USING LIDAR TO ASSESS THE ROLES OF CLIMATE AND LAND-COVER DYNAMICS AS DRIVERS OF CHANGES IN BIODIVERSITY

PRINCIPAL INVESTIGATORS

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PHD STUDENTS

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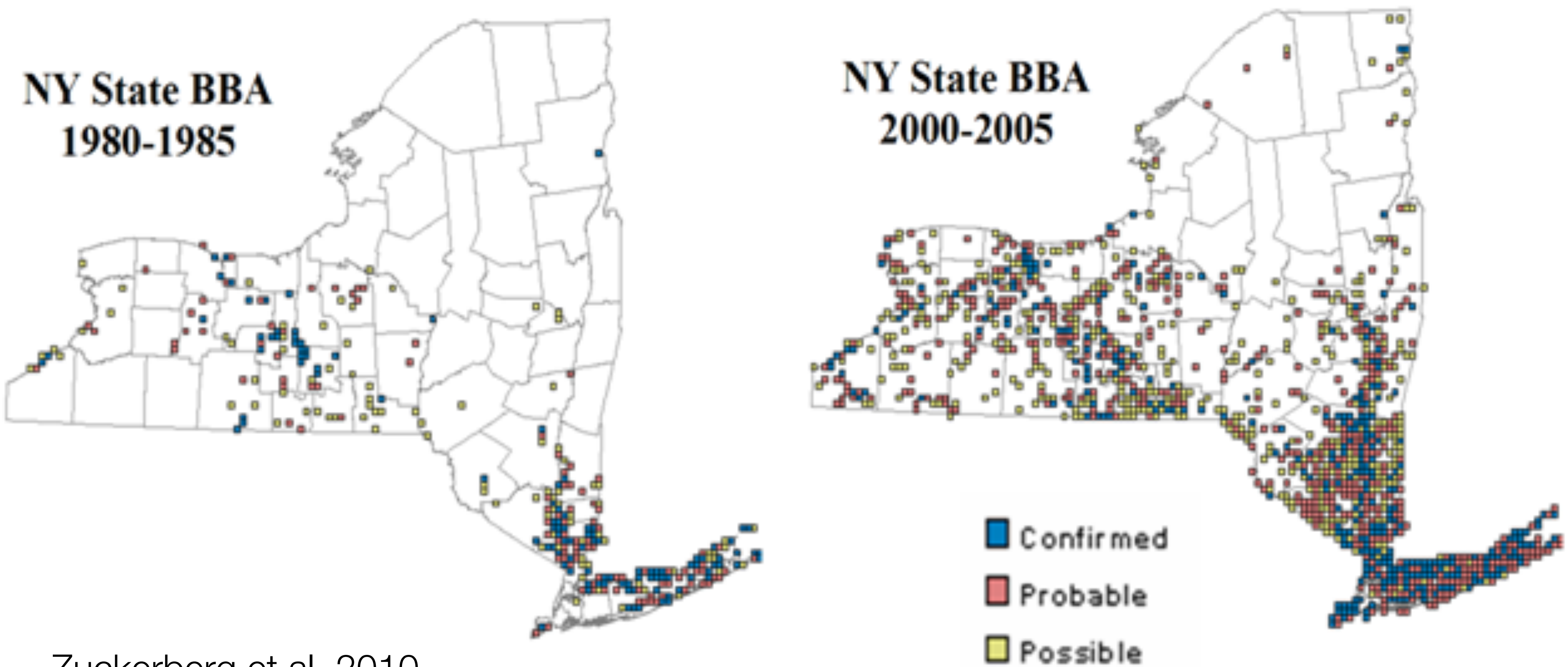
2-Michigan State University
3-University of Wisconsin-Madison
4-NASA Goddard Space Flight Center

Motivation for research



Zuckerberg et al. 2010

Carolina Wren (Thryothorus ludovicianus)

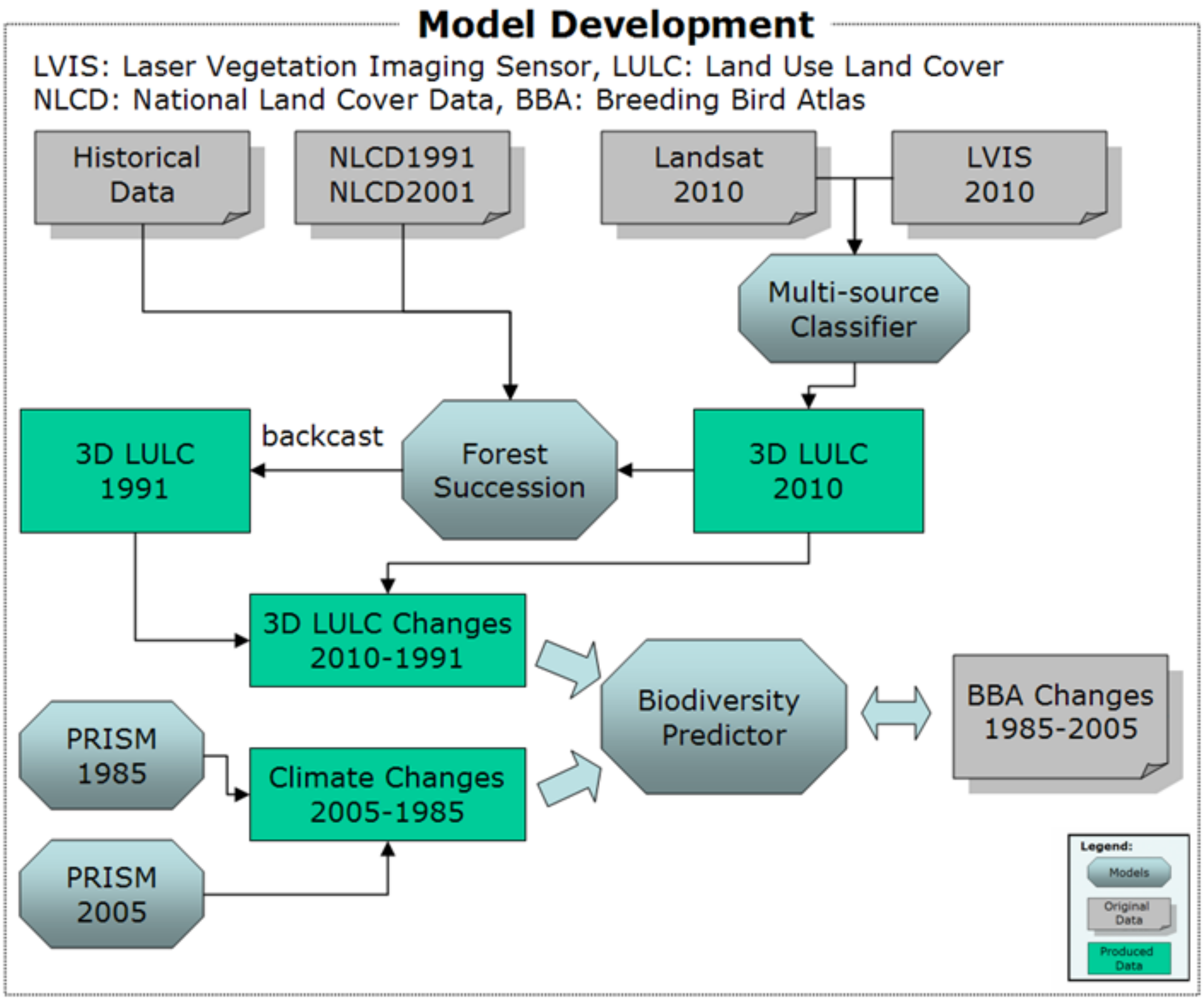
NY State Breeding Bird Atlas (1980-85 & 2000-05)

Of 129 bird species, 57.4% experienced a northward shift in the mean latitude of their distribution

Southern range limits of 43 high-latitude species have shifted northward an average of 11.4 km

Both climate and land use changes may be drivers

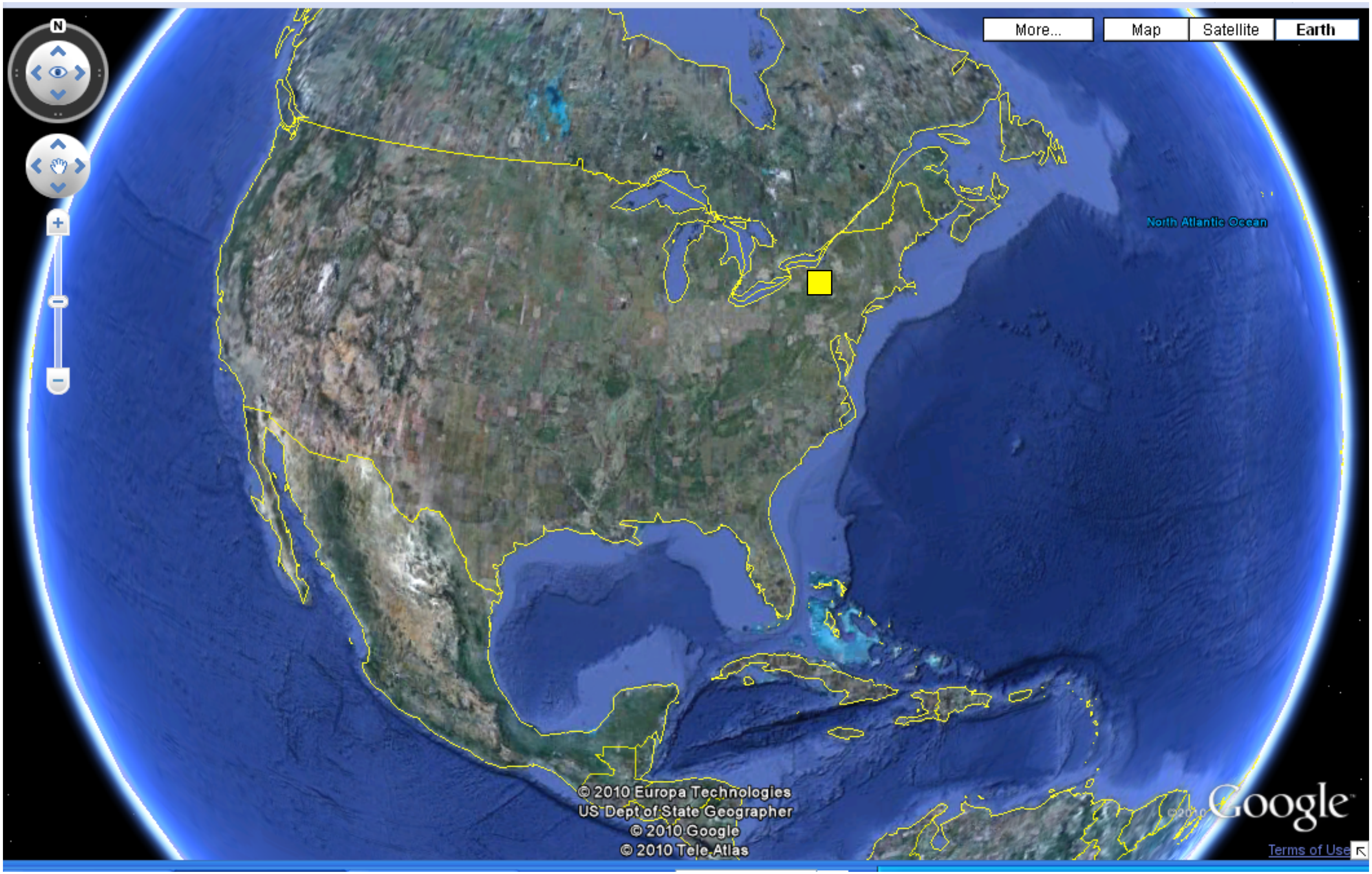
Approach


Model Development
LVIS: Laser Vegetation Imaging Sensor, LULC: Land Use Land Cover
NLCD: National Land Cover Data, BBA: Breeding Bird Atlas
Historical Data
NLCD1991 NLCD2001
Landsat 2010
LVIS 2010
Multi-source Classifier
3D LULC 1991
backcast
Forest Succession
3D LULC 2010
3D LULC Changes 2010-1991
Biodiversity Predictor
BBA Changes 1985-2005
PRISM 1985
Climate Changes 2005-1985
PRISM 2005
Legend:
Models
Original Data
Produced Data

Progress on several fronts...

- LVIS Ground-Truthing
- Land Cover - Land Use Change
- Succession Modeling
- High Resolution Climate Change Analysis
- Biodiversity Modeling

Study Area



More...
Map
Satellite
Earth
North Atlantic Ocean
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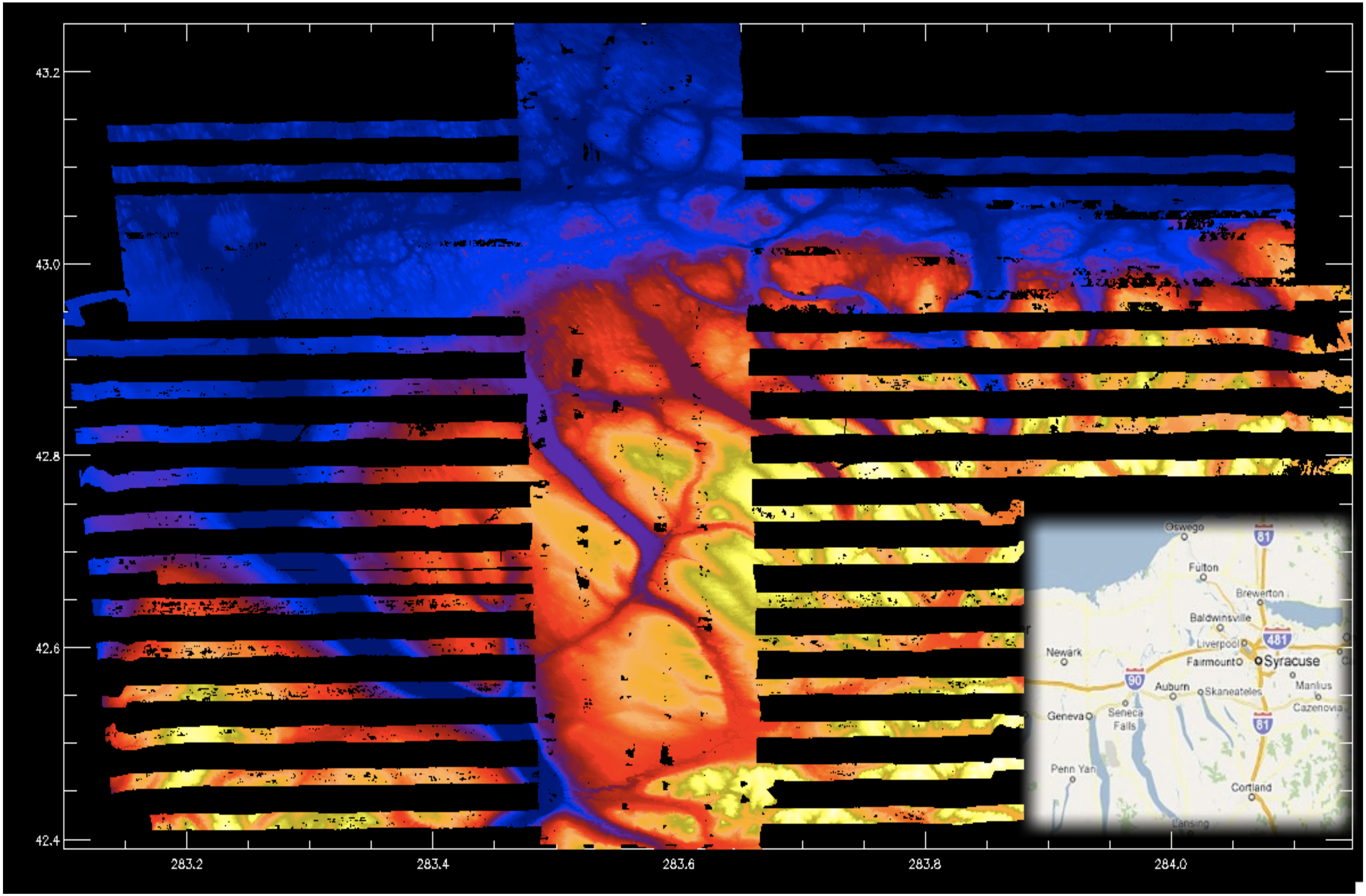
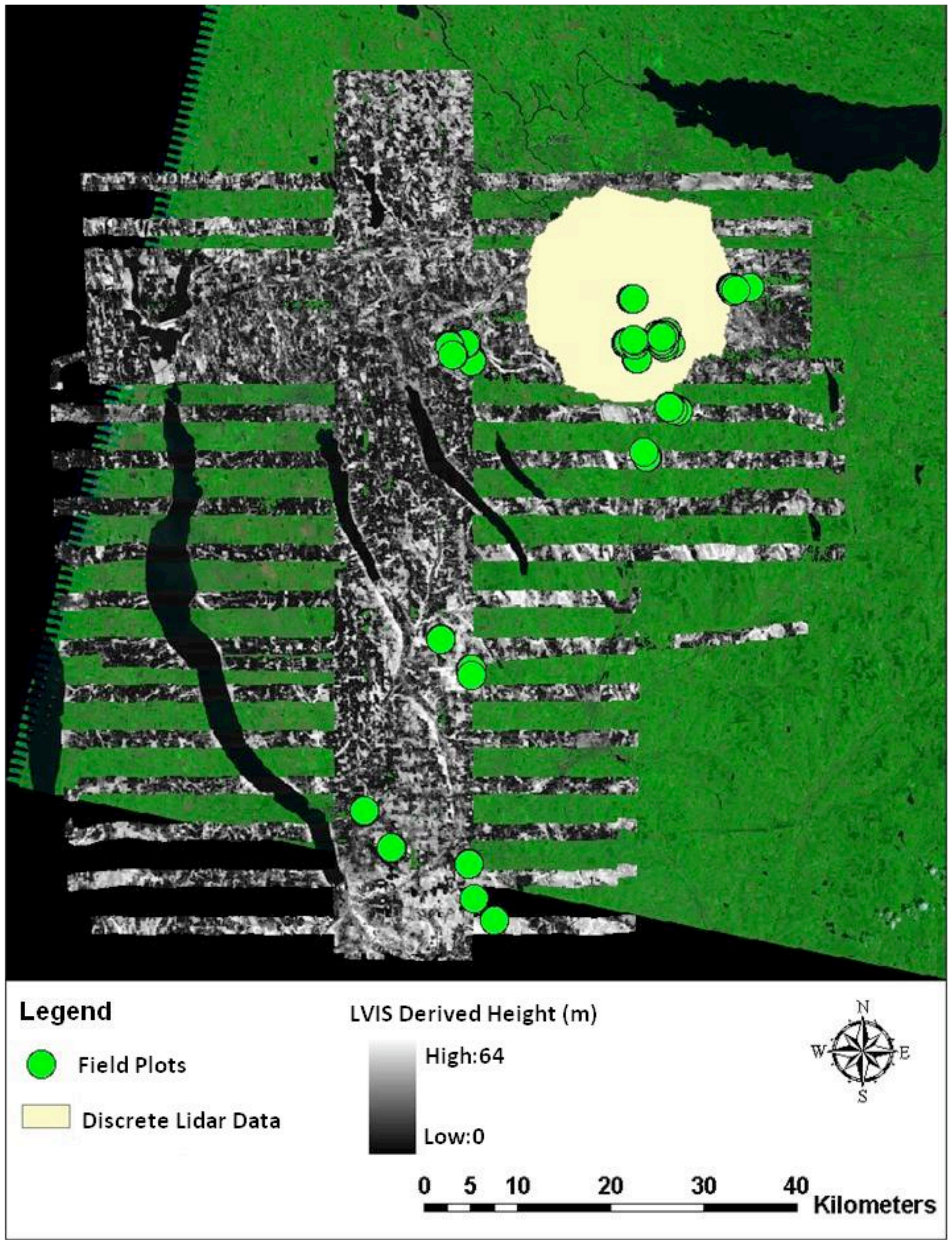
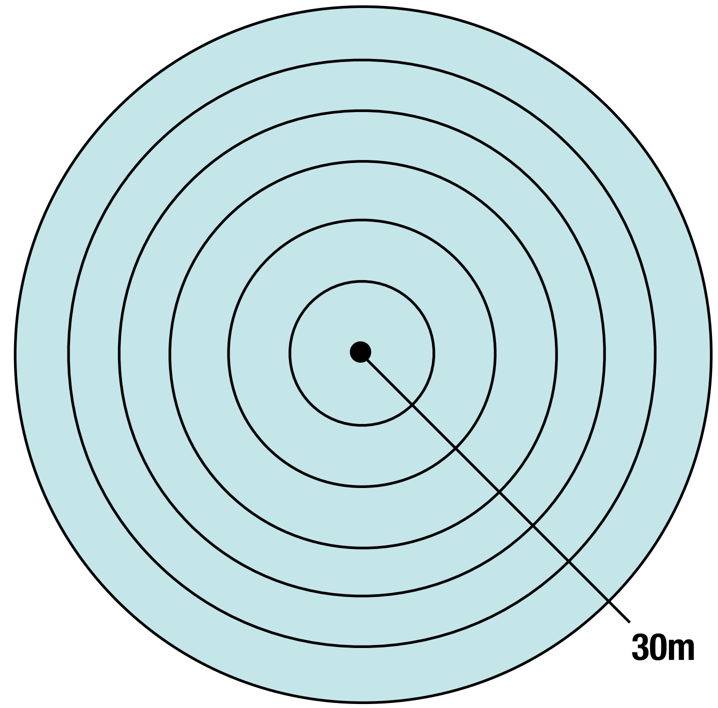
LVIS DATA COLLECTION (July 2009 flight)

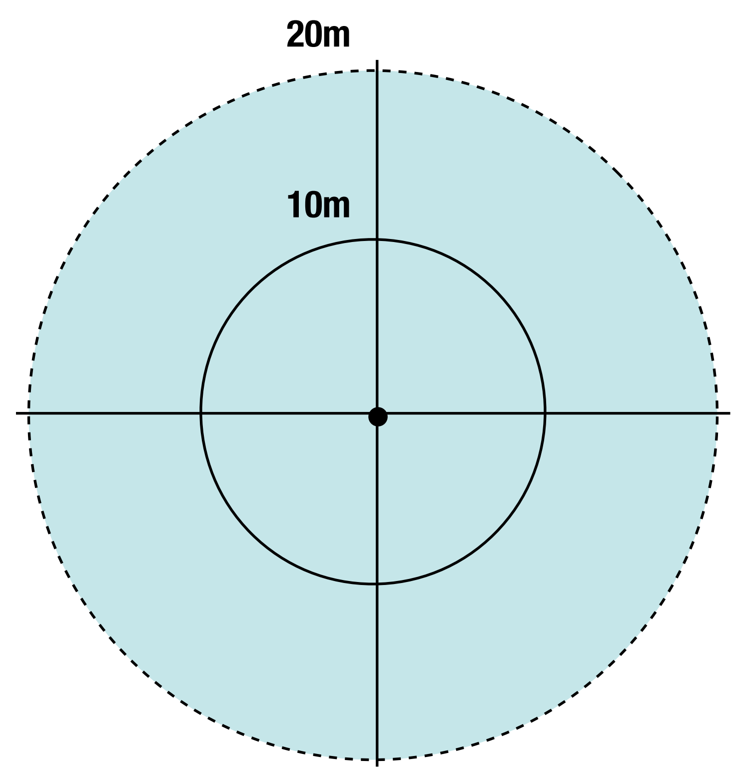


Field Sampling for LVIS Ground-Truthing: May-Sep 2011





VARIABLE RADIUS PLOTS



FINAL PLOT DESIGN

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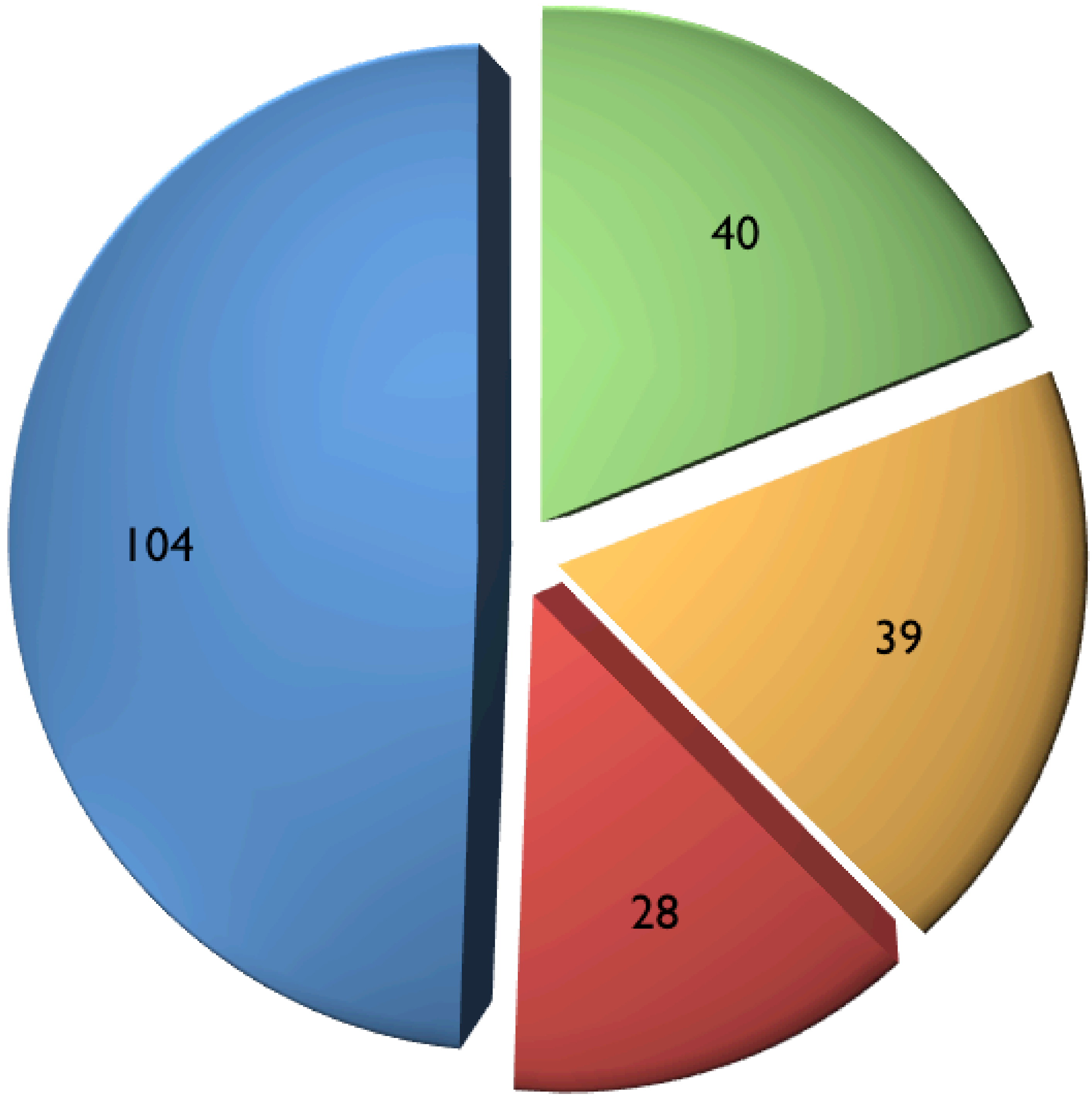

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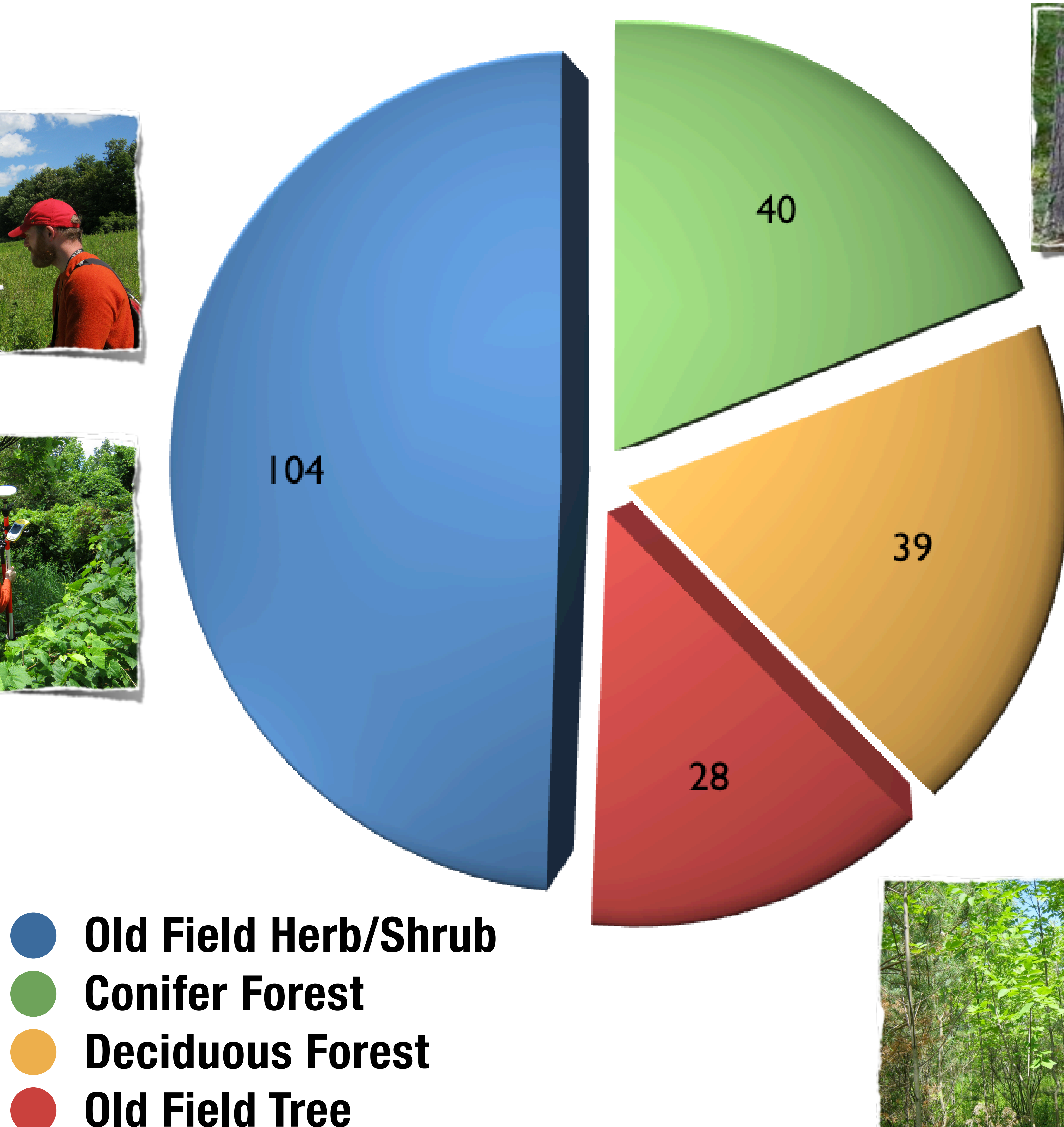
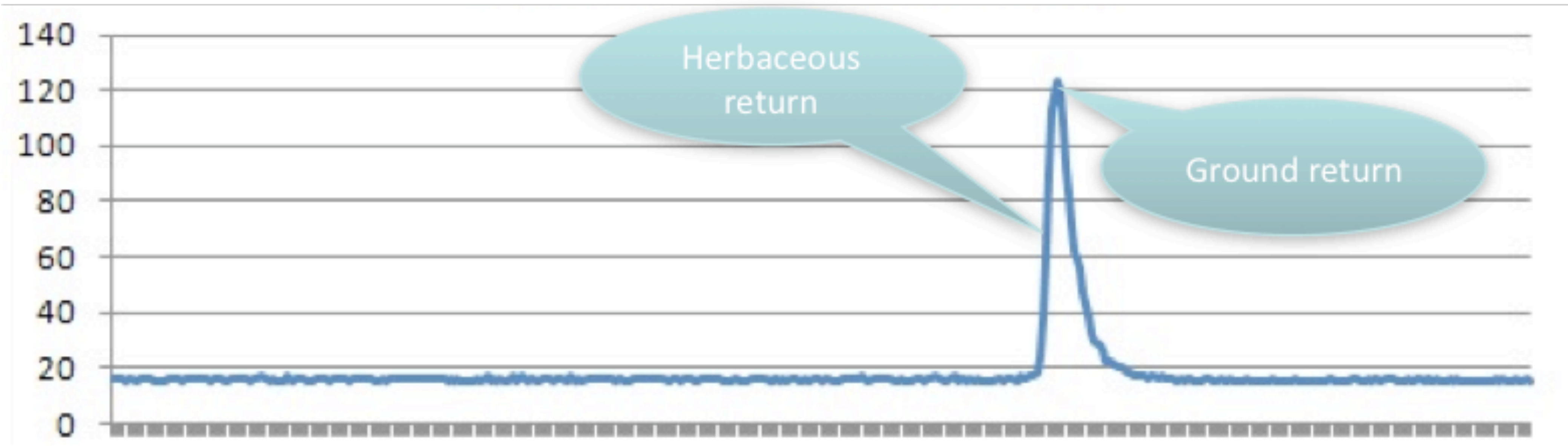


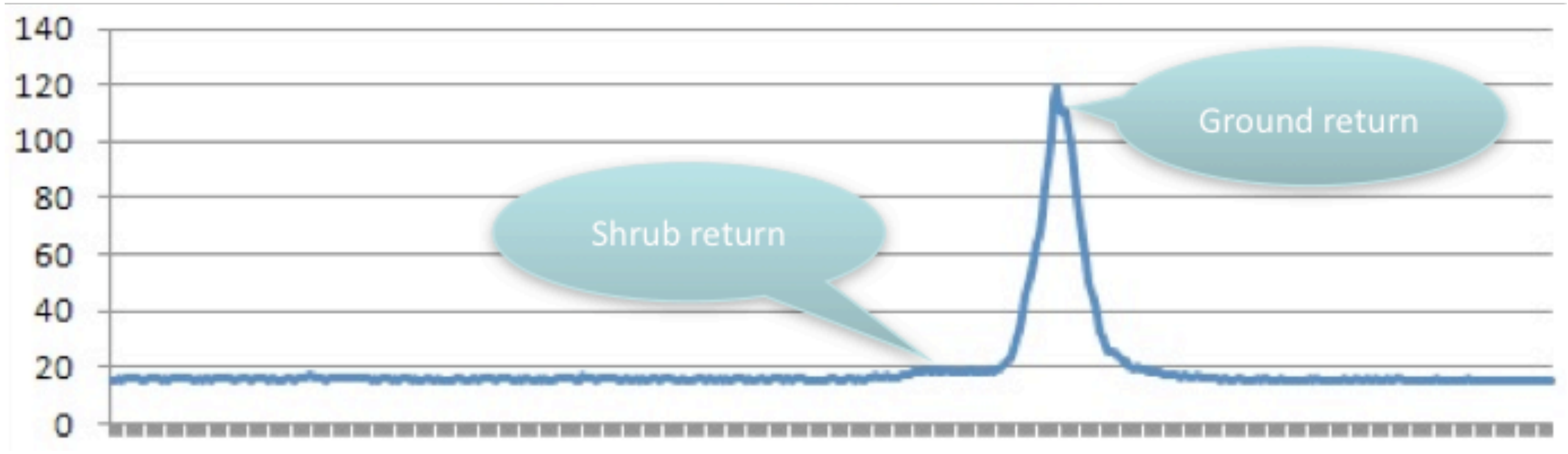
Relating waveforms to vegetation structure

Old-field herbaceous vegetation (<1m)



Relating waveforms to vegetation structure

Old-field shrub vegetation (1-5m)

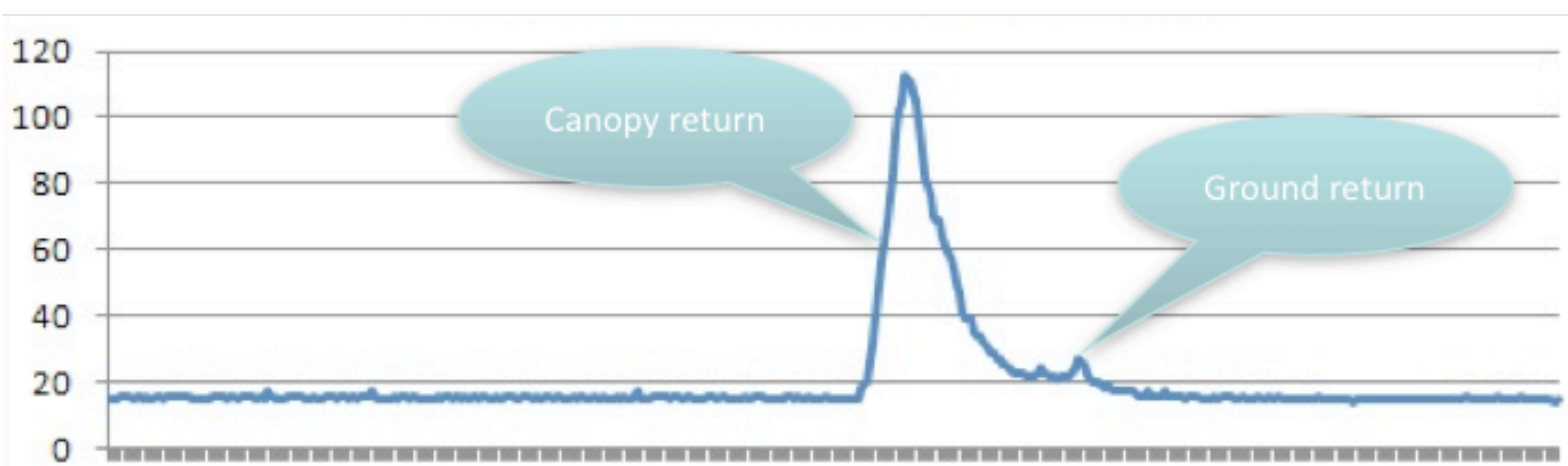


Relating waveforms to vegetation structure

Old-field young forest (5-12m)

Relating waveforms to vegetation structure

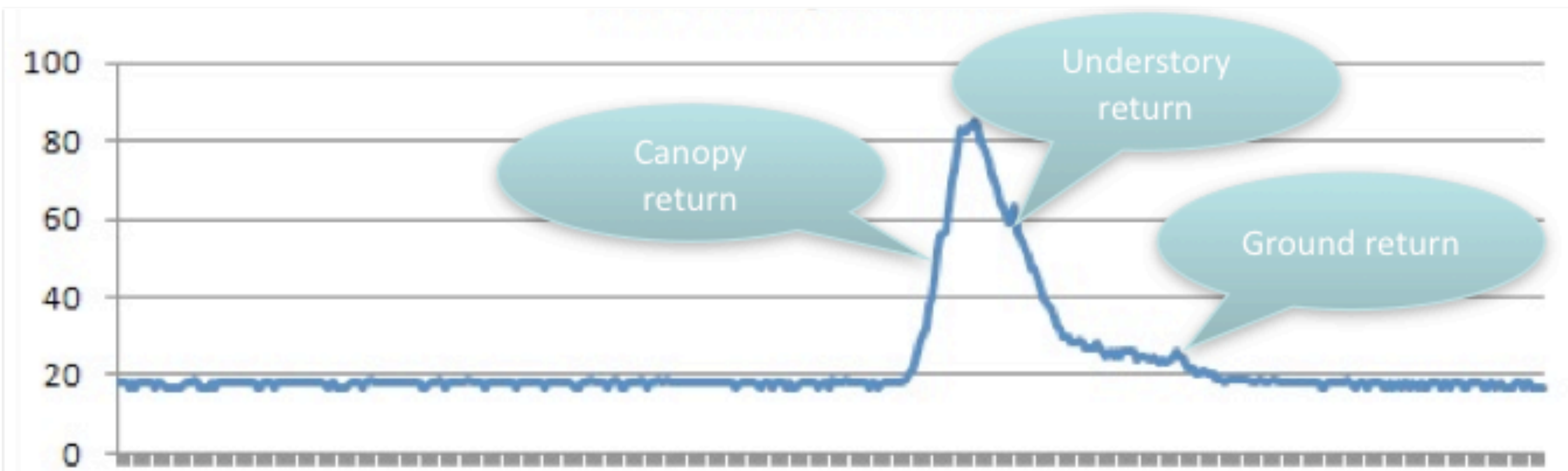
Young growth forest (even aged)



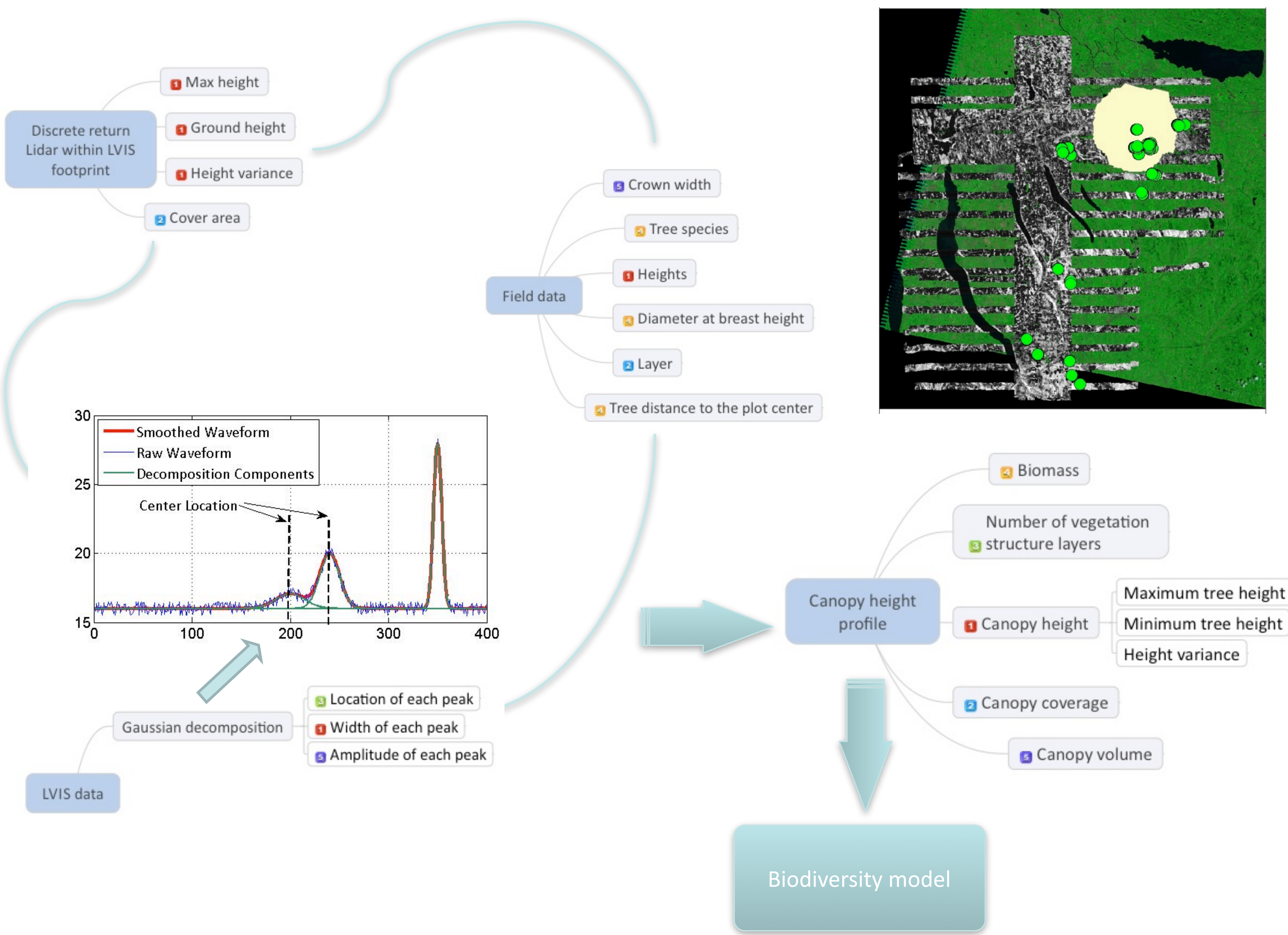
Relating waveforms to vegetation structure

Relating waveforms to vegetation structure

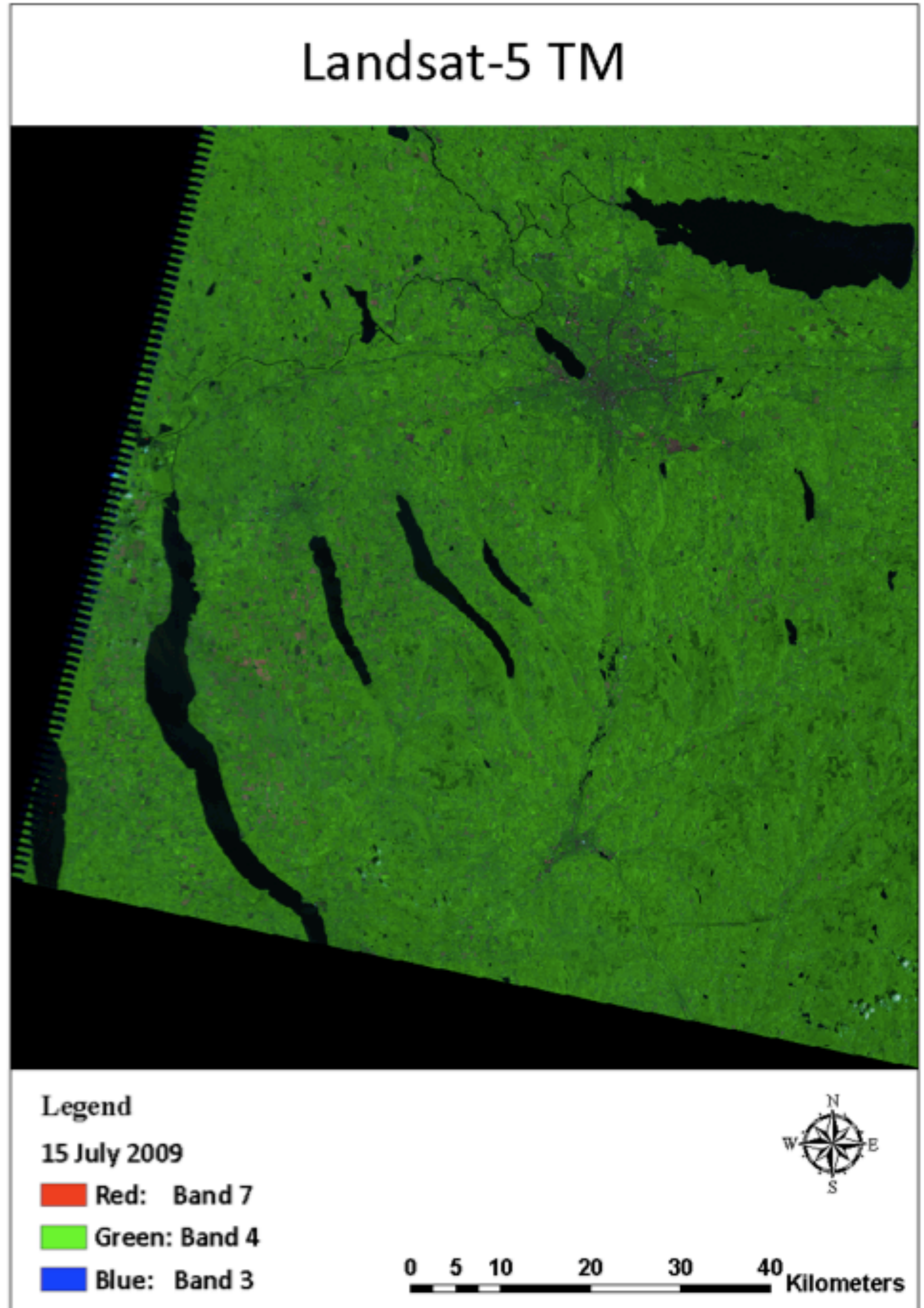
Old-Growth Forest



Data Integration ➜ Vegetation Structure



Land Use-Land Cover Extraction



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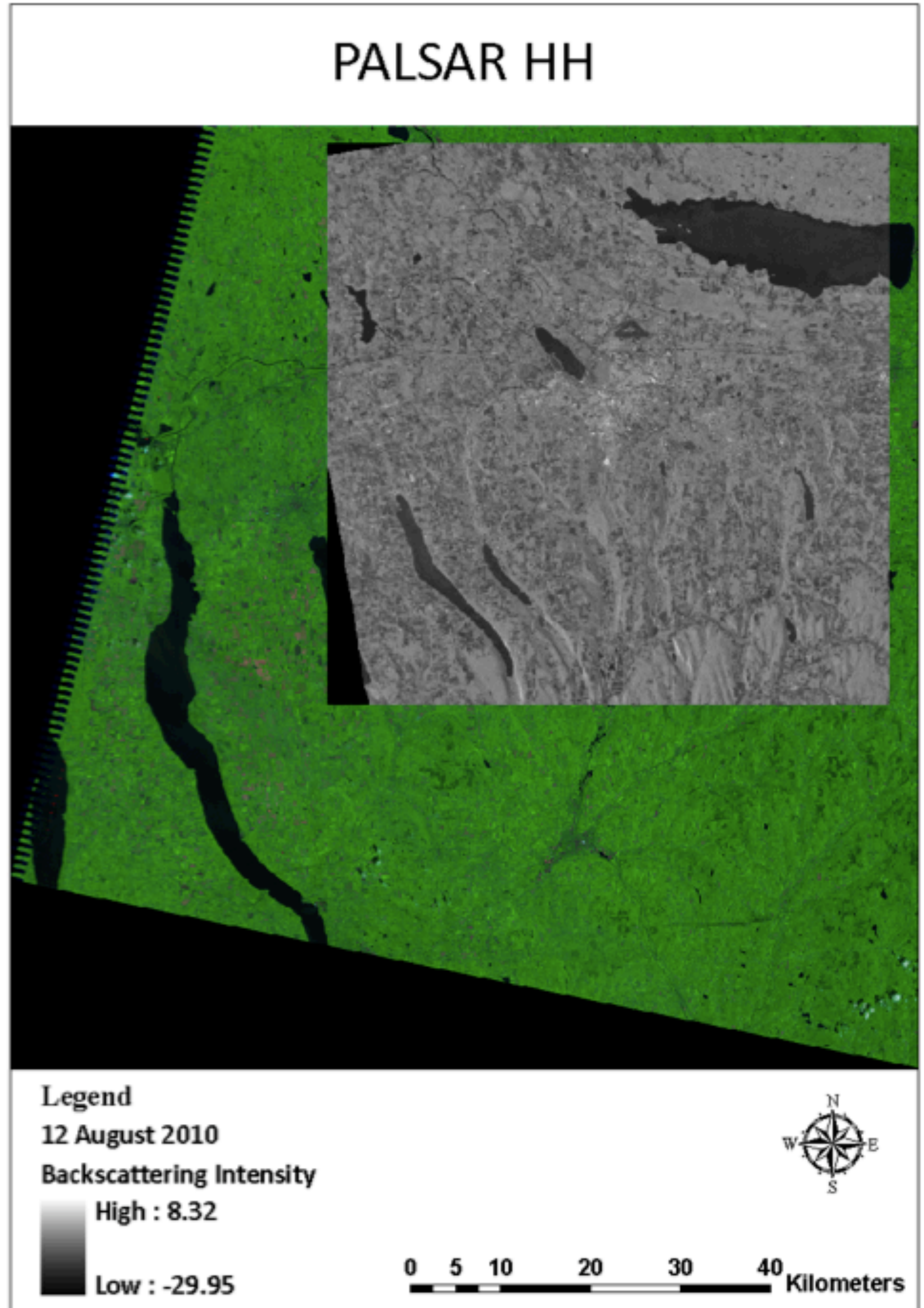

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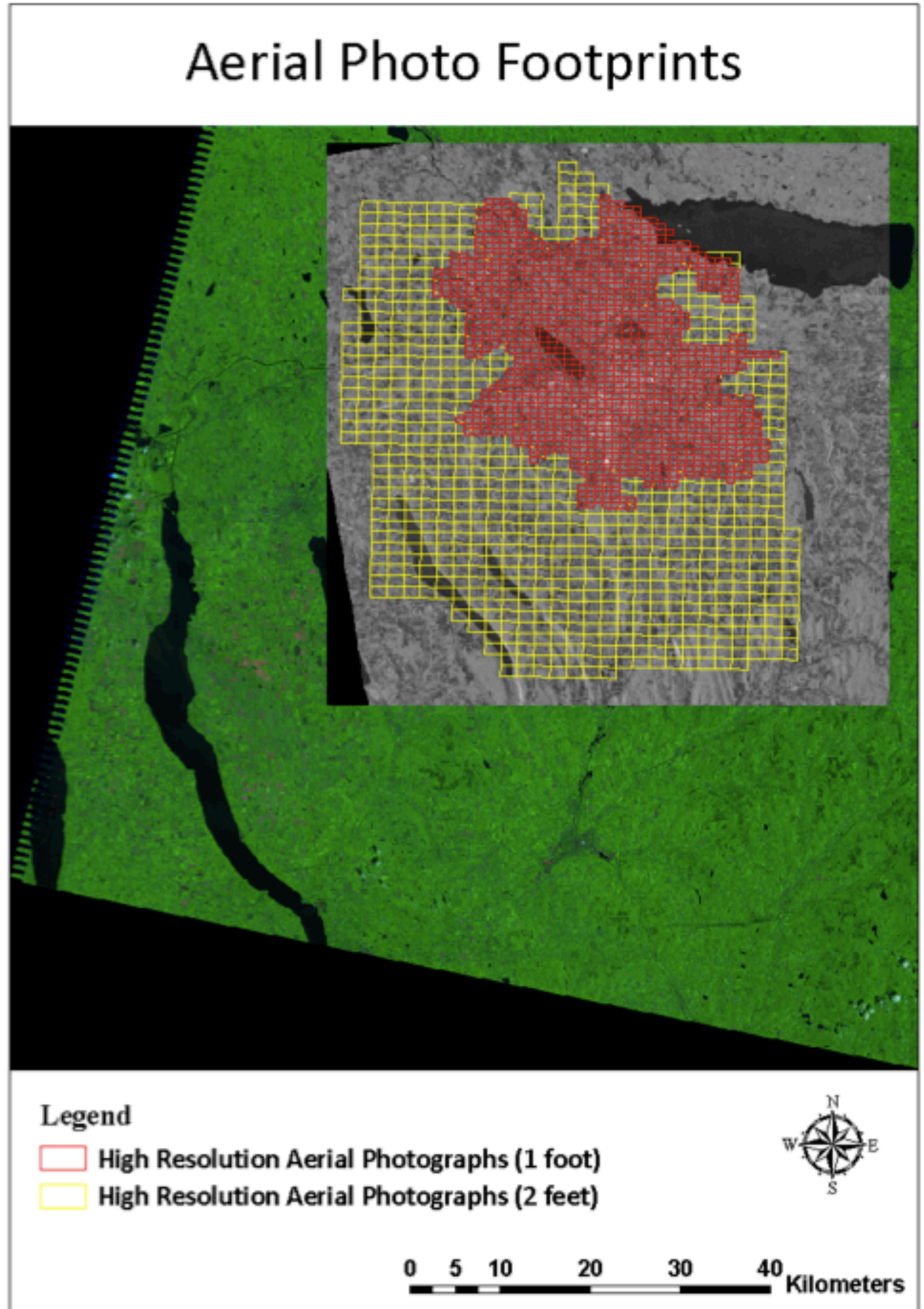

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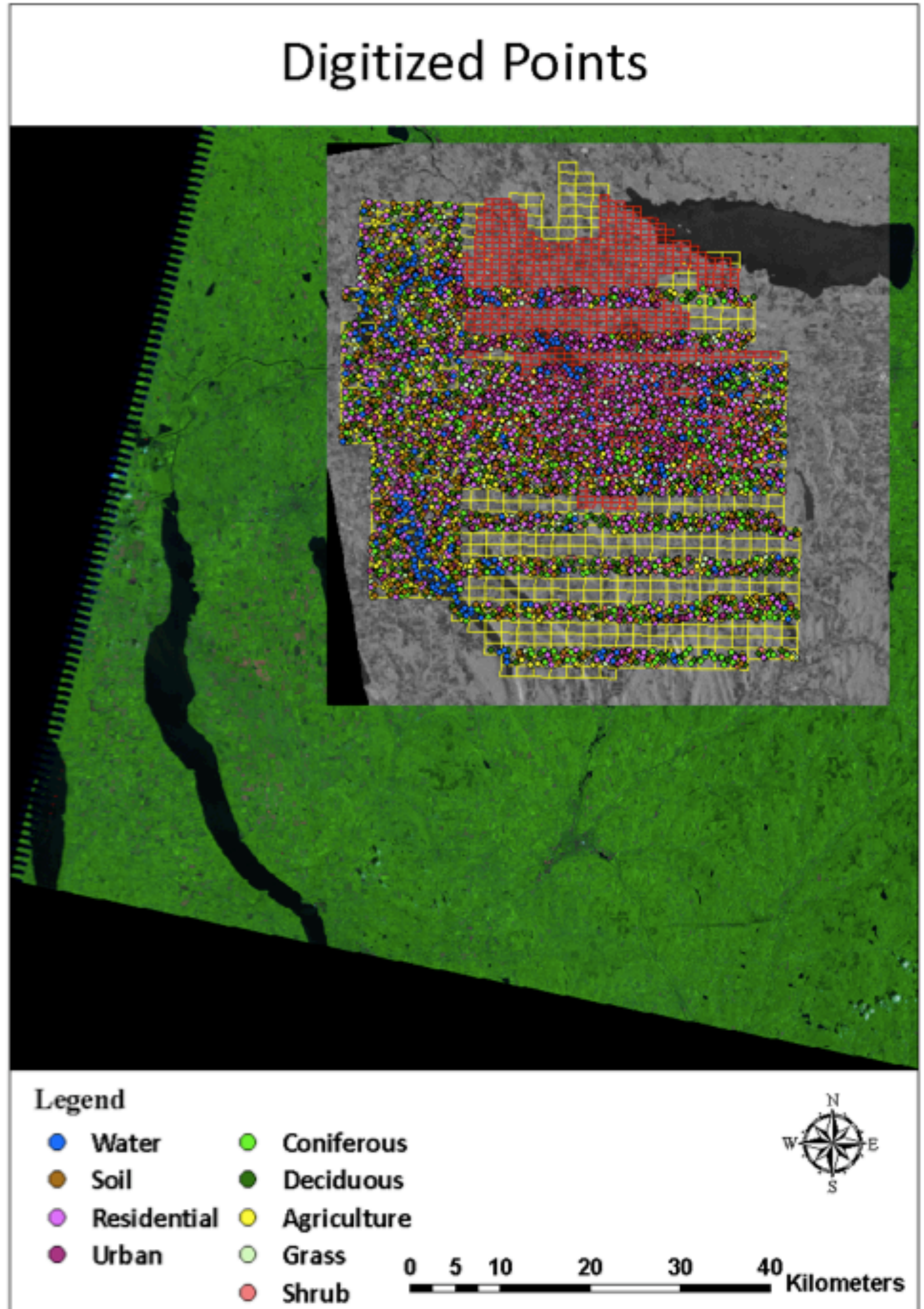
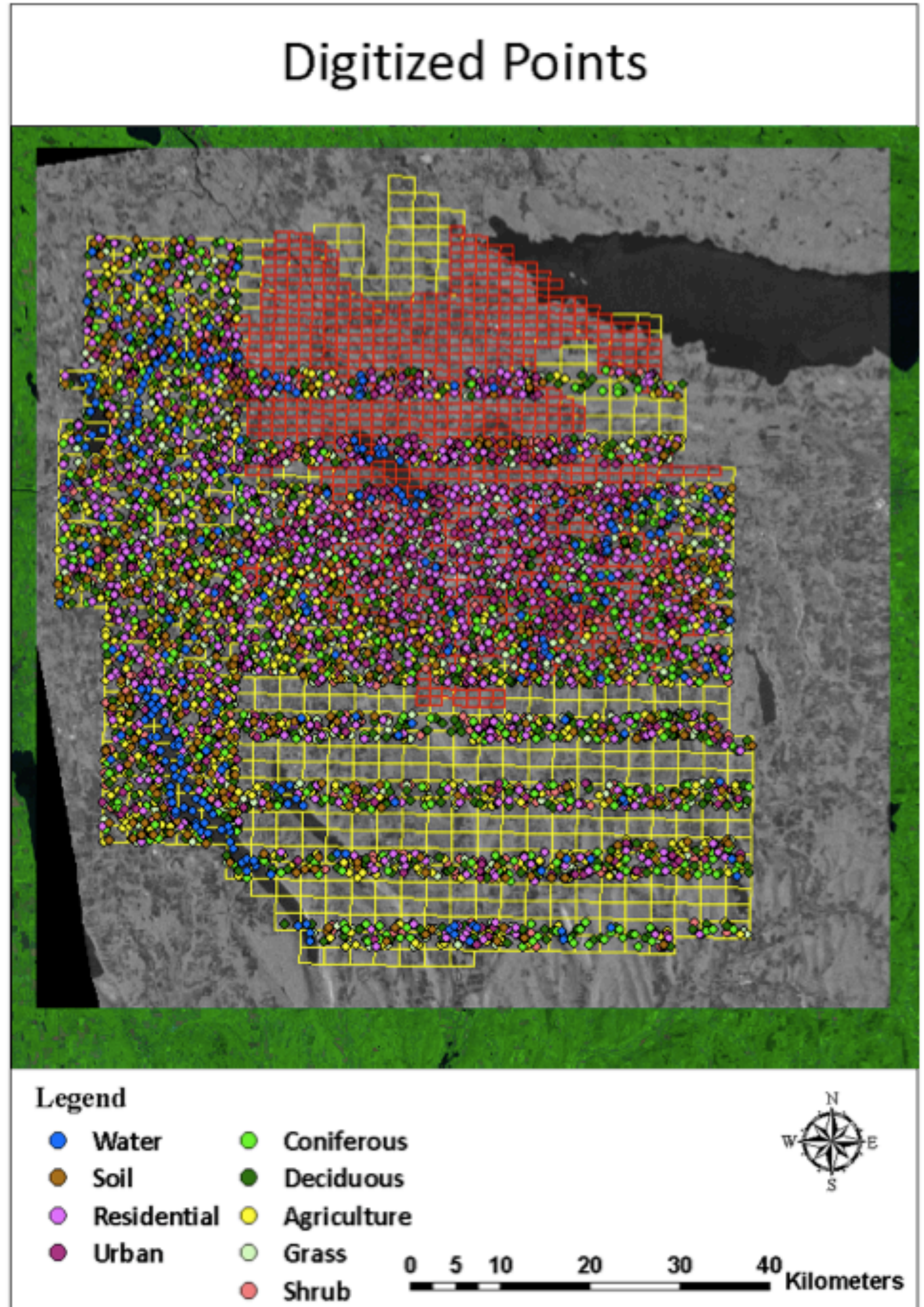
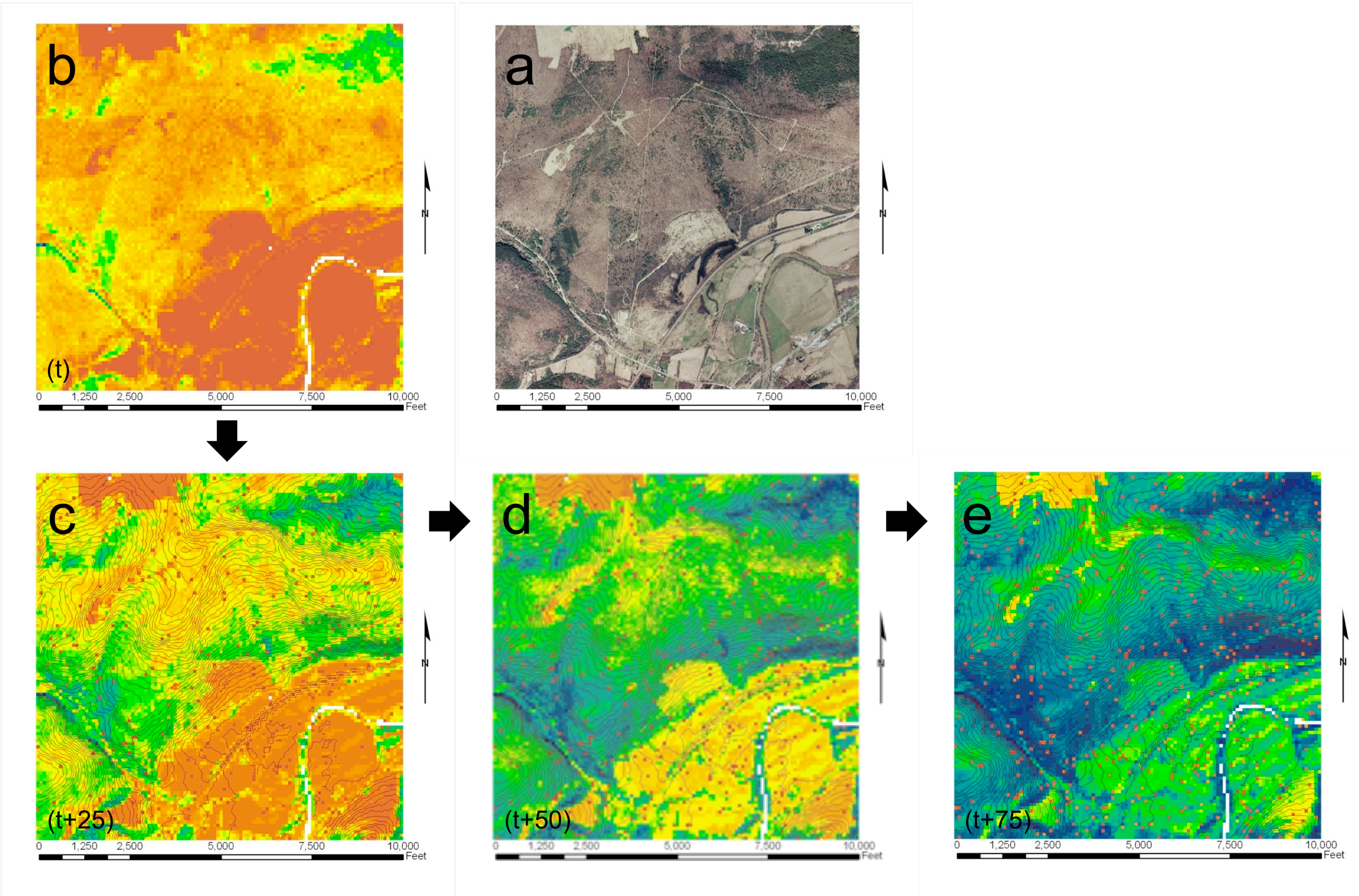


Land Use-Land Cover Extraction

Land cover type	n (points)
Water	279
Soil	402
Residential	731
Urban	525
Coniferous	494
Deciduous	703
Agriculture	793
Grass	730
Shrub	500
Total	5157

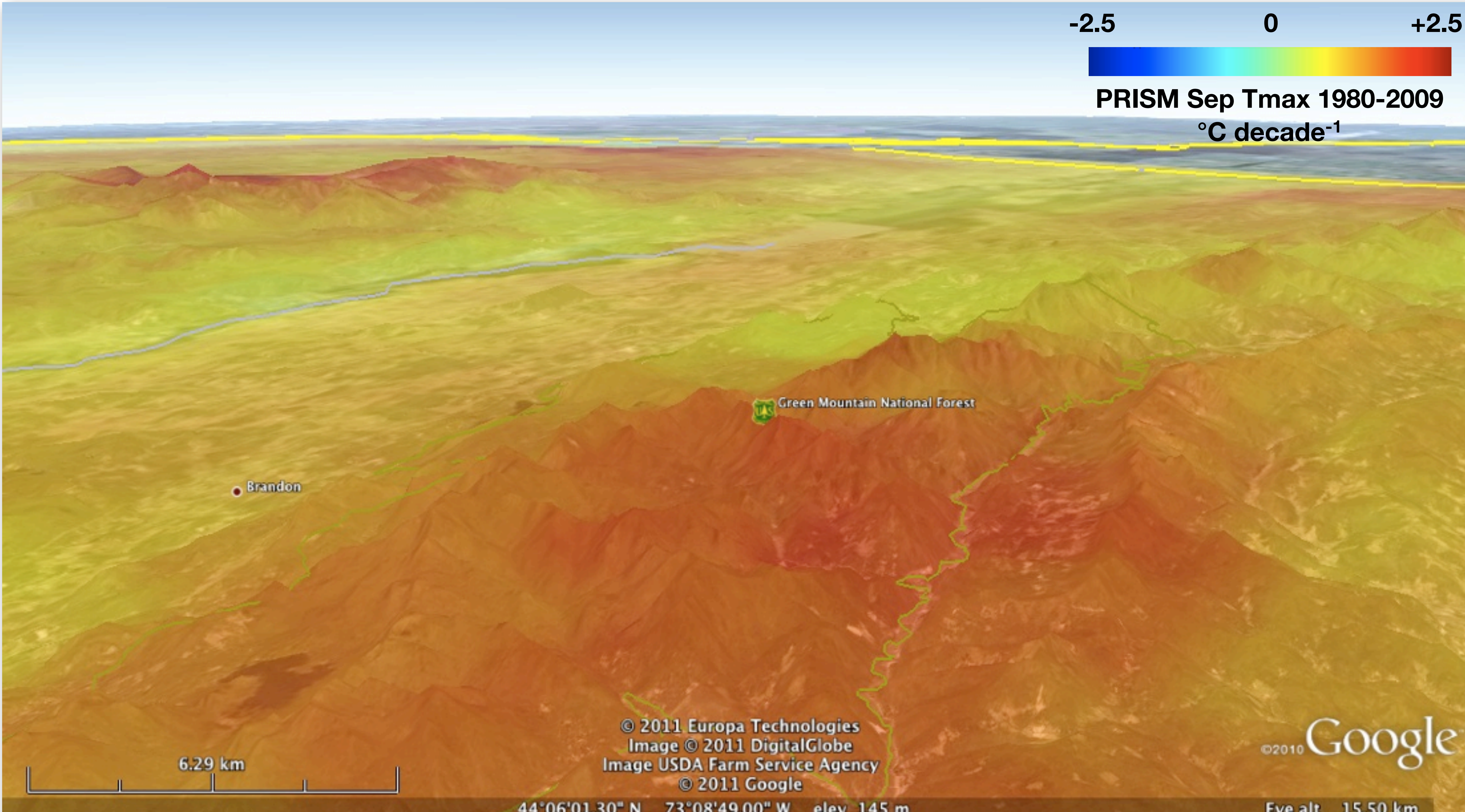


LiDAR-based successional modeling



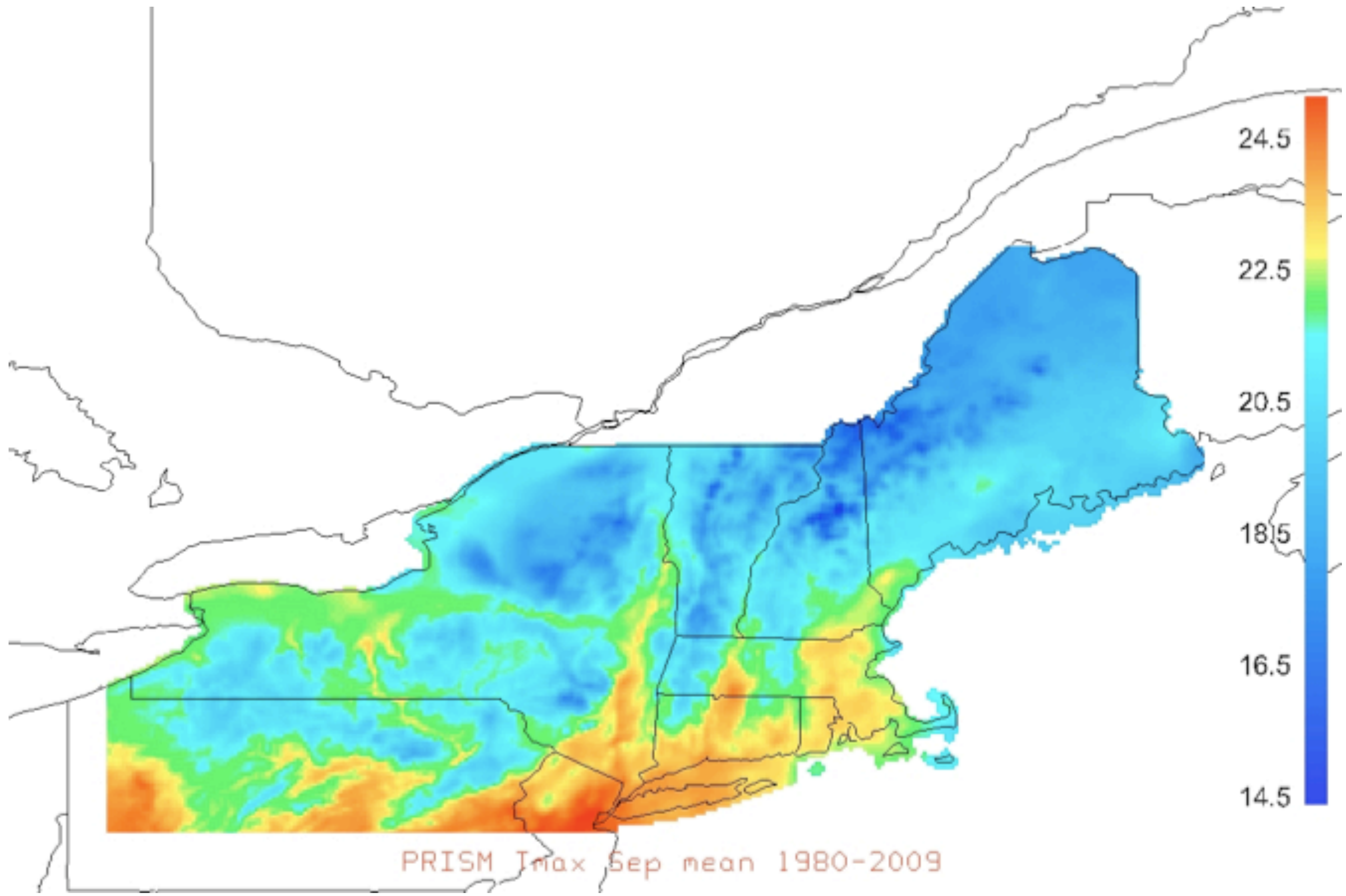
Example of forest regeneration model outputs for a 10,000 ha area of north-central Pennsylvania, based on 5 ± 1 foot window LiDAR data summarized to 20 m raster cells. Panes include: a) orthophotograph of sample landscape, b) initial (t) vegetation height based on LiDAR; c) vegetation height at 25 years (t+25); d) height at 50 years (t+50); and e) height at 75 years (t+50). Vegetation height estimates range from red (low) to green (high), and no data (white). (Wiley et al. 2011)

High-resolution climate change analysis



Generate high-resolution, continuous surfaces of trends in temperature and precipitation for analysis with observed breeding bird distribution shifts during the last 20 years in NY State

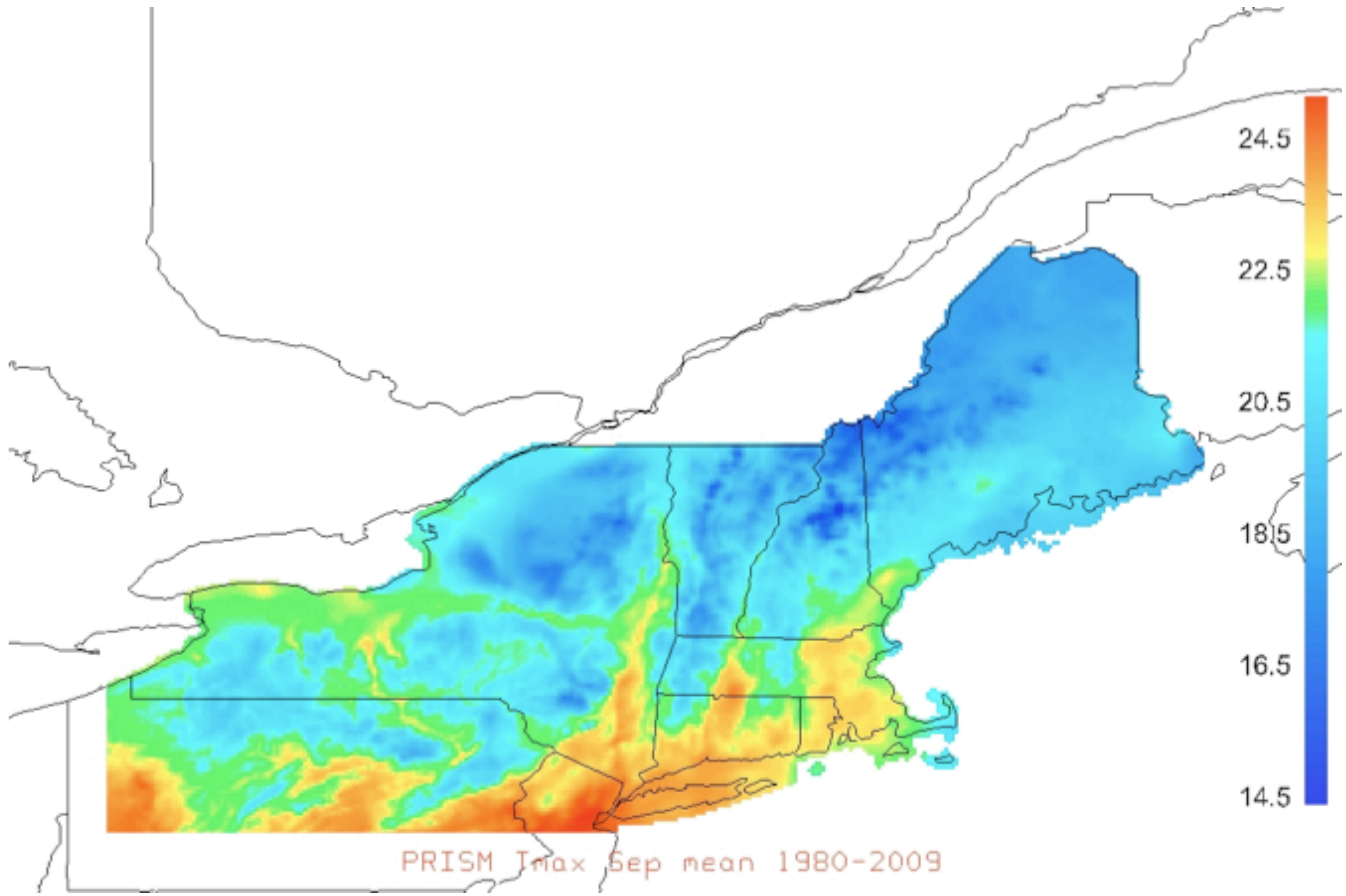
Methods



Beier et al. in review

Methods

Compiled PRISM (Daly et al. 2002)
4km monthly data from
1980-2009 (>20K rasters)



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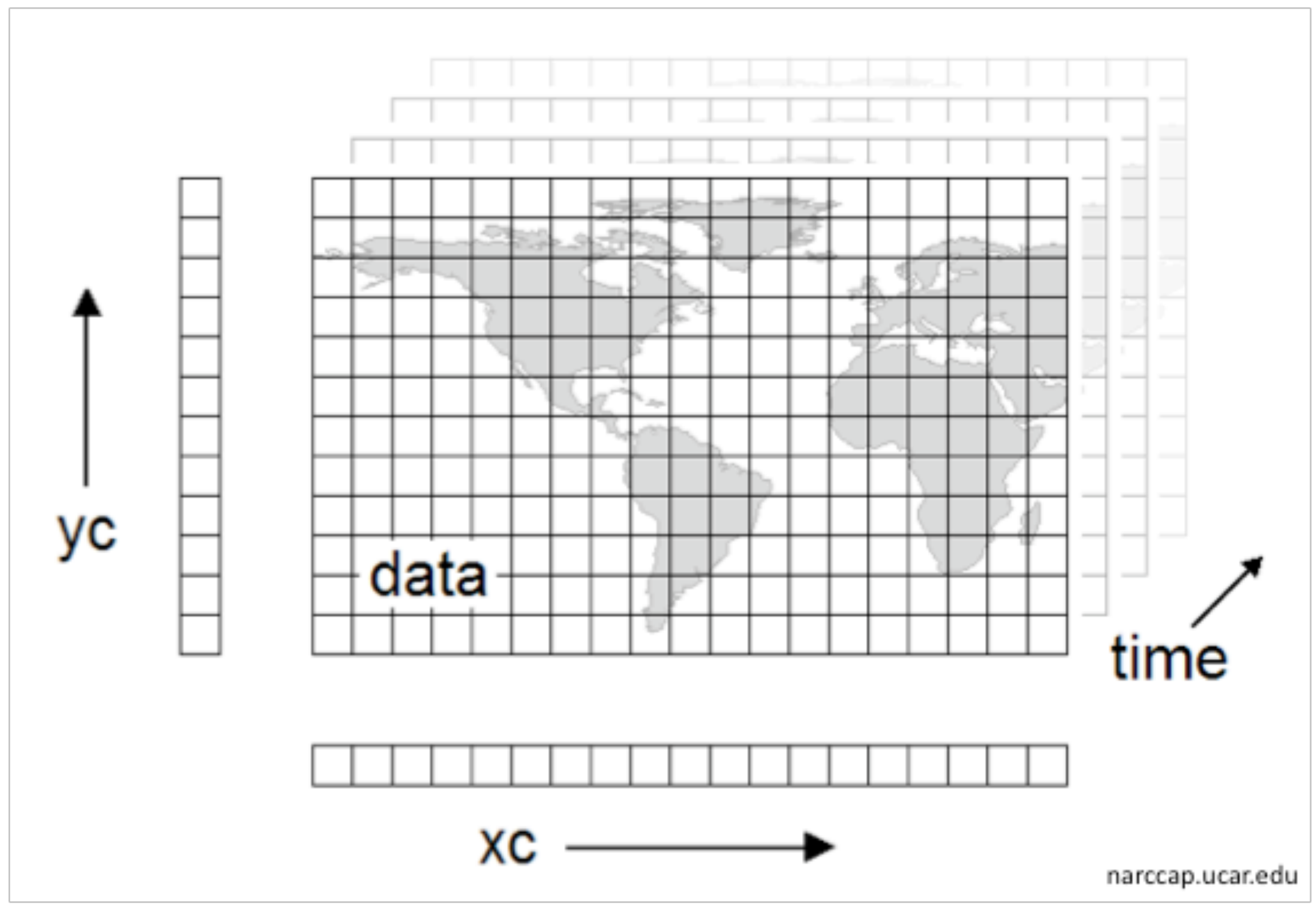
Created **netCDF** libraries of gridded time-series

netCDF

http://www.unidata.ucar.edu/software/netcdf/

Network Common Data Form: efficient storage of multidimensional rasters



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Analysis cell-by-cell:

- Mean, SD
- Linear Regression - Slope coefficient and intercept
- Mann-Kendall - τ statistic and p value
- Theil-Sen estimator (nonparametric trend)

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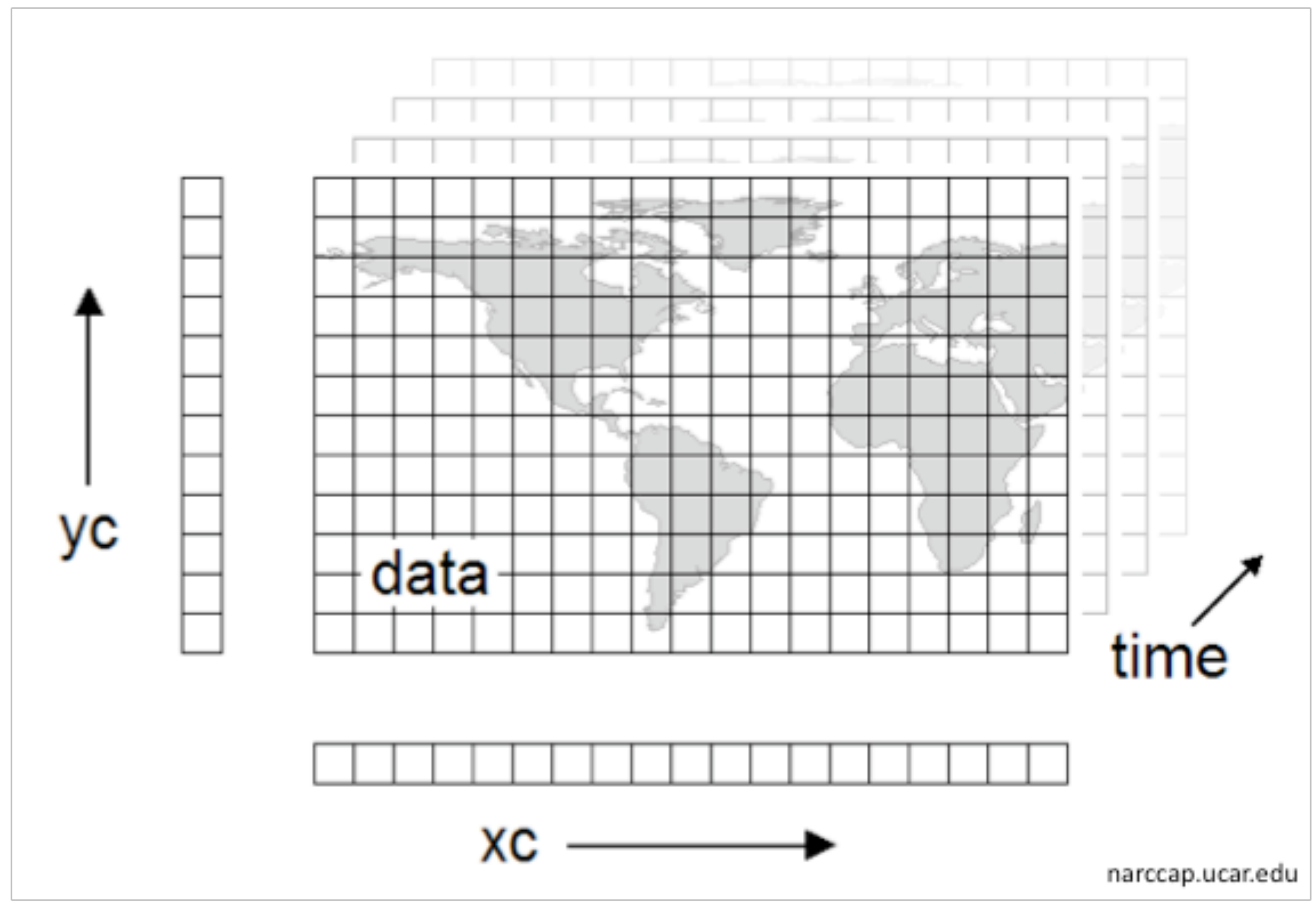

Beier et al. in review

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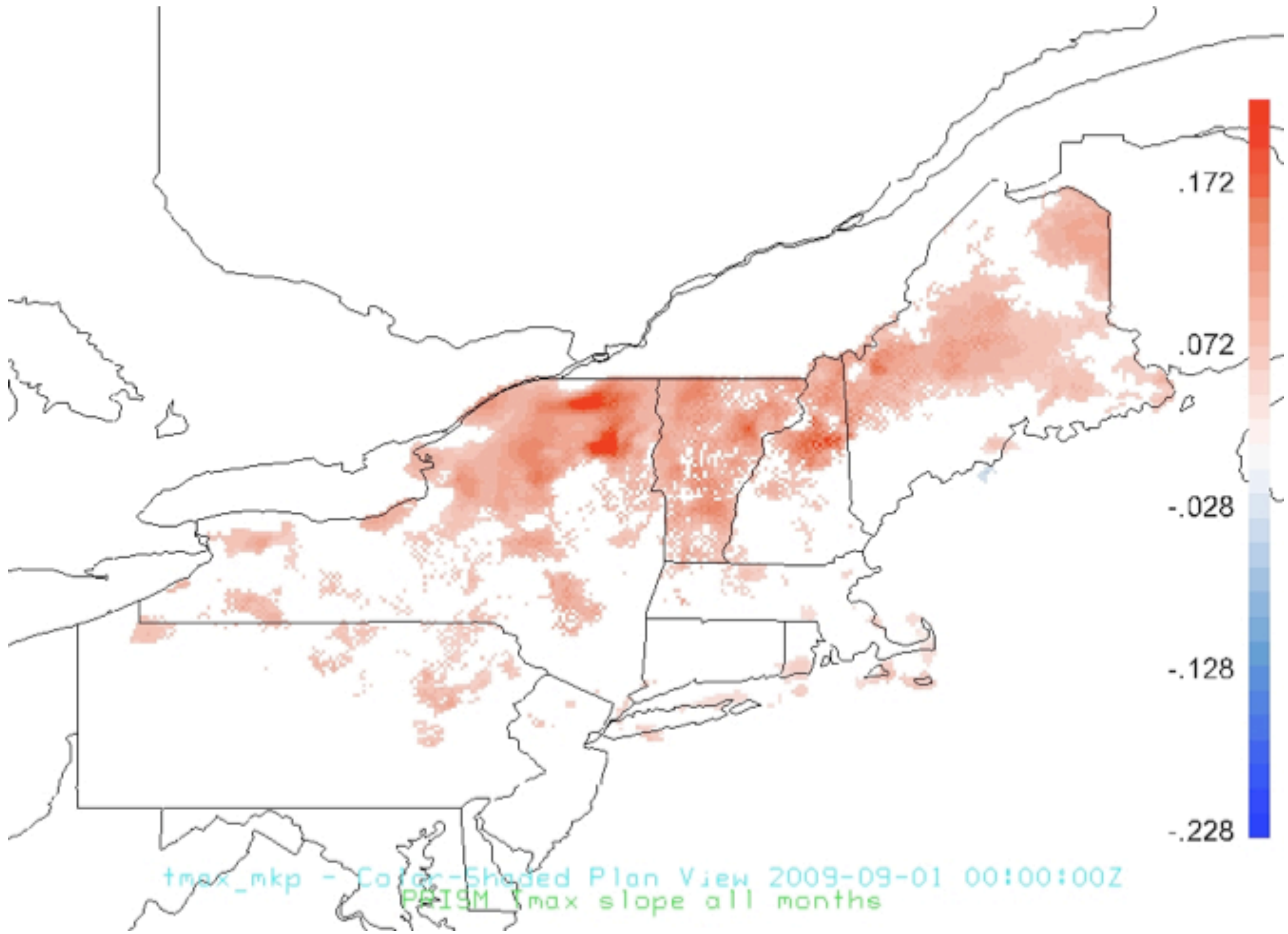
- Theil-Sen estimator (nonparametric trend)

'Masked' trend maps using Mann-Kendall p value



Beier et al. in review

Regional temperature trend maps: 1980-2009

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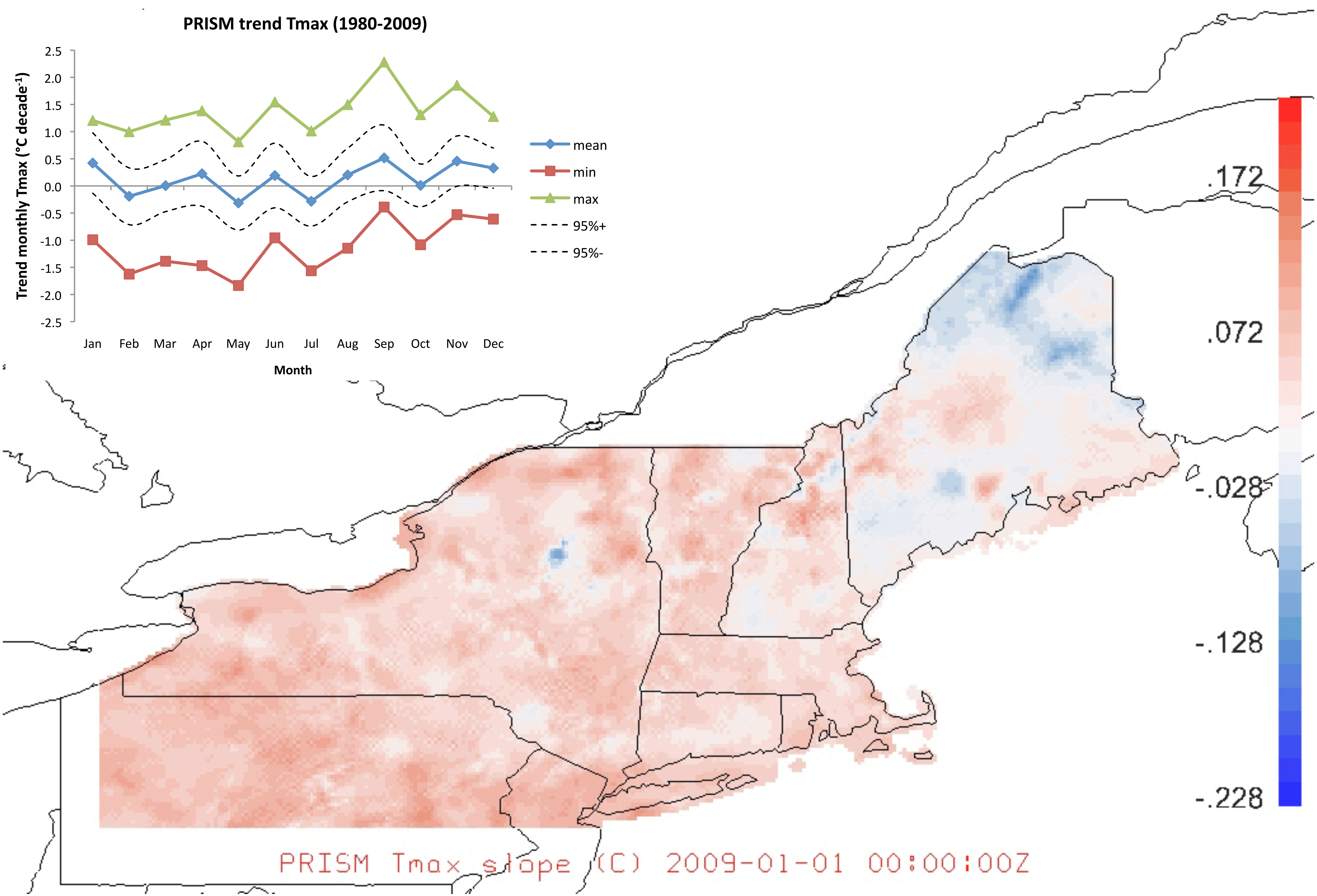

Beier et al. in review

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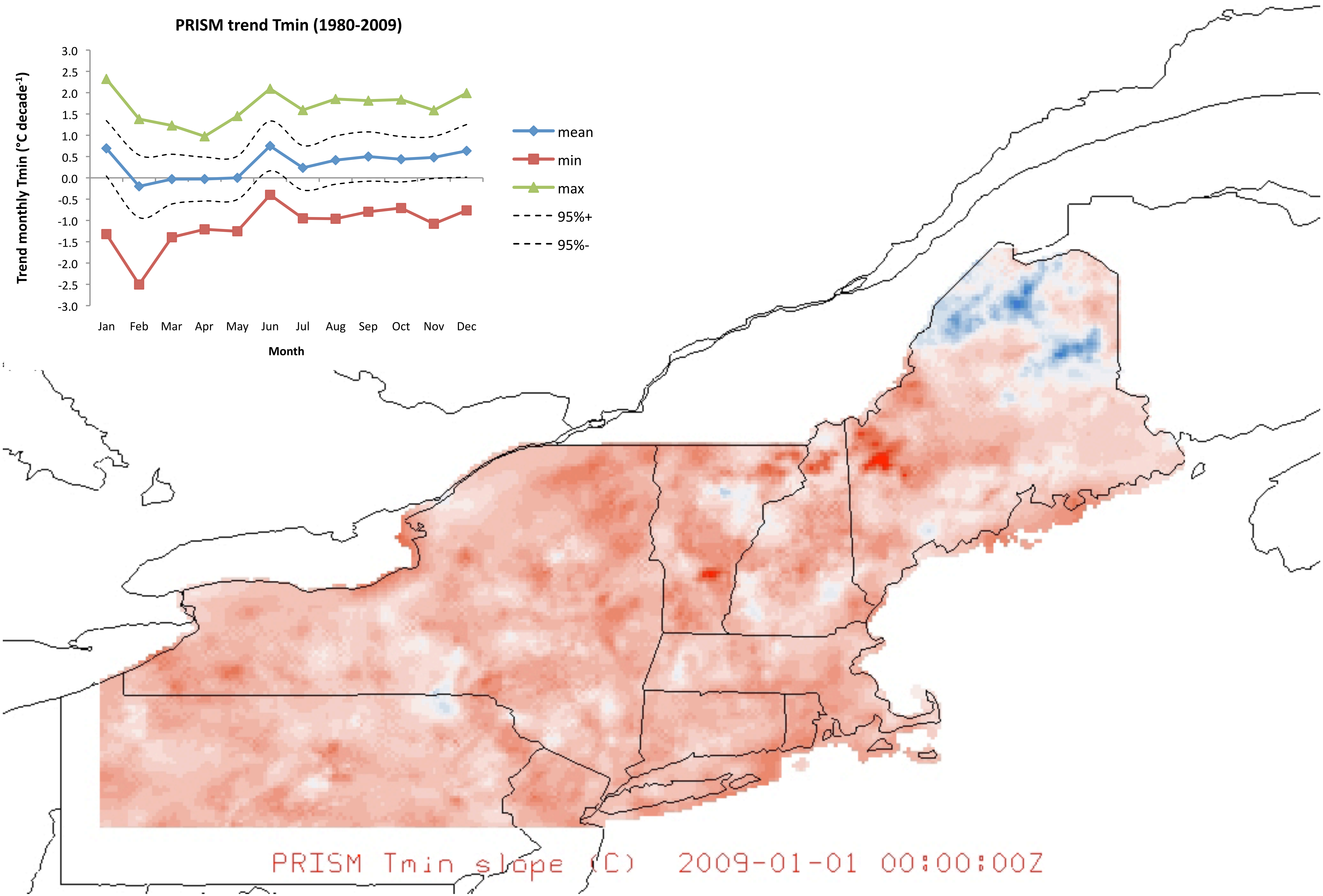
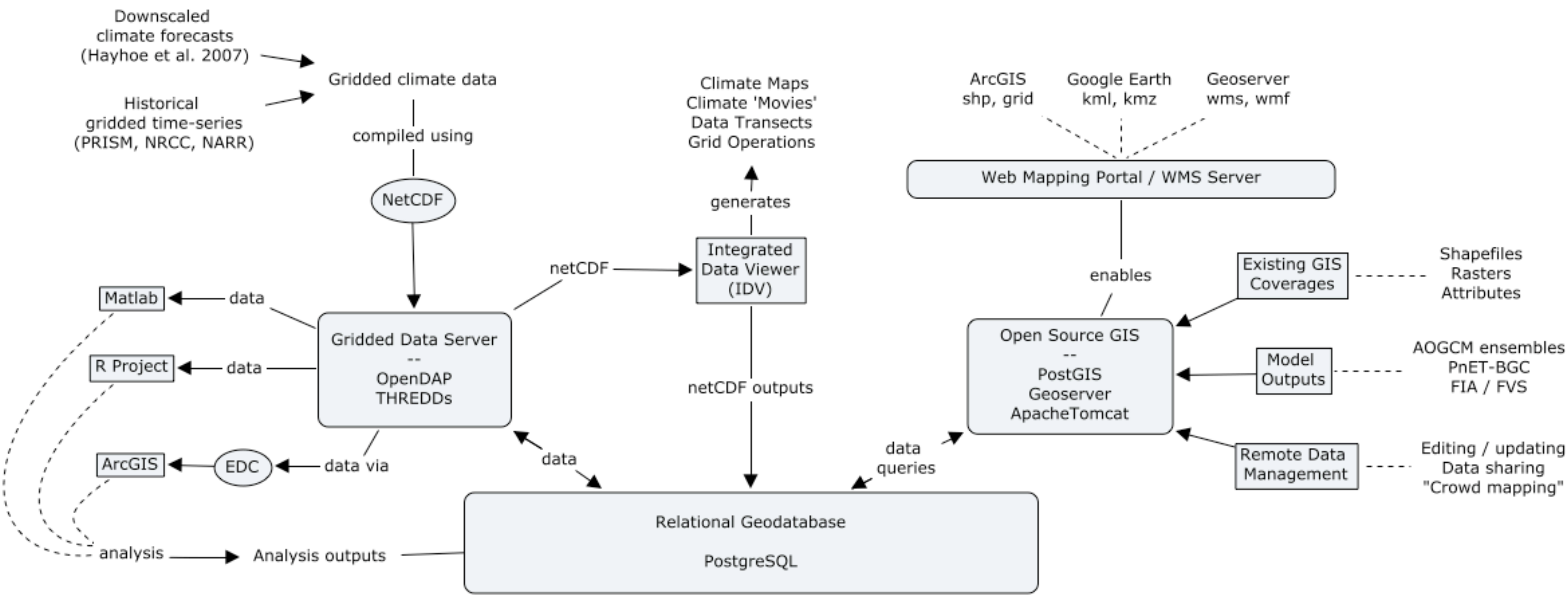


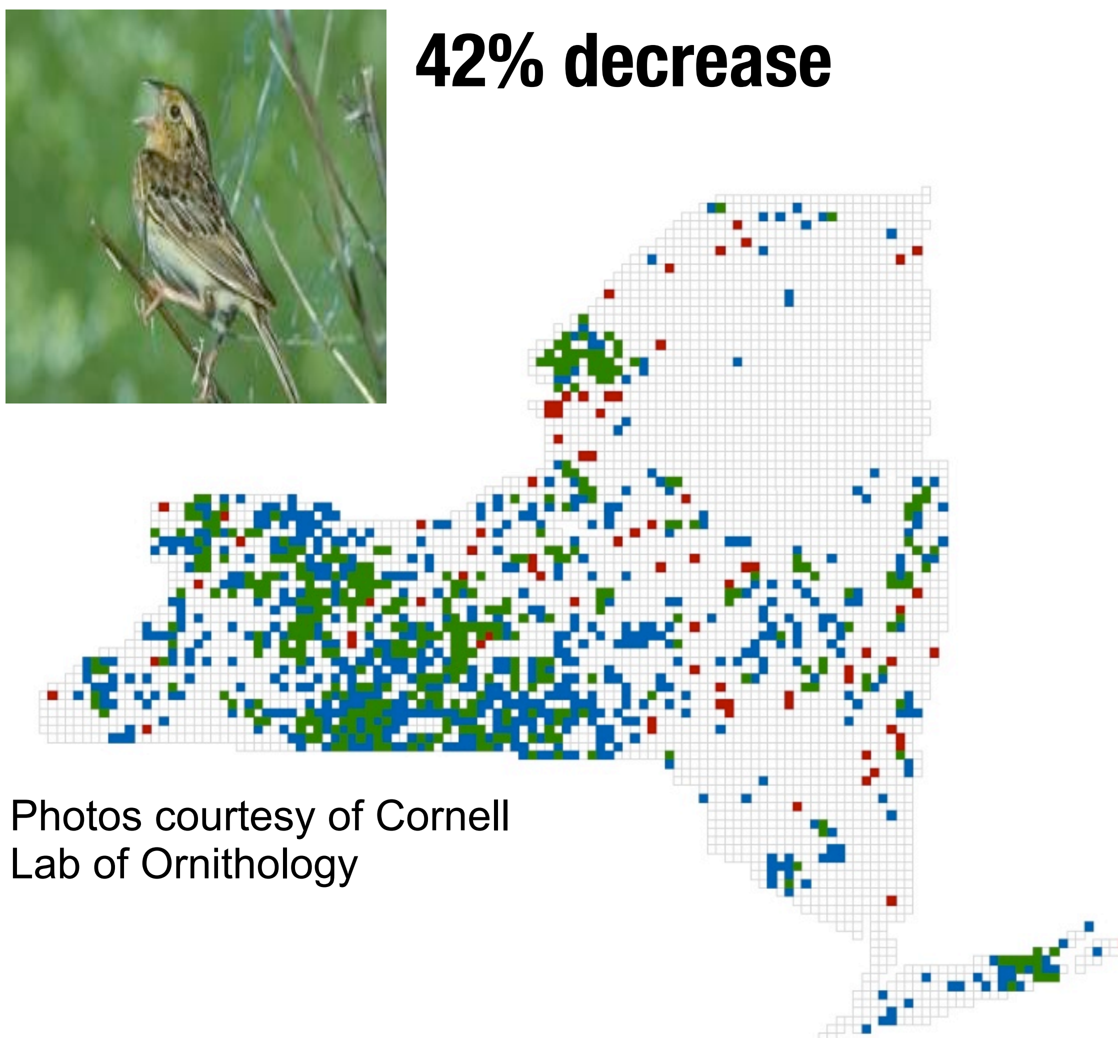
Spatial data infrastructure



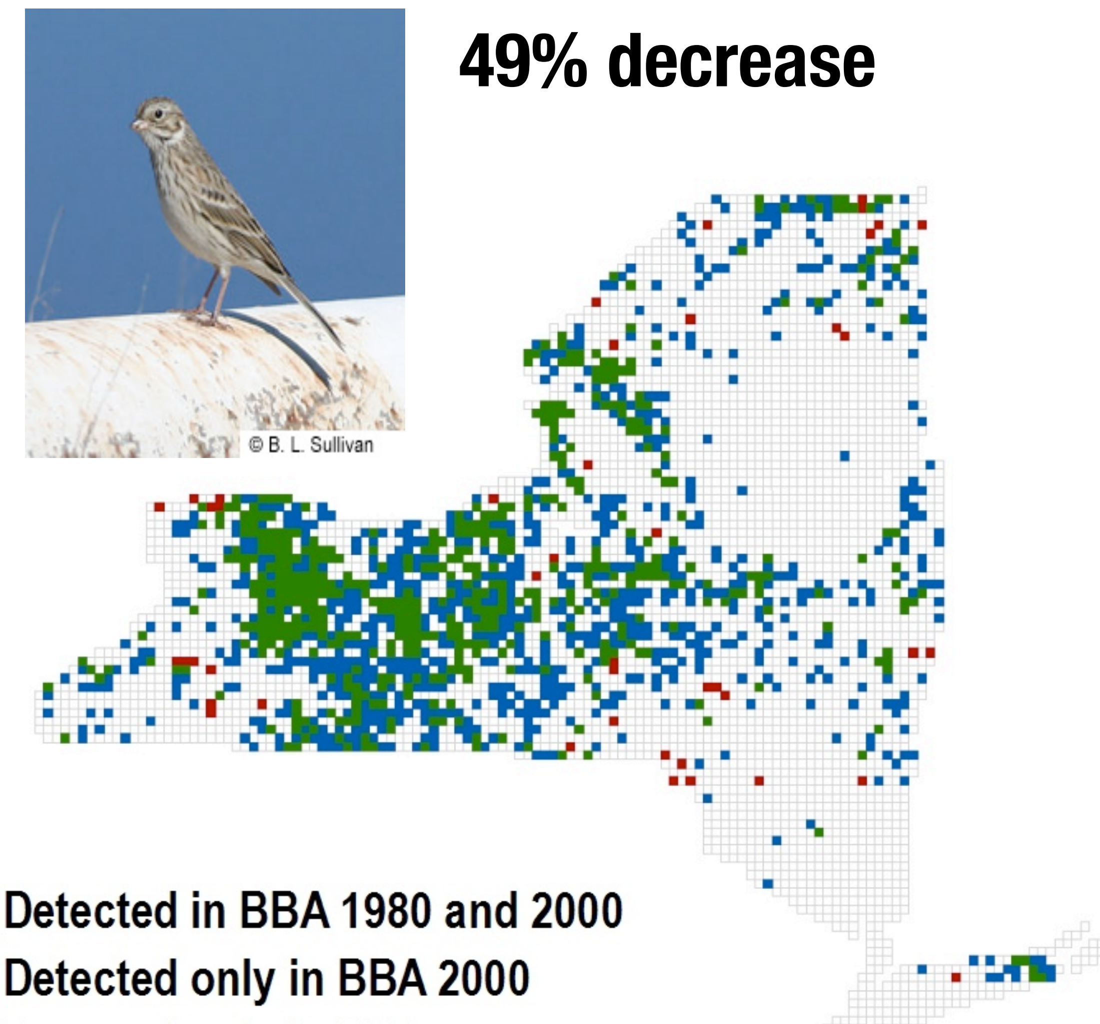
- Data transfer, analysis & mapping integrated with open-source tools
- Links with R project and Matlab for custom analyses
- Import into ArcGIS using the Environmental Data Connector
- UNIDATA Integrated Data Viewer (IDV)
- Exports to multiple platforms via web mapping service

Biodiversity Modeling

Example: Observed changes in species occurrence between 1980 and 2000 for Grasshopper Sparrow (left) and Vesper Sparrow (right) (Zuckerberg et al. 2010)



Photos courtesy of Cornell Lab of Ornithology



Detected in BBA 1980 and 2000
Detected only in BBA 2000
Detected only in BBA 1980

Biodiversity Modeling

Methods

- Hierarchical Bayesian framework to account for multiple sources of uncertainty, including spatial autocorrelation.
- To model responses of grassland birds to changes in land cover - **segmented logistic regression** model (in Bayesian framework)

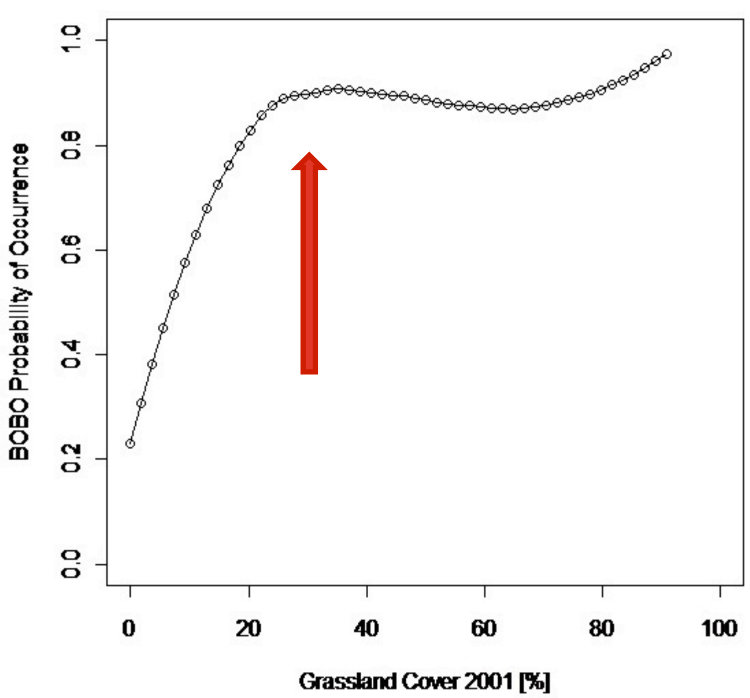
$$y_i = \begin{cases} \beta_0 + \beta_1 x_i + e_i & \text{for } x_i \le \alpha \\ \beta_0 + \beta_1 x_i + \beta_2 (x_i - \alpha) + e_i & \text{for } x_i > \alpha \end{cases}$$

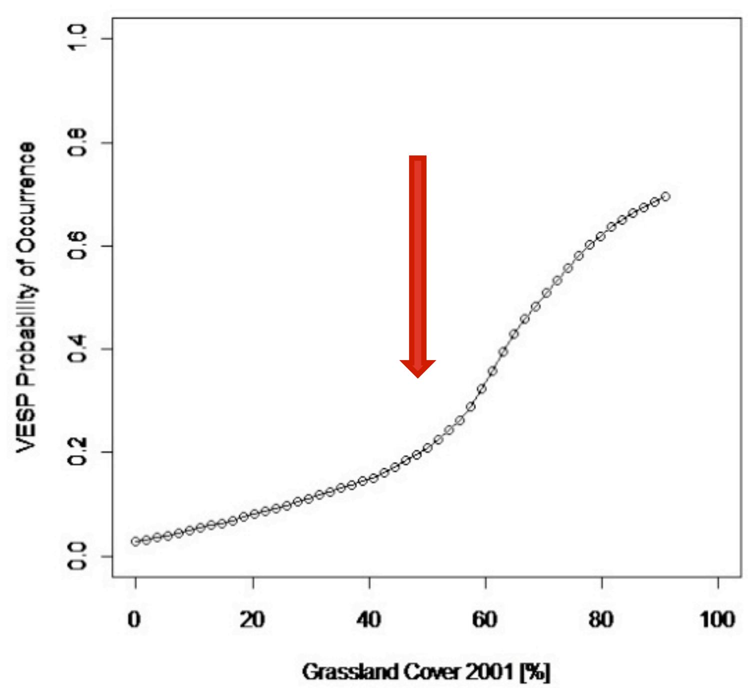
where y_i is the value for *i*th observation, x_i is the corresponding value for the independent variable, α is the threshold, and e_i is the error term. The slopes of the lines are β_1 and $\beta_1 + \beta_2$, so β_2 can be interpreted as difference in slopes.

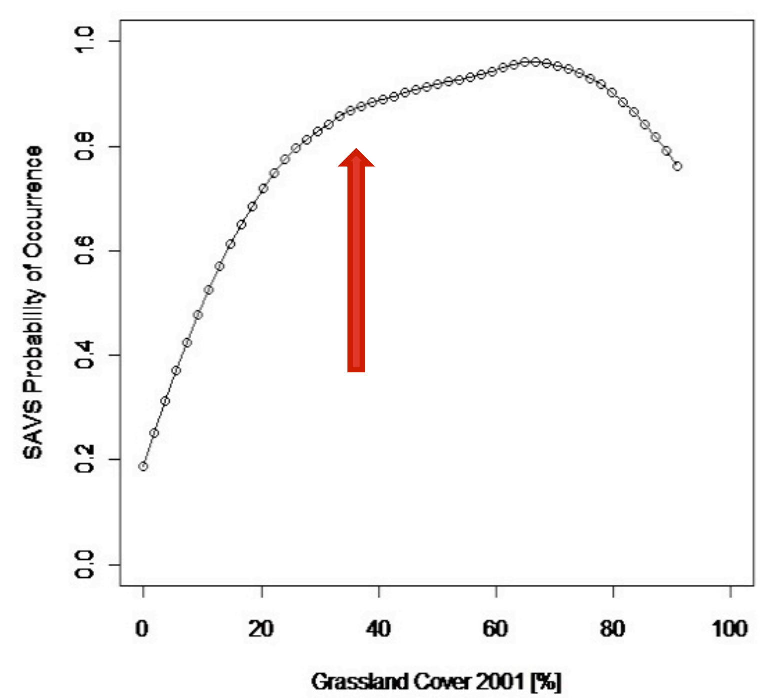
Biodiversity Modeling

Preliminary Results:

- Thresholds are common in responses of grassland birds to changes in land-cover
- Percent Grassland Cover thresholds ranged from 5% to 70%
- Breeding bird species have a diversity of responses to land cover change







Next steps...

- LVIS Ground-Truthing
  - **Complete data analysis**
- Land Cover - Land Use Change
  - **Complete multi-sensor data integration for 3D LULCC coverage**
- Succession Modeling
  - **Build, parameterize and validate models of vegetation structure vs. site age**
  - **Implement model(s) spatially, identify field validation sites for 2012**
- High Resolution Climate Change Analysis
  - **Resampling of trend maps for modeling of breeding bird shifts**
  - **Acquisition of daily PRISM for analysis of growing season and degree days**
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  - **Apply Bayesian framework for modeling multiple factors biodiversity**

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Questions?