Monitoring Surface Soil Moisture by Combining SMOS and MODIS Products with In-situ Measurements

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Outline

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- Soil Moisture Moisture Monitoring with MODIS
- Soil Moisture- Remotely Monitoring and Analysis System (SM-RMAS)
- Integrated SMOS and MODIS SM data
- Africa Soil Moisture Project
- WMO Soil Moisture Demonstration Project (SMDP)
- Summary and Discussions

Overview of Soil Moisture Monitoring

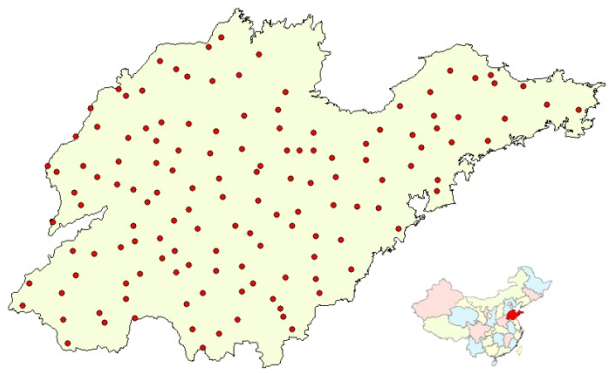
- **Soil moisture** is defined as the amount of water in soil.
- **Soil moisture** is an important factor for agricultural drought.
- **Soil moisture** is one of important climate change indicators.
- **Soil moisture** is a critical parameter for IPCC and GFCS.

Soil Moisture Monitoring with MODIS

- Combining MODIS and ground measurements for soil moisture estimation
  - *Wang et al., 2007a. International Journal of Remote Sensing*
- Using multiple NIR-SWIR channels to estimate soil and vegetation moisture
  - *Wang et al., 2007b. International Journal of Remote Sensing*
  - *Wang and Qu, 2007. GRL*

Soil Moisture Estimation Using MODIS and In-situ Measurements

Study Area: Shandong, China



Data:

Ground Measurements (~100km^2/station)

- >11 years (2003 ~ present) data from 137 ground stations
- 10 cm, 20 cm and 40 cm soil moisture at 8 AM on every 6th, 16th, and 26th

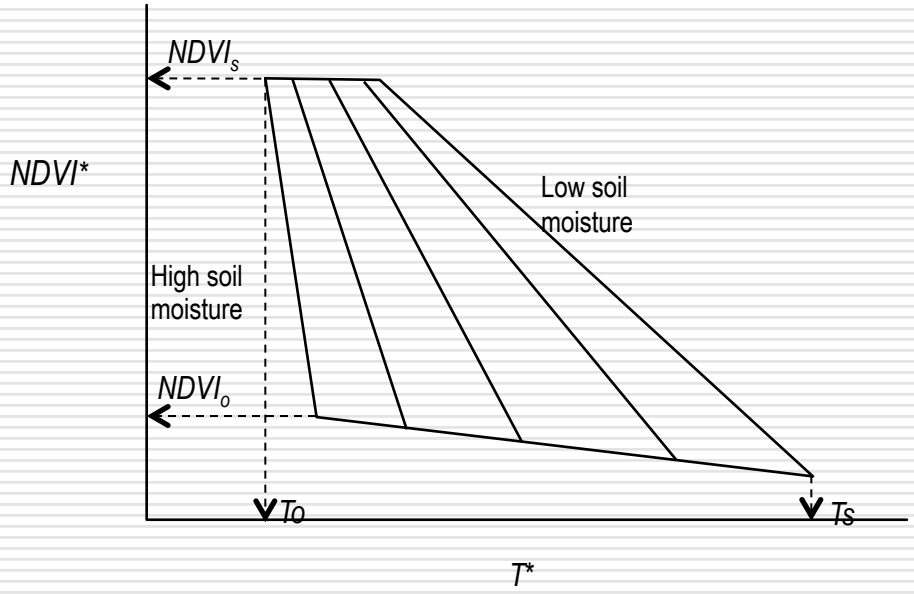
Remote sensing

MODIS NDVI and LST:	1 km resolution
Surface cover and soil type	1 km resolution

Soil Moisture Estimation Using MODIS and Ground Measurements

Universal Triangle (Semi-Physical)

(Carlson et al. 1994, Chauhan et al. 2003)



$$T^* = \frac{T - T_o}{T_s - T_o} \quad (1)$$

$$NDVI^* = \frac{NDVI - NDVI_o}{NDVI_s - NDVI_o} \quad (2)$$

$$\theta = \sum_{i=0}^{i=n} \sum_{j=0}^{j=n} a_{ij} NDVI^{*(i)} T^{*(j)} \quad (3)$$

θ: soil moisture

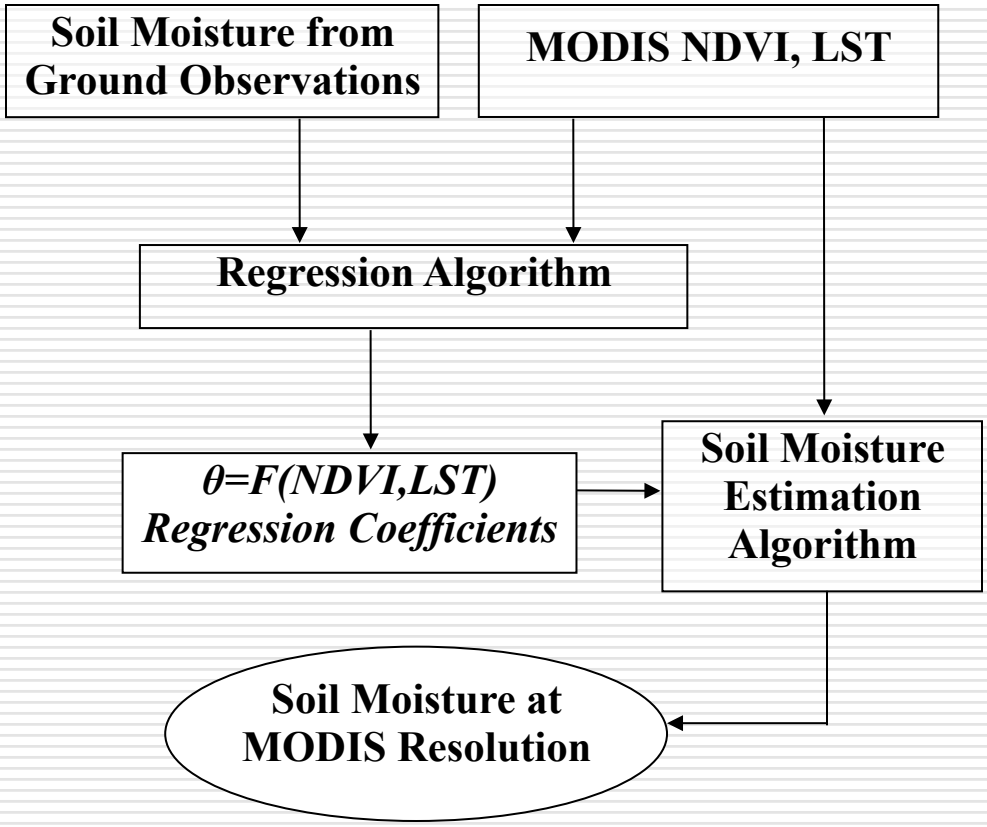
The vegetation T is always close to air T, the spatial variation in surface T is small (except for emission from underlying bare soil) over a full vegetation.

The surface T over bare soil varies depending on θ: from warm to cold when θ increases.

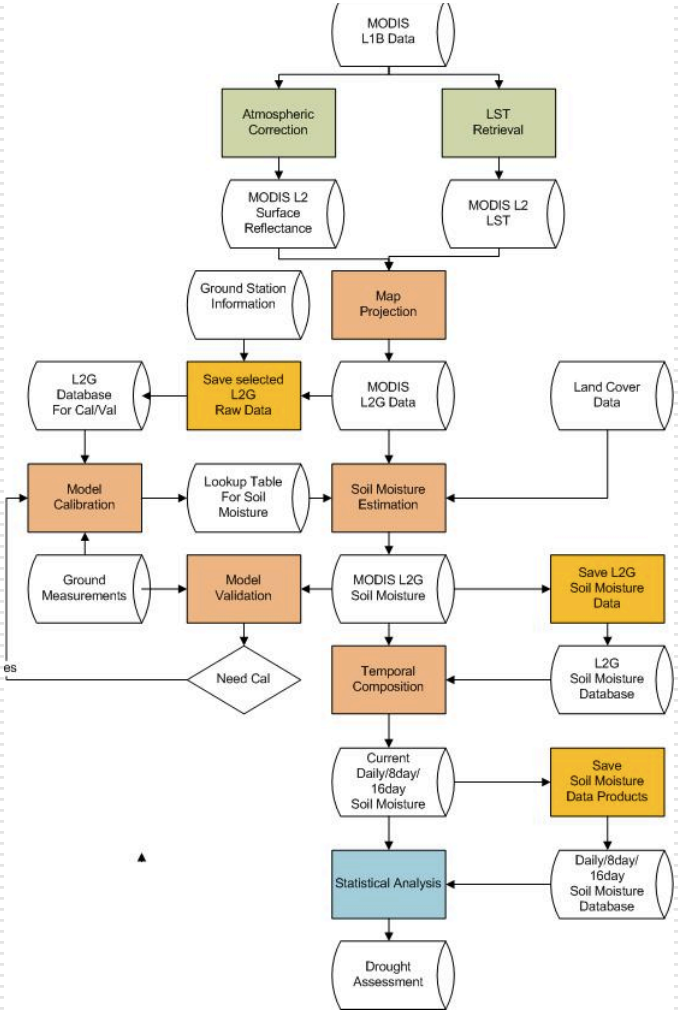
Soil Moisture Estimation Using MODIS and Ground Measurements

Regression Model

$$\theta = \sum_{i=0}^{i=2} \sum_{j=0}^{j=2} a_{ij} NDVI^{*(i)} T^{*(j)}$$

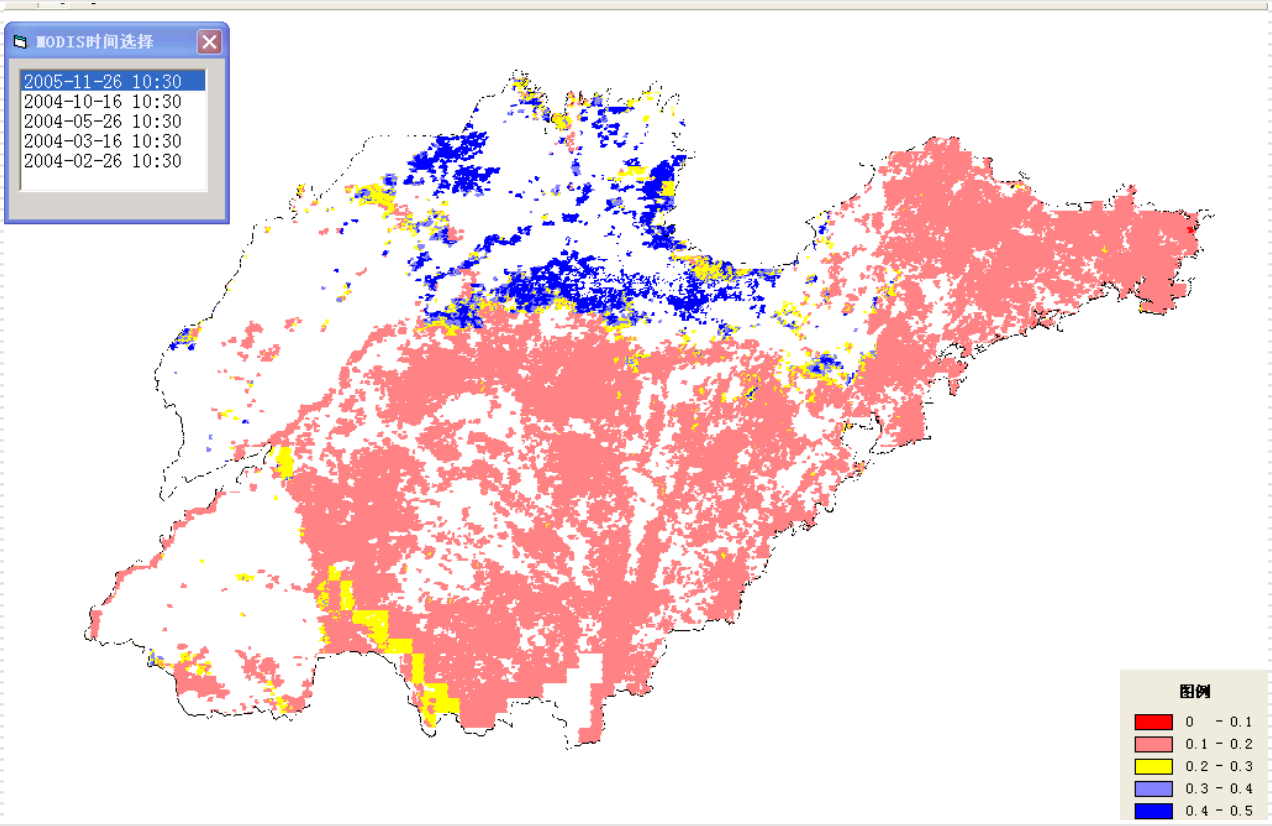


MODIS Soil Moisture Product Flowchart



Soil Moisture Estimation Using MODIS and Ground Measurements

Soil moisture product at MODIS resolution



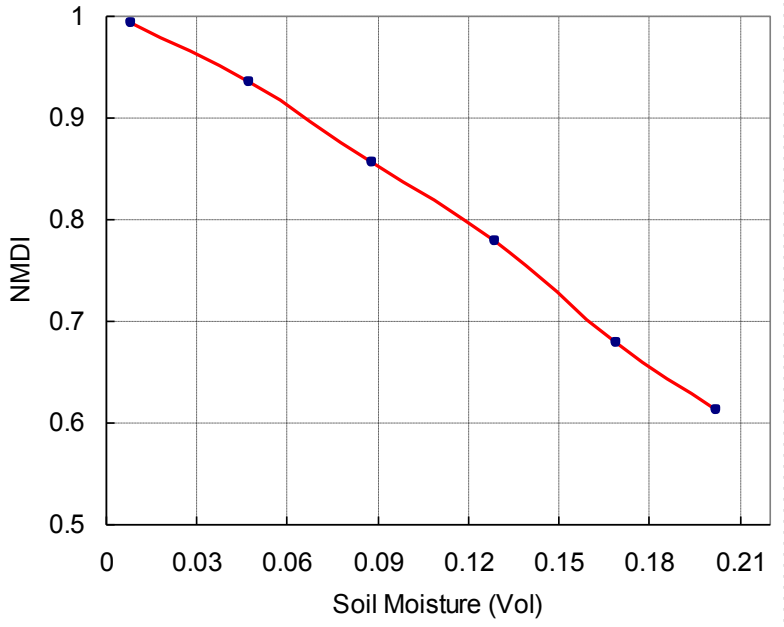
Soil Moisture Estimation Using MODIS and Ground Measurements

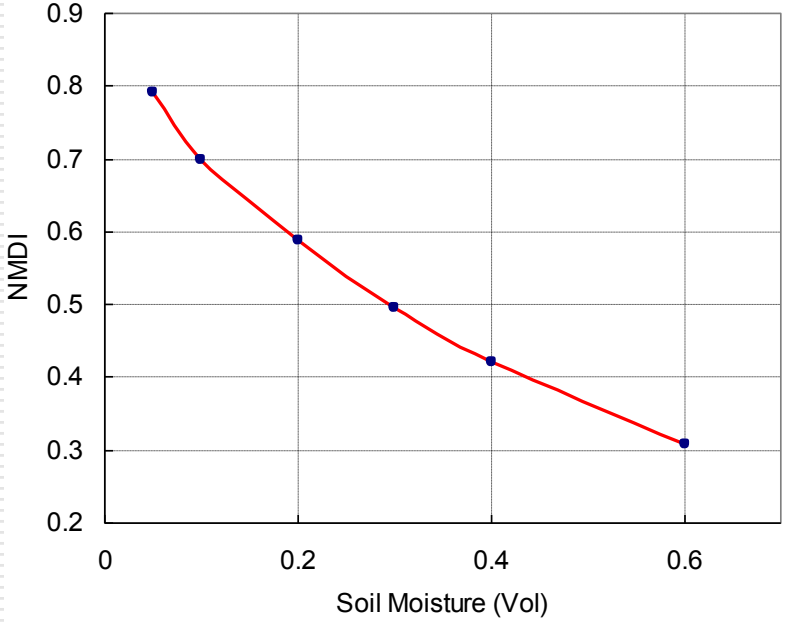
- The successful application of 'Universal Triangle' relation reinforced this theory;
- A good agreement between ground observed and MODIS derived soil moisture suggested soil moisture retrieval by combining in-situ and MODIS measurements is feasible;
- The soil moisture map at 1 km resolution provides more regional soil moisture details and spatial pattern.

Soil Moisture Estimation Using Multiple Sensor Measurements

- Moisture effect on canopy reflectance
- A new drought index (NMDI) for monitoring soil and vegetation moisture
- Integration of multi-space sensor, such as SMOS, SMAP and MODIS and in-situ soil moisture measurements

Validation: MODIS Soil Moisture Products





- Higher NMDI, drier soil.
- θ <0.1,NMDI = 0.7~1; θ=0.2, NMDI≈ 0.6; θ >*0.5,* NMDI<0.4.
- Suggest that soil moisture conditions can be monitored by NMDI with different thresholds.

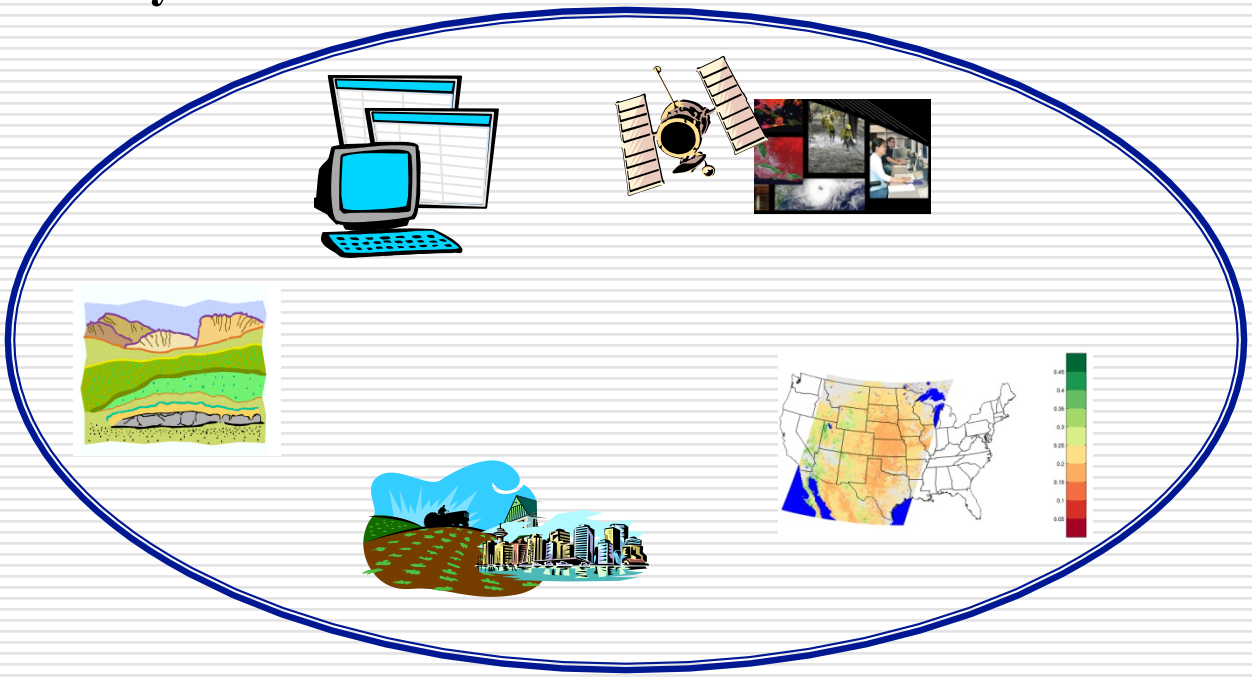
θ: soil moisture

Soil Moisture Estimation Using Multiple MODIS SRB Measurements

- NMDI is well suited to estimate both soil and vegetation drought.
- NMDI demonstrated high performance and discrimination power for fire detection.
- The new index will provide a new foundation for monitoring soil moisture for the next generation of MODIS sensor – VIIRS.

Soil Moisture- Remotely Monitoring and Analysis System (SM-RMAS)

SM-RMAS (Soil Moisture- Remotely Monitoring and Analysis is a near real time operational system including: (1) satellite remote sensing data processing sub-system, (2) ground measurement database; (3), SM computing sub-system, (4) SM prediction sub-system, and (5) SM analysis and DSS sub-system.



Africa Soil Moisture Monitoring Project

Data Products

Satellite Remote Sensing Data

Integrated GIS Agromet Data Products

Soil & Crop Moisture

Decision Support System

GMU, USDA & UFl
Crop Modeling & DSS Tools for Data Management

WAMIS

GEORGE MASON UNIVERSITY

IBIMET
SNU/NCAM

Decision-Making

Policy Making

National Drought Policy

Extension & Training

Drought/Flood/ Heat

WC&F Seminars and Training

Farm Decisions

Drought/Flood/ Heat

Rain Gauge On Site Data

User Community

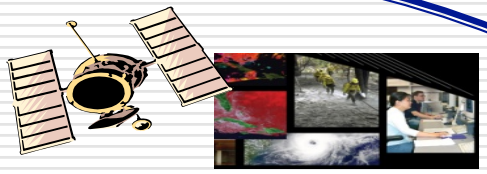
Kenya & Other African Nations

Australian Centre for Sustainable Catchments

Agricultural Extension

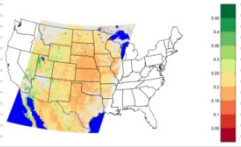
Africa SM System Infrastructure

Ground Measurements



Satellite Remote Sensing

Soil/Vegetation Moisture Estimation



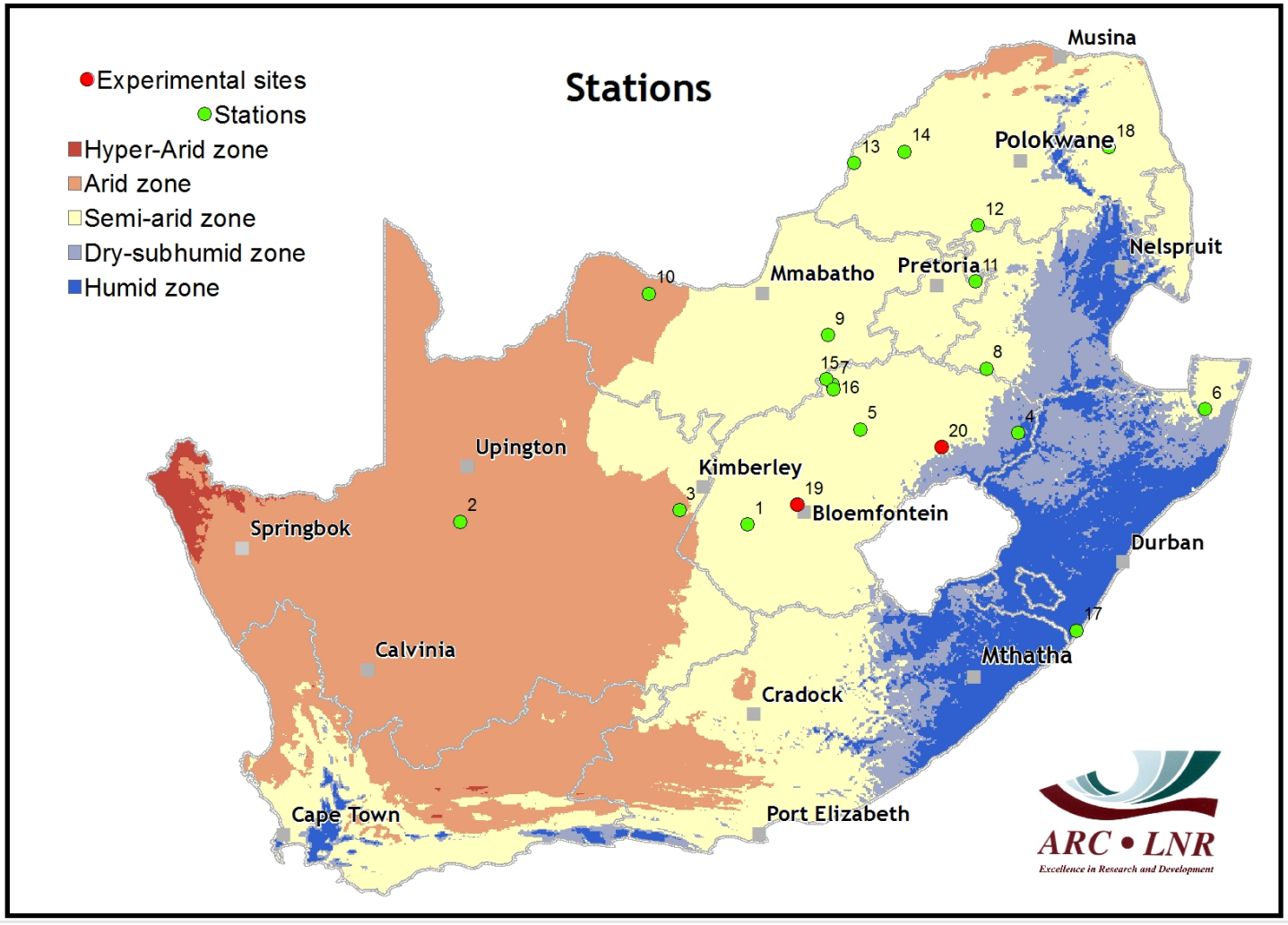
Drought Assessment

Decision Support

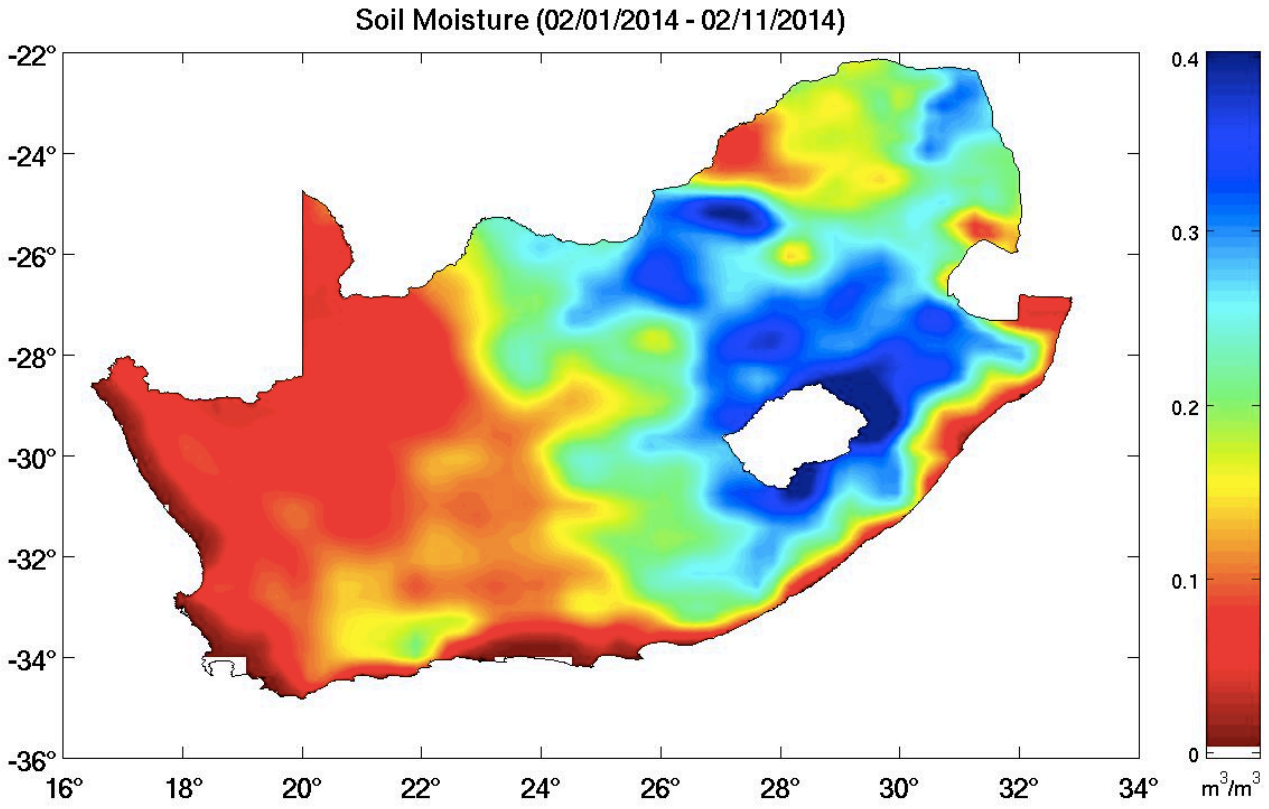
http://wamis.gmu.edu/Africa/

South Africa SM Project Workshop

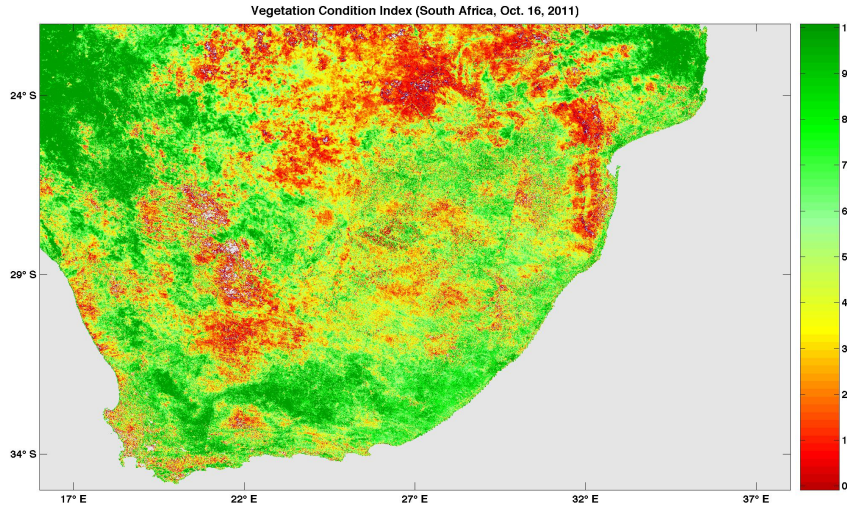
In-situ Soil Moisture Monitoring Sites in South Africa



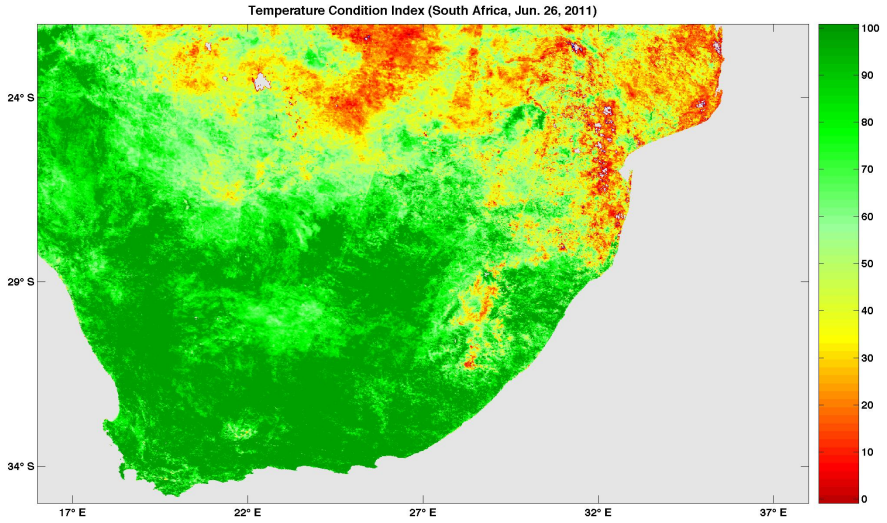
Soil Moisture Monitoring in South Africa



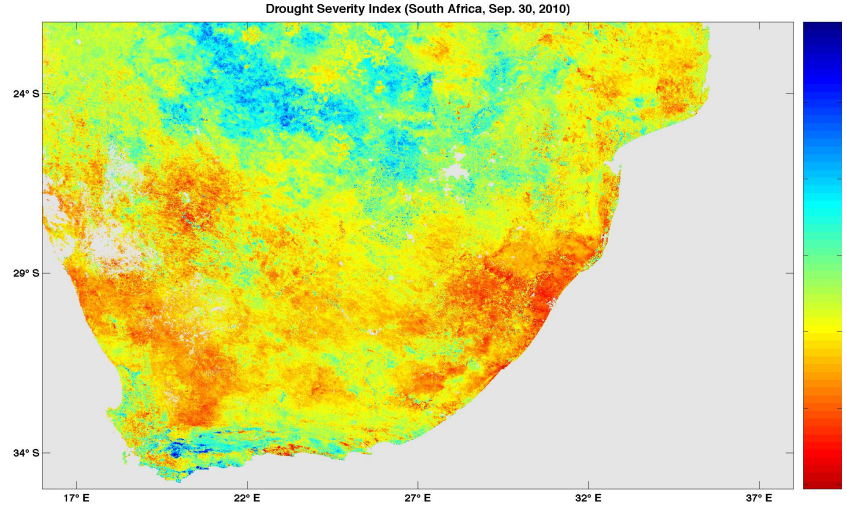
Soil Moisture Measurements from SMOS/MODIS



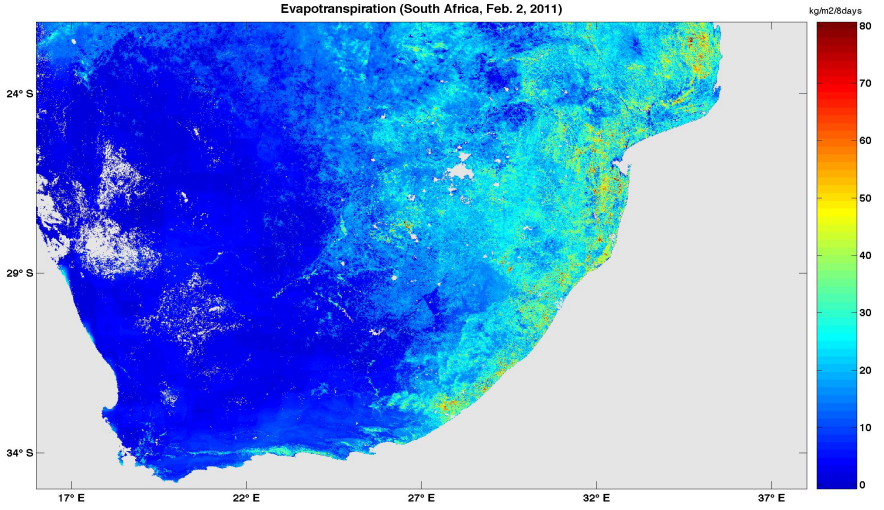
Vegetation Condition Index



Temperature Condition Index

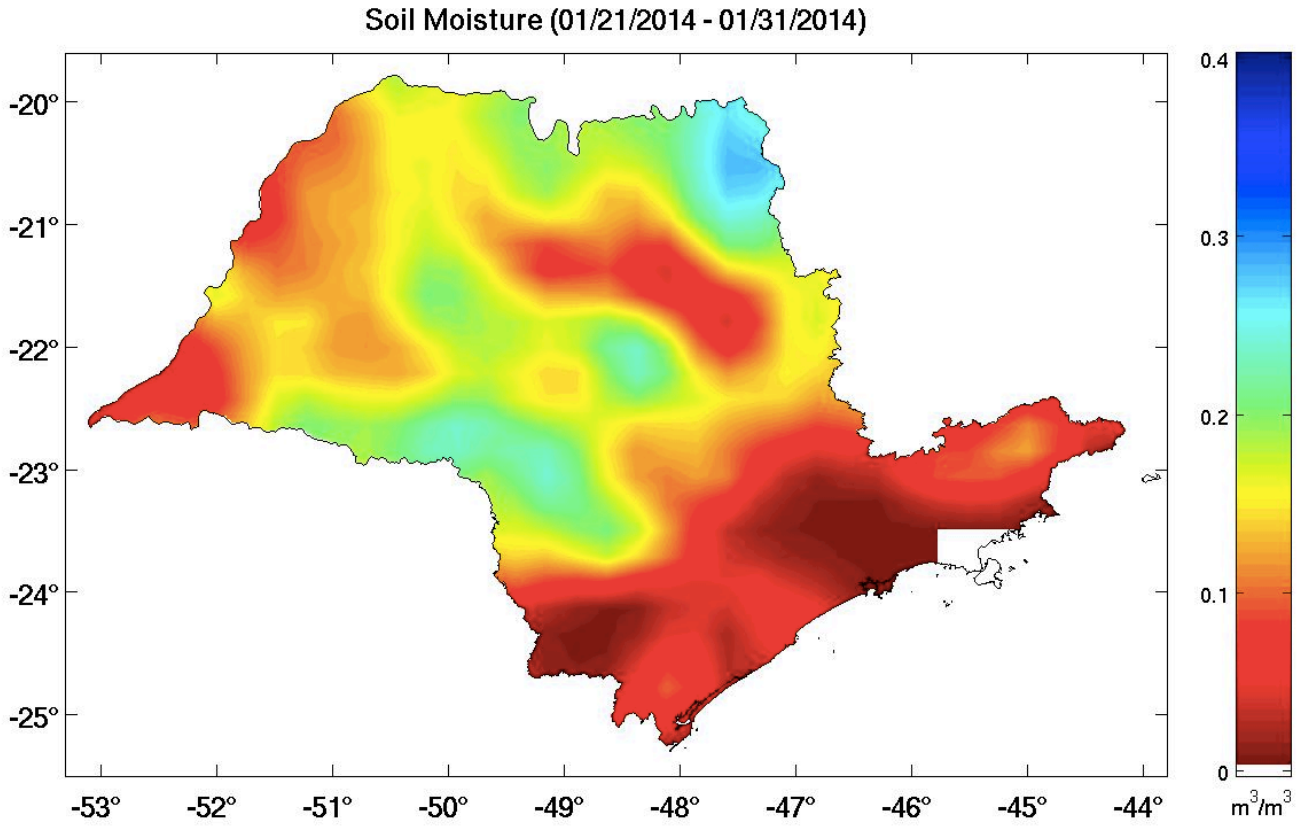


Drought Severity Index



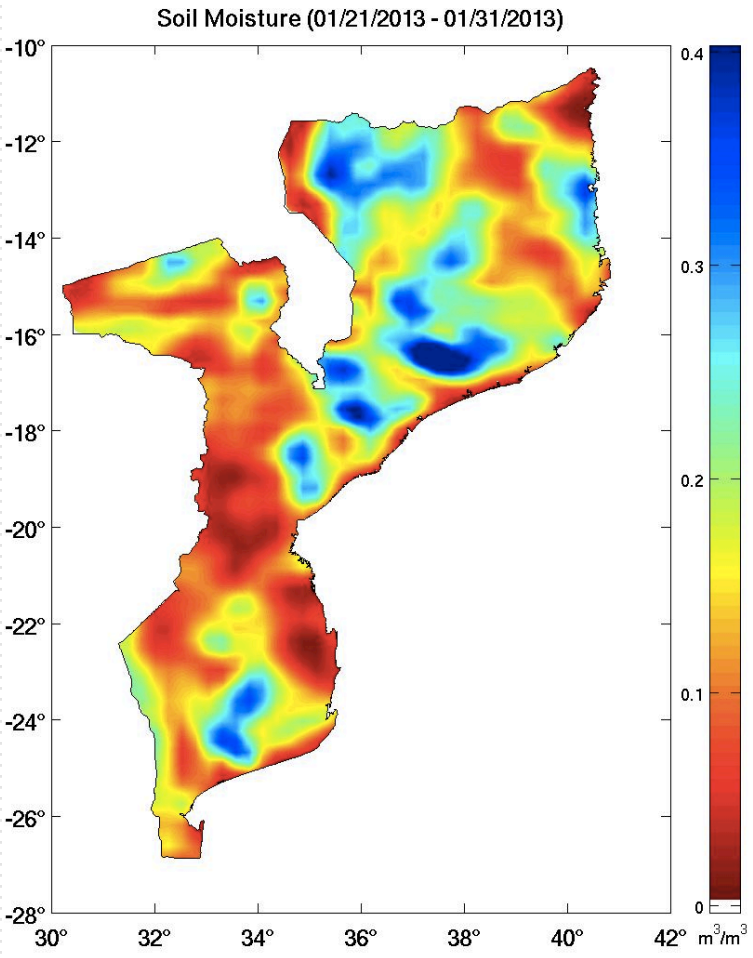
Evapotranspiration

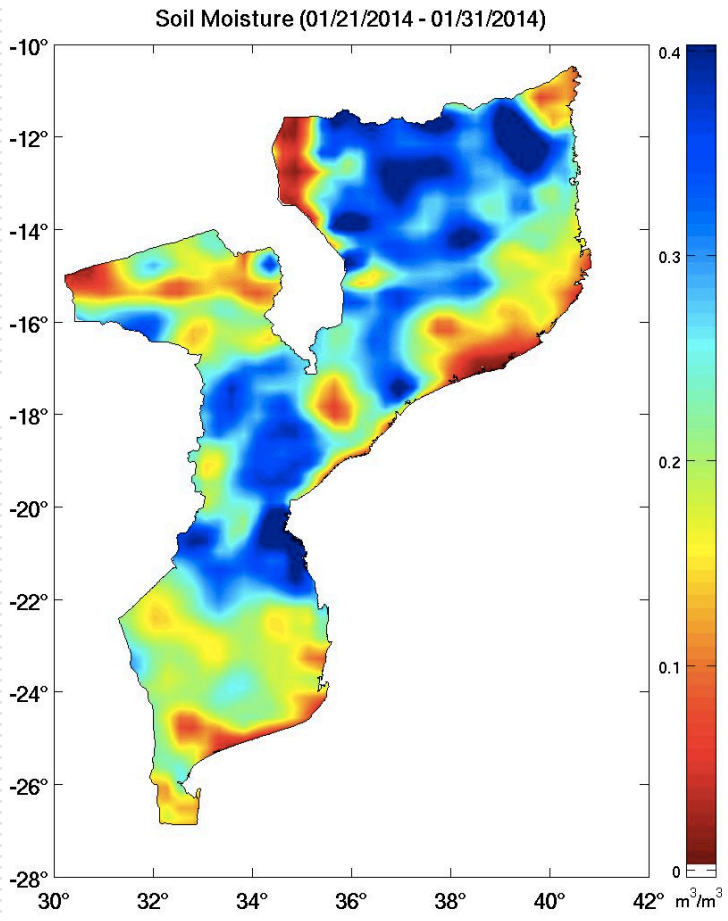
Soil Moisture Monitoring in Brazil



Soil Moisture Measurements from SMOS/MODIS

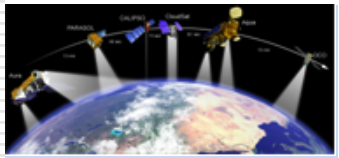
Soil Moisture Monitoring in Mozambique





Soil Moisture Measurements from SMOS/MODIS

Soil Moisture Processing System Infrastructure



Remote Sensing data

Surface Information

Ground Measurements

Satellite & Ground Measurements

Real-time RS Data Processing

Level 2 Data Production

RS Data Analysis

Inversion Model Cal/Val

Moisture Content Estimation

Data Processing System

Soil Moisture

Vegetation Moisture

Drought Index

Drought Rating

Data Products

Drought Assessment

Drought Forecasting

Decision Support

Application and Decision Support

Africa SM Data Dissemination

- Public web site
  - Provide GIS based web services to public users and agencies
- Dedicated data transfer protocols
  - For institutions and agencies to get data for decision support and further analysis
- Mobile applications
  - For public users to view information on mobile devices

WMO Soil Moisture Activities

- 16th Session of WMO Commission for Agricultural Meteorology (CAgM - April 2014 in Turkey)
- Report and make recommendations based on review of current measuring techniques and instrumentation for water and carbon budgets
- Establish Soil Moisture Demonstration Project (SMDP) to develop SM standards and guidelines
- WMO to establish CAgM Expert Team to coordinate project and outputs – to start by Oct/Nov 2014
- Expressions of interest welcomed.

Soil Moisture Demo Project

- South Africa – Agricultural Research Council
- 20 additional stations to be installed
- Project Meeting – March 2014 – Pretoria
- Discussions with South African Wx Service
- Possible project activity in Ethiopia

Future Plans

- Possible Joint meeting with CAgM SM ET in 2015
- Possible link to GEO JECAM

Summary and Discussion

- Soil moisture estimation by combining the strengths of SMOS, SMAP, MODIS and ground measurements to achieve higher accuracy and spatial resolution.
- System (SM-RMAS) is under development. We need to work with our international partners to collect more ground measurements.
- We have tested our approach with SMOS and MODIS & in-situ measurements applying it in multiple regions, including China, South Africa, Brazil, and Mozambique (Ethiopia).
- There is a urgent need to develop standards and guidelines for global soil moisture measurements.
- WMO SMDP will provide chance to work together.

Thank You !

Related Publications

- Di Wu, 2014, **An Investigation of Agricultural Drought on the United State Corn Belt Using Satellite Remote Sensing and GIS Technology,** GMU Ph.D Thesis
- Wang, Lingli, 2008, **Remote Sensing Techniques for Soil Moisture and Agricultural Drought Monitoring,** GMU Ph.D. Thesis.
- Dasgupta, Swarvanu, 2007, **Remote Sensing Techniques for Vegetation Moisture and Fire Risk Estimation,** GMU Ph.D. Thesis.
- Hao, Xianjun, 2006, **Estimation of Live Fuel Moisture and Soil Moisture Using Satellite Remote Sensing**, GMU Ph.D. Thesis.
- Soriano, Melissa, 2008, **Estimation of Soil Moisture in the Southern United States in 2003 Using Multi-Satellite Remote Sensing Measurements.** GMU, Master Thesis
- Li, Min 2010, **Remote Sensing Techniques for Detecting Vegetation Phenology**, GMU Ph.D. Thesis.
- Wang, Wanting, 2009, **Satellite Remote Sensing of Forest Disturbances Caused by Hurricanes and Wildland Fires**. GMU Ph.D. Thesis.
- Xie, Yong, 2009, Detection of Smoke and Dust Aerosols Using Multi-sensor Satellite Remote Sensing Measurements. GMU Ph.D. Thesis