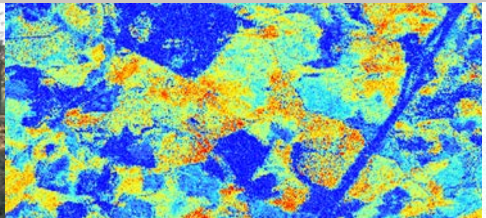
Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

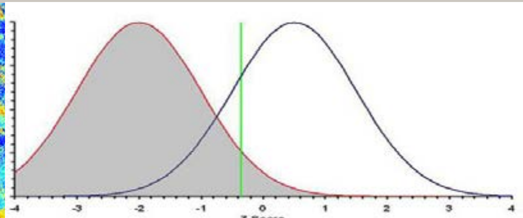
Influence of reference data accuracy in remote sensing studies

ForestSAT, 2. Oct. 2018, Washington D.C.

Henrik Persson, Nils Lindgren, Göran Ståhl

SLU, Umeå, Sweden





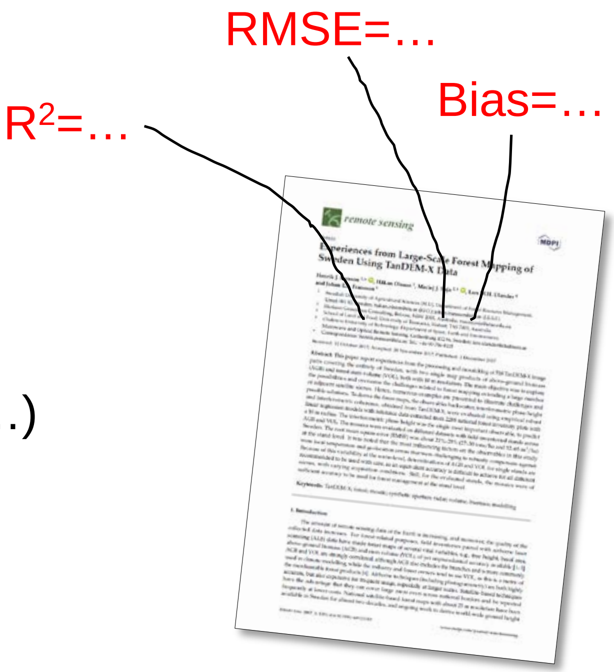
Outline

- Background
- Uncertainty metrics
- Alternative error model
- Non-perfect reference data
- Field errors propagated into RS uncertainty
- Conclusions

Background

<u>Plot and stand level</u>

- “Train” a RS model or use á priori information
- Report explained uncertainty (RMSE, R^2, bias…)
- Predict unknown values, often wall-to-wall
- Evaluate predictions with reference data



(at least) **two major problems**

- Uncertainty metrics are insufficient (RMSE, R^2, bias…)
- Reference data possess errors that are ignored

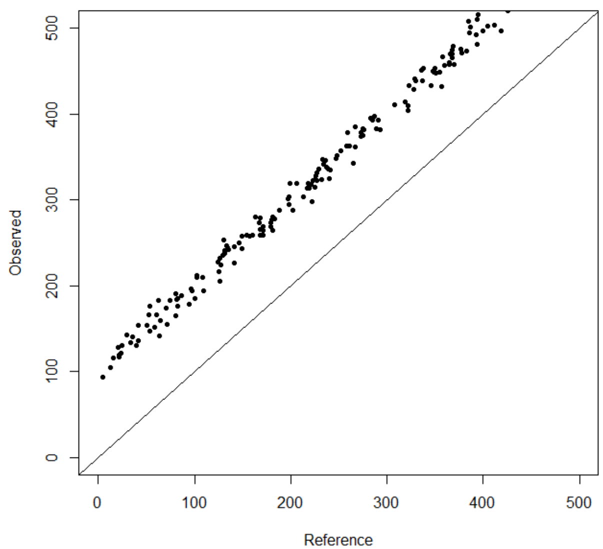
$$MSE = Bias^2 + \sigma(\varepsilon)^2$$

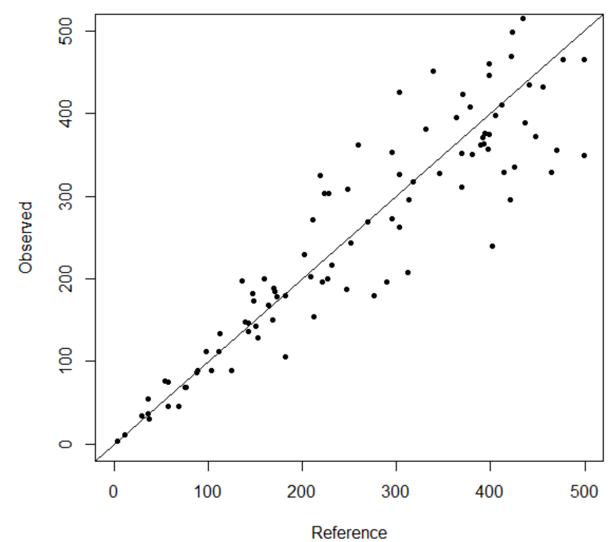
Uncertainty metrics

Most common: RMSE – root mean square error

- Mean error in units of the interesting variable
- Negatively oriented - lower is better, indifferent to direction

- Requires constant error, or
- Constant magnitude change of RMSE (RMSE%)

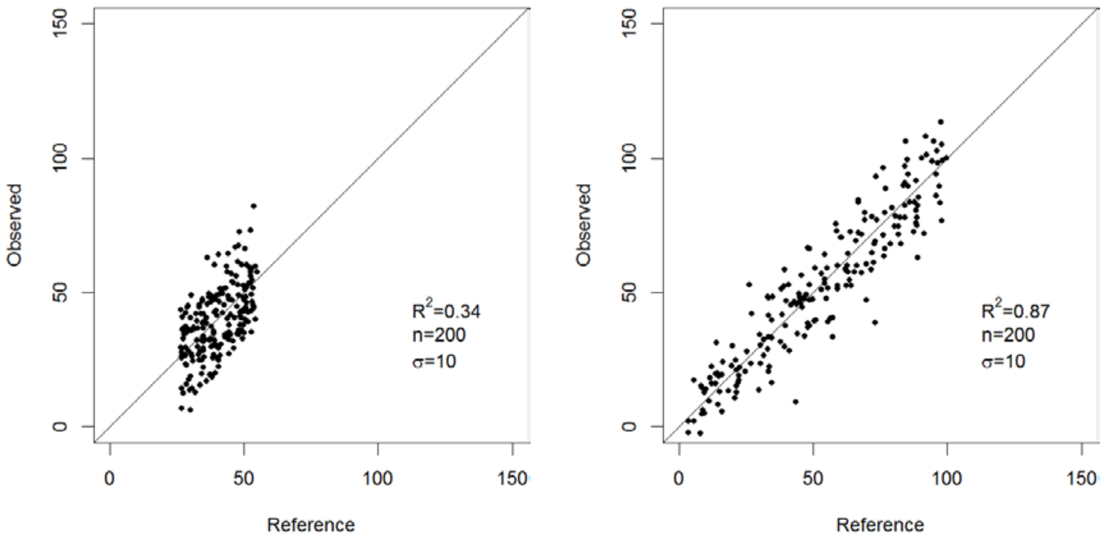




Uncertainty metrics

Other metrics:

- R^2
- Bias
- mean deviation
- correlation coefficient
- …



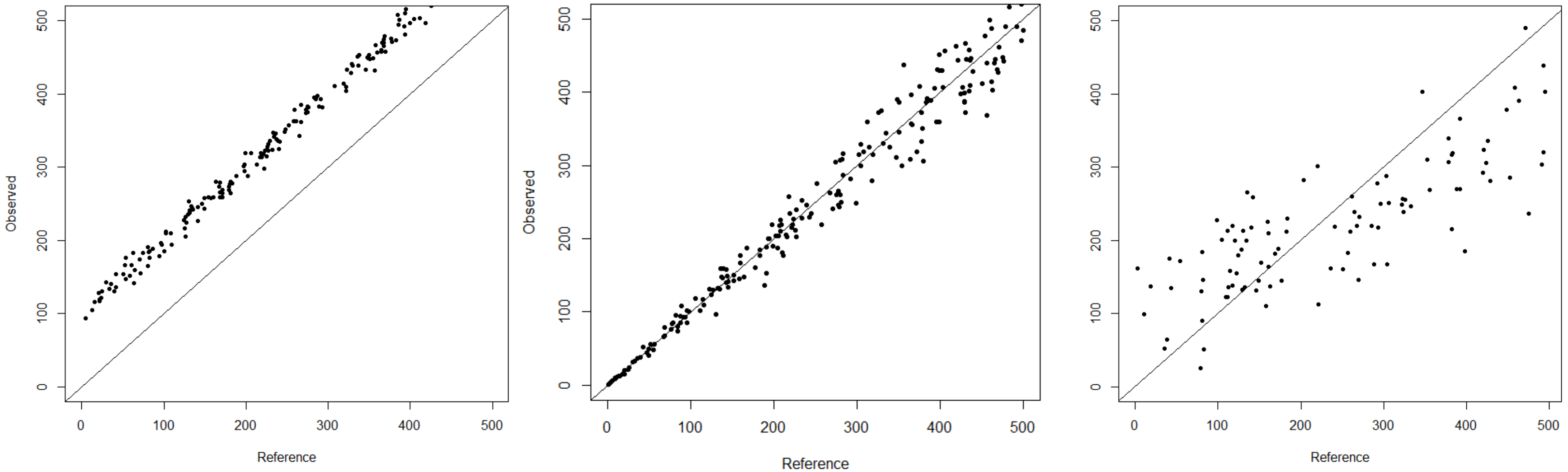
How many and which metrics should be used for a sufficient reporting?

Alternative error model

- We propose a linear parametric error model

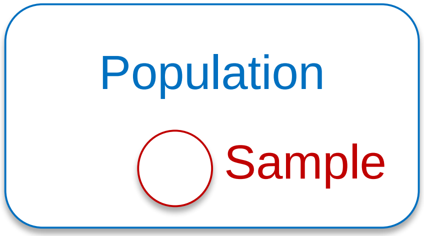
$$\hat{T}_{RS} = \lambda_0 + \lambda_1 \cdot T + \varepsilon$$

- Three parameters to be reported: λ_0, λ_1, $\sigma(\varepsilon)^2$
- Sufficient to describe bias, scaling, and spread for any value



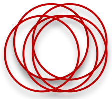
Second objective:
Non-perfect reference data

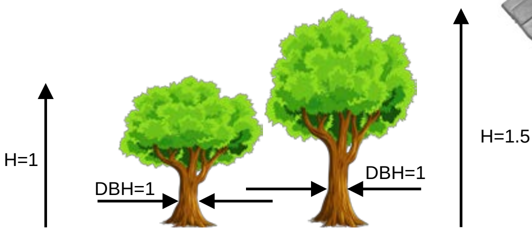
Errors in reference data



Dominating error sources are expected to be:

- Sampling errors
- Positioning errors
- Measuring errors
- Model errors





Every error source will possess different degrees of systematic and random error contributions.

The magnitude of respective error source is still to be investigated, e.g., by studying large number of plots from the national forest inventory.

Modeling reference data

Proposed error model:
$$\hat{T} = \lambda_0 + \lambda_1 \cdot T + \varepsilon$$

We assume that reference data can be collected with correct expectation values, when using sufficiently large sample size

$$\hat{T}_{Ref} = T + \delta$$

To evaluate the estimations, we define the difference between the RS estimate and the reference data (commonly used as estimator for bias, RMSE…)

$$\hat{D} = \hat{T}_{RS} - \hat{T}_{Ref}$$

Common estimator:
$$\widehat{\mathrm{MSE}} = \frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2$$

Common estimator:
$$\widehat{\mathrm{Bias}} = \frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)$$

Finding error model parameters

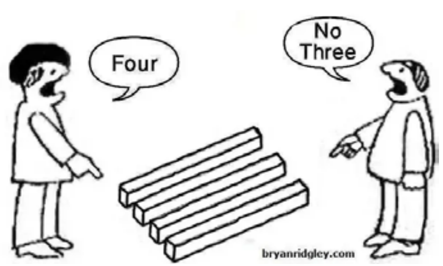
- E.g. linear regression can be used to find the parameters
- Variability in the dependent variable causes uncertainty in the estimated slope, but not bias
- Variability in the independent variable causes bias and imprecision in the slope

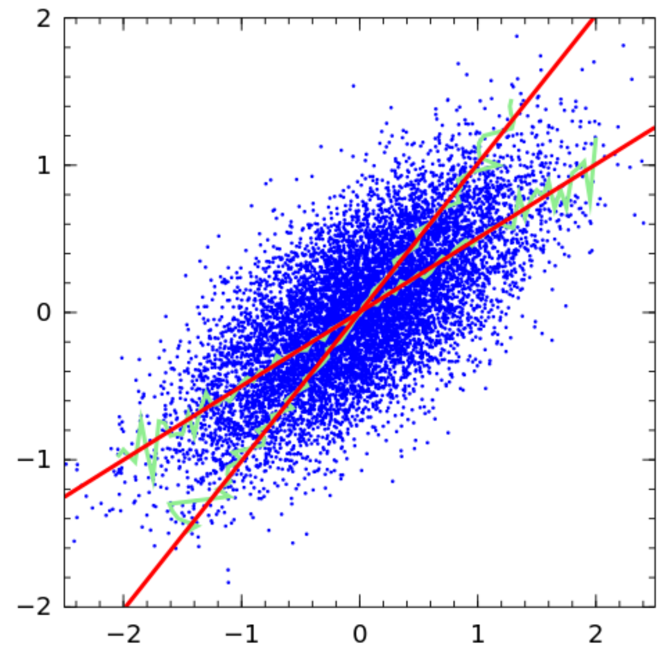
Proposed error model:
$$\hat{T} = \lambda_0 + \lambda_1 \cdot T + \varepsilon$$

$$\hat{D} = \hat{T}_{RS} - \hat{T}_{Ref}$$

Challenge: finding unbiased estimations of the parameters

Two cases:
$\lambda_1 = 1$
$\lambda_1 \neq 1$





Use of unbiased error model

$\lambda_1 = 1$: → $\widehat{D} = \widehat{D}(\lambda_0, \varepsilon)$
$\lambda_1 \neq 1$: → $\widehat{D} = \widehat{D}(\lambda_0, \lambda_1, \varepsilon, T)$

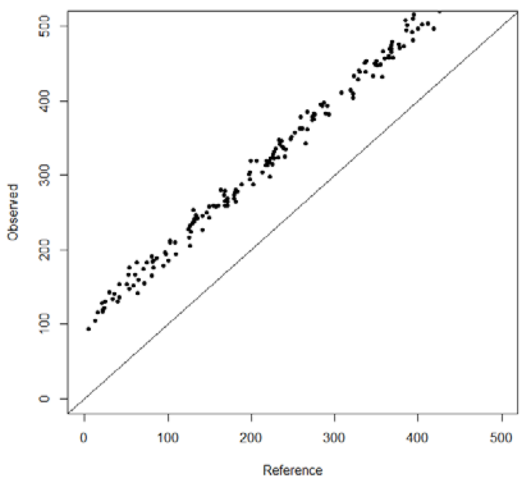
Proposed error model:
$\widehat{T} = \lambda_0 + \lambda_1 \cdot T + \varepsilon$

We provide unbiased parameters!

Example for simple case, $\lambda_1 = 1$:

$\lambda_0 = E[\widehat{D}] = Bias$

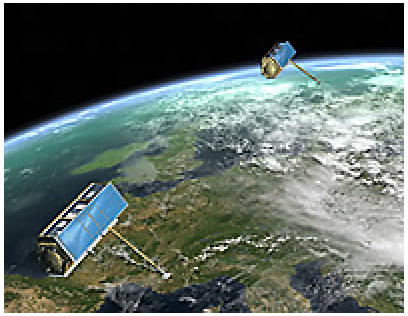
$\sigma(\varepsilon)^2 = \mathrm{Var}(\widehat{D}) = Var(\delta) + Var(\varepsilon)$



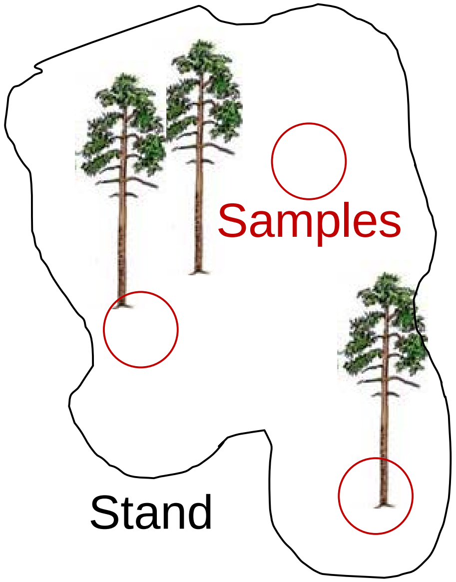
Hence the contribution due to random errors in the reference data can be removed in reported (R)MSE:

$$\widehat{MSE}_{RS} = \widehat{MSE} - Var(\delta)$$

Real applications



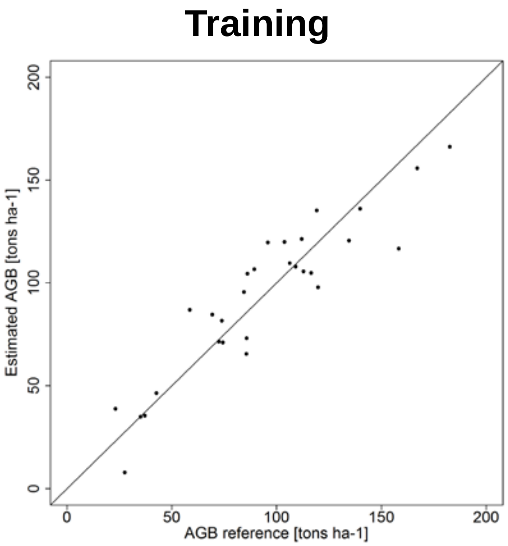
- A dataset of TanDEM-X and field inventory data.
- Models trained at a northern test site, Krycklan.
- Models predicted and evaluated at southern test site, Remningstorp.
- Training stands were sampled, n=10,
- Evaluation stands were completely inventoried, hence δ=0
- Assume the sampling error to dominate the random error

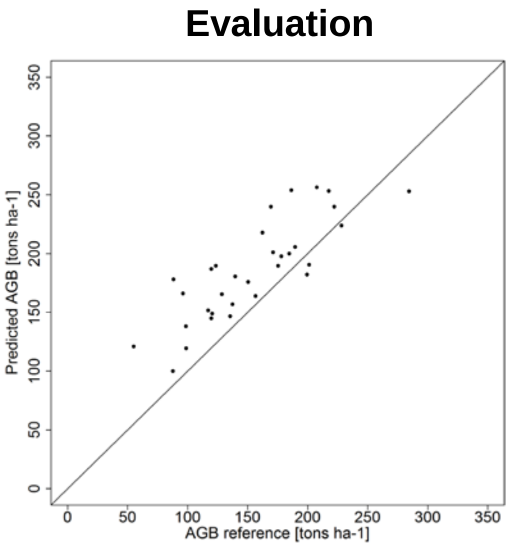


Errors reported as parameter values and traditional RMSE.

Results with real data

Data type	λ_0	λ_1	σ_ε^2	t_{score}	λ_1-case	MSE tons^2 ha^{-2}	RMSE tons^1 ha^{-1}
Training	Traditional estimator				–	231	15.2
Training	0	1	139	-2.24	= 1	139	11.8
Training	9.03	0.904	50.9	-2.24	≠ 1	50.9	7.14
Evaluation	79.1	0.688	569	-3.66	≠ 1	1,520	39.0
Evaluation	Traditional estimator				–	1,722	41.5

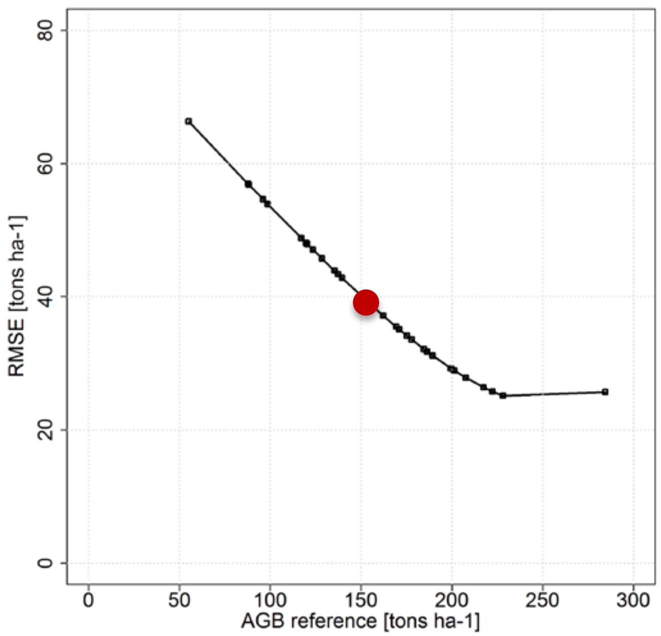




Error varies with reference

$\lambda_1 \neq 1$: →

Error for different reference values

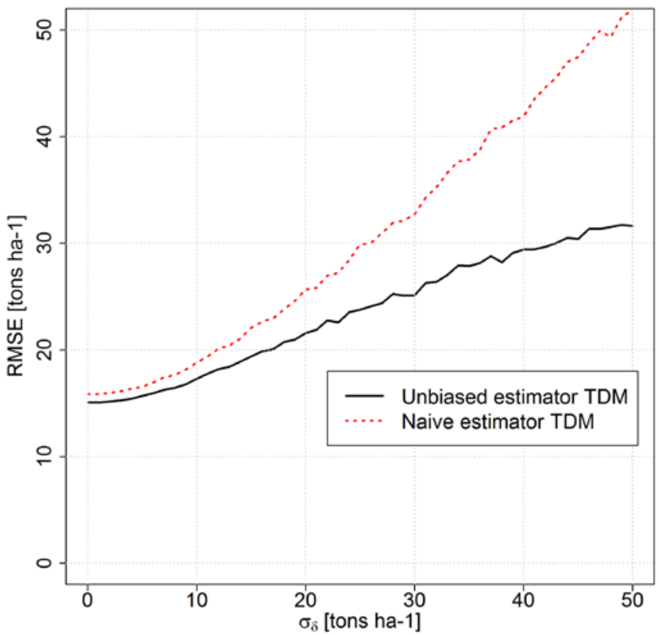


Evaluation

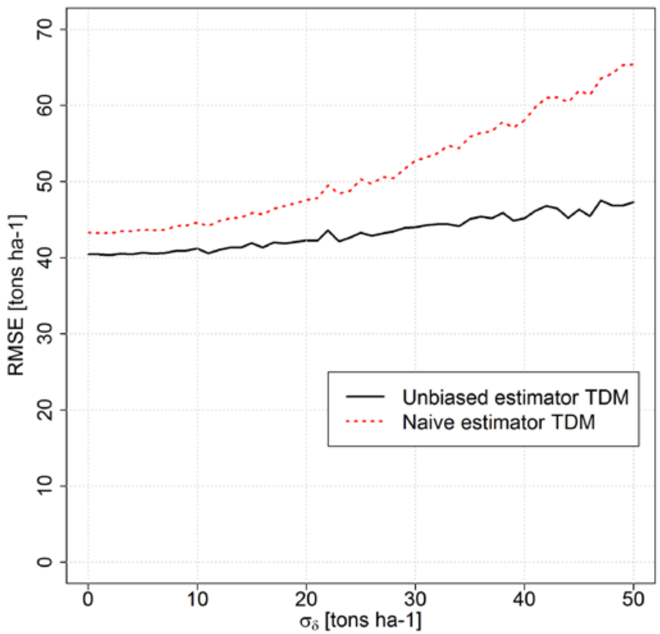
$$\widehat{MSE} = \left(\overline{\hat{T}_{RS}} - \bar{T}\right)^2 + (\lambda_1 - 1)^2\sigma_T^2 + \sigma_\varepsilon^2$$

Influence of reference data error

RMSE with additional random errors in reference data
Average from 100 iterations



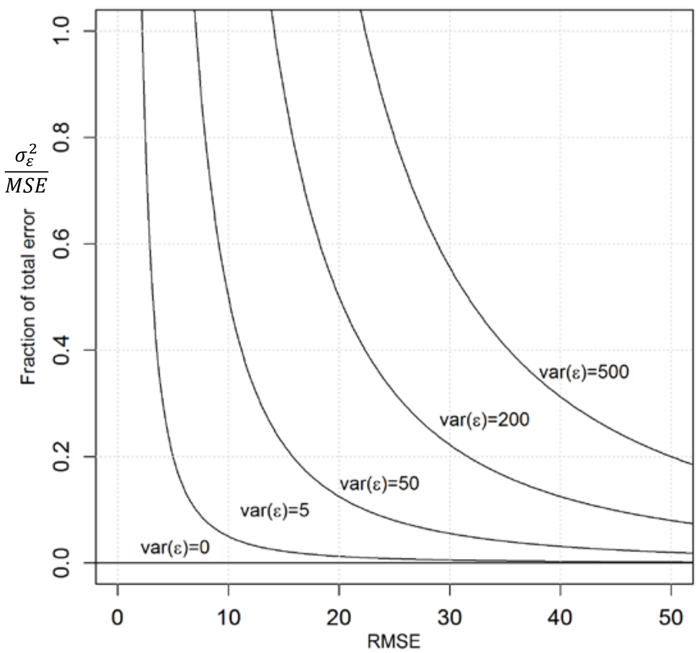
Training



Evaluation

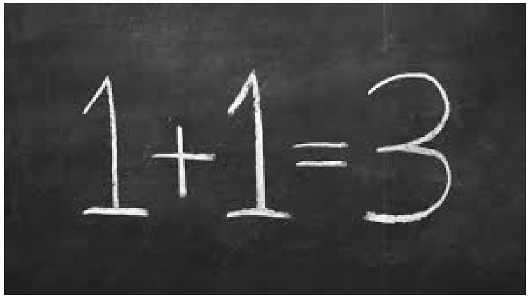
Influence of random error

- When $\lambda_1 = 1$, the reference random error simply added up directly (linearly) to the total random error
- When $\lambda_1 \neq 1$, the relation becomes more complex, but the reference random error still adds up with similar properties
- As a consequence, this figure shows the contribution of the random error to RMSE for various RMSE



Conclusions

- Proposed parametric error model can be used to sufficiently report common linear errors
- Unbiased estimators provided to model reference data vs. truth
- Computing RMSE from unbiased estimators ‘improves’ the RMSE compared to traditional reporting



Outlook

Within this project, we further plan to:

- Investigate the magnitude of different common error sources
- Compute the total influence of commonly ignored errors, on the reported error
- Evaluate how the proposed estimators respond to different error sources

Reflections, criticism, or experiences welcome!

Thank you!