INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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Thermal Remote Sensing for analyses of landscape functions

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HYDAP
The latest remote sensing technologies in the service of research, education and application for regional development
1st Announcement Kick-off Meeting, November 14-16, 2012, Czech Globe AV ČR v.v.i. Brno

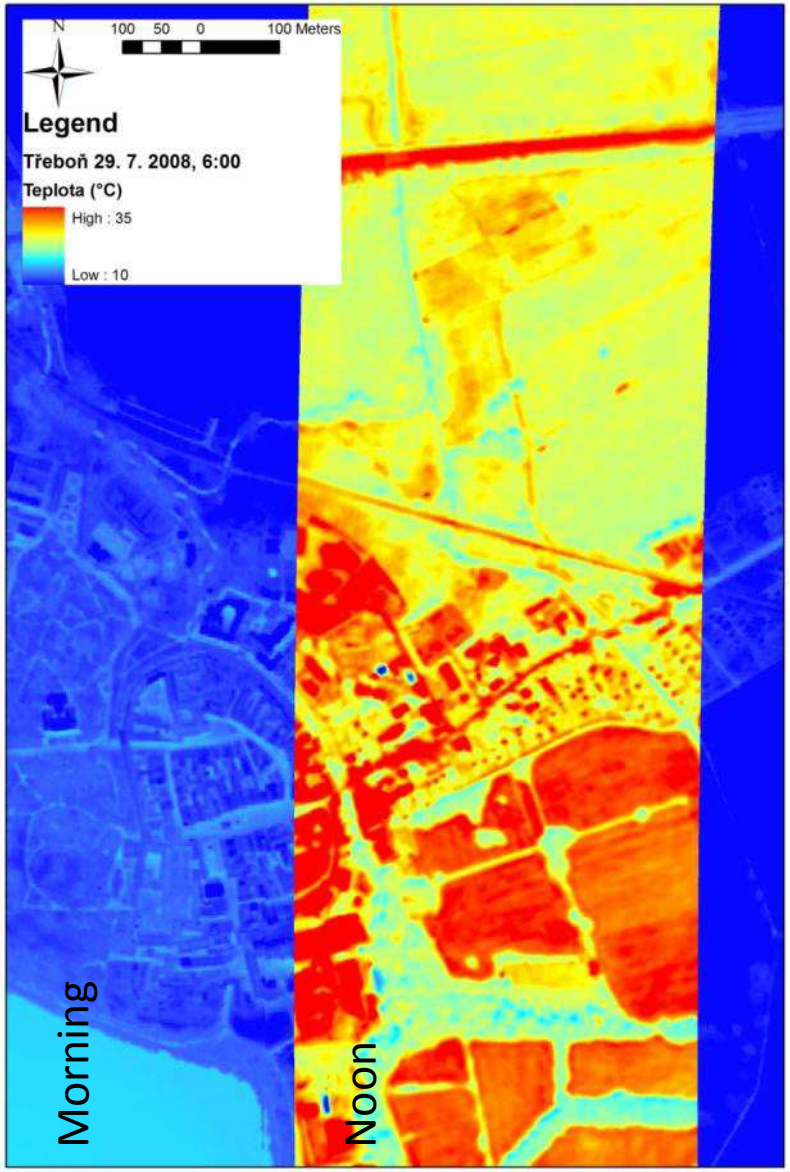
Usage of TIR data

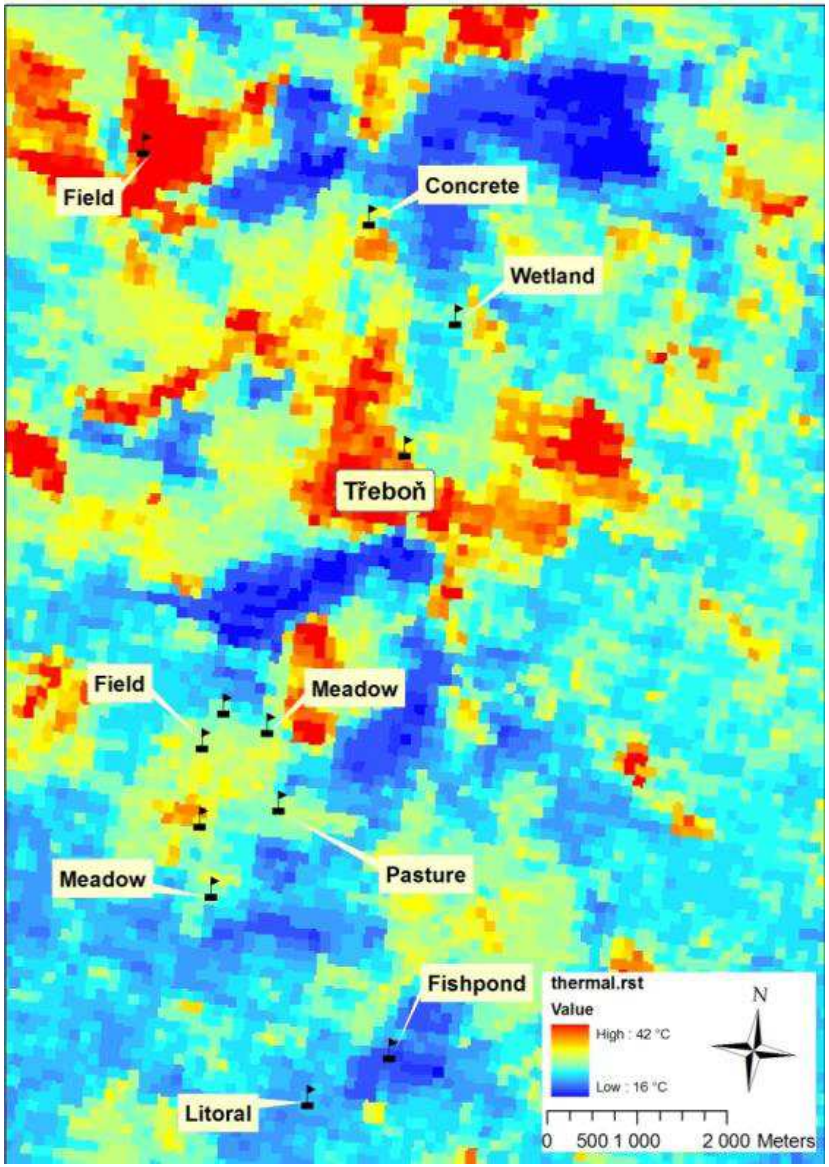
- TIR layer
- Combination of TIR and MS/HS data
- Modelling of energy balance features

TIR layer

- Surface temperature is a result of land surface biophysical behaviour
  - Exchange of energy
  - Physical properties of surface (colour, shape, roughness, heat accumulation ability, amount of water)
  - Biological processes – vegetation behaviour (transpiration, changing of shape)

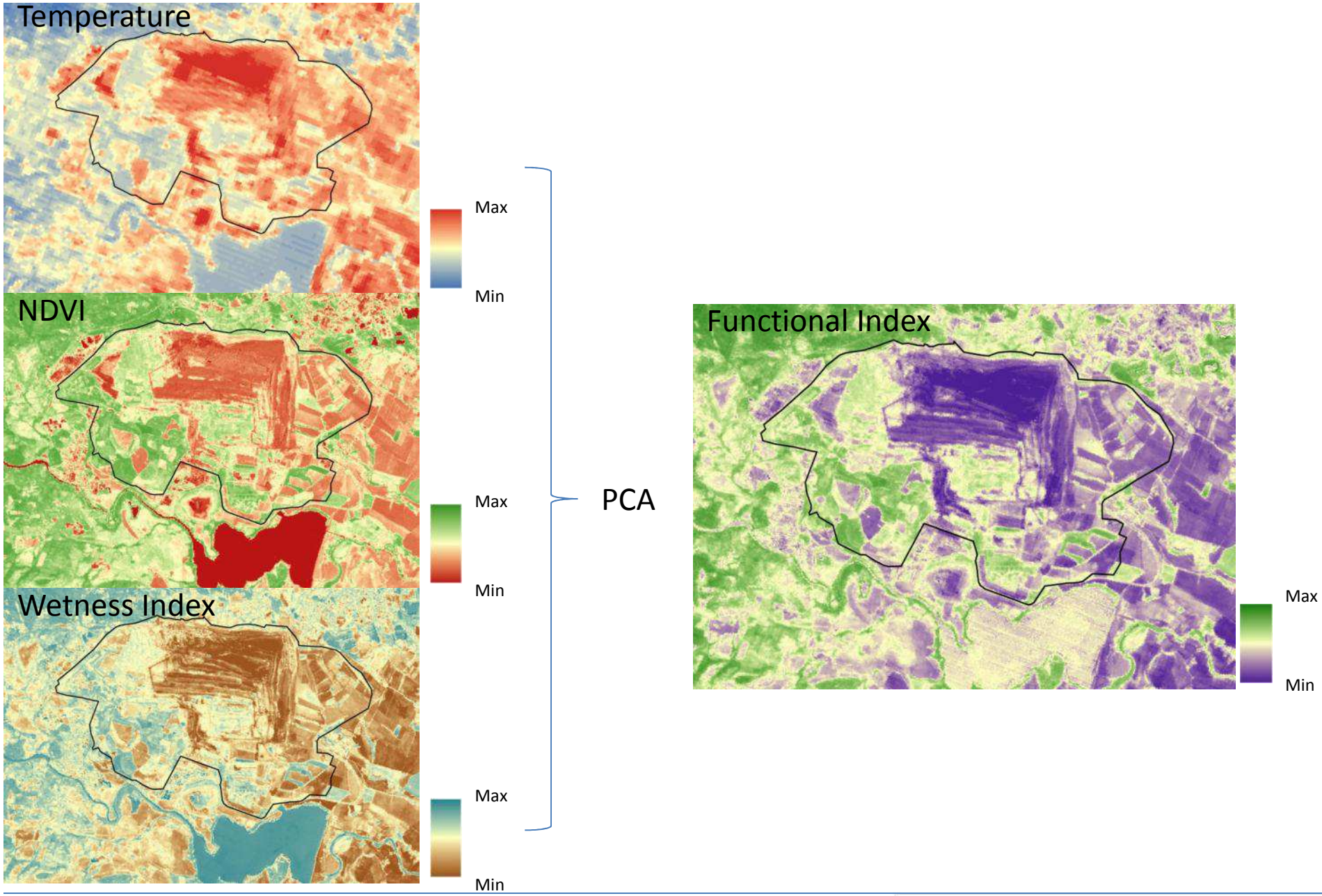
➢ Surface temperature is an integral indicator





Combination of TIR and additional RS data

- Spectral indices creation
  - Empirical approach
  - (non)linear combination – e.i. PCA
- No physical extent – relative scale
- Indices allow take more information about land surface into account
- Enlarging ability for analysis (e.i. classification)



Modelling of energy balance features

- Pursuit of processes description on physical basis
- +/- physical, semi-empirical or empirical approaches
- Need for additional data
  - Additional RS data (MS/HS optical data)
  - Meteorological data (air temperature, humidity, wind speed etc.)
  - Field data (vegetation height, units of LULC etc.)

➢ Complex issue

Energy balance features

- Energy fluxes (net radiation (Rn), latent (LE), sensible (H) and ground (G) heat fluxes)

$$Rn = G + H + LE$$

- Intensity of evapotranspiration
- Energy balance indices
  - Bowen ratio
  - Evaporative fraction
  - Decoupling coefficient (relative evaporation)
- Vegetation (crop) water stress
- Etc.

Energy balance – Net radiation

- Combination of optical and TIR data

$$Rn = Rs_{\downarrow} - Rs_{\uparrow} + Rl_{\downarrow} - Rl_{\uparrow}$$

- Rs↓ - shortwave radiation (meteostation)
- Rs↑ - reflection (optical data)
- Rl↓↑ - balance of longwave radiation (TIR data)

Energy balance – Ground heat flux

- Combination of net radiation and optical data

$$G = \frac{T_s}{\alpha}\left(0{,}0038\alpha + 0{,}0074\alpha^2\right)\left(1 - 0{,}98NDVI^4\right)Rn$$

- Ts – surface temperature (TIR)
- α – albedo (rel.; optical data)
- NDVI – Normalized Difference Vegetation Index (optical data)
- Rn – net radiation

Energy balance – latent heat flux

- „Big leaf“ approach
- Depends on surface humidity -> it is not possible computing LE directly or there are important limitations

$LE = Rn – G – H$

➢ LE is result of computing H and solution of energy balance equation

Energy balance – sensible heat flux

- H can be computed using Ohm´s law

$$H = \frac{\rho c_p \left(T_s - T_a\right)}{r_a}$$

- ρ – dry air density (kg.m^{-3}; constant)
- c_p – specific heat of air (J.kg^{-1}.K^{-1}; constant)
- Ts – surface temperature (°C; TIR data)
- Ta – air temperature (°C; meteostation)
- r_a – aerodynamic resistance of surface

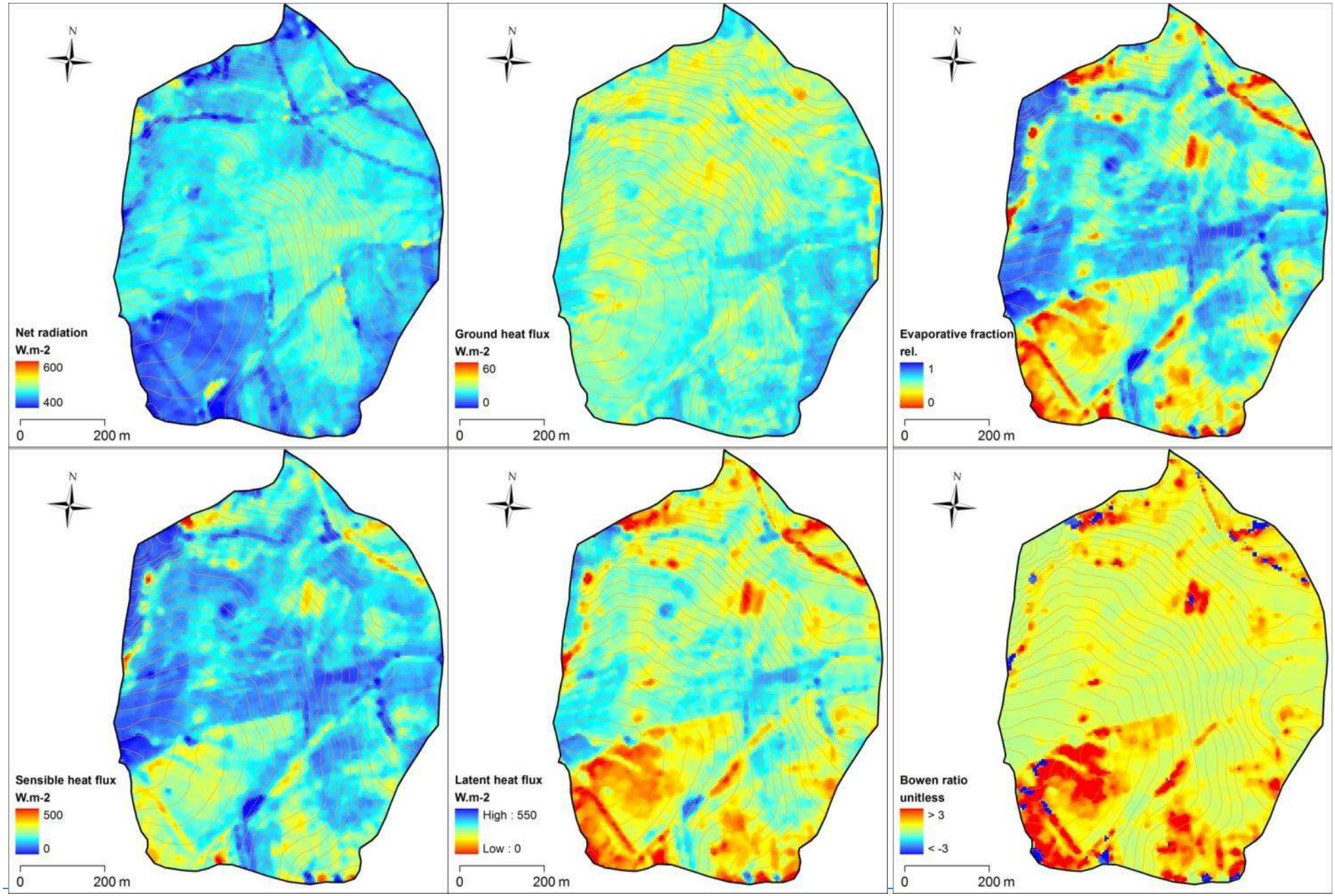
Aerodynamic resistance of surface

- Depends on:
  - Vegetation shape (height, LAI) – using MSAVI
  - Wind speed (measured – meteo)
  - Atmospheric stability
    - Computed according to Richardson number
    - Monin-Obukhov similarity theory (iterative process with system of equations)

$$r_a = \frac{\left[\ln\left(\frac{z-d}{z_{0m}}\right) - \Psi_m(\varsigma)\right] \cdot \left[\ln\left(\frac{z-d}{z_{0h}}\right) - \Psi_h(\varsigma)\right]}{U \cdot k^2}$$

Energy balance - indices

- Complemetary information about dissipative processes at relative or unitless scale
- Evaporative fraction – ratio of available energy used in evaporation (rel.) $EF = \frac{LE}{Rn - G} = \frac{1}{1 + \beta}$
- Bowen ratio $\beta = \frac{H}{LE}$
- Omega factor (Decoupling coefficient) $\Omega = \frac{LE}{LE_p}$



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Crop water stress

- Result of changing water amount in plant´s tissues
- Closing of stomata
- Reduction of transpiration
- Changes in spectral reflectance
- Changes in energy balance

Crop water stress

- Spectral changes – in NIR (700-1300 nm) and SWIR (1300-3000 nm) -> 970, 1200, 1400 a 1940 nm
  - Spectral indices
    - Water Index (WI)
    - WI/NDVI ratio
    - Moisture Stress Index (MSI)
    - Normalized Difference Water Index (NDWI)
    - Normalized Difference Moisture Index (NDMI) etc.
- Indices following from energy balance modelling
  - CWSI (Crop Water Stress Index)

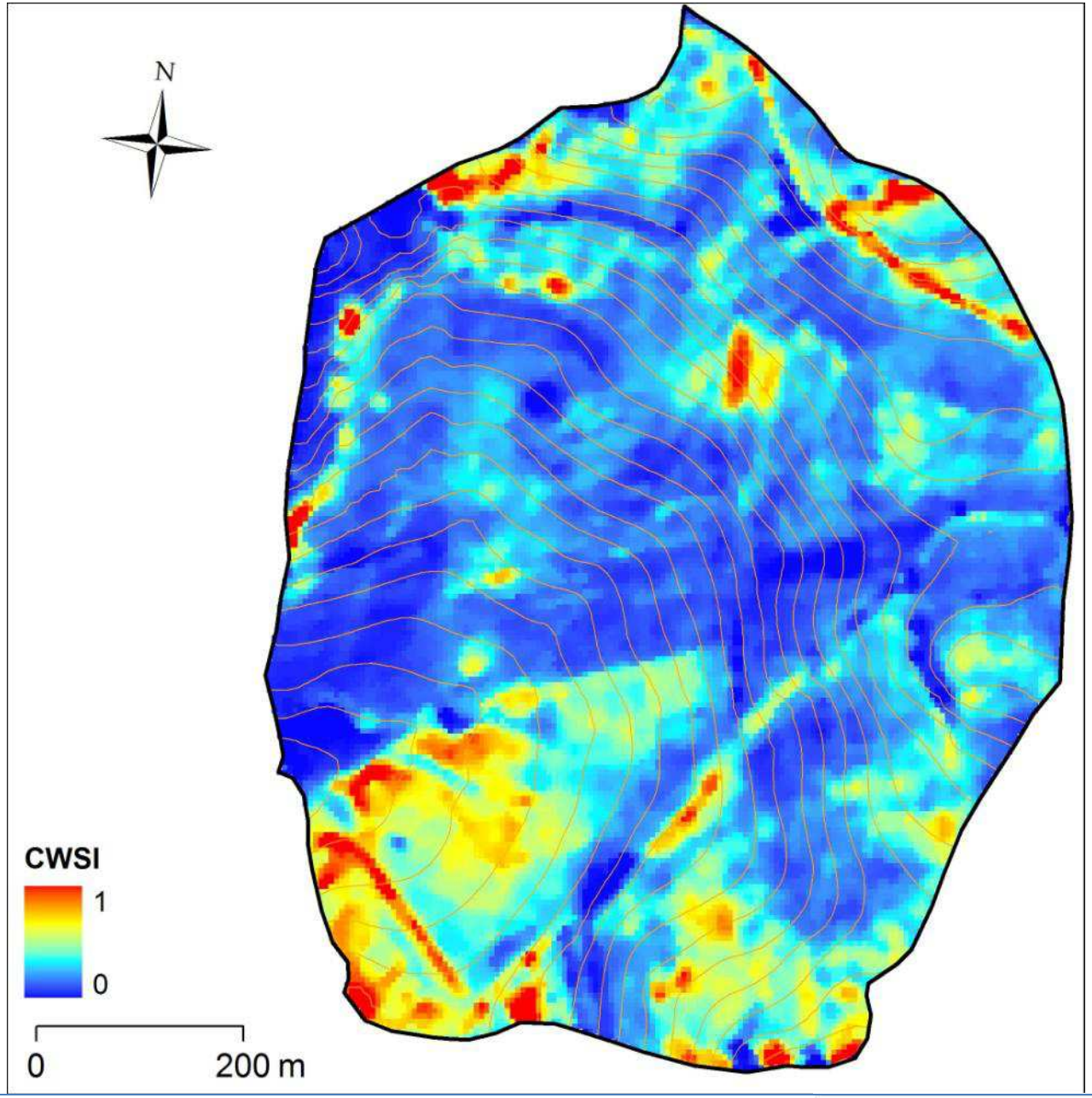
Crop Water Stress Index

- Plant surface temperature is changing with changes in transpiration

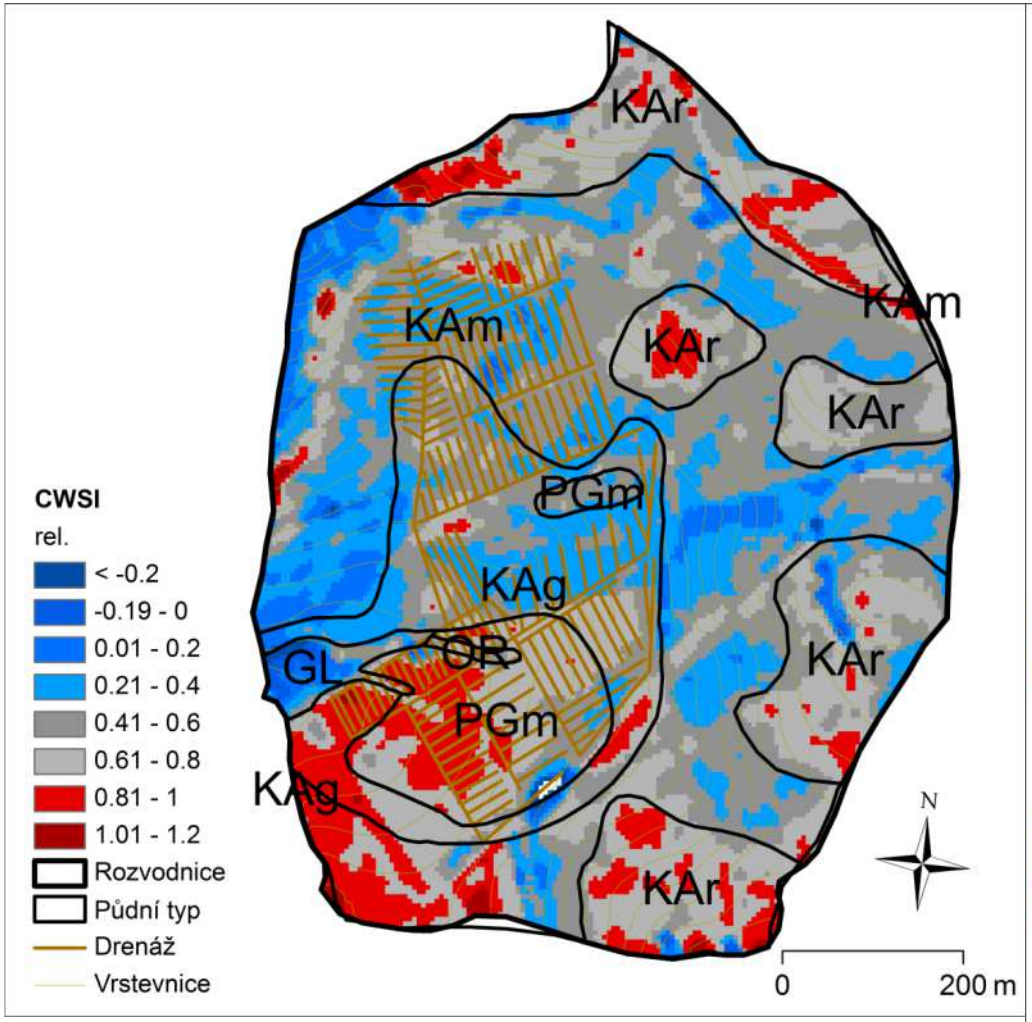
➢ change in cooling effect of water evaporation

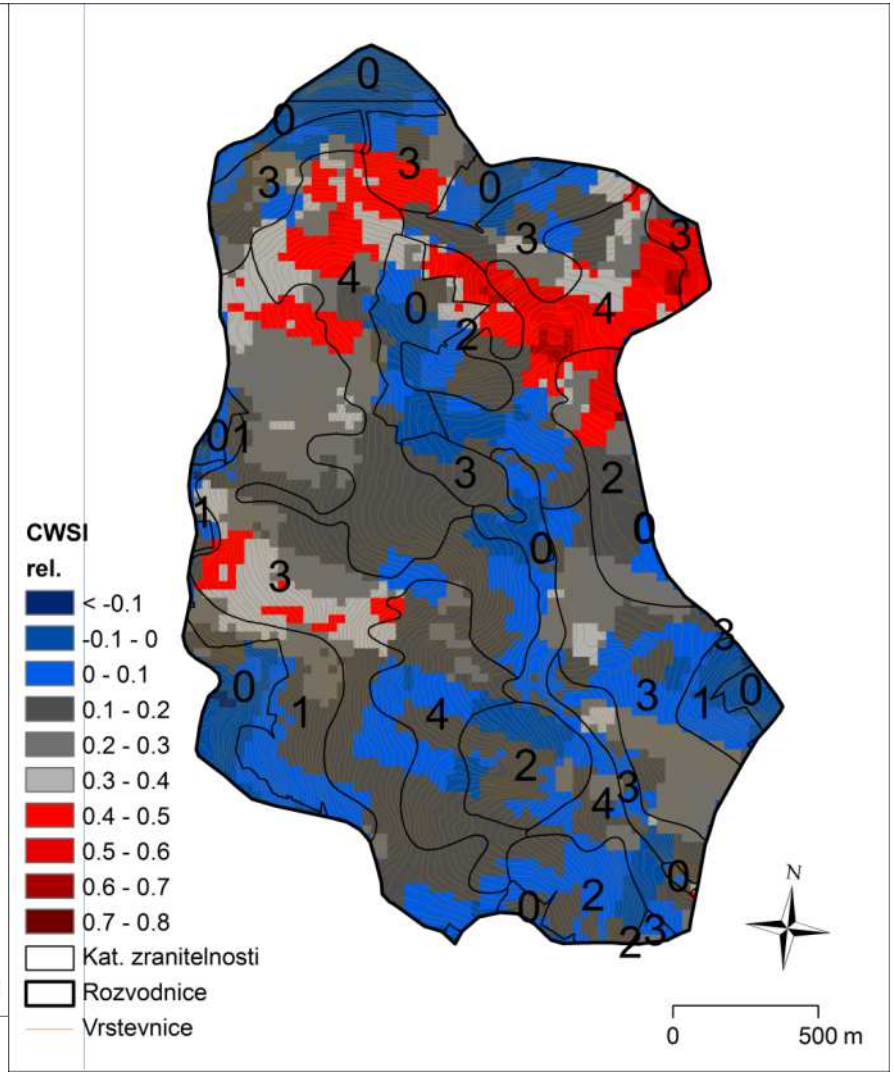
$$CWSI = \frac{\gamma\left(1+\frac{r_c}{r_a}\right)-\gamma^*}{\Delta+\gamma\left(1+\frac{r_c}{r_a}\right)} = \frac{\left(T_c-T_a\right)_{ll}-\left(T_c-T_a\right)}{\left(T_c-T_a\right)_{ll}-\left(T_c-T_a\right)_{ul}} = \frac{T_{c\_\min}-T_c}{T_{c\_\min}-T_{c\_\max}}$$

- Thermometry applications, irrigation etc.



Example – Identification of infiltration zones





Thank You for Your Attention!

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