Soil moisture estimation using Passive DTS: Theory and field application

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Content

• Background
  - DTS and soil moisture
  - 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

~5 cm
~10 cm
~15 cm
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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

• Background

• Improved Passive DTS
  ⇒ Soil moisture selection
  ⇒ Estimating cable separation distances
  ⇒ Including soil thermal property profile

• Data assimilation in Passive DTS

• Conclusion and future work
Improved Passive DTS
Selecting “correct” soil moisture estimates

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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 along a 61m transect.

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Improved Passive DTS
Importance of considering vertical heterogeneity in soil profile

Synthetic Experiment

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Improved Passive DTS

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

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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 in Passive DTS
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Data assimilation & DTS

Ensemble Kalman Filter (EnKF)

\[ Y(t)^{a} = Y(t) + K(t)(T_{obs} - T_{f}) \]

\[ K(t) = C_{YM} \left( C_{M} + R_{e} \right)^{-1} \]
Data assimilation & DTS

Ensemble Kalman Filter (EnKF): Soil Moisture Profile
Data assimilation & DTS
Using data assimilation to design DTS experiments

RMSE in Soil Moisture Estimates

![Graph showing RMSE in Soil Moisture Estimates with different depth levels and EnOL comparison.](image-url)
Content

• Background
• Improved Passive DTS
• Data assimilation in Passive DTS
• Conclusion and future work
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.
Thank you!