MOXXI Measurements & Observations in the 21st Century
Working Group - International Association of Hydrological Sciences

→ MEASUREMENTS AND OBSERVATIONS IN THE 21st CENTURY CONFERENCE

Soil moisture derived from ASAR sensor in a Mulargia Basin

The influence of typical Mediterranean vegetation on the RADAR signal

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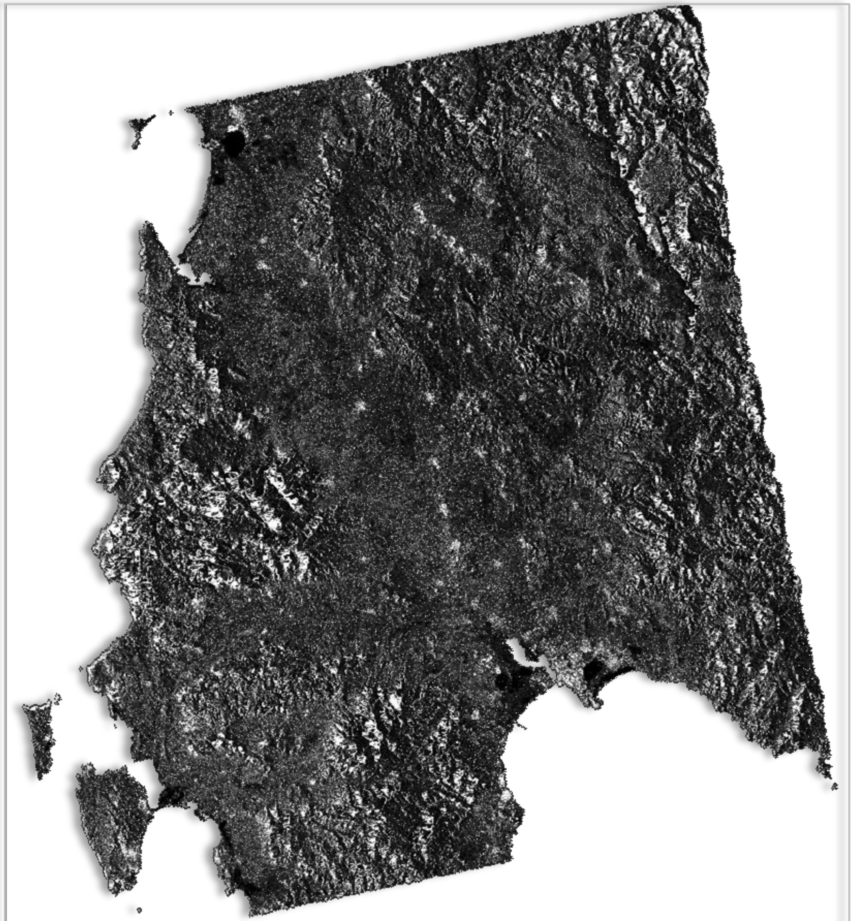
GOALS

- Test ASAR (Envisat) radar sensor to estimate **surface soil moisture** in a typical mediterranean context
- Develop a methodology to assess **soil surface roughness** through multipolarization data
- Evaluate the dependence of results on topographic spatial variability and land cover variables

Advanced Synthetic Aperture Radar (ASAR)



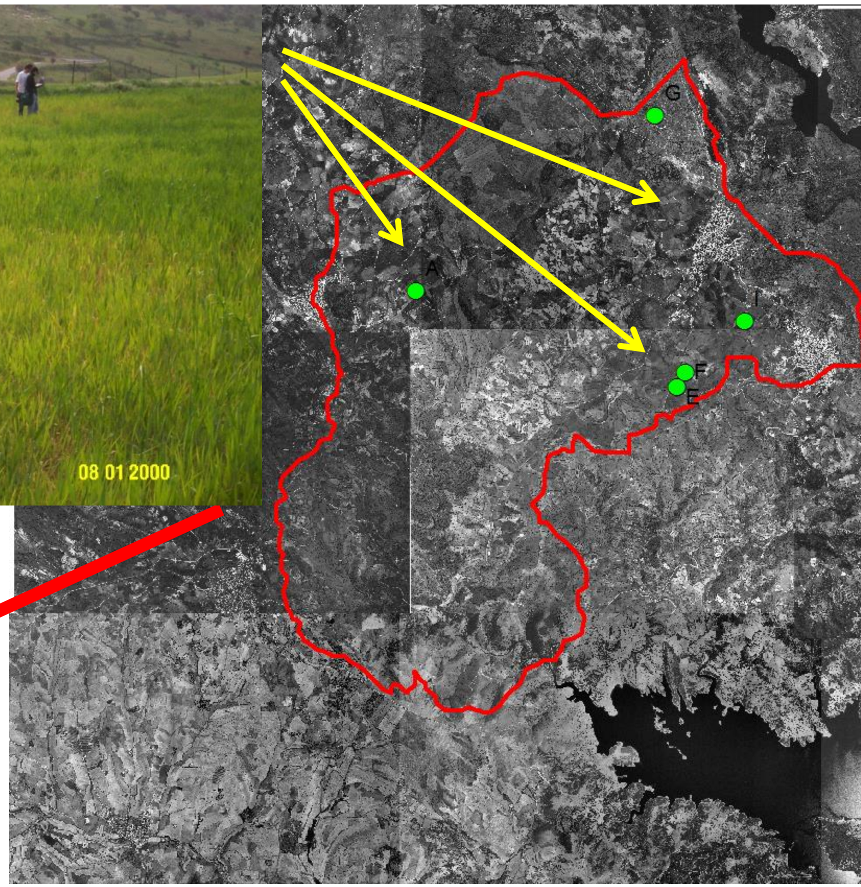
ASAR APP 01/09/2003, Southern of Sardinia

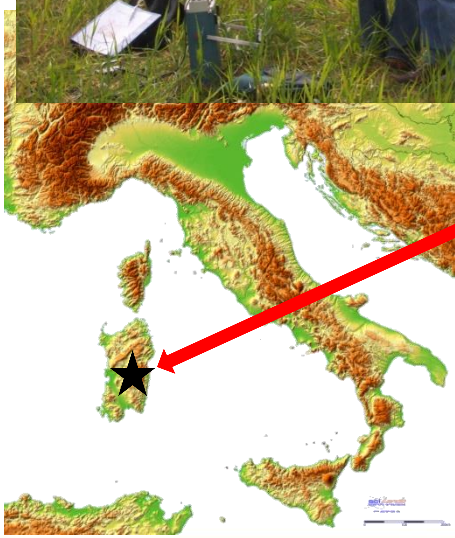
ASAR ENVISAT	
Band	C (5.33 GHz)
Polarization	HH/VV VV/VH HH/HV
Resolution [m]	6 – 1000
Incidence angle	15° - 45°
Swath width [km]	5 – 400
Repeat cycle [d]	35*

* average revisit frequency per 35-day orbit cycle as function of latitude and incidence angle (descending tracks only)

SOIL MOISTURE - MICROWAVE REMOTE SENSING
DIELECTRIC CONSTANT
water (~80)
dry soil(~3-4)
Ulaby et al. 1986

Mulargia Basin





Attività finanziata dal progetto ASI 2003-2005, PRIN 2006, L

ASAR data

	Product ID			Processing Stage Flag	Originator ID	Start Day	Start Time	PASS	Duration	Mission Phase Identifier	Cycle	Relative Orbit	Absolute Orbit	Counter	Satellite ID	Polarization
		Product														
1	ASA	IMP	1P	N	PDE	26/03/2003	21:07:08	ASCENDING	16	2	15	29	5594	4	N1	VV
2	ASA	IMP	1P	N	PDE	08/04/2003	09:42:29	DESCENDING	16	2	15	208	5773	5	N1	VV
3	ASA	IMP	1P	N	UPA	30/04/2003	21:07:09	ASCENDING	16	2	16	29	6095	133	N1	VV
4	ASA	IMP	1P	N	DPA	13/08/2003	21:07:15	ASCENDING	16	2	19	29	7598	15	N1	HH
5	ASA	APP	1P	N	DPA	01/09/2003	0.882083	ASCENDING	16	2	19	301	7870	115	N1	VV-VH
6	ASA	APP	1P	N	DPA	06/10/2003	21:10:08	ASCENDING	16	2	20	301	8371	119	N1	VV-HH
7	ASA	APS	1P	N	UPA	15/12/2003	21:10:05	ASCENDING	16	2	22	301	9373	89	N1	VV-HH **
8	ASA	APS	1P	N	UPA	25/12/2003	09:39:45	DESCENDING	15	2	22	437	9509	77	N1	VV-HH **
9	ASA	APS	1P	N	UPA	19/01/2004	21:10:04	ASCENDING	16	2	23	301	9874	88	N1	VV-HH **
10	ASA	APP	1P	N	UPA	23/02/2004	21:10:03	ASCENDING	16	2	24	301	10375	311	N1	VH-HH
11	ASA	APP	1P	N	UPA	29/03/2004	21:10:06	ASCENDING	16	2	25	301	10876	167	N1	VV-HH
12	ASA	APP	1P	N	UPA	30/04/2004	21:04:19	ASCENDING	16	2	26	258	11334	248	N1	VV-HH
13	ASA	APP	1P	N	UPA	30/04/2004	21:04:35	ASCENDING	16	2	26	258	11334	246	N1	VV-HH
14	ASA	APP	1P	N	PDK	03/05/2004	21:10:04	ASCENDING	16	2	26	301	11377	3	N1	VV-HH
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19	ASA	APP	1P	N	UPA	04/06/2004	21:04:40	ASCENDING	16	2	27	258	11835	335	N1	VV-HH
20	ASA	APP	1P	N	UPA	07/06/2004	21:10:10	ASCENDING	16	2	27	301	11878	338	N1	VV-HH
21	ASA	APP	1P	N	UPA	17/06/2004	09:39:46	DESCENDING	16	2	27	437	12014	47	N1	VV-HH
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23	ASA	APP	1P	N	UPA	12/07/2004	21:10:10	ASCENDING	16	2	28	301	12379	170	N1	VV-HH
24	ASA	APP	1P	N	DPA	28/07/2004	21:07:19	ASCENDING	15	2	29	29	12608	13	N1	VV-HH

Integral Equation Model (IEM) by Fung (1992)

$$\boxed{\sigma_{pq}^{0}} = \frac{k^2}{2}\exp(-2k_z^2\boxed{\sigma}^2)\sum_{n=1}^{\infty}\boxed{\sigma}^{2n}\left|I_{pq}^{n}\right|^2\frac{W^n(-2k_x,0)}{n!}$$

$$I_{pq}^{n} = (2k_z)^n f_{pq}\exp(-k_z^2\sigma^2) + \frac{k_z^{\ n}\left[F_{pq}(-k_x,0)+F_{pq}(k_x,0)\right]}{2}$$

$$f_{VV} = \frac{2R_{\parallel}}{\cos\theta} \qquad f_{HH} = \frac{2R_{\perp}}{\cos\theta}$$

FRESNEL COEFFICIENT

$$F_{VV}(-k_x,0)+F_{VV}(k_x,0) = \frac{2sen^2\theta(1+R_{\parallel})^2}{\cos\theta}\left[\left(1-\frac{1}{\varepsilon_r}\right)+\frac{\mu_r\boxed{\varepsilon_r}-sen^2\theta-\varepsilon_r\cos^2\theta}{\varepsilon_r^2\cos^2\theta}\right]$$

$$F_{HH}(-k_x,0)+F_{HH}(k_x,0) = -\frac{2sen^2\theta(1+R_{\perp})^2}{\cos\theta}\left[\left(1-\frac{1}{\mu_r}\right)+\frac{\mu_r\boxed{\varepsilon_r}-sen^2\theta-\mu_r\cos^2\theta}{\mu_r^2\cos^2\theta}\right]$$

$$W^n(k_x,k_y) = \frac{1}{2\pi}\iint\rho^n(x,y)\exp(jk_x x + jk_y y)dxdy$$

FOURIER TRANSFORM OF THE NTH POWER OF THE SURFACE CORRELATION FUNCTION

$$\rho^n(x,y) = \exp\{-(|x|+|y|)/\boxed{L}\}$$

SURFACE CORRELATION FUNCTION (EXPONENTIAL DISTRIBUTION)

Integral Equation Model (IEM) by Fung (1992)

$$\begin{cases} \sigma_{VV}{}^{0} = \sigma^{0}(\ldots\varepsilon,\sigma,L) \\ \sigma_{HH}{}^{0} = \sigma^{0}(\ldots\varepsilon,\sigma,L) \end{cases}$$

2 EQUATIONS

DIELECTRIC CONSTANT, FUNCTION OF SOIL MOISTURE ε

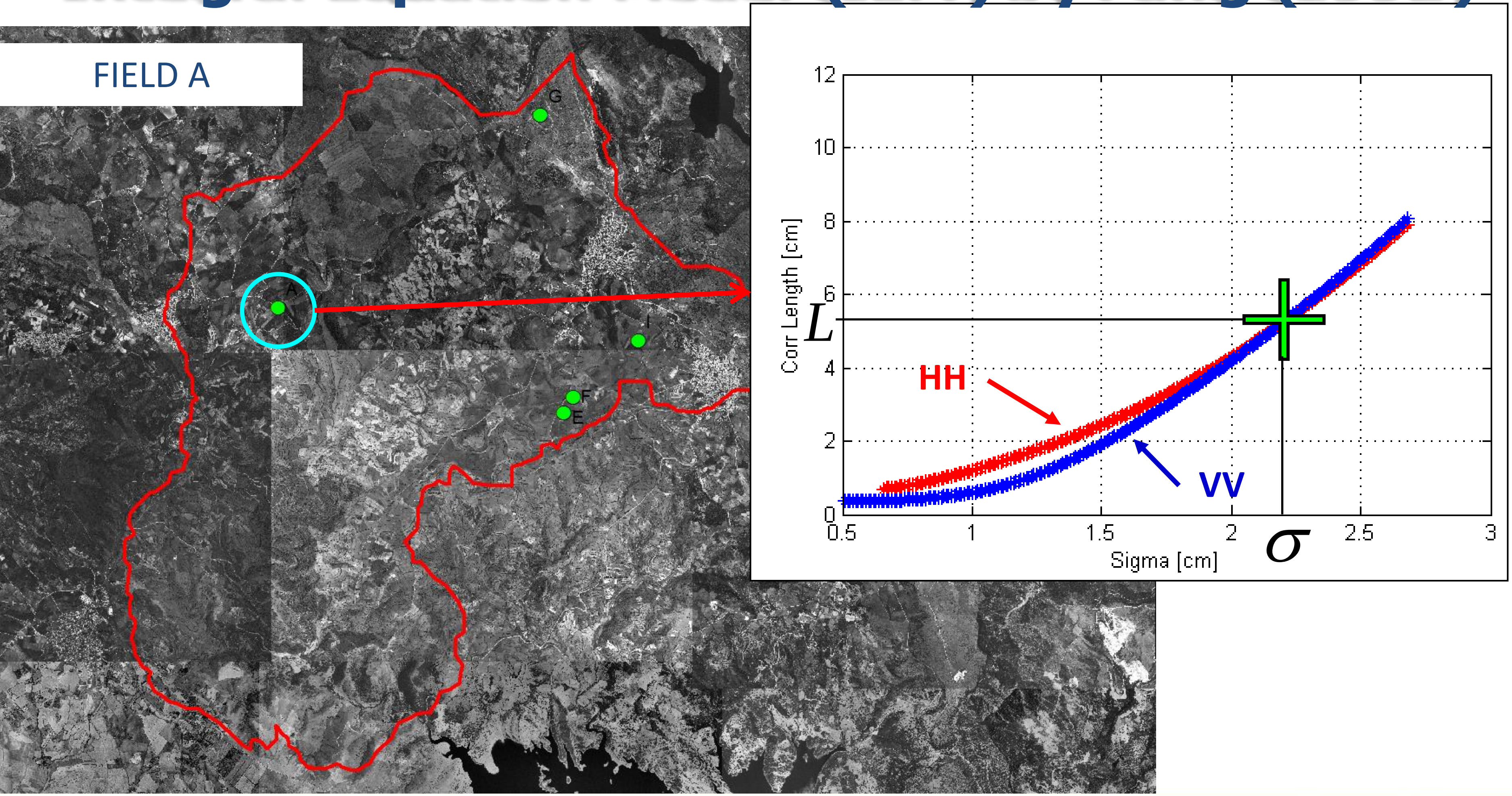
UNKNOWN

STANDAR DEVIATION OF SURFACE HEIGHT σ

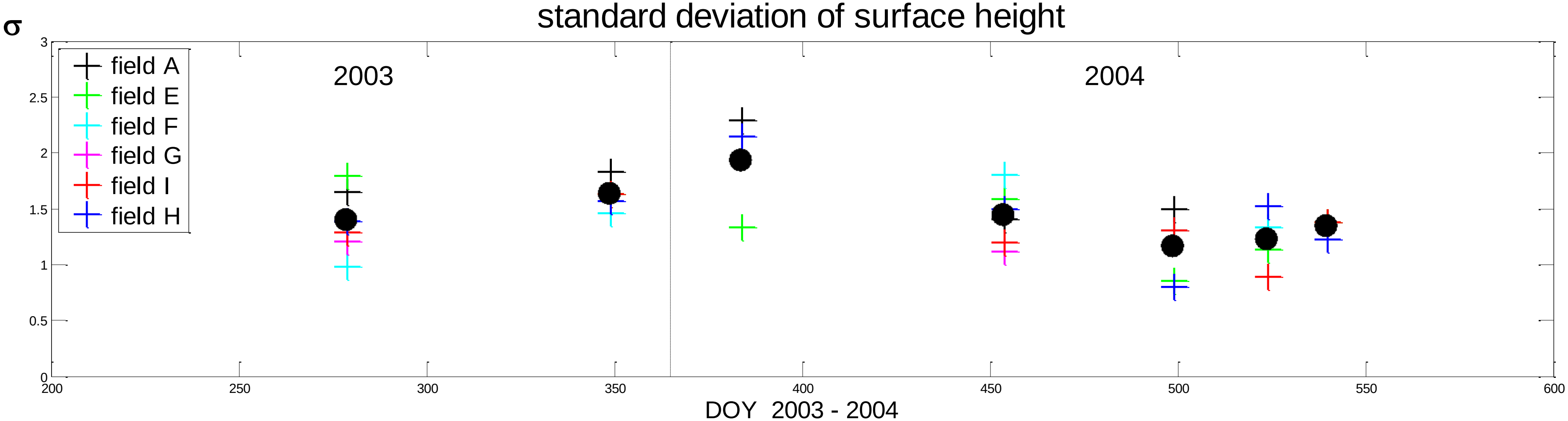
CORRELATION FUNCTION L

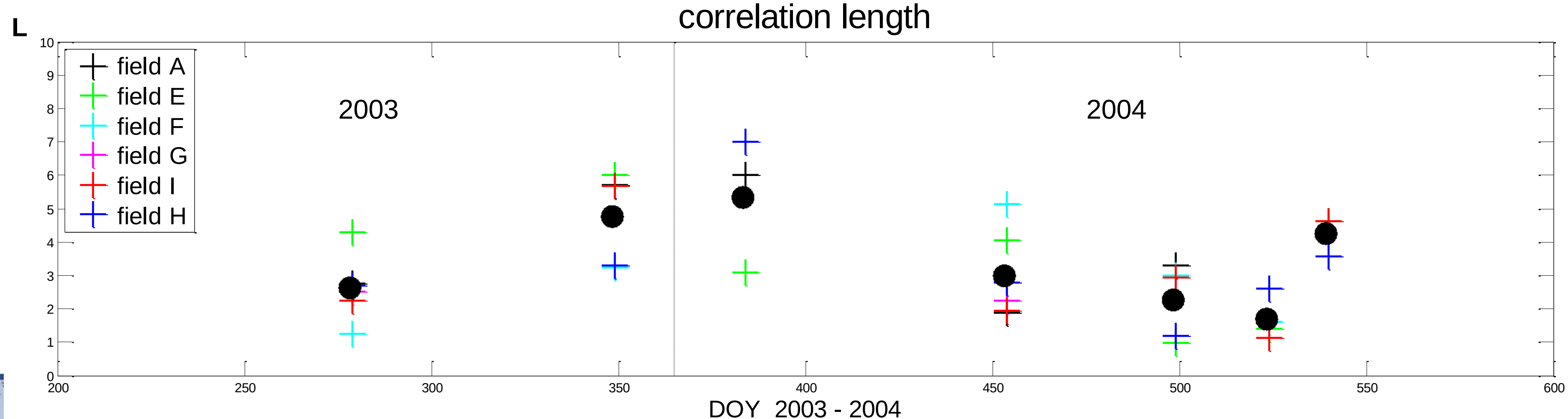
2 PARAMETERS

Integral Equation Model (IEM) by Fung (1992)



Soil Roughness parameters *σ* and *L*





Integral Equation Model (IEM) by Fung (1992)

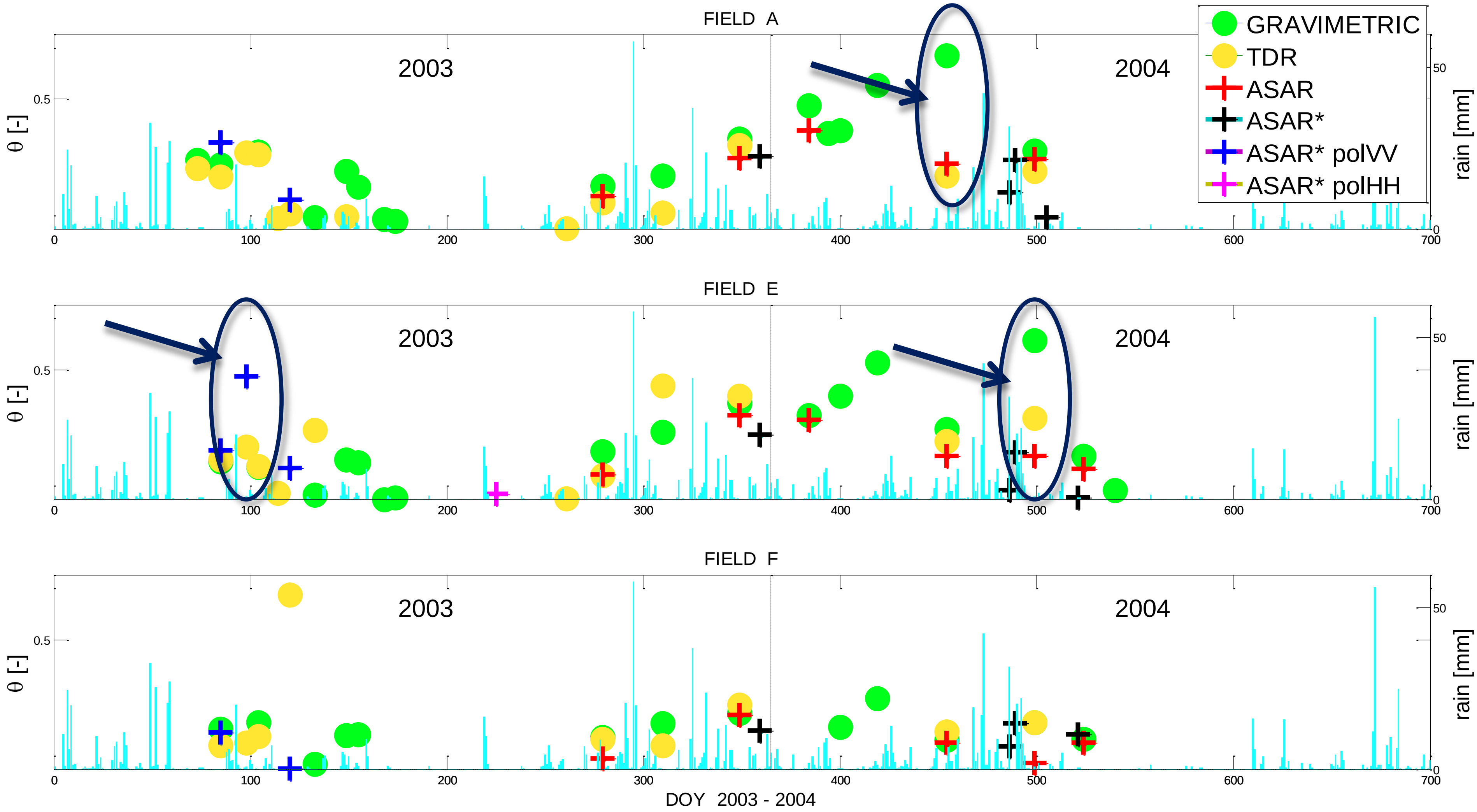
1. Estimated **σ** and **L** variables

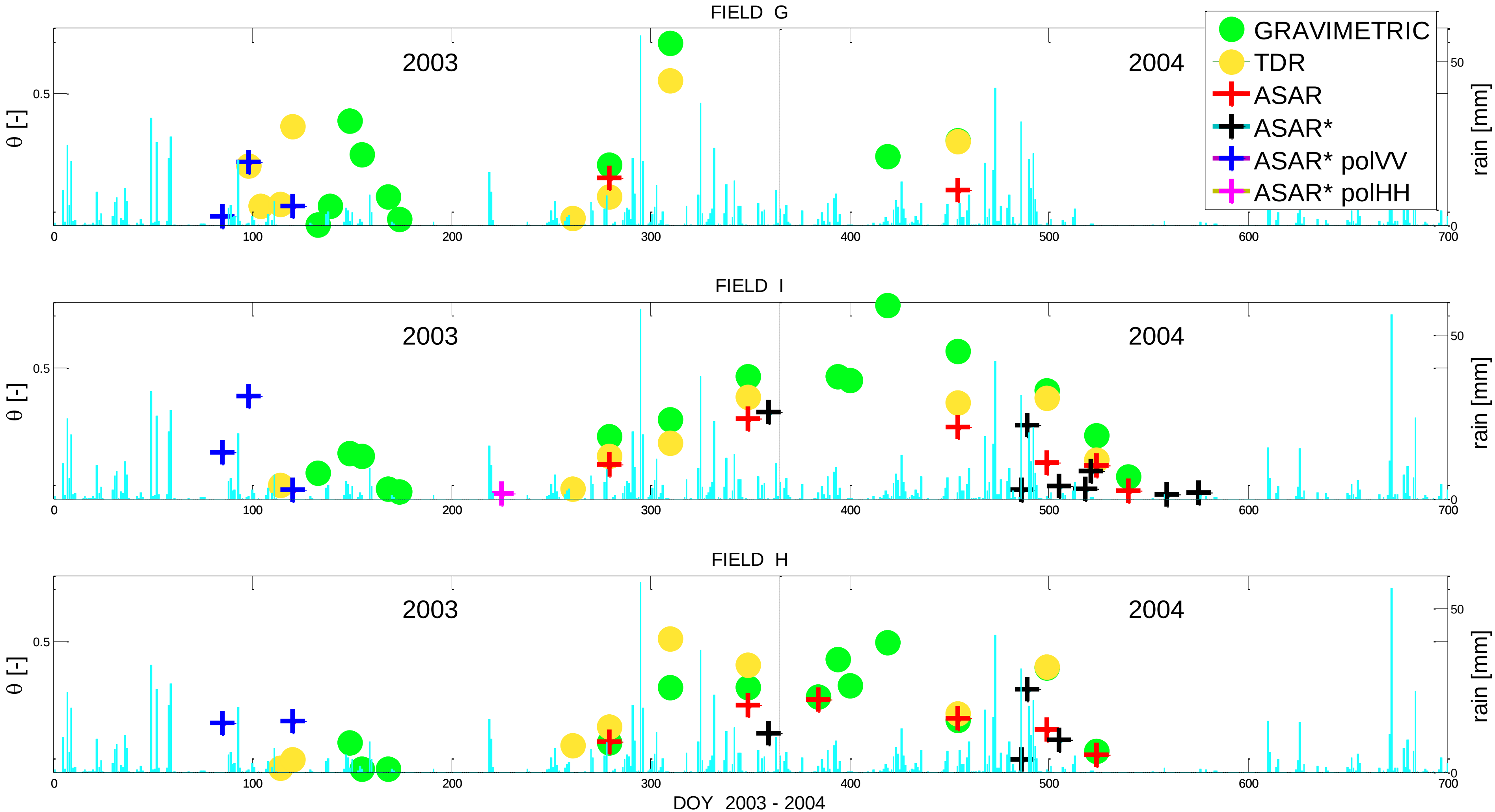
2. By the inversion of equation model by Fung find the dielectric constant

3. From dielectric constant to soil moisture

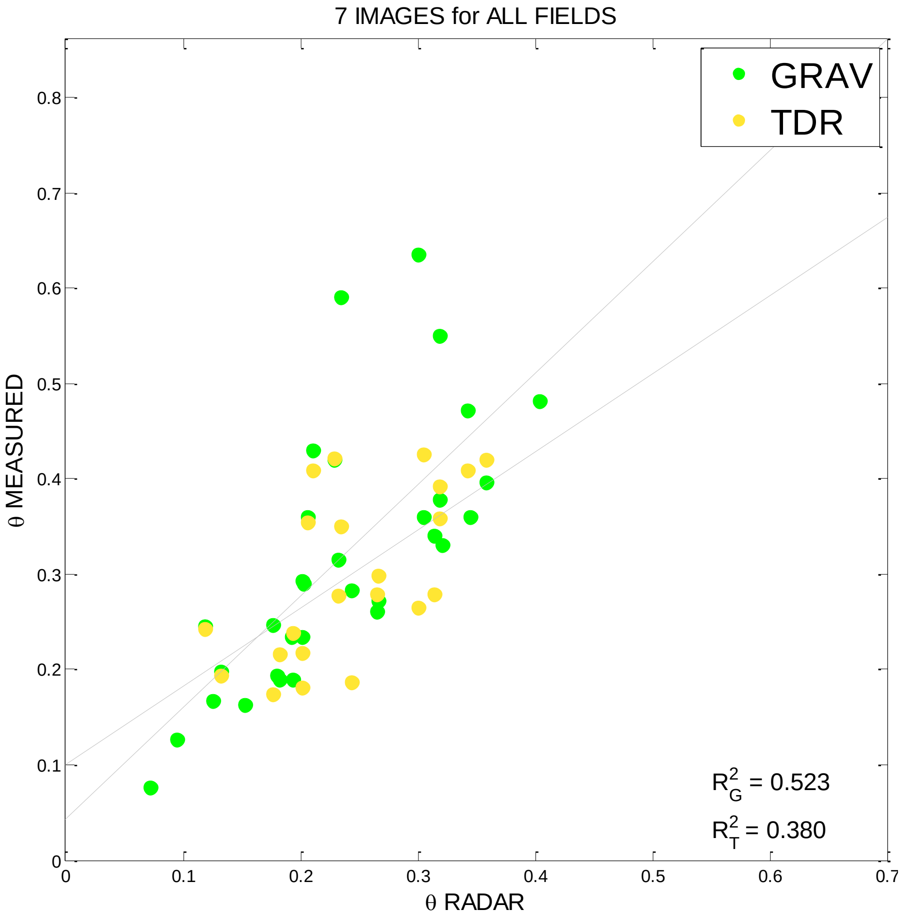
For example Topp equation (1980)

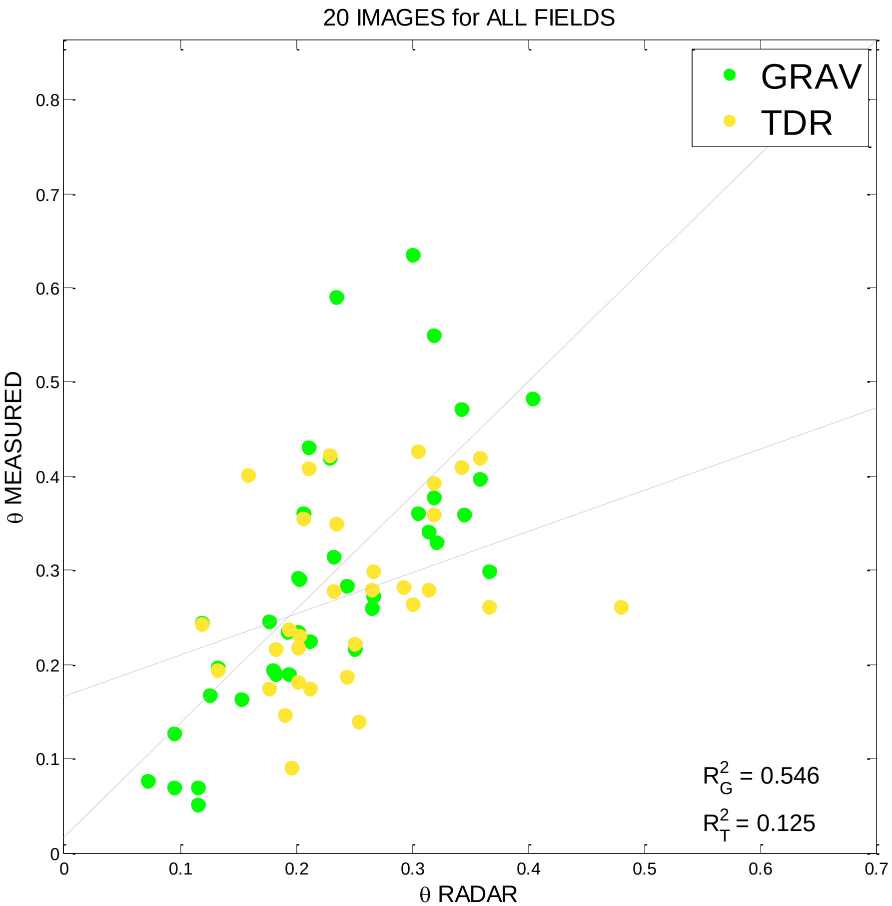
$$\vartheta = -5.3*10^{-2} + 2.29*10^{-2}\varepsilon - 5.5*10^{-4}\varepsilon^{2} + 4.3*10^{-6}\varepsilon^{3}$$


FIELD A
FIELD E
FIELD F
2003
2004
GRAVIMETRIC
TDR
ASAR
ASAR*
ASAR* polVV
ASAR* polHH
θ [-]
rain [mm]
0.5
50
0
0
100
200
300
400
500
600
700
DOY 2003 - 2004

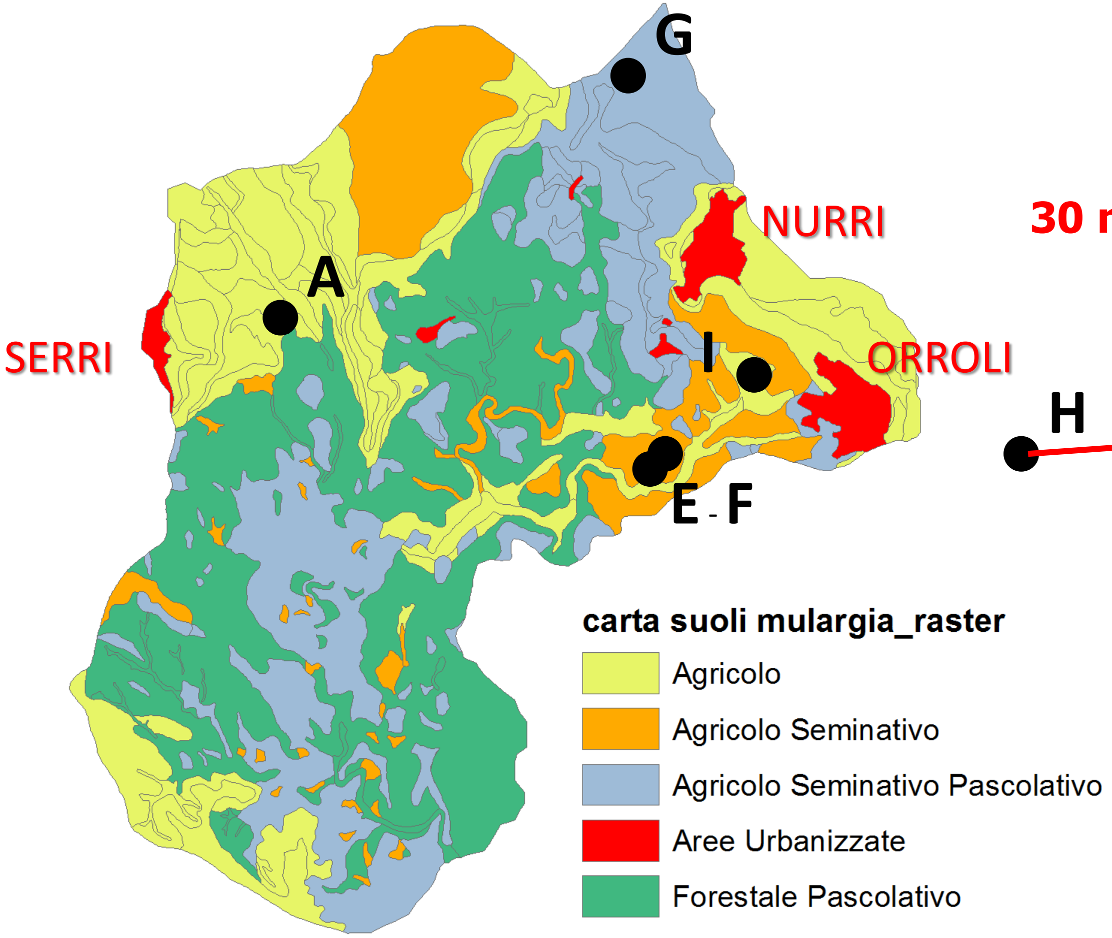

FIELD G
FIELD I
FIELD H
2003
2004
GRAVIMETRIC
TDR
ASAR
ASAR*
ASAR* polVV
ASAR* polHH
θ [-]
rain [mm]
0.5
50
0
100
200
300
400
500
600
700
DOY 2003 - 2004

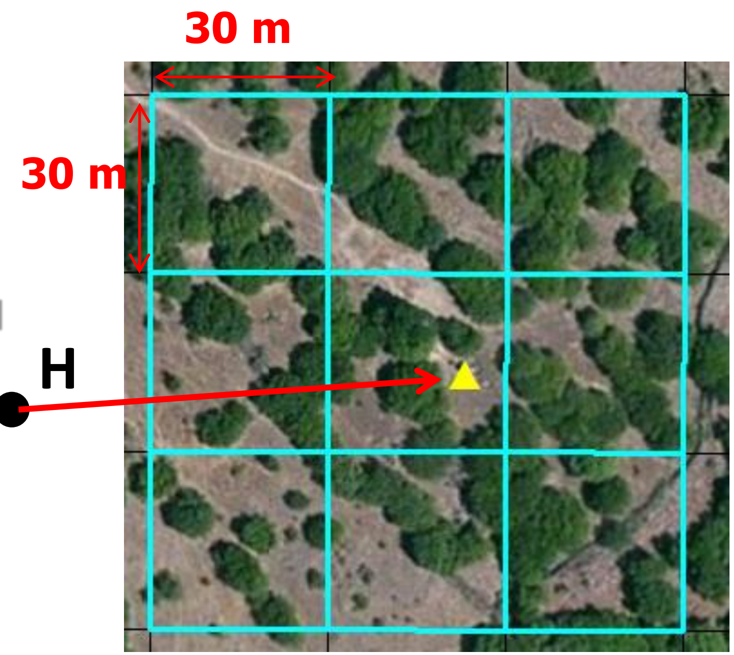
Soil Moisture at field scale

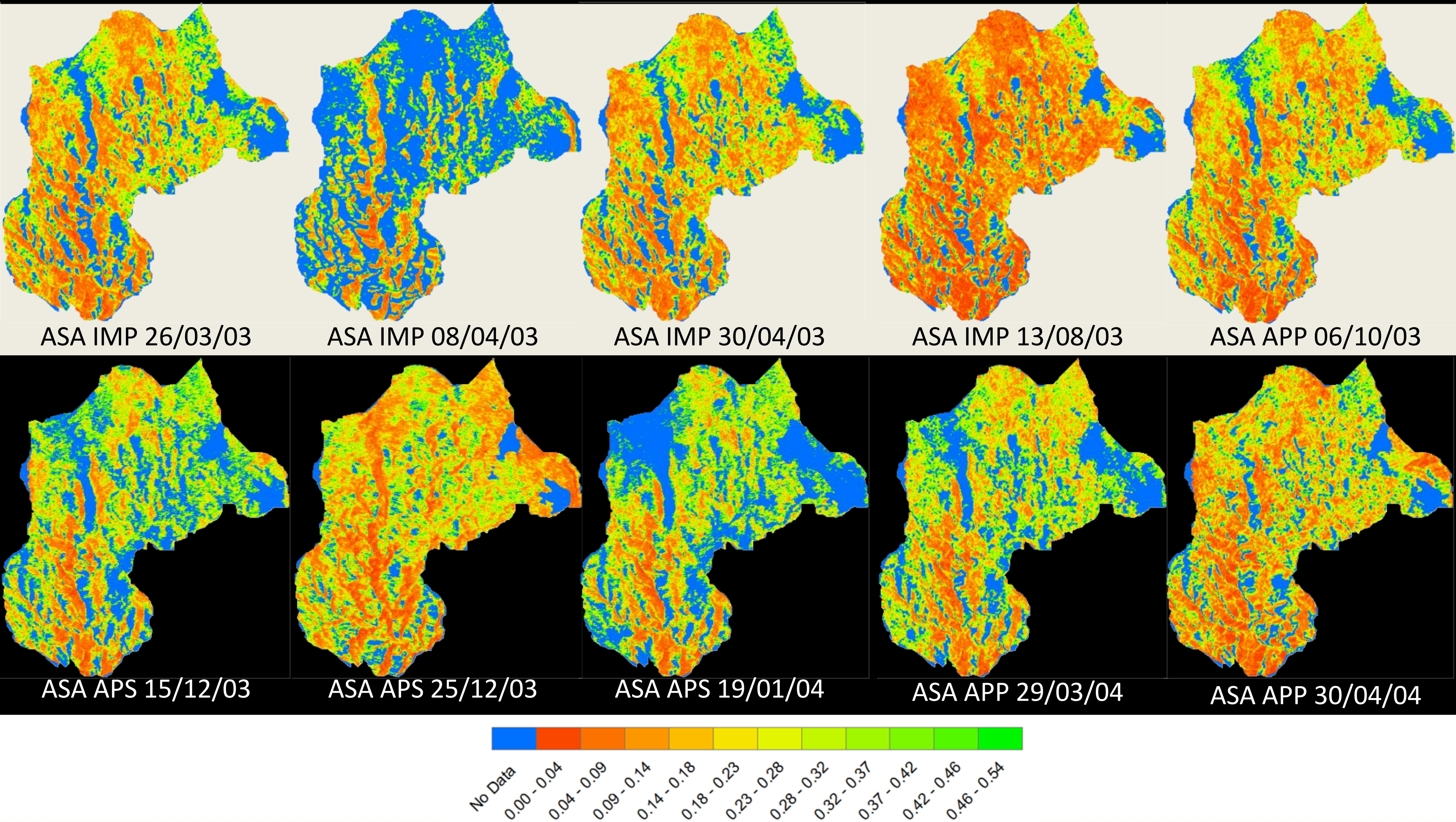




Land use/cover classification



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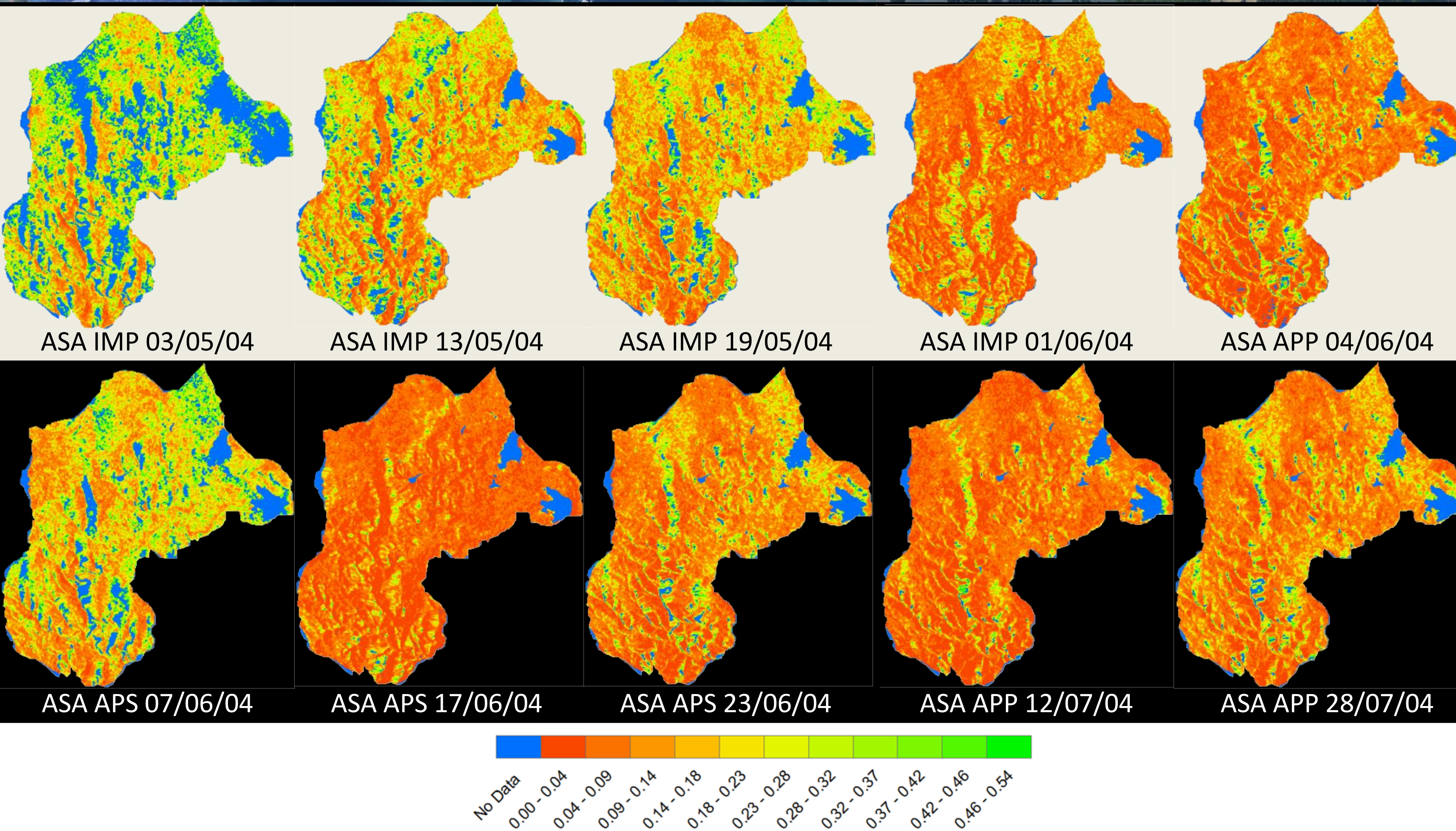
ASA IMP 08/04/03
ASA IMP 30/04/03
ASA IMP 13/08/03
ASA APP 06/10/03
ASA APS 15/12/03
ASA APS 25/12/03
ASA APS 19/01/04
ASA APP 29/03/04
ASA APP 30/04/04
No Data
0.00 - 0.04
0.04 - 0.09
0.09 - 0.14
0.14 - 0.18
0.18 - 0.23
0.23 - 0.28
0.28 - 0.32
0.32 - 0.37
0.37 - 0.42
0.42 - 0.46
0.46 - 0.54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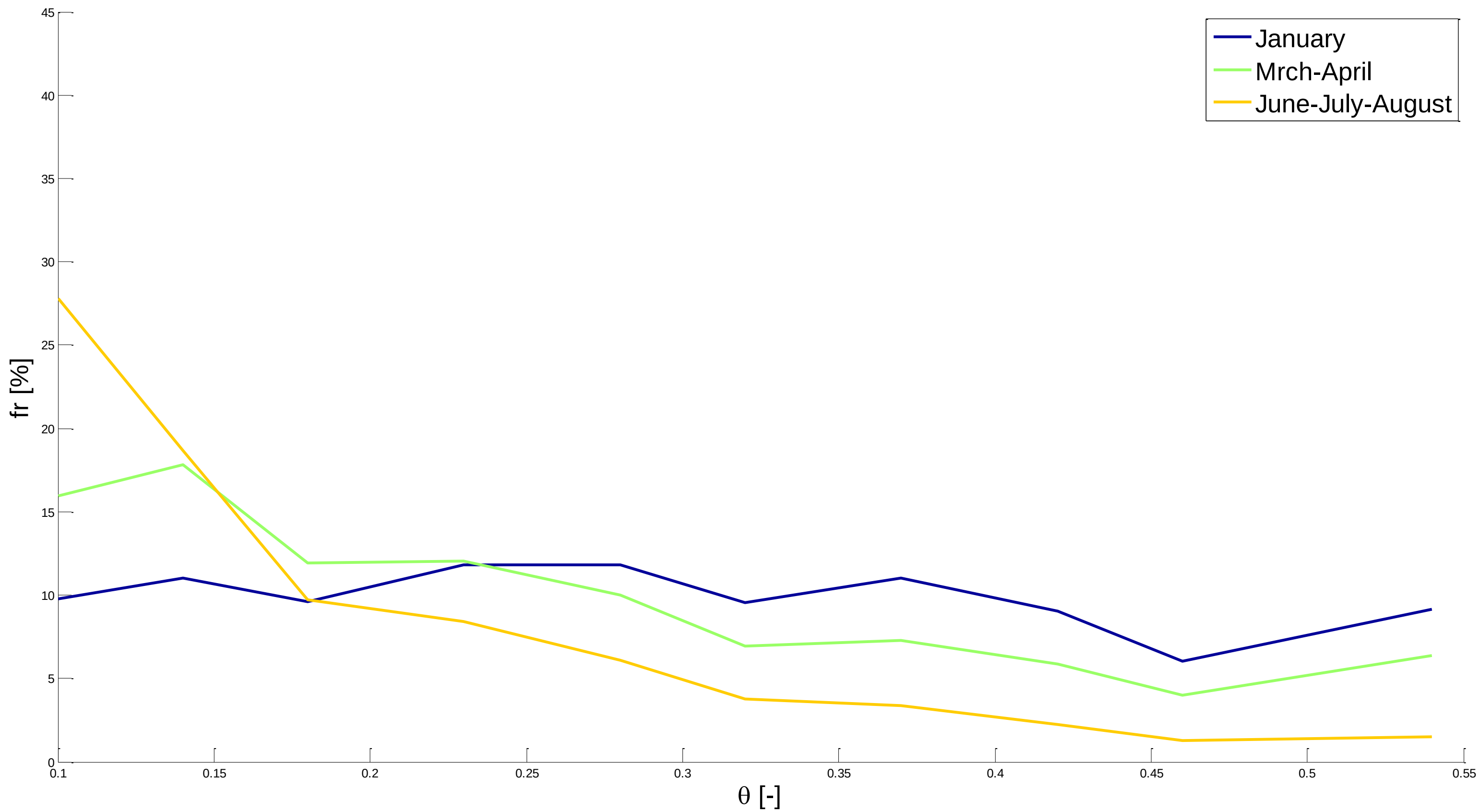
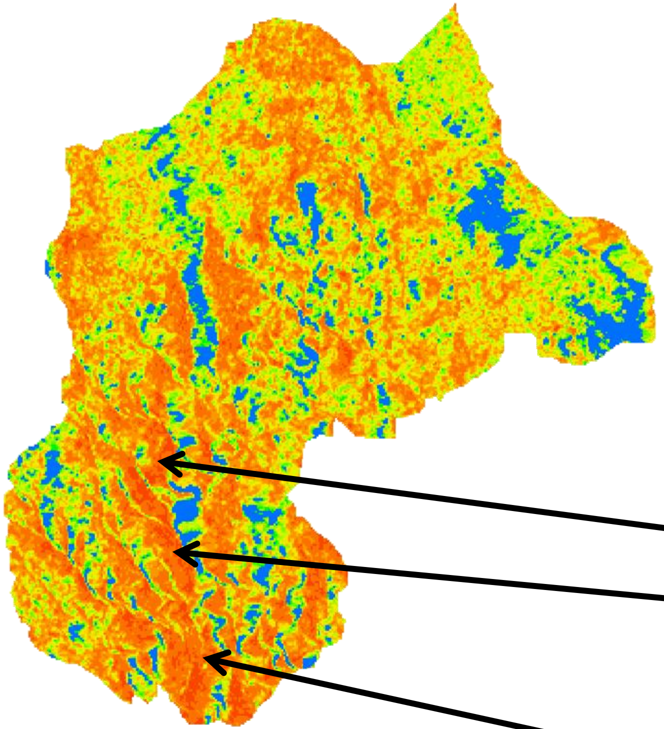
ASA IMP 13/05/04
ASA IMP 19/05/04
ASA IMP 01/06/04
ASA APP 04/06/04
ASA APS 07/06/04
ASA APS 17/06/04
ASA APS 23/06/04
ASA APP 12/07/04
ASA APP 28/07/04
No Data
0.00 - 0.04
0.04 - 0.09
0.09 - 0.14
0.14 - 0.18
0.18 - 0.23
0.23 - 0.28
0.28 - 0.32
0.32 - 0.37
0.37 - 0.42
0.42 - 0.46
0.46 - 0.54

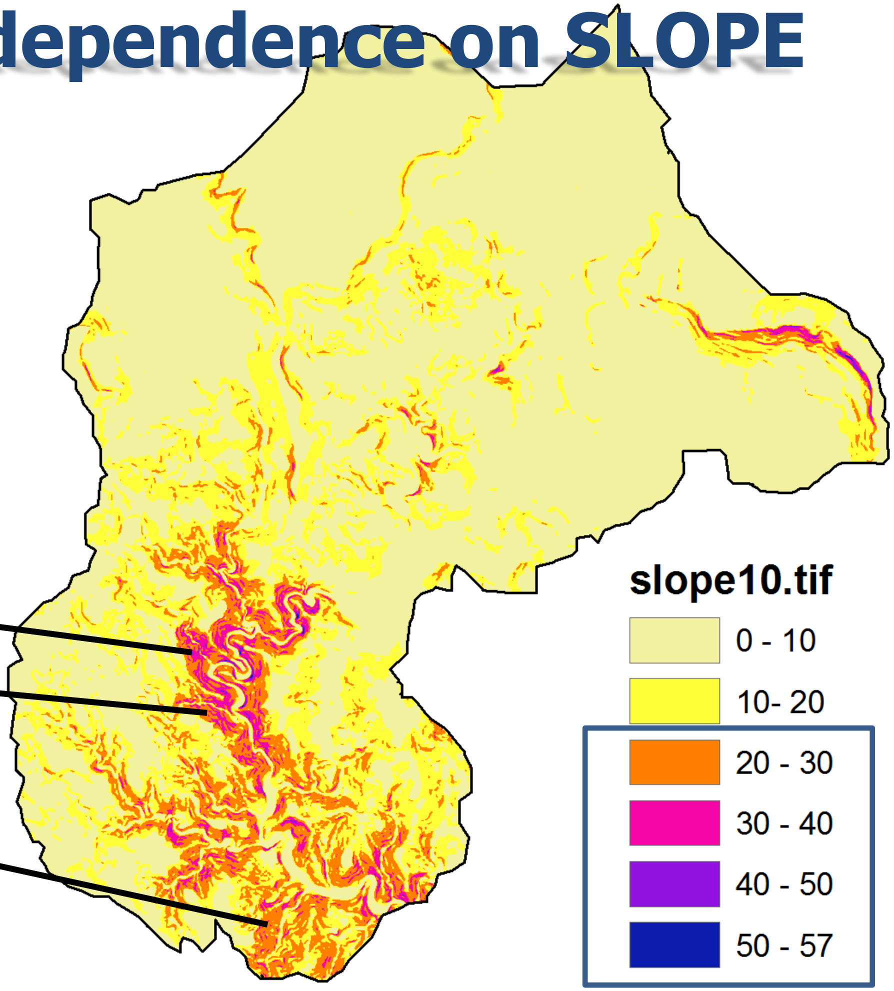
Soil moisture at basin scale



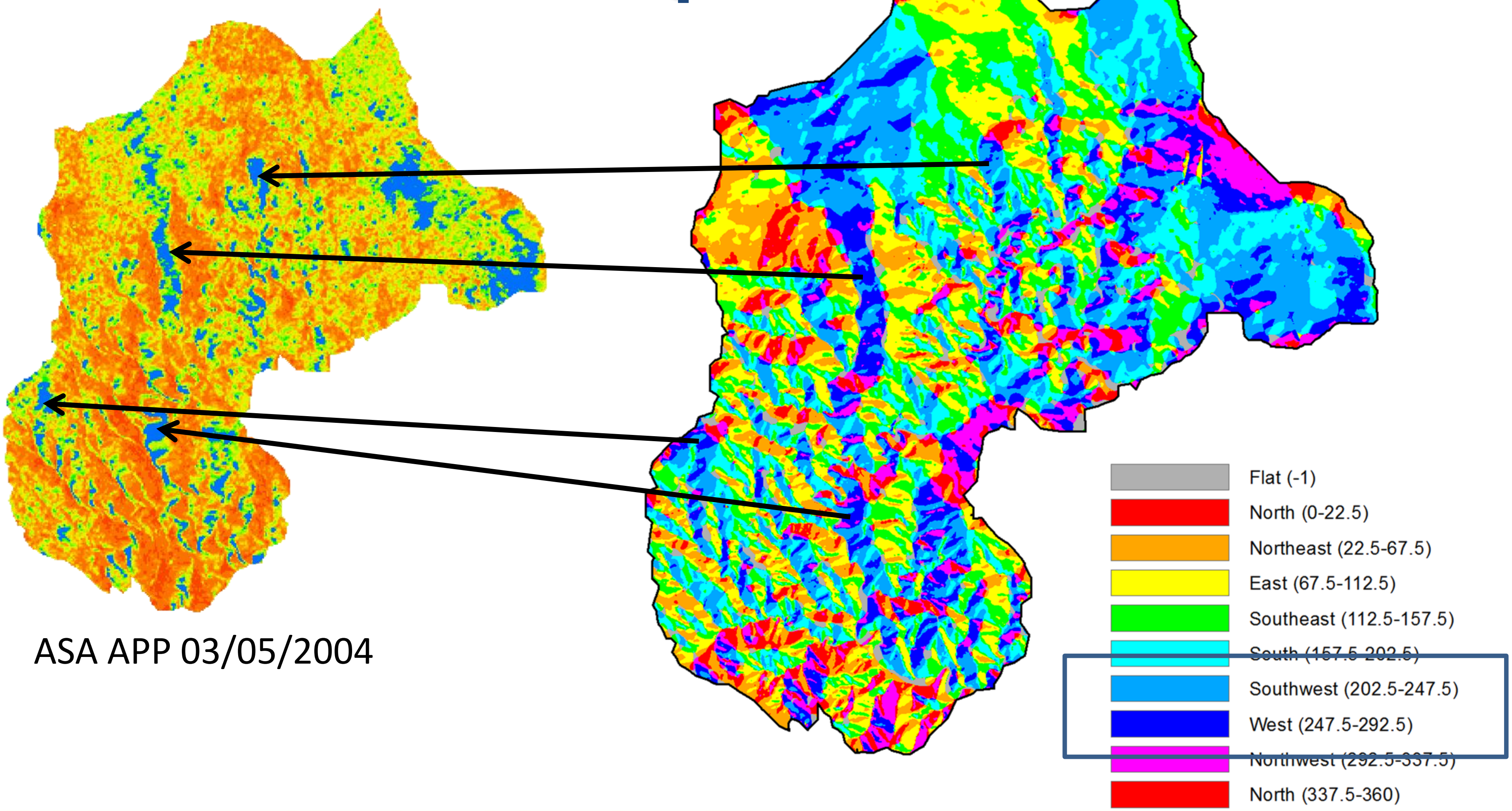
Soil moisture dependence on SLOPE



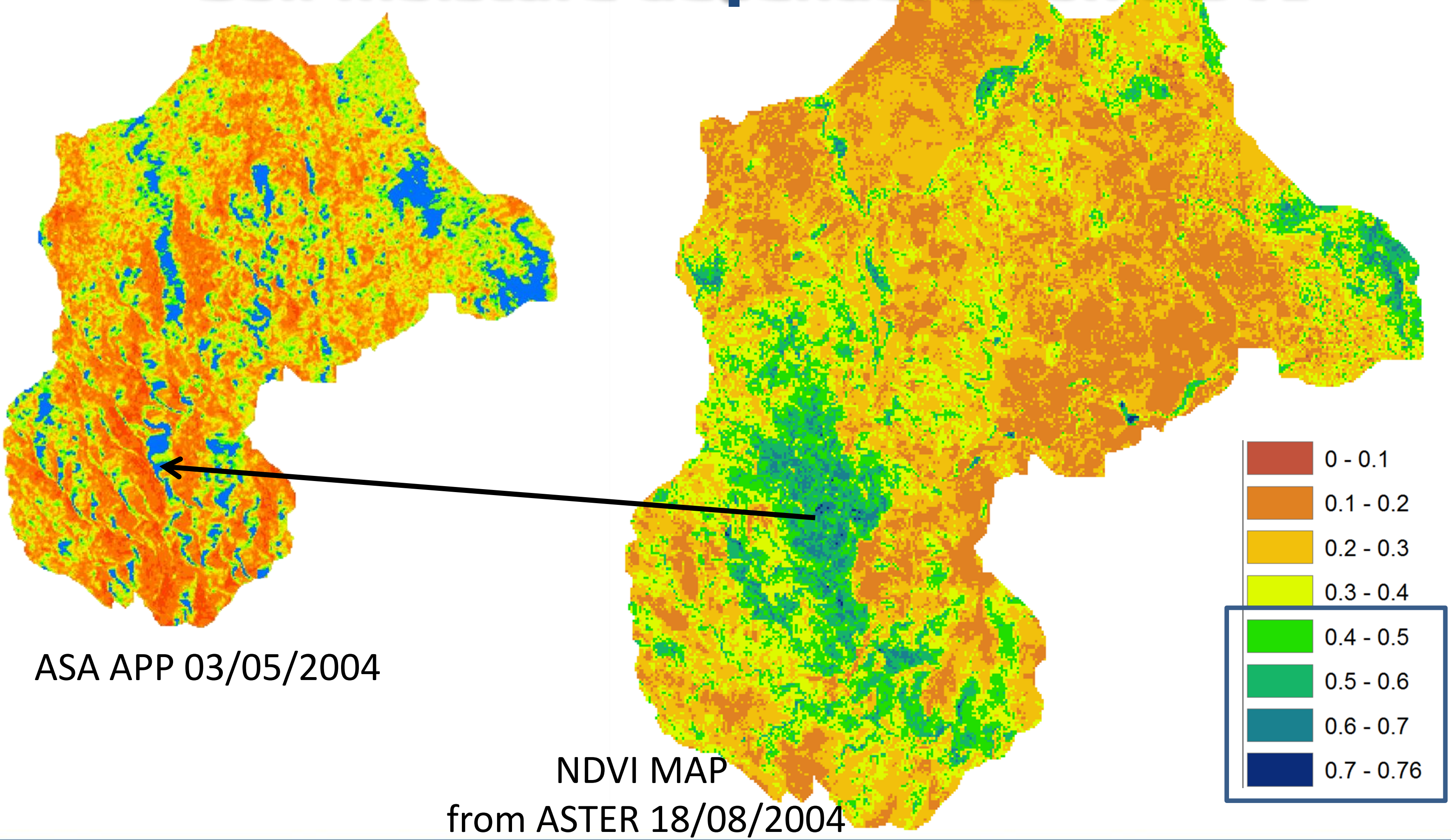
ASA APP 03/05/2004



Soil moisture dependence on ASPECT



Soil moisture dependence on NDVI



ASA APP 03/05/2004

NDVI MAP
from ASTER 18/08/2004

CONCLUSION

- The potential of high resolution ASAR imagery for estimating surface soil moisture at field scale even without direct estimation of surface roughness parameters
- The accuracy of high resolution ASAR imagery for producing maps of surface soil moisture patterns at the catchment scale and their reliability for different seasons (wet vs dry)

Future Plans

- Backscattering vegetation effect
- Relationships between soil moisture spatial variability and soil depth, cover/type vegetation
- Use more innovative radar sensors (Cosmo-SkyMed or Sentinel)

Thank you for your attention!

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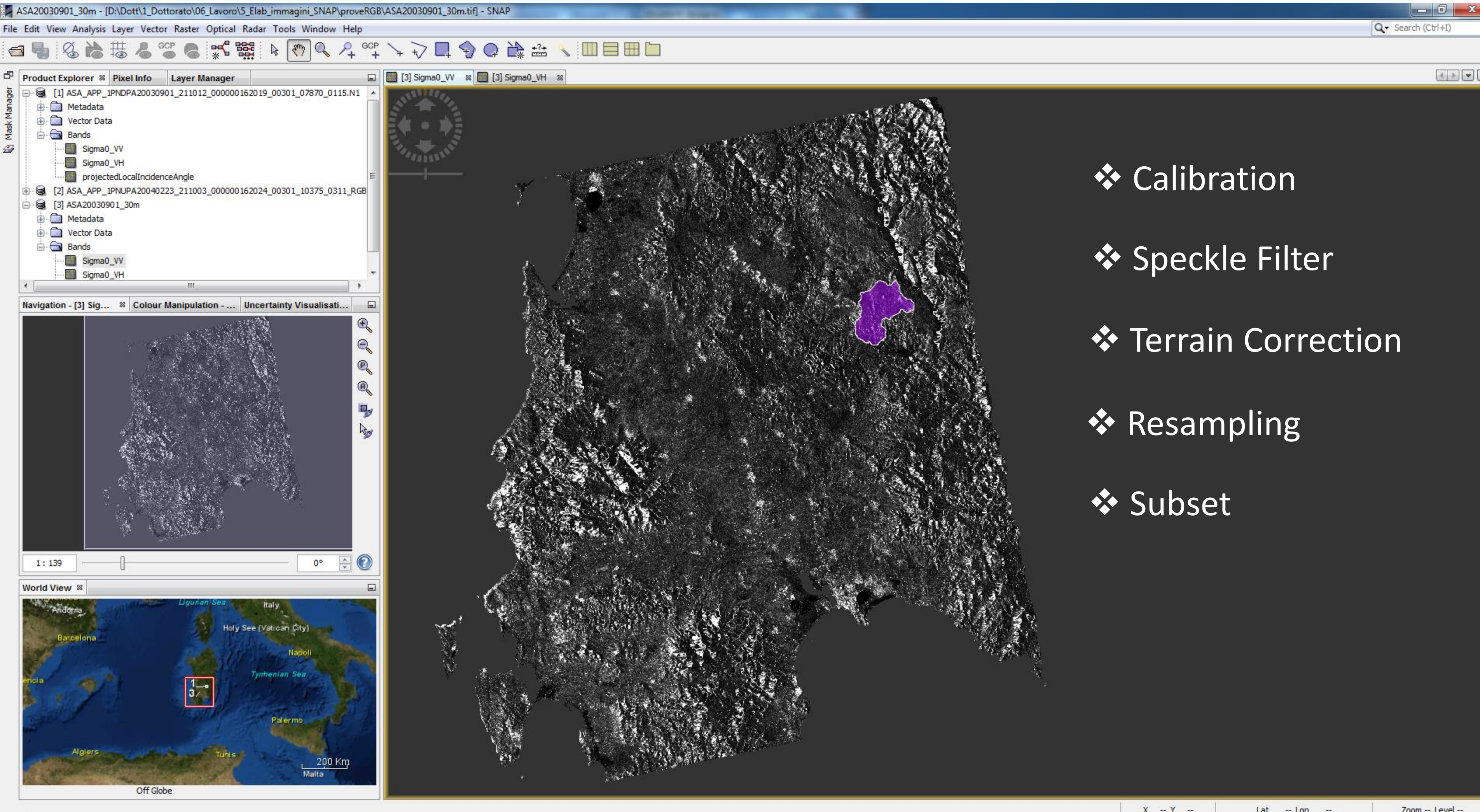
ASAR image processing



- Calibration
- Speckle Filter
- Terrain Correction
- Resampling
- Subset