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Evapotranspiration as a part of water balance – comparison of ground and satellite measurements

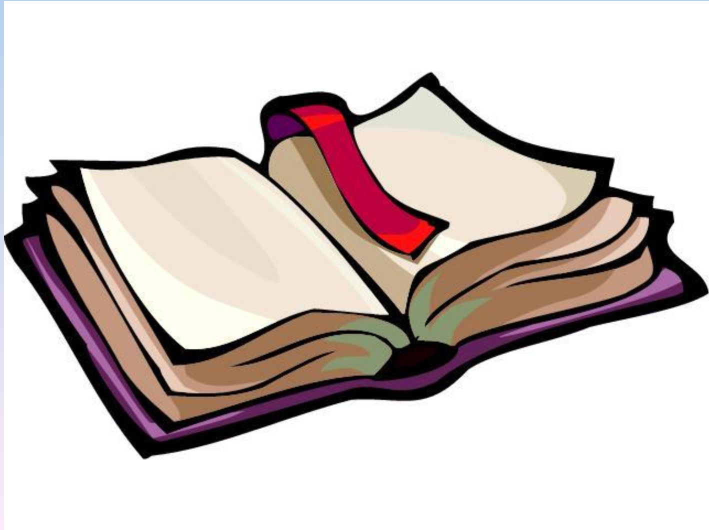
COST 734 Final Conference

3-6.05.2011 Topolcianky

COST 734 CASE STUDY

- National Project of Polish Ministry of Science and Higer Education

„Correlation between Climatic Water Balance and Estimate of Plant Development Stage Based on Satellite Technologies"

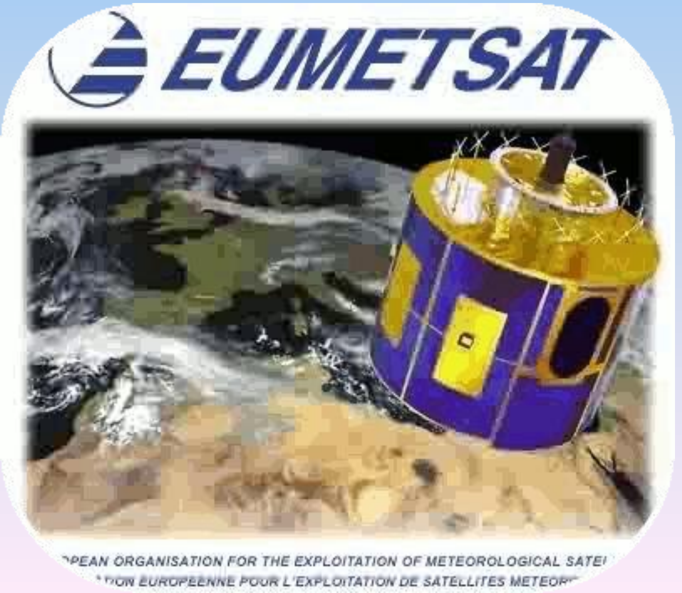


COST 734 CASE STUDY

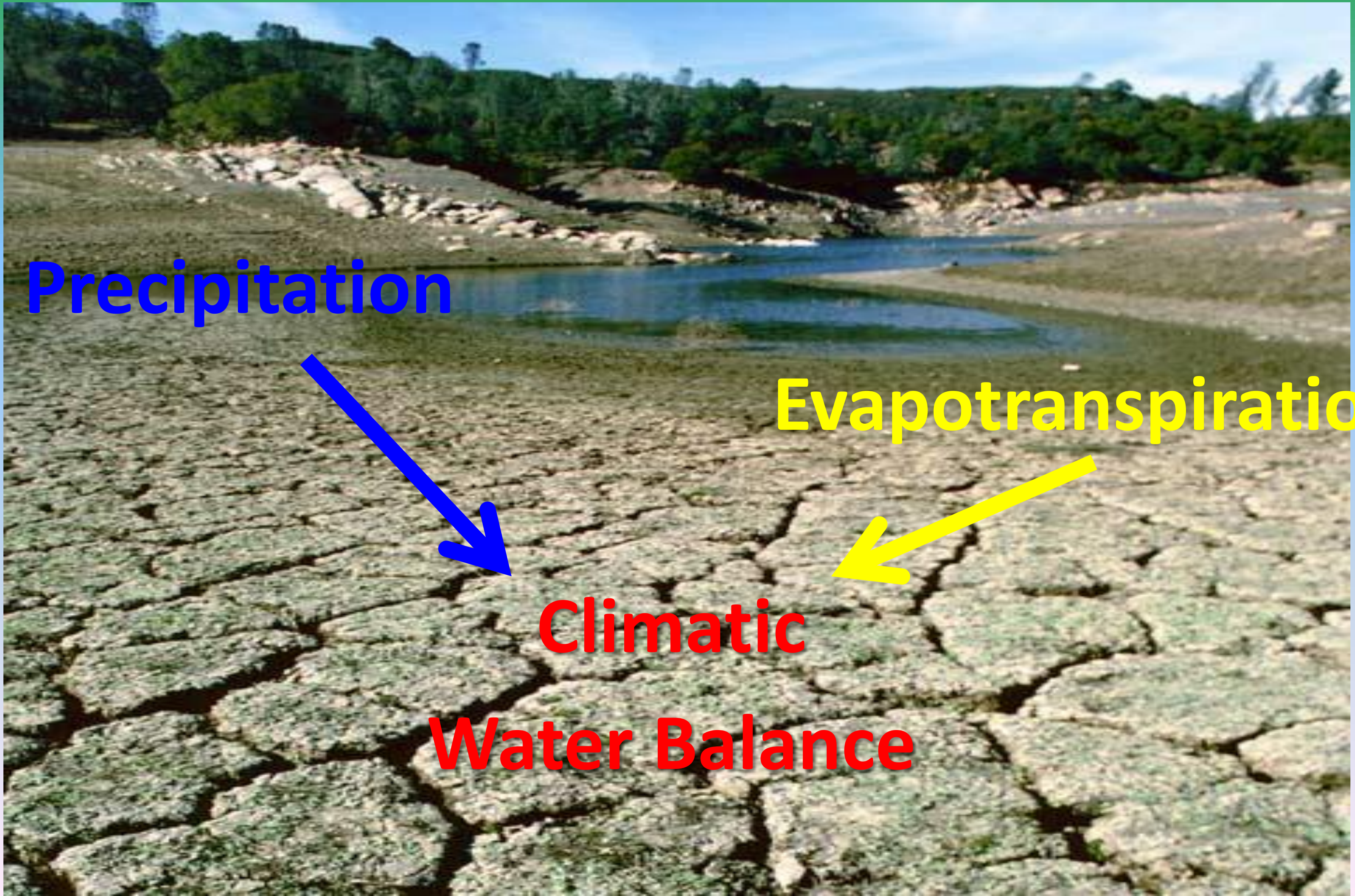
- One of the aims of the project – calculation of evapotranspiration
- Comparison of values of evapotranspiration obtained with two different methods:

    - Penman-Monteith method (FAO 56)

    - satellite product „Evapotranspiration”



EVAPOTRANSPIRATION AS A PART OF WATER BALANCE



CLIMATIC WATER BALANCE

- indicates deficits of precipitation in comparison with evapotranspiration;
- allows for estimation of soil moisture
- provides estimation of water available for plants during growth period;
- is the basis for prognoses regarding expected crop yields;
- is one of indices of drought;
- contributes directly to activities aimed at mitigation of drought events;
- in Poland is officially used (Min. of Agriculture) as an indicator of agricultural drought

CLIMATIC WATER BALANCE

- can be useful for water resources (discharge) estimation in case of lack of hydrological data

EVAPOTRANSPIRATION

- there are almost no ground measurements of evapotranspiration
- because of the lack of measurements for balances, various indirect methods (empirical equations) are used to calculate evapotranspiration
- satellite methods provide better solution to this problem

FAO 56 PENMAN-MONTEITH EQUATION

$$ET_o = \frac{0,408\Delta\left(R_n - G\right) + \gamma \dfrac{900}{t+273} u_2\left(e_s - e_a\right)}{\Delta + \gamma\left(1 + 0,34 u_2\right)}$$

where:

ET_o - reference evapotranspiration [mm day^{-1}]

R_n - net radiation at the crop surface [MJ m^{-2} day^{-1}]

G - soil heat flux density [MJ m^{-2} day^{-1}]

T - air temperature at 2 m height [°C]

u_2 - wind speed at 2 m height [m s^{-1}]

e_s - saturation vapour pressure [kPa]

e_a - actual vapour pressure [kPa]

Δ -slope vapour pressure curve [kPa $°C^{-1}$]

γ -psychrometric constant [kPa $°C^{-1}$]

REQUIRED DATA

The adapted method of evapotranspiration determination requires the following daily meteorological data:

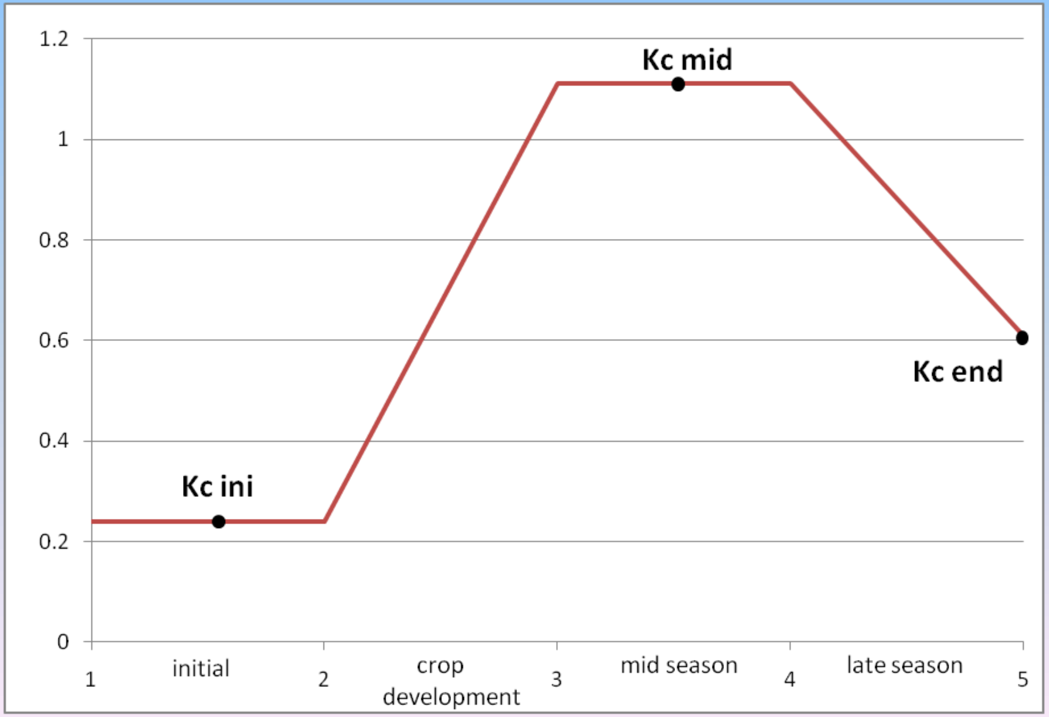
- maximum air temperature
- minimum air temperature
- humidity
- wind speed
- sunshine duration

CROP EVAPOTRANSPIRATION

$$ET_c = K_c * ET_o$$

where:

- ET_c – crop evapotranspiration [mm d^{-1}],
- ET_o – reference evapotraspiration [mm d^{-1}],
- K_c – crop coefficient [dimensionless].



EVAPOTRANSPIRATION FROM SATELLITE DATA

- Satellite remote sensing (SRS) stays as the only method capable of providing wide area coverage of environmental variables at economically affordable costs.
- Major difficulty in the use of SRS for monitoring ET at regional and global scale is that the phase change of water molecules produces neither emission nor absorption of an electromagnetic signal.
- Therefore, ET process is not directly quantifiable from satellite observations.
- The simplest empirical methods are only applicable locally, where they were calibrated.
- The complex deterministic models based on SVAT modules compute the different components of the energy budget.

EVAPOTRANSPIRATION FROM SATELLITE DATA – Land SAF ET Product

Radiative data	Meteorological data	Land cover database
Source: Remote sensing	Source: NWP model	Source: Remote sensing
dynamic	dynamic	semi-static

Radiative data:
Short wave radiation
Long wave radiation
Albedo

Meteorological data:
Air temp.
Dew point temp.
Wind speed
Pressure
Soil moisture
Soil temp.

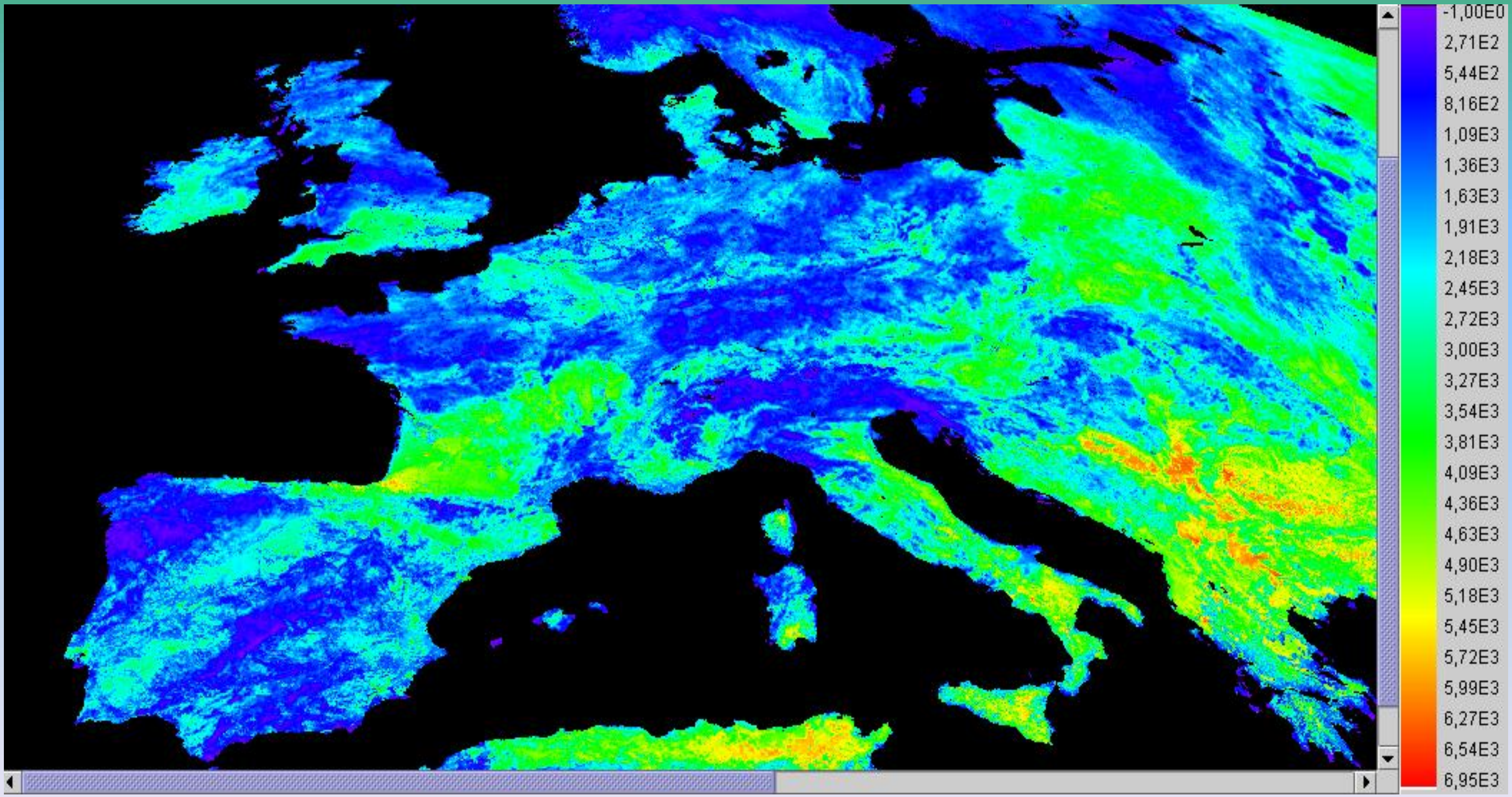
Land cover database:
ECOCLIMAP 1 km
Monthly values:
Vegetation cover
- Tiles distribution
- Leaf Area Index
- Roughness length
- Minimum stomatal resistance

ECMWF TESSEL SVAT scheme” - Soil-Vegetation-Atmosphere Transfer. → ET

EVAPOTRANSPIRATION FROM SATELLITE DATA – Land SAF ET Product

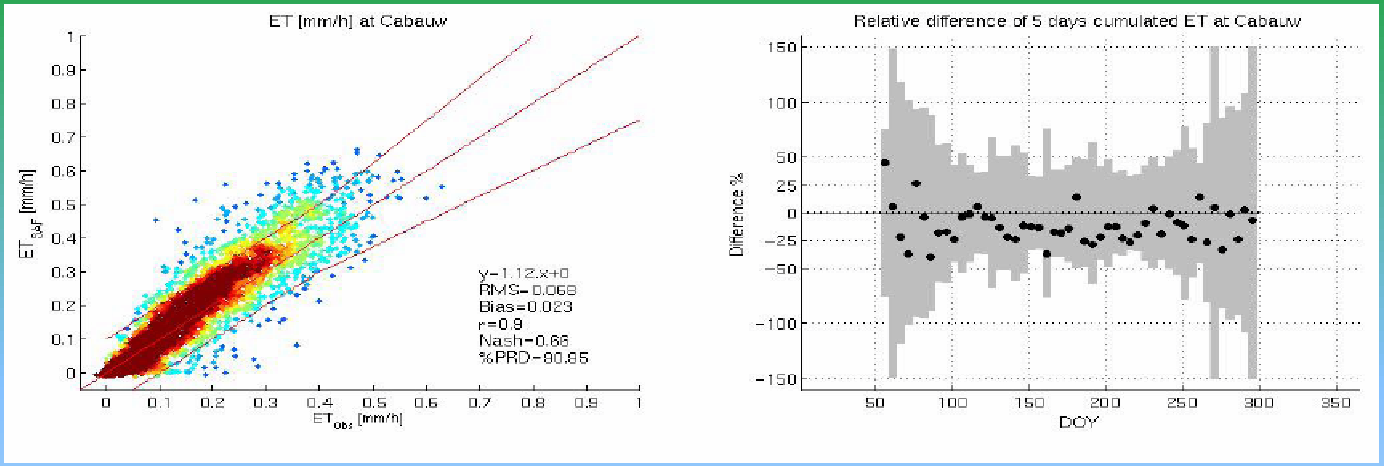
- Product generated operationally by EUMETSAT Land SAF.
- Distributed in near real-time by EUMETCast system
- Area – hemisphere visible from 0 deg geostationary satellite position
- Time step:
  - 30 min (instantaneous value) – 48 products per day
  - 24 hours (cumulated value)
- Spatial resolution – MSG/SEVIRI pixel,
  for Poland approx. 5-6 km.
- Represent spatial distribution of actual evapotranspiration.

EXAMPLE of 30 min PRODUCT

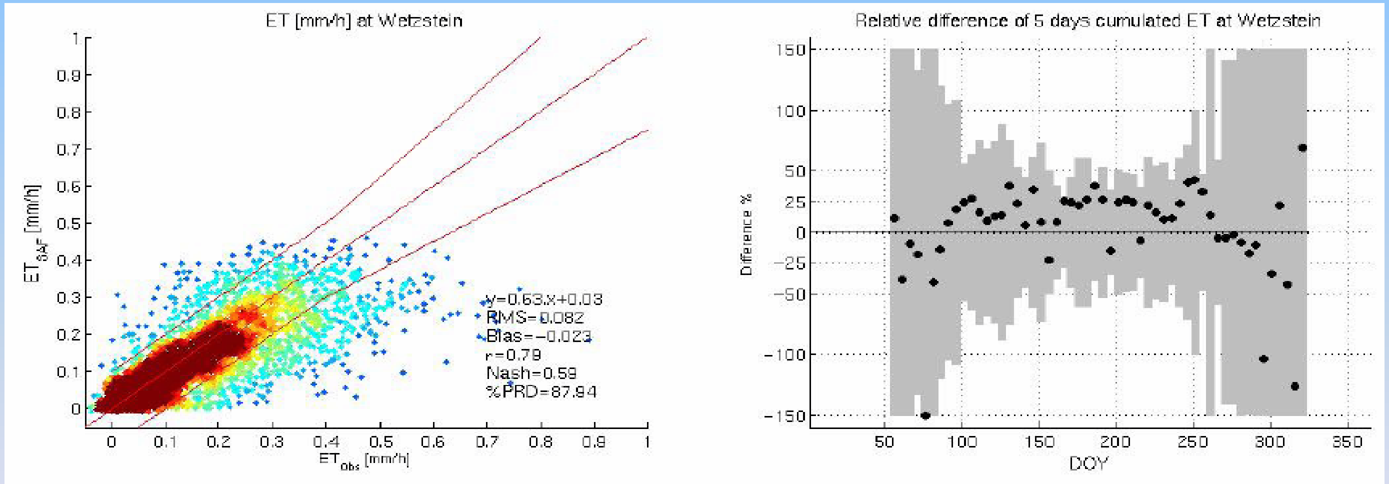


Scaling: ET * 10 000

VALIDATION RESULTS



Grassland



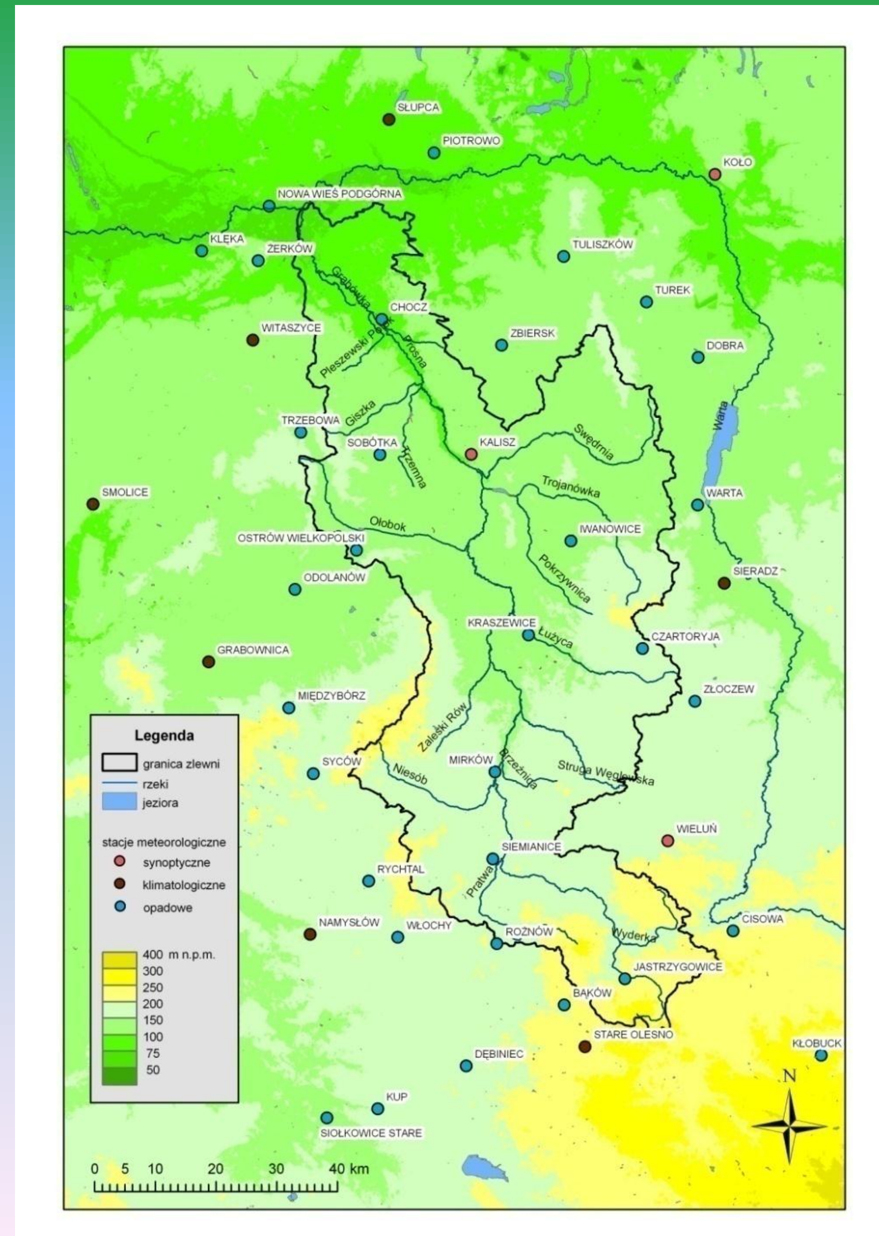
Coniferous forest

ET product 30 min - selected validation results

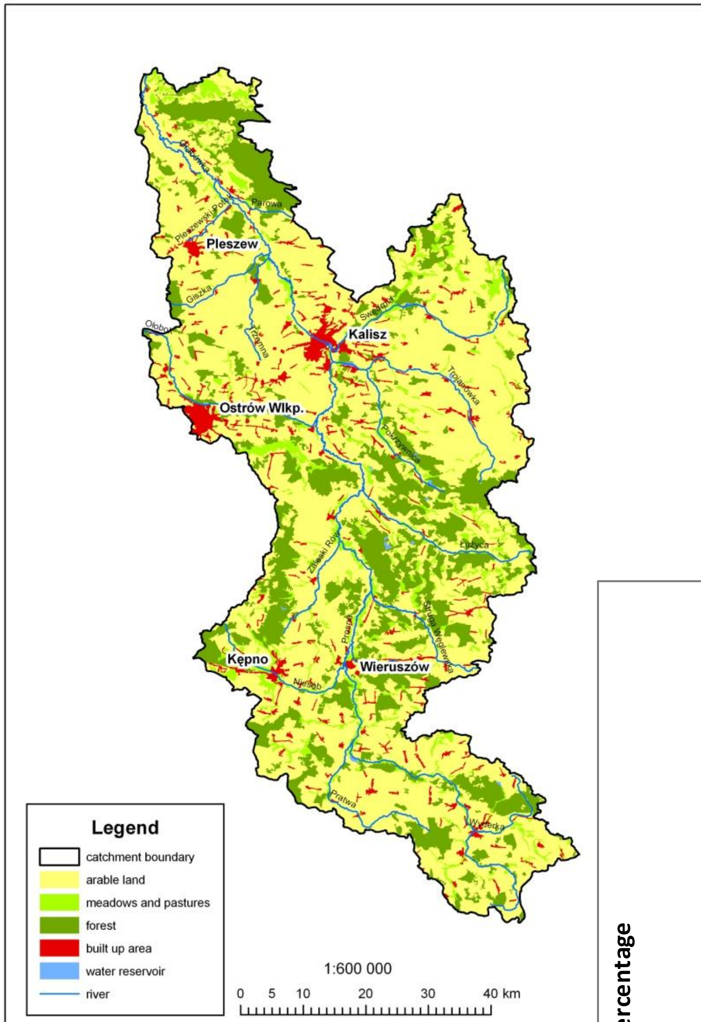
Source: SAF/LAND/IM/PUM_MET Issue 2.2, 15/03/2010

PROSNA CATCHMENT

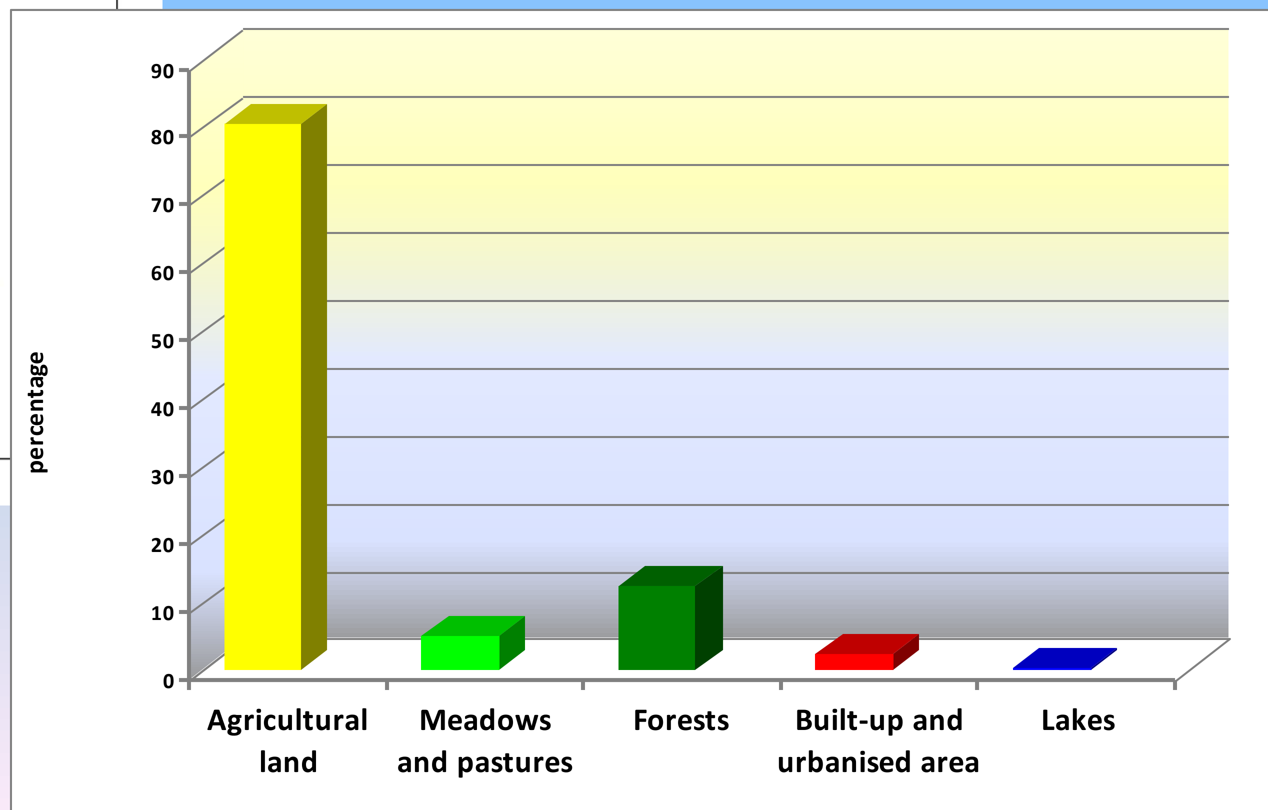
5000 km2
3 Synop
7 Climate
32 Raingauges
539 Satellite SEVIRI pixels



LAND USE

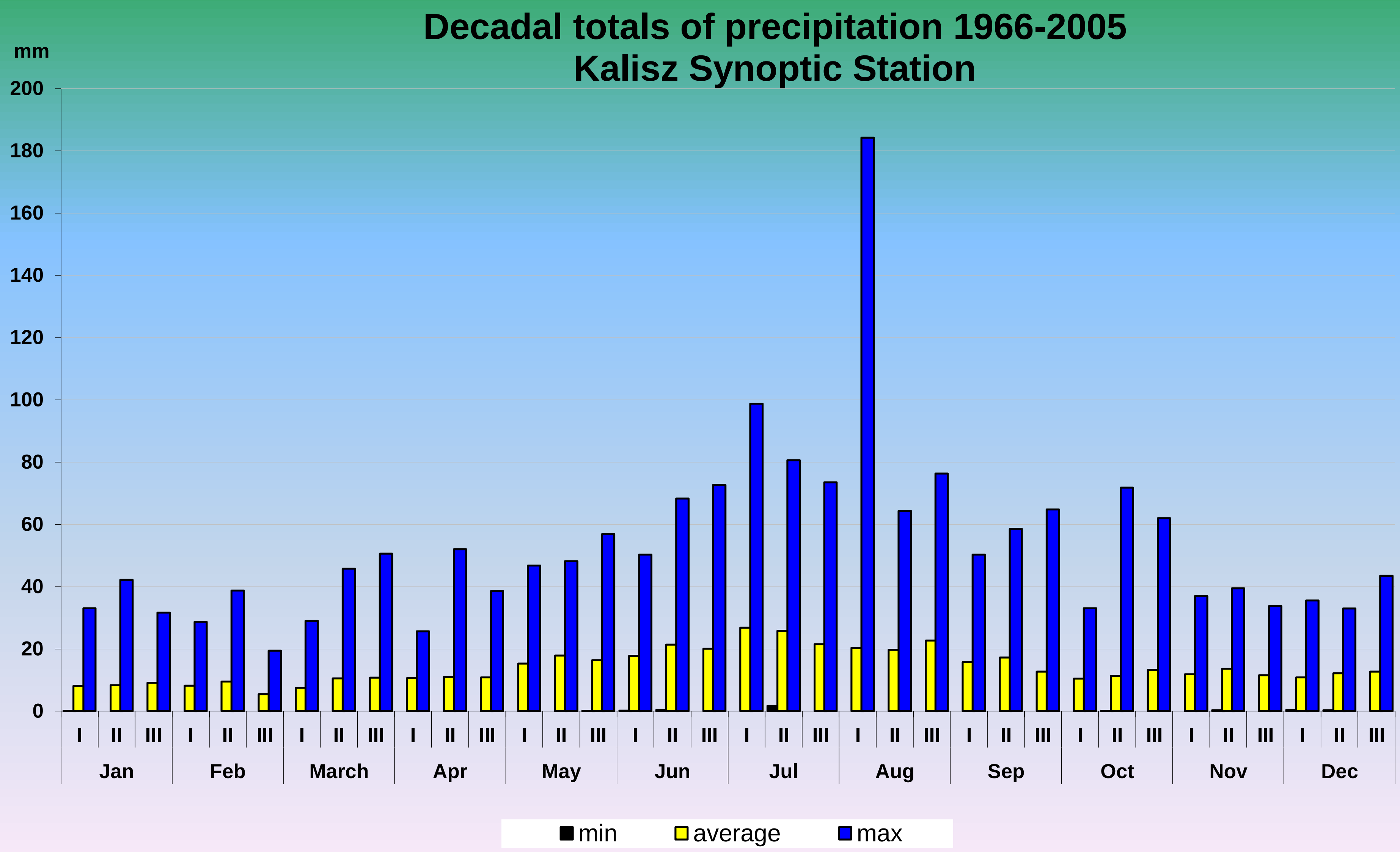


Pleszew
Kalisz
Ostrów Wlkp.
Kępno
Wieruszów
Legend
catchment boundary
arable land
meadows and pastures
forest
built up area
water reservoir
river
1:600 000
0 5 10 20 30 40 km

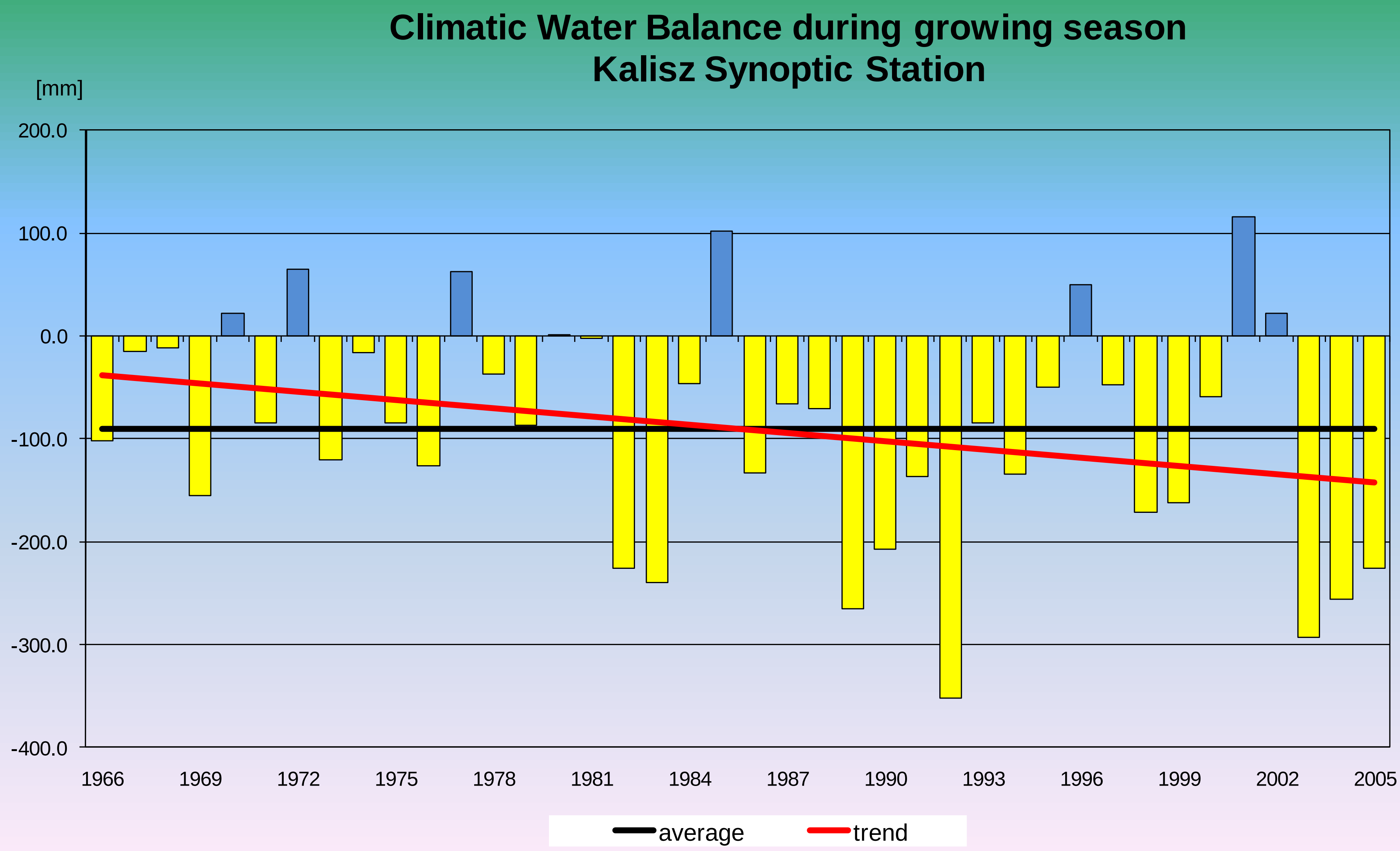


percentage
0
10
20
30
40
50
60
70
80
90
Agricultural land
Meadows and pastures
Forests
Built-up and urbanised area
Lakes

CLIMATE CONDITIONS OF PROSNA CATCHMENT



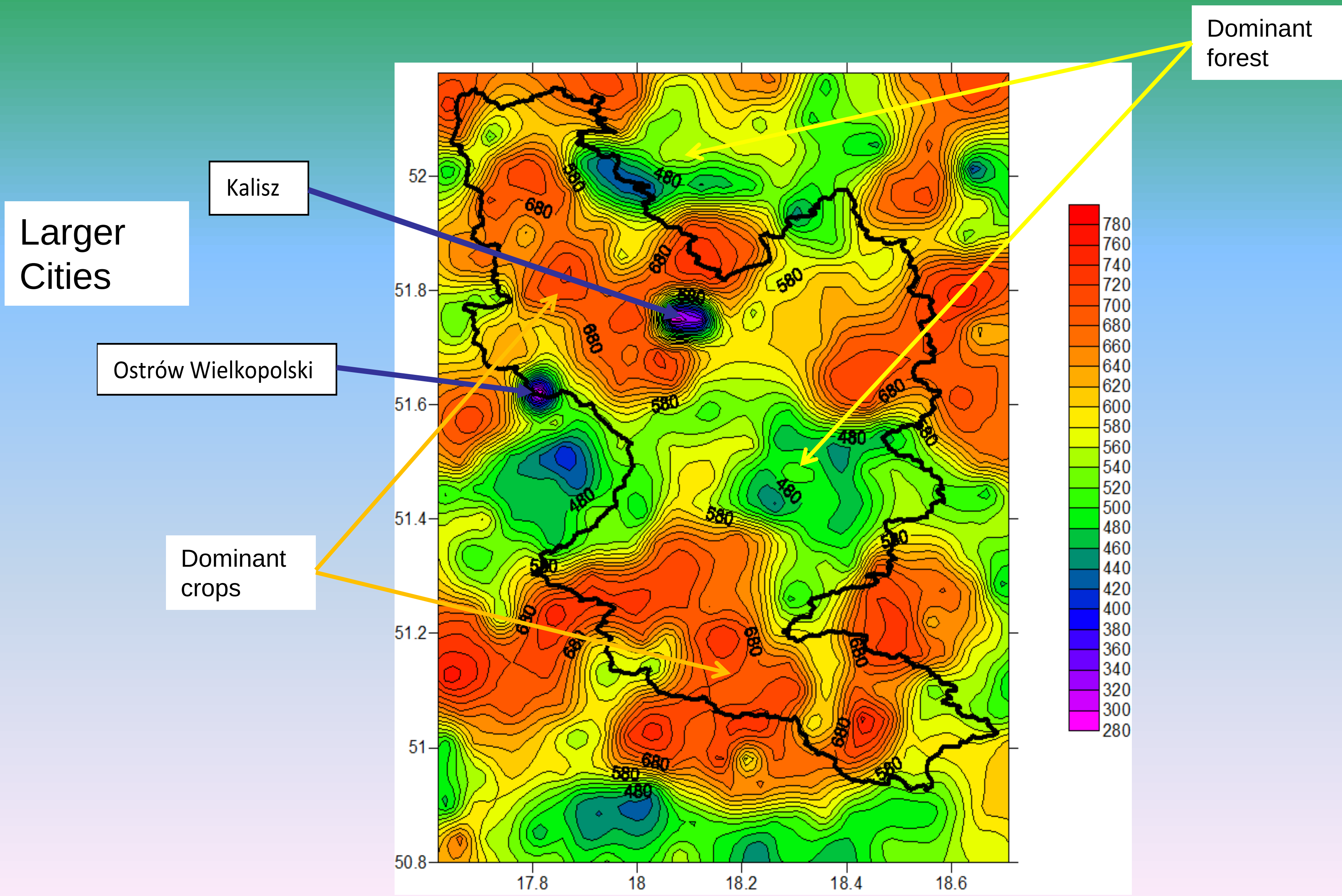
CLIMATE CONDITIONS OF PROSNA CATCHMENT



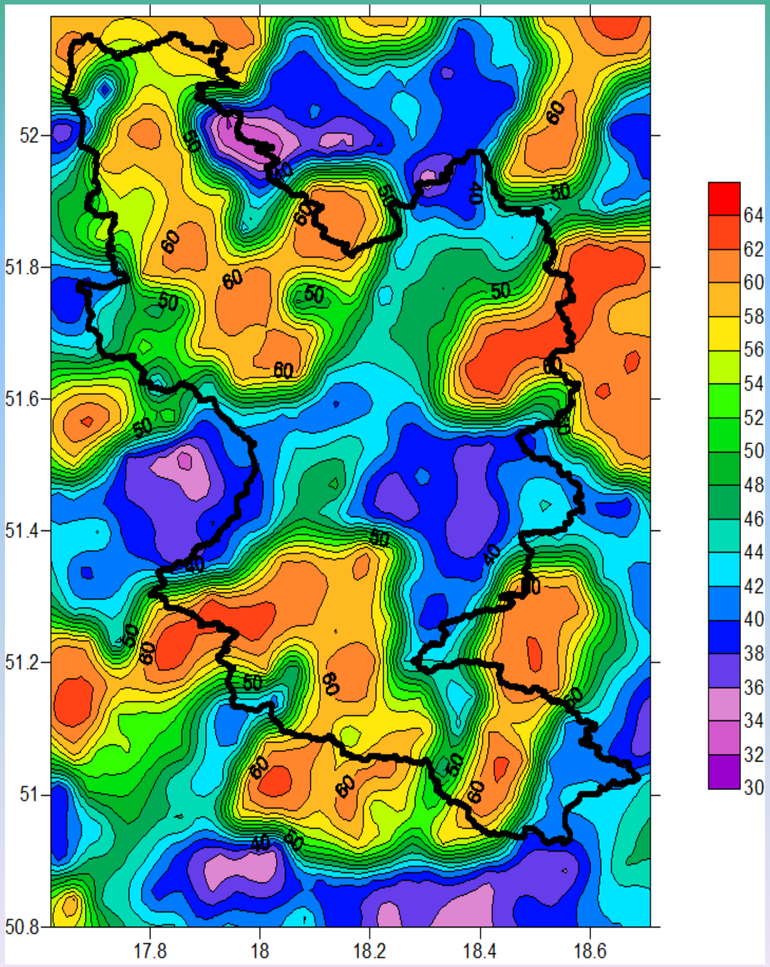
COMPARISON of ETo and ETc AT PROSNA CATCHMENT - 2007

- We received two data series for each station and each day of 2007: reference (potential) evapotranspiration calculated with the Penman-Monteith method (ETo), and actual evapotranspiration based on satellite data (ETc).
- 2007 was very warm and humid in the analyzed area.

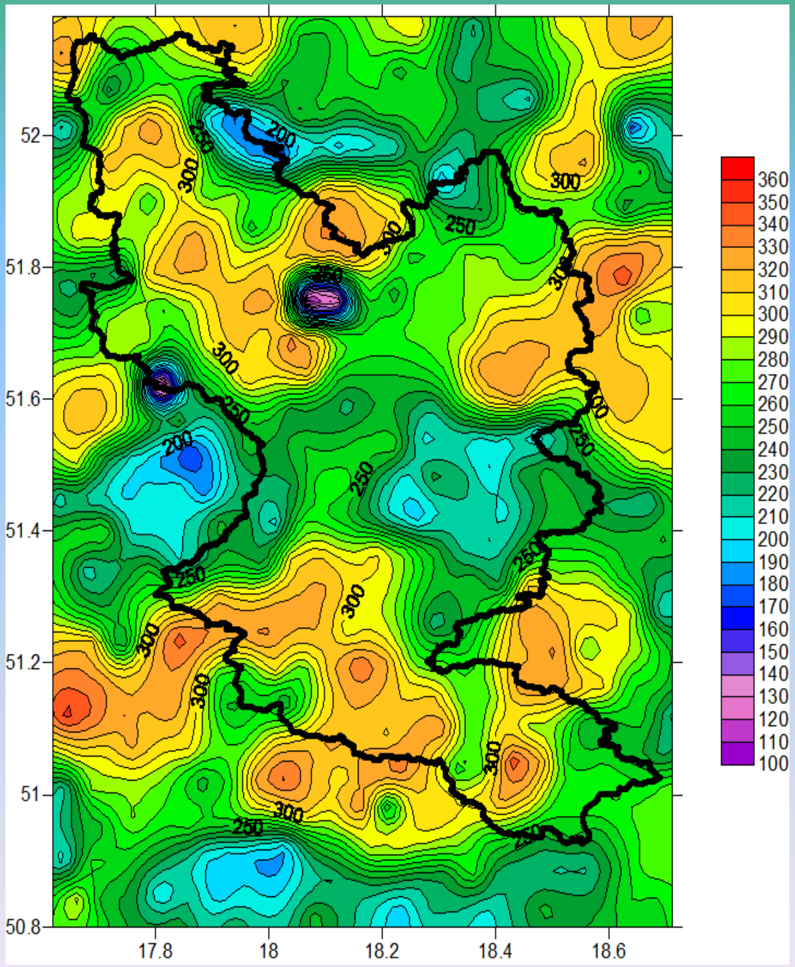
SATELLITE DERIVED ET for PROSNA CATCHMENT – Annual amount



SATELLITE DERIVED ET for PROSNA CATCHMENT – quarterly amount

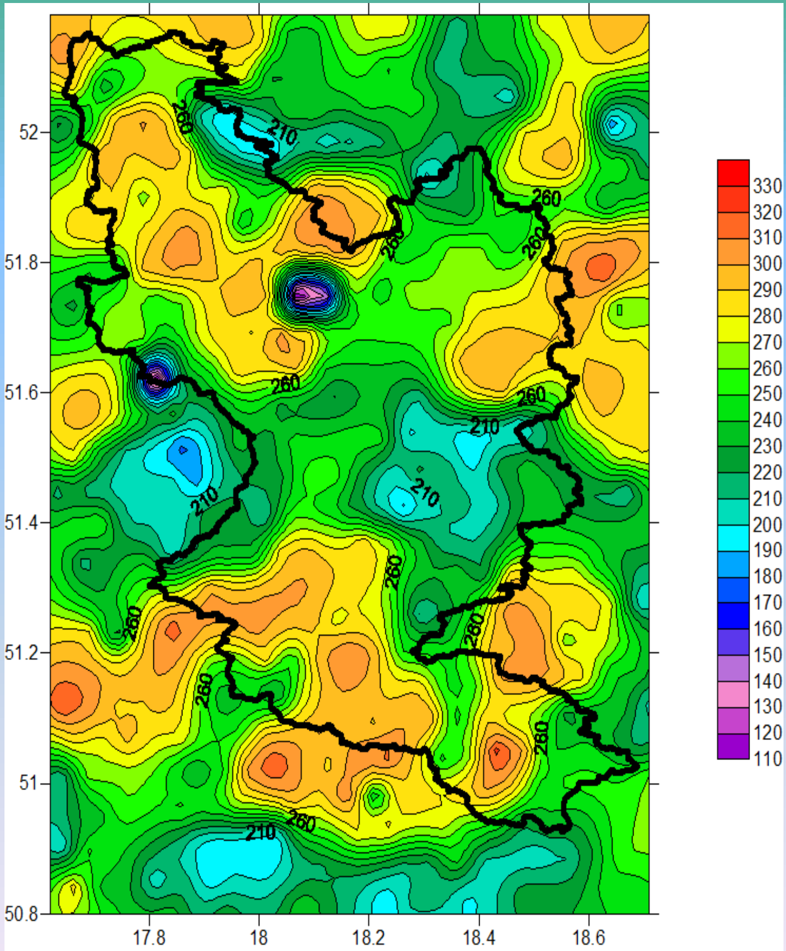


I quarter 2007

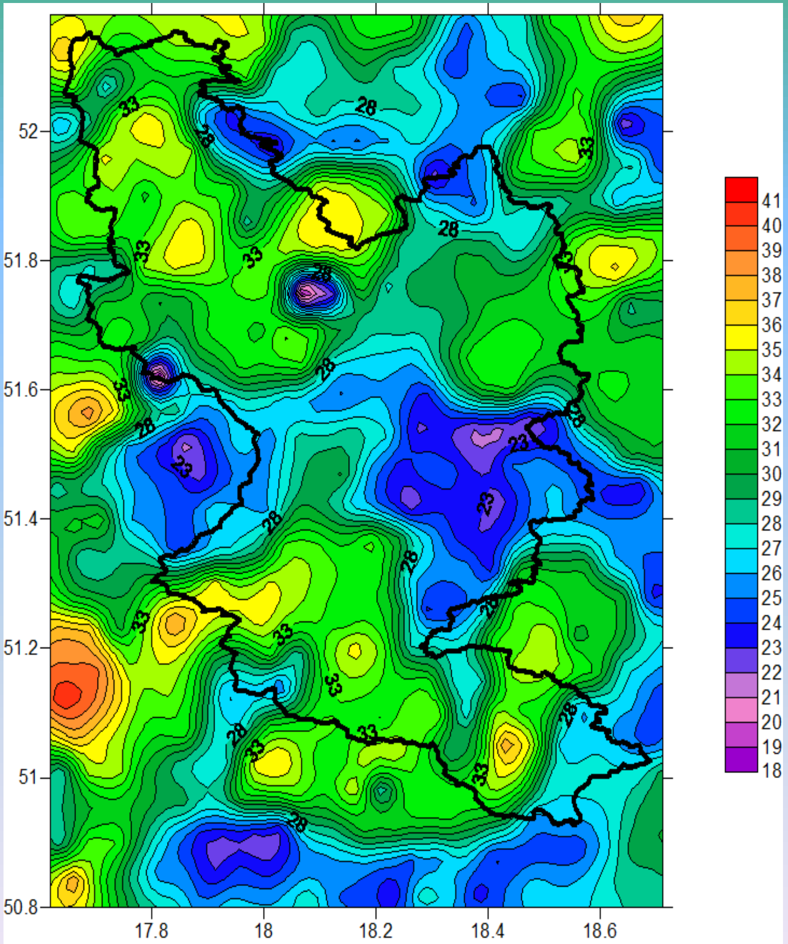


II quarter 2007

SATELLITE DERIVED ET for PROSNA CATCHMENT – quarterly amount



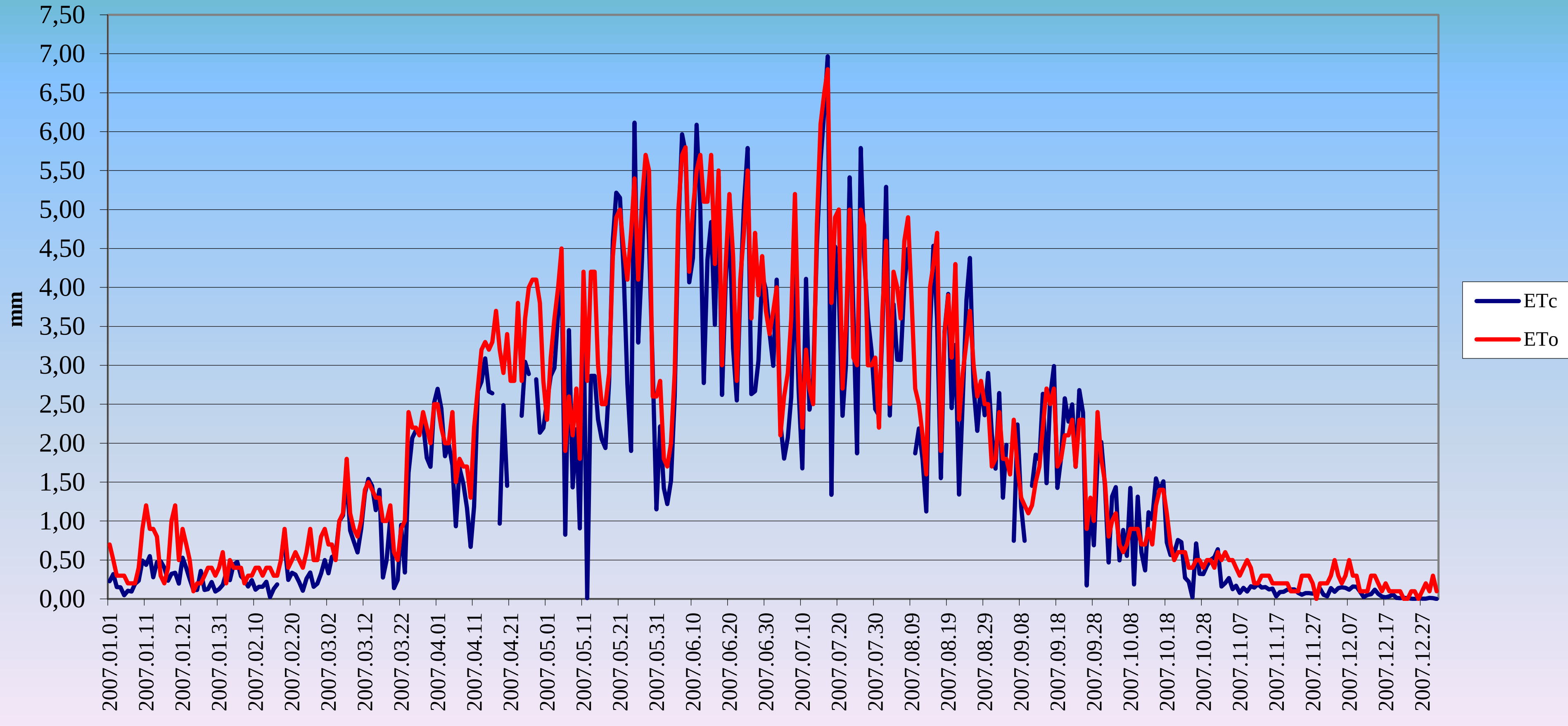
III quarter 2007



IV quarter 2007

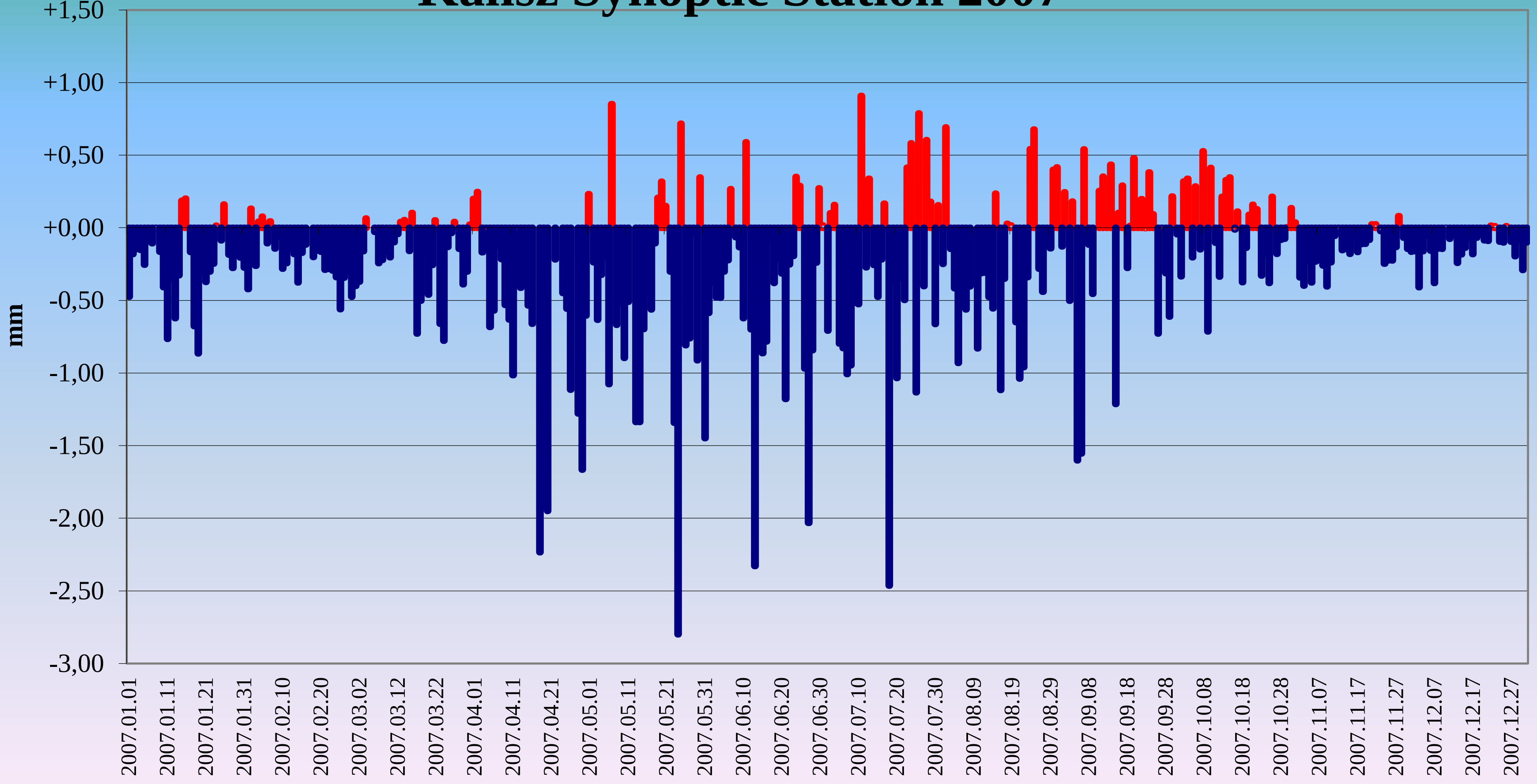
RESULTS

Daily values of actual (ETc) and potential (ETo) evapotranspiration
Kalisz Synoptic Station - 2007



RESULTS

Differences between daily values of actual (ETc) and potential (ETo) evapotranspiration Kalisz Synoptic Station 2007

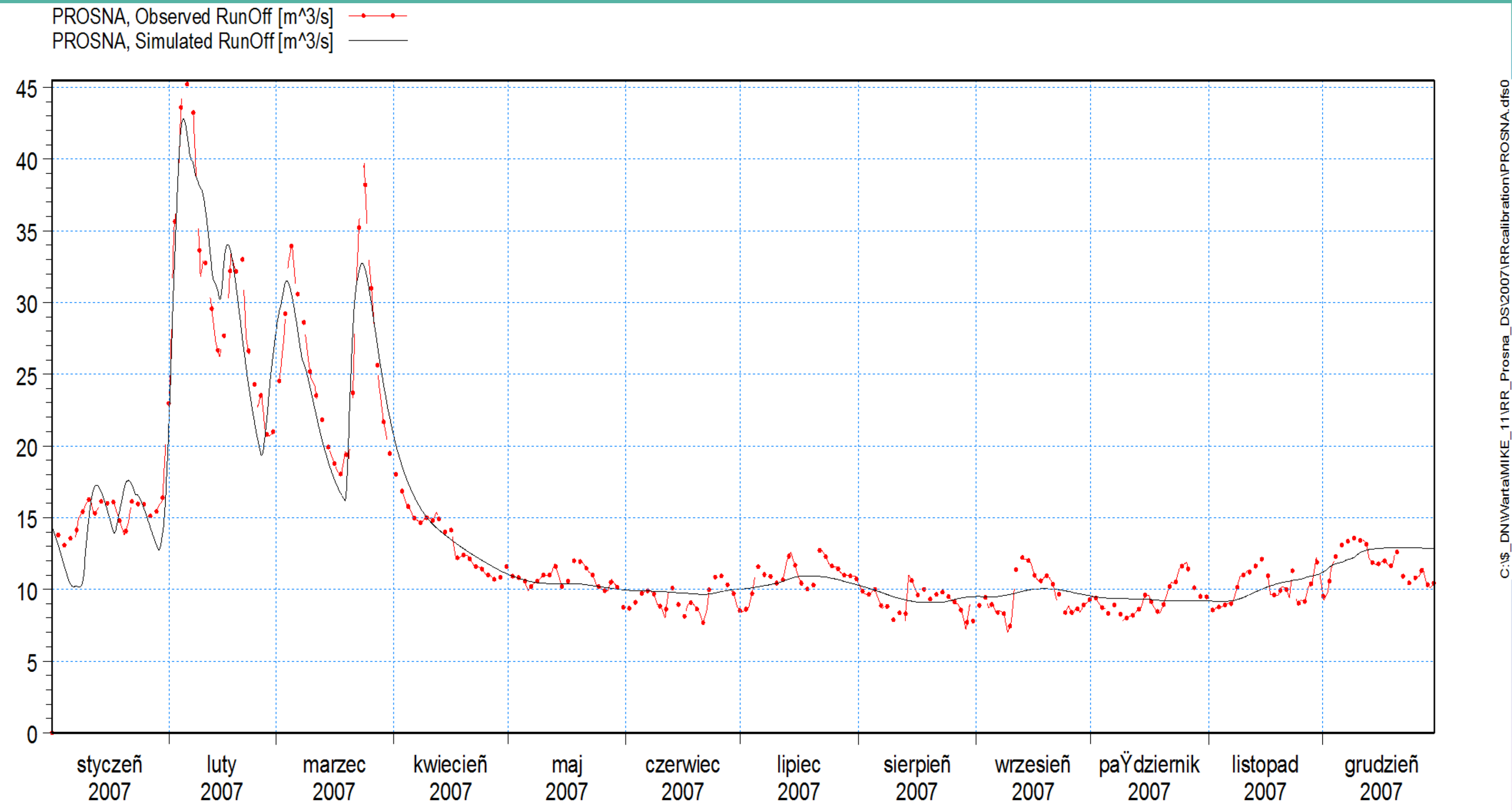


RESULTS

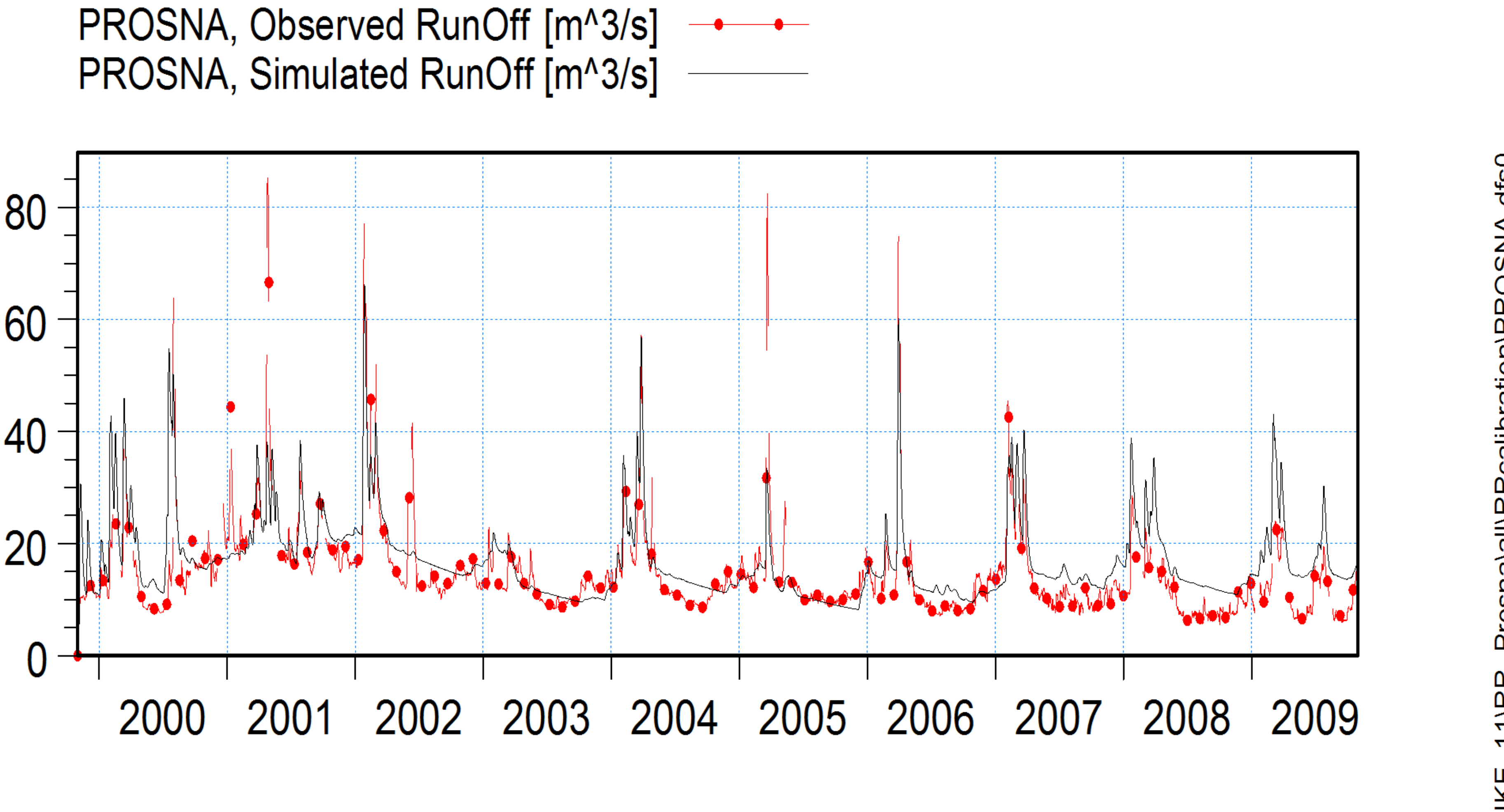
Characteric values of actual (ETc) and potential (ETo) evapotranspiration Kalisz Synoptic Station 2007

Month	Characteric values of actual (ETc) i potential (ETo)								
	average			minimum			maximum		
	ETc	ETo	ETc-ETo	ETc	ETo	ETc-ETo	ETc	ETo	ETc-ETo
Jan	0.3	0.5	-0.2	0.0	0.1	-0.1	0.6	1.2	-0.6
Feb	0.3	0.5	-0.2	0.0	0.2	-0.2	0.7	0.9	-0.2
March	1.1	1.3	-0.2	0.1	0.5	-0.4	2.5	2.5	0.0
Apr	2.1	2.8	-0.7	0.7	1.3	-0.6	3.1	4.1	-1.0
May	3.1	3.7	-0.6	0.0	1.8	-1.8	6.1	5.7	+0.4
Jun	3.8	4.3	-0.5	1.2	1.7	-0.5	6.1	5.8	+0.3
Jul	3.5	3.8	-0.3	1.3	2.1	-0.8	7.0	6.8	+0.2
Aug	3.0	3.3	-0.3	1.1	1.6	-0.5	5.3	4.9	+0.4
Sep	1.8	1.8	0.0	0.2	0.9	-0.7	3.0	2.7	+0.3
Oct	0.8	0.8	0.0	0.0	0.4	-0.4	1.5	1.5	0.0
Nov	0.1	0.3	-0.2	0.0	0.0	0.0	0.6	0.6	0.0
Dec	0.1	0.2	-0.1	0.0	0.0	0.0	0.2	0.5	-0.3
Year	1.7	1.9	-0.2	0.0	0.0	0.0	7.0	6.8	+0.2

RESULTS – MIKE 11 NAM MODEL (using PENMAN-MONTEITH)



RESULTS – MIKE 11 NAM MODEL



RESULTS – MIKE 11 NAM MODEL (comparison between PENMAN-MONTEITH and SATELLITE)

Catchment	Year	Method of evapotranspiration	determination coefficient R^2	Model evaluation
Prosna	2007	Penman-Monteith	0,92	very good
Prosna	2007	Satellite data	0,95	very good

For testing NAM-model algorithm of „Evapotranspiration” satellite product for 2007 was used

CONCLUSIONS

1. Accuracy of evapotranspiration estimate based on ground observation bears the 20% error margine.

2. Satellite product error can result from several factors:

- accuracy of radiation components evaluation,
- accuracy of estimation of actual status of vegetation cover,
- impact of actual soil moisture (on-going work on its inclusion – H-SAF + Land SAF).

CONCLUSIONS

There are no direct measuring methods
for estimation
of evapotranspiration

there are no representative reference ground data to compare with satellite data.

CONCLUSIONS

1. Algorithm for 2010 is almost ready
2. On-going work on improvement of this product
3. Probability of better results in the near future
4. Results in „real-time”
5. Use of satellite data in all-weather conditions on
6. High spatial differentiation of this parameter

Satellite data seems to be

the only economical method

Thank you for your attention