Aspects of Devastating Flood Events in Texas

Texas Floodplain Management Association
March 11, 2016

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Meteorologist In Charge
NOAA - National Weather Service
Weather Forecast Office – Austin/San Antonio
NWS Strategic Outcome: A Weather-Ready Nation

Involves entire US Weather, Water and Climate Enterprise WORKING TOGETHER to achieve far-reaching national preparedness for weather events
Today’s Outline

- Your National Weather Service
- Heavy Rain Study for Central Texas
- Mechanics of Flood Deaths - TADD
- May 2015 and Memorial Day Flood
- Recent and Past Significant Flood Events
- What Happened to El Niño and Spring Outlook
- CoCoRaHS
122 Weather Forecast Offices in the NWS
- Severe Warnings
- Public Forecast
- River Stage
- Aviation Forecast
- Decision Support Services
- Air Quality/Hazmat
- Fire Weather
- Social Media
WFO Austin/San Antonio
National Weather Service Office
Our Primary Mission…
13 NWS Offices Supporting Texas
YOUR Local NWS Forecast Office

• Serving # Counties
• Staffed 24x7
• ~25 staff employees
  - 10 Meteorologists
  - 3 Hydro-Met Techs
  - 1 Hydrologist
  - 1 ITO
  - 3 Electronic Techs
  - 2 Met-Interns
  - 5 Mgmt & Admin

Weather Forecast Office
New Braunfels, TX
Why Forecast and Warn?

On average, the U.S. experiences:

- 7 hurricanes each year
- 1,000 tornadoes
- 10,000 violent thunderstorms
- 5,000 floods
- 500 weather-related deaths
- 5,000 weather-related injuries
- $14 Billion in weather & flood-related costs
Hundreds of chasers hit the road every day in the Spring and early Summer.

U.S. Billion Dollar Weather Disasters

Texas Leads Country (1980-2013)

Annual Avg of $14 Billion in Weather & Flood Related Costs in U.S.
Getting the Word Out

The average person only sees the tip of the iceberg

NATIONAL WEATHER SERVICE

122 Weather Forecast Offices Issue Local Forecasts & Warnings

National Centers for Environmental Prediction

Model Simulations
Climate & Seasonal Outlooks
Aviation & Marine Forecasts
Storm & Tornado Prediction
Hurricane Tracks

River Forecasts
Hydropower, Flood warnings
Irrigation, River Navigation

Observations
Radar Network, Satellites, Weather Balloons, Ground-level observations at airports, Aircraft, Lightning Network, Data Buoys, Stream Gauge Network, 11,000 Volunteer daily-data collectors,
Thousands of Volunteer storm spotters

Internet
Private Weather Companies

TV
Radio
Severe Weather Possible Early Next Week

Synopsis:
A strong upper low will move across NW Texas early to mid next week and provide energy for strong to severe storms. Locally heavy rainfall could also be possible across portions of the region Monday afternoon into Wednesday Morning.

*Forecast details like timing and location may change over the next few days. To keep up with the latest updates, visit www.weather.gov/ewx
“In Texas, Water Is A Blessing . . . And A Curse.”
South Texas owns most US rainfall records

Stalled or slow fronts. . .
Ingram, 1932 - 36” in 24 hrs
D’Hanis, 1935 - 22” in 3 hrs
Zorn, 1998 - 32” in 18 hrs
New Braunfels, 1972 - 10” in 1 hr

Dying tropical systems. . .
Thrall (H), 1921 - 36” in 18 hrs
Pandale (H), 1954 - 35” in 24 hrs
Amelia (TS), 1978 - 48” in 52 hrs
Claudette (TS), 1979 - 43” in 24 hrs
Charley (TS), 1998 - 18” in 4 hrs
Combine terrain, record rainfall events

Flash Flood Alley
Hydrological Challenges

- Lack of soil infiltration
Hydrological Challenges

- Lack of soil infiltration and terrain along the I-35 corridor

Edwards Plateau
(1800-3000 feet)

Balcones Escarpment

Coastal Plains
(< 600 feet)
Social Challenges

- Lack of soil infiltration and terrain along the I-35 corridor combines with rapid population growth!

Austin-San Antonio Mega-Region Population 2000-2050
(If 2000-2012 Growth Rates Continue)

Source: urbanscale.com
Texas Hill Country is Flash Flood Alley!

• #1 Storm related killer
• Especially dangerous at night
• Turn Around Don’t Drown!

NWS Austin/San Antonio
www.srh.weather.gov/ewx
Motivation for Study = Flood Deaths 1996 - 2015

144 Fatalities in South Central Texas since 1996

25 in 2015
May 18: 1
May 23-24: 13
May 25: 2
Sep 10: 2
Oct 8: 2
Oct 30: 5
Flash Flooding

Don’t drive through low water crossings!

#1 weather-related killer

Nearly half of all flash flood-related deaths involve automobiles
Floods are deceptive.

Water is deeper than it appears.

Water flows faster than it appears.

Floods hide damage and debris.
Hidden Road Damage
Tropical Storm Hermine September 2010

Car Trapped near Spicewood
Don’t Rely on Your Big Vehicles

They Won’t Save You

Forces on Vehicles From High Water

The car will be carried when:
Buoyancy Force Greater Than Vehicle Weight

Vehicle Weight

Friction Force

Buoyancy Force

There is no friction force once the vehicle is lifted off the road

Nearly half of all flood fatalities are vehicle related
Turn Around – Don't Drown!
Rapid City, SD flood in 1972
Ingredients for Severe Storms Often Come Together Across Texas
Severe hail, wind, and tornado reports increase across South Central Texas from March until May, before decreasing in June.

Flash flooding a concern, but greatest late May-June and in Fall.

Severe Weather Reports 1955-2013

- Tornadoes
- Hail
- Thunderstorm Winds
- Flash Floods (1996-2013)

Climatology Courtesy Bob Fogarty
Wet Pattern through the Weekend
Locally Heavy Rainfall & Flooding Possible Thu-Sat Night
National Weather Service Austin / San Antonio

“Squeeze Play” Ingredients for a Heavy Rain Event

1. Upper Level Low Moves Towards the Region Thu-Sun

2. Gulf & Western Caribbean Moisture Drawn Northwest into Texas

3. Pacific Moisture Drawn Northeast into Texas, Peaking Saturday with Remnants of “Patricia”
Heavy Rain Events: > 6 Inches from 2005-2015

South-Central Texas

50 Unique Events
Diurnal Characteristics - Season & Time

#Cases = 16 Spring   22 Summer   11 Fall   (1 Winter)
(32%)            (44%)          (22%)        (2%)
Precipitable Water Analysis

PW Values

- Spring
- Summer
- Fall

PW Value:
- <1.4"
- 1.4"-1.69"
- 1.70"-1.99"
- 2.00"-2.29"
- 2.30"+
Surface Boundary Analysis by Season

**Spring**
- % Cases With Boundary:
  - Yes: 69
  - No: 31

- % Boundary Type:
  - Meso: 36
  - Syn: 64

**Summer**
- % Cases With Boundary:
  - Yes: 73
  - No: 27

- % Boundary Type:
  - Meso: 73
  - Syn: 27

**Fall**
- % Cases With Boundary:
  - Yes: 100

- % Boundary Type:
  - Meso: 73
  - Syn: 27
500 mb Pressure Pattern Analysis

500 mb = ~18,000 feet in height
Low Level Wind Speed Analysis

**Upwind Propogation Vector Speed**

- **Spring**
- **Summer**
- **Fall**

The chart shows the distribution of wind speeds in different seasons. The x-axis represents speed in knots, while the y-axis represents the number of cases. The chart indicates that summer has the highest number of cases at speeds of 10 knots and 15 knots.
Prevailing Wind At 5,000 feet by Season

X – Spring
X – Summer
X – Fall
Most events occur:
- Near the Escarpment
Meteorological Challenges

- Most events occur:
  - Near the Escarpment
  - At night (7 PM – 7 AM) from April to November

![Map of Balcones Escarpment with occurrences marked]

![Bar chart showing occurrences by season and time of day]

- Spring
- Summer
- Fall
Most events occur:
- Near the Escarpment
- At night (7 PM – 7 AM) from April to November
- With S/SE low level jets
- With deep Gulf and/or Pacific moisture taps
Major Findings of Favorable Conditions for Heavy Rain Events in S. Central Texas

• Southerly nocturnal low-level jet plays a strong role

• Summer Cases were meso-scale driven and always with PW > 2” with weak closed lows at 500 mb being dominant pattern

• Spring and Fall cases were mainly synoptic-scale driven with surface boundaries and PW > 2 standard deviations above normal.
The Guadalupe River…one of the flashiest and deadliest!


- 11 inches near Hunt, TX
- 8 foot wall of water
- 10 Fatalities
500 mb Map July 17, 1987 at 7 AM
Surface Map July 17, 1987 at 7 AM
The Setup – Upper Level Winds and Pressure

May 2015 Weather Pattern

500 mb May 23, 2015
May 2015 Record Rainfall

Totals of 8 to 20+ inches across South Central Texas
May 2015 Percent of Normal Rainfall

200% to 600% of Normal Across Central Texas
The Hydrologic Setup

- Leading into the event May 4 through May 24–
- 20 consecutive days of at least 4” of rain somewhere in TX
- 10 out of 11 days of at least 6” in TX
Dual-Polarization Radar Storm Total Rainfall Estimates
Note 9 to 11 inches with Max near 13 inches along Blanco/Kendall County Line
Flood Impacts

11 Fatalities
3000 Structures Impacted
300 Homes Destroyed
Some Stats...

Notes:

I. WGRFC Senior Hydrologists estimate 8,445,560,000 cubic feet through Wimberley

II. This equates to 195,000 acre feet

III. GBRA stats show Canyon Lake can store 378,852 acre feet (Conservation Pool)

IV. This would have filled AT&T Stadium 82 times and then some

All numbers were preliminary estimates (our numbers turned out low)
FM 165 Bridge in Blanco Co.

Fischer Store Bridge Near Wimberley

Water flowing down drainage ditch/frontage road from Blanco to San Marcos River

Blanco/San Marcos River across I-35

Fischer Store Bridge Near Wimberley
Bastrop State Park Dam Break
16 Total Tornadoes between May 23\textsuperscript{rd} and 25\textsuperscript{th}
May 25 Tornadoes

Floresville, TX TOR

Fayette Co. TOR
October Heavy Rain Events

Wet Pattern through the Weekend
Locally Heavy Rainfall & Flooding Possible Thu-Sat Night

National Weather Service Austin / San Antonio

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Much like the devastating October flood of 1998!!
5 hours later…at 1215 PM - 10/17/98
9 hours later at 415 PM – 10/17/98
13 hours later at 815 PM 10/17/98
Maximum Rainfall - 32 inches at Zorn!!
Near the city of Cuero on the Guadalupe River, 1998 flood
July 2, 2002 - 500 mb Pattern – Weak Low
Texas Flood of July 2002

San Antonio deluge of 9.52 inches on July 1 sets a daily and monthly record for July.
July 2002 - 6 Day Storm Totals

= 30 in.

= 25 in.
July 2002 vs Oct 1998 Flood

6 Days Total

1 Day Total
US Highway 281 at Basse Road

San Antonio
July 2, 2002
Least “Widespread” Case in Study

New Braunfels/Gruene Flood
9-10 June 2010
79% coverage

Still produces a major flood from 11.55” max!
San Antonio Memorial Weekend Flood on May 25, 2013

Flash Flood Emergency Issued for San Antonio
Weakness in the upper levels
Cell Mergers Over Olmos Basin 4-7AM

Record Rainfall
The Aftermath

300+ home affected
2 of 3 deaths were in vehicles
Millions in damage
*On a Saturday likely saved lives*
Eagle Pass Flooding - June 14-15, 2013

17+ inches of rain

Hundreds of homes flooded
Marble Falls – June 27, 2007
Weak Flow & Weak Closed Low

19 inches in 8 hours!

$130 Million Damage in Burnet Co.

Report of 8.5 inches in one hour!

Approached the one hour U.S. record of 10 inches set at New Braunfels, TX in May 1972
Austin Area Halloween Flood, October 30-31, 2013
Austin Williamson Creek Flood
October 13, 2013
CoCoRaHS Reports 10/13/13

10 to 12 inches
Meteorological Challenges

- Efficient warm rain processes often interact with multiple mesoscale factors to enhance orographic lifting
  - Low-level jets, slow-moving fronts, outflows, etc.

Onion Creek Flood 30-31 October 2013

7PM – 7AM
500 mb Heights - Oct 31, 2013

500 Millibar Height Contours at 7:00 A.M. E.S.T.
12 hour loop from 7 pm Oct 30 to 7 am Oct 31, 2013
Onion Creek @ HWY 183 – ATIT2 – River Gauge

Previous Record Crest: 38’ (1921, 1869)

Major Flood: 24’

Moderate Flood: 20’

Flood Stage: 17’

Action Stage: 15’

October 31st, 2013

Time (Local)

November 1st, 2013
Then Two Years Later…The Austin Area Halloween Flood, October 30-31, 2015
Wet Pattern through the Weekend
Locally Heavy Rainfall & Flooding Possible Thu-Sat Night
National Weather Service Austin / San Antonio

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@NWSSanAntonio
weather.gov/ewx
Heavy Rains Prior to 2015 Halloween Floods

3 Day Rainfall Ending
10 AM Sunday, October 25, 2015

Images are created from a combination of Doppler radar precipitation estimates and reliable ground-based rain gauges. Some totals may be unrepresentative.
Radar Loop on Oct 30, 2015 from 6 AM to Noon
2015 Halloween Weekend Rain Totals

10-14 + Inches of Rain

2 Day Rainfall Ending Sat Oct 31st
Historical Rainfall

- The 14.21” experienced in 6 hours at the LCRA Gauge at Onion Creek from 5:55-15:55 am October 30, 2015 had an annual exceedance probability of less than 0.2%! (1/500)
Texas Flooding

10 – 15 in. of rain caused multiple Flash Flood Emergencies

- San Marcos Area
- Travis County
- N. San Antonio

Observed Precip 12h Accumulation October 30, 2015
October 30th, 2015 Tornadoes

For Detailed Information Visit: go.usa.gov/cam6T

**Centerpoint**
- Time: 7:28 am – 7:38 am CDT
- **EF-1**: 90-100 MPH
- Path Length: 2.25 miles
- Path Width: 0.25 Miles

**D’Hanis**
- Time: 4:00 am – 4:05 am CDT
- **EF-0**: 85 MPH
- Path Length: 3.00 miles
- Path Width: 100 Yards

**Floresville**
- Time: 6:02 am – 6:11 am CDT
- **EF-2**: 120 MPH
- Path Length: 5.25 miles
- Path Width: 0.25 Miles

**Geronimo**
- Time: 7:11 am – 7:30 am CDT
- **EF-2**: 111-120 MPH
- Path Length: 8.25 miles
- Path Width: 0.25 Miles
On Sep 7th, sustained winds of 48 mph with gusts to 64 mph in San Antonio.

Widespread 10 to 15 inches of rain in a 12 hour period on Sep 7, 2010.

North Austin had some of the worst flooding since the Memorial Day Flood of 1981.
Tropical Storm Hermine
September 6-9, 2010
Tropical Rainfall Facts

- Greatest loss of life in tropical systems is due to inland flooding.
- Intensity of storm not a factor in rainfall amounts.
- The speed of movement is primary influence on rain amounts.
- As a storm moves inland…rain areal coverage decreases.
- Rain amounts don’t necessarily decrease as storm intensity decreases. (Charley 1998)

Rule of thumb…

Maximum rainfall = 100 divided by speed of the storm
Applying the “100-Rule” In Texas. . .

As tropical systems approach

The “100-Rule” for Tropical Rainfall
for past Texas Hurricanes. . .

<table>
<thead>
<tr>
<th>Storm</th>
<th>Year</th>
<th>Speed</th>
<th>Est. Rain</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alicia</td>
<td>1983</td>
<td>10mph</td>
<td>10”</td>
<td>8-11”</td>
</tr>
<tr>
<td>Allison</td>
<td>1989</td>
<td>5mph</td>
<td>20”</td>
<td>17-22”</td>
</tr>
<tr>
<td>Chantal</td>
<td>1989</td>
<td>12mph</td>
<td>8”</td>
<td>8-10”</td>
</tr>
<tr>
<td>Bret</td>
<td>1999</td>
<td>7mph</td>
<td>14”</td>
<td>14-16”</td>
</tr>
<tr>
<td>Claudette</td>
<td>2003</td>
<td>12mph</td>
<td>8”</td>
<td>8-10”</td>
</tr>
</tbody>
</table>
Current models are low and slow, but WRF-Hydro RAPID is on the way.
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Figure 1. The NWS WFO Austin/San Antonio domain with 33 Texas counties (a). The WRF-HydroRAPID modeling framework will provide streamflow forecasts for 16,427 NHDPlus “blue lines” in gauged and ungauged river reaches (b).

Courtesy Liang Yang and Peirong Lin, UT-Austin
Little Dry, but No Drought Concerns

- Abnormally dry parts of Texas, but drought not expected to develop this spring.

U.S. Seasonal Drought Outlook
Drought Tendency During the Valid Period
Valid for February 18 - May 31, 2016
Released February 18, 2016

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought

- Drought persists
- Drought remains but improves
- Drought removal likely
- Drought development likely

February 16
45% Dry (D0)
4% Drought

February 9
12% Dry (D0)
0% Drought

March 1
25% Dry (D0)
1% Drought

March 8
30% Dry (D0)
1.5% Drought

Author: Rich Tinker
NOAA/NWS/NCEP/Climate Prediction Center
Strong El Niño Conditions Continue…

- Much warmer than normal SSTs in Pacific continue
- One of the three strongest El Niños since 1950!

Niño 3.4 SSTs exceeding +0.5°C for at least five 3-month periods denotes an El Niño
How Does El Niño Usually Affect Texas?

- El Niño typically causes subtropical jet to be active over southern U.S. and polar jet to be displaced to the north.

Thus, Texas is more likely to be wet and cool during El Niño.
What Happened to our Wet and Cool Winter?

1) El Niño tilts the odds towards a wet and cool winter for us, but we are *drier and/or warmer than normal 30-40% of the time!*

![Map showing weather patterns](image)
What Happened to our Wet and Cool Winter?

- 1) El Niño tilts the odds towards a wet and cool winter for us, but we are drier and/or warmer than normal 30-40% of the time!
- 2) Lack of Arctic outbreaks this winter associated with a very persistent positive Arctic Oscillation resulted in fewer freezes.

![Diagram showing Arctic Oscillation phases and temperature departures](image-url)

**AO: Observed & ENSM forecasts**

- Positive Phase: Lower pressure than normal at poles
- Negative Phase: Higher pressure than normal at poles

**Freeze Days (32° and Below)**

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of Days</th>
<th>El Niño (9)</th>
<th>All Others (21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austin (Mabry)</td>
<td>10</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>San Antonio</td>
<td>11</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>Del Rio</td>
<td>10</td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>
What Happened to our Wet and Cool Winter?

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3) Storm tracks shifted north with polar jet as expected during El Niño, but subtropical jet moved south and east of our area.
What Happened to our Wet and Cool Winter?

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3) Storm tracks shifted north with polar jet as expected during El Niño, but subtropical jet moved south and east of our area.

However, El Niño’s greatest impacts last through March, so the odds are still tilted towards wetter than normal conditions.
March and Spring Outlooks: Getting Wetter!

- Odds tilted towards wetter than normal conditions this spring, particularly for March (temperature forecast less confident).
El Niño Continues Into Spring, But Weakens

- Sea surface temperatures are decreasing in East Pacific
- Models agree that El Niño will rapidly weaken during spring
- Most models predict neutral conditions develop by summer
- La Niña possible by fall

![Graph showing El Niño predictions](image-url)
Sneak Preview: Summer Outlook

- Summer will likely be warmer than normal, but no clear signal for rainfall forecast yet.
- If we transition into La Niña, rainfall will generally be below normal, but the chance of a hurricanes goes up!
El Niño vs. La Niña Hurricane Seasons

GULF HURRICANES CATEGORIES 1-5
NEUTRAL 1925-2005  EL NINO 1925-2005

Dolly, Gustav, and Ike (2008)
Issac (2012)

LA NINA 1925-2005

<table>
<thead>
<tr>
<th>ENSO Phase</th>
<th>Tropical Storms/Hurricanes (per year)</th>
<th>Hurricanes (per year)</th>
<th>LA/MS Notable Landfalling Hurricanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>EL NINO (24 years)</td>
<td>8.5</td>
<td>4.9</td>
<td>Betsy 1965 Camille 1969</td>
</tr>
<tr>
<td>NEUTRAL (33 years)</td>
<td>10.8</td>
<td>6.3</td>
<td>Katrina 2005 Andrew 1992</td>
</tr>
<tr>
<td>LA NINA (24 years)</td>
<td>11.2</td>
<td>6.8</td>
<td>Florence 1988 Georges 1998</td>
</tr>
</tbody>
</table>

Humberto (2007)
Hurricanes in Western Gulf
El Niño -vs- La Niña
CoCoRaHS

“Because every drop counts”

Community Collaborative Rain, Hail & Snow Network
Why CoCoRaHS??

Precipitation is important and highly variable.

Data sources are few and rain gauges are far apart.

CoCoRaHS
Community Collaborative Rain, Hail & Snow Network

PRISM: used by permission

Precipitation (in.)
- 0
- 0.1
- 0.6-1.2
- 1.2-3.2
- 3.2-10
- 10-20
- 20-24
- 24-60
- >60

Credit: Copyright © 2007, PRISM Group, Oregon State University.
http://www.prism.oregonstate.edu/PRISM --- Map created Feb 13 2007
“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”
CoCoRaHS
Community Collaborative Rain, Hail & Snow Network
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cocorahs.org
“We can’t help everyone, but everyone can help someone”
- Ronald Reagan
Thank You!

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