SPECTRAL TRANSFORMS
Spectral Vegetation Indices

GEO 827

October 15, 2015

- Read EVI ATBD at the following site:
  - http://modis.gsfc.nasa.gov/data/atbd/atbd_mod13.pdf
- Answer the following questions:
  - What are the major reasons to include blue band in EVI and how does the blue band improve the "quality" of EVI index?
  - How were the coefficients a, b, c derived and are they suitable for your study?

Need for SVI

- Simplified PCT or first few principal components
- Feature-Space
  - Each eigenvalue "represents" a feature
- What if you are primarily interested in vegetation or crop or forest information?
- Greenness is primarily associated with "green" which can be directly linked to
  - Total amount of green biomass
  - Total amount of green cover (percentage covered with green materials)
  - Direct links to the *f*PAR (fraction of absorbed photosynthetically active radiation)

Topics to Be Addressed

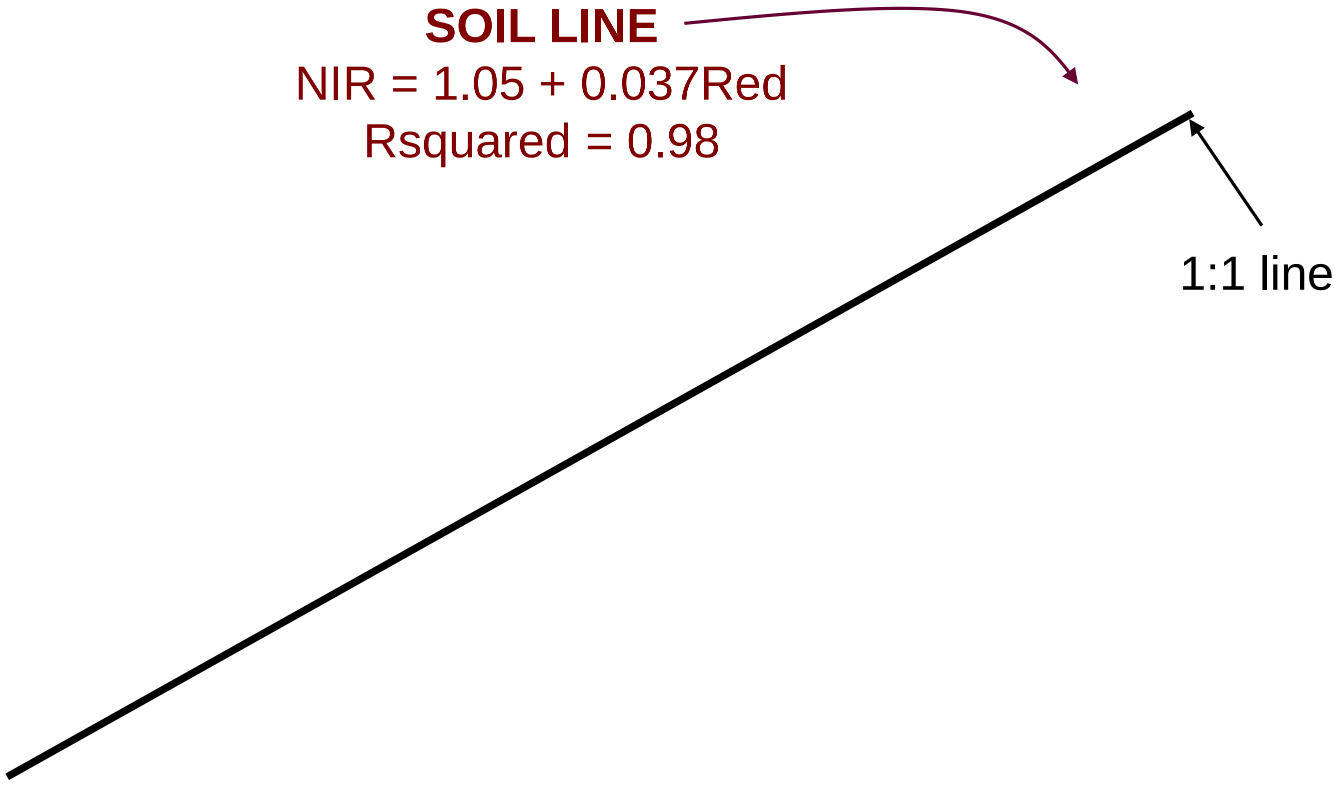
- *VI Development*
- *Computation*
- *Comparison*
- *Limitation,*
- *Interpretation*
- *Their relationships biophysical parameters*

Topics to Be Covered

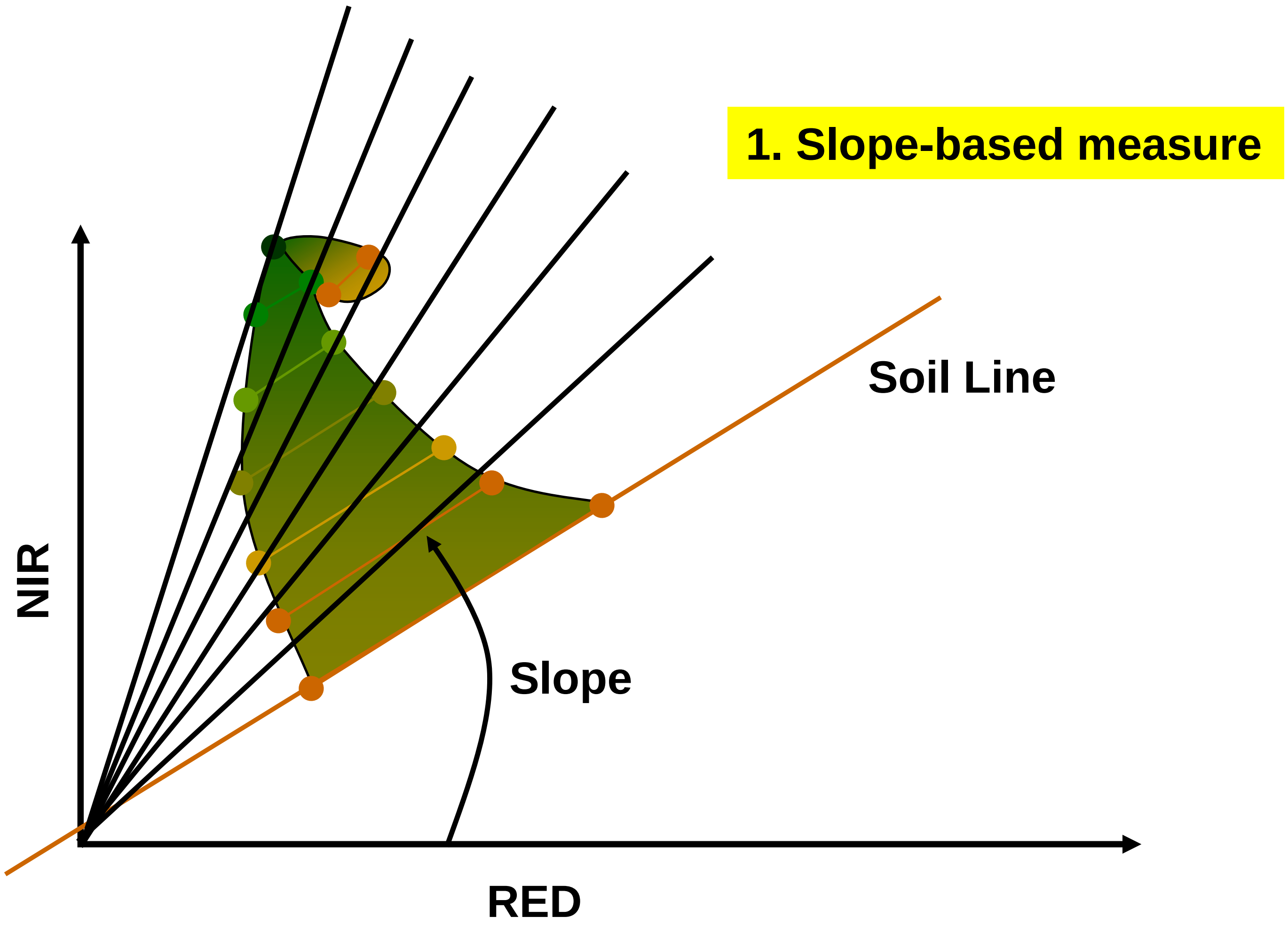
- Background on Vegetation Indices
- New Development
- Potentials
- Issues

Rationale

Soil Line Concept



Types of VIs



Vegetation Indices

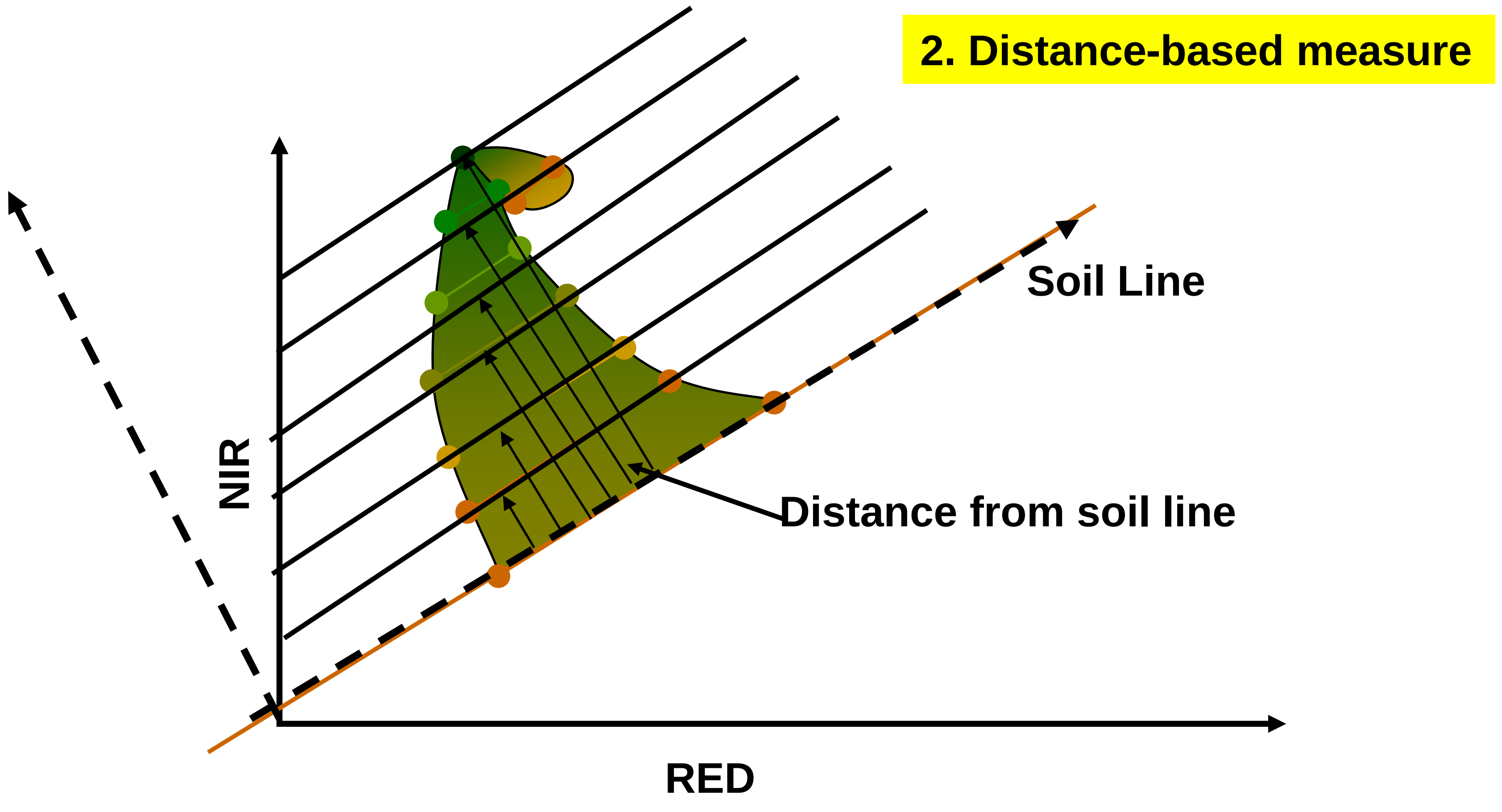
- **RATION BASED INDICES**:
  - RVI (SR)

$$RVI(SR) = \frac{NIR}{RED}$$

  - NDVI: Normalized difference vegetation index

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Vegetation Indices



Vegetation Indices

- **DISTANCE BASED INDICES**
  - PVI: Perpendicular Vegetation Index

$$PVI = \alpha NIR - \beta RED$$

WDVI:Weighted Difference Vegetation Index

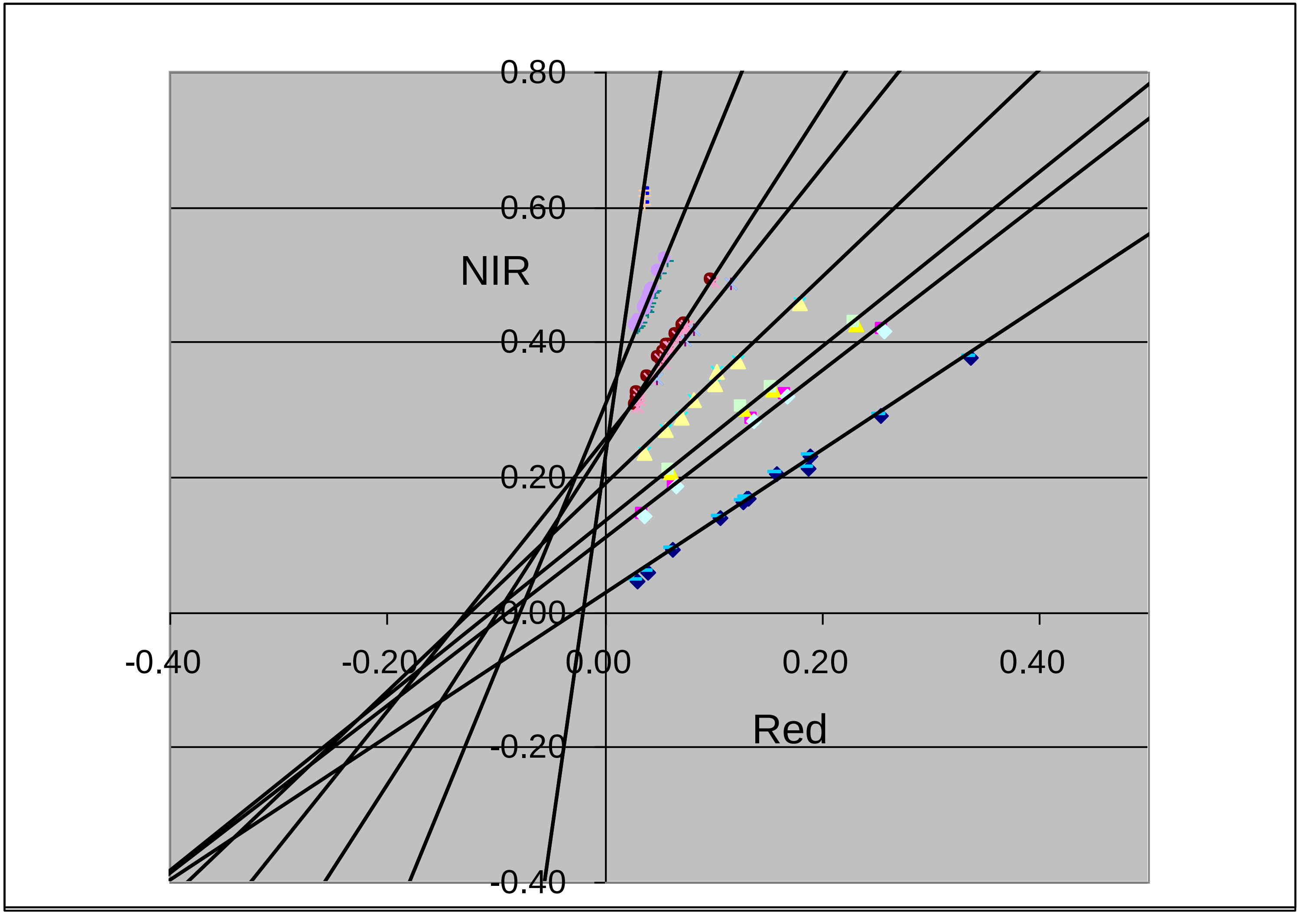
$$WDVI = NIR - \beta RED$$

Vegetation Indices

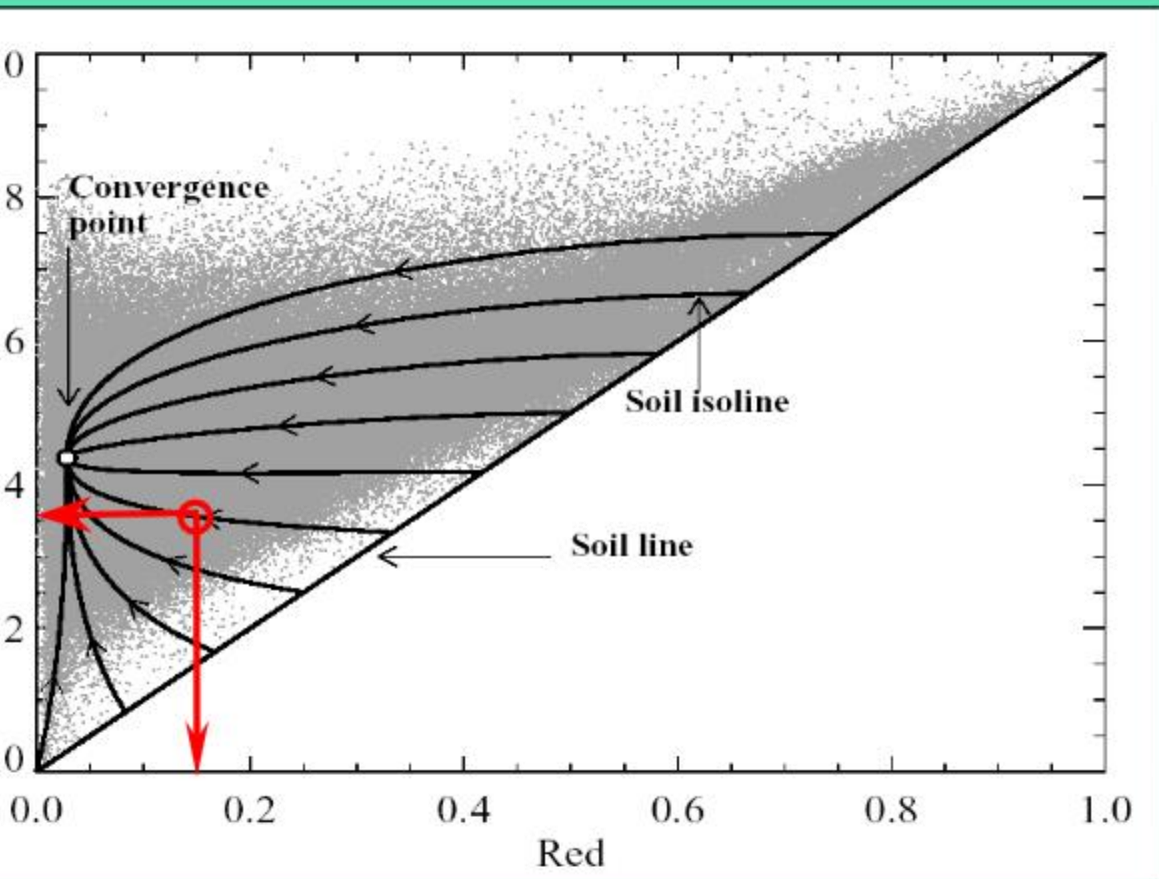
- **DEVELOPMENT FOCUS:**

1. Soil noise reduction
2. Atmospheric reduction
3. Vegetation sensitivity
4. Bidirectional Normalization

Isoline Concept



Retrieval Technique of the Main Algorithm



MODIS surface reflectances

RT Model simulations

- To preserve information co
of input data, MODIS chan
data are used directly in L
retrievals, instead of conv
to Vegetation Indexes.

- During retrievals, surface
reflectances predicted by
model are compared with
data to identify LAI and FF

- The algorithm is Look-Up
based. LUTs parameterize
vegetation type, leaf optica
properties, soil reflectance
patterns, vegetation
heterogeneity

- Retrieval technique takes
account uncertainties of m

Vegetation Indices

- SAVI: Soil Adjusted Vegetation Index

$$SAVI = \frac{NIR - RED}{NIR + RED + L}(1 + L)$$

- Various versions of this index include:
  - TSAVI: Transformed SAVI
  - SAVI2
  - MSAVI: Modified SAVI
  - OSAVI:Optimized SAVI

Vegetation Indices

- MSAVI: Modified Soil Adjusted Vegetation Index

$$MSAVI = \frac{NIR - RED}{NIR + RED + (1 - MSAVI)}(1 + 1 - MSAVI)$$

- By solving this equation, MSAVI is like this:

$$MSAVI = \frac{2NIR + 1 - \sqrt{(2NIR + 1)^2 - 8(NIR - RED)}}{2}$$

Vegetation Indices

- Introducing a combination of red and blue bands,

$$RB = Red + \gamma(Blue - Red)$$

- Using this equation to replace the Red in NDVI yields Atmospheric Resistance Vegetation Index (ARVI)

$$ARVI = \frac{NIR - RB}{NIR + RB}$$

Vegetation Indices

- Soil Adjusted ARVI (SARVI) and later improved EVI (enhanced vegetation index) is proposed as a MODIS product:

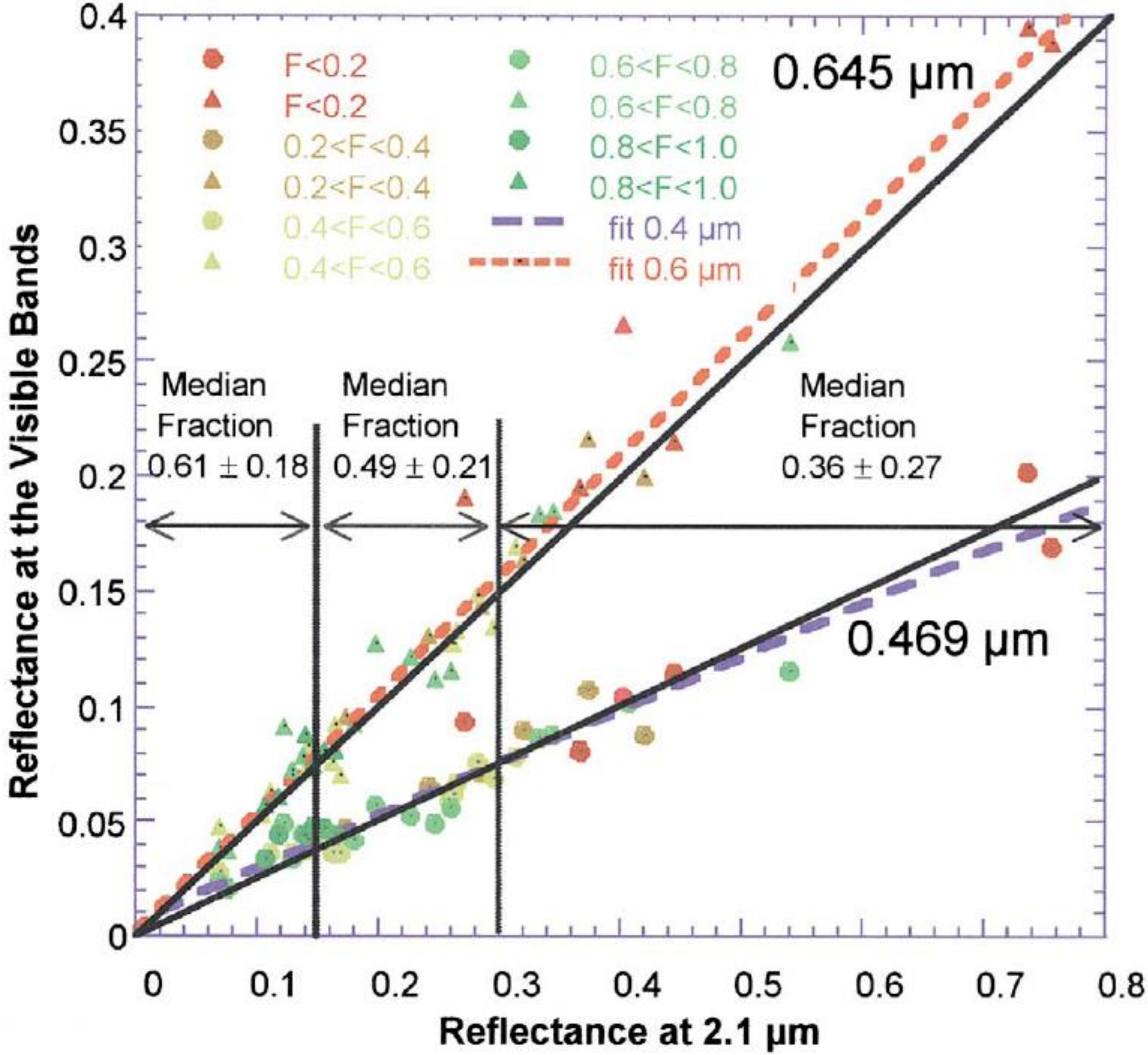
$$EVI = \frac{NIR - RED}{NIR + C_1 RED - C_2 Blue + L}(1 + L)$$

C_1, C_2, L are empirically determined to be 6.0, 7.5, and 1.0

Aerosol Free Vegetation Index

- Longer wavelengths tend to have less or little scattering
- What if we found that there is a correlation between red and MIR spectral bands? Can we then use such relationship to reduce atmospheric effect?

- Karnieli et al., RSE 77 (2001), pp10-21



0.645 µm
0.469 µm
F<0.2
F<0.2
0.2<F<0.4
0.2<F<0.4
0.4<F<0.6
0.4<F<0.6
0.6<F<0.8
0.6<F<0.8
0.8<F<1.0
0.8<F<1.0
fit 0.4 µm
fit 0.6 µm
Median Fraction 0.61 ± 0.18
Median Fraction 0.49 ± 0.21
Median Fraction 0.36 ± 0.27
Reflectance at the Visible Bands
Reflectance at 2.1 µm
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

AFRI *(Continued)*

- $\rho_{0.469} = 0.25\ \rho_{2.1}$

- $\rho_{0.645} = 0.5\ \rho_{2.1}$

$$NDVI_{MIR} = \frac{\rho_{NIR} - \rho_{MIR}}{\rho_{NIR} + \rho_{MIR}}$$

Here MIR can be either band 5 or band 7 of Landsat TM or ETM+

From Karnieli et al., RSE 77 (2001), pp10-21

AFRI *(Continued)*

- $\rho_{0.469} = 0.25\ \rho_{2.1}$

- $\rho_{0.645} = 0.5\ \rho_{2.1}$

$$SAVI_{MIR} = \frac{\rho_{NIR} - \rho_{MIR}}{\rho_{NIR} + \rho_{MIR} + L}(1 + L)$$

Here MIR can be either band 5 or band 7 of Landsat TM or ETM+

From Karnieli et al., RSE 77 (2001), pp10-21

AFRI *(Continued)*

- $\rho_{0.469} = 0.25\ \rho_{2.1}$

- $\rho_{0.645} = 0.5\ \rho_{2.1}$

$$AFRI_{MIR} = \frac{\rho_{NIR} - a\rho_{MIR}}{\rho_{NIR} + a\rho_{MIR}}$$

Here MIR can be either band 5 or band 7 of Landsat TM or ETM+

From Karnieli et al., RSE 77 (2001), pp10-21

AFRI *(Continued)*

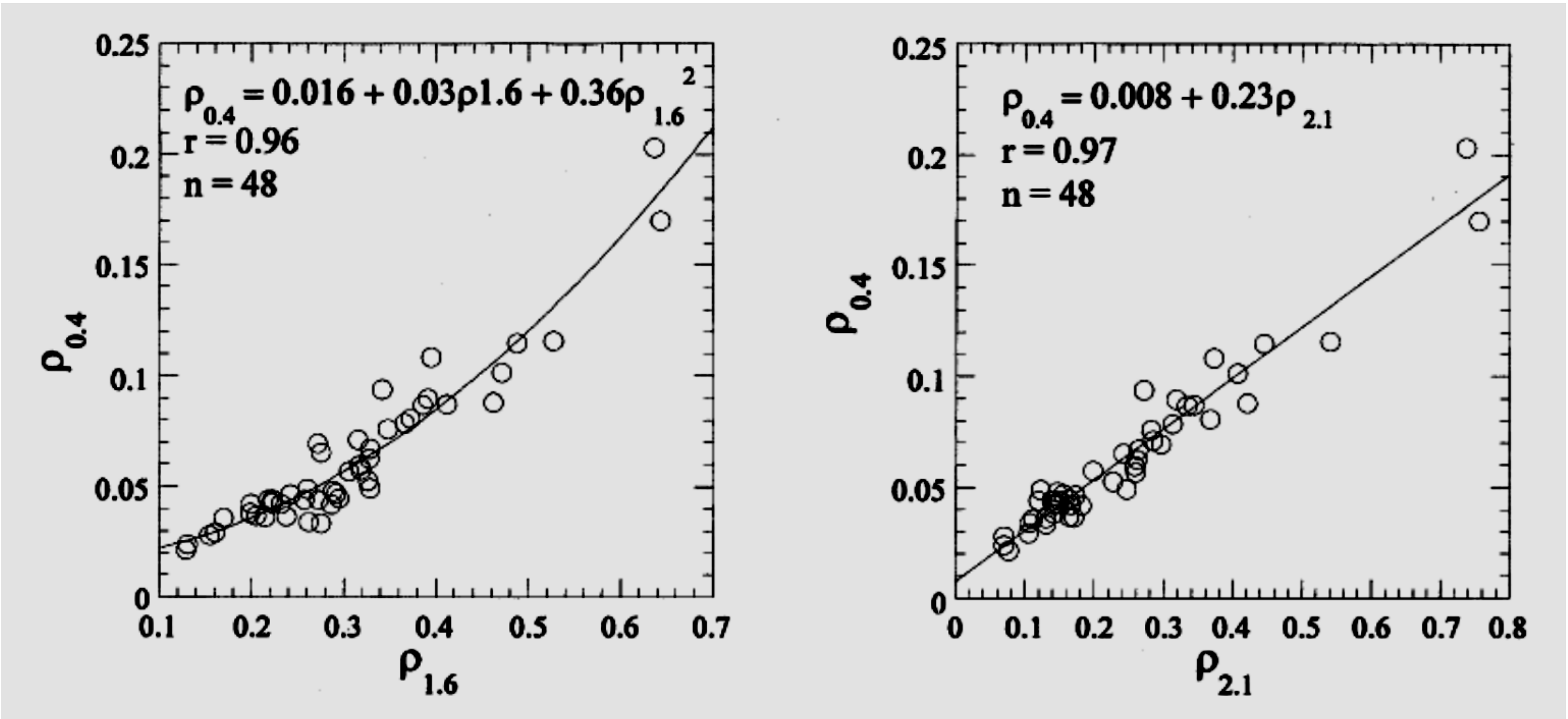
- $\rho_{0.469} = 0.25\ \rho_{2.1}$

- $\rho_{0.645} = 0.5\ \rho_{2.1}$

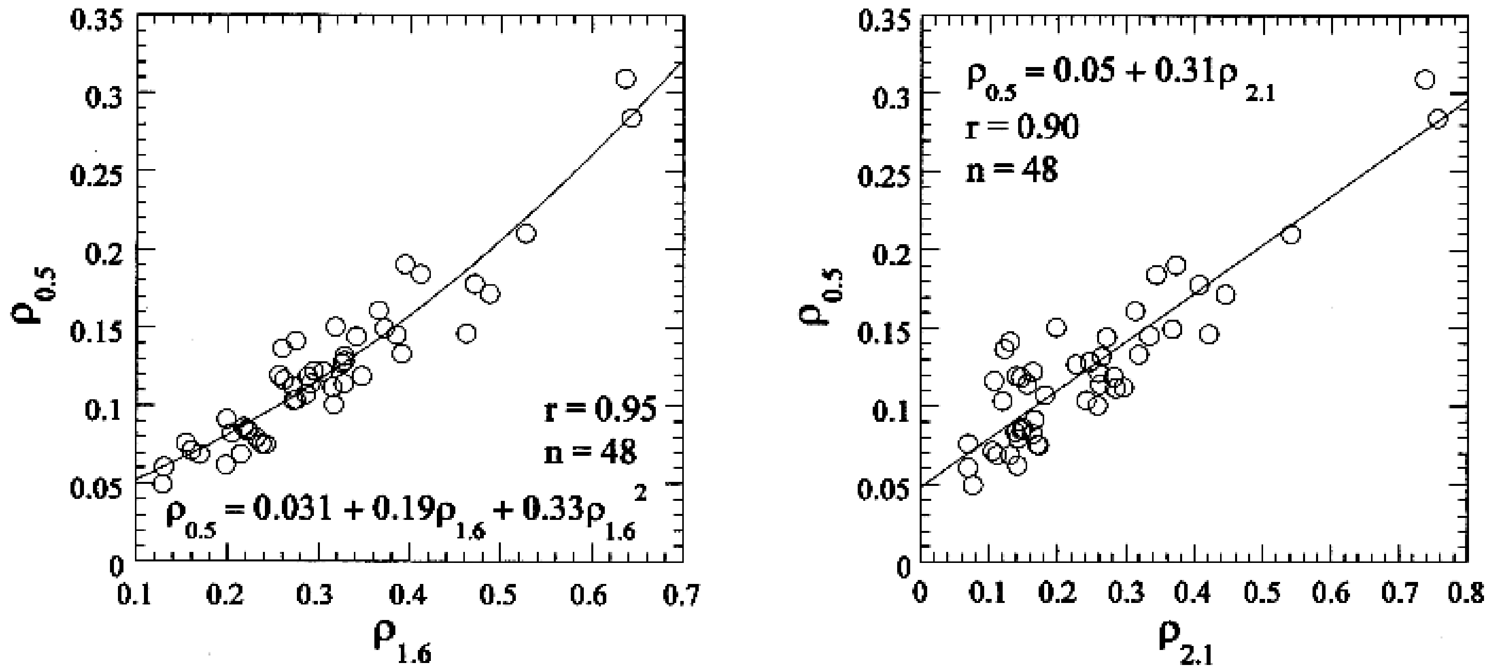
$$AFRI_{save} = \frac{\rho_{NIR} - a\rho_{MIR}}{\rho_{NIR} + a\rho_{MIR} + L}(1 + L)$$

Here MIR can be either band 5 or band 7 of Landsat TM or ETM+

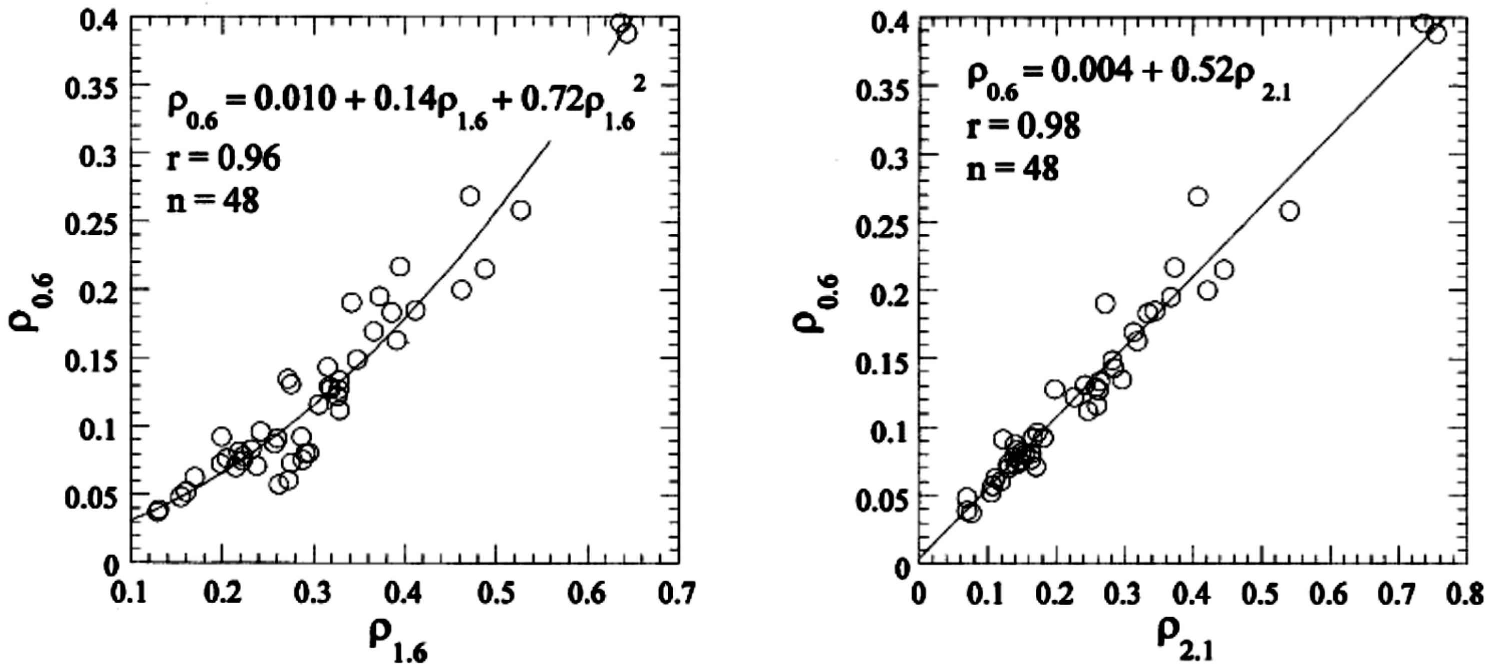
From Karnieli et al., RSE 77 (2001), pp10-21



ρ0.4 = 0.016 + 0.03ρ1.6 + 0.36ρ1.6 2
r = 0.96
n = 48
ρ0.4
ρ1.6
0.25
0.2
0.15
0.1
0.05
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
ρ0.4 = 0.008 + 0.23ρ2.1
r = 0.97
n = 48
ρ0.4
ρ2.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8



0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
ρ0.5
0.1 0.2 0.3 0.4 0.5 0.6 0.7
ρ1.6
r = 0.95
n = 48
ρ0.5 = 0.031 + 0.19ρ1.6 + 0.33ρ1.6 2
ρ0.5 = 0.05 + 0.31ρ 2.1
r = 0.90
n = 48
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
ρ2.1



$\rho_{0.6} = 0.010 + 0.14\rho_{1.6} + 0.72\rho_{1.6}^2$
r = 0.96
n = 48
$\rho_{0.6}$
$\rho_{1.6}$
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
$\rho_{0.6} = 0.004 + 0.52\rho_{2.1}$
r = 0.98
n = 48
$\rho_{0.6}$
$\rho_{2.1}$
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

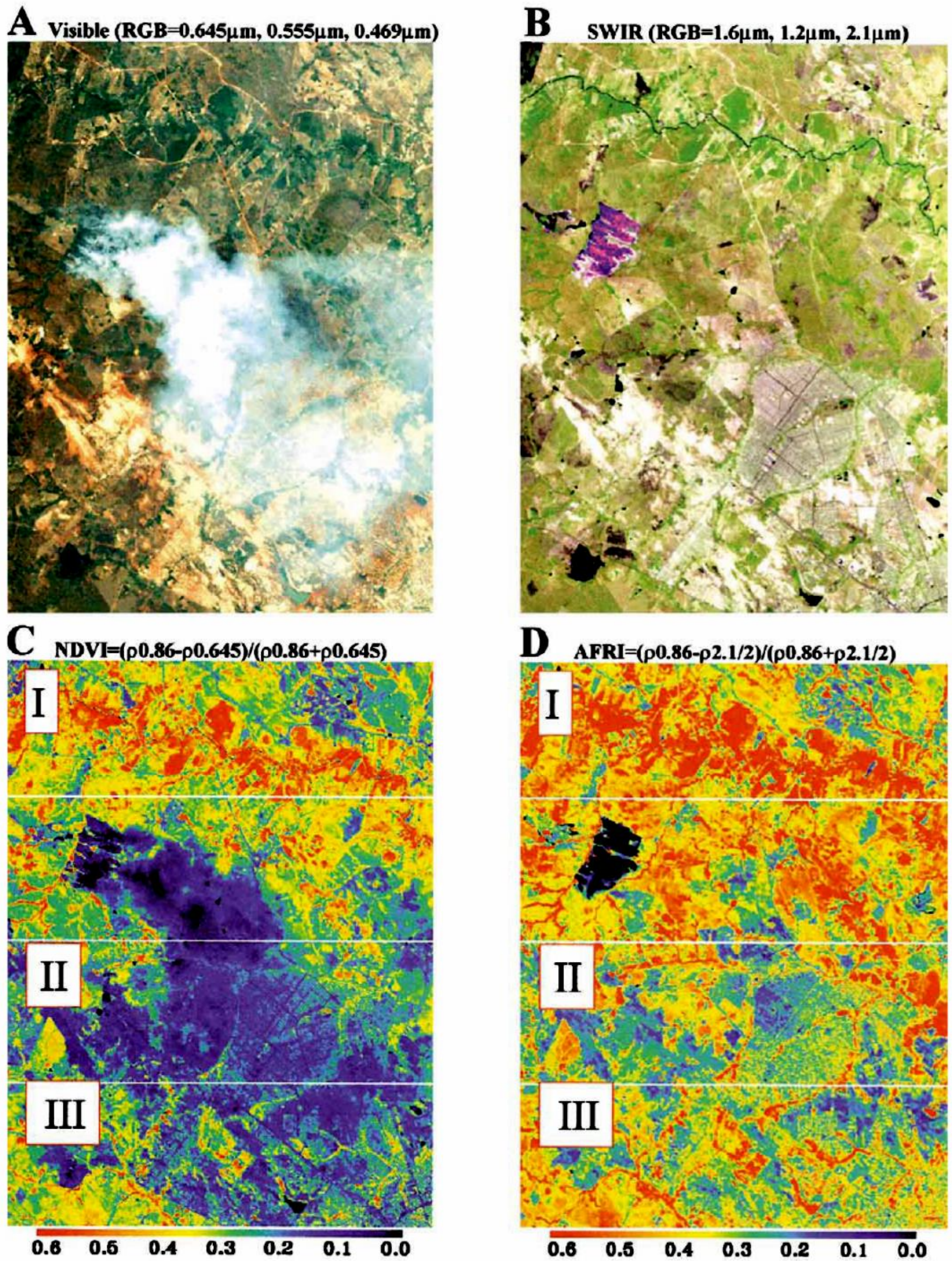


Fig. 5. AVIRIS image of one of the case studies for the SCAR-B campaign in Brazil, 1995. (A) True color composite (RGB = 0.645, 0.555, 0.469); (B) SWIR composite (RGB = 1.6, 1.2, 2.1); (C) NDVI; (D) AFRI: (I) smoke-free zone, (II) heavy-smoke zone, (III) light-smoke zone.

Vegetation Indices

- Non-Linear Vegetation Index
  - Global Environmental Monitoring Index

$$GEMI = \eta(1 - 0.25\eta) - \frac{RED - 0.125}{1 - RED}$$

$$\eta = \frac{2(NIR^2 - RED^2) + 1.5NIR - .5RED}{NIR + RED + 0.5}$$

Vegetation Indices

$$\rho_{vi} = \frac{\kappa_1 \rho_i^2 + \kappa_2 \rho_{Blue}^2 + \kappa_3 \rho_i \rho_{Blue} + \kappa_4 \rho_i + \kappa_5 \rho_{Blue} + \kappa_6}{\alpha_1 \rho_i^2 + \alpha_2 \rho_{Blue}^2 + \alpha_3 \rho_i \rho_{Blue} + \alpha_4 \rho_i + \alpha_1 \rho_{Blue} + \alpha_6}$$

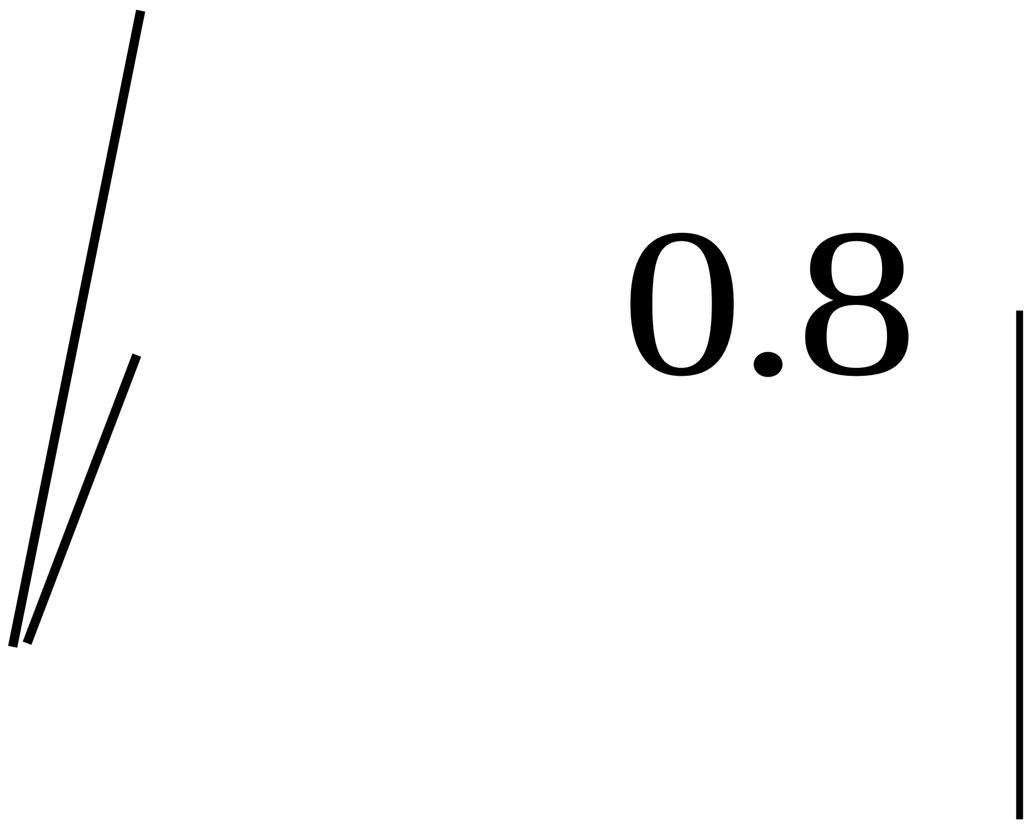
Step 1. Optimize this equation against model prediction at the top of the atmosphere

Step 2. Optimize it again against biophysical parameter such as *f*PAR

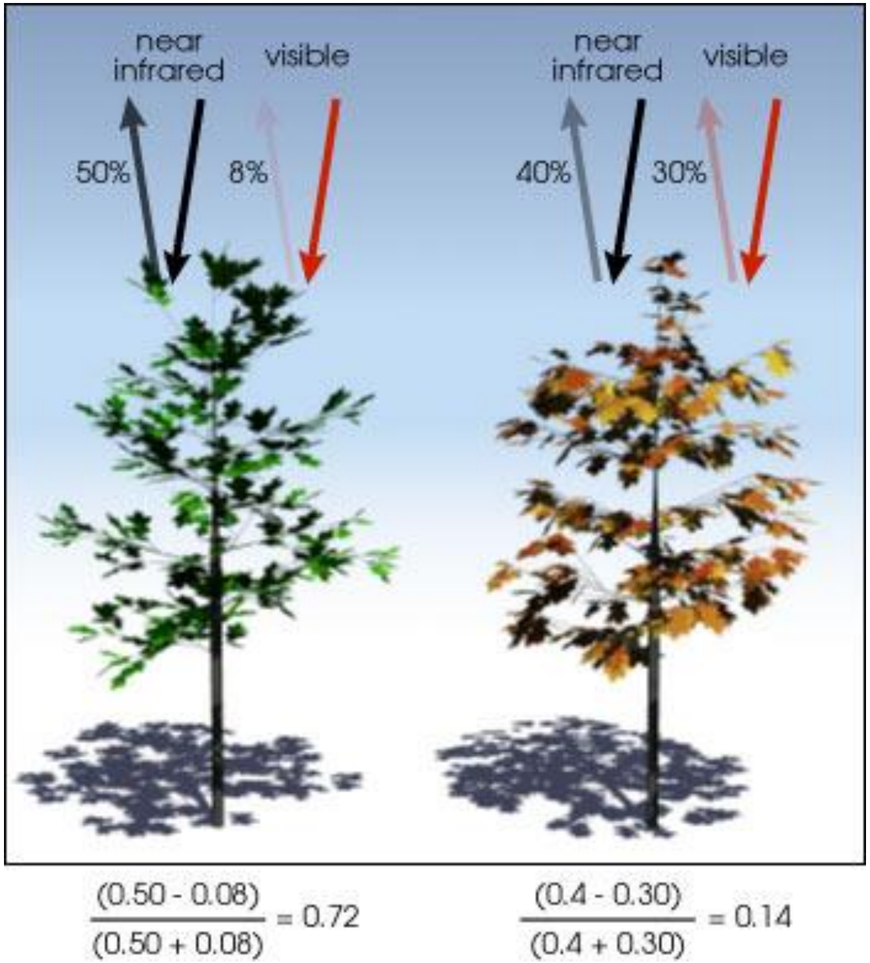
Step 3. Obtain a set of coefficients and compute the VI value

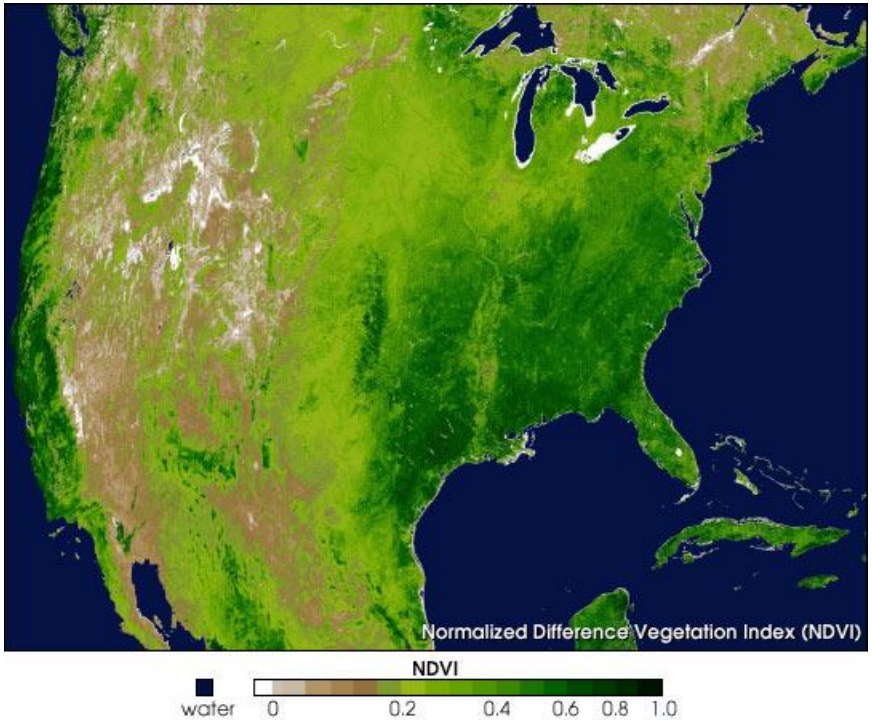
Vegetation Indices

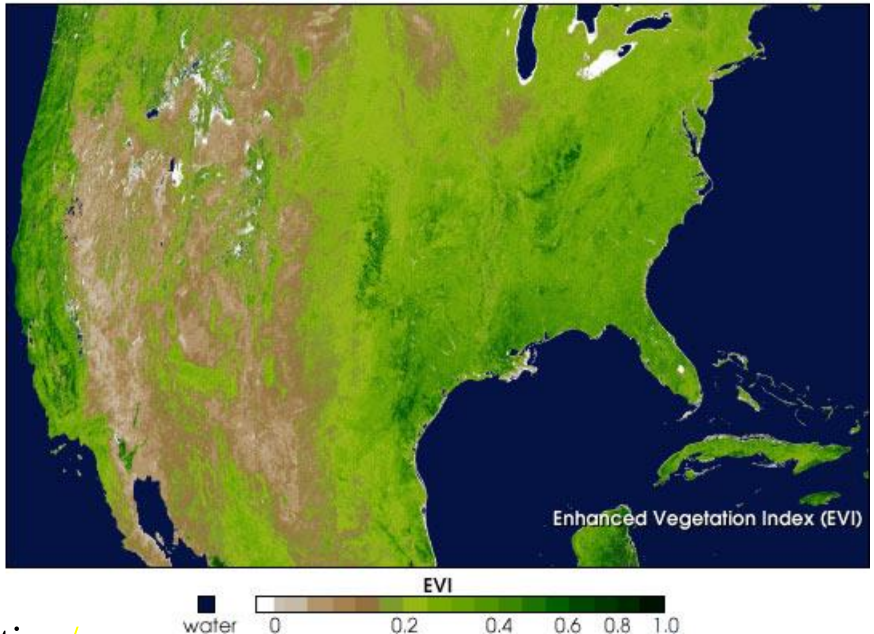
- Angular Vegetation Index
  - 1st and 2nd Derivatives
  - AVI



NDVI = (NIR — VIS)/(NIR + VIS)







http://earthobservatory.nasa.gov/Library/MeasuringVegetation/

VI Family Tree

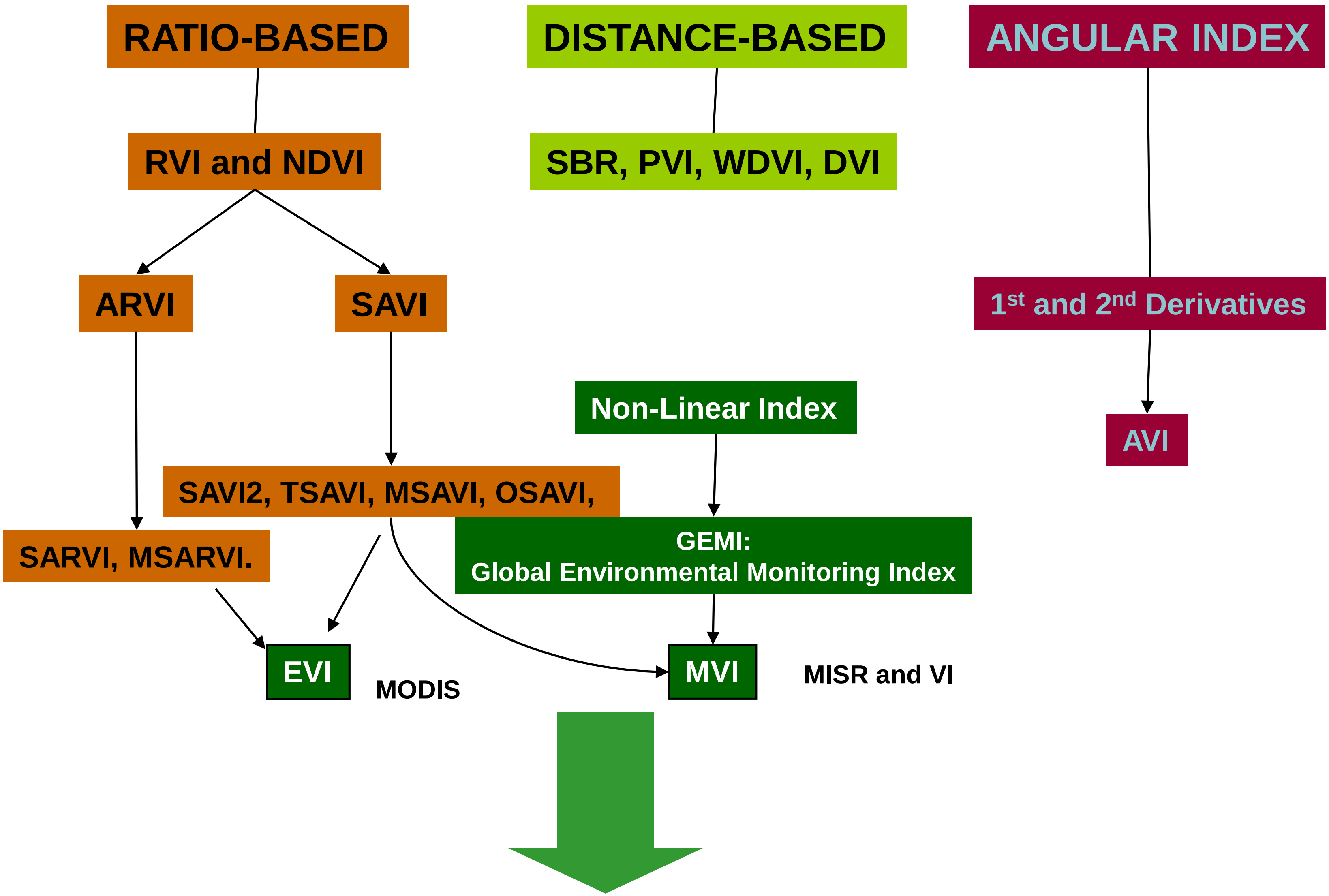


Table 2
VI formulae

Acronym	Name	VI	Reference
RVI	Ratio vegetation index	$\mathrm{RVI} = \frac{\rho_{\mathrm{NIR}}}{\rho_{\mathrm{Red}}}$	(Pearson & Miller, 1972)
NDVI	Normalized difference vegetation index	$\mathrm{NDVI} = \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{Red}}}{\rho_{\mathrm{NIR}} + \rho_{\mathrm{Red}}} = \frac{\mathrm{RVI} - 1}{\mathrm{RVI} + 1}$	(Rouse, Haas, Schell, Deering, & Harlan, 1974)
PVI	Perpendicular vegetation index	$\mathrm{PVI} = \frac{\rho_{\mathrm{NIR}} - a\rho_{\mathrm{Red}} - b}{\sqrt{1 + a^2}}$	(Richardson & Wiegand, 1977)
DVI	Difference vegetation index	$\mathrm{DVI} = \rho_{\mathrm{NIR}} - \rho_{\mathrm{Red}}$	(Jordan, 1969)
TSAVI	Transformed soil-adjusted vegetation index	$\mathrm{TSAVI} = \frac{a(\rho_{\mathrm{NIR}} - a\rho_{\mathrm{Red}} - b)}{a\rho_{\mathrm{NIR}} + \rho_{\mathrm{Red}} - ab}$	(Baret, Guyot, & Major, 1989)
ATSAVI[a]	Adjusted transformed soil adjusted vegetation index	$\mathrm{ATSAVI} = \frac{a(-a\rho_{\mathrm{Red}} - b)}{a\rho_{\mathrm{NIR}} + \rho_{\mathrm{Red}} - ab + X(1 + a^2)}$	(Baret & Guyot, 1991)
SAVI2	Second soil-adjusted vegetation index	$\mathrm{SAVI2} = \frac{\rho_{\mathrm{NIR}}}{\rho_{\mathrm{Red}} + b/a}$	(Major et al., 1990)
MSAVI2	Modified second soil-adjusted vegetation index	$\mathrm{MSAVI2} = \frac{1}{2}\left[2(\rho_{\mathrm{NIR}} + 1) - \sqrt{(2\rho_{\mathrm{NIR}} + 1)^2 - 8(\rho_{\mathrm{NIR}} - \rho_{\mathrm{Red}})}\right]$	(Qi, Chehbouni, Huete, Kerr, & Sorooshian, 1994)

N.H. Broge, J.V. Mortensen / Remote Sensing of Environment 81 (2002) 45–57

RDVI	Renormalized difference vegetation index	$\mathrm{RDVI} = \sqrt{\mathrm{NDVI} \times \mathrm{DVI}}$	(Reujean & Breon, 1995)
CARI	Chlorophyll absorption ratio index	$\mathrm{CARI} = \frac{\lvert(a \times 670 + \rho_{670} + b)\rvert}{\sqrt{(a^2+1)}} \frac{\rho_{700}}{\rho_{670}}$ $a = (\rho_{700} - \rho_{550})/150, \quad b = \rho_{550} - (a \times 550)$	(Kim et al., 1994)
R750/R700	R750/R700	$\frac{\rho_{750}}{\rho_{700}}$	(Gitelson & Merzlyak, 1996)
R750/R550	R750/R550	$\frac{\rho_{750}}{\rho_{550}}$	(Gitelson & Merzlyak, 1996)
TVI	Triangular vegetation index	$\mathrm{TVI} = 60(\rho_{\mathrm{NIR}} - \rho_{\mathrm{Green}}) - 100(\rho_{\mathrm{Red}} - \rho_{\mathrm{Green}})$	(Broge & Leblanc, 2001)
REIP_Gaus[b]	Red edge inflection point (Gaussian model)	$R(\lambda) = R_s - (R_s - R_0)\exp\left(\frac{-(\lambda_0 - \lambda)^2}{2\sigma^2}\right)$ $\mathrm{REIP\_Gaus} = \lambda_i + \sigma$	(Miller et al., 1990) (Broge & Leblanc, 2001)
REIP_Poly[c]	Red edge inflection point (polynomial model)	$R(\lambda) = c_0 + c_1\lambda + c_2\lambda + c_3\lambda + c_4\lambda + c_5\lambda + c_6\lambda$ REIP_Poly = root of the second derivative ($R''(\lambda) = 0$), where λ is closer to 720 nm	(Broge & Leblanc, 2001)
REIP_Lagr[d]	Red edge inflection point (Lagrangian model)	$\mathrm{REIP\_Lagr} = \frac{A(\lambda_i + \lambda_{i+1}) + B(\lambda_{i-1} + \lambda_{i+1}) + C(\lambda_{i-1} + \lambda_i)}{2(A+B+C)}$ $A = \frac{D_{\lambda(i-1)}}{(\lambda_{i-1} - \lambda_i)(\lambda_{i-1} - \lambda_{i+1})}$ $B = \frac{D_{\lambda(i)}}{(\lambda_i - \lambda_{i-1})(\lambda_i - \lambda_{i+1})}$ $C = \frac{D_{\lambda(i+1)}}{(\lambda_{i+1} - \lambda_{i-1})(\lambda_{i+1} - \lambda_i)}$	(Dawson & Curran, 1998)

Table 2 (*continued*)

1DZ_DGVI[e]	First-order derivative green vegetation index (zero baseline)	$1DZ\_DGVI = \sum_{\lambda_i}^{\lambda_n} \lvert\rho'(\lambda_i)\rvert \Delta\lambda_i$	(Elvidge & Chen, 1995)
2DZ_DGVI[e]	Second-order derivative green vegetation index (zero baseline)	$2DZ\_DGVI = \sum_{\lambda_i}^{\lambda_n} \lvert\rho''(\lambda_i)\rvert \Delta\lambda_i$	(Elvidge & Chen, 1995)
CACI[f]	Chlorophyll absorption continuum index	$CACI = \sum_{\lambda_i}^{\lambda_n} (\rho_i^c - \rho_i)\Delta\lambda_i, \quad \rho_i^c = \rho_i + i\frac{d\rho^c}{d\lambda}\Delta\lambda_i$	(Broge & Leblanc, 2001)
CRCAI	Continuum-removed chlorophyll absorption index	$CRCAI = \sum_{\lambda_i}^{\lambda_n} \frac{\rho_i^c - \rho_i}{\rho_i^c}\Delta\lambda_i, \quad \rho_i^c = \rho_i + i\frac{d\rho^c}{d\lambda}\Delta\lambda_i$	(Broge & Leblanc, 2001)
CRCWD	Continuum-removed chlorophyll well depth	$CRCAI = 1 - \rho_{670}^c$	(Broge & Leblanc, 2001)

ρ denotes reflectance, λ denzotes wavelength, and a and b are the soil line coefficients.

[a] X is an adjustment factor, which is set to minimize background effects (X=0.08 in the original paper).

[b] R_s is the "shoulder" spectral reflectance, R_0 is the minimum spectral reflectance at wavelength λ_0 corresponding to the chlorophyll absorption well. λ is wavelength, and σ is the Gaussian function deviation parameter.

[c] $c_0, c_1, \ldots, c_6$ are the coefficients associated with the polynomial fit in reflectance space.

[d] $D_{\lambda(i)}$ is the first derivative value of the band i with the maximum first derivative. $D_{\lambda(i-1)}$ and $D_{\lambda(i+1)}$ are the first derivative values of adjacent bands.

[e] Δλ denotes the band width.

[f] ρ^c is the reflectance continuum.

Water stress :use of SWIR Band

- SWIR bands are not only sensitive to water content, but also to senescent components such as litters and crop residues
- Example use is to extract senescent grasses (normalized difference senescent vegetation index or normalized difference water index (NDWI))

$$LSWI = \frac{NIR - SWIR}{NIR + SWIR} \quad NDSVI = \frac{SWIR - NIR}{SWIR + NIR}$$

Water Content Indices

Land Surface Water Index:

$LSWI = (\rho_{red} - \rho_{swir}) / (\rho_{red} + \rho_{swir})$

-Xiao et al., 2002

Senescent Vegetation Index:

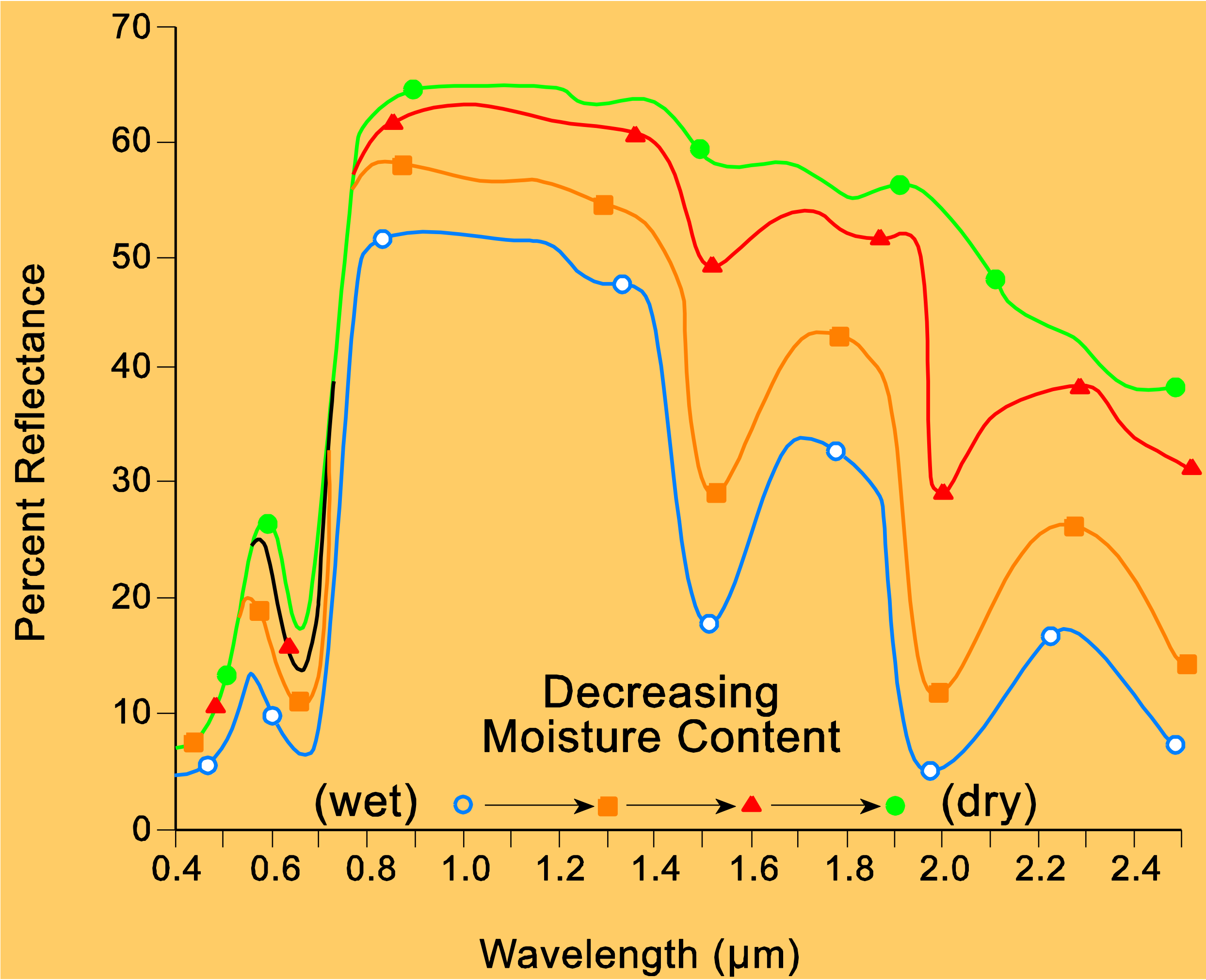
$NDSVI = (\rho swir - \rho red) / (\rho swir + \rho red)$

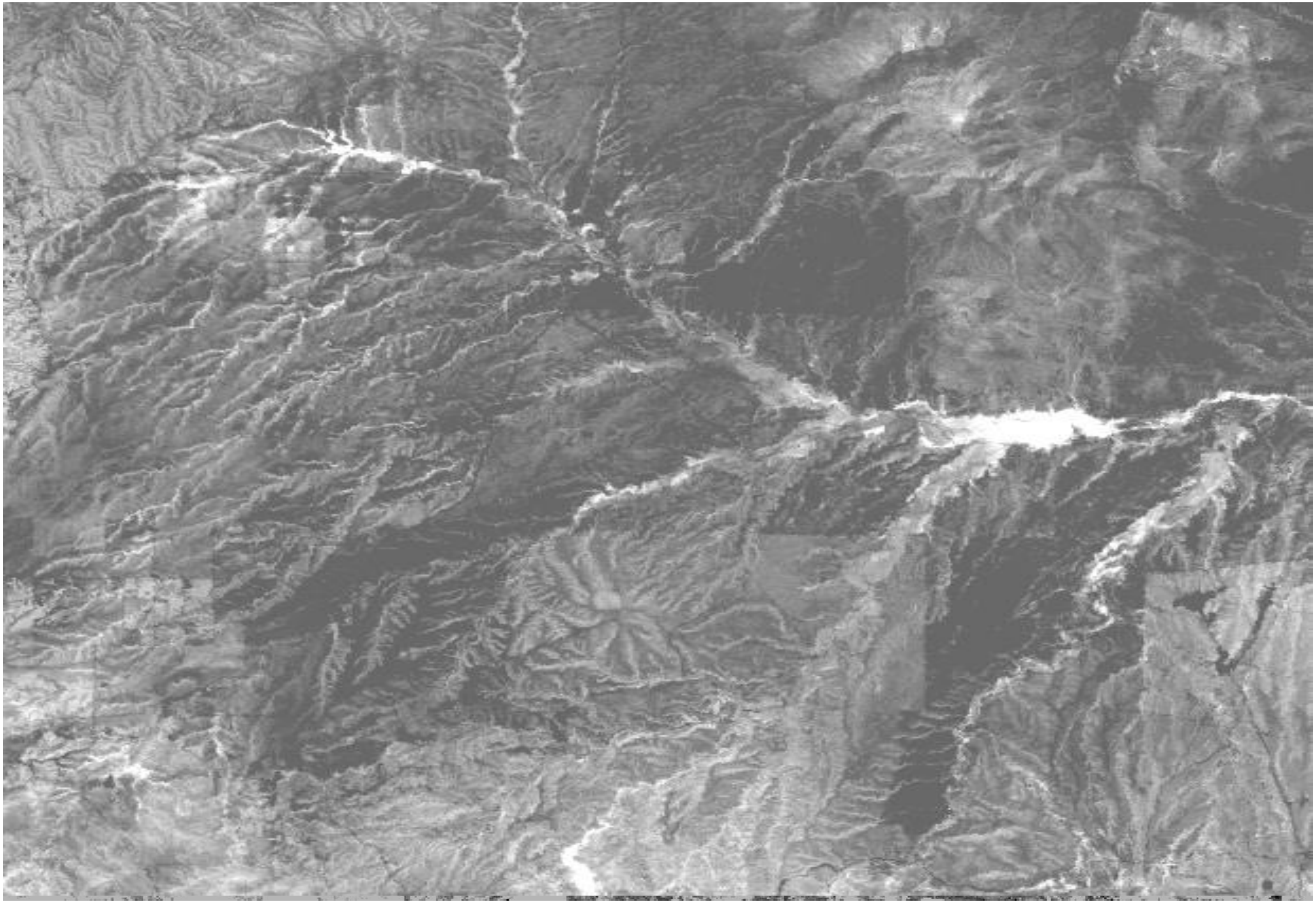
Qi et al., 2002

ρ_{red} and ρ_{swir} **=** atmospherically corrected surface reflectance in the red (620–670 nm), short wave infrared (SWIR1: 1628–1652 nm) wavelength, respectively

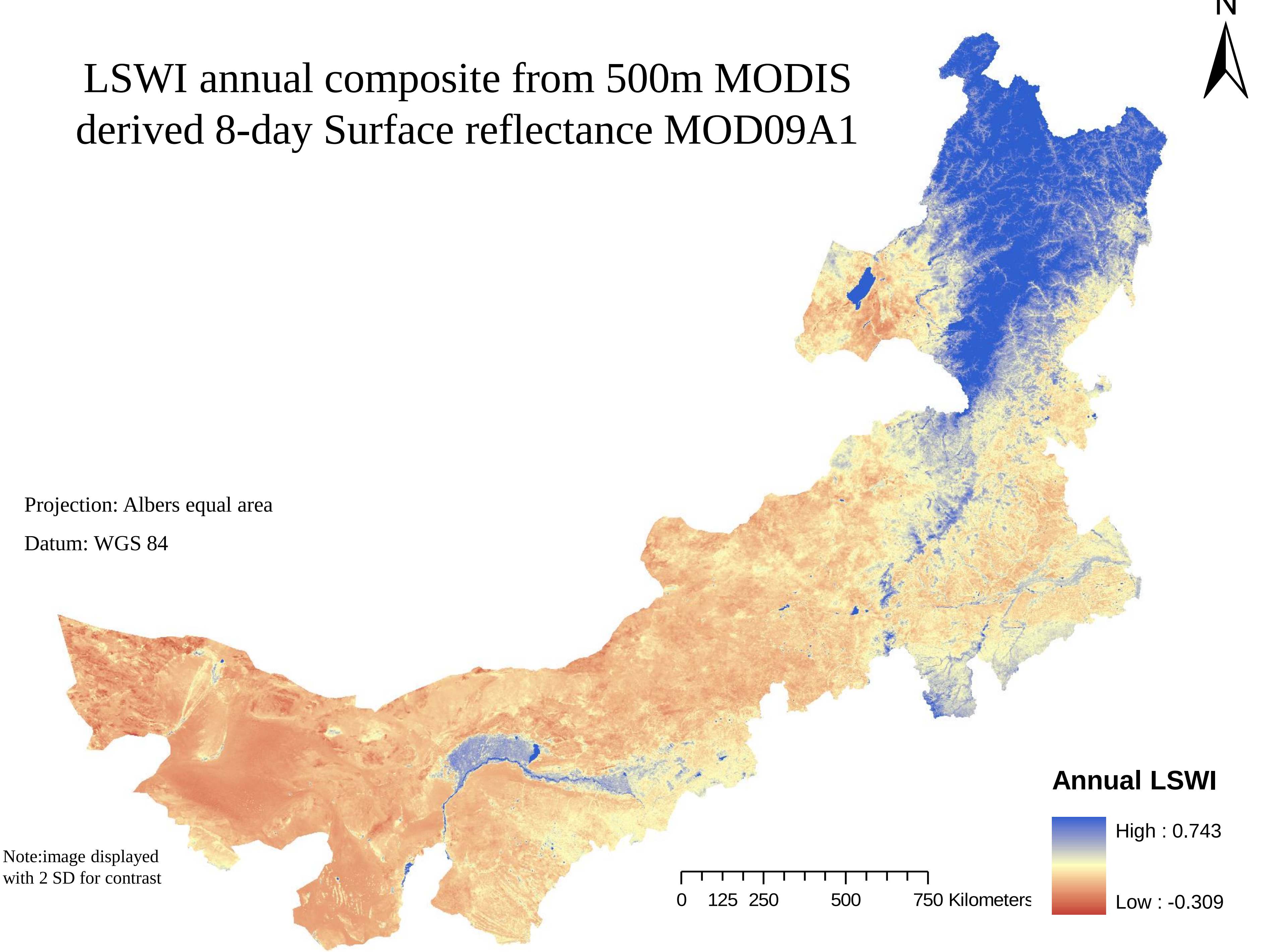
Physical Basis of Remote Sensing

- Vegetation reflectance in the SWIR
  - Primary biophysical control of reflectance
    - ✓ Internal leaf moisture content

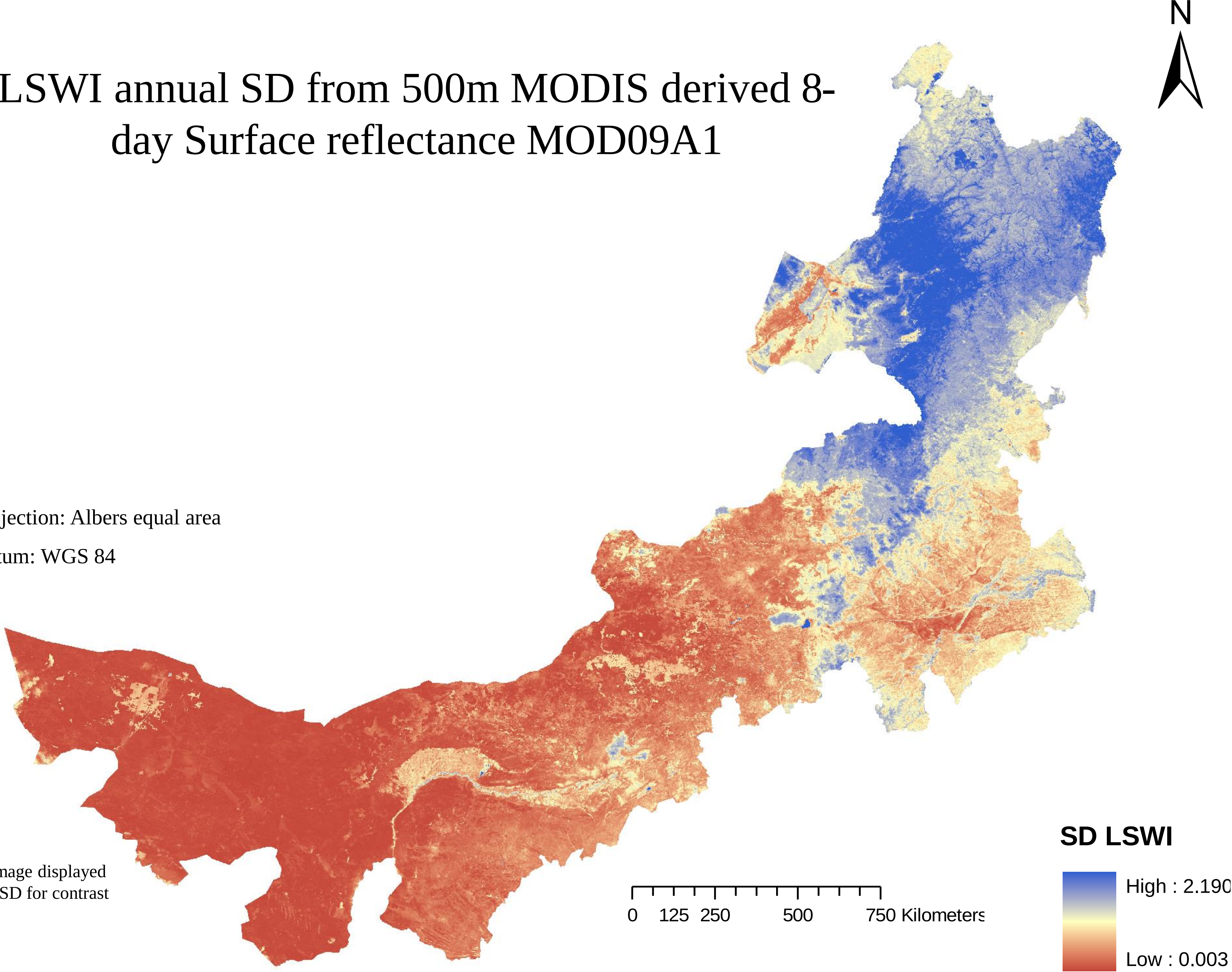




LSWI annual composite from 500m MODIS derived 8-day Surface reflectance MOD09A1



LSWI annual SD from 500m MODIS derived 8-day Surface reflectance MOD09A1

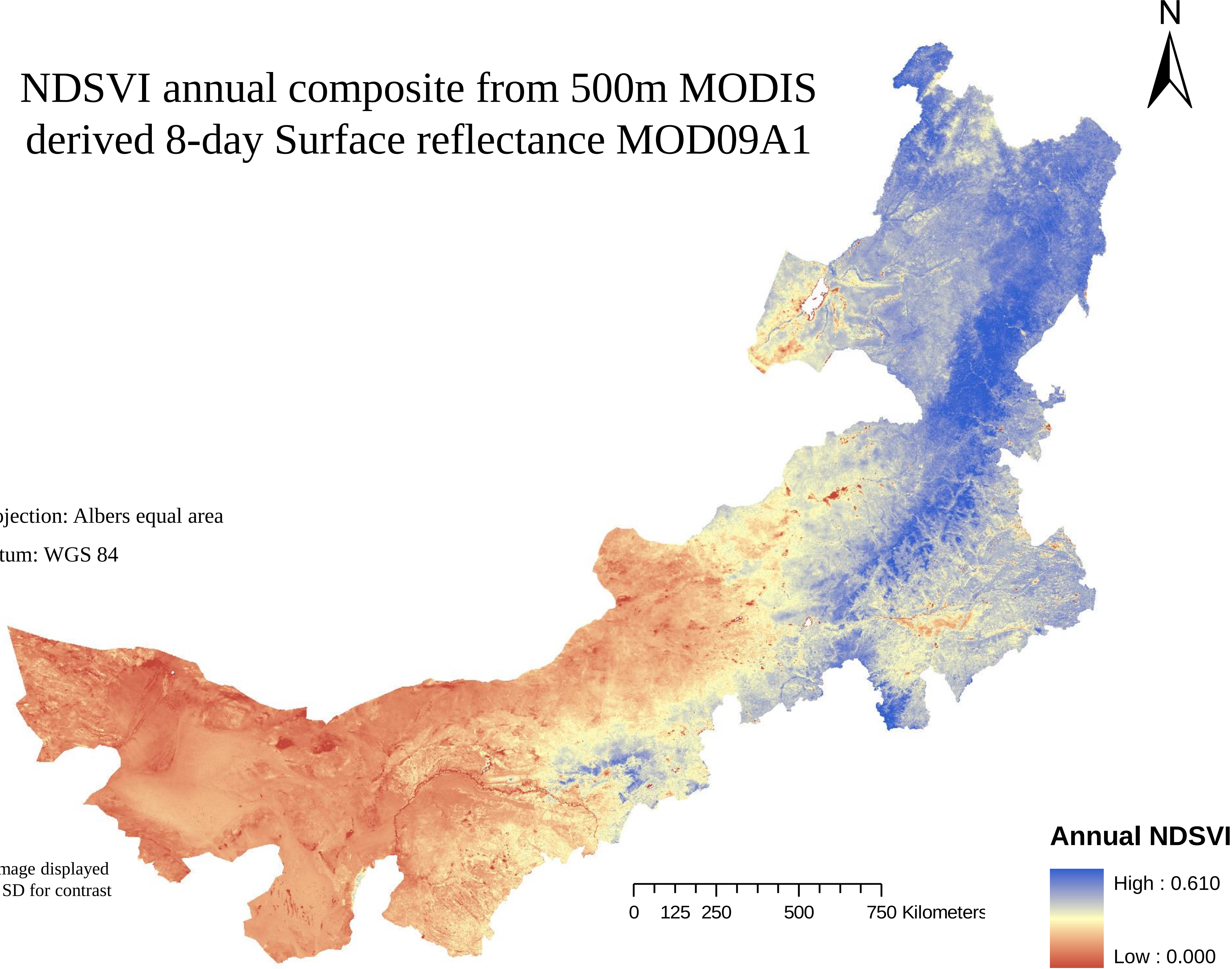


Projection: Albers equal area

Datum: WGS 84

Note:image displayed with 2 SD for contrast

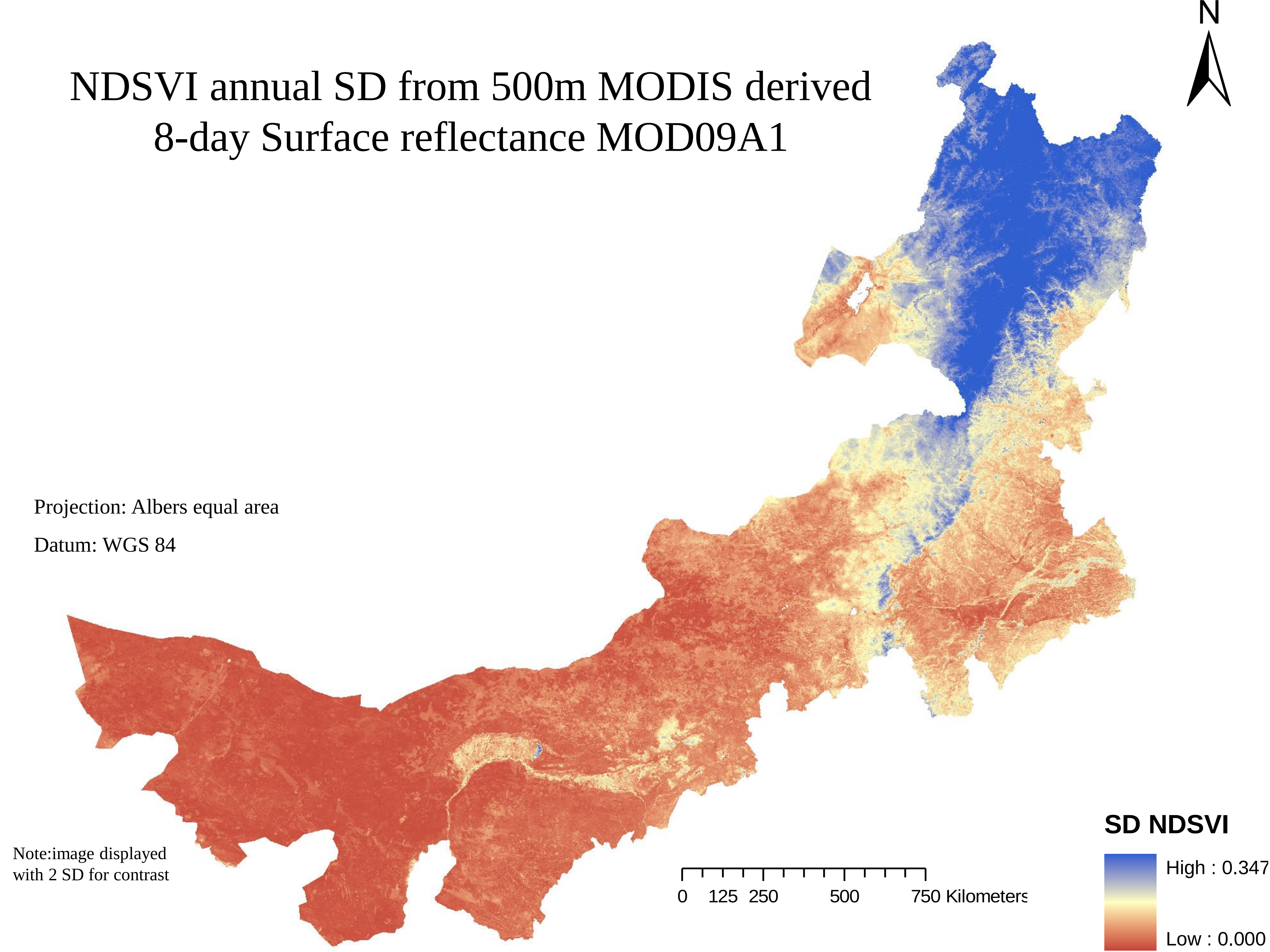
NDSVI annual composite from 500m MODIS derived 8-day Surface reflectance MOD09A1



Projection: Albers equal area

Datum: WGS 84

Note:image displayed with 2 SD for contrast


NDSVI annual SD from 500m MODIS derived
8-day Surface reflectance MOD09A1
N
Projection: Albers equal area
Datum: WGS 84
Note:image displayed
with 2 SD for contrast
0 125 250 500 750 Kilometers
SD NDSVI
High : 0.347
Low : 0.000

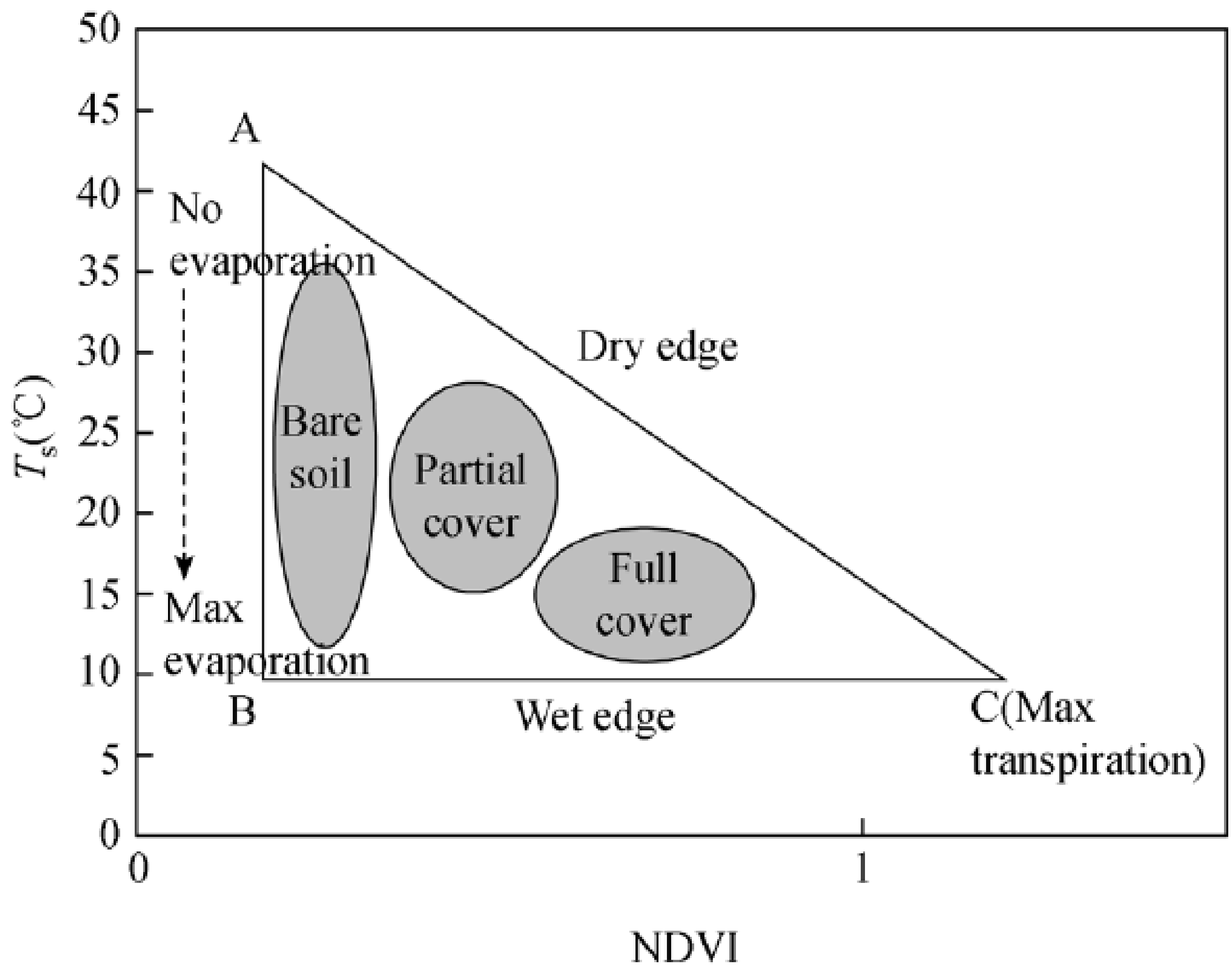
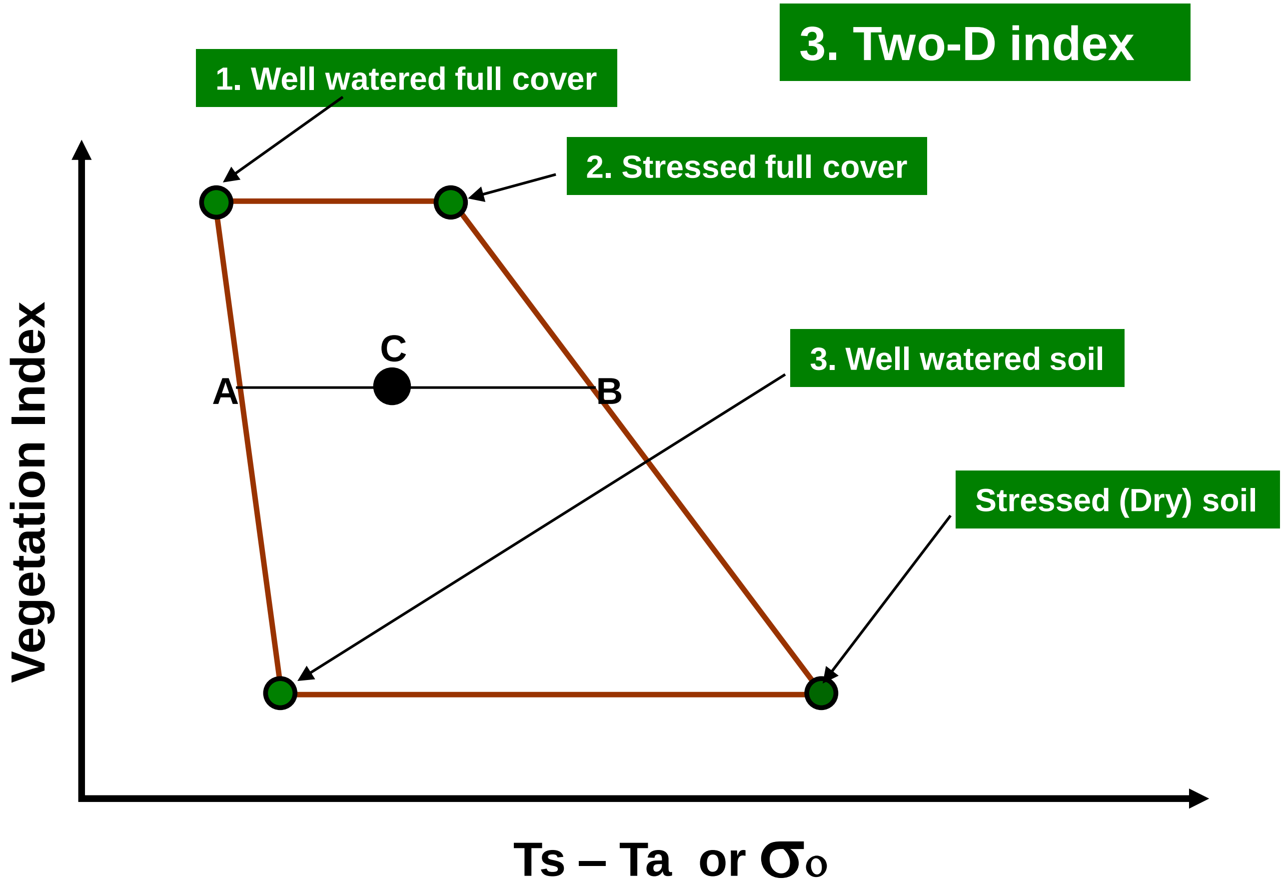


Fig. 1. T_s and NDVI triangular space (adapted from Price[5]).

Han et al 2006

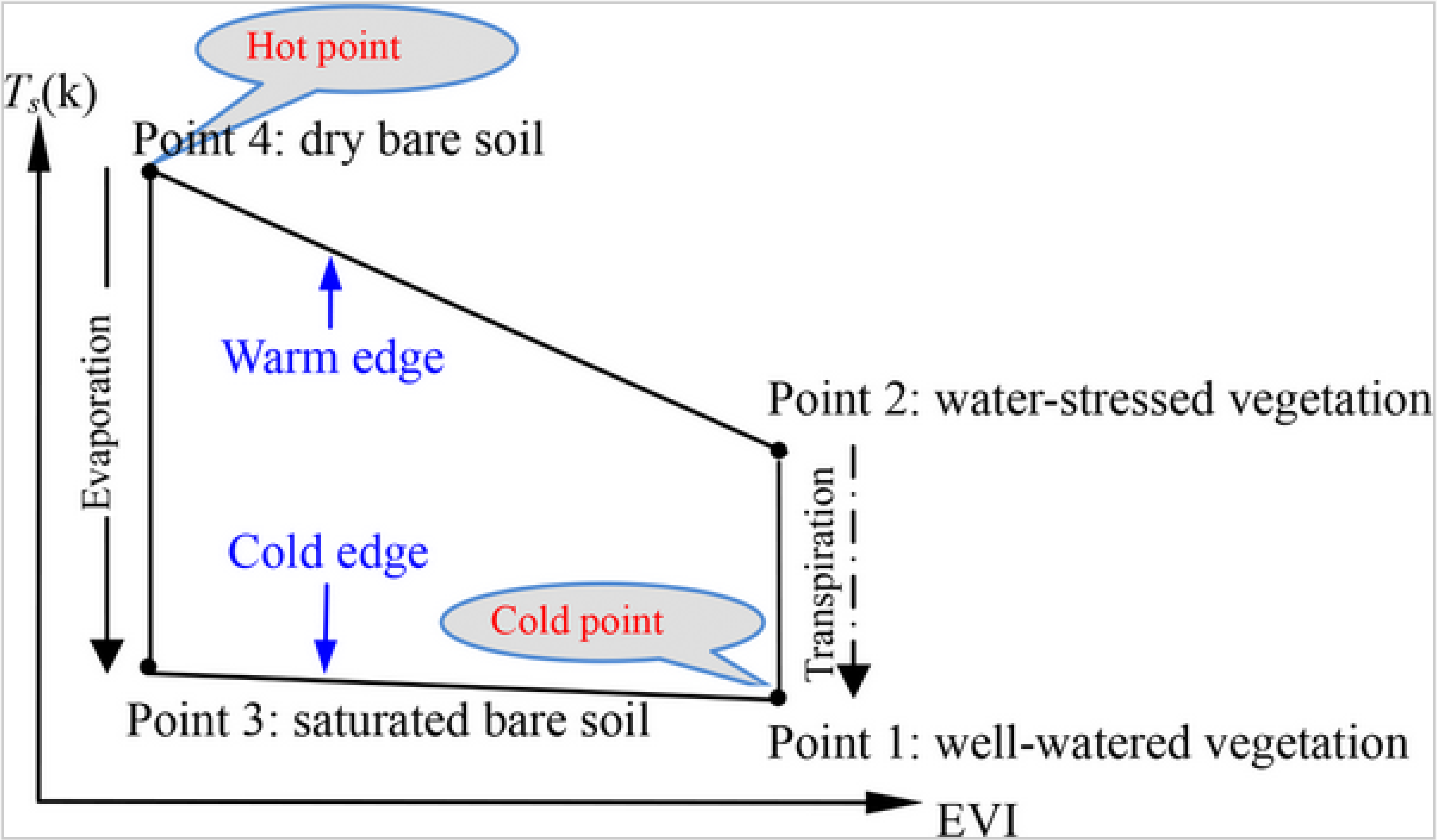
Plannar Indices



WDI = AC / AB is a measure of stress or components

×

Figure 1. Structure of the $T_s \sim VI$ trapezoidal space.

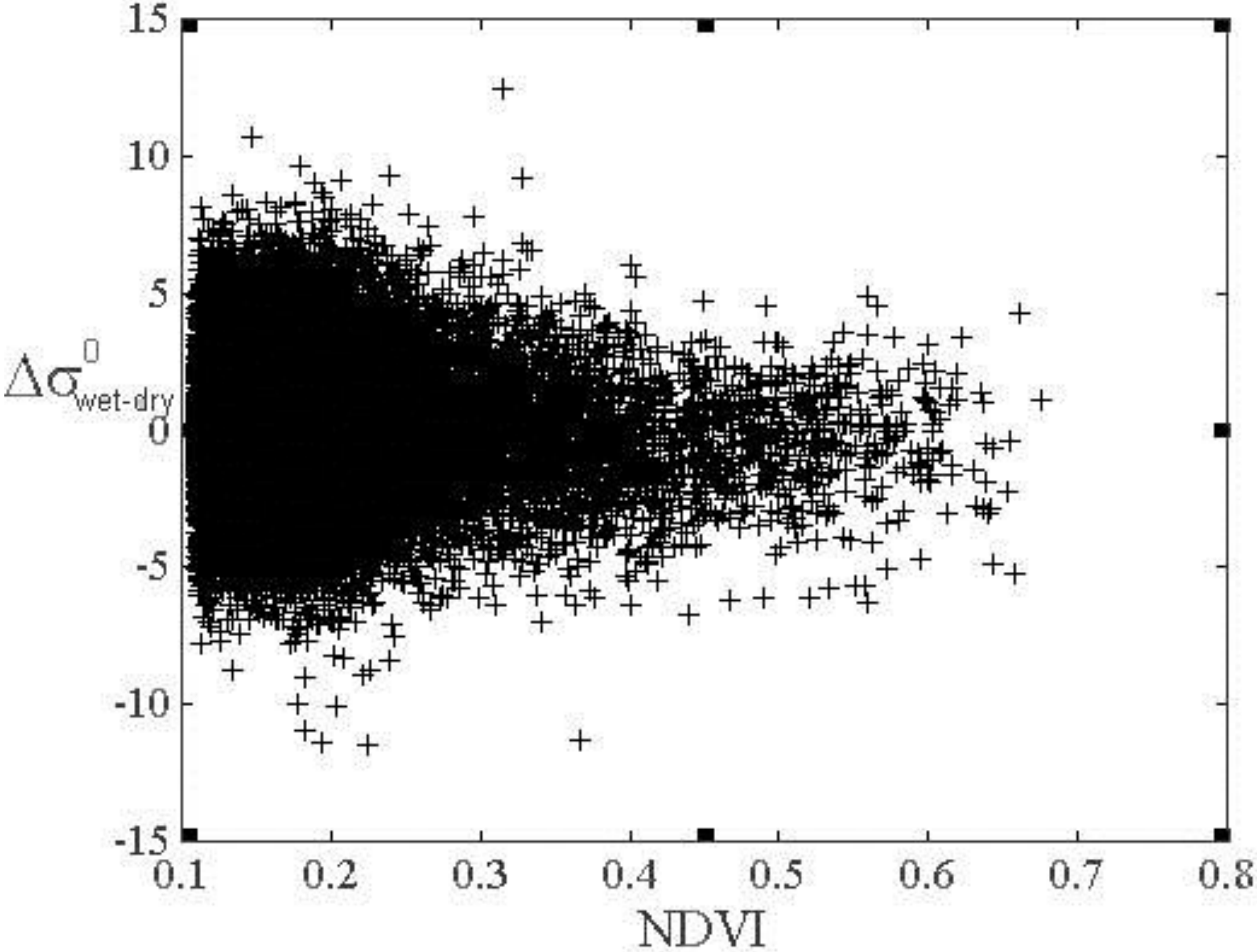


Wang et al 2014

Characteristics of P-Index

- Use more than one spectral dimension usually measured in very different spectral regions
- Unlike “Red-NIR”, these indices extract different features
- Usually different data sources

Planner Indices



Crop Water Stress Index (CWSI): estimate of crop water status for min and max levels of water stress that can occur due to availability or unavailability of water

$CWSI = (dT_m - dT_{LL})/(dT_{UL} - dT_{LL})$ ……………………………….(1)

where dT is difference between canopy and air ($T_{lst} - T_{air}$) and m, LL, and UL represent measured, lower limit (non-water-stressed), and upper limit (severely-stressed) of dT, respectively.

Upper and lower limits of dT can be estimated through the empirical approach. This is based on the assumption that there is a linear relationship between dT_{LL} and vapor pressure deficit (VPD) for a non-water-stressed crop under specific climatic conditions.

Similarly, there is a linear relationship between dT_{UL} and the vapor pressure gradient (VPG) for the same crop when its transpiration is halted due to severe water stress:

$dT_{LL} = a\,(VPD) + b$ ....(2)
$dT_{UL} = a\,(VPG) + b$ ....(3)

where “a” and “b” are slope and intercept of the linear relationship, respectively.
VPG is estimated as the difference between saturated vapor pressure at air temperature and at a higher temperature equal to air temperature plus the coefficient “b”

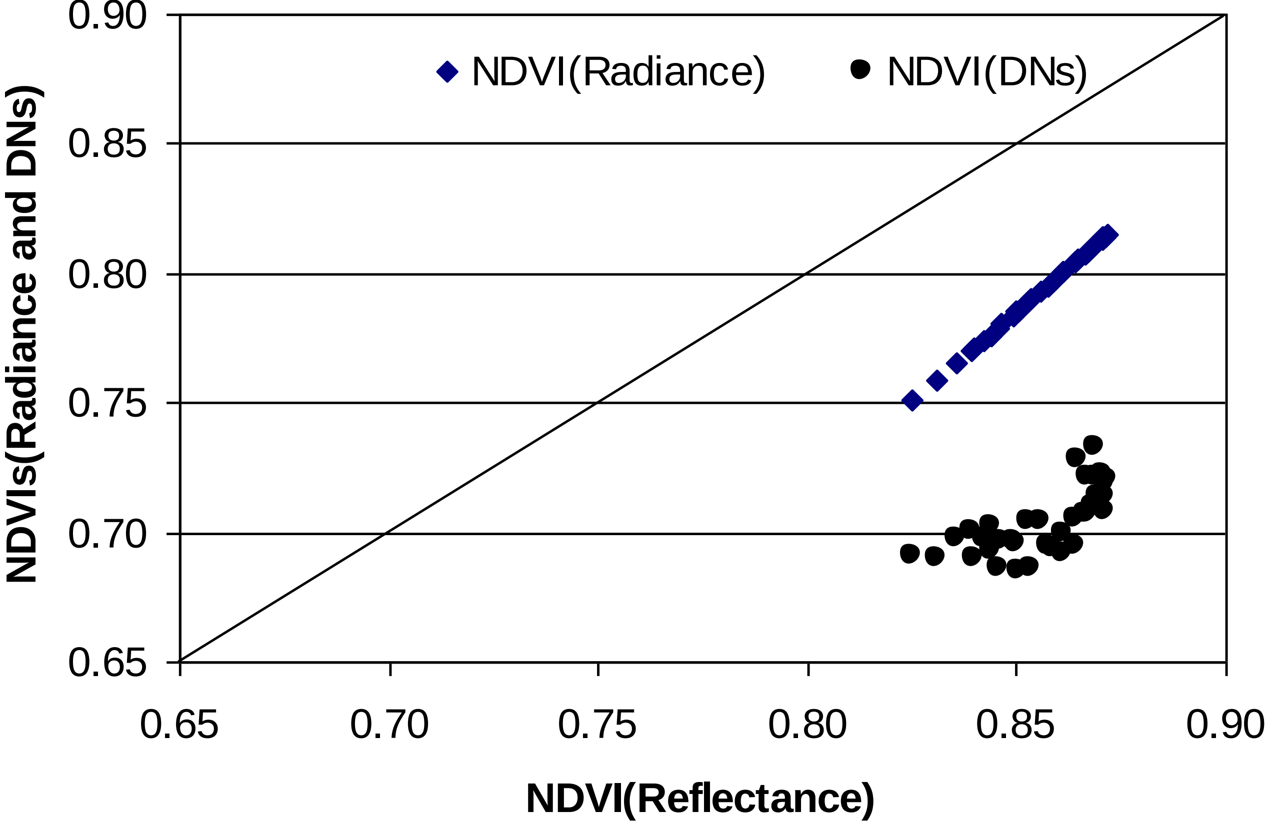
Taghvaeian et al 2012

Potentials

- Sensitive to vegetation
- Related to *f*PAR, GLAI, and other biophysical parameters
- Easy computation
- MODIS Backup system

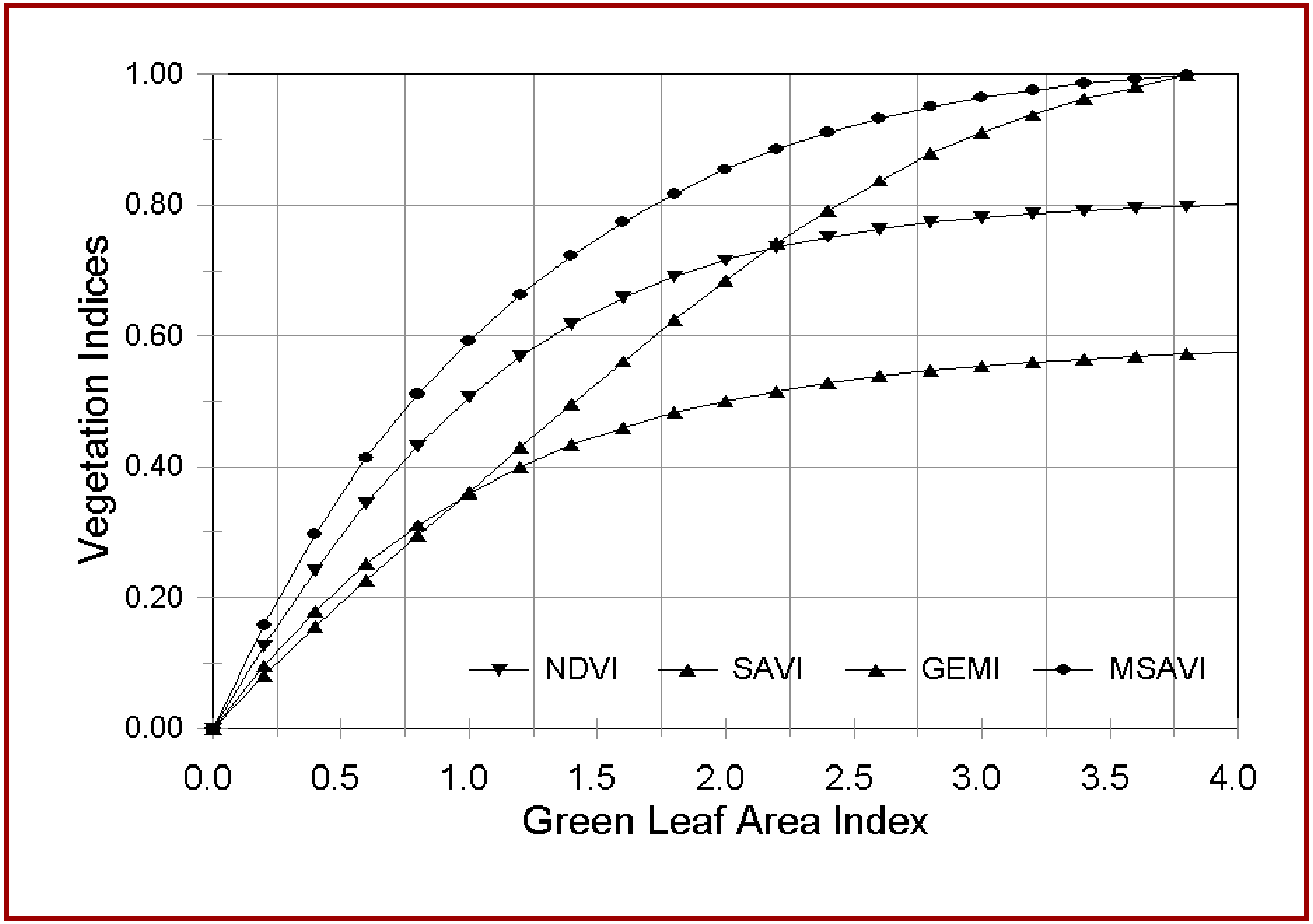
Issues

- Computation
  – Depends on data type and levels of correction
    - DNs vs. Radiance vs. Reflectance



Issues (*cont.*)

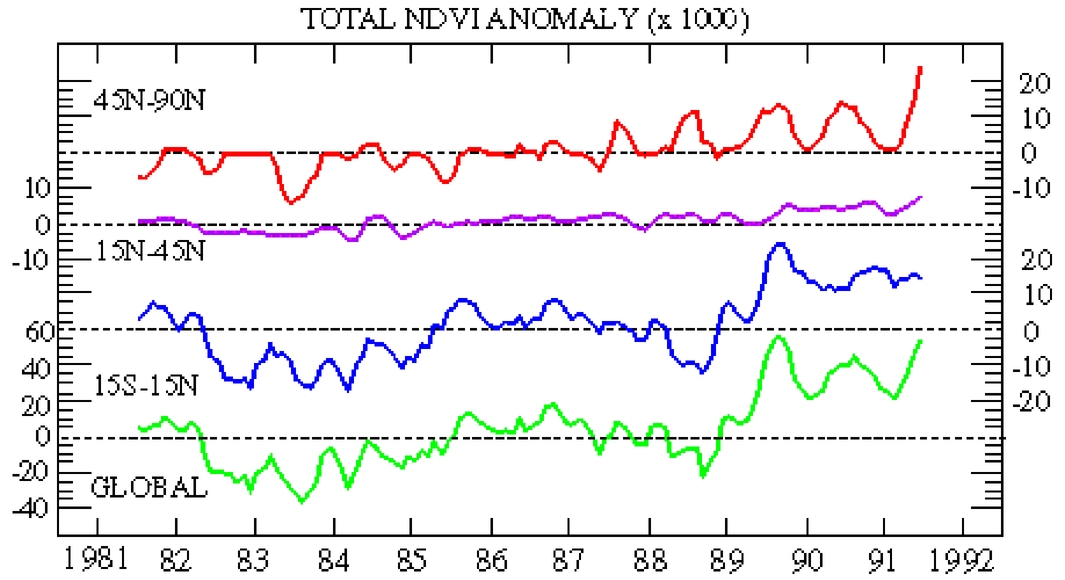
- Dynamic Ranges
  - Depends on crop and soil types

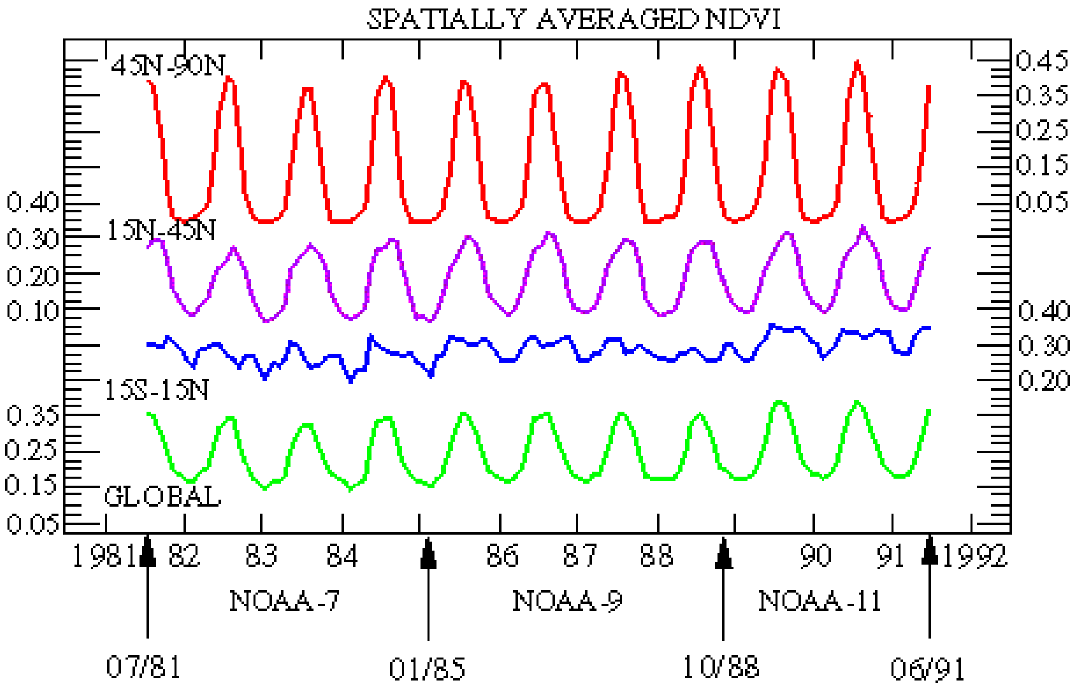


Issues (*cont.*)

- Spectral bands
- Location and bandwidth
  - Teillet et al., 1997 summarized potential uncertainties associated with spatial and spectral resolutions when computing NDVI and other spectral indices
- Sensitive to sensor characteristics??
  - An example of NDVI from a long term study with AVHRR for the North America

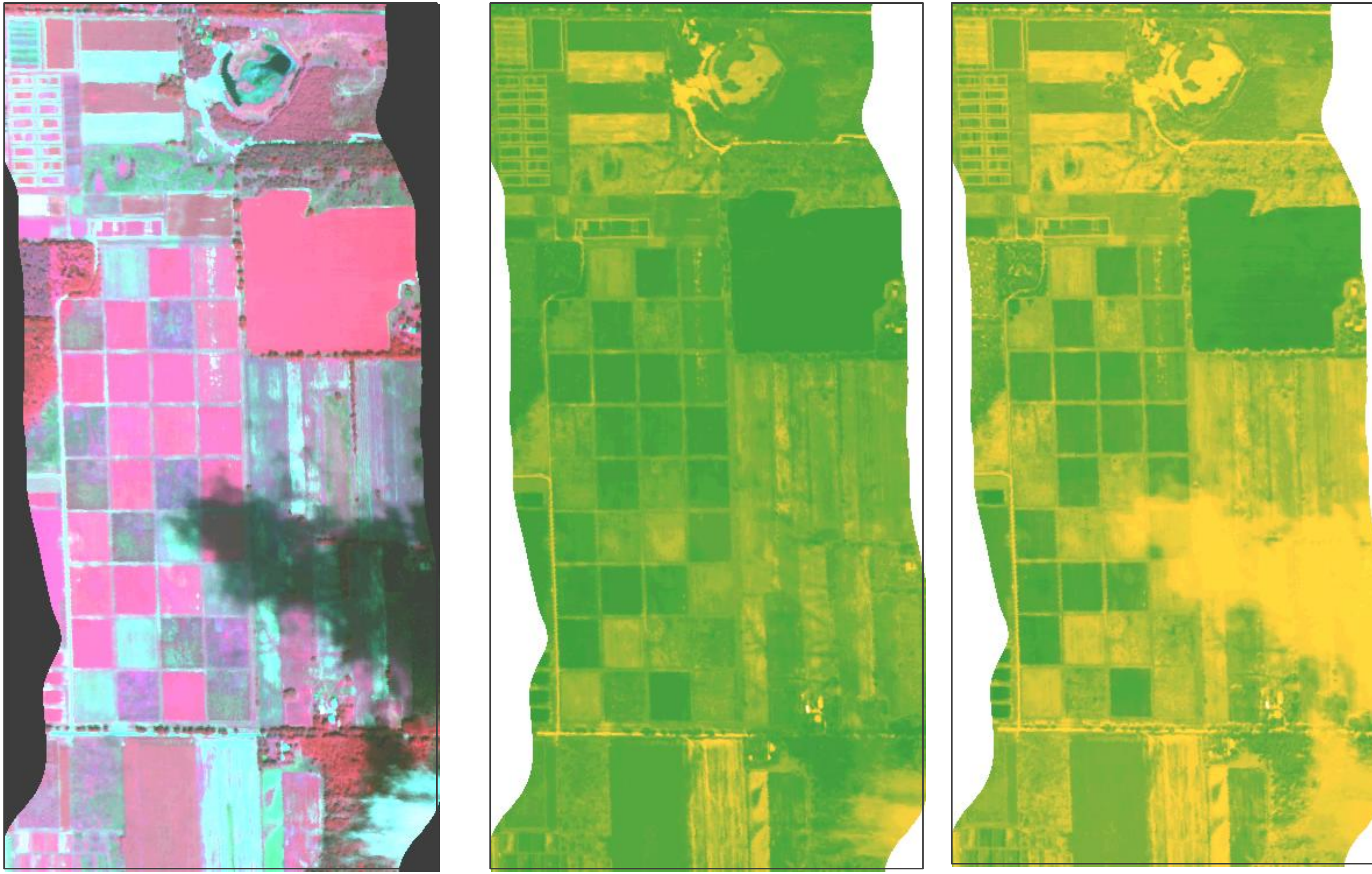
Example of "Greenner North"





Issues (*cont.*)

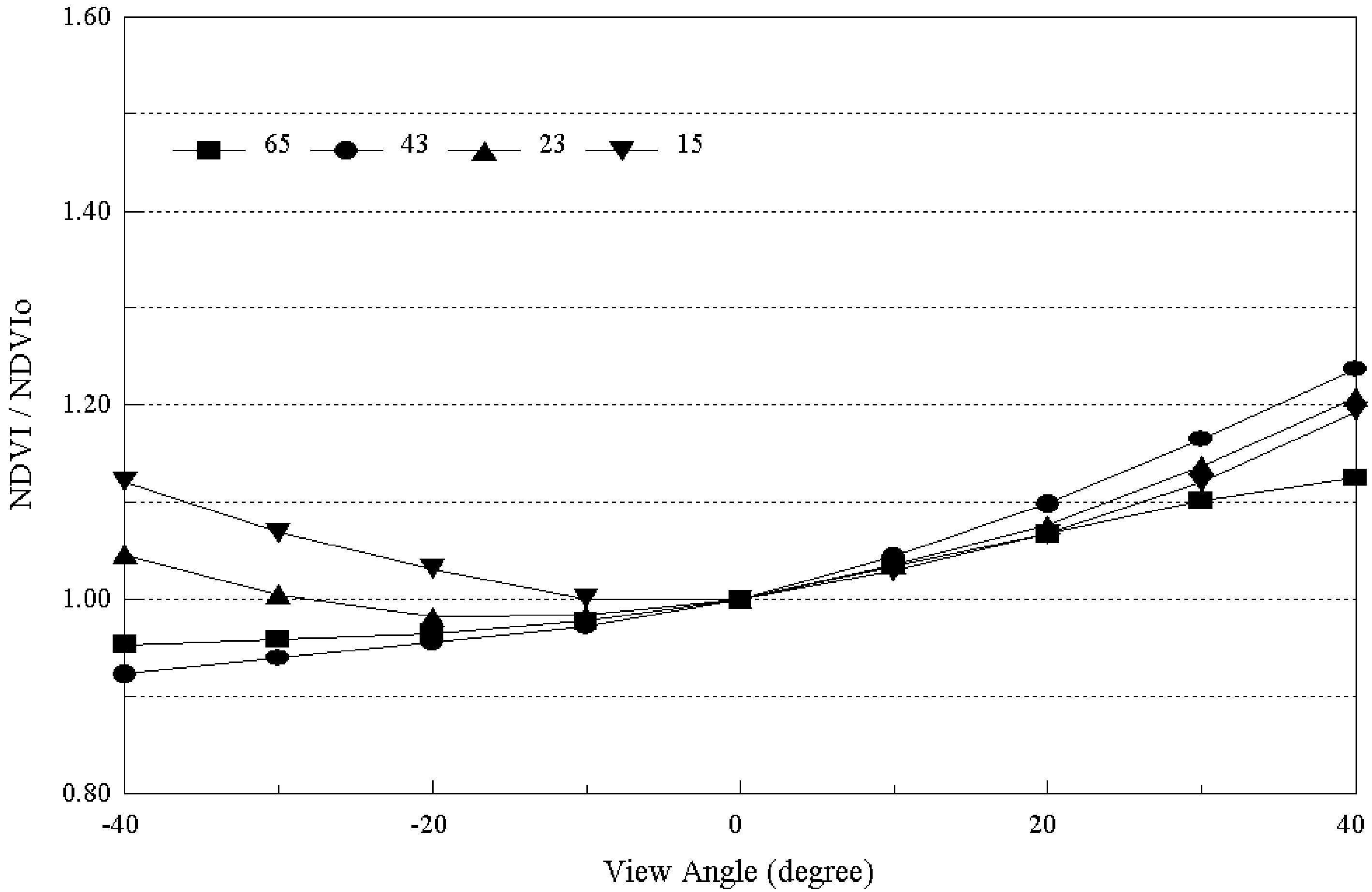
- What about radiometric resolution effects?
- How much detail can you “see”?
  - If you calculate SVIs from ETM and IKONOS images of the same targets, would you see the same thing? If not, why?



Issues (*cont.*)

- Sensitivity to Vegetation Changes
  - Depends on crop and soil types

- Sensitivity to Vegetation
  - Types and conditions (canopy architecture effect)
    - Vary with crop type: Corn vs. soybean for example
    - Coupled with stress conditions and density



1.60
1.40
1.20
1.00
0.80
65
43
23
15
NDVI / NDVIo
-40
-20
0
20
40
View Angle (degree)

Issues (*cont.*)

- Relationship with Biophysical Variables
- Is linear relationship better?

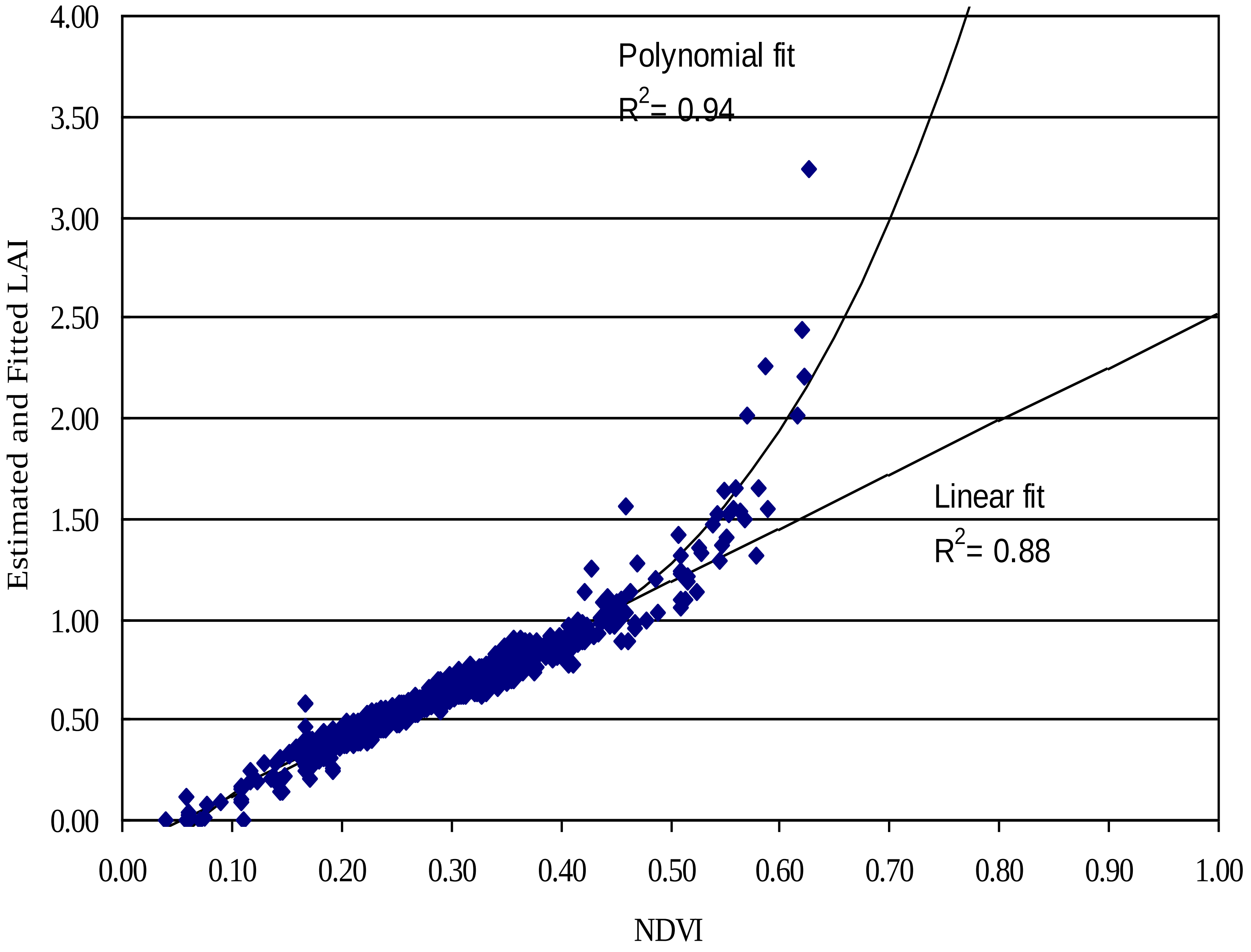
$LAI = ax^3 + bx^2 + cx + d,$

$LAI = a + bx^c,$

$LAI = -1/2a \ln (1 - x),$

$LAI = f(x)$

"..where x is either vegetation indices or reflectances derived from remotely sensed data. Coefficients a, b, c, and d are empirical parameters and vary with vegetation types. The last equation is a generic function of any form" (Qi et al 2002).



Polynomial fit
R^2= 0.94
Linear fit
R^2= 0.88
Estimated and Fitted LAI
NDVI
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

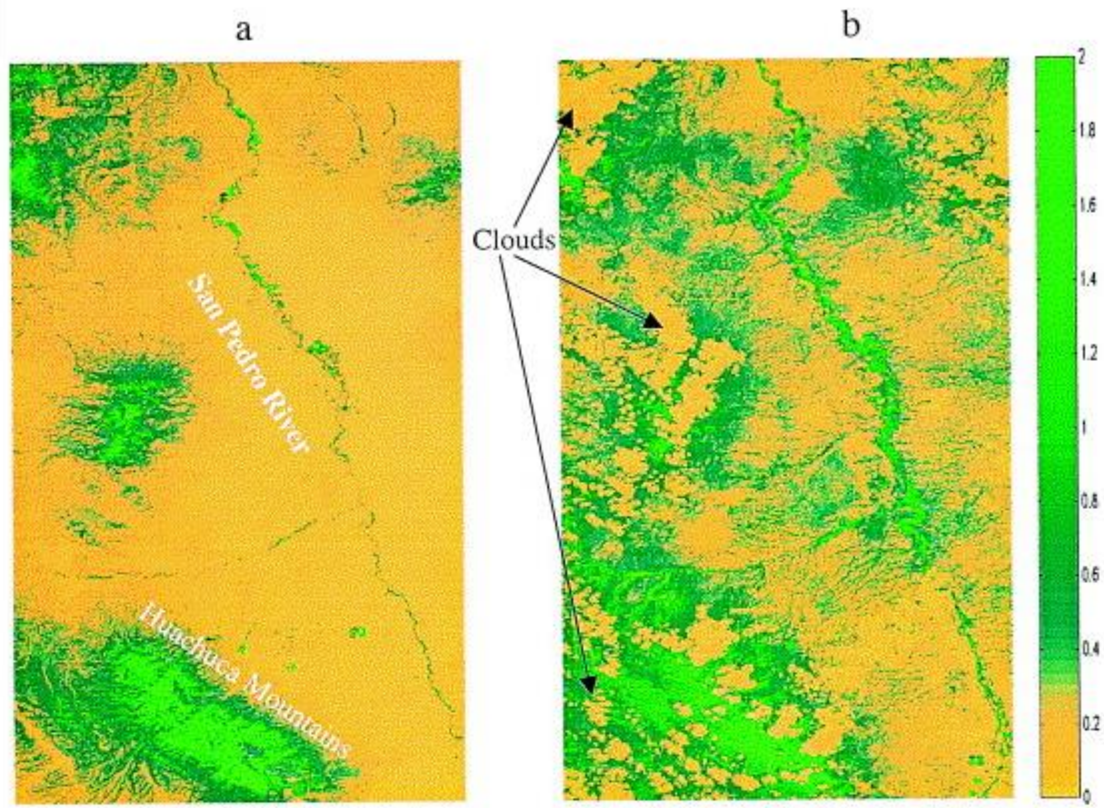


Fig. 4.

GLAI maps derived from TM imagery of: (a) 21 April 1997, DOY 111; 12 September 1997, DOY 255.

	LAI @ 50% fPAR	k
AW	4.62	0.15
SC	2.04	0.34
W	1.16	0.60
CW	0.55	1.25

$$fPAR = 1 - e^{-kLAI}$$

Glenn et al 2008, http://www.mdpi.com/1424-8220/8/4/2136

Criteria of VI Evaluation

1. Sensitive to vegetation
2. Insensitive to external factors
3. Easy computation
4. What about bidirectional effect?
5. Should we try to normalize VIs to a single sun angle?

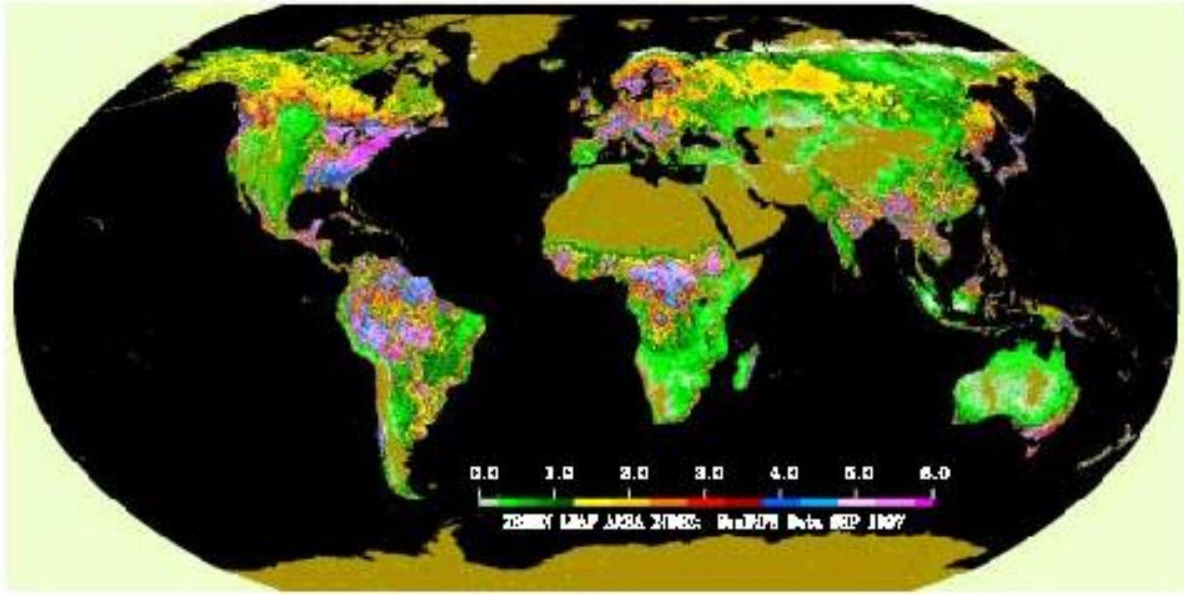
Criteria of VI Evaluation

$$dVI = \frac{\partial VI}{\partial S}dS + \frac{\partial VI}{\partial V}dV + \frac{\partial VI}{\partial A}dA + \frac{\partial VI}{\partial B}dB + \ldots$$

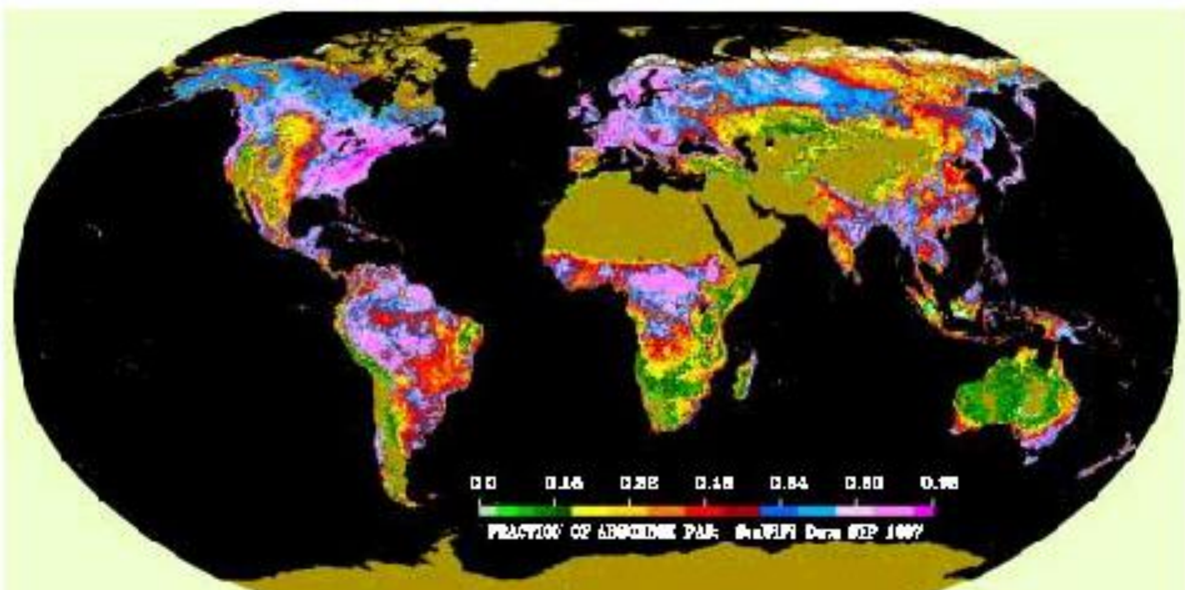
$$S/N = \frac{\frac{\partial VI}{\partial V}dV}{\frac{\partial VI}{\partial S}dS + \frac{\partial VI}{\partial A}dA + \frac{\partial VI}{\partial B}dB} ?$$

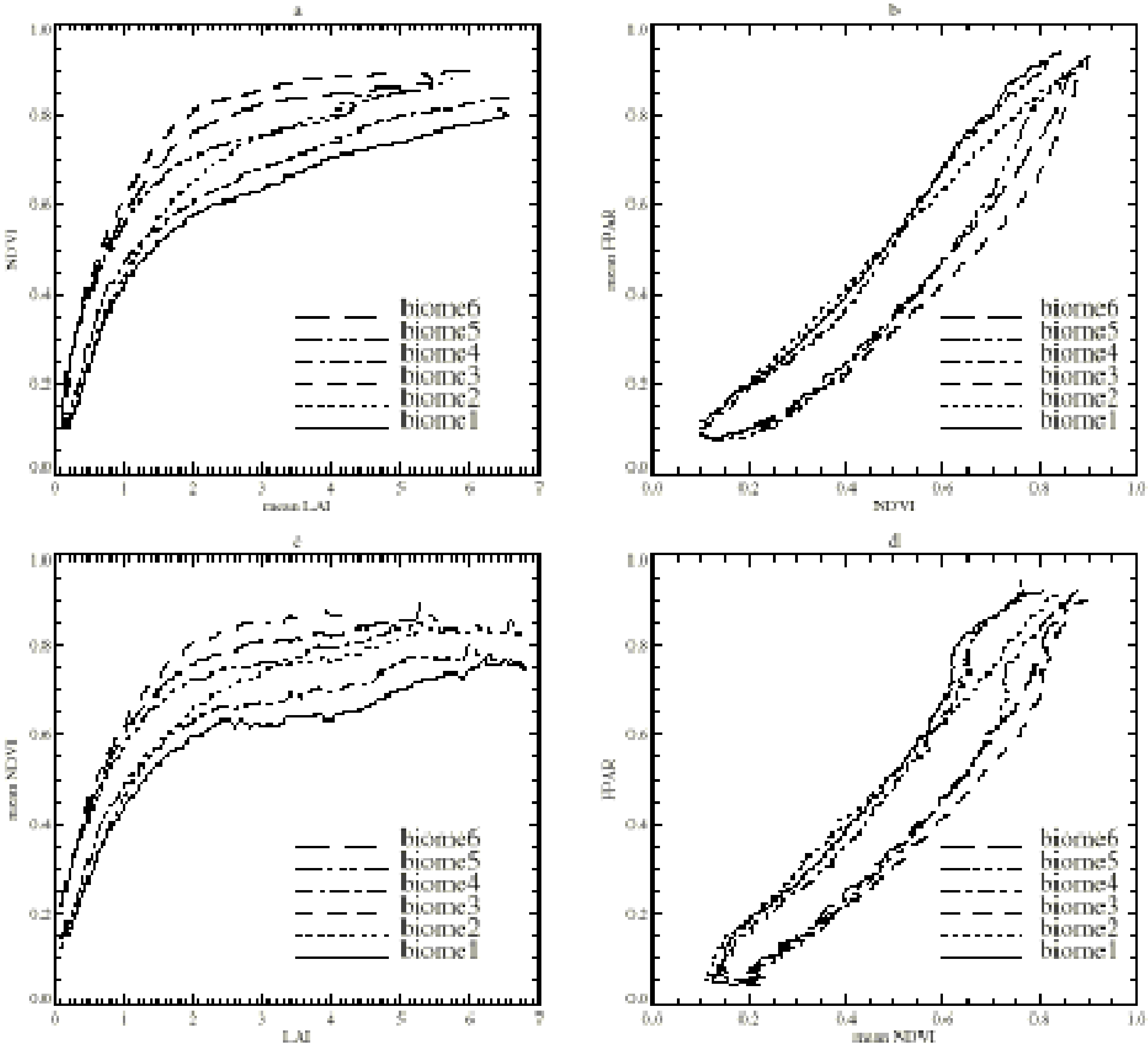
VI Applications

- VIs are primarily sensitive to “green” vegetation.
- Can be quantitatively related to *f*PAR, GLAI, and other biophysical parameters
- Can be easily computed
- Have been used in MODIS fPAR and LAI retrievals as a backup system

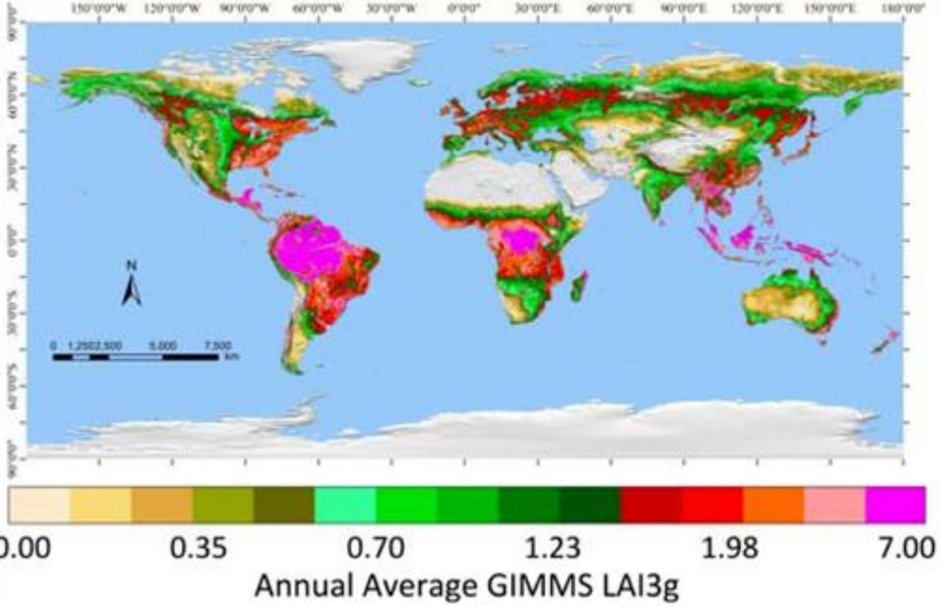


a)

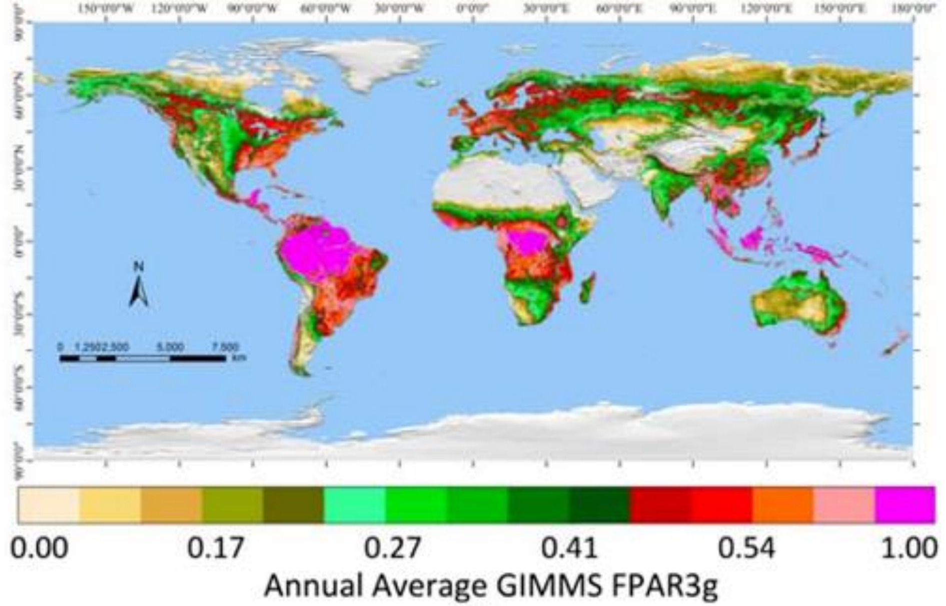




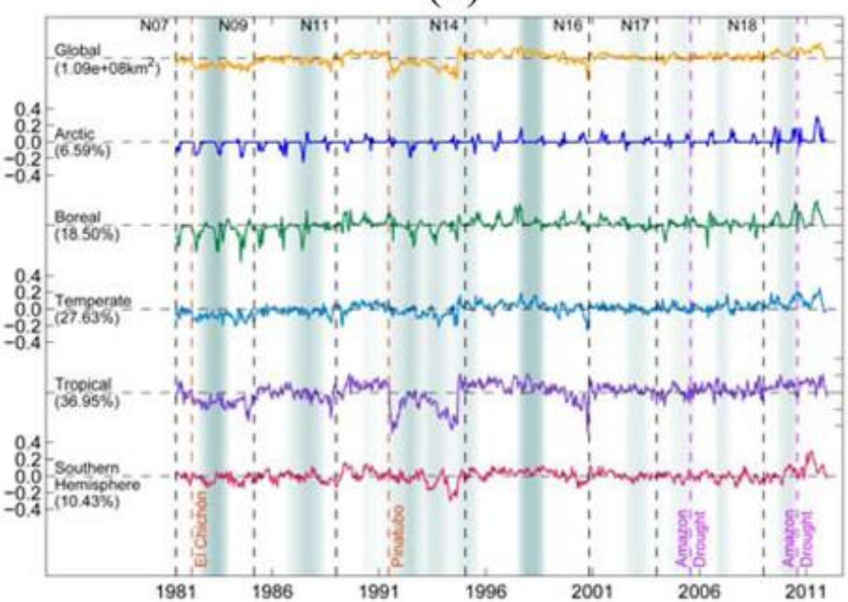
a
b
c
d
NDVI
mean LAI
mean FPAR
NDVI
mean NDVI
LAI
FPAR
mean NDVI
biome6
biome5
biome4
biome3
biome2
biome1


0.00
0.35
0.70
1.23
1.98
7.00
Annual Average GIMMS LAI3g

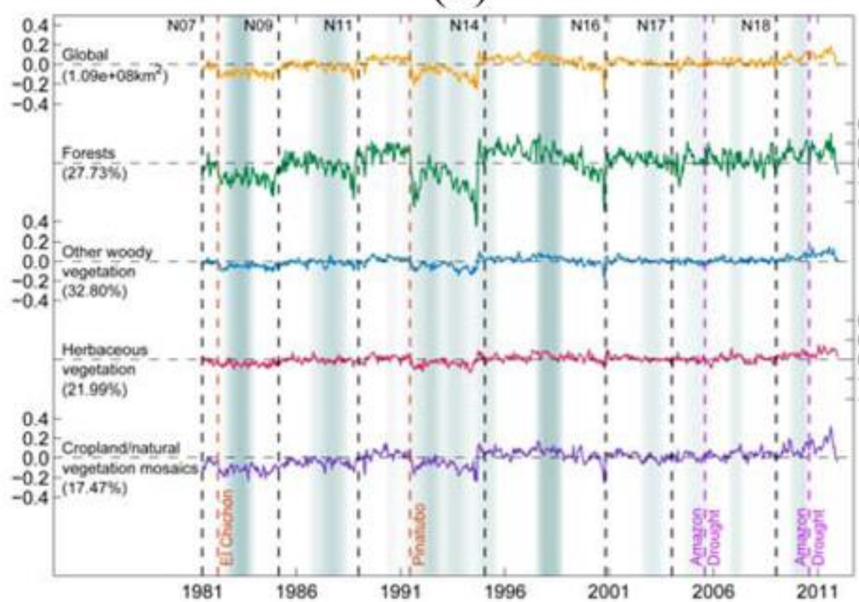
(**a**)


0.00
0.17
0.27
0.41
0.54
1.00
Annual Average GIMMS FPAR3g

(**b**)

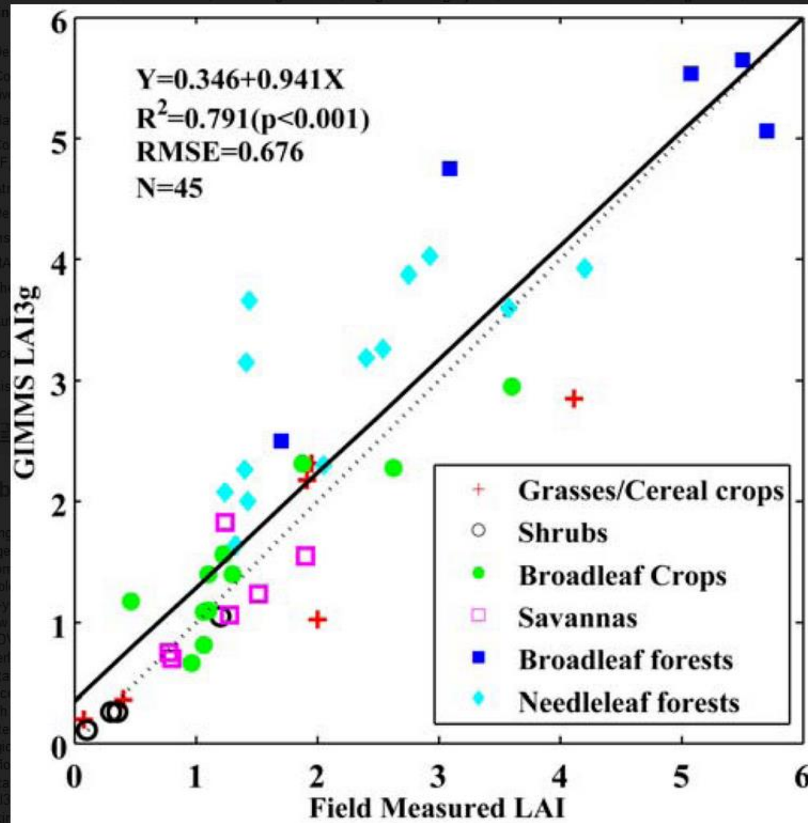

N07
N09
N11
N14
N16
N17
N18
Global
(1.09e+08km2)
Arctic
(6.59%)
Boreal
(18.50%)
Temperate
(27.63%)
Tropical
(36.95%)
Southern
Hemisphere
(10.43%)
El Chichon
Pinatubo
Amazon
Drought
Amazon
Drought
1981
1986
1991
1996
2001
2006
2011

(**c**)


N07
N09
N11
N14
N16
N17
N18
Global
(1.09e+08km2)
Forests
(27.73%)
Other woody
vegetation
(32.80%)
Herbaceous
vegetation
(21.99%)
Cropland/natural
vegetation mosaics
(17.47%)
El Chichon
Pinatubo
Amazon
Drought
Amazon
Drought
1981
1986
1991
1996
2001
2006
2011

(**d**)

Figure 2. Comparison of LAI3g with scaled field measurements from six biomes representative of the global land cover classes. A total of 45 field data sets from 29 sites listed in Table A4 of [40] were used (details of field data handling to derive LAI values comparable to satellite retrievals of LAI can be found in [36]).



Vegetation Fractional Cover

- Two components only: soil and vegetation. If vegetation cover is *fc*, then percent soil is 1 – *fc*. The synthesized signal ρ is:

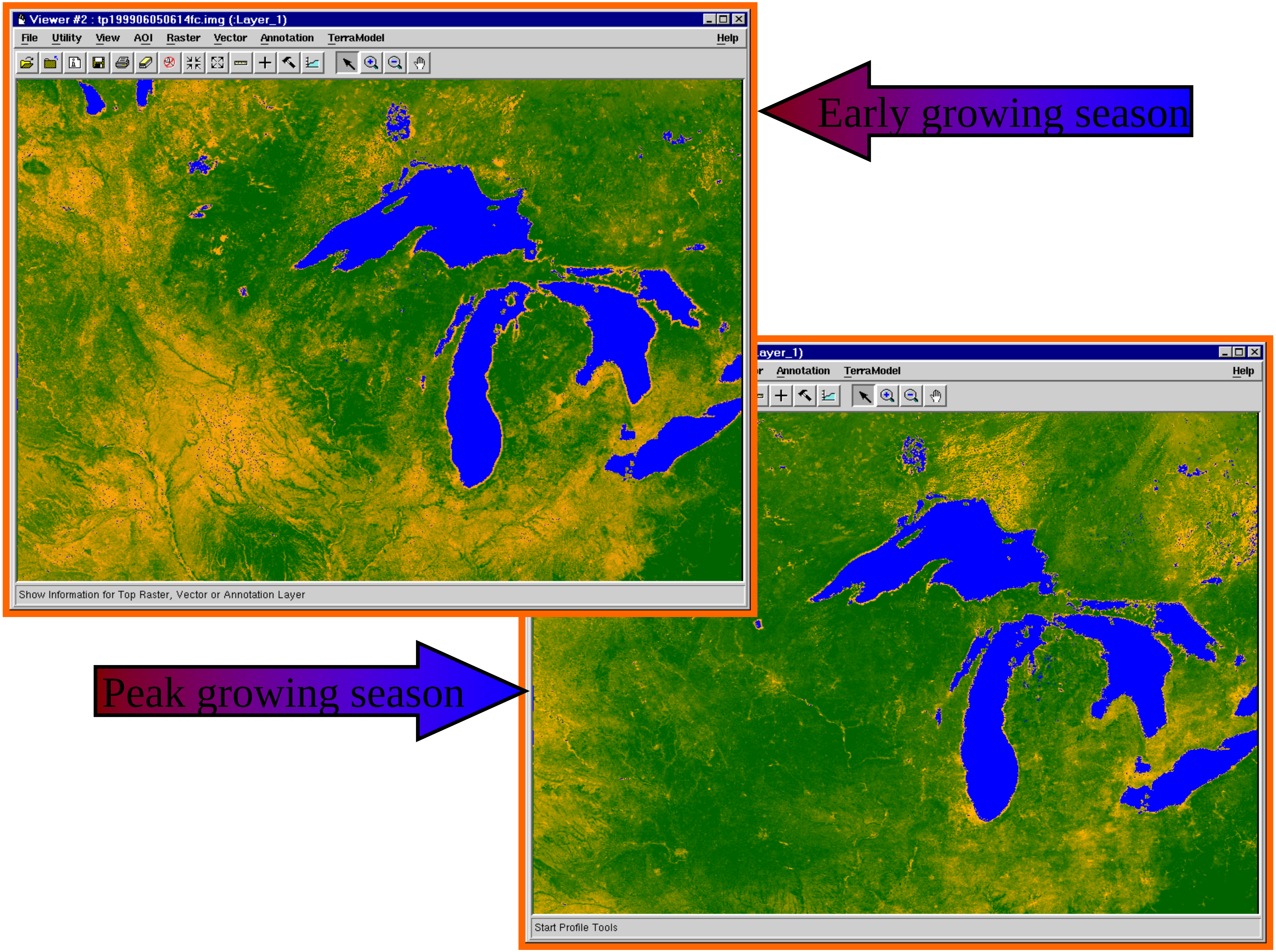
$$\rho = fc \times \rho_{canopy} + (1 - fc)\rho_{soil}$$

Vegetation Fractional Cover

- Solving for *fc*, we get:

$$fc = \frac{\rho - \rho_{soil}}{\rho_{canopy} - \rho_{soil}}$$

$$fc = \frac{vi - vi_{soil}}{vi_{canopy} - vi_{soil}}$$


Viewer #2 : tp199906050614fc.img (:Layer_1)
File Utility View AOI Raster Vector Annotation TerraModel Help
Show Information for Top Raster, Vector or Annotation Layer
Early growing season
ayer_1)
r Annotation TerraModel Help
Start Profile Tools
Peak growing season

Remarks

- Most indices are indicators of “green”, which can be related to crop yields and total biomass
- Lack of effort on the development of new indicators of other vegetation/surface characteristics such as chlorophyll concentration, N stress, water stress, etc.
- Some caution should be considered:
  - Soil, atmosphere, and BRDF

Remarks

- Spectral information needs to be further explored, especially with hyperspectral sensors.
- Aware of these potentials and limitations – it helps on the interpretation of your findings
- VIs should be combined with modeling effort.
- Overall, it is a practical way of mapping vegetation spatial variability, which can be used for many other applications.

SVI in Global Change

- The accumulation of carbon dioxide in the atmosphere is considered to be the primary forcing agent for global climate change, so forecasts of future climate require that the fate of carbon dioxide released into the atmosphere be understood.
- Recent analyses of the global carbon cycle suggest a significant role for terrestrial uptake in the Northern Hemisphere of CO_2 in the overall budget (missing carbon).
- Characterizing the location and mechanism of carbon sinks is of scientific and political importance (the Kyoto Protocol of the UNFCCC).
- SVI has been used to show “evidence” of greener high latitude.

SVI in Global Change

- Satellite observations of vegetation have provided global coverage with relatively high spatial resolution and consistent time coverage since the early 1980s.
- Satellite observations of vegetation greenness is a measurement of the amount and functioning of plants which consume atmospheric carbon dioxide and synthesize sugars (photosynthesis). Watching the greening over the years is a good indication of carbon sequestration.
- Vegetation biomass cannot be directly measured from space yet, but , remotely sensed greenness can be used as an effective surrogate for biomass on decadal and longer time scales in regions of distinct seasonality.