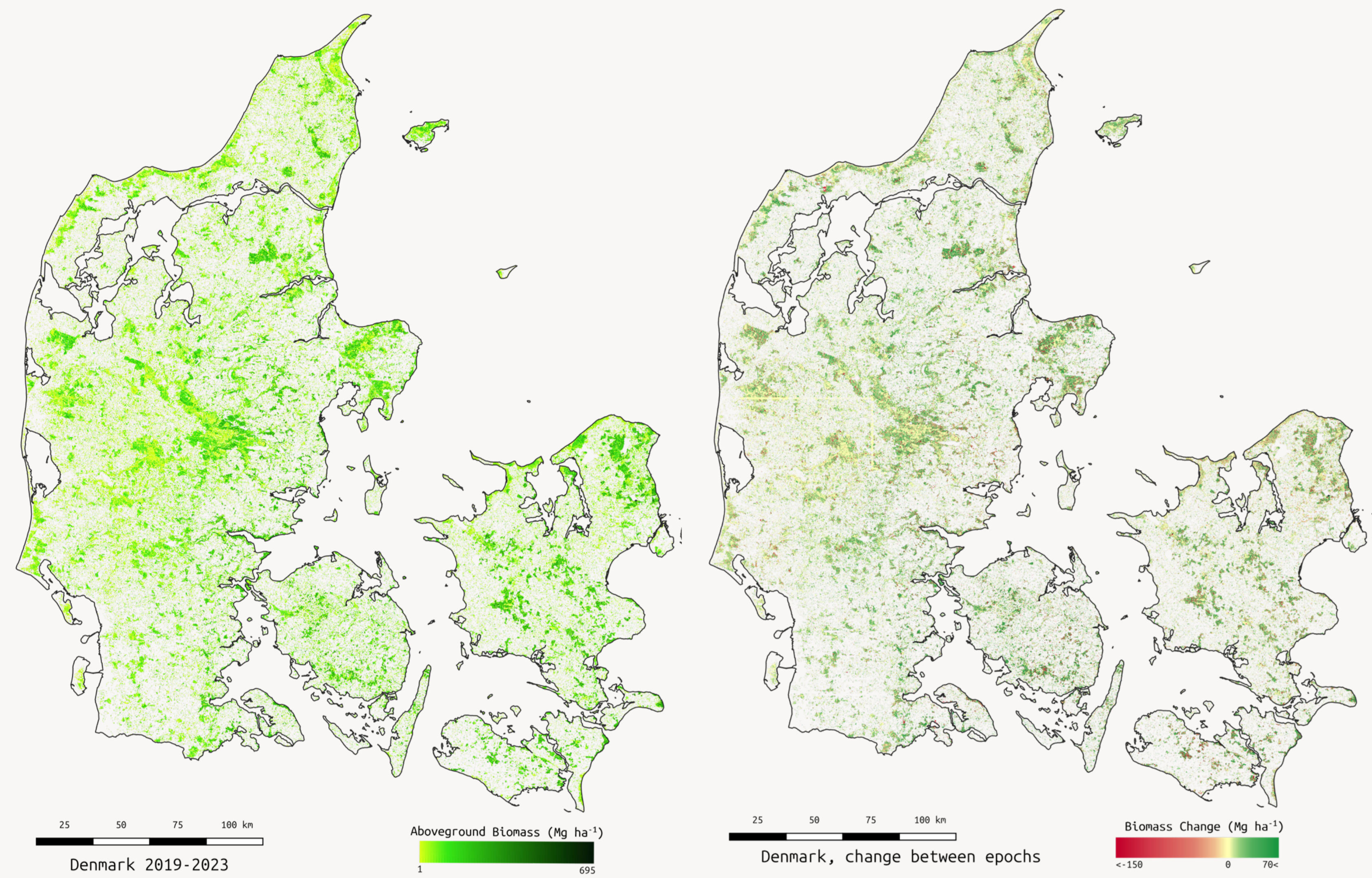


# Time series of national biomass maps from deep learning applied to airborne laser scanning point clouds



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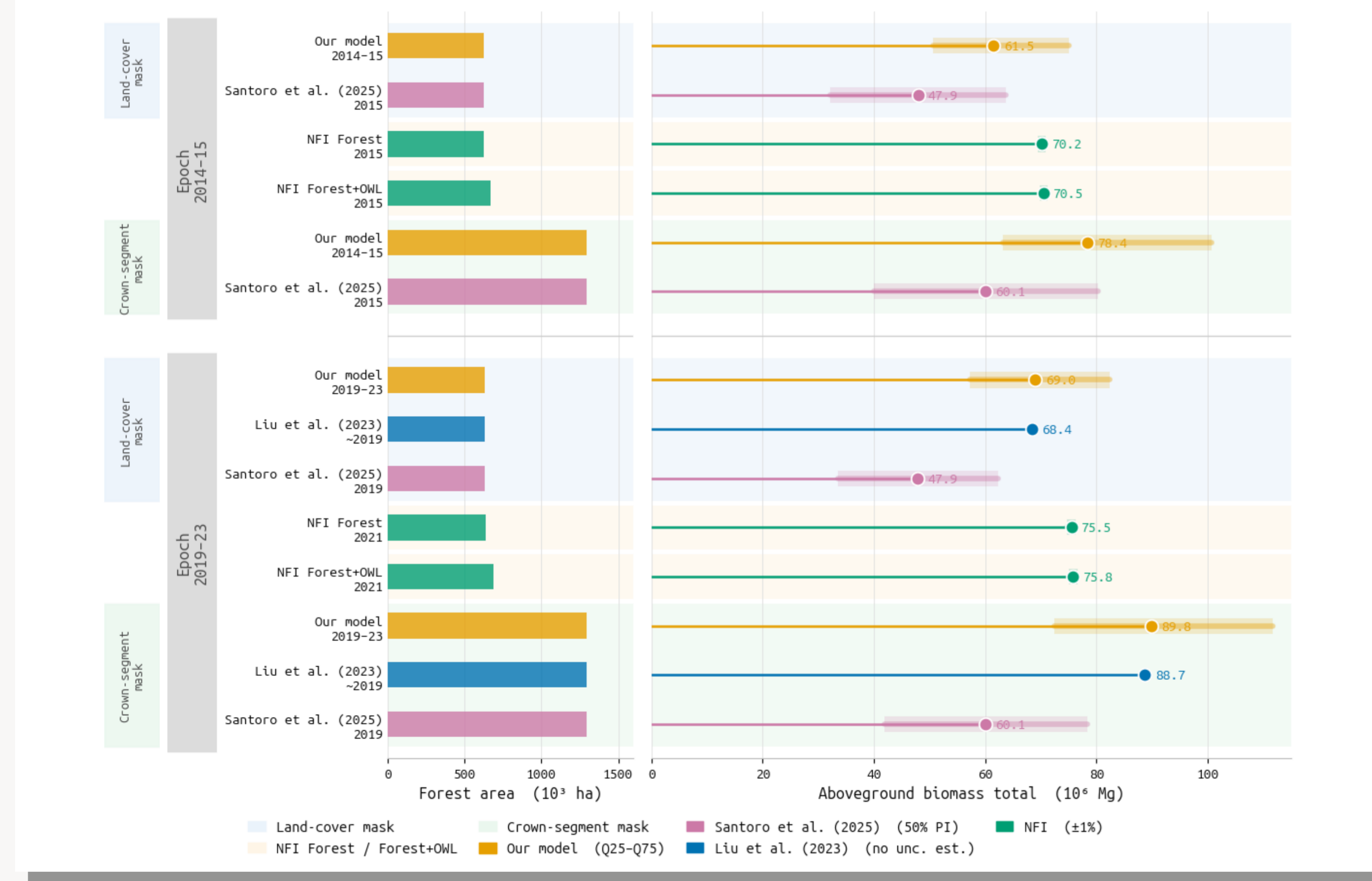
## The first remotely-sensed forest attribute maps tracking national change...



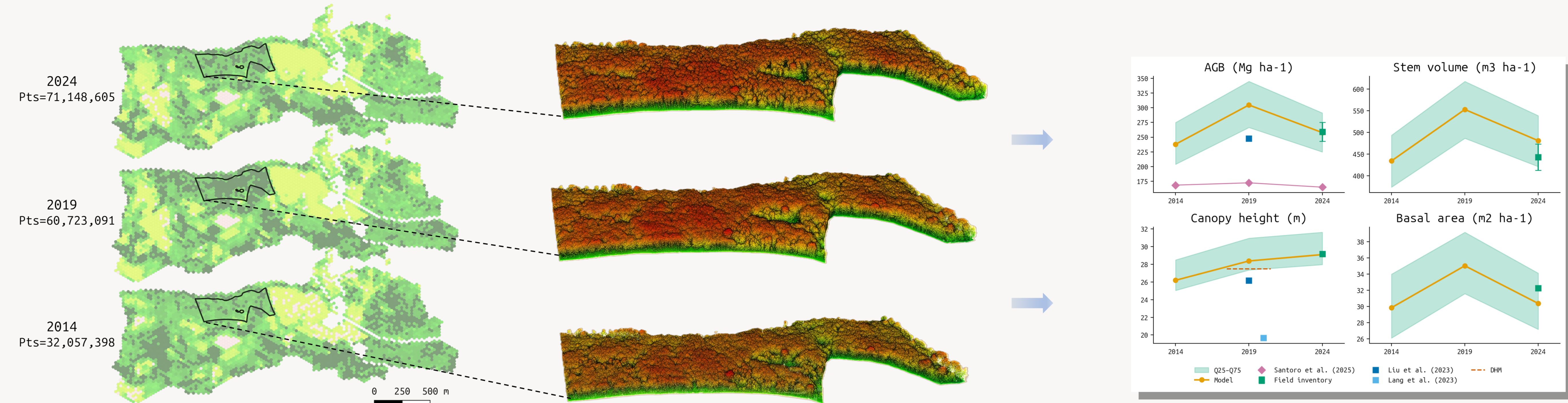
1. Ongoing airborne LiDAR campaigns in Denmark since 2014 have made it possible to produce a time series of two complete composite national scans. A third epoch is underway. We have used this data as input for our model, predicting forest attributes at 15m resolution.

Epoch 1: 2014-2015 / Epoch 2: 2019-2023 / Epoch 3: 2024-

National aboveground biomass: model vs. benchmarks across forest masks and epochs

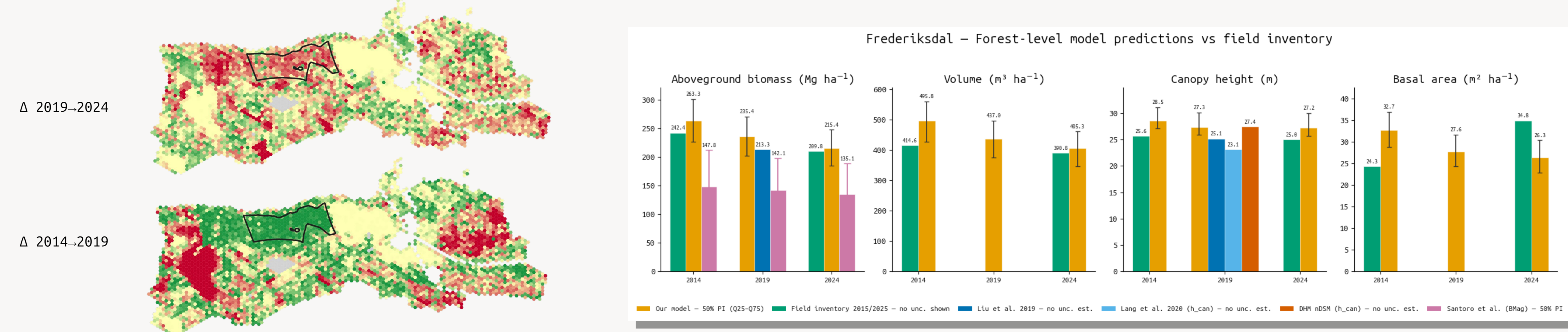


2. We applied the model to the available LiDAR epochs using two different masks: forest areas according to land cover maps, and a more expansive mapping of the presence of tree crowns.



...with local accuracy:

Frederiksdal Forest Estate: 274.6 ha



Frederiksdal Estate  
Stand: 45\_a  
Species: Beech (*Fagus sylvatica*)  
Area: 12.1 ha

Biomass loss due to thinning detected by the model, even though canopy height increases.

An allometric canopy height-to-biomass model would miss this signal.

The model is closely aligned with the most recent field inventory measurements across all four attributes in this one compartment.



3. Multi-temporal benchmarks are rare, but analysis showed the existing methods underestimate forest biomass, especially in high biomass areas and older and more heterogeneous unmanaged forests. Frederiksdal is a managed forest. See supplemental material for an unmanaged benchmark example.

4. Our model: we extended the 3D CNN Minkowski SENet50 architecture with quantile regression to provide prediction intervals. We trained on more than 19,000 pairs of Danish national forest inventory plot point clouds and ground truth labels for aboveground biomass, volume, canopy height, and tree basal area.

