Overview of Vegetation Structure Missions

DESDynI Mission Concept & Synergism with ICESAT2, BIOMASS

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Vegetation Structure Workshop – Charlottesville, VA Mar 3-5, 2008

The Workshop

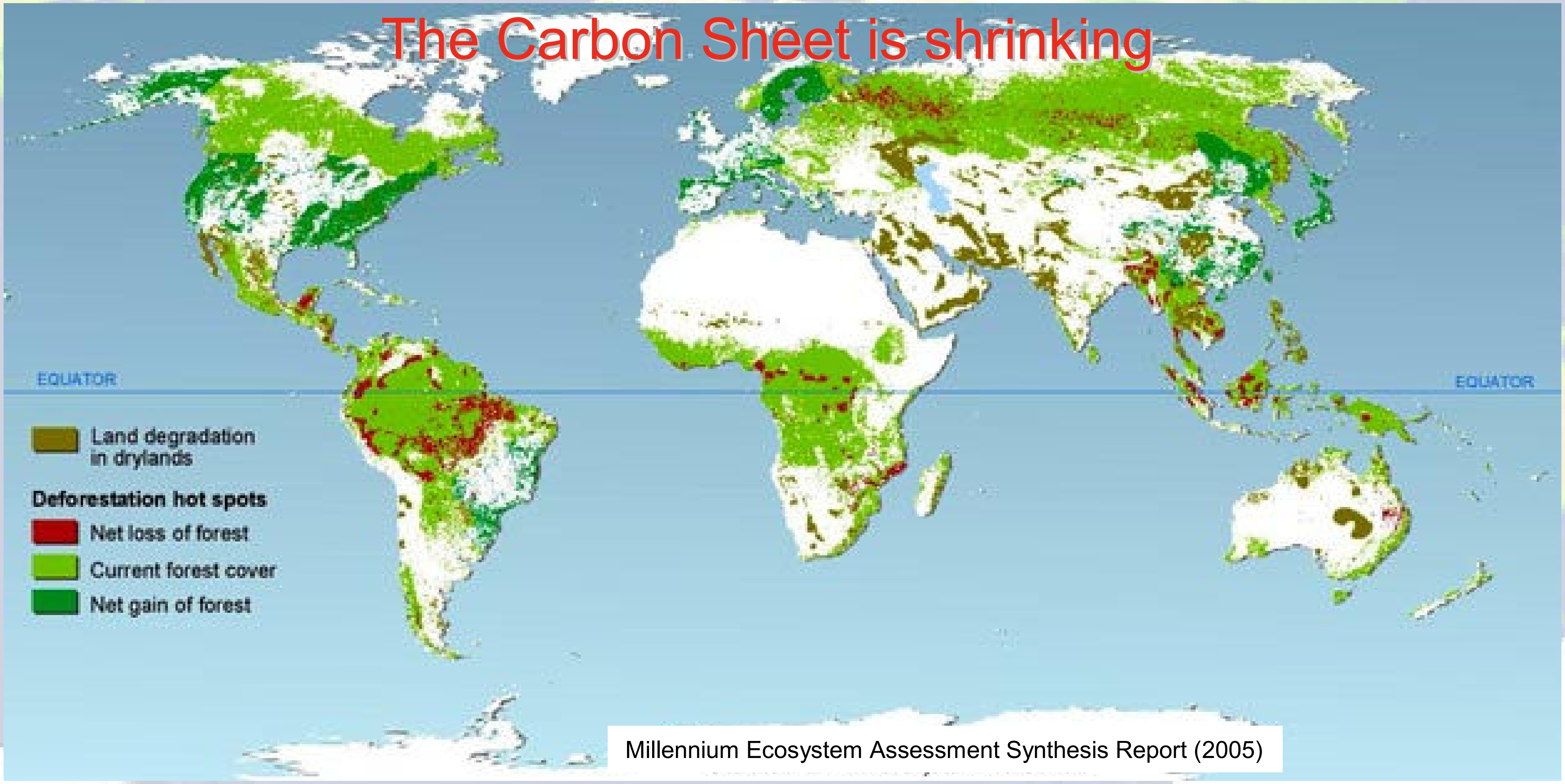
- The workshop will particularly focus on the NRC Decadal Survey mission recommendations to:
  - map vegetation structure and biomass,
  - examine the outcomes of two recent NASA workshops, the ICESAT2 (GLAS) and DESDynI (L-band polarimetry & InSAR and multi-beam Lidar),
  - and assess to what extent these missions could satisfy the global carbon cycle and ecosystem measurements identified so far.

Carbon Cycle Constellation

- PAST AND PRESENT
  - LANDSAT (1972-2008) Area disturbed & recovery, age, veg type
  - AVHRR (1981-2008) Recovery rate, annual variation (Fpar, LAI)
  - Terra/Aqua (2000-2008) Recovery rate, annual variation (Fpar, LAI)
  - ICESAT (2003-2008) Vegetation structure
  - Shuttle - SRTM (2000) Topography, Vegetation structure
  - Shuttle - Sir C (1994) Disturbance, Veg type, biomass
  - ESA MISSIONS
    - SPOT, MERIS Area disturbed & recovery, age, veg type
    - SCHIMACHY CO_2
  - JAXA MISSIONS (1990s,2000s) Disturbance, veg type
    - JERS-1 and ALOS - PALSAR
  - CHINA-BRAZIL (1993-2008) CBRS Disturbance, veg type, recovery
  - INDIA (1988-2008) IRS Disturbance, veg type, recovery
- FUTURE
  - NPP, VIIRS (2012) EOS, MODIS Follow on
  - OCO (2009) CO_2
  - ICESat 2 (2010 - 2013) Veg Structure, biomass
  - DESDynI (2010 - 2013) Veg Structure, disturbance & recovery rate
  - BIOMASS (ESA) Biomass
  - LiST(2016) Vegetation structure
  - HYSPERI Vegetation type and function

Carbon Cycle and Ecosystems Science Question

How are the Earth's carbon cycle and ecosystems changing, and what are the consequences for the Earth's carbon budget, ecosystem sustainability, and biodiversity?**



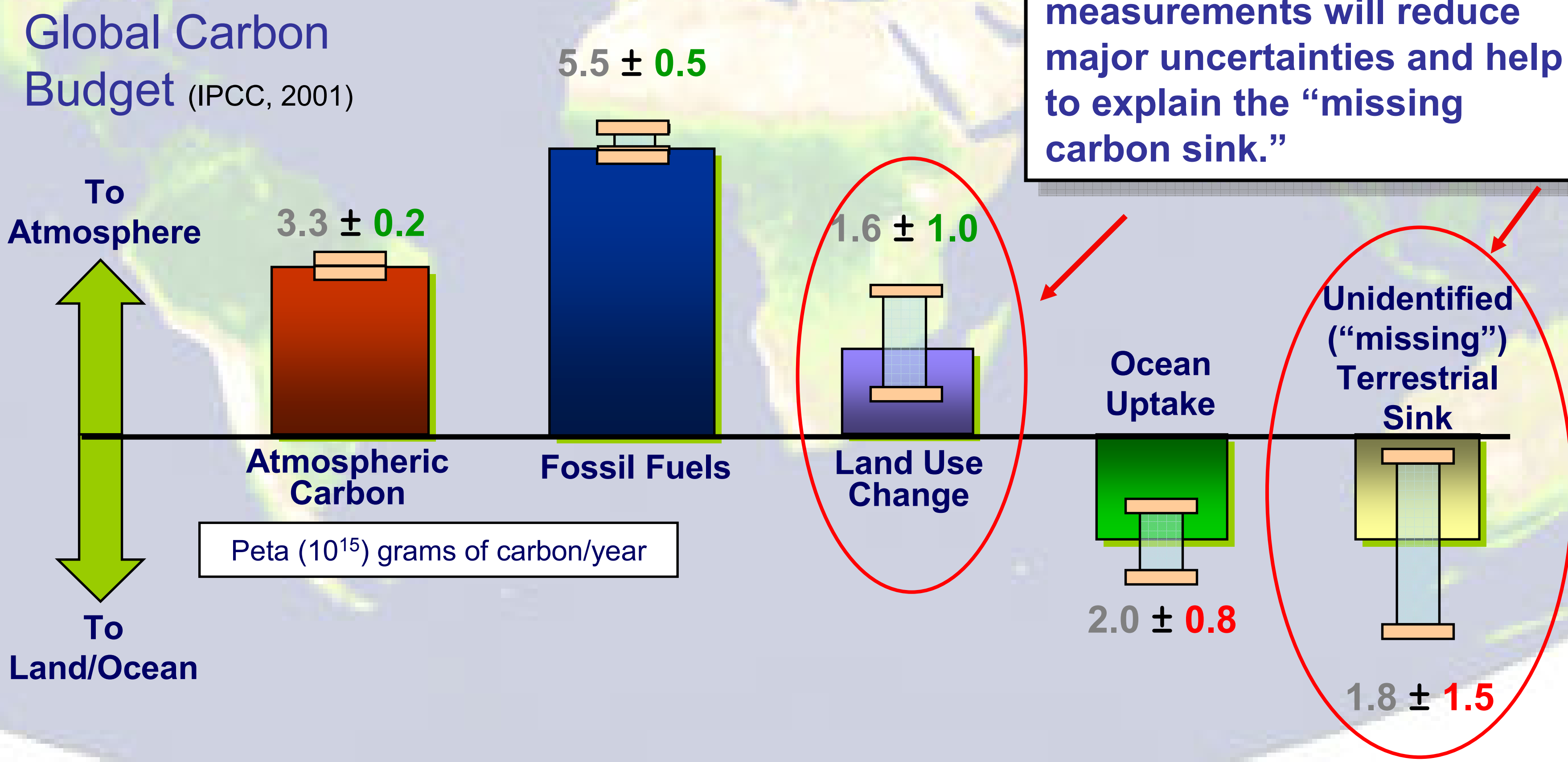
Millennium Ecosystem Assessment Synthesis Report (2005)

**Earth Science Enterprise Strategy, October 2003
Science Mission Directorate Draft Science Plan, 2006

Carbon in Aboveground Vegetation

Largest remaining uncertainties about the Earth's carbon budget are in its terrestrial components.

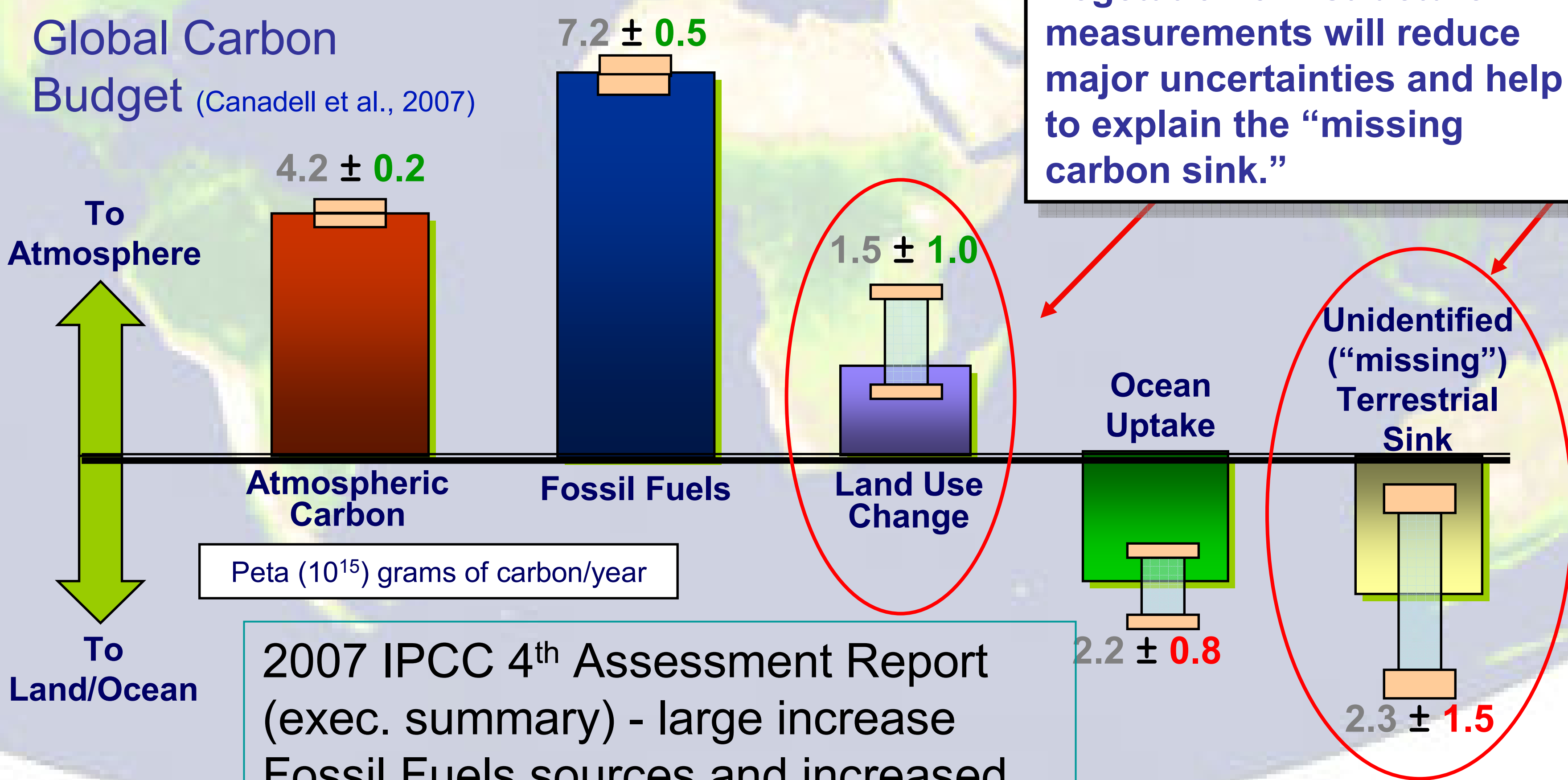
Vegetation 3-D structure measurements will reduce major uncertainties and help to explain the "missing carbon sink."



Carbon in Aboveground Vegetation

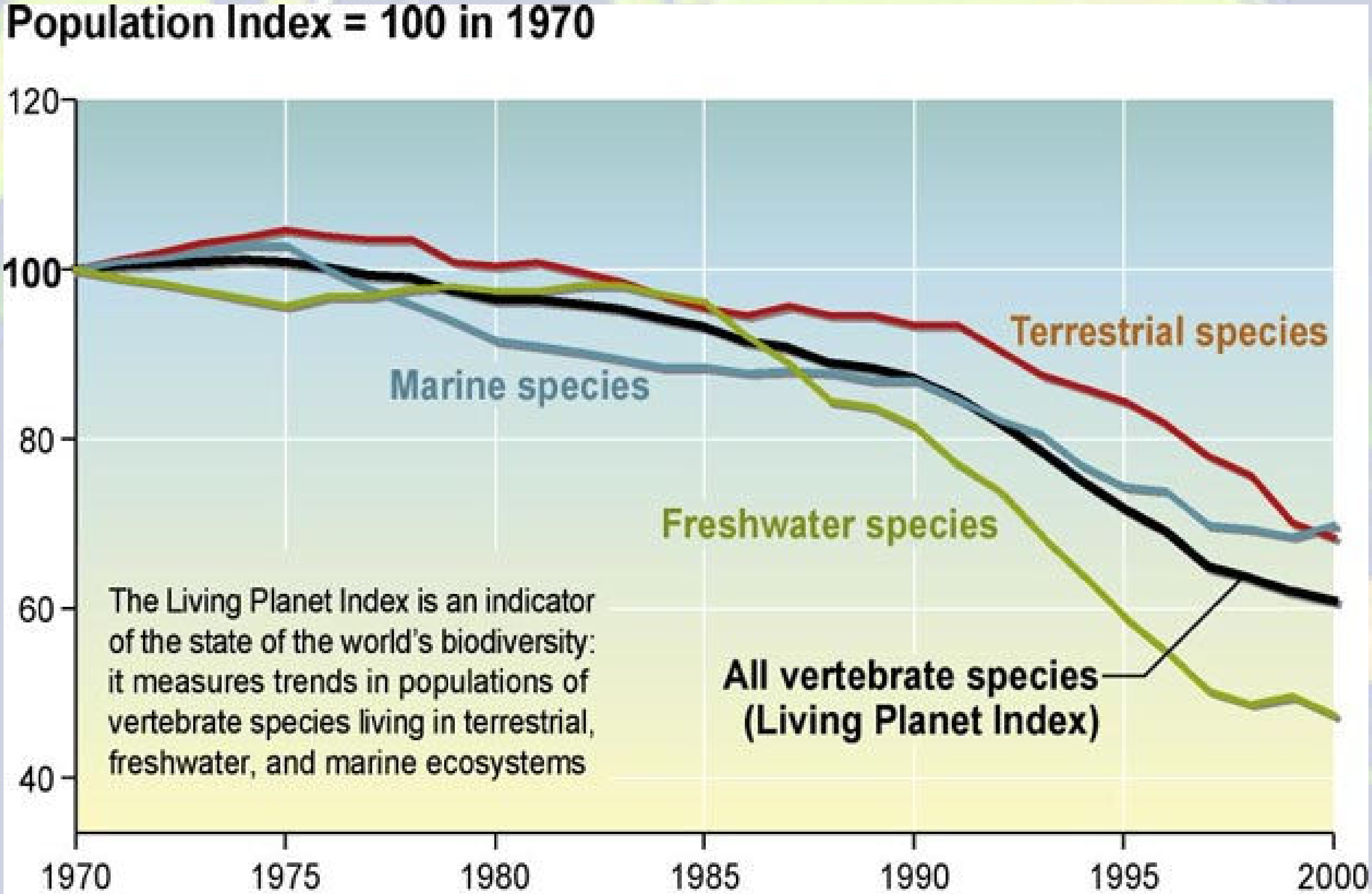
Even with new like Landsat 7 ETM+ and MODIS land vegetation component uncertainties still unacceptable and the missing carbon is still a mystery

Vegetation 3-D structure measurements will reduce major uncertainties and help to explain the "missing carbon sink."



2007 IPCC 4th Assessment Report (exec. summary) - large increase Fossil Fuels sources and increased uncertainty in land component errors

MANY ECOSYSTEMS ARE DEGRADING

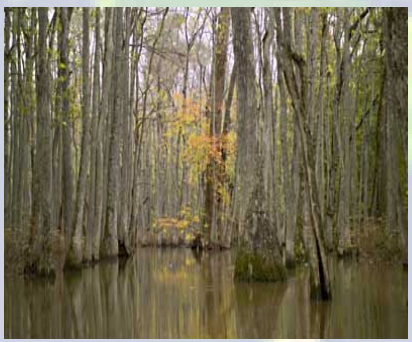


LIVING PLANET INDEX, World Wildlife Fund
Technical notes, p. 37 of the 2006 report
http://assets.panda.org/downloads/living_planet_report.pdf

Ecosystem Properties

Changes in landscape spatial heterogeneity - vegetation type, height profiles and biomass relate strongly to ecosystem state and condition.

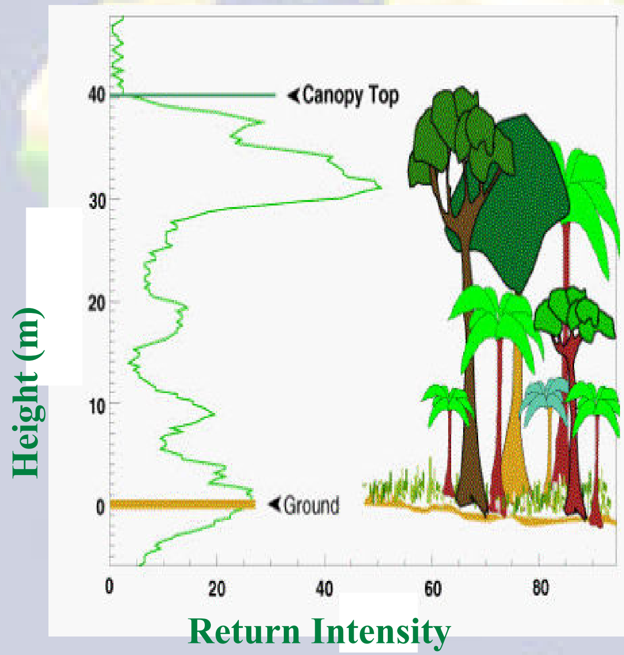
primary tropical forest



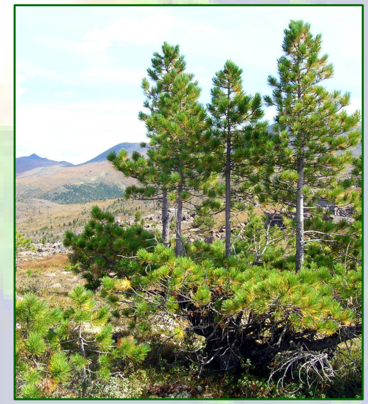
unique habitats

Vegetation height and the vertical distribution of leaves and branches influence where and how other species utilize the ecosystem for food, shelter, and territory.

Vertical Structure



The vertical dimension provides key insight into ecosystem state and function based on the heights of canopy and understory



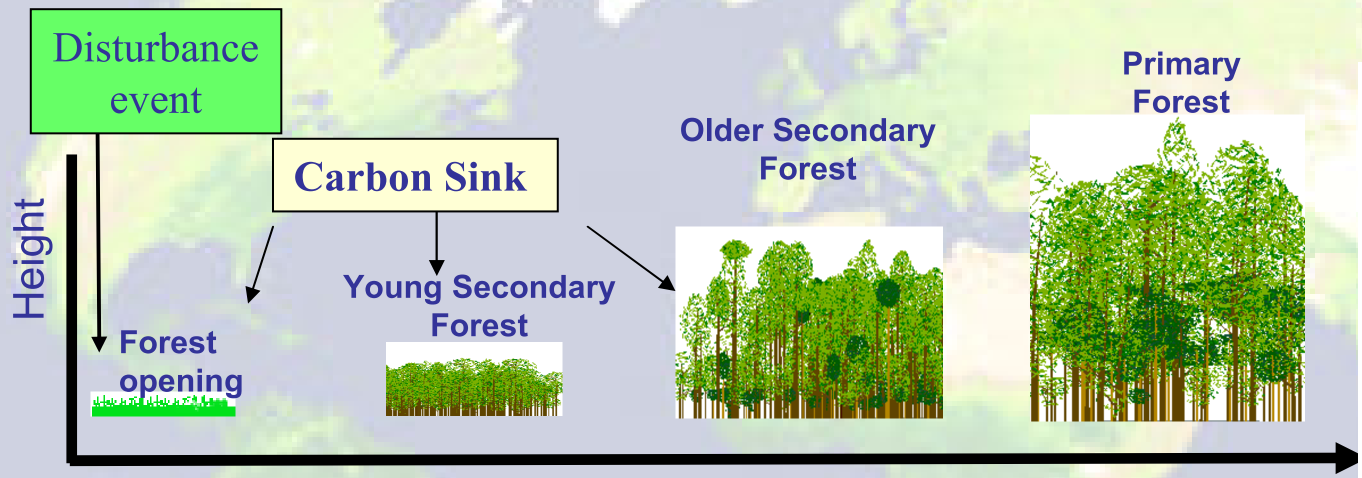
Ecosystem structure may change in response to climate. Top – change in tree form from bush to erect Bottom – new species appearing in the understory of this larch forest in Siberia

How are the Earth's carbon cycle and ecosystems changing, and what are the consequences for the Earth's carbon budget, ecosystem sustainability, and biodiversity?

To address our science questions, we must measure the horizontal and vertical heterogeneity and temporal dynamics of vegetation.

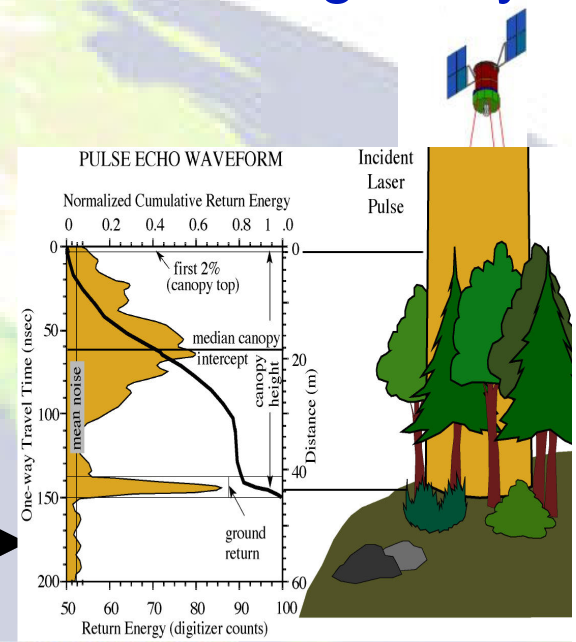
- Vertical structure (height, density and arrangement of branches and foliage) is critical to estimating biomass, age and vegetation type.
- Horizontal structure as density and spatial arrangement is strongly related to habitat type and successional processes.
- Changes in structure are indicators of growth, successional processes, disturbance and recovery.

Ecosystem changes are reflected strongly in the vertical height and density distribution of vegetation and its horizontal heterogeneity



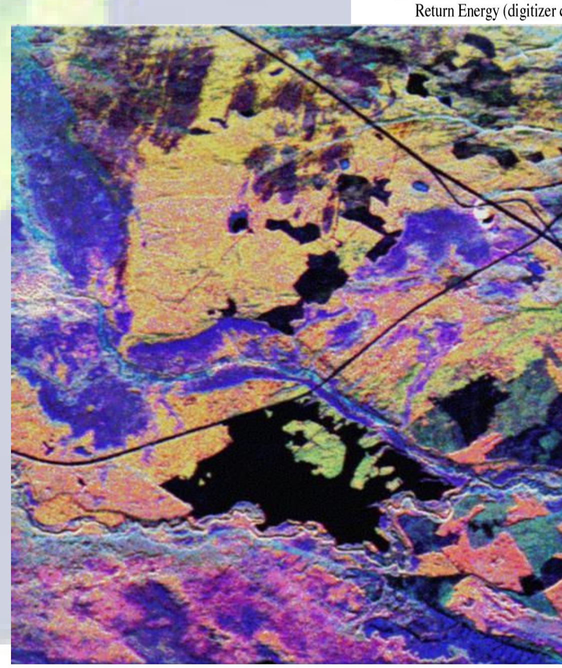
(figure from J. Drake)

More Biomass →



Both human-induced and natural disturbance are major driving forces that determine the transition of forest stands, landscapes, and regions from carbon sink to source and back.

Disturbance form fire, insects, disease, logging, storms



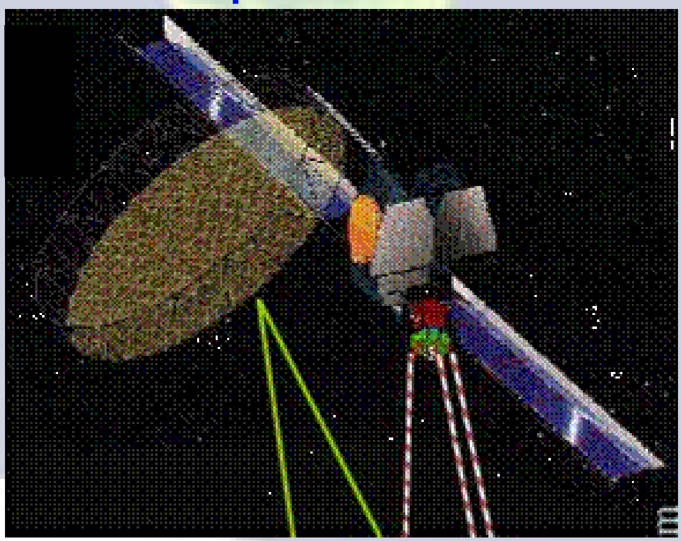
Forests tend to be patchy due to natural and human disturbance. In this radar image from Canada there is evidence of fires (dark areas at top) and logging (e.g.,black features in center)

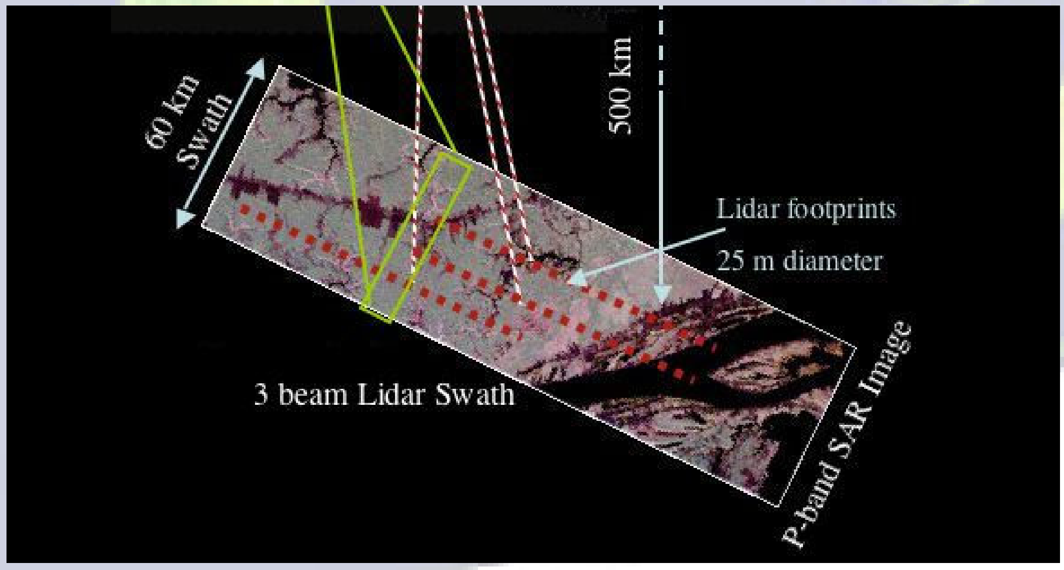
THE ROAD TO A VEGETATION STRUCTURE MISSION

- Spadework
  - Airborne radar and lidar, SIR-C, ICESat, VCL, BIOMM AND BIOMM-L, 2003 VEG Structure Workshop
- Decadal White Paper Submissions
- Preliminary VEG-3D Decadal Survey And ICESat II MISSION Studies By NASA (GSFC and JPL with HQ)
- Decadal Survey Ecosystem Panel
  - Deliberations During Panel Sessions
  - Tradeoffs
    - Solid Earth Panel
    - Ice Panel
    - Ecosystems Panel
- ICESat II and DESDynI Workshops
- This Workshop helps provides a way forward

Vegetation 3D Structure, Biomass and Disturbance Concept Study

- Recognition of critical importance of the 3rd dimension for measurements of vegetation
- Directed by NASA HQ to study LIDAR and SAR together
- Study led by GSFC with direct participation of JPL and supported by the Vegetation Structure Science Working Group





Mission Science Objectives

1) Develop globally consistent and spatially resolved estimates of aboveground biomass and carbon stocks.
2) Make globally consistent and spatially resolved measurements of vegetation vertical structure to understand changes and trends in terrestrial ecosystems and their functioning as carbon sources and sinks.
3) Characterize and quantify the three-dimensional structural response to disturbance.
4) Quantify changes in terrestrial carbon sources and sinks resulting from disturbance and recovery.
5) Characterize habitat structure for biodiversity assessments.

Ecosystem Structure Requirements
DESDynI Workshop

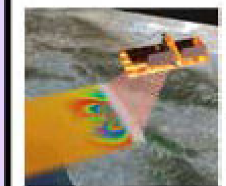
1. Measurements over Earth's terrestrial ecosystems comprising a statistically rigorous sampling of height and profiles and/or contiguous global coverage
2. Vegetation height and profiles: Maximum vertical height measurement accuracy to ~1 m, vertical resolution of canopy profile of 2 to 3 m, and at ~25 m spatial resolution or better in a sampling mode
3. Aboveground biomass and changes including disturbance, at a spatial resolution of 100 m to 1 km for contiguous forest biomass, and within-pixel accuracy of +/- 10 tons or 20% (whichever is greater) at 1 ha spatial resolution for sampled forest biomass
4. Changes at a scale of 1 km and precision of 2-4 tons/ha/year.
5. Re-visit time monthly to seasonal
6. The measurement technique must produce useful results within the above uncertainties over areas with significant topographic relief.

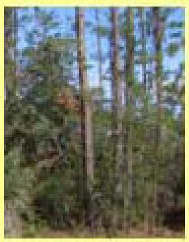
[boxed] → Requires SAR complement to lidar

DESDynI

Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI)

Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI)
Launch: 2010-2013
Mission Size: Large





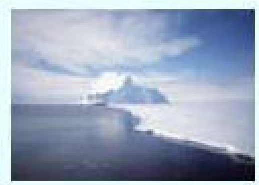
Height and structure of forests

Changes in carbon storage in vegetation

Ice sheet deformation and dynamics

Changes in Earth's surface and the movement of magma

Effects of changing climate and land use on species habitats and atmospheric CO_2



Response of ice sheets to climate change and impact on sea level

Forecast likelihood of earthquakes, volcanic eruptions, and landslides

DESDynI
Mission and Payload

- This mission combines two sensors that, taken together, provide observations important for solid-Earth (surface deformation), ecosystems (terrestrial biomass structure) and climate (ice dynamics).
- Instruments may be on single or dual platforms
- The sensors are:
  - an L-Band Synthetic Aperture Radar with multiple polarizations, also used as an Interferometric SAR (InSAR) system, (Mapper)
  - a multiple beam lidar operating in the infrared (~ 1064 nm) with <25 m spatial resolution and 1 m vertical accuracy. (Sampler)
- *Many mission requirements for DESDnyl are similar to those for VEG 3D except 8-12 day vs 45 day repeat and L-band (InSAR) vs P-band SAR to accommodate surface deformation needs.*

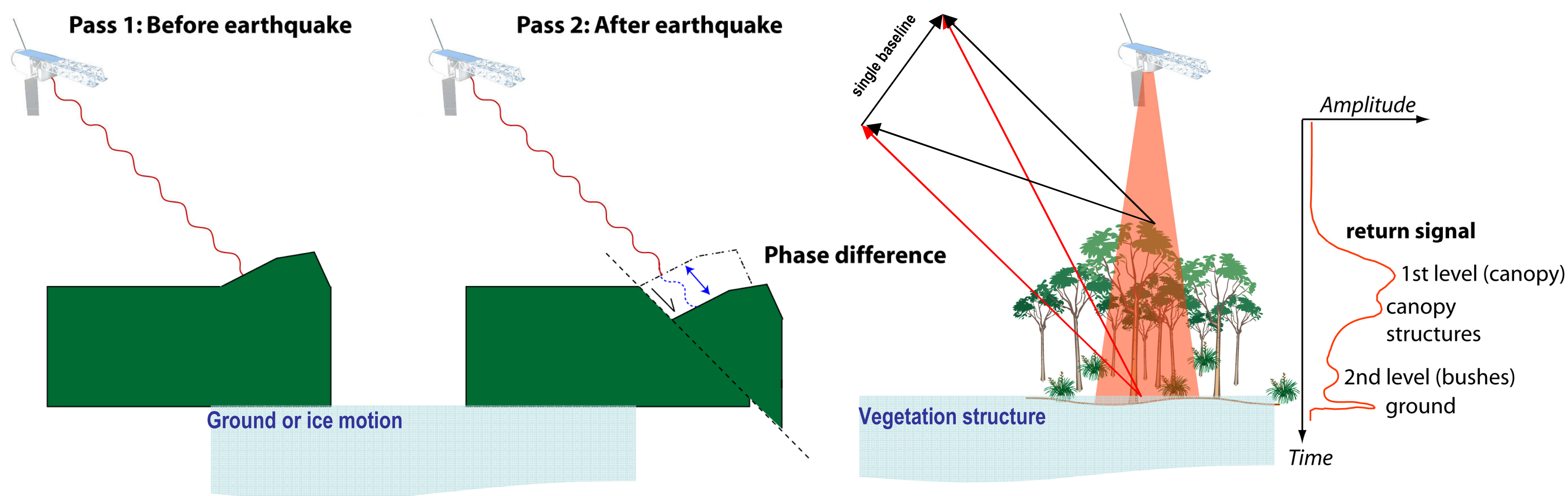
DESDynI Concept

- DESDynI is an **L-band InSAR** and **multibeam LIDAR** mission for improving our understanding of hazards, ice sheet dynamics, and ecosystems

Repeat Pass InSAR

Polarimetric SAR and Finite Baseline InSAR

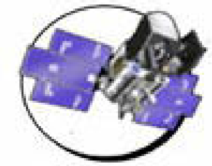
Multibeam LIDAR



A. Donnellan, NASA JPL)

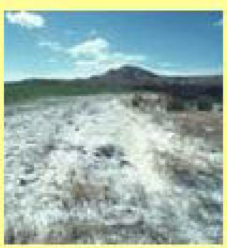
OTHER MISSIONS

ICESat-II
Launch: 2010-2013
Mission Size: Medium

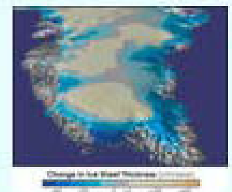


Ice sheet thickness and volume

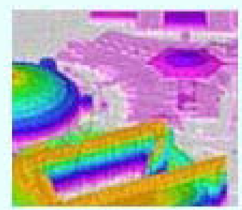
Vegetation canopy depth as an estimate of biomass



Estimate of flux of low-salinity ice out of Arctic basin



Changes in volume of ice sheets in response to climate change

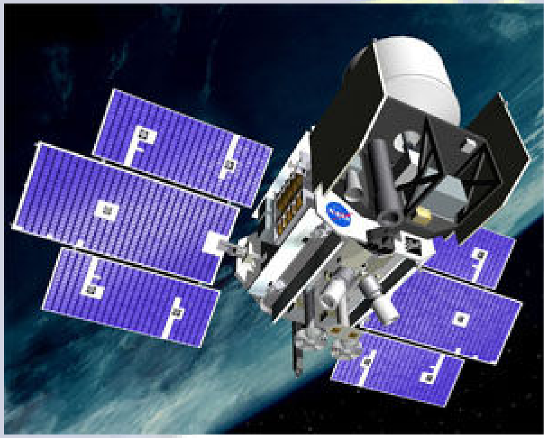


Effects of changing climate and land use on level of CO_2 in atmosphere

Prediction of changes in sea level

ICESat II

- Single Beam Lidar, 70m footprints spaced 140 m apart
- 94^{o} inclination orbit to ensure polar coverage to >86 degrees
- Repeat of ICESat tracks is required to fully utilize baseline of ICESat elevations and cross-track slope information.
- 5-7 years of measurement duration to establish climatological significance
  - Combined with ICESat I to obtain >10 years of elevation change and sea ice thickness information
  - Sufficient continuous sampling for ice sheet and sea ice model development and validation
- New Start Funding from NASA!



ICESAT II

- Configured The Same As ICESat I, ICESat II:
  - Can make lidar measurements of vegetation canopies that can satisfy 10% of vegetation measurement requirements
  - Loses sensitivity in tropics where most needed due to high inclination non-sun synchronous orbit
  - Has $\pm$5 M height and $\pm$50 mg/ha biomass errors

- HQ supported concept study showed it is feasible to fly a multibeam small footprint lidar along with the ICESat Lidar

ESA BIOMASS

➢The objective of the BIOMASS mission is to acquire global measurements of forest biomass to assess terrestrial carbon stocks and fluxes. Expected sensitivity of up to 100-150 Mg/Ha

➢The mission concept is envisaged as a spaceborne P-band synthetic aperture polarimetric radar operating at 435 MHz and a 6 MHz bandwidth.

➢One of six missions to be selected in 2010 and flown by 2015

- Mission duration: 5 years
- Orbit: Sun-synchronous, local time ~06:00
- Coverage: global, vegetated areas
- Revisit time: 25 days
- Polarisation: full polarimetry and/or
- circular/dual polarisation
- Data acquisition: single-pass/repeat-pass
- polarimetric interferometry
- Resolution: ≤50 x 50 m (≥4 looks)
- Swath width: ≥100 km

http://www.esa.int/esapub/bulletin/bulletin131/bul131d_bensi.pdf

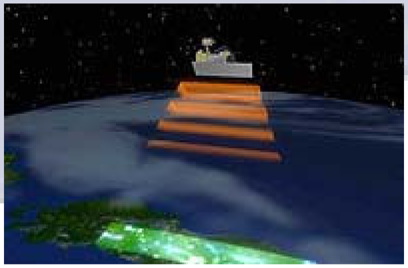
JAXA ALOS PALSAR

Phased Array Type L-band Synthetic Aperture Radar

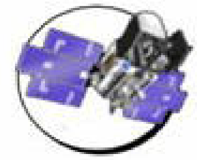
- PALSAR is an L-band SAR with 10 and 100 m resolutions that are capable of detailed, all-weather, day and night observations and repeat-pass interferometry.
- Data since October 2006

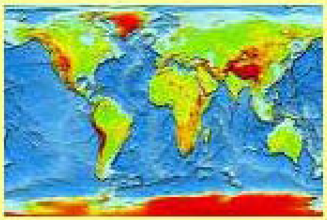
	High Resolution	**ScanSAR**
Polarization	HH, VV, HH&HV, VV&VH	HH, VV
Spatial Resolution	10 m	100 m
Number of Looks	2	8
Swath Width	70 km	250-350 km
Wavelength (Frequency)	L-Band (1.27 GHz)	
Off-nadir Angle	41.5° (default)	
NE Sigma 0	Approximately -23 dB	

Orbit	Sun synchronous
Altitude	691.65 km
Recurrent period	46 days
Inclination	98.16 degree



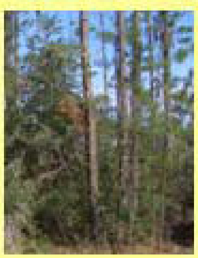
LIDAR Surface Topography (LIST)
Launch: 2016-2020
Mission Size: Medium





Global high resolution topography

Detection of active faults



Global shifts in vegetation patterns and forest stand structure

Quantified assessment of wildfire risk

Monitoring land use change and the effects of land management

Forecast likelihood of volcanic eruptions, earthquakes, and landslides

Expectations from this workshop

- Engagement of a broad community of scientists, remote sensing specialists, and institutions interested in terrestrial carbon cycle, forest biomass and carbon accounting and Veg3D structure in support of DESDynI and BIOMASS
- Definition of measurement requirements, scientific products and applications for reducing uncertainties about global carbon balance, national and global carbon accounting, process models and predictions, and biodiversity and habitat assessment.
- Identification and assessments of the science derived from radar and multi-beam lidar sensors recommended for DESDynI and BIOMASS concepts and their complementary measurements
  - Identification of areas of research and further development/ investigation
  - Plan for the publication of review articles, recent case studies, and algorithms to document the state-of-the-art of active remote sensing of vegetation structure and biomass and to promote the mission concepts
  - Planning for community “education” and outreach towards the implementation of the mission concepts.

Concluding remarks

- Excellent opportunity to exploit 3rd dimension of vegetation canopies:
  - close carbon budget
  - make ecosystem structure discoveries
- DESDynI mission is Decadal Survey response to need for lidar and radar for carbon and ecosystems
  - Needs careful study to accommodate multidisciplinary science requirements
  - Carefully consider Decadal Survey options including flying lidar separately from radar to optimize science of overall mission.
- Other missions can provide additional data useful but not sufficient alone for answering our science questions.
- Need to be consistent, collaborative, and creative to make progress in this workshop.