# Climate Changes Prediction Using Remote Sensing Data

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"Earth Observations for Development and Security of Ukraine"

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# Abstract

The analysis for Greenhouse Effect forecasting is performed. A new methodology has been proposed to estimate the Greenhouse Effect and its escalation through coupled ground experimental $CO_2$ and $CH_4$ flows estimation and satellite data analysis was applied. The observed variations of land covers in the areas with different vegetation species and their photosynthetic activity have been analyzed. The detected atmospheric $CO_2$ and $CH_4$ flows values were converted into the air temperature changes and applied to the models of energy-mass exchange in the geospheres for the computer modeling of global and regional climate changes.

# Foresight of Climatic and Socio-Economic Changes in Europe during XXI Century: a View from Space

Lyalko V.I.

## Model of the Global Climate

[Moiseev N.N., Alexandrov V.V., Tarko A.M., 1985]

The model is composed of three non-linear equations, which describe the dynamics of temperature and water of the Earth and the equation river dynamics:

for the air temperature:

$$c\frac{dT}{dt} = Q[1-\alpha(T,X)] - l(T)$$

for the holard:

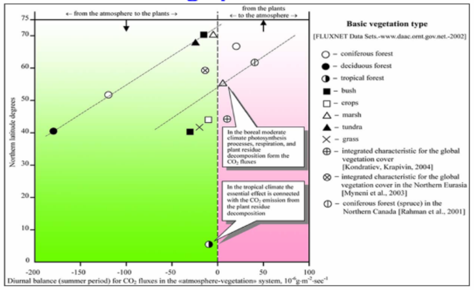
$$\frac{dX}{dt} = P(T) - E(X,T) - Y$$

for the river flow to:

$$\frac{dY}{dt} = G(X) - \frac{Y}{k(X)}$$

where T, X and Y are the global air temperature, general continental holard and the river flow respectively; Q, l(T), $\alpha(T,X)$ – solar constant, solar radiation outflow on the upper atmosphere, and planet albedo accordingly; c – the heat capacity of the «atmosphere-active surface» system, P(T), E(X,T) – precipitate and evaporation from the continental surface, G(X), k(X) – gravity acceleration and the differential time of the river flow relaxation. On this model the presumption about the stable water mass on the Earth was used, which allow to exclude from the description the oceanic water balance

## Balance of $CO_2$ Fluxes in the «Atmosphere-Vegetation» System vs. Species and Geographical Differences

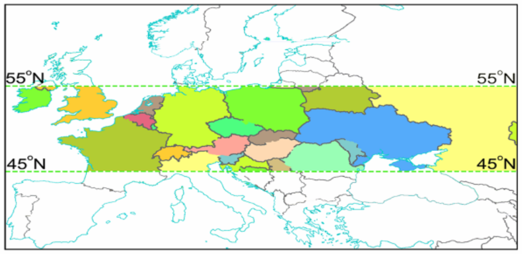


## What needs for the prediction:

- multitemporal space imagery data
- ground measurements of $CO_2$, temperature, moisture
- complex modeling according to the scenarios
- elaboration of preventive decisions for the socio-economical and migration problem optimization

## Scheme

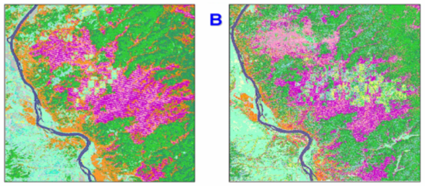
for the Forecasting Average Annual Temperature (to 1,5°C – 2,0°C) and Precipitation Increase (to 10%) in Some European Countries to the Middle of the XXI Century




## Conclusion

- Complex of remote sensing of the Earth, ground $CO_2$ flux measurements, models is the key tool for the climate change prediction
- Climate changes provoke the changes of socio-economical and migration processes
- Climate change in Europe will be optimal for the countries locating within 45°N – 55°N and non-optimal for more southern (dryness) and more northern (turn coldier, windy) countries
- This will induce to the change of socio-economical processes into the different countries and entail the migration flux redistribution of the population
- Therefore now it is needed to carry out the study on the optimization of the migration and socio-economical processes

## Clearings of Dark Coniferous Woodland Within the Bolshoe are Revealed Using the Classified Images Acquired by Landsat MSS (A) and Landsat-7 (B) 21.06 1977 and 22.06.2000




Coniferous forest degradation and disafforestation promote the $CO_2$ return into the atmosphere

Total effect of higher atmosphere temperature induced by technogenic and natural $CO_2$ discharge into the atmosphere may be determined according the simplified expression [Kondratiev C.Ya., Krapivin V.F., 2004]:

$$\Delta T_{CO_2} = -0{,}677 + 3{,}019 \ln \frac{C_a(t)}{C_a(t_0)},$$

where t is time (predicting year) $t_0$ corresponds to 1980, when the $CO_2$ content $(C_a)$ in the atmosphere was estimated as 345ppmV

## Prediction of the Socio-Economic Processes Caused by Climatic Changes Equation for the Artificial Evolution Index (AEI)

[Bushuev V.V., Golubev V.S., Tarko A.M., 2004]:

$$AEI = \alpha E + \beta(SSE) + \gamma(SSC) + \lambda(SVC) + \eta P,$$

where AEI is the synthetic evolution index involving specific capital production (per capita): physical one (PCP) or GDP – gross domestic product), human one (HCP) and ecological one (ECP), AEI=PCP (or GDP) + HCP + ECP.

The society produces physical and human capital and the biota gives ecological one. E – power consumption; SSE – specific social expenses of the country; SSC – specific intellectual capital (a human gains this capital during his life); SVC – specific vital capital (vitality resource that a human has from the birth);

P is specific natural biota annual productivity (tons of carbon per capita). This characteristic and is changes may be determined by remote sensing methods over the vast areas

# The average photosynthetic parameters for the key botanic-geographical formations (adapted for the conditions of Ukraine)

| Botany-geographical formation | Specific chlorophyll, kg / ha | Net $CO_2$ sink mg $CO_2$ / dm yr | Leaf area index, LAI, $m^2$ $m^{-2}$ | Net primary production, NPP, t $ha^{-1}yr^{-1}$ | Specific annual sink, *Ph* t C / ha yr |
|---|---|---|---|---|---|
| Bogs | 20,0–30,0 | 20-40 | 7 | 30 | 2 |
| Coniferous forest | 20,0-40,0 | 4-15 | 12 | 8-13 | 2-4 |
| Deciduous forest | 20,0-40,0 | 5-20 | 5 | 12 | 5 |
| Meadows | 13,0-20,0 | 20-50 | 3,6 | 6 | 2,7 |
| Forest-steepe | 13,0-15,0 | 5-15 | 4 | 7 | 4,5 |
| Steepe | 13,0-24,0 | 6-12 | 3,6 | 6 | 4 |
| Water bodies | 2,0-5,0 | 4-6 | | 4 | 0,6 |
| Agricultural zones, i.e. | 15,0-24,0 | 6-12 | 4 | 6,5 | 4 |
| *C3-plants* | | 20-40 | 4-12 | | |
| Sunflower | | 44 | | | |
| Wheat | | 31 | | | |
| Sugar-beet | | 25 | | | |
| Barley | | 14-22 | | | |
| Rice (puddy) | | 14-23 | | | |
| *C4-plants* | | 50-80 | | | |
| Corn | | 85 | | | |
| References | [5; 6] | [3; 7] | [5] | [5] | [6] |

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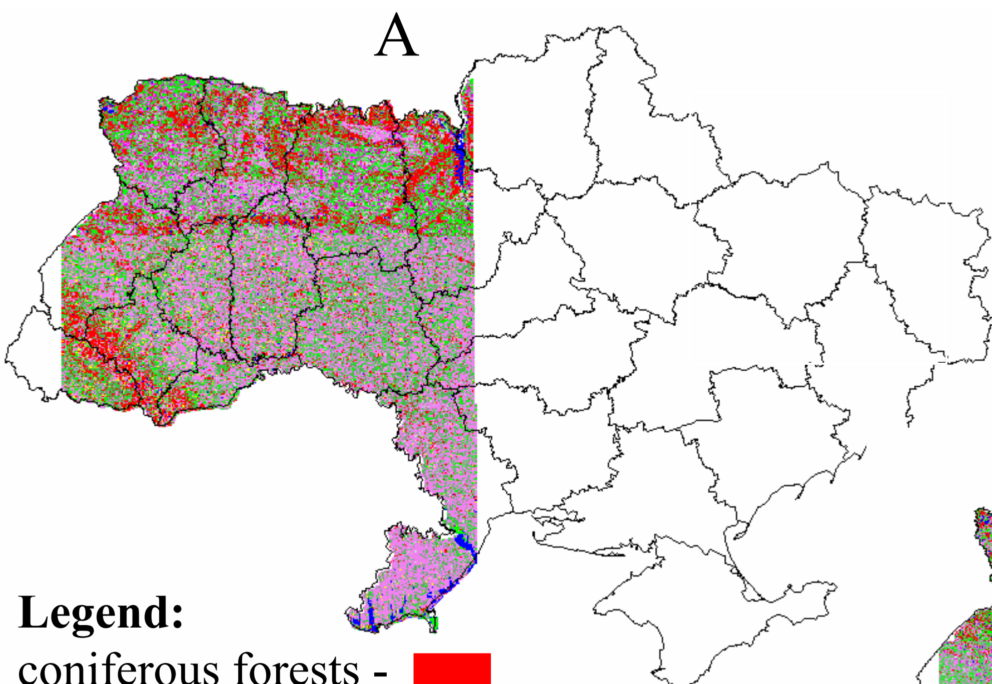
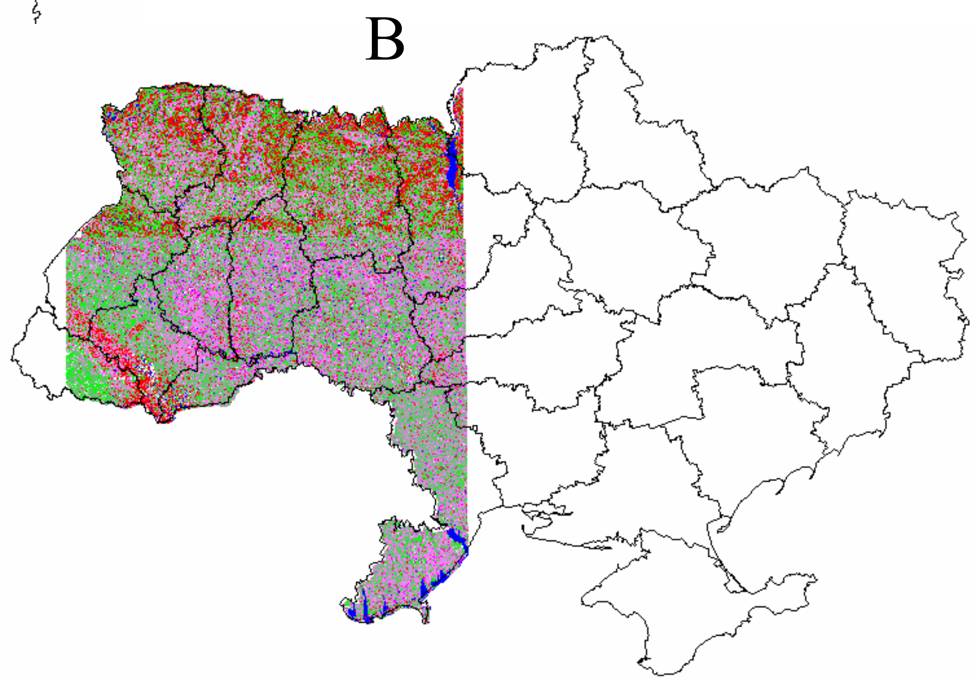
## Preliminary results of land cover classification for west part of Ukraine on mosaic Landsat TM (1990 ) (A) and Landsat ETM (2000) images (B)




**Legend:**

- coniferous forests -
- deciduous forests -
- grassland -
- arable (agro) land-
- settlements -
- bogs -
- water -
- clouds -

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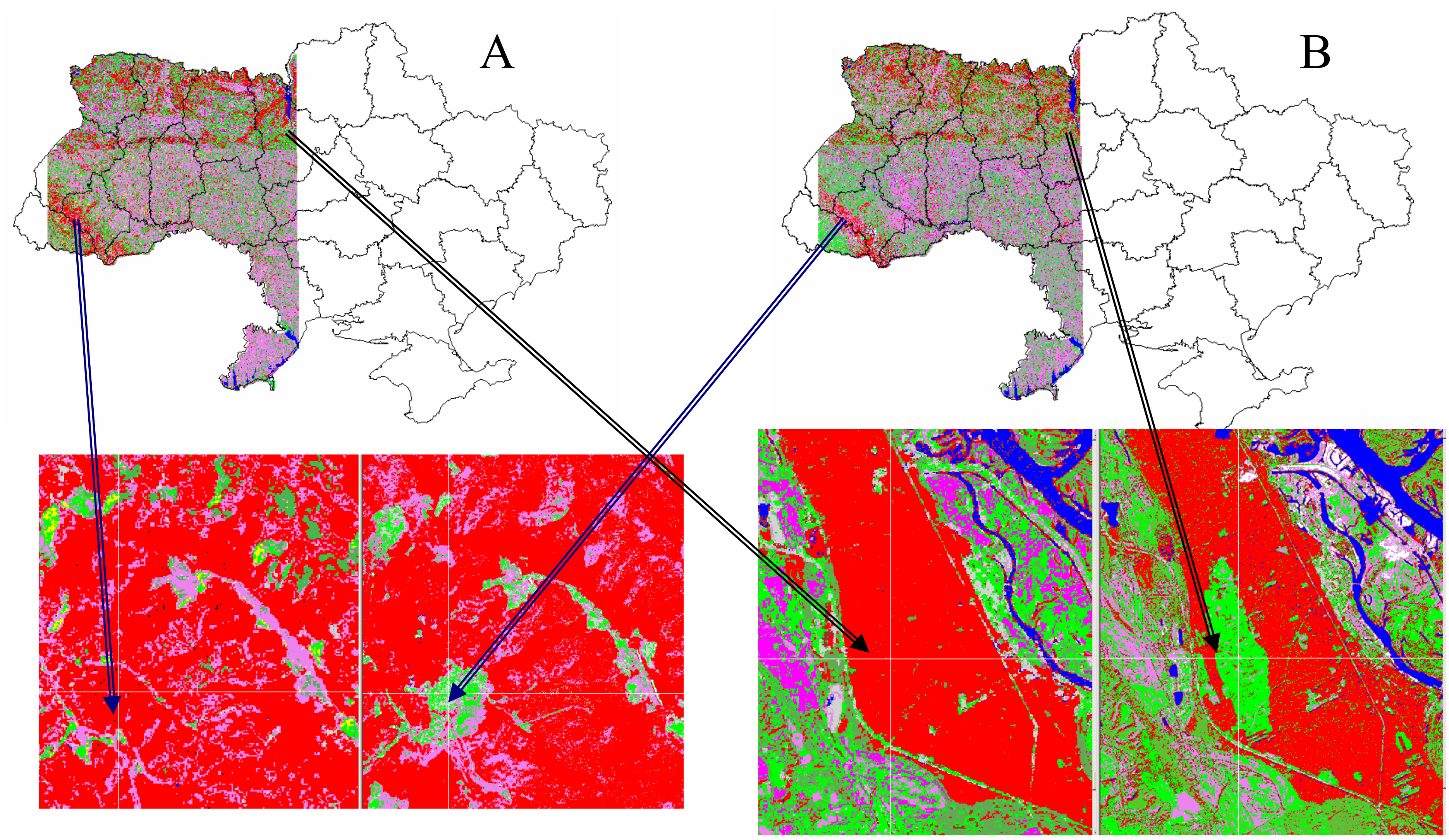
**Cutting down areas within forest sites in the Carpathians and Kiev region detected on classified mosaic images from Landsat TM (1990 ) (A) and Landsat ETM (2000) (B)**



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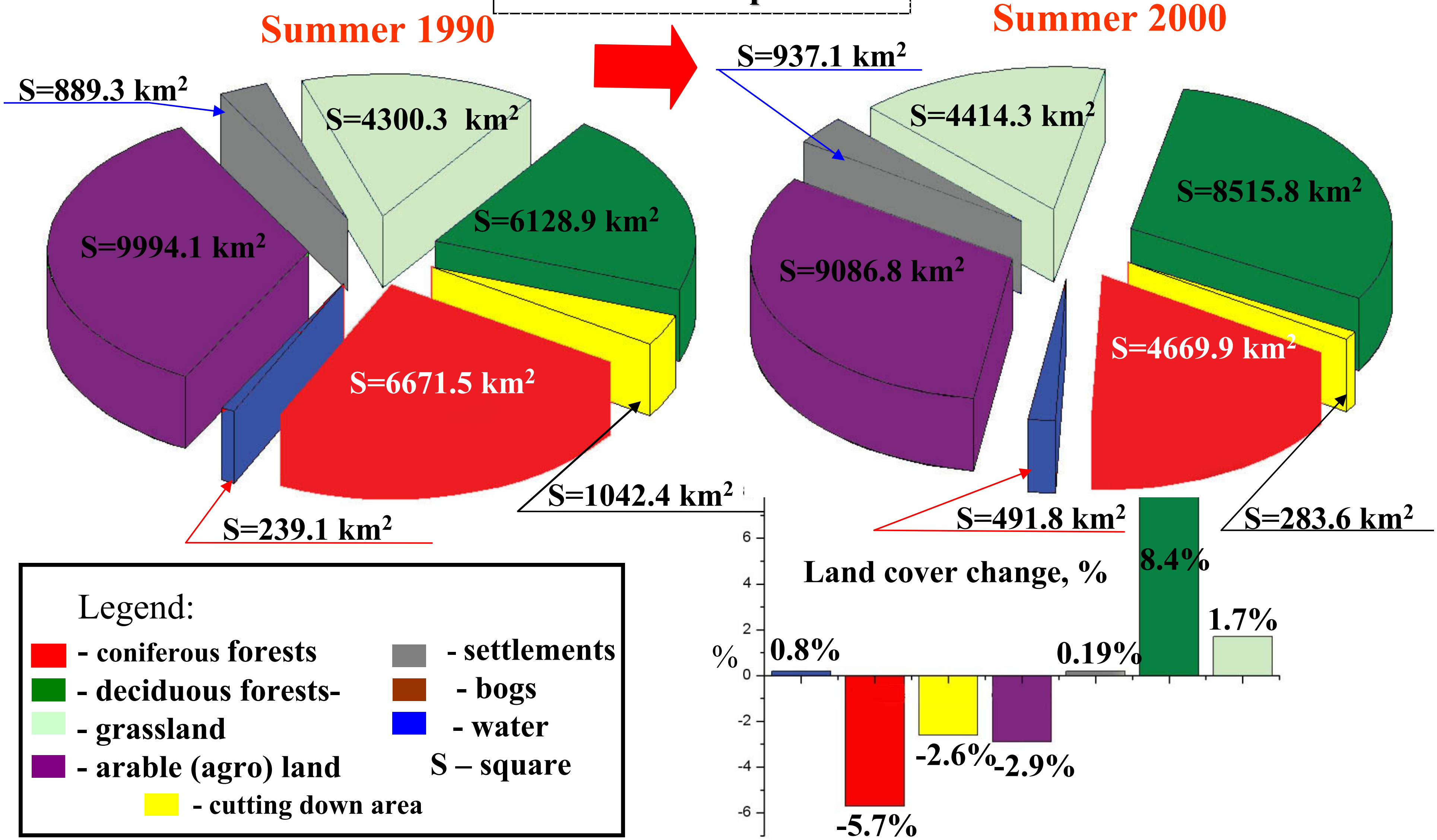
# Land cover changes

## Ukrainian Carpathians



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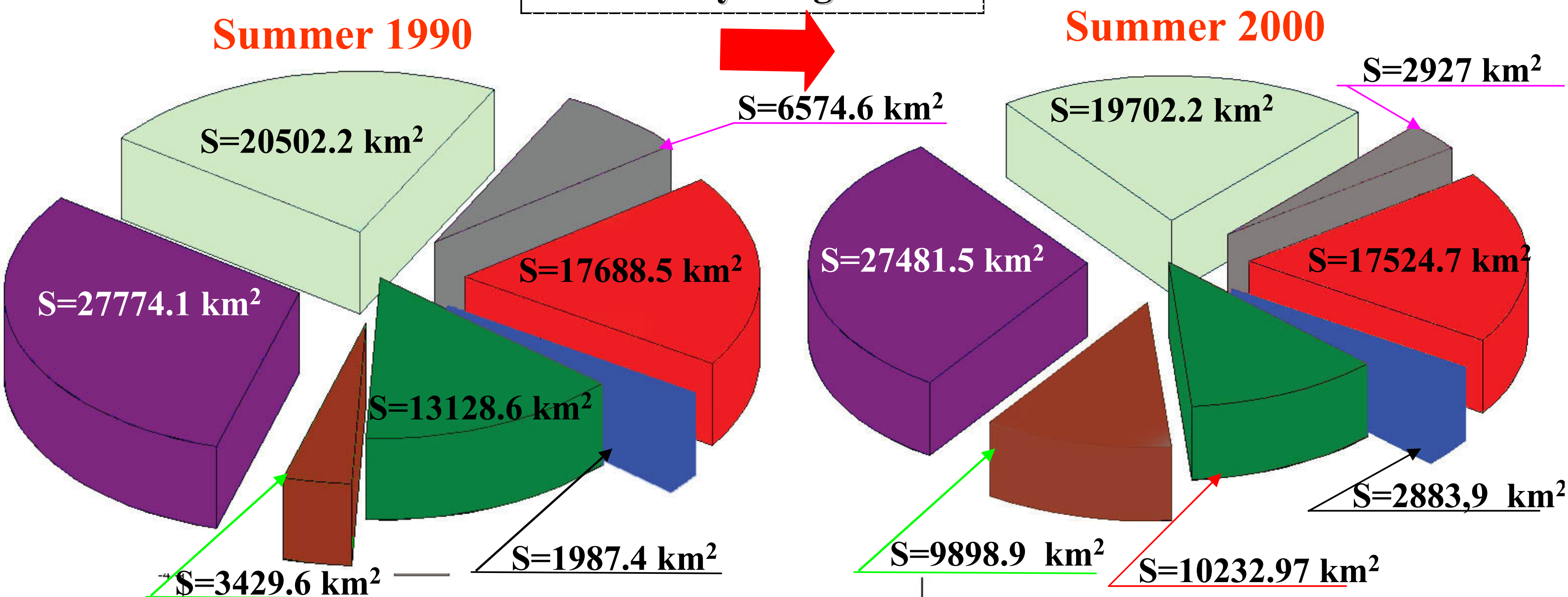
# Land cover change

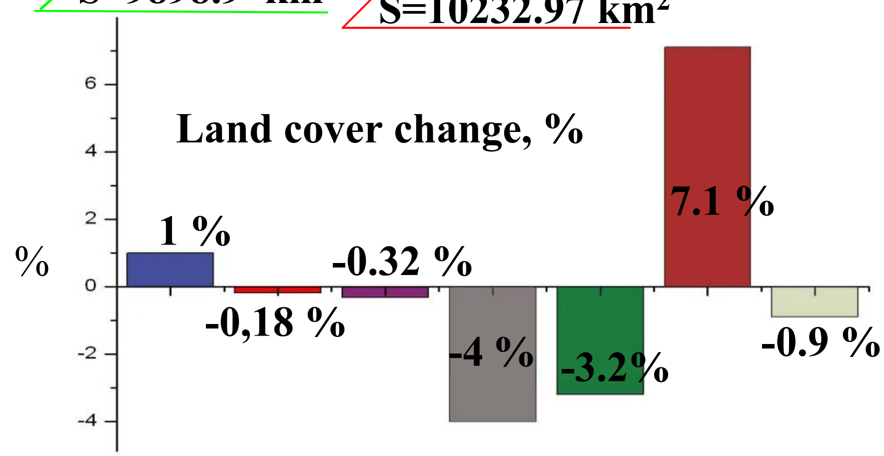
**Polissya Region**




Legend:

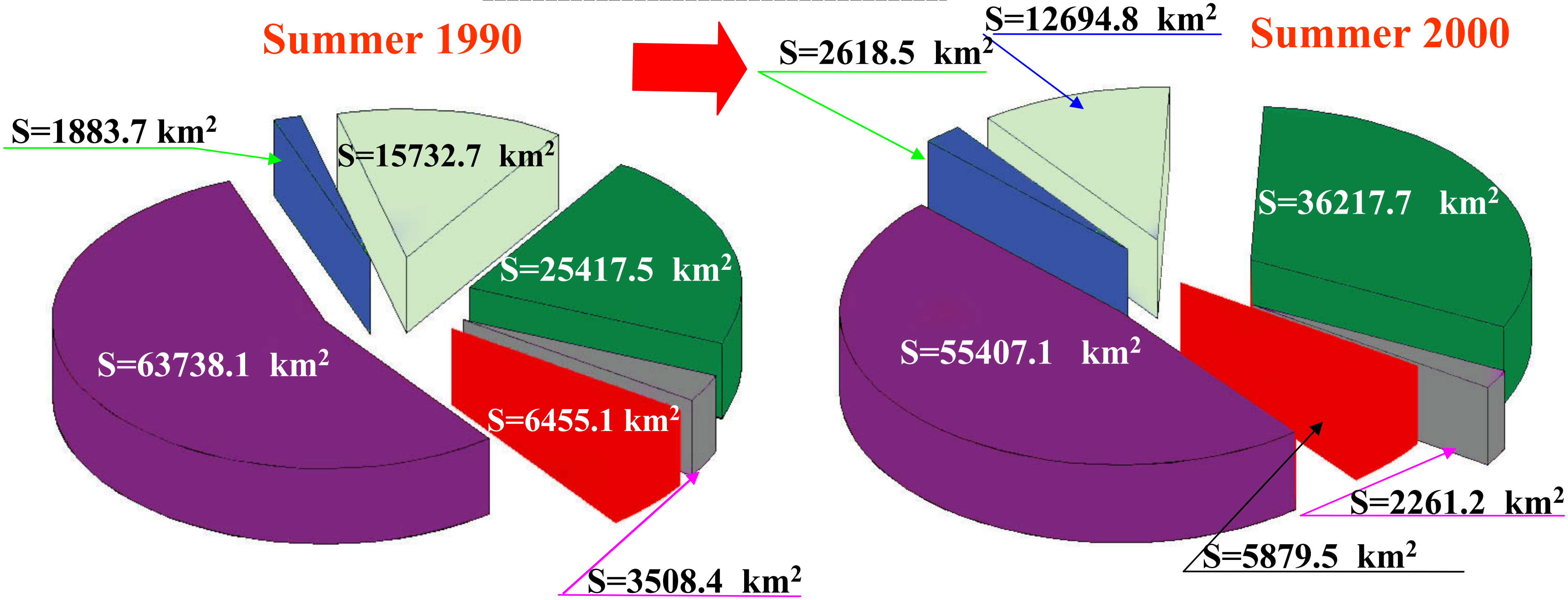
- coniferous forests
- deciduous forests-
- grassland
- arable (agro) land
- settlements
- bogs
- water

S – square



# Land cover change

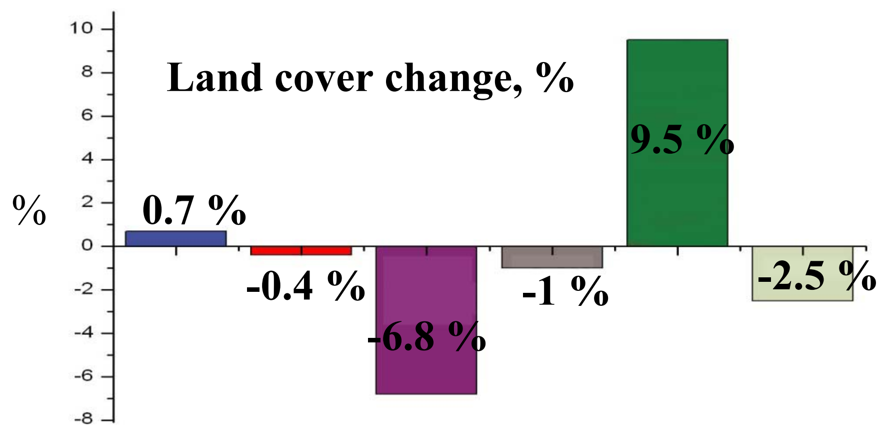
## South-West Region



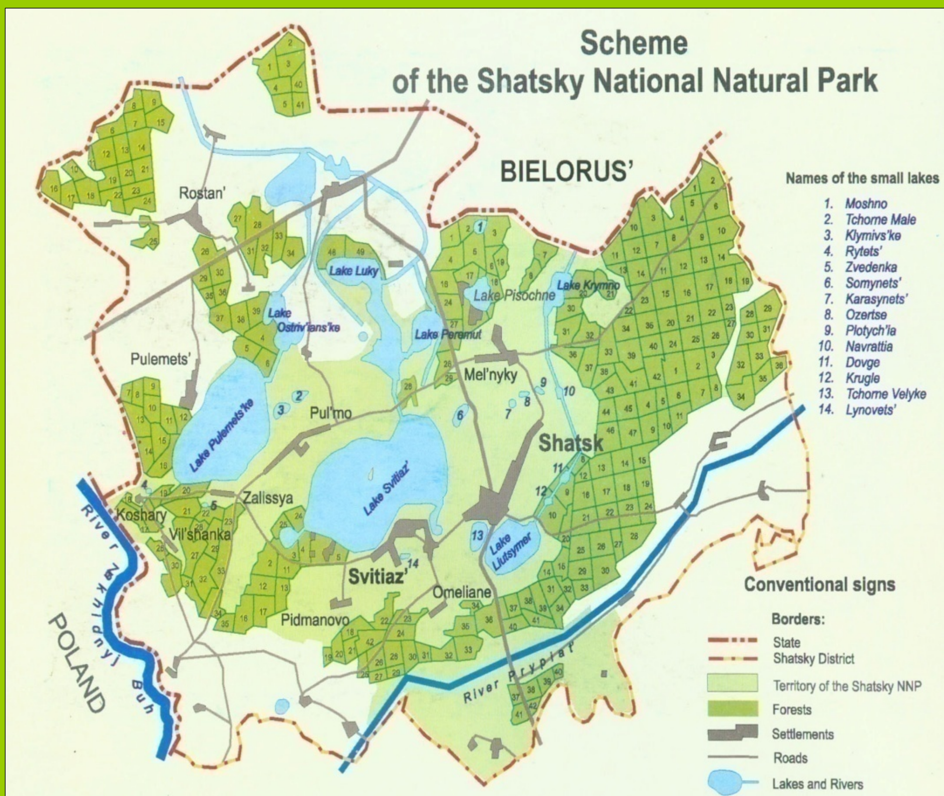

Legend:

- coniferous forests
- deciduous forests-
- grassland
- arable (agro) land
- settlements
- bogs
- water

S – square



# Shatsky National Natural Park




National Committee of Ukraine on the UNESCO Program "Human and Biosphere" is coordinating body for scientific and methodological support of research in field of ecology and sustainable use of natural resources in this area since 2006. In the framework of this activity have been prepared the propositions for relevant UNESCO Programs on development of trans-boundary biospherical natural reservation and regional environmental network "West Polissya" including Shatsky Biospherical Reservation.

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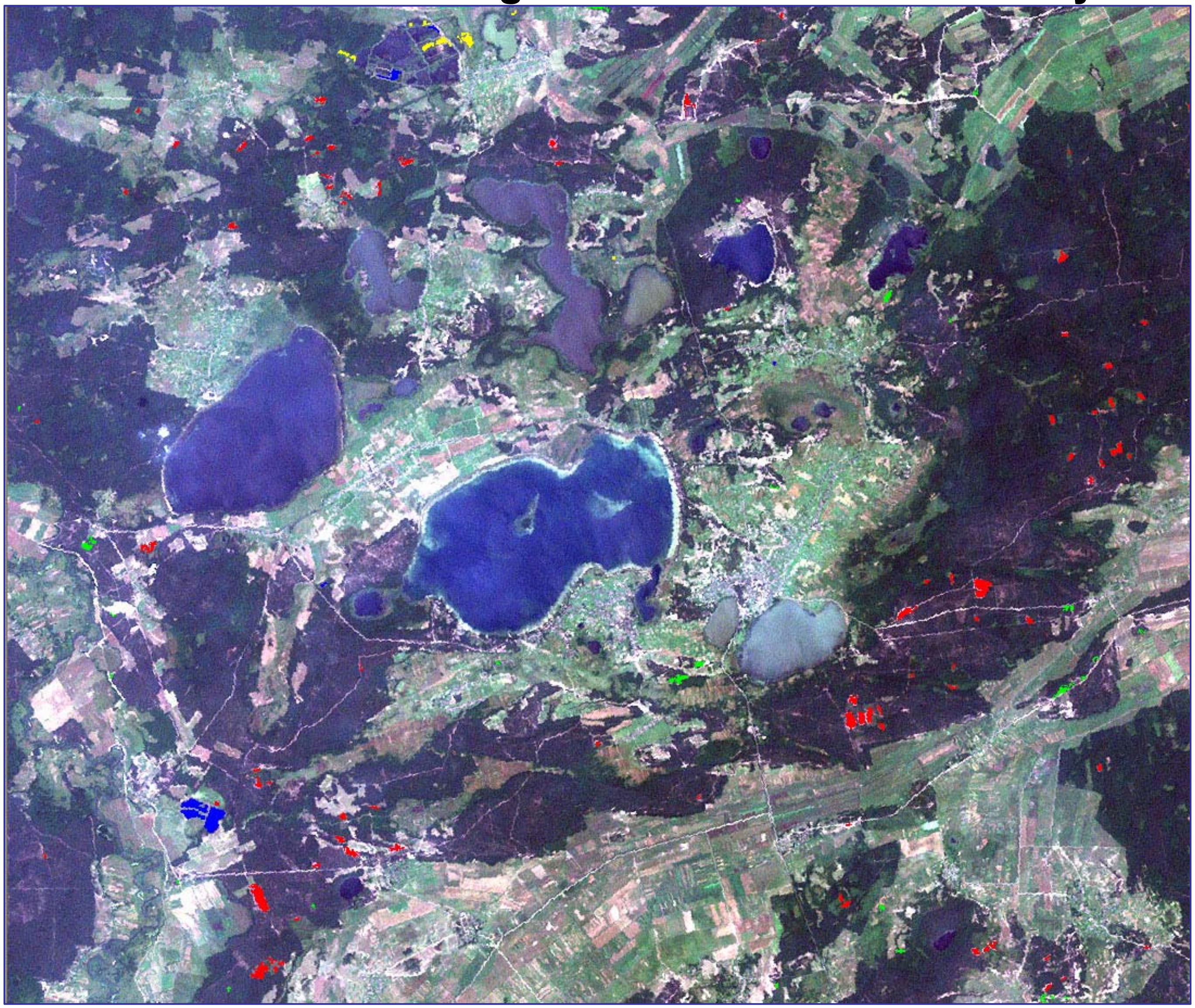
## Terrain change detection on Shatsky Lakes area on the base of satellite images Landsat 1989 - 2001 analysis




Forest recovering

Forest extinction

Water bodies uprising

Water bodies extinction


**Ukrainian Land and Resource Management Center**

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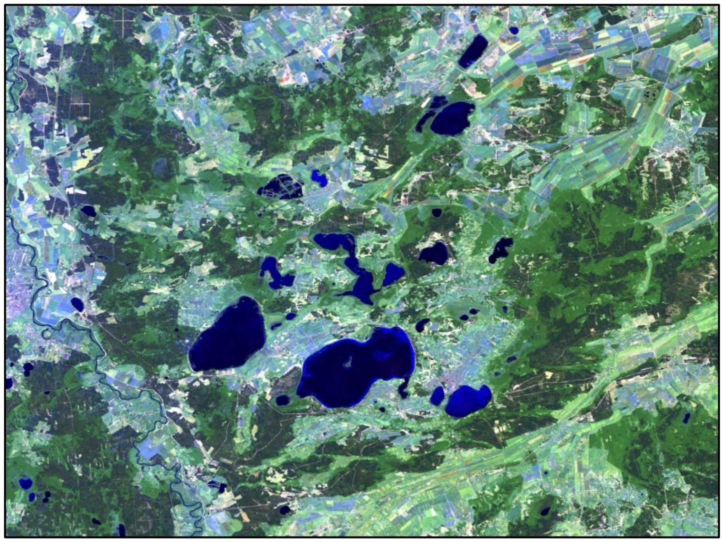
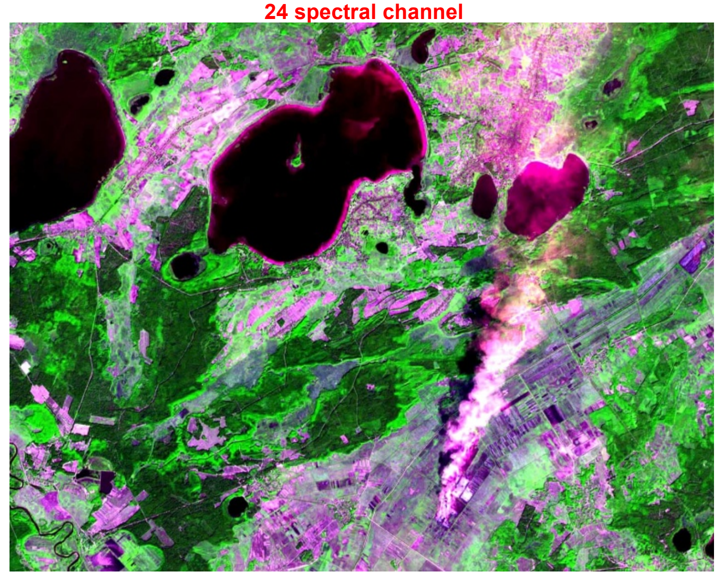
# Comparative analysis of the different satellite images

- Landsat-7 ETM+ 15.07.2001
- Spatial resolution is 30 м ,
- 8 spectral channel



EOS AM-1 (Terra} ASTER 23.05. 2003
Spatial resolution is 15 м
24 spectral channel



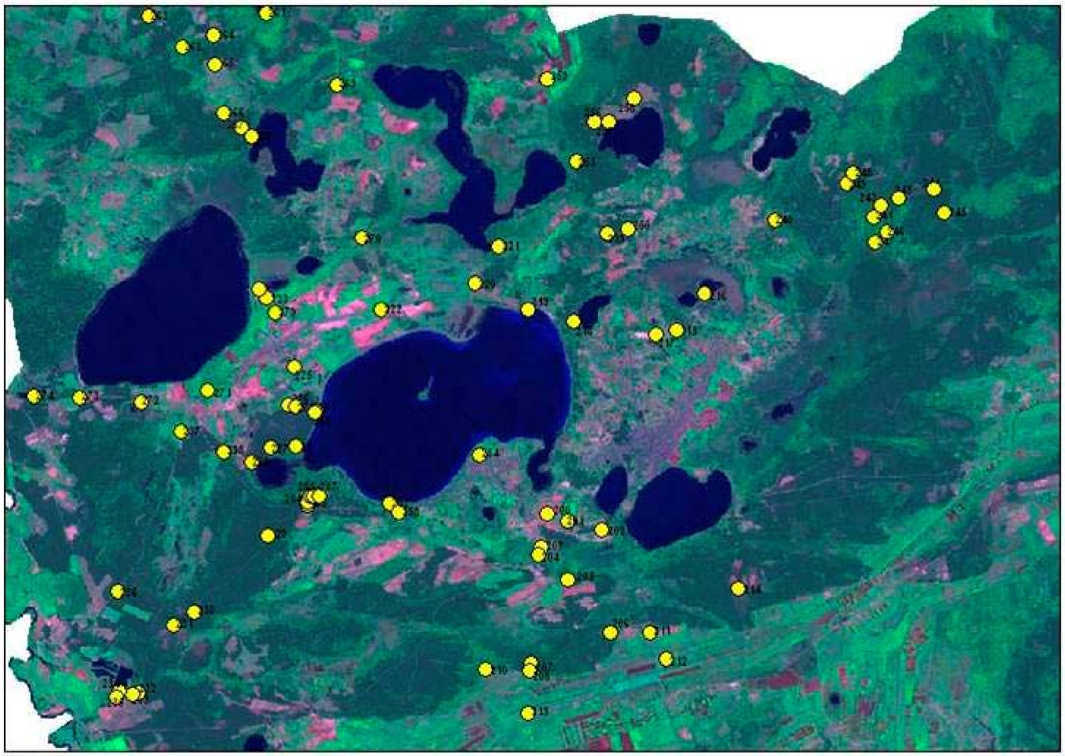

Quick Bird, 2006

Spatial resolution is 2,4м, 4 spectral channel

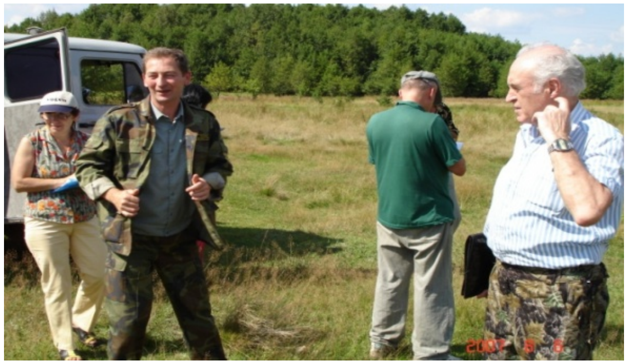
a) wetlands and bogs

б) burned peat-beds

# In-field Tests



229 Points field test



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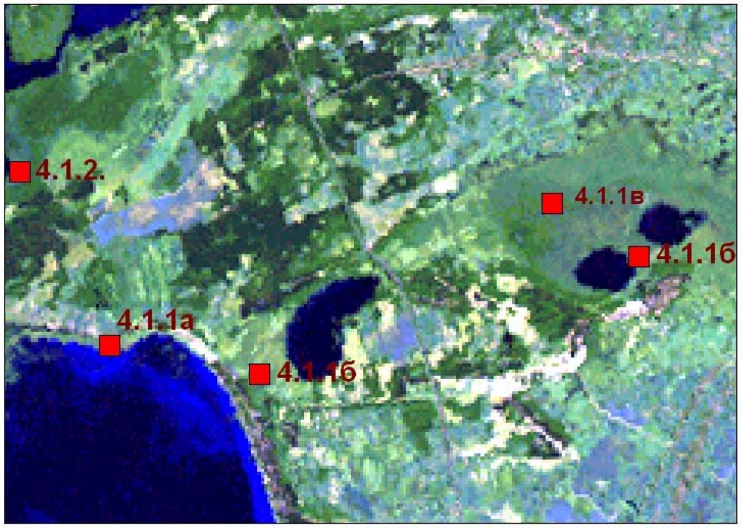
# Wetlands, bogs (class 4.1)





■ Test sites:

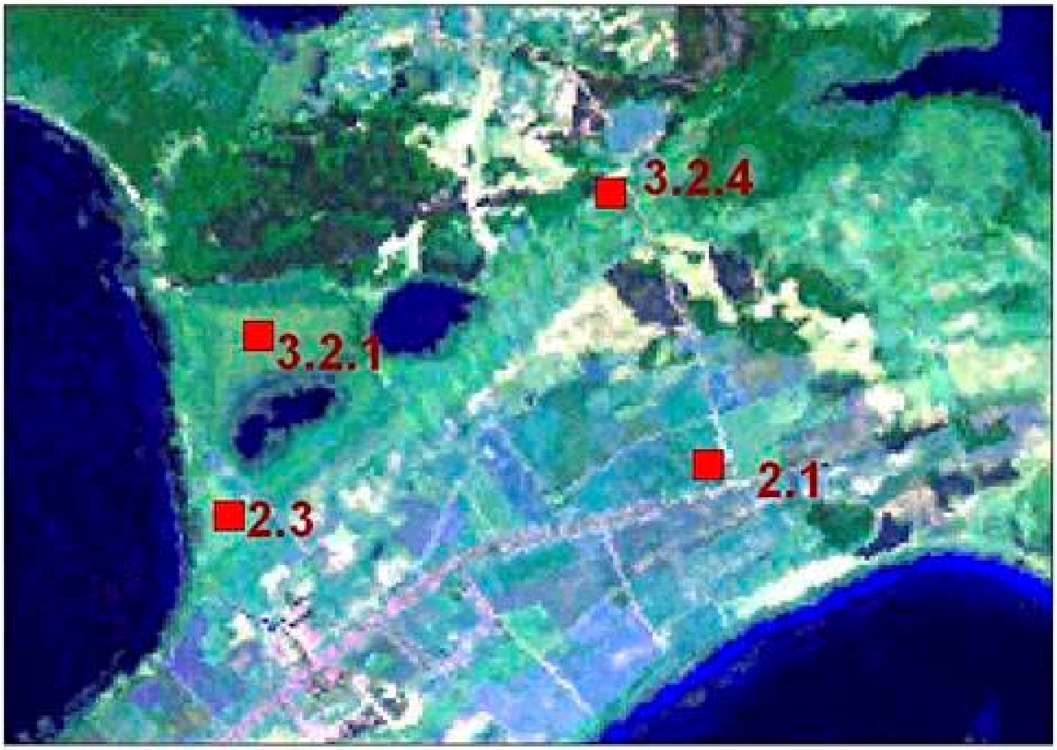
4.1.1a - Reed bogs at the lakes on the mineral soils

4.1.1б - Grass valley bogs with hygrophilous

4.1.1в - Brush and wood bogs

4.1.2 - Turf and moss bogs


# Farming lands (class 2.1) and natural vegetation covers (class 3)






■ Test sites:
4.1.1a – Ploughlands, non meliorated
4.1.1б - Pastures
4.1.1в - Natural fields, grasslands
4.1.2 - Woody brushlands

# Land cover classification of the Shatsky National Natural Park

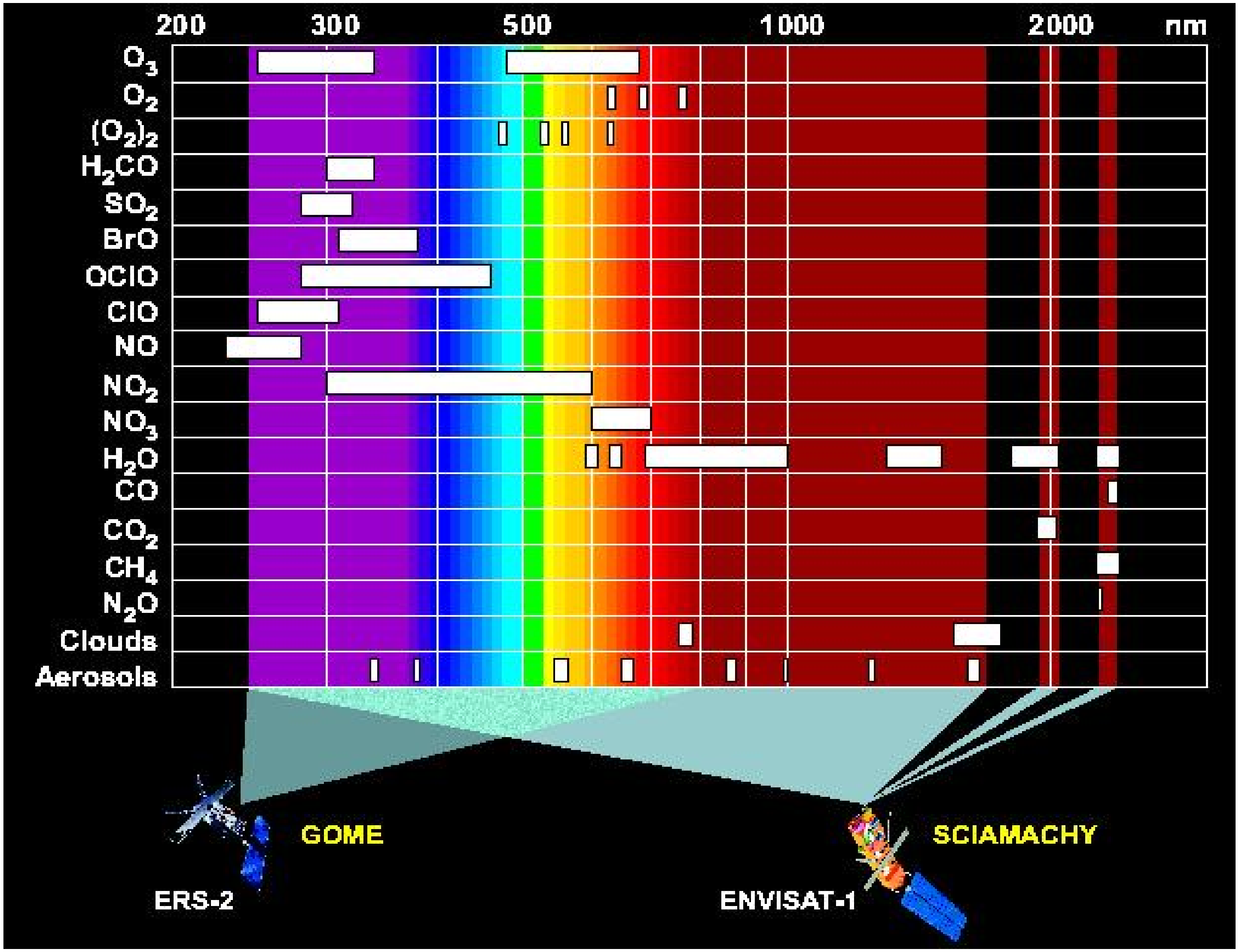
| | | |
|---|---|---|
| **1 class** **Artificial surface , anthropogenic and man-caused territories** | ***1.1 Urbanized territories*** | 1.1.1 Compact urban construction |
| | | 1.1.2 Partial urban construction |
| | | 1.1.3 Cottage type construction |
| | | 1.1.4 Social and Municipal objects |
| | ***1.2 Industrial objects*** | 1.2.1 Industrial objects |
| | | 1.2.2 Roads and surroundings |
| | ***1.3 Dump piles and building*** | 1.3.1 Quarries |
| | | 1.3.2 Dumps |
| | | 1.3.3 Building sites |
| | ***1.4 Artificial planting on the non-agricultural lends*** | 1.4.2 Recreative territories and centres |

| | | |
|---|---|---|
| **3 class** **Semi-natural forest and natural vegetation covers** | ***3.1 Forest*** | 3.1.1 Desideous forests (woods) |
| | | 3.1.2. Coniferous forests |
| | | 3.1.3 Mixed forests |
| | ***3.2.Brushlands and grass*** | 3.2.1 Natural fields, grasslands |
| | | 3.2.2 Low brushlands, bushes and grass |
| | | 3.2.3 Sclerophyllous vegetation |
| | | 3.2.4 Woody brushlands |
| | ***3.3 Open lands*** | 3.3.1 Banks, dunes, grits |
| | | 3.3.3 Sparse vegetations |

| | | |
|---|---|---|
| **2 class** **Farming land** | ***2.1 Ploughlands*** | 2.1.1 Non-meliorated ploughlands |
| | | 2.1.2. Meliorated ploughlands |
| | ***2.2 Multiyear cultures*** | |
| | ***2.3 Pastures*** | 2.3.1 Pastures (use >5 year) |
| | ***2.4 Farming land*** | 2.4.1 Annual vegetations |
| | | |
| | | 2.4.2 Complex cultivation site |
| | | 2.4.3 Non-cultivated lands |
| | | 2.4.4 agro forests, forest belts |

| | | |
|---|---|---|
| **4 class** **Unfit lands** | **4.5 Postindustrial lands** | 4.5.1 Wastelands |
| | | 4.5.2 Out-burned sites |
| | | 4.5.3 Timberlands |
| | ***4.6 Wetlands, bogs*** | 4.6.1 Valley swamps |
| | | 4.6.2. Bogs and turf moors |
| | | 4.1.2 Dried peat-bogs |
| **5. Water objects** | ***5.1 Rivers*** | |
| | *5.2 **Reservoirs*** | 5.2.1 Natural lakes |
| | | |

## SCIAMACHY spectral range

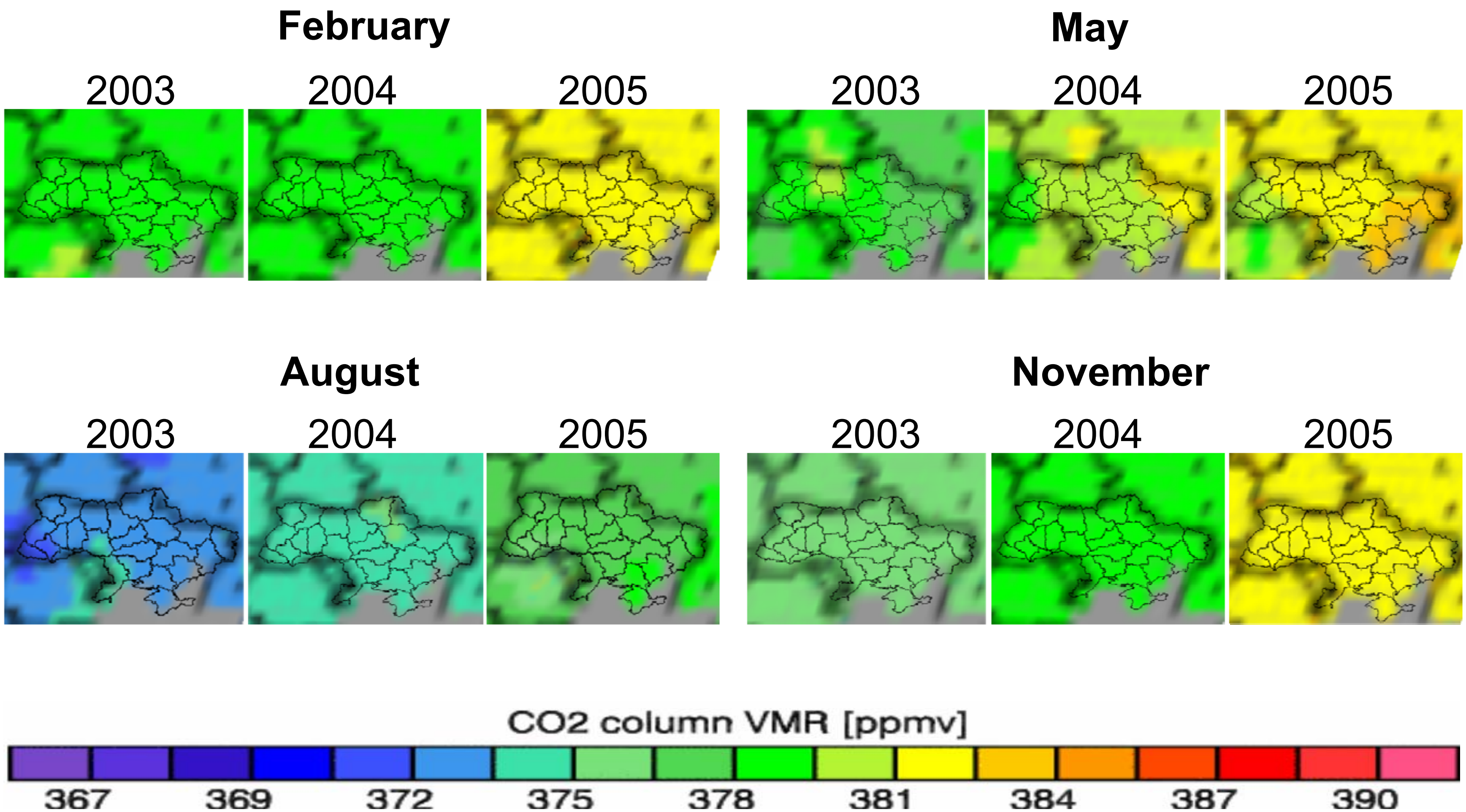


## Overview of the SCIAMACHY/ENVISAT sensor characteristic

**SCIAMACHY is a spectrometer that measures reflected, scattered and transmitted solar radiation in the spectral range 214–2380 nm with moderate spectral resolution (0.2–1.6 nm). On the Earth's day side SCIAMACHY mainly performs a sequence of alternating nadir and limb observations. The horizontal resolution of the nadir measurements depends on orbital position and spectral interval but is typically 60 km (e.g., for methane and $CO_2$) or 120 km (e.g., for CO) across track times 30 km along track.**

**Overall, the in flight optical performance of SCIAMACHY is as expected from the on ground activities. One exception is time dependent optical throughput variation in the SCIAMACHY near-infrared (NIR) channels 7 (the main $CO_2$ channel) and 8 (the only CO channel and main $CH_4$ channel) due to ice build-up on the detectors which adversely affects the trace gas retrieval (Buchwitz et al., 2005b; Gloudemans et al., 2005). This effect is limited by regular heating of the instrument.**

# Carbon dioxide SCIAMACHY/ENVISAT data over Ukraine (2003-2005)



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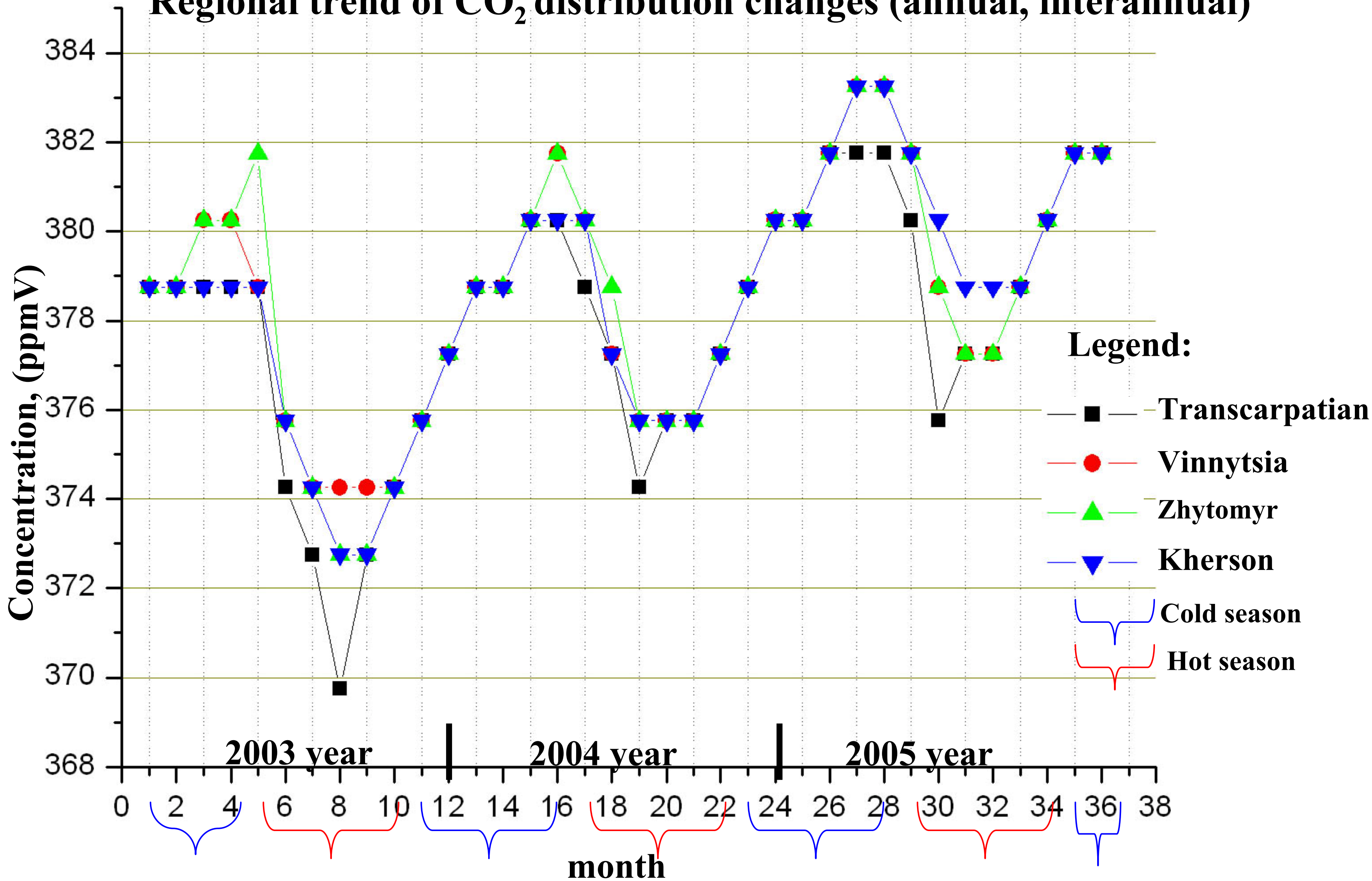
## Regional trend of $CO_2$ distribution changes (annual, interannual)



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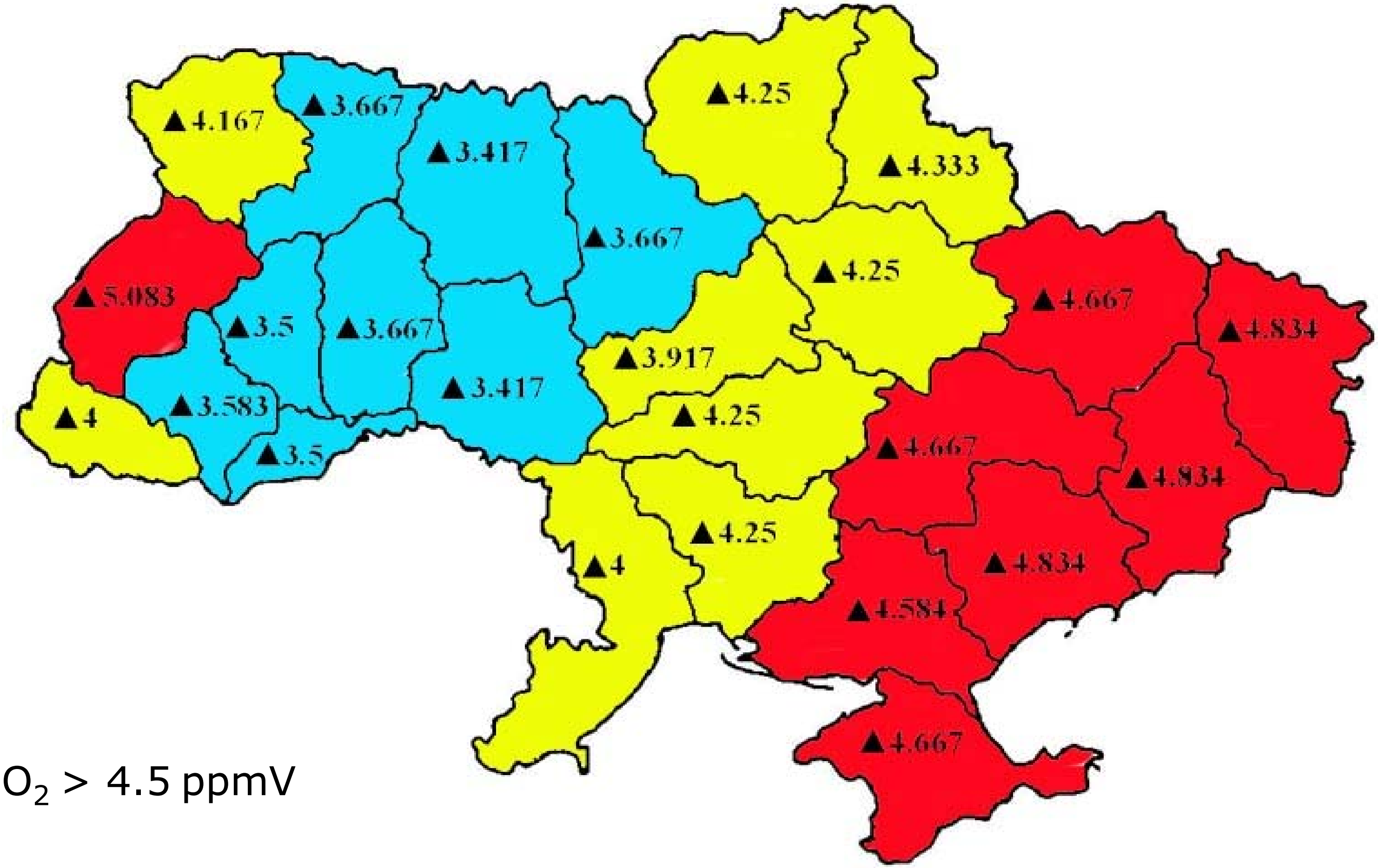
# Increasing of the averaged annual $CO_2$ concentrations (ppmV) during 2003 – 2005




**Legend :**

- increasing $CO_2$ > 4.5 ppmV

- increasing $CO_2$ < 4 ppmV

- increasing $CO_2$ from 3.9 ppmV to 4.5 ppmV

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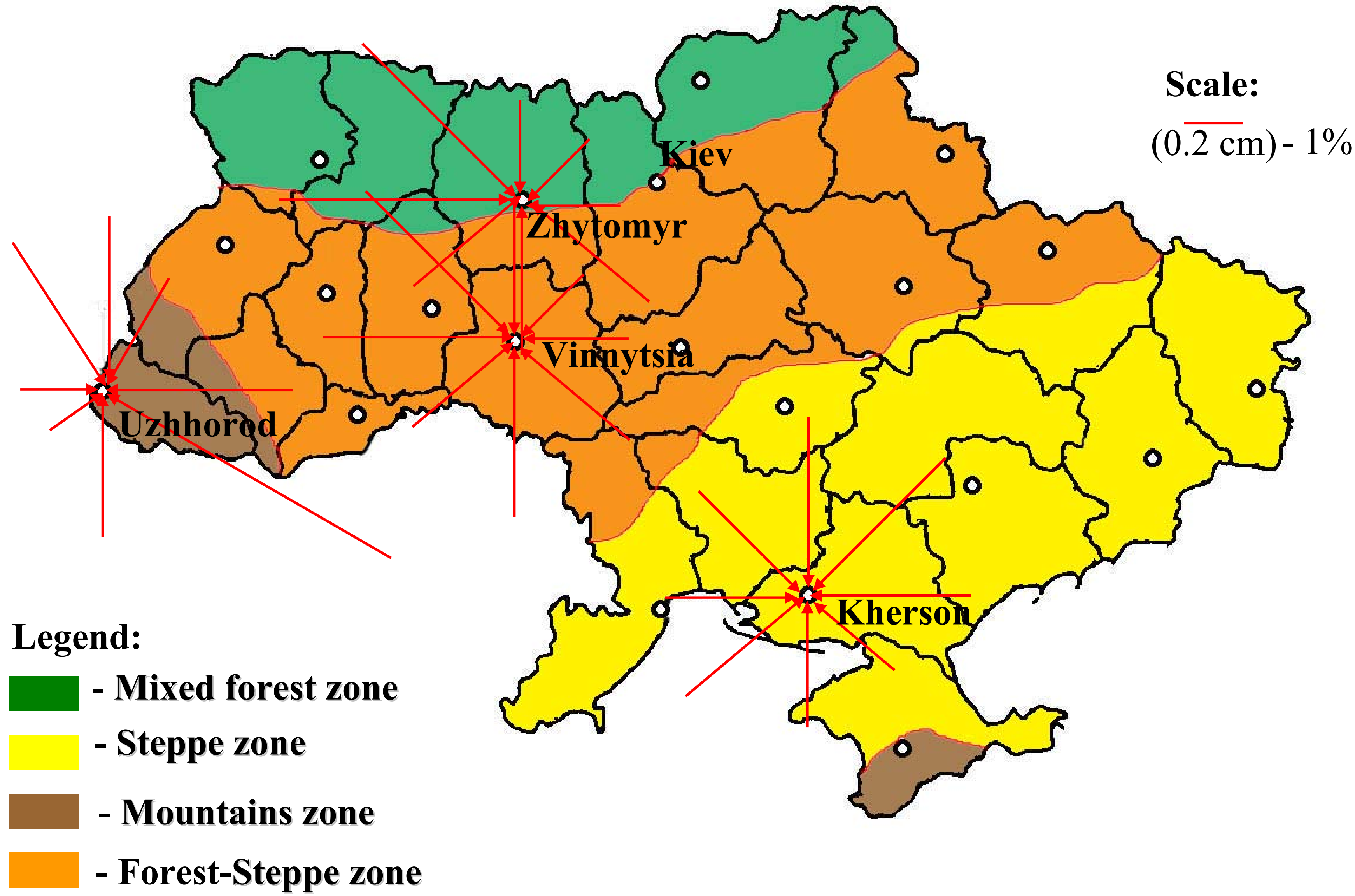
## Wind transfer is given in % of the total observations without variability



## Estimation of sum increasing of the annual air temperature over Ukraine up to 2030 concerned to change of atmospheric $CO_2$

## (based on measurements of atmospheric $CO_2$ concentrations be SCIAMACHY sensor of ENVISAT satellite during 2003 - 2005)

$$\Delta T(t) = -0,1 + 3\ln\frac{C(t)}{C(t_0)}$$

where $t$ – time by years; $C_0$ – initial concentration of atmospheric $CO_2$ (375 ppmv) at the time $t_0$ (2003);
C($t$) – estimated concentration of atmospheric $CO_2$ (420 ppmv) at the moment $t$ (2030).

Possible estimation of the temperature increasing during 2003 – 2030 is:

$$\Delta T(t_{2030}) = -0,1 + 3\ln\frac{420\,ppmv}{375\,ppmv} = -0,1 + 0,3 \approx 0,2^o C$$

Where $C(t_{2003})$ = 375 ppm; $C(t_{2030})$ = 420 ppm.

This result for 2030 with value about 0,2°C is less than forecasting of national hydrometeorologists (which is about 1,0 – 1,5 °C) for this period. The reason of this deference could be explained through the absence in our model the influence of other greenhouse gases, changes of surface albedo, and concentration of aerosols to regional temperature.

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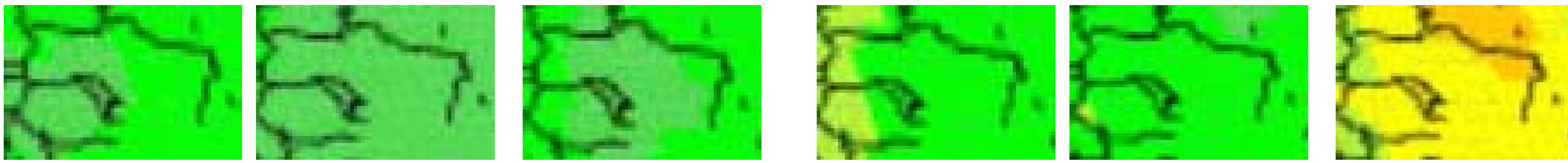
# Methane SCIAMACHY/ENVISAT data over Ukraine (2003-2005)

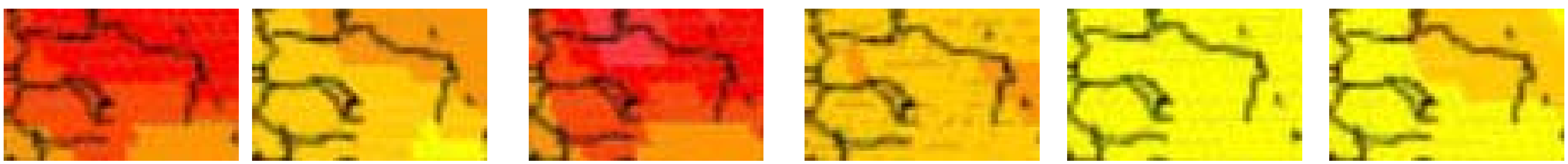
**March** | **May**

2003 2004 2005 | 2003 2004 2005

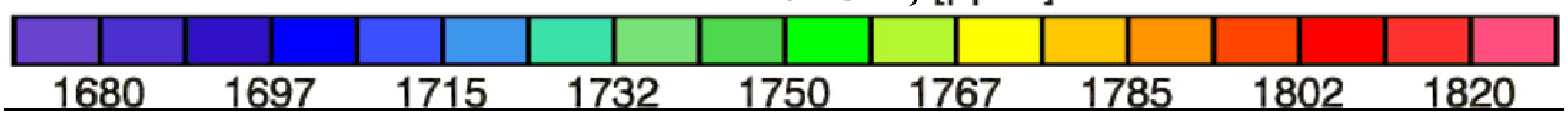


**July** | **October**

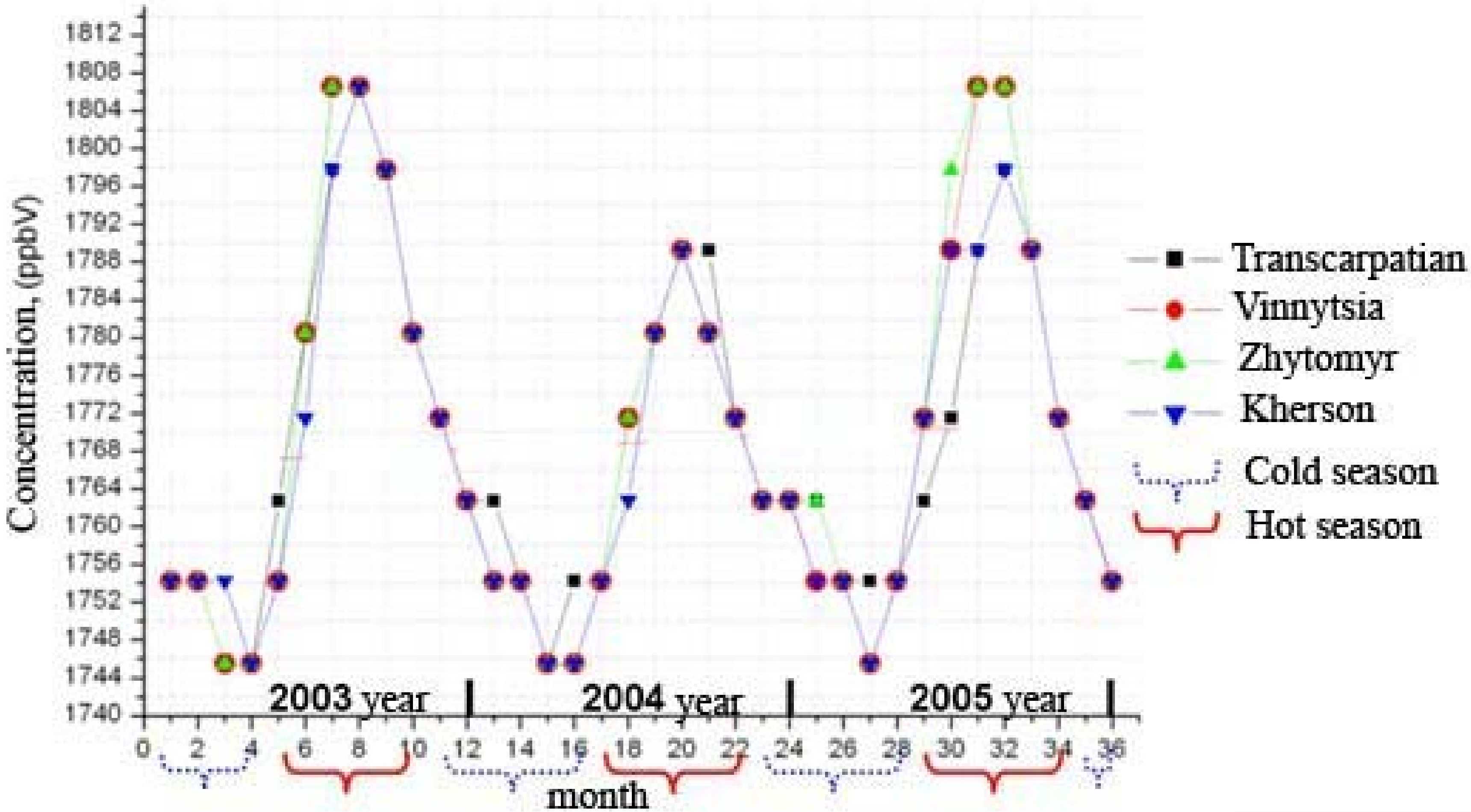
2003 2004 2005 | 2003 2004 2005



**Вміст $CH_4$, [ppbv]**



# Regional trend of $CH_4$ distribution changes (annual, interannual)



# Changes of the averaged annual $CH_4$ concentrations (ppmV) during 2003 – 2005

## Estimation of sum increasing of the annual air temperature over Ukraine up to 2030 concerned to change of atmospheric $CH_4$ (based on measurements of atmospheric $CH_4$ concentrations be SCIAMACHY sensor of ENVISAT satellite during 2003 – 2005)

$$\Delta T_{CH4} = 0{,}19\left\{CH_4(t)^{1/2} - CH_4(t_0)^{1/2}\right\}$$

where $t$ – time by years; $CH_4(t_0)$ – initial concentration of atmospheric $CH_4$ (1766.6 ppbv) at the time $t_0$ (2003 рік); $CH_4(t_0)$ – estimated concentration of atmospheric $CH_4$ ( 2200 ppbv) ) at the moment $t$ (2030 рік).

Possible estimation of the temperature increasing during 2003 – 2030 is:

$$\Delta T(t_{2030}) = 0.1^{\circ} C$$

# CONCLUSIONS 1

1. The problem of acceleration for regional and global scale environmental changes including climatic ones has gained a top priority importance last years that attested by adoption of several international agreements and programs aiming to study and mitigate the causes of negative impact of these changes onto humankind.

2. Among researchers investigating the causes of recent climatic changes there is no consensus about mechanisms driving at global warming observed now: on parity with conventional explanation linking it with growth of greenhouse gases in the atmosphere ($CO_2$ as a main agent) of man-made origin there are also counter-concepts treating such a warming as the result of more intensive solar radiation and other astronomic factors including those that could lead to another “glacial period” on the Earth in future.

3. To avoid such an ambiguity in forecasting of climatic changes as of regional as global scales there is a need to envisage wide-ranging measurements of greenhouse gases bulk concentration (and $CO_2$ first of all) in the atmosphere of the whole planet (together with an inventory of greenhouse gases from industrial sources that carrying out now) and also to trace the trends of vegetation cover changes for last decades (when the beginning of global warming was detected).

4. An effective solution for such tasks is only possible by employing of specialized space-born imagery. For example, using the data provided by SCIMACHY sensor installed on ENVISAT satellite to measure concentration of $CO_2$ in the atmosphere.

# CONCLUSIONS 2

**To find out how $CO_2$ balance in the atmosphere impacts the changes of vegetation cover of which different species absorb it with individual intensity under photosynthesis process it is necessary to interpret multitemporal images acquired by Landsat, SPOT and other satellites.**

5. **It was such approach to analyze specialized space-born images allowed us to make several conclusions on some climate change factors for Ukraine's territory as follows:**

- **the character of vegetation cover changes for 1990-2000 in the West Ukraine detected by multitemporal Landsat imagery (decreasing of coniferous and increasing of deciduous vegetation and agroconenoses) promotes accumulation of $CO_2$ in the atmosphere**
- **character of atmospheric $CO_2$ variations over Ukraine for 2003-2005 detected by multitemporal images acquired by SCIMACHY sensor of ENVISAT satellite testifies that $CO_2$ concentration in the atmosphere**
- **is subjected by seasonal variations governed by annual pace of plants vegetation**
- **has a tendency to increase in time as for season as for average annual indexes**
- **has a tendency to increase over western regions of Ukraine due to wind transfer from industrial areas of Europe and Ukraine itself (Donbas, along-Dniper industrial centers)**

# CONCLUSIONS 3

• Thus, its is instrumentally proved that “greenhouse effect” over Ukraine’s territory is input not only carbon dioxide generated by domestic industry but the tendencies to decrease country’s vegetation cover stipulating less absorption of $CO_2$ from air as well.

• Further studies should be aimed to design National Climatic Program for Ukraine as am element of related modules of GEOSS-GMES program. Under its auspices the following steps should be done in coordination with international scientific community:

• establishing of test sites network for ground measurement of $CO_2$ fluxes for different landscape and climatic regions

• comparison of measured $CO_2$ fluxes on the ground synchronized with $CO_2$ measurements in atmosphere by SCIMACHY sensor over test sites

• development of regional and global energy mass transfer models in Earth’s geospheres based on acquired hydro-meteorological and other data and validation procedures at test sites for computerized forecasting of possible scenarios of climatic changes and elaboration of decision-making solutions to optimize socio-economic processes subjected by climate changes.

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# Thank you!