Assessing Remote Sensing Techniques for Measuring Vegetation Phenology

GEOMAP
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The Problem

- The advance of spring has been documented on all but one continent, in every major ocean, and in all well-studied marine, freshwater and terrestrial groups (Parmsen, 2006).

- The recorded advance of spring ranges from 2.3 to 5.1 days per decade (Permesan and Yohe, 2003; Root *et al*, 2003).

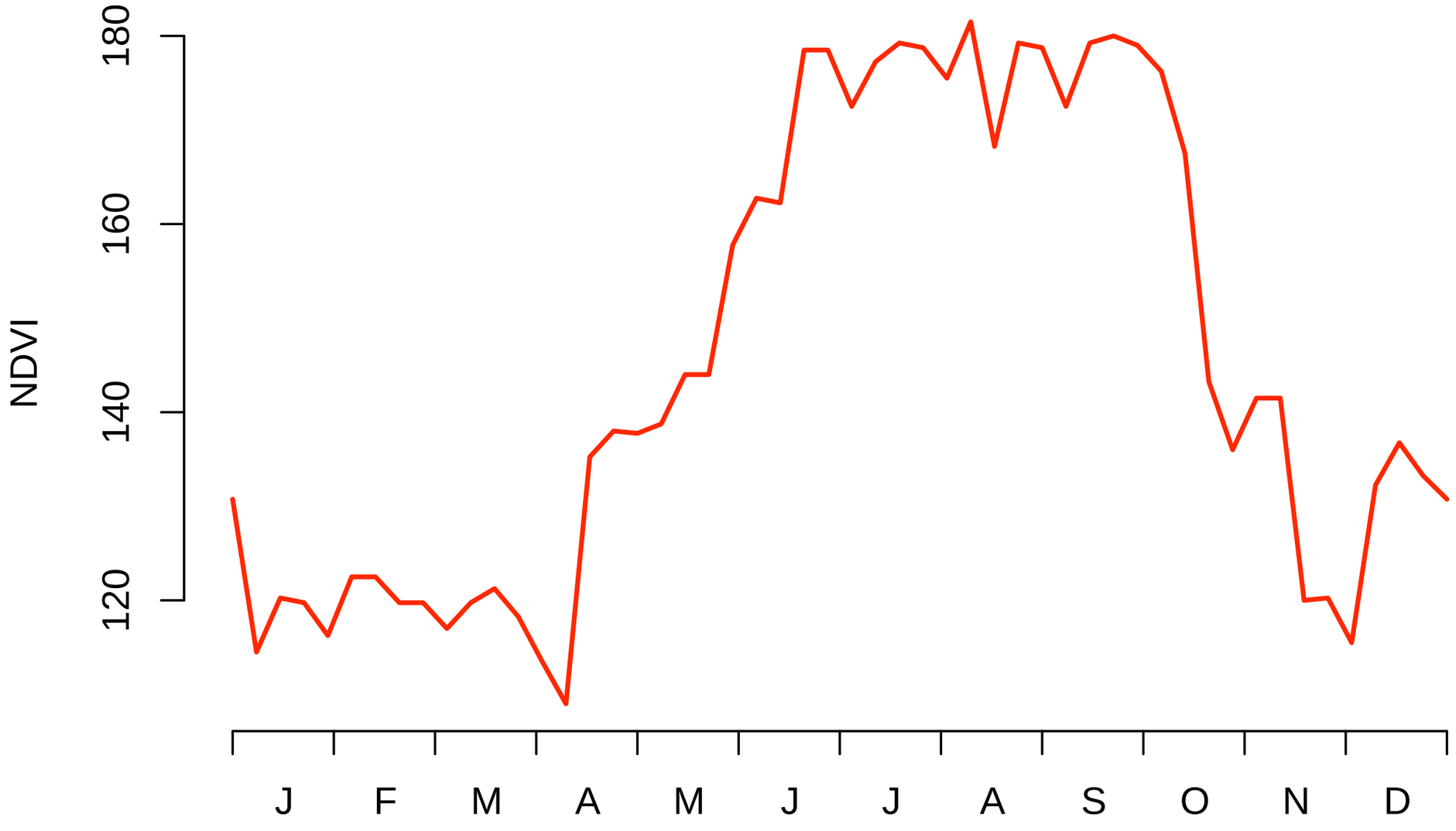
- Researchers who have used satellite imagery and urban heat islands to study the effects of increased temperature on vegetation phenology have determined that urban trees green-up 5-9 days earlier than their rural counterparts (Fisher *et al*, 2006; White *et al,* 2002; Zhang *et al,* 2004).

The Problem

- In a best case scenario, we are using a daily measure to detect a change that occurs at a rate of < 0.5 days per decade.

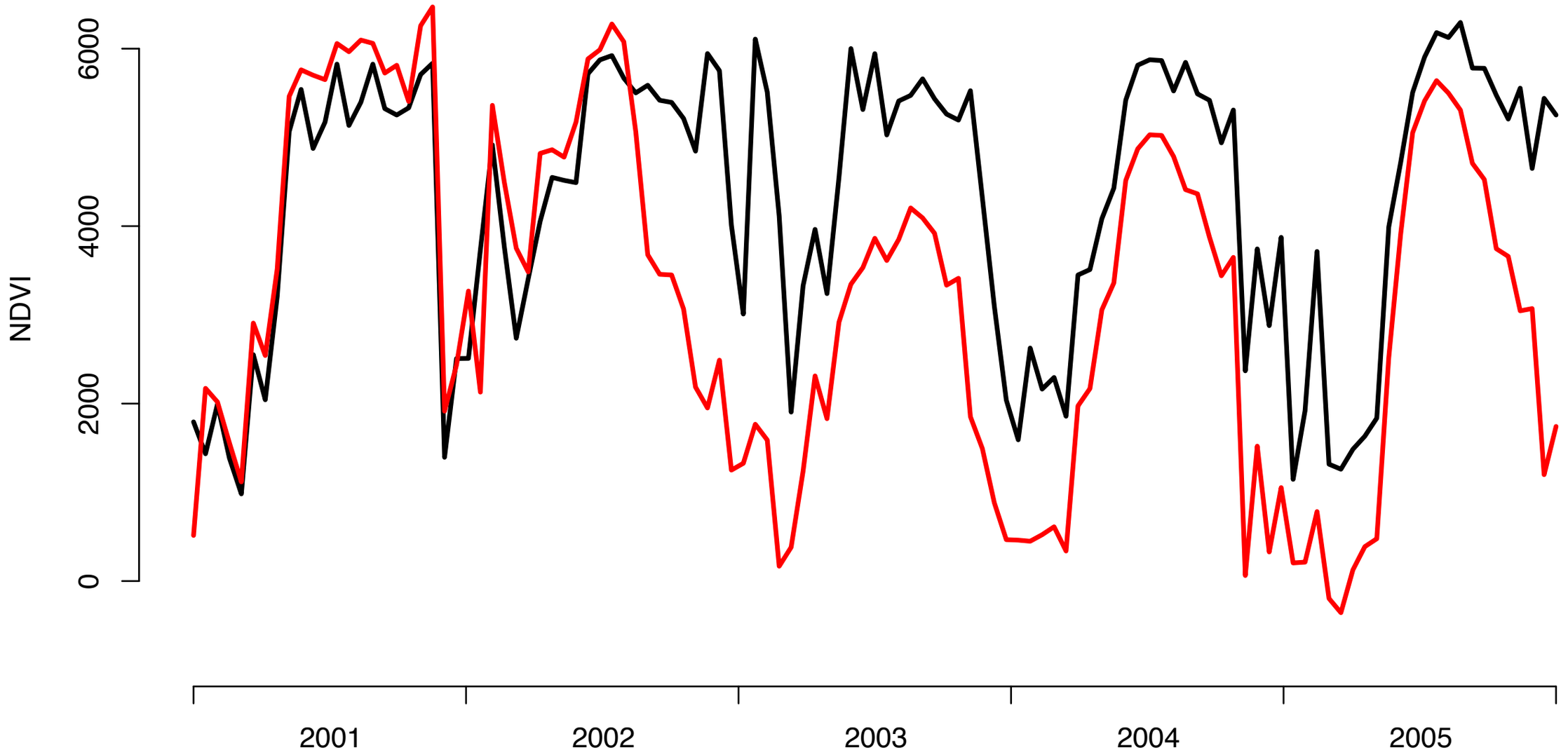
- Few studies have compared model results with actual biophysical variables collected on the calculated date of greenness onset. This presentation will report the physical condition of Central Illinois corn on the date of onset calculated using the Zhang Method.

Example Time-Series



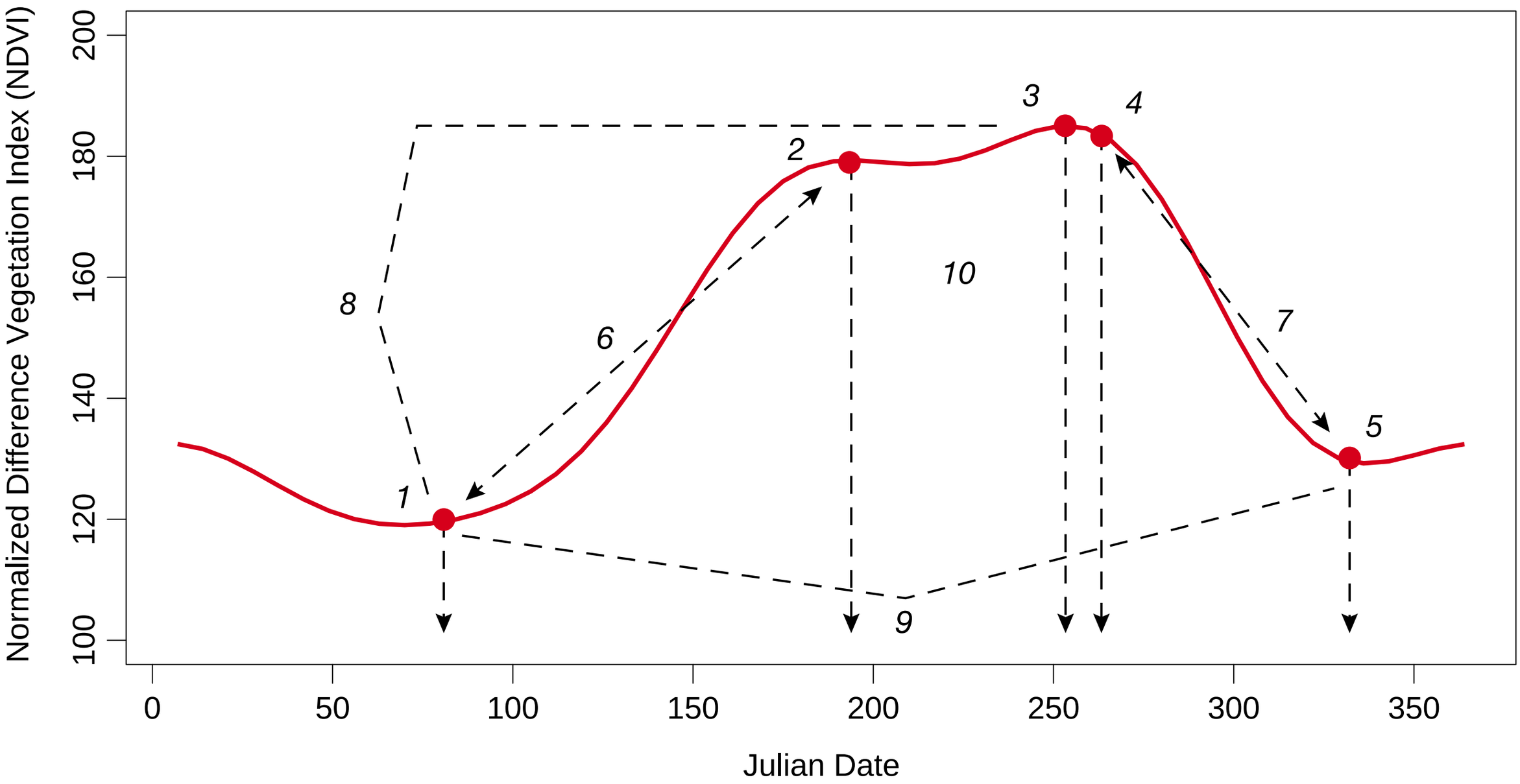
Time-series of AVHRR NDVI collected over Stockton Island, Wisconsin (Deciduous Forest).

Example Time-Series



Time-series of MODIS NDVI collected within and near a burn scar in southeastern Utah.

Vegetation Phenology Metrics



Reed *et al,* 1994. Since spring is advancing, we are interested in the onset of greenness, point 1.

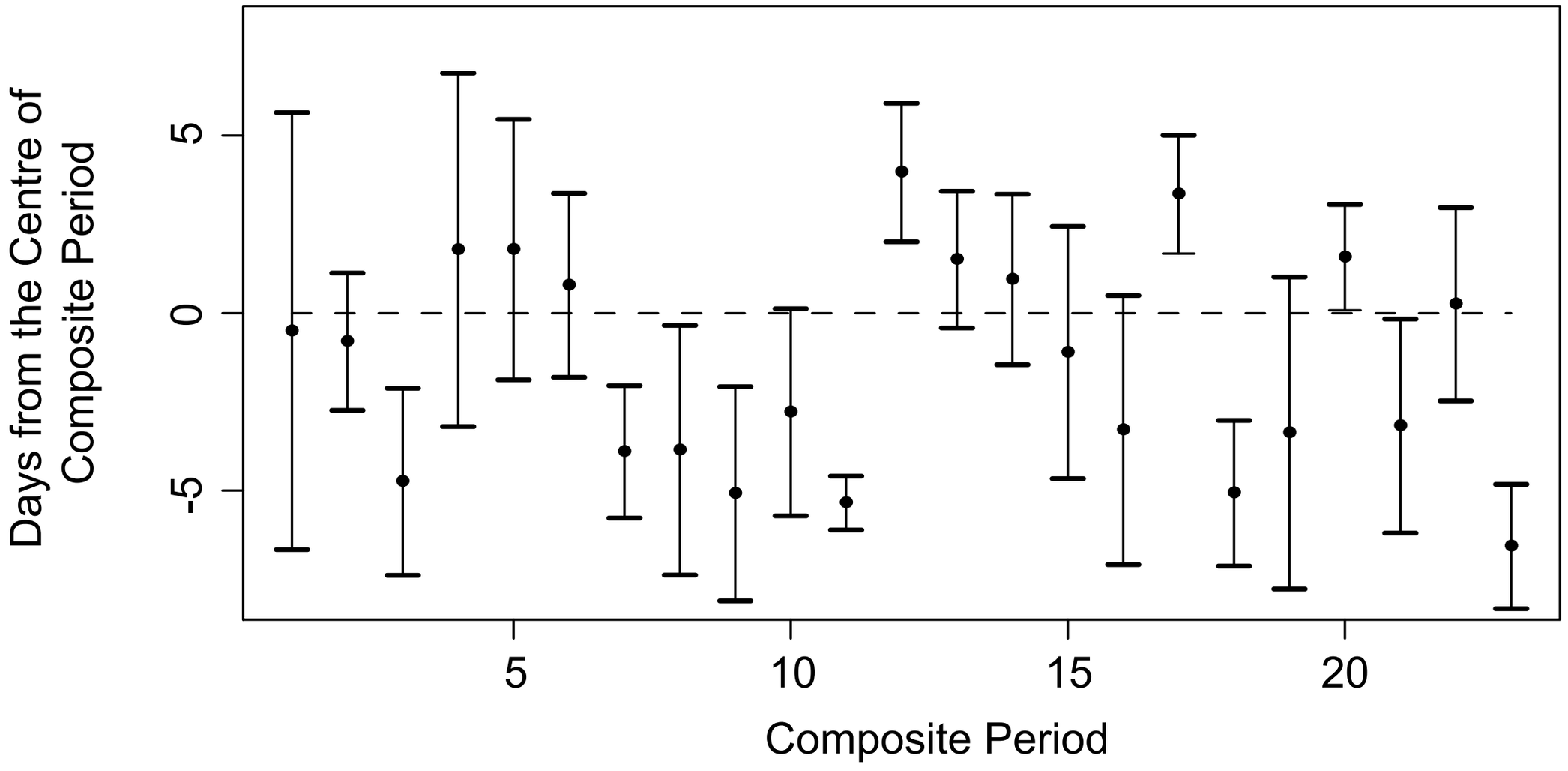
The Zhang Method

- Does not rely on potentially incorrectly selected thresholds.

- Can interpolate between satellite image collection dates so that the results are not limited to only those dates on which satellites passed overhead.

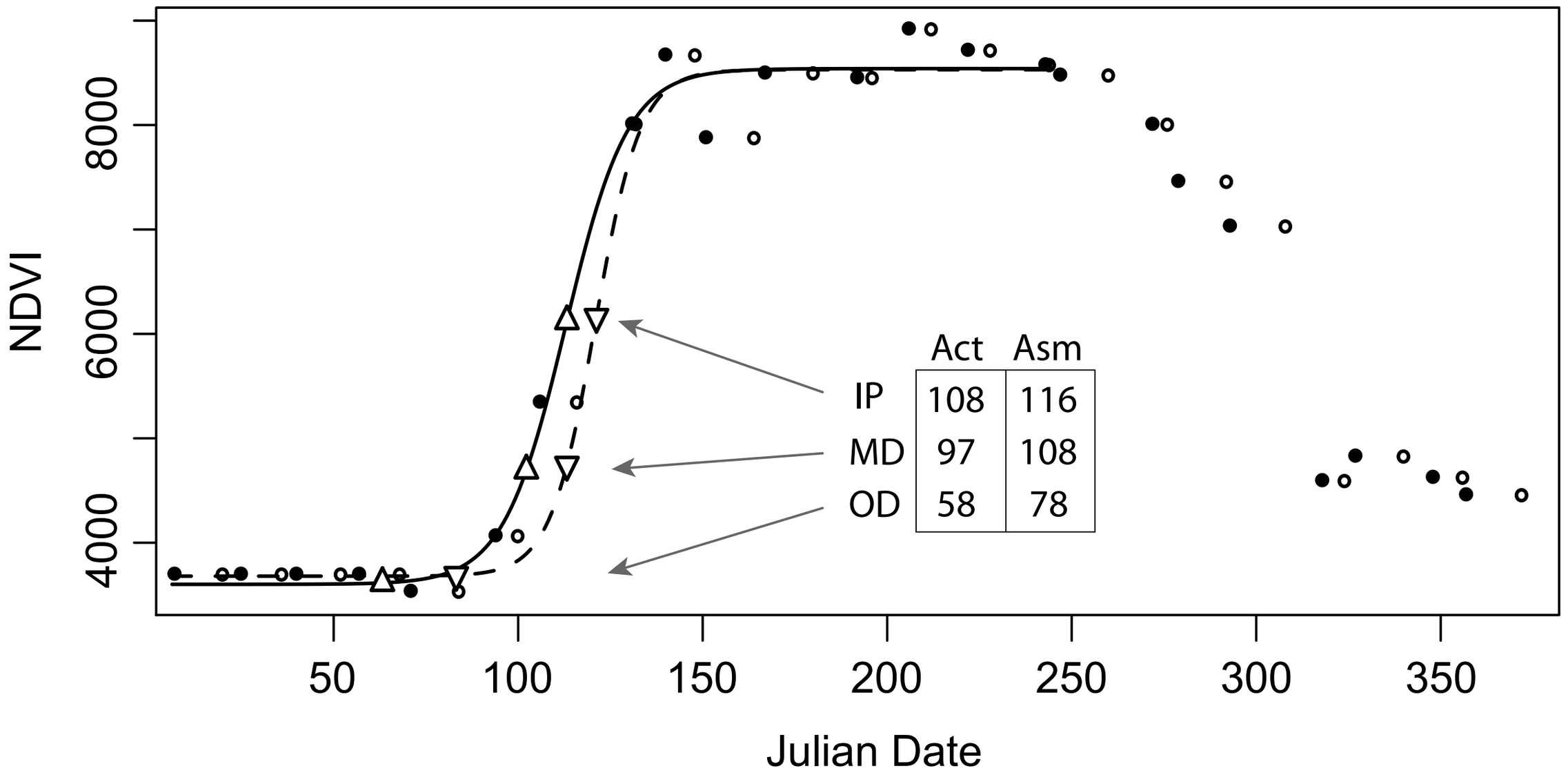
- Does not require equally spaced date points in the time series. This is especially important since research has shown that there is no reliable pattern behind date selection in the maximum value compositing process (Thayn and Price, 2008).

Date Selection Pattern



Thayn and Price, 2008. There is no reliable pattern of date selection.

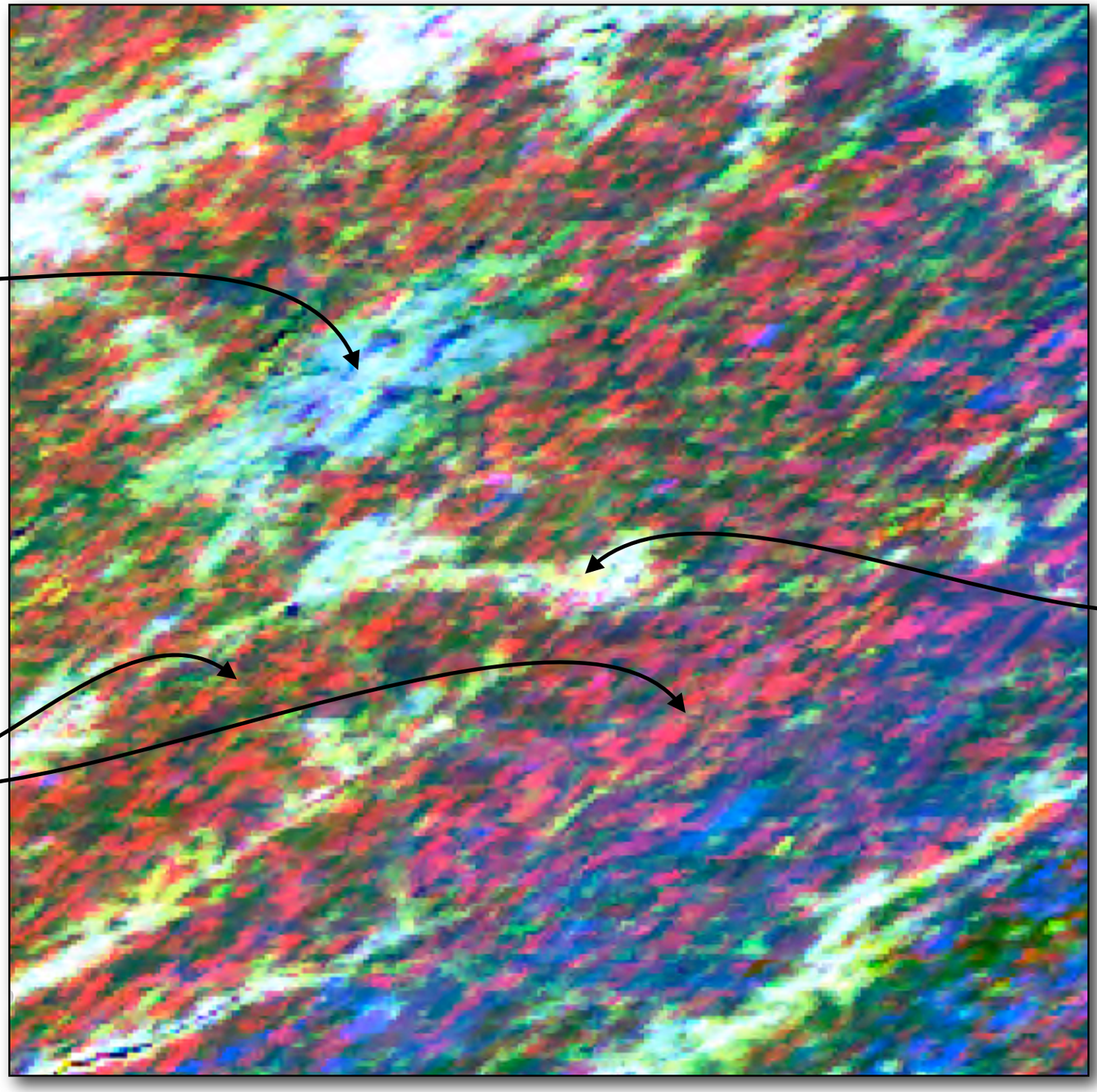
Introduced Temporal Error



Thayn and Price, 2008. Introduced errors ranged from 11.6 to 16.1 days.

The Study Site: NDVI

Bloomington
and Normal, IL

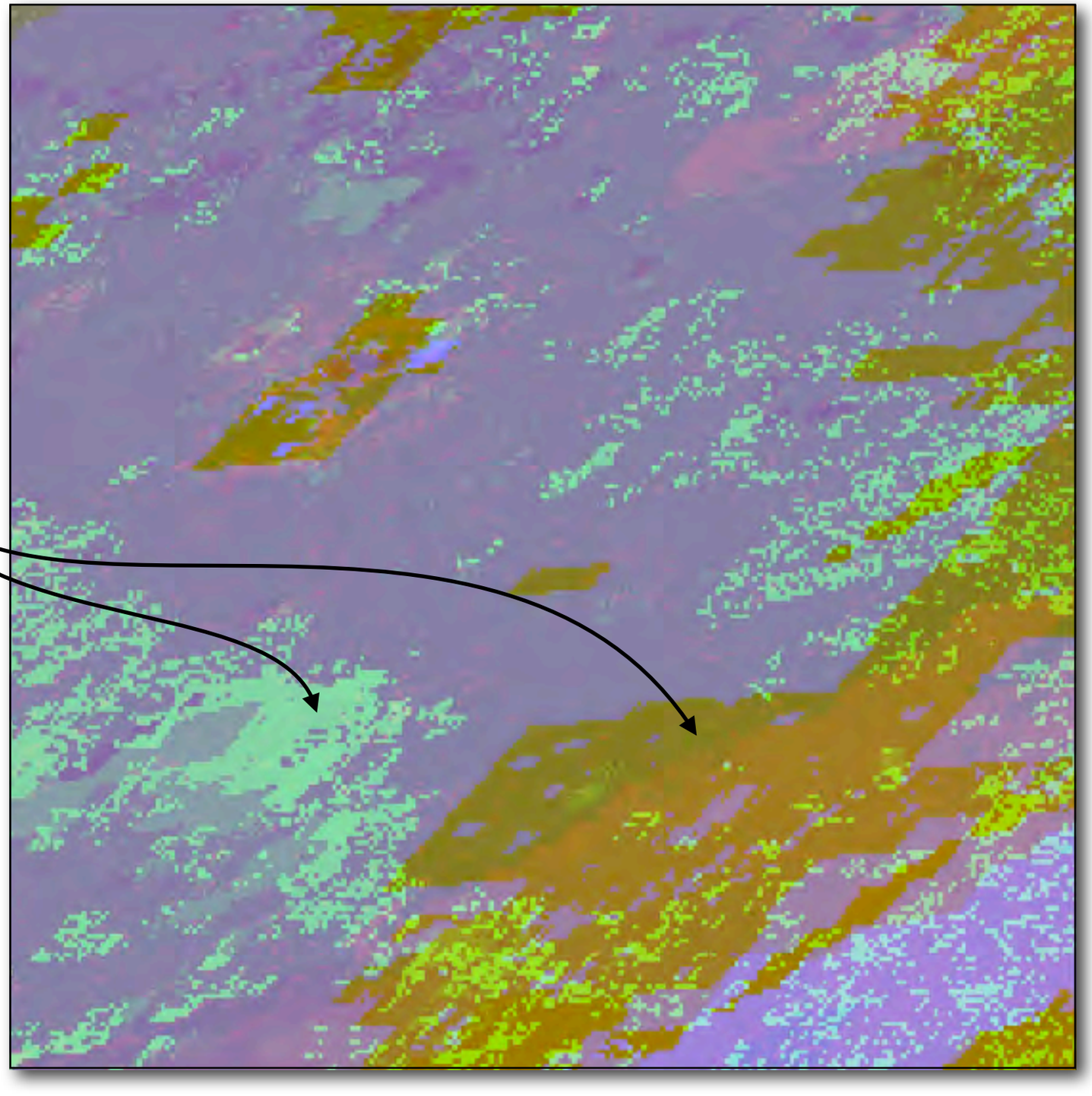


Deciduous
Forest

Corn and Soy
Fields

Bands 1, 8, 16

The Study Site: NDVI



Cloud patches

Bands 1, 8, 16

Explanation of the Zhang Method

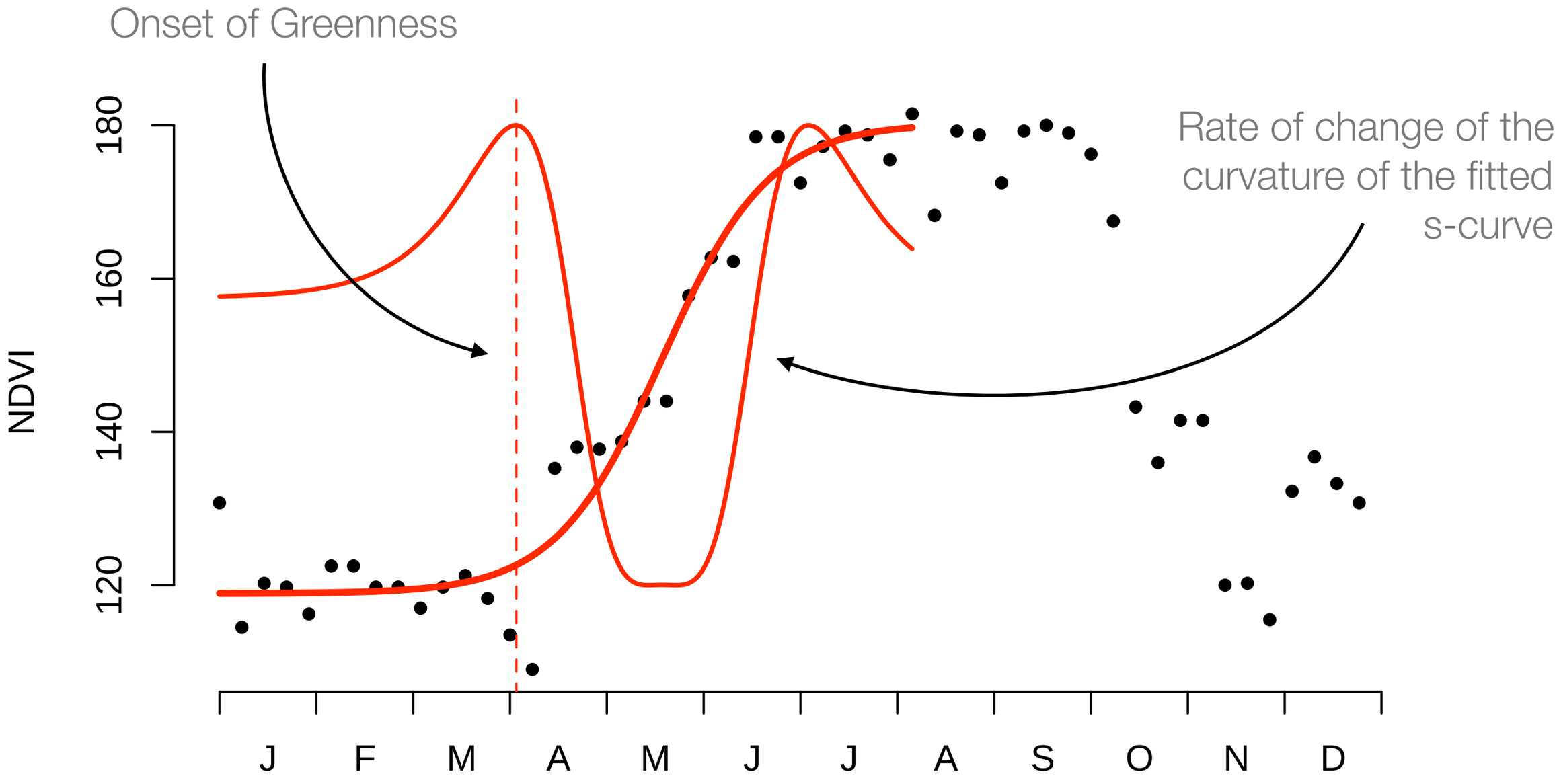
- A piecewise logistic s-curve is fitted to the time-series data. The data need not be smoothed, although tapering the first few points (by replacing them with their own median) seems to make the curve more realistic since it eliminates vegetation values occluded by snow.

- The s-curve is based upon four parameters (a, b, c, and d). Zhang originally optimized only a and b. Wardlow *et al* (2006) included c and d in the optimization, making the curve fit even stronger.

- The rate of change of the curvature of the s-curve is found.

- The Julian date when the curve first begins to climb, i.e., when the rate of change of the curvature peaks, is identified.

Example of the Zhang Method



Julian Date = 94, April 4

Zhang Method Equations

Logistic S-Curve

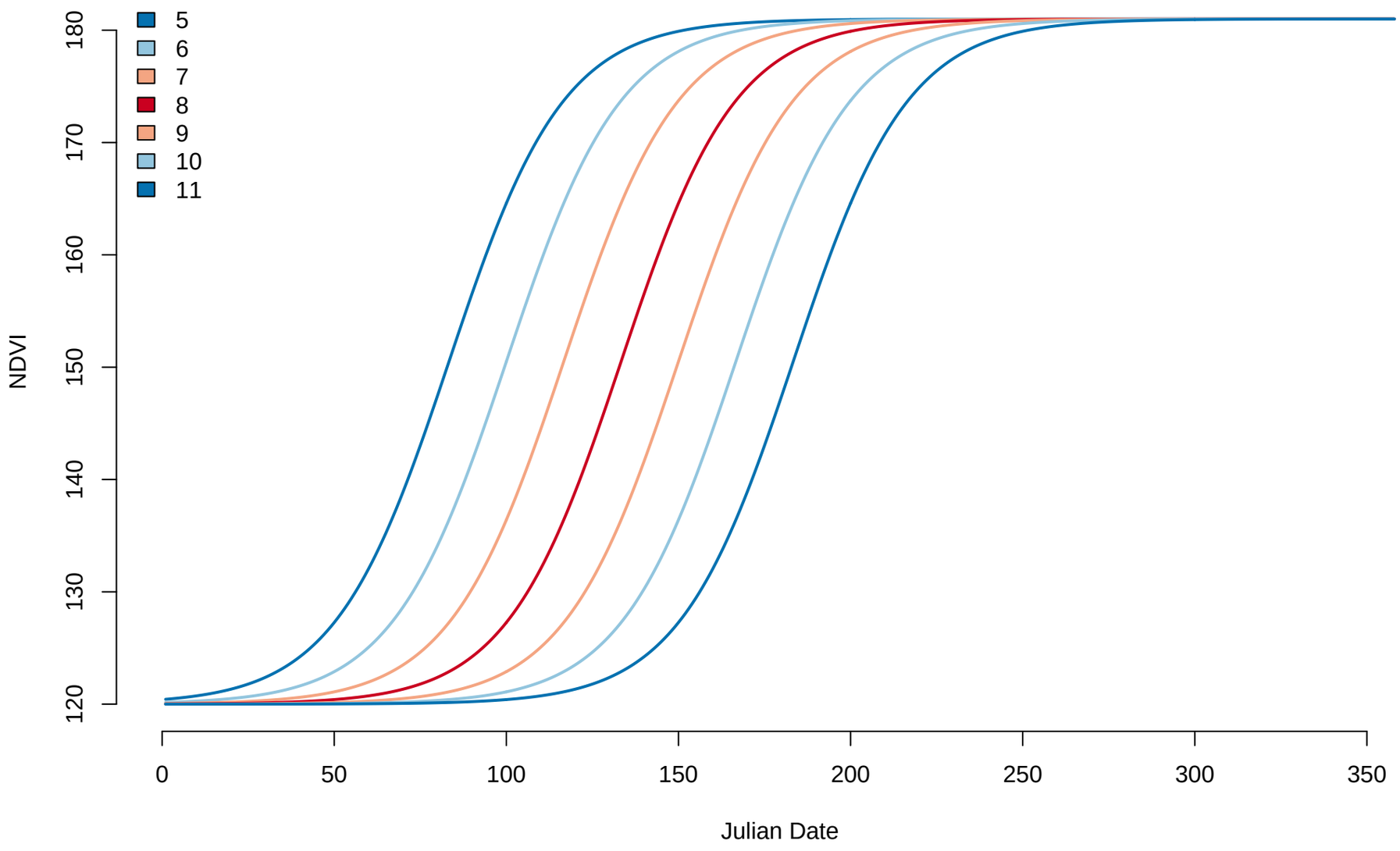
$$y(t) = \frac{c}{1 + e^{a+bt}} + d$$

Rate of Change of the Curvature of the S-Curve

$$K' = b^3 cz \left\{ \frac{3z(1-z)(1+z)^3 \left[2(1+3)^3 + b^2 c^2 z \right]}{\left[(1+z)^4 + (bcz)^2 \right]^{\frac{5}{2}}} - \frac{(1+z)^2 \left(1 + 2z - 5z^2\right)}{\left[(1+z)^4 + (bcz)^2 \right]^{\frac{3}{2}}} \right\}$$

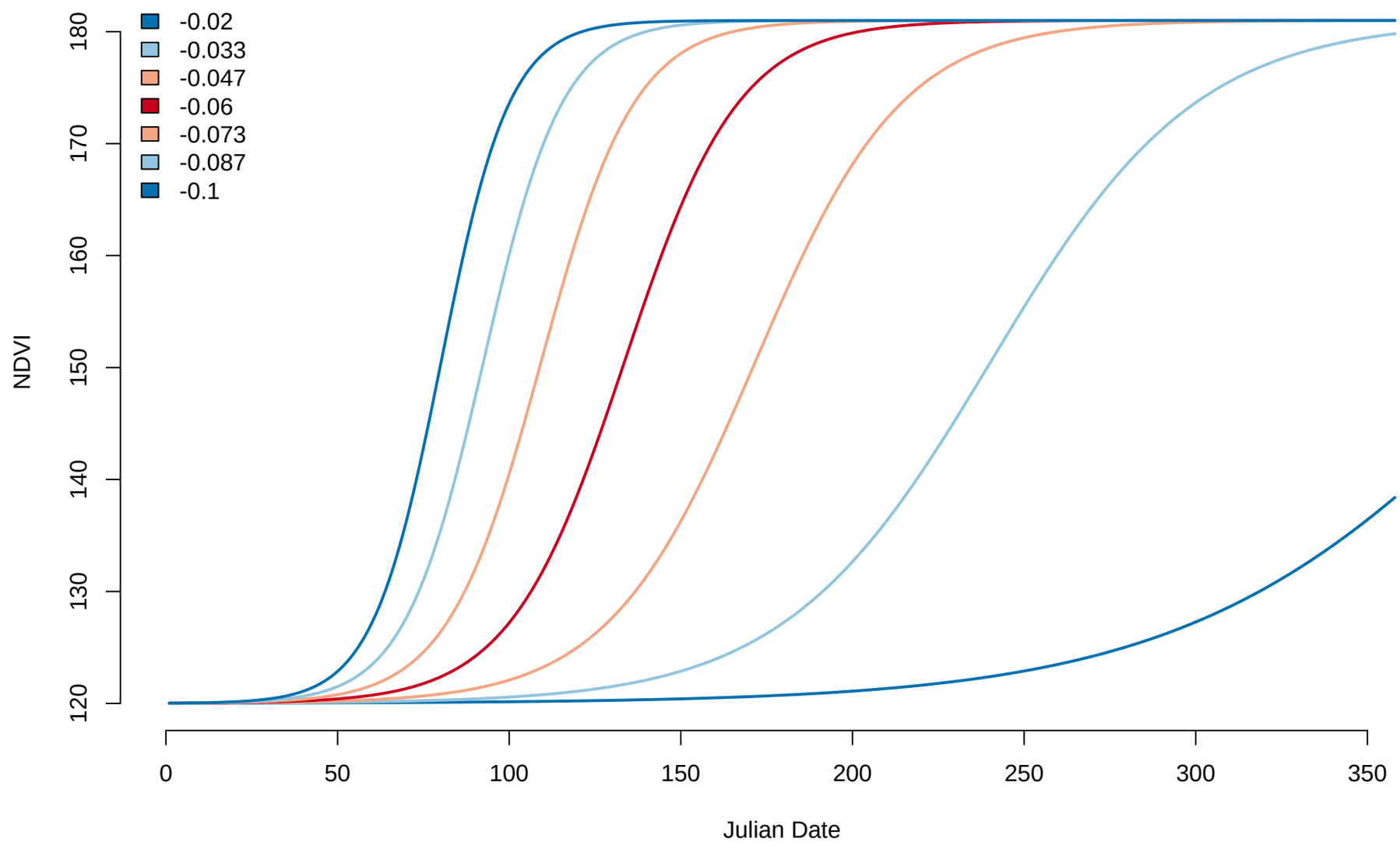
Zhang *et al*, 2003

Meaning of Parameter a



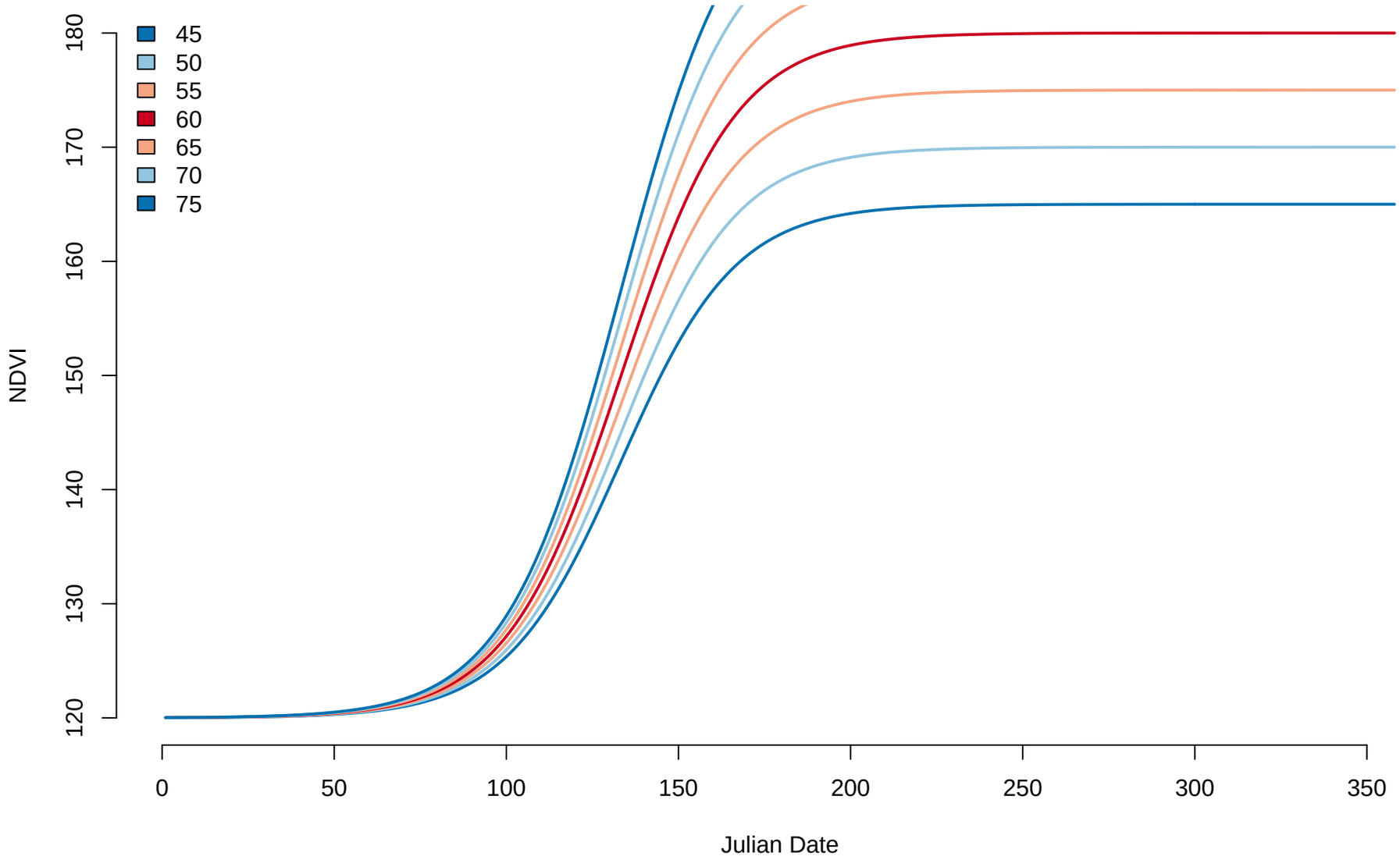
a is the position of the s-curve along the x-axis.

Meaning of Parameter b



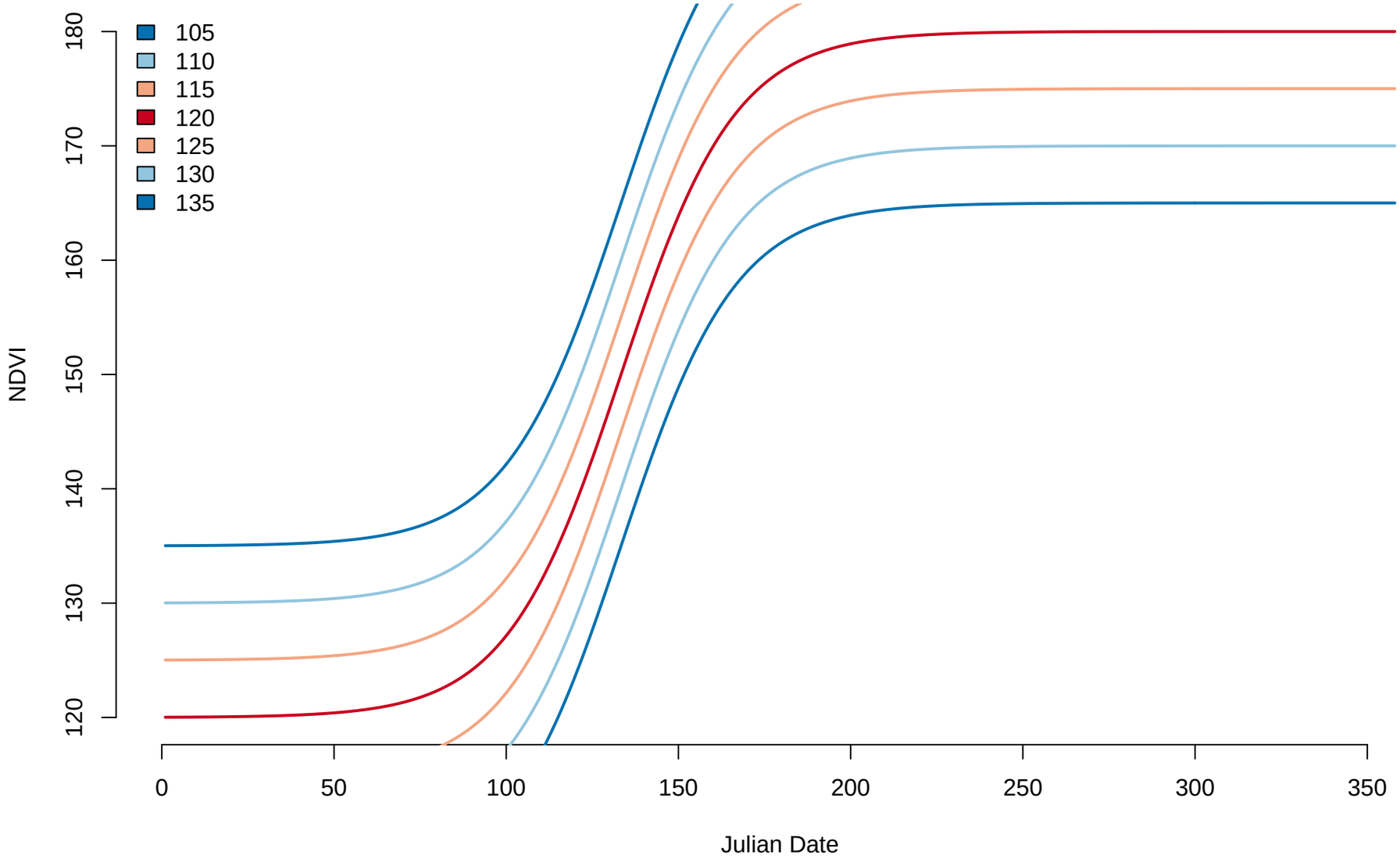
b is the steepness of the s-curve.

Meaning of Parameter c



c is the height of the s-curve.

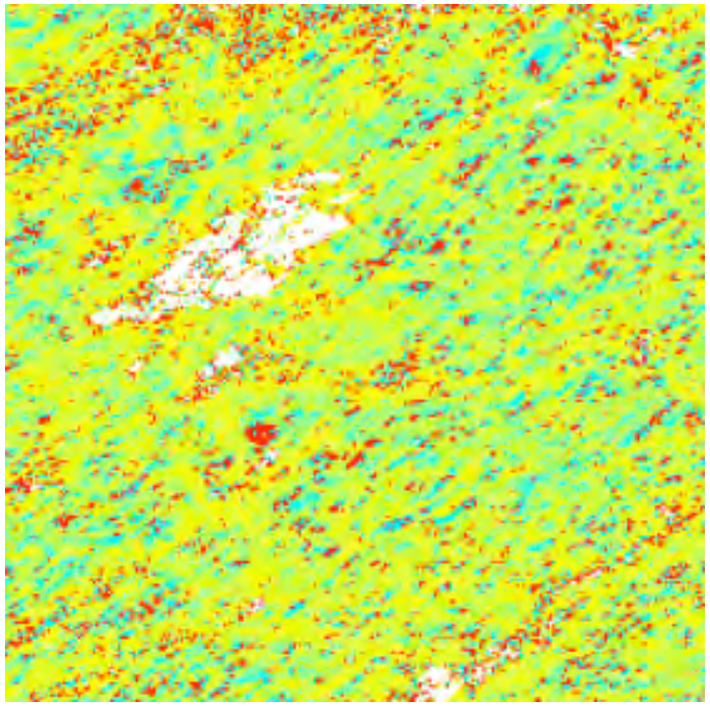
Meaning of Parameter d



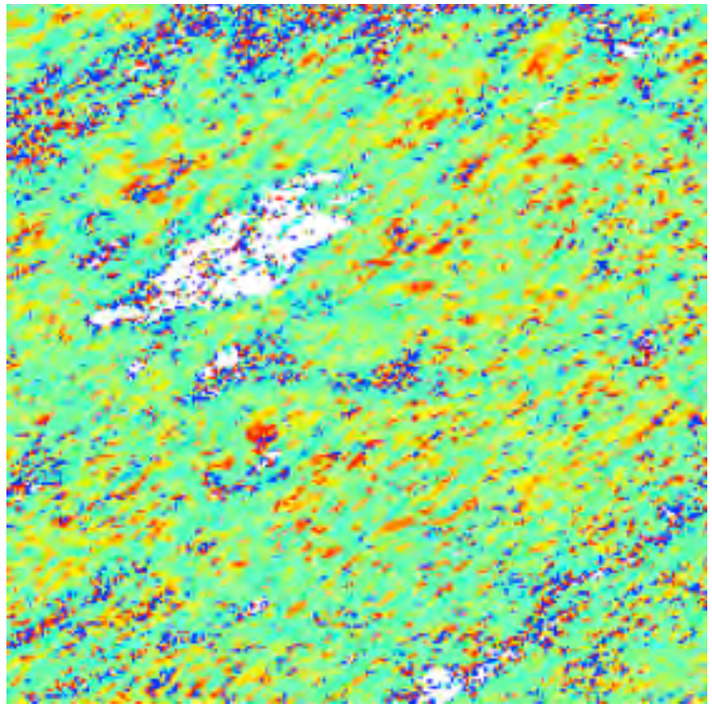
d is the lowest value of the s-curve.

Images of the Parameters

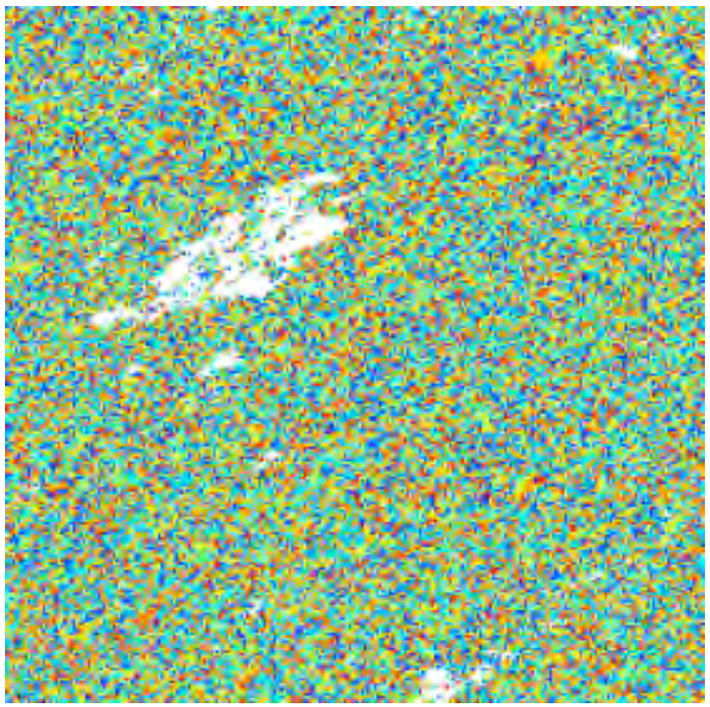
a



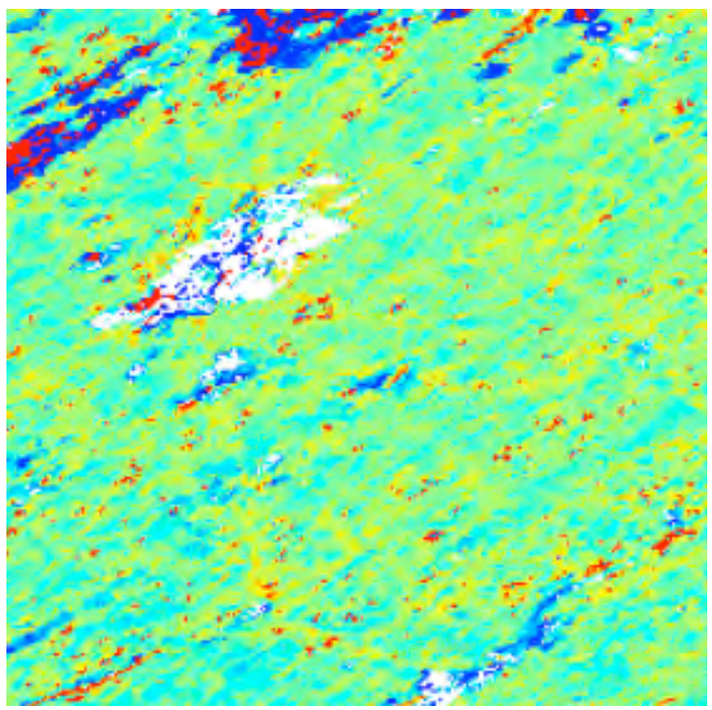
b



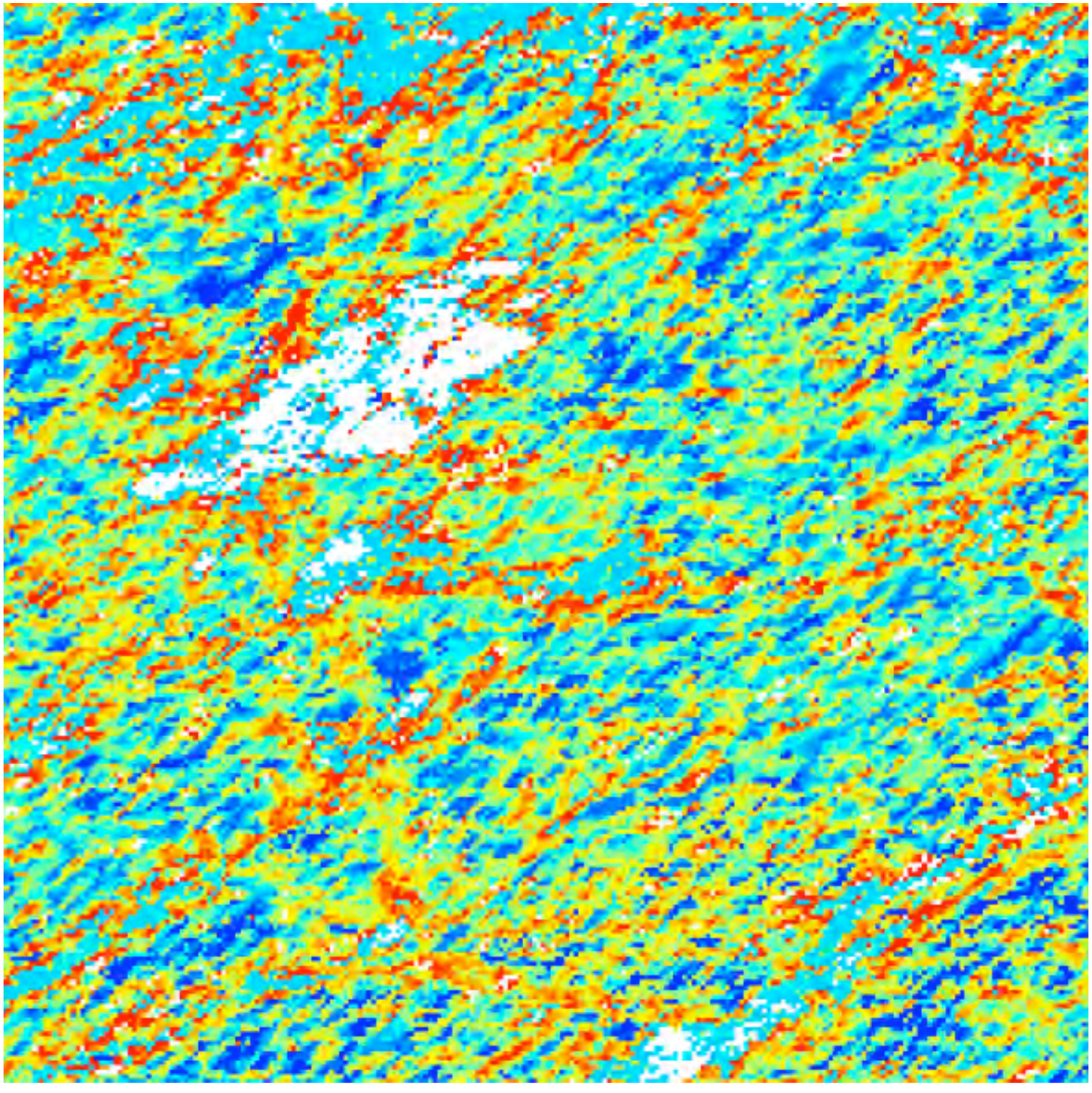
c



d



Onset of Greenness



Field Data

- Five corn fields were selected in Central Illinois. These were visited from May 10 through July 22 so that each field was visited at least every four days.

- Collected corn height measurements and photographs.

- Collected high spatial resolution VNIR images using Kite Aerial Photography (KAP).

Kite Aerial Photography (KAP)

- An ITW Triton kite measuring 8.5’ wide and 3.667’ tall (>31 ft^2). The line has been marked in 5-meter increments and an inclinometer is attached to the line spool.

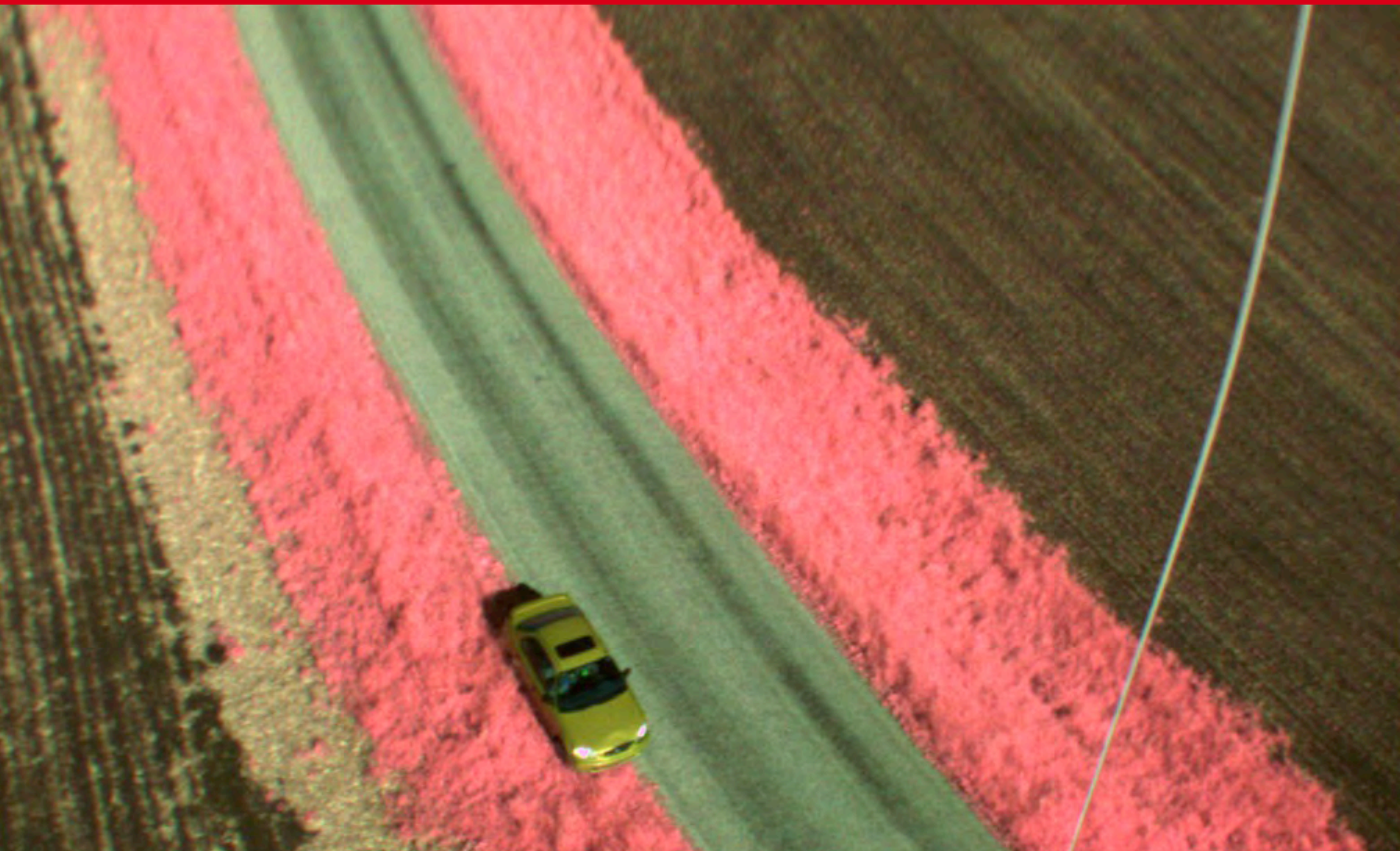
- Once 80-100 meters of line has been unspooled, the camera is attached to the line using a cradle suspended from four pulleys which keep the camera horizontal. More line is then unspooled. Using a little trigonometric magic, the elevation of the camera can be roughly estimated.

- Using a radio controller, the tilt, pan, and direction of the camera can be controlled.

- The camera is a TetraCam ADC, designed to collect images from the same portions of the EM spectrum as Landsat bands 2, 3, and 4.

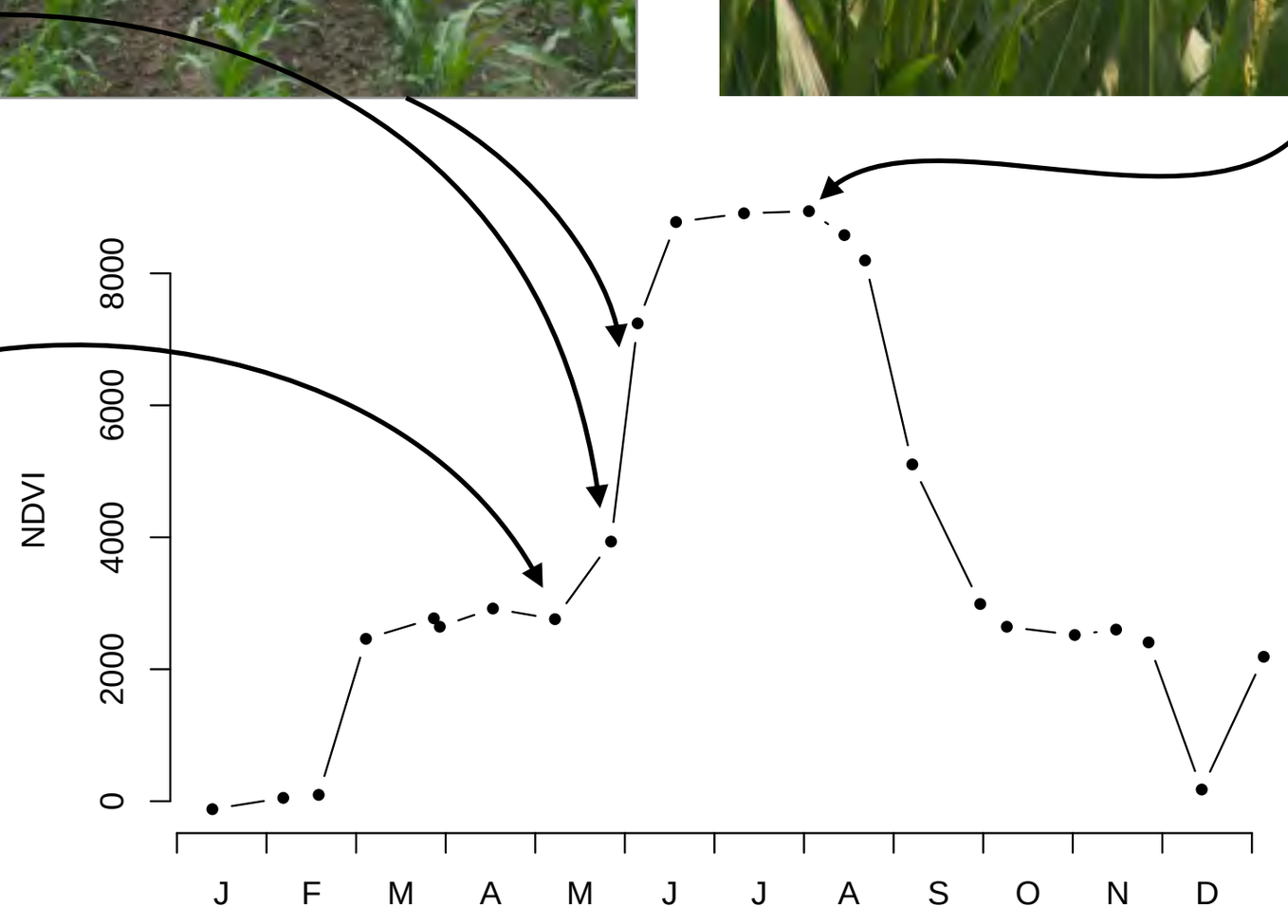
Kite Aerial Photography (KAP)

Kite Aerial Photography (KAP)



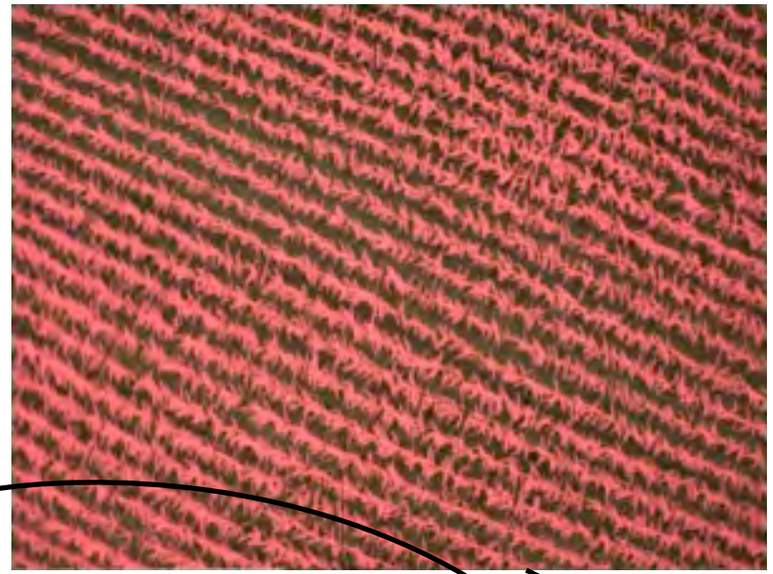
Kite Aerial Photography (KAP)

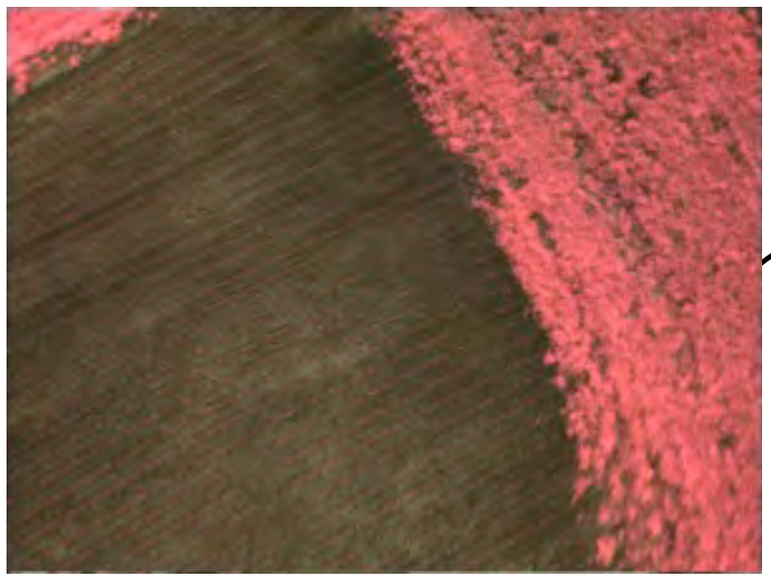
Example of a Corn Field

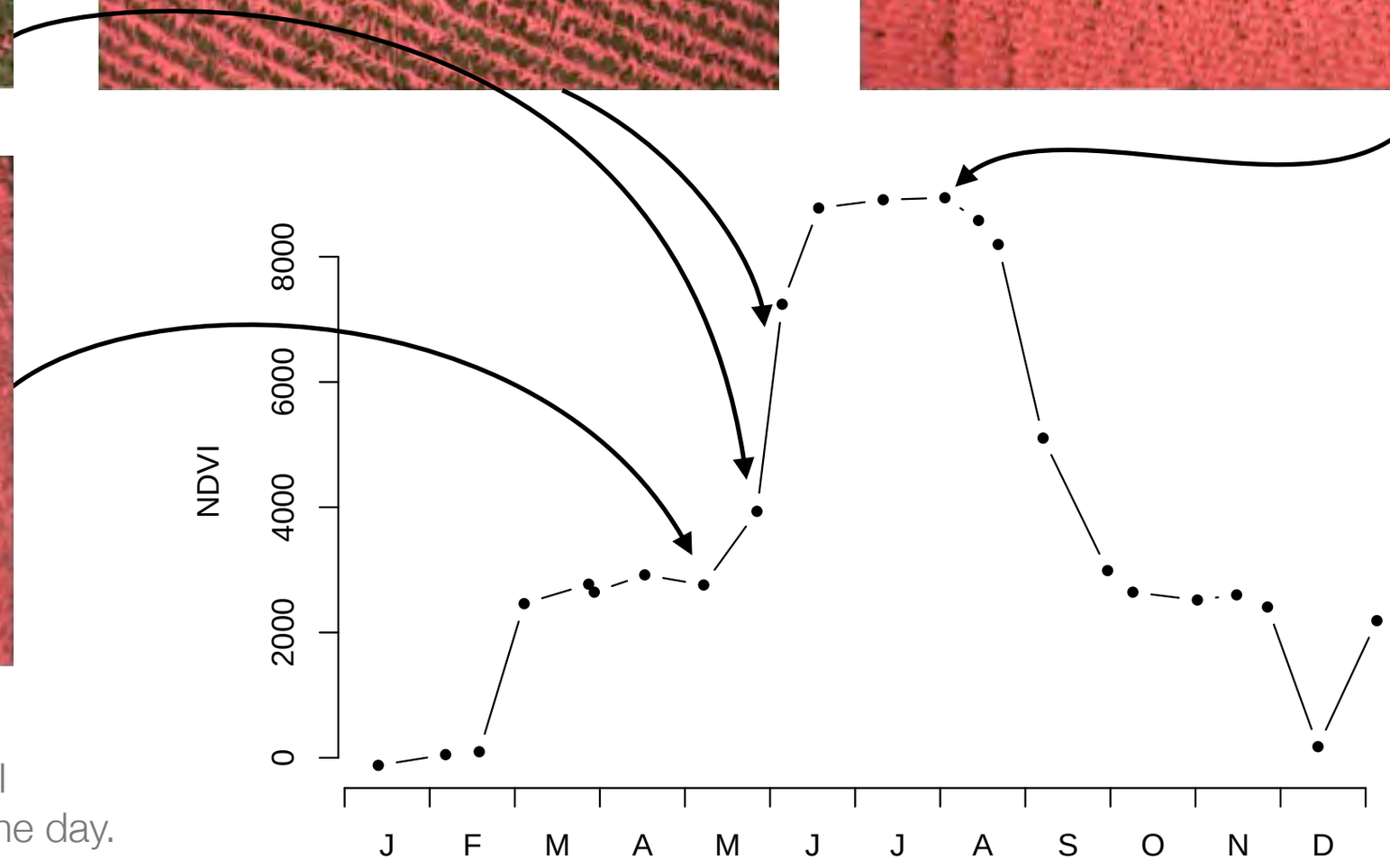


The photographs and the satellite NDVI images were not collected on the same day.

Example of a Corn Field



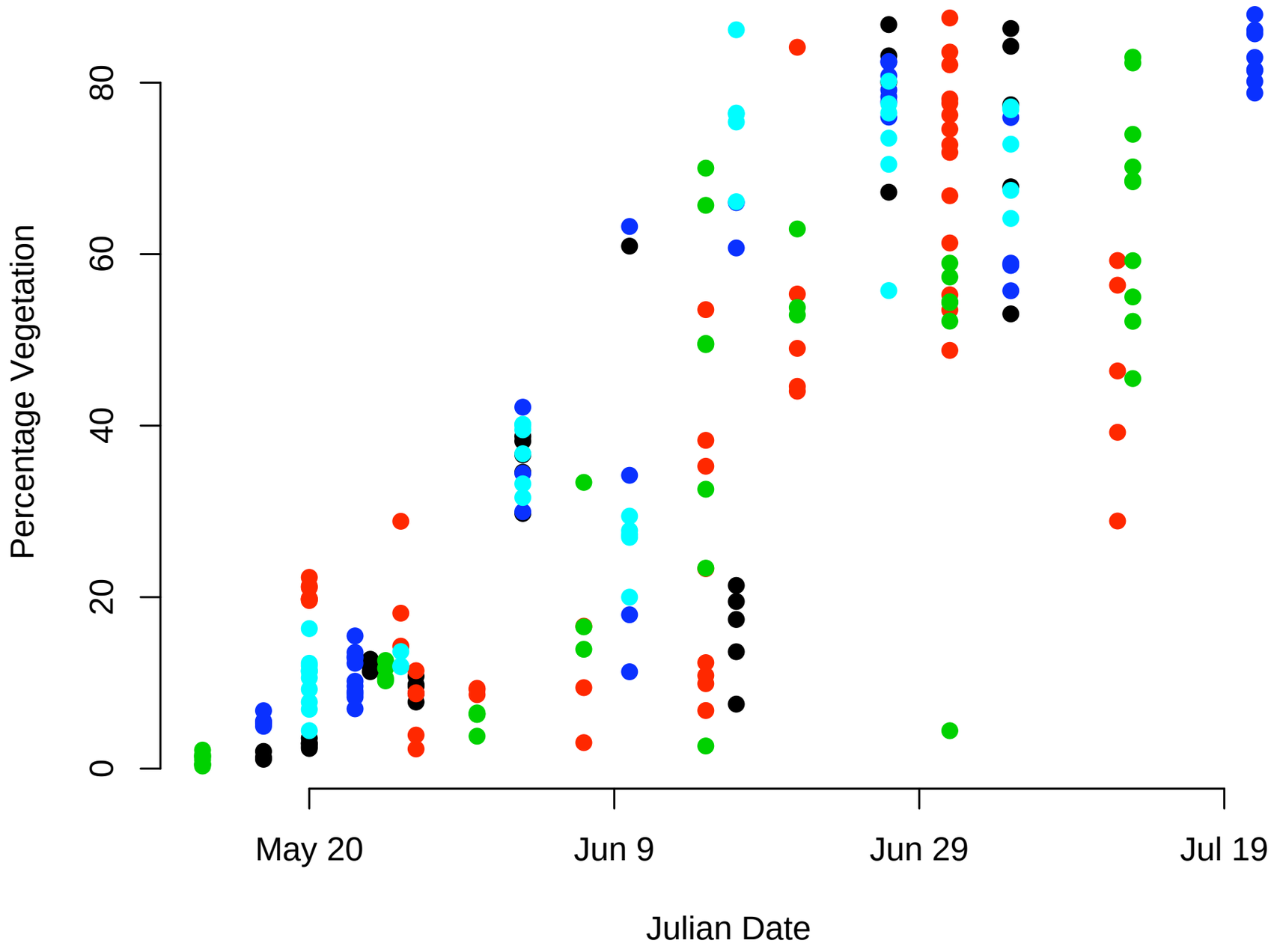




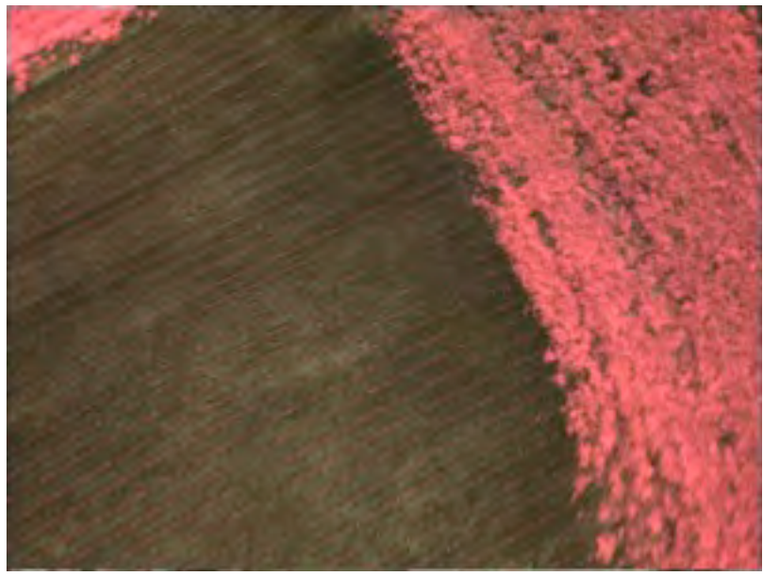
The kite images and the satellite NDVI images were not collected on the same day.

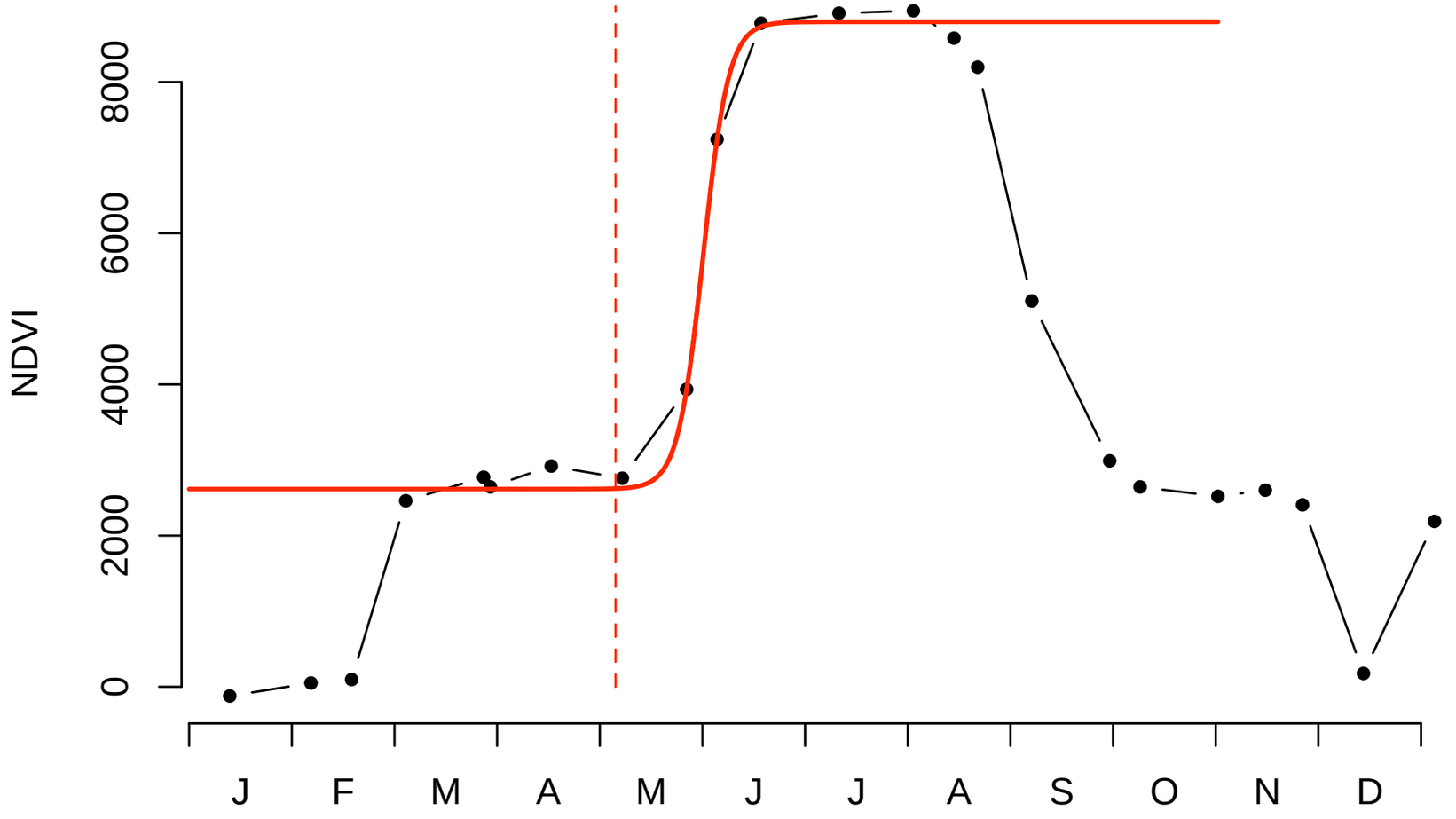
Aerial Ground Cover Percentages

The aerial percentage of ground cover occupied by green vegetation was calculated for the kite images using a discriminant function transform and a threshold which was applied to each image individually. Each color represents a different corn field in the study site. Multiple kite images were collected per visit.



Results





The calculated day of greenness onset was 127 for this site. The images are from day 130. The average aerial percentage ground cover vegetated on day 127 was 1.5%. The corn was 2-3’ tall.

Results

	Onset Date	% Aerial Green	Field Date	Days Off
Site 1	127	1.50%	130	3
Site 2	101	20.50%	140	39
Site 3	129	1.10%	133	4
Site 4	85	5.60%	137	52
Site 5	128	1.30%	140	12

Strengths of the Zhang Method

- Results seem to indicate that the method is reliable, at least for corn in Central Illinois. Wardlow *et al* (2006) found that the Zhang method predicted greenness onset up to two weeks behind the date reported by the USDA as 50% crop emerged, so these results are very encouraging.

- Differences between agricultural and natural forest vegetation were obvious. Differences between corn and soy beans were also apparent.

- Kite flying is fun; although an imperfect method of data collection. Too little or too much wind can be problematic. KAP holds great, untapped potential for monitoring small ecological study sites.

Weaknesses of the Zhang Method

- The method fails if there is not a fairly strong upswing in NDVI during the spring, e.g., there were errors over urban sites.

- Selecting the segment to which the s-curve is fitted is somewhat complicated. I'm sure the differences between researchers' results stems from this.

- Ultimately we are still measuring a phenomena with a rate of change of < 0.5 days per decade with satellites that collect images daily (or on 16-day composites, as was done in this study). The method would work well at regional to continental scales to study the relationships between greenness onset and climate variables, e.g., the interplay between the timing of precipitation and greenness onset.

Thank you.

Bibliography

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