Using Land Surface Phenologies for Change Analysis

Geoffrey M. Henebry, Ph.D., C.S.E.
Professor of Natural Resource Management
Co-Director & Senior Research Scientist
Geographic Information Science Center of Excellence (GIScCE)
South Dakota State University, USA

geoffrey.henebry@sdstate.edu
http://globalmonitoring.sdstate.edu

SCERIN-1
Prague, June 18

Support from NASA LCLUC and IDS programs. ***Thanks!***

Steps in Change Analysis

1. **Change Detection:** What has changed? When and where?
2. **Change Quantification:** How much has changed?
3. **Change Assessment:** How significant are the changes?
4. **Change Attribution:** What are the causes of the changes?
5. **Change Consequences:** How do the changes affect other things?

Phenology: timing of recurrent life history events of organisms linked to environmental drivers and cues.

Examples: *timing of bud break, leaf out, leaf coloring, leaf fall; timing of animal migration & mating; timing of flowering & pollination*

Land Surface Phenology: timing of recurrent patterns of EM radiation associated with biological phenomena.

Example: *timing of the vernal "green wave"; timing of "brown-down"*

Seasonality: timing of recurrent abiotic events.

Examples: *timing of soil freeze/thaw; timing of ice on/ice off; timing of reduction in the diel temperature range; timing of center of mass flow*

Land Surface Seasonality: timing of recurrent patterns of EM radiation associated with abiotic phenomena.

Example: *timing of soil thaw period; timing of peak fractional water*

Whose time ?

If phenology attends to the timing of recurrent biological events, then whose “clock” and “calendar” should track that time?

Calendars are anthropocentric.

Do plants pay attention to our calendars ?

Can we link vegetation dynamics to a biometeorological calendar ?

Accumulated Growing Degree-Days (also known as **thermal time**) is a simple biometeorological variable that weights the passage of days by the quantity of "growing degrees" – that portion of the diel temperature range that is useful for plant growth, broadly construed.

The calculation of AGDD is straightforward:

(1) $AverageTemp_t = (MaxTemp_t + MinTemp_t)/2$

(2) $AGDD_t = AGDD_{t-1} + \max[(AverageTemp_t - Base),0]$

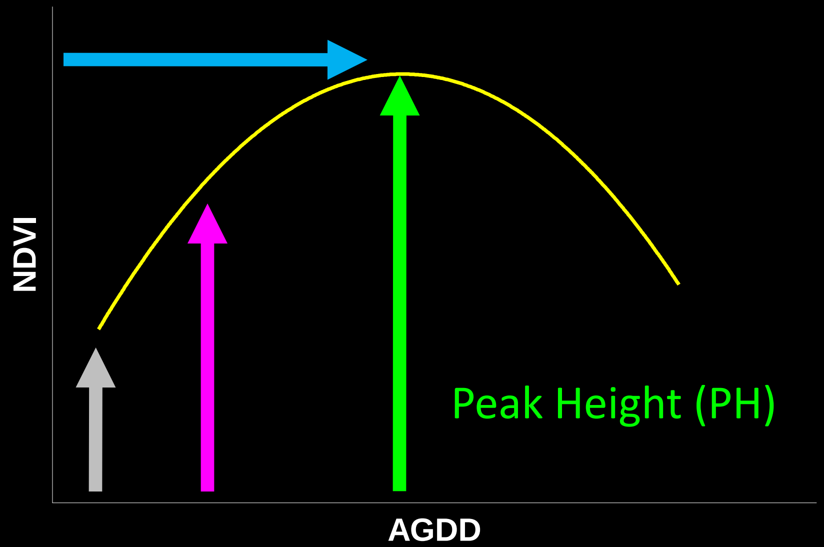
Here we will use a base of 273.15 K (0 °C) with an annual reset each winter solstice.

Convex Quadratic model of Land Surface Phenology (CxQ LSP)

Simple quadratic models that link the NDVI to the temporal progression of accumulated growing degree-days (AGDD) have been successfully applied to a variety of settings and scales.

$$NDVI = \alpha + \beta AGDD - \gamma AGDD^2$$

Thermal Time to Peak (TTP)



intercept

phenometrics

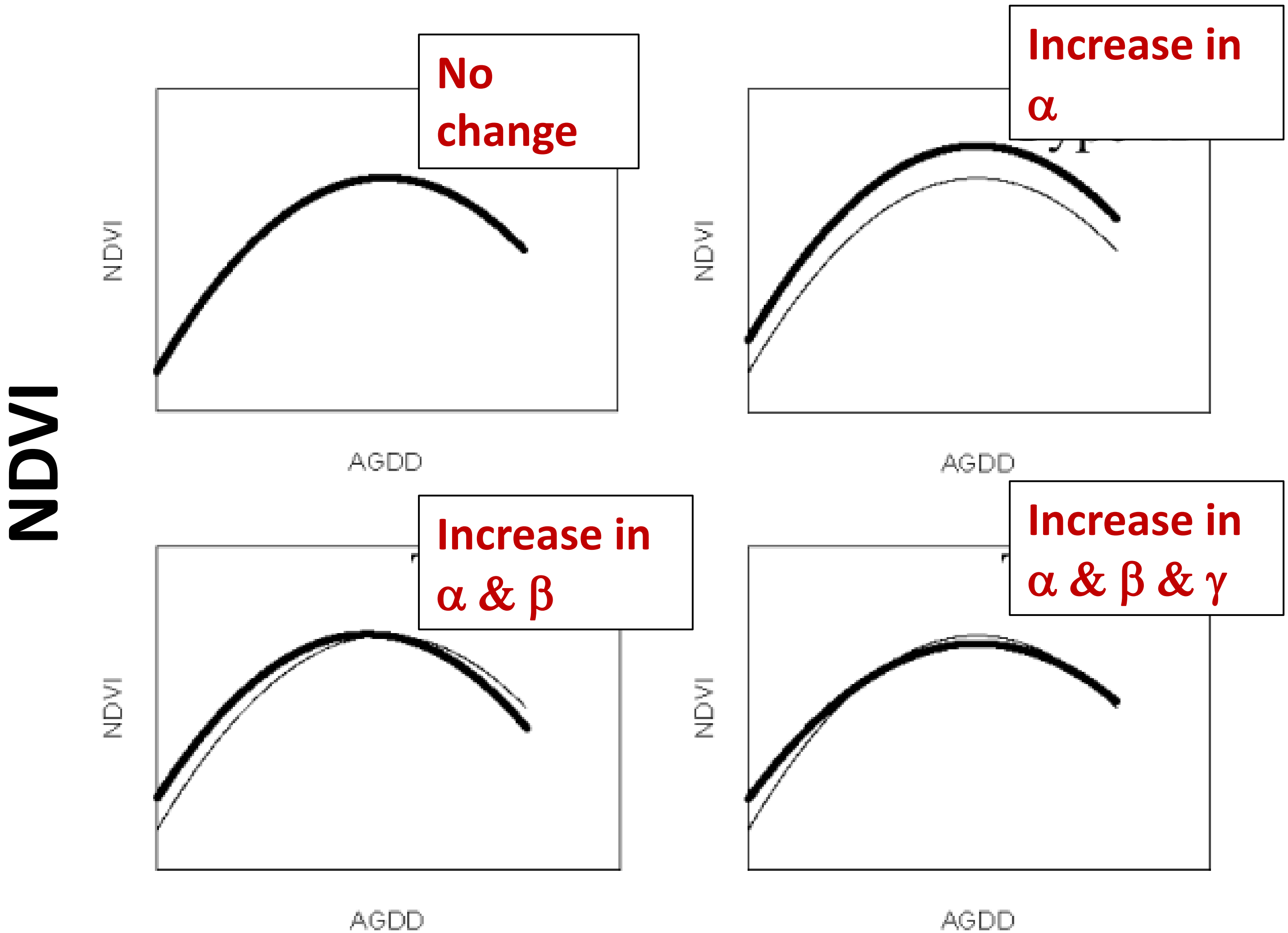
$PH = \alpha - (\beta^2/4\gamma)$

$TTP = -\beta/2\gamma$

NDVI @ half-TTP

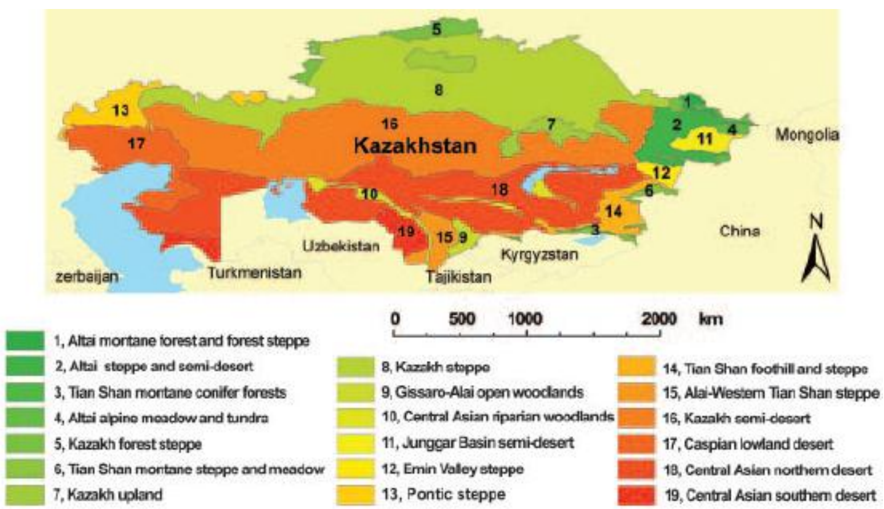
de Beurs & Henebry. 2005a. Land surface phenology and temperature variation in the IGBP high-latitude transects. ***Global Change Biology*** 11(5): 779-790.

$$NDVI = \alpha + \beta AGDD - \gamma AGDD^2$$



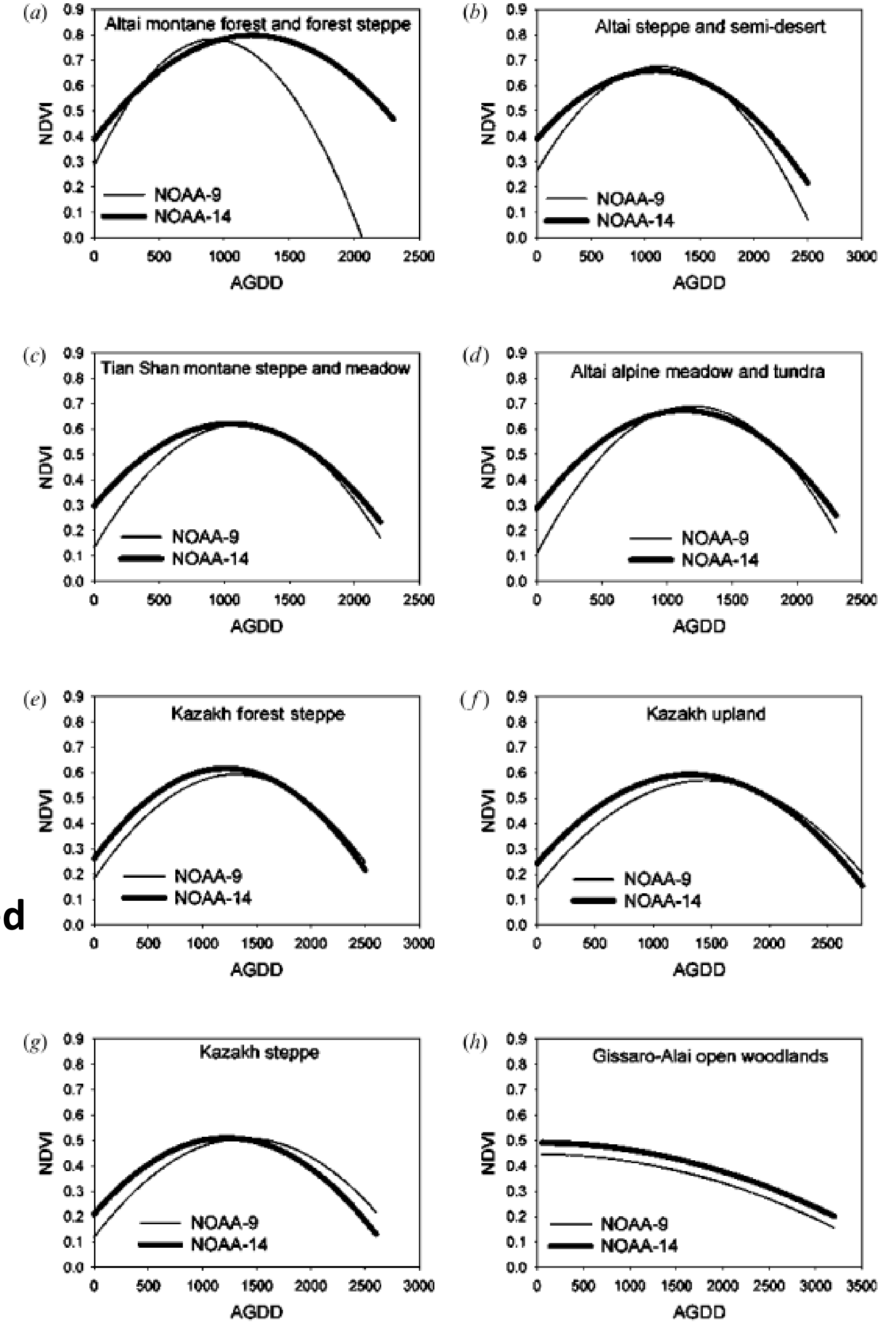
AGDD

Significant LSP changes found in 12 of 19* Kazakhstan ecoregions following the collapse of the Soviet Union

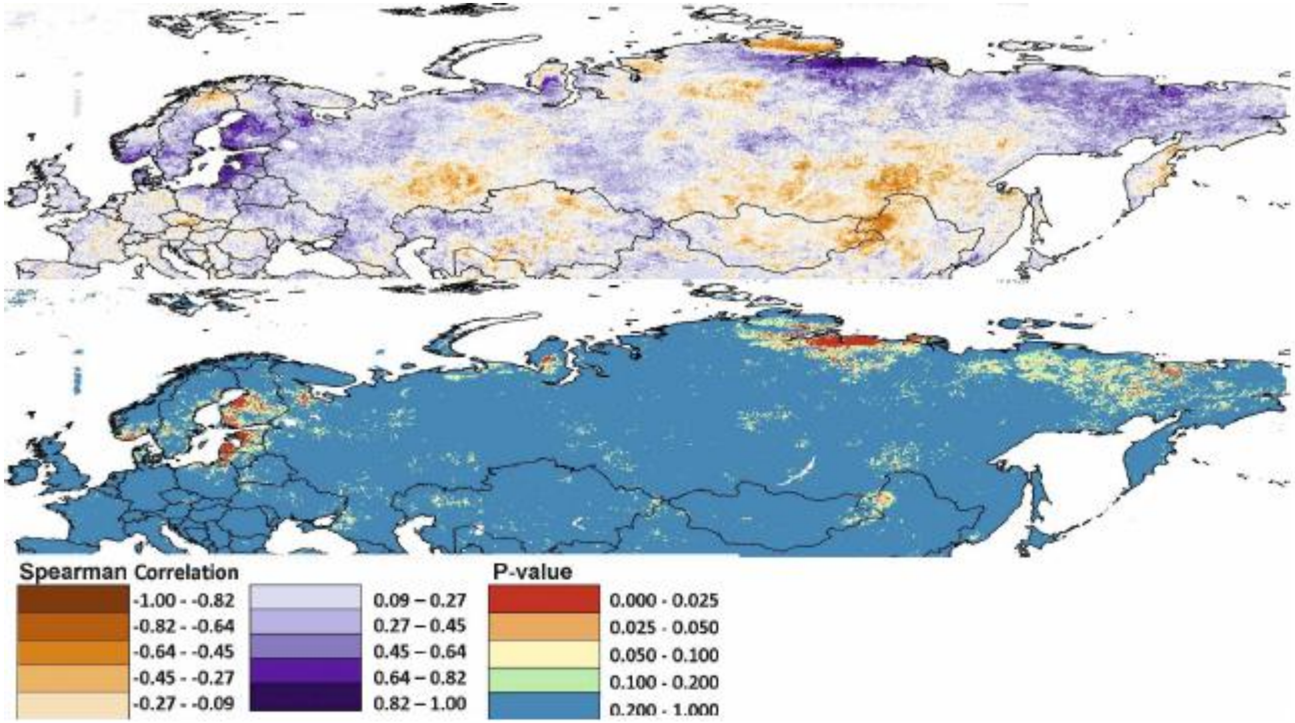


- 15 of 19 ecoregions modeled; 4 deserts omitted
- 12 of 15 showed significant LSP changes
- 3 of 15 showed no change

de Beurs & Henebry. 2005b. A statistical framework for the analysis of long image time series. ***International Journal of Remote Sensing*** 26(8): 1551-1573.

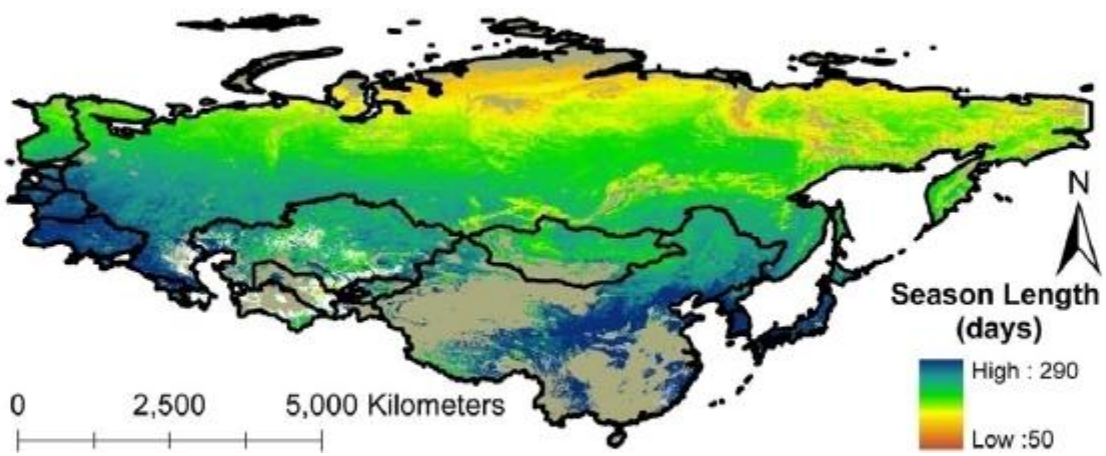


Using the CxQ LSP model with AVHRR NDVI to link DJF Arctic Oscillation to TTP



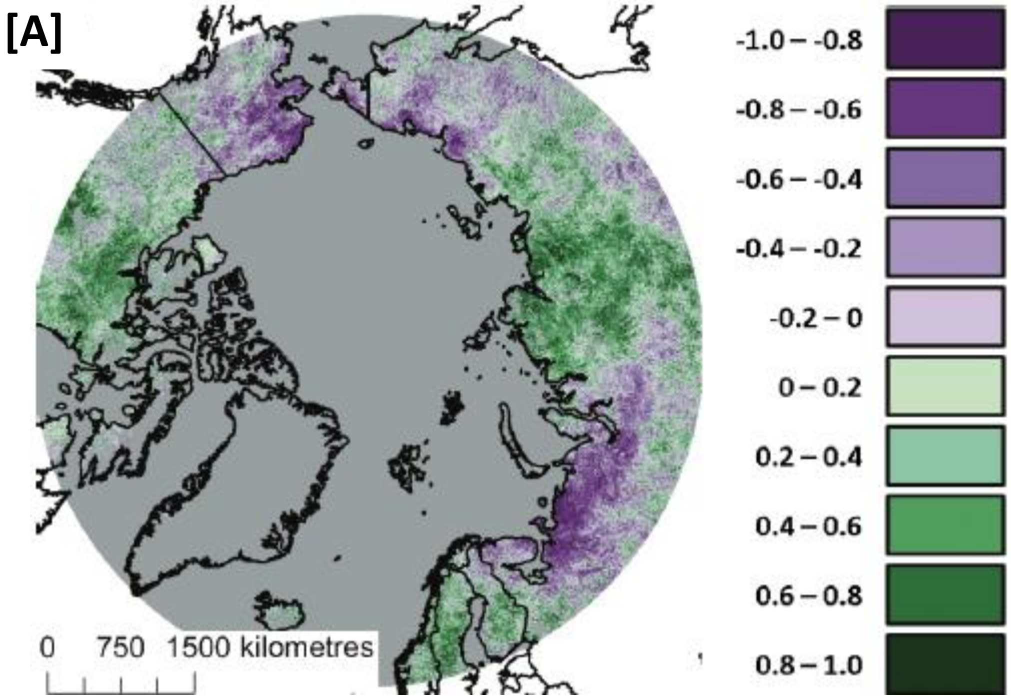
de Beurs & Henebry. 2008. Northern Annular Mode effects on the land surface phenologies of Northern Eurasia. ***Journal of Climate*** 21:4257-4279.

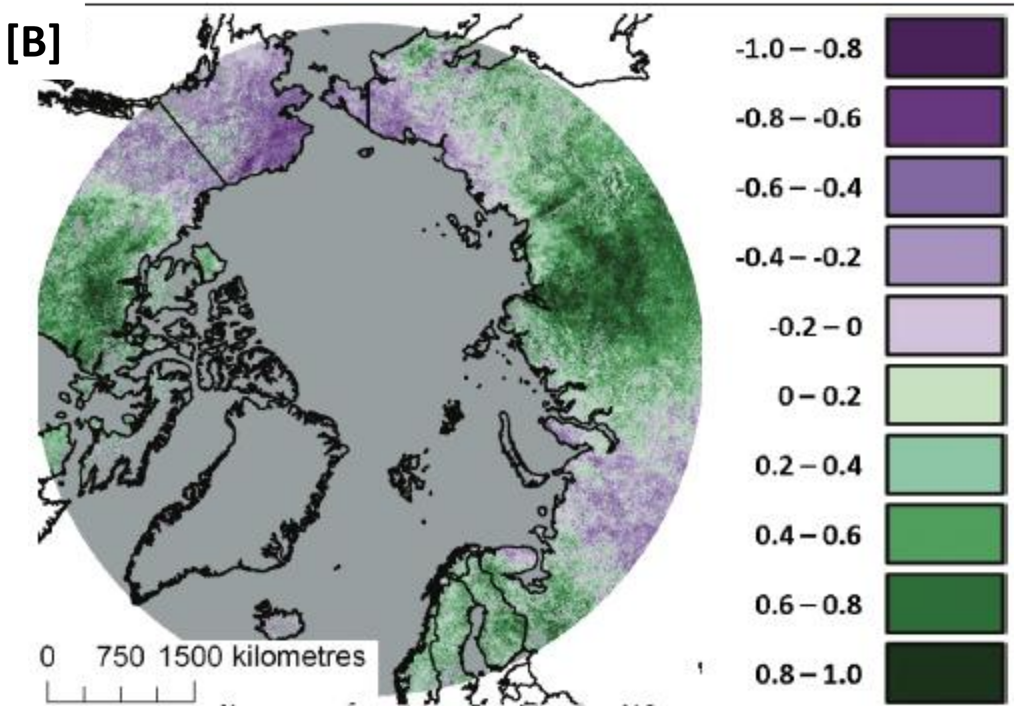
Using the CxQ LSP model with MODIS NDVI & NDII to derive the snow-free season length



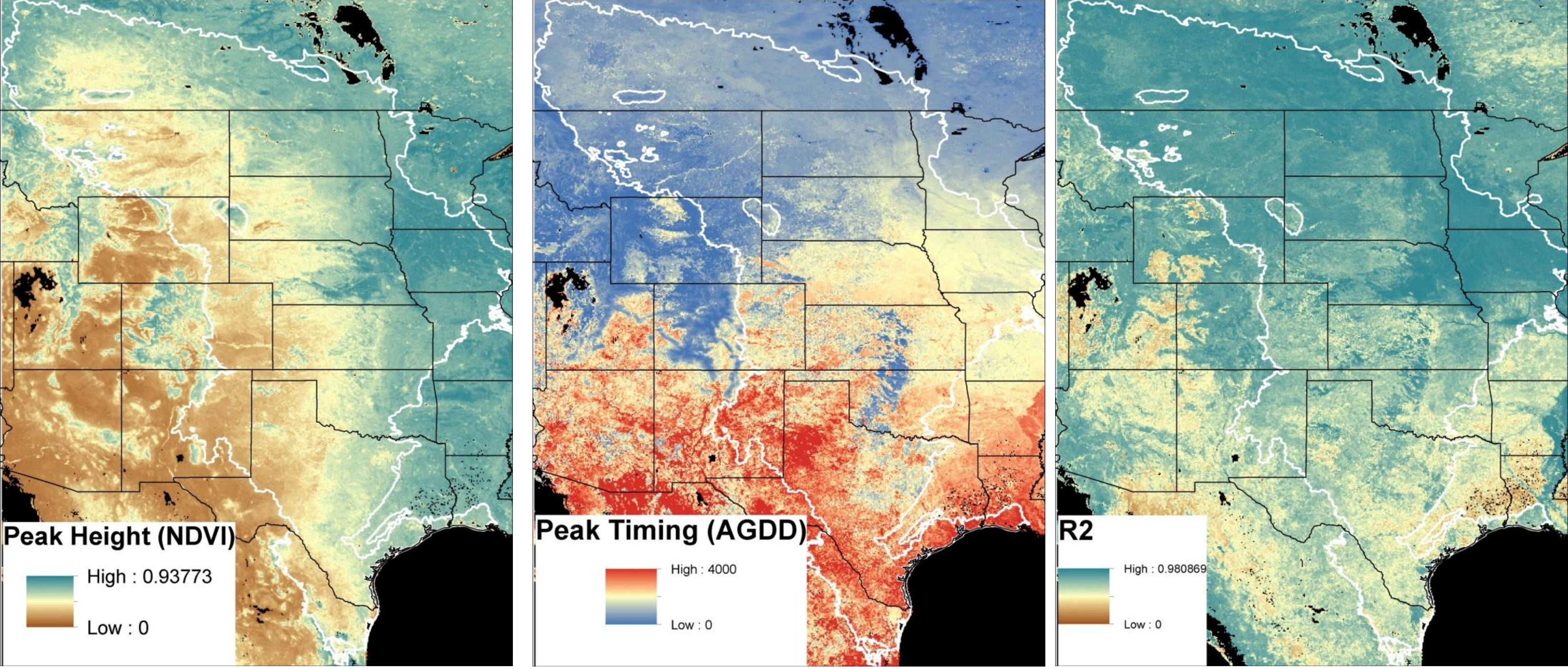
de Beurs, Wright, Henebry. 2009. Dual scale trend analysis distinguishes climatic from anthropogenic effects on the vegetated land surface. ***Environmental Research Letters*** 4:045012

Using CxQ LSP model to link JJA Arctic Oscillation to MODIS NBAR NDVI
[A] PH and [B] TTP





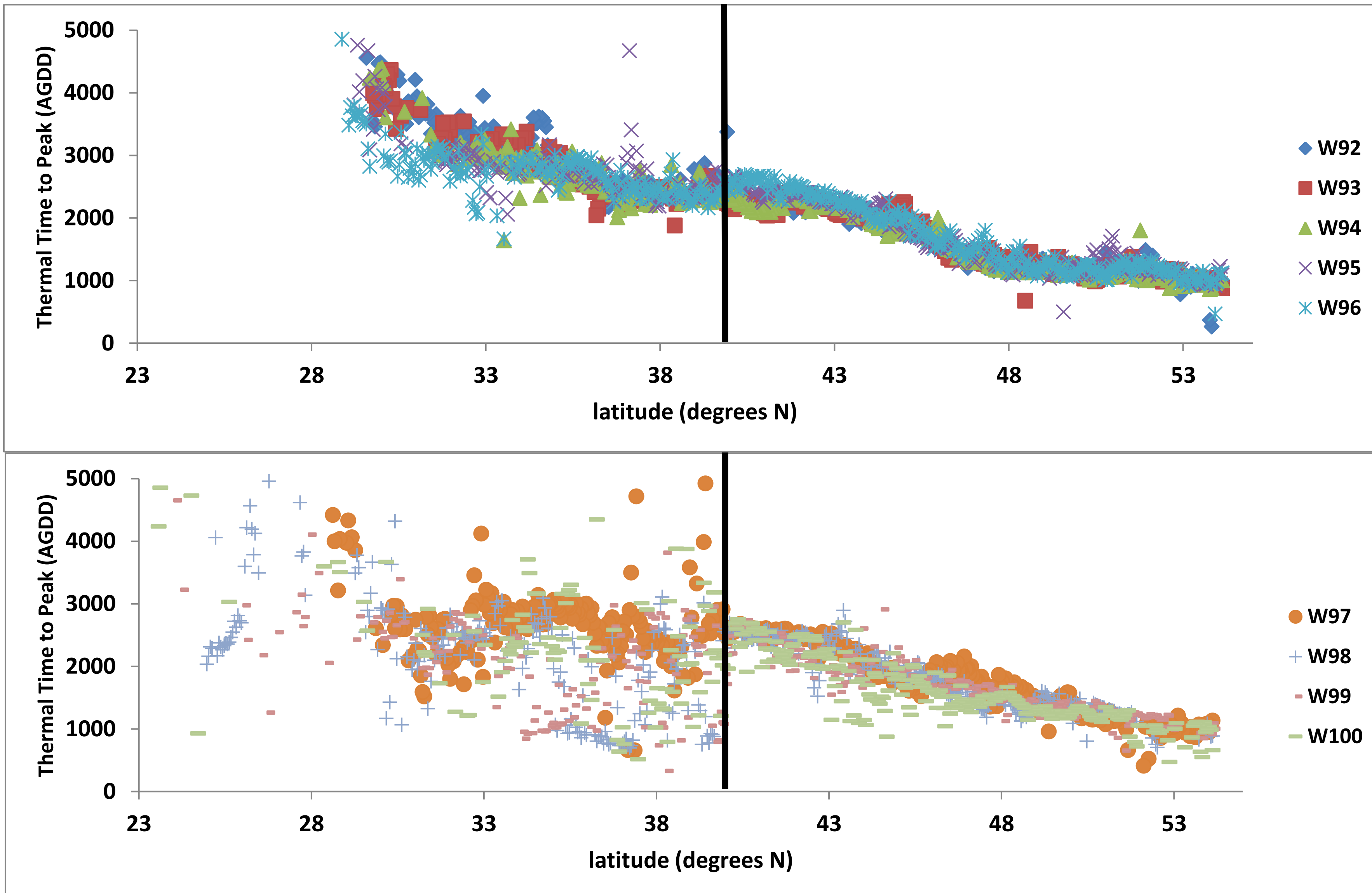
de Beurs & Henebry. 2010.
A land surface phenology assessment of the northern polar regions using MODIS reflectance time series.
Canadian Journal of Remote Sensing
36(Suppl. 1): S87–S110.
[*Special Issue on International Polar Year*]



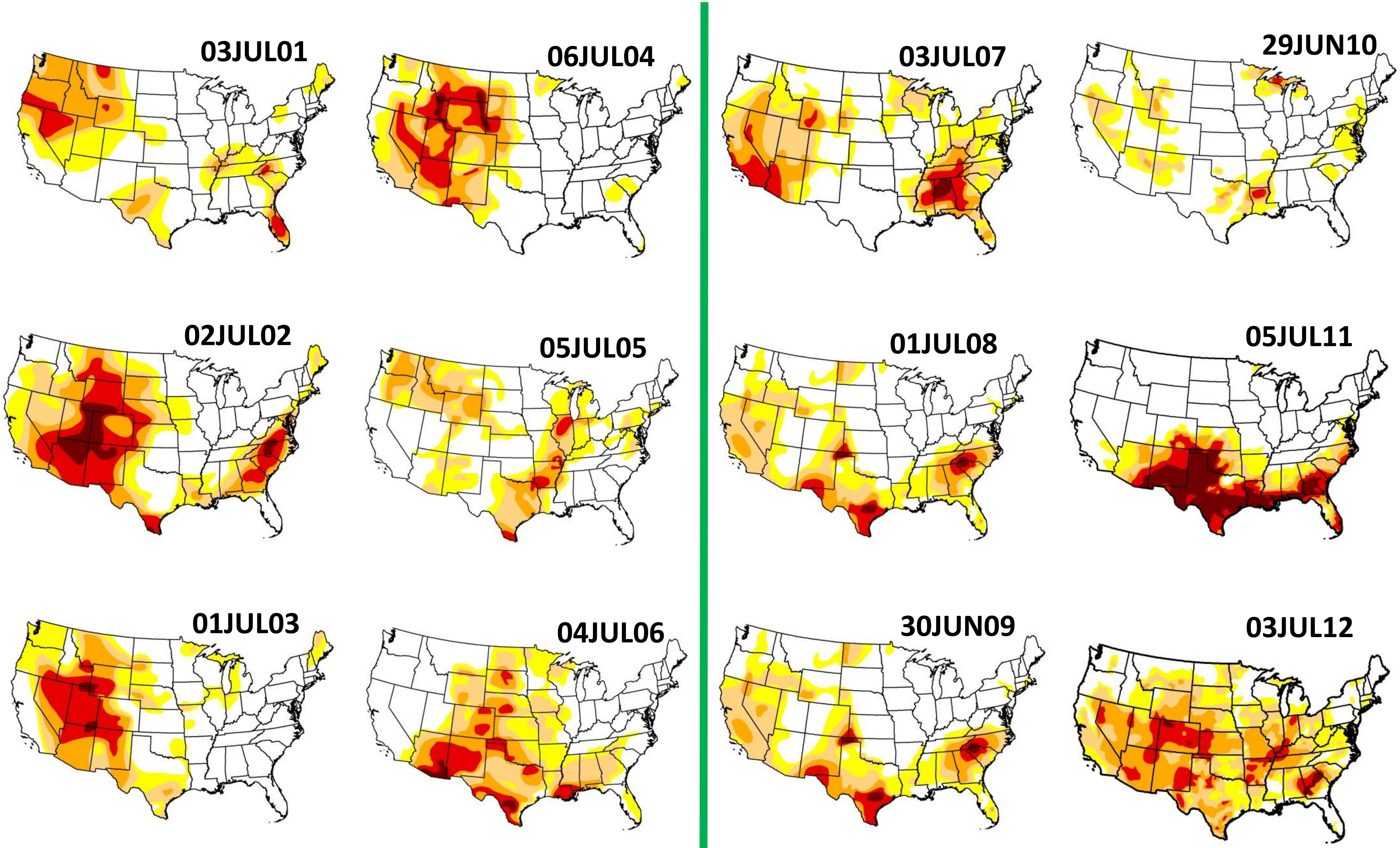
Convex Quadratic (CxQ) Model of Land Surface Phenology fitted to MODIS NBAR NDVI & MODIS LST data

Henebry & de Beurs. 2013. Remote sensing of land surface phenology: a prospectus. In: (Schwartz, ed) Phenology: An Integrative Environmental Science, 2e . Chapter 21.

Thermal Time to Peak shows a strong latitudinal gradient, especially north of ~N40 and east of ~W98



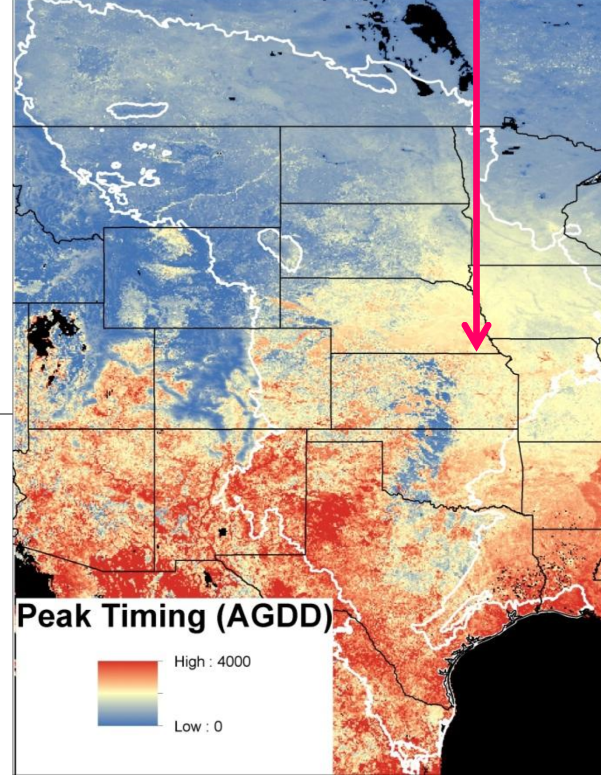
US Drought Monitor: late June/early July 2001-2011



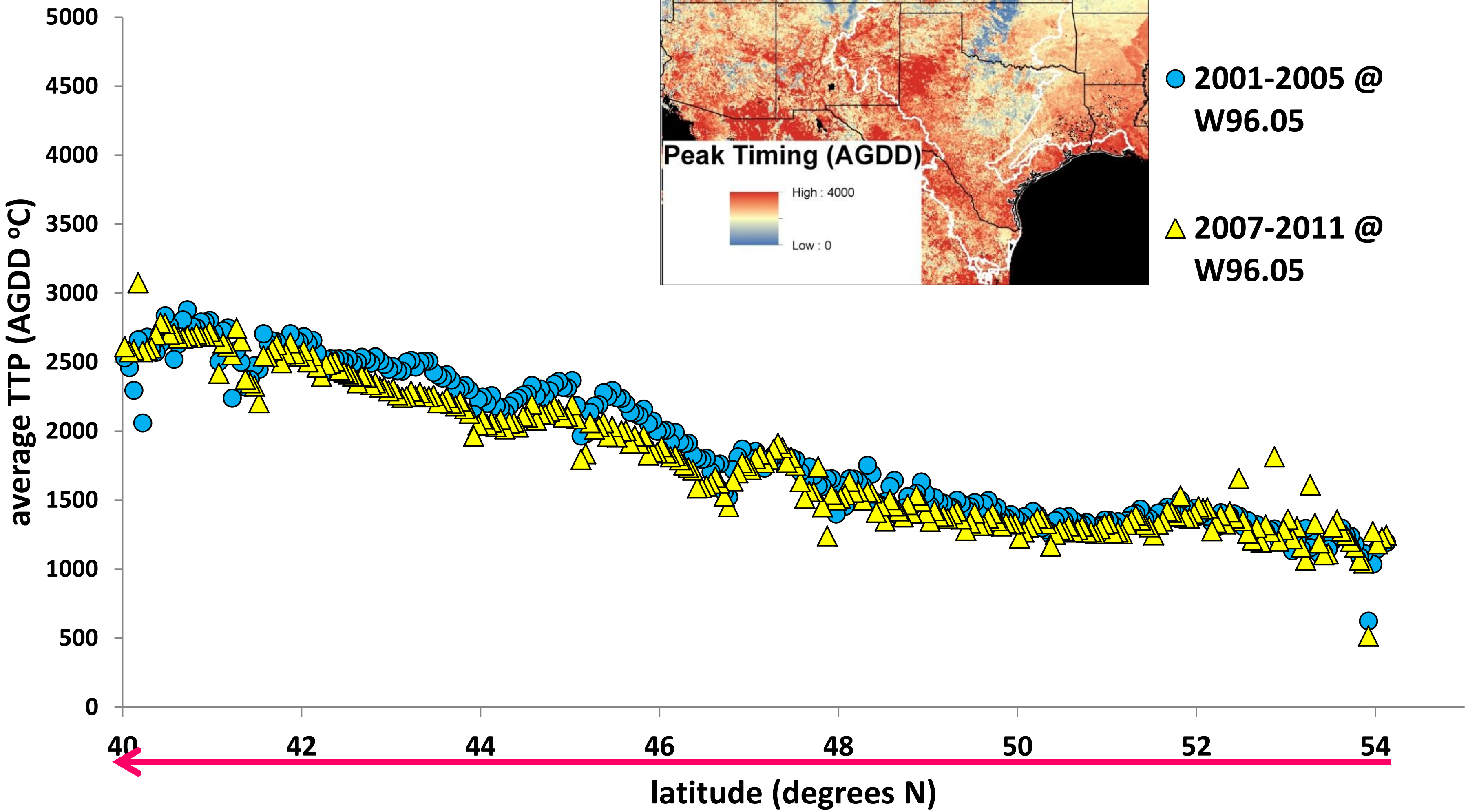
Source: http://droughtmonitor.unl.edu/archive.html

Average Thermal Time to Peak North of N40° at W96.05°:

- Larger in earlier period (2001-2005)
- Smaller in later period (2007-2011)

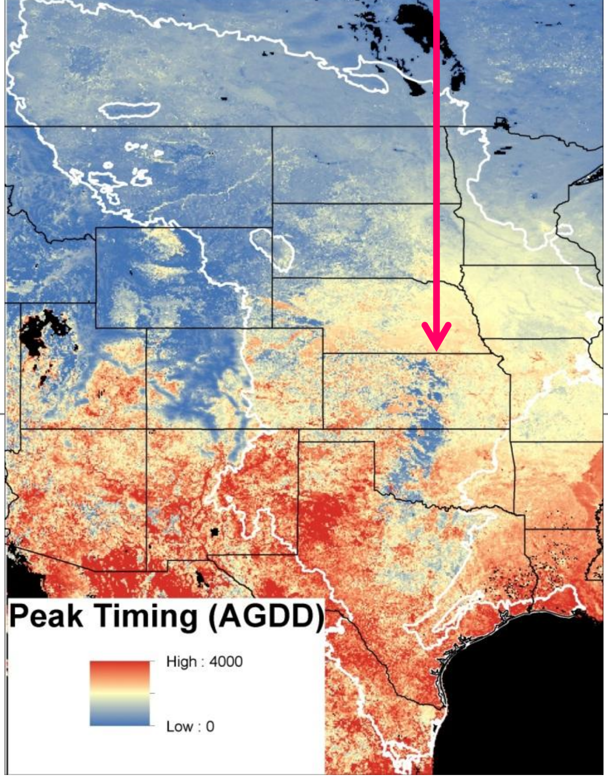


Corn canopy development occurs earlier than soy, due to planting practices and life cycle.

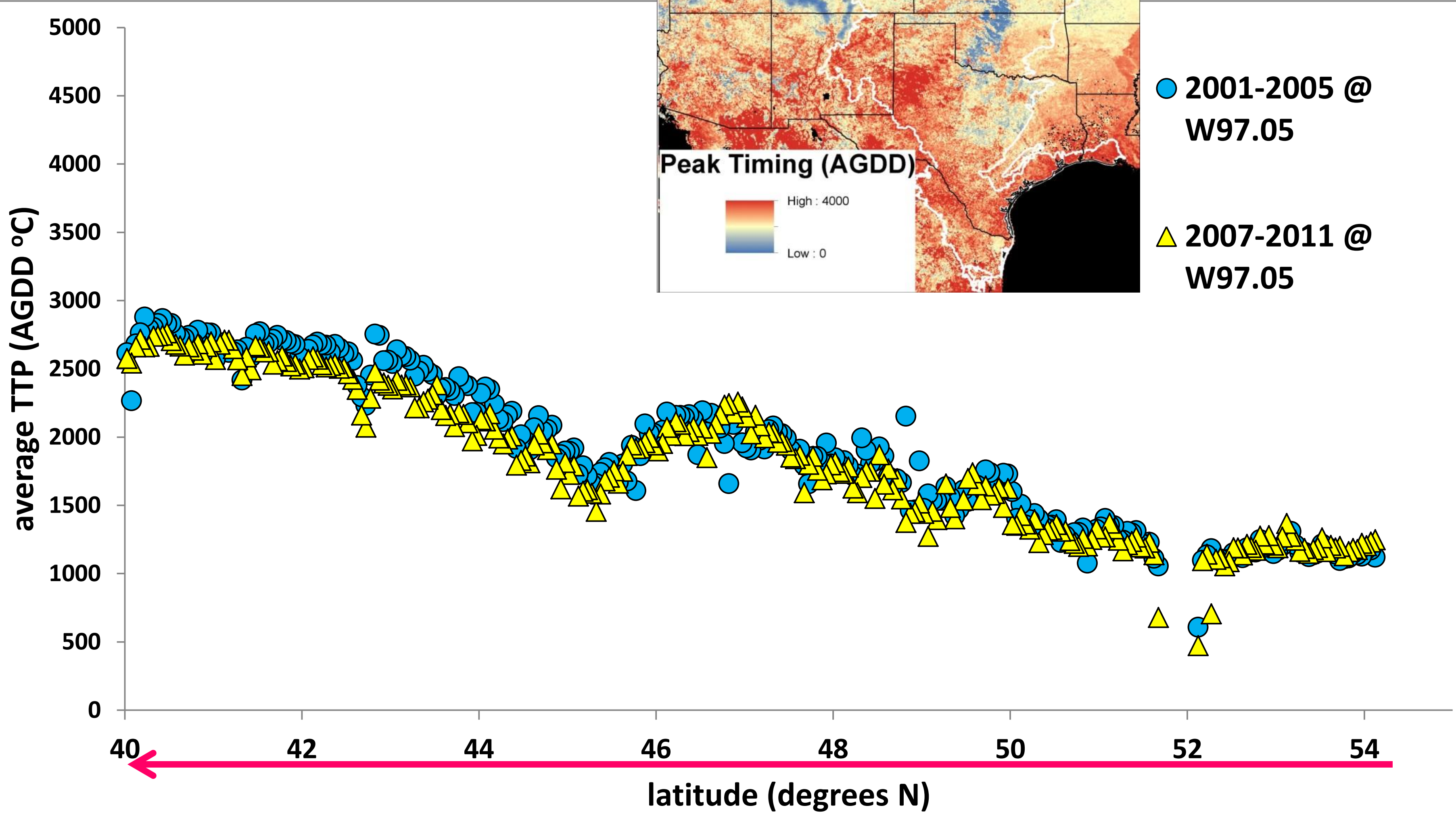


Average Thermal Time to Peak North of N40° at W97.05°:

- Larger in earlier period (2001-2005)
- Smaller in later period (2007-2011)



Corn canopy development occurs earlier than soy, due to planting practices and life cycle.



Trend Analysis for Hotspot Change Detection

Although simple linear regression using time as the independent variable is commonly used, but it has many statistical problems [1,2].

Instead, nonparametric trend analysis is more robust and can handle seasonality.

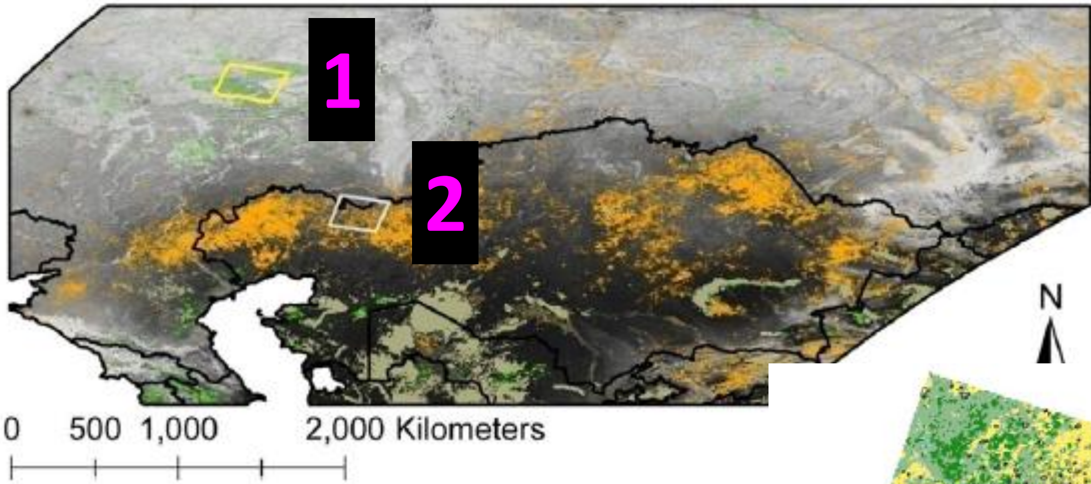
Better tool: the Seasonal Kendall trend test corrected for first-order temporal autocorrelation is a generalization of the Mann-Kendall trend test. [1,3]

CAVEAT: Trend tests are retrospective and do not predict the future!

[1] de Beurs KM, GM Henebry. 2004. Trend analysis of the Pathfinder AVHRR Land (PAL) NDVI data for the deserts of Central Asia. ***IEEE Geoscience and Remote Sensing Letters*** 1(4): 282-286.

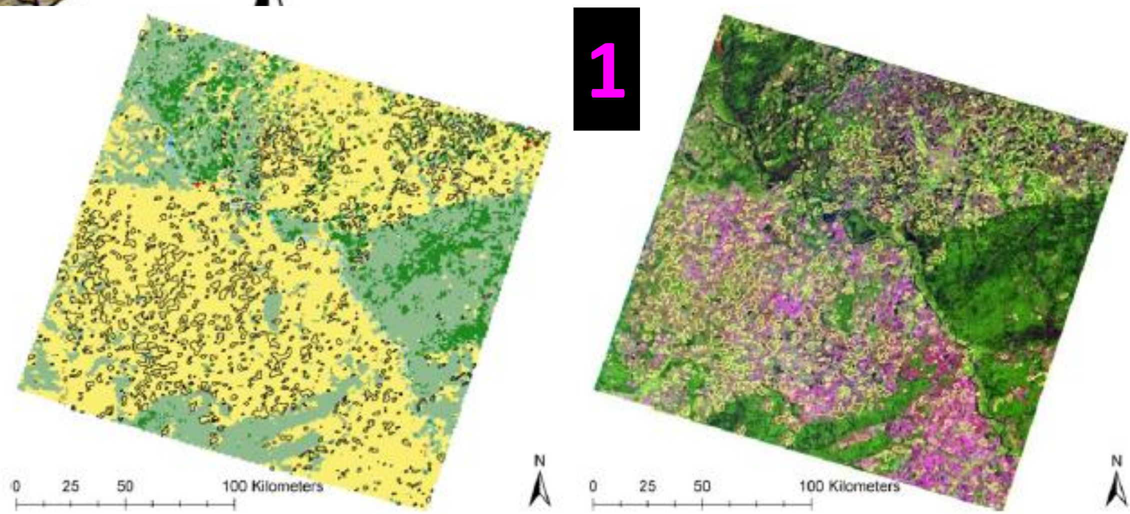
[2] de Beurs KM, GM Henebry. 2005b. A statistical framework for the analysis of long image time series. ***International Journal of Remote Sensing*** 26(8): 1551-1573.

[3] Hirsch RM, JR Slack. 1984. A nonparametric trend test for seasonal data with serial dependence. ***Water Resources Research*** 20:727-732.



Dual Scale Change Analysis using Trend Hotspots

← Hotspot detection with SK trend test on MODIS & two Landsat scenes

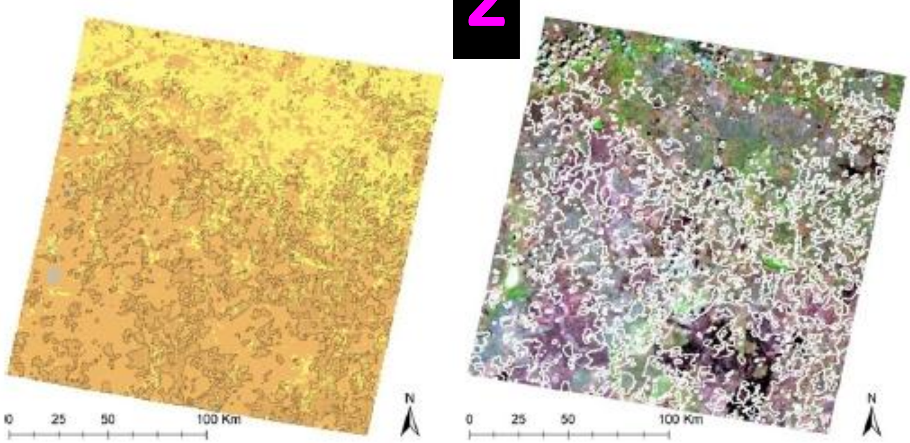


MODIS LC (left), Landsat 5,4,3 (right)

RU (right): positive trend in abandoned croplands

KZ (below): negative trends in grasslands

2



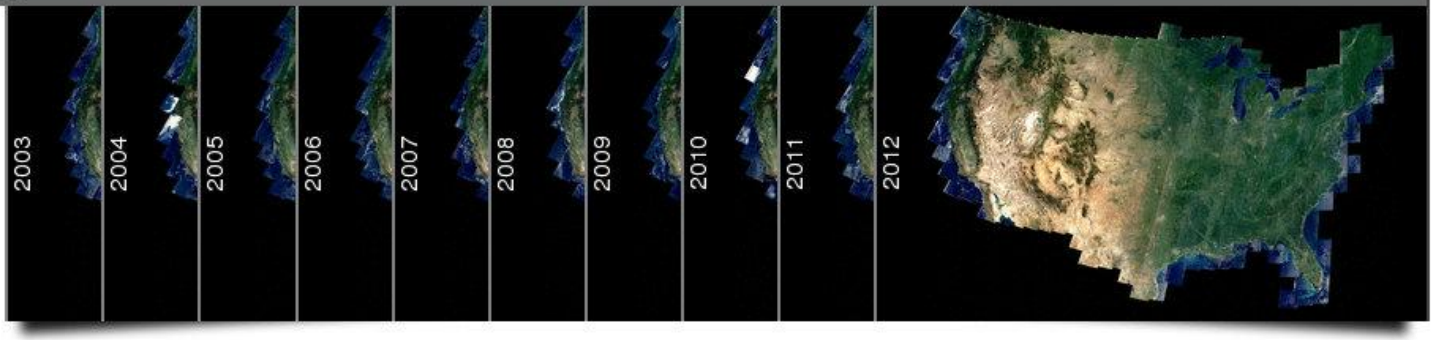
de Beurs, Wright, Henebry. 2009. Dual scale trend analysis distinguishes climatic from anthropogenic effects on the vegetated land surface. ***Environmental Research Letters*, 4:045012.**

Location of WELD time series in southeastern South Dakota

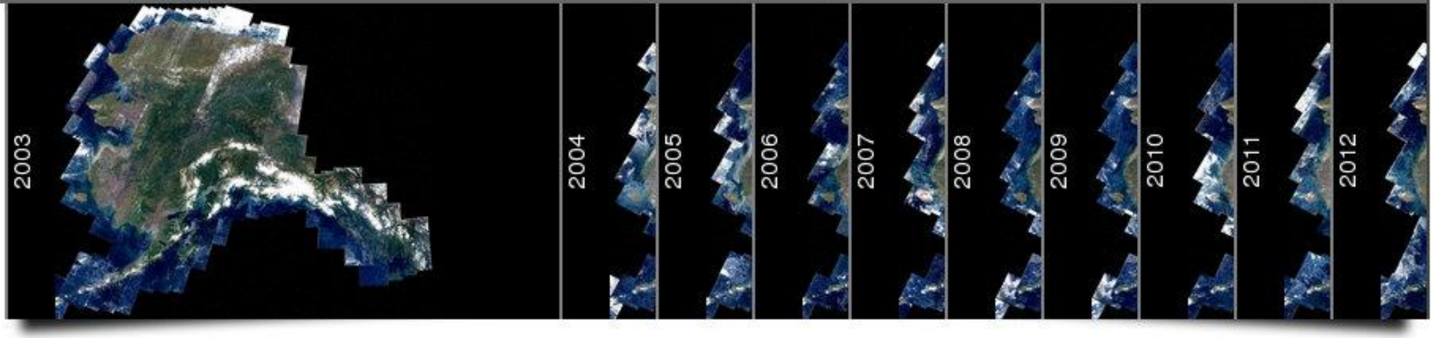
http://weld.cr.usgs.gov

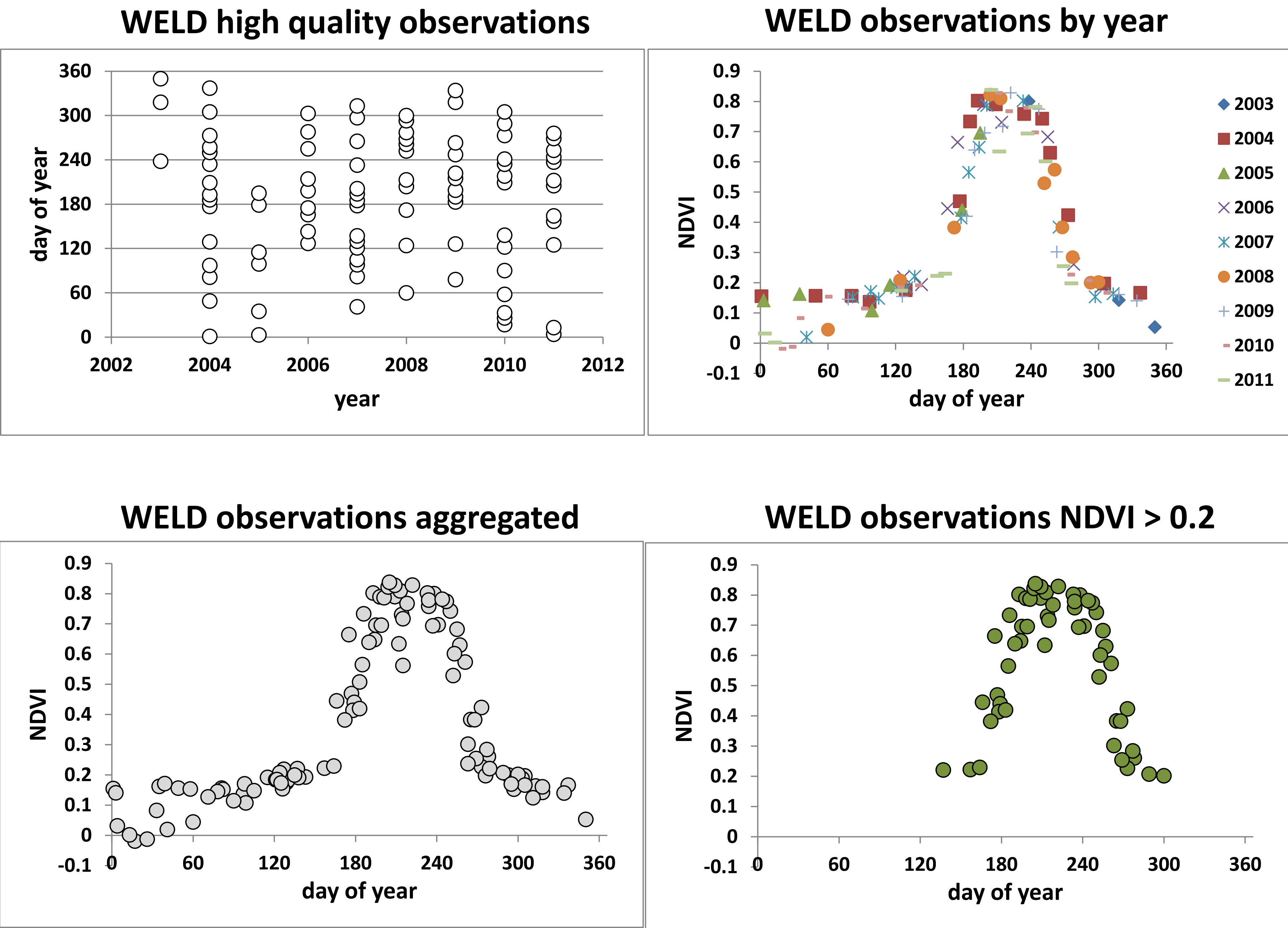
Available Years:

CONUS

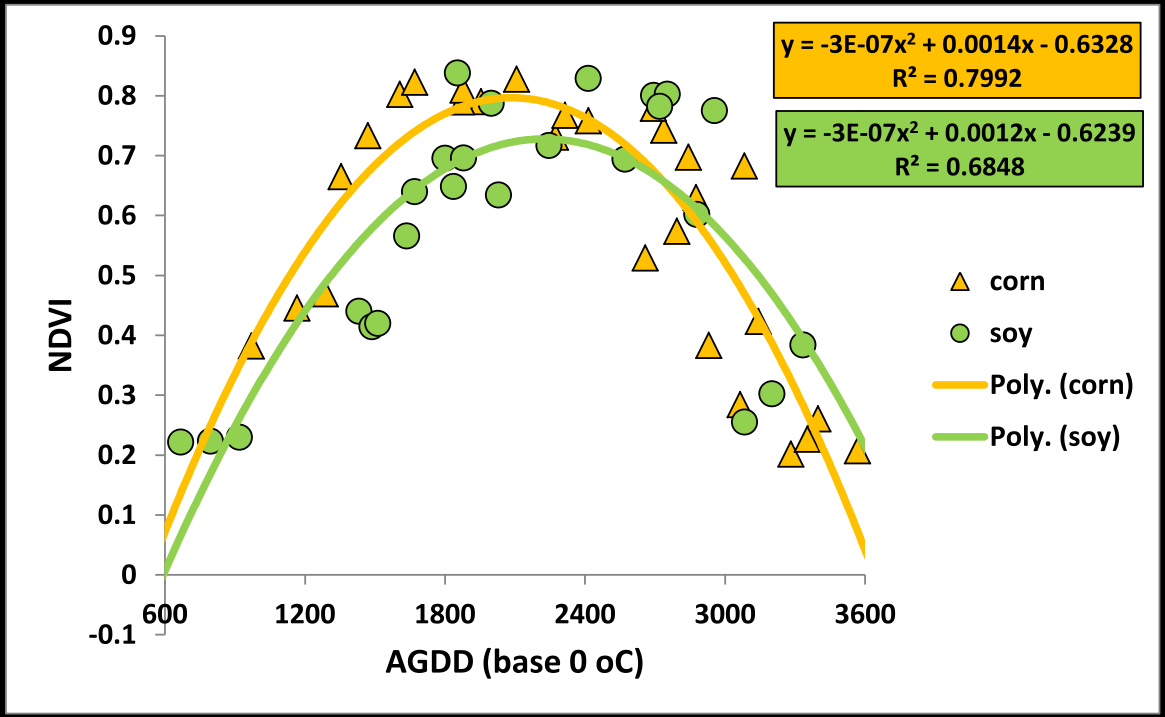


Alaska



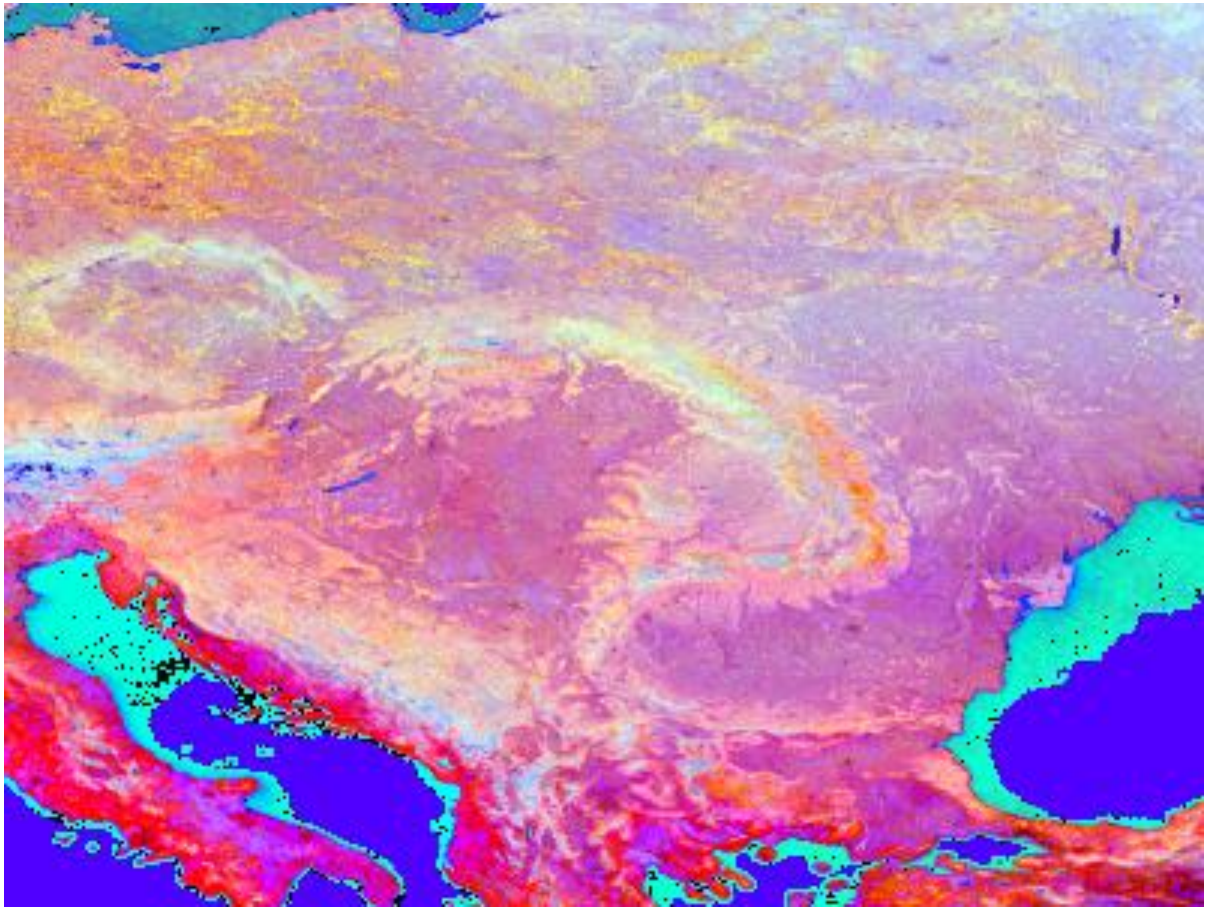


WELD high quality observations
day of year
year
360
300
240
180
120
60
0
2002
2004
2006
2008
2010
2012
WELD observations by year
NDVI
day of year
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
60
120
180
240
300
360
2003
2004
2005
2006
2007
2008
2009
2010
2011
WELD observations aggregated
NDVI
day of year
WELD observations NDVI > 0.2
NDVI
day of year

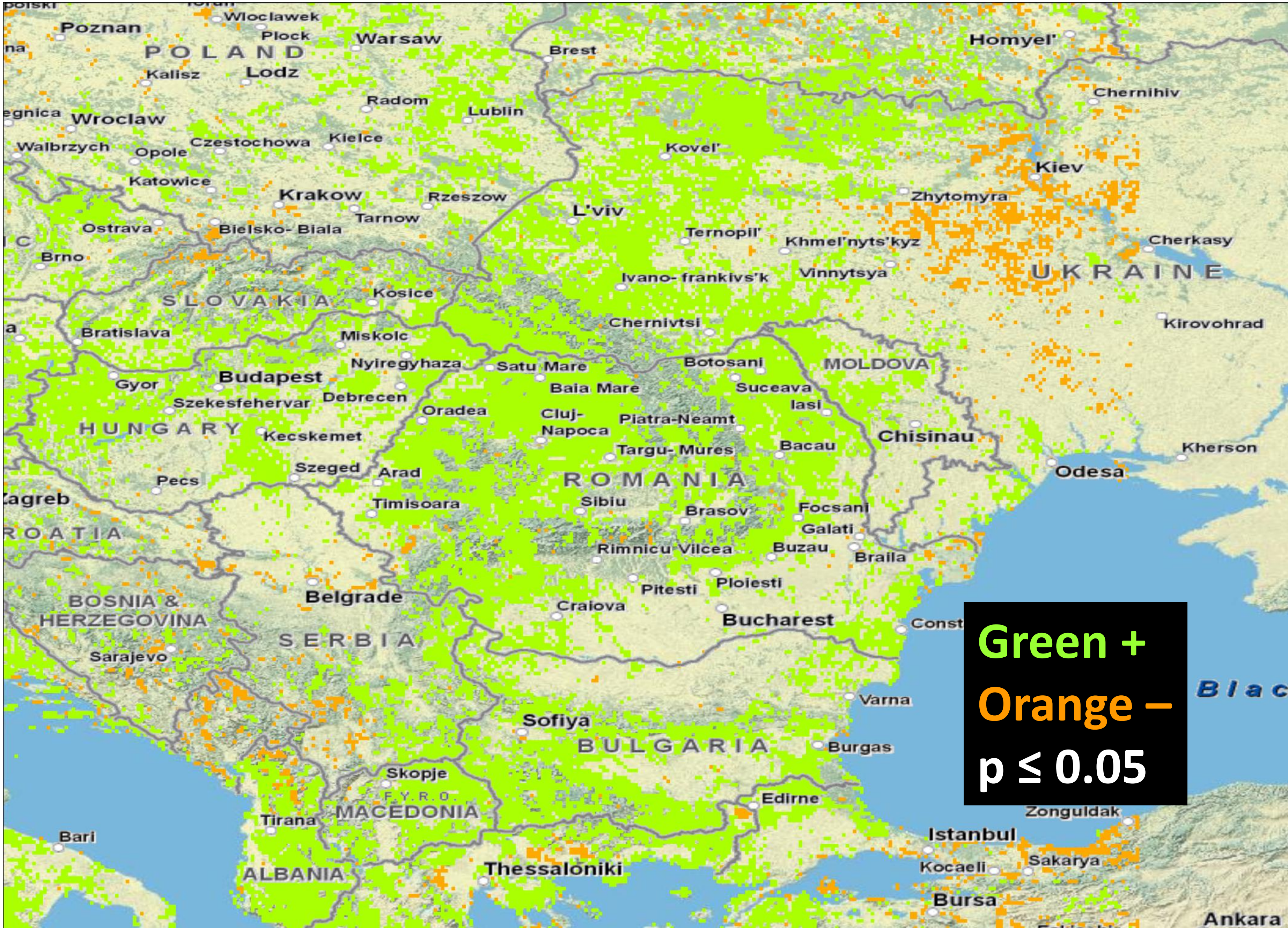


	PH	TTP	NDVI @ half-TTP
Corn	0.797	2084	0.439
Soy	0.728	2227	0.390

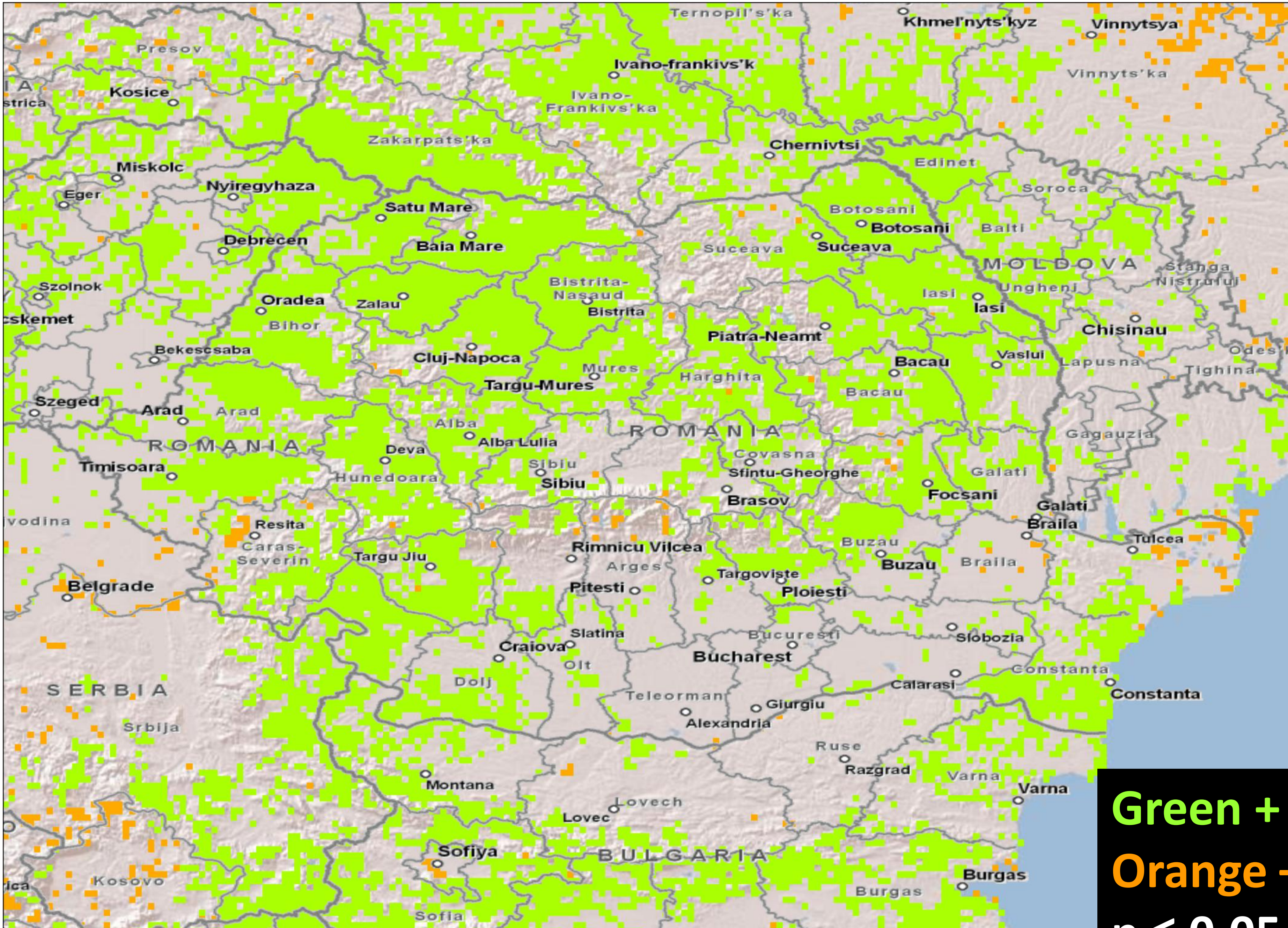
What about South Central and Eastern Europe?



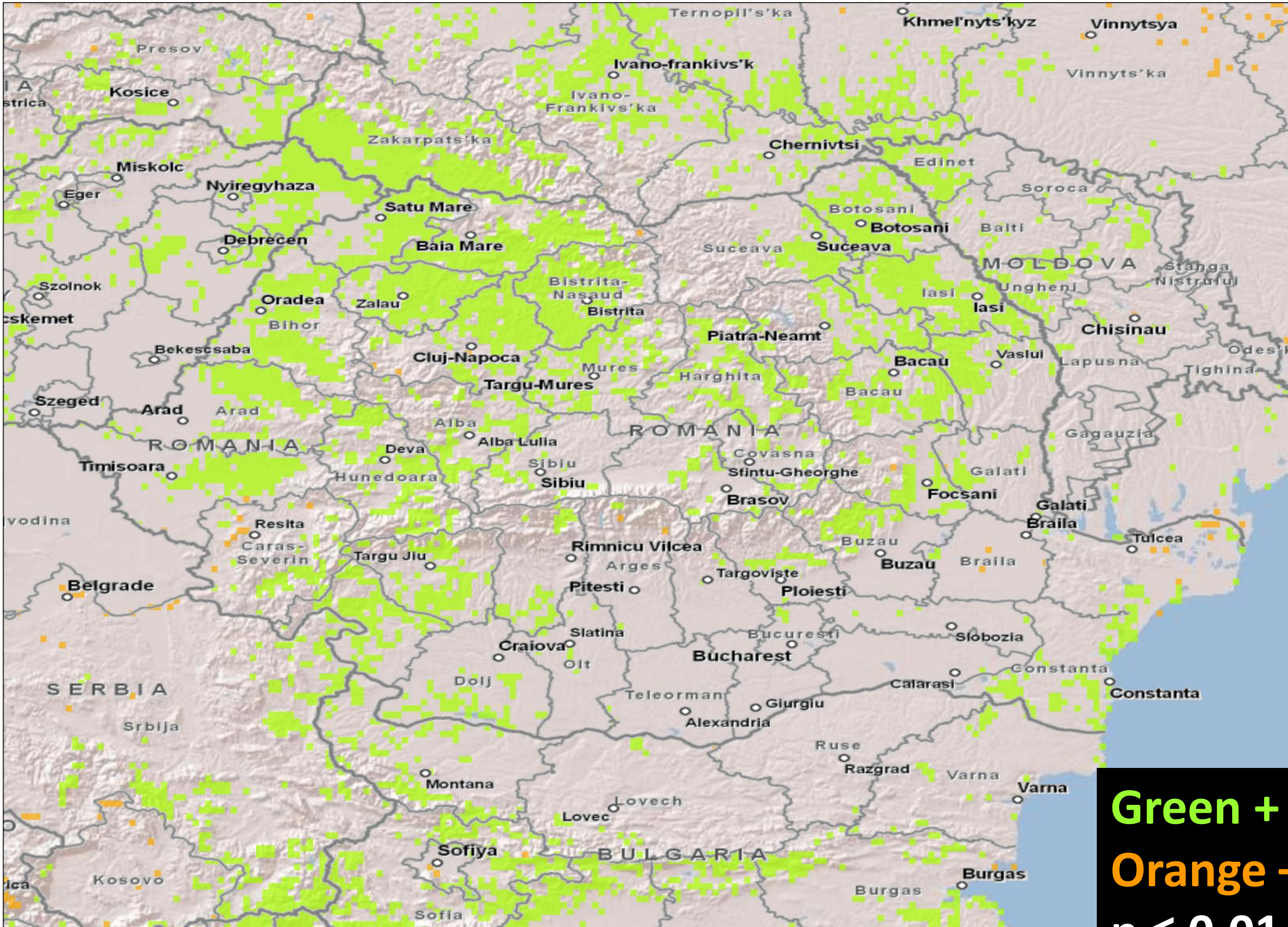
MODIS NBAR NDVI CMG 2001-2010 doy 81-265
R=mean; G=std dev; B=skew


Poznan
Wloclawek
Plock
Warsaw
POLAND
Kalisz
Lodz
Brest
Homyel'
Chernihiv
Radom
Lublin
Wroclaw
Walbrzych
Opole
Czestochowa
Kielce
Kovel'
Kiev
Katowice
Krakow
Rzeszow
Zhytomyra
L'viv
Ostrava
Bielsko- Biala
Tarnow
Ternopil'
Khmel'nyts'kyz
Cherkasy
Brno
Ivano- frankivs'k
Vinnytsya
UKRAINE
SLOVAKIA
Kosice
Chernivtsi
Kirovohrad
Bratislava
Miskolc
Nyiregyhaza
Satu Mare
Botosani
MOLDOVA
Gyor
Budapest
Baia Mare
Suceava
Szekesfehervar
Debrecen
Oradea
Cluj-Napoca
Iasi
Piatra-Neamt
HUNGARY
Kecskemet
Chisinau
Targu- Mures
Bacau
Kherson
Szeged
Arad
ROMANIA
Odesa
Pecs
Zagreb
Timisoara
Sibiu
Brasov
Focsani
Galati
ROATIA
Rimnicu Vilcea
Buzau
Braila
Pitesti
Ploiesti
Belgrade
BOSNIA & HERZEGOVINA
Craiova
Bucharest
Const
SERBIA
Sarajevo
Varna
Sofiya
BULGARIA
Burgas
Skopje
F.Y.R.O.
MACEDONIA
Edirne
Zonguldak
Tirana
Bari
Istanbul
ALBANIA
Thessaloniki
Sakarya
Kocaeli
Bursa
Ankara
Eskisehir
Green +
Orange –
p ≤ 0.05


Green +
Orange –
p ≤ 0.01
Poznan
POLAND
Wloclawek
Plock
Warsaw
Kalisz
Lodz
Radom
Lublin
Wroclaw
Walbrzych
Opole
Czestochowa
Kielce
Katowice
Krakow
Rzeszow
Tarnow
Ostrava
Bielsko- Biala
Brno
SLOVAKIA
Kosice
Bratislava
Miskolc
Nyiregyhaza
Budapest
Gyor
Szekesfehervar
Debrecen
HUNGARY
Kecskemet
Szeged
Pecs
Zagreb
Brest
Homyel'
Chernihiv
Kovel'
Kiev
L'viv
Zhytomyra
Ternopil'
Khmel'nyts'kyz
Cherkasy
UKRAINE
Ivano- frankivs'k
Vinnytsya
Chernivtsi
Kirovohrad
Satu Mare
Baia Mare
Botosani
MOLDOVA
Suceava
Iasi
Oradea
Cluj-
Napoca
Piatra-Neamt
Chisinau
Targu- Mures
Bacau
Kherson
Odesa
Arad
ROMANIA
Timisoara
Sibiu
Brasov
Focsani
Galati
Rimnicu Vilcea
Buzau
Braila
Pitesti
Ploiesti
Belgrade
Craiova
Bucharest
BOSNIA &
HERZEGOVINA
SERBIA
Sarajevo
Varna
Sofiya
BULGARIA
Burgas
Skopje
F.Y.R.O.
MACEDONIA
Edirne
Zonguldak
Tirana
Istanbul
Bari
Kocaeli
Sakarya
ALBANIA
Thessaloniki
Bursa
Ankara
Eskisehir



Green +
Orange –
$p \leq 0.05$



Green +

Orange –

p ≤ 0.01

These changes appear at coarse resolution of 0.05°, but how and where do they appear at finer resolutions of 500 & 30 m?

To which phenomena can these changes be linked?

What are consequences/implications of these changes?

Thanks to…

Funding from the NASA LCLUC & IDS programs

Dr. Garik Gutman (NASA HQ)

Dr. Pasha Groisman (NOAA/NEESPI)

Prof. Anatoly Gitelson (Univ of Nebraska-Lincoln)

Prof. Kirsten de Beurs (Univ of Oklahoma)

Dr. Valeriy Kovalskyy (SDSU)

Dr. Chris Wright (SDSU)

geoffrey.henebry@sdstate.edu
http://globalmonitoring.sdstate.edu