Remote sensing based yield model and application to major exporting countries

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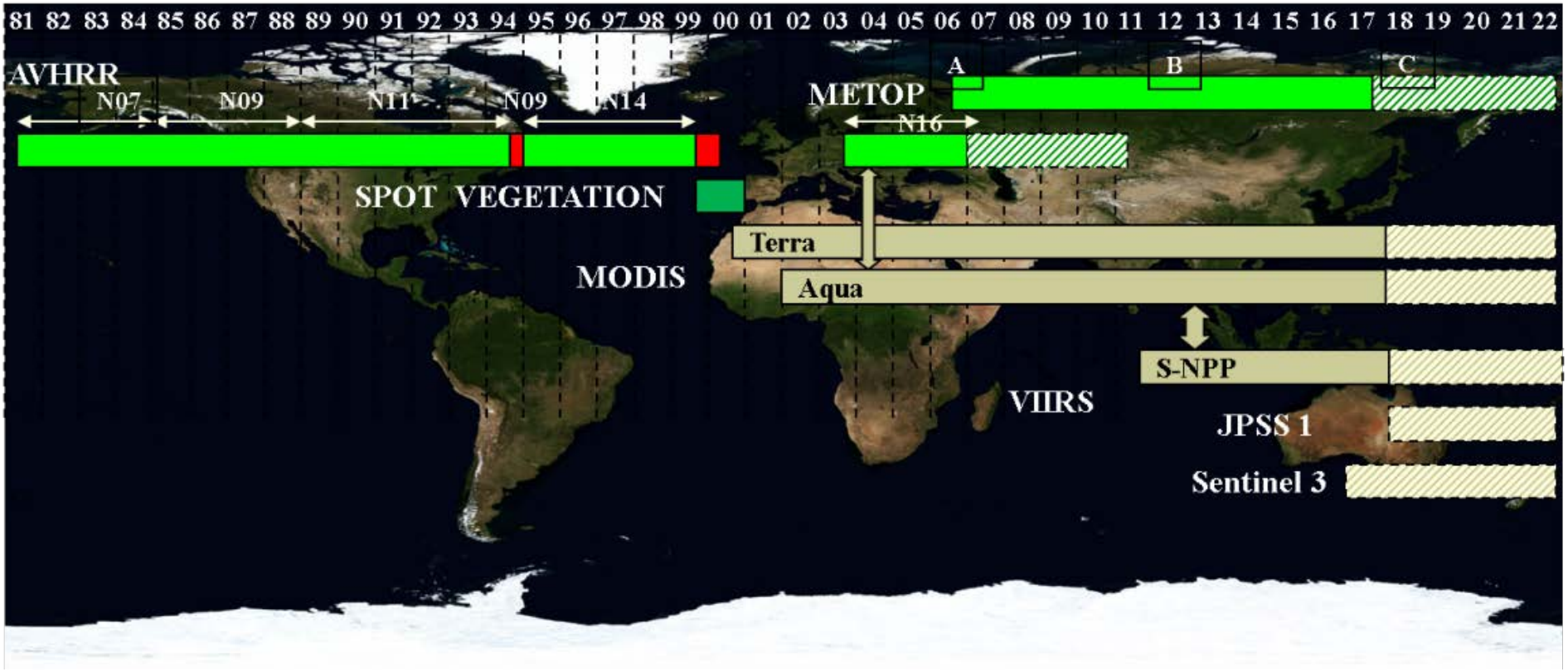
Why do we use coarse resolution?

Land Climate Data Record

Multi instrument/Multi sensor Science Quality Data Records used to quantify trends and changes

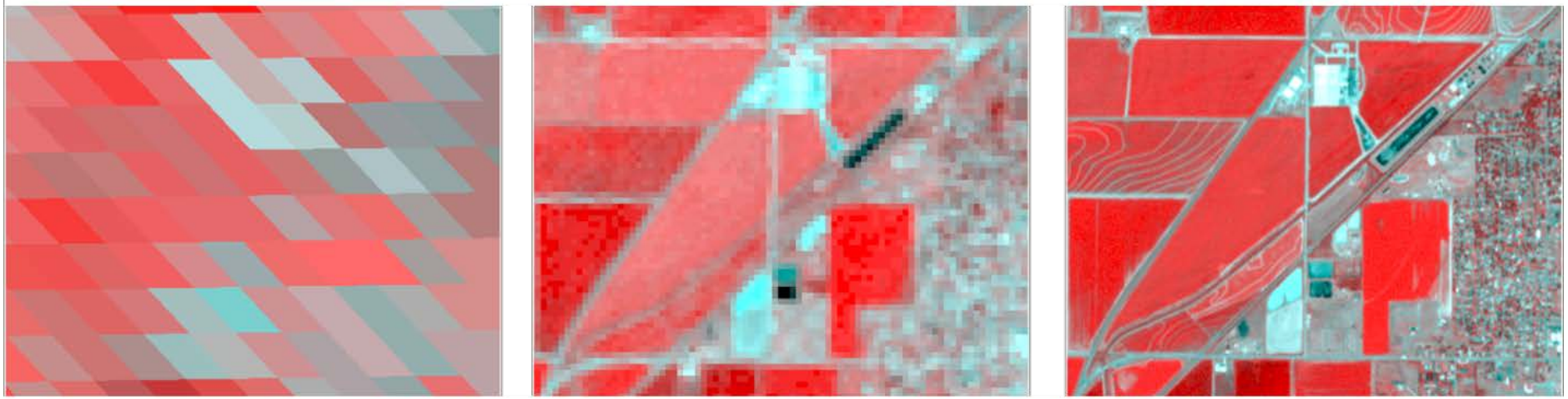
Emphasis on data consistency



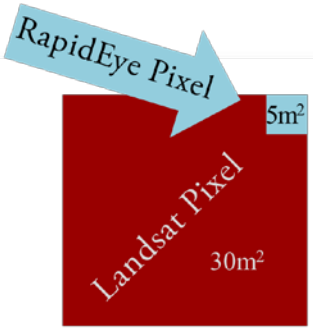
Problems when working with coarse spatial resolution data

Coarse (250m)	Moderate (30m)	Fine (5m)

MODIS – Landsat – RapidEye



5km x 4.7km near Stuttgart, Arkansas



Pixel Size Ratio

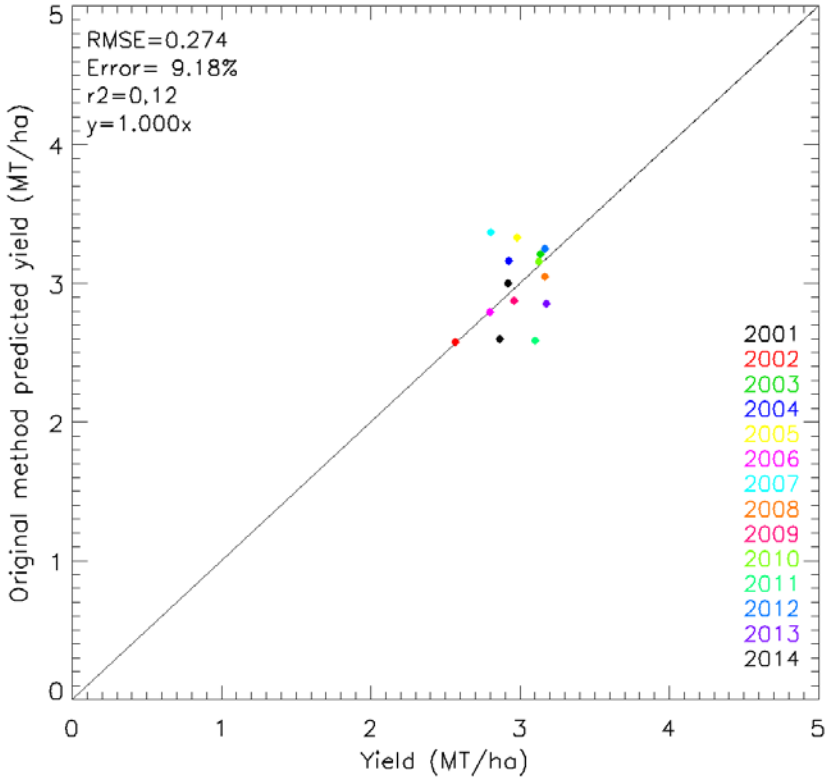
Previous remote sensing methods

(Becker-Reshef et al., 2010)

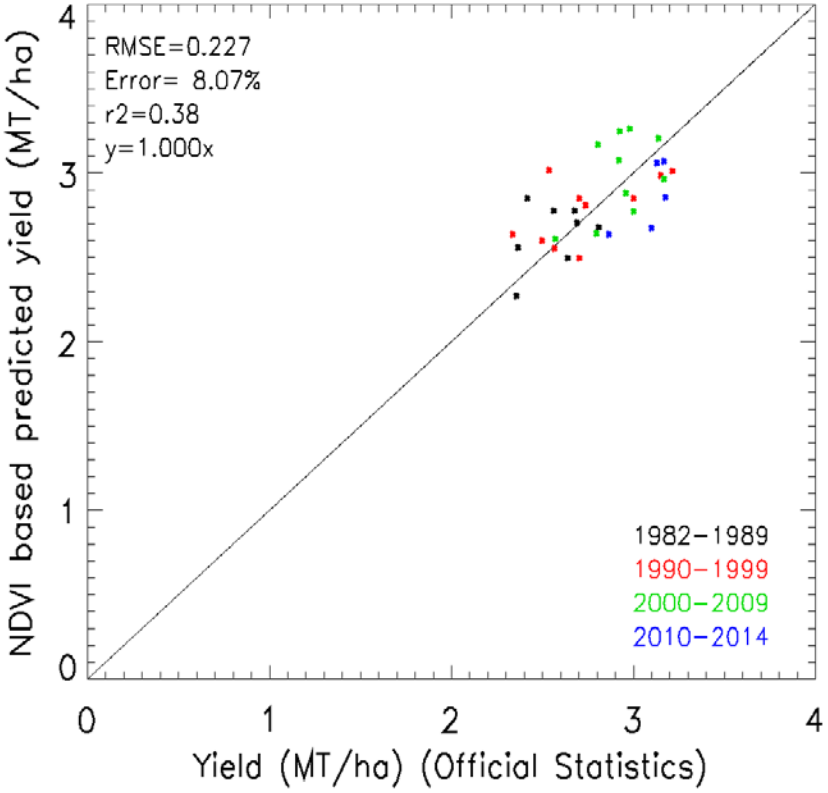
Basis: **Strong correlation between NDVI Peak and yield**

Tucker 1980, Hatfield 1983, Benedetti 1993, Doraiswamy 1995, Rasmussen 1997, Mika 2002

USA (MODIS)



USA (AVHRR)



Becker-Reshef I, Vermote E, Lindeman M, Justice C. 2010. In Remote Sensing of Environment, 114, 1312–1323.

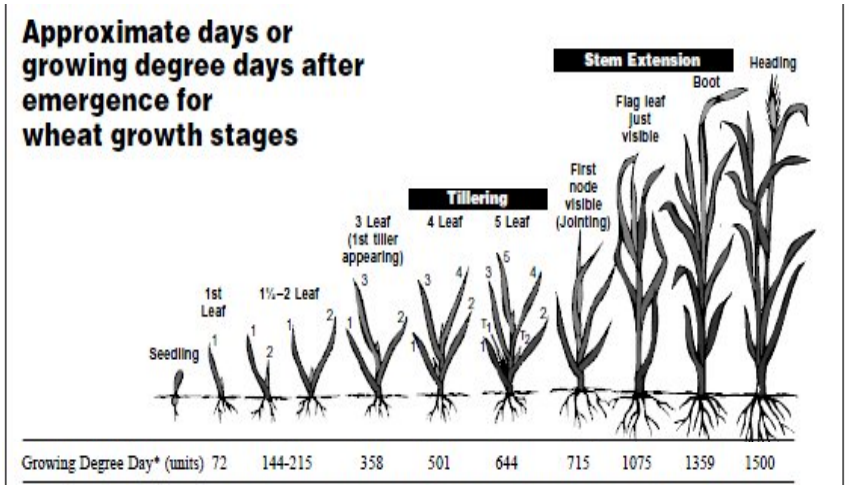
Franch, B., Vermote, E., Roger, J.C., Murphy, E., Becker-Reshef, I., Justice, C., Claverie, M., Nagol, J., Csiszar, I., Meyer, D., Baret, F., Masuoka, E., Wolfe, R. and Devadiga, S., (2017) A 30+ year AVHRR Land Surface Reflectance Climate Data Record and its application to wheat yield monitoring, Remote Sensing, 9, 296

YIELD MONITORING

Improvement of the method

The NDVI peak occurs around **1 month** prior to the harvest (earliest forecast using this method)

Inclusion of an **additional parameter (the Growing Degree Days, GDD)** to improve the timeliness of the prediction



$$GDD = \frac{T_{max} + T_{min}}{2} - T_{base}$$

T_{base} = 0 °C

$$GDD_{accum}(day) = \sum_{i=biofix\ date}^{day} GDD_i$$

Franch, B., E. F. Vermote, I. Becker-Reshef, M. Claverie, J. Huang, J. Zhang, C. Justice and J. A. Sobrino, 2015. Remote Sensing of Environment

YIELD MONITORING

USA

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The NDVI peak
1 month prior
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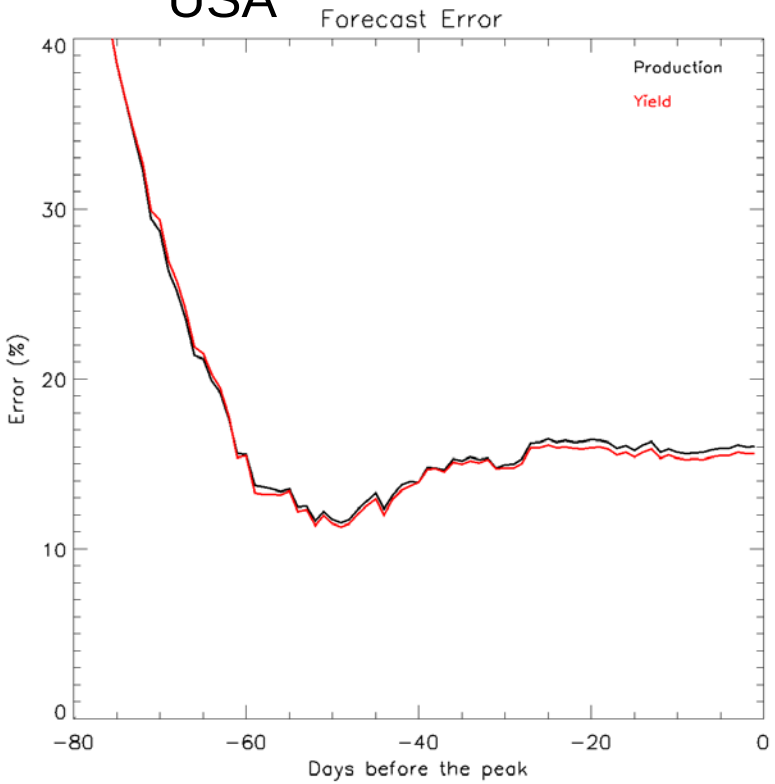
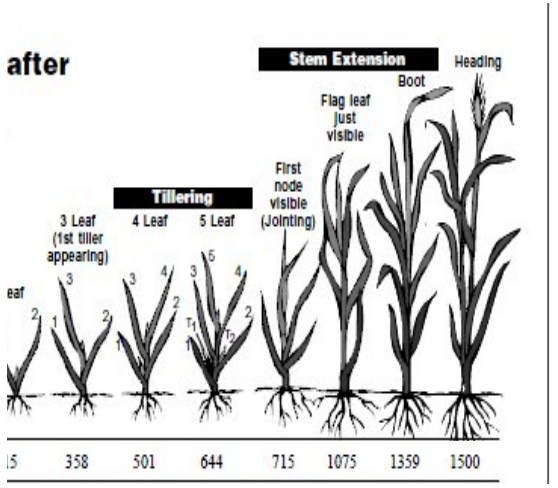




Inclusion of a
paramete
Days,
timelin

Reliable estimation (10% error) between 1-1.5 month prior to the peak NDVI (meaning **2-2.5 months prior to harvest**)

se = 0 °C

$$\gamma) = \sum_{i=biofix\ date}^{day} GDD_i$$

Franch, B., E. F. Vermote, I. Becker-Reshef, M. Claverie, J. Huang, J. Zhang, C. Justice and J. A. Sobrino, 2015. Remote Sensing of Environment

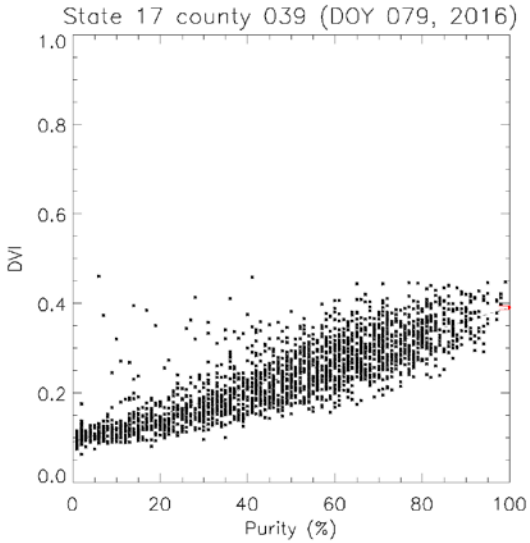
New method

ARYA AGRICULTURE REMOTELY SENSED YIELD ALGORITHM

For each AU and a given date, the total DVI signal from each pixel can be written as:

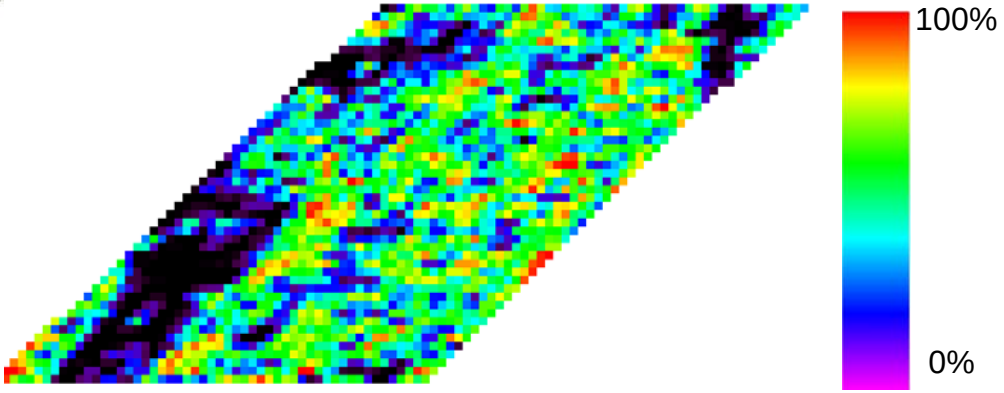
$$DVI_i = (DVI_{wheat} - DVI_{others}) \cdot Wpct_i + DVI_{others}$$

DVI_{wheat} : DVI signal from the wheat
DVI_{others}: DVI from other surfaces within the pixel
Wpct: percentage of wheat within the pixel or wheat purity



MODIS 1km RGB (2/21/2017)
Harper county (Kansas)

2017 wheat mask (from CDL)
Harper county (Kansas)



Franch, B., Vermote, E. F., Skakun, S., Roger, J. C., Becker-Reshef, I., Murphy, E., & Justice, C. (2019). Remote sensing based yield monitoring: Application to winter wheat in United States and Ukraine. *International Journal of Applied Earth Observation and Geoinformation*, *76*, 112-127.

Calibration equations

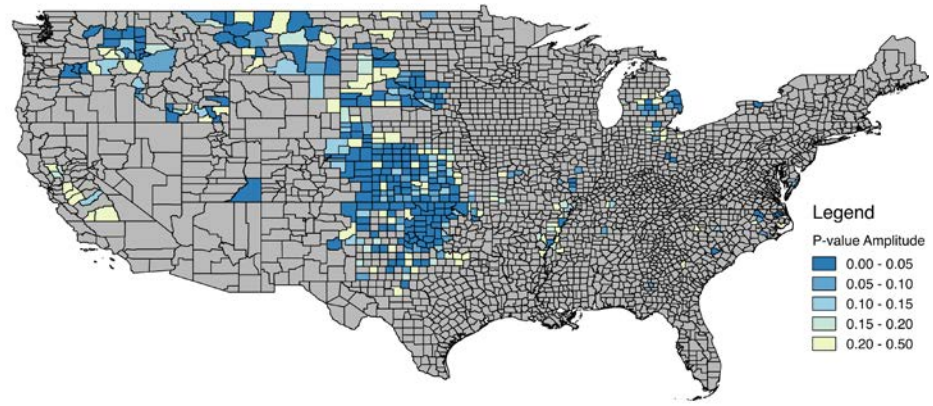
Input parameters

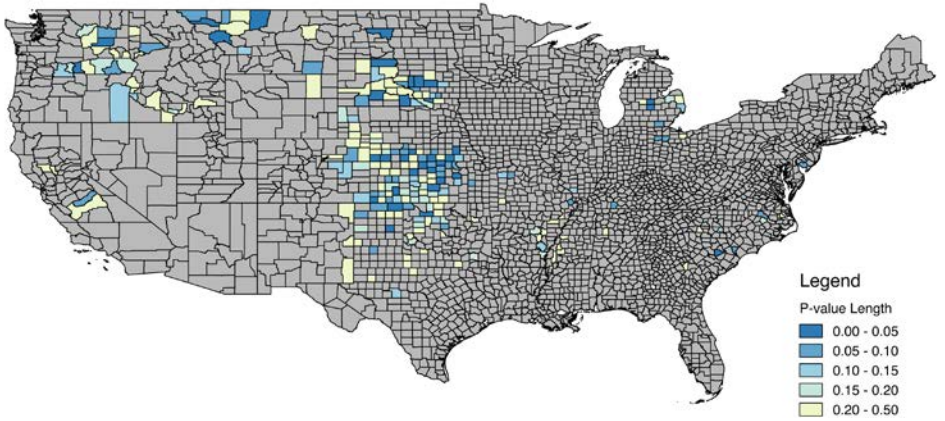
Seasonal Peak

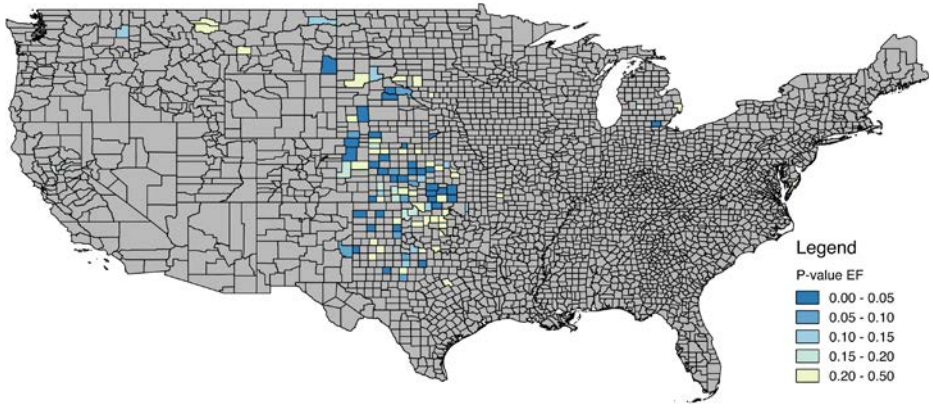
Peak length

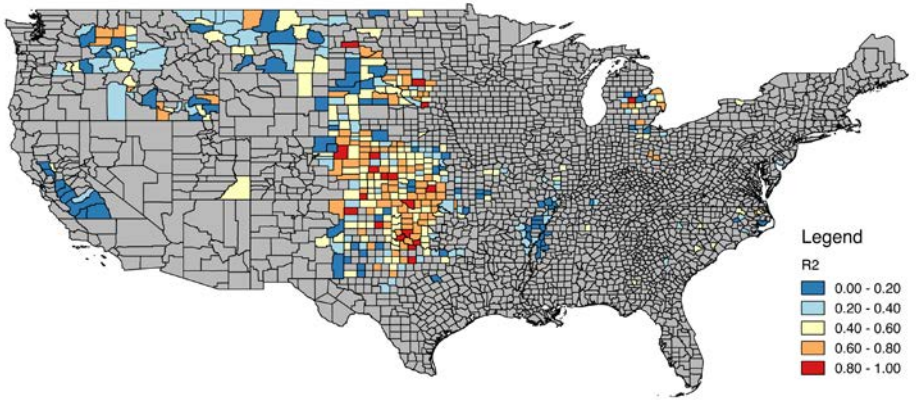
Evaporative Fraction (after the peak)

For each AU, a separate linear regression was built with different combinations of regressors

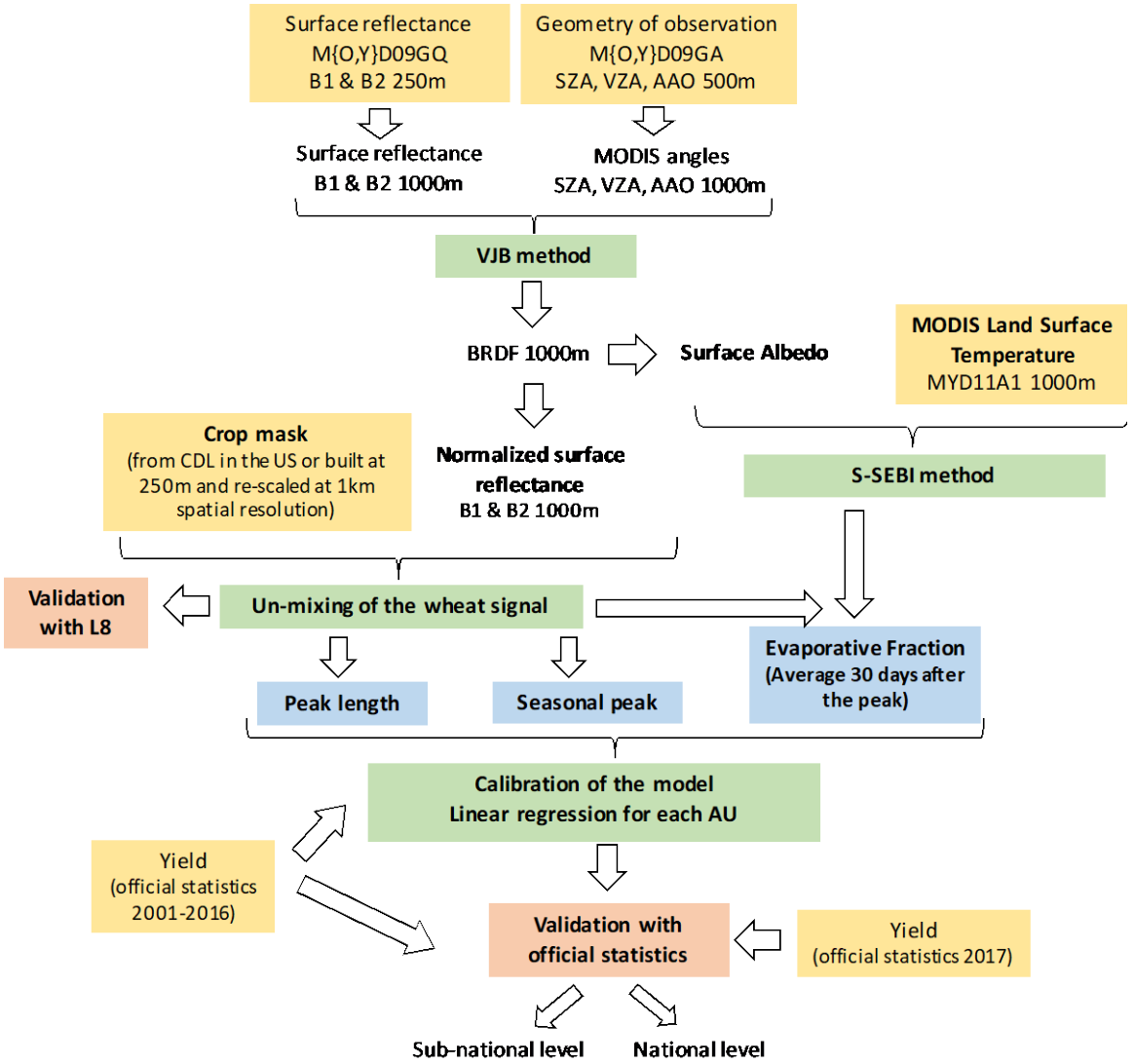






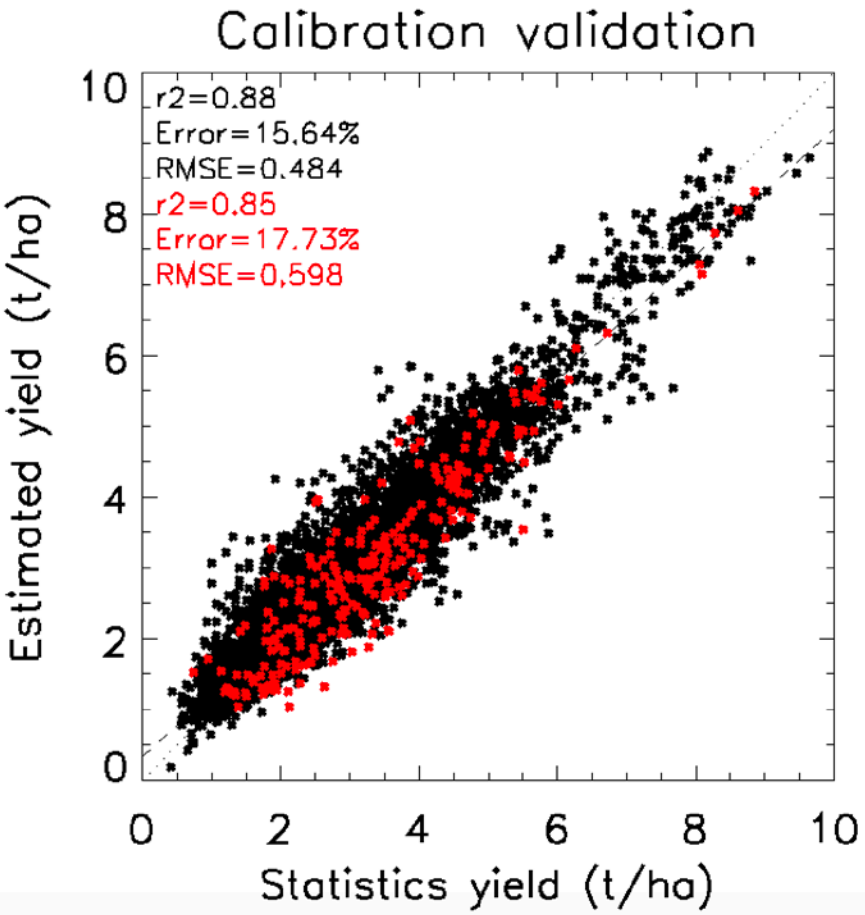


New method


Surface reflectance
M{O,Y}D09GQ
B1 & B2 250m
Geometry of observation
M{O,Y}D09GA
SZA, VZA, AAO 500m
Surface reflectance
B1 & B2 1000m
MODIS angles
SZA, VZA, AAO 1000m
VJB method
BRDF 1000m
Surface Albedo
MODIS Land Surface Temperature
MYD11A1 1000m
Crop mask
(from CDL in the US or built at 250m and re-scaled at 1km spatial resolution)
Normalized surface reflectance
B1 & B2 1000m
S-SEBI method
Validation with L8
Un-mixing of the wheat signal
Evaporative Fraction
(Average 30 days after the peak)
Peak length
Seasonal peak
Calibration of the model
Linear regression for each AU
Yield
(official statistics 2001-2016)
Validation with official statistics
Yield
(official statistics 2017)
Sub-national level
National level

US winter wheat validation

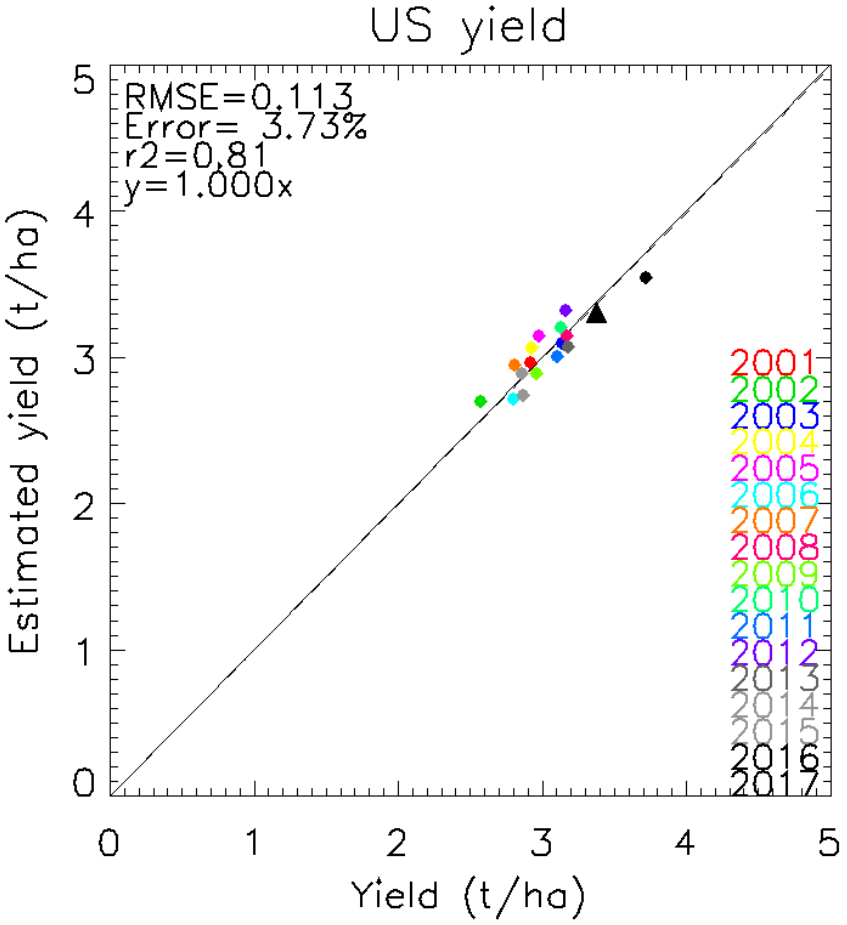
County level validation



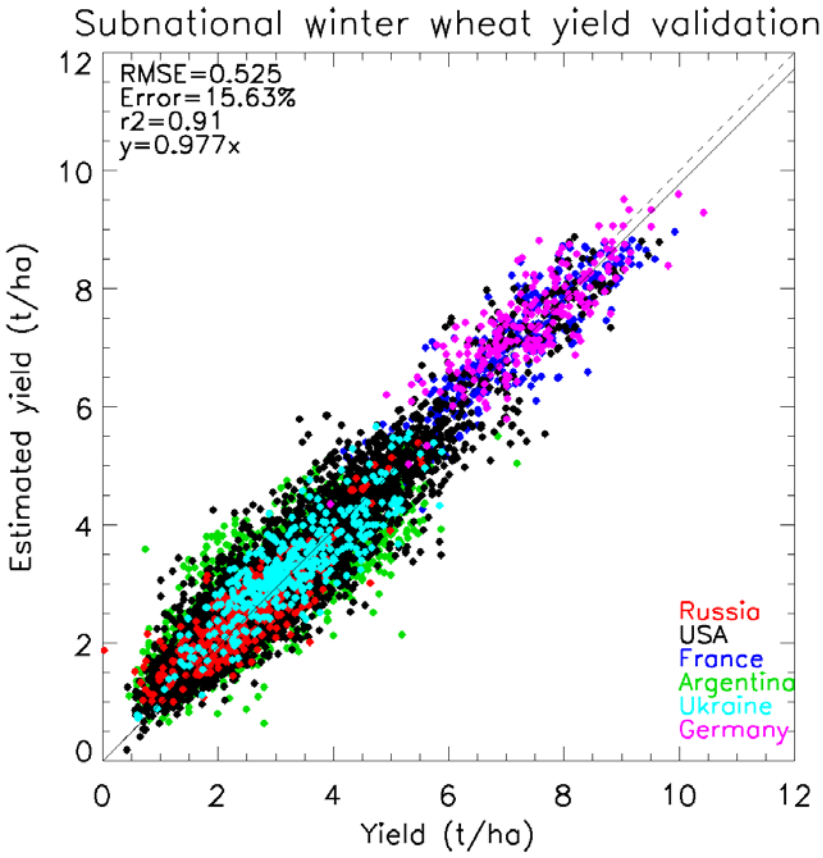
Black dots: each county and year from 2001-2016

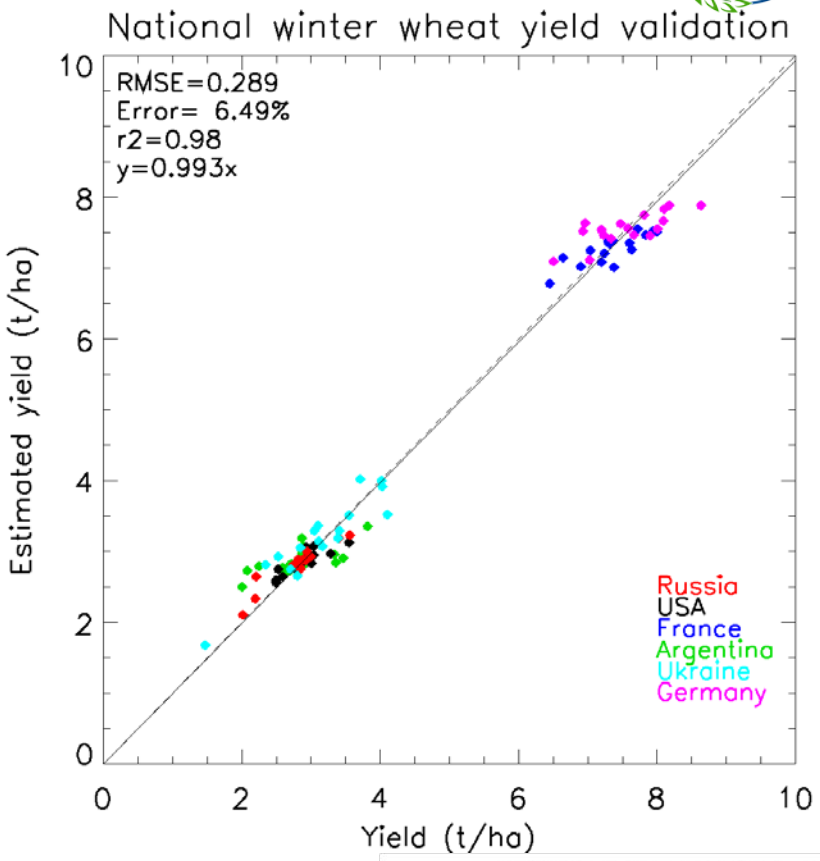
Red dots: each county in 2017

National level validation

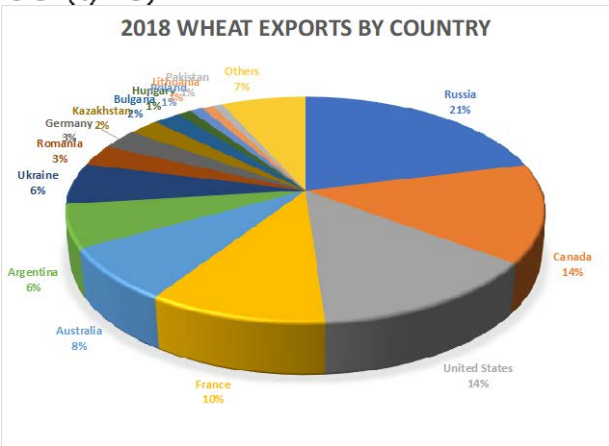


Application to other countries



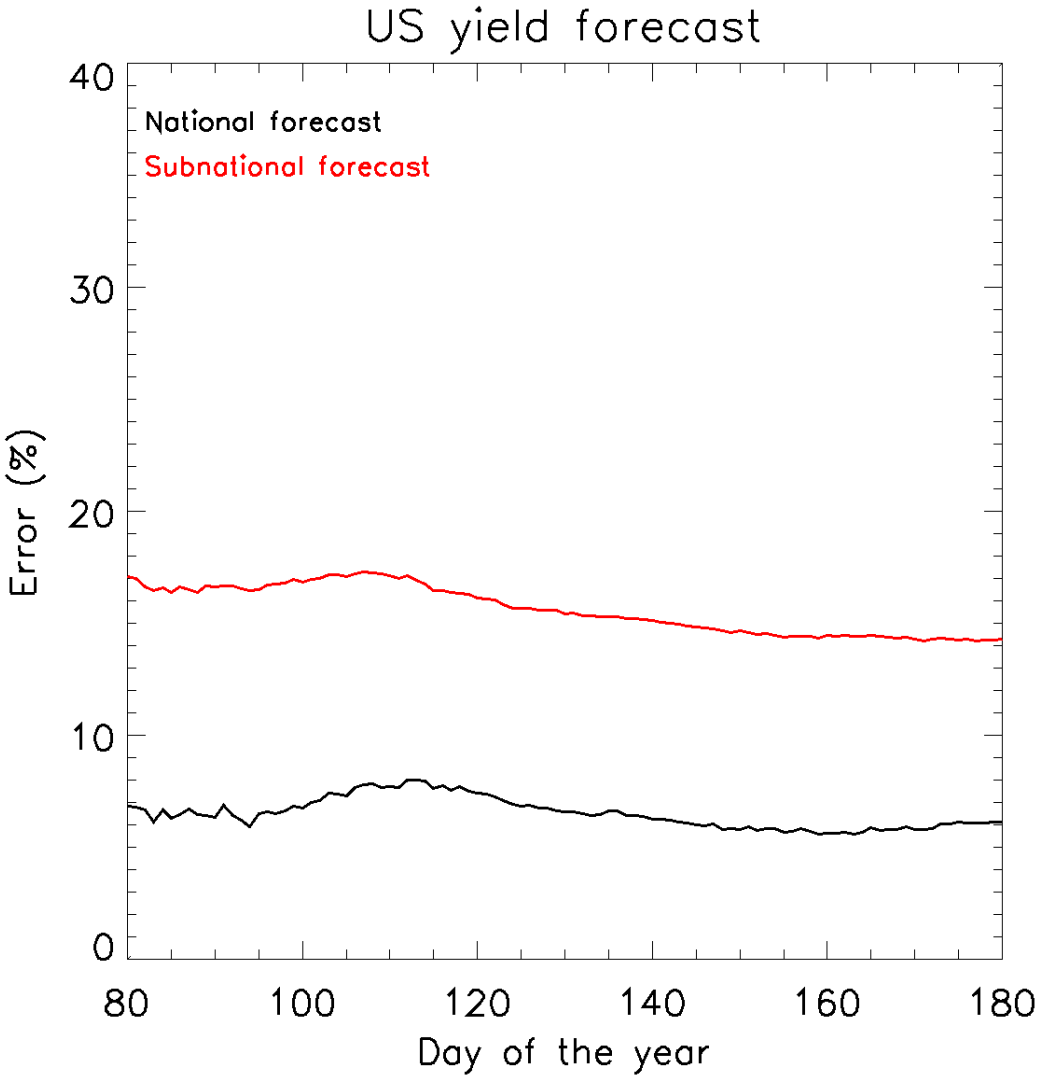


60% of the global wheat exports in 2018



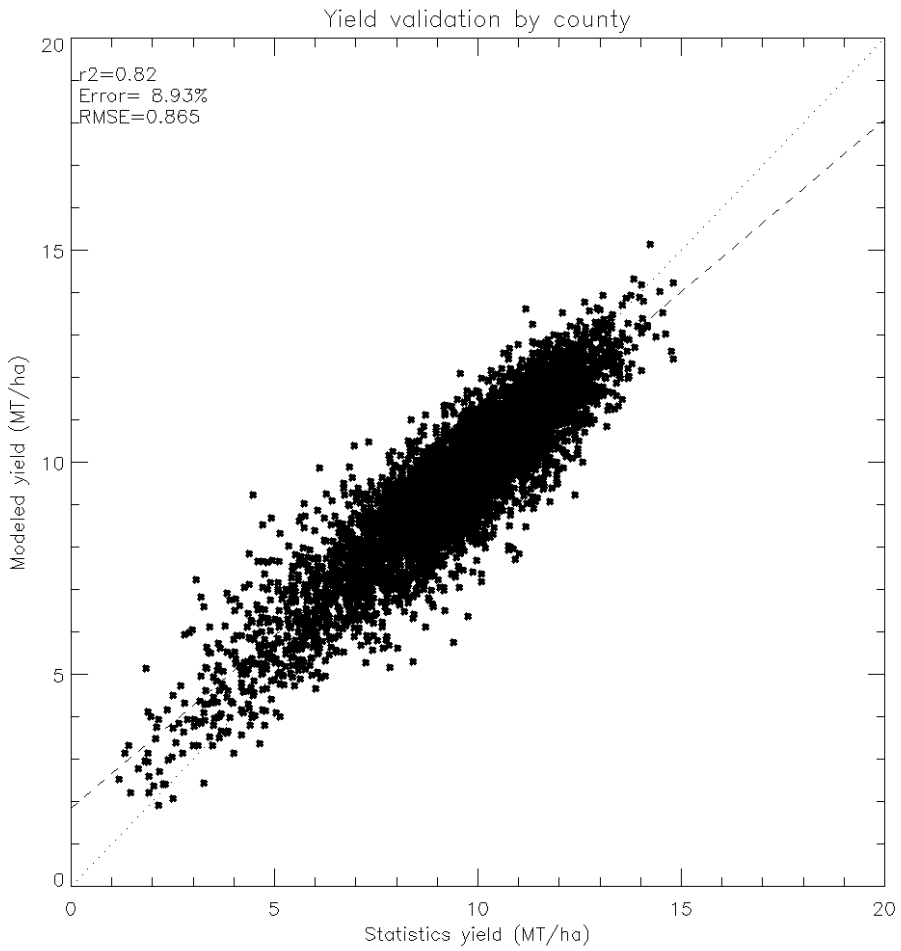
Yield forecasting

Working on adapting Franch et al. (2015) to the new method

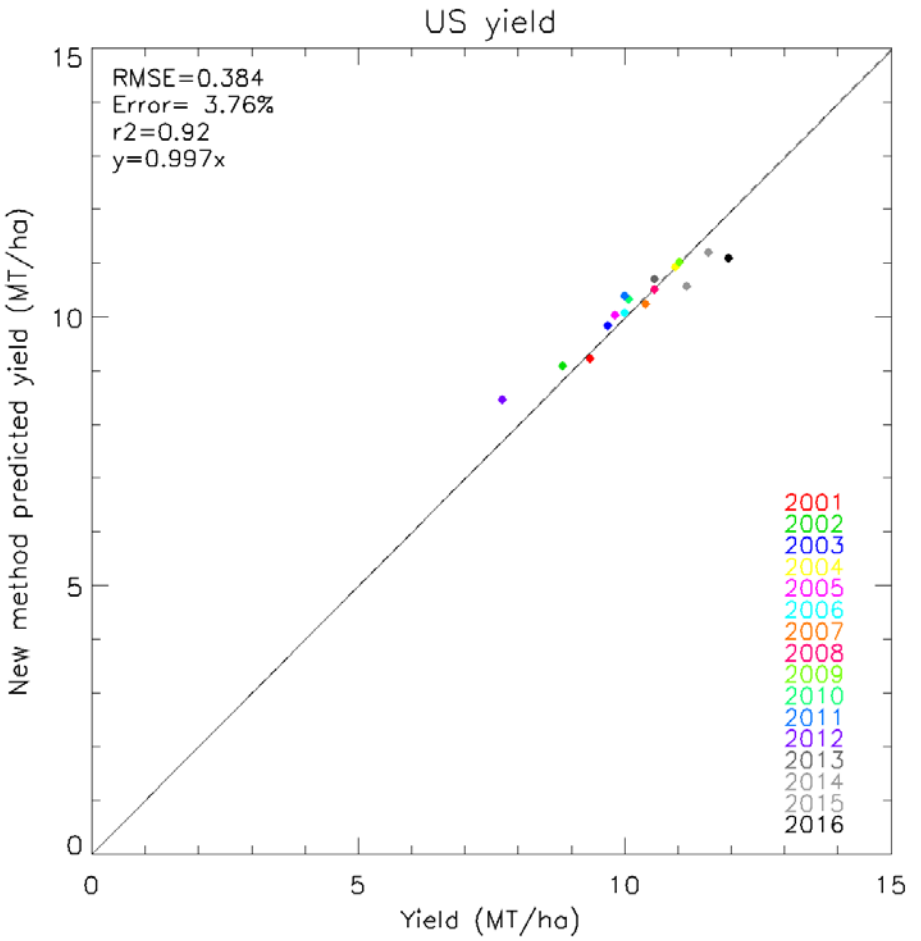


US corn validation

County level validation

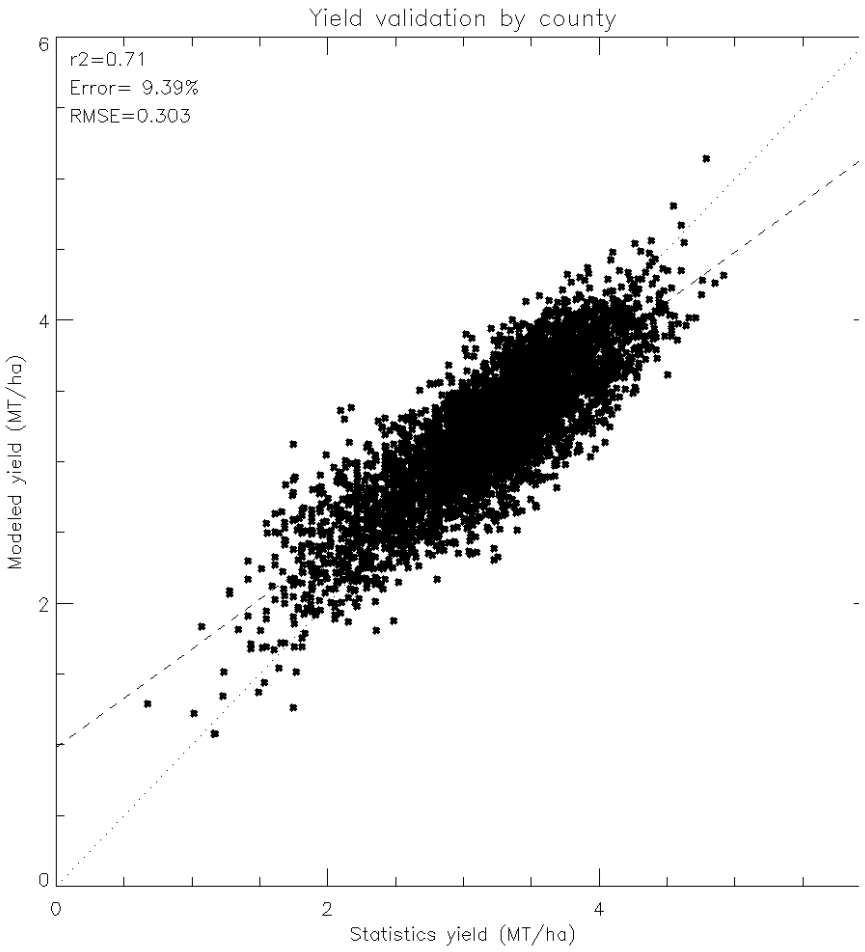


National level validation

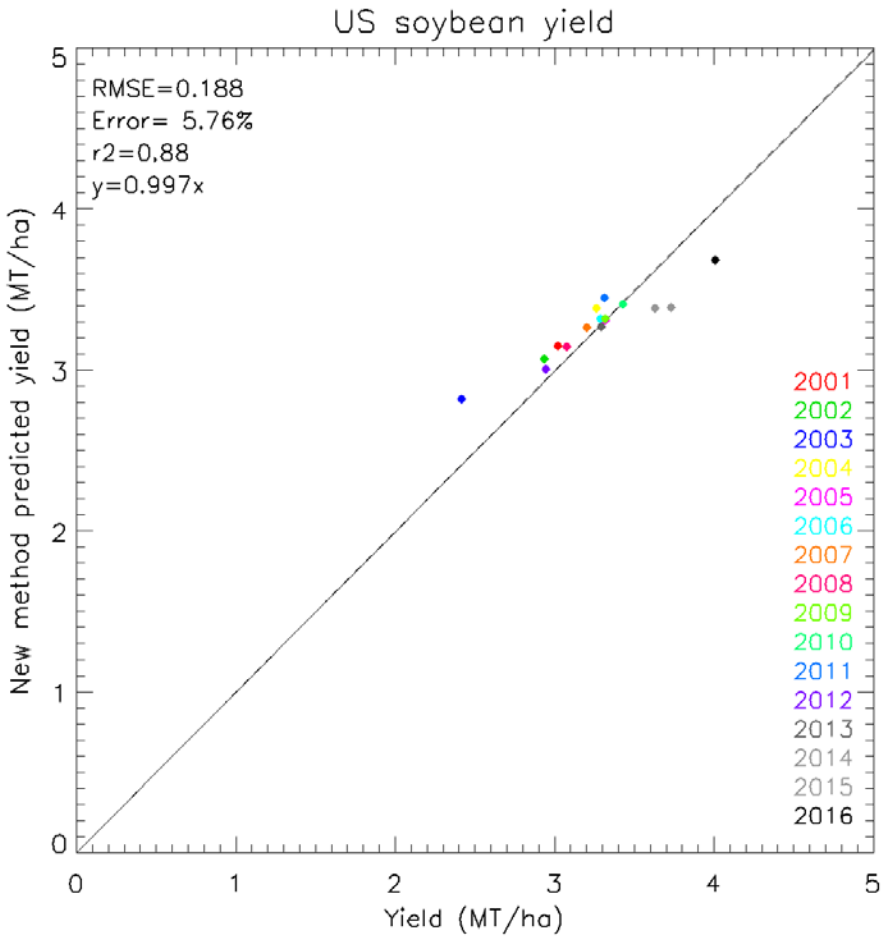


US soybean validation

County level validation



National level validation



Conclusions

- A generic crop yield simple regression model has been developed based on a the “wheat” DVI at the **peak** of the growing process, the **length** of the peak and **EF** information.
- Can estimate yield for the main wheat exporting countries with an accuracy
  - **7%** at national level
  - **15%** at sub-national level
- The new method shows high correlation with official statistics and captures well **extreme yield conditions** (maximum and minimum). Freezing and flooding is still a problem
- First results on yield **forecasting** show promising results
- The model is also applicable to **other cereals** (corn and soybean)