MONITORING PEATLAND WATER TABLE DEPTH USING POLARIMETRIC SAR

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PEATLANDS

https://commons.wikimedia.org/wiki/File:Moorland_peat_and_grasses_-_geograph.org.uk_-_3220285.jpg

- Vital ecosystems covering 3% of land.
- Stores a 1/3 of all soil carbon (UNEP 2022).
- Peat formed from peat forming vegetation (sphagnum moss).
- Waterlogged condition reduces the rate of decomposition.

THE CONDITION OF PEATLANDS

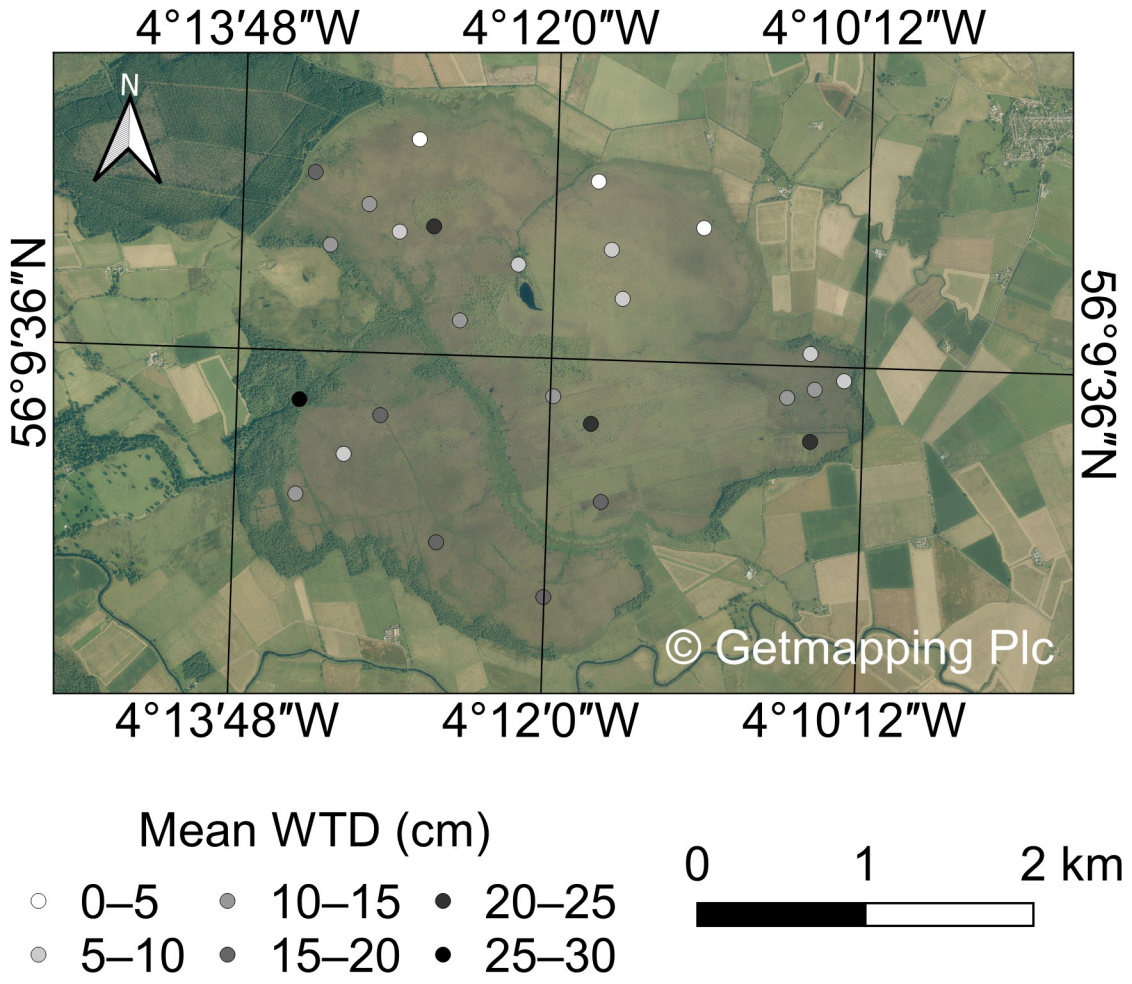
- Degrading peatlands are responsible for 4% of all anthropogenic carbon emissions (UNEP 2022).
- Require management; restoration techniques must be applied, informed by long-term monitoring of key characteristics.
- Specifically, measures to raise and monitor Water Table Depth (WTD) are key.

REMOTE SENSING

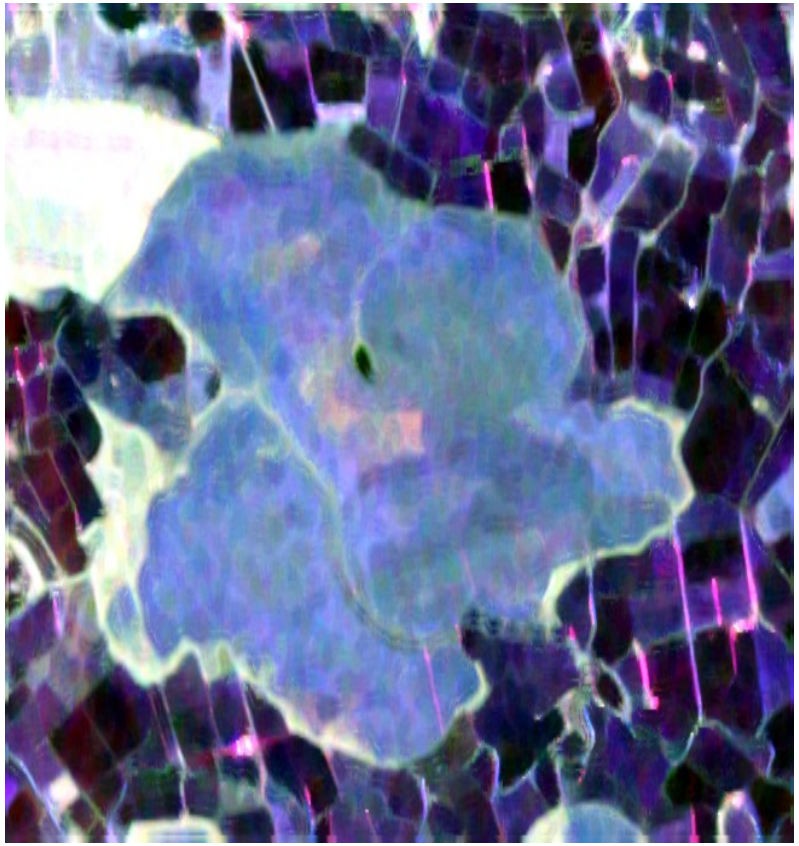
- Ground-based monitoring is expensive; remote sensing can cost-effectively cover a wide spatiotemporal extent albeit with limited accuracy.
- Research shows optical and C-band SAR imagery can predict WTD across multiple points: R^2 = 0.41 (Räsänen et al. 2022).
- Hypothesis: L-band quad-polarised SAR may improve accuracy due to its ground penetration, fully polarimetric nature, and known ability to detect sub-surface water flows (Touzi et al. 2011).

STUDY AREA

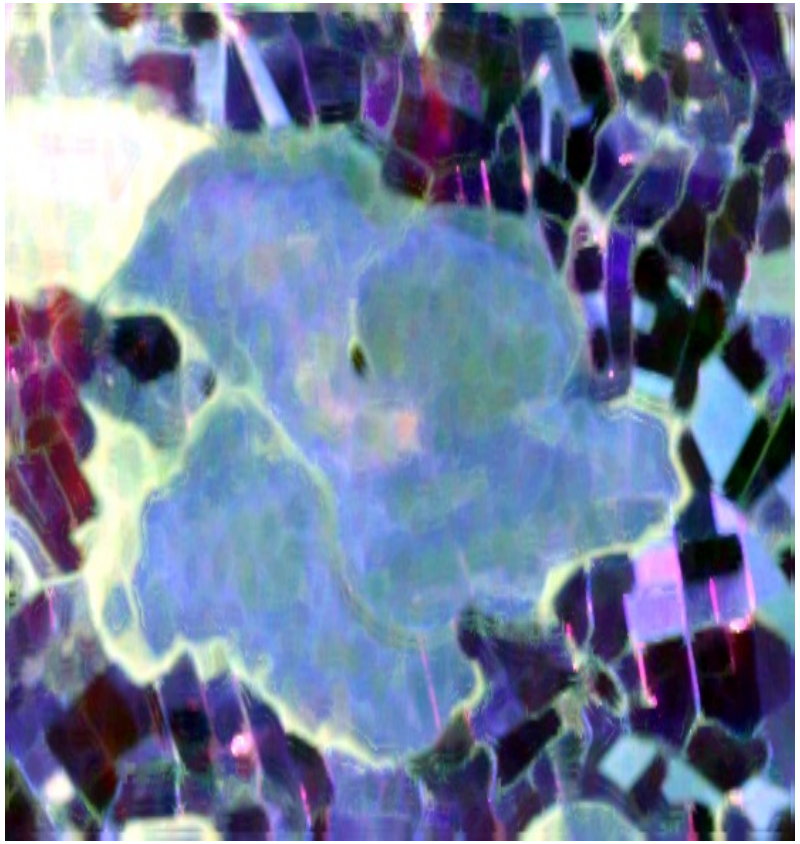
- Flanders Moss, a raised bog in Stirlingshire, Scotland.
- WTD data was obtained from 34 NatureScot WTD loggers.
- Across 5 ALOS-2 products covering the Forth Valley during 2016 and 2017, 93 datapoints were found where imaged WTD loggers had corresponding recorded WTDs.



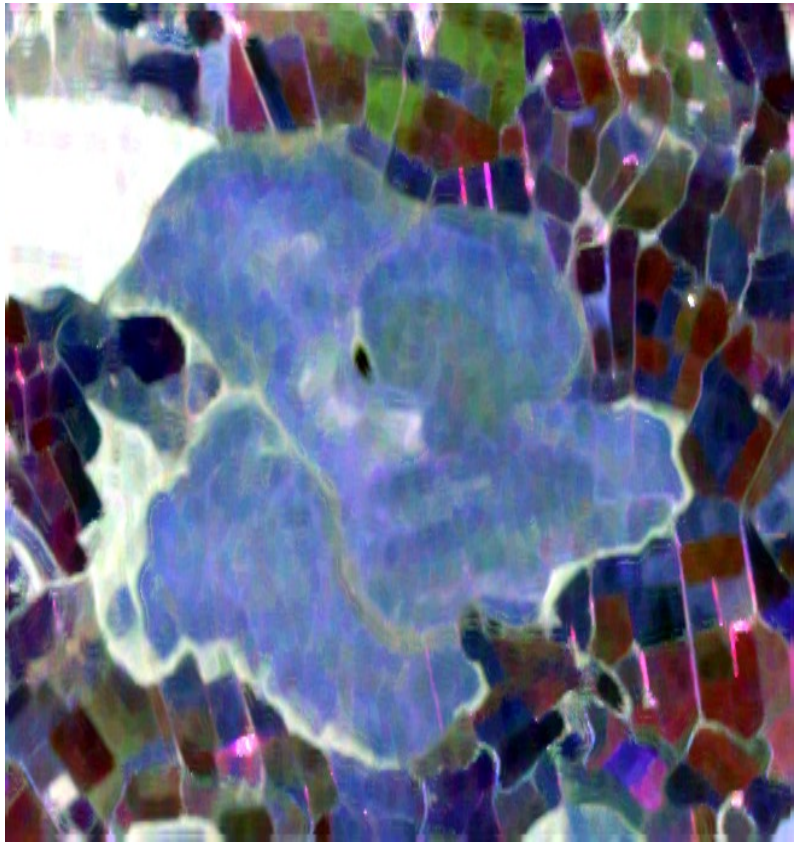
DATA



7 March 2016



12 April 2017



29 May 2017

PROCESSING

Speckle Filter	Speckle Filter Size	Polarimetric Decomposition Parameters
Box Car	5 x 5	H-A-Alpha Quad Pol - (3 param.)
Refined Lee	7 x 7	Huyen - (3 param.)
Improved Lee Sigma	9 x 9	Pauli - (3 param.)
IDAN	11 x 11	Touzi - (16 param.)
		Van Zyl - (3 param.)
		Yamaguchi - (4 param.)

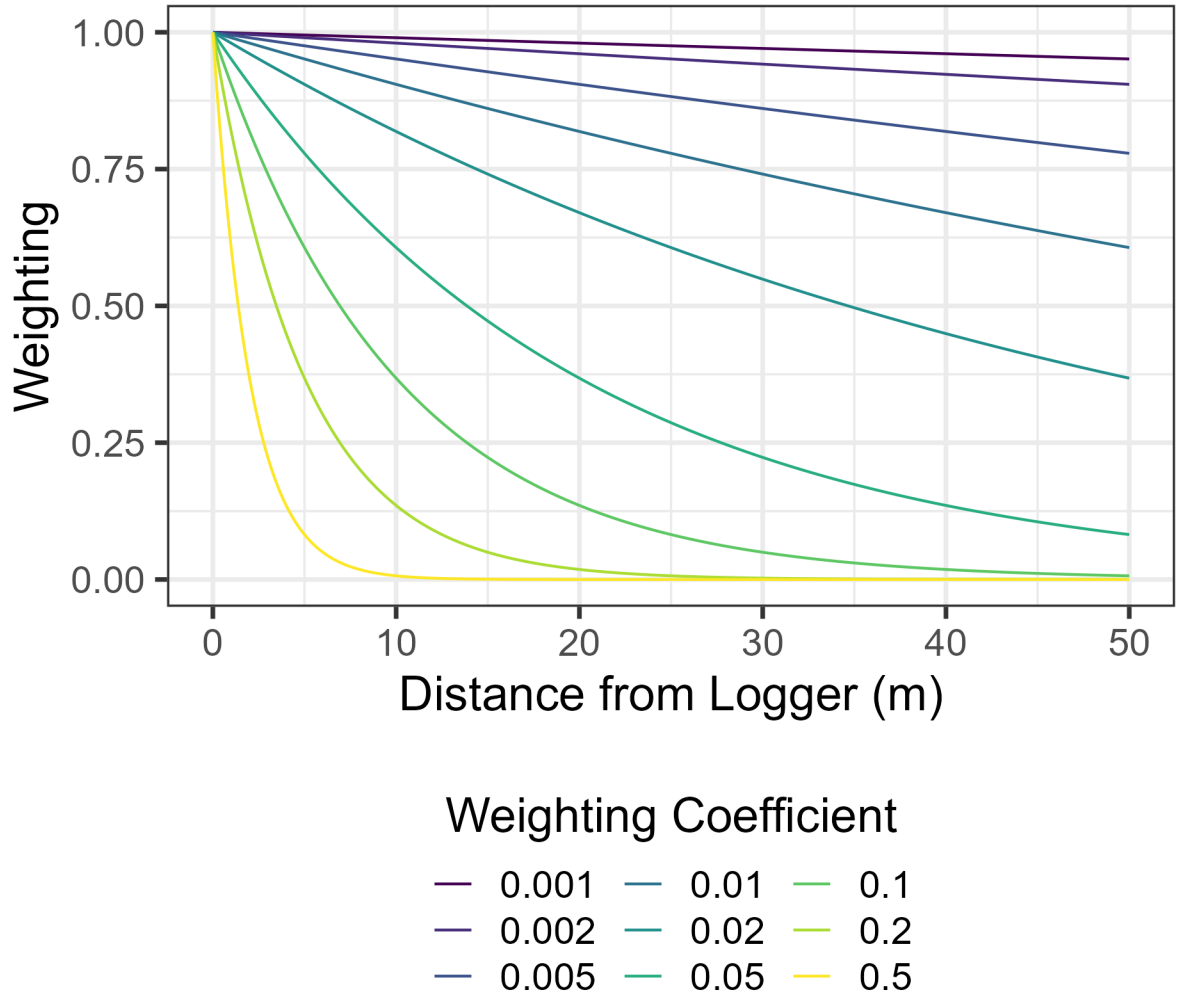
4 x 4 x 32 = 512

- Various speckle filters, speckle filter sizes, and polarimetric decompositions were used.
- Data was processed using each possible combination of these, giving 512 observables.

WEIGHTING COEFFICIENT

$$weighting = e^{-weighting\ coefficient \times distance\ from\ logger}$$

- Pixels were weighted exponentially depending on the distance from the logger.
- 9 different weighting coefficients processed each against the 512 observables.
- 512 x 9 = 4608 observables.



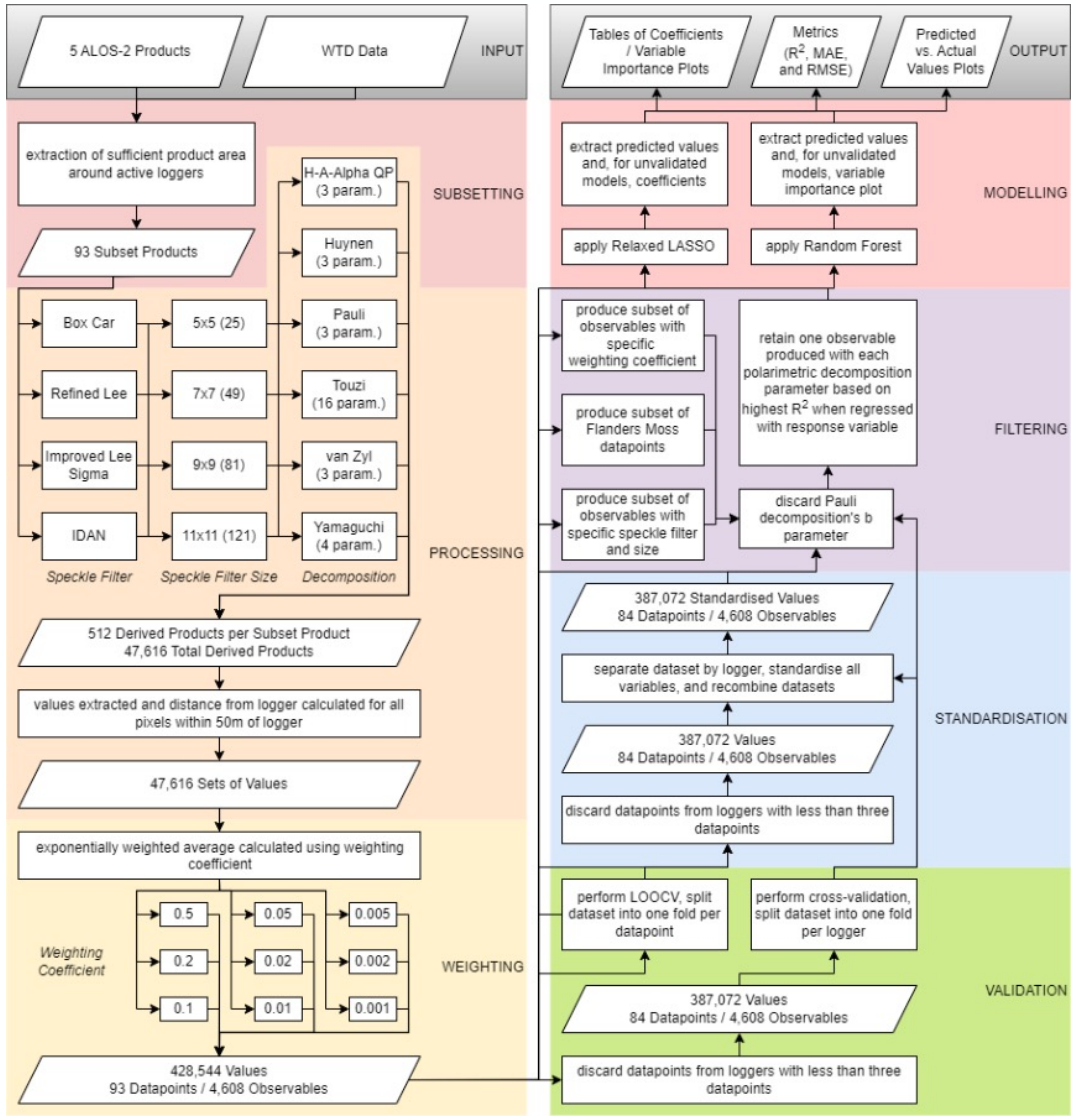
STANDARDISATION

$$standardised\ value = \frac{absolute\ value\ - mean\ of\ value}{standard\ deviation\ of\ values}$$

- Additionally, dataset was produced with values standardised across each logger.
- Hypothesis: by retaining observables' temporal but not spatial variations, correlation with WTD will improve as other characteristics SAR is sensitive to – e.g. surface roughness – vary more spatially

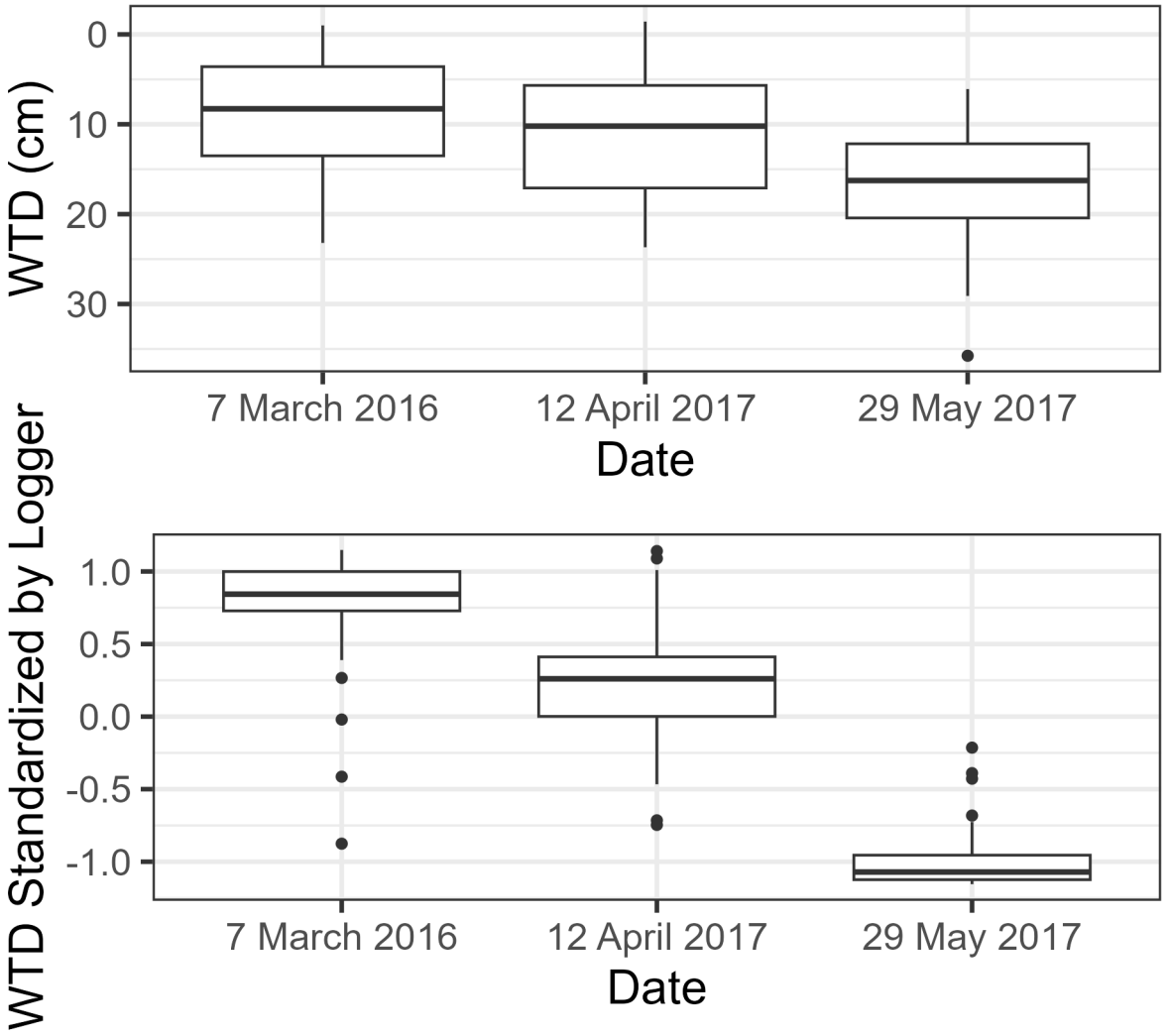
METHOD

- Performed variable selection, retaining 31 observables: one observable per polarimetric decomposition parameter.
- Using RandomForest, Relaxed Lasso, produced models predicting absolute and standardised WTD based on observables.
- Validated using 2 different methods:
  - Leave-One-Out-Cross-Validation (LOOCV)
  - Leave-Location-Out-Cross-Validation (LLOCV)

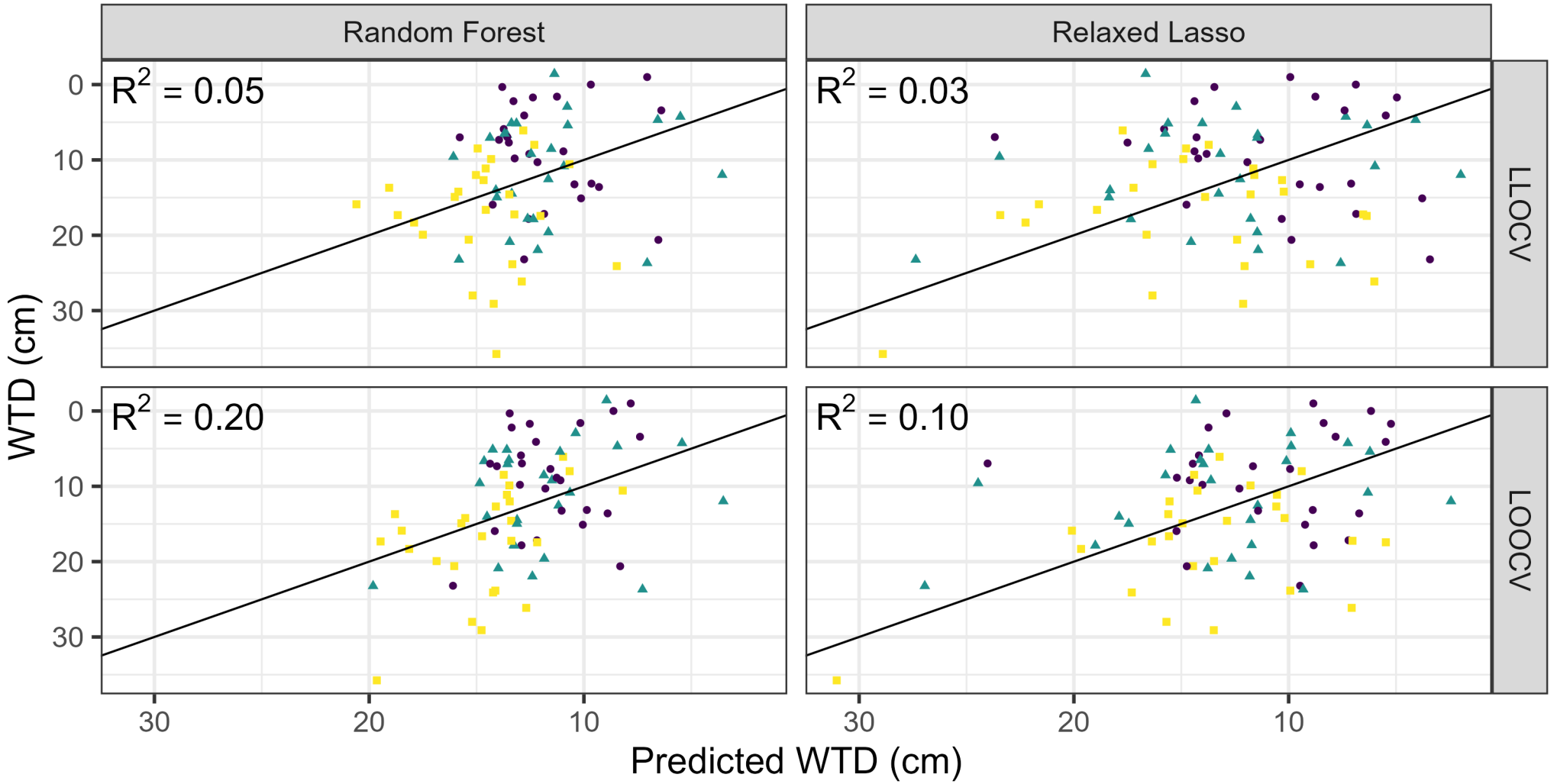


VALIDATION & STANDARDIZATION

- Box plots shows the temporal changes of the WTD decreasing over time.
- Standardization made a significant difference and changes to results.

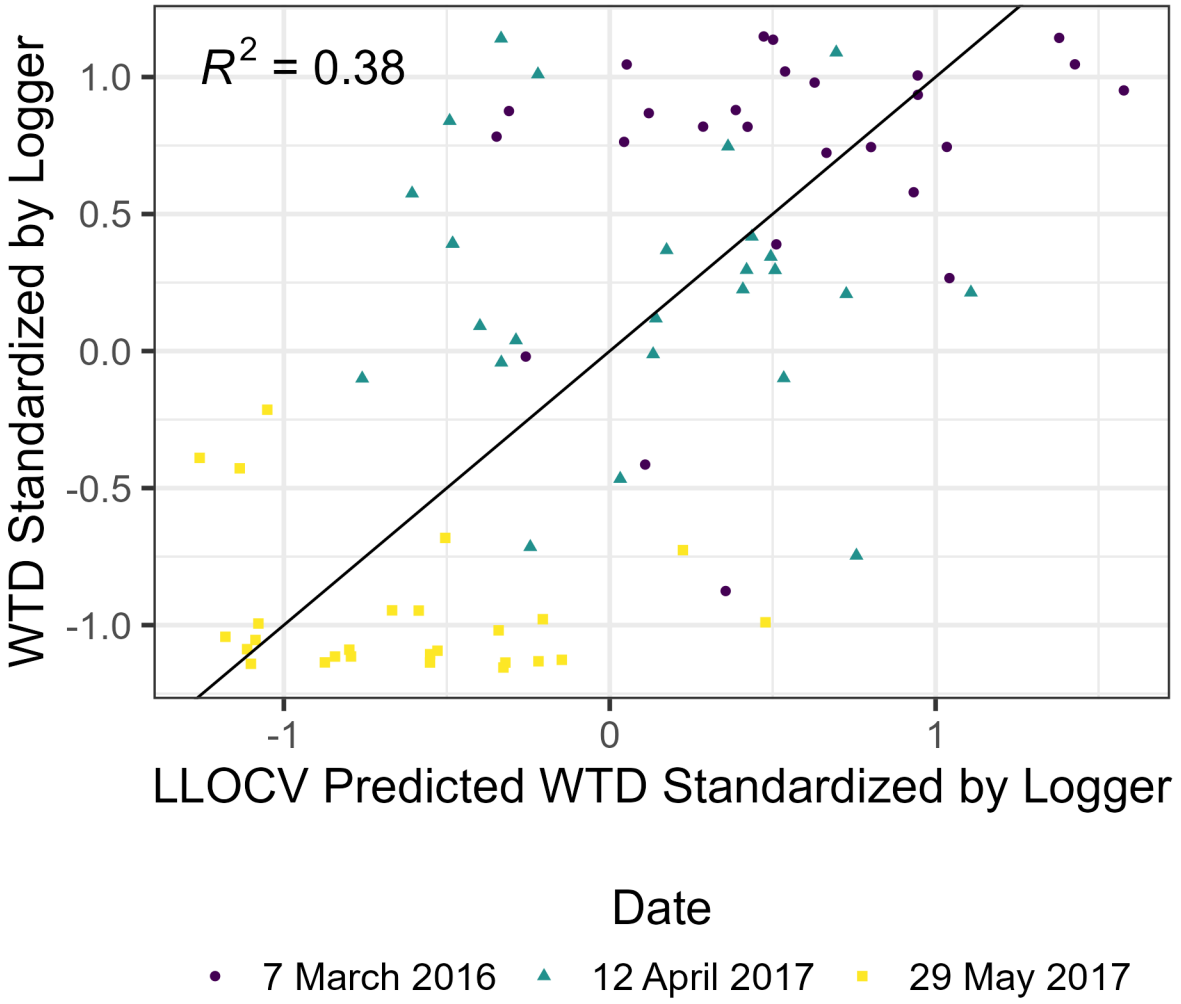


RESULTS (ABSOLUTE)



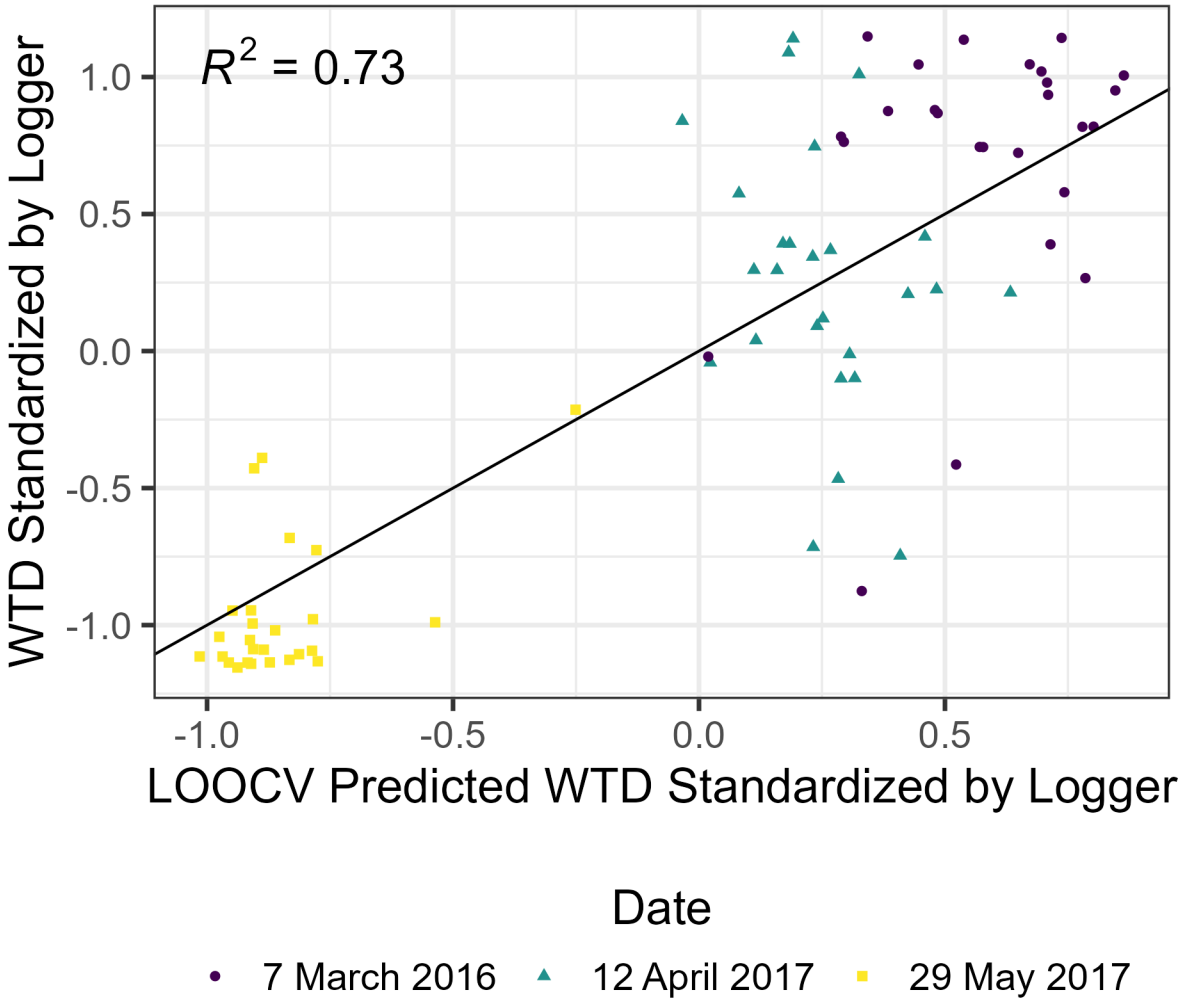
RESULTS (STANDARDIZED – RELAXED LASSO, LLOCV)

- Model had R^2 of 0.38.
- Using Relaxed Lasso to predict the standardized WTD, with LLOCV slightly improved results.



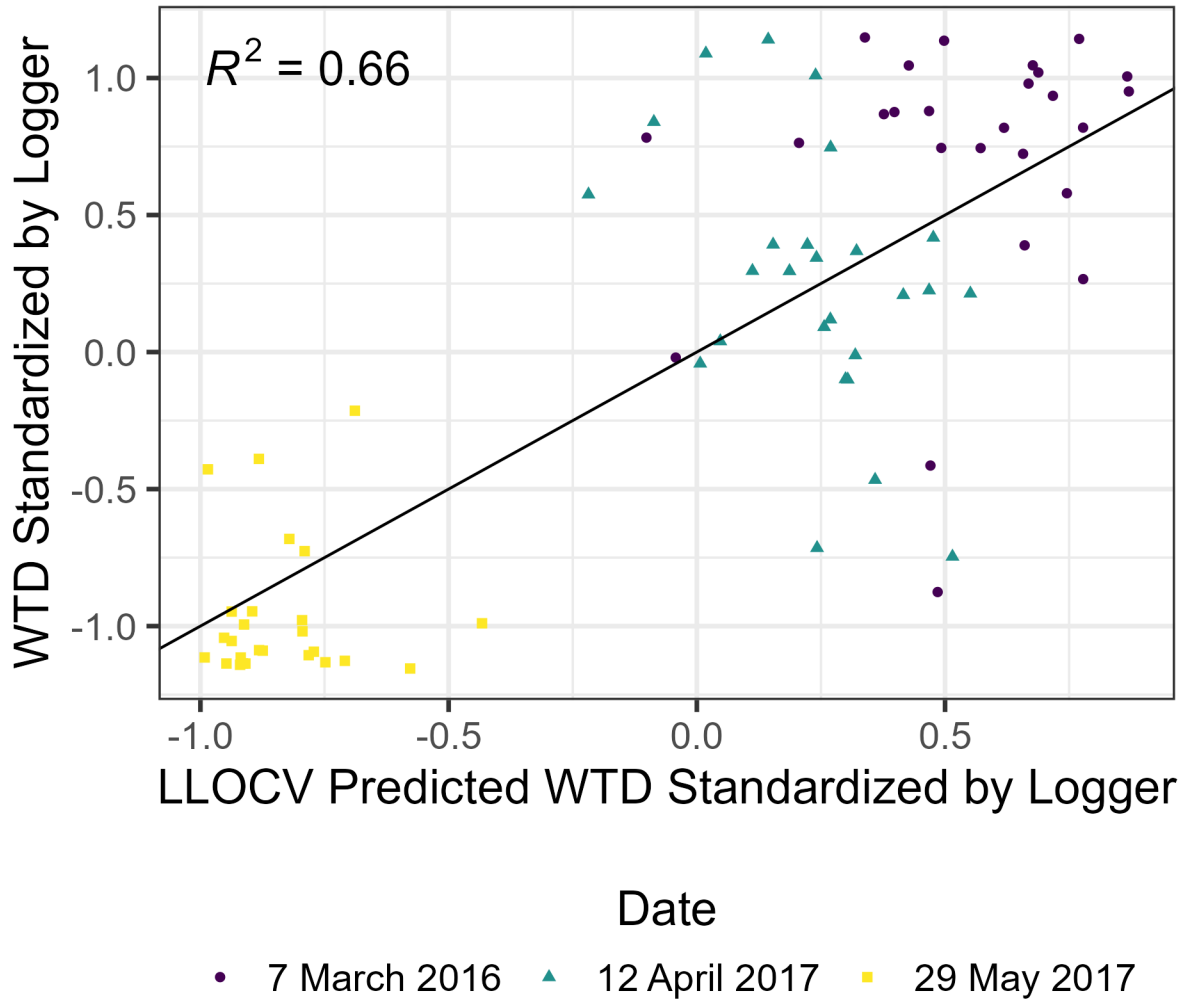
RESULTS (STANDARDIZED – RF, LOOCV)

- Model had R^2 of 0.73.
- Using RandomForest to predict the standardized WTD with LOOCV.
- Shows quad-polarised L-band SAR can be used for predicting WTD.



RESULTS (STANDARDIZED – RF, LLOCV)

- Model had R^2 of 0.66.
- Shows observables vary more in accordance with WTD when spatial variations – closely linked to non-WTD characteristics – are eliminated.
- Suggests models' performance can improve if non-WTD characteristics are controlled for, such as via classification, or via observables that are mostly only sensitive to WTD.



CONCLUSIONS

- Quad-polarised L-band SAR data can be used to predict WTD, even at unseen locations.
  - Can predict standardised WTD
  - RandomForest with LLOCV gave R^2 of 0.66.
- Further performance improvements likely possible using multi-sensor models, or if impacts of non-WTD characteristics on signal are controlled for.

THANK YOU FOR LISTENING