Assimilation of EO data in the CROPWAT model

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Objectives

- Analyze the possible use of satellite information as input for CROPWAT model;
- Estimate daily evapotranspiration during maize growing season from climatic data by using CROPWAT model;
- Calculate daily actual evapotranspiration from satellite images based on the surface energy balance;
- Analyze and compare the model results with satellite estimations on test areas in the Romanian Plain.

CROPWAT model

DATA	INPUT	OUTPUT
Climatic	Eto measured or calculated with Penman-Monteith rainfall data	crop water requirement irrigation requirement
Crop	Kc, crop description, max. rooting depth, % area covered by plant	actual crop evapotranspiration daily soil moisture deficit
Soil	initial soil moisture condition and available soil moisture	irrigation scheduling
Irrigation	irrigation scheduling criteria	estimated yield reduction due to crop stress

Data input used for the CROPWAT model

Climatic data:

- Monthly means of:minimum temperature (?C), maximum temperature (?C), air relative humidity (%), sunshine duration (hours), wind speed at 2m high (m/s)
- Monthly Rainfall

Crop data:

- sowing date: 20 / 25 April 2000
- crop coefficient (Kc): standard
- crop description: according to the observed crop phenology

Soil data:

- initial available soil moisture: 86/75 mm
- maximum root infiltration rate: 40 mm/day
- maximum rooting depth: 1m

Scheduling criteria: rainfed conditions

Use of EO data in the CROPWAT model

The CROWAT model operates in two modes:

- computing the actual evapotranspiration using climatic parameters;
- using directly the evapotranspiration measurements values.

The possibilities of the use of the satellite-based data as input into the CROPWAT model are limited, because this model was not considered to directly use of satellite-derived information.

This information can be useful for comparison/validation procedures of some model input/output data, like precipitation, sunshine duration and evapotranspiration.

Use of EO data in the CROPWAT model

The CROPWAT model can use the satellite-derived information in different ways:

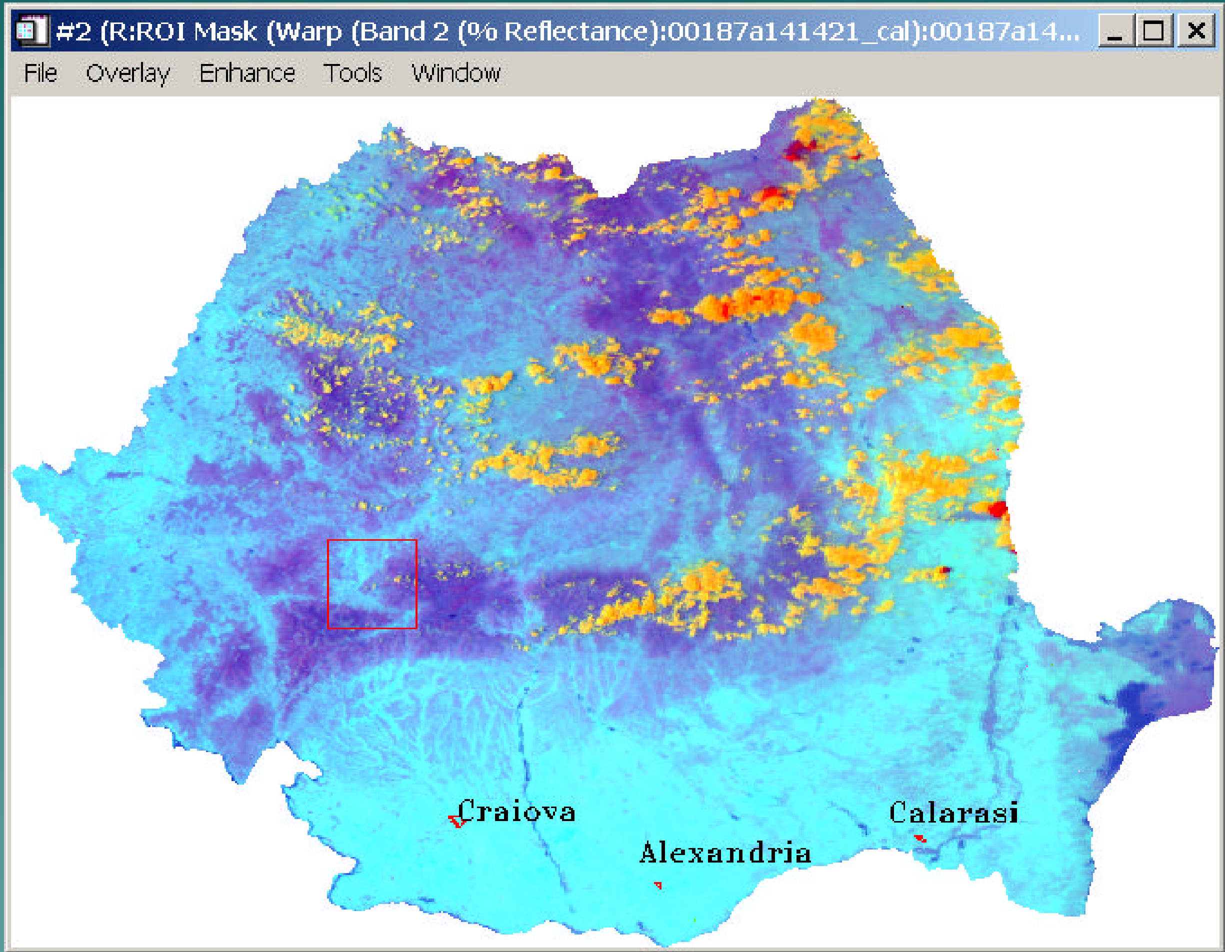
- the measured evapotranspiration could be replaced with estimation derived from satellite data, for comparison and validation procedures;

- the satellite-derived evapotranspiration values could bring a better accuracy for the spatialisation of the punctual computing values;

- the satellite information can be used for the assessment of the some reference parameters of the actual evapotranspiration (e.g. land surface temperature, vegetation indexes, etc)

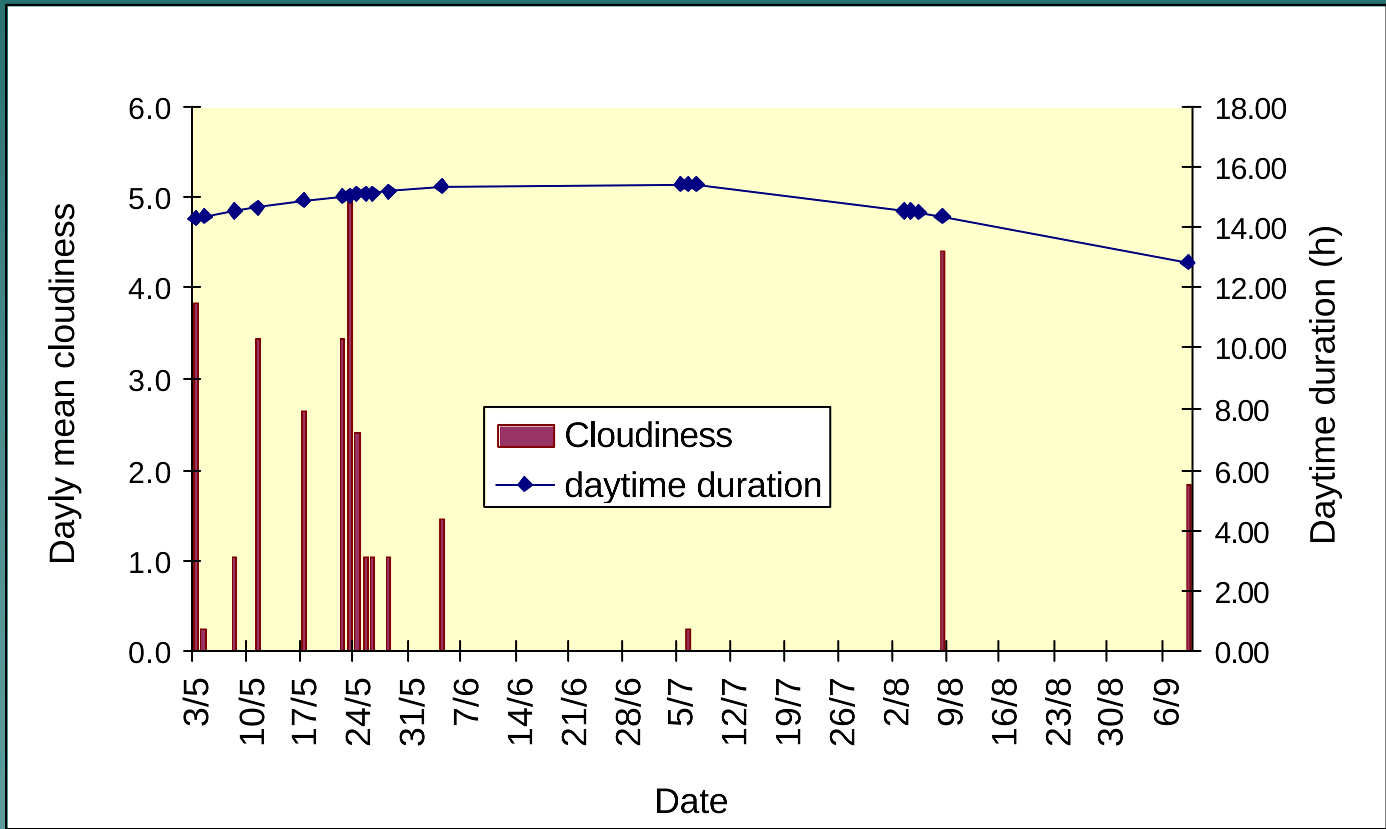
Satellite data

- NOAA-AVHRR archive images for the year 2000;
- 23 images for the Romanian territory, (especially for the Romanian Plain) associated to the following data from the maize vegetation period: 7.04, 12.04, 13.04, 3.05, 4.05, 8.05, 11.05, 17.05, 22.05, 23.05, 24.05, 25.05, 26.05, 28.05, 4.06, 5.07, 6.07, 7.07, 3.08, 4.08, 5.08, 8.08, 9.09.2000.

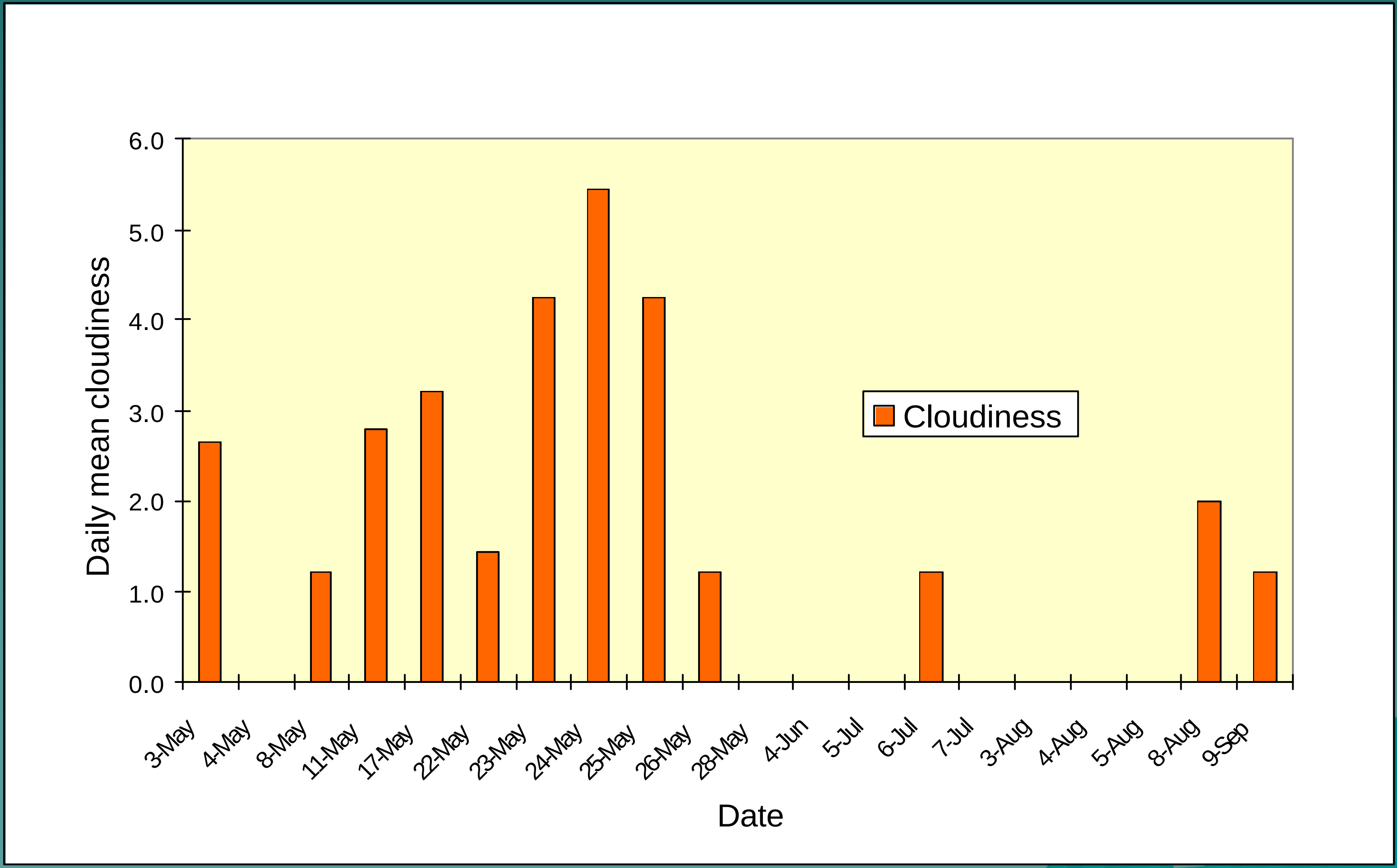


NOAA/AVHRR image of 6July 2000 - color composite (2,3,4)

Daily mean cloudiness and daytime duration variation in the Craiova test-area during the satellite pass period



Daily mean cloudiness in the Alexandria test-area during the satellite pass period



Method for the assessment of the crop actual evapotranspiration using satellite data

- The method used in this study for the computation of daily actual crop evapotranspiration, (ETcj), is based on the energy balance of the surface expressed in two simplified versions.

- The method uses the connection between evapotranspiration, net radiation and the difference between surface (Ts) and air (Ta) temperature measured around 1400 hrs. L.T. – the time of the satellite passage.

- The air temperature around local noon is well approximated by the daily air temperature maximum (Tamax)

Method for the assessment of the crop actual ET – version 1

The **version 1** of the method used a simplified linear relationship of the form:

$$ETcj - Rnj = A - B \times (Ts - (Tamax)$$

where: Rnj is the daily net radiation;
Ts and Tamax is the surface and air maximum temperature
A, B are coefficients which depend on the surface type and the daily mean wind speed.

- Coefficients A and B could be determined either analytically, on the basis of the relationships given by Lagouarde and Brunet (1991) or statistically.
- The A and B coefficients are stable in the case of mature crop vegetation cover and for clear sky conditions.
- Especially the B coefficient vary considerably, function of the land vegetation cover percent.

Method for the assessment of the crop actual ET – version 2

In case of soil with great thermal inertie, the heat flux changed by conduction at the soil-atmosphere interface, can be neglected and the computing relationship for daily actual crop evapotranspiration can be expressed in a **version 2** of the proposed method:

$$ETcj = Rnj - B'.(Ts - Tamax)$$

where:

$$B' = 0.0253 + [1.0016/\log2(2/zh)].v$$

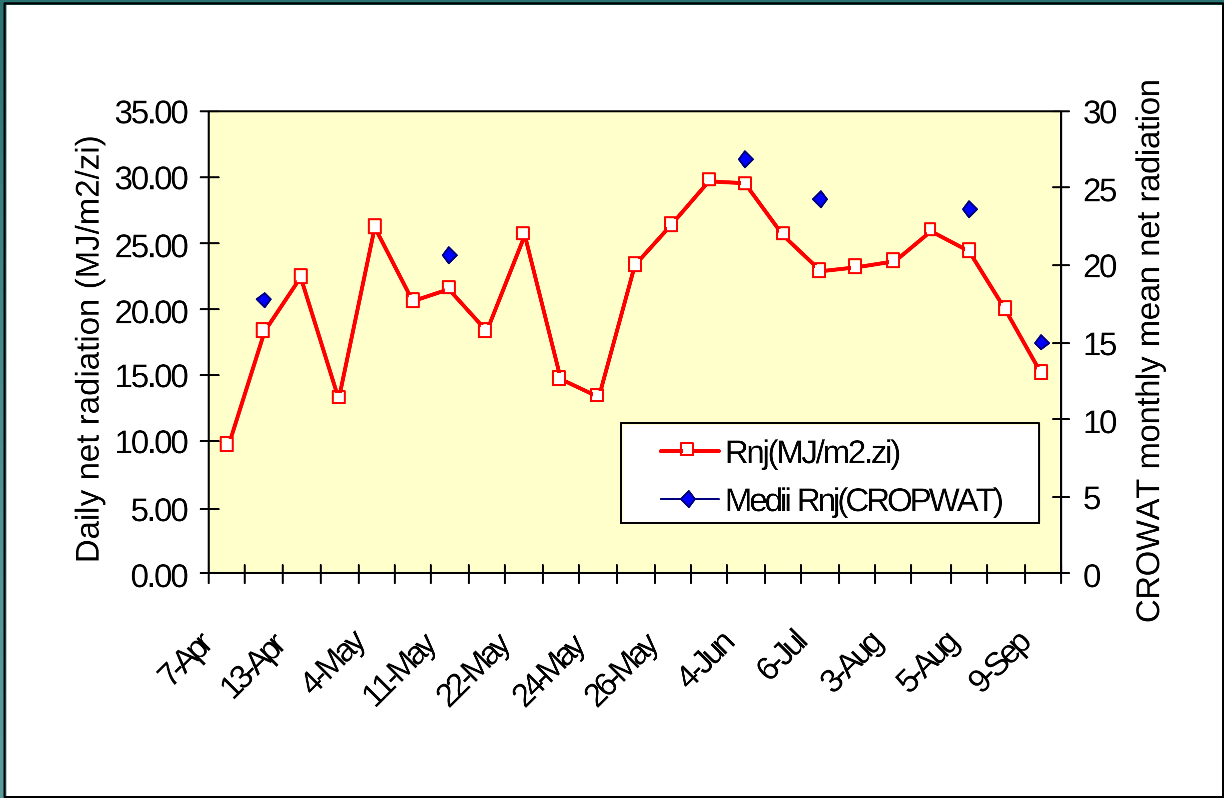
with: v – the daily average wind speed and zh being expressed by the relationship:

$$zh = [1-\exp(-LAI)].[\exp(-LAI/2)]$$

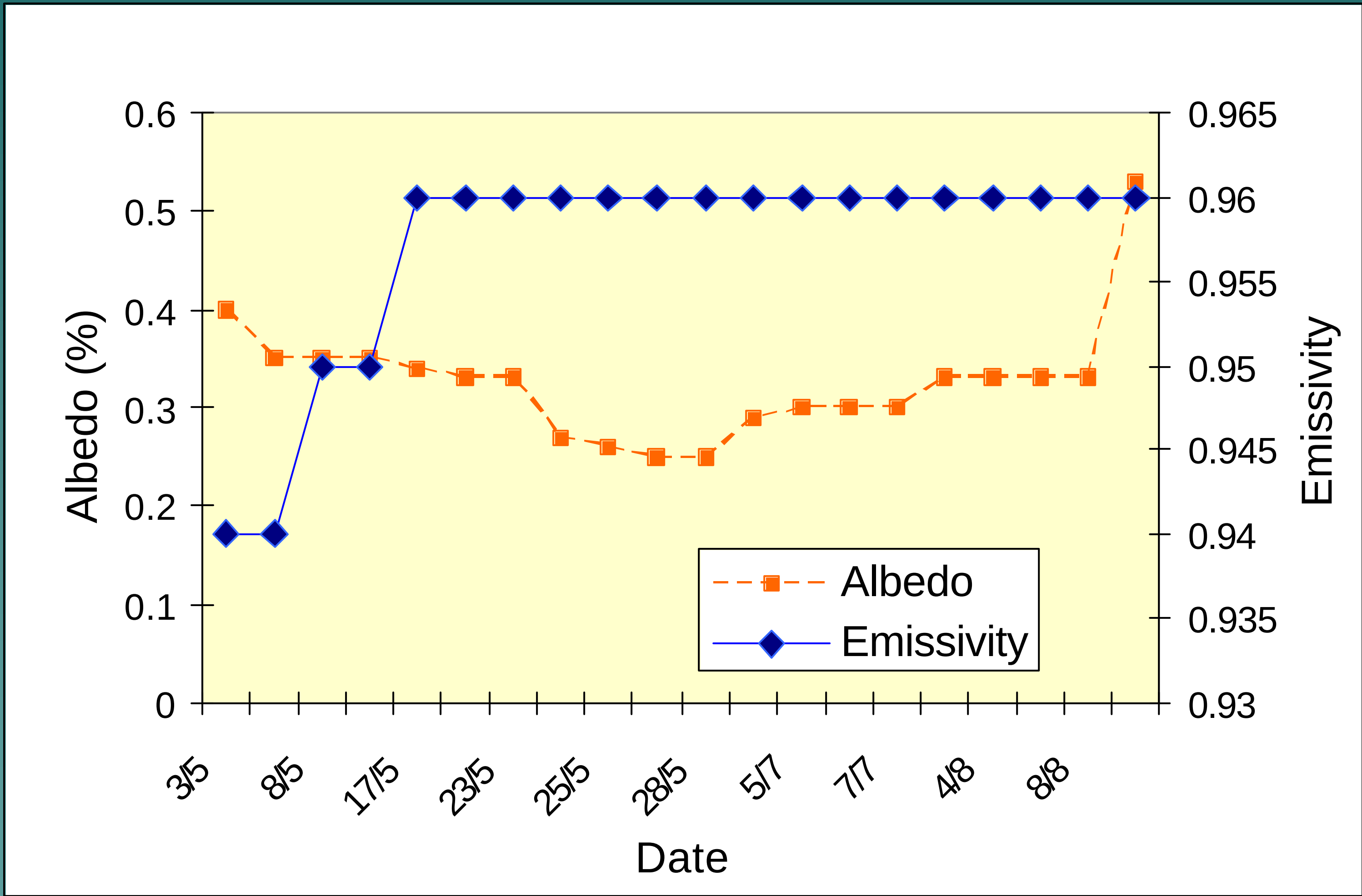
where: zh is the vegetation roughness and LAI the foliar index;

Net radiation

Comparison between daily net radiation values, computed using the balance equation and the monthly means net radiation ones, estimated by the CROPWAT model



Albedo and emissivity variation for the maize in the test areas May – September 2000



The "split window" method to determine surface land temperature

$$Ts = T4 + A1 \times (T4 - T5) + B1$$

Where: *A*1 and *B*1 - coefficients depending on the weather conditions, especially on the precipitable water amount in the atmosphere (absorption prevailing in the IR thermal channels) and on surface emissivity.

✍ Analyze of the atmospheric effects on the *A*1 and *B*1 coefficients using 3 models of atmosphere:

- the mid–latitude summer atmosphere
- the US 1976 standard atmosphere
- the mid–latitude winter atmospheric

✍ Analyze of the on surface emissivity (associated to vegetation–covered surfaces (0.96–0.99) on the *A*1 and *B*1 coefficients.

Analyze of the atmospheric effects on the *A*1 coefficient associated to NOAA / AVHRR 4 and 5 channels

Atmospheric model	Total precipitable water amount W(g / m²)	Effective radiative air temperature (°C)	Absorb.coef fin ch. 4 (cm² / g)	Absorb.coef f in ch. 5 (cm² / g)
Mean latitude summer	2.36	286	0.113	0.166
US 1976	1.13	77	0.092	0.146
Mean latitude winter	0.69	265	0.088	0.144

A1 = a0(W) + a1(W) (1 – ?4) + a2(W) × ? ?

Atmospheric model	a0	a1	a2
Mean latitude–summer	2.15	3.2	–7.5
US 1976	1.75	0.8	–9.2
Mean latitude–winter	1.60	0.8	–9.1

- A strong dependence of *A*1 coefficient is noticed on the type of atmosphere.
- To cut errors it is necessary to know this parameter as accurately as possible in the area of concern. In these sense, data from atmosphere radiosoundings could be most useful.

Analyze of the atmospheric effects on the B1 coefficient, associated to NOAA / AVHRR 4 and 5 channels

B14,5 = b04,5(W) + b14,5(W) ??

Atmospheric Model	b04(W)	b14(W)	b05(W)	b15(W)
Mean latitude–summer	0.217	–0.513	0.059	–0.260
US 1976 standard	0.407	–1.338	0.219	–1.252
Mean latitude–winter	0.452	–1.586	0.26	–1.586

- A large variability of the B1 coefficient with the atmosphere is noticed

Analyze of the on surface emissivity on the *A*1 and *B*1 coefficients

The influences of emissivity variations associated to vegetation–covered surfaces (0.96–0.99) for a summer atmosphere model in the mid latitudes regions.

??4	? e	A1	B1
0.96	–0.01	2.71	1.69
	0	2.66	1.60
	0.01	2.61	1.56
0.97	–0.01	2.67	1.68
	0	2.62	1.59
	0.01	2.57	1.50
0.98	–0.01	2.63	1.68
	0	2.58	1.59
	0.01	2.53	1.49
0.99	–0.01	2.59	1.67
	0	2.53	1.58
	0.01	2.48	1.49

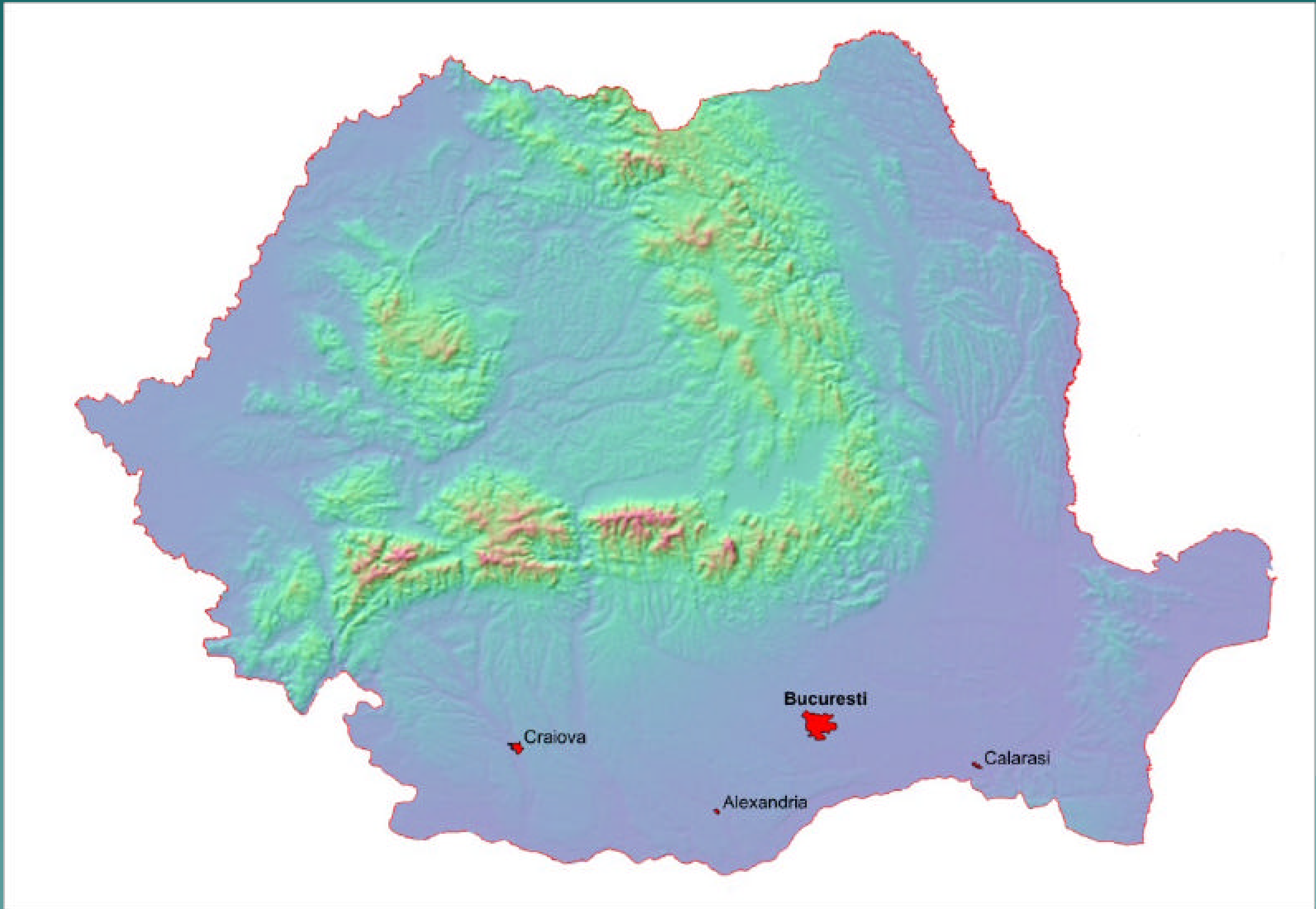
✍ The variation of the coefficients dependency on emissivity, though small, imposes precise knowledge of terrestrial surface emissivities.

Various "split-window" tested algorithms

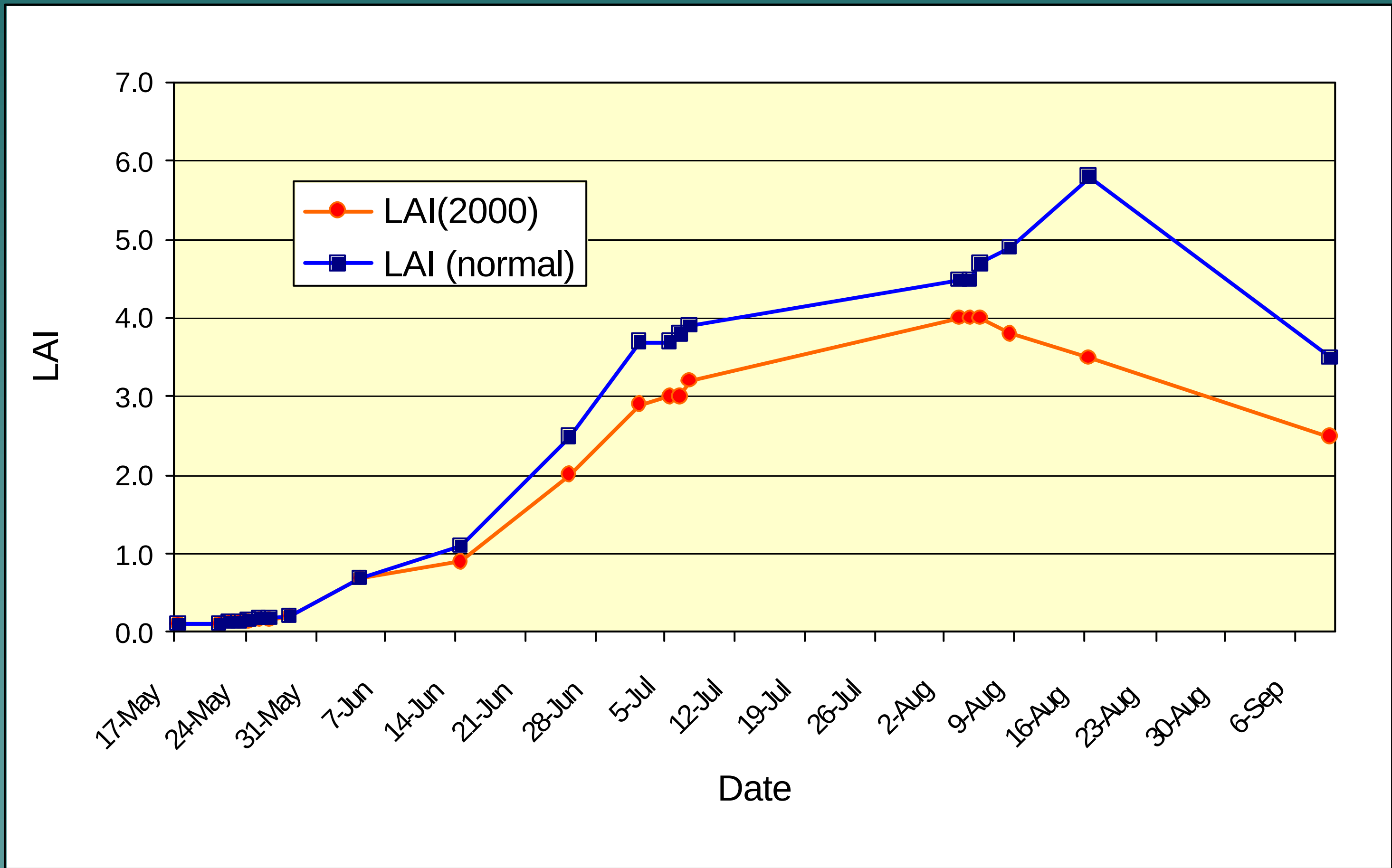
Author or Group	Abbrev.	Algorithms
Becker & Ki(1995)	LO	$TS = A0 + P(T4 + T5)/2 + M(T4 – T5)/2$
Becker & Li(1990)	BL	$TS = 1.274 + PA(T4 + T5)/2 + MA(T4 – T5)/2$
Prata & Platt(1991)	FP	$TS = 3.45(T4 – T0)\ e4 –2.45(T5 – T0)/e5 + 40(1 – e4)/\ e4 + T0$
Price (1984)	JP	$TS = [T4 + 3.33(T4 – T5)] *[(5.5 – ee4)/4.5] + 0.75T5(e4 – e5)$
Ulivieri (1985)	U1	$TS = T4 + 3.00(T4 – T5) + 51.57–52.45e$
Ulivieri (1994)	U2	$TS = T4 + 1.8(T4– T5) + 48(1 – e) – 75\ (e4– e5)$
Sobrino (1993)	S1	$TS = T4 + 1.06(T4 – T5) + 0.46(T4 – T5)2 + 53(1 – e4) – 53(e4– e5)$
Sobrino (1991)	S2	$TS = T4 + A(T4 – T5) + B$
NESDIS (1992)	NE	$TS=1.0162T4 + 2.657(T4 – T5) + 0.5265(secq – 1)\ (T4–T5) – 4.58$

• Algorithms *U*2, *S*1 and *S*2 are recommended to use along with LO algorithm for the determination of surface temperature.

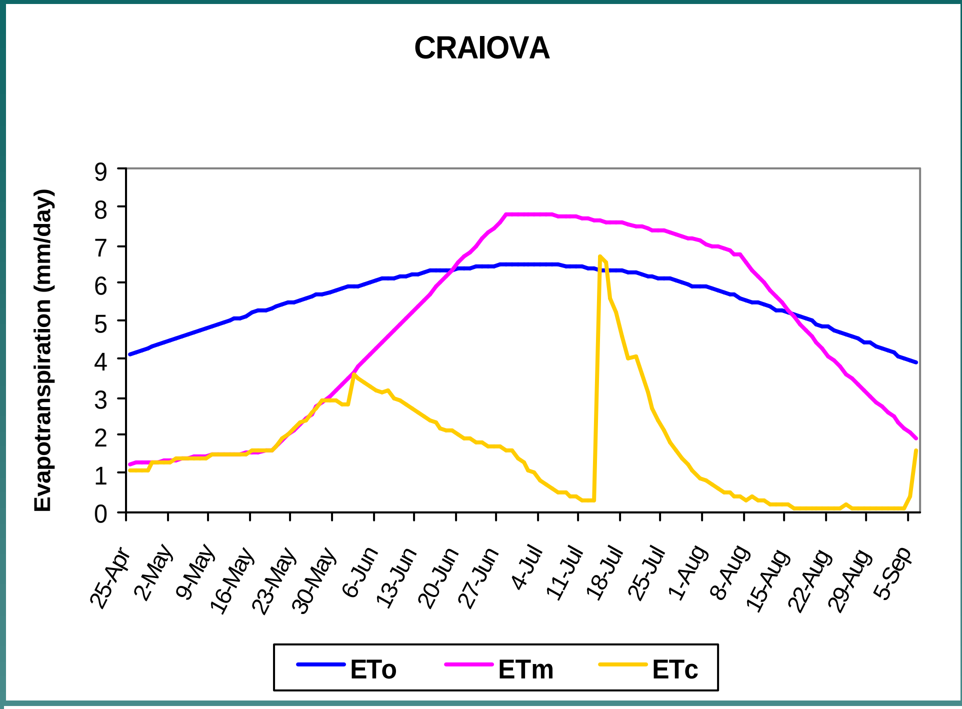
Test-areas in the Romanian Plane



LAI evolution during maize growing season in normal climatic conditions and in the drought situation of the year 2000 in Romania



Results

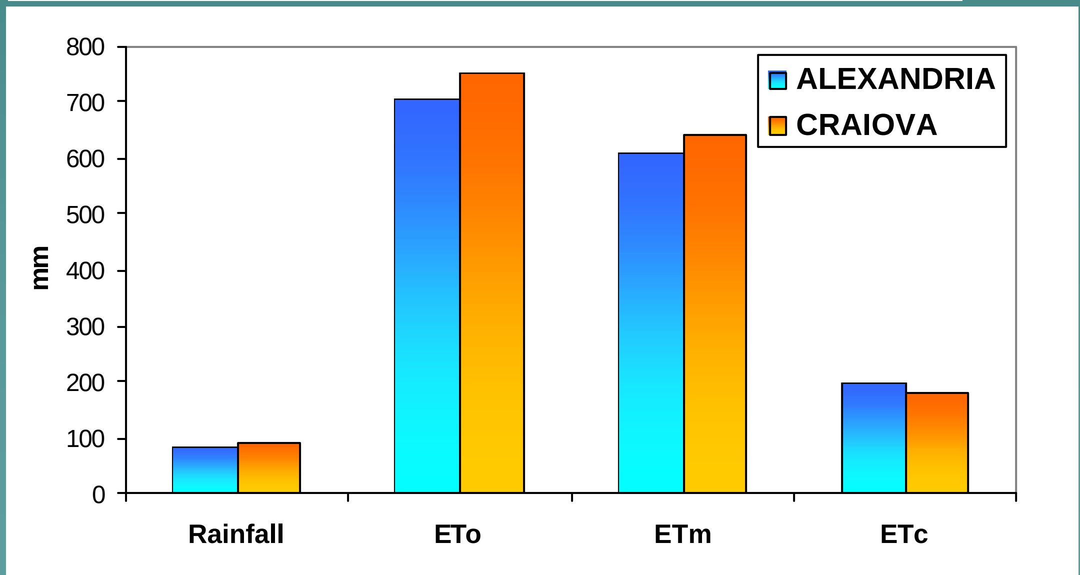


Example for Craiova site

Daily evolution of:

- reference evapotranspiration (Eto),
- maximum evapotranspiration (ETm)
- actual crop evapotranspiration (ETc)

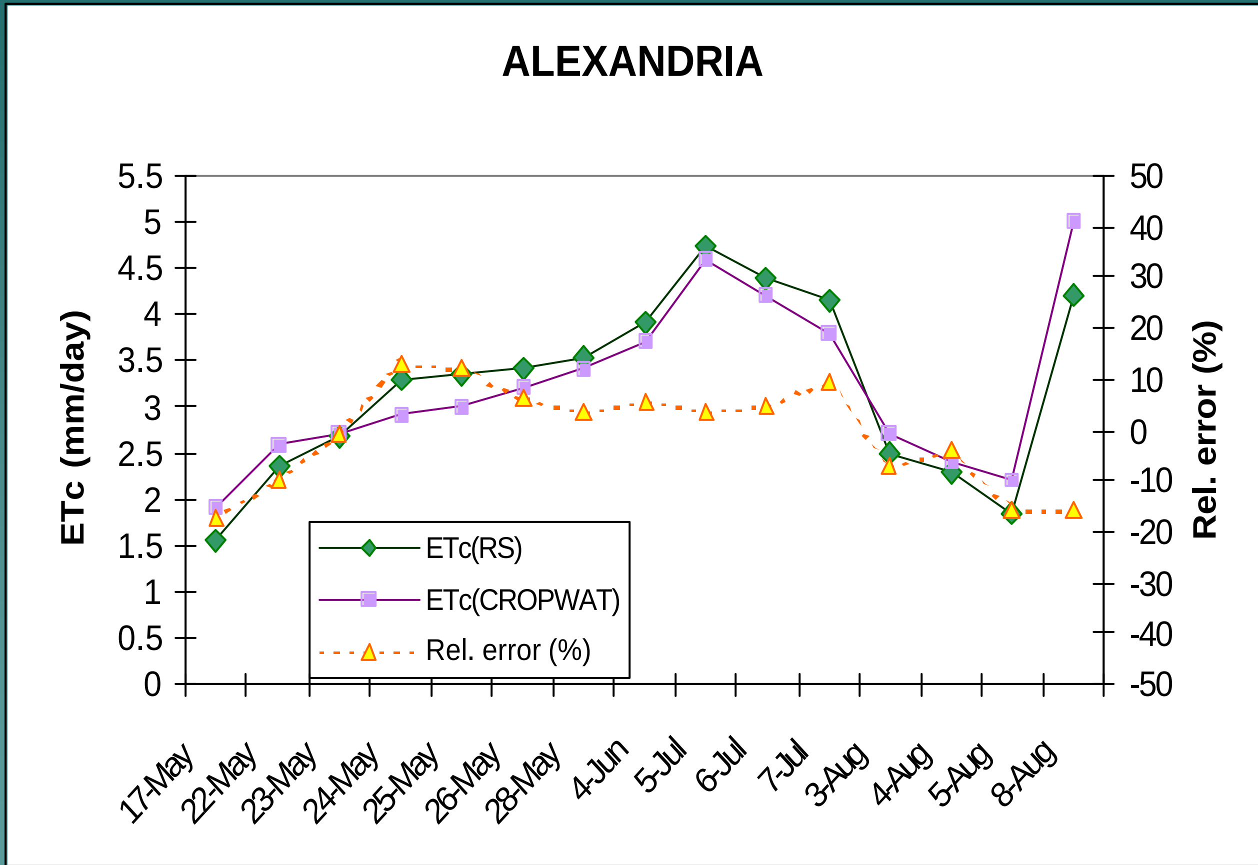
simulated with CROPWAT model during maize growing season



Cumulative values of maize variables simulated with CROPWAT model, on the whole vegetation period at both test - sites, in the weather conditions of year 2000

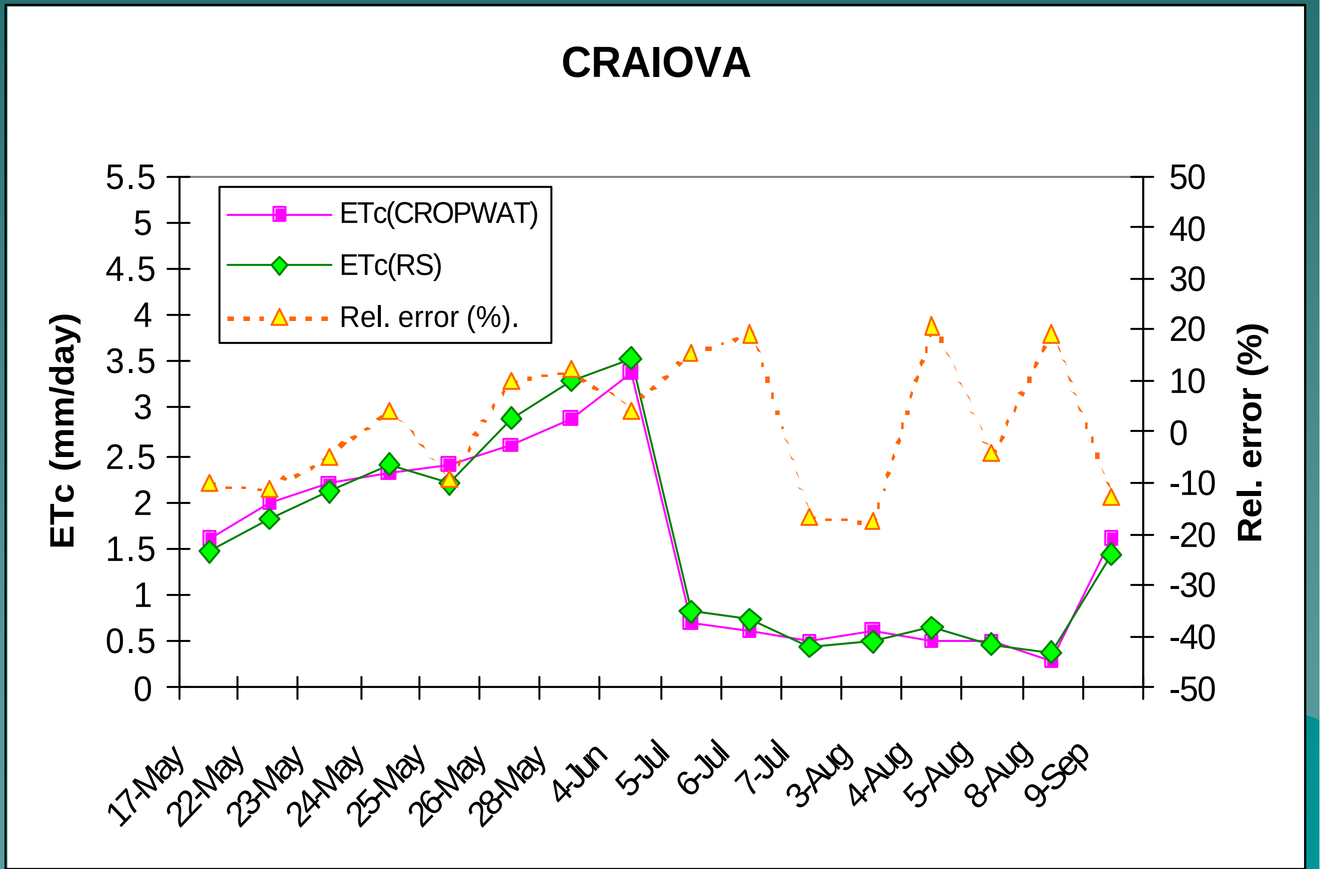
Results

Comparison between daily crop evapotranspiration values computed by the CROPWAT model and by the energy balance method (v. 1) using remotely sensed data at the Alexandria station



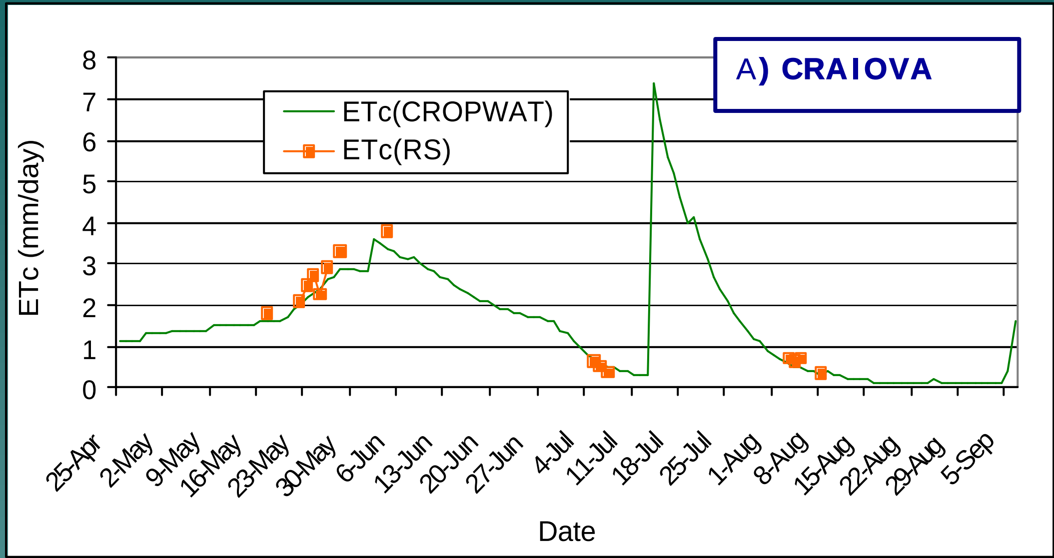
Results

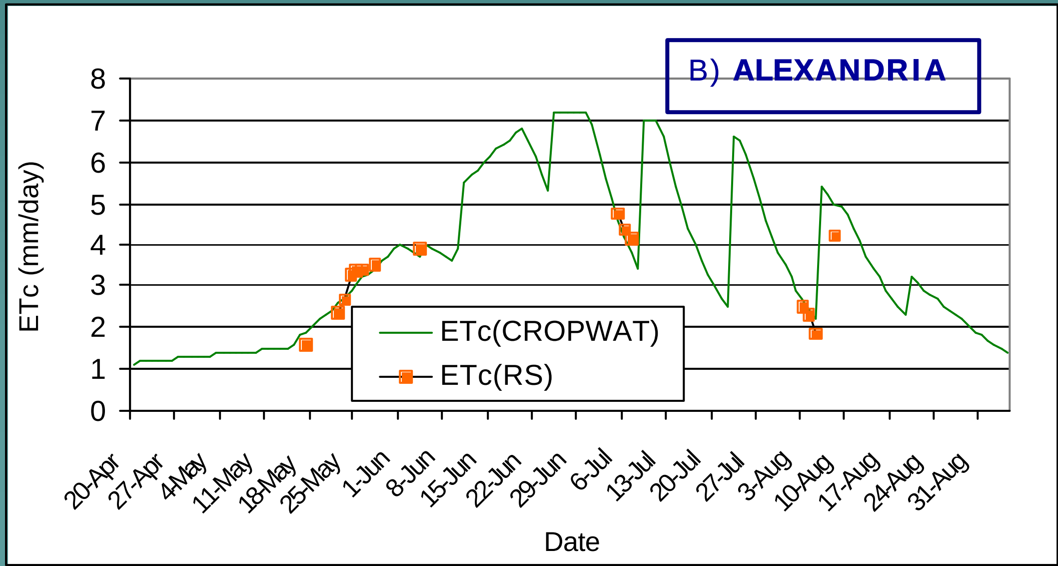
Comparison between daily crop evapotranspiration values computed by the CROPWAT model and by the energy balance method (v. 1) using remotely sensed data at the Craiova station



Results

Comparison between daily crop ET values computed by the CROPWAT model and by the energy balance method – v.2 using EO data, at the Craiova (A) and Alexandria (B) agro-meteorological stations, for the maize vegetative development period in 2000.





Conclusions

• The use of the multispectral satellite data can assure the improvement of the classical methods applied in determining the agrometeorological parameters, including evapotranspiration.

• The satellite data could bring an important contribution for comparison and validation of the model outputs for some parameters

• Analysis of the CROPWAT model results concerning comparison of daily actual crop evapotranspiration (ETc) calculated by using climatic data vs. satellite estimations based on the surface energetic balance showed that generally ETc values from satellite information are higher than those simulated by the model, the differences being by +0.45 and -1.9 mm/day

• The preliminaries results emphasized a good correlation between the simulated values (CROPWAT) and those derived from the satellite data, with relative errors of ? 10%-20%.