

# Boreal forest biomass classification with TanDEM-X

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# **Boreal Forest Biomass**

- Boreal forests contain 1/3 world biomass.
- Biomass stock is well known, however there is a lack of periodic information.
- Rate of biomass change (e.g. fire) is critical for carbon cycles assessment (Houghton, 2005).Very high percentage of carbon is stored in the soil and thus, highly affected by land cover changes.
- Periodic and systematic land cover classifications, as well as, biomass estimations are highly needed.
- Existing classifications:
  - Mainly based on optical systems
  - Generally not updated.
  - Qualitative classifications
- CORINE: Europe 100x100 m
- SIBERIA Project:
  - Coherence and backscattering
  - From ERS and JERS 900000 km2 in 50x50m
  - Classes: Bare soil, sparse shrub, forest (1-20, 21-50, 51-80, >80 T/ha)







# **Biomass Structure in the Boreal Forest**

- Forest Above-Ground Biomass can be retrieved from forest height using allometric equations
- Forest structure limits the accuracy of allometric equations
- However boreal forests are characterized by a homogenous structure that optimizes the use of these equations

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• Biomass can be estimated with adequate accuracy from height







# TanDEM-X Operational DEM Mode

Primary mission objective is the generation of a consistent global digital elevation model (DEM)

- Specifications:
  - X-band (3cm wavelength)
  - Bistatic
  - Polarisation: HH
  - Incidence Angle Range: 30° 48,5°
  - Minimum Height of Ambiguity First acquisition: 45m (kz = 0.14)
  - Minimum Height of Ambiguity Second acquisition: 30m (kz = 0.21)
  - Stripmap mode: 30 km wide, 50 km long
  - Spatial resolution 12 m x 12m
  - No threshold for seasonality of second acquisition (repetition is arbitrary)

### Global DEM acquisitions can be used for biomass classification

 $\Delta\theta = 3.7^{\circ}$ 

First acquisiton



acquisition	1	
biomass		

Stripmap mode

 $\frac{\Delta\theta}{2}$ 

Second

# **Coherence Modeling**

### **Noise Correction**





### Random Volume over Ground (RVoG)



# **Test Sites and Data**

### Two boreal forests:

- Krycklan: North Sweden, biomass up to 250Mg/ha
- Remningstorp: Southern Sweden, biomass up to 300Mg/ha
- LiDAR H100
- LiDAR derived biomass
- Ground inventory data

### TanDEM-X data:

### Acquisitions in Krycklan:

- 28 July 2010, Mean k<sub>z</sub>: 0,186
- 19 September 2011 Mean k<sub>z</sub>: 0,113
- 1 standard DEM bistatic:
  - 27 February 2012, Mean k<sub>2</sub>: 0.153 •
- Acquisitions in Remningstorp
  - 28 August 2011, Mean k<sub>z</sub>=0.08
  - 20 August 2012, Mean k<sub>z</sub>=0.117
  - 12 February 2012, Mean k<sub>7</sub>=0.171 •
  - 1 standard DEM bistatic:
    - 30 January 2011, Mean k<sub>7</sub>: 0.110



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### Test Sites and Data



- Optimum fixed extinction = 0.2 dB/m
- This Extinction value is lower than expected for X-band due to significant ground contribution.

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# **Biomass Classification Performance**

Coherence



Biomass

- Classification performance depends on two deviation sources:
  - Height estimation from coherence
  - Biomass estimation from Height

$$\Delta B_{tot} = \frac{\partial B}{\partial h_v} \Delta h_v + \Delta B \quad ; \quad B = 0.25 h_v^2 \quad ; \quad \Delta B_{tot} = 0.5 H \Delta h_v + \Delta B$$



- Four biomass classes are chosen:
  - <10 Mg/ha
  - 10-50
  - 50-150
  - >150





## Height Inversion, Krycklan - 28-07-2010, kz=0.187



# Height Inversion, Remningstorp 28-08-2012, kz=0.169

#### Lidar Height

### Estimated height

#### DiffereBiom(EssinclasesesLiDAR)





# **Biomass Validation in Pre-defined Stands**





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r2 = 0.45

r2 = 0.75

20

10

estimated height (Mg/ha)

150 estimated biomass (Mg/ha)

200

250

250

200

150

100

30

20

eference height (Mg/ha)

50

100

eference biomass (Mg/ha)



# Dual baseline biomass classification

Remningstorp: Single-pol VV bistatic mode

First baseline (20-08-2011). Kz = 0.08

Second baseline (28-08-2012). Kz = 0.117 Extinction map

**Dual classification** 





# Influence of seasonality





# **CORINE Classification Evaluation**



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# **CORINE Classification Evaluation**

### Remninsgtorp









# **Conclusions and Outlook**

- The TDX standard acquisition mode has a great potential for forest biomass classification in the boreal region
- Longer baselines are more sensitive to lower biomass while shorter baselines at higher biomass levels
- Winter acquisitions tend to overestimate biomass
- Four biomass classes until 150 Mg/ha for single baseline
- Five classes up to 250 Mg/ha for dual baseline can be distinguished.
- Winter acquisitions tend to overestimate biomass
- This biomass classification is very sensitive to land use changes between acquisitions
- The obtained classification maps can improve thematic mapping in forested areas like provided by the European Thematic Map CORINE

# Dual baseline biomass classification

### Krycklan: Alternating bistatic mode HH First baseline (19-009-Second baseline (19-Extinction map **Dual classification** 2011). Kz = 0.113 09-2012). Kz = 0.113 0.4 0.2 [dB ] <10 Mg/ha 10 - 75Mg/ha <10 Mg/ha 75 - 150 Mg/ha 10 - 50 Mg/ha 150 - 250 Mg/ha 50 - 150 Mg/ha >250 Mg/ha >150 Mg/ha 0



### Height Estimation Performance, Kz and seasonality

- Height estimation accuracy is limited by the baseline (Kz).
- Winter acquisitions show higher penetrations, i.e. lower extinction values





### One baseline does not cover all possible heights!







# Biomass Classification, Krycklan - 28-07-2010

### Height Inversion



#### **Biomass estimation**



#### **Biomass classification**



<10 Mg/ha 10 - 50 Mg/ha 50 - 150 Mg/ha >150 Mg/ha

 $B = 0.25 h_v^2$ **Deutsches Zentrum** für Luft- und Raumfahrt e.V. DLR in der Helmholtz-Gemeinschaft

# Biomass Classification, Remningstorp 29-08-2010

### Height Inversion



#### **Biomass classification**











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 $B = 0.25 h_{v}^{2}$ 

# Standard DEM Acquisition Krycklan 27-02-2011

#### Biomass



### **Biomass Classification**

















### Krycklan



### Remningstorp













# Forest classifications in the boreal region

Existing classifications:

- Mainly based on optical systems.
  - Qualitative classifications
- Different classifications for each region
  - Corine thematic mapping in Europe (100 \* 100 m spatial resolution)
- There is a need for quantitative and standard classifications for the boreal biome
- SAR classification: SIBERIA project
  - Coherence and backscattering
  - From ERS and JERS 900000 km2 in 50x50m
  - Classes: Bare soil, sparse shrub, forest (1-20, 21-50, 51-80, >80 T/ha)







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# **Coherence Modelling**



- Coherence
  - Optimum fixed extinction = 0.2 dB/m
  - This Extinction value is lower than expected for X-band due to significant ground contribution.
  - Extinction values decrease in winter



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