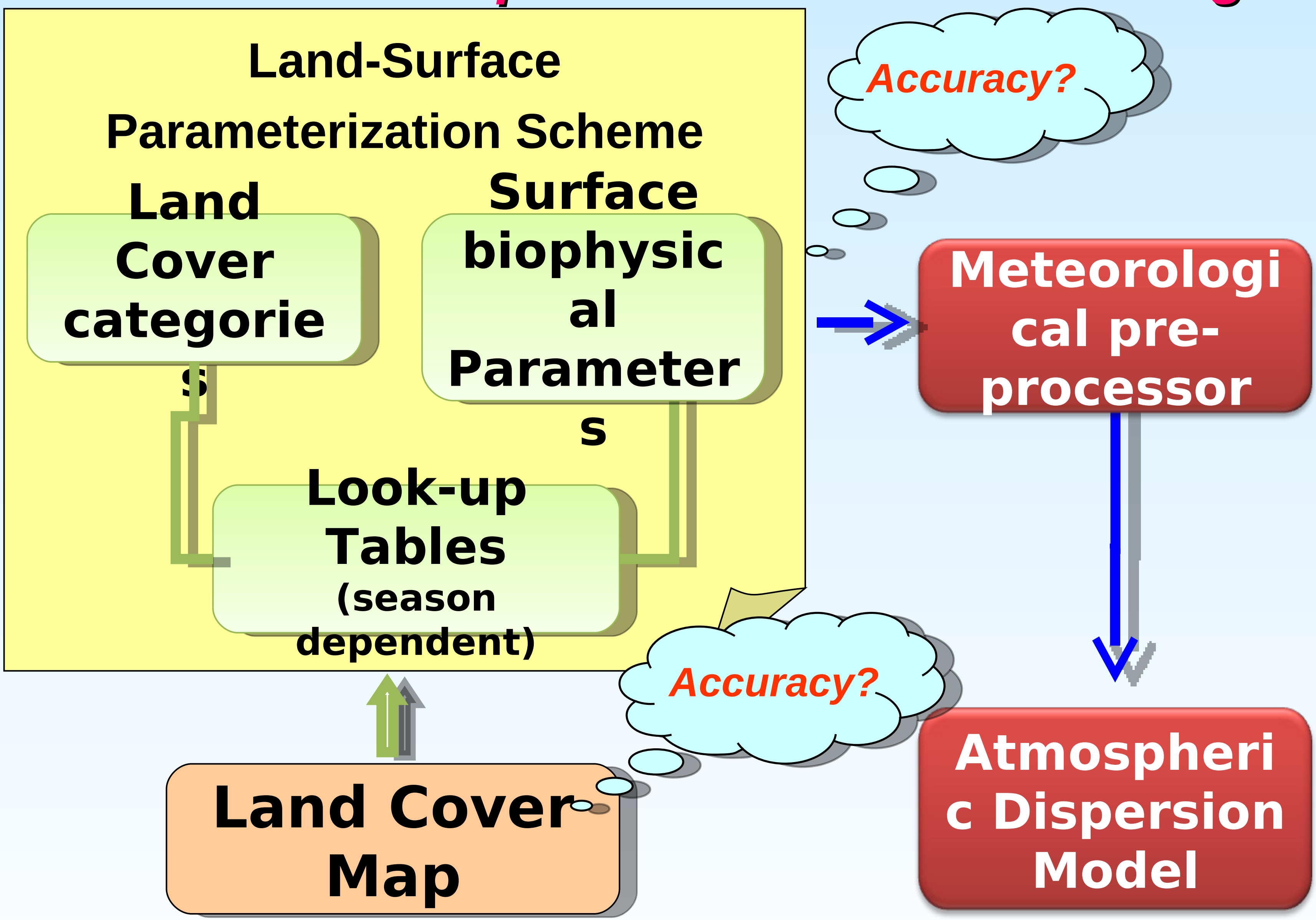
Surface parameters evaluated from satellite remote sensing images for pollutant atmospheric dispersion modelling

Teggi S.[*], Bogliolo M.P.[**], Ghermandi G.[*], Fabbi S.[*], Funaro M.[**], Gariazzo C.[**]

[*] University of Modena and Reggio Emilia, Modena, Italy

[**] ISPESL – DIPIA, Monteporzio Catone, Rome, Italy

Surface-Atmosphere Interaction Modelling



Work Rationale

Satellite remote sensing can contribute to increase accuracy by:

- updating the land cover maps,
- directly estimating some surface biophysical parameters.

But WE NEED

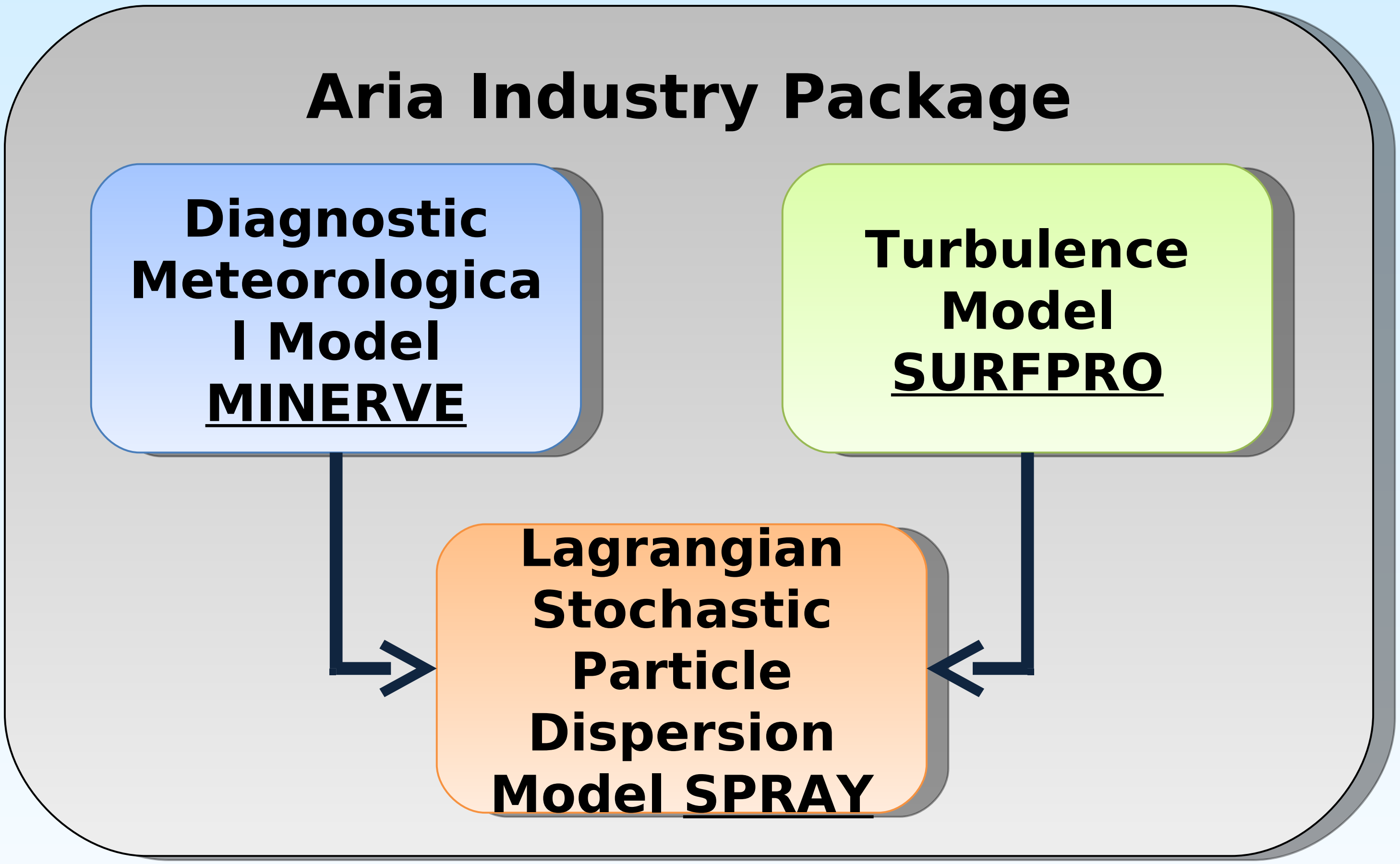
- operational methodologies of data processing;
- suitable interfaces to feed atmospheric models

Work Summary

We simulated the dispersion of the pollutants emitted from industrial sources using ASTER satellite images to feed the model with:

- **updated CORINE Land Cover map**
- **calculated surface albedo map**

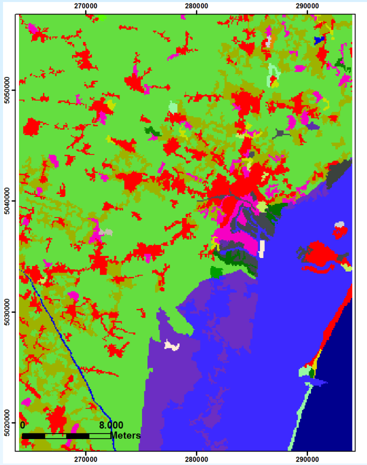
Atmospheric Dispersion Model



Tinarelli G. et al., 1998; Geai P., 1987; ARIANet R2006.23, 2006

Land-Surface Parameterization in the SURFPRO model

Land Cover Land Use map



(2D array)

LOOK-UP Tables

(season dependent)

Surface Parameters:

- Roughness length
- Albedo
- Bowen ratio
- Soil heat flux
- Leaf area index
- Canopy height
- Internal resistance

The ARIA Industry Package includes **2** parameterization schemes:

Aggregate CORINE Scheme and **BATS Scheme**

Aggregated CORINE scheme

CORINE Legend - Level 3	New Aggregated CORINE Scheme
Continuous urban fabric	**Continuous urban fabric**
Discontinuous urban fabric	**Discontinuous urban fabric**
Industrial or commercial units	**Industrial**
Port areas	
Road and rail networks and associated land	**Open, mostly artificial surfaces**
Airports	
Construction sites	
Dump sites	
Non-irrigated arable land	**Cultivated land**
Permanently irrigated land	
Rice fields	**Rice fields**
Vineyards	**Permanent/woody crops**
Fruit trees and berry plantations	
Olive groves	
Pastures	**Pastures**
Annual crops associated with permanent crops	**Crops/wood mosaic**
Land principally occupied by agricult., with signific. areas of natural	
Green urban areas	
Sport and leisure facilities	
Complex cultivation patterns	**Scattered settlement (farms, villages, trees, hedge**
Broad-leaved forest	**Broad-leaved forest**
Coniferous forest	**Coniferous forest**
Mixed forest	**Mixed forest**
Agro-forestry areas	
Moors and heathland	**Deciduous or evergreen Bush/Shrub vegetation**
Sclerophyllous vegetation	
Transitional woodland-shrub	
Beaches, dunes, and sand plains	**Beaches, dunes, and sand plains**
Bare rock	**Bare rock**
Mineral extraction sites	
Sparsely vegetated areas	**Sparsely vegetated areas**
Burnt areas	
Natural grassland	
Glaciers and perpetual snow	**Glaciers and perpetual snow**
Inland marshes	**Inland and coastal wetlands**
Peatbogs	
Salt marshes	
Salines	
Intertidal flats	
Water courses	**Water bodies**
Water bodies	
Coastal lagoons	
Estuaries	
Sea and ocean	

Classes added for remote sensing

based on the European CORINE Land Cover classification

Cultivated land: Fallow ground/Stubbles	(FA)
Cultivated land: Very young crops	(SP)
Cultivated land: Low mature green crops	(SU)
Cultivated land: High senescent crops	(SU)
Cultivated land - generic	
Pastures - generic	
Pastures: Low/sparse grass	(SP)
Pastures: Thick/homogeneous grass	(SU)

21 land use categories obtained grouping the 44 classes of the CORINE Level 3 legend

Parameters were assigned using values of the original class, for the season when the considered phenological condition is predominant

Slightly modified by the authors

used to run the model using the original CORINE updated maps.

using the Regional SCORINE maps

Simulation Domain and Model Setup

- 30 km x 40 km domain
- Part of the Venice lagoon (N Italy)
- Porto Marghera industrial site
- Almost flat coastal area
- Sea-breeze development
- Complex land use pattern

(urban and industrial areas, cultivated land, sea, lagoon, marsh areas)

Period: 01-10 September 2007 (10 days)

Time step: 1 hour

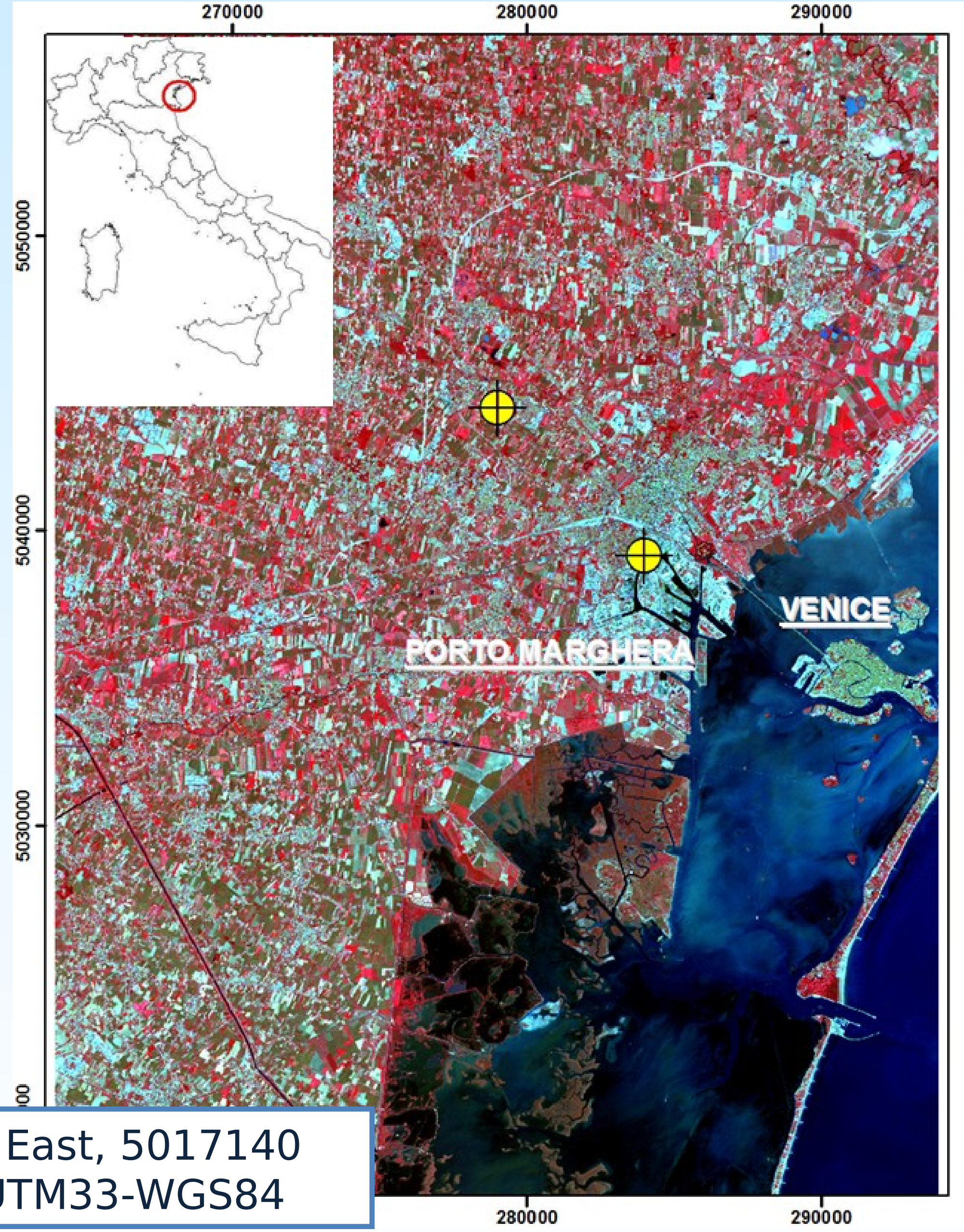
Spatial domain of the 3D grid:

Horizontal: 121 x161 nodes, step = 250 m;

Vertical: 30 nodes, from ground to 1500 m, variable step starting from 10 m

Emission sources: 2 virtual stacks

Height: 100 m
Diameter: 4 m
Temperature of gases: 140 °C
Efflux velocity: 10 m s-1
Emission: 3240 particles h-1



264000 m East, 5017140 m North UTM33-WGS84

Meteorological Dataset

"Ente Zona" – Porto Marghera

"Istituto Cavanis" – Venice

ARPA Veneto

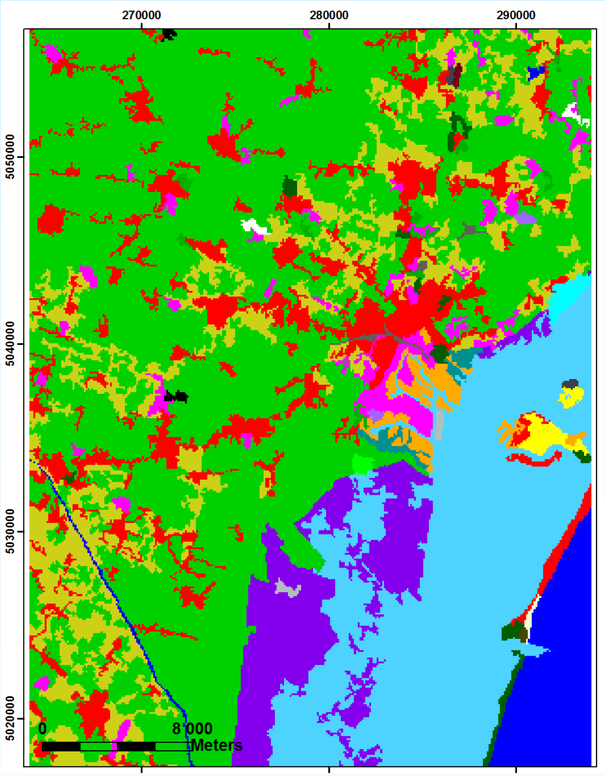
- Hourly time series of: Wind speed and direction, Air Temperature, Air Pressure, Relative Humidity, Solar radiation
- Atmospheric Vertical Profiles of Wind speed and direction and Air Temperature
- Water (Sea, lagoon) Temperature

4 Stations

1 SODAR-RASS Station

Land Cover map

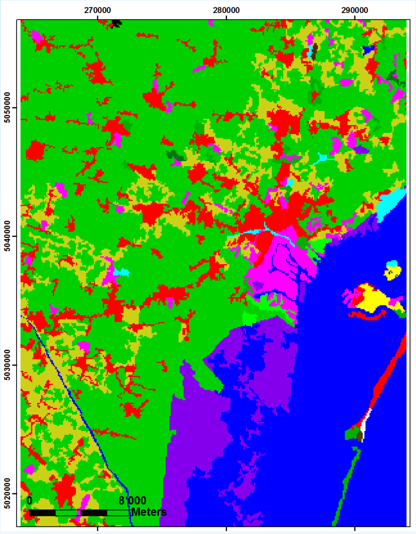
CLC2000 CORINE map – Level 3



Resolution: 100 m

grouped
resampled

Aggregated CORINE map

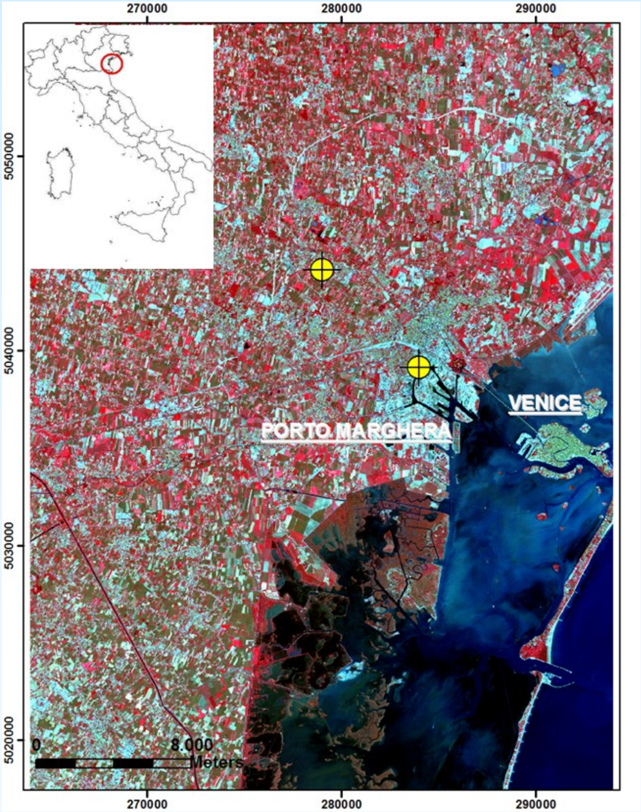


Resolution: 250 m

Data set

ASTER Satellite Image

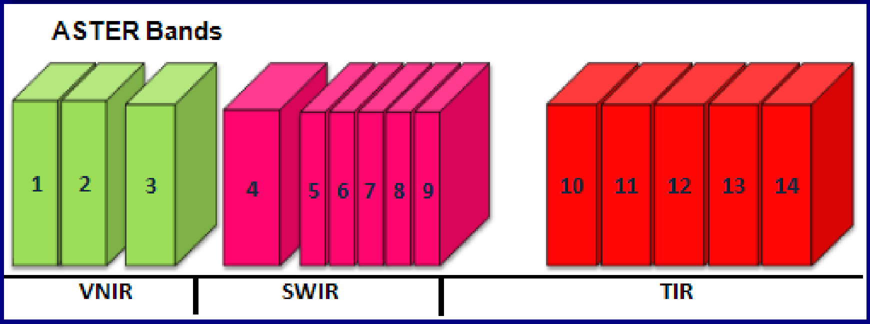
Image acquired on 5 September 2007



Pre processed to obtain geroreferenced images of spectral surface reflectance, corrected for atmospheric effects.

ASTER Sensor

Band Number	Electromagnetic Range (µm)		Spatial Resolution (m)
1	VNIR	0.52-0.60	15
2		0.63-0.69	
3N/3B		0.78-0.86	
4	SWIR	1.60-1.70	30
5		2.145-2.185	
6		2.185-2.225	
7		2.235-2.285	
8		2.295-2.365	
9		2.360-2.430	
10	TIR	8.125-8.475	90
11		8.475-8.825	
12		8.925-9.275	
13		10.25-10.95	
14		10.95-11.65	



Calculation of Surface Albedo from ASTER data

computed for each pixel of the ASTER image using the relation of Liang (2000):

$$\alpha = 0.484\,\rho_1 + 0.335\,\rho_3 - 0.324\rho_5 + 0.551\rho_6 + 0.305\rho_8 - 0.367\rho_9 - 0.0015$$

ρ_i = surface reflectance in the ASTER band *i*

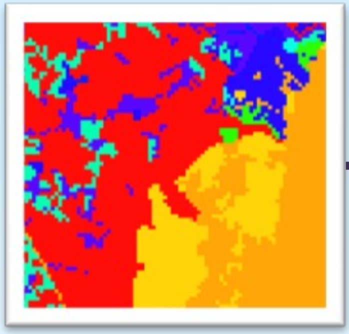
Processing steps:

- Albedo was computed with a ground resolution of 30 m;
- The average value for each land cover class was calculated;
- The obtained values were used in place of the values contained in the parameterization scheme.

Results

Surface Albedo from ASTER data

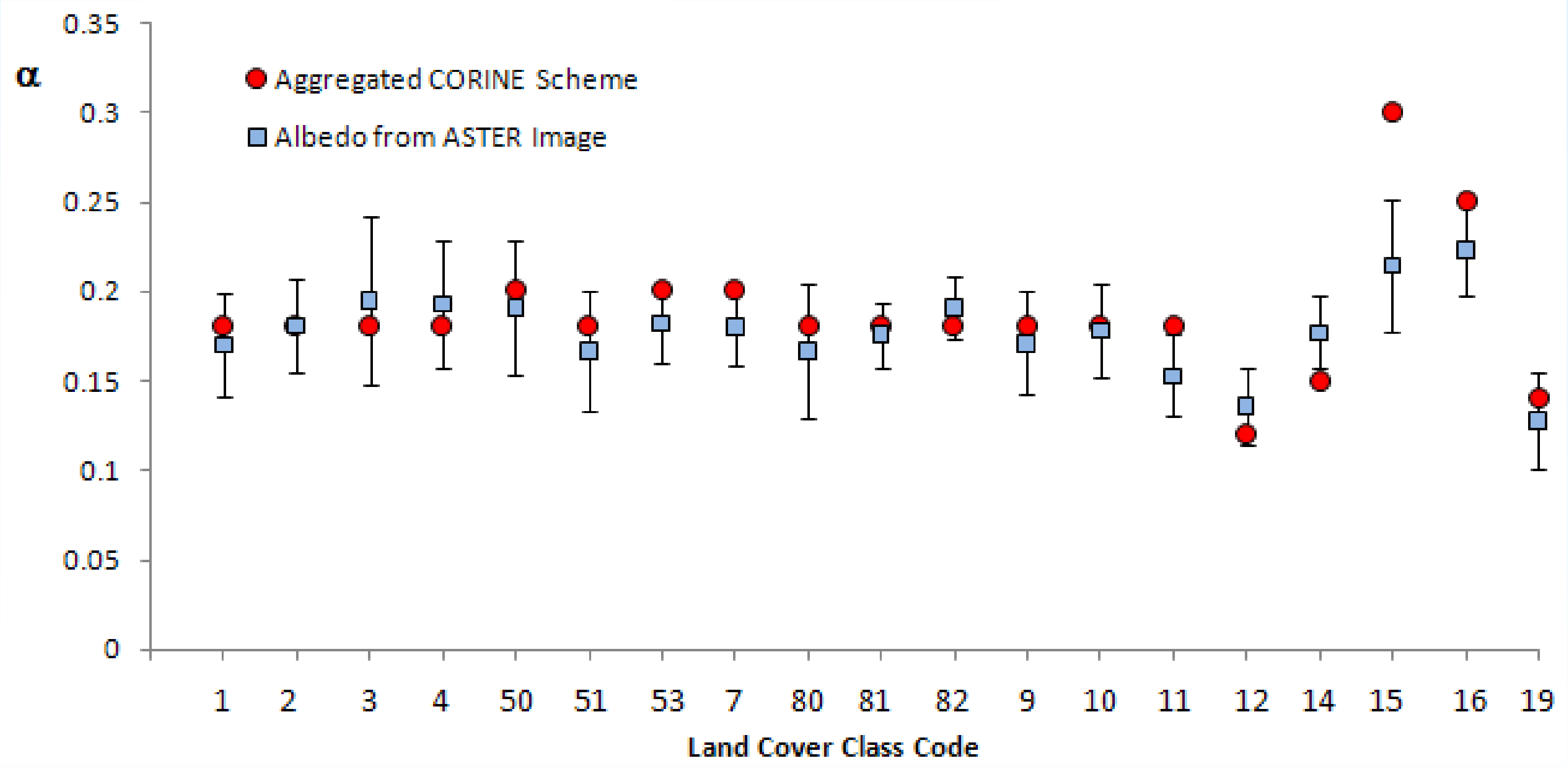
Updated CORINE Classification



Pixels belonging to class *i*

ASTER Albedo Image

Albedo Mean Value and Standard Deviation for Class *i*



Updating the CORINE dat set

with ASTER retrieved land cover map

We developed a **set of rules and procedures**, with the goal of increasing the repeatability of the process, reducing errors and subjectivity.

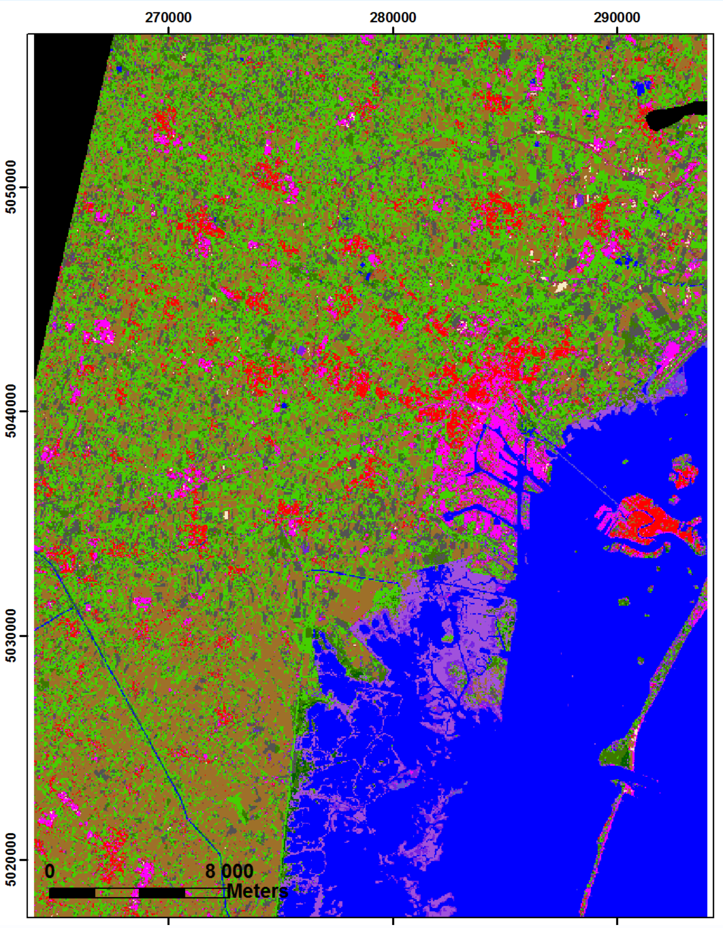
- **Standard legend of cover types** to be retrieved from the image. CRITERIA: classes easily separable with remote sensing and having significant differences in the bio-physical properties affecting surface-atmosphere interactions.

Legend for classification of Remote Sensing images
Urban
Industrial
Concrete
Fallow ground/Stubbles
Green vegetation (crops or grass) sparse/mix with dry vegetation
Green vegetation (crops or grass) quite homogeneous
Green vegetation (crops or grass) dense/homogeneous (mature)
Senescent dry vegetation dense/homogeneous (mature cereals)
Coniferous homogeneous canopy
Broadleaved homogeneous canopy
Mix coniferous-broadleaved homogeneous canopy
Broadleaved unhomogeneous wood
Woody crops
Coniferous unhomogeneous wood
Bare rock (fresh cut) (quarries)
Sand (beaches)
Exposed bare rock/dry bare ground with low humus content
Evergreen high and low bush/shrubs (Maquis)
Burnt areas
Lagoon - Emersed marsh vegetation
Lagoon - Wet bare ground
Lagoon - Wet vegetated ground
Water
Snow/Ice

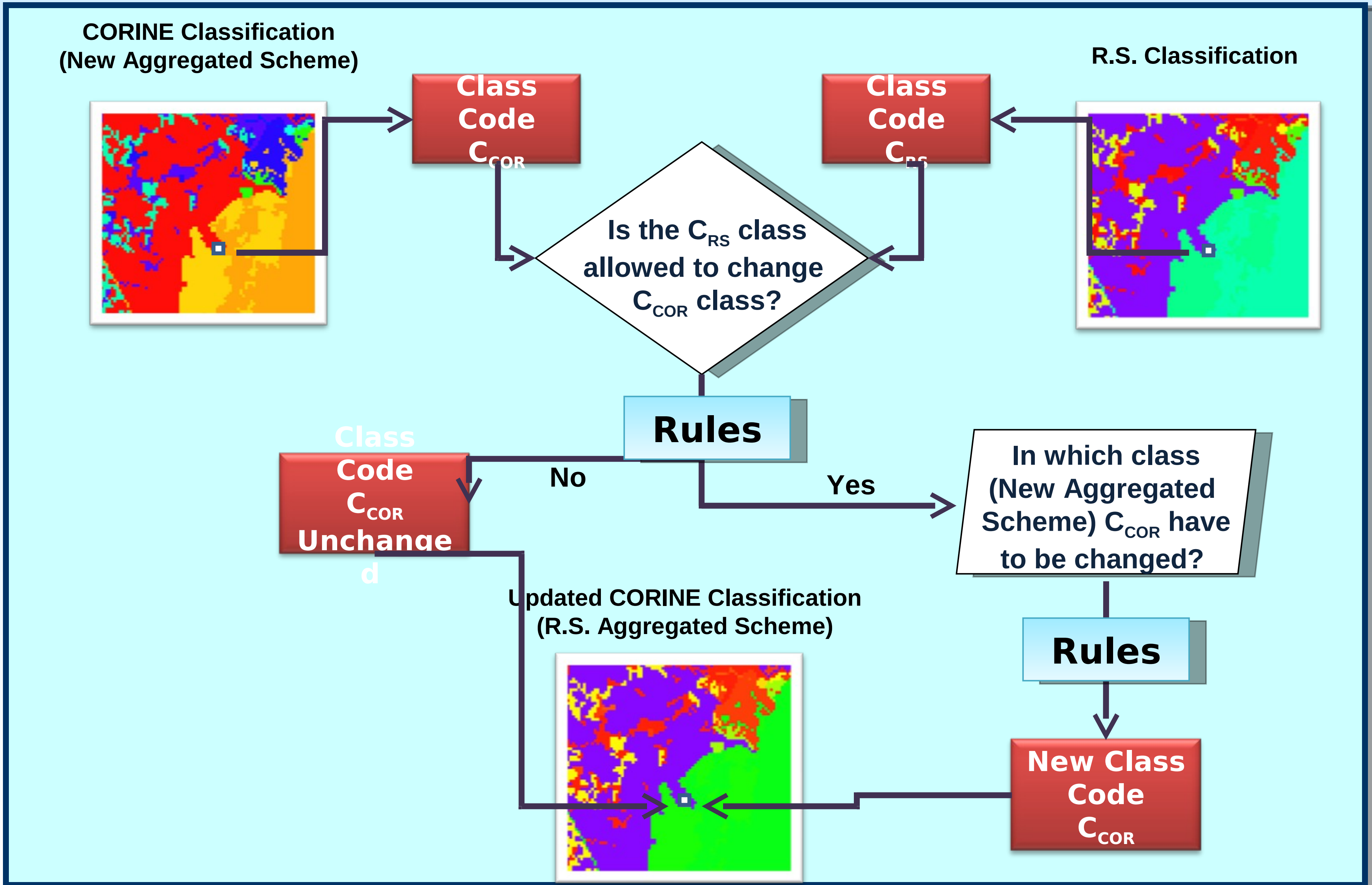
Updating of the CORINE land cover map with ASTER information

We developed a **set of rules and procedures**, with the goal of increase the repeatability of the process, reducing errors and subjectivity.

- **Standard procedure of image classification**. CRITERIA: use of binary decisions wherever possible, to assign pixels to classes.

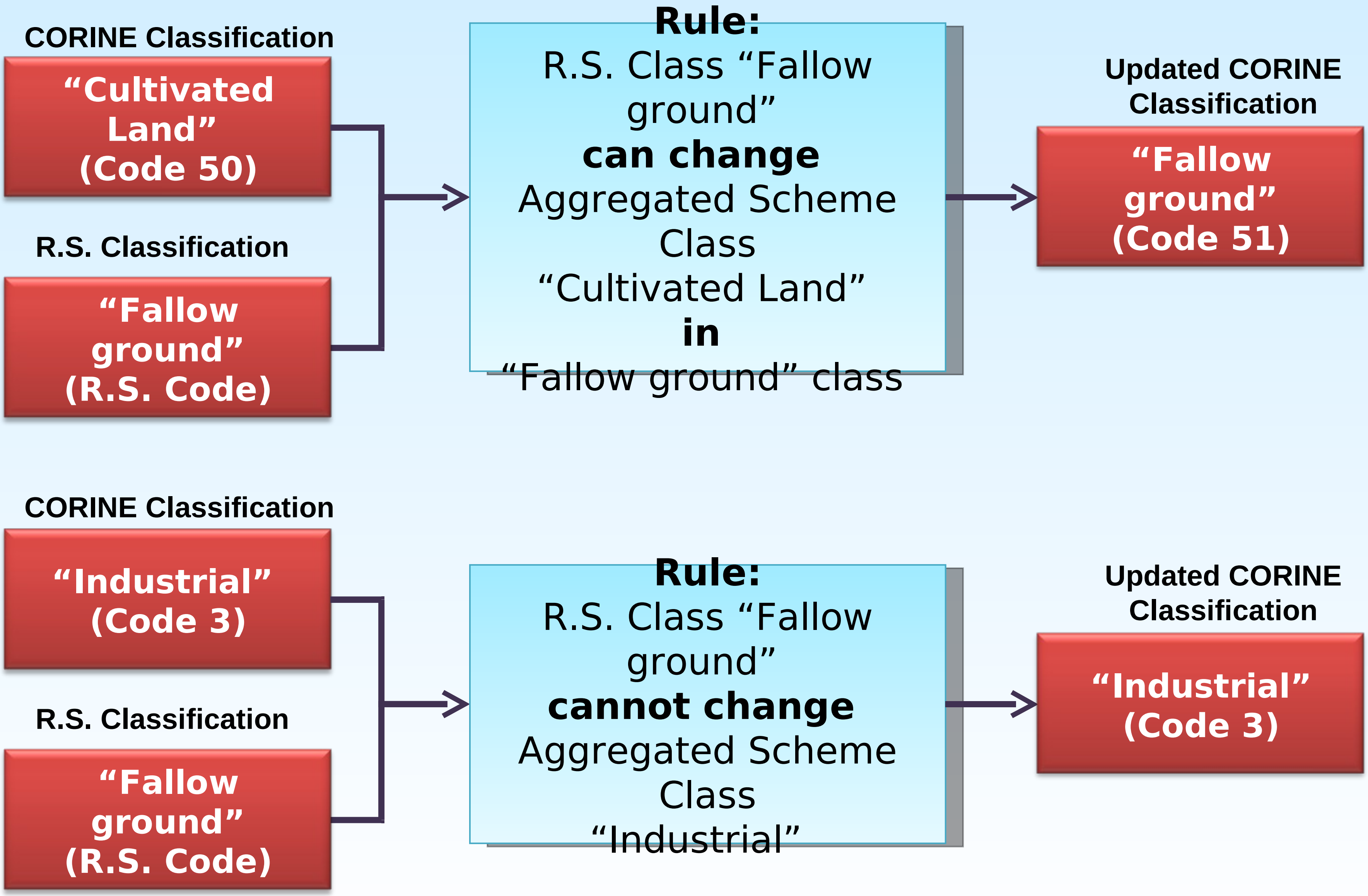


- **Set of RULES** that control **the way the remote sensing classification modifies the Aggregated CORINE Land Cover**. CRITERIA: maximizing the input of significant information; minimizing the influence of possible R.S. classification errors.



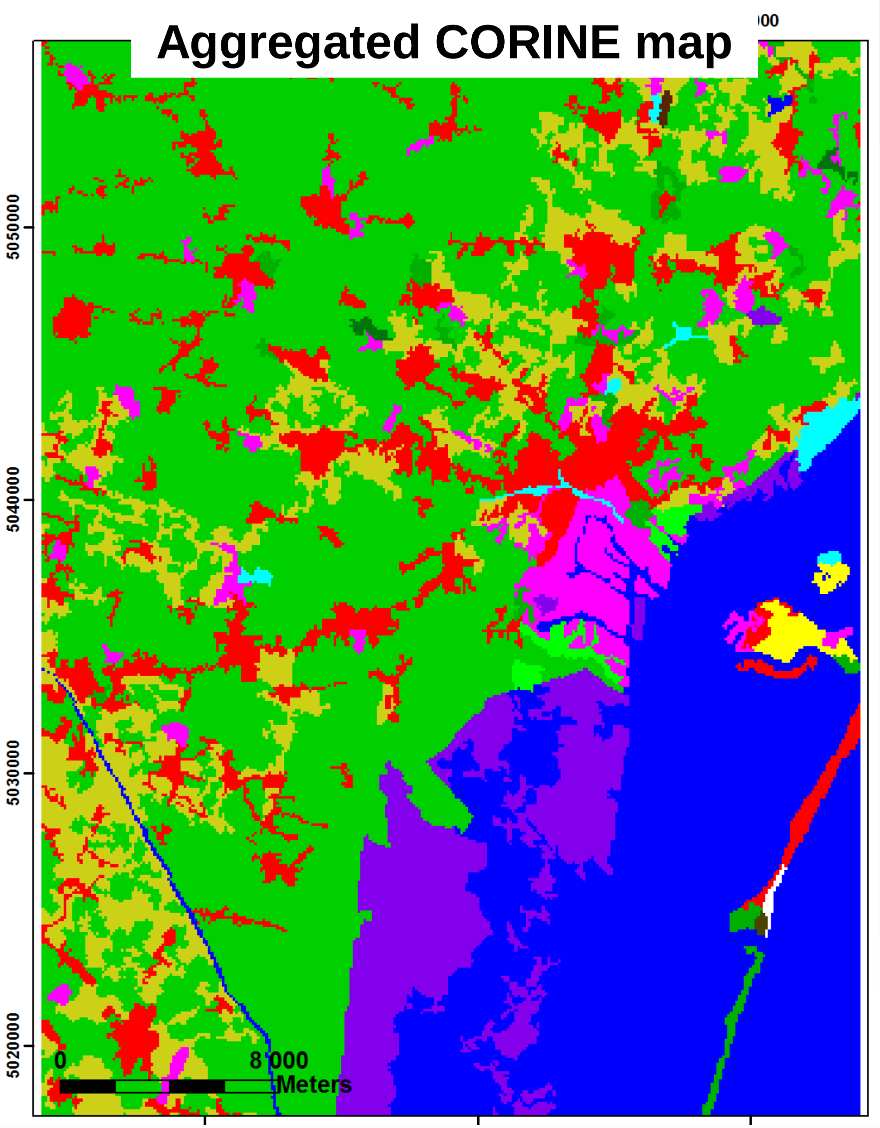
<u>Way the remote sensing classification modifies the Aggregated CORINE Land Cover</u>.

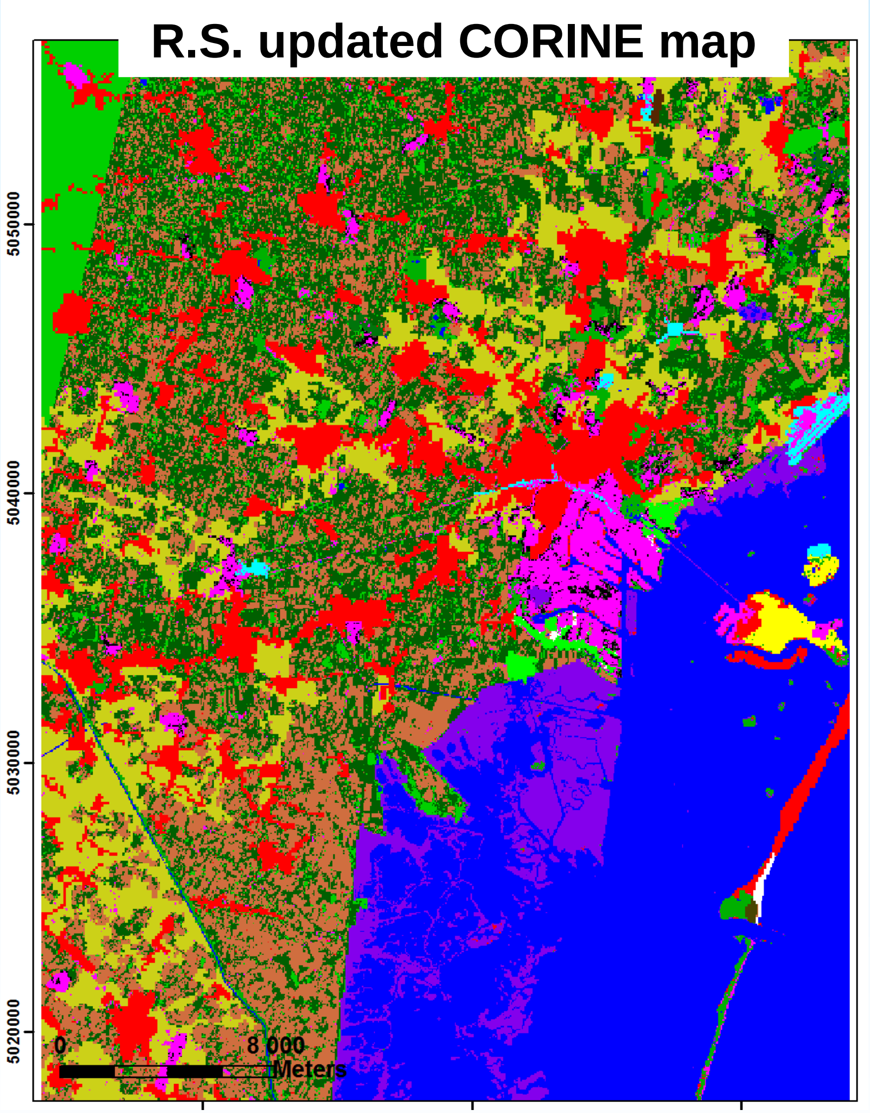
Examples of ***RULES***



Results

Land Cover changes induced by Remote Sensing

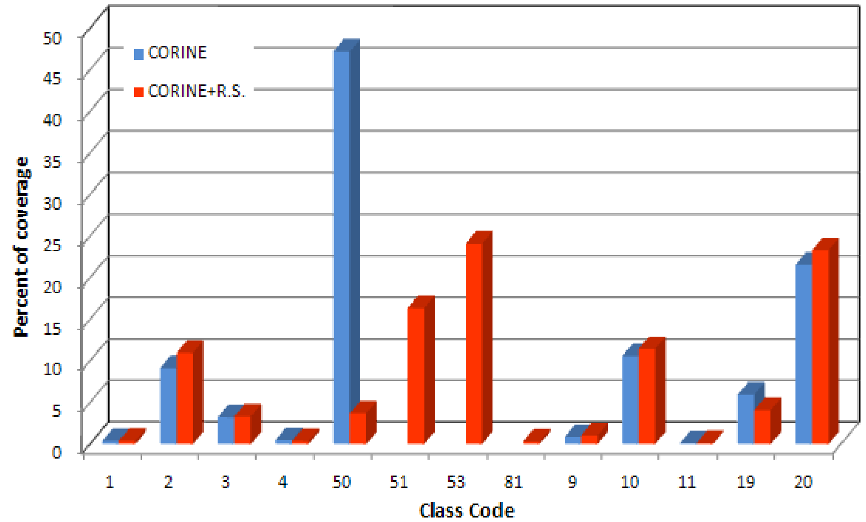




Results

Land Cover changes induced by Remote Sensing

CODE	New Aggregated CORINE Scheme - R.S.	Percent of Coverage	
		CORINE	CORINE + R.S.
1	Continuous urban fabric	0.4	0.4
2	Discontinuous urban fabric	9.1	11.0
3	Industrial	3.2	3.3
4	Open, mostly artificial surfaces	0.5	0.4
50	Cultivated land - generic	47.2	3.7
51	Cultivated land: Fallow ground/Stubbles	-	16.3
52	Cultivated land: Very young crops	-	0.0
53	Cultivated land: Low mature green crops	-	24.1
54	Cultivated land: High senescent crops	-	0.0
6	Rice fields	0.0	0.0
7	Permanent/woody crops	0.0	0.0
80	Pastures - generic	0.0	0.0
81	Pastures: Low-sparse grass	-	0.3
82	Pastures: Thick/homogeneous grass	-	0.0
9	Crops/wood mosaic	0.8	1.0
10	Scattered settlement (farms, villages, trees, ...)	10.6	11.4
11	Broadleaved forest	0.1	0.1
12	Coniferous forest	0.0	0.0
13	Mixed forest	0.0	0.0
14	Deciduous or evergreen Bush/Shrub vegetation	0.4	0.4
15	Beaches, dunes and sand plains	0.0	0.0
16	Bare rock	0.0	0.0
17	Sparsely vegetated areas	0.0	0.0
18	Glaciers and perpetual snow	0.0	0.0
19	Inland and coastal wetlands	5.9	4.1
20	Water bodies	21.5	23.3



Only classes with percent of coverage greater than 0.1 are plotted

Percents of Coverage have been extracted from the land cover maps given as input to the dispersion model (250 m x 250 m grid)

Results

Effects of ASTER information on Dispersion results

Variable (units)	Run	Land, Day		Land, Night		Water, Day		Water, Night	
		Mean, σ	RMSD	Mean, σ	RMSD	Mean, σ	RMSD	Mean, σ	RMSD
z_0 (cm)	R0	32.8, 30.8	17.3	32.8, 30.8	17.3	0.5, 2.3	6.5	0.5, 2.3	6.5
	R1	31.5, 34.4		31.5, 34.4		0.6, 6.0		0.6, 6.0	
u^* (m s^{-1})	R0	0.50, 0.21	0.10	0.25, 0.16	0.07	0.43, 0.27	0.19	0.24, 0.14	0.13
	R1	0.49, 0.21		0.25, 0.17		0.49, 0.25		0.29, 0.18	
w^* (m s^{-1})	R0	1.07, 0.63	0.12	0.03, 0.11	0.01	0.86, 0.39	0.34	0.72, 0.38	0.42
	R1	1.11, 0.65		0.03, 0.11		0.99, 0.36		0.89, 0.39	
L (m)	R0	-206, 357	125	45, 173	73	-278, 342	267	-30, 111	132
	R1	-190, 343		46, 177		-304, 321		-48, 138	
h (m)	R0	1163, 681	111	162, 130	50	676, 398	256	346,208	180
	R1	1202, 713		163, 136		772, 370		435, 244	

$$RMSD = \sqrt{mean\left(f_{R_1} - f_{R_0}\right)^2}$$

f : model output

R0 = reference run
R1 = run using remote sensing

z_0 : roughness length
u* : friction velocity
w*: convective scale velocity
L: Monin-Obukhov length
h: mixing height

R.S. changed the spatial distribution of the outputs.

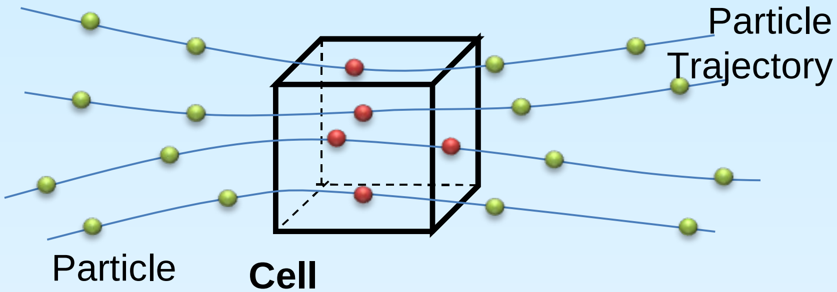
Their statistic distribution is little affected.

Changes are more important over water than over land,

and during day than during night.

Results

Effects of ASTER information on Particle distribution



Cell
Horizontal: 250 m x 250 m
Vertical: 20 m, ground based

n_p = Number of particles that transitated through a given surface cell		
$\max(n_p) = 16$	$\overline{n_p} = 1.2$	$\sigma_{n_p} = 1.8$

mean and standard deviations obtained from the two runs differ by less than 10^{-2}

Number of surface cells (***n***) crossed by a n. of particles greater than a given threshold $\boldsymbol{n_t}$

Run	$\boldsymbol{n_t = 5}$	$\boldsymbol{n_t = 6}$	$\boldsymbol{n_t = 7}$	$\boldsymbol{n_t = 8}$	$\boldsymbol{n_t = 9}$	$\boldsymbol{n_t = 10}$
R0	$n = 1202$	$n = 710$	$n = 402$	$n = 213$	$n = 123$	$n = 74$
R1	$n = 1166$	$n = 659$	$n = 349$	$n = 185$	$n = 97$	$n = 55$
$100 \cdot (n_{R1} - n_{R0})/n_{R0}$	-3%	-6%	-13%	-13%	-21%	-26%

R0 = reference run
R1 = run using remote sensing

The reference run produces more cells with high number of particles than run R1
→ the Run using R.S. produces more dispersion

Conclusions

Results for a single case study!!

Updating the land use map with ASTER classification

- **Very small** differences on the **mean values** of the outputs of the model;
- **Significant changes** in their **distribution** over the domain.
- Causes of these differences should be further investigated.

Using ASTER albedo in the model

- Satellite albedo values are **very close** to the values contained in the model **internal tables**; → Remote sensing images can be used as an alternative way to obtain reliable values of this parameter.

Further work

- Application to different case studies, to confirm the present first results;
- Attempt to extract other surface parameters needed by the models.