The ESA BIOMASS Mission

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Credit: AOES Medialab
Presentation Outline

- The ESA Observation program
- The BIOMASS mission
  - Scientific Objectives
  - Technical concept
  - Support activities
- Synergies with DESDynI
- Conclusions
ESA Earth Explorers

**GOCE**
Gravity Field and Steady State Ocean Circulation Explorer

**ADM-Aeolus**
Atmospheric Dynamics Mission

**EarthCARE**
Cloud, Aerosols & Radiation Explorer

Core

Opportunity

**Earth Explorer 7**

- **Cryosat 1 & 2**
  Sea Ice thickness and Ice sheet topography

- **SMOS**
  Soil Moisture and Ocean Salinity

- **Swarm**
  Geomagnetic field survey

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2008 Veg3D and BIOMASS Workshop, Charlottesville VA, March 3-5, 2008
The selection process

Step 1: Call and selection
- Call for Ideas: March - July 2005
- ESAC Recommendation / PB-EO Selection: May 2006

Step 2: Mission Assessment Groups / Phase 0
- Reports for Assessment: Nov 2006 - June 2008
- User Consultation Meeting: July - August 2008
- ESAC Recommendation / PB-EO Selection: January 2009
- Mission Assessment: March 2009

Step 3: Mission Feasibility / Phase A
- Mission Advisory Groups/Phase A: 2009 - 2010
- Reports for Mission Selection
- User Consultation Meeting
- ESAC Recommendation / PB-EO Selection

Step 4: Implementation (Phases B, C/D, E1)
- Implementation: Phase B/C/D: 2010 - 2014

Ceiling Cost Range: 200 - 220 M€ at 2007 e.c.
Excluding ESA internal Cost, Mission Operation Cost and Science Support Activities
The Next Earth Explorer

Call for ideas issued in 2005

- Science priorities
  - The Global Water Cycle
  - The Global Carbon Cycle
  - Atmospheric Chemistry
  - The Human Element

- 24 proposals evaluated

- 6 Candidate Missions selected for further study
  - BIOMASS: BIOMASS Monitoring Mission for Carbon Assessment
  - TRAQ: TRopospheric composition and Air Quality
  - PREMIER: Process Exploration through Measurements of Infrared and millimeter Emitted Radiation
  - FLEX: Fluorescence Explorer
  - A-SCOPE: Advanced Space Carbon and Climate Observation of Planet Earth
  - CoRe-H20: Cold Regions Hydrology High-resolution Observatory

- Expected launch 2014-2015
BIOMASS Phase-0 Organisation

- Reports for Assessment provide updated mission details (scientific, technical)

Mission Assessment Group (MAG)

ESA Mission Scientist

Scientific Support Studies
Campaigns

ESA Technical Studies leader

Phase 0 Industrial Studies
System Support Studies
Technology Support Studies

Report for Mission Assessment
Mission Assessment Group

- Help define the scientific objectives
- Advice on mission concept
- Support writing of report for assessment
- Meetings approx. 3 times/year

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BIOMASS Mission objectives

- **Improved understanding and quantification of land contribution to global carbon cycle**
  - Quantify flux of carbon from land use change
  - Greatly improved modelling of terrestrial carbon cycle

- **Objectives achieved through**
  - Gridded high-resolution global estimates of **above ground biomass**
  - Monitoring and quantification of **forest disturbance and recovery**
  - Monitoring and quantification of **wetland areas and forest inundation**

- **Additional objectives related to opportunity for spaceborne P-Band SAR images**
  - Mapping subsurface structures, polar regions,
  - Mapping subsurface geomorphology in arid zones
Scientific Background

- Terrestrial contribution to the global carbon cycle poorly understood
- Forest biomass information critical for inventory of CO2 stocks and fluxes
  - Fluctuations in total forest biomass provide immediate feedback on CO2 release
  - Provide initial condition for biophysical models
  - Biomass changes with time integrator of CO2 production and loss processes
- No consistent source of biomass suitable for climate models
  - National reporting not spatially explicit and with unspecified errors
  - Only 1 gridded low-resolution mono-temporal dataset compiled from country/sample plot information (Olson map)
Use of biomass information in CO₂ models

**CO₂ dynamics**
- Integrates production and loss processes
- Modulates released of CO₂
- Determines temporal profile of carbon uptake and released
- Provides initial model conditions

**Carbon Models**
- Improved modelling of terrestrial carbon cycle
Biomass information within carbon models

Biomass predicted by Global Dynamic Vegetation Model

Biomass map derived from SAR measurements

Le Toan et al, 2004
Forest wetland extent

- Methane strong contributor to global warming
- Extent and temporal evolution of floodplain under forest canopy not well known

Varzea Dry Season

Varzea Wet Season

P-band backscatter

P-band backscatter
## BIOMASS mission requirements

<table>
<thead>
<tr>
<th>Information Product</th>
<th>Mission Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest Biomass (above ground)</td>
<td>• 20% accuracy&lt;br&gt;• 100-300m resolution/16 looks&lt;br&gt;• 2 biomass maps/year&lt;br&gt;• Polarimetric Interferometric mode&lt;br&gt;• Global coverage of forests</td>
</tr>
<tr>
<td>Forest Disturbance</td>
<td>• Maps of disturbed area with 10% classification accuracy&lt;br&gt;• 100m resolution/16 looks&lt;br&gt;• 1-2 forest disturbance maps every 2 months&lt;br&gt;• Global coverage</td>
</tr>
<tr>
<td>Forest Regrowth</td>
<td>• Biomass information 20% accuracy&lt;br&gt;• Biomass rate of change – 20% accuracy&lt;br&gt;• 100-200m resolution/16 looks&lt;br&gt;• 2 revisits/year&lt;br&gt;• Global coverage with focus on tropical forests</td>
</tr>
<tr>
<td>Forest seasonal floods</td>
<td>• Inundation area information – 10% classification accuracy&lt;br&gt;• 100m resolution/16 looks&lt;br&gt;• 1 revisit/month during flood season&lt;br&gt;• tropical forests (main target) + boreal wetlands (secondary target) for methane emission</td>
</tr>
</tbody>
</table>
Achieving the BIOMASS requirements

- Global forest biomass estimates to be derived using three different techniques
  - Exploitation of biomass-intensity relationship at P-Band
  - Forest height retrieval using Polarimetric-Interferometric techniques
  - Classification using polarimetric signature
- Final product may combine intensity and forest height information
- Interpretation and validation of biomass products and algorithms supported by tomographic mission phase
Achieving the BIOMASS requirements

- Mission implemented using two phases (Main Phase, Tomographic Phase)
  - Main Phase (98% of time)
    - Dedicated to mapping of forest biomass, recovery and flooding
    - To support intensity and polarimetric interferometry
  - Tomographic phase (2% of time)
    - 10-12 baselines – short revisit time
    - Identify the sources of the radar signal
    - Validate intensity/PollInSAR techniques

2007 BioSAR Campaign – Boreal Forest

Tomographic Product
Power scattered from ground

L1 - HH

L1 - HV

20% accuracy requirement
**Technical Concept**

- ESA Industrial study running from April 2007 to September 2008 to define P-Band SAR payload and mission characteristics
- Mid-term review held in Dec.2007: no major show-stoppers identified

<table>
<thead>
<tr>
<th>Instrument Type</th>
<th>P-band Synthetic Aperture Radar (SAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre Frequency</td>
<td>435 MHz (P-Band)</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>≤6 MHz</td>
</tr>
<tr>
<td>Polarisation</td>
<td>Full Polarimetry/Compact pol.</td>
</tr>
<tr>
<td>Data Acquisition</td>
<td>Single Pass/Repeat Pass polarimetric interferometry</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>≤ 50 x 50m (4 looks)</td>
</tr>
<tr>
<td>Swath Width</td>
<td>≥ 100 km</td>
</tr>
<tr>
<td>Noise Equivalent $\sigma_0$</td>
<td>≤ 27 dB (T), -30 dB (G)</td>
</tr>
<tr>
<td>Absolute Radiometric Calibration</td>
<td>≤ 1 dB</td>
</tr>
<tr>
<td>Radiometric Stability</td>
<td>≤ 0.5 dB</td>
</tr>
</tbody>
</table>
Technical Concept

- At P-Band, antenna area of 50 to 100 m² would be required!

12 m aperture diameter unfurlable reflector built by Thales Alenia Space and Russian NPO EGS

Astrium’s FLATS antenna concept (17.29 m × 2.82 m)
## Mid-Term Review - Baselines

<table>
<thead>
<tr>
<th></th>
<th>Deployable Flat Array</th>
<th>Reflector</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Antenna Aperture</strong></td>
<td>Length 17.9m</td>
<td>Diameter 12m</td>
</tr>
<tr>
<td></td>
<td>Height 4.5m</td>
<td></td>
</tr>
<tr>
<td><strong>Surface</strong></td>
<td>80 m²</td>
<td>113 m²</td>
</tr>
<tr>
<td><strong>ITU</strong></td>
<td>Compliant with tapering</td>
<td>Compliant with tapering</td>
</tr>
<tr>
<td><strong>Gain</strong></td>
<td>27.4 dB</td>
<td>32.5 dB</td>
</tr>
<tr>
<td><strong>RF peak Power</strong></td>
<td>600 Watts</td>
<td>500 Watts</td>
</tr>
<tr>
<td><strong>PRF</strong></td>
<td>1700Hz-1800Hz</td>
<td>3600Hz-3800Hz</td>
</tr>
<tr>
<td><strong>Total Swath</strong></td>
<td>80 km (STRIPMAP)</td>
<td>55-60km (STRIPMAP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>110km (SCANSAR 2 swaths)</td>
</tr>
<tr>
<td><strong>Coverage time</strong></td>
<td>35 days</td>
<td>45-50 days (STRIPMAP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25 days (SCANSAR)</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>≤50 mx50 m (≥ 4 looks)</td>
<td>≤ 50mx60m (≥ 4 looks)</td>
</tr>
<tr>
<td><strong>NeSigma0</strong></td>
<td>-30dB/-26.5dB</td>
<td>-31dB/-28dB</td>
</tr>
<tr>
<td><strong>Total Ambiguity Ratio</strong></td>
<td>&lt;-20dB</td>
<td>&lt;-20dB</td>
</tr>
<tr>
<td><strong>Data Rate Instrument</strong></td>
<td>80 Mbit/sec (5 bits)</td>
<td>133 Mbit/sec (8 bits)</td>
</tr>
</tbody>
</table>
Several scientific supporting activities have been initiated to better define the overall mission concept.
Synergies and Collaboration

- **Scientific collaboration**
  - MAG expected to consult with user community
  - Scientific support studies
  - Documented airborne campaign datasets

- **Forest Biomass constellation?**
  - Cross-validation of products e.g. radar forest height P- and L-Band and lidar forest height
  - Exploit advantages of each mission e.g. lower resolution BIOMASS product with higher-resolution DESDynl products

- **Programmatic collaboration**
  - Always most difficult (funding cycles often incompatible with mission development milestones)
  - BIOMASS design stand-alone but participation from other agencies not excluded
  - Start of Phase-A in March 2009 (assuming selection) would provide ideal opportunity
ESA Campaigns

- Active airborne SAR campaigns underway to address BIOMASS mission definition
- Consolidated datasets from ESA airborne campaigns accessible to scientific community
- Category 1 proposal required
  - [http://eopi.esa.int/esa/esa](http://eopi.esa.int/esa/esa) and click on ESA Campaigns link
- Existing campaign datasets of interest to the SAR community
  - TreeSAR 2003 (DLR E-SAR, Traunstein test site SE Germany)
  - Indrex-2 2004 (DLR E-SAR, Tropical forests and plantations, Kalimantan Indonesia)
  - BioSAR 2006 (DLR E-SAR, Boreal forests in Sweden)
Conclusions

- BIOMASS represents a dedicated mission to:
  - Quantify flux of carbon from land use change
  - Greatly improved modelling of terrestrial carbon cycle to improve our understanding and quantification of land contribution to global carbon cycle

- Mission objectives to be achieved through provision of consistent global information on forest biomass, forest disturbance and recovery and seasonal forest flooding retrieved using long-wavelength SAR (P-Band current baseline)

- Final decision on build and launch expected in 2010