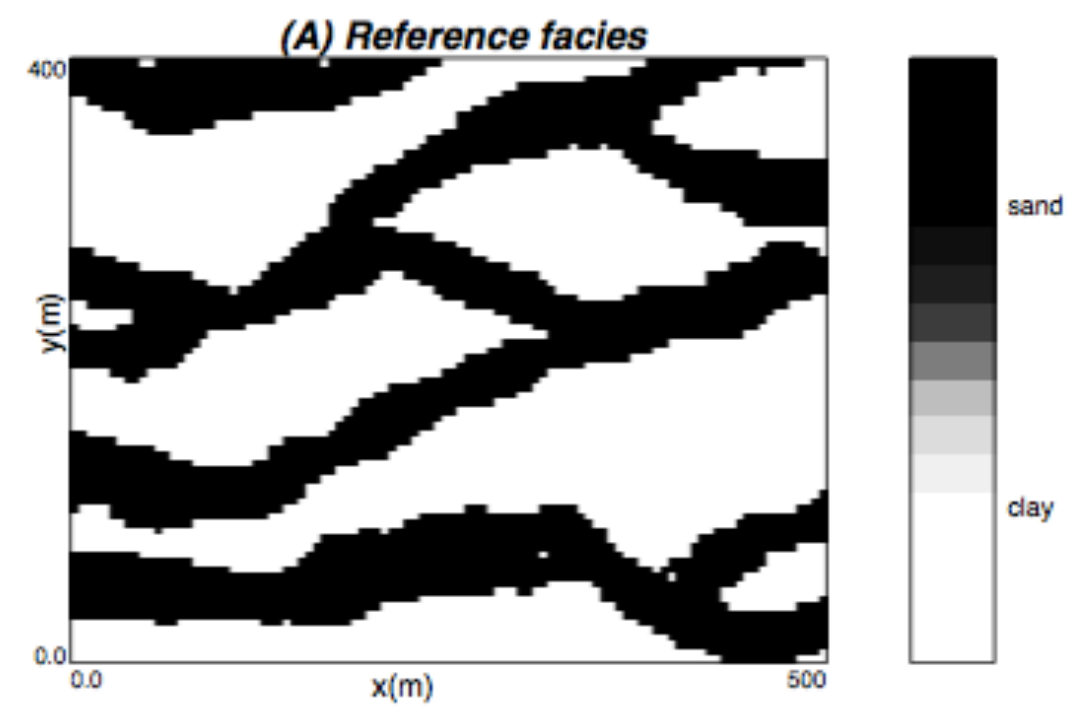
$$\mathbf{y}_t = \Phi_t(F(\Phi_{t-1}^{-1}(\mathbf{y}_{t-1})))$$

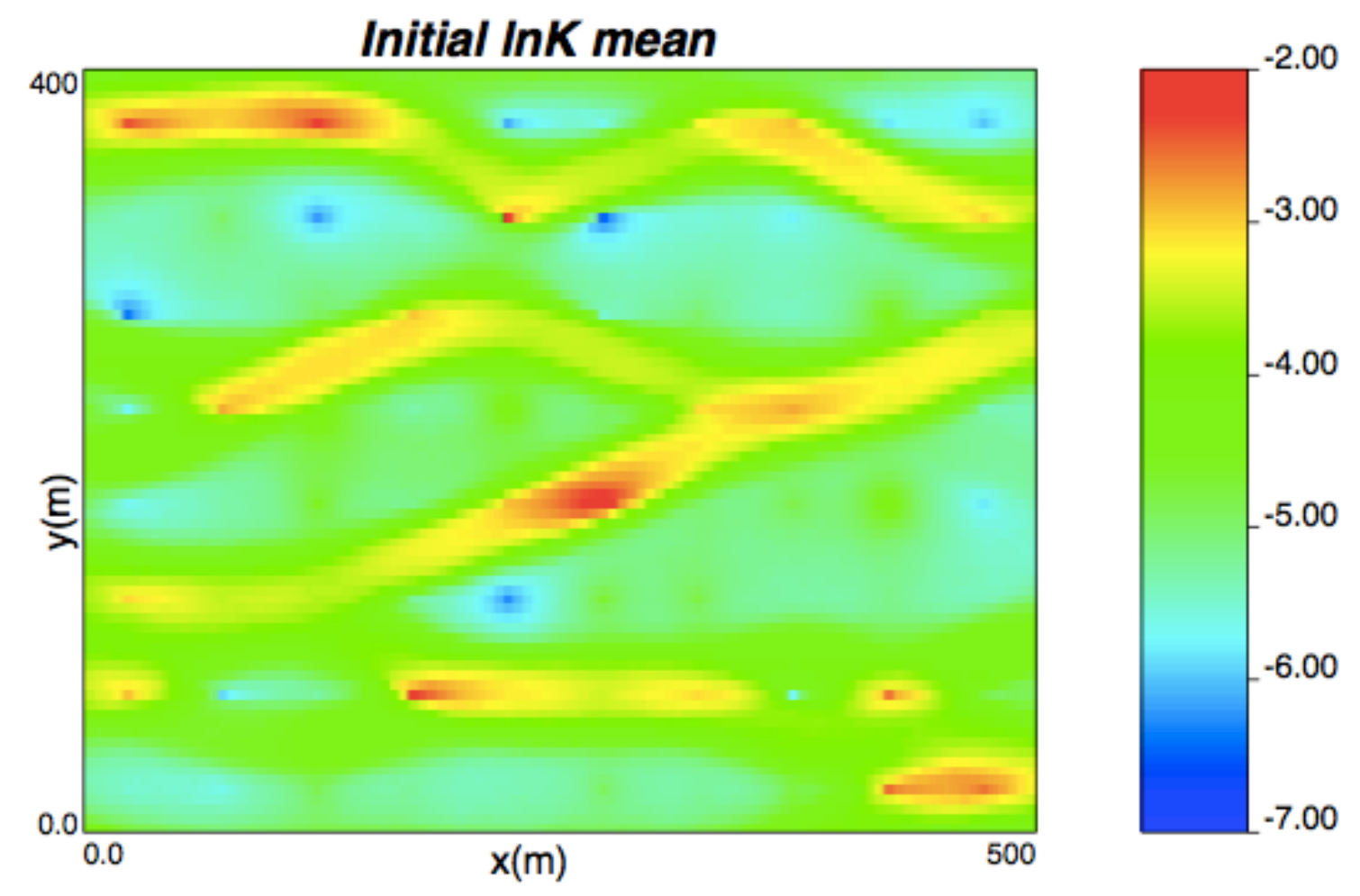
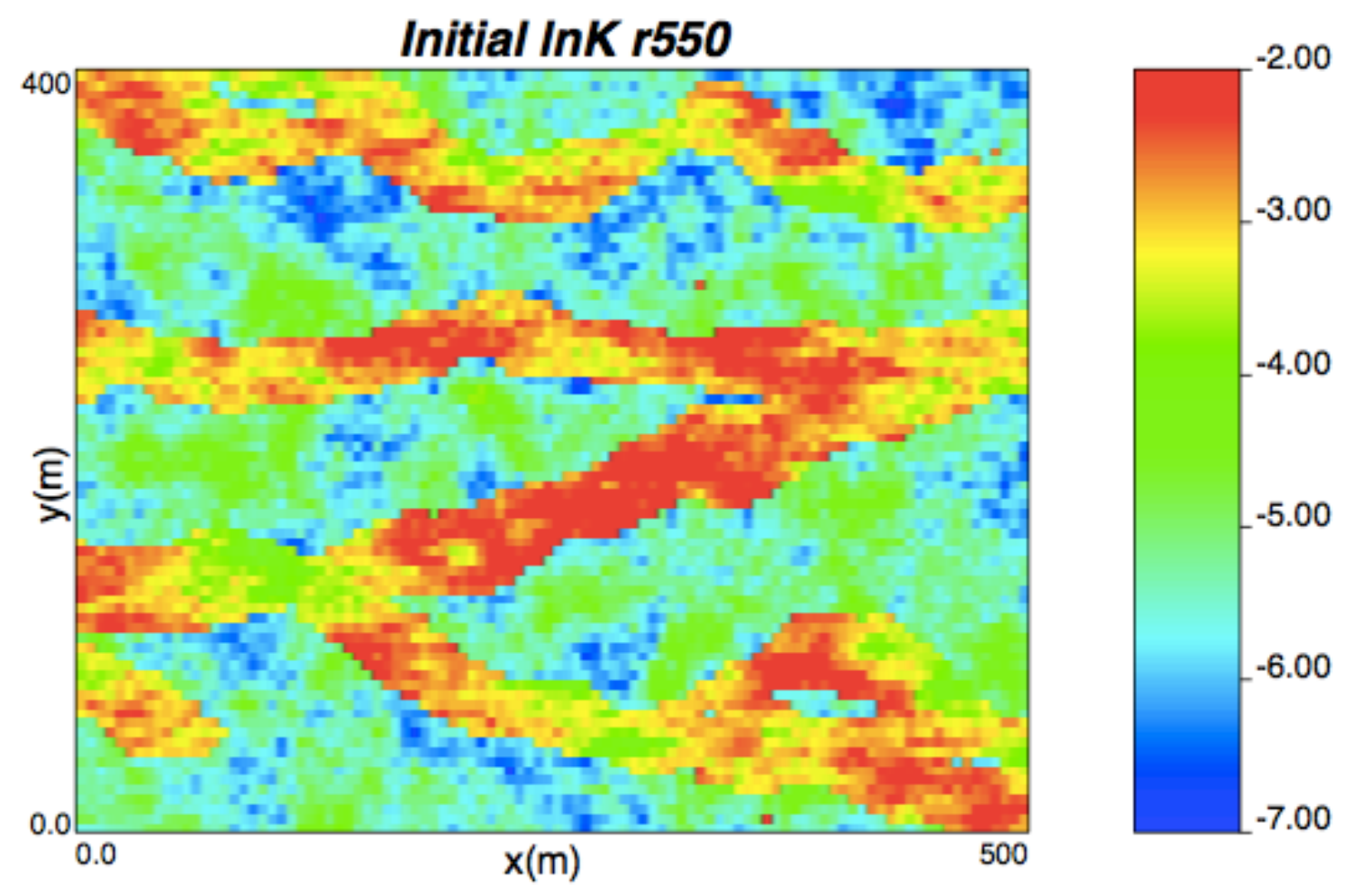
$$\mathbf{y}_t = \varphi_t(\mathbf{y}_{t-1})$$

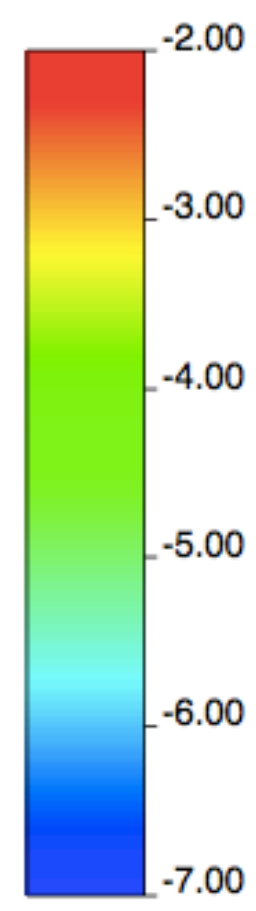
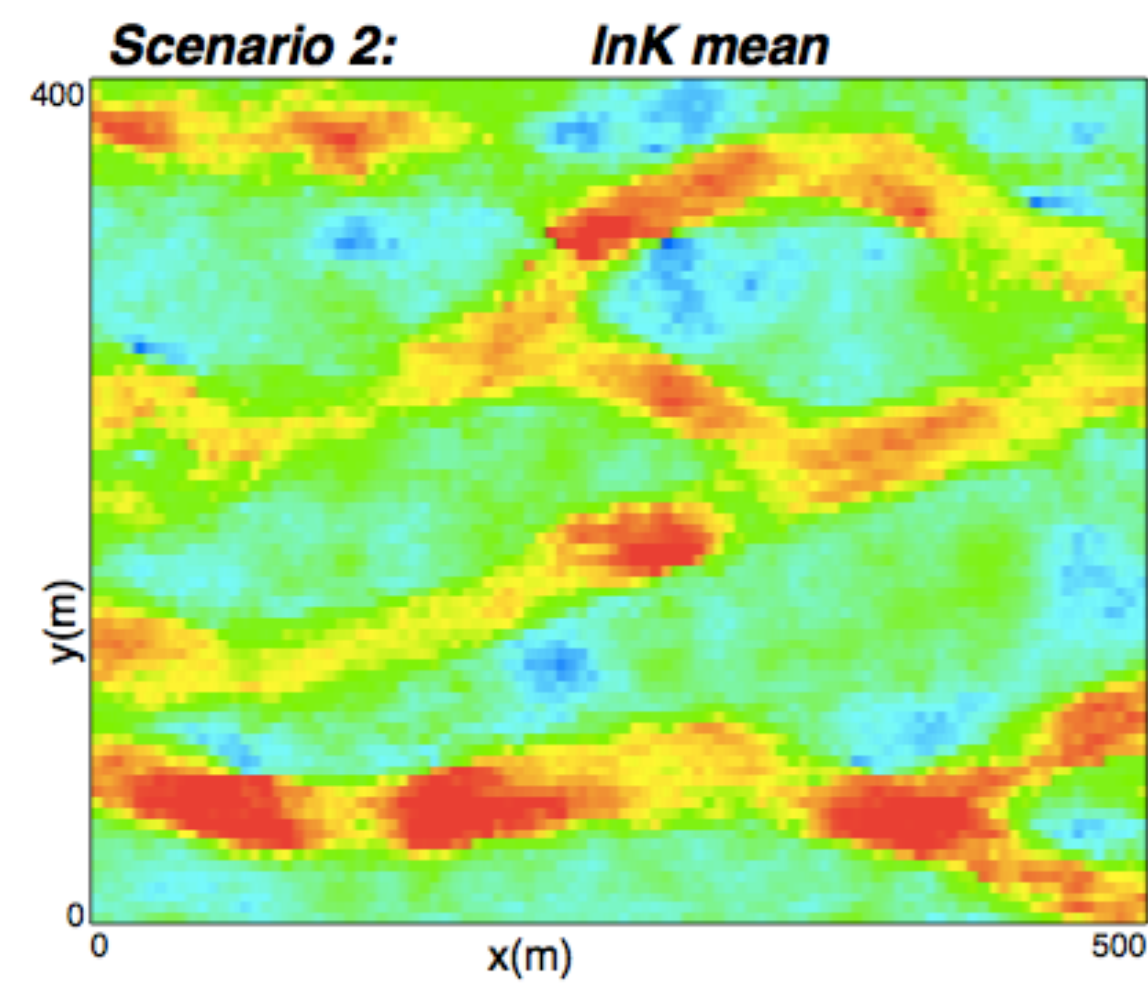
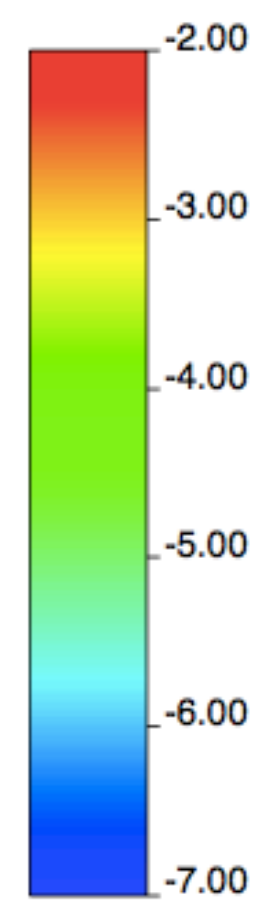
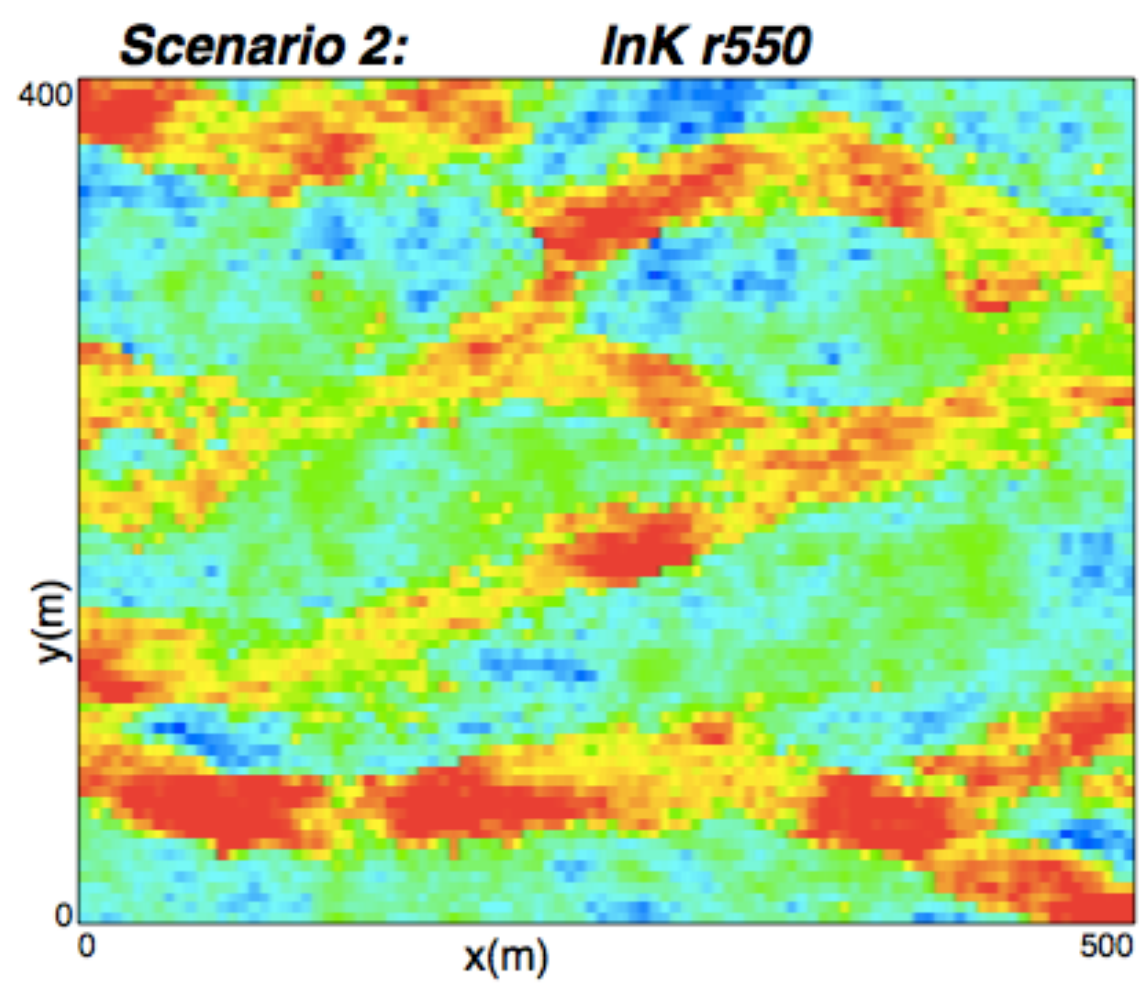
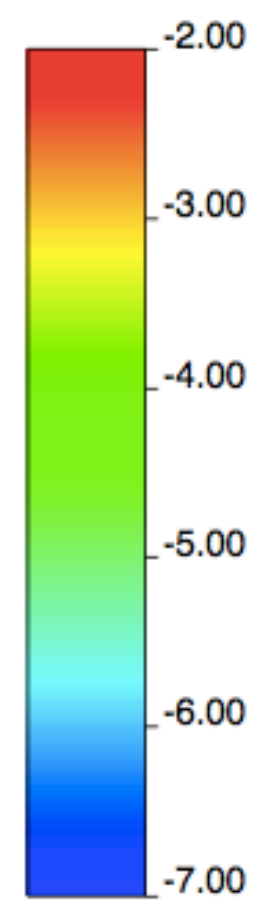
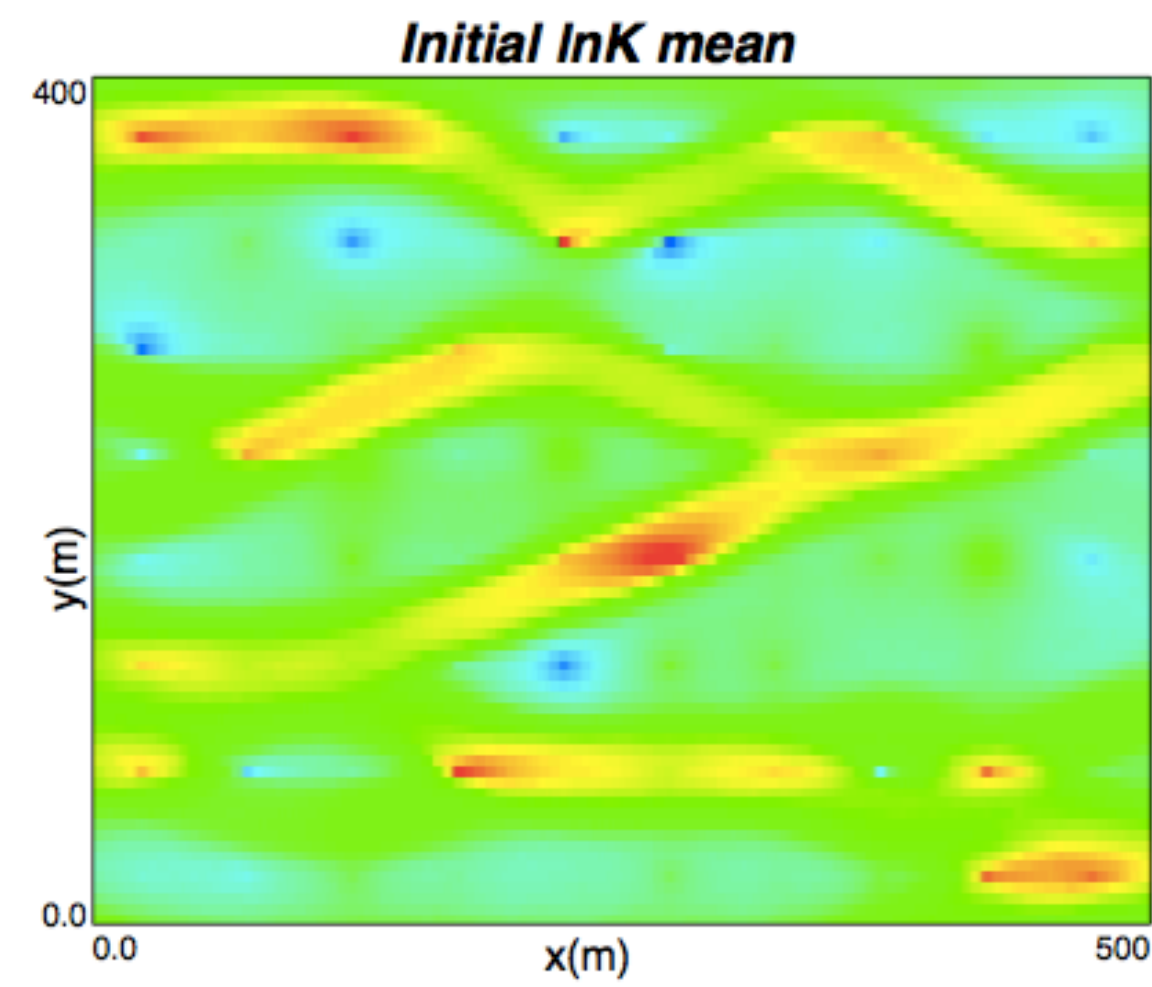
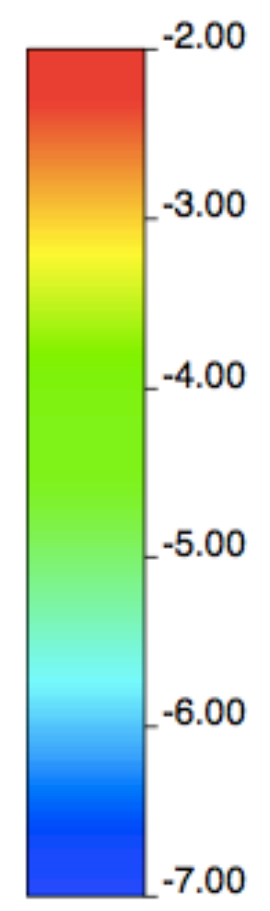
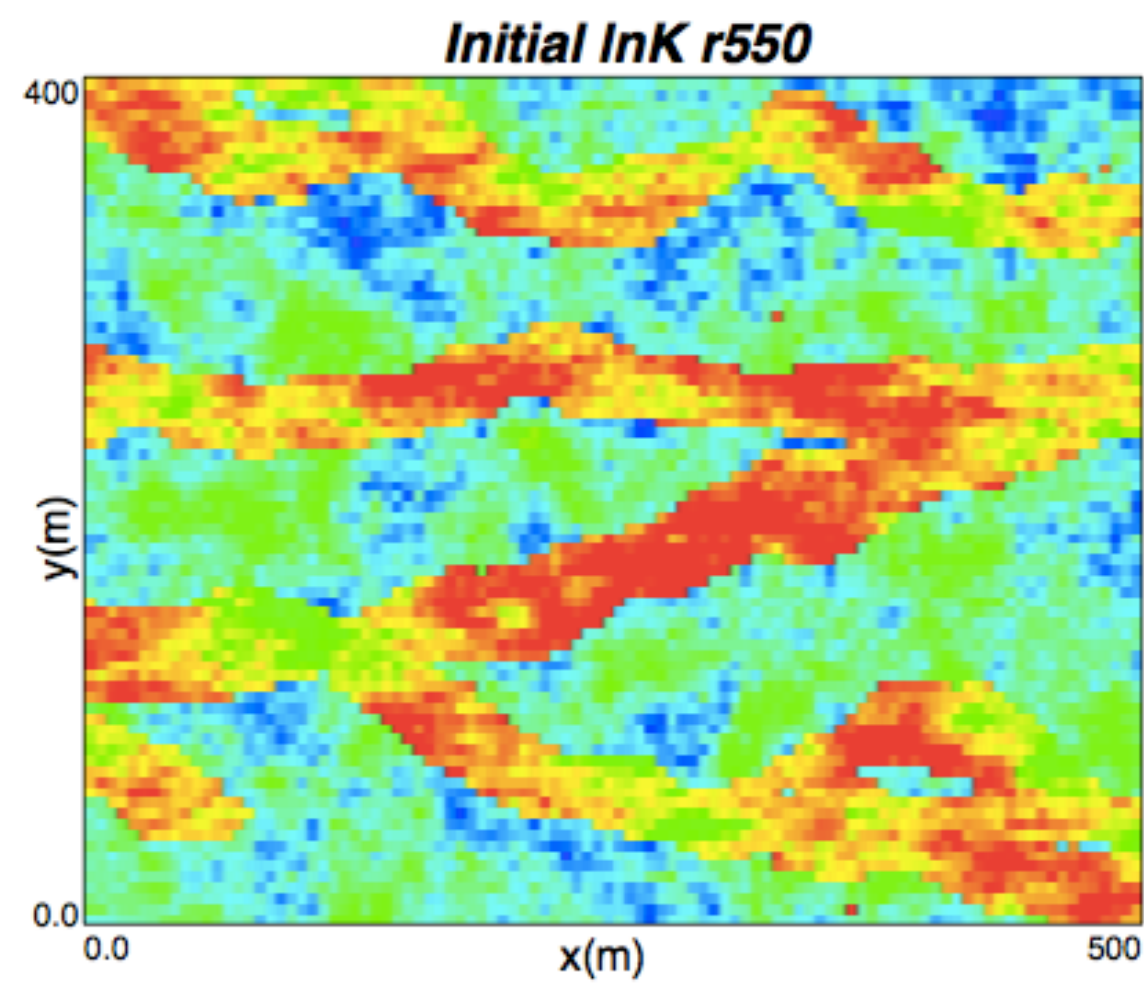
$$\varphi_t = \Phi_t \cdot F \cdot \Phi_{t-1}^{-1}$$

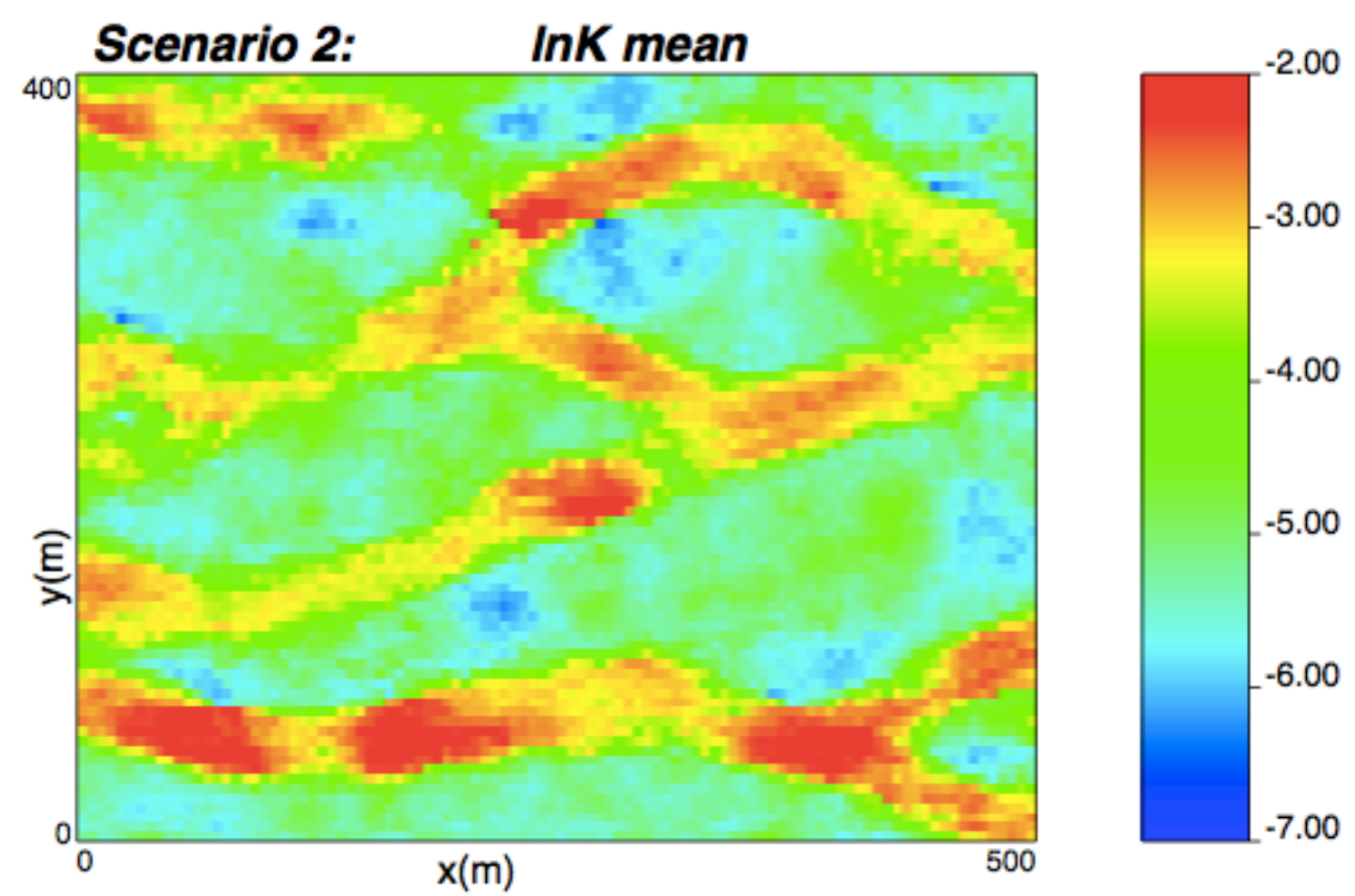
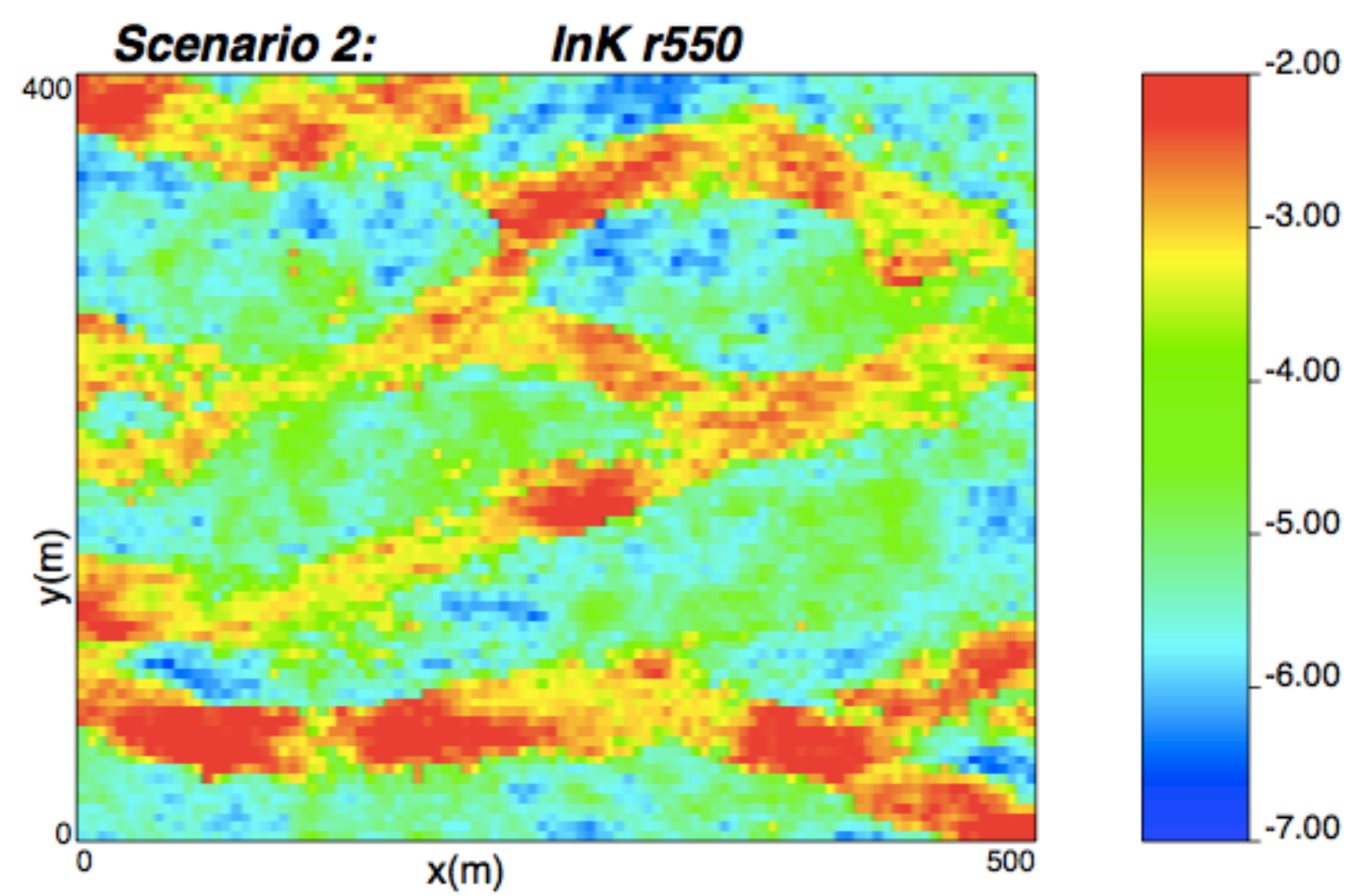
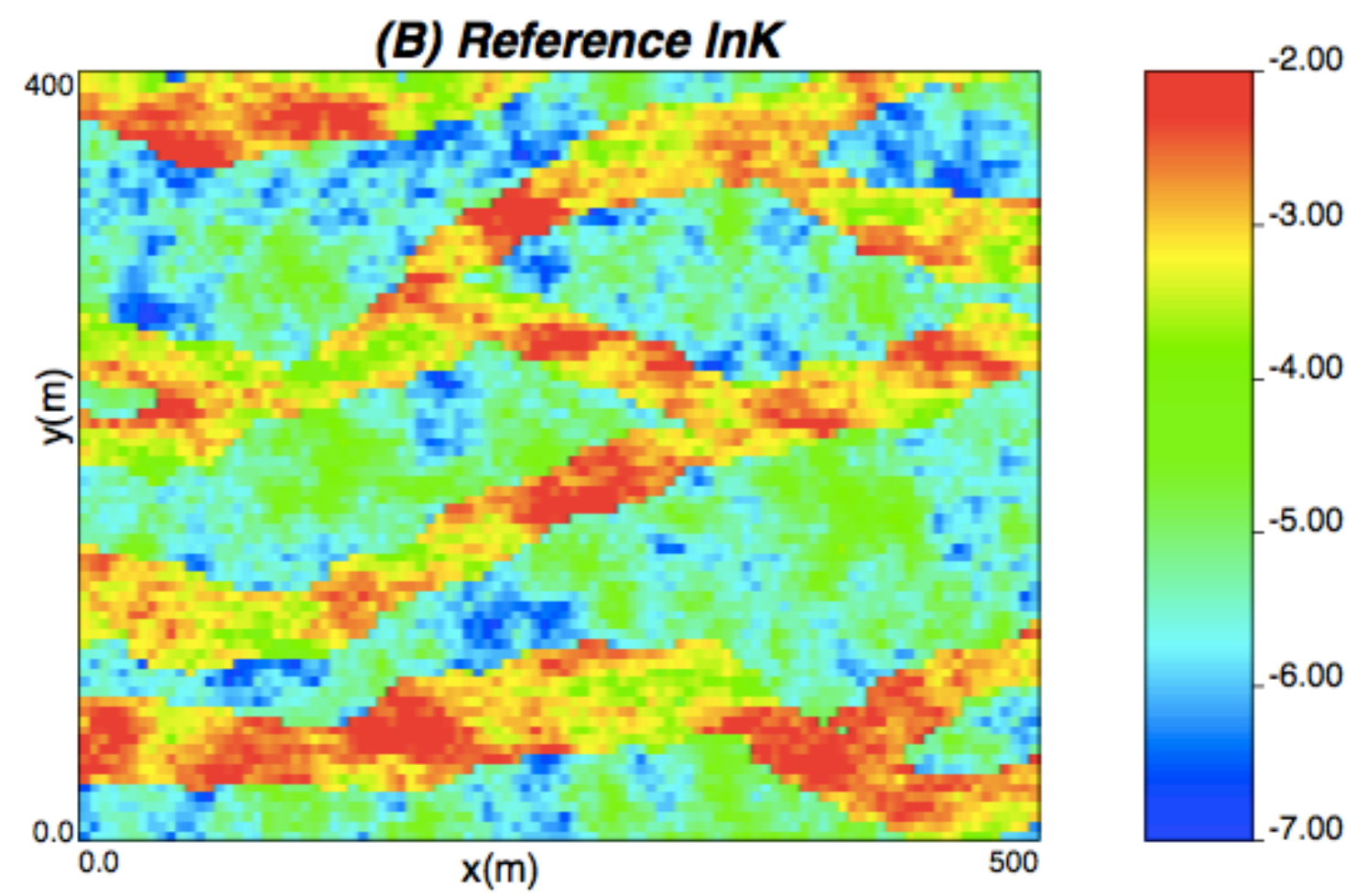




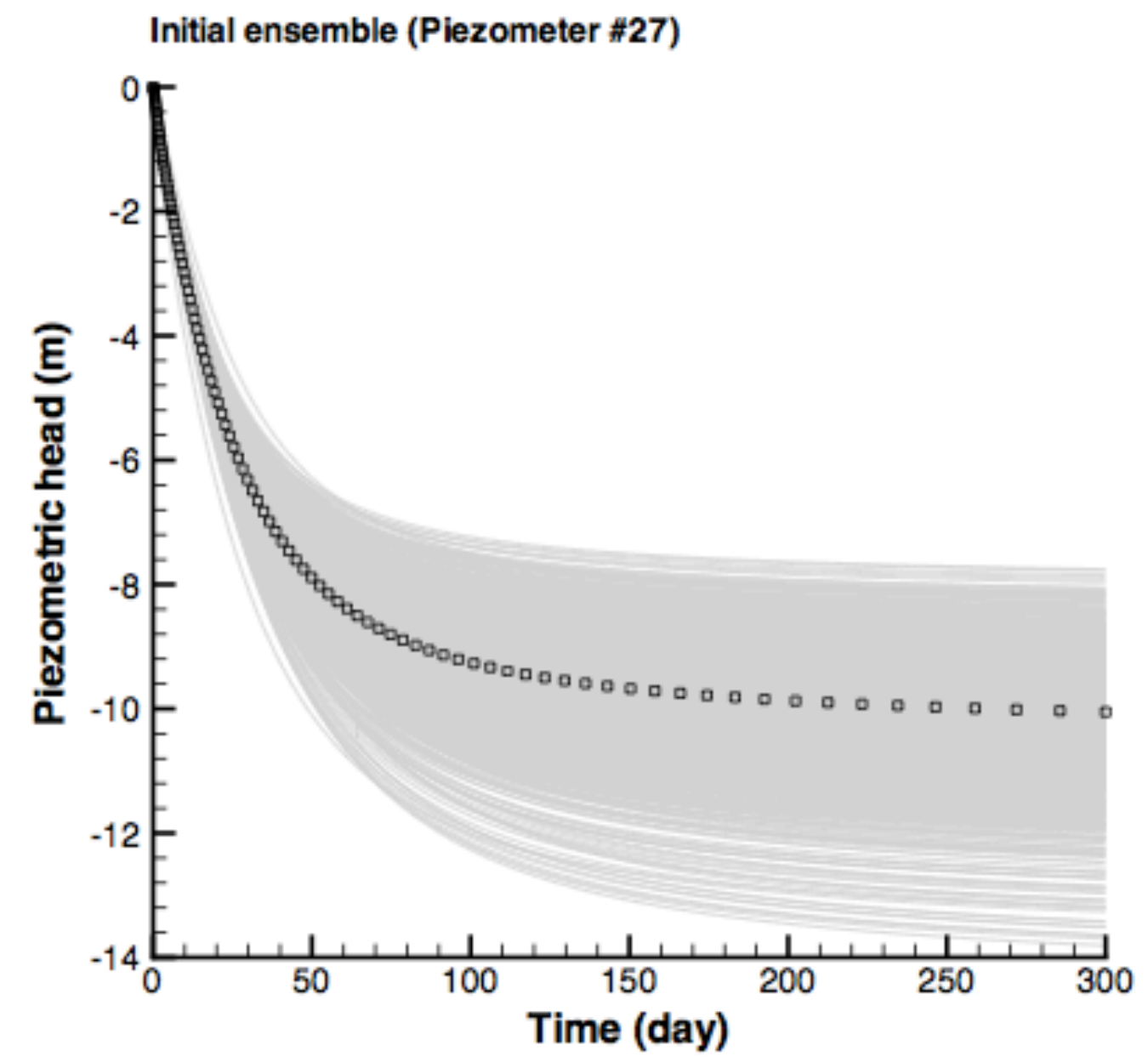
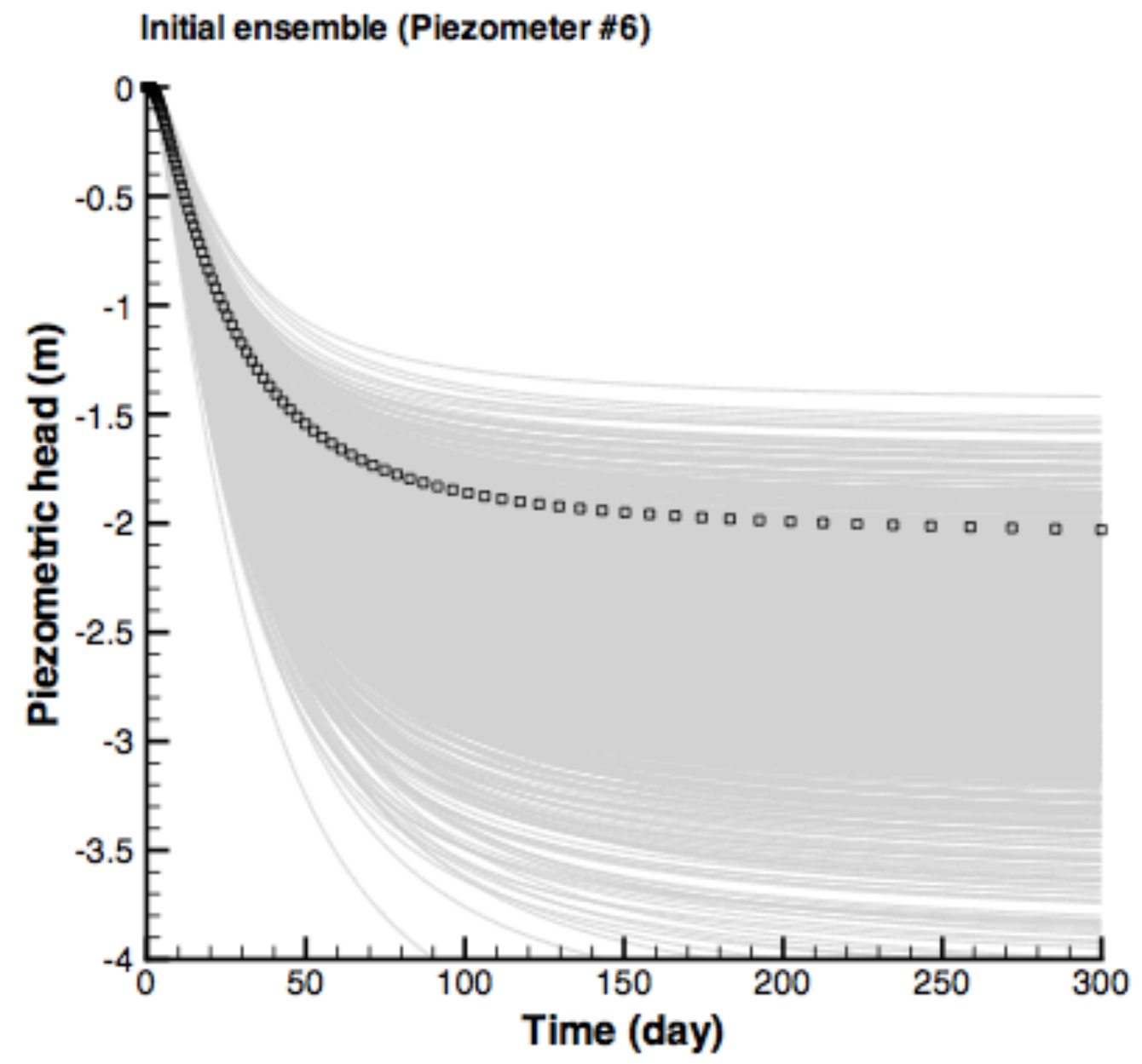


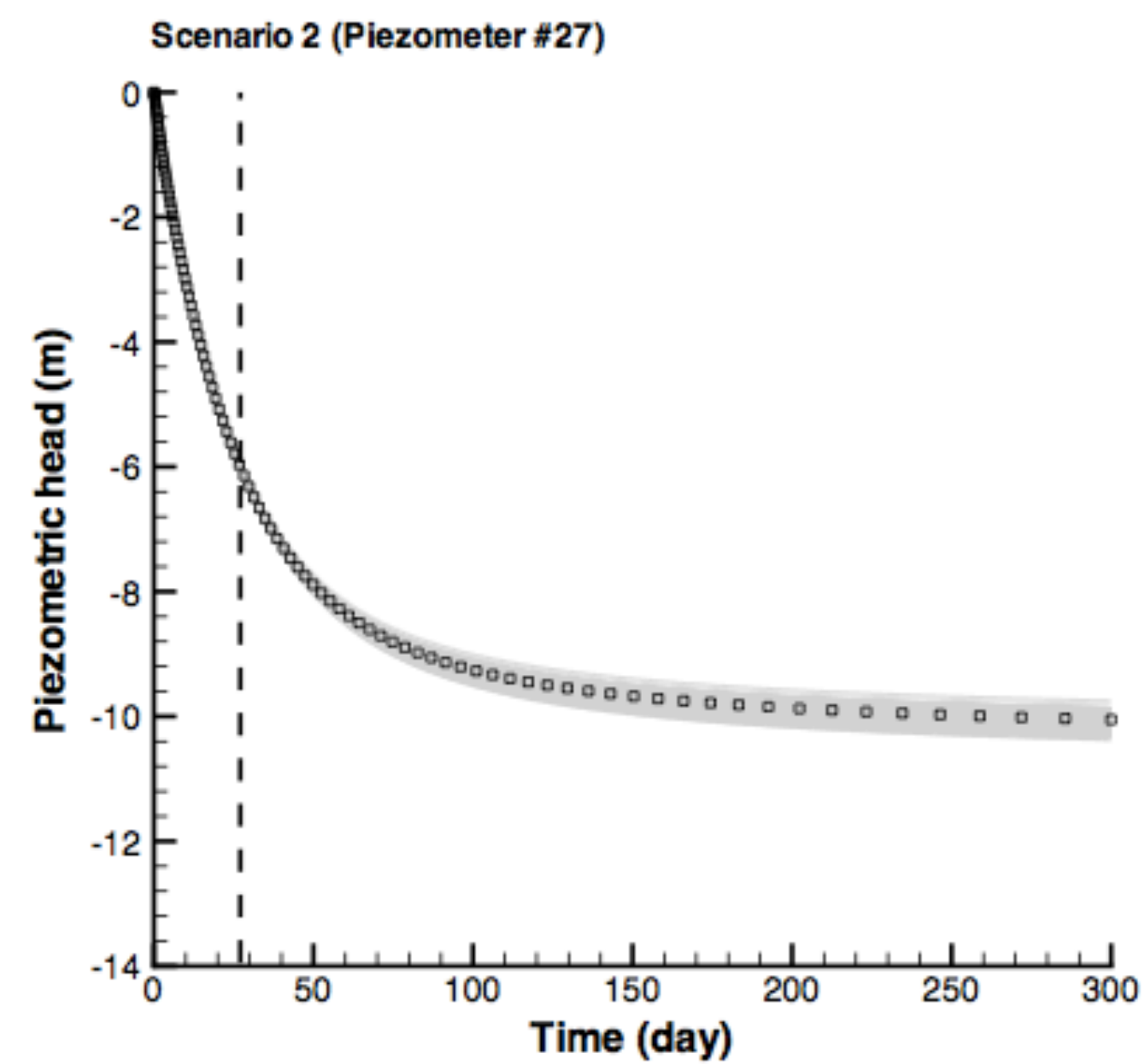
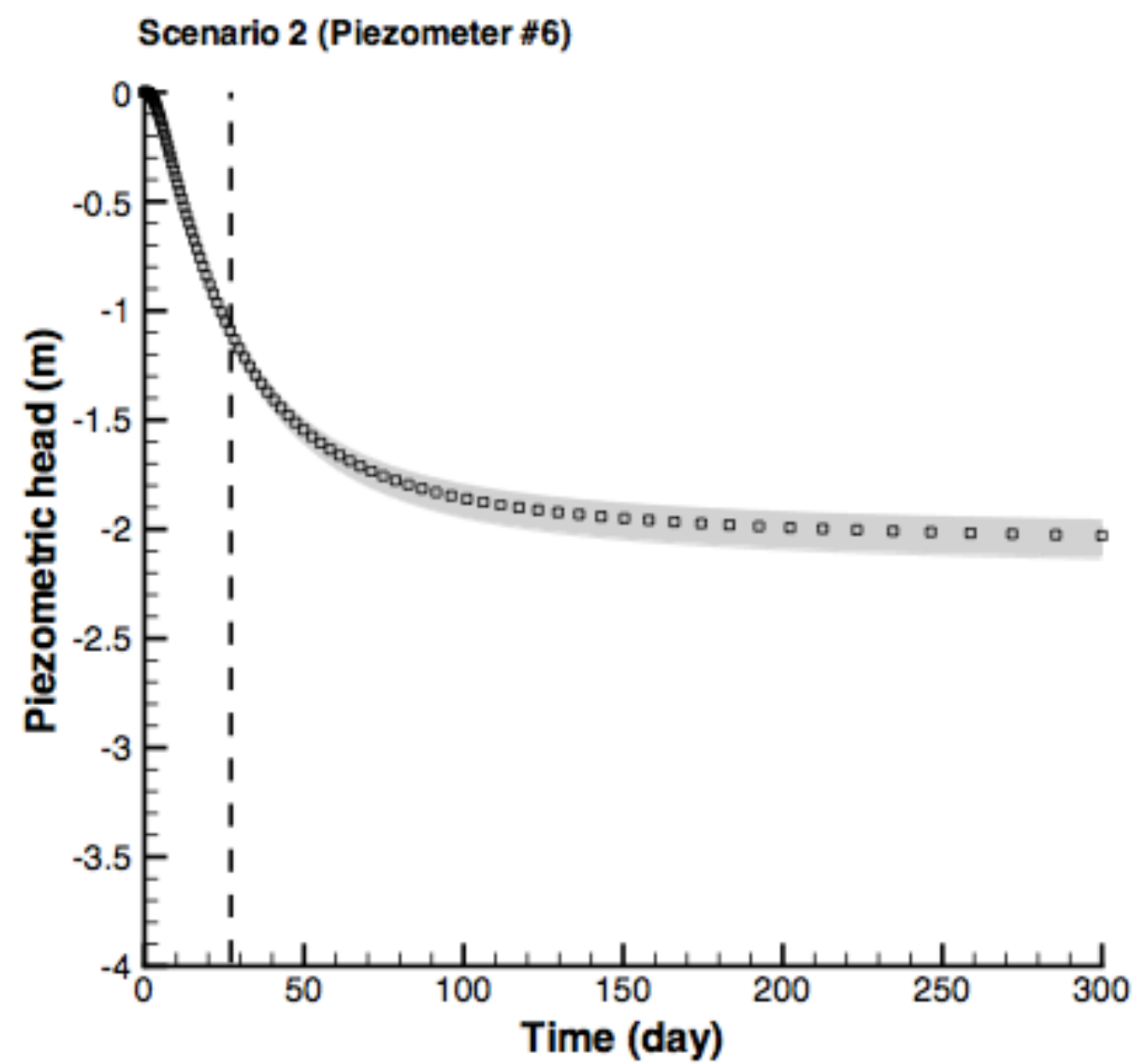
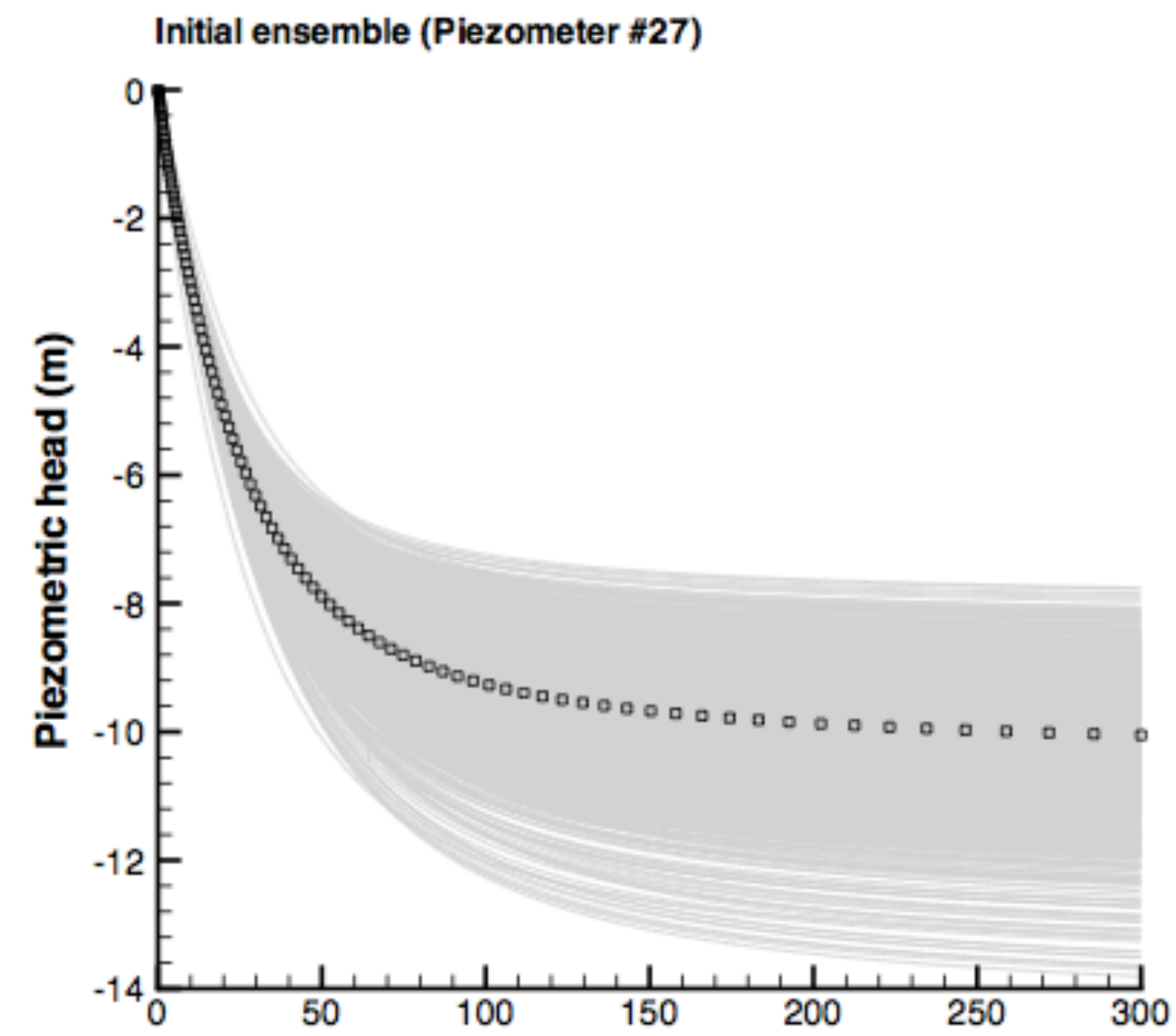
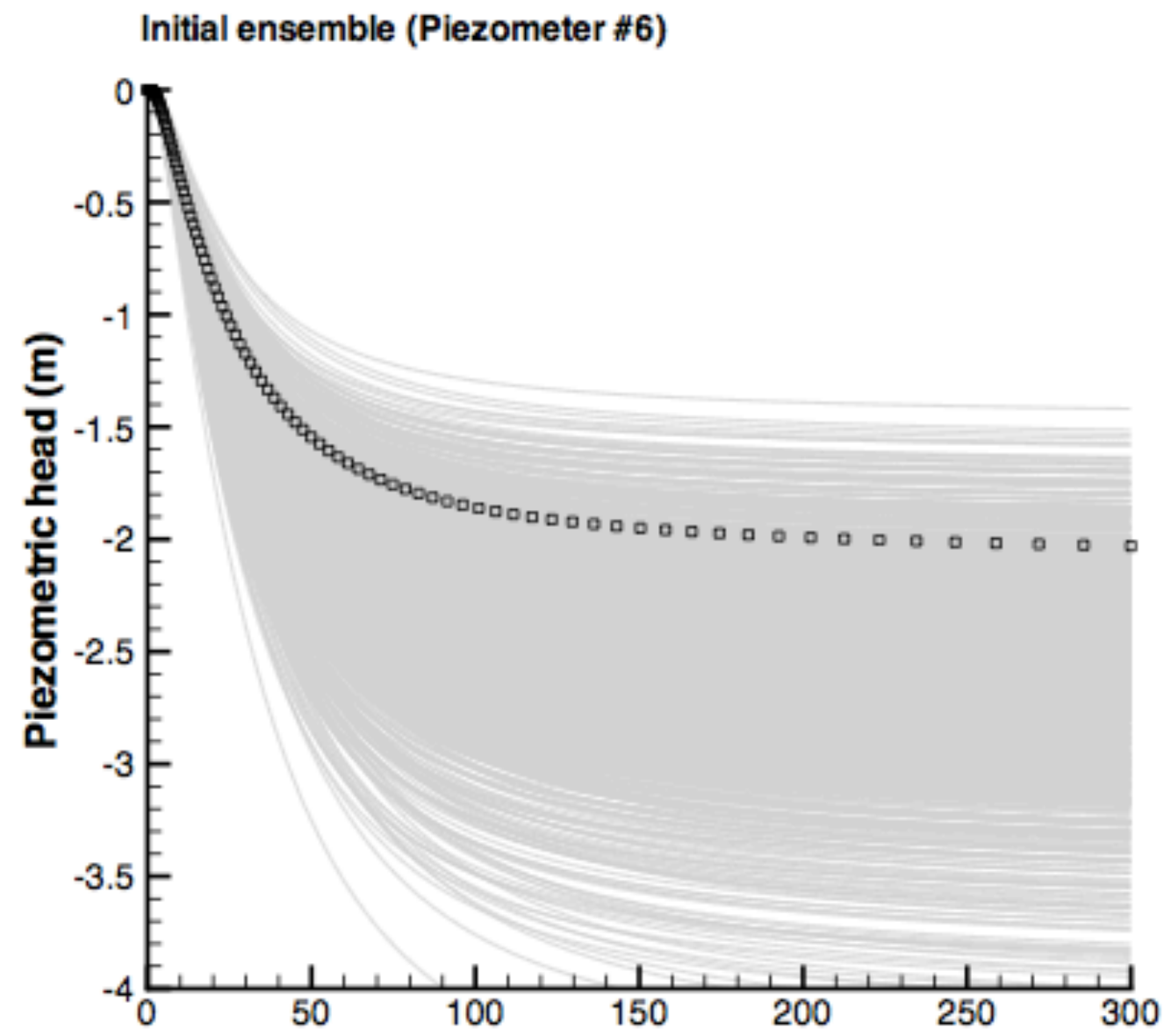


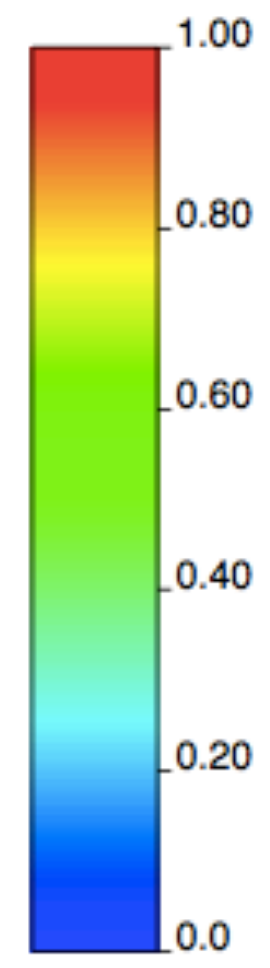
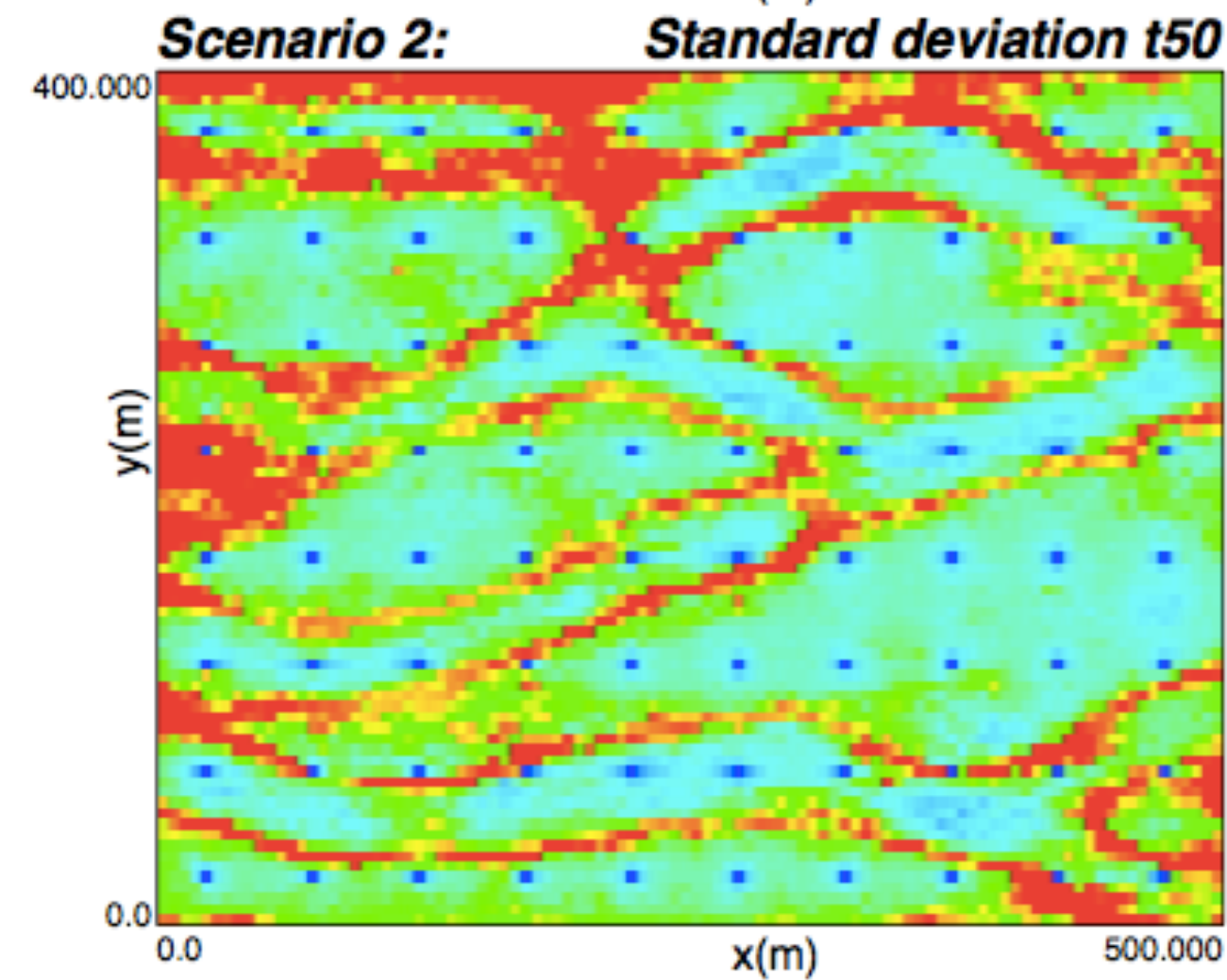
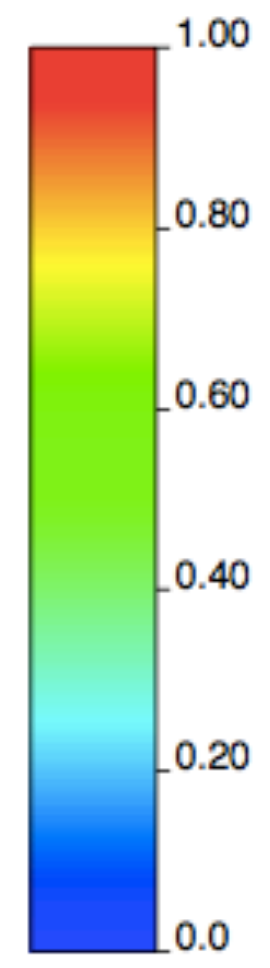
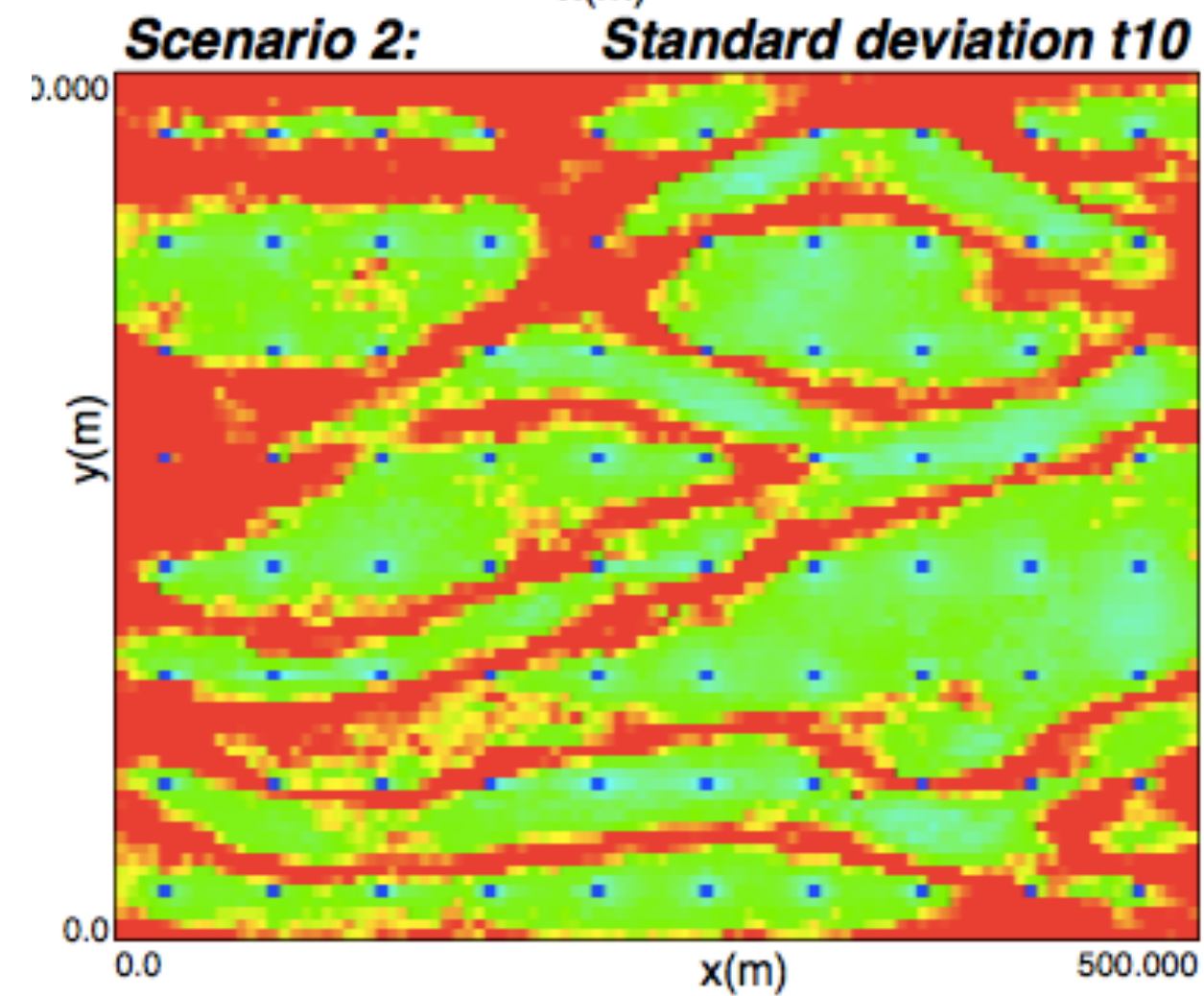
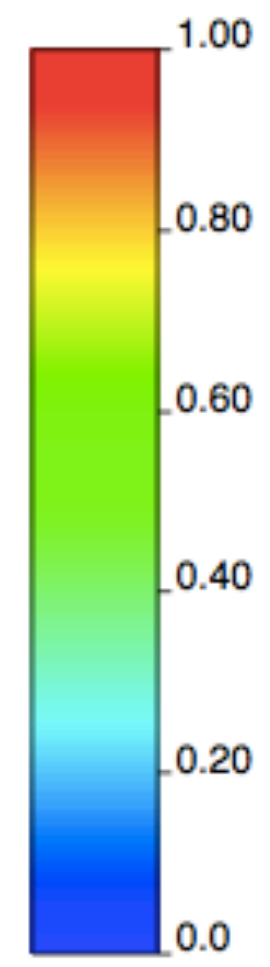
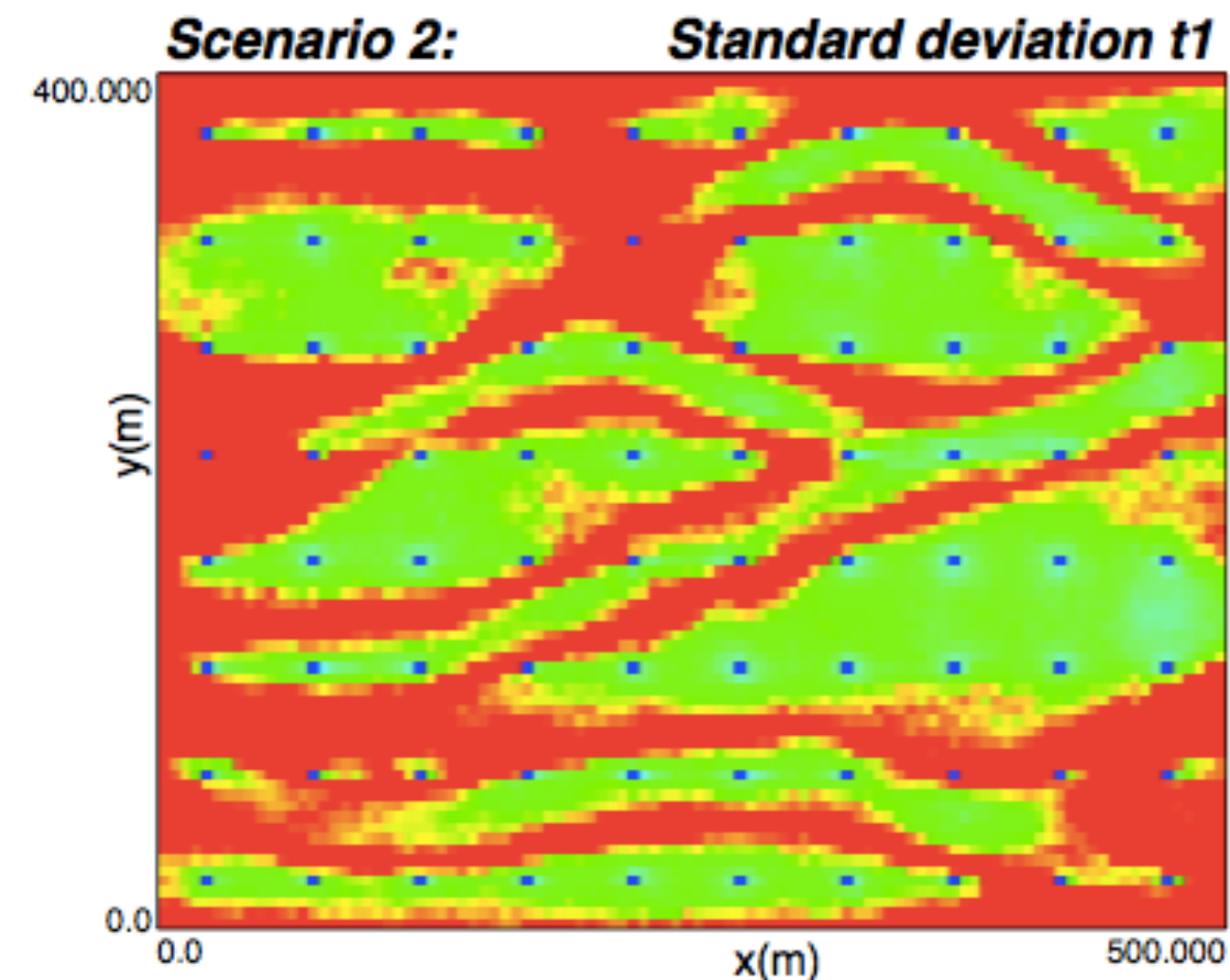
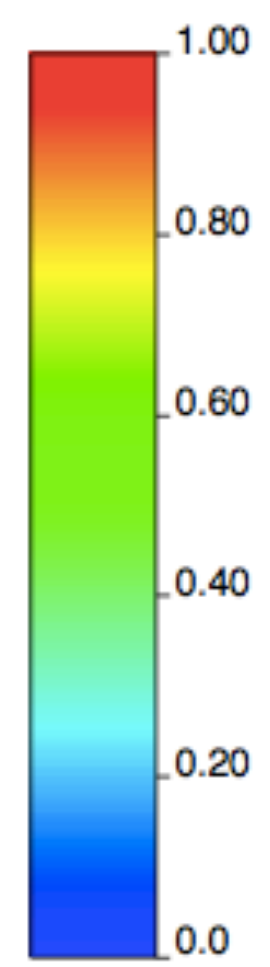
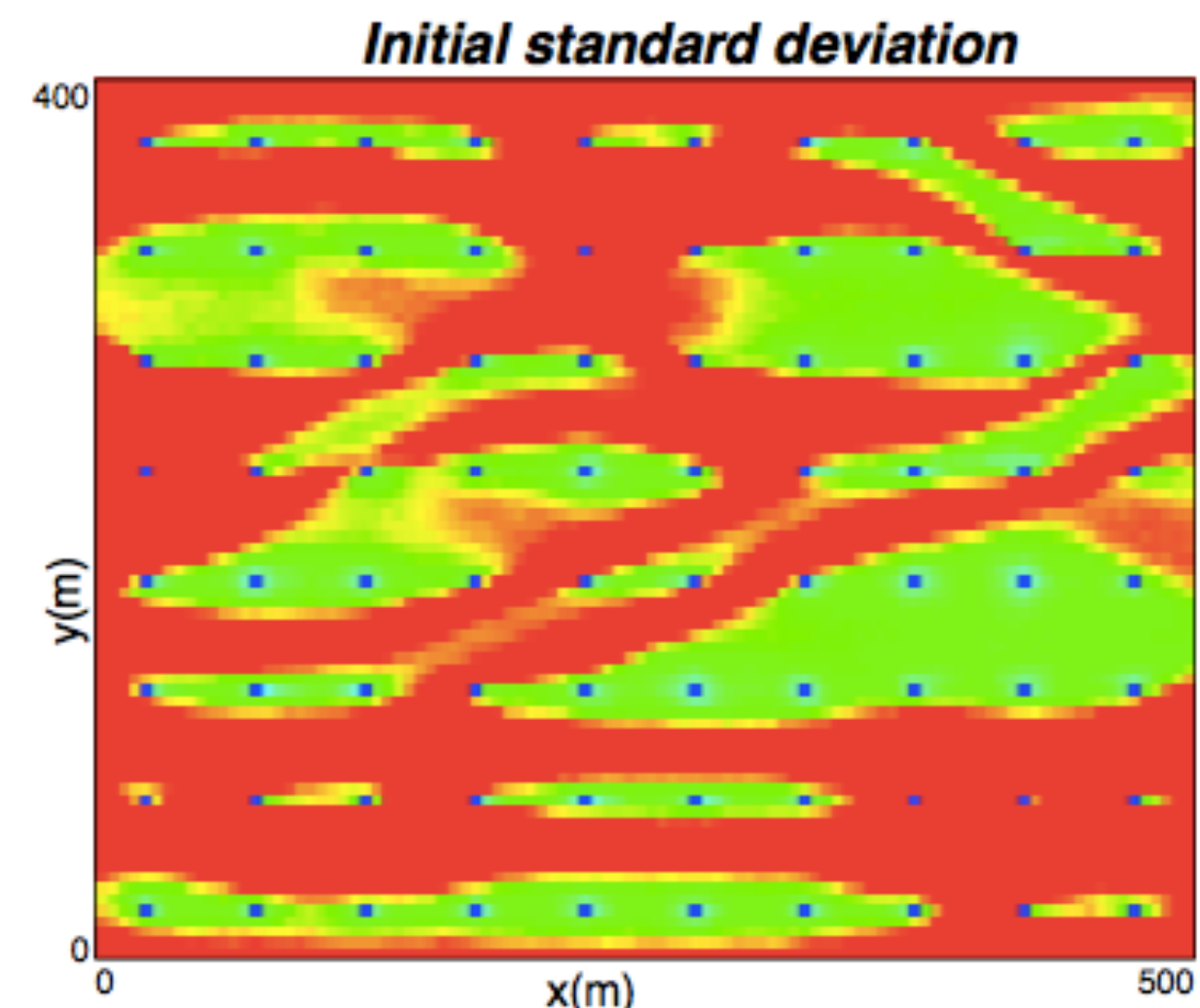


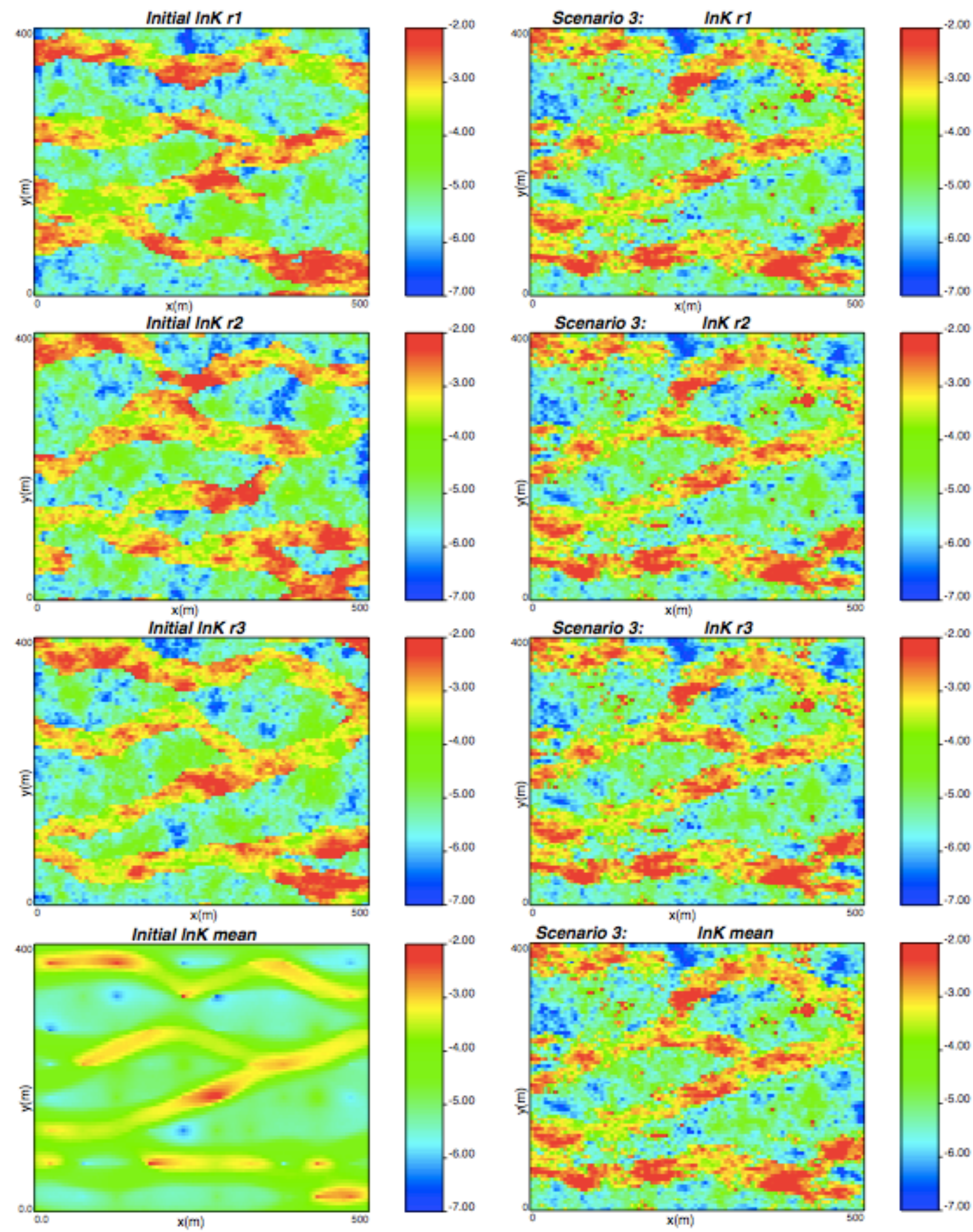


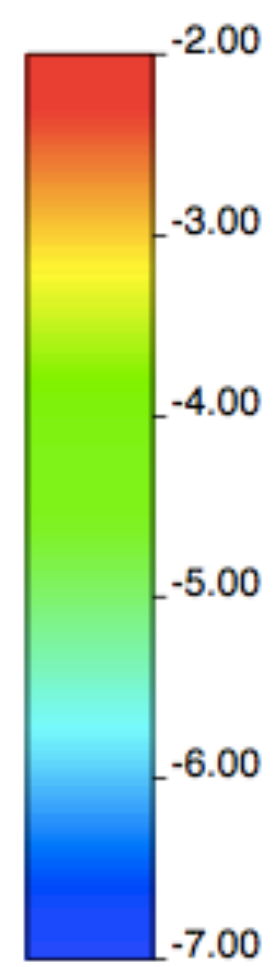
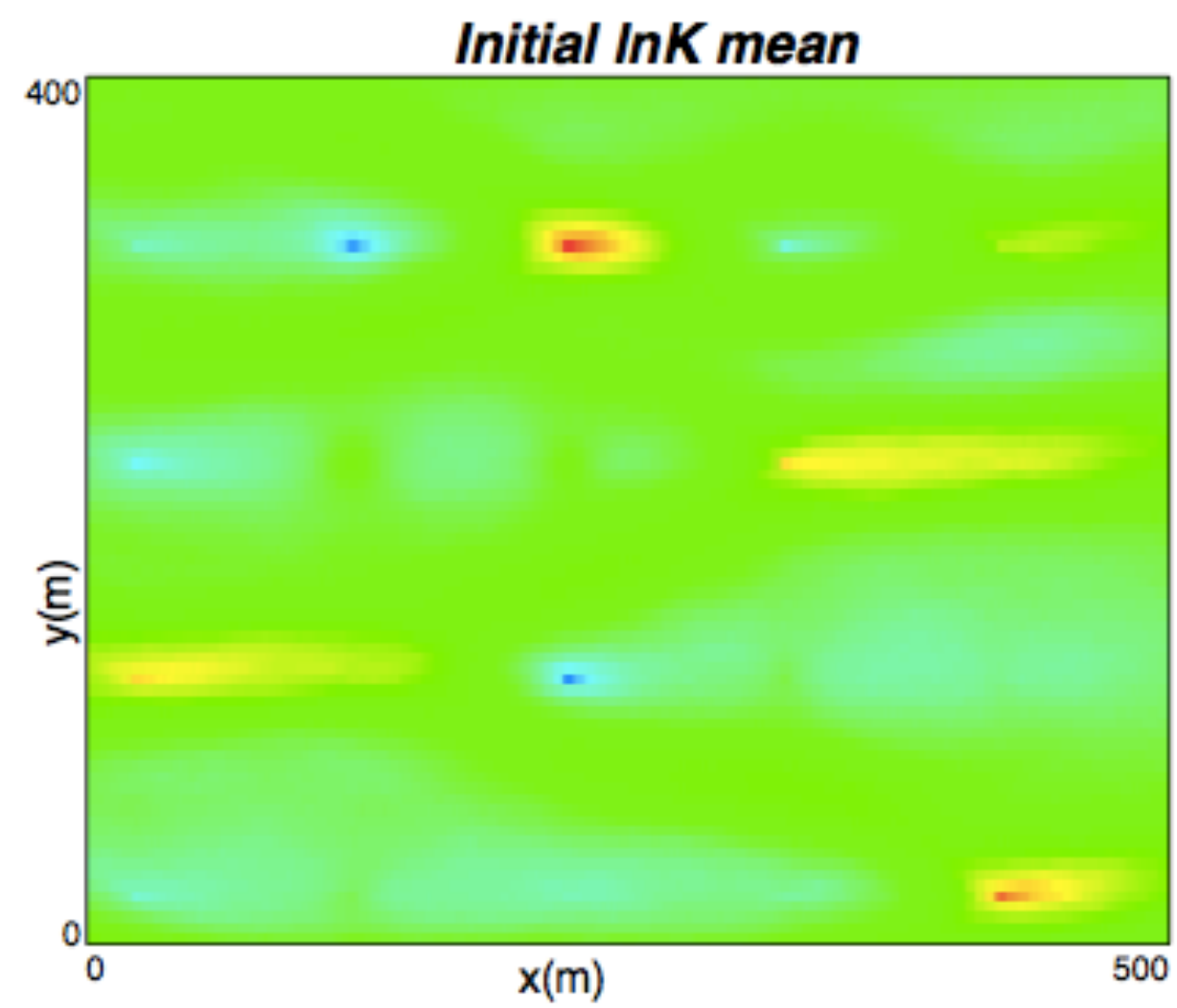
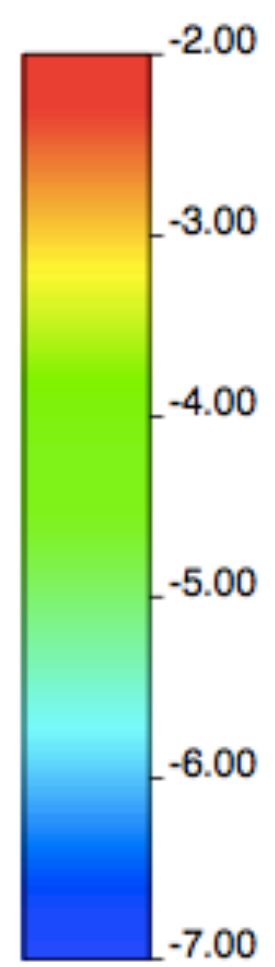
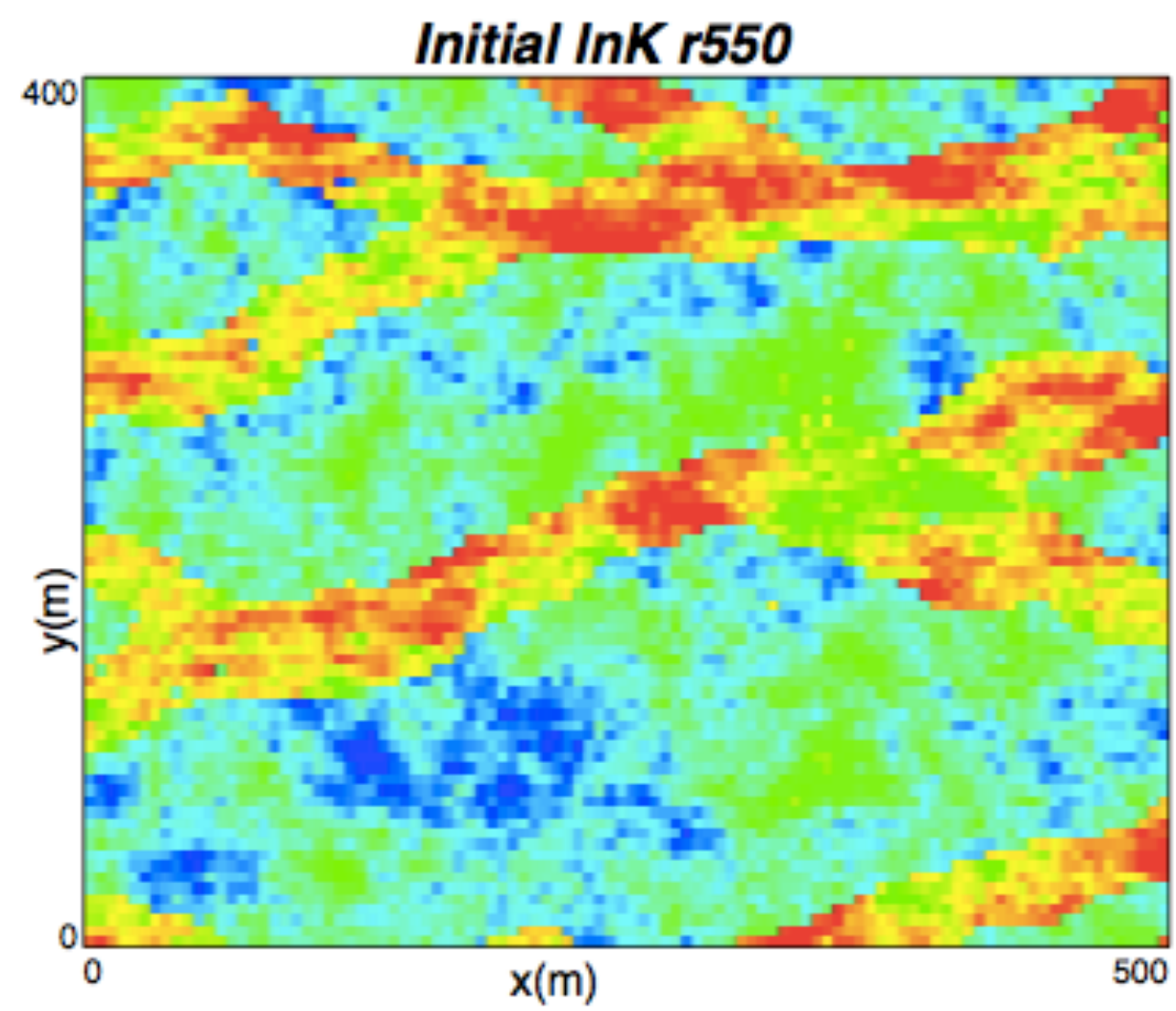


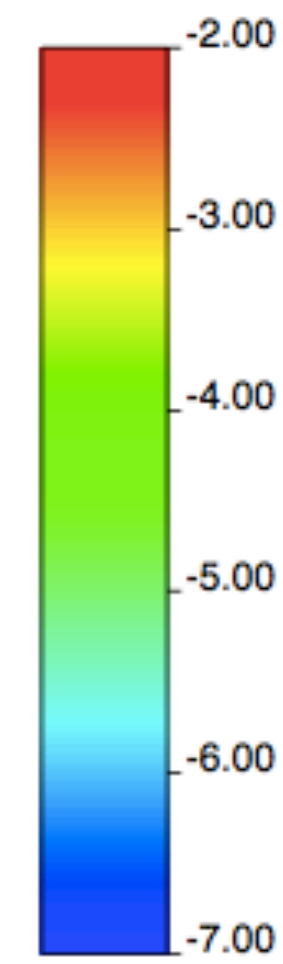
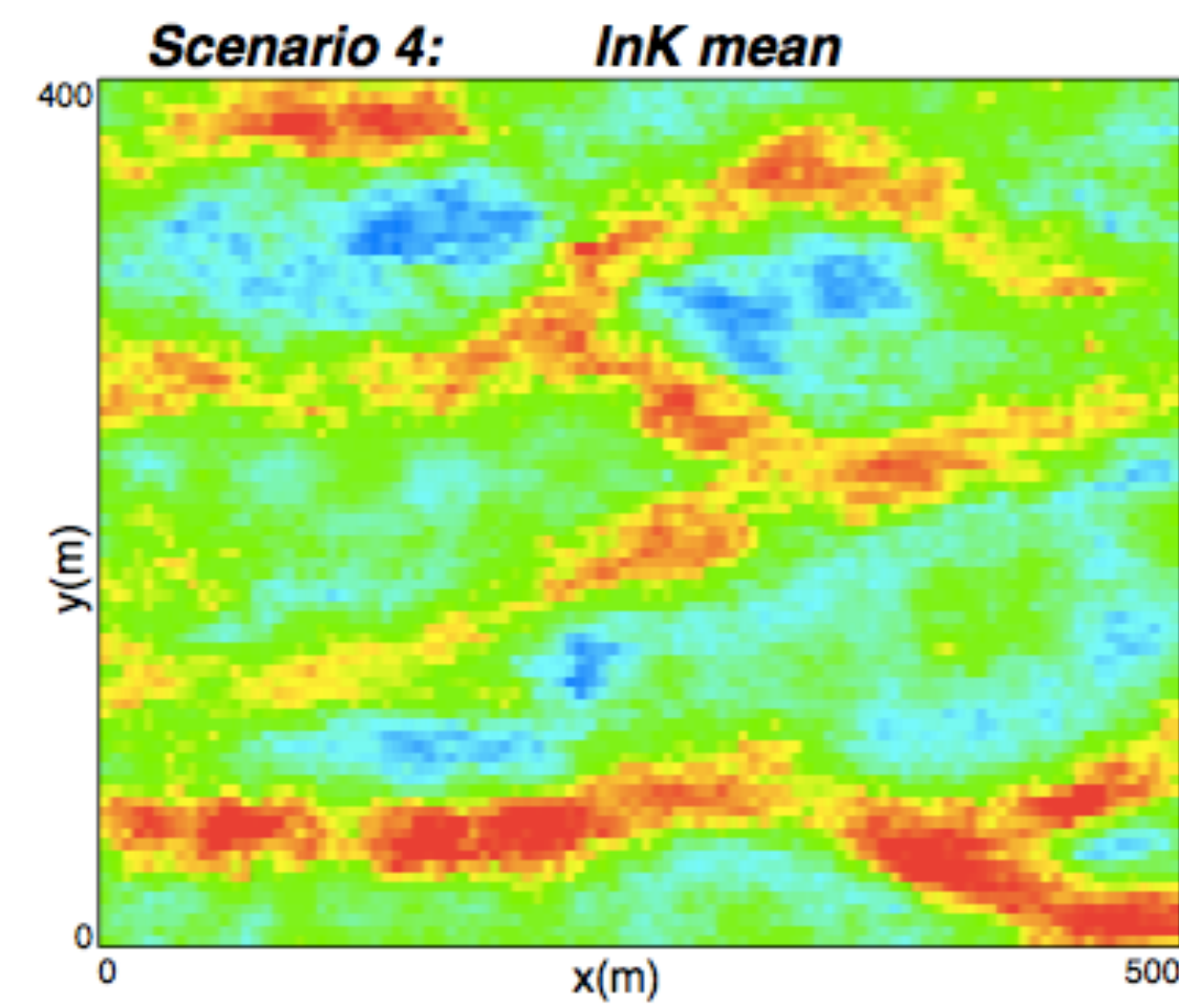
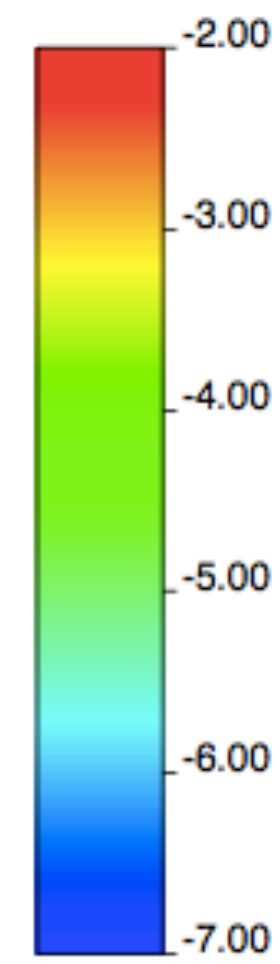
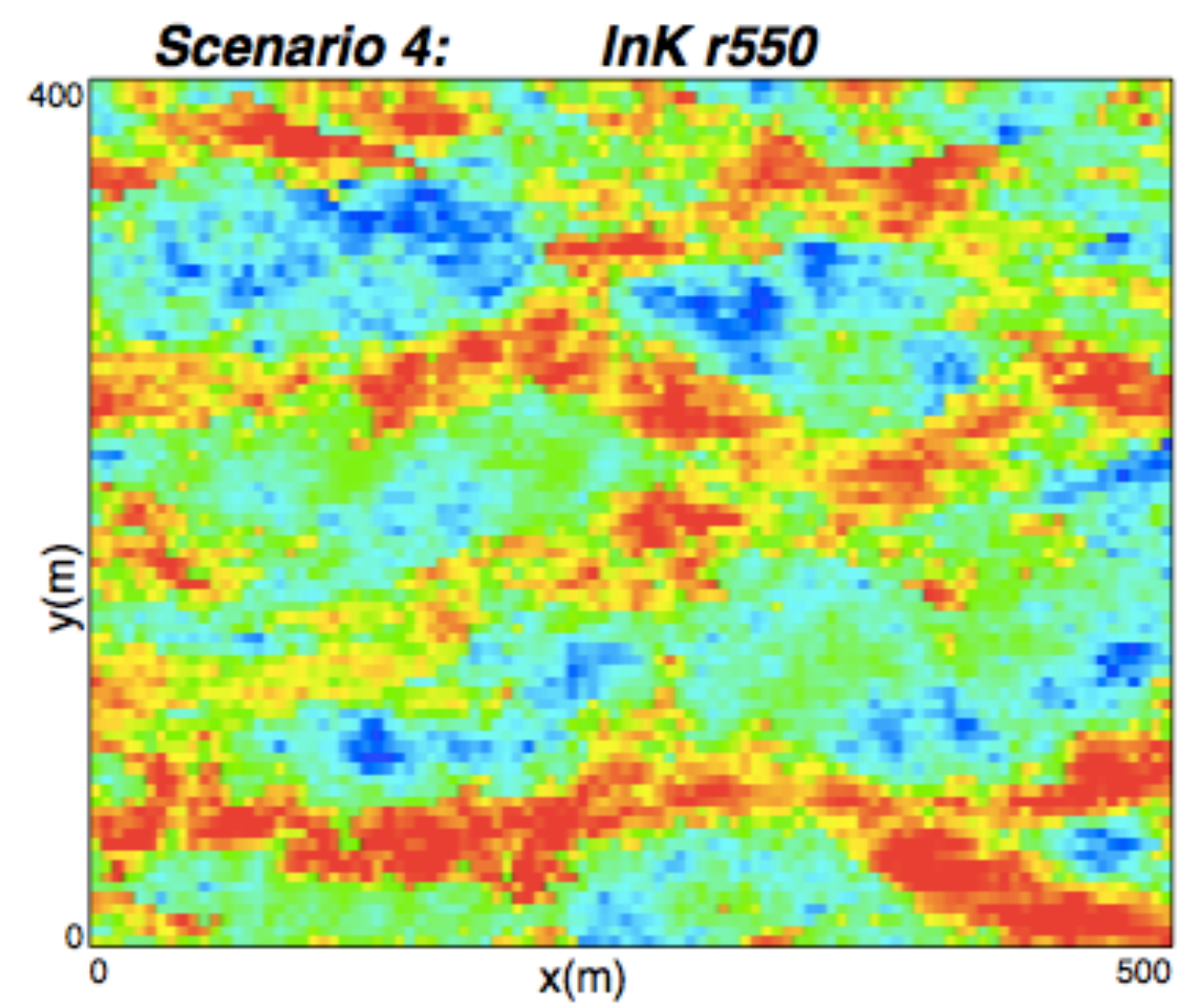
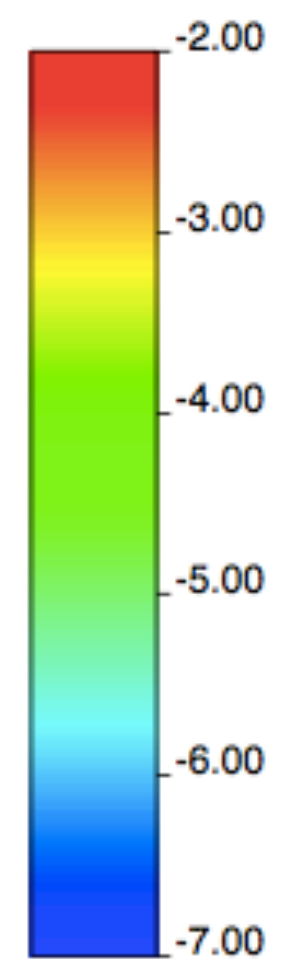
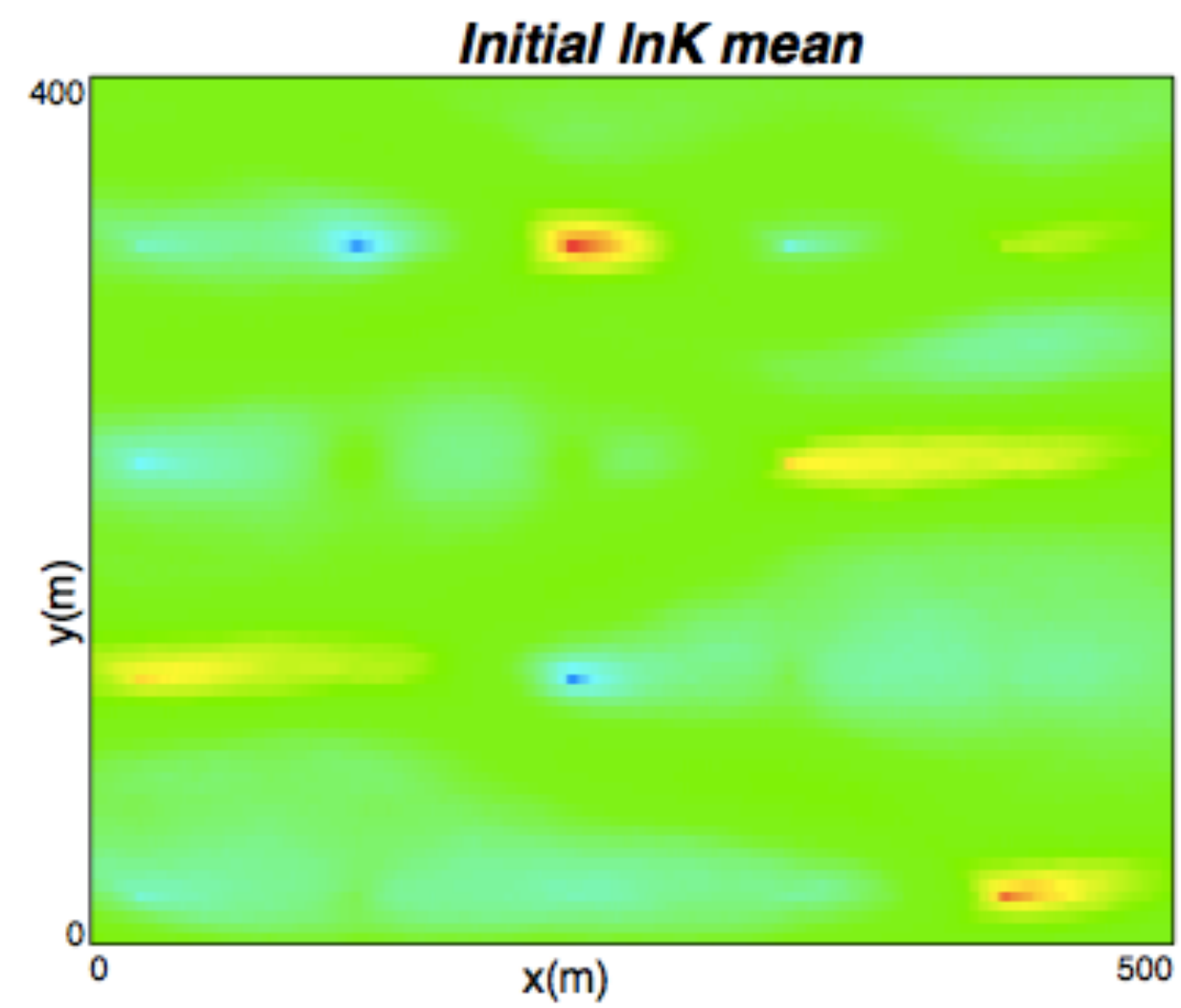
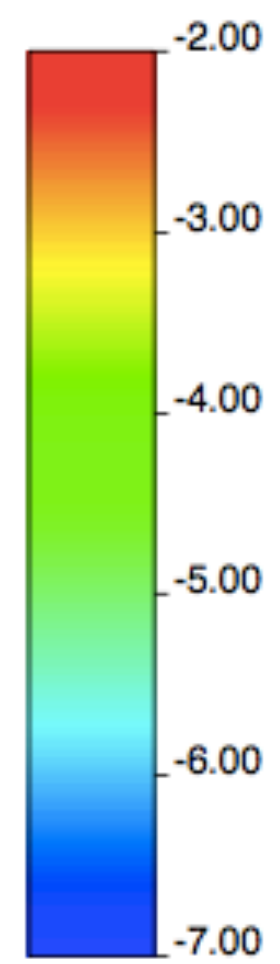
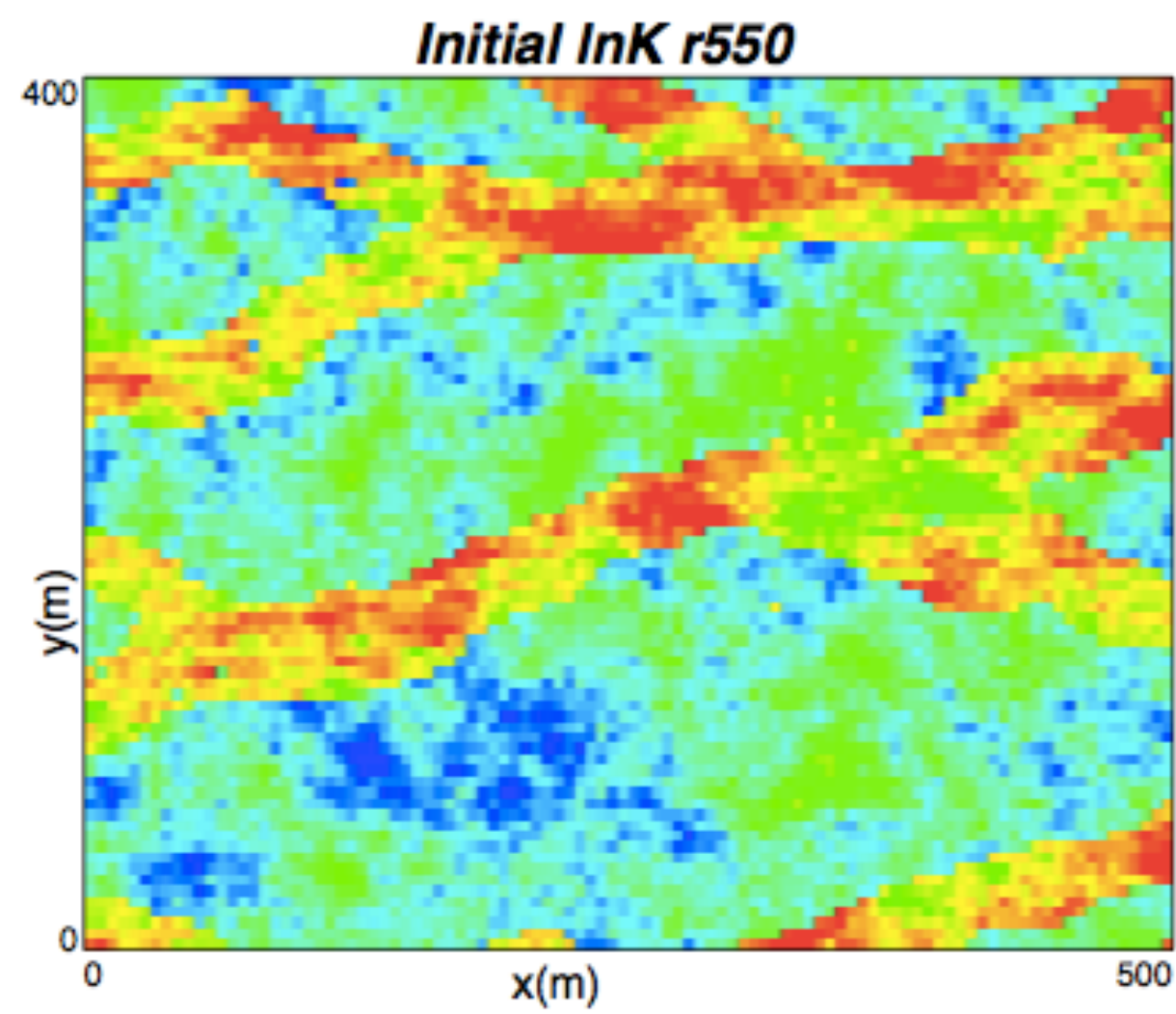






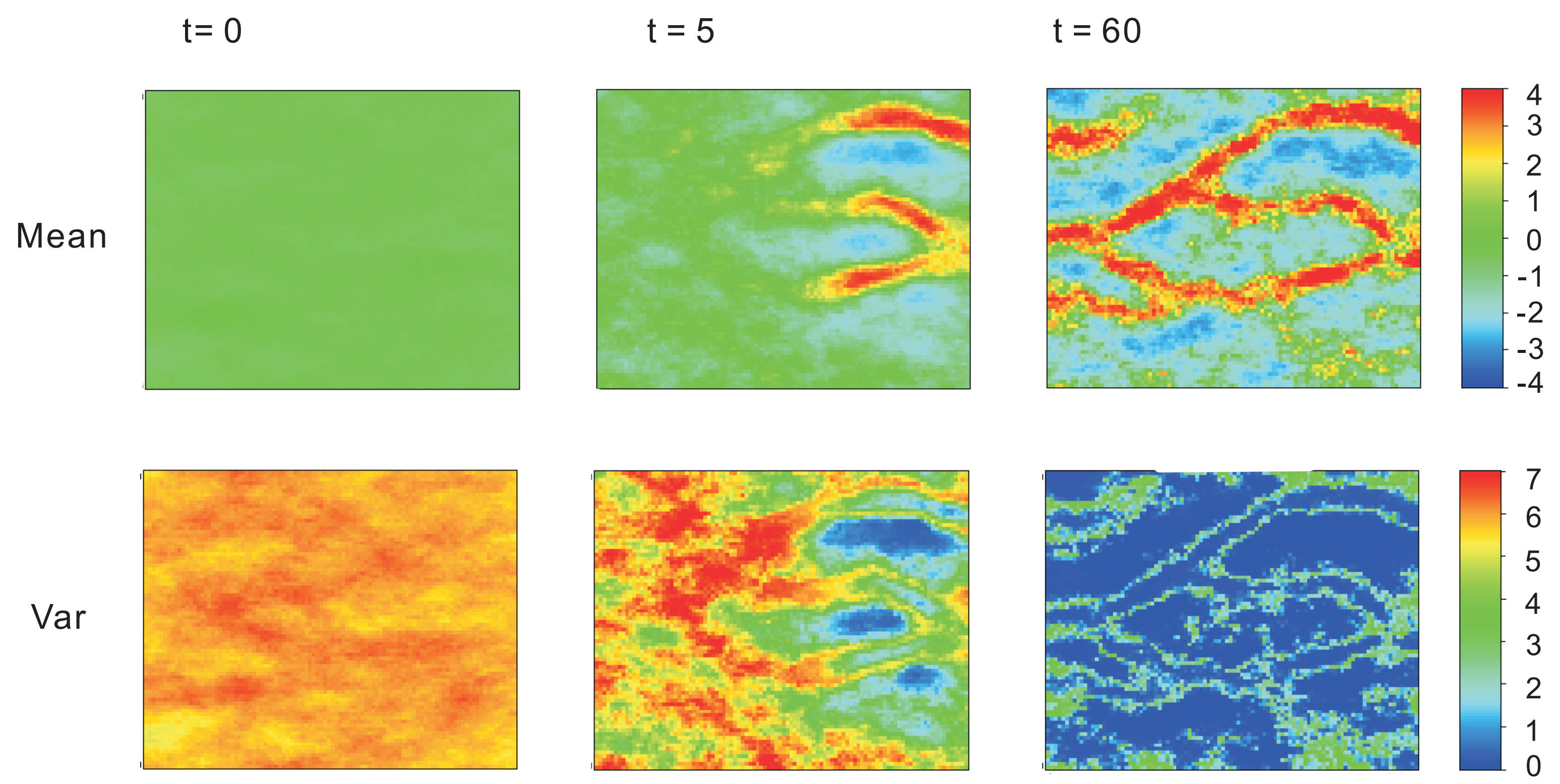




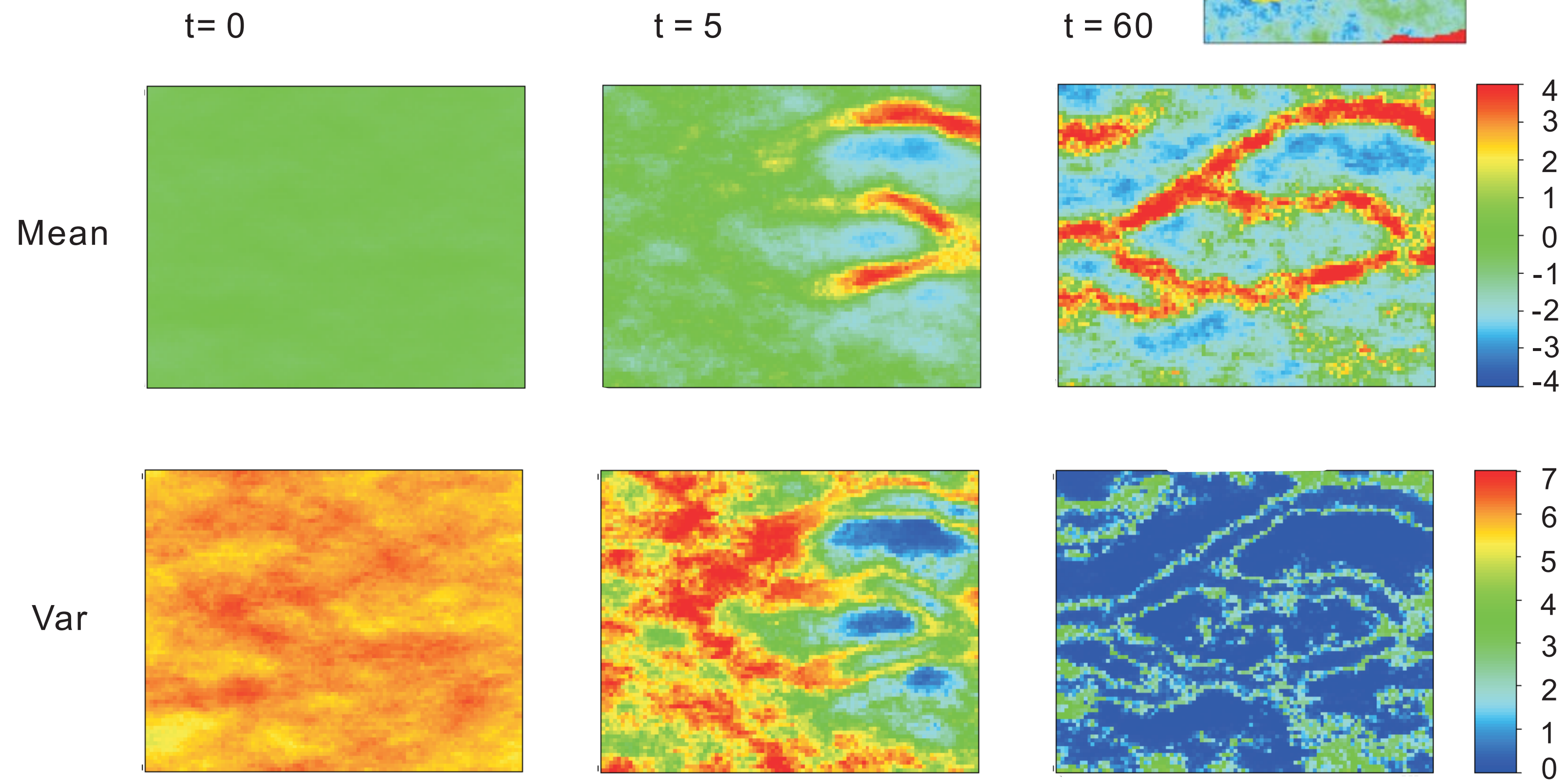


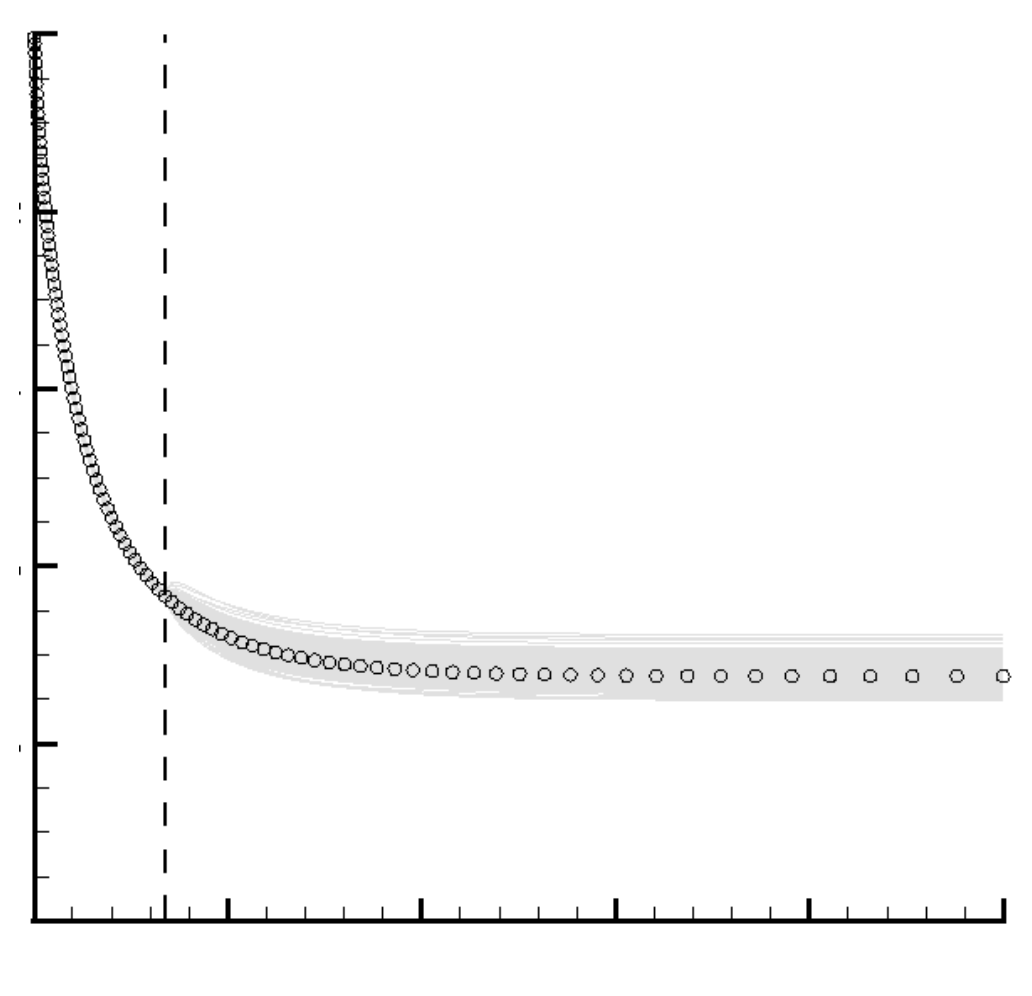
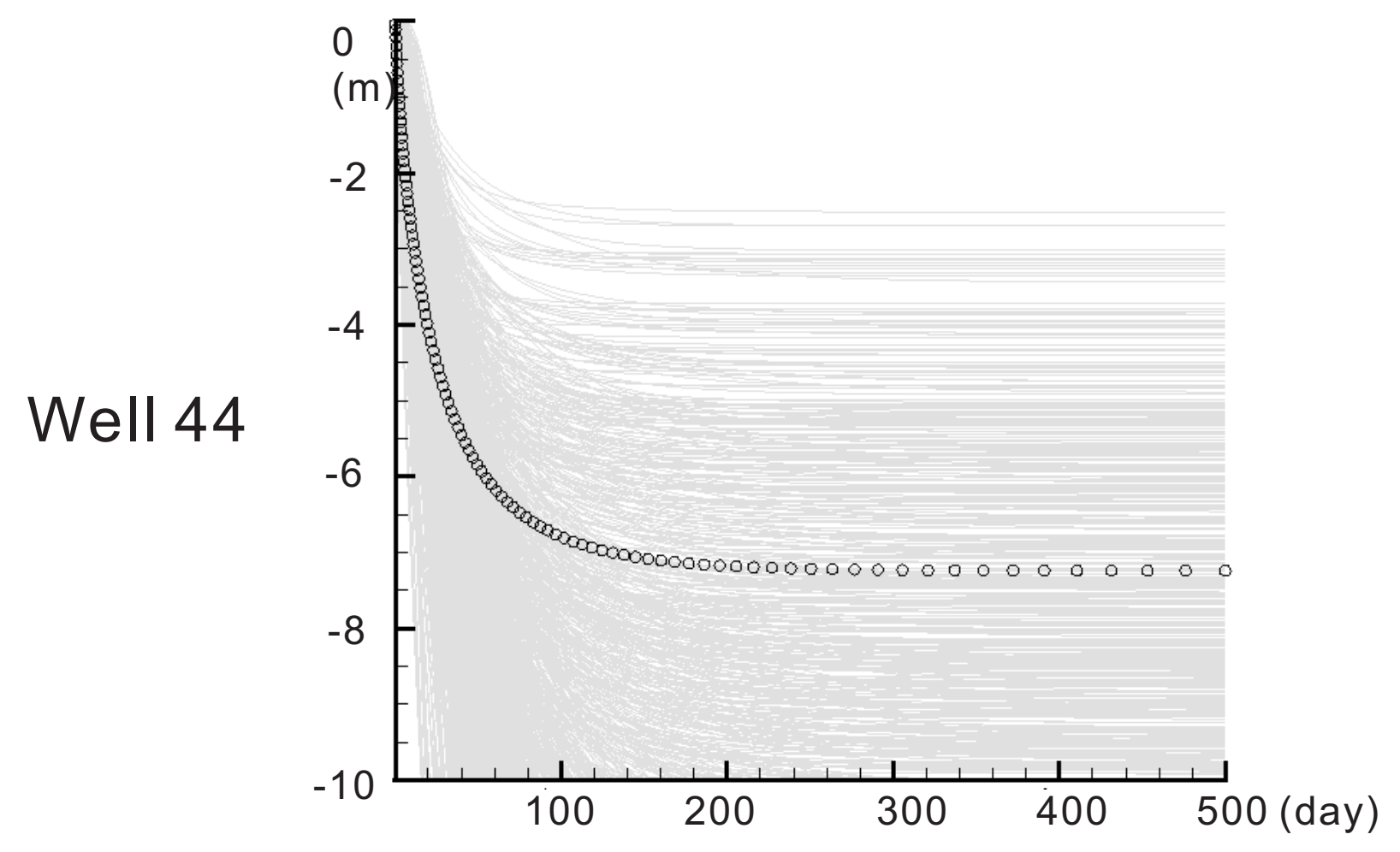
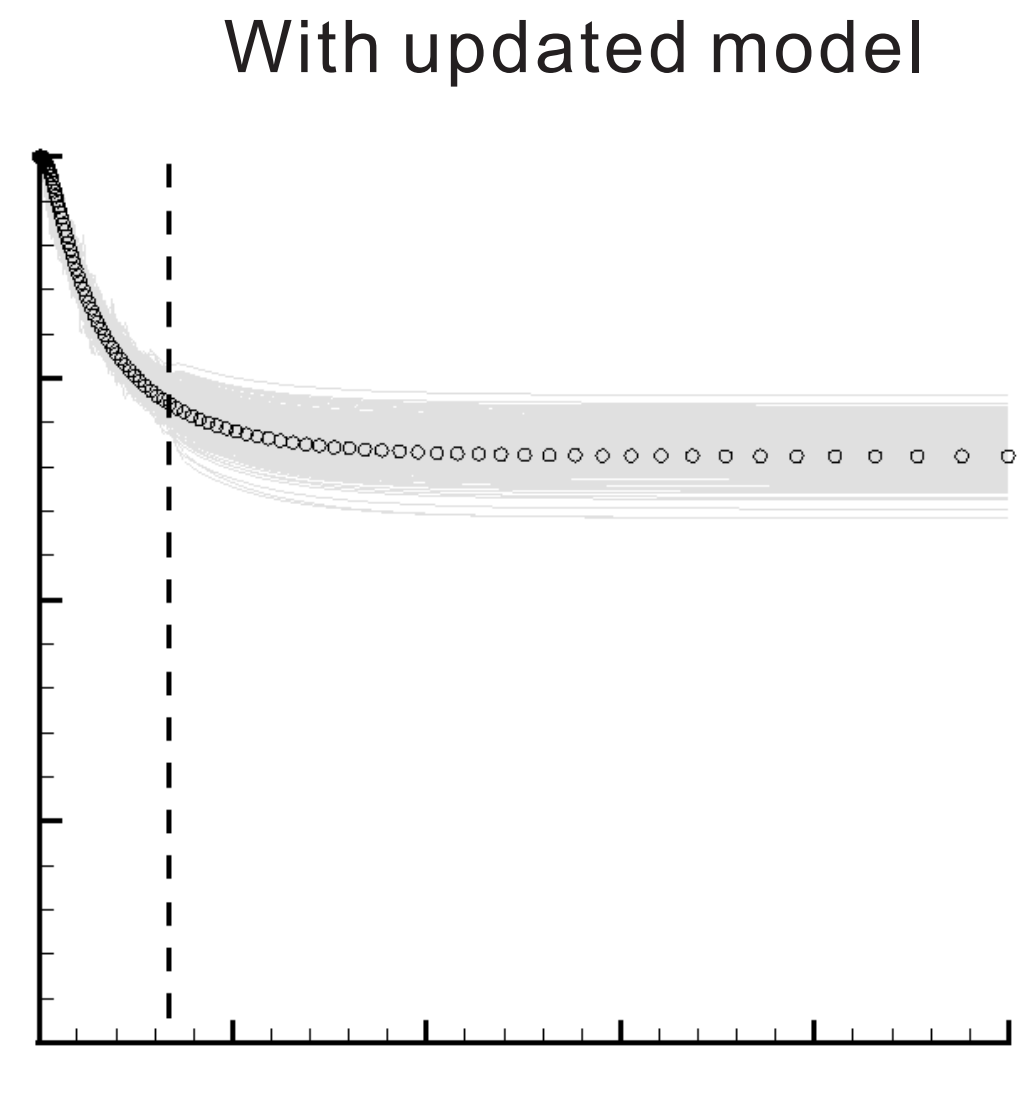
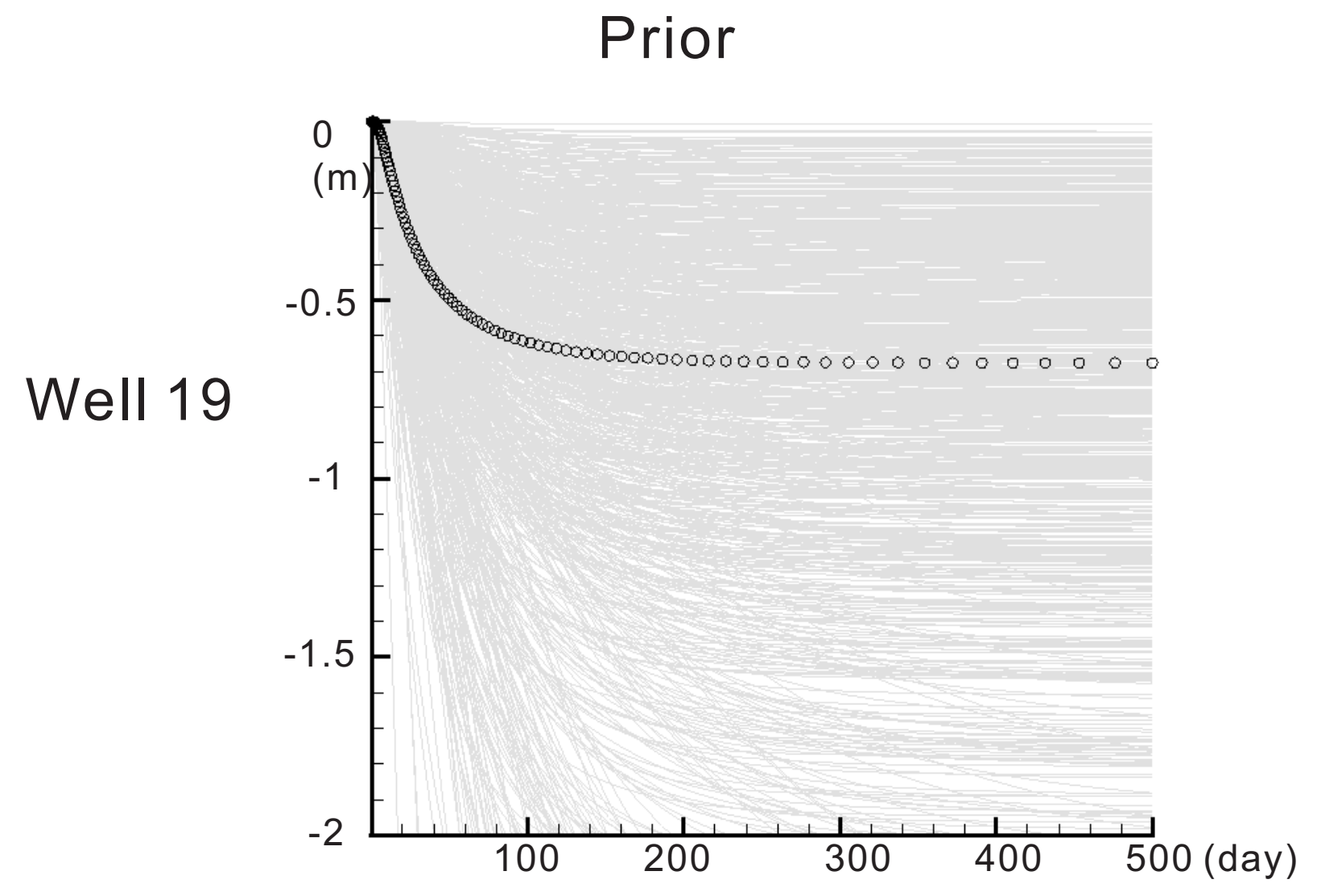
# Valencia - The Opera House



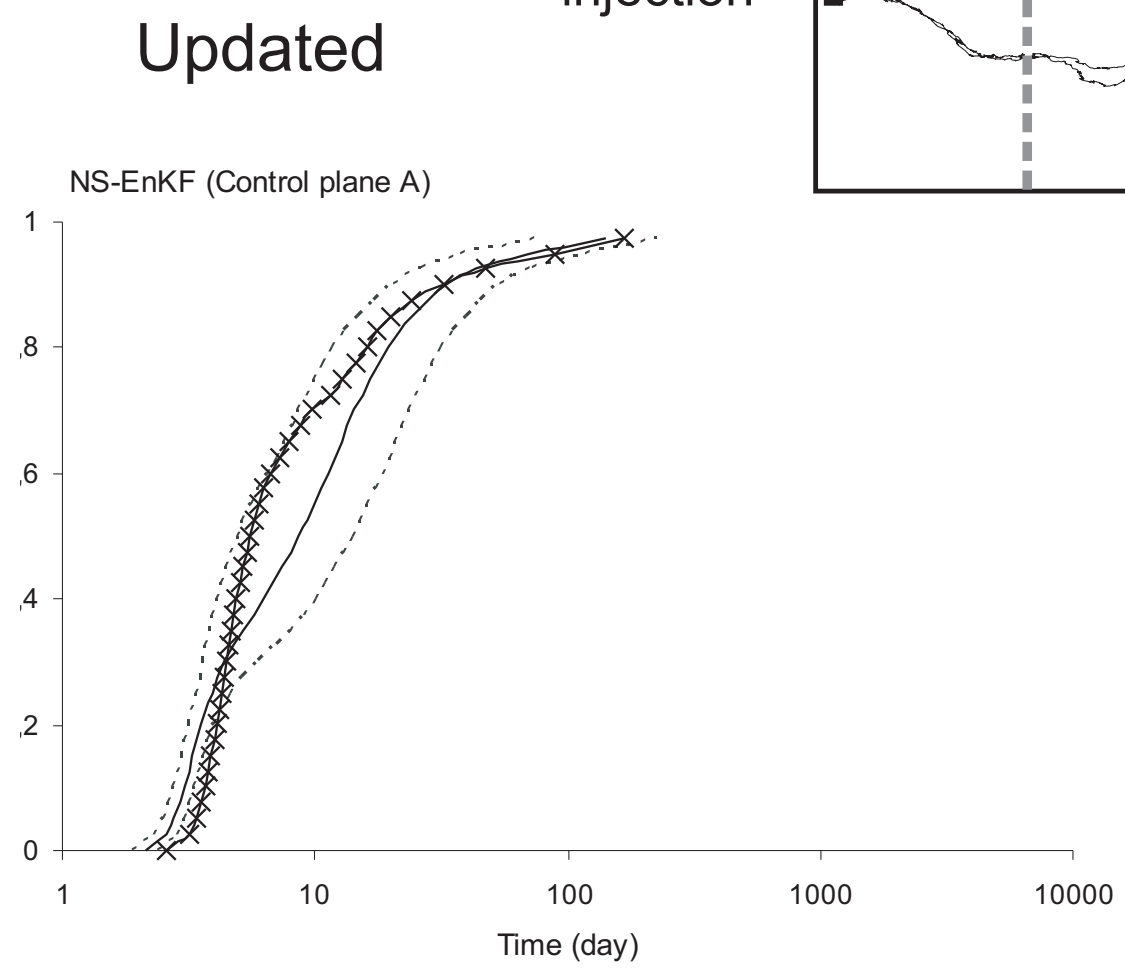
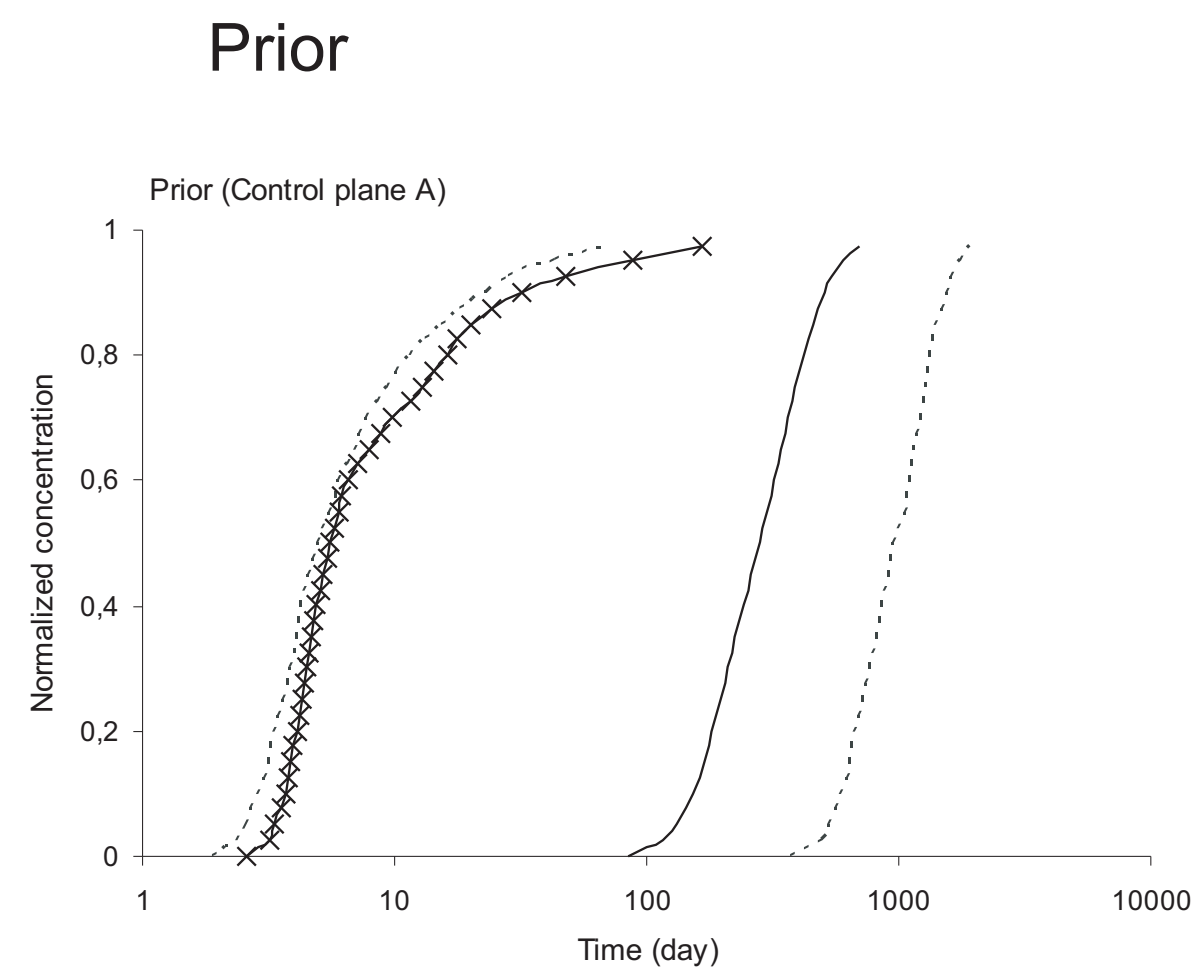






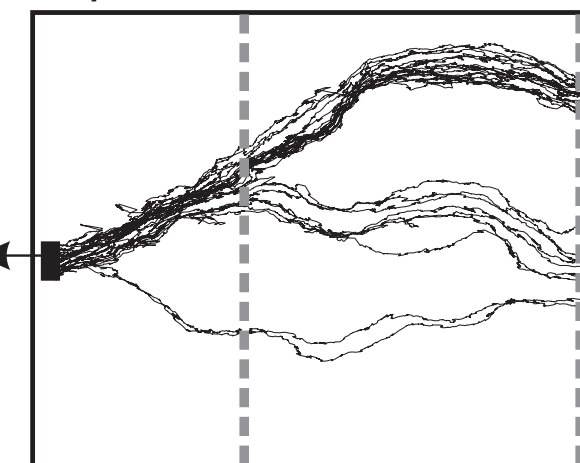


Control plane A

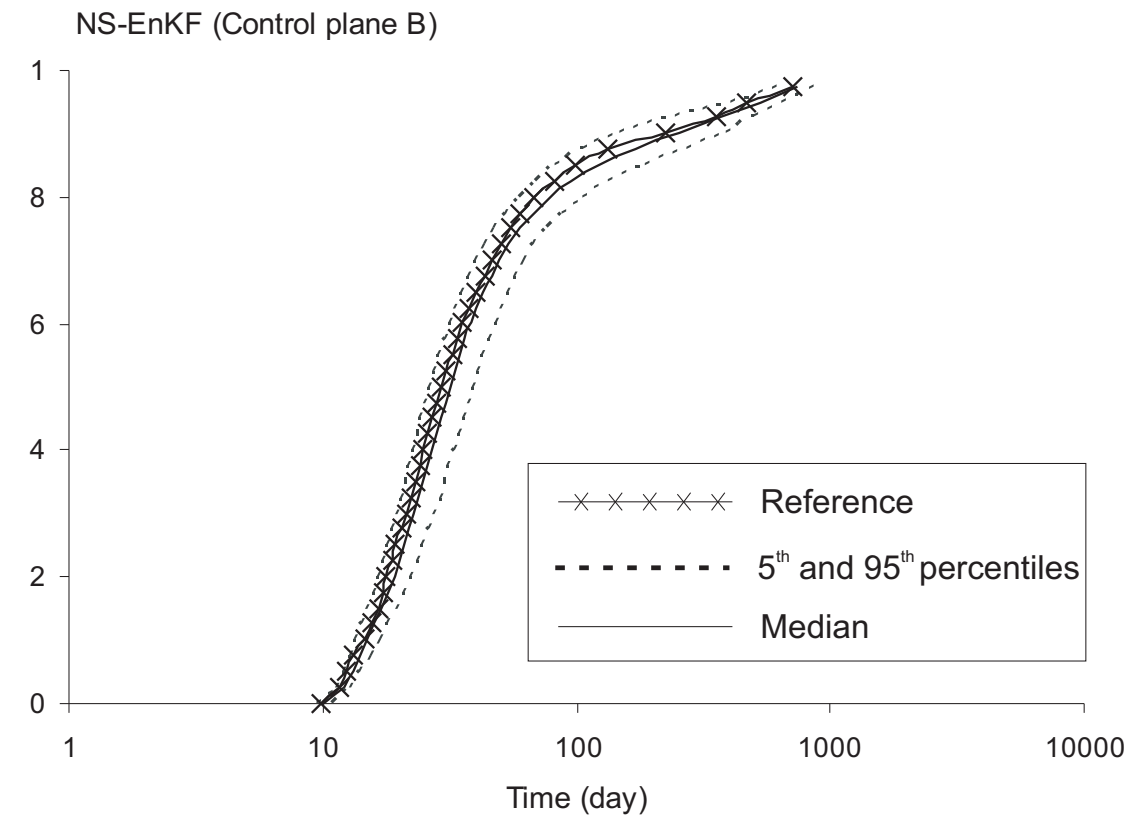
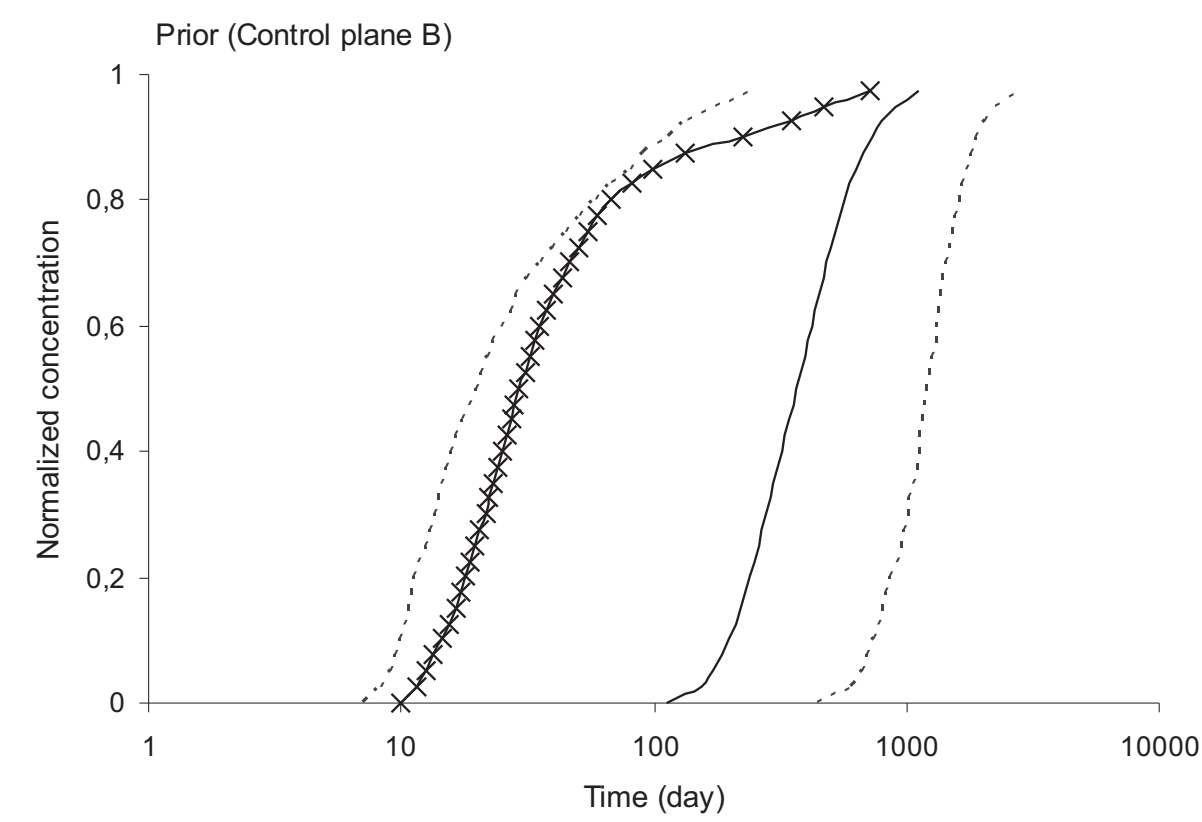


Control plane A B

Particle injection

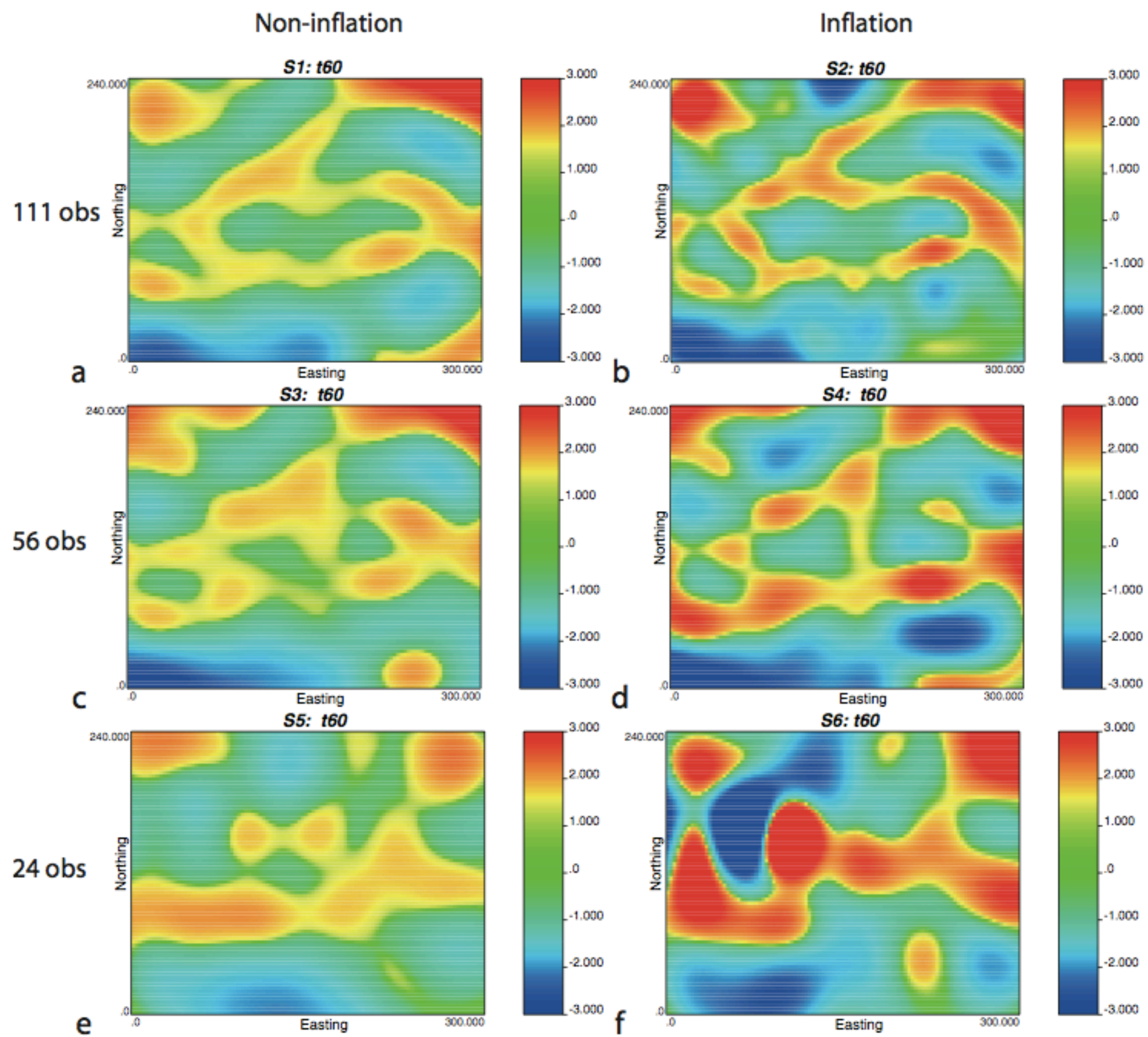


Control plane B



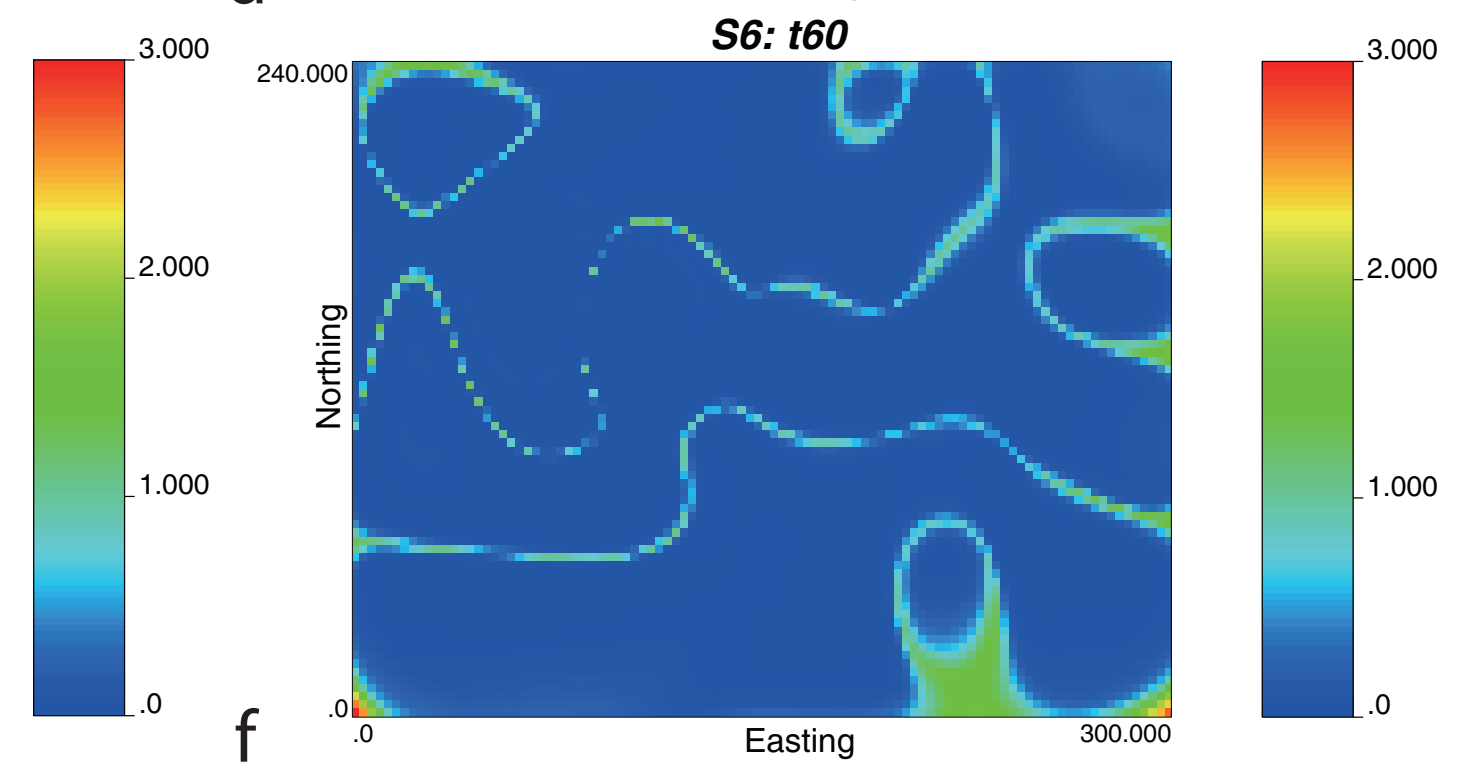
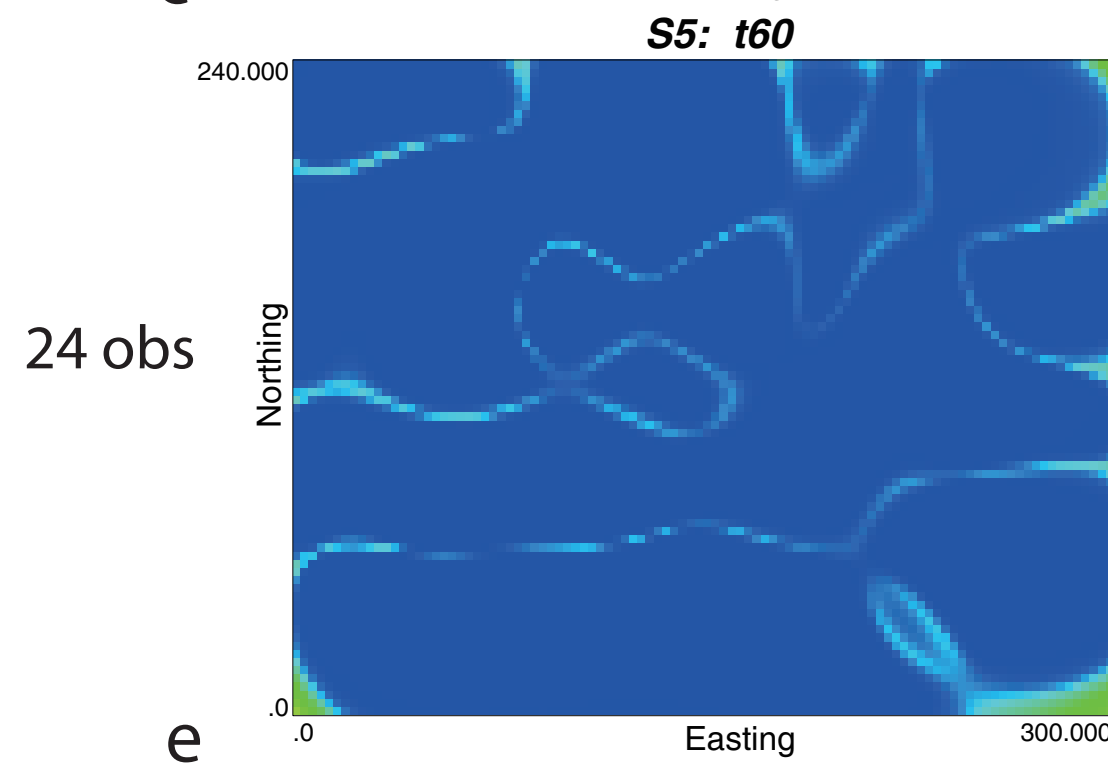
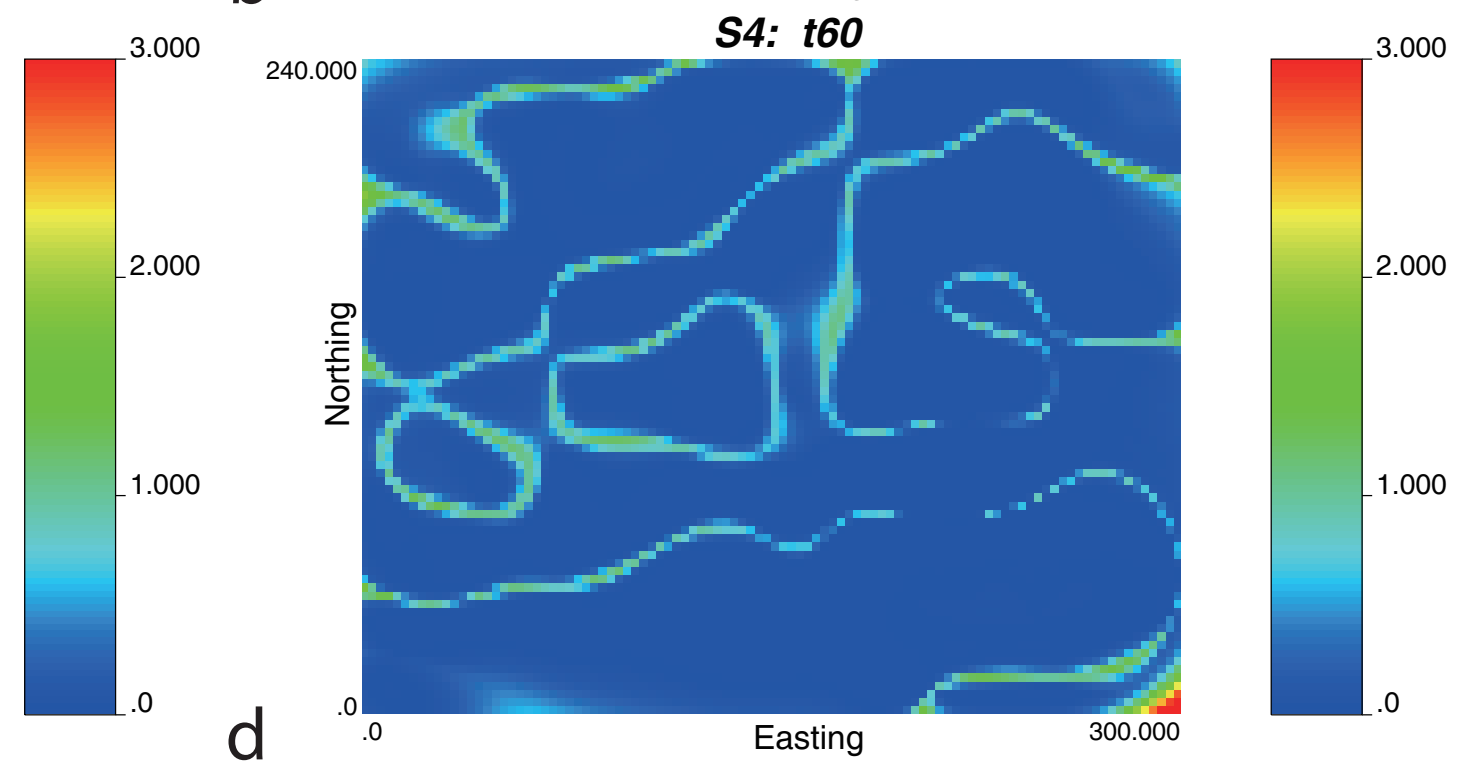
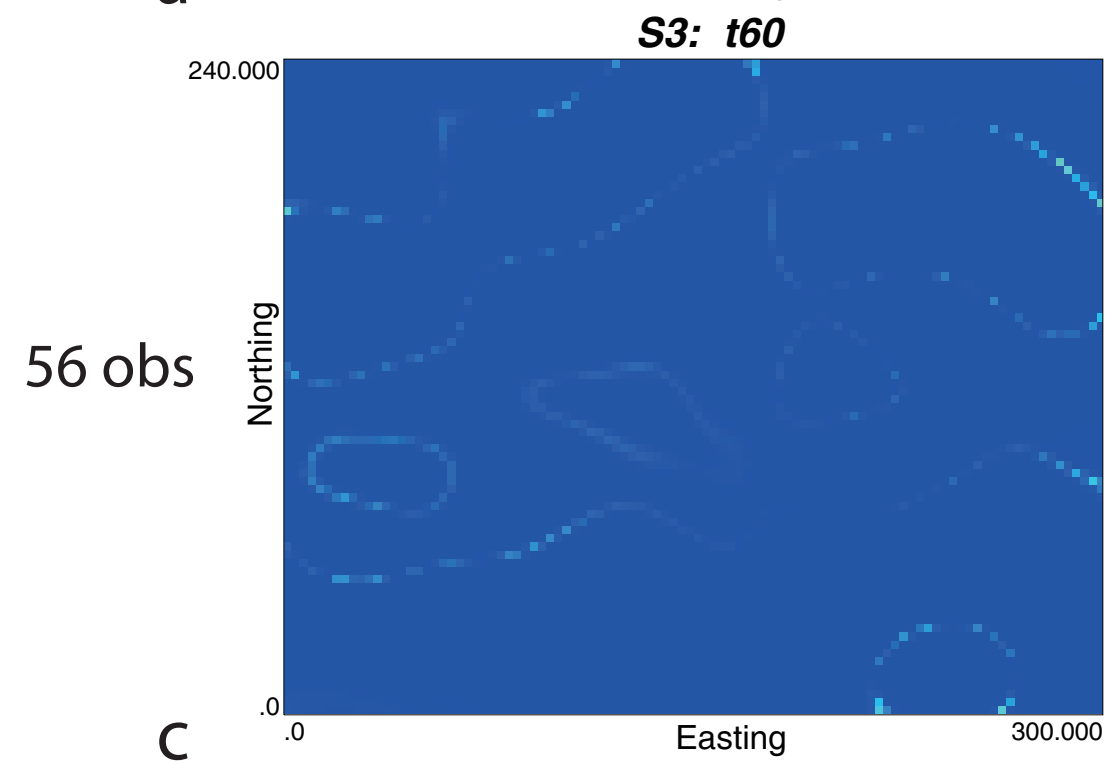
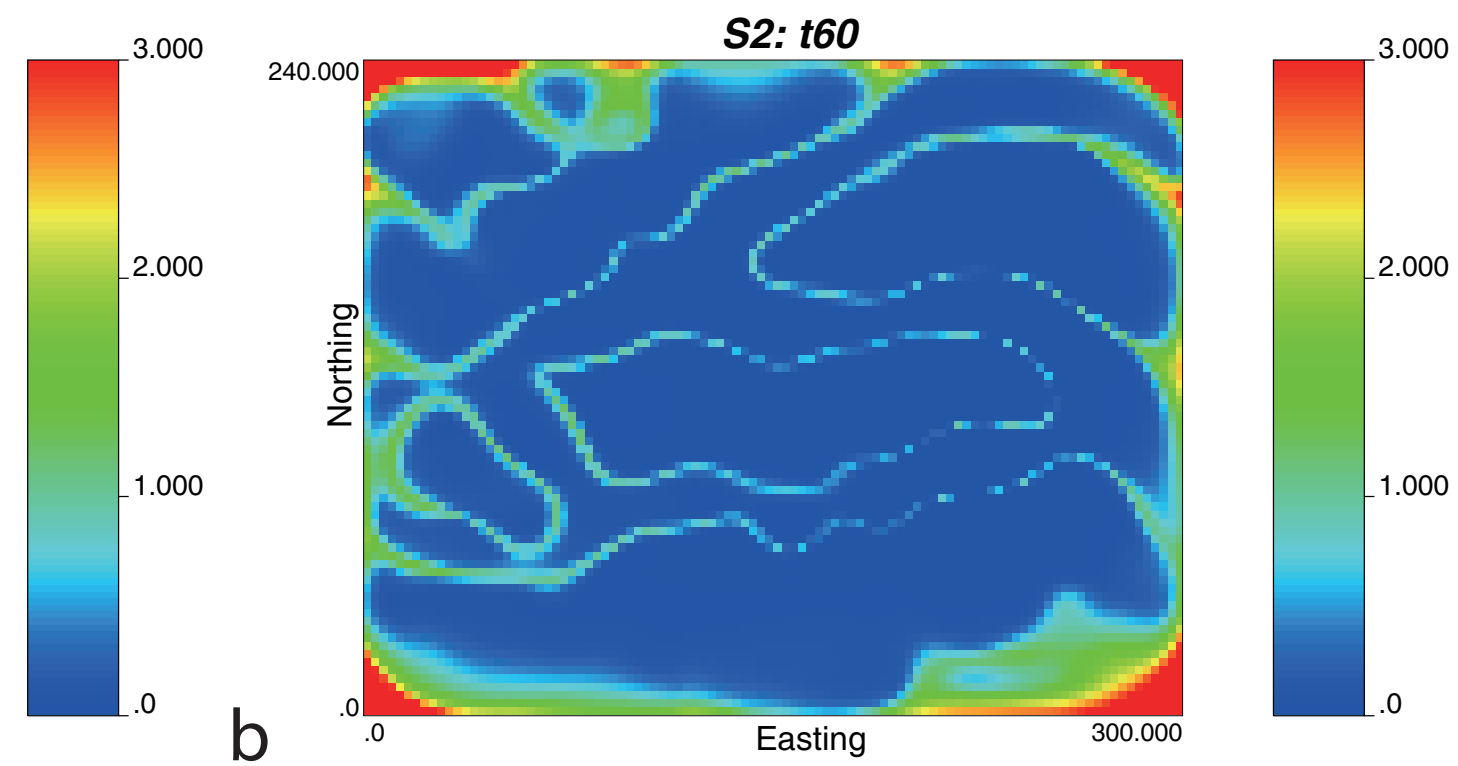
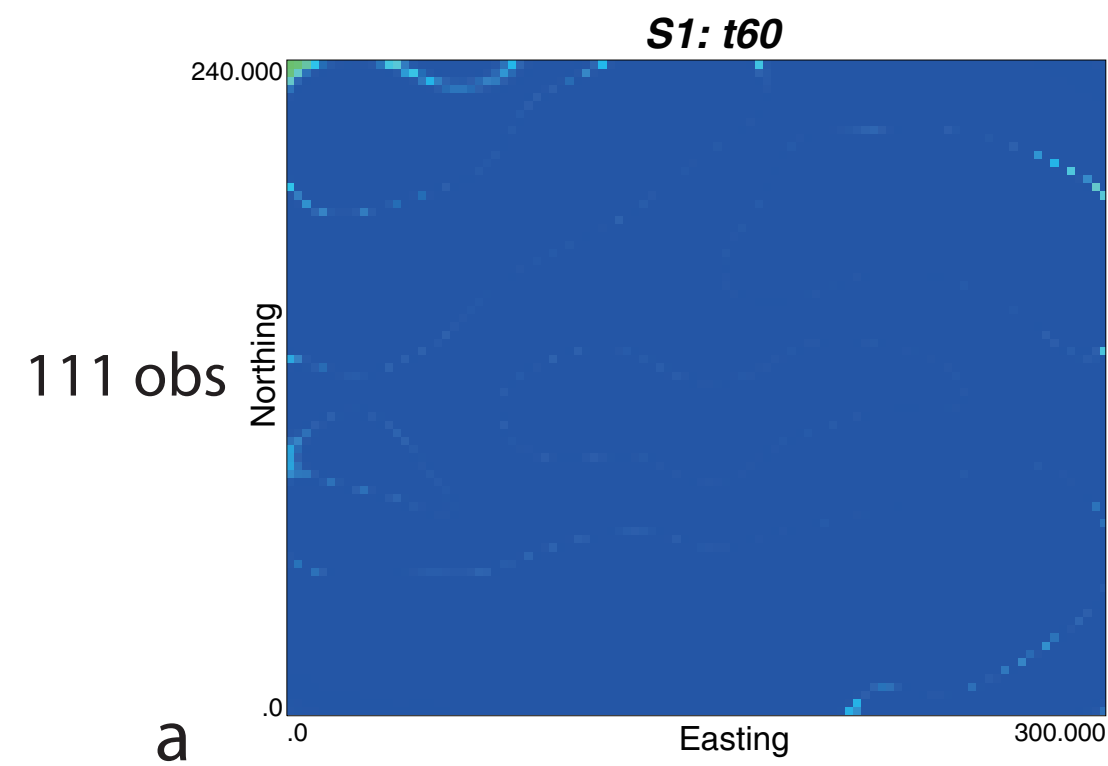
# Valencia - The Opera House

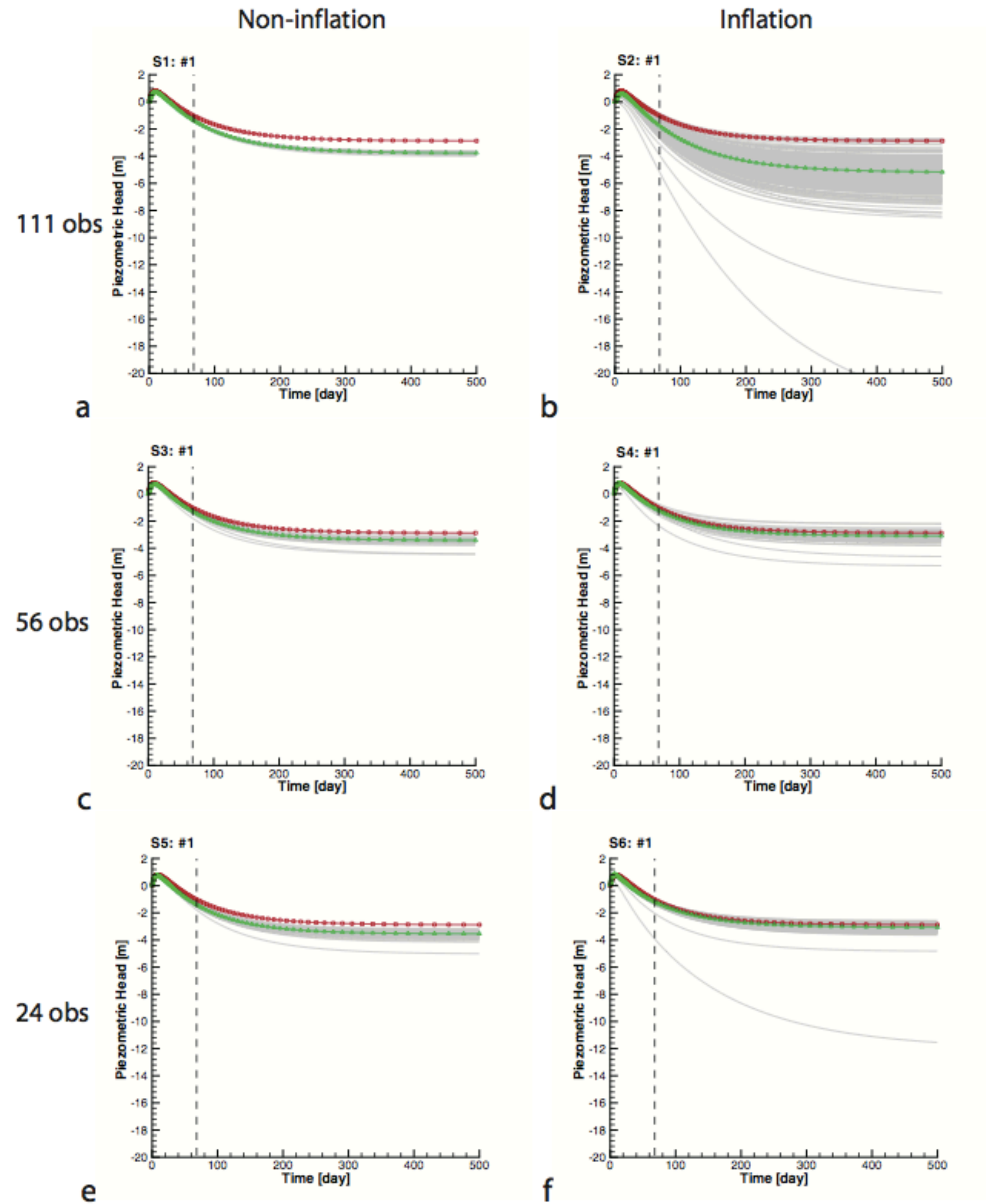




Non-inflation

Inflation





# Conclusions



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- A marginal transformation helps a lot
- Even if there are not hard data
- There is lot of info in the transient heads
- I am not a normal guy

# Marginally non-Gaussian Inverse Stochastic Modeling

Zu, Gómez-Hernández, Hendricks, Li  
Adv. Water Res. 34(7), 2011  
<http://jgomez.webs.upv.es>

# It is Normal Not to be Gaussian

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# Fully non-Gaussian Inverse Stochastic Modeling

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[jgomez@upv.es](mailto:jgomez@upv.es)  
<http://jgomez.webs.upv.es>

# A pattern-search-based inverse method

Zhou, Gómez-Hernández, Li  
Water Resour. Res., vol. 38, 2012  
<http://jgomez.webs.upv.es>



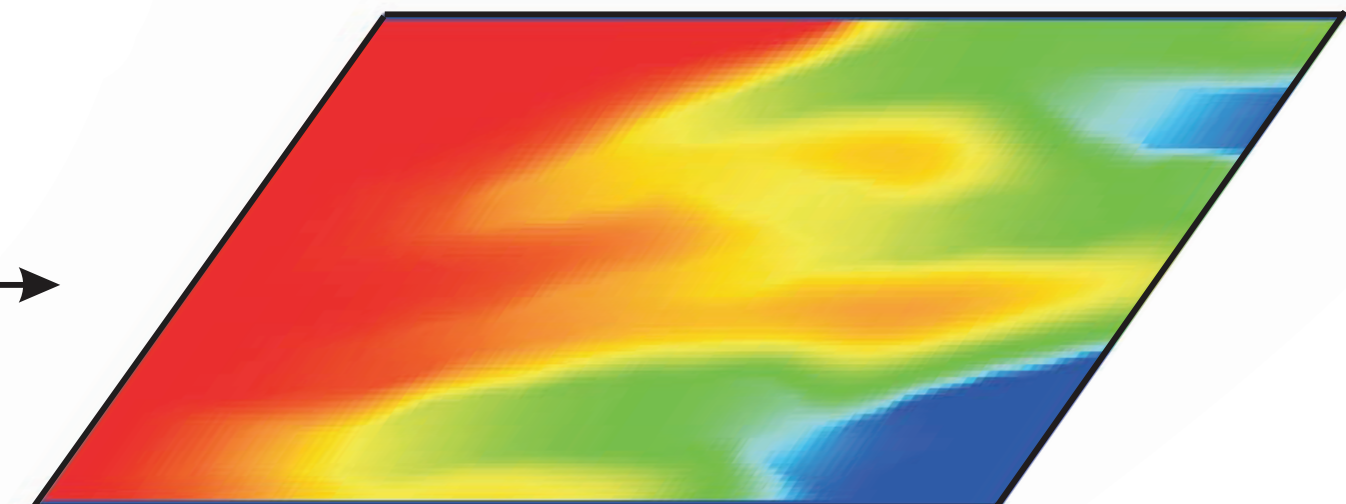
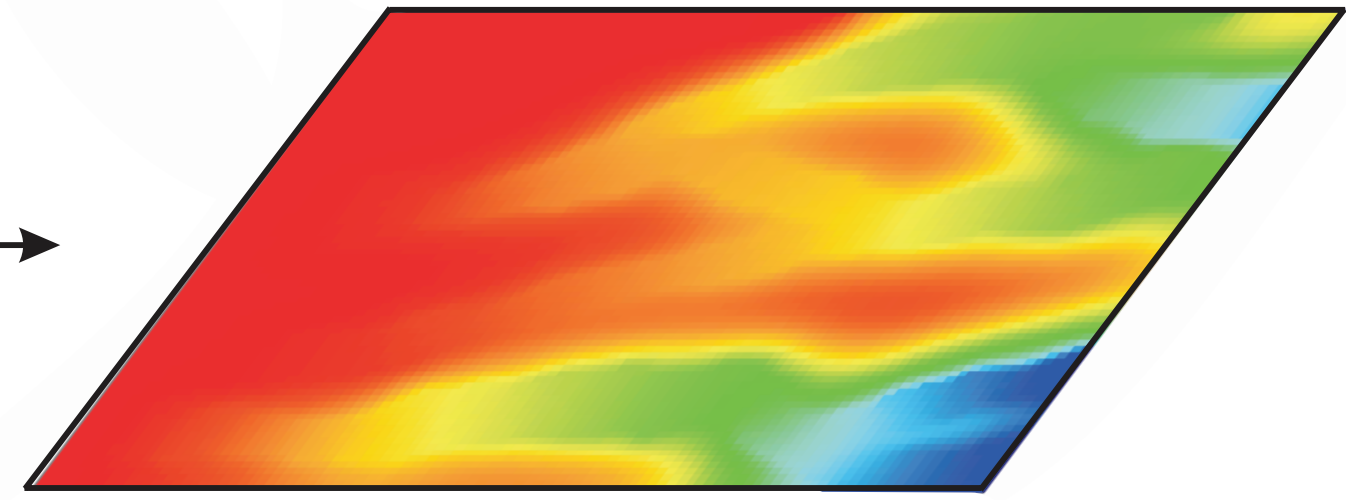
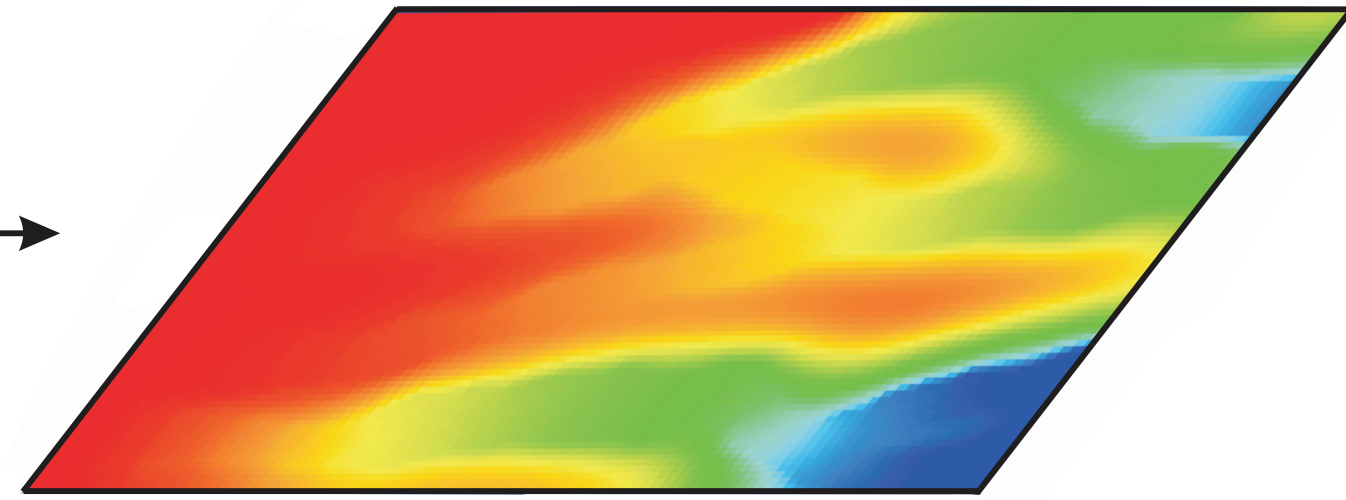
# Replace cokriging

- Try to use multiple point geostatistics to capture higher-order statistics
- We do not have a training image of forecast errors

K ensemble



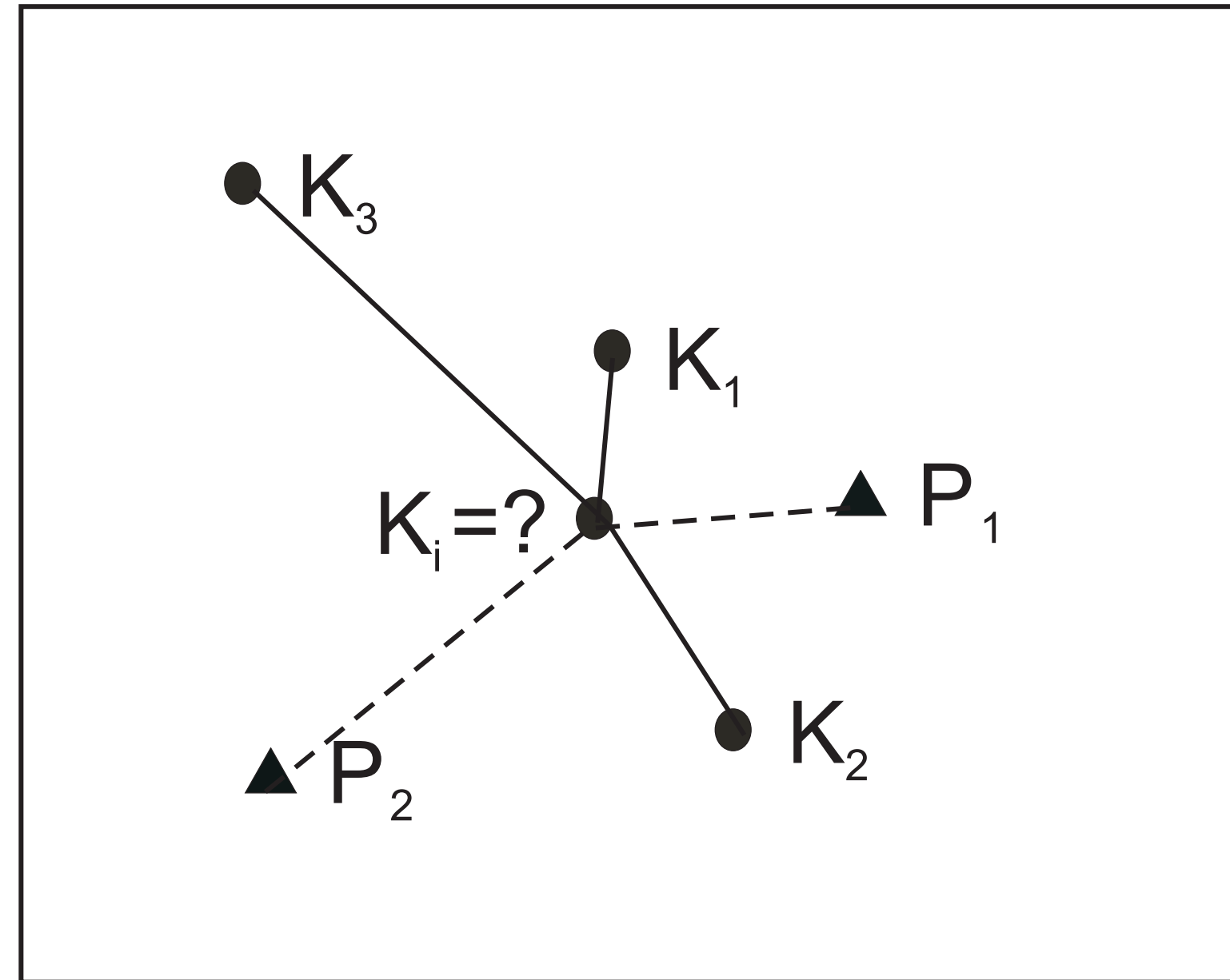
P ensemble

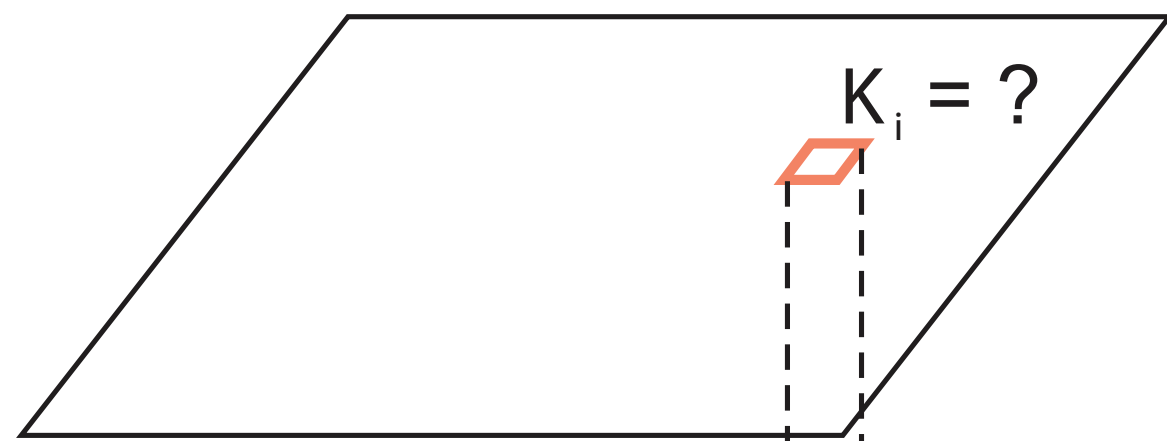


.....

# Multiple small training images

Look for a data event including both permeability and pressure in the ensemble of realizations

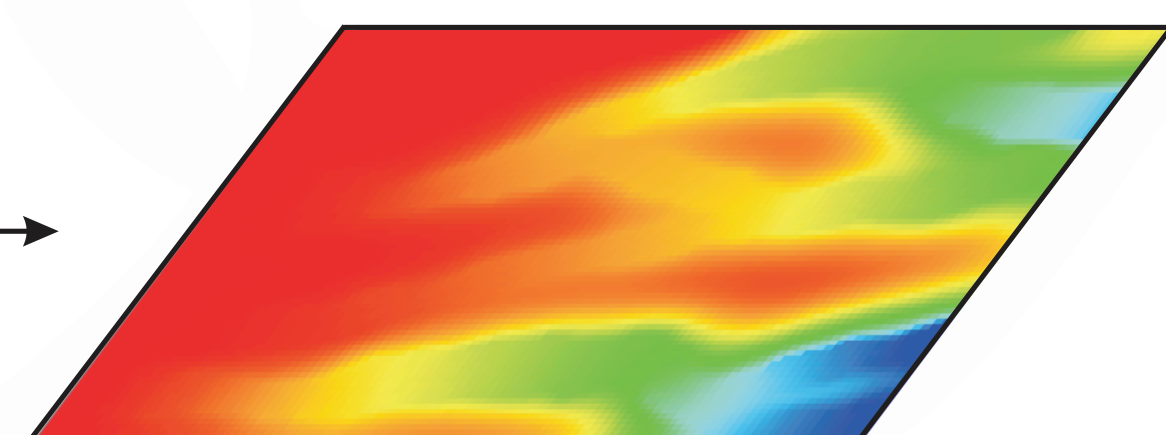
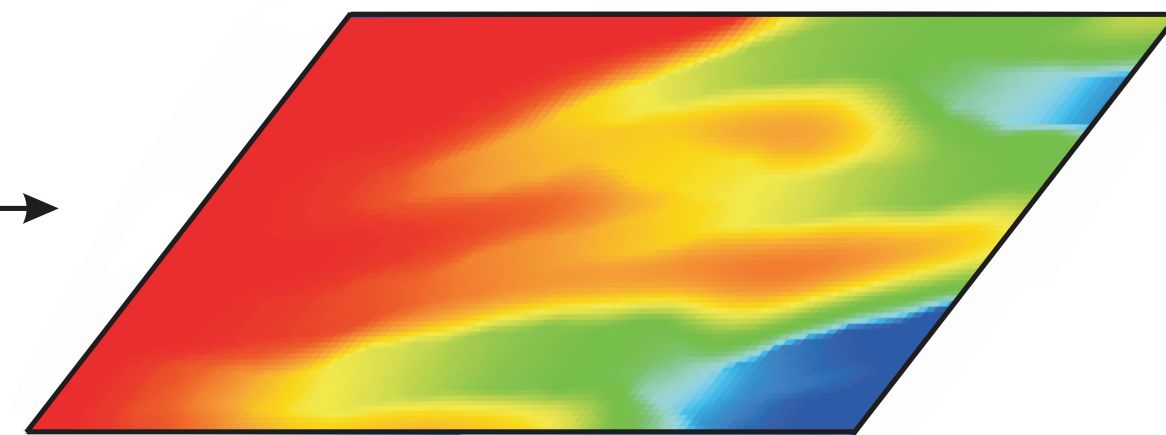


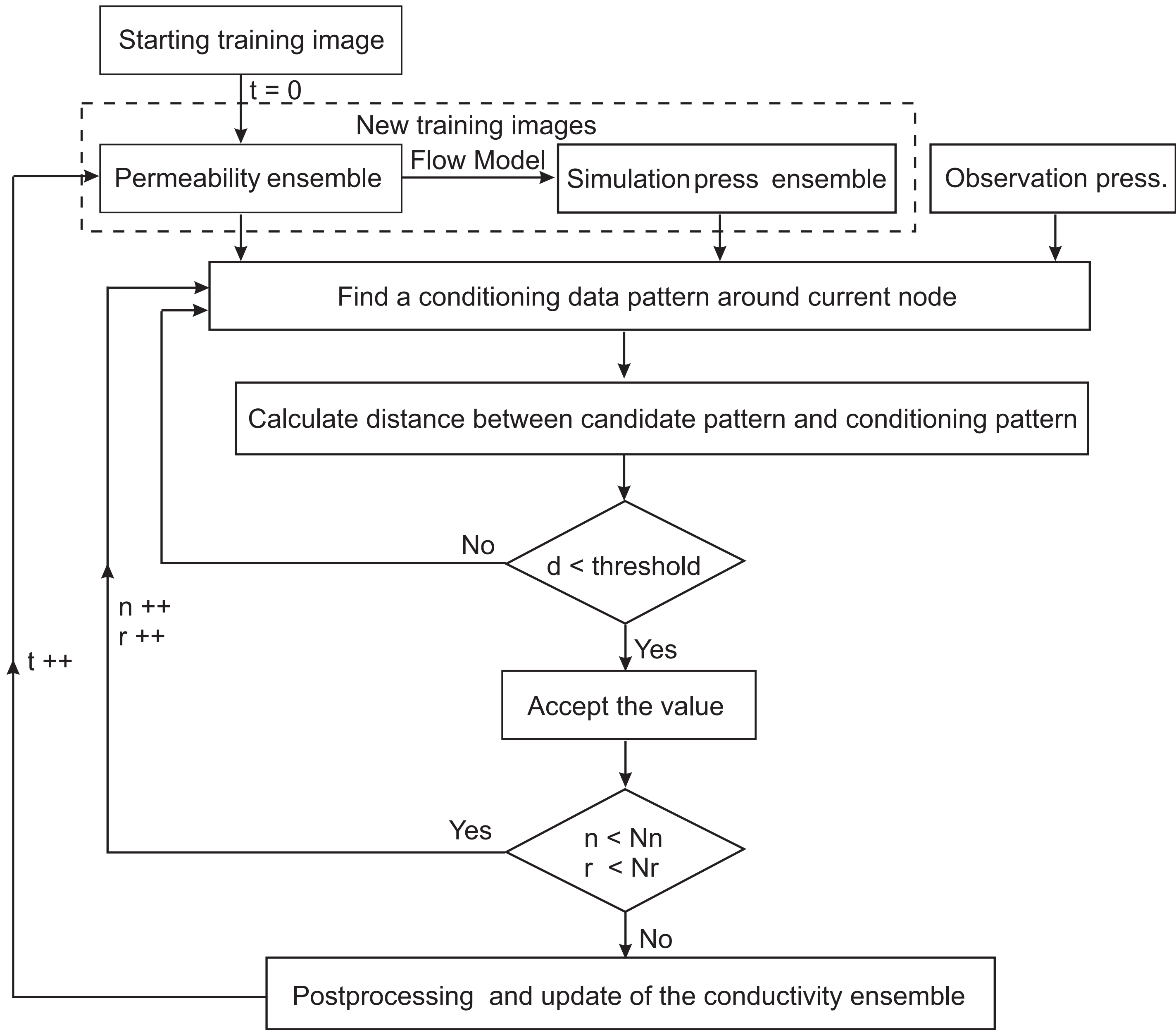


K ensemble

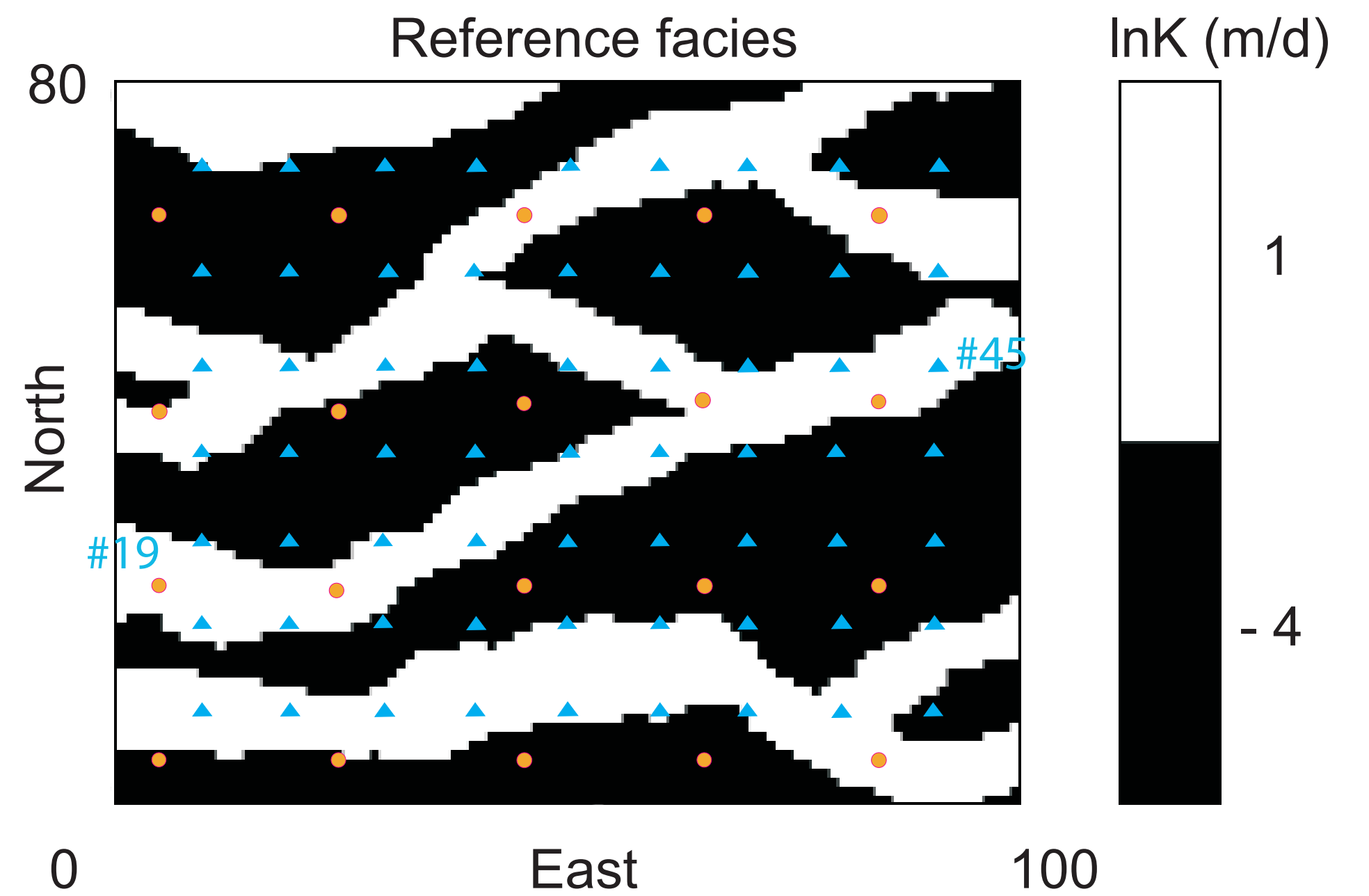
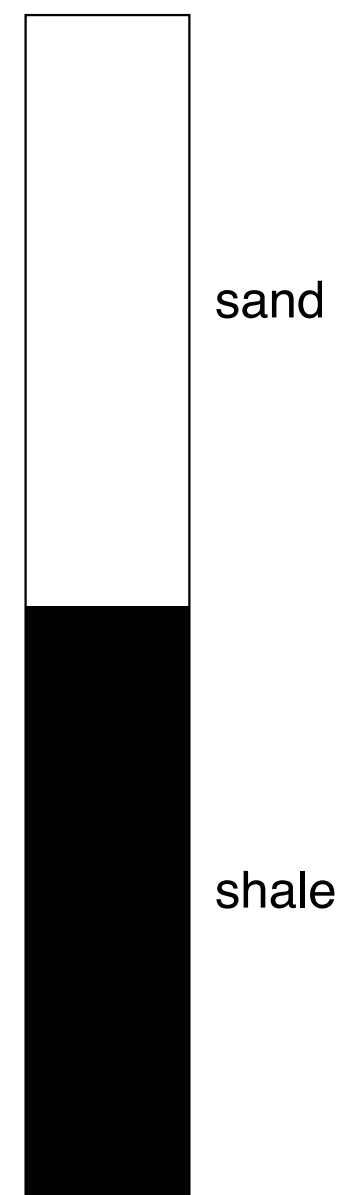
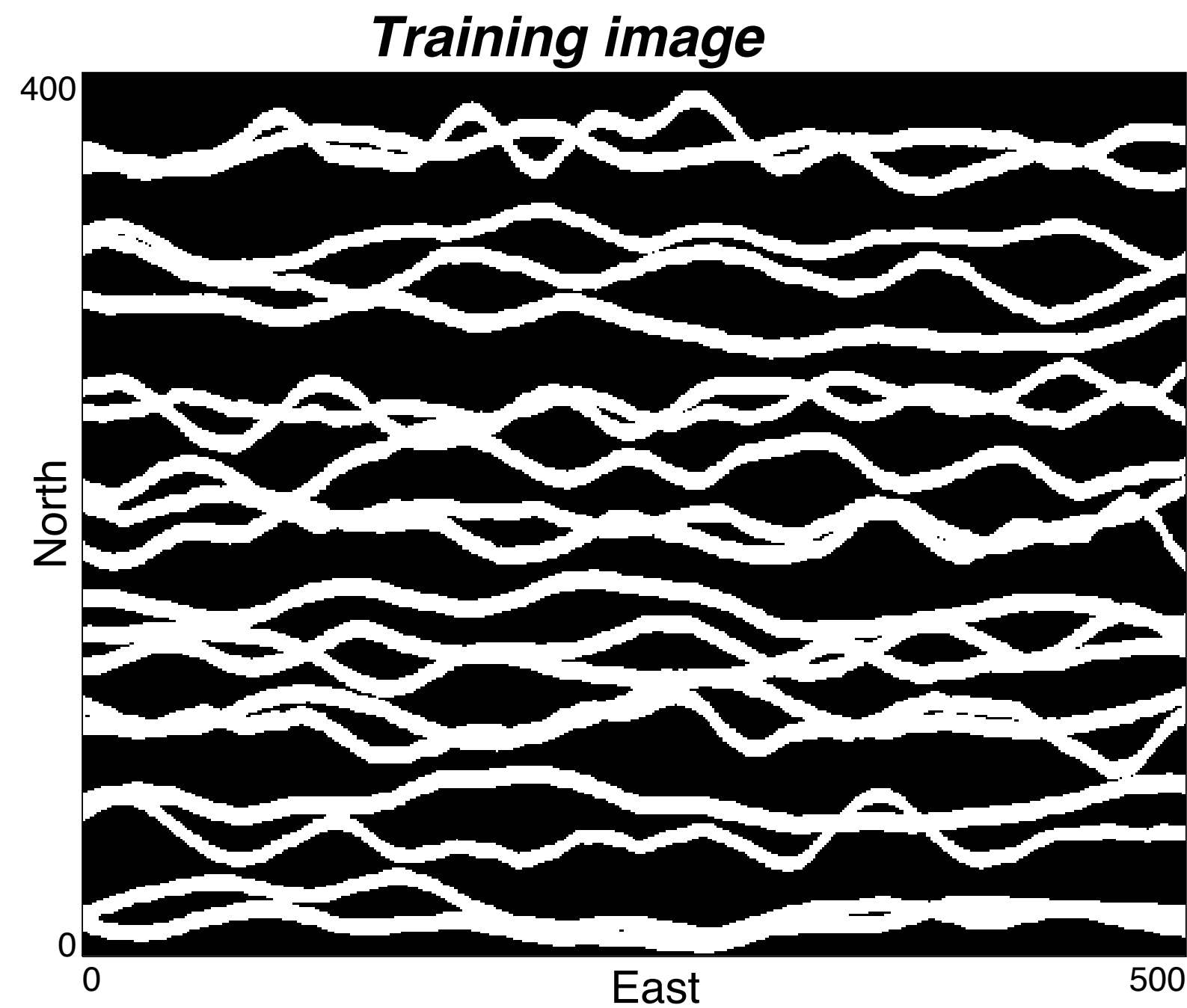


P ensemble

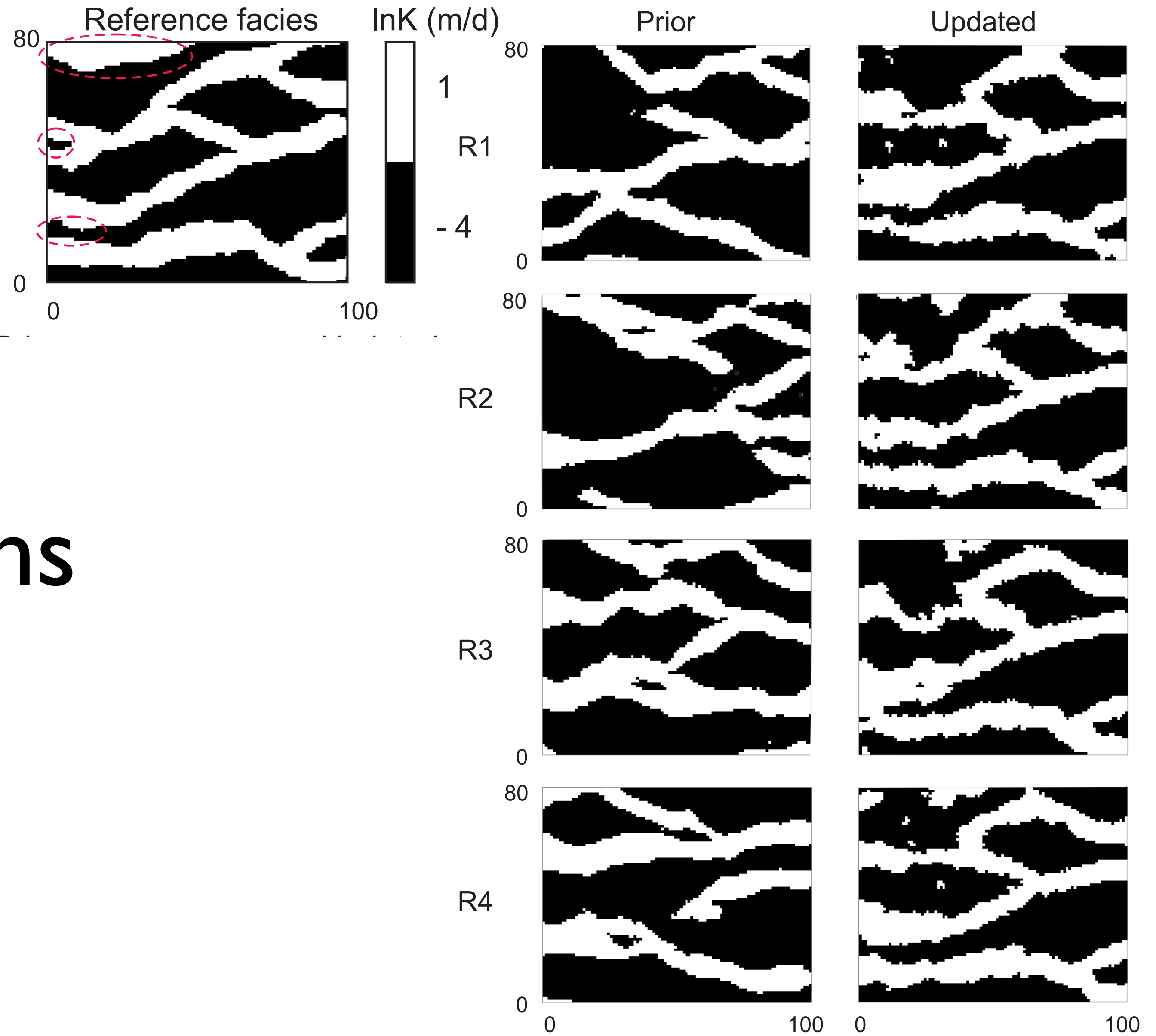




# Example



- Permeability measurement
- ▲ Pressure observation

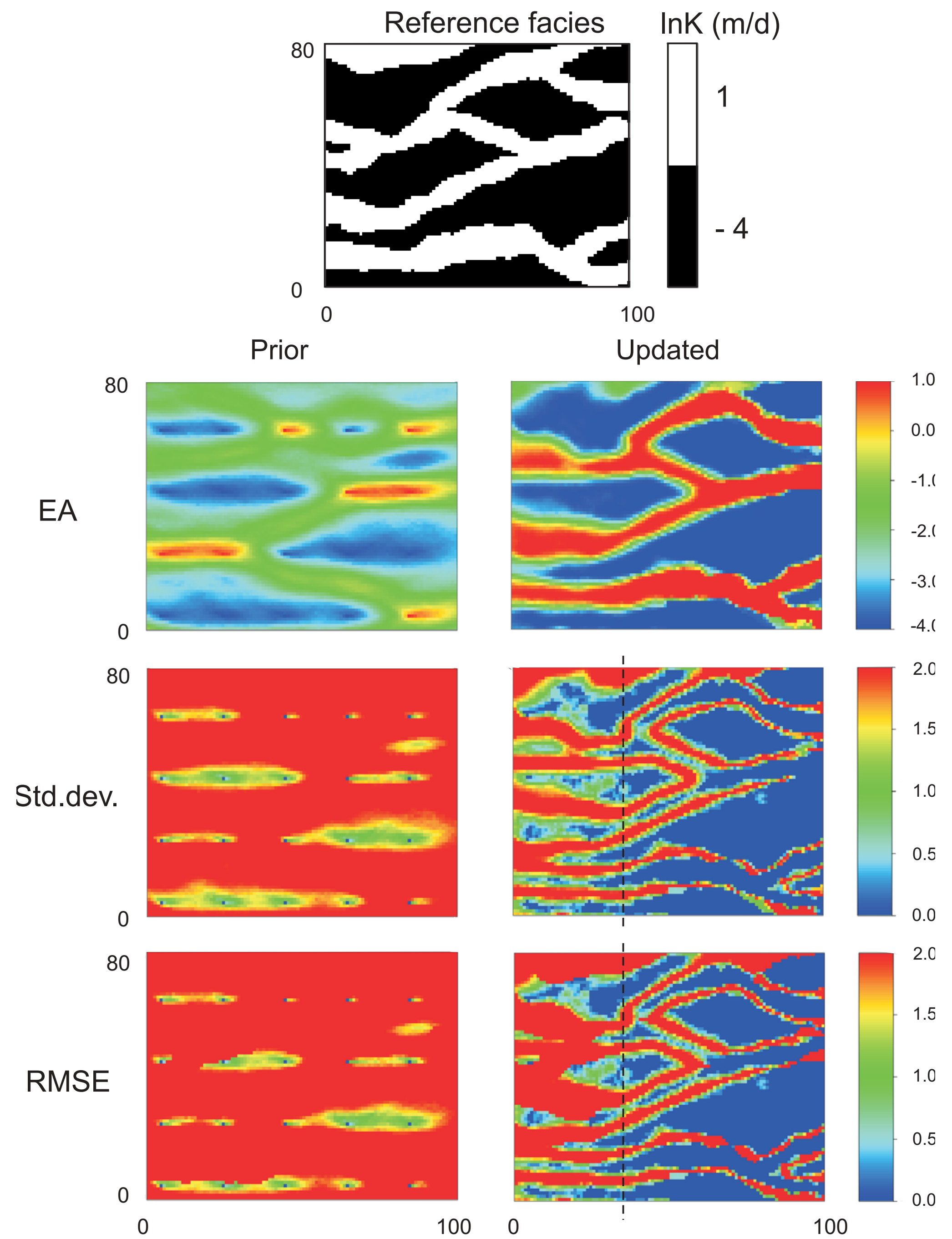


# Realizations

Prior vs. updated

# 500 realizations

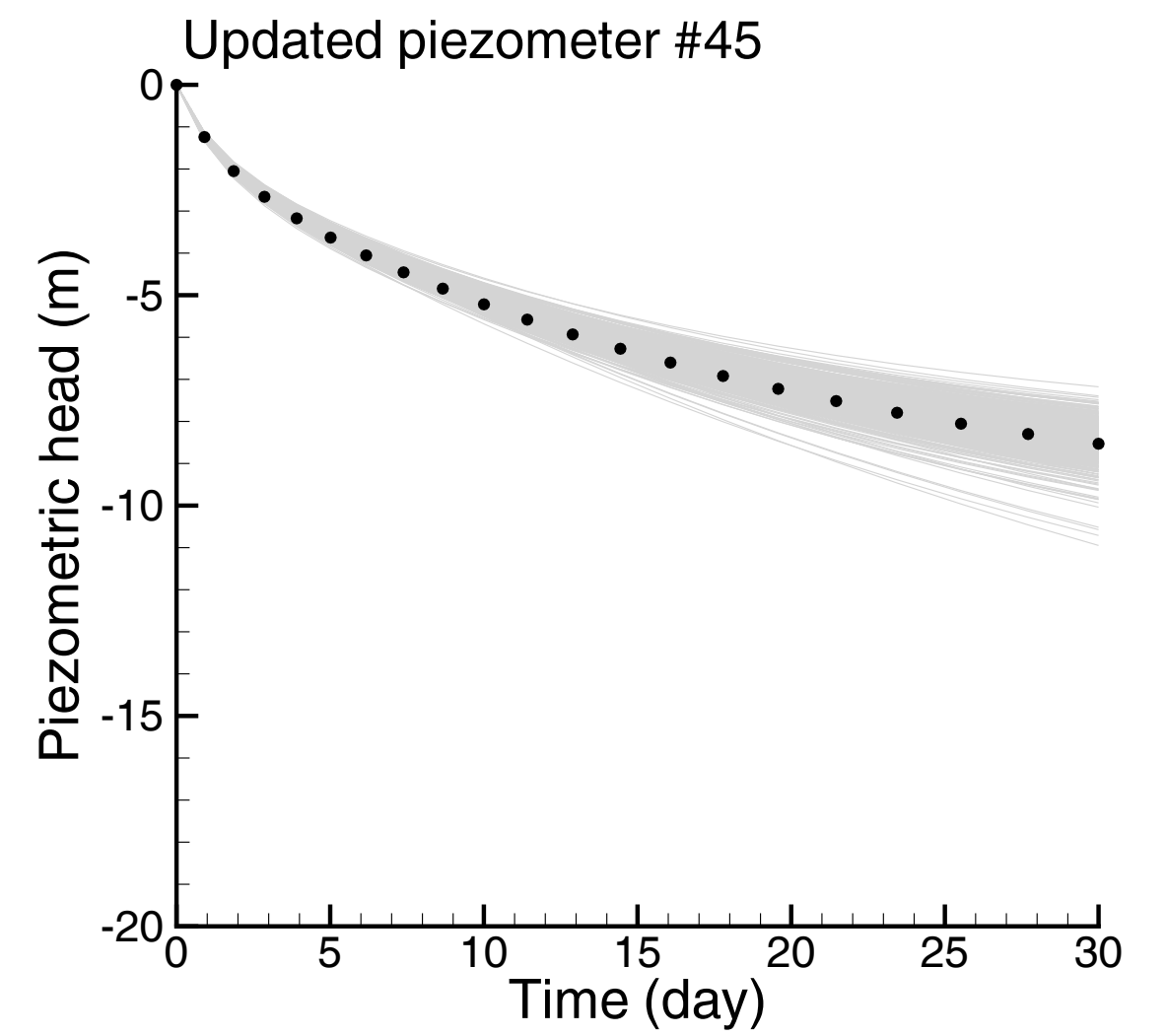
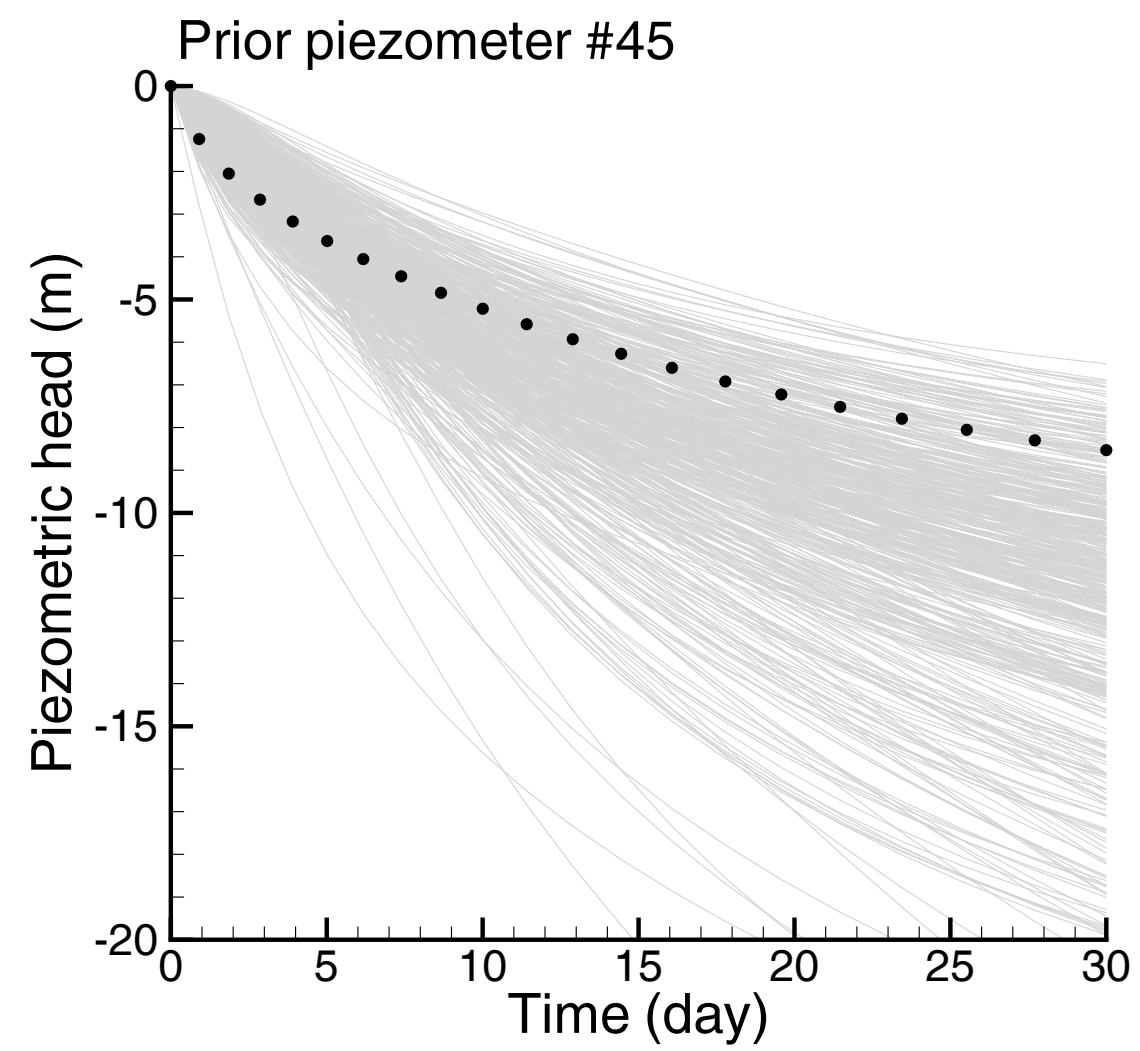
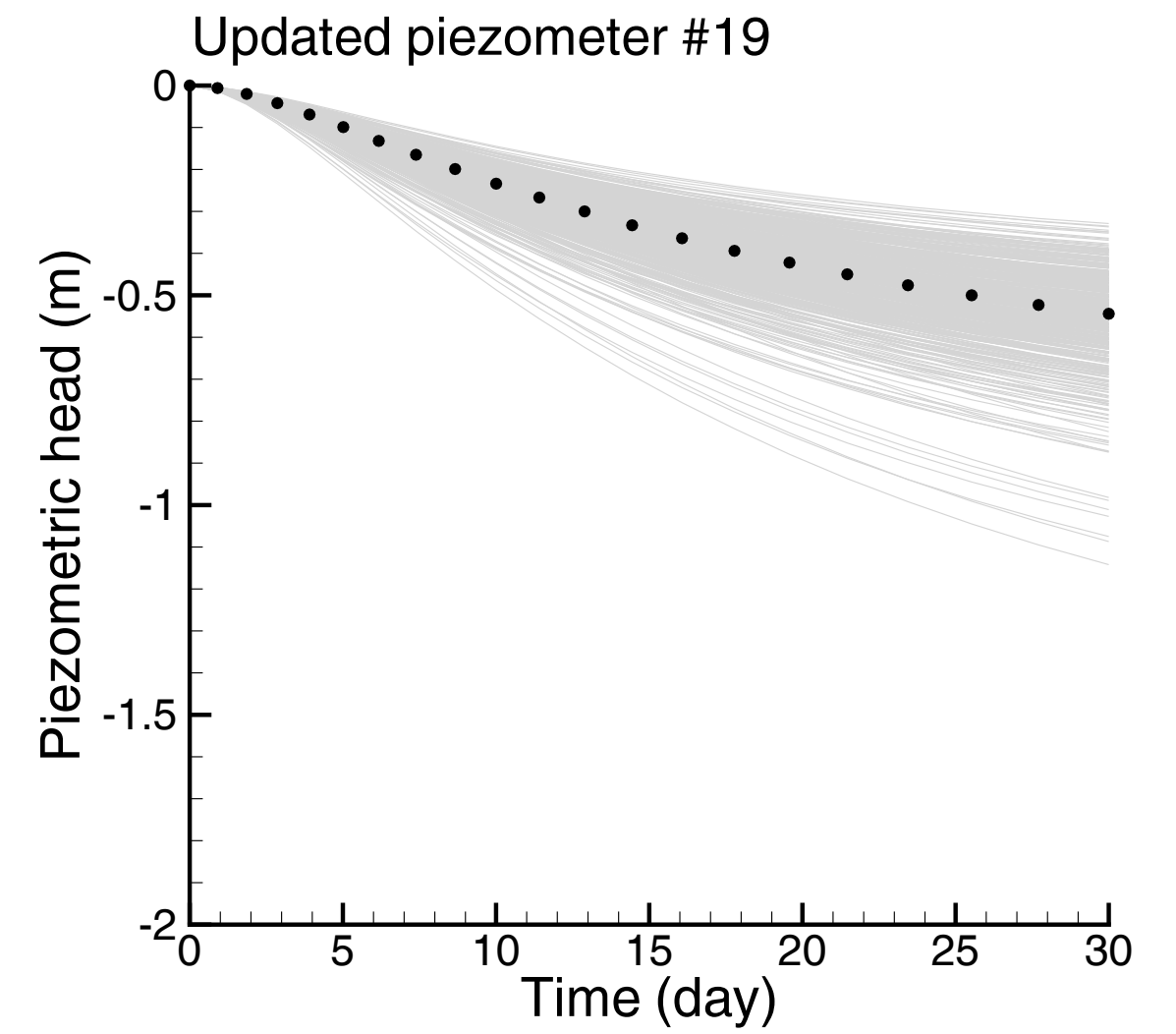
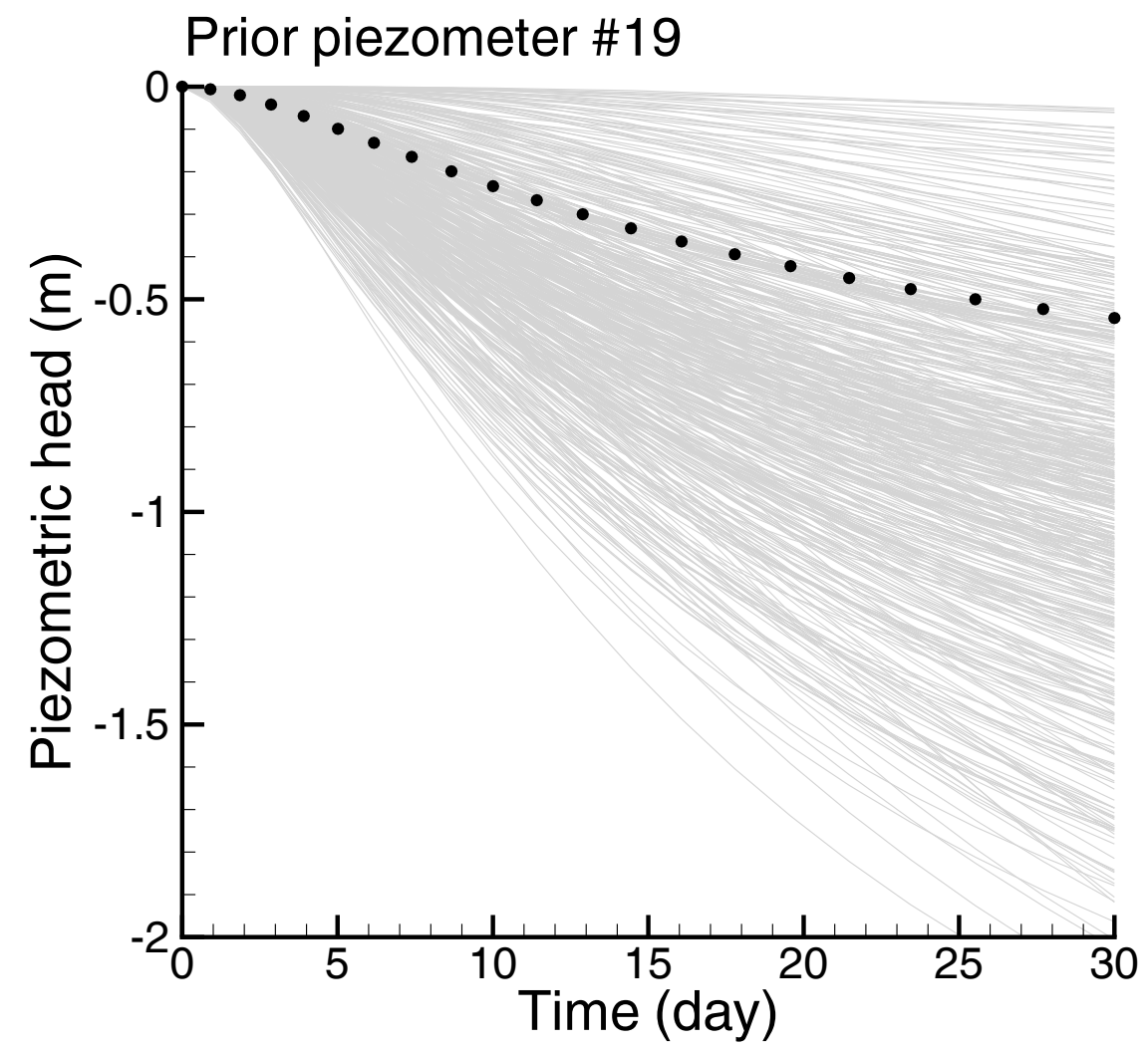
After 20 time steps





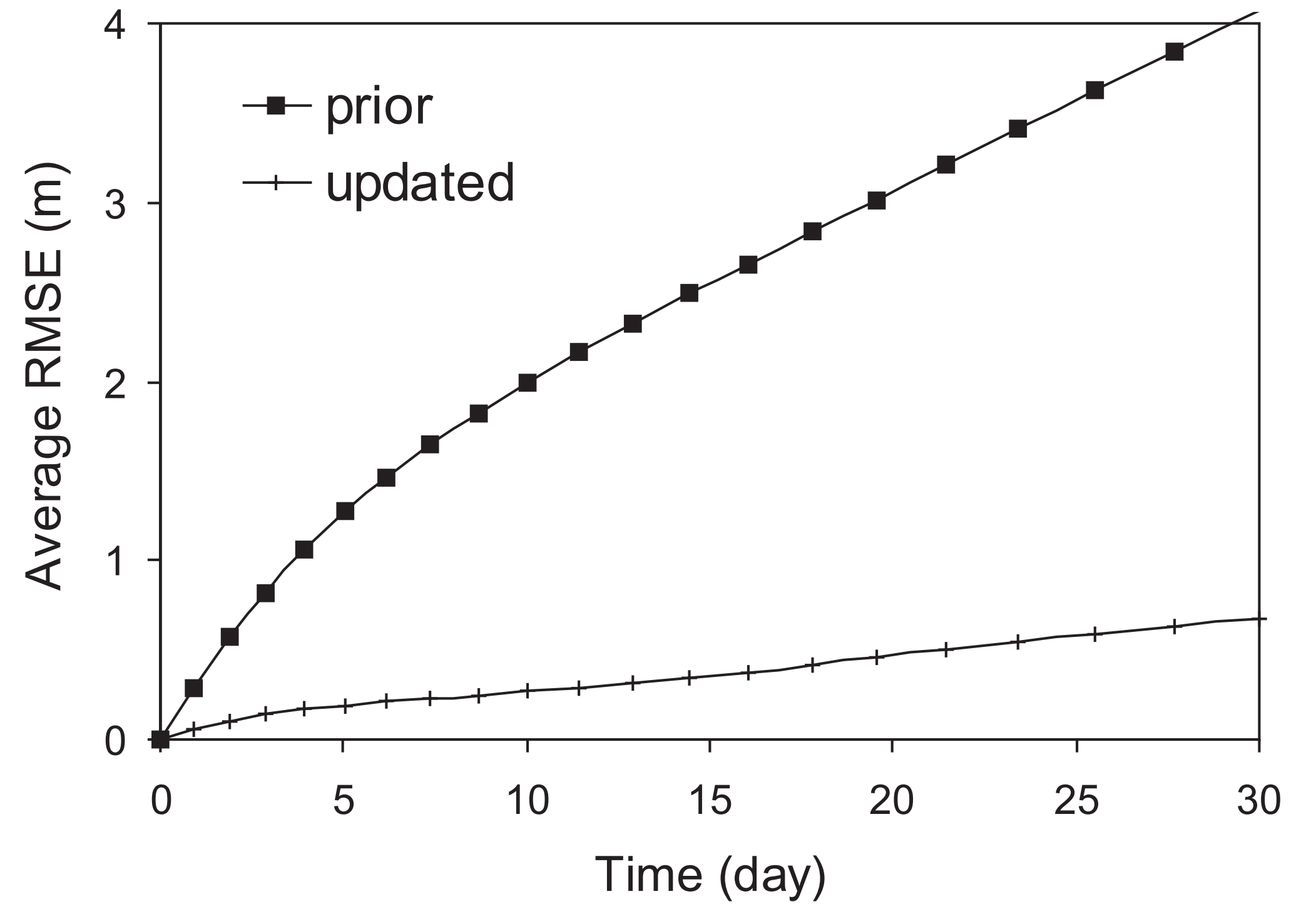
# Pressure

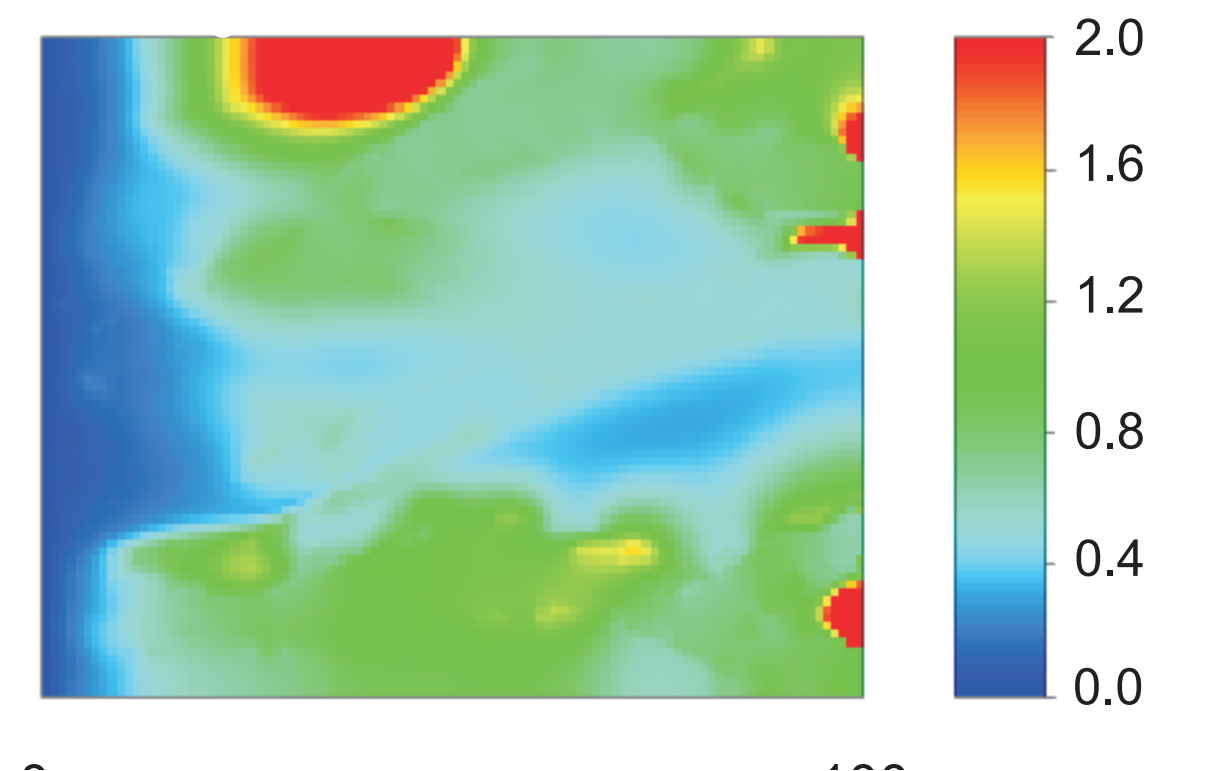
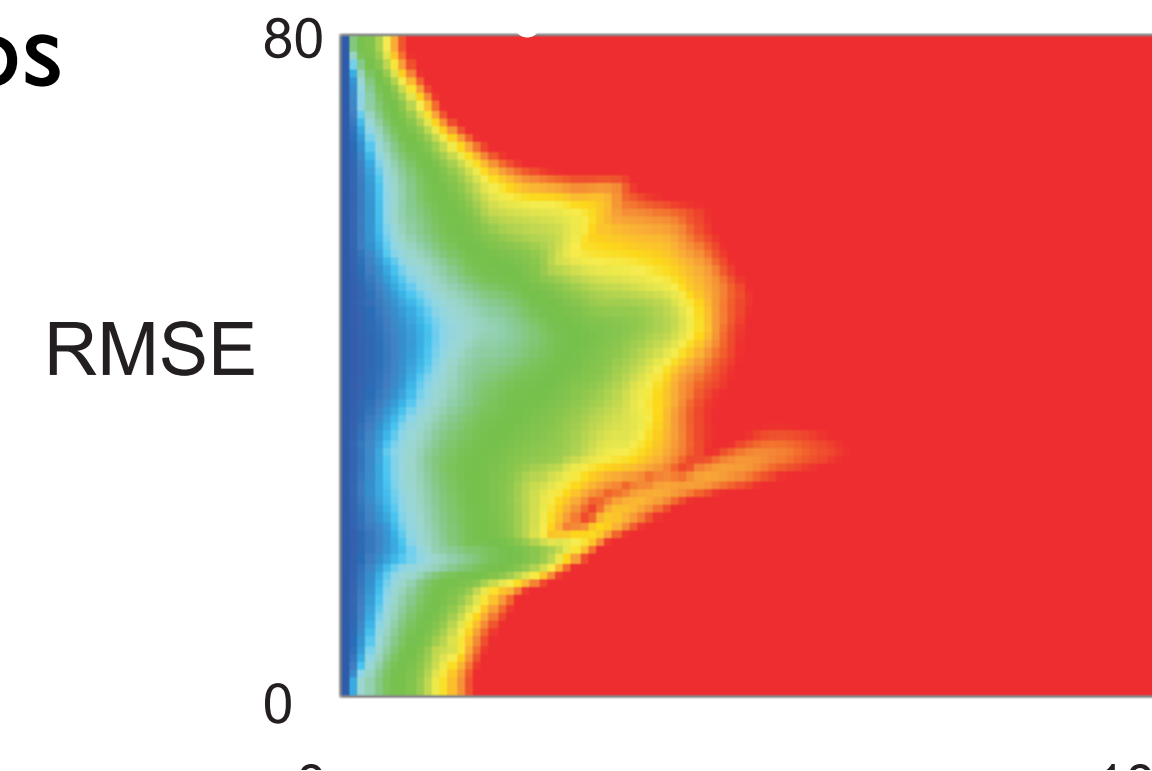
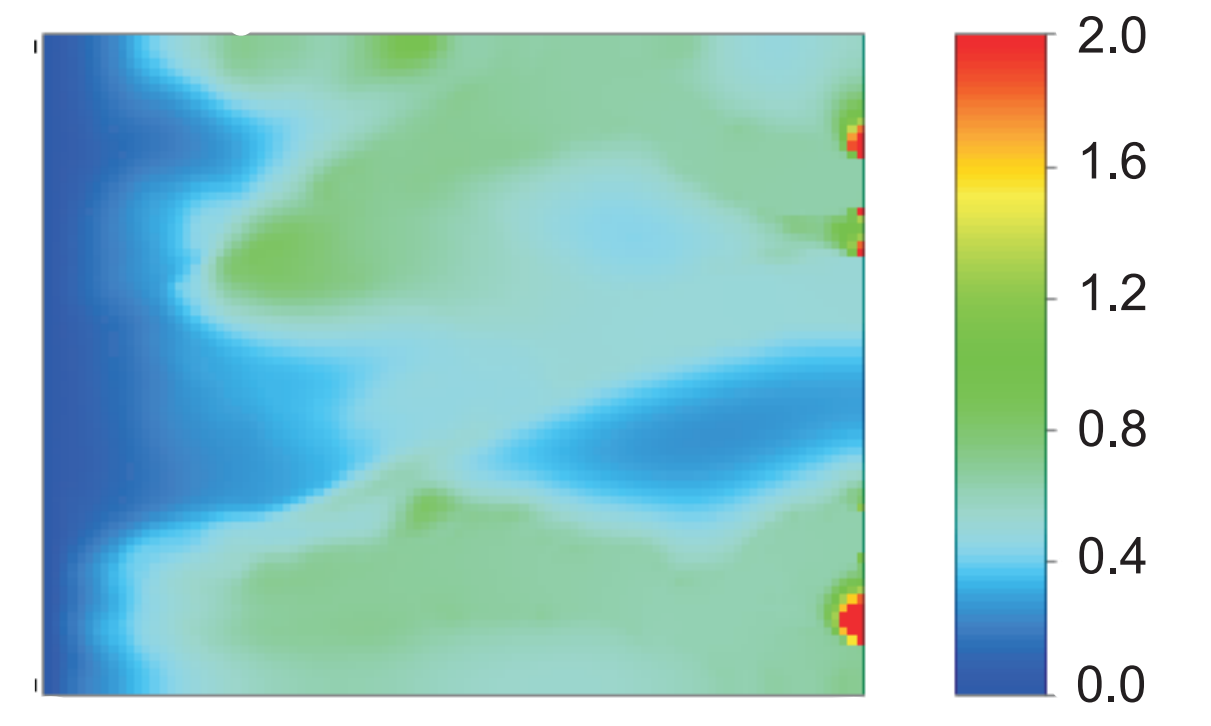
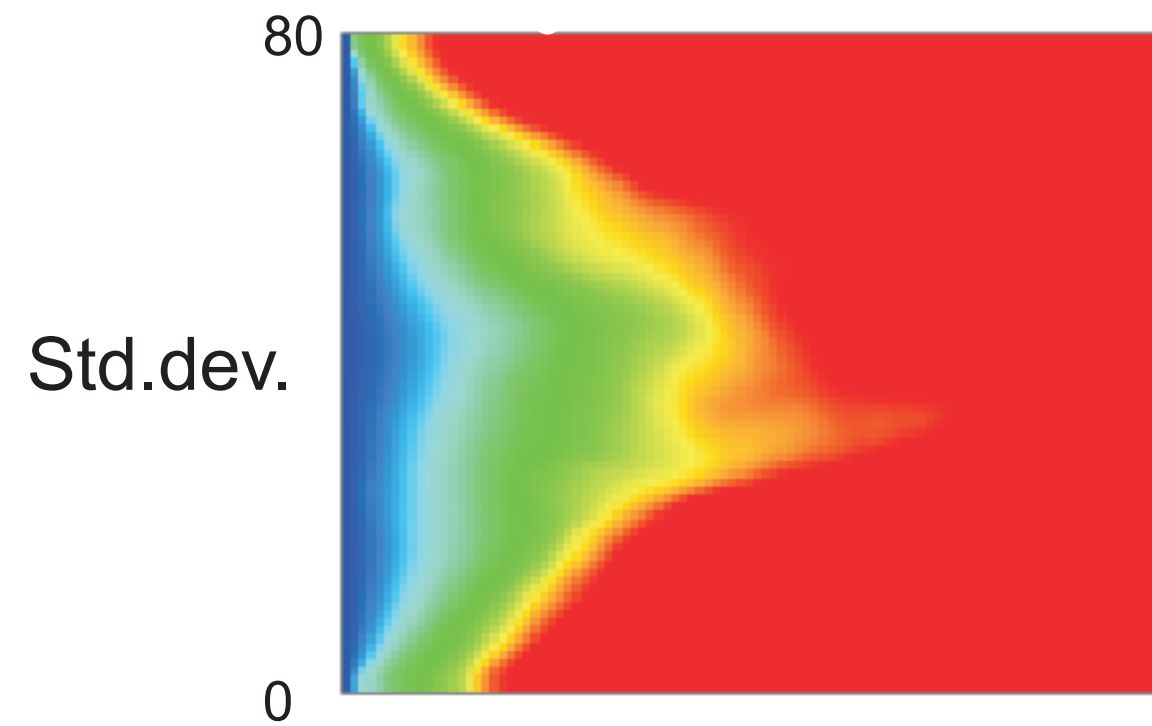
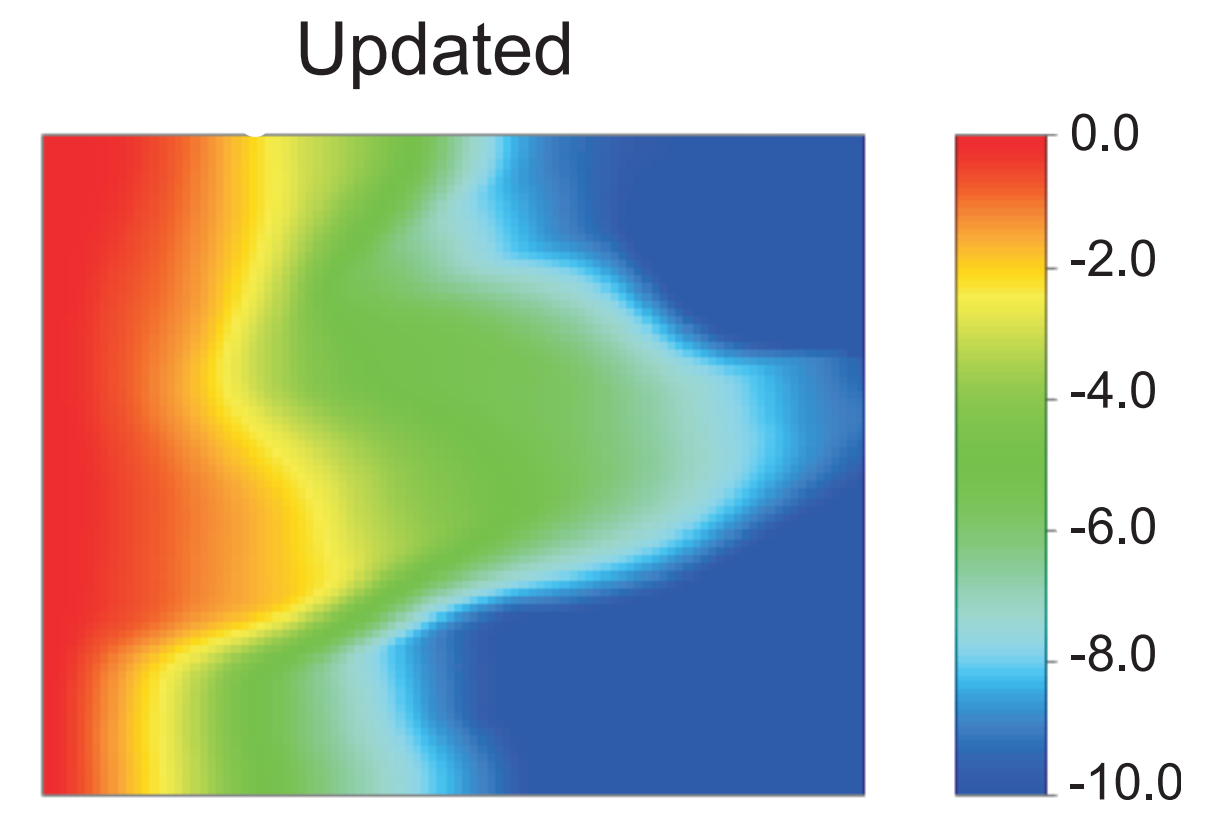
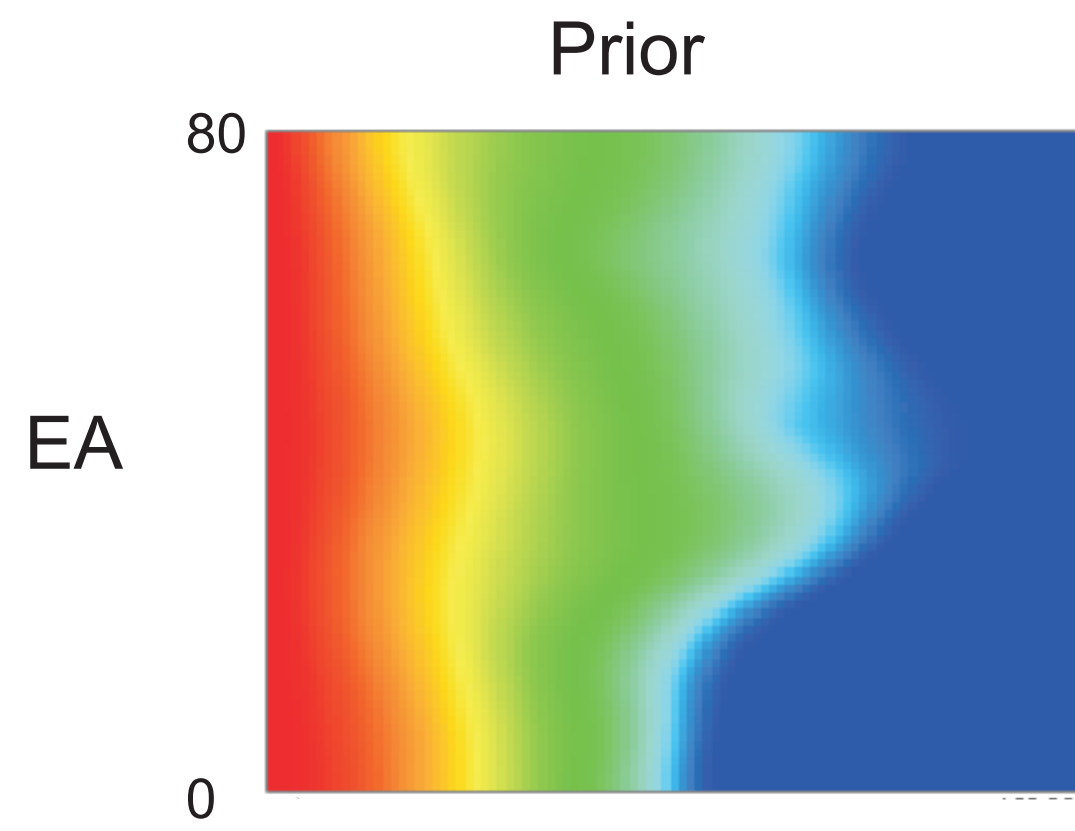
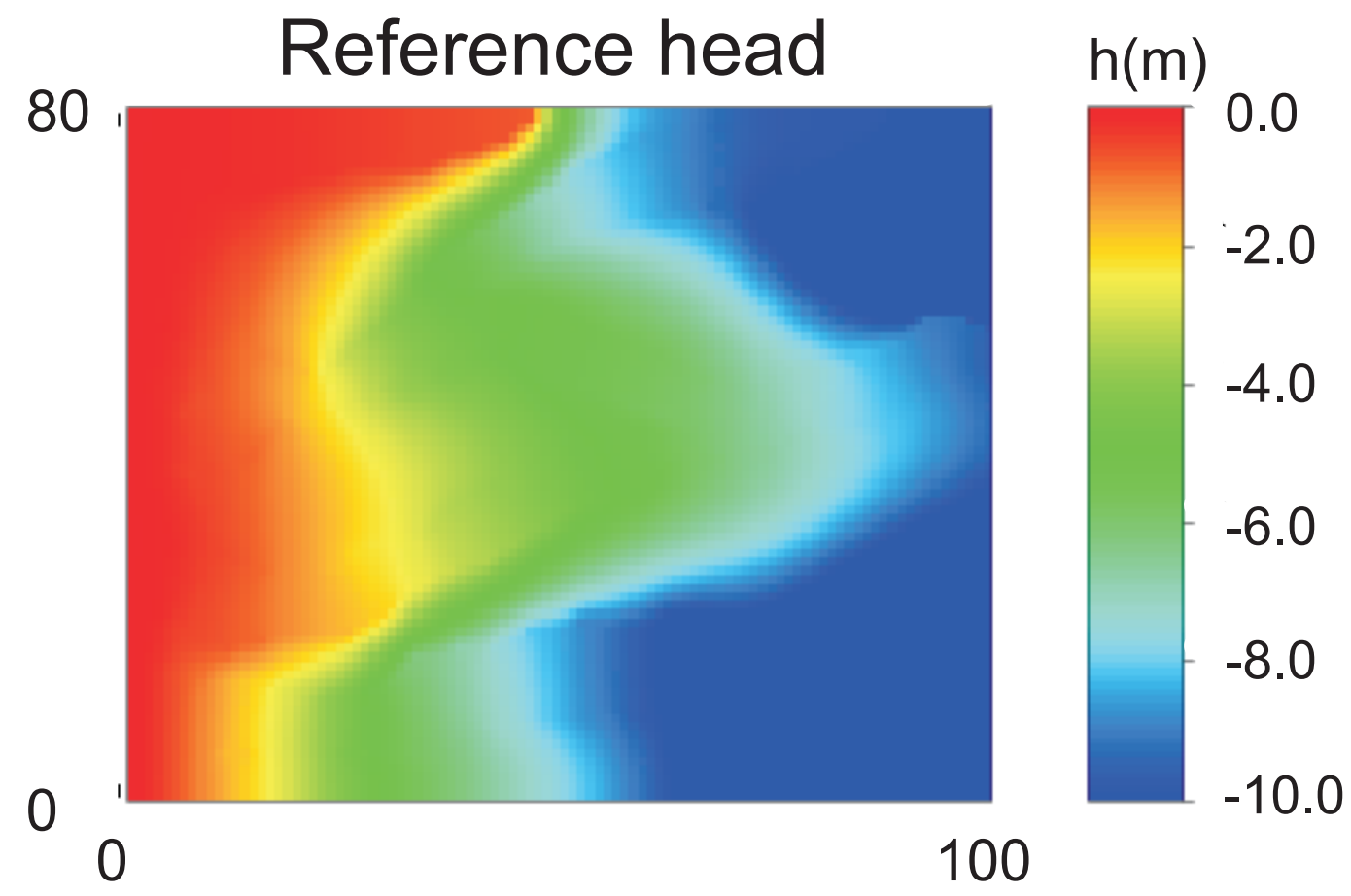
500 realizations after 20 time steps



# RMSE

500 realizations after 20 time steps



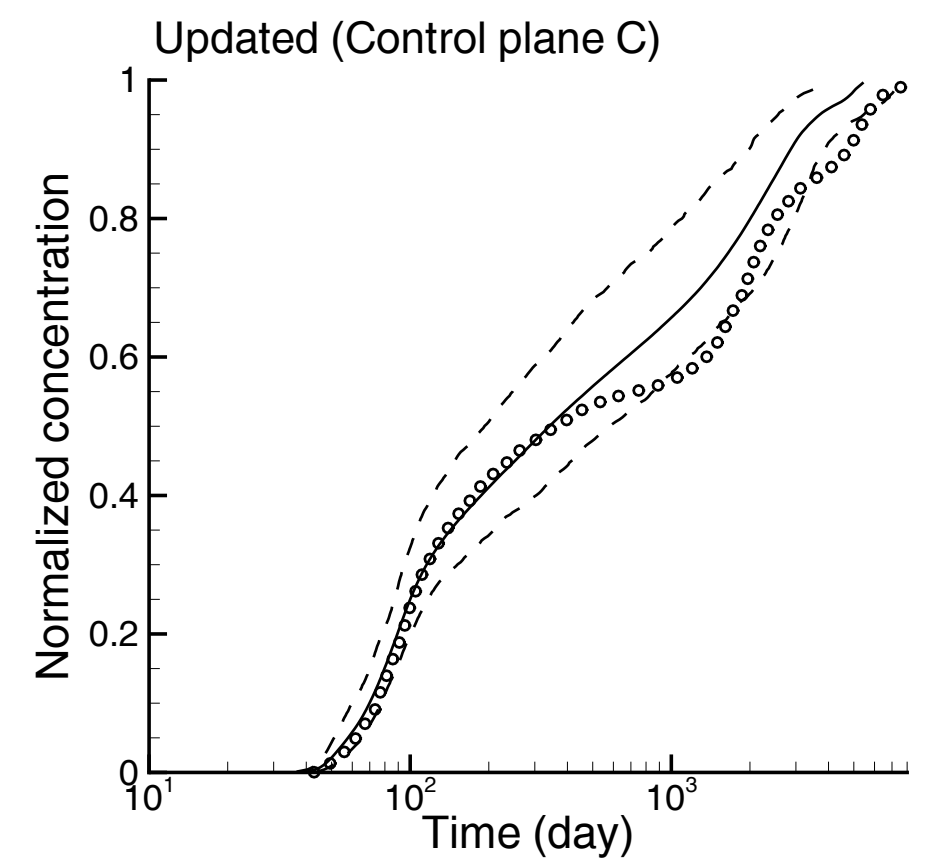
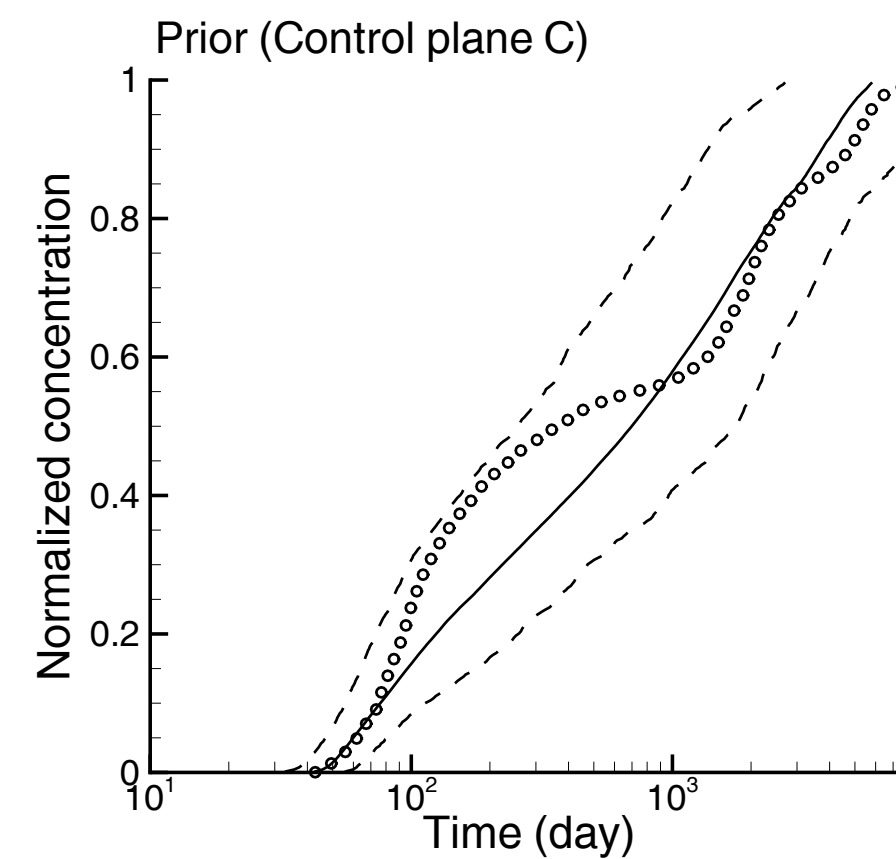
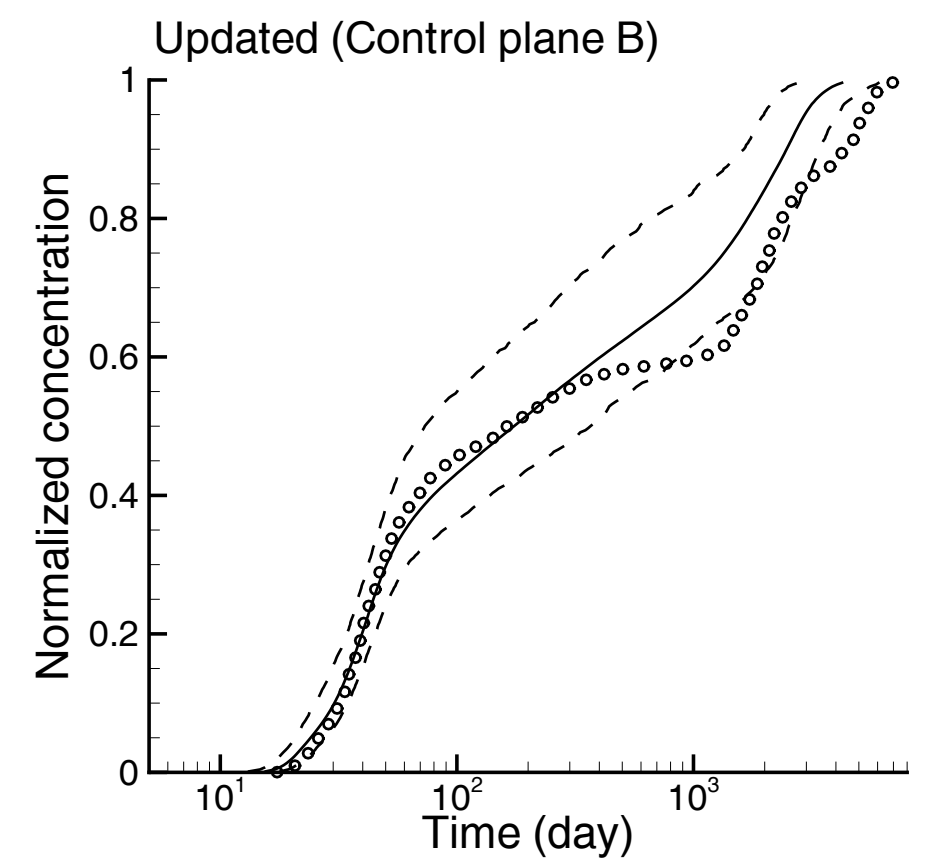
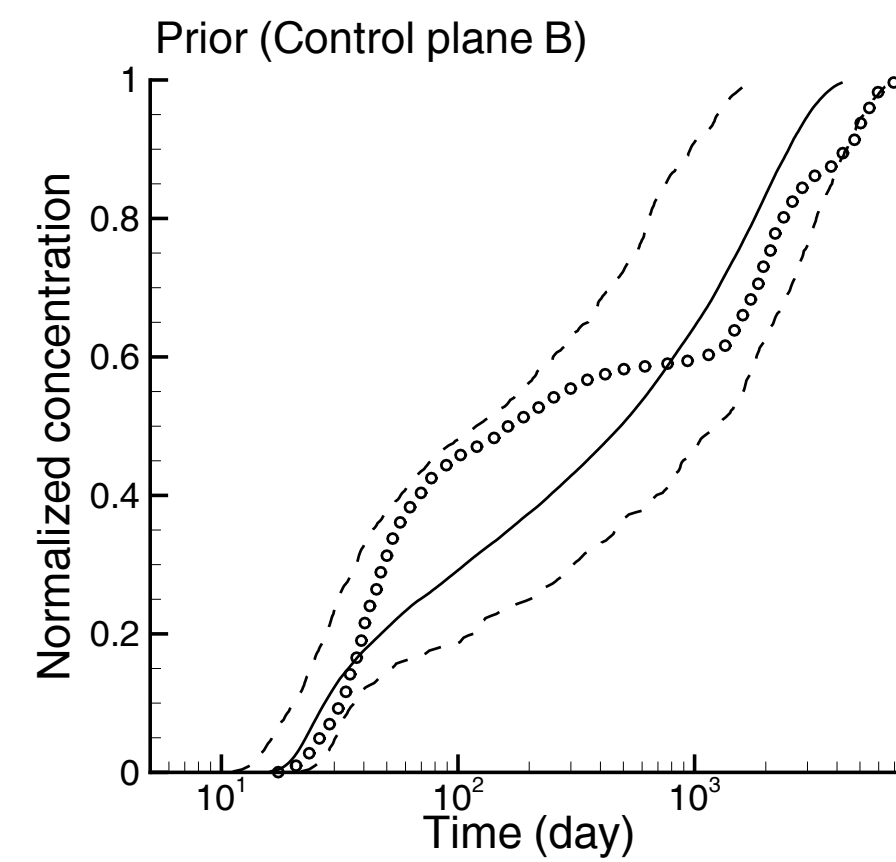
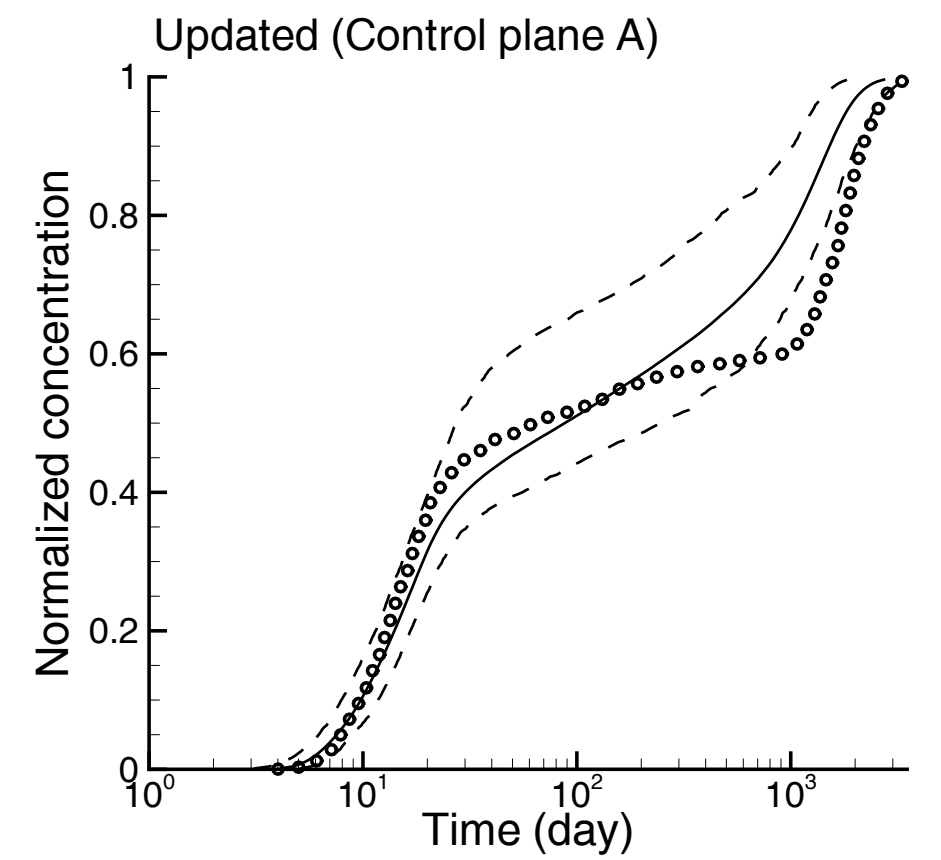
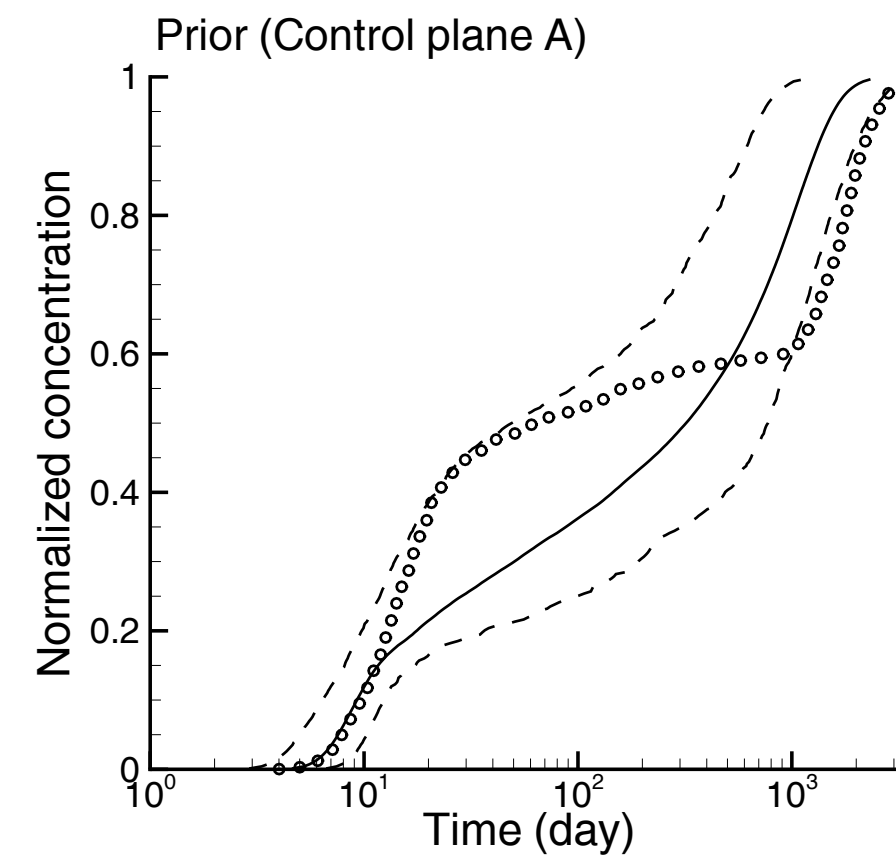


# Pressure

500 realizations after 20 time steps

# Fractional flow at 3 cross-sections

95% confidence intervals, median and reference prior vs. updated

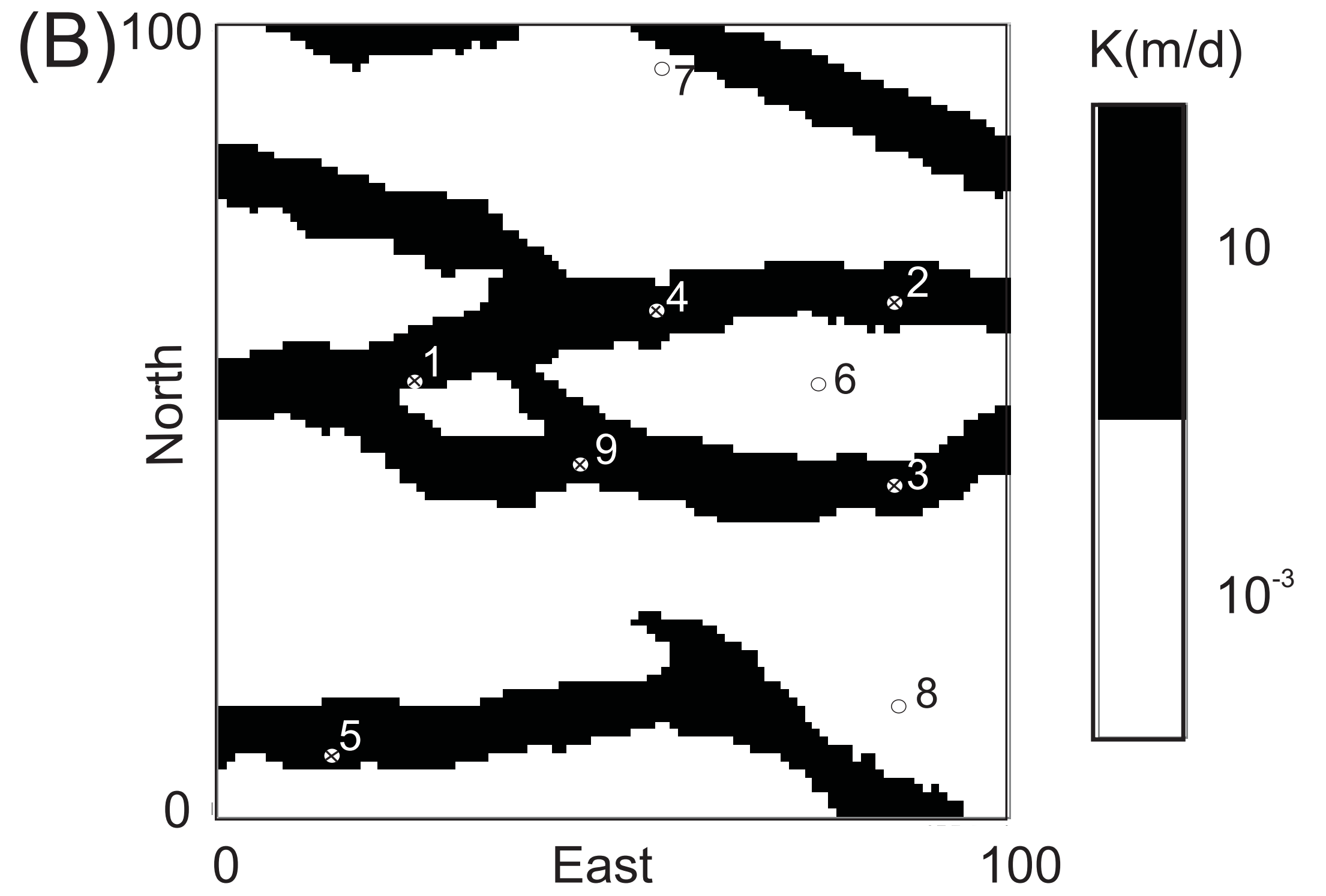
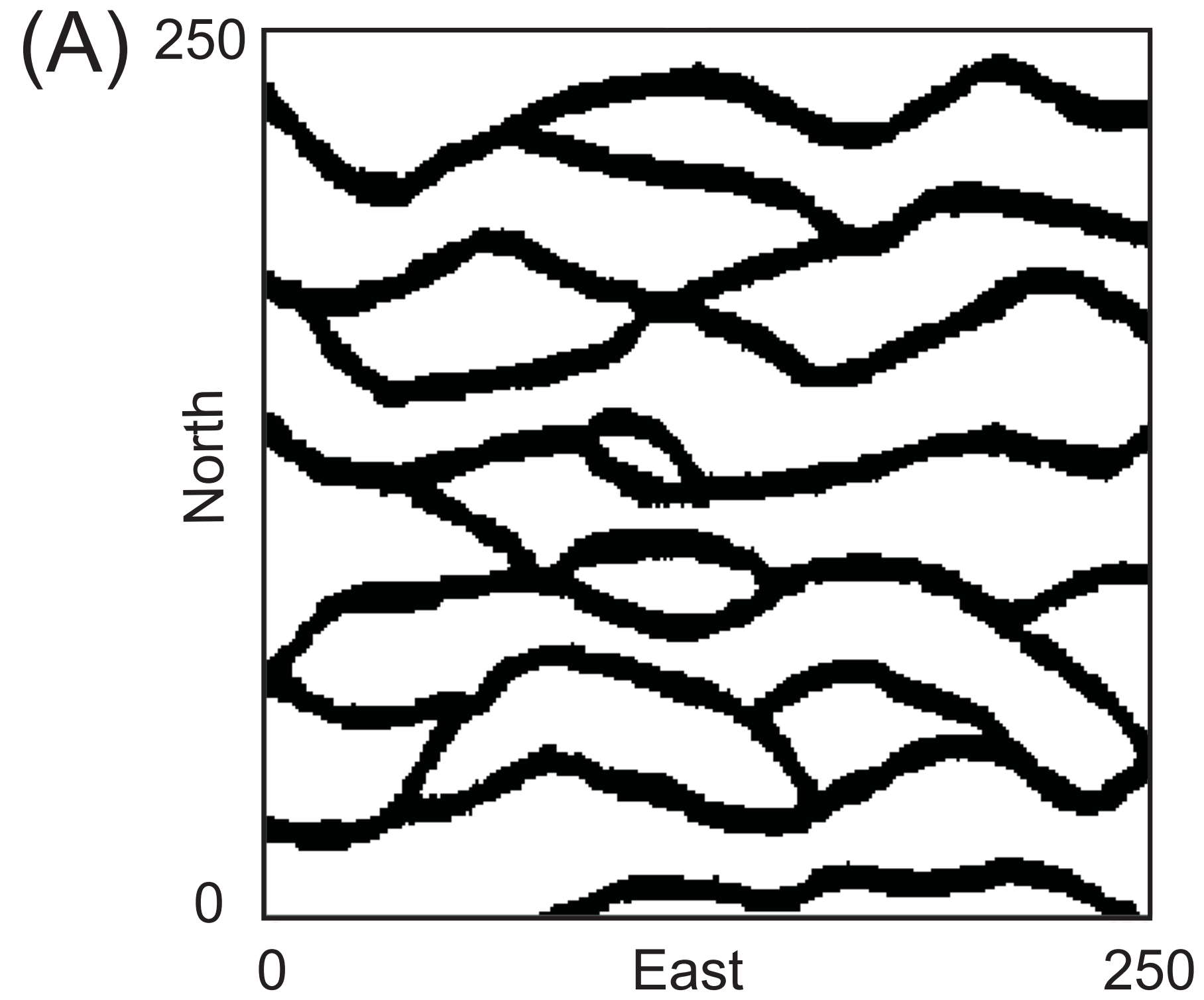


# Conclusions

- Method to include transient state data into multiple point simulation for history matching
- Including pressure in the data event requires considering the location in the updating
- Replace a large single training images by many smaller ones associated with a flow solution with wells and boundary conditions

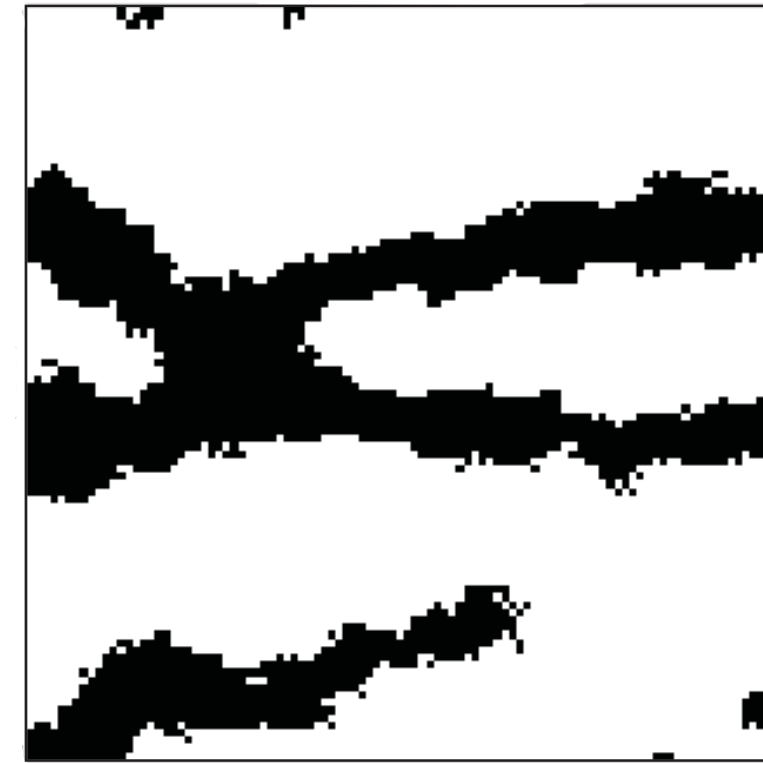
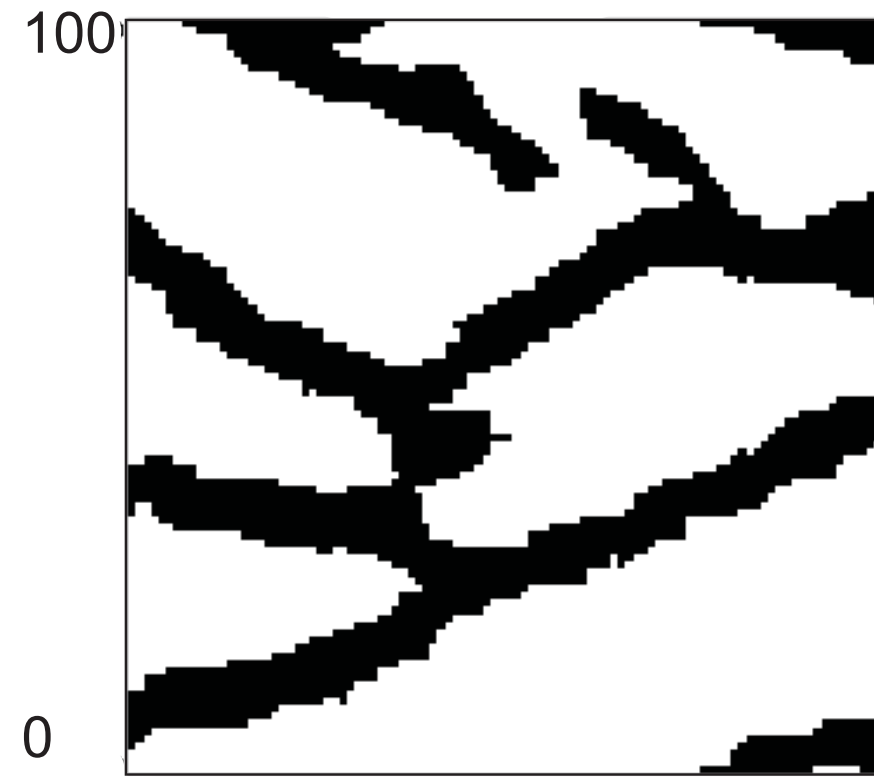
# Pattern-search-based inverse method

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Universitat Politècnica de València - Spain  
[jgomez@upv.es](mailto:jgomez@upv.es)  
<http://jgomez.webs.upv.es>

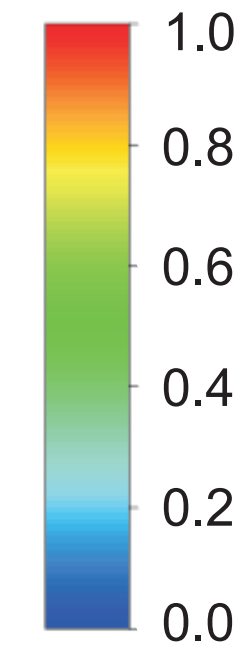
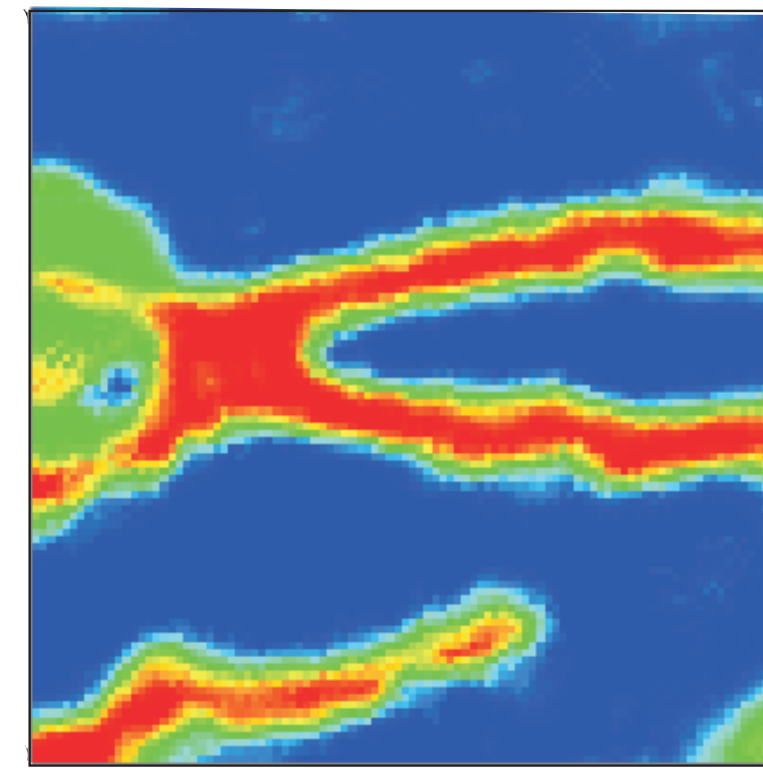
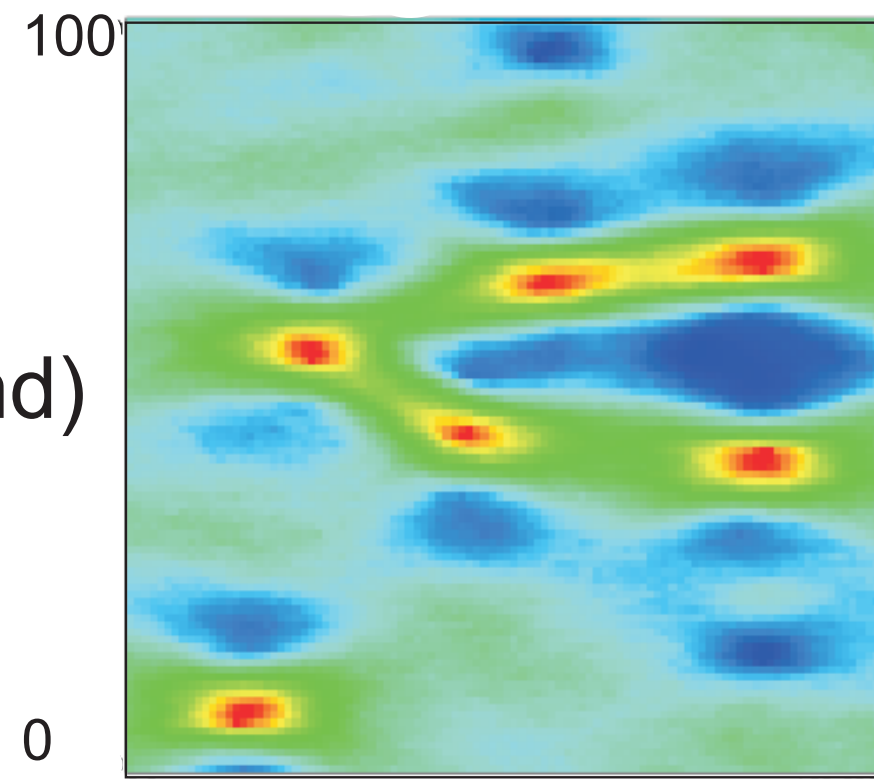


Prior

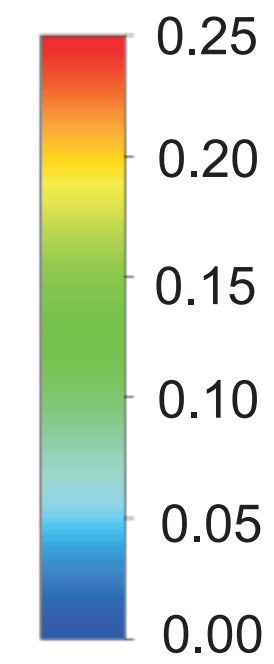
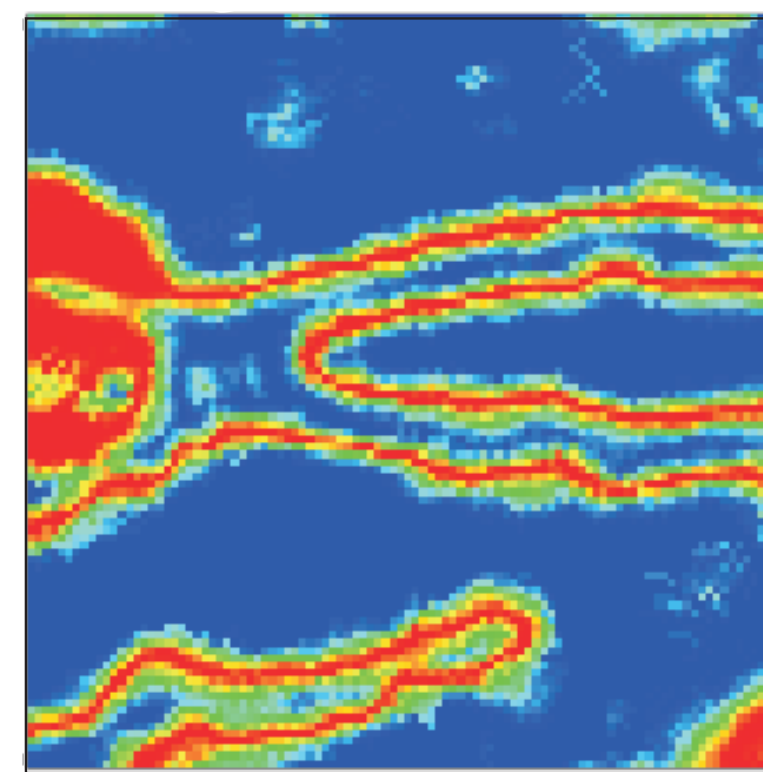
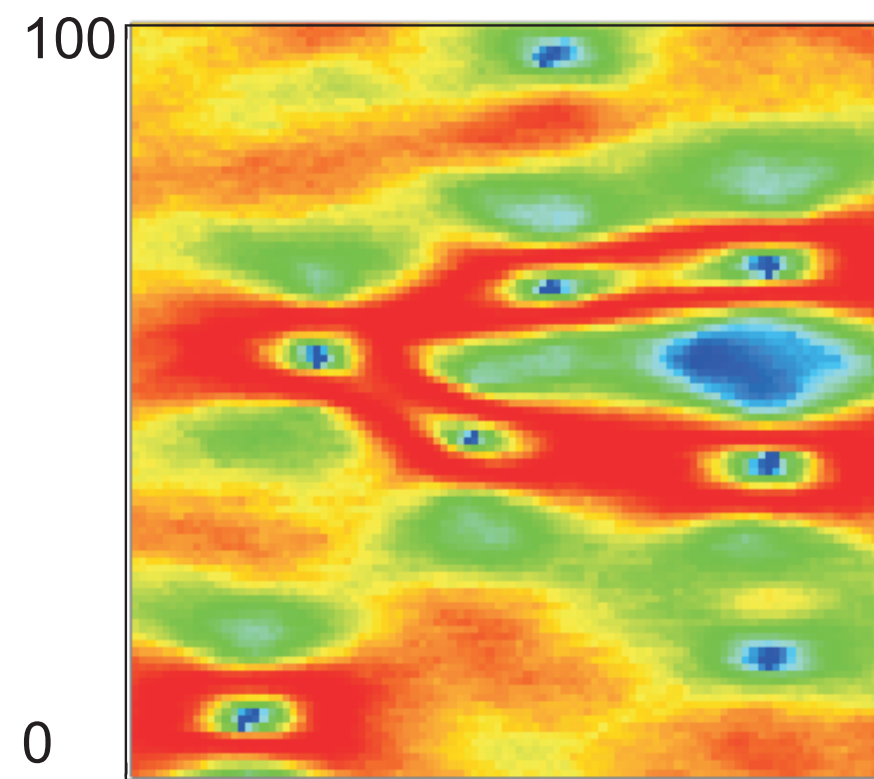
Updated



Prob (sand)



Var.



0

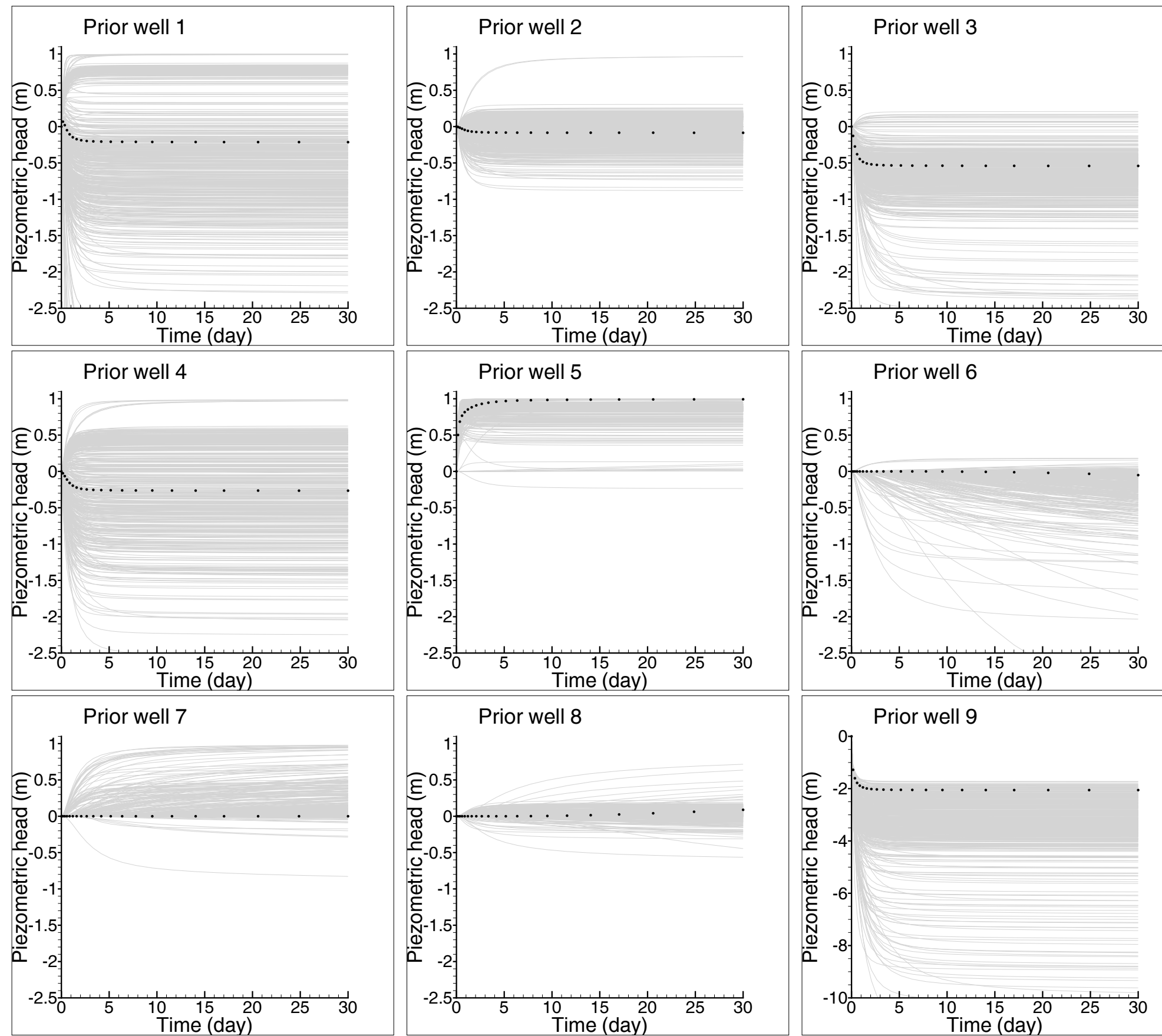
100

0

100



# Prior



# Updated

