North Carolina Climate Variations

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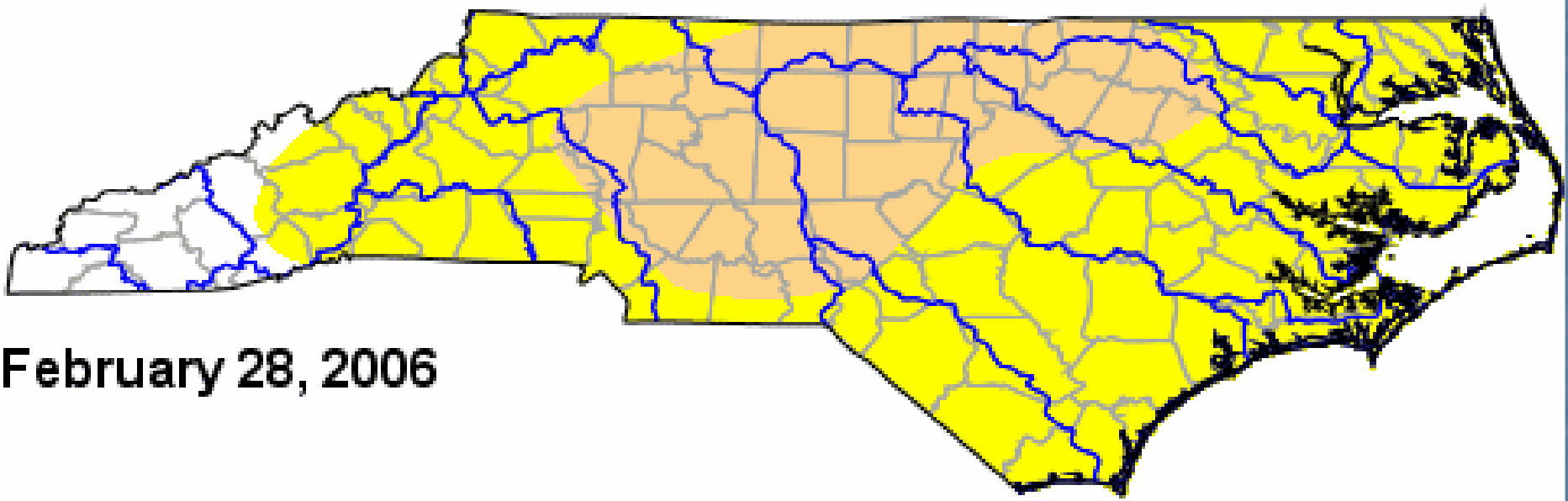
North Carolina State University

Latest Drought Conditions

US Drought Monitor of
NORTH CAROLINA



February 28, 2006

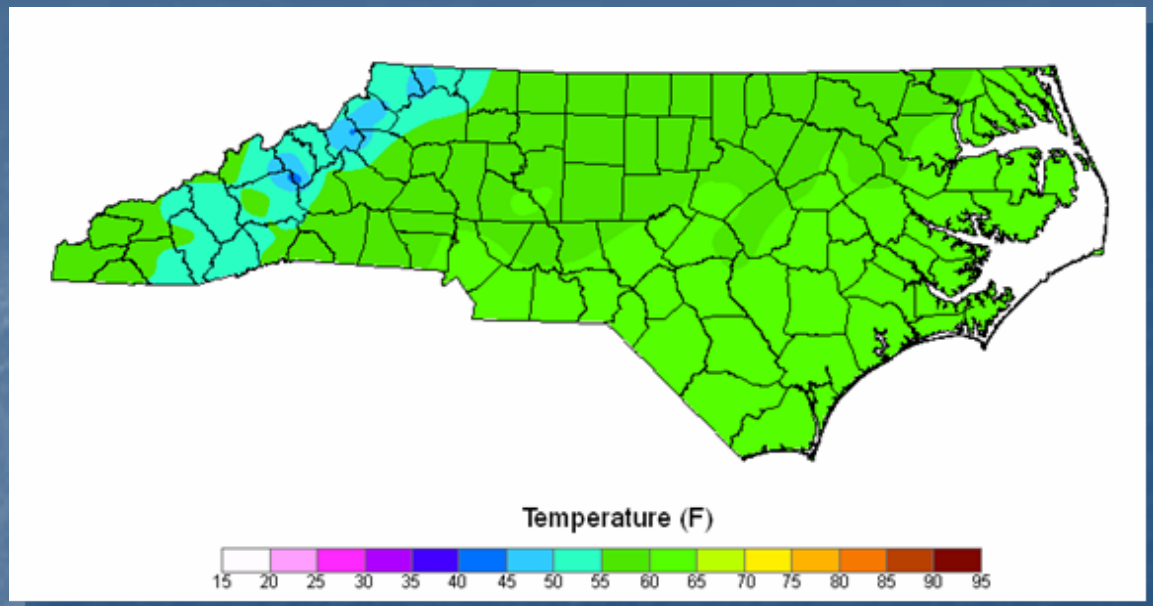
Drought Classifications

- D0 - Abnormally Dry
- D1 - Moderate Drought
- D2 - Severe Drought
- D3 - Extreme Drought
- D4 - Exceptional Drought

Conditions based on input from SCO and NC Drought Management Advisory Council

Way Points

- State Climate Office of NC, brief introduction
- NC teleconnections
- Observing NC climate
- Short term trends in NC climate
- Longer term NC climate trends
- Summary

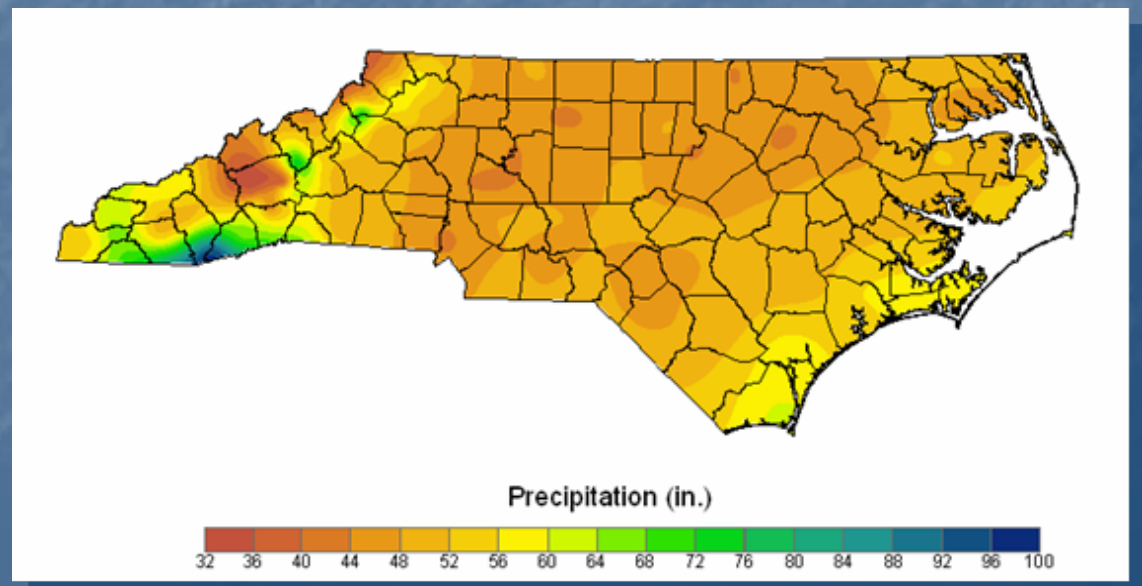


Normal Annual Mean Temperature

(based on 1971-2000 normals)

Normal Annual Precipitation

(based on 1971-2000 normals)



State Climate Office of North Carolina

A Public Service Center for Climate - Environment Interactions

SCO Staff and Students

- Sethu Raman, Director and State Climatologist
- Peter Robinson, NC Climate Program Coordinator
- Ryan Boyles, Associate State Climatologist
- Ameenulla Syed, Instrumentation Meteorologist
- Aaron Sims, Environmental Meteorologist
- Mark Brooks, Environmental Meteorologist
- Ashley Frazier, Meteorologist
- 20 Graduate Students in past 10 years
- 30 Undergraduate Students in past 10 years

History of SCO

1976	SCO established at UNC-CH
1976-1980	Dr. Peter Robinson, *State Climatologist*
1980	SCO transferred to NC State
1981-1996	Dr. Jerry Davis, *State Climatologist*
Sept 1996- *present* ...	Dr. Sethu Raman, *State Climatologist*
October 1998	Public Service Center for Climate – Environment Interactions
Today	**#2 Climate Office in US**

Mission

EXTENSION & OUTREACH

- Provide the most accurate climate information available to the citizens of North Carolina.
- Assist North Carolina state agencies in climate-environment issues and related applications.
- Establish, operate, and maintain an extensive meteorological network across North Carolina and archive and disseminate this data to the public in a timely fashion.
- Assist in applications such as agriculture and environment.
- Increase public awareness of North Carolina climate.

Mission

RESEARCH

- Study North Carolina's climate and its interaction with the environment.
- Investigate the effects of climatic variations on agriculture, air pollution, and natural resources and develop forecast techniques for resource management.

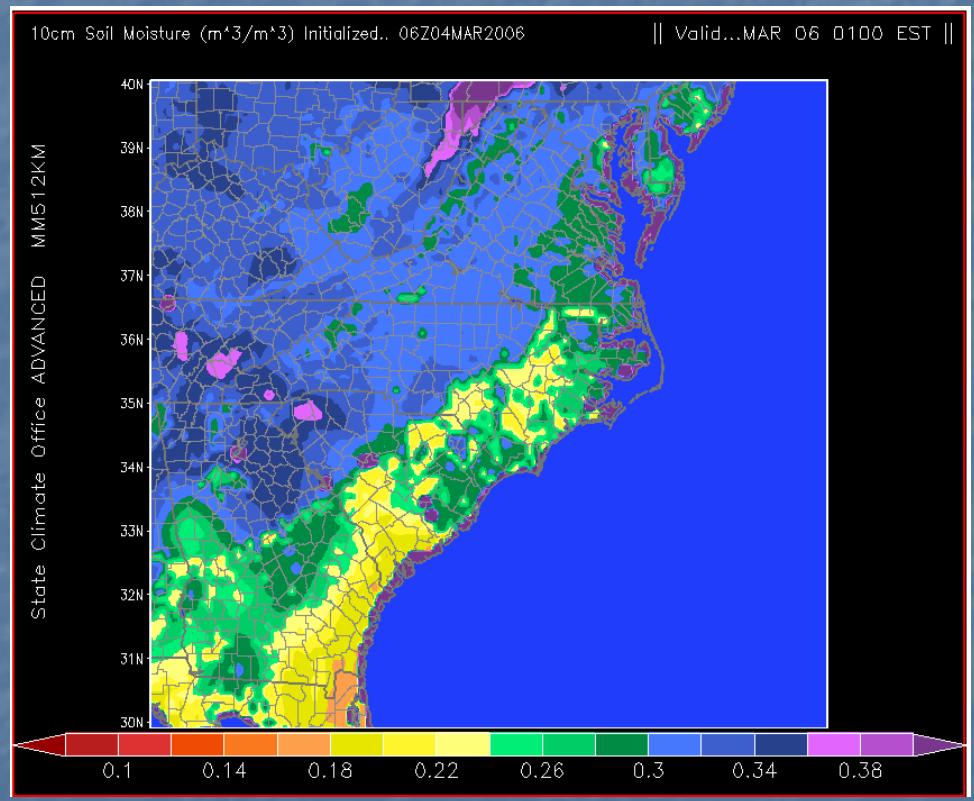
EDUCATION

- Interact with K-12, undergraduate and graduate students, and with community organizations.

Agriculture Outreach

Advisories for crop management

Real-time high resolution weather model for agriculture



Soil moisture forecast for Mar 4, 2006

Partnering with State Agencies

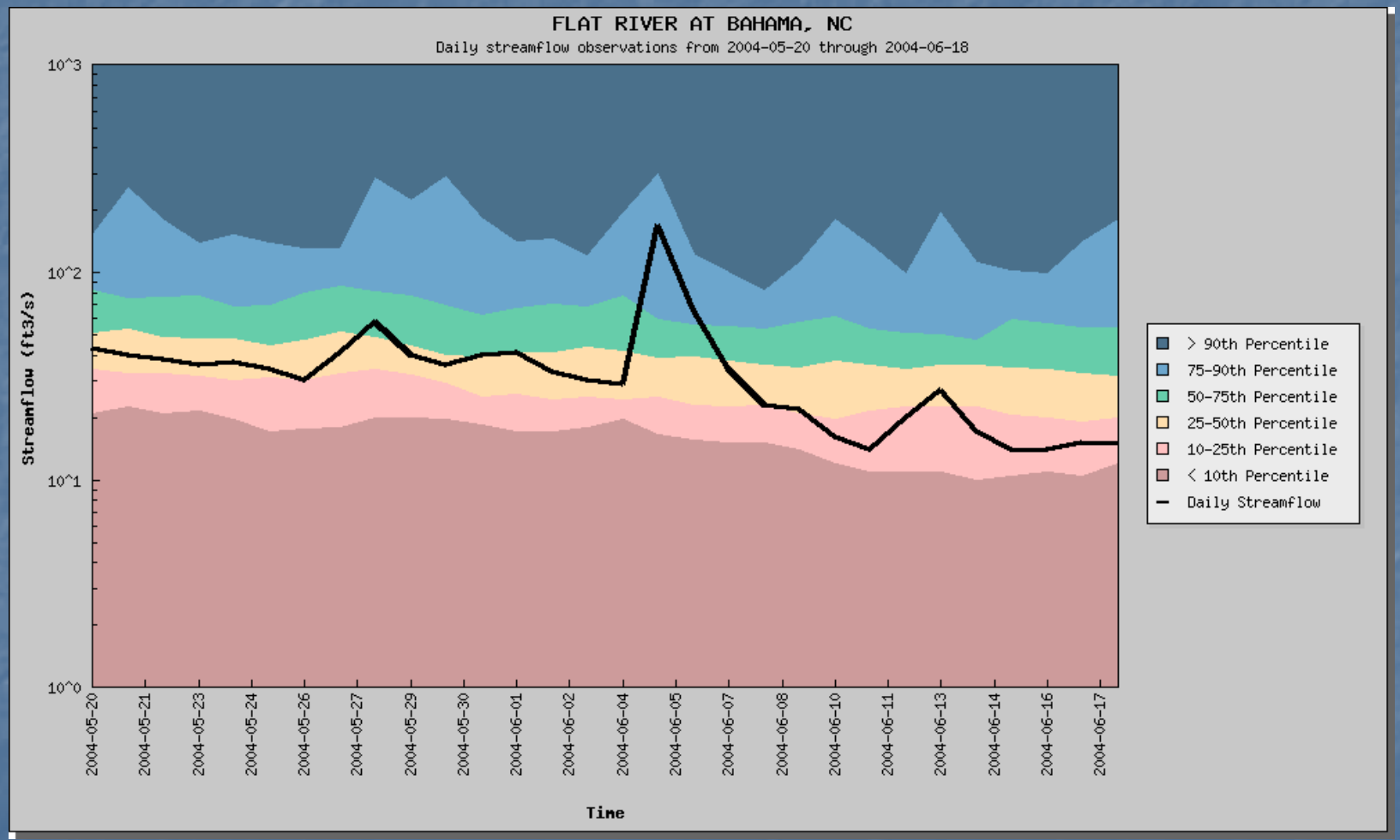
2002 Drought Conference

DENR Air Quality

Install and maintain monitoring sensors needed by DAQ

In 2005, helped DAQ save NC $650 million in federal transportation funds

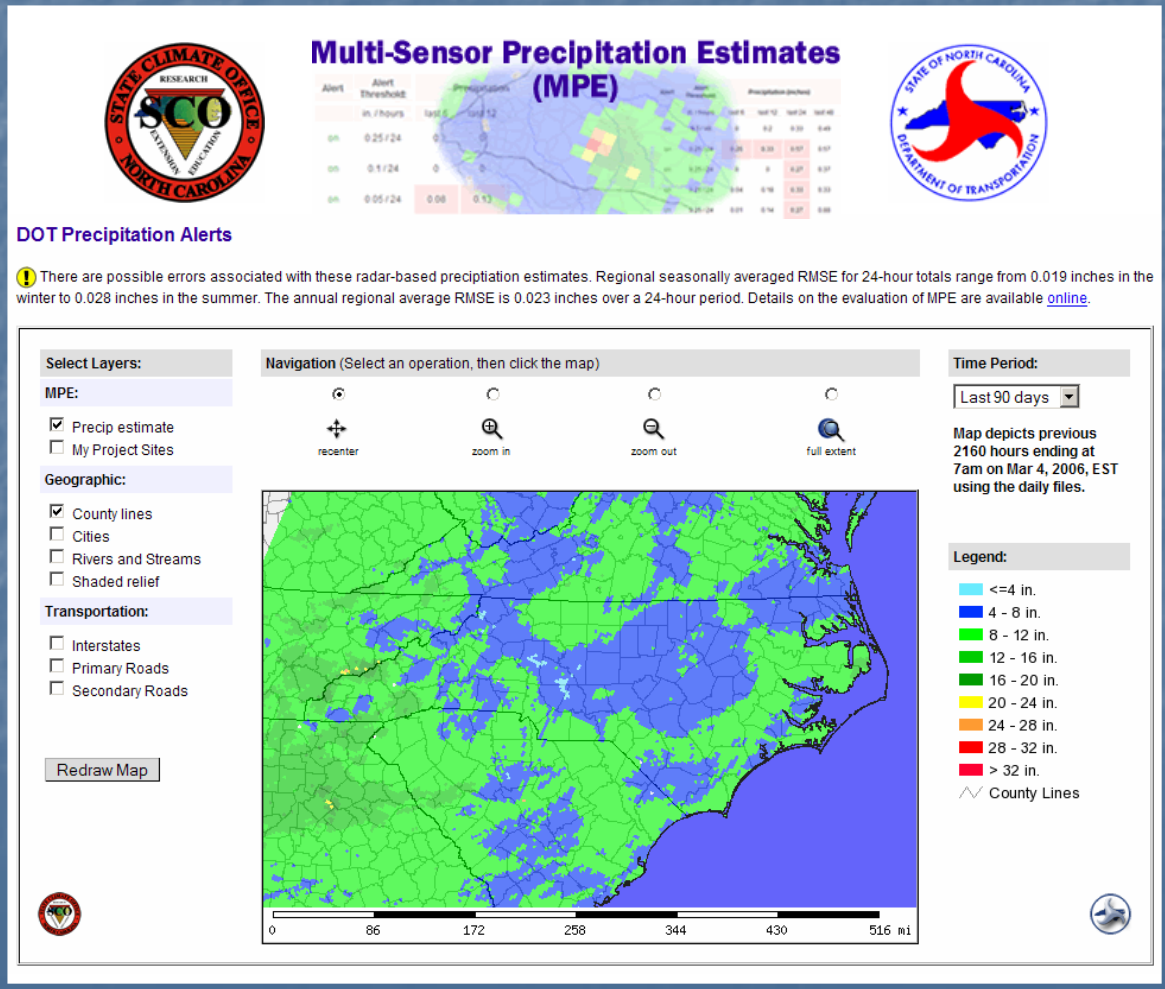
DENR Water Resources



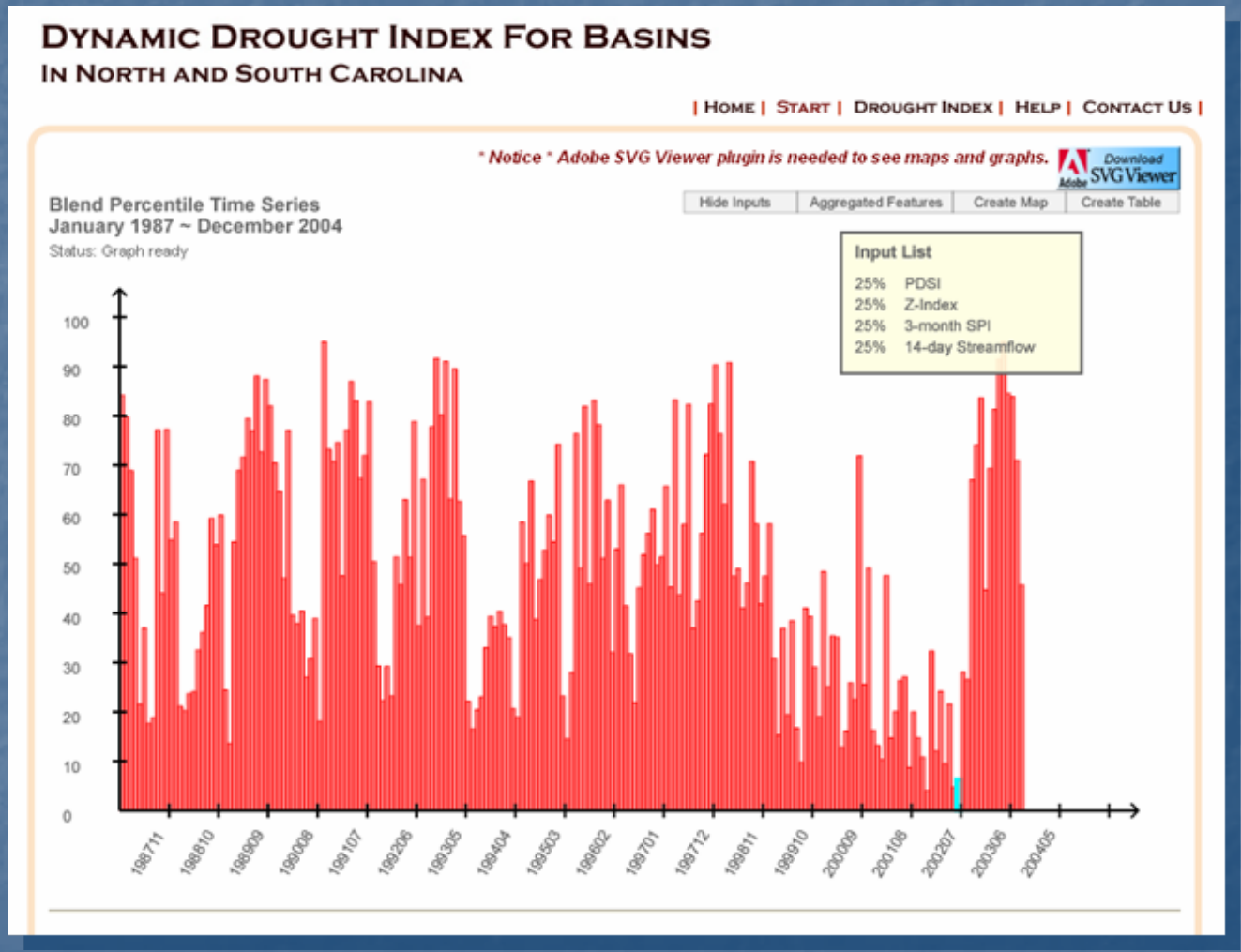
Creating comprehensive water resource database

NC DOT Roadside Environmental Unit

Developing a heavy rainfall alert tool using radar and surface gage data



Duke Power



Improving drought planning in Catawba Basin

NC Electric Cooperatives

Providing climate data for short- and long-term energy planning

New weather monitors at peaking plants in Anson, Richmond Counties

Education

- Education & Training of Undergraduate and Graduate Students

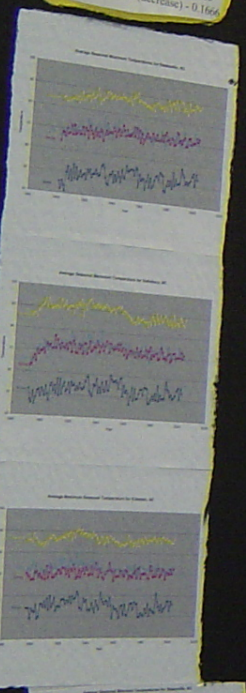
- K-12 Outreach: Classroom presentations, host student interns

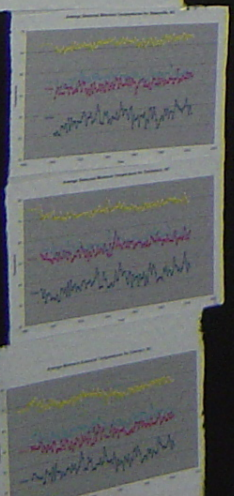
Brad Stackhouse (7th), Rob Collis (8th), Alex Vail (7th), and Melissa Gregory (8th)

WINNER of CCMS 2006 SCIENCE FAIR

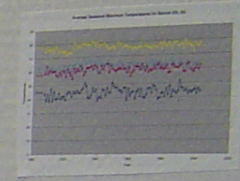
Global Warming & Urban Heating?

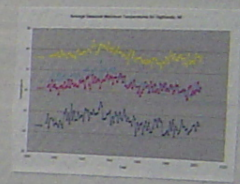
Averages
Major Cities
Maximum Average
Positive Correlation (increase) - 0.375
Even Correlation (unchanged) - 0.3333
Negative Correlation (decrease) - 0.2916
Minimum Average
Positive Correlation (increase) - 0.5833
Even Correlation (unchanged) - 0.25
Negative Correlation (decrease) - 0.1666

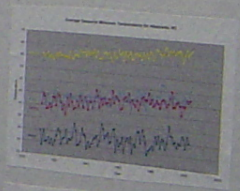


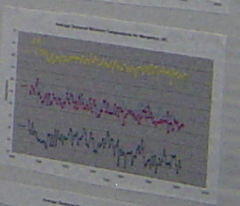


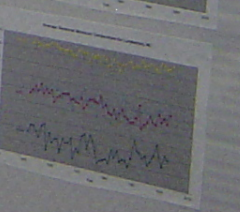
Averages
Smaller Cities
Maximum Average
Positive Correlation (increase) - 0.575
Even Correlation (unchanged) - 0.25
Negative Correlation (decrease) - 0.5
Minimum Average
Positive Correlation (increase) - 0.25
Even Correlation (unchanged) - 0.25
Negative Correlation (decrease) - 0.5











Problem
How have average monthly minimum and maximum temperatures changed over the last one hundred years? Are the changes a result of *global warming*? Does *urban heating* play a role in the temperature changes?

Research
- In Asheville, average annual temperatures have declined 1.1°F since 1946.
- Difficult to distinguish between climate noise and rise in global temperature.
- The second hottest year on record was 2005.
- With the exception of 1996 & 2000, the last 10 years (1996-2005) have been the warmest years on record.
- Average maximum temperatures at airports in North Carolina were between 1.5% and 3.1% higher than the historical baseline.
- Average minimum temperatures at airports in North Carolina were between 0.4% and 6.0% higher than the historical baseline.

Hypothesis
We believe that we will find that average monthly minimum and maximum temperatures have increased moderately over the last one hundred years. We do believe that this is a result of *global warming* as well as *urban heating*. Moreover, we believe that we will find that temperatures have increased more around larger, more populated cities in North Carolina while the smaller, less populated cities' temperatures have not increased as much.

Materials
- US HCN Monthly Data
- Data
- Graphs
- Tri-fold Poster
- Glue

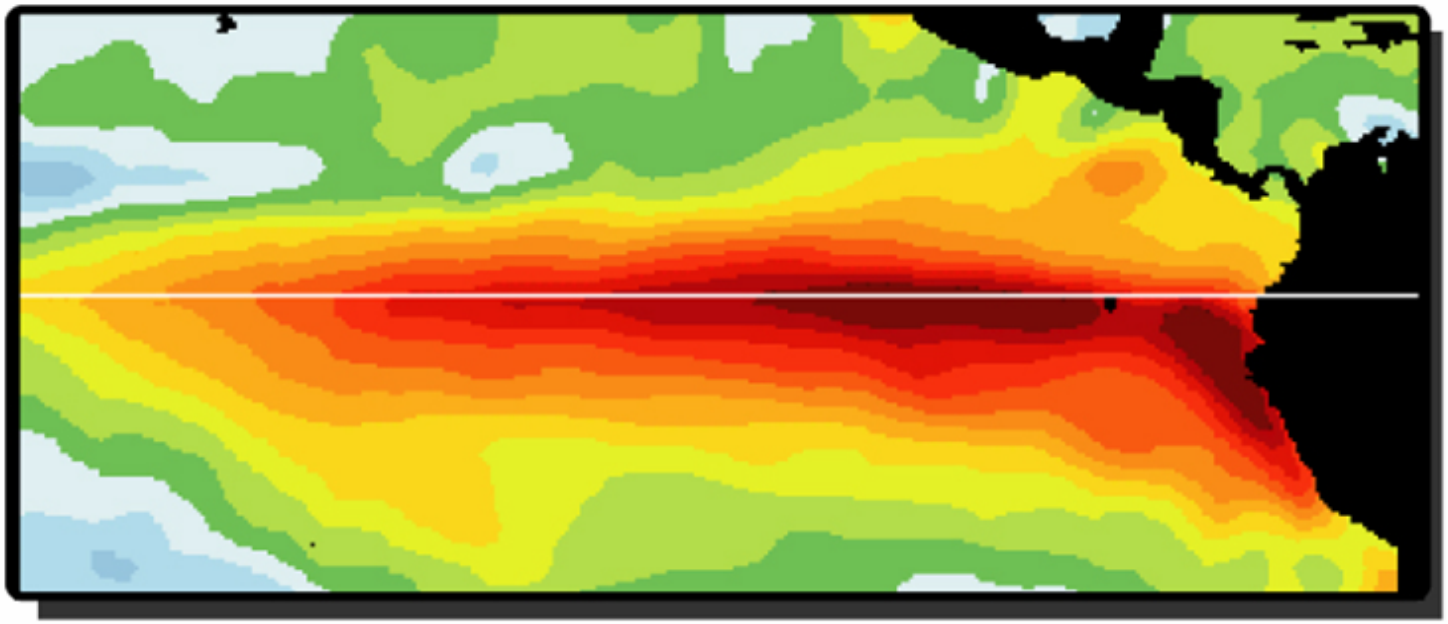
Procedure
1) Collect data.
2) Graph data.
3) Analyze graphs.
4) Record observations and compare with research.
5) Draw conclusions from observations.
6) Put together presentation.

Results
- Positive correlations are most common in both minimum and maximum averages for major cities.
- Even correlations and negative correlations are equally common in minimum and maximum averages for major cities.
- Positive correlations are most common in the maximum averages only.
- Positive correlations are equally common with even correlations in the minimum averages.
- Even correlations are least common in the maximum averages.
- Even correlations are equally common with positive correlations in the minimum averages.
- Negative correlations are second most common in the maximum averages but single most common in minimum averages.

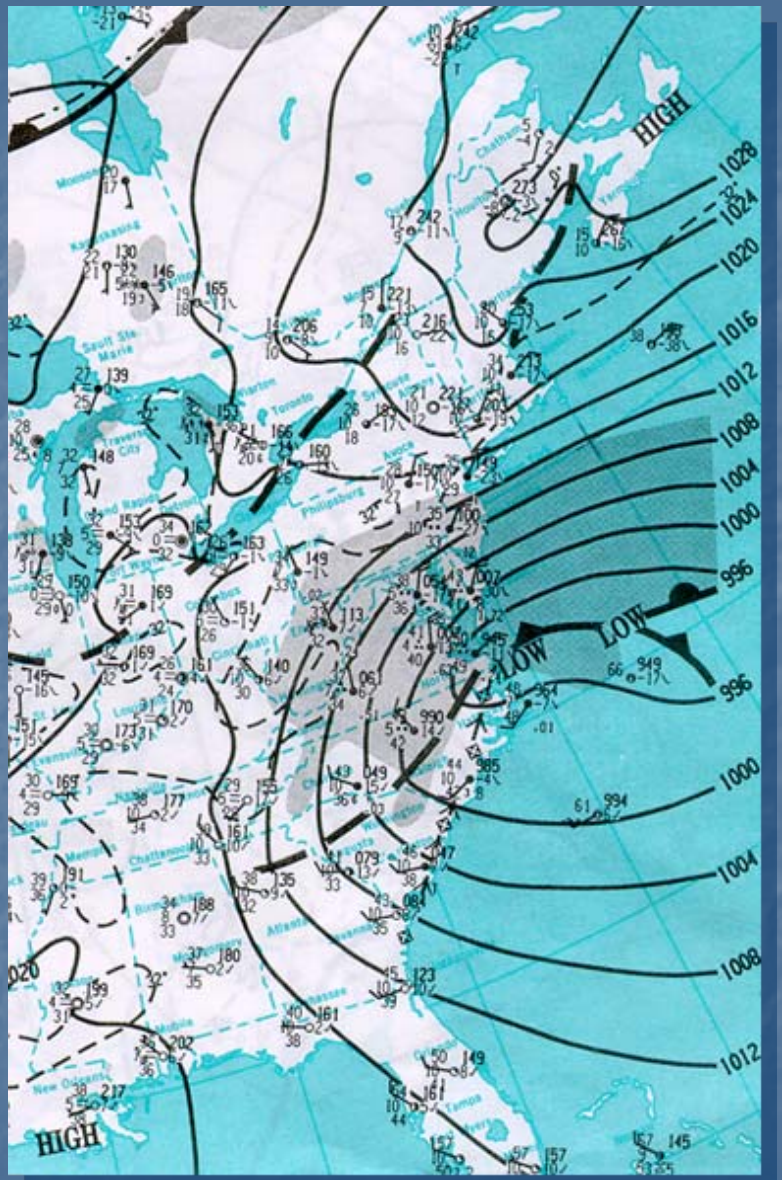
Conclusion
We found our hypothesis to be **almost** true. Major cities' temperatures have increased as we predicted, as have temperatures in smaller cities.

Global Teleconnections and North Carolina

El Nino / Southern Oscillation



El Niño is the abnormal warming of ocean temperatures in the eastern tropical Pacific Ocean. La Niña is the opposite - the cooling of ocean temperatures in the tropical Pacific. These patterns, which occur every 2- 7 years, affect the climate in North Carolina.



Surface Weather Map @ 7:00 AM EST Jan 28, 1998

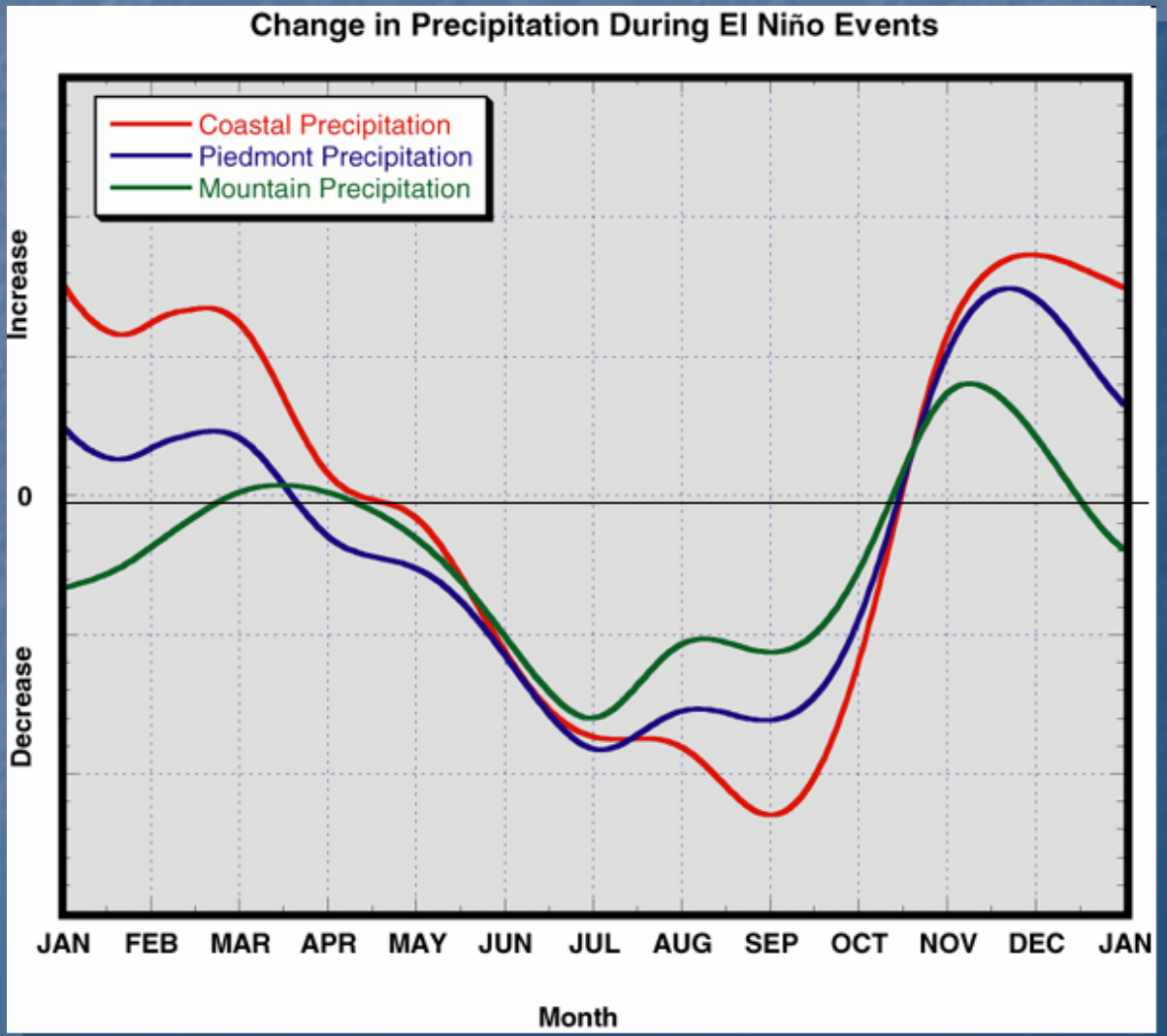
Winter Storm Frequency

Average Number of Strong Winter Storms during December through February

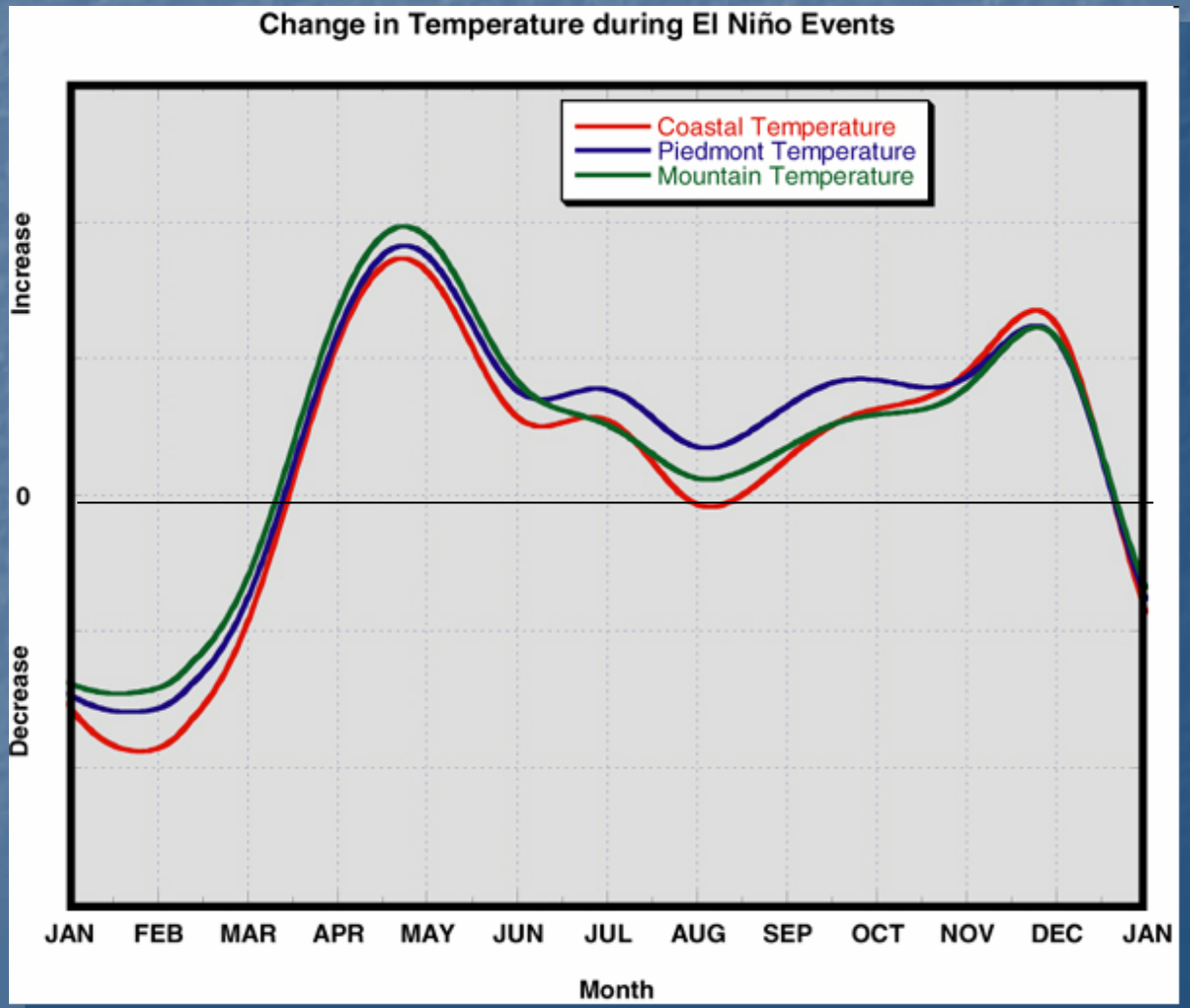
El Niño Year	Non-El Niño
12	5

This classic “Nor’easter” quickly formed off the coast of North Carolina January 27-28, 1998. The storm dumped up to 40 inches of snow in the mountains of North Carolina and over 2 inches of rain along the coast.

ENSO Affects NC Precipitation

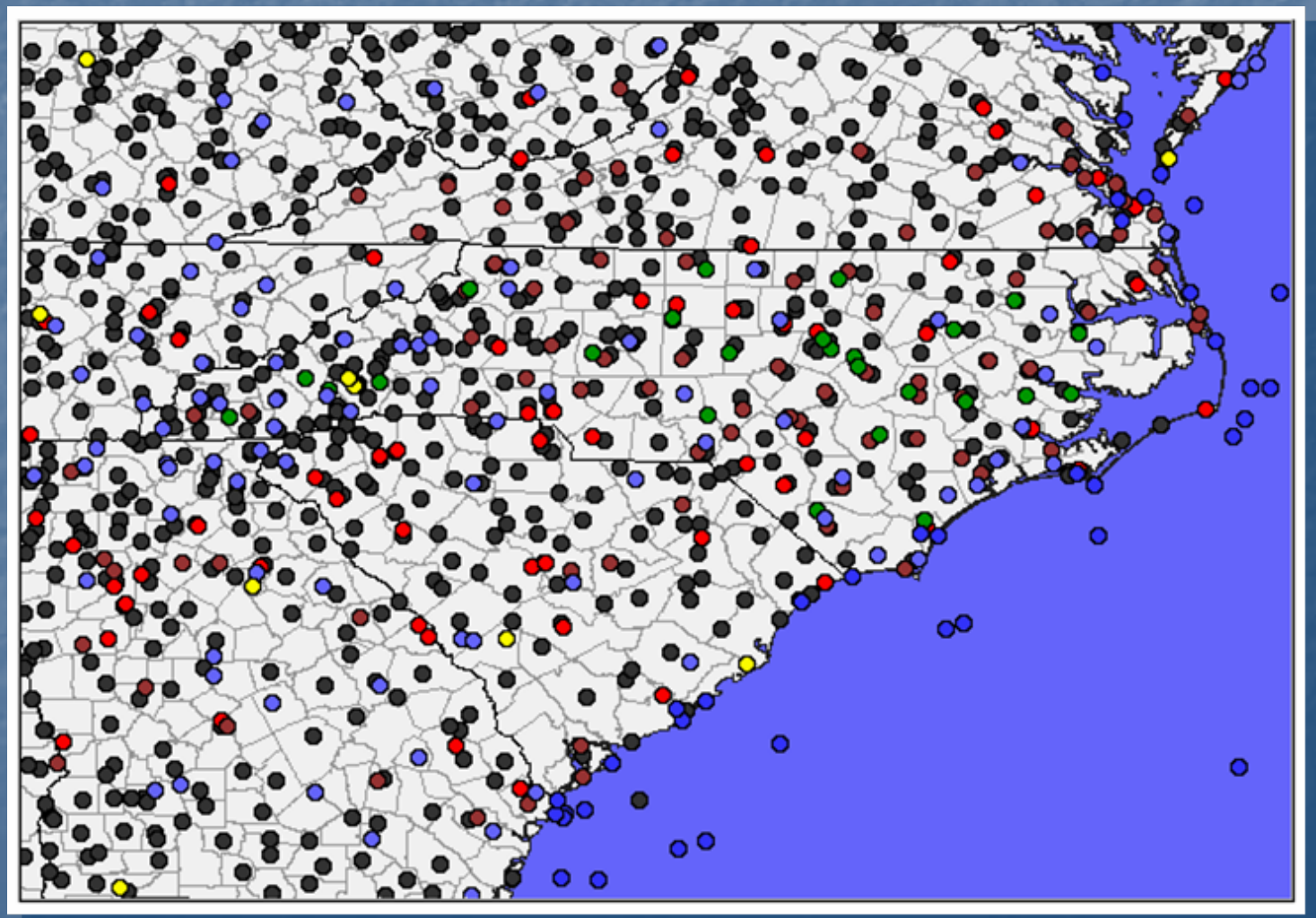


ENSO Affects NC Temperatures

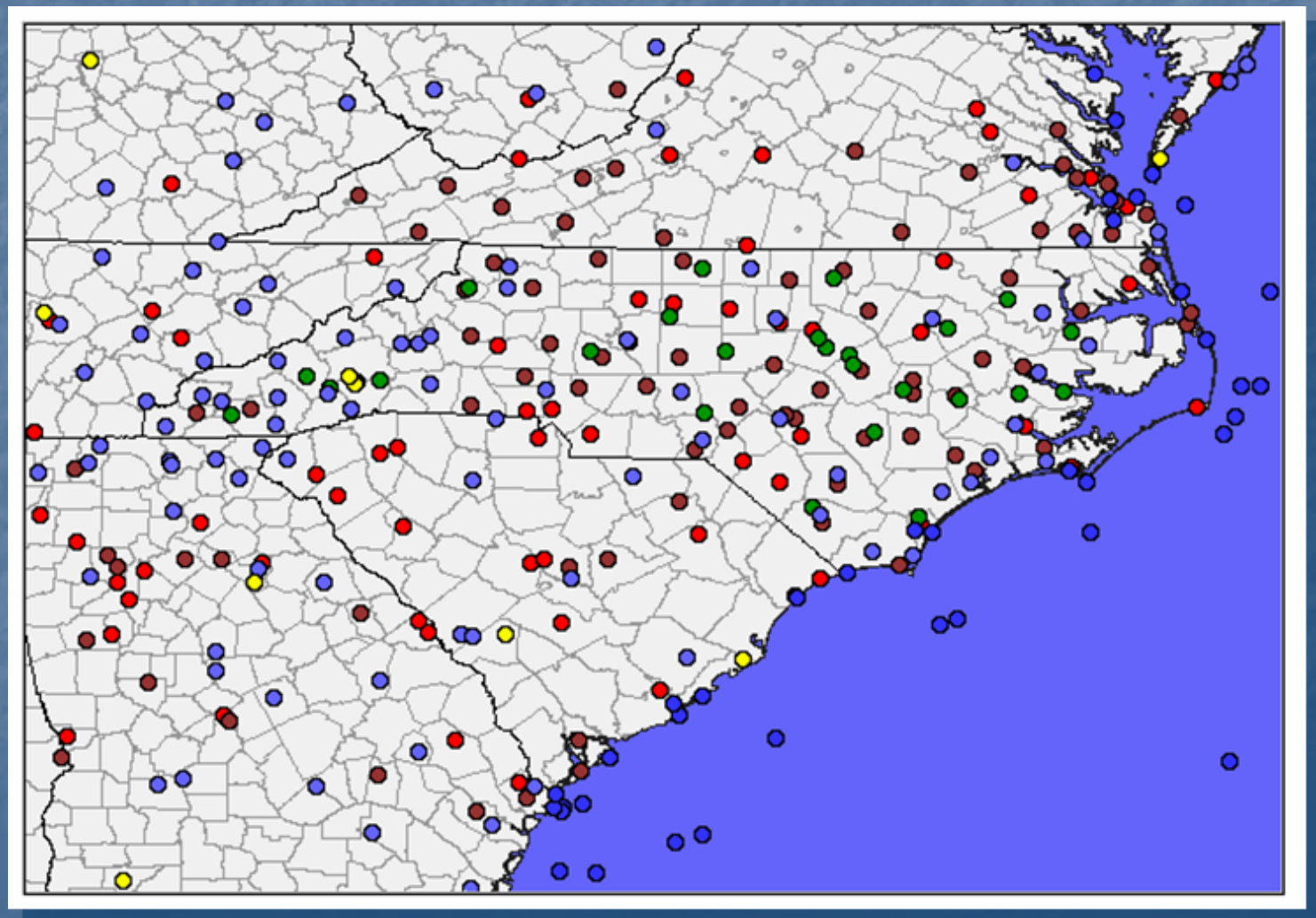


Observing North Carolina Climate

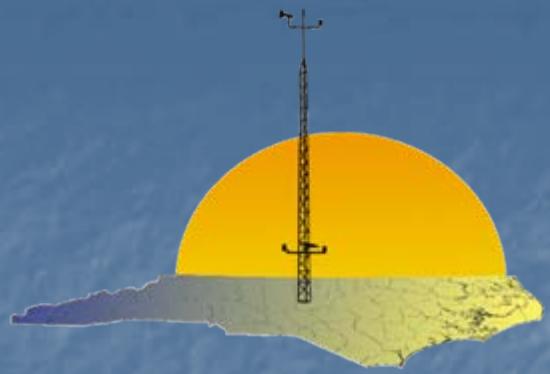
Observations from >1000 Active Stations



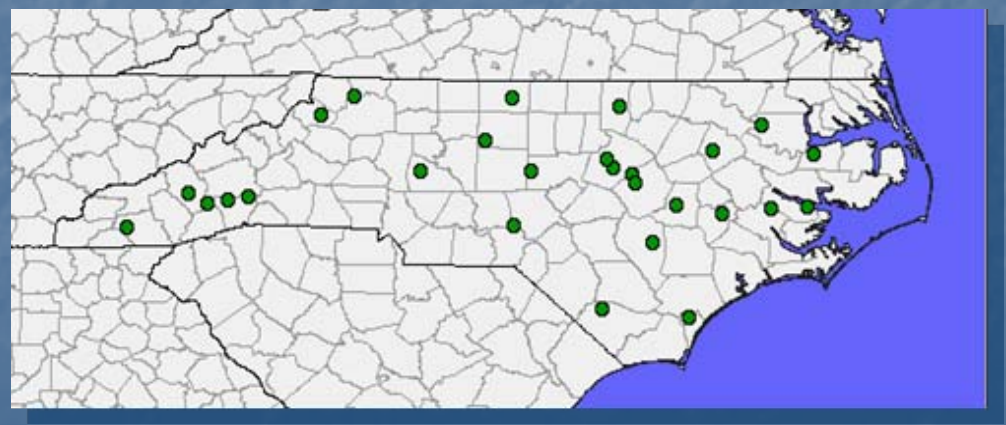
Hourly Data from >200 Sites



NC ECONet



N*orth*
C*arolina*
E*nvironment &*
C*limate*
O*bserving*
Net *work*



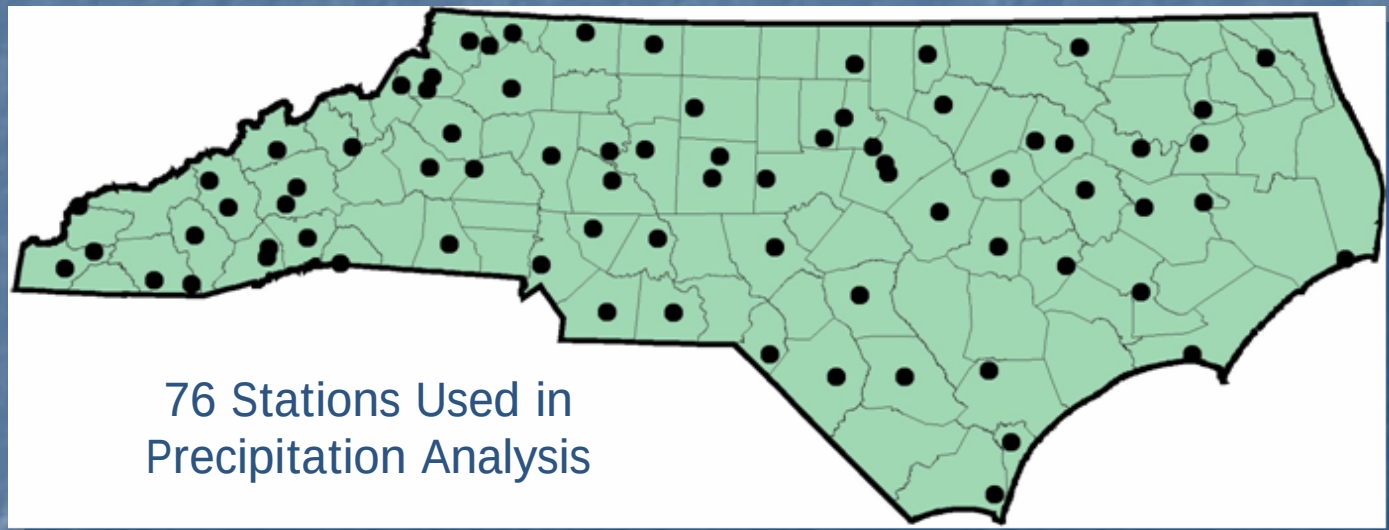
Concept….

- Provide unique measurements – soil temperature, soil moisture, solar radiation, evaporation
- An advanced, state-of-the-art network for climate and environmental observations.
- The NC ECONet, in its full capacity, will have more than 100 weather and environmental observing stations across North Carolina with a minimum of one per county!

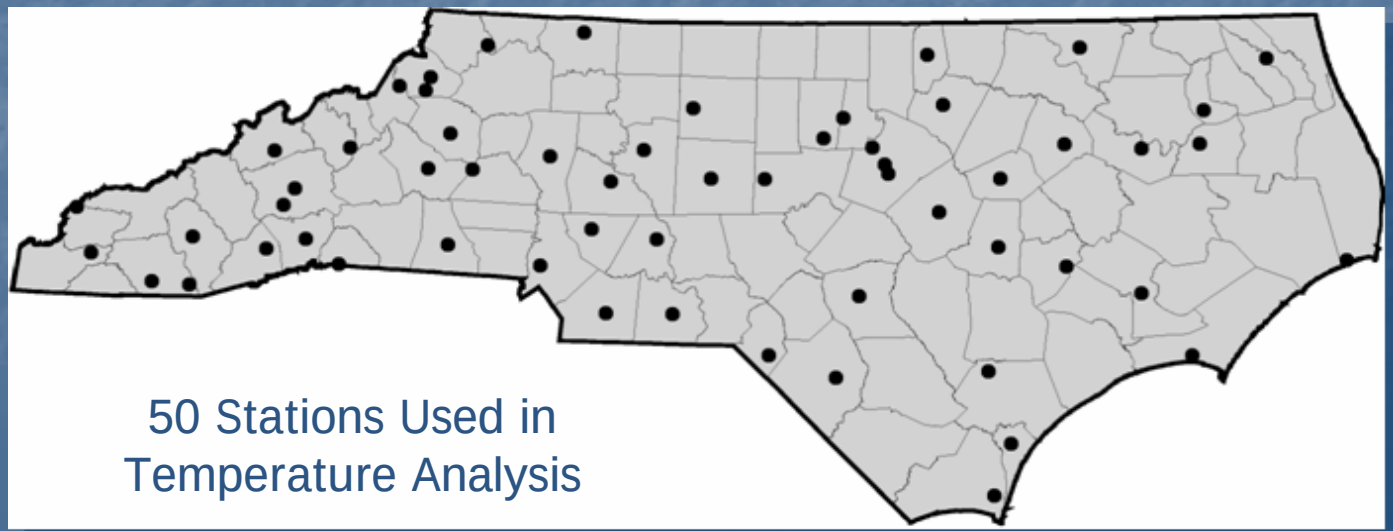
10 m Towers and Sensors at International Standards

Climate Variations over the past 50 years

Temperature & Precipitation 1949-1998



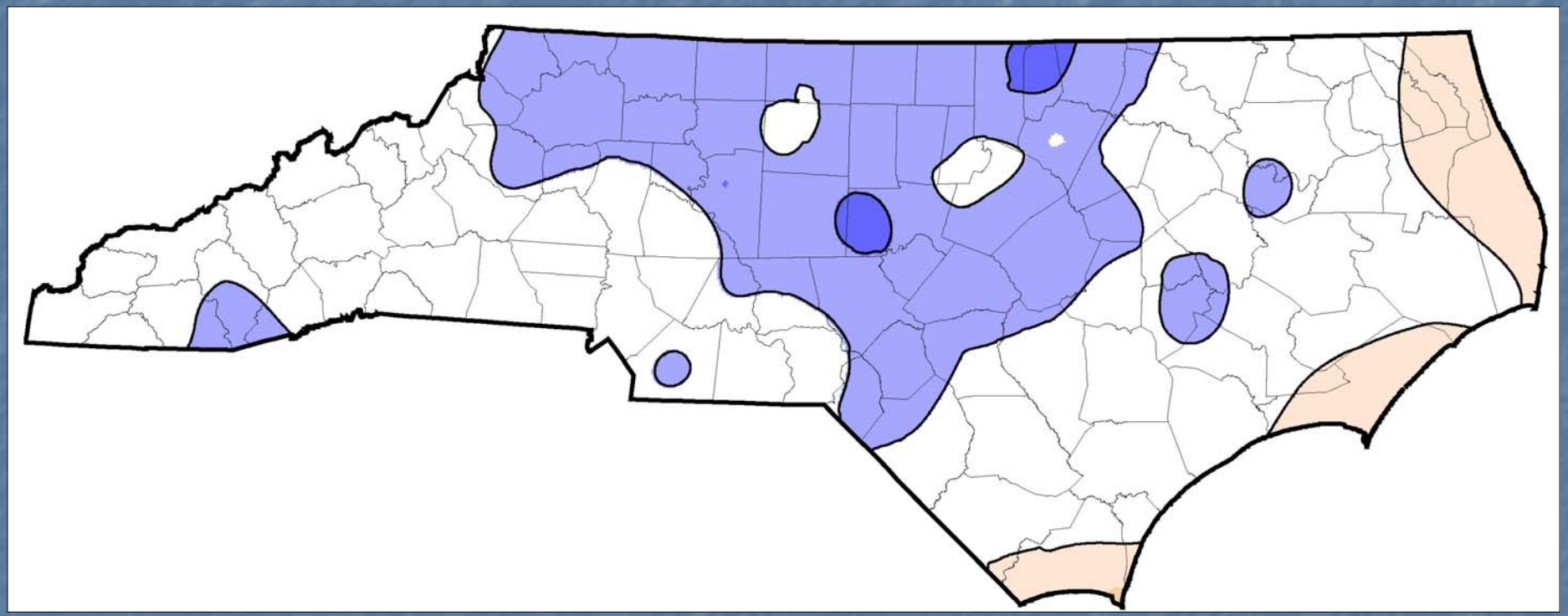
76 Stations Used in Precipitation Analysis



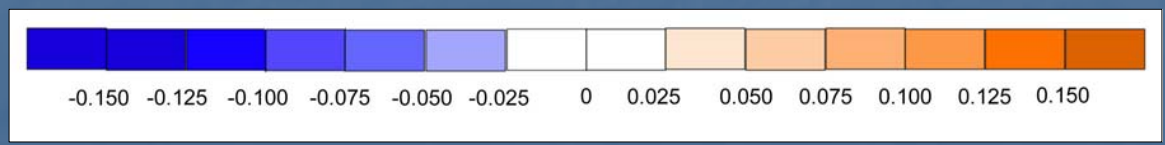
50 Stations Used in Temperature Analysis

Maximum Temperature Trends

Annual Maximum Temperature Trends

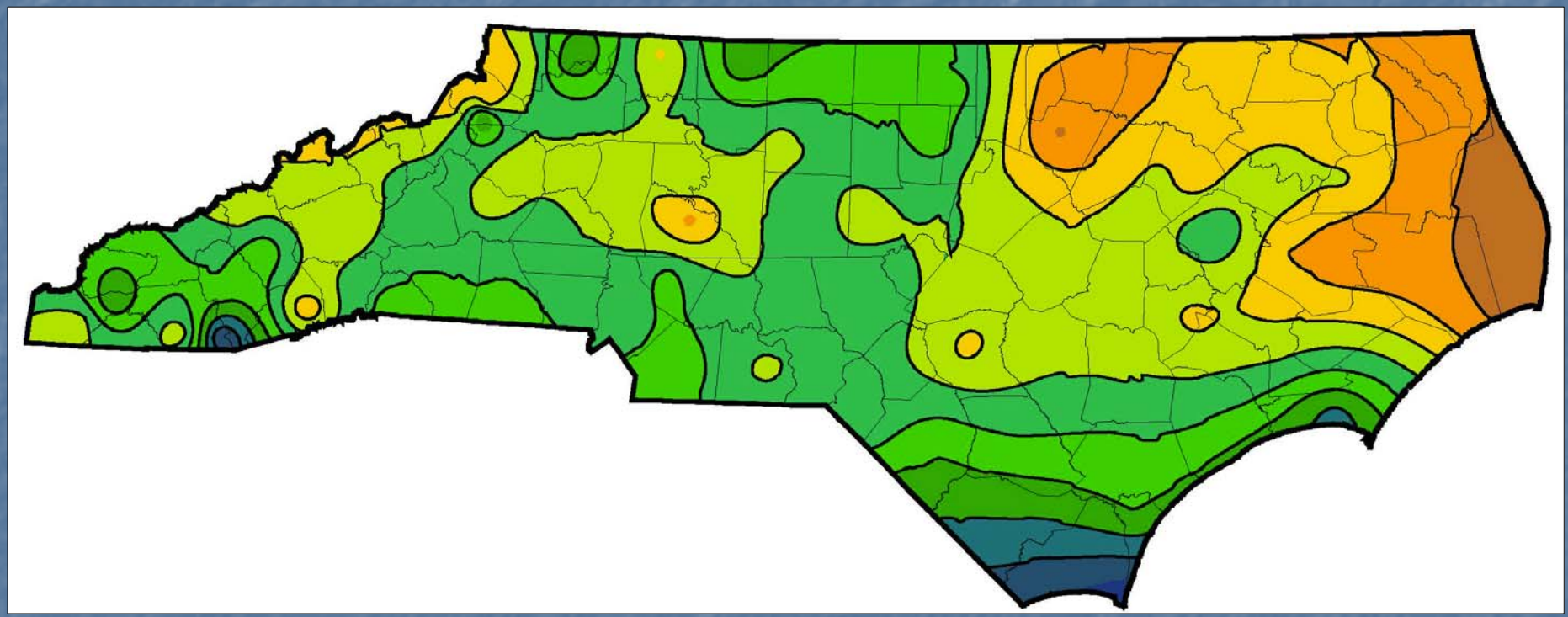


Temperature change in degrees Fahrenheit per year

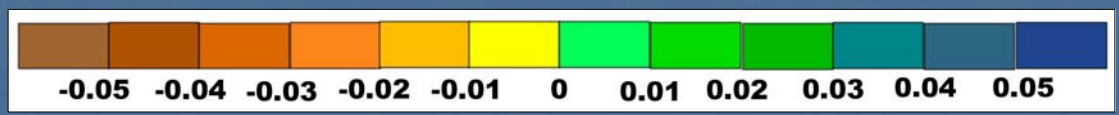


Precipitation Trends

Annual Precipitation Trends



Precipitation change in inches per year

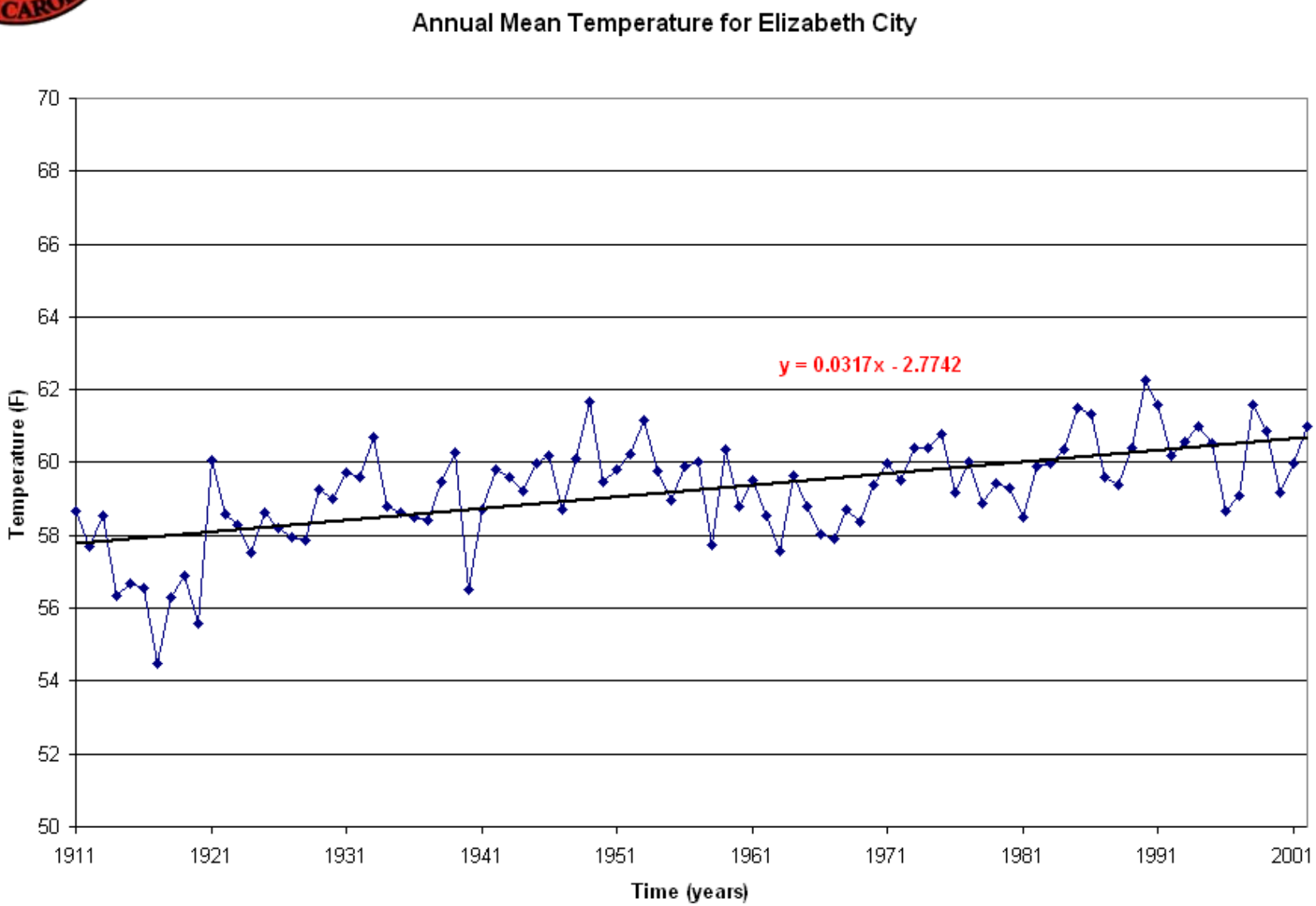


Historical Climate Network
25 stations in NC

Stations Analyzed

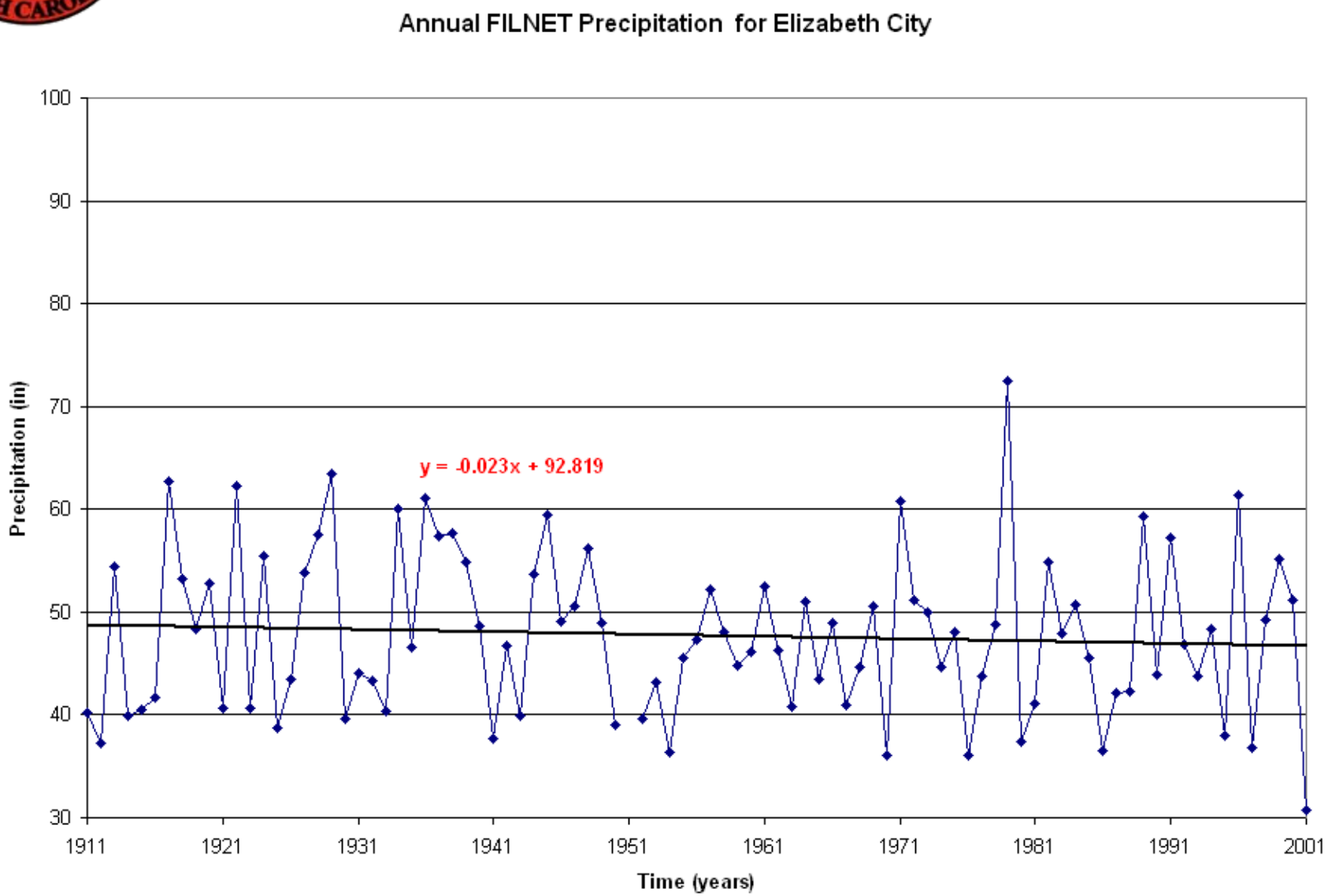
Coastal: Elizabeth City (Mean T)

~3.17°F increase over 100 years



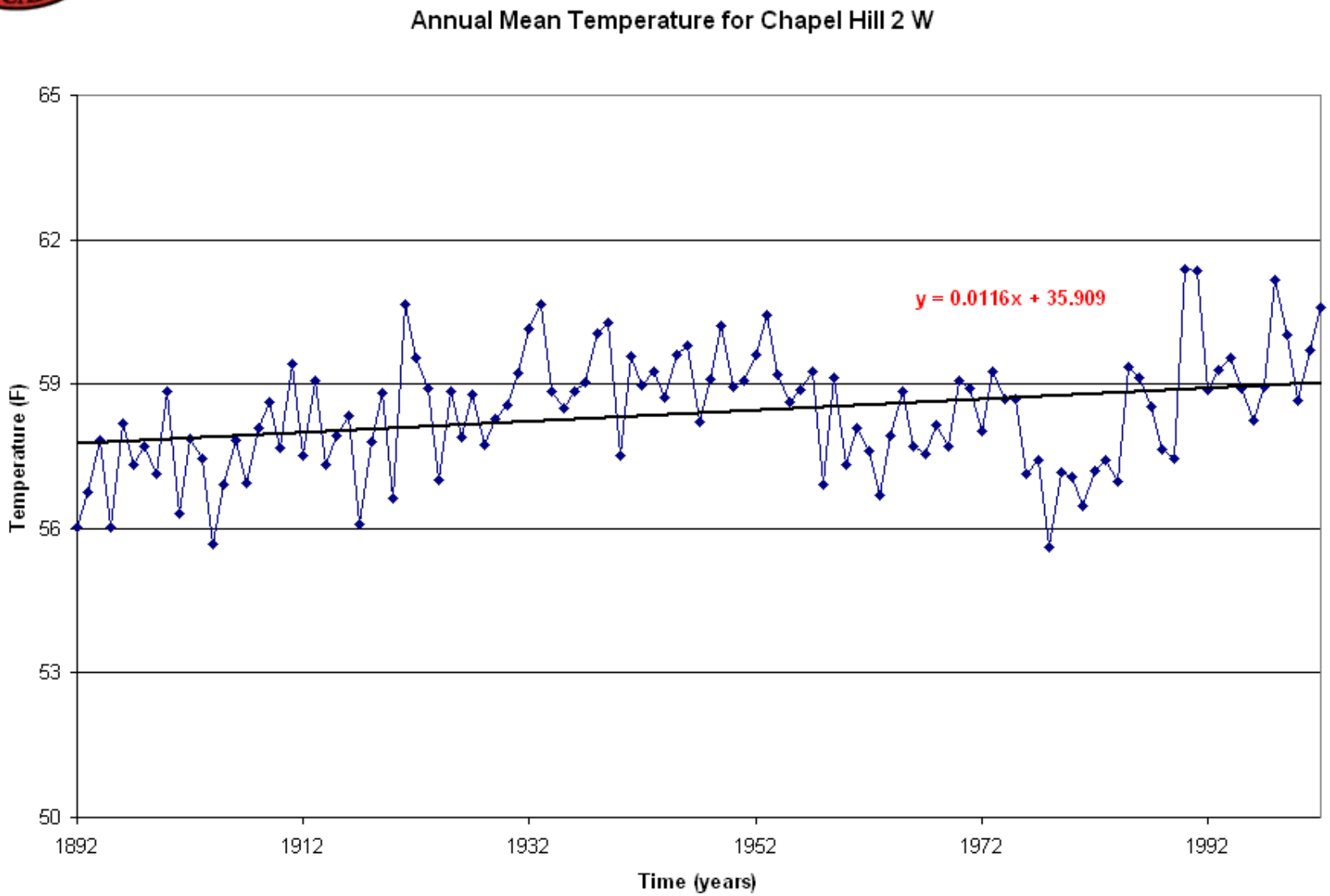
Coastal: Elizabeth City (Annual)

~2.3 in decrease over 100 years



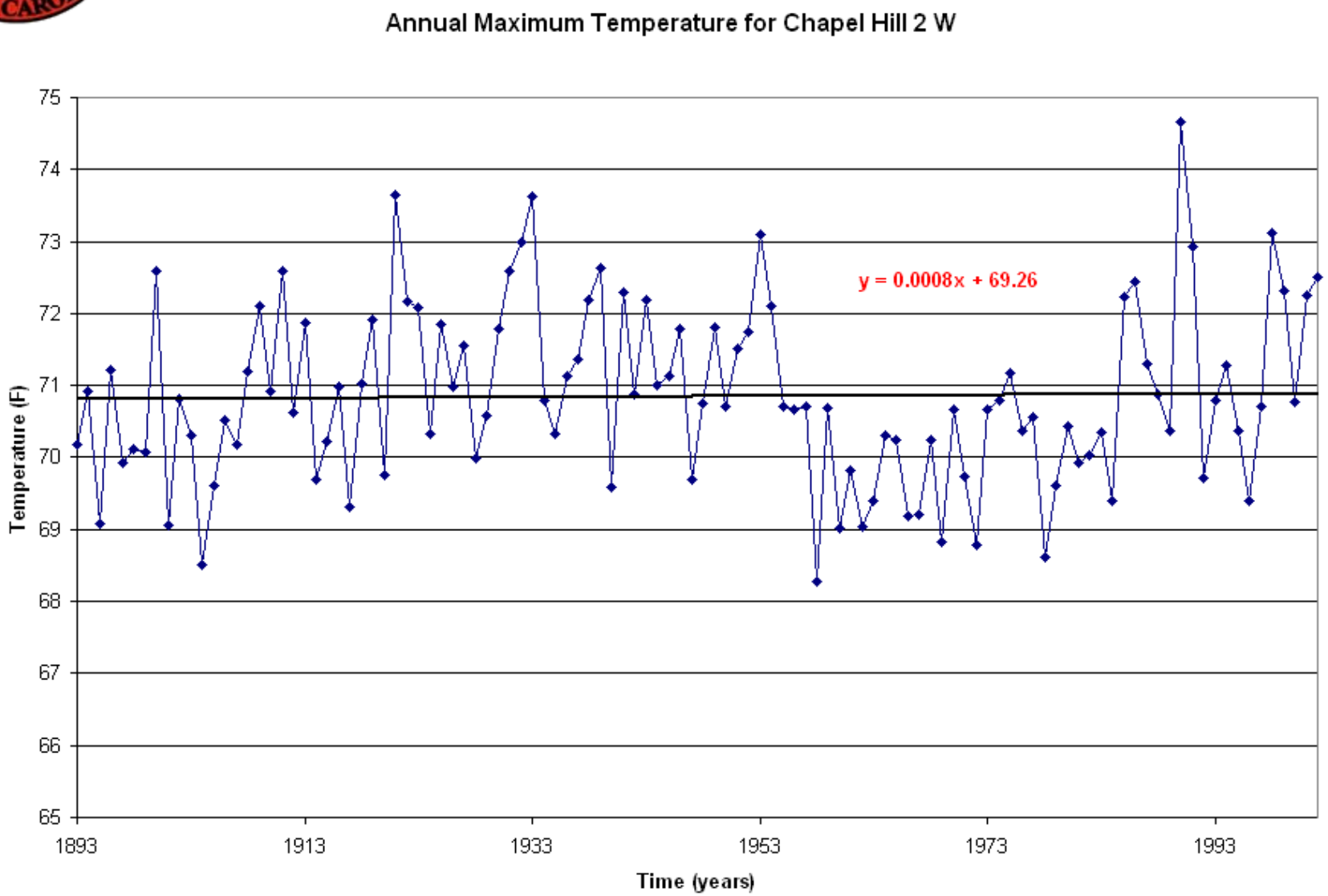
Piedmont: Chapel Hill 2 W (Mean T)

~1.16°F increase over 100 years



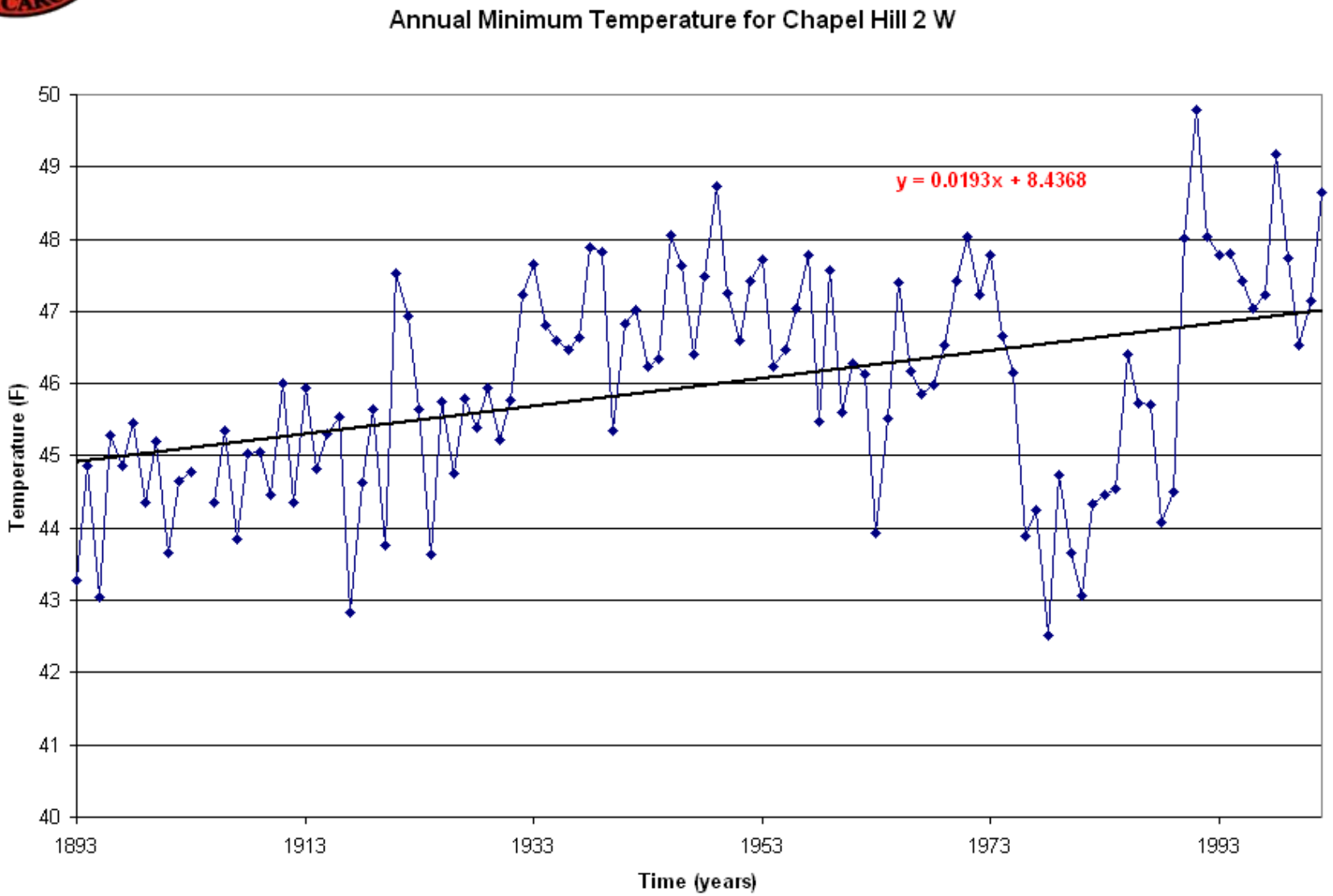
Piedmont: Chapel Hill 2 W (Maximum T)

~0.08ºF increase over 100 years



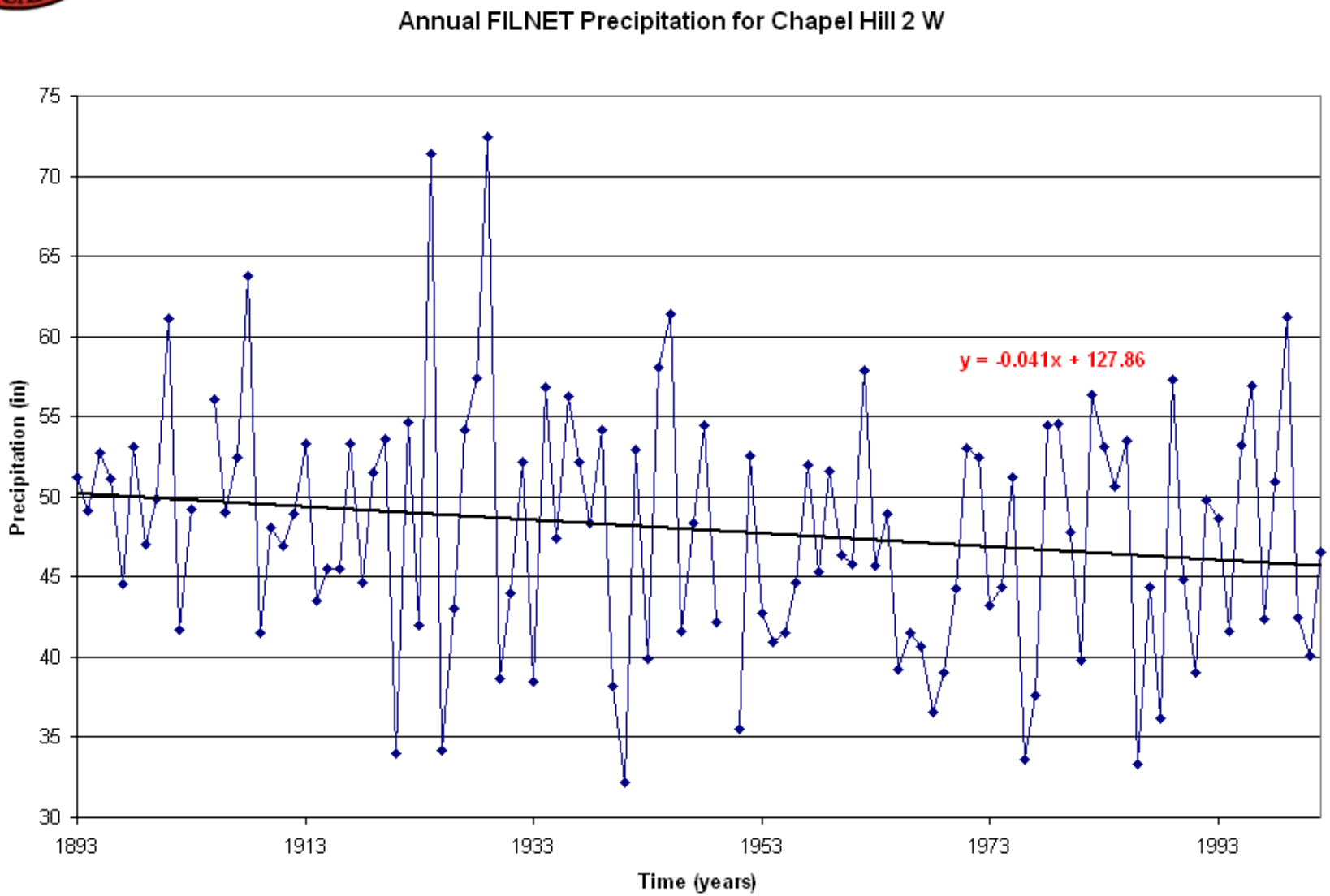
iedmont: Chapel Hill 2 W (Minimum T)

~1.93ºF increase over 100 years



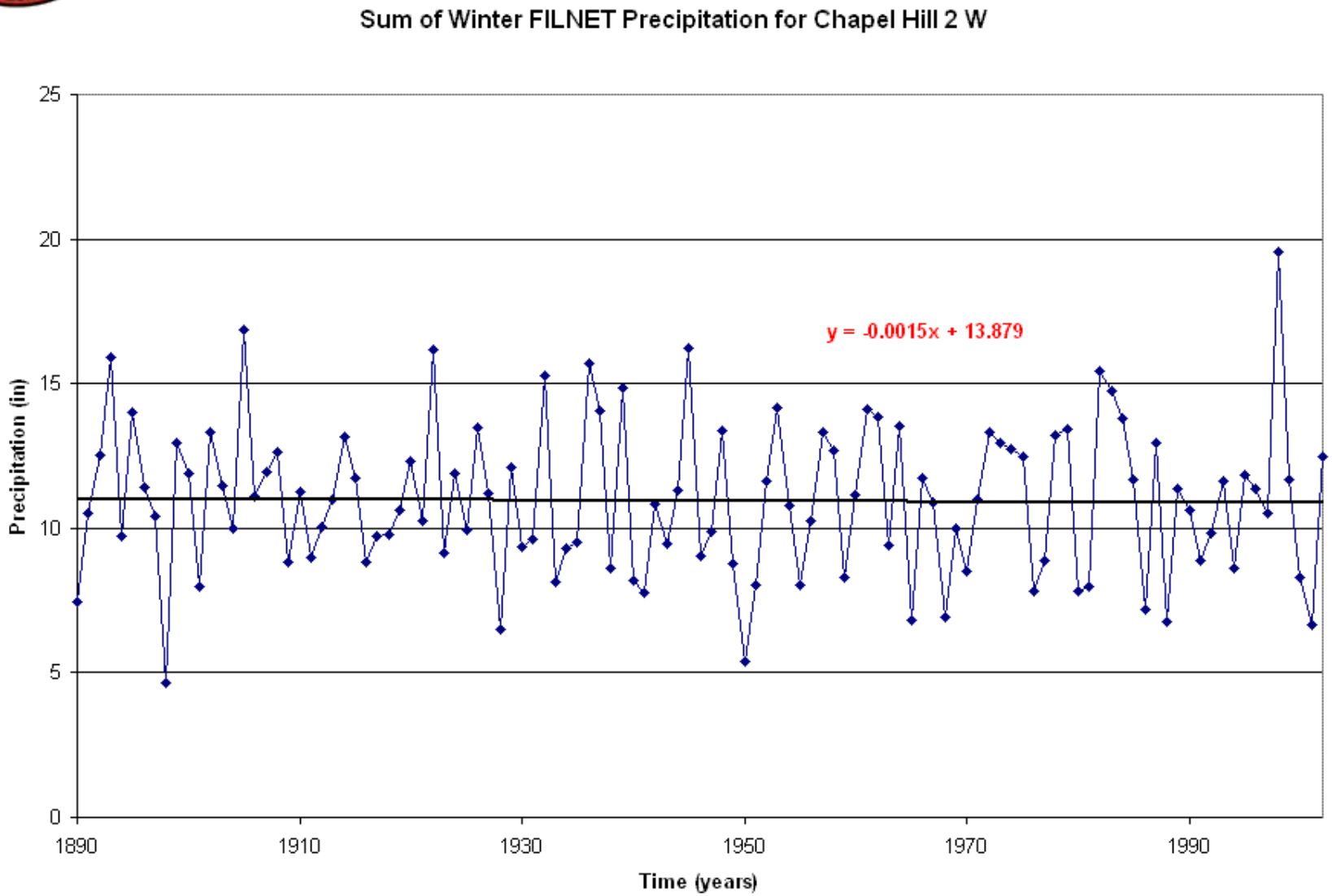
Piedmont: Chapel Hill 2 W (Annual)

~4.1 in decrease over 100 years



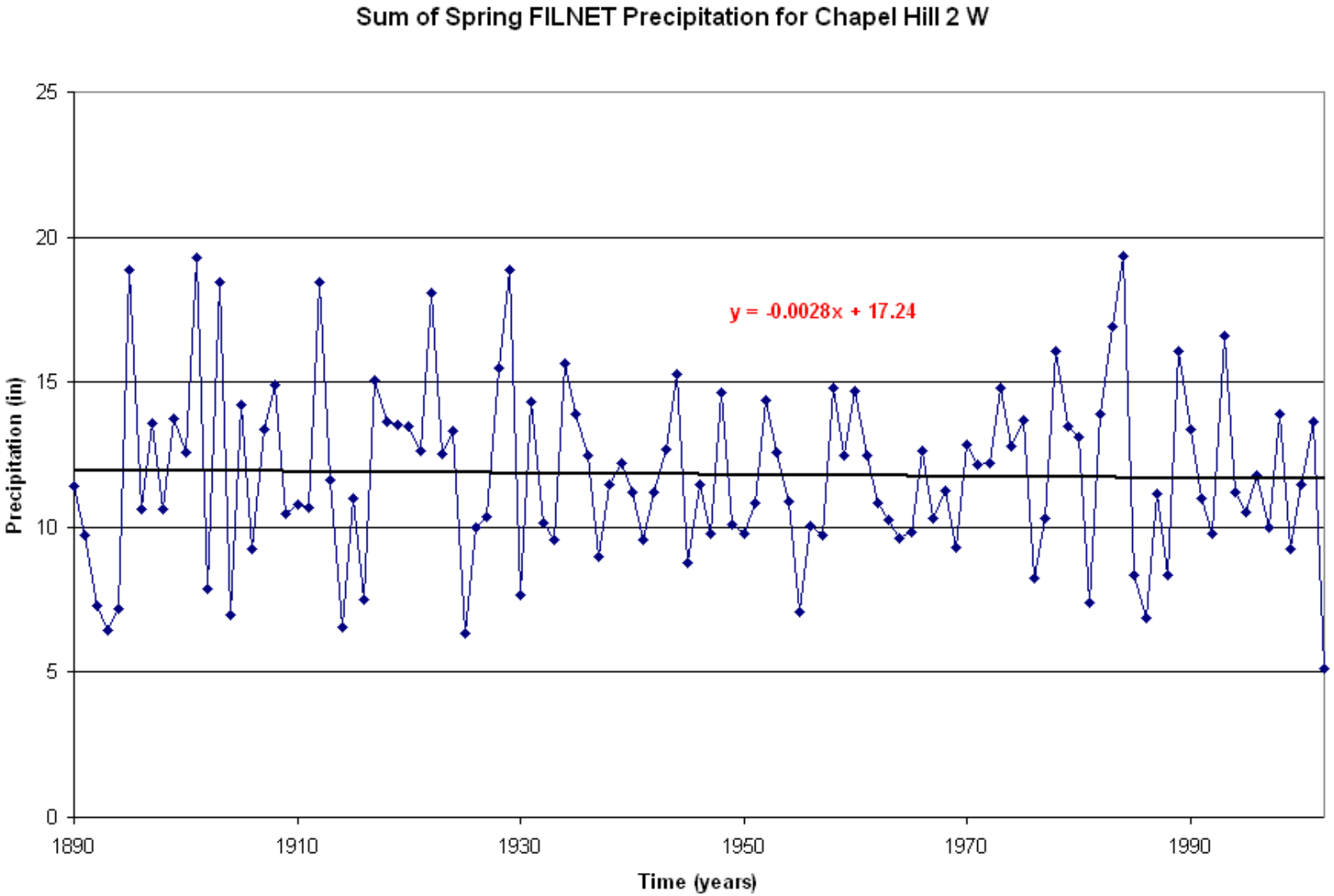
Piedmont: Chapel Hill 2 W (Winter Precip)

~0.15 in decrease over 100 years



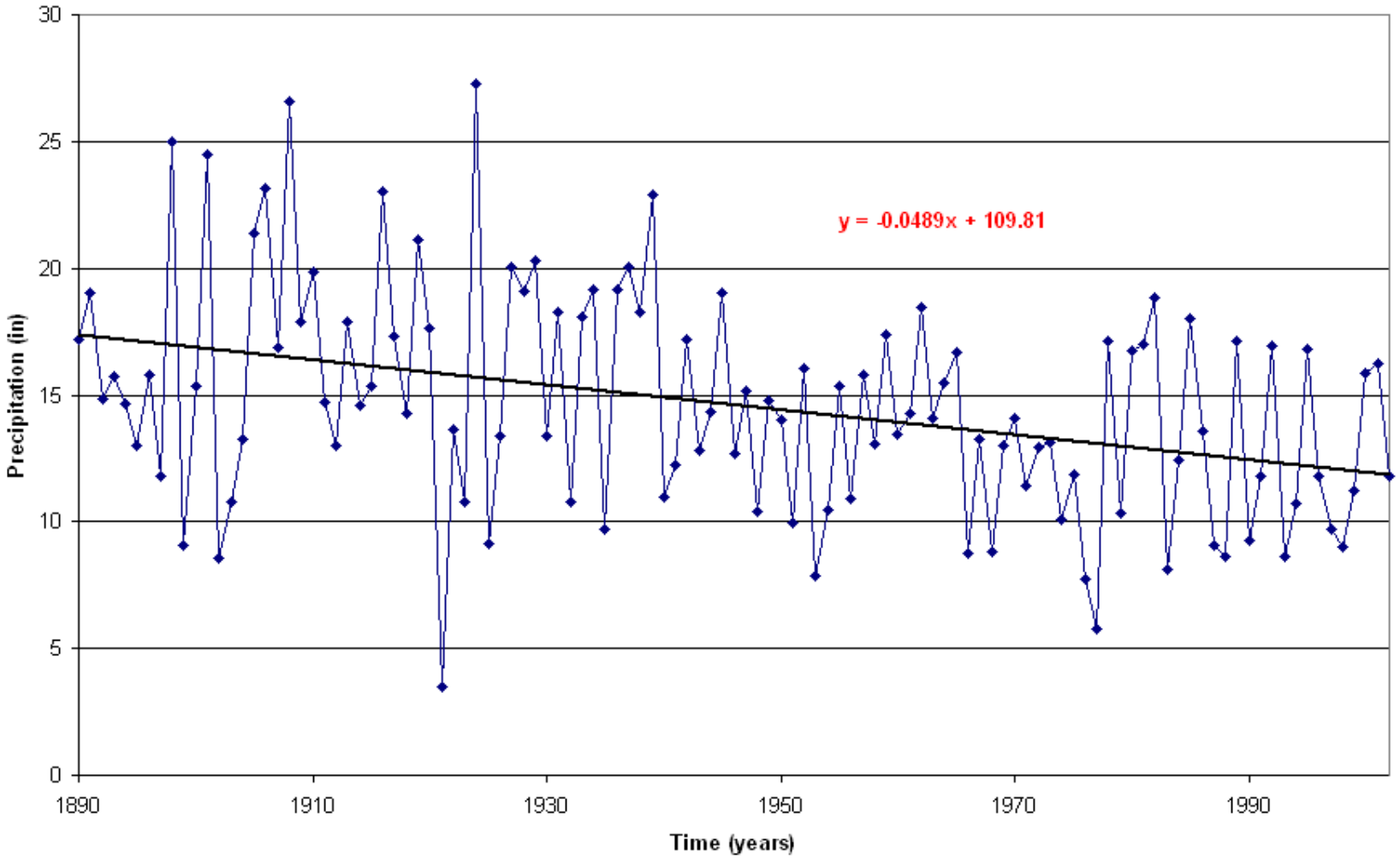
Piedmont: Chapel Hill 2 W (Spring)

~0.28 in decrease over 100 years



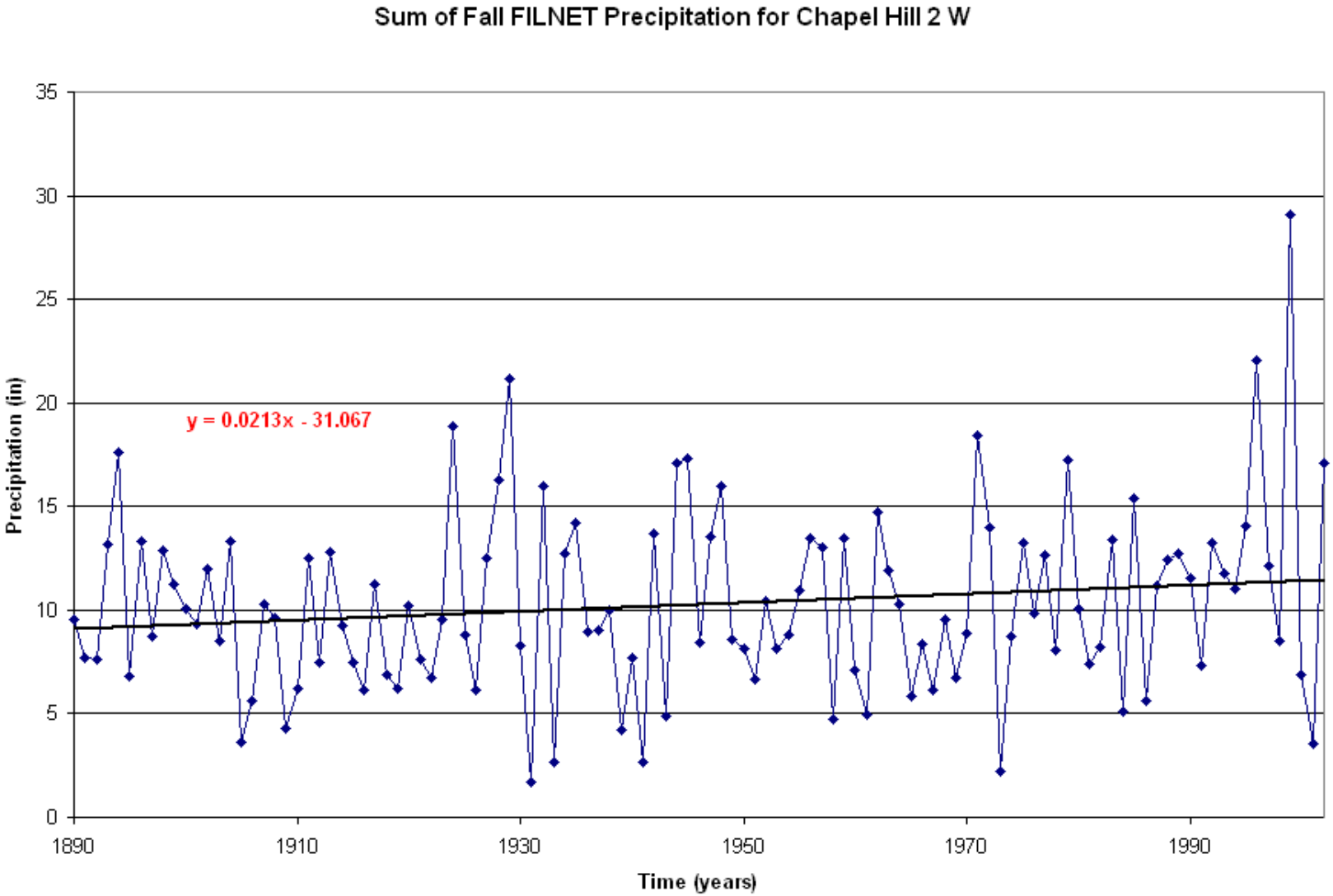
Piedmont: Chapel Hill 2 W (Summer)

~ 4.89 in decrease over 100 years



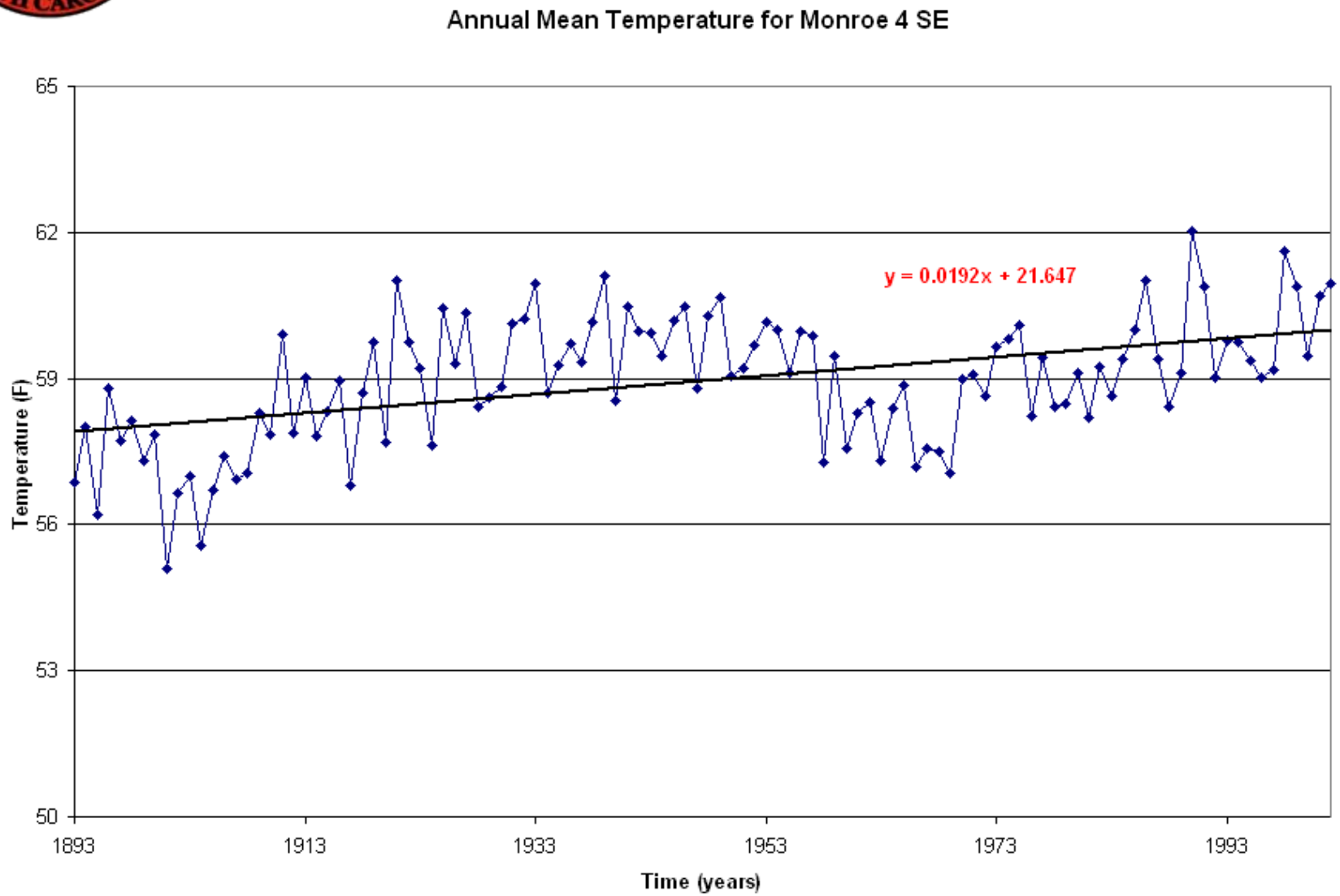
Piedmont: Chapel Hill 2 W (Fall)

~ 2.13 in increase over 100 years



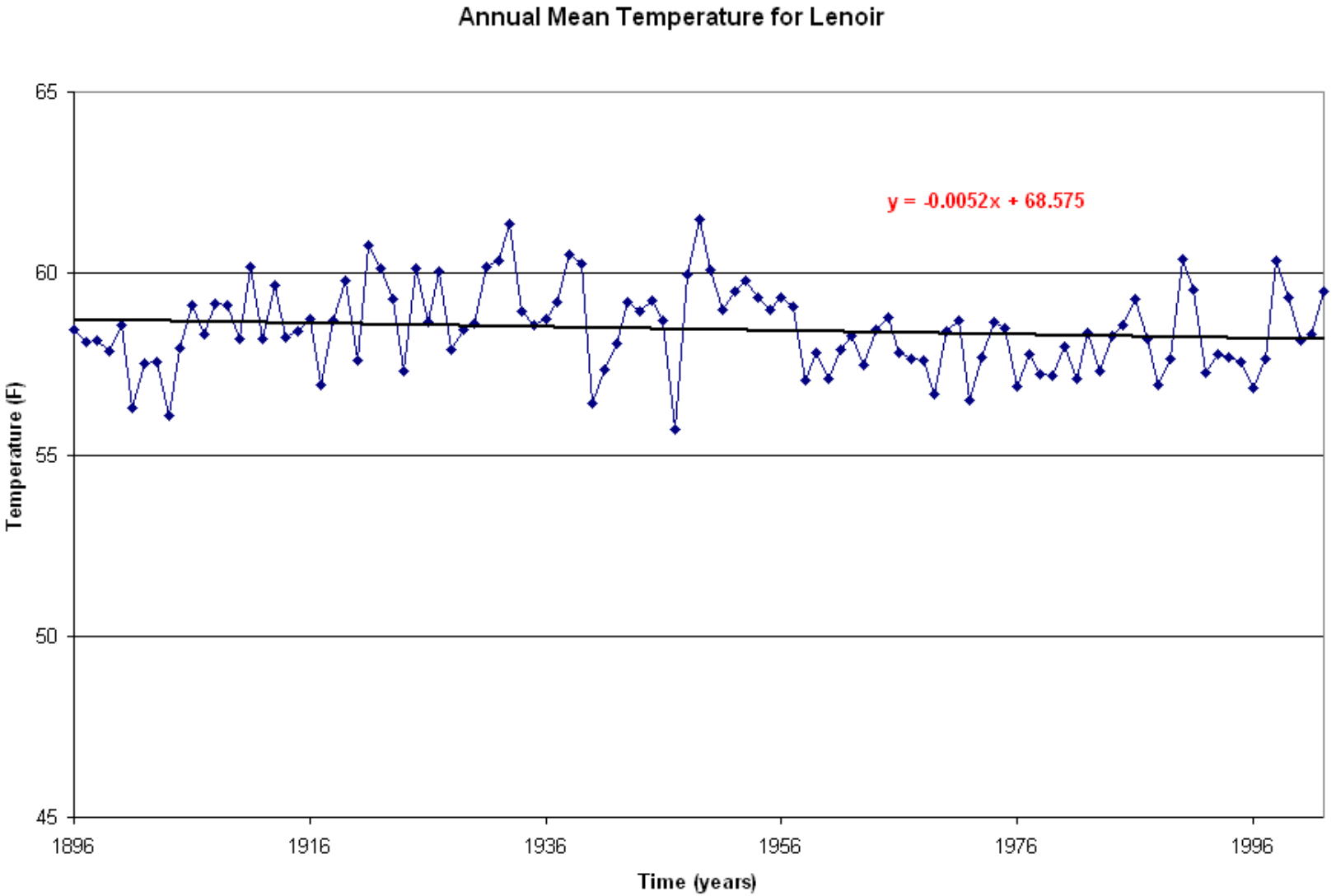
Piedmont: Monroe 4 SE

~1.92ºF increase over 100 years



Mountain: Lenoir

~0.52°F decrease over 100 years



Mountain: Lenoir (cont'd)

~2.79 in increase over 100 years

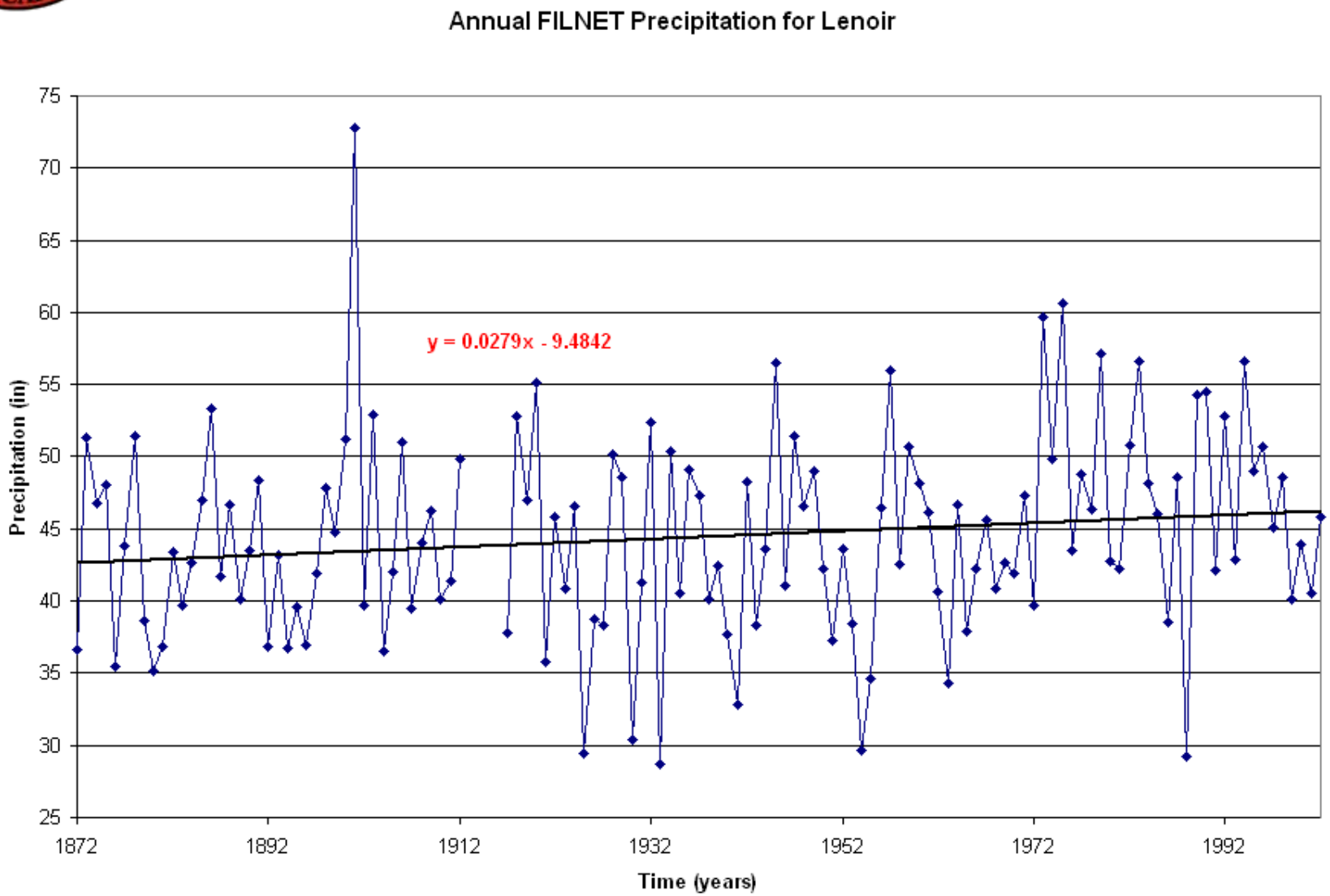


Table of Changes in Annual Mean Temperature

Station	Region	Begin Year	End Year	Total Change (F)	Total Change (C)	Change Per Year (F)	Change Per Year (C)
Chapel Hill 2 W	piedmont	1893	2002	1.16	0.6444	0.0106	0.0059
Charlotte Douglas AP	piedmont	1948	2002	0.53	0.2944	0.0098	0.0055
Elizabeth City	*coastal*	*1911*	*2002*	*3.17*	*1.7611*	*0.0348*	*0.0194*
Henderson 2 NNW	piedmont	1893	2002	1.38	0.7667	0.0127	0.0070
Goldsboro 4 SE	coastal	1893	2002	1.72	0.9556	0.0158	0.0088
Lenoir	mountain	1896	2002	-0.52	-0.2889	-0.0049	-0.0027
Monroe 4 SE	piedmont	1896	2002	1.92	1.0667	0.0181	0.0101
Banner Elk	*mountain*	*1907*	*2002*	*-0.62*	*-0.3444*	*-0.0065*	*-0.0036*
Southport 5 N	coastal	1893	2002	0.6	0.3333	0.0055	0.0031
Waynesville 1 E	*mountain*	*1894*	*2002*	*0.19*	*0.1056*	*0.0018*	*0.0010*

Red: greatest positive change

Green: least change

Blue: greatest negative change

Table of Changes in Annual Precipitation

Station	Region	Begin Year	End Year	Total Change (in)	Change Per Year (in)
Chapel Hill 2 W	*piedmont*	*1893*	*2002*	*-4.1*	*-0.0376*
Charlotte Douglas AP	piedmont	1948	2002	0.95	0.0176
Elizabeth City	coastal	1911	2002	-2.3	-0.0253
Henderson 2 NNW	piedmont	1893	2002	-3.41	-0.0313
Goldsboro 4 SE	*coastal*	*1893*	*2002*	*-0.62*	*-0.0057*
Lenoir	mountain	1896	2002	2.79	0.0263
Monroe 4 SE	piedmont	1896	2002	-0.86	-0.0081
Banner Elk	*mountain*	*1908*	*2002*	*3.33*	*0.0354*
Southport 5 N	coastal	1893	2002	-2.19	-0.0201
Waynesville 1 E	mountain	1894	2002	1.65	0.0153

Red: greatest positive change

Green: least change

Blue: greatest negative change

Correlation Coefficients

Station	TAVG	TMAX	TMIN	PRCP
Southport 5 N	0.41	0.52	0.32	-0.27
Elizabeth City	0.78	0.49	0.68	-0.28
Goldsboro 4 SE	0.65	0.55	0.51	-0.16
Chapel Hill 2 W	0.55	0.14	0.64	-0.41
Henderson 2 NNW	0.60	0.19	0.60	-0.39
Monroe 4 SE	0.68	0.42	0.69	-0.19
Banner Elk	0.39	0.30	0.51	0.35
Lenoir	0.37	0.51	0.47	0.39

Summary

- North Carolina climate is influenced by global tele-connections
- There are (statistically) significant variations in North Carolina climate at different locations during the past 100 years
- There is a need for improved density of climate observations (at least one in each county) in North Carolina

Thank You !