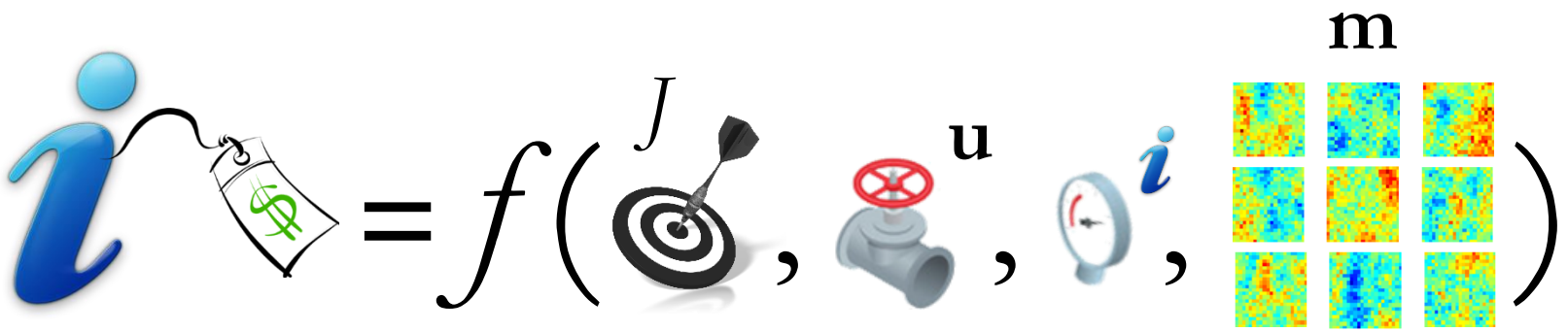
VALUE OF INFORMATION IN CO_2 STORAGE

Eduardo Barros, TNO



TNO innovation for life

PRE-ACT

Pre-ACT workshop WP3, TNO Utrecht
21-2-2018

OUTLINE

- Background
- Value of information
- Conformance in CO_2 storage
- Concluding remarks

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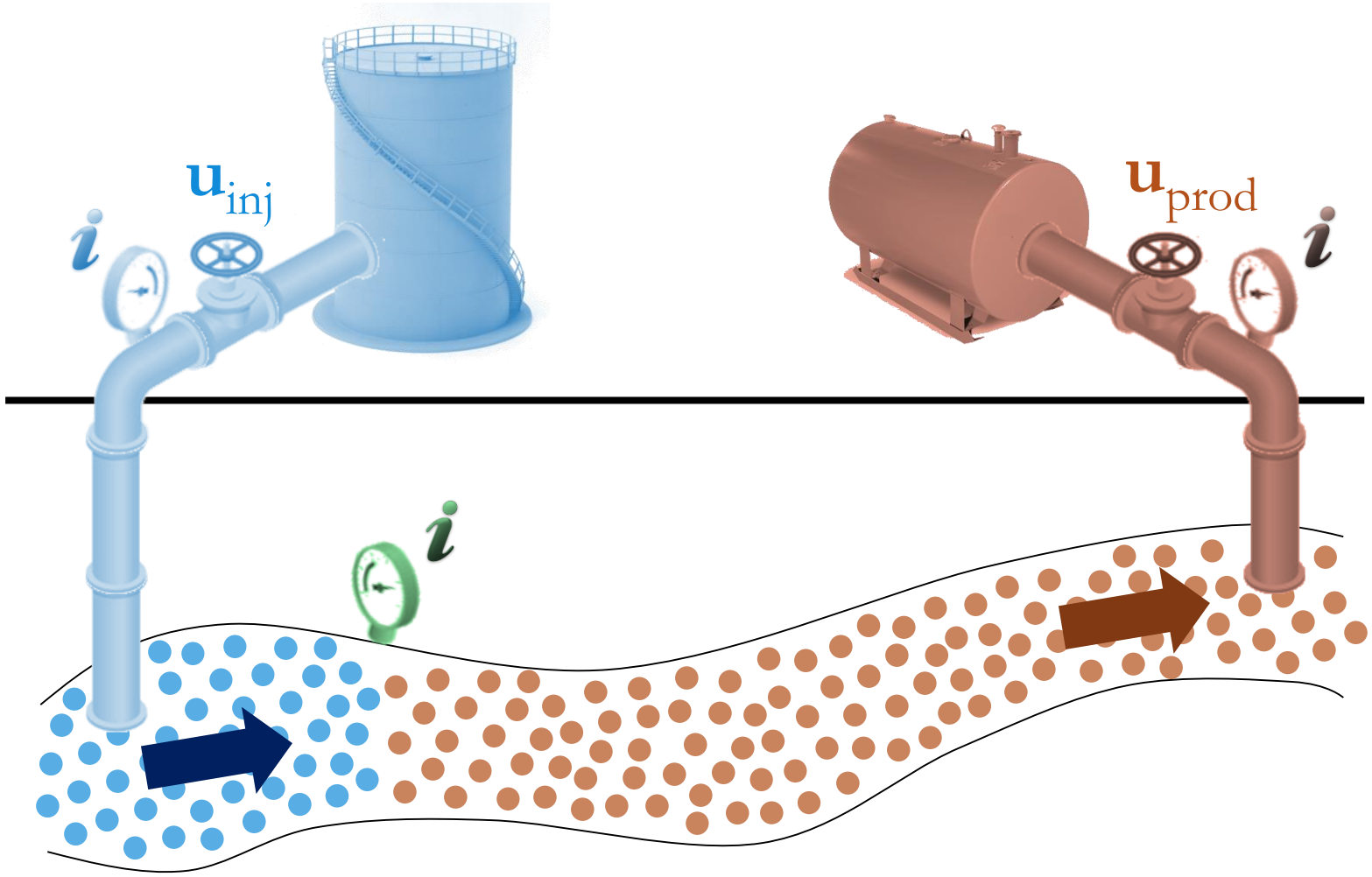
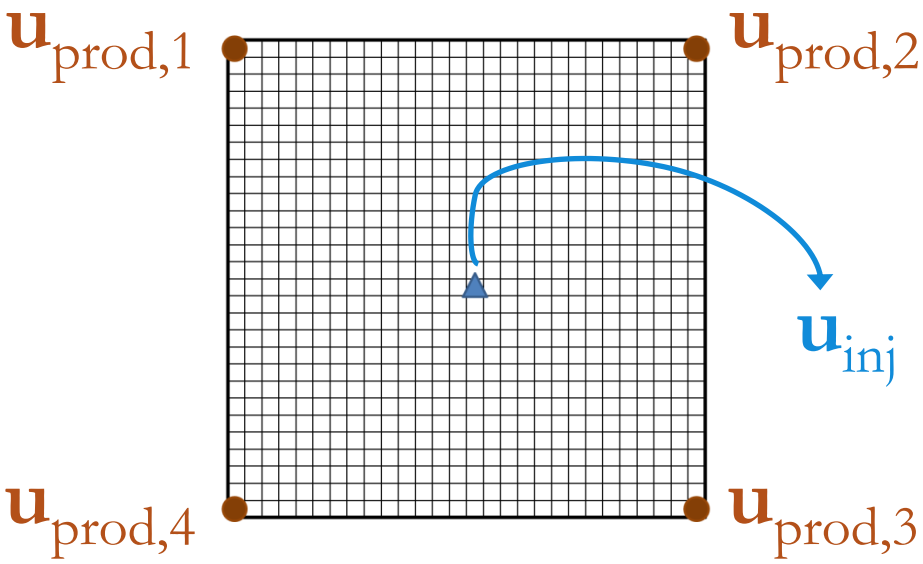
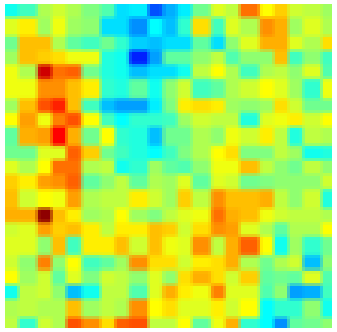
RESERVOIR MANAGEMENT



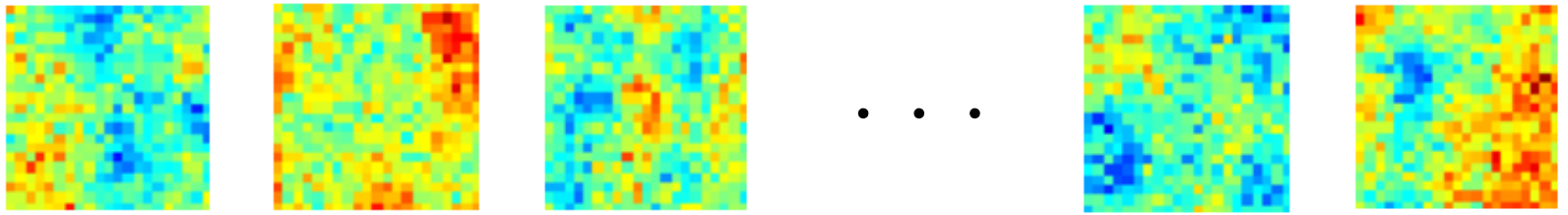
GEOLOGICAL UNCERTAINTY



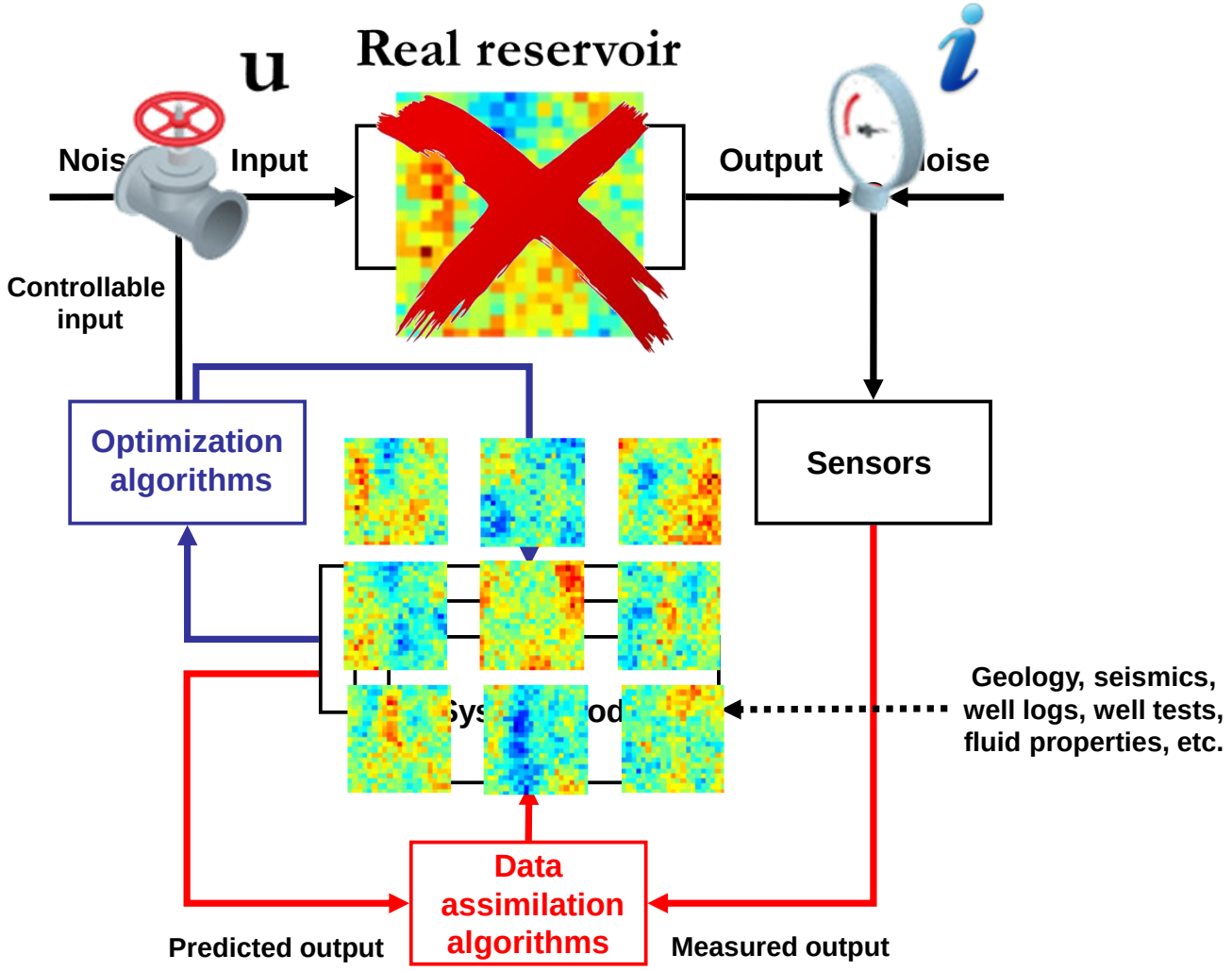
Real reservoir



$\mathbf{m}_1$ $\mathbf{m}_2$ $\mathbf{m}_3$ . . . $\mathbf{m}_{N-1}$ $\mathbf{m}_N$



CLOSED-LOOP FRAMEWORK



OUTLINE

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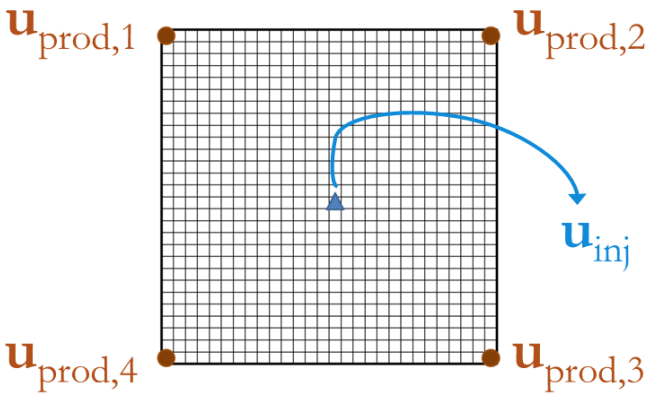
VALUE OF INFORMATION (VOI)

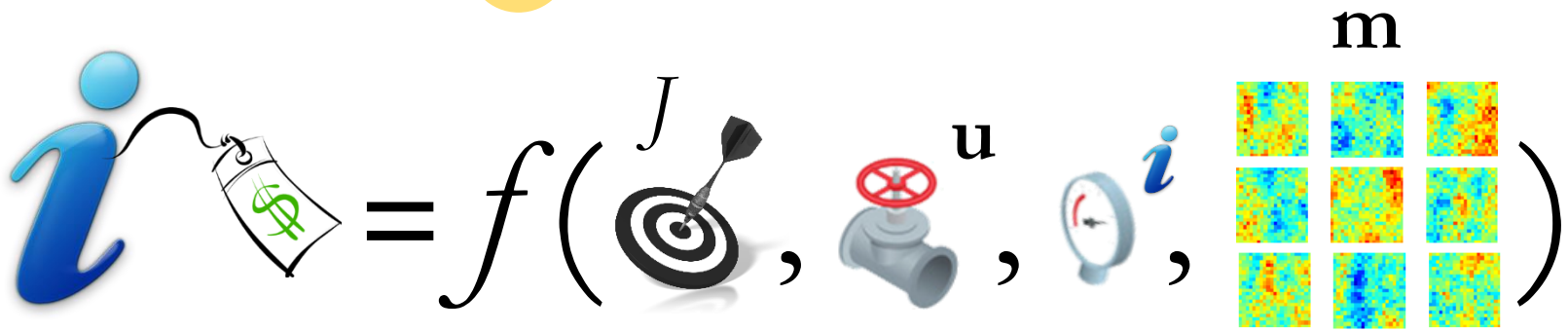


- Production strategy $\mathbf{u}$
- Reservoir surveillance i

VOI assessment in **reservoir management**

$$i = f(J, \mathbf{u}, i, \mathbf{m})$$

VOI ASSESSMENT 1



To evaluate VOI for a given measurement scenario:

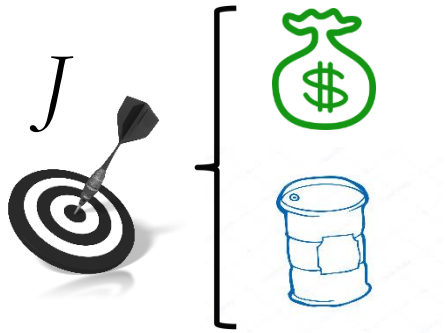
- fixed i
- $\mathbf{u}$ changes → J changes

$$\mathbf{u}_{prior} \xrightarrow{i} \mathbf{u}_{post}$$
$$J_{prior} \longrightarrow J_{post}$$

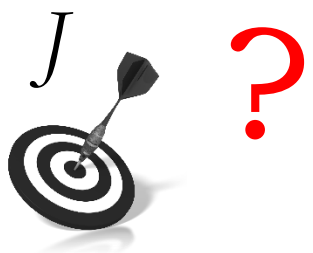
$$VOI = J_{post} - J_{prior}$$

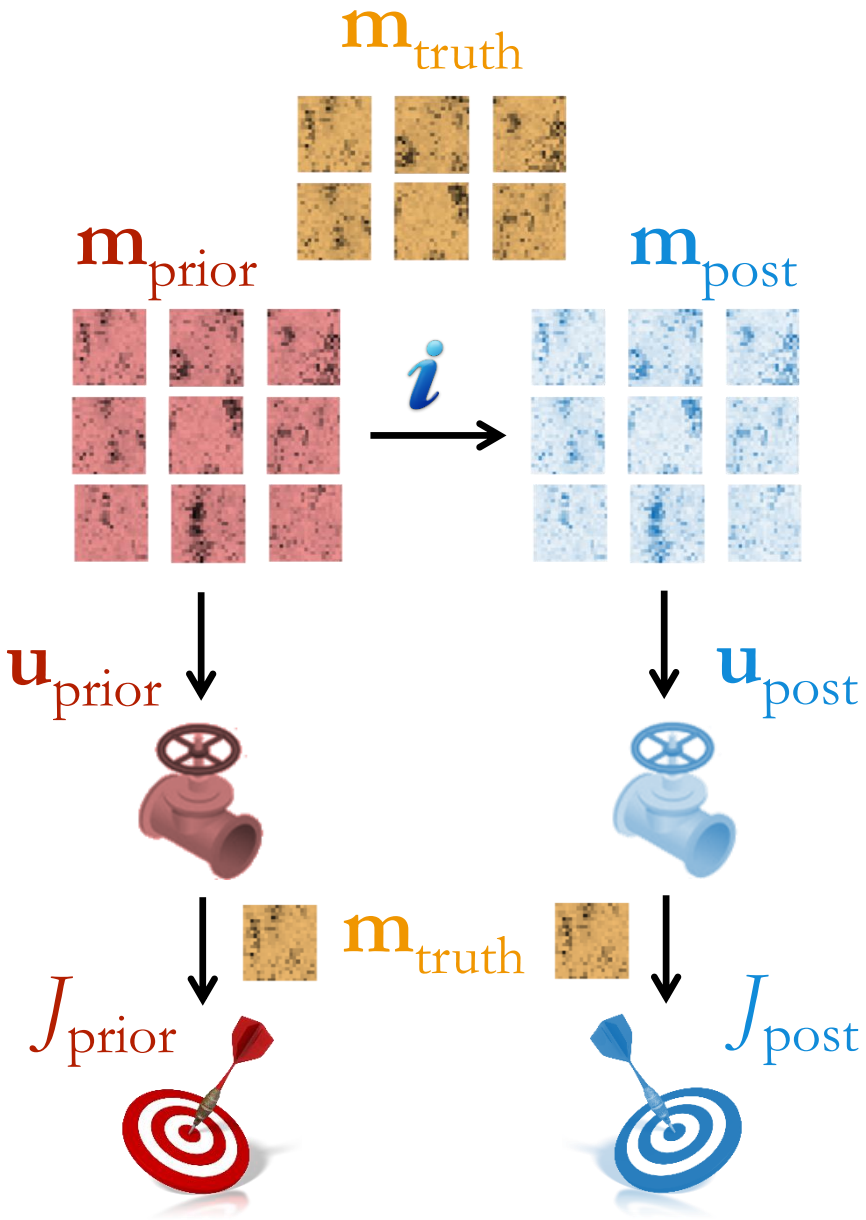
VOI ASSESSMENT 1

- Production optimization

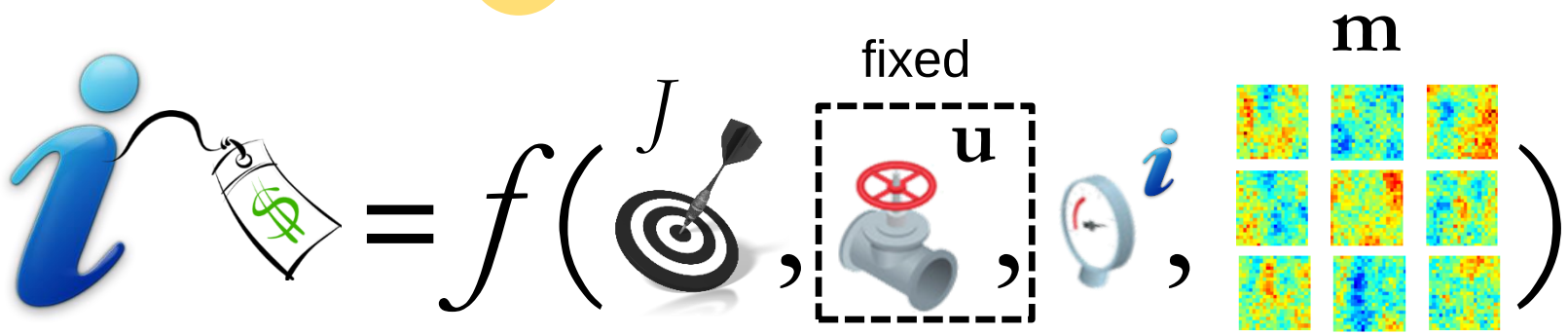


- CO_2 storage





VOI ASSESSMENT 2



To evaluate VOI for a given measurement scenario:

- **u** is fixed
- i → J changes

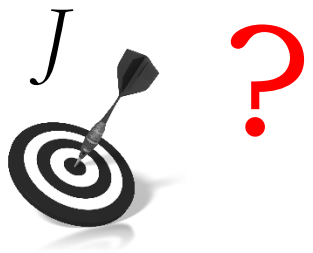
$$\emptyset \longrightarrow J_{\text{without}}$$

$$i \longrightarrow J_{\text{with}}$$

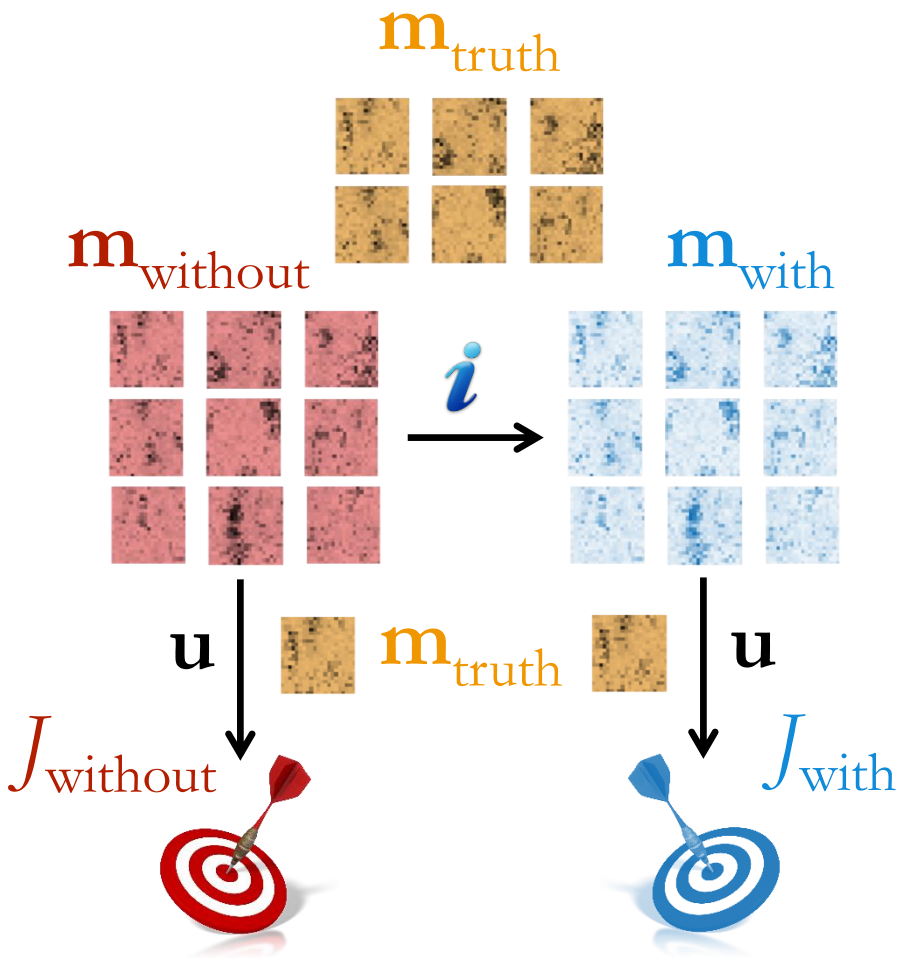
$$\text{VOI} = J_{\text{with}} - J_{\text{without}}$$

VOI ASSESSMENT 2

- CO_2 storage



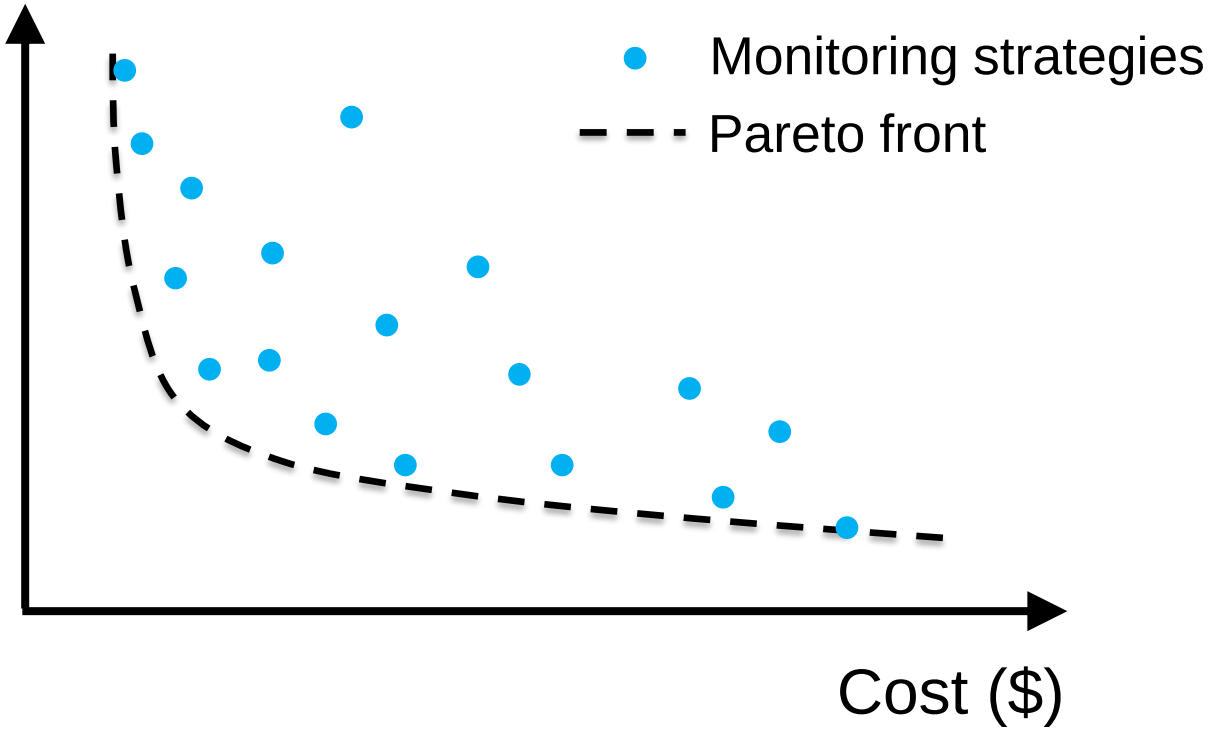
- Conformance



DESIGN OF MONITORING STRATEGIES

$$VOI = J_{with} - J_{without}$$

J (in  units)



REFERENCE FOR VOI ASSESSMENT

- Data addition:

$$\emptyset \longrightarrow J_{without}$$
$$i \longrightarrow J_{with}$$

$$VOI = J_{with} - J_{without}$$

- Data denial:

$$\{i_1, i_2, i_3, i_4\} \longrightarrow J_{all}$$
$$\{\emptyset, i_2, i_3, i_4\} \longrightarrow J_{subset}$$

$$VOI = J_{all} - J_{subset}$$

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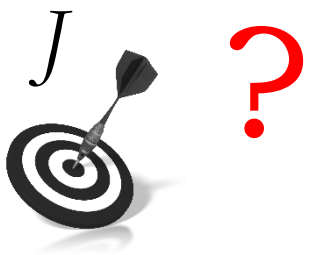
CONFORMANCE IN CO_2 STORAGE



(I) Model × measurement conformance

- Conformance

a) **Conformance**?

- We can only quantify **non-conformance** (i.e., deviations)
- In history matching, we minimize mismatches between model predictions and measured data
- Here we are interested in minimizing deviations in the future (i.e., no measurements available yet)

b) How do we compute non-conformance given an **ensemble of realizations** and **different sources of information**?

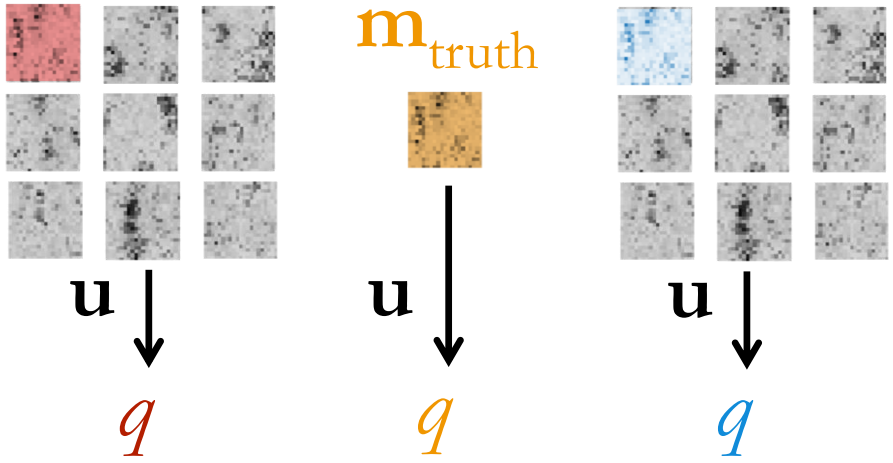
- We need a **unified measure** so that we can compare different monitoring systems

CONFORMANCE IN CO_2 STORAGE

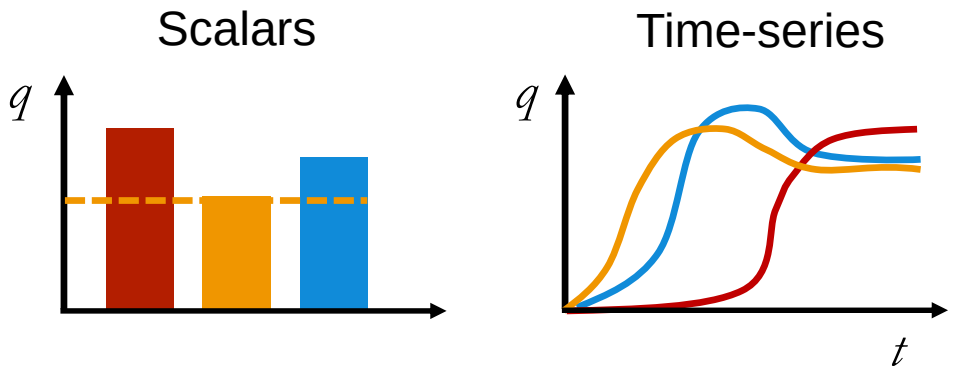
- Conformance

(I) Model × measurement conformance

c) Quantity of interest, q: **measurement** or **forecast** variables?



$$J_{\text{without}} = |q - q|$$
$$J_{\text{with}} = |q - q|$$



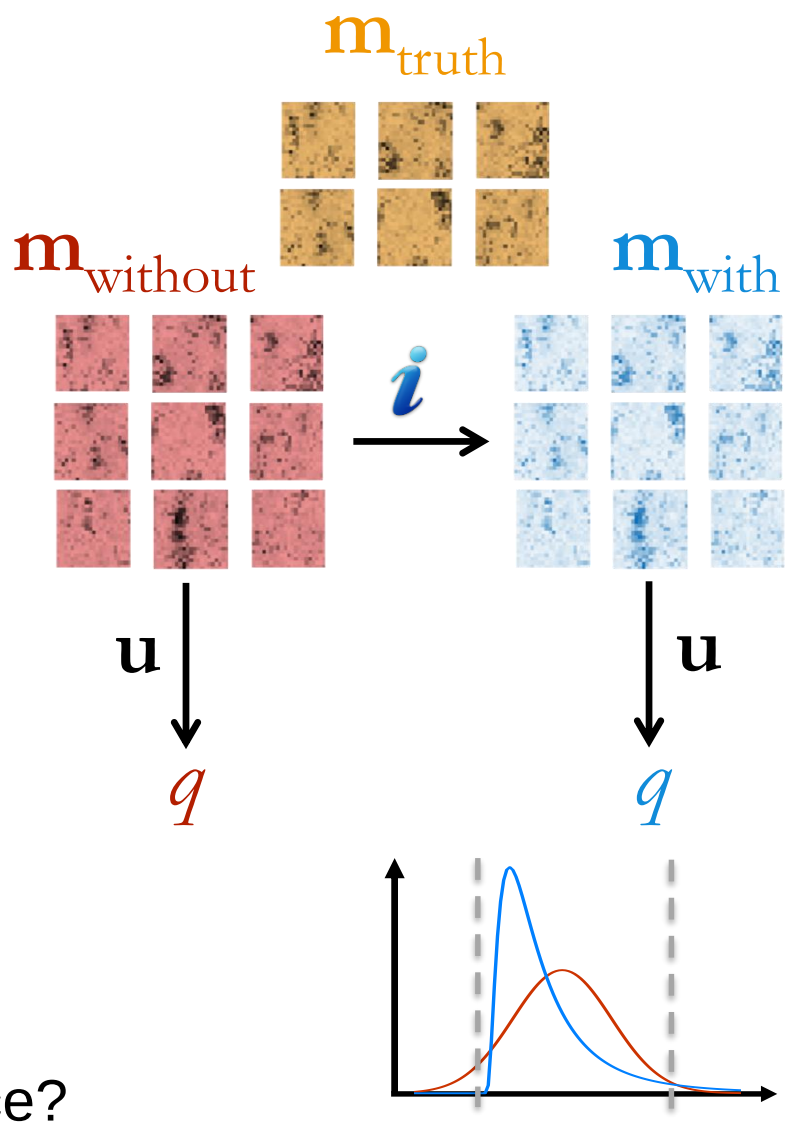
Maps

CONFORMANCE IN CO_2 STORAGE

(II) Model uncertainty

d) **Spread** of quantity of interest, q:

- std. deviation, P_{90} - P_{10}, min - max, …
- Based on model forecasts



(III) Model × regulation conformance

e) Clearly defined **bounds** for the quantity of interest

- Model forecasts to quantify confidence on meeting these requirements

f) **Measurements for verification** of this type of conformance?

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CONCLUDING REMARKS

- **Complete VOI assessment** in reservoir management
  - Impact of measurements on **operational decisions** (incl. **optimization**)
  - What are the operational decisions in CO_2 storage?
    - Injection rates/pressures? Location of brine discharge wells?
  - **Computationally demanding** workflows
- New idea for VOI assessment in CO_2 storage
  - Fixed operational decisions → More practical workflows
  - Conformance is the target
    - Types of conformance:

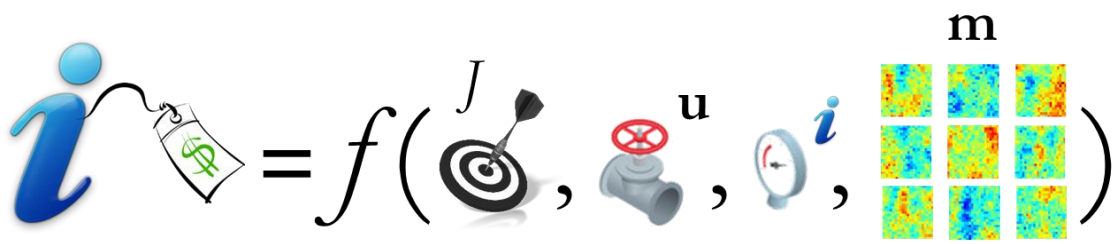
    (I) Model × measurement, (II) Model uncertainty, (III) Model × regulation

CONCLUDING REMARKS

- Importance of **unified measure** of conformance
- Who defines the **boundary** between **conformance / non-conformance**?
  - Acceptable bounds → regulation?
- Design of monitoring strategies for conformance verification
  - We need to consider **scenarios** that will lead to non-conformance
    - Simulated measurements from **plausible true-models**
    - We cannot assess VOI in cases with *unknown unknowns*
- Risk of designing a system based on a measure
  - **Observed non-conformance** × **Actual non-conformance**

THANK YOU FOR YOUR ATTENTION

TIME FOR DISCUSSION!



VOI = J_{with} - $J_{without}$

(J in units)