



# Forecasting Vegetation Greenness with Satellite and Climate Data

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# 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)  
$$RG (\%) = 100 \cdot NDVI / mean$$
  - **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

Vegetation and Temperature Condition Index Home Pages - Microsoft Internet Explorer

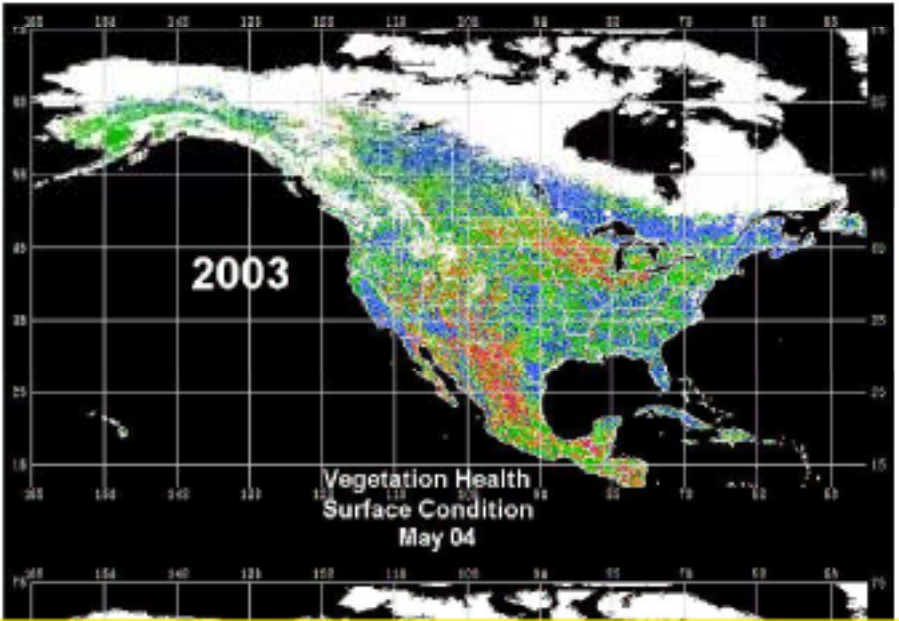
File Edit View Favorites Tools Help

Bad. Search Favorites Media

Address <http://orbis-net.noaa.gov/orad/sat/surf/vci/> Go Links

### North American Continent Vegetation Health (VT - index)

Vegetation Health: Red - stressed, Green - fair, Blue - favorable



2003

Vegetation Health  
Surface Condition  
May 04

[Vegetation Health Image Map Resources](#)

[Current Vegetation Image Maps](#)

[Archived Vegetation Image Maps](#)

[Moisture and Thermal Condition Global Map](#)

[Fire Potential Maps](#)

[Focus On: El Nino Impacts South Africa](#)

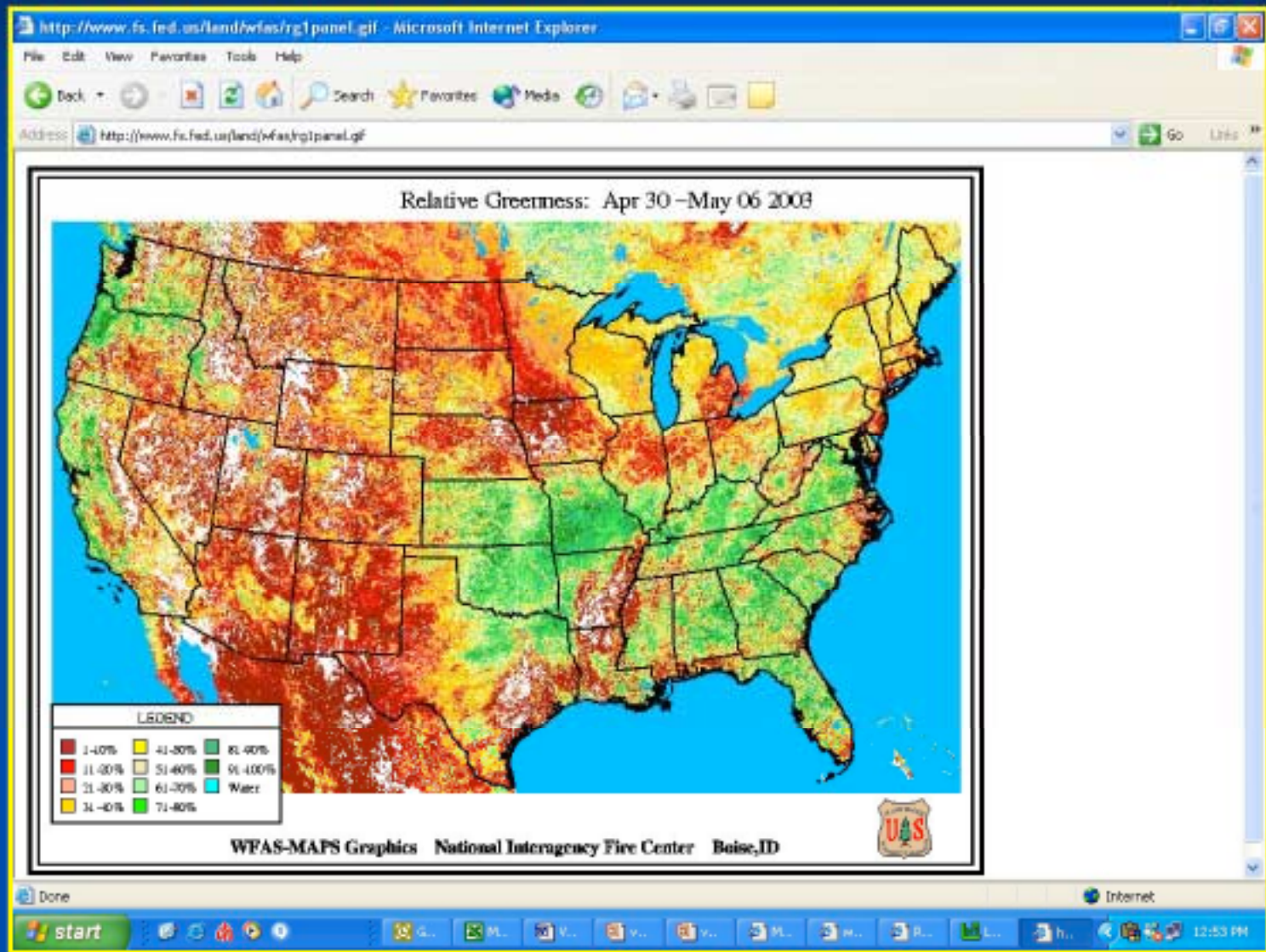
[Focus On: Horn of Africa 2000-2003](#)

[Fire Risk Maps](#)

[Technical Background](#)

# 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

Kansas Applied Remote Sensing Program (KARS) | Green Report - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address: http://mapster.igs.ukans.edu/kars/map.cfm

### The GreenReport® State of Kansas

Green Report® Weekly Summary  
May 12, 2003 - May 18, 2003

[About the Green Report](#) [Weekly Maps](#) [Outlook & Commentary](#)

**1. choose your map** [update map](#)

Greenness  
 Vegetation Condition Index  
 This week vs last week  
 This week vs same week last year  
 This week vs long term average for this week

**2. add custom layers** [update map](#)

Zoom In [Rivers and Streams]  
Zoom In [Roads]  
 Highways  
 County Boundary

**3. print your map** [print map](#) After you have prepared your map to your location of interest, click the 'Print Map' button to create your custom report. You will have options to include various national and state forecasts in addition to your map.

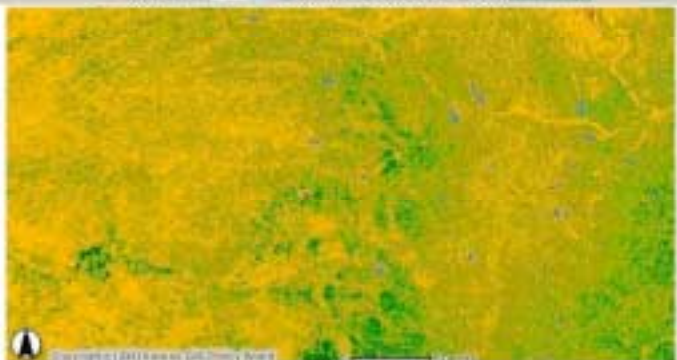
Key

Zoom Level: 1.5 | [Zoom In](#) | [Zoom Out](#) | [Pan \(Hold Map\)](#)

**Greenness**

Dark brown	Low Biomass
Light brown	
Yellow	
Light green	
Dark green	High Biomass
Blue	Water
White	Snow/Clouds

Dark green indicates areas with abundant live vegetation such as forests, actively growing croplands, or healthy pasture. Intermediate shades mean lesser amounts of actively growing and/or healthy vegetation. Dark brown generally means there is small amounts of live vegetation. This may be either because the area is normally bare, as in urban areas, or because the vegetation is dead or has been harvested.

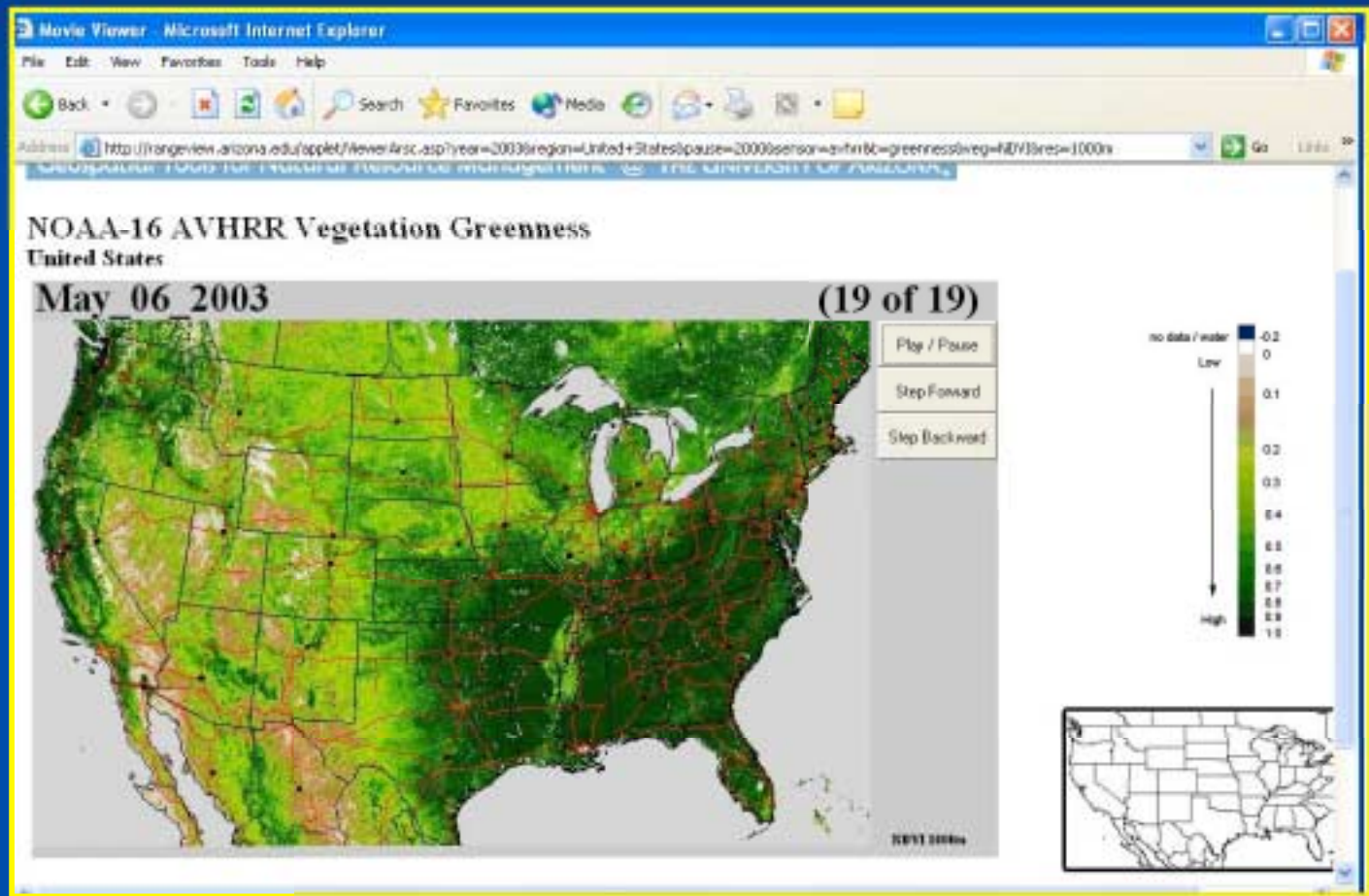


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Internet

University of Arizona, College of Agriculture and Life Sciences

## RangeView: NDVI and NDVI Difference





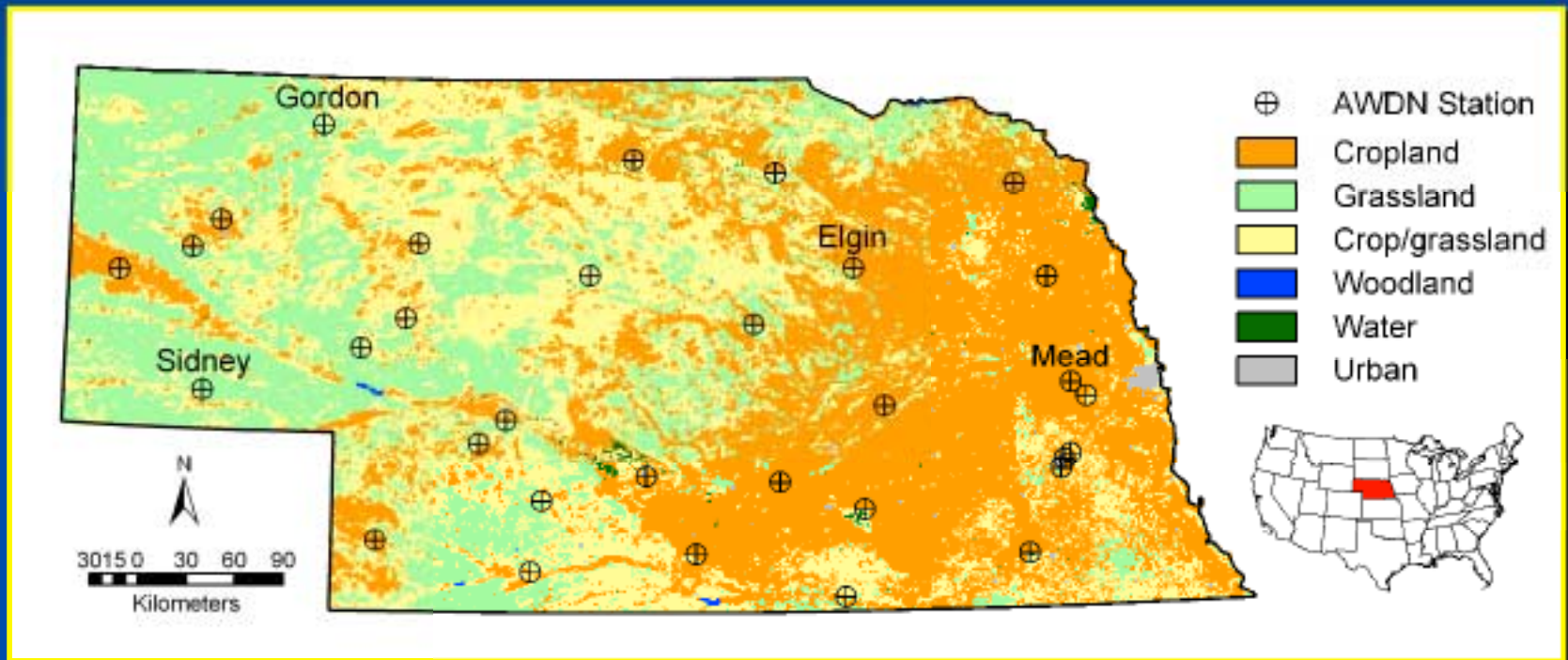
# Introduction

- 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

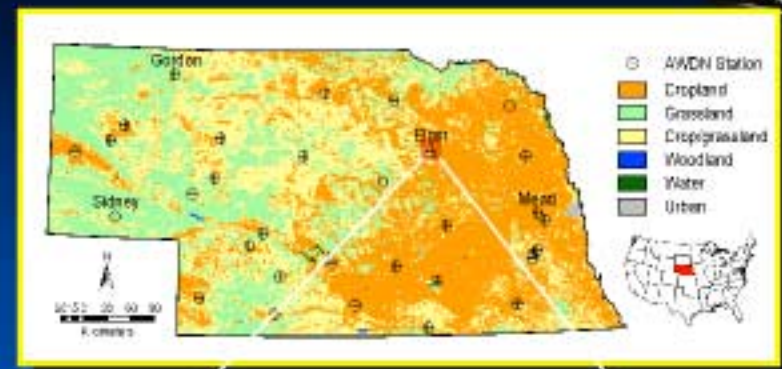


# Data Preparation

- 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

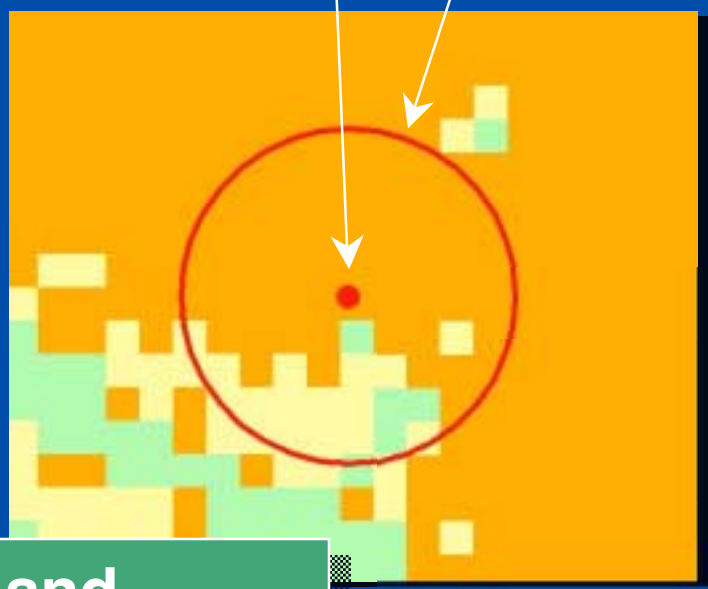


# Data

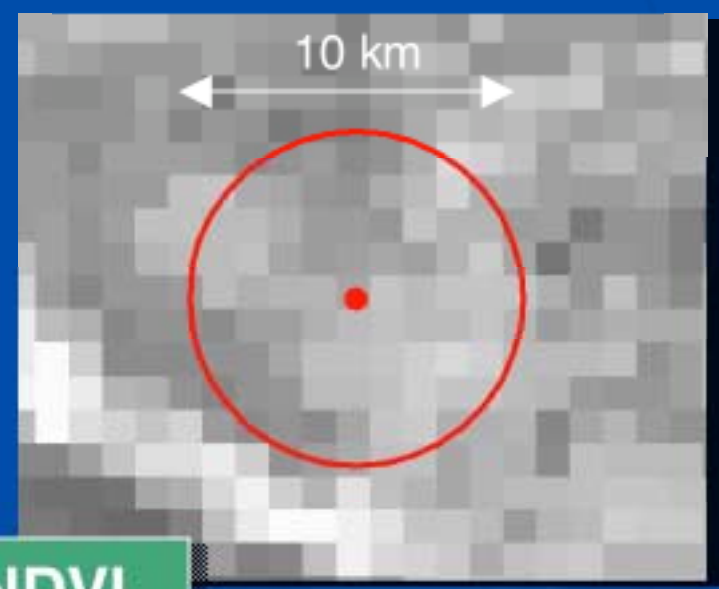


AWDN station

Buffer



Land Cover

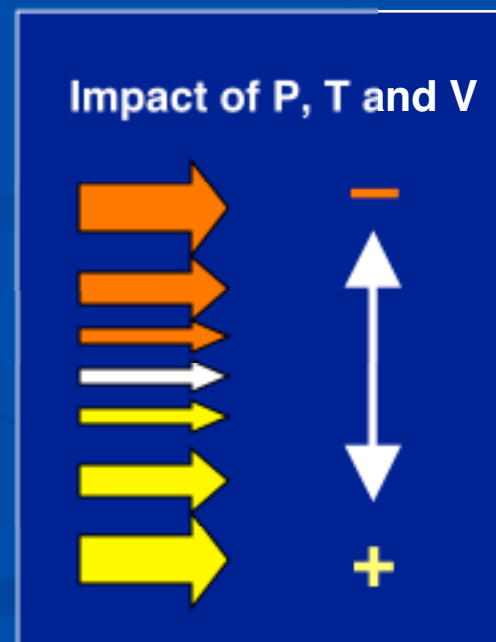
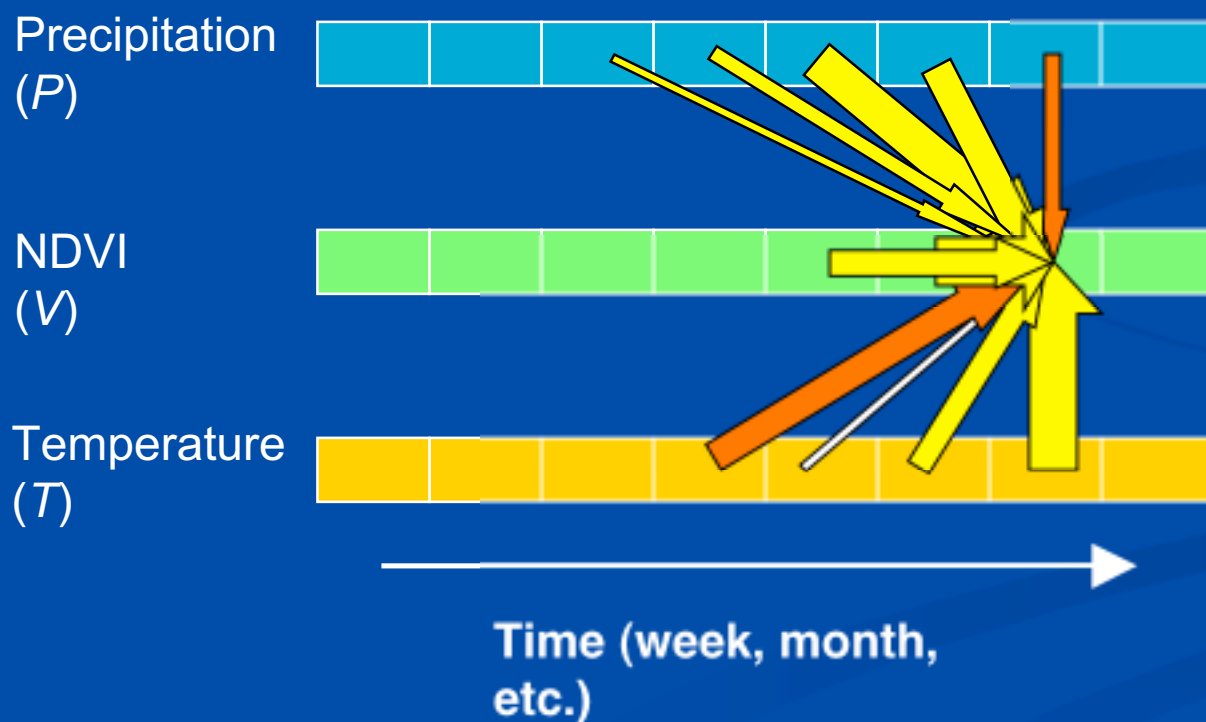


NDVI



## 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 autoregressive distributed-lag model:

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

$V_{t+s}$  = forecasted NDVI at  $s$  weeks ahead ( $s = 1, 2, \dots$ )

$V_{t-i}$  = NDVI measured at lag  $i$  ( $i = 0, 1, \dots, l$ )

$P_{t-j}$  = precipitation measured at lag  $j$  ( $j = 0, 1, \dots, m$ )

$T_{t-k}$  = temperature measured at lag  $k$  ( $k = 0, 1, \dots, n$ )

$l$ ,  $m$  and  $n$  = lag lengths for  $V_{t-i}$ ,  $P_{t-j}$  and  $T_{t-k}$

$\alpha$ ,  $\beta_i$ ,  $\gamma_j$  and  $\delta_k$  = the regression coefficients;

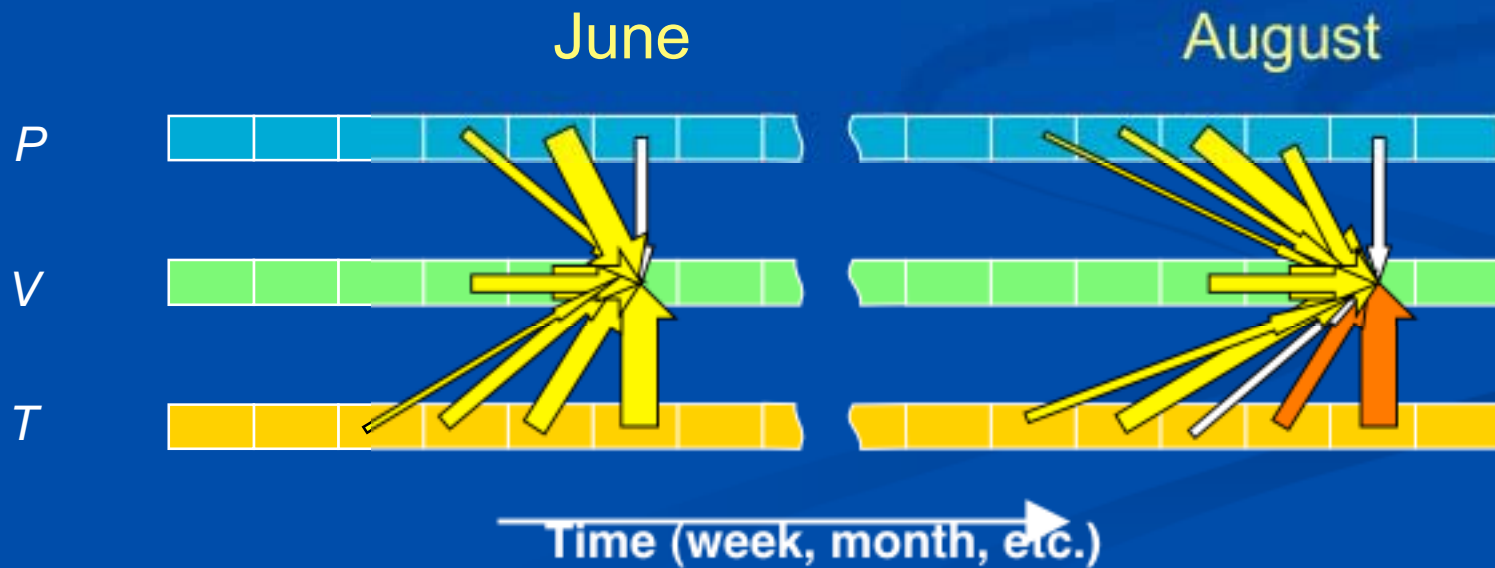
$\varepsilon_t$  = random error.





## Methods and Results

- Lag lengths  $l$ ,  $m$ , and  $n$  for  $V_{t-l}$ ,  $V_{t-m}$  and  $V_{t-n}$  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

$$MAPE = (1/n) \sum_{i=1}^n 100 |V - V^p| / V$$

$V$  = observed NDVI

$V^p$  = predicted NDVI

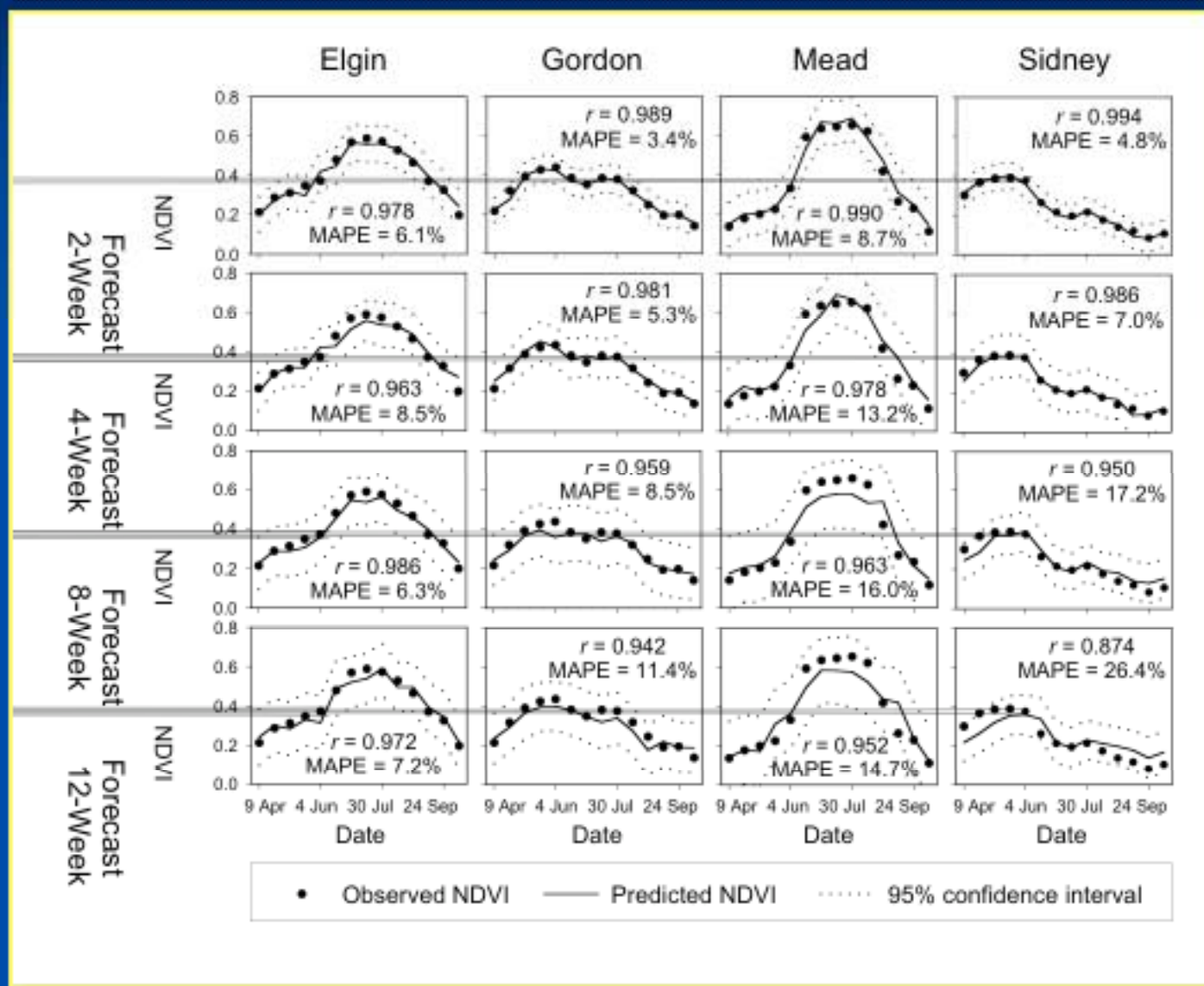
$n$  = number of observations

- 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%

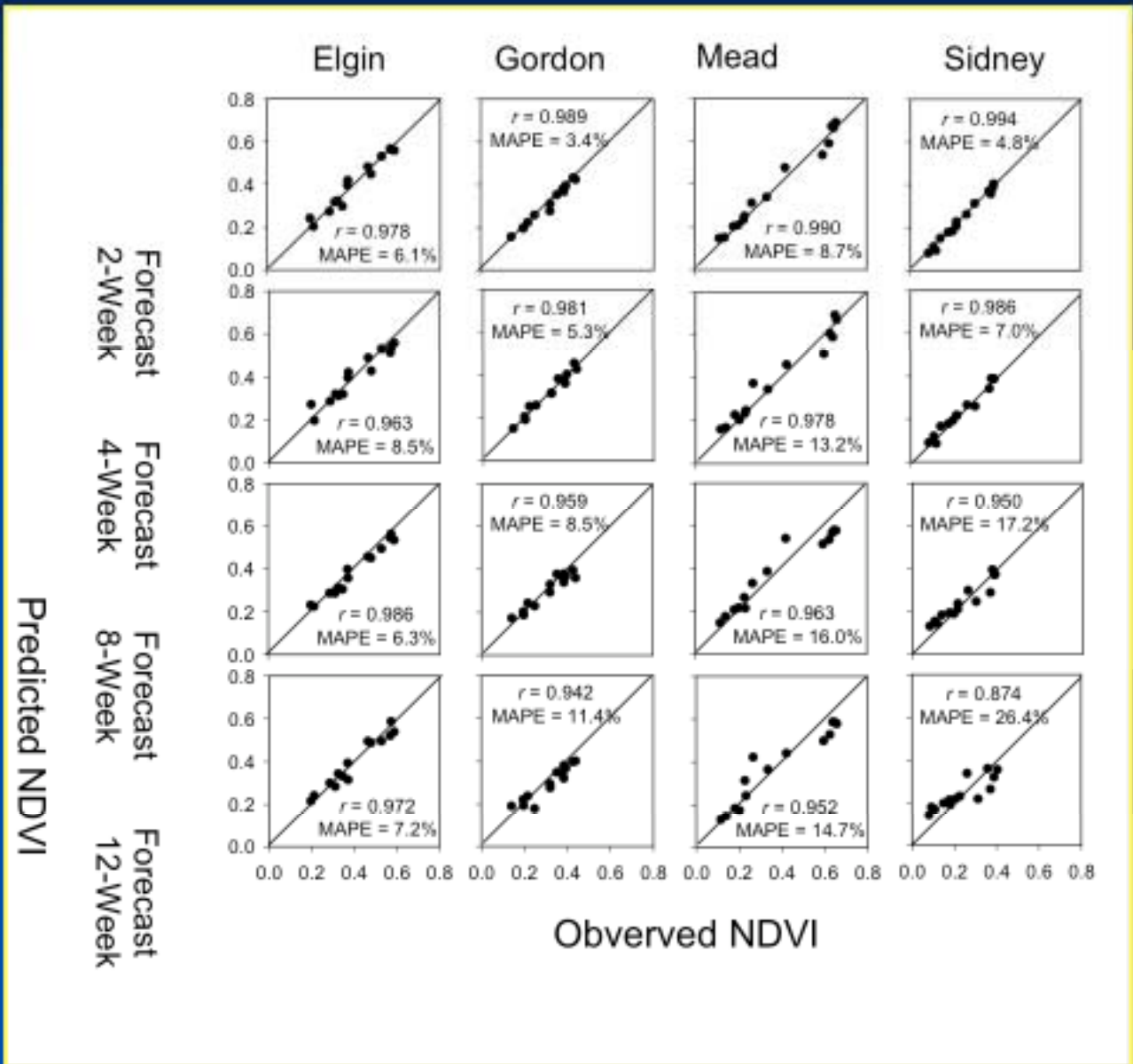


# Predicted and observed NDVI in 2000





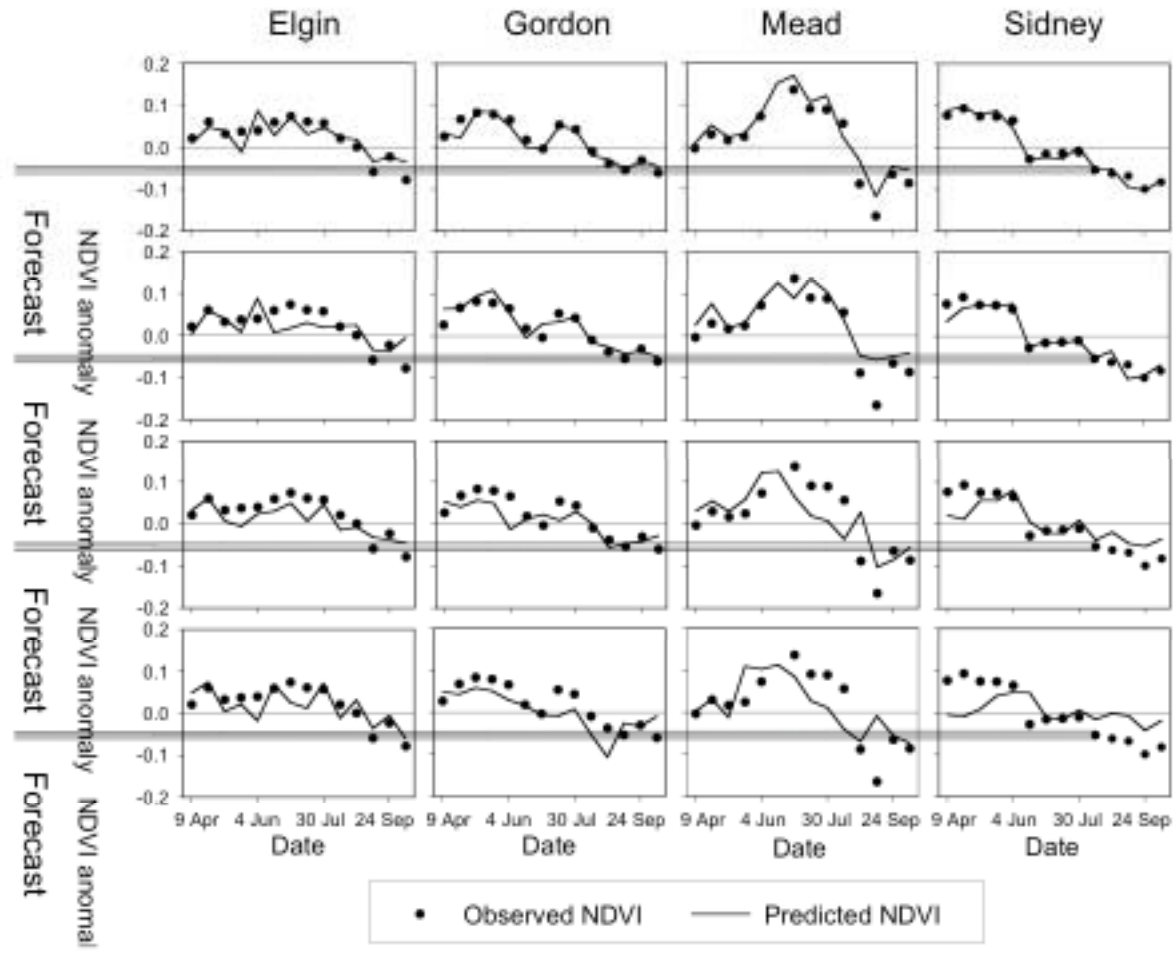
# Predicted and Observed NDVI in 2000







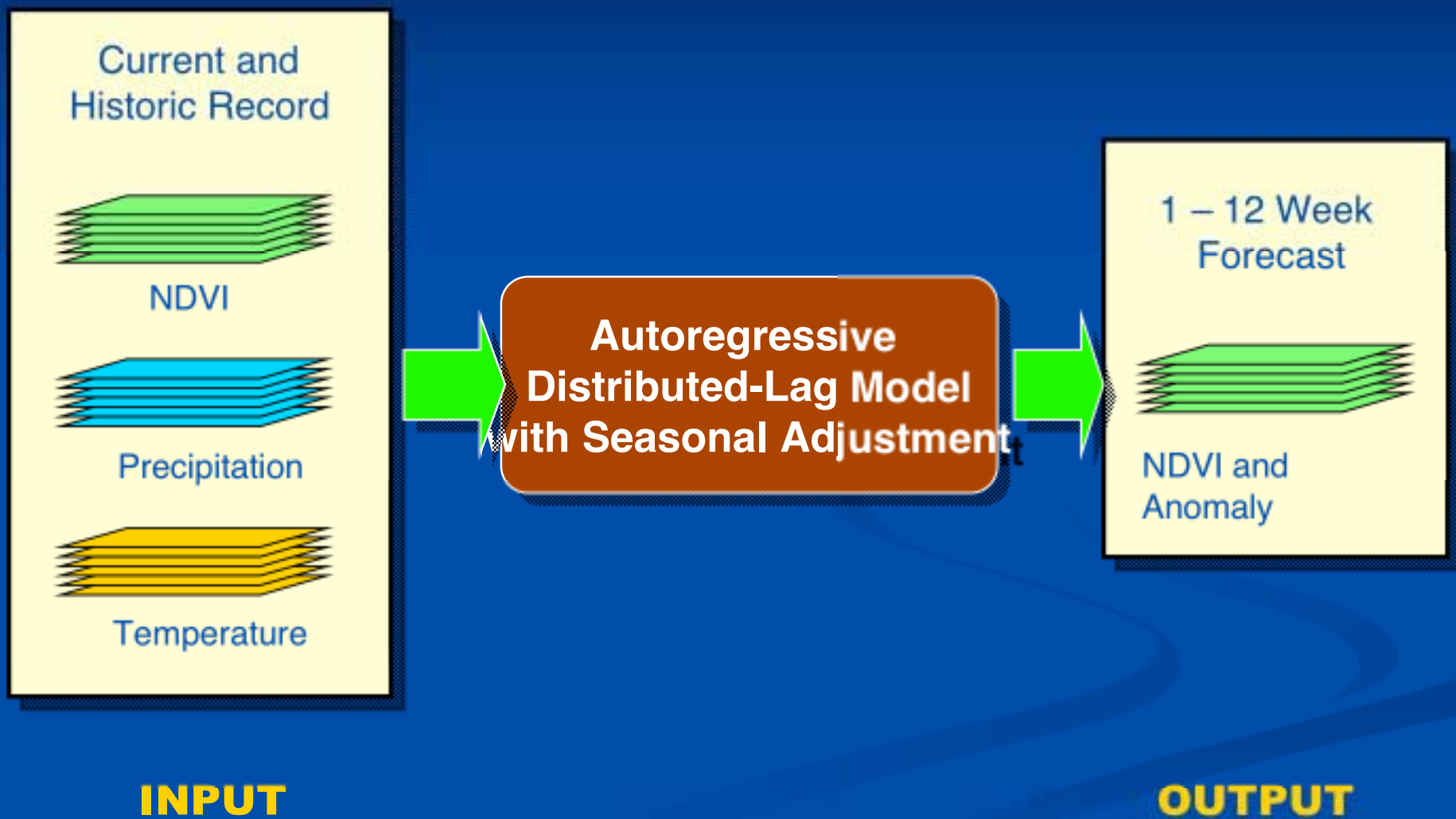
# Predicted and observed NDVI anomaly - 2000



*NDVI anomaly = NDVI – average NDVI*



# Summary: VGF Model





# 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  $R^2$ s 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