# Experiments in soil physics – „bare soil"parameterization aspects

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# Content

- Brief outline of weak points of evaporation parameterization of „bare" soil.
- Changes and results from numerical experiments.
- Plans until September 2014.

## Current parameterization

- At the moment a fit to the evaporation rate is obtained from:

$$E_b = \min\left(E_p, F_m\right)$$

- where:

$$F_m = \rho_w \left( 1 + 1550 \frac{D_{\min}}{D_{\max}} \frac{B - 3{,}7 + \frac{5}{B}}{B+5} \right) 1{,}02 D_{\max} s_u^{B+2} \left( \frac{s_t}{s_u} \right)^{\left\{ 5{,}5 - 0{,}8 B \left[ 1 + 0{,}1 (B-4) \log \frac{K_0}{K_R} \right] \right\}} \frac{s_t}{\sqrt{z_u z_t}}$$

- and:

$$D_{\max} = \frac{B \phi_0 K_0}{\rho_{wm}}$$

# Currently description is based on:

- Dimensional analysis.
- Physical reasoning.
- Detailed structure was inferred from trial and errors numerical integration.

# Weak points current parameterization in COSMO Model

## Weak points (conclusion come from papers R. E. Dickinson „*Modeling evaporation for 3D Global Climate Models*”), :

a) Overestimation of evaporation during morning hours (about 50 %).

b) Underestimation of evaporation during afternoon hours (about 10 % - 20 %).

c) Overestimate the actual evaporation for wet soils

d) Underestimate for dry soils.

e) Evaporation for the dry case is an order of magnitude smaller than that of the wet case so these errors are small compared to the range of evaporation that has been parameterization.

f) For $K=10^{-6}$ m/s, the daily mean evaporation was overestimated by about 20 % for the wet case and underestimated by a factor of 4 for the dry case.

g) A source of errors comes from difficulties in specifying the soil hydraulic properties due to their vertical and horizontal variability.

## Changed in description flux through the surface

- We changed flux water through the soil, we considered two options:

$$F_m = \rho_w \left( 1 + 1550 \frac{D_{\min}}{D_{\max}} \frac{B - 3{,}7 + \frac{5}{B}}{B+5} \right) 1{,}02 D_{\max} s_u^{B+2} \left( \frac{s_t}{s_u} \right)^{\left\{ 5{,}5 - 0{,}8B \left[ 1 + 0{,}1(B-4)\log \frac{K_0}{K_R} \right] \right\}} \frac{s_t}{\sqrt{z_u z_t}}$$

$$\Downarrow$$

- Version 1: $$F_m = -D(\theta) \nabla \theta$$

- Version 2: $$F_m = -D(\theta) \left( \frac{T}{T_0} \right)^a \nabla \theta$$

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## Meteorological and agrophysical fields

- **We considered following meteorological and agrophysical fields:**

a) **Soil Water Content in soil: 1 cm, 2 cm, 6cm, 18 cm, 54 cm, 162 cm, 486 cm, 1458 cm.**

b) **Soil Temperature: 1 cm, 2 cm, 6 cm, 18 cm, 54 cm, 162 cm, 486 cm, 1458 cm.**

c) **Soil Temperature on surface.**

d) **Air temperature and dew point temperature at 2 m a. g. l.**

e) **Humidity of air at 2 m a. g. l.**

f) **Component wind speed at 10 m a. g. l.**

g) **Atmospherical precipitation.**

h) **Humidity of air at surface soil level.**

# Dates numerical experimentals

- **We chose following dates:**

a) **1 February 2009**
b) **22 February 2009**
c) **16 October 2009 – (0 UTC, 12 UTC)**
d) **4 November 2009**
e) **21 November 2009**
f) **3 February 2012**
g) **18 May 2012**
h) **1 July 2012**
i) **14 December 2012**
j) **16 December 2012**

## What we compared…

- We compared:

a) **Results from COSMO Model (without change flux) – data from meteo stations.**

b) **Results from COSMO Model (after changed flux) – data from meteo stations.**

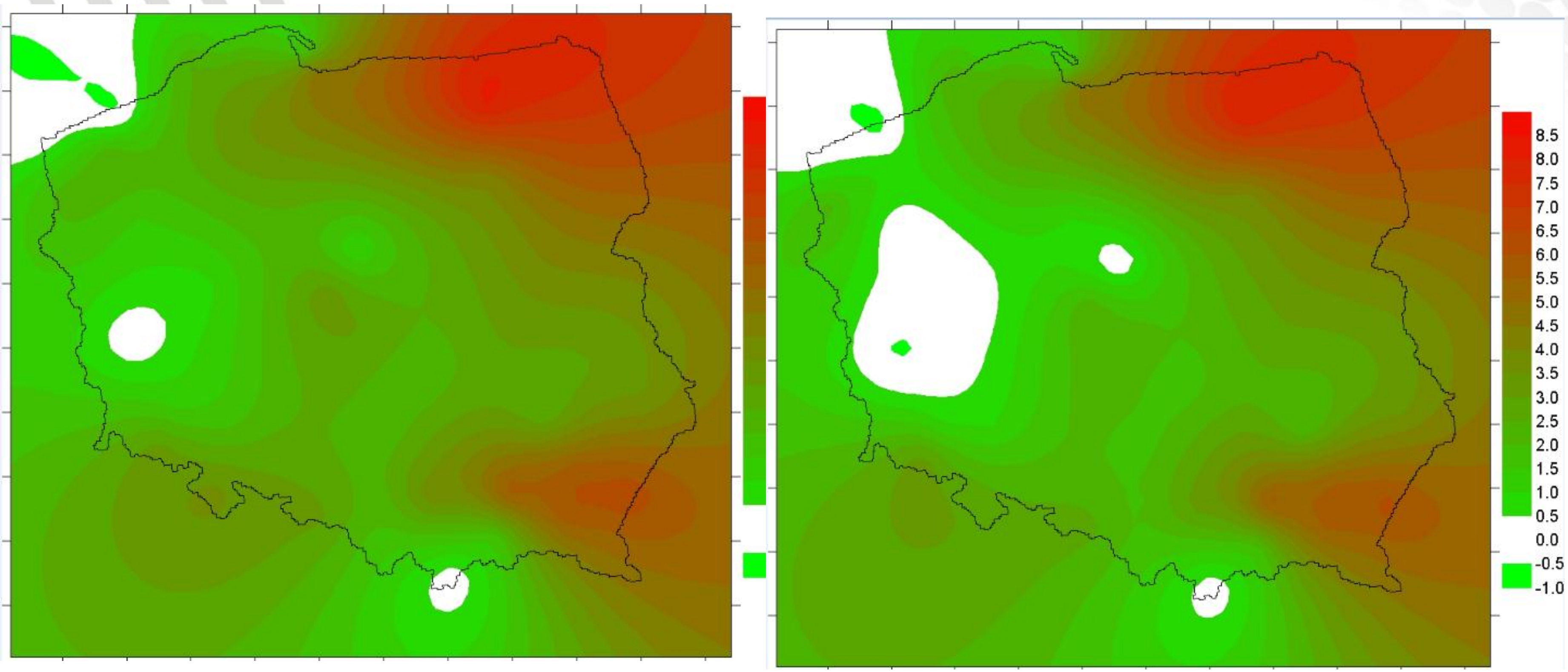
c) **Results from COSMO Model (after changed flux (T)) – data from meteo stations.**

d) **Results from COSMO Model (changed only soil diffusivity – dependance on temperature) – data from meteo stations.**

e) **Comparison between different version model.**

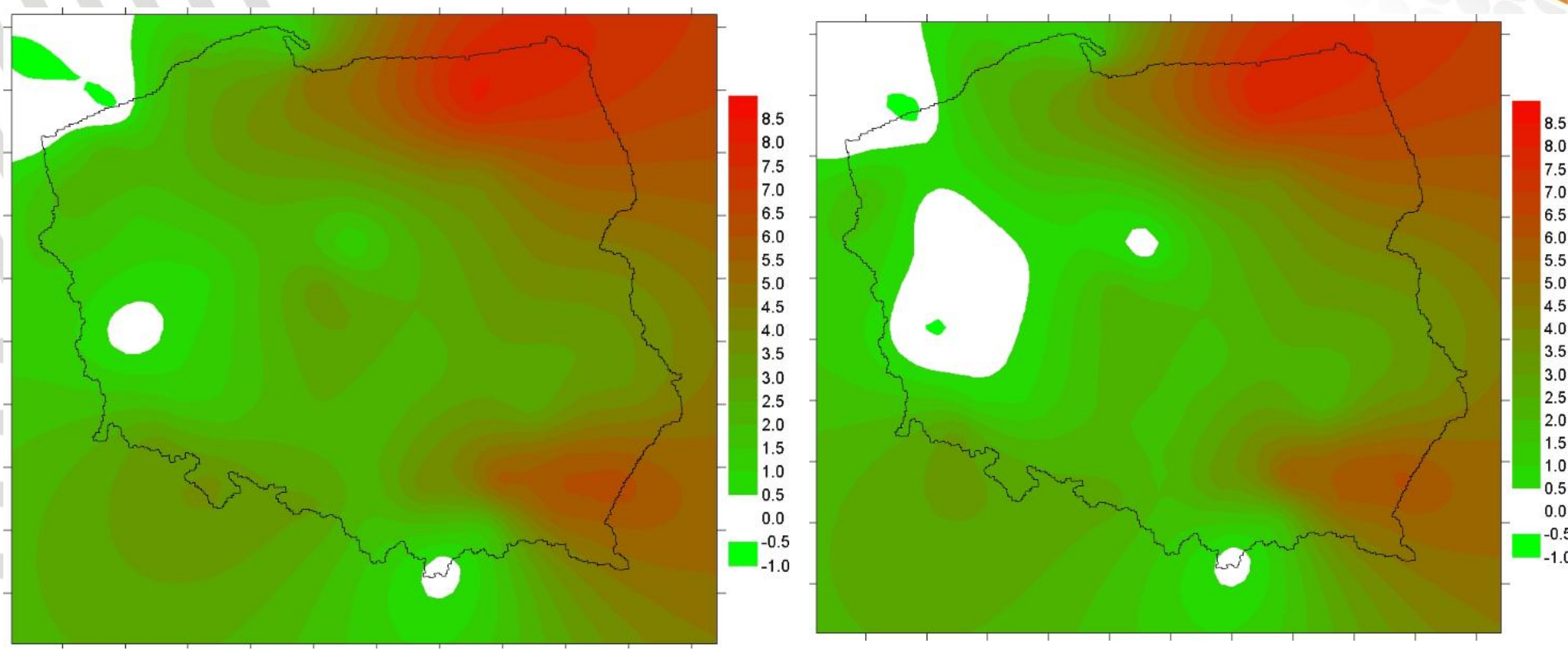
## Numerical experiments for „a=0,5”

Dew point temperature – before flux change (left), after flux change (right) - winter



# Numerical experiments for „a=0,5”

## Dew point temperature: flux plus (T) (left), only „old” +(T) (right)- winter



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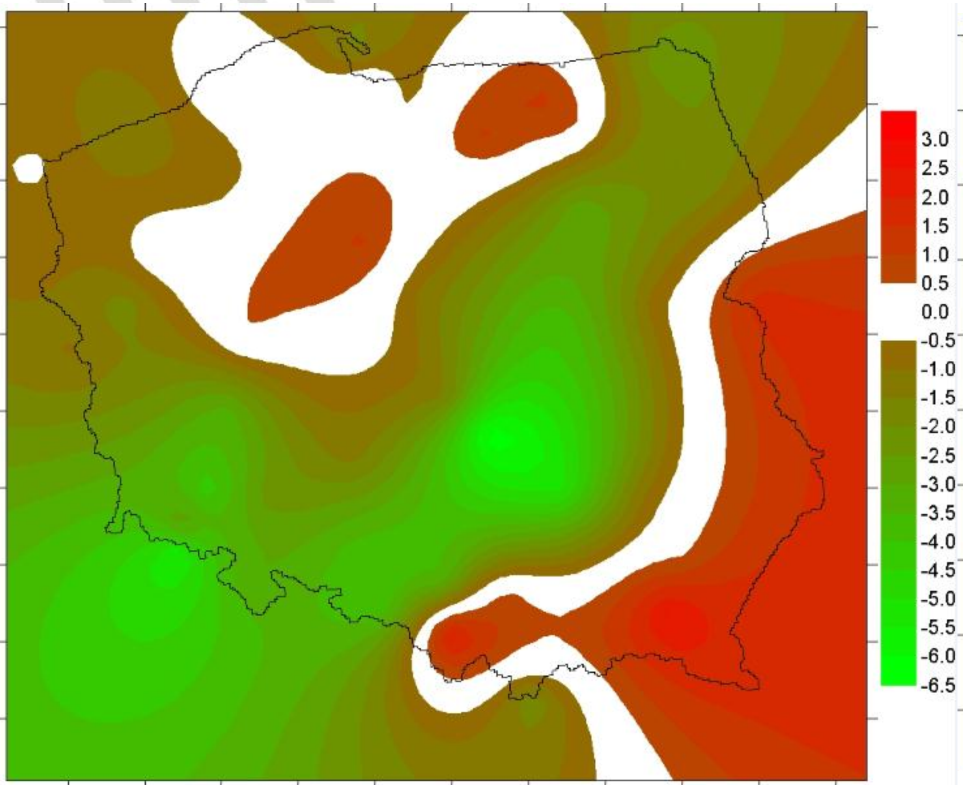
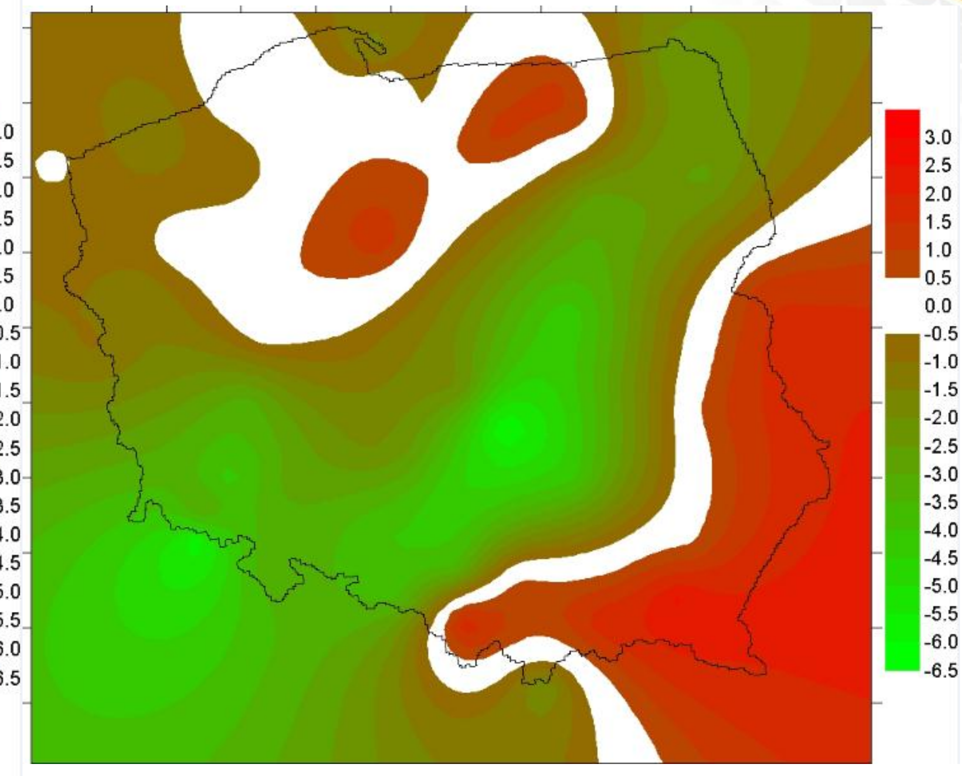
Air temperature – before flux change (left), after flux change (right) - summer



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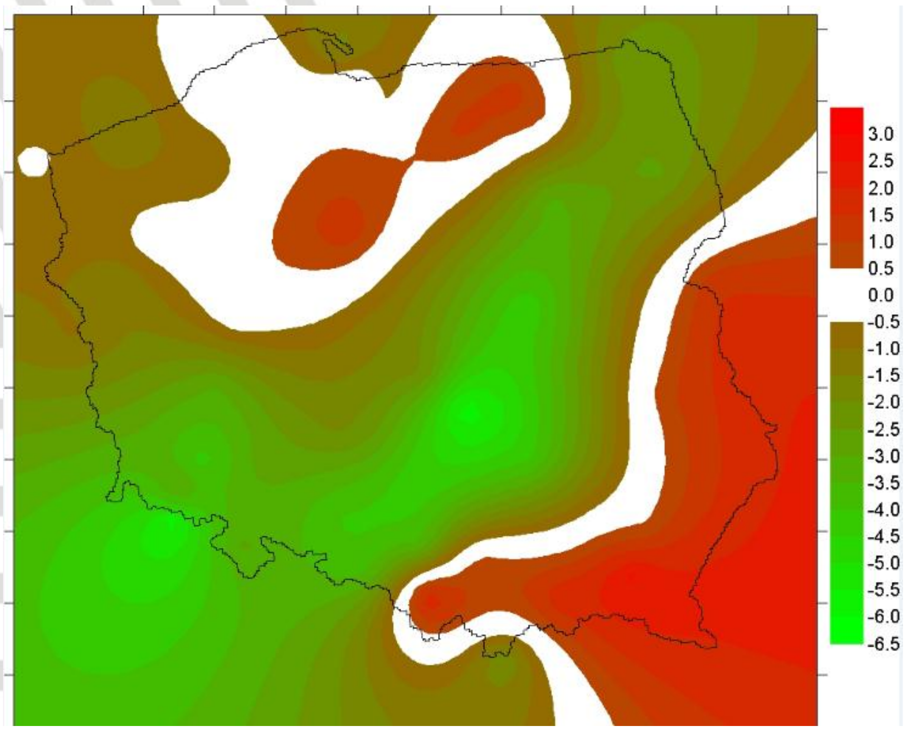


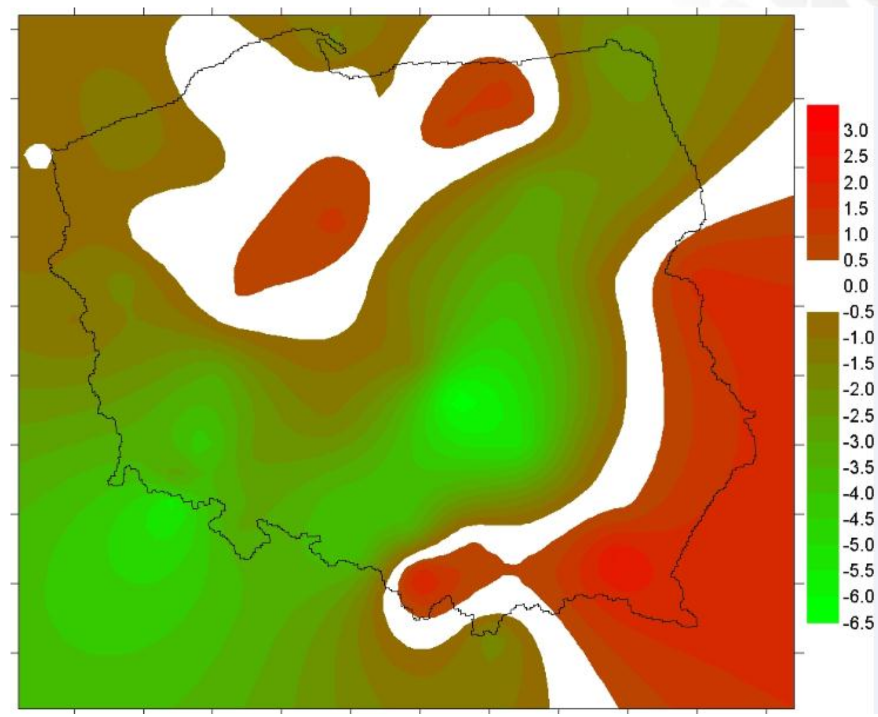

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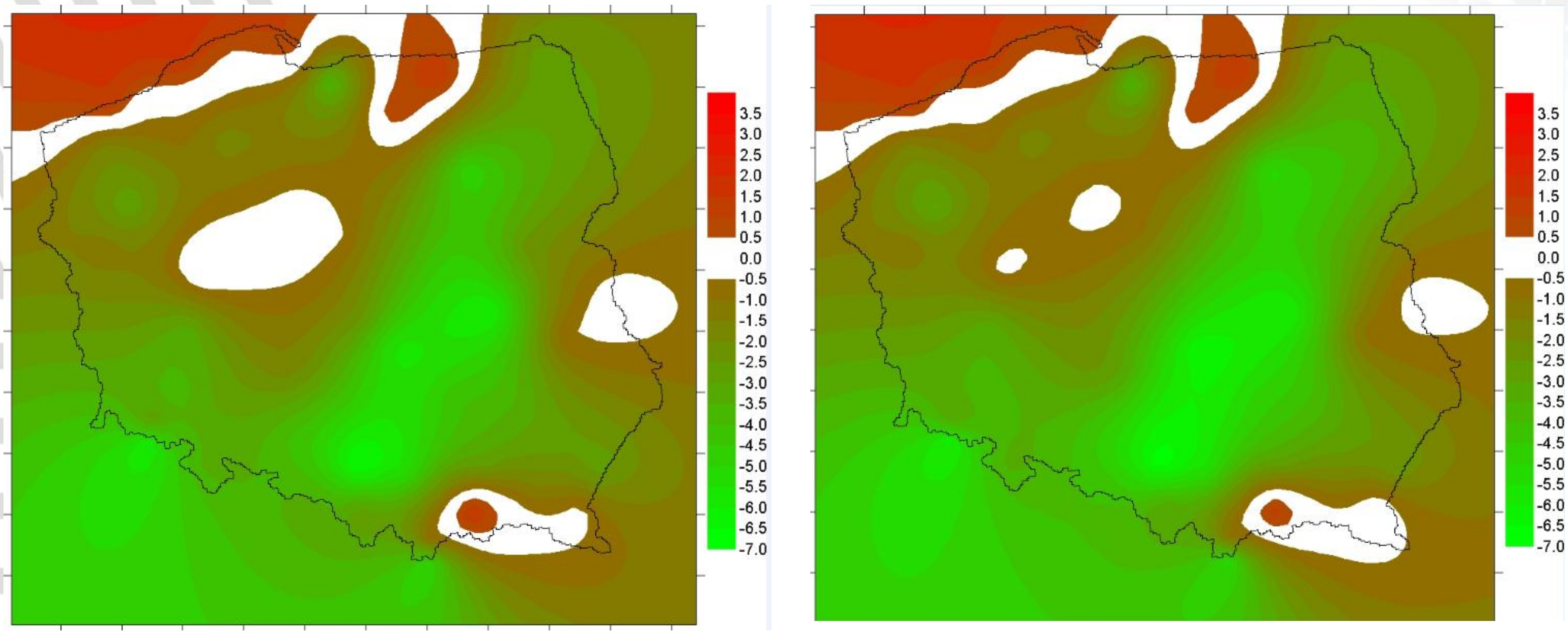

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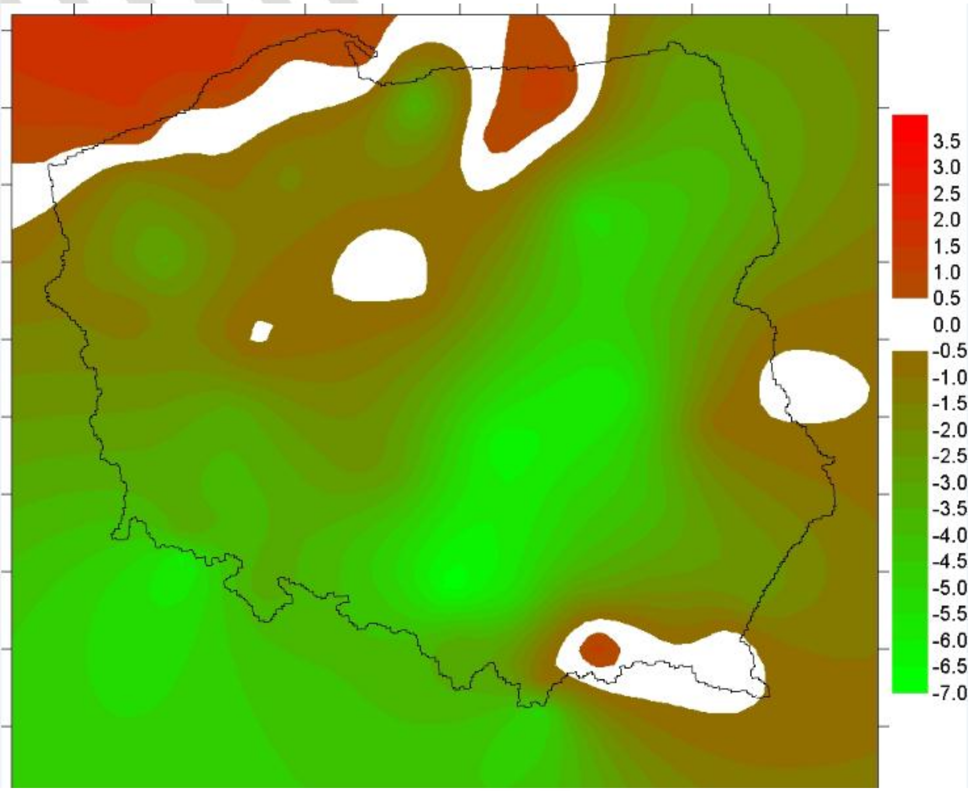
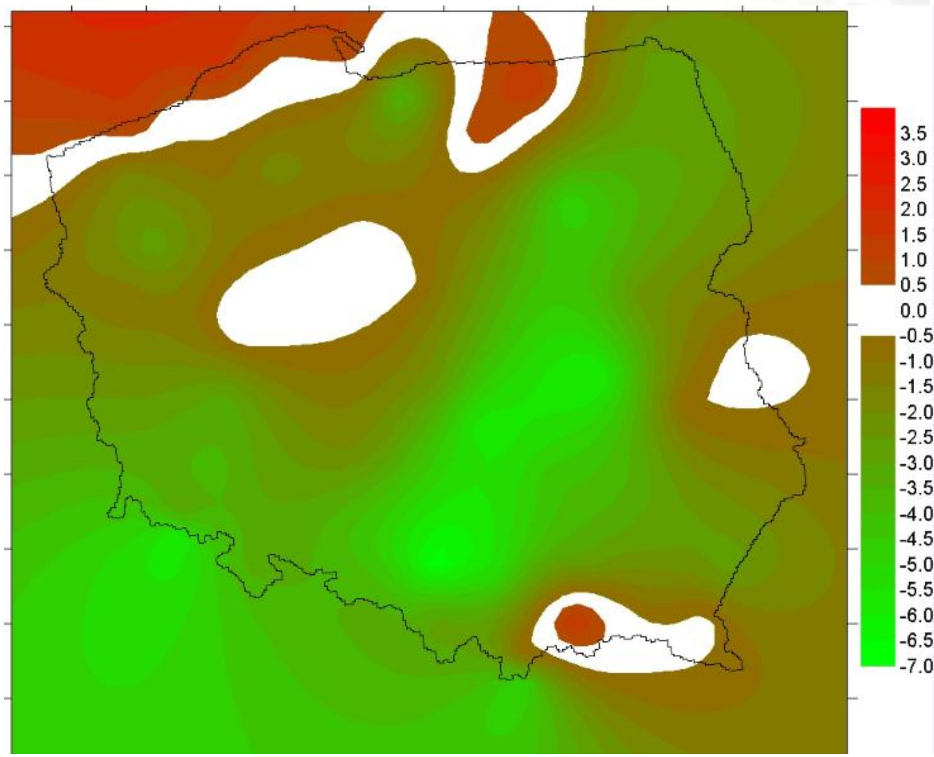
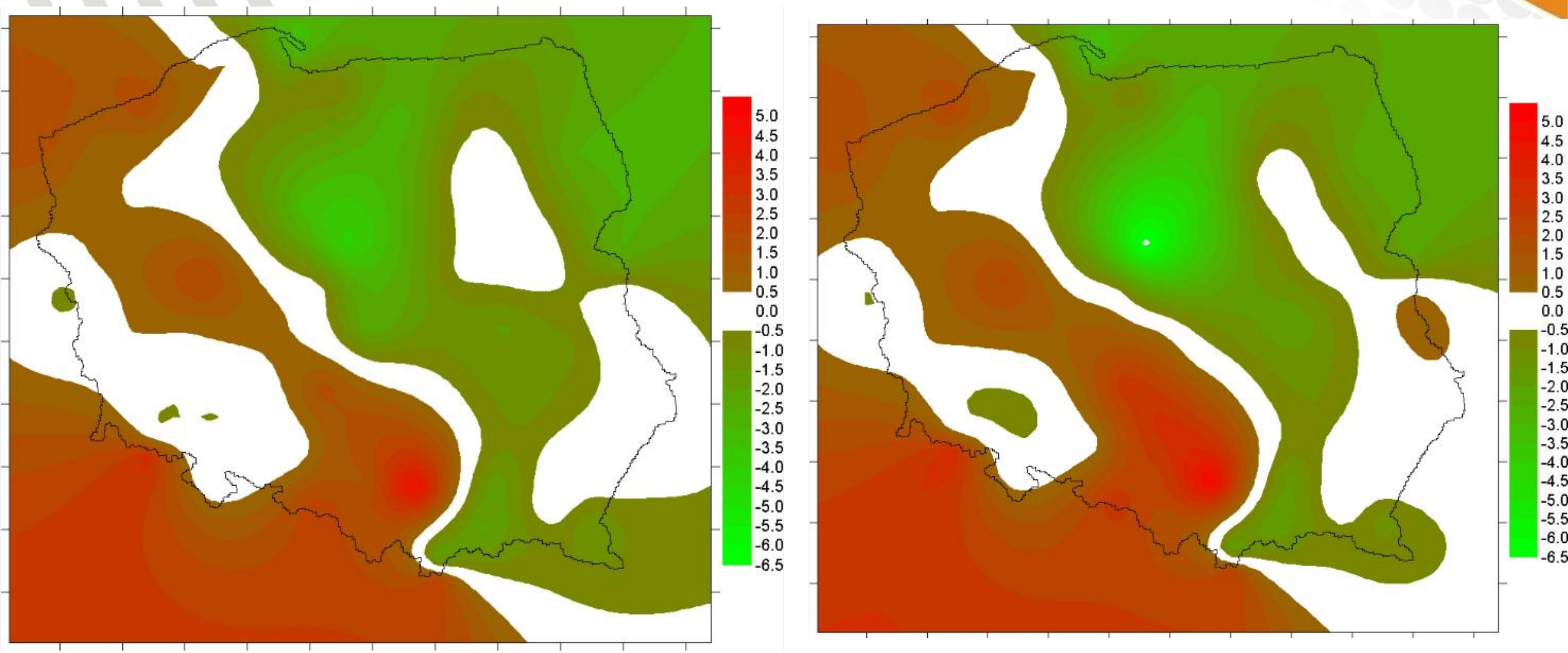


# Numerical experiments for „a=0,5”

Wind speed – before flux change (left), after flux change (right) -  summer



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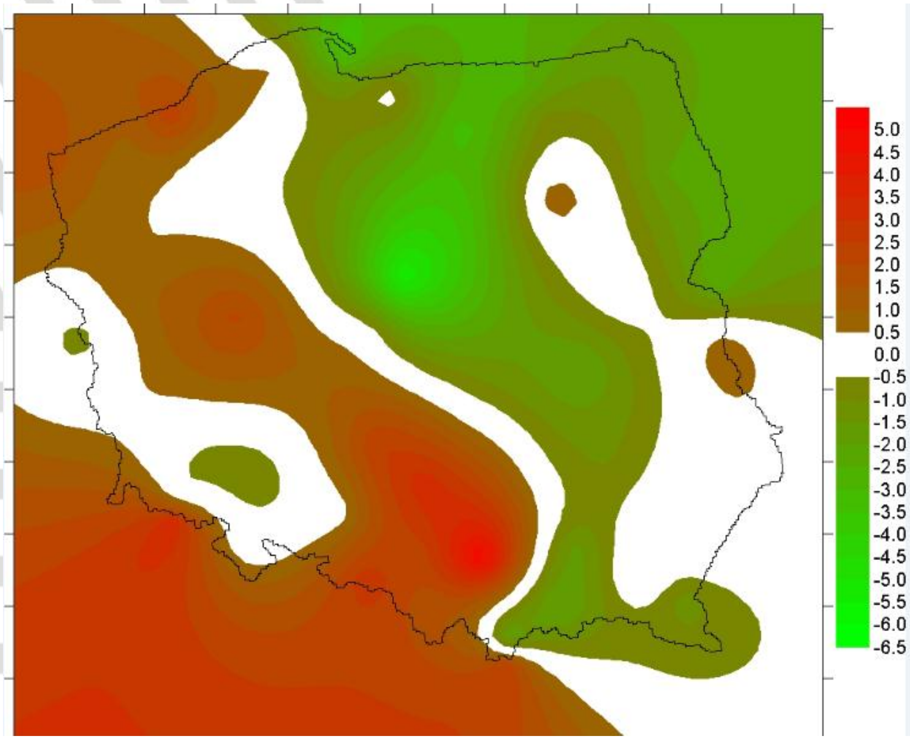


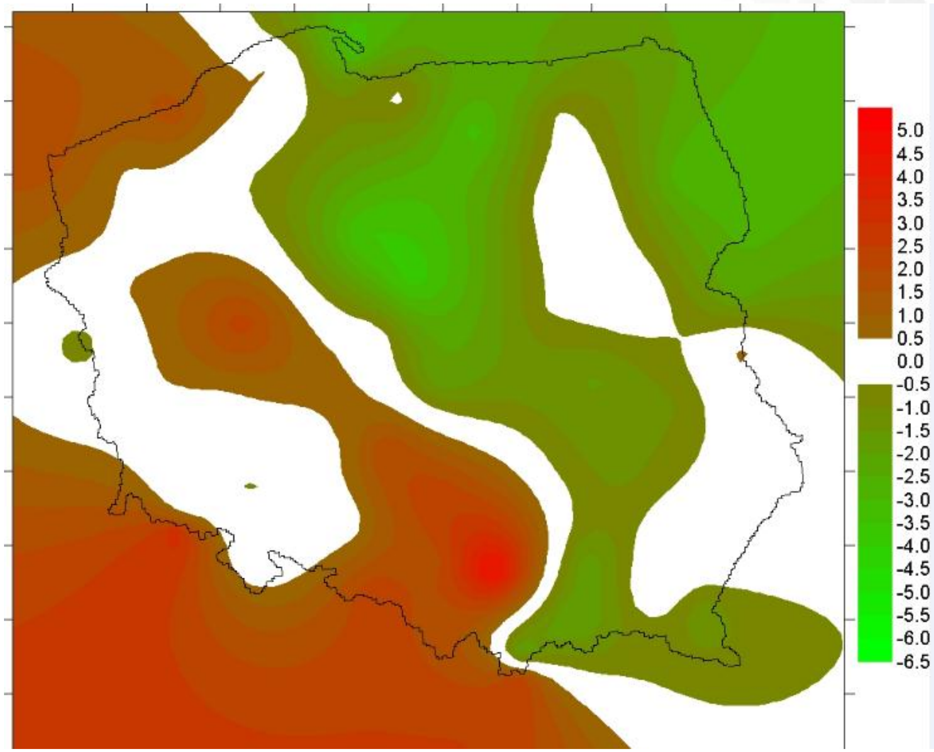

# Numerical experiments for „a=0,5” – conclusive flow chart for all dates

| *BAS-STREAM* | 1.II.9 | 22.II.9 | 16.10.9 0 UTC | 16.10.9 12 UTC | 4.11.9 | 21.11.9 | 3.2.12 | 18.5.12 | 1.7.12 | 14.12.12 | 16.12.12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WSO1 | + | X | + | + | + | + | + | + | + | + | + |
| WSO2 | + | X | + | + | + | + | + | + | + | + | + |
| WSO6 | + | X | + | + | + | + | + | + | + | + | + |
| WSO18 | - | X | + | + | + | - | + | - | - | X | + |
| WSO54 | + | X | + | + | + | - | X | - | - | X | X |
| WSO162 | X | X | X | X | X | X | X | - | - | X | X |
| WSO486 | + | X | X | X | X | X | X | - | - | X | X |
| WSO1458 | - | X | X | X | - | + | X | - | - | X | X |
| TSO0 | - | X | - | + | + | - | - | + | + | + | + |
| TSO1 | - | X | - | + | + | - | - | + | + | + | + |
| TSO2 | - | X | - | + | + | - | - | + | + | - | - |
| TSO6 | - | X | - | + | + | + | - | + | + | + | - |
| TSO18 | + | X | - | + | + | + | + | + | + | + | + |
| TSO54 | + | X | - | + | + | + | + | + | + | + | X |
| TSO162 | + | X | - | + | + | + | + | + | + | X | X |
| TSO486 | X | X | X | X | X | X | X | X | X | X | X |
| TSO1458 | X | X | X | X | X | X | X | X | X | X | X |
| T2m | - | X | + | + | + | - | - | + | + | - | + |
| T2d | - | X | + | + | - | - | - | - | - | + | + |
| Wilg | - | X | - | - | - | - | - | - | - | + | + |
| U10 | + | X | + | - | + | + | - | - | - | - | + |
| V10 | - | X | + | - | + | - | - | + | - | - | + |
| Precipitation | - | X | + | - | - | - | - | - | + | + | + |
| QV | - | X | + | - | - | - | - | - | - | - | + |

„+” – results from numerical model after “parameterization” change are bigger in comparison with results from reference running

„-” – results from numerical model after “parameterization” change are smaller in comparison with results from reference running

„x” – no changes

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# Numerical experiments for „a=0,5" – conclusive flow chart for all dates

| ***BAS-STREAM-ZDLW*** | 1.II.9 | 22.II.9 | 16.10.9 0 UTC | 16.10.9 12 UTC | 4.11.9 | 21.11.9 | 3.2.12 | 18.5.12 | 1.7.12 | 14.12.12 | 16.12.12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WSO1 | + | - | + | + | + | + | + | + | + | + | + |
| WSO2 | + | - | + | + | + | + | + | + | + | + | + |
| WSO6 | + | - | + | + | + | + | + | + | + | + | - |
| WSO18 | - | X | + | + | + | + | + | - | - | X | + |
| WSO54 | + | X | + | + | + | + | + | - | - | X | X |
| WSO162 | + | X | X | + | + | X | X | - | - | X | X |
| WSO486 | - | X | X | X | X | X | X | - | - | X | X |
| WSO1458 | - | X | X | X | X | X | X | - | - | X | X |
| TSO0 | - | X | + | + | + | - | - | + | + | + | - |
| TSO1 | - | X | + | + | + | - | - | + | + | + | - |
| TSO2 | - | X | + | + | + | - | - | + | + | + | + |
| TSO6 | - | X | + | + | + | + | - | + | + | + | + |
| TSO18 | + | X | + | + | + | + | + | + | + | + | X |
| TSO54 | + | X | + | + | + | + | + | + | + | + | X |
| TSO162 | + | X | + | + | + | + | + | + | + | X | X |
| TSO486 | X | X | X | X | X | X | X | X | X | X | X |
| TSO1458 | X | X | X | X | X | X | X | X | X | X | X |
| T2m | - | X | + | + | + | - | - | + | + | + | + |
| T2d | - | X | - | - | + | - | - | - | - | + | + |
| Wilg | - | X | - | - | - | - | - | - | + | + | + |
| U10 | + | X | + | - | + | + | - | - | + | + | + |
| V10 | - | X | + | - | + | - | - | + | - | + | - |
| Precipitation | - | X | + | - | - | - | - | - | + | + | - |
| QV | - | X | + | - | - | - | - | - | - | + | + |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| WSO1 | + | - | + | + | + | + | + | - | - | + | - |
| WSO2 | - | - | + | + | + | + | - | - | - | + | - |
| WSO6 | - | - | + | + | + | + | - | + | - | - | + |
| WSO18 | - | - | - | + | + | + | - | + | + | - | + |
| WSO54 | + | + | - | - | X | - | + | - | + | + | + |
| WSO162 | - | - | + | + | - | - | - | - | - | - | - |
| WSO486 | - | - | + | + | - | - | - | - | - | - | - |
| WSO1458 | - | - | + | + | - | - | - | - | - | - | - |
| TSO0 | + | - | - | + | + | - | - | - | - | + | + |
| TSO1 | + | - | - | + | + | - | - | - | - | + | + |
| TSO2 | + | - | - | - | + | - | - | - | - | + | + |
| TSO6 | + | - | - | - | - | - | - | - | - | + | - |
| TSO18 | - | - | + | + | - | - | - | - | - | - | + |
| TSO54 | X | X | - | X | + | - | + | + | + | - | - |
| TSO162 | X | X | - | X | + | X | + | + | X | X | X |
| TSO486 | x | X | X | X | X | X | X | X | X | X | X |
| TSO1458 | x | X | X | X | X | X | X | X | X | X | X |
| T2m | + | - | - | - | + | - | - | - | - | + | + |
| T2d | + | + | - | + | + | - | + | + | - | + | + |
| Wilg | - | + | - | + | - | - | + | + | - | + | + |
| U10 | - | - | - | + | + | - | - | - | + | - | - |
| V10 | + | + | - | - | - | - | - | + | - | + | + |
| Precipitation | + | - | + | - | - | + | + | + | + | - | + |
| QV | + | - | - | + | + | - | - | - | - | - | + |

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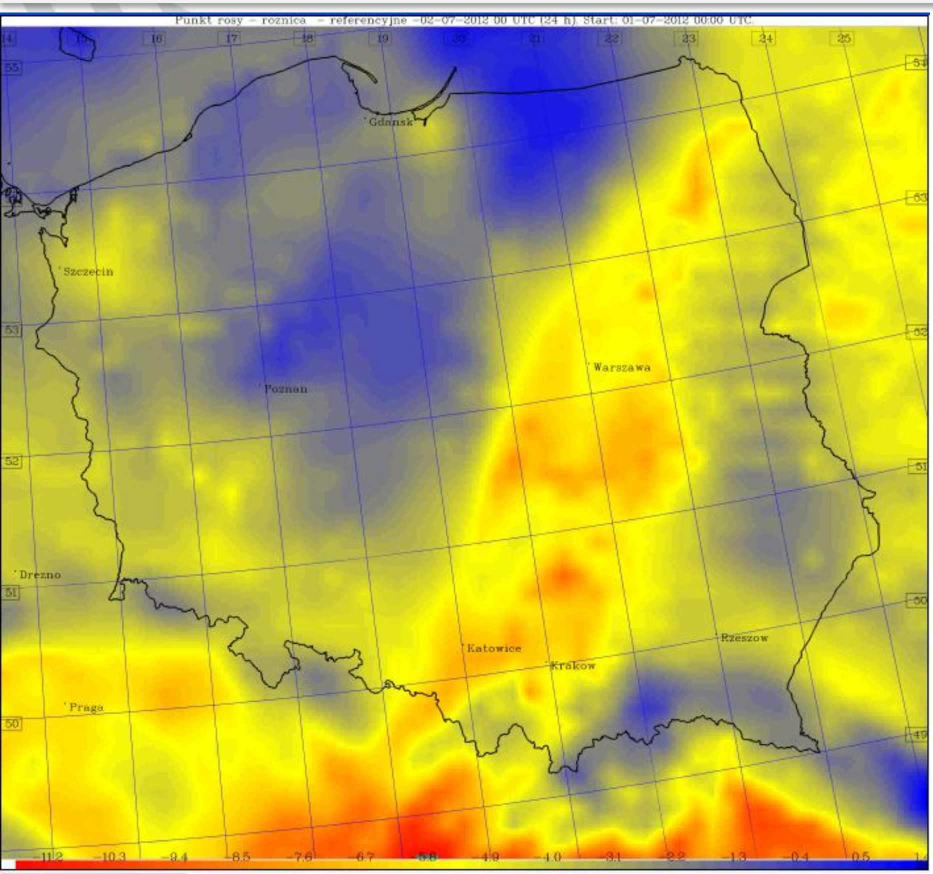
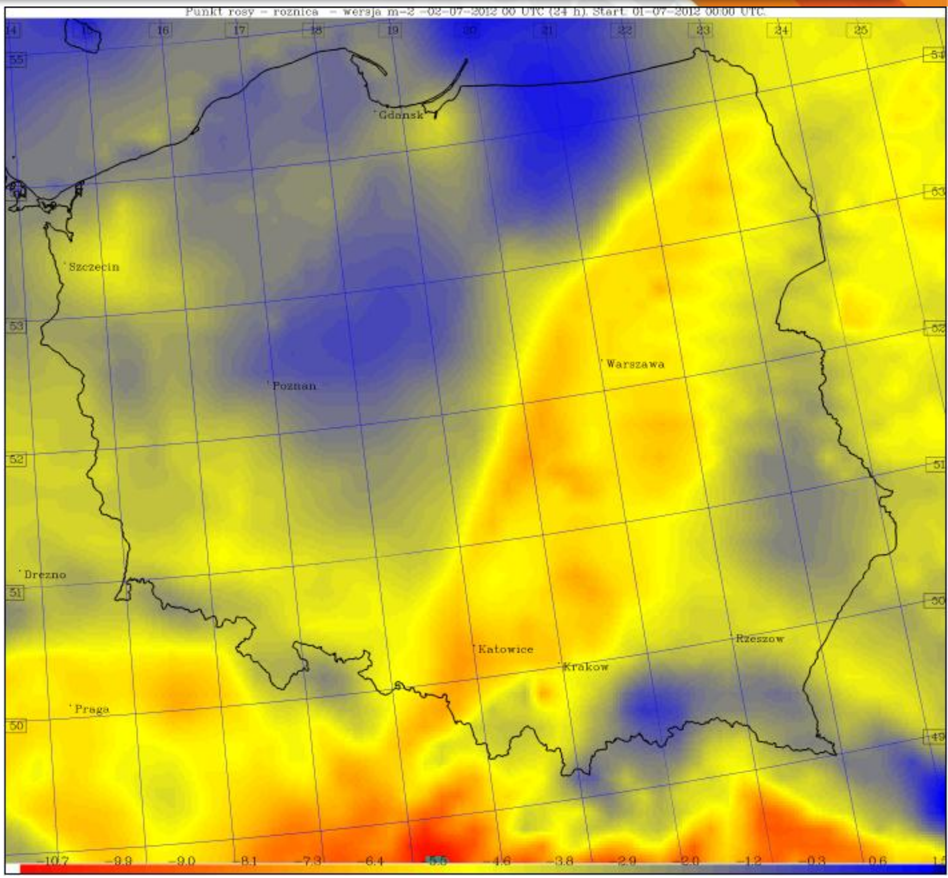
Numerical experiments for different „a”

# Results for:

- *a*= -1,
- a= 1,
- a = 2,

# Differences between observation and model results for dew point temperature (1 VII 2012)



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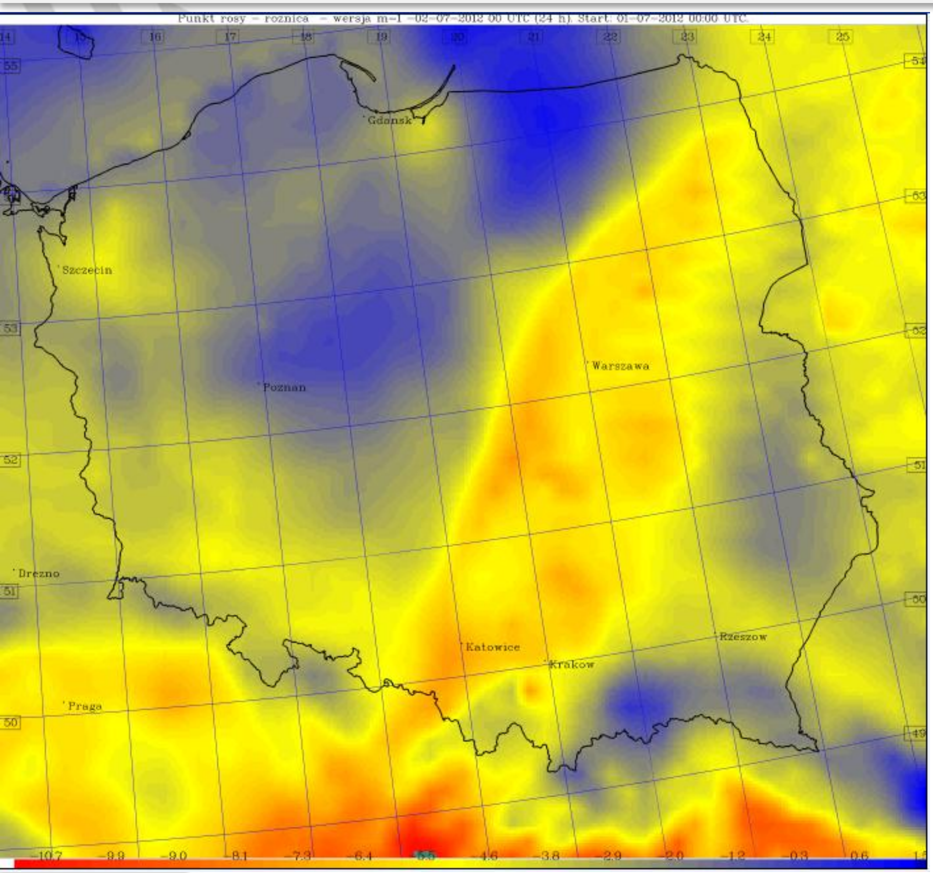


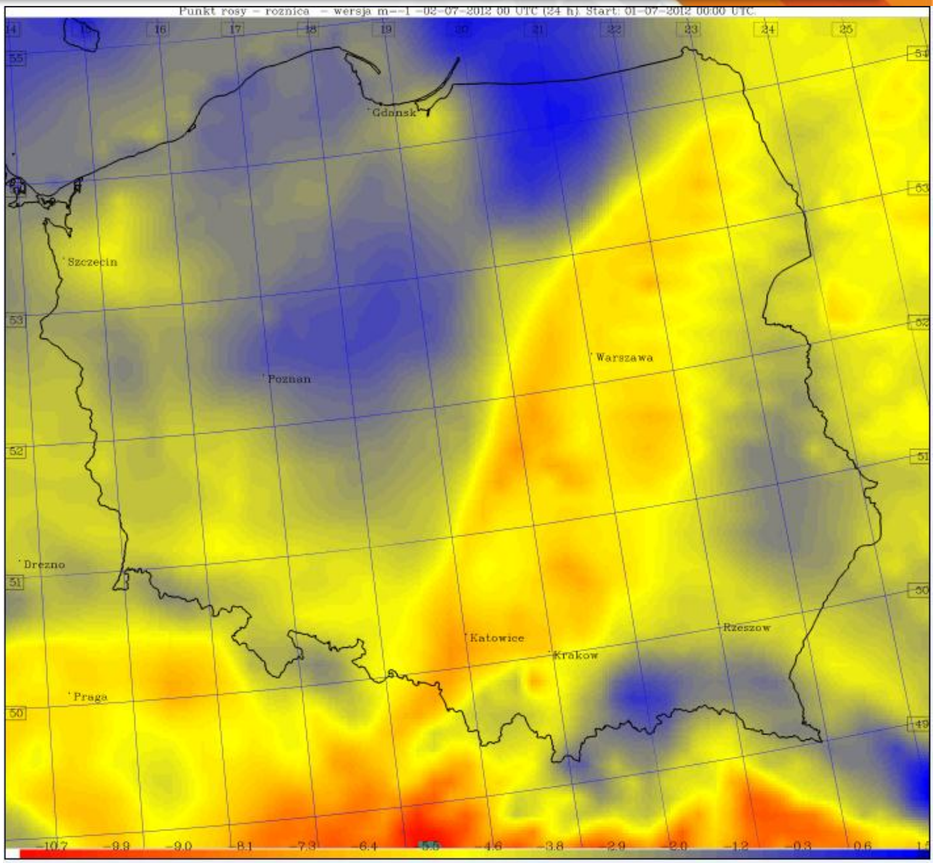

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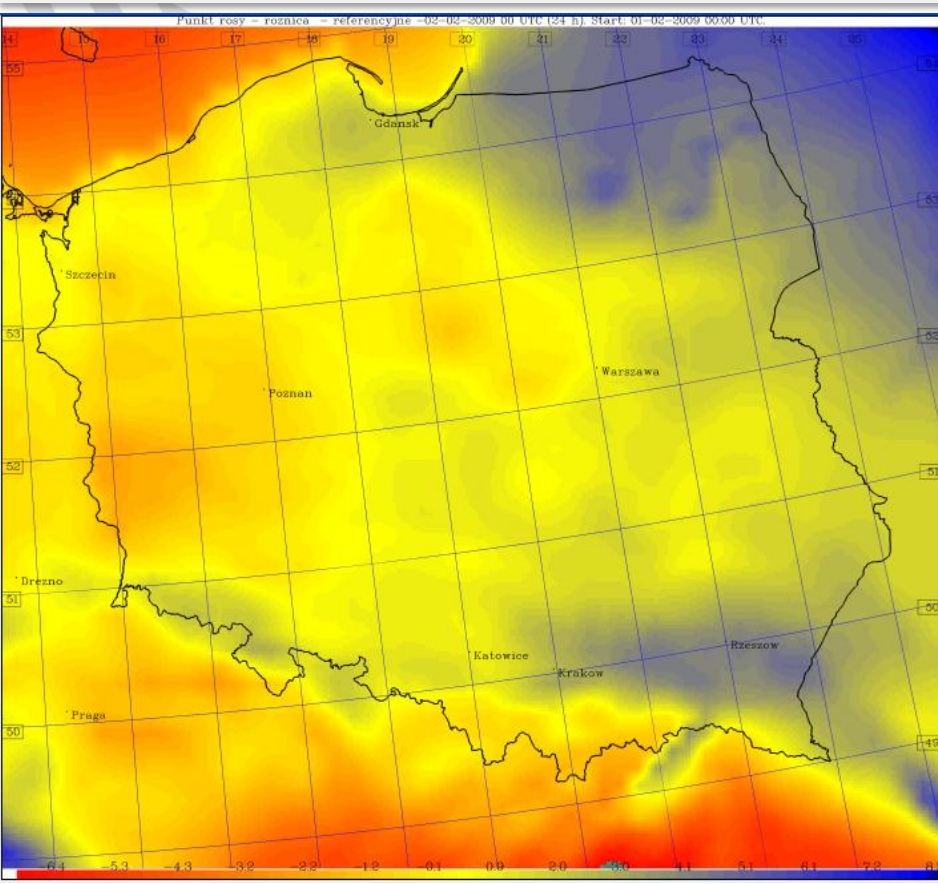


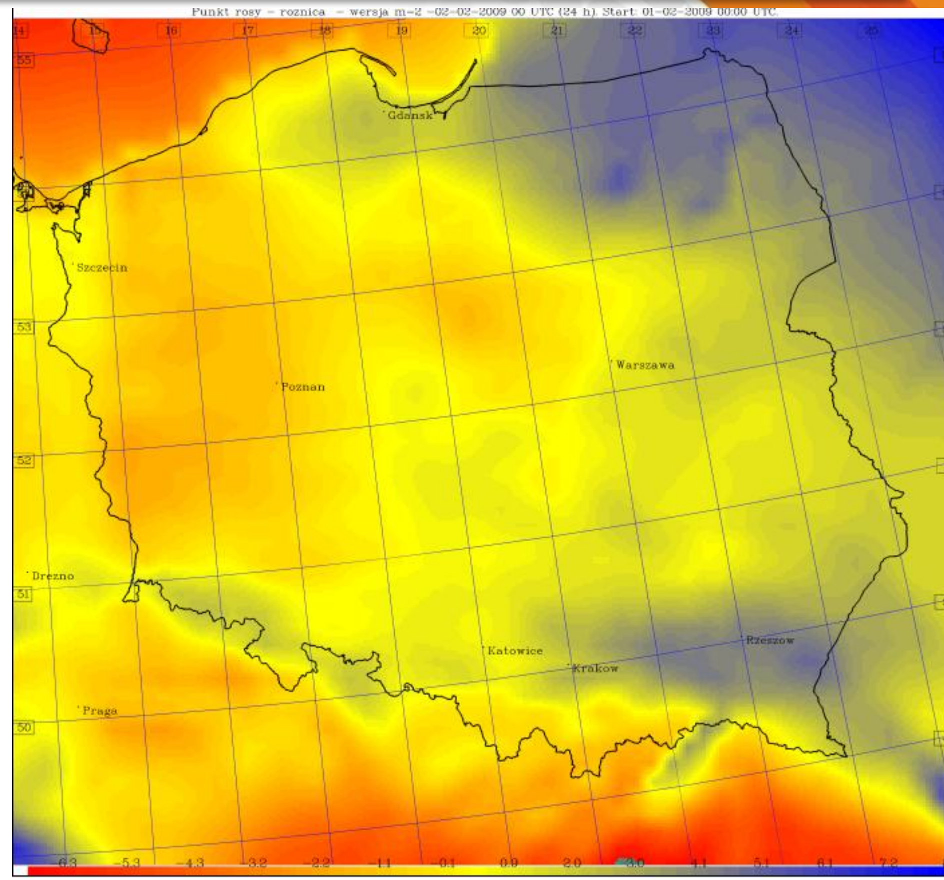

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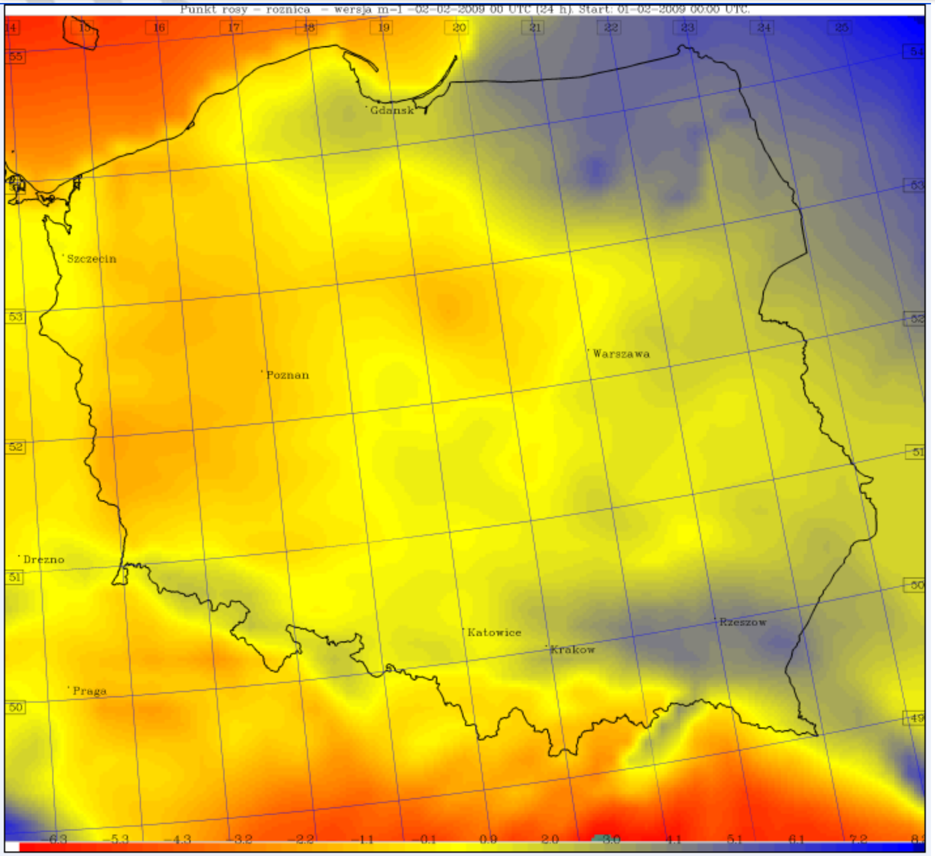


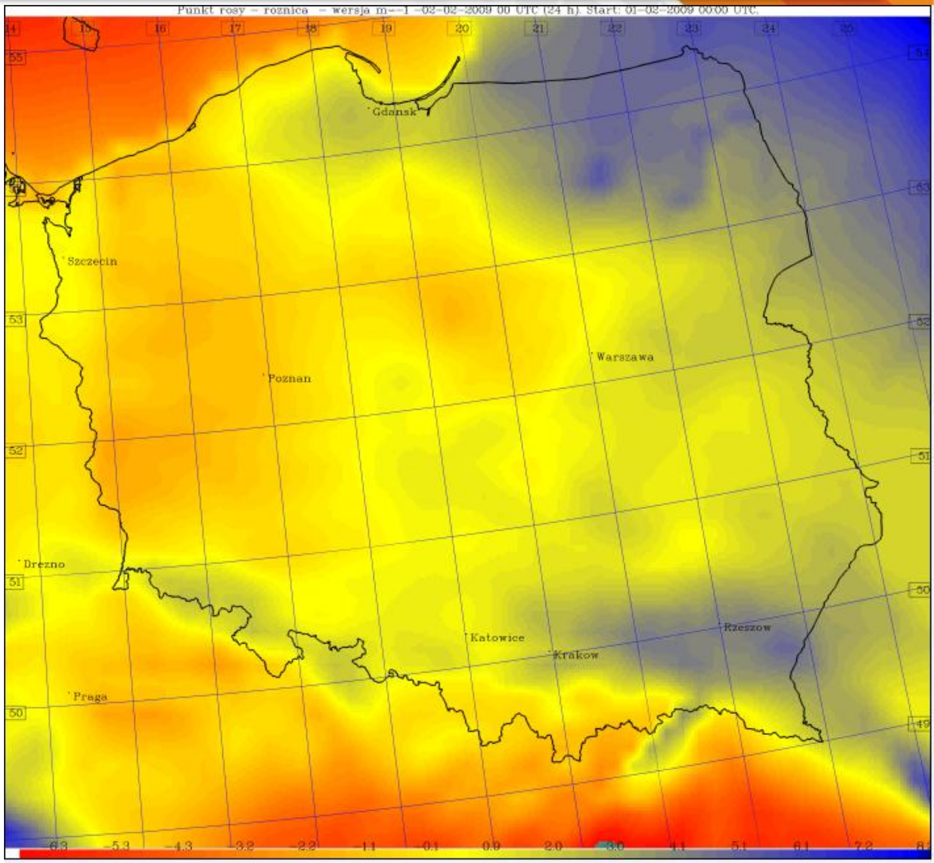

# Outline results

- „a” for clay soil a = -1
- „a” for sandy soil a = 0,5
- „a” for loam soil a ~ 1

## Theoretical changes – Richards' equation

- We will implement Richards equation in form:

$$\frac{\partial\theta}{\partial t}=D_0\left(\frac{T}{T_0}\right)^{a-1}\exp\left(D_1\frac{\theta_1-\theta}{\theta_1-\theta_2}\right)\cdot\left\{-\frac{D_1T}{(\theta_1-\theta_2)T_0}\frac{\partial\theta}{\partial z}+\frac{a}{T_0}\frac{\partial T}{\partial z}\frac{\partial\theta}{\partial z}+\left(\frac{T}{T_0}\right)\frac{\partial^2\theta}{\partial z^2}\right\}+$$

$$+\frac{K_0K_1}{\theta_1-\theta_2}\frac{\partial\theta}{\partial z}\exp\left(K_1\frac{\theta_1-\theta}{\theta_1-\theta_2}\right)$$

- We will compare results from COSMO Model (will replaced „old" version stream by „new" stream and equation Richardsa for different „a") with dates from meteo stations.

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## Based on terrains experimental

- Correction of Darcian equation „version 1”:

$$F_m = -D(\theta)e^{\left(a+b\frac{T}{T_0}\right)}\nabla\theta$$

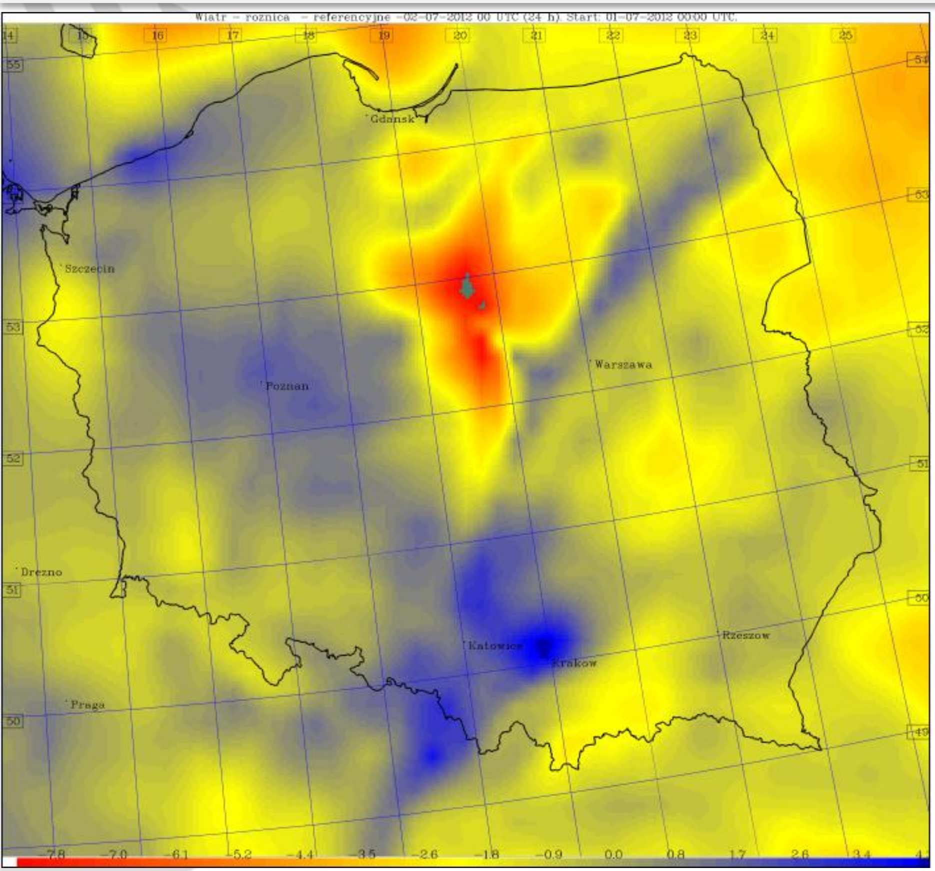
## Richards' equation

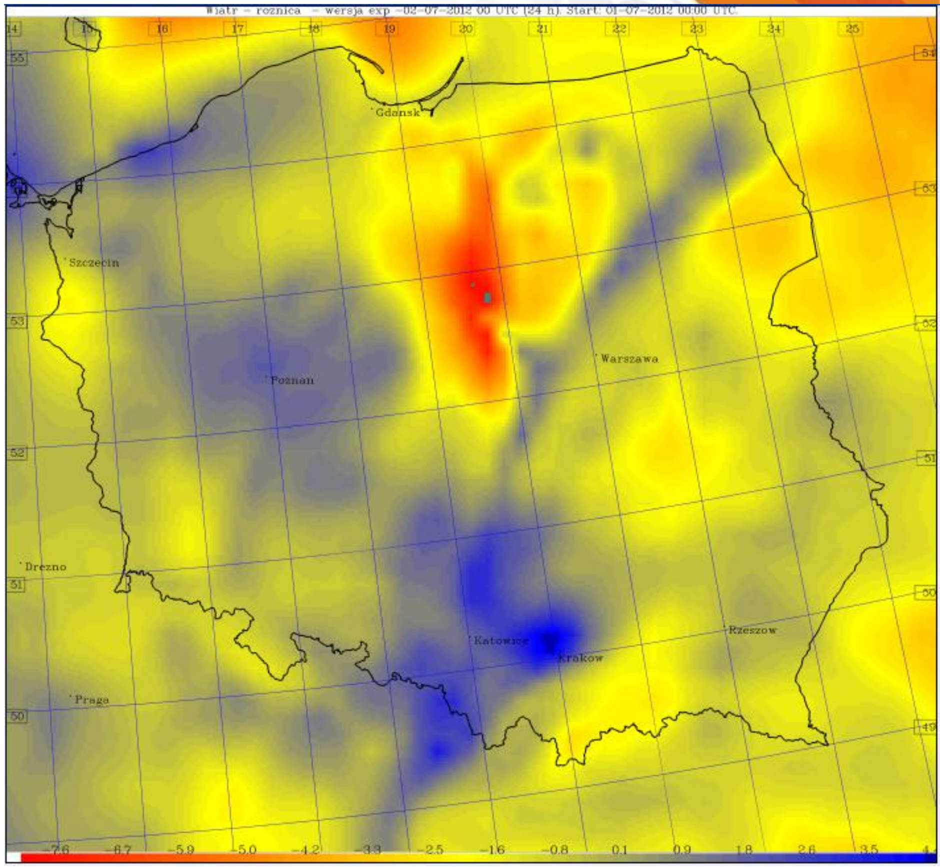
- Richards' equation for „version 1”:

$$\frac{\partial\theta}{\partial t}=D_0\left\{-\frac{D_1}{\theta_1-\theta_2}\left(\frac{\partial\theta}{\partial z}\right)^2+\frac{b}{T_0}\frac{\partial\theta}{\partial z}\frac{\partial T}{\partial z}+\frac{\partial^2\theta}{\partial z^2}\right\}e^{-D_1\frac{\theta_1-\theta}{\theta_1-\theta_2}+a+b\frac{T}{T_0}}+$$

$$+\frac{K_0K_1}{\theta_1-\theta_2}\frac{\partial\theta}{\partial z}\exp\left(K_1\frac{\theta_1-\theta}{\theta_1-\theta_2}\right)+\nabla\left(D_T\nabla T\right)$$

## Differences between observation and model results for wind (1 VII 2012)



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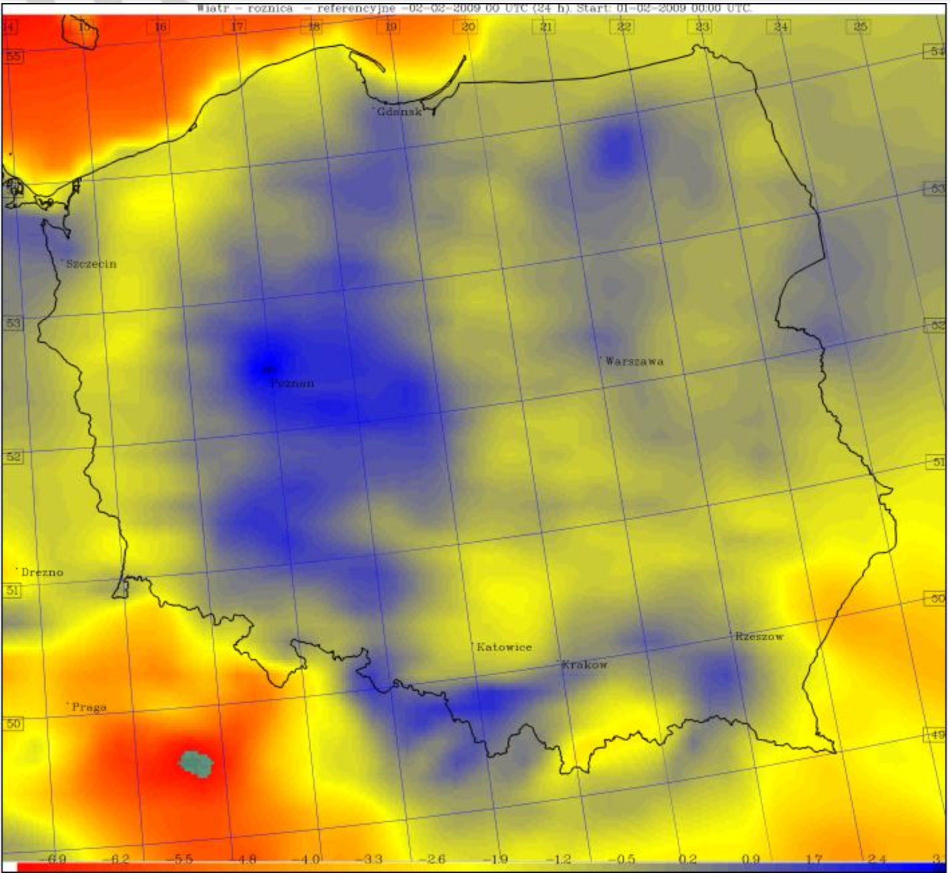
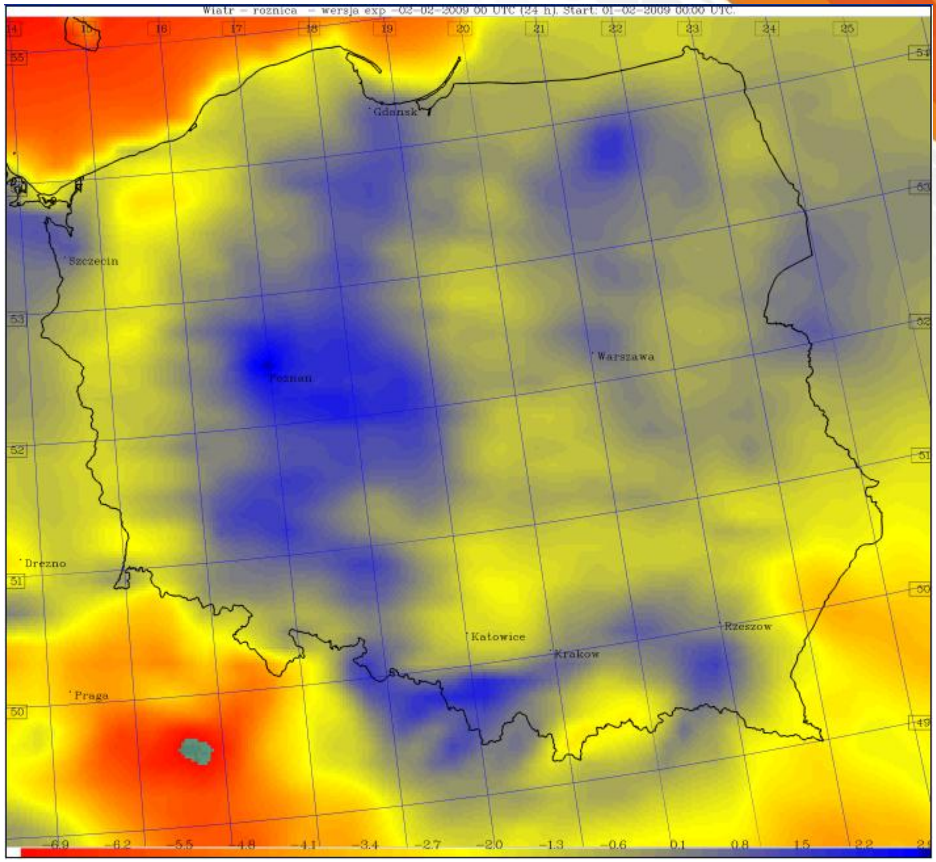
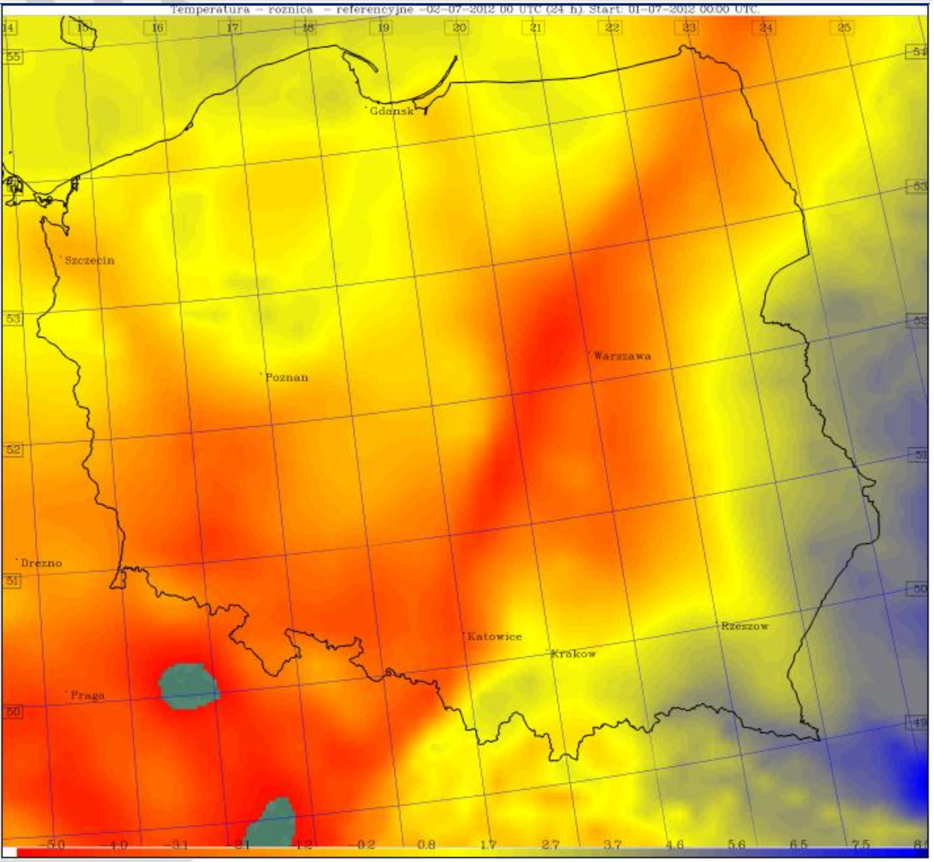
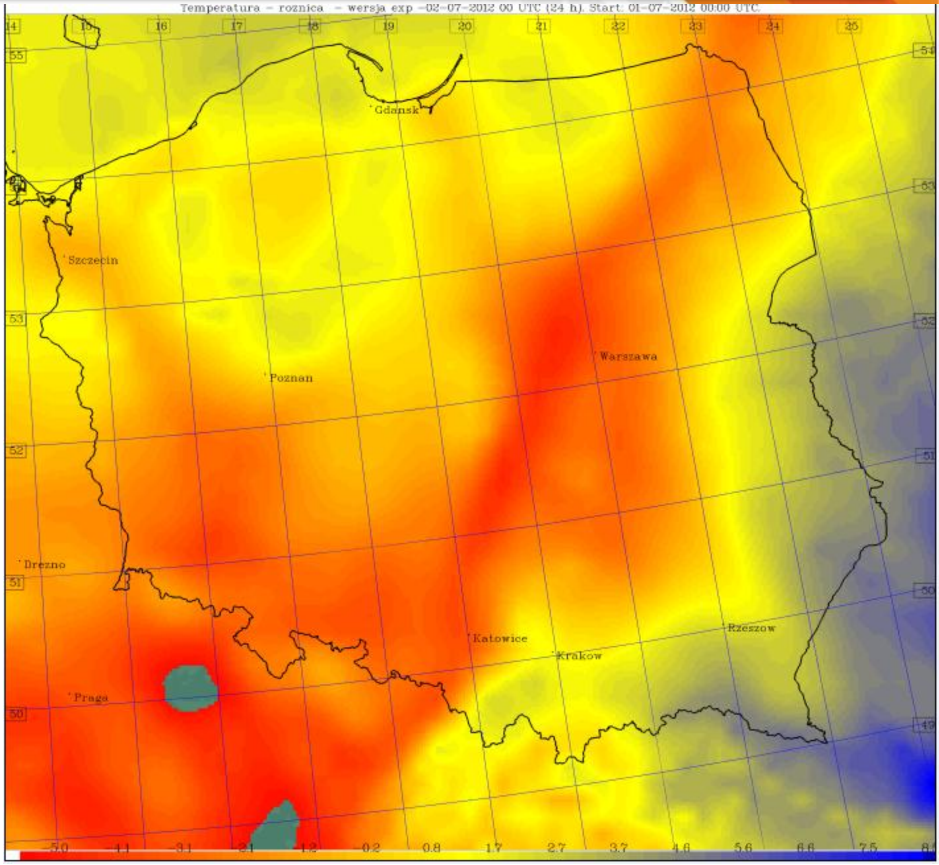


# Differences between observation and model results for temperature (1 VII 2012)



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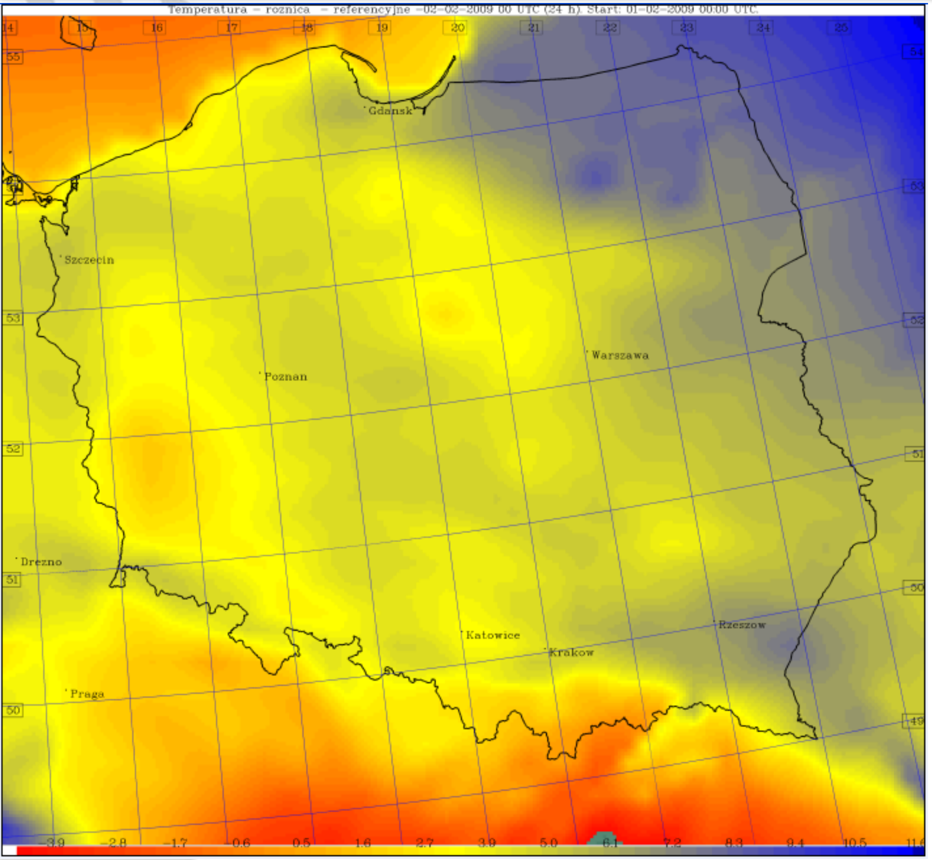
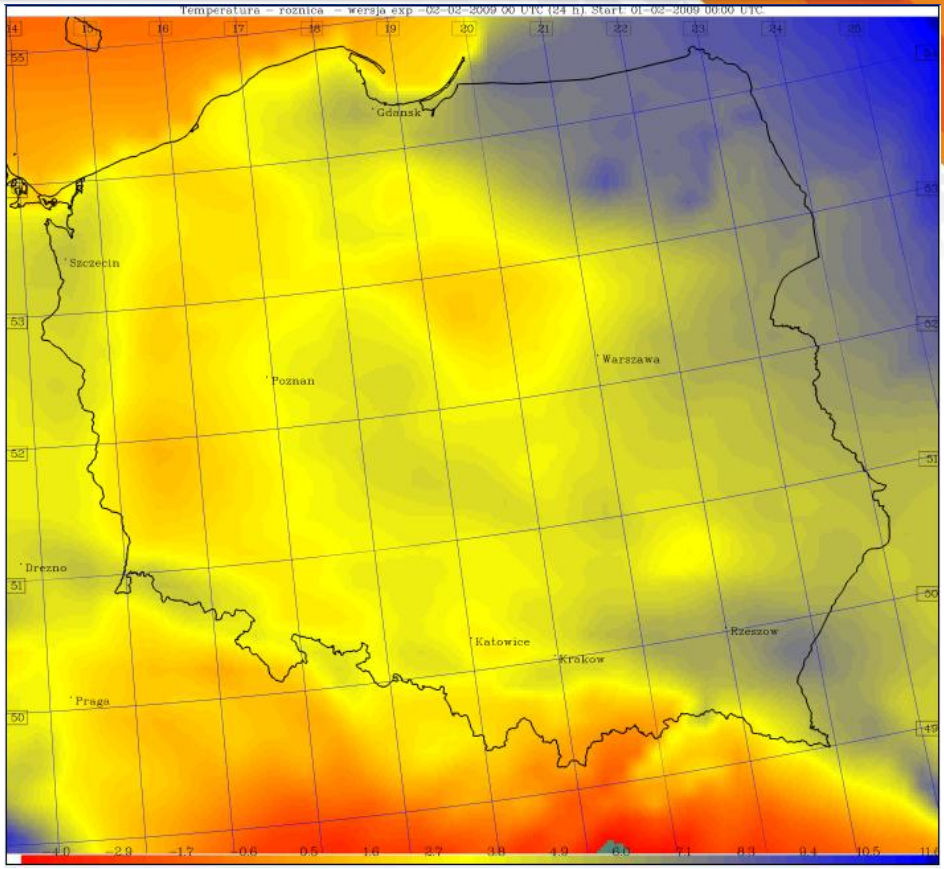
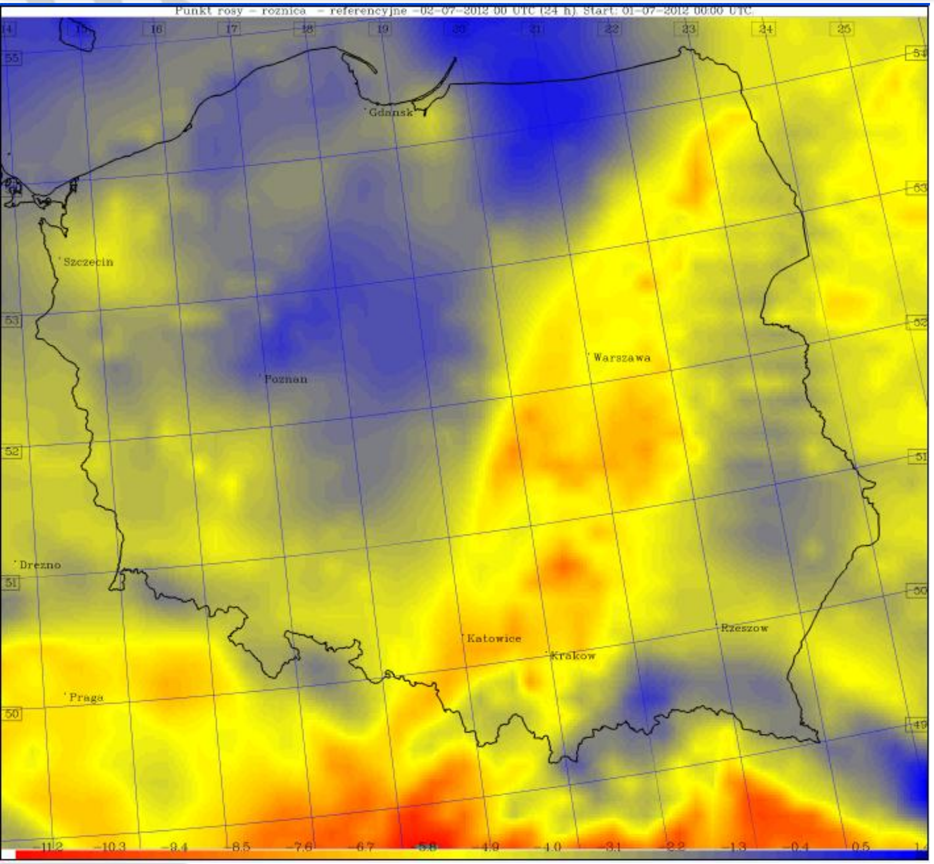
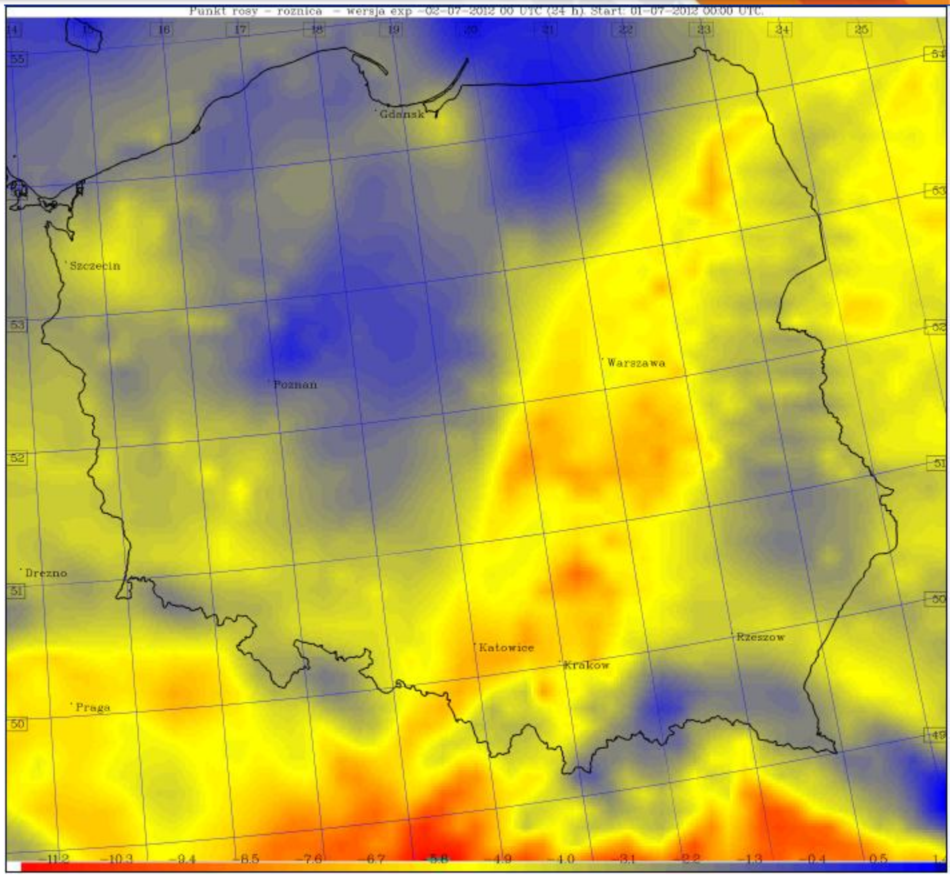


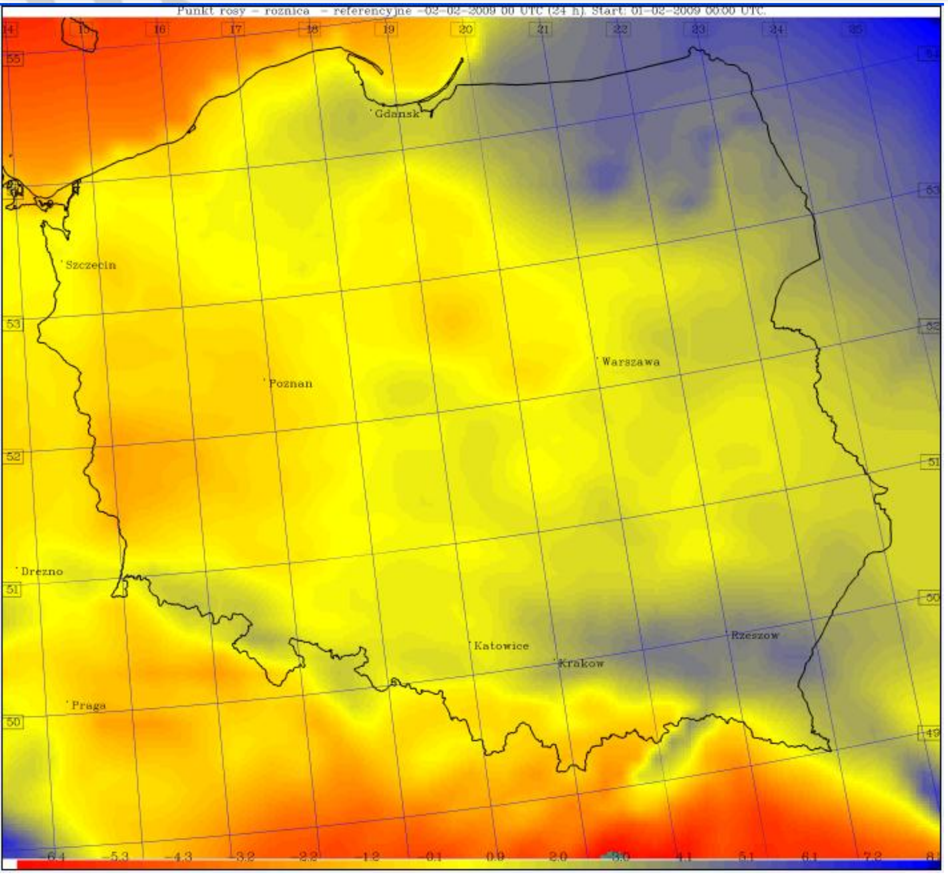



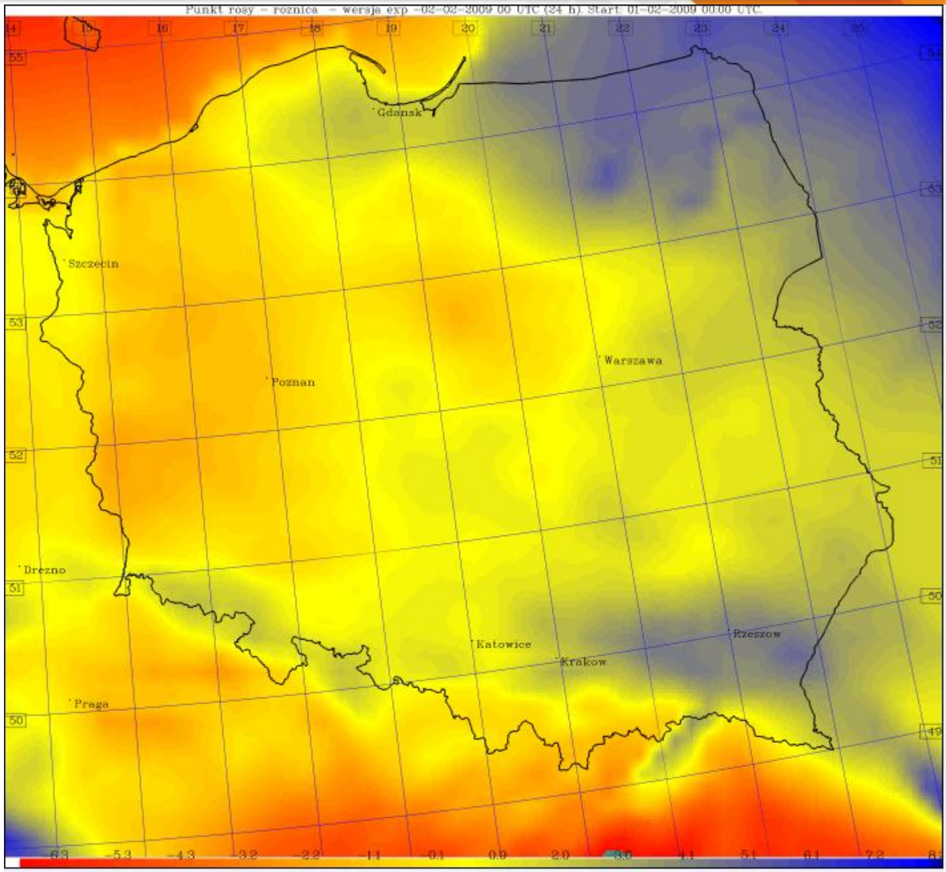
# Differences between observation and model results for dew point temperature (1 VII 2012)



## Differences between observation and model results for dew point temperature (1 II 2009)



# Outline results

- exponential function of soil temperature for loam and sandy soil

## Another version

- Correction of Darcian equation „version 2”:

$$F_m = -D(\theta) e^{b(\theta)\frac{T}{T_0}} \nabla \theta$$

Richards' equation

- Richards' equation for „version 2":

$$\frac{\partial\theta}{\partial t}=D_0\left\{-\frac{D_1}{\theta_1-\theta_2}\left(\frac{\partial\theta}{\partial z}\right)^2+\left(\frac{\partial b(\theta)}{\partial z}\frac{T}{T_0}+\frac{b}{T_0}\frac{\partial T}{\partial z}\right)\frac{\partial\theta}{\partial z}+\frac{\partial^2\theta}{\partial z^2}\right\}e^{-D_1\frac{\theta_1-\theta}{\theta_1-\theta_2}+a+b\frac{T}{T_0}}+$$

$$+\frac{K_0K_1}{\theta_1-\theta_2}\frac{\partial\theta}{\partial z}\exp\left(K_1\frac{\theta_1-\theta}{\theta_1-\theta_2}\right)+\nabla\left(D_T\nabla T\right)$$

## Next correction

- Correction of Darcian equation – „version 3"

$$F_m = -D(\theta) e^{b(\theta)\left(\frac{T}{T_0}\right)^{\alpha(\theta)}} \nabla \theta$$

## Richards' equation

- Richards' equation for „version 3":

$$\frac{\partial\theta}{\partial t}=D_0\left\{-\frac{D_1}{\theta_1-\theta_2}\left(\frac{\partial\theta}{\partial z}\right)^2+\left(\frac{\partial b(\theta)}{\partial z}\left(\frac{T}{T_0}\right)^{\alpha(\theta)}+b(\theta)\frac{\partial\alpha(\theta)}{\partial z}\left(\frac{T}{T_0}\right)^{\alpha(\theta)-1}\frac{\partial T}{\partial z}\right)\frac{\partial\theta}{\partial z}+\frac{\partial^2\theta}{\partial z^2}\right\}e^{-D_1\frac{\theta_1-\theta}{\theta_1-\theta_2}+a+b\frac{T}{T_0}}+$$

$$+\frac{K_0K_1}{\theta_1-\theta_2}\frac{\partial\theta}{\partial z}\exp\left(K_1\frac{\theta_1-\theta}{\theta_1-\theta_2}\right)+\nabla\left(D_T\nabla T\right)$$

# Outline results

- MOSAIC – „don’t satisfy” – results were much worse
- Changes were connected with SWC and soil temperature (about 1‰).
- Air temperature, dew point temperature, wind speed without change.

## Alternative equation for moisture flux through surface

- Alternative equation for „F" – modification of Campbell's parameterization :

a) version 1:

$$F_m = -K_0 \phi_0 B \left( \frac{\theta}{\theta_0} \right)^{B+2} \left( \frac{T}{T_0} \right)^{B} \frac{\partial \theta}{\partial z} - D_T \nabla T - K(\theta) \nabla z$$

b) version 2:

$$F_m = -K_0 \phi_0 B \left( \frac{\theta}{\theta_0} \right)^{B+2} e^{\left( a + b \frac{T}{T_0} \right)} \frac{\partial \theta}{\partial z} - D_T \nabla T - K \nabla z$$

## Alternative equation for moisture flux through surface

- Alternative equation for „F" – modification of Campbell's parameterization:

a) version 3 :

$$F_m = -K_0\phi_0 B\left(\frac{\theta}{\theta_0}\right)^{B+2} e^{\left(b(\theta)\frac{T}{T_0}\right)} \frac{\partial\theta}{\partial z} - D_T\nabla T - K\nabla z$$

b) version 4:

$$F_m = -K_0\phi_0 B\left(\frac{\theta}{\theta_0}\right)^{B+2} e^{\left(b(\theta)\left(\frac{T}{T_0}\right)^{\alpha(\theta)}\right)} \frac{\partial\theta}{\partial z} - D_T\nabla T - K\nabla z$$

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SERWIS POGODOWY IMGW-PIB

- Richards equation „for version 1”:

$$\frac{\partial\theta}{\partial t} = K_0\phi_0 B\left(\frac{\theta}{\theta_0}\right)^{B+1}\left(\frac{T}{T_0}\right)^{B-1}\left\{\frac{T}{T_0}\frac{B+2}{\theta_0}\left(\frac{\partial\theta}{\partial z}\right)^2 + \frac{\theta}{\theta_0}\frac{B}{T_0}\frac{\partial\theta}{\partial z}\frac{\partial T}{\partial z} + \frac{\theta}{\theta_0}\frac{T}{T_0}\frac{\partial^2\theta}{\partial z^2}\right\} +$$

$$+\frac{K_0 K_1}{\theta_1-\theta_2}\frac{\partial\theta}{\partial z}\exp\left(K_1\frac{\theta_1-\theta}{\theta_1-\theta_2}\right) + \nabla\left(D_T\nabla T\right)$$

Richards' equation

- Richards equation „for version 2":

$$\frac{\partial\theta}{\partial t} = K_0\phi_0 B\left(\frac{\theta}{\theta_0}\right)^{B+1}\left(\frac{T}{T_0}\right)^{B-1}\left\{\frac{T}{T_0}\frac{B+2}{\theta_0}\left(\frac{\partial\theta}{\partial z}\right)^2+\frac{\theta}{\theta_0}\frac{b}{T_0}\frac{\partial T}{\partial z}\frac{\partial\theta}{\partial z}+\frac{\theta}{\theta_0}\frac{T}{T_0}\frac{\partial^2\theta}{\partial z^2}\right\}+$$

$$+\frac{K_0K_1}{\theta_1-\theta_2}\frac{\partial\theta}{\partial z}\exp\left(K_1\frac{\theta_1-\theta}{\theta_1-\theta_2}\right)+\nabla\left(D_T\nabla T\right)$$

- Richards equation „for version 3":

$$\frac{\partial\theta}{\partial t}=K_0\phi_0 B\left(\frac{\theta}{\theta_0}\right)^{B+1}\left(\frac{T}{T_0}\right)^{B-1}\left\{\frac{T}{T_0}\frac{B+2}{\theta_0}\left(\frac{\partial\theta}{\partial z}\right)^2+\frac{\theta}{\theta_0}\left(\frac{\partial b(\theta)}{\partial z}\frac{T}{T_0}+\frac{B}{T_0}\frac{\partial T}{\partial z}\right)\frac{\partial\theta}{\partial z}+\frac{\theta}{\theta_0}\frac{T}{T_0}\frac{\partial^2\theta}{\partial z^2}\right\}+$$

$$+\frac{K_0K_1}{\theta_1-\theta_2}\frac{\partial\theta}{\partial z}\exp\left(K_1\frac{\theta_1-\theta}{\theta_1-\theta_2}\right)+\nabla\left(D_T\nabla T\right)$$

- Richards equation „for version 4”:

$$\frac{\partial\theta}{\partial t}=K_0\phi_0 B\left(\frac{\theta}{\theta_0}\right)^{B+1}\left(\frac{T}{T_0}\right)^{B-1}\left\{\frac{T}{T_0}\frac{B+2}{\theta_0}\left(\frac{\partial\theta}{\partial z}\right)^2+\frac{\theta}{\theta_0}\left(\frac{\partial b(\theta)}{\partial z}+b(\theta)\left(\frac{\partial\alpha(\theta)}{\partial z}\ln\left(\frac{T}{T_0}\right)+\frac{\alpha(\theta)T_0}{T}\frac{\partial T}{\partial z}\right)\right)\left(\frac{T}{T_0}\right)^{\alpha(\theta)}\frac{\partial\theta}{\partial z}+\frac{\theta}{\theta_0}\frac{T}{T_0}\frac{\partial^2\theta}{\partial z^2}\right\}+$$

$$+\frac{K_0K_1}{\theta_1-\theta_2}\frac{\partial\theta}{\partial z}\exp\left(K_1\frac{\theta_1-\theta}{\theta_1-\theta_2}\right)+\nabla\left(D_T\nabla T\right)$$

## Change hydraulic diffusivity

- Based on terrain observation:

$$D(\theta)=\eta\frac{\theta}{\theta_0}\left(1+\frac{\ln\frac{\theta}{\theta_0}}{\ln 10}\right)^2+D_{\min}$$

- and moisture flux through the surface :

$$F_m=-\left(\eta\frac{\theta}{\theta_0}\left(1+\frac{\ln\frac{\theta}{\theta_0}}{\ln 10}\right)^2+D_{\min}\right)f\left(\frac{T}{T_0},\frac{\theta}{\theta_0}\right)\nabla\theta$$

# Summary

a) By the end of August we will have finished the work on „bare soil" parameterization and we will publish our results.

b) In the next steps we will include plant coverage in our description.

Thank you for your attention ☺

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