Facing the scientific challenges of the BIOMASS mission

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The effects of forest changes on climate

8.3 ± 0.4 GtC/yr

1.0 ± 0.5 GtC/yr net flux

95% of net flux is in the tropics

4.3 ± 0.1 GtC/yr

2.6 ± 0.9 GtC/yr

2.5 ± 0.5 GtC/yr

Calculated as the residual of other flux components

Global Carbon Project, 2012
Forest biomass and forest height:
global, 200 m scale, every 6 months for 4 years, 20% accuracy in biomass, 20-30% accuracy in height

Disturbances: global, at 50 m scale

Biomass will map forest biomass, height and change with unprecedented accuracy
Scientific challenge 1: environmental changes

Major recent ESA campaigns:

1. Kalimantan 2004 (Indrex)
2. Remningstorp 2007 (BioSAR 1), 2010 (BioSAR 3)
3. Krycklan 2008 (BioSAR 2)
4. F. Guiana 2009 (TropiSAR), 2011-13 (TropiScat)
Inversion techniques must deal with data dispersion and differences between different types of forest.
Scientific challenge 1: environmental changes (3)

Remningstorp 70 MHz data: varying environmental conditions over 3 months

Blue - from airborne lidar map, std. error = 25 ton/ha
Black - from 80 m x 80 m in situ plots, std. error = few %

Training on stratified subset of Krycklan data.
Performance assessed on data from Remningstorp.
Scientific challenge 2: combining measurement modes

PolSAR (SAR Polarimetry)

PolInSAR (Polarimetric SAR Interferometry)

TomoSAR (SAR Tomography)
Challenge 2: combining measurement modes

Polarised intensities only

Intensity + height

Biomass (t/ha)

RMSE = 35.6 t/ha

Height retrieval

Height (m)

RMSE = 16.3 t/ha
Challenge 2: combining measurement modes

- **PolSAR Covariance Matrix**
- **PollnSAR Covariance Matrix**
- **Ionosphere Correction**

**Steps:**
1. **Biomass Estimation from Intensity**
2. **TomoSAR results**
   - **DEM**
   - **In situ data**
3. **Forest Height Estimation**
4. **Allometric Biomass Estimation**
5. **Minimum Mean Square (MMSE) Estimate**
6. **Biomass Map & Error Map**

**Estimates:**
- **Biomass Estimate 1**
- **Biomass Estimate 2**
- **Biomass Map**
Scientific challenge 3: training and validation

In situ network led by Smithsonian, including Centre for Tropical Forest Science

Rainfor

Afritron
Scientific challenge 3: training and validation (2)

Key message:
Training inversion algorithms at 4 ha resolution (the Biomass estimation scale) with in situ data at smaller scales leads to an estimation bias.

Rejou-Mechain et al. (2014)
Scientific challenge 4: the physics of P-band scattering

Inversion techniques need to deal with data dispersion and differences between different types of forest.
Power-law relationships between HV backscatter and biomass are found for all forests where we have data. What determines the exponent?

<table>
<thead>
<tr>
<th>Site</th>
<th>Intercept=a</th>
<th>Slope=q</th>
<th>R²</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Paracou</td>
<td>-3.3 ± 0.46</td>
<td>0.79 ± 0.17</td>
<td>0.46</td>
<td>&lt; 0.001</td>
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<tr>
<td>La Selva</td>
<td>-2.8 ± 0.07</td>
<td>0.60 ± 0.03</td>
<td>0.92</td>
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<tr>
<td>Remningstorp, March 9th</td>
<td>-2.1 ± 0.08</td>
<td>0.47 ± 0.04</td>
<td>0.71</td>
<td>&lt; 0.001</td>
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<tr>
<td>Remningstorp, April 2nd</td>
<td>-2.1 ± 0.07</td>
<td>0.44 ± 0.03</td>
<td>0.71</td>
<td>&lt; 0.001</td>
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<td>Remningstorp, May 2nd</td>
<td>-2.1 ± 0.07</td>
<td>0.42 ± 0.03</td>
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<td>Landes</td>
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<td>1.01 ± 0.03</td>
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<td>&lt; 0.001</td>
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<td>Maine</td>
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<td>0.41 ± 0.04</td>
<td>0.75</td>
<td>&lt; 0.001</td>
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</tbody>
</table>
Scientific challenge 5: getting BIOMASS data into carbon cycle estimates (& IPCC & REDD+)

AGU 2014: Informing carbon dynamics in the Community Land Model with observations from across timescales (Andy Fox [NEON] & Tim Hoar [NCAR])

Conclusions
• Annual AGB biomass observations are a powerful constraint on many large C and N pools
• Annual Net Primary Production estimates are less helpful than we expected
Carbon flux depends on the disturbance regime

Mean Disturbance flux (tC ha$^{-1}$ yr$^{-1}$)

$M$ = mean loss of biomass
$F$ = severity of disturbance
$P$ = probability of disturbance
Summary

1. BIOMASS is the first P-band radar in space, the first space mission exploiting Pol-InSAR for global forest height mapping, and the first space radar tomographic mission.

2. The experimental data supporting BIOMASS is heavily undersampled in time and space.

3. 1 & 2 imply that
   1. We have to make as much use as possible of physical, modelling and statistical reasoning in preparing for BIOMASS
   2. In practice many aspects of using the data will only become clear after launch

4. The BIOMASS mission already has significant buy-in from the ecological and carbon science communities.

5. More needs to be done to make sure that BIOMASS meets the needs of its non-science users