GNSS/GALILEO Technology Helpful for Precision Farming

(i.e. GNSS as an Earth's Remote Sensing Tool)

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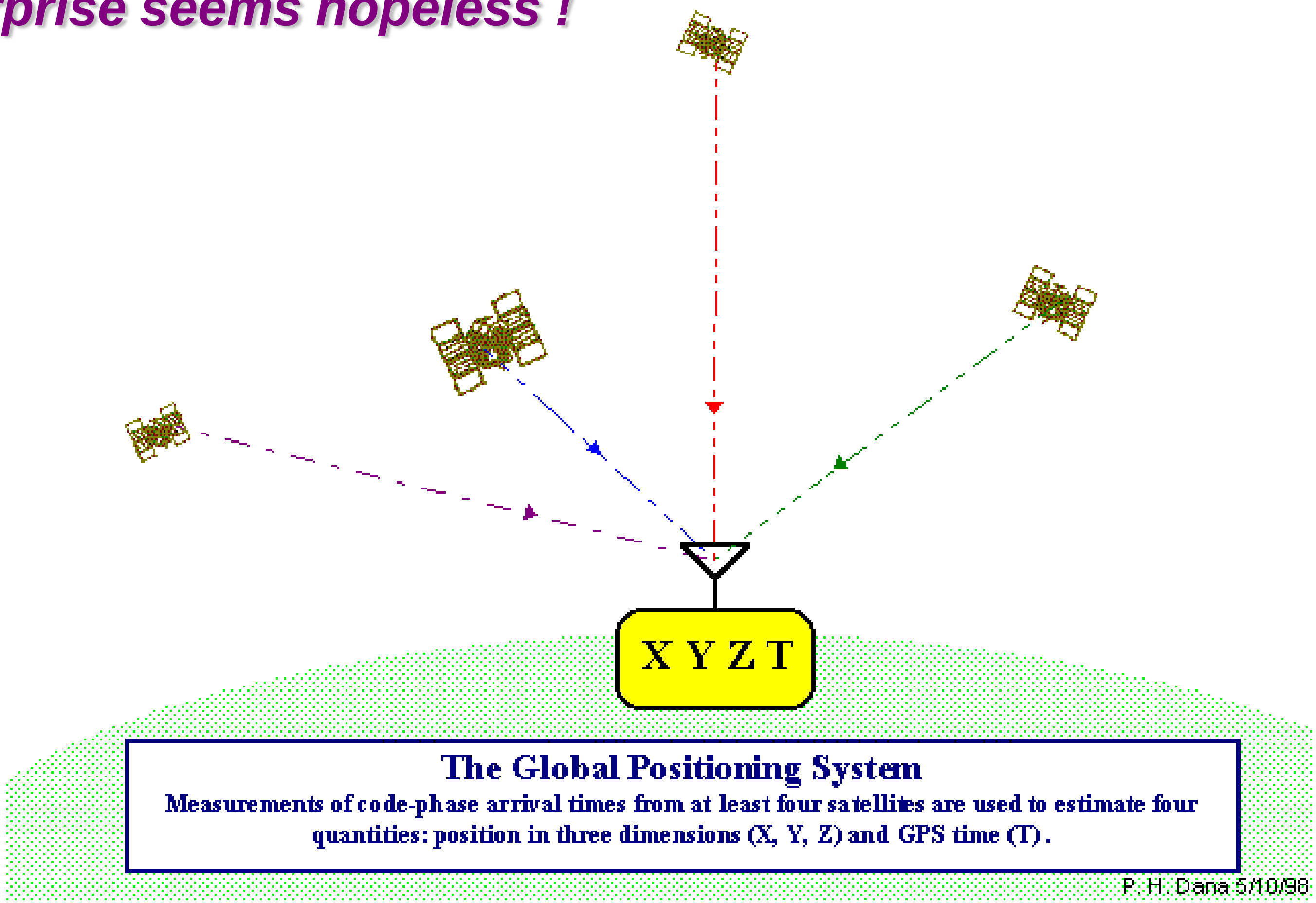
Content

- Brief Description of GNSS Systems
- Potentials App. of GNSS with Zenith Pointing Antennas (Ground and Spaceborne)
- ....with Limb Pointing Antennas (GNSS -RO)
- ....with Nadir Pointing Antennas (GNSS-R)
- Focus on Precision Farming applications
- Conclusions

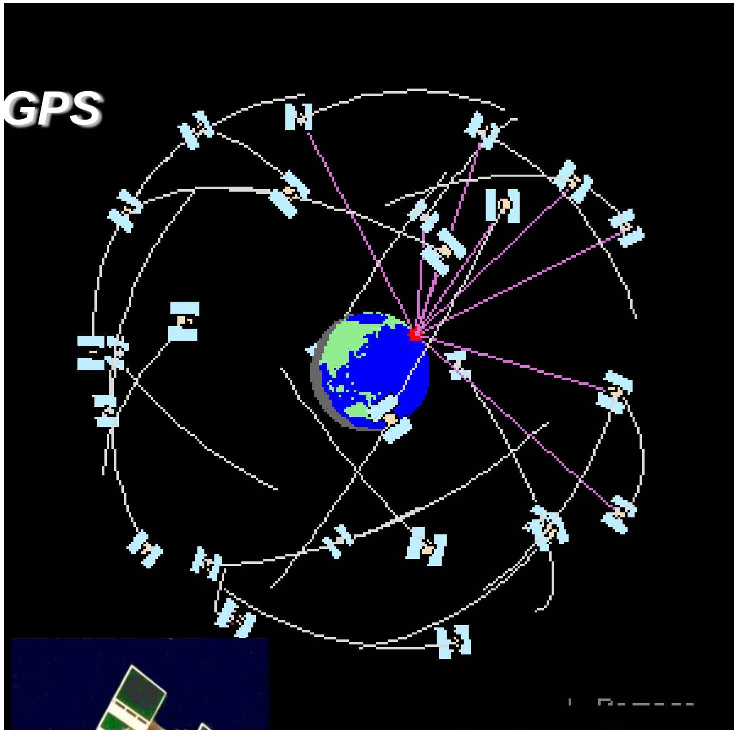
Potentials App. of GNSS with Zenith Pointing Antennas (Ground and Spaceborne)

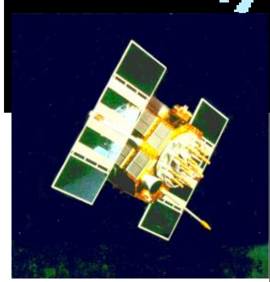
The Global Navigation Satellite Systems: The Principles

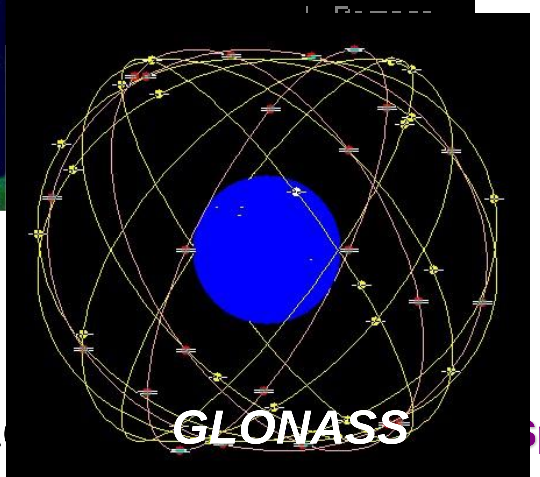
Accuracy ” few meters
The enterprise seems hopeless !
But…..

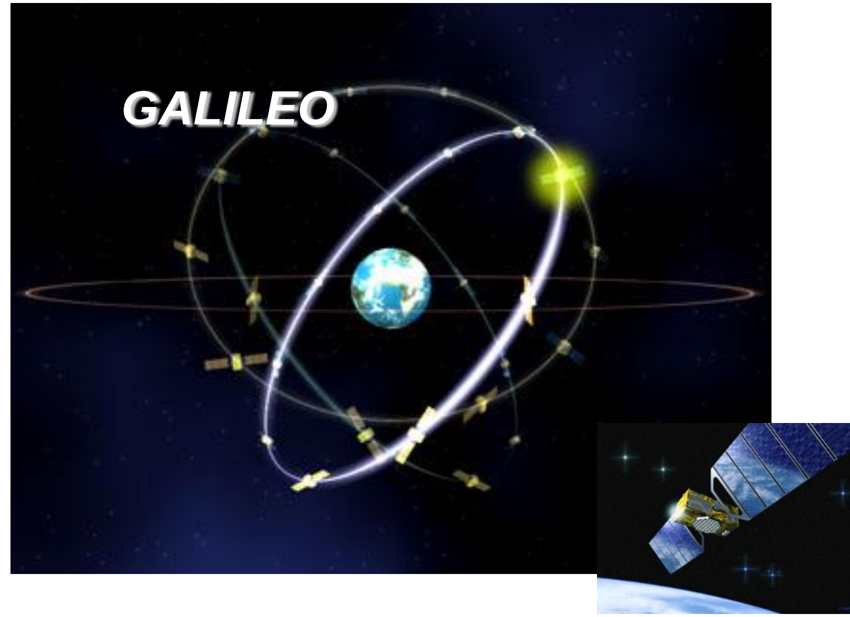


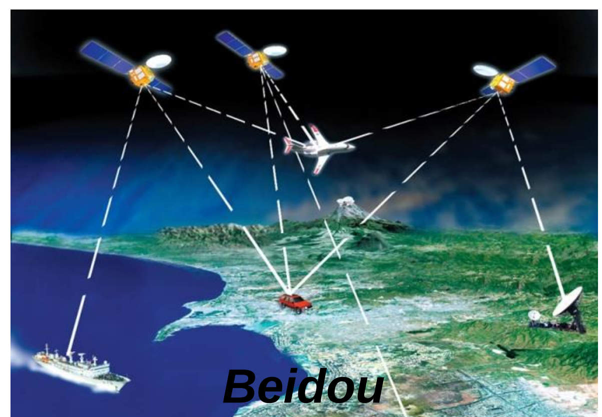
Space Missions:



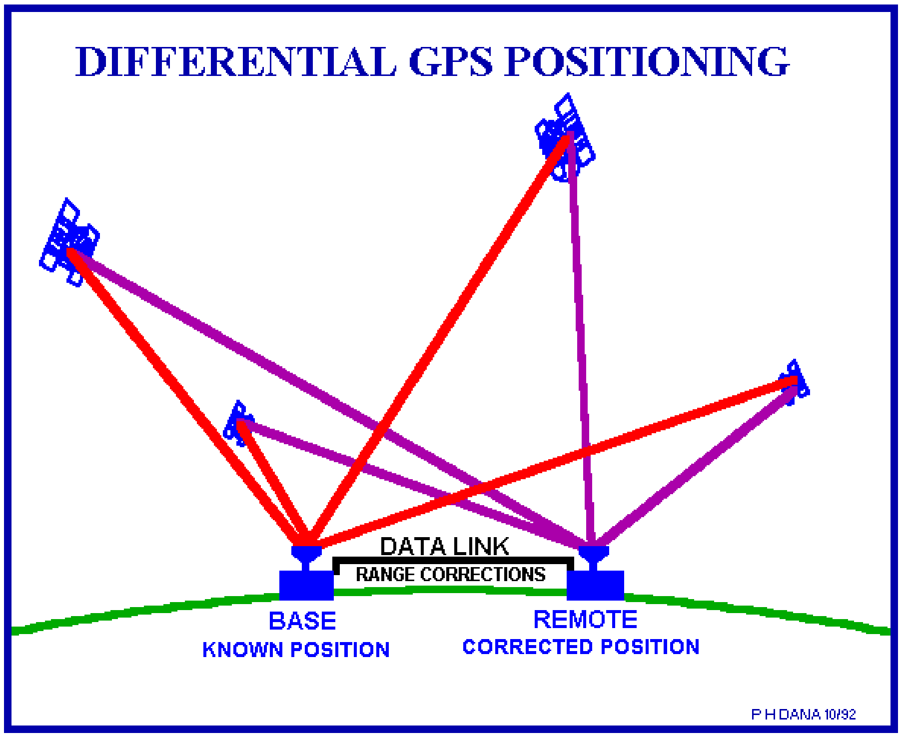


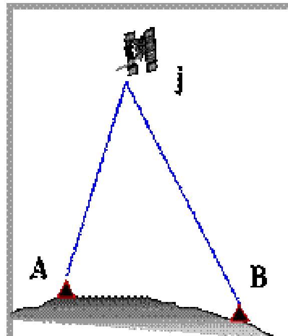






The Differential Approach

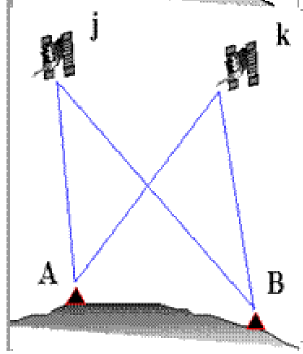




Single Differences

These are used to reduce satellite clock and orbit errors, and localised atmospheric errors.

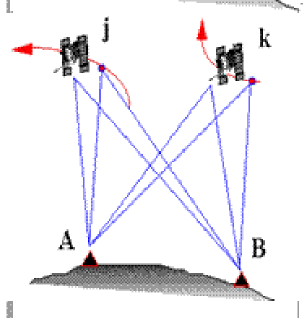
This is the technique used by DGPS.



Double Differences

These are used to reduce satellite clock and orbit errors, localised atmospheric errors, and receiver clock errors.

This is usually the technique adopted by the final carrier phase GPS solution. Relative GPS also uses this approach.



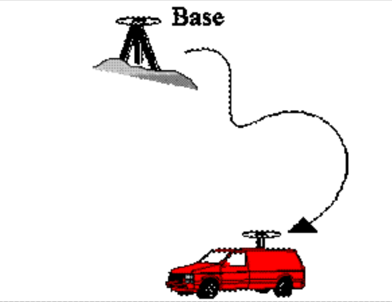
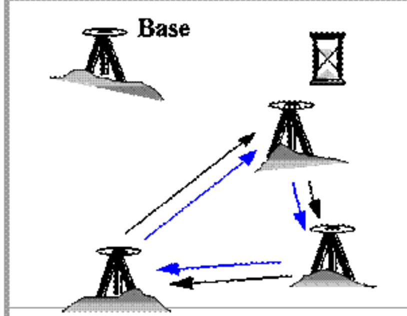
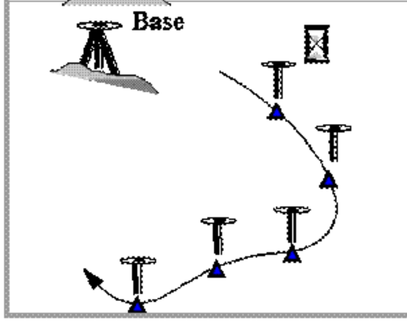
Triple Differences

This is the difference between two double differences from measurements recorded at subsequent epochs.

Assuming no cycle slips, or loss of lock has occurred, this eliminates the integer ambiguity. It is therefore used to detect for cycle slips and loss of lock.

The uncertainties are reduced at few mm level !!

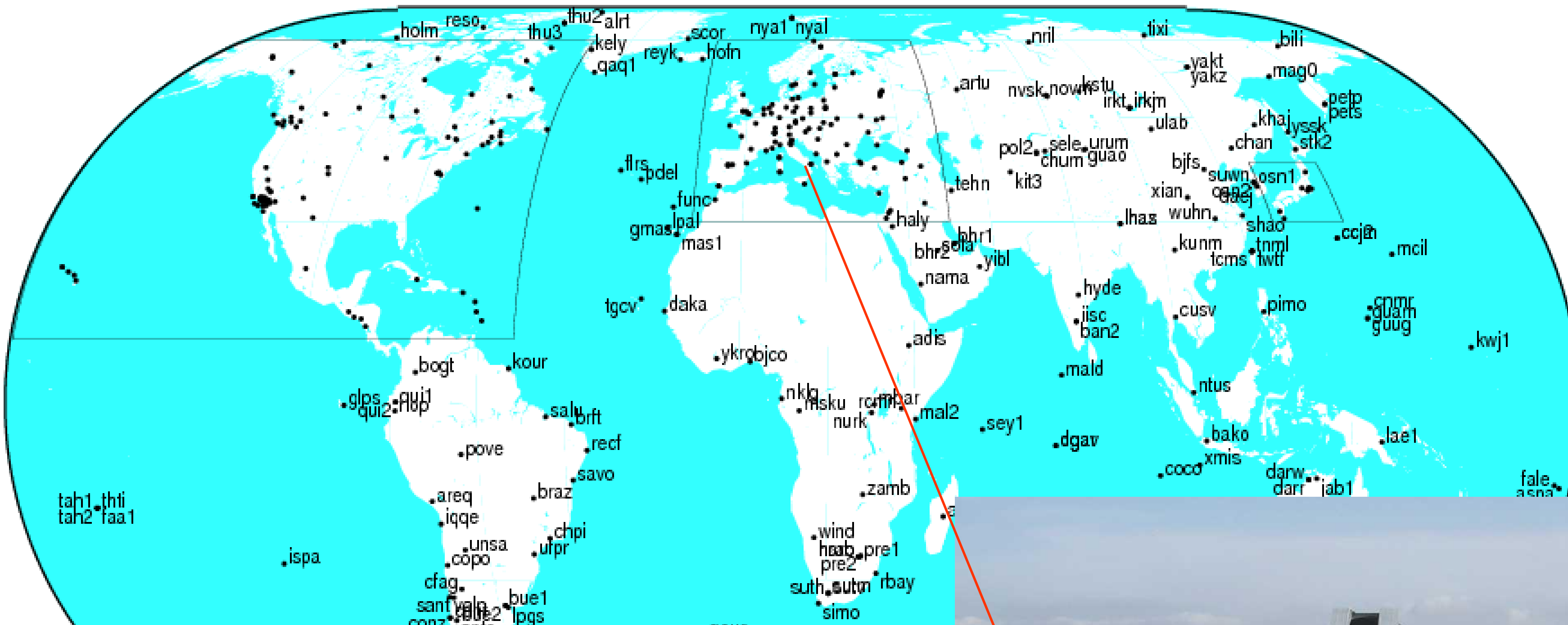
Survey modes

	**Continuous Kinematic** After initialisation, or resolution of the ambiguities, one receiver is allowed to roam. You must however keep track of the satellites so that lock is not lost, and only few cycle slips occur.
	**Pseudo Kinematic** This allows you to compute the coordinates of a large number of points without observing a static network. You set up for approximately one minute twice on each of the points you wish to be coordinated. The two occupations of a point must be separated by at least one hour in time.
	**Semi Kinematic/Stop and Go** Here you spend a few minutes on each point. When moving between points you must still keep lock on the satellites, although positions are not computed.

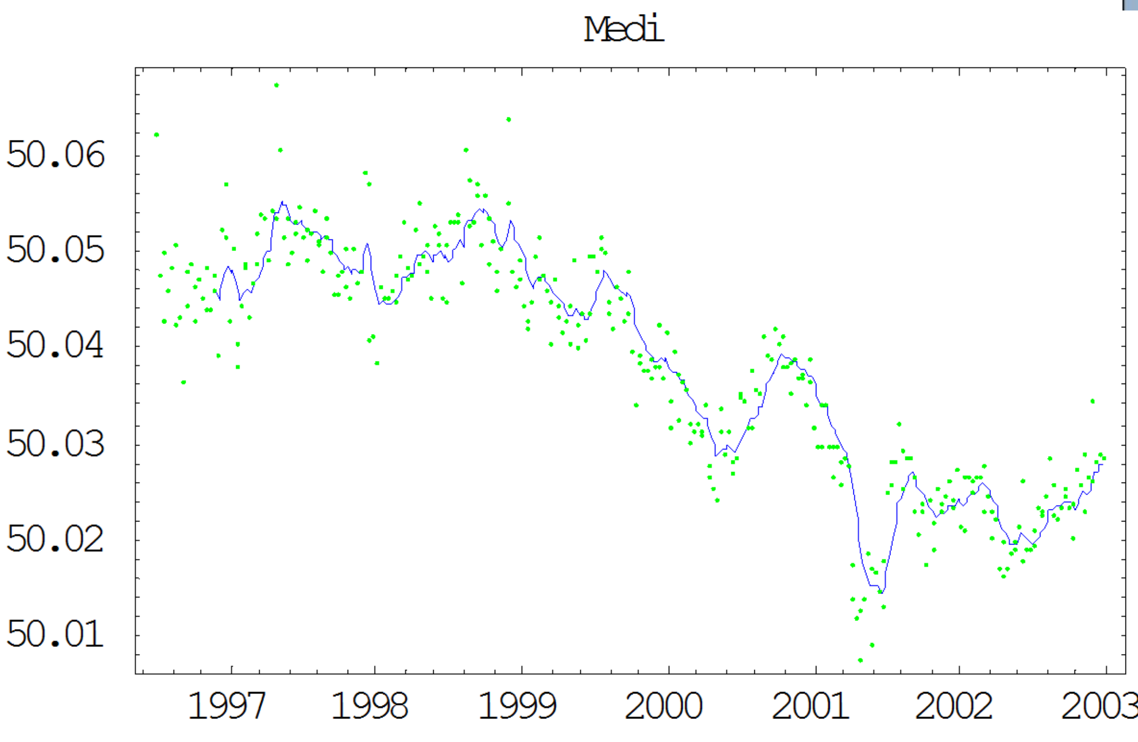
Performances of GPS Survey

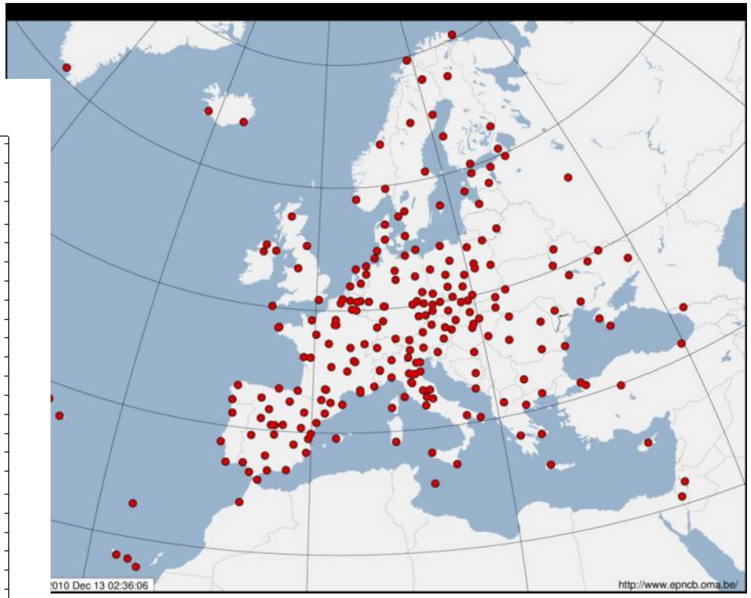
- 2-3 mm horizontal in PP
- 4-7 mm height in PP
- 1 cm <30' of data
- 5 cm in RTK
- Continuous acquisition 24/24 365/yr
- Very long baselines >1000 Km

1991 Matera GPS Station became part of IGS network

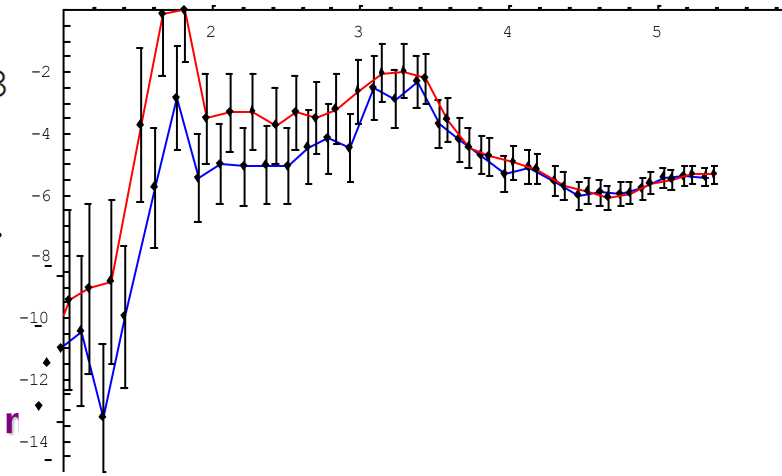


1996 ASI joined EUREF service as Local Analysis Center



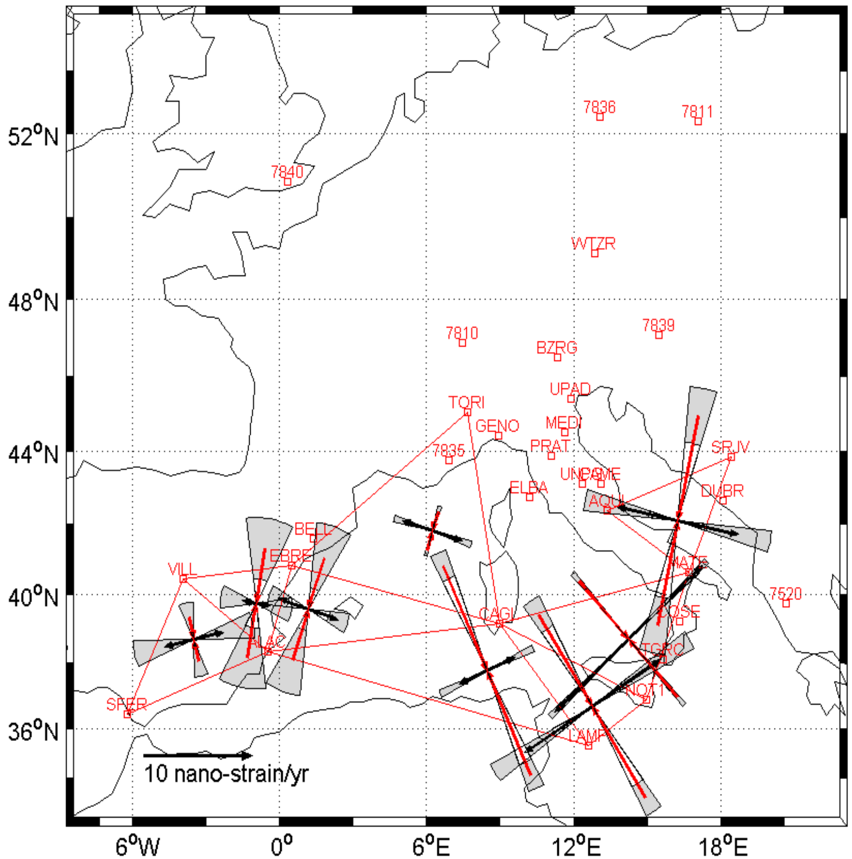


$$V_{tot} = V_{tect} + V_{sl} + V_{sc} + V_{pgr} + V_{wl} + V_{antr.}$$



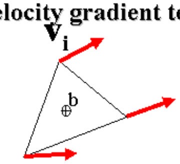
Seismicity

Strain rate in the Western Mediterranean Area



Strain Rate Computation

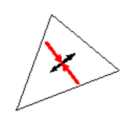
1 The planar (x,y) velocities in the vertices of each selected triangle are expanded at the first order by means of the **velocity gradient tensor L**



$$\mathbf{v_i} = \mathbf{L}\,\Delta\mathbf{x_i} + \mathbf{v_b} \qquad L = \begin{bmatrix} \frac{\partial V_x}{\partial x} & \frac{\partial V_x}{\partial y} \\ \frac{\partial V_y}{\partial x} & \frac{\partial V_y}{\partial y} \end{bmatrix}$$

2 Estimation of the **tensor L** in a least squares sense

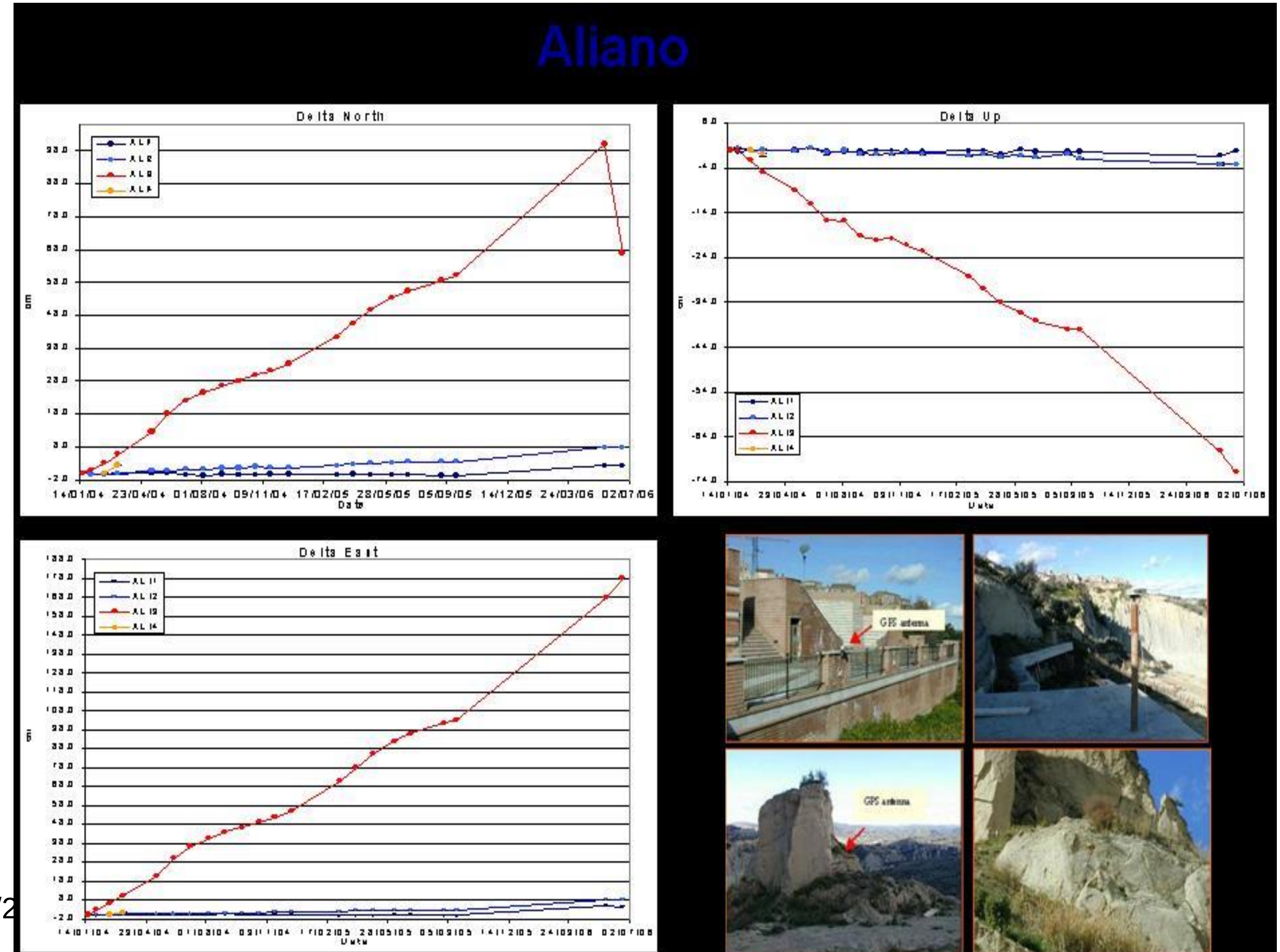
3 **Strain rate (E)** computation



$$\mathbf{E} = \frac{1}{2}\left(\mathbf{L} + \mathbf{L}^{\mathbf{T}}\right)$$

4 Measurement unit of strain rate: 1 nano-strain/yr is equal to a deformation of 1mm/yr per 1000 Km

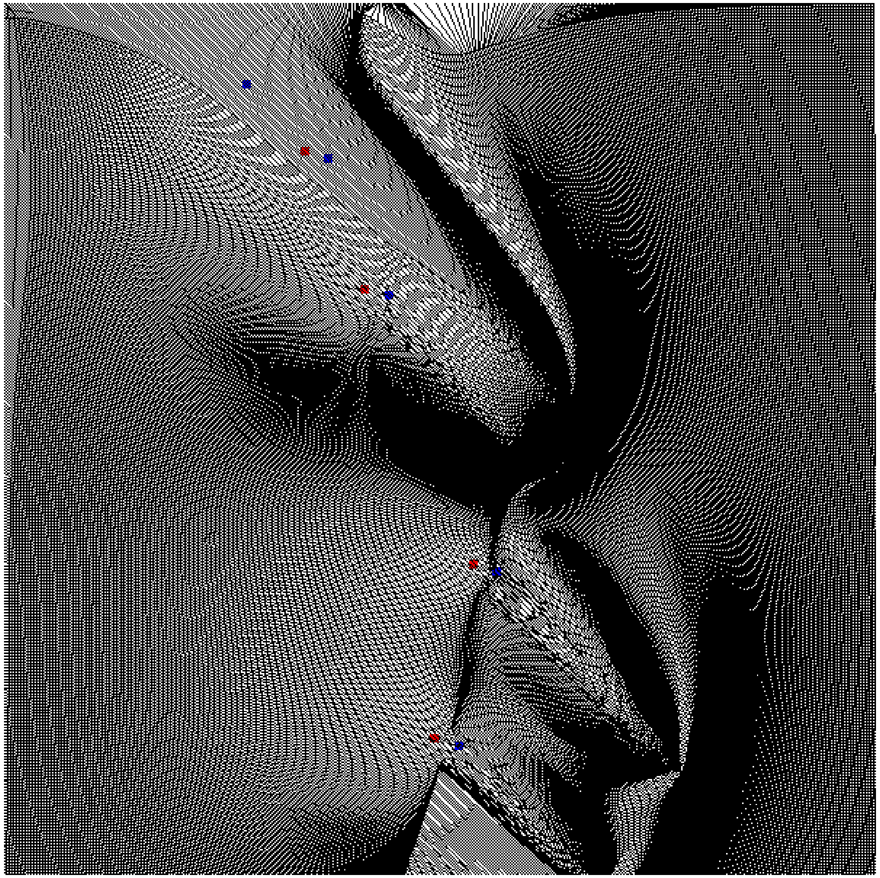
Landslides



Aliano
Delta North
14/01/04 23/04/04 01/08/04 09/11/04 17/02/05 28/05/05 05/09/05 14/12/05 24/03/06 02/07/06
Date
Delta Up
Delta East
GPS antenna
GPS antenna

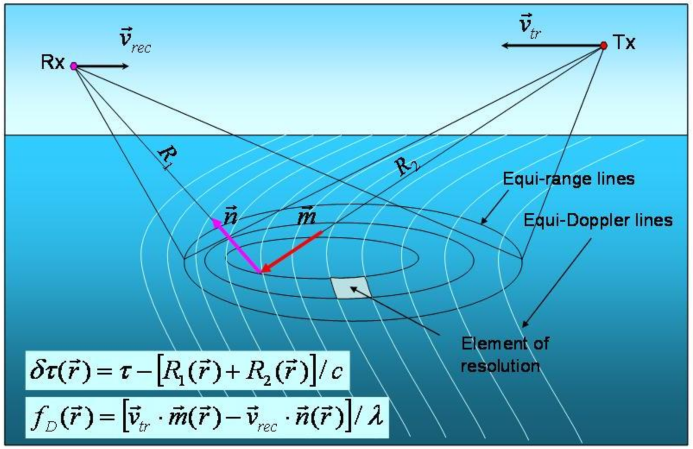
Extension of the experiment to Craco (Mt)

A site Included in WMF list



Livello del Mare/Erosione delle Coste

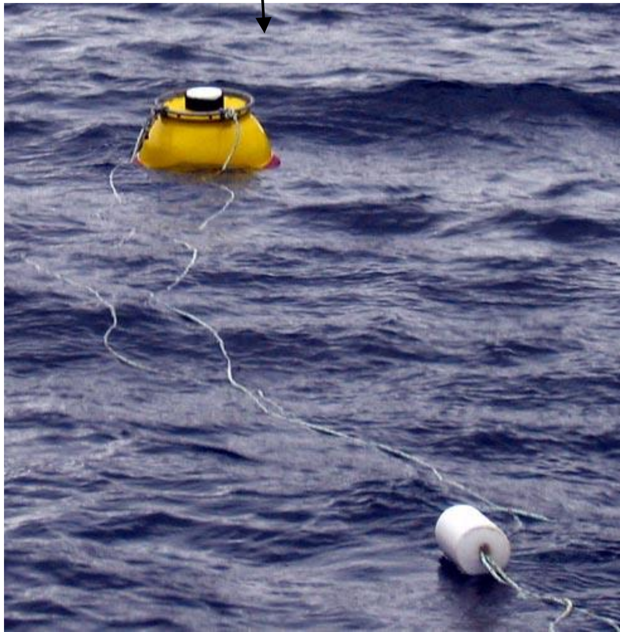
Uso modalità Bi-statica



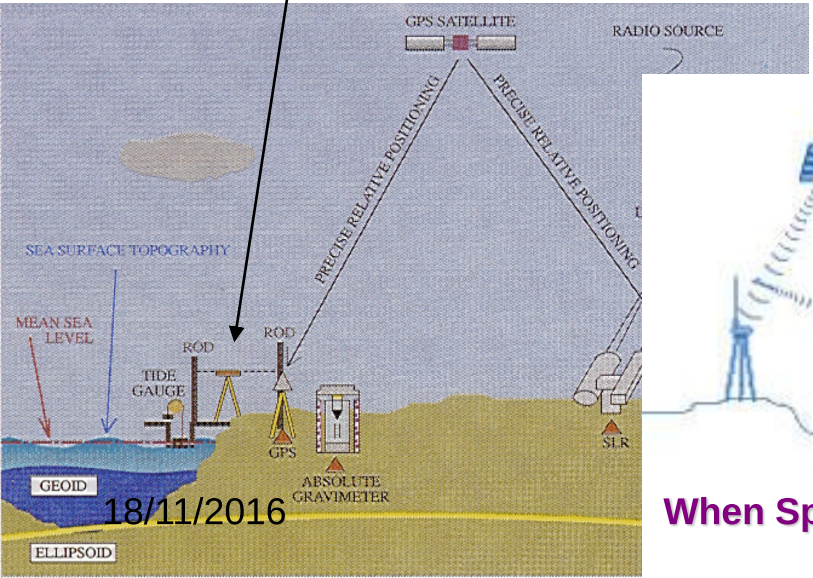
Linee di costa

Un operatore esegue la misura della linea di riva mediante rilievo RTK continuo.

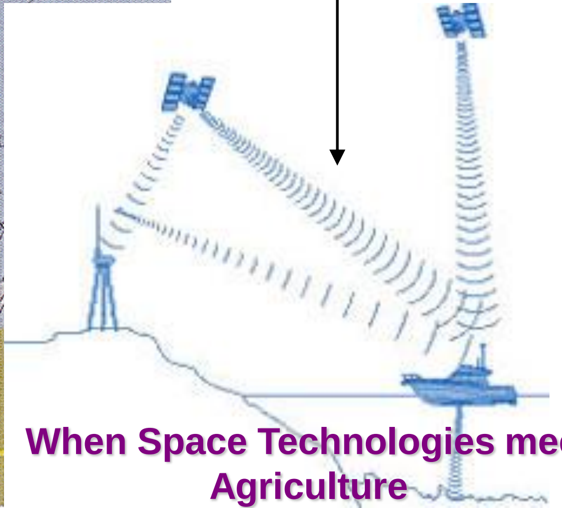
Boe Marine GPS
Moto Ondoso, Maree, Allarme Tsunami, ecc.



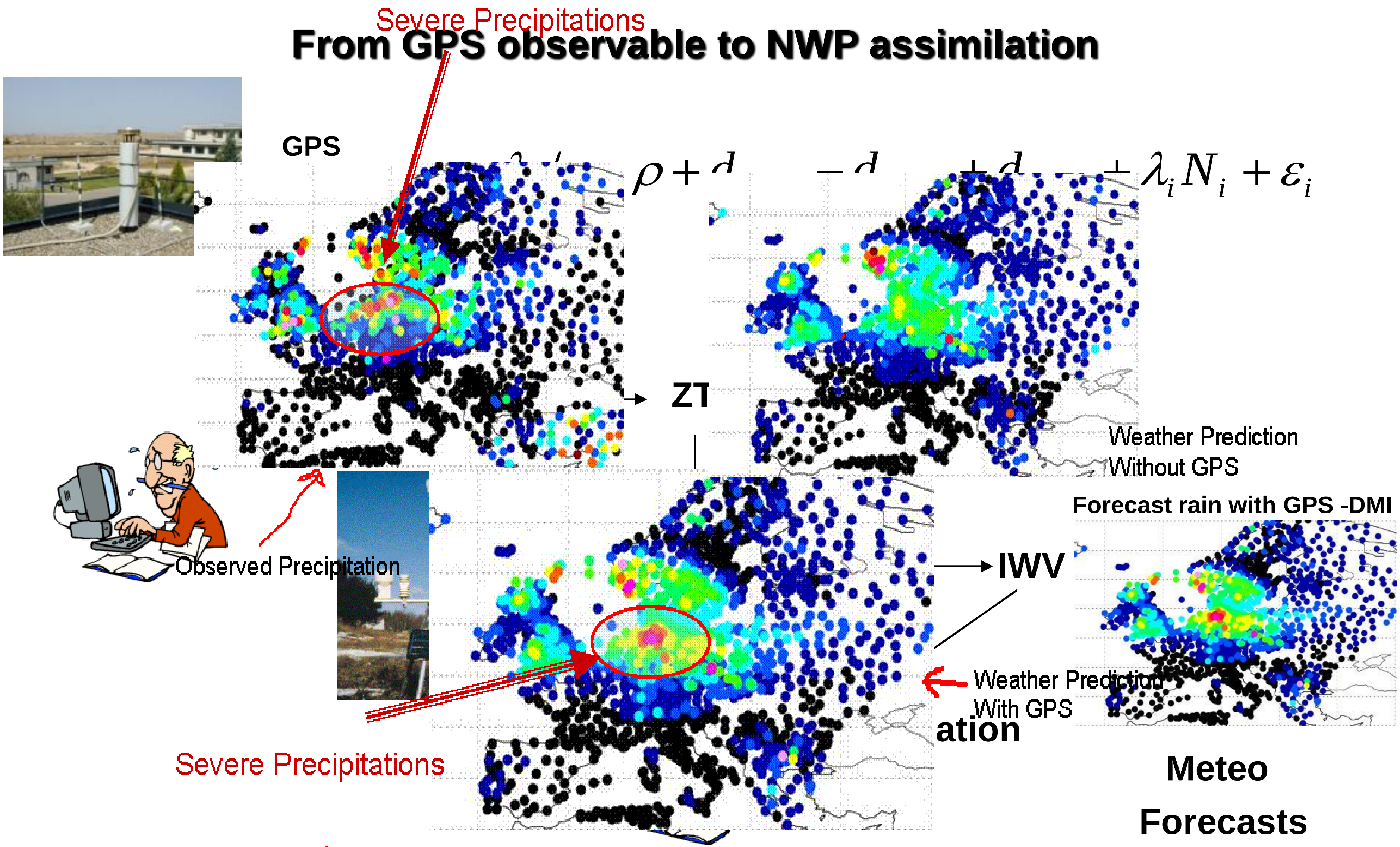
Co-locazione con Mareografi



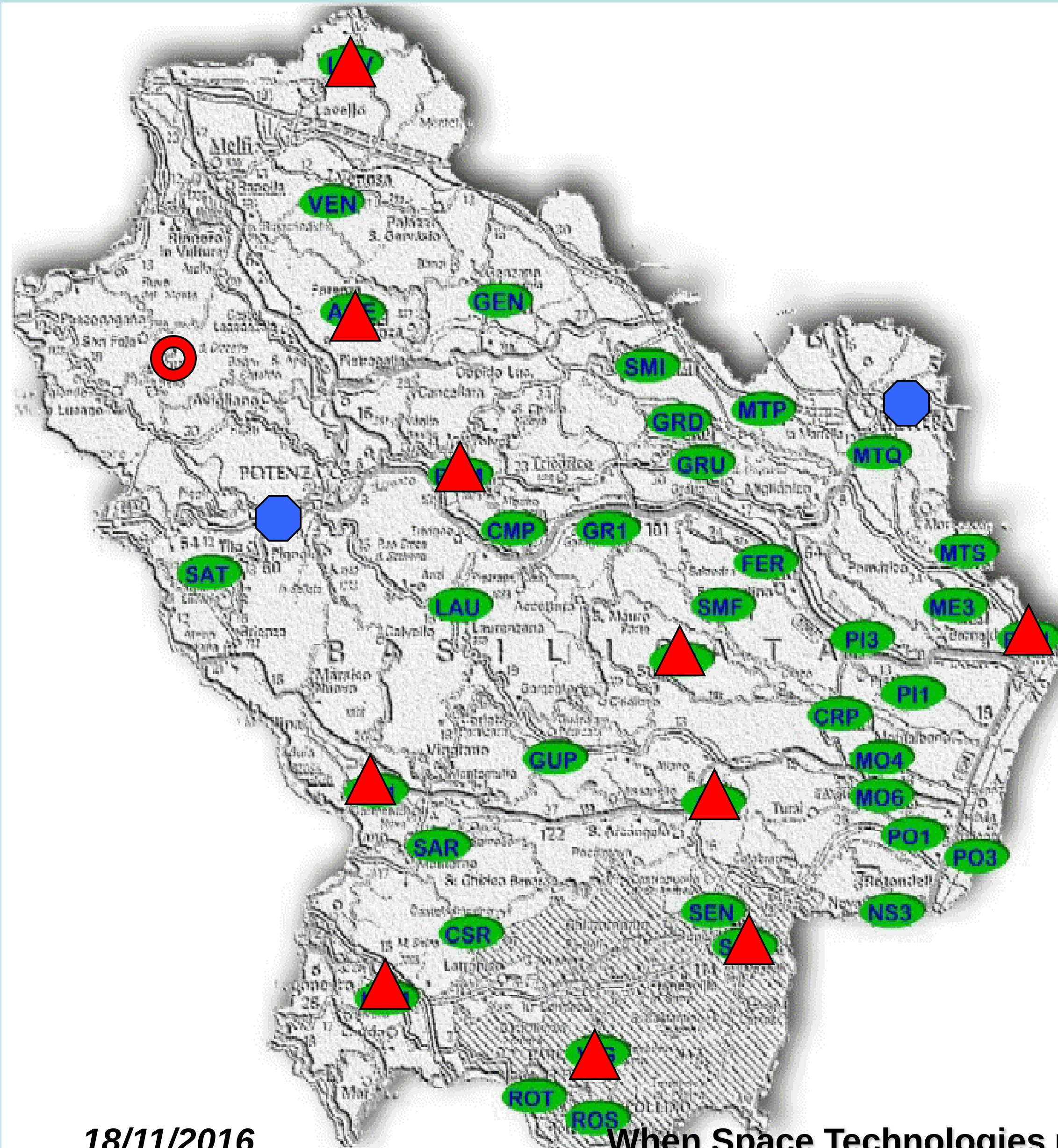
Batimetria



Meteorology



Il Progetto MAGIC II



Siti ALSIA selezionati ▲

Lavello	(LAV)	q.s.m.	300 m
Brindisi di Montagna	(BRM)	q.s.m.	900 m
Marsico Vetere	(BG1)	q.s.m.	1000 m
Aliano	(ALI)	q.s.m.	600 m
Nemoli	(NEM)	q.s.m.	700 m
Viggianello	(VIG)	q.s.m.	550 m
S. Giorgio Lucano	(SGL)	q.s.m.	400 m
Metaponto	(PAN)	q.s.m.	30 m
Stigliano	(STI)	q.s.m.	1000 m
Acerenza	(ACE)	q.s.m.	300 m

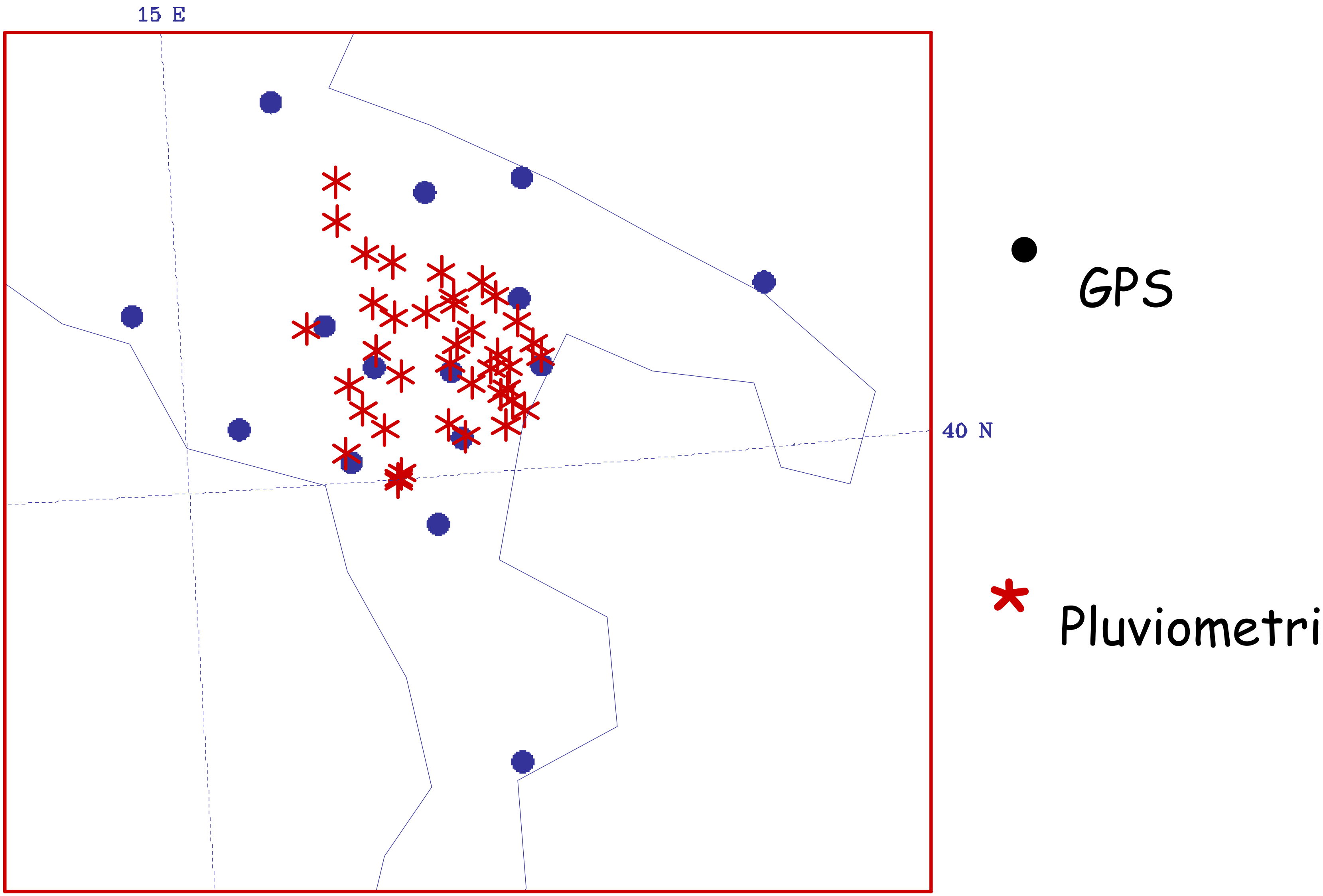
Ulteriori siti disponibili

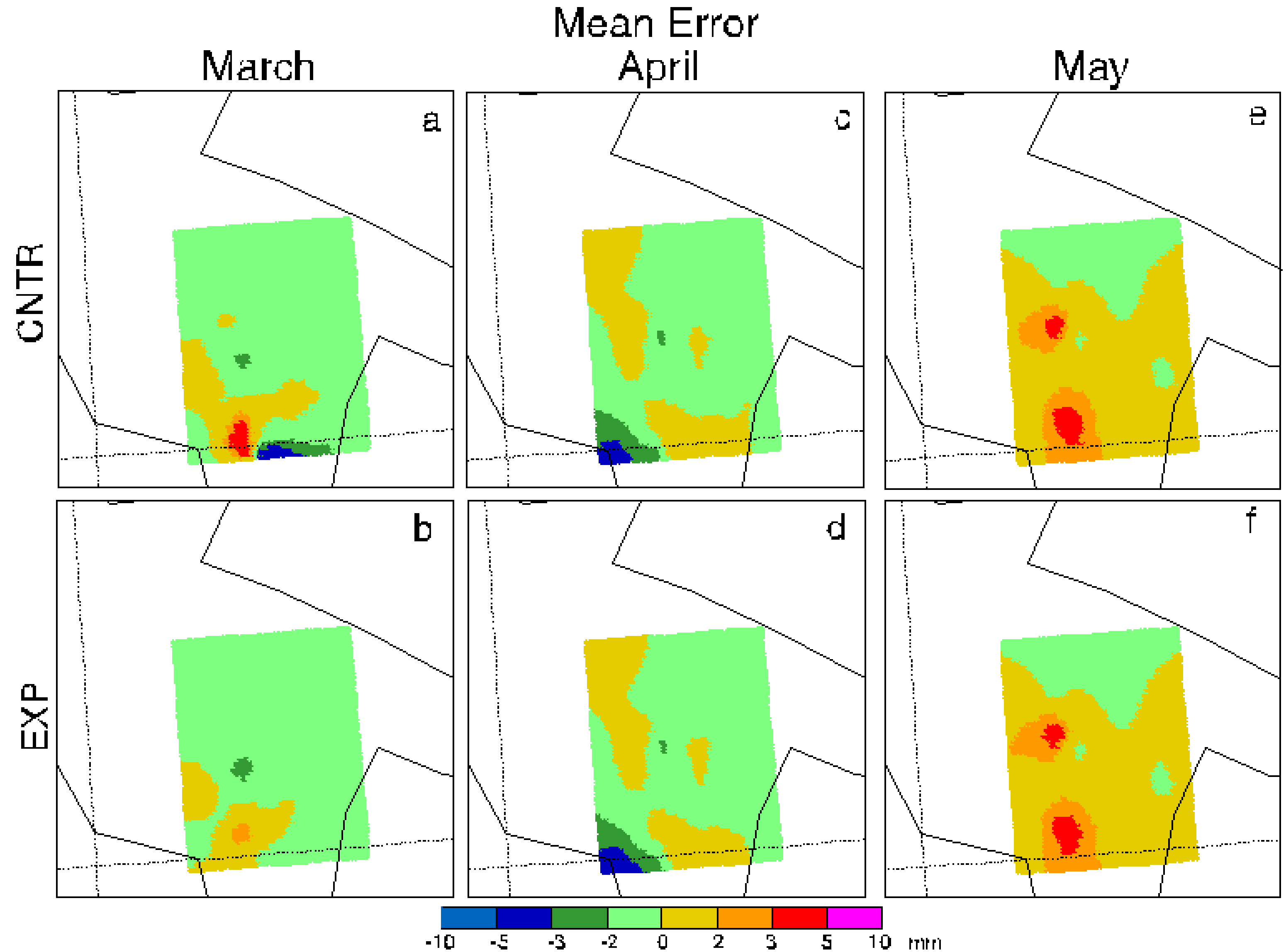
Matera	(CGS)	q.s.m.	500 m
Tito	(TIT)	q.s.m.	600 m

Siti completamene da installare

Toppo di Castelgrande

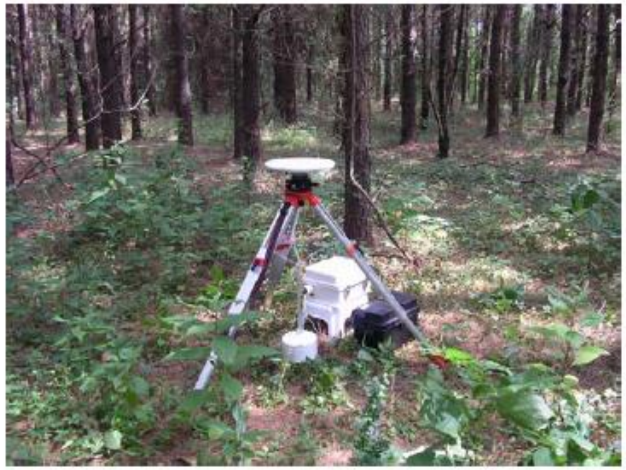
Rete di stazioni GPS e Pluviometri




Mean Error
March
April
May
CNTR
EXP
a
b
c
d
e
f
-10
-5
-3
-2
0
2
3
5
10
mm

Deployment in Pine Forest

Species
Loblolly Pine
Honeylocust

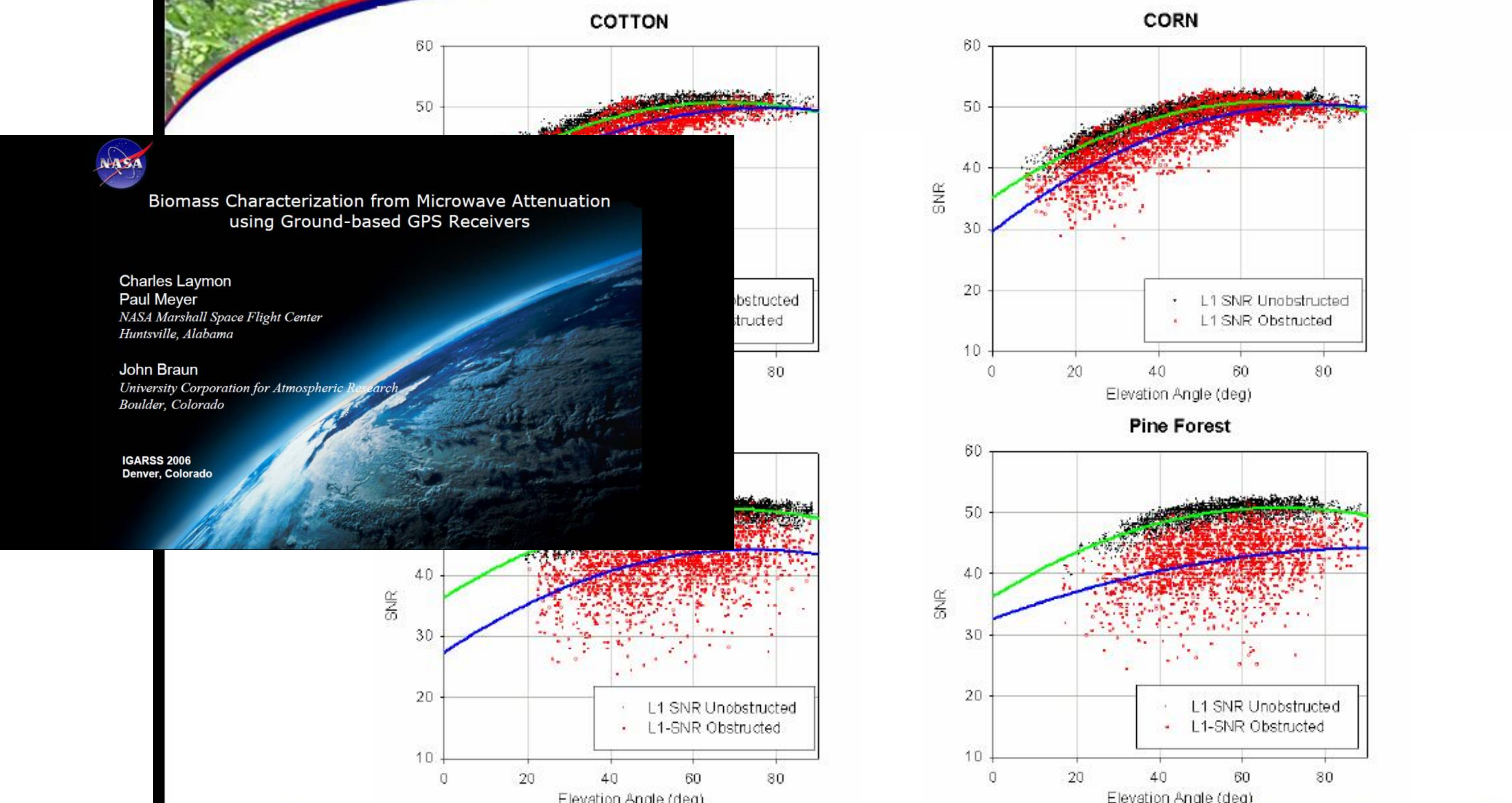


Overhead view of canopy

IGARSS 2006, Denver, CO

NASA Marshall Space Flight Center, Earth Science Office

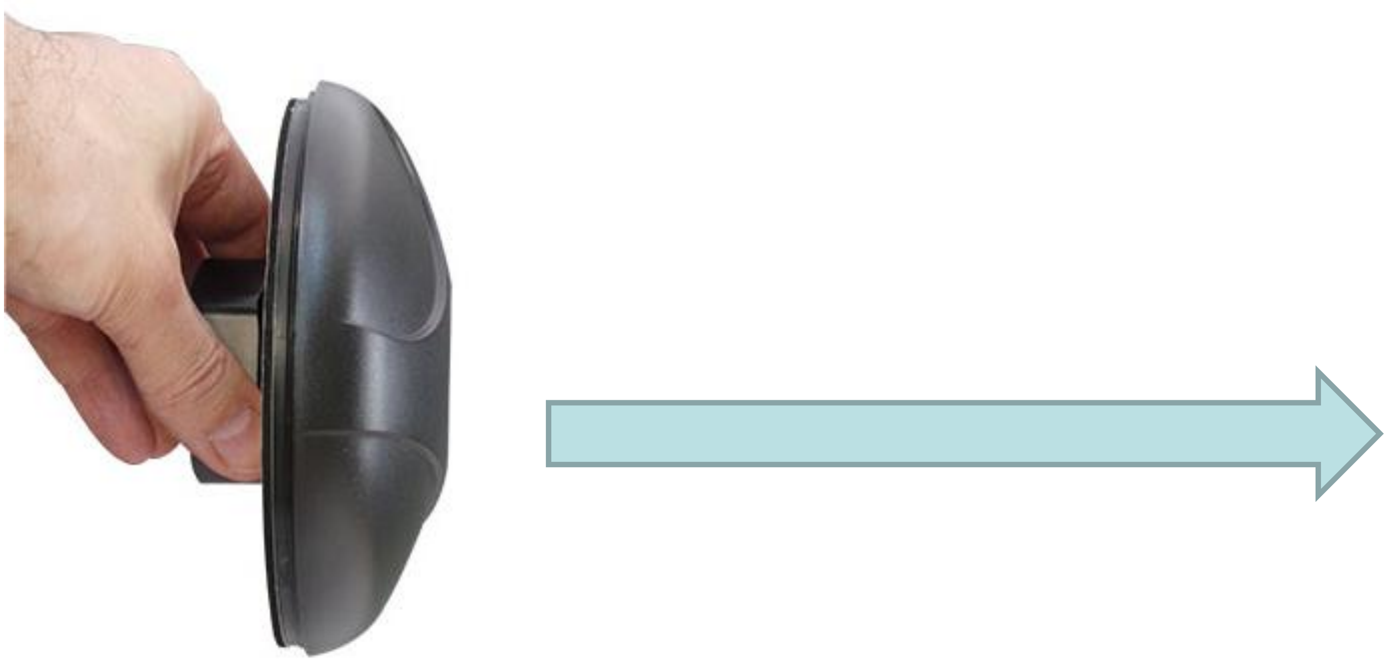
L1 SNR for Different Vegetation Types



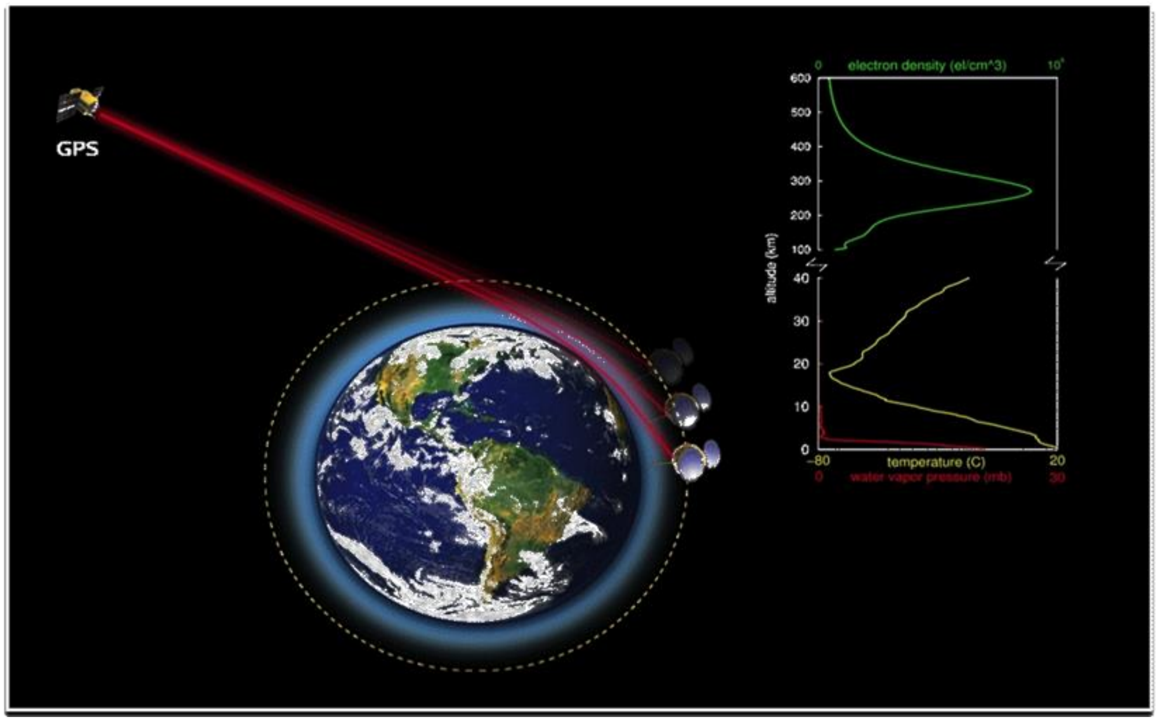
IGARSS 2006, Denver, CO

NASA Marshall Space Flight Center, Earth Science Office

Potentials App. of GNSS with Limb Pointing Antennas

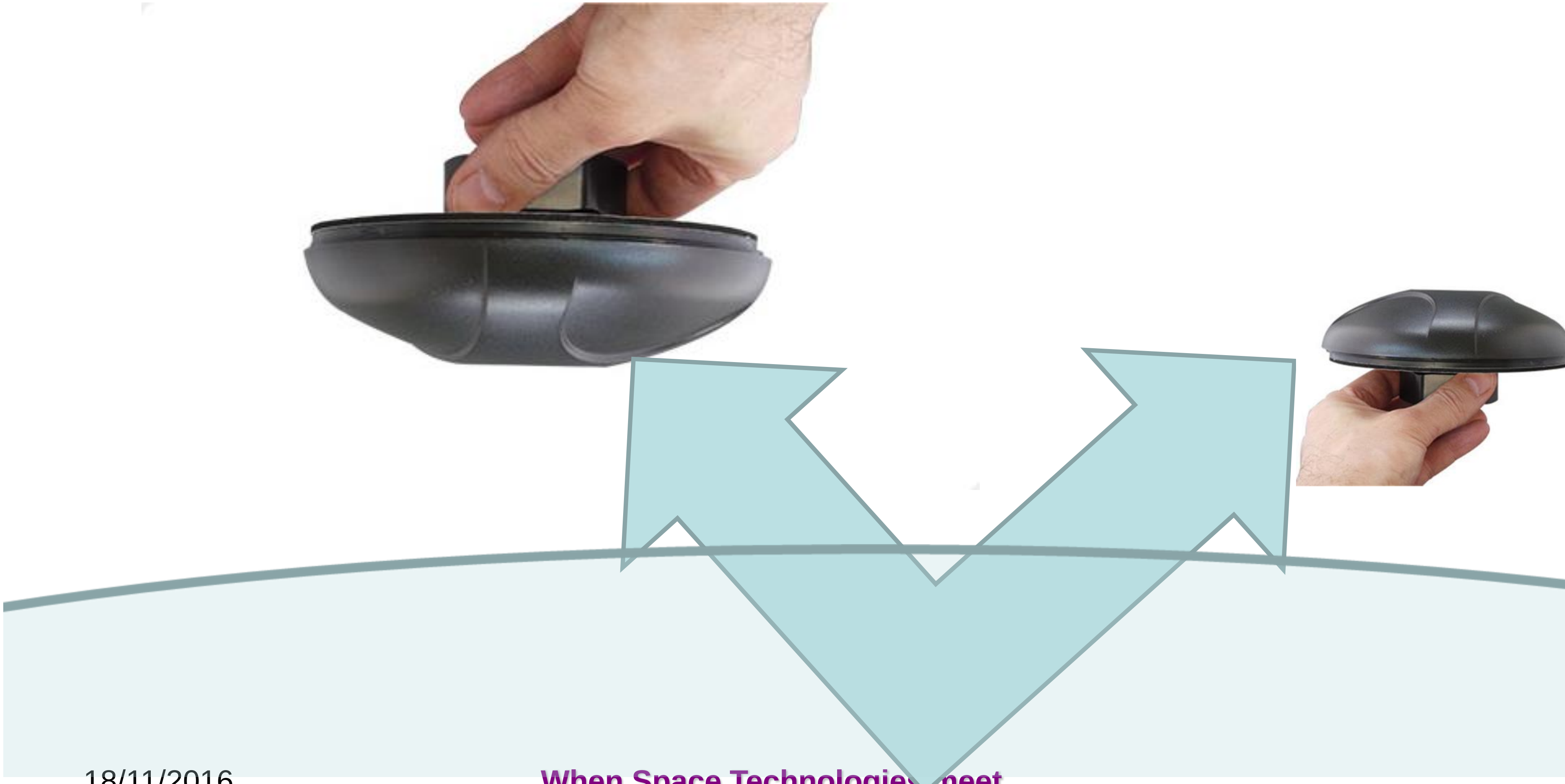


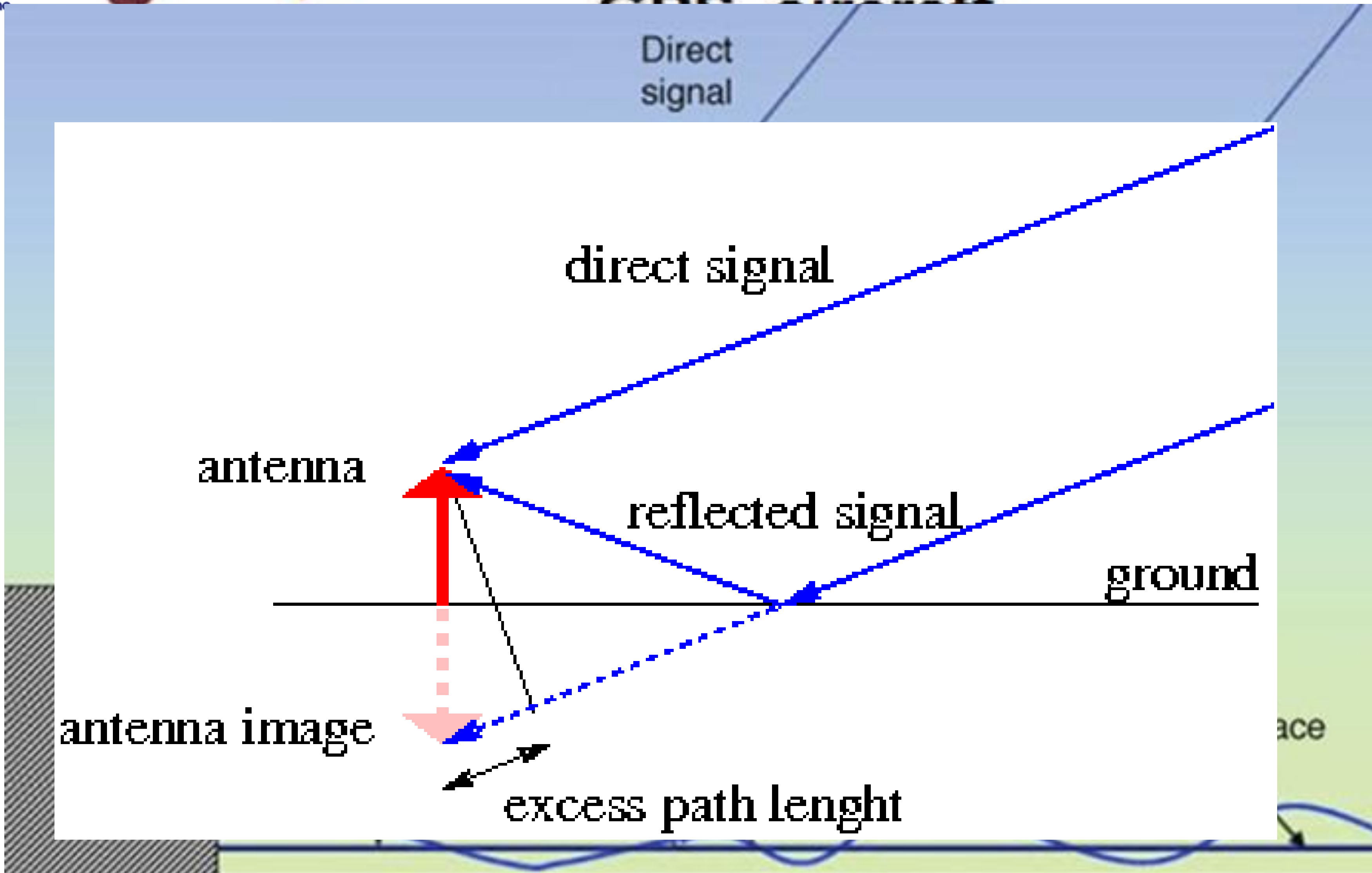
Radio Occultation



- Limb Directed antenna
  - Climate
  - Meteorology
  - Space Weather

Potentials App. of GNSS with Upside down Pointing Antennas (Ground and Spaceborne)




Direct
signal
direct signal
antenna
reflected signal
ground
antenna image
excess path lenght

Starlab

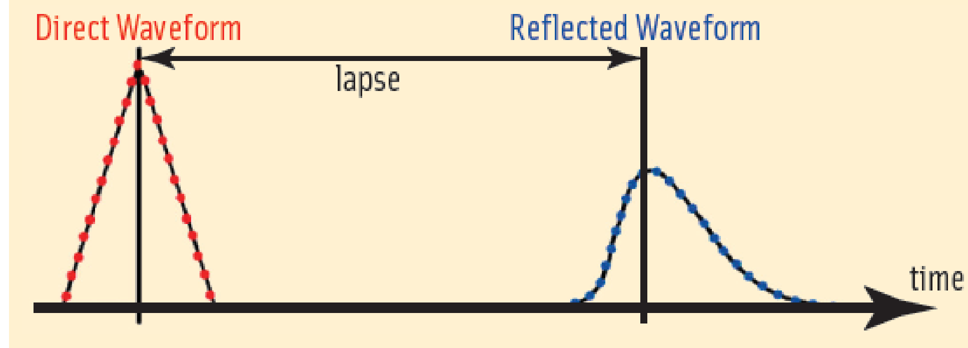


FIGURE 1 Direct and reflected correlation peak (From the article by F. Soulat *et alia* cited in Additional Resources)

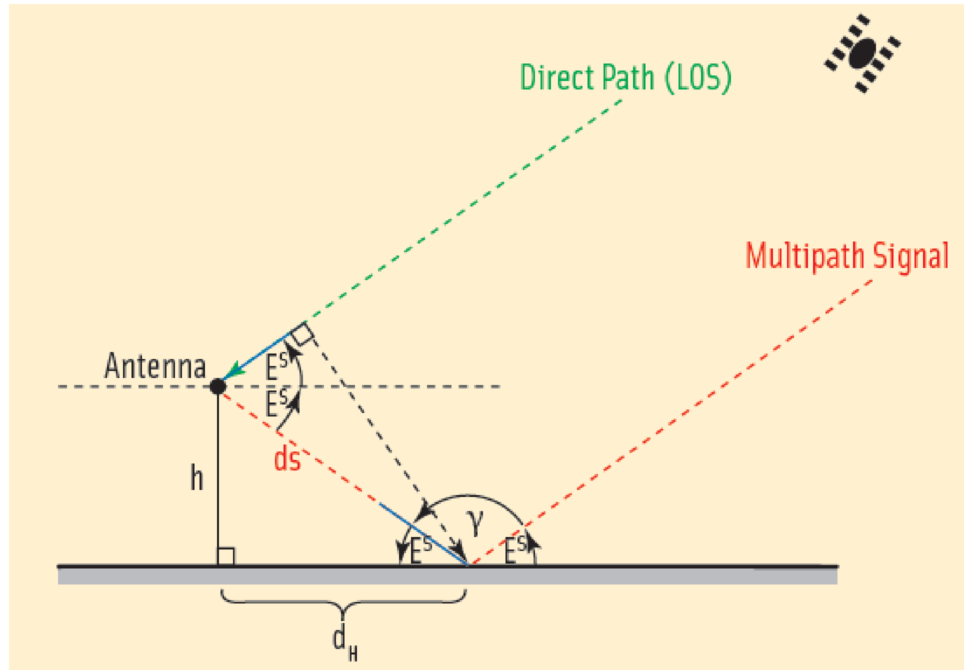
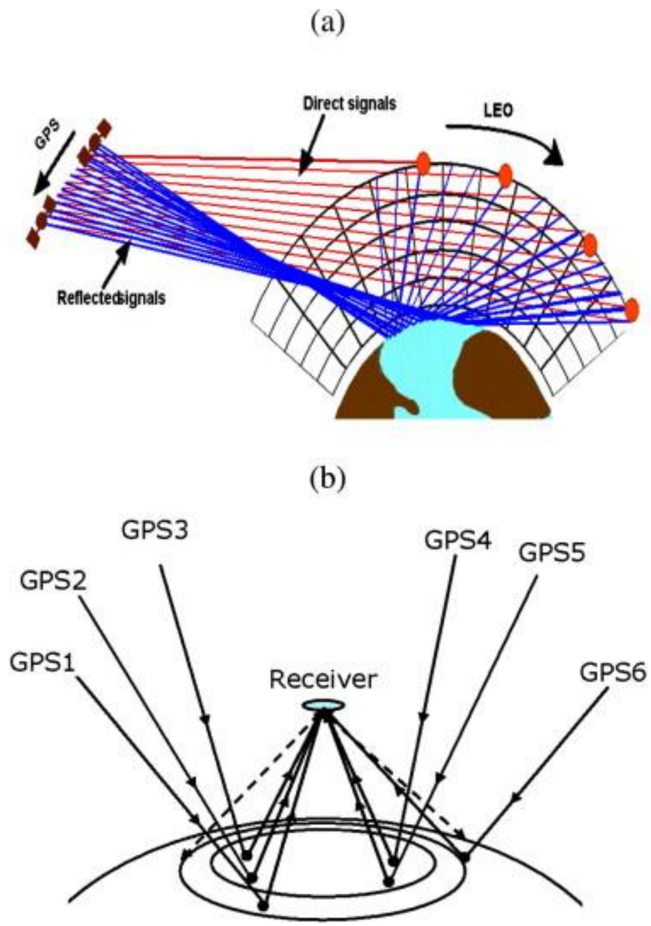


FIGURE 2 Use of ground multipath for altimetry (after M. Irsigler, Additional Resources)



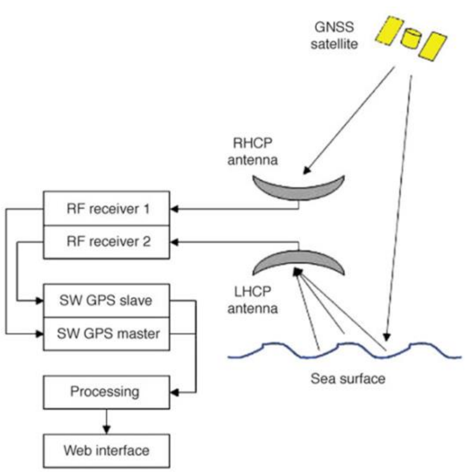
GNSS Reflectometry:

========Land=====

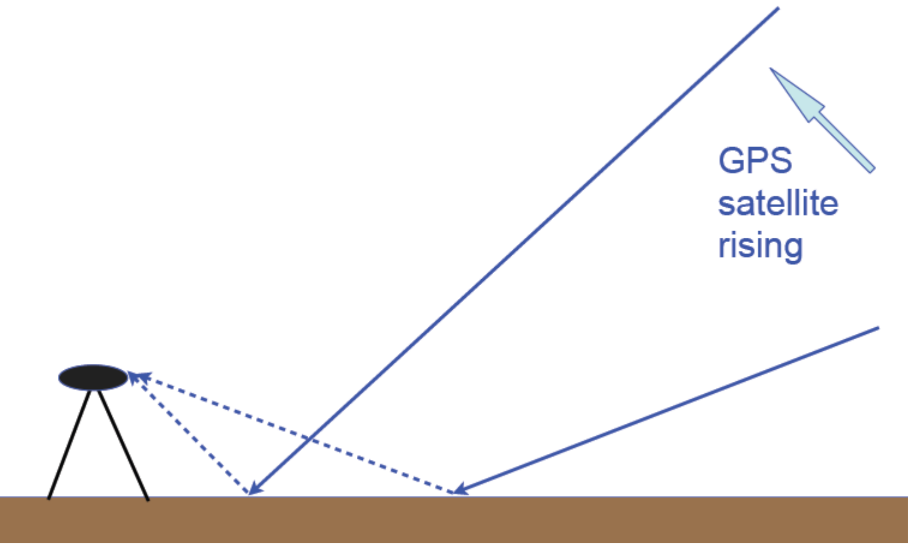
- Ocean height
- Wind speed
- Wind direction

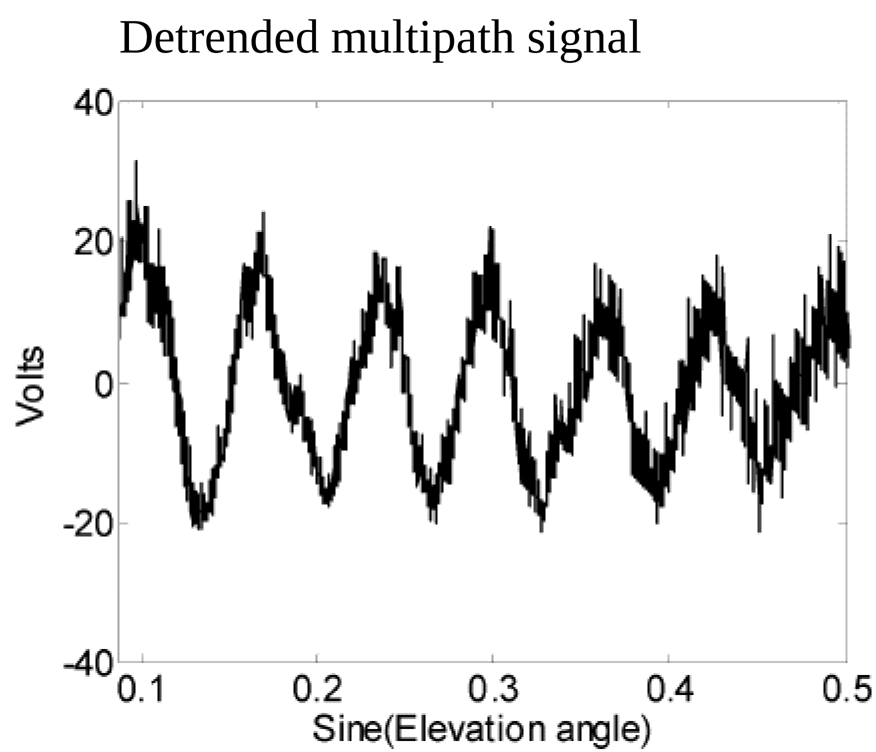
========Land=====

- *Soil moisture*
- Ice and snow thickness
- *Biomass thickness*



Use interference pattern to estimate hydrologic variables





Soil moisture → phase shift

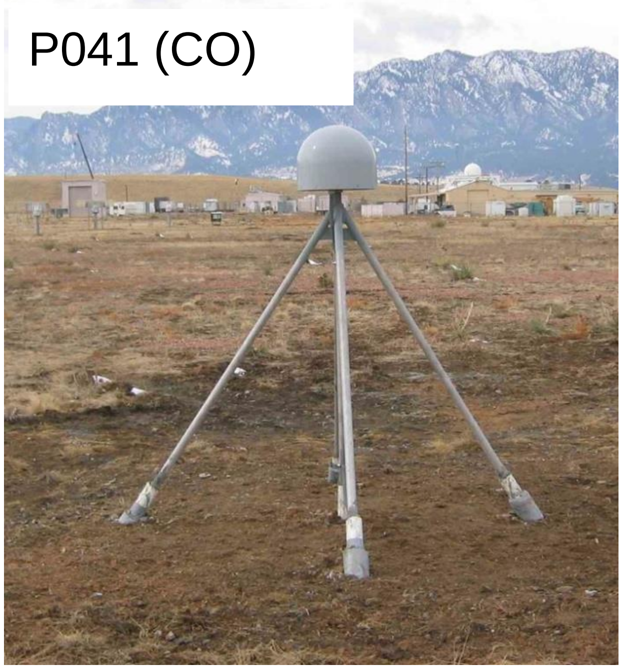
Snow depth → frequency

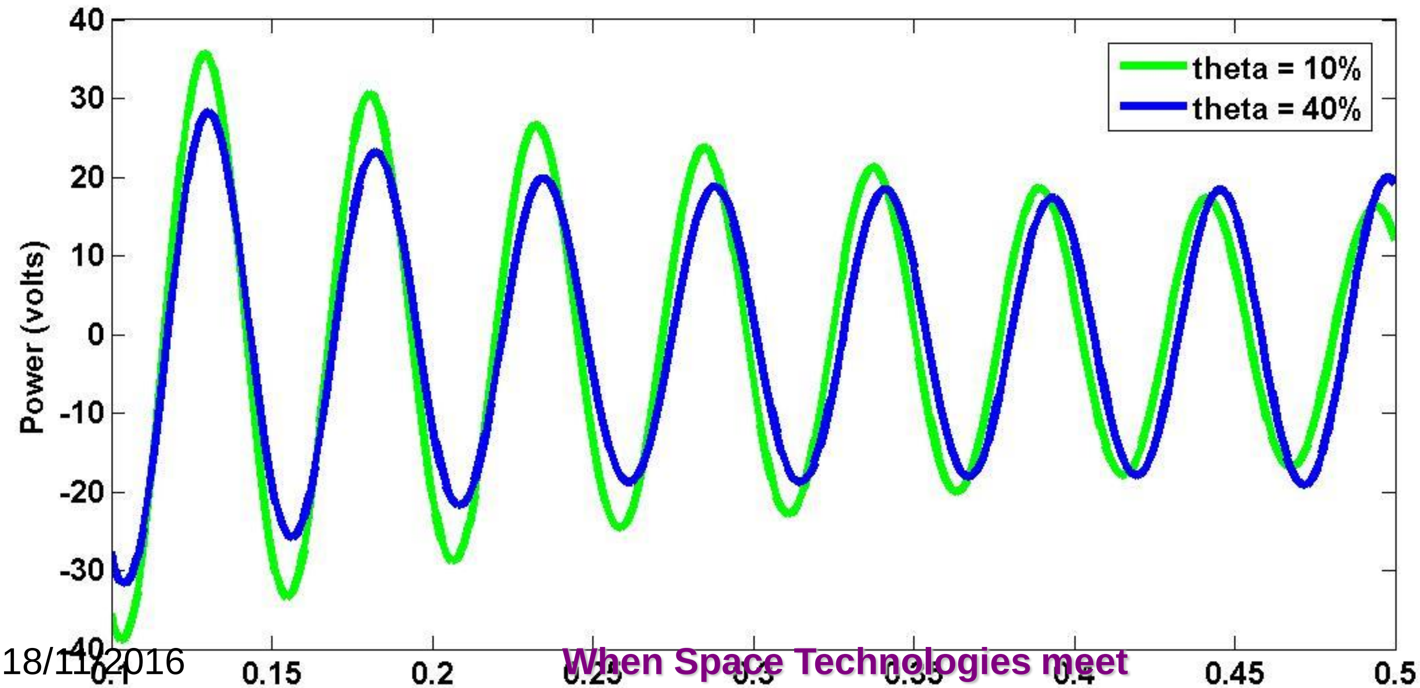
Vegetation → amplitude & MP1

Soil Moisture

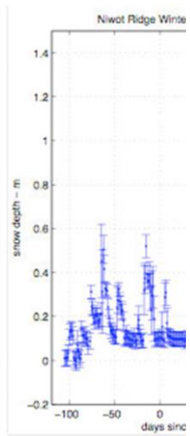
volumetric water content is linearly related to phase of interference pattern

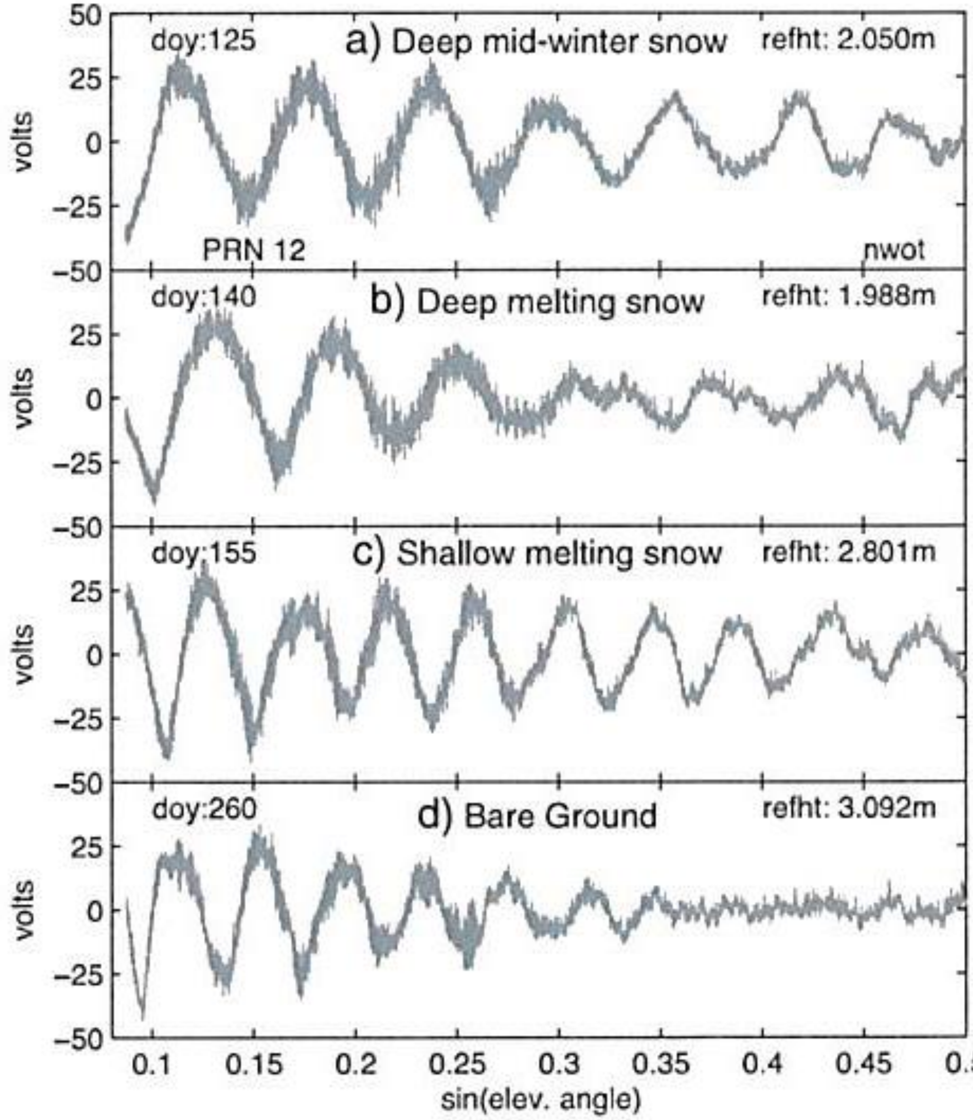
$$SNR = A\cos(f\sin E + \phi)$$

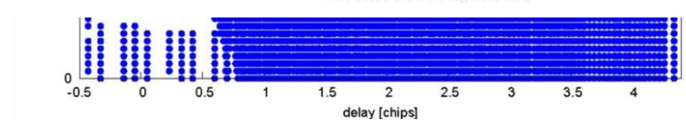




Snow a







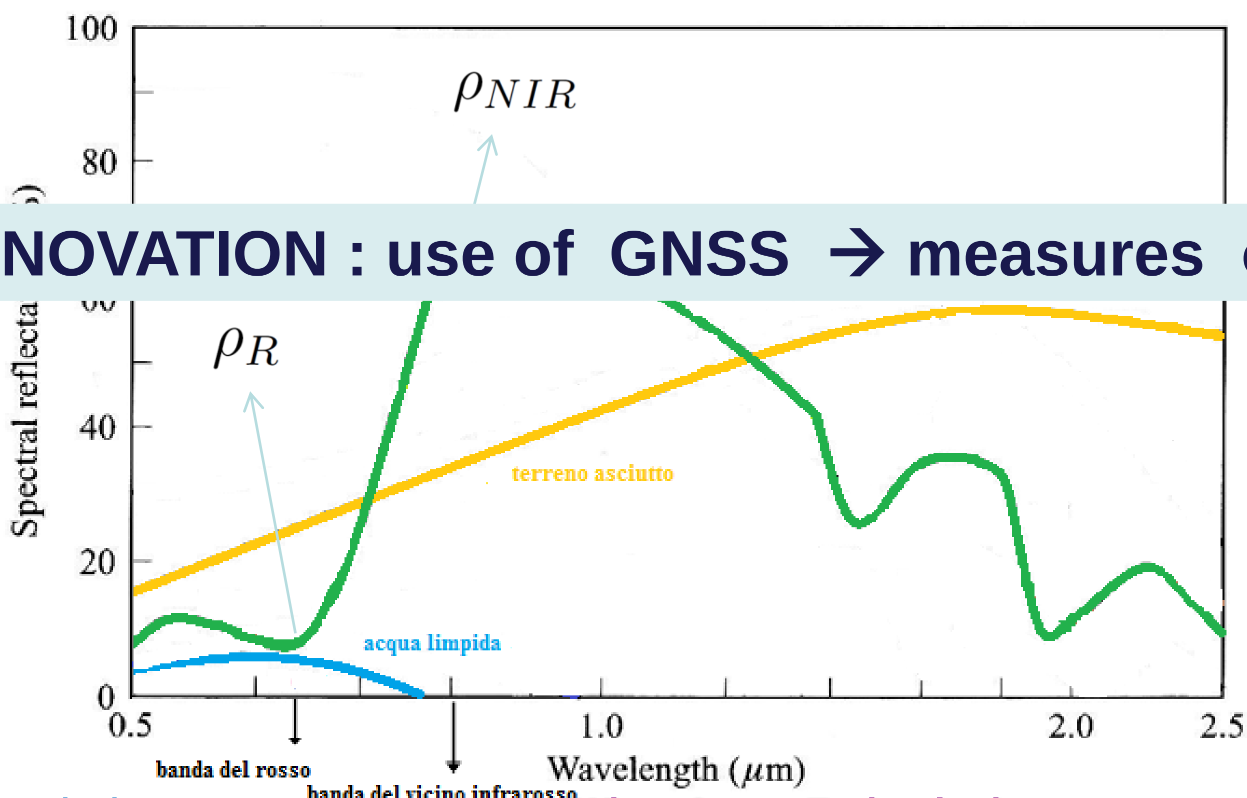
18/11/2016

Vegetation Robustness → capacity for growth and survival of the plant

Relevant for :

- Vegetation Robustness maps
- Precise Farming **and** forestry

STATE of ART for the estimate of the Vegetation Robustness → NDVI



$$NDVI = \frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R}$$

INNOVATION : use of GNSS → measures of MP1

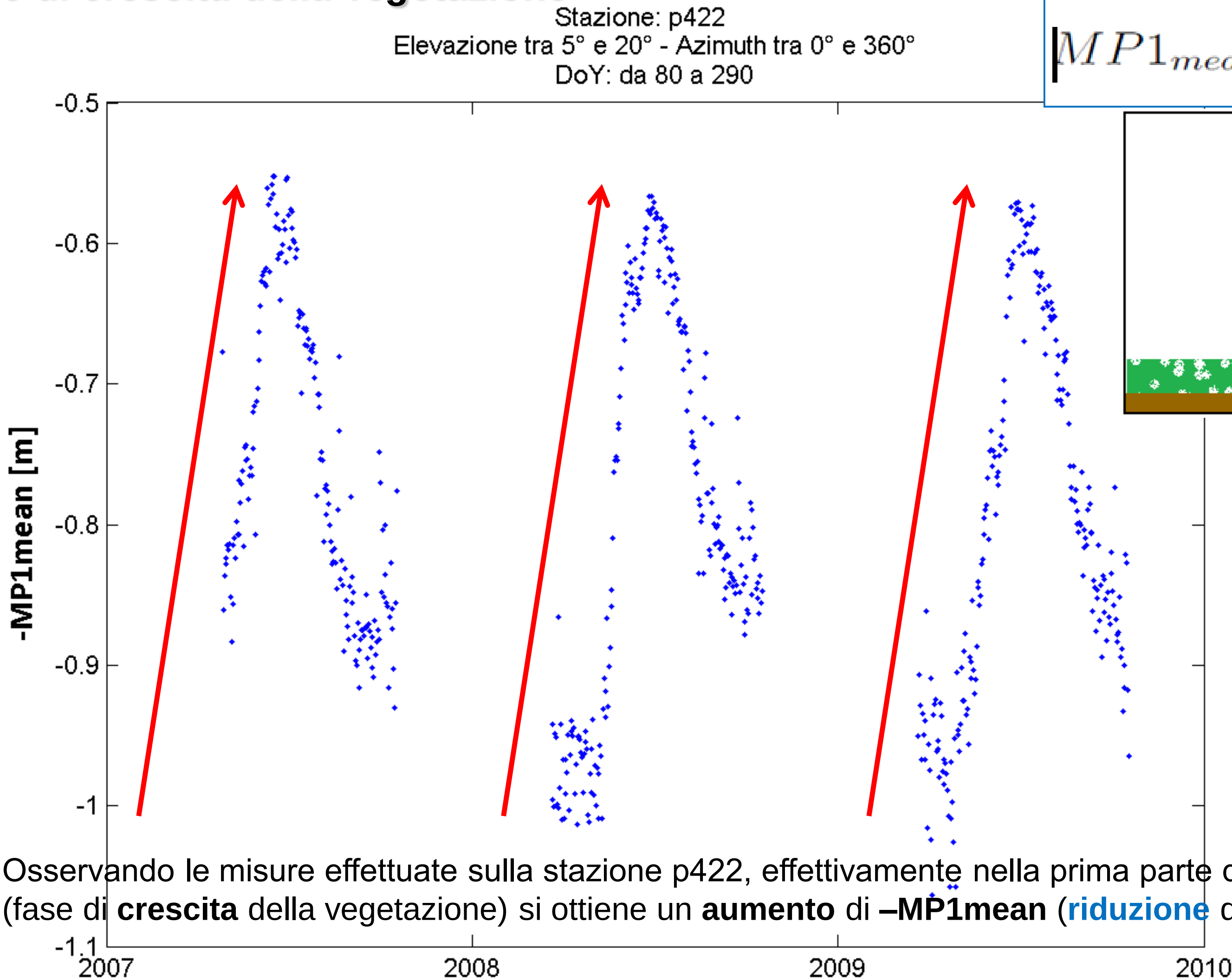
Optical Sensors:

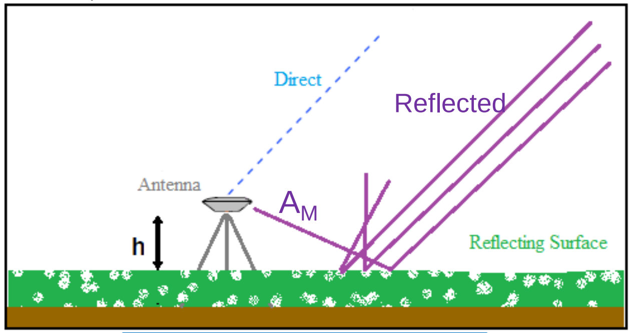
- **Rover** (GreenSeeker)
- **airplanes-Drones**
- **Satellites** (LANDSAT, MODIS, etc…)

COSA DICE IL MODELLO MATEMATICO di MP1mean(g)

Fase di crescita della vegetazione

$$|MP1_{mean}(g)| \propto A_M(g) \times h(g)$$





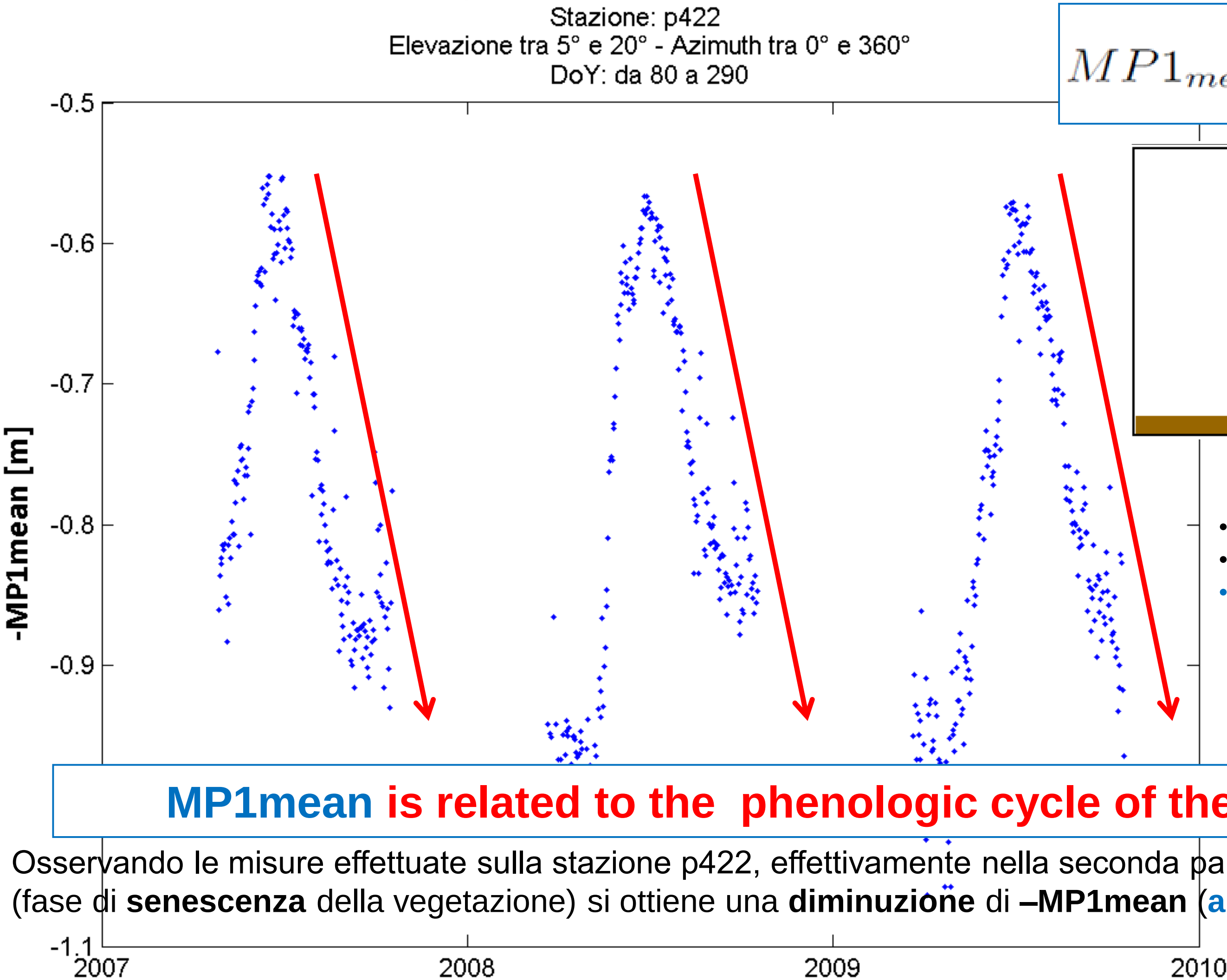
Fase di crescita

- **si riduce h**
- **si riduce A_M**
- **si riduce MP1mean**

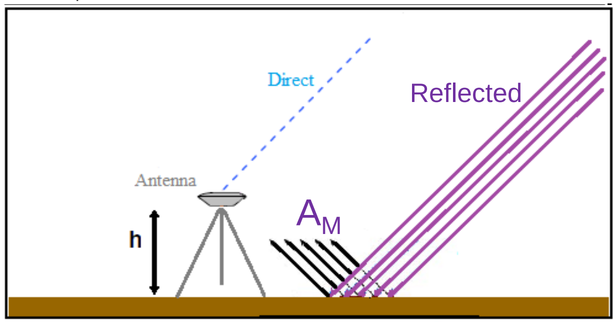
Osservando le misure effettuate sulla stazione p422, effettivamente nella prima parte dell'anno (fase di **crescita** della vegetazione) si ottiene un **aumento** di **–MP1mean** (**riduzione** di **MP1mean**)

COSA DICE IL MODELLO MATEMATICO di MP1mean(g)

Fase di senescenza della vegetazione



$$MP1_{mean}(g) \propto A_M(g) \times h(g)$$



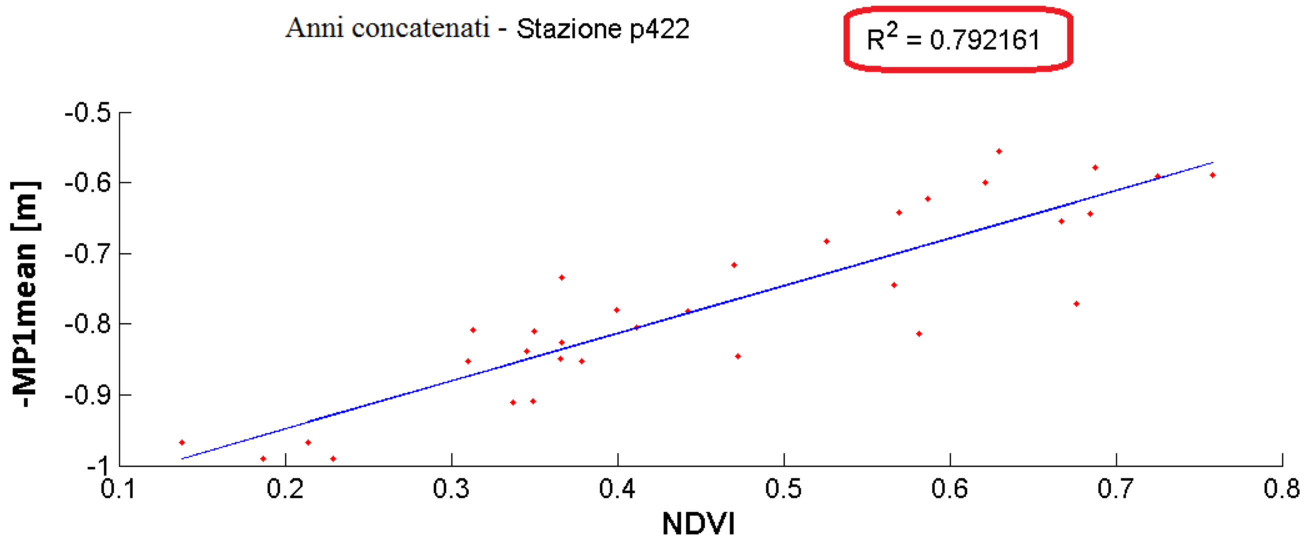
Fase di senescenza

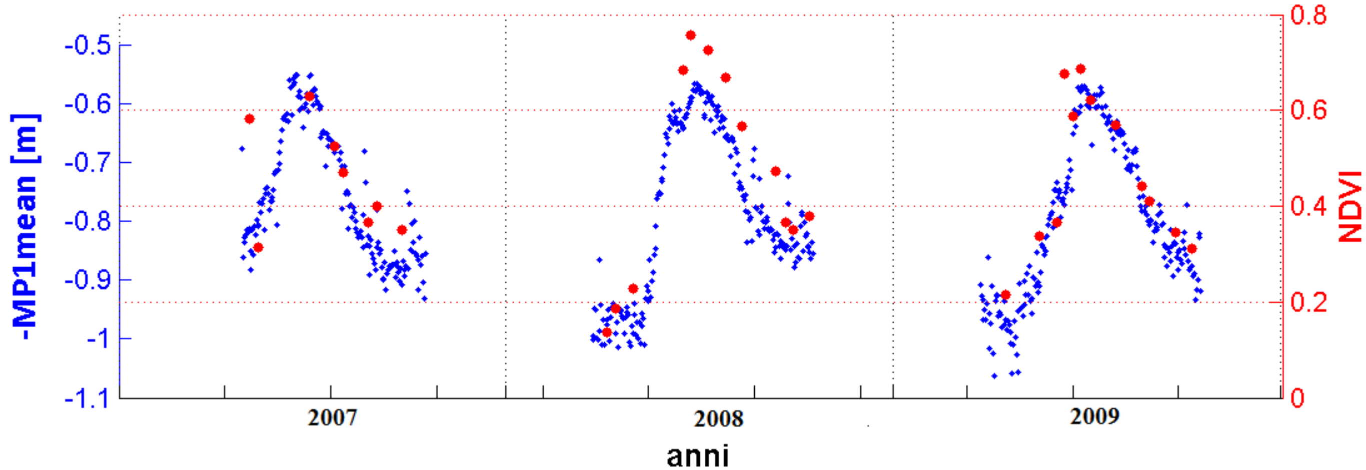
- **aumenta h**
- **aumenta A_M**
- **aumenta MP1mean**

MP1mean is related to the phenologic cycle of the vegetation

Osservando le misure effettuate sulla stazione p422, effettivamente nella seconda parte dell'anno (fase di **senescenza** della vegetazione) si ottiene una **diminuzione** di **–MP1mean** (**aumento** di **MP1mean**)

Comparison between MP1mean e NDVI (LANDSAT)





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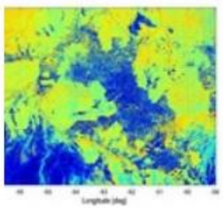

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COREGAL: Combined Positioning-Reflectometry Galileo Code Receiver for Forest Management

By Izabela Prates | 17h14, 13 de March de 2015

Coregal aims at developing a low cost unmanned aerial platform and service for biomass mapping will allow wide scale mapping in the Brazilian context of forest management. A first of a kind combined Position-Reflectometry Galileo receiver is developed as main sensor for platform positioning and biomass estimation, the latter using reflected Global Navigation Satellite Systems (GNSS) signals (also called GNSS-R) that propagate through tree canopies,

...m/en/blog/2015/03/13/coregal-combined-positioning-reflectometry-galileo-code-receiver-for-forest-management/coregal/

Conclusions

- The cheap cost of GNSS receivers and their very high performances (few mm in positioning and few hundredth of mm in phase measurements) allows a wide field of applications of GNSS in Remote Sensing (Geophysics, Meteorology, Climate, Space Weather,etc)

- Some applications can be helpful and sound very promising for Precision Farming...

- ASI/CGS has developped till now only geodetic/meteo applications but the plan is to cover also special applications like PF
- **The broader band of GALILEO will enhance the performances of RS GNSS !!**