Novel satellite measurement techniques for land-use

Monitoring a bio-based economy

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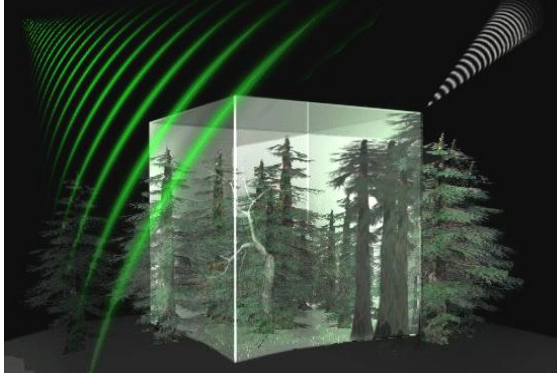
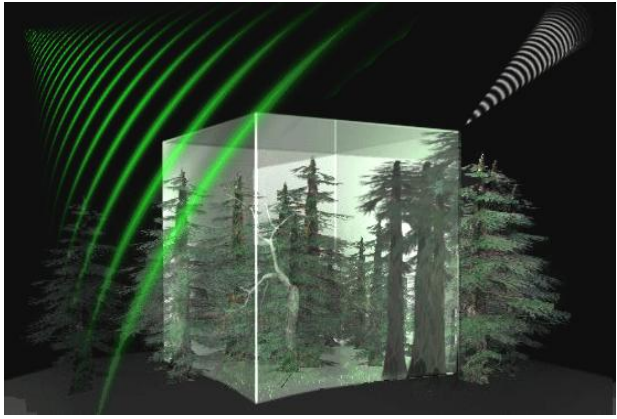
18-8-2011

Rationale



- A bio-based society will impact our environment
  - Land use
  - Food production
  - Water usage
  - Biodiversity
  - ??
- Societal embedding is key, sustainable solutions
- Sustainability issues need to be identified, qualified and quantified (BE-Basic Flagship 9.1)
- Need for relevant, precise and reliable geo-information, with adequate spatio-temporal characteristics

What is needed?



- Geo-information:
  - *Geographic extent, spatial resolution*
- Temporal:
  - *Revisit rate, monitoring extent, e.g. in relation to harvest*,
  - Spatio-temporal trends
- Parameters:
  - Crop –*type (land use), -yield, -health,*
  - Change detection: *burning/ non-burning , harvesting, long term/seasonal*
  - Biomass volume
  - Soil –*quality, degradation, moisture,…*
  - Evapotranspiration

The tools. What is possible?

- Types of satellite orbits : LEO and HEO
- Types of instruments (optical, microwave/radar)
- Satellite programs (GMES, Earth Explorers -BIOMASS mission)
- Operational (monitoring) and proof-of-concept
- System-of-systems

Systematic observations

- Monitoring should be global, weather independent, frequent, precise, and with useful quantities

Optical satellites

- passive
- need solar illumination
- High frequencies, multiple bands

Microwave satellites

- active
- weather independent
- Low frequencies,
- polarization

Satellite programs: GMES

Goal of GMES

GMES aims at developing operational services, following the example of meteorology, but for other domains such as:

- emergency management
- air quality monitoring
- land monitoring
- ocean & sea ice monitoring etc…

In addition, science is needed to create and continuously improve operational services

Sentinel–1: C-band SAR mission

- ✓ **Data continuity of ERS and ENVISAT missions**
- ✓ **GMES radar imaging mission for ocean and land services**
- ✓ **Applications:**
  - monitoring sea ice zones and the arctic environment
  - surveillance of marine environment
  - monitoring land surface motion
  - mapping in support of humanitarian aid in crisis situations
  - mapping of land surfaces: forest, water and soil, agriculture, etc.

The Sentinel-1 mission is based on a constellation of 2 satellites
Sentinel-1A to be launched end 2012
Sentinel-1B under procurement, launch date is TBD (indicatively 2014/2015)

Sentinel Data Policy

ESA Member States have adopted a FREE and OPEN data policy

Anybody can access Sentinel data; no difference is made between public, commercial and scientific use
→ open access

Sentinel data will be made available to the users via a 'generic' online access mode
→ free of charge

This Data Policy still needs approval on the European Union side

→ security restrictions might be implemented on the data distribution.

System of systems

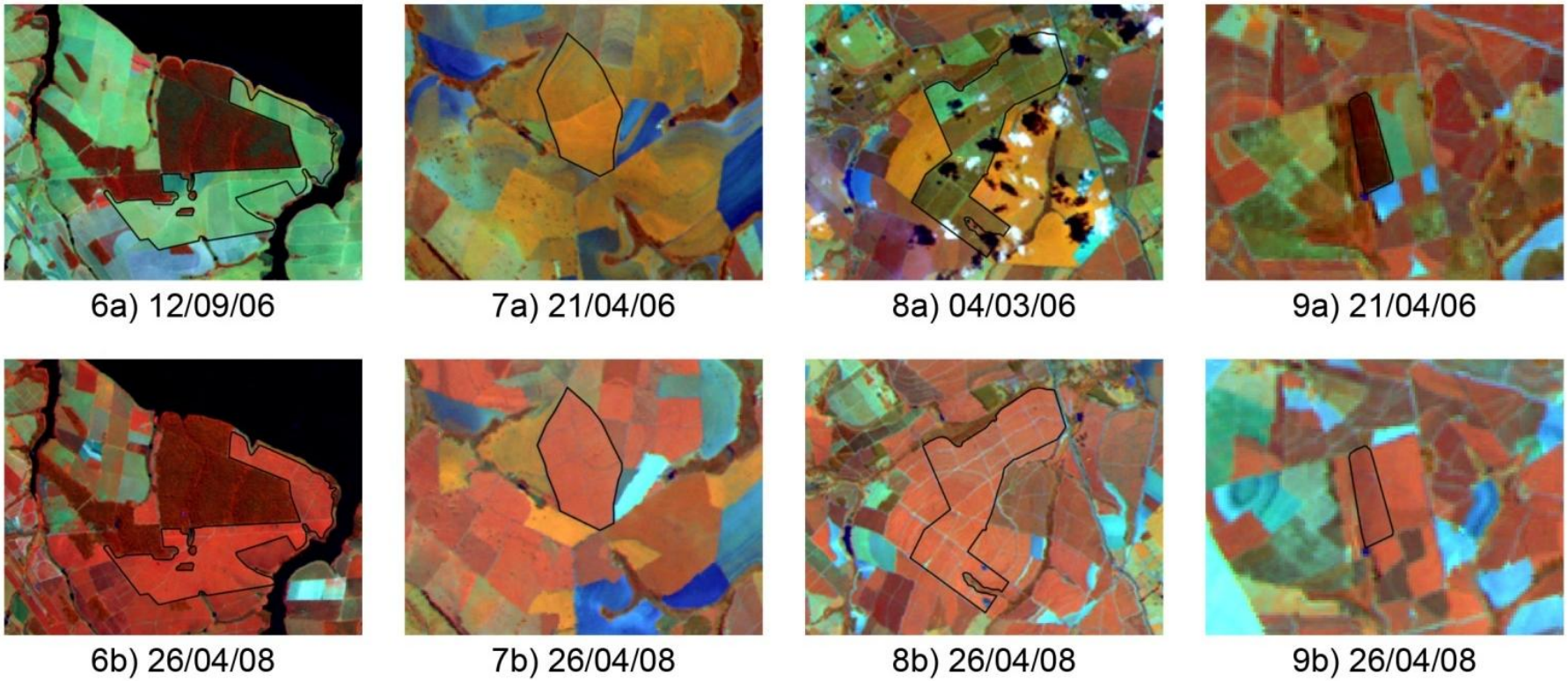
- Many satellites in orbit.
- Different orbits, sensors, revisit rates, resolutions, parameters
- E.g. sensitivity to cloud cover: initialize time series with multispectral optical, and continue with radar. (Kalman filter)


N30°
Tropic of Cancer
N10°
Prime Meridian
W 40°
Equator
W 60°
S 10°
W 80°
W100°
Tropic of Capricorn
W120°
S 30°
W140°
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2011 Europa Technologies
US Dept of State Geographer
© 2011 Google
S 50°
2°18'28.82" N 79°58'43.15" W elev -355 m
©2010 Goog
Eye alt 10805

Examples

direct Land Use Change: optical

Pasture | Soybean | Citrus | Arboreous Vegetation



6a) 12/09/06 | 7a) 21/04/06 | 8a) 04/03/06 | 9a) 21/04/06

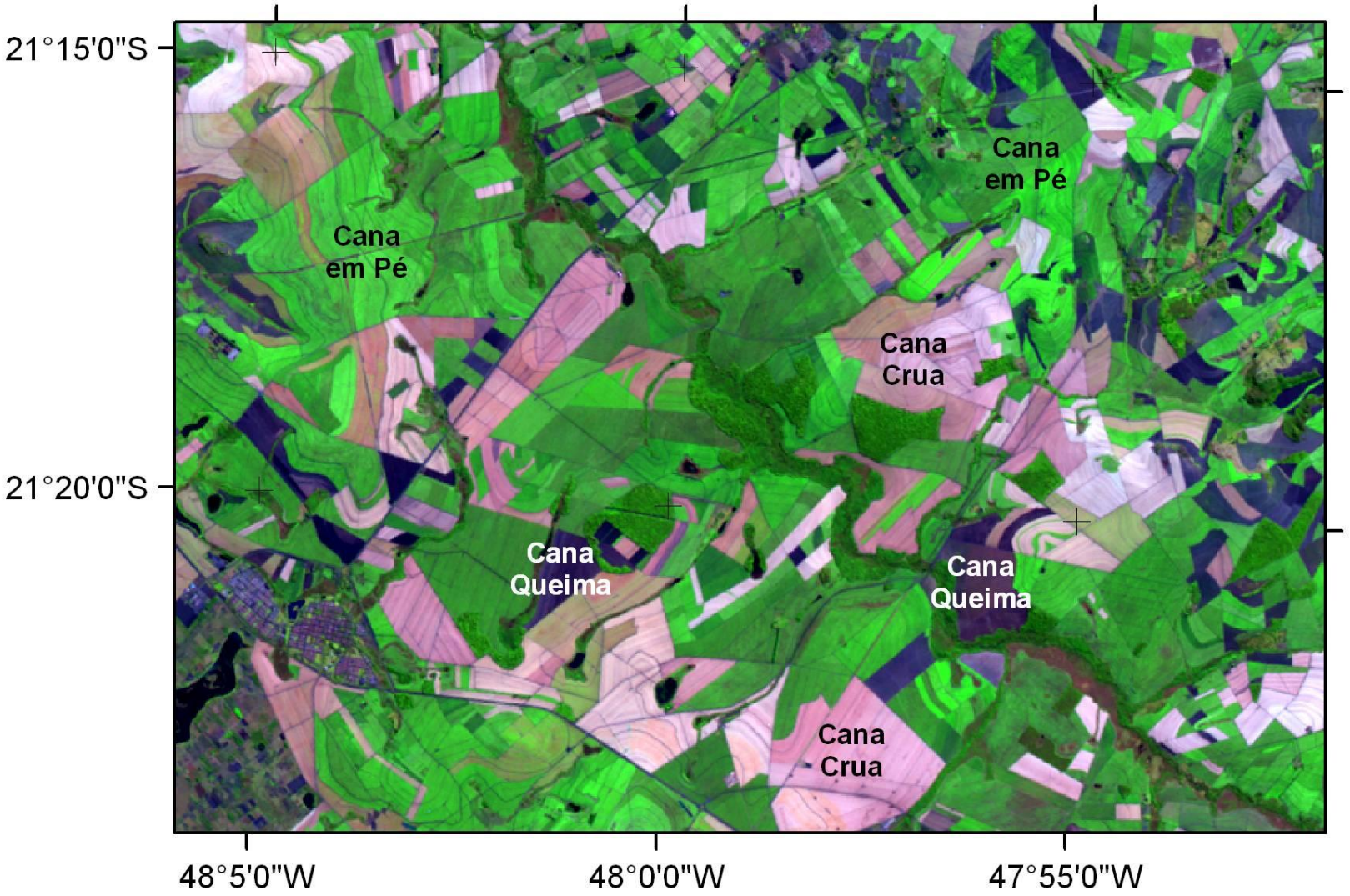
6b) 26/04/08 | 7b) 26/04/08 | 8b) 26/04/08 | 9b) 26/04/08

Source: Bernardo Rudorff, INPE

Harvest: with and without straw burning

Source: Bernardo Rudorff, INPE

Sugarcane harvested with and without straw burning

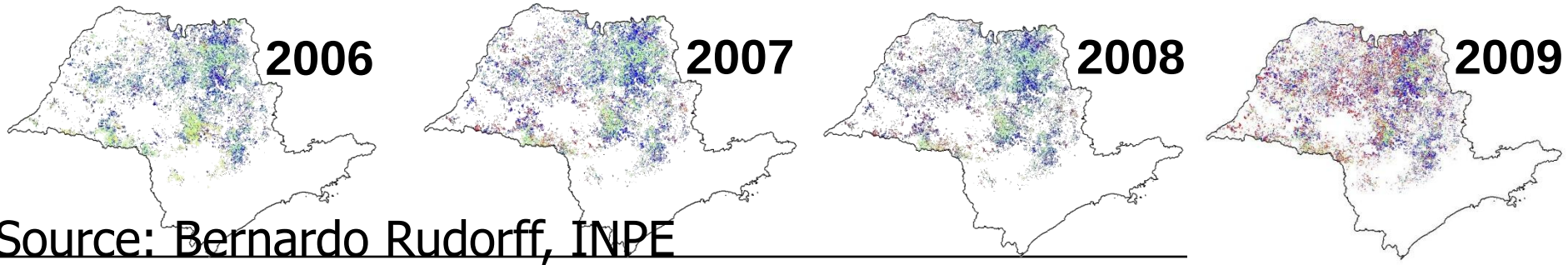


Source: Bernardo Rudorff, INPE

Percentage of sugarcane area harvested without and with straw burning

Harvest Season	Harvest Type	
	Without Burning	With Burning
2006	34.2	65.8
2007	46.6	53.4
2008	49.1	50.9
2009	55.5	44.5
2010	58.2	41.8

In progres



Source: Bernardo Rudorff, INPE

Past collaborations

EU STD3

Climatological and hydrological determinants of agricultural production in South America.

Remote sensing and numerical simulation

- University Sao Paulo: prof. dr. William Tsong Liu
- University of Campinas: Prof. Dr. Hilton Silveira Pinto, dr. Jurandir Zullo
- EMBRAPA

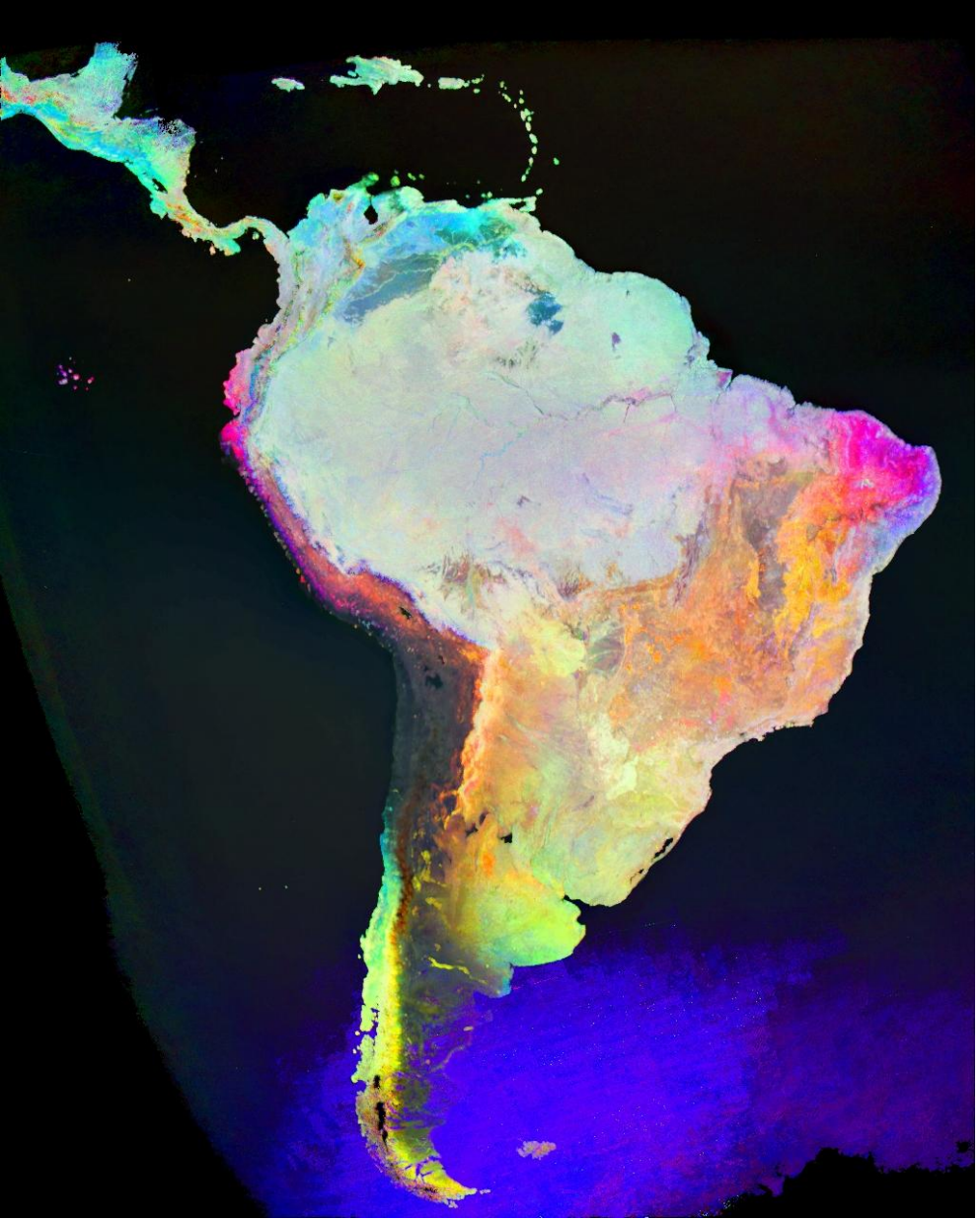
Fourier analysis of time series of satellite data

- Estimate time lag of local land surface temperature in large TIR images from geostationary satellites.

  (Meteosat North Africa + Middle East : 48 slots per day: 1987 - 88)

  (Menenti and Verhoef)

- Anomalies in crop phenology: AVHRR NDVI Zambia: 1989 - 90 (Menenti et al.)
- Applications:
  - classifications of biomes
  - determination of the length of growing season
  - observation of vegetation response to climate variability
  - Monitoring evapotranspiration



South America

108 NOAA-AVHRR NDVI monthly composites of 1982-1991 (source NASA GSFC) processed by HANTS algorithm

IHS colour transformation:

Annual mean	**=> Intensity**
Phase	**=> Hue**
Annual amplitude	**=> Saturation**

Phase of maximum NDVI <> Colour:

Jul	**Blue**
Sep	**Cyan**
Nov	**Green**
Jan	**Yellow**
Mar	**Red**
May	**Magenta**

(blue region is an artifact due to the “terminator effect”, which gives artificially high NDVIs in the winter period)

Radar Images at different Frequencies

X-band

L-band

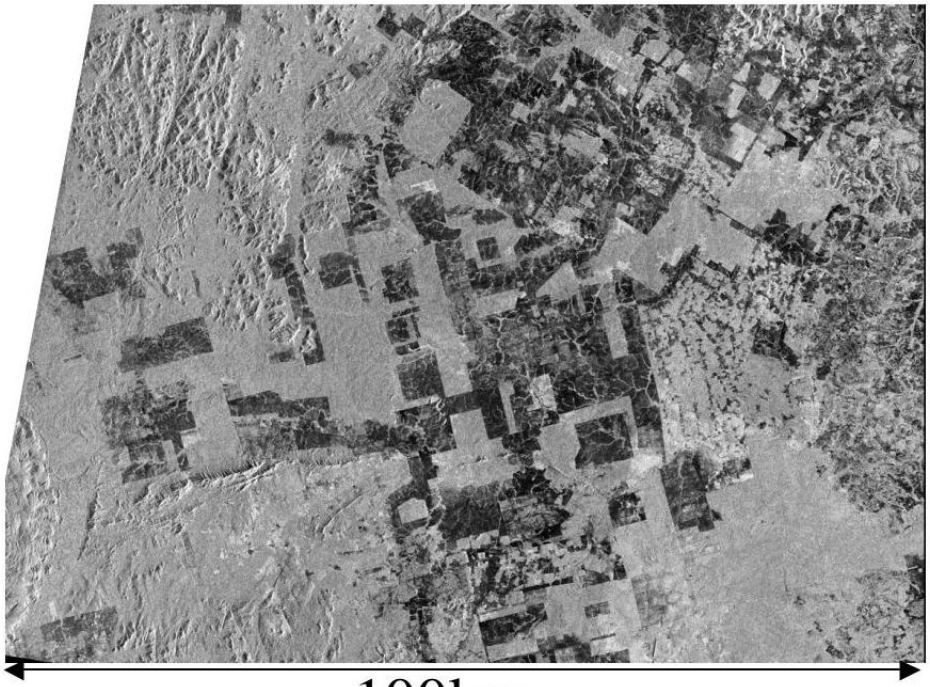
P-band

Radar biomass observables & parameters

- Traditional Observables
  - Amplitude (backscatter)
  - Phase (interferometry: height of canopy)
  - Coherence (volume and temporal decorrelation)
- Additional (new) observables
  - Multi-temporal acquisitions
  - Polarimetric InSAR (POLINSAR)
  - Multi-baseline InSAR
- Parameters
  - Tree/crop height
  - Crop yield
  - Forest/crop basal area
  - Soil moisture
  - Canopy Density/LAI
  - Canopy Structure
  - Emergents + density profiles

The Amazon overview: clearcuts

Amazon Deforestation in 10 years

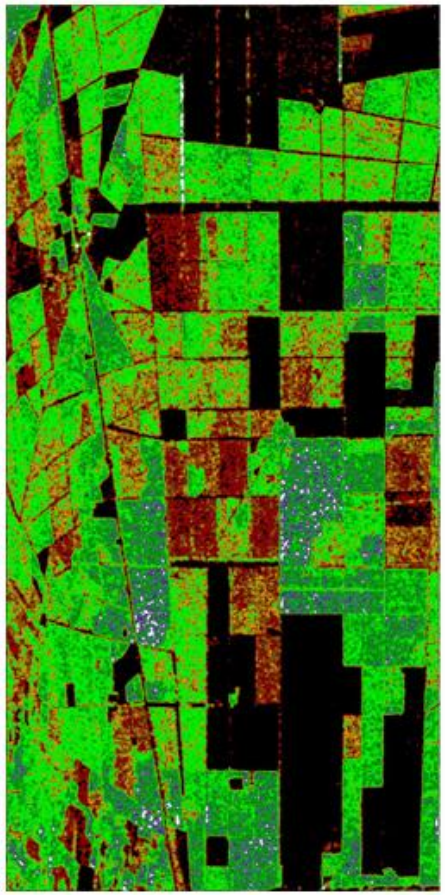


100km

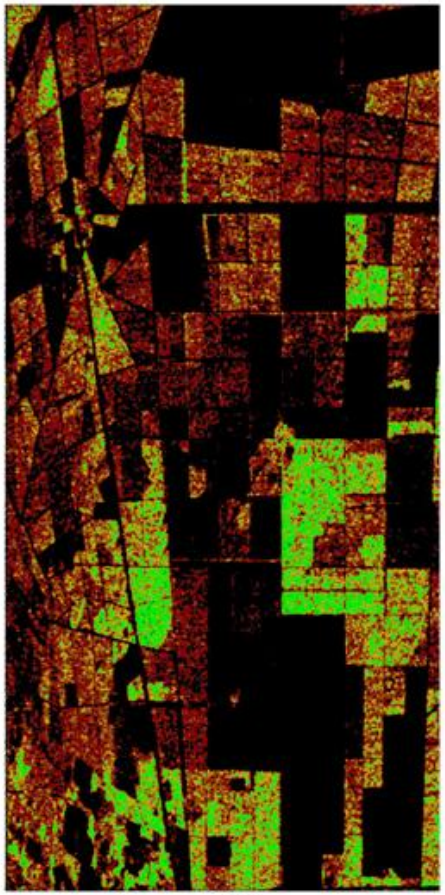
October 1996 (JERS-1)

June 2006 (PALSAR)

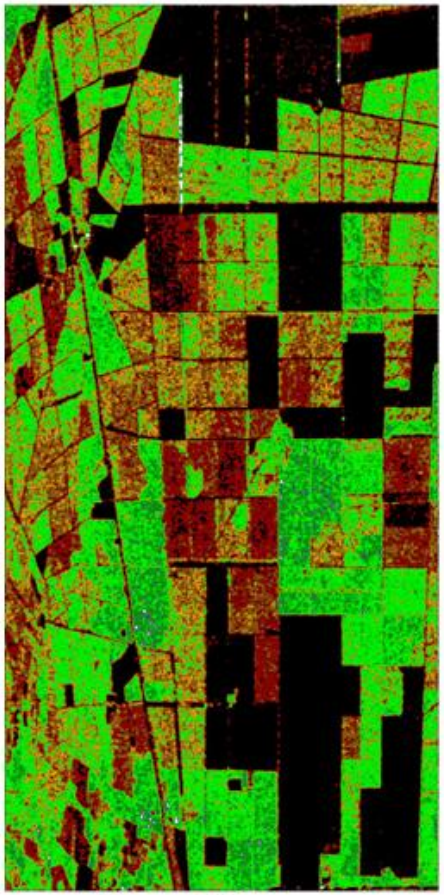
Biomass in tons/ha, observed by radar (P-band)



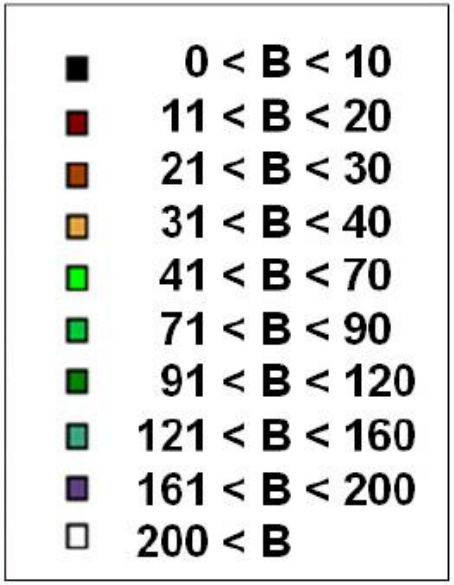
Above-ground biomass



Crown biomass



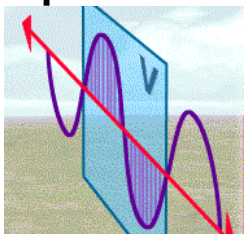
Stem biomass



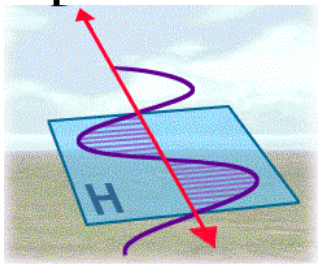
(LeToan et al, Saatchi et al (2007)

Polarization

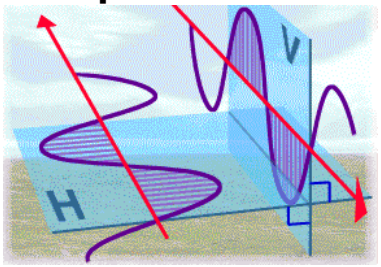
Vertical polarization

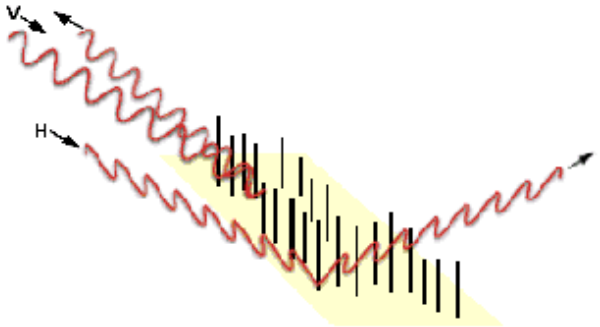


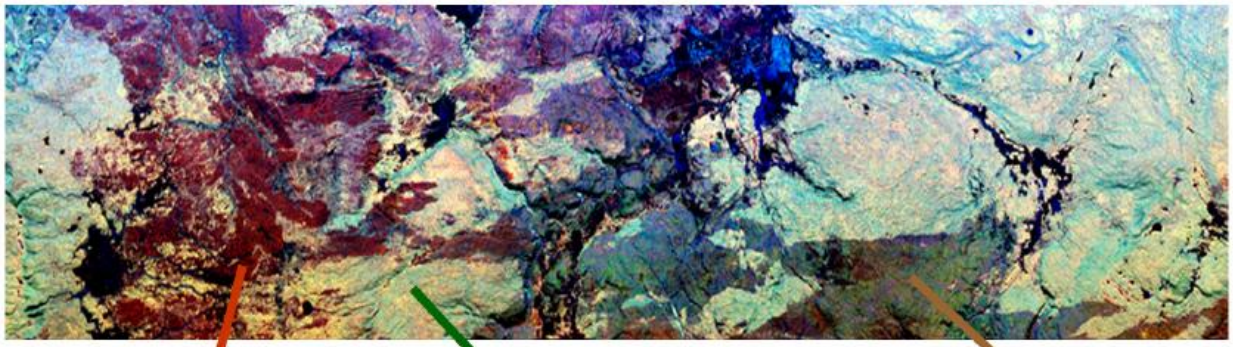
Horizontal polarization



Cross polarization







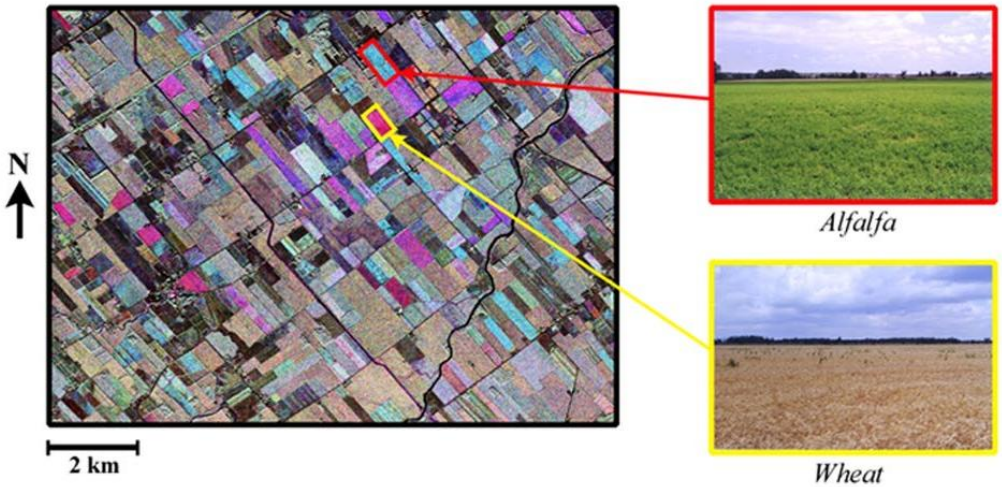
A week after burn
P-HV = - 27 dB

60-80 years after burn
P-HV = - 12 dB

15 years after burn
P-HV = - 19 dB

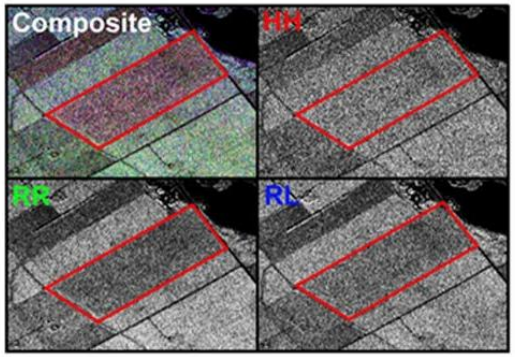
CROP IDENTIFICATION AND MAPPING

CV-580 C-band SAR, South of Ottawa, 9 July 1998
Linear Polarization Composite: R = HH; G = HV; B = VV

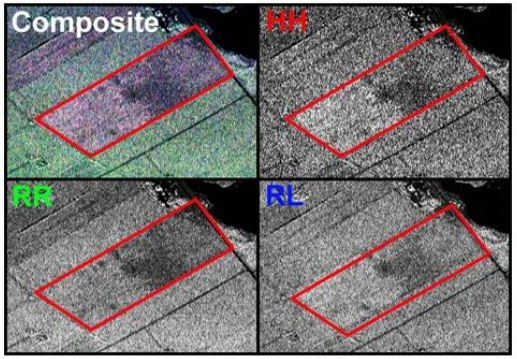


CROP CONDITION

Within Field Variability: Wheat Crop
Ottawa, Ontario
CV-580 SAR



June 19, 1998



July 9, 1998

Summary and Conclusions

- Satellite observations invaluable for the bio-based economy
- …needed for increased sustainability and social acceptance
- Need for dedicated algorithms for parameter estimation
- Dedicated satellite programs (GMES)
- Developing the system-of-systems approach

Main challenges / problems

1. **Fixing the parameters of interest.** How do we move from 'what is possible' to 'what is needed'.

2. **Fixing operational requirements.** How should the information be communicated and to whom?

3. **Finding appropriate partners.** Please contact us:

   r.f.hanssen@tudelft.nl