Determining Regional Arctic Tundra Carbon Exchange: A Bottom-Up Approach

Thanks to:

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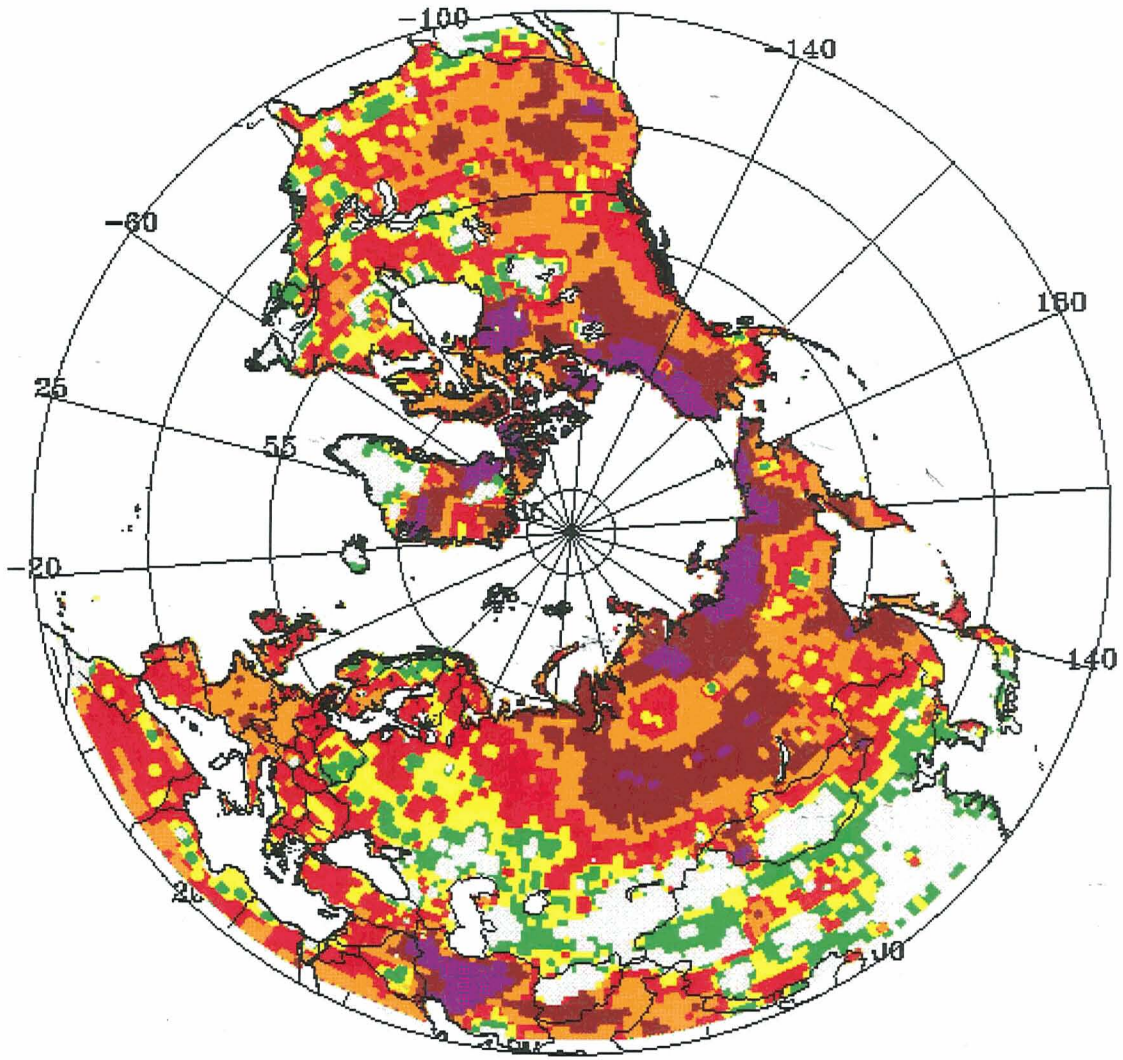
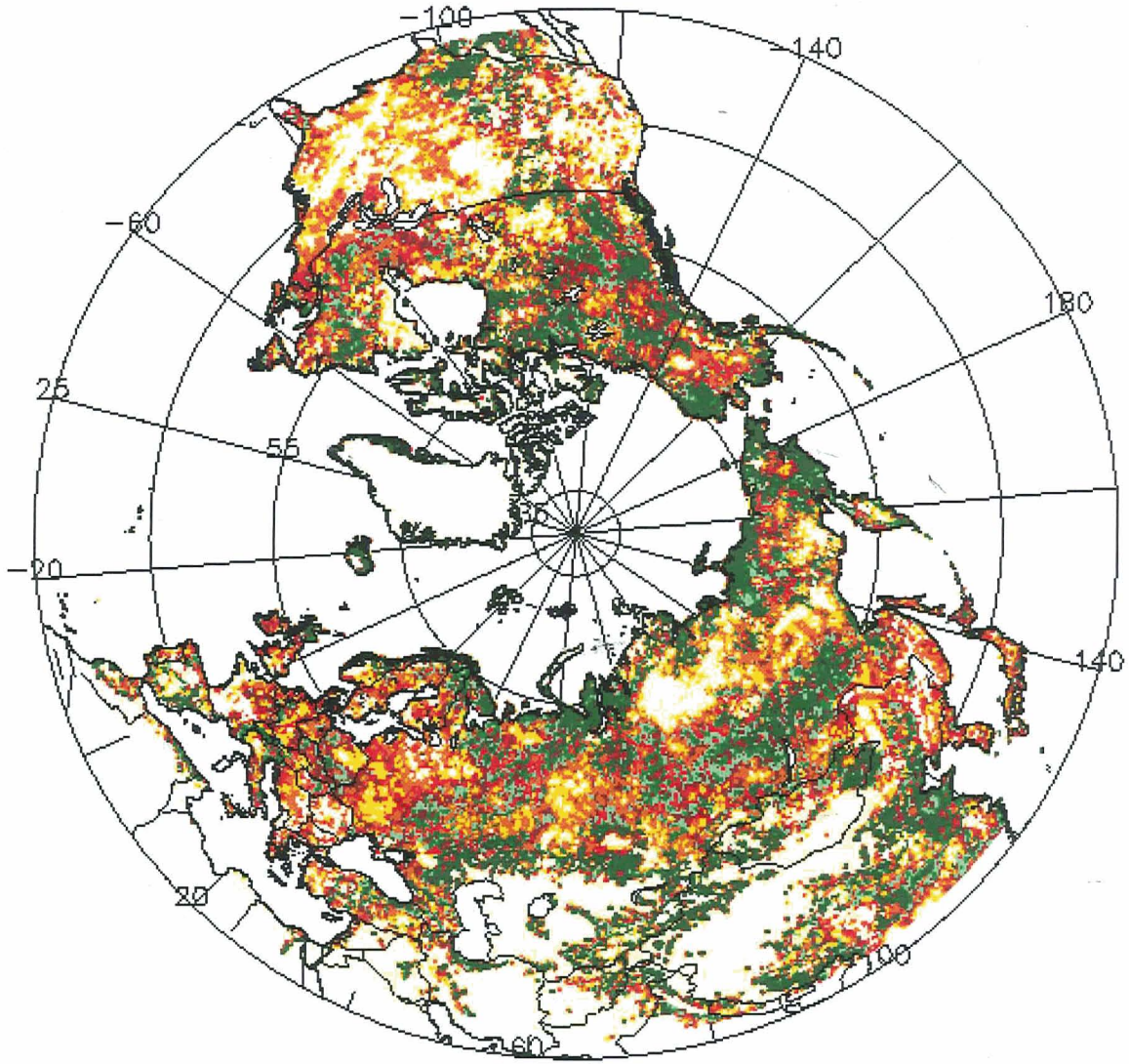
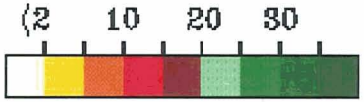
SPRING TEMPERATURE TREND (1982-1990)



UNITS: DEGREES C/YEAR

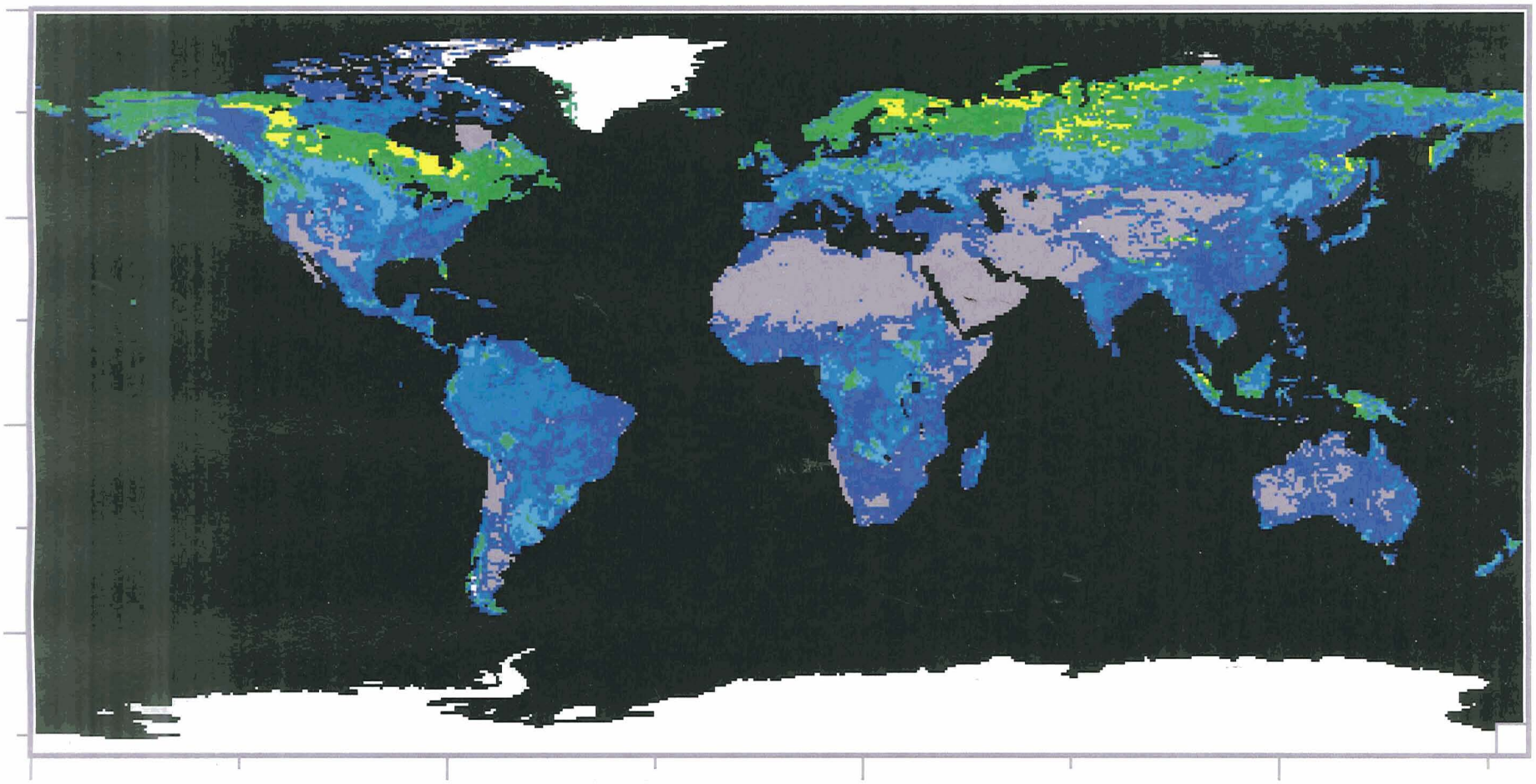
HIGH LATITUDE GREENING TREND (1982-1991)

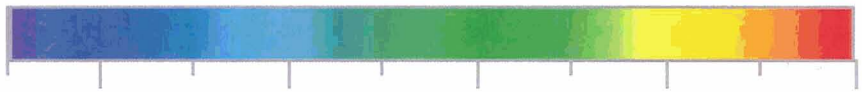




% CHANGE IN MAY:SEP AVERAGE NDVI

Soil Carbon





Less carbon

More carbon

For centuries the ecosystems at high latitudes been a net carbon sinks.

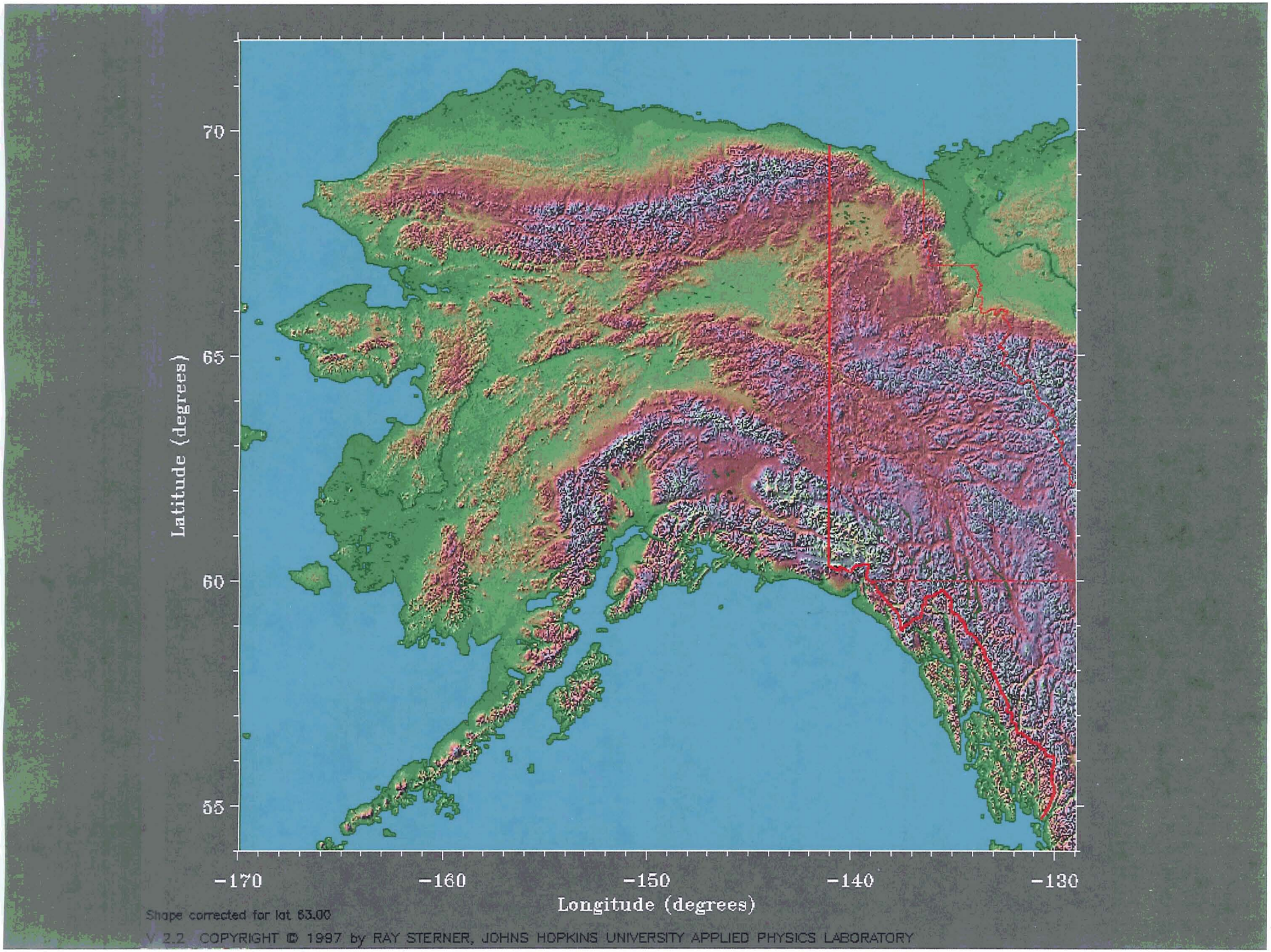
- The carbon is mostly stored in the soils.
- Permafrost and seasonally frozen soils have between 250 and 455 Pg of carbon stored in them
- Compared to the approximately 780 Pg of carbon presently in the atmosphere

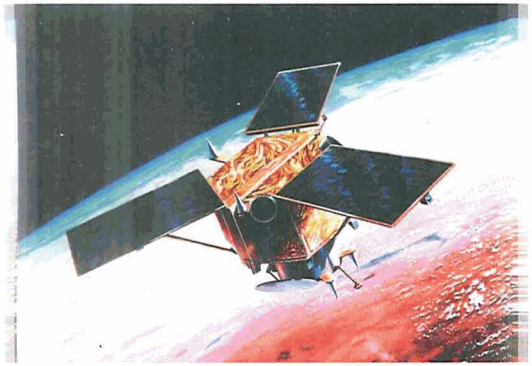
How might climate warming effect high latitude ecosystems and the Earth system?

Warming may change the carbon balance, releasing this large amount of carbon into the atmosphere.

How do we monitor these changes?

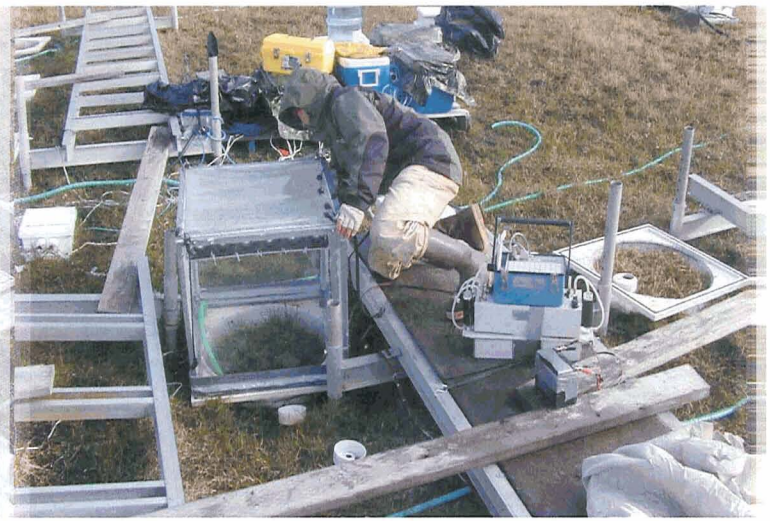

Welcome To
THE TOP OF THE WORLD
BARROW, ALASKA
DANGER!
Polar Bears
NO VEHICLES BEYOND THIS POINT!
DISTURBING THE BEARS NEAR THE POINT MAY CAUSE THEM TO RETURN TO BARROW AND THE DUMP AREA
PLEASE HELP REDUCE THE CHANCE OF HUMAN INJURY!


70
65
60
55
Latitude (degrees)
-170
-160
-150
-140
-130
Longitude (degrees)
Shape corrected for lat 63.00
V 2.2 COPYRIGHT © 1997 by RAY STERNER, JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY



Satellite Level

Tower Level



Plot Level

Light Use Efficiency Models provide an approach for determining Gross Ecosystem Exchange (GEE) of carbon

$$GEE = \varepsilon f_{APAR} PAR_{in}$$

Where:

PAR_{in} is the incident Photosynthetically Active Radiation (PAR)

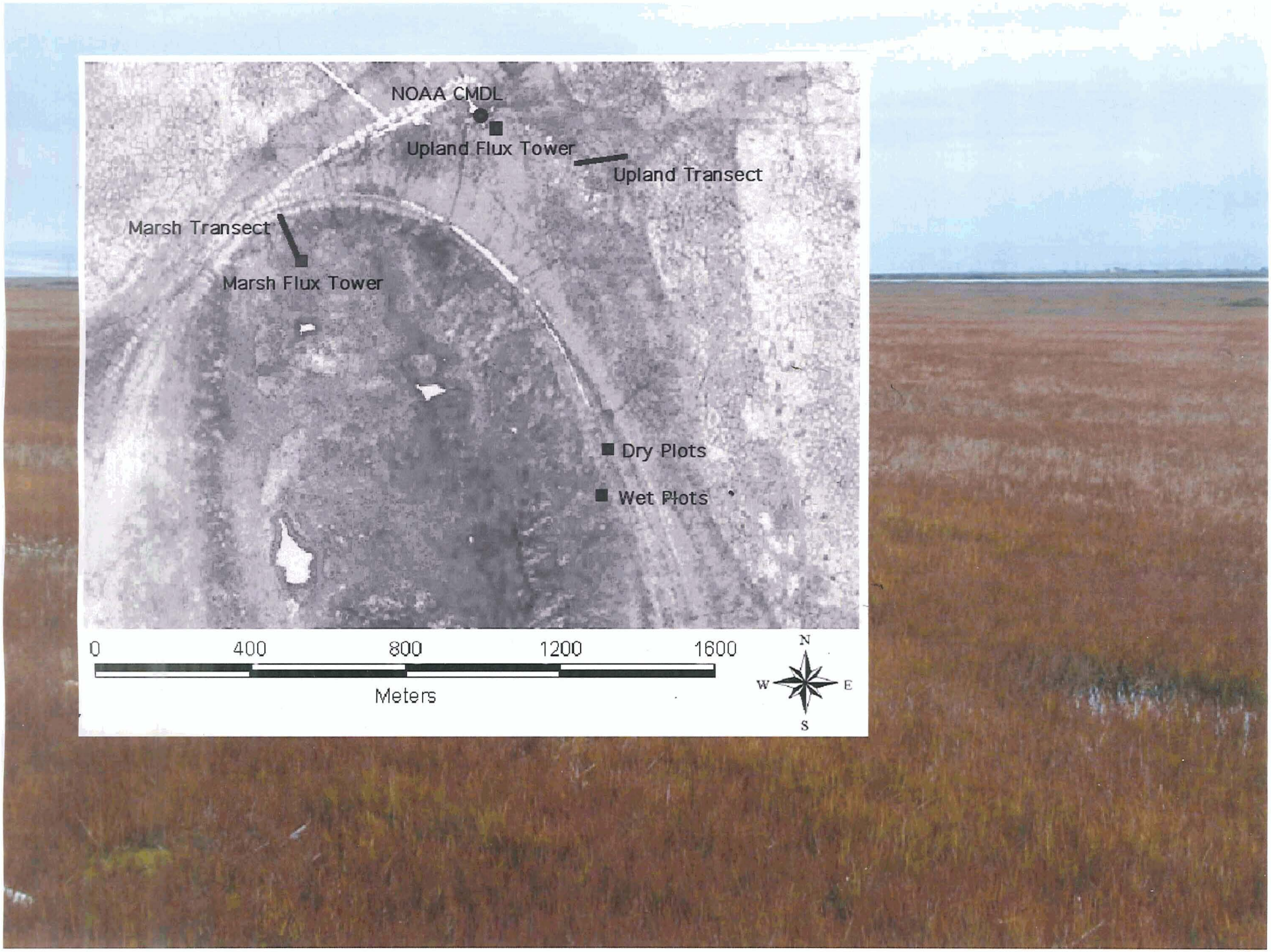
f_{APAR} is the fraction of PAR absorbed by vegetation

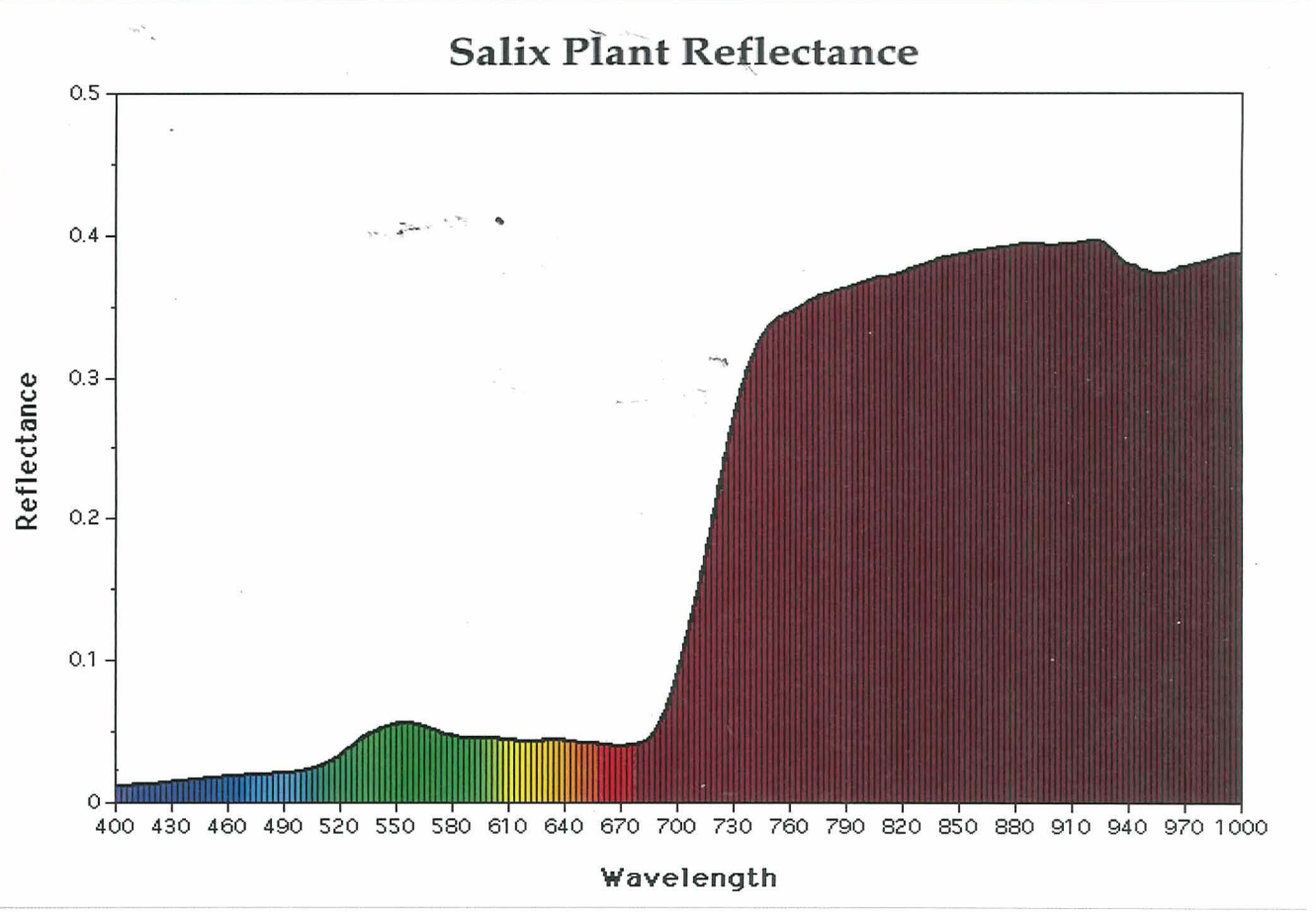
ε is the light use efficiency, the conversion factor between energy and absorbed carbon

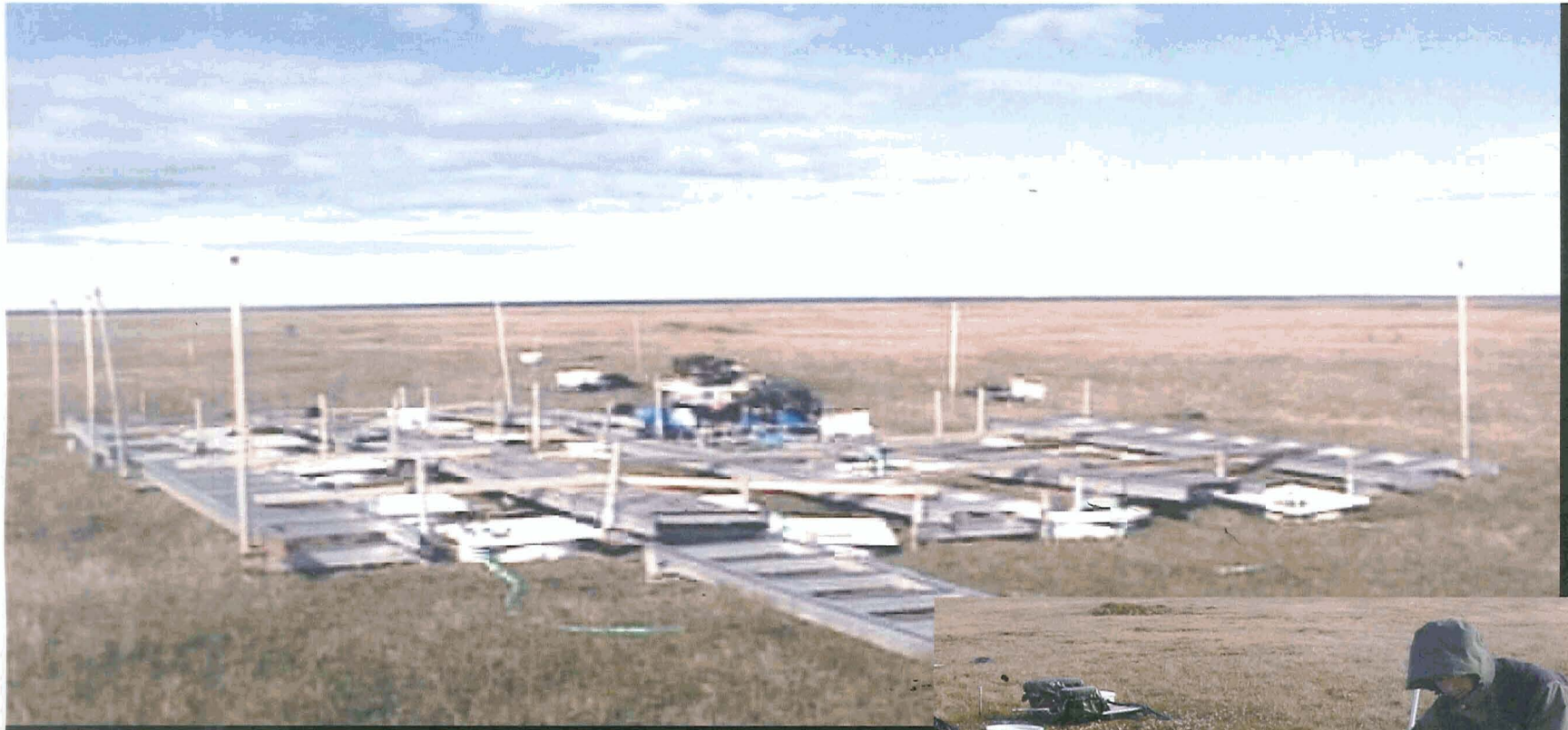
LUE models are particularly useful when used in conjunction with remote sensing

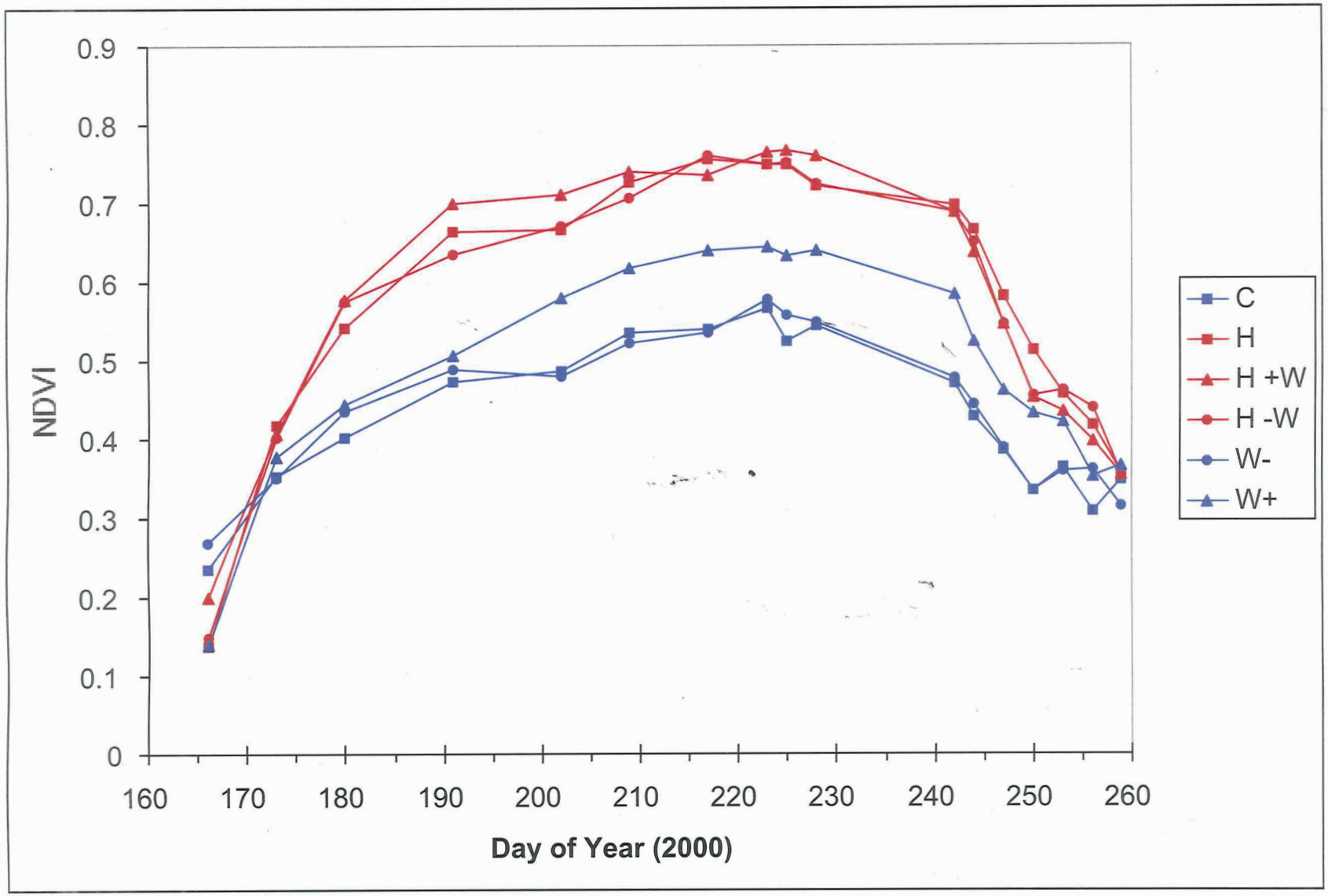
The Normalized Difference Vegetation Index (NDVI) is related to f_{APAR}

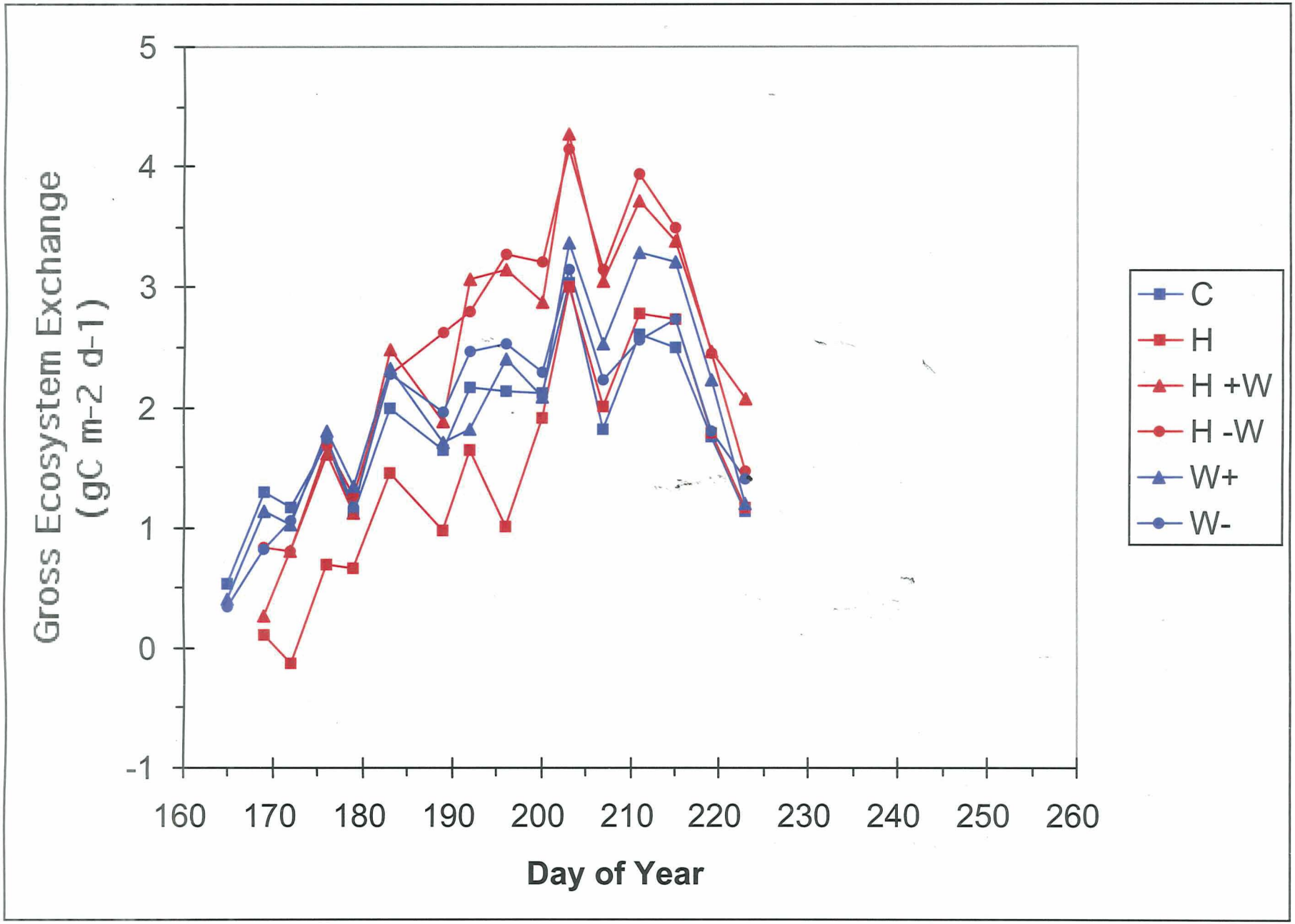
$$NDVI = \frac{\rho_{NIR} - \rho_{VIS}}{\rho_{NIR} + \rho_{VIS}}$$

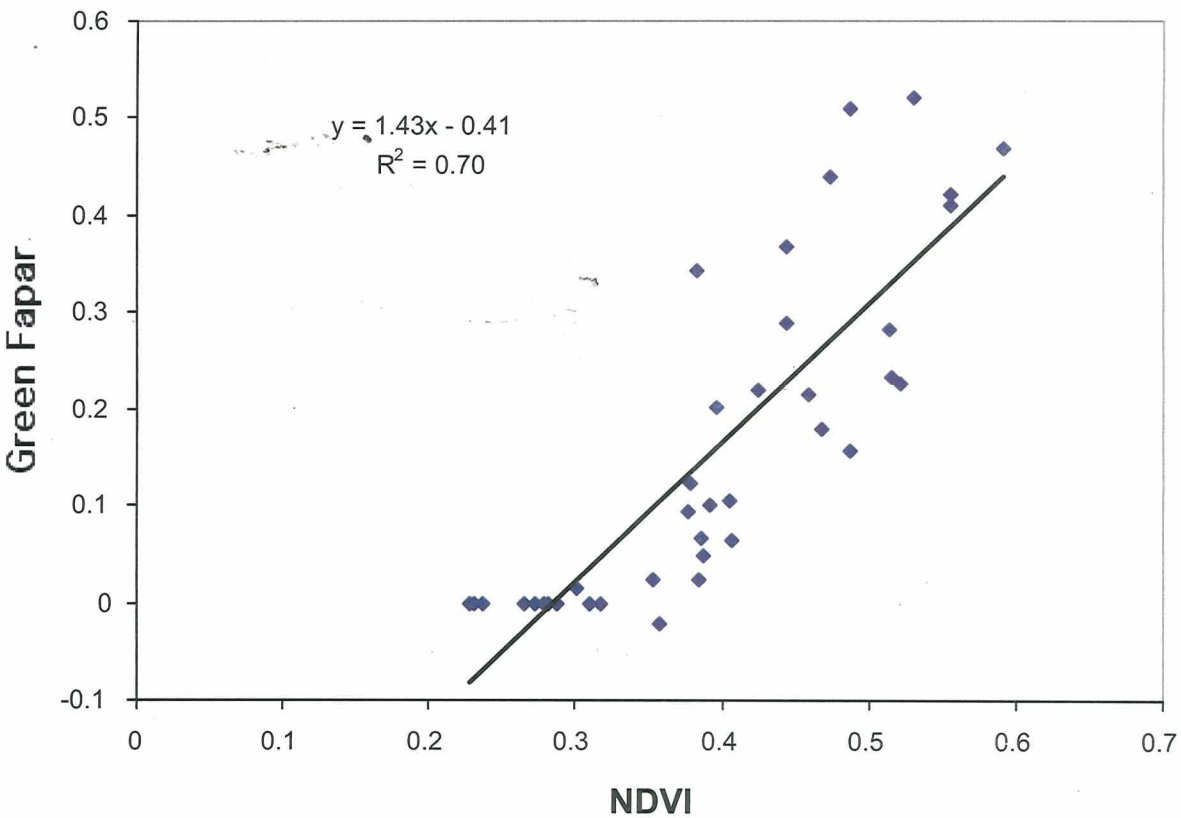

NOAA CMDL
Upland Flux Tower
Upland Transect
Marsh Transect
Marsh Flux Tower
Dry Plots
Wet Plots
0
400
800
1200
1600
Meters
N
W
E
S

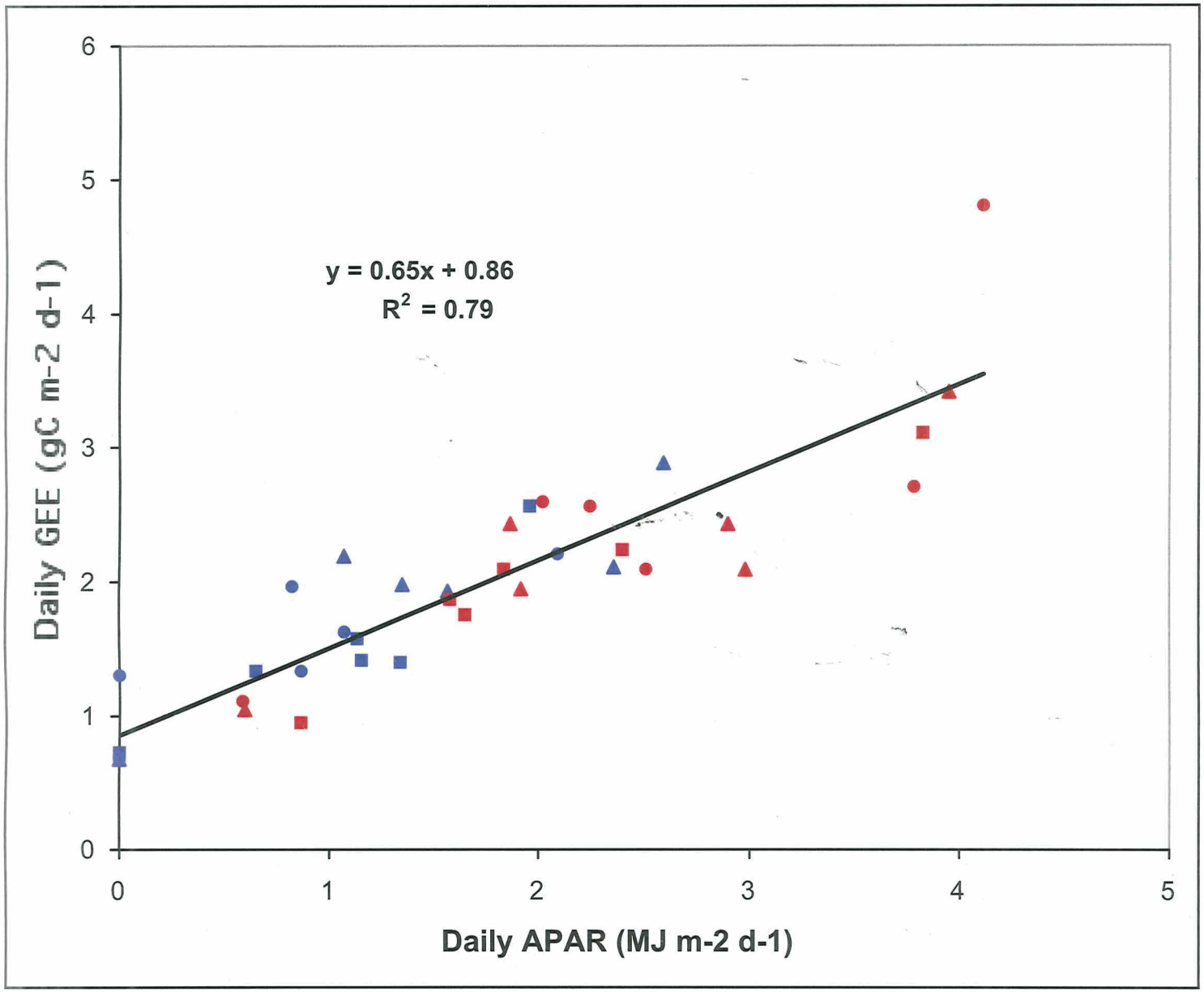

Salix Plant Reflectance
Reflectance
0.5
0.4
0.3
0.2
0.1
0
400 430 460 490 520 550 580 610 640 670 700 730 760 790 820 850 880 910 940 970 1000
Wavelength

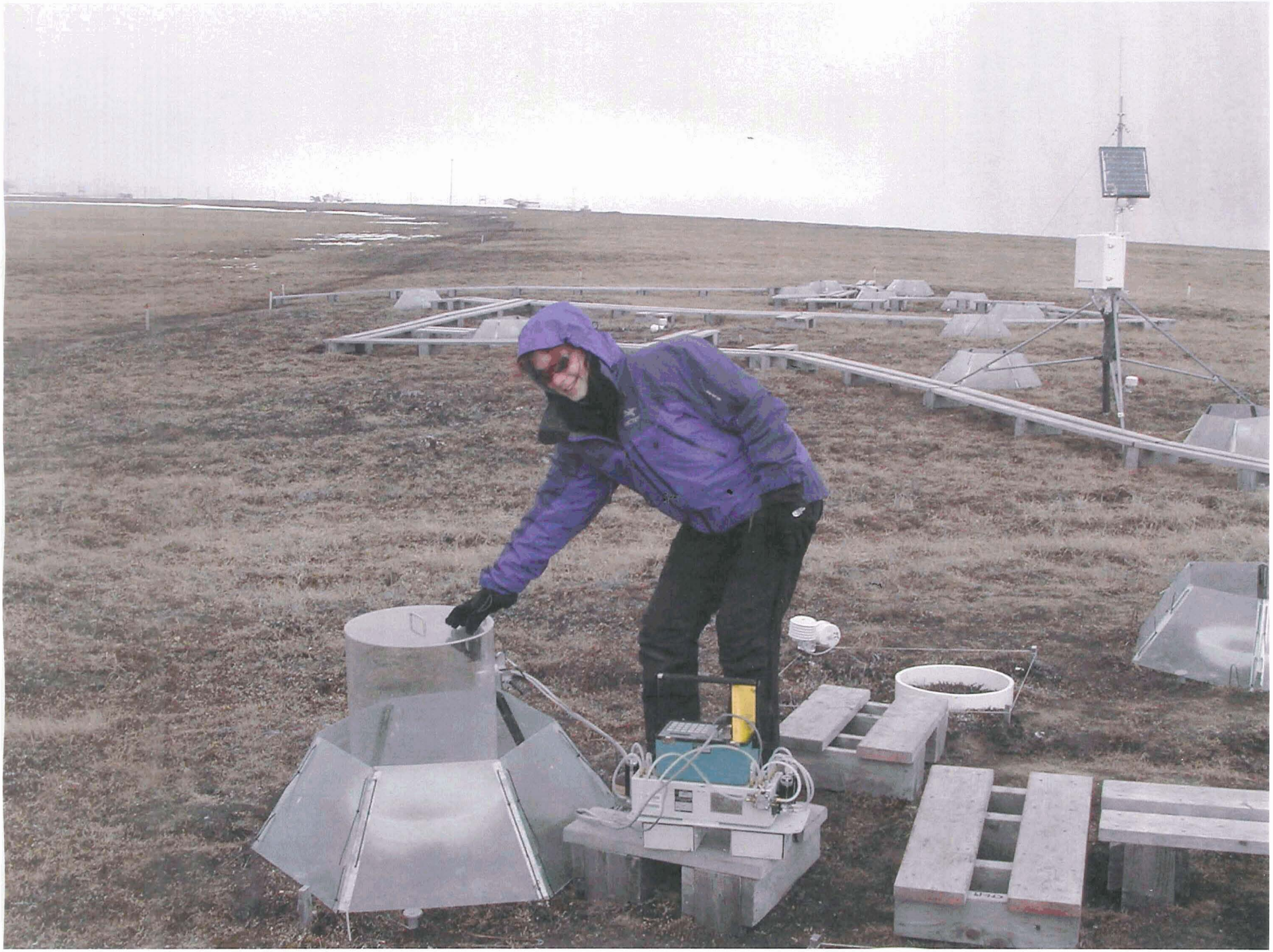


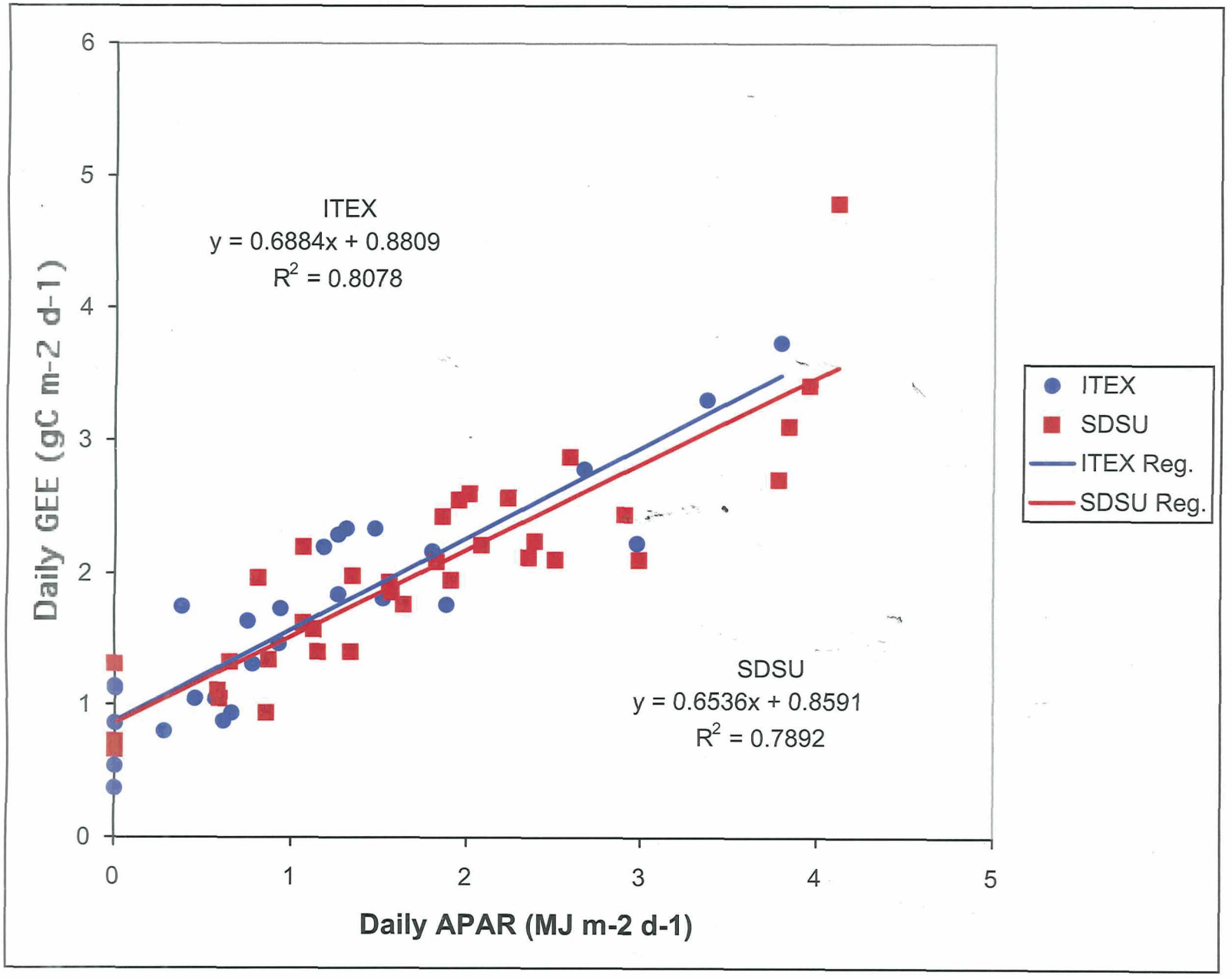

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
NDVI
160
170
180
190
200
210
220
230
240
250
260
Day of Year (2000)
C
H
H +W
H -W
W-
W+

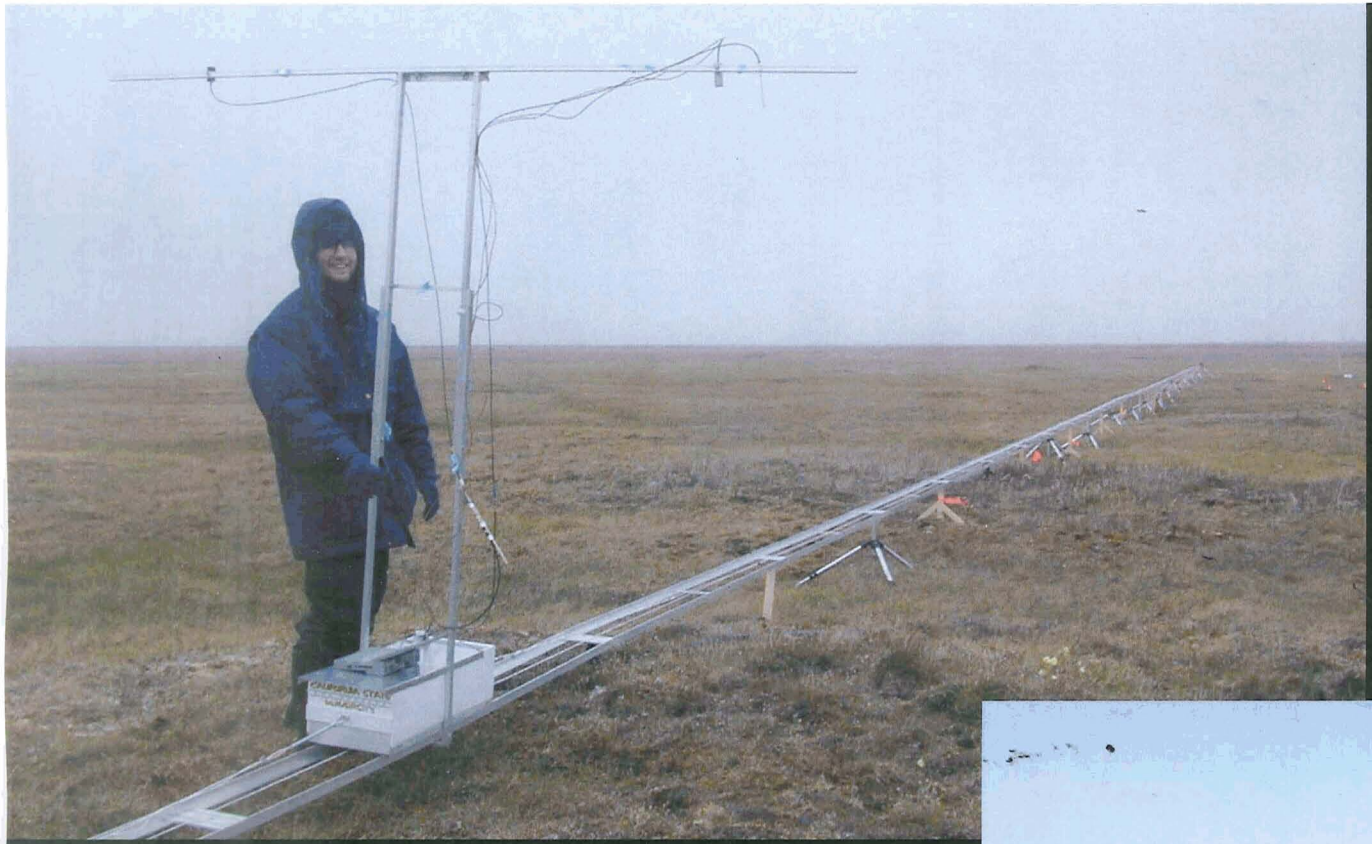

Gross Ecosystem Exchange
(gC m-2 d-1)
5
4
3
2
1
0
-1
160
170
180
190
200
210
220
230
240
250
260
Day of Year
C
H
H +W
H -W
W+
W-

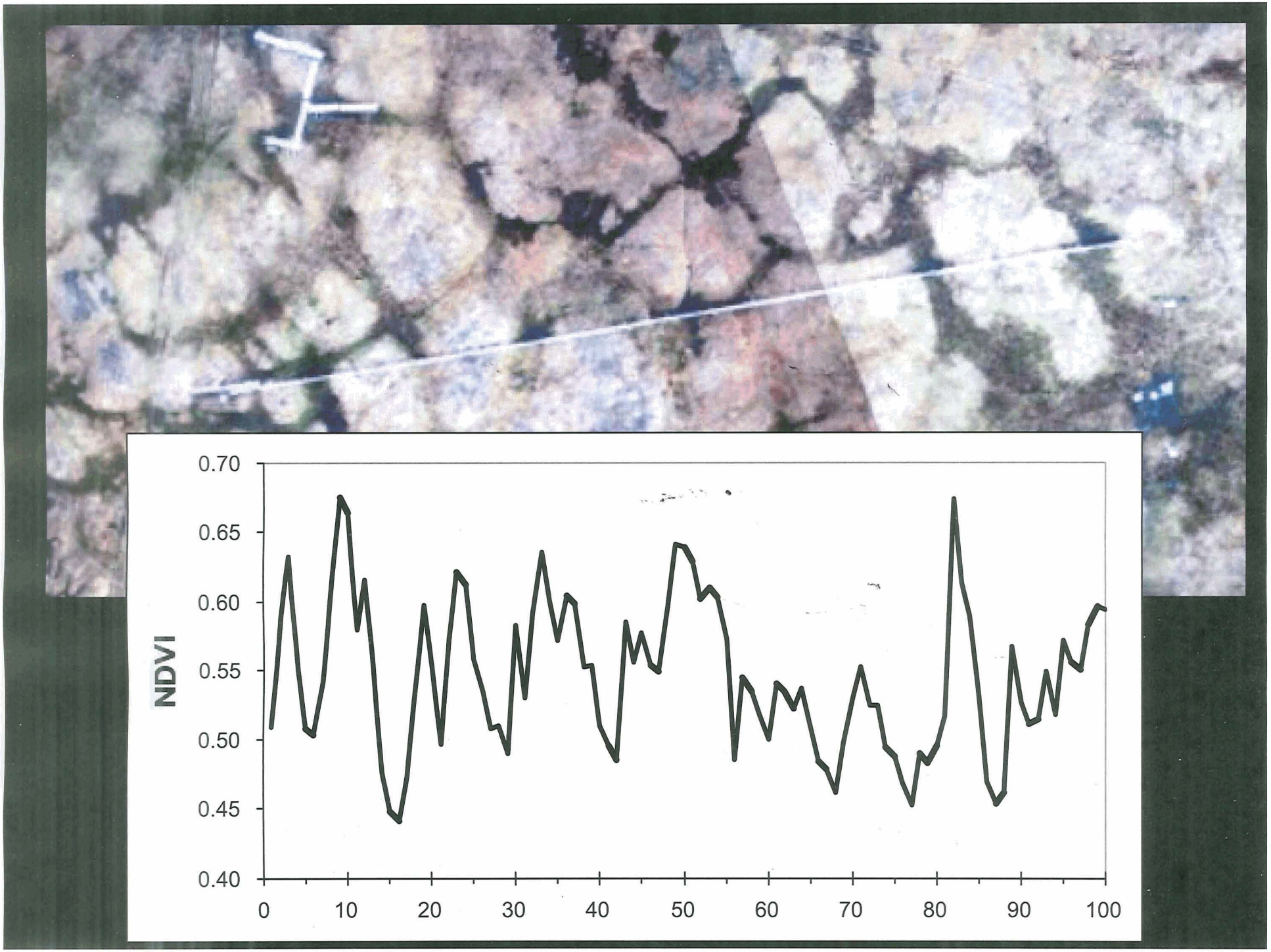

y = 1.43x - 0.41
R2 = 0.70
Green Fapar
NDVI
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

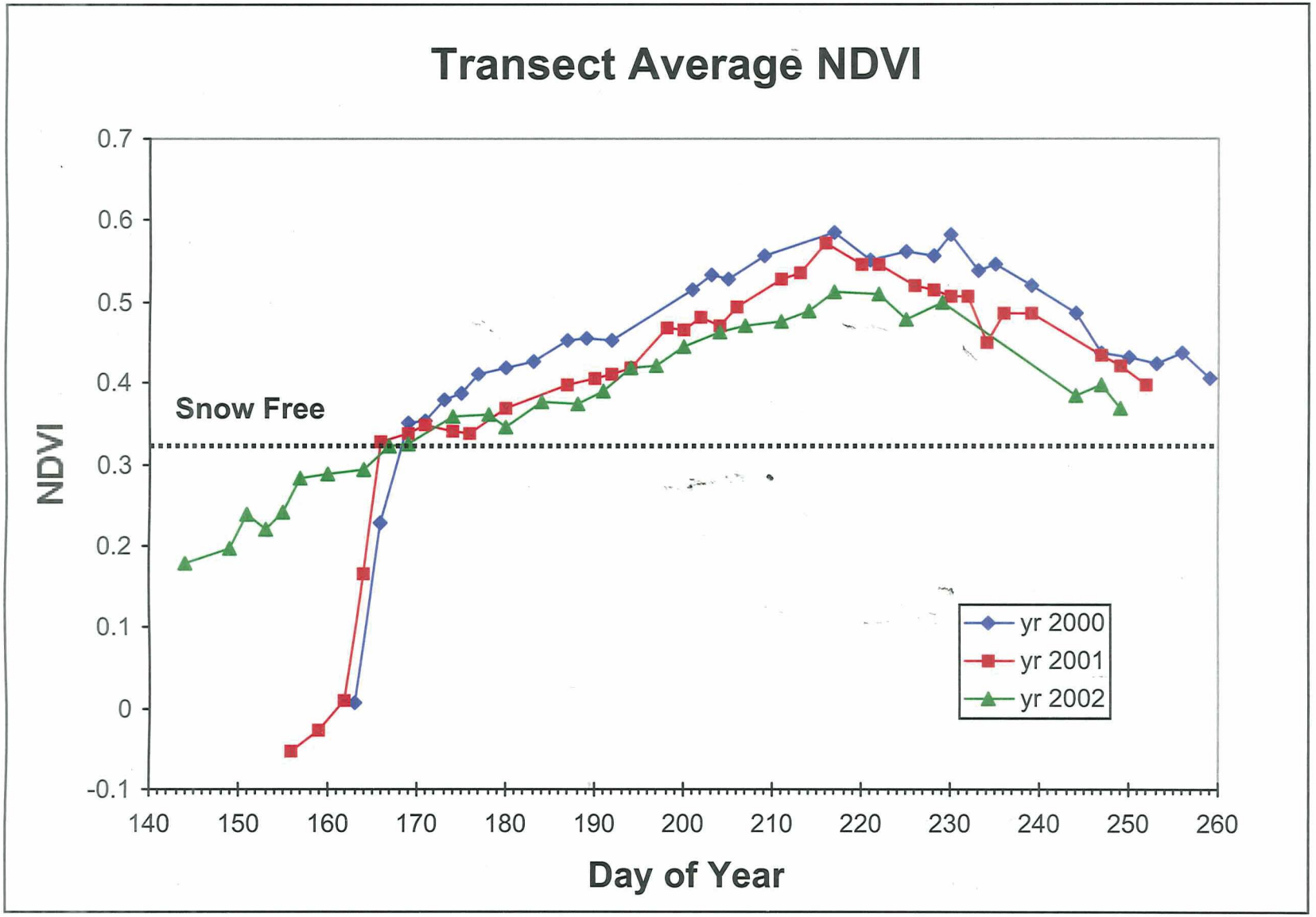

y = 0.65x + 0.86
R2 = 0.79
Daily GEE (gC m-2 d-1)
Daily APAR (MJ m-2 d-1)
0
1
2
3
4
5
6

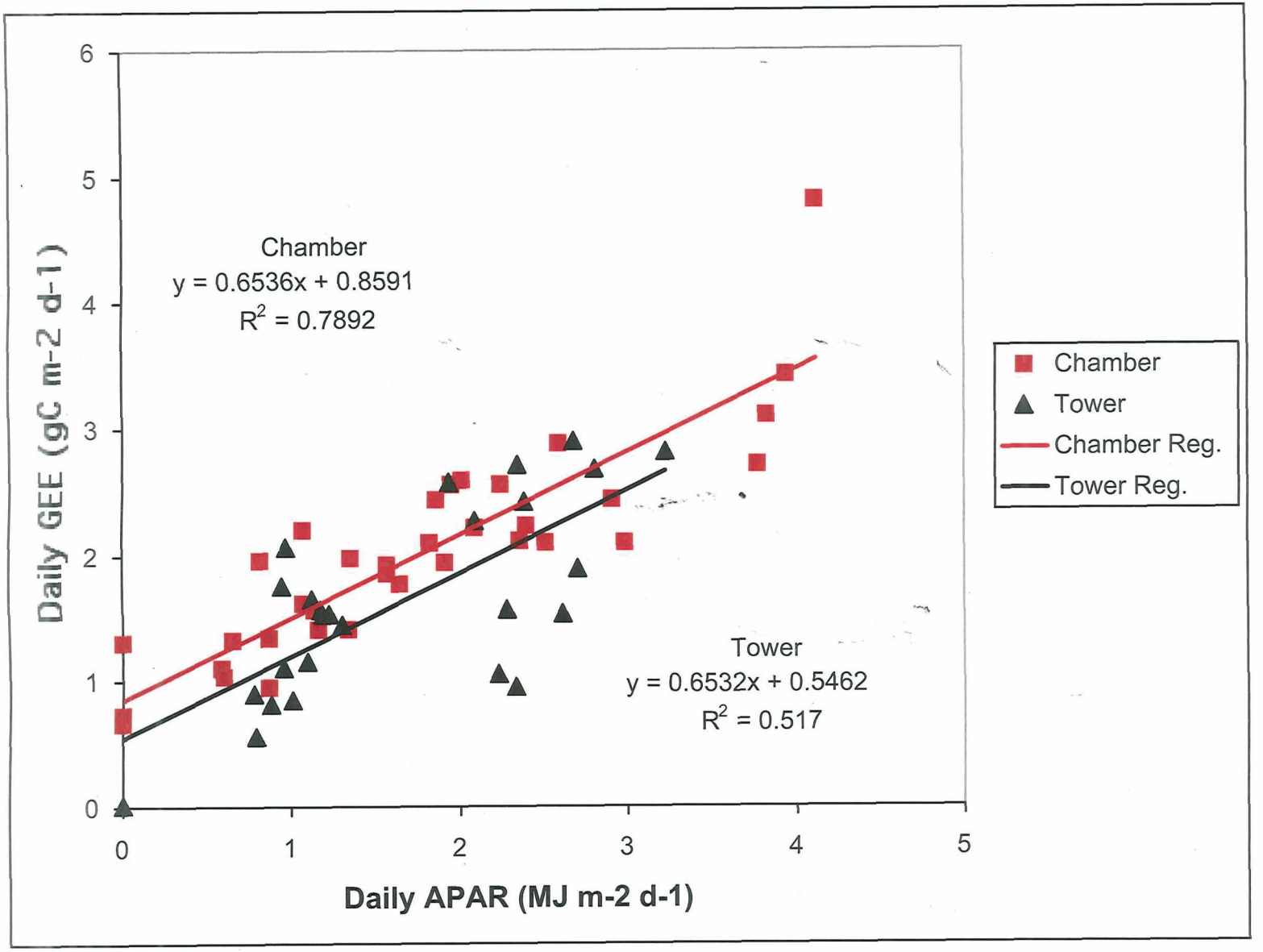


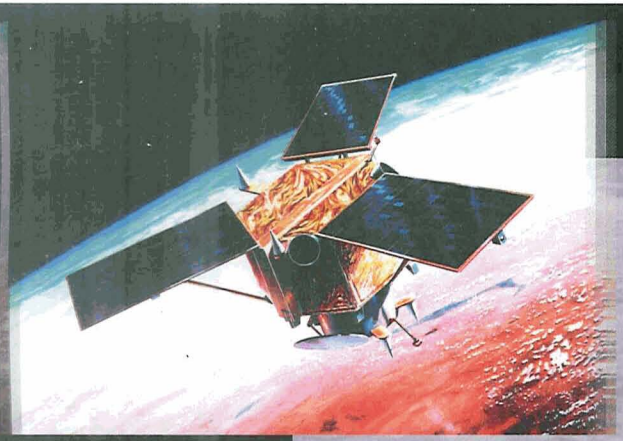

ITEX
y = 0.6884x + 0.8809
R2 = 0.8078
SDSU
y = 0.6536x + 0.8591
R2 = 0.7892
Daily GEE (gC m-2 d-1)
Daily APAR (MJ m-2 d-1)
0
1
2
3
4
5
6
ITEX
SDSU
ITEX Reg.
SDSU Reg.

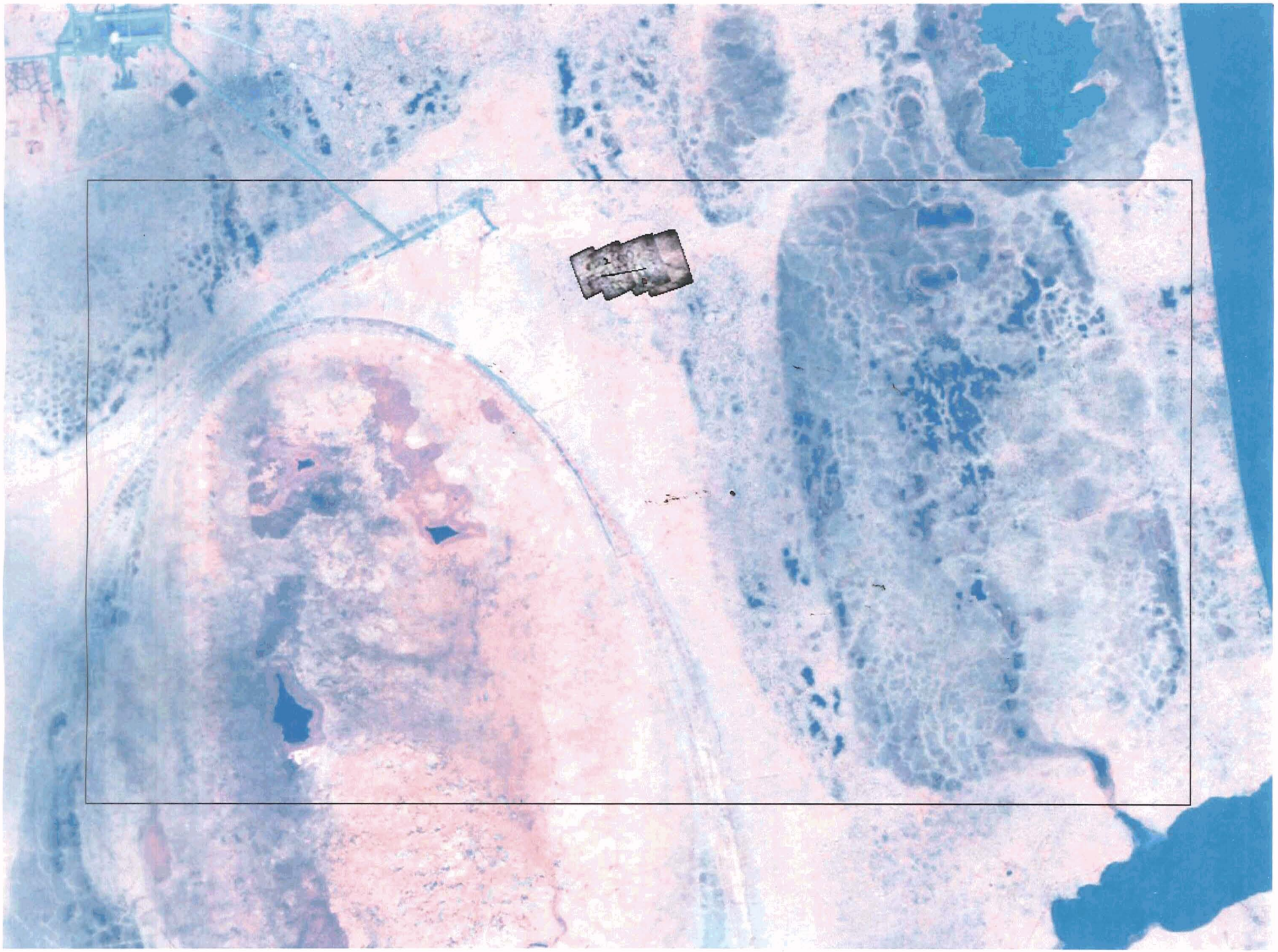


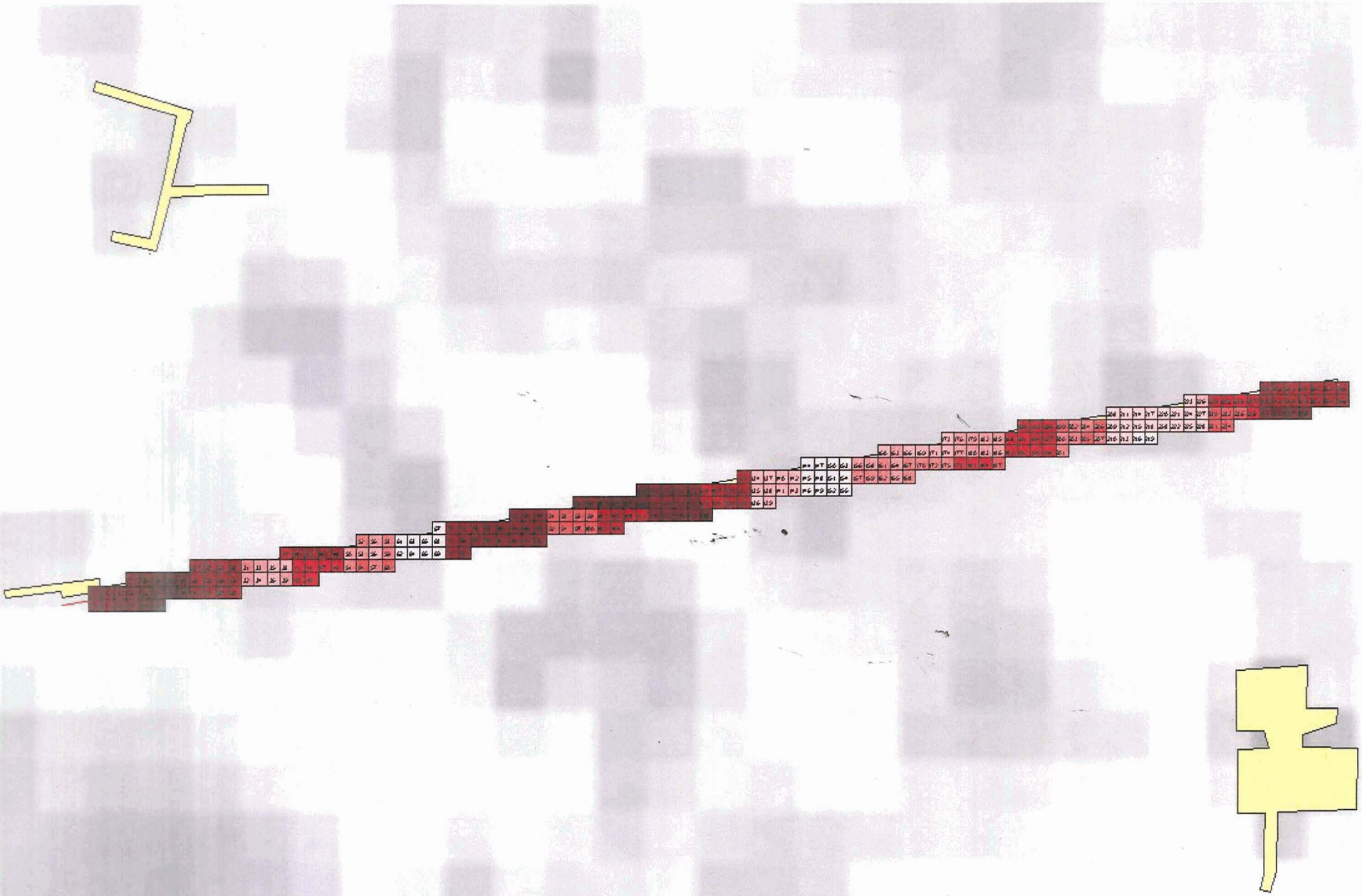

NDVI
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0
10
20
30
40
50
60
70
80
90
100


Transect Average NDVI
NDVI
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
Snow Free
140
150
160
170
180
190
200
210
220
230
240
250
260
Day of Year
yr 2000
yr 2001
yr 2002

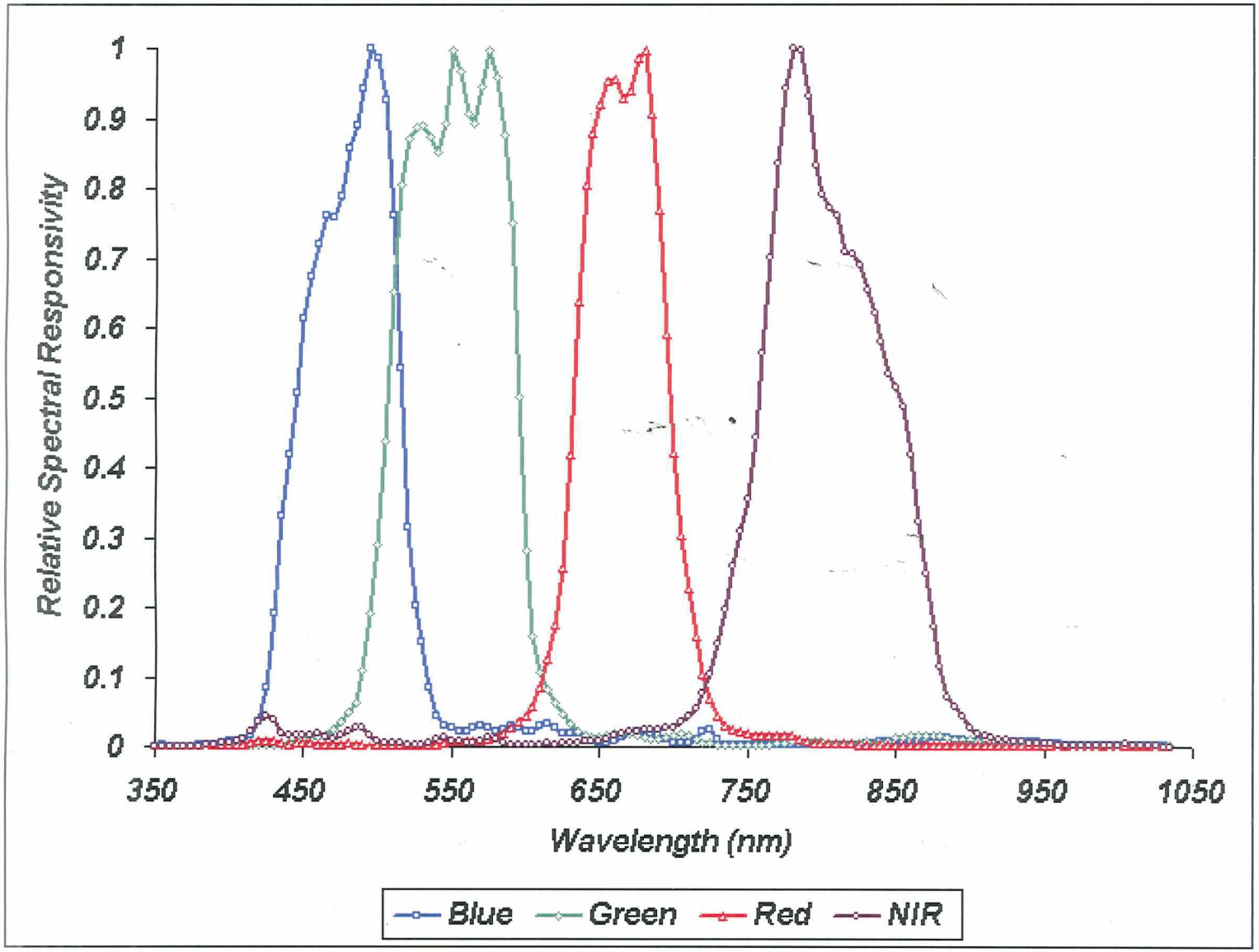

Daily GEE (gC m-2 d-1)
Daily APAR (MJ m-2 d-1)
0
1
2
3
4
5
6
Chamber
y = 0.6536x + 0.8591
R2 = 0.7892
Tower
y = 0.6532x + 0.5462
R2 = 0.517
Chamber
Tower
Chamber Reg.
Tower Reg.

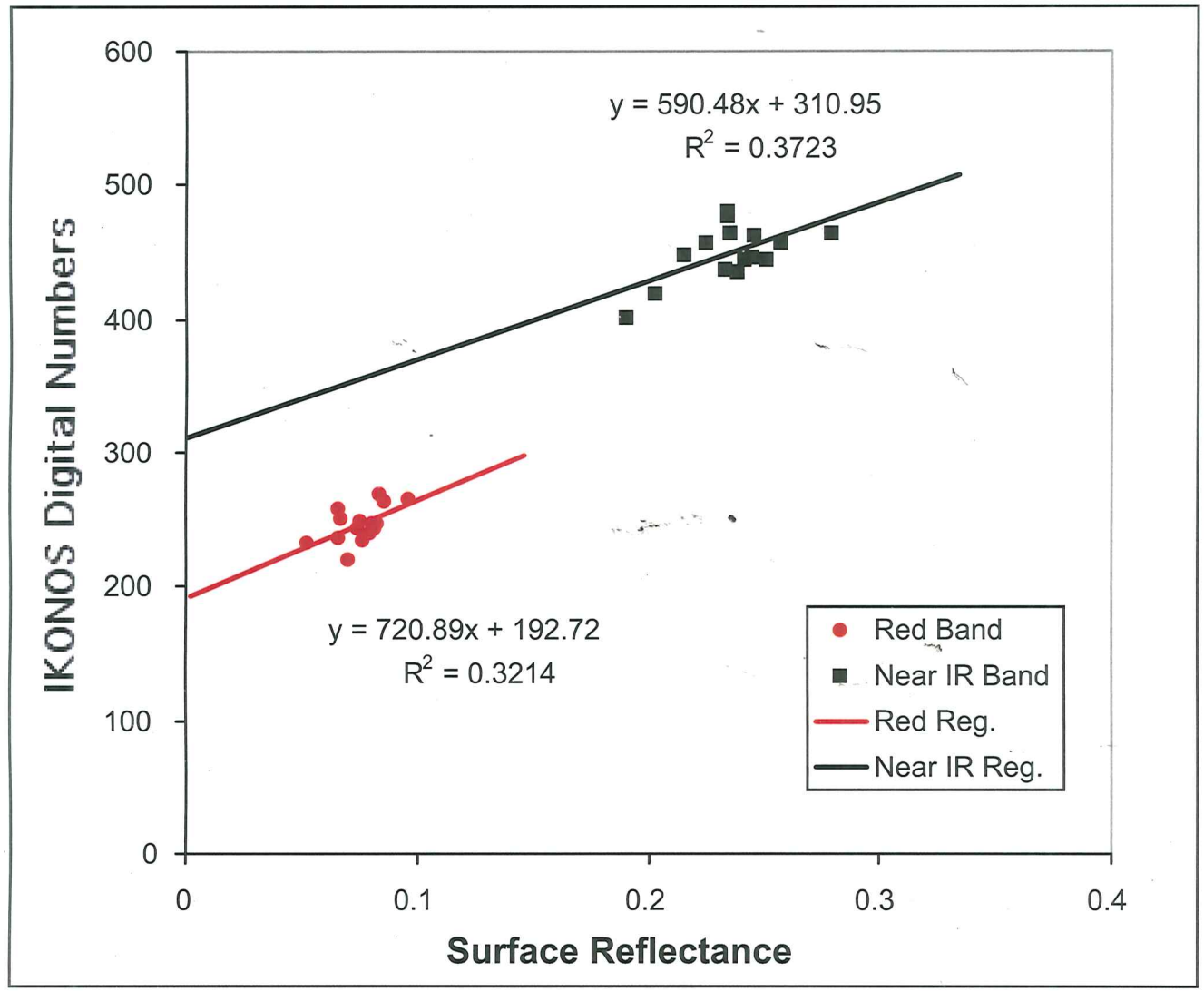




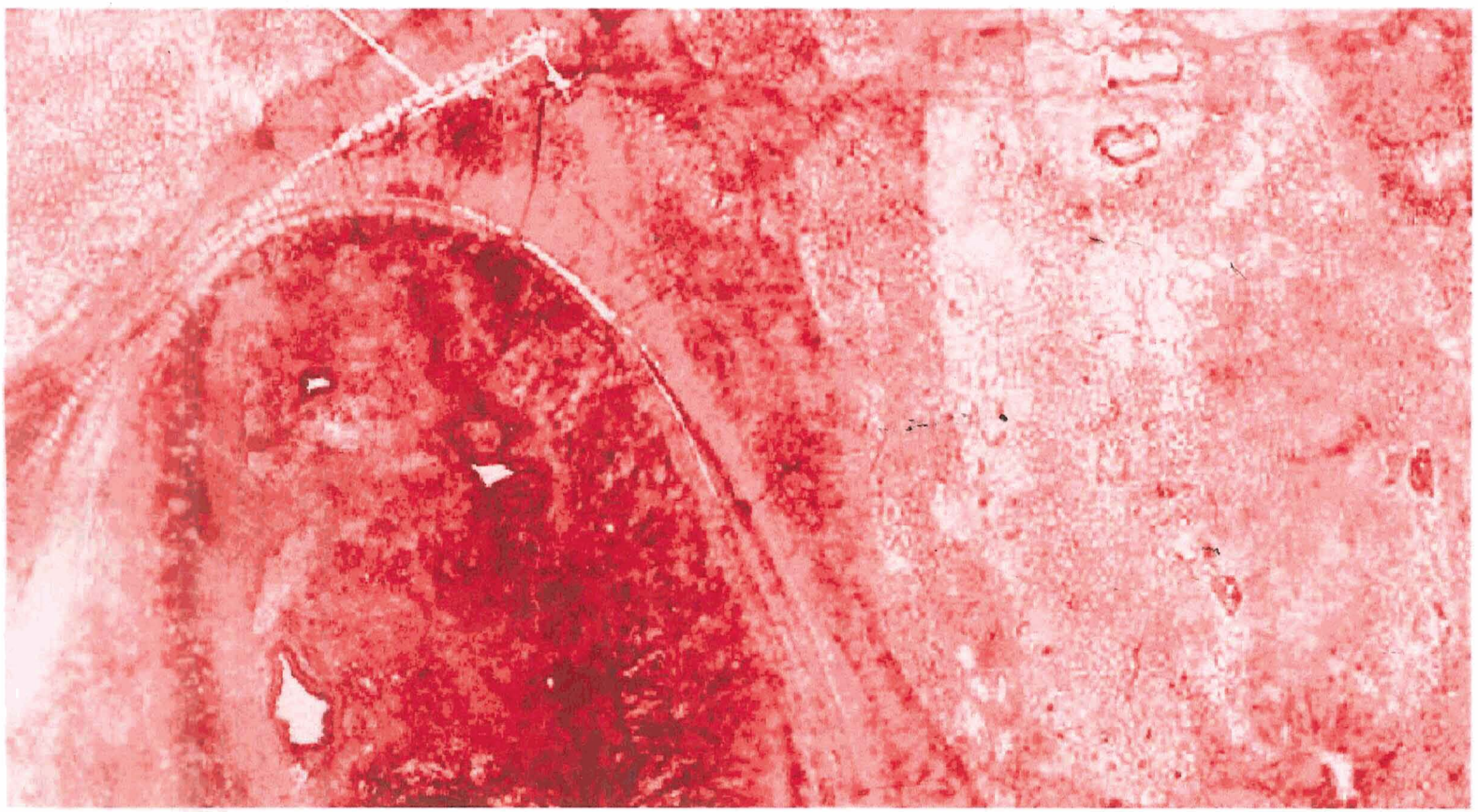


IKONOS Spectral Response Functions

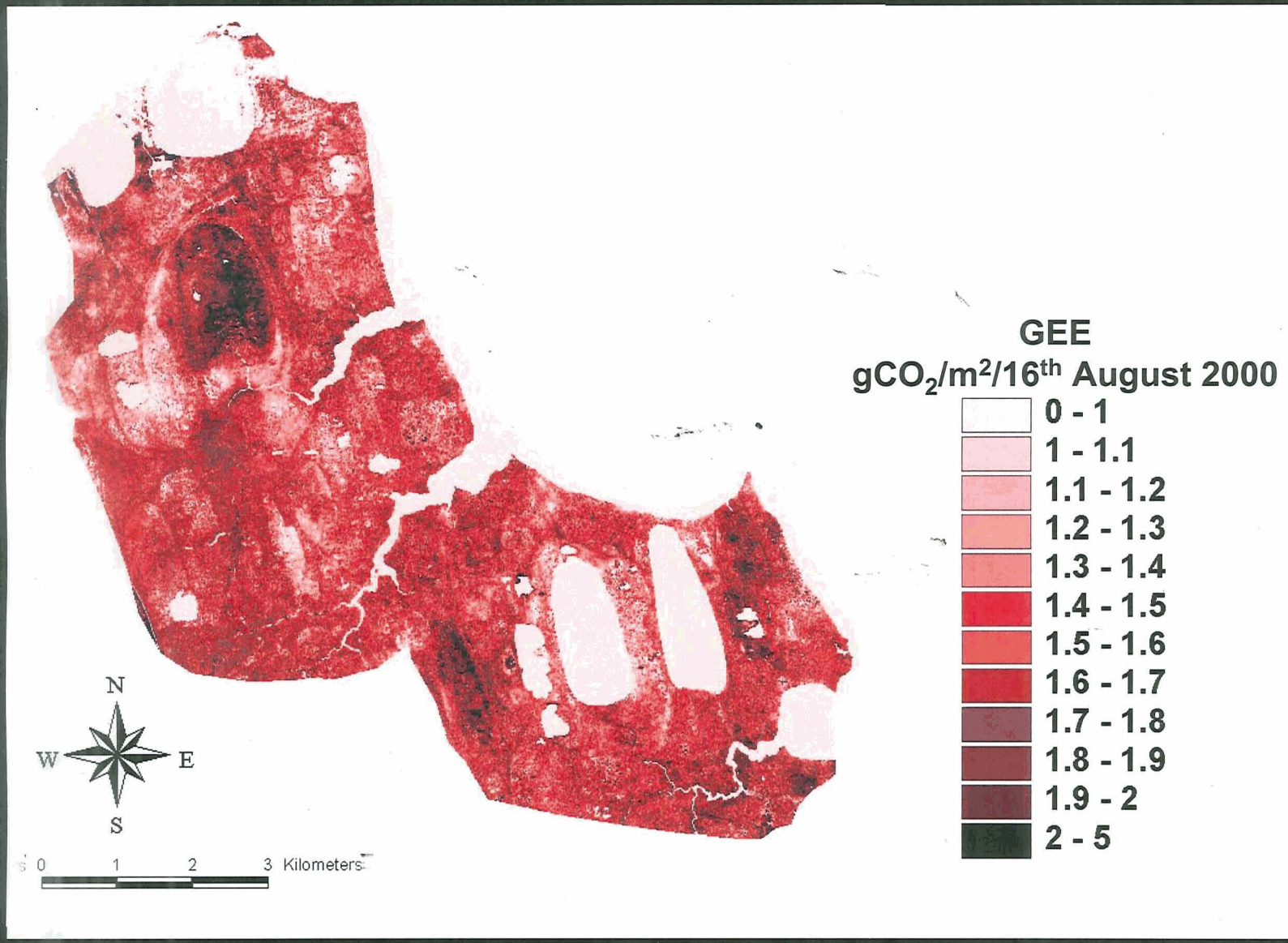



y = 590.48x + 310.95
R2 = 0.3723
y = 720.89x + 192.72
R2 = 0.3214
Red Band
Near IR Band
Red Reg.
Near IR Reg.
IKONOS Digital Numbers
Surface Reflectance
600
500
400
300
200
100
0
0
0.1
0.2
0.3
0.4

Gross Ecosystem Exchange
GEE (g/m2/day)



GEE Map:



C. Tweedie & F. Huemmrich

Some Conclusions:

- Linking spectral reflectance with gas exchange measurements is a useful approach for understanding carbon exchange
- At a plot scale we developed a model of carbon uptake driven by reflectance data
- We tested that model at a larger scale using flux tower data and reflectance data from the tram transect
- Surface reflectance data, collected as part of our study, were used to correct the satellite observations
- We were able to apply the model regionally using IKONOS data
- The spatial patterns of GEE indicate that hydrologic changes in the tundra may be as important as warming on the future status of the carbon balance

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JACIE Future

- Support Commercial Remote Sensing Policy (CRSP)
  - Take advantage of CRSP near-term requirements data to influence priorities
  - Increases confidence in U.S. commercial sources in the marketplace
  - Showcases successful applications
  - Provides a model of government/industry cooperation
- Demonstrate relevance of JACIE to US role in terrestrial monitoring including water and carbon cycle monitoring
- Prepare for the next-generation of higher-resolution US commercial satellites
- Broaden scope to include all commercial sensors useful to the U.S. base
  - National or international
  - Aerial or satellite
  - Optical, Light Detection And Ranging (LiDAR), Interferometric Synthetic Aperture Radar (IfSAR), hyperspectral, multispectral, etc…

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JACIE Future

- Understand and characterize new sensors
- Document of JACIE quality processes
- Consider more of an applications focus, e.g., hazards/risk mgt.
- Support new applications and understanding of remotely sensed data
  - Provide tools and applications
- Help agencies use remotely sensed information
- Publish results

High Spatial Resolution Commercial Imagery Workshop

November 8-10, 2004

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JACIE Support

- **Support new applications and understanding of remotely sensed data**
  - Extracting Impervious Surface Info from Multi & Hyperspectral Data
  - Defining Landscape Characteristics from Remote Sensing Data in Support of Human Health Investigations
  - Development of Remote Sensing Technologies for other sensors
  - Multi-sensor applications for Landscape and Regional Quantification of Climate Change Impacts and Carbon Dynamics
  - Mapping Invasive Species with Hyperspectral Data
- **Help agencies use remotely sensed information; such as,**
  - Analysis of Hydrologic Derivatives from high resolution data
  - Subsidence Studies of Coastal Regions
  - Monitoring of Earthquake, Volcano, & Landslide Processes
  - Analysis of High Resolution Data for Extracting Land Surface Information
  - Predicting Soil Suitability for Application of Coal bed Methane Produced Water

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Thank you for a Great Workshop

- CRS Space Imagery Companies
  - Space Imaging
  - DigitalGlobe
  - ORBIMAGE
- NASA, NGA, and USGS, and their partners
- JACIE presenters and poster developers

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Special Thanks

- JACIE Conference Support Team
  - Bill Hughes
  - Laura Pair
  - Karen Hoselle
- JACIE Conference Technical Support
  - Mary Pagnutti
- JACIE Session Chairs –Terry Lehman (NGA) , Mike Duncan (USGS), Mary Pagnutti (NASA), Vicki Zanoni (NASA), Spencer Roylance (NGA)
- JACIE Host
  - USGS and USGS support staff