Introduction to Climate Science

Virginia Office of Environmental Education

DEQ
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

Virginia Coastal Zone
MANAGEMENT PROGRAM

Approach for the Day

1) Summarize some of the key ***scientific findings***, with discussion of time & space scales.
2) Provide some ***reference materials*** for further inquiry.
3) Give ***Virginia examples*** of climate concerns.

Terms to Know

- Science
- Climate
- Greenhouse Effect
- Milankovitch Cycles

What is Science?

The systematic observation of natural events and conditions in order to discover facts about them and to formulate laws and principles based on these facts.

- Academic Press Dictionary of Science & Technology

Science is a way of learning about the natural world and the knowledge gained through that process.

- Prentice Hall, *Science Explorer Grade 6*

To do science is to search for repeated patterns, not simply to accumulate facts.

- Robert H. MacArthur, *Geographical Ecology*

Terms to Know

- Science
- **Climate**
- Greenhouse Effect
- Milankovitch Cycles

What is Climate?

Climate is the average, year-after-year conditions of temperature, precipitation, winds, and clouds in an area.

- Prentice Hall, Science Explorer, Grade 6

Climate is determined by the long-term pattern of temperature and precipitation averages and extremes at a location.

- Climate Literacy, U.S. Global Change Research Program

Is the planet's climate changing in significant ways?

Scientists agree that warming of the climate system is occurring due observations of:

- Increases in global average air and ocean temperatures
- Widespread melting of snow and ice
- Rising global average sea level

Source: Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., et al., (eds). [hereafter IPCC 2007 WG1-AR4]
http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm

Terms to Know

- Science
- Climate
- **Greenhouse Effect**
- Milankovitch Cycles

Why is the Greenhouse Effect important?

The **greenhouse effect** helps maintain a consistent temperature on the planet Earth which makes our planet livable.

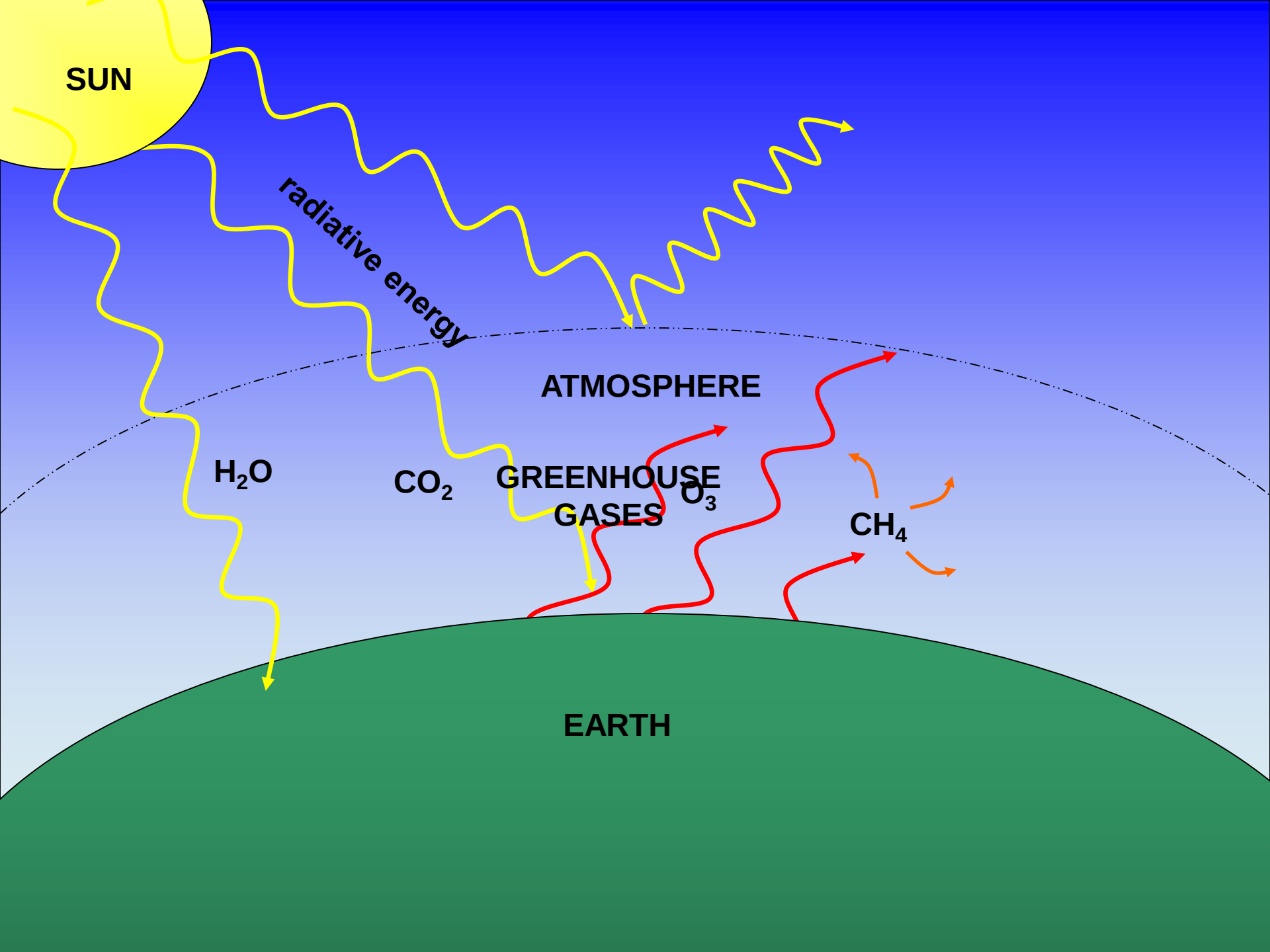
Greenhouse Effect

- 1824 – Discovery is attributed to Joseph Fourier
- 1858 - Reliably experimented on by John Tyndall
  - Water Vapor (H_2O), Carbon Dioxide (CO_2), Ozone (O_3), and Methane (CH_4)
- 1896 - Reported quantitatively by Svante Arrhenius

What is the Greenhouse Effect?

The **greenhouse effect** is a process by which ***radiative energy*** leaving a planetary surface is ***absorbed by some atmospheric gases***, called greenhouse gases. They transfer this energy to other components of the atmosphere, and it is ***re-radiated in all directions***, including back down towards the surface.

This transfers energy to the surface and lower atmosphere, so the temperature there is higher than it would be if direct heating by solar radiation were the only warming mechanism.


SUN
radiative energy
ATMOSPHERE
H_2O
CO_2
GREENHOUSE GASES
O_3
CH_4
EARTH

Terms to Know

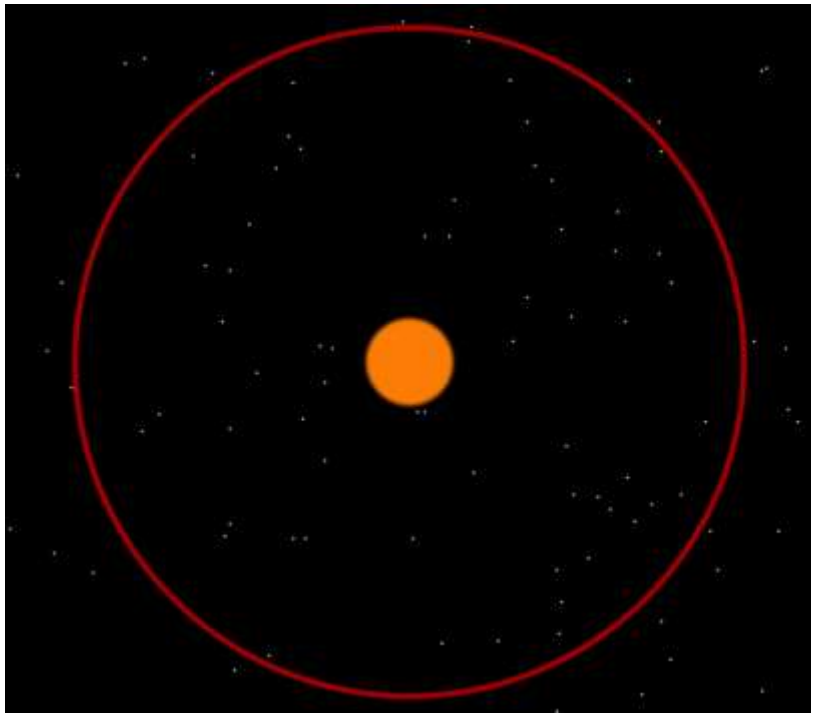
- Science
- Climate
- Greenhouse Effect
- **Milankovitch Cycles**

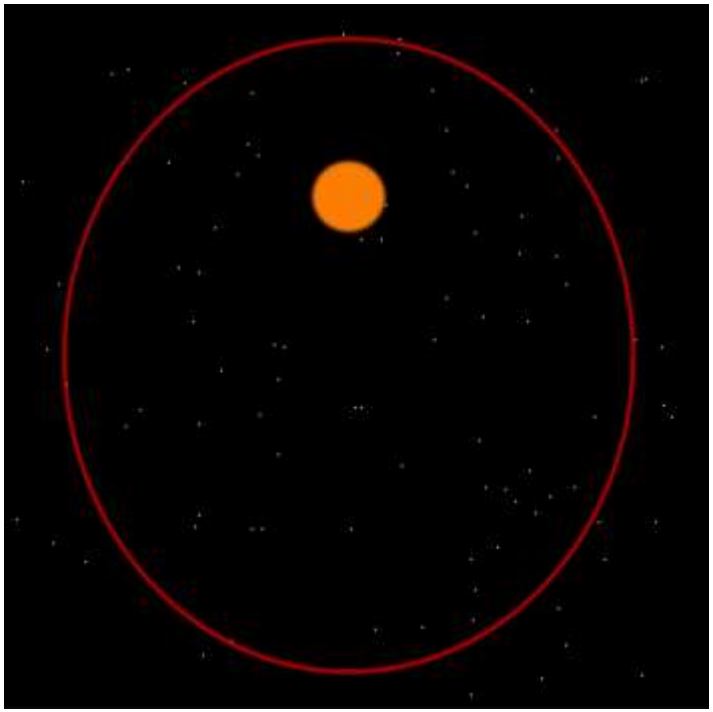
What are the Milankovitch Cycles?

- Named after the Serbian astronomer Milutin Milankovitch
- Theorized effects of changes in the Earth's movements upon its climate
  - Eccentricity
  - Obliquity
  - Precession (Wobble)

http://www.wwnorton.com/college/geo/egeo/flash/18_2.swf

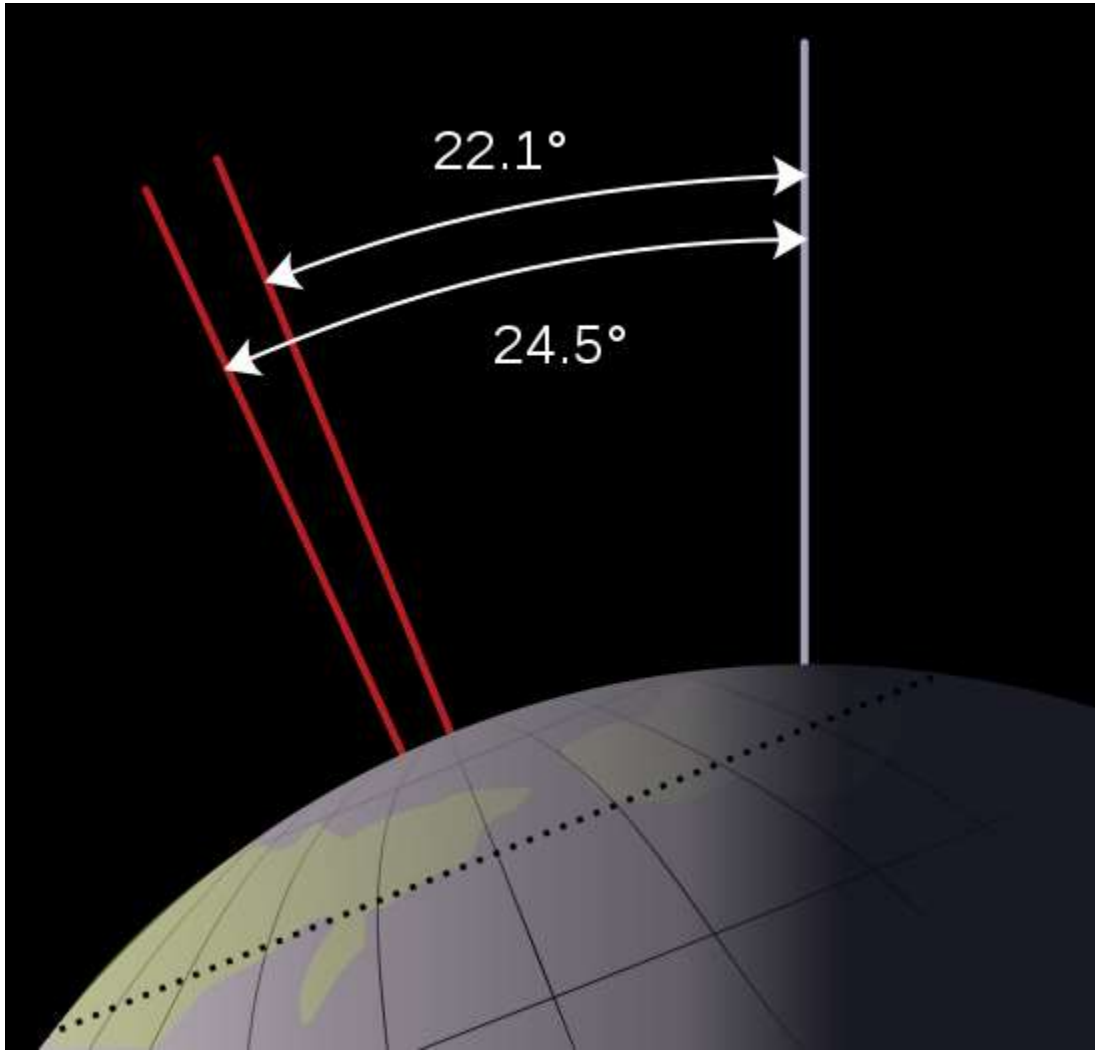
Eccentricity – Orbital shape





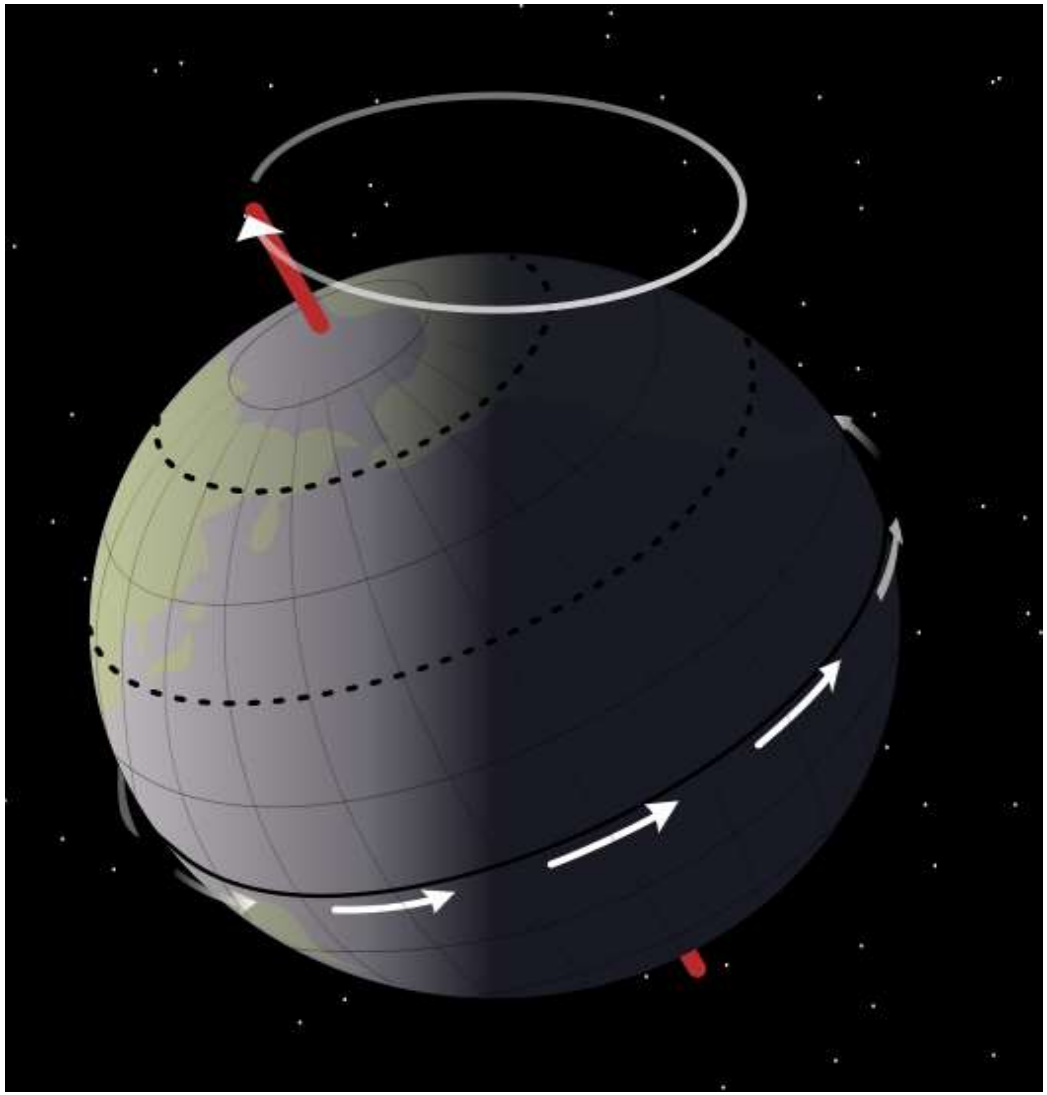
~ 100,000 year cycle

Obliquity – Axial tilt



~ 41,000 year cycle

Precession - Wobble

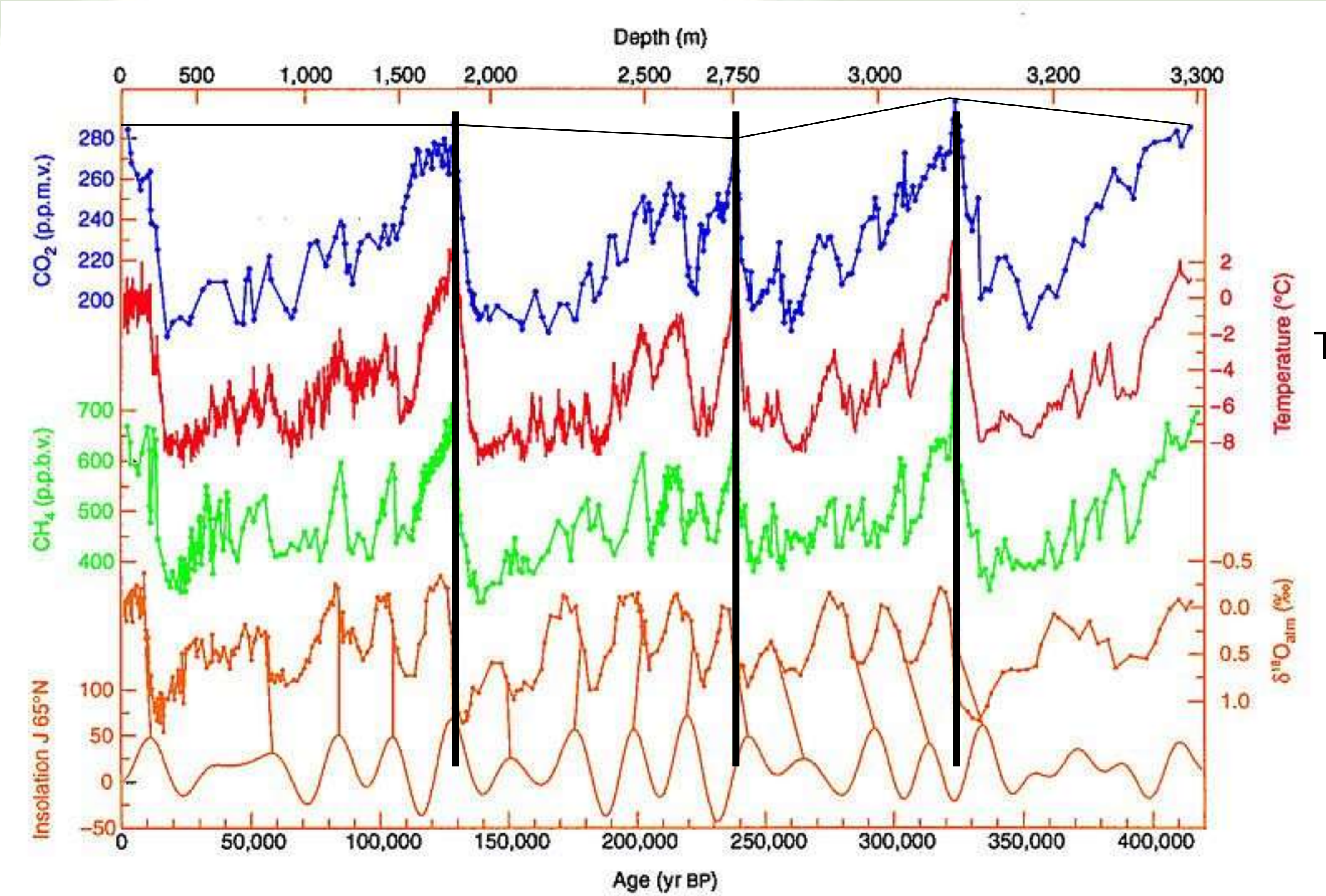


~ 25,000 year cycle

What is the relationship between Milankovitch Cycles and Greenhouse Gases?

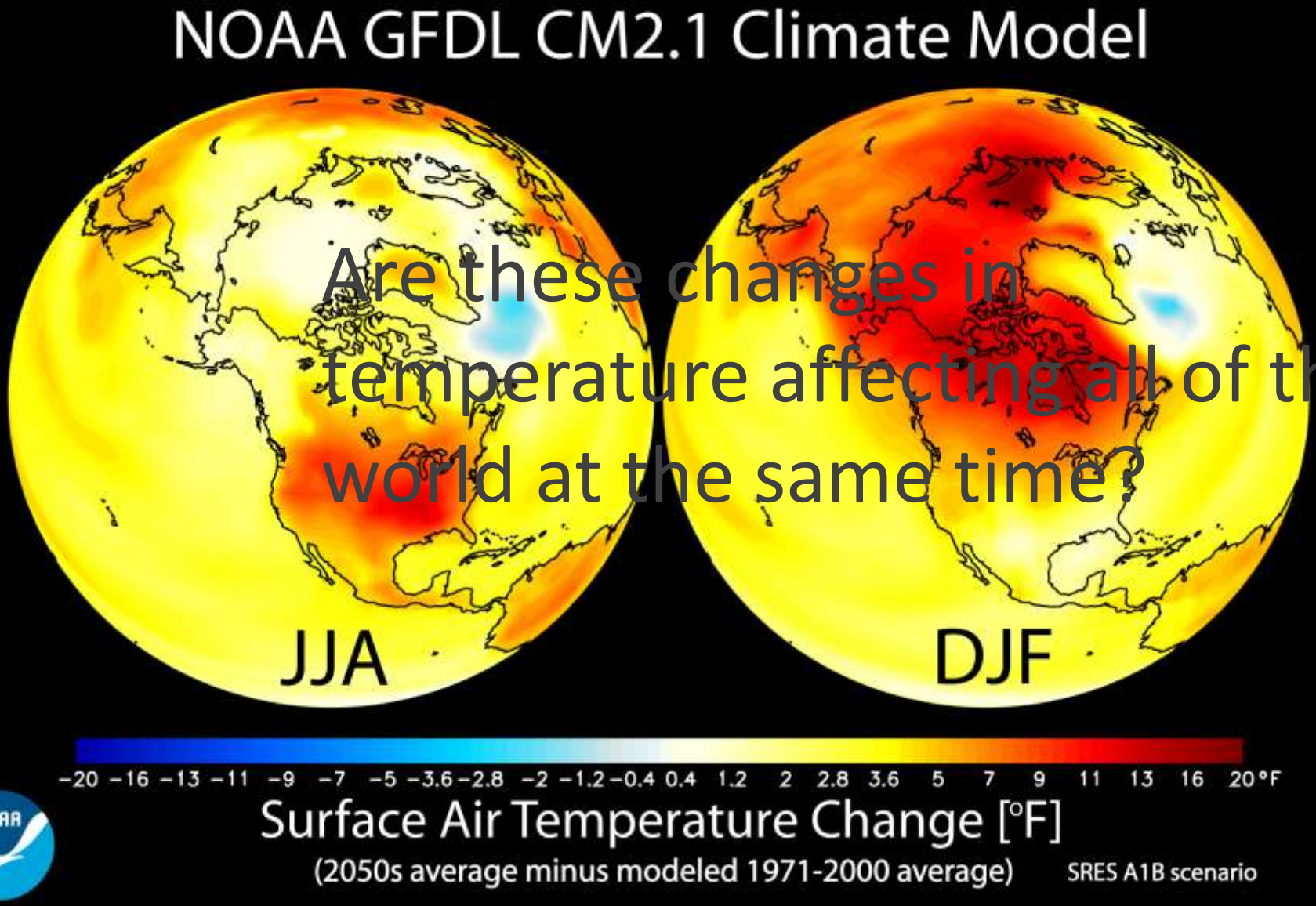
420,000 years ... Vostok ... Antarctica research station

been above 280 - 300 ... historic record



http://en.wikipedia.org/wiki/File:Vostok_420ky_4curves_insolation.jpg

Climate Change Responses Are Not Geographically Uniform



Visitors passing through

Audubon Society study bird migration shift to climate change

By MATTHEW TRESAUGUE

Feb. 10, 2009, 2:18AM

DAVE CRUZ Arizona Republic
The changes in migration coincide with temperature variations over time, researchers said.

There was a time when the American goldfinch, a gregarious nesting bird, could be found in backyard feeders throughout Houston. But now, as climate change seems to be leaving its first footprints here, the bird is slowly moving its territory to the north.

The goldfinch's subtle shift is hardly unique. Of 305 species tracked by the Audubon Society, more than half are spending the winter about 40 miles farther north than they did 40 years ago, according to the

The changes in migration coincide with variations in temperature over time, researchers said. The average January temperature for Oklahoma climbed by about 5 degrees Fahrenheit over the four decades covered in the study.

Plants and animals have always had to adjust to shifting climates, and birds have proved remarkably resilient, ranging from urban backyards to the Arctic tundra. The study covers a variety of species throughout North America, prompting researchers to suspect that larger forces are at work in their changing migration habits.

"This is as close as science at this scale gets to proof," said Greg Butcher, the lead scientist on the study and the director of bird conservation at the Audubon Society. "It is not what each of these individual birds did. It is the wide diversity of birds that suggests it has something to do with temperature, rather than ecology."

Terry Root, a Stanford University biologist who worked on the study, said the researchers "don't know for a fact that it is warming. But when one keeps finding the same thing over and over ... we know it is not just a figment of our imagination."

The research is based on data collected during the Audubon Society's annual bird count in early winter, when temperature is the primary driver for birds' migration and survival.

In some cases, species' ranges have shifted 100 miles or more in recent decades, according to the study.

Life on Earth depends on
and is shaped by the
affects of climate.

http://www.chron.com/disp/story.mpl/nation/6255181.html

Avian migration phenology and global climate change

Peter A. Cotton*

School of Biological Sciences, University of Plymouth, Plymouth PL4 8AA, United Kingdom

Edited by Stephen H. Schneider, Stanford University, Stanford, CA, and approved July 24, 2003 (received for review January 29, 2003)

Over the past 30 years in Oxfordshire, U.K., the average arrival and departure dates of 20 migrant bird species have both advanced by 8 days; consequently, the overall residence time in Oxfordshire has remained unchanged. The timing of arrival has advanced in relation to increasing winter temperatures in sub-Saharan Africa, whereas the timing of departure has advanced after elevated summer temperatures in Oxfordshire. This finding demonstrates that migratory phenology is quite likely to be affected by global climate change and links events in tropical winter quarters with those in temperate breeding areas.

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Global warming (1) has altered the phenology and distribution of many plant and animal species, resulting in marked changes from the level of individuals to whole communities (2–7). Elevated temperatures have affected population dynamics (8) and have advanced events such as leaf unfolding (9), flowering (10), emergence (11), and breeding (12–15), whereas leaf fall has become delayed, leading to an extended growing season (9). In some cases there is evidence that the timing of avian migration is affected by climatic variation (2, 16–20). Climate

climatic indices such as the NAOI and the Southern Oscillation productivity of Africa (29, 30) and may be proxies for a

Here, I show that the U.K. arrival date of 17 of 20 species of birds has advanced over the past 30 years, responding to increased temperature trends in their African over-wintering grounds. The departure date of migrant birds has also advanced in parallel with the change in arrival date. The timing of departure of migrant birds from the U.K. is correlated with increased summer minimum temperatures. Overall, the duration of stay of migrant birds in the U.K. has remained unchanged over time, but the whole period has shifted earlier by an average of 8 days over the last 30 years.

Methods

Data for SOI and NAOI were obtained from the Climate Analysis Section of the National Center for Atmospheric Research (www.cgd.ucar.edu/cas/catalog/climind/soi.html). The winter (December, January, and February) SOI is computed by using the difference between monthly mean sea level pressure anomalies (mb) at Tahiti and Darwin (32). The winter and summer (June, July, and August) NAOI used are based on the difference of normalized sea level pressures (mb) between Ponta

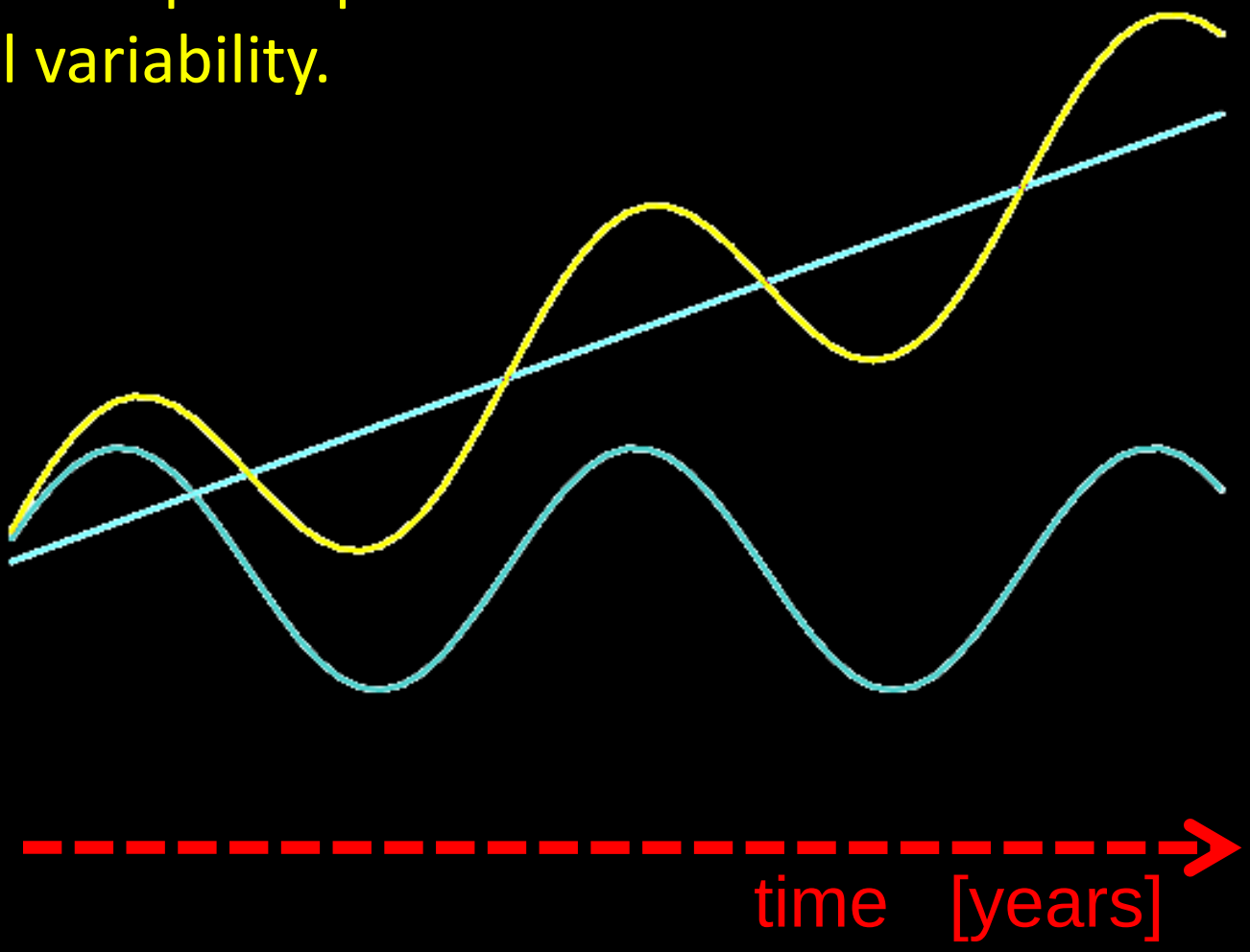
ECOLOGY

Proceedings of the National Academy of the Sciences

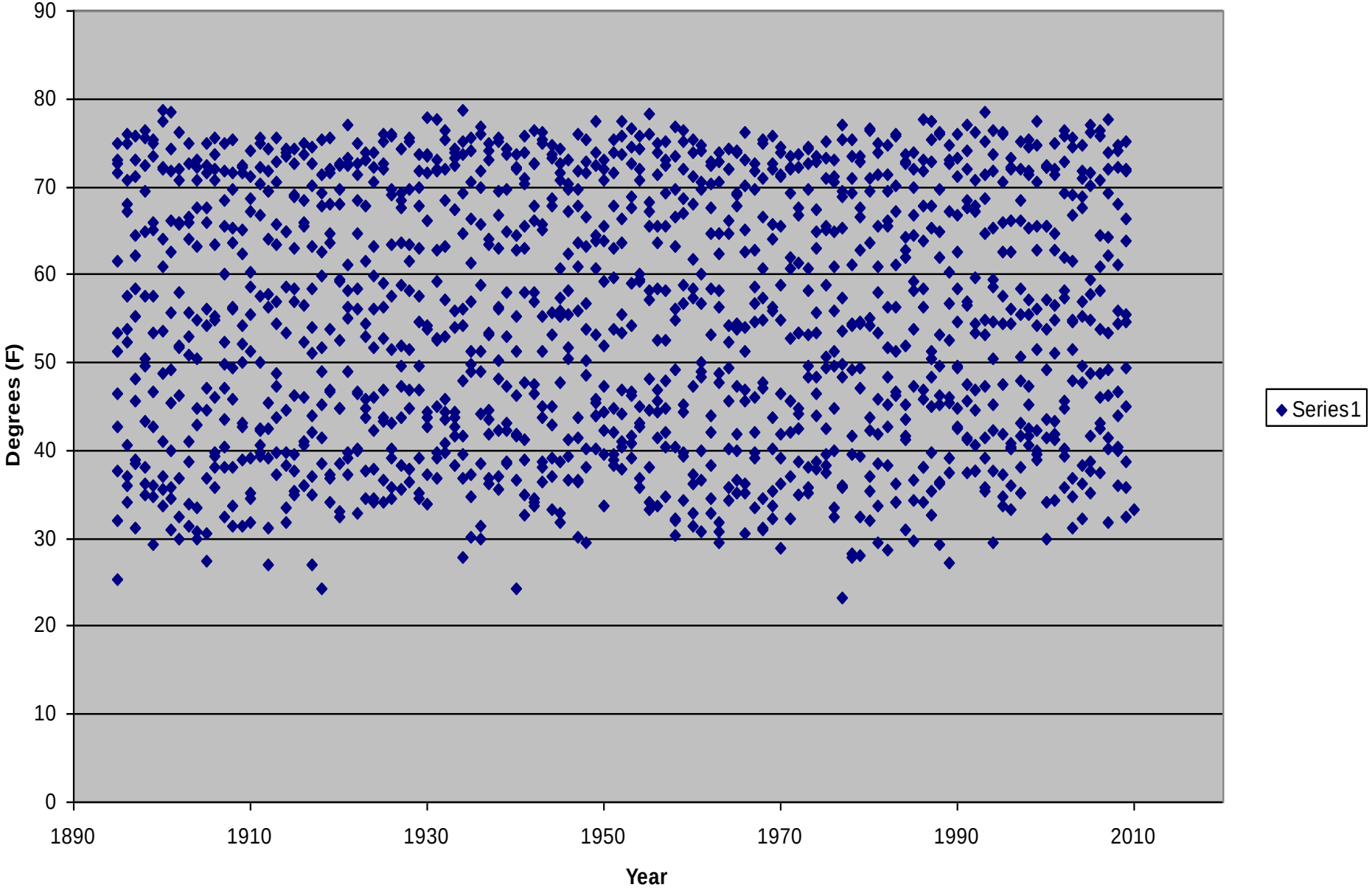
What about Virginia?

- Historic month-to-month temperature averages from NOAA
- Frost date and growing season length changes
- Sewell's Point tide gauge

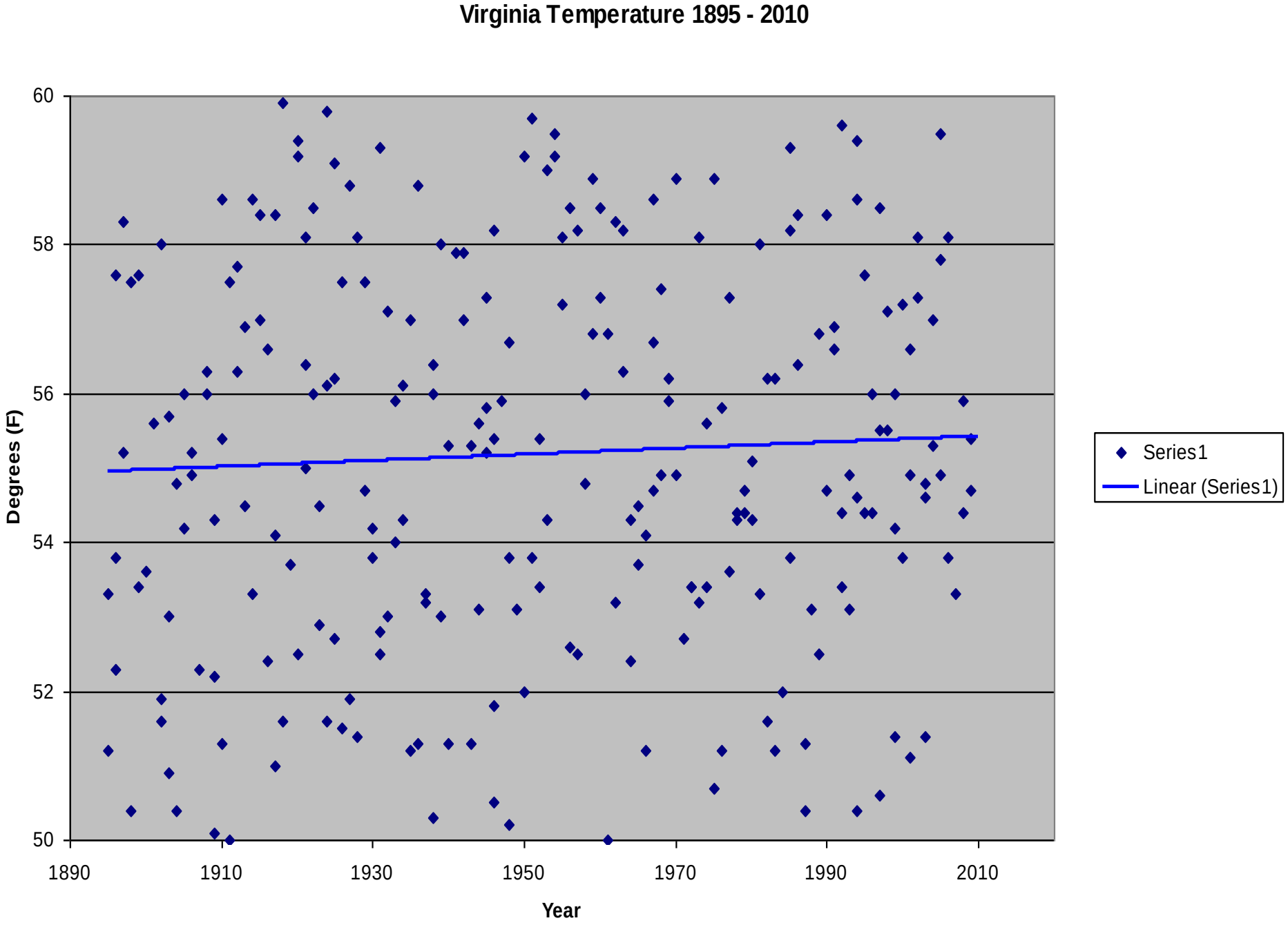
What we see in observations
is a trend superimposed onto the
natural variability.

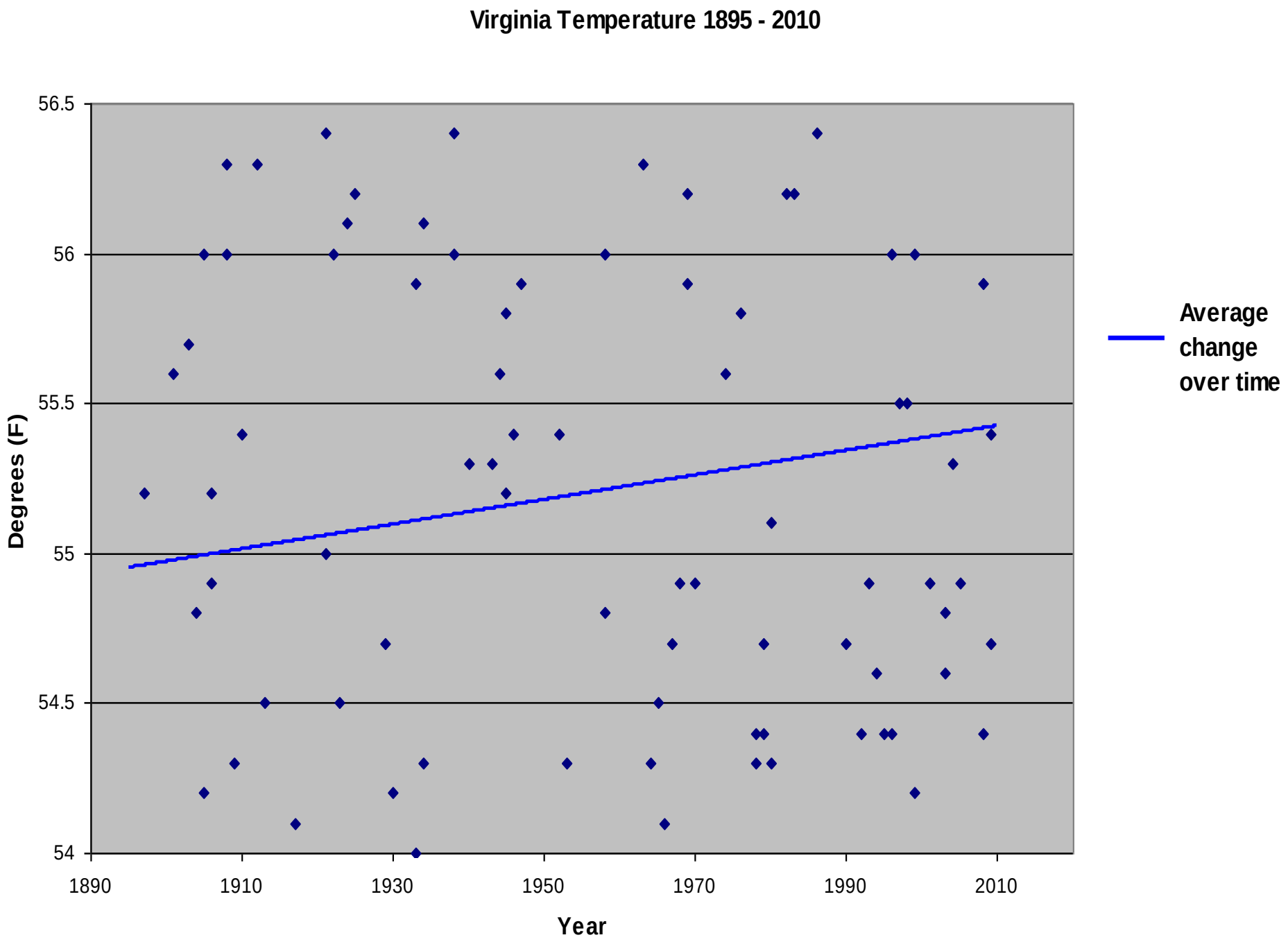


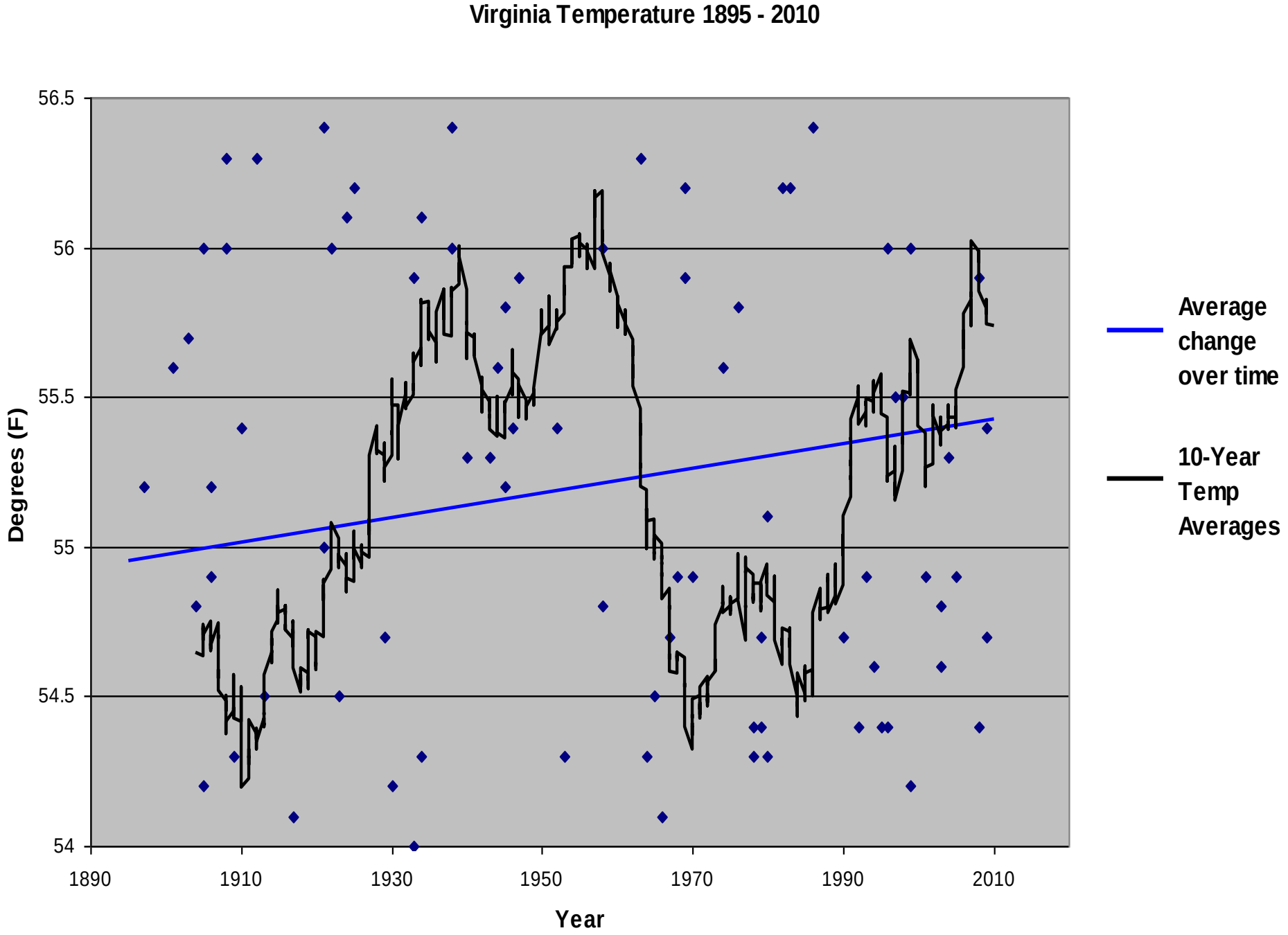
Virginia Temperature 1895 - 2010



http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#


Virginia Temperature 1895 - 2010
60
58
56
54
52
50
Degrees (F)
1890
1910
1930
1950
1970
1990
2010
Year
Series1
Linear (Series1)


Virginia Temperature 1895 - 2010
56.5
56
55.5
55
54.5
54
Degrees (F)
1890
1910
1930
1950
1970
1990
2010
Year
Average change over time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56.5
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55
54.5
54
Degrees (F)
1890
1910
1930
1950
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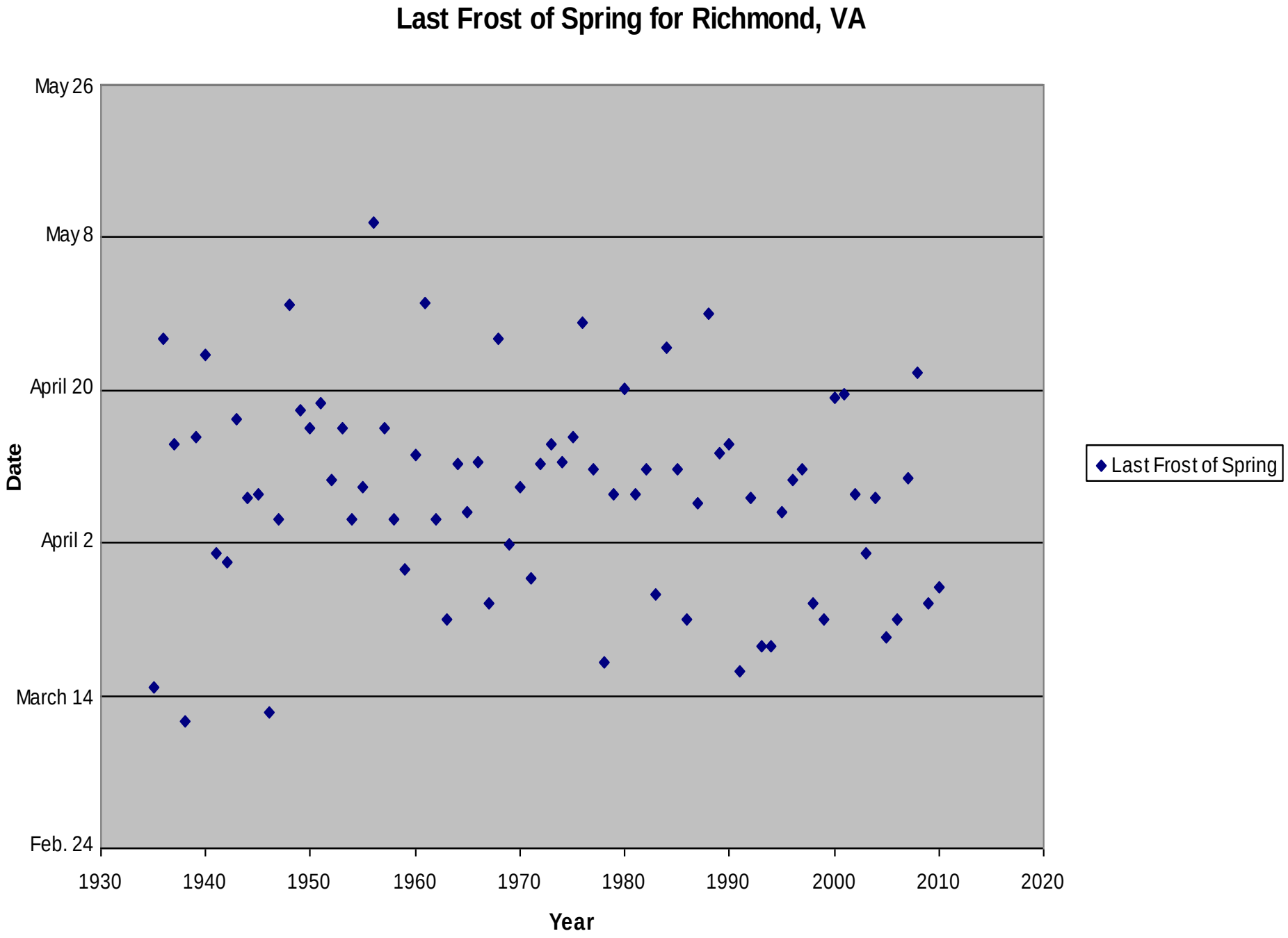
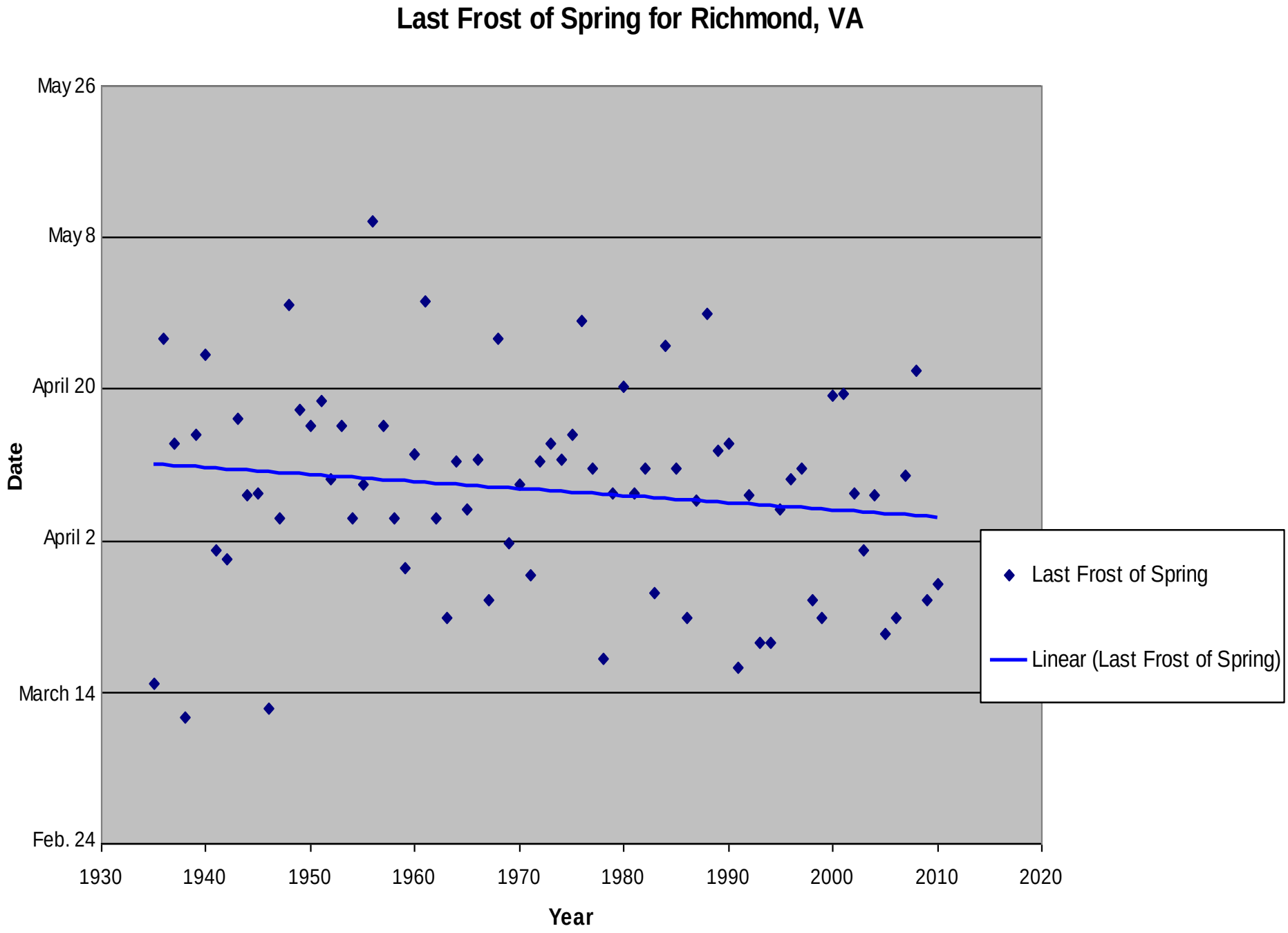
1990
2010
Year
Average change over time
10-Year Temp Averages

What about Frost Dates?


Last Frost of Spring for Richmond, VA
May 26
May 8
April 20
April 2
March 14
Feb. 24
Date
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
Last Frost of Spring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2020
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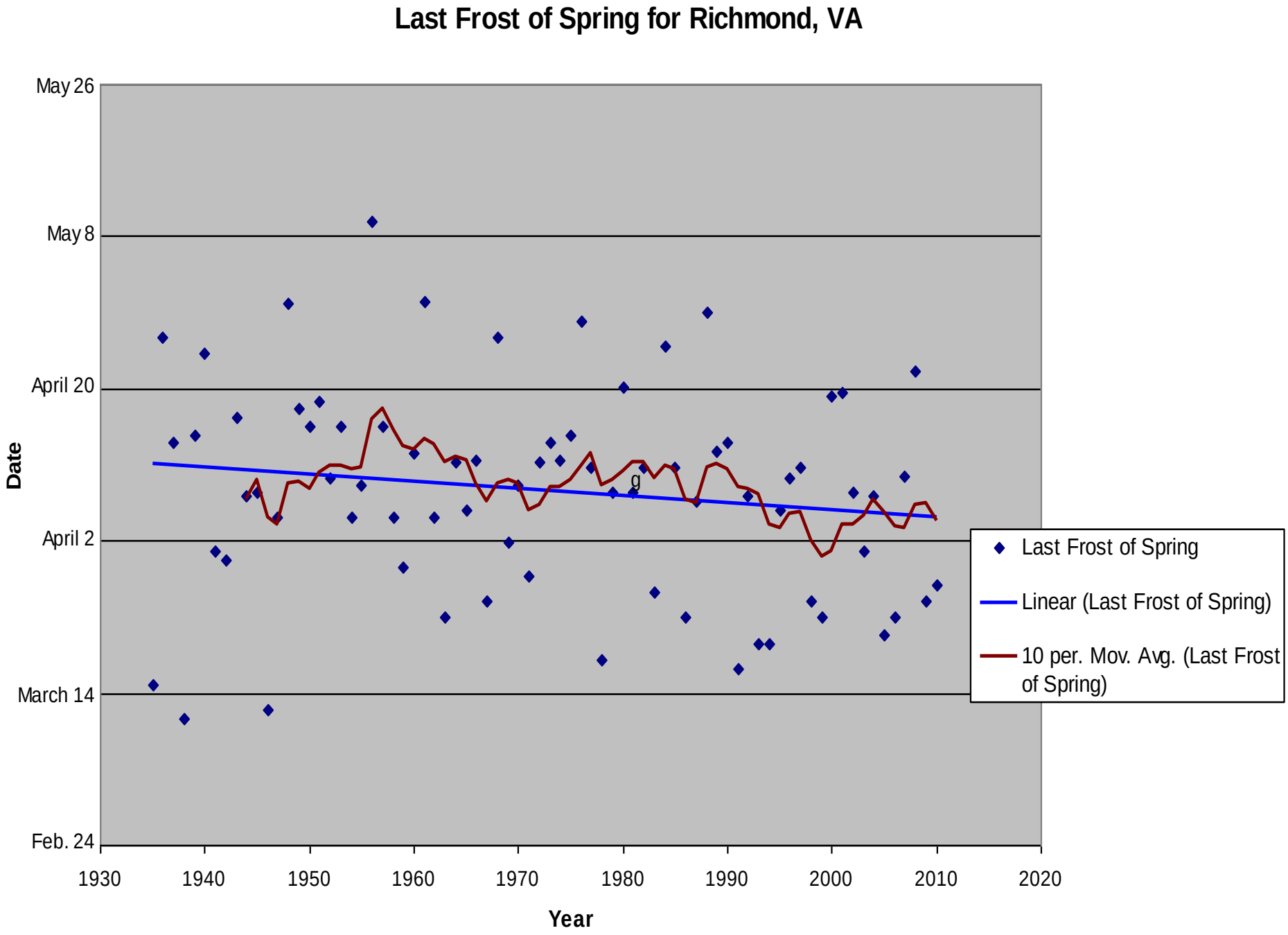
Last Frost of Spring
Linear (Last Frost of Spring)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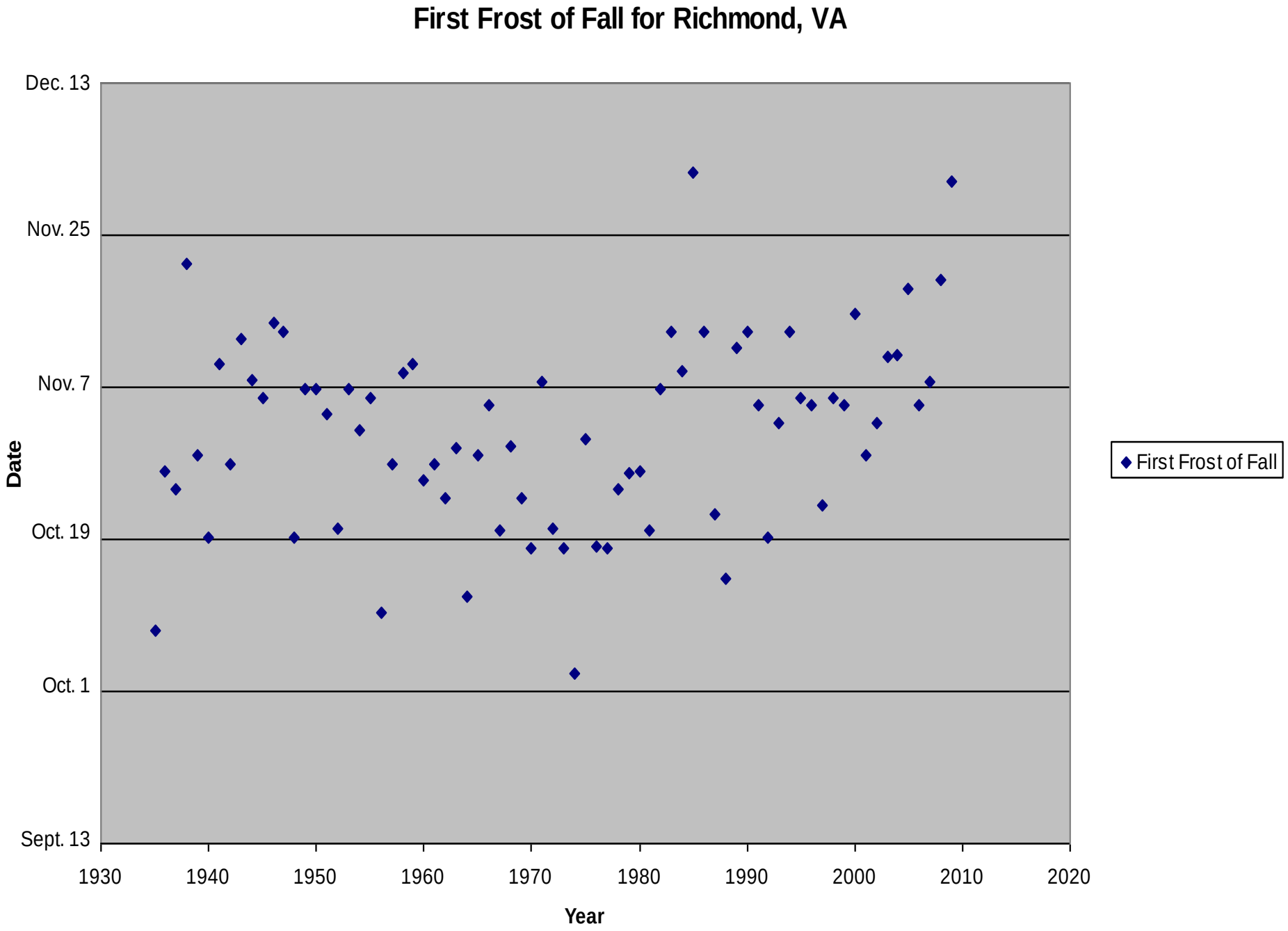
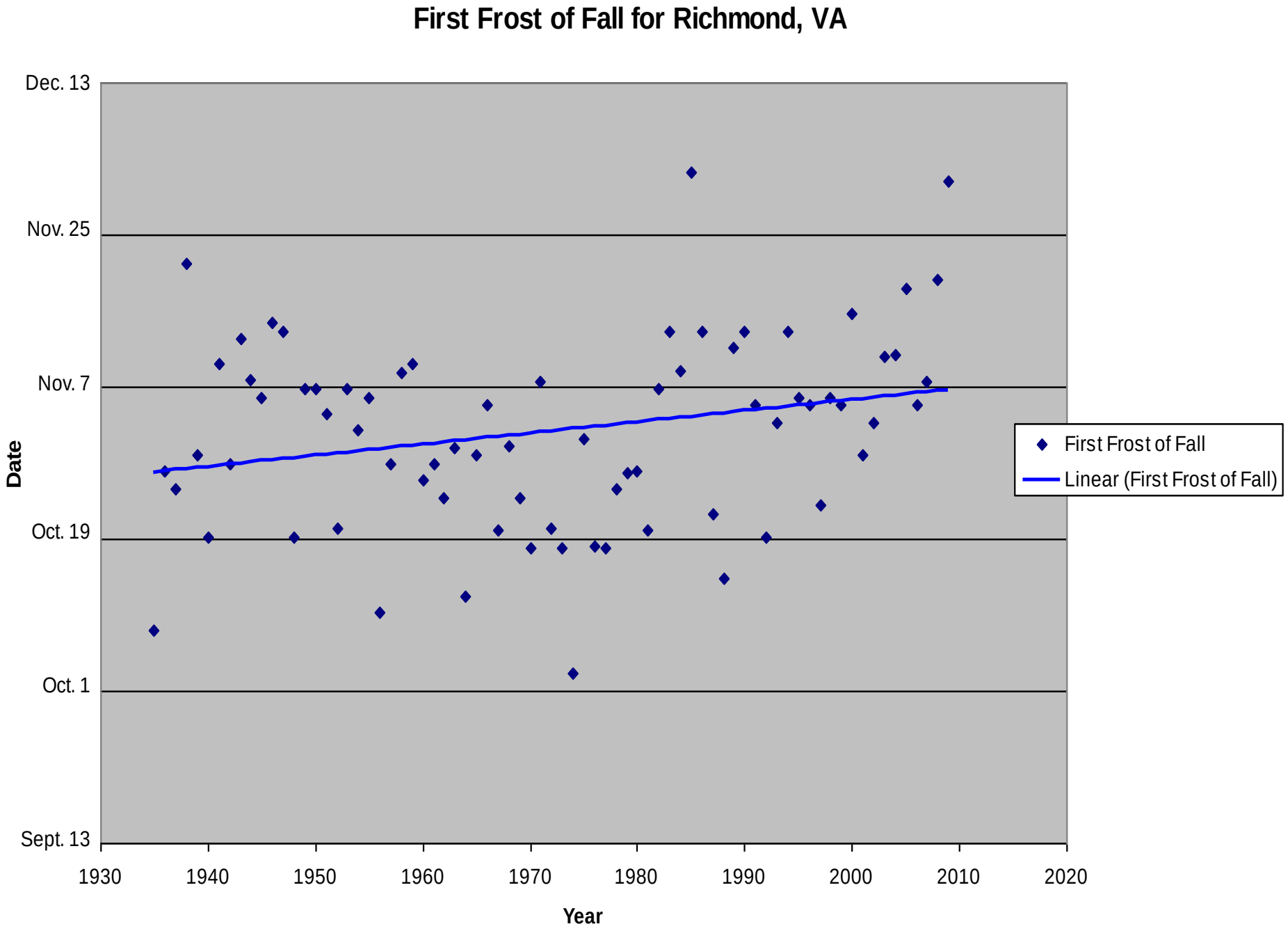
May 26
May 8
April 20
April 2
March 14
Feb. 24
Date
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
Last Frost of Spring
Linear (Last Frost of Spring)
10 per. Mov. Avg. (Last Frost of Spring)


First Frost of Fall for Richmond, VA
Dec. 13
Nov. 25
Nov. 7
Oct. 19
Oct. 1
Sept. 13
Date
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
First Frost of Fall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1990
2000
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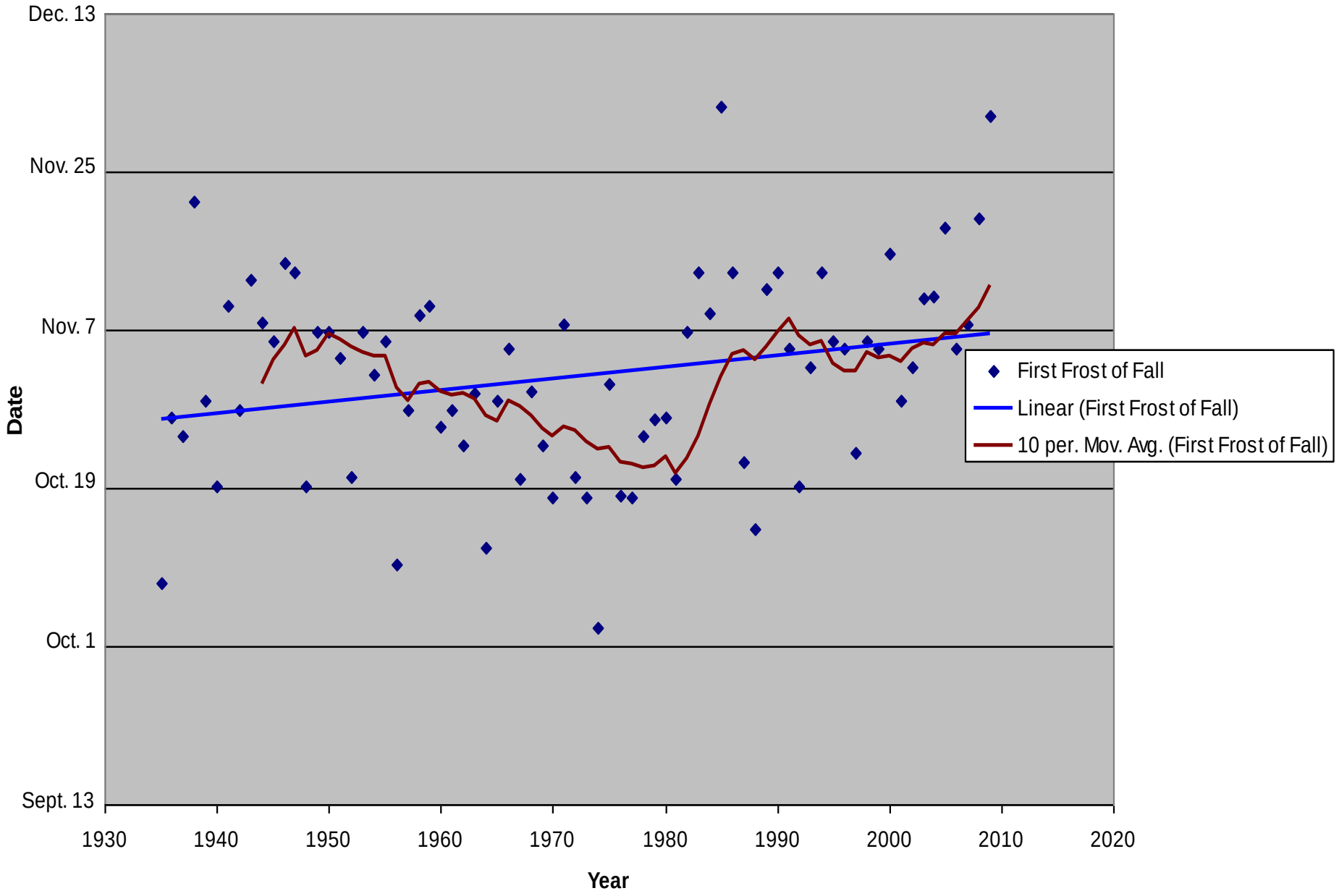
2020
Year
First Frost of Fall
Linear (First Frost of Fall)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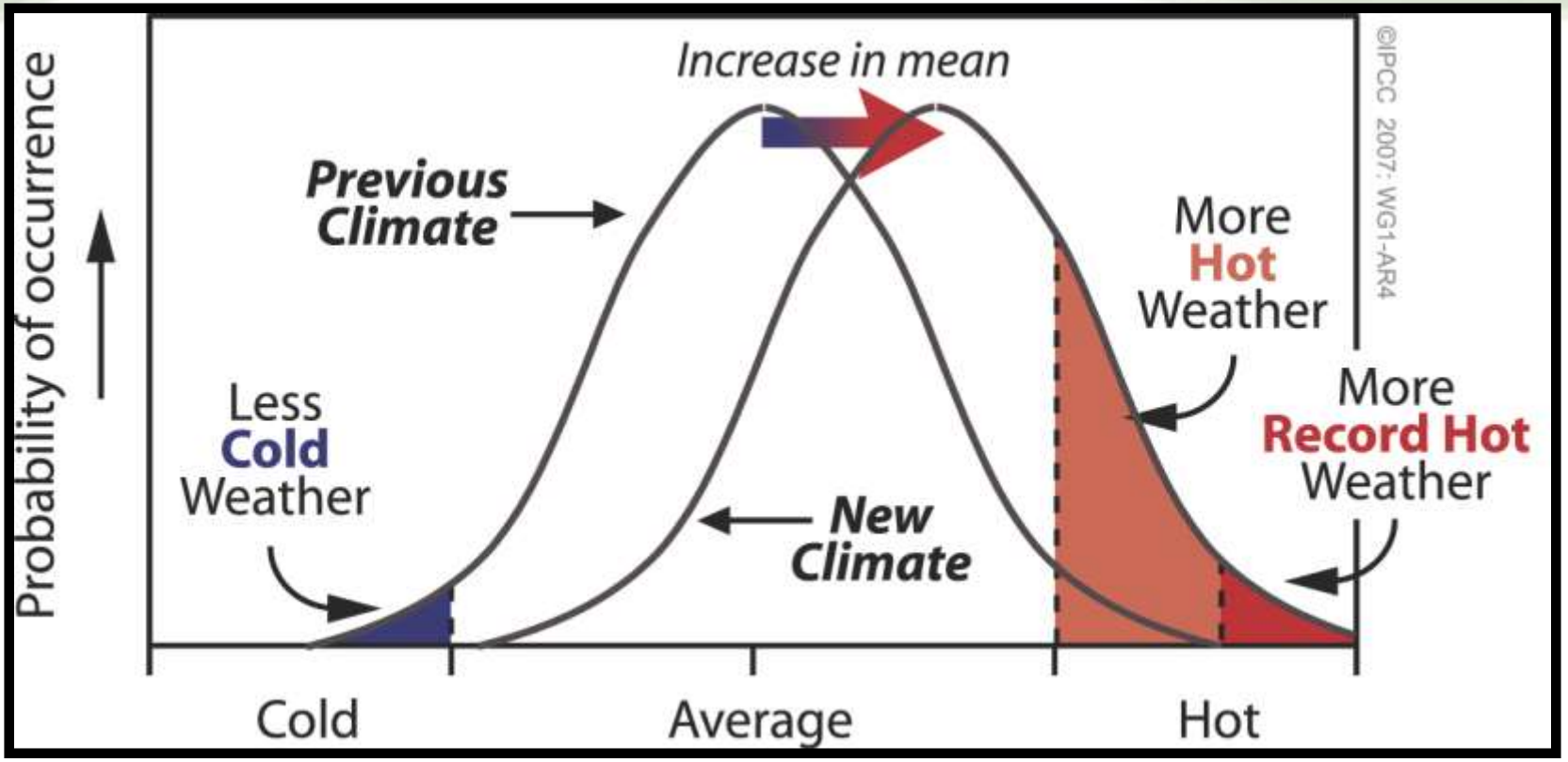
2000
2010
2020
Year
First Frost of Fall
Linear (First Frost of Fall)
10 per. Mov. Avg. (First Frost of Fall)

It is difficult to attribute any individual event to a change in the climate.

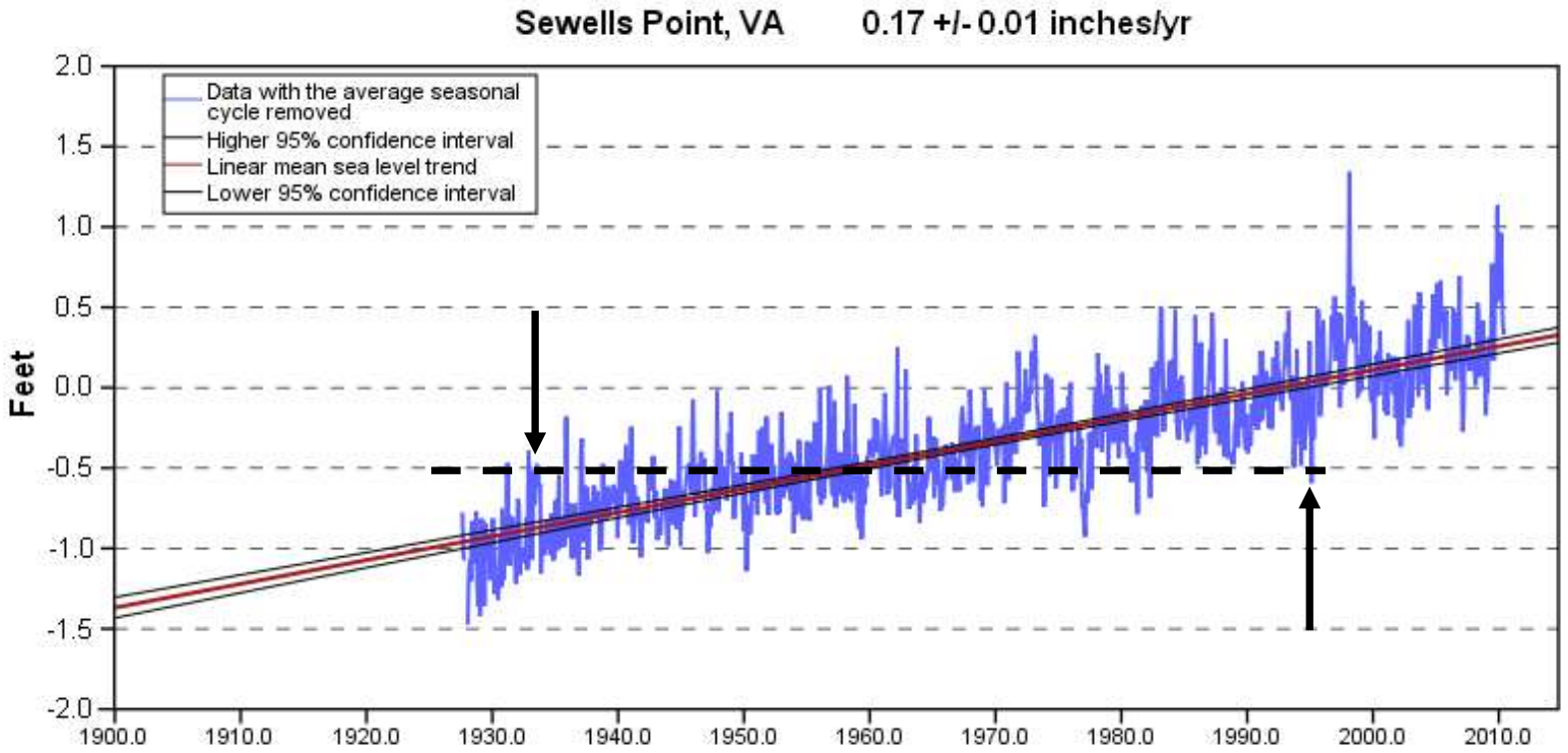


Source: IPCC 2007 WG1-AR4, Box TS.5, Fig 1

Sewells Point Tide Gauge

- Digitized tide record at the U.S. Naval Base alongside Willoughby Bay in Norfolk.
- The easily-accessed record begins in 1928.

Mean Sea Level Trend
8638610 Sewells Point, Virginia

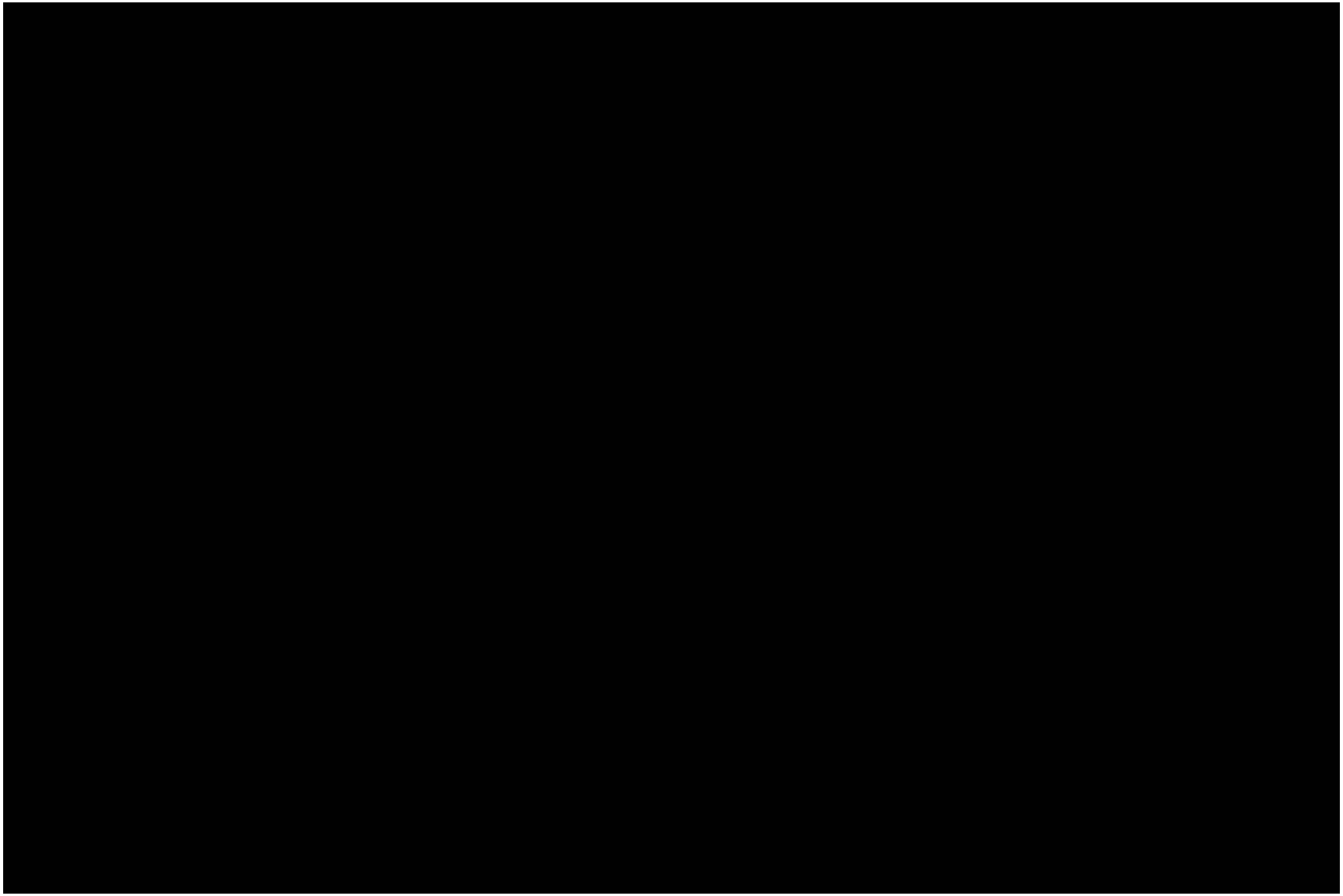


The mean sea level trend is 4.44 millimeters/year with a 95% confidence interval of +/- 0.27 mm/yr based on monthly mean sea level data from 1927 to 2006 which is equivalent to a change of 1.46 feet in 100 years.

Sea Level Rise

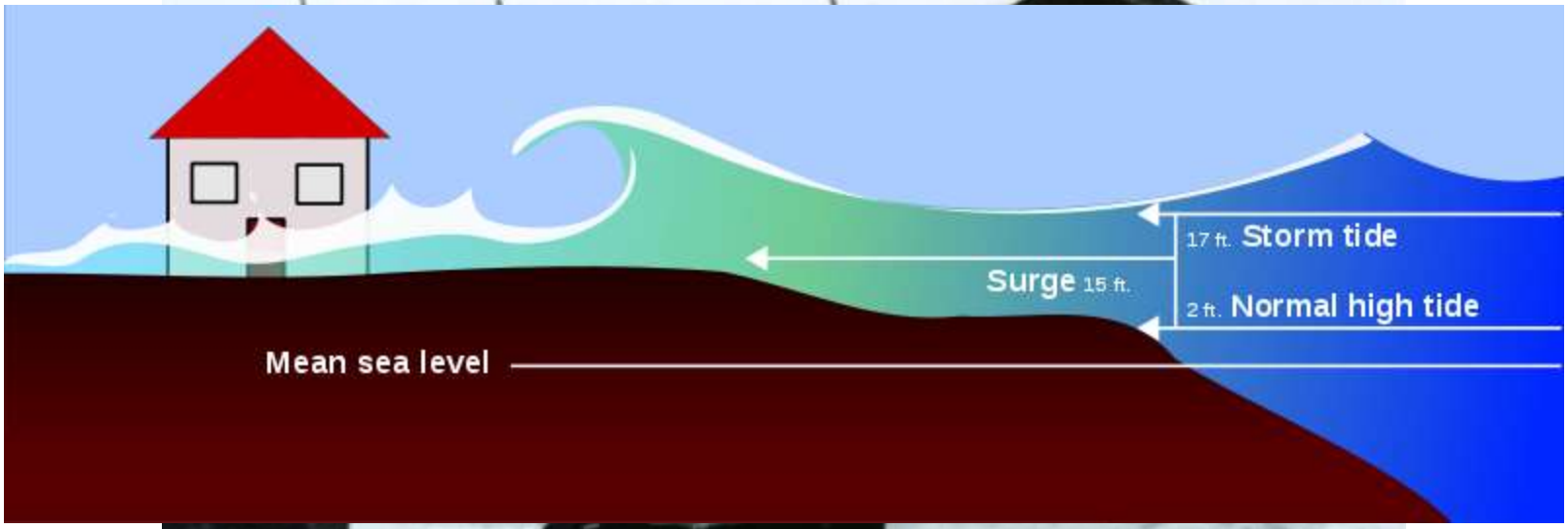
- Coastal Erosion
- Coastal Inundation
- Storm Surge

Coastal Erosion




CLEAN AIR
COOL PLANET
64
Chesapeake Bay
Area at risk of inundation from 1-meter (3.3 ft.)
Current sea level
Low estimate
Central estimate
High estimate
Elevations based on computer models, not actual surveys. High, central, and low estimates indicate amount of land potentially inundated. Range in estimates reflects uncertainty in underlying elevation model. Inundation shown does not reflect coastal protection efforts that may prevent some low-lying areas from being flooded as sea level rises. Map does not depict inland areas below modeled sea level
2 Miles
Int'l Terminal Blvd

Storm Surge


17 ft. Storm tide
Surge 15 ft.
2 ft. Normal high tide
Mean sea level

What does this mean for Virginia?

- Rising Temperature
- Rising Sea Level
- Longer growing season from the shifting frosts

How will the Earth's climate change?

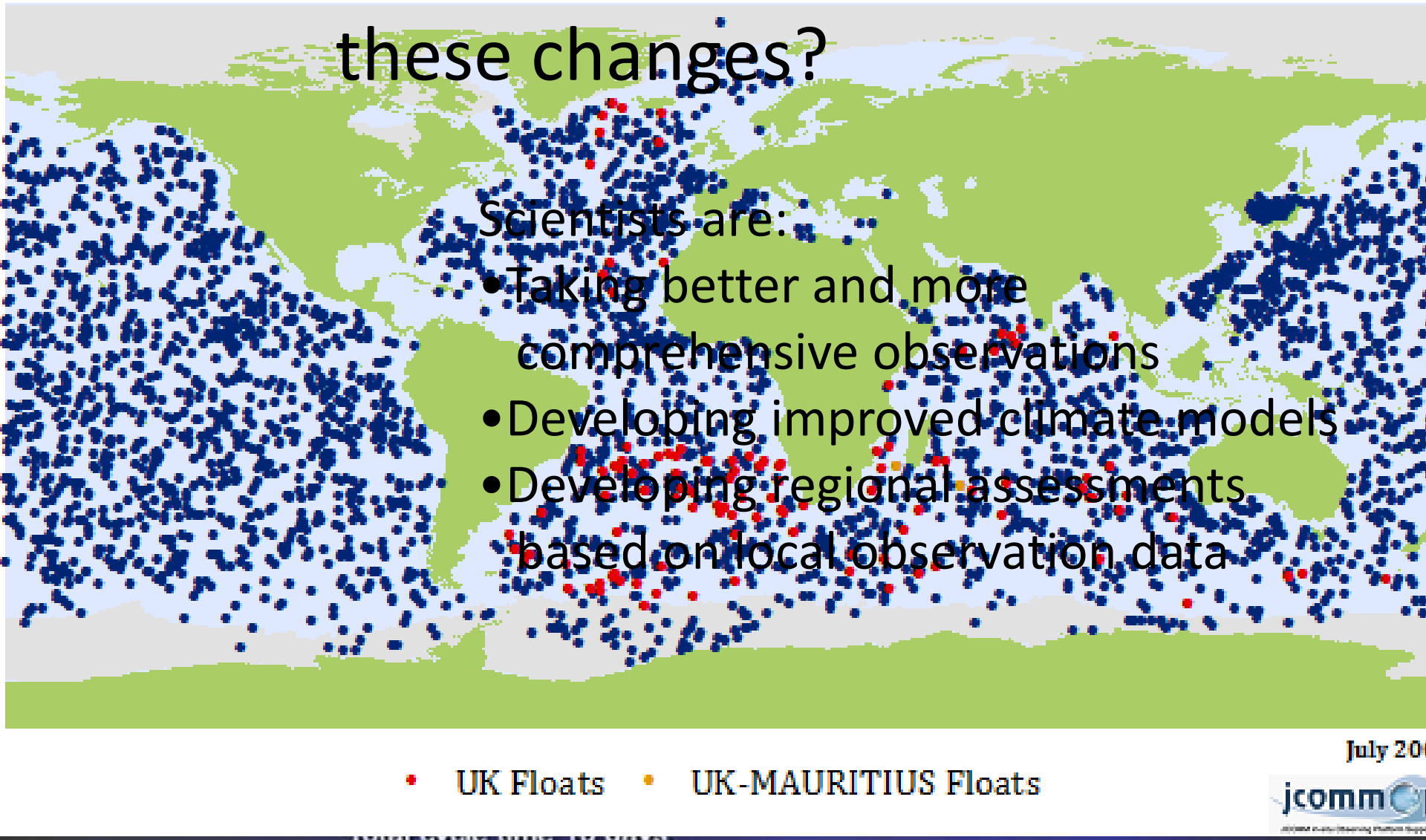
Scientists agree globally that:

- Wet areas will get wetter and dry areas will get drier
- Frequency of extreme weather events may increase
- Sea level will rise

How is science addressing these changes?

Scientists are:

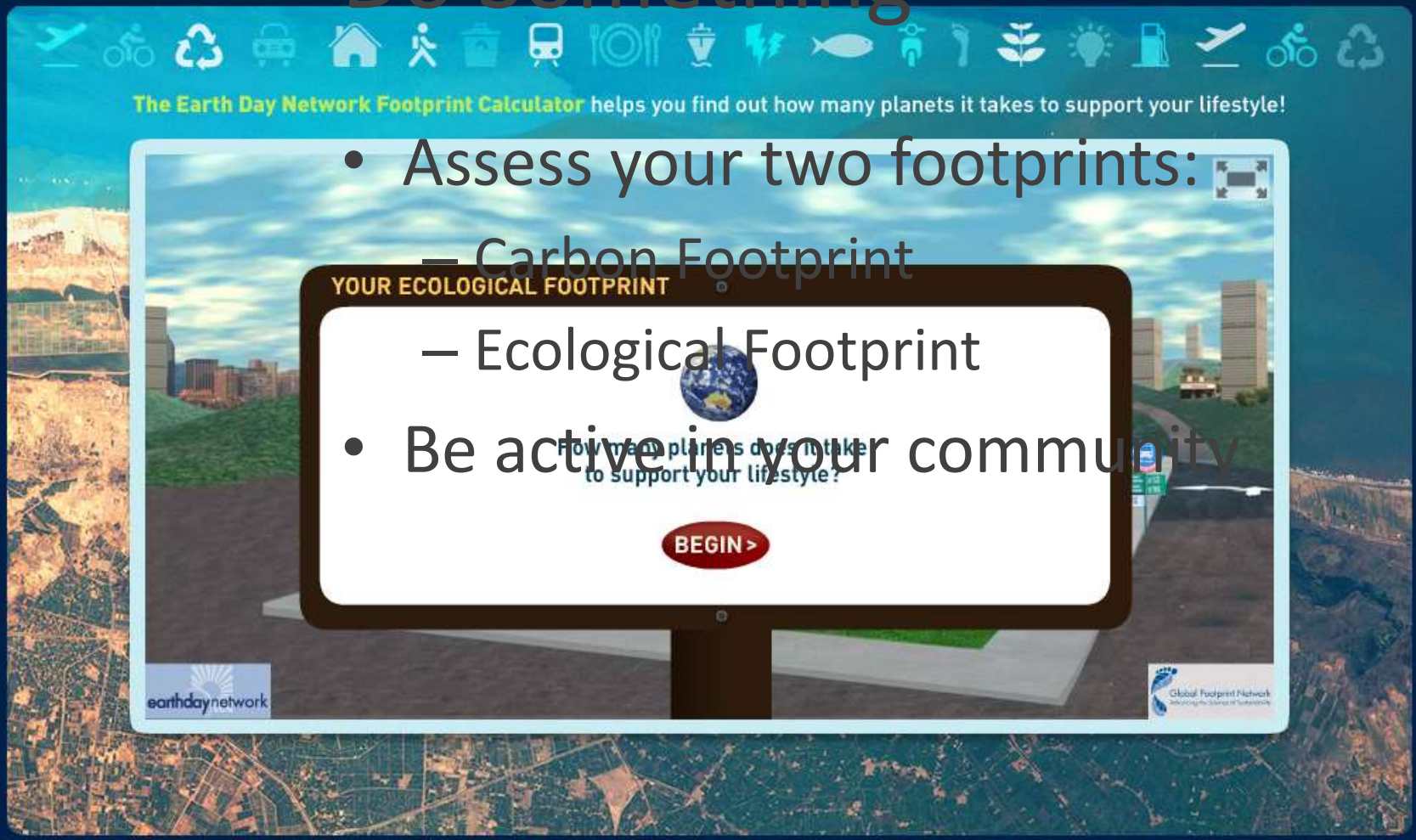
- Taking better and more comprehensive observations
- Developing improved climate models
- Developing regional assessments based on local observation data



Next Steps

- Learn more
  - www.climate.gov
- Review the Virginia Plan
  - http://www.deq.virginia.gov/info/climatechange.html

Do Something



- Assess your two footprints:
  - Carbon Footprint
  - Ecological Footprint
- Be active in your community

Recap

- Science
- Climate
- Greenhouse Effect
- Milankovitch Cycles
- Virginia examples
- Next Steps to Do Something

Introduction to Climate Science

Virginia Office of Environmental Education

DEQ
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

Virginia Coastal Zone
MANAGEMENT PROGRAM