Forecasting Vegetation Greenness with Satellite and Climate Data

Lei Ji

Cooperative Institute for Research in the Atmosphere, Colorado State University

Albert J. Peters

Center for Advanced Land Management Information Technologies, University of Nebraska-Lincoln

Introduction

- NDVI imagery derived from the NOAA AVHRR has played a key role in investigation of vegetation condition.
  - frequent observation (daily)
  - large area coverage (continental)
  - **long historical record (>20 years)**

- **Some NDVI-based vegetation indices have been designed to indicate NDVI variation relative to normal.**
  - **V**egetation **C**ondition **I**ndex (Kogan 1995)

    $$VCI = (NDVI - min_i)(max - min)$$

  - **R**elative **G**reenness (Burgan et al. 1996)

    $$RG\ (\%) = 100\ \_\ NDVI / mean$$

  - **S**tandardized **V**egetation **I**ndex (Peters et al. 2002)

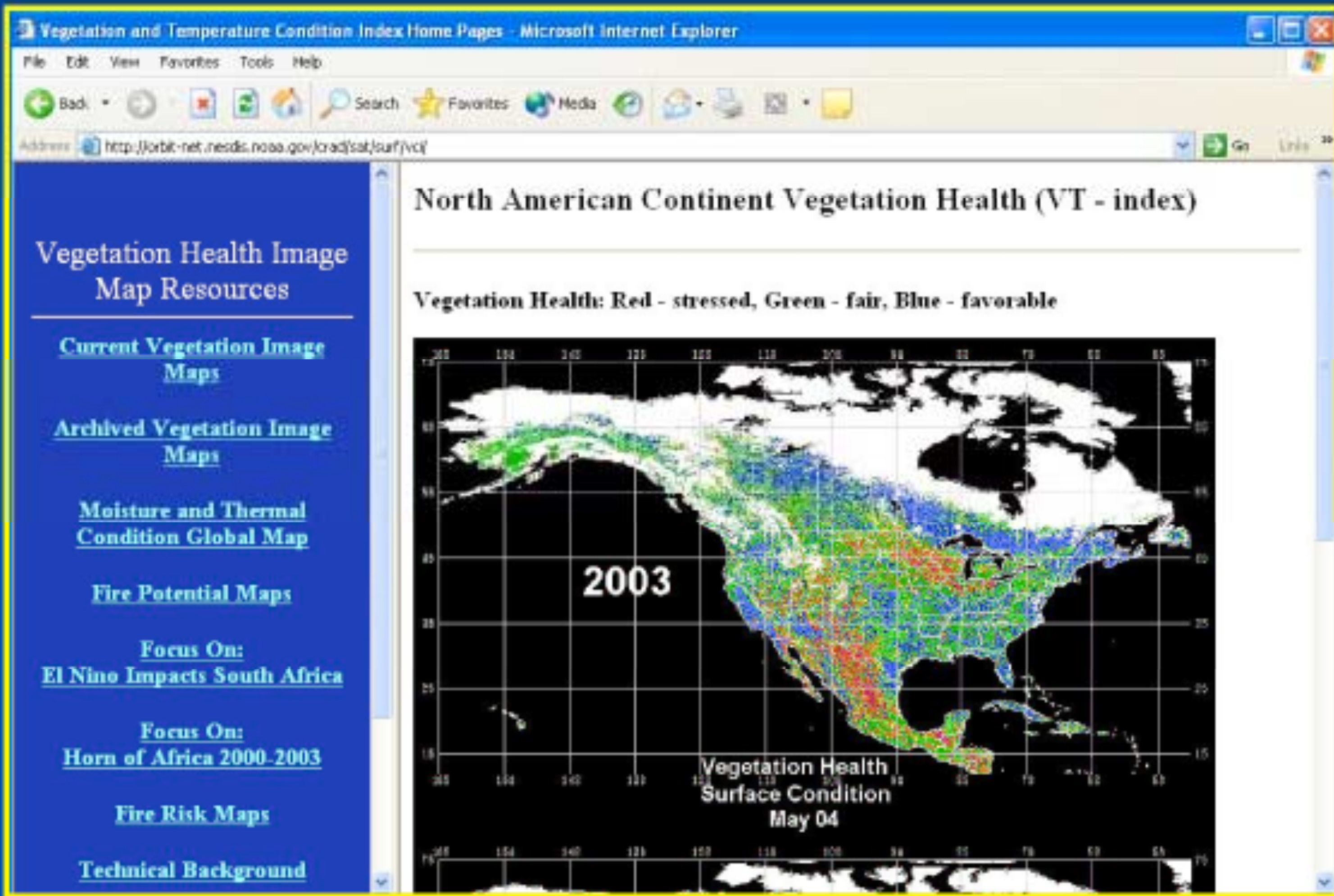
    $$SVI = (NDVI - mean)/std$$

Introduction

- Real-time NDVI images and their derivatives are routinely produced and published on the World Wide Web, providing valuable information for
  - agribusiness and farming
  - natural resource management
  - drought monitoring
  - wild land fire assessment
  - academic research and education

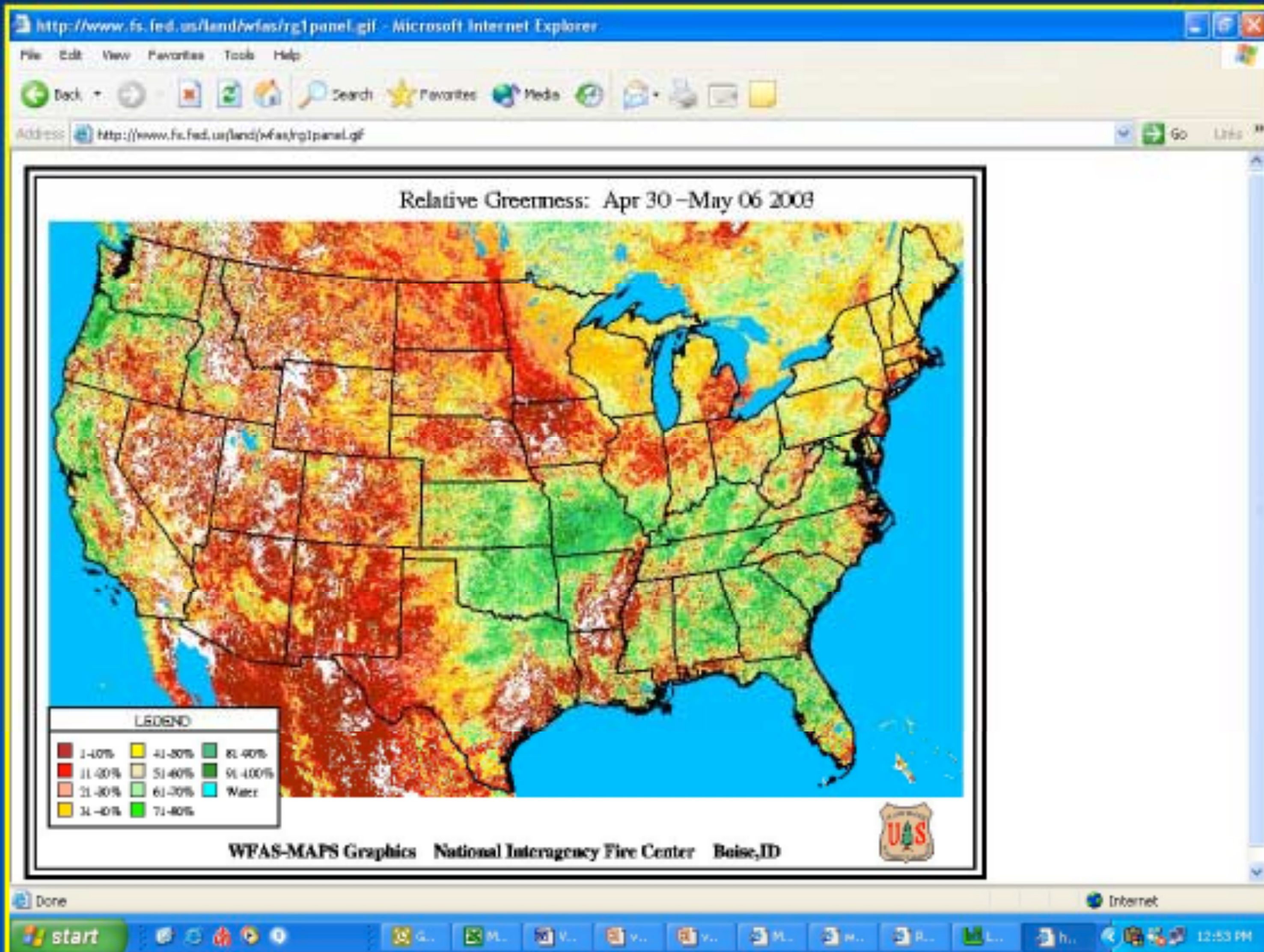
NOAA, National Environmental Satellite, Data, and Information Service

Vegetation Health: VCI



USDA, Forest Service, Fire and Aviation Management

Vegetation Greenness: Relative Greenness (RG)

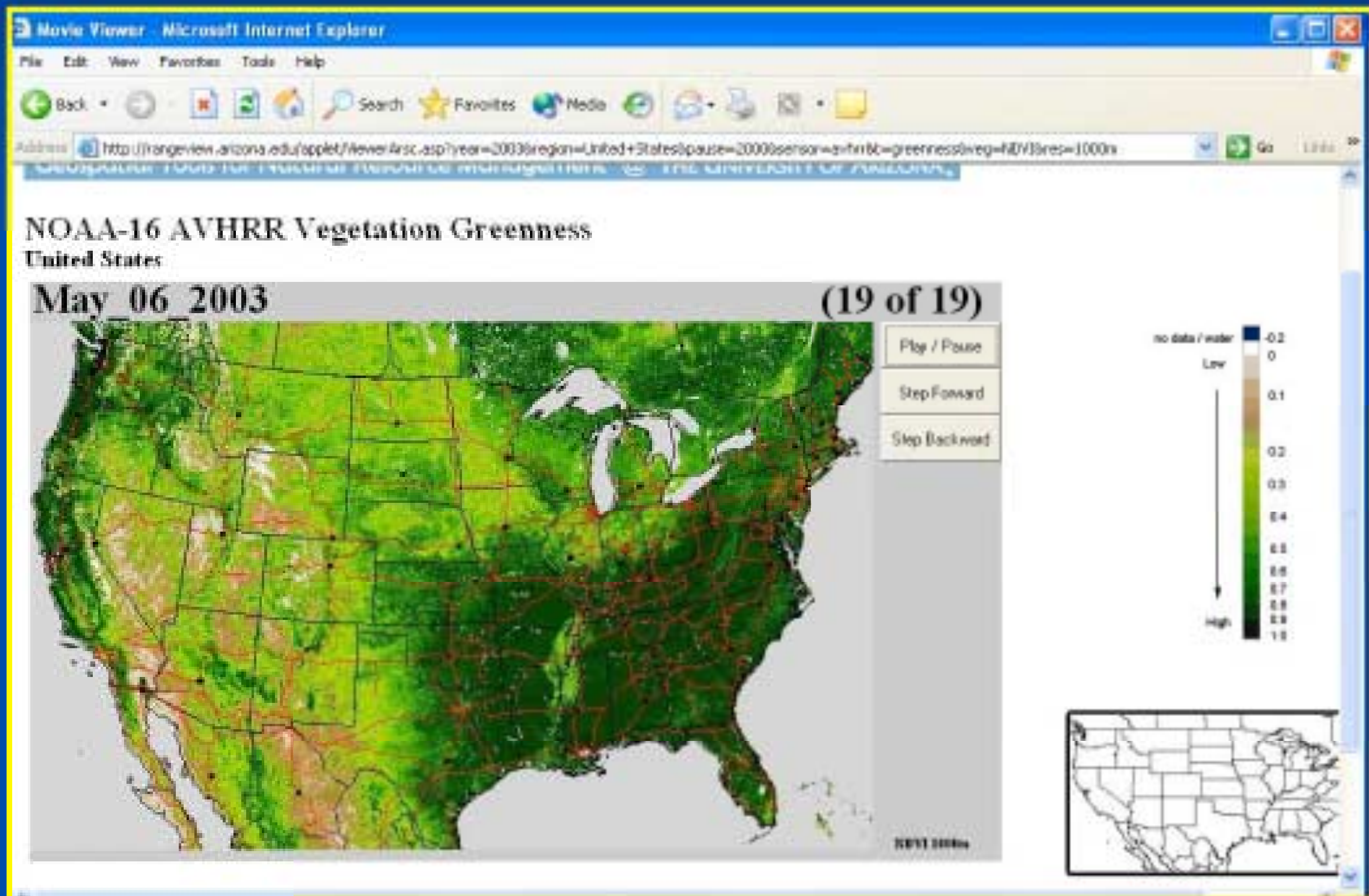


University of Kansas, Kansas Applied Remote Sensing Program

GreenReport®: NDVI, DNVI Difference, VCI

University of Arizona, College of Agriculture and life Sciences

RangeView: NDVI and NDVI Difference



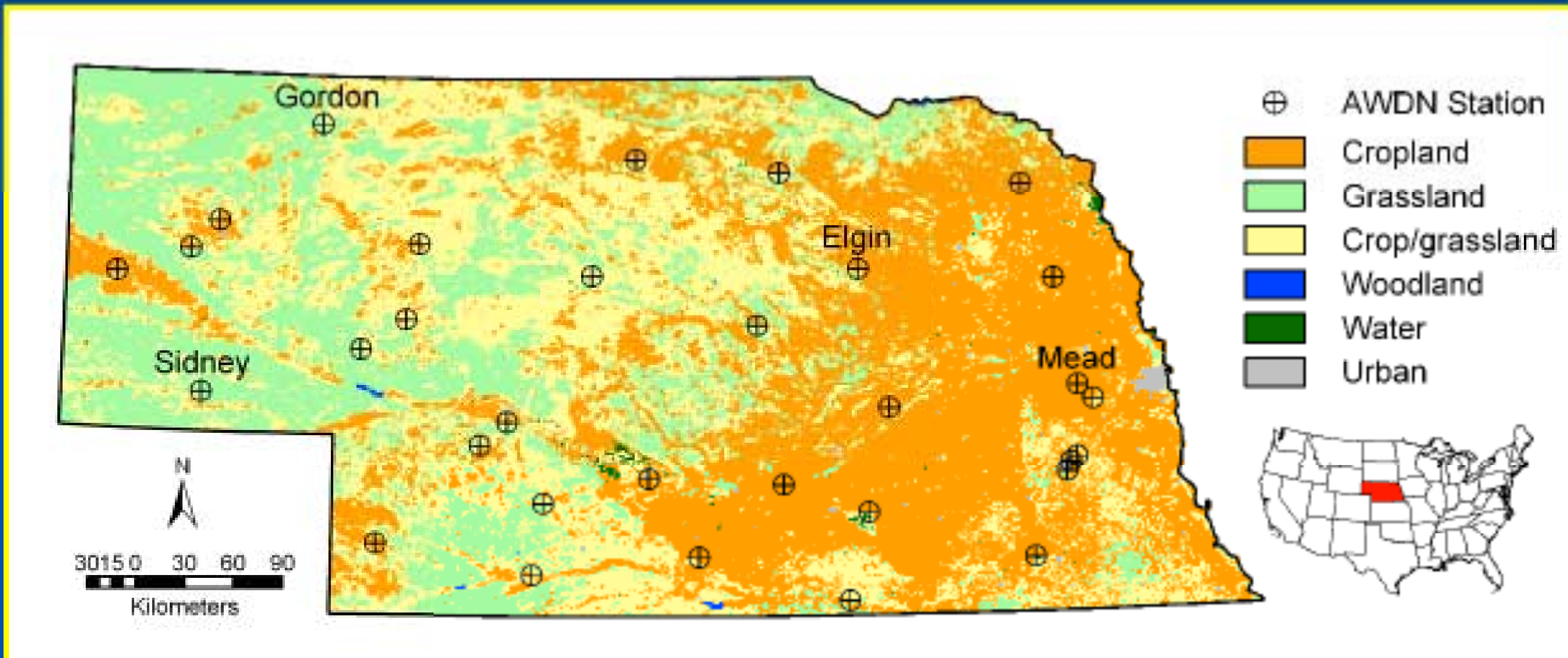
Introduction

- Forecasts of vegetation status for the next few months would be of great value to decision makers and managers of agricultural and natural vegetation resources
- Forecasting is a challenge. No publication on this subject was found.

- Objective:

  To design a Vegetation Greenness Forecast (VGF) model that is capable of forecasting vegetation status in advance.

Study Area



Nebraska: Cropland and Grassland

Data

- **NDVI (1989 – 2000):**
  Biweekly Maximum Value Composite NDVI produced at the USGS EROS Data Center

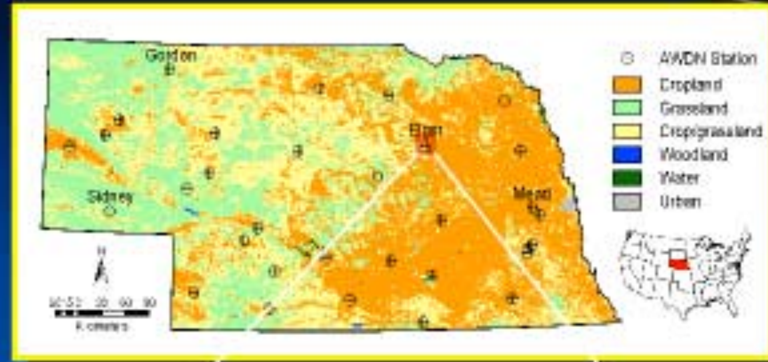
Mead AWDN Station

- **Precipitation and temperature (1988 – 2000):**
  Daily precipitation and air temperature from Automated Weather Data Network (AWDN) operated at the High Plains Regional Climate Center

Data Preparation

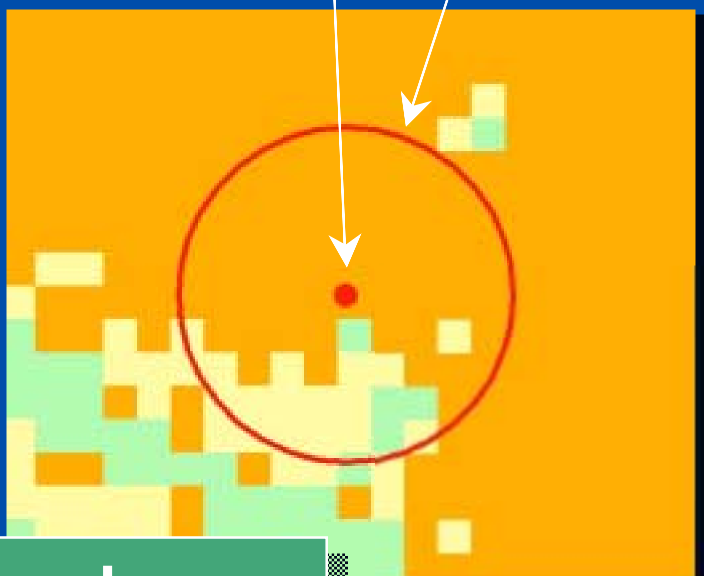
- Biweekly-time series of NDVI, precipitation and temperature for each AWDN station:
  - 14-day total precipitation
  - 14-day average temperature
  - NDVI
- NDVI for each AWND station: average NDVI of all cropland or grassland pixels within circular buffers 10km in diameter around each weather station

Data

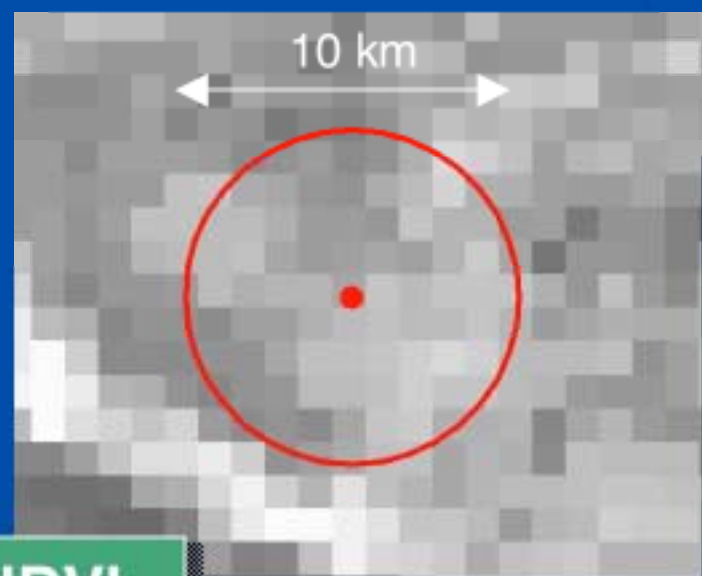


AWDN station

Buffer



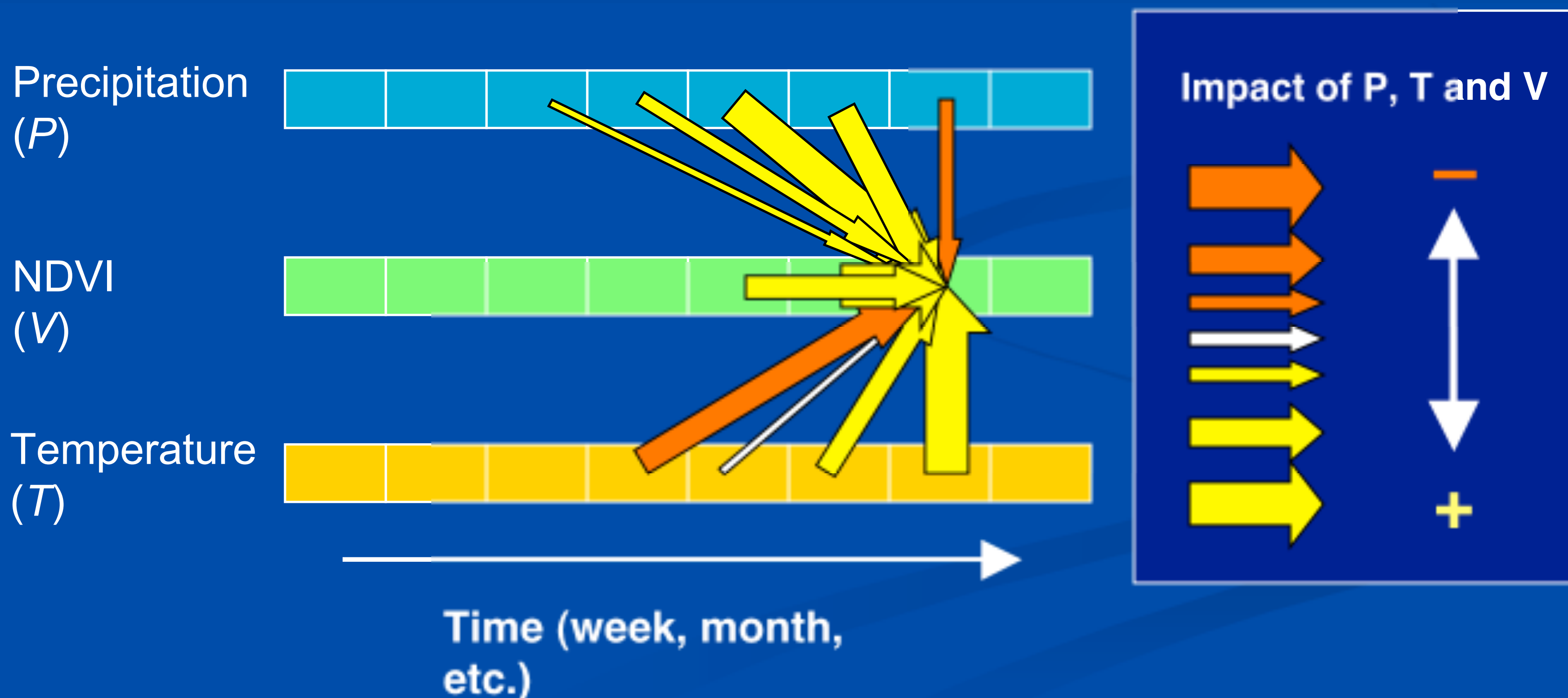
Land Cover



NDVI

Foundation of the VGF Model

According to our research, current NDVI is affected by antecedent precipitation, temperature and NDVI of the past few months



Methods and Results

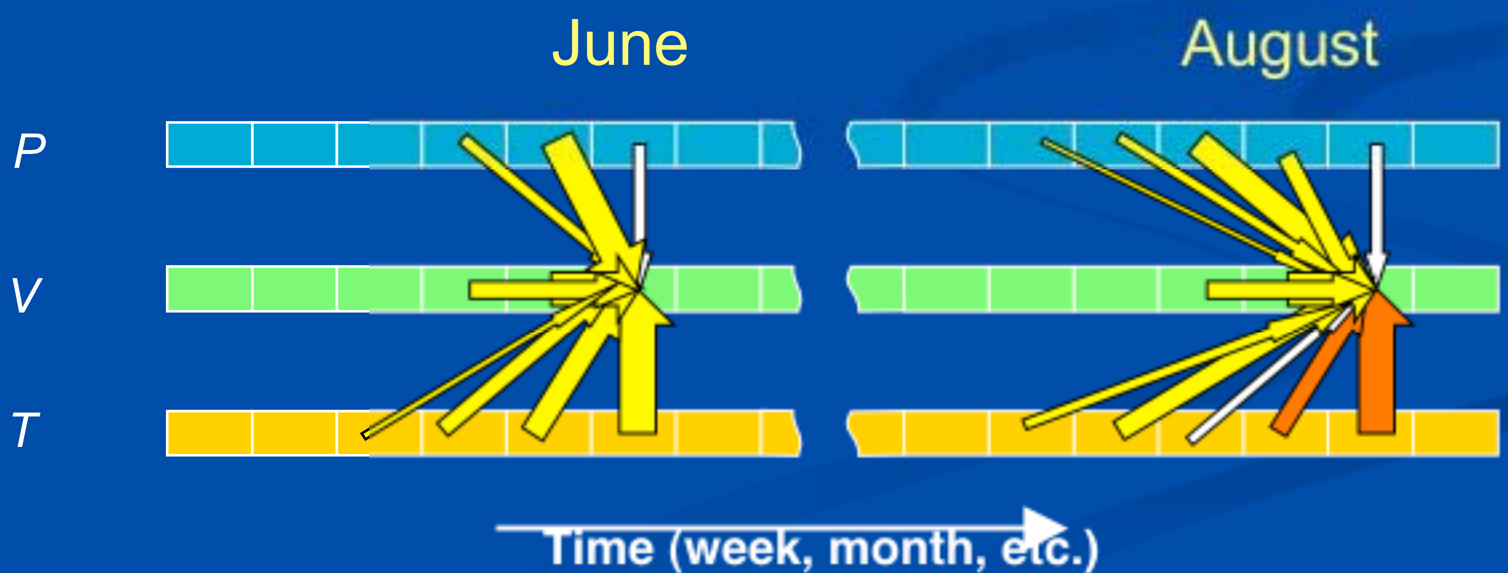
- The Vegetation Greenness Forecast (VGF) model is a statistical regression technique called an <u>autoregressive distributed-lag model:</u>

$$V_{t+s} = \alpha + \sum_{i=0}^{l} \beta_i V_{t-i} + \sum_{j=0}^{m} \gamma_j P_{t-j} + \sum_{k=0}^{n} \delta_k T_{t-k} + \varepsilon_t$$

V_{t+s} = forecasted NDVI at s weeks ahead (s = 1, 2, …)
V_{t-i} = NDVI measured at lag i (i = 0, 1, …, l)
P_{t-j} = precipitation measured at lag j (j = 0, 1, …, m)
T_{t-k} = temperature measured at lag k (k = 0, 1, …, n)
l, m and n = lag lengths for V_{t-i}, V_{t-j} and V_{t-k}
_, _*i* , _*j* and _*k* = the regression coefficients;
_*t* = random error.

Methods and Results

- Lag lengths *l*, *m*, and *n* for V_{t-i}, V_{t-j} and V_{t-k} are determined as 8, 8, and 6, according to the analysis of the autocorrelation/ correlation - lag relationships.
- Time-Lag Patterns of precipitation and temperature impacts on NDVI vary among the seasonal periods.



Methods and Results

- An adjustment for the ***seasonal effect*** is important to make the model suitable for all time periods within the growing season (See RSE 87: 85-98, 2003).
- A set of levels assigned to the five-seasonal time periods were added to the autoregressive distributed lag model.

Methods and Results

- **Assumptions** of the VGF model:
  - Other factors (soil type, terrain, vegetation type) are constant throughout the time series.
  - NDVI has a linear relationship to precipitation and temperature within each seasonal time period.
  - There is no interaction between precipitation and temperature.
- The VGF model is site-dependent. i.e., the regression coefficients vary among different spatial locations.

Model Performance and Validation

- R^2, Mean Absolute Percent Error (*MAPE*), was used to assess the accuracy of the model.
  - MAPE measures relative error

$$MAPE = (1/n)\sum 100|V - V^p|/V$$

V = observed NDVI

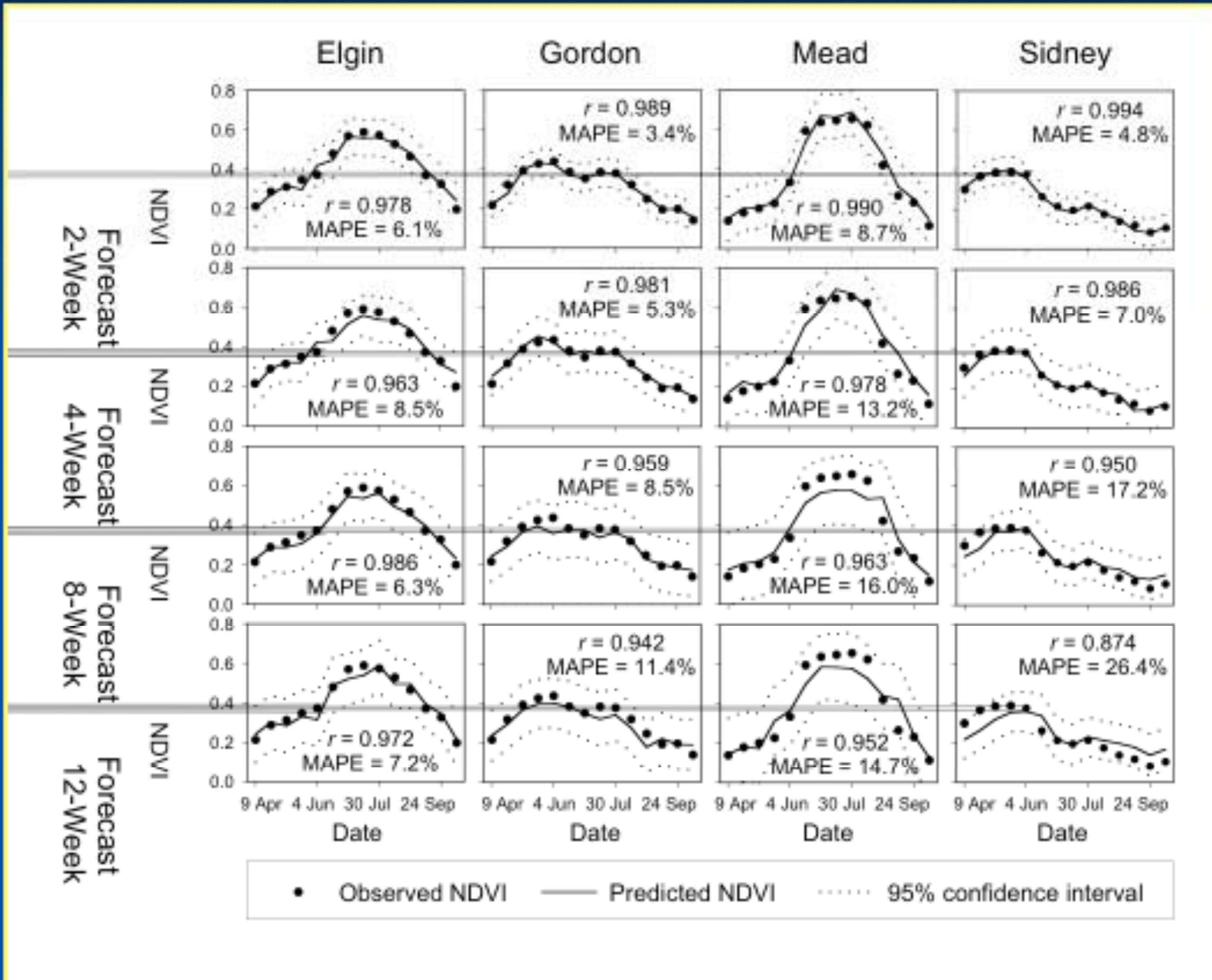
V^p = predicted NDVI

n = number of observations

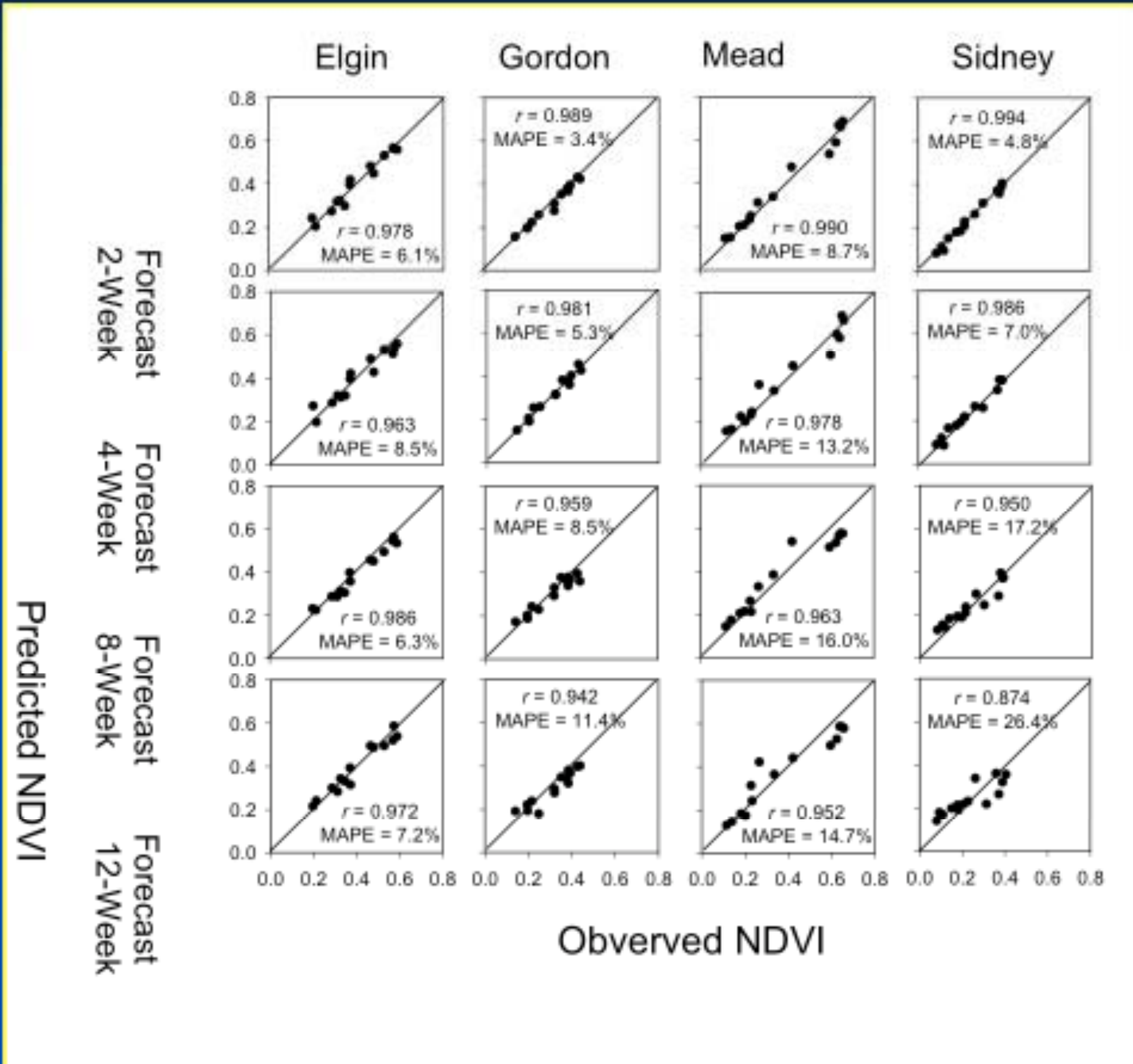
- The VGF model was applied to forecast NDVI for 2 – 12 weeks. The average R^2 and *MAPE* of the regression models for the 31 weather stations are:

2-week forecast	$R^2 = 0.966$	MAPE = 5.0%
4-week forecast	$R^2 = 0.931$	MAPE = 7.4%
8-week forecast	$R^2 = 0.854$	MAPE = 11.1%
12-week forecast	$R^2 = 0.798$	MAPE = 12.9%

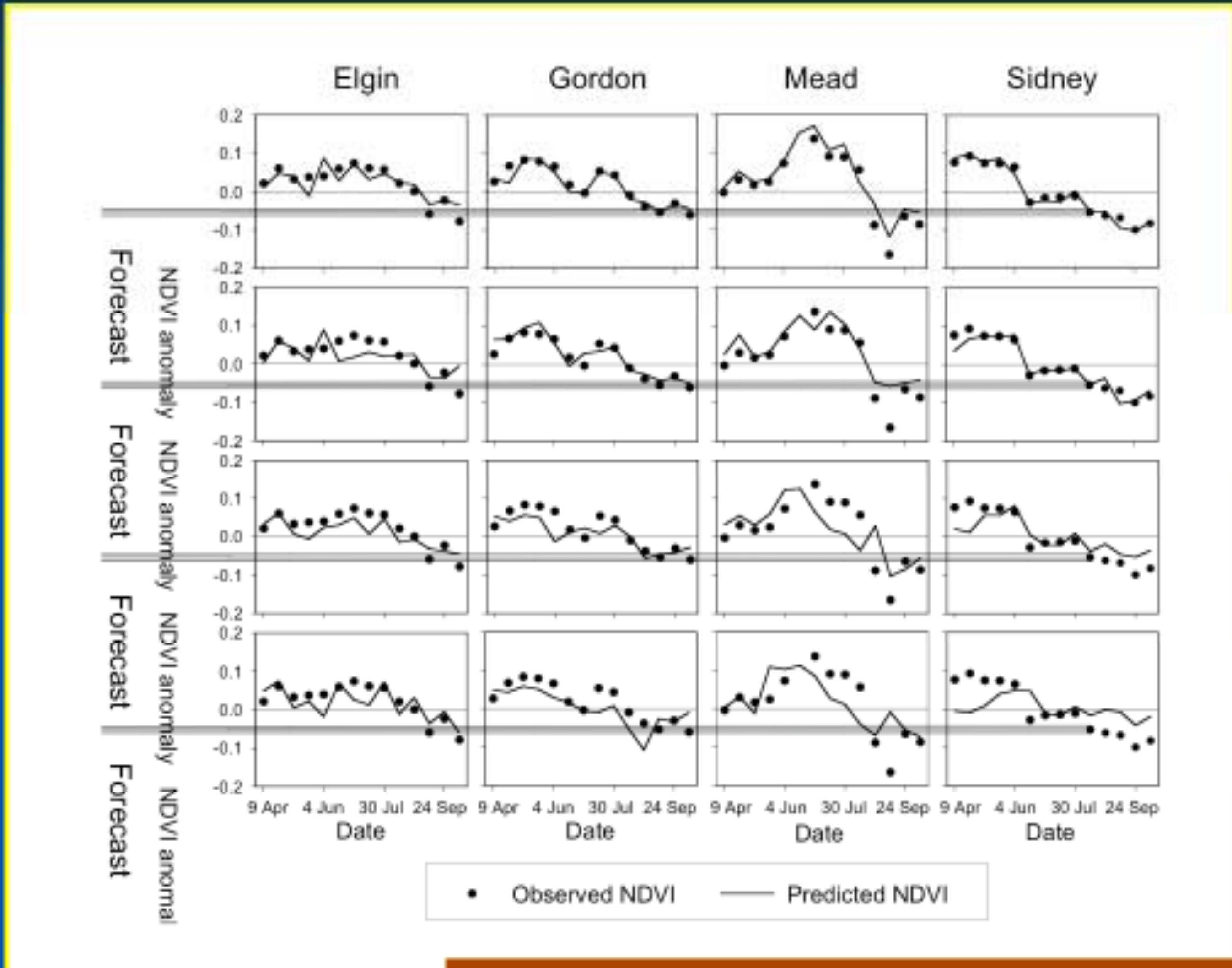
Predicted and observed NDVI in 2000



Predicted and Observed NDVI in 2000



Predicted and observed NDVI anomaly - 2000



NDVI anomaly = NDVI – average NDVI

Summary: VGF Model

INPUT

Current and Historic Record

- NDVI
- Precipitation
- Temperature

→ **Autoregressive Distributed-Lag Model with Seasonal Adjustment** →

OUTPUT

1 – 12 Week Forecast

NDVI and Anomaly

Summary

- Current vegetation greenness is strongly affected by antecedent precipitation, temperature and vegetation greenness status of the past few months.
- Based on this knowledge, a VGF model was designed that can reliably forecast vegetation condition up to 12 weeks.
- Regression R^2 values range from 0.97 – 0.80 for 2 – 12 week forecasts; the higher R^2s are associated with a shorter prediction time.
- The model could also be used for production of real-time VGF maps over large geographic areas through the integration of satellite images and appropriate climate data.
- Potential usefulness of the VGF model includes assessment of crop status, drought monitoring, and wild fire warning systems.

Recommendations for Future Research

- Test and improve VGF model for different cover types (forest, desert, etc.)
- Produce vegetation greenness forecast images in 2-D space
- Create web-based real time forecast system
- Transfer to MODIS VI