

**American Public Health Association (APHA) 2010 Annual Meeting
Nov 6-10, 2010, Denver, CO**

Presenter (Oral Presentation):

Sarah N. Hemmings

Authors:

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Session:

NASA session titled: Using Remote Sensing for the Study of the Environment and Possible Associations with Disease Occurrence

Title:

Reducing tick-borne disease in Alabama: Linking health risk perception with spatial analysis using the NASA Earth Observing System

Abstract

Lyme disease (LD) accounts for most vector-borne disease reports in the U.S., and although its existence in Alabama remains controversial, other tick-borne illnesses (TBI) such as Southern Tick-Associated Rash Illness (STARI) pose a health concern in the state. Phase One of the Marshall Space Flight Center-UAB DEVELOP study of TBI identified the presence of the chain of infection for LD (*Ixodes scapularis* ticks carrying *Borrelia burgdorferi* bacteria) and STARI (*Amblyomma americanum* ticks and an as-yet-unconfirmed agent) in Alabama. Both LD and STARI are associated with the development of *erythema migrans* rashes around an infected tick bite, and while treatable with oral antibiotics, a review of educational resources available to state residents revealed low levels of prevention information.

To improve prevention, recognition, and treatment of TBI in Alabama, Phase Two builds a health communication campaign based on vector habitat mapping and risk perception assessment. NASA Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite imagery identified likely tick habitats using remotely sensed measurements of vegetation vigor (Normalized Difference Vegetation Index) and soil moisture. Likely tick habitats, identified as those containing both high vegetation density and soil moisture, included Oak Mountain State Park, Bankhead National Forest, and Talladega National Forest. To target a high-risk group — outdoor recreation program participants at Alabama universities — the study developed a behavior survey instrument based on existing studies of LD risk factors and theoretical constructs from the Social Ecological Model and Health Belief Model. The survey instrument was amended to include geographic variables in the assessment of TBI knowledge, attitudes, and prevention behaviors, and the vector habitat model will be expanded to incorporate additional environmental variables and *in situ* data. Remotely sensed environmental data combined with risk perception assessments inform an ongoing outreach campaign consisting of stakeholder meetings and educational seminars.

APHA 2010 Annual Meeting, Nov 2010, Denver, CO
Proposed submission on 2/4/10 by UAB-MSFC DEVELOP Fall 2009 Team

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Title:

Reducing tick-borne disease in Alabama: Linking health risk perception with spatial analysis using the NASA Earth Observing System

Learning Objectives

- 1) Describe the use of remotely sensed NASA Earth Science Data for projects related to human health.
- 2) Discuss the benefits of using remote sensing in the prediction and mitigation of diseases.
- 3) Discuss the combination of health behavior data with vector habitat mapping to inform a health communication campaign.

Abstract (max. 300 words; 5 sections):

Background

Lyme disease (LD) accounts for most vector-borne disease reports in the U.S., and although its existence in Alabama remains controversial, other tick-borne illnesses (TBI) such as Southern Tick-Associated Rash Illness (STARI) pose a health concern in the state. Phase One of the Marshall Space Flight Center-UAB DEVELOP study of TBI identified the presence of the chain of infection for both LD (*Ixodes scapularis* ticks carrying *Borrelia burgdorferi* bacteria) and STARI (*Amblyomma americanum* ticks and an as-yet-unidentified agent) in Alabama.

Objective/Purpose

Both LD and STARI are associated with the development of *erythema migrans* rashes around an infected tick bite, and while treatable with oral antibiotics, a review of educational resources available to state residents revealed low levels of prevention information. To improve prevention, recognition, and treatment of TBI in Alabama, Phase Two builds a health communication campaign based on vector habitat mapping and risk perception assessment.

Methods

NASA Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite imagery identified likely tick habitats based on remotely sensed measurements of vegetation vigor (Normalized Difference Vegetation Index) and soil moisture. To target a high-risk group —outdoor recreation program participants at Alabama universities—

the study developed a behavior survey instrument based on existing studies of LD risk factors and theoretical constructs from the Social Ecological Model and Health Belief Model.

Results

Likely tick habitats, identified as those containing both high vegetation density and soil moisture, included Oak Mountain State Park, Bankhead National Forest, and Talladega National Forest. The survey instrument was amended to include geographic variables in the assessment of TBI knowledge, attitudes, and prevention behaviors.

Discussion/Conclusions

Remotely sensed environmental data combined with risk perception assessments inform an ongoing outreach campaign consisting of stakeholder meetings and educational seminars. The vector habitat model will incorporate additional environmental variables and *in situ* data.

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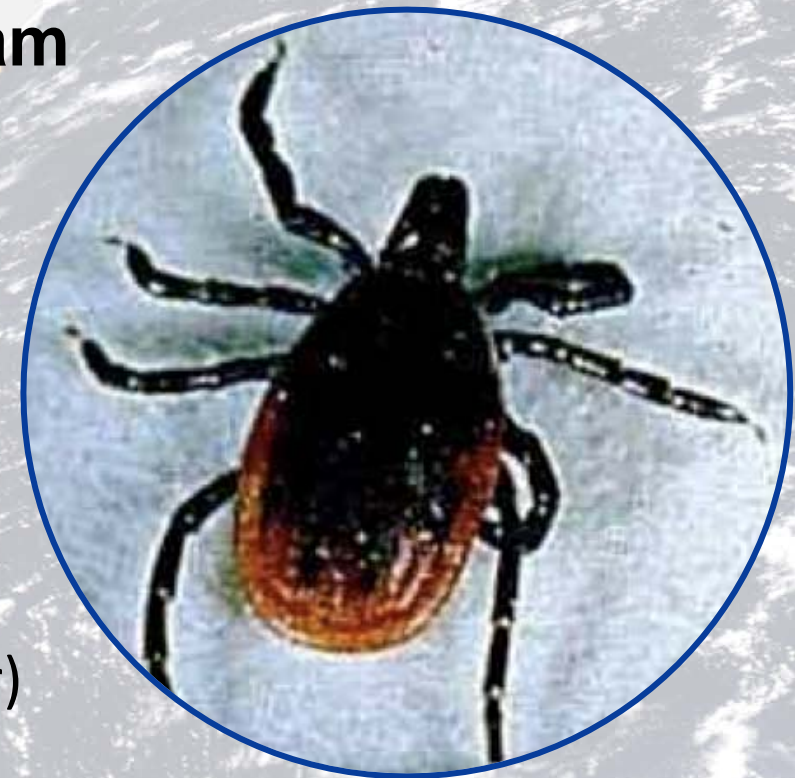
DEVELOP Summer 2009 Team Members



Reducing tick-borne disease in Alabama: Linking health risk perception with spatial analysis using the NASA Earth Observing System

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Presenter Disclosures

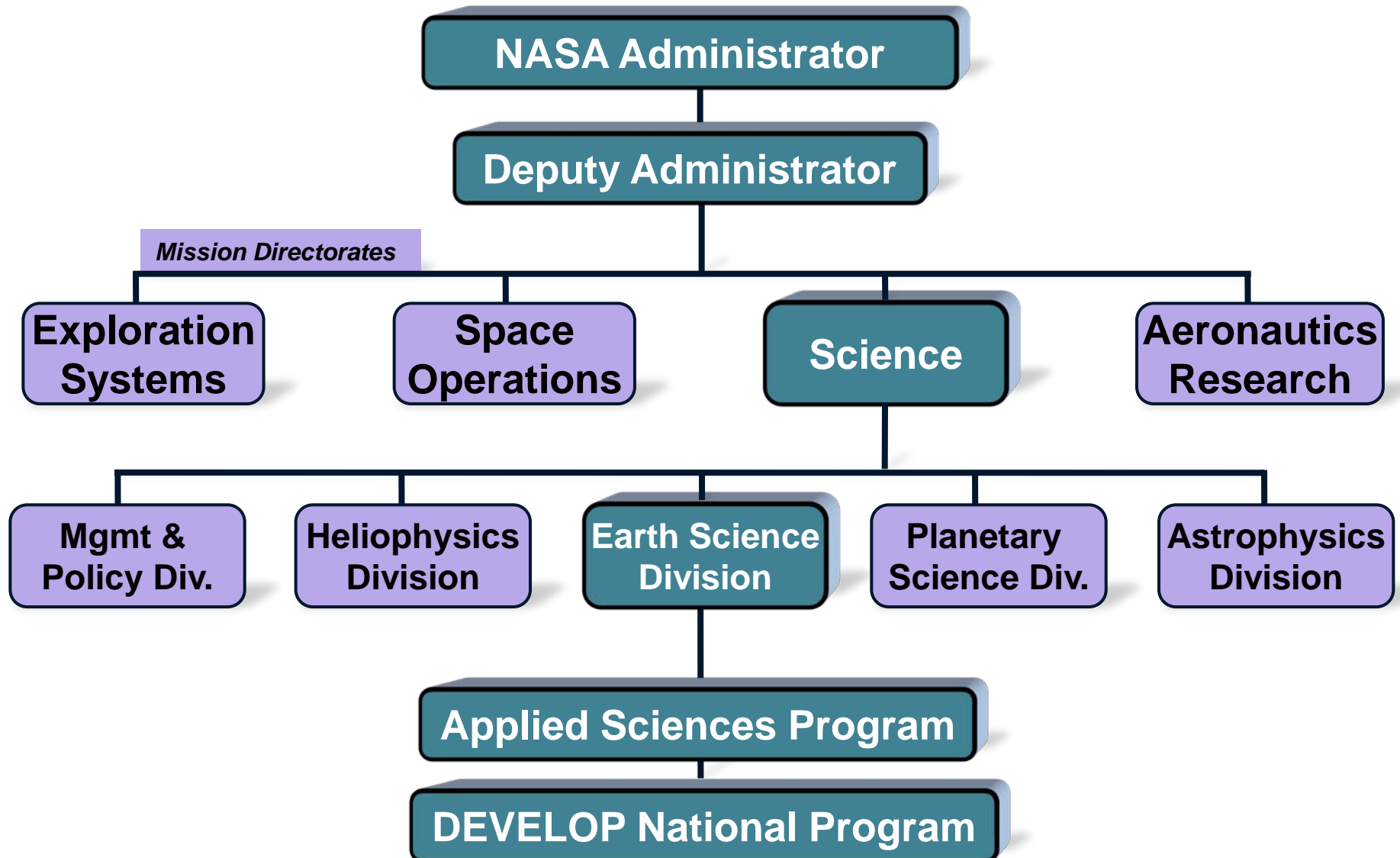
Sarah Hemmings



The following personal financial relationships with commercial interests relevant to this presentation existed during the past 12 months:

No relationships to disclose

NASA Organization



What is DEVELOP?



DEVELOP demonstrates applications of NASA technology
to science and community policy makers

to establish student projects,

supported by leveraged partnerships.

Projects address Applied Science Application Areas and

demonstrate how NASA information

can enhance decision support and

generate demand for NASA science predictions.

DEVELOP Locations



NASA Applied Sciences Program – NASA Headquarters, Washington D.C.

Ames
Research
Center

Moffett Field,
CA

Goddard
Space Flight
Center

Greenbelt,
MD

Jet Propulsion
Laboratory

Pasadena, CA

Langley
Research
Center

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Marshall
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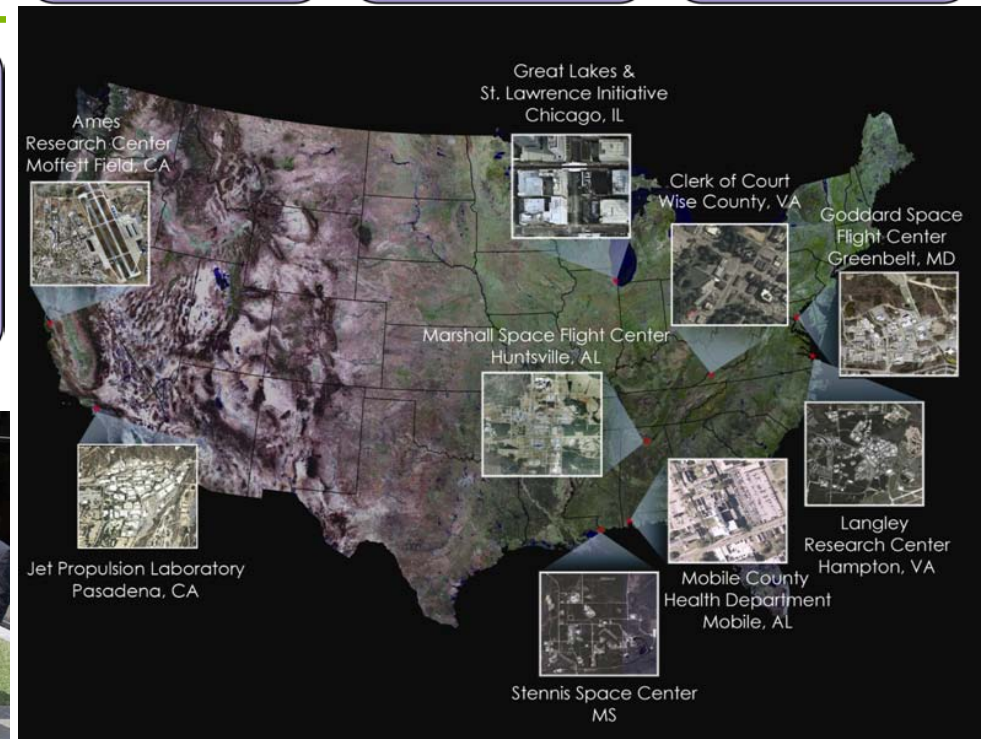
Chicago, IL

Mobile County
Health
Department

Mobile, AL

Clerk of Court
Office

Wise County,
VA



Lyme Disease



Accounts for 95% of vector borne disease case reports in U.S.

- Bites from Blacklegged tick (*Ixodes scapularis*) can transmit *Borrelia burgdorferi* (spirochete) from tick gut
- 1993-2008: 300,000 CDC confirmed U.S. cases
- 2008: 29,000 cases

Lyme Disease Symptoms



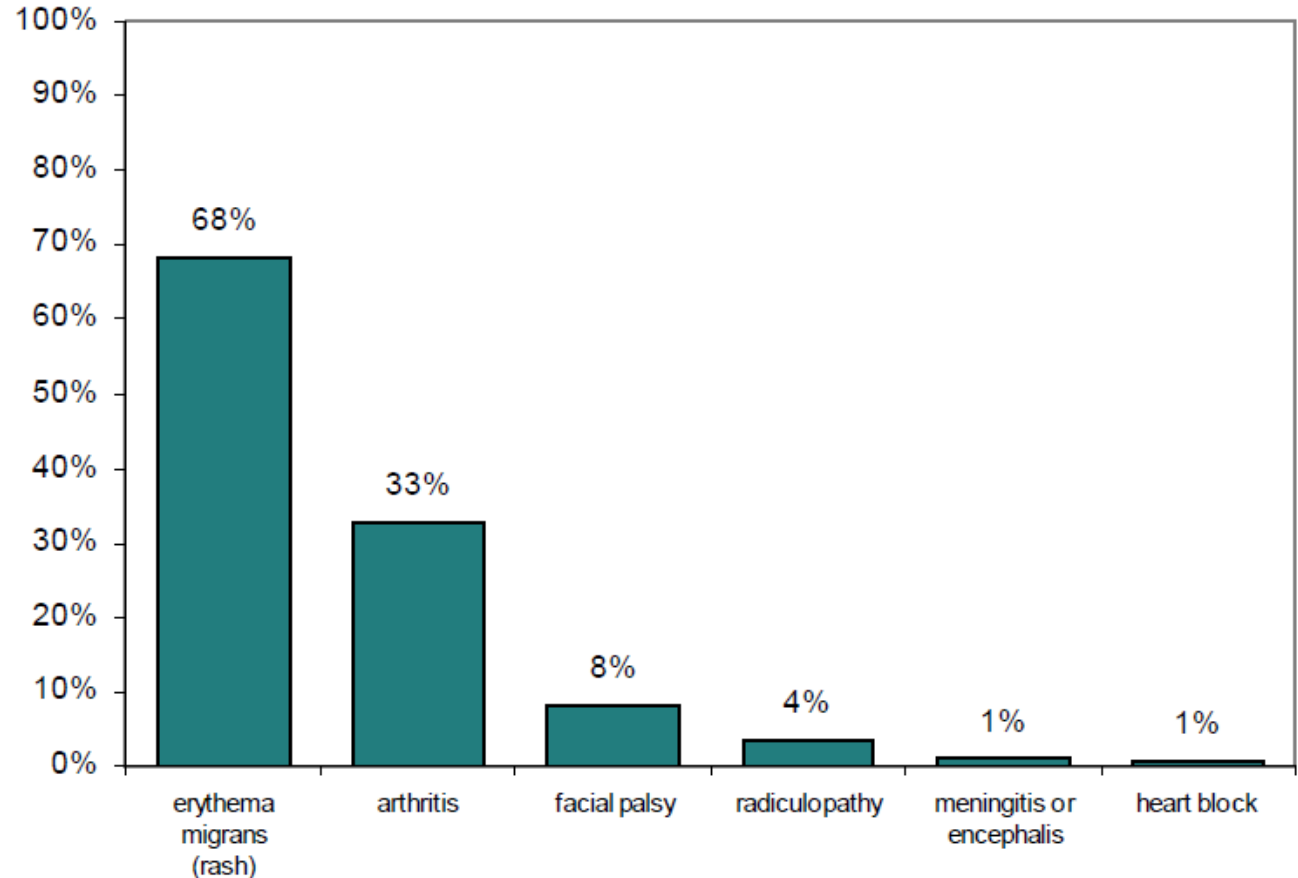
Reported Clinical Findings for Lyme Disease Cases United States, 1992-2004

Acute:

- Erythema migrans
- Fever
- Fatigue
- Headache

Chronic:

- Arthritis
- Neuro-cognitive difficulties
- Fatigue



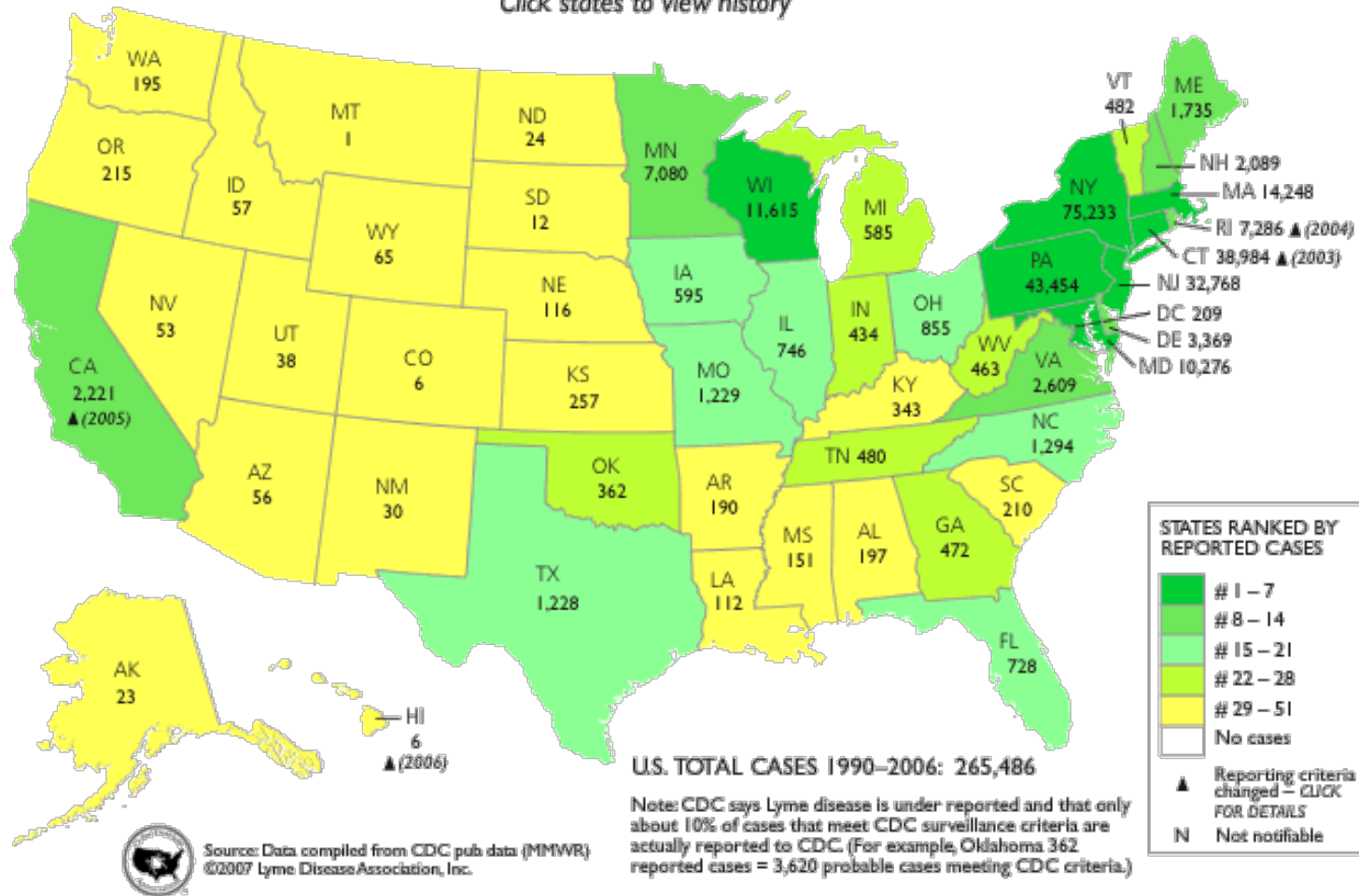
Percent of clinical findings among 119,965 patients for whom at least one symptom was reported.

CDC Lyme Disease Cases



TOTAL LYME CASES REPORTED BY CDC 1990–2006

Click states to view history

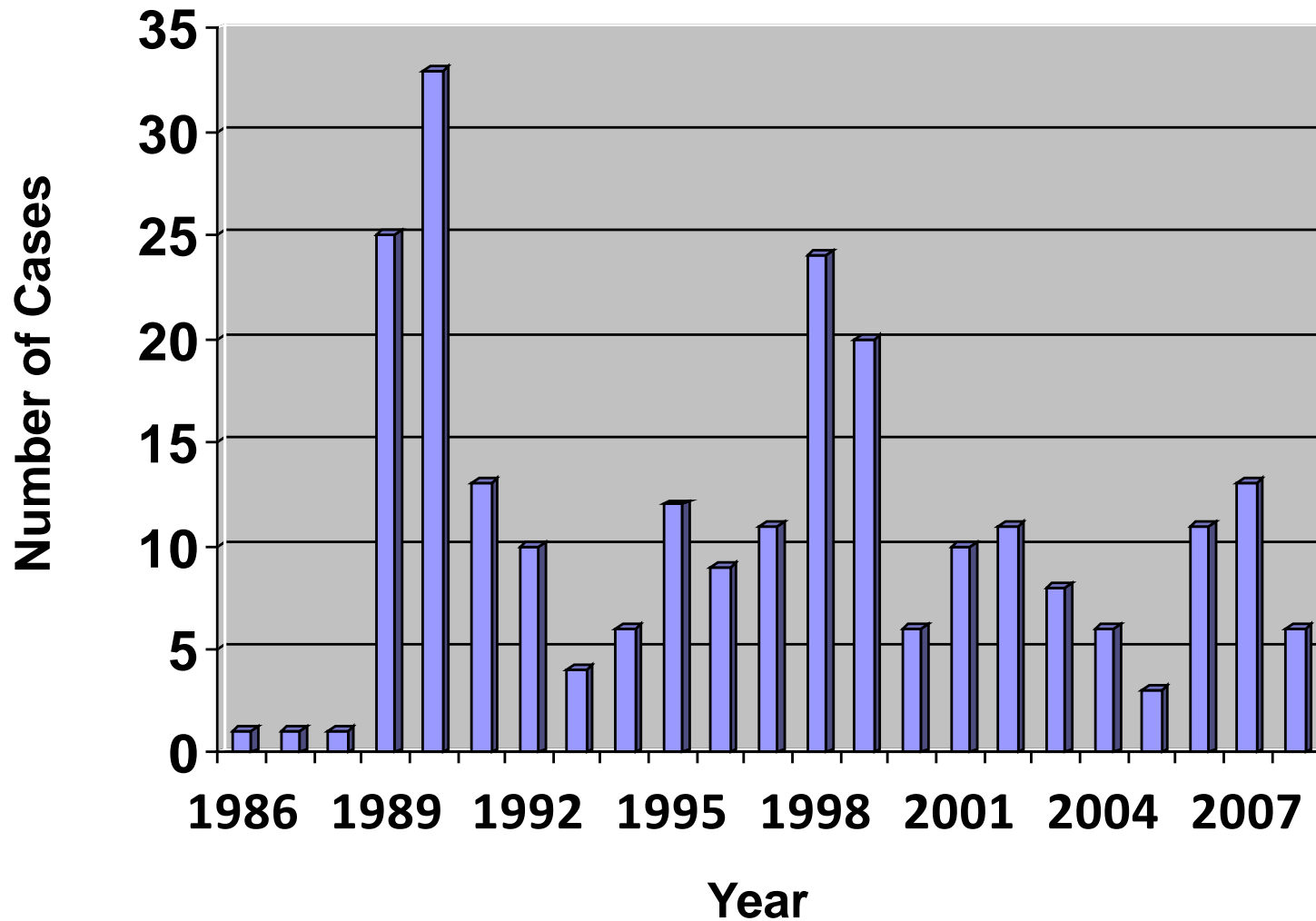


It has been suggested that underreporting issues may exist (Young, 1998; Coyle et al., 1996; Meek et al., 1996)

Lyme Disease in Alabama



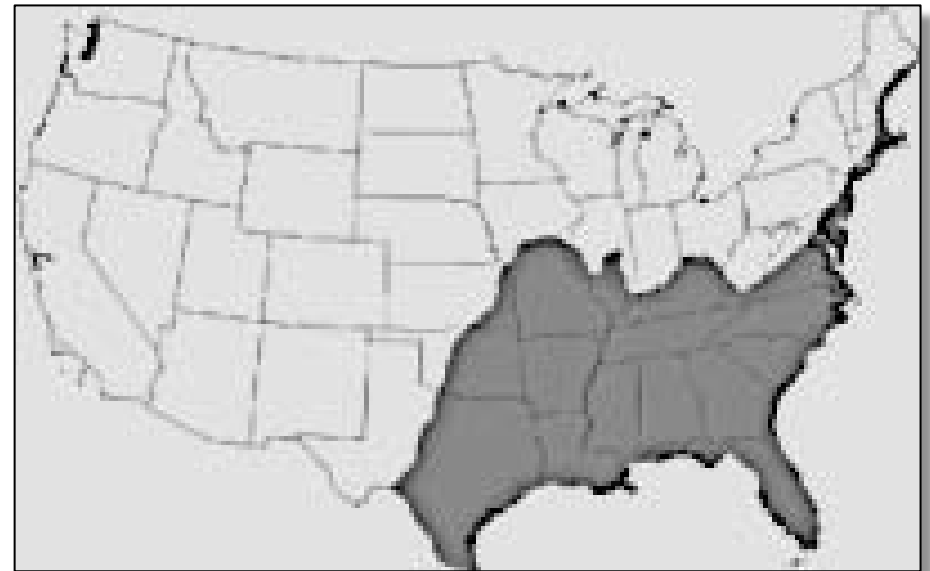
Yearly Lyme disease cases in Alabama, 1986 to 2008 (CDC)



Southern Tick-Associated Rash Illness (STARI)



- Lone star tick (*Amblyomma americanum*)
- Most common in Southeast
- Produces “bulls eye” lesion
- Symptoms: fatigue, fever, headache, muscle and joint pains



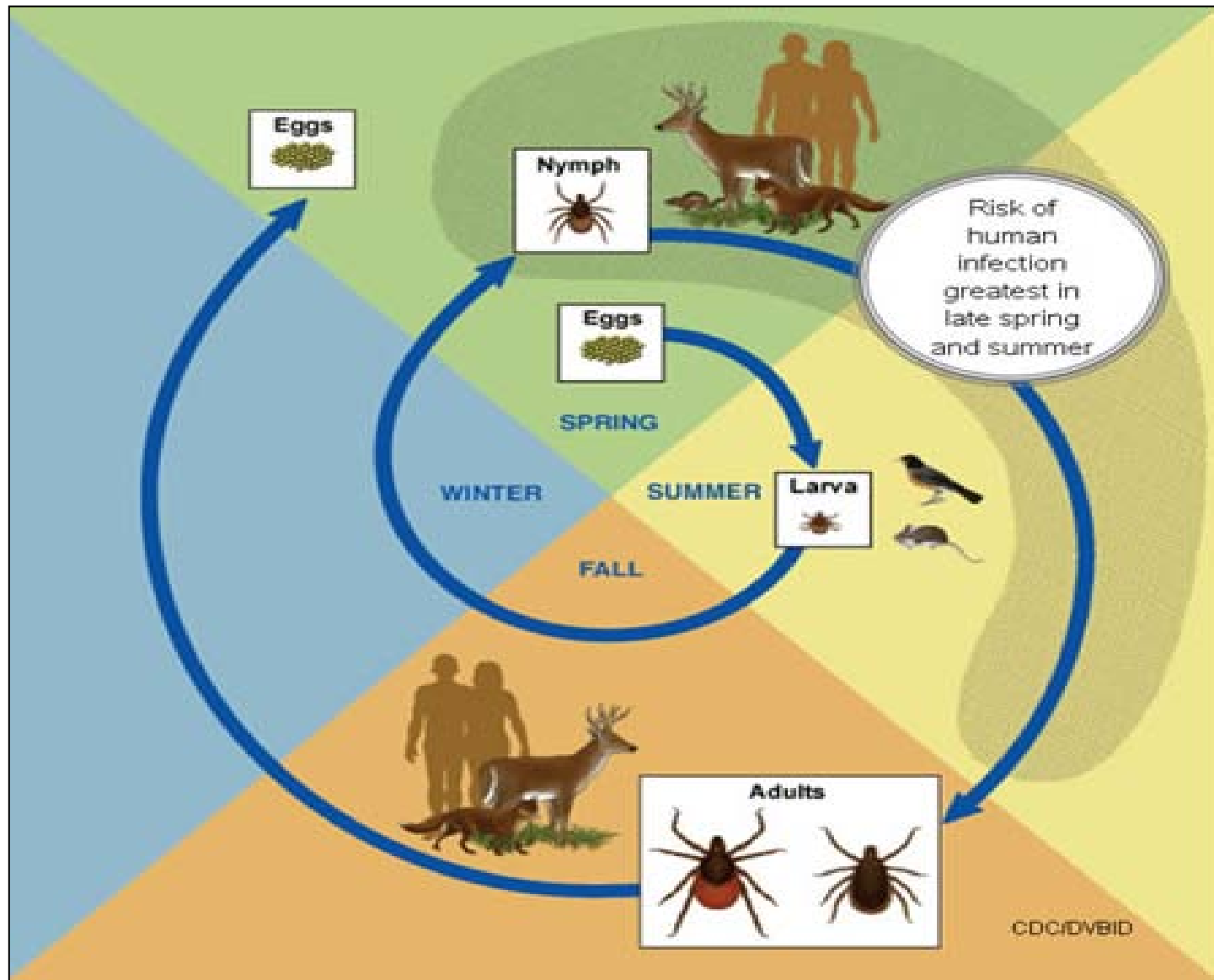
STARI presence in the US

Other Tick-Borne Diseases



Disease	Vector
Rocky Mountain Spotted Fever	<i>Dermacentor variabilis</i>
Babesiosis	<i>Ixodes scapularis</i>
Ehrlichiosis	<i>Amblyomma americanum</i>
Anaplasmosis	<i>Ixodes scapularis</i>
Tularemia	Several

Tick Life Cycle



Stages:

Egg

Larva

Nymph

Adult

(2 years)

Tick Hosts



- Small mammals
 - Larval and nymphal stages
- Nymph stage more likely to cause LD due to small size
- White-tailed deer
 - Tick adult stage

30+ types of wild animals and birds



PHASE 1: Established Chain of Infection in Alabama



Lyme Disease

Causative agent:

- *Borrelia burgdorferi*
- Presence identified through literature review

Vector:

- *Ixodes scapularis*
- Presence identified through literature review

Vector hosts:

- Presence identified through literature review

STARI

Causative agent:

- Unconfirmed; under investigation

Vector:

- *Amblyomma americanum*
- Presence identified through literature review, tick drags

Vector hosts:

- Presence identified through literature review

CDC Prevention Info



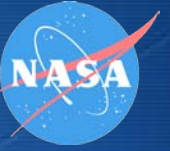
State of Alabama
Courtesy of Google Earth

CDC Lyme disease prevention webpage states:

- “Ask your local health department and park or extension service about tick infested areas to avoid.”
- However, NO local health department and park or extension service in the state of Alabama provide information about tick infested areas.

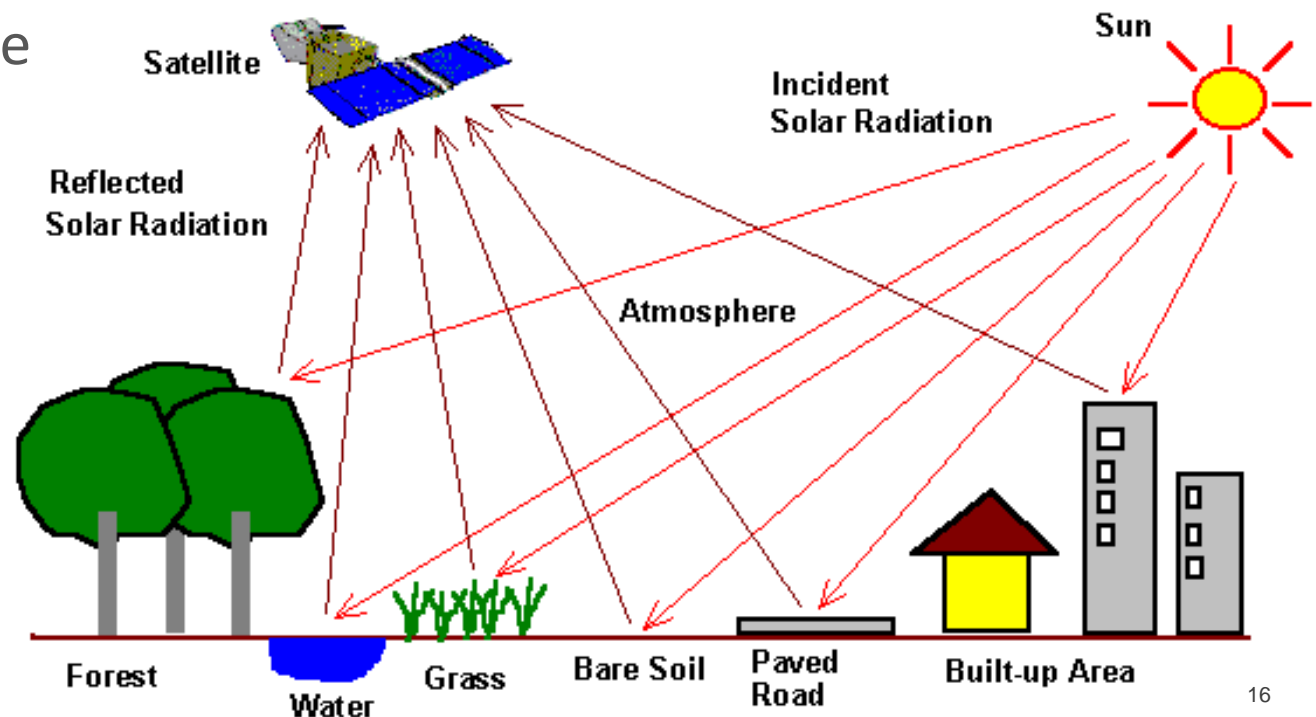


PHASE 1: Map Likely Vector Habitats to Inform a Primary Prevention Campaign



Remote Sensing

- Observing an object without touching it
- Emitted and reflected energy from earth in multiple parts of the electromagnetic spectrum
- Captured by aircraft and satellites



Satellite Imagery

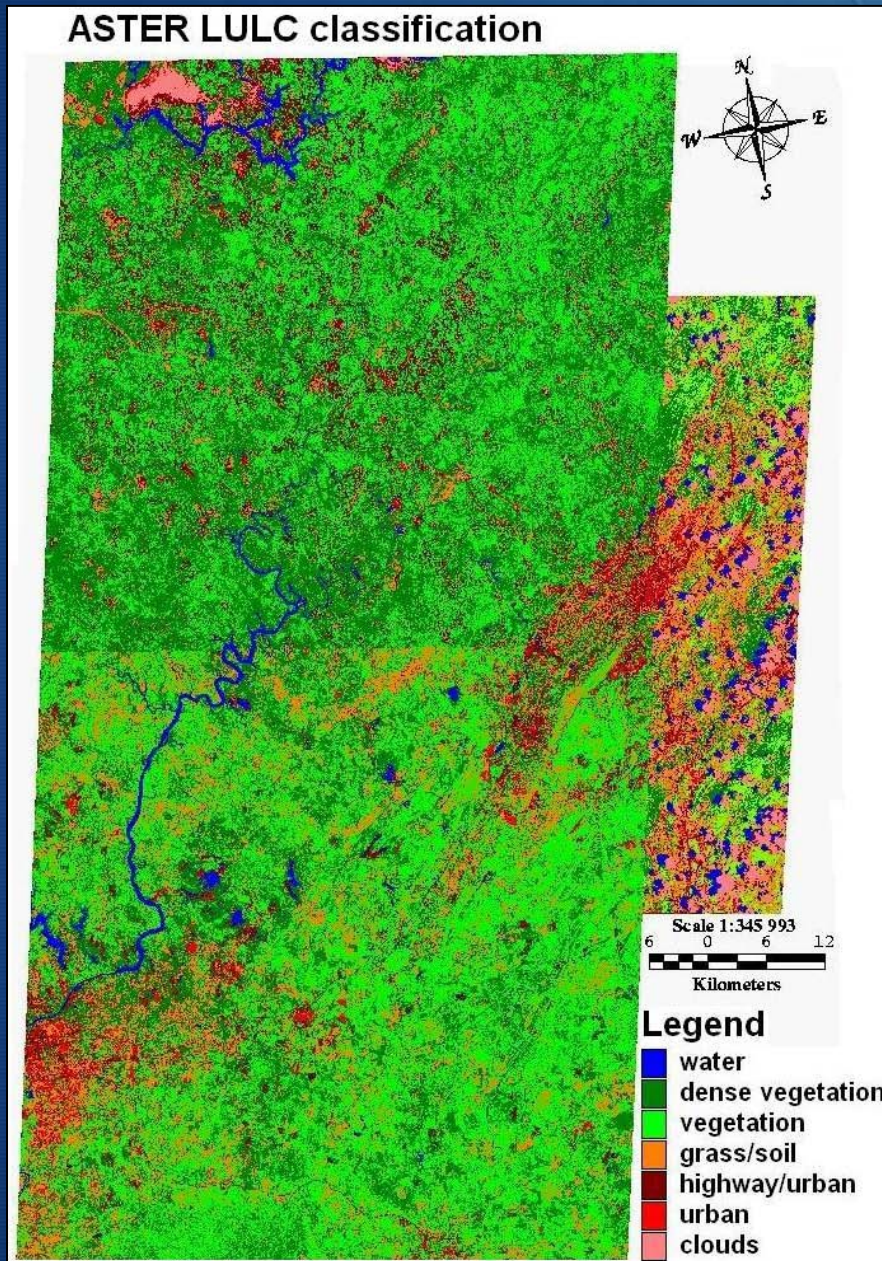




Satellite Imagery: ASTER

Advanced Spaceborne Thermal Emission and Reflection Radiometer

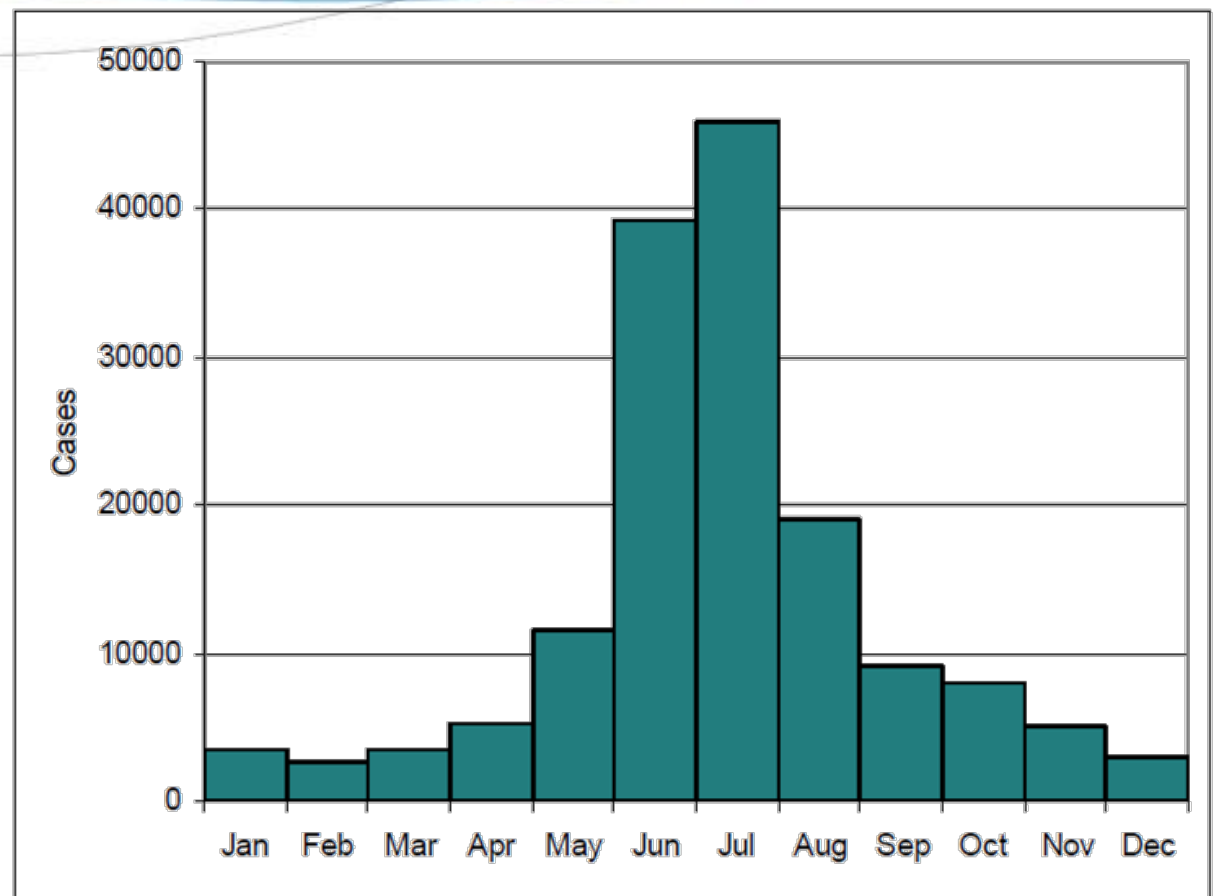
- 15 bands
- Visible (15m resolution)
- Near infrared (15m)
- Mid infrared (30m)
- Thermal infrared (90m)



Environmental Factors Related to Tick Habitats



- Temperature:
-10 to 35°C
- Vegetation:
forest cover
- Soil characteristic:
moist soil
- Landscape:
edge effects

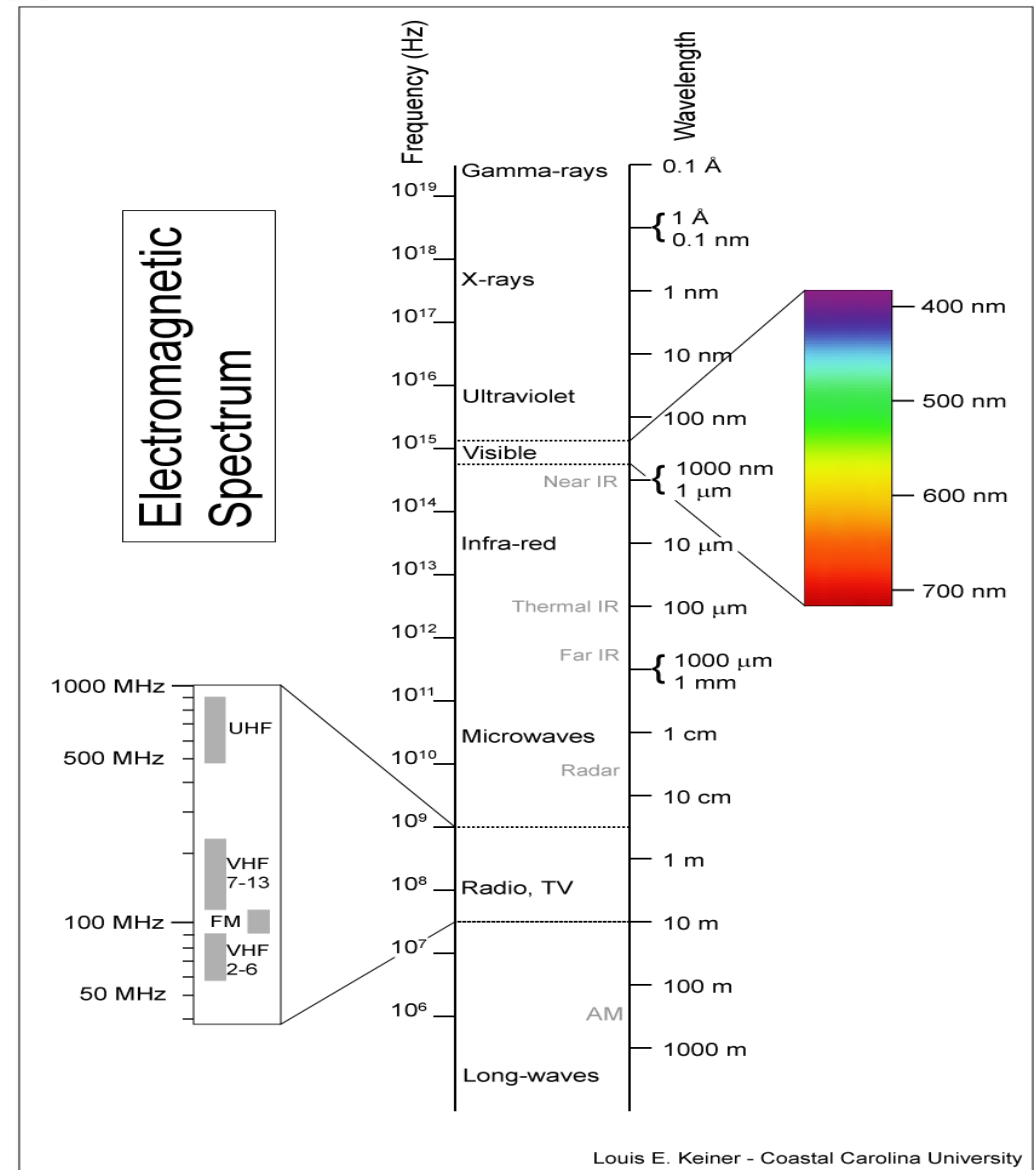


**Reported Cases of Lyme by Month of Illness
Onset, U.S., 1992-2004**

Vegetation: NDVI



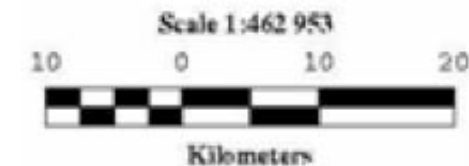
- Normalized Difference Vegetation Index (NDVI) algorithm was applied to ASTER imagery
- Vegetation reflects and emits 20% of its energy in the visible light range
- 50% reflected in NIR
- $NDVI = \frac{NIR-RED}{NIR+RED}$



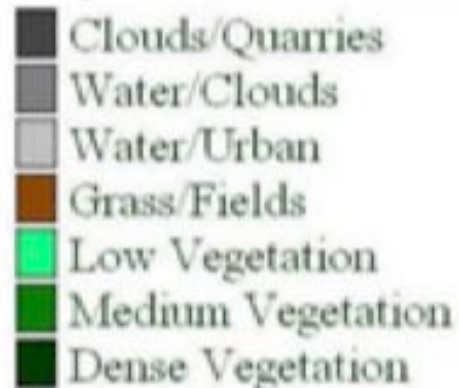
Vegetation: NDVI



- NDVI map of Mobile Bay, Alabama, showing vegetation vigor and types.



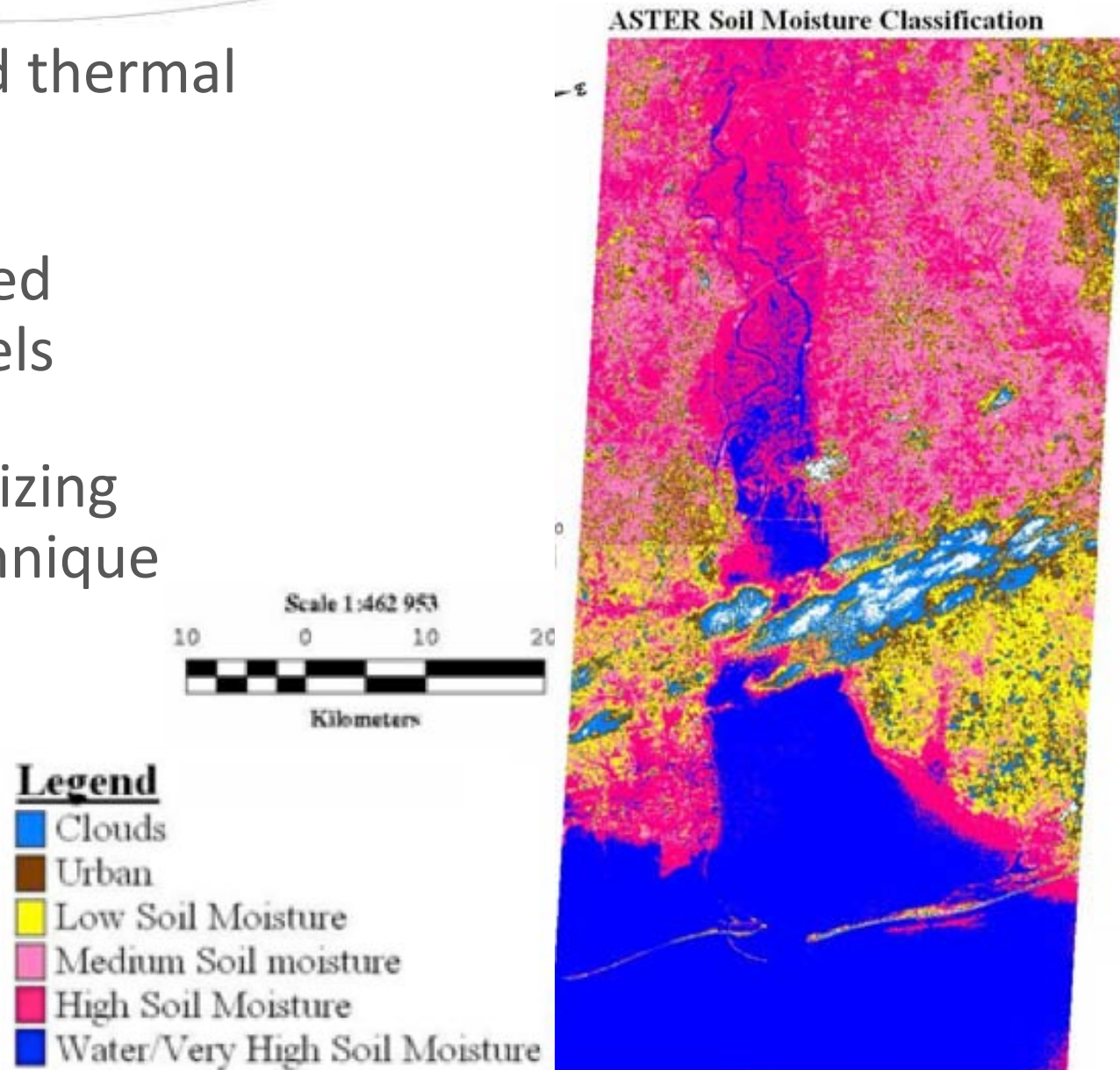
Legend



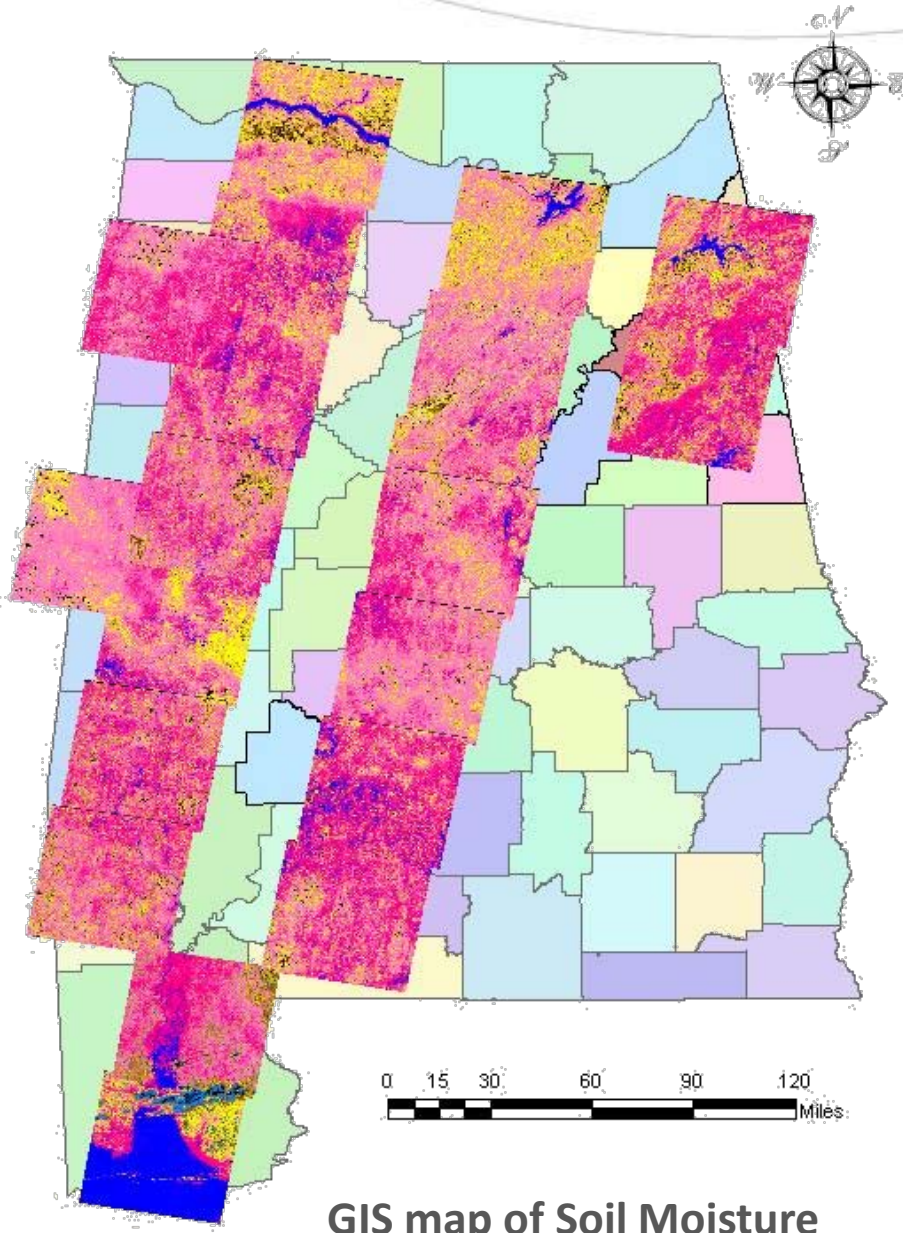
Soil Moisture & Classification



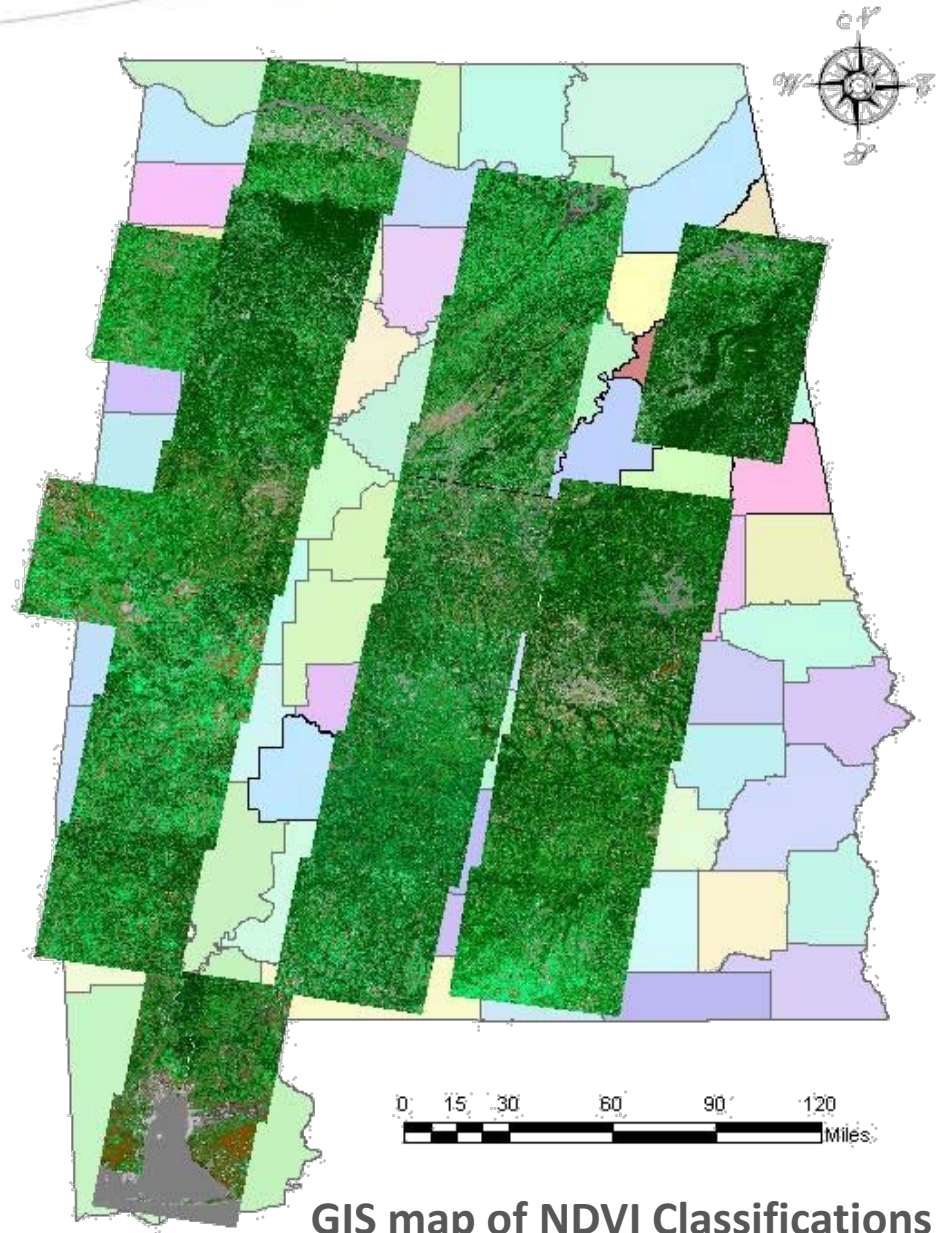
- Ratio of the mid and thermal infrared bands
- Image pixels classified by soil moisture levels
- Iterative Self- Organizing Data (ISODATA) Technique
- Groups pixels into similar “classes”
- Supervised or Unsupervised



Results



GIS map of Soil Moisture Classifications of ASTER for Alabama



GIS map of NDVI Classifications of ASTER for Alabama

Results



Likely Tick Habitats:

Oak Mountain State Park, Bankhead National Forest, and Talladega National Forest showed coincident high NDVI and high Soil Moisture

ASTER Soil Moisture Classification

ASTER NDVI Classification

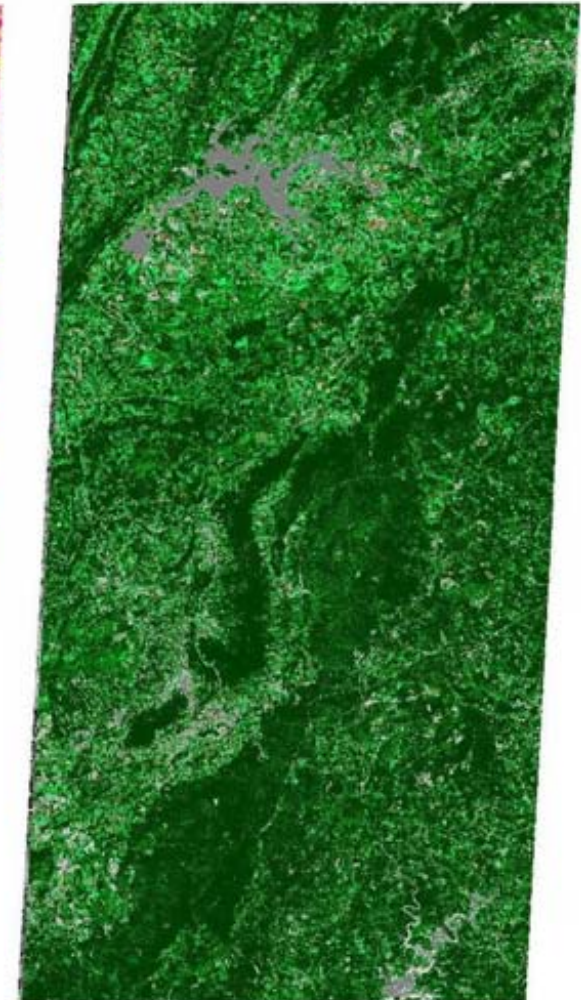
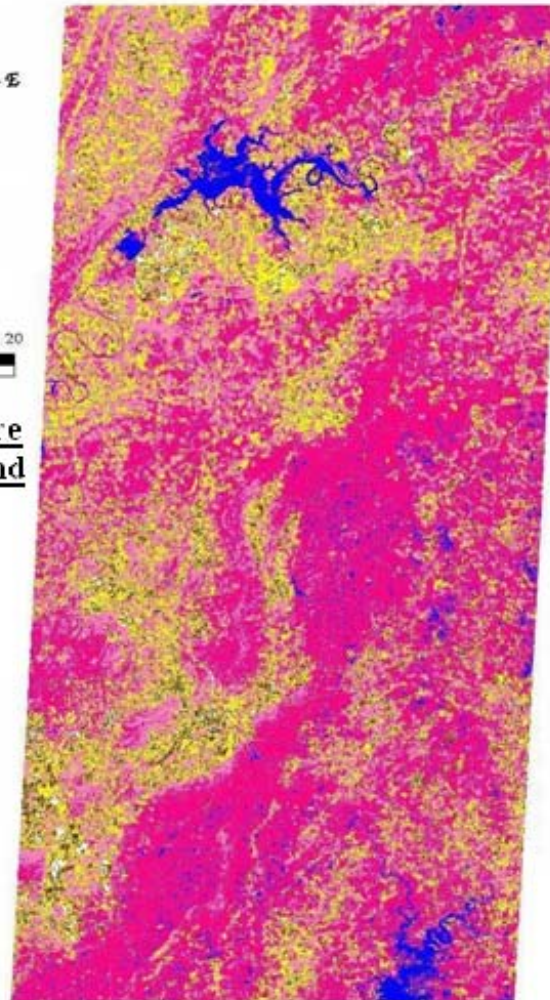


ASTER Soil Moisture Classification Legend

- Clouds
- Urban
- Low Soil Moisture
- Medium Soil moisture
- High Soil Moisture
- Water/Very High Soil Moi

ASTER NDVI Classification Legend

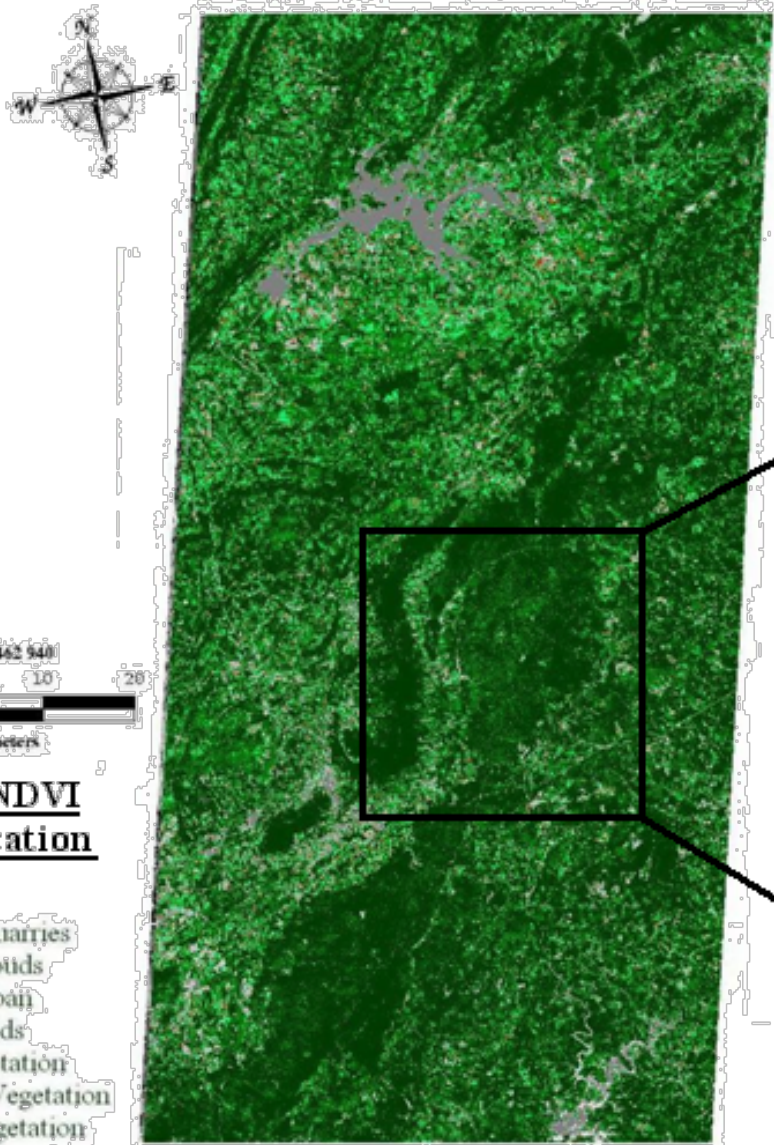
- Clouds/Quarries
- Water/Clouds
- Water/Urban
- Grass/Fields
- Low Vegetation
- Medium Vegetation
- Dense Vegetation



Ground Truthing

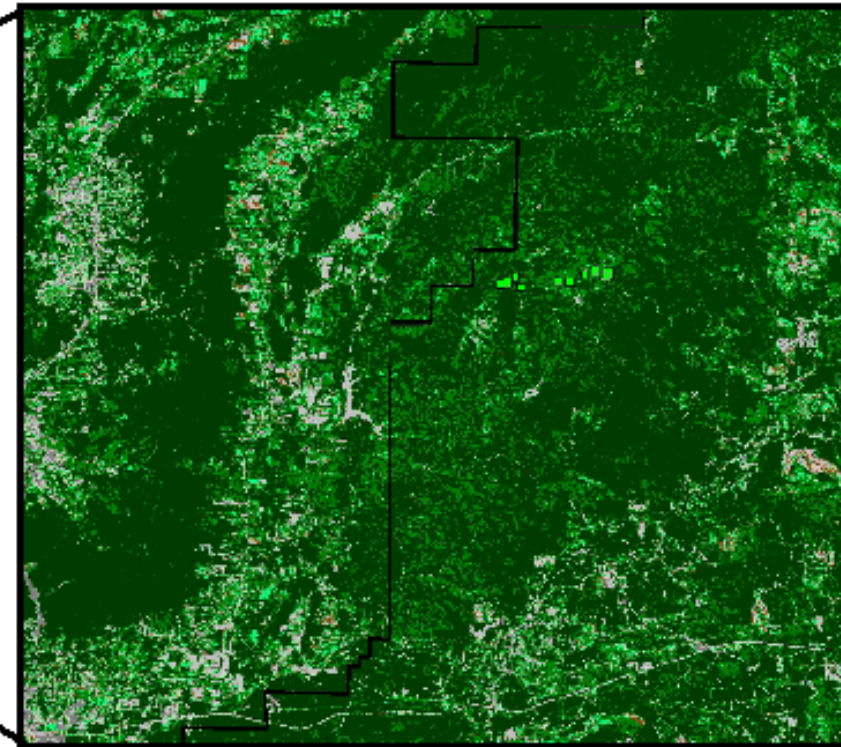


ASTER NDVI Classification



In situ soil and tick data gathered at Talladega National Forest

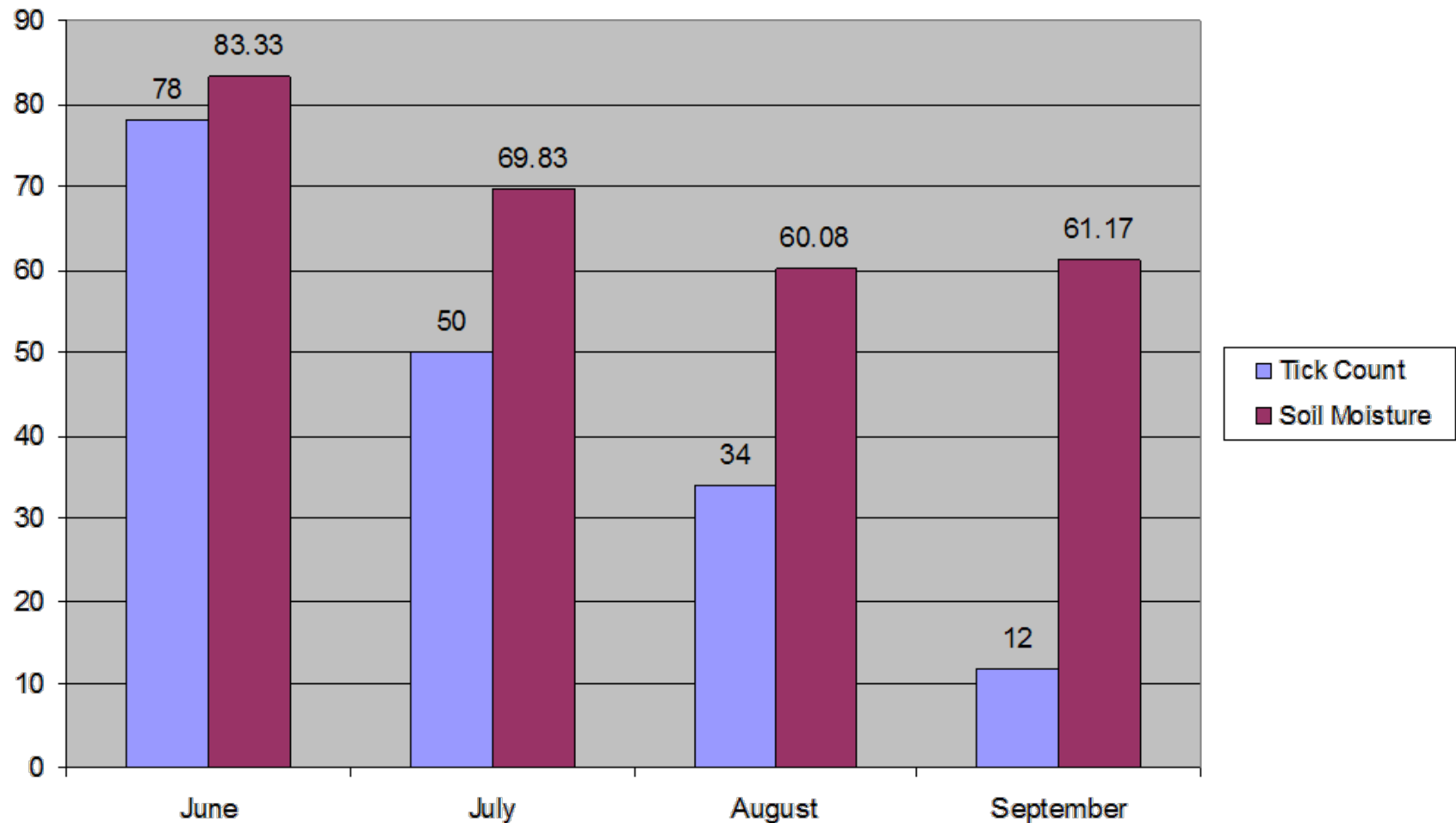
Talladega National Forrest



Results



Camp Coleman - 2008
Tick Count vs. Soil Moisture

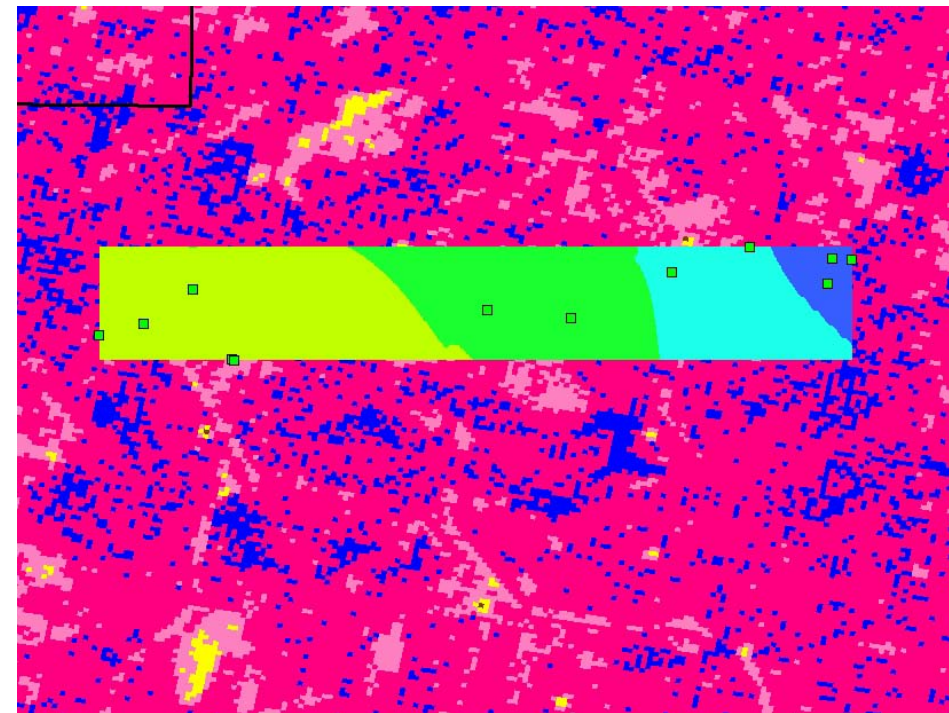
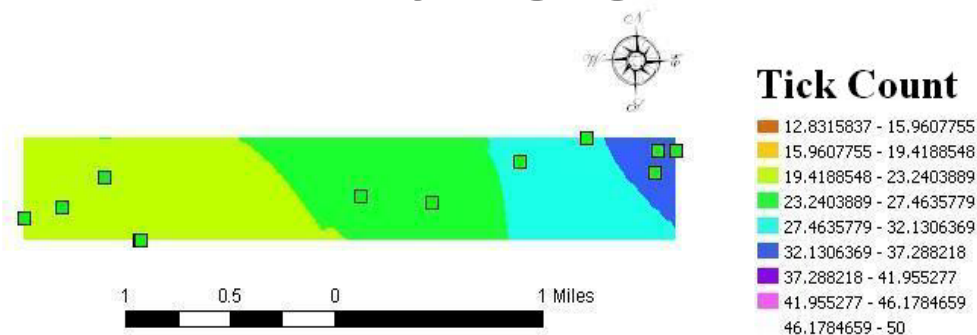


Spatial Statistics

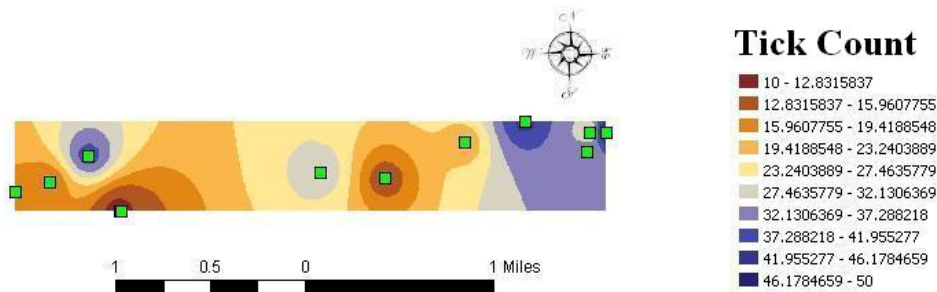


Compared Ordinary Kriging and Inverse Distance Weighting to model tick collection points and predicted tick counts in Talladega National Forest.

Ordinary Kriging



Inverse Distance Weighting



Ordinary Kriging had lowest root mean square error → better fit

Community Outreach



Literature review revealed:

- Prevention campaigns and interventions common in NE and West Coast States
- Simple to highly sophisticated
- Materials and messages distributed by state and local public health departments, non-profits, physicians, teachers
- Campaigns and information less common in SE
- Little-to-no materials available to Alabamians from state health and natural resource organizations

→ Team Decision: Develop a Primary Prevention Campaign for High-Risk Groups in Alabama, informed by tick habitat mapping.

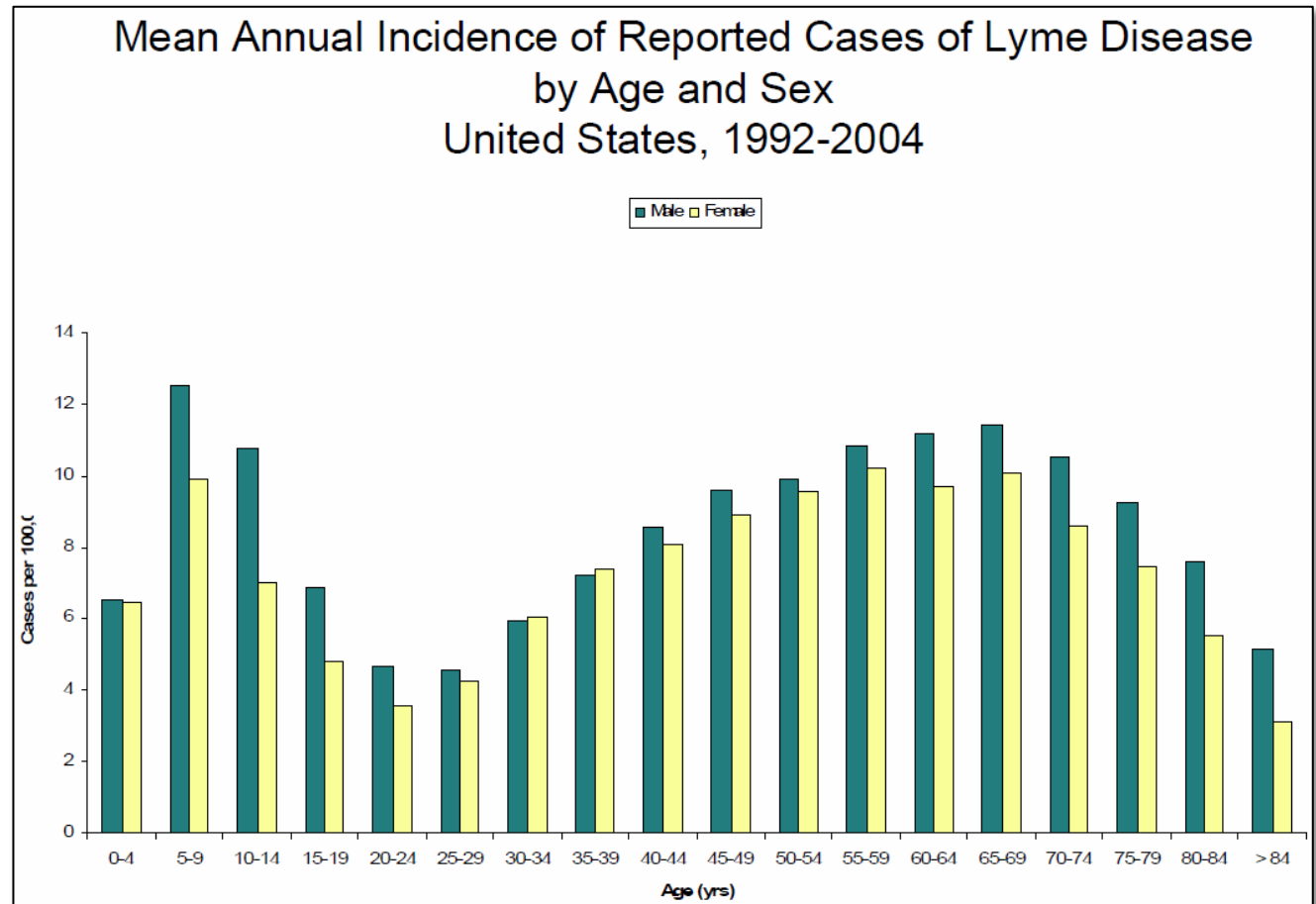
Community Outreach



Population at Risk

- Outdoor enthusiasts
- Outdoor workers
- Rural/peripheral settlement dwellers
- Pet owners and veterinarians

Age & Gender Factors



Ongoing Work: Outreach



Educational seminars for Girl Scouts of North-Central Alabama

- Camp Coleman and Kanawahala, summer 2010
- Content based on literature
- Structure based on Health Belief Model

KAP assessment of tick borne illness prevention behaviors

- Assess beliefs and practices of high-risk groups (Campus Outdoor Recreation Club participants)
- Online using Survey Monkey
- Target prevention messages

Health Belief Model

Components:

- 1) Perceived susceptibility
- 2) Perceived severity
- 3) Perceived benefits
- 4) Perceived barriers
- 5) Cues to action
- 6) Self-efficacy

Ongoing Work: Outreach



Prevention Messages (CDC Website)

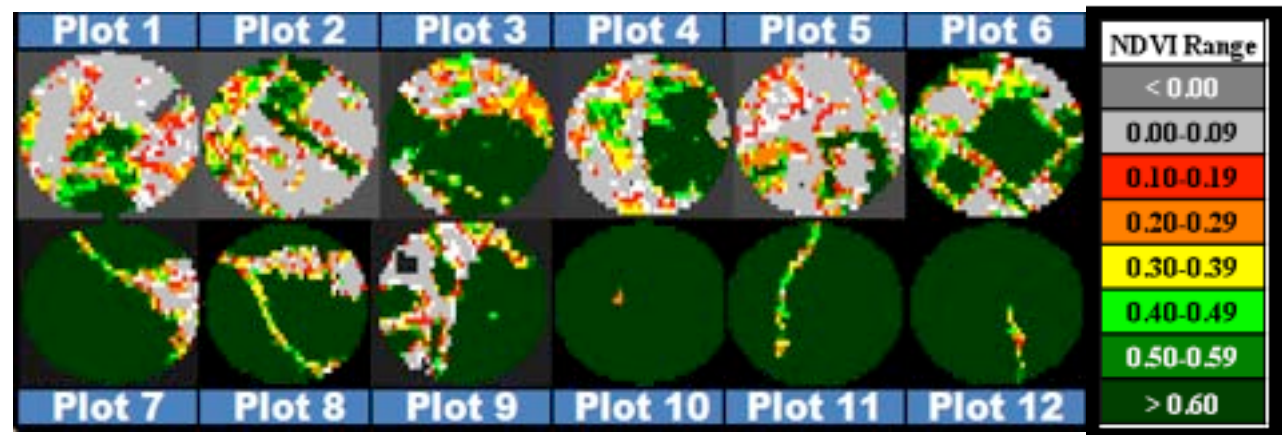
- Avoid or reduce time spent in likely tick habitats
- Wear protective clothing (long sleeved, light colored clothes)
- Tuck in pants and shirts
- Use tick repellants such as DEET or permethrin
- Perform tick checks
- Remove ticks properly (with tweezers, slowly pulling tick out straight from close to its embedded mouthparts)
- Remove ticks within 24 hours of attachment

Phases 3 & 4



- Analyze Landsat satellite imagery to identify likely tick habitats in areas not covered by ASTER
- Perform geo-located tick drags at Fort McClellan to establish correlations between tick populations and additional environmental variables
- PCR analysis of tick infection rates for multiple diseases
- “Task” (request) NASA Terra Satellite to take ASTER images for summer 2010

- Use new ASTER and tick data to test accuracy of predictive model



- Investigate edge effects and patch size in the spatial model

Conclusions



Remote sensing can be useful for:

- Conducting surveillance
- Targeting prevention messages

DEVELOP is an exceptional model for student collaboration, research training, and community outreach:

- Student-led team (graduate, undergrad, high school)
- Diverse, interdisciplinary group: 6 countries, 6 disciplines
- Training in remote sensing, GIS, modeling
- Community outreach of NASA assets and products for societal benefit



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UAB Laboratory for Global Health Observation

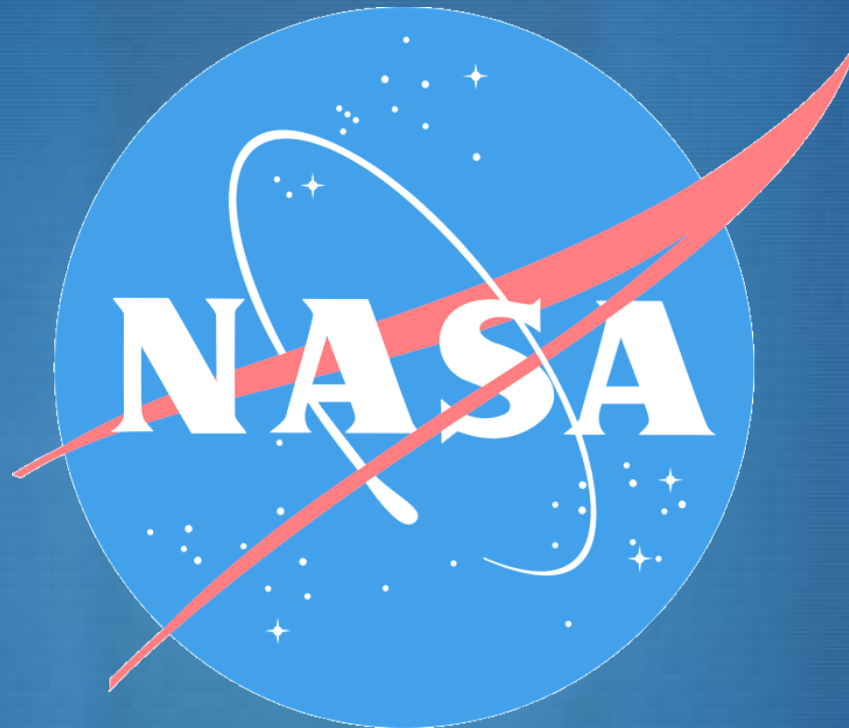
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- Dr. Donna Burnett
- Steve Padgett-Vasquez, current DEVELOP lead
- Dr. Herman Foushee
- Kartikey Acharya, University of Arkansas
- Jacksonville State University

Previous and current DEVELOP team members



Works Cited

- Luckhart, S, Mullen, GR, Durden, A et al. *Borrelia* sp. in ticks recovered from white-tailed deer in Alabama. *Journal of Wildlife Diseases*. 1992; 28: 449-452.
- Luckhart, S, Mullen, GR & Wright, C. Etiologic agent of Lyme Disease, *Borrelia burgdorferi*, detected in ticks (Acari:Ixodidae) collected at a focus in Alabama. *Journal of Med Entomol*. 1993; 28:652-657.
- Magnarelli, LA, Olivers, JR, Hutcheson, HJ et al. Antibodies to *Borrelia burgdorferi* in Rodents in the Eastern and Southern United States. *Journal of Clinical Microbiology*. 1992; 30: 1449-1452.
- Durden, LA, Luckhart, S, Mullen, GR et al. Tick infestations of white-tailed deer in Alabama. *Journal of Wildlife Diseases*. 1991; 27(4): 606-614
- Guerra, M, Walker E, Jones, CJ et al. Predicting the risk of Lyme disease: Habitat suitability for *Ixodes scapularis* in the north central United States. *Emerging Infectious Diseases*. 2002; 8(3): 289-297.
- Killilea, M, Swei, A, Lane, RS et al. Spatial dynamics of Lyme disease: A review. *EcoHealth*. 2008; 5: 167-195.
- Estrada-Pena. Increasing habitat suitability in the United States for the Tick that Transmits Lyme disease: A remote sensing approach. *Environmental Health Perspectives*. 2002; 110(7): 635-640.
- Eisen, RJ, Lane, RS, Fritz, CL et al. Spatial patterns of Lyme disease risk in California based on disease incidence data and modeling of vector-tick exposure. *Am. J. Trop. Med. Hyg*. 2006; 75(4): 669-676.
- Lubelczyk, CB, Elias, SP, Rand, PW, et al. Habitat associations of *Ixodes scapularis* (Acari: Ixodidae) in Maine. *Environmental Entomol*. 2005; 33(4): 900-906
- Rodgers, SE, Zolnik, CP & Mather, TN. Duration of exposure to suboptimal atmospheric moisture affects nymphal blacklegged tick survival. *J. Med. Entomol*. 2007; 44(2): 372-375.



Questions?

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