Relation between Ground-based Soil Moisture and Satellite Image-based NDVI

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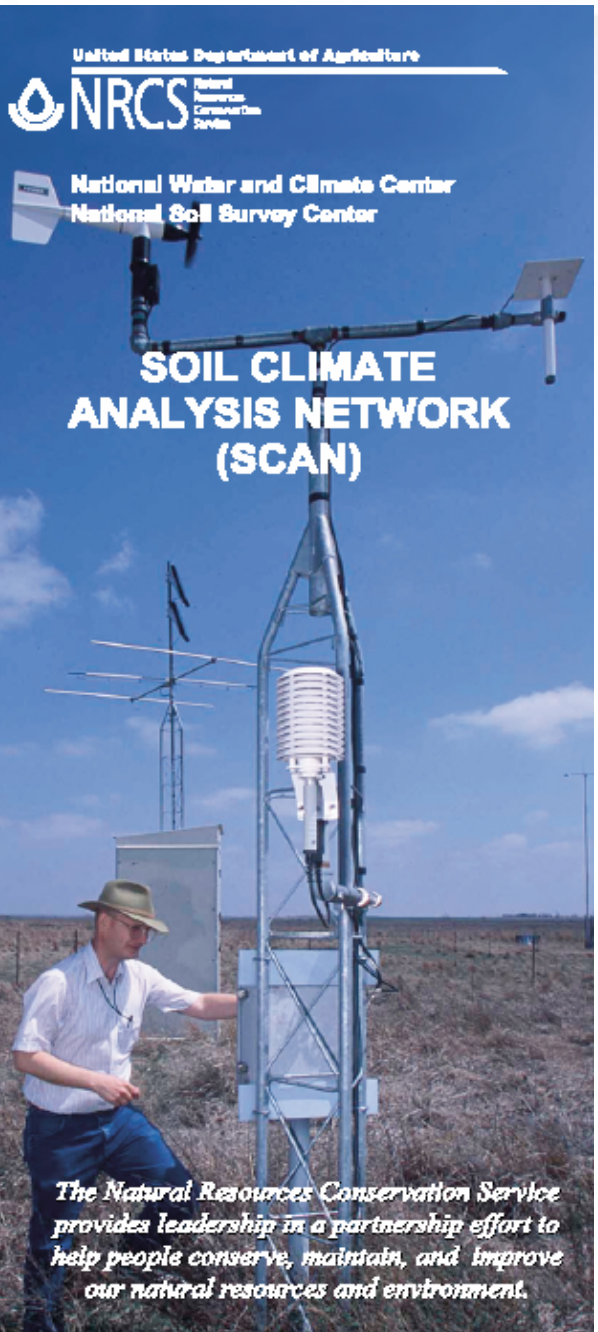
Introduction

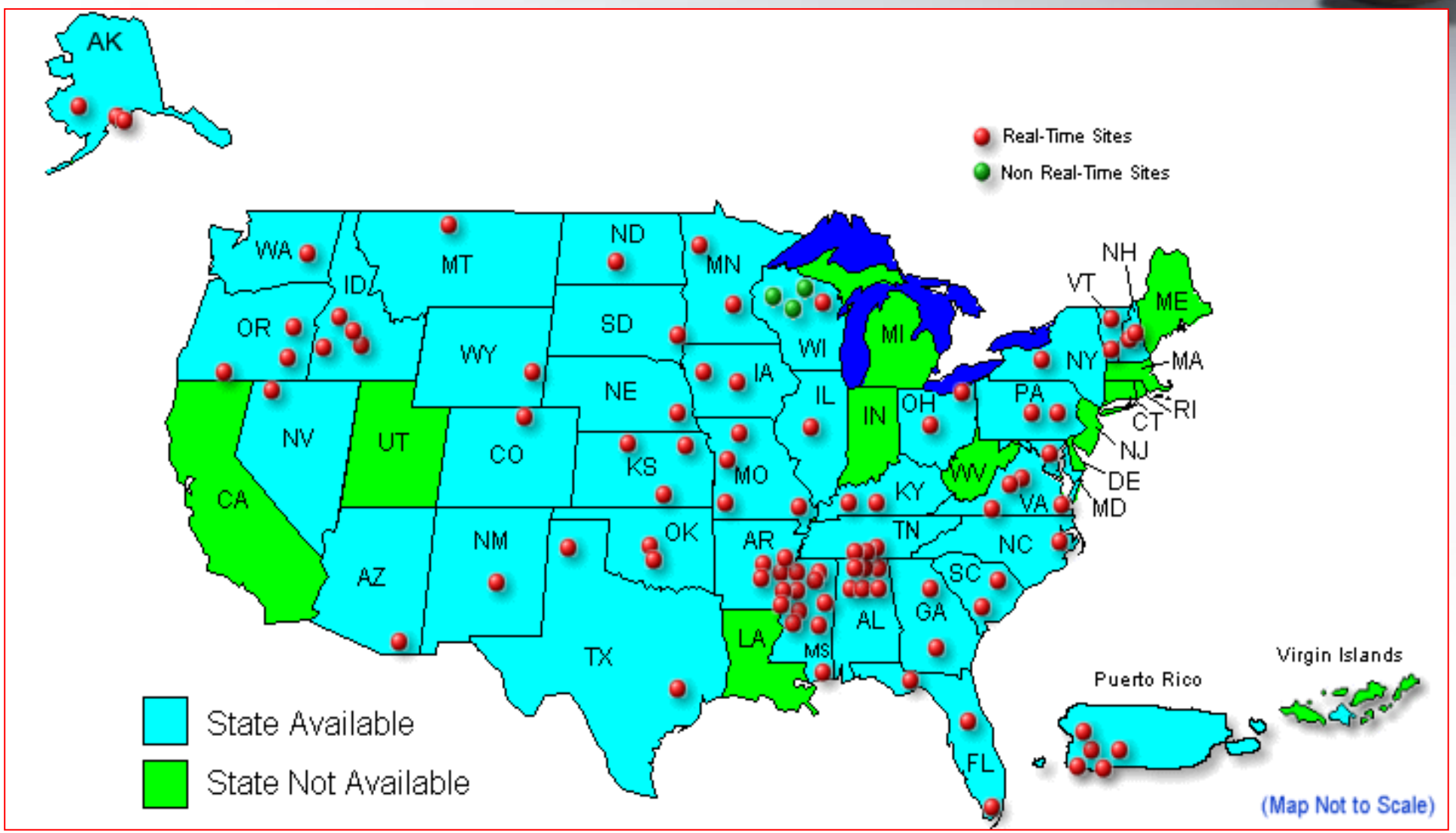
- Soil moisture is very important parameters for vegetation growth and climatic and hydrological modeling. Surface soil moisture (<10cm) can be easily acquired, like remotely sensing by microwave, or estimating with satellite surface vegetation index. However, there was few ways to obtain the deeper zone soil moisture. Ground-based measurement of soil moisture is very expensive and can’t satisfy the need of climatic and hydrological modeling. The Soil Climate Analysis Network (SCAN) provides the hourly profile soil moisture, which provides us chance to estimate soil moisture using MODIS NDVI.

Objectivity



- To find if there is any correlation between soil moisture and MODIS image-based NDVI.
- To estimate the soil moisture using NDVI if there is good correlation between soil moisture and NDVI.

Soil Climate Analysis Network (SCAN) Sites



http://www.wcc.nrcs.usda.gov/scan/

Research Areas and Period

- Three sites with different climate and vegetation.
  - Adams Ranch (2015) in New Mexico, semi-arid region, grassland.
  - Walnut Gulch (2026) in Arizona, semi-arid region, shrubland;
  - Prairie View (2016) in Texas, moderate humid region, grassland, to be completed.
- Period is from Feb 26, 2000 to Apr 31, 2004.

SCAN Site Information

Adams Ranch: 2015
- Lincoln County in New Mexico
- Latitude: 34° 15' N
- Longitude: 105° 25' W
- Elevation: 6175 feet
- Period of Record: 10/1/1994 to Present

Walnut Gulch: 2026
- Cochise County, in Arizona
- Latitude: 31° 44' N
- Longitude: 110° 03' W
- Elevation: 4500 feet
- Period of Record: 3/19/1999 to Present

Prairie View: 2016
- Waller County in Texas
- Latitude: 30° 05' N
- Longitude: 95° 59' W
- Elevation: 270 feet
- Period of Record: 10/1/1994 to Present

Data Sources

- **Soil moisture**

  Soil Moisture data was downloaded from three SCAN Sites.

  - Measured with neutron probe;
  - Including 5cm, 10cm, 20cm, 50cm, and 100cm depth.
  - Frequency: hourly
  - Period is from Feb, 2000 through Apr, 2004

Data Source

- **NDVI**
  - NDVI was calculated using band1 and band2 from the **MODIS** images downloaded from Earth Observation System (EOS) data gateway.

    NDVI= (R2-R1) / (R2+R1)

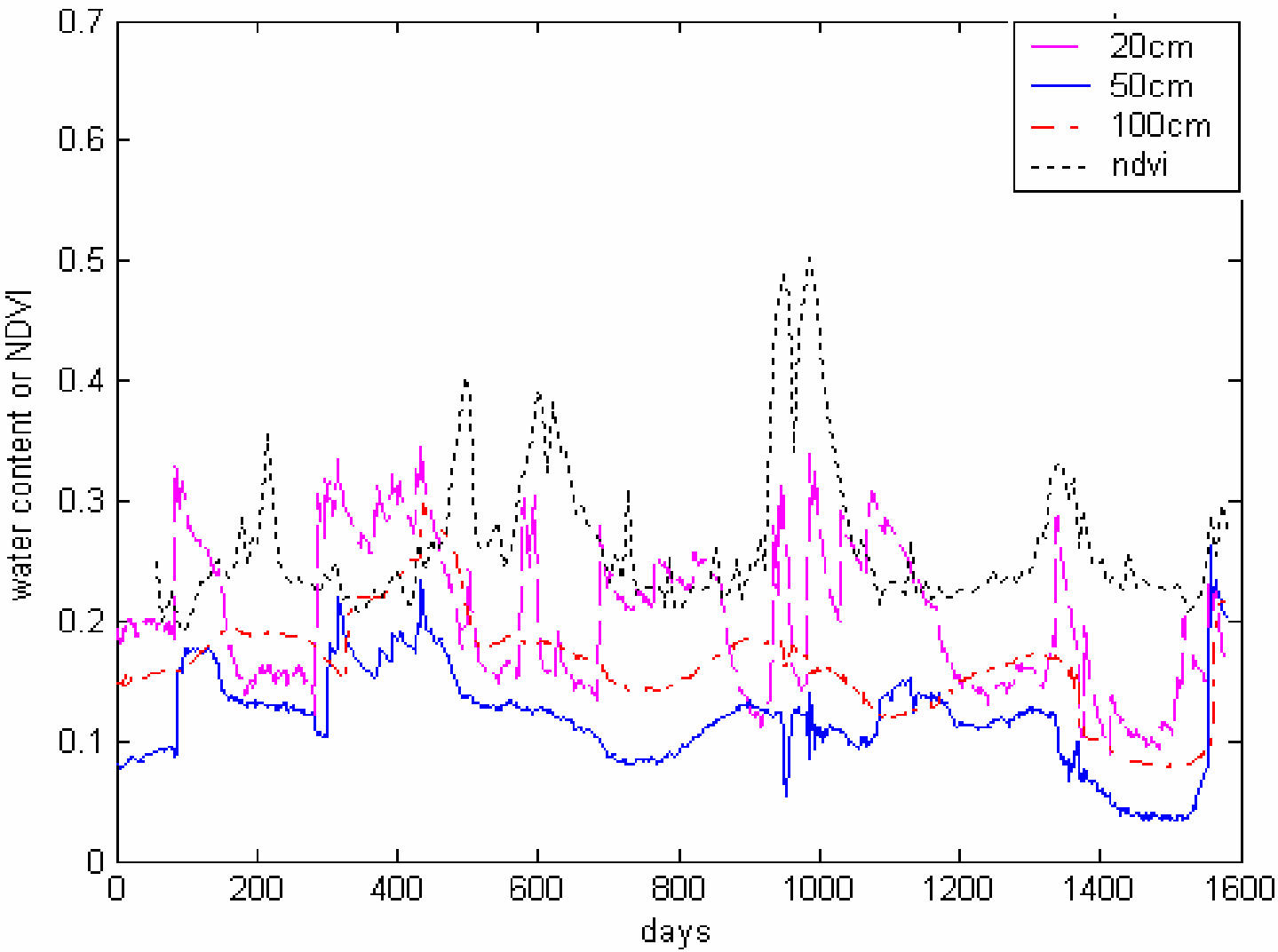
    R1, R2: Reflectance of band1, 2.

  - Period is from Feb, 2000 through Apr, 2004
  - 250 by 250 meter spatial resolution
  - Frequency: daily
  - 8-day average

1	2	3
4	5	6
7	8	9

Research Methods

- Compare time-series data (8-day average)



Methods

- **Time series average of five-year data**

$$SM(d) = \frac{\sum_{i=1}^{n} SM(d,i)}{n}$$

- **Cross Correlation analysis**

$$R^2 = \frac{C(i,j)}{SQRT(C(i,j) * C(i,j))}$$

  - R^2 is a matrix of correlation coefficients from matrix X.
  - C is the covariance matrix of Matrix X.
  - SQRT(X) is the square root of the elements of Matrix X.
  - X is a matrix composed of soil moisture and NDVI

Methods

- **Regression Analysis**

$$y = X\beta + \varepsilon$$

$$b = \beta = (X'X)^{-1}X'y$$

$$\hat{y} = Xb = Hy$$

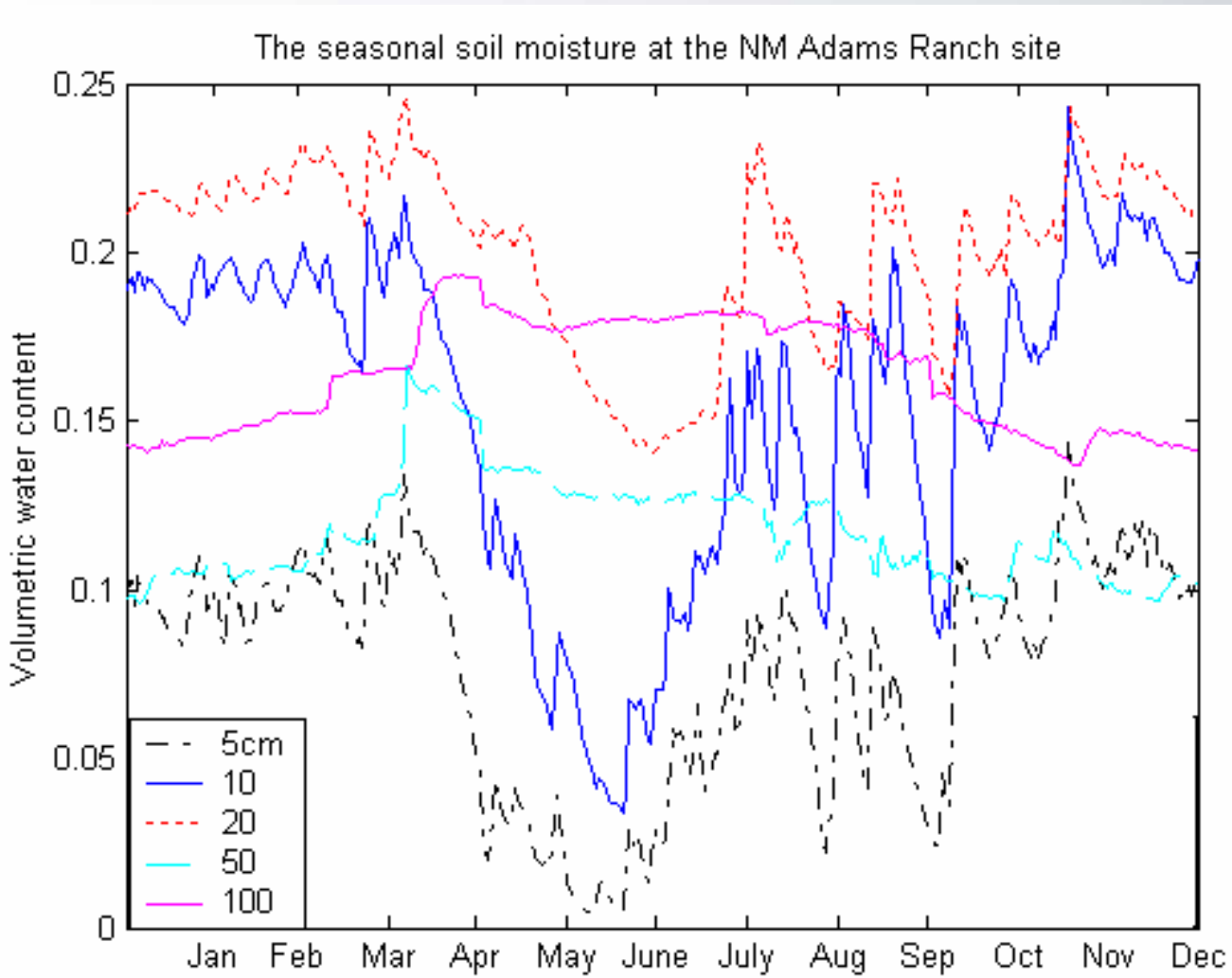
$$H = X(X'X)^{-1}X'$$

$$r = y - \hat{y} = (I - H)y$$

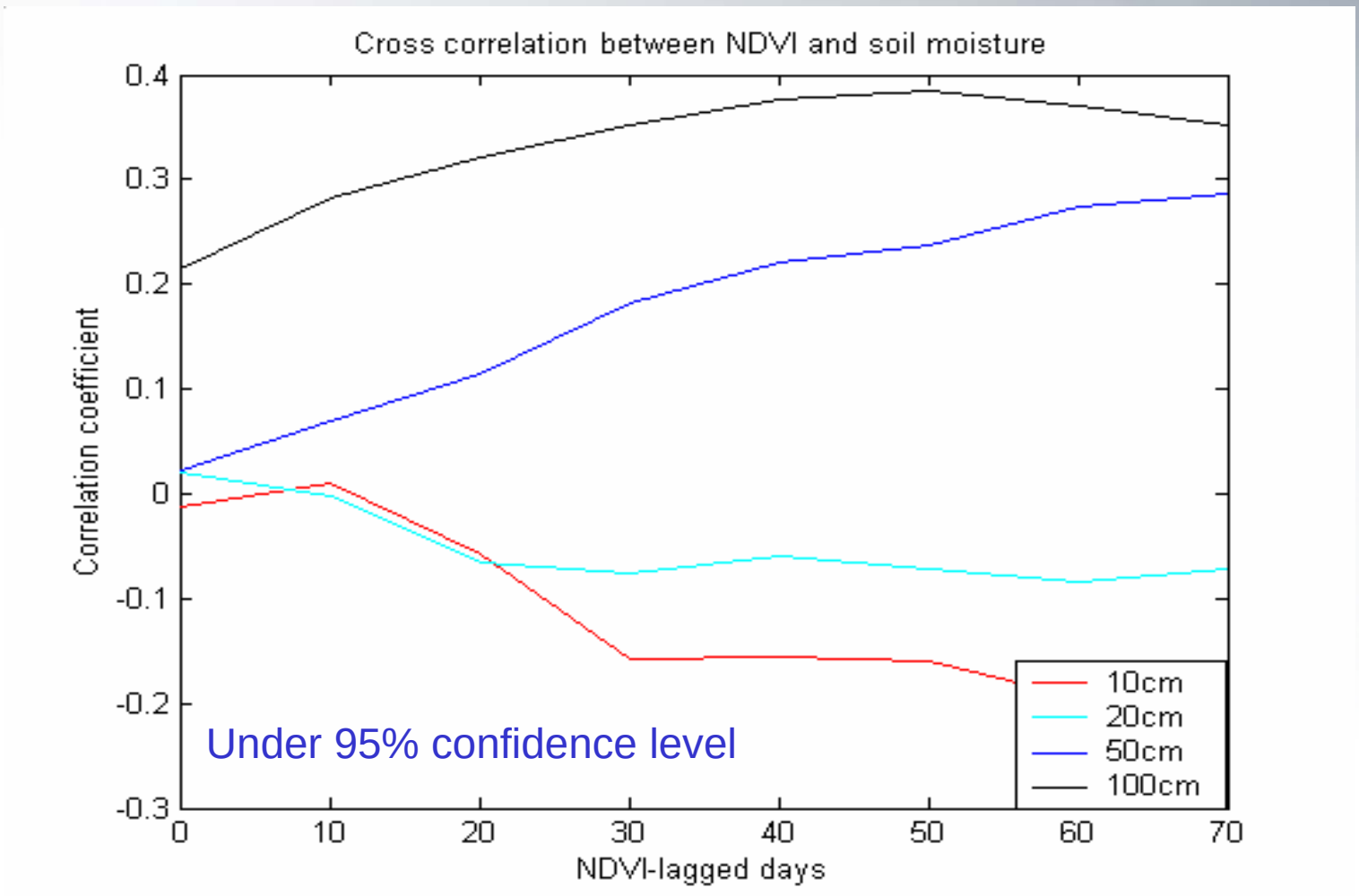
- Y is an n by 1 vector of observed soil moisture.
- X is an n by 2 matrix composed of 1 and NDVI.
- b is a p by 1 constant vector calculated from X and Y
- ^Y, estimated n by 1 vector.
- r or e is an n by 1 vector error between observed soil moisture and estimated soil moisture.

Results: Plot Data

Five-year average soil moisture at NM Ranch

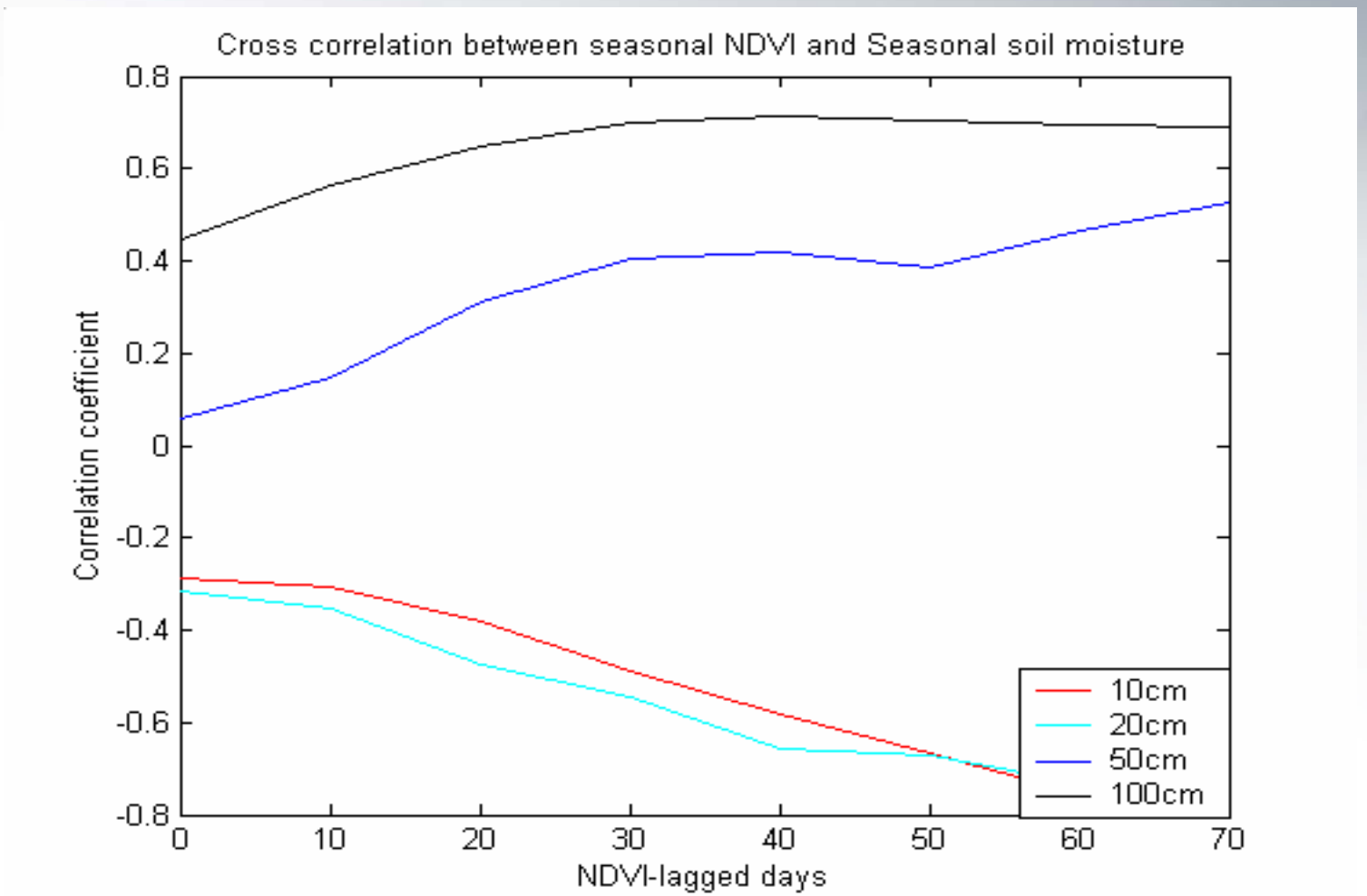


Correlation between NDVI and soil moisture (through five years) at NM Ranch



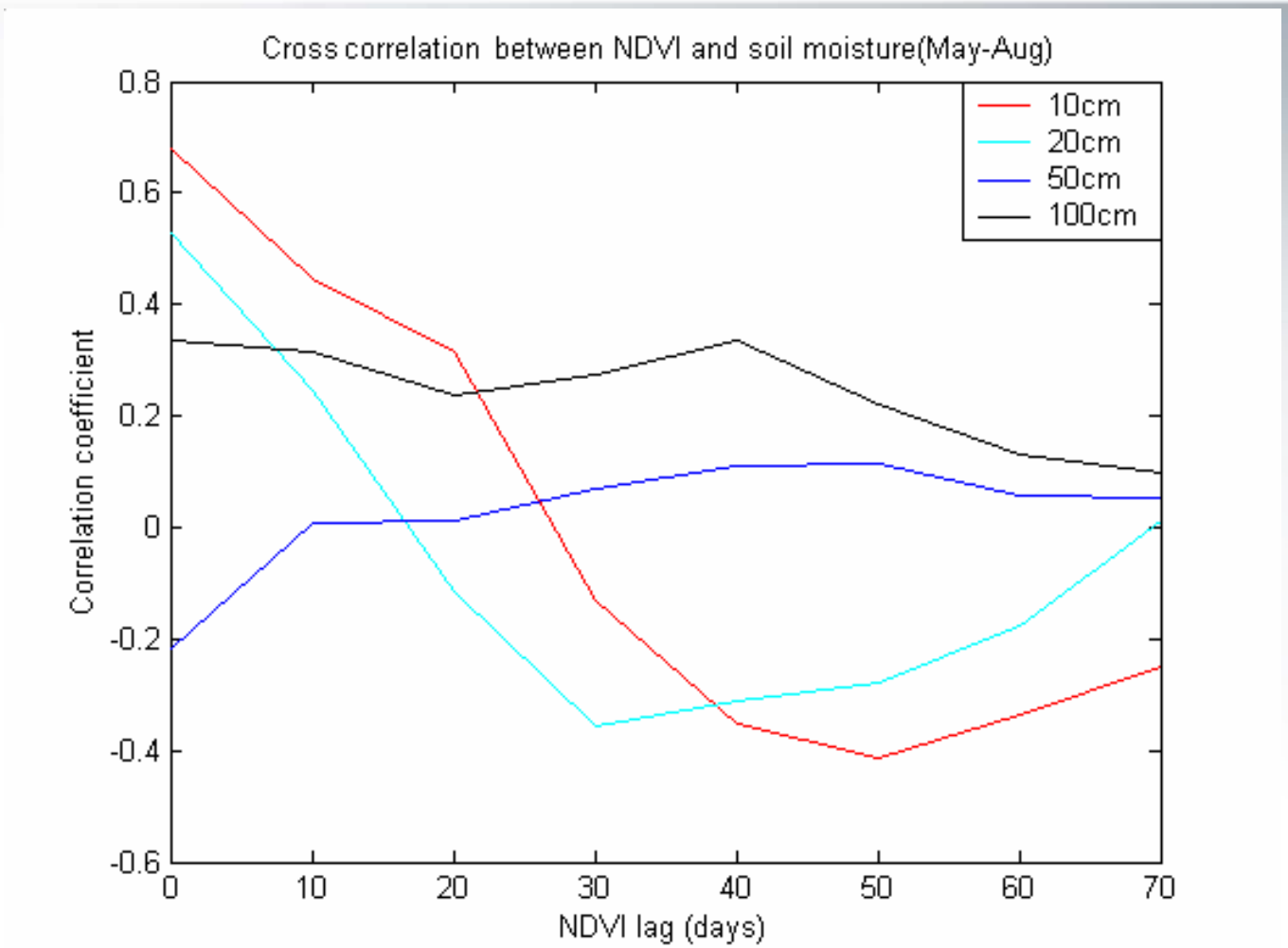
Soil moisture has small correlation with simultaneous NDVI through five years. But the time-lagged NDVI increases their correlation.

Correlation between average NDVI and average soil moisture (through a year) at NM



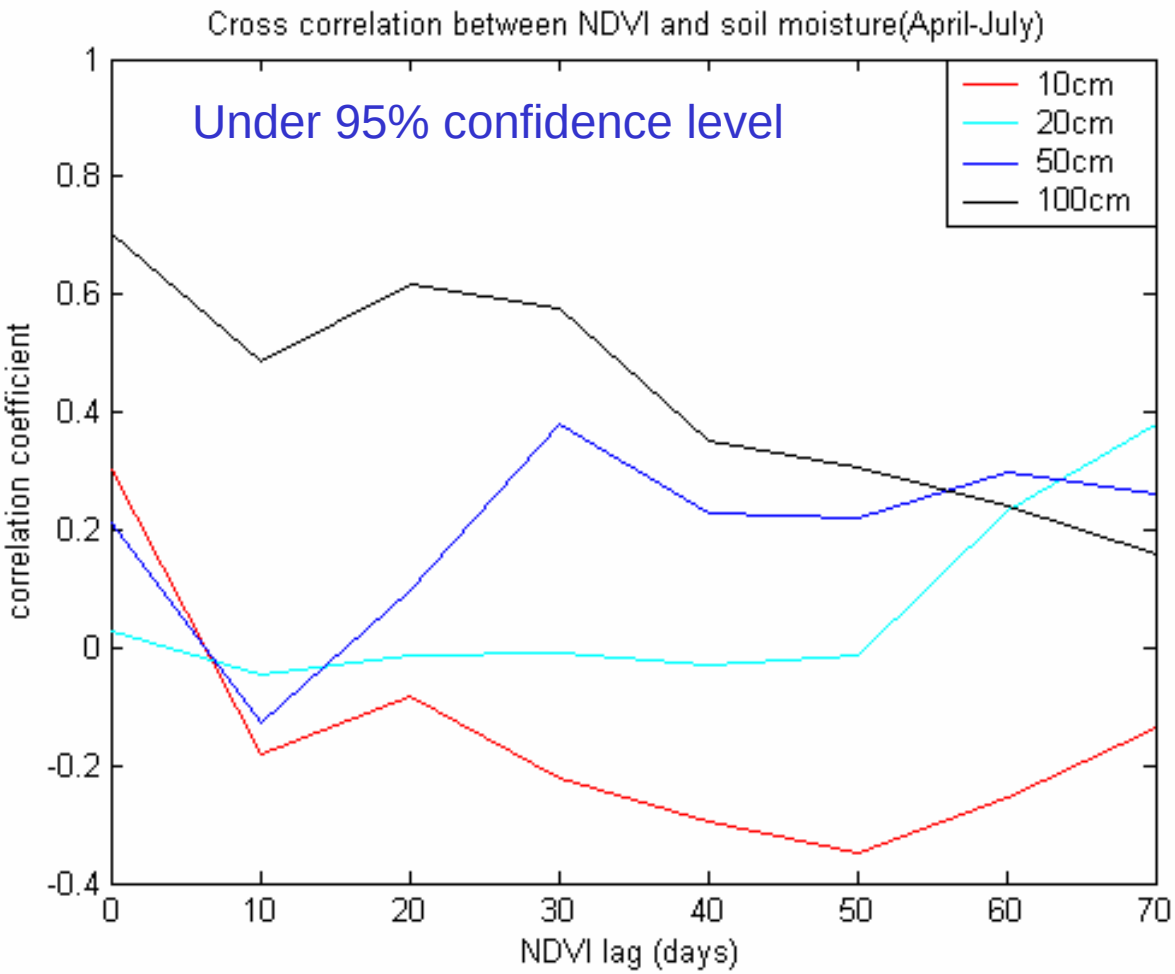
Five years time-series average soil moisture has a better correlation with average NDVI. Their correlation increases up to 0.7 at 100cm deep when NDVI lags SM 40 days.

Correlation between SM and NDVI at NM (May-Aug)



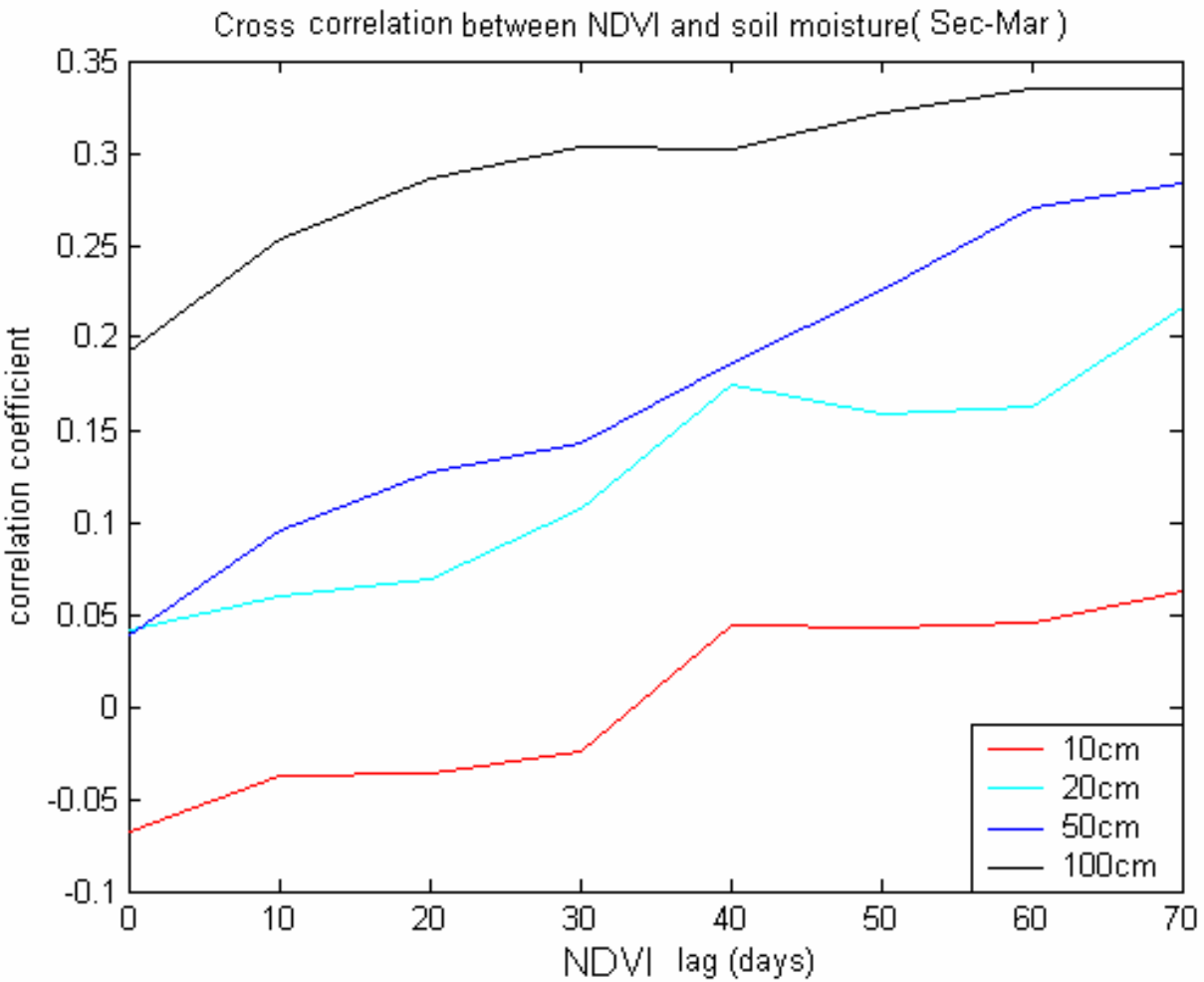
NDVI has good correlation with 10 and 20cm soil moisture, but small correlation With 50cm and 100cm deep soil moisture during May-Aug.

Correlation between SM and NDVI at NM (April-July)



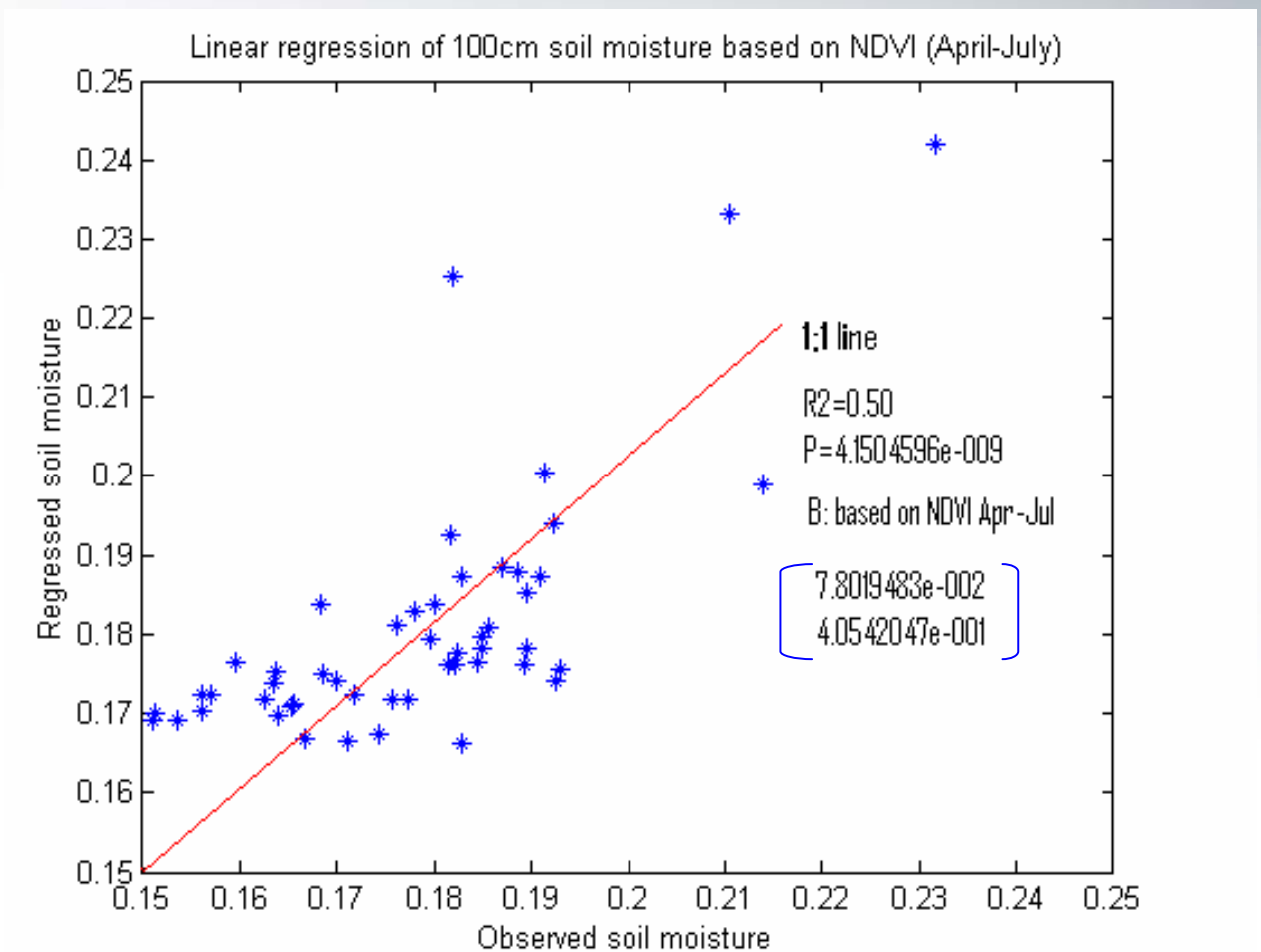
NDVI has good correlation with 100cm soil moisture, but small correlation With 10cm, 20cm and 50cm deep soil moisture during April-July.

Correlation between SM and NDVI at NM (Sep-Mar)



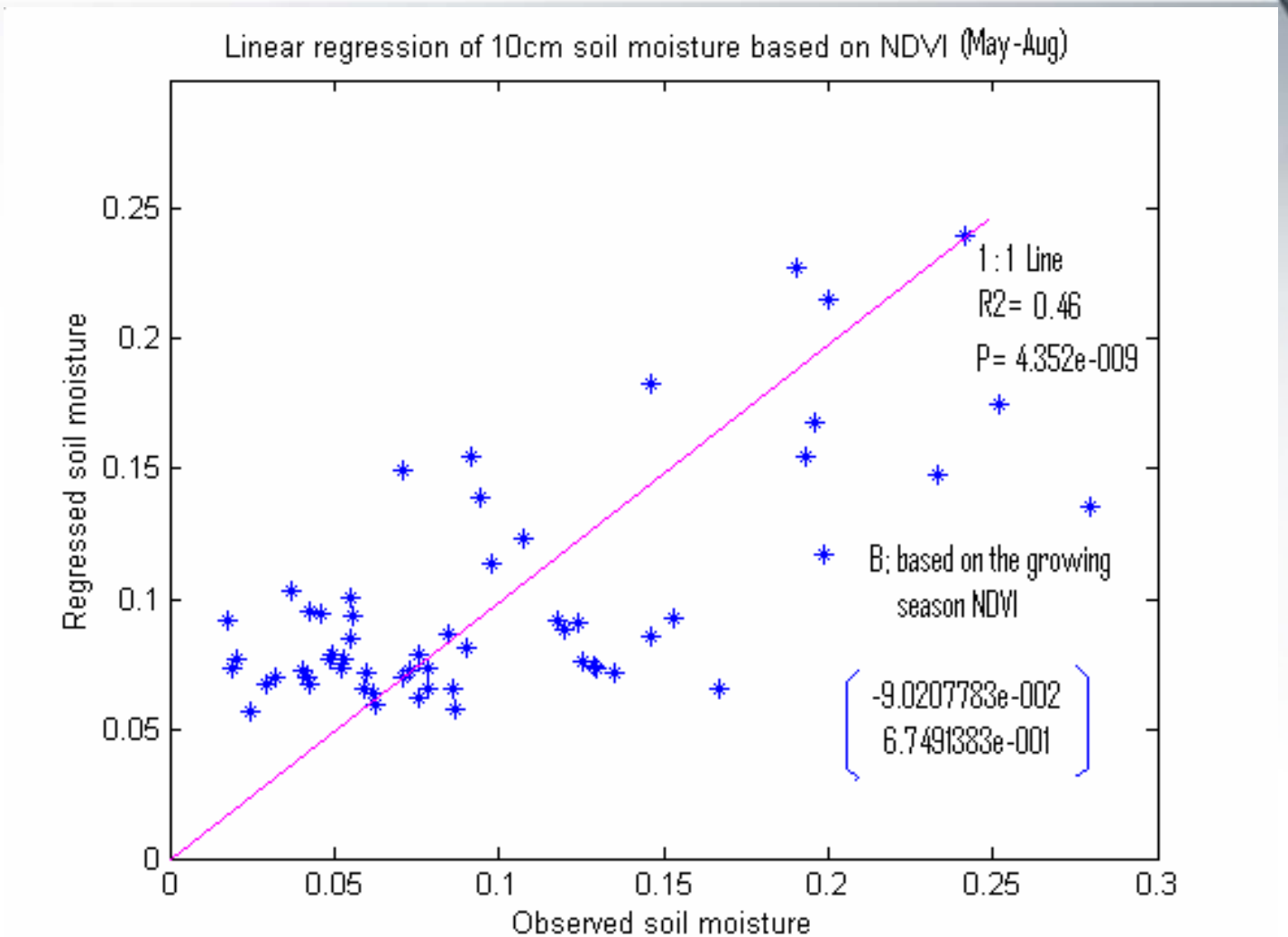
NDVI has small correlation with soil moisture during non-growing season, while slightly increase as time lags.

Regressed 100cm SM based on growing-season NDVI VS observed growing-season SM at NM

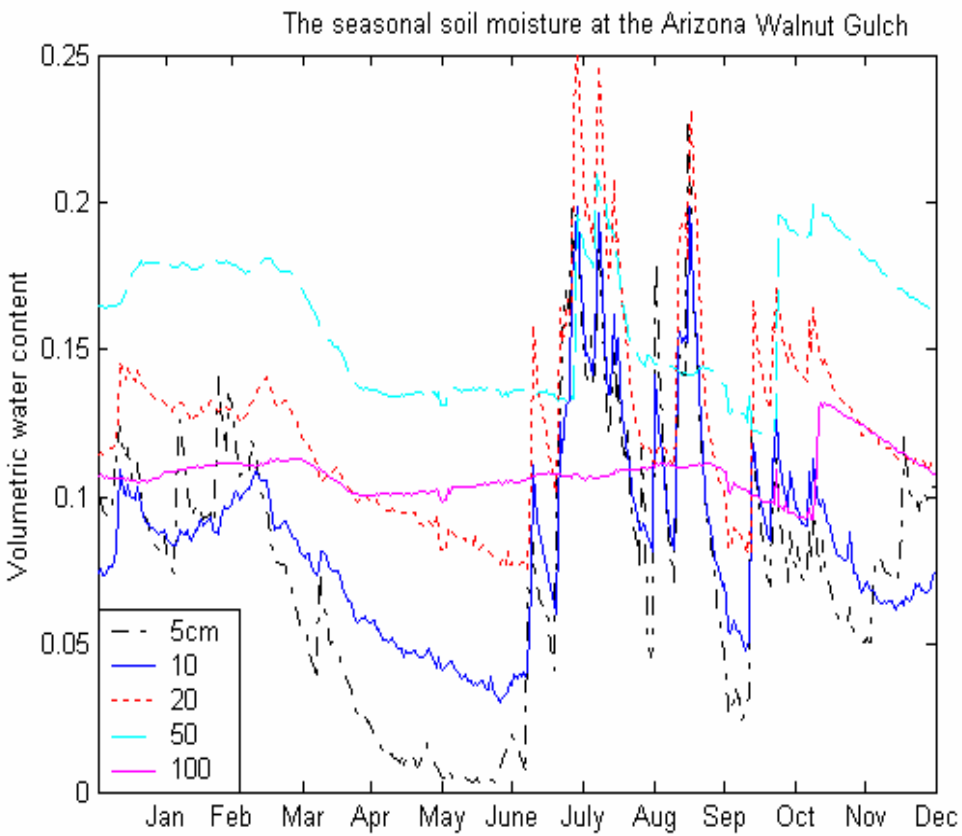


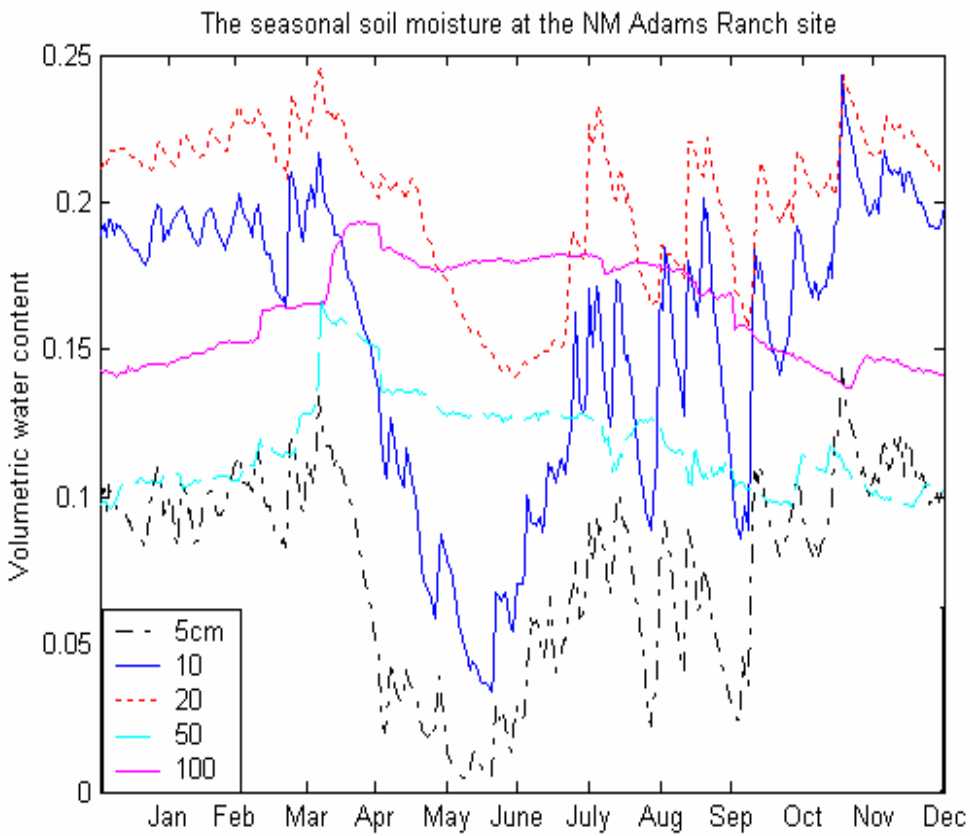
Regression based on simultaneous growing season NDVI at 95% CL

Regressed 10cm SM based on growing-season NDVI VS observed growing-season SM at NM



Average soil moisture at AZ and NM

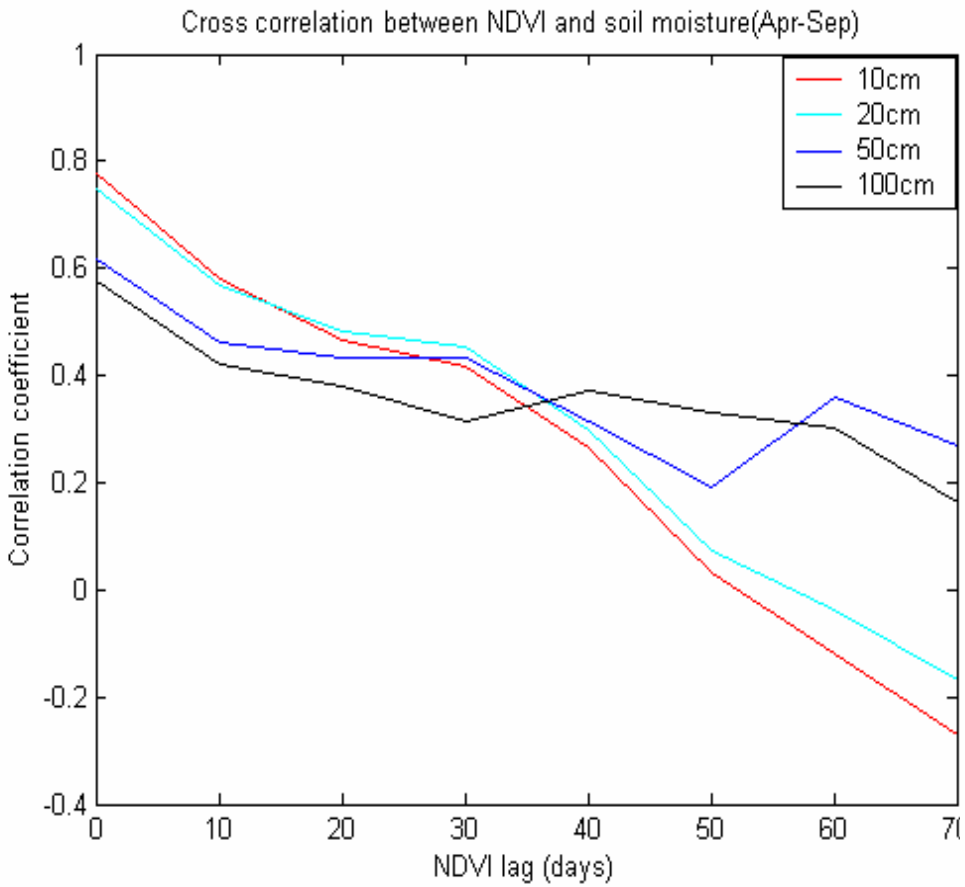


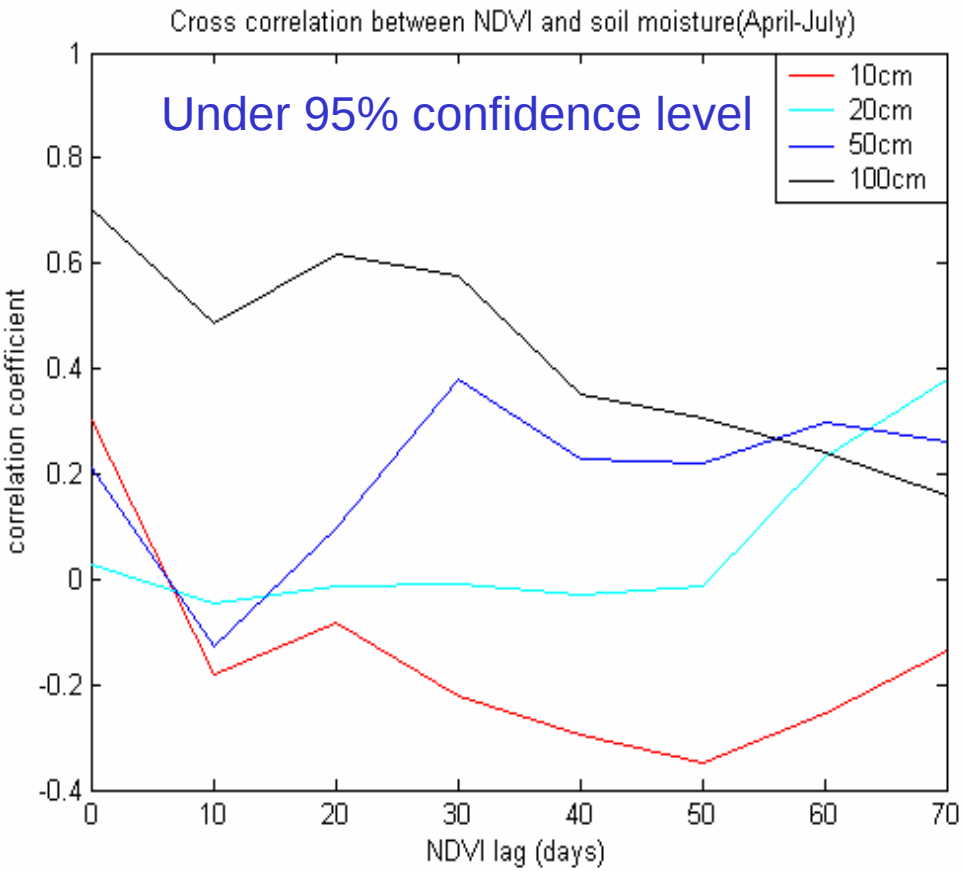


Arizona

New Mexico

Correlation between 100cm SM and NDVI on both sites

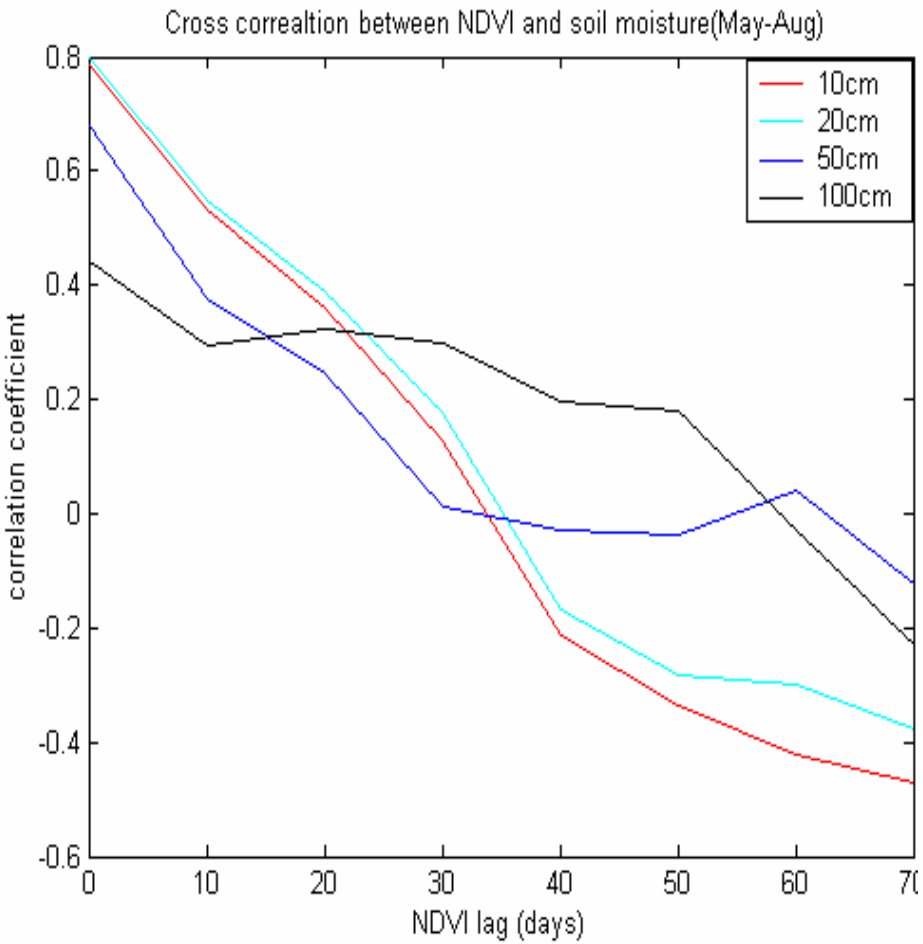


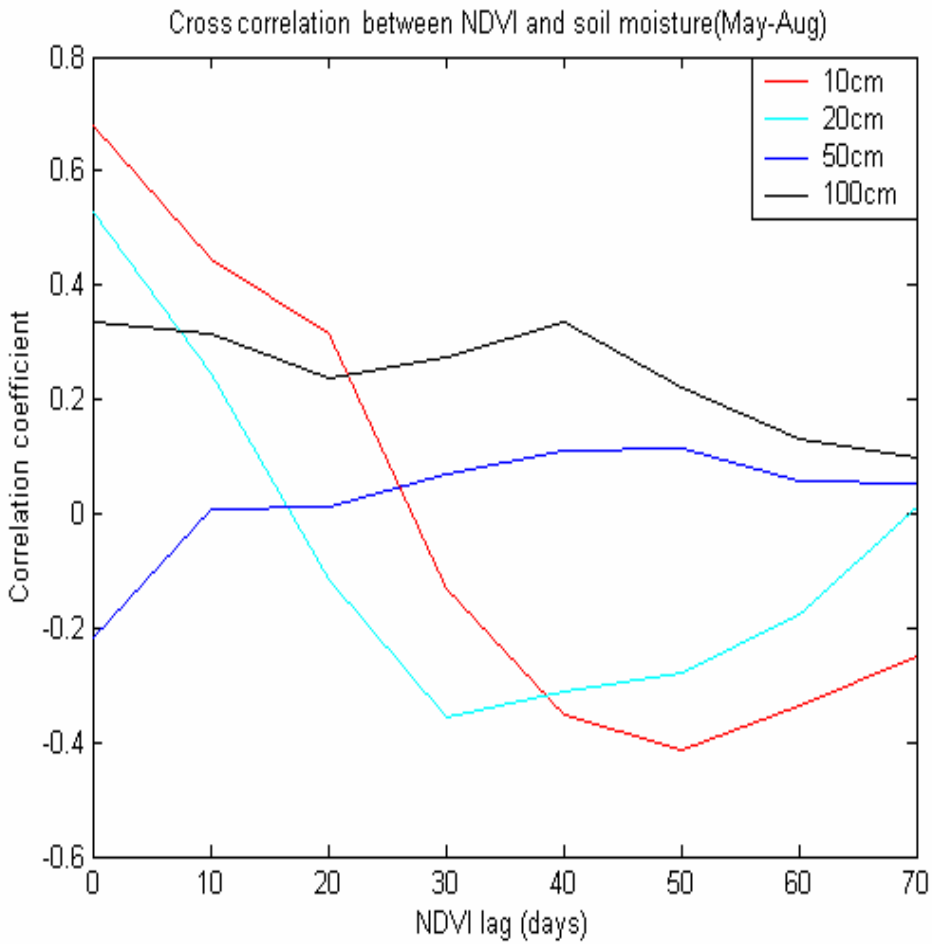


Arizona

New Mexico

Correlation between 10cm SM and NDVI during growing season (May-Aug)

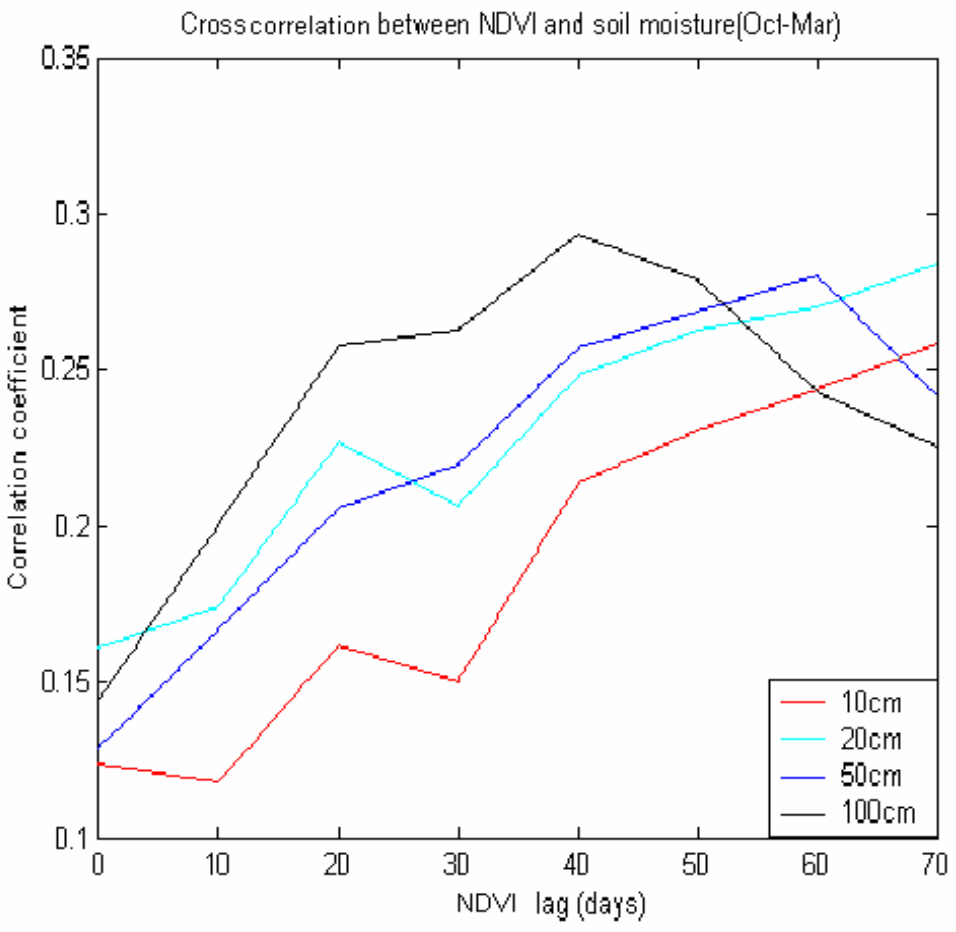


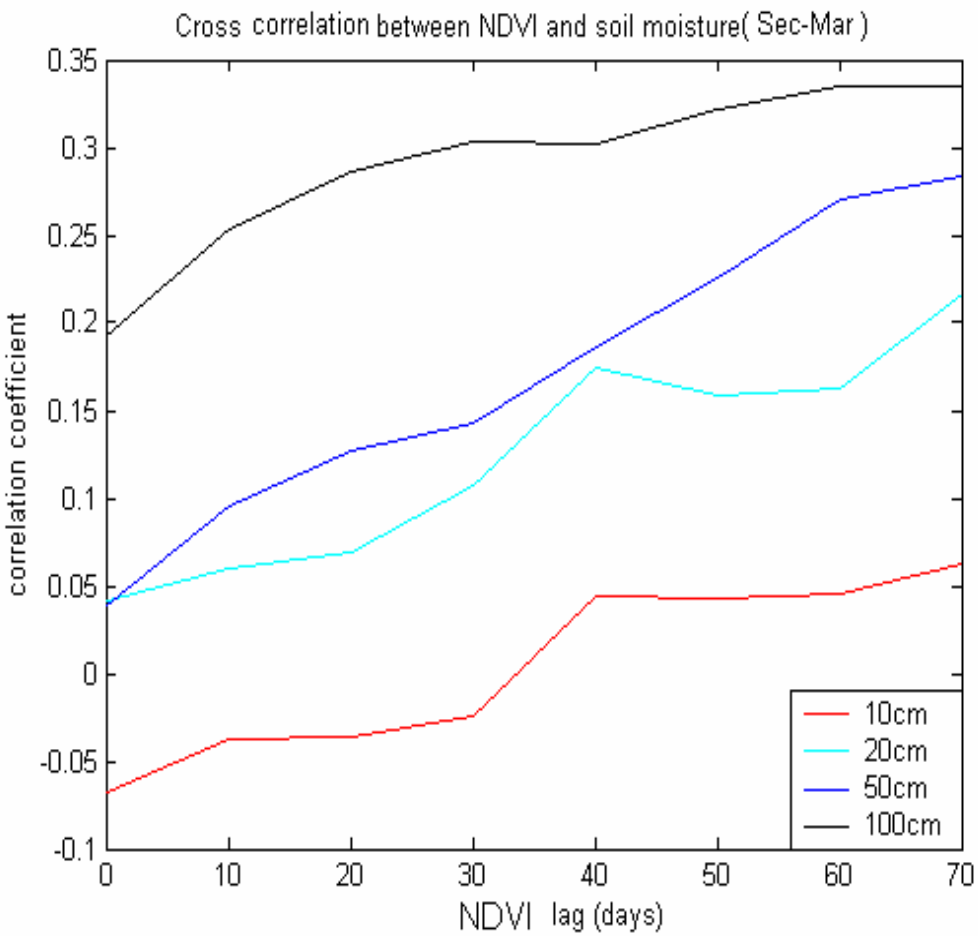


Arizona

New Mexico

Correlation between SM and NDVI during non-growing season



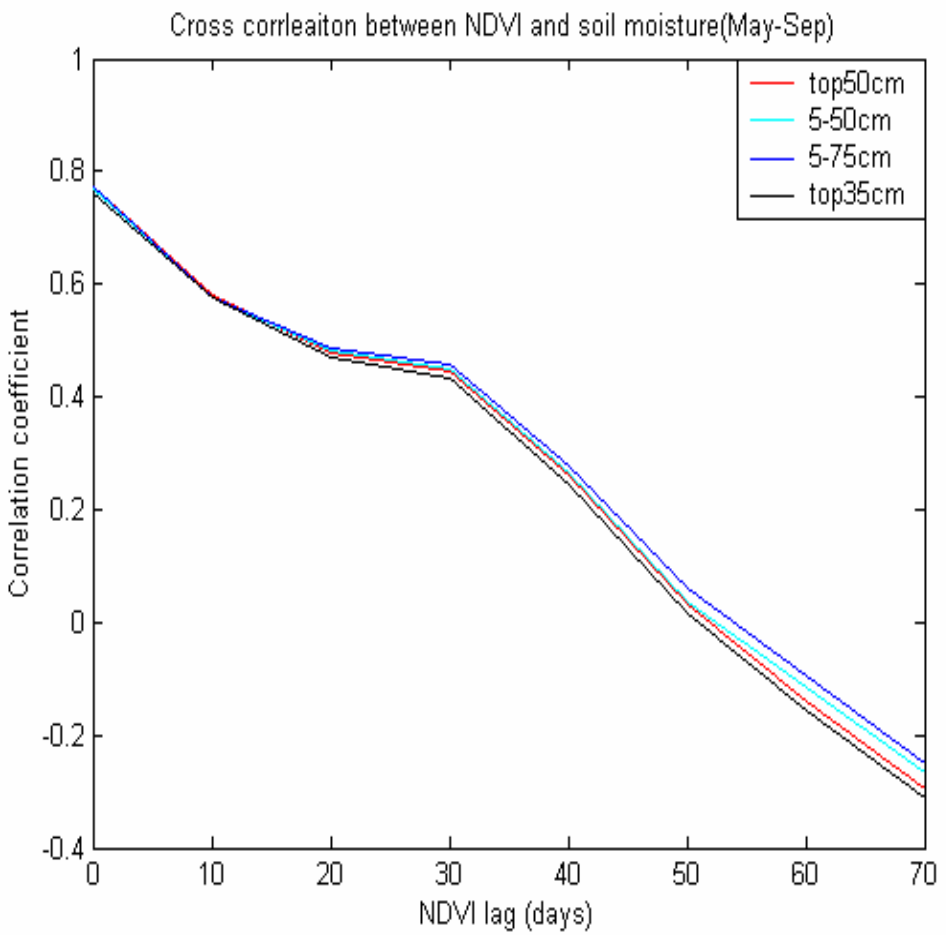


Arizona

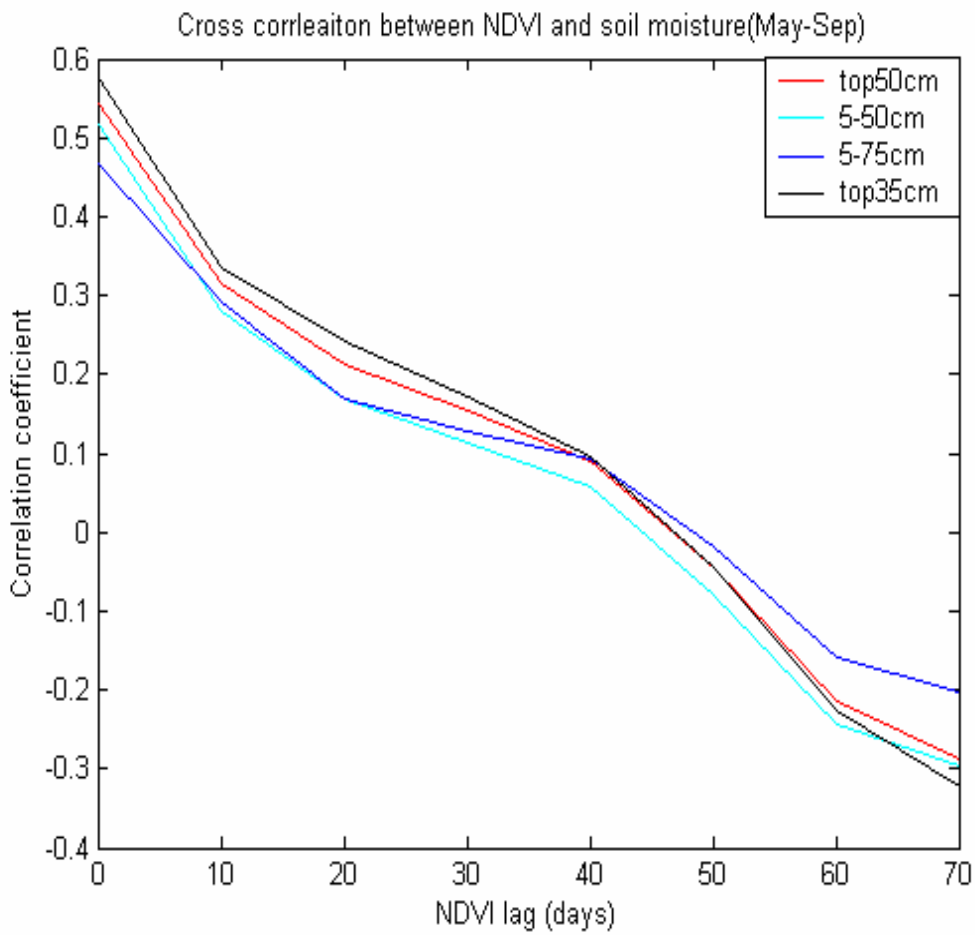
New Mexico

NDVI has small correlation with soil moisture during non-growing season, while slightly increase as time lags.

Correlation between different-depth average SM and NDVI during growing season

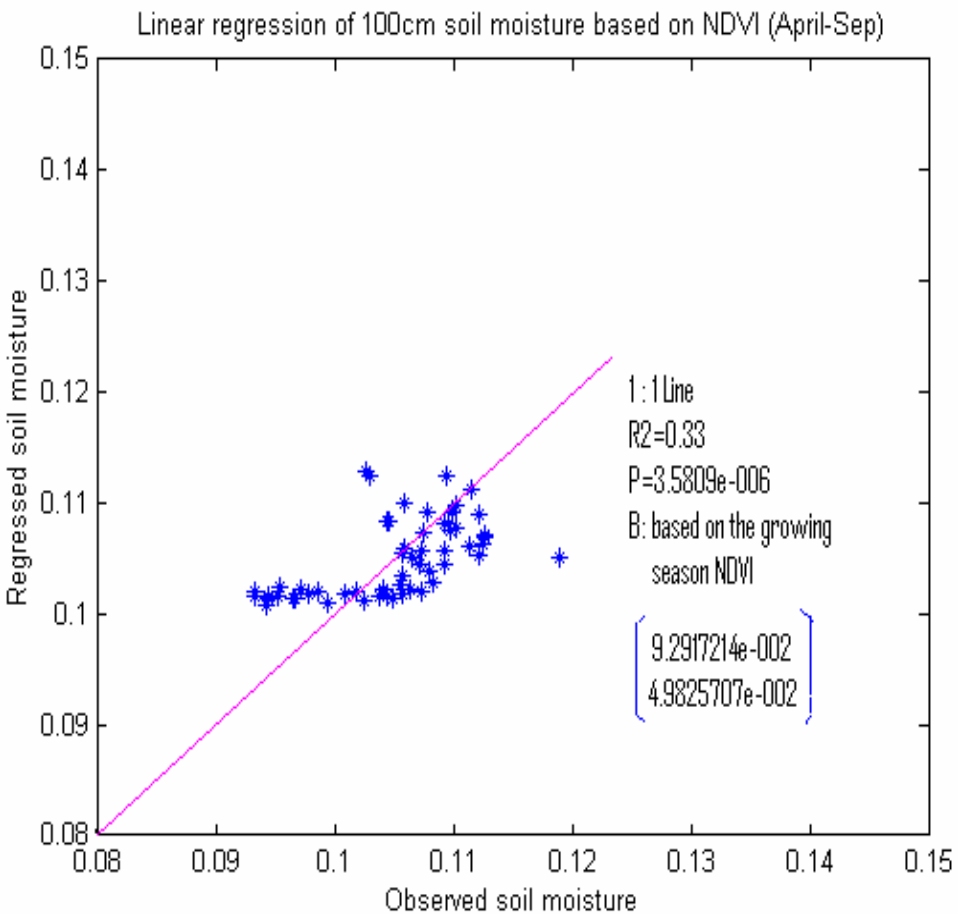


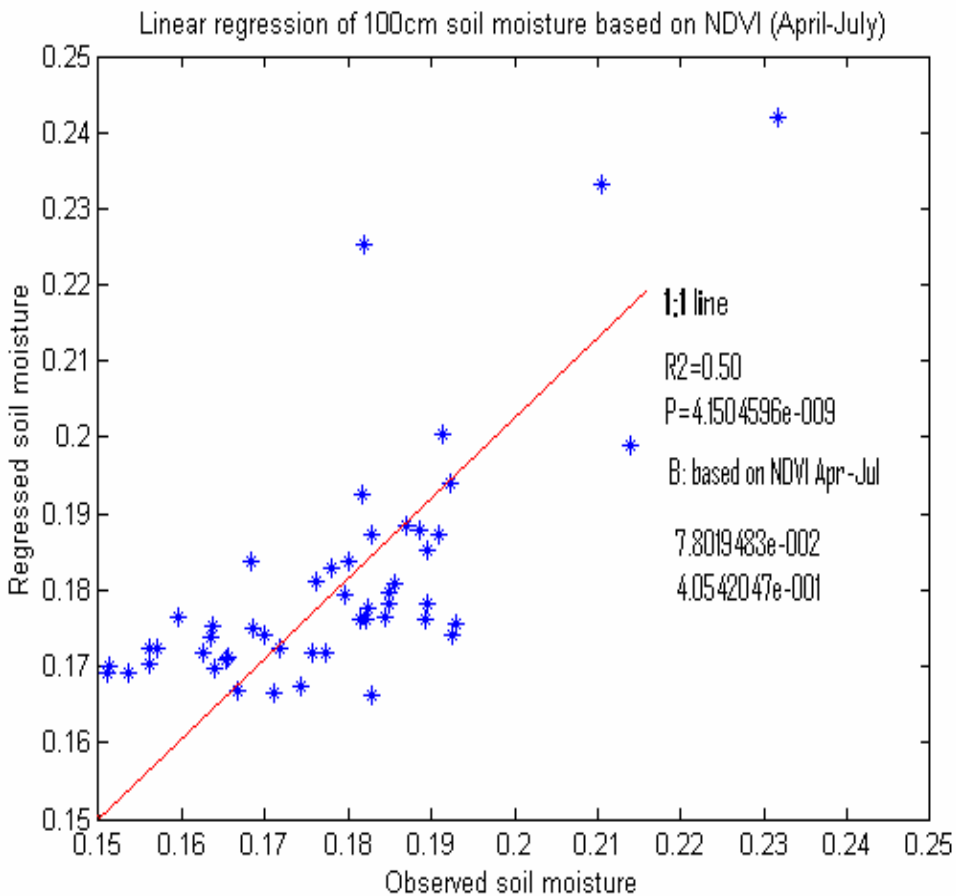
Arizona



New Mexico

Regressed 100cm SM based on growing-season NDVI VS observed growing-season SM



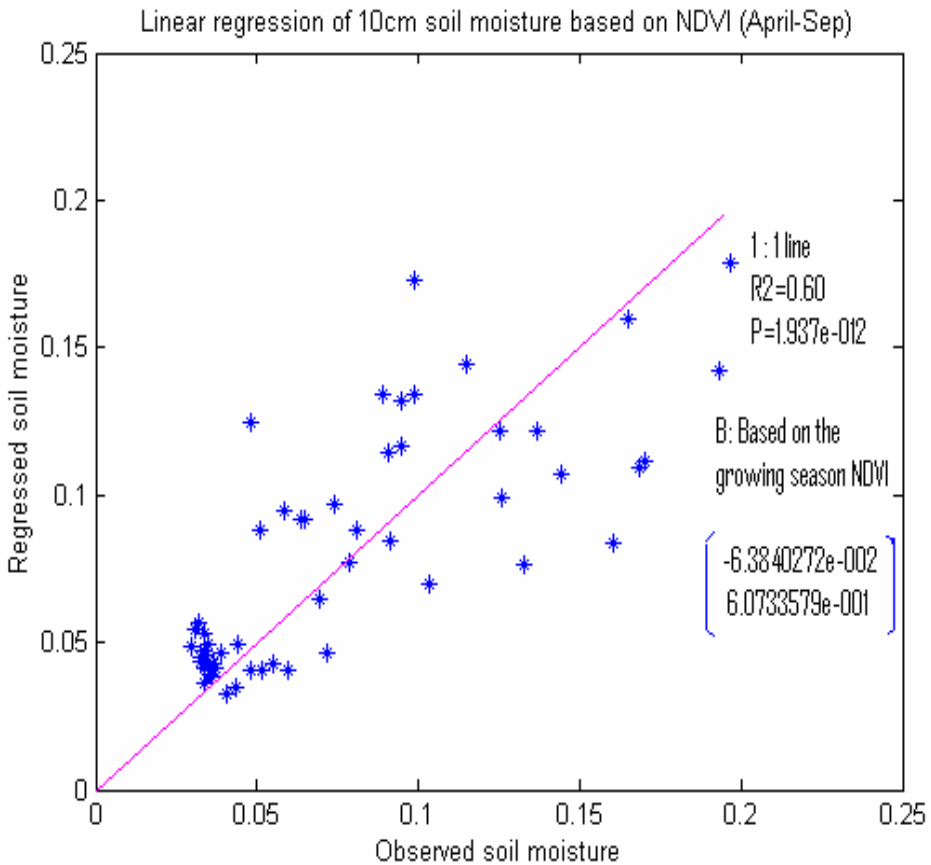


Arizona

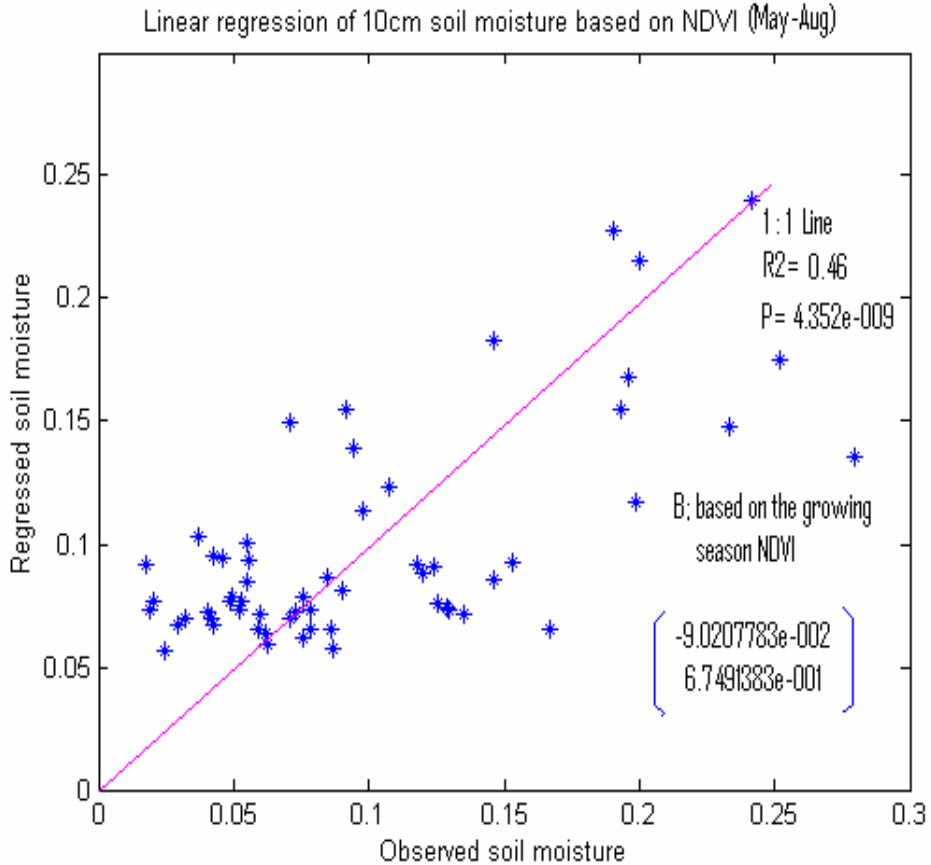
New Mexico

Regression based on simultaneous growing season NDVI at 95% CL

Regressed 10cm SM based on growing-season NDVI VS observed growing-season SM

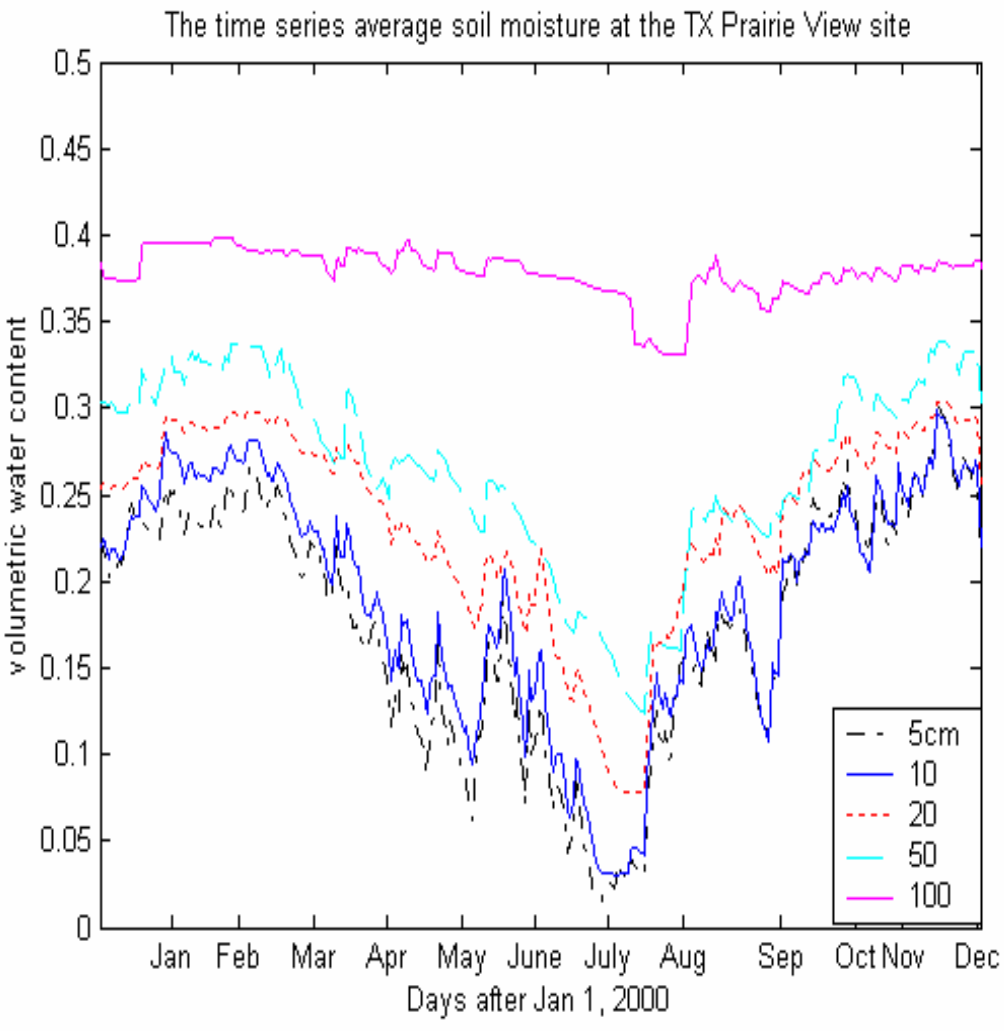


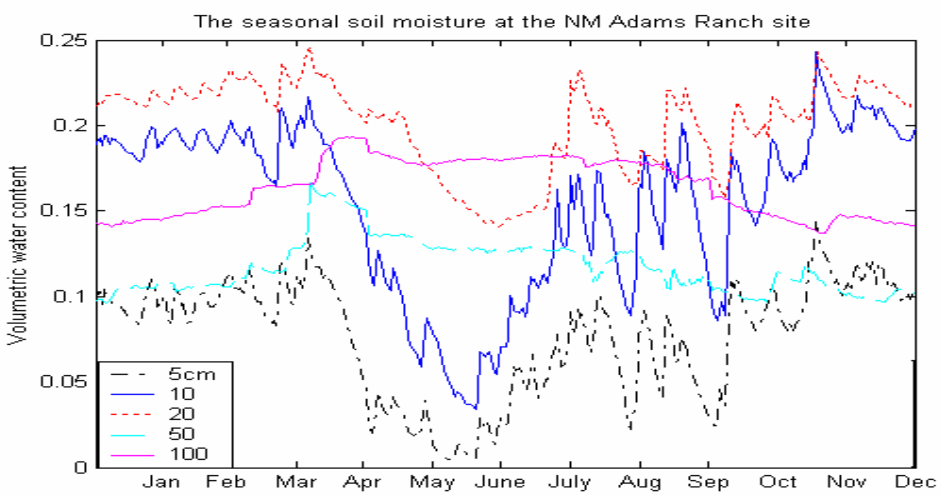
Arizona



New Mexico

Five-year average soil moisture at TX Prairie View and NM Ranch

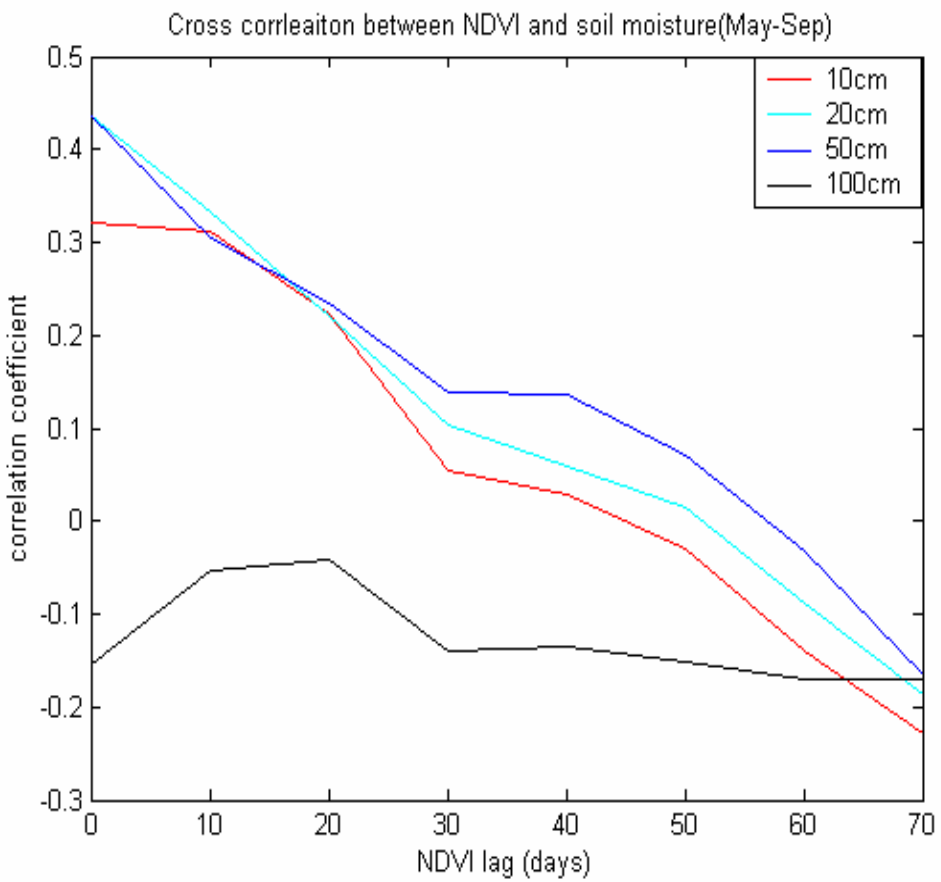




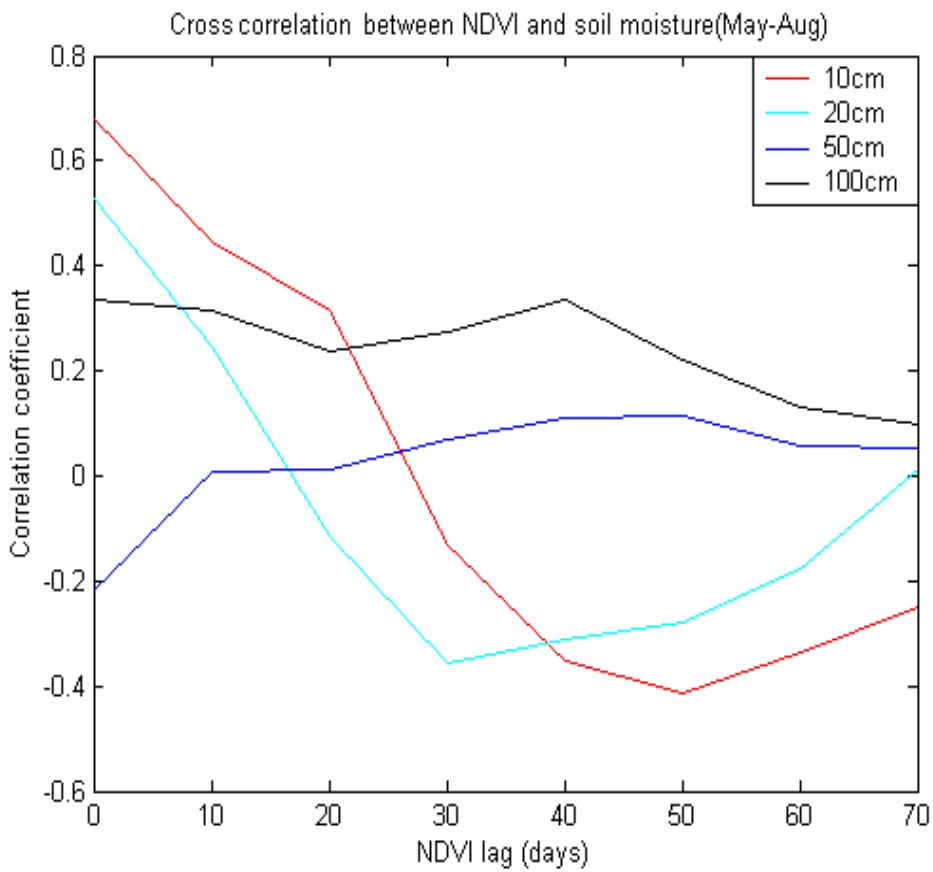
Texas

New Mexico

Correlation between SM and NDVI during growing season (May-Sep) at TX and NM



Texas



New Mexico

Conclusion

- The root and below-root zone soil moisture in semi-arid climate has good correlation with simultaneous NDVI and can be estimated using NDVI during growing season.
- The root zone soil moisture in humid climate also has moderate correlation with simultaneous NDVI and can be estimated using NDVI during growing season.
- The below-root soil moisture in humid climate has small correlation with NDVI and can’t be effectively estimated using NDVI.
- Soil moisture has small correlation with NDVI and can’t be effectively estimated using NDVI during non-growing season (Oct-March).