

# LC Change Validation/Uncertainty in Emissions Estimation (C. Woodcock)

- GOFC-GOLD Overview and LC-IT
  - Sourcebook
  - Accuracy Assessment and Area Estimation
  - Global Land Cover Validation/Best Available Land Cover Map
- Landsat
  - Access etc.
- EVI
- Comments (based on yesterday's proceedings)

# What is GOFC-GOLD?

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- GOFC-GOLD is a coordinated international effort:
  - to ensure a continuous program of space-based and on-the-ground forest and land cover observations for global monitoring of terrestrial resources and the study of global change.
- A technical panel of the Global Terrestrial Observing System (GTOS)
- A network of participants implementing coordinated research, demonstration and operational projects
- A vision to share data, information and knowledge, leading to informed action and decision support
- A long term process of building an improved match between Observations, Data Products and User Needs
- GOFC-GOLD operates through:
  - Executive committee, Science and technical board
  - Implementation teams and 3 project offices (CA, US, Germany)
  - Dedicated working groups (i.e. on REDD, GEO etc.)
  - 6 Regional networks



# Land Cover Implementation Team

## Membership

- Co-Chairs
  - Martin Herold (Freidrich Schiller University)
  - Curtis Woodcock (Boston University)
- Members
  - Frederic Achard (JRC)
  - Sergey Bartalev (Space Research Institute, Moscow)
  - Ruth Defries (Columbia University)
  - Matt Hansen (South Dakota State University)
  - Alex Held (CSIRO)
  - Herve Jeanjean (GMES)
  - Tom Loveland (USGS-EDC)
  - Philippe Mayaux (JRC)
  - Hakan Olssen (Swedish University of Agricultural Sciences)
  - Devendra Pandey (Forest Survey of India)
  - Carlos Sousa (IMAZON, Brazil)
  - Chris Schmillius (Freidrich Schiller University)
  - John Townshend (University of Maryland)
  - Mike Wulder (Canadian Forest Service)

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# Land Cover Team Current Activities

UNFCCC ECV Standards

REDD Sourcebook

Decadal Survey and GEOS LSI Constellation

GEO Land Cover Task

Global Validation/Best Map Effort

FAO FRA Activities

Support for Regional Networks

“Best Practices” for Land Cover Change and Area Estimation

# Observing Essential Climate Variables (ECVs)

Terrestrial ECV	Observing System (i.e. ESA, others)
<i>River Discharge</i>	In situ networks,
<i>Water Use</i>	In situ networks, regional remote sensing activities
<i>Groundwater</i>	In situ networks,
<i>Lake and Reservoir Levels &amp; Volumes</i>	In situ networks, regional remote sensing activities
<i>Snow Cover</i>	GLOBSNOW
<i>Glaciers and Ice Caps</i>	GLOBGLACIER
<i>Permafrost</i>	Regional activities (i.e. circum-arctic)
<i>Albedo and Reflectance Anisotropy</i>	GLOBALBEDO
<i>Land Cover</i>	GLOBCOVER, MODIS land cover ...
<i>Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)</i>	GLOBCARBON, MODIS and Seawifs products
<i>Leaf Area Index</i>	GLOBCARBON, MODIS products
<i>Biomass</i>	Regional activities, e.g. Siberia
<i>Fire Disturbance</i>	Several global products from AATSR or MODIS
<i>Soil moisture</i>	SMOS satellite mission

# Relevant tasks in the GEO 2007-09 Work Plan

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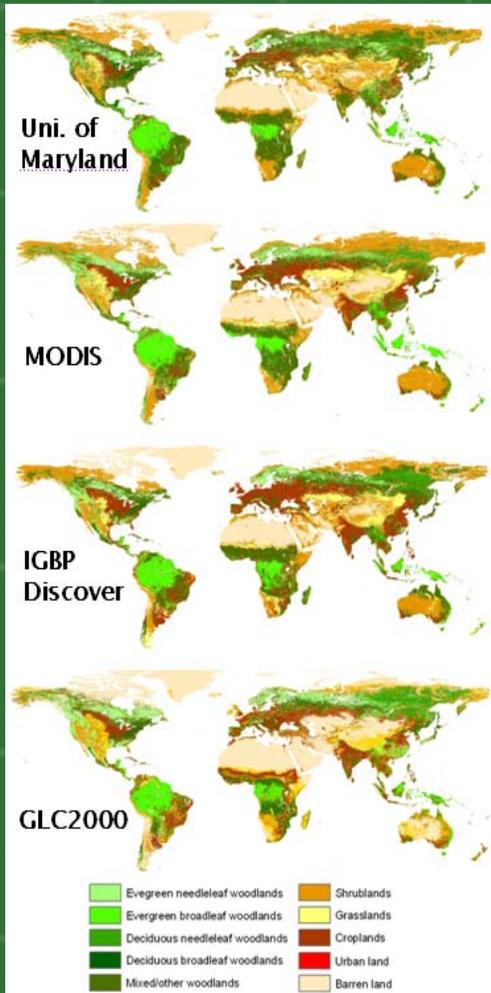
## ➤ DA-07-02 Land Cover (Data and Architecture)

*“Provide a suite of global land cover datasets, initially based on improved and validated moderate resolution land cover maps and eventually including land-cover change at high resolution.”*

- Continuation of 2006 workplan task: AG-06-03
- Hosted under Architecture and Data Committee
- Task lead US/USGS + GOFC-GOLD

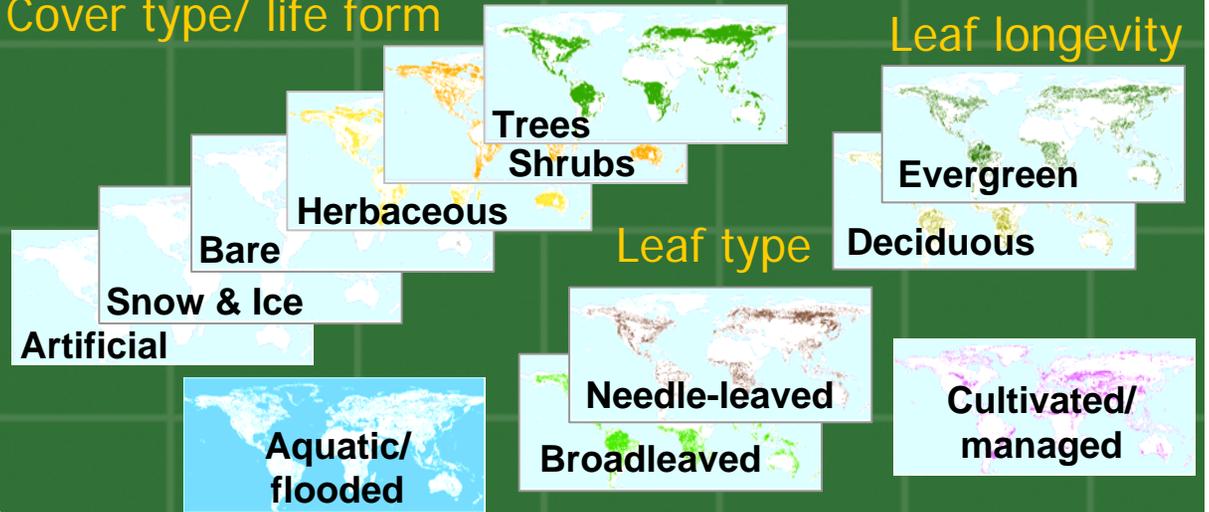
# Harmonized land cover characterization

Existing global land cover datasets



Common land cover classifiers (LCCS)

Cover type/ life form



"Living" validation database for comparative assessment



GOFC-GOEB-GOLD

# Next GOFC-GOLD symposium

3<sup>rd</sup> GOFC-GOLD Land Cover Symposium , 13-17. Oct. 2008, Jena, Germany

## Agenda overview

Day	Morning	Afternoon
Monday, 13 October	Workshop on Monitoring Tropical Deforestation and Degradation (REDD)	Workshop on Monitoring Boreal Forests
Tuesday, 14 October	GOFC-GOLD/CEOS Workshop on Land Cover Change Accuracy Assessment	GOFC-GOLD Strategic Meeting - Review
Wednesday, 15 October	Land Cover Symposium	
Thursday, 16 October	Land Cover Symposium - Break out group discussions	Land Cover Implementation Team Meeting (internal)      GOFC-GOLD Strategic Meeting - Conclusion
Friday, 17 October	LCCS and harmonization workshop & Regional Network Meeting	

More info: [www.gofc-gold.uni-jena.de/](http://www.gofc-gold.uni-jena.de/)



Canada



GOFC-GOLD

# GOFC-GOLD

Global Observation of Forest and Land Cover Dynamics



Building national forest  
carbon monitoring  
capabilities using the GOFC  
REDD sourcebook



*GOFC-GOLD Land Cover Office, FSU Jena, Germany*  
*[www.gofc-gold.uni-jena.de](http://www.gofc-gold.uni-jena.de)*



GLOBAL TERRESTRIAL OBSERVING SYSTEM

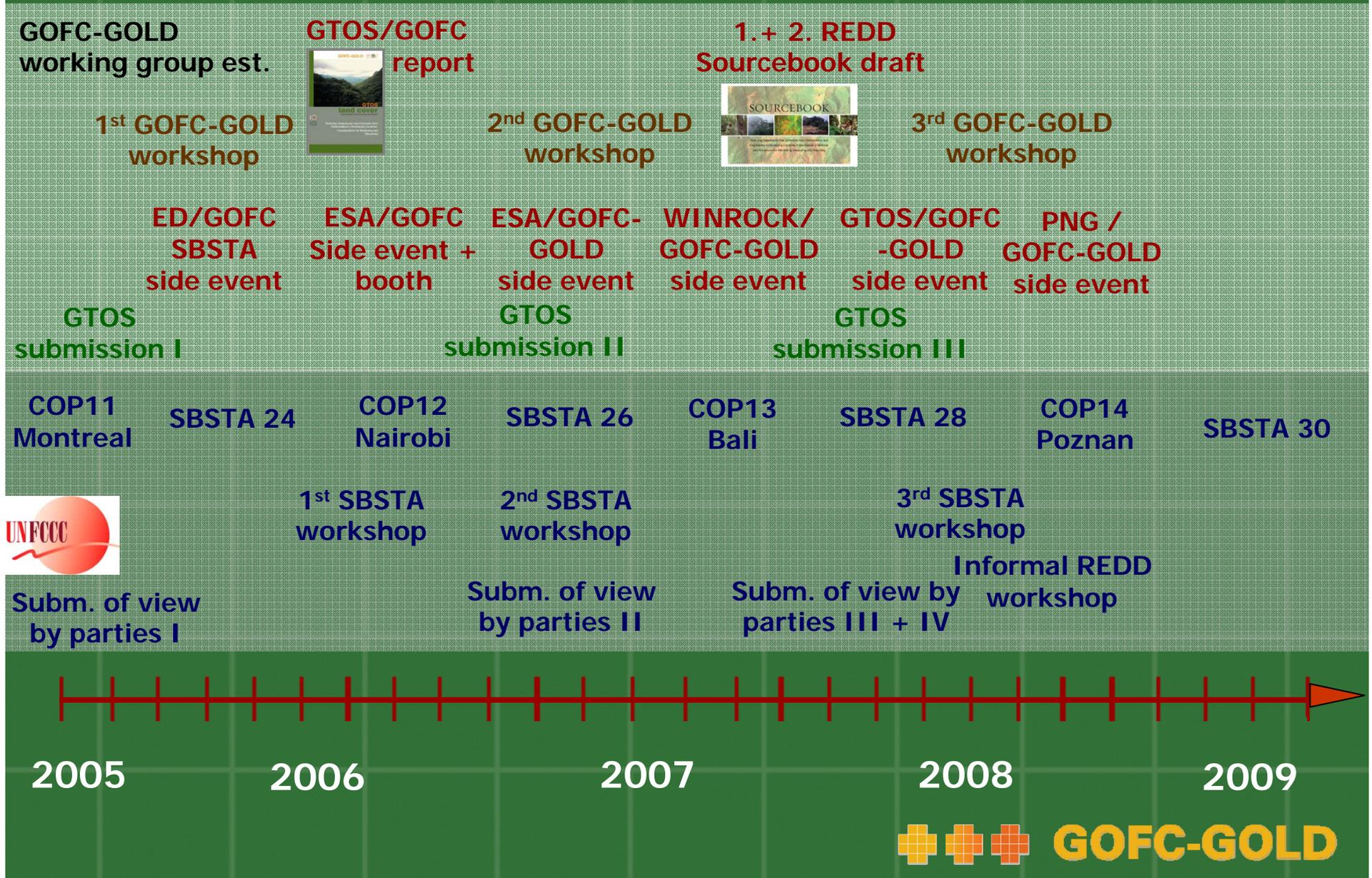


# REDD and implementation

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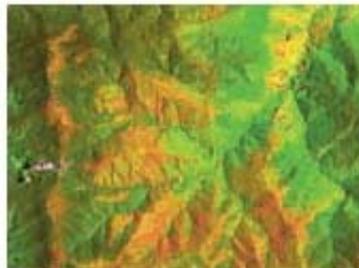
- Tools for estimating, accounting, reporting on REDD:
  - *IPCC Good Practice Guidelines and Guidance*
  - *Stronger role for satellite remote sensing*
  - *Dedicated research and case studies*
- 2005: Establishment of GOFC-GOLD REDD working group
  - *Promote satellite monitoring as objective and efficient approach in developing countries*
  - *Forest changes can be monitored with confidence for assessing and comparing historical and future rates of deforestation*
  - *Consensus technical guidance in development (REDD sourcebook)*

# Earth observation contribution to UNFCCC-REDD



# Sourcebook version COP13.2

## SOURCEBOOK



Version COP13.2 includes:

- Edits from comments received through international review process
- Updated sections, i.e. on fire monitoring, accuracy assessment, national forest inventories ...

# Acknowledgement

## Sponsors of the Global Terrestrial Observing System:



## Sourcebook authors:

*Core authors: Frederic Achard, Sandra Brown, Ruth De Fries, Giacomo Grassi, Martin Herold, Danilo Mollicone, Carlos Souza Jr.*

*Contributing authors: Barbara Braatz, Ivan Csiszar, Diane Davies, Bill de Groot, Sandro Federici, Nancy Harris, Suvi Monni, Devendra Pandey, Tim Pearson, David Shoch, Curtis Woodcock*

## Support for GOFC-GOLD REDD working group and Sourcebook preparation:



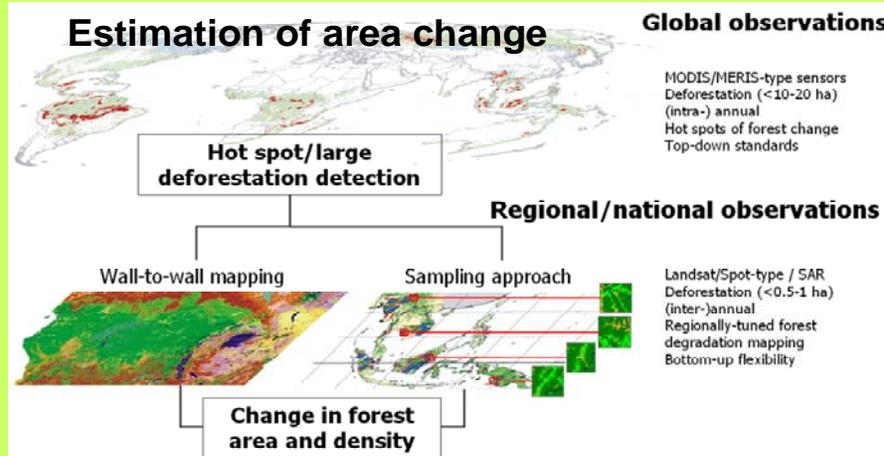
# Sourcebook objectives

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1. to provide transparent methods that are designed to produce estimates of changes in forest area and carbon emissions from deforestation and degradation
  - in a format that is user-friendly
2. to complement the IPCC GPG-LULUCF (2003) and IPCC Guidelines-AFOLU (2006) by providing additional explanation, clarification and enhanced methodologies for obtaining and analyzing key data
3. to support REDD early actions and readiness mechanisms on national level

# Sourcebook initial format

## Chapter 1 and 2: Introduction and definitions



## Chapter 3

**Estimation of carbon stocks**

Good Practice Guidance for Land Use, Land-Use Change and Forestry

**SOURCEBOOK FOR LAND USE, LAND-USE CHANGE AND FORESTRY PROJECTS**

Timothy Pearson, Sarah Walker and Sandra Brown

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS  
helping to build a world without hunger

Forestry

Forestry home | FAO home | english | français | español

## Chapter 4

**Chapter 5**  
**Estimation of CO<sub>2</sub> emissions**

**Chapter 6**  
**Guidance on reporting of CO<sub>2</sub> emissions**

# Implementation remarks

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1. Building a national forest carbon monitoring system is a process (that can start now):
  - *Assessment of existing national capacities and available data*
  - *Methods and guidance exist*
2. Capacity building as key factor for “readiness phase”:
  - *Technical monitoring capabilities*
  - *IPCC compliant estimation, accounting and reporting*
3. Start conservative with motivation to improve monitoring system over time

# Building national capabilities

<i>Important components</i>	<i>Practical considerations</i>
<b>FOREST AREA CHANGE</b>	Primary source: Landsat-type satellite data
Deforestation	Starting point for historical assessment 1990-2005 (3 time steps minimum) Build basic satellite data proc. capabilities
Monitoring of forest degradation Forest fire and burned area	Relevance and characteristics for human-induced carbon emissions Definition of suitable monitoring system
Accuracy assessment	Using best/transparent methods and efforts for continuous improvement Prepare for statistically robust approach
<b>CHANGE in CARBON STOCKS</b>	Primary source: ground/inventory data
Existing stratifications and forest carbon estimates	Inventory of available data Decide on carbon pool/TIER level to report
Towards improved carbon stock change estimations	New inventory including other carbon pools Stratification in relevant areas/forest types
<b>ACCOUNTING &amp; REPORTING</b>	Provide conservative estimates



# Global land cover validation and a “Best Currently Available” LC Map

Curtis Woodcock, Steve Stehman and Martin Herold (Jena)  
And the LC IT

[www.fao.org/gtos/gofc-gold](http://www.fao.org/gtos/gofc-gold)  
[www.gofc-gold.uni-jena.de](http://www.gofc-gold.uni-jena.de)



**GOFC-GOLD**

*Global Observations of Forest Cover and Land Dynamics*

# International drivers

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- 1. United Framework Convention on Climate Change:**
  - Reduce uncertainties in monitoring the global climate system through observing essential climate variables
  - Capacity building needs to address stronger role of developing countries in post-2012 agreement
- 2. Group on Earth Observation (GEO) task DA-07-02:**
  - “Provide a suite of global land cover datasets, initially based on improved and validated moderate resolution land cover maps and eventually including land-cover change at high resolution (task co-lead by USGS and GOFC-GOLD)”
- 3. Global land cover monitoring and assessments:**
  - GLOBCOVER, FAO-Forest Resources Assessm. 2010
  - Operational validation / Efforts for deriving “Best map”

# Overview

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1. As the land cover community matures, an increasing emphasis on validation and accuracy assessment - a difficult, somewhat unpleasant and somewhat surprisingly expensive activity
2. The LC IT has decided to try to support the broader community through validation
3. Idea is to collect ground reference data independent of any single land cover product to support validation of many land cover datasets
4. Intent is to supplement and complement ongoing validation activities associated with individual land cover datasets



## Notion of a “Best Currently Available” Land Cover Map

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Combine the strengths of multiple sources of land cover data across multiple extents and resolutions (national, regional and global sources)

Based on what is learned in the validation exercise

A transparent and community endorsed activity

LCCS compatibility is critical

Simple guidance criteria:

- more accurate is better

- finer spatial resolution is better

- more thematic detail is better

# DA-07-02 key activities

2006

2007

2008

2009

2010

Global level

Strategies (IGOS): Integrated Global  
Observations for land (IGOL)

Integration of IGOL into GEO

Standards: LCCS land cover classifiers and validation procedures  
Harmonization: "best" available map

New global products: GLOBCOVER (link to regional level)

Continuity of observations:

Mid-decadal global Landsat survey (MDGLS)      Global Land Survey 2010

Specifications for fine-scale global land cover  
change dataset (incl. validation framework)

Technical guidance for UNFCCC/REDD (GOFC-GOLD sourcebook)

Capacity building and support of global assessments:

GLCN + GOFC-GOLD networks / FAO-FRA global remote sensing survey

National level

# Supporting Developments

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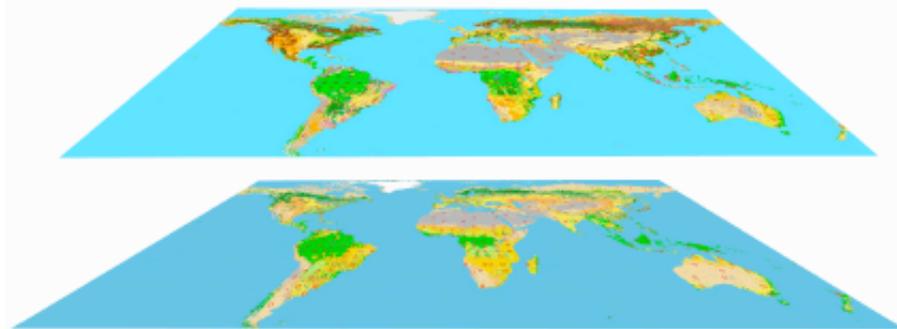
1. Prior experiences with global land cover validation
2. Emergence of LCCS - and its value in promoting consistency in land cover descriptors used in the development of legends for land cover datasets
3. Development of community consensus on “best practices for global land cover accuracy assessment (CEOS WGC report)

# International consensus on technical issues

**“Best Practices  
Document”**

**Strahler et al., 2006**

**GLOBAL LAND COVER VALIDATION:  
RECOMMENDATIONS FOR EVALUATION AND  
ACCURACY ASSESSMENT OF  
GLOBAL LAND COVER MAPS**



**GOFC-GOLD** GLOBAL OBSERVATION OF FOREST  
AND LAND COVER DYNAMICS



**EUROPEAN COMMISSION**  
DIRECTORATE-GENERAL  
**Joint Research Centre**

2006

EUR. 22156 EN



# Best Practices Document

## Joint CEOS / GOFC-GOLD Initiative

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- Community Consensus
  - Two workshops (JRC, Ispra and Boston University)
- Methods
  - Sample Design
  - Response Design
  - Analysis Design
- Guidance for baseline of accuracy assessment procedures
- Flexibility beyond baseline requirements
- Provides cover or credibility to efforts
  - “We followed community consensus “best practices”



# What's Missing?

- Thorough treatment of area estimation
  - Critical for estimating uncertainty in estimates of carbon emissions
- Land Cover Change
  - Issues of estimating the area of small classes with low standard errors
- In Progress - new working group
  - Builds off last effort - many issues the same (sample design, etc)
  - Focus on response design as reference data for historical time periods frequently unavailable
- Anticipate a similar “best practices” document on Area Estimation and Accuracy Assessment of Land Cover Change
  - First meeting of working group last October in Jena



# A "Living Reference Dataset"

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A set of validation sites distributed around the globe

Based on high resolution (a few meters) imagery interpreted by regional experts (the regional networks)

Checked annually for land cover change, and updated periodically

Limited set of land cover classifiers

life form - (trees, shrubs, herbaceous)

cover

leaf type

leaf phenology

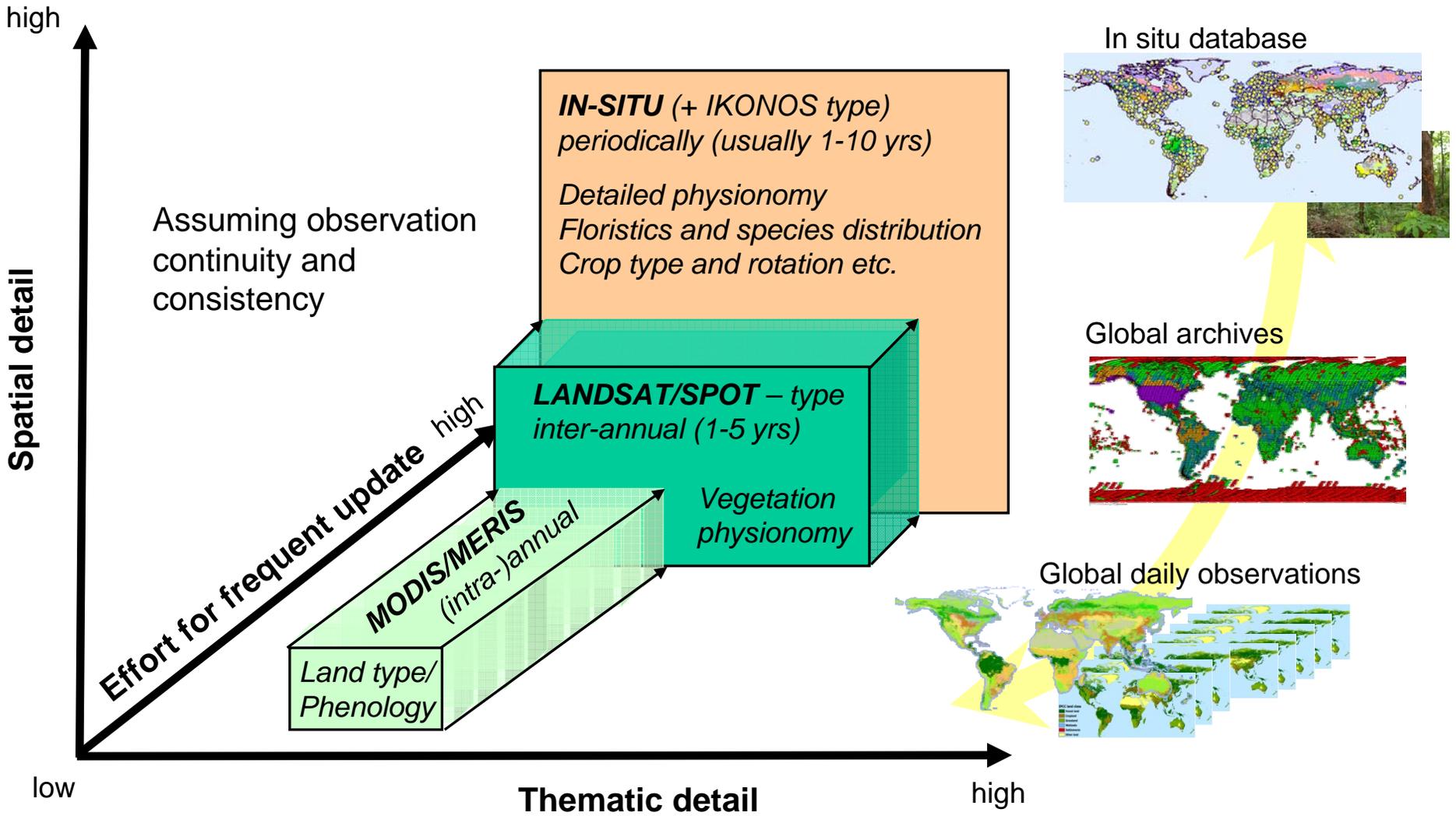
# Land Cover validation framework

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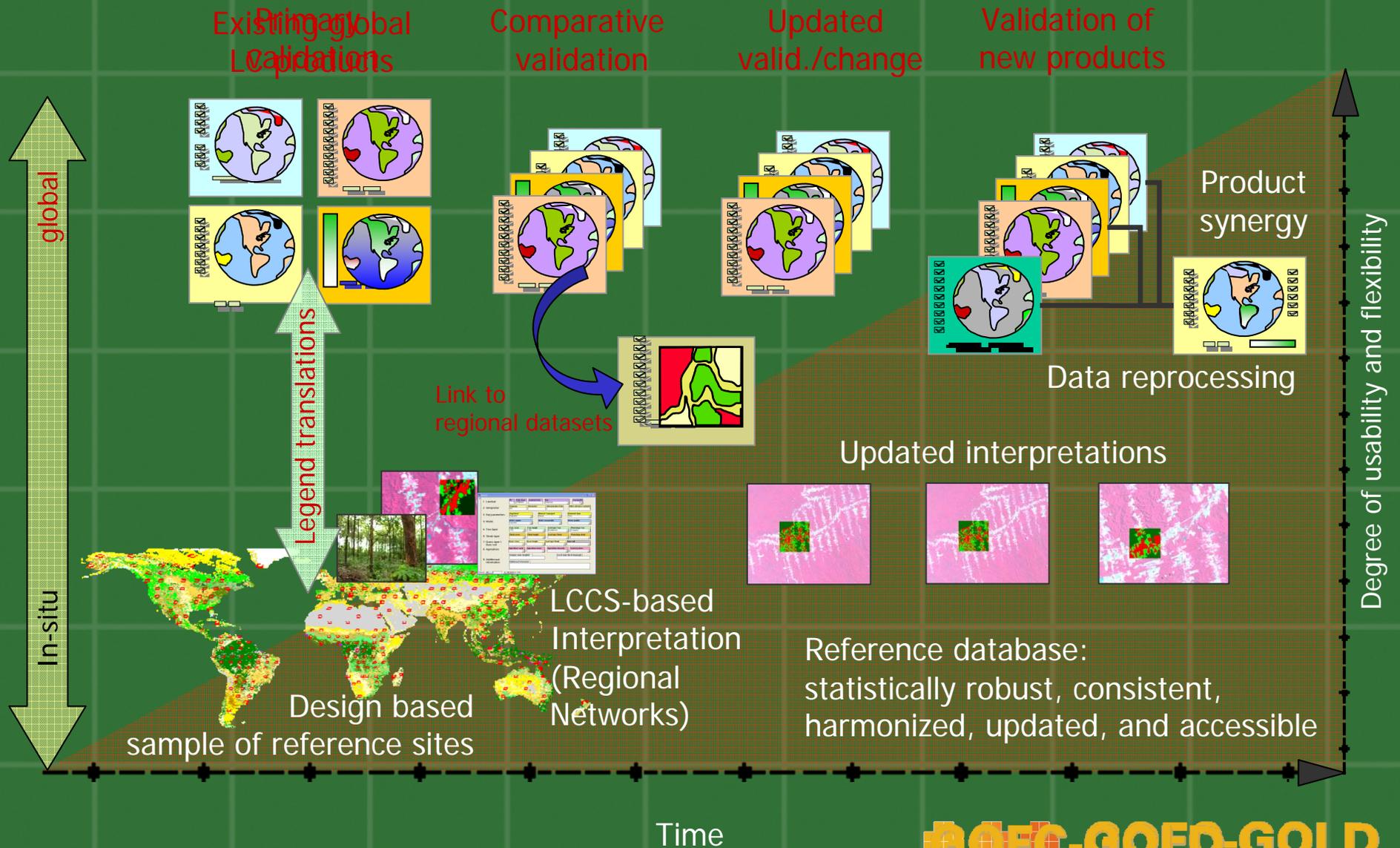
- Effort serves purpose for estimating:
  - Individual map accuracy / best available map
  - Area of land-cover classes
- Sampling design:
  - 10 km by 10 km block (Landsat – MODIS)
  - Flexible to increase sample size to provide precise country or region specific estimates
  - Stratification by geographic reporting regions, areas where maps differ, important rare land-cover classes
- Response design:
  - Reference data (high resolution) interpreted by regional experts (i.e. GOFC-GOLD networks) using LCCS classifiers
- Analysis design:
  - Error matrix for each map and region
  - Estimates of class area
  - Supplementary accuracy information on land-cover composition and landscape pattern

# Integrated land cover observations

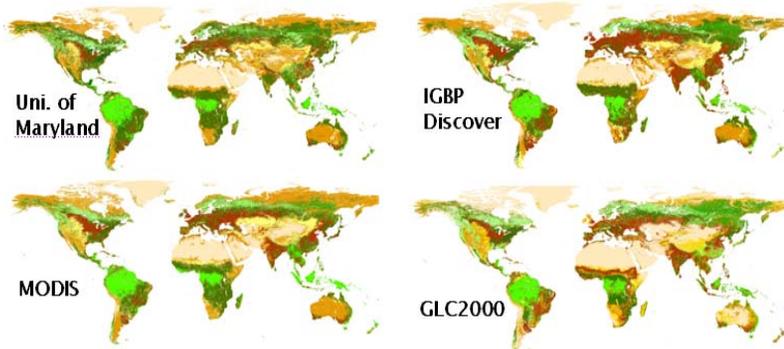
Completed and endorsed by IGOS partnership and GEO in 2007



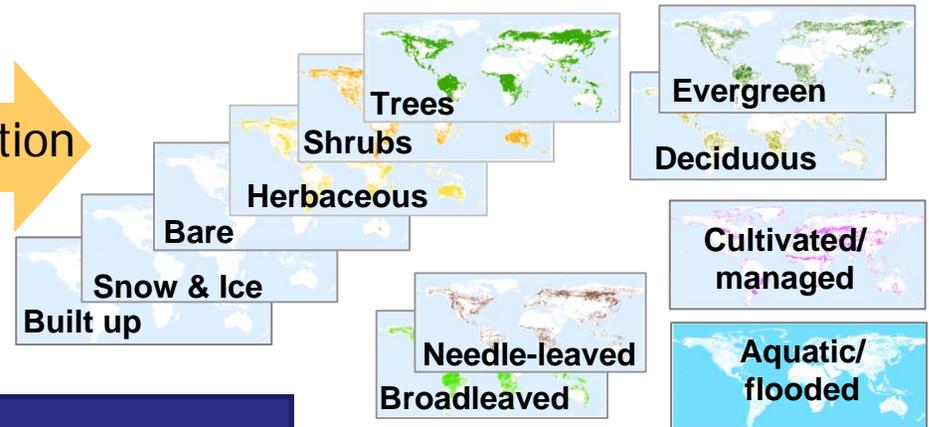
# Operational Ic validation framework



## Categories in existing global datasets



## Terminology: land cover classifiers (LCCS)



### Common classifiers (Terminology standard)

- Classifiers commonly used to characterize land cover worldwide
- i.e. life form & surface type, leaf type & phenology, terrestrial/aquatic

### Generic classes (Thematic standard)

- Basic set of standardized classes based on combination of common classifiers and independent of any cartographic standard
- i.e. broadleaved evergreen trees, herbaceous crops, built up area

### Mapping Categories (Cartographic standard)

- Application of cartographic generalization (MMU) to generic classes
- Definition of mixed categories or using density thresholds
- i.e. Closed to open (>15%) broadleaved evergreen forest (> 5m)

# Thematic standards

## Common classifiers (Terminology standard)

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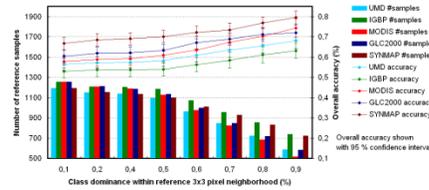
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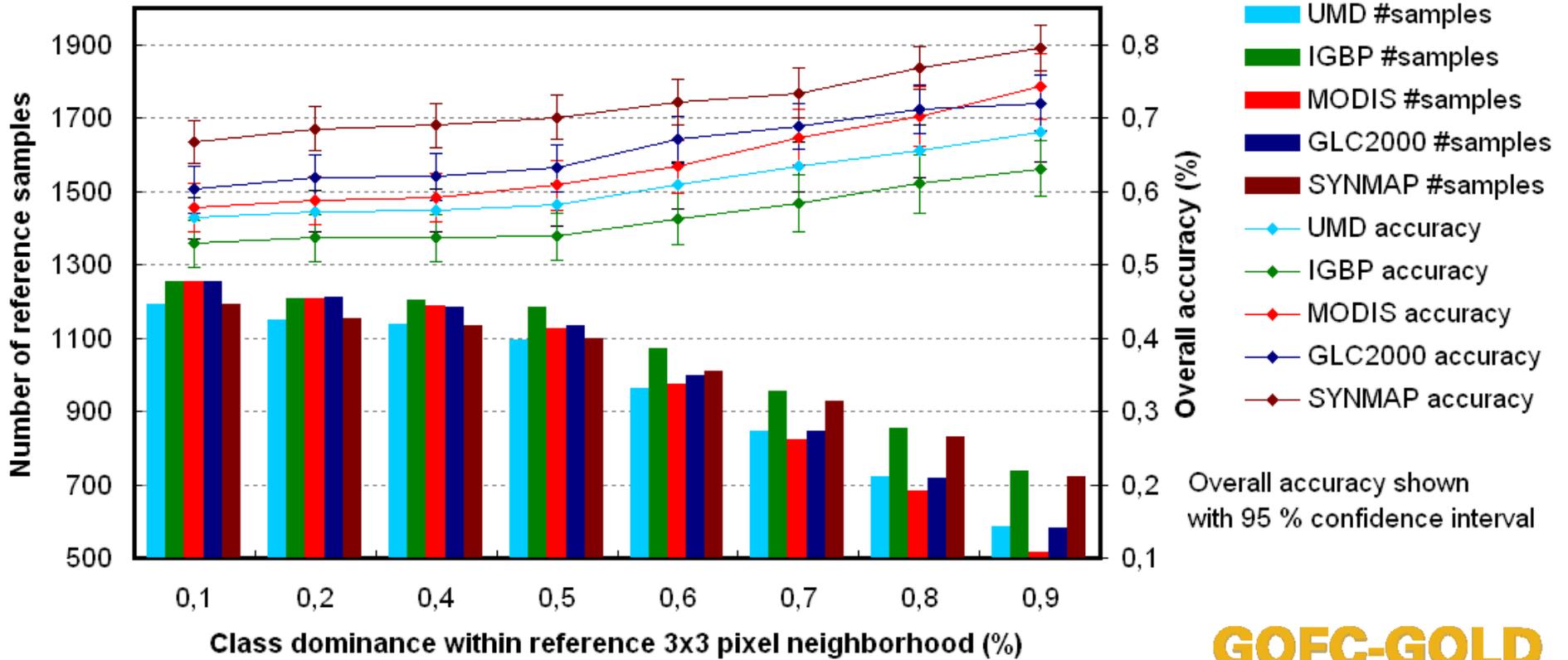
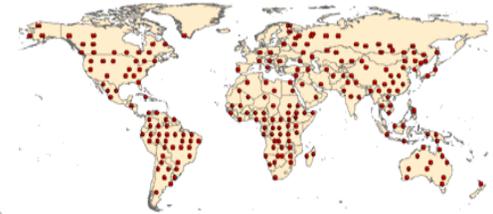
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- Application of cartographic generalization (MMU) to generic classes
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# Comparative validation & assessment



# Reference database (GLC2000)



# Thematic standards

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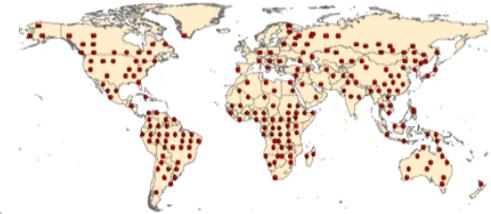
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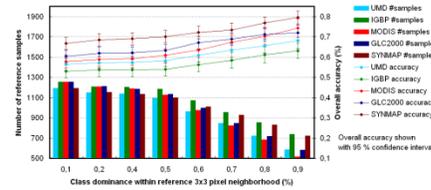
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# Reference database (GLC2000)



# Comparative validation & assessment



## Trees (>15%)

## shrubland

## grassland

## agricultural cropland

## Non vegetated land

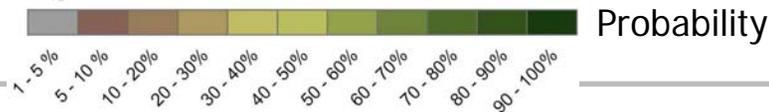
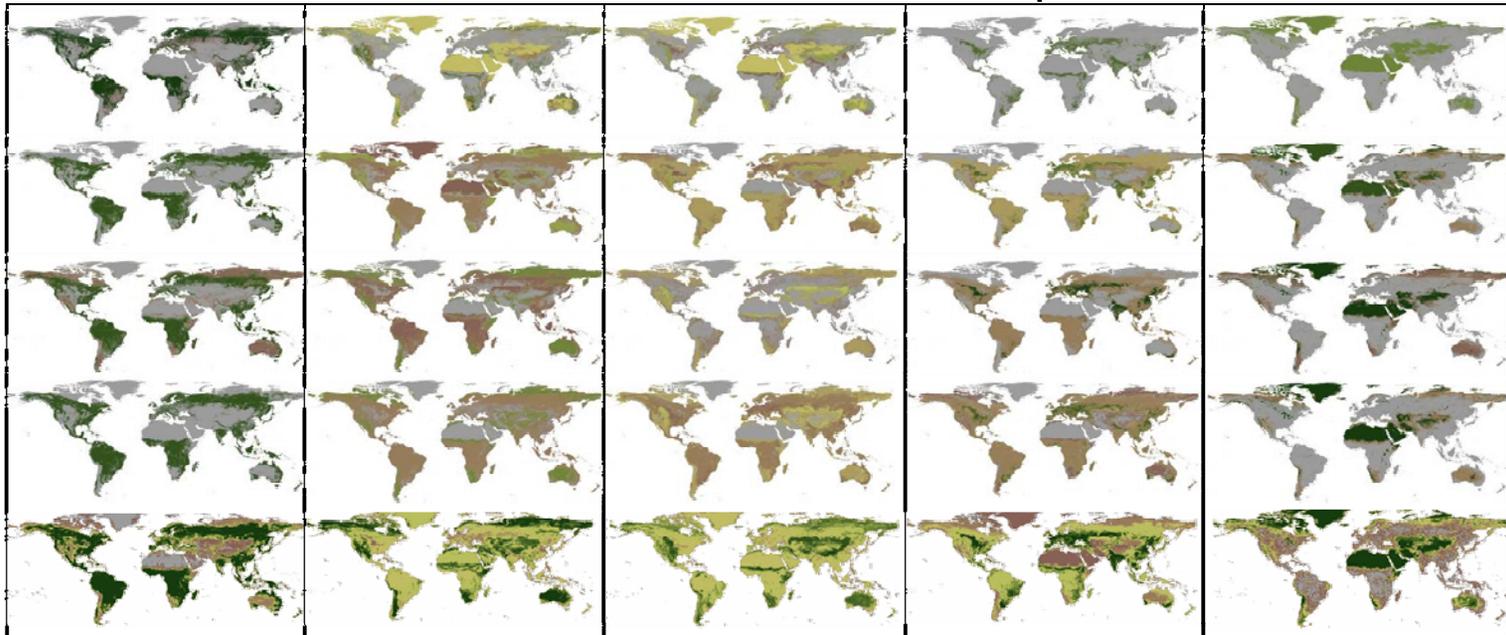
GLC2000

IGBP

MODIS

UMD

Combined Classes



# Thematic standards

## Common classifiers (Terminology standard)

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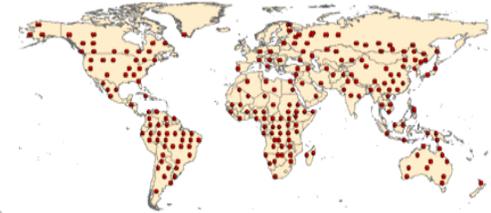
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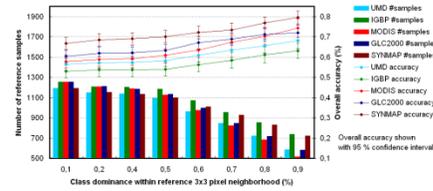
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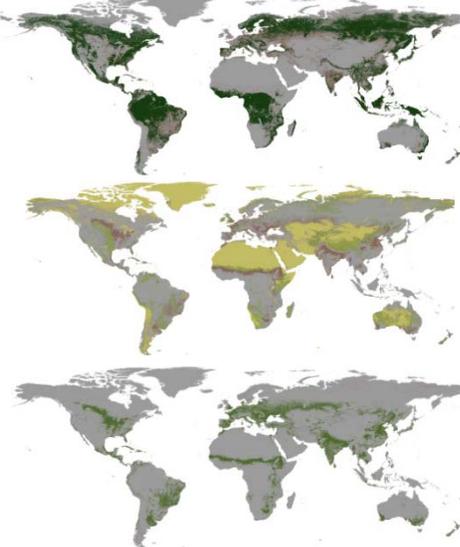
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# Comparative validation & assessment

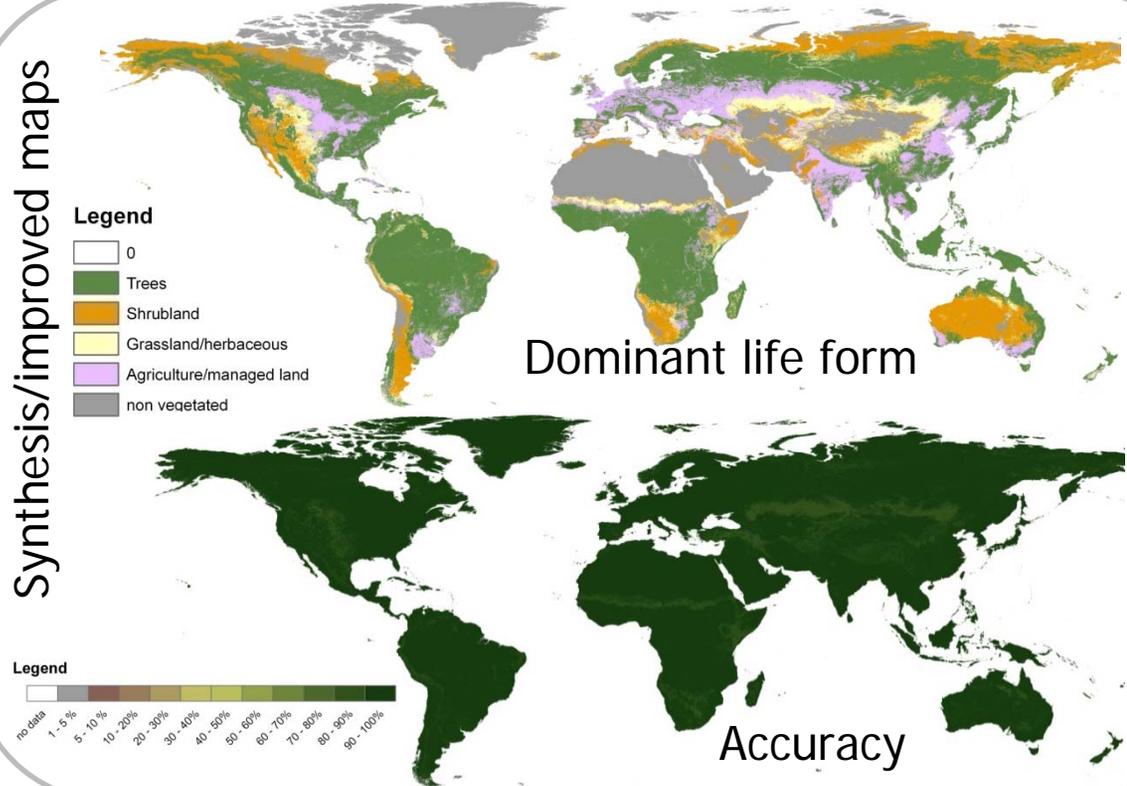


# Probability maps



For different datasets, classifiers and landscape heterogeneities

# Synthesis/improved maps



# Next Steps

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1. Sample Site Selection
2. Find a source for the imagery (several meters)
3. Get the imagery collected and processed
4. Prototype effort
5. Identify regional experts for interpretation
6. Find support for the interpretation by the regional experts
  - training workshops
  - capacity building
  - support for the interpreters
7. Begin validation analysis (working with the land cover data providers)

# Landsat Science Team: Issues and Priorities

- Curtis Woodcock (Boston University)
- Tom Loveland (USGS EDC)



EDC Jan 08

# Data Access: All Landsat Data in the US Archive is Available for **free!!!**

- Data Policy
  - new agreement signed in Jan 08 by both NASA and USGS
- Web-Enabled Access
  - System had to be simplified
    - <http://glovis.usgs.gov>
    - <http://earthexplorer.gov>
- Number of scenes delivered has gone up by a factor of about **50!**
- Downloadable vs orderable
  - A limited number of scenes can be kept online (downloadable)
  - Reprocessing is inevitable and will be done “on demand”
  - New mantras “*when in doubt download it*” - meaning that newer is always going to be better “*No reason to hoard data*”

# U.S. Landsat Archive Overview

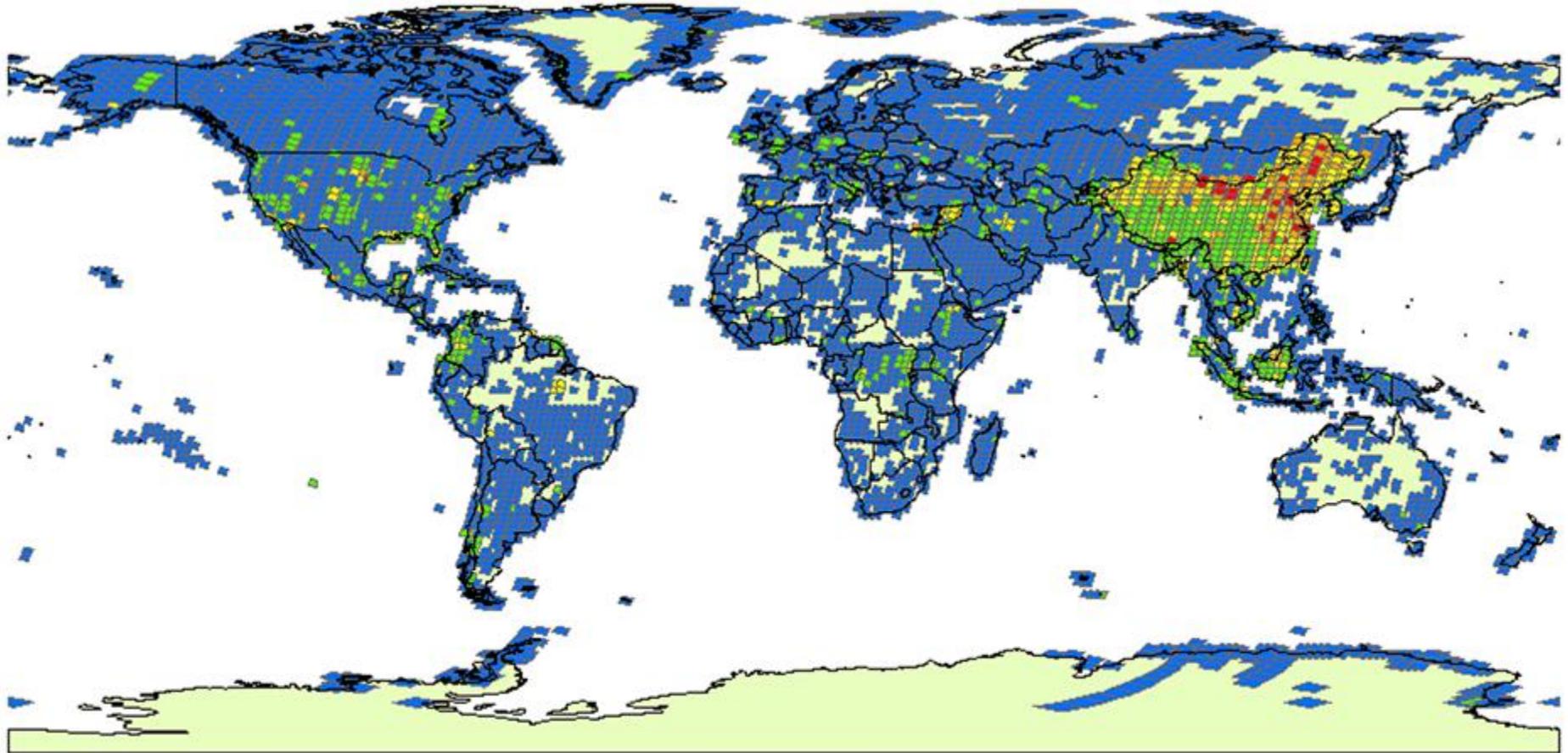
(Marketable Scenes through December 31, 2008)

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- **ETM+: Landsat 7**
  - ◆ 892,051 scenes
  - ◆ 828 TB RCC and L0Ra Data
  - ◆ Archive grows by 260 GB Daily
- **TM: Landsat 4 & Landsat 5**
  - ◆ 780,191 scenes
  - ◆ 391 TB of RCC and L0Ra Data
  - ◆ Archive Grows by 40 GB Daily
- **MSS: Landsat 1 through 5**
  - ◆ 652,173 scenes
  - ◆ 20 TB of Data



# Downloads through EE/Glovis (ETM+)



Slide from "free data lady" (Kristi Kline)

Landsat Project Status- Landsat Science Team  
January 2009

# Standard Level-1T Products

Consistency with heritage Landsat products

- Pixel size: 15m/30m
- Media type: FTP
- Product type: Level-1T (precision, terrain correction)
- Output format: GeoTIFF
- Map projection: UTM (Polar Stereographic for Antarctica)
- Datum: WGS84
- Orientation: North up
- Resampling: Cubic convolution
- Accuracy: 12m circular error, 90% confidence



Slide from John Dwyer

# Current Working Groups (issues)

- Future Missions
  - Recommendations for future missions - standards- requirements
  - What constitutes “operational”?
  - Long Term Goals and Purpose of Landsat Missions (Climate emphasis - land cover ECV)
- Data Gap Working Group
  - Recommendations for an operational plan for the USGS to acquire moderate resolution data during a data gap
- Global Consolidated Landsat Archive
  - More images outside the US Archive than within
  - Considerable overlap, but difficult to resolve
  - Provide guidance on priorities

# Current Working Groups (issues)

- Cloud and Shadow Masking
  - Pursue methods for improved capabilities
  - Spatial, Temporal, Geographic Context
- Surface Reflectance and Temperature
  - Recommendations for standard products
- Carbon Mapping and Monitoring
  - White paper on state of the art

# Future Issues (my take)

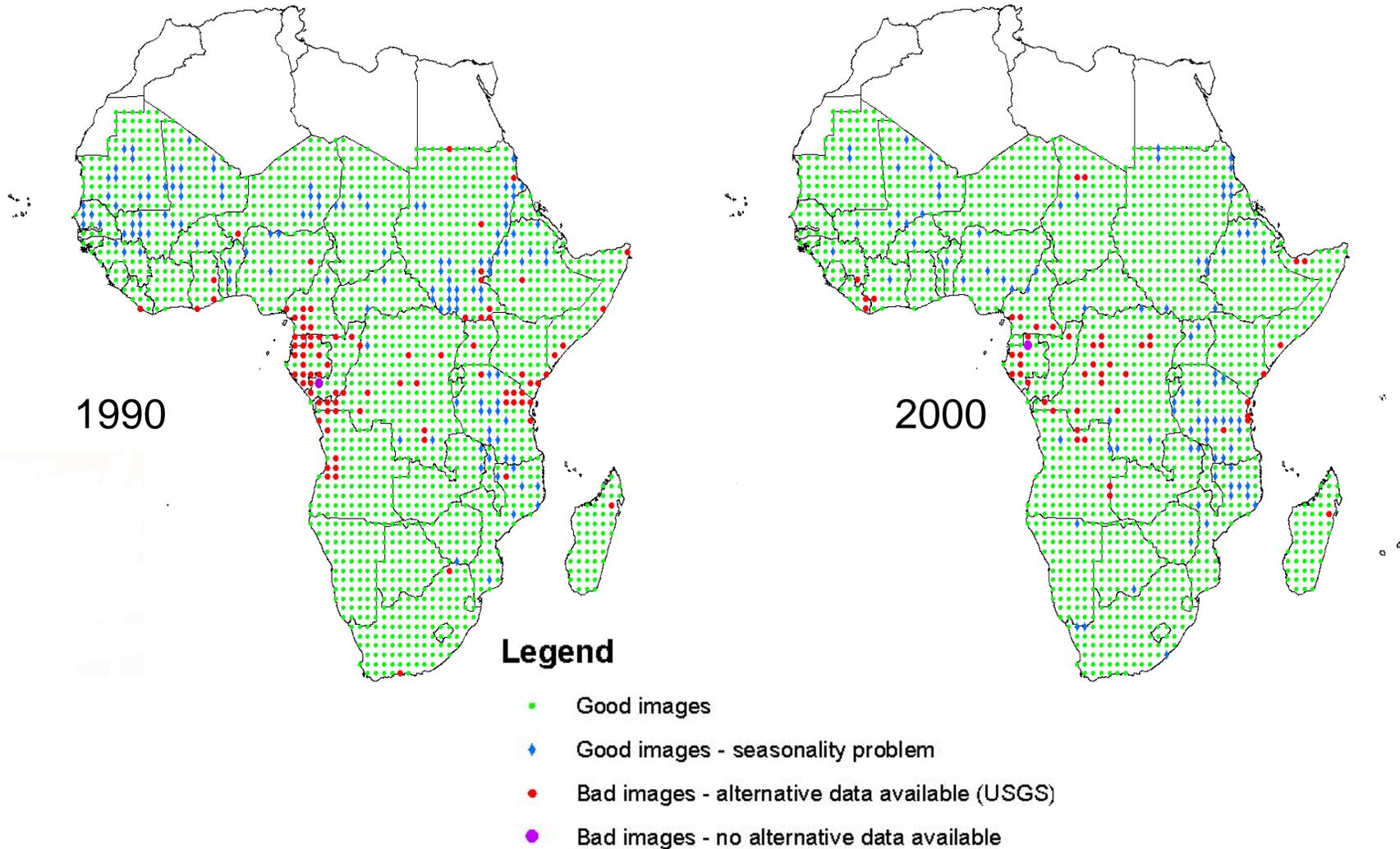
- Operational global land cover change monitoring
  - Definition and implementation of a standard product
- Cloud screening the archive
  - Routinely cited as the primary impediment to more automated use of Landsat imagery over large areas/multiple time periods
- Reconstructing the history of the surface of Earth in the satellite era
  - A community agenda
- Definition of longer term sensing scenarios
  - What should happen after L9?

# Landsat and Clouds

- The issue of availability of cloud-free imagery is partially a function of access to the archive!
- Next slides from Alan Belward of JRC and their TREES project
- Bottom line: The ability to replace images from the GLS datasets with others from the archive dramatically reduces cloud problems
- More advanced techniques like compositing will improve the situation even more (more from Mike Wulder)

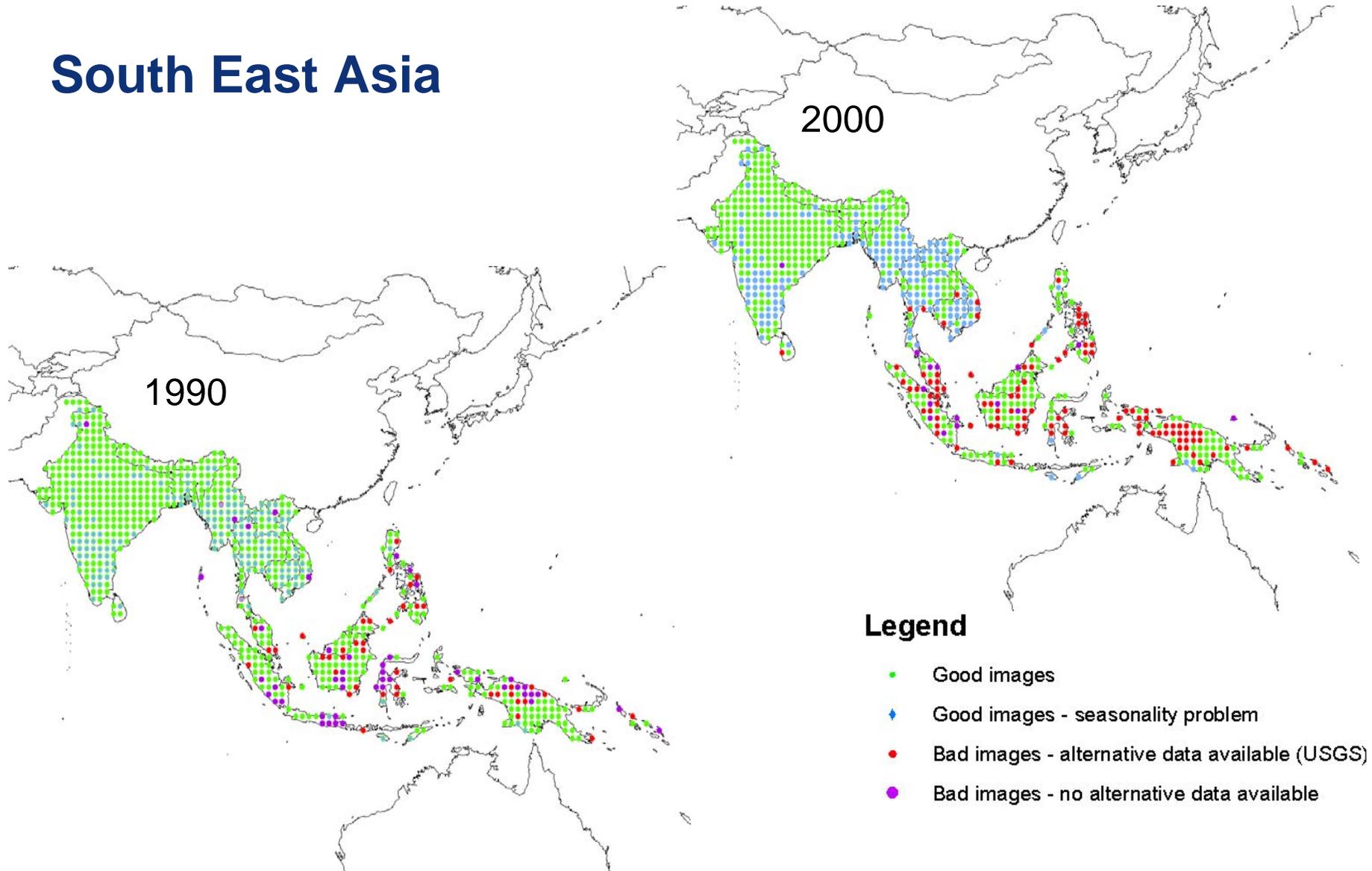
2047 sample points; 90% good, 141 replacement scenes identified  
139 of these are held by USGS

# Africa



741 sample points; 80 % good, 224 replacement scenes identified  
162 of these held by USGS

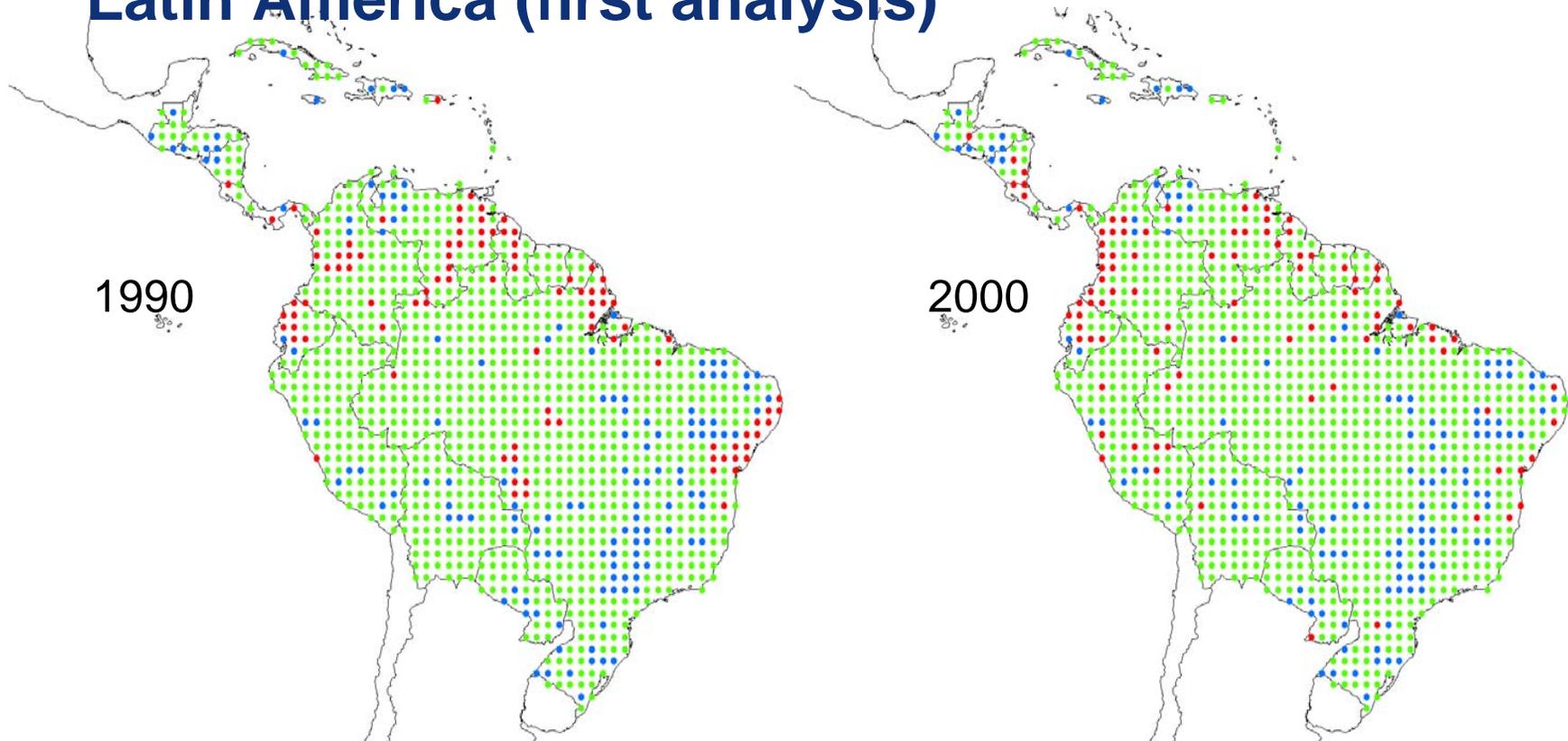
## South East Asia



1230 sample points; 80% good, 187 replacement scenes identified

...

## Latin America (first analysis)

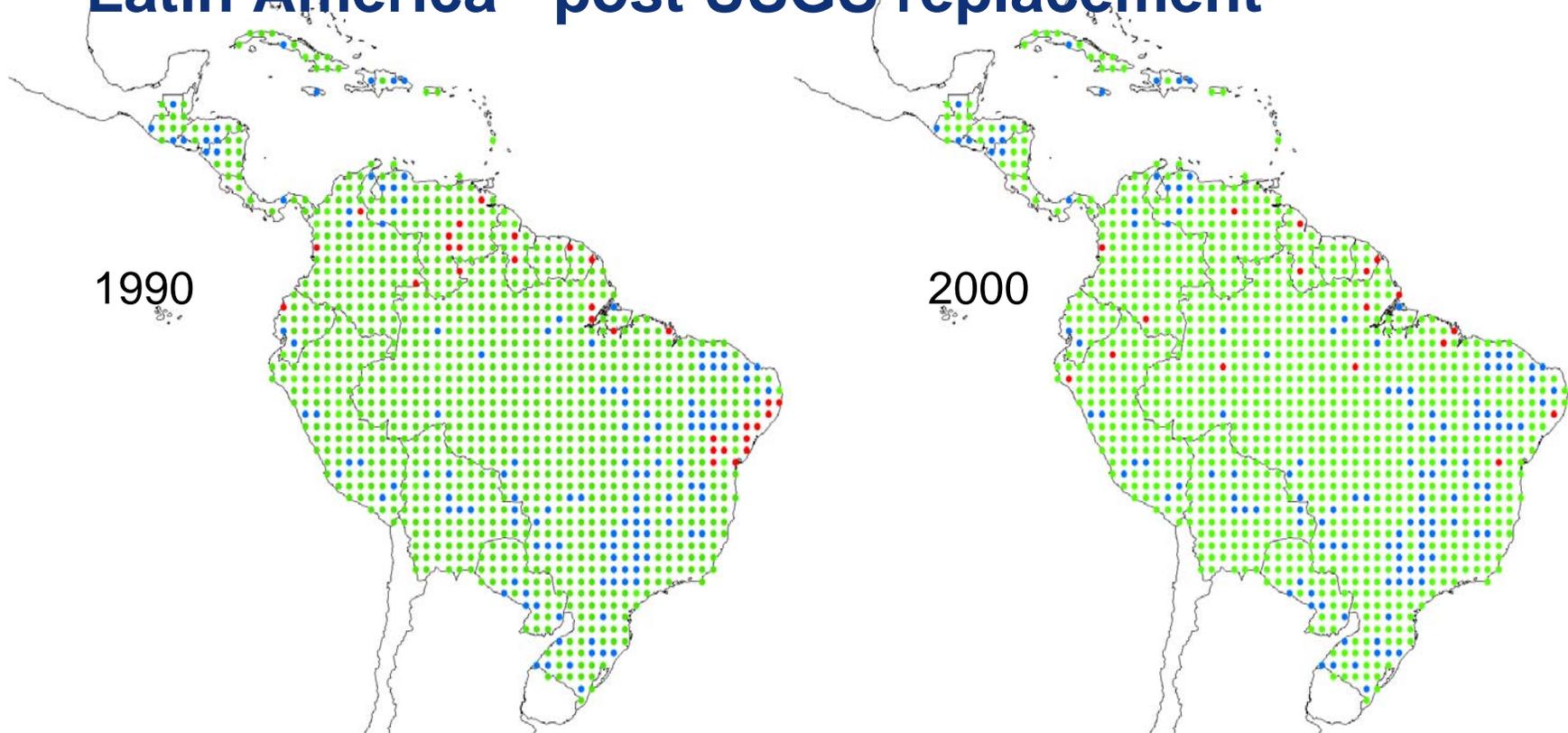


### Legend

- Good images
- Good images - seasonality problem
- Bad images

1230 sample points; 80% good, 187 replacement scenes identified  
...146 of these delivered by USGS

## Latin America - post USGS replacement



### Legend

- Good images
- ◆ Good images - seasonality problem
- Bad images



## The CSIRO Canopy Lidar Initiative, its ECHIDNA® and an EVI

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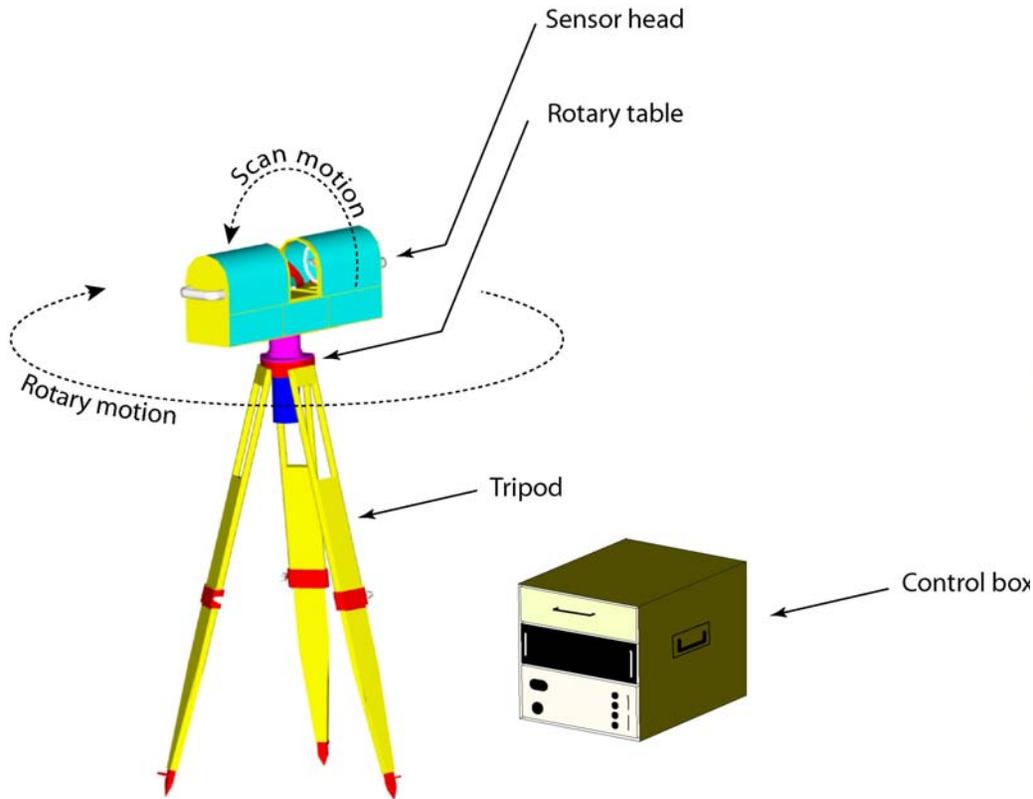
Presented at the IWMMM-4 Meeting in Sydney, Australia, March 20-24 2006

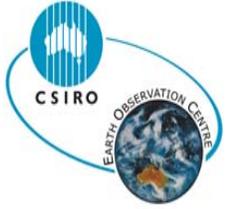


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# Ground Based Lidar (ECHIDNA®)





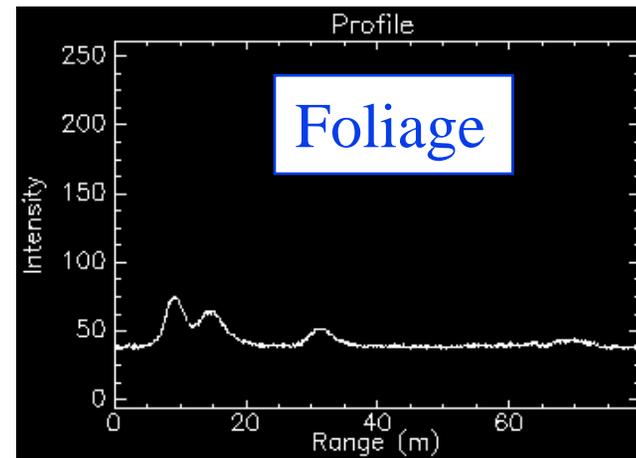
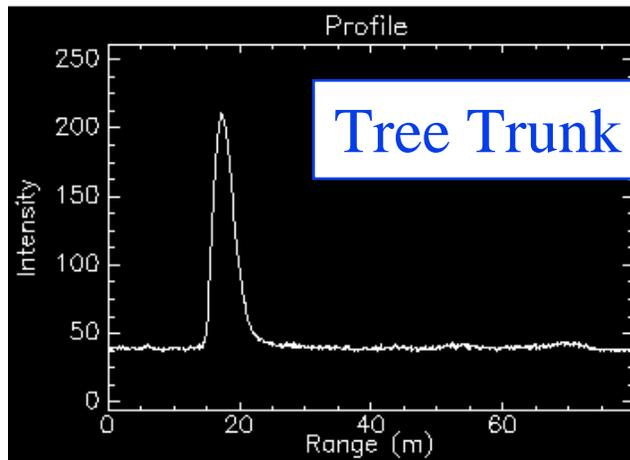
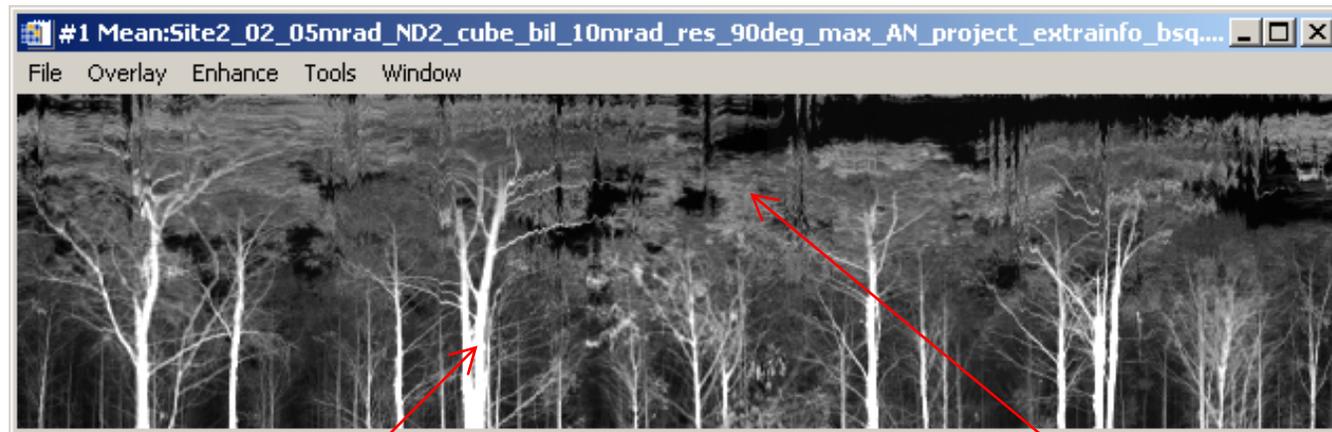
# EVI (The ECHIDNA<sup>®</sup> Validation Instrument)



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# Hard & Soft Returns in EVI Data



- Show the EVI movie!

# General Comments (from yesterday's discussions)

- Credibility of arguments for being ready for operational monitoring of forest change are undermined by the focus on SAR
  - That said, the potential for monitoring forest change illustrated yesterday with PALSAR is the most impressive I've seen to date!
  - To argue it is ready for operational efforts is premature
- LIDAR is critical to future measurement of forest biomass
- Don't forget areas outside the tropics
- I'm skeptical of data access problems being solved
  - Difference between agreeing to provide the observations being collected and agreeing to collect the observations required