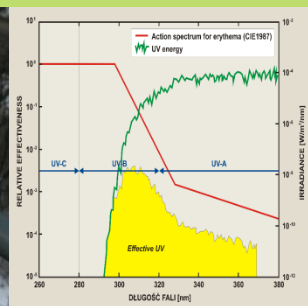

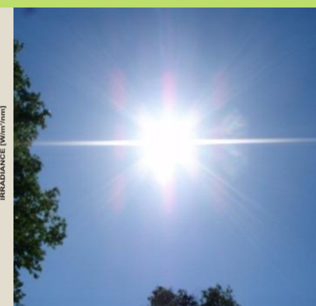

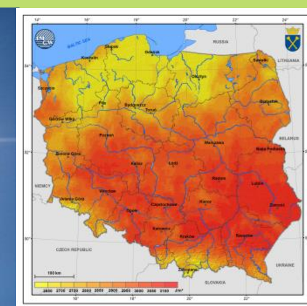

Application of the CM-SAF SIS product for geostatistical modeling of solar erythemal UV radiation over Poland

Preliminary results

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Introduction

Title of my Ph.D. thesis:

Spatial distribution and temporal variability of biologically effective UV radiation (UV_{BIO}) over Poland

3 main activities:

1. Mapping UV_{BIO} climatologies
2. UV_{BIO} time series analysis for selected locations
3. Evaluating Influence of local environmental factors on personal UV_{BIO} exposure

Activity 1-2: based on reconstructed hourly erythemal doses and satellite data (CM-SAF SIS, SRTM, NIWA/Bodeker TCO) $\rightarrow$ *gridded UV_{BIO} climatology (1986-2010)*

COOPERATION WITH AEROLOGY CENTER, IMGW-PIB WARSAW (data reconstruction)

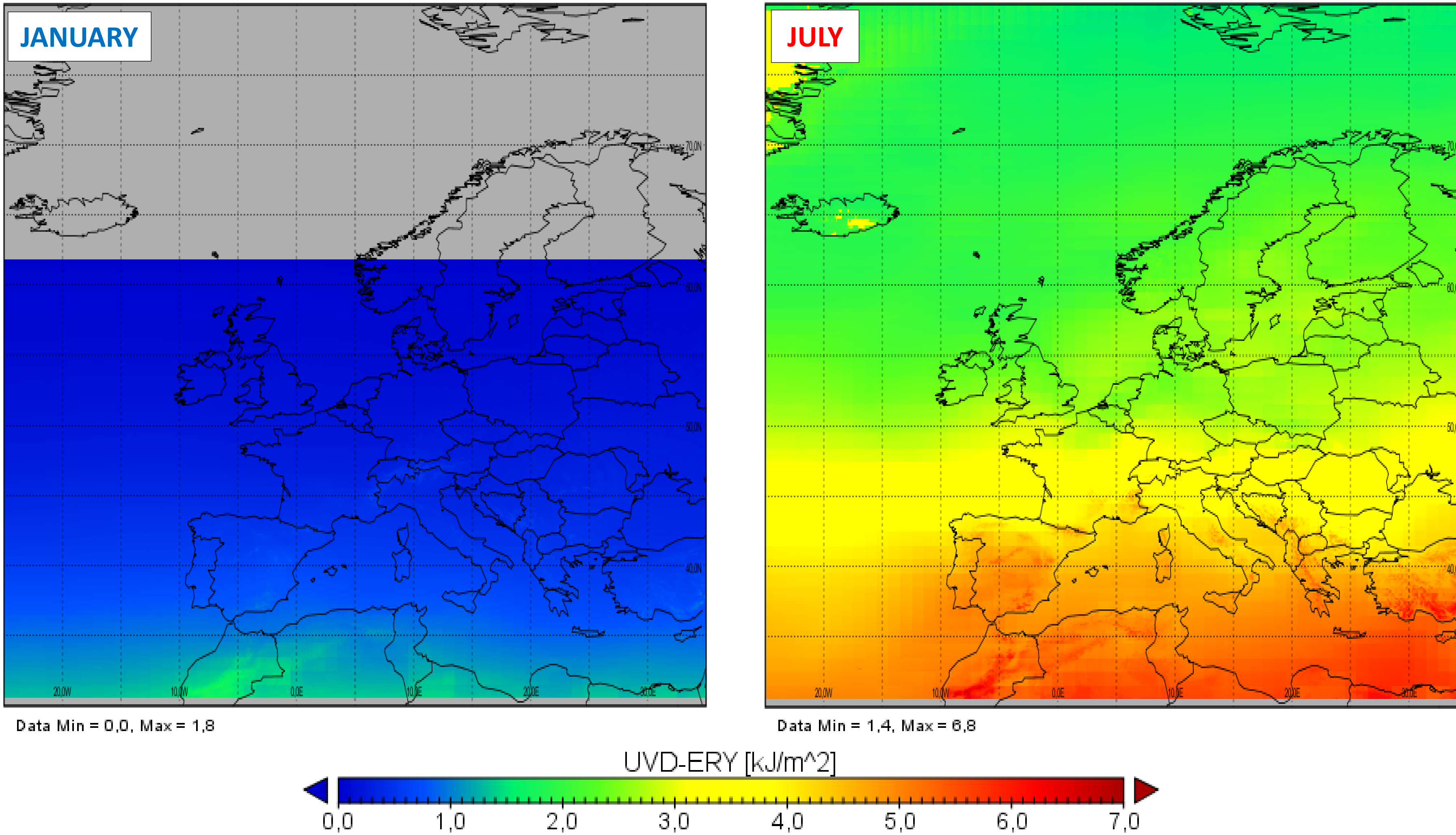
Activity 3: based on field measurements of erythemal UV radiation in summer seasons (2011-2013) $\rightarrow$ *UV_{BIO} dosimetry*

COOPERATION WITH DMI AND BBH IN COPENHAGEN (measurement instruments and strategy)

Mapping UV_{BIO} climatologies and time series analysis

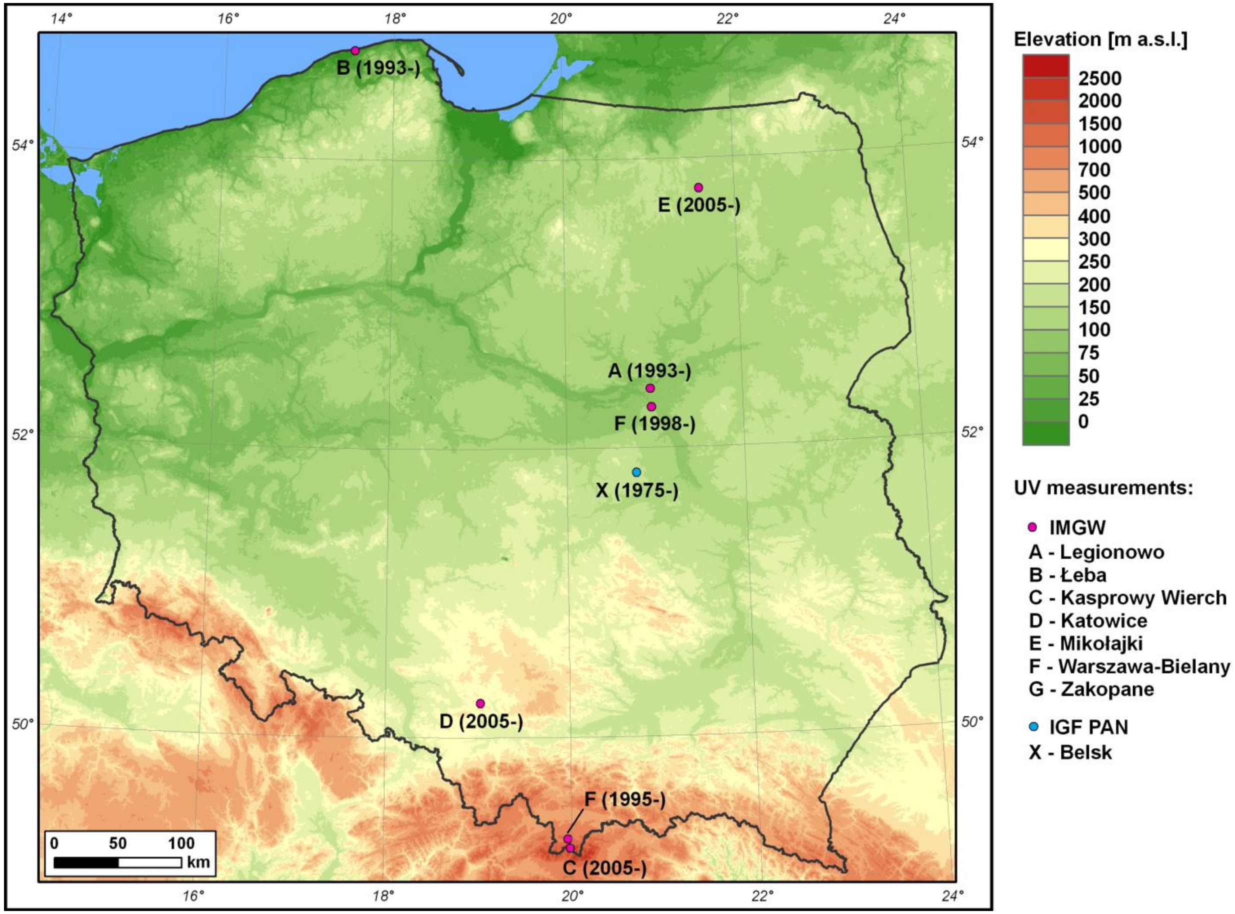
- Creation of high-resolution (~1x1km) erythemally effective solar UV radiation maps over Poland at monthly time steps for the period 1986-2010 (25-years)
- Application of spatial prediction algorithm with the use of satellite data
- Evaluation of spatial pattern and temporal changes with particular emphasis on extreme values.
- Online dissemination of research outcome in the form of informative web service with e-atlas showing regions and periods with extremely high and low UV values over Poland and its potential impacts on human health

Monthly mean erythemal daily dose in Europe (1952-2002)



Source data: *COST-726 – 'Long term changes and climatology of UV radiation over Europe'*
Product algorithm: *Jean Verdebout (JRC, Ispra, IT)*
Spatial resolution: *0.05° × 0.05°*

UV solar radiation measurements in Poland

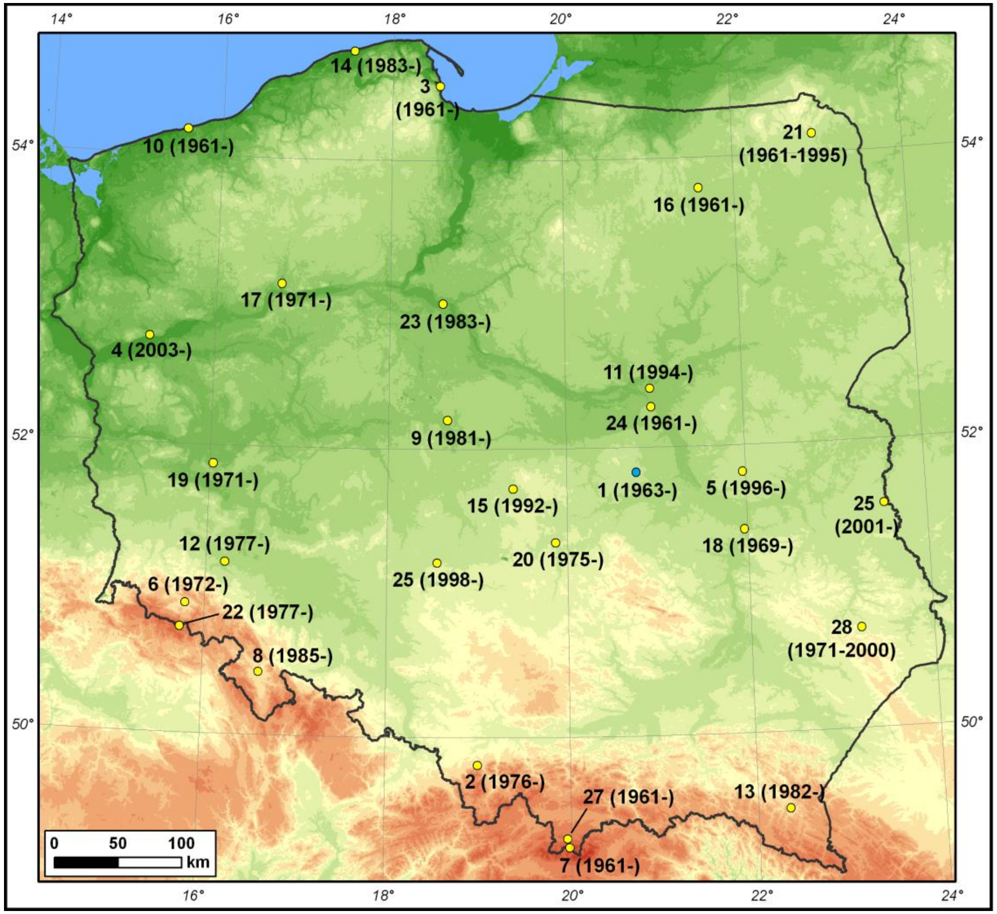


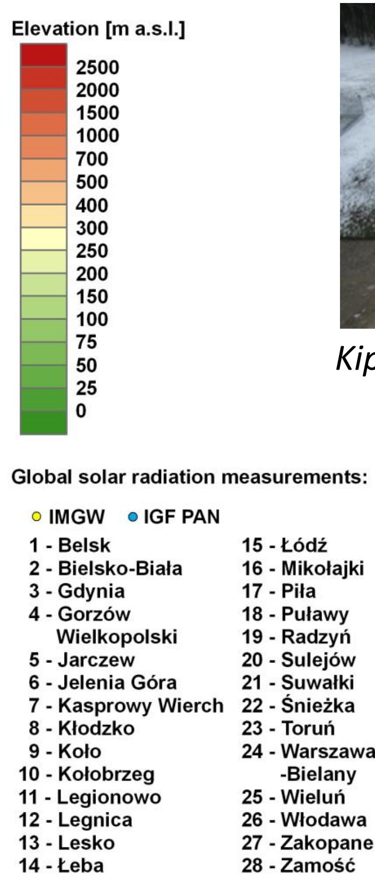
Solar Light 501 UVB Biometer with broadband sensor [Legionowo]

Optix UVEM-6C Multi sensor UVB radiometer [Zakopane]

NILU-UV018 multispectral radiometer [Legionowo]

Global solar radiation measurements in Poland

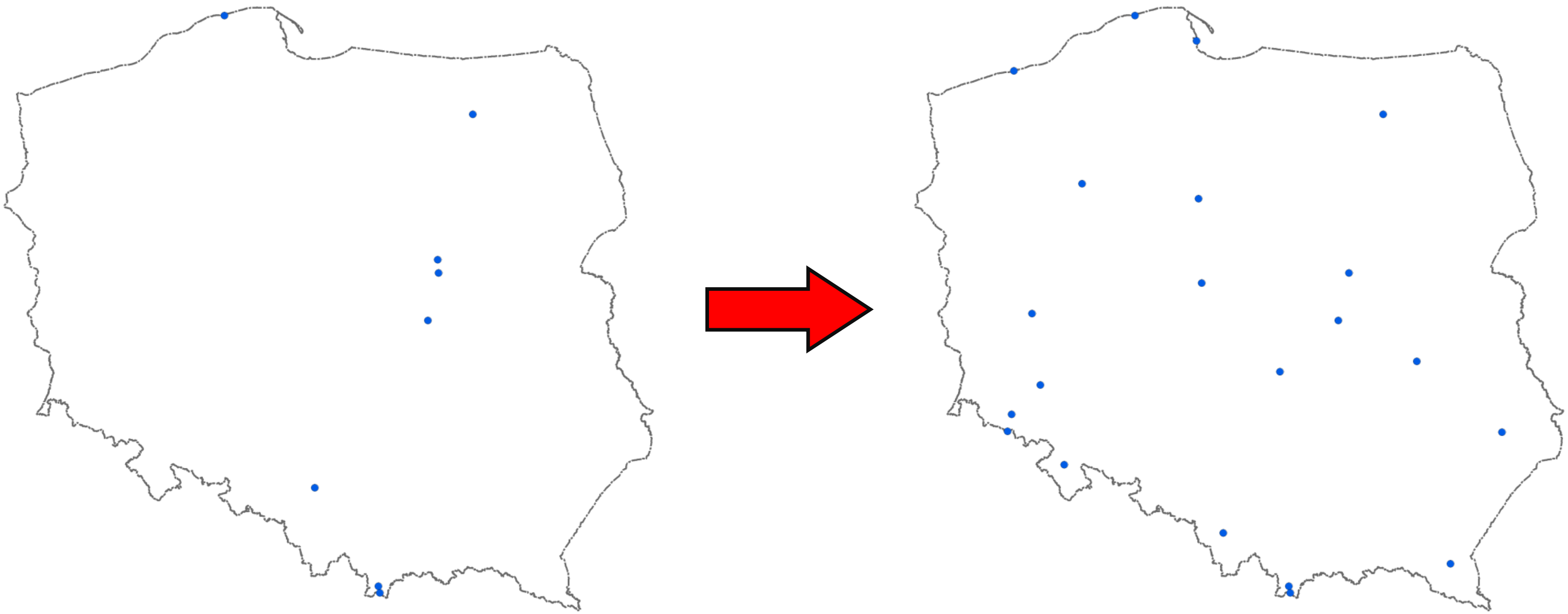




Kipp&Zonen CM6B Pyranometer [Legionowo]

Kipp&Zonen CM6B Pyranometer supplied with ventilation fan and heater [Zakopane]

UV reconstruction



- **Empirical formula** based on several years of concurrent GSR and UVR measurements in Legionowo, including auxiliary data: total ozone content, cloud cover, aerosol properties, solar zenith angle and snow cover

***Number of stations (sample points) selected:** 21*

***Time-series length:** 25 years (1986 – 2010)*

- **Made it possible to reconstruct hourly UV irradiance for longer period and for more locations.**

ACKNOWLEDGEMENT:
ALEKSANDER CURYŁO (AEROLOGY CENTRE, IMGW-PIB,)

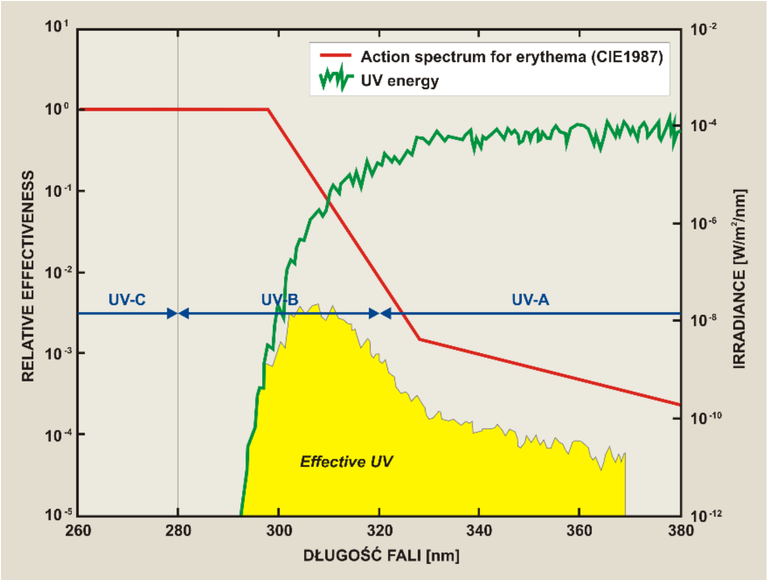
Erythemally effective UV irradiance (UV_{ERY}):

- **Definition**:

$$UV_{ERY} = \int_{200}^{400} F(\lambda) B(\lambda) d\lambda$$

$F(\lambda)$ - monochromatic UV irradiance at a given wavelength λ [$W \cdot m^{-2} \cdot nm^{-1}$]

$B(\lambda)$ - action spectrum for erythema (CIE 1987) at a given wavelength λ



Relative effectiveness of the UV energy in reddening of the skin

- **Pre-processing workflow:**

EMPIRICA RECONSTRUTION

↓

HOURLY UV_{ERY} IRRADIANCE [$mW \cdot m^{-2}$]

↓ **INTEGRATION OVER TIME**

HOURLY UV_{ERY} DOSE [$J \cdot m^{-2}$]

→ **AVERAGING OVER TIME**

MEAN MONTHLY UV_{ERY} DOSE [$J \cdot m^{-2}$]

Additional environmental (explanatory) variables

Static variables (constat over time, spatial resolution: 0.01 x 0.01 dg):

- CGIAR-CSI post-processed 3-arc second SRTM digital **elevation** database
- gridded **latitude**

Dynamic variables (changing over time, resolution: 0.05 x 0.05 dg):

- CM-SAF SIS (monthly mean **solar surface irradiance**), merged Meteosat MVIRI and SEVIRI datasets)
- NIWA/Bodeker-Scientific TCO (monthly mean **total column ozone** dataset combining measurements from a number of different satellite-based instruments (TOMS, GOME, SBUV)

Spatial prediction procedure

Multiple Linear Regression Kriging (MLRK)

- **Multiple Linear Regression Analysis** – explanation of deterministic part with the use of additional (explanatory) variables:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \varepsilon$$

y – dependent variable, the variable we are trying to model (predict)

x_1, x_2, x_n – explanatory variables , strongly correlated with dependent variable, which can help to explain its spatial distribution

$\beta_0, \beta_1, \beta_n$ – coefficients, reflecting the relationship and strength of each explanatory variable to dependent variable

ε – the portion of the dependent variable that is not explained by the regression model, residual error

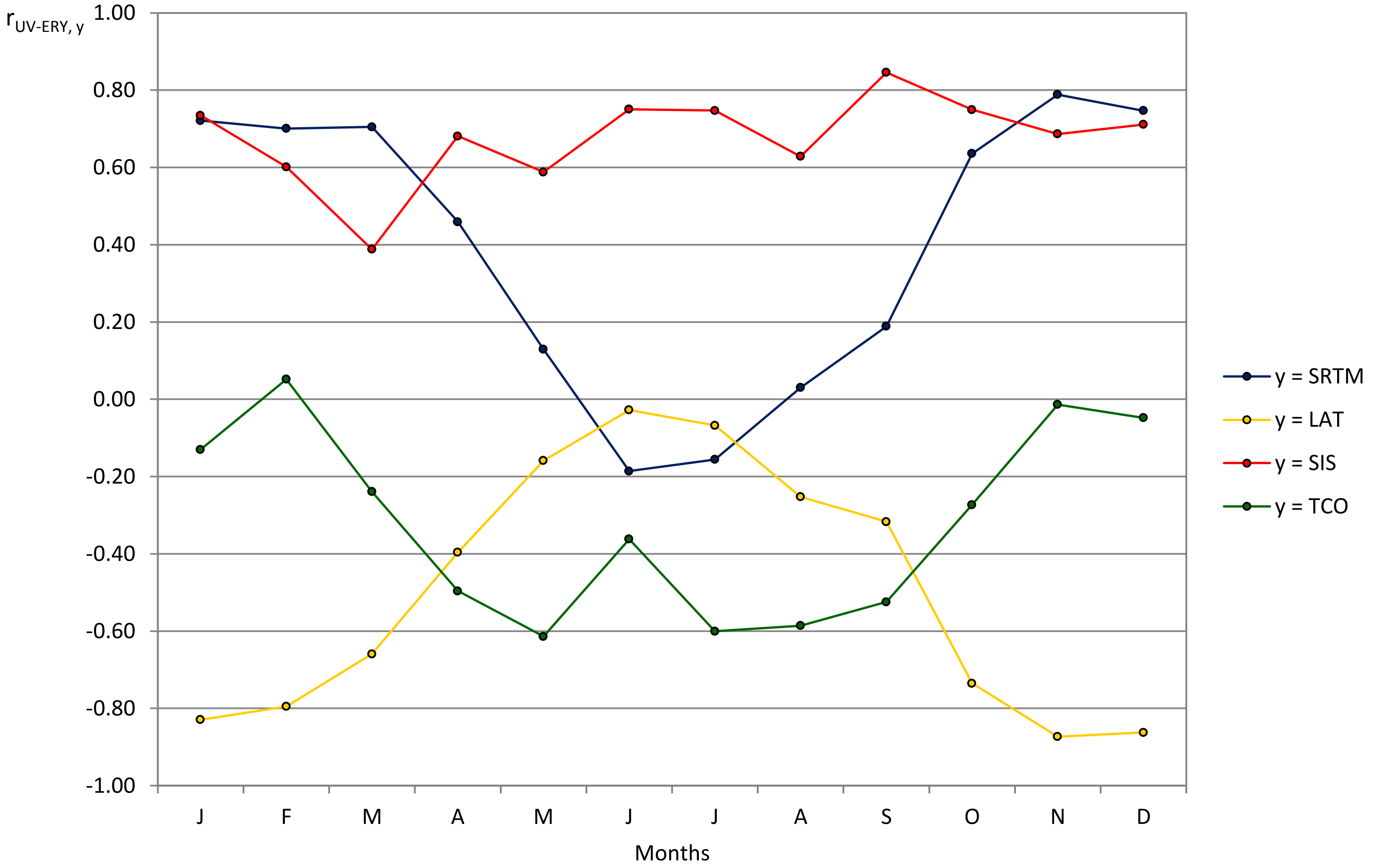
$$UV_{ERY} = \beta_0 + \beta_1 \times SRTM + \beta_2 \times LAT + \beta_3 \times SIS + \beta_4 \times TCO + \varepsilon$$

- **Spatial interpolation of the regression residuals (ε)** with Ordinary Kriging (OK)

- **Accuracy assessment** of the spatial prediction model

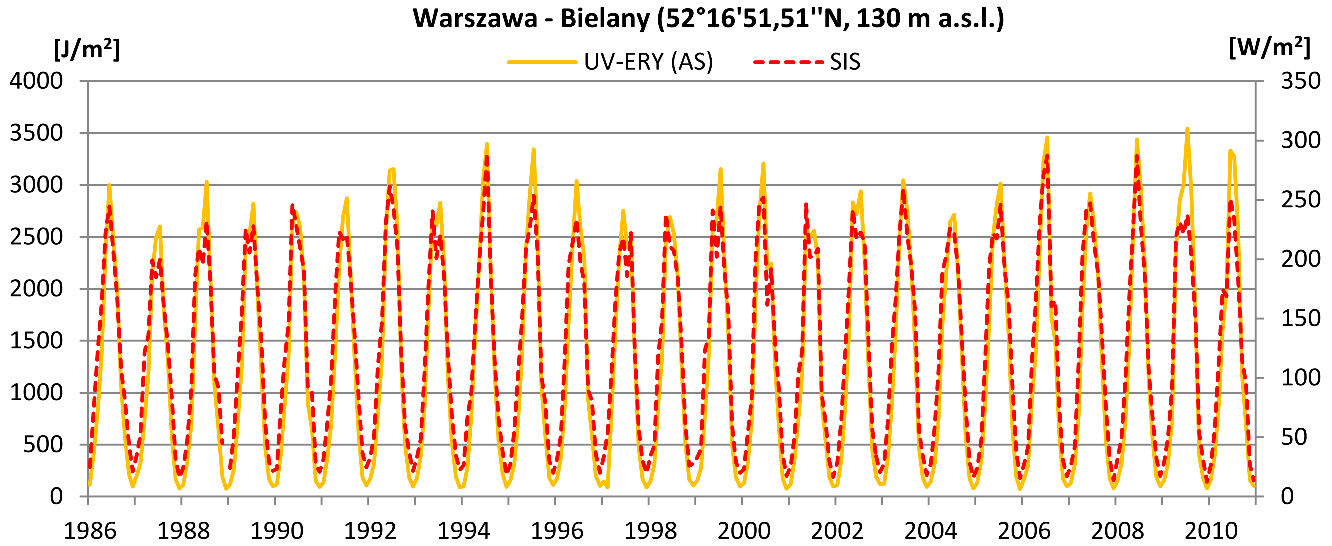
  Cross-**v**alidation(***CV***) → *leave-one-out* routine → evaluation of prediction errors,

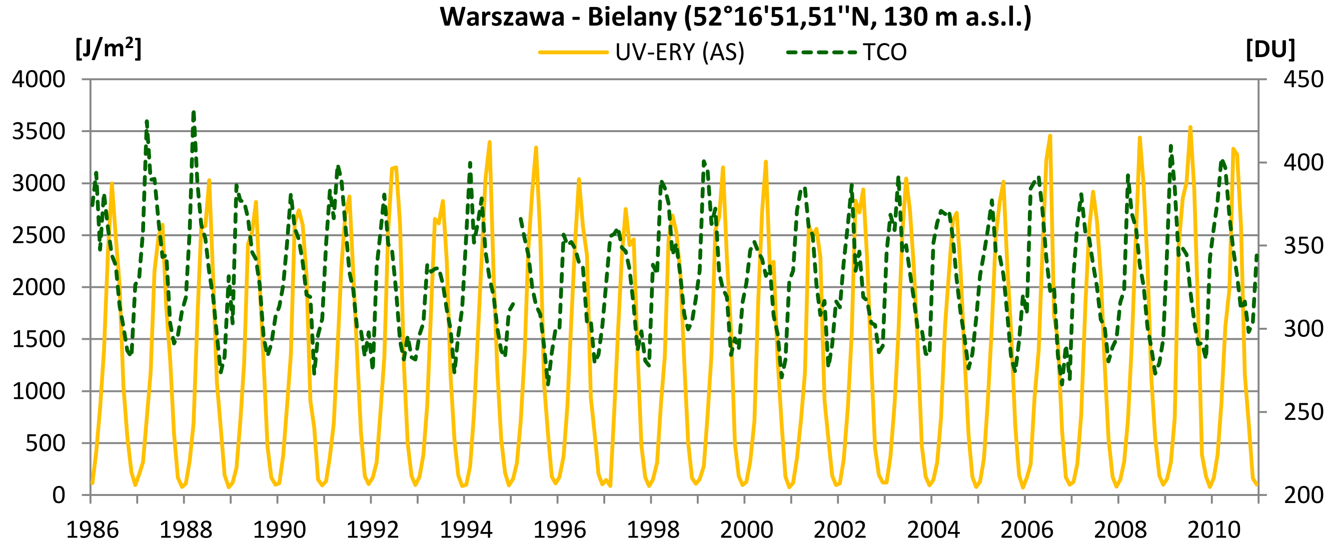
Comparison of correlation coefficients



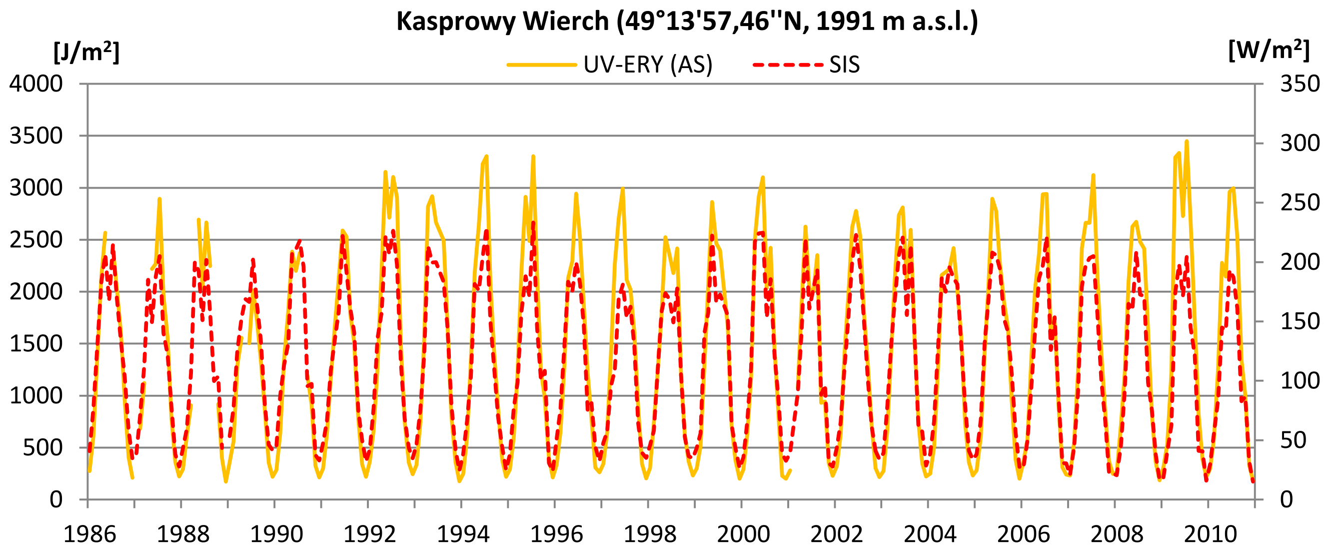
ALL 300 GRIDS INCLUDED!

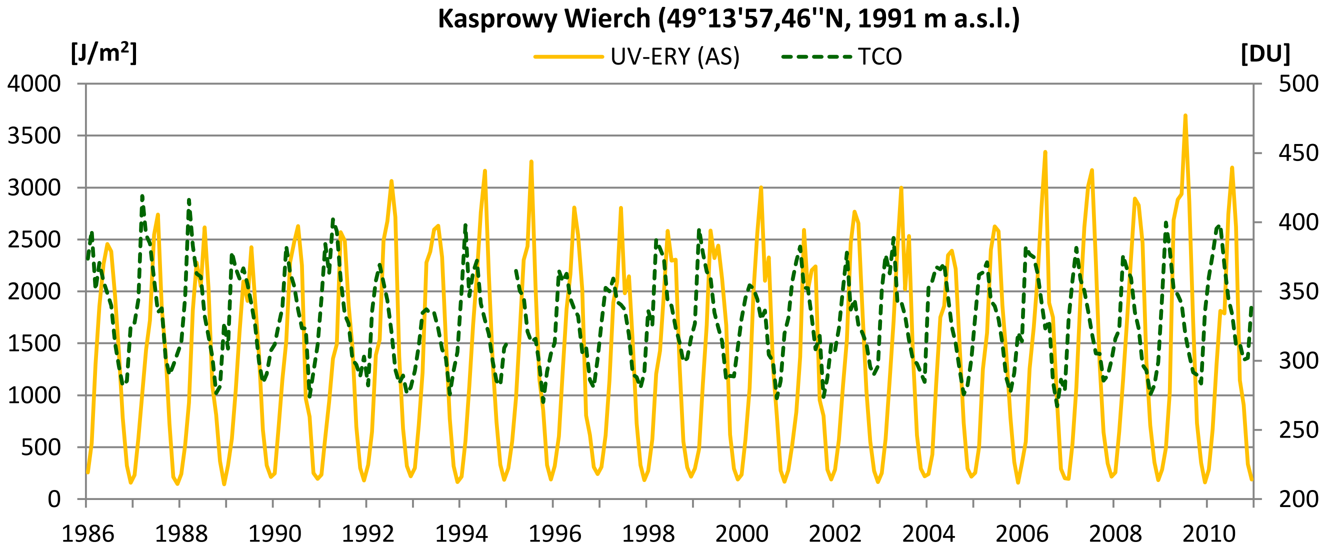
Comparison of UV_{BIO}, SIS and TCO time series





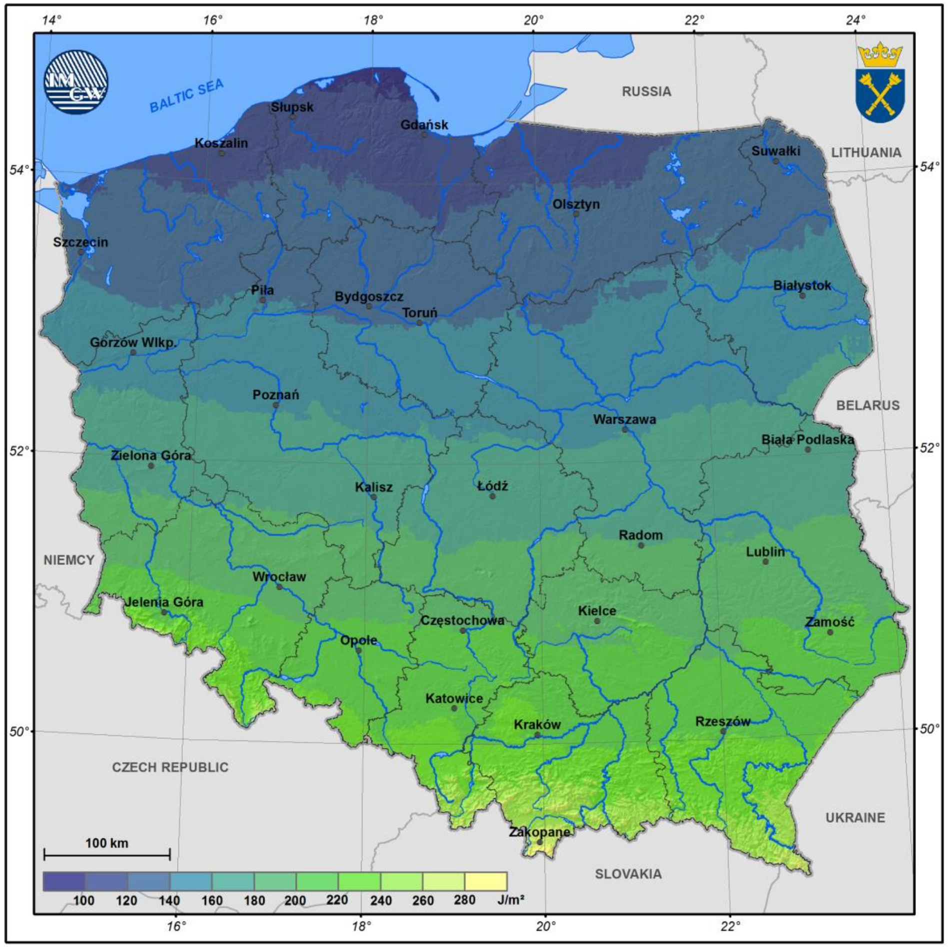
Comparison of UV_{BIO}, SIS and TCO time series



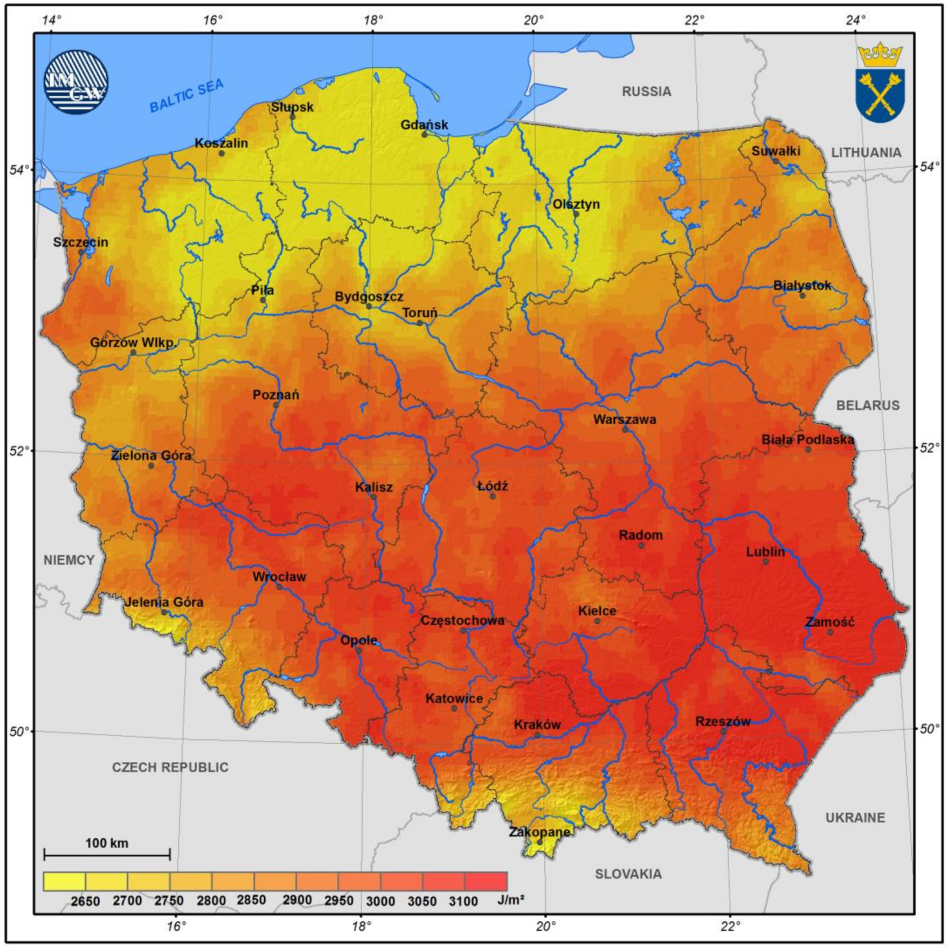


Monthly mean UV_{ERY} daily dose (1986-2010)

JANUARY



JULY



Time series: COST-726 + MLRK

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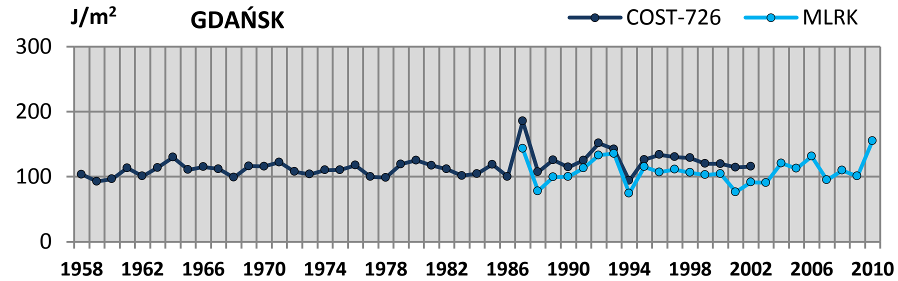
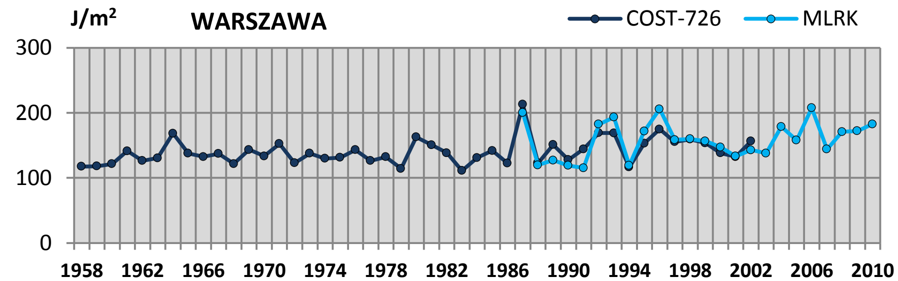
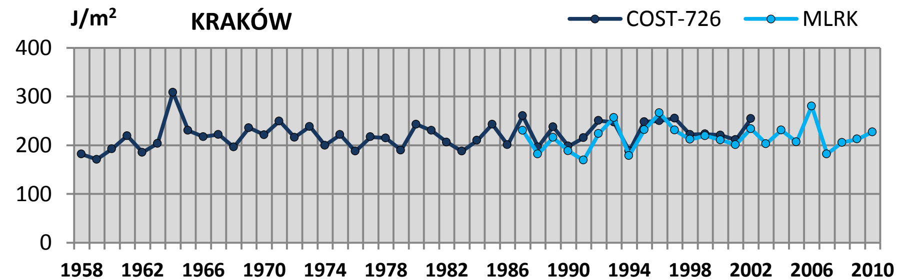
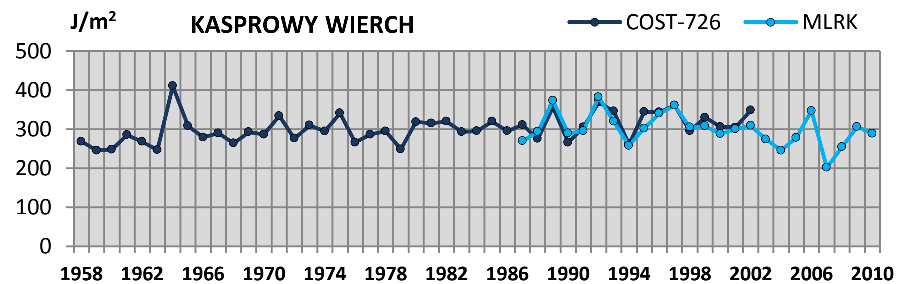


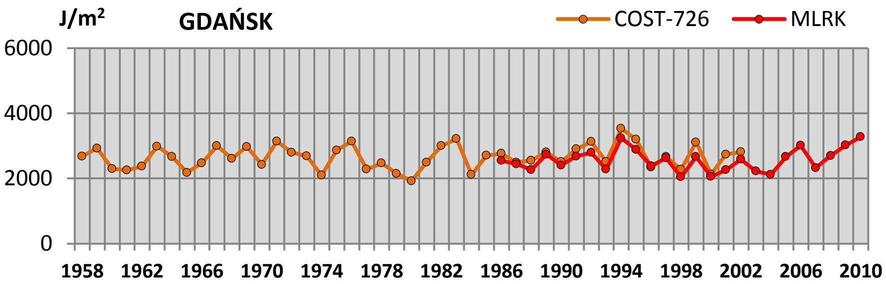


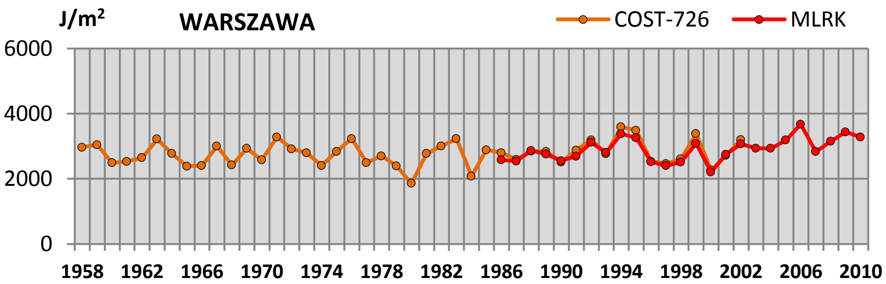


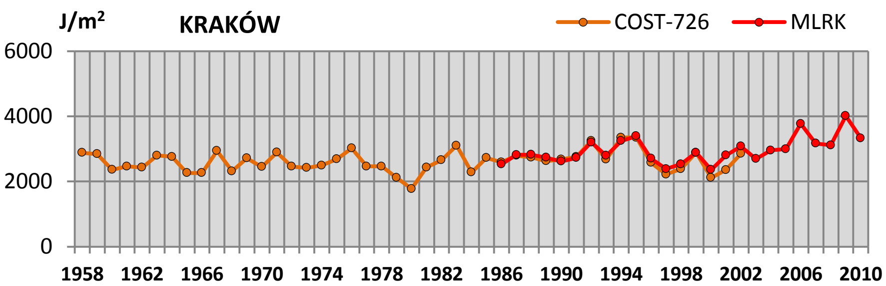


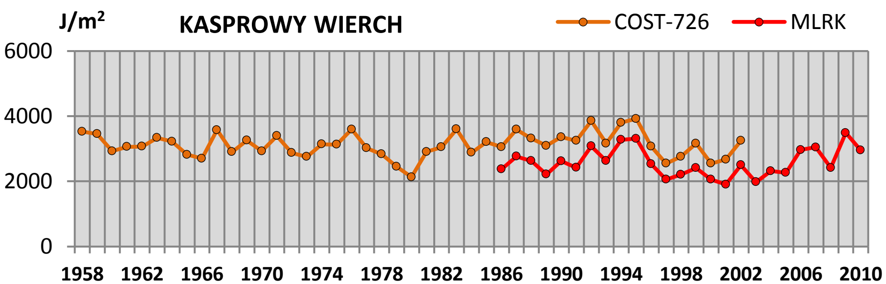
Time series: COST-726 + MLRK

JULY



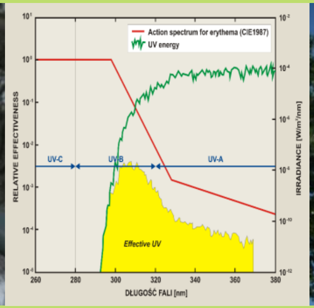


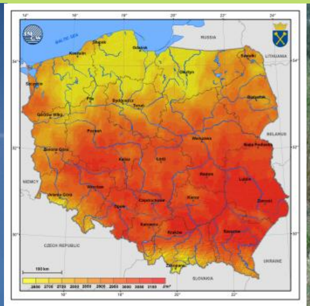




Concluding remarks

- Empirical formula on the basis of global solar radiation measurements enabled reconstruction hourly solar erythemal UV radiation record for 21 locations all over Poland and a period 25-years (1986-2010)
- Presented spatial prediction model (MLRK) was successfully used to compute high resolution (~1x1km) UV_{BIO} grids (spatially continuous satellite data as predictors!)
- GIS made it possible to integrate data from different sources, implement geostatistical formulas, automate processing of data (Model builder + Python scripting) and create output maps in appropriate digital cartography standards.
- Model limitations:
    - sparse UV monitoring network
    - assumption of linear relationship between elevation and UV data.
    - underestimation of UV levels on mountain tops (spatial resolution of grids)





Thank you for your attention

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