Real-time mapping of soil moisture at the field scale using ground-penetrating radar

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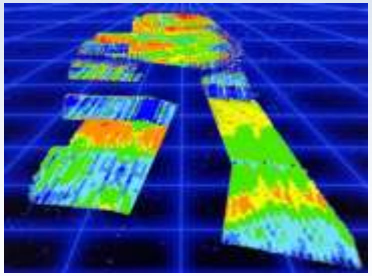


Université catholique de Louvain (Belgium)

Education

- Funded in 1425
- 26000 students, 120 nationalities
- Staff: 5500 (professors, scientists, etc.)
- Budget 360 millions EUR
- 10 Faculties, 50 departments, 200 laboratories
- 37 bachelor and 172 master programmes, etc.
- 3 science parks, 2 university hospitals
- Nobel price in medicine: de Duve, 1974
- 126th university in the world (THES 09)





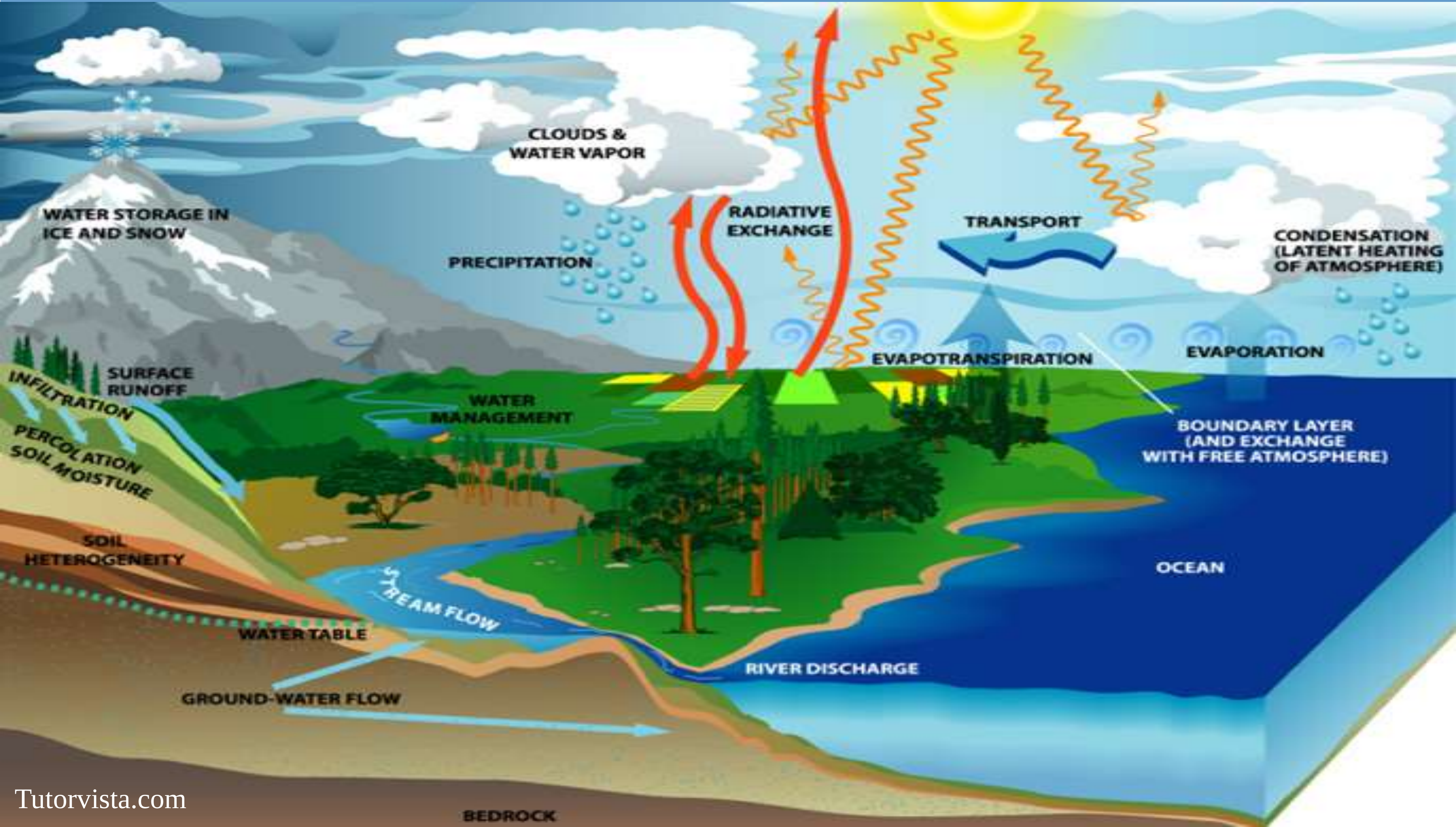

Research and Development

- Biotechnology
- Cancerology
- Environment and suistainable development
- Biomedical engineering

- Cryopreservation
- Materials
- Communication and IT
- Nanotechnologies

Introduction

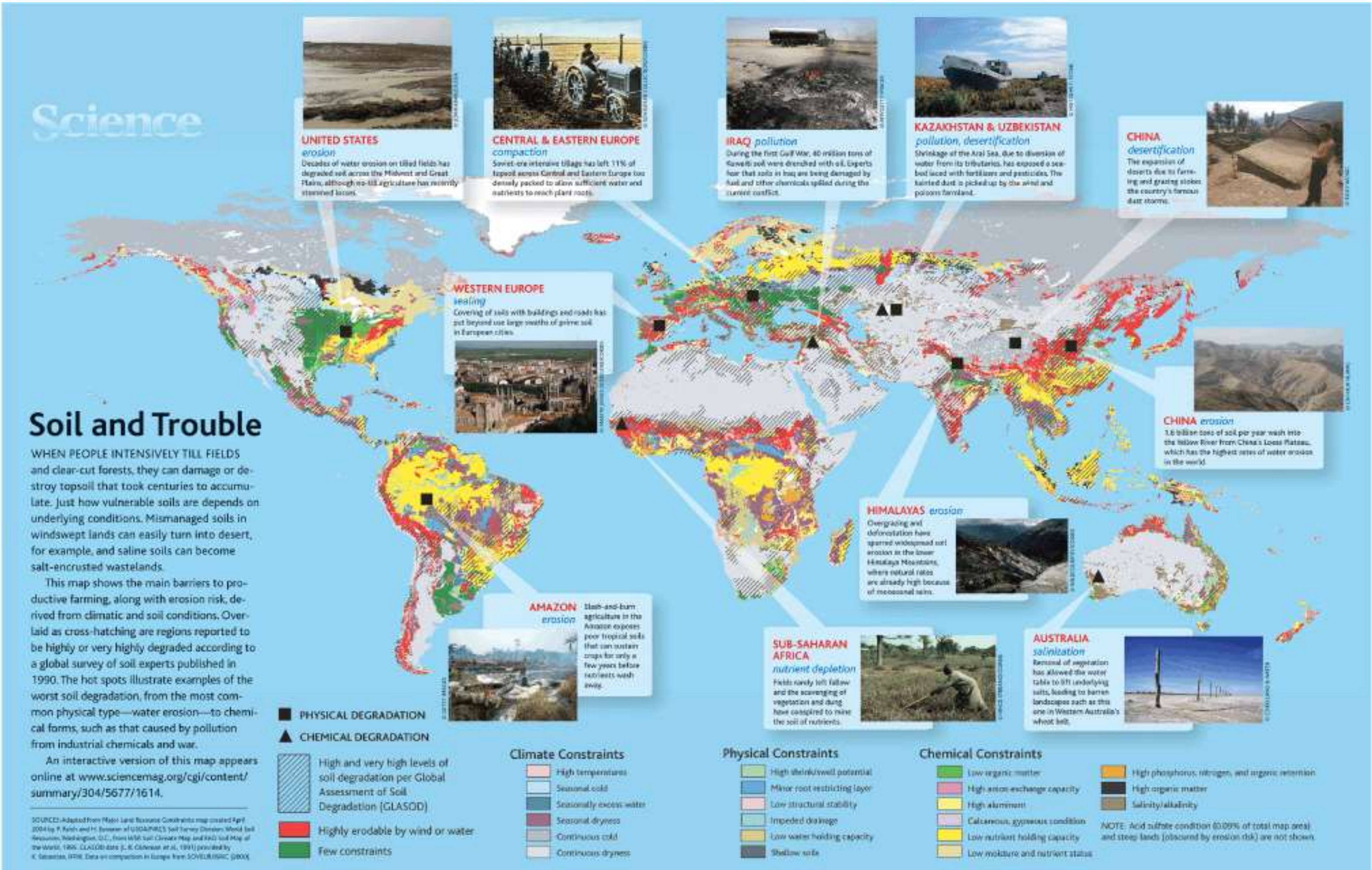
Soil moisture governs: infiltration and runoff, evaporation, energy exchanges with atmosphere, plant growth (food & energy production), contamination



Tutorvista.com

Human activities, but also natural processes, lead to soil degradation worldwide:

erosion, compaction, pollution, desertification, sealing, salinization, nutrient depletion

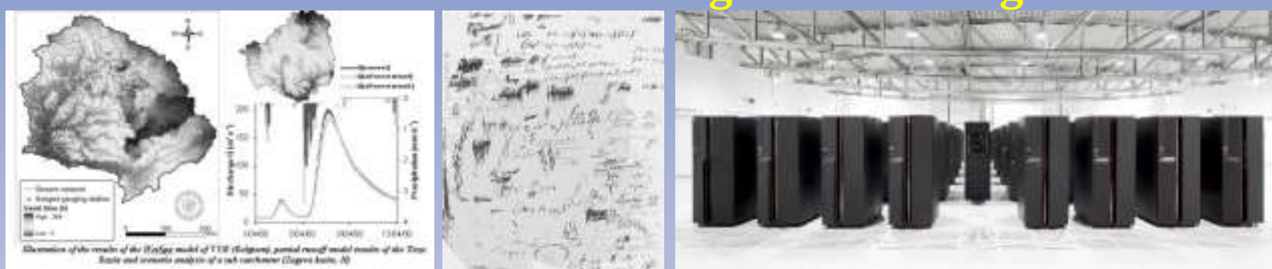


➡ from observations to optimal and sustainable soil and water management

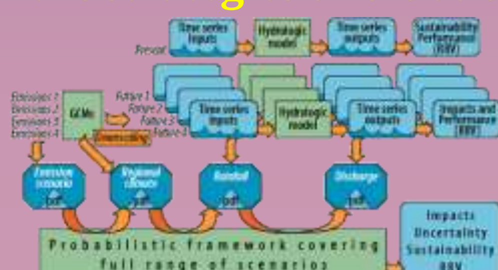
Observation: soil characterization and monitoring

Soil:
- Inaccessibility
- High variability

Process understanding and modeling



Management strategies and decision support

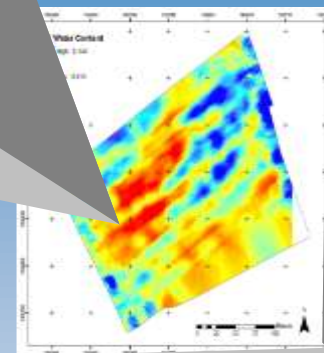


Bridging the scale gaps between observations, modeling, and management

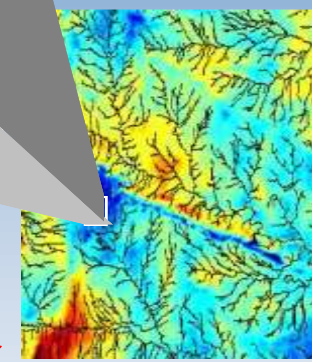
Soil moisture determination

Local scale

Field scale



Catchment scale



Soil sampling
Dielectric sensors

Advantages:

- Easy to use

Disadvantages:

- Laborious (intrusive)
- Local characterization (100 -500 cm^3)
- Shallow characterization (5-20 cm)

Geophysical methods
(ground-penetrating radar)

Advantages:

- Non-invasive
- Real-time mapping
- Root zone characterization

Disadvantages:

- Complex data processing
- Cost of equipment

Remote sensing
(airborne, spaceborne)

Advantages:

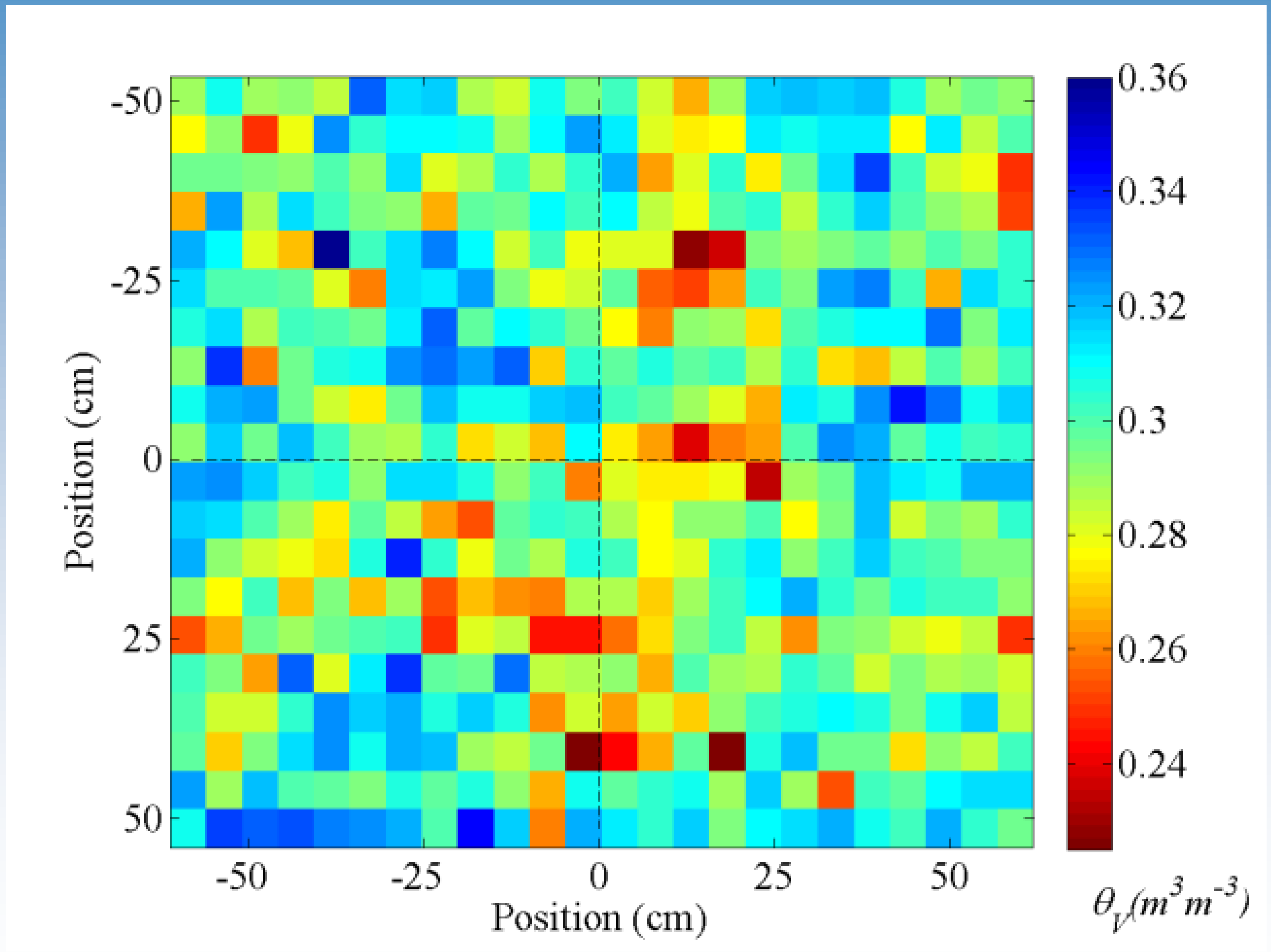
- Large scale characterization

Disadvantages:

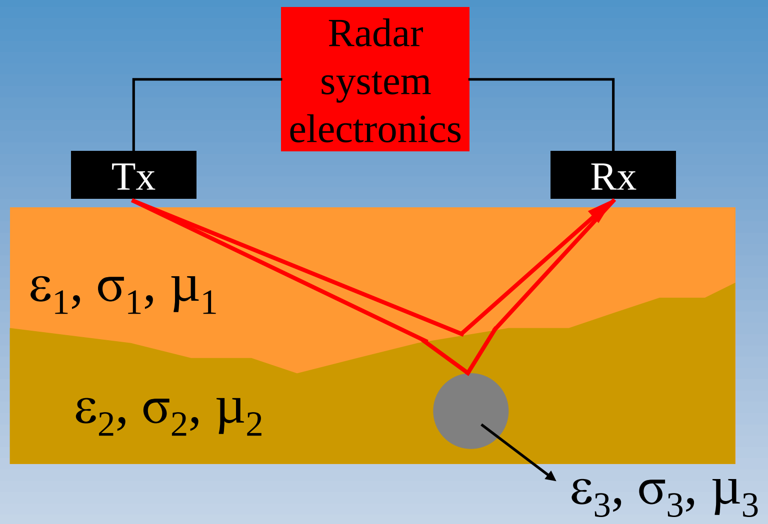
- Shallow characterization (0-5 cm)
- Availability of remote sensing data
- Accuracy limitations

Example of soil moisture variability at the 1 m² scale

➡ Local sensors are usually not representative of the larger scale moisture



Ground-penetrating radar (GPR) basic principles



- Dielectric permittivity ε ➡ wave velocity
- Electric conductivity σ ➡ wave attenuation
- Magnetic permeability μ

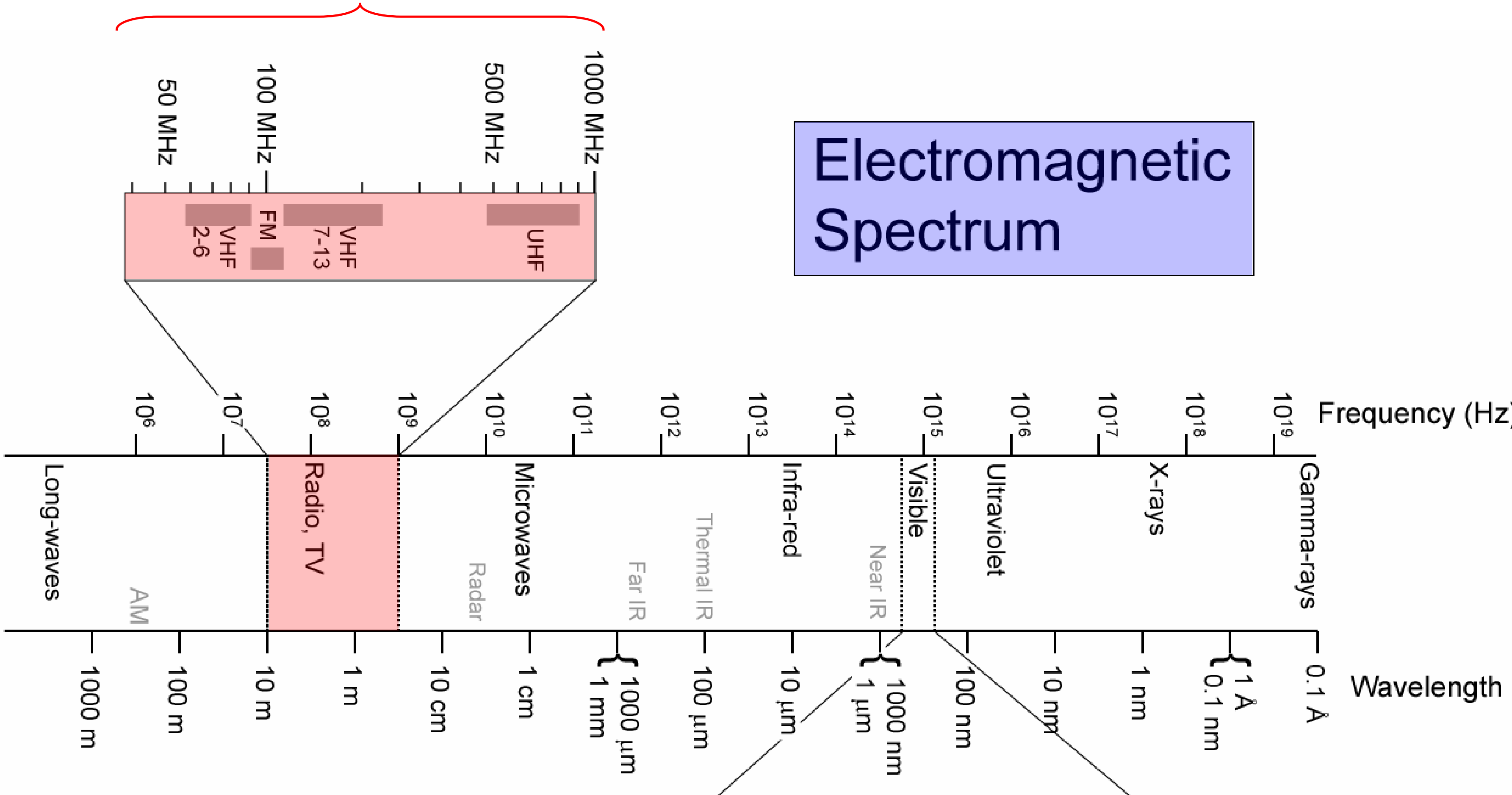
Electromagnetic contrasts

➡ Reflection, transmission

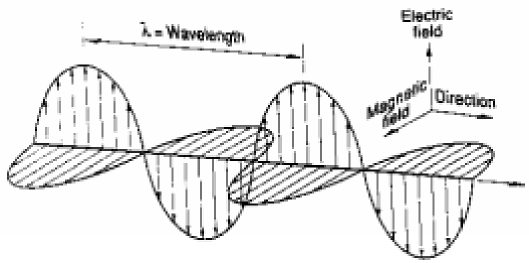
GPR operates by transmitting microwave electromagnetic energy down into the ground through an antenna. The transmitted energy is reflected from various electromagnetic interfaces. An antenna then receives the reflected signal.

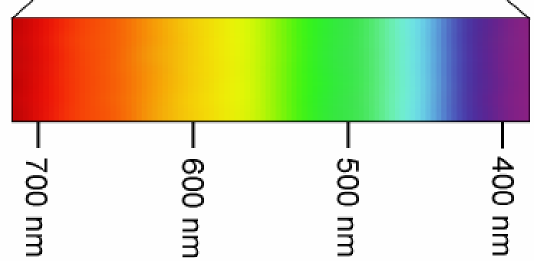
Ground-penetrating radar

Electromagnetic Spectrum

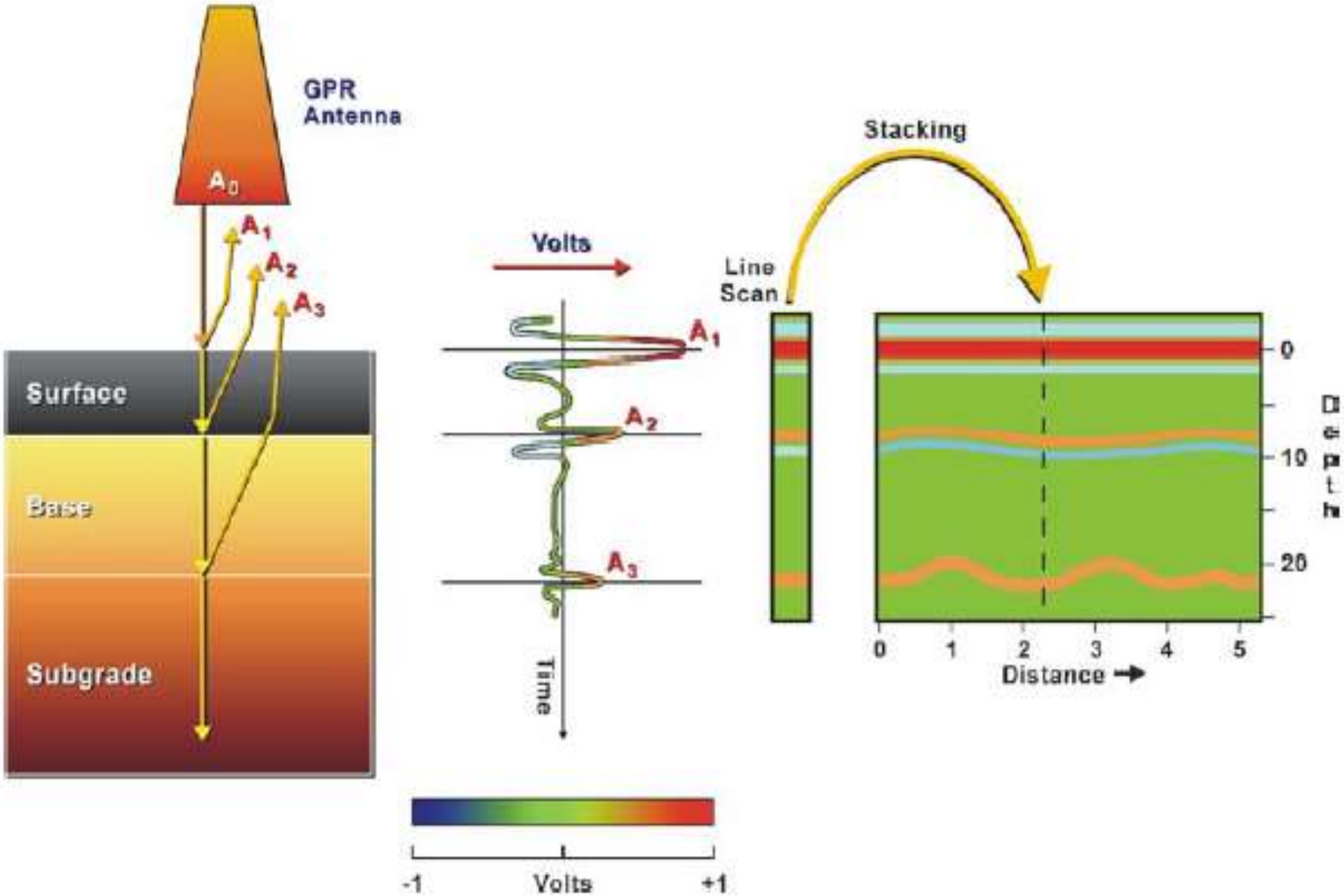


$$\lambda = \frac{c}{f}$$

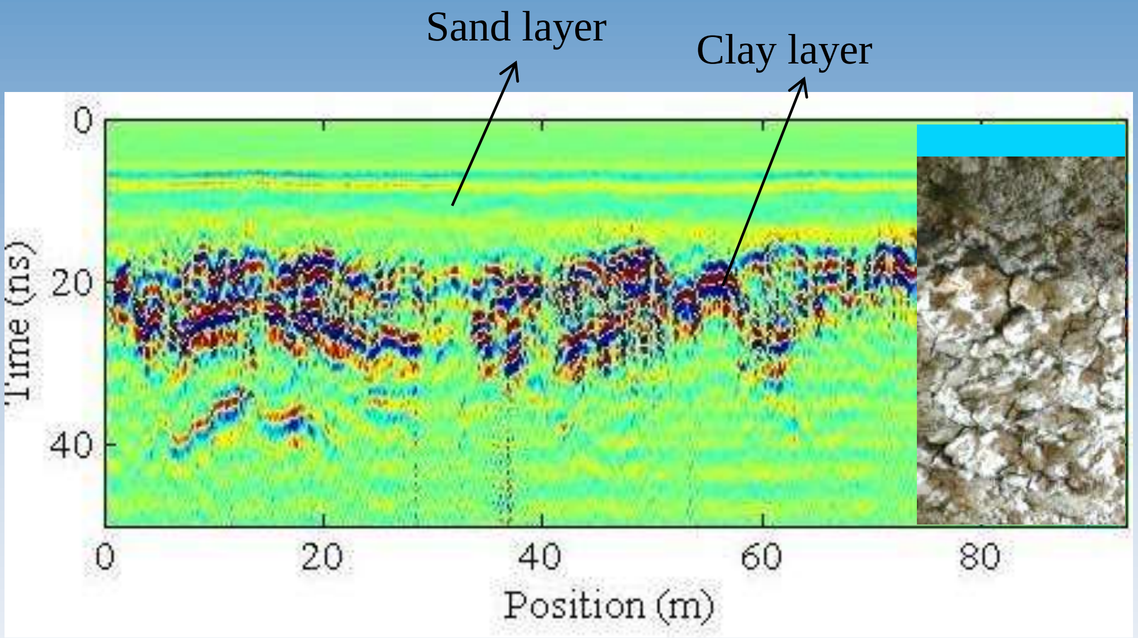




Subsurface imaging principles



Example of GPR measurements in a vineyard (Saint-Emilion, France)



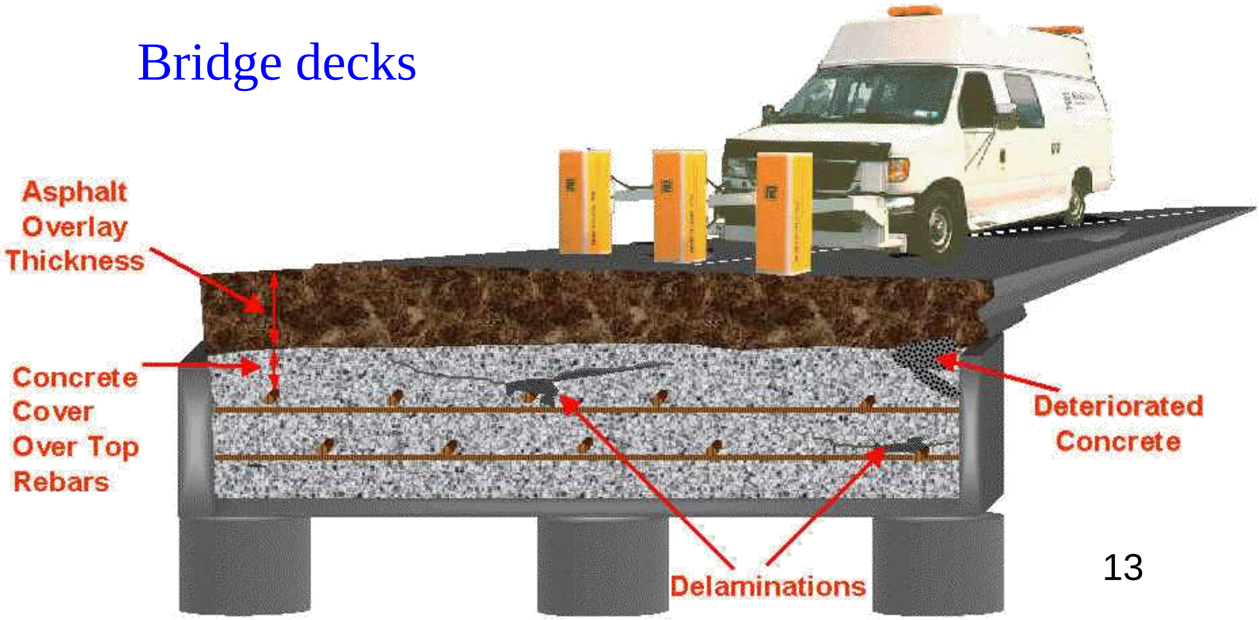
Management of city infrastructures: project control, monitoring and maintenance

Roads, underground pipes and cables

Buried tanks

Tunnels

Bridge decks



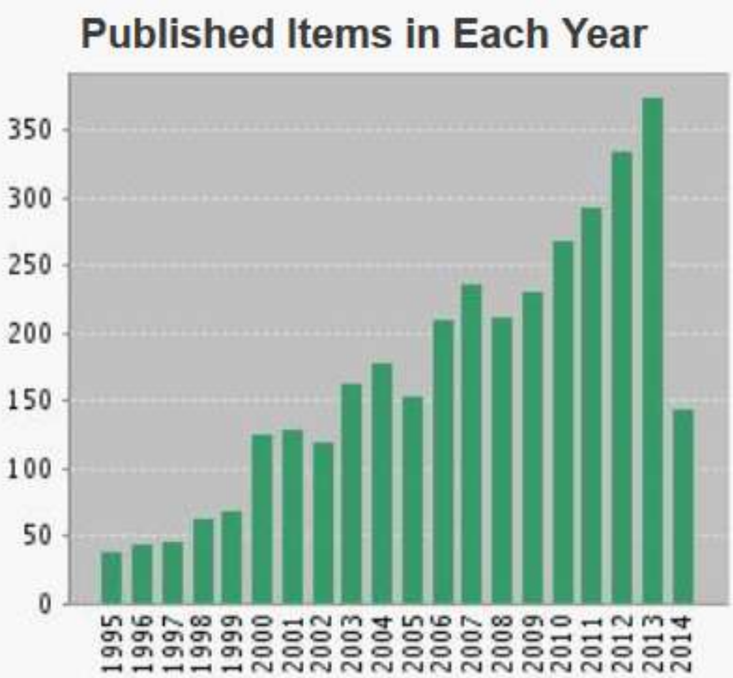
Archeology

Geology

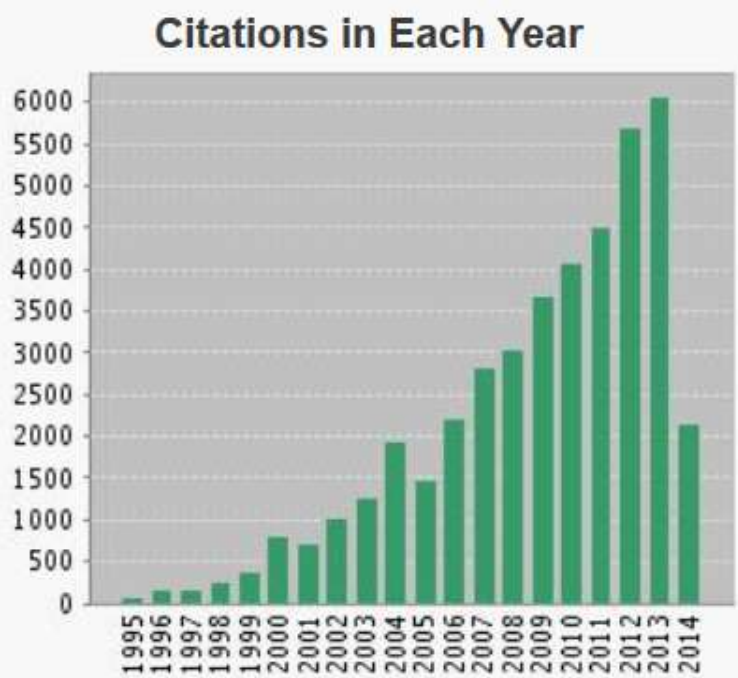
Security

Forensics

Evolution of GPR research in the world



The latest 20 years are displayed.
View a graph with all years.



The latest 20 years are displayed.
View a graph with all years.

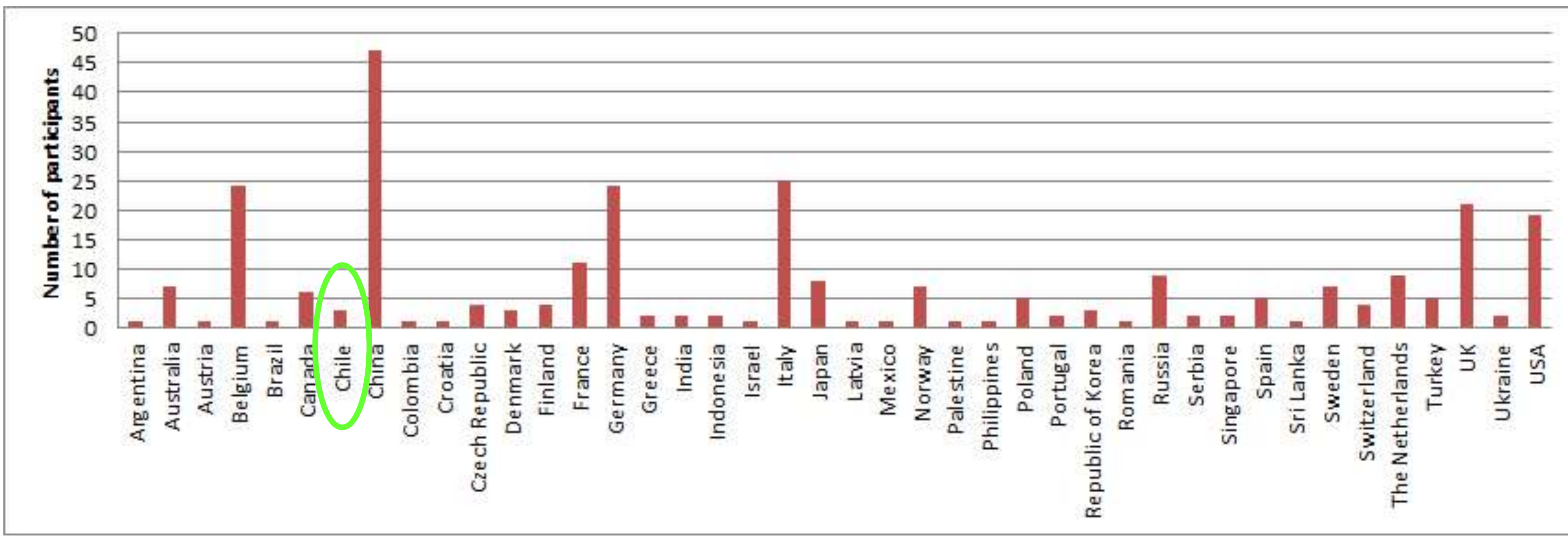
Results found:	3532
Sum of the Times Cited [?] :	42770
Sum of Times Cited without self-citations [?] :	24440
Citing Articles [?] :	18744
Citing Articles without self-citations [?] :	15827
Average Citations per Item [?] :	12.11
h-index [?] :	72

Université catholique de Louvain UCL

GPR 2014
June 30 - July 4, 2014
Brussels, Belgium

cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Participants per country (300)



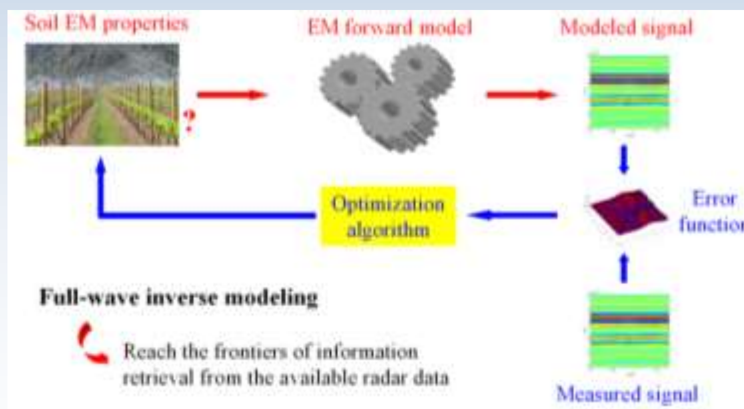
GPR for determining soil permittivity and water content

➡ Resorting to advanced GPR data processing is necessary to maximize information retrieval capabilities and accurate estimates

The UCL invention

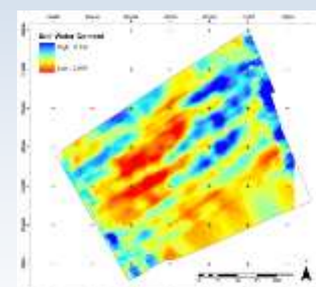
Patent PCT/EP2012/055416 (WO 2012/130847 A1)
« Method and device for characterization of physical properties of a target volume by electromagnetic inspection »
by Sébastien Lambot, Université catholique de Louvain, Belgium

System design



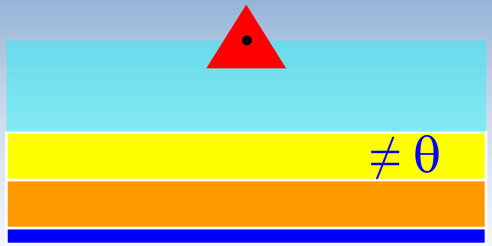
Signal inversion

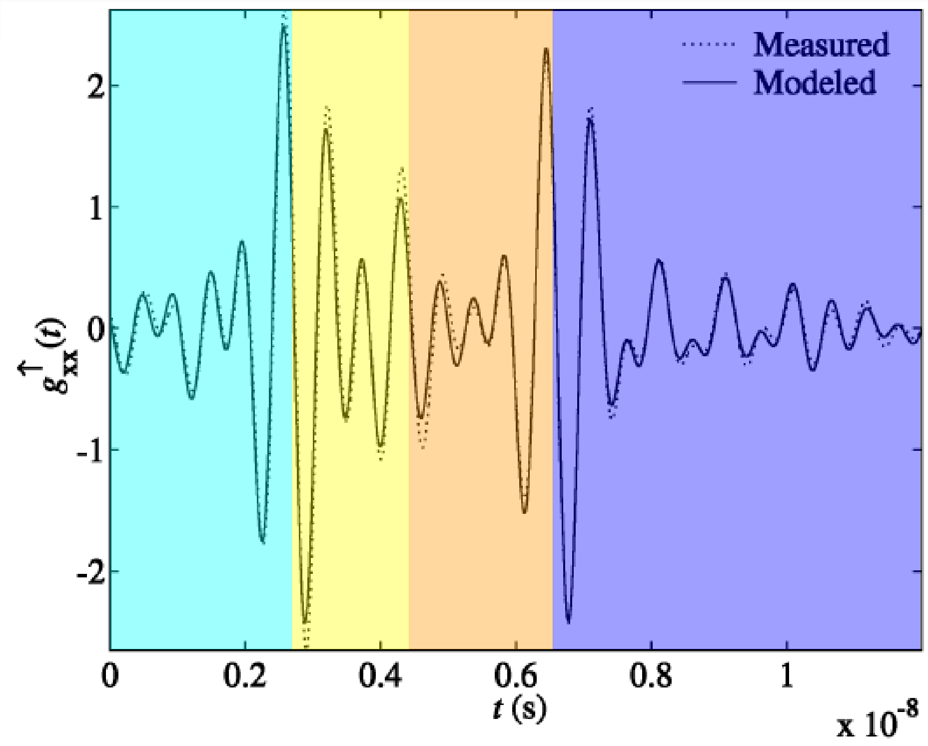
Product



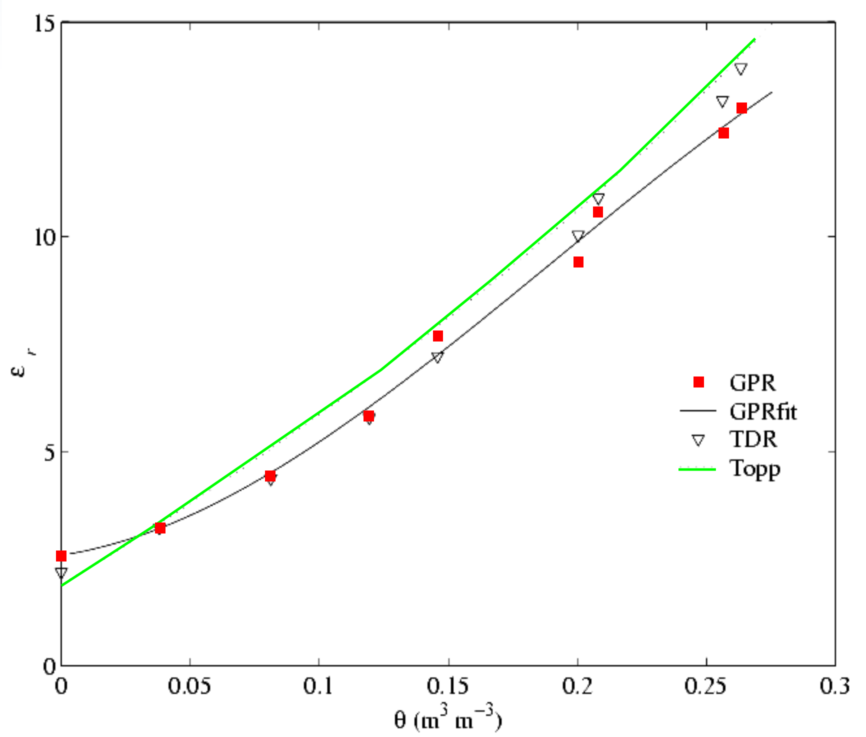
Electromagnetic model validation

Configuration





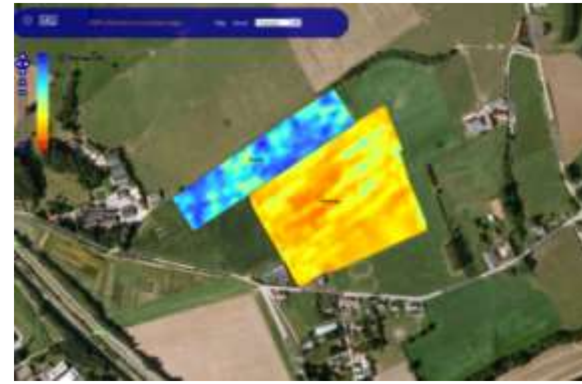
Frequency domain



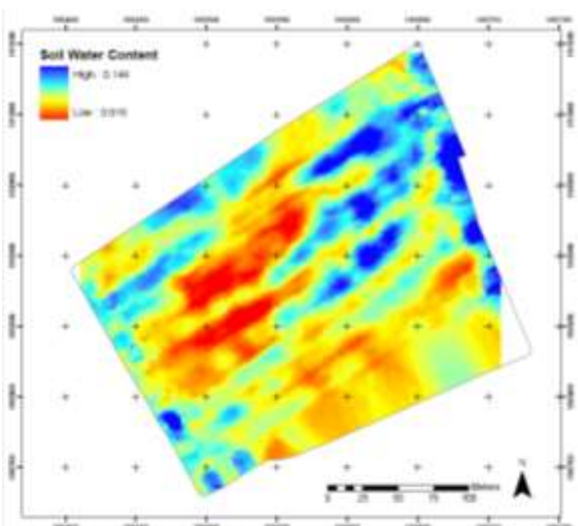
Inversion results

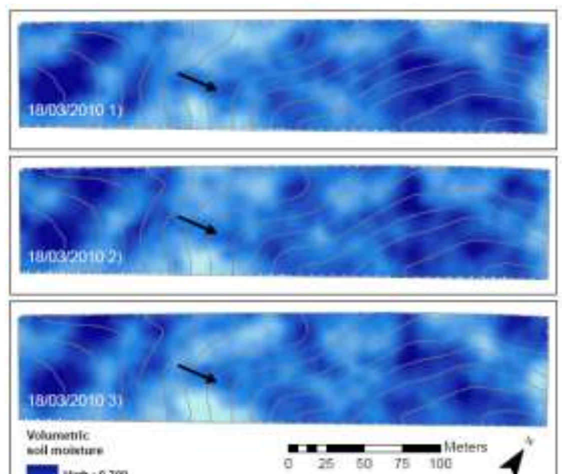
High-resolution, real-time mapping of soil moisture

Handheld system	Automated platforms



(e.g., EU-FP7 DIGISOIL, SENSAR projects)





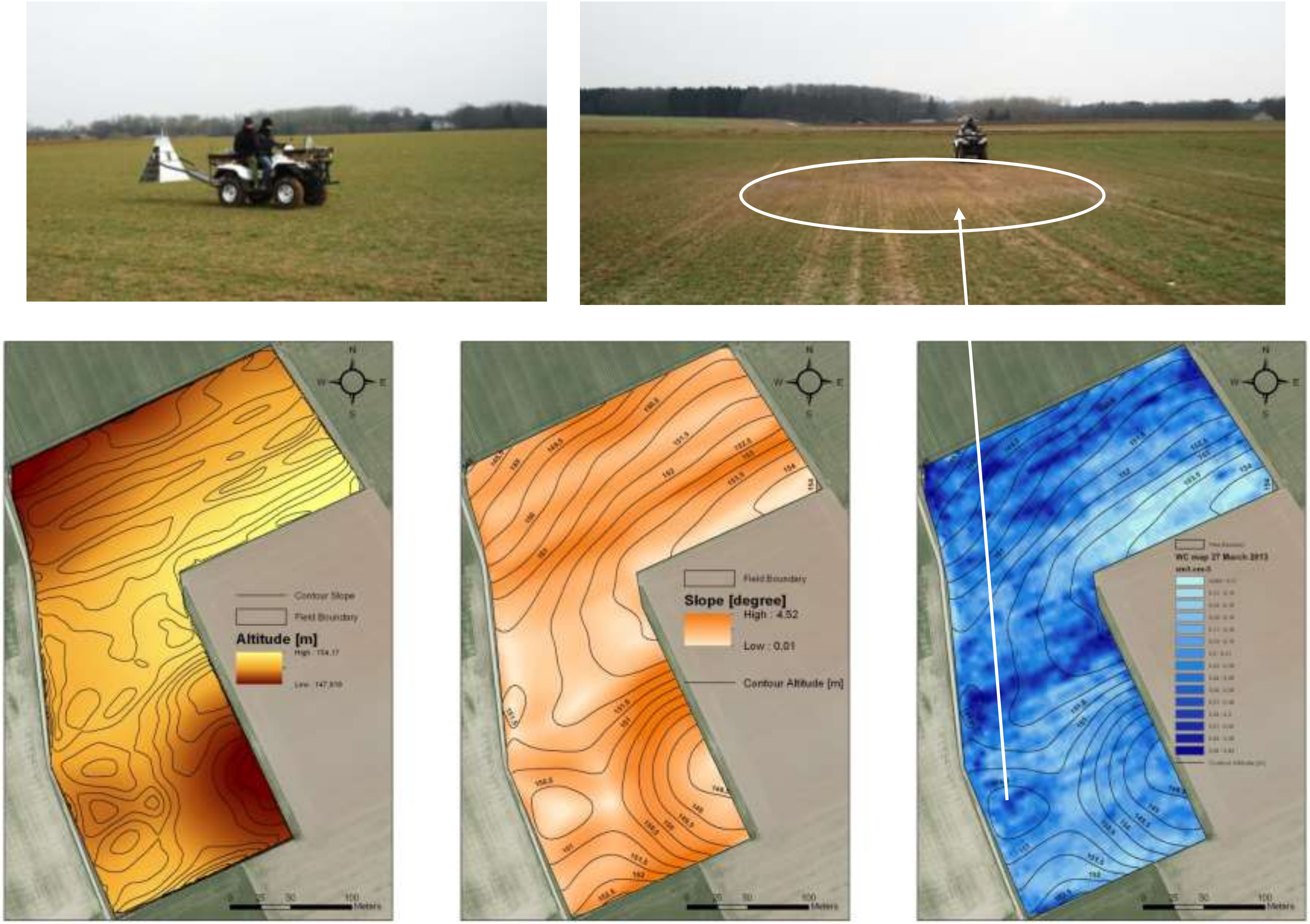
(Minet *et al.*, 2011)

Radarsat

Catchment scale

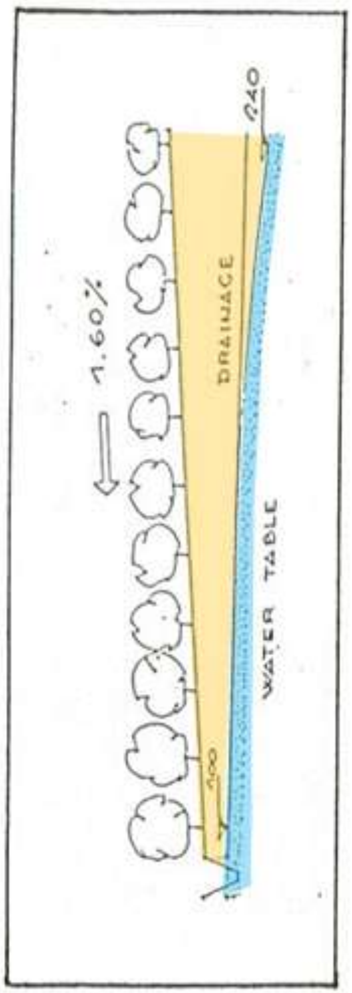
➡ Towards digital soil mapping – improving remote sensing data products

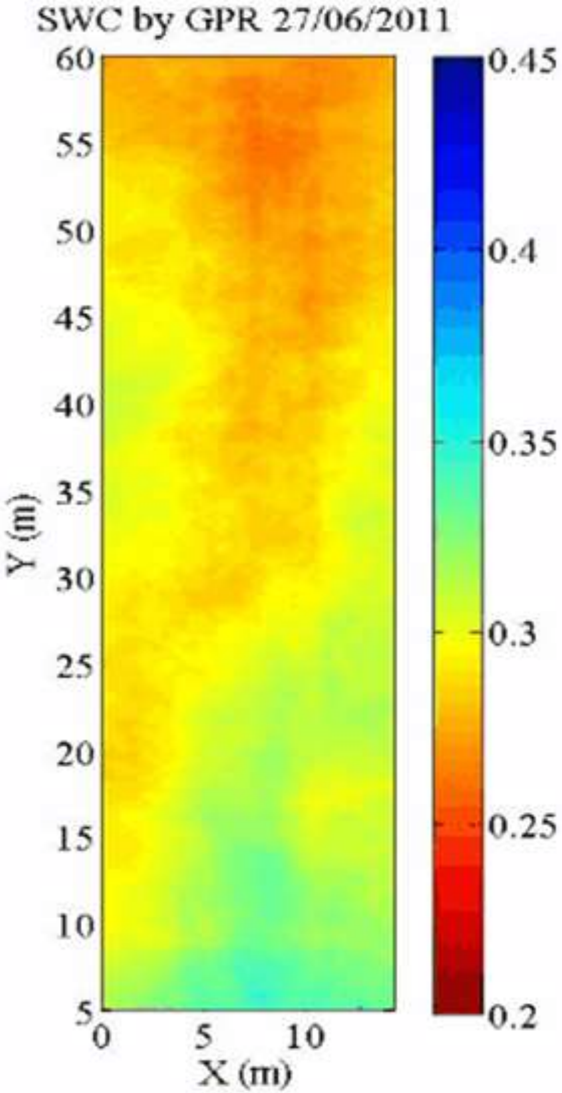
High-resolution, real-time mapping of soil moisture



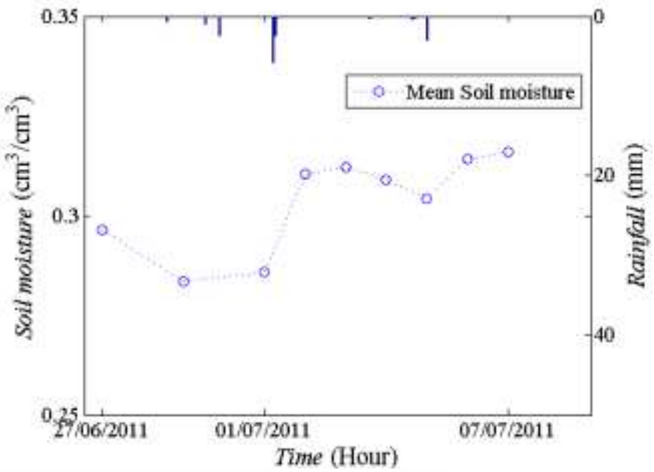
Field-scale applications

Test site in Bologna (Italy)





400 MHz GSSI antenna

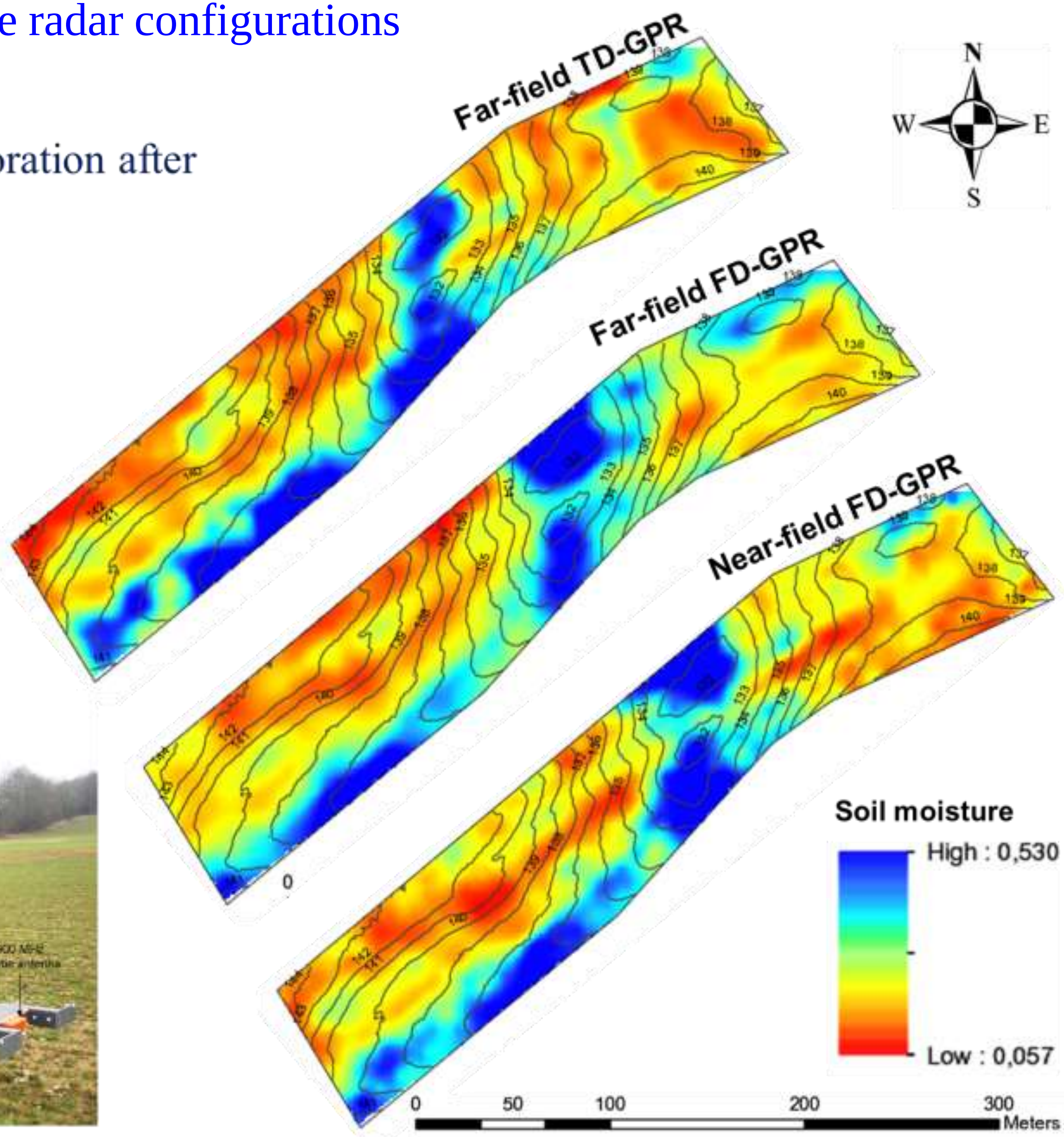


Time-lapse monitoring

Comparison between three radar configurations

Field condition: 4 days evaporation after a precipitation event.

All GPR approaches show relatively similar soil moisture patterns within the field. The differences could be explained by different characterization scales.



Conclusions

- *Ground penetrating radar is useful in many fields*
- *Intrinsic GPR electromagnetic models have been developed*
- *Full-wave inverse modeling permits non-invasive soil characterization and real-time mapping of soil moisture*

Perspectives

- *Adaptation to specific application contexts*
- *Integration with soil-plant-atmosphere models and management tools*

→ **Precision agriculture**

SEVENTH FRAMEWORK PROGRAMME
DIGISOIL
cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY
DROPS
belspo
fnrs
UCL Université catholique de Louvain

Gracias por su atención!