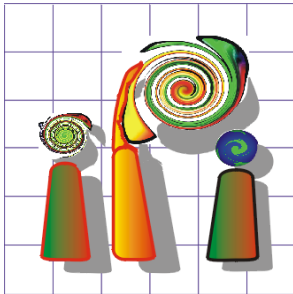
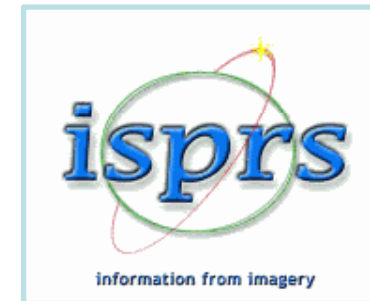


# Photogrammetry and remote sensing: challenges in research and development

Christian Heipke



**IPI** - Institute for Photogrammetry  
and GeoInformation  
Leibniz Universität Hannover



Secretary General, ISPRS



Institut für Photogrammetrie und GeoInformation



Leibniz  
Universität  
Hannover

# Greetings from ISPRS president Chen Jun



**ISPRS: Serving society with information from images**





# ISPRS is ...



- an international NGO with a focus on
  - **science and development** in
    - photogrammetry, remote sensing, spatial information
  - cooperation between **different stake holders**
    - academia, private industry, government, end users
  - truly **global** cooperation
    - **education**, technology transfer, capacity building



# ISPRS Student Consortium



- ... represents students and young professionals of photogrammetry, remote sensing and spatial information sciences
- very active group, founded in 2004
- Chair: Ursa Kanjir (Slovenia)



2011 Summer School in Fayetteville,  
see also <http://www.isprs-sc.org>





# Individual membership

## Application for ISPRS Individual Membership

Titel:

First Name:

Last (Familiy) Name:

Gender:    
preferably the employer's one

Address:

Country:

Phone:

Employer:

Type of Employer:

# Table of content

- **Changes and challenges**
  - Society and policy
  - Information & Communication Technology
- **Trends in photogrammetry and rem. sens.**
  - Data acquisition and processing
  - Status of topographic mapping
  - Examples
- **Conclusions**



# Principle of photogrammetry & remote sensing

- determination of **characteristics of the electromagnetic radiation** of a given wave length, reflected or emitted from some surface
  - energy, phase, polarisation, signal form, travel time
- derivation of **object and surface characteristics** from these measurements
  - **geometry**: position, size, shape
  - **radiometry**: orthophoto mosaic
  - **semantics**: object-ID, attributes



# Changes and challenges: society, policy

- **Stronger quest for sustainable development**
  - understanding the Earth as a system; climate change, envir. mon.
  - food, energy, water resources and supply, flora & fauna
- **Globally increasing population**
  - in particular in emerging countries and coastal areas
  - shrinking population in some developed areas, aging society
- **Incr. sense of security (personal, data, homeland, ...)**
  - disaster management and mitigation
  - refugees and migration
- **Increasing globalisation**
  - mobility of people, markets, capital, education, ...
  - communication and information distribution and retrieval in real-time across the world (yet: globally 2 in 3 without internet access)



# Changes and challenges: society, policy

- **Changing communication**
  - social networks (facebook, twitter, ...)
- **Changing role of governments**
  - lean state: from producer to clearing house: GDI
  - not the only provider of GI information any more
- **Increased need for global GI and GI management**
  - coordination among countries and commercial companies
  - coordination between **countries and internat. organisations**, e.g. GEO, GEOSS, UN-GGIM, INSPIRE, ...
- **GI has reached the centre of society and is big business (spatial is not special any more)**



## THE GLOBAL EARTH OBSERVATION SYSTEM OF SYSTEMS



© GEO

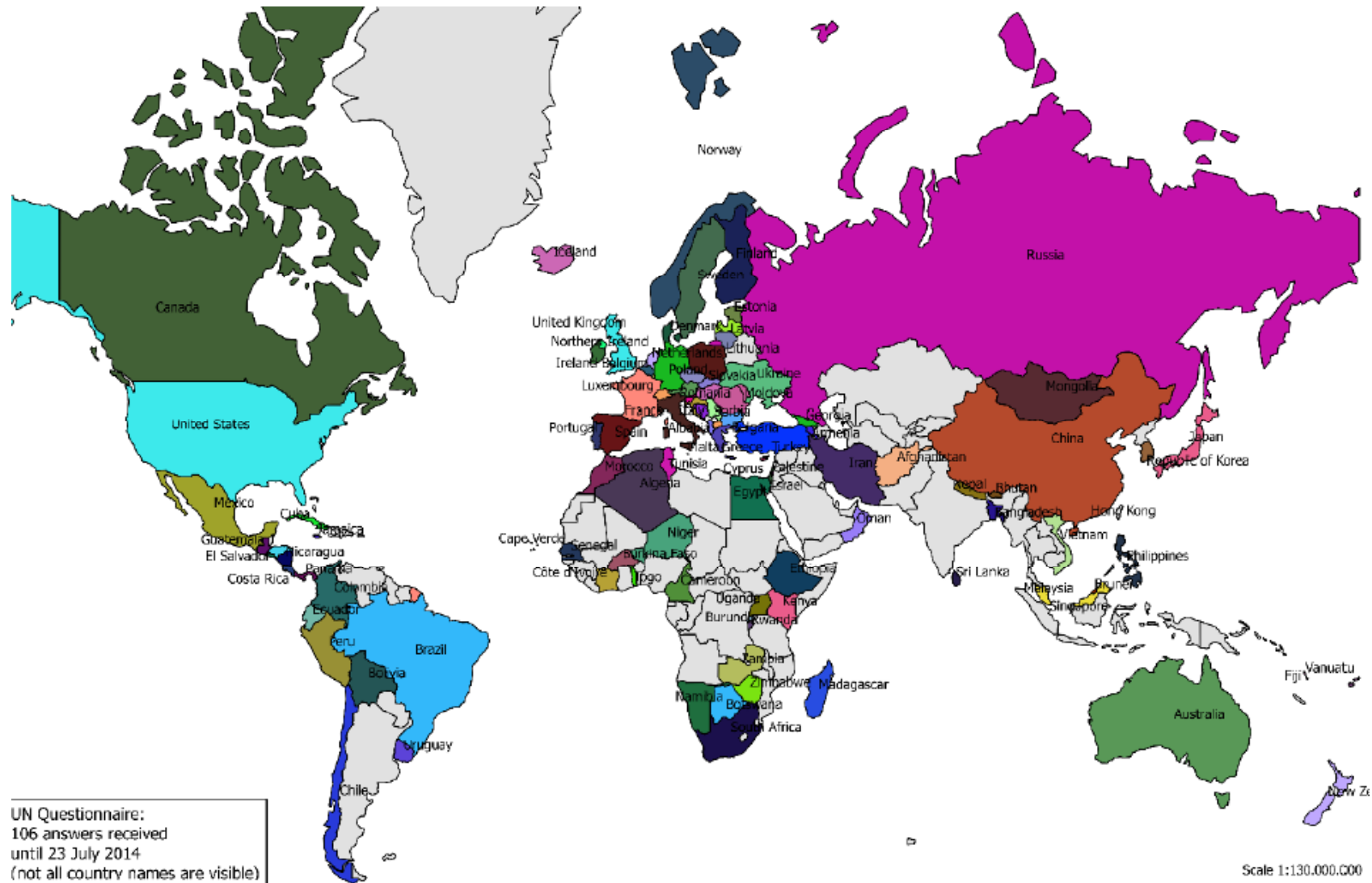
**GEO – Group on Earth Observation**

**GEOSS – Global Earth Observation System of Systems**





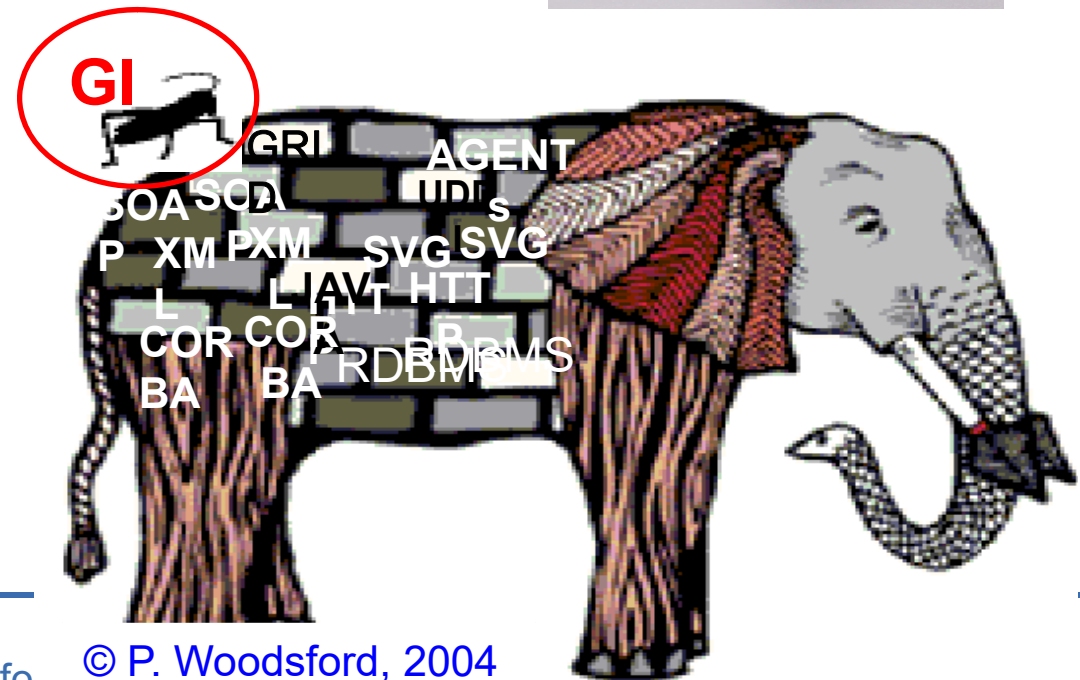
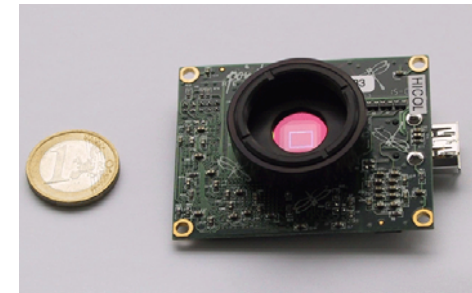
# Status of Mapping of the World



106 official country replies (of 193 UN Member Countries) – July 23, 2014

# Information & Communication Technology

- ever smaller sensors, mobile devices, wireless communication - **ubiquitous computing**
- Web 2.0 – **user participation**
- developments support **merger of GI sub-disciplines** (e.g. (LBS, smart phone)
- scope of ICT much **wider than GI**



# Information & Communication Technology

- **big data** (PB for satellite imagery)
  - 1 PB =  $(1000)^5 = 10^{15} = 1.000.000.000.000.000$  bytes
  - 1 PB =  $(1024)^5 = 2^{50} = 1.125.899.906.842.624$  bytes
  - selection, automation, security, scalability (speed)
- parallel processing (the „**cloud**“)
  - > 10.000 processors simultaneously
- no more „unlimited“ processing, storage and bandwidth
  - **bandwidth is bottleneck**
- data location does matter (where to store data?)
  - software needs to come to data
    - -> need for **cooperation** (incl. community projects)
    - -> IPR issues

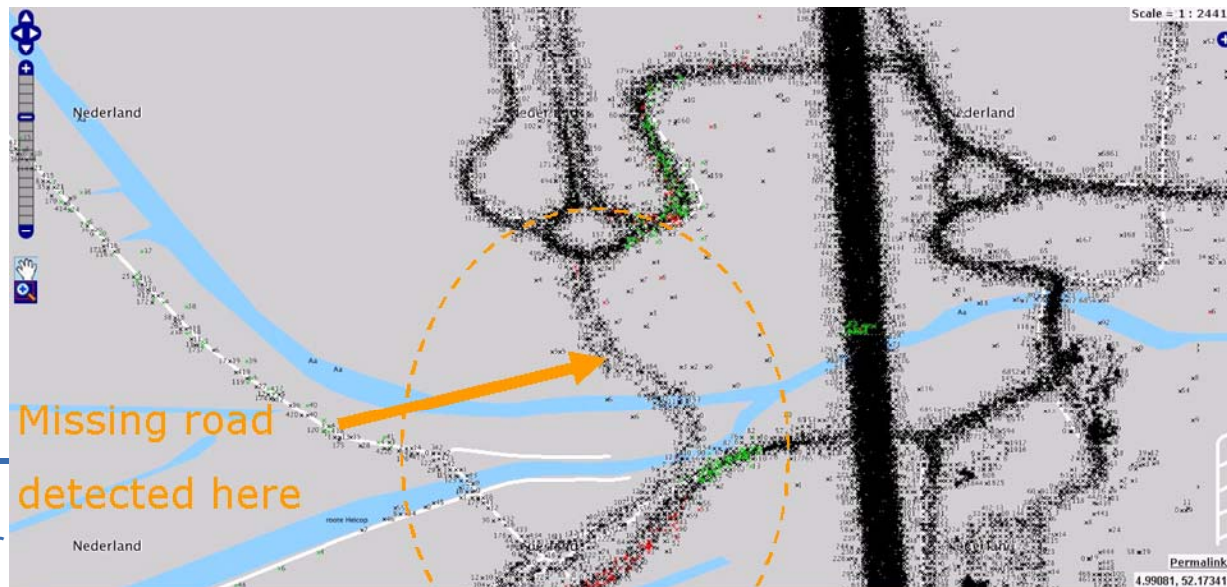


# Information & Communication Technology

- **Internet time, instant accessibility of services**
  - 24/7, „I want it NOW“ (real-time)
- **Crowd sourcing**
  - millions of users and devices, billions of processors – new horizons
  - humans as sensors
- **Open\_X and interoperability**
  - **software**: increasing use in GI, OSGeo
  - **data**: OpenStreetMap, free sat. images of medium resolution
  - **standards**: OGC solutions: WMS, WFS, CityGML, ...
- **Sensor web and the Internet of things**
  - communication between devices
  - $33,3 * 10^9$  devices by 2020,  $26 * 10^9$  of which fully autonomous



# Crowd sourcing and VGI



© Teleatlas, 2008



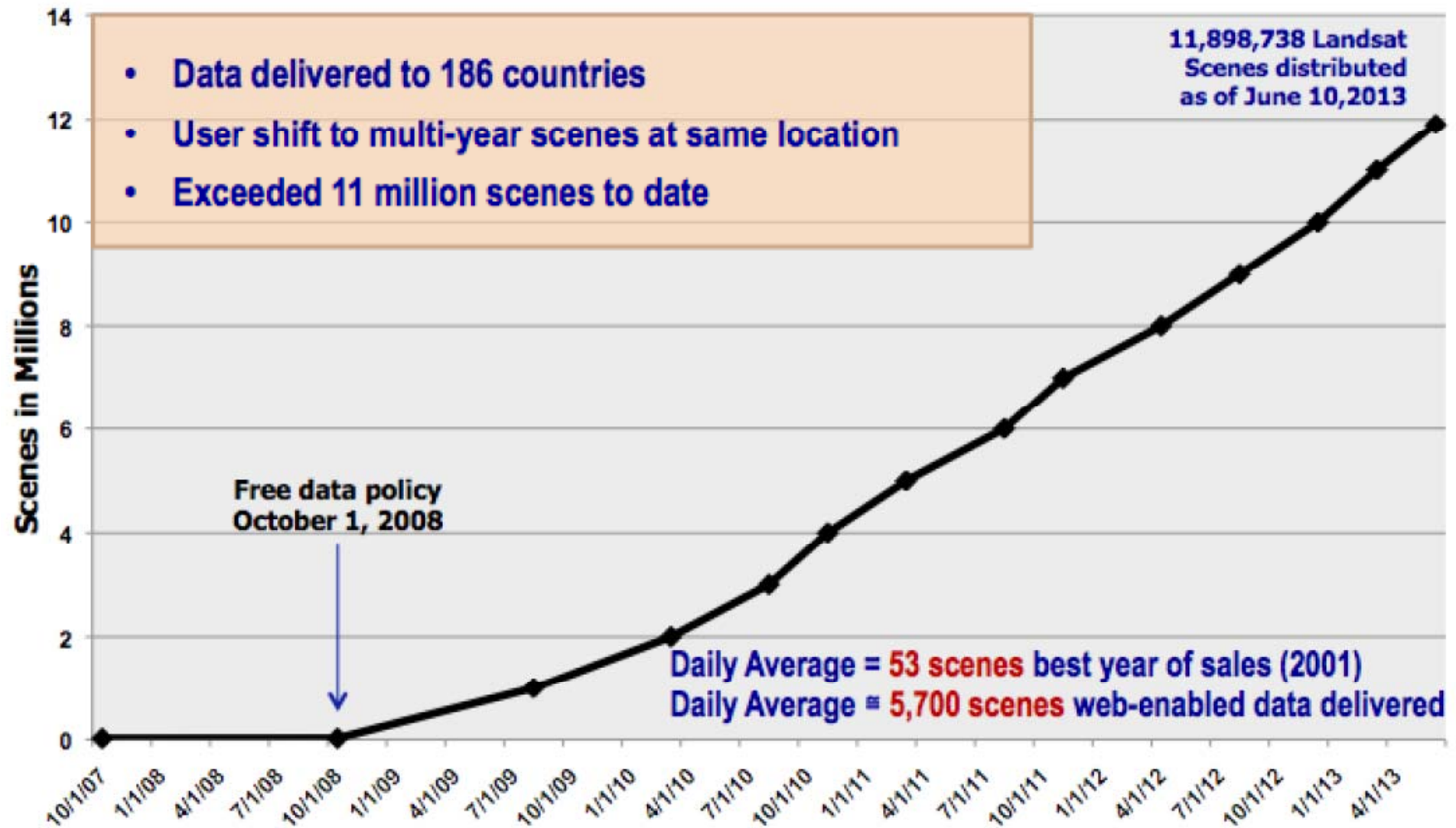
Institut für



Leibniz  
Universität  
Hannover



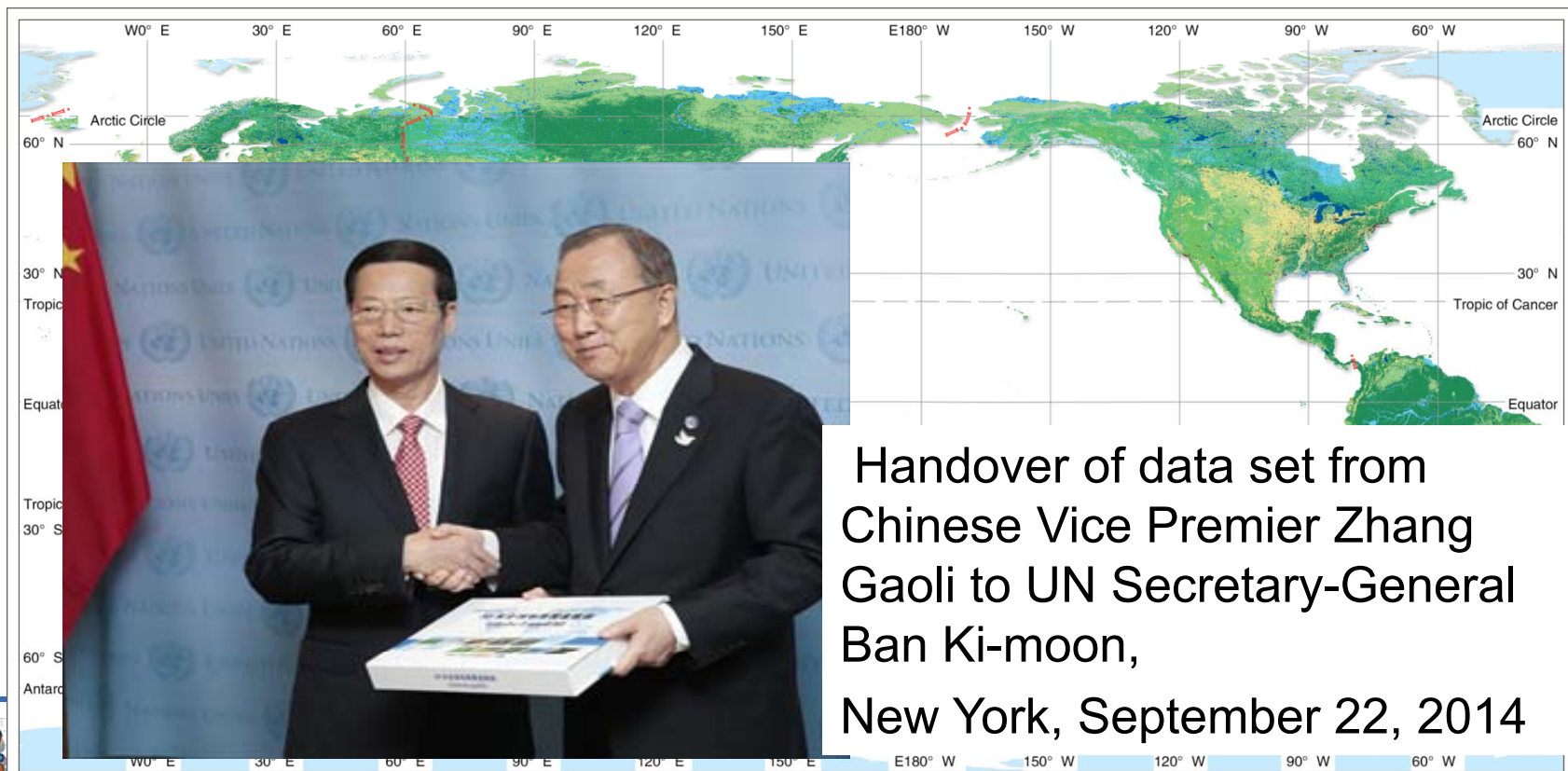
# Increasing demand for free Landsat data





# Global landcover data @ 30 m (2000/2010)

- generated by Chinese government
- donated to UN at recent Climate Change Summit
- distribution endorsed and supported by ISPRS



Handover of data set from  
Chinese Vice Premier Zhang  
Gaoli to UN Secretary-General  
Ban Ki-moon,

New York, September 22, 2014

# Trends in photogrammetry and remote sensing



# Trends in photogrammetry and remote sensing

- **new and better sensors, new platforms**
  - image sequences, oblique imaging, full waveform lidar
  - UAV, mobile mapping
- **sensor and data fusion: images, point clouds etc.**
- **update, change detection, monitoring**
- **real-time monitoring** (traffic, safety and security, ...)
- **distributed processing**
  - geosensor networks, cloud computing
- **terrabbytes (and soon petabaytes) of dump data (pixels) per day**



# Digital aerial cameras

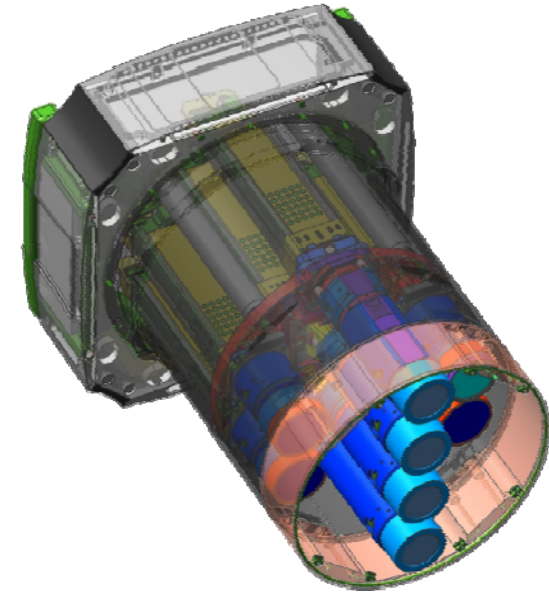


ADS – Leica

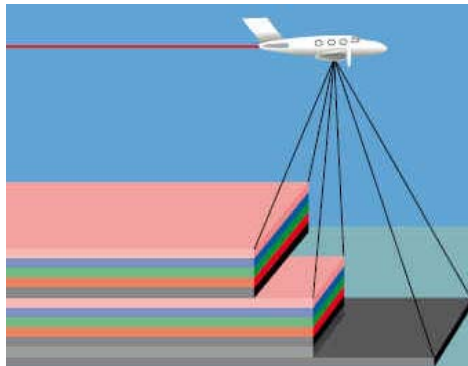


© Intergraph

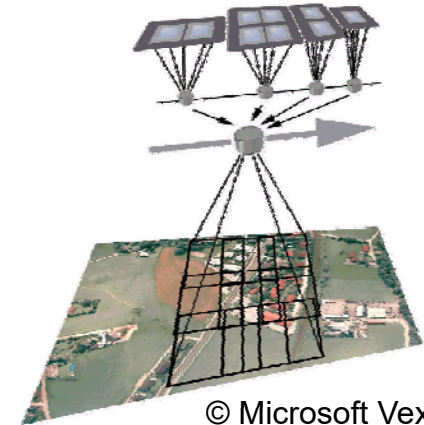
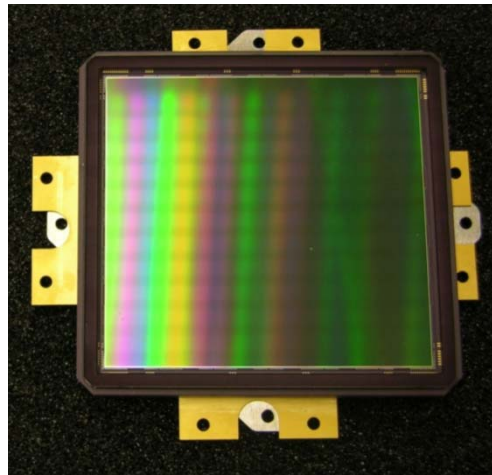
DMC – ZI-Imaging



UltraCam Eagle –  
Microsoft Vexcel



© Leica

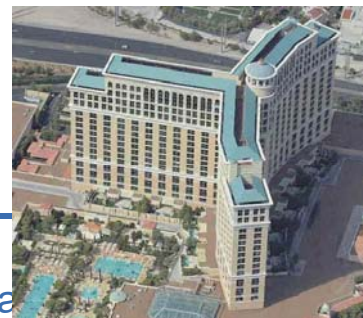
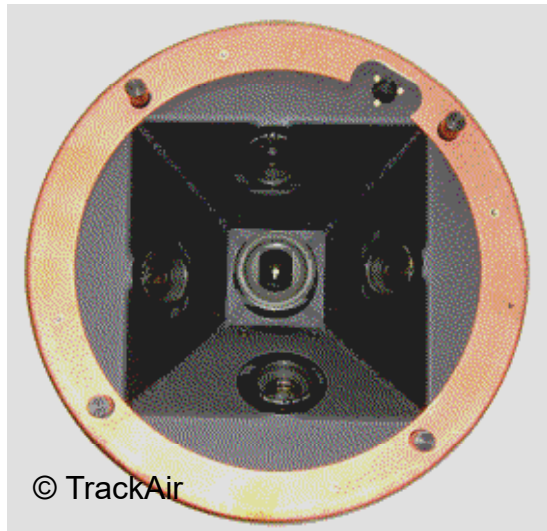


© Microsoft Vexcel





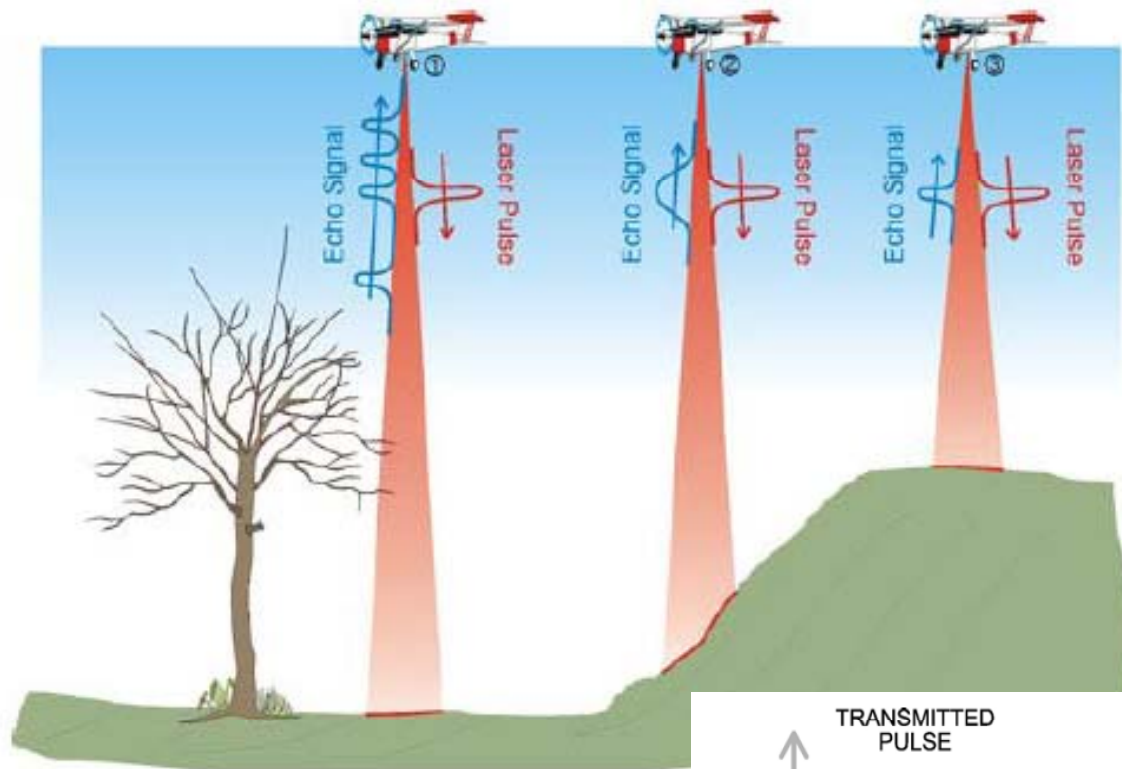
# Vertical + oblique viewing



© Pictometry



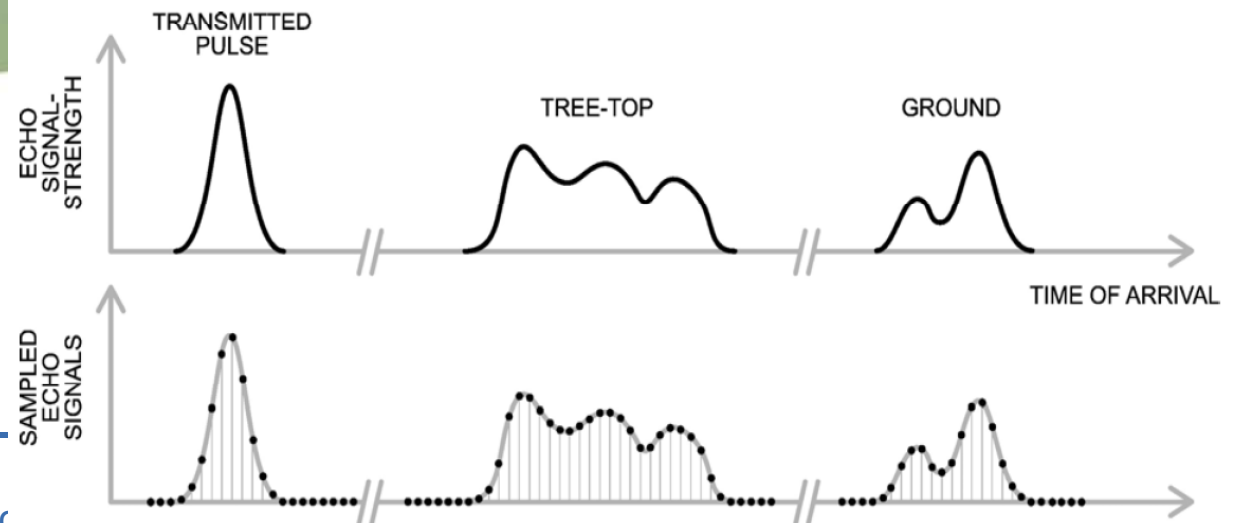
# Laser scanning - Lidar



© Hug et al., 2004

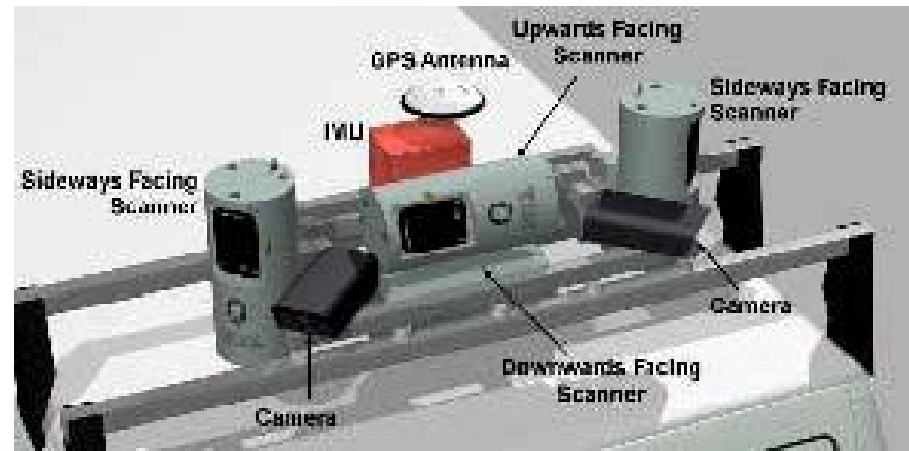
- multiple echoes
- full waveform

© Wagner et al., 2006

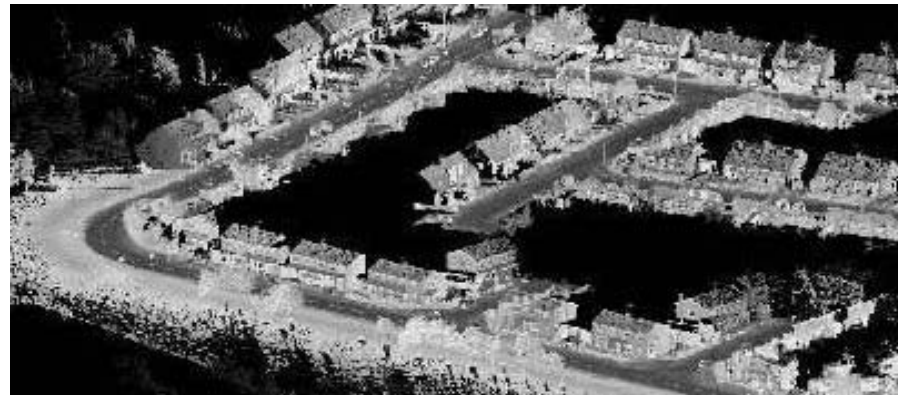




# Mobile mapping systems



© Streetmapper, UK



# Unmanned aircraft systems



# Change of coast lines



Juist, Westteil

© Thorenz,

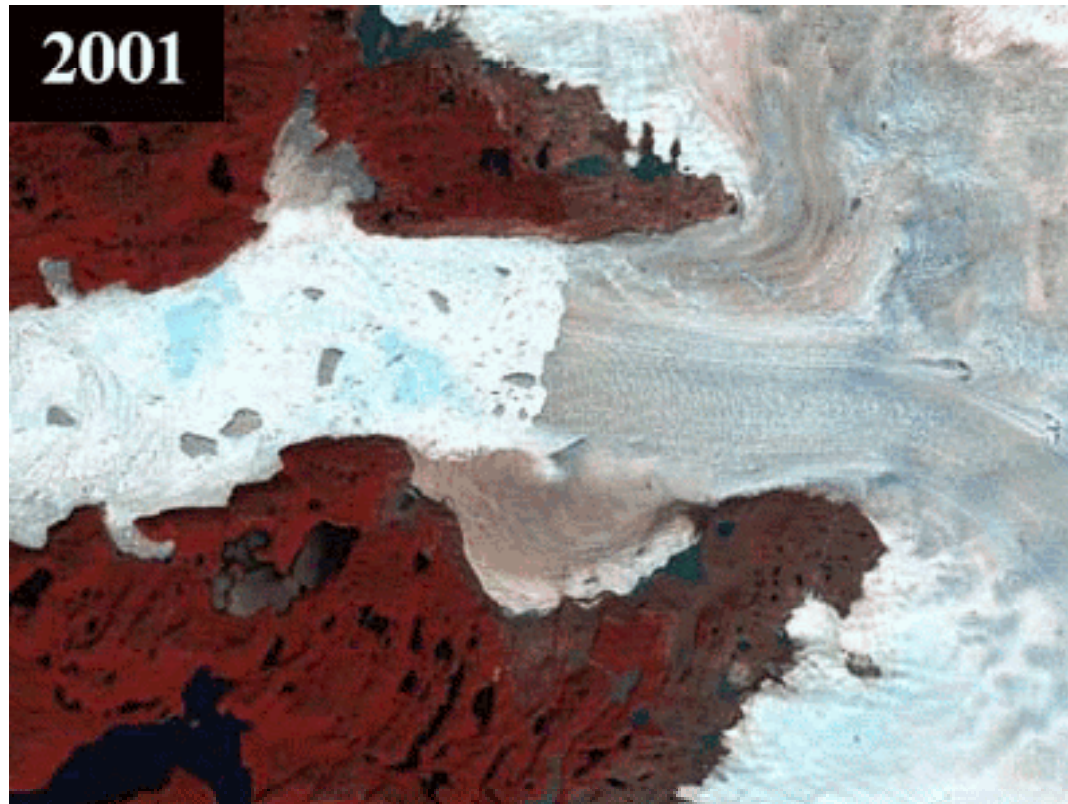
NLWK 2005

Coast line approx.  
1960





# Glacier movement



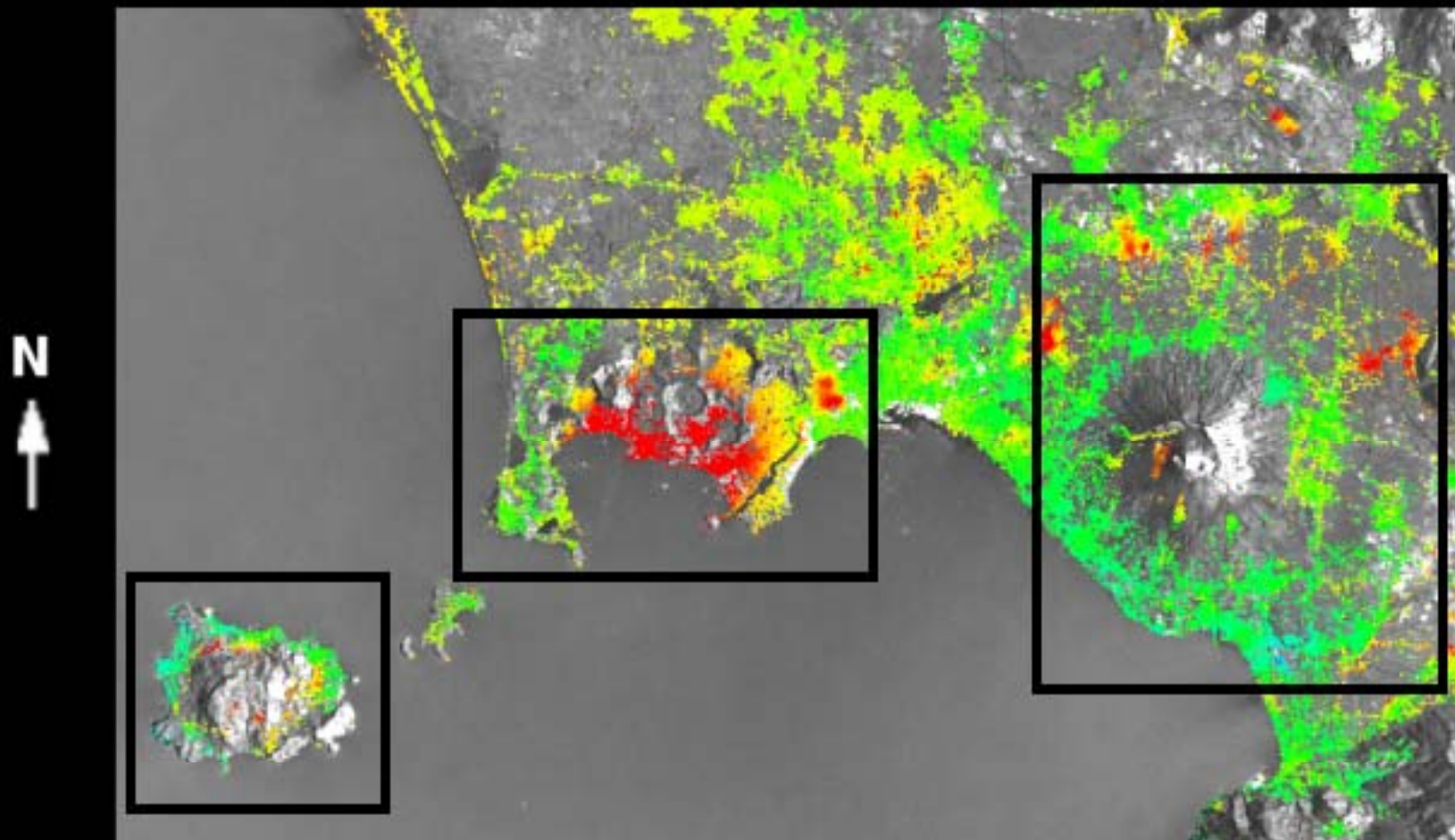
Landsat images of Jakobshavn Isbrae, Greenland  
Maas et al., PFG 2006



**IREA-CNR**

[www.irea.cnr.it/webgis](http://www.irea.cnr.it/webgis)

**Napoli Bay (1992-2003)**



**Height changes**

# Land cover – time series

Landsat time series (80 m), Las Vegas - [Google Earth Engine](#)





# Multi-temporal data acquisition

Feb

Mar

Apr

May

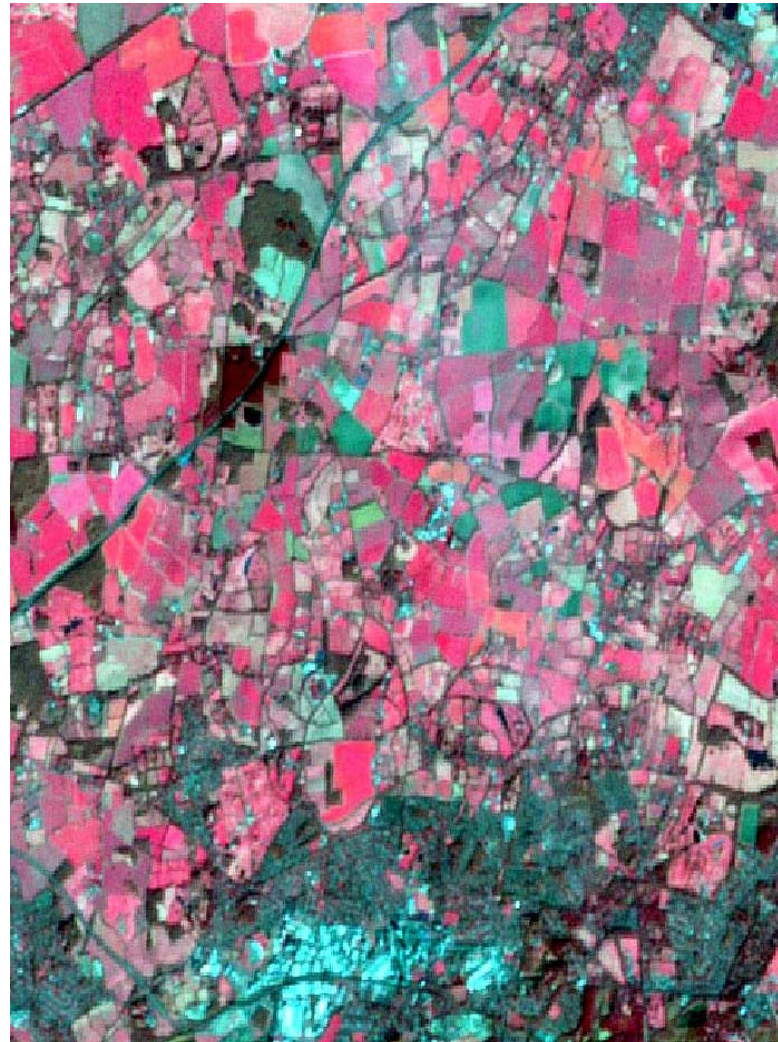
Jun

Jul

Aug

Sep

Oct



# Multi-temporal data acquisition

Feb

Mar

Apr

May

Jun

Jul

Aug

Sep

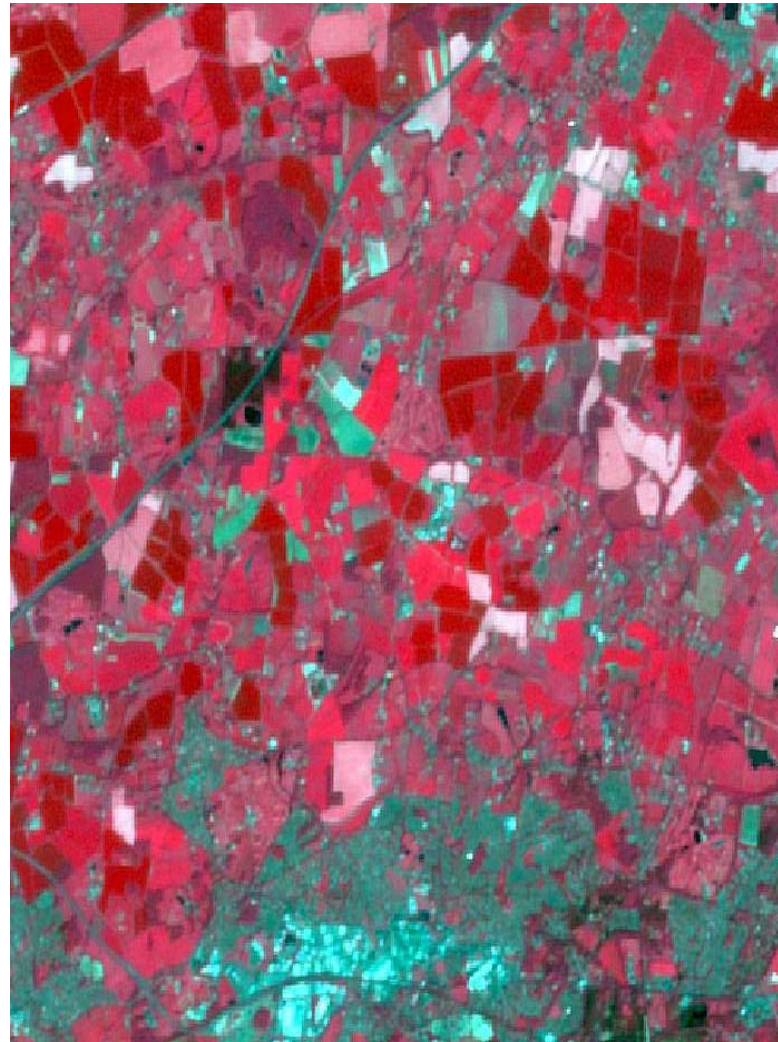
Oct





# Multi-temporal data acquisition

Feb  
Mar  
**Apr**  
May  
Jun  
Jul  
Aug  
Sep  
Oct



# Multi-temporal data acquisition

Feb

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Apr

May

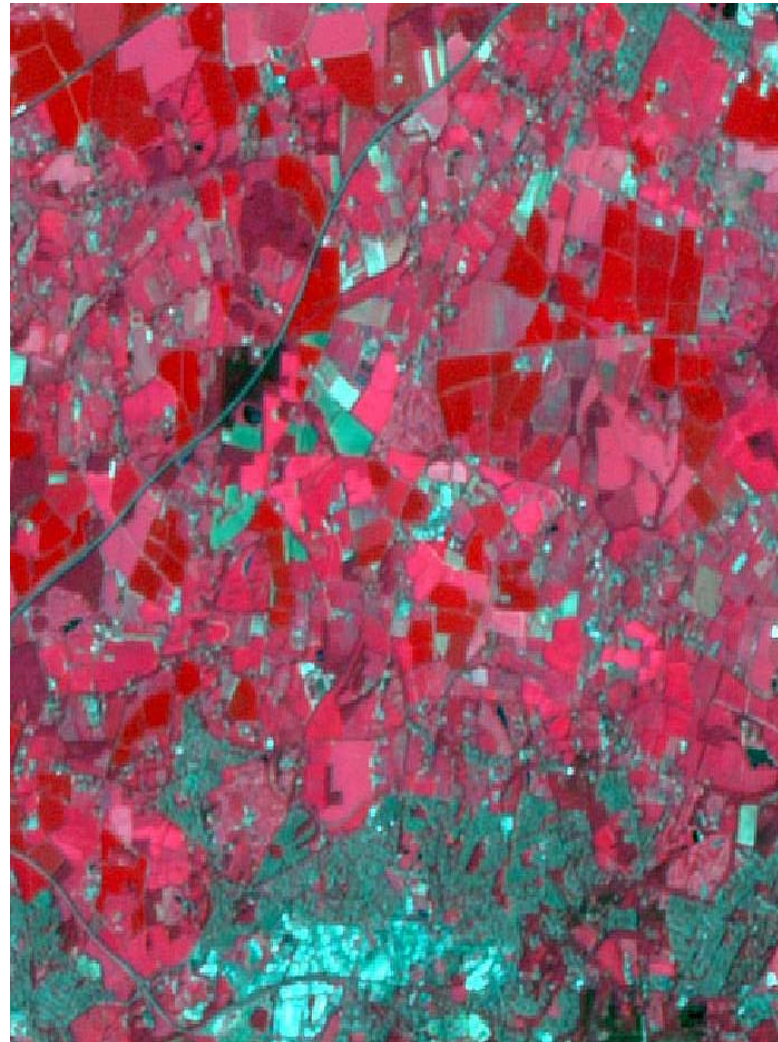
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# Multi-temporal data acquisition

Feb

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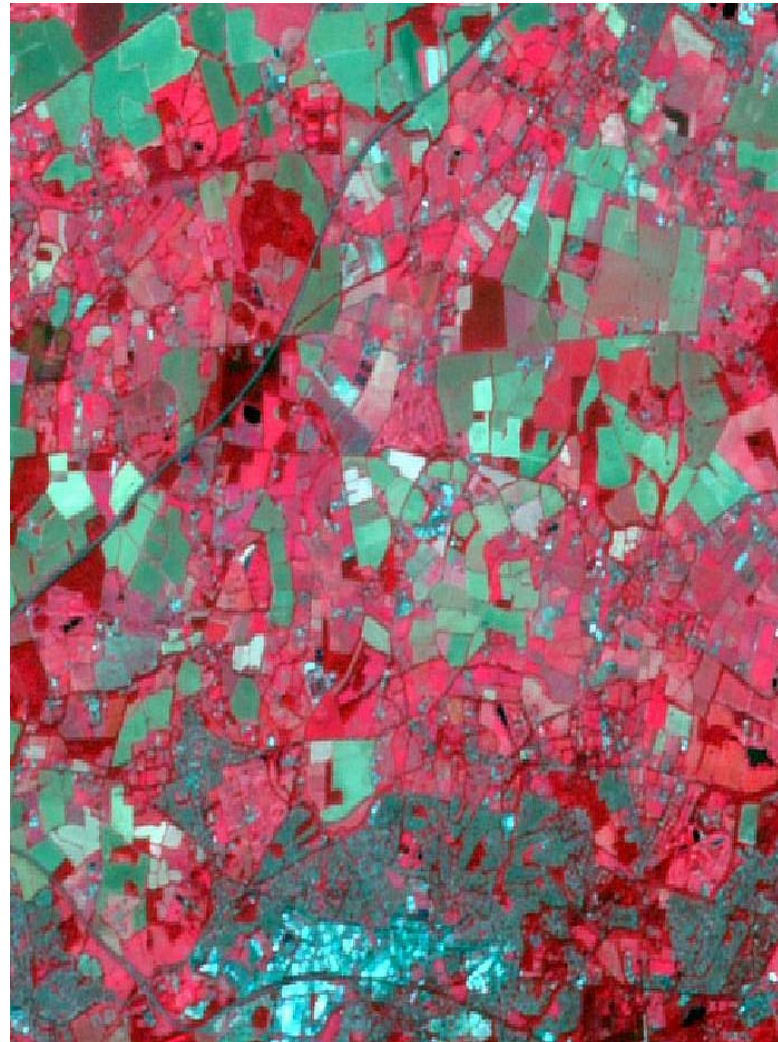
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# Multi-temporal data acquisition

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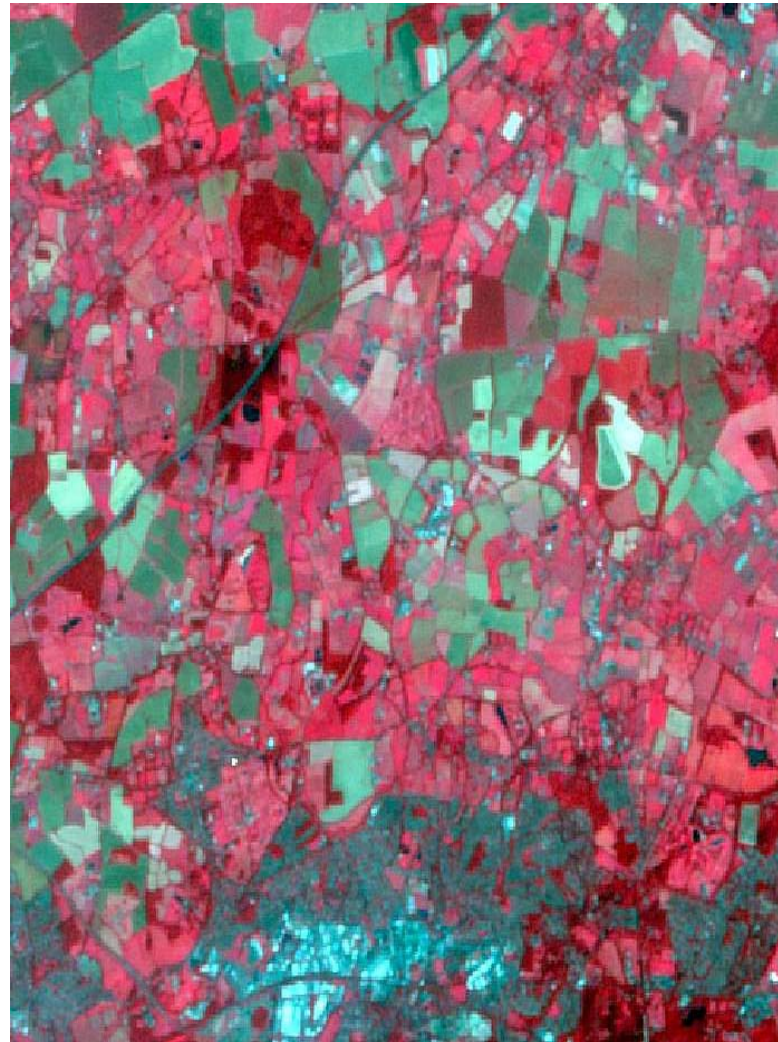
Jun

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# Multi-temporal data acquisition

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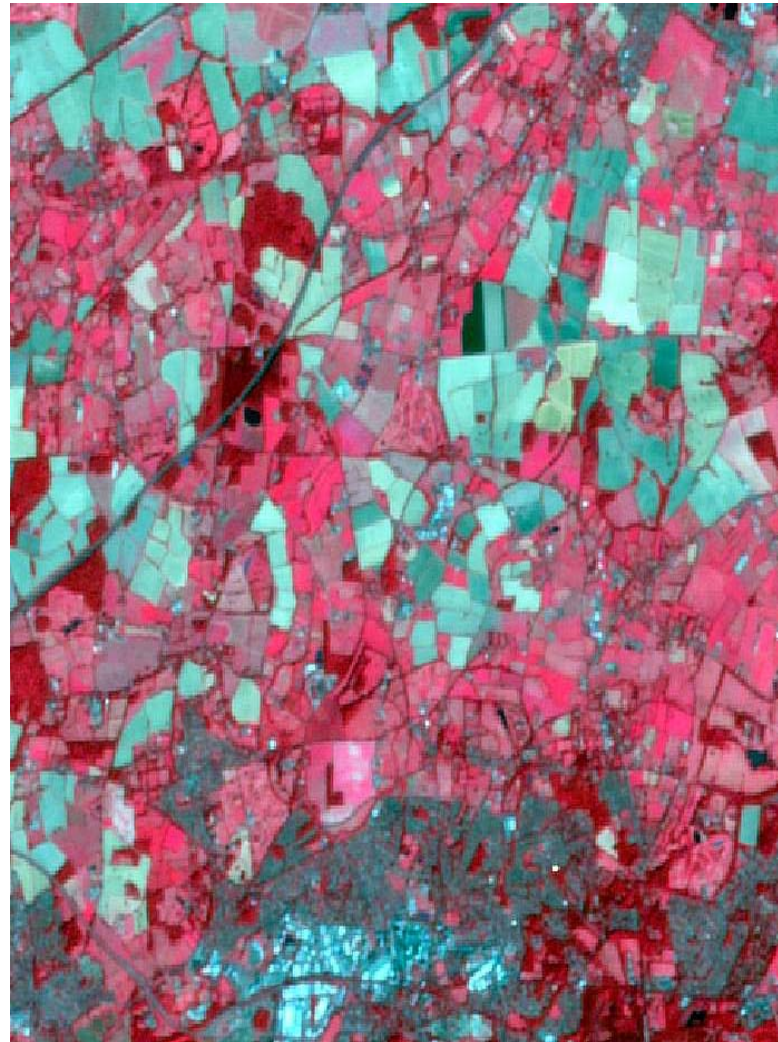
Jun

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# Multi-temporal data acquisition

Feb

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# Multi-temporal data acquisition

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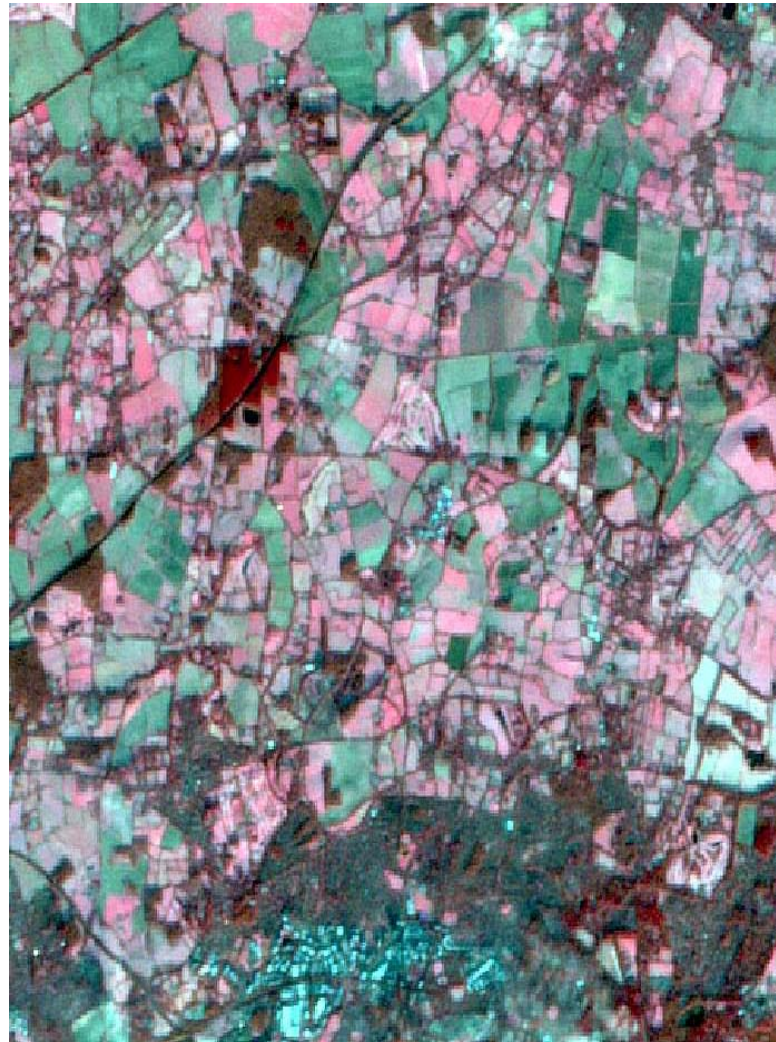
Jun

Jul

Aug

Sep

Oct



# Real-time processing and new markets



Referee Jorge Larrionda, Uruguay (June 27, 2010): **no goal**

[http://www.sportschau.de/sp/fifawm2010/news201006/27/wembley\\_tor.jsp](http://www.sportschau.de/sp/fifawm2010/news201006/27/wembley_tor.jsp)





# Photogrammetry and tourism - consumer market products



Noah Snavely - <http://phototour.cs.washington.edu/bundler/>

basic development for Microsoft Photosynth

Web based bundle adjustment



# Photogrammetry and the movie industry - consumer market products

- **John Gaeta, Oscar 2000 winner** (visual effects in THE MATRIX):

“We began with this idea of dimensional representation of a space and performances in the 1990s, when people first started connecting spatial analysis and **photo-grammetry** with computer graphics....”

- **Photogrammetry:**  
**reality-based 3D modelling**



Motion and  
modelling capture  
for Spider Man 2



# Status-quo of data acquisition for GI

- **digital** imaging, completely digital workflow
  - **automatic** orientation (georeferencing)
  - **automatic** DSM/DTM capture
  - **automatic** generation of orthophoto mosaicks (true orthos)
- 
- **MANUAL** feature collection - > **automatic image analysis**



# Automatic relative orientation



*Manhattan, scale 1:24.000, 73 conjugate points, 12.5  $\mu\text{m}$  pixel size,  $\sigma_0 = 4.7 \mu\text{m}$*

*Images courtesy of The Ohio State University*





# Automatic aerial triangulation

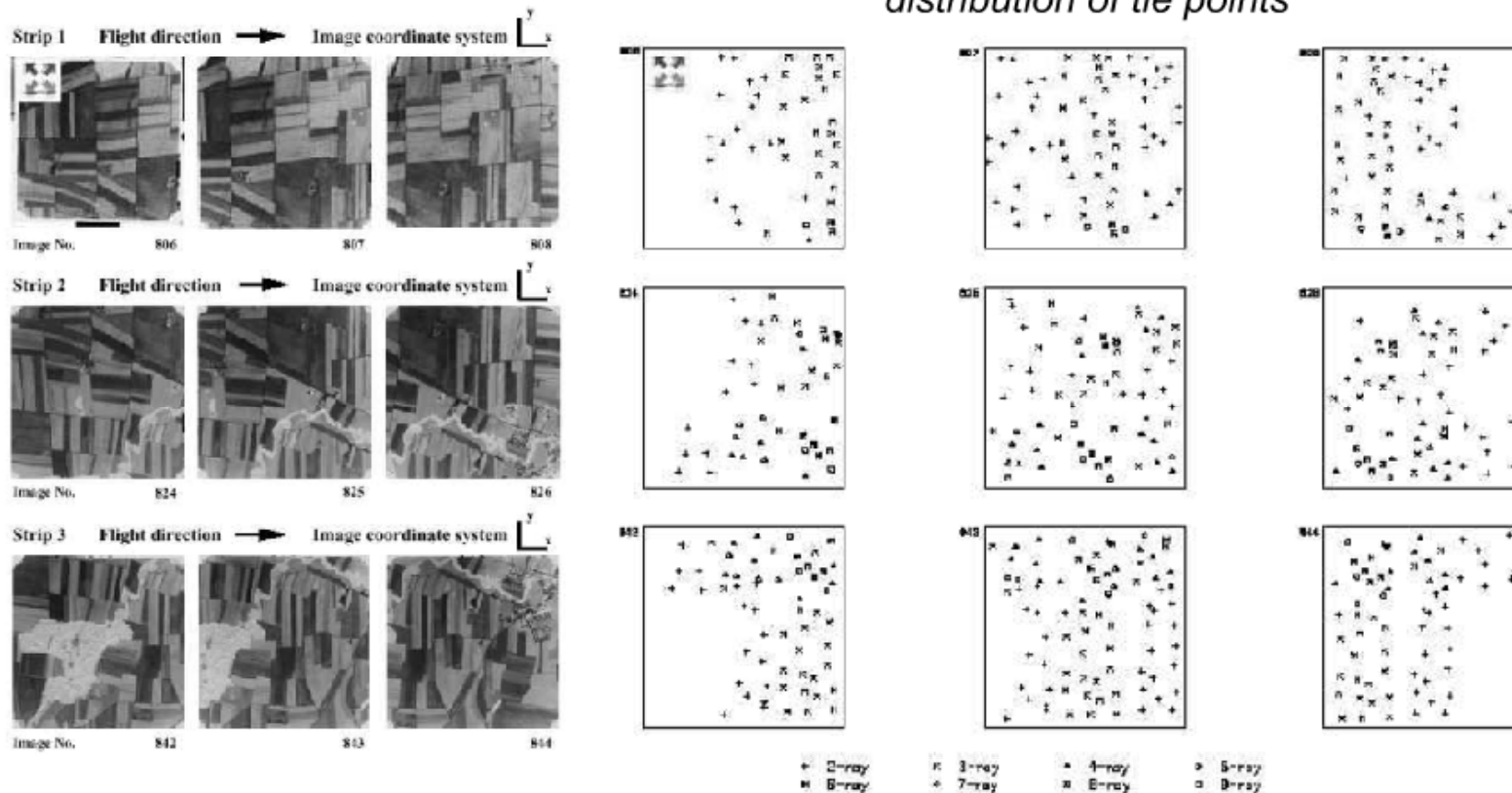
Example Echallens  
wide angel lens

$$\sigma_n = 4 \mu\text{m} = 0.2 \text{ pixel}$$

RMS at independent check points:

3 cm in planimetry,  
4 cm in height

*distribution of tie points*





# Derivation of DSM - Digital Surface Model



Untextured 3D reconstruction



Textured 3D reconstruction



# Image analysis

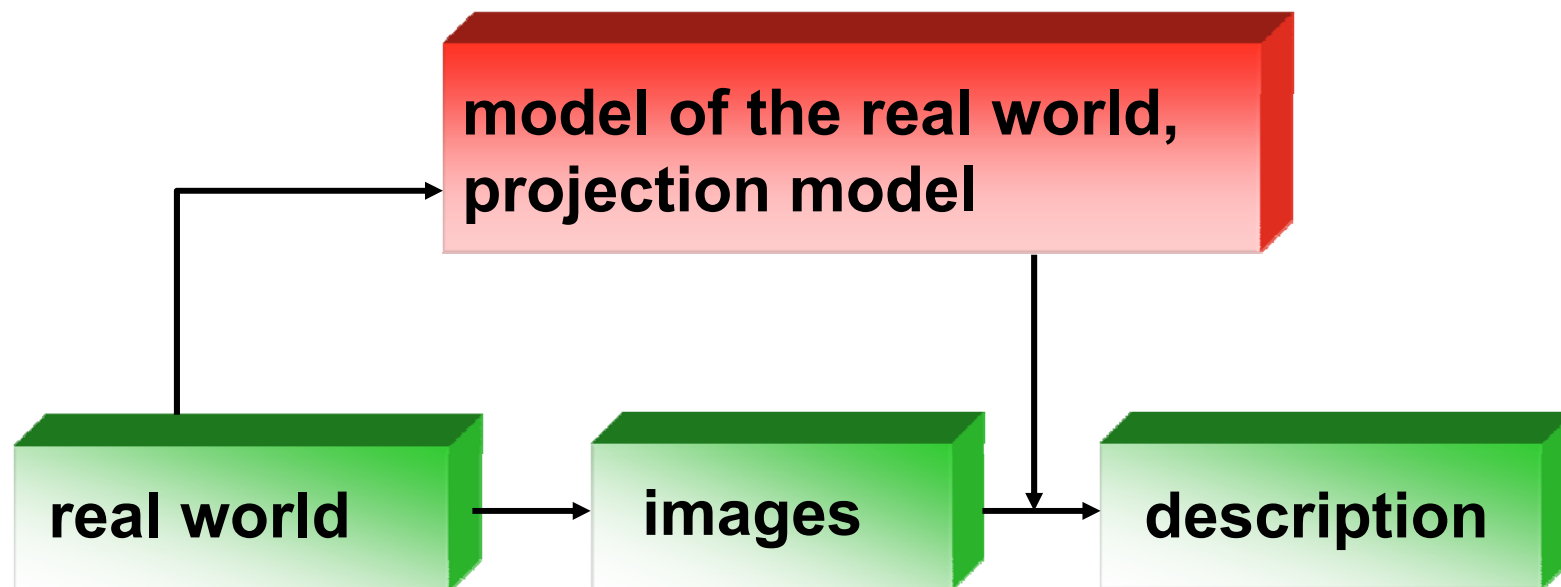
- Typical questions
  - Were are the roads?
  - Which building is this?
  - How many people live here?
  - Which type of animal is this?
  - I would like to have an image concerning this topic
  - I need more images concerning this building
- Identification, localisation, typification, recognition of detail, search (e.g. on the web)



# Image analysis - definition

automatic generation of an explicit meaningful description  
of physical objects in the real world from images

(Rosenfeld, 1982)



# Strategies in image analysis

- Automatic recognition of objects in sensor data requires  
knowledge about objects
- Differentiation according to employed type of knowledge:

## Model based approaches

- Knowledge incorporated in the form of explicit object models
- Object classes are treated separately (no/little relations)

## Statistical approaches

- Knowledge is learnt from examples
- Image is treated as a whole (incl. context)



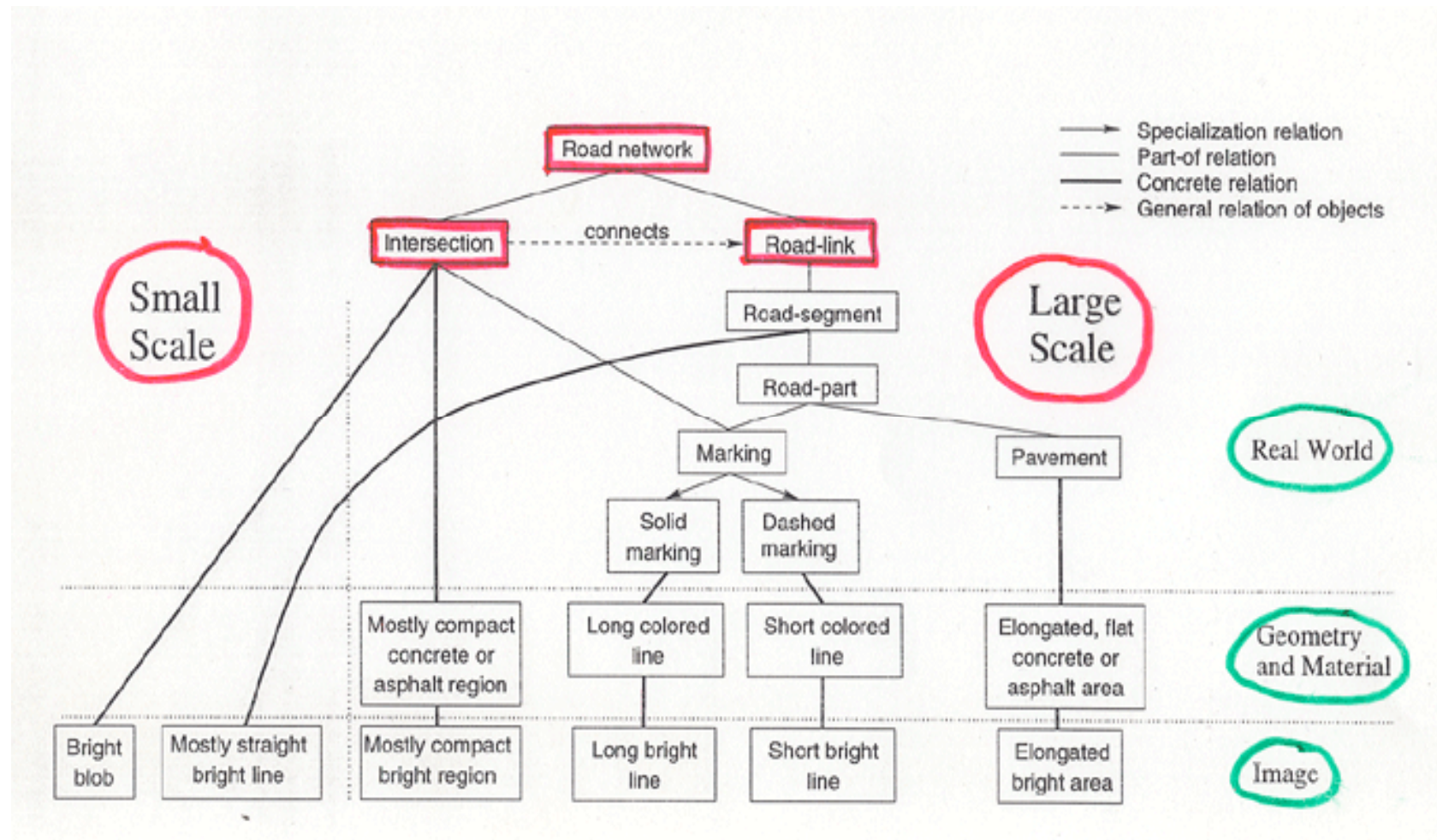
# Examples

...





# Road extraction in rural areas



Mayer 1998





## Result

Rural areas:  
completeness and  
correctness up to 90 %

Baumgartner et  
al.1999





# Road extraction based on NC segmentation



Good correctness, completeness to be improved

- fusion of multiple road models
- road crossings to be considered separately



Grote et al.2011







**On the need for multiple road models**



# Road extraction based on snakes



Ravanbakhsh et al.,  
2008



# Building and tree ex- traction from image and lidar data

Grangemouth

Size of the testsite 60,000 m<sup>2</sup>

No of Trees	235
Completeness	95%
Correctness	89%

Error in Position	0.9 m
Error in Height	0.2 m
Error in Radius	0.7 m





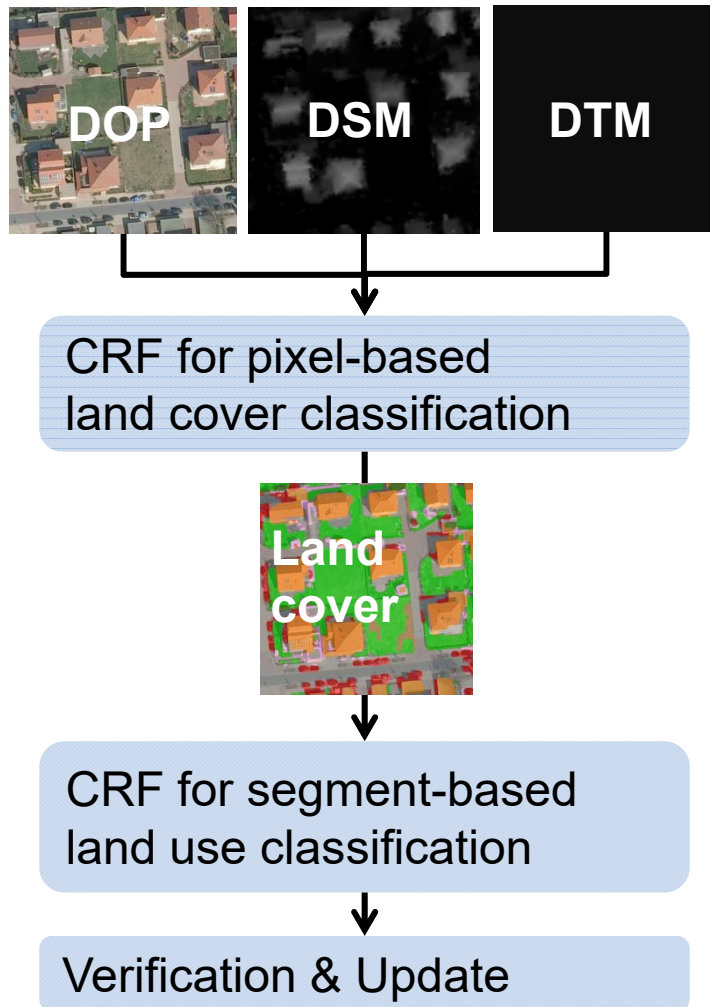
# Building and tree ex- traction from image and lidar data





# LU / LC classification in cadastre

WORKFLOW



L. Albert et al., ISPRS TC IV 2014





# Land cover classification

Ground truth



CRF approach



Random Forest (RF)  
classification



Overall accuracy:

Kappa index:

81.3 %

76.2 %

80.2 %

74.9 %

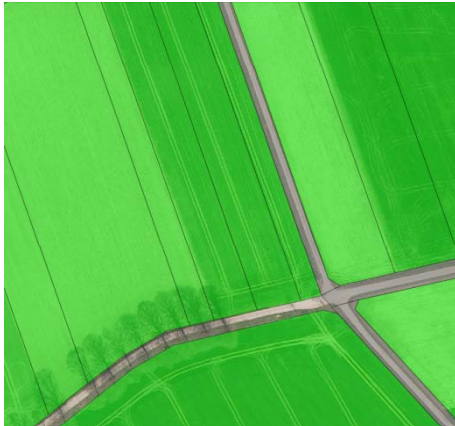


L. Albert et al.,  
2014



# Land use classification

Ground truth



CRF approach



RF classification



L. Albert et al.,  
2014



- settlement
- road
- railway
- water
- agriculture
- forest
- others

Overall accuracy:  
Kappa index:

85.5 %  
73.4 %

85.0 %  
72.2 %



# Conclusions and outlook

Image analysis can offer today:

- good results for **simple scenes**
  - roads in open landscape
  - simple buildings in suburban areas
- good result for **special applications**
  - Quality control of GIS databases
- **first commercial** systems available

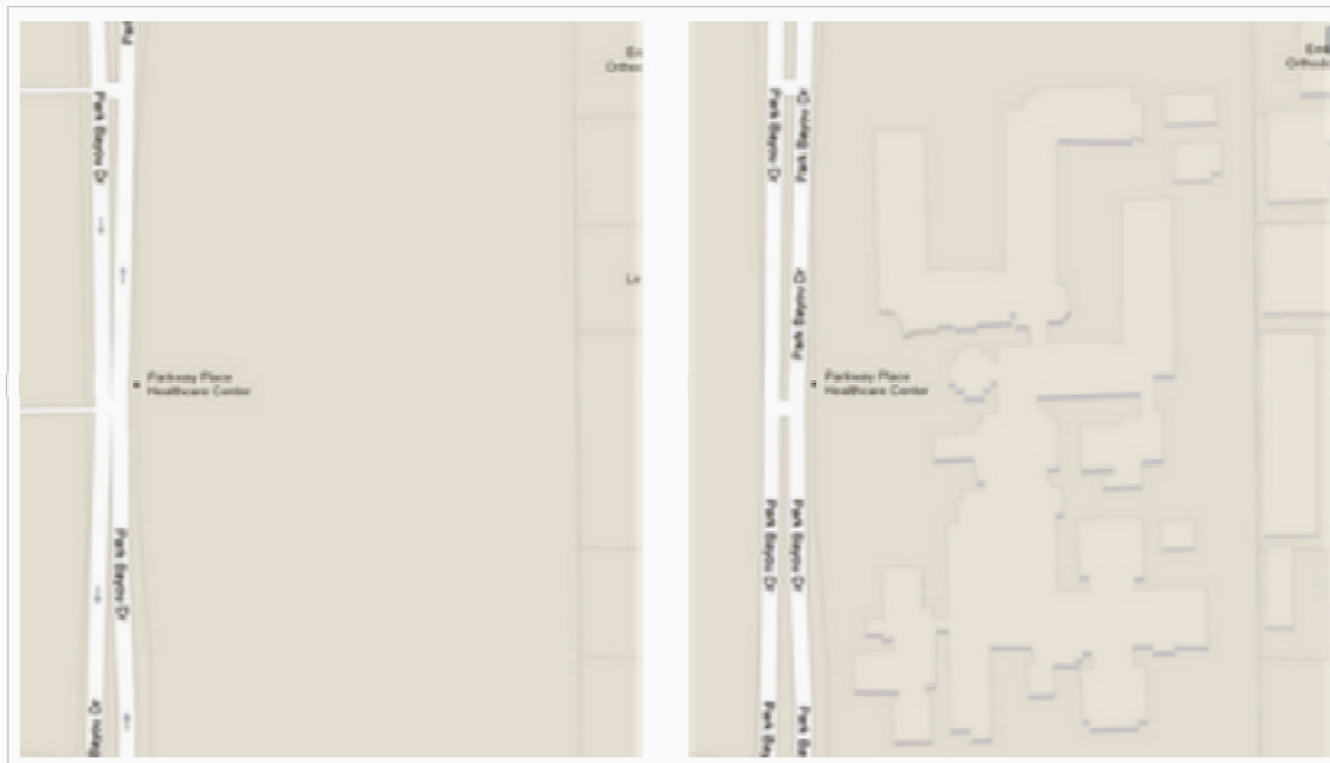


# Building footprints in Google Maps

- 25 million new building footprints added to Google Maps.
- footprints, complete with height detail, were created by taking aerial imagery and using computer vision techniques.

<http://google-latlong.blogspot.de/2012/10/expanded-coverage-of-building.html>,

(Oct. 18, 2012)





# Conclusions and outlook

- fully **autonomous solutions** still many years away
  - **machine learning** for flexible 3D object and scene models
    - simple brute force approaches with very many training data might be successful than sophisticated geometric/radiometric modelling
  - **spatio-temporal reasoning** under uncertainty, taking into account conflicts
- **automatic vision** a hope in many other areas
  - robotics, driver assistance systems, medicine, film industry, ...





Pleiades Satellite Image - Galešnjak,  
"Island of Love", Croatia

Resolution: 50 cm

Date: 12/06/2012

Copyright: CNES 2012

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