**Wuhan University**



# Time-based auxiliary Bayesian updating of embankment settlement

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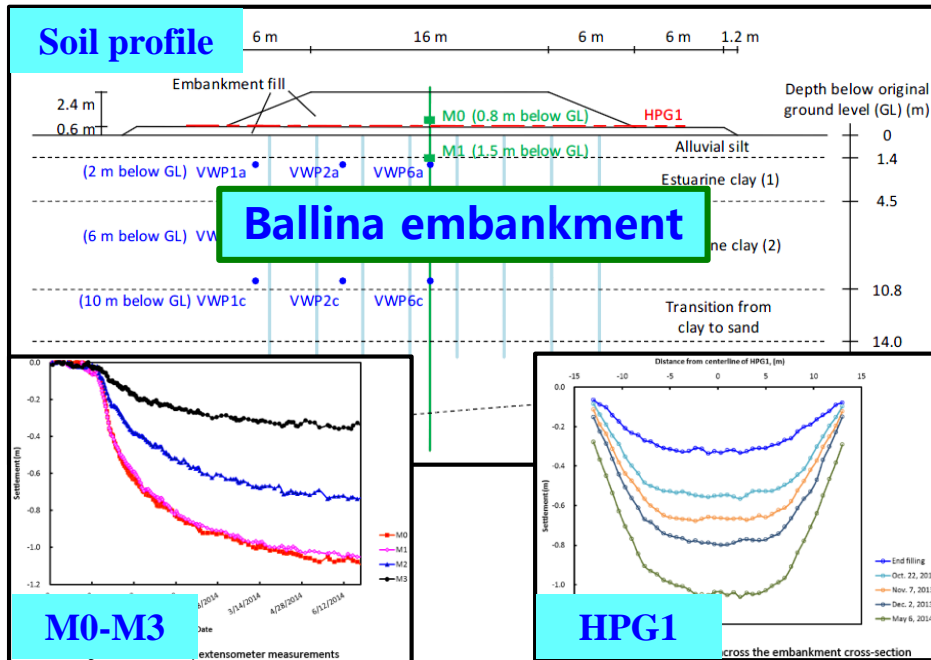
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# Background & Motivation

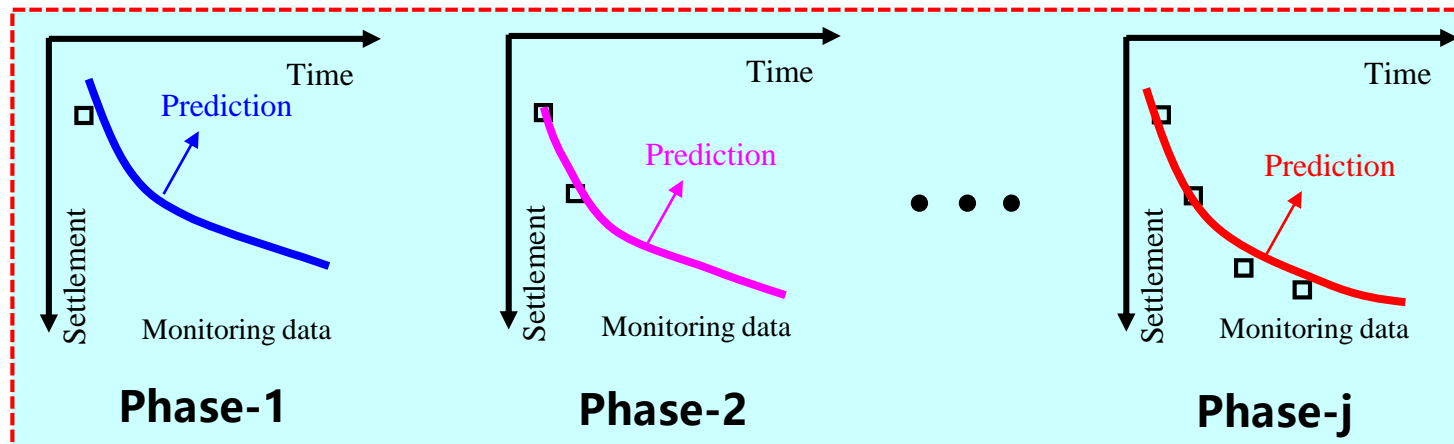# Real-time predictions of embankment settlement

## ➤ Background & purpose



Soil profile

Ballina embankment

M0-M3

HPG1

Provided by **TC304/309**

**Real-time predictions of embankment settlement**

⬇

**Bayesian framework**

⬇

**Computationally challenging**

⬇



Phase-1

Phase-2

Phase-j

4

# Real-time predictions of embankment settlement

## ▶▶ Motivation & literature review



**Slope**

(Zhang et al., 2009 a, b, 2013, 2014; Yang et al., 2018; Sun et al., 2019; Jiang et al., 2018, 2020, etc.)



**Foundation**

(Wang et al., 2012; Juang et al., 2013; Wu et al., 2014; Qi and Zhou, 2017; Lo and Leung, 2019, etc.)



PDF 2

Selected samples

PDF 1

$\theta$

**PDFs overlap**

⇩
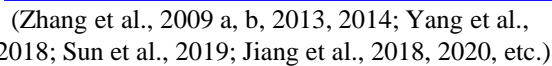
**Select posterior samples**



**Tunnel**

(Špacková et al., 2013; Janda et al., 2018; Feng et al., 2019, etc.)



**Embankment**

(Schweckendiek and Vrouwenvelder, 2013; Kelly and Huang, 2015; Zheng et al., 2018; Huang et al., 2019, etc.)
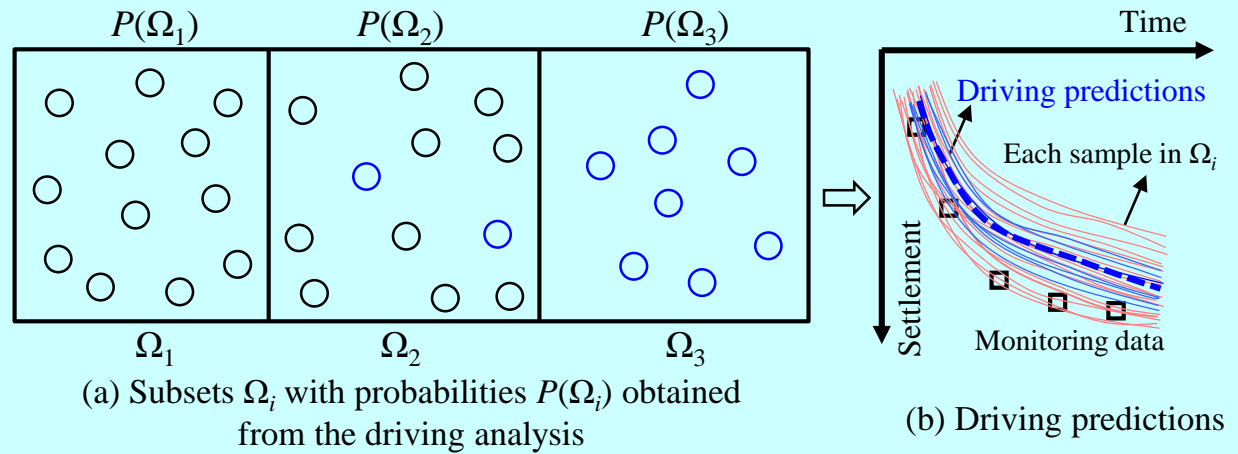
# Methodology

# Time-based auxiliary Bayesian updating framework

## Driving Bayesian analysis

**BUS &
Subset Simulation**

(Straub and Papaioannou, 2015)

**Driving Bayesian analysis with driving data $y^*$**

$P(\Omega_1)$  $P(\Omega_2)$  $P(\Omega_3)$

Time

Driving predictions

Each sample in $\Omega_i$

Settlement

Monitoring data

$\Omega_1$  $\Omega_2$  $\Omega_3$

(a) Subsets $\Omega_i$ with probabilities $P(\Omega_i)$ obtained
from the driving analysis

(b) Driving predictions
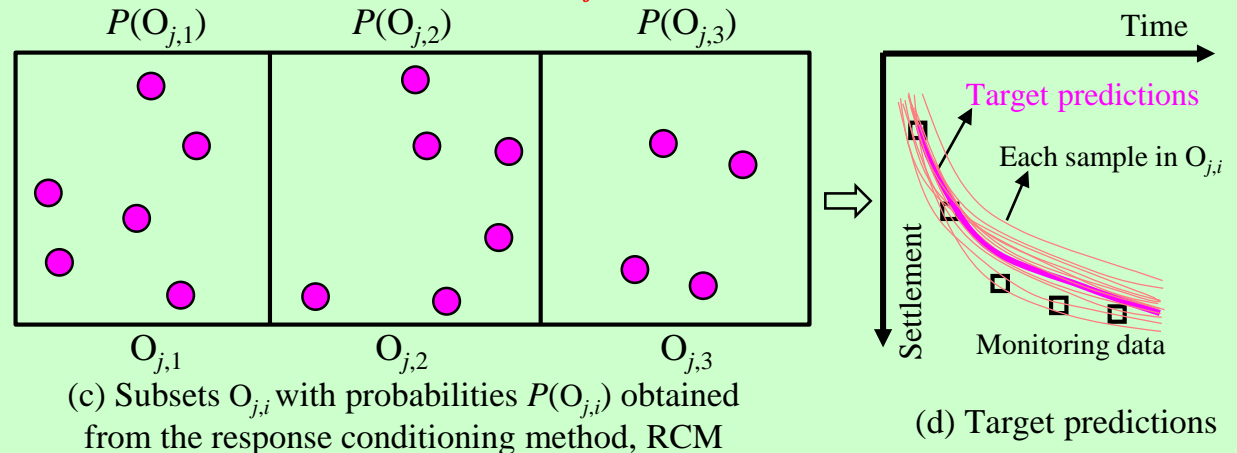
## Target Bayesian analysis

Selection of target samples

$$F_j = \{w - c \cdot L(\boldsymbol{\theta}|\mathbf{y}_j) \leq 0\}$$

Predictions

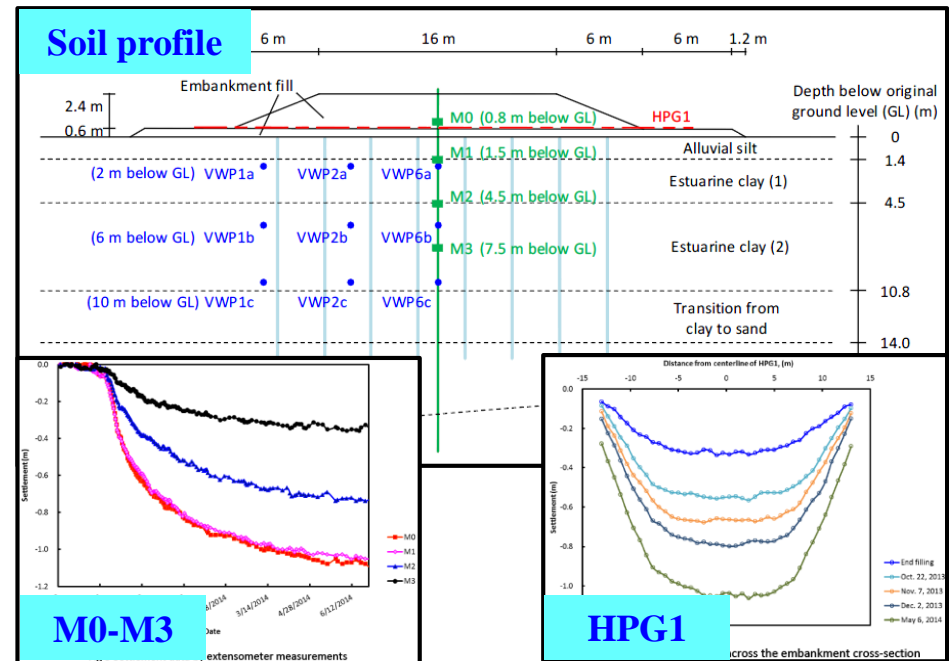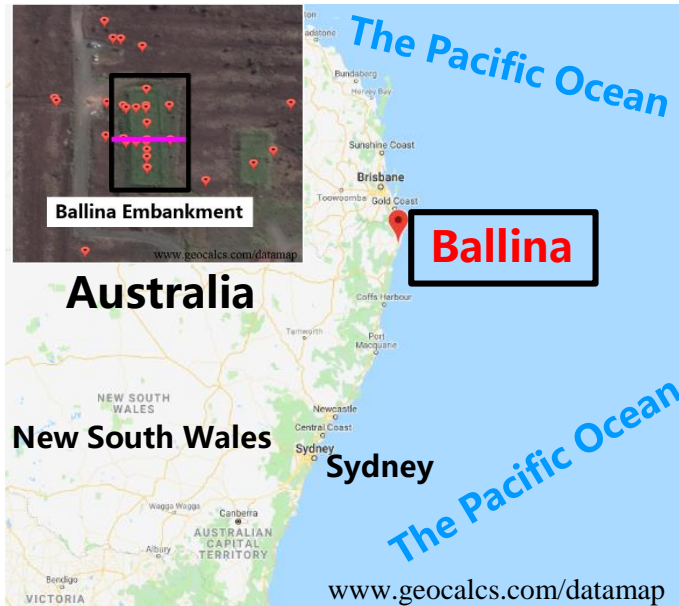$$\tilde{Y}_t = \sum_{i=0}^{m} E(M_t(\boldsymbol{\theta})|O_{j,i})P(O_{j,i})$$

(Au, 2007)

**Target Bayesian analysis with data $y_j$**

$P(O_{j,1})$  $P(O_{j,2})$  $P(O_{j,3})$

Time

Target predictions

Each sample in $O_{j,i}$

Settlement

Monitoring data

$O_{j,1}$  $O_{j,2}$  $O_{j,3}$

(c) Subsets $O_{j,i}$ with probabilities $P(O_{j,i})$ obtained
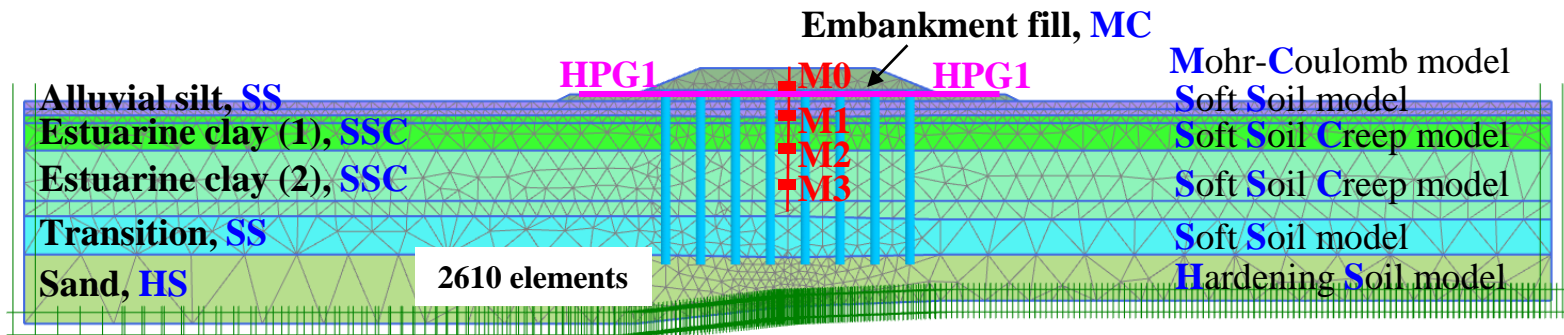from the response conditioning method, RCM

(d) Target predictions

# Illustrative Example

# Ballina embankment, New South Wales, Australia

## Ballina Embankment



Ballina Embankment

The Pacific Ocean

Australia

Ballina

NEW SOUTH WALES

New South Wales

Sydney

The Pacific Ocean

www.geocalcs.com/datamap

**Soil profile**



| 6 m | 16 m | 6 m | 6 m | 1.2 m |

Embankment fill

2.4 m
0.6 m

M0 (0.8 m below GL)    HPG1

M1 (1.5 m below GL)    Alluvial silt

(2 m below GL) VWP1a    VWP2a    VWP6a

M2 (4.5 m below GL)    Estuarine clay (1)

(6 m below GL) VWP1b    VWP2b    VWP6b

M3 (7.5 m below GL)    Estuarine clay (2)

(10 m below GL) VWP1c    VWP2c    VWP6c

Transition from clay to sand

Depth below original ground level (GL) (m)

0
1.4
4.5
10.8
14.0

**M0-M3**

**HPG1**

Provided by **TC304/309**

Embankment fill, **MC**    **M**ohr-**C**oulomb model

HPG1    M0    HPG1

Alluvial silt, **SS**    **S**oft **S**oil model

Estuarine clay (1), **SSC**    M1    **S**oft **S**oil **C**reep model

Estuarine clay (2), **SSC**    M2    **S**oft **S**oil **C**reep model
                               M3

Transition, **SS**    **S**oft **S**oil model

Sand, **HS**    **H**ardening **S**oil model

2610 elements

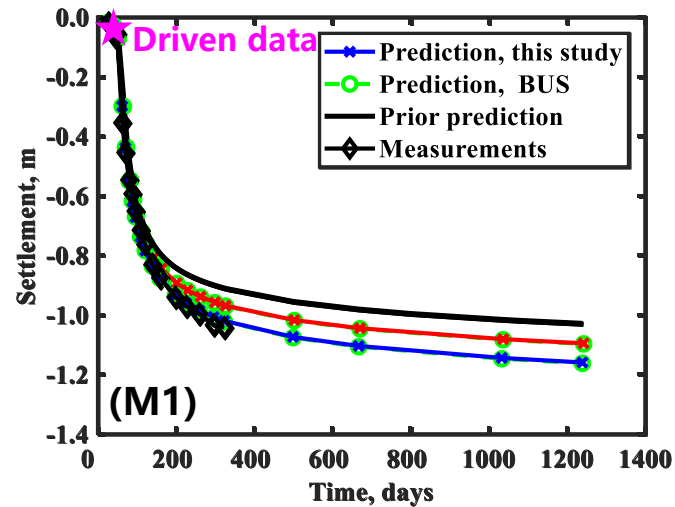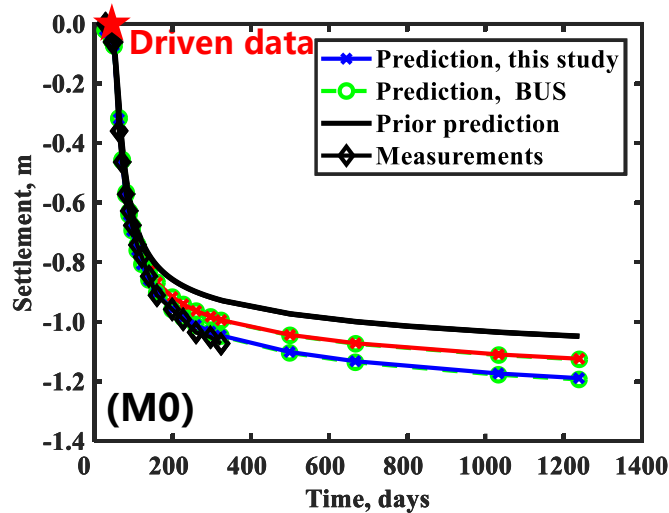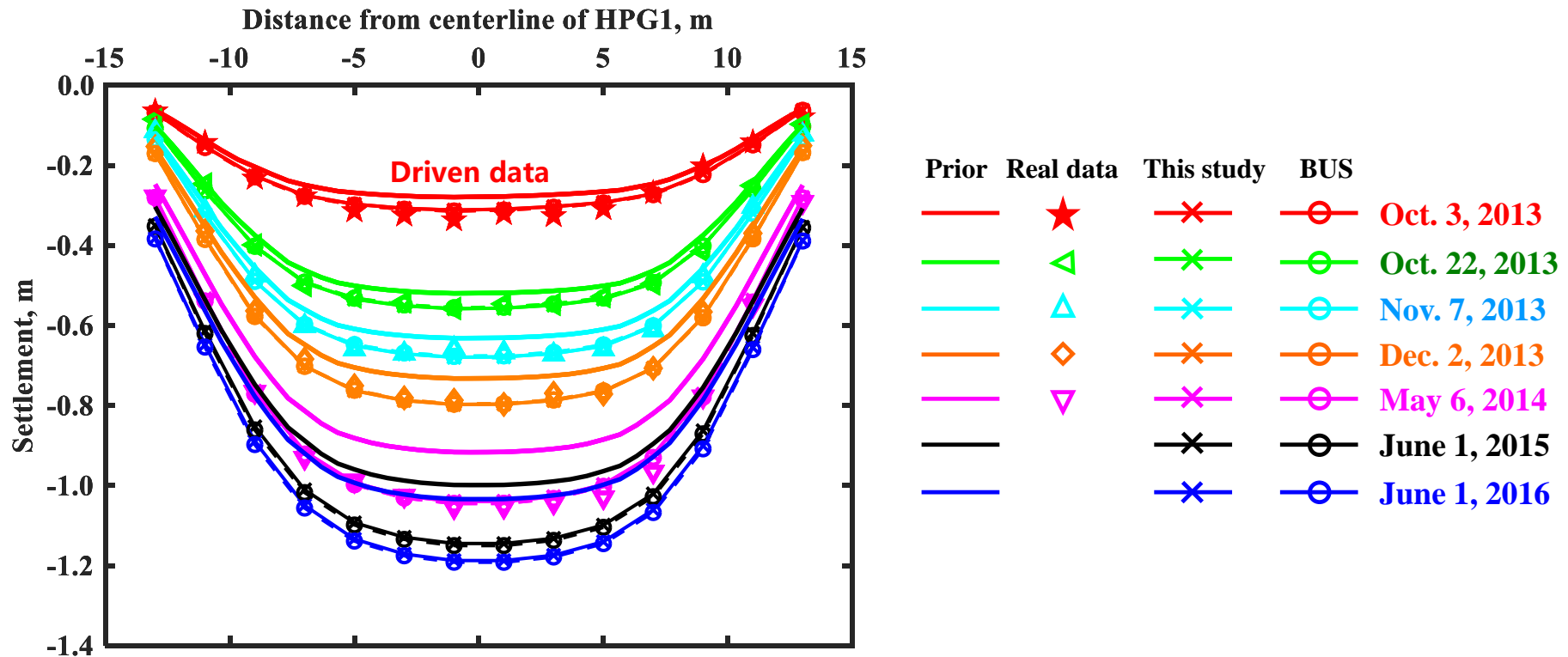## Numerical finite element model by PLAXIS 2020

**Predictions considering real data from 97 and 324 days**
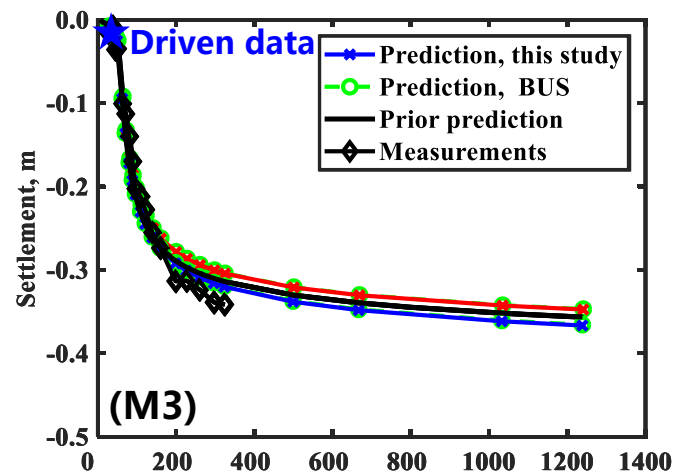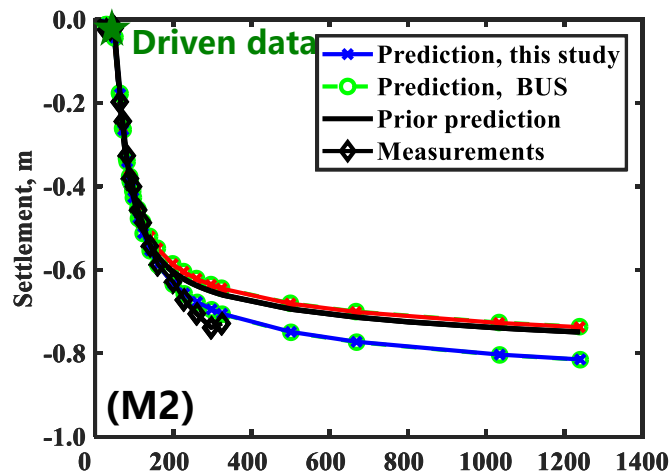


**Prediction accuracy is improved;
Efficiency for real-time predictions is achieved**

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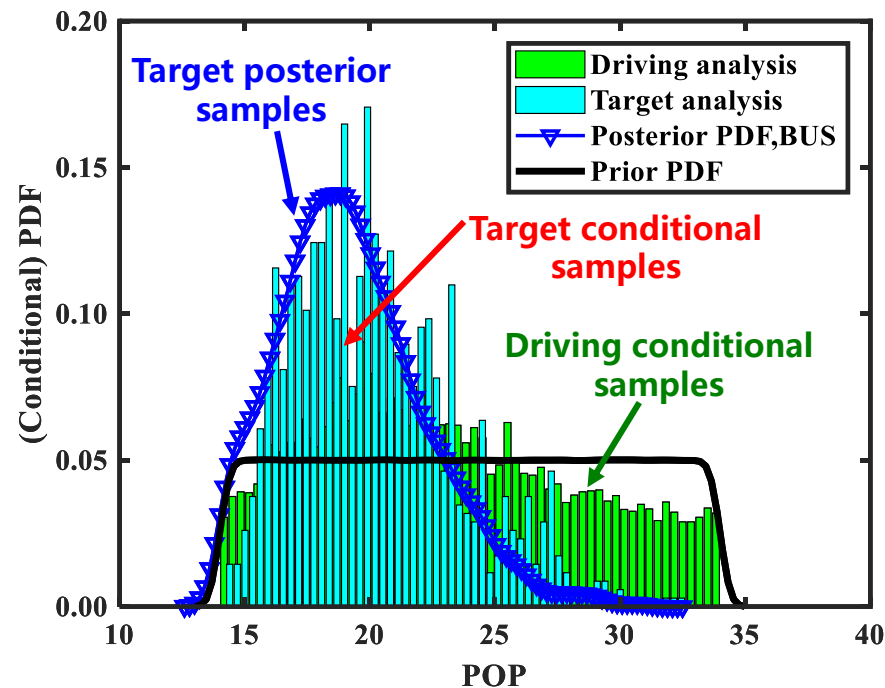## Predictions driven by HPG1 profile at Oct. 3, 2013



**Once again, demonstrate the efficiency for real-time predictions of embankment settlement**

# Discussions & Applications

## Conditional PDF comparisons



Case2: Target analysis driven by HPG1

Legend:
- Driving analysis
- Target analysis
- Posterior PDF, BUS
- Prior PDF

Target posterior samples

Target conditional samples

Driving conditional samples

Y-axis: (Conditional) PDF
X-axis: POP

**Overlap between driving samples and target posterior samples ensures the success of the proposed approach**

# Conclusions & Summary

# Conclusions & Summary

- [ ] An **auxiliary Bayesian framework** is proposed for **real-time predictions** of embankment settlement. It starts with **driving Bayesian analysis with BUS** by selecting driving data, followed by **target Bayesian analysis** constantly performed for target predictions when new data appears. The proposed approach is illustrated by an embankment settlement prediction example

- [ ] The **accuracy** of settlement predictions can be improved by incorporating monitoring information. The proposed approach is validated by the reference BUS approach, demonstrating its **efficiency** for real-time predictions of embankment settlement considering driving analysis with various amount of driven data. The **overlap** between the driving conditional samples and target posterior samples guarantees the success of the proposed approach

# Thank YOU
# ありがとうございます
# 谢谢大家