Looking back Looking forward

John Townshend,

Chengquan Huang, Jeffrey Masek, Matthew Hansen, Samuel Goward, Compton Tucker, Saurabh Channan, Greg Ederer, Min Feng, Feng Gao, DoHyung Kim, Raghuram Narasimhan, Peter Potapov, Joseph Sexton, Alex Shatalin, Danxia Song, Kuan Song, Xiaopeng Song, Bin Tan, Eric Vermote, Robert Wolfe, Guangxiao Zhang

AVHRR 1km Land Cover Project

- Initiated in the late 90s to generate multiple 1km products (Land cover, fire, NPP).
- Highest resolution data set then was AVHRR-GAC – nominally 8km.
- Creation of a 1km AVHRR data set was a major challenge
- Deciding how to generate a consistent global data set was highly contentious.

Participants IGBP LCWG University of Maryland, Dec 1991

- Joseph Cihlar (Canada Center for Remote Sensing, Ottawa)
- Christopher Justice (University of Maryland and NASA's Goddard Space Flight Center)
- Gilbert Saint (Laboratoire d'Etudes et de Recheches en Teledetection Spatiale, Toulouse)
- John Townshend (University of Maryland, College Park) (Chair)
- Compton J. Tucker (NASA's Goddard Space Flight Center, Greenbelt, MD, USA)
- Olivier Arino (European Space Agency, Frascati, Italy)
- Jeff Eidenshink (EROS Data Center, Sioux Falls, South Dakota, USA)
- Kevin Gallo (National Ocanic and Atmospheric Administration, USA)
- Brent Holben (NASA's Goddard Space Flight Center, Greenbelt, MD, USA)
- Yorum Kaufman (NASA's Goddard Space Flight Center, Greenbelt, MD, USA)
- Pam Kennedy (Joint Research Center, Ispra, Italy)
- Martha Maiden (NASA HQ, Washington D.C. USA)
- Phil Teillet (Canada Center for Remote Sensing, Ottawa)
- Eric Vermote (University of Maryland and NASA's Goddard Space Flight Center)
- Murray Wilson (CSIRO, Australia)
- Dr Xu Jianmin (Chinese Meteorological Agency, Beijing, China)

Acquiring global 1 km data

- Priorities for acquiring 1 km LAC AVHRR data

1. National emergencies.
2. Situations where human life is in immediate danger.
3. U.S. strategic requirements (e.g., U.S. Department of Defence).
4. Commercial requirements and U.S. non-strategic requirements.
5. Scientific investigations and studies.
6. Other miscellaneous activities.

- Managed to get priorities changed.
- But also heavy reliance on ground receiving stations (HRPT data).
- Great variety in formats – major practical problems of deriving 12 X 30 day composites for the year

AVHRR Pre-processing

The recommended AVHRR data preprocessing sequence was originally scheduled as follows:

(*a*) Modelling the satellite orbit.
(*b*) Location of ground control.
(*c*) Establish transformation to map projection.
(*d*) Radiometric calibration.
(*e*) Atmospheric correction.
(*f*) Computation of NDVI and geophysical parameters.
(*g*) Geometric correction and resampling.
(*h*) Compositing.
(*i*) Generation of output products.

Radiometric and atmospheric correction

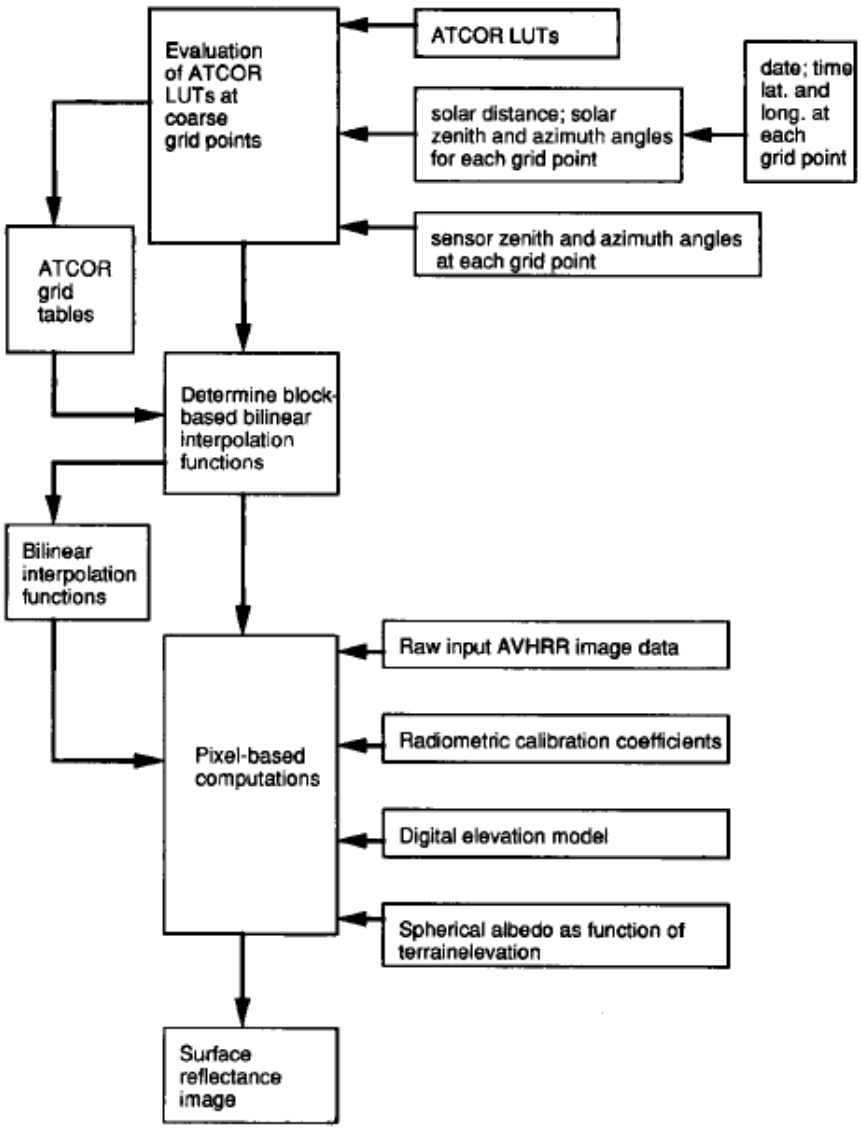


Figure 5. Proposed data flows for AVHRR radiometric and atmospheric correction (Cihlar and Teillet 1992).

Having defined the data set, what did we see as the likely problems in 1990?

- Better atmospheric correction (water vapor and aerosols).
- Better cloud screening
- Resampling methods needed to be investigated
- Different compositing methods (not just max NDVI)
- BRDF
- Alternative spectral indices
- Processing sequence
- Archiving and distribution
- High volumes of data set *("tens of gigabytes of on-line storage and several hundred megabytes of CPU")*

So why did we cooperate internationally and did it work?

- The problem was too big for any one group.
  - **Needed a comprehensive scientific justification.**
  - Lack of knowledge of pre-processing of AVHRR data.
  - **Needed international acquisition**
  - Processing in fact was performed almost entirely at EDC.
  - **Land cover classification based on internationally agreed legend through IGBP Working Group.**
  - Implementation was primarily bilateral effort between EDC and JRC.
  - **Validation performed subsequently under leadership of Jack Estes (largely US funding) bringing in experts to EDC from across the world.**
  - *Archiving and distribution was seen as a big international deal but was not – EDC did the work.*
- Overall a great success but group consensus effort led to us being overly cautious
  - the Lowest Common Denominator problem (Martha Maiden)

Are there lessons for the future for global Landsat analyses?

- Global Landsat wall-to-wall land cover
  - *Measures* Global Deforestation (UMD)
  - Sloan Global Forest Project
  - Global Land Cover Monitoring (China)
- Very large area Landsat analysis
  - JRC 10km sampling at 1 degree intersections
  - INPE Brazil
- Landsat - MODIS synergy
  - SDSU Roy for North America
  - SDSU Hansen for forest cover for the world

Challenges

- Data acquisition
- Atmospheric correction
- Terrain correction
- BRDF
- Industrial production for information extraction.
- Virtual constellation
- Computing power.

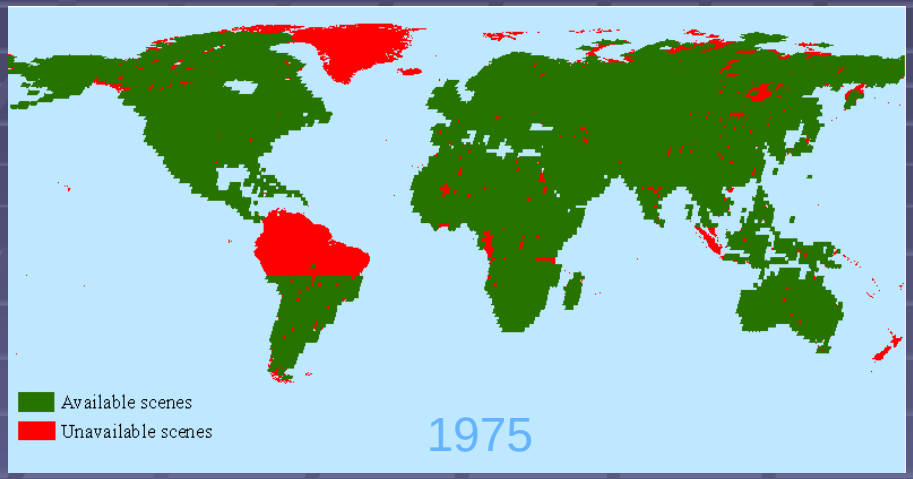
Processing and storage is not a real problem

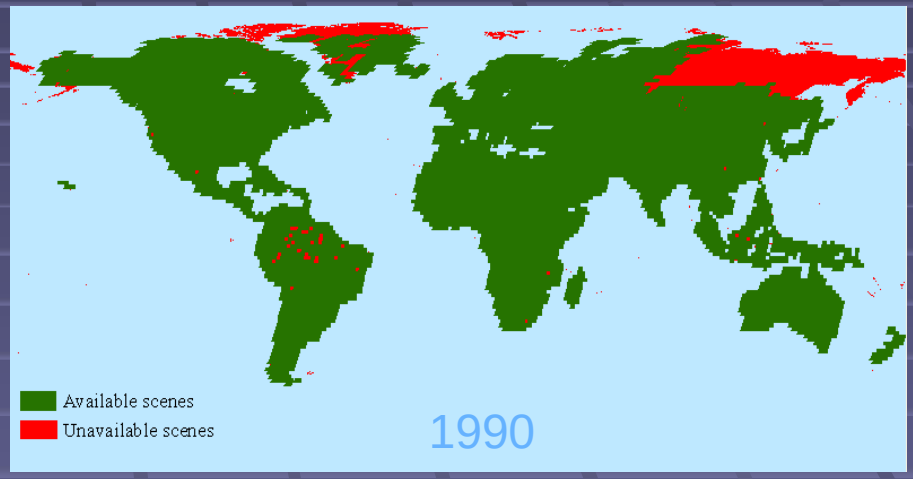
- UMD Measures Science Computing Facility
- Purchased 23 Oracle 4150 servers
  - 2 Quad Core processor per server
    - 184 processing cores in total
- Purchased Oracle StorageTek
  - Approximately 32 TB of disk space
- Total cost
  - $110K after 50% educational discount
- Both processors and storages scalable
- Global pre-processing of Landsat data and tree cover change in < 1 week.

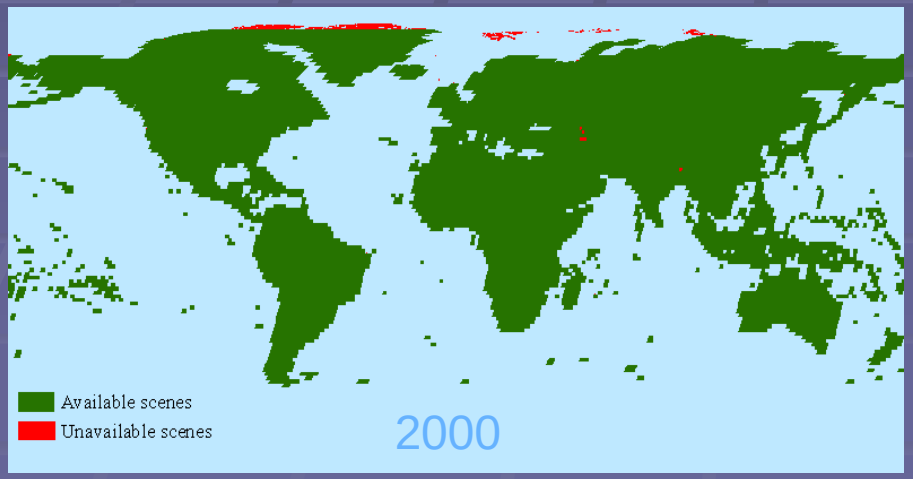
Challenges - 1

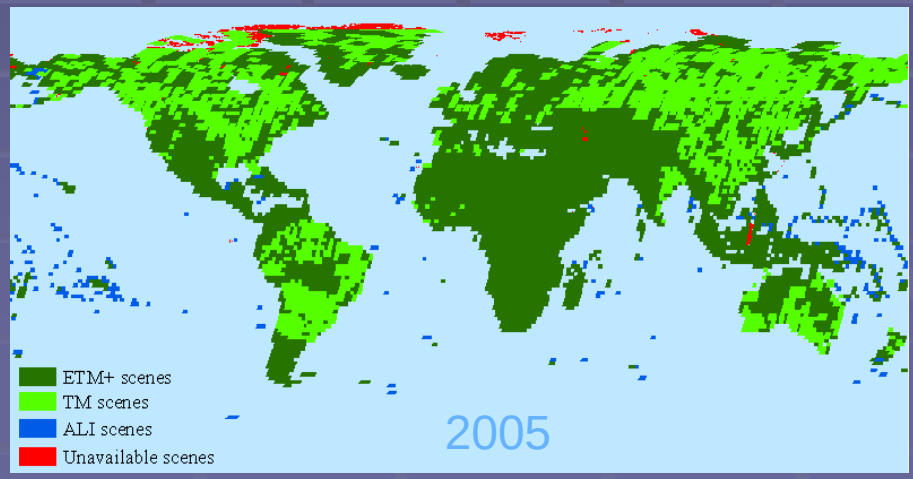
- Acquiring global data sets.
  - GLS is a wonderful start
  - But gaps in coverage
    - Importance of local ground receiving stations
  - Some scenes are very cloudy.
  - Some scenes have inappropriate phenology.
  - Calibration issues.
  - Inconsistencies in meta-data.
  - Perhaps we need multiple images per scene
    - Compositing
    - Cloudiness
    - To capture phenology
  - Need for annual or biannual imaging for areas of rapid LC changes.
- *GLS plus* needs defining ?

GLS Data Coverage

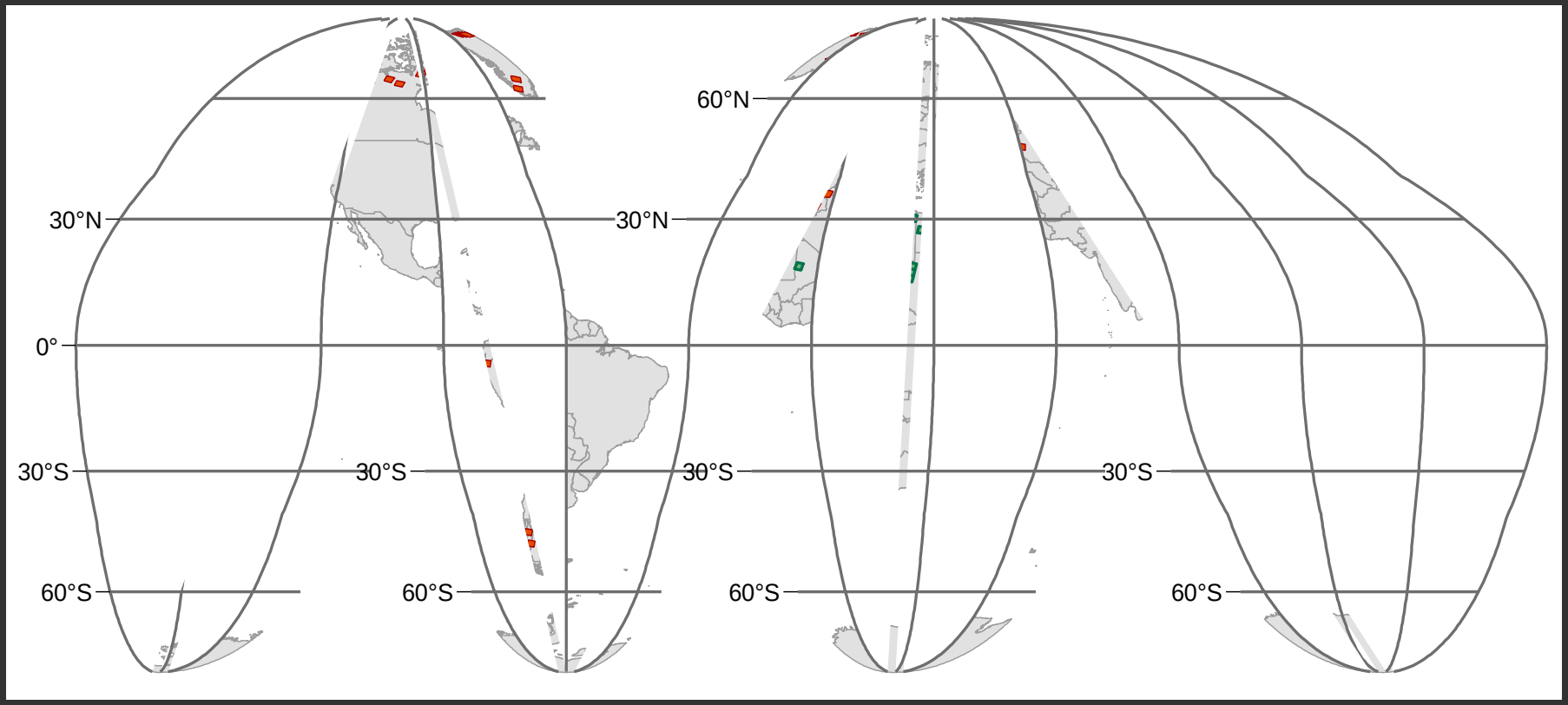






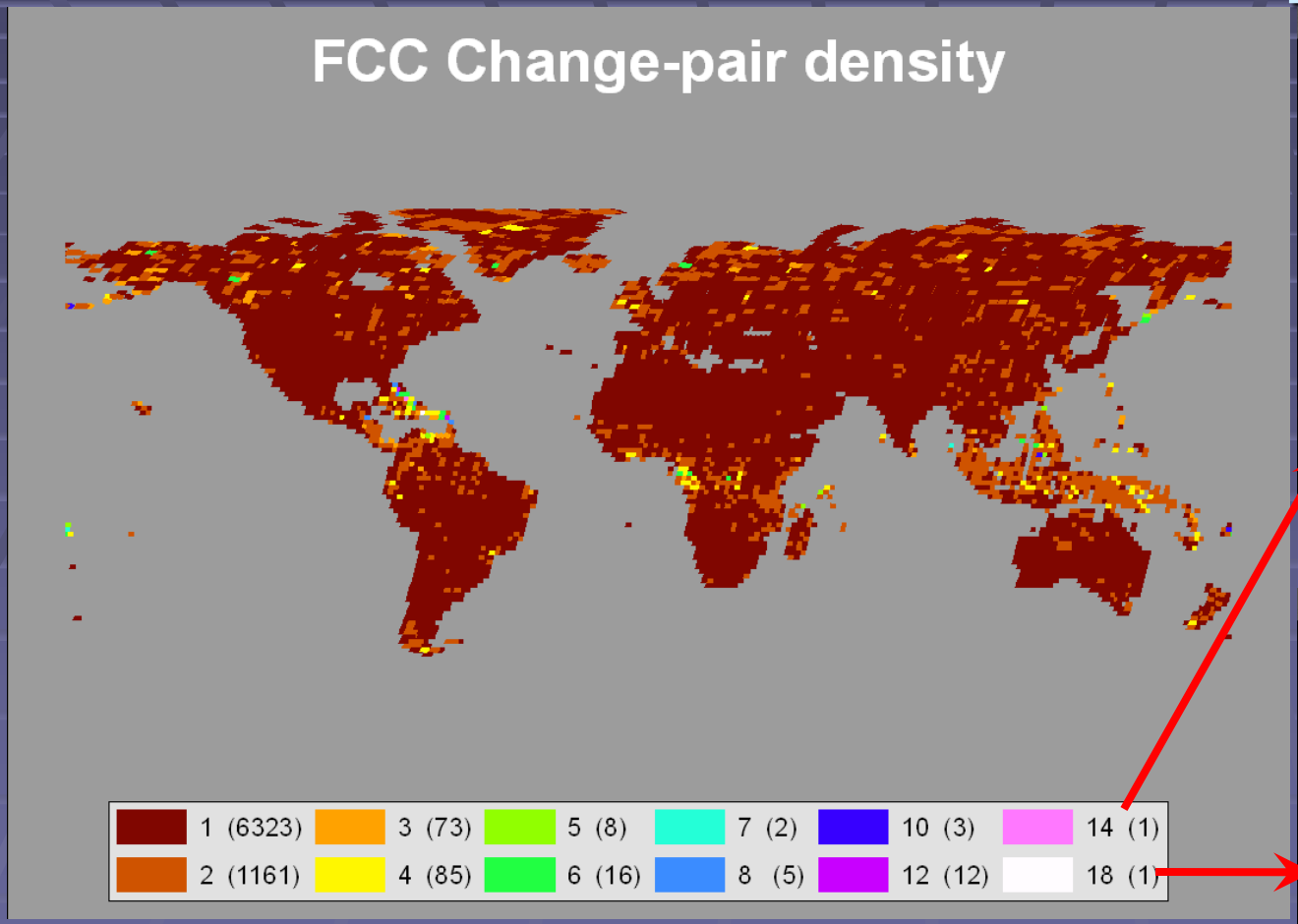


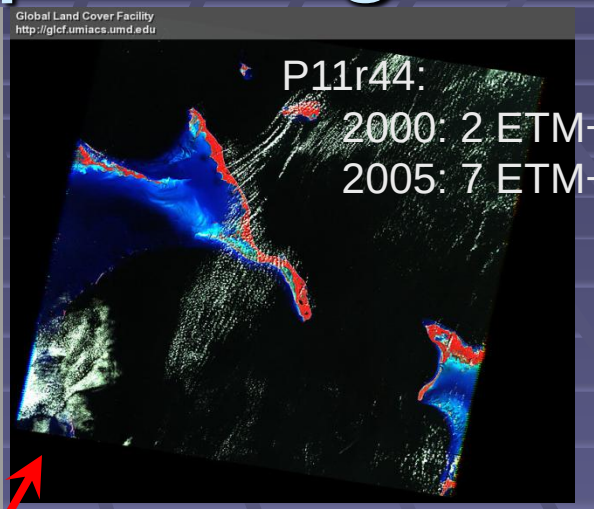
Problematic Scenes

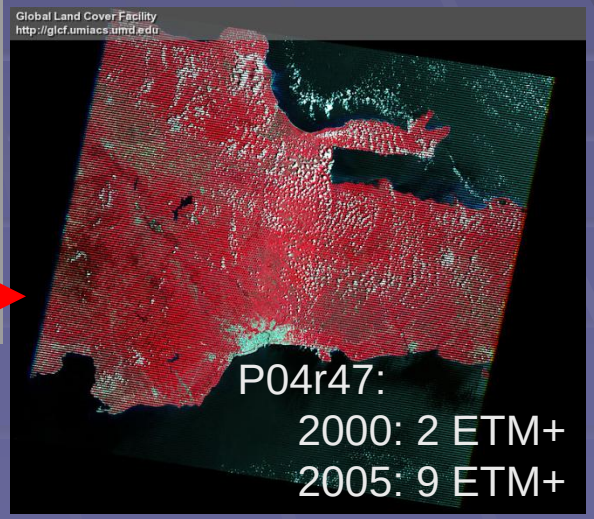


- GLS 2000 ETM+ scenes with gain-issue
- GLS 2005 ETM+ scenes with gain-issue
- GLS 2000 ETM+ scenes with erroneous values in its counterpart MODIS SR LWIR band

FCC: selection vs. compositing?



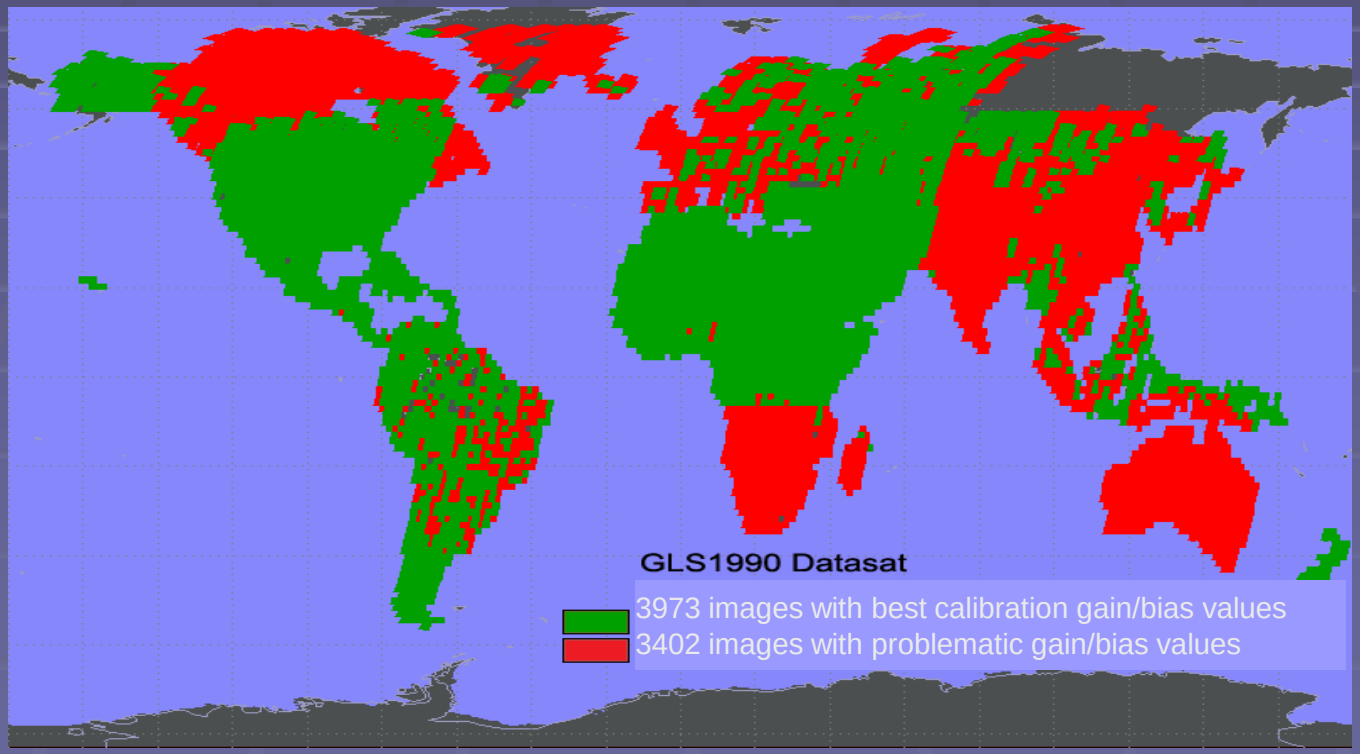




- Most scenes have a single or two change pairs,
- High change-pair density scenes are in cloudy/ snowy areas

GLS 1990 Data Set Reprocessed

- GLS 1990 calibration gain/bias inconsistent
  - L0 (~55% of total) already reprocessed by USGS
  - Actions for remainder to be detailed by Masek later

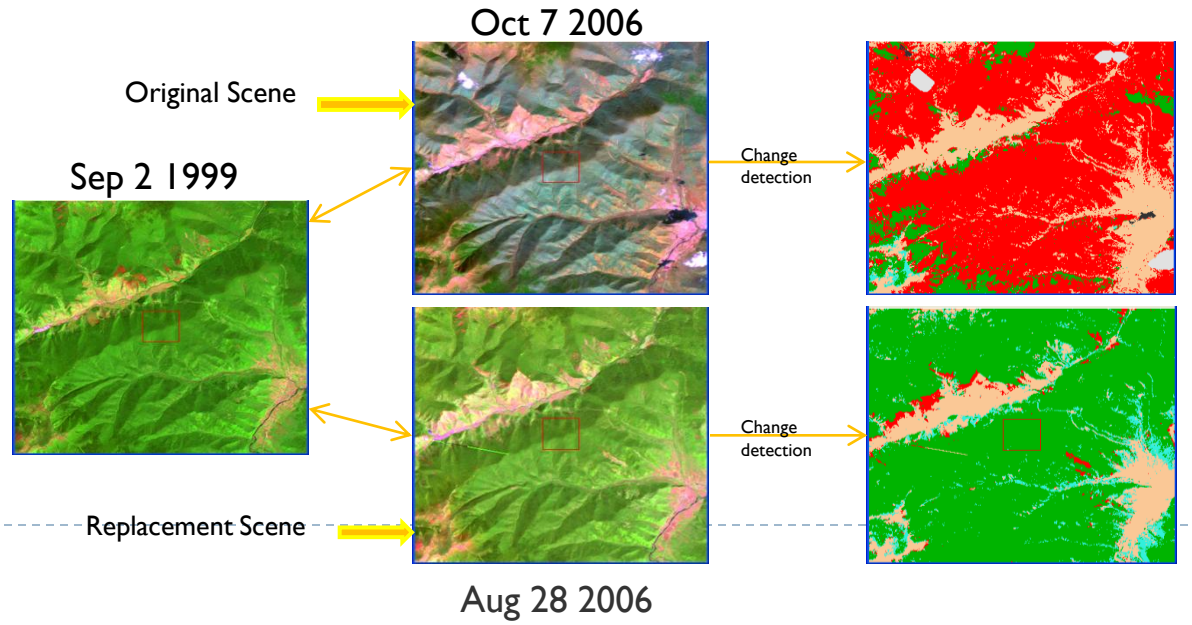


Effects of uncertainties from phenology on forest cover change detection? (Do-Hyung Kim)

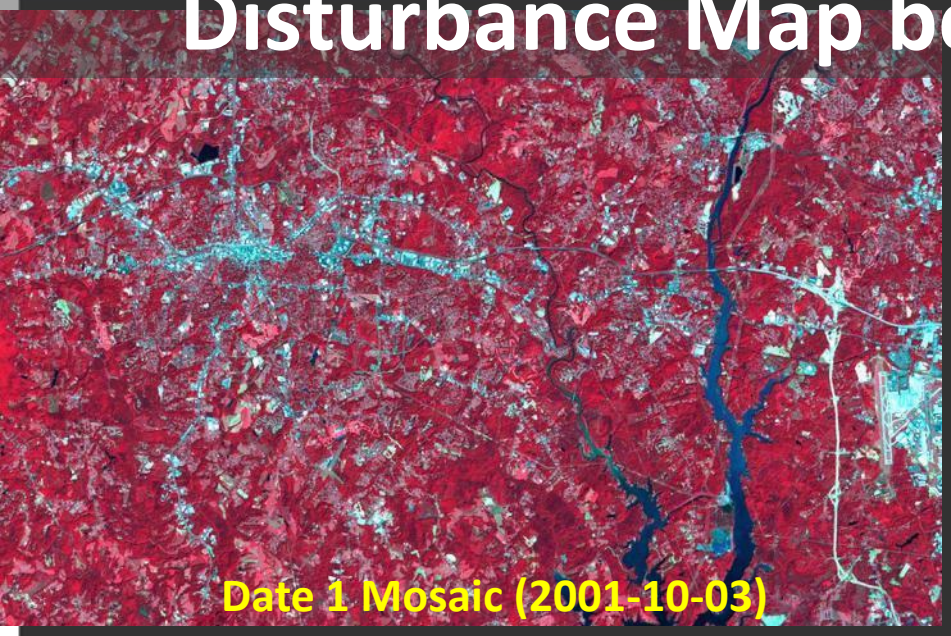
- Alternative scenes found for Korean area
  - Pilot study is done for Korean area
  - Using 70% of maximumNDVI threshold , phenologically unsuitable GLS scenes are detected and replacement L1T scenes are selected

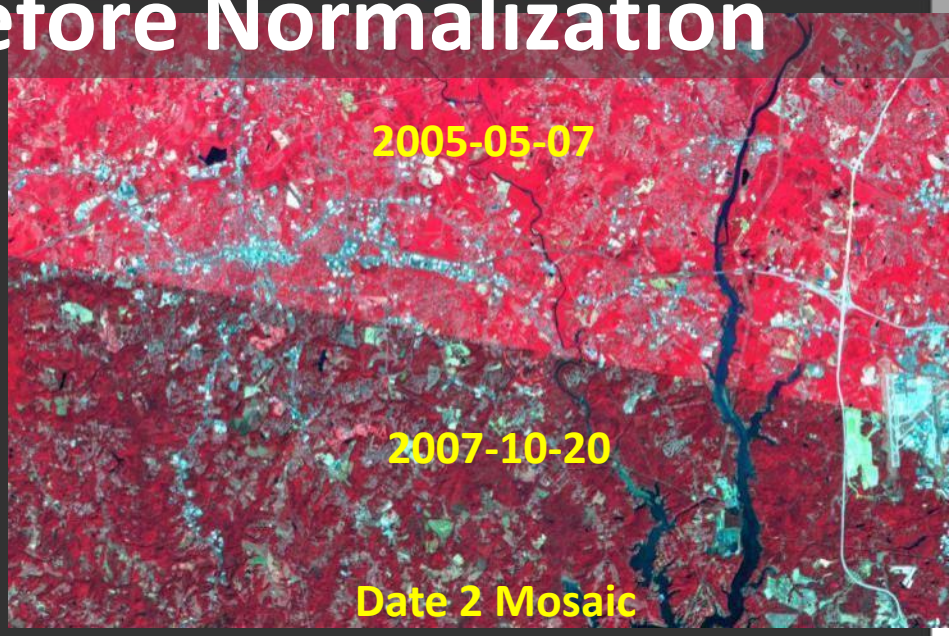
	Unsuitable image	Replacement image
GLS 2000	11 out of 23	9
GLS 2005	12 out of 23	11

- Change detection result comparison GLS vs. Replaced image



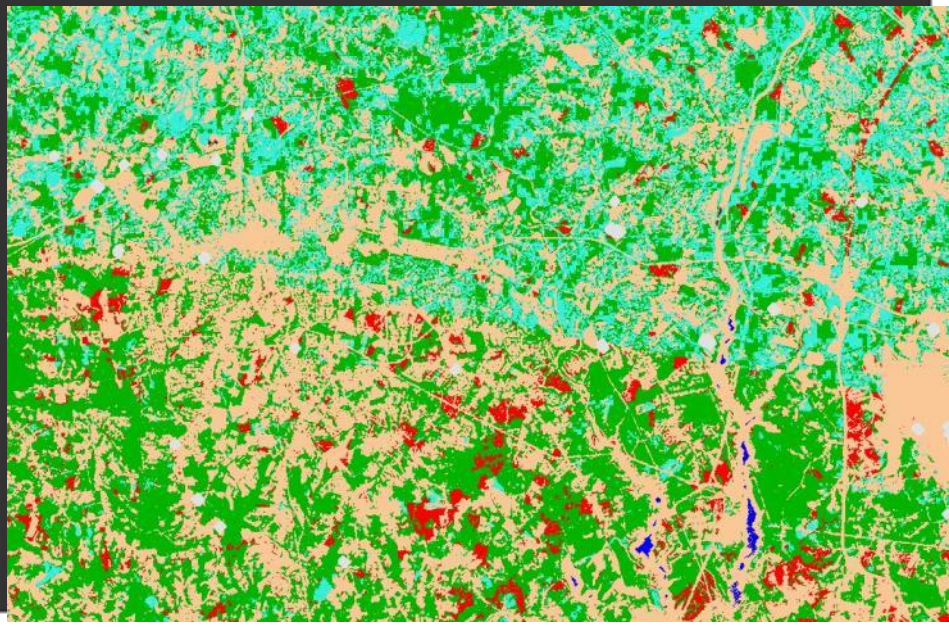
Disturbance Map before Normalization





GLS Landsat Scenes	Date1	Date2
P17r35 (NC)	2001-10-03	2005-05-07
p17r36	2001-10-03	2007-10-20

Red: forest->non-forest
Cyan: non-forest->forest
Yellow: non-forest
Green: forest



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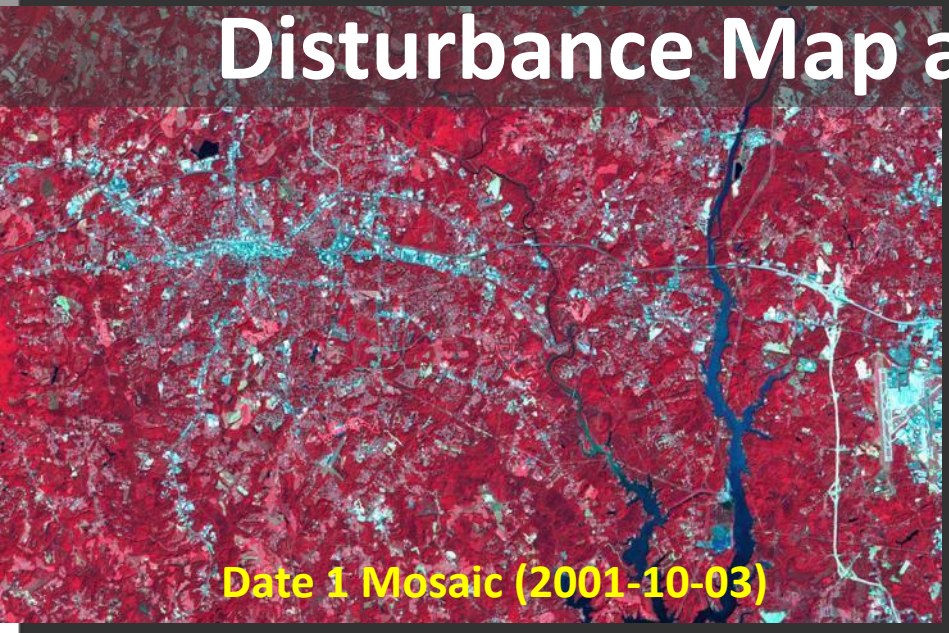

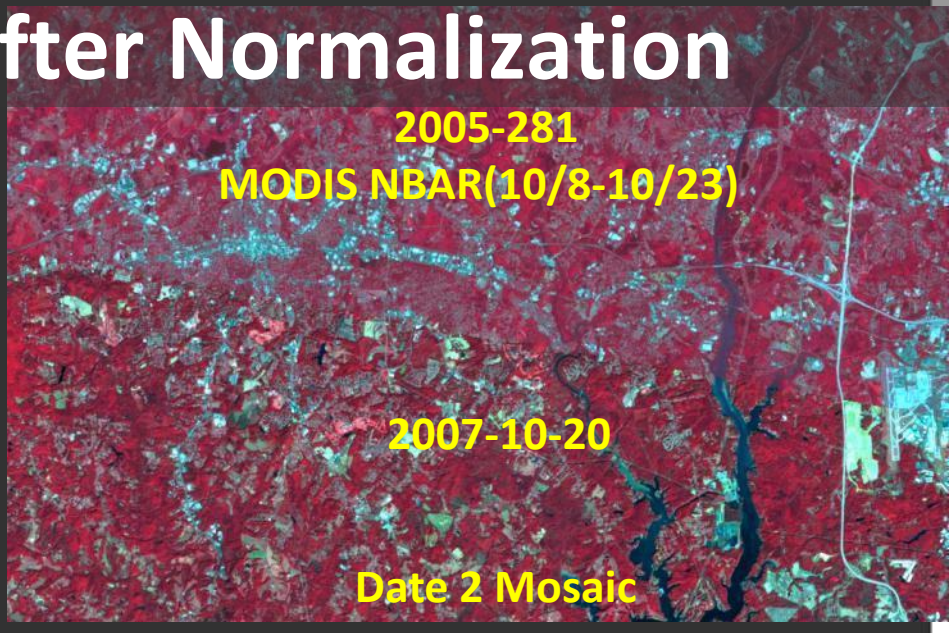

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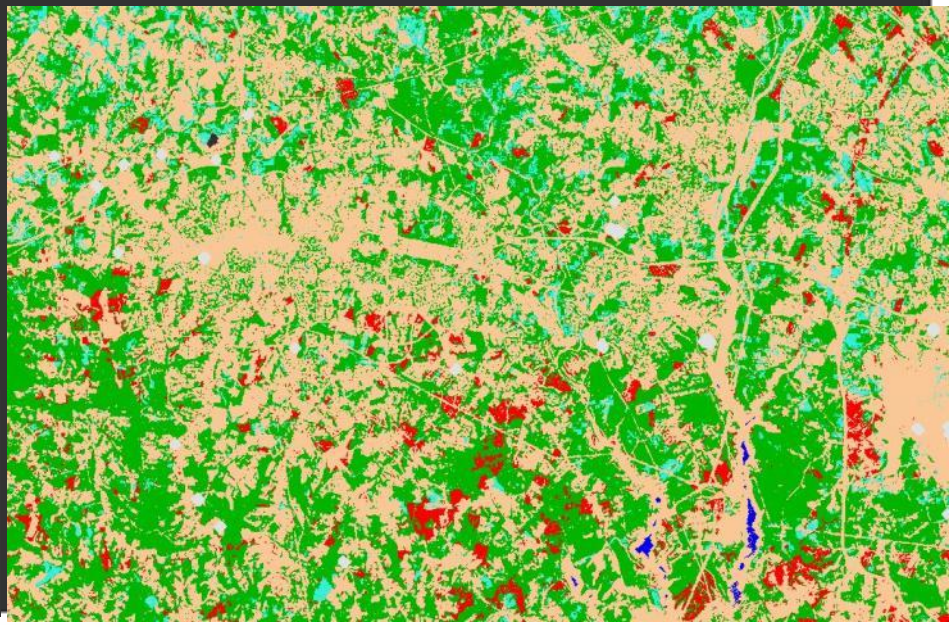
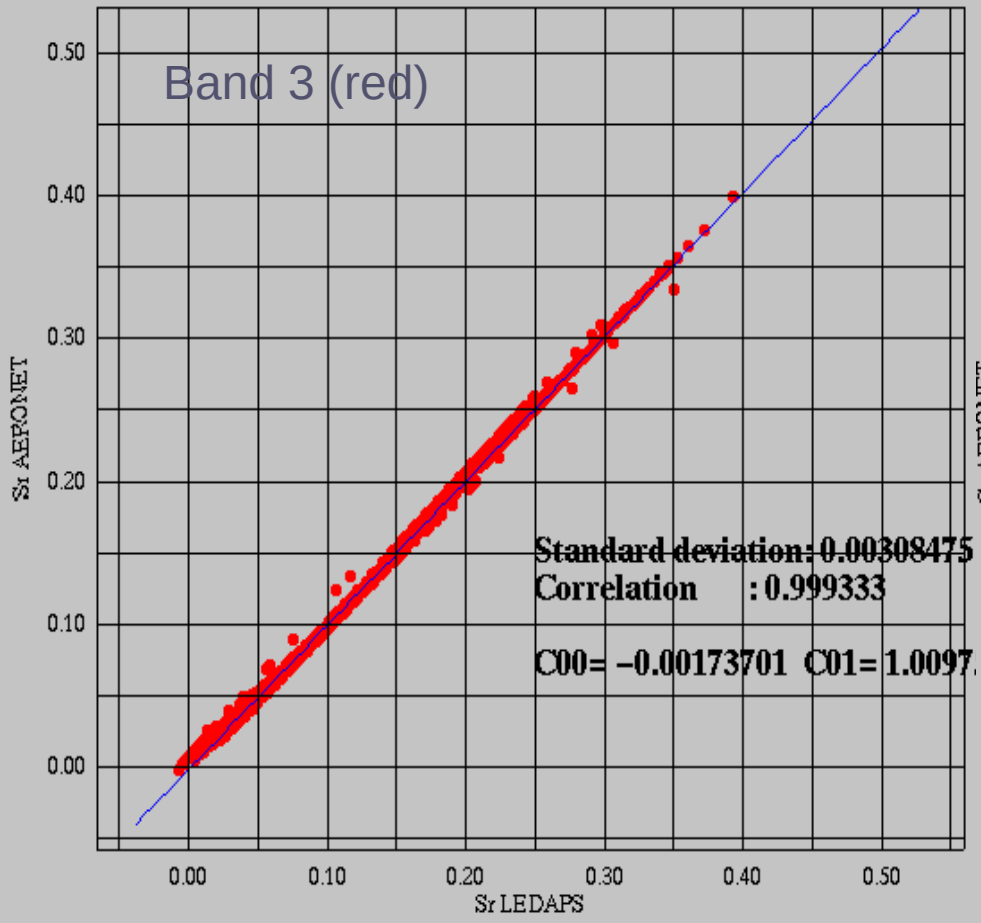
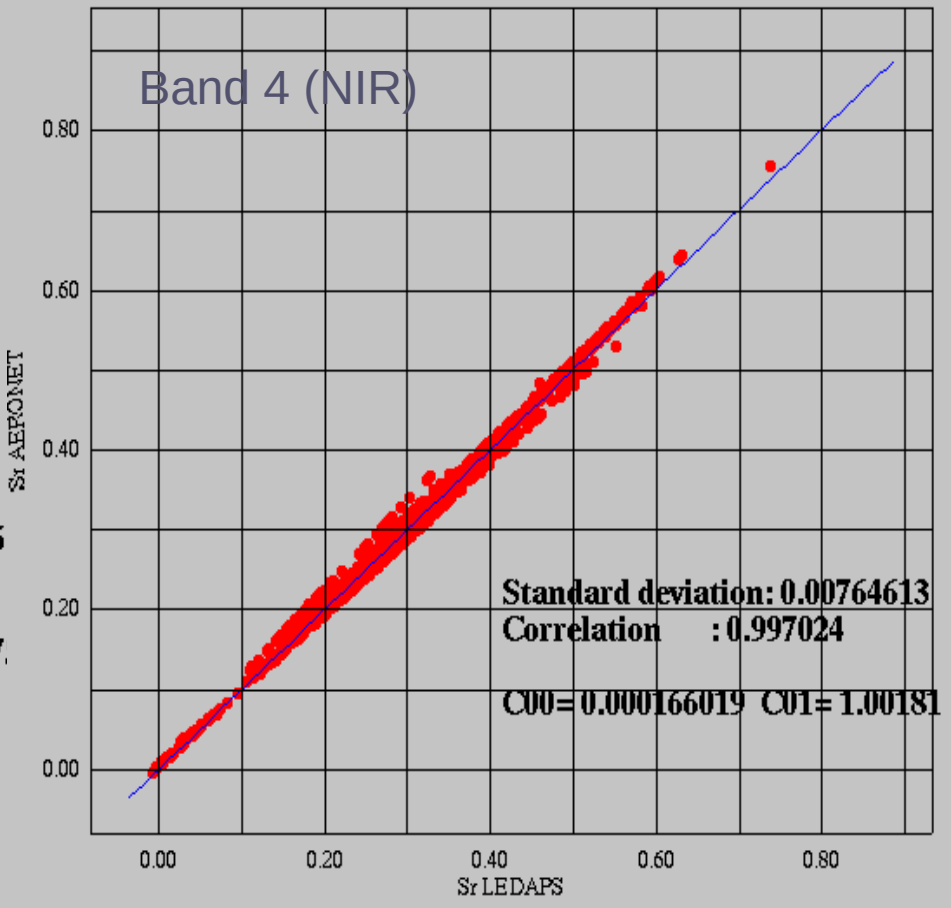


Challenges - 2

- Atmospheric correction.
  - Essential to have consistent data sets temporally and spatially.
  - Hence need for surface reflectance and atmospheric correction.
  - LEDAPs has shown the way.
  - Soon to be a standard USGS product for Landsat 8 and possibly for earlier data.
- Terrain correction.
- What about BRDF?

Evaluation of the LEDAPS ETM+ SR: 6S using Aeronet vs 6S with Landsat AOT

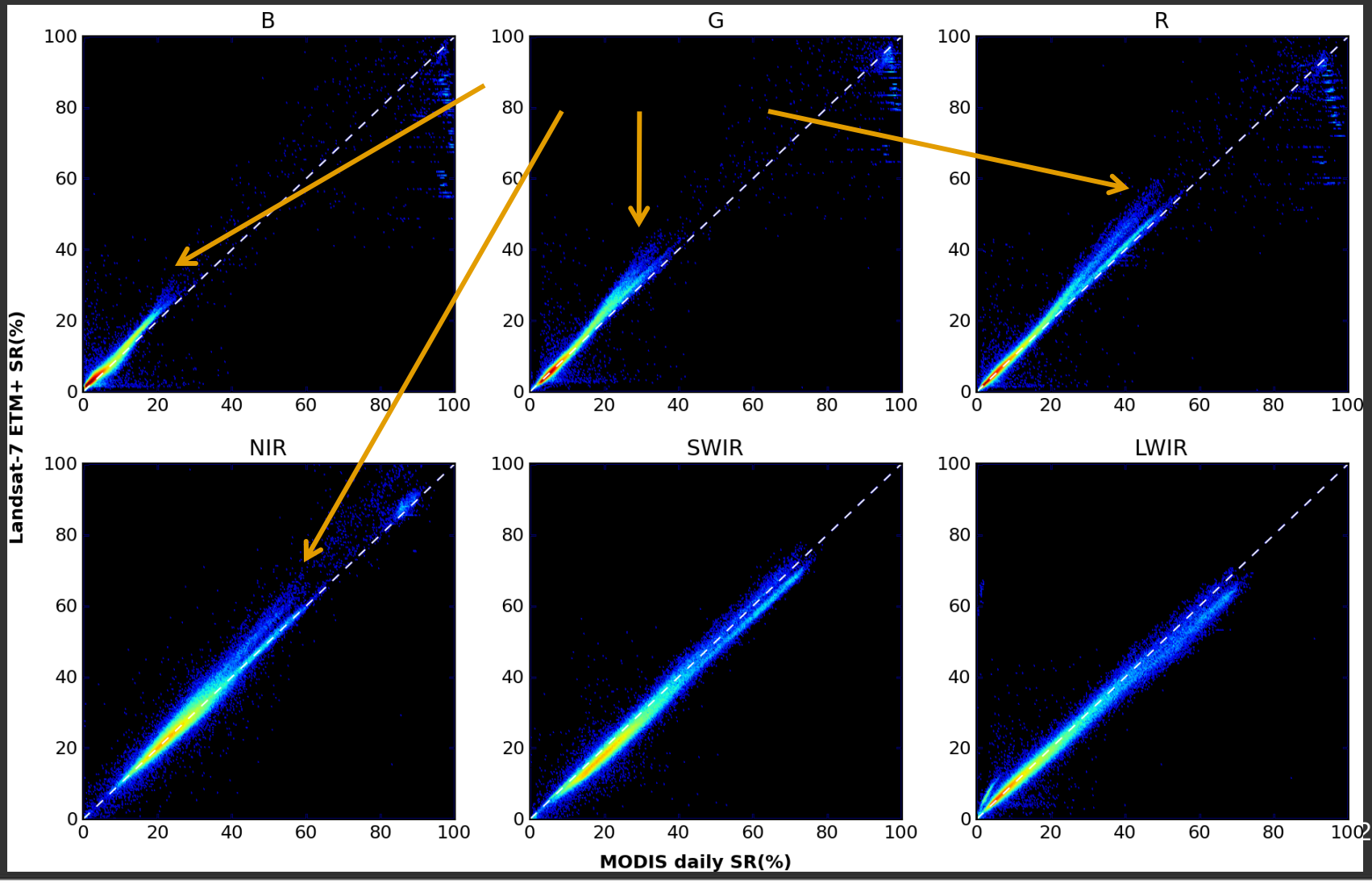




Co-incident observations from 13 US Aeronet sites and GLS2000 Landsat data

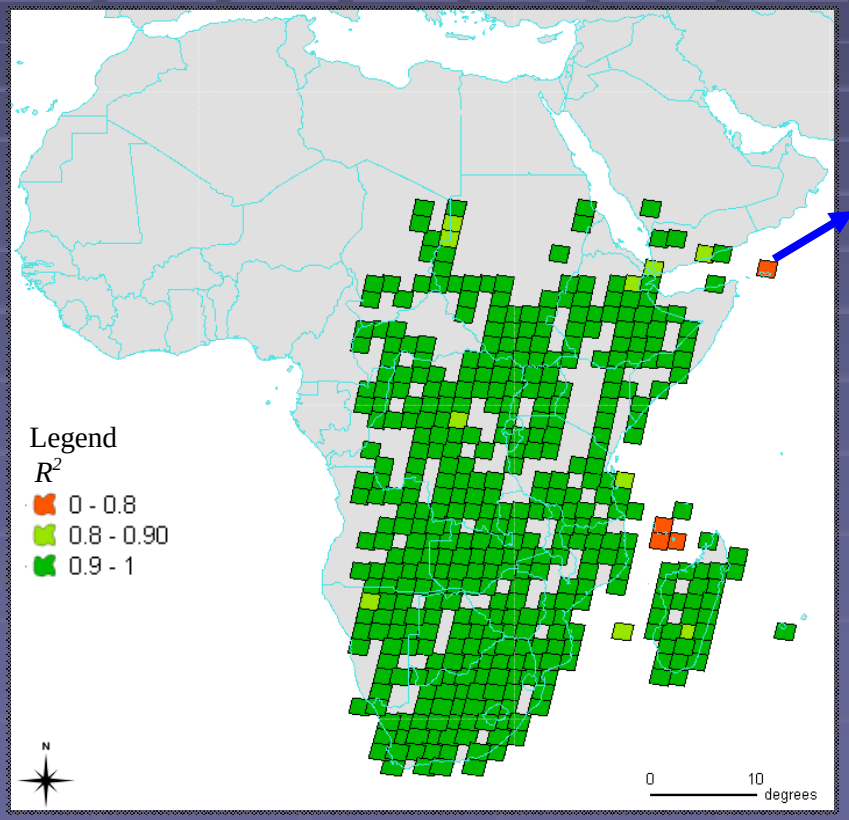
Positive trend over bright targets

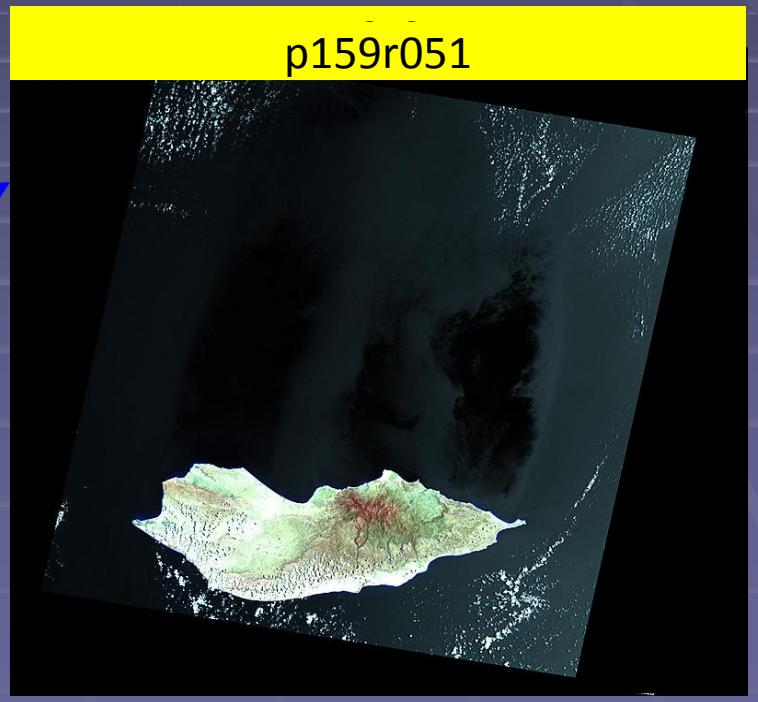
After removing Landsat scenes with previous quality issues



Operational QA in Africa

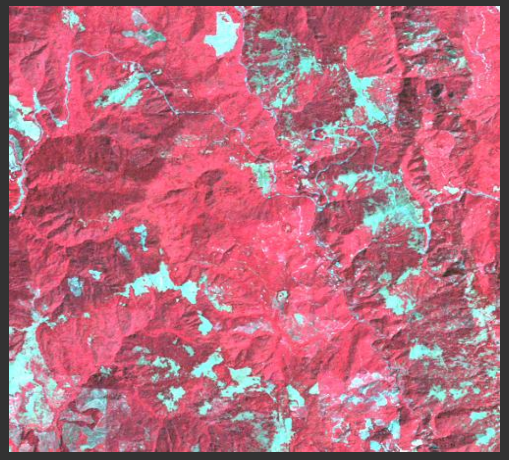
Example: East African GLS 2000 data compared to MODIS (R^2)



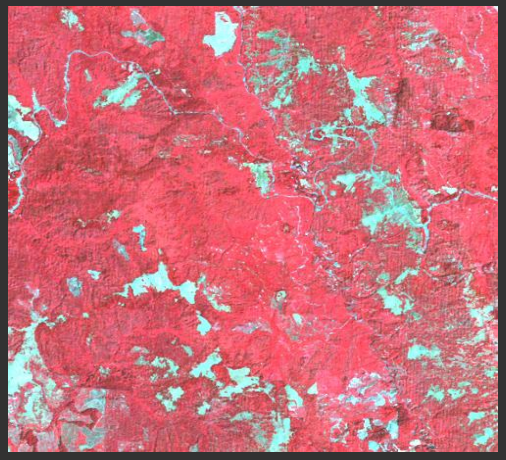


Terrain Illumination Correction

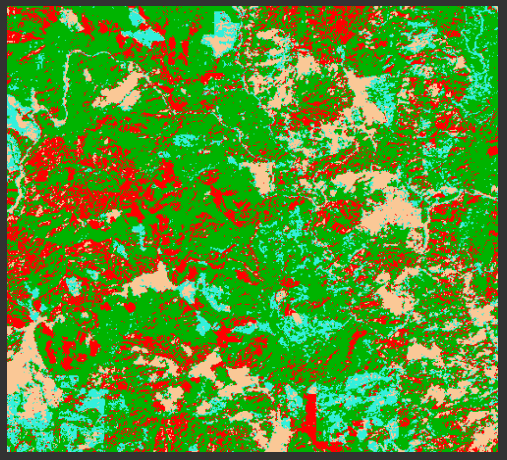
1989-09-03



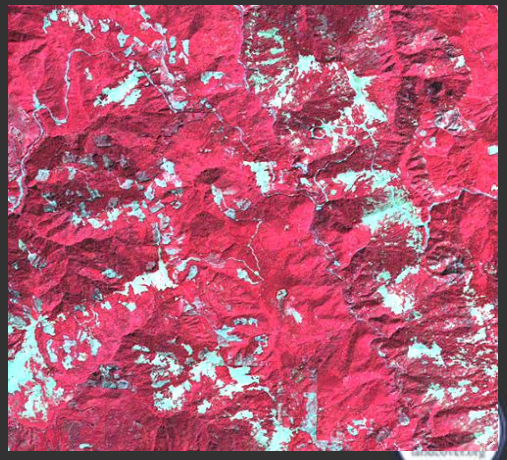
1989-09-03 Corrected



SVM w/o IC

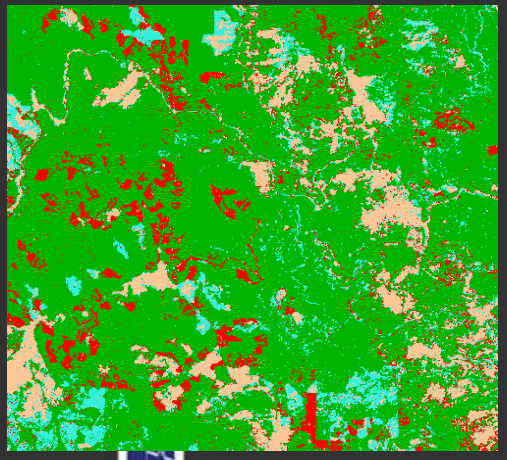


2002-10-01



2002-10-01 Corrected

SVM w IC



Deforest

Regrowth

Forest

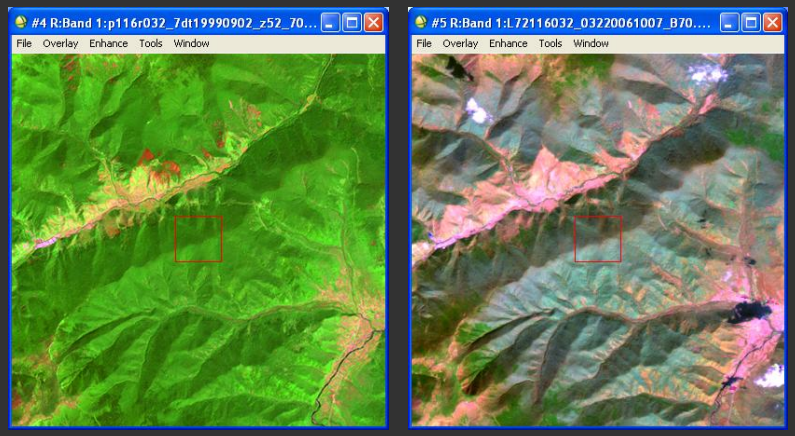
Non Forest

SDSU

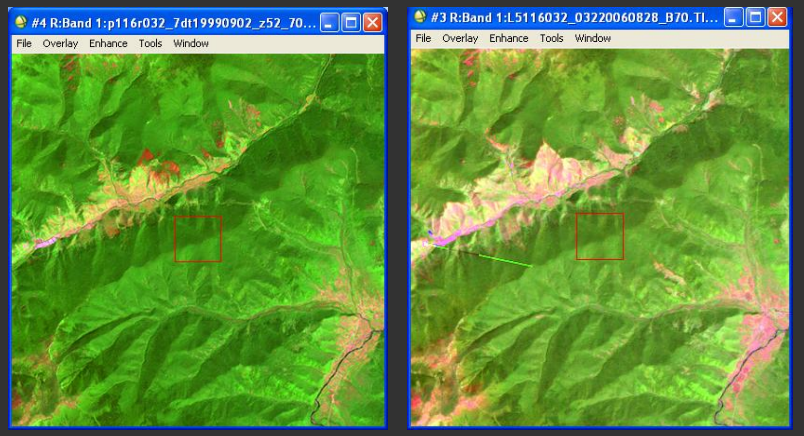
Phenology differences

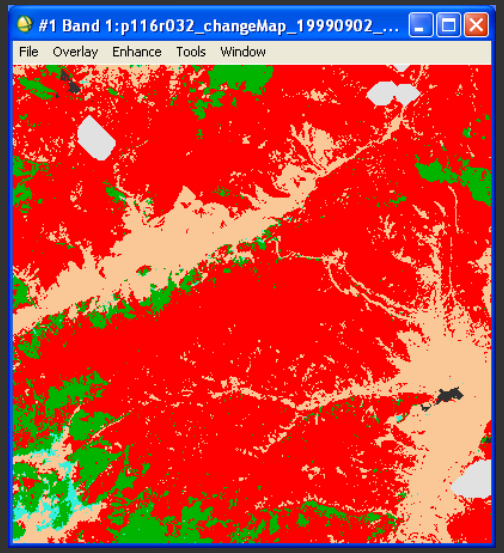
- GLS acquisition (LASSI) not optimized for forest classification
- Many scenes acquired during dormant season
- Training Data Automation assumes forests have leaves

09/02/1999 – 10/07/2006

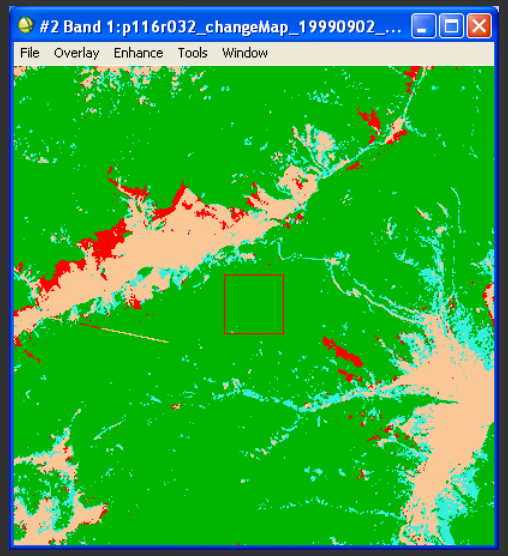


09/02/1999 – 08/28/2006





vs.



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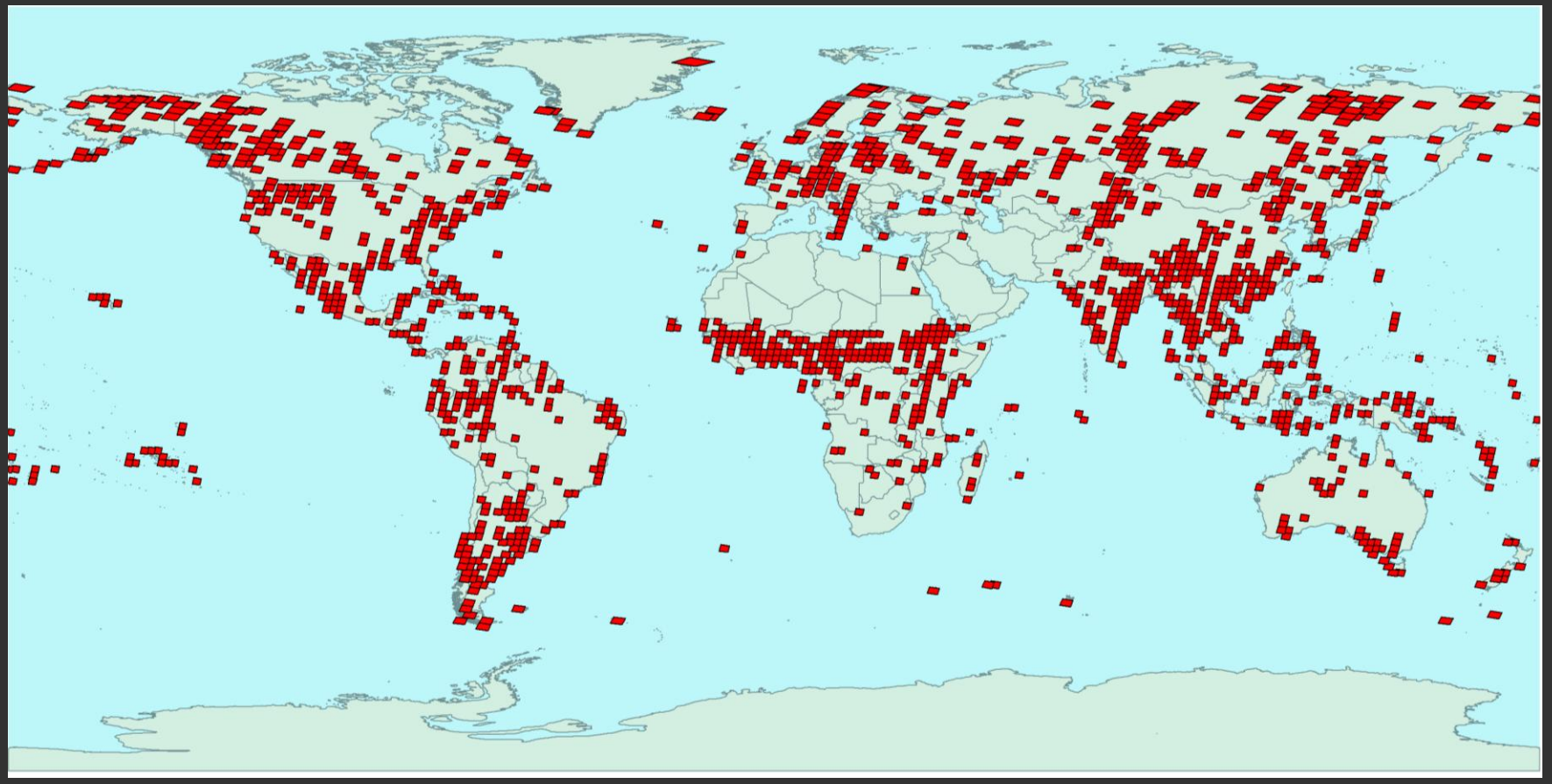

1516 GLS2000 images eligible to be replaced under 70% Rule.

GLCF landcover.org

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Global Forest Cover Change

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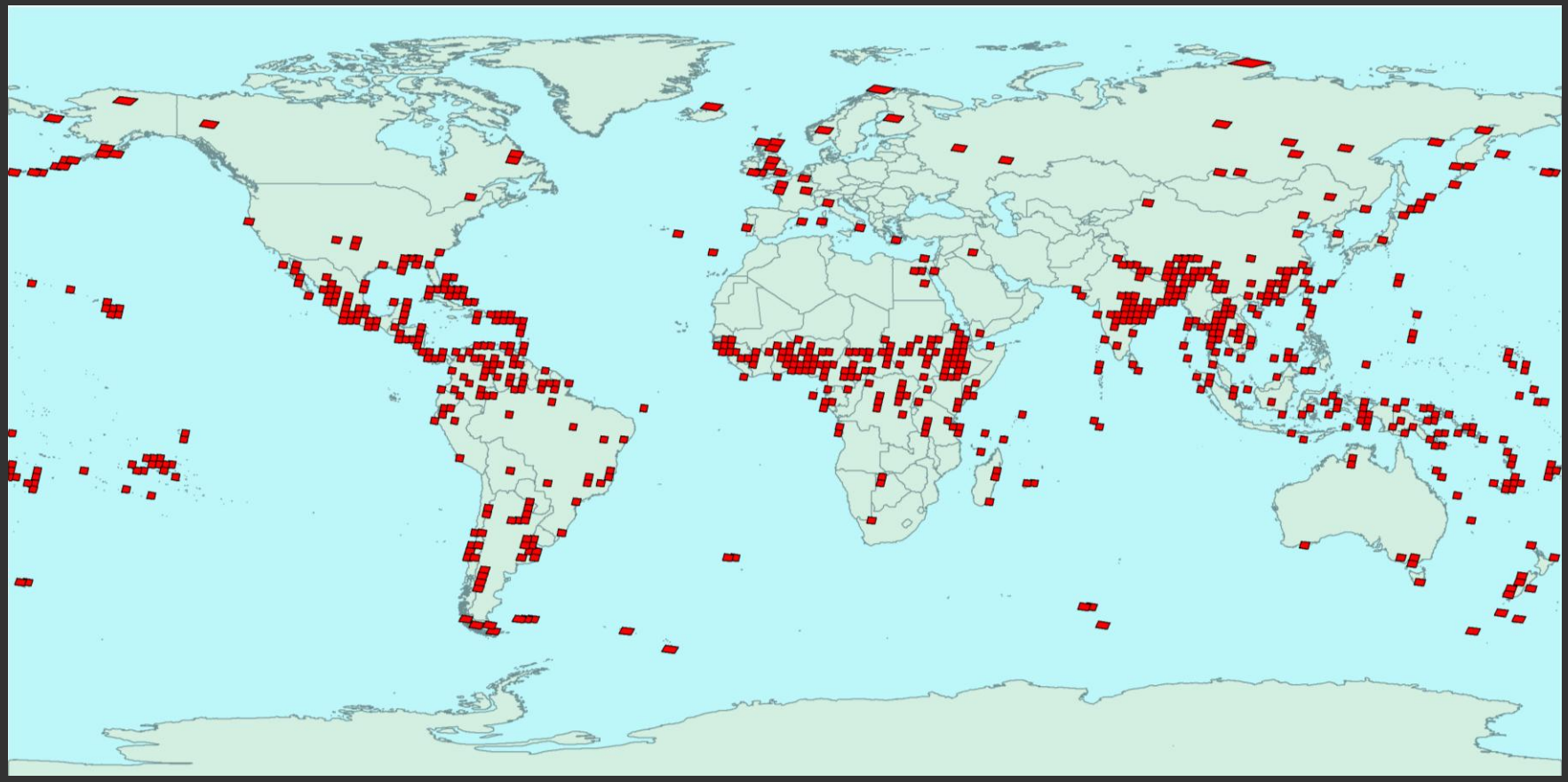

812 GLS2005 images eligible to be replaced under 70% Rule.

GLCF landcover.org

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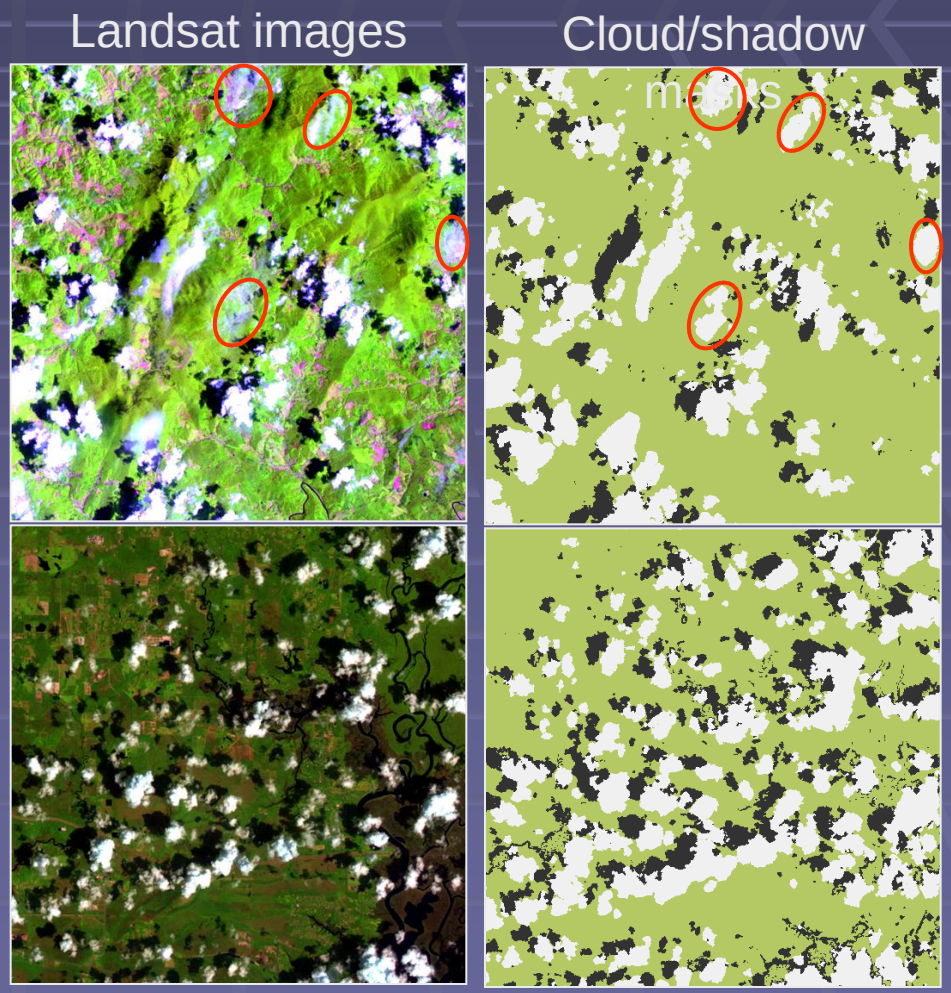
Challenges - 3

- Several earlier large-area Landsat products
  - But in past largely the result of brute force with significant human post-processing.
  - Need to revisit Agristars (developed for yield and production forecasting)
- *Industrial production* is essential
  - Comprehensive training data needed
    - Need for international sharing.
    - Wider availability of digital sub-5m data.
    - Information extraction methods which can withstand errors in training data.
  - Robust test data for error estimation.
    - Just as ground truth was always a dumb term – so is validation. So stop using it!
    - Error estimation is needed.
    - Again requires international sharing of data.
    - GOFC-GOLD needs to step up involving GEO and CEOS.

Cloud and Shadow Masking

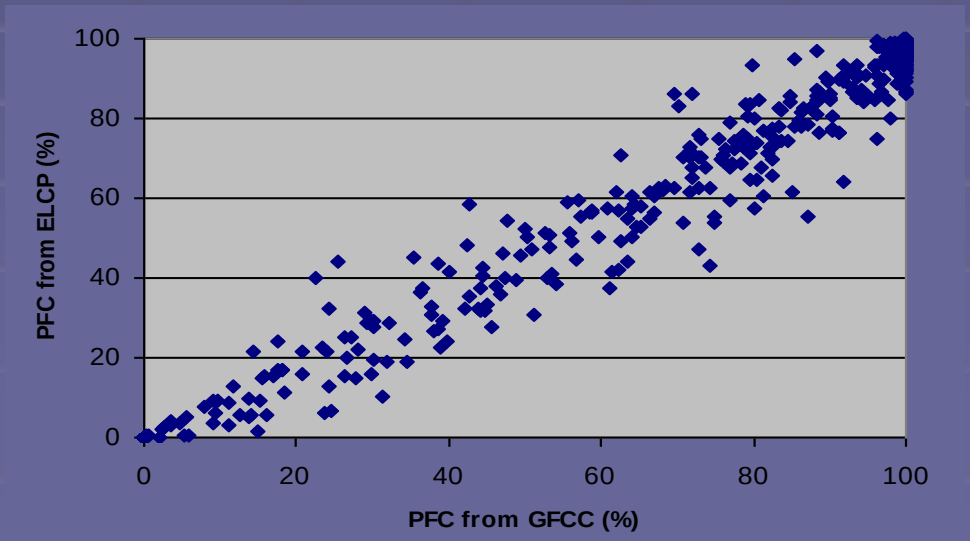
- Cloud could be mapped as change if not masked
  - Small omission could lead to significant bias
  - Change is often a small portion of the land area
- Automated method developed
  - Brightness-T based
  - Detect both thick and thin clouds
  - shadow too
  - Tested in many places



Huang et al, 2010

Operational QA

- Every Landsat path/row tile checked for consistency with existing land cover products (ELCP)
- Inconsistency may indicate issues
  - ELCP reflects forest distribution
  - More accurate when aggregated properly to coarser spatial resolutions (Huang, 1999)
  - Percent forest cover (PFC) from GFCC and ELCP should agree at 5 km – 10 km resolutions



Need to go international again

- Training and testing data assembly needs international cooperation.
- Practitioners working group for those trying to go global with Landsat data.
  - Within framework of GOFC-GOLD.

Goals of WG

- i) Ensuring consistent meta-data.
- ii) Surface reflectance product generation.
- iii) Automated analyses
- iv) Sharing of data for training and error estimates.
- v) Exchange of preliminary products.

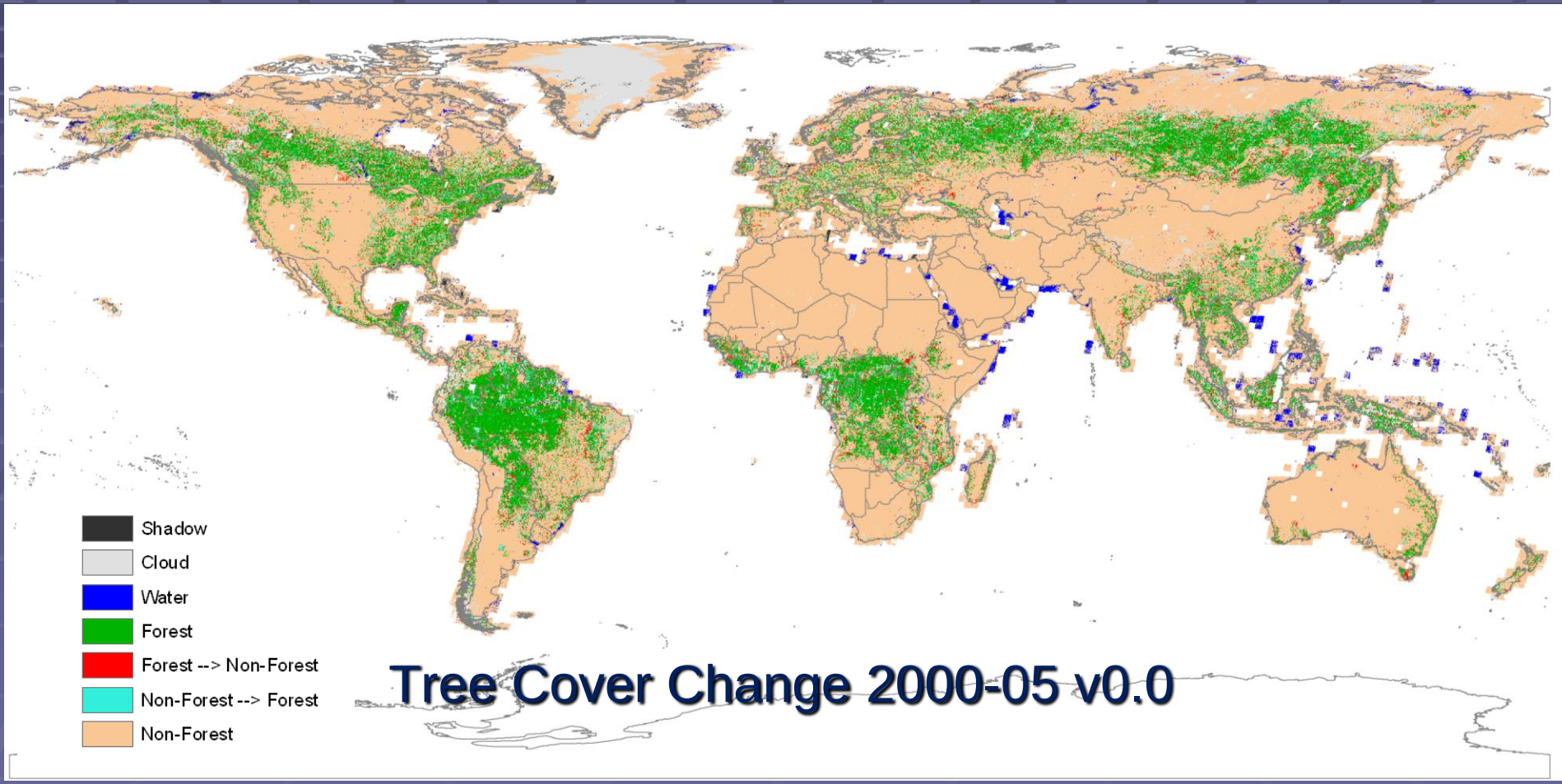
Going international again 2

- Virtual constellations for global data sets.
  - Currently very modest efforts under CEOS and GEO.
  - Greatly hindered by selfish data policies.
    - Only US and Brazil are sharing data sufficient for global analysis.
    - Shame on those countries that will take but not donate.
    - Will Europe share Sentinel 2 data without the need to beg?
  - Little work to show just how inter-operable are the data if they are used for large area studies.
    - Different resolutions
    - Different fields of view
    - Different band passes and radiometric resolutions.

We're still spending too much time playing in the sand box

Let's get to work!

Thank you


Shadow
Cloud
Water
Forest
Forest --> Non-Forest
Non-Forest --> Forest
Non-Forest
Tree Cover Change 2000-05 v0.0