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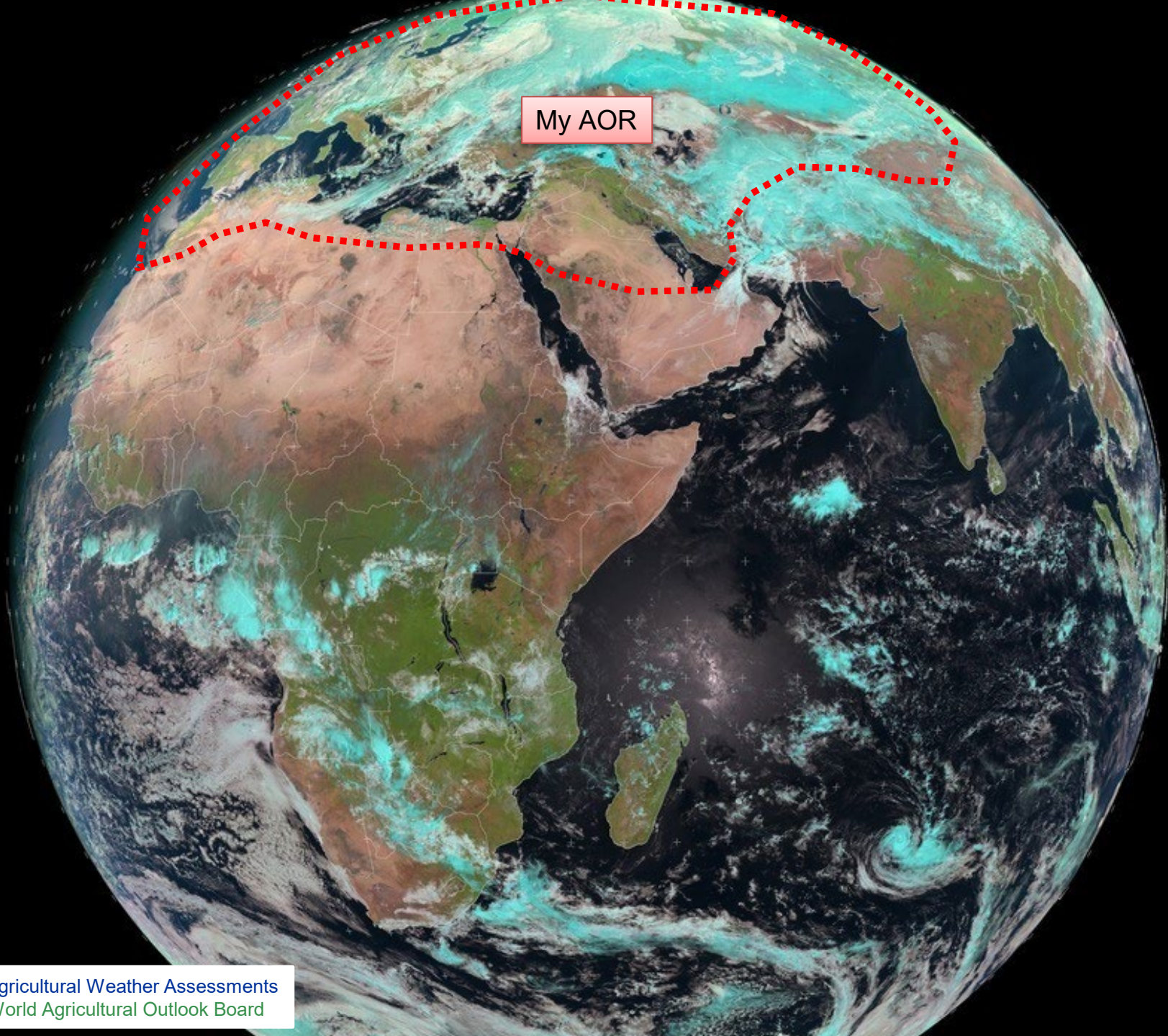
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A satellite view of the Earth showing the Northern Hemisphere. The image is centered on the North Pole, with the Arctic region at the top. The continents of North America, Europe, and Asia are visible, along with the surrounding oceans. The text is overlaid in yellow on the image.

**Northern Hemisphere  
Crop Prospects and Stage-Based Yield Modeling**

**Eric  
Luebehusen**

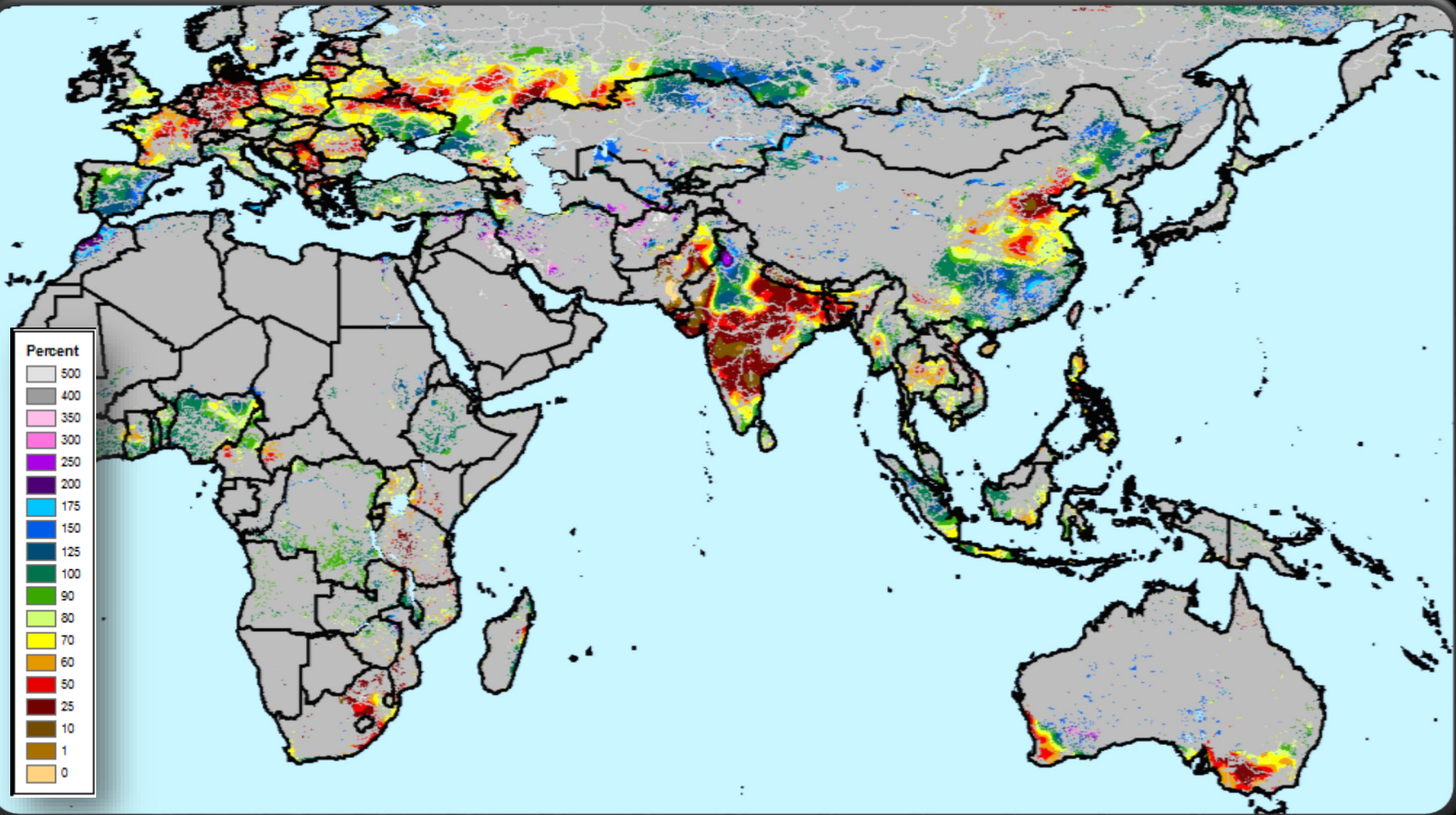
**Meteorologist  
USDA/OCE/WAOB**



My AOR

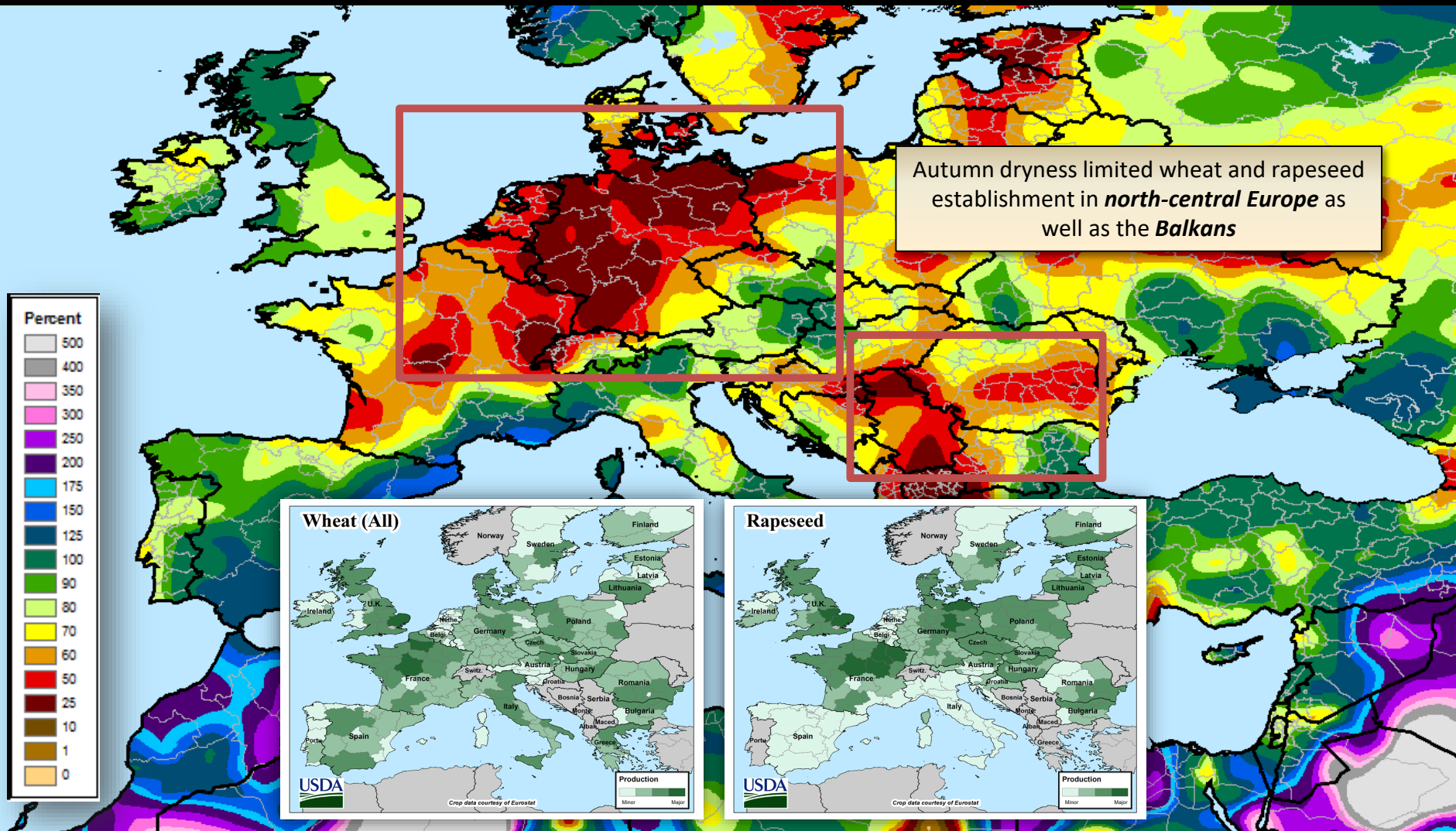
# Percent-of-Normal Precipitation

September-November, 2018



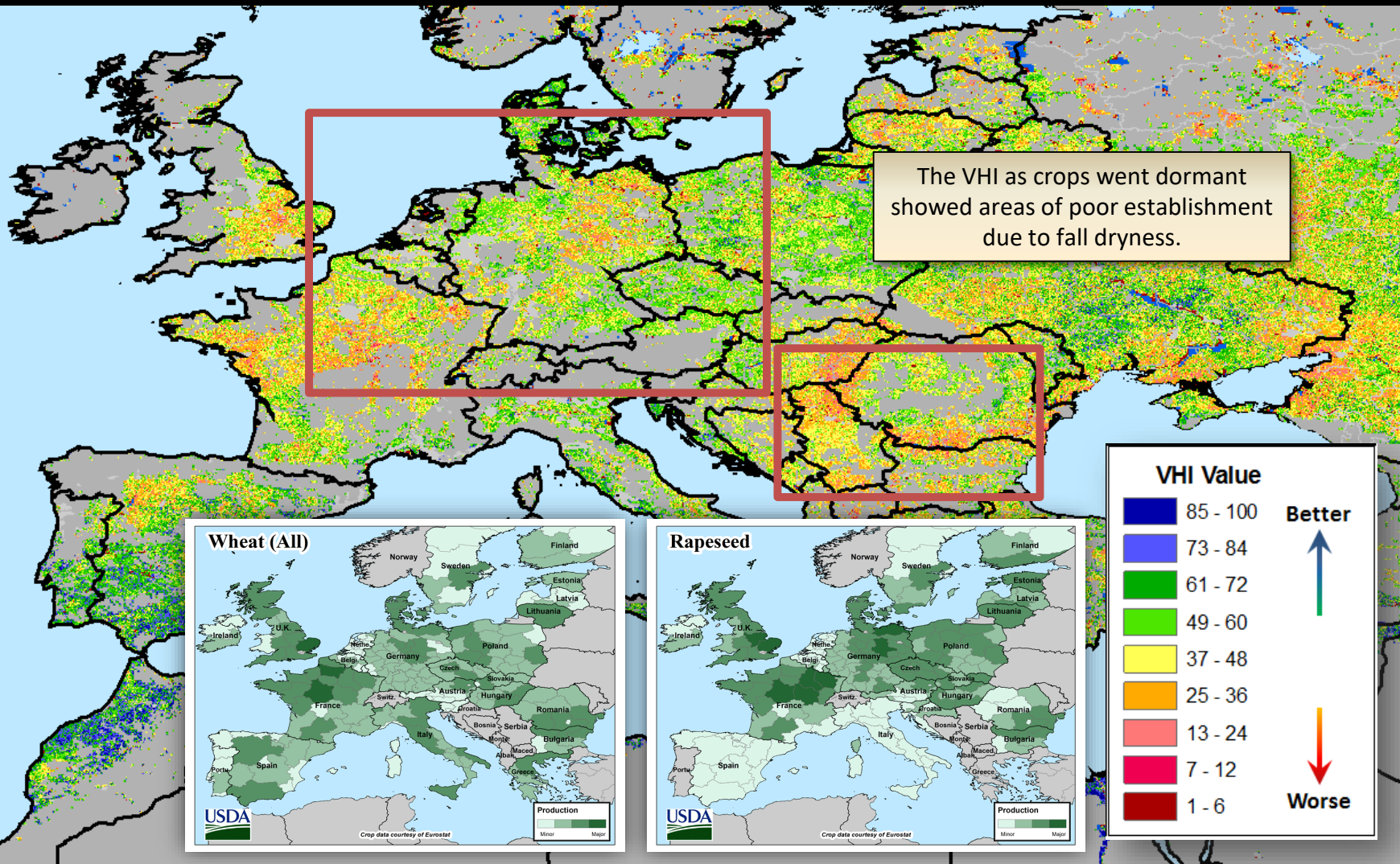
# Percent-of-Normal Precipitation

September-November, 2018

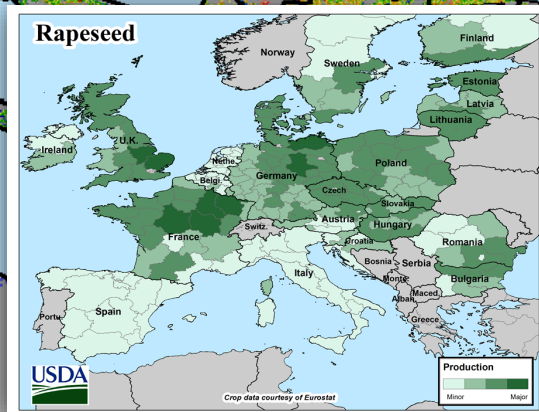
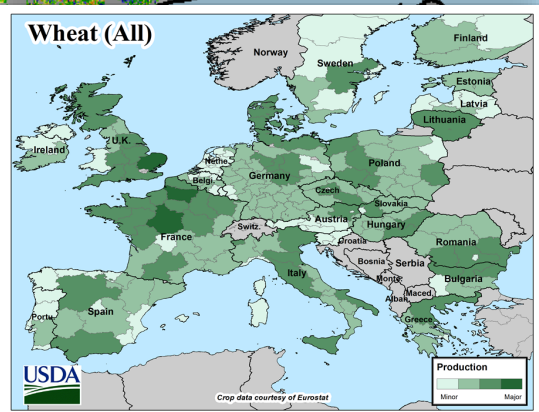
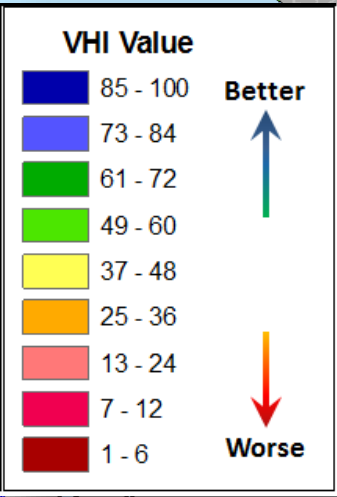


# Vegetative Health Index

Nov 18, 2018

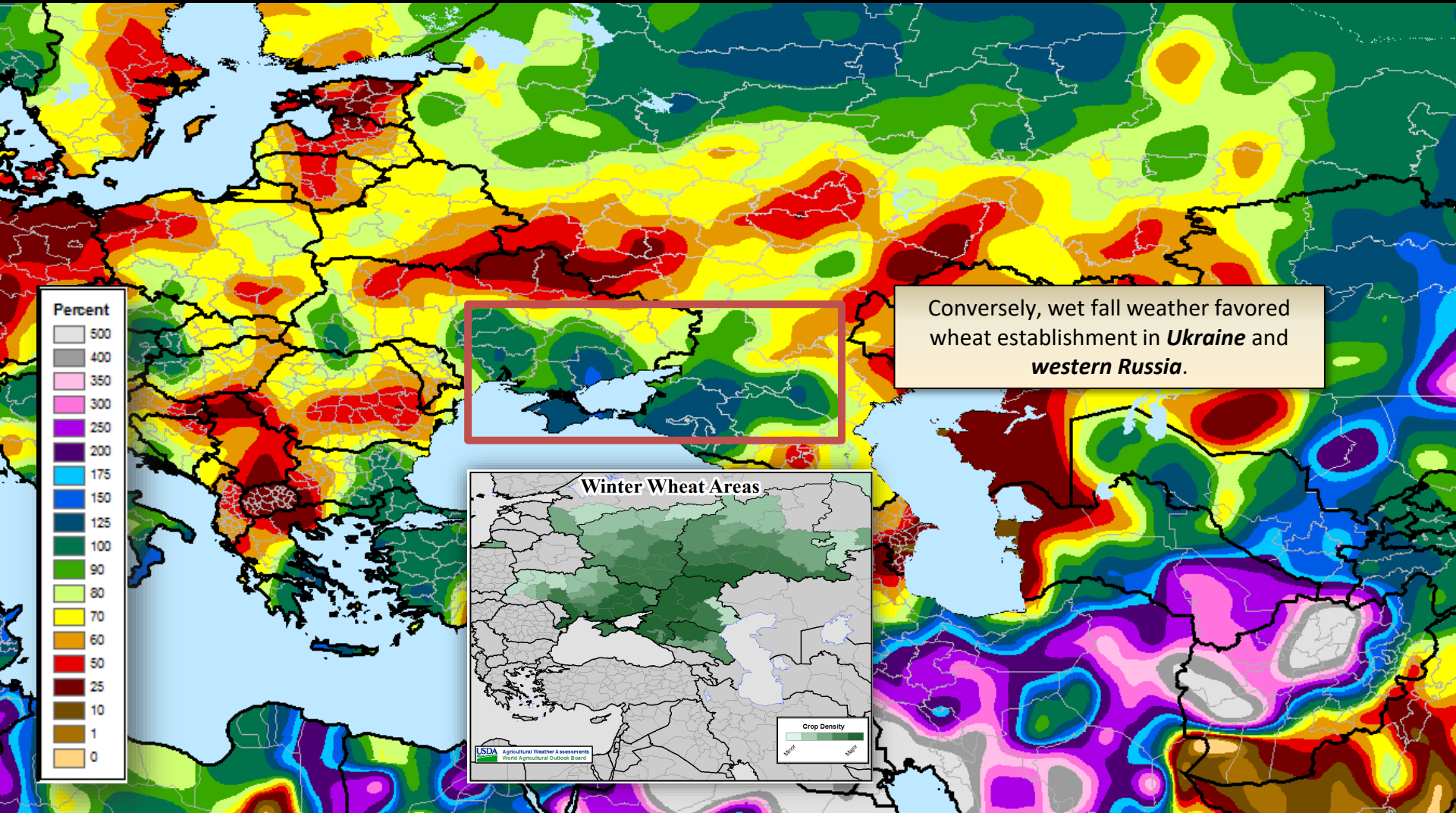


The VHI as crops went dormant showed areas of poor establishment due to fall dryness.



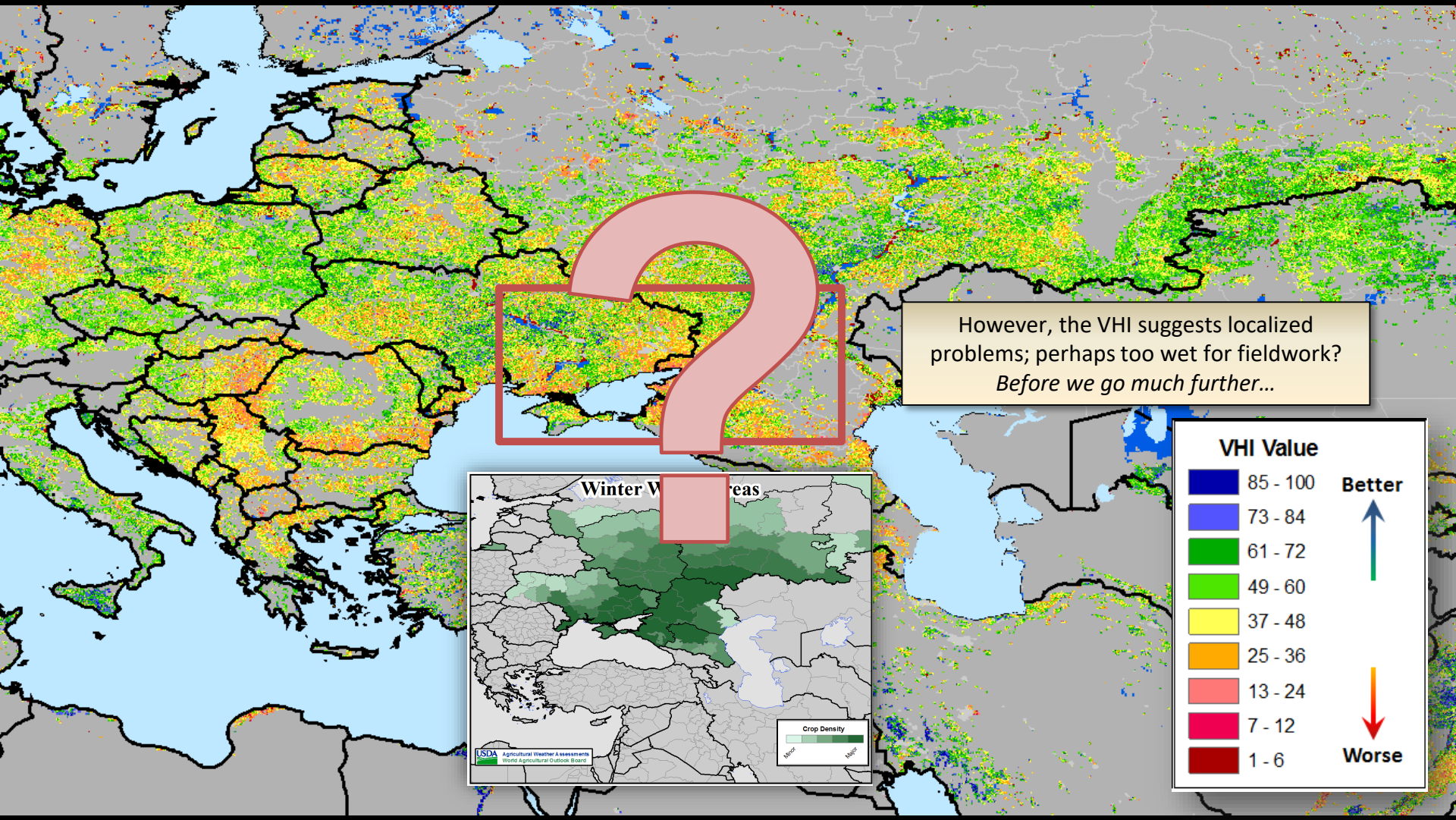
# Percent-of-Normal Precipitation

September-November, 2018

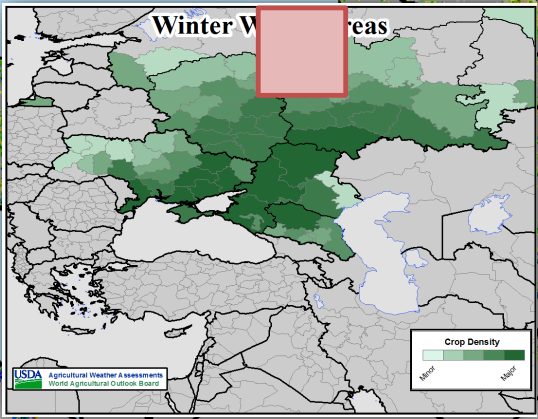
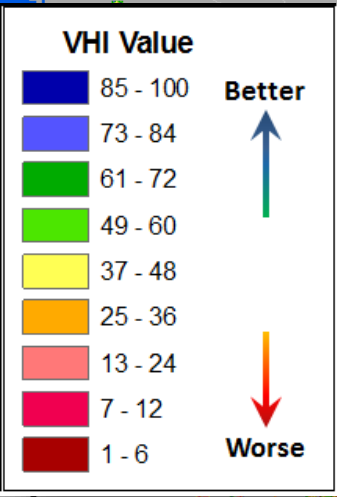


# Vegetative Health Index

Nov 18, 2018



However, the VHI suggests localized problems; perhaps too wet for fieldwork?  
*Before we go much further...*

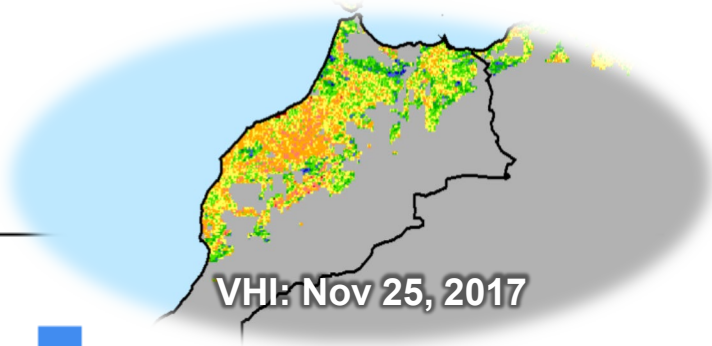




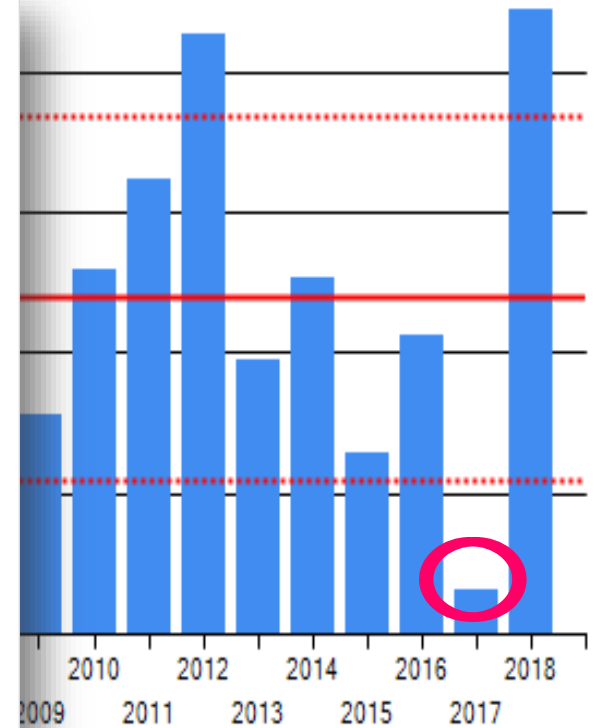
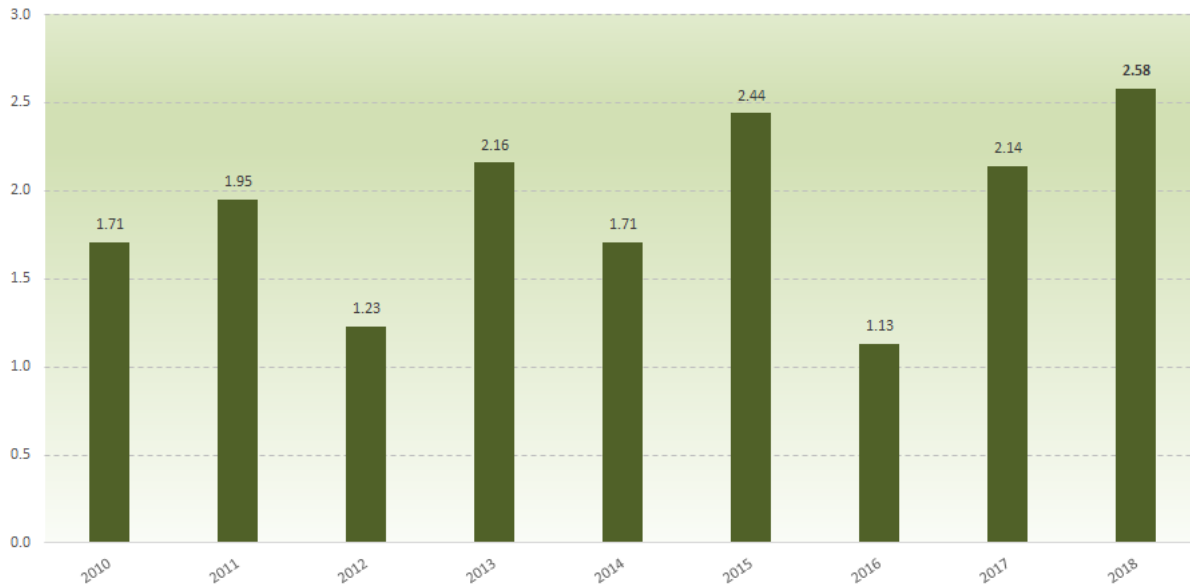
# Northern Morocco

Total Precipitation: Sep 1 to Nov 28

## 2017-18



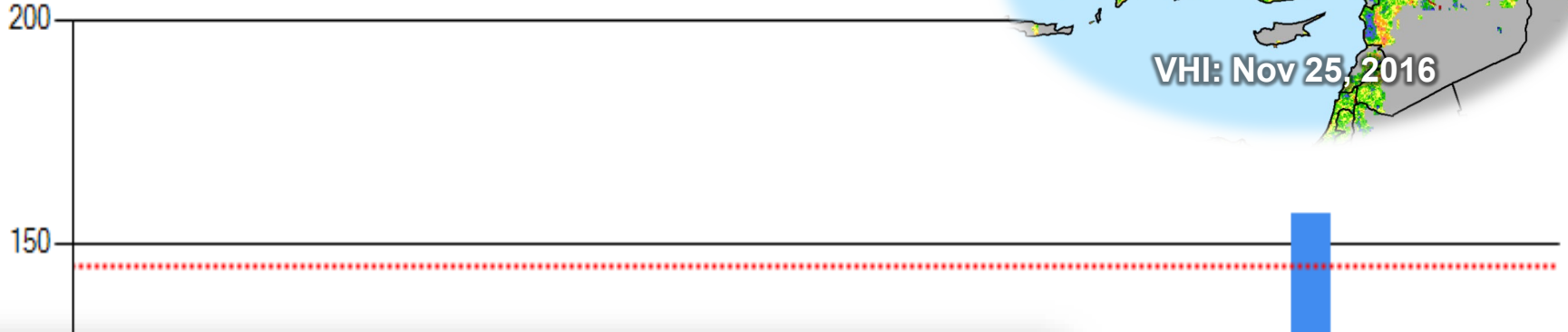
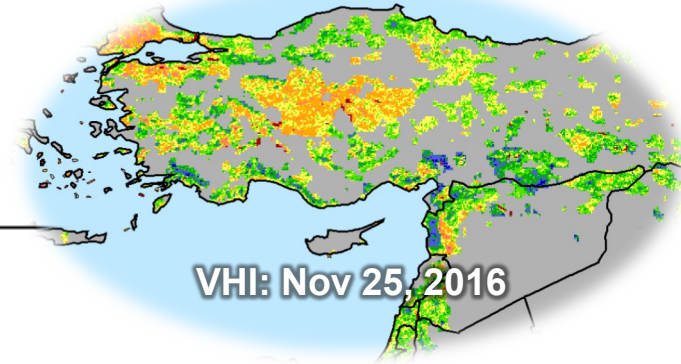
### Morocco Wheat Yield: 2010—2018



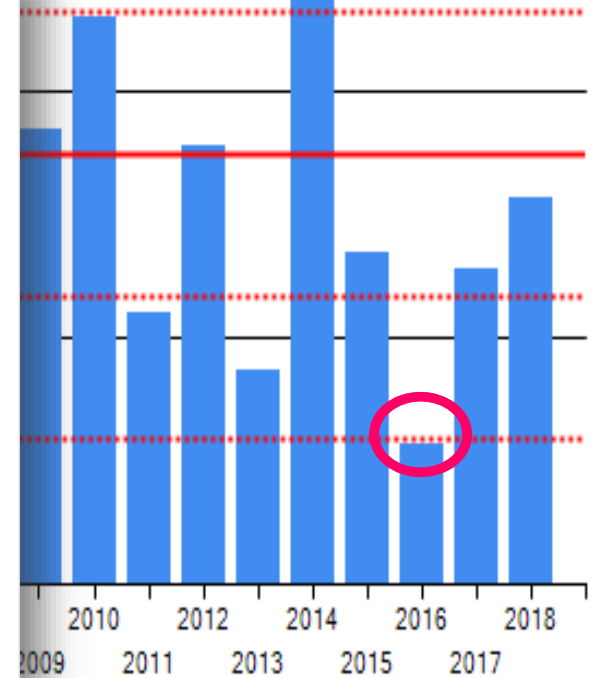
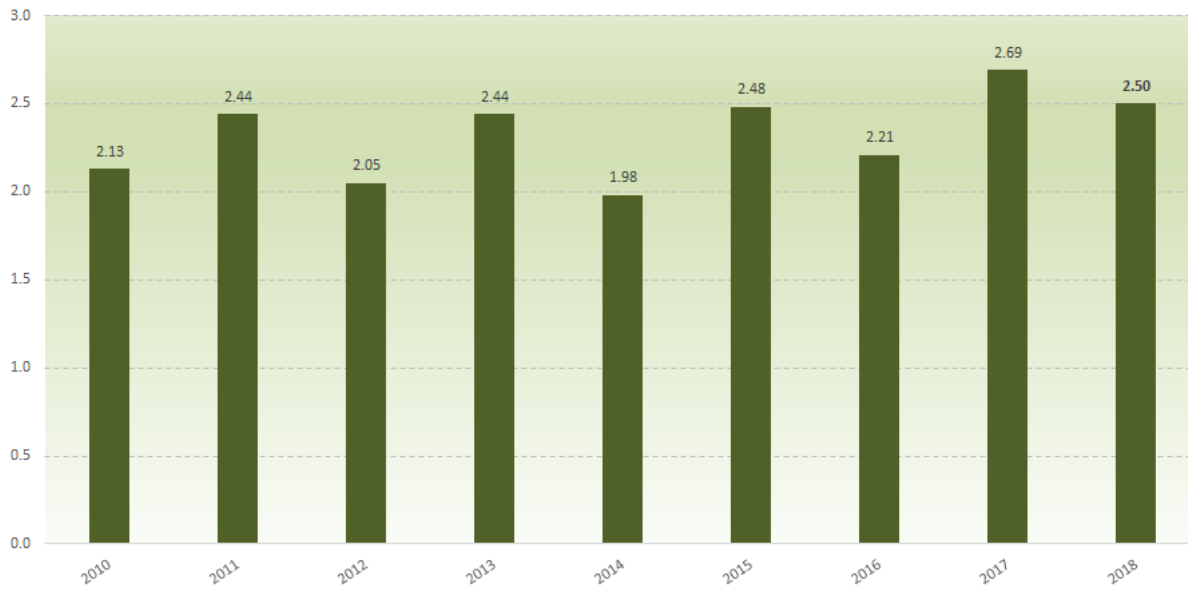
# Turkey – Anatolian Plateau

Total Precipitation: Sep 1 to Nov 28

## 2016-17



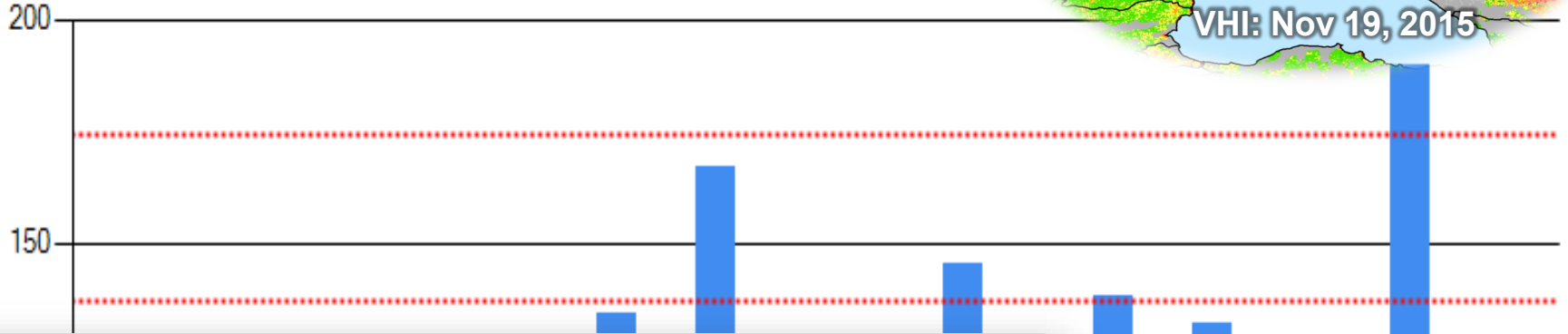
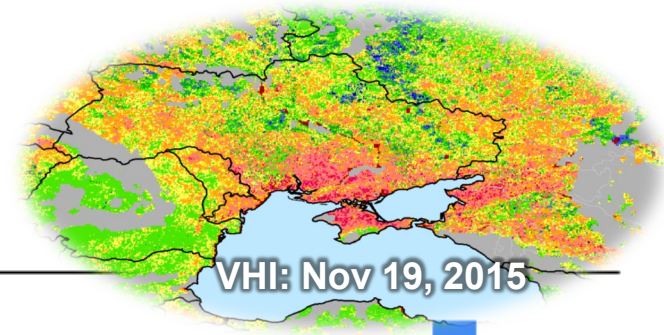
### Turkey Wheat Yield: 2010—2018



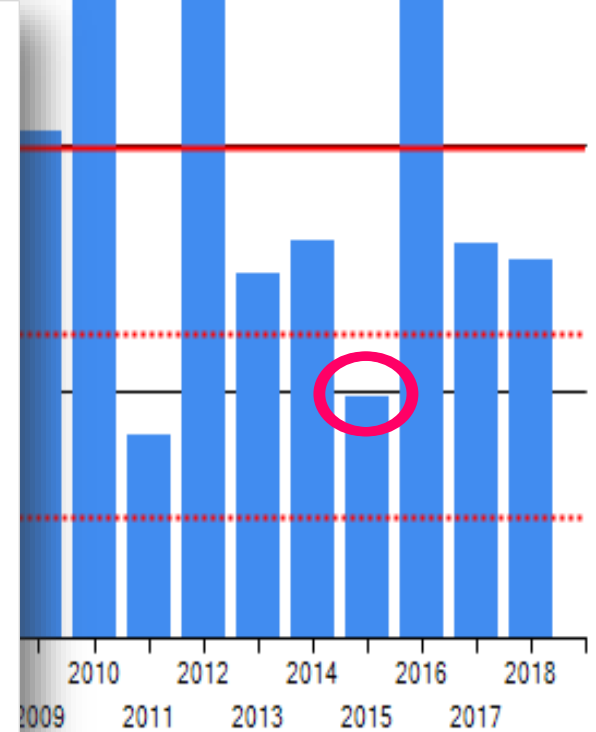
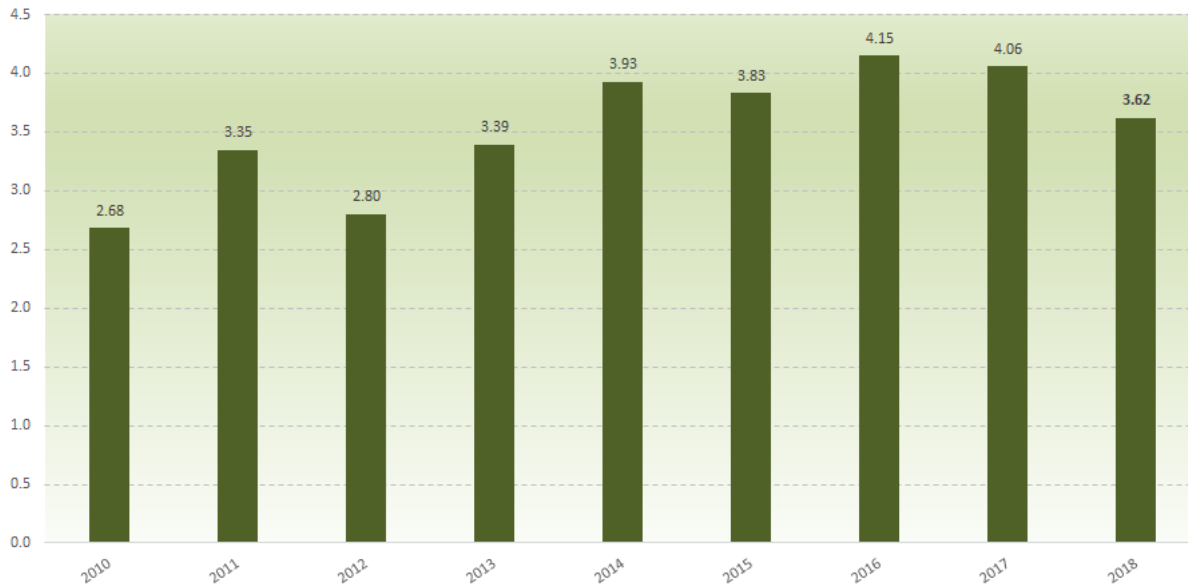
# South-Central Ukraine

Total Precipitation: Sep 1 to Nov 15

## 2015-16



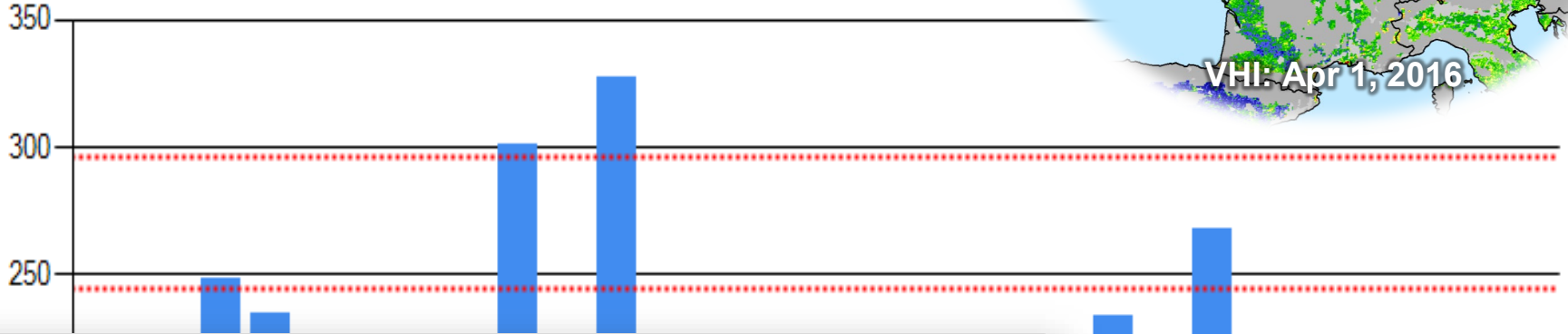
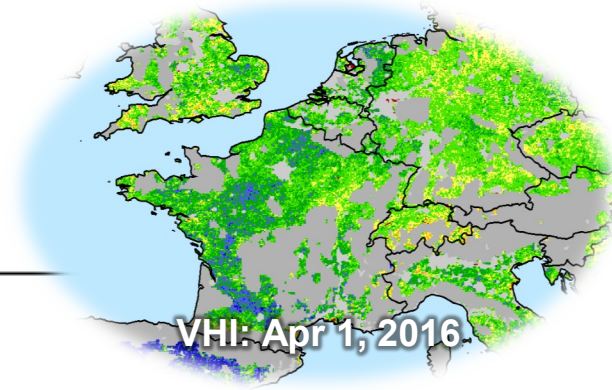
### Ukraine Wheat Yield: 2010—2018



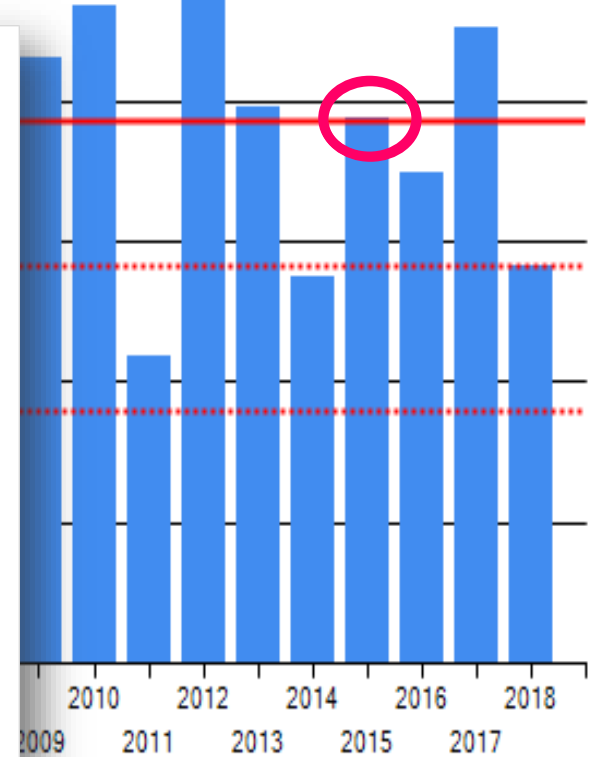
# Northern France

Total Precipitation: Sep 1 to Nov 30

## 2015-16

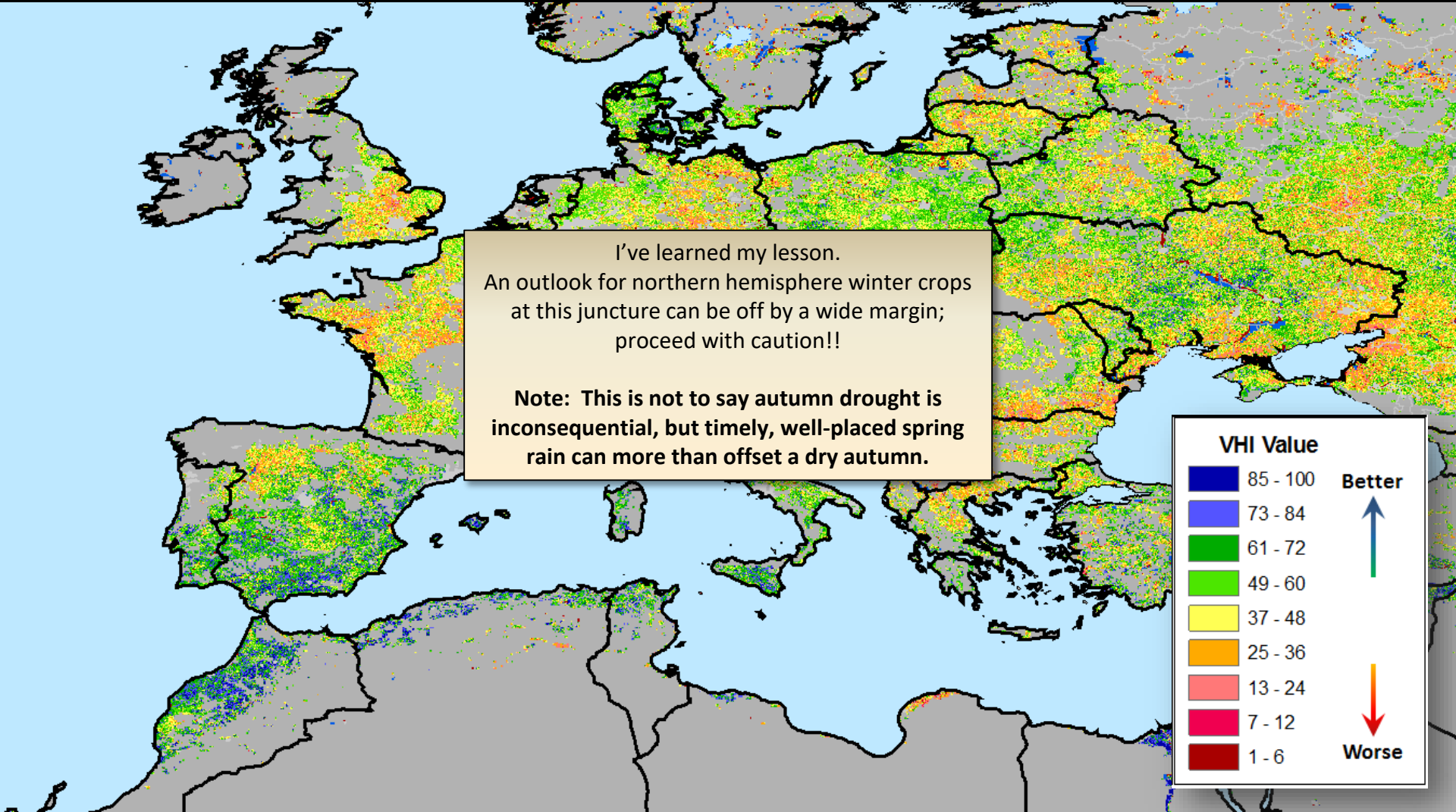


France Wheat Yield: 2010—2018



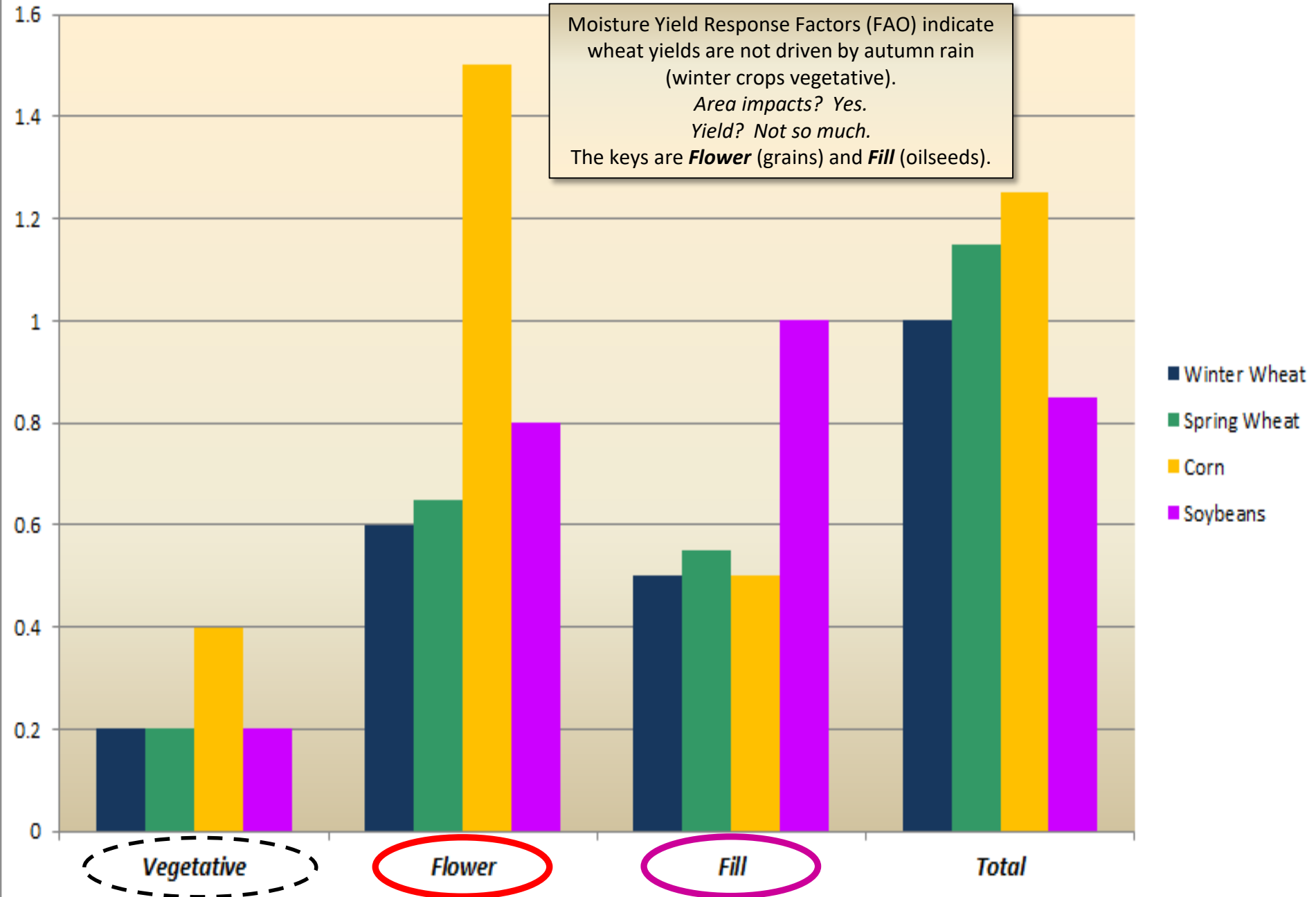
# Vegetative Health Index

Nov 18, 2018



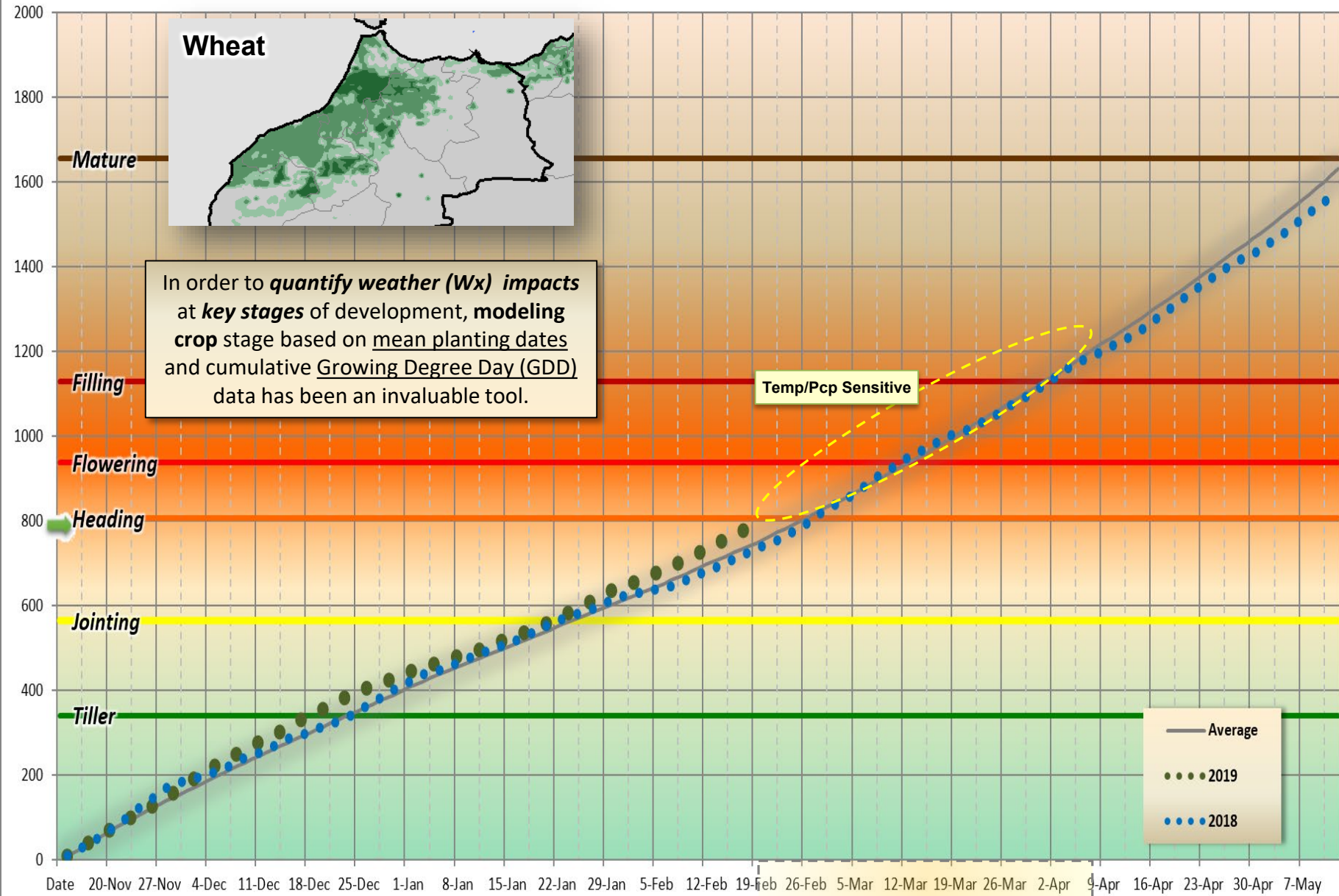
# Water Deficit Yield Response Factors ( $ET_{actual}/ET_{measured}$ )

Moisture Yield Response Factors (FAO) indicate wheat yields are not driven by autumn rain (winter crops vegetative).  
*Area impacts? Yes.*  
*Yield? Not so much.*  
The keys are **Flower** (grains) and **Fill** (oilseeds).



# Wheat: Morocco (North)

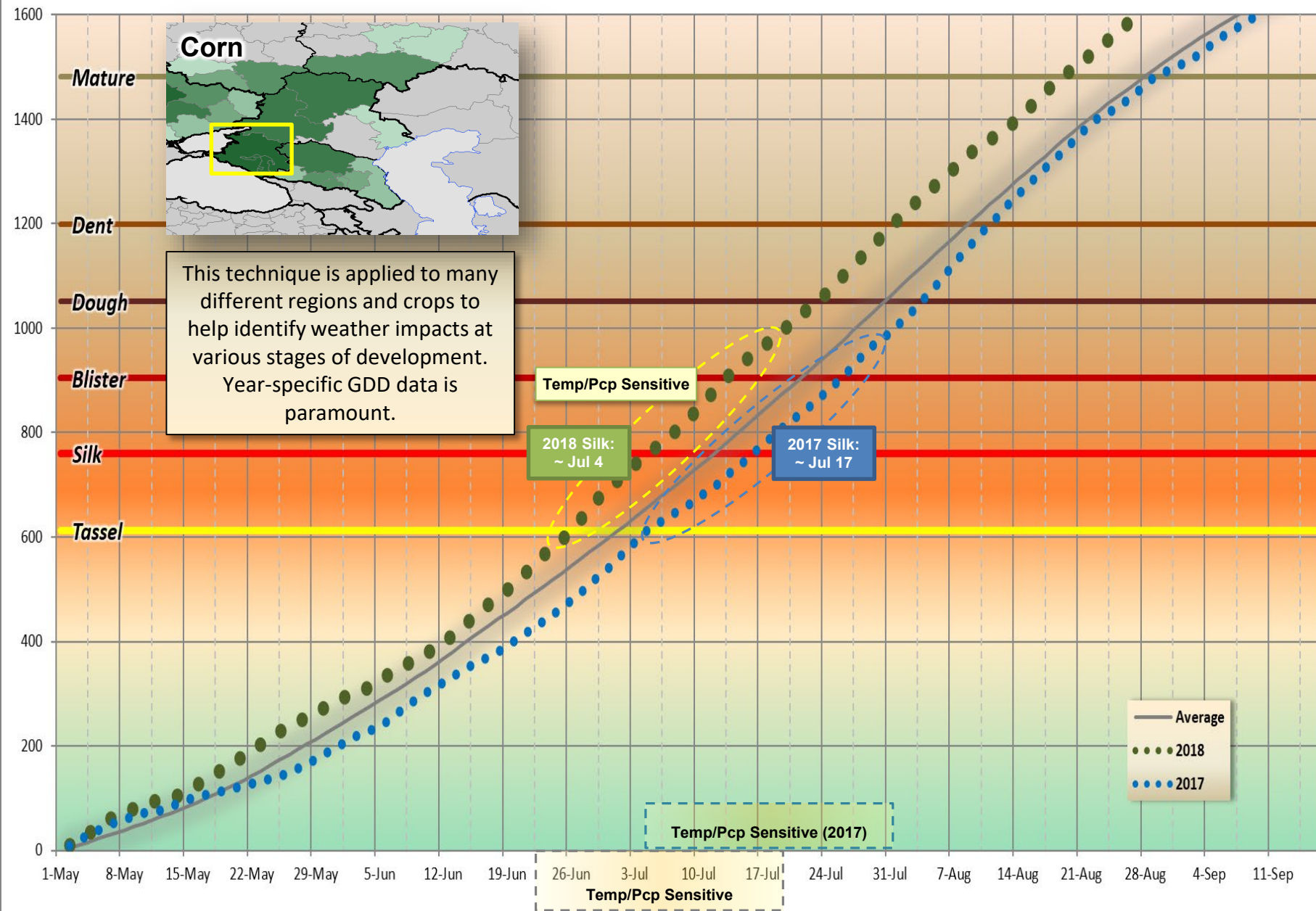
GDD



5 days ahead of Avg / 7 days ahead of 2018

# Corn: Russia (Southern - Krasnodar)

GDD



16 days ahead of Avg / 14 days ahead of 2017



# Russia (Southern - Krasnodar) - 2018

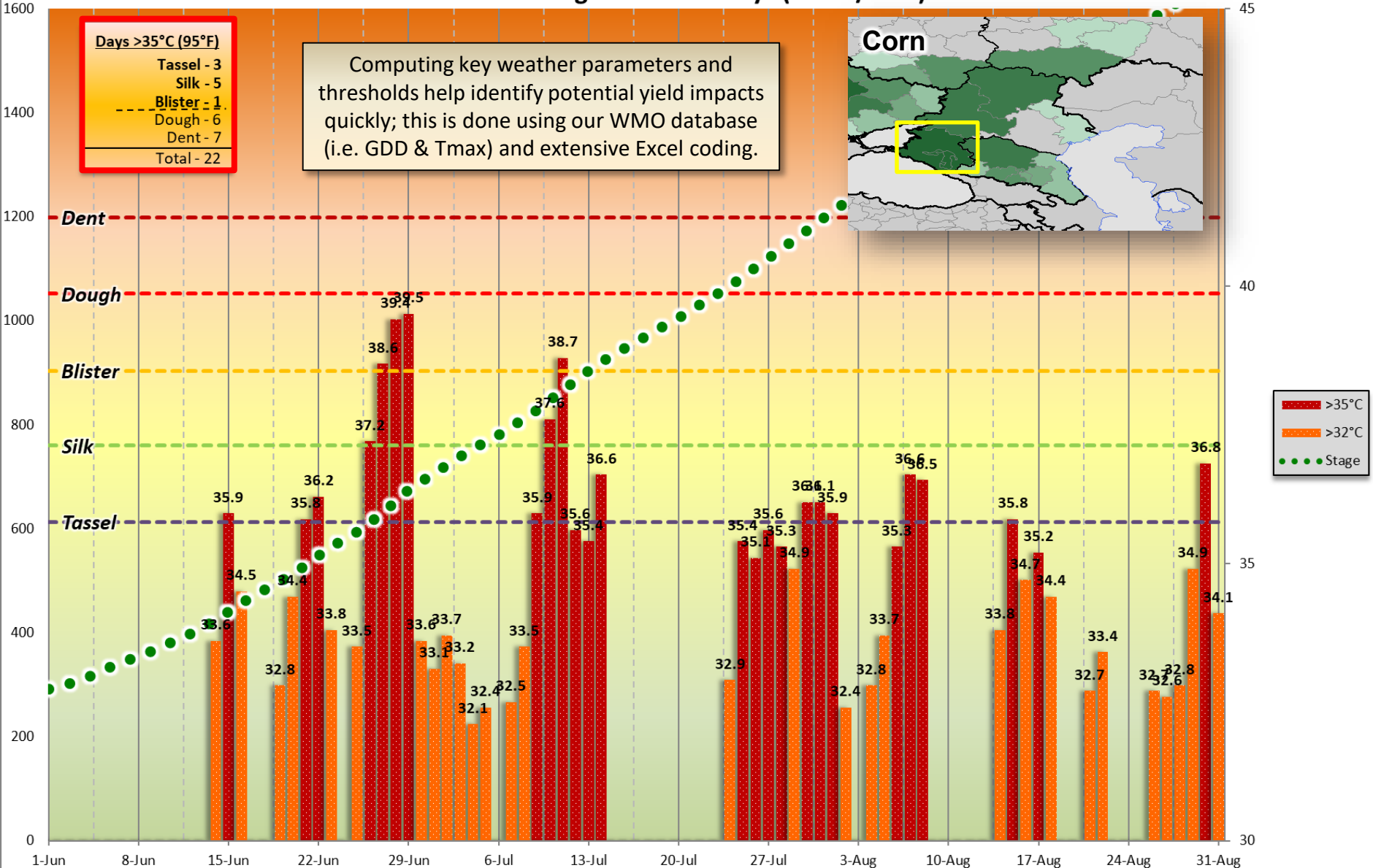
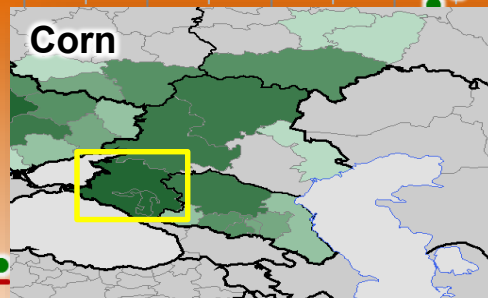
## Corn Stage and Heat Days (>32°C/90°F)

GDD

°C

Days >35°C (95°F)	
Tassel	3
Silk	5
Blister	1
Dough	6
Dent	7
<b>Total</b>	<b>22</b>

Computing key weather parameters and thresholds help identify potential yield impacts quickly; this is done using our WMO database (i.e. GDD & Tmax) and extensive Excel coding.



- >35°C
- >32°C
- Stage

# Russia (Southern - Krasnodar) - 2018

## Corn Stage and Heat Days (>32°C/90°F)

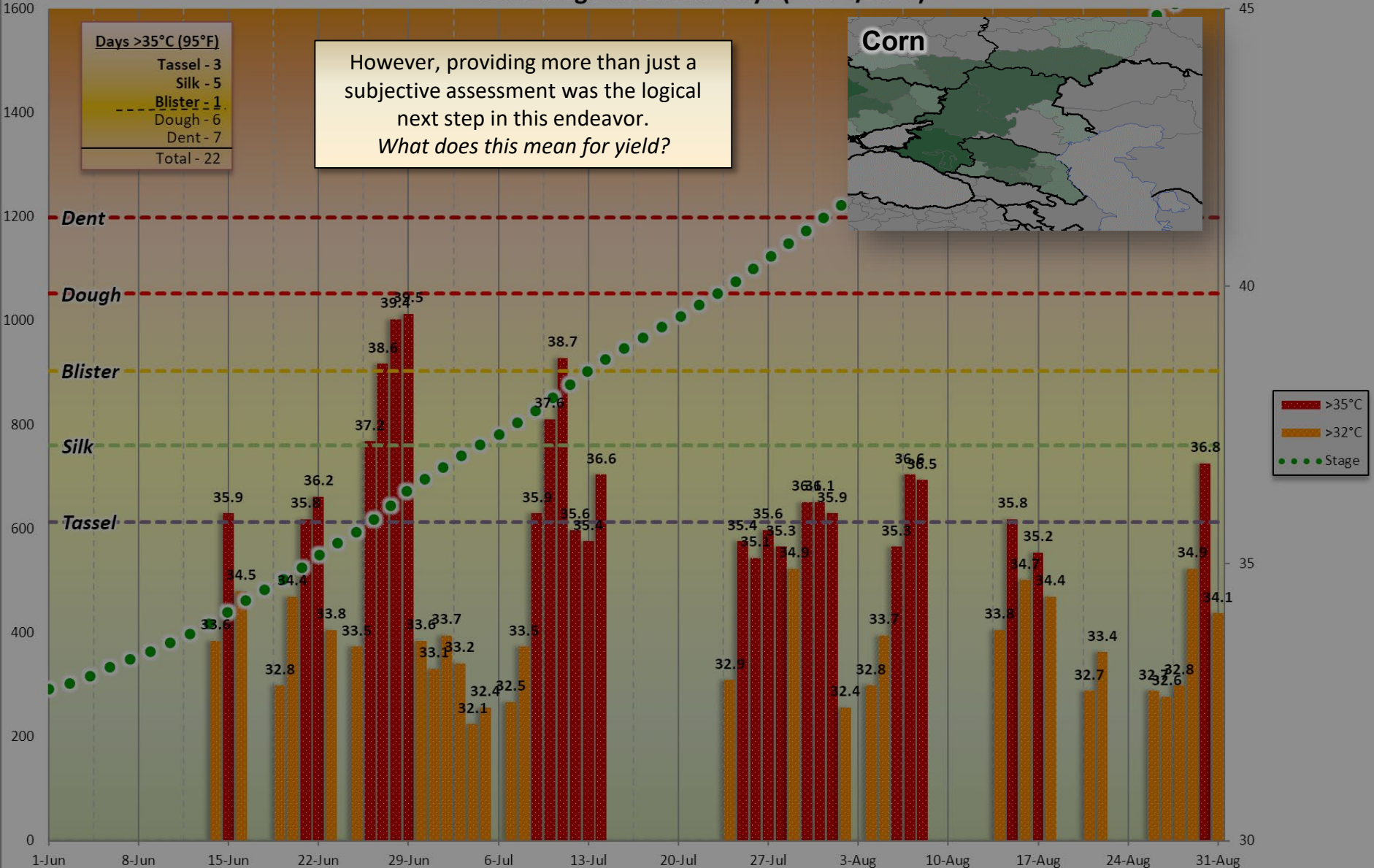
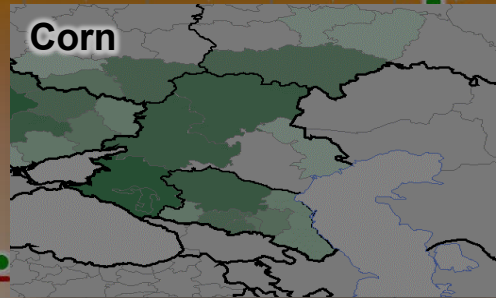
GDD

°C

**Days >35°C (95°F)**

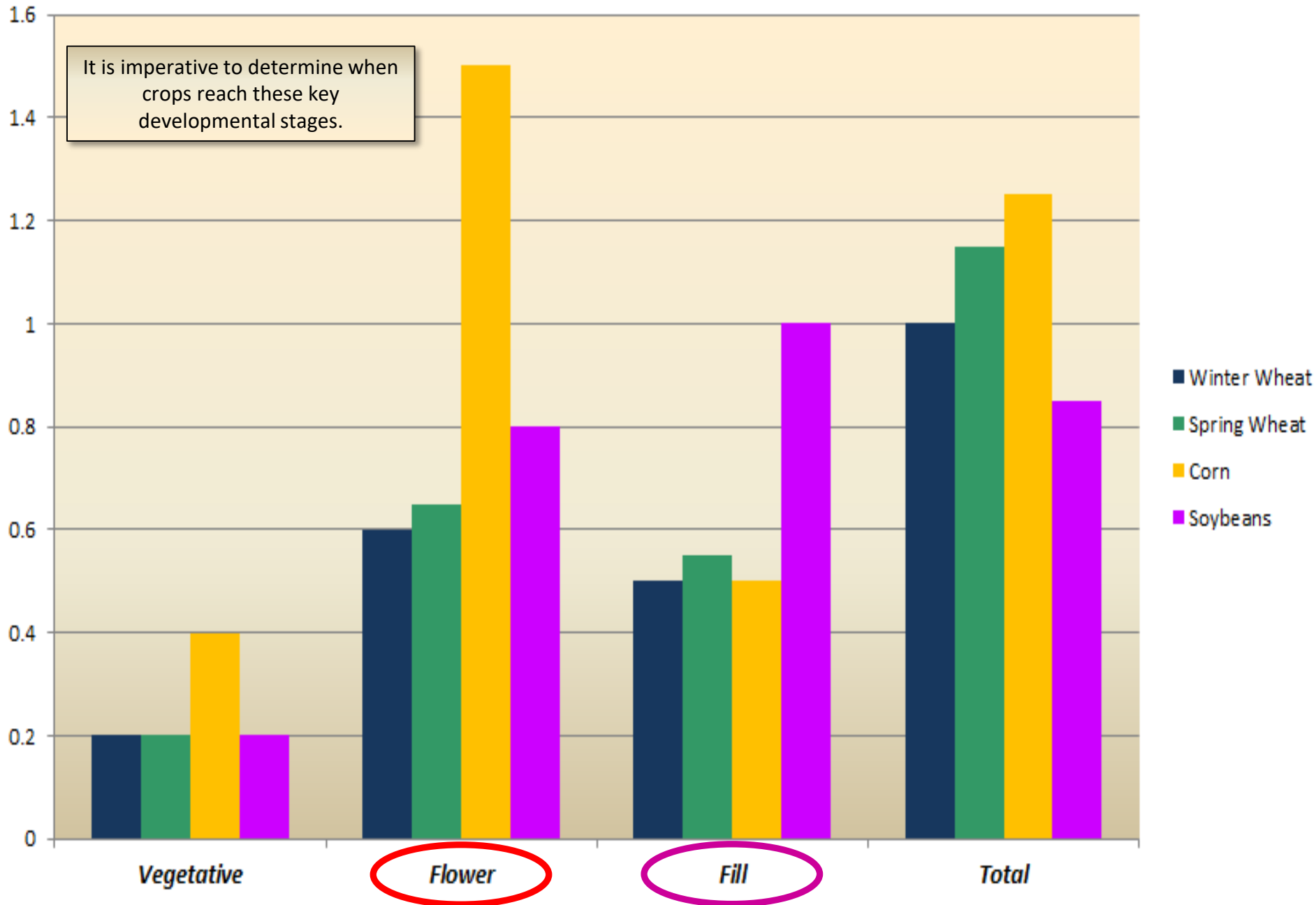
- Tassel - 3
- Silk - 5
- Blister - 1
- Dough - 6
- Dent - 7
- Total - 22

However, providing more than just a subjective assessment was the logical next step in this endeavor.  
What does this mean for yield?

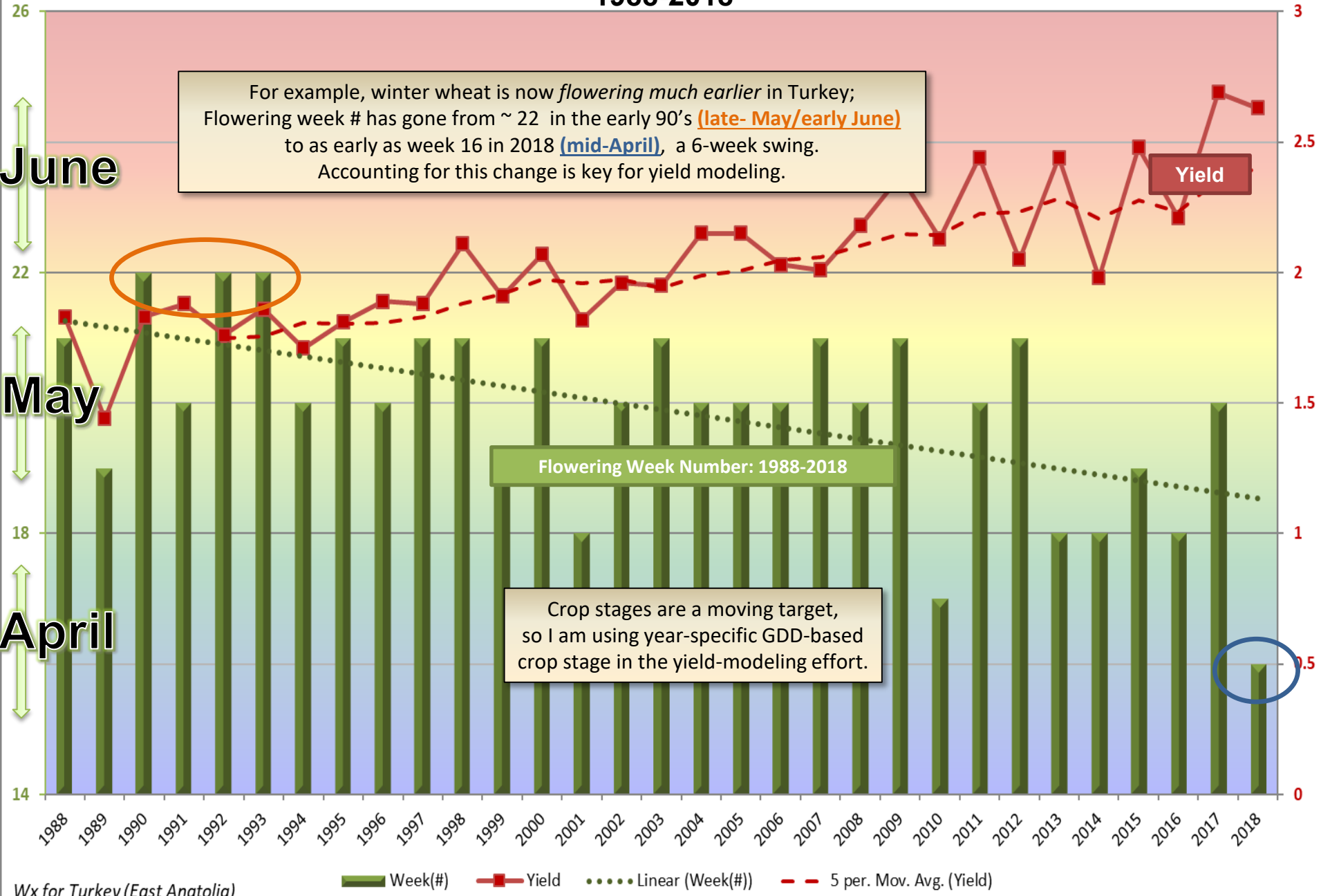


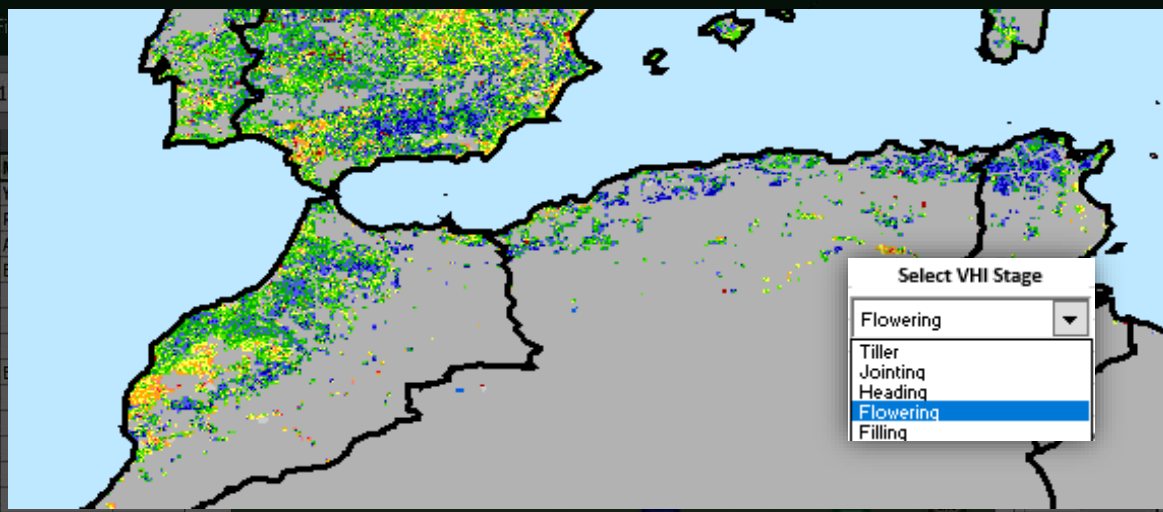
- >35°C
- >32°C
- Stage

# Water Deficit Yield Response Factors ( $ET_{\text{actual}}/ET_{\text{measured}}$ )



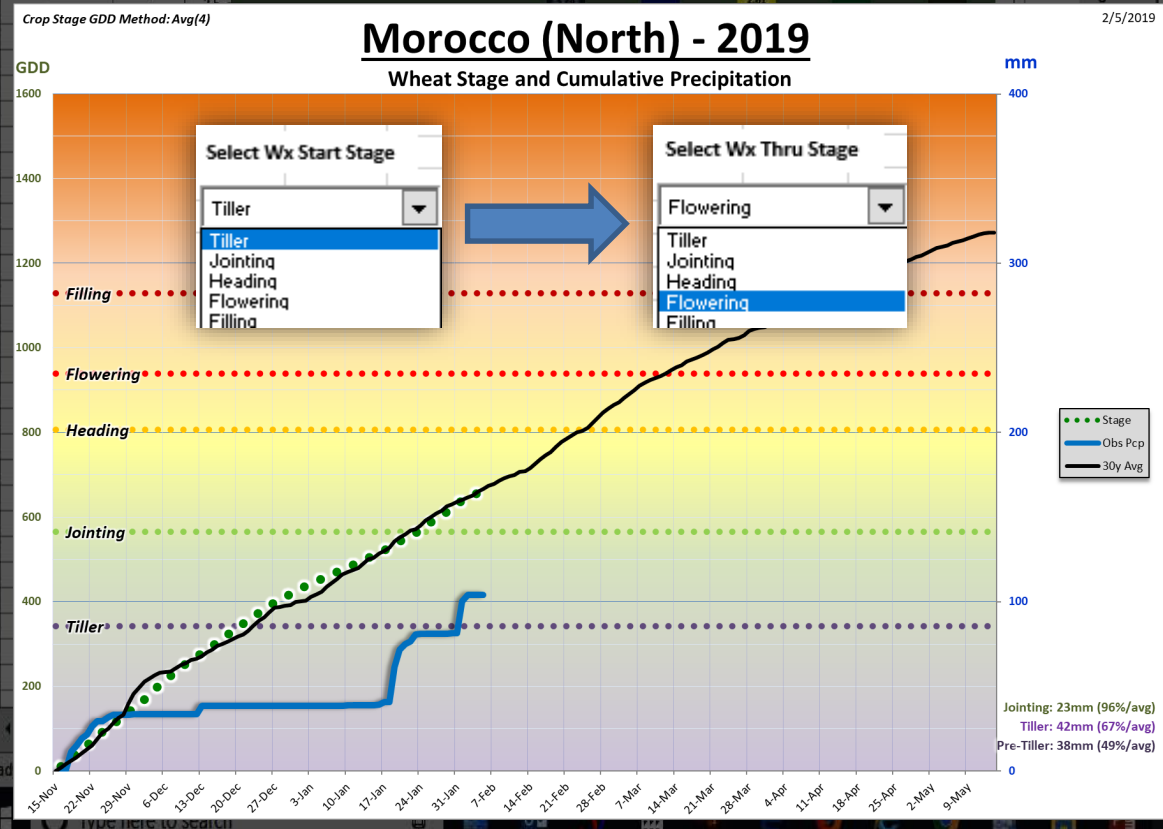
# Turkey: Week # for Wheat @ Flowering 1988-2018





Select VHI Stage	Year	Yield	Morocco Wheat: Regression Hindcast vs Observed
Flowering	1985	1.08	Morocco Wheat
	1986	1.71	Regression: 2005-2017
	1987	1.06	VHI for Wheat @ Flowering
Select Wx Start Stage	1988	1.73	Wx for Morocco (North)
	1989	1.49	Wx Begin @ Tiller
	1990	1.33	Wx thru Flowering
	1991	1.87	VHI data for MAR (Ghar/Taza/Marr/Douk)
Select Wx Thru Stage	1992	0.7	
	1993	0.68	
	1994	1.81	

Linking our VHI and WMO databases into Excel, **stage-specific VHI & Weather** are analyzed. This ensures year-to-year consistency allows easy testing of different scenarios.

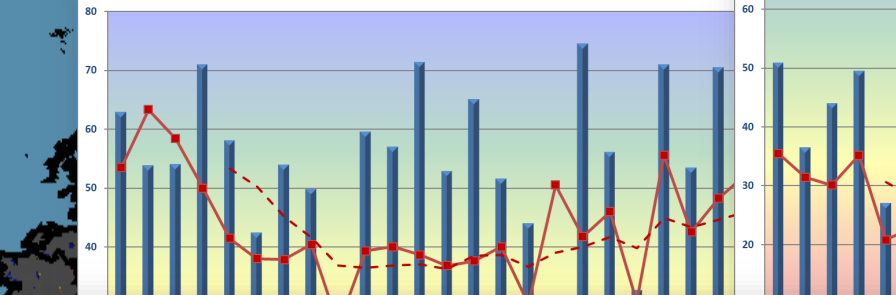


Year	Yield
2002	1.28
2003	1.72
2004	1.81
2005	1.03
2006	3.04
2007	0.62
2008	1.32
2009	2.14
2010	1.71
2011	1.95
2012	1.23
2013	2.16
2014	1.71

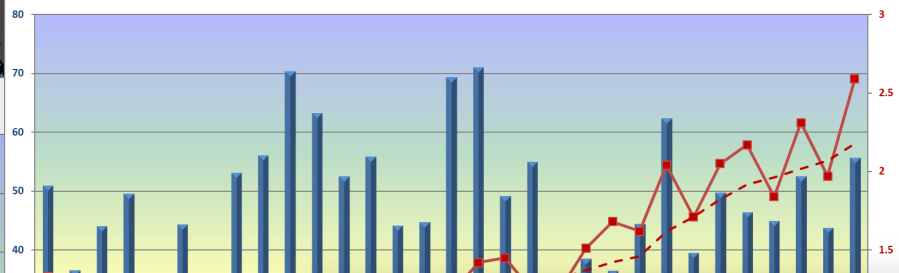
Morocco Wheat  
Regression: 2005-2017

Wheat @ Flowering  
Morocco (North)  
in @ Tiller

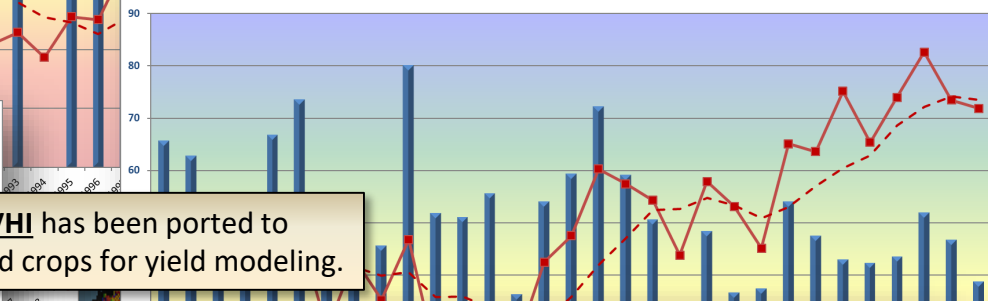
**Bulgaria VHI for Wheat @ Filling**



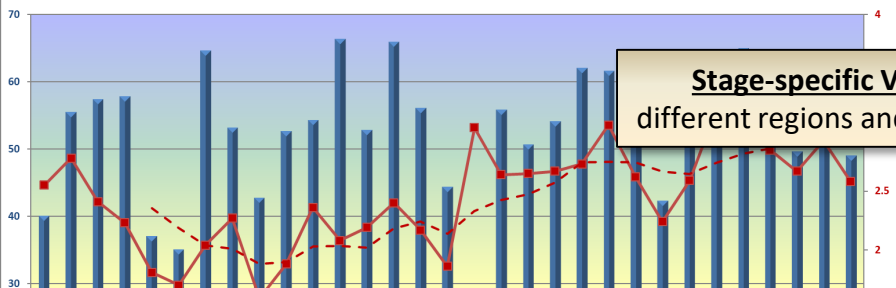
**Ukraine VHI for Soybeans @ Pod Set**



**Russia VHI for Corn @ Blister**

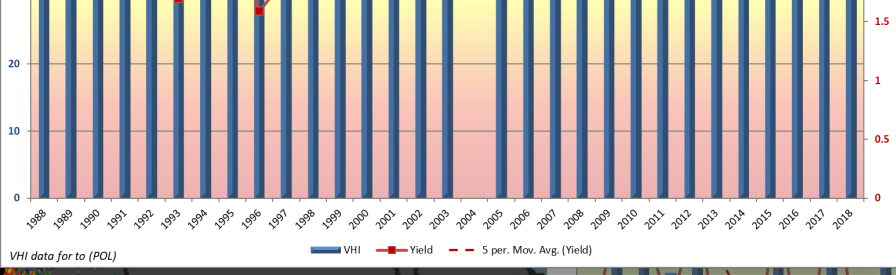
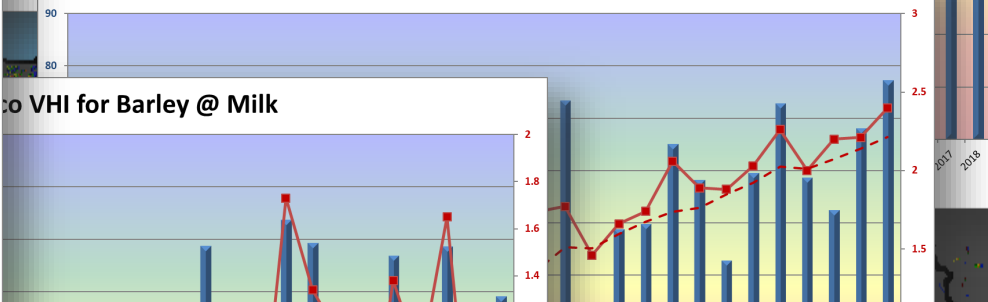


**Poland VHI for Rapeseed @ 50% Flower**

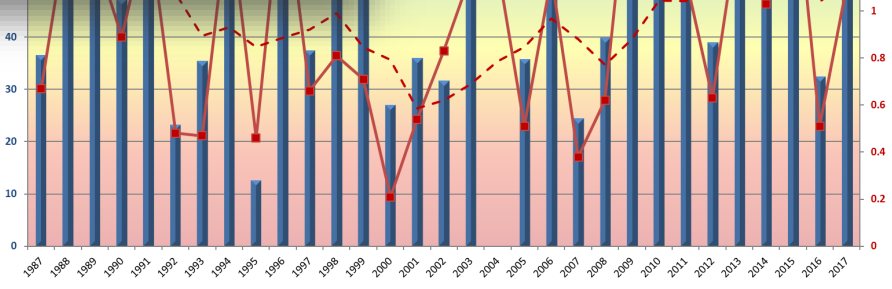


**Stage-specific VHI** has been ported to different regions and crops for yield modeling.

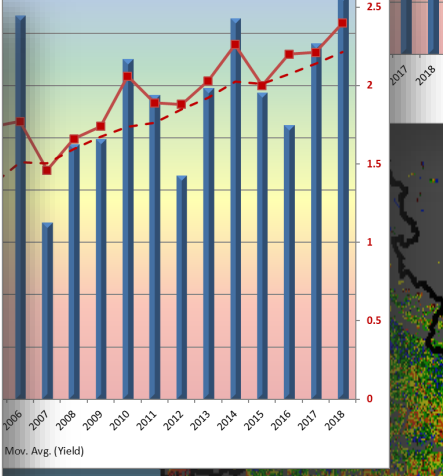
**Turkey VHI for Sunflowers @ Anthesis Complete**



VHI data for to (POL)      ■ VHI    ■ Yield    - - - 5 per. Mov. Avg. (Yield)

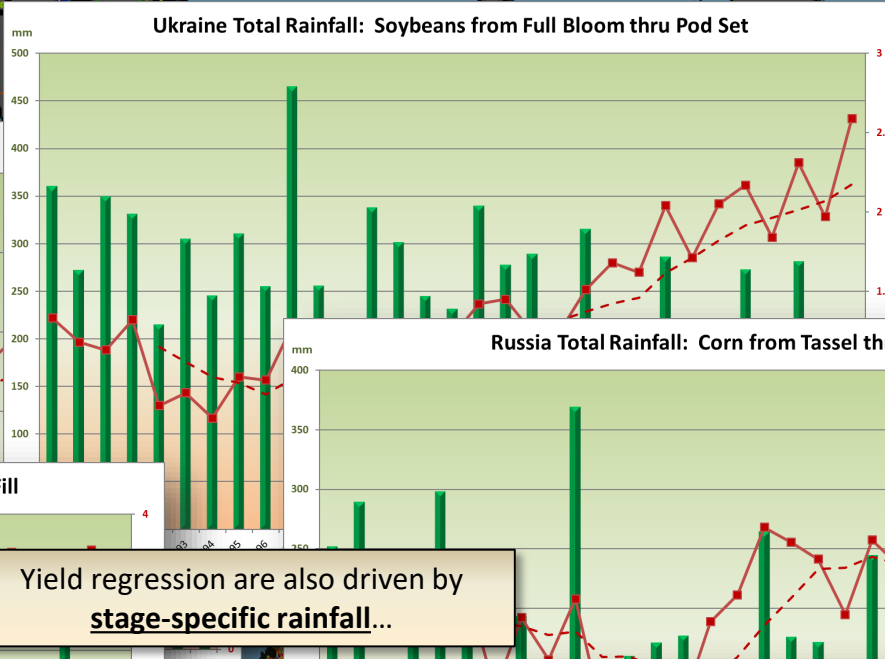


VHI data for Algeria (Taza/Chao/Marr/Douk)      ■ VHI    ■ Yield    - - - 5 per. Mov. Avg. (Yield)

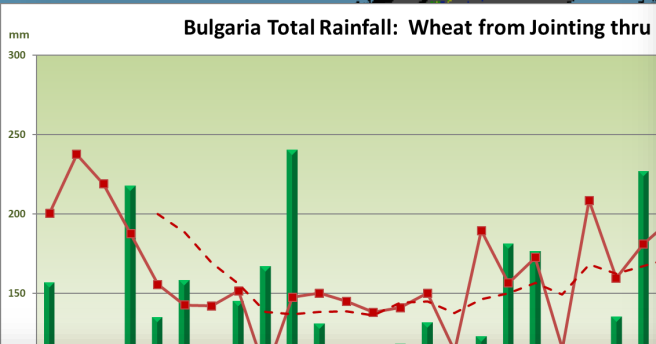


Mov. Avg. (Yield)

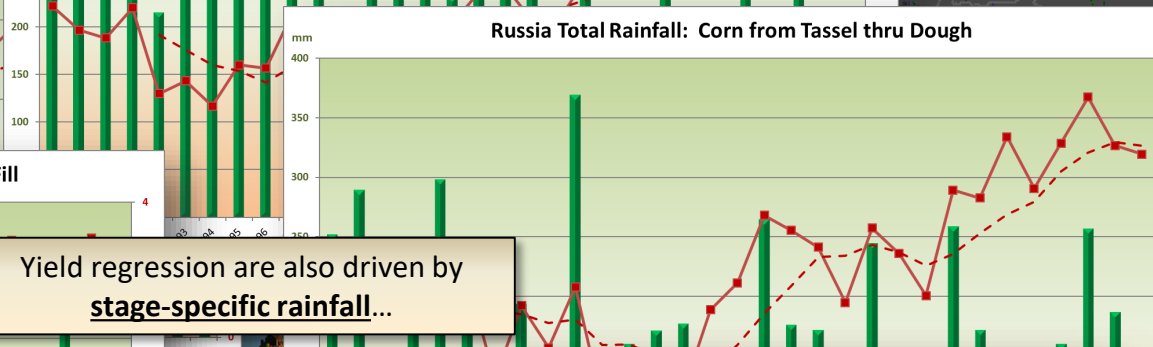
Ukraine Total Rainfall: Soybeans from Full Bloom thru Pod Set



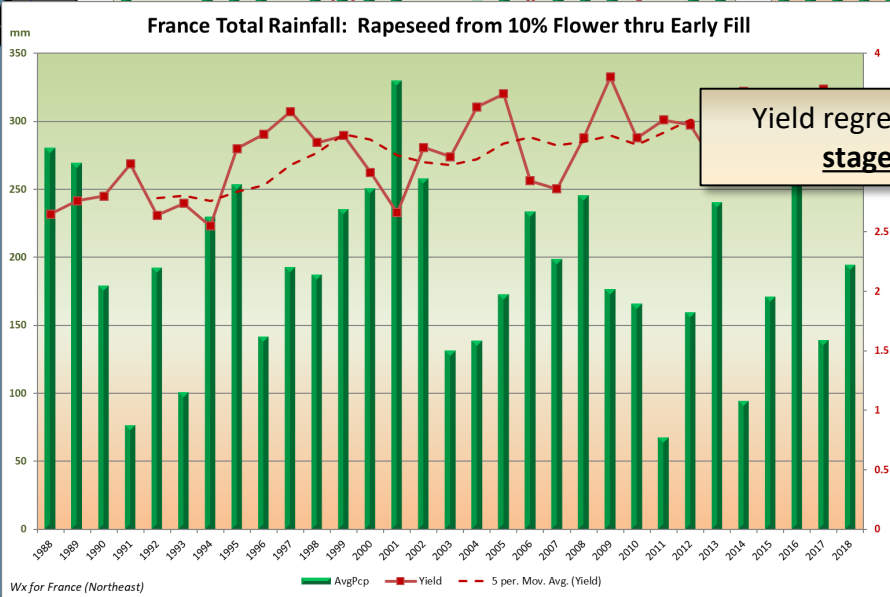
Bulgaria Total Rainfall: Wheat from Jointing thru



Russia Total Rainfall: Corn from Tassel thru Dough

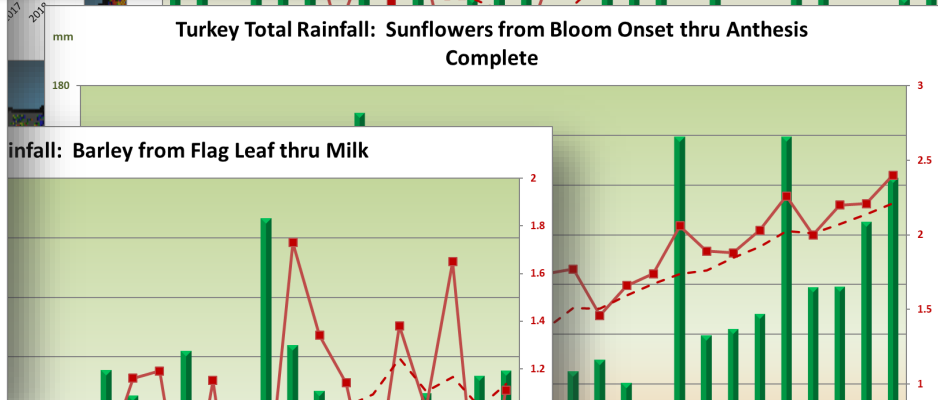


France Total Rainfall: Rapeseed from 10% Flower thru Early Fill

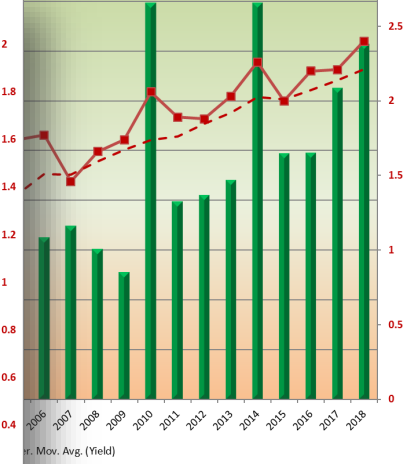
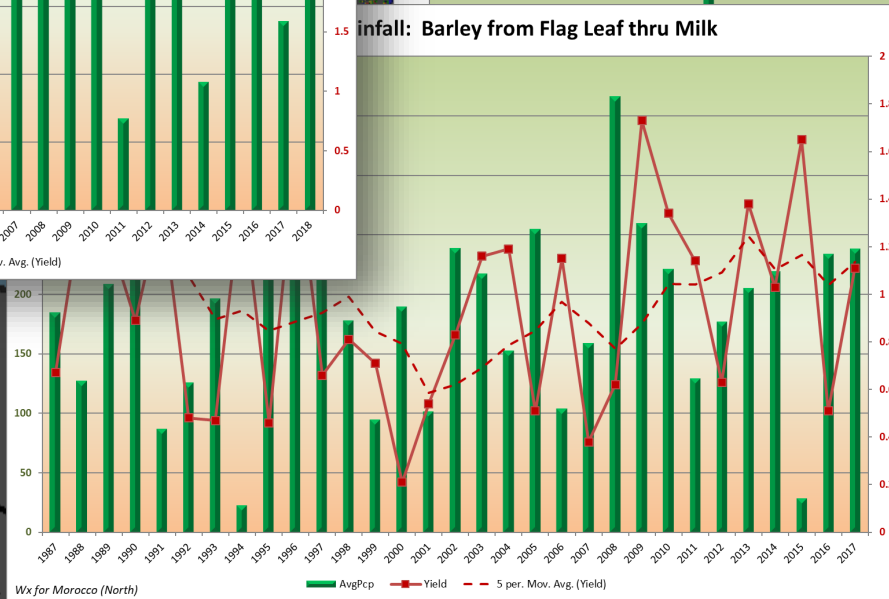


Yield regression are also driven by stage-specific rainfall...

Turkey Total Rainfall: Sunflowers from Bloom Onset thru Anthesis Complete



Rainfall: Barley from Flag Leaf thru Milk

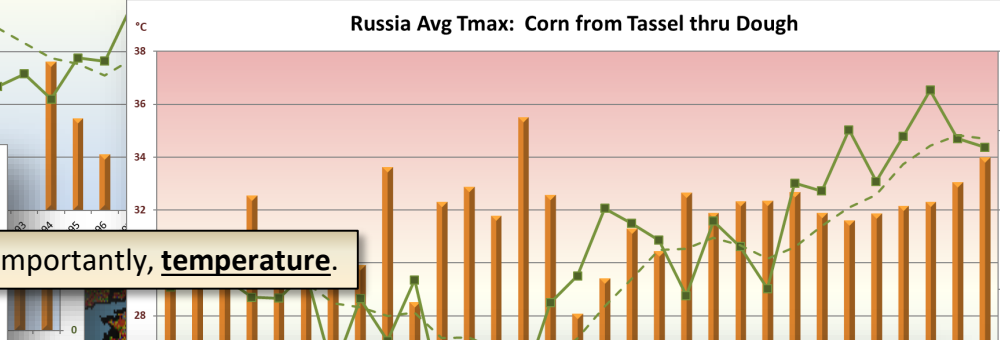
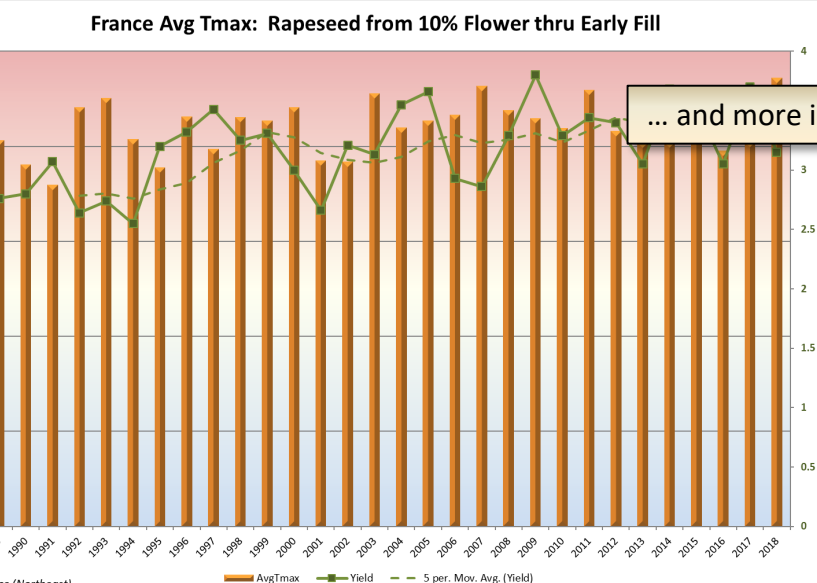
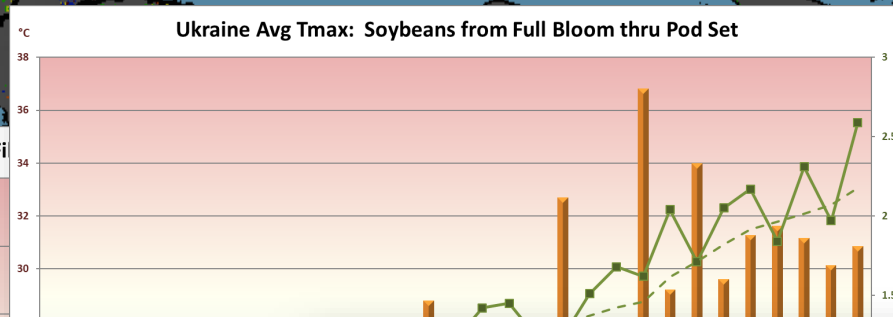
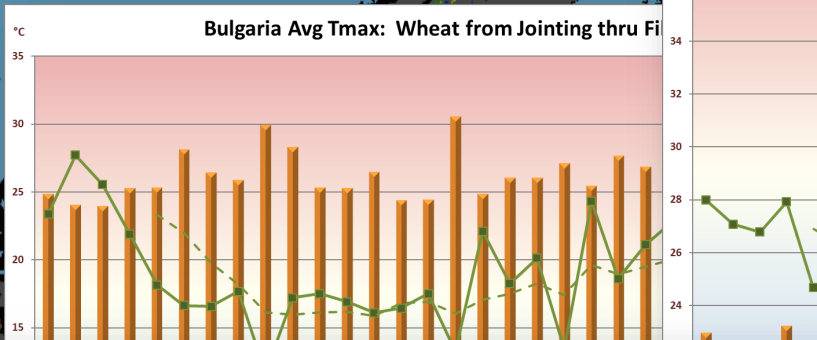


Wx for France (Northeast)

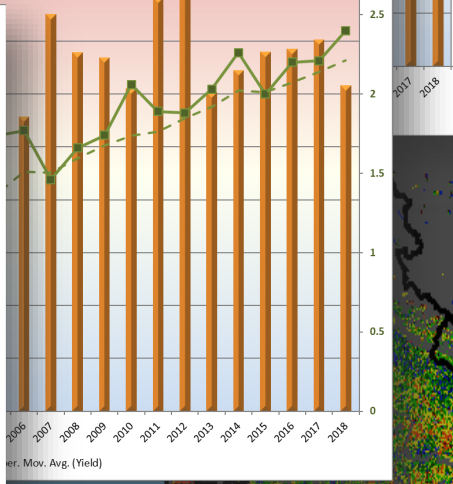
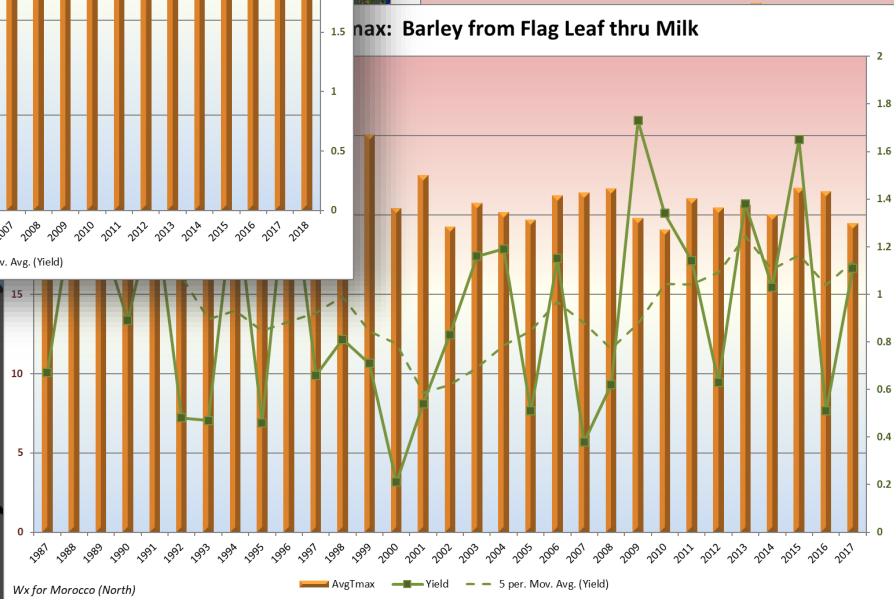
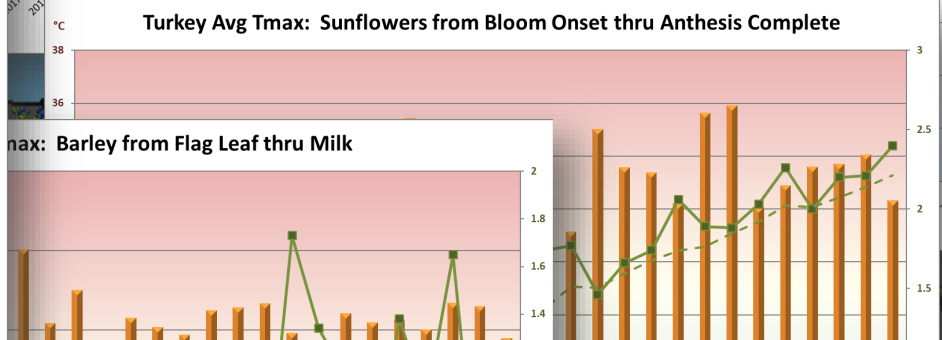
AvgPcp Yield 5 per. Mov. Avg. (Yield)

Wx for Morocco (North)

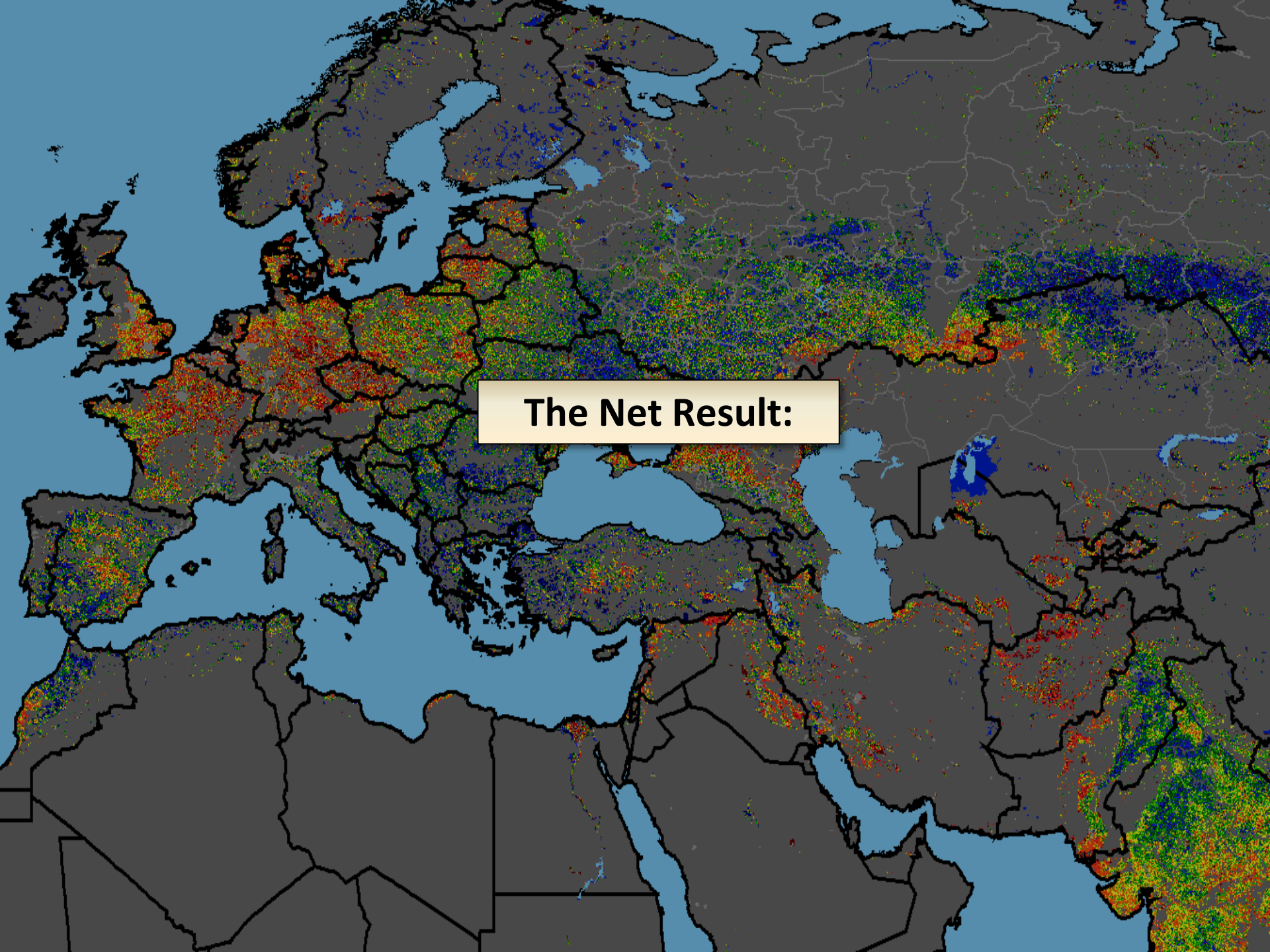
AvgPcp Yield 5 per. Mov. Avg. (Yield)



... and more importantly, temperature.



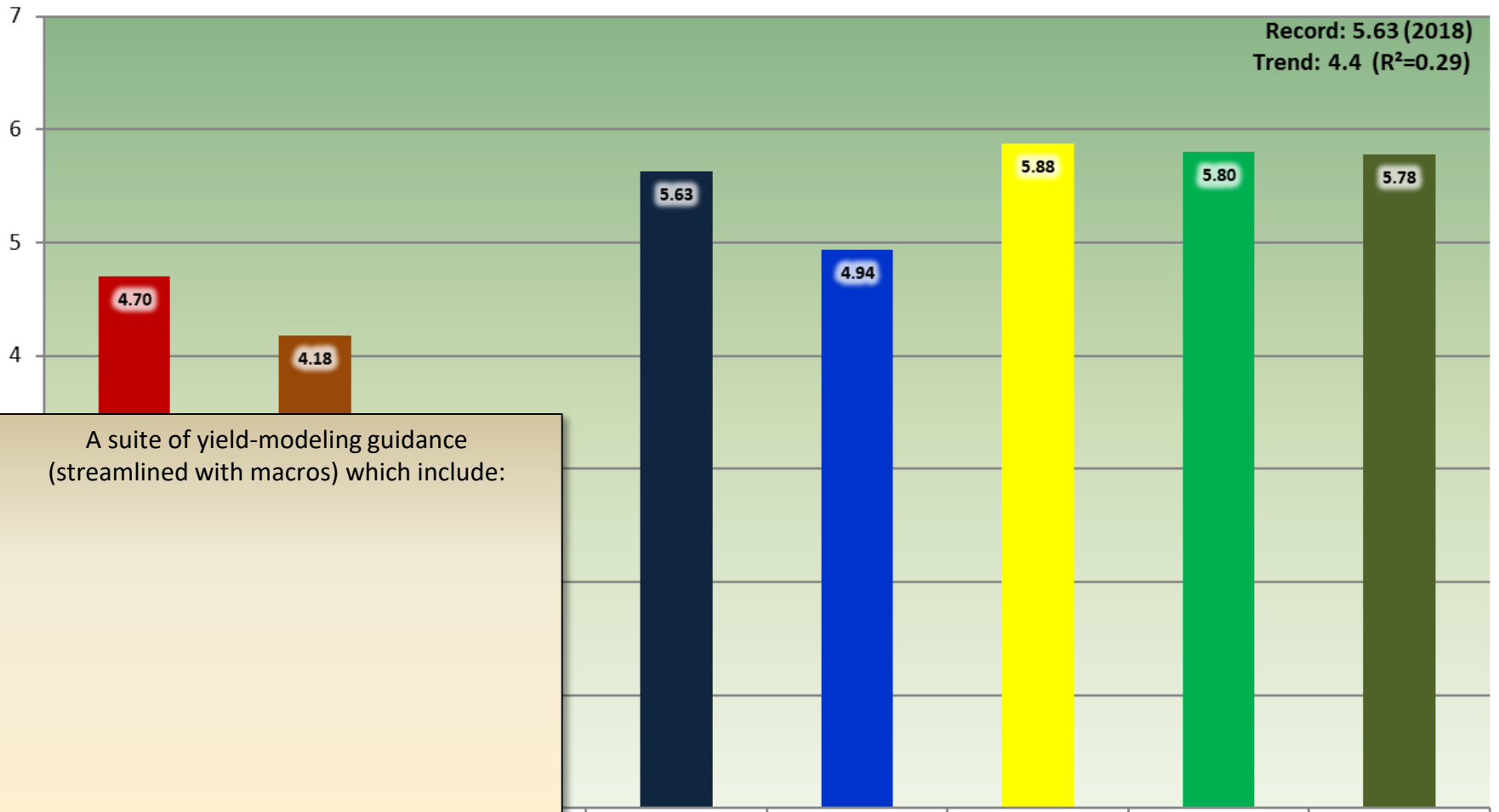




**The Net Result:**

# Romania Corn Regression

Regression: 2005-2017  
 Median Regression Yield: 5.79



A suite of yield-modeling guidance (streamlined with macros) which include:

\*Includes Trend

R<sup>2</sup>= 0.78  
 +/- 0.45

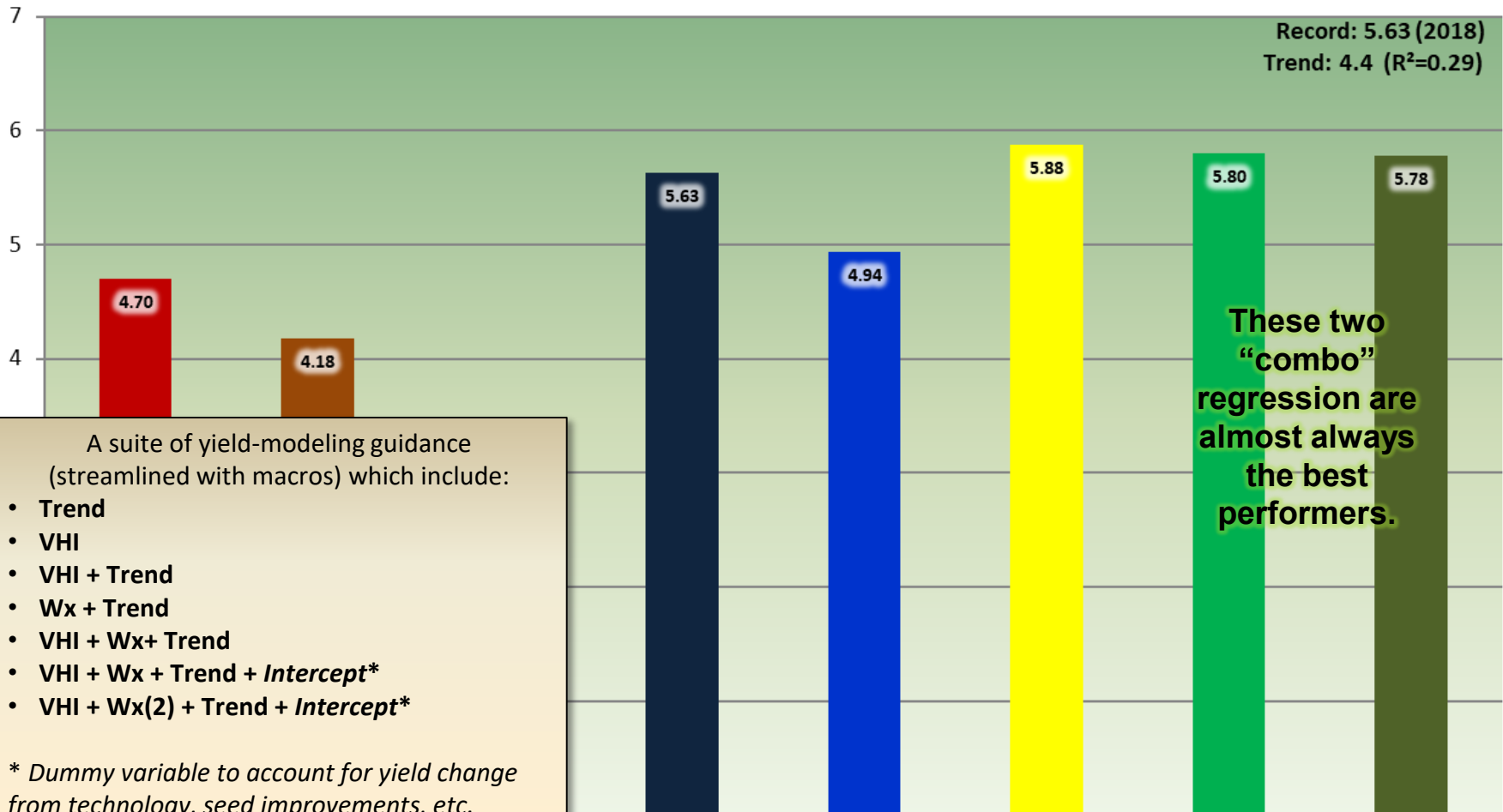
R<sup>2</sup>= 0.92  
 +/- 0.3

R<sup>2</sup>= 0.97  
 +/- 0.17

R<sup>2</sup>= 0.98  
 +/- 0.18

# Romania Corn Regression

Regression: 2005-2017  
 Median Regression Yield: 5.79



A suite of yield-modeling guidance (streamlined with macros) which include:

- Trend
- VHI
- VHI + Trend
- Wx + Trend
- VHI + Wx+ Trend
- VHI + Wx + Trend + *Intercept*\*
- VHI + Wx(2) + Trend + *Intercept*\*

\* *Dummy variable to account for yield change from technology, seed improvements, etc.*

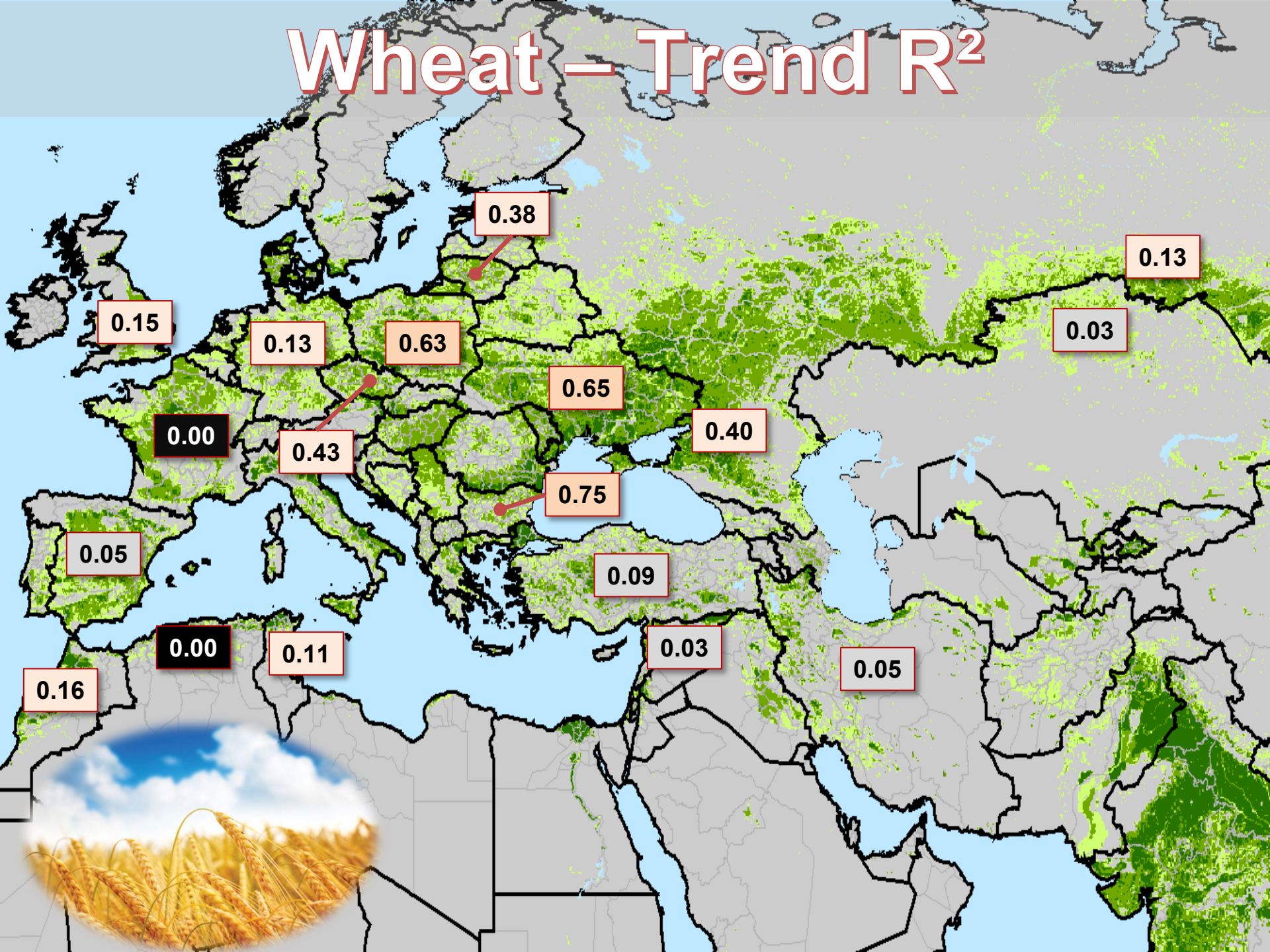
Model	Yield	R <sup>2</sup>	±
Last Year	4.70		
5-Year Avg	4.18		
Last Month	5.63		
VHI*	4.94	0.78	±0.45
Wx*	5.88	0.92	±0.3
VHI+Wx*	5.80	0.97	±0.17
VHI+Wx/Intcpt* (2011)	5.78	0.98	±0.18

\*Includes Trend

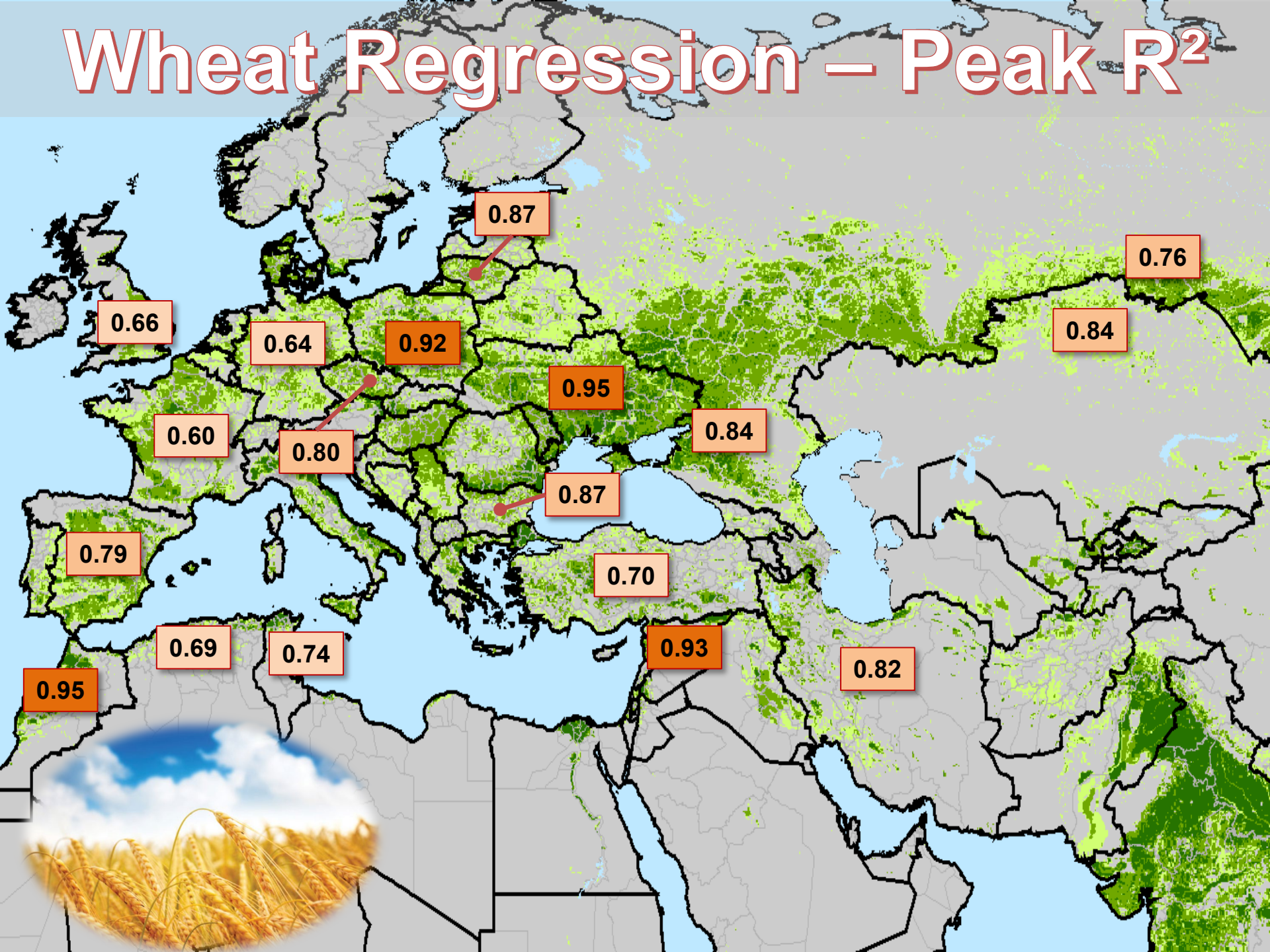


A quick look at some  
Skill Scores...

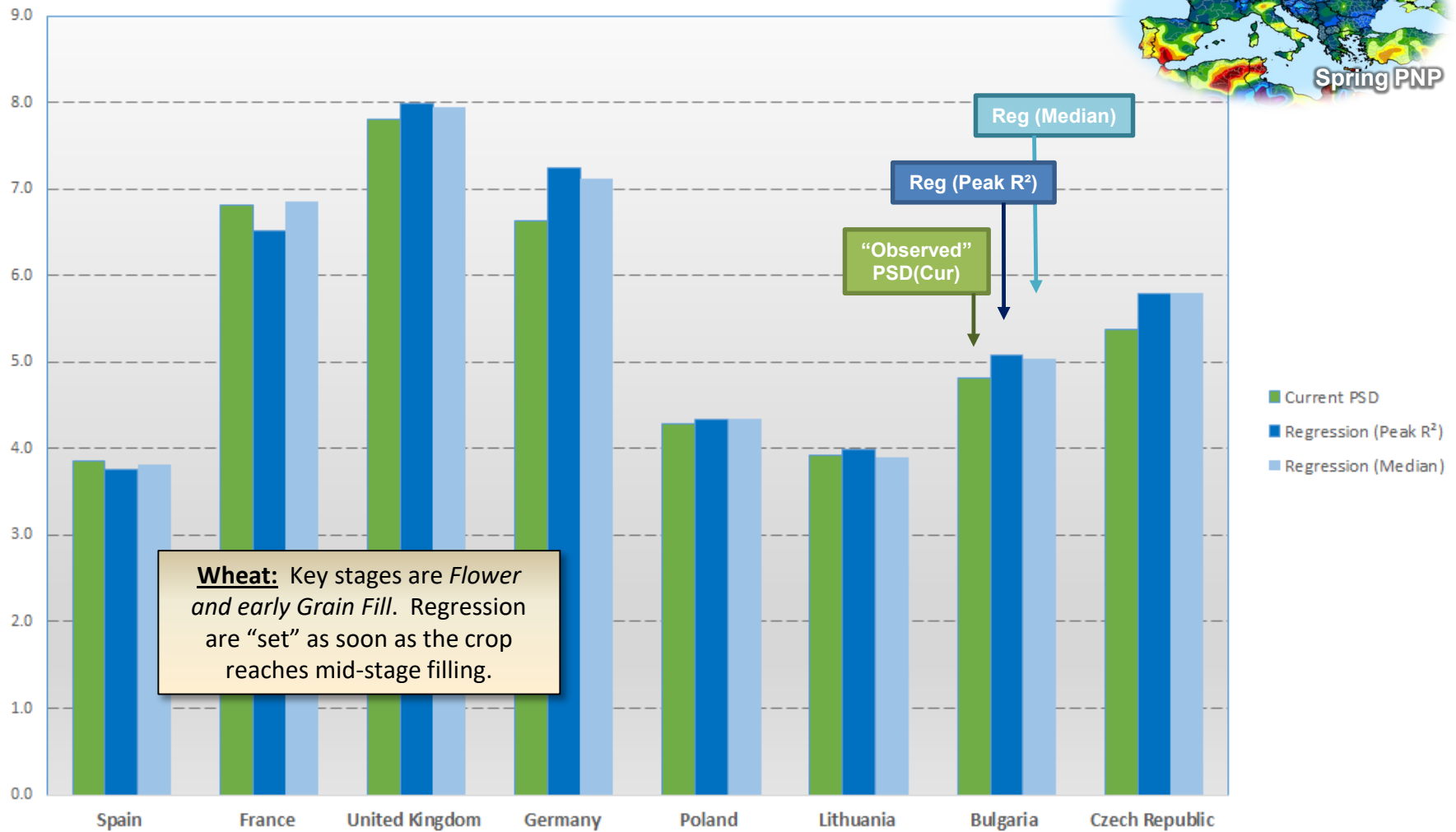
# Wheat – Trend $R^2$



# Wheat Regression – Peak R<sup>2</sup>

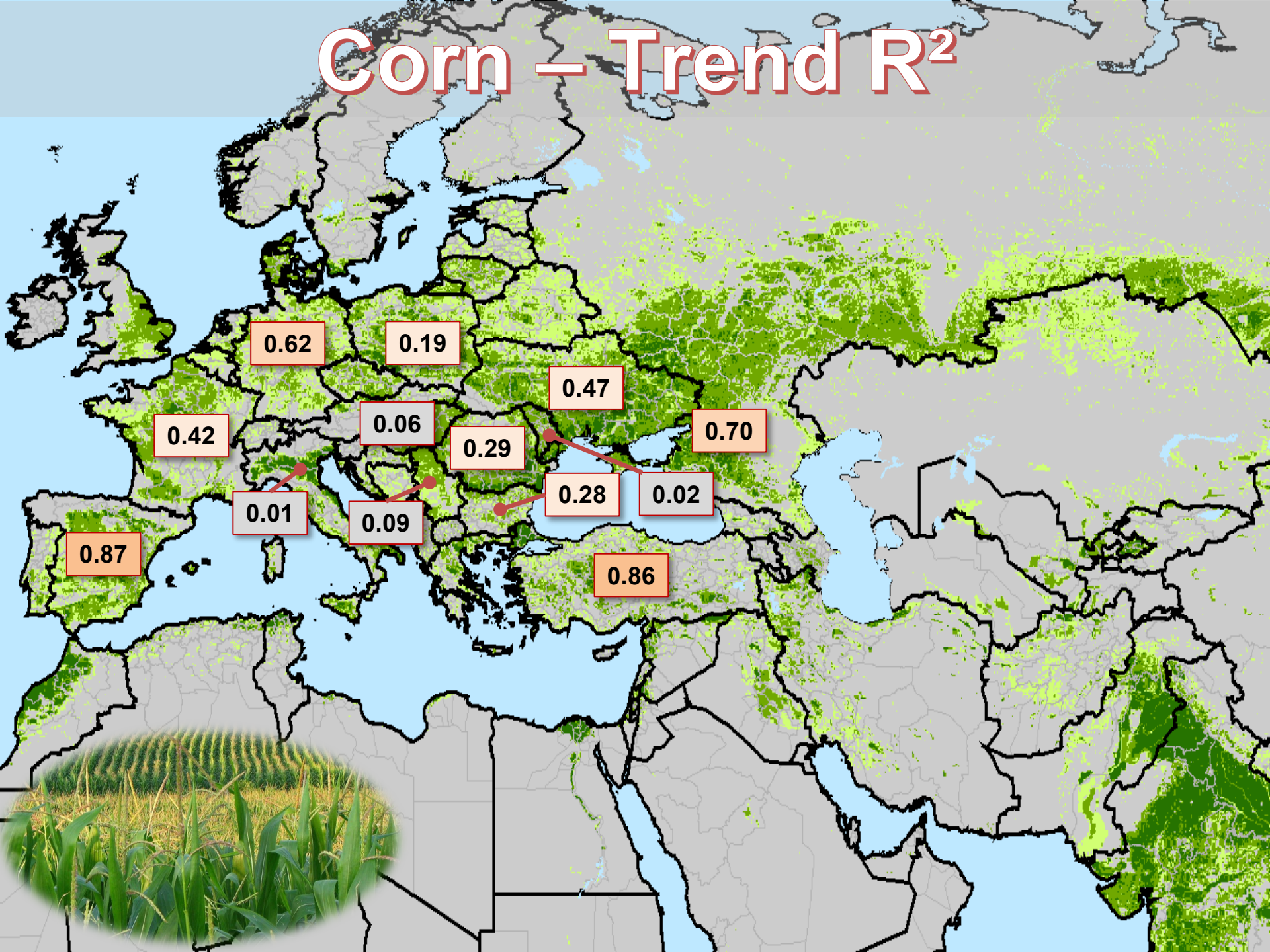


# Europe Wheat Regression (2018)



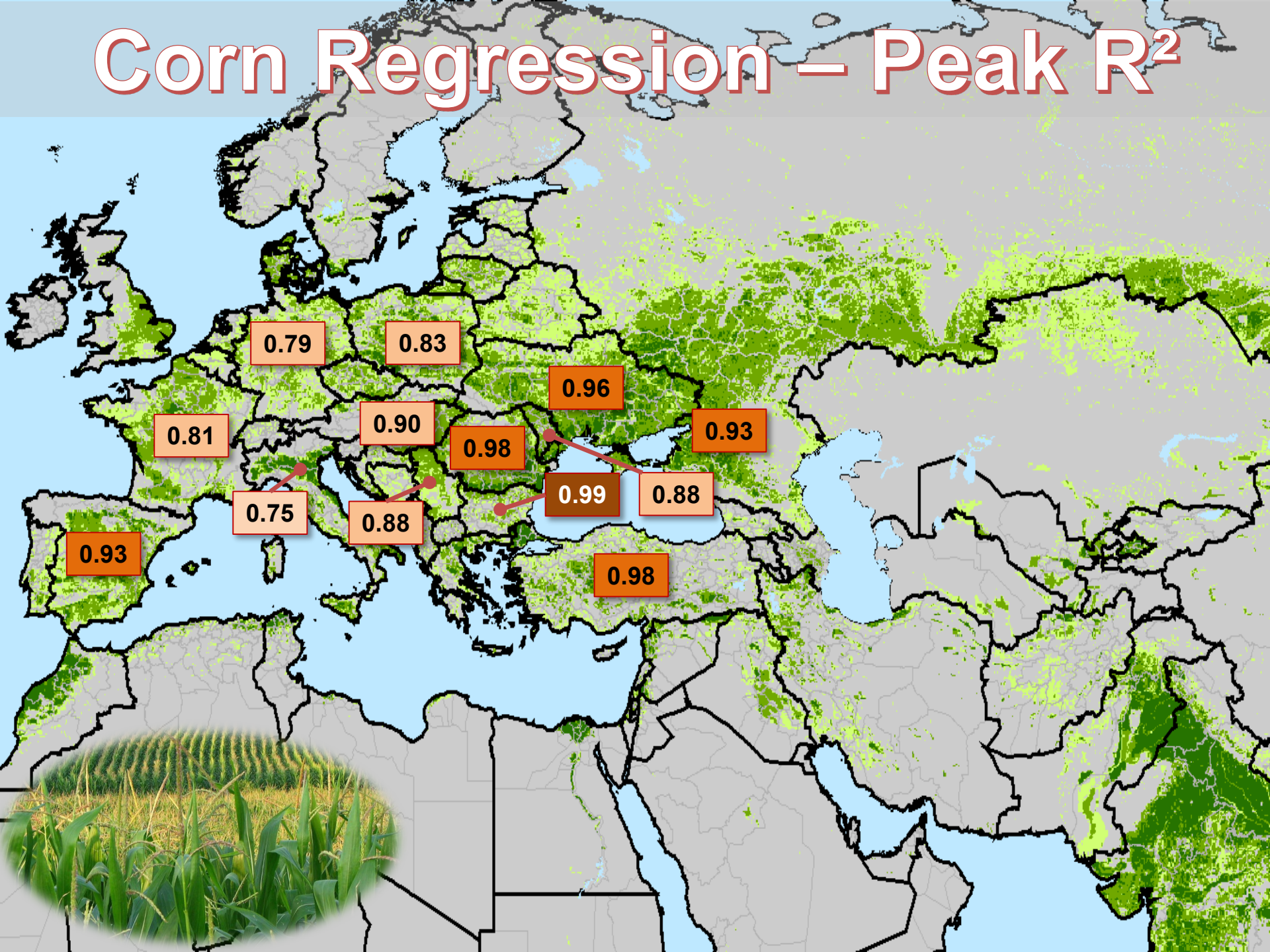
**Wheat:** Key stages are *Flower* and *early Grain Fill*. Regression are "set" as soon as the crop reaches mid-stage filling.

# Corn – Trend $R^2$

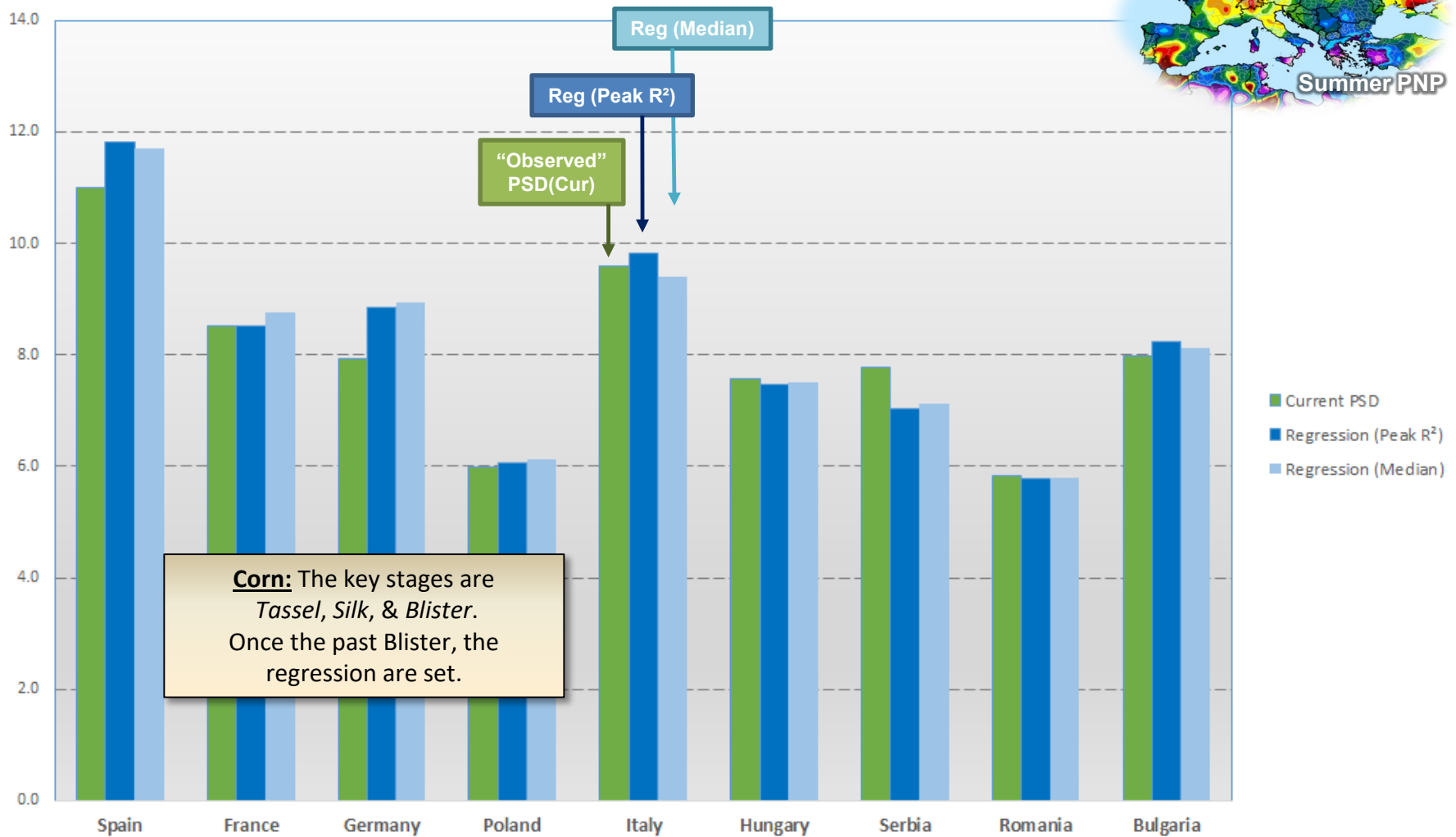
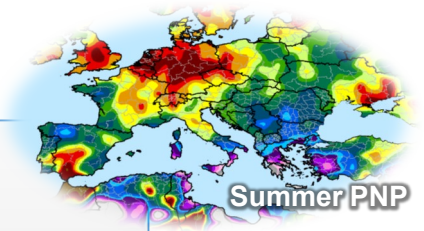




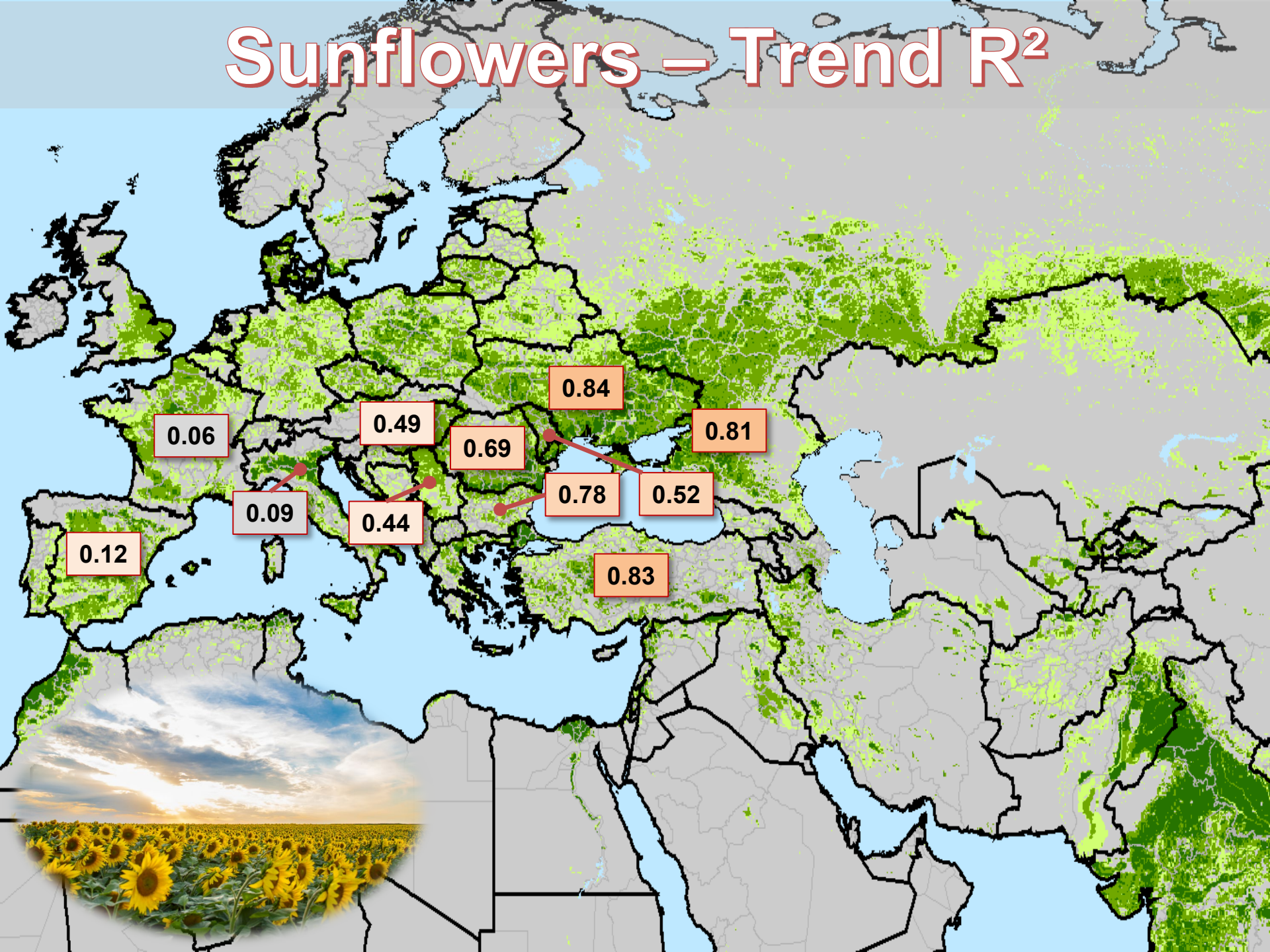
# Corn Regression – Peak R<sup>2</sup>



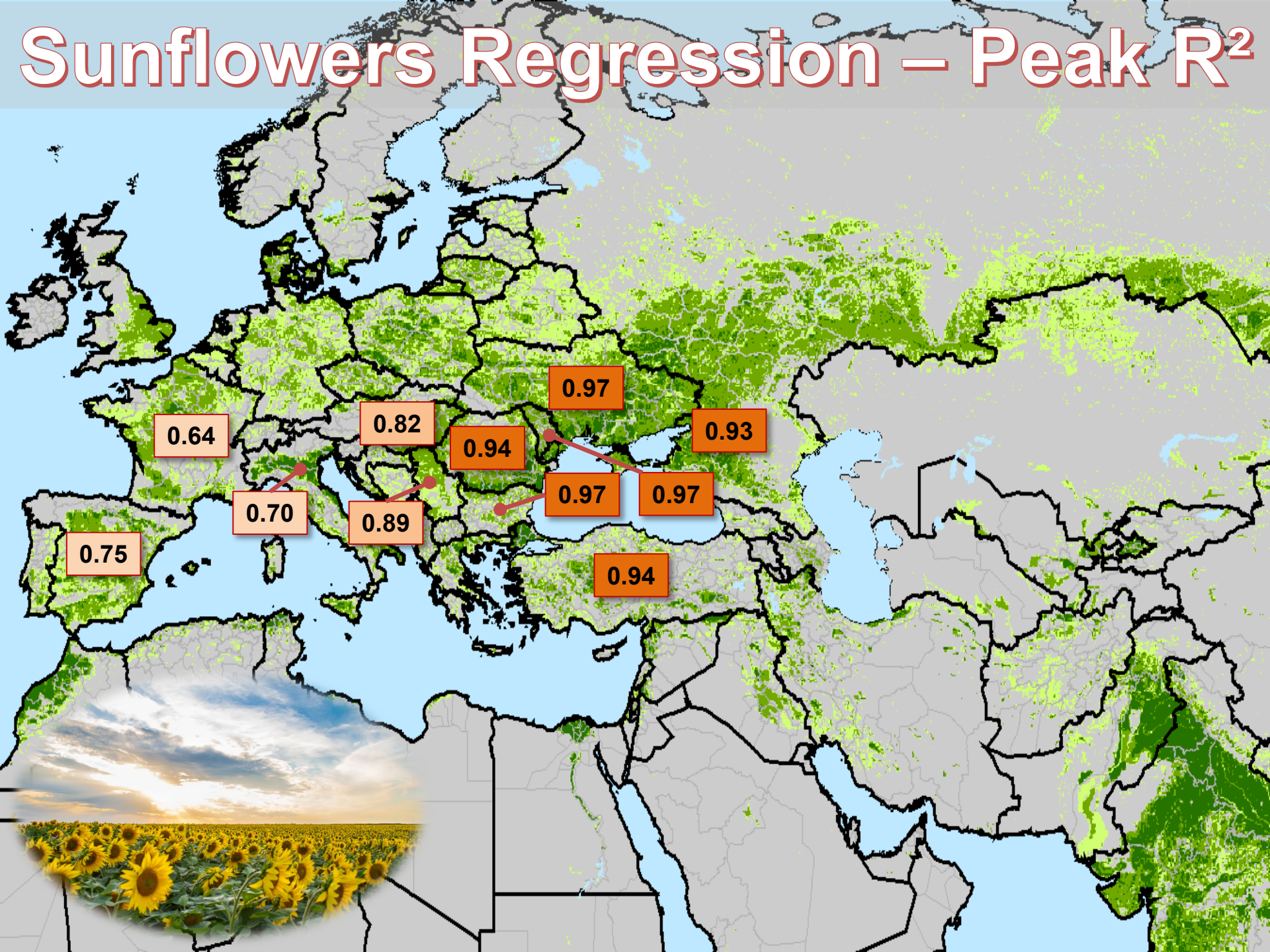
# Europe Corn Regression (2018)



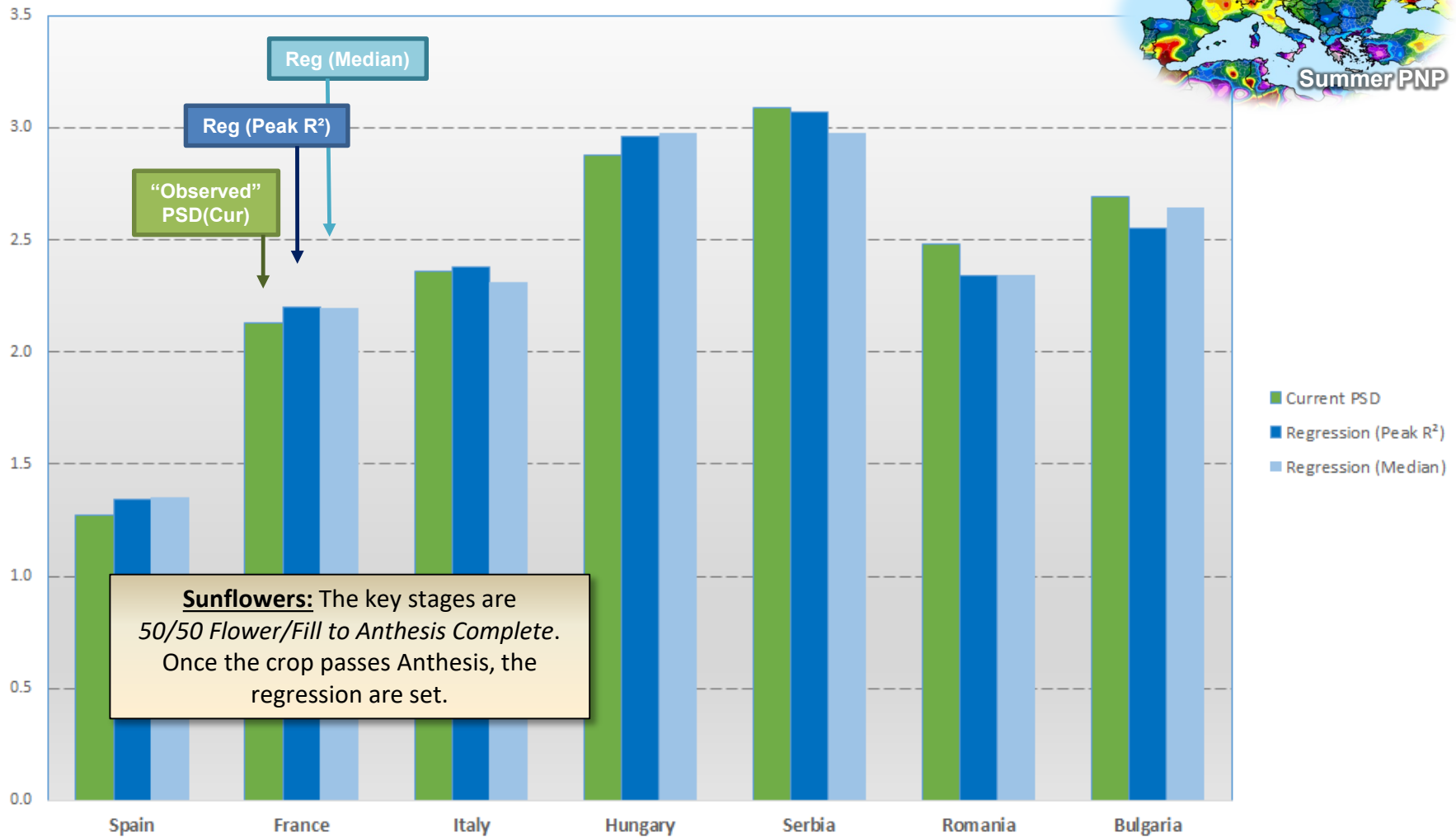
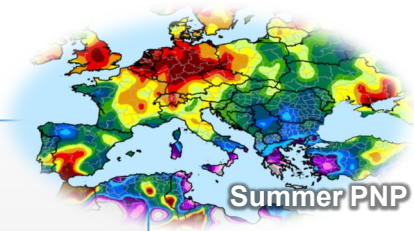
# Sunflowers – Trend $R^2$



# Sunflowers Regression – Peak R<sup>2</sup>

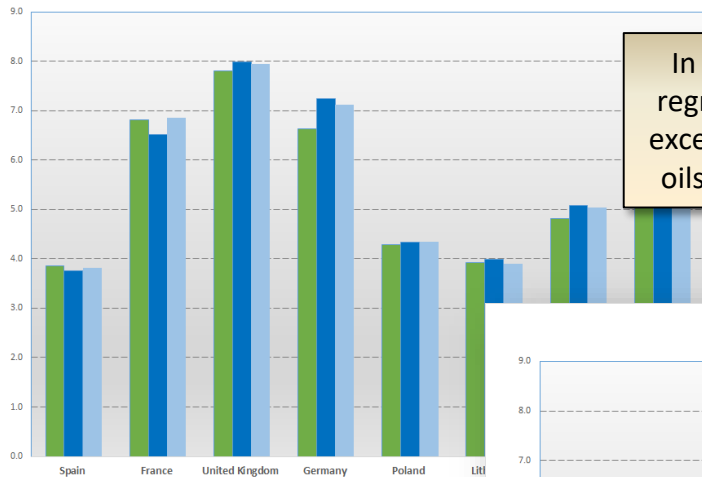


# Europe Sunflower Regression (2018)

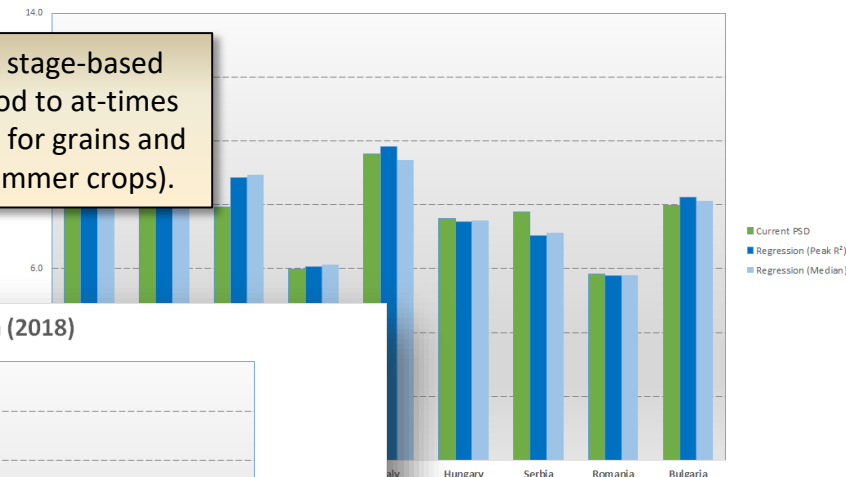


**Sunflowers:** The key stages are 50/50 Flower/Fill to Anthesis Complete. Once the crop passes Anthesis, the regression are set.

Europe Wheat Regression (2018)

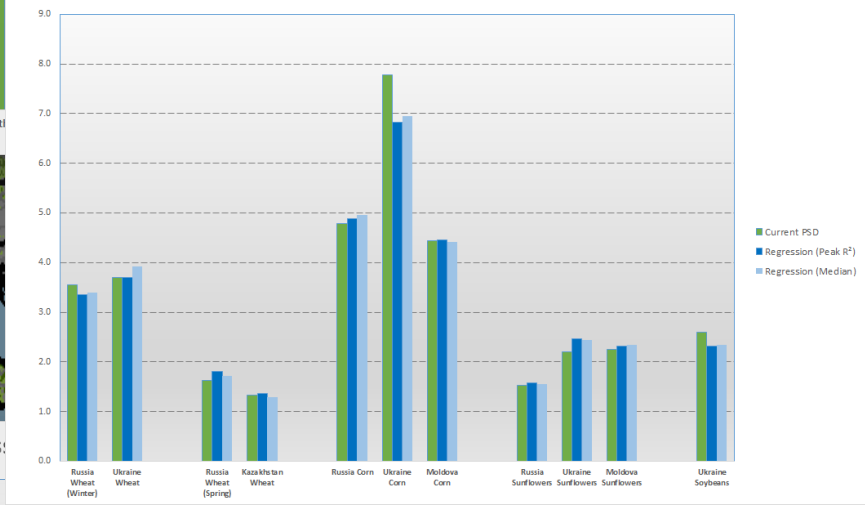


Europe Corn Regression (2018)

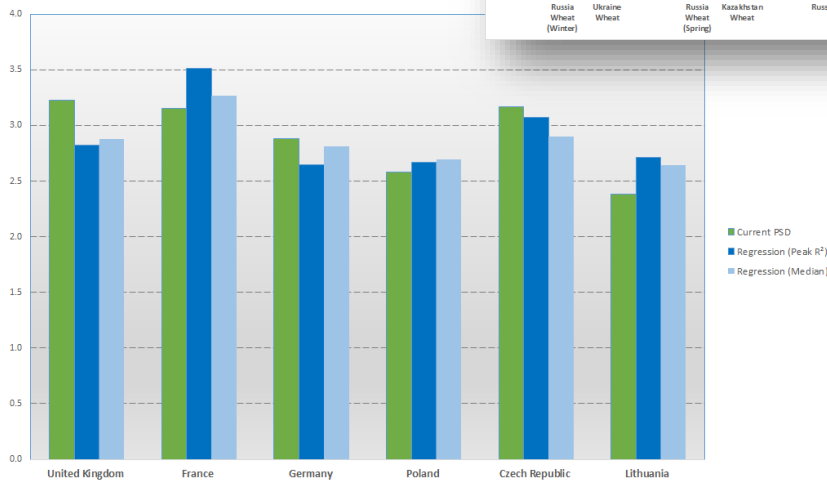


In 2018, the Wx & VHI stage-based regression provided good to at-times excellent yield guidance for grains and oilseeds (winter and summer crops).

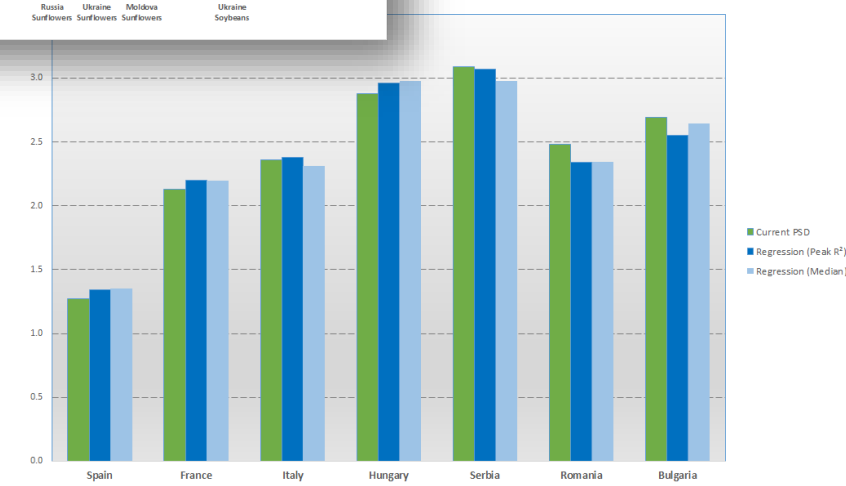
FSU Regression (2018)



Europe Rapeseed Regression (2018)



Europe Oilseed Regression (2018)

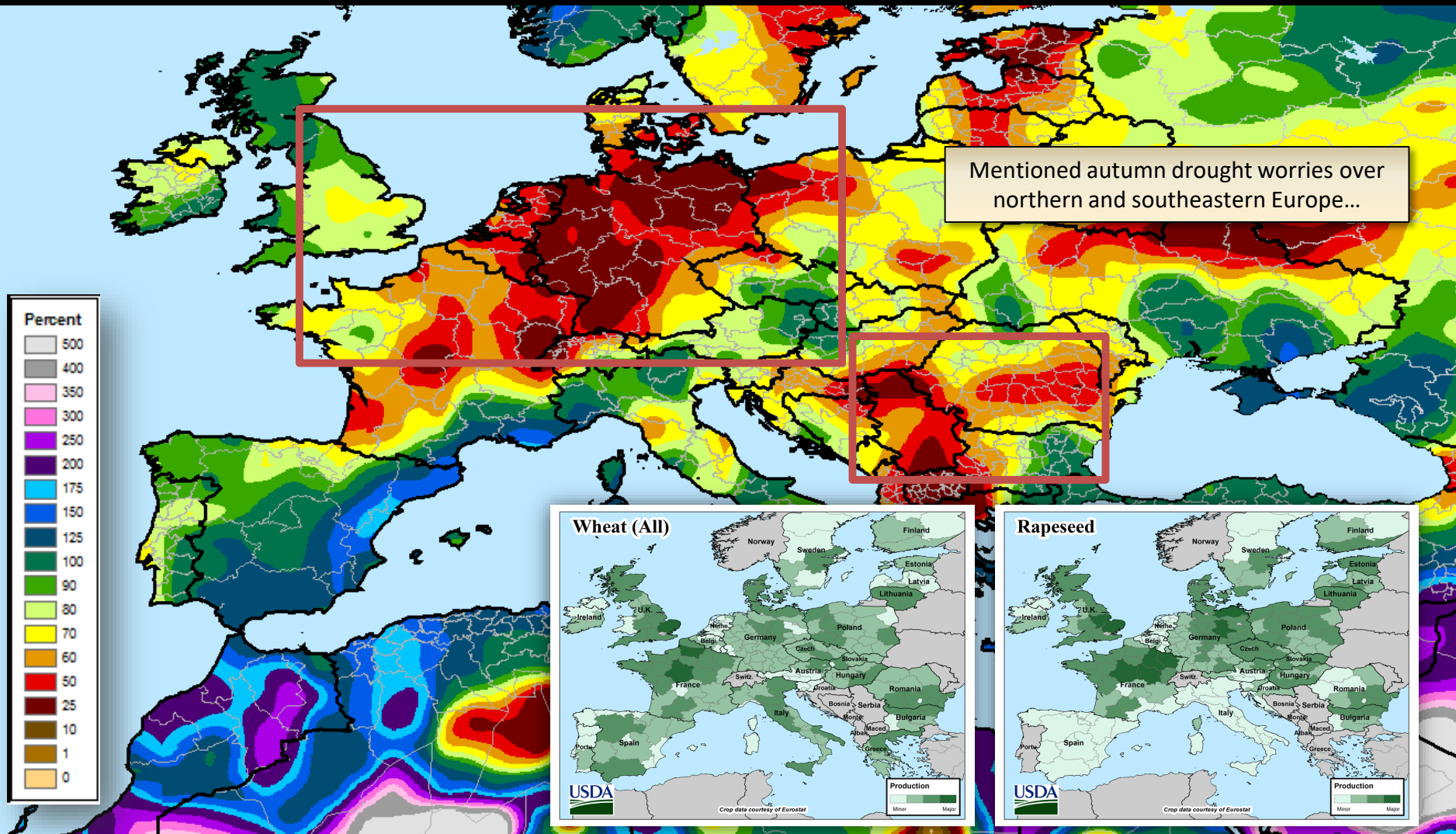




**Back to the Outlook!!**

# Percent-of-Normal Precipitation

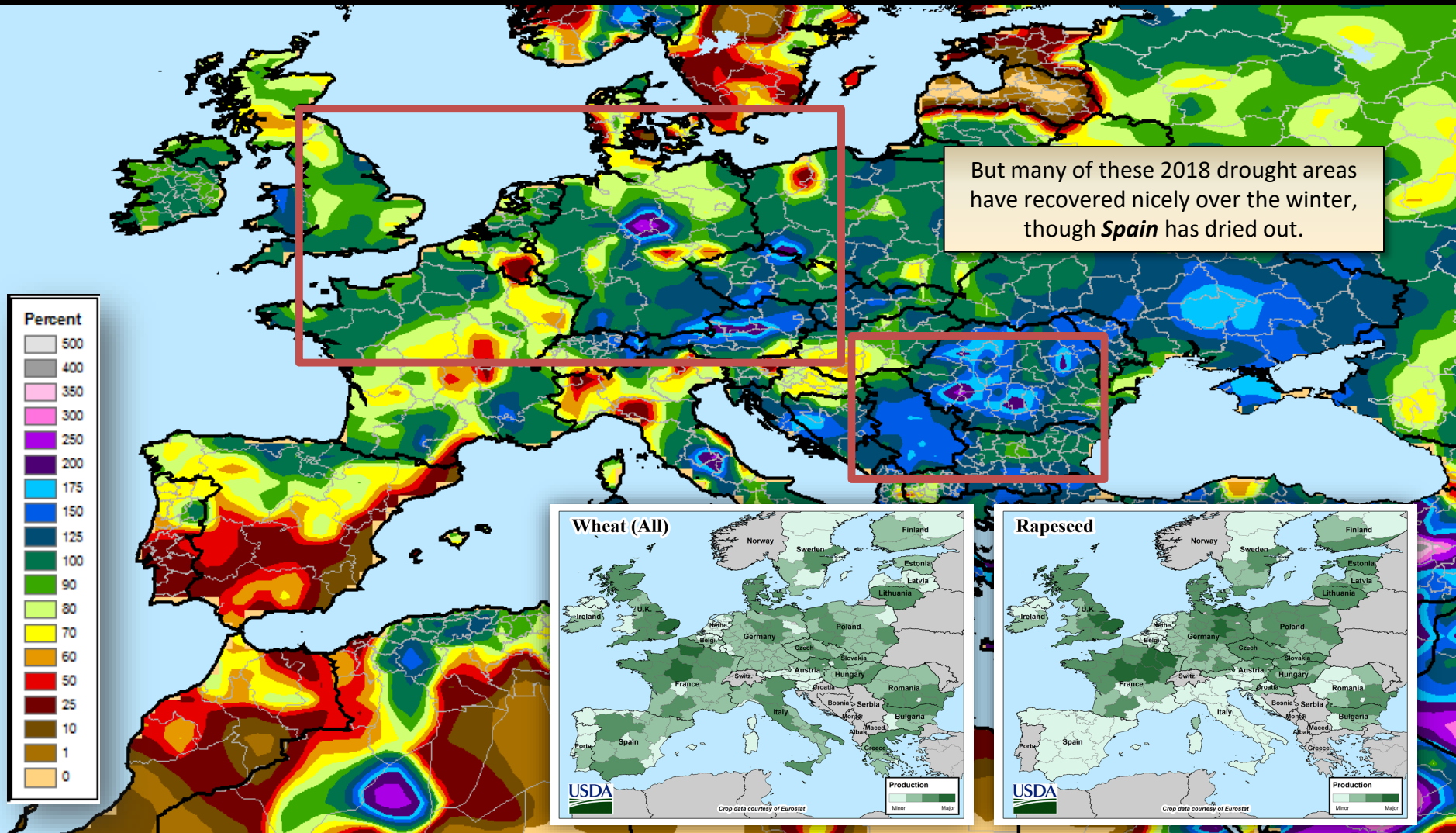
September-November, 2018





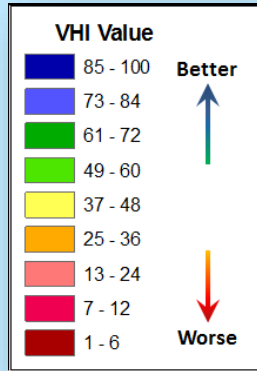
# 90-day Percent-of-Normal Precipitation

February 20, 2019

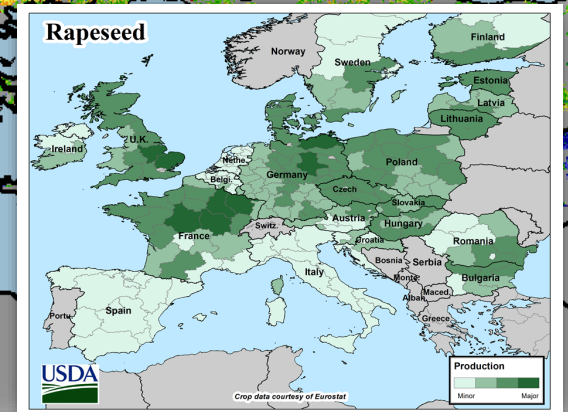
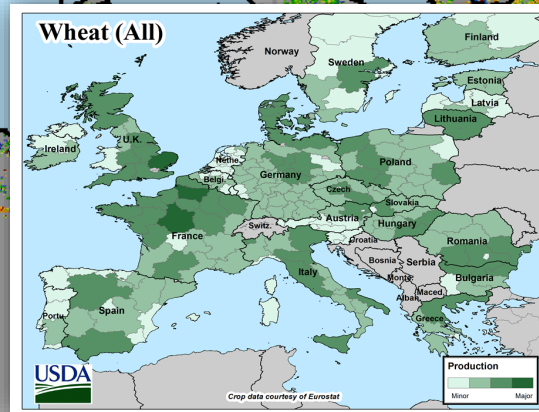


# Vegetation Health Index

February 20, 2019

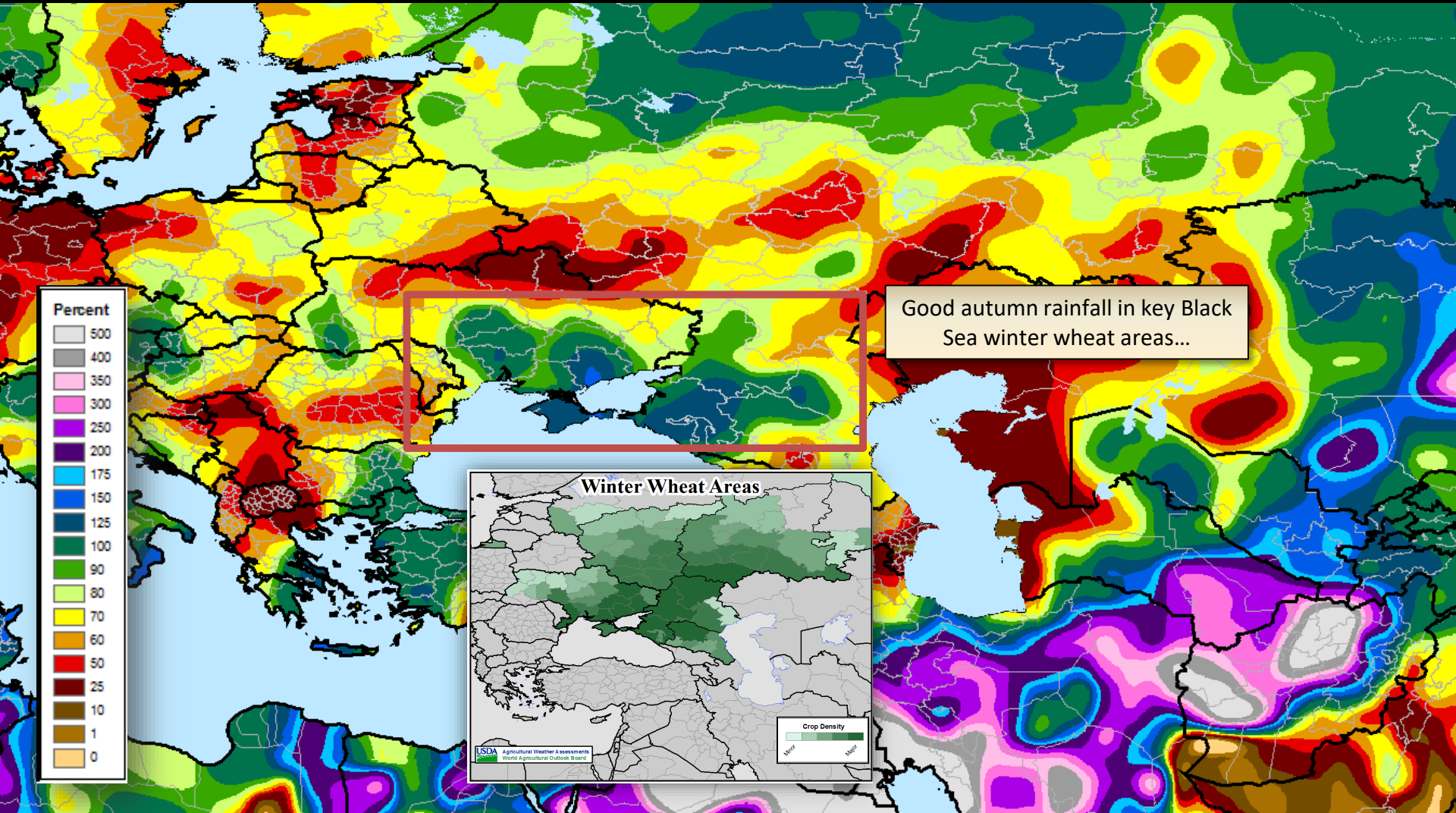


Latest VHI shows lingering impacts of fall dryness in eastern Europe.



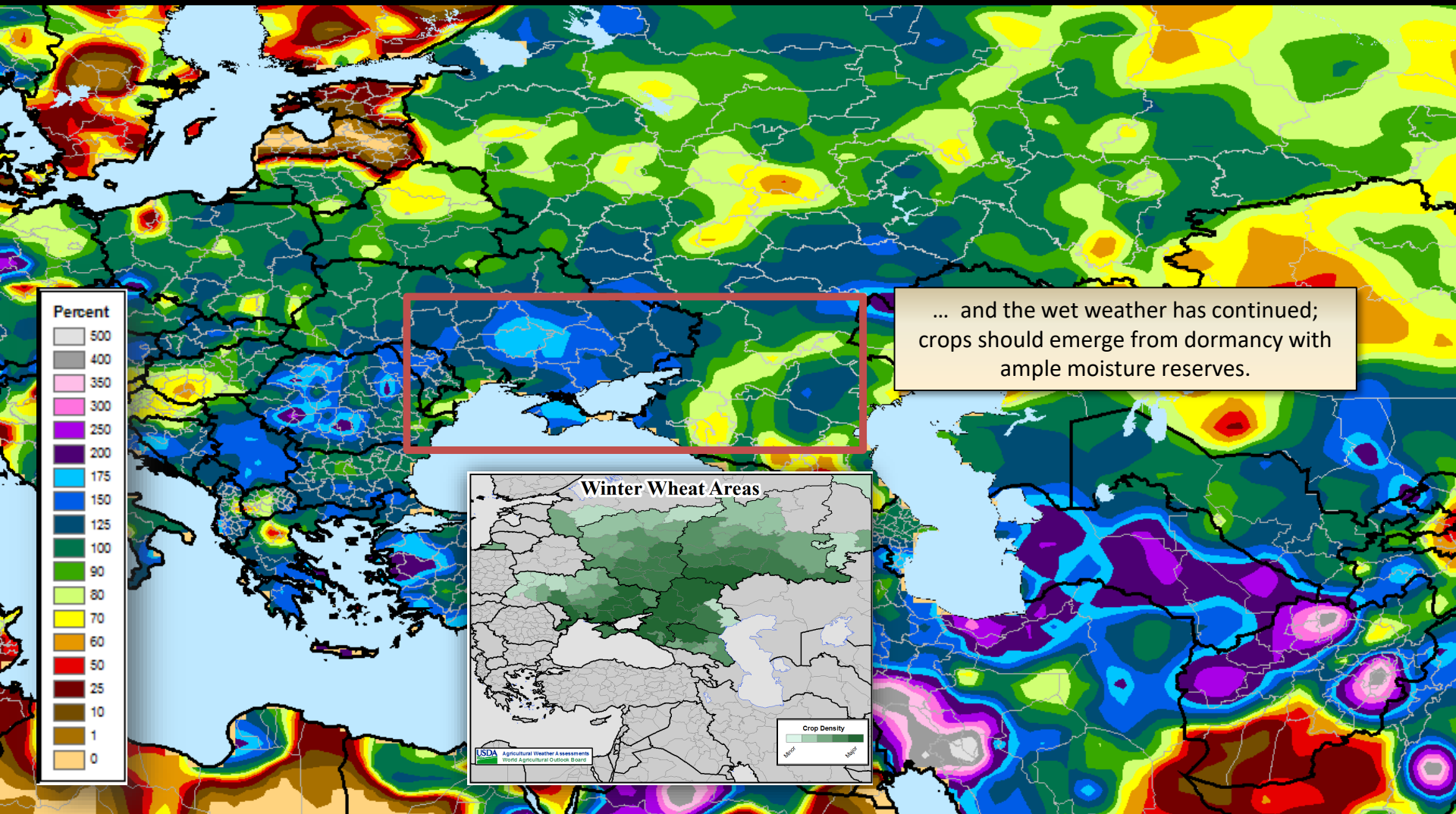
# Percent-of-Normal Precipitation

September-November, 2018



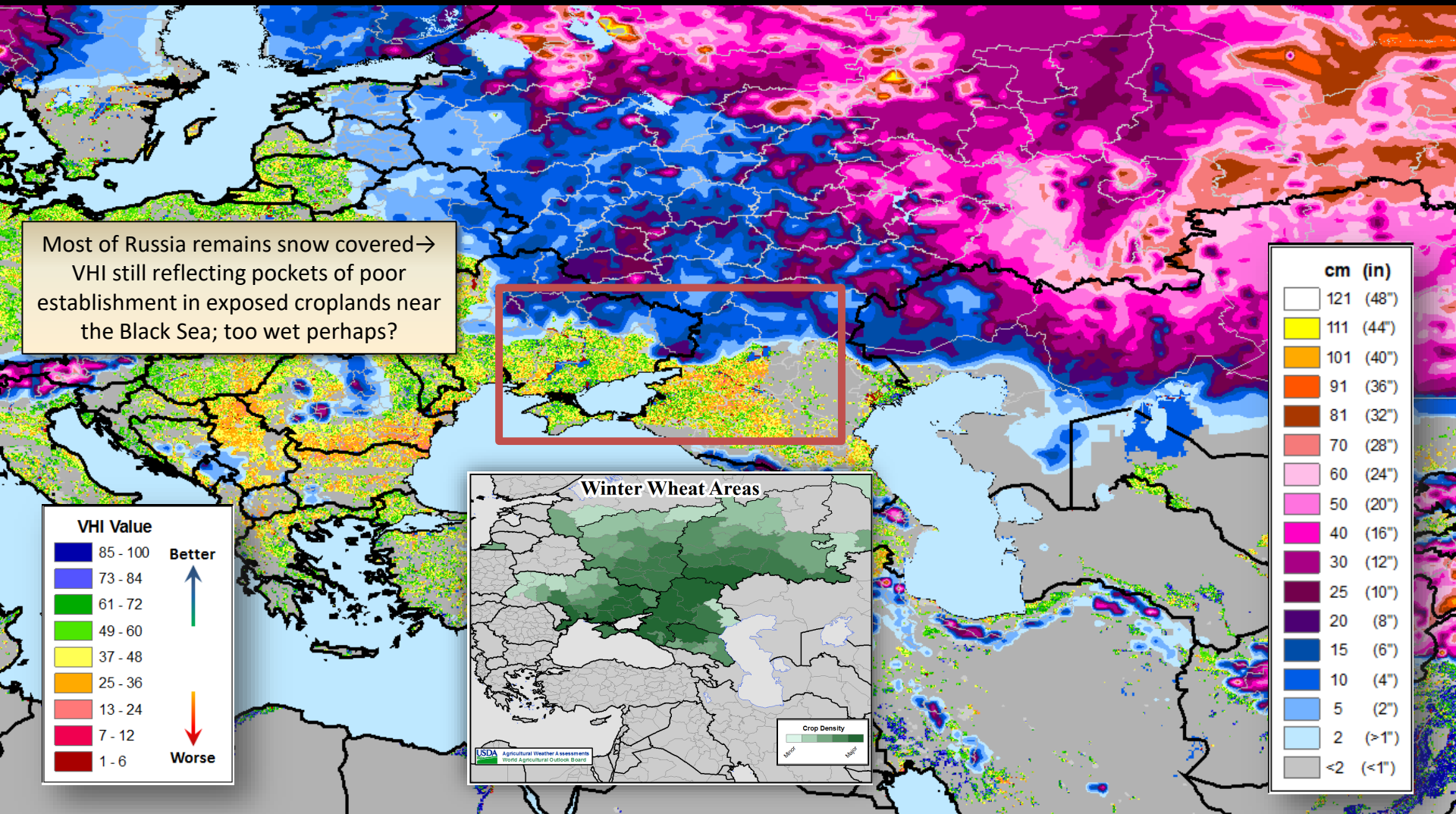
# 90-day Percent-of-Normal Precipitation

February 20, 2019



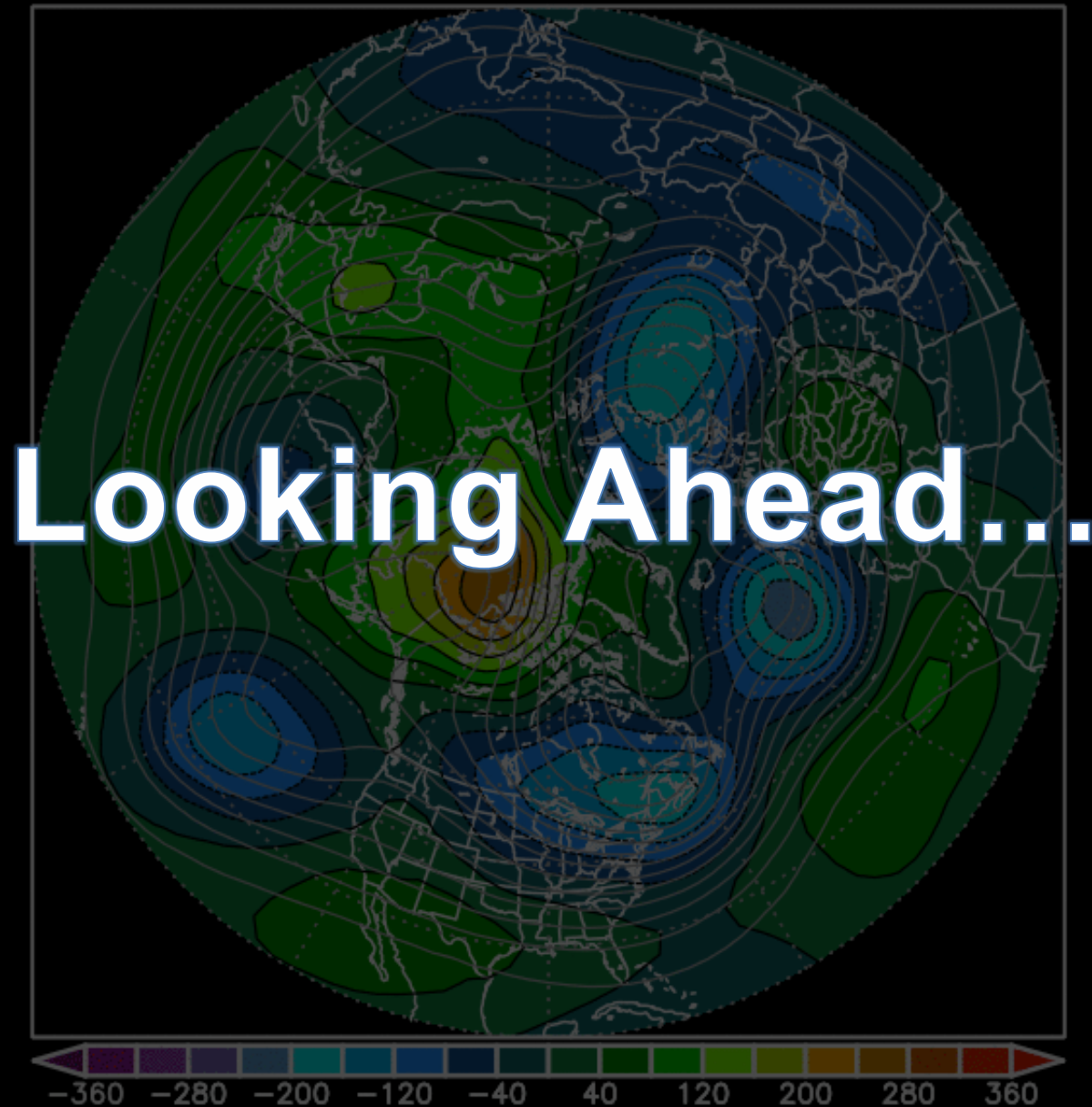
# 90-day Percent-of-Normal Precipitation

February 20, 2019



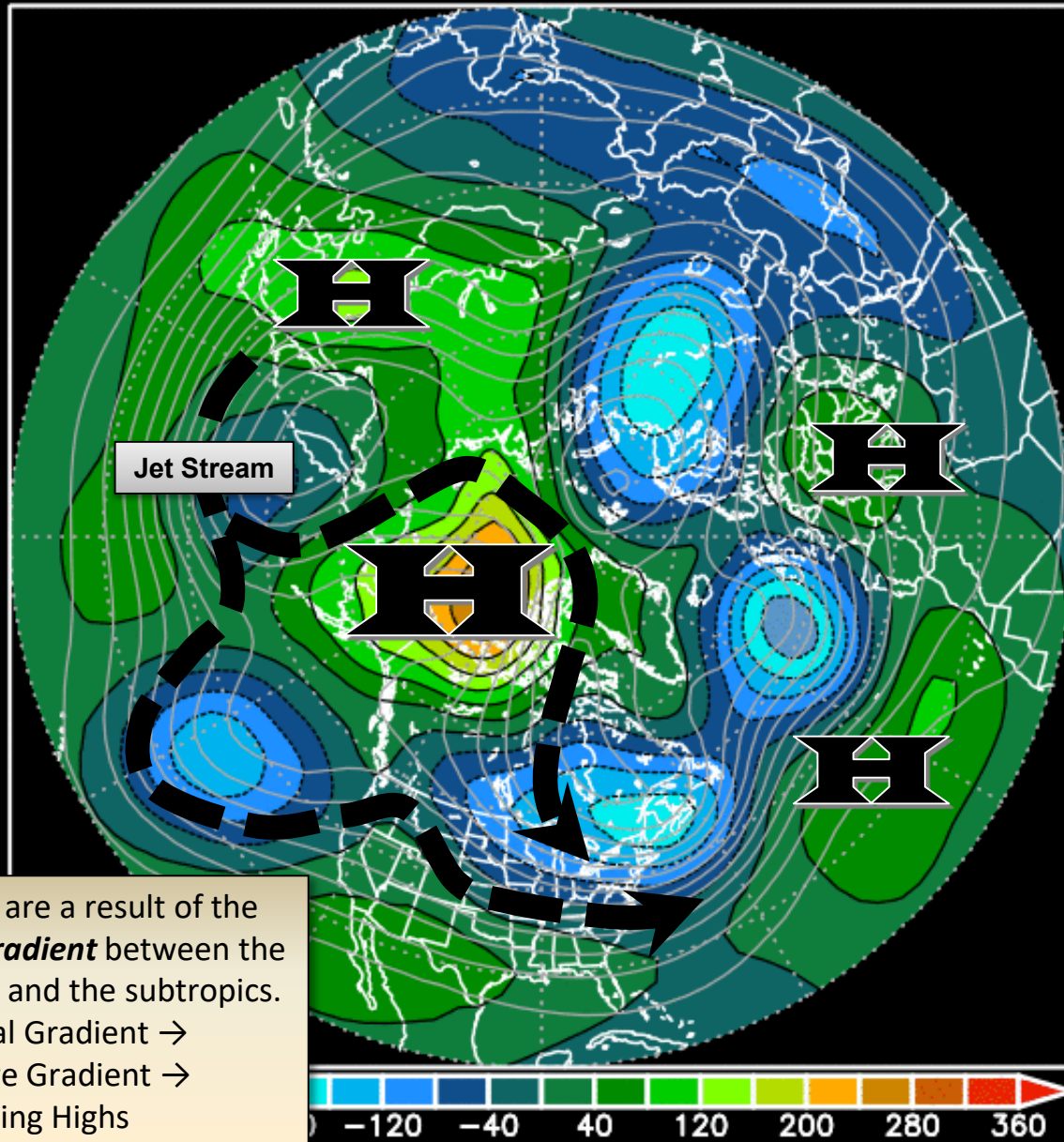
# The “New” Normal: Blocking Highs

Pressure Anomaly Forecast @ ~15,000' for March 4, 2019



# The “New” Normal: Blocking Highs

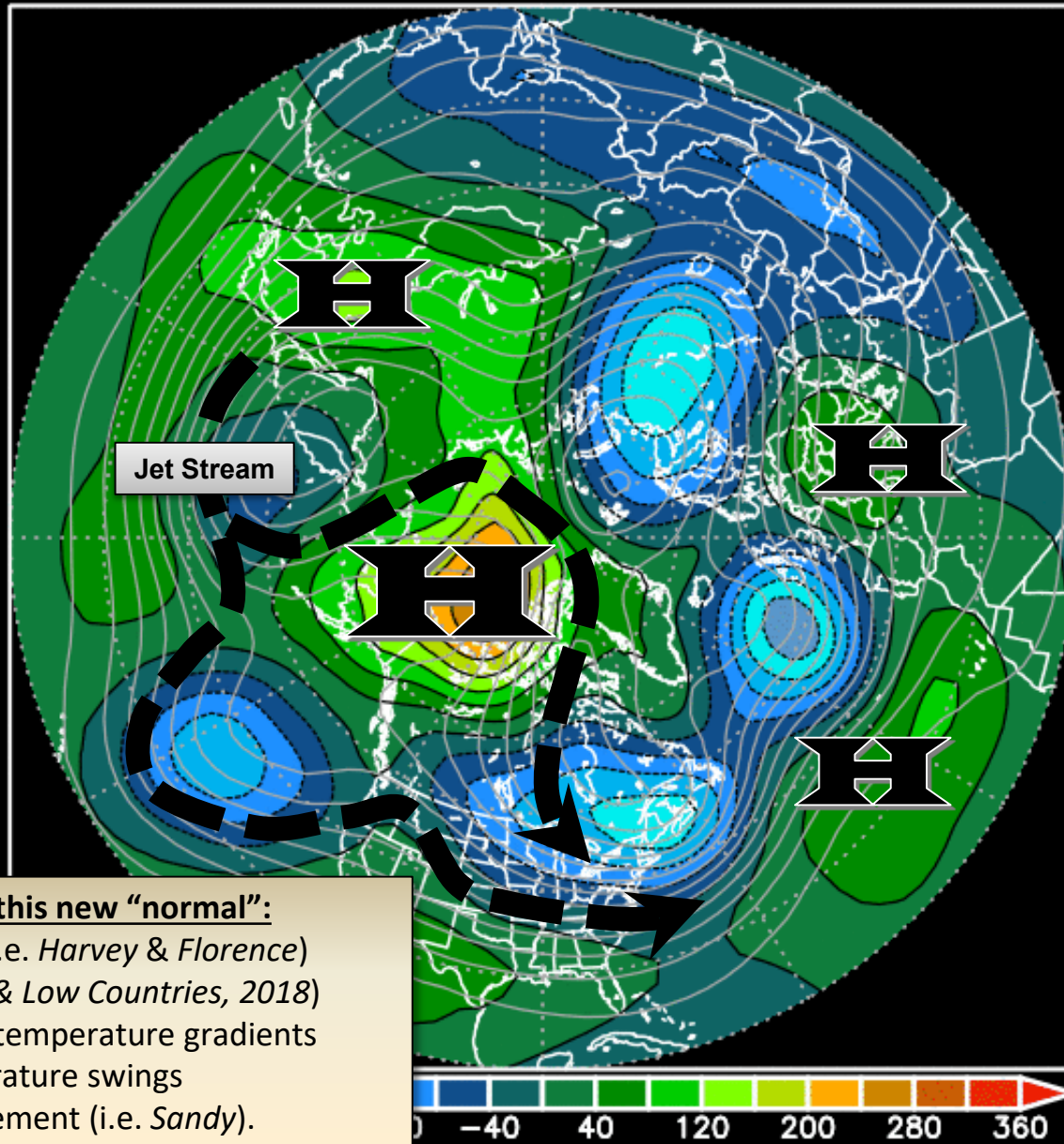
Pressure Anomaly Forecast @ ~15,000' for March 4, 2019



More blocking highs are a result of the *weakening thermal gradient* between the warmer high latitudes and the subtropics.  
Weaker Thermal Gradient →  
Weaker Pressure Gradient →  
More Blocking Highs

# The “New” Normal: Blocking Highs

Pressure Anomaly Forecast @ ~15,000' for March 4, 2019



## Net result of this new “normal”:

- Stationary storms (i.e. *Harvey* & *Florence*)
- Drought (*Germany* & *Low Countries*, 2018)
- Sharp west-to-east temperature gradients
- Pronounced temperature swings
- Strange storm movement (i.e. *Sandy*).



# Acknowledgements:

VHI Data – Felix Kogan, Wei Guo, & Hanjun Ding (NOAA, NESDIS)

WMO Data – David Miskus, Brad Pugh, Rich Tinker, et al (NOAA, CPC)

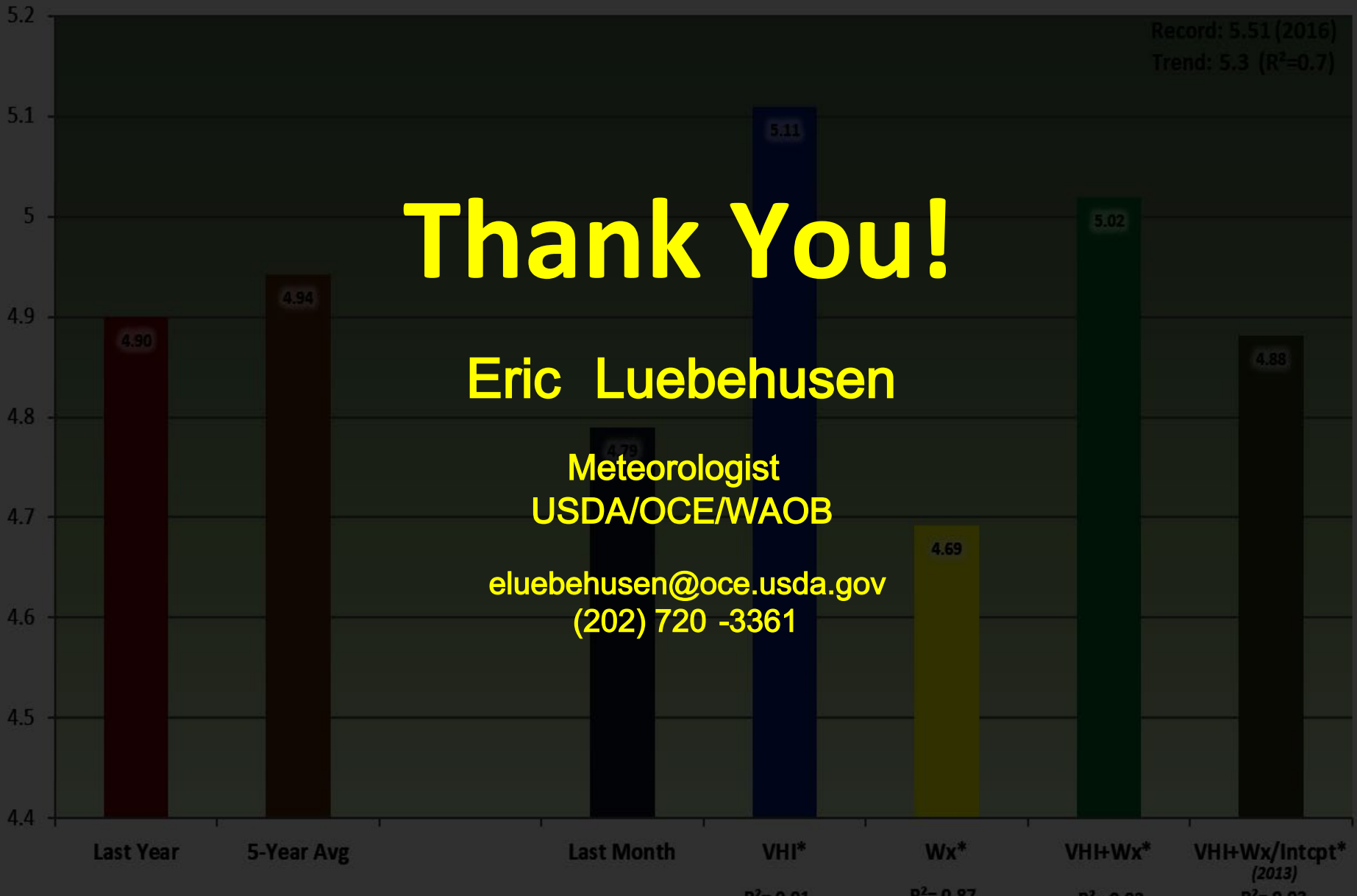
USDA WMO Database – Brian Morris (USDA, WAOB)

USDA PSD Database – IPAD (USDA, FAS); Mark Brusberg & Brian Morris (USDA, WAOB)

# Russia Corn Regression

Regression: 2001-2017  
Median Regression Yield: 4.95

Record: 5.51 (2016)  
Trend: 5.3 (R<sup>2</sup>=0.7)



# Thank You!

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USDA/OCE/WAOB

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(202) 720 -3361

	R <sup>2</sup> = 0.91	R <sup>2</sup> = 0.87	R <sup>2</sup> = 0.92	R <sup>2</sup> = 0.93
	+/- 0.3	+/- 0.37	+/- 0.31	+/- 0.29

\*Includes Trend