Canopy height estimation from Sentinel-2 time series images using machine learning

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NEXTLAND

The NEXTLAND services

AGRICULTURE

- Biomass production — *vito*
- Crop phenology — *vito*
- Crop type classification — *vito*
- Crop water needs — *DHI*

AGRICULTURE & FORESTRY

- Anomaly detection — *vito*
- Potential and actual evapotranspiration — *DHI*
- Soil moisture
- Vegetation indices — *vito* *deimos*
- Vegetation water content — *vito*

FORESTRY

- Change detection (Deforestation & single tree cut) — *deimos*
- Forest classification — *deimos*
- Forest density & statistics — *deimos*
- Forest fire burn scar — *deimos*
- Tree health indices — *vito*

INTEGRATION SUPPORT & OPERATION

deimos   *Terradue*   Centralised operations   Scalable services   Customer support

The NEXTLAND service can be used for:

1. **Support to Irrigation** - Continuously calibrate water distribution

2. **Crop Planning Optimization** - An important tool to increase your yields

3. **Early Stress/ Anomaly Identification** - Detect anomalies and react faster

4. **Improved Crop Monitoring & Yield Prediction** – Increasing production in a sustainable way

5. **Forest Clearcutting & Thinning Detection** - Quickly spot clear-cut over large area, single tree cut, thinning and bush clearance

6. **Forest Regeneration Monitoring** – Ensuring the establishment of future forest generation

7. **Forest Inventory Support** – Managing large forest areas in a sustainable manner

8. **Fire Impact & Risk Assessment** - Take preventive measures in time

9. **Forest Health** - Observe changes every 5 days

Service Delivery

NextLand offers all its services on
a single, user-friendly platform –
paving the way for a wide variety of
organizations to benefit from EO.

Competitive pricing (prices beginning at 0,25€/ha).

Services can be single or bundled.

Payment options (pricing unit per hectare):

- Pay-per-use
- Purchasing credits
- Subscription (premium, unlimited, and customized)

Free trial promotion period.

Ask for a demo

Sales contact: sales@ec-nextland.eu

Canopy Height Model (CHM)

Canopy height of forests is a fundamental parameter for environmental studies and applications

- Airborne LiDAR sensors

- Yield measured 3-D point clouds

- Ground sampling distance (GSD) <1 m

- High accuracy considered as ground truth

- Limited to local scale due to high cost and lack of repetition

Source: https://glad.umd.edu/dataset/gedi
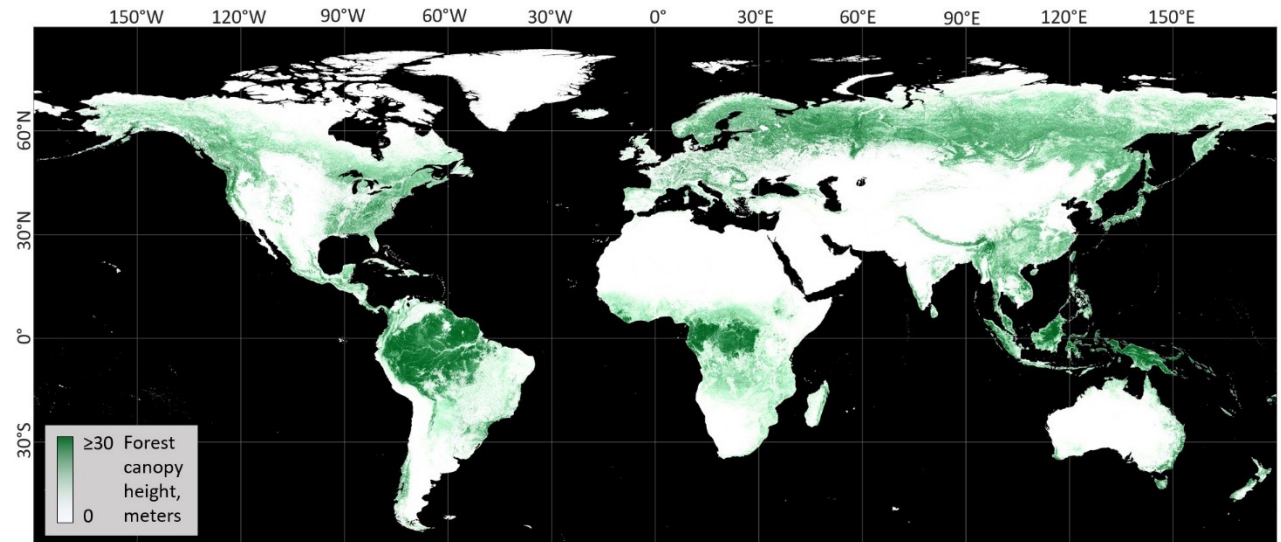
Our CHM service

- **Annual** Canopy Height map estimation

- Based on **sequences of Sentinel-2** images

- Lightweight NN model (320k trainable parameters)

- State-of-the-art results | Comparison with single-shot approaches

- **Calibrated Uncertainty Quantification**

- Transferable in time

- Transferable in location with very limited fine-tuning dataset
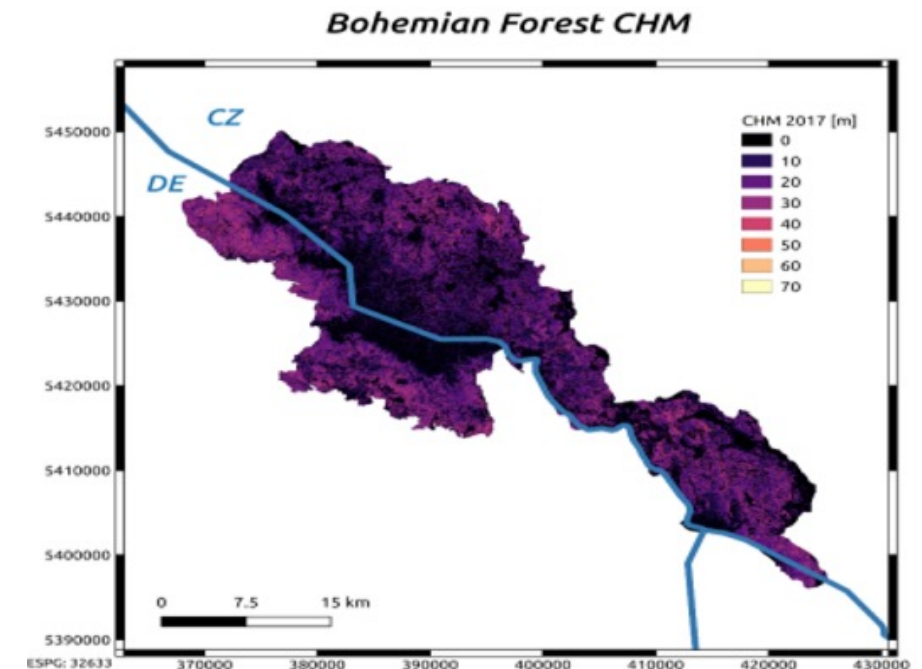

[m]
- 0
- 10
- 20
- 30

0 0.25 0.5 km
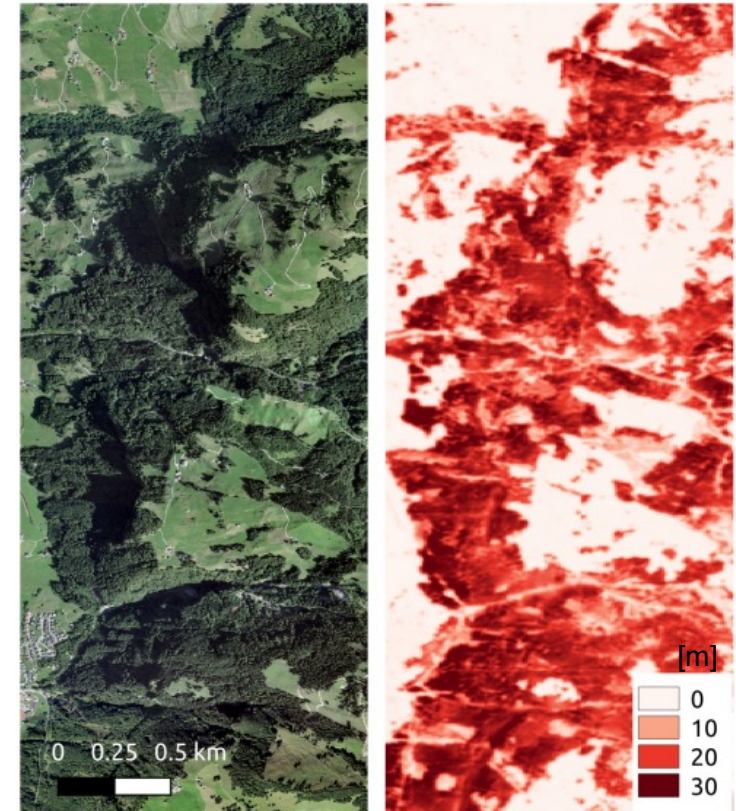
L. Alagialoglou, I. Manakos, M. Heurich, J. Cervenka, A. Delopoulos, A learnable model with calibrated uncertainty quantification for estimating canopy height from spaceborne sequential imagery, 2022, IEEE Transactions on Geoscience and Remote Sensing, DOI: 10.1109/TGRS.2022.3171407

Study Area

- Bohemian Forest (BF) ecosystem

- Area: 942 km2

- Location: Borders between southeastern Germany and Czech Republic

- Forest area: Heavily forested mountains, altitudes ranging from 570 to 1453 m

- Dominant tree species: Norway spruce (Picea abies), silver fir (Abies alba), European beech (Fagus sylvatica)

Data Acquired

- Ground-truth CHM: LiDAR measurements with Riegl 680i sensor in June 2017

- Annual sequences of Sentinel-2 Level-1C products (2017, 2018-2021)

- Land cover map, used for evaluation and comparison with previous works

Bohemian Forest CHM

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Experimental Results

Pixel-wise comparison of spatiotempCHM model with state-of-the-art results

Our **lightweight model** (320k trainable parameters) achieves mean absolute error **MAE=1,29m** in the Bohemian forest.

Method	Location	Area	MAE [m]	RMSE [m]
Lang et al. [1]	Switzerland	91Mpx	1.7	3.4
Lang et al. [1]	Gabon	25Mpx	4.3	5.6
ConvEnc-Dec [2]	BF	9.4Mpx	2.29	3.15
ConvEnc-Dec-mean40	BF	9.4Mpx	2.04	3.05
spatioTempCHM	BF	9.4Mpx	**1.29**	**1.87**

Ground-truth [m]   Prediction mean [m]   Prediction std [m]   Absolute error [m]
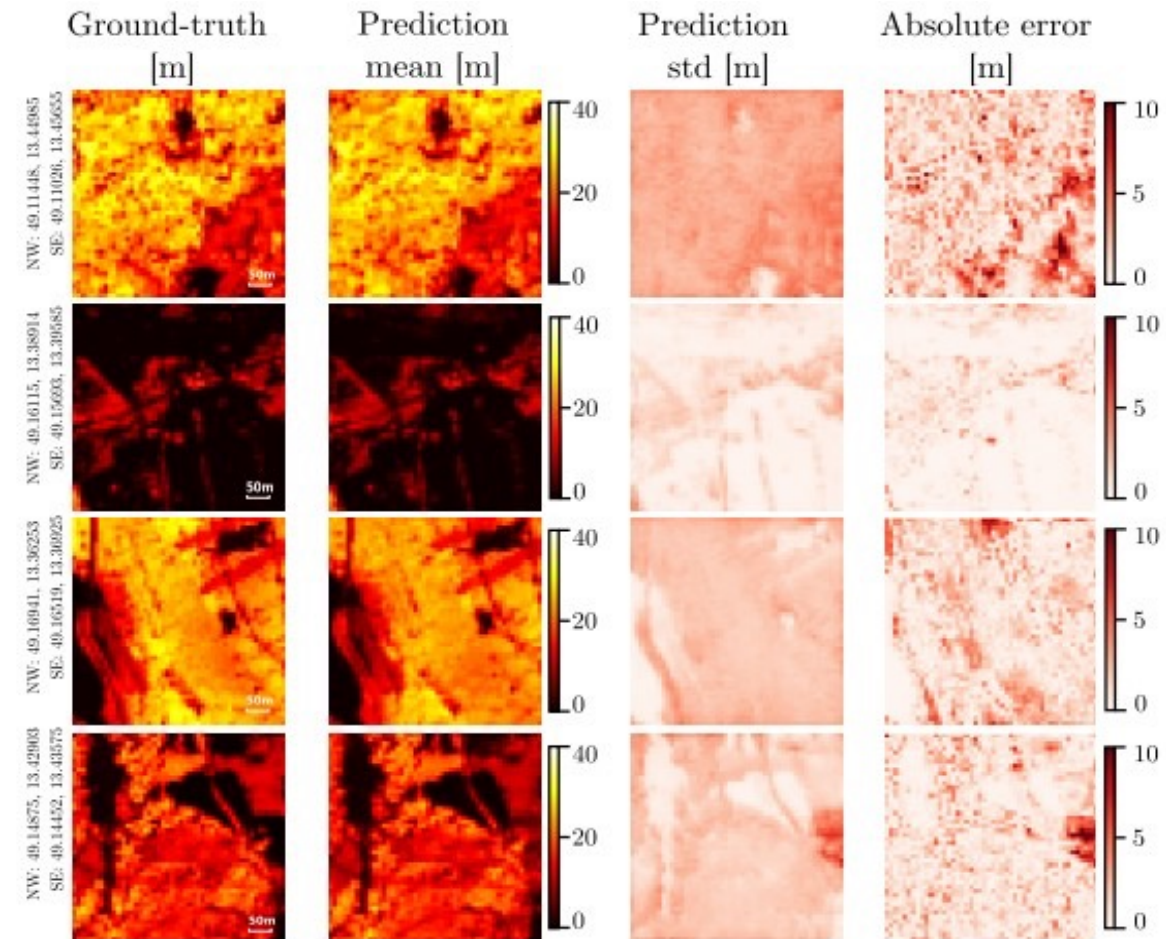
[1] Lang, N., et al., (2019). Country-wide high-resolution vegetation height mapping with Sentinel-2. Remote Sensing of Environment, 233, 111347.

[2] Alagialoglou, L. et al.,(2021). Canopy Height Estimation from Spaceborne Imagery Using Convolutional Encoder-Decoder. In MultiMedia Modeling: 27th International Conference, MMM 2021, Prague, Czech Republic, June 22–24, 2021, Proceedings, Part II 27 (pp. 307-317). Springer International Publishing.
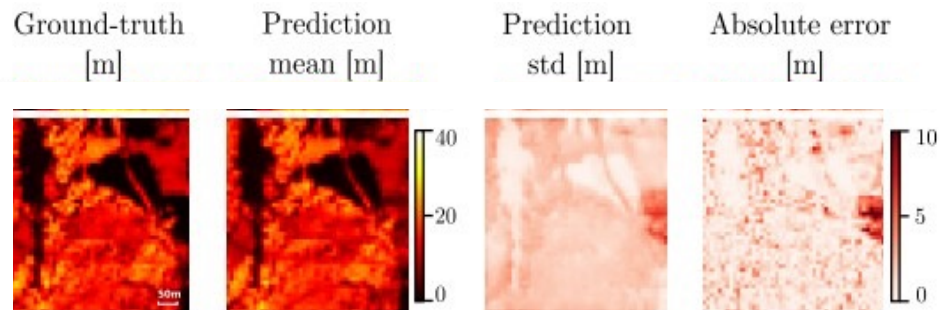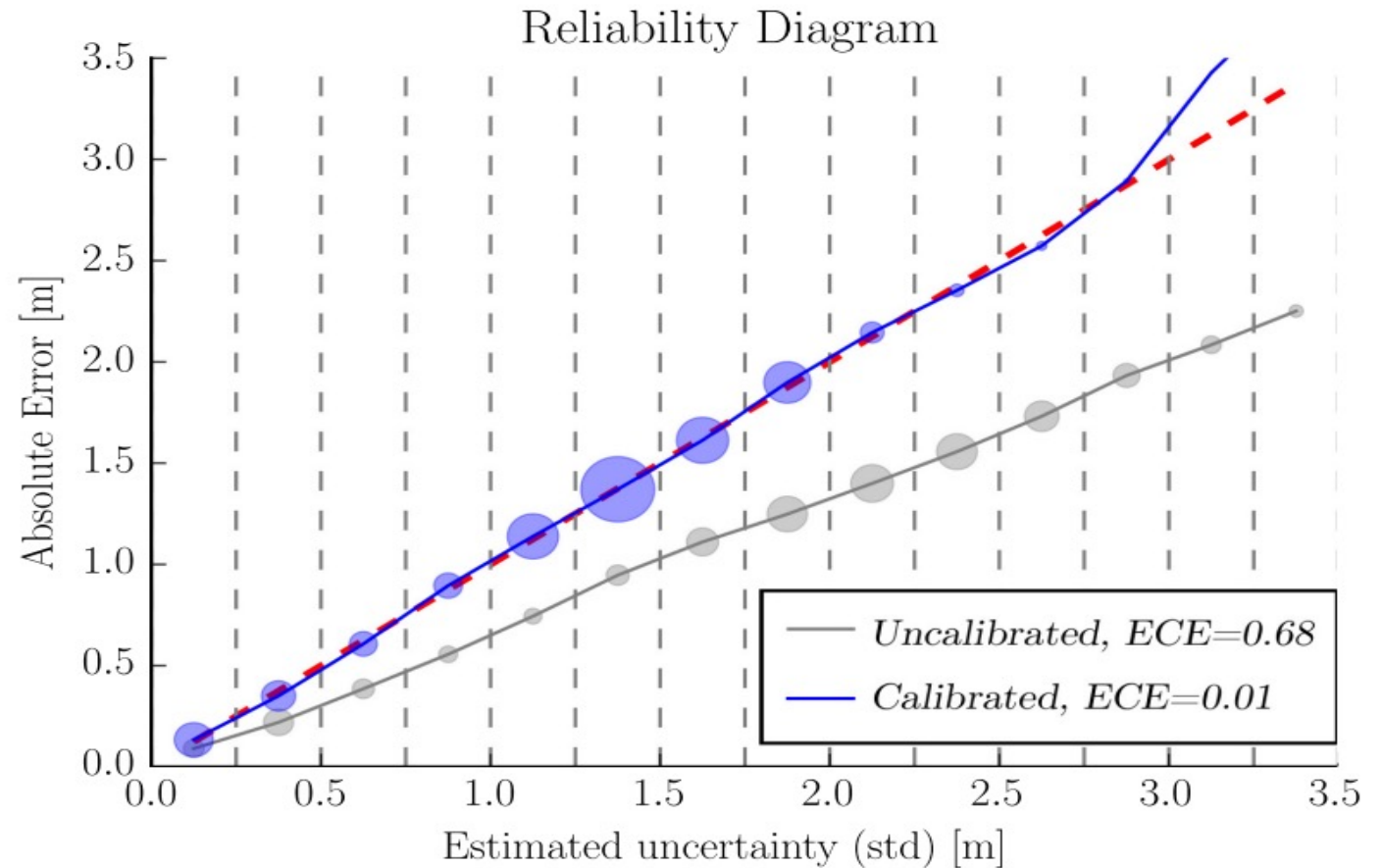
Transferability in location

- Transferability Study Area: **Switzerland**

- Ground truth CHM: **stereo aerial imagery** [1 × 1 m GSD]

- Photogrammetric image matching used for map generation

The trained model is transferable in Switzerland using a fine-tuning area of as low as 2km² with MAE = 1,94m.

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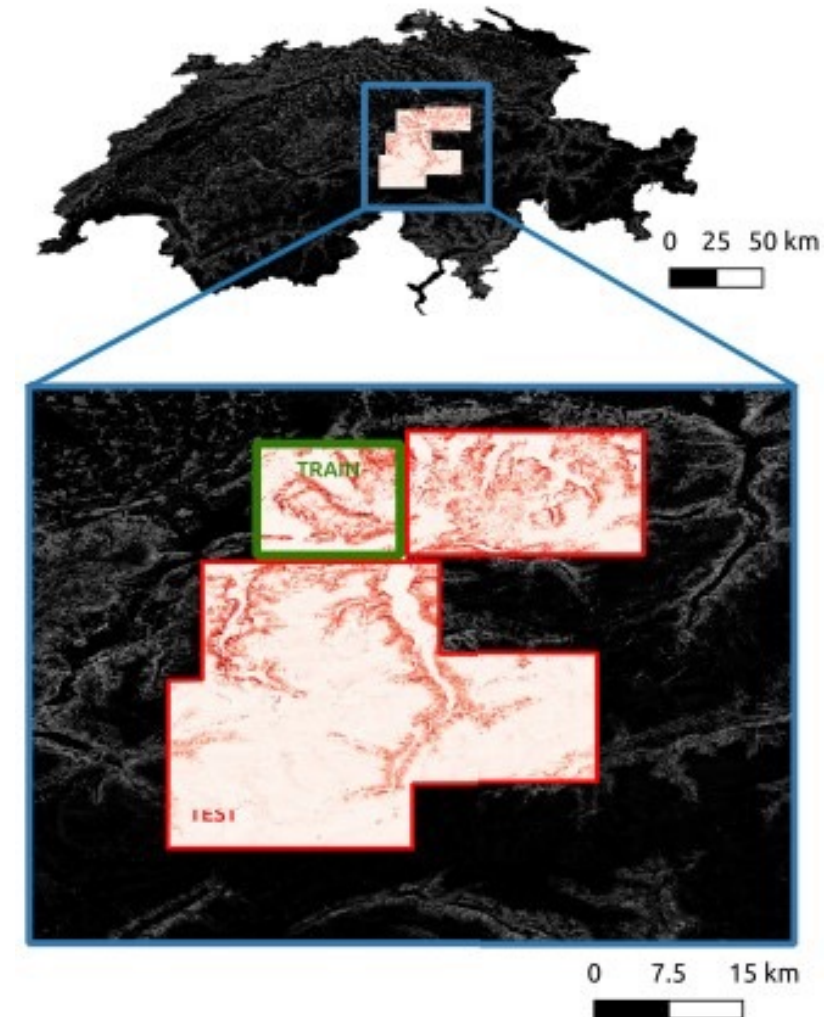
Calibrated Uncertainty Quantification

Reliability diagram using 6-ensemble spatioTempCHM model, before (uncalibrated) and after (calibrated) **isotonic regression** calibration technique.
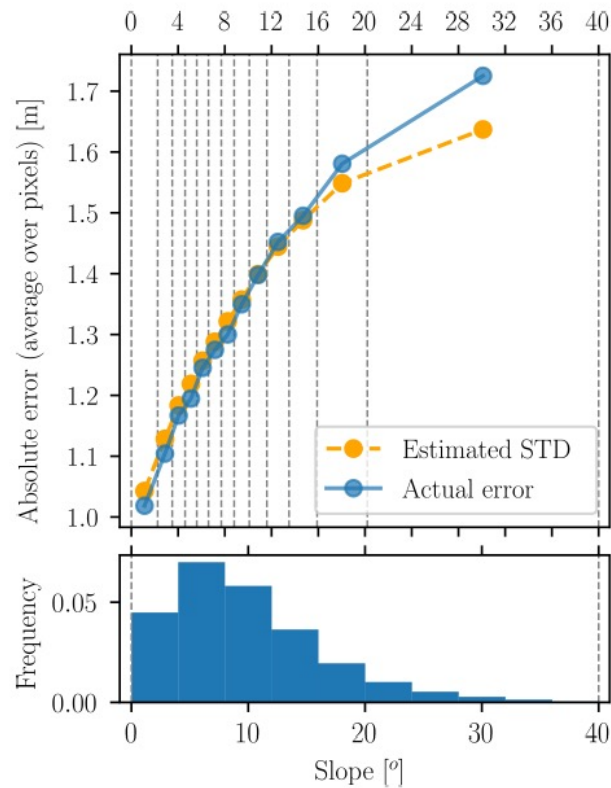

Reliability Diagram

Uncalibrated, ECE=0.68
Calibrated, ECE=0.01

Estimated uncertainty (std) [m]

Absolute Error [m]

Ground-truth [m]
Prediction mean [m]
Prediction std [m]
Absolute error [m]

Mean absolute error of the model for different **input sequence length**
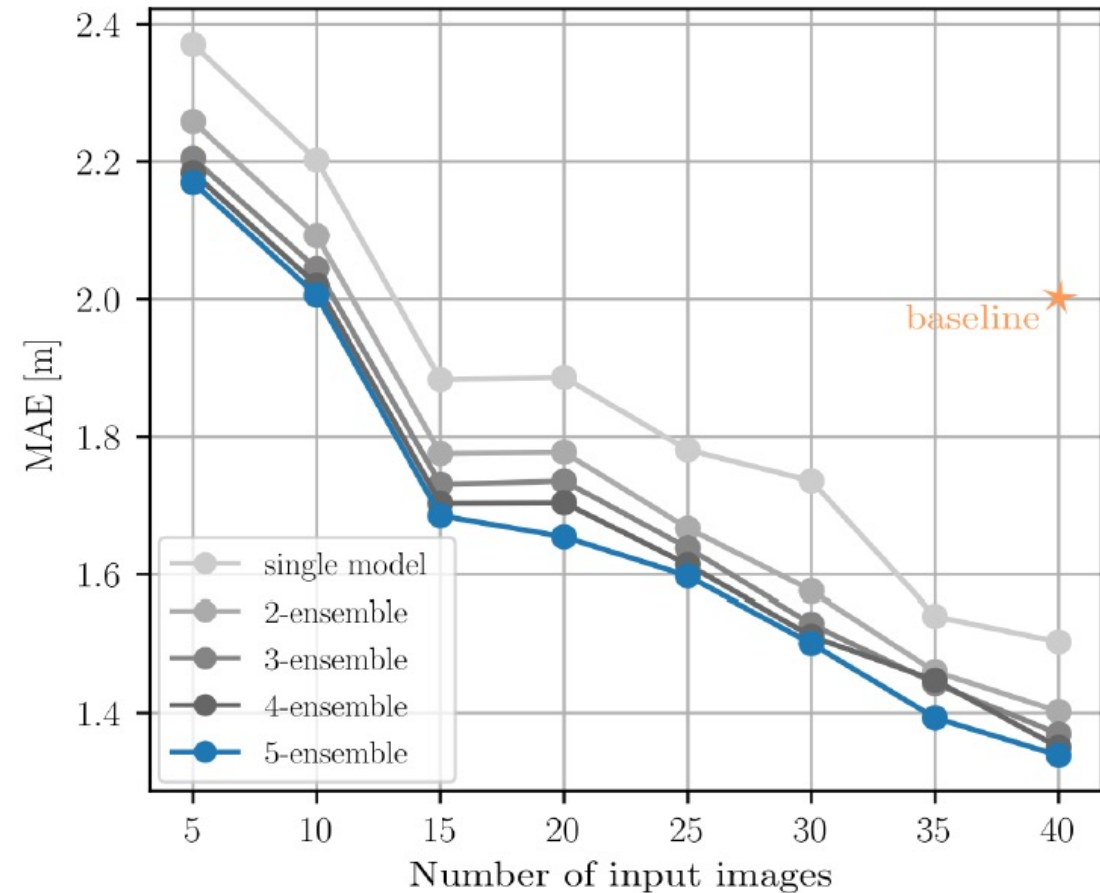
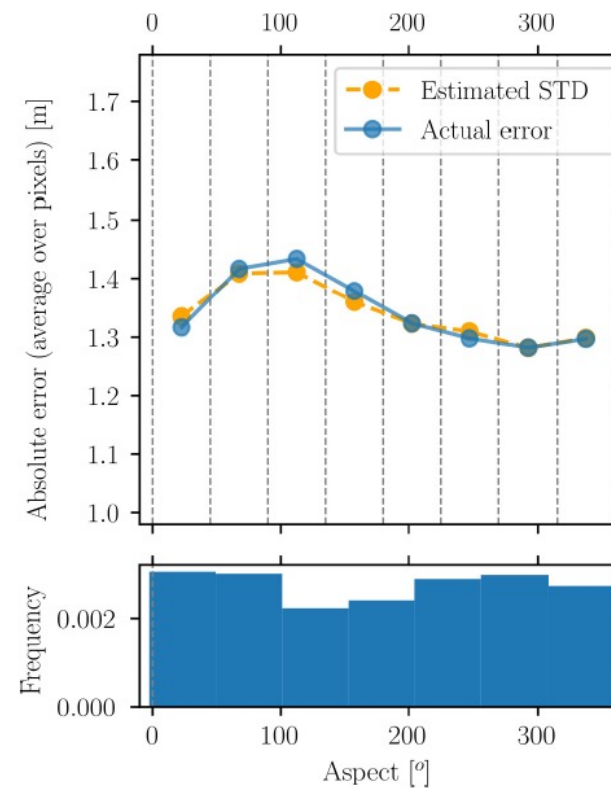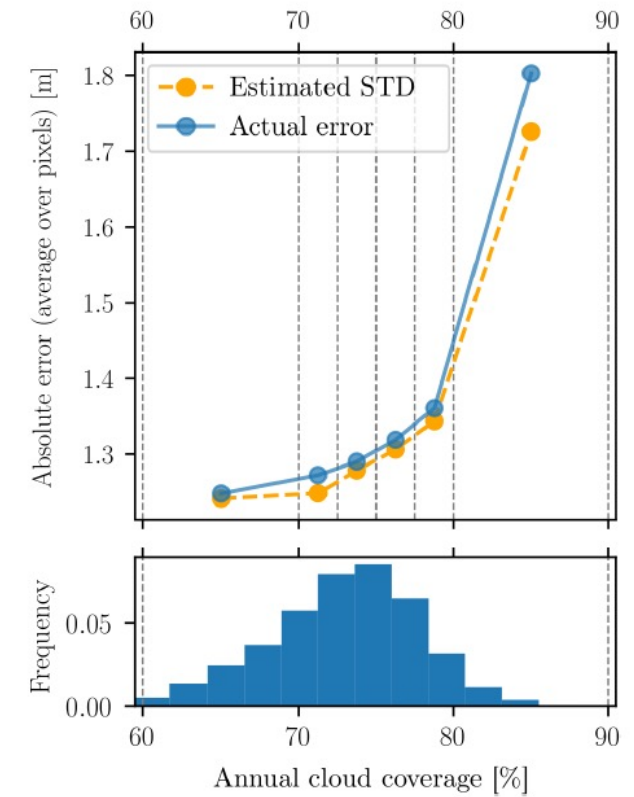# Influence of topography & cloudiness factors

(a) Error vs slope

(b) Error vs aspect

(c) Error vs annual cloud coverage

Thank you