Frost Susceptibility Assessment

Frost Mitigation With Wind Machines

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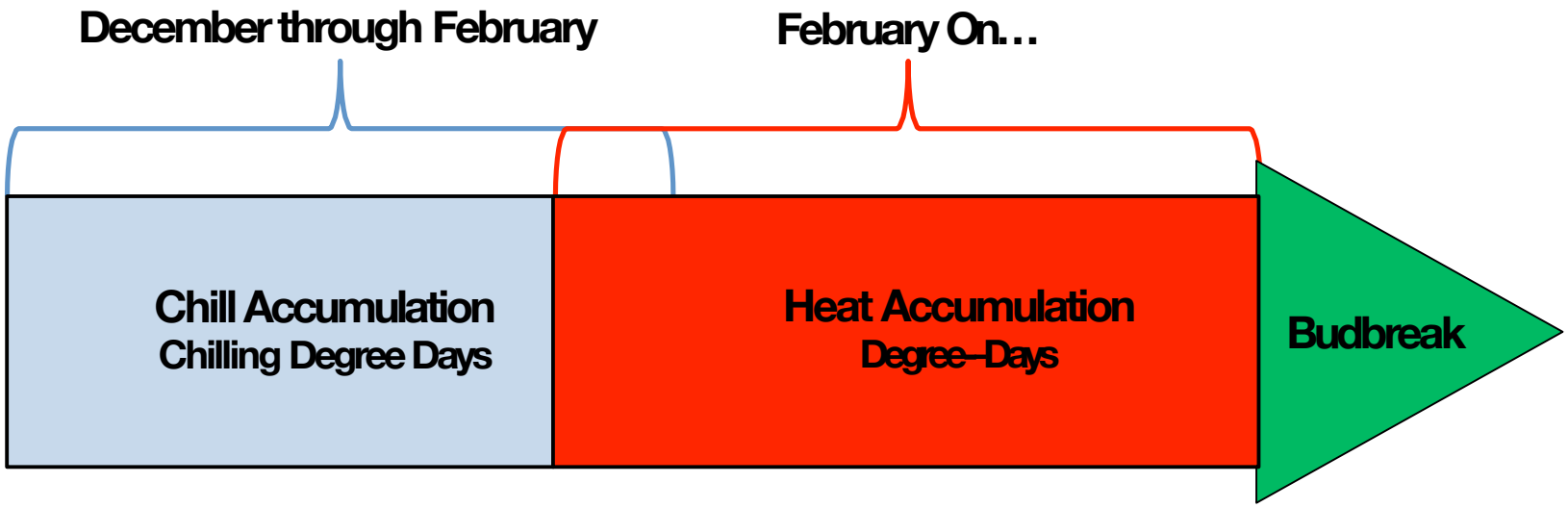
THE UNIVERSITY OF ARIZONA

ARIZONA COLLEGE OF AGRICULTURE AND LIFE SCIENCES COOPERATIVE EXTENSION

Are We More Susceptible to Frost?

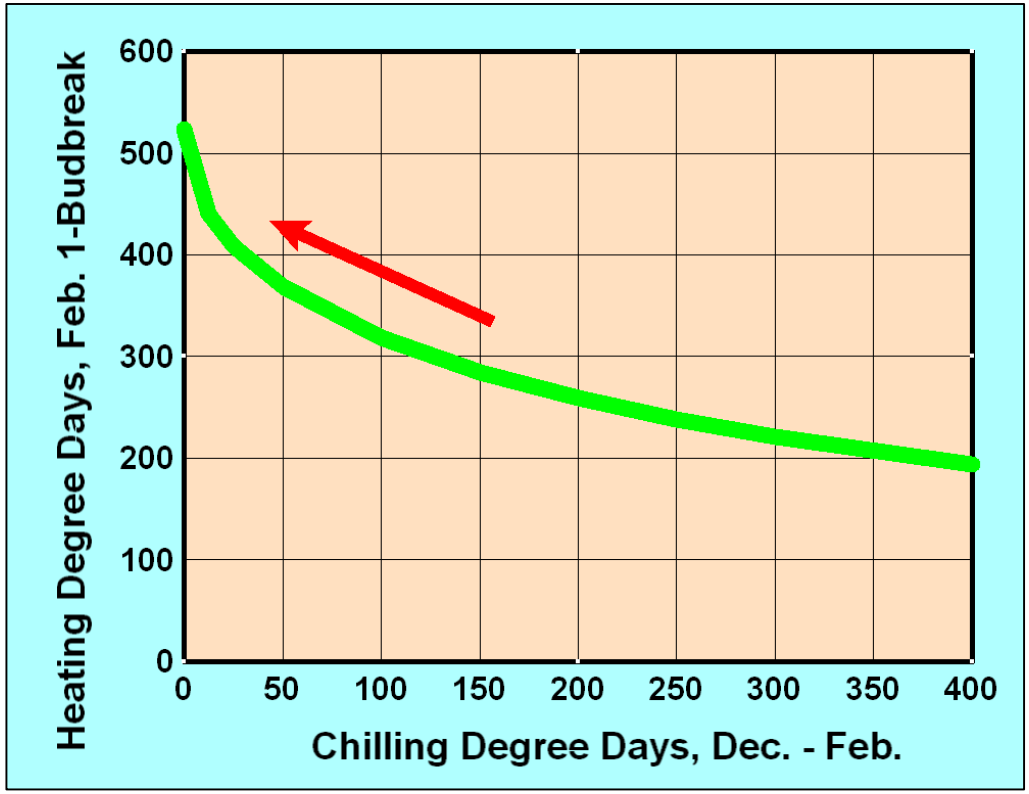
- **Pecan Phenology/Budbreak**
- **Spring Weather Conditions/Trends**
- **Frost Date Trends**

Sparks Pecan Budbreak Model



Winter chill accumulation followed by heat accumulation

Sparks Budbreak Model

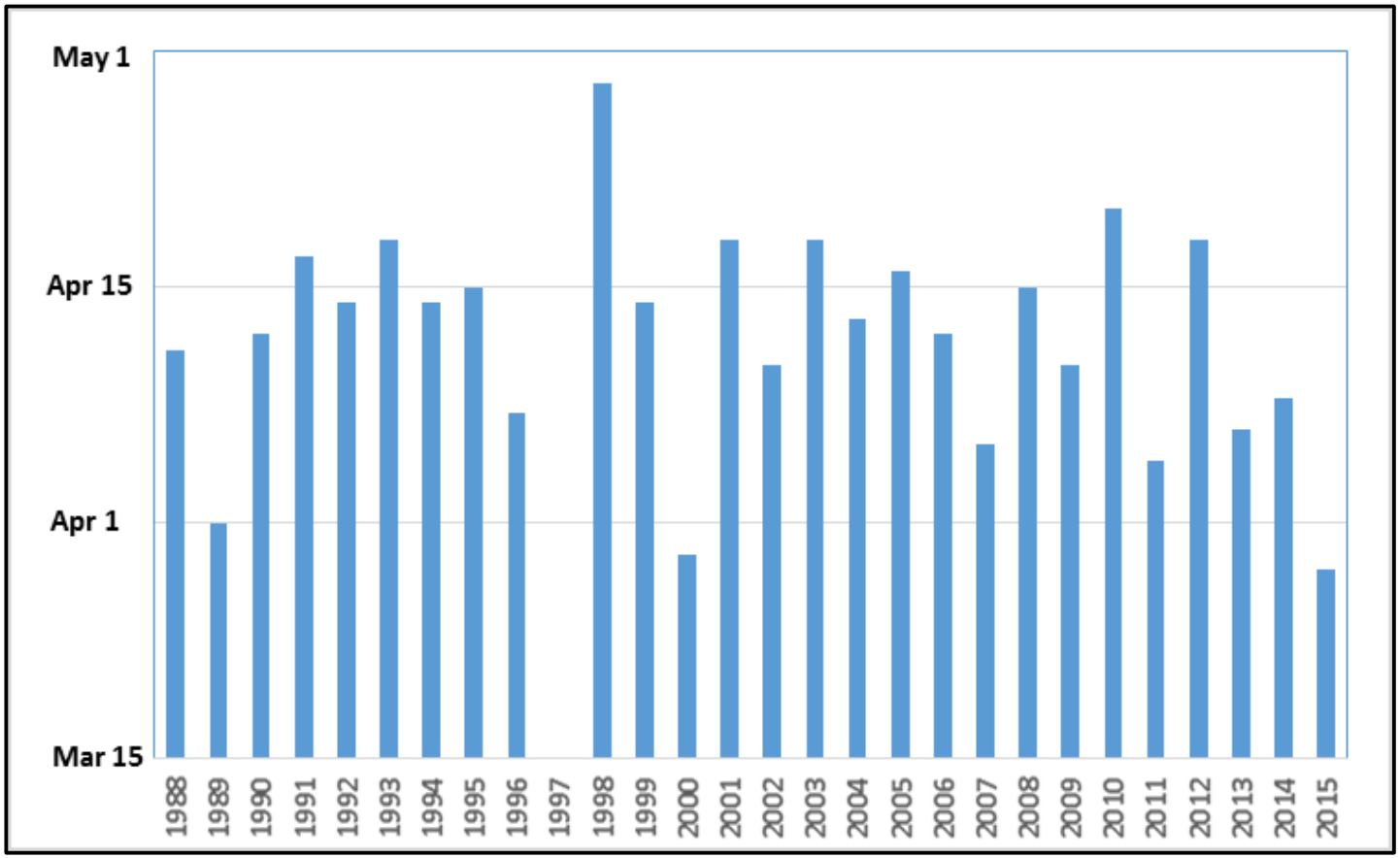


Year	Chill DDs	Heat DDs
2011	64	408
2012	26	450
2013	117	370
2014	22	455
2015	29	445
2016	59	412

Less Chill Means More Degree Days to Budbreak

Bud Break Estimates

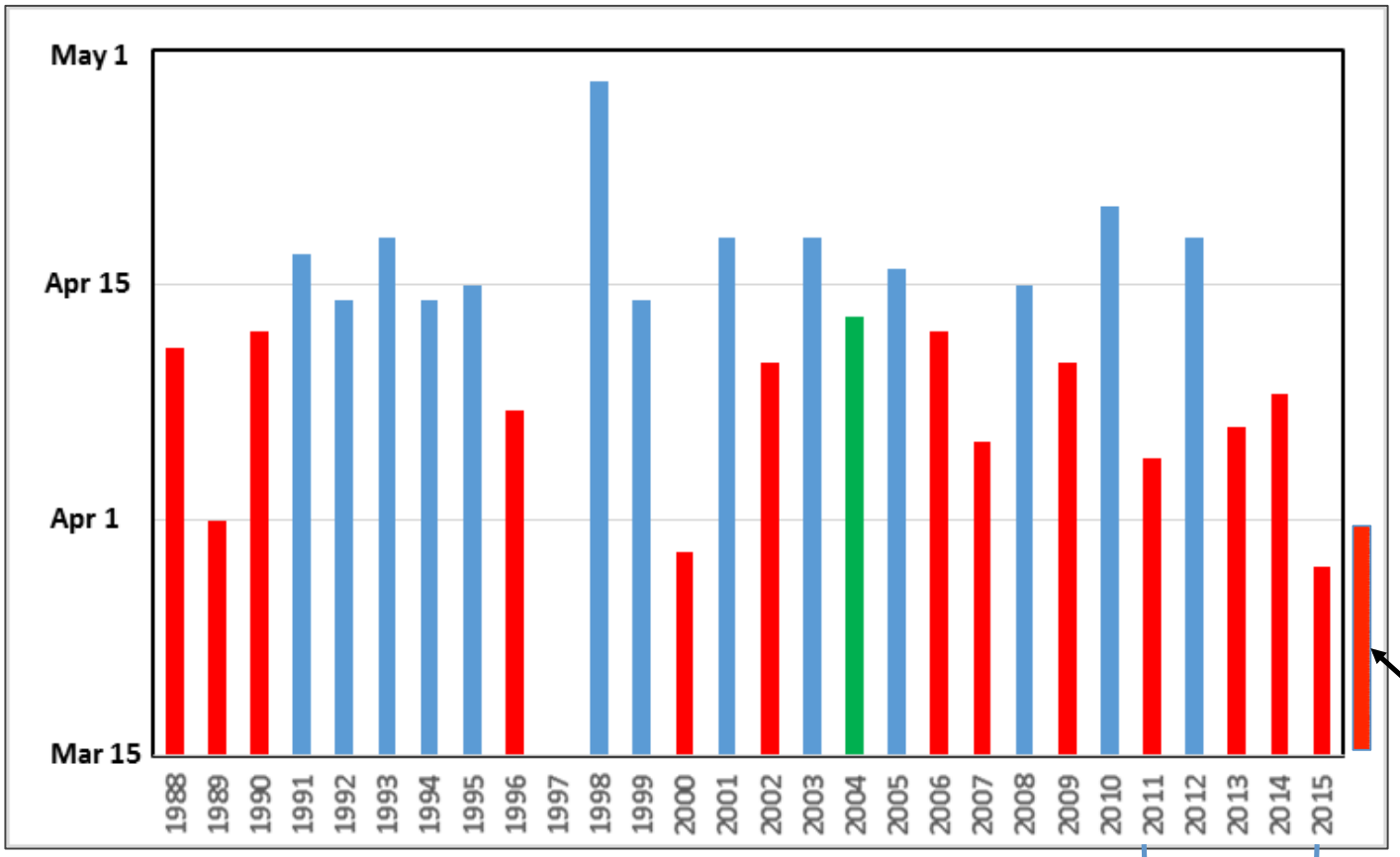
Arizona @ 4200’



Average = 12 April

Median = 13 April

Budbreak Estimates
Arizona @ 4200’



Green: Median

Red: Before Median

Blue: After Median

2016 Estimate

4 of last 5 Years: Early Estimated Budbreak

Budbreak Estimates
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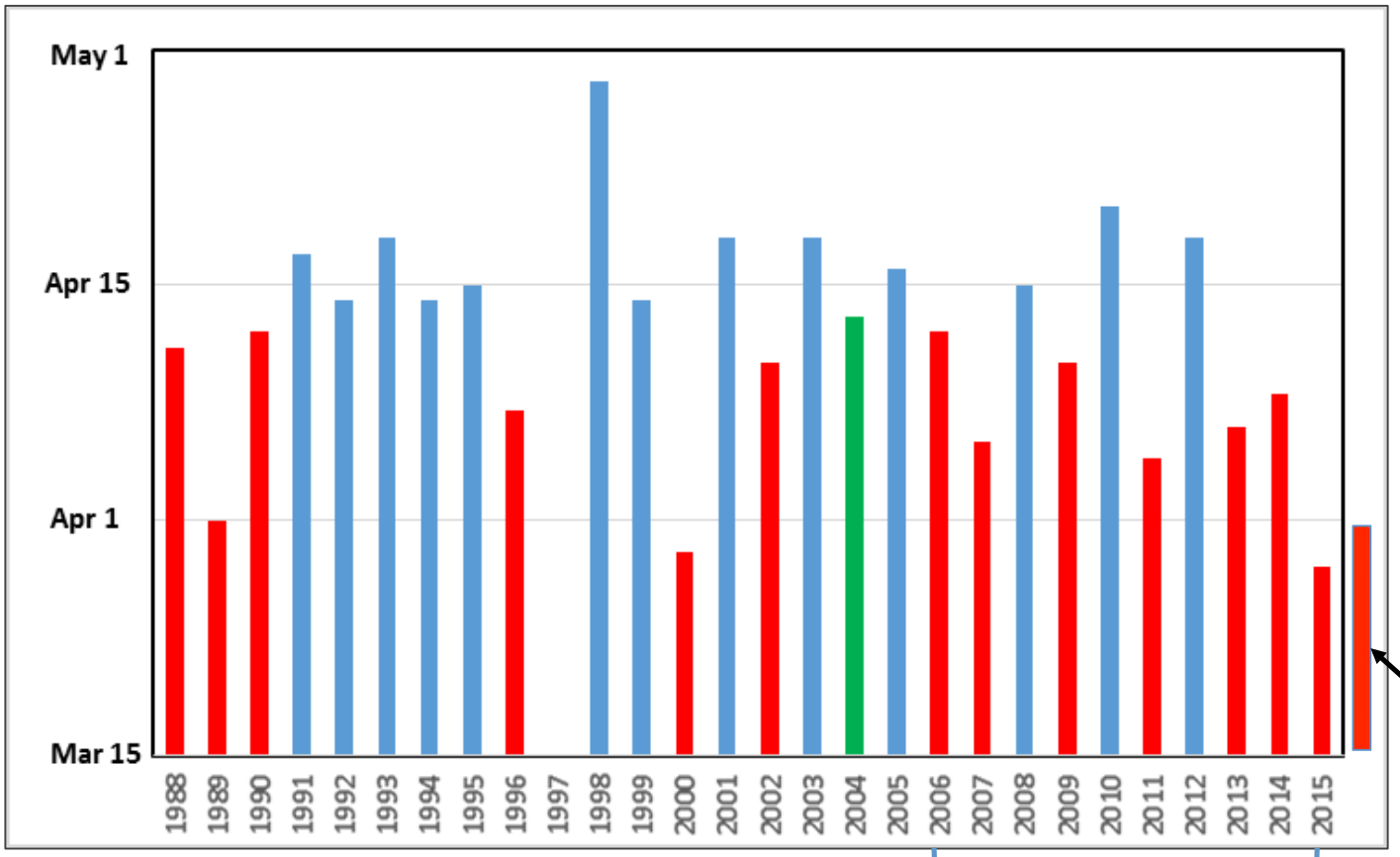

Green: Median

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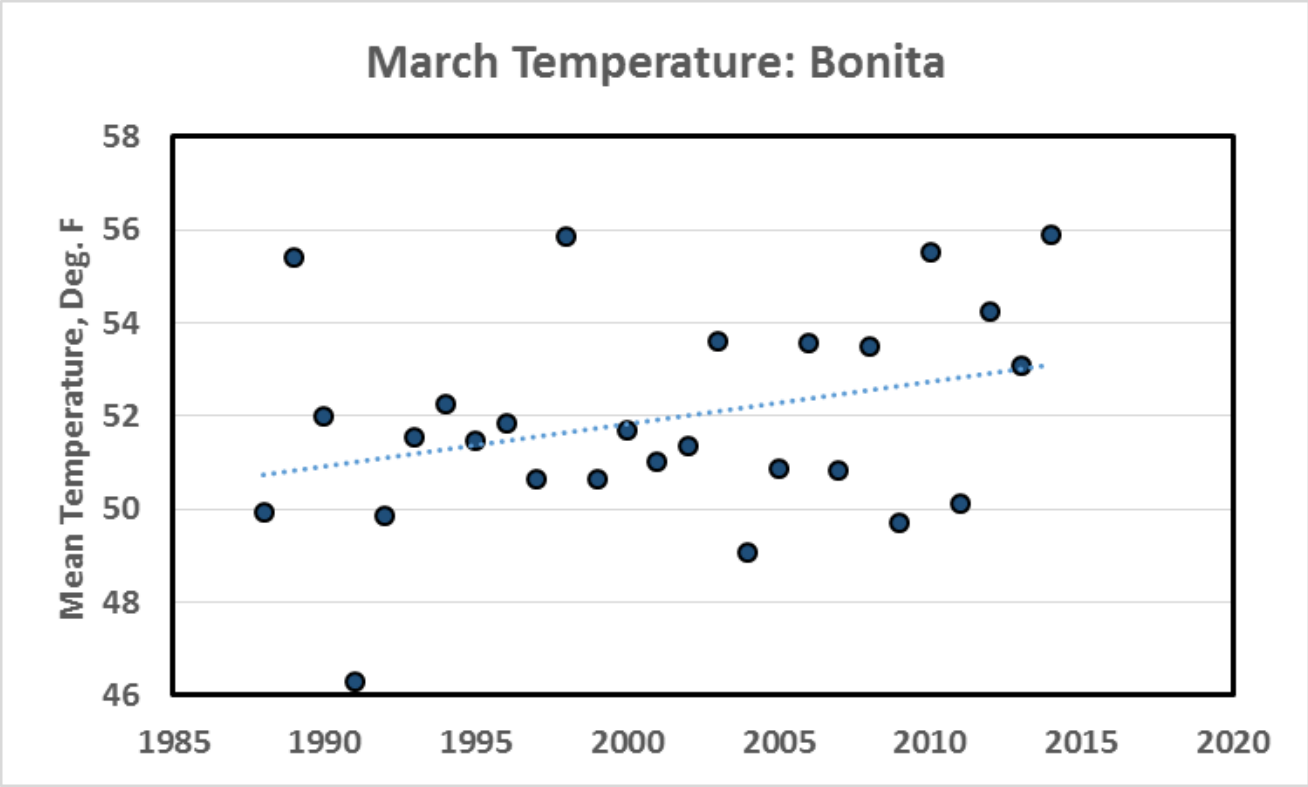
2016 Estimate

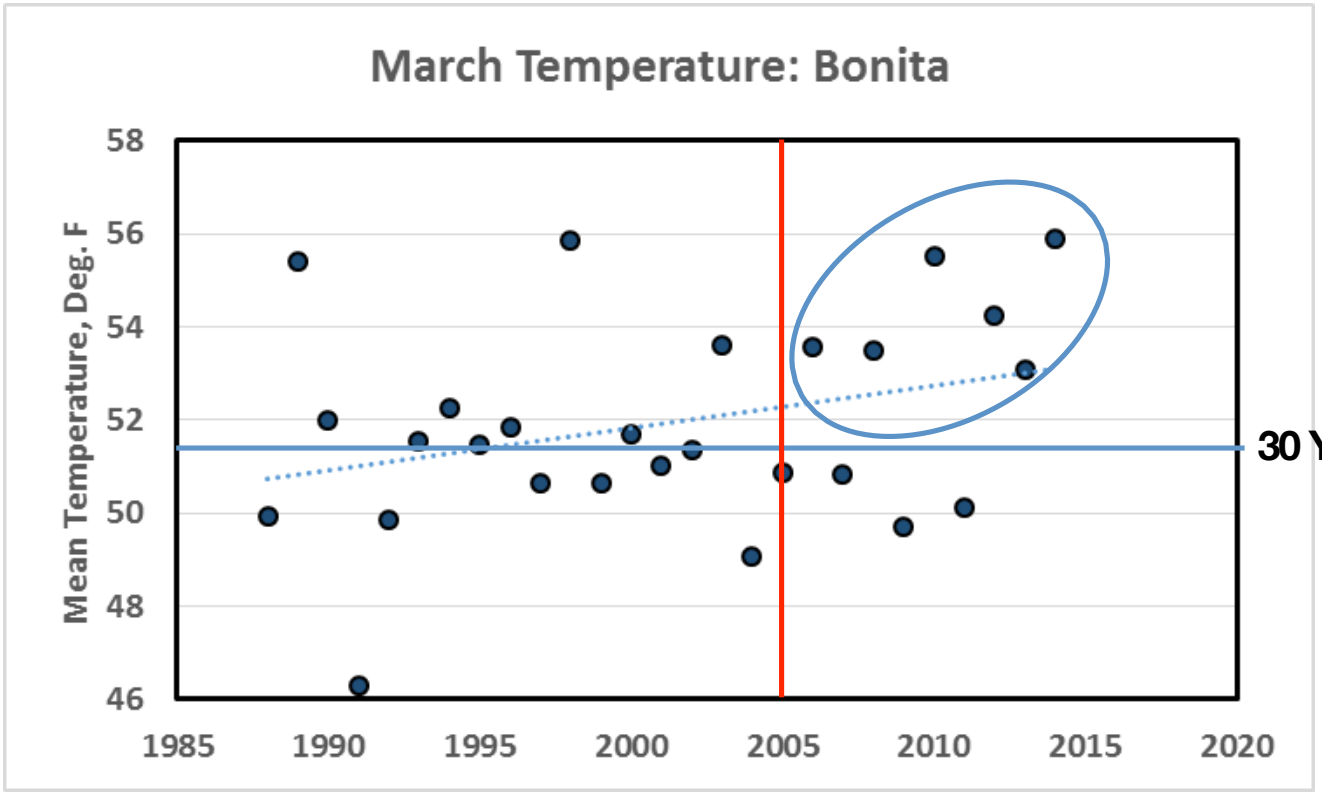
7 of Last 10 Years: Early Estimated Budbreak

March Warming Trend



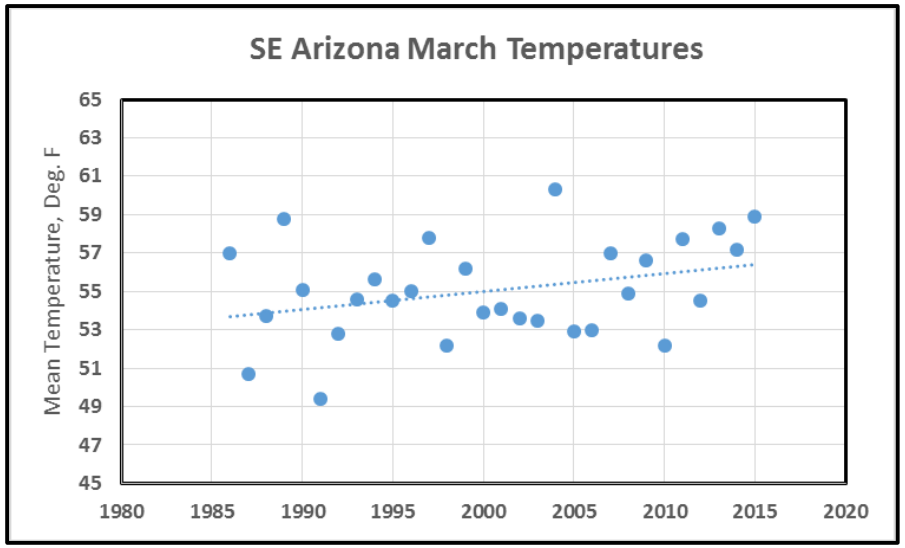
General Warming Trend Over 30 Years

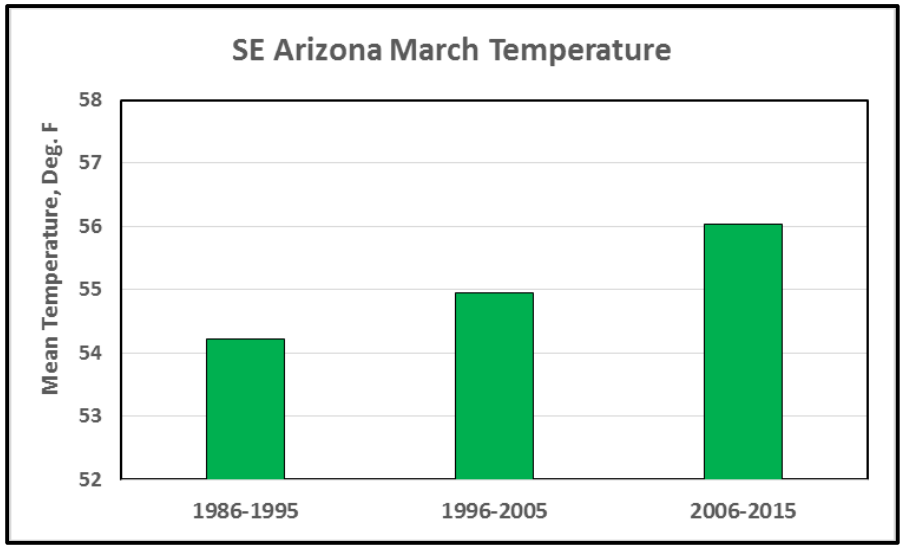
March Warming Trend



General Warming Trend Over 30 Years
Especially Last 10 Years

Spring Temperature Trends
Warmer March Temperatures





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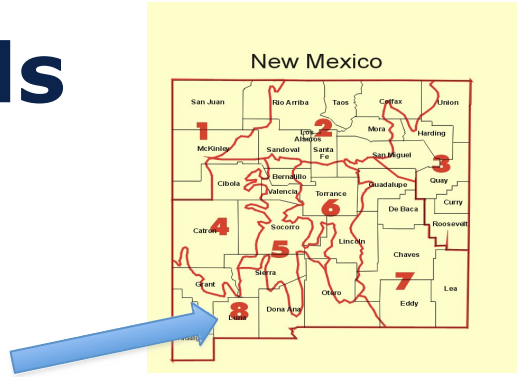

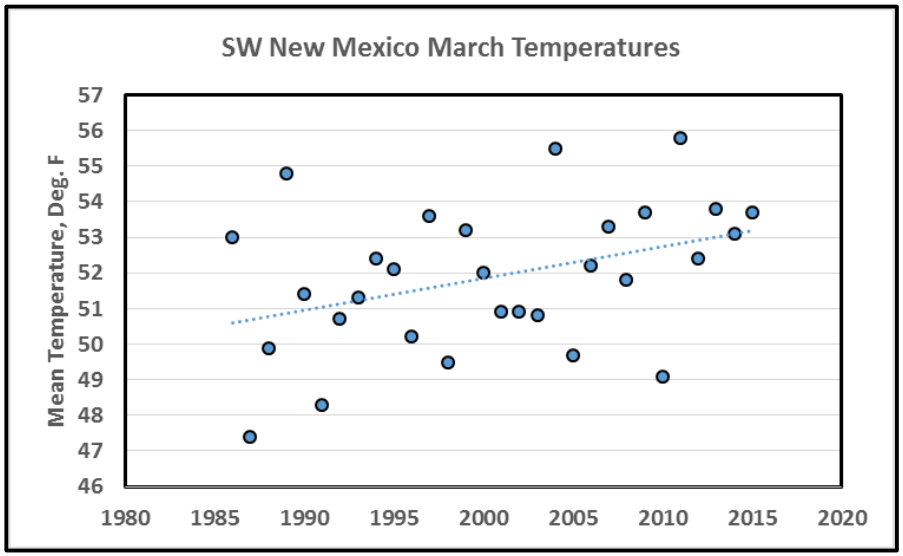

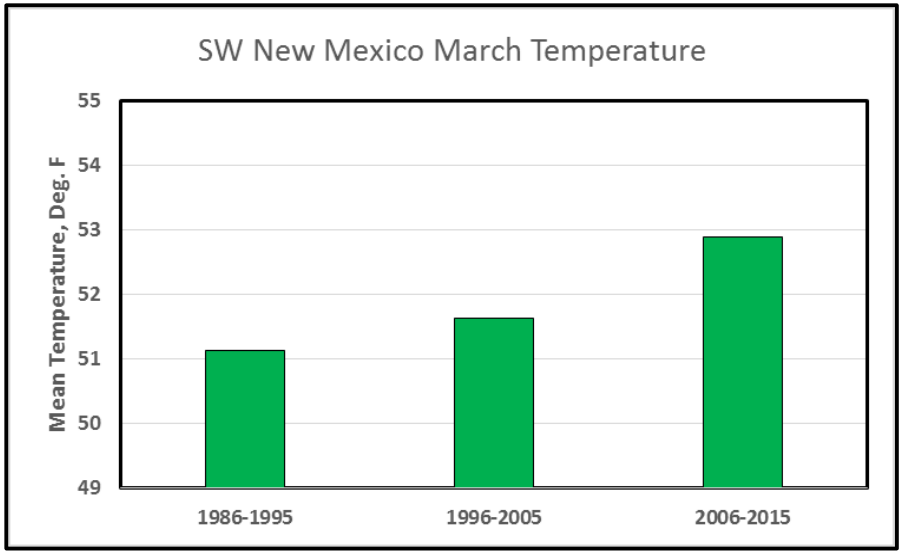

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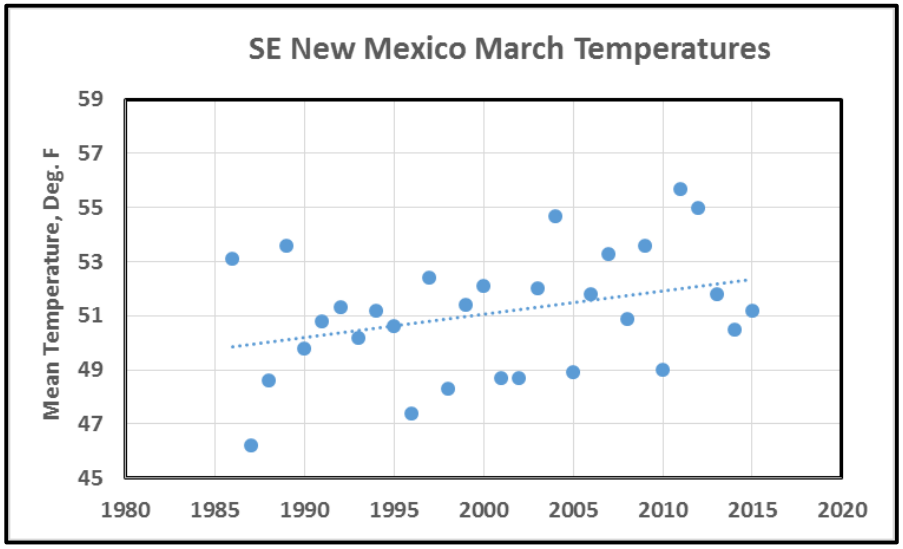
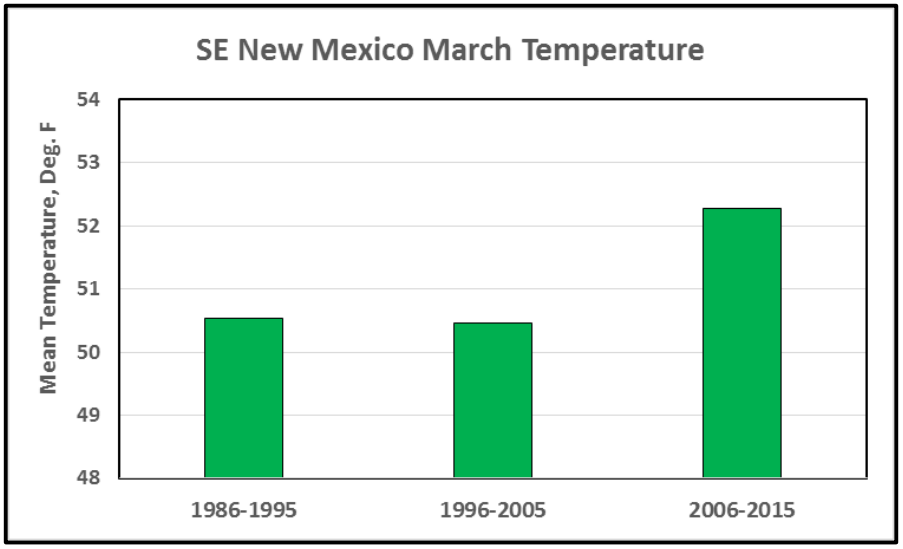
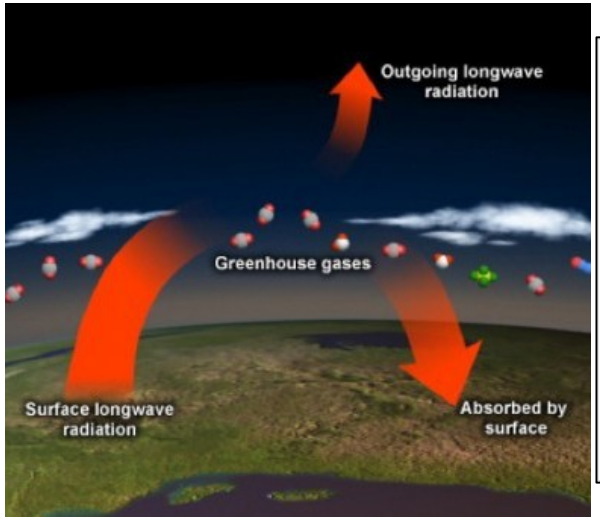
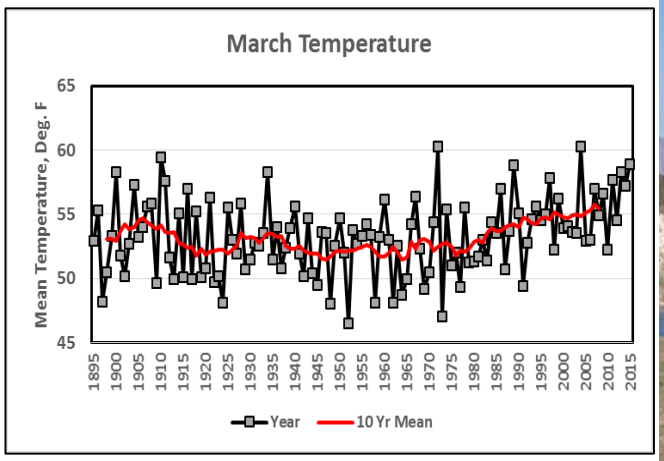




Factors Leading To Warming



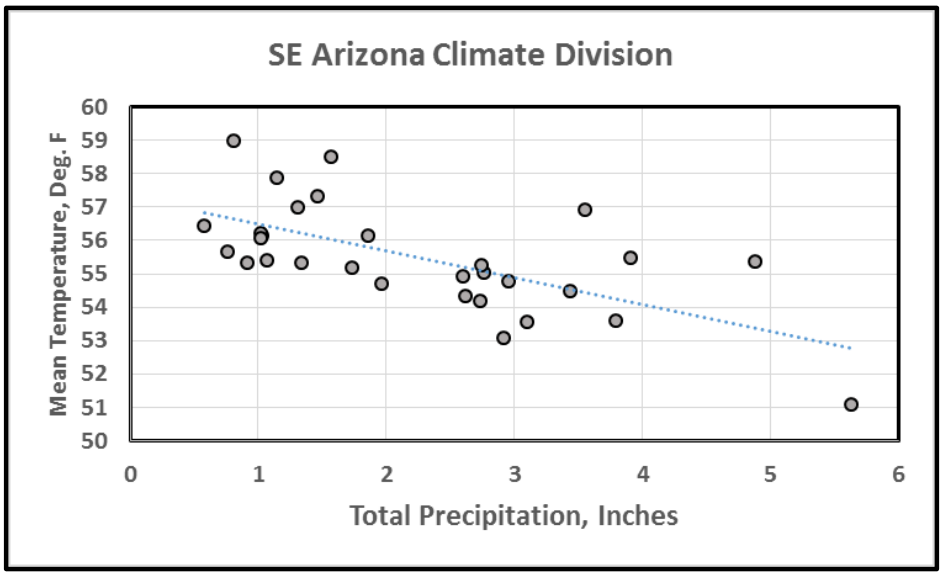
Warming from Greenhouse Gases



Cyclical Weather/Climate

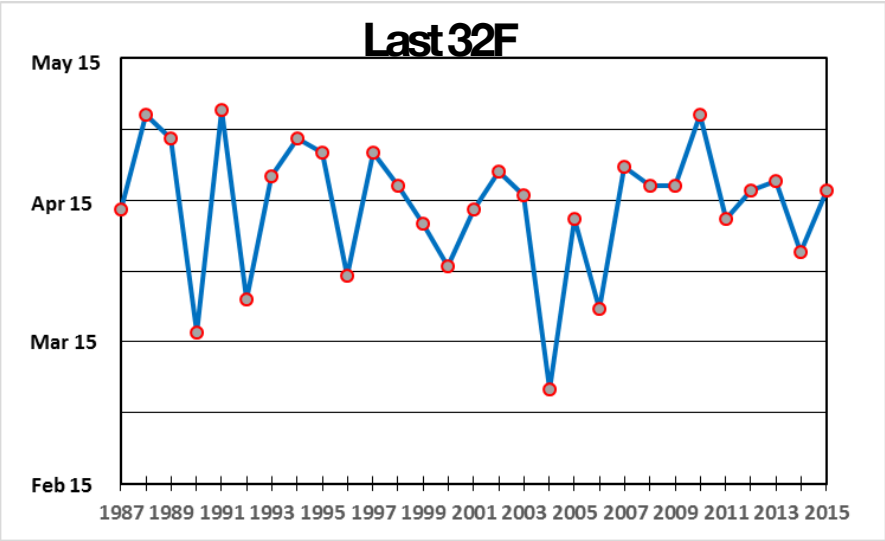
Drought

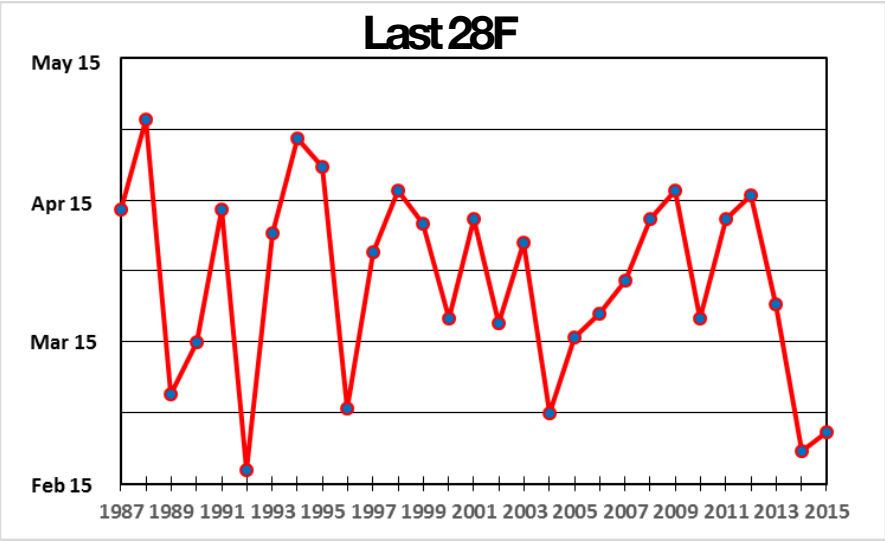
Spring Precipitation/Drought
February-April



	Cool	Warm
Wet	12 Years 54.1F	3 Years
Dry	3 Years	12 Years 56.8F

Frost Dates

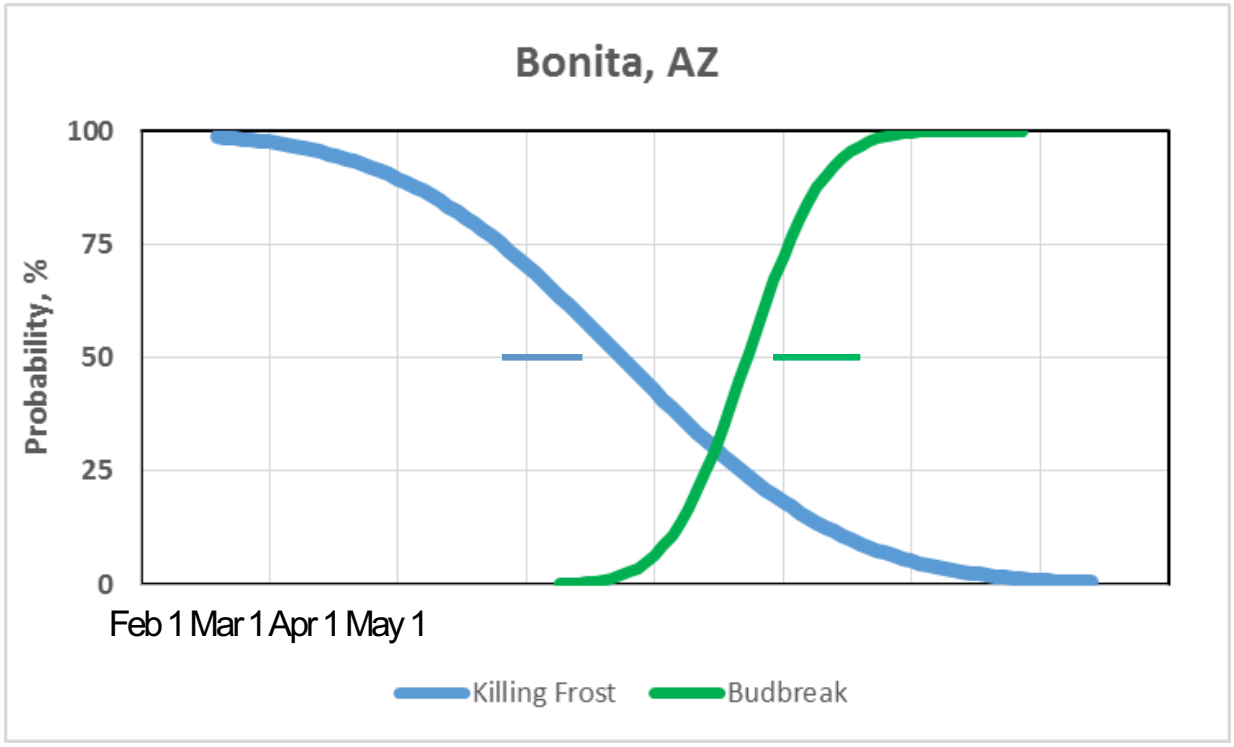




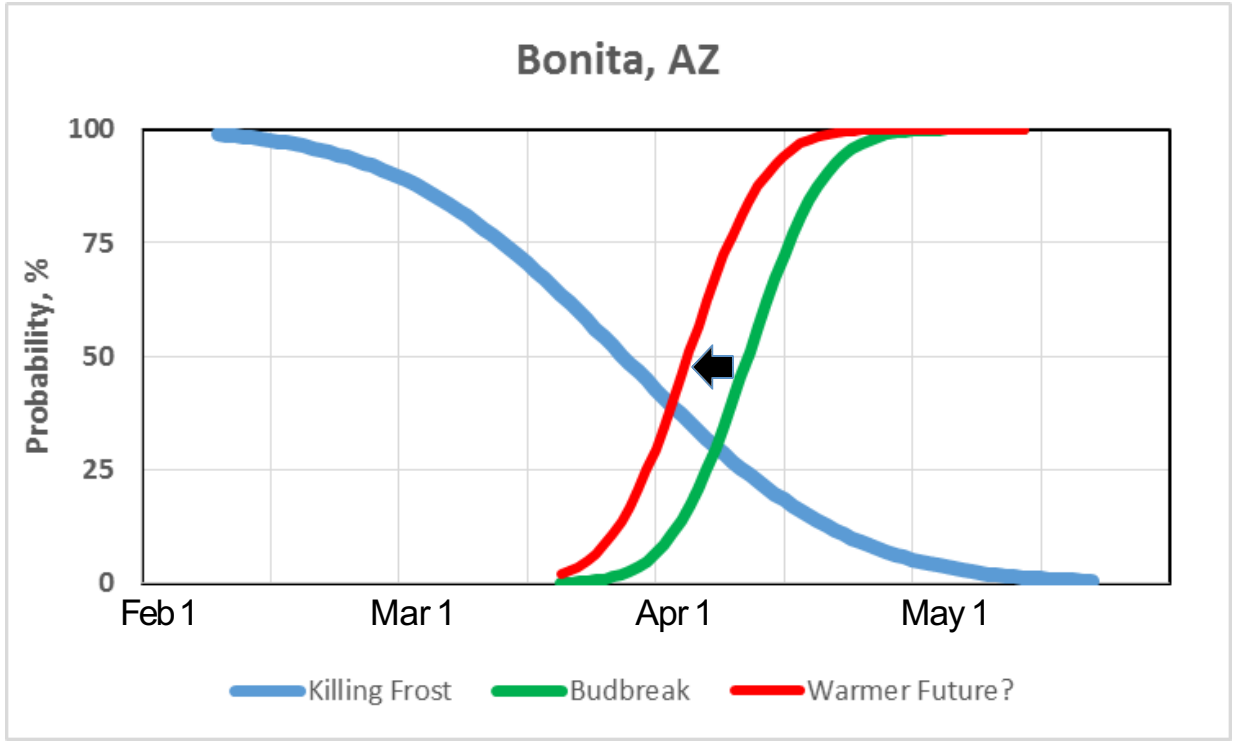
Slight, non–significant trend toward earlier last frost date

Note high variability of last frost date, especially last 28F frost

The Most Recent 30 Years



The Danger
Warmer Future With Similar Frost Activity

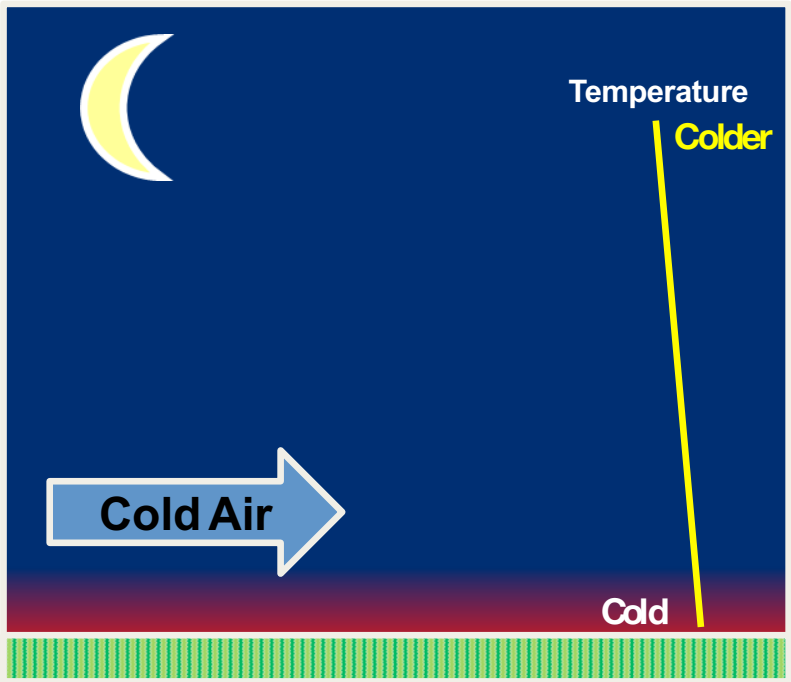


We need a better arid regional phenology model to address this issue!

Wind Machines for Frost Protection

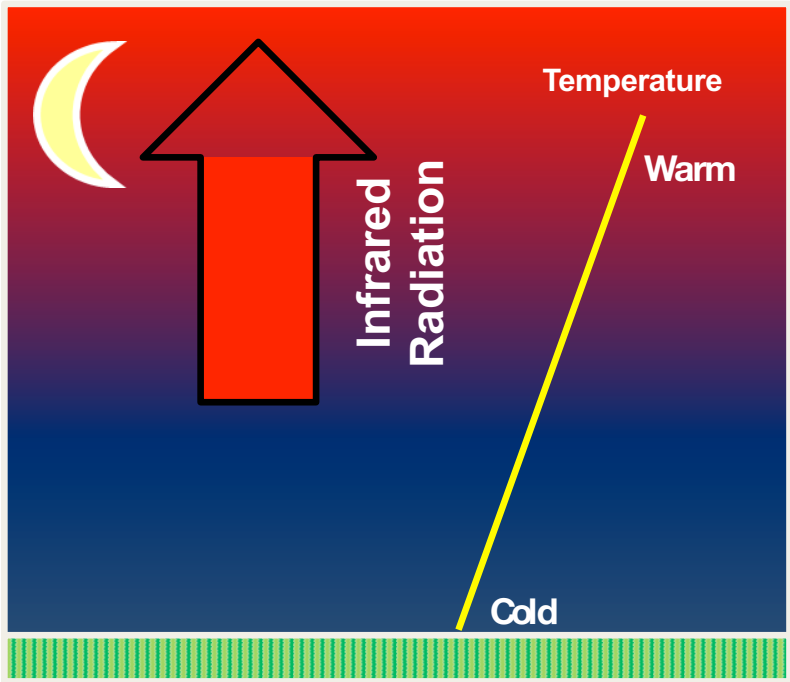
Types of Frost Events

Advective



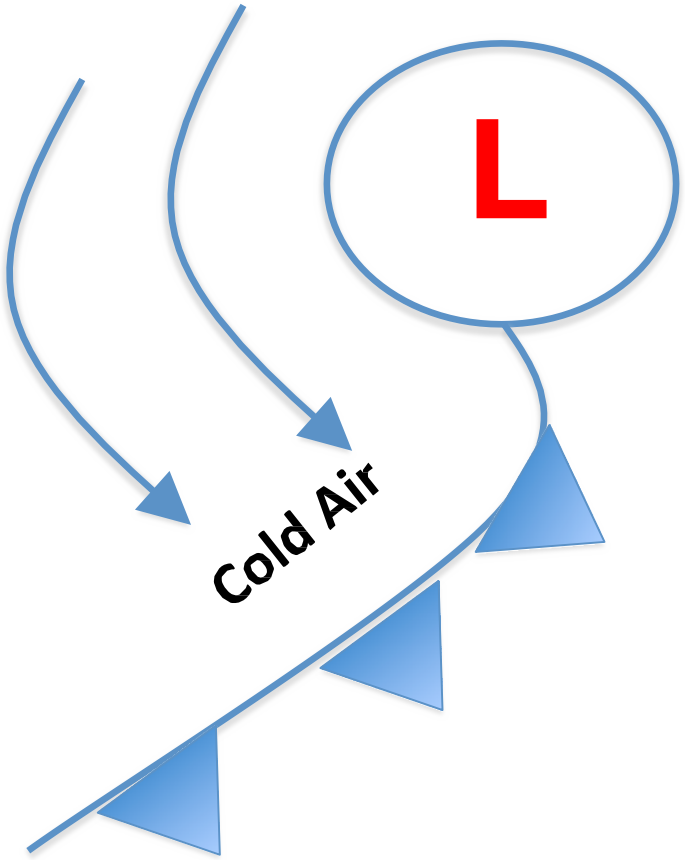
- Associated With Cold Front
- Windy, Often Clear & Dry
- Colder Aloft
- Frost May Not Be Visible

Radiation



- Associated With High Pressure
- Clear, Calm & Often Dry
- Warmer Aloft
- Frost Often Visible

Most Severe Frosts in Southwest Combination Events



- **Strong Storm System Passes**
  - **Mid-Day**
  - **Cold Front Displaces Warm Air**
  - **Extracts Heat From Surface**
  - **Limited Heat Aloft in Air**
- **High Pressure Moves in Quickly**
  - **Skies Clear**
  - **Wind Dies**
  - **Radiation Frost**
  - **Limited Inversion**

Wind Machines

Both permanent & portable models

- **Large Rotating Fans**
  - Typically on Tower
  - Slight Downward Angle
    Mix Warmer Air Aloft With Colder Surface Air
  - Increase Surface Temperature
- **Powered By**
  - Electricity
  - Diesel
  - Gasoline
  - LP Gas
- **Require Presence of Inversion**
  - Radiation Frost Events

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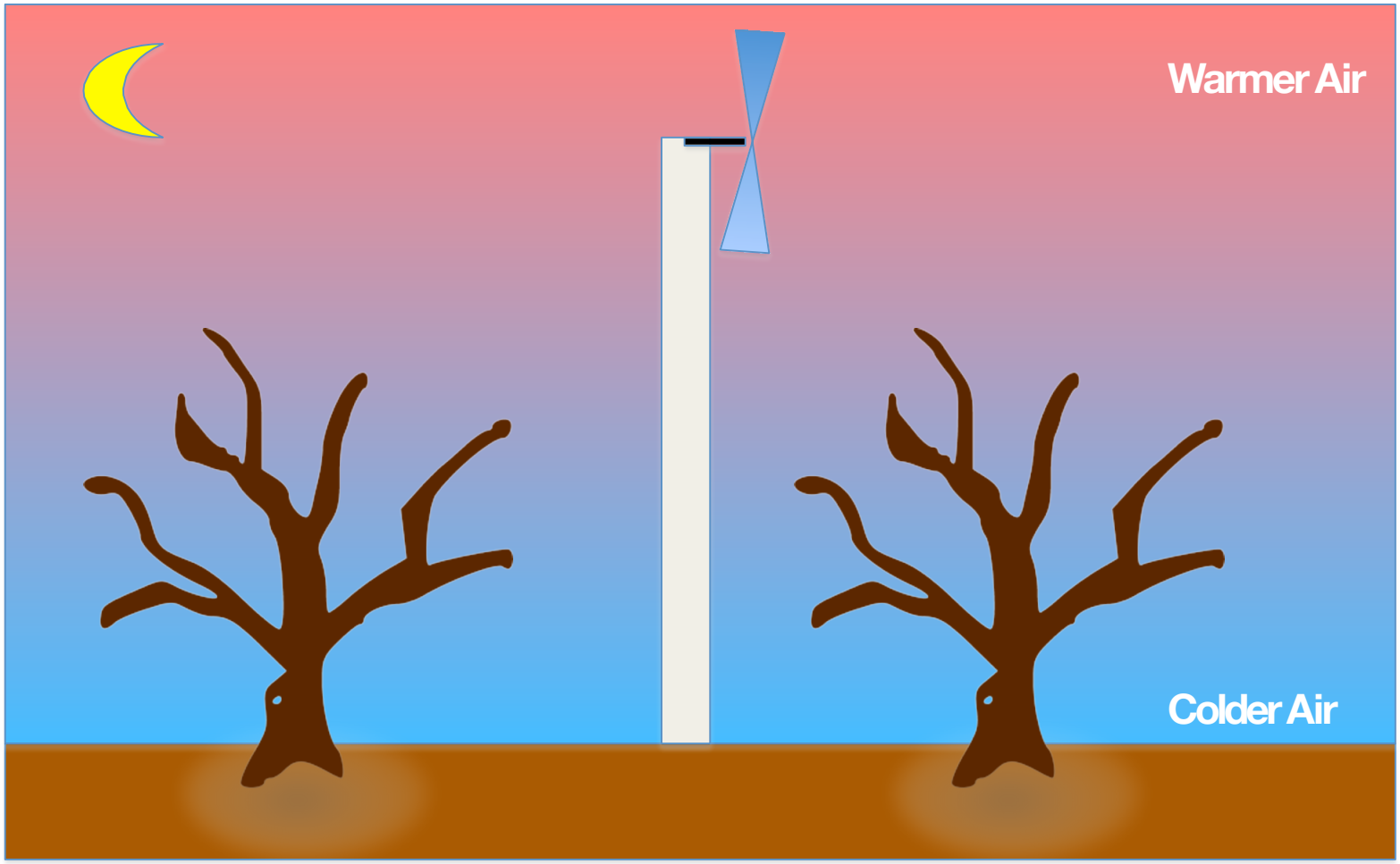
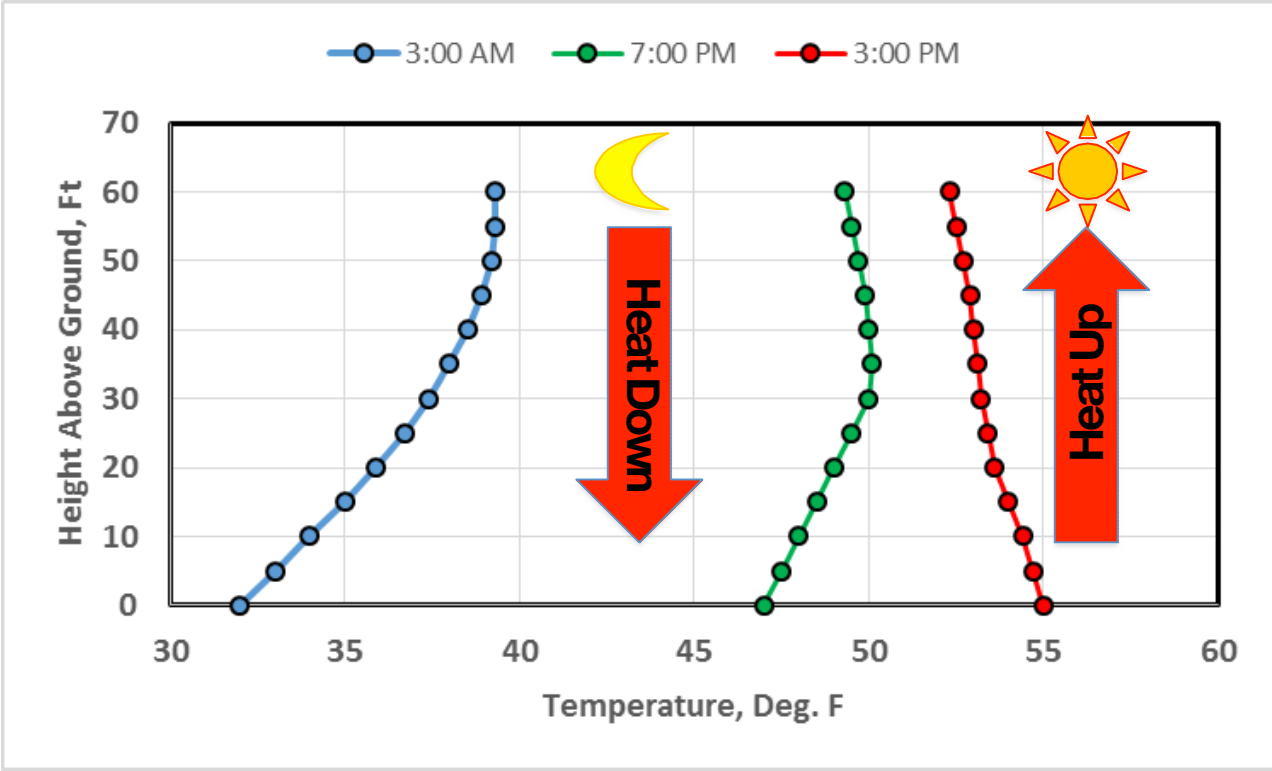
Radiation Frost
Generally Good Protection

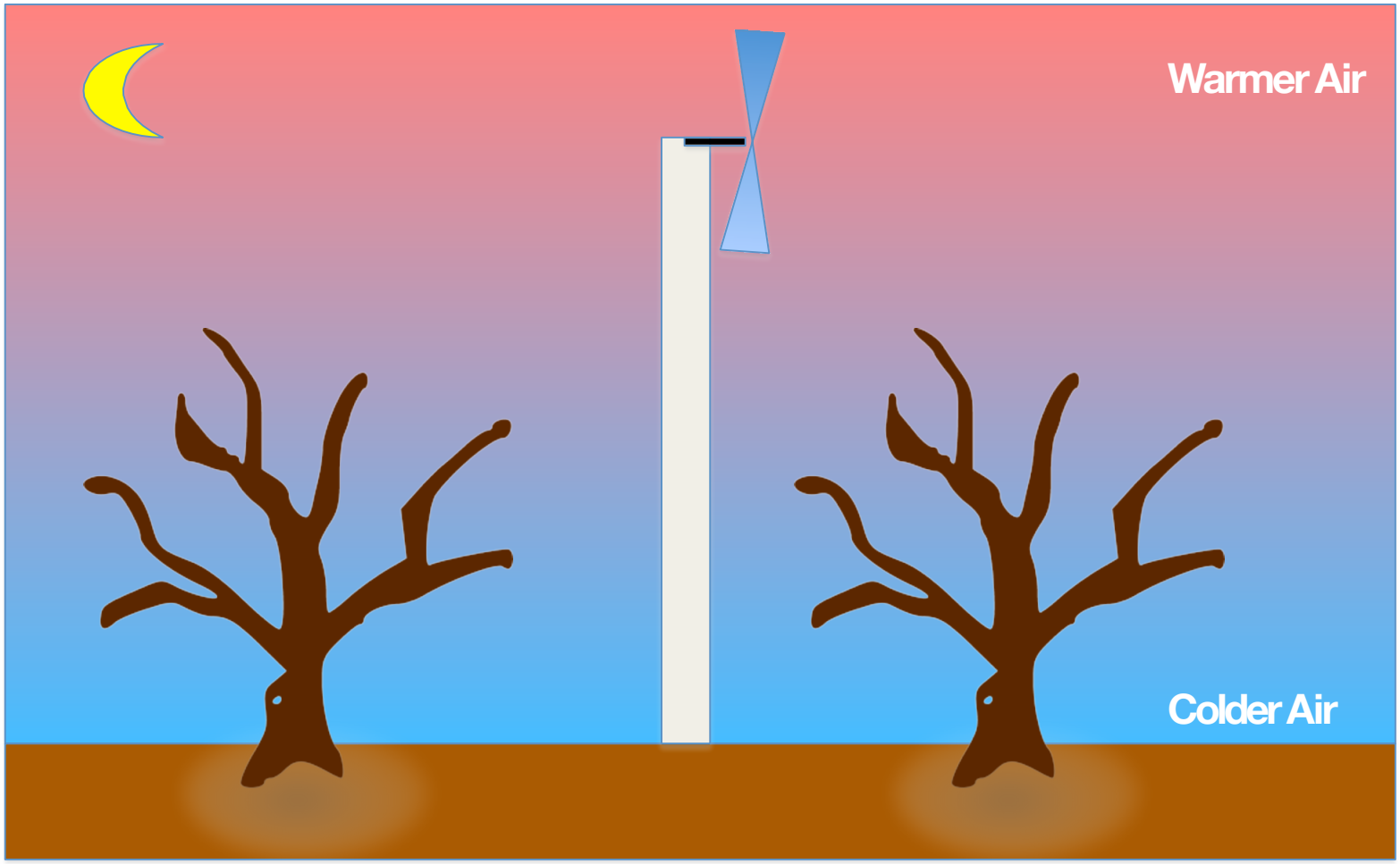


Inversion Development



Air both heats and cools through contact with the surface. Air picks up heat from the surface during the day. Air near the surface cools more rapidly at night through contact with the cooler surface, resulting in warmer air aloft – the inversion.

Radiation Frost
Generally Good Protection



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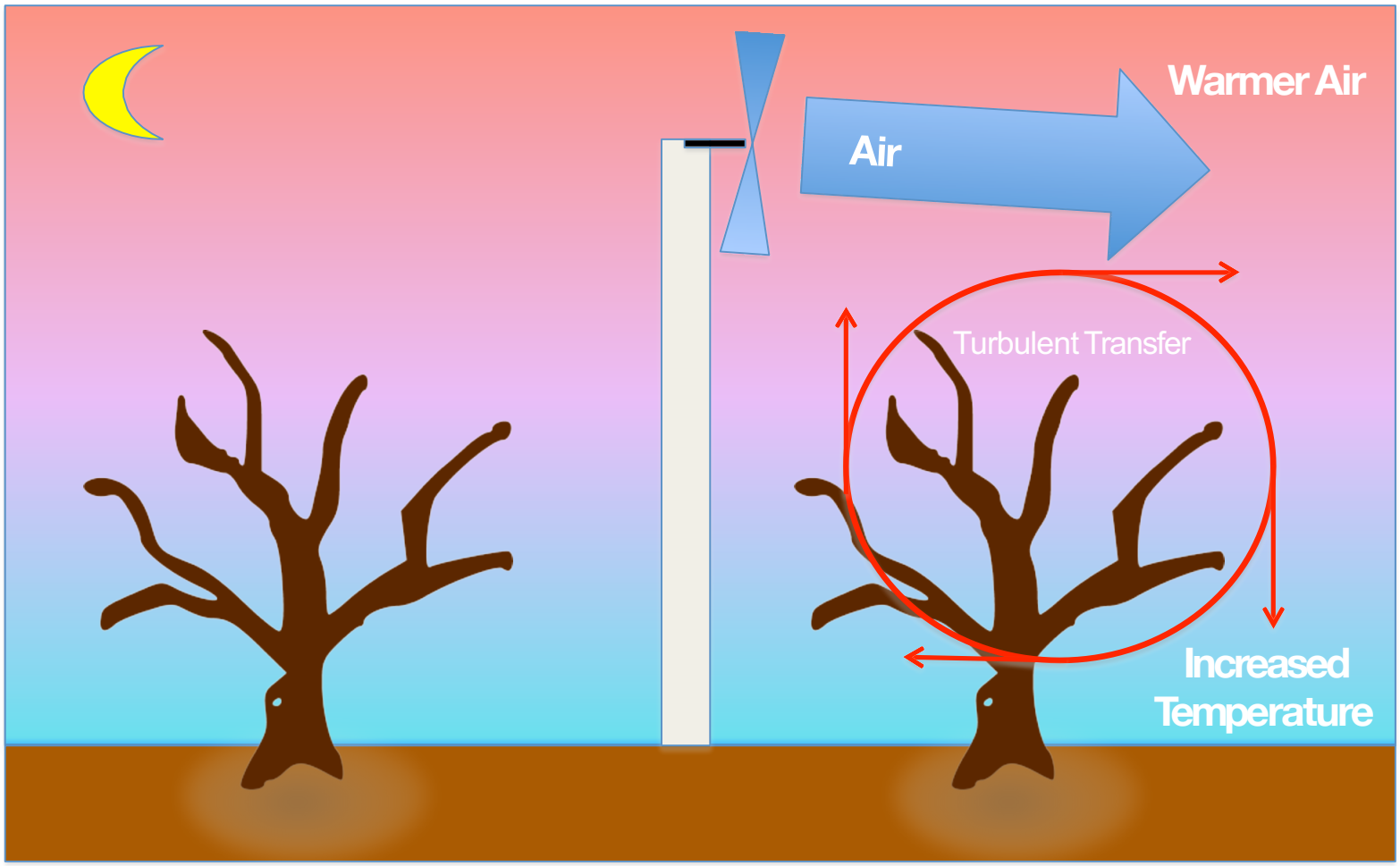
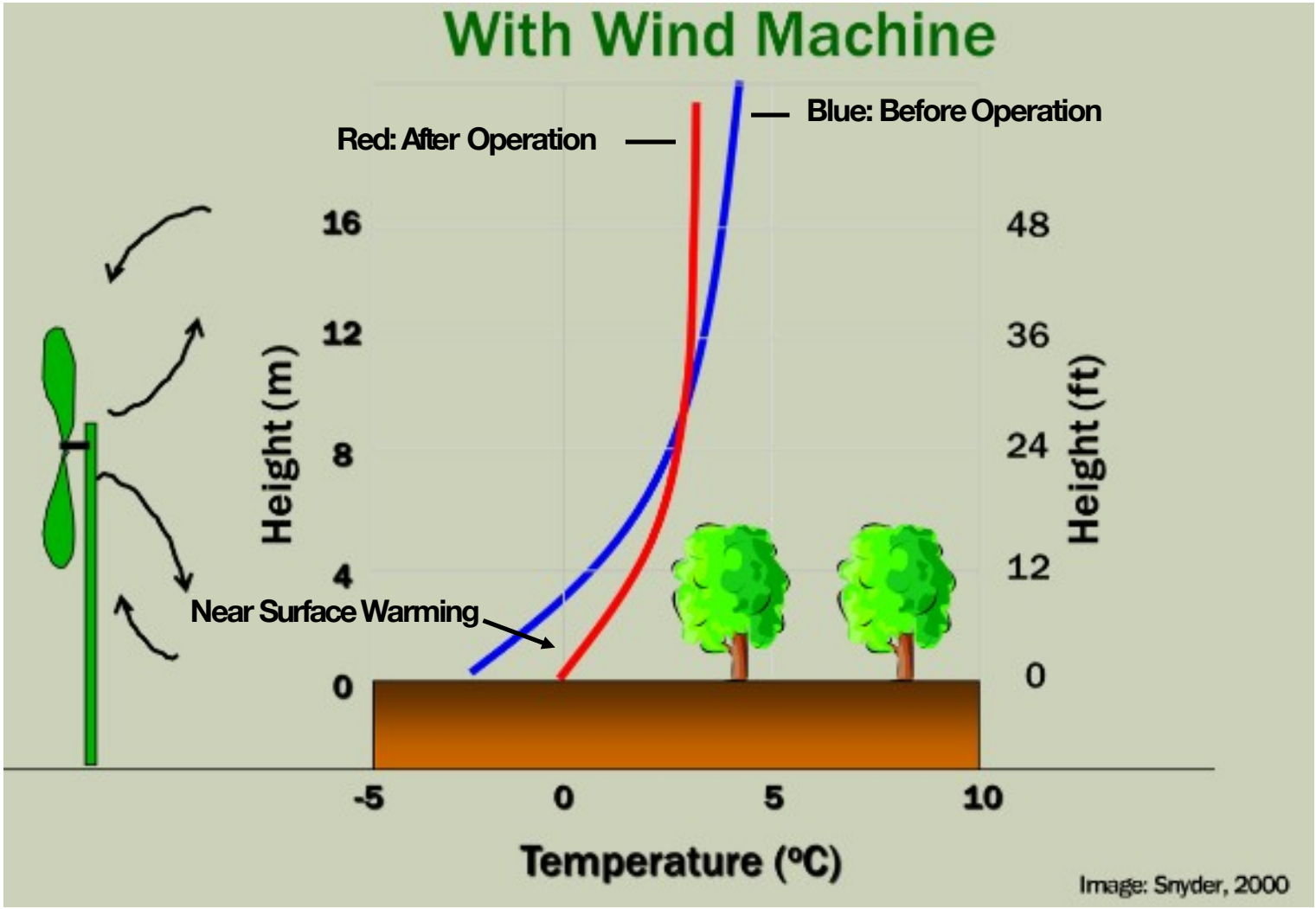
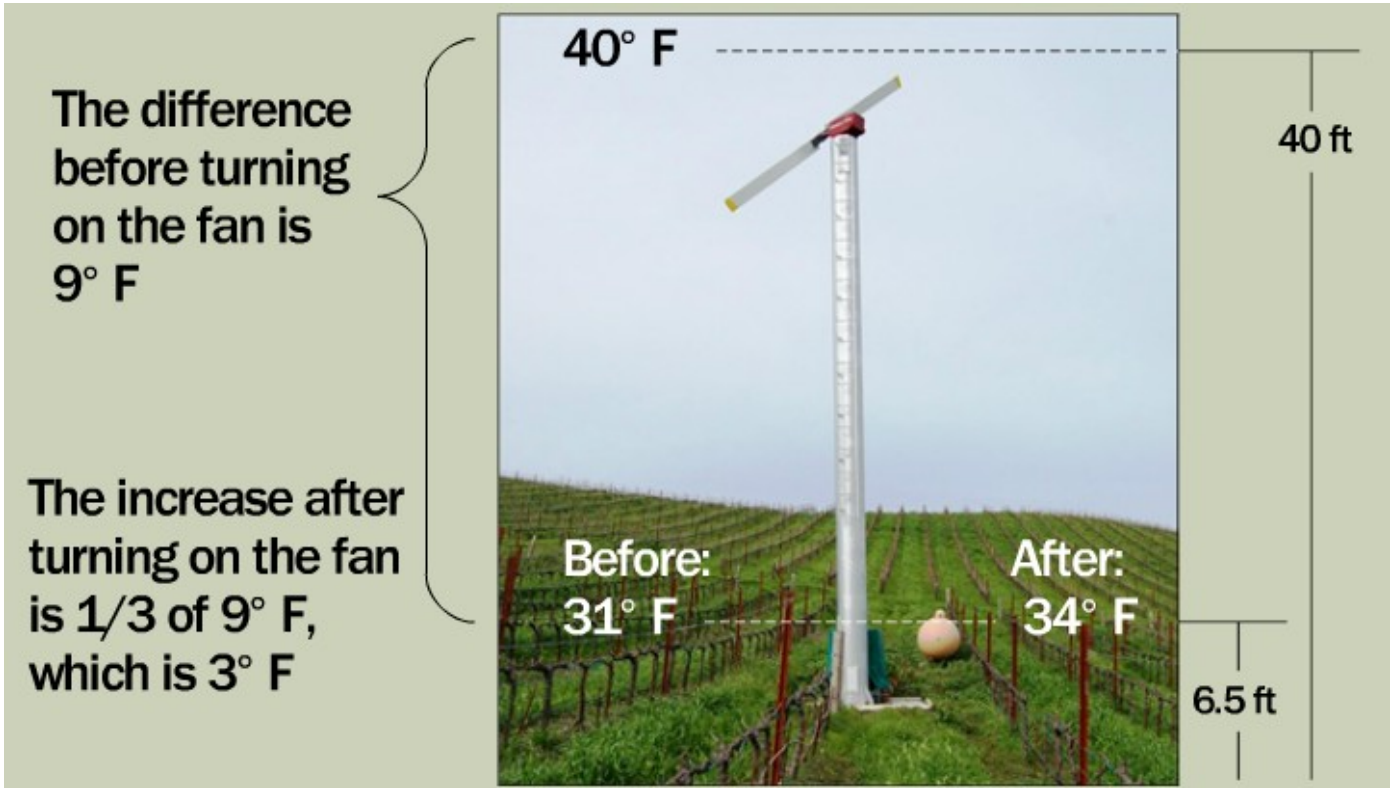




Source: Rick Snyder, Univ. of California, Davis

Warming Depends on Inversion Strength

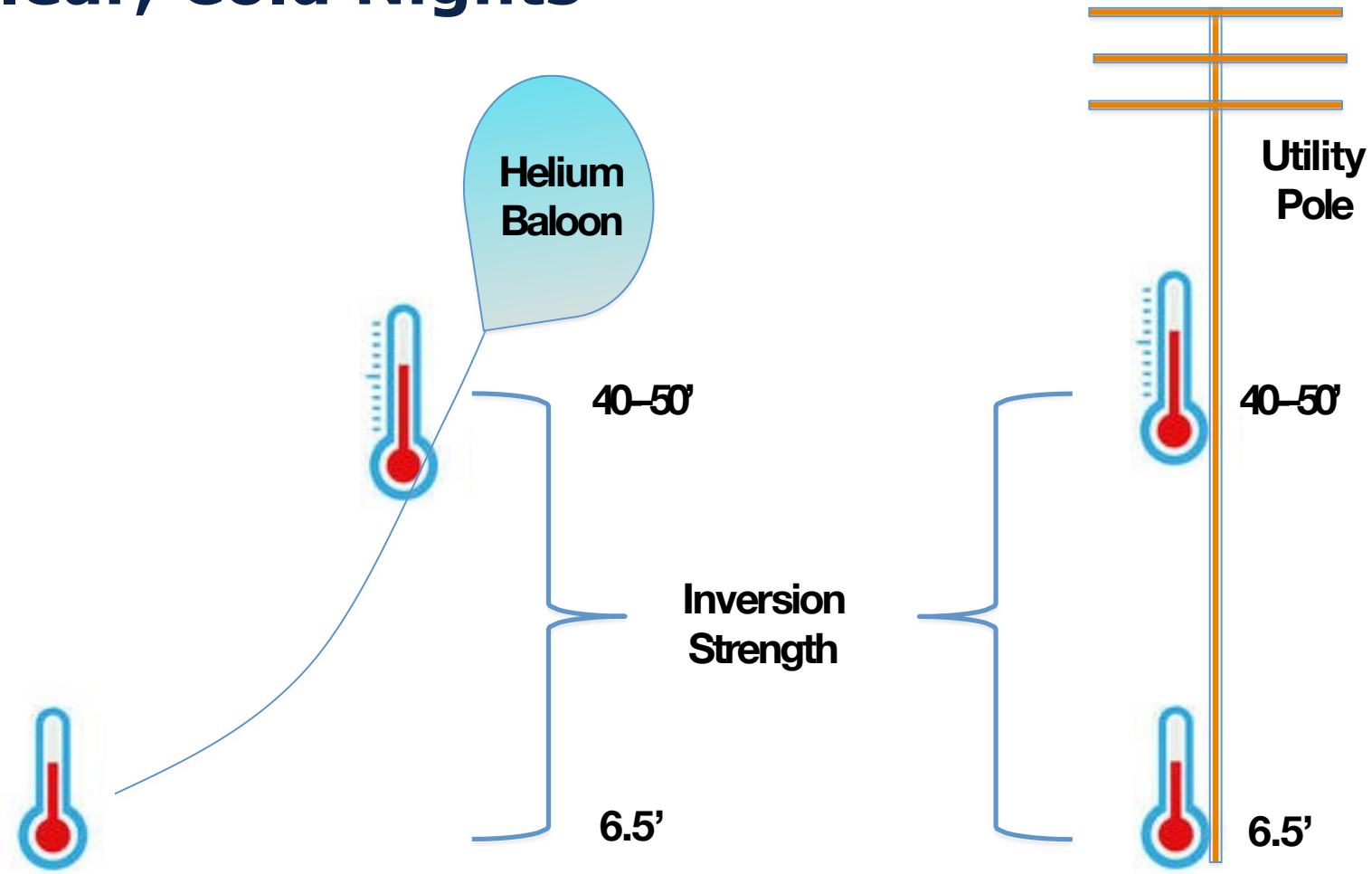


Source: Rick Snyder, Univ. of California, Davis

—Inversion Strength: Difference in Temperature Between 6.5' and ~40' (Fan Height)

—Maximum Warming at 6.5' Equals 1/2 of Inversion Strength; Typically 1/3!

Inversion Assessment
Clear, Cold Nights



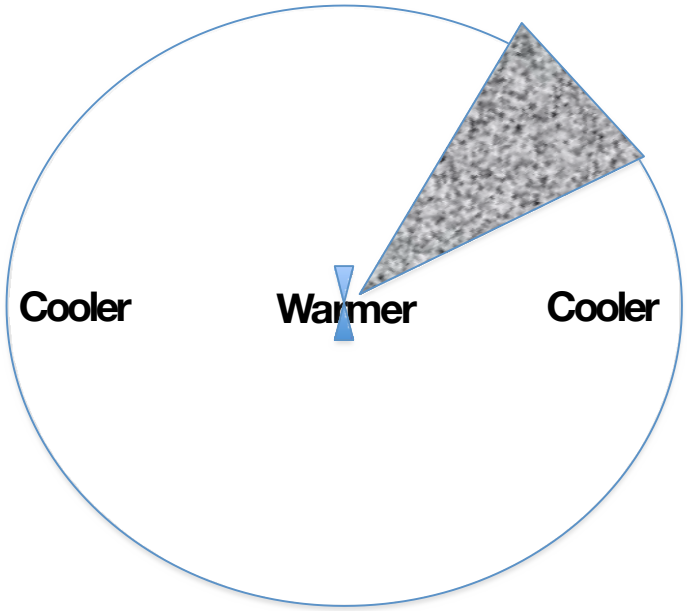
–Measure Temperature at 6.5' & 40–50' Above Surface
–Electronic Sensors That Can Transmit/Store Data Are Best

Inversion Assessment
Graham County AZ

Date	Temp (50')	Temp (5')	Inversion	Minimum
4/3/79	34F	25F	9F	21F
4/4/79	35	25	10	23
4/5/79	40	30	10	23
3/20/80	30	27	3	24
3/21/80	42	32	10	29
3/31/82	38	31	7	31
4/3/82	41	31	10	31
4/5/82	46	31	15	31
4/8/82	39	29	10	29
4/20/82	42	32	10	32

Areal Coverage

- **8-12 Acres/Machine**
  - **Radial Impact: 375-400’**
  - **Single Machines: 8 Acres**
- **Depends**
  - **Warming Required**
  - **Inversion Strength**
  - **Wind Drift**
  - **Design/Height/Power**
    - **12-15 BHP/Acre**
- **Not Spatially Uniform**
  - **Placement Based On…**
    - **Wind/Drainage Patterns**
    - **Topography**
    - **Inversions**



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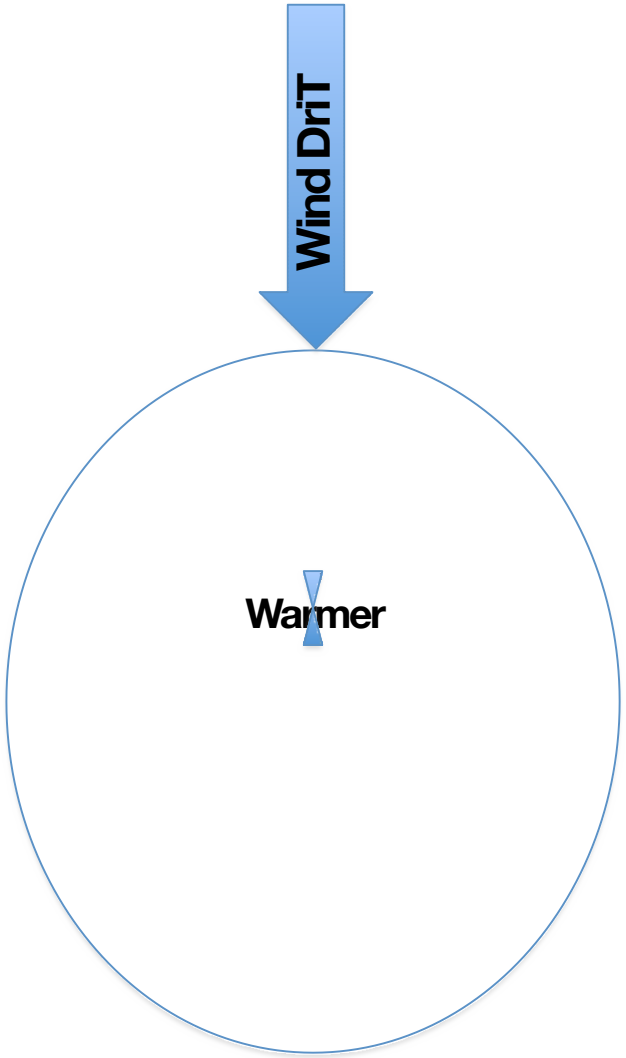
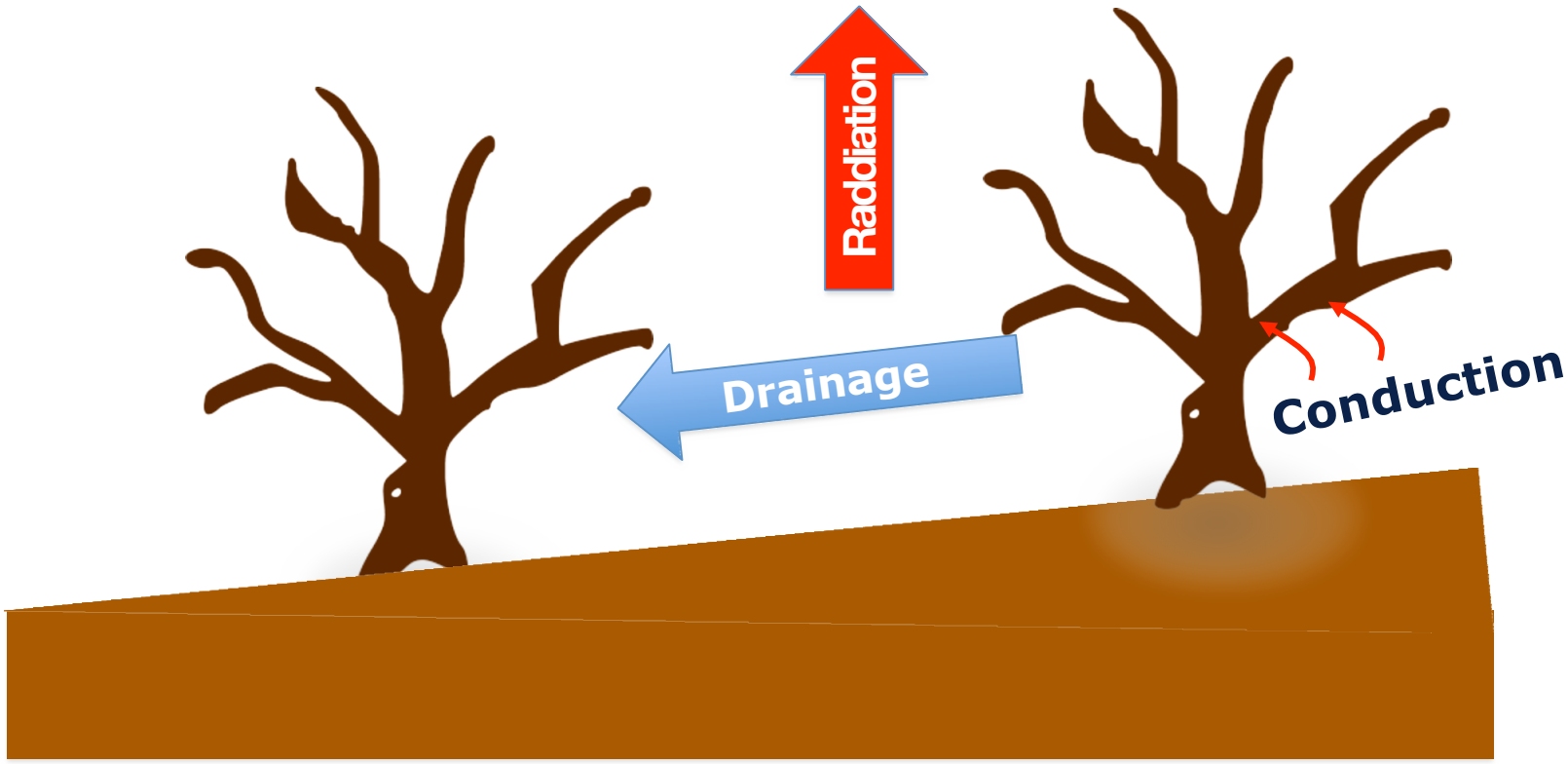


Protection Area Shaped Like Oval With Wind Drift

Fan Rotation

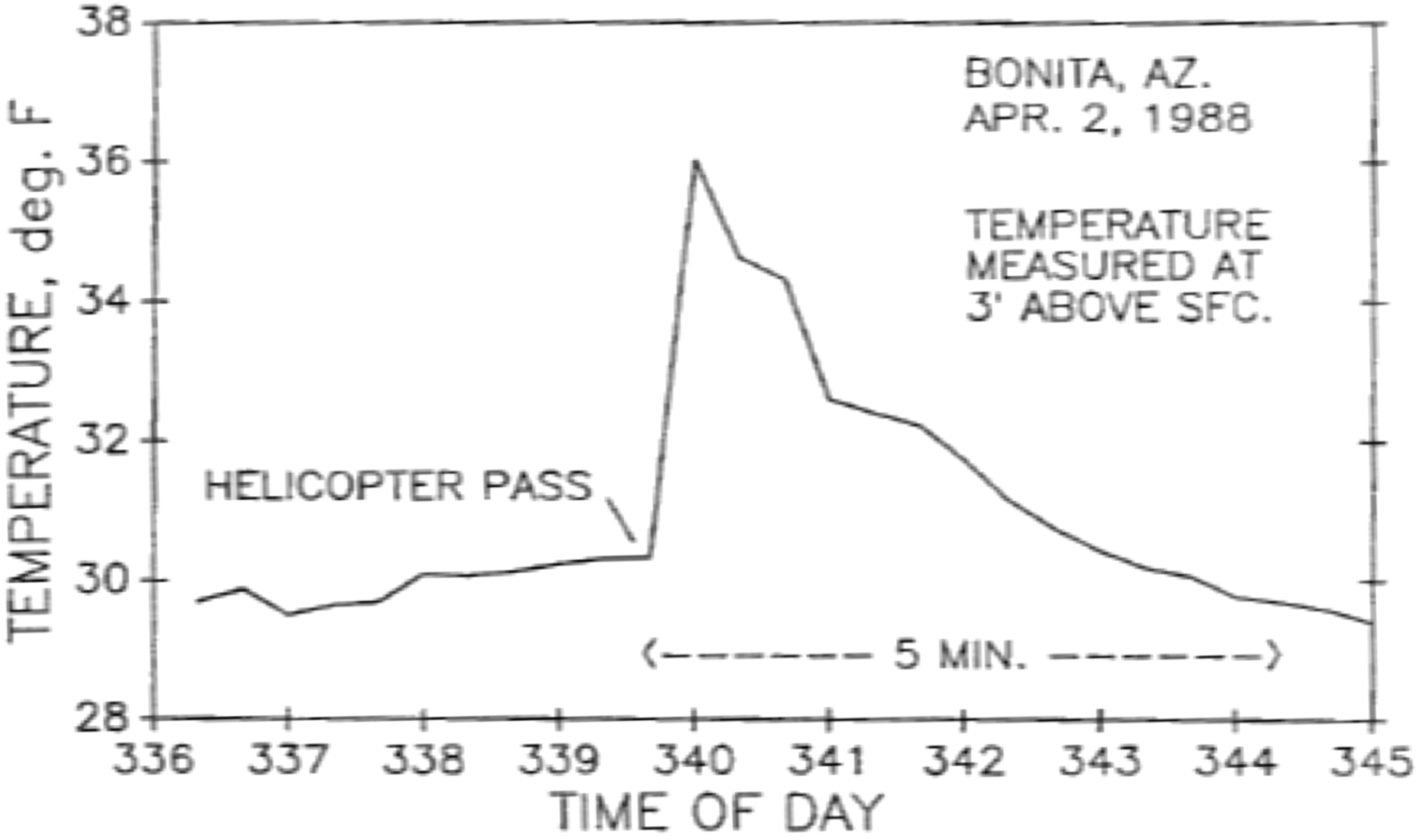
Required Every 4-6 Minutes



Fan Rotation Restores Heat Lost to Drainage, Radiation and Conduction into Plant Materials

Fan Rotation

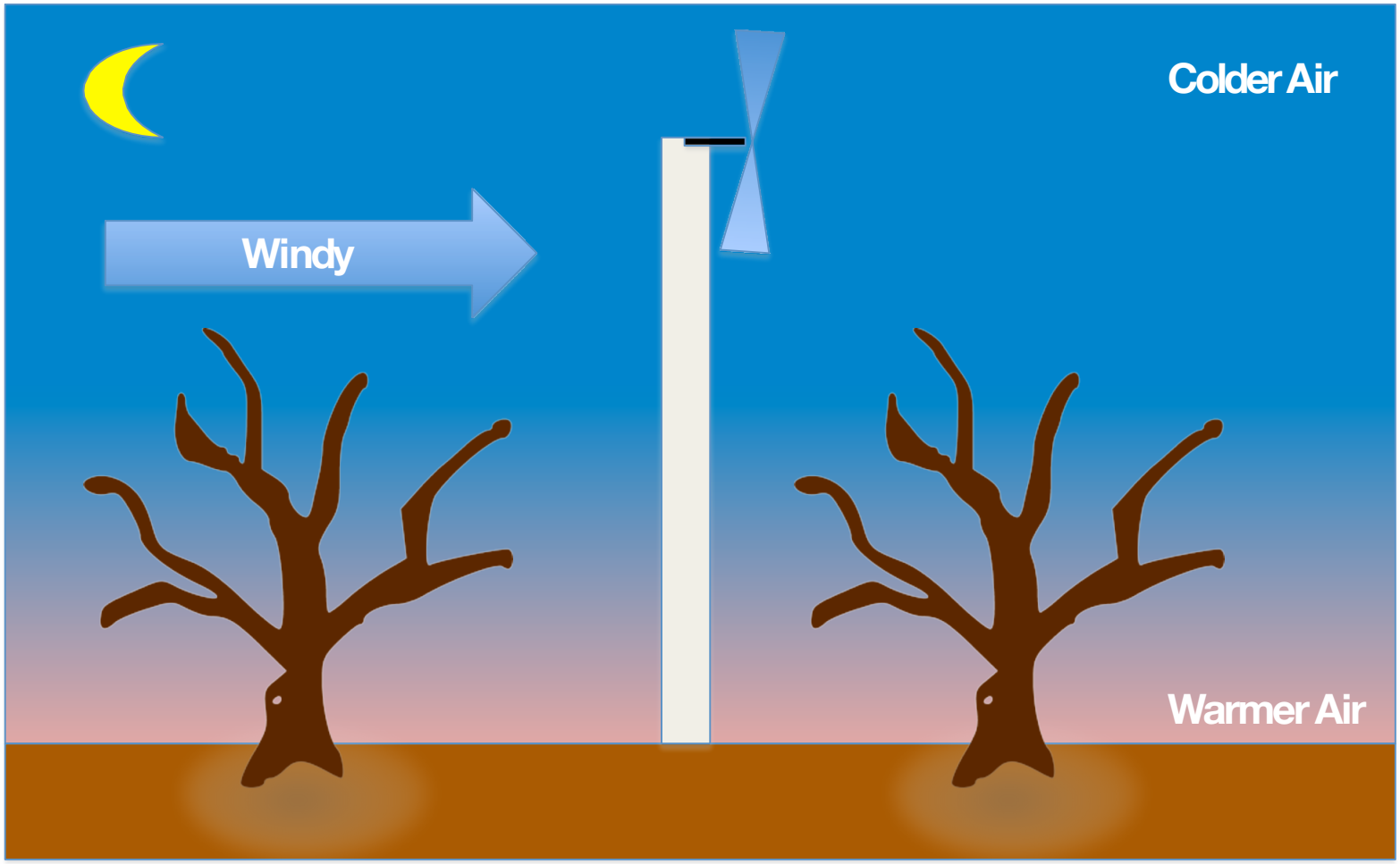
Required Every 4-6 Minutes



Machine Operation

- **General Starting Recommendation**
  - **Slightly Above Critical Temperatures**
  - **Foliage Below Air Temperature**
  - **Warming Results Quickly if Inversion Present**
  - **Can Be Automated**
- **Older Literature**
  - **Start Early Before Inversion Forms**
  - **Inversions Begin to Form Before Sunset in SW**
- **Run Until Temperatures Exceed Critical in Morning**
  - **Can Be Hour or Two After Sunrise**
- **Can Be Matched With Heaters/Irrigation**
  - **Improved Protection**

Advective Frost
Poor Protection



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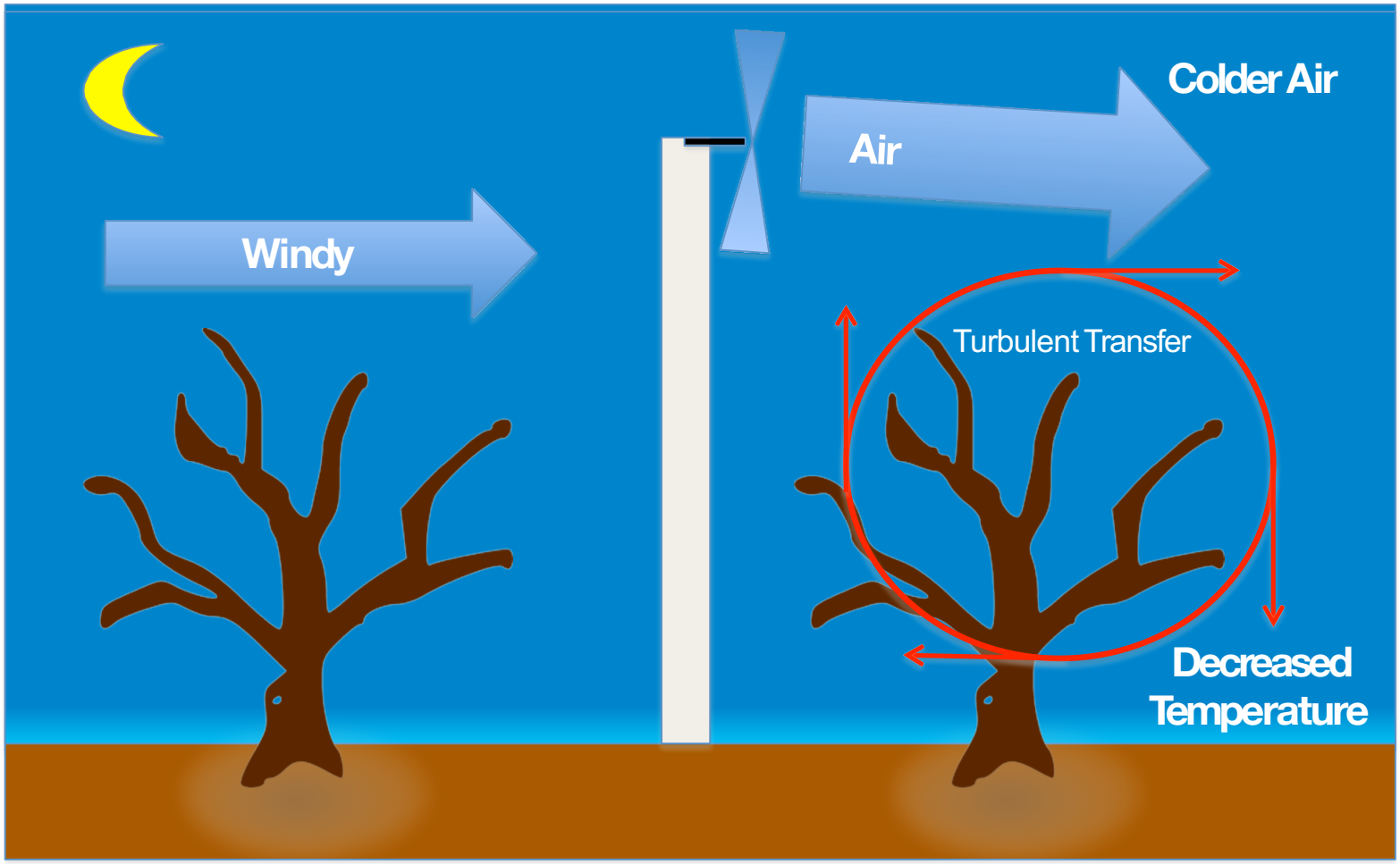
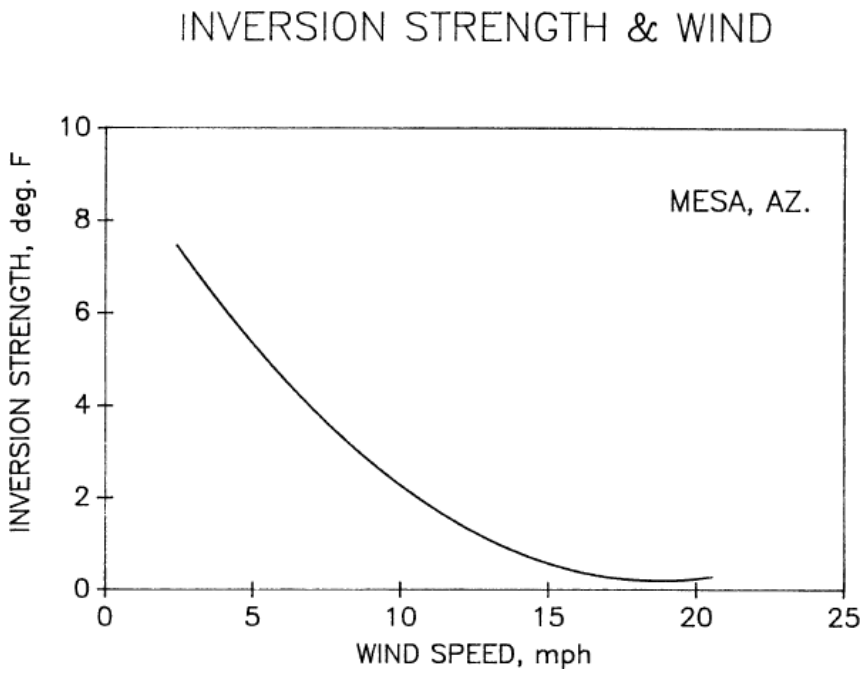


Wind Machines
Limited Value During Windy Conditions

Under windy conditions the air becomes thoroughly mixed and inversion dissipates or disappears. Inversions do not exist under advective frost conditions.



Inversion strength: difference in temperature between wind machine height & standard measurement height

Concluding Comments

- Warmer Springs Driving Earlier Budbreak
- More Vulnerable to Frost
  - If Last Frost Dates Don't Recede
- Wind Machines
  - Effective Frost Mitigation Strategy
  - Coverage: 8-12 Acres
  - Protection: 3-5F
  - Require Inversions
  - Seek Experienced Professional Help (Large Investment)
    - Siting
    - Power
    - Environmental Regulations
  - Additional Arid Region Studies Needed
    - Further Optimize Operation