

# Enhanced Forecasting of Mosquito-Borne Disease Outbreaks Using AMSR-E

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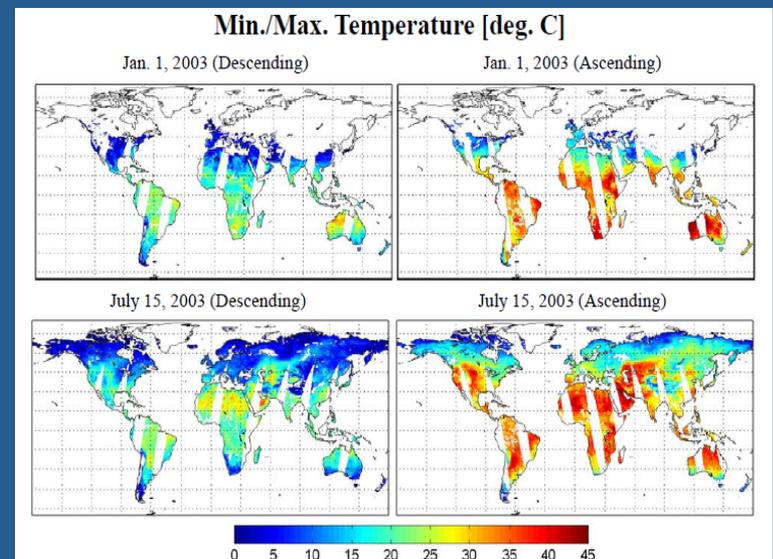
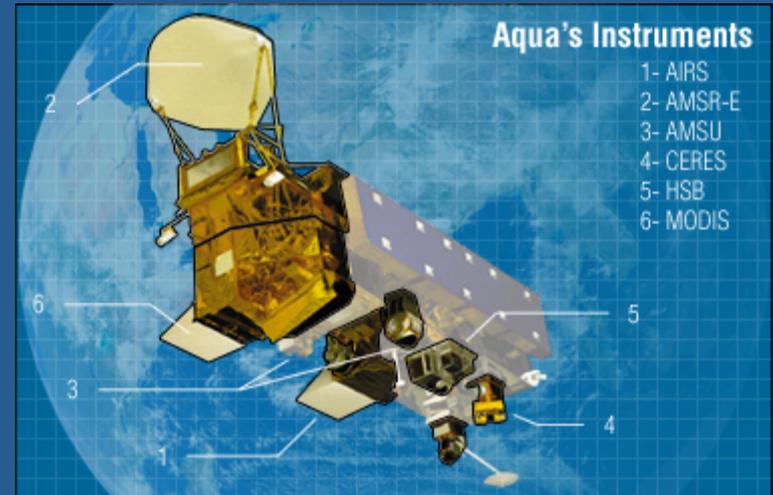


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# Background – AMSR-E Land Surface Parameters

- Satellite-retrieved geophysical parameters generated from the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) instrument on the Aqua satellite
  - Near-surface air temperature
  - Surface soil moisture
  - Fractional open water cover
  - Vegetation canopy opacity
- Daily record extends from 19 June 2002 to 27 September 2011
- Spatial resolution is 25 km



# Research Objectives

- Objective 1: Develop statistical models of mosquito population dynamics and WNV incidence using AMSR-E land surface parameters.
- Objective 2: Compare the performance of the AMSR-E driven models with similar models derived from other sources of environmental monitoring data to quantify improvements in the forecasting of mosquito-borne disease outbreaks.
- Objective 3: Generate WNV risk forecasts from models based on AMSR-E variables, disseminate these predictions to public health practitioners, and obtain qualitative feedback on the value and utility of these predictions.

# Objectives 1 and 2

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## Satellite microwave remote sensing for environmental modeling of mosquito population dynamics

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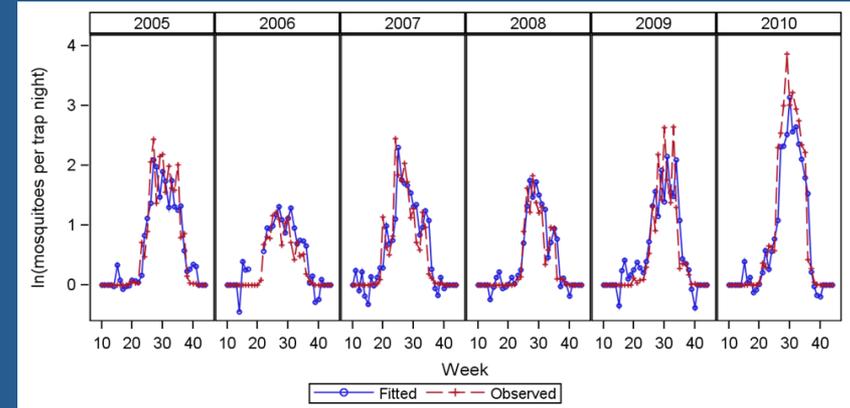
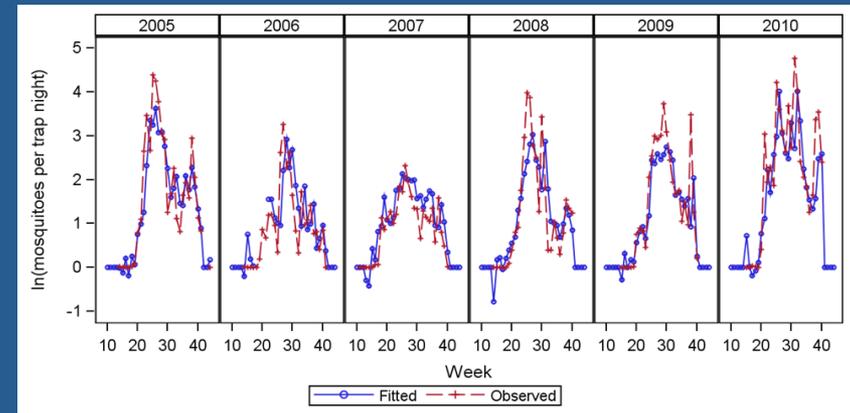
Public Health

### ABSTRACT

Environmental variability has important influences on mosquito life cycles and understanding the spatial and temporal patterns of mosquito populations is critical for mosquito control and vector-borne disease prevention. Meteorological data used for model-based predictions of mosquito abundance and life cycle dynamics are typically acquired from ground-based weather stations; however, data availability and completeness are often limited by sparse networks and resource availability. In contrast, environmental measurements from satellite remote sensing are more spatially continuous and can be retrieved automatically. This study compared environmental measurements from the NASA Advanced Microwave Scanning Radiometer on EOS (AMSR-E) and *in situ* weather station data to examine their ability to predict the abundance of two important mosquito species (*Aedes vexans* and *Culex tarsalis*) in Sioux Falls, South Dakota, USA from 2005 to 2010. The AMSR-E land parameters included daily surface water inundation fraction, surface air temperature, soil moisture, and microwave vegetation opacity. The AMSR-E derived models had better fits and higher forecasting accuracy than models based on weather station data despite the relatively coarse (25-km) spatial resolution of the satellite data. In the AMSR-E models, air temperature and surface water fraction were the best predictors of *Aedes vexans*, whereas air temperature and vegetation opacity were the best predictors of *Cx. tarsalis* abundance. The models were used to extrapolate spatial, seasonal, and interannual patterns of climatic suitability for mosquitoes across eastern South Dakota. Our findings demonstrate that environmental metrics derived from satellite passive microwave radiometry are suitable for predicting mosquito population dynamics and can potentially improve the effectiveness of mosquito-borne disease early warning systems.

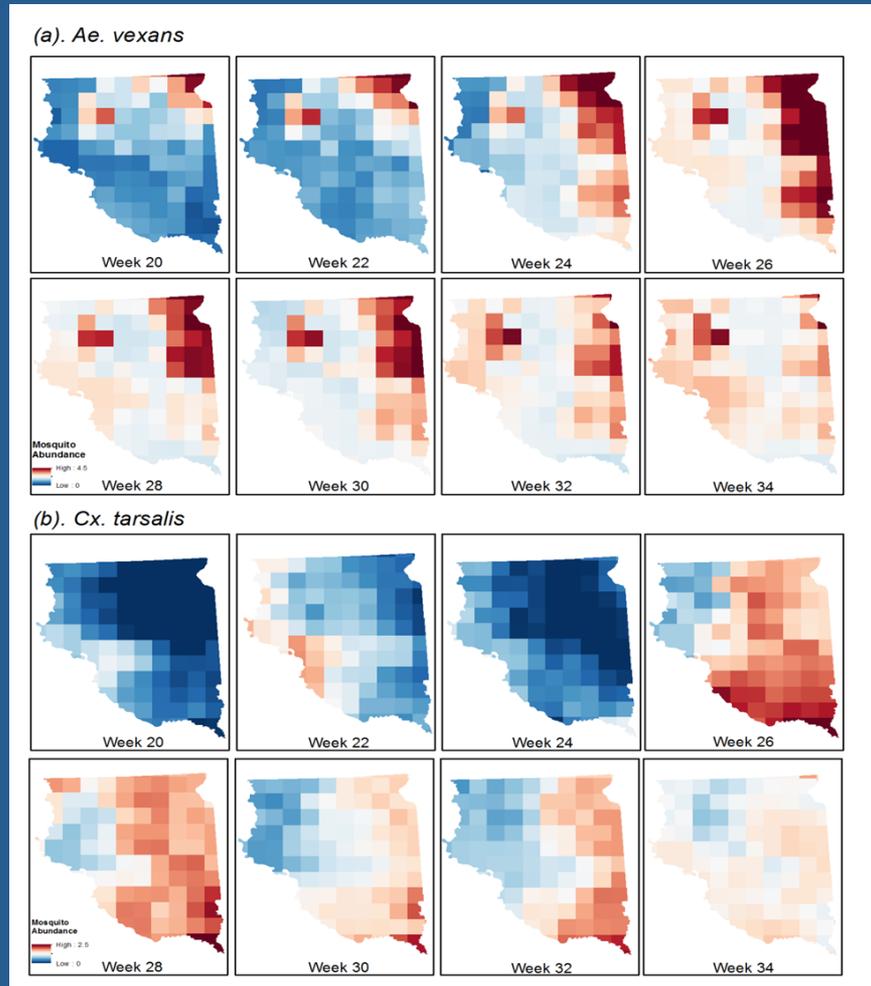
# Overview of Major Results

- Compared environmental models based on AMSR-E land surface parameters versus meteorological variables
- Models based on AMSR-E had better fits
  - Fractional water strongly associated with *Aedes vexans*
  - Vegetation opacity improved the fit of the *Culex tarsalis* model



# Overview of Major Results

- Model evaluation
  - Cross-validation indicated high potential for predicting mosquito activity at the same location where the model was parameterized
  - Validation against data from an independent site indicated moderate potential for predicting seasonal and interannual variability at different locations



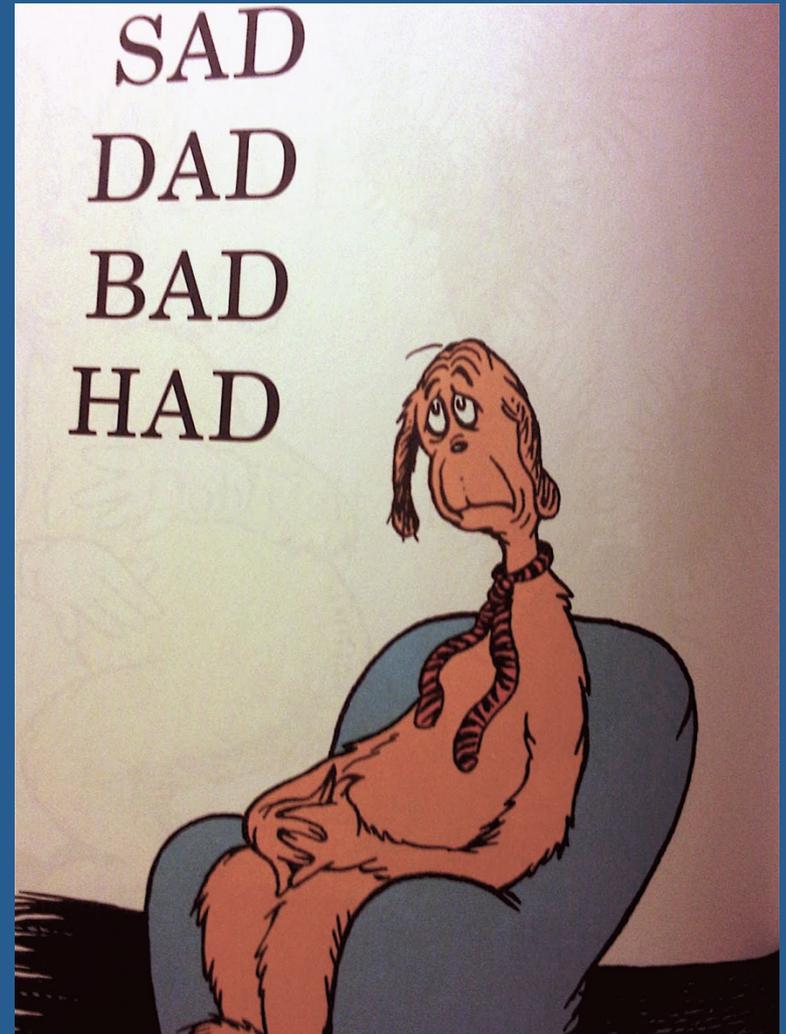
# Summary – Mosquito Population Models

- AMSR-E land surface parameters were as effective as weather station data for modeling mosquitoes
- Unique measurements of biophysical Earth-surface characteristics - not simply a remote “proxy” for ground data
- Integrates information over broad spatial extents



# Objective 3

*The AMSR-E antenna stopped spinning at 0726GMT Oct 4, 2011 most likely due to aging lubricant in the mechanism. AMSR-E is currently not producing any data. The Aqua spacecraft accommodated the spin-down, which occurred over a period of about 25 minutes, and continues to operate normally, with all other instruments functioning in science mode. NASA will work with JAXA to understand the condition of the AMSR-E instrument and possible future steps.*

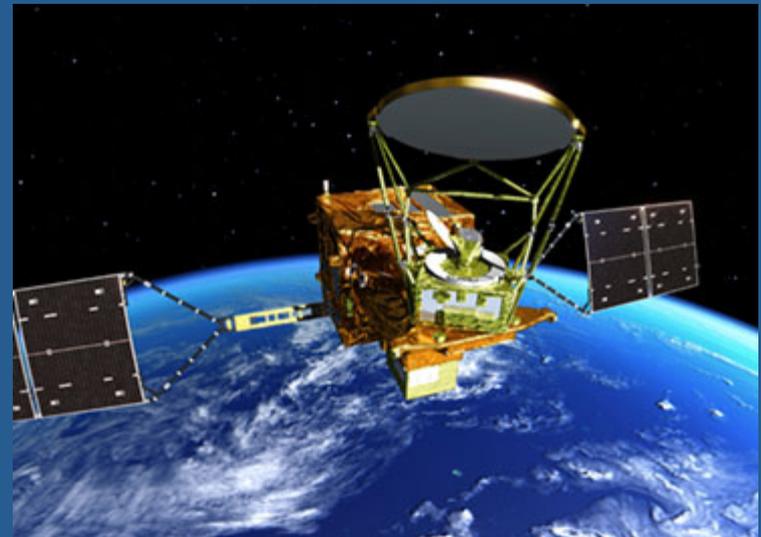


# Dealing with the Pitfall

- Short-term: Develop and test forecasting models based on MODIS and other sources of optical-IR RS data.
- Long term:
  - WindSat microwave radiometer has similar channels and an overlapping record with AMSR-E
  - AMSR2 launched in May 2012 onboard GCOM-W1
  - Potential for continuous, uninterrupted brightness temperature and land parameter retrievals

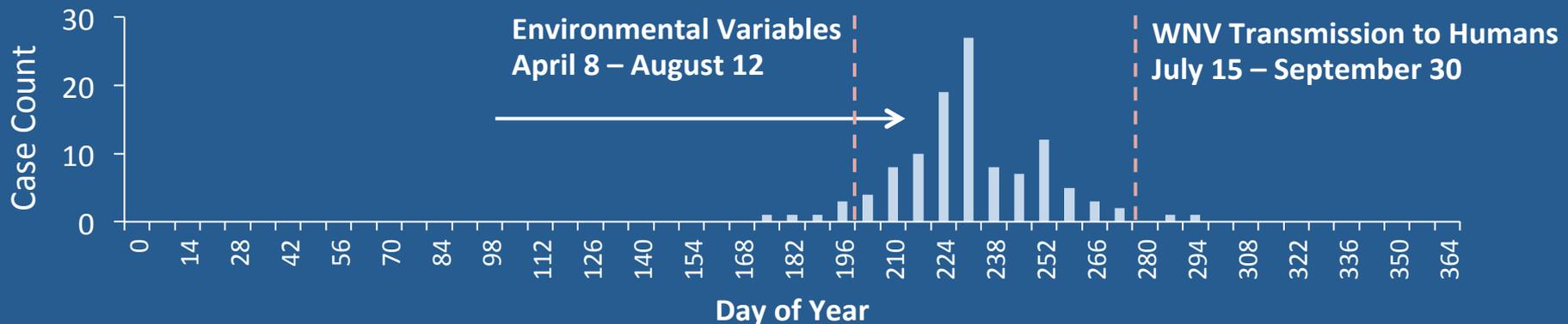
Satellites and Spacecraft

Global Change Observation Mission 1st - Water  
"SHIZUKU" (GCOM-W1)



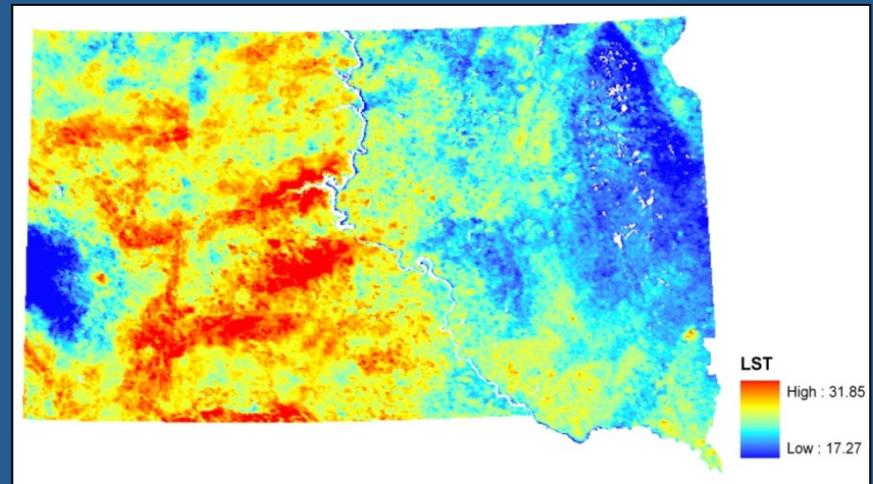
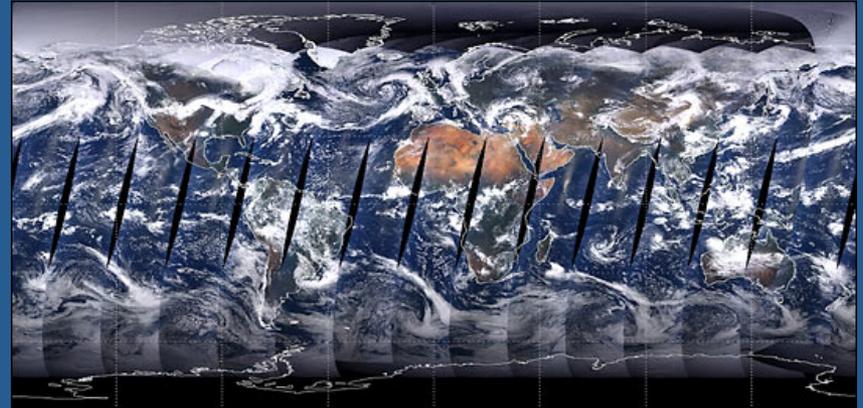
# Modeling WNV Incidence in Humans Across the Northern Great Plains

- Response Variable – Log relative risk (LRR) computed for each county in each year
- Predictor Variables – Cumulative environmental metrics for different days of the year (DOY 105-217 at 8-day intervals).
- Fit generalized additive models (GAMs) to historical environmental and case data
- Predict using 2011 environmental data



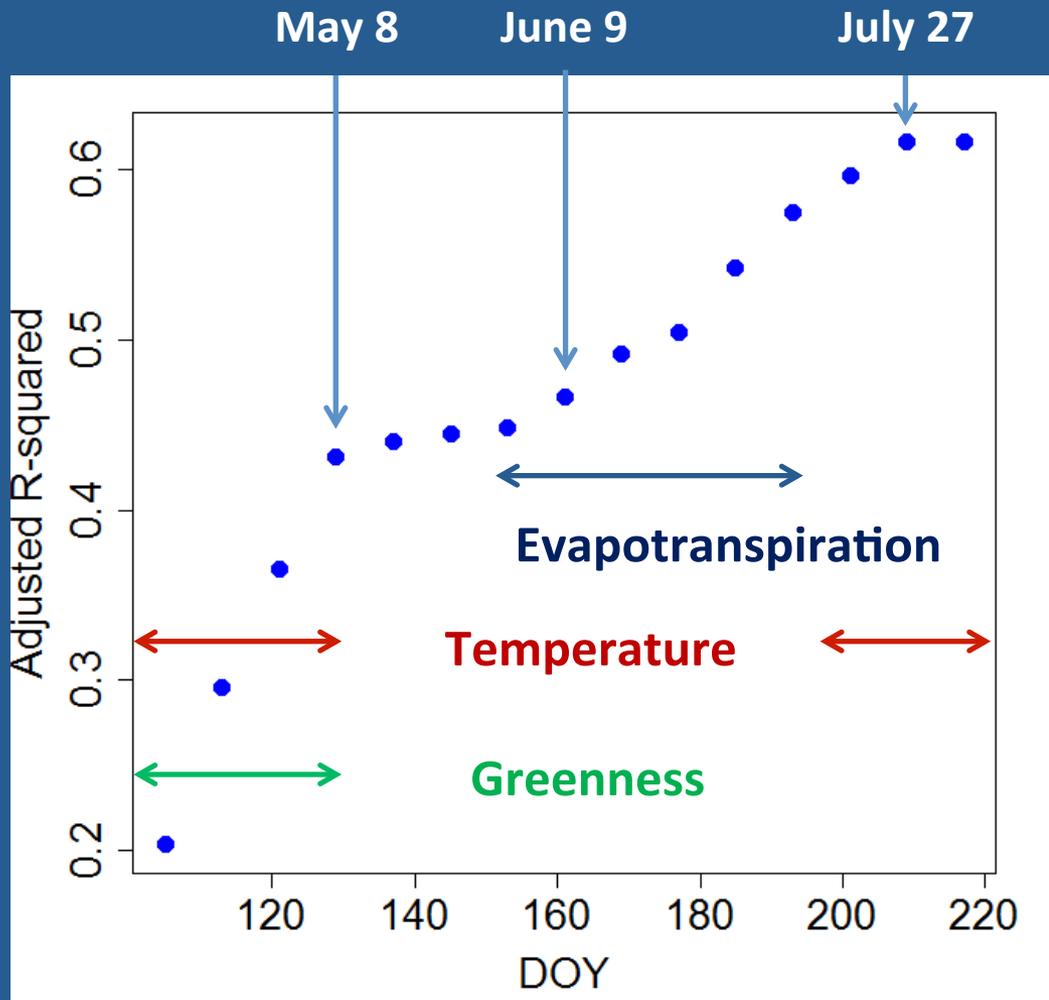
# Sources of Remote Sensing Data

- Greenness
  - NDVI from MODIS nadir BRDF-adjusted reflectance
- Temperature
  - MODIS/Terra Land surface temperature
- Evapotranspiration
  - Simplified surface energy balance method



Land surface temperature in early July in SD, 2010 (MOD11A2 product)

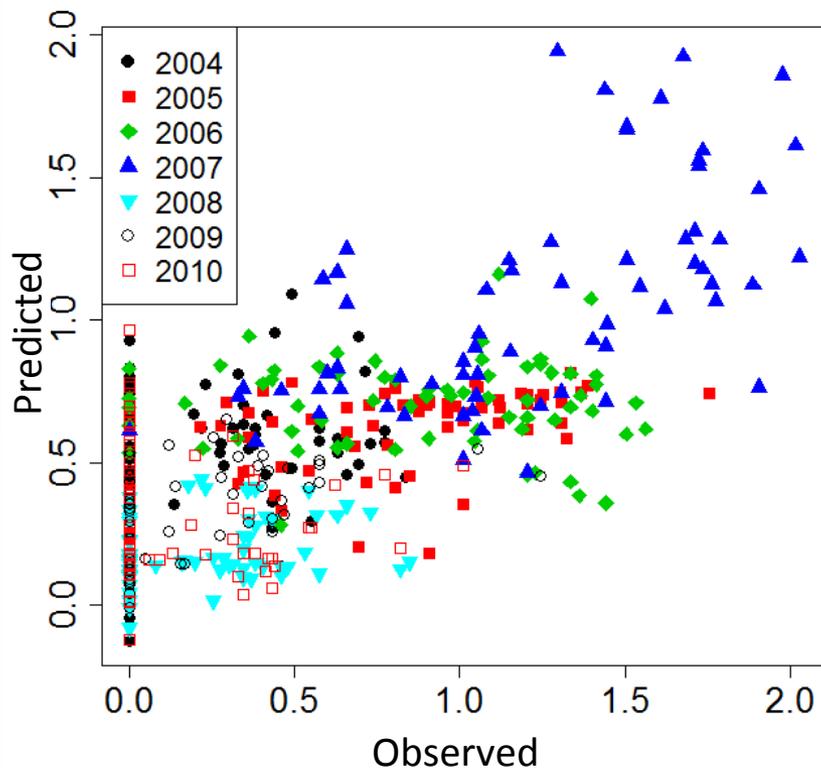
# Model Fit Improves as Environmental Data from Later in the Season is Included



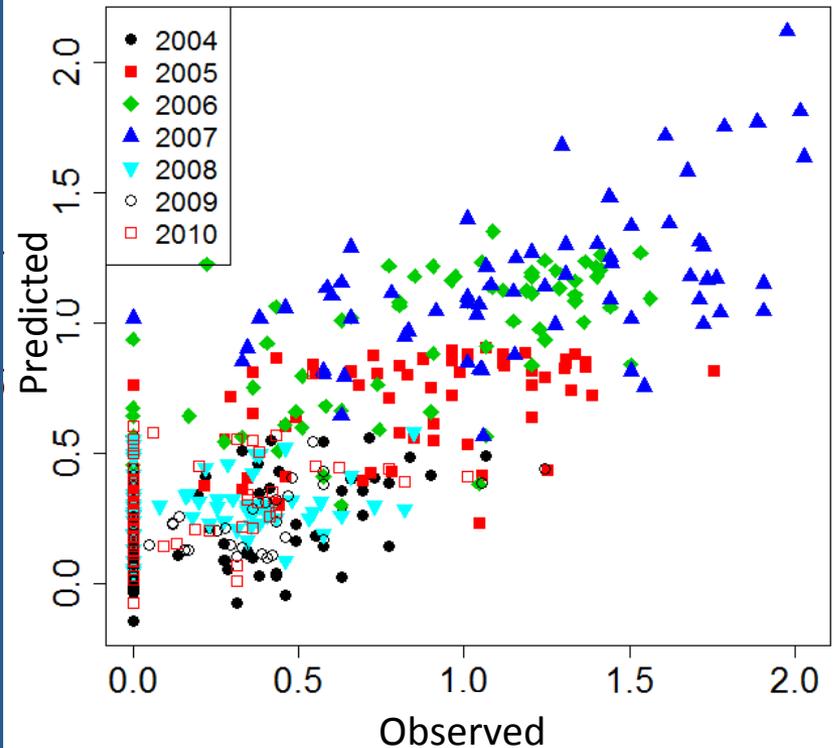
- Greenness and temperature measure onset of spring in early season models
- Temperature and evapotranspiration measured accumulated degree days and moisture in the late-season models

# Model Fit Improves as Environmental Data from Later in the Season is Included

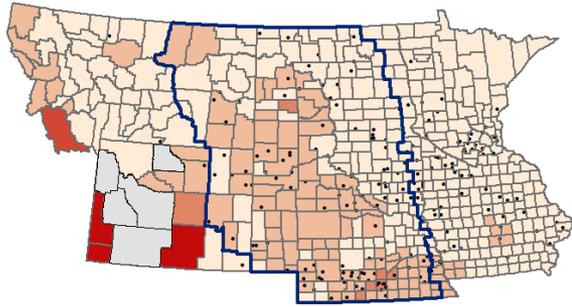
Model fit using environmental data through May 15



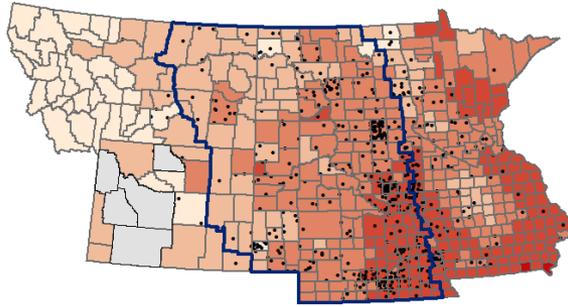
Model fit using environmental data through July 18



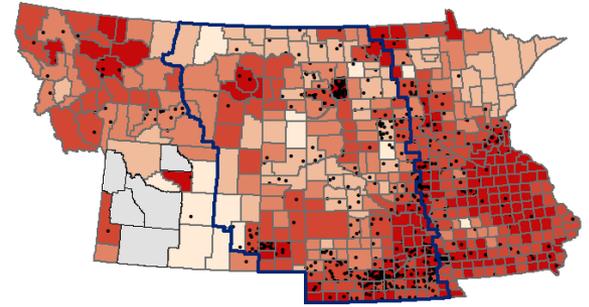
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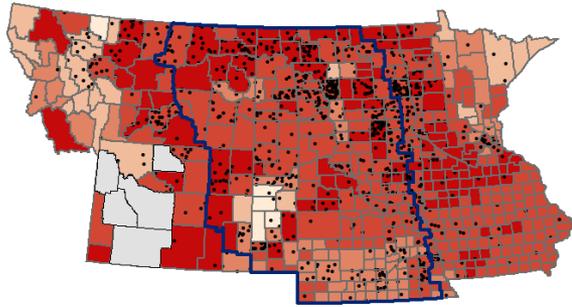
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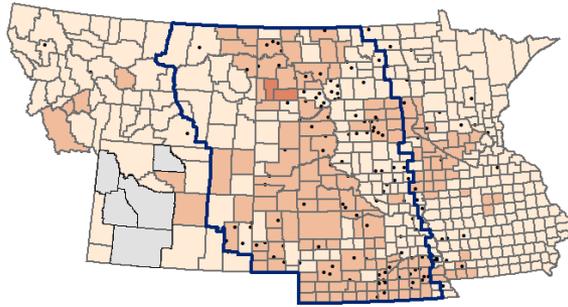
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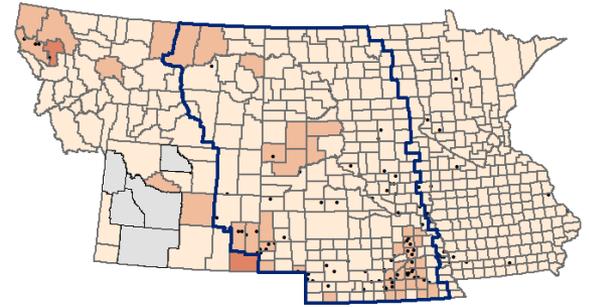
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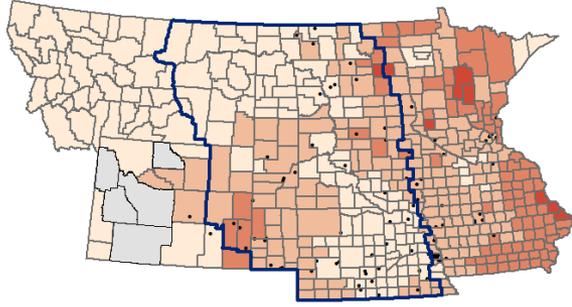
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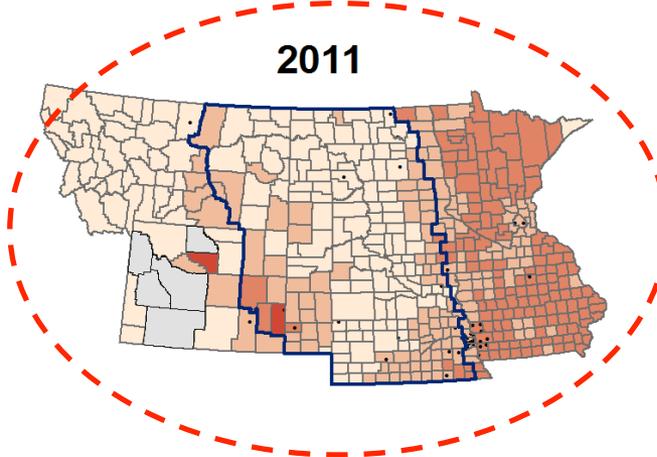
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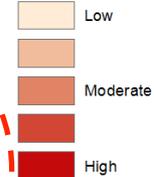
2010



2011



WNV Risk Index



Missing Data

WNV Cases



# 2012 Predictions

August 2010

Whatever happened to We x

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Monday, August 16, 2010

## Whatever happened to West Nile virus?

David Brooks

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As mid-August arrives, it's time once again to participate in the interesting nationwide medical experiment called "Whither West Nile virus?"

You remember WNV, if I may use the acronym. A virus carried by various mosquitoes, it can, when transmitted to birds or animals through a bite, cause flu-like symptoms, which in rare cases can cause inflammation of the brain and be fatal.

WNV showed up here in 2001 as part of its spread from New York City, where it cropped up in 1999 after arriving in the guts of a mosquito carried by international shipping or air travel.

New Hampshire medical officials, and us media folks, went into overdrive. People picked up dead birds and took them to Concord for testing in the state lab, because the virus proved particularly dangerous to the avian population.

When the first New Hampshire human cases were diagnosed in 2003 we really freaked out. It seemed like a new peril was descending on our summers; WNV became a big part of my reporting beat.

And then pffft! – it pretty much went away.

Starting in 2004, cases in birds, animals and clusters or "pools" of mosquitoes declined



Staff Photo by Grant Morris

Stacy Miller, of Dragon Mosquito Control checks mosquito trap set near the Main Dunstable Ball Fields, Thursday afternoon. Miller takes the captured mosquitoes to the lab where they are tested for various diseases including West Nile Virus and EEE. The trap on the ground is set to try to capture pregnant mosquitoes when they lay their eggs, the hanging trap is for hungry mosquitoes. The blue container slowly releases the by-product of dry ice, carbon dioxide, which mosquitoes are attracted to.

Enlarge Purchase Photo

September 2012

CDC: Nation on track for d x

seattletimes.com/html/health/2019133704\_apusmedwestnilevi

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Originally published Wednesday, September 12, 2012 at 11:00 AM

## CDC: Nation on track for deadliest West Nile year

Health officials say they're convinced this will be the worst year for West Nile virus deaths and severe illnesses since the disease hit America's shores in 1999.

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By MIKE STOBBE AP Medical Writer

NEW YORK —

Health officials say they're convinced this will be the worst year for West Nile virus deaths and severe illnesses since the disease hit America's shores in 1999.

So far, 1,405 serious illnesses and 118 deaths from West Nile have been reported across the country. The bulk are in Texas but Louisiana, Mississippi, Oklahoma, South Dakota and Michigan have also seen substantial numbers.

The worst year for the mosquito-borne disease was 2002, which saw nearly 2,000 cases across

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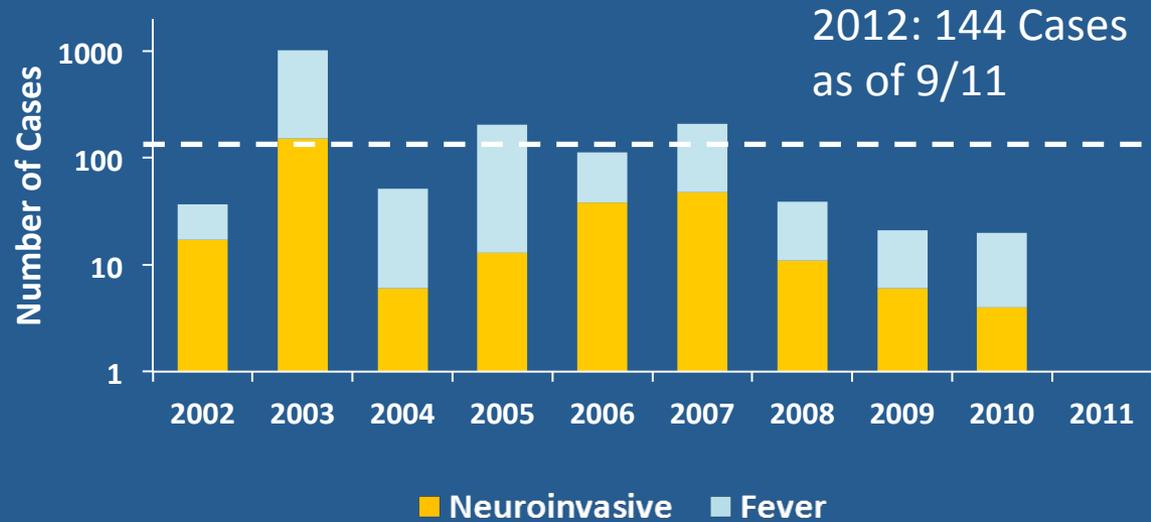
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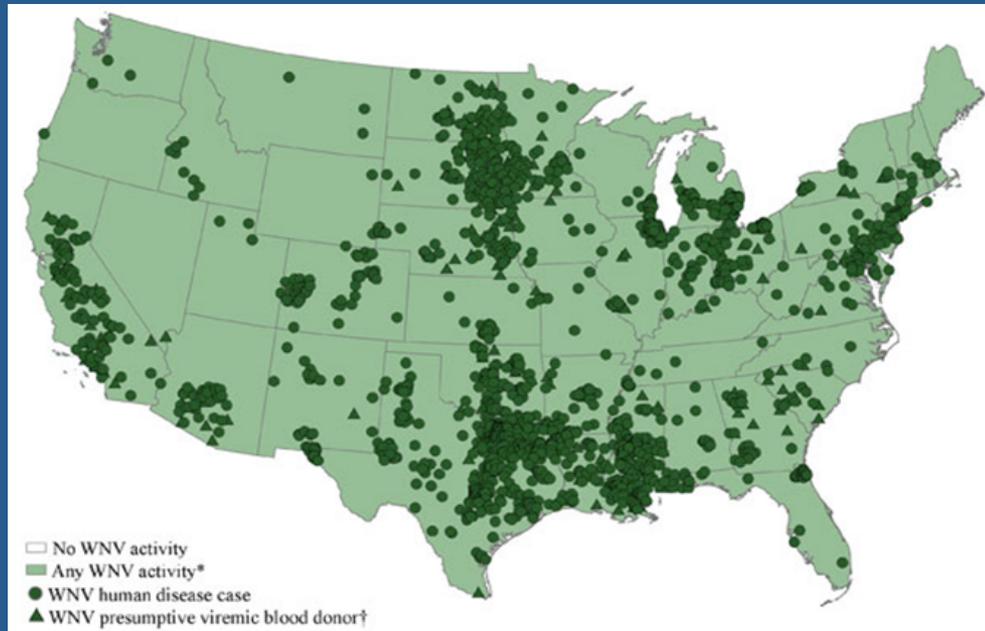
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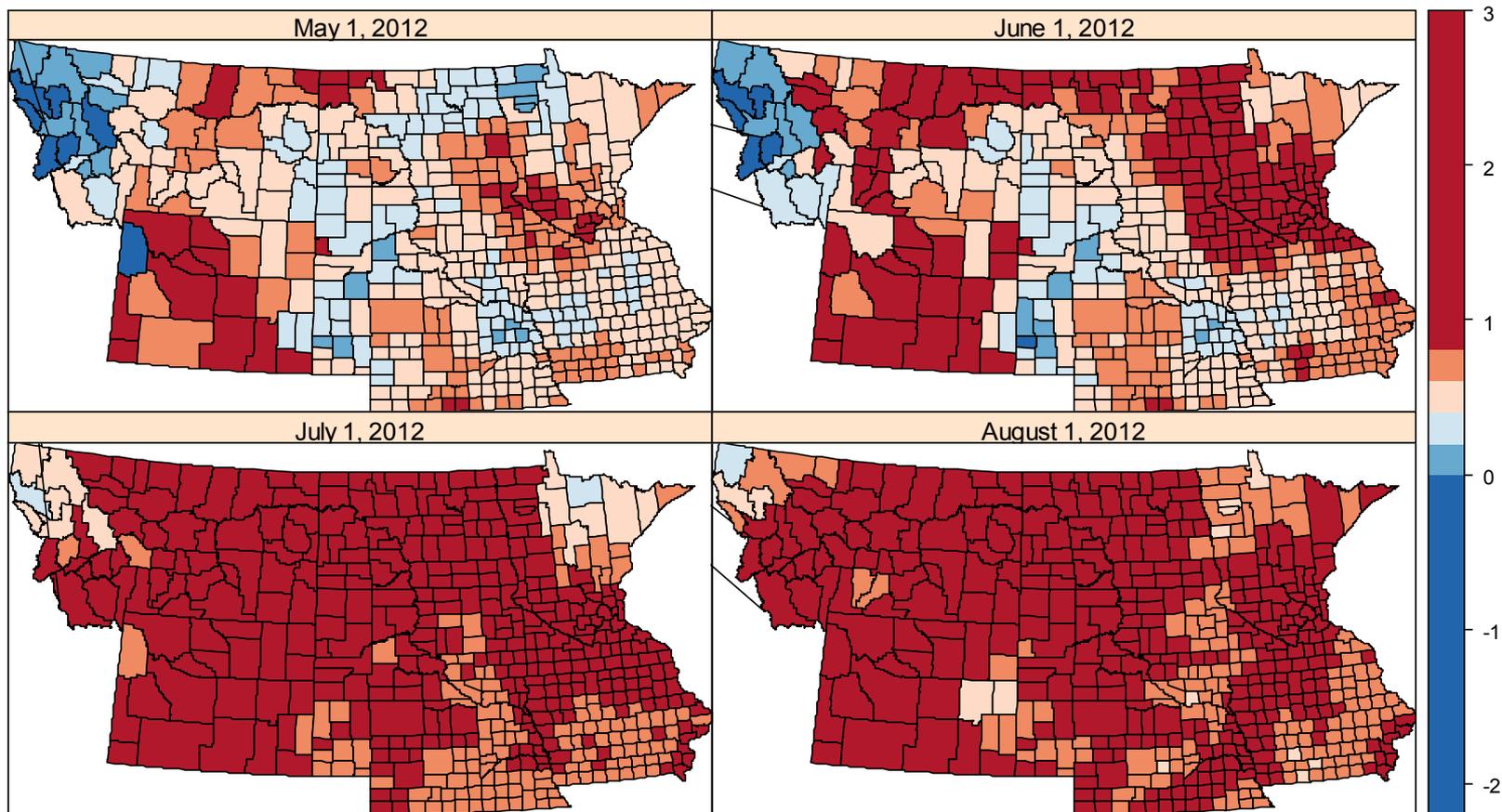
# South Dakota



West Nile virus (WNV) activity reported to ArboNET, by state, United States, 2012 (as of September 11, 2012)



# WNV Relative Risk Forecasts for the 2012 Transmission Season



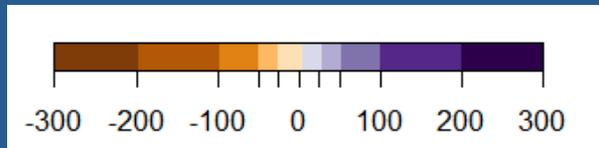
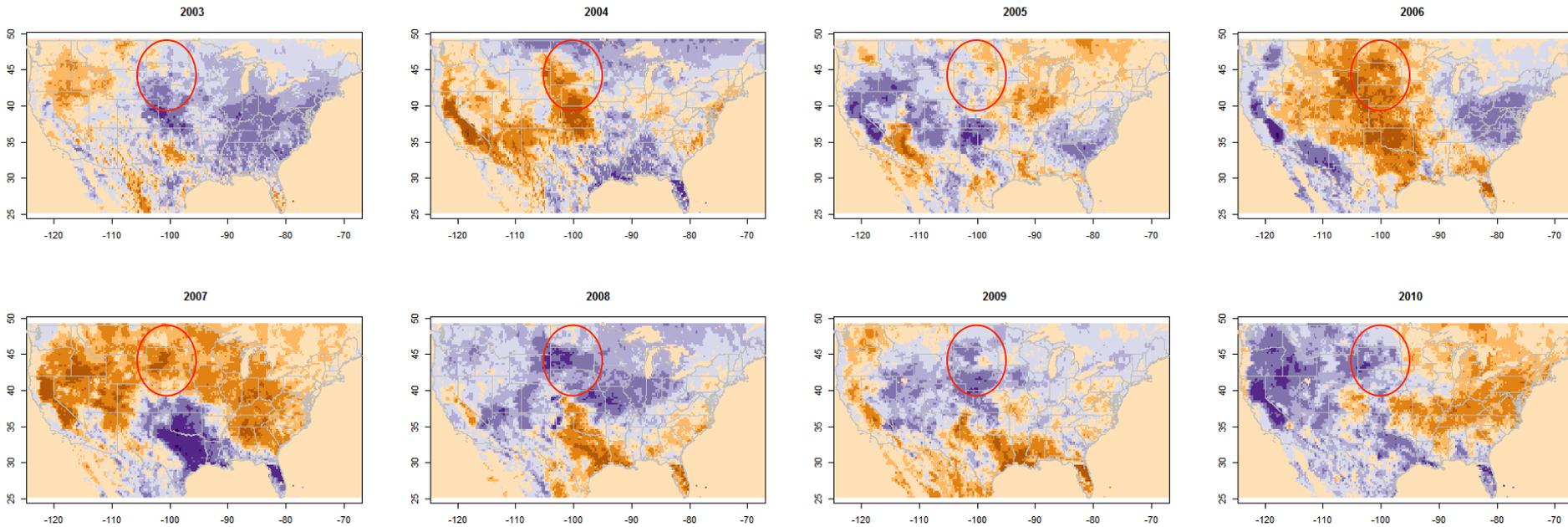
Higher than Average  
Lower than Average

# Summary

- Strong temperature effects are predictive of outbreaks at a regional level
  - *Culex tarsalis* development rates, survival, biting rates
  - WNV extrinsic incubation period
- Surface moisture and breeding habitats may help to delineate the spatial locations of outbreaks
  - Non-linear relationships with moisture
  - Relationships not always consistent from year to year
- Host (bird) community composition and immunity status is also important
- Chuang, T., and M. C. Wimberly (*In Press*) Remote Sensing of Climatic Anomalies and West Nile Virus Incidence in the Northern Great Plains of the United States. *PLoS One*.

# AMSR-E Air Temperature Anomalies

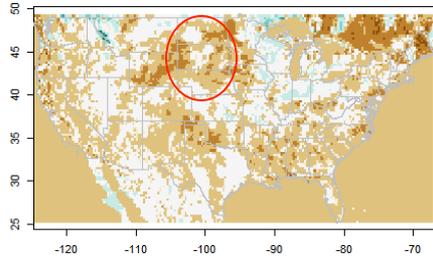
## Accumulated Degree Days (Through July 1<sup>st</sup>) Above the 14.3° C Threshold for Virus Development



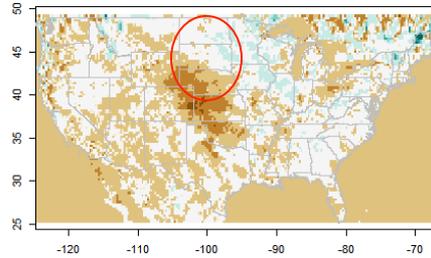
# AMSR-E Soil Moisture Anomalies

## Volumetric Soil Moisture for the first week in July

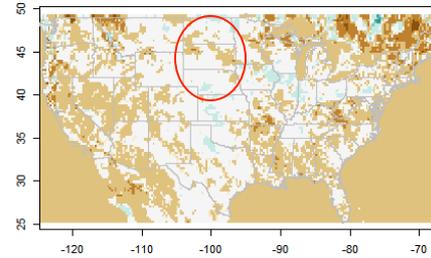
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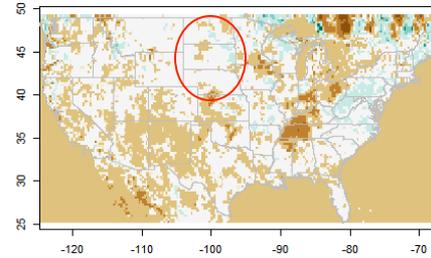
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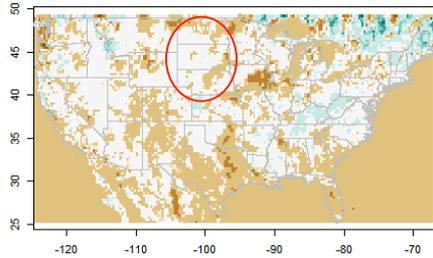
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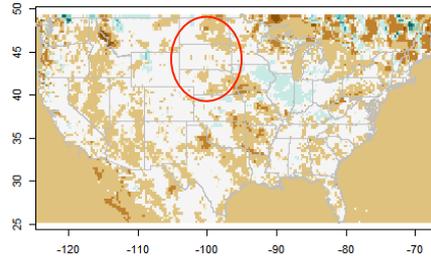
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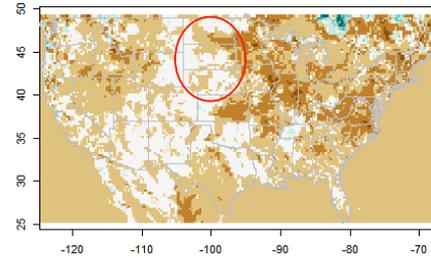
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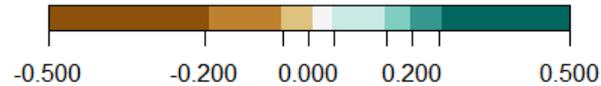
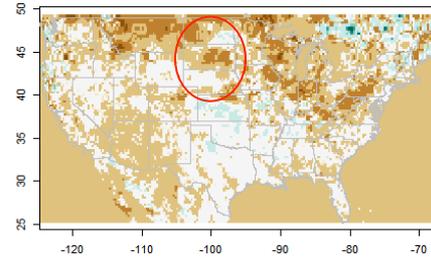
2008



2009



2010



# Completing the Feasibility Study

- 60% of funds expended, on track to spend all funds and complete work by project end date (3/31/2012)
- Follow-up meeting with SD Department of Health to discuss prospects for WNV forecasting
- Update models of WNV human disease with AMSR-E land surface parameters (through 2011) and compare with models based on optical-IR data
- Examine associations between environmental anomalies and WNV outbreaks at a national level

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- Aashis Lamsal, GIScCE
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- Yi Liu, Dept. of Electrical Engineering and Computer Science
- Jim Wilson, Plant Science Department



- USGS Center for EROS

- Gabriel Senay



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- NASA (NNX11AF67G)



<http://globalmonitoring.sdstate.edu/eastweb/>