CLIMATE MATTERS: PROGRESS REPORT ON DELINEATING SUB-REGIONAL CLIMATE PATTERNS IN NORTH DAKOTA WITH GIS FOR HYDROLOGIC AND BOND RELEASE ASSESSMENT.

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Executive Summary

The original goal of this project was to delineate sub-regional climatic patterns from historic, instrument based weather observations supplemented with proxy records in areas where no measured observations are available. The original plan for early tree analysis was deferred to organization and analysis of the instrument data to better focus proxy data acquisition. For about 1.5 years, work was set aside to combat an IT reorganization that would have made project data management unfeasible. Over the last two years, most available time as been spent with ArcGIS and database issues, including simple learning, to cope with the magnitude of data and analysis required by the project.

GIS was always seen as essential to the project. It is now apparent that the modeling capabilities of GIS make possible a more cost effective and valid approach to the problem than had been initially planned.

Two variations on the approach to using instrument and proxy data to delineate sub-regional climates

1. Explore for patterns in existing regional climatic data and newly acquired proxy data. Identify groupings and patterns and correlate them with environmental variables to infer controlling mechanisms. This implies systematic or random collection of proxy data in the absence of a guiding model.

2. Develop graphic model(s) of sub-regional climatic zones inferred from existing climatic information and known controlling variables. Use these models to direct proxy data acquisition, then refine and test models in iterations.

These differences seem trivial; however, they involve significant differences in project cost and philosophy.

Explore for patterns in existing regional climatic data and newly acquired proxy data. Identify groupings and patterns and correlate them with environmental variables to infer controlling mechanisms.

Steps:

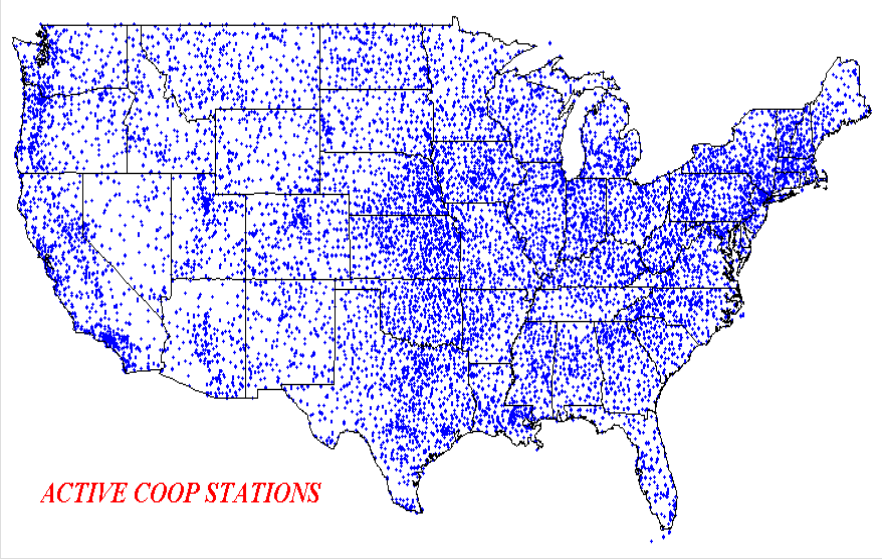
- gather and evaluate climatic instrument data
- attempt to fill time and space gaps with tree ring proxy data
- analyze the instrument and proxy data to delineate spatial and temporal patterns
- relate these patterns to environmental factors (eg. topography, land use, surface waters, larger scale climatic patterns) to infer controlling mechanisms
- delineate the spatial extent and boundaries of these relationships
  - Advantages: Classic methodology, “unbiased” empirical use of data, permits analysis of instrument data and collection of proxy data to begin without the burden of initially developing complex models.
  - Disadvantages: The data set is a large amount of space/time weather data with significant gaps. Gap recognition, without a guiding model, will indicate extensive proxy data needs with a “blind eye” to probable key areas. Acquiring proxy data to fill the data gaps is time and resource consuming. To be feasible, this sampling must be efficiently directed to critical areas, rather than done systematically or randomly.

Develop graphic model(s) of sub-regional climatic zones inferred from existing climatic information and known controlling variables. Use these models to direct proxy data acquisition, then refine and test models in iterations.

Steps:

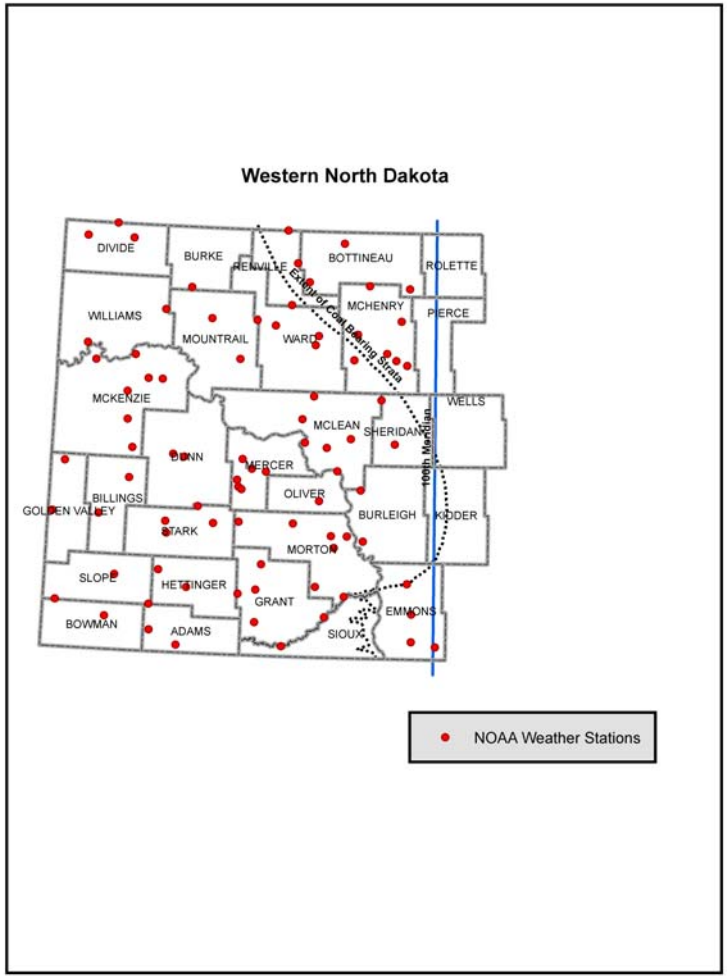
- Develop hypothesis of mechanisms controlling sub-regional variability
- Acquire data on relevant environmental controls (eg. topography, land use, surface waters) and readily available climate information
- Analyze environmental data to delineate probable patterns influencing climate, build preliminary models of climate sub-regions using GIS tools
- analyze climate data, test model, collect proxy data in areas critical to model testing
- test model patterns against these data, refine model(s)
  - Advantages: Fully utilizes existing information. Proxy data acquisition focuses on data gaps critical to model validation and will require less sampling. Data analysis and model building iterative, and the final model is possibly better documented as to causative factors since they are inferred model elements from the beginning.
  - Disadvantages: Requires complex and detailed models up front with environmental data to support them - relatively easy with GIS tools. Bias is a risk in the presence of detailed and persuasive GIS based models.

Instrument data is NOAA “U.S. Weather Service” data. The weather stations range from large installations at major airports to a network of Cooperative weather observers. While the major stations collect an important array of sophisticated data, such as Doppler Radar imagery, the network of Cooperative stations have generated the data over time and space needed for climatic investigation.

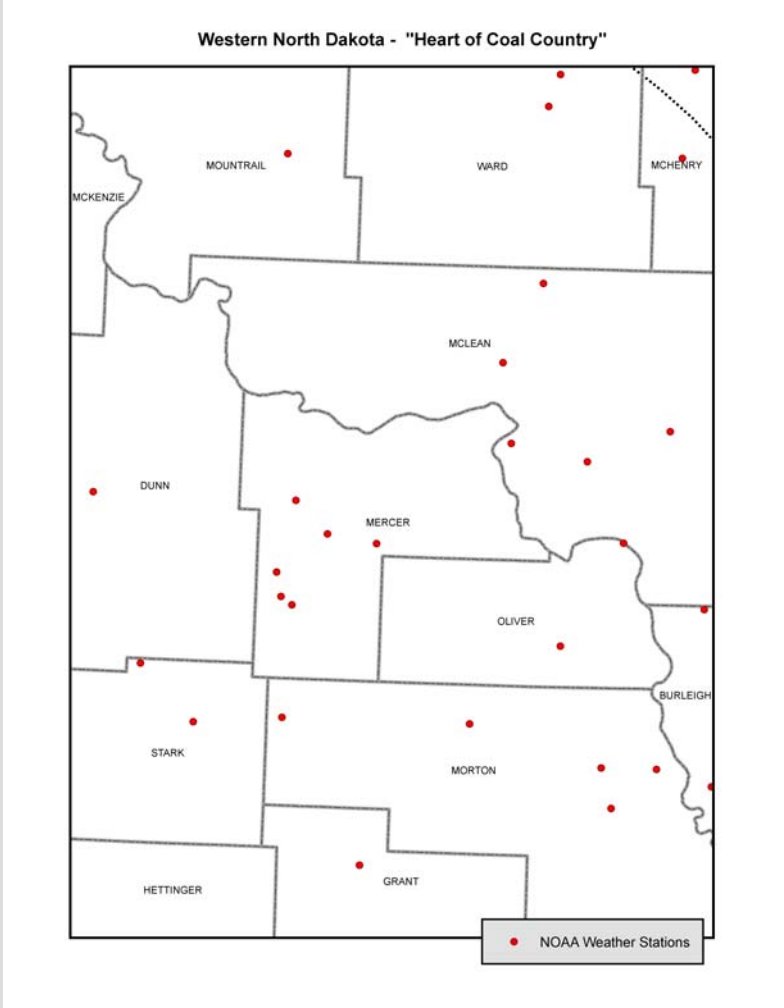


Although daily instrument weather records in the region extend back to 1911, the network of weather stations providing useful coverage over the area dates from the 1940's. Geographic coverage is uneven and the intervals of station data are variable. There are 84 NOAA weather stations in western North Dakota, west of the 100th Meridian.

Regional Scale View

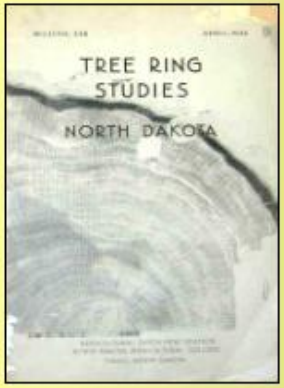


Sub-regional Scale View



Tree ring research on the Northern Plains has been limited and its potential seems uncertain.

The potential for dendrochronology seems very limited. Longer lived species are confined to major stream valleys. However, a useful 1400-year flood chronology has been developed for the lower Red River by the Geological Survey of Canada.



Dendrochronology - tree annual rings used for event dating

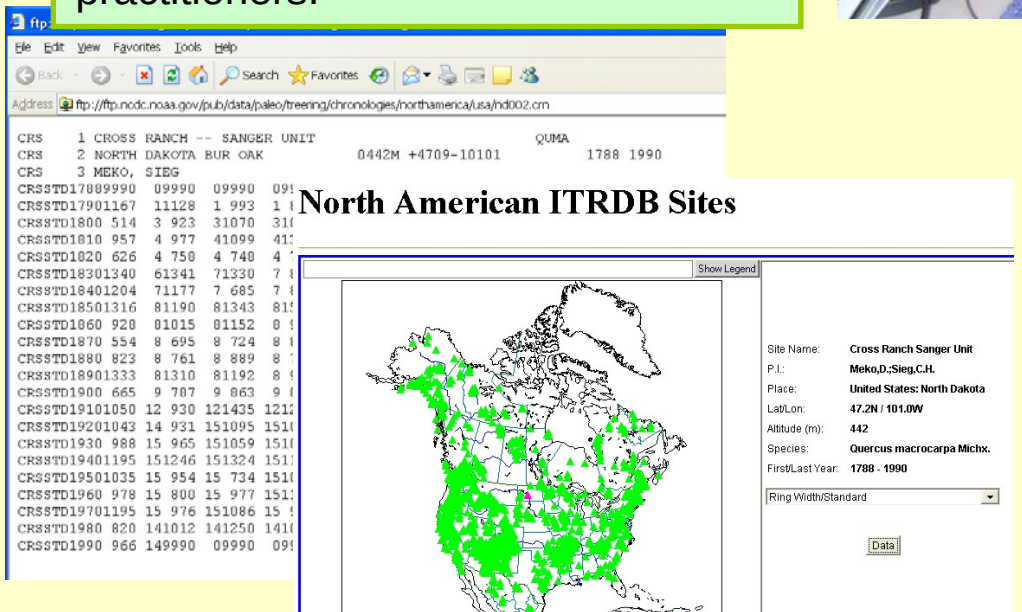
A useful 300-year proxy for the Palmer Drought Severity Index in west-central North Dakota was developed with tree ring records from over a wider area.

In paleoclimatology tree annual ring width can be reliable climate data recorders

The common wisdom still seems to be that the Northern Plains holds minimal potential for finding useful climatic or chronologic records in the rings of its trees.

Acquiring data to the standards of modern tree ring science is labor and skill intensive.

Suitable trees must be located, cored, cores mounted, surfaced, finished, and measured. The raw data must be organized and analyzed by fairly standard methods. Data are deposited in the International Tree Ring Data Bank (ITRDB) for peer review and use. In the controversy-filled world of climate science, this open records philosophy helps insure the integrity of the science as well as its practitioners.



Prior to European settlement, trees on the Northern Plains were limited to major stream valleys, their woody draws, and fairly large groundwater discharge areas. Most if not all trees on uplands today are the result of human cultivation. In most cases, these are the trees that are suitably located to fill gaps in the climatic record from instruments.

The species that survive in Northern Plains upland plantings tend to be short lived. Drought, wind stress, competition from grasses, temperature extremes and evolving agricultural practices impact growth and survival. Because of their short lives and apparent limited value as climatic records, rings of these species have received little attention from dendrochronologists.

However, the suboptimal habitat of the typical tree row or shelter belt on the Northern Plains suggests that these trees may record better climatic responses than plants of the same species growing in more favorable situations. They may be less spectacular examples of trees surviving in marginal habitat much like the famed Bristle Cone Pine.

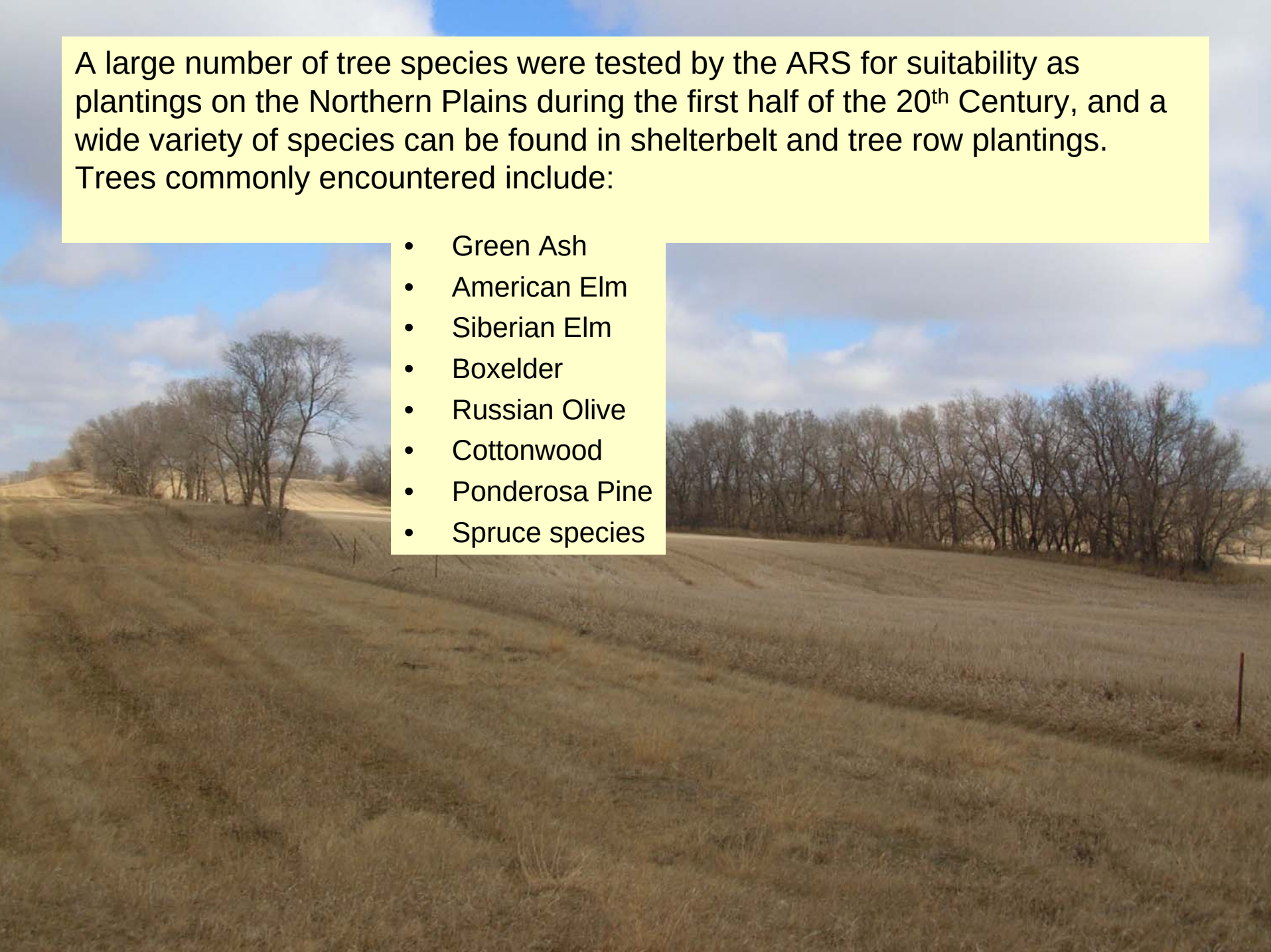
Apart from stands along major streams, most of the trees in western North Dakota available to provide climatic data are human plantings and short lived species – trees older than 50 years will be atypical. But upland plantings are common and promise good aerial coverage. Climatic information recorded in tree rings will be used in this project to augment an instrument record covering about the same time interval as most of the available trees.

So, who planted trees in western North Dakota?

- Homesteaders - homestead perfection with tree plantings (Tree Claims) - extent of activity in western North Dakota uncertain.
- Railroads – primarily as shelter along right-of-way, but also as an emergency fuel source and to enhance "curb appeal" of land holdings – extent of activity in early western North Dakota uncertain.
- Landowners with support from USDA – shelter for farmsteads, cropland wind breaks – a large and well documented effort of the USDA Northern Great Plains Field Station in Mandan, ND from about 1916 to 1938. Similar agriculture-related programs to date.

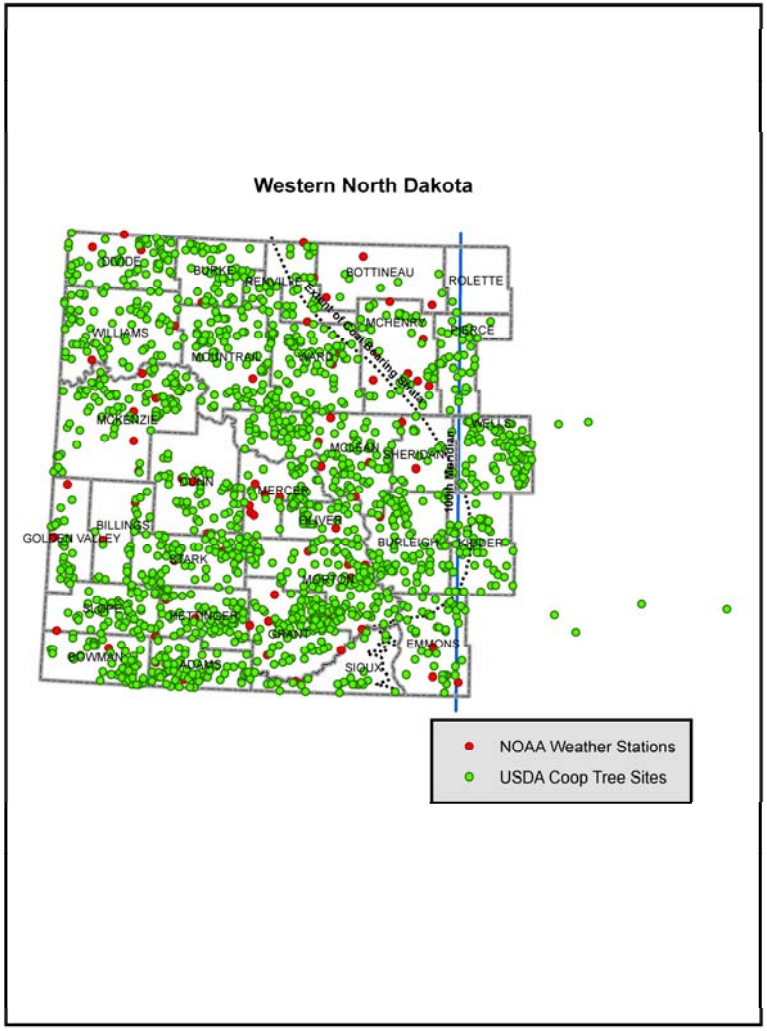
A large number of tree species were tested by the ARS for suitability as plantings on the Northern Plains during the first half of the 20th Century, and a wide variety of species can be found in shelterbelt and tree row plantings. Trees commonly encountered include:

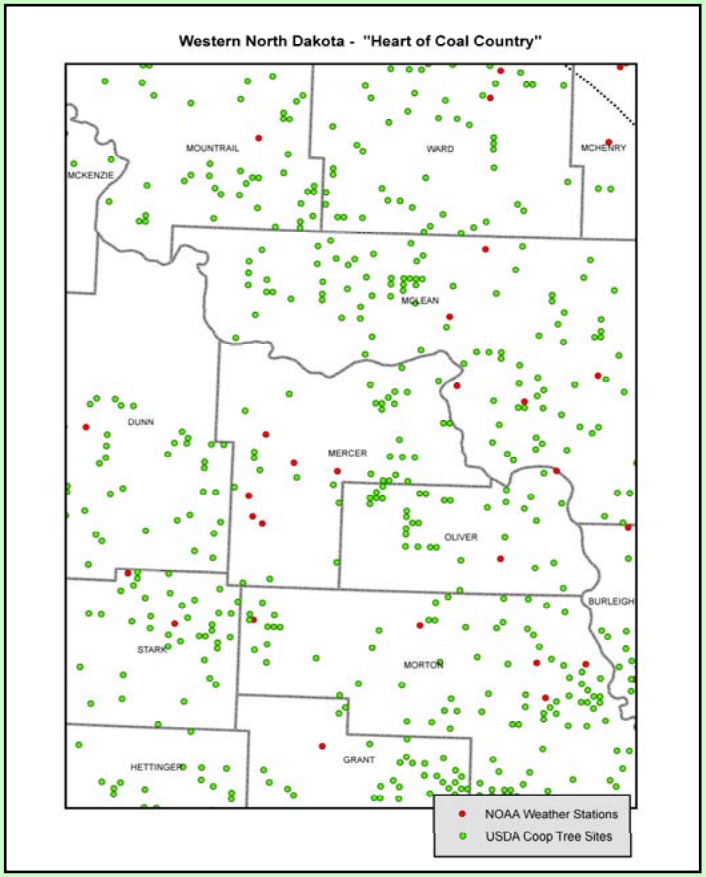
- Green Ash
- American Elm
- Siberian Elm
- Boxelder
- Russian Olive
- Cottonwood
- Ponderosa Pine
- Spruce species



The pioneering Cooperative Tree Planting program of USDA covered much of the Northern Plains and resulted in about 1700 tree row and shelter belt plantings in North Dakota alone. It set attitudes toward tree planting that were reinforced by post-Dust Bowl conservation efforts and that continue today.

USDA records only gave PLSS locations for planting sites. The PLSS section locations were converted to geographic coordinates using a freeware product.

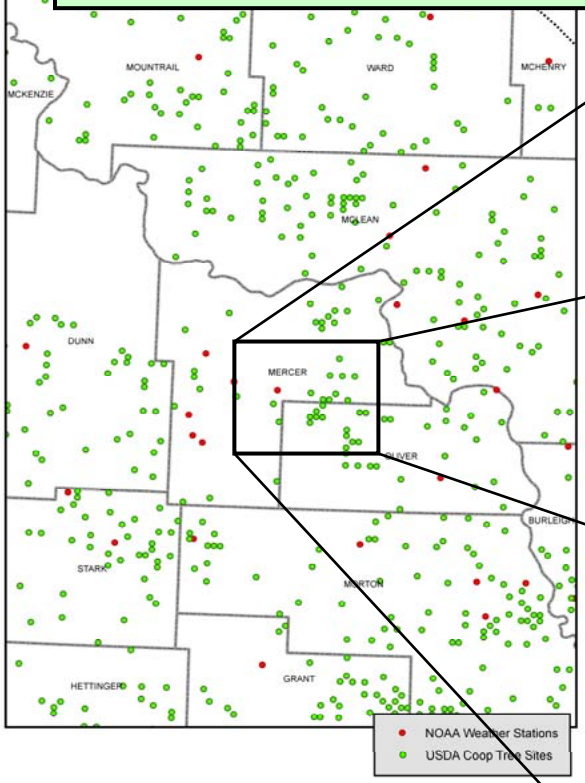


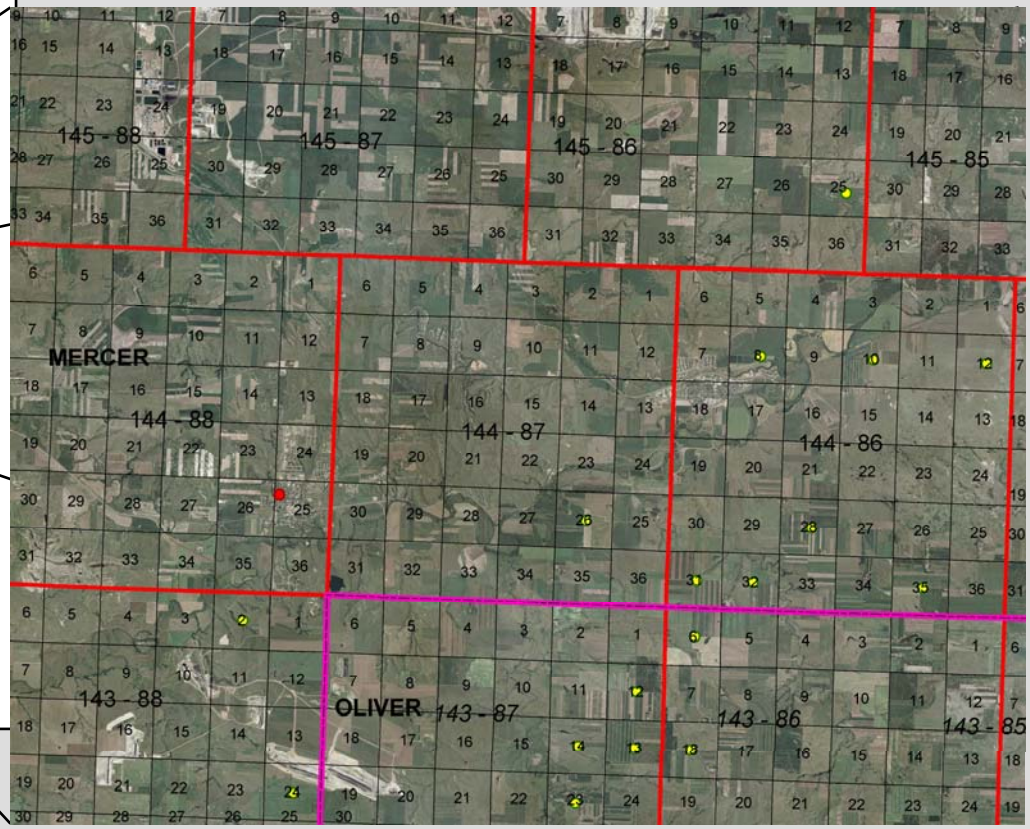


ArcGIS provides tools to –

- **Map the planting sites**
- **Project their location on NRCS National Agricultural Imagery Program (NAIP) color photography for assessment of current site conditions and ring sampling potential.**
- **Conveniently manipulate and analyze both NOAA weather data and proxy information.**
- **Most importantly, it can save countless man-hours and cost in inventorying plantings and natural stands and optimizing tree ring sampling targets.**

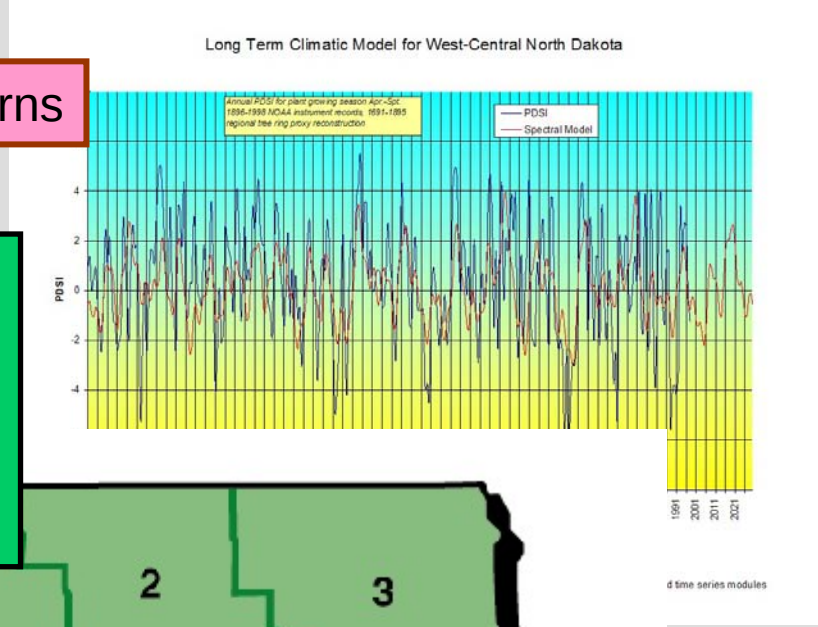
•Most of the original planted trees did not survive stresses of the 1930s drought years, and replacement plantings have been a common practice on original sites.
•Finding original trees at these sites is the most likely source of long run proxy climatic records away from the major stream valleys.
•More recent plantings and natural stands, most less than 50 years old, are far more abundant over the area than these historic sites.

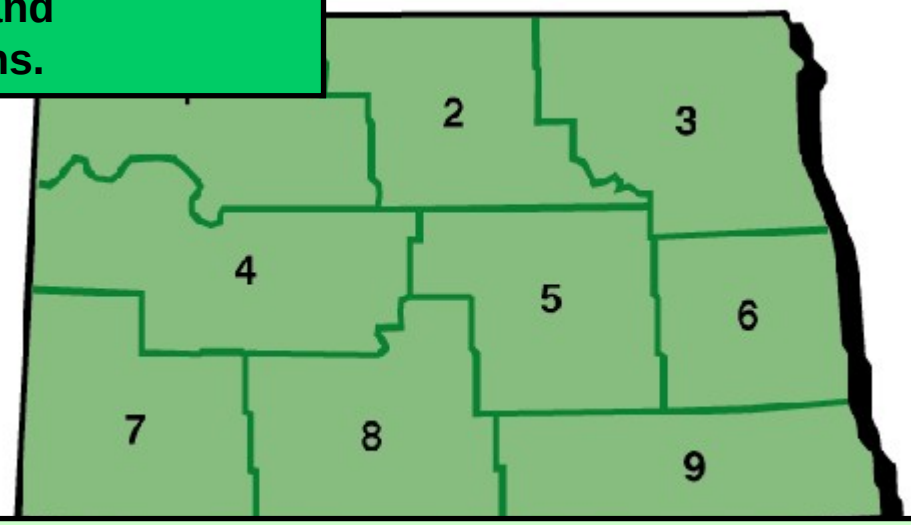




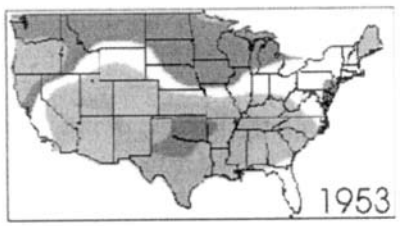
Modeling regional and sub-regional climatic patterns

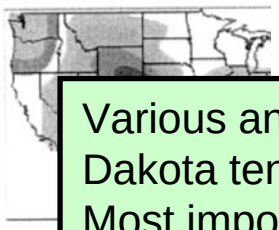
The NOAA climate divisions for each state seem to be roughly based on physiographic regions, but are not necessarily good models of climatic zonation. They are important because NOAA climatic data are often organized and summarized around these Divisions.

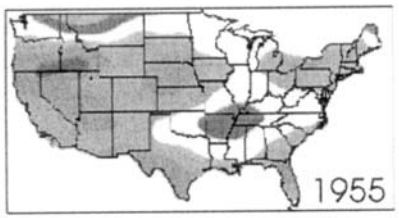


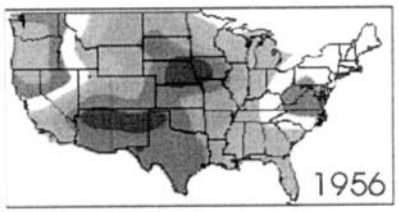


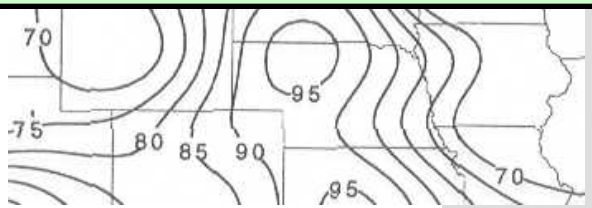
Various analyses suggest that Wisconsin, Minnesota and North Dakota tend to fall in the same broad area of North American climate. Most importantly, sharp climatic boundaries do not exist in the state.





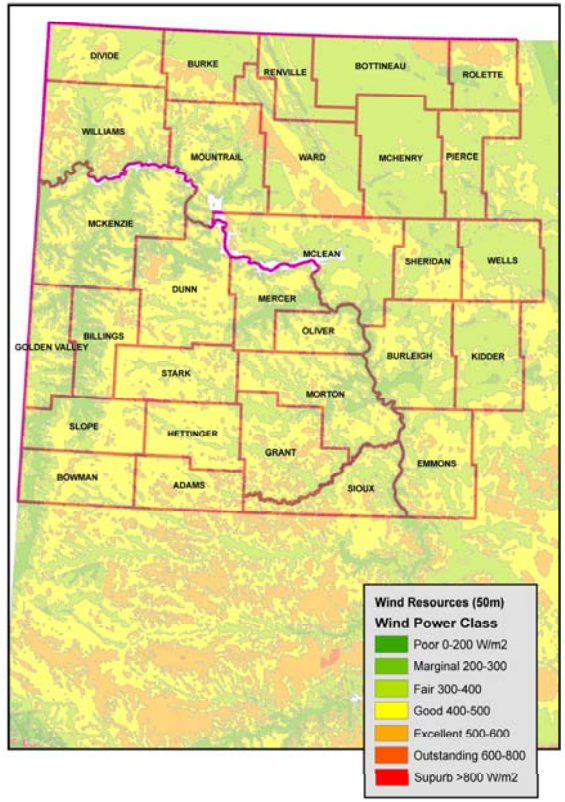




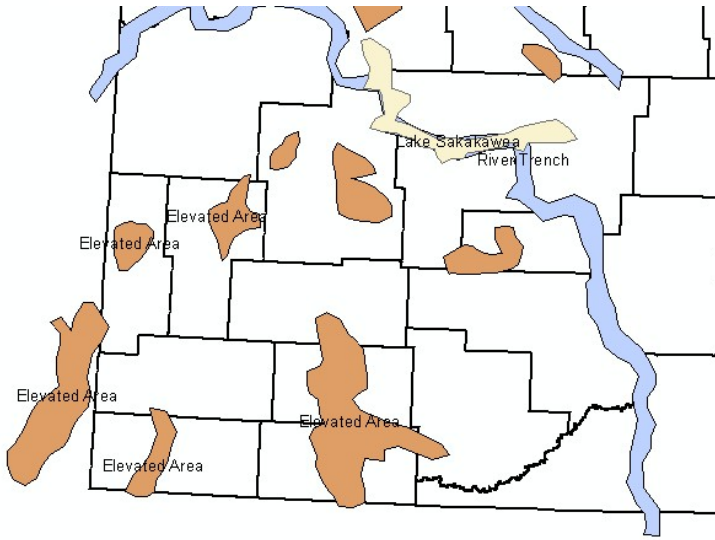


An initial model of sub-regional climate can be inferred from surface variables known to influence local weather patterns when they are compared with meterologic data. These surface variables include:

- topography and relief
- large surface water bodies
- vegetation
- land use and cover, including urbanization



Data on these features are available for western North Dakota from Internet sources and usually mapped at scales that are adequate for pattern recognition on the sub-regional level.



An initial model of sub-regional climate can be inferred from the surface variables known to influence local weather patterns:

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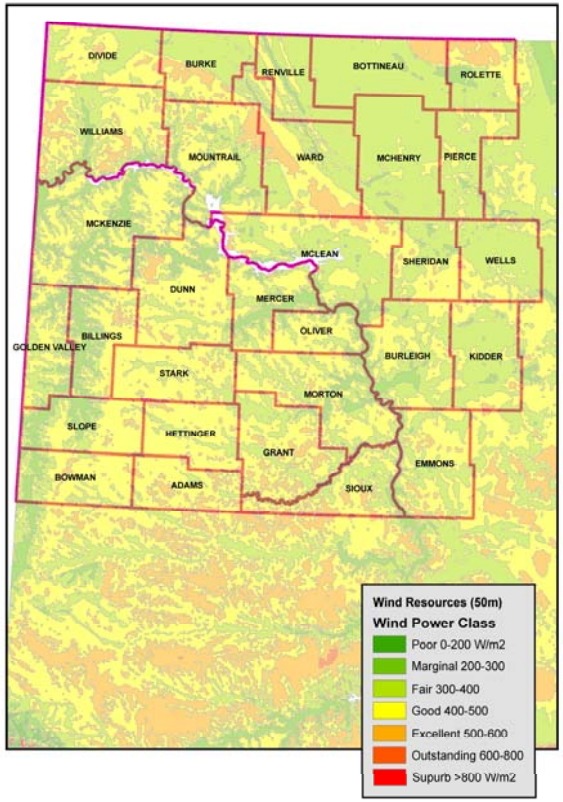
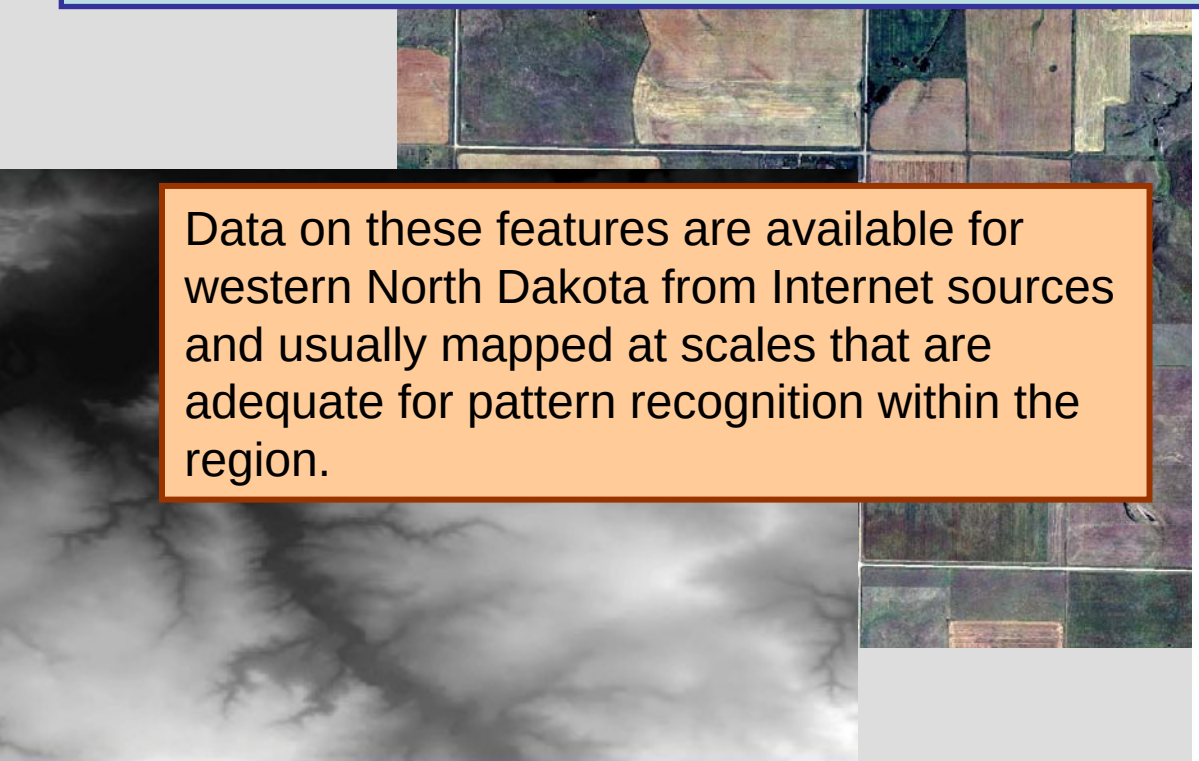
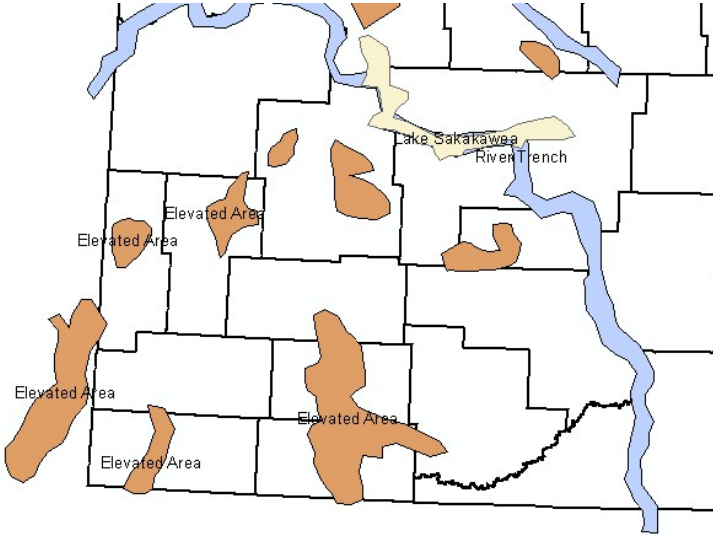




Data on these features are available for western North Dakota from Internet sources and usually mapped at scales that are adequate for pattern recognition within the region.



Summary:

The project is now at the point of starting analysis of the historic instrument data in search of persistent patterns and comparing them with likely causes. The geostatistical tools for this analysis have not been selected. Areas where proxy data would be desirable will be identified, and the search for tree species with useful climatic records resumed. These data will be used for refinement of initial models.

A study of long-term regional climate seems far afield from typical reclamation research; however, usable climatic information is essential for substantive understanding of hydrologic regimes, spatial and temporal variation in plant productivity, and predicting the permanence of vegetative cover and landform stability. Long-term patterns in the regional climate of western North Dakota have been shown to be deterministic (meaning they can be modeled mathematically) and therefore can be projected into the future for prediction. If sub-regional patterns can be delineated, then the same deterministic models can be applied at a more localized scale that will be useful and important to future energy development. It was the absence of this certainty about climate and environmental responses to it that prompted the framers of SMCRA to impose a 10-year liability period on lands west of the 100th Meridan.

THE END