The use of satellite data for drought monitoring & food security in Ukraine in the context of climate change

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Objective of the study

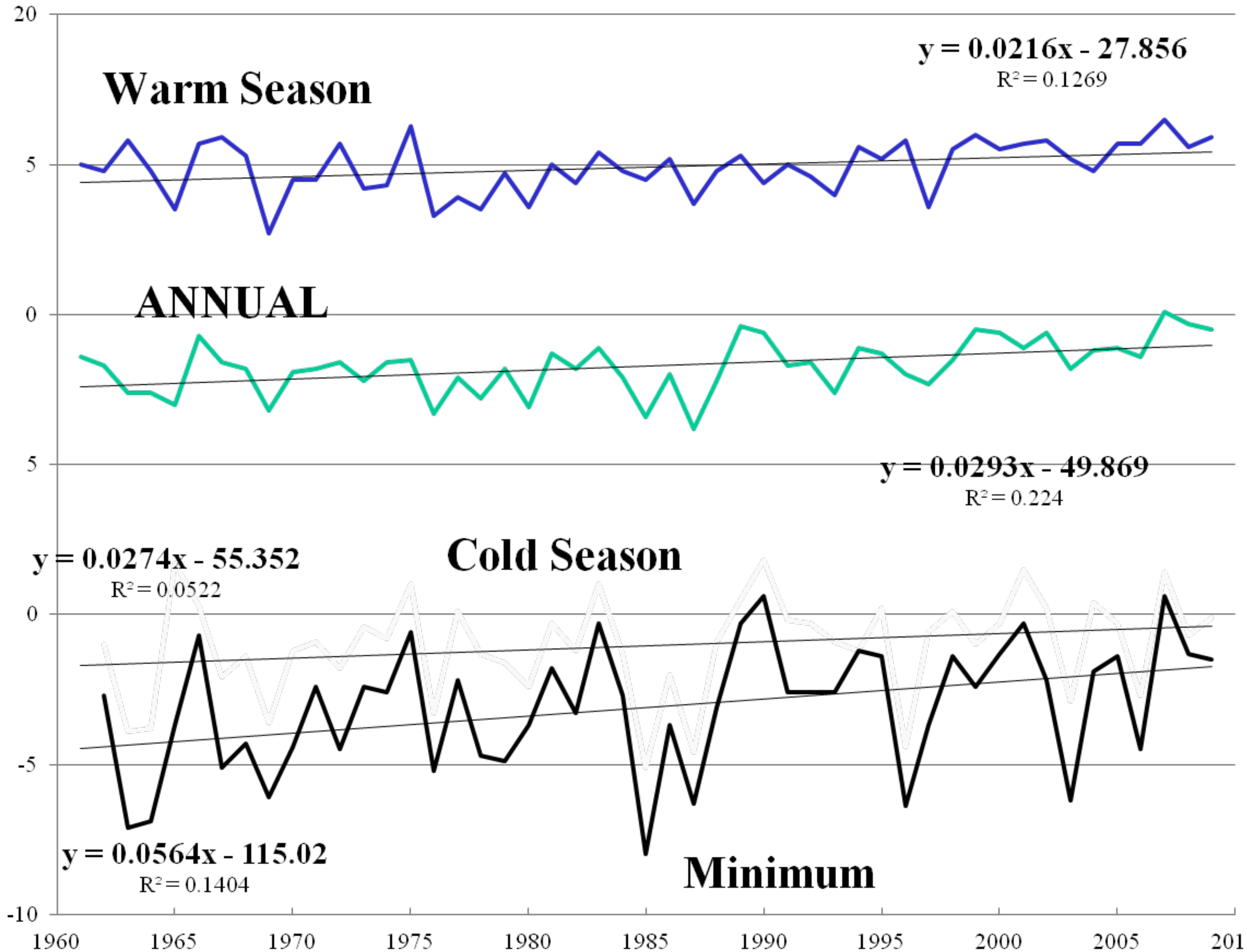
- The two main components of **crop production monitoring** are
  - **crop yield forecasting** and
  - **crop area estimation**.
- Accurate crop yield forecasts several months in advance of the harvest is crucial at **global**, **national** and **region** scale
- **Yield** is an **indicator** of **droughts**
- **Ukraine**
  - 8th largest exporter and 10th largest producer of **wheat** in the world in 2011, world leader producer of sunflower oil
- Objectives
  - to assess relative efficiency of using satellite data for winter wheat yield forecasting for Ukraine at oblast level
  - to compare performance of regression models to crop growth simulation

1960-2010 Average Annual Temperature (deg C) - Mean for UKRAINE

T/50y growth (Degree C)

Annual	1.45
Warm M	1.10
Cold M	1.35
Min	2.80

Global
0.74/130y



1960-2010 Total Annual Precipitation (mm) - Mean for UKRAINE

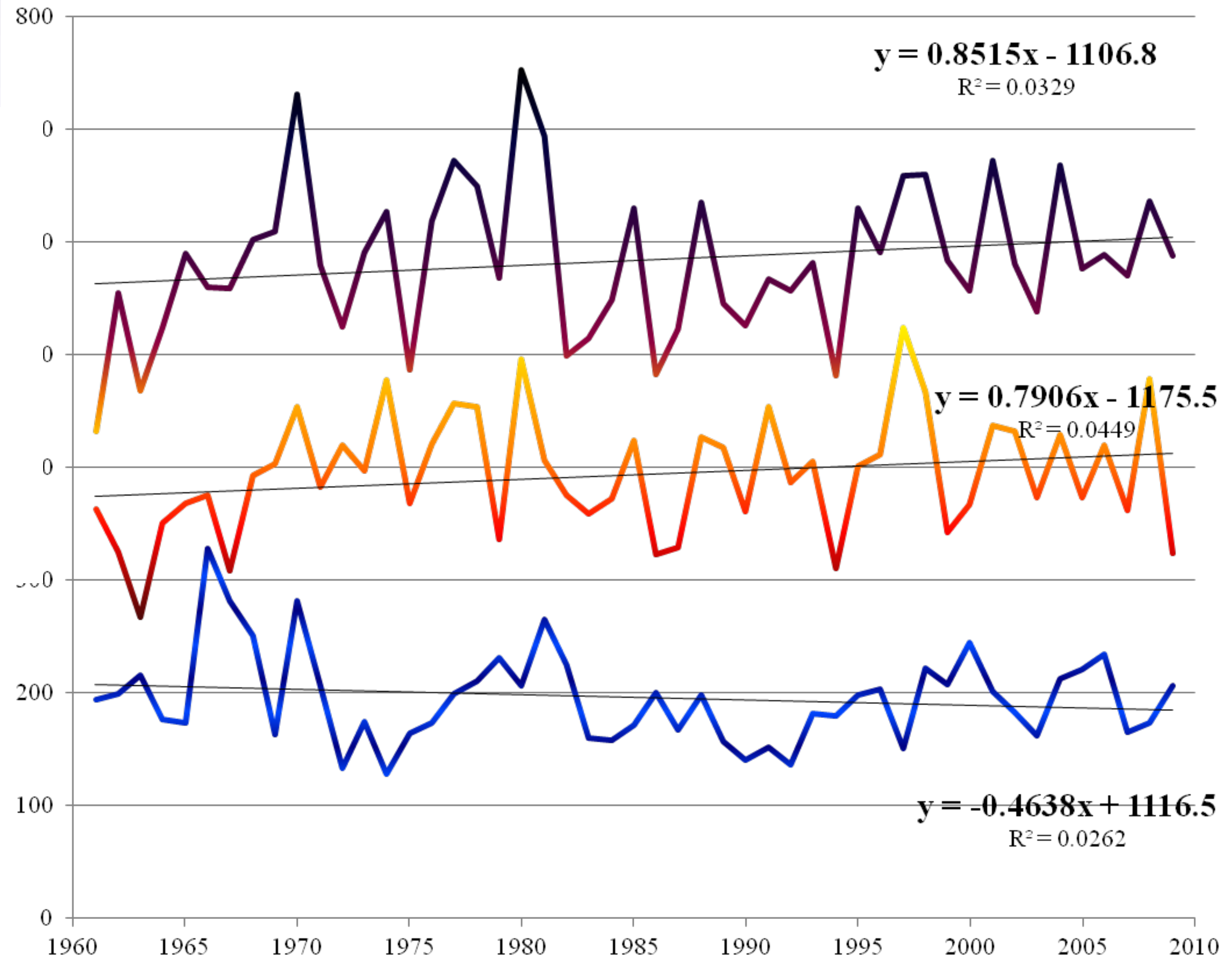
P/50y growth (mm)

Annual **42.5**

Warm **39.5**

Cold **-23.0**

GLOBAL
No Change



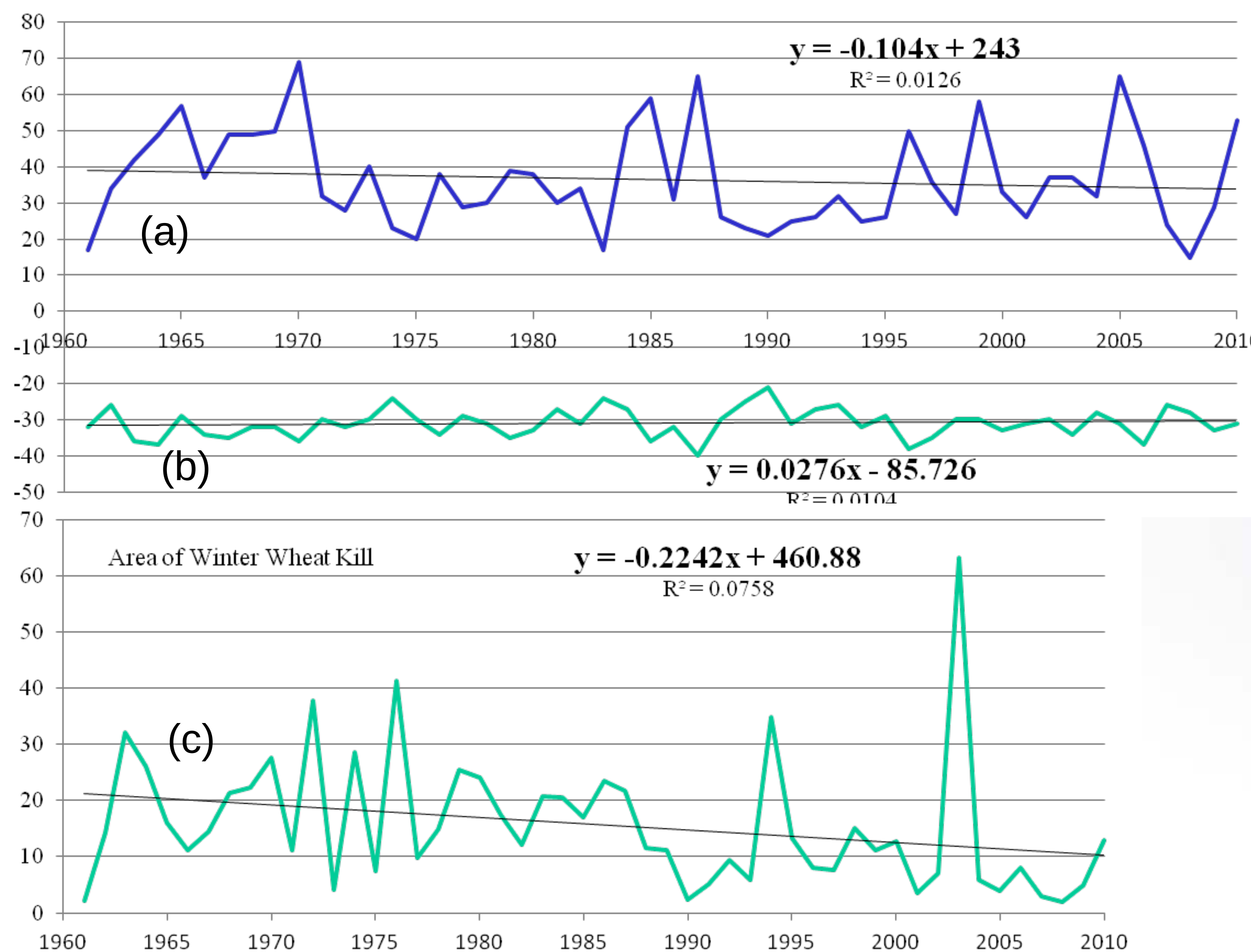
Snow Depth (a), Abs Min Winter T in Deg C (b) & % Winter Wheat Kill Area (c), UKRAINE

CHANGES /Per 50-y

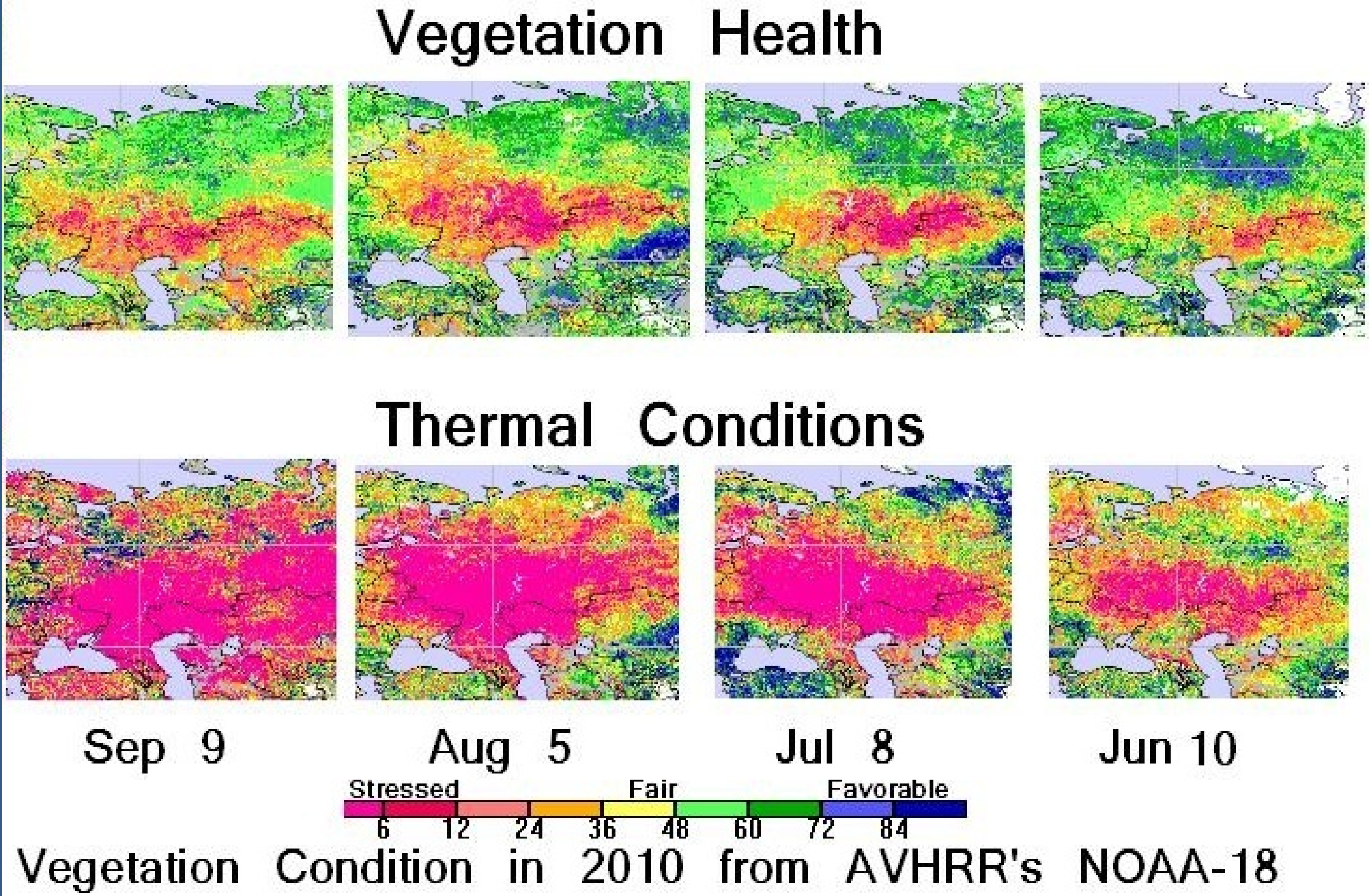
SNOW: -10 cm reduction

TAbs.Min +1.5 deg C increase

WW kill Area -10% reduction



Dynamics: Drought Detection & Monitoring 2010, RUSSIA, UKRAINE

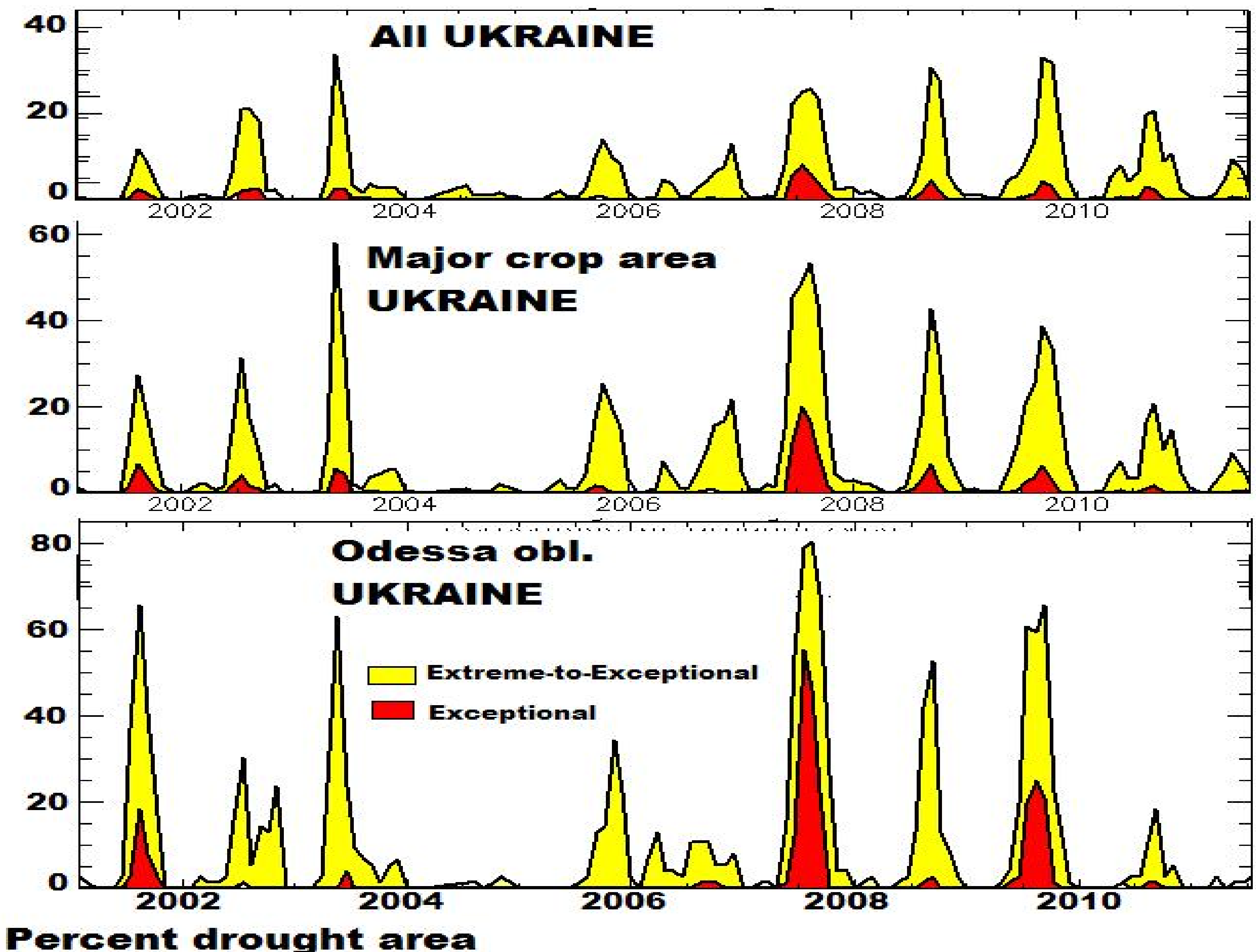


AFFECTED

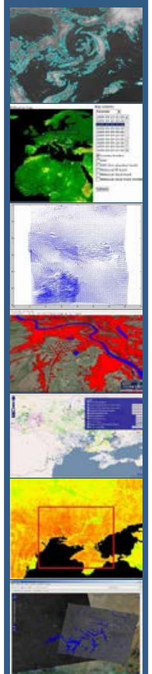
* Air pollution
I(ntensive & long Smog)
* Crop losses
* Swamps Burning
* Grain exports restriction
* International grain price
* Human health
* Tourism
* River shipping

The method is based on estimation of green canopy stress/no stress from indices, characterizing moisture (M) and thermal (T) conditions of vegetation canopy (Kogan 1990, 1997). These conditions are derived from the reflectance/emission in the red (R), near infrared (NIR) and infrared (IR, 10.3-11.3 µm) parts of solar spectrum measured by the Advanced Very High Resolution Radiometer (AVHRR) flown on the NOAA afternoon polar-orbiting satellites since 1981.

Percent Drought Area & Intensity 2001-2011



Existing approaches to yield forecasting

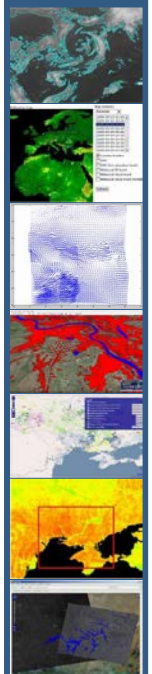


- **Empirical models**
  - connect **crop yield** with some selected **predictors** (vegetation indices, meteorological observations)
  - Pros
    - require little data inputs
    - easy to implement
  - Cons
    - lack robustness and generalization ability
    - data-driven, i.e. their performance strongly depends on available datasets
- **Crop growth models**
  - simulate the growth of crops to retrieve biophysical crop parameters such as **crop production**, **biomass**, **water use**, etc.
  - Pros
    - quite generic and robust
  - Cons
    - numerous input parameters to run the model
    - proper adaptation still needed

Data used

- **MOD13 product** (NDVI) at the 250 m resolution for 2000-2011
- ESA Global Land Cover map (**GlobCover**) at the 300 m resolution for 2008
- Monthly **meteorological observations** from 180 stations in Ukraine for 2000-2011
- **Official statistics of winter wheat yield** for Ukraine at oblast level for 2000-2011

Methodology



- Empirical regression-based model that uses as a predictor **16-day NDVI composites** derived from **MODIS**
  - NDVI averaged for oblasts by crop masks
  - trend eliminated from yield
  - robust regression
  - model specific for each oblast
- Adapted for Ukraine **Crop Growth Monitoring System (CGMS)** that is based on **WOFOST** crop growth simulation model and meteorological parameters [*UHMI*]

Methodology – cont’

- Empirical regression-based model that uses as predictors **meteorological parameters**
  - **parameters**
    - Maximum temperature
    - Minimum temperature
    - Average temperature
    - Precipitation
    - Soil moisture
      - 0-20 cm depth
      - Available for months: Sept, Oct, Apr, May, June
  - Non-linear multivariate regression – Gaussian process

Efficiency assessment

- Cross-validation
  - leave-one-out cross-validation (**LOOCV**)
  - using a single observation from the original sample as the testing data, and the remaining observations as the training data
- Criteria
  - RMSE on testing data $RMSE = \sqrt{\frac{1}{n}\sum_i (P_i - O_i)^2}$
    - P_i and O_i are predicted and observed winter wheat yields
- Relative efficiency

$$\text{Rel.eff.} = \frac{V(Y_{sample})}{V(Y_{satellite})} = \frac{\frac{1}{n}\sum_i (dY_i)^2}{RMSE^2}$$

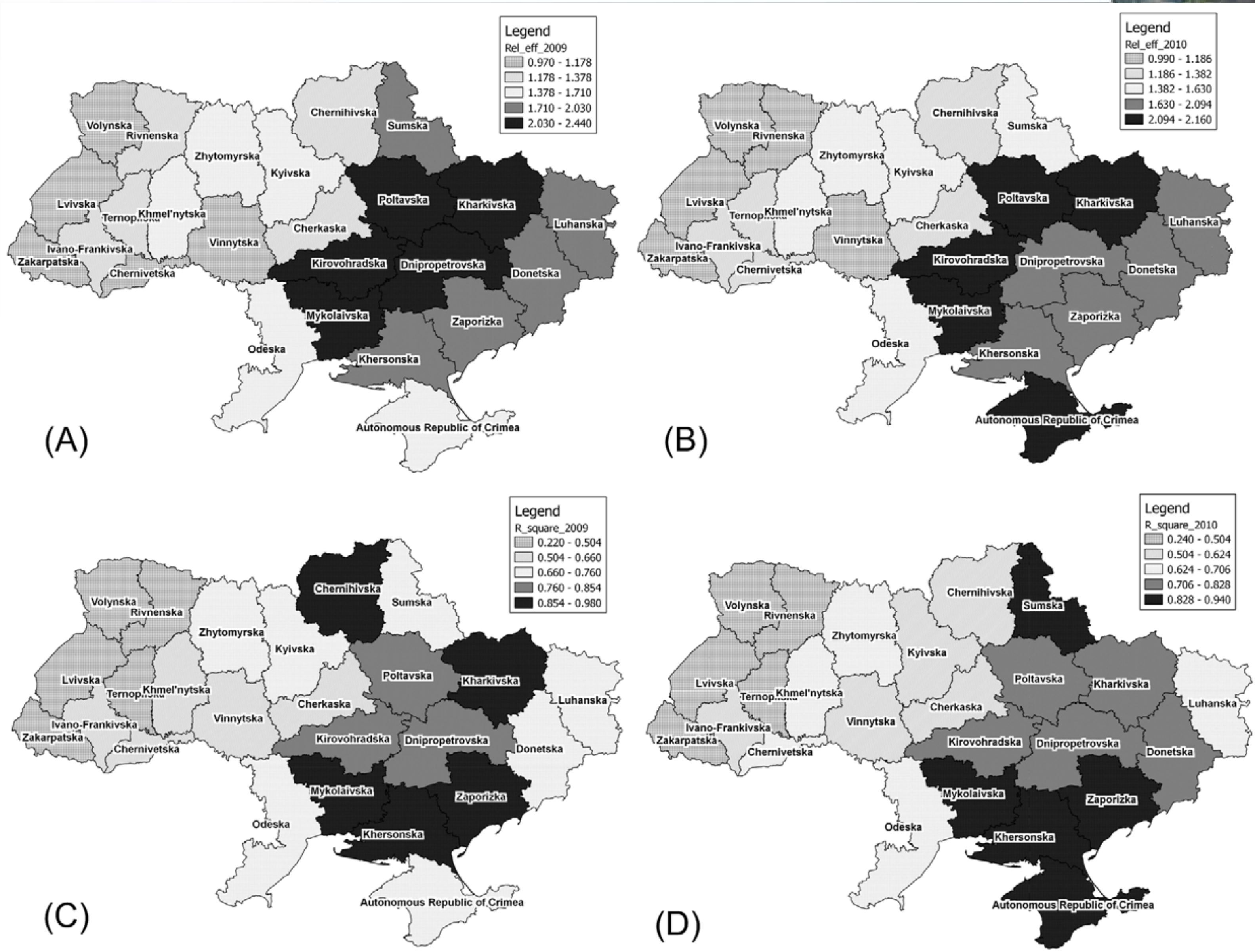
  - dY_i deviation from trend

Results for NDVI regression model – cont'

- Relative efficiency and coefficient of determination of the regression model for different agro-climatic zones averaged by oblasts

	Model 2000-2009		Model 2000-2010	
Agro-climatic zone	**Rel. eff.**	**R-square**	**Rel. eff.**	**R-square**
Plane-Polissya	1.182	0.479	1.177	0.433
Forest-Steppe	1.576	0.667	1.532	0.680
Steppe	1.883	0.804	1.894	0.796

Results for NDVI regression model – cont’



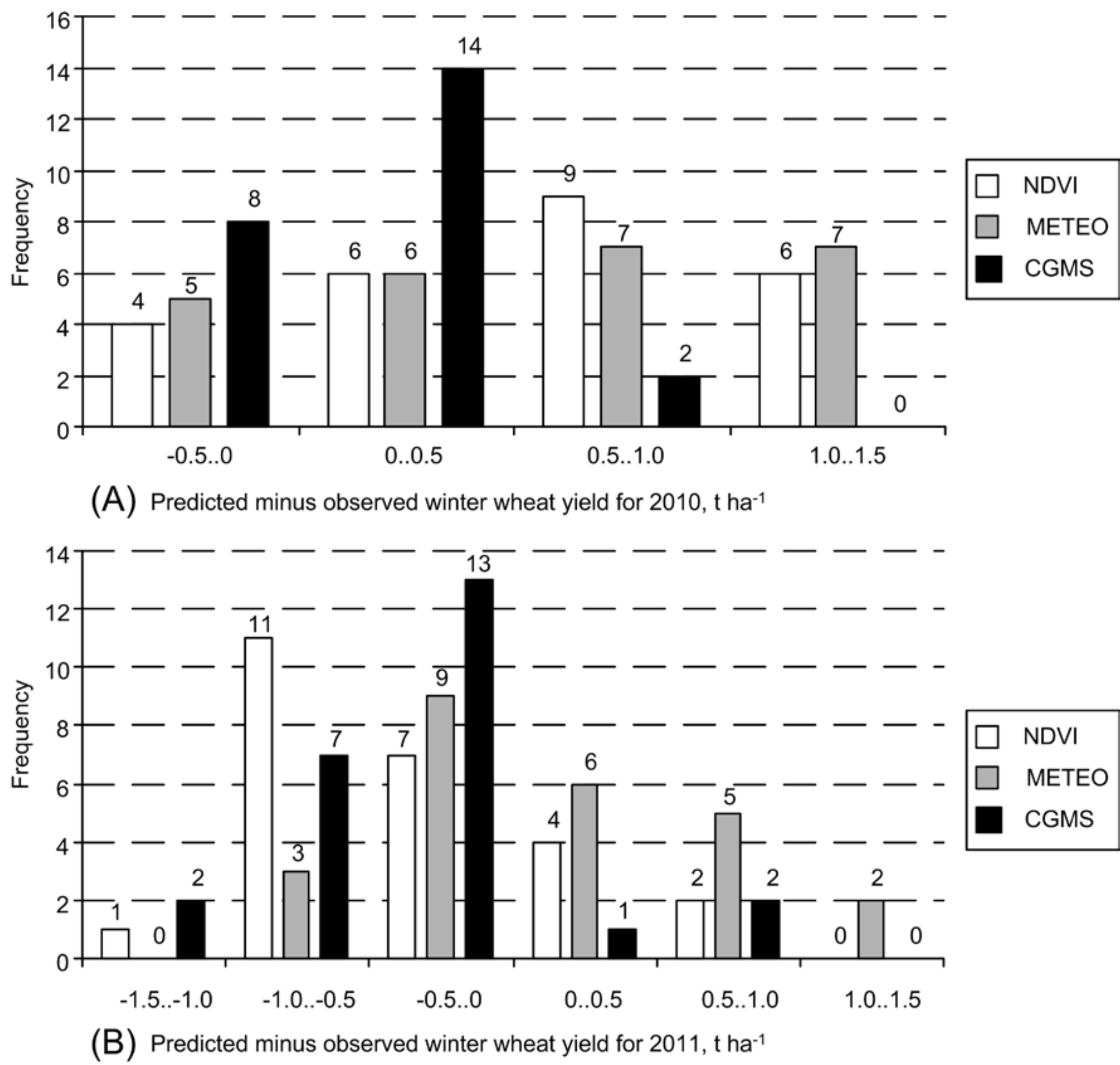
Comparison of models

- **All three approaches** were used to forecast winter wheat yield for independent data sets for **2010** and **2011**,
  - i.e. on data that were not used within model calibration process

Model	**RMSE for 2010, t ha^{-1}**	**RMSE for 2011, t ha^{-1}**
MODIS NDVI (2000-2009)	0.794	0.585
MODIS NDVI (2000-2010)	-	0.625
Meteorological (2000-2009)	0.779	0.565
CGMS (2000-2009)	0.304	-
CGMS (2000-2010)	-	0.579

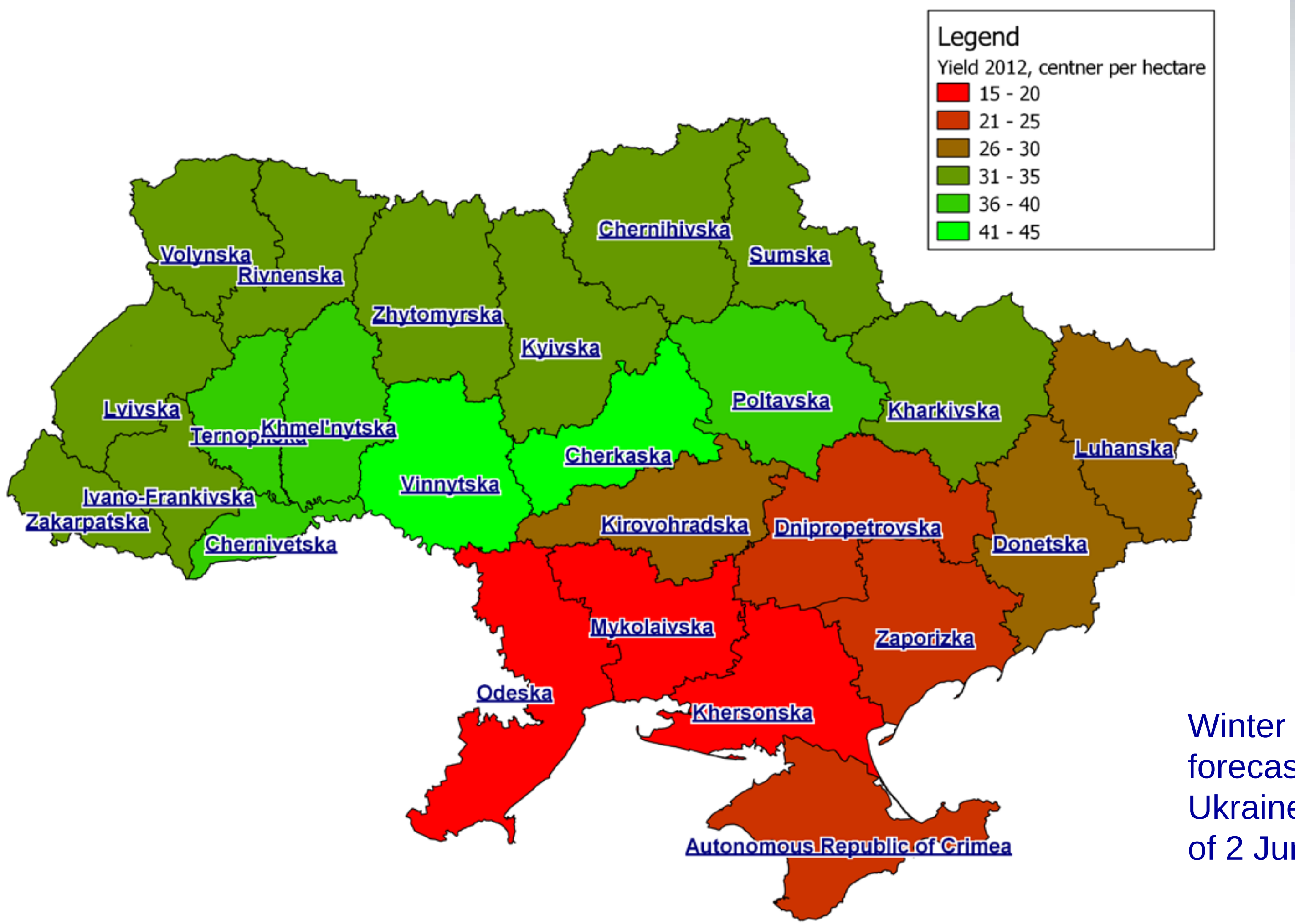
Comparison of models – cont'

- Histogram of the RMSE values for winter wheat yield forecasting for 2010 (A) and 2011 (B)



Winter wheat forecast for 2012

- **Operational forecasting of winter wheat yield in Ukraine for 2012 based on Earth observation**



Winter wheat forecasts for Ukraine for 2012 as of 2 June 2012

Conclusions

- NDVI-based regression model was effective in producing yield forecasts in April-May, i.e. 2-3 months prior to harvest
- Relative efficiency of NDVI-based model was dependent on agro-climatic zones ranging from 1.2 to 1.9
- The sign of errors for all three approaches was the same
- Drought area in Ukraine does not experience any trend after 2000, although the last 50-year country average annual temperature increased 1.45°C (twice above the global increase)
- Total annual precipitation increased by 40 mm offsetting drought intensification due to a warmer climate.

Thank you!