Frost and Freeze Data and Impacts to the Agriculture, Construction and Transportation Industry

Anthony Arguez

Frost-Freeze Normals

March 20, 2013

Takeaway Messages

- Frost and Freeze events are costly and dangerous
- "Frost-Freeze" products are based on select minimum temperature thresholds
- NCDC provides a wide variety of products that characterize the climatological likelihood and timing of frost and freeze events
- Since 1951, the median freeze-free period over the U.S. has increased by about a week

Frost and Freeze Events

- Technically frost formation and freezing are physical processes that meteorologists don't directly measure
- Meteorologists do observe air temperature and, to a lesser degree, dew point temperature
- Plants have varying tolerances to "cold" weather
- NCDC provides "frost-freeze" normals for a wide range of temperatures (16°F-36°F) near or below the freezing point of water

Frost and Freeze Date Normals (32F)

Station/City	P	Spring Dates			Fall Dates		
		90%	50%	10%	10%	50%	90%
Ithaca, NY	100%	Apr 30	May 14	May 30	Sep 21	Oct 3	Oct 17
Charleston, SC	100%	Feb 16	Mar 8	Mar 29	Nov 8	Nov 29	Dec 19
Kansas City, MO	100%	Mar 31	Apr 12	Apr 27	Oct 6	Oct 23	Nov 6

- 90% of the time, you will reach 32F or below after April 30 in Ithaca.
- Be first to market.
- Half of the time the first fall freeze will occur before October 23 in Kansas City and half the time after October 23.

Frost and Freeze Date Normals (32F)

Station/City	P	Spring Dates			Fall Dates		
		90%	50%	10%	10%	50%	90%
Bellevue, NE	100%	Apr 8	Apr 21	May 3	Sep 27	Oct 11	Oct 26
Manhattan, KS	100%	Apr 8	Apr 23	May 6	Sep 29	Oct 13	Oct 27
Houston, TX	94%	Jan 2	Feb 3	Mar 6	Dec 1	Dec 20	Jan 20

- Bellevue and Manhattan have very similar dates (~170 miles apart)
- Houston doesn't reach 32F every year (94% chance)
- "Spring" and "Fall" are applicable for much of the U.S. but not for warmer stations like Houston.

Frost and Freeze Date Normals (32F)

Station/City	P	Spring Dates			Fall Dates		
		90%	50%	10%	10%	50%	90%
Missoula, MT	100%	May 4	May 18	Jun 2	Sep 11	Sep 24	Oct 5
Las Cruces, NM	100%	Mar 6	Mar 23	Apr 10	Oct 28	Nov 9	Nov 21
Peoria, AZ	89%	Dec 18	Jan 13	Feb 10	Dec 1	Dec 19	Jan 14

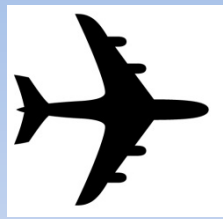
- 10% chance of reaching 32F or below after June 2 in Missoula
- Cold Season is defined as August 1 – July 31
- Some stations are too cold or too warm to calculate dates
- Peoria's "fall" and "spring" date ranges overlap (just like Houston)

NOAA's 1981-2010 Climate Normals:

Frost- and Freeze-related Products

- Probabilities of Occurrence (Monthly & Annual) — 36F 32F 28F 24F 20F 16F
- Frost-Freeze Probability Dates (First & Last)
- Growing Season Length Normals
- Frequencies of Threshold Exceedance — 40F 32F 20F 10F 0F
- Air Freezing Index – Rocky Bilotta — 32F

Methodology



- First and Last Frost-Freeze dates are very “noisy” parameters
- Very sensitive to missing data

- STEP 1: create serially-complete daily minimum temperature product for 1981-2010
- STEP 2: create 10,000 simulations based on the serially-complete estimates for each station
- STEP 3: compute statistics

new

Probabilities of Occurrence

- The likelihood that a given minimum temperature will be experienced at least once during a month or year
- 100% chance that the temperature will drop to 16°F or below at least once in the year in Minneapolis, and an 18.7% chance of this occurring at least once in April
- 15.7% chance that the temperature will drop to 36°F or below at least once in the year in Miami, FL
- If less than 10%, probability dates are not calculated

Probabilities of 32F Occurrence

Station	Annual	OCT	JAN	APR
Missoula	100%	100%	100%	100%
Ithaca	100%	98%	100%	100%
Bellevue	100%	96%	100%	98%
Manhattan	100%	95%	100%	97%
Kansas City	100%	76%	100%	88%
Las Cruces	100%	18%	100%	27%
Charleston	100%	1%	99%	7%
Houston	94%	0%	71%	0%
Peoria	89%	0%	56%	0%

Frost and Freeze Date Normals: Kansas City

Temperature	P	Spring Dates			Fall Dates		
		90%	50%	10%	10%	50%	90%
16F	100%	Feb 13	Mar 4	Mar 22	Nov 12	Dec 1	Dec 19
20F	100%	Feb 25	Mar 14	Apr 1	Nov 4	Nov 22	Dec 9
24F	100%	Mar 7	Mar 25	Apr 9	Oct 29	Nov 12	Nov 30
28F	100%	Mar 20	Apr 4	Apr 18	Oct 18	Nov 2	Nov 18
32F	100%	Mar 31	Apr 12	Apr 27	Oct 6	Oct 23	Nov 6
36F	100%	Apr 9	Apr 23	May 5	Sep 26	Oct 12	Oct 26

Frost and Freeze Date Normals

- Computed as *conditional probabilities* new

Temperature	P	Spring Dates			Fall Dates		
		90%	50%	10%	10%	50%	90%
Houston 28F	68%	Dec 20	Jan 19	Feb 22	Dec 6	Dec 31	Feb 3

This only affects a minority of (warmer) stations

- Not computed if probability of occurrence is too low (<10%) – affects very warm stations in FL, TX, Pacific, PR, etc. new
- Not computed for stations that have year-round risk of reaching the minimum temperature threshold new

Ronnie Leeper will present First and Last Day of Frost: A USCRN Perspective

Growing Season Length Normals:
aka Freeze-Free Period Normals

- Growing season: the time period between the last "spring" frost-freeze and the first "autumn" frost-freeze
- Growing season length normals: the likelihood that the growing season will be at least the specified number of days
- Houston, 32F: 10% 354 days, 50% 320 days, 90% 285 days
- Missoula, 32F: 10% 147 days, 50% 128 days, 90% 106 days

Jesse Bell will discuss a growing season analysis tomorrow

03/13/2013

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Summary of Annual Normals
1981-2010

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801
www.ncdc.noaa.gov

Station: **DENVER INTERNATIONAL AIRPORT, CO US**

GHCND:USW00003017
Elev: 1650 ft. Lat: 39.833° N Lon: 104.658° W

Freeze Data

Spring Freeze Dates (Month/Day)

Temp (F)	Probabilty of later date in spring (through Jul 31) than indicated(*)								
	.10	.20	.30	.40	.50	.60	.70	.80	.90
36	6/03	5/28	5/24	5/20	5/18	5/15	5/12	5/09	5/04
32	5/20	5/15	5/11	5/08	5/06	5/04	5/01	4/29	4/24
28	5/10	5/05	5/03	4/30	4/28	4/25	4/22	4/18	4/13
24	5/01	4/27	4/23	4/20	4/17	4/14	4/11	4/07	4/02
20	4/21	4/16	4/12	4/09	4/06	4/03	3/31	3/26	3/19
16	4/12	4/06	4/01	3/29	3/25	3/20	3/16	3/11	3/04

Fall Freeze Dates (Month/Day)

Temp (F)	Probabilty of earlier date in fall (beginning Aug 1) than indicated(*)								
	.10	.20	.30	.40	.50	.60	.70	.80	.90
36	9/15	9/20	9/24	9/26	9/29	10/01	10/03	10/06	10/10
32	9/22	9/27	9/30	10/03	10/06	10/09	10/12	10/15	10/19
28	9/29	10/05	10/10	10/13	10/16	10/19	10/22	10/25	10/30
24	10/10	10/17	10/20	10/23	10/26	10/29	11/01	11/04	11/09
20	10/21	10/26	10/30	11/01	11/04	11/07	11/11	11/14	11/18
16	10/29	11/02	11/05	11/09	11/12	11/15	11/18	11/21	11/25

Freeze Free Period

Temp (F)	Probabilty of longer than indicate freeze free period (Days)								
	.10	.20	.30	.40	.50	.60	.70	.80	.90
36	150	144	140	136	133	129	125	120	113
32	170	164	159	155	151	147	143	138	132
28	192	185	180	175	171	167	163	157	150
24	212	206	201	196	192	188	183	178	170
20	235	228	222	217	213	209	204	199	191
16	257	249	243	238	233	228	223	217	209

(*) Probability of observing a temperature as cold, or colder, later in the spring or earlier in the fall than the indicated date

0/00 Indicates that the probability of occurrence of threshold temperature is less than the indicated probability.
Derived from 1981-2010 serially complete daily data

Complete Documentation available from:
www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

Freeze Free Period

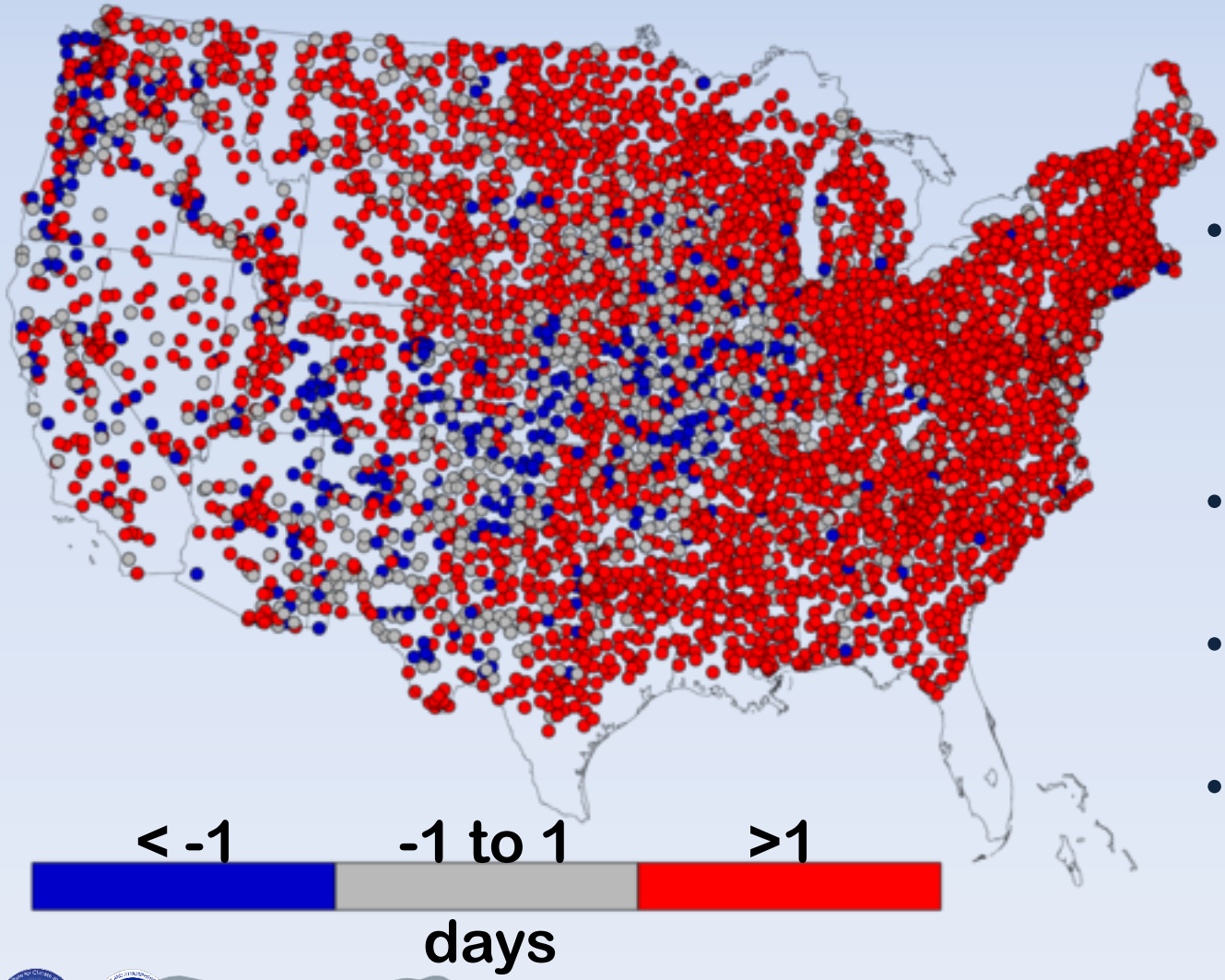
Temp (F)	Probabilty of longer than indicate				
	.10	.20	.30	.40	.50
36	150	144	140	136	133
32	170	164	159	155	151
28	192	185	180	175	171
24	212	206	201	196	192
20	235	228	222	217	213
16	257	249	243	238	233

Frequencies of Threshold Exceedance

- Translation: Expected number of days per month above or below a given temperature
- Example: In Cleveland, on how many January days will the maximum temperature stay below 32°F?
- Answer: 13.1 days on average
- On how many days in January will the minimum temperature drop to 32°F or below?
- Answer: 25.0 days on average

1981-2010 Versus 1951-1980

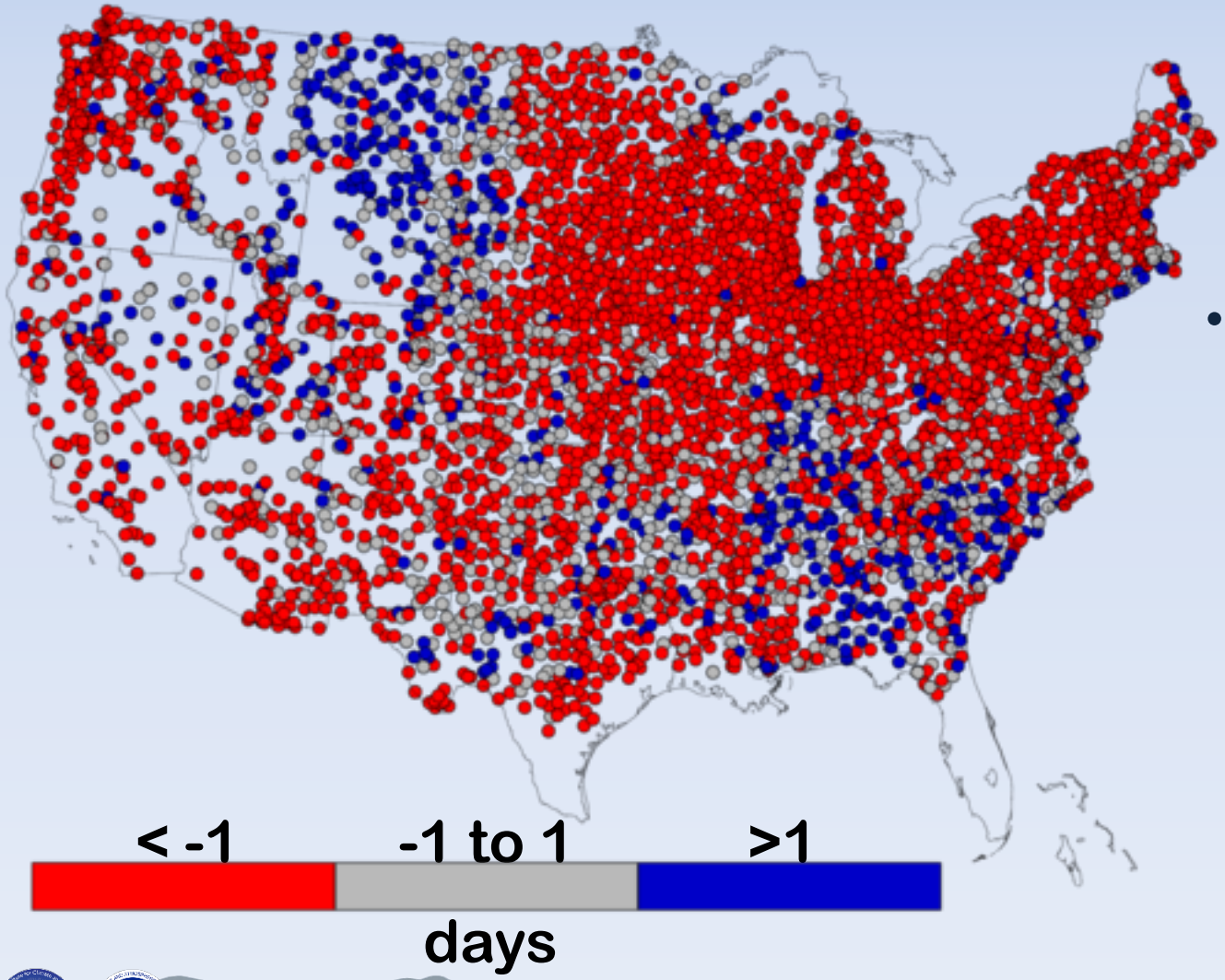
change in median date of first "fall" freeze



- Ignores stations that are too warm or too cold to report date normals
- Median of red dots is +5 days
- Median of blue dots is -3 days
- Overall median is +3.5 days

1981-2010 Versus 1951-1980

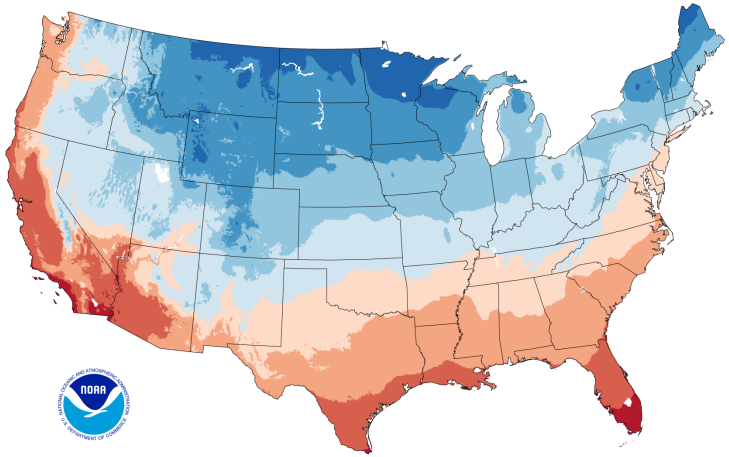
change in median date of last "spring" freeze



- Overall median is -3.5 days

Climate-Related Planting Zones

Based on 1971-2000 Climate Normals



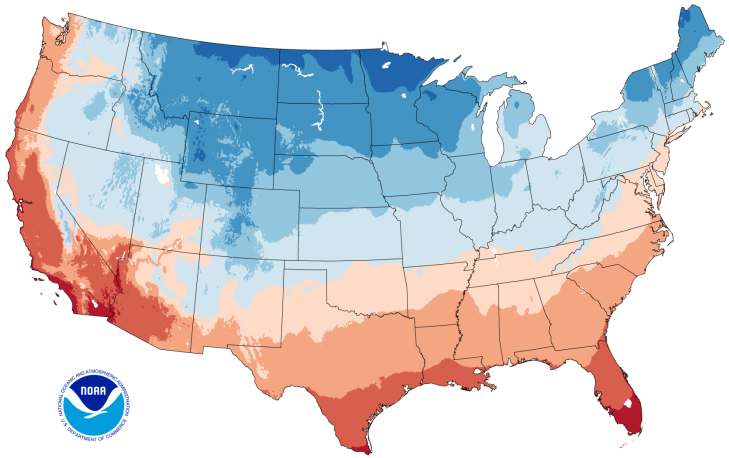
Average Annual Minimum Temperature by Climate-Related Planting Zone

Zone 3 (-39 to -30 F)	Zone 5 (-19 to -10 F)	Zone 7 (1 to 10 F)	Zone 9 (21 to 30 F)
Zone 4 (-29 to -20 F)	Zone 6 (-9 to 0 F)	Zone 8 (11 to 20 F)	Zone 10 (31 to 40 F)

Disclaimer: This illustration of nationwide patterns and changes in climate-related planting zones for gardeners was created as a special service to the American Public Gardens Association by the National Oceanic and Atmospheric Administration (NOAA). The official Plant Hardiness Zone map was prepared by the U.S. Department of Agriculture (USDA) in 1990 using data collected and distributed by NOAA. USDA is currently updating its official map, which will soon be available via the Internet.

Climate-Related Planting Zones

Based on New 1981-2010 Climate Normals



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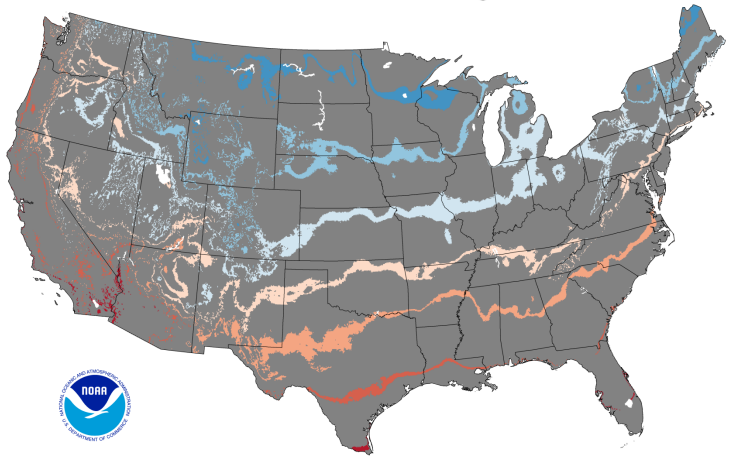
Zone Changes in Past 10 Years

In Color of New Planting Zone



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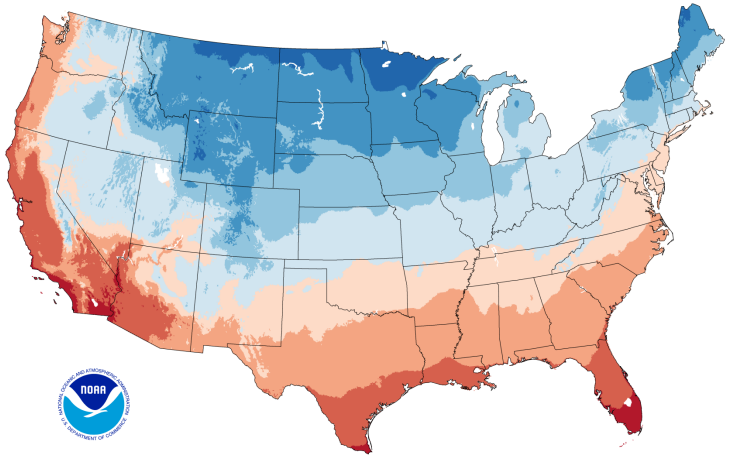

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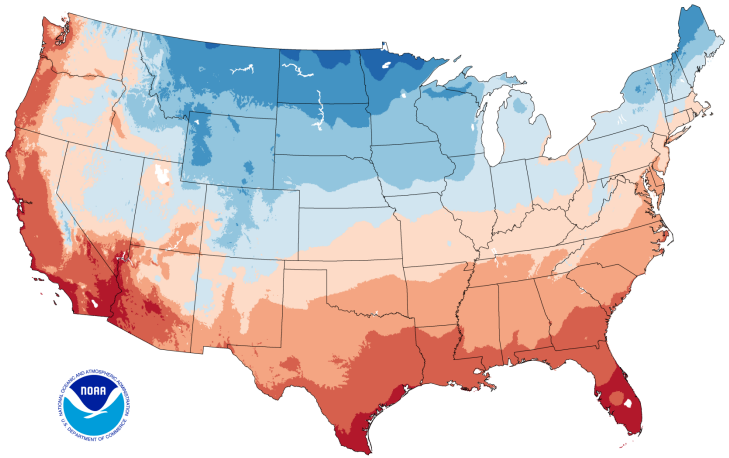
Climate-Related Planting Zones: 2011-2040

Based on 1971-2010 Trends



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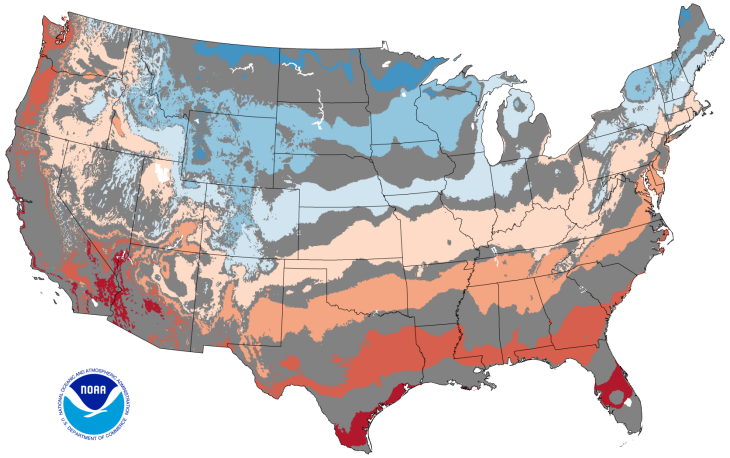
Projected Zone Changes in Next 30 Years

In Color of New Planting Zone



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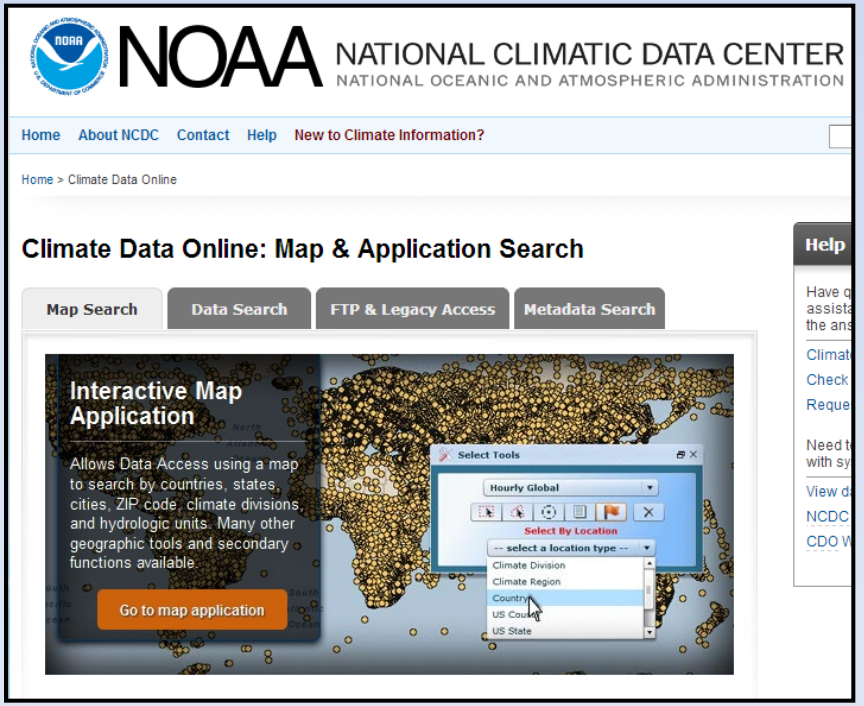
NOAA's 1981-2010 Agricultural Normals

Access Details

- Status: Released Early 2013
- Access Points:
  1. NCDC's Climate Data Online
  2. NCDC Orders (telephone)
  3. FTP
- Supplement to NOAA's 1981-2010 Climate Normals



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- "Frost-Freeze" products are based on select minimum temperature thresholds
- NCDC provides a wide variety of products that characterize the climatological likelihood and timing of frost and freeze events
- Since 1951, the median freeze-free period over the U.S. has increased by about a week

Serially-Complete Tmin

FACT:

Very few stations (<5%) have complete daily minimum temperature data over any thirty year period, including 1981-2010

Missing values occur either because no observation exists in our records, or because an observation was flagged as erroneous by the GHCN-Daily Quality Control

Serially-Complete Tmin

- Missing values are filled using a simple anomaly approach
- Non-missing values from the 5 nearest neighbors are used
- Compute anomalies: subtract daily normal from the observations
- The filled value is the target station's daily normal plus the mean anomaly:

$$T_o(y,j) = N(j) + \frac{1}{5}\sum_{i=1}^{5}[T_i(y,j) - N_i(j)]$$

Serially-Complete Tmin

- The serially-complete data are adjusted to be consistent with the homogenized monthly minimum temperature values used to compute 1981-2010 normals

- Rare instances of inter-month discontinuities are suppressed using an iterative smoothing approach
  - Helps ensure that frost-freeze date probabilities are not disproportionately concentrated near the beginning or end of a month

Weather Generator Simulations

- Each 30-year serially-complete station record is bootstrapped to arrive at 10,000 annual time series

Martinsville, VA (USC00445300)									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
16F	11/21	11/22	11/28	12/7	12/8	12/13	12/18	12/25	12/25
20F	11/5	11/8	11/13	11/13	11/17	11/21	11/30	12/3	12/13

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20F	11/5	11/8	**11/13**	**11/13**	11/17	11/21	11/30	12/3	12/13

Martinsville, VA (USC00445300) using weather generator									
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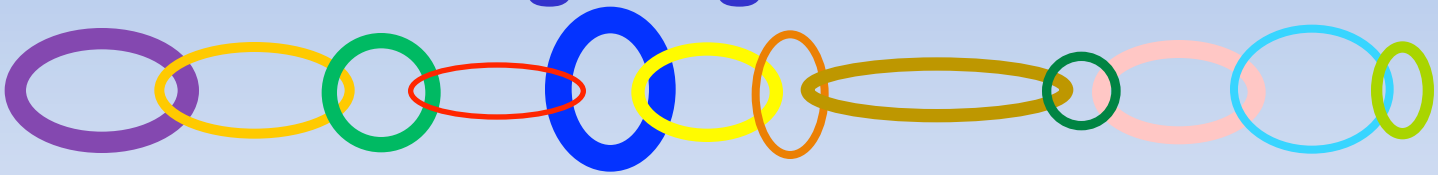
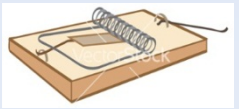
20F	11/5	11/10	**11/13**	**11/17**	11/21	11/25	11/30	12/5	12/11

Piecing Together Each Simulation



- Each simulation is a 365-day time series, pieced together from 12 sequences of 28-31 values (one per month)
- Three randomized components
  - Year sequence is draw from (anomaly series)
  - Window start date (+/-14 days)
  - Mean value imposed on sequence (from 30 years)

- Simple traps are set to abort construction of implausible simulations (based on extremes and endpoints)



Example

- Begin with July
- Draw year 1985
- Draw window offset of -7
- 31-point sequence is 6/24/85-7/24/85
- Remove mean
- Draw 2007
- Add July 2007 mean tmin to sequence values
- Check extremes

Example, Cont'd

- Repeat for August
- Check July-August transition
- Check August extremes
- Continue with September-June
- If any traps are triggered, discard simulation and start anew with July
- Continue until 1000 simulations are generated

Findings

- No bias for earlier or later dates
- As expected, simulation monthly means are consistent with observations
- As expected, simulations on average have a slightly larger standard deviation (up to 7% higher in winter) than the observations (can tweak traps)
- As expected, weather generator approach effectively smooths the date normals