COMPARISON OF DIFFERENT CORRELATION APPROACHES BETWEEN GNSS-R AND GROUND SOIL MOISTURE DATA OVER THE VALENCIA ANCHOR STATION SITE DURING THE SMOS VALIDATION REHEARSAL CAMPING 2008

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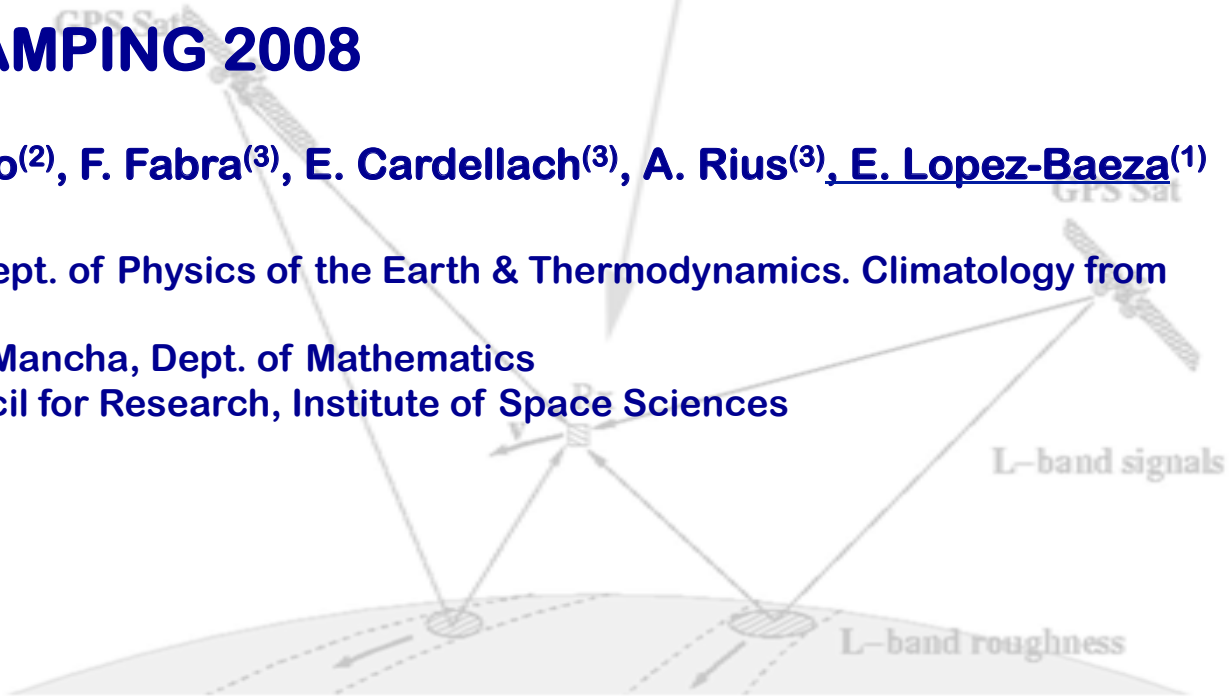
(3) Spanish Advanced Council for Research, Institute of Space Sciences



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- The ESA SMOS Validation Rehearsal Campaign in 2008
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- Analysis of the use of geostatistical models to increase data correspondence
  - Selection of homogeneous conditions to optimize correlations
- Regression models used
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Objectives

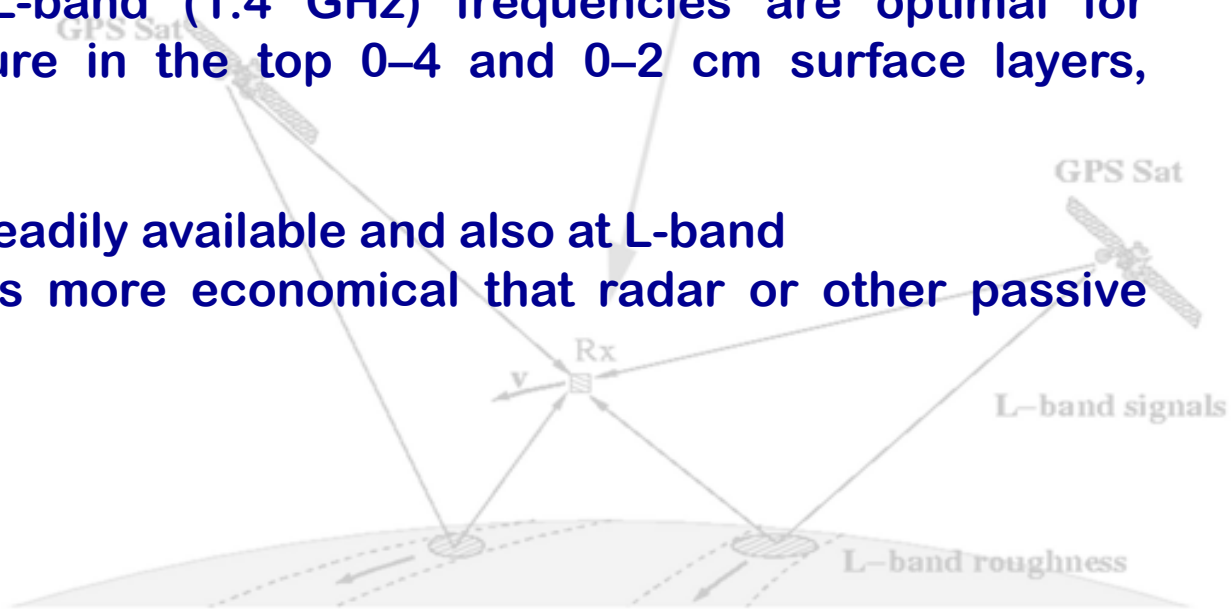
Contribute to the development of a methodology to measure soil moisture using the free GPS signals

Take advantage of the soil moisture network and of the SMOS campaigns data and of the significant characteristics of the Valencia Anchor Station area

Why do we try to estimate soil moisture with GPS signals?

Observation of soil moisture from satellites has always been predominantly performed in the microwave electromagnetic region, mainly in the range 1-3 GHz. This is because atmospheric attenuation in that range is largely reduced and better penetration of vegetation at longer wavelengths. **Njoku and O´Neill** (1982) showed that P-band (0.775 GHz) and L-band (1.4 GHz) frequencies are optimal for sensing soil moisture in the top 0–4 and 0–2 cm surface layers, respectively.

- GPS signals are readily available and also at L-band
- GPS equipment is more economical that radar or other passive instruments

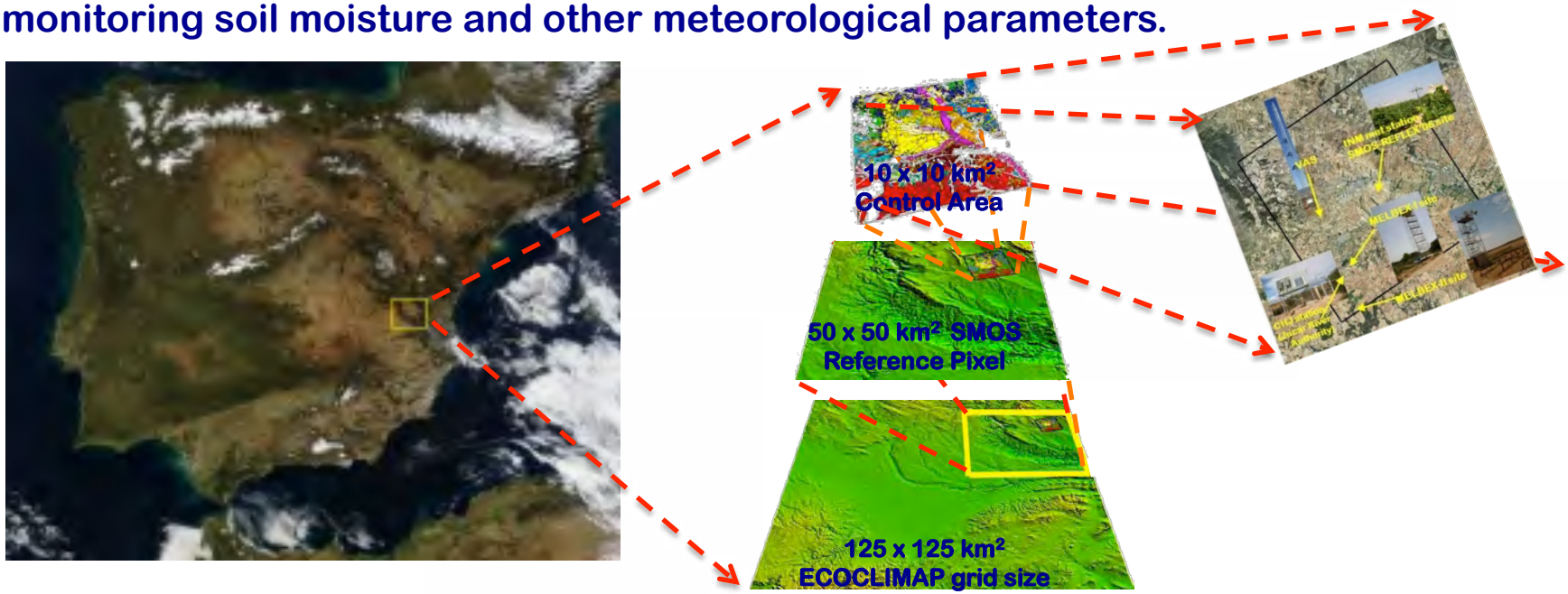


Study Area

The study area includes the reference area of the Valencia Anchor Station in the natural region of the Utiel-Requena Plateau, located west of the province of Valencia. It represents a fairly homogeneous area of about 2500 km^2, mainly dedicated to the cultivation of vine, with dry continental climate.

Coordinates: Latitude: 39.838°- 39.199 ° N Longitude: 1.541°-0.884°W

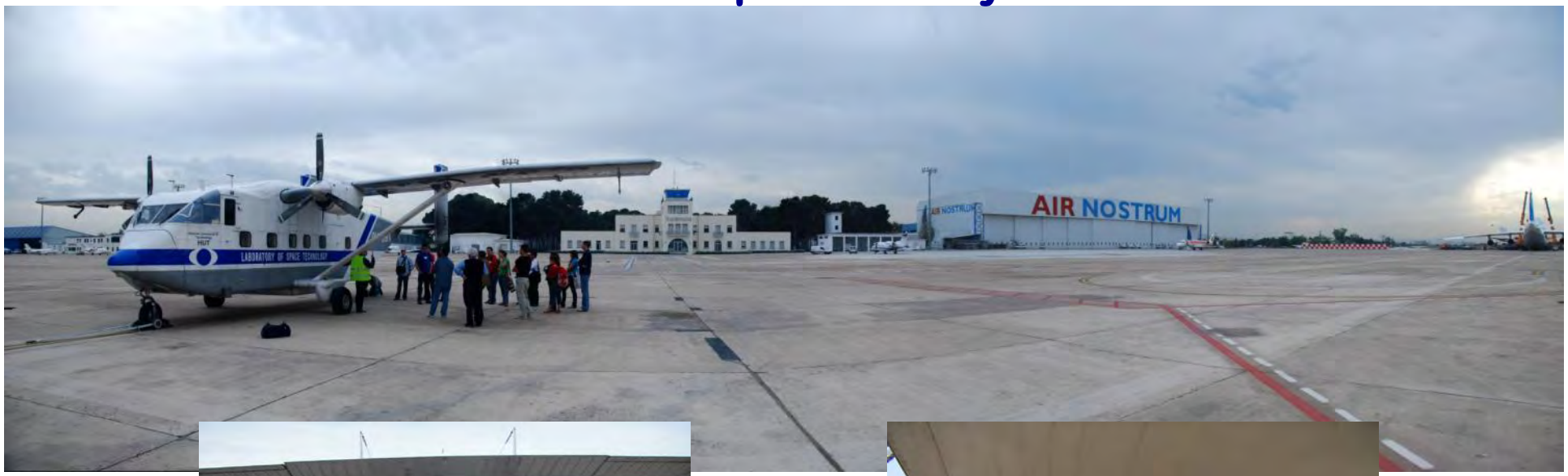
Within this area a robustly equiped control zone of 10 x 10 km^2 is dedicated to monitoring soil moisture and other meteorological parameters.



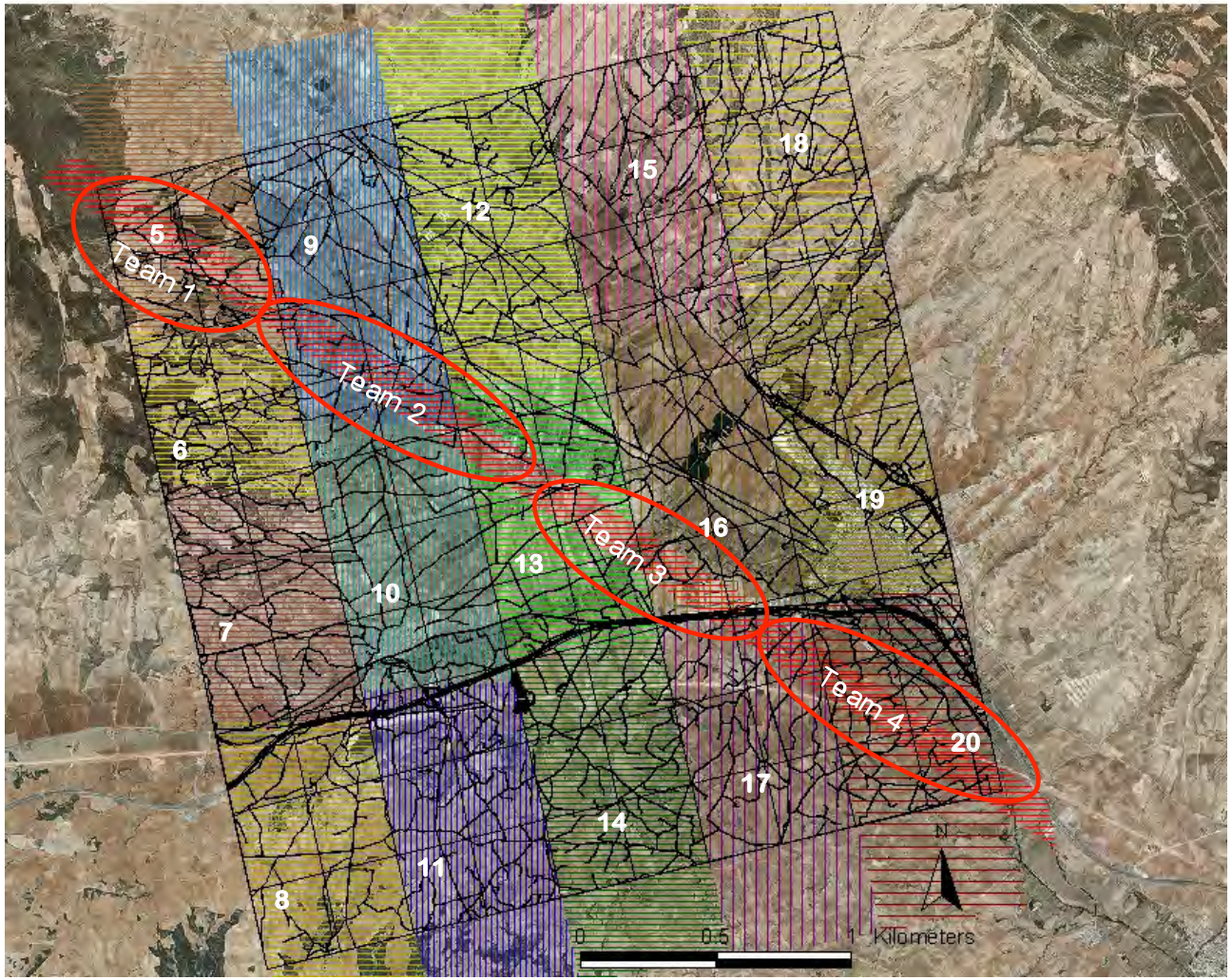
The ESA SMOS Validation Rehearsal Campaign

The Valencia Anchor Station Site

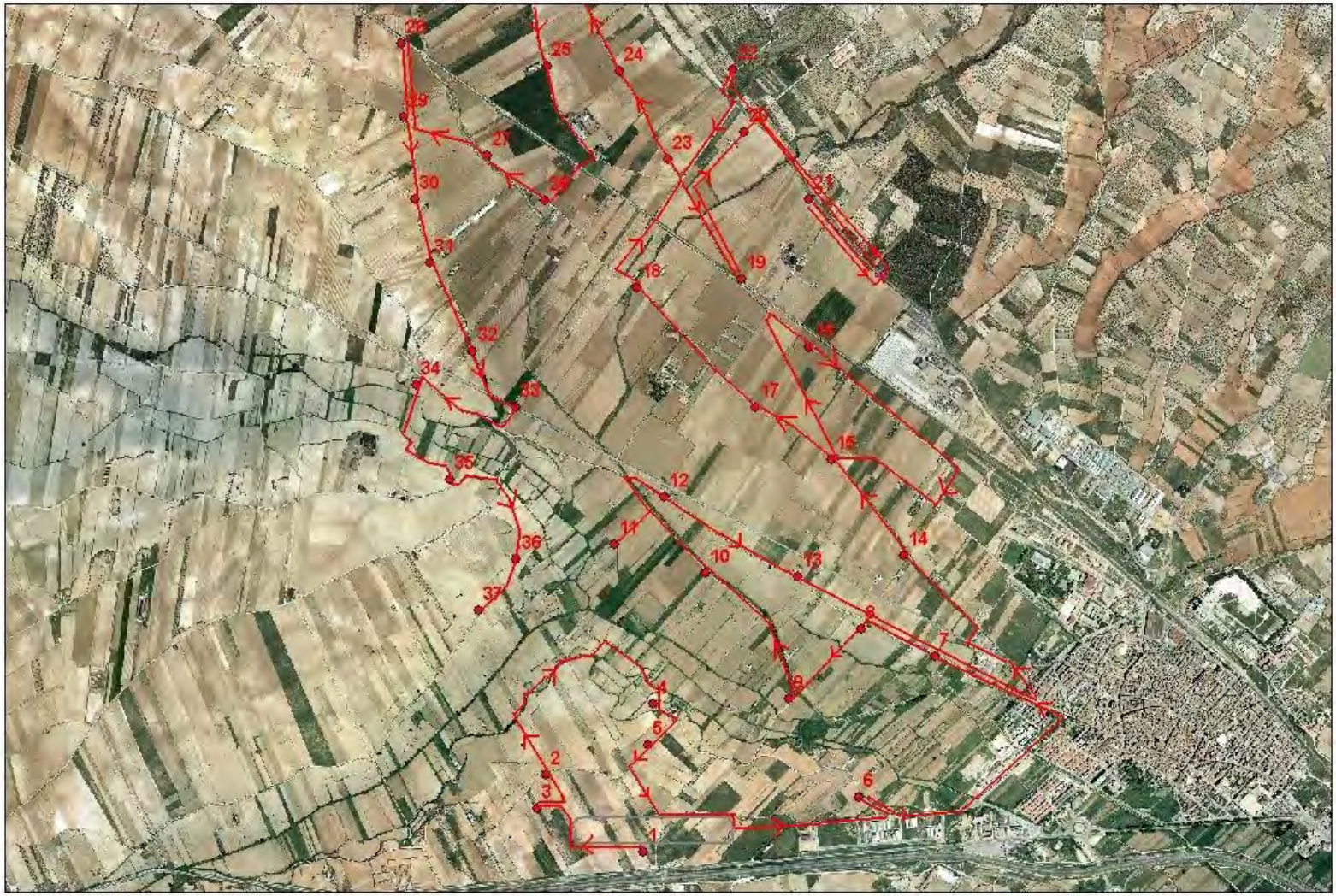
19th April – 2nd May 2008



Ground Team Distribution Along the Flight Lines



Example of Itinerary: Ground Team 16




Busy night, tonight!!!

Ground Measurements

Summary of Ground Measurements

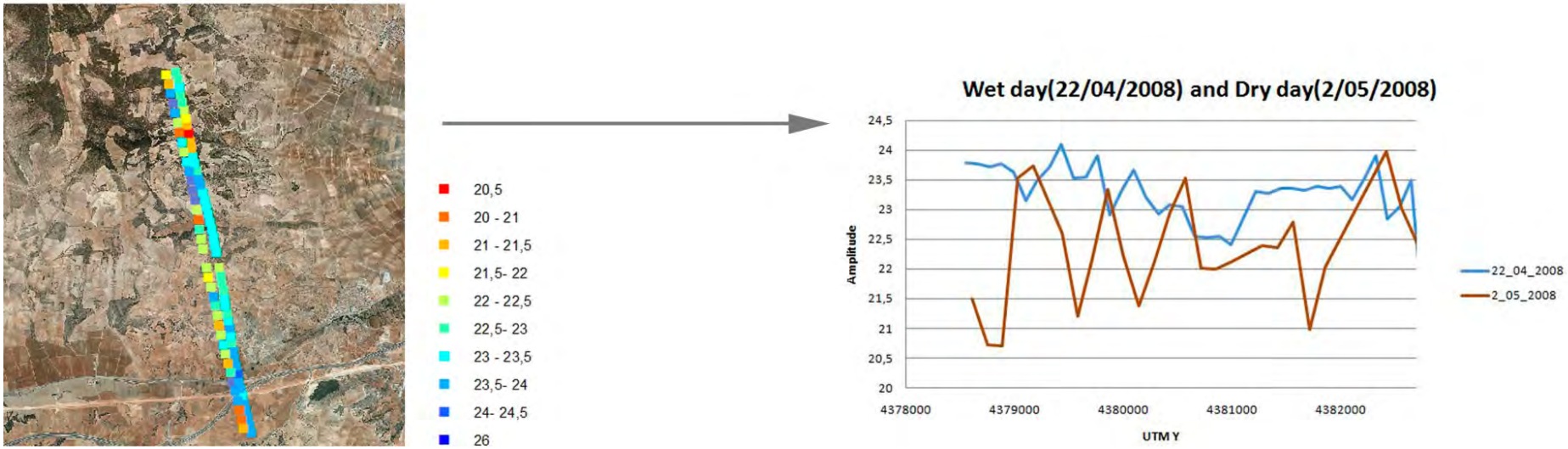
- 20 measuring teams with itineraries defined with 35-38 measuring points (40 to 80 m^2 each), each team using a 4-wheel drive car
- Approximately 20 x 35 = 700 measuring plots. Around 400 soil texture samples from these measuring plots obtained during the definition of the itineraries
- 4 volumetric SM cylinder samples at each measuring point. Total number of actual cylinder samples = 10.425 samples
- 7 Delta-T Theta Probe measurements at each measuring point (with 3 repetitions each). Total approximate number of measurements:

  20 teams x 35 measuring sites x 7 measurements x 4 nights =
  = 19.600 measurements (58.800 measurements considering the 3 repetitions of each measurement)

Note 1: 4 out of the 7 Theta probe measurements at each measuring point were taken within < 50 cm distance of the volumetric SM cylinder sample in order to be able to correlate both SM measurements and for Delta-T Theta probe calibration purposes
Note 2: All SM measurements are properly geo-referenced

Ground *vs* Airborne Data

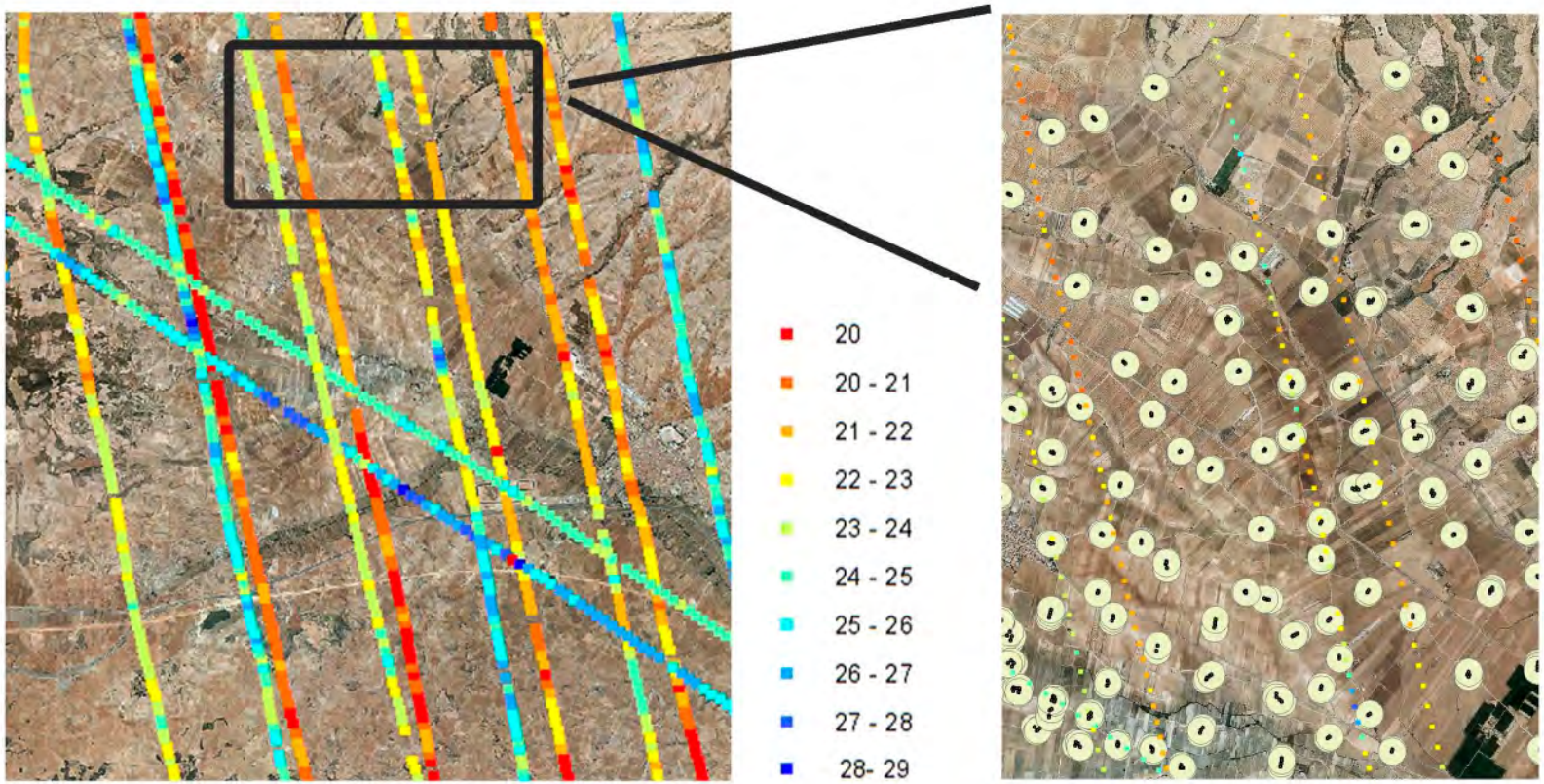
Firstly we show the comparison between ground and airbone data for the wetest (22/04/2008) and the driest day (02/5/2008) to analize the signal variation.



Variation of amplitude from a wet to a dry day.

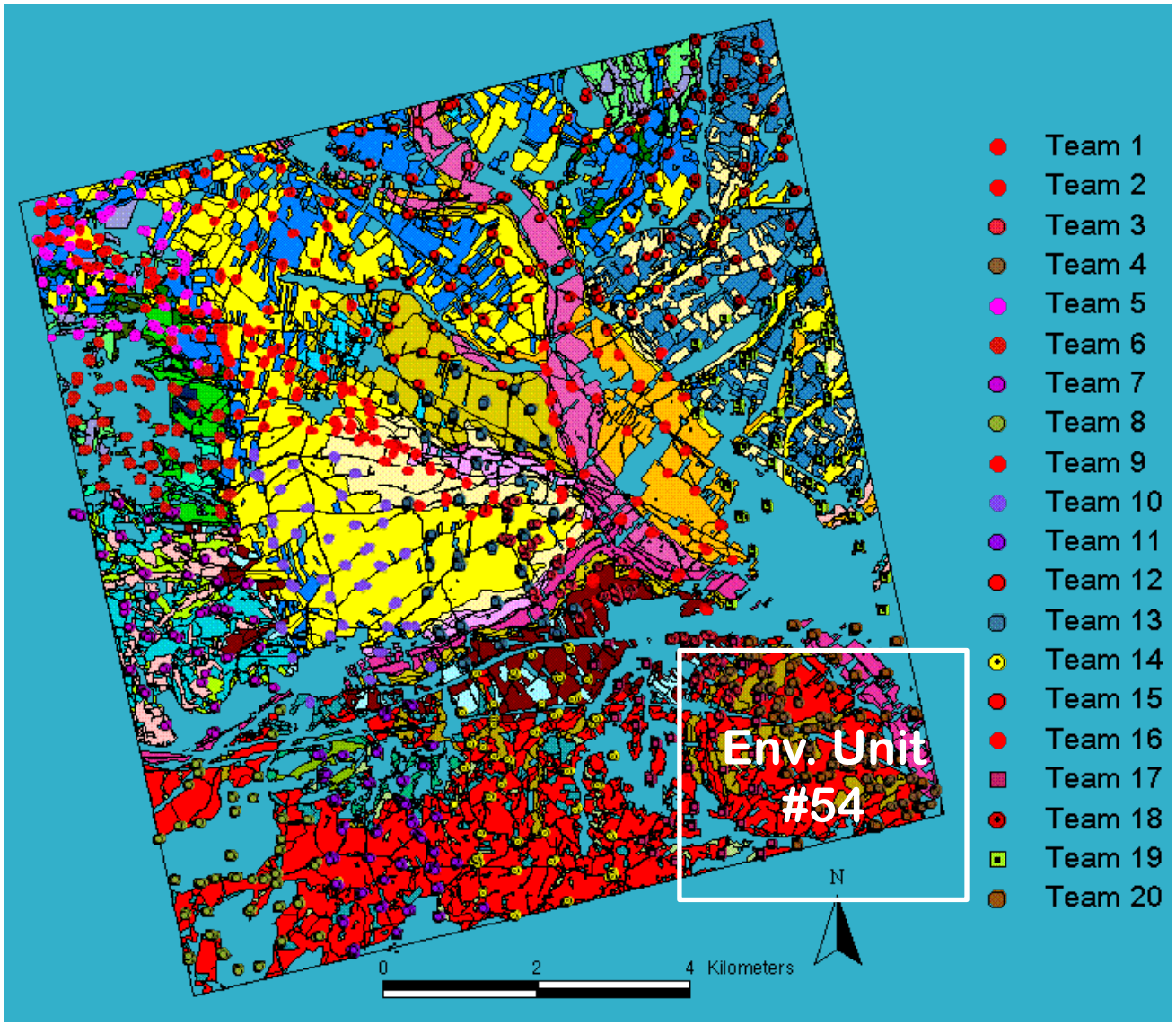
Ground *vs* Airborne Data

The footprint was approximately 30 m and rarely fully coincided with *in situ* data, so we established a 100-m diameter threshold



Buffer between *in situ* and airborne data (22/04/2008)

Dense Sampling Over the Environmental Unit Distribution



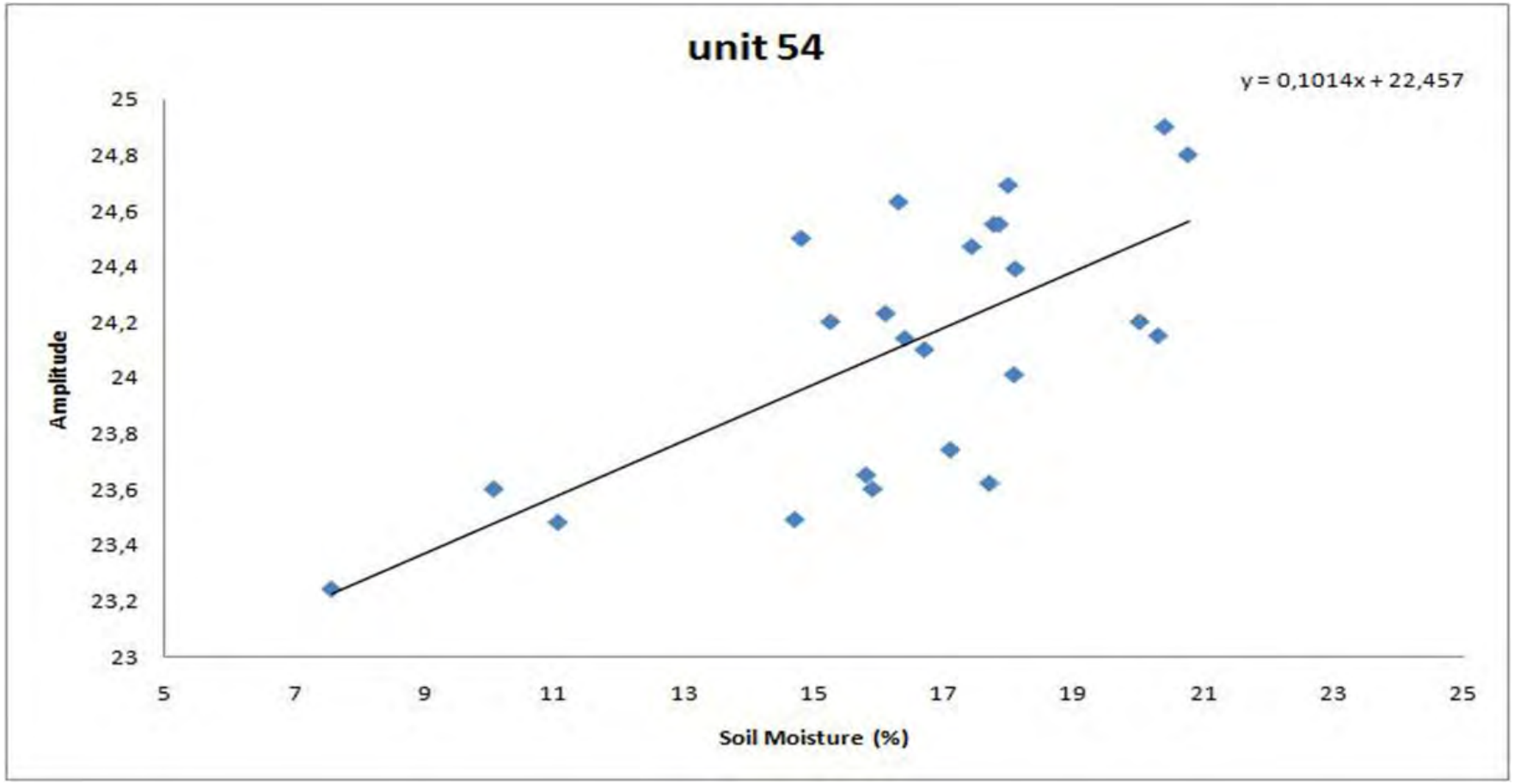
Ground *vs* Airborne Data for Unit 54 (Diagonal Flight-line)

Environmental Unit #54 was selected for being notably homogeneous (predominantly dedicated to vineyards) and gathering a significant number of sampling points.

Unit 54 during the campaign SMOS Validation 2008

Ground *vs* Airborne Data (Unit #54)

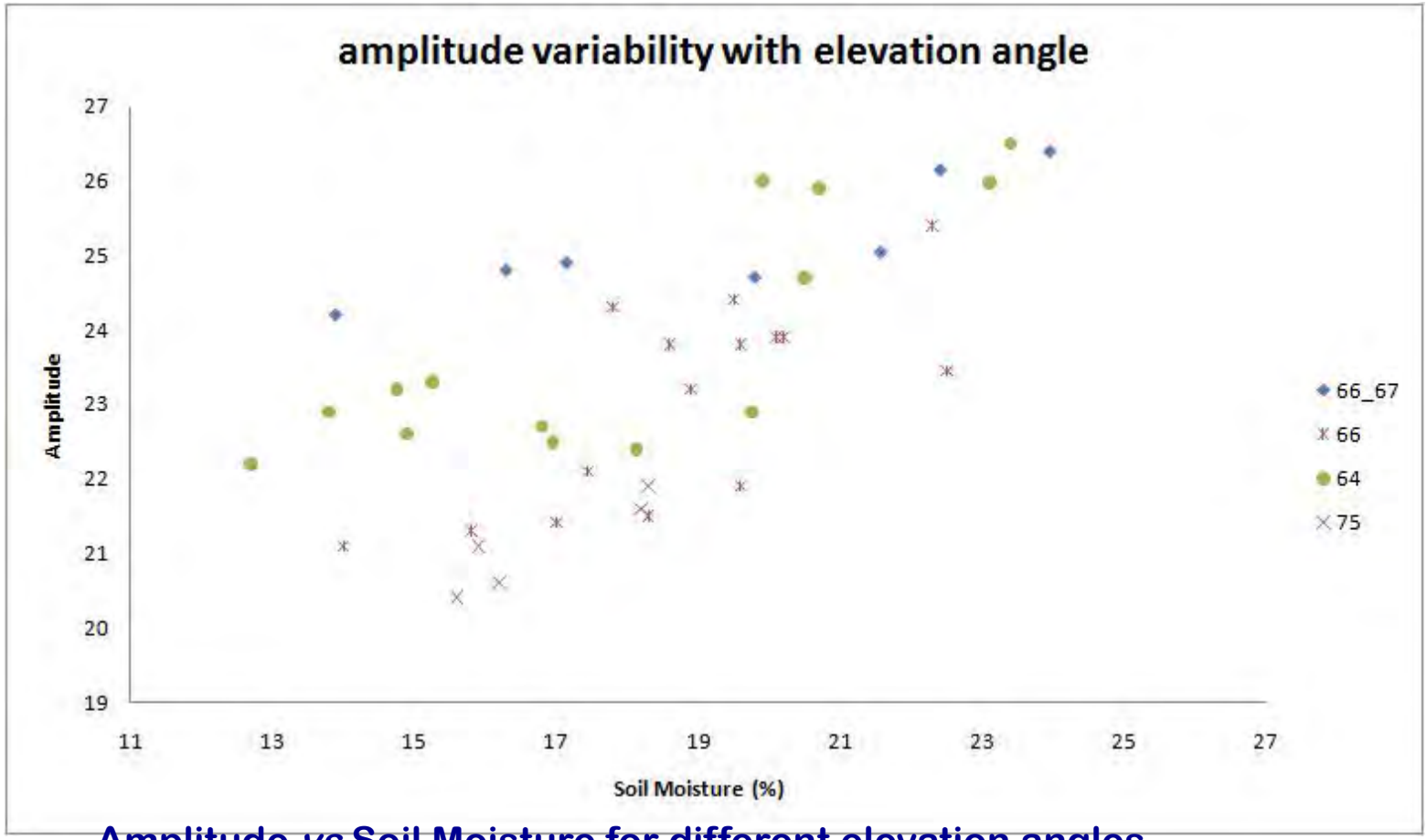
Airborne data *vs in situ* data for Unit 54 (R= 0,69).



Relationship between airborne data and in situ data in Unit 54.

Ground *vs* Airborne Data for Central Flight-lines

Central flight-lines where footprints are more homogeneous
Significant influence of the elevation angle
Parameterize as a function of elevation angle



R_{65}=0,73

R_{67} =0,87

R_{63} =0,82

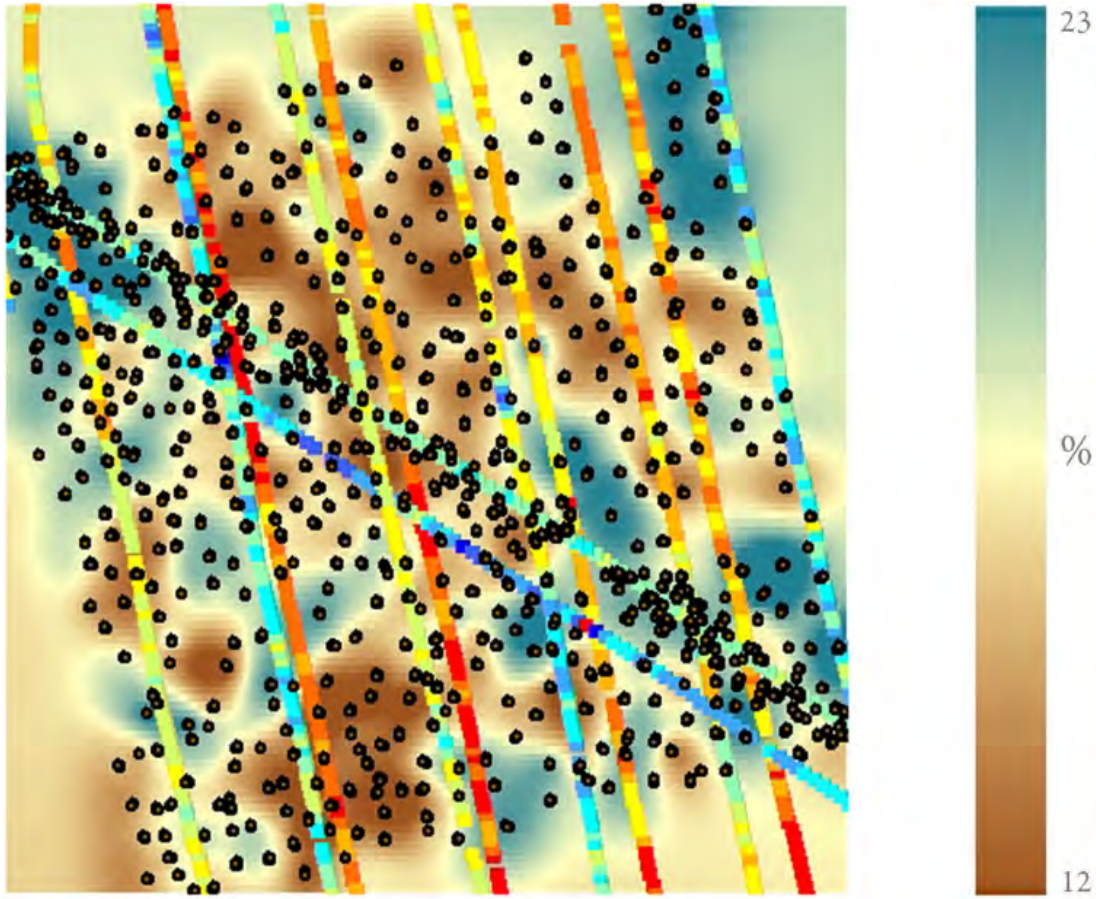
R_{75} =0,91

Amplitude *vs* Soil Moisture for different elevation angles.

Geostatistical *vs* Airborne Data

Why use geostatistical modeling of the ground data?

The basic idea is to get a continuous map of the soil moisture area in order to be able to use the largest number of aircraft data observations



Universal kriging map, *In situ* (.) and airborne data for 22 /04/ 2008

Geostatistical *vs* Airborne Data

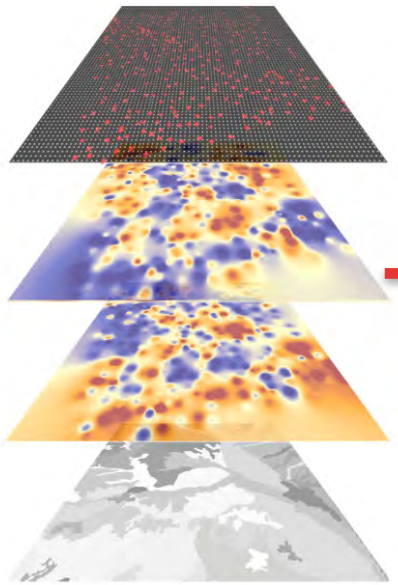
Geostatistics is a branch of statistics focusing on spatial or spatio-temporal datasets. Developed originally to predict probability distributions of ore grades for mining operations, it is currently applied in diverse disciplines including petroleum geology, hydrogeology, hydrology, meteorology, ...

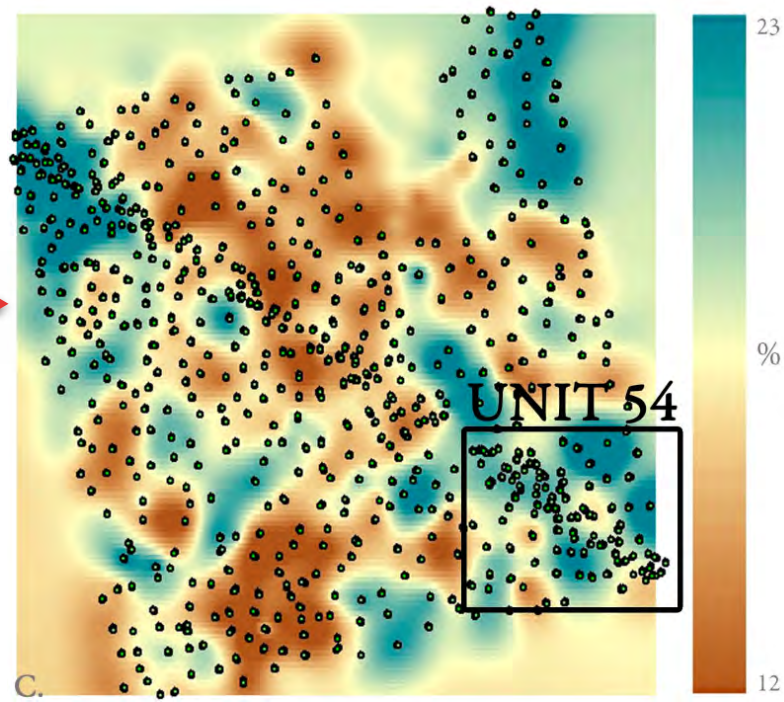
Kriging is a group of geostatistical techniques to interpolate the value of a random field at an unobserved location from observations of its value at nearby locations.

Universal kriging can handle a large number of parameters at the same time

Geostatistical *vs* Airborne Data

With universal kriging we included clay and sand content as additional information (covariates) obviously associated with soil moisture content

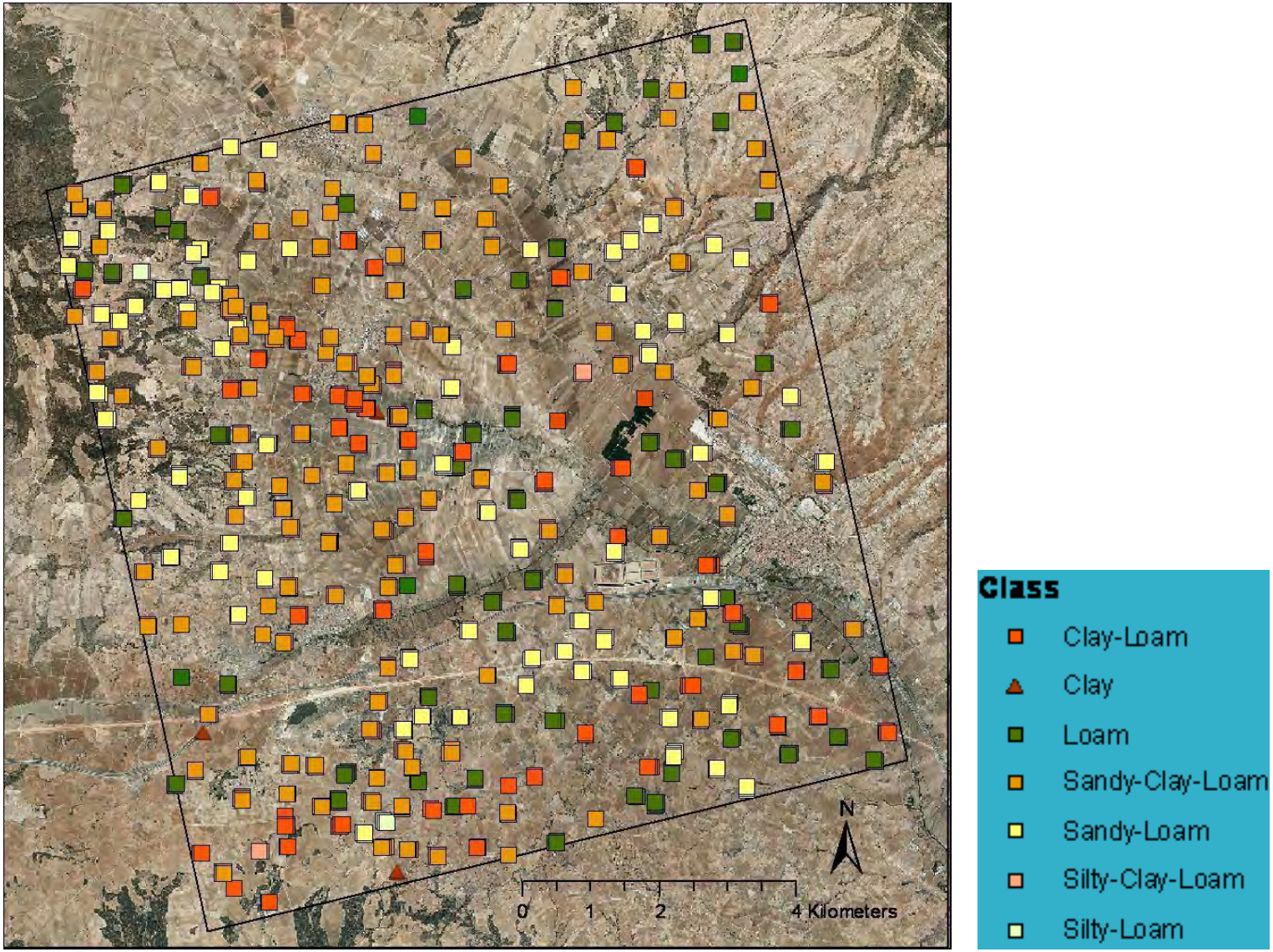




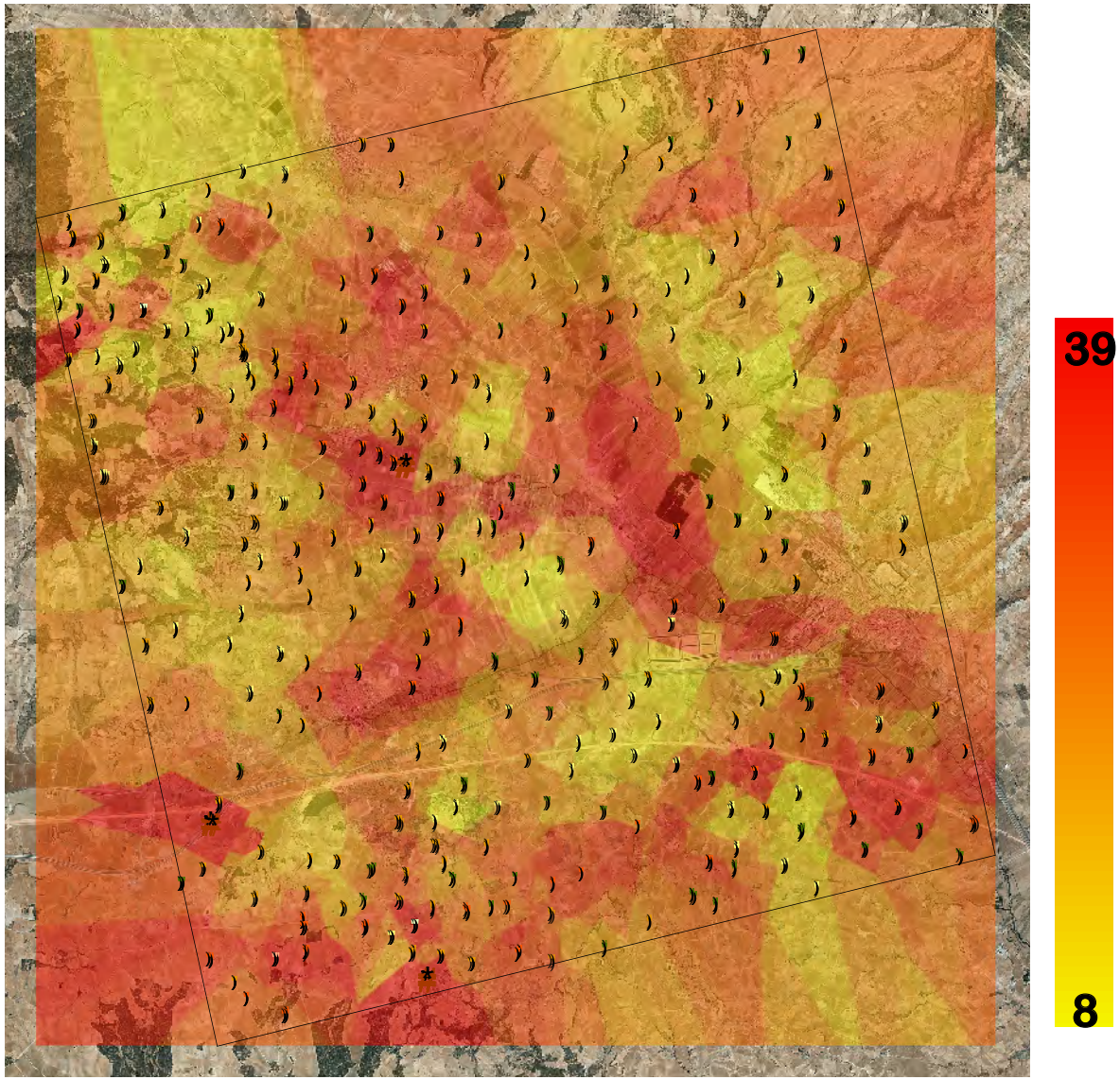
Multilayer sampling point composed of: grid, soil moisture sand content, clay content, and enviornamental units

Universal kriging map obtained

332 Soil Texture Samples



Soil Texture, % Clay

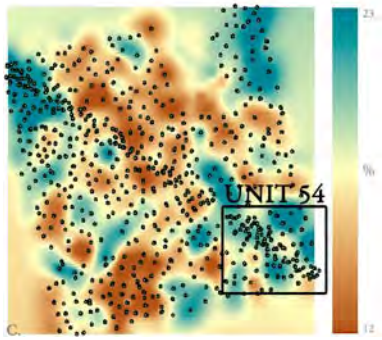


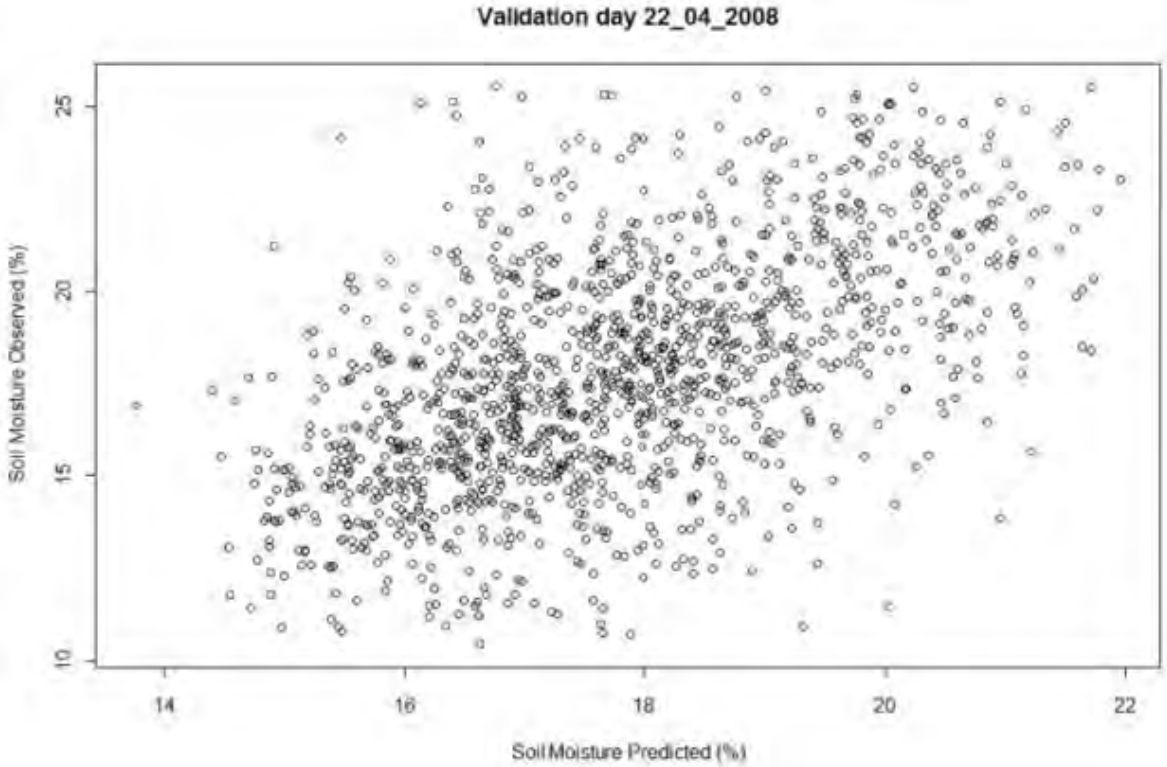
Geostatistical *vs* Airborne Data

Model cross-validation

R (between observed and predicted values) = 0,56

- Mainly due to the low sampling density that exists in some areas
- In other areas sampling was sufficiently large so that the variance was very low (diagonal flight-line)

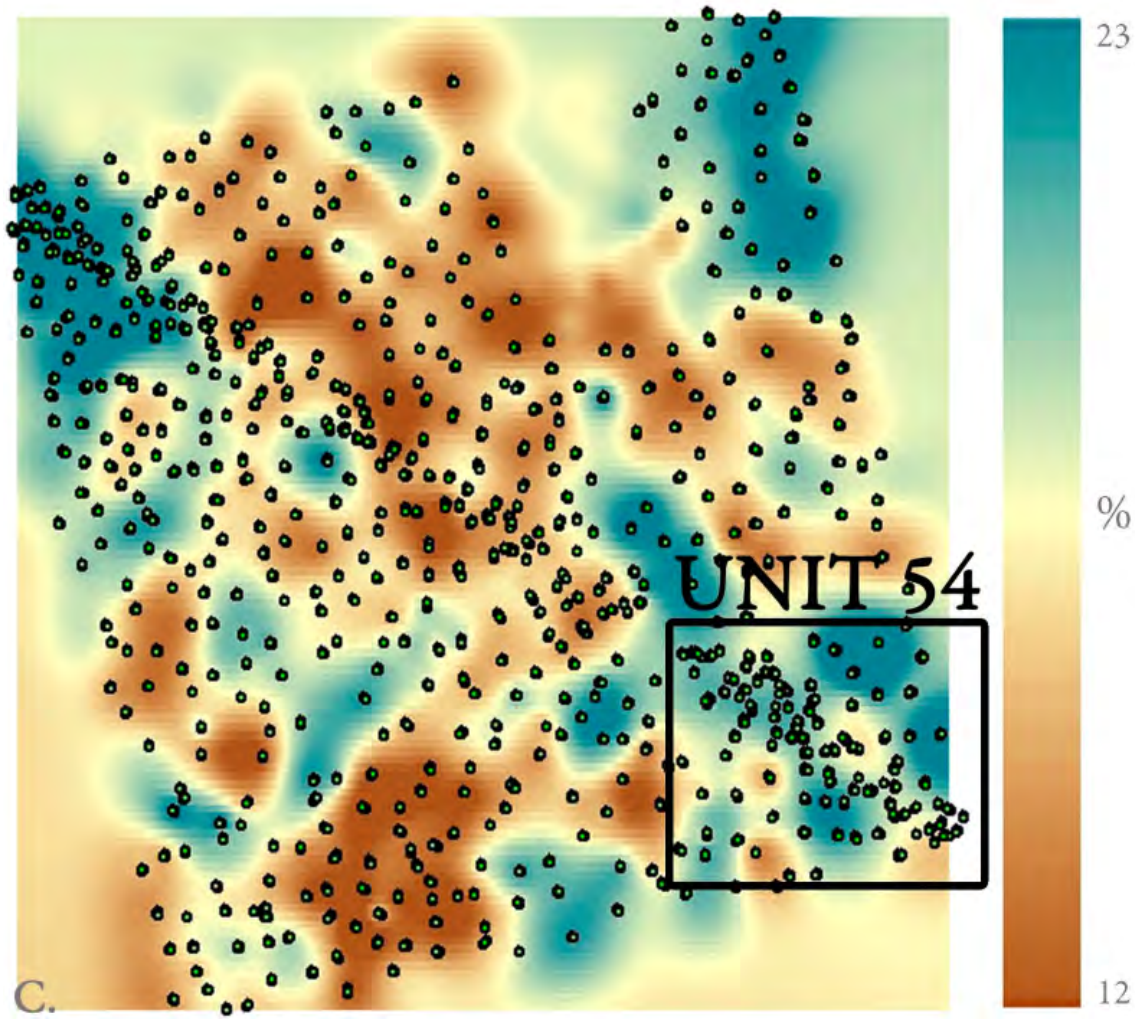




Geostatistical *vs* Airborne Data

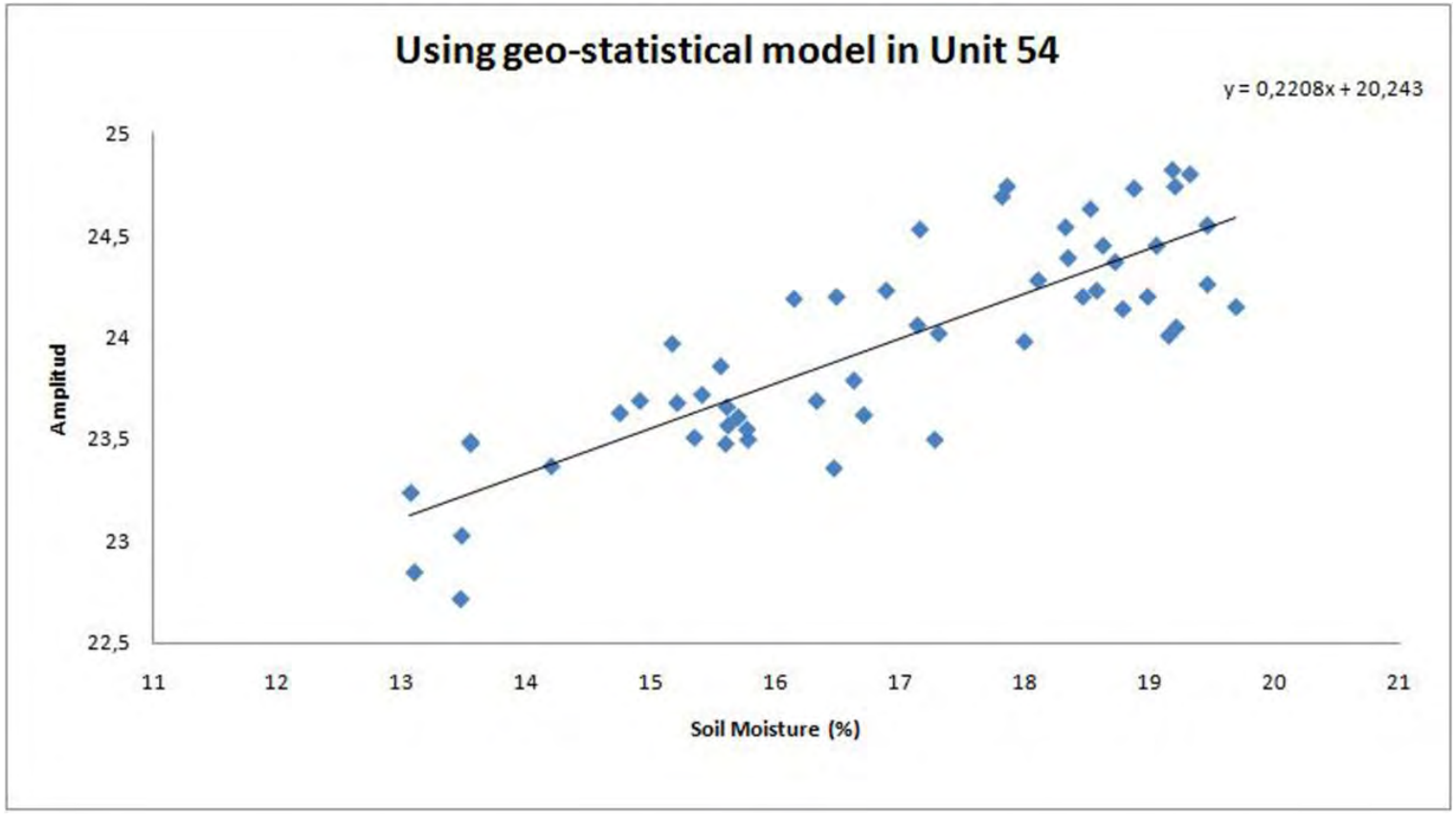
Select an area of low variance to make this comparison (mainly areas on the diagonal flight-line).

Environmental Unit #54, under bare soil conditions with almost no interference from other sources



Geostatistical *vs* Airborne Data (Env. Unit #54)

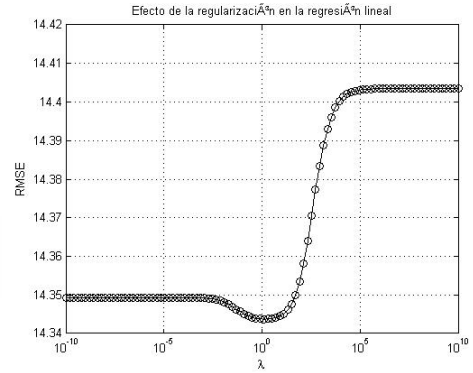
R = 0.84

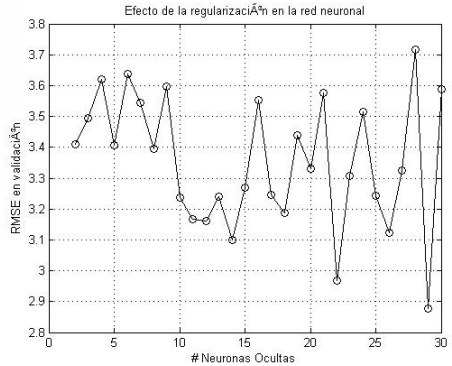


Relationship between geo-statistical model and airborne data for Environmental Unit #54

Regression Models Applied

4 regression methods have been tried, namely
- multiple linear regression (MLR
- regularized linear regression (RIR)
- kernel ridge regression (KRR)
- neural network regression (NNR)





Inputs for each day
- GPS signal amplitude
- elevation angle
- soil texture as clay, sand and silt contents

Output
- soil moisture

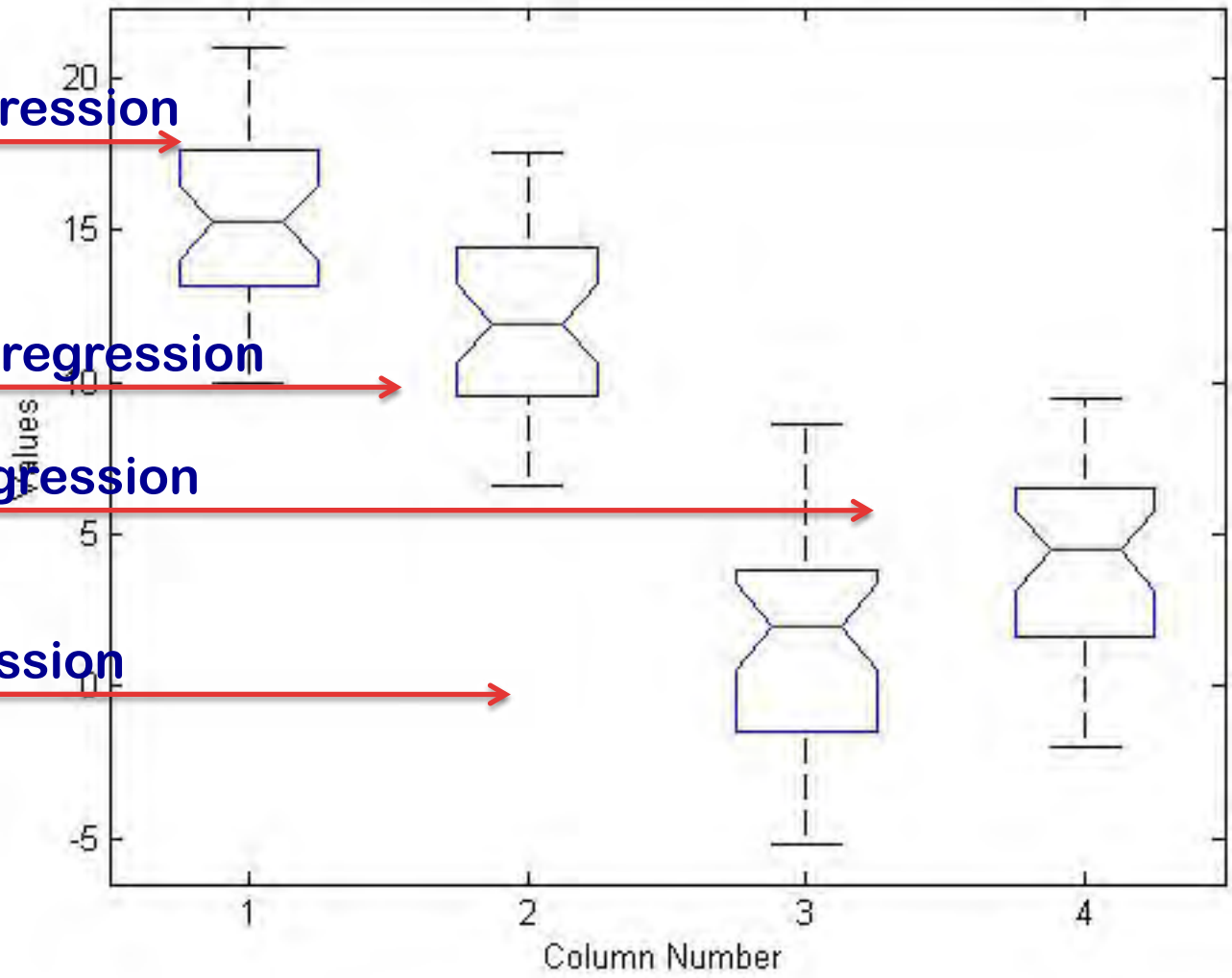
Regression Models Applied

multiple linear regression

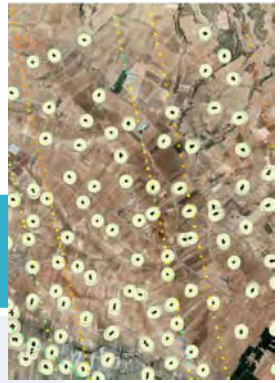
regularized linear regression

neural network regression

kernel ridge regression



Regression Models Applied. Results



Day	R	RMSE	Methods
02/05/2008 (100-m threshold)	0,71	2,74	KRR
	0,42	3,86	NNR
02/05/2008 (200-m threshold)	0,24	5,12	KRR
	0,25	3,67	NNR

Regression Models Applied. Results

100-m threshold

Day	R	RMSE	Methods
22/04/2008	0,65	2,7	KRR
24/04/2008	0,77	1,9	KRR
28/04/2008	0,76	2,68	KRR
02/05/2008	0,71	2,74	KRR

Conclusions

- For the studied area of the Valencia Anchor Station, the amplitude of the waveform is closely related to soil moisture, but with a strong dependence on the elevation angle. We found that the best results corresponded to bare soil areas.

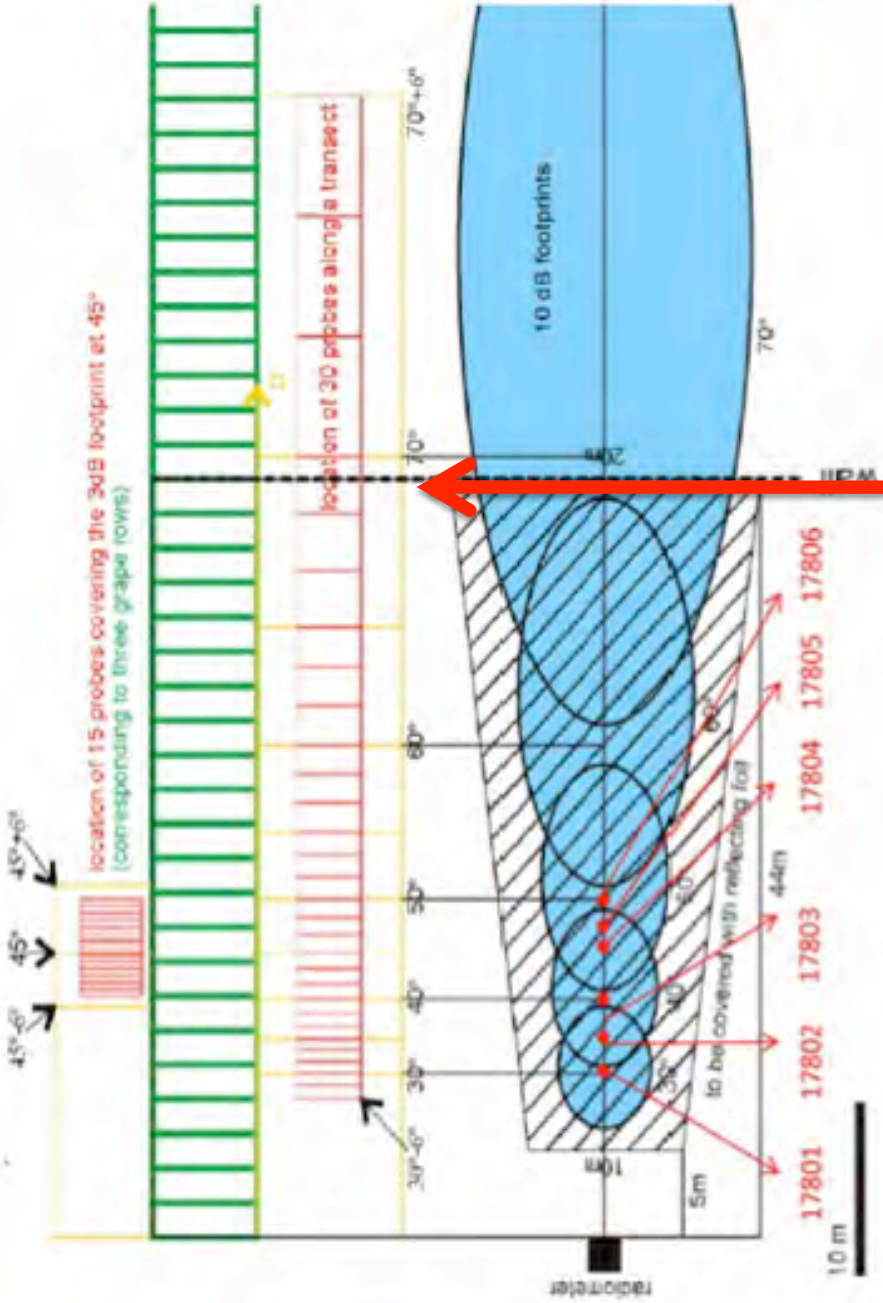
-The geostatistical model (universal kriging) used for the prediction of soil moisture from the measuring sampling points is not as satisfactory as expected (R = 0.56), although the results could be used in areas where the sampling density is relatively high.

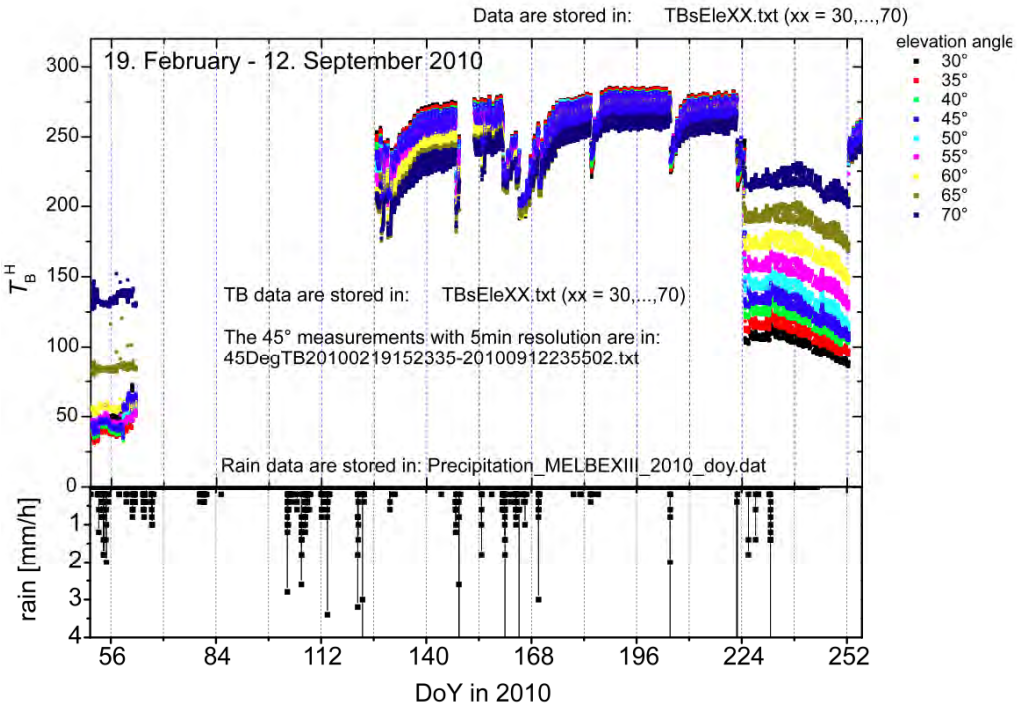
-Thus, by comparing model ground (kriging) to airborne data we get good relationships for the conditions above mentioned, namely, bare soil, high sampling density and a specific elevation angle, always above 60 deg.

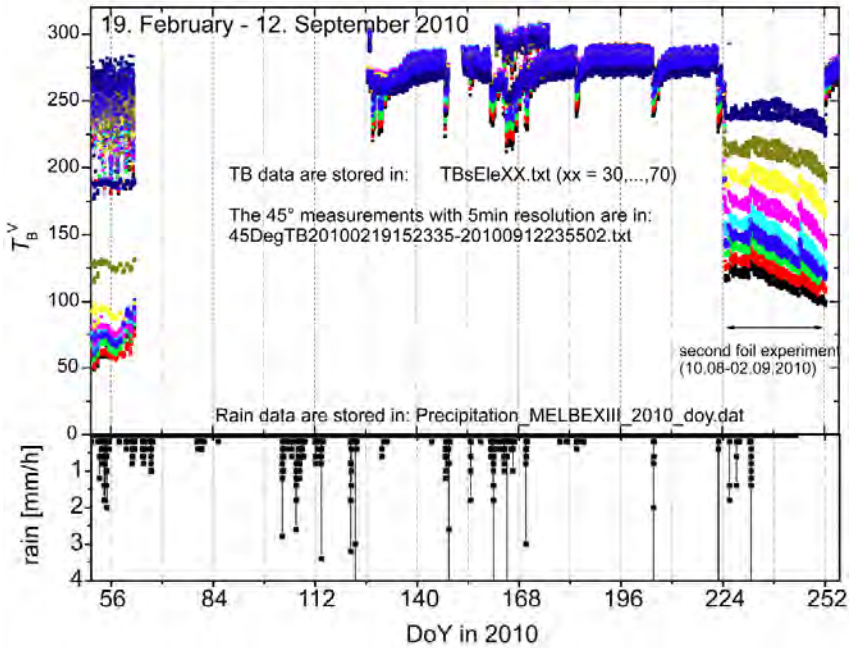
Conclusions

- KRR and NNR regressions are acceptable result set (for a few data is better kernel ridge regression). To improve the prediction we would need many more data.

Ideas for Future Work


location of 15 probes covering the 3dB footprint at 45°
(corresponding to three grape rows)
location of 30 probes along a transect
10 dB footprints
20m
70°
70°+δ°
60°
50°
40°
30°
30°-δ°
45°-δ°
45°
45°+δ°
10m
5m
44m
to be covered with reflecting foil
radiometer
17801
17802
17803
17804
17805
17806
10 m


Data are stored in: TBsEleXX.txt (xx = 30,...,70)
19. February - 12. September 2010
elevation angle
30°
35°
40°
45°
50°
55°
60°
65°
70°
TB data are stored in: TBsEleXX.txt (xx = 30,...,70)
The 45° measurements with 5min resolution are in:
45DegTB20100219152335-20100912235502.txt
Rain data are stored in: Precipitation_MELBEXIII_2010_doy.dat
T_B^H
rain [mm/h]
DoY in 2010


19. February - 12. September 2010
TB data are stored in: TBsEleXX.txt (xx = 30,...,70)
The 45° measurements with 5min resolution are in:
45DegTB20100219152335-20100912235502.txt
second foil experiment
(10.08-02.09.2010)
Rain data are stored in: Precipitation_MELBEXIII_2010_doy.dat
T_B^V
rain [mm/h]
DoY in 2010

M. Schwank

Acknowledgments

- Spanish Research Programme on Space, Ministry for Science and Education
- Directorate General for Climate Change, Regional Ministry for Environment, Water, Urban Planning and Housing, Generalitat Valenciana
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- Aeropuertos Españoles y Navegación Aérea (AENA)
- Valenciana de Aprovechamiento Energético de Residuos S.A. (VAERSA)
- Agencia Estatal de Meteorología (AEMet)
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- Jucar River Basin Authority. Hydrological Planning Office and Automatic Service for Hydrological Planning (SAIH)
- Excmo. Ayuntamiento de Utiel. Concejalía de Medio Ambiente
- Excmo. Ayuntamiento de Caudete de las Fuentes
- Bodegas IRANZO, Caudete de las Fuentes (cellars)
- Bodegas y Viñedos de Utiel (cellars)
- Bodega La Cubera, Utiel (cellars)
- Nicolás Guaita, Caudete de las Fuentes