The cosmic-ray neutron method

Identifying the environmental effect on the cosmic-ray neutron signal

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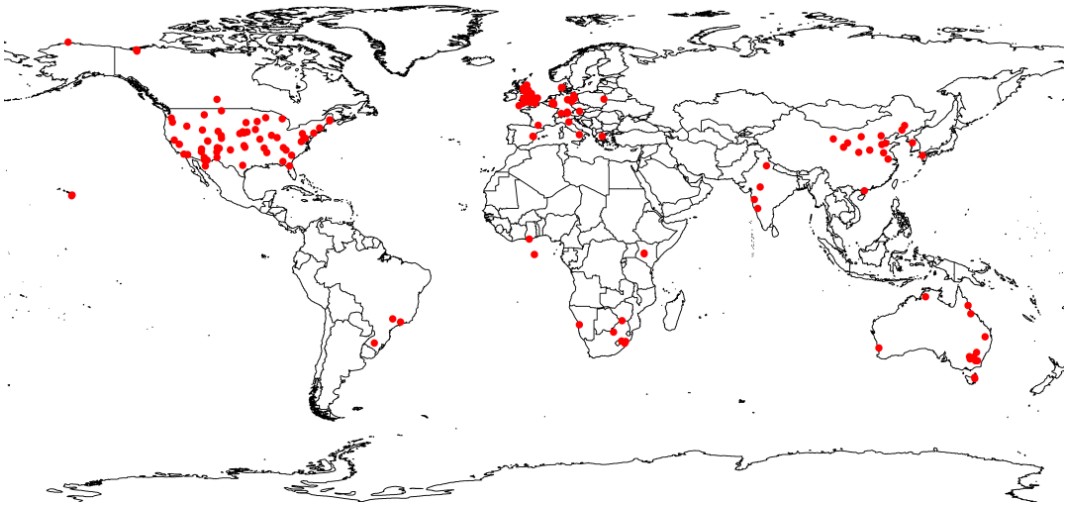
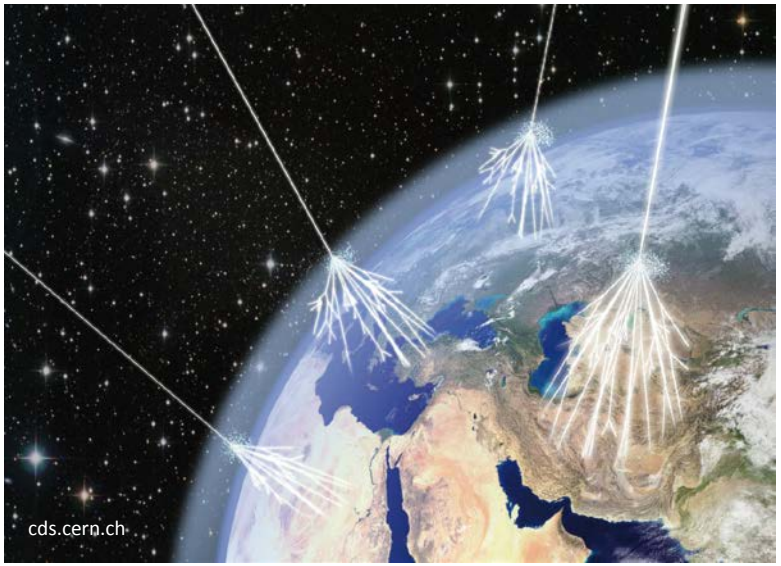
Introduction – the method

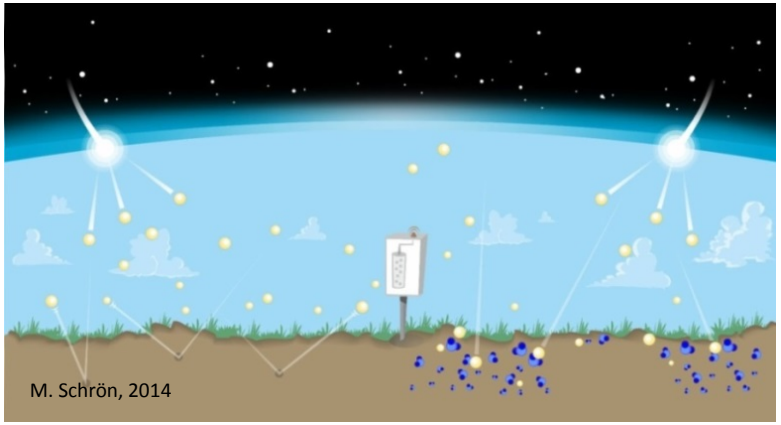
The cosmic-ray neutron soil moisture method:
- Inverse relationship between hydrogen content and cosmic-ray neutron intensity
- Non-invasive measurements (stationary, and roving products)
- Measurement scale:
  The upper decimeters of the ground within a radius of hectometers

Convenient method for:
- Constraining hydrological models
- Data assimilation
- Precision agriculture
- Validation/calibration of satellite products

Cosmic-ray neutron stations







Introduction – the challenge

The environmental effect:
- Vegetation
- Litter
- Canopy interception
- Soil chemistry and bulk density
- Snow
- Soil moisture

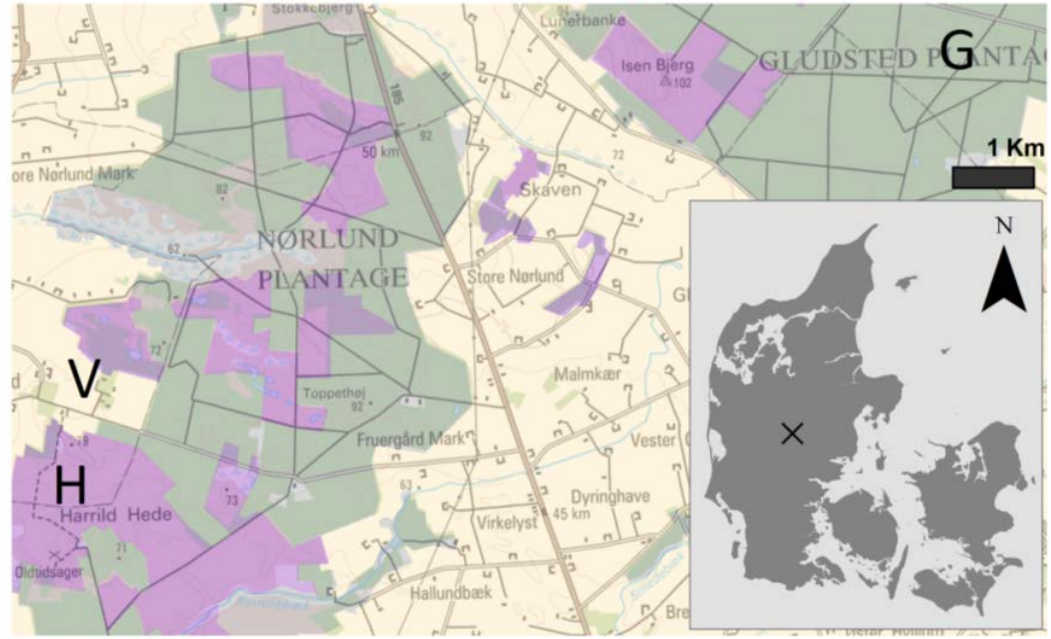
Neutron intensity correction:
- Barometric pressure
- Incoming cosmic radiation
- Atmospheric water vapor

Identifying the signal of the different components will allows us to:

Isolate the signal of soil moisture
> *improve the cosmic-ray neutron soil moisture method*

Isolate the signal of e.g., biomass
> *additional application; cosmic-ray neutron biomass estimation*

Field sites



Three field sites:

V Voulund Farmland
No biomass and no litter layer

G Gludsted Plantation
Large biomass and thick litter layer

H Harrild Heathland
Small biomass and thick litter layer

Similarities:
Soil chemistry, elevation and weather conditions

Dissimilarities:
Vegetation, litter layer thickness and canopy interception

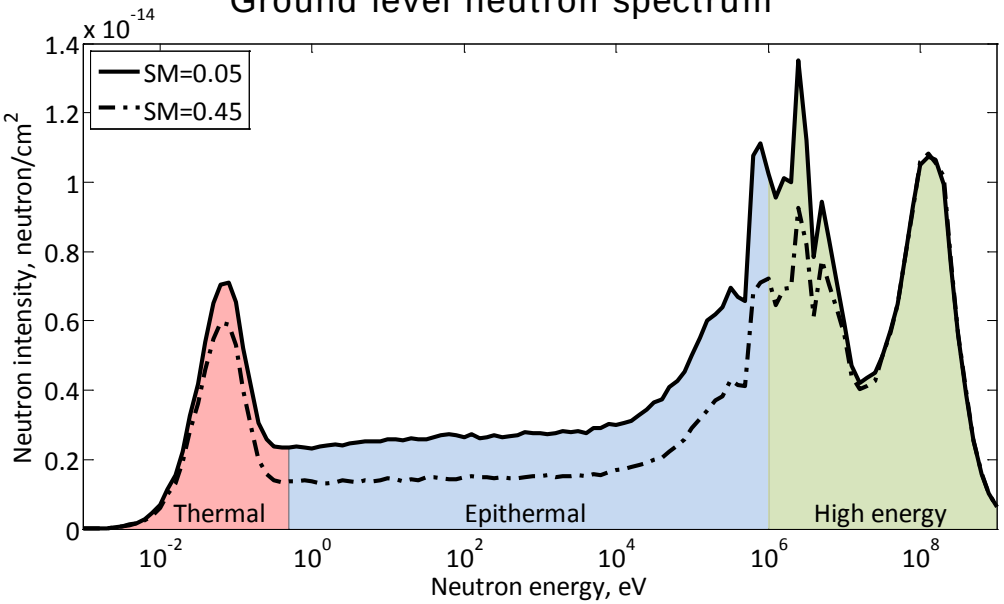
Method

Examining the environmental effect on neutron transport:

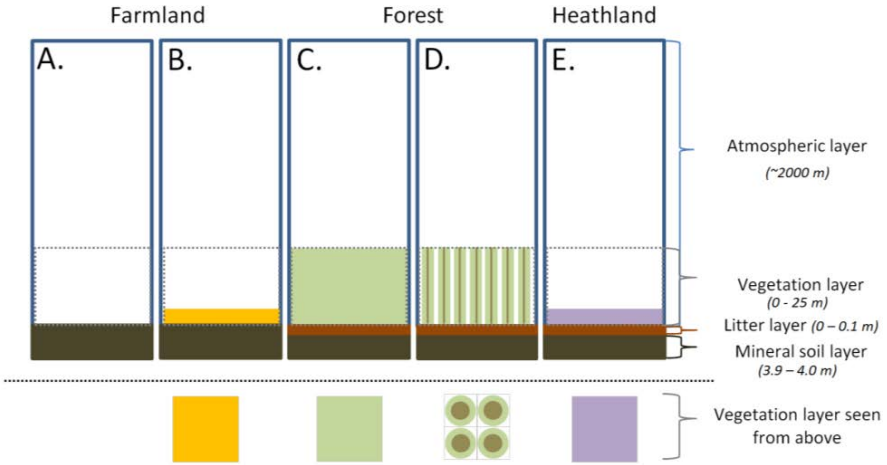
Model:
- Monte Carlo N-Particle transport code (MCNP)
- Site-specific modeling of the three field sites (soil chemistry, vegetation and litter layer)

Measurements:
- Thermal and epithermal neutron energies
- One or more height levels

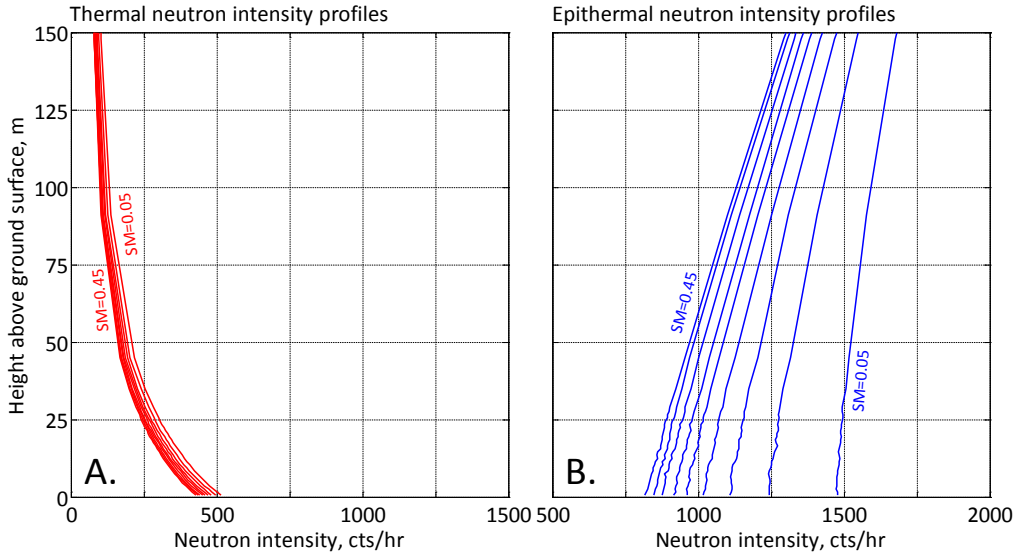
Ground level neutron spectrum



Model conceptualization



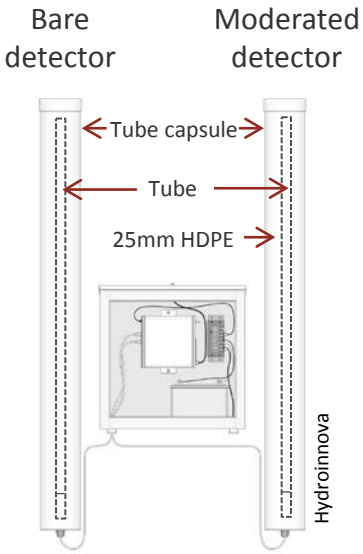
Neutron intensity height profiles

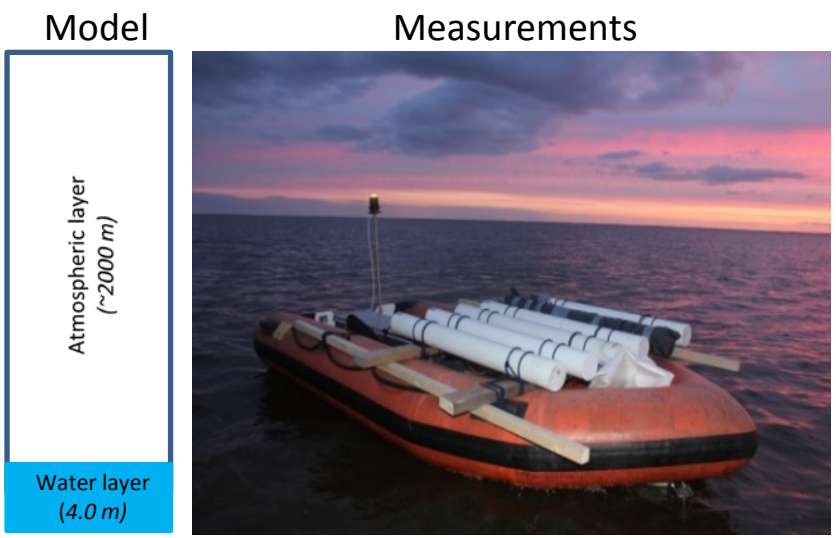


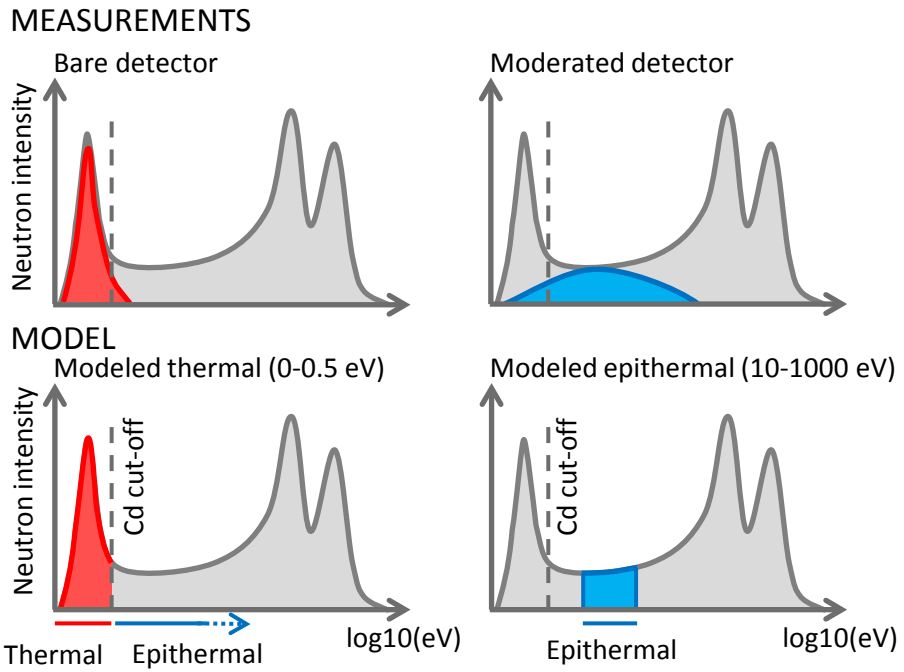
Measurements and modeling

Comparability of modeled and measured neutron intensity
– a 2-step procedure:

1. Cadmium difference method or neutron energy correction factors
2. Model-to-measurement correction models





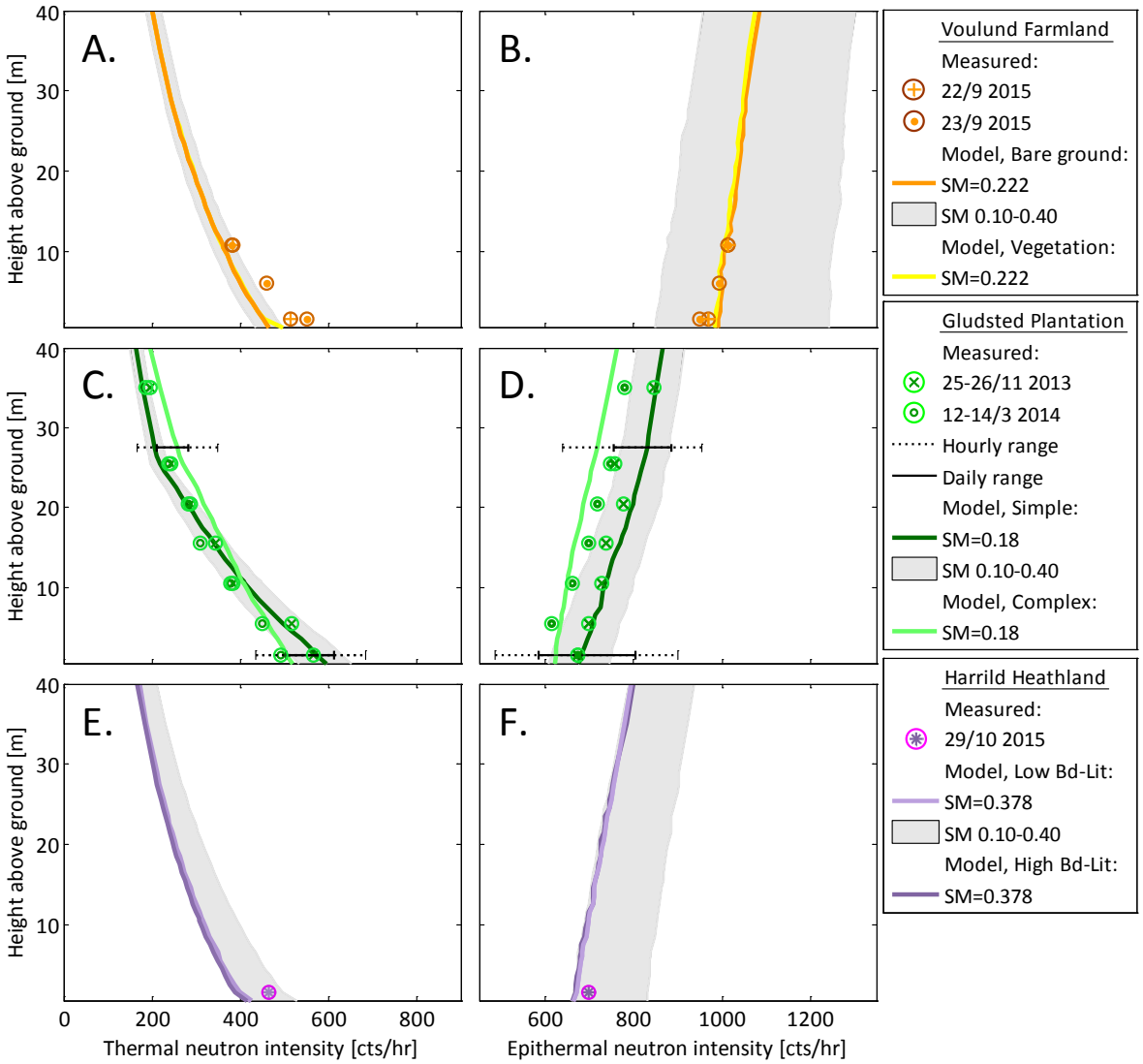


Measurements and modeling at the three field sites

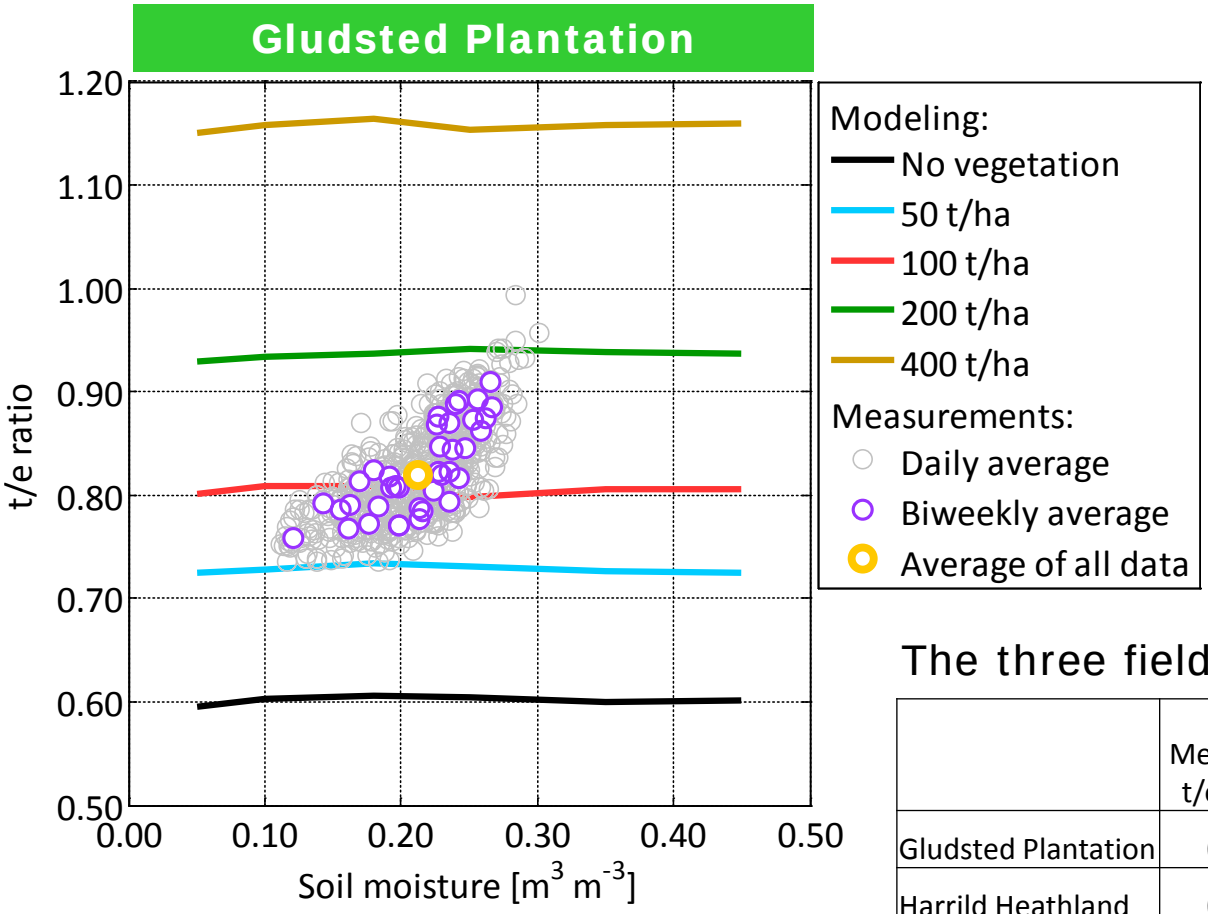
Voulund Farmland

Gludsted Plantation

Harrild Heathland



The effect of biomass

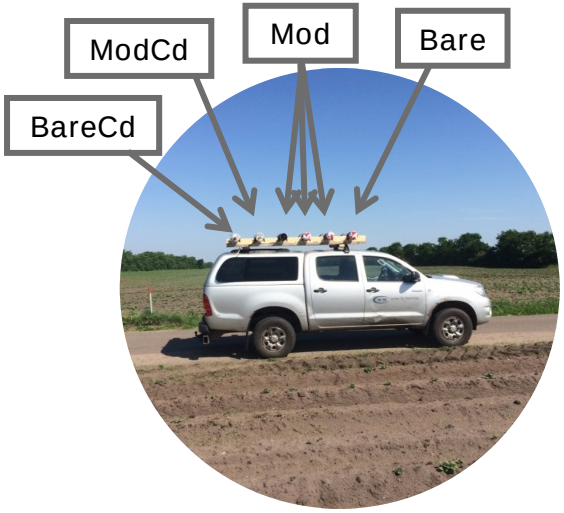


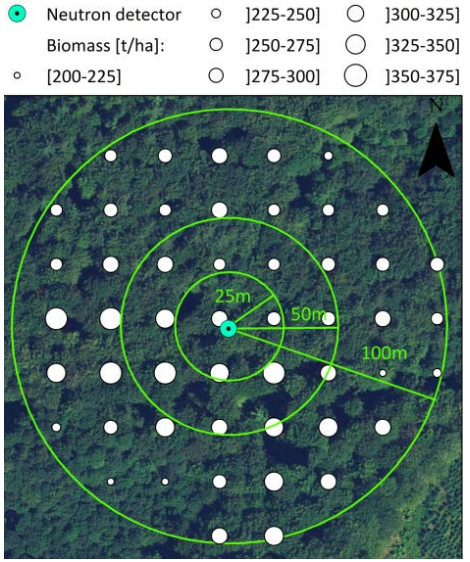
The three field sites:

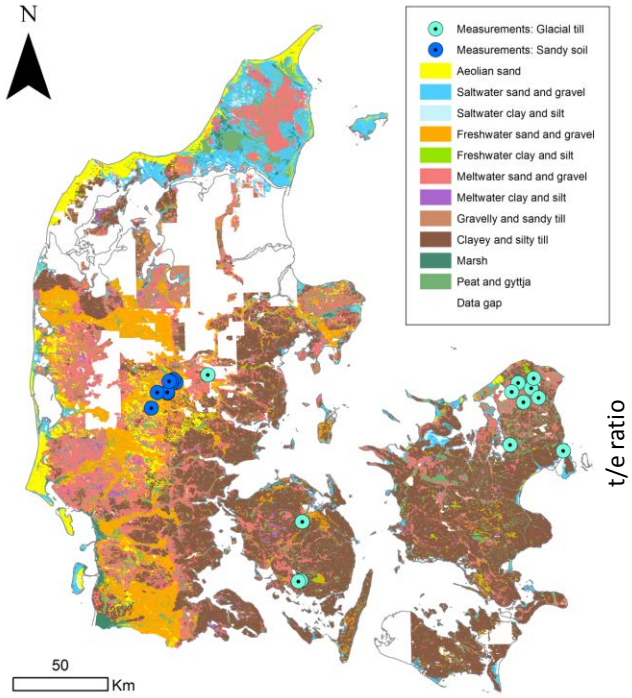
	Measured t/e ratio	Modeled t/e ratio	Litter, cm	Biomass, t/ha
Gludsted Plantation	0.82	0.80	10	100
Harrild Heathland	0.66	0.61	10	< 50
Voulund Farmland	0.56	0.56	0	0

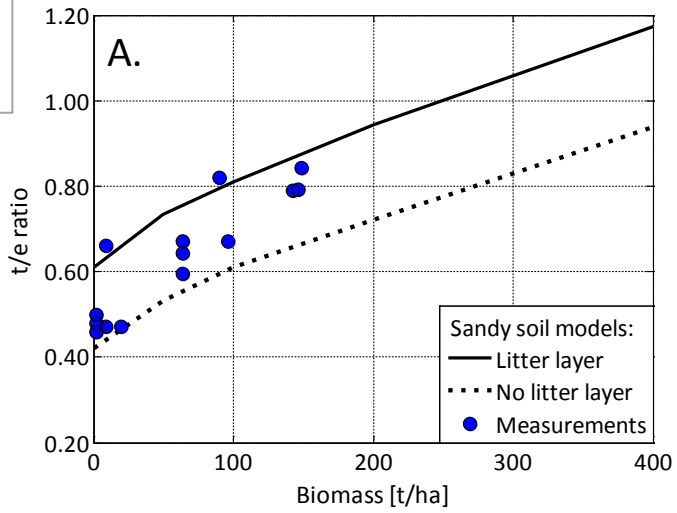
The relationship of t/e ratios and biomass - sandy soils and glacial tills

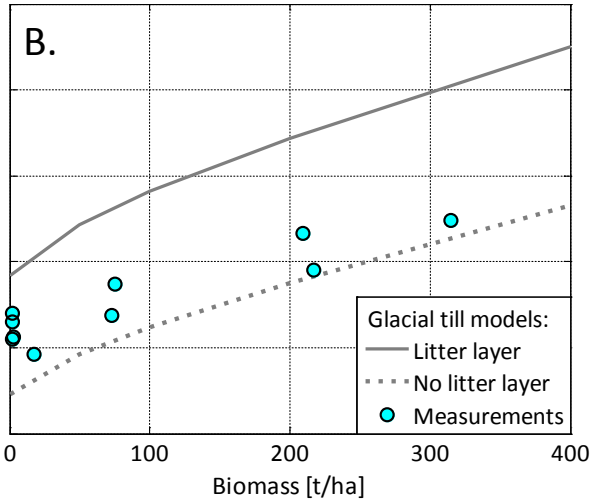
Biomass estimation:
- Lidar images from 2006 and 2007
- Radius of 100 m from the detector



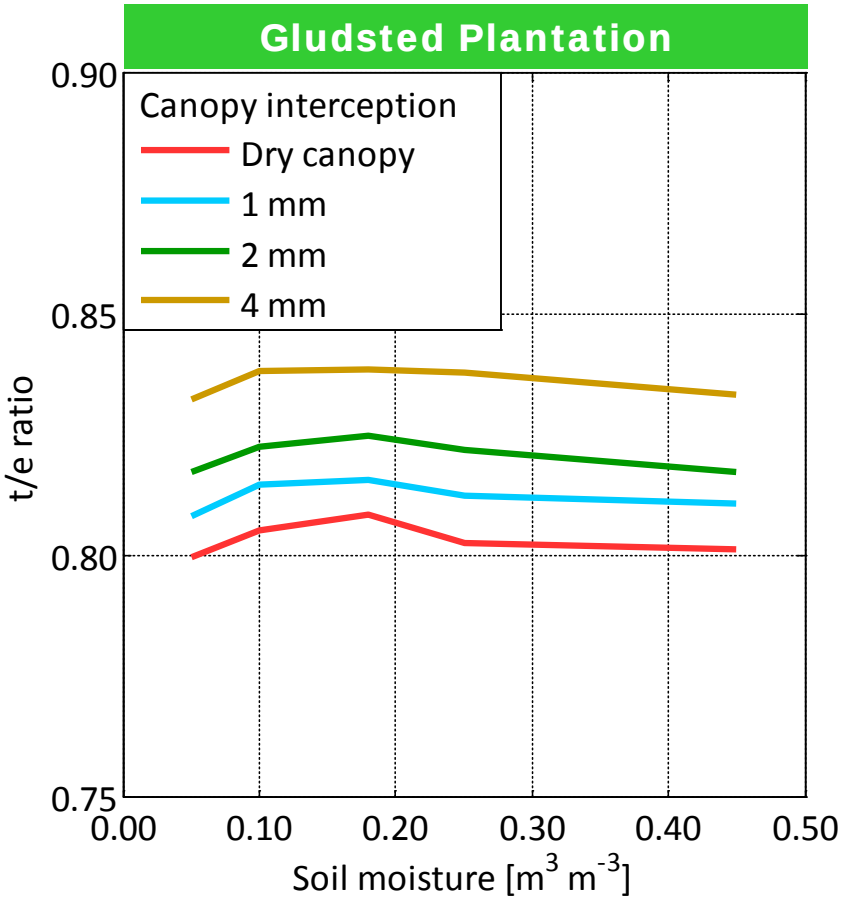








The effect of canopy interception



The ground level thermal neutron intensity increases with canopy interception

The signal of canopy interception is within the uncertainty of the measurements

- Higher count rates (e.g., more neutron detectors)
- Canopy interception of longer residence time or greater quantities (snow)

Take-home messages

The sensitivity of neutron intensity to soil moisture is dependent on the land cover type
- Vegetation and litter are important

The t/e ratio increases with increasing amounts of vegetation
- The soil type is important

The effect of canopy interception on the neutron intensity is small

Future work:
- Forest canopy conceptualization
- Modeling the neutron detector response
- Bare and moderated detector footprint
- Biomass estimation
- The effect of soil chemistry

Thank you