Tor Vergata University –Rome

Earth Observation Laboratory

GEO-K s.r.l.

REFORESTATION OF BURNED AREAS MONITORED BY SAR DATA AND A SCATTERING MODEL

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Optical/TIR sensors employed for:

- mappping and monitoring active fires and fire scars
- some post-fire recovery

Problems: hindrance from weather conditions,
errors due to spectral overlaps

SAR (all weather) complements and enhances multi-spectral observations

Successful in monitoring and mapping extent and severity of fires (Alaska, Indonesia, Mediterranean)

Few studies on SAR monitoring the re-growth

We report on

- an investigation on the potential of (C-band) SAR in providing a measurement of the re-growth process after a fire
- the retrieval of the rate of biomass increase (ton/ha per year) after the fire from time series of SAR images by using an electromagnetic scattering model.

The study site

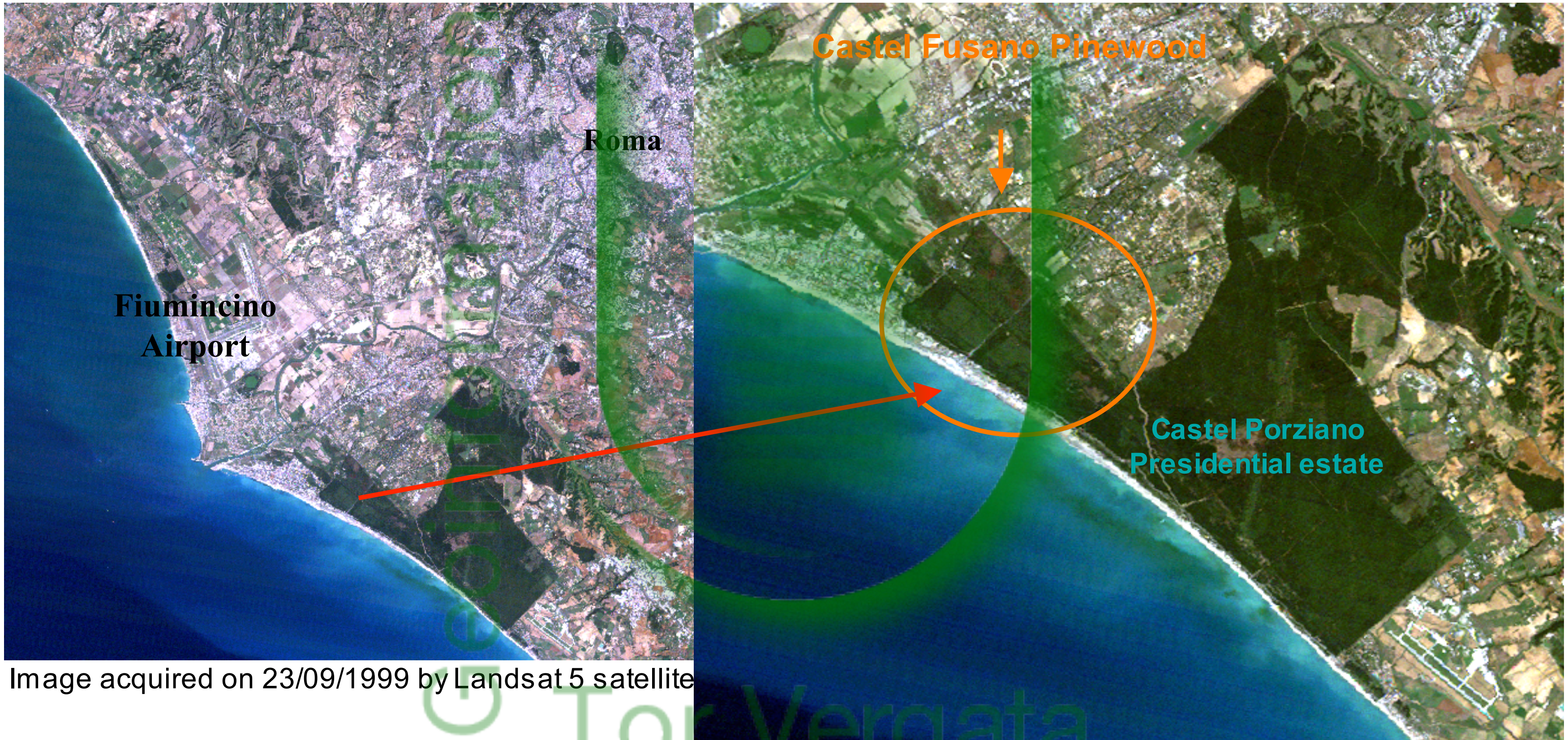
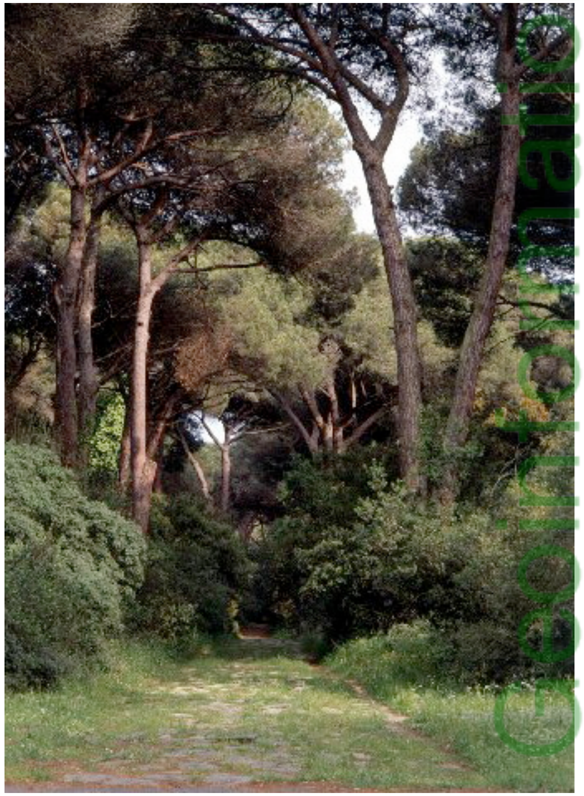


Image acquired on 23/09/1999 by Landsat 5 satellite

The Castel Fusano pinewood is located south of Rome, 5 km from the estuary of Tiber River, and covers an area of approximately 1,100 ha.



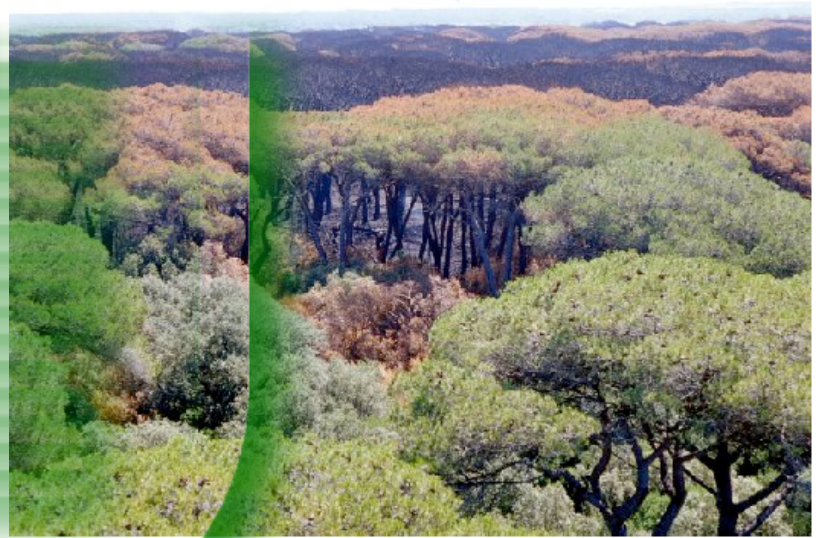
Main vegetation species:

- Quercus ilex, Phillyrea latifoglia, Pistacia lentiscus.
- Anthropic Pinus pinea introduced from 18th century

“the old pinewood” (130-150 years old)

“the young woodland” (50-60 years old)

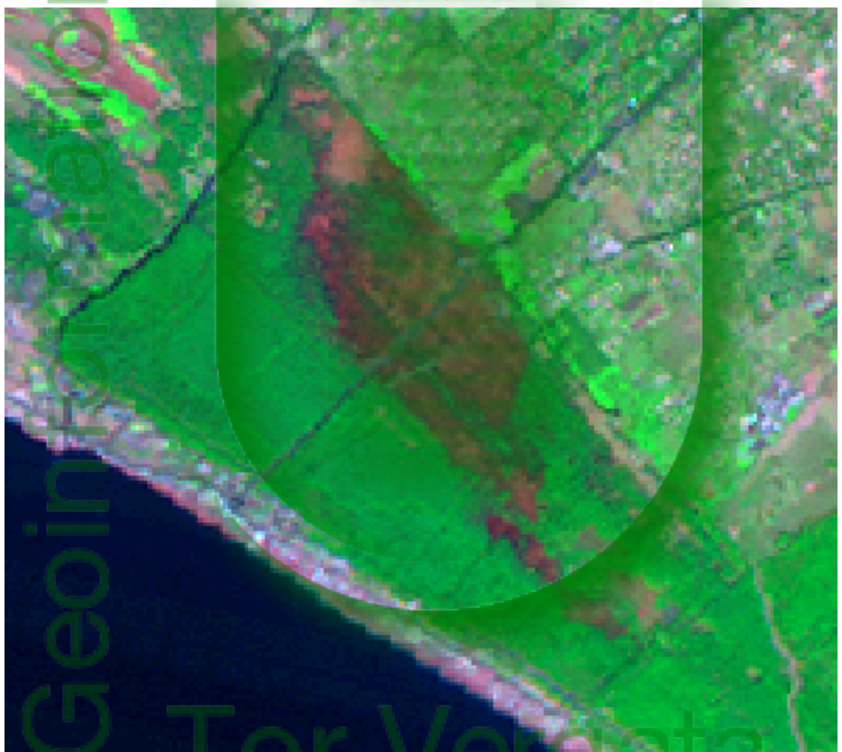
The Fire (3rd and 4th July 2000)



100 ha damaged

250 ha

destroyed



Fire scar observed by LANDSAT

Monitoring the recovery

after 18 months

after 3 years

after 10 months

after 3 years

The data set

- Georeferenced orthophotos, 1m resolution, acquired in 1998, to reconstruct the scenario before the fire (Terraitaly "it2000").
- Airborne visible and near infrared images about 1m resolution immediately after the fire (18-21 July 2000, Municipality of Rome)
- **2 Landsat 5 TM** imagery, taken on 09/23/1999 and on 09/25/2000.
- **34 ERS-SLCI** (Single Look Complex full frame) SAR images

Methodology

- Generation of ground range backscatter intensity time series from SLCI-SAR images before and after the fire (1999 to 2003)
- Integration of SAR time series with medium and hi-res images
- Segmention of areas of interest
- Analysis

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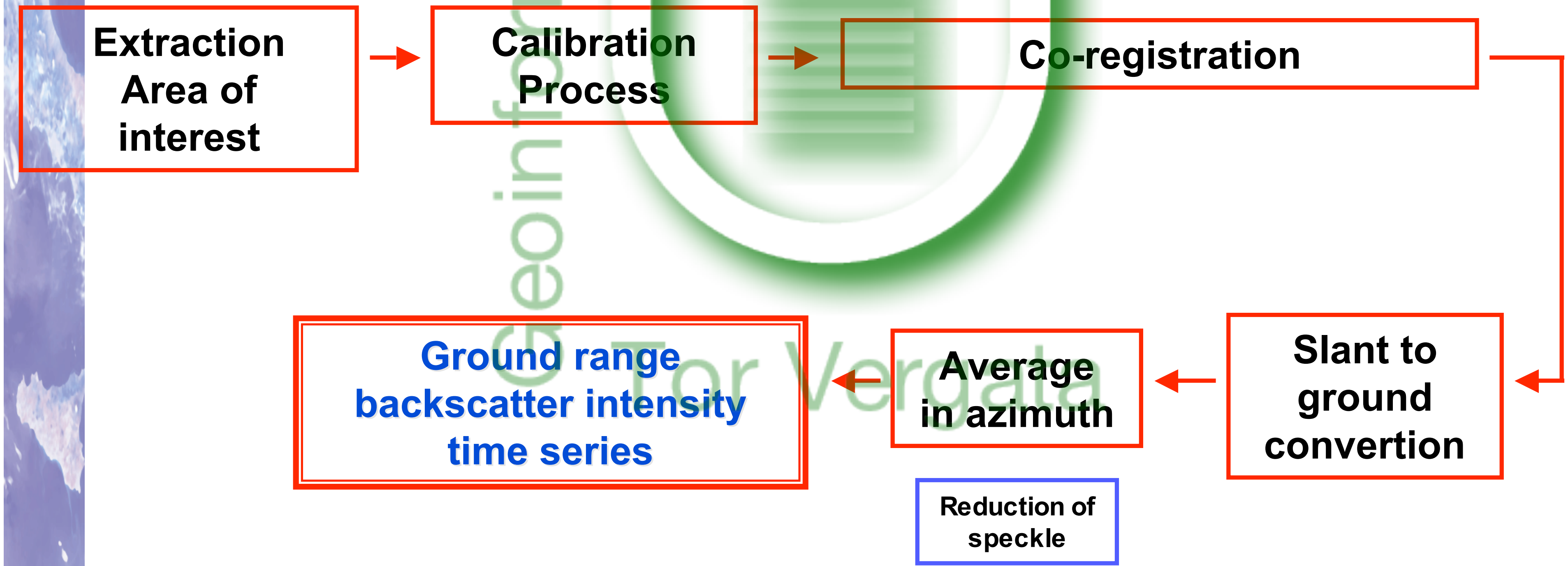
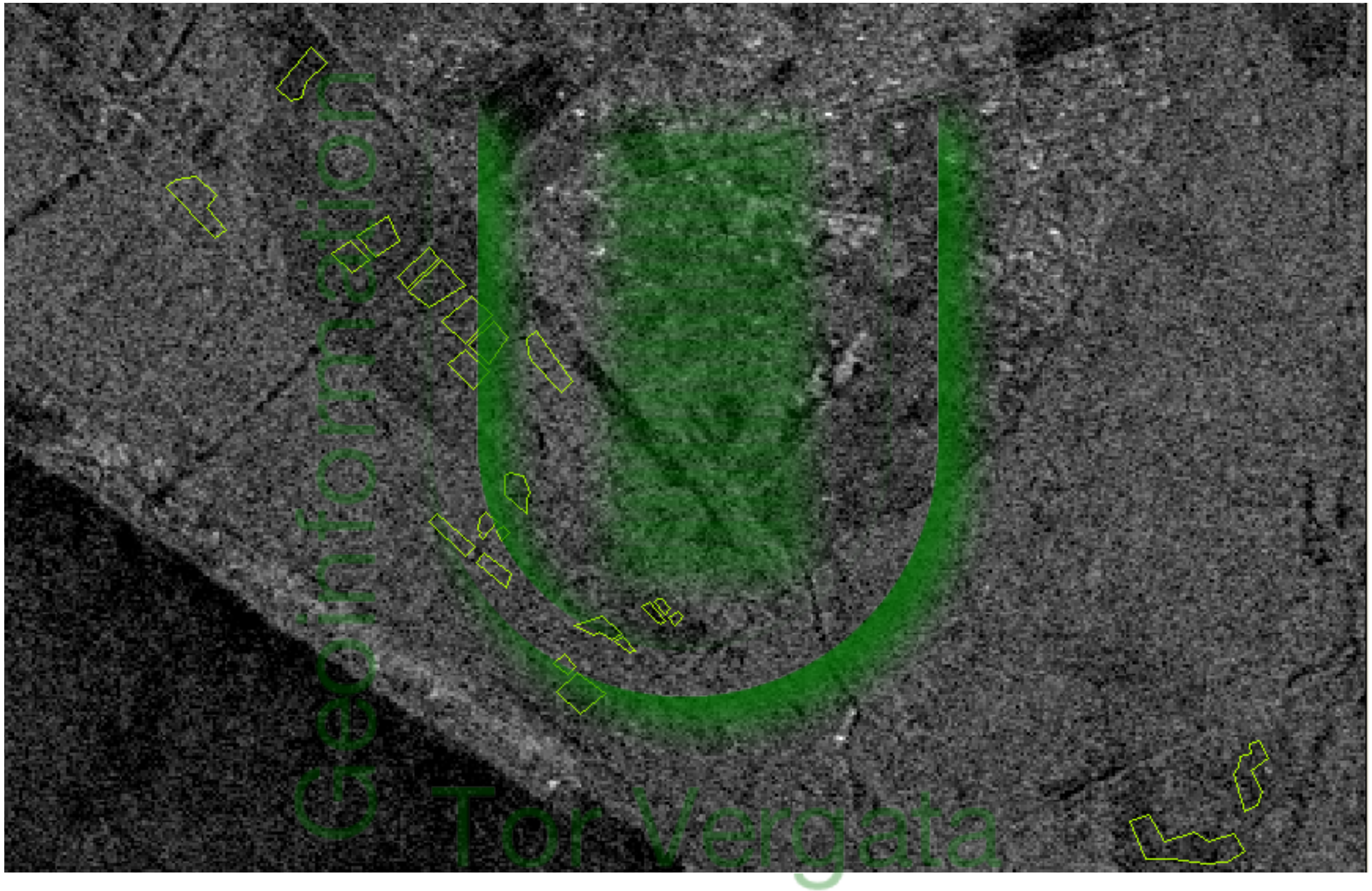
Date	Days from event fire	Satellite	Orbit	Passage	Frame	Track	Weather cond.	UP
18 Feb. 2001	+229	ERS-2	30494	D	2763	79	Partly Cloudy	-
03 June 2001	-334	ERS-2	31997	D	2763	79	Scattered Clouds	-
8 Jul. 2001	+369	ERS-2	32498	D	2763	79	Scattered Clouds	-
12 Aug2001	+434	ERS-2	32999	D	2763	79	Clear	-
16 Sep. 2001	+439	ERS-2	33500	D	2763	79	Mostly Cloudy	1
21 Oct 2001	+474	ERS-2	34001	D	2763	79	Clear	-
25 Nov. 2001	+509	ERS-2	34502	D	2763	79	Clear	6
14 Apr. 2002	+649	ERS-2	36506	D	2763	79	Light Rain	0
23 Jun. 2002	+719	ERS-2	37508	D	2763	79	Clear	-
28 Jul. 2002	+754	ERS-2	38009	D	2763	79	Clear	-
1 Sep. 2002	+789	ERS-2	38510	D	2763	79	Mostly Cloudy	1
10 Nov. 2002	+859	ERS-2	39512	D	2763	79	Partly Cloudy	2
19 Jan. 2003	+929	ERS-2	40514	D	2763	79	Clear	1
30 Mar. 2003	+999	ERS-2	41516	D	2763	79	Clear	-
8 Jun. 2003	+1069	ERS-2	42518	D	2763	79	Scattered Clouds	-
17 Aug. 2003	+1139	ERS-2	43520	D	2763	79	Clear	-
26 Oct. 2003	+1209	ERS-2	44522	D	2763	79	Clear	3

SAR- SLCI ERS1-2

- 34 passes from February 1999 to October 2003 (same frame)
- Investigation on meteorological condition
- Developing and optimising procedures to co-register and calibrate the images automatically





Selected AOI

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Data fusion aspects

Integration of SAR time series with Medium and Hi-Re Optical-XS images → ***The georeferencing process***

Ground range backscatter intensity time series

Landsat imagery

Airborne photographs about 1m resolution Mosaic

Registration on the **Georeferenced Orthophoto (Terraitaly "it2000"), 1m of resolution**, with an RMSe less than one pixel

Map projection: UTM ED50

All the data georeferenced and overlapped to be integrated in G.I.S.

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The 14 ROIs grouped into 3 classes

1. Burned areas (*Ba*) ← **ab1, ab2, ALotto2, AS, AT, APG, ATP, A77-00**

Total extention 26.2 ha

Destroyed by fire and undergoing re-growth

2. Undamaged areas (*NBa*) ← **AC, APGc, A77**

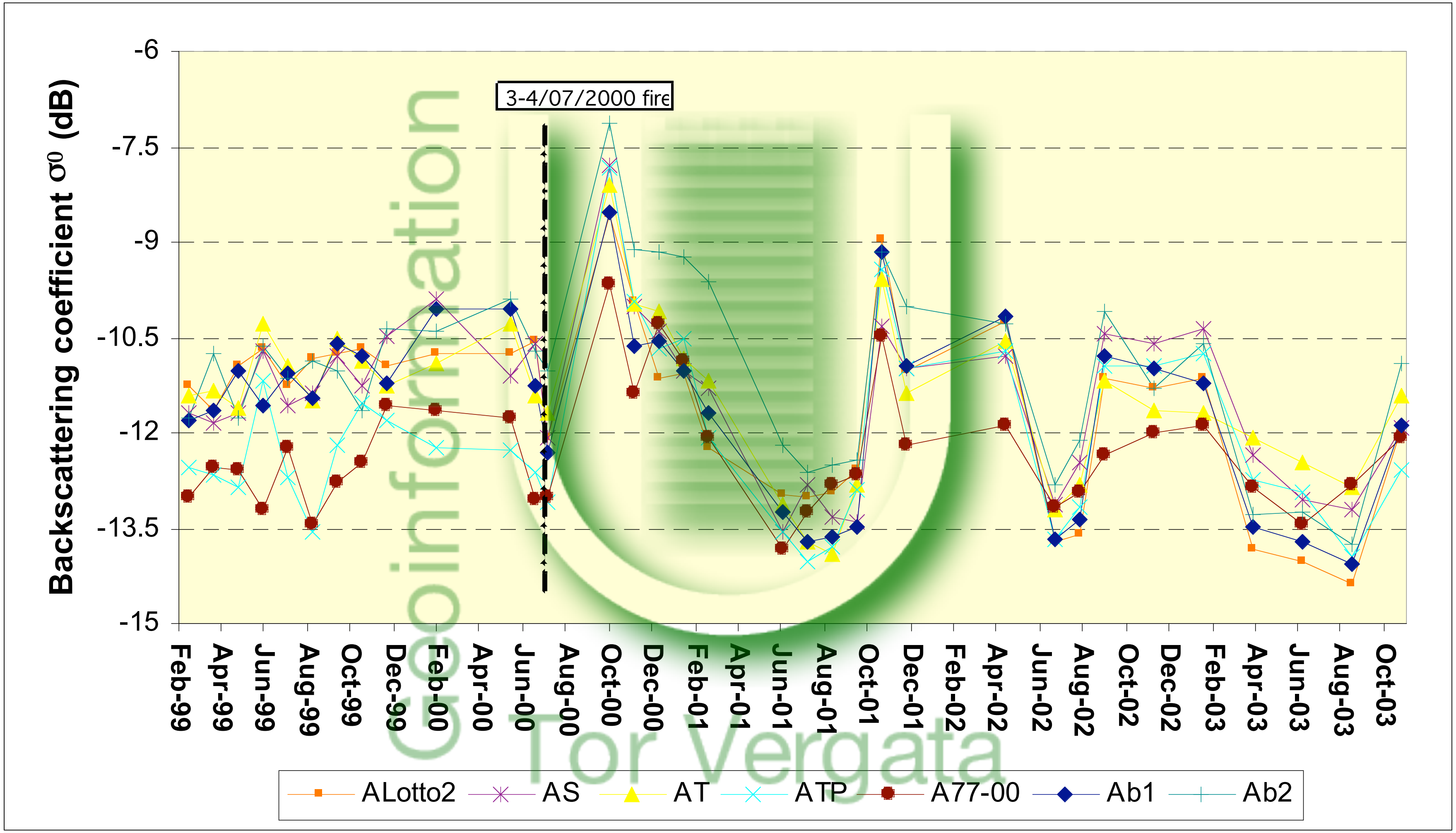
Total extention 17.4 ha

Young and old pinewood and Mediterranean scrub not damaged by fire

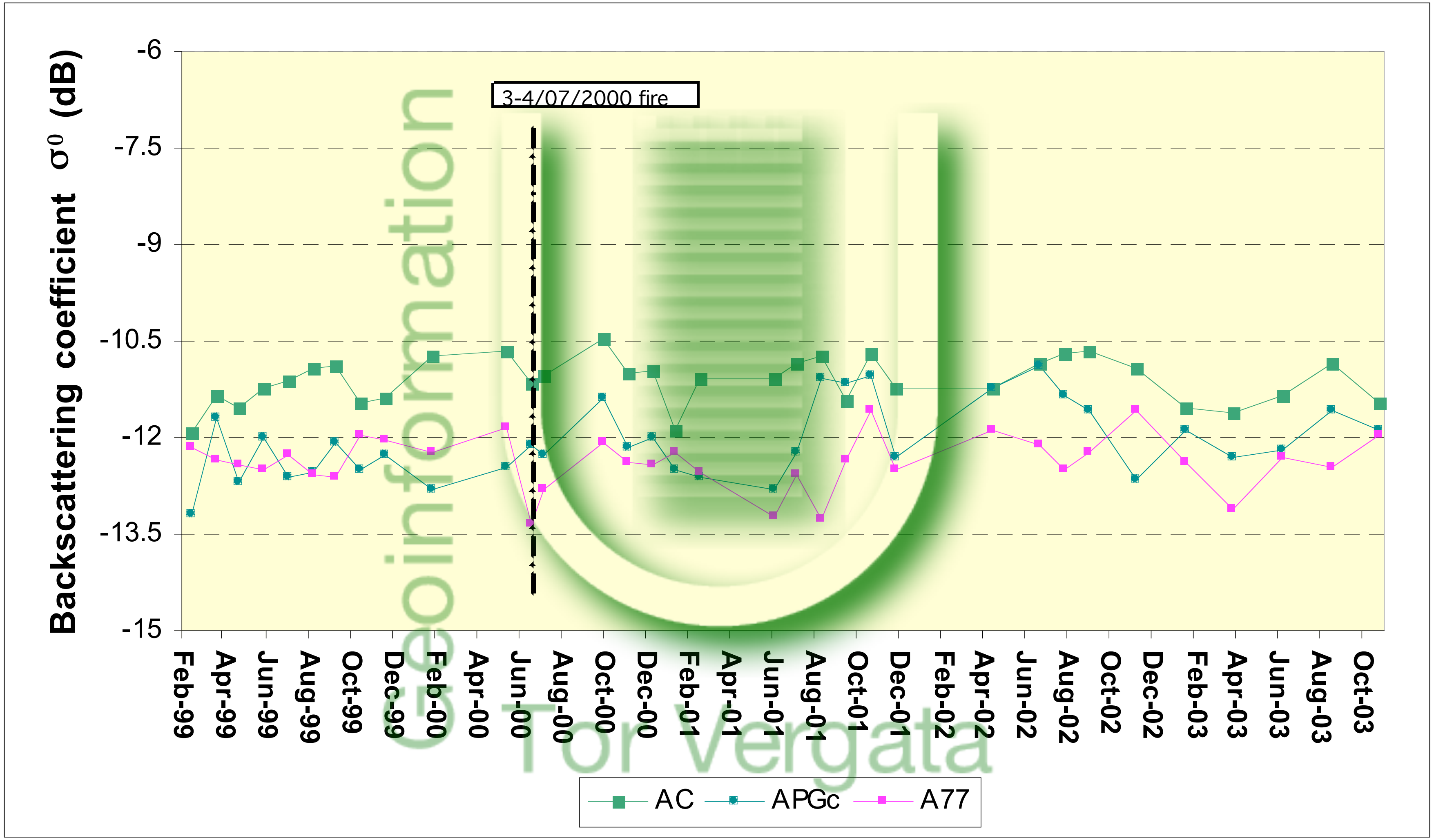
3. Bare Soil Like areas (*BSLa*) ← **VCNord, AGariga, NoVegetation**

Total extention 20.2 ha

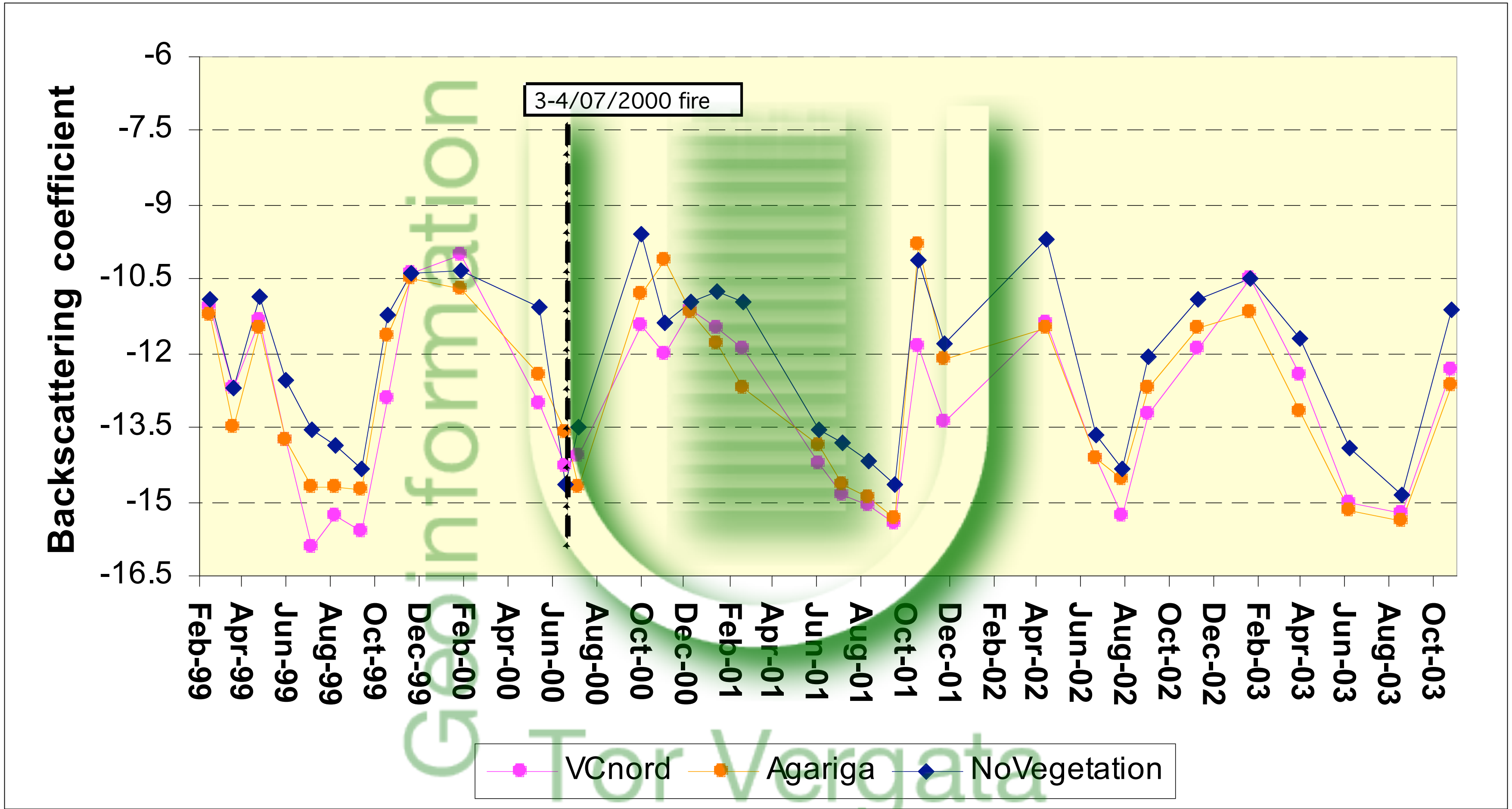
Bare soil or light sparse grass



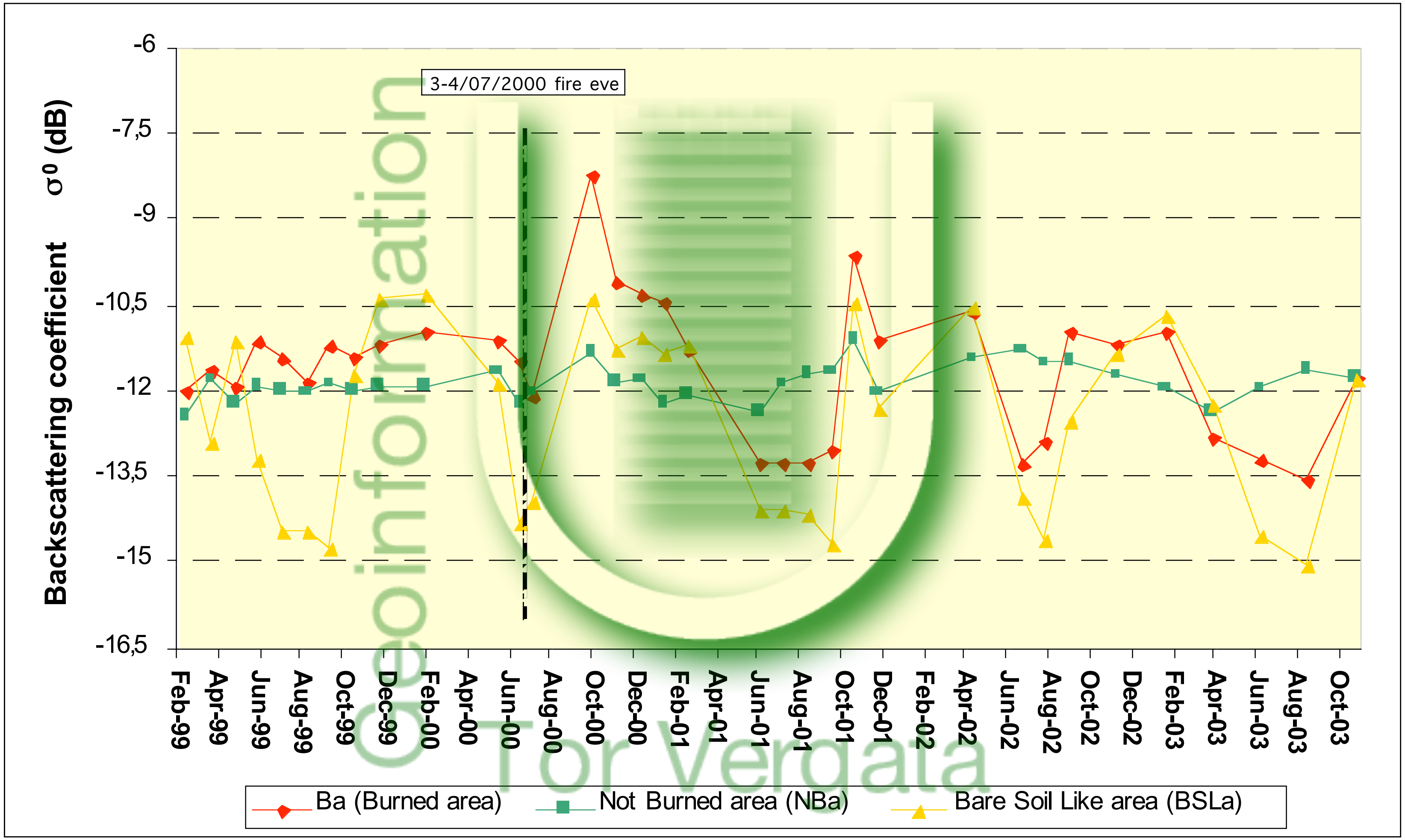
Time behaviour of backscattering of burnt pinewood areas



Time behaviour of backscattering of undamaged pinewood



Time behaviour of backscattering of near bare soil



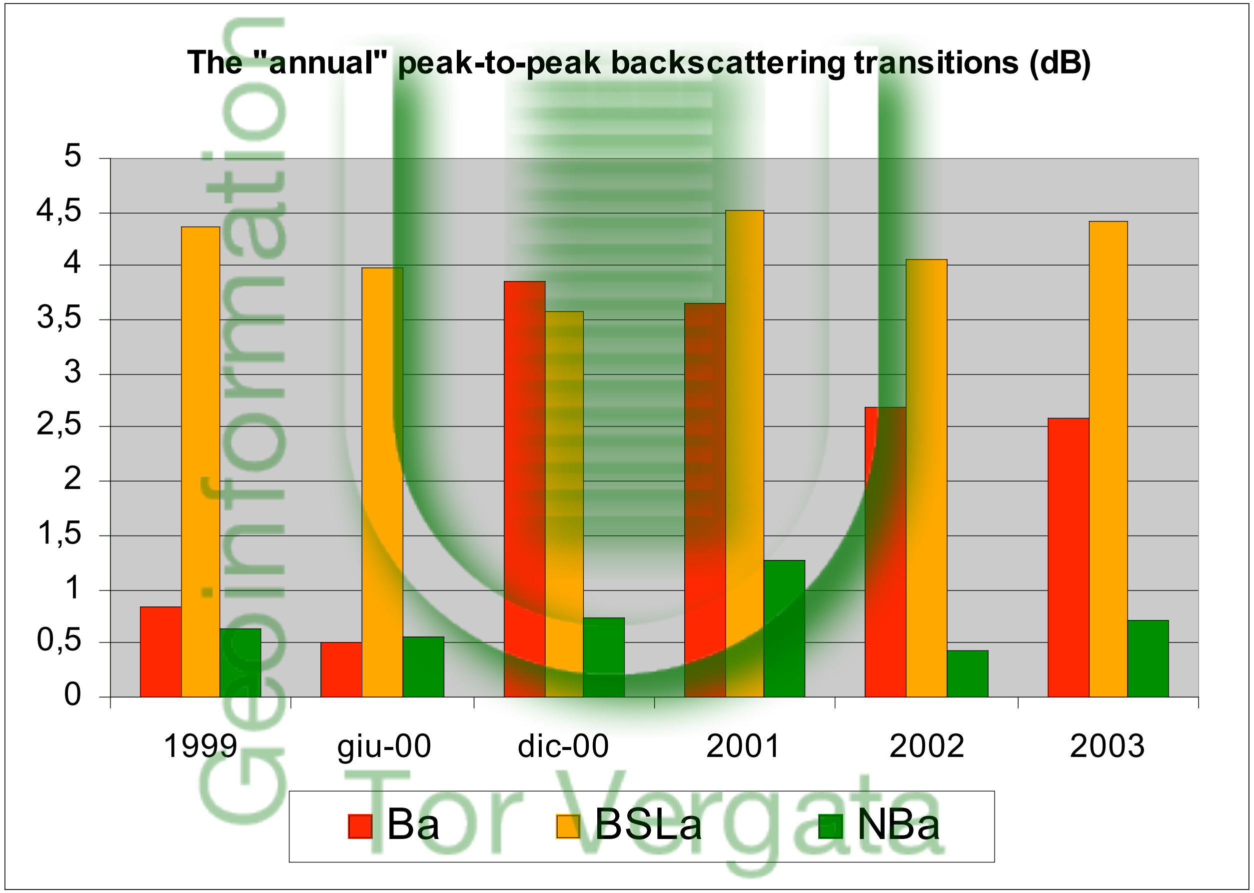
Time behaviour of backscattering corresponding to the 3 classes

Before the fire, the backscattering of all pinewood areas has small seasonal variations

after the fire, the backscattering of undamaged pinewood maintains this flat pattern

whereas the backscattering of burnt pinewood areas exhibits large seasonal variations, like those of bare soil

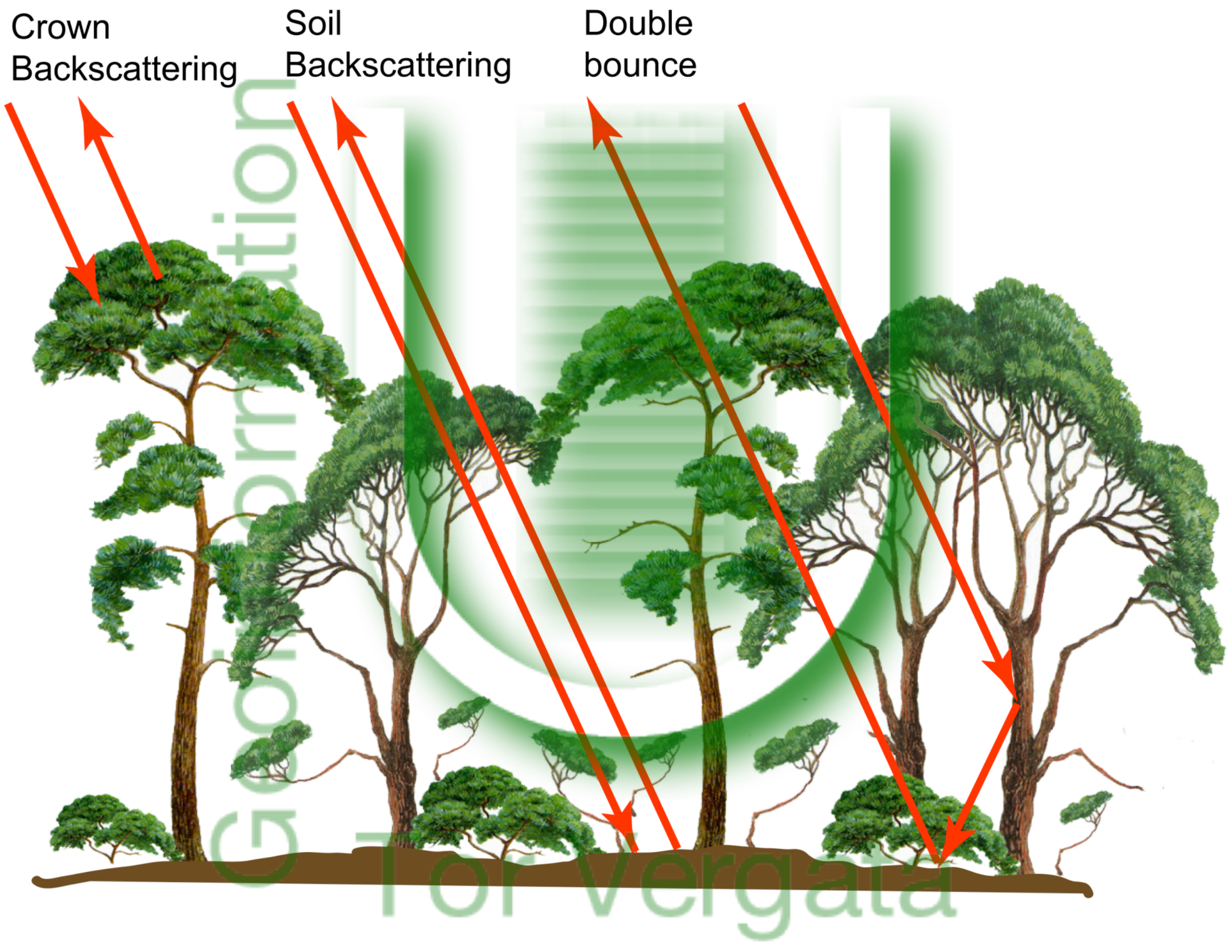
the peak-to-peak value decreases with time, as re-forestation progresses



The "annual" peak-to-peak backscattering transitions (dB)
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
1999
giu-00
dic-00
2001
2002
2003
Ba
BSLa
NBa

The decrease of the seasonal peak-to-peak value with time hints at measuring the re-growth rate of vegetation

Use of an electromagnetic scattering model (Tor Vergata model, by P. Ferrazzoli and L. Guerriero) for the quantitative retrieval of the biomass regrowth rate (ton/ha per year)



The backscattering coefficient s^0 depends on vegetation and soil characteristics, through direct scattering, extinction and interaction.

Tor Vergata scattering model based on Radiative Transfer Theory

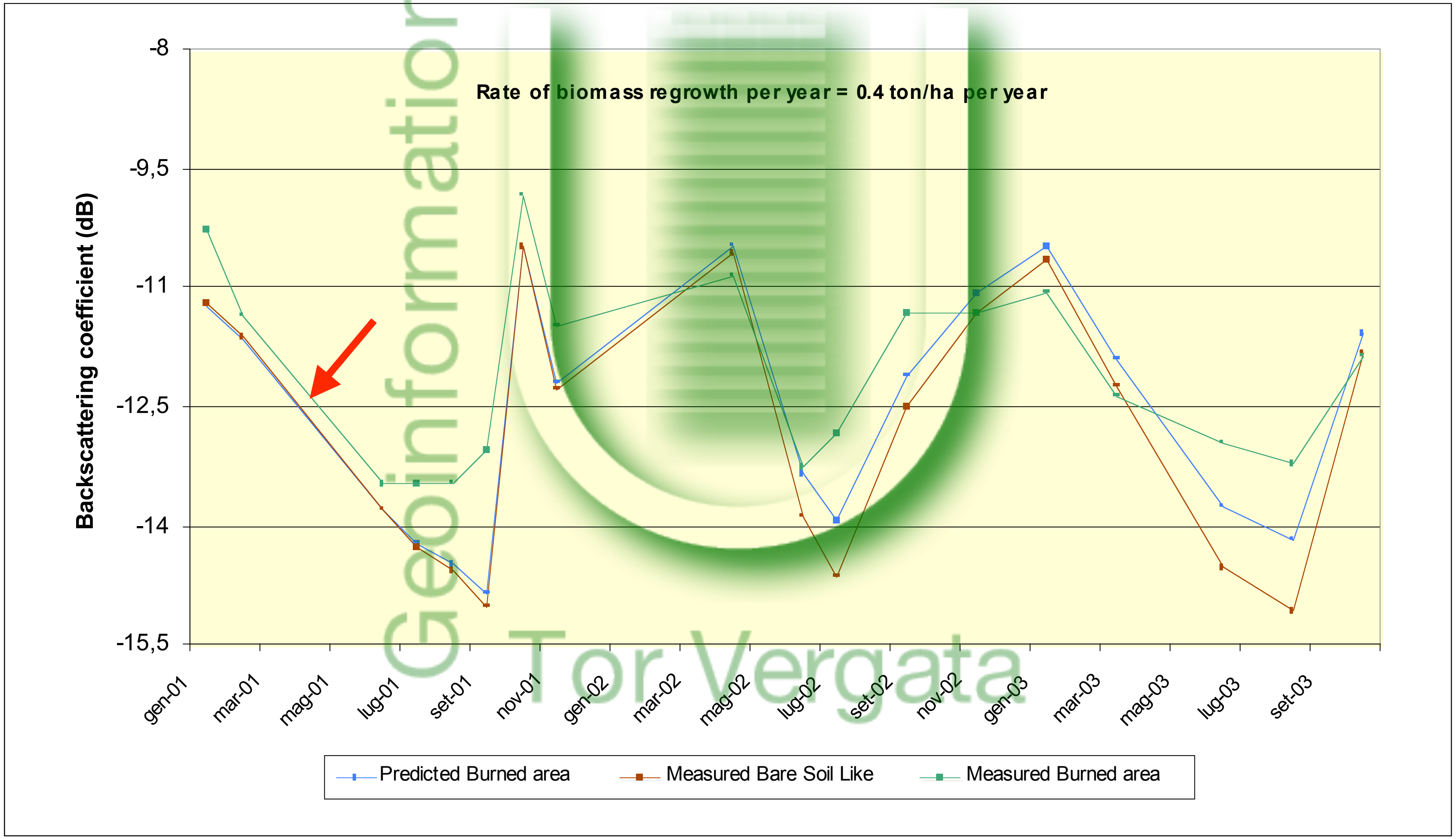
Elements of coniferous vegetation modelled as cylinders

Canopy subdivided into three regions: crown (ensemble of cylindrical elements of different size representing leaves (needles), twigs and branches), trunks (large nearly vertical cylinders), soil (rough dielectric half-space).

Scattering and extinction are computed taking into account:
- geometrical variables, i. e. length, thickness, orientation, density
- permittivity (from moisture content)

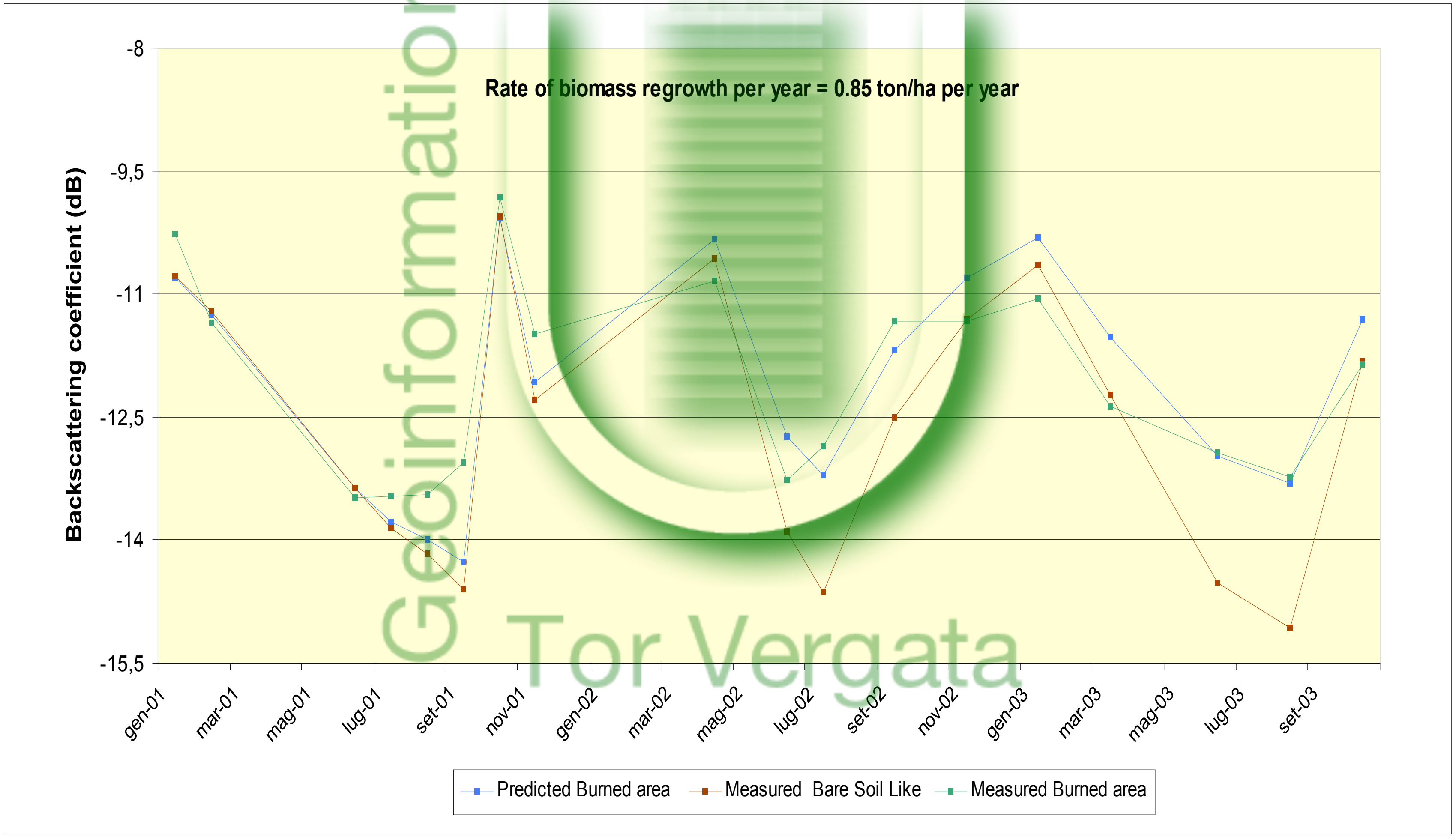
Backscattering coefficient computed as a function of soil moisture content for a range of above-ground biomass, assumed linearly increasing with yearly rate R_B

Determination of the value of R_B that minimizes the r.m.s. distance between model simulated and measured backscattering coefficient

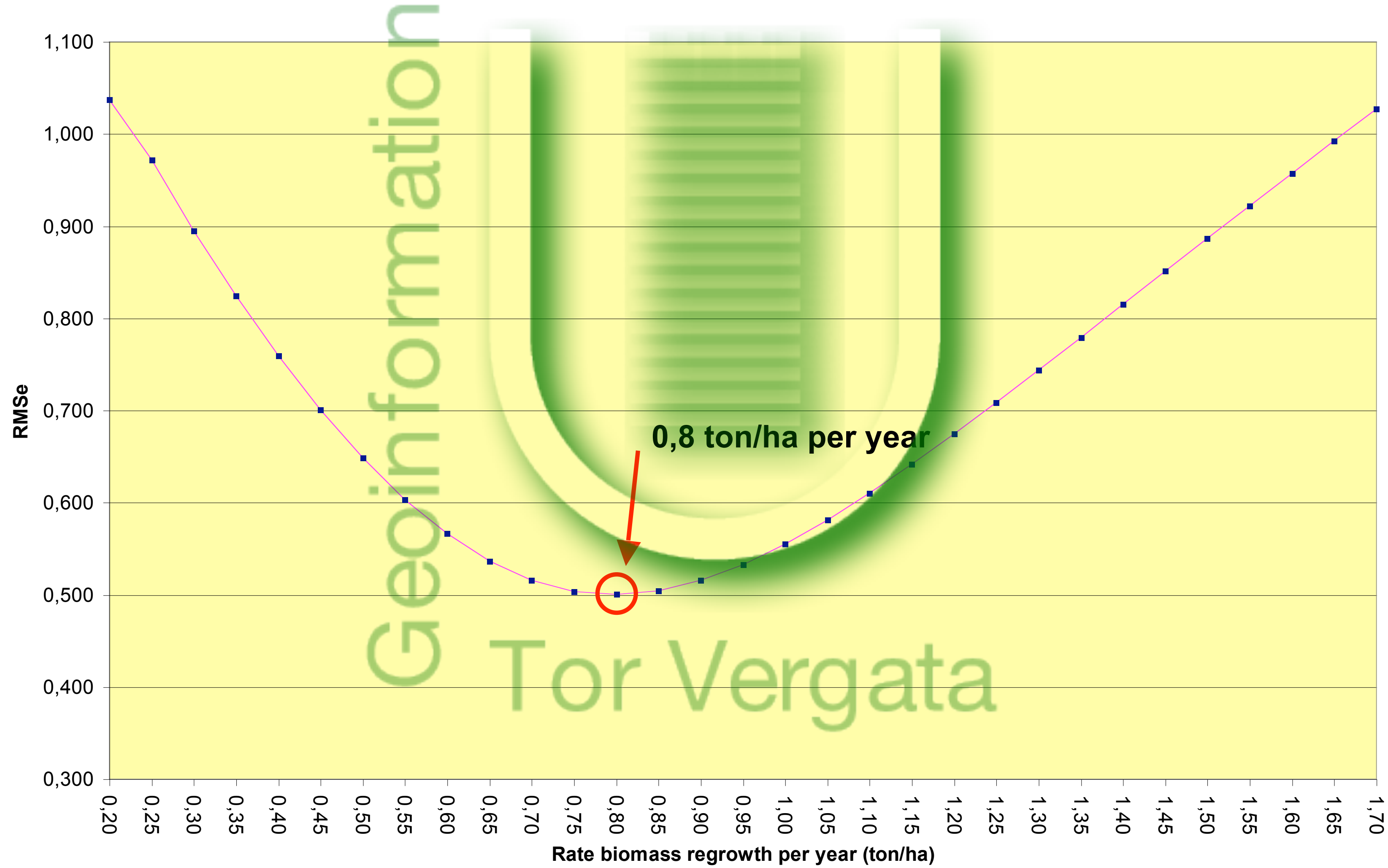


Rate of biomass regrowth per year = 0.4 ton/ha per year
Backscattering coefficient (dB)
-8
-9,5
-11
-12,5
-14
-15,5
gen-01
mar-01
mag-01
lug-01
set-01
nov-01
gen-02
mar-02
mag-02
lug-02
set-02
nov-02
gen-03
mar-03
mag-03
lug-03
set-03
Predicted Burned area
Measured Bare Soil Like
Measured Burned area

Result of simulation with RMSe minimum considering 2001, 2002 and 2003



RMSe calculated considering 2002 and 2003



In summary

A multitemporal analysis of the backscattering coefficient measured over the Castel Fusano pinewood, partially destroyed by a fire in July 2000, has been carried out.

After the fire, the backscattering of the burnt pinewood areas behaves like that of bare soil, with a seasonal cycle related to SMC

The peak-to-peak value of backscattering decreases with time, hence with the re-growth of vegetation

The backscattering peak-to-peak values have been computed by the Tor Vergata scattering model for a range of vegetation biomass

The minimization of the difference between simulated and measured backscattering yields the value of the biomass increase rate (ton/ha per year)

The obtained values are in agreement with ground measurements taken by biologists from "La Sapienza" University, Rome.