Soil moisture estimation using Passive DTS: Theory and field application

Jianzhi Dong, Susan C. Steele-Dunne, Tyson E. Ochsner, Christine Hatch, John Selker, Scott Tyler, Michael H. Cosh, and Nick van de Giesen.
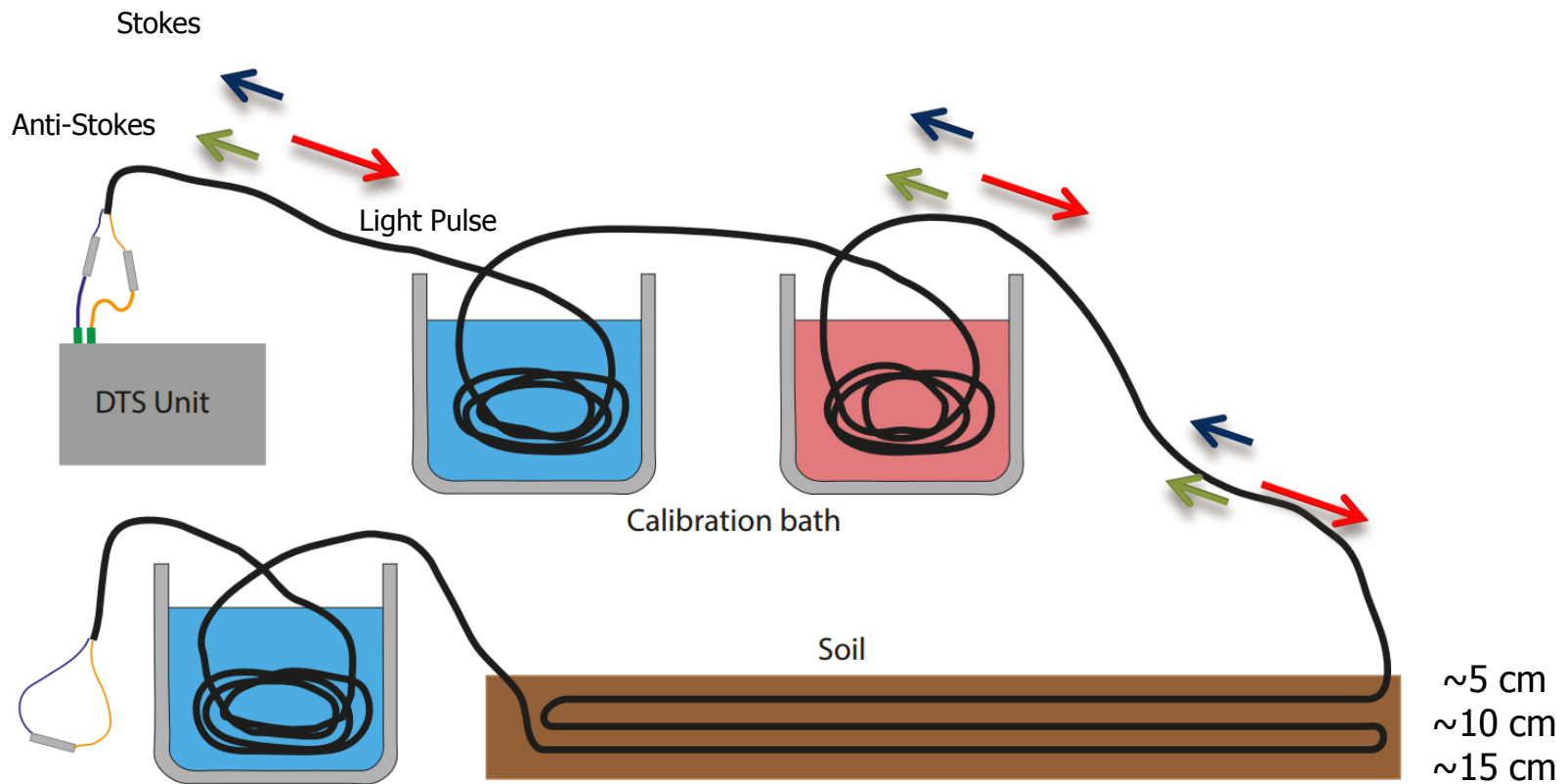
Content

- Background

  $\Rightarrow$ DTS and soil moisture
  $\Rightarrow$ Key challenges in Passive DTS

- Improved Passive DTS

- Data assimilation in Passive DTS

- Conclusion and future work

Background

Distributed temperature sensing (DTS)

Temporal resolution: < 1min
Spatial resolution: < 1m

Stokes

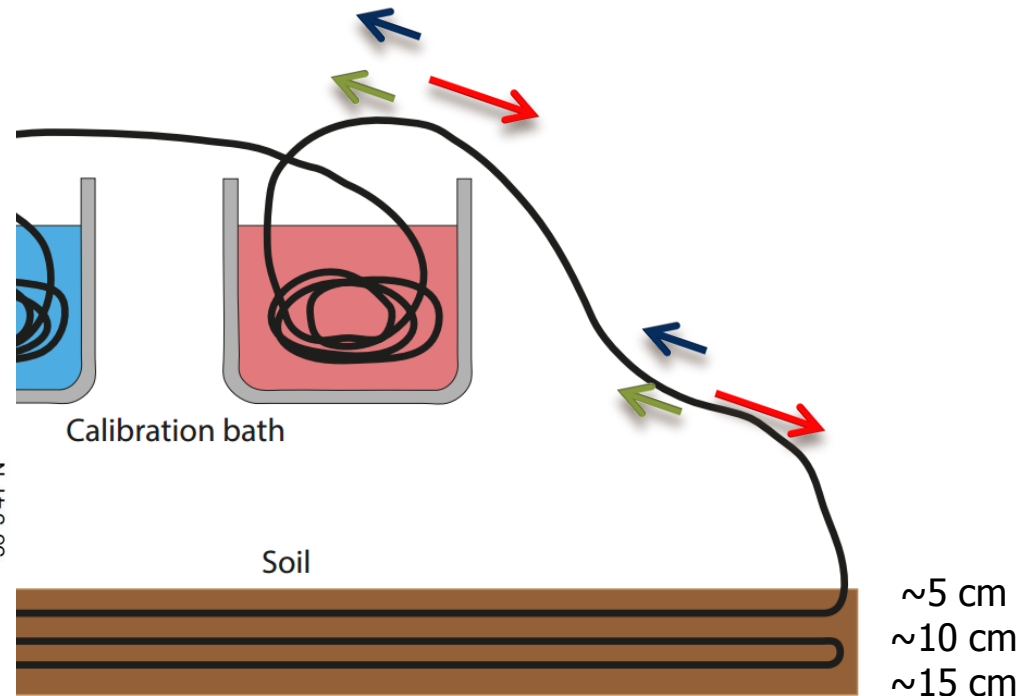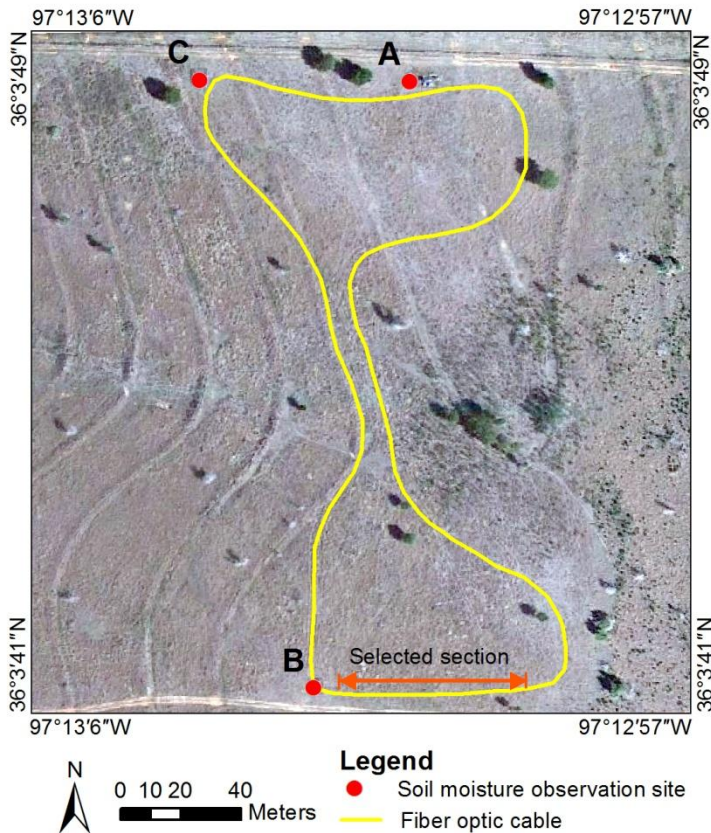Anti-Stokes

Light Pulse

DTS Unit

Calibration bath

Soil

~5 cm
~10 cm
~15 cm

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Background

Distributed temperature sensing (DTS)
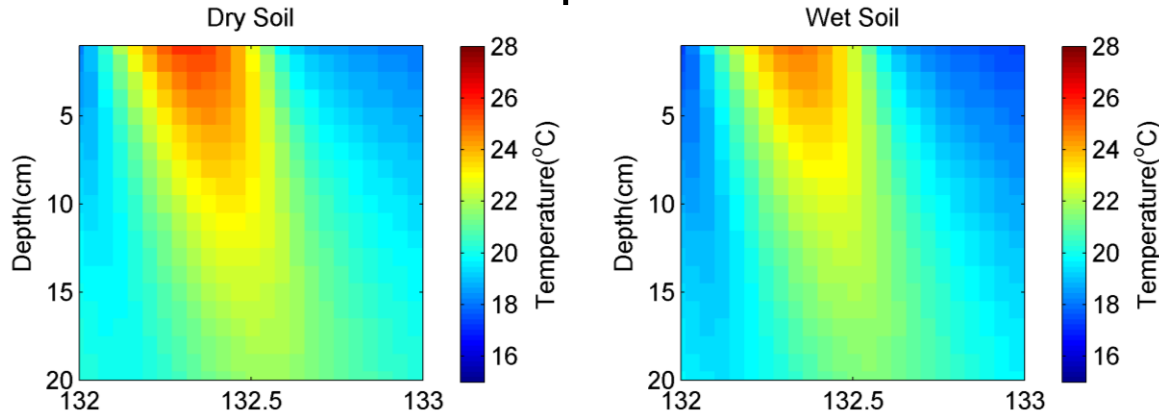
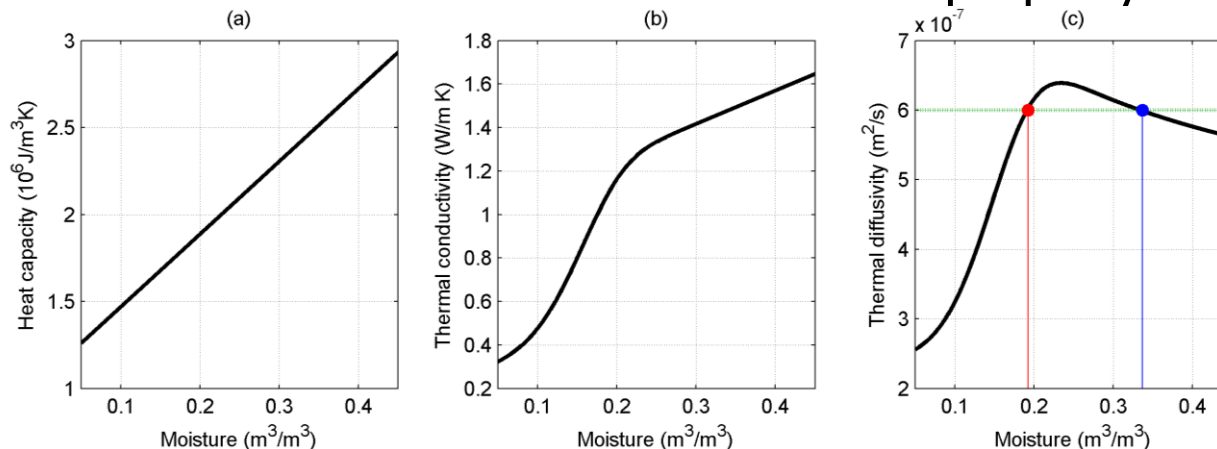Temporal resolution: < 1min
Spatial resolution: < 1m

Background

Passive DTS

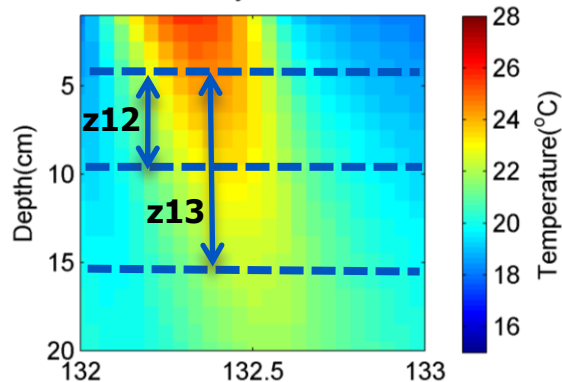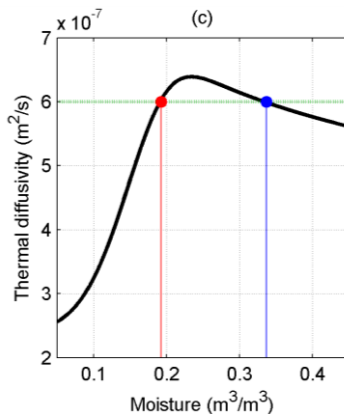- Soil heat transfer depends on soil moisture

- Soil moisture determines soil thermal property

Background

Passive DTS

- Steele-Dunne et al (2009):
  Use T observation at 3 depths -> diffusivity -> moisture

- Challenges:
  Two soil moisture might be retrieved
  Very sensitive with cable separation distances
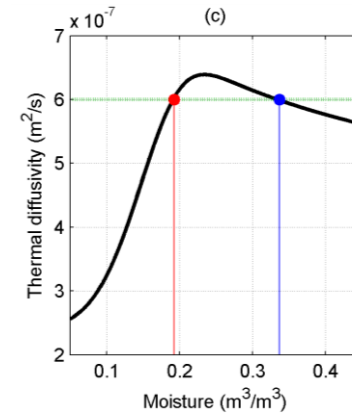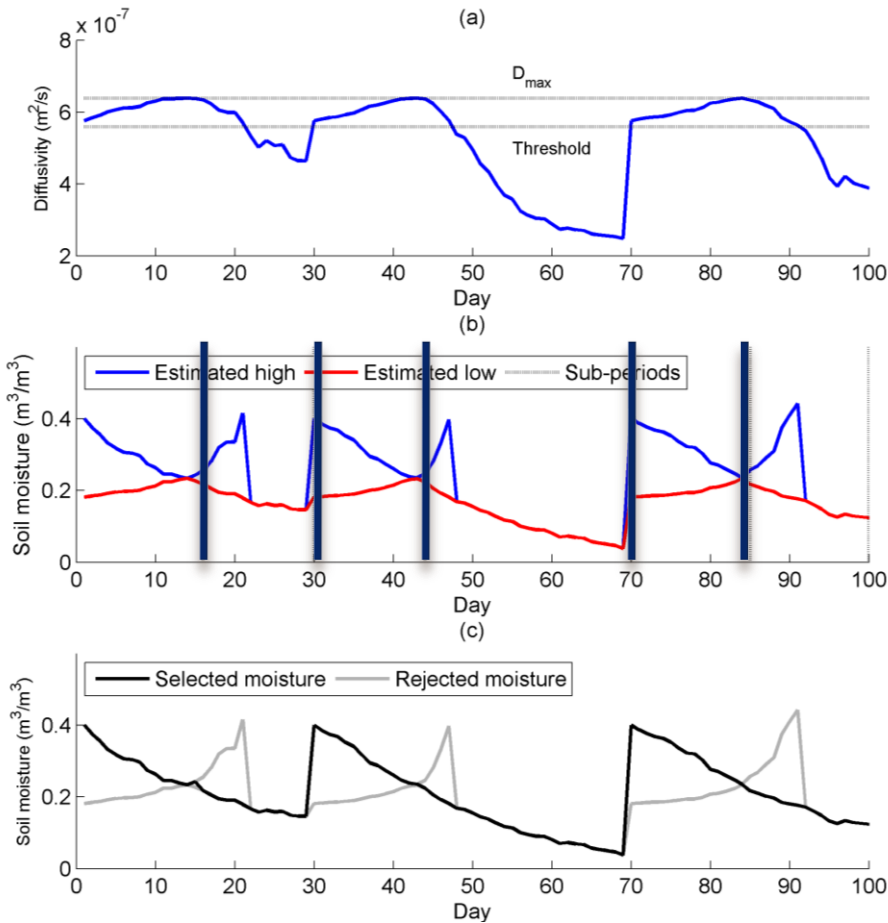 Assume moisture/thermal property profile is uniform

Content

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- Improved Passive DTS

  ⇒ Soil moisture selection
  ⇒ Estimating cable separation distances
  ⇒ Including soil thermal property profile

- Data assimilation in Passive DTS

- Conclusion and future work

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Improved Passive DTS

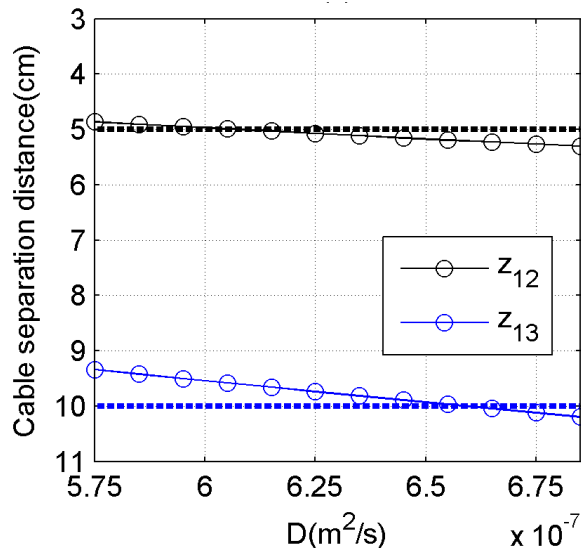## Selecting "correct" soil moisture estimates
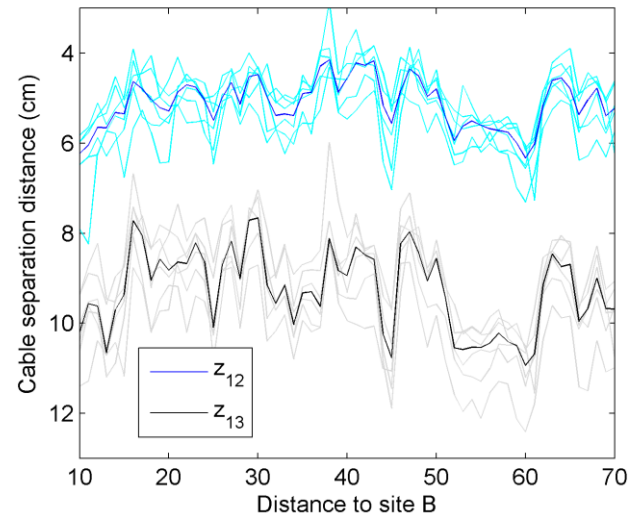

J. Dong et al., submitted to WRR

Improved Passive DTS

Cable separation distance estimation

Use temperature amplitude analysis to determine cable separation distance:

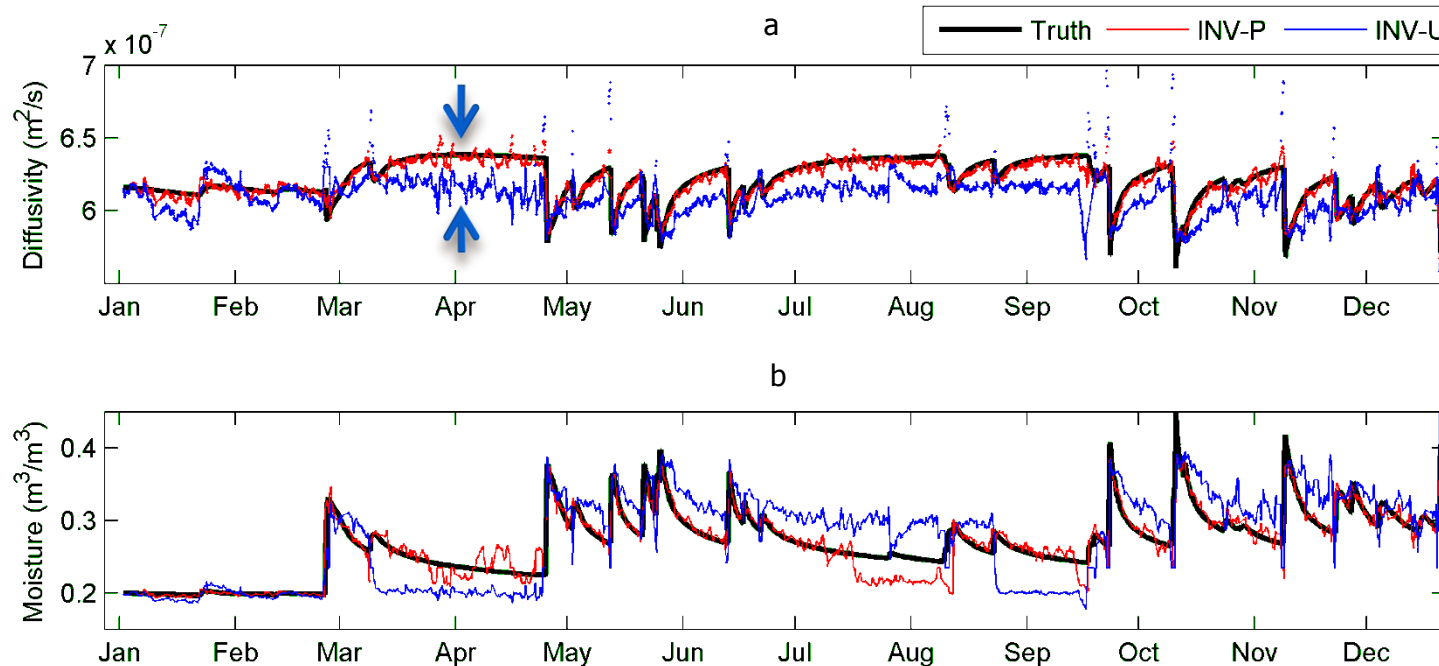**Estimated cable separation distance, synthetic experiment.**

Estimated cable separation distance in real cable data a long a 61m transect.

J. Dong et al., submitted to WRR

Improved Passive DTS

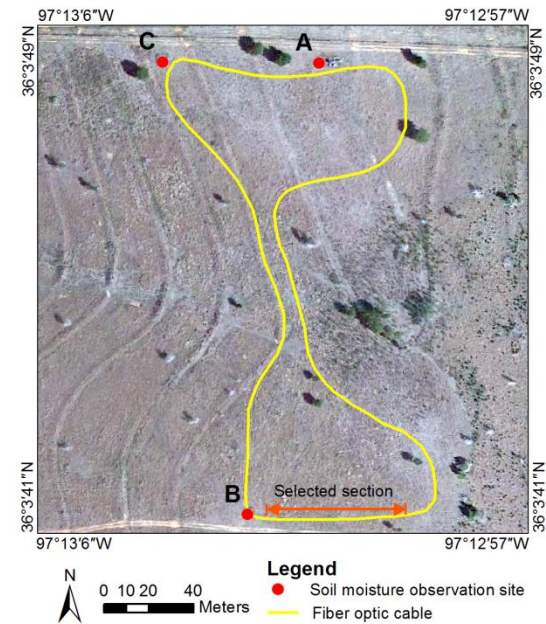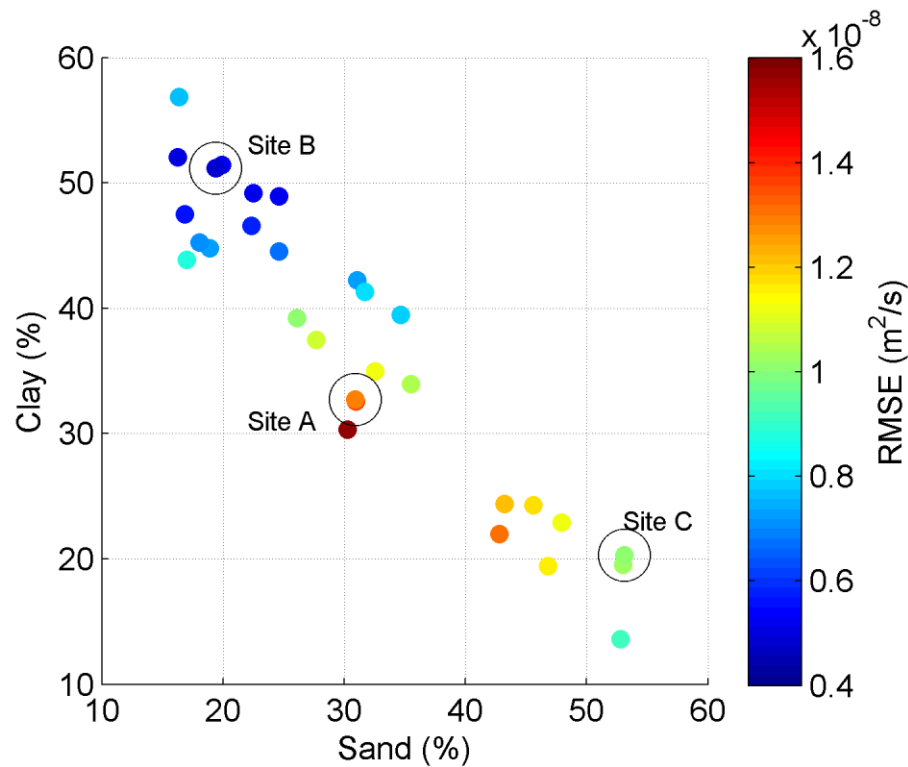## Importance of considering verticle heterogeneity soil profile

Synthetic Experiment

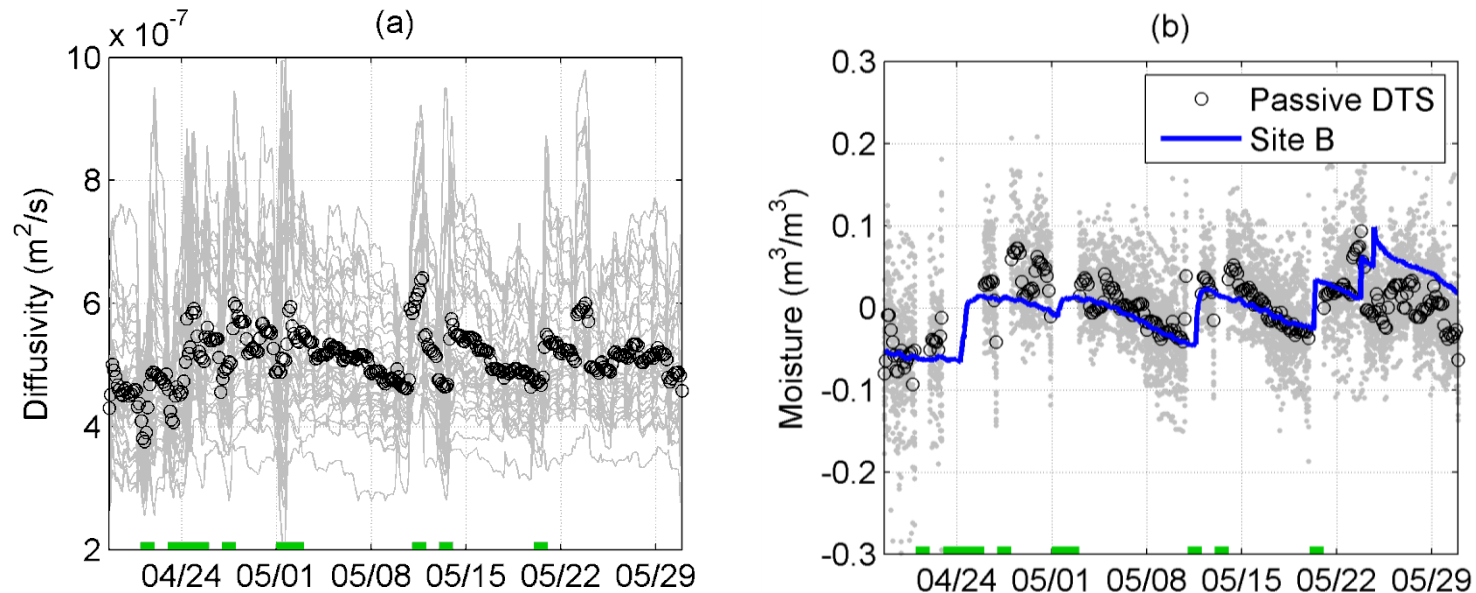*J. Dong et al., submitted to WRR*

Improved Passive DTS

Impact of soil texture uncertainty on estimated diffusivity (Synthetic experiment)

J. Dong et al., submitted to WRR

Improved Passive DTS

Estimated diffusivity and soil moisture anomalies at SMAP MOISST

Gray line/dots: soil diffusivity/moisture anomaly at each meter of cable
Black circle: median
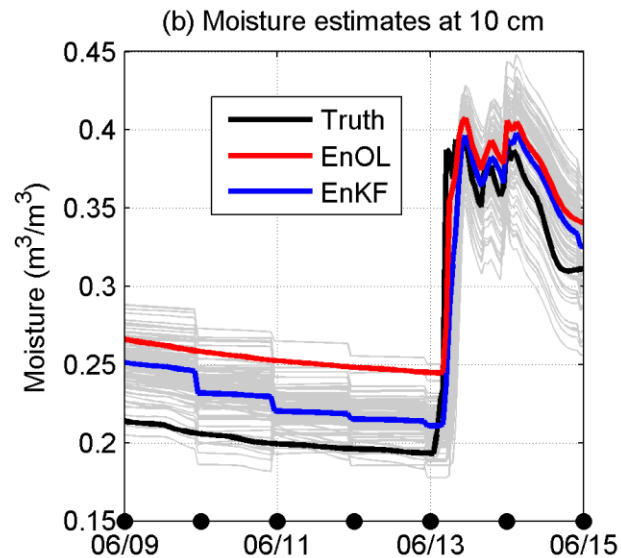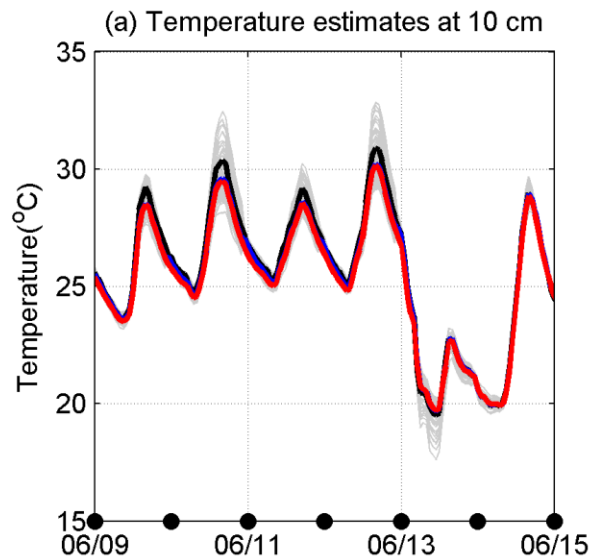
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Data assimilation & DTS

Ensemble Kalman Filter (EnKF)

$$Y(t)^a = Y(t) + K(t)(T_{obs} - T_f)$$

$$K(t) = C_{YM}\left(C_M + R_e\right)^{-1}$$

(a) Temperature estimates at 10 cm

(b) Moisture estimates at 10 cm

Data assimilation & DTS

Ensemble Kalman Filter (EnKF): Soil Moisture Profile

(a) Truth

(b) EnOL

(c) EnKF
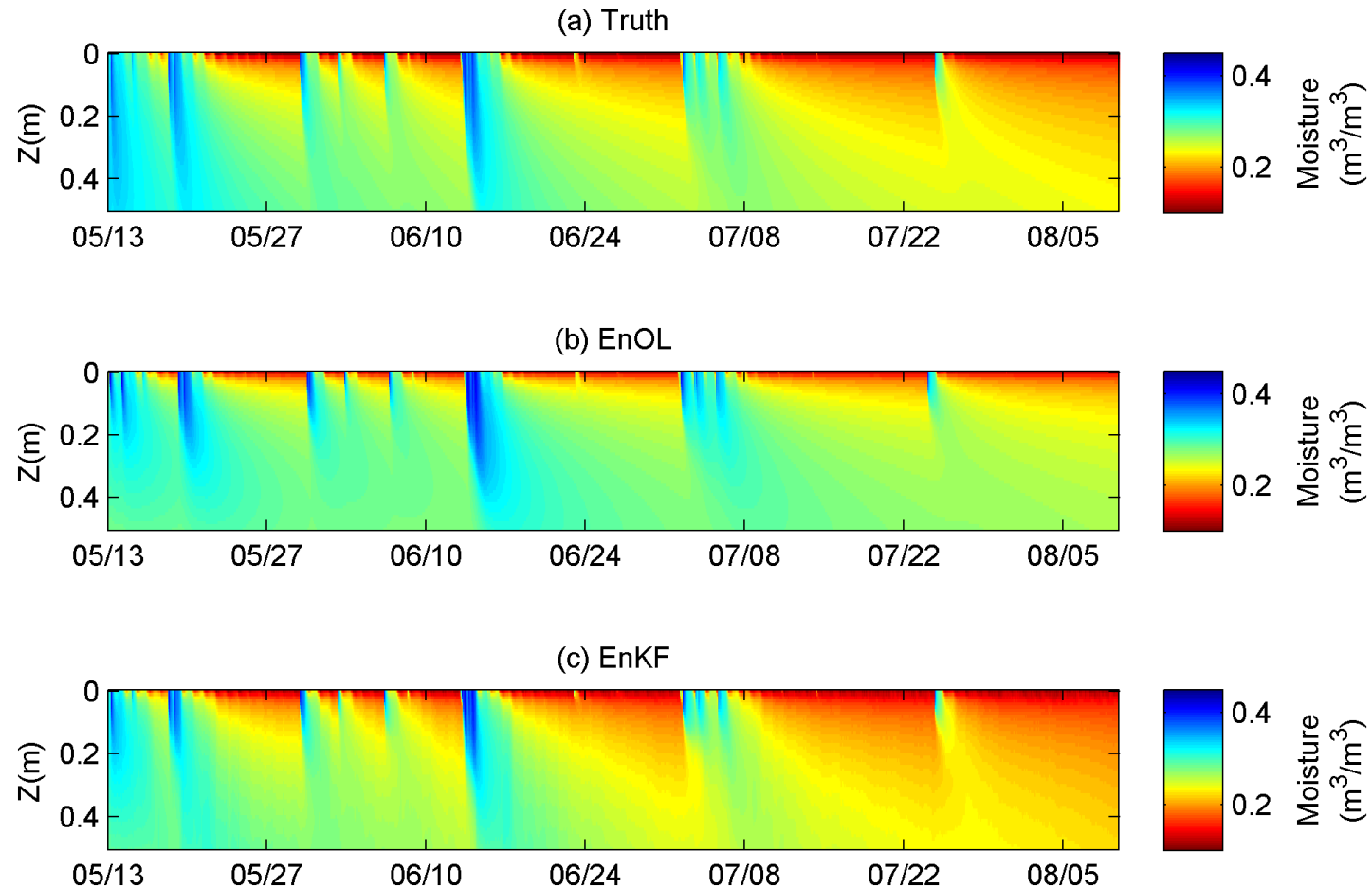
Data assimilation & DTS

Using data assimilation to design DTS experiments

RMSE in Soil Moisture Estimates
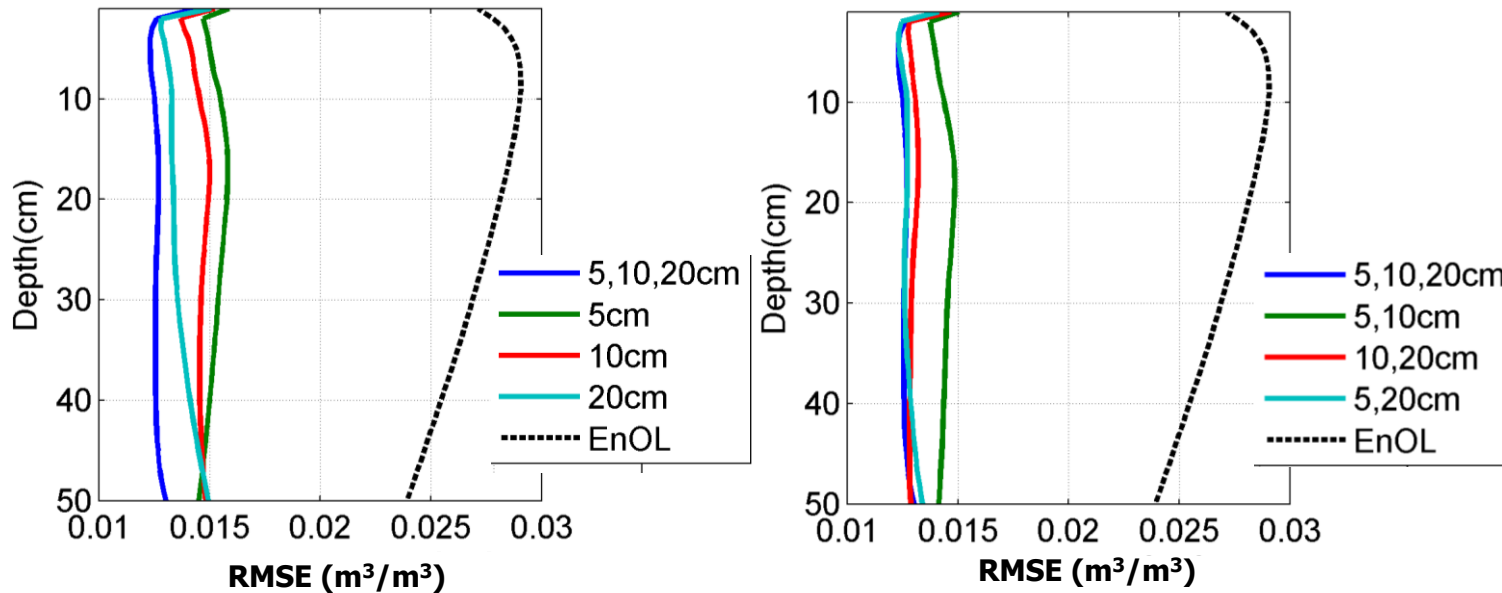
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- **Conclusion and future work**

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Conclusions and future work

- We improved Passive DTS, and tested it using real and synthetic DTS data.

❑ Non-unique soil moisture estimates is distinguished using a simple method

❑ Cable separation distance can be estimated using amplitude analysis

❑ Including soil thermal property profile information improves moisture estimates

- We demonstrated data assimilation might be useful for Passive DTS

❑ Improves entire profile

❑ Stable and capable to account for large uncertainties.

- We will test and apply DA approach in real data.

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Thank you!