Master Naturalist
Weather and Climate

Jon W. Zeitler
Science and Operations Officer
NOAA/National Weather Service
Austin-San Antonio TX
- Severe Warnings
- Public Forecast
- River Forecast
- Aviation Forecast
- Air Quality/Hazmat
- Fire Weather
<table>
<thead>
<tr>
<th></th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>78.08%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>20.95%</td>
</tr>
<tr>
<td>Argon</td>
<td>0.93%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>0.035%</td>
</tr>
<tr>
<td>Neon</td>
<td>0.0018%</td>
</tr>
<tr>
<td>Helium</td>
<td>0.00052%</td>
</tr>
<tr>
<td>Methane</td>
<td>0.0014%</td>
</tr>
<tr>
<td>Krypton</td>
<td>0.0010%</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>0.0005%</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>0.0005%</td>
</tr>
<tr>
<td>Xenon</td>
<td>0.00009%</td>
</tr>
<tr>
<td>Ozone</td>
<td>0.00007%</td>
</tr>
</tbody>
</table>

Dry air in lowest 80 km of atmosphere
Weather Defined

• The state of the atmosphere at some place and time, described in terms of such variables such as:
  – Temperature
  – Cloudiness
  – Precipitation
  – Wind speed and direction
Climate Defined

• Weather conditions at some locality averaged over a specified time period.
  – Departures from long-term averages
  – Extremes in weather
Meteorology is the study of the atmosphere and the processes that cause weather.
Climatology is the study of the climate, its controls and variability.
This is a map of annual precipitation averaged over the period 1961-1990. Station observations were collected from the NOAA Cooperative and USDA-NRCS SnoTel networks, plus other state and local networks. The PRISM modeling system was used to create the gridded estimates from which this map was made. The size of each grid pixel is approximately 4x4 km. Support was provided by the NRCS Water and Climate Center.

For information on the PRISM modeling system, visit the SCAS web site at http://www.ocs.orst.edu/prism

The latest PRISM digital data sets created by the SCAS can be obtained from the Climate Source at http://www.climatesource.com
The Atmosphere

Diagram showing layers of the atmosphere:
- Exosphere
- Thermosphere
- Mesosphere
  - Mesopause
  - Stratopause
- Stratosphere
- Troposphere
- Planetary Boundary Layer

Temperature gradient: sea level to atmosphere, ranging from -100°C to 40°C.

Satellite, polar lights, meteors, and other atmospheric phenomena are illustrated.
Troposphere

- Lowest part of the atmosphere
- 4 miles deep at North Pole
- 10 miles deep at equator
- **Most of the weather occurs**
- Strong wind circulations
- Temperature cools with height
Stratosphere

- Above the troposphere
- 6 - 30 miles above earth
- Ideal for jet aircrafts
- Temperatures warm with height
- Pollution worries
- Ozone
What Causes The Weather?

- The sun heats Earth unequally
  - Only half the planet receives sun at one time
  - Amount of radiation varies from place to place
  - Earth tilts as it revolves around the sun
Albedo values (% reflected)

- Fresh snow: 80%–95%
- Forests: 10%–20%
- Crops, grasslands: 10%–25%
- Grass: 25%–30%
- Asphalt (black top): 5%–10%
- Concrete, dry: 17%–27%
- Brick, stone: 20%–40%
- Dark roof: 8%–18%
- Light roof: 35%–50%

Earth's albedo (average) 31%

Water bodies: 10%–60% (varies with Sun altitude)

Moon: 6%–8%
World Solar Radiation
U.S. Solar Radiation

Higher Terrain, Less Cloud cover
Seasons

- **Seasons**
  - Equal Day/Night
  - Night > Day
  - Day > Night

- **23.5°**
- **September 23**
  - Autumnal Equinox
- **December 22**
  - Winter Solstice
  - Night > Day
  - 14+ hours
- **March 21**
  - Vernal Equinox
  - Equal Day/Night
- **June 22**
  - Summer Solstice
  - 14+ hours
  - Day > Night

- **Austin**:
  - Max 14 hours 7 minutes
  - Min 10 hours 12 minutes

- **San Antonio**:
  - Max 14 hours 2 minutes
  - Min 10 hours 16 minutes
Summer solstice

Spring or Fall equinox

Winter solstice
Temperature

A measure of heat
Effects of Clouds on Temperature in daytime

Clear skies = warmer temperatures

Cloudy skies = cooler temperatures
Effects of Clouds on Temperature at night

Clear skies = cooler temperatures

Cloudy skies = warmer temperatures
Water and Phase Change

Heat energy taken from environment

Sublimation

Melting → Evaporation

Freezing → Condensation

Deposition

Heat energy released to environment
Hydrologic Cycle
Dew Point

The temperature at which water vapor begins to condense into liquid water
Temperature, Dew Point, and Relative Humidity Relationships
Air Pressure

A measure of the force or weight of air
Air Pressure Trends

Air pressure rises and falls two times a day
Forces that affect Wind

- Air pressure
  - Temperature
  - humidity
- Centripetal
- Coriolis
- Friction
- Gravity
Air Pressure Affect on Wind

Wind flows from high pressure to low pressure
Coriolis Effect on Wind

Because the Earth is rotating, it is not a direct path.

High Pressure

Coriolis Effect (NH)

Low Pressure
Coriolis Effect on Wind

While one perceives it traveling straight over short or long distances, in atmospheric dimensions, there is always some degree of curving taking place.
Coriolis Effect on Wind

A high pressure and a low pressure center with wind directions (northern hemisphere). Circles are isobars with pressure in mb.
Coriolis Effect on Wind

Animation displays air flow with a High Pressure System (Left) and Low Pressure System (Right).

Courtesy of NASA
Air Pressure Trends
Rising air pressure = clearing or continued fair weather
Air Pressure Trends
Falling air pressure = stormy weather
Adding it all Together…
Air Mass

Large body of air with similar temperature and moisture characteristics in any horizontal direction.
## Types of Air Masses

<table>
<thead>
<tr>
<th>Air mass</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continental Arctic</td>
<td>Bitter cold and dry</td>
<td>n/a</td>
</tr>
<tr>
<td>Continental Polar</td>
<td>Very cold and dry</td>
<td>Cool and dry</td>
</tr>
<tr>
<td>Continental Tropical</td>
<td>Warm and dry</td>
<td>Hot and dry</td>
</tr>
<tr>
<td>Maritime Polar</td>
<td>Mild and humid</td>
<td>Mild and humid</td>
</tr>
<tr>
<td>Maritime Tropical</td>
<td>Warm and humid</td>
<td>Warm and humid</td>
</tr>
</tbody>
</table>
Fronts

Fronts are boundaries between different air masses
Cold Front

Cooler, denser air is advancing to replace warm air.
Cold Front

Cooler, denser air is advancing to replace warm air
Warm Front

Transition between warm air and colder air
Warm Front
Transition between warm air and colder air

Lenni Armstrong, informmation/Martos Hoffman, TERC
Other Fronts

- **Stationary front**
  - Little movement
- **Occluded front**
  - Two fronts overlayed on each other
- **Squall line**
  - Line of thunderstorms
- **Dry line**
  - Boundary between dry and moist air
Other Boundaries

Sea breeze and land breeze
Other Boundaries

Sea breeze and land breeze

Local time: 8:00 a.m.
Land 65°F  Ocean 65°F

Animation of Differential heating between land and water

Courtesy of www.classzone.com
What are clouds?

A bunch of tiny droplets of water or ice
Clouds cover 50 percent of the earth at any given time
4 Ways To Make A Cloud

1. Surface Heating - evaporation
4 Ways To Make A Cloud

2. Mountains – orographic lift
4 Ways To Make A Cloud

3. Air Pressure
4 Ways To Make A Cloud

4. Cold or Warm Front

- Advancing cold air behind cold front
- Receding warm air ahead of cold front
- Cloud development because of frontal lifting of warm moist air
- Direction of frontal movement
- Cold front map symbol
Cirrus Clouds

Highest clouds – above 18,000 ft
3 Types Of Clouds

2. Cumulus
Cumulus Clouds
Mid-level heights – 5000 to 12000 ft
Cumulonimbus Clouds
Can produce lightning
Stratus Clouds
Very low – sometimes touch the Earth
Weird Clouds
Mammatus
Ways to Monitor Clouds
Weather Satellites
Two Main Types of Weather Satellites

Polar Orbiting

- Travel pole to pole
- Every 12 hours
- 530 miles above earth
- High resolution
Two Main Types of Weather Satellites

Geostationary

- Stationary over the equator
- Every 15 minutes
- 22,300 miles above earth
- High resolution
Satellite Imagery

- **Visible**
- **Black and white photo of Earth from space**
- **Resolution of 0.6 mi**
- Can locate storm centers, fronts, fog banks, thunderstorms
- Also sees dust storms and snow and ice cover
Satellite Imagery

- Infrared
- Measures the surface temperature of all objects
- Distinguish low and high clouds
- Available day or night
Cool Texas Satellite Pictures

December 2004 snow

Image courtesy of the Cooperative Institute for Meteorological Satellite Studies, Univ. Wisconsin - Madison
Thunderstorm Climatology
Thunderstorm Ingredients

- Moisture
- Instability
- Lift

Diagram showing the relationship between cold/dry and warm/moist conditions, indicating the ingredients needed for thunderstorms.
Thunderstorm Life Cycle

Towering Cumulus Stage

Mature Stage

Dissipating Stage
Thunderstorm Hazards
Why South Central Texas is “Flash Flood Alley”
1996-2012: Over 100 Flood Deaths in South Central Texas

Why Does This Happen?
Winter 2017-18 Outlook

- COLD
- HOW DO YOU PEOPLE LIVE LIKE THIS?
- UNUSUALLY COOL
- IT'S 39°! SHUT EVERYTHING DOWN WE'RE GONNA DIE!
- COLD
- HOTH
- ON FIRE
- THANKS OBAMA

CONTINENTAL UNITED STATES REGIONAL WEATHER FORECAST
What goes into long range forecasts?

1. El Niño/La Niña
2. Trends
3. Tropical Oscillation
4. NAO
5. Pacific Decadal Oscillation (like ENSO but longer time scale)
6. Wet or Dry Soils
7. Statistical Tools
8. Dynamic Models
9. Consolidation (first guess based on models)
What’s the Driving Force?

El Niño – Warming of Pacific waters
La Niña – Cooling of Pacific waters
Main Focus Area

Niño 3.4 Region

Week centered on 06 SEP 2017
SST Anomalies (°C)
Typical Wintertime El Nino Impacts

[Map showing typical wintertime El Nino impacts with areas of low pressure, warm, wet, dry, and persistent extended Pacific jet stream and amplified storm track.]
Typical Wintertime La Nina Impacts
+0.5°C above normal = El Niño

-0.5°C below normal = La Niña
Cycles? Million $ Question…Is Weather Getting Worse?

Drought  Flood  Tornadoes
Is the Reporting Getting Better?

Hundreds of chasers hit the road every day in the Spring and early Summer.
Drought Severity Cycle

No Rain

Dry Soil

Low Moisture, Low Humidity

Dry Plants
Is Drought Unexpected?

Climate Trends – State: TX, Season: Annual

Wet

Dry

Precipitation (inches)

Year


14.99 14.88
U.S. Drought Monitor
Texas

November 28, 2017
(Released Thursday, Nov. 30, 2017)
Valid 7 a.m. EST

Drought Conditions (Percent Area)

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>D0-D4</th>
<th>D1-D4</th>
<th>D2-D4</th>
<th>D3-D4</th>
<th>D4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>28.73</td>
<td>71.27</td>
<td>35.11</td>
<td>5.50</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Last Week</td>
<td>40.02</td>
<td>59.98</td>
<td>20.23</td>
<td>3.25</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>3 Months Ago</td>
<td>96.14</td>
<td>3.86</td>
<td>0.87</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Start of Calendar Year</td>
<td>81.50</td>
<td>18.50</td>
<td>6.29</td>
<td>1.97</td>
<td>0.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Start of Water Year</td>
<td>70.64</td>
<td>29.46</td>
<td>4.17</td>
<td>0.04</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>One Year Ago</td>
<td>66.37</td>
<td>33.63</td>
<td>14.18</td>
<td>3.27</td>
<td>0.08</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Intensity:
- Yellow: D0 Abnormally Dry
- Red: D3 Extreme Drought
- Brown: D1 Moderate Drought
- Brown: D4 Exceptional Drought
- Orange: D2 Severe Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
David Simmeral
Western Regional Climate Center

http://droughtmonitor.unl.edu/
U.S. Monthly Drought Outlook
Drought Tendency During the Valid Period

Valid for December 2017
Released November 30, 2017

Depicts large-scale trends based on subjectively derived probabilities guided by short- and long-range statistical and dynamical forecasts. Use caution for applications that can be affected by short lived events. "Ongoing" drought areas are based on the U.S. Drought Monitor areas (intensities of D1 to D4).

NOTE: The tan areas imply at least a 1-category improvement in the Drought Monitor intensity levels by the end of the period, although drought will remain. The green areas imply drought removal by the end of the period (D0 or none).

Author:
Anthony Artusa
NOAA/NWS/NCEP/Climate Prediction Center

http://go.usa.gov/3eZGd
Precipitation is important and highly variable. Data sources are few and rain gauges are far apart.
Once trained, volunteers collect data using low-cost measurement tools...

4-inch diameter high capacity rain gauges

Aluminum foil-wrapped Styrofoam hail pads

Training is important to assure accurate, high quality data
“CoCoRaHS is a national grassroots, non-profit community based, high-density precipitation network made up of volunteers of all backgrounds and ages . . .

. . . who take daily measurements of “just precipitation” right in their own backyards”
www.cocorahs.org
Daily Precipitation (inches x.xx), for the 24 hour period ending ~7:00 am
USA 12/1/2017
Daily Precipitation (inches x.xx), for the 24 hour period ending ~7:00 am
Texas 10/31/2015
Daily Precipitation (inches x.xx), for the 24 hour period ending ~7:00 am
Austin/San Antonio/Del Rio Region, Texas 10/31/2015
Daily Precipitation (inches x.xx), for the 24 hour period ending ~7:00 am
Travis County, Texas 10/31/2015
Station Number: TX-TV-142
Station Name: Austin 6.5 NE
Report Date: 2015-10-31 07:00 AM
Precipitation: 4.21 in.
Snowfall: NA
Snowfall SWE: NA
Snow Depth: NA
Snow Depth SWE: NA
Go to report details
Heavy rain, strong winds expected across Pacific Northwest and northern California

A weather system tapping into subtropical moisture will bring abundant rainfall to the Pacific Northwest and northern California through the weekend. The heaviest rainfall is expected Thursday night into Friday. Rainfall amounts in excess of 5 in. are possible through Saturday evening, especially across northern Calif. This system will also bring high winds to the region, with gusts up to 60 mph.

Read More...
Cloudy and Cool; Gusty North Winds

High Temperatures

Lower 50s

AM  PM

Mid 40s

Near 50

### Current Hazards
- Local
- Nationwide
- Outlooks
- Storm Prediction Center

### Forecasts
- Local Forecast Discussion
- Activity Planner
- Graphical
- Tropical Weather
- Fire Weather
- Aviation Weather
- Hurricane Center
- En Español

### Current Weather
- Observations
- Satellite Images
- Rivers/Lakes
- Hydrology
- Daily Rainfall Map
- Radar Imagery
- Nationwide
# Tombstone Forecast

## Current Conditions

- **Partly Cloudy**
- **Temperature**: 73°F (23°C)
- **Humidity**: 53%
- **Wind Speed**: E 5 mph
- **Barometer**: 30.05 in
- **Dewpoint**: 55°F (13°C)
- **Visibility**: 10.00 mi

Last Update on 24 Feb 2:50 pm CST

Current conditions at San Marcos Municipal Airport (KHYI)
Lat: 29.9°N Lon: 97.87°W Elev: 597 ft.

[More Local Wx](#) | [3 Day History](#) | [Mobile Weather](#)

## 2 Miles SSW Lockhart TX

### 7 Day Forecast

<table>
<thead>
<tr>
<th>THIS AFTERNOON</th>
<th>TONIGHT</th>
<th>TUESDAY</th>
<th>TUESDAY NIGHT</th>
<th>WEDNESDAY</th>
<th>WEDNESDAY NIGHT</th>
<th>THURSDAY</th>
<th>THURSDAY NIGHT</th>
<th>FRIDAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mostly Cloudy</td>
<td>Isolated Sprinkles</td>
<td>Chance Showers</td>
<td>Chance Showers</td>
<td>Showers Likely</td>
<td>Slight Chc Showers</td>
<td>Mostly Cloudy</td>
<td>Mostly Cloudy</td>
<td>Partly Sunny</td>
</tr>
<tr>
<td>High: 73 °F</td>
<td>Low: 63 °F</td>
<td>High: 73 °F</td>
<td>Low: 44 °F</td>
<td>High: 45 °F</td>
<td>Low: 35 °F</td>
<td>High: 60 °F</td>
<td>High: 46 °F</td>
<td>High: 77 °F</td>
</tr>
</tbody>
</table>

Austin/San Antonio, TX
NWS Weather Forecast Office
## Detailed Forecast

<table>
<thead>
<tr>
<th>Day</th>
<th>Weather Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Afternoon</td>
<td>Mostly sunny, with a high near 75. South southeast wind around 5 mph.</td>
</tr>
<tr>
<td>Tonight</td>
<td>Mostly clear, with a low around 50. Southeast wind around 5 mph becoming calm after midnight.</td>
</tr>
<tr>
<td>Saturday</td>
<td>Mostly sunny, with a high near 77. Calm wind becoming south around 5 mph in the afternoon.</td>
</tr>
<tr>
<td>Saturday Night</td>
<td>Increasing clouds, with a low around 57. South southeast wind around 5 mph.</td>
</tr>
<tr>
<td>Sunday</td>
<td>A 30 percent chance of showers. Mostly cloudy, with a high near 73. Southeast wind 5 to 10 mph.</td>
</tr>
<tr>
<td>Sunday Night</td>
<td>Mostly cloudy, with a low around 54. Southeast wind around 10 mph.</td>
</tr>
<tr>
<td>Monday</td>
<td>A 20 percent chance of showers. Partly sunny, with a high near 80. South wind 10 to 15 mph.</td>
</tr>
<tr>
<td>Monday Night</td>
<td>A 30 percent chance of showers and thunderstorms. Mostly cloudy, with a low around 63. South wind 5 to 10 mph.</td>
</tr>
<tr>
<td>Tuesday</td>
<td>A 50 percent chance of showers. Mostly cloudy, with a high near 66. South wind 5 to 15 mph becoming north in the afternoon. Winds could gust as high as 20 mph.</td>
</tr>
<tr>
<td>Tuesday Night</td>
<td>Mostly cloudy, with a low around 42.</td>
</tr>
<tr>
<td>Wednesday</td>
<td>Partly sunny, with a high near 57.</td>
</tr>
<tr>
<td>Wednesday Night</td>
<td>Mostly cloudy, with a low around 36.</td>
</tr>
<tr>
<td>Thursday</td>
<td>Mostly sunny, with a high near 61.</td>
</tr>
</tbody>
</table>
Hourly Graph
Major to Record Flooding Expected along the Mississippi and Atchafalaya Rivers

River Data

4867 Total Gauges
182 Locations in Flood

- 247 Gauges: Observations older than 24 hours
- 7 Gauges: Out of Service

Additional Resources
- National Significant River Flood Outlook
- U.S. Geological Survey Streamflow Information
- Snow Information
- NWS Precipitation and River Forecasting
- Water Resources Outlook
- Hourly Precipitation Analysis
- Guide to Hydrologic Information on the Web
Questions? Comments? Thank You!

Jon W. Zeitler
Science and Operations Officer

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