Southwest Climate Change Projections – Increasing Extreme Weather Events?

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IMPACTS of extreme weather events stem from a combination of several weather and climate variables, as well as where the event occurs.
Urban environments can compound impacts of extreme weather events.
Asphalt can intensify heat waves by releasing heat at night and increasing minimum temperatures.
WEATHER ALERT

RECORD-BREAKING RAIN IN THE VALLEY

PHOENIX: I-10 & 35TH AVE
Impermeability of urban surfaces like asphalt and buildings reduces infiltration and increases flooding potential.
Intense rainfall can result in flooding and overloaded drainage infrastructure, as well as pavement damage and washout.
WEATHER ALERT

RECORD-BREAKING RAIN IN THE VALLEY

PHOENIX: I-10 & 35TH AVE

TOP STORIES: ODED ROADS NEAR BROADWAY & RURAL IN TEMPE
Urban environments can compound impacts of extreme weather events.

*Is the environment designed to handle extreme weather events?*
“Indeed, the main way in which climate change is likely to affect societies around the world is through changes in extremes.”

--Trenberth et al. (2015)
Indications of a warming world already are present.
Global Temperature and Carbon Dioxide

Karl et al. 2009
carbon dioxide, methane, and nitrous oxide are major greenhouse gases

climatechange.gc.ca
Different and sometimes complex definitions are often used for extreme weather and climate events.
Such events may be considered:

in a strictly statistical context;

as a maximum value or an exceedance of a threshold;

even in combinations with aspects of social or ecological vulnerabilities.
Such events may arise from a mixture of conditions that are not extreme individually and that are caused by natural variations of weather and climate.
Human-caused climate change may alter characteristics of extreme weather and climate events, such as frequency, intensity, and duration.
1991-2011 compared to 1901-1960 average
(NCA 2014)

differences by decade compared to 1901-1960 average
(NCA 2014)
four-day periods colder (left) and warmer (right) than one in-five-year occurrence, 1901–2010 (SWCCAR 2013)

Relatively small shifts in mean climatic conditions can lead to relatively large changes in the occurrence of extreme events.
INCREASE IN AVERAGE TEMPERATURE

PROBABILITY OF OCCURRENCE

PREVIOUS CLIMATE

NEW CLIMATE

COLD

Average

HOT

Less cold weather

More hot weather

More record hot weather

PREVIOUS RECORD

NEW RECORD
Observed Precipitation Change

1991-2011 annual total compared to 1901-1960 average (NCA 2014)
differences by decade compared to
1901-1960 average (NCA 2014)
Observed Changes in Very Heavy Precipitation

Heaviest 1% of daily events 1901-2011 compared to 1901-1960 average (NCA 2014)
“Prediction is very difficult, especially if it’s about the future”

--Niels Bohr
seasonal changes compared to 1971-2000 (SWCCAR 2013)
NARCCAP, SRES A2, ANNUAL MAXIMUM NUMBER OF CONSECUTIVE DAYS TMAX > 95F
Difference (2041-2070 minus 1971-2000)

Number of Days per Year
0 3 6 9 12 15 18 21 24 27 30

(Kunkel et al. 2012, prepared for NCA 2014)
<table>
<thead>
<tr>
<th>parameter</th>
<th>direction of change</th>
<th>confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>average annual temperature</td>
<td>increase</td>
<td>high</td>
</tr>
<tr>
<td>seasonal temperatures</td>
<td>increase</td>
<td>high</td>
</tr>
<tr>
<td>heat waves</td>
<td>increase</td>
<td>high</td>
</tr>
<tr>
<td>cold snaps</td>
<td>decrease</td>
<td>medium-high</td>
</tr>
</tbody>
</table>

(SWCCAR 2013)
“a subjective judgment of the reliability of an assertion, based on systematic evaluation of the type, amount, quality, and consistency of evidence, and the degree of agreement among experts”

--SWCCAR 2013
Confidence in projections of extreme events varies by type and season, as well as by the scientific understanding of processes that drive these events.
Precipitation change (as % of historical)
High-emissions scenario

annual changes compared to 1971-2000 (SWCCAR 2013)
Projected Precipitation Change by Season

Higher Emissions (A2)

Winter
Spring
Summer
Fall

Percent Change

seasonal change by 2070-2099 compared to 1901-1960
(NCA 2014)
Rare Heavy Precipitation Events Become More Common

- Low Pathway (RCP 2.6)
- High Pathway (RCP 8.5)

Future Change Multiplier

increase in frequency by 2081-2100 compared to 1981-2000 (NCA 2014)
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<tr>
<th>parameter</th>
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<th>confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>average annual precipitation</td>
<td>decrease</td>
<td>medium-low</td>
</tr>
<tr>
<td>spring precipitation</td>
<td>decrease</td>
<td>medium-high</td>
</tr>
<tr>
<td>extreme daily precipitation</td>
<td>increase</td>
<td>medium-low</td>
</tr>
</tbody>
</table>

(SWCCAR 2013)
Projections of future ENSO variability and frequency of El Niño and La Niña events are inconsistent.
Because of this large uncertainty, the IPCC assigned ‘low’ confidence to projected changes in the intensity and spatial pattern of this phenomenon.
However, there is ‘high’ confidence in ENSO dominating year-to-year variations in global climate.
Modeling and projecting future variability of the North American monsoon is extremely challenging.
Because of this large uncertainty, the IPCC assigned ‘low’ confidence to projected changes of precipitation from this phenomenon.
However, there is ‘high’ confidence that precipitation extremes will increase.
Inconsistent projections of these global-and regional-scale phenomena, however, make projections of drought difficult.
Nonetheless, other aspects of dryness or aridity that relate additionally to temperature can provide insight into the nature of droughts that possibly occur in coming decades.
There is ‘high’ confidence that droughts will become more severe under warmer temperatures as soil moisture decreases with greater atmospheric demand for evaporation and transpiration.
WEATHER ALERT

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PHOENIX: I-10 & 35TH AVE
The potential for heavy precipitation events due to a warmer atmosphere that can hold more moisture implies possible changes in the timing, frequency, and magnitude of floods.
Much as is the case with drought, inconsistent projections of phenomena that influence precipitation translate into uncertainties about future changes in flooding.
There is ‘high’ confidence that climate in the Southwest will continue to change in coming decades, but not all aspects – such as extremes – can be projected with equal confidence.
Nonetheless, current knowledge is sufficient to identify impacts from possible changes in future extreme weather events.
RESOURCES

Southwest Climate Change Assessment Report
www.swcarr.arizona.edu

National Climate Assessment
nca2014.globalchange.gov

IPCC AR5
www.ipcc.ch/report/ar5

IPCC SREX
ipcc-wg2.gov/SREX
<extra information>
“Overall, the most robust global changes in climate extremes are seen in measures of daily temperature, including to some extent, heat waves. Precipitation extremes also appear to be increasing, but there is large spatial variability.”

“There is limited evidence of changes in extremes associated with other climate variables since the mid-20th century.”

“Current datasets indicate no significant observed trends in global tropical cyclone frequency over the past century … No robust trends in annual numbers of tropical storms, hurricanes and major hurricanes counts have been identified over the past 100 years in the North Atlantic basin.”

“In summary, there continues to be a lack of evidence and thus low confidence regarding the sign of trend in the magnitude and/or frequency of floods on a global scale”

“In summary, there is low confidence in observed trends in small-scale severe weather phenomena such as hail and thunderstorms because of historical data inhomogeneities and inadequacies in monitoring systems”

“In summary, the current assessment concludes that there is not enough evidence at present to suggest more than low confidence in a global-scale observed trend in drought or dryness (lack of rainfall) since the middle of the 20th century due to lack of direct observations, geographical inconsistencies in the trends, and dependencies of inferred trends on the index choice.”

“In summary, confidence in large scale changes in the intensity of extreme extratropical cyclones since 1900 is low. Likewise, confidence in trends in extreme winds is low, owing to quality and consistency issues with analysed data.”
Separating Human and Natural Influences on Climate

Global Temperature Change (°F)

Year

-1.0 | -0.5 | 0.0 | 0.5 | 1.0 | 1.5 | 2.0

1900 | 1920 | 1940 | 1960 | 1980 | 2000

Observations
Natural and Human Factors
Natural Factors Only

NCA 2014