Center for Disaster Management and Risk Reduction Technology

Analysis of U.S. extreme drought and record heat 2012

Information as of 21.09.2012, 2nd report

Bernhard Mühr[1], James Daniell[2], Bijan Khazai[2], Daniel Köbele[1], Michael Kunz[1], Tina Kunz-Plapp[2], Adrian Leyser[1], Marjorie Vannieuwenhuyse[3]

Center for Disaster Management and Risk Reduction Technology CEDIM

[1] Institute for Meteorology and Climate Research / Karlsruhe Institute of Technology (KIT)

[2] Geophysical Institute, KIT

[3] Institute for Industrial Production, KIT

Content

1 Summary

After a record-breaking hot spring, the heat persisted in the U.S. and North America through summer 2012. July 2012 was the hottest July on record in the U.S. with the summer (June to August) ranking 3rd since 1895. Extreme drought above all occurred in the Great Plains. The Canadian-Arctic Archipelago and Greenland saw massive ice shrinkage resulting in a new record low extent in September.

2 Temperature

2.1 Evolution of the heat wave in the U.S.

The extraordinary warm weather continued through July and August 2012. This is mainly due to the persistent large-scale flow pattern above North America and in the Northern hemisphere. It resulted in very long lasting and stable general weather situations that made very warm air masses of southern origin advance to and stay in the U.S. Frequently, a long wave mid and upper troposphere ridge filled with very warm air developed above the North American continent. It brought much sunshine, few clouds, hardly any precipitation, and very high temperatures. Long waves in the upper level tend to hardly move east or west and, hence, remain quasi-stationarily at the same position. The planetary frontal zone appeared to be pushed back very far into the north of North America. This planetary frontal zone is mainly responsible for low pressure activity and large-scale precipitation. Due to these conditions, dry and very hot air of subtropical origin remained over the U.S. for a very long time, with a few short interruptions only.

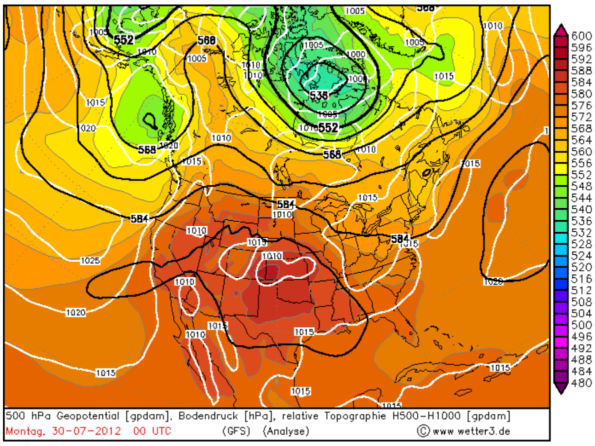

Figure 1:
Synoptic weather pattern over North America, July 30, 2012, 00 UTC: 500 hPa geopotential height and sea level pressure analysis
Image Credit: wetter3.de

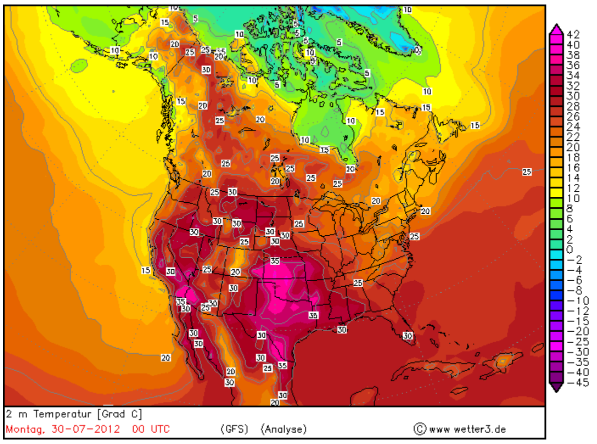

Figure 2:
Synoptic weather pattern over North America, July 30, 2012, 00 UTC: 2 meter temperature analysis
Image Credit: wetter3.de

2.2 Extremely hot June 2012 in the Great Plains and in the Midwest

Extreme and extraordinarily high temperatures are present in North America and in particular in the U.S. in 2012. After an already record-breaking spring (see article Record heat in March 2012 on Wettergefahren-Frühwarnung), the extreme heat continued over the summer without any noteworthy interruption (see also the article Heat in June/July 2012 on Wettergefahren-Frühwarnung).

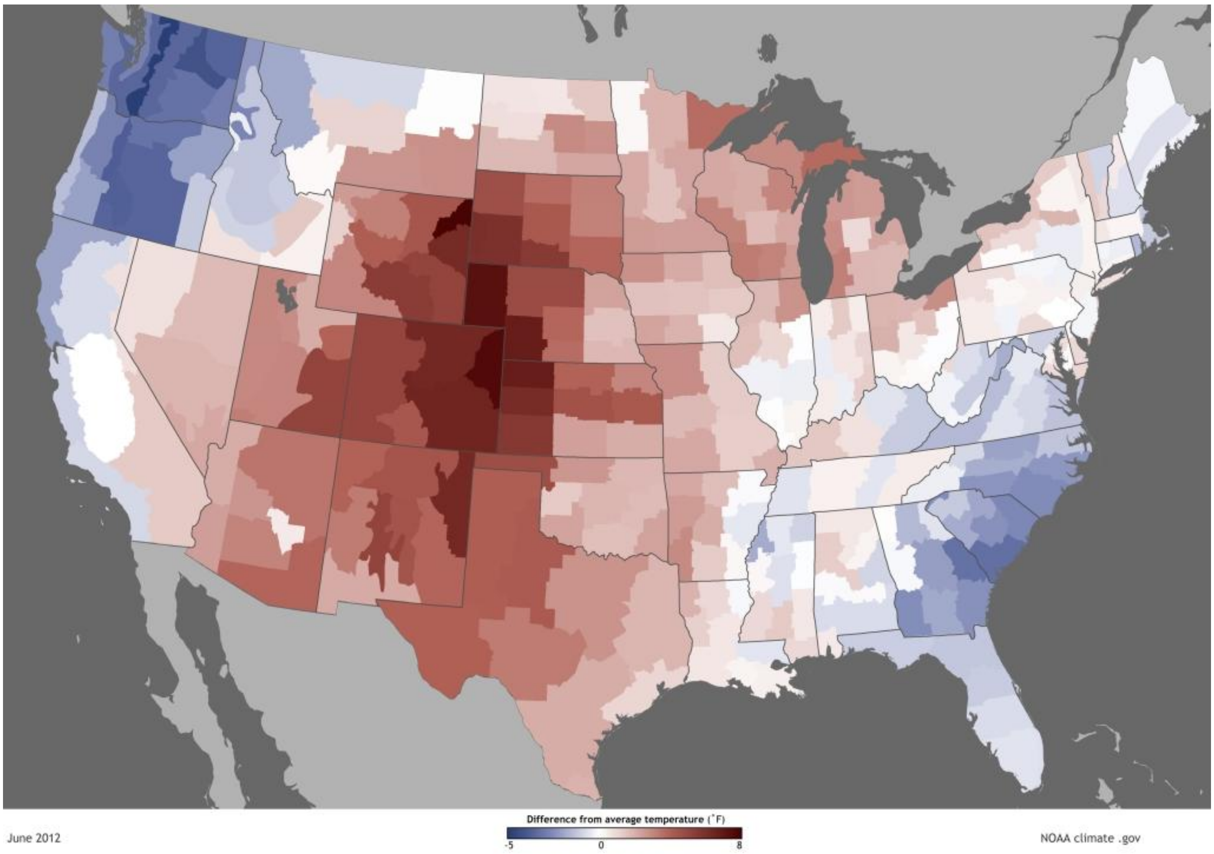

Figure 3:
Temperature anomaly [°F], U.S., June 2012
Image Credit: NOAA ClimateWatch

As obvious from Figure 3, June 2012 also was too hot like many other months. Temperatures in June exceeded the U.S.-wide average by about 2°F (about 1.2 K). While temperature deviations along the coasts tended to be negative, high positive anomalies occurred especially in the Great Plains and the Midwest. The state of Colorado saw the hottest June on record with a deviation of +6°F (about +3 K). In seven other states, June 2012 was listed under the top ten of the hottest June months. All over the U.S., 170 old records of daily high temperature were tied or broken.

2.3 Hottest July on record

Figures 4 and 5 show the mean July temperature recorded and its significant positive deviation by up to 8°F (about 4.5K). The state of Virginia recorded the hottest July since the beginning of observations. In 32 states, July 2012 was listed under the top ten of hottest months of July. Averaged over the U.S., July 2012 is the hottest July since the beginning of recording in 1895.

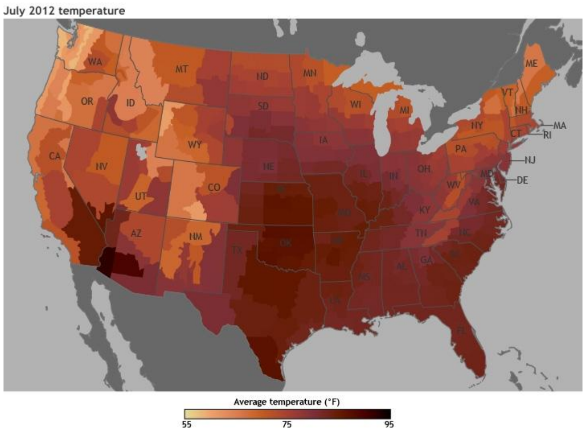

Figure 4:
Mean temperature [°F] U.S., July 2012
Image Credit: NOAA ClimateWatch

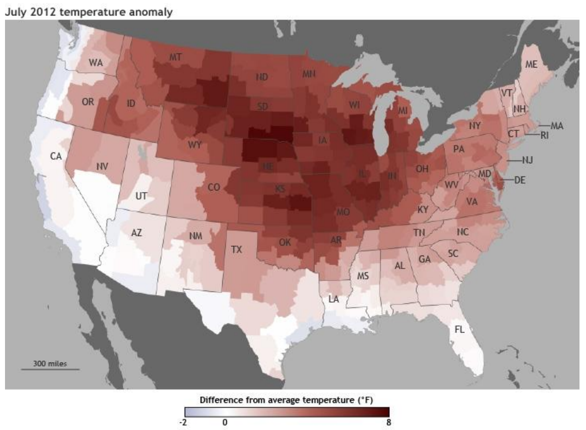

Figure 5:
Temperature anomaly [°F] U.S., July 2012
Image Credit: NOAA ClimateWatch

71 New all-time records of highest temperature in July 2012

After 170 all-time records had been tied or even surpassed in June, highest temperature records again were surpassed in July mainly in the eastern part of the U.S. 102 stations tied their previous records. At 71 places, a new all-time record was measured.

Springview (NE)	45 °C	43 °C	2006
Poplar Bluff (MO)	45 °C	44 °C	1930
Ralston (OK)	45 °C	44 °C	1996
Lewisburg (TN)	44 °C	43 °C	1930
Siloam (GA)	43 °C	42 °C	1983
Bremo Bluff (VA)	43 °C	42 °C	2007
Burlington (IA)	42 °C	40 °C	1983
Covington (MI)	40 °C	39 °C	1988
Battle Creek (MI)	39 °C	38 °C	1971
Hesperia (MI)	38 °C	37 °C	1953

Table 1:
Selection of new all-time records of highest temperatures in July 2012
Image Credit: NOAA/NCDC Records

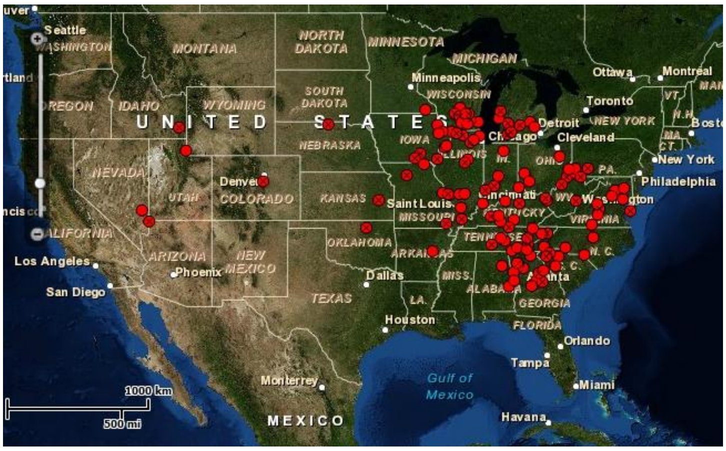

Figure 6:
High temperature all-time records tied or surpassed in July 2012
Image Credit: NOAA/NCDC Records

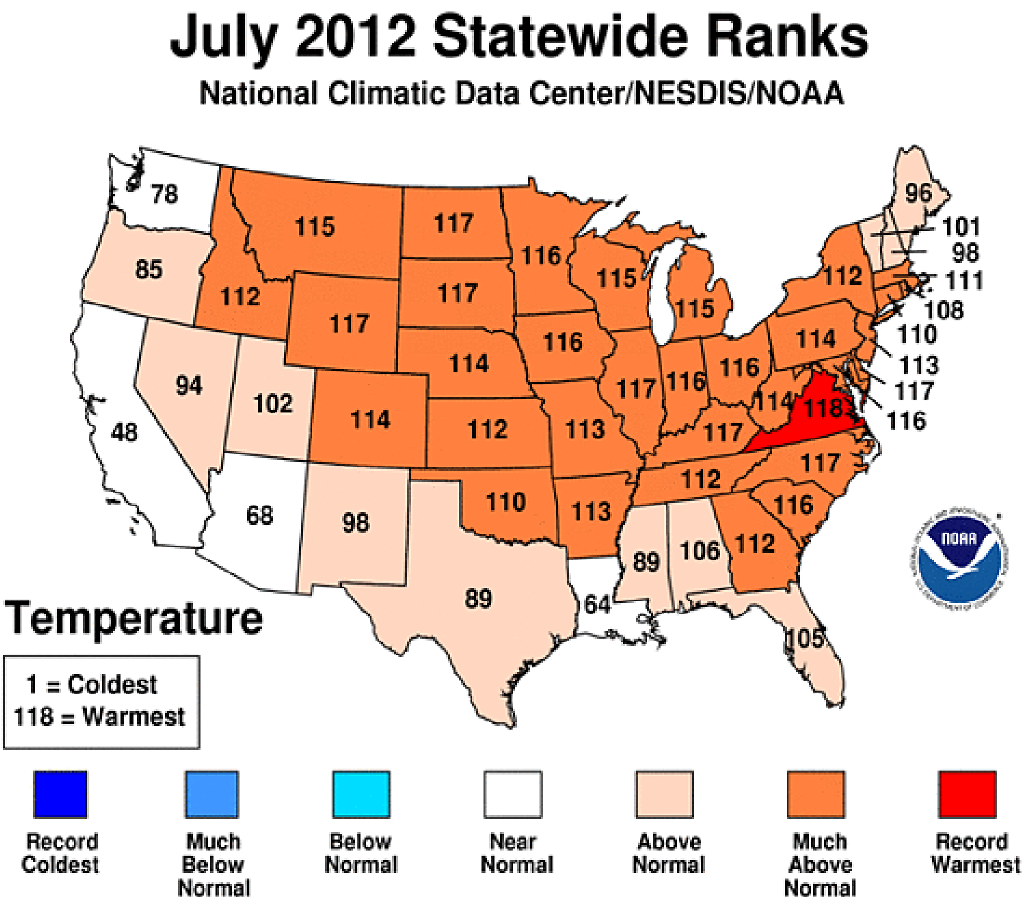

Figure 7:
July 2012 Statewide Ranks for Contiguous U.S. (118 Years)
Image Credit: NOAA NESDIS / NCDC

2.4 Summer 2012 – ranking 3rd since 1895, year 2012 – warmest on record in the U.S. so far

The United States are experiencing the hottest year on record. After the hottest March, the third-hottest April, and the second-hottest May, the hottest July of 2012 even outshines the record July of the dust-bowl year 1936. Together with the past and extraordinarily hot year 2011 (with the second-hottest summer at that time), the temperature statistics exhibits a heat episode that has never been observed before in the U.S. The twelve-month period from August 2011 to July 2012 saw record heats in 24 states. All over the U.S., this was the hottest twelve-month period ever measured. Analysis of temperature deviations from the start of this year to July produces a curve which is beyond all observations made so far. About 132 million inhabitants were directly affected by the heat. They were informed about the current weather situation by the American Weather Agency NOAA.

In 2012, the United States recorded the third-warmest summer since monitoring began in 1895. Nationwide, the average temperature of the three summer months of June, July and August exceeded the long term mean by 2.3°F (1.4K). Slightly negative temperature deviations could only be found in the southeast and in the very northwestern U.S. The rest of the country experienced large positive temperature anomalies, most notably the western United States, the Great Plains, the Midwest and much of the northeast. In 16 U.S. states, the summer 2012 lined up to the top 10 list of the hottest summers since 1895. Wyoming and Colorado recorded even the hottest summer since records began; at Denver (CO) the old record average temperature (1954) of the climatological summer was surpassed by 2°F (1.2K).

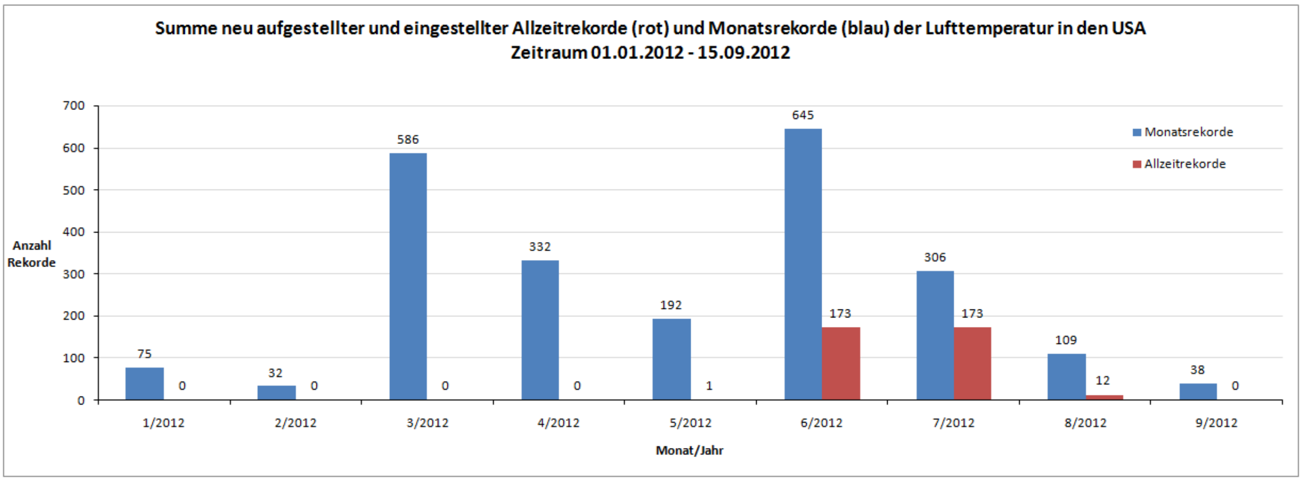

Figure 8:
Number of new or tied records per month (January 1st to September 15th, 2012). Red: All time records. Blue: Monthly records.
Image Credit: Wettergefahren-Frühwarnung; Data source: NOAA/NCDC Records

Nationwide, the summer 2012 was very close to the first place of the climatological hit list of average temperature. Only the “Great Dust Bowl Summer” of 1936 (+0.2°F) and the last year’s summer months (+0.1°F) were slightly warmer. Summer 2012 continued the series of unusual warm months that already began in record-breaking warm spring 2012 with the extremely hot July being of particular impact. The persistence of the exceptional warmth throughout the year 2012 is also reflected by the high number of new or tied all time records as well as by the number of new monthly records in the U.S. weather station network (Figure 8.).

Considering the period from the beginning of the year to the end of August, the year 2012 is ahead of the record warm year 2006 by 1°F (0.6K). Even though all remaining months would show average temperatures, 2012 would end as the warmest year since 1895, thanks to its temperature surplus so far (see Figure 10.).

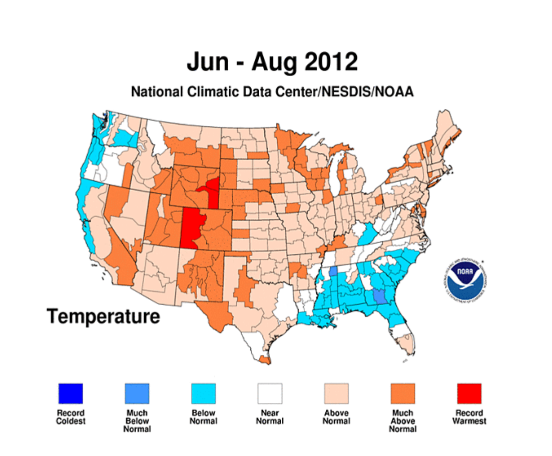

Figure 9:
Summer average temperature summary: 3 areas with new record temperature
Image Credit: NOAA NESDIS/NCDC

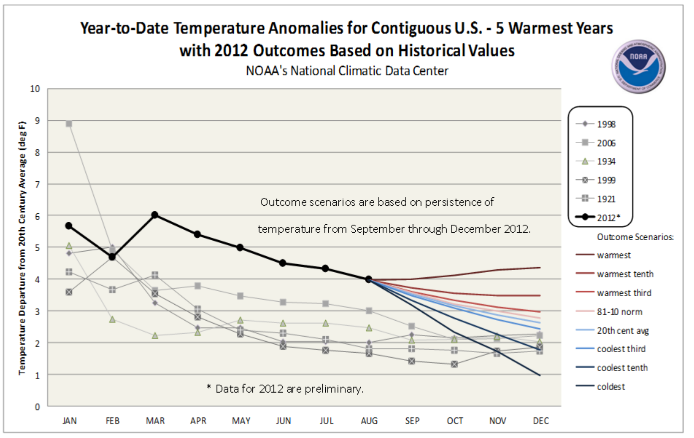

Figure 10:
U.S. monthly average temperature of 5 warmest years in comparison to 2012 and outcome scenarios
Image Credit: NOAA NESDIS/NCDC

2.5 Records from Oklahoma

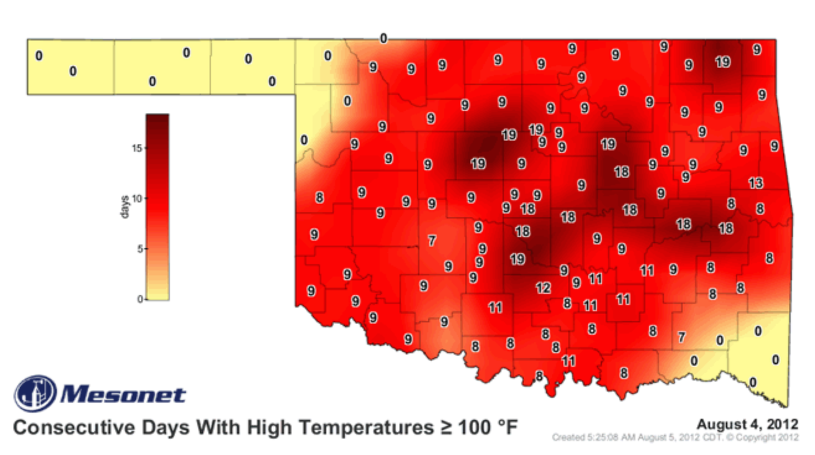

Figure 11:
Consecutive Days With High Temperatures >100°F
Image Credit: Mesonet OK

Full-blown heat waves occurred in parts of the U.S., also in the state of Oklahoma. In Oklahoma City, the old record temperature of 45°C of observations made since 1891 was tied. On 19 successive days, the thermometer measured above 100°F (corresponding to 37.8°C). This value was exceeded only once in the climate recordings of Oklahoma. This was during the “Great Dust Bowl Summer” in 1936 when such high temperatures were reached or exceeded on 22 successive days.

Regarding days with a temperature in excess of 110°F (corresponding to 43.3°C), the heat wave of summer 2012 has already drawn level with the record summer of 1936. In both cases, such a high temperature was observed on three days. Records were also tied for the highest minimum temperatures, for example at Tulsa (OK), where the lowest daily temperature was not below 31°C.

3 Precipitation

3.1 Summary

Due to the persistent general weather situation, extreme heat in many parts of the U.S. was accompanied by longer-term sparse or lacking precipitation. Passing troughs with large-scale precipitation brought relief to some regions only. Sunshine, dry and hot air, and wind stimulated evaporation and resulted in a high precipitation deficit that was still growing at the beginning of August at many places.

From mid-August onwards greater heat waves haven't occurred any more, nevertheless widespread above normal temperatures have been recorded until September. The still relatively persistent large-scale circulation patterns over the North American continent made the very dry and often with only little or no rain associated and sometimes windy weather prevail.

Regarding the long term precipitation average, the continental U.S. can look back to an almost average rainfall activity during the summer 2012. But this hides the fact that the precipitation pattern couldn't have been more variable throughout the U.S.

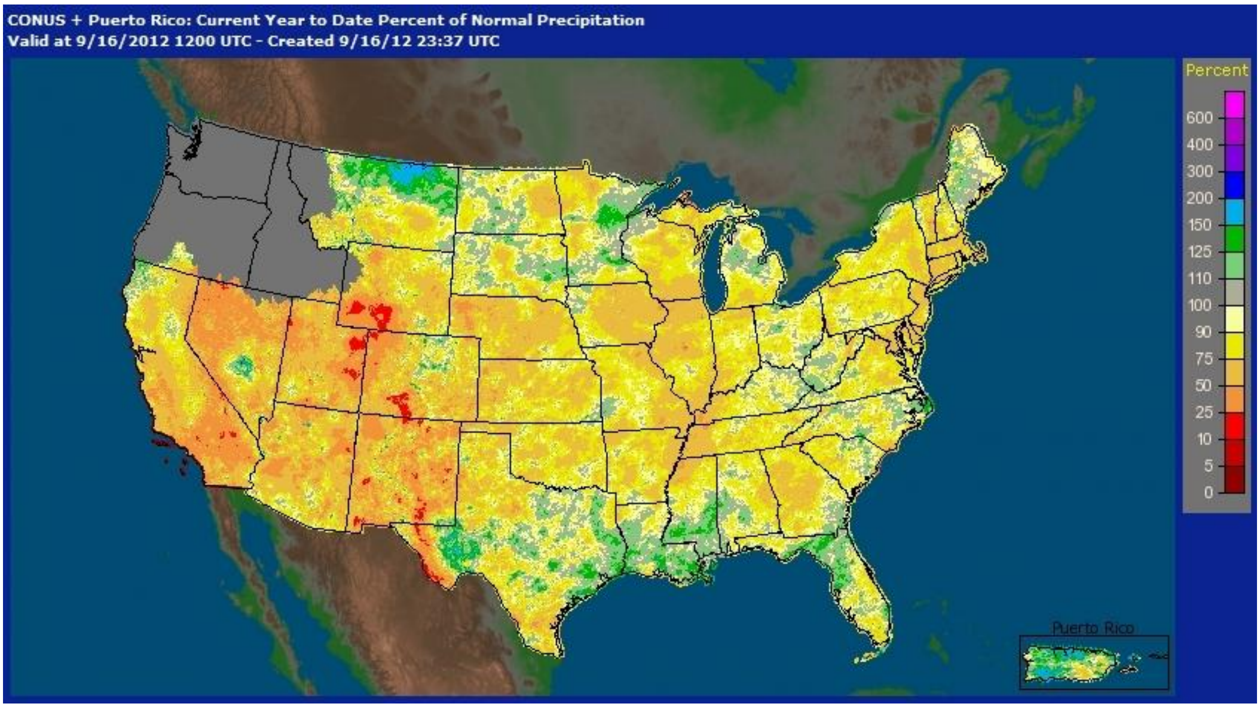

Figure 12:
U.S. Precipitation anomaly [%], January to September 15, 2012. Orange and red colors indicate greatest precipitation deficit, while green and blue colors show above normal rain amounts.
Image Credit: NOAA AHPS

3.2 Palmer Drought Severity Index (PDSI)

Wayne Palmer developed the Palmer Drought Severity Index (PDSI) in the 1960s; the index is used today mainly in the U.S. as an indicator for precipitation or drought conditions lasting several months at a particular place. The index considers information about temperature, precipitation, soil type and runoff which are processed into a dimensionless value according to Palmer's investigation. With a value of 0 we find normal conditions, negative values indicate dry conditions: values lower than -1.0 are referred to as light, under -2.0 as moderate, from below -3.0 as severe and values lower than -4.0 as extreme drought. Analogously are positive values called as mild, moderate, severe and extreme wet conditions. It is complained that the PDSI is calculated only on observations in parts of the U.S. states of Kansas and Iowa and is not transferable to other regions of the world without any problems. Snow also is not taken into account. However, the PDSI has proven to assess the rainfall and drought situations and is used by numerous U.S. authorities.

3.3 High precipitation deficit and extreme drought - very wet Florida

Colorado, Wyoming, and Nebraska passed the driest summer on record. In Missouri, Illinois, Iowa, South Dakota and New Mexico the summer 2012 managed to jump into the top-10 list of the driest summer months. At Joplin (MO), no drop of rain was measured in July. The last time, this happened in the year 1946. At Springfield (MO), 8.3 mm monthly precipitation was measured, the driest July since 1953. Also at Sioux Falls (SD), precipitation was measured to be 6.1 mm only. Normally, precipitation in July would amount to about 78 mm.

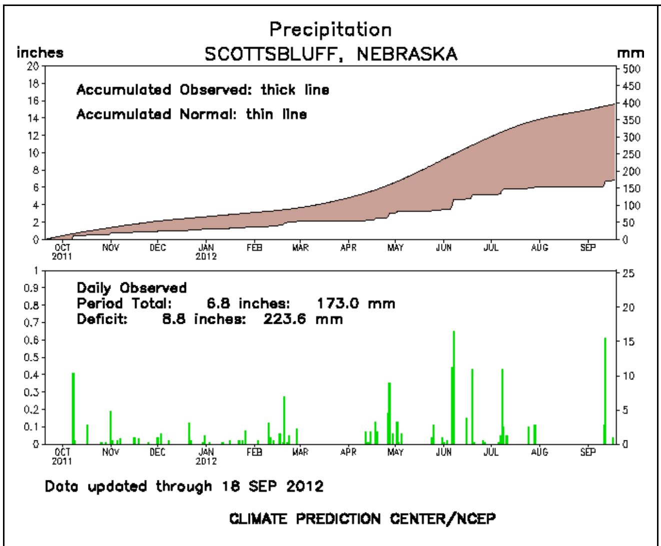

Figure 13:
Precipitation (Sept 19, 2011 – Sept 18, 2012) at Scottsbluff, Nebraska, and deviation from normal
Image Credit: NOAA CPC

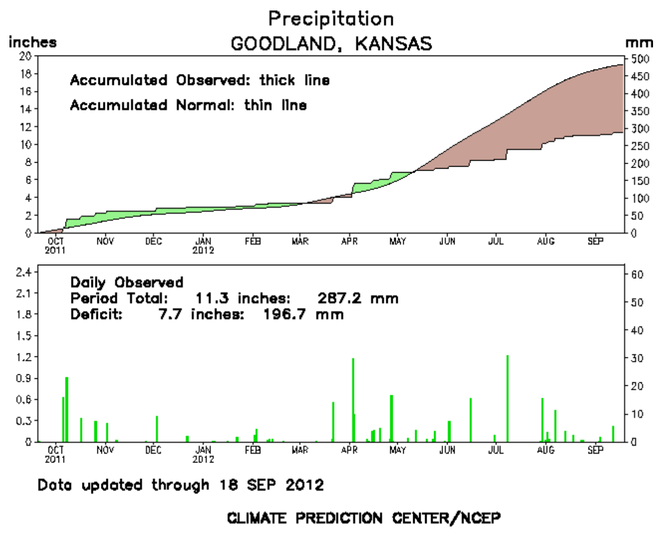

Figure 14:
Precipitation (Sept 19, 2011 – Sept 18, 2012) at Goodland, Kansas, and deviation from normal
Image Credit: NOAA CPC

Quite different is the situation in Louisiana and Mississippi, where the summer 2012 is found in the top-10 of the wettest summers due to Hurricane "Isaac" (see below). In Florida hurricane “Isaac” and tropical storm “Debby” caused the wettest summer since records began. On August 22, Las Vegas got heavy rain, an amount of 43 mm fell within 24 hours, which is the second largest daily precipitation amount ever; an outstanding amount, especially in comparison to the annual average of only 105 mm.

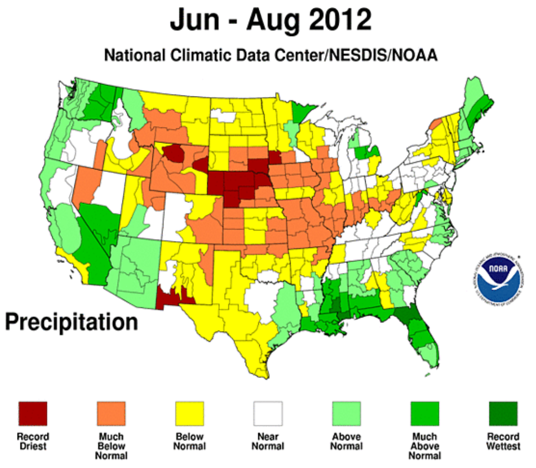

Figure 15:
Continental U.S. precipitation anomaly, summer 2012
Image Credit: NCDC/NESDIS/NOAA

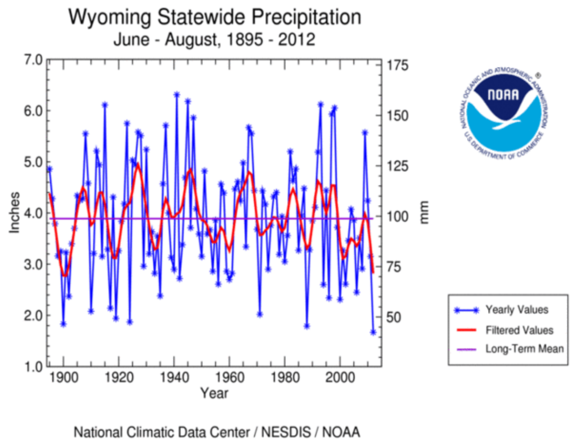

Figure 16:
Wyoming statewide summer precipitation (1895-2012)
Image Credit: NCDC/NESDIS/NOAA

3.4 Fifth largest drought since 1895

The percentage of areas that are at least moderately affected by the drought increased to 75 % in July according to the Palmer Drought Severity Index. This is the fifth largest drought on record reaching back to the early 20th century. The area affected by extreme drought increased to more than twice the value from June to July. The state of Maine experienced the fifth-driest July since the beginning of observations. Judging from the three-month precipitation amount, the months from May to July have to be considered record-dry in Nebraska, Kansas, and Arkansas. The last great drought occurred more than 50 years ago in December 1956.

In many regions sparse or no rain and high evaporation rates exacerbated the already severe drought situation in the U.S. in the course of the summer. The area affected by at least moderate drought (according to the Palmer Drought Severity Index) decreased by 2 % to 55 %; but the percentage with at least severe drought increased further to 39 %. The area with extreme drought enlarged by 2 % (overall 6 %). With these numbers the 2012 drought still is the fifth-largest since 1895 and the worst drought for 56 years (see table 2.)

07/1934	80 %
12/1939	62 %
07/1954	60 %
12/1956	58 %
07/2012	**57 %**

07/1934	63 %
09/1954	50 %
12/1956	43 %
08/1936	43 %
08/2012	**39 %**

Table 2:
Largest droughts since 1895 in the U.S. (percentage of area that is at least moderately (above) and severely (below) affected by the drought) according to the Palmer Drought Severity Index
Data Sourcet: NOAA NCDC

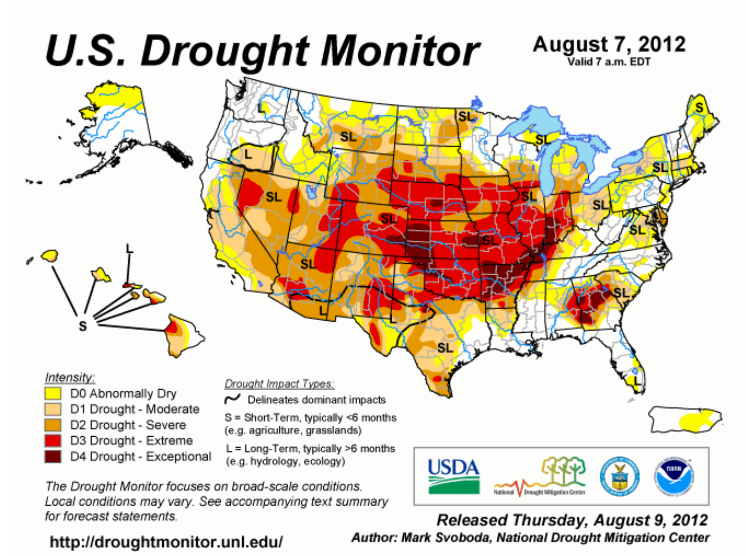

Figure 17:
Drought intensity at August 7,2012
Image Credit: U.S. Drought Monitor

The largest drought so far in the U.S. happened in the 1930s, when most of the country's area was dry and events such as the "Great Dust Bowl Summer" in 1936 including dust storms and major erosion damage became possible. In 2012 the drought is not that dramatic, especially because of the major river flooding that occurred in several states last year (e.g. Mississippi, Ohio, Missouri - see article on Wettergefahren-Frühwarnung). Hence, a multi-year and sustainable drought period hasn't been established yet.

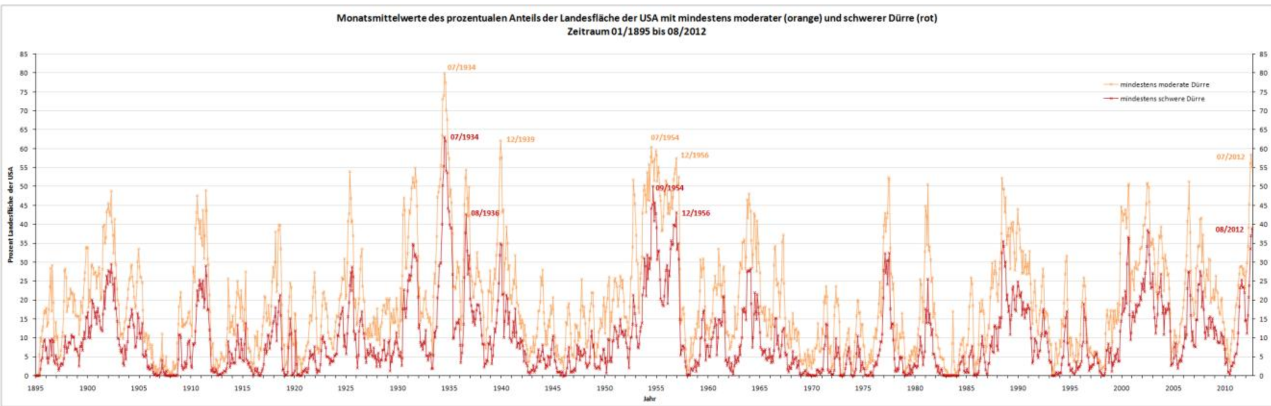

Figure 18:
Percentage of the area with at least moderate (orange) or severe (red) drought in the continental U.S. 1895-2012, Image Credit: Wettergefahren-Frühwarnung; Data source: NOAA NCDC

4 Consequences of heat and drought

4.1 Crop failures

The drought situation in 2012 is serious. Mainly the states of Kansas, Nebraska and Oklahoma are suffering from the dry conditions, but also most of the West and even some areas in the Pacific Northwest as well as Northern Mexico are seriously affected by the drought. The situation in the Midwest (cornbelt) and the Great Plains (the breadbasket) is highly critical. Now, as a result of lacking precipitation, all grain fields and farms are completely dry. Significant decrease in cattle and crop failures of up to 50% are expected. By mid of August 2012, 85% of the total U.S. crop area and 71% of the cattle ranges suffered from drought.

Figure 19:
Dry corn, Noblesville, IN
Image Credit: wunderground.com

In the medium term, food prices are expected to increase. The price of grain has already increased by about 25%. According to estimates the grain harvest is expected to decline by 13% compared to 2011. That would be the third consecutive poor harvest and the worst since 1995. Additionally, the maize harvest will be the worst since 2006, when about one-sixth of the crop withered within just one month. More hope is associated with soybeans – their price increased by 40% since the beginning of the year and now is on a record high. Many U.S. insurance companies fear enormous damage due to the bad harvest. Last year, the amount insured already amounted to about 11 billion dollars. It is expected that this sum will not be sufficient this year.

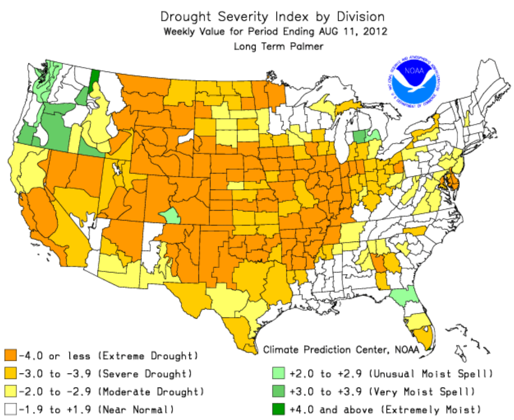

Figure 20:
Drought Intensity until August 11, 2012
Image Credit: NOAA CPC

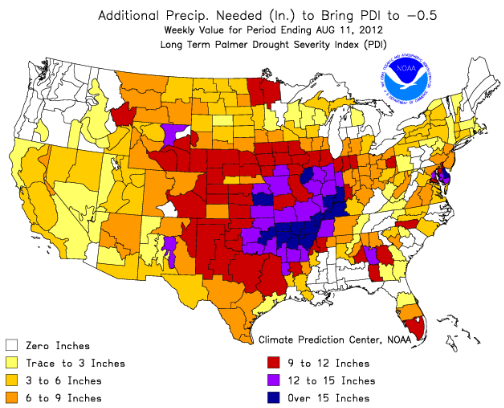

Figure 21:
Precipitation needed until August 11, 2012
Image Credit: NOAA CPC

In more than every second U.S. county, emergency has been declared. More than 1500 counties in 32 federal states are on the list of the Department of Agriculture for rapid help by the state, with increasing tendency. In large parts, drinking water was rationed, as reservoirs and lakes are presently using all water they have.

For more detailed information about socio-economic consequences of the drought see chapter 6.

4.2 Bush and forest fires - record area affected in the U.S.

The dry heat with lacking precipitation promotes forest fires fanned by wind gusts or lightning, mainly in the north and northwest of the country.

From the beginning of the year to the end of August 2012 more than 31.000 square kilometers of land were burnt by forest and bushfires. This corresponds to an area larger than Belgium. Since the surveys in 2000 such a large land area has never been affected by fires before in the period between January and August. In the month of August, the fires raged on a total of more than 14.500 square kilometers. Throughout the summer especially the U.S. states of California, Idaho, Oregon and Nevada have been affected.

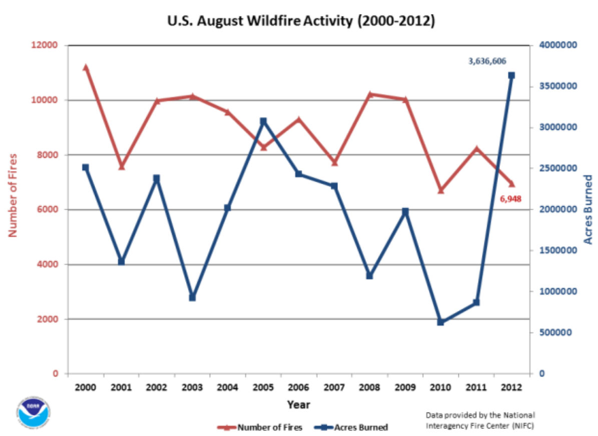

Figure 22:
U.S. August wildfire activity (2000-2012): Numbers of fires and acres burnt
Image Credit: NOAA NCDC

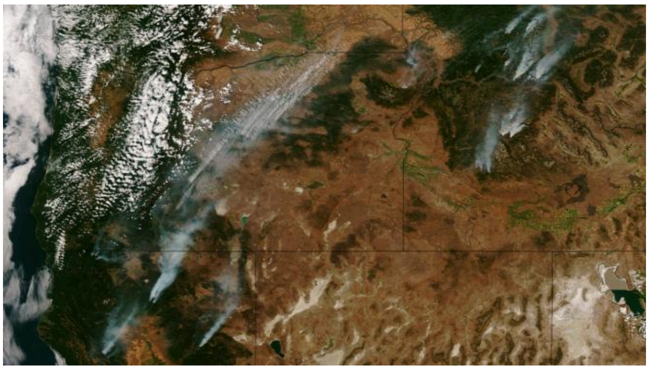

Figure 23:
Satellite images: Wildfires across California, Oregon and Idaho
Image Credit: NOAA NNVL

4.3 Record low Arctic sea ice extent

The extreme heat surplus on the North American continent did not only result in a record heat wave in the U.S., but also affected the Canadian-Arctic Archipelago and Greenland. This is reflected by two temperature values:

- Alert, Nunavut, Canada, 82°N: Tmax 19.6°C on July 18, 2012 (old record being only marginally higher with 20.0°C on July 18, 1956)
- Summit on the ice shield of Greenland (3300 m above sea level): Tmax +3.6°C on July 16, 2012 (first positive temperature since the start of measurements)

For the first time, 97% of the Greenland inland ice showed signs of melting, a consequence of extraordinarily high temperatures up to the positive range.

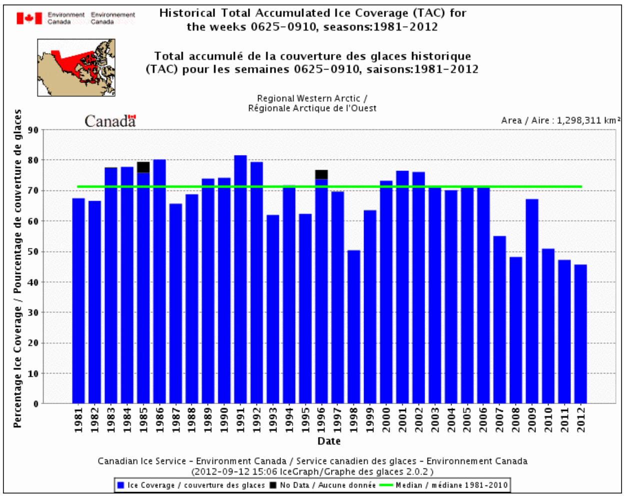

Figure 24:
Western Arctic Ice Coverage [%] (1981-2012)
Image Credit: Canadian Ice Service

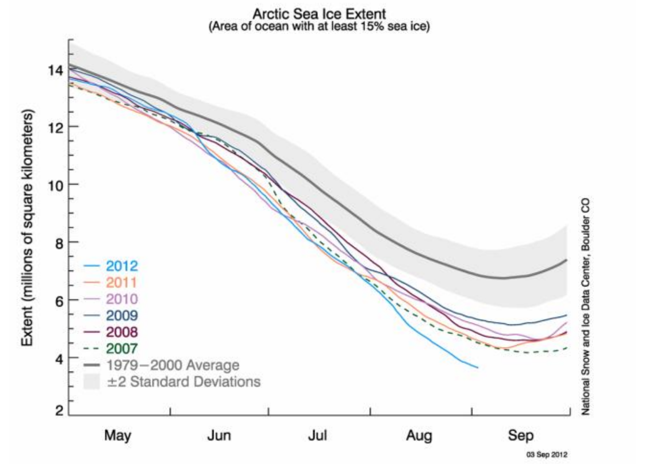

Figure 25:
Arctic Sea Ice Extent [%]
Image Credit: NSIDC

Since 2000, there has never been so little ice on Greenland in a July than this summer. The North West Passage known as an important sea route experienced an unequal shrinkage of sea ice during the second half of July. In early August, only 25% of the sea surface was covered by ice. According to the 30-year-mean (1981-2010), more than two thirds of this passage is normally covered by ice at this time of the year.

In August 2012, it was necessary to expand the focus to the entire Arctic region. There, in the 925-hPa level (approximately 800 meters above sea level), positive deviations of the monthly mean temperature of 1 K to 3 K were analyzed, over the Beaufort Sea even to 4 K. According to climate.gov, on August 26, 2012, the arctic sea ice extent broke the 2007 record low with an area of less than 4 million km²; and in early September on the 5th, the sea ice stretched only across 3.5 million km² which is the lowest value since the beginning of the regular satellite observations in 1979.

Compared with the September conditions in the 1980s and 1990s, this is a decrease of the ice extent by about 50%. The last record low ice extent was recorded on September 19, 2007. In mid-September the melting season in the Arctic usually ends followed by an increase again during the northern winter.

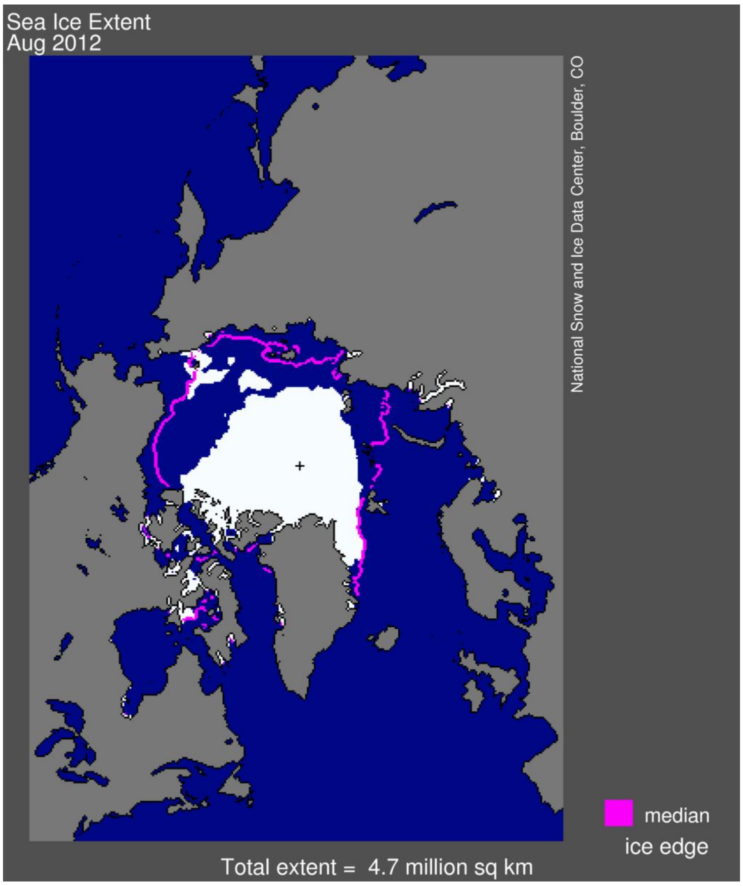

Figure 26:
Arctic Sea Ice extent in August 2012 in comparison to median ice edge
Image Credit: NSIDC

5 Hurricane “Isaac”

5.1 Summary

Hurricane "Isaac" didn't cause an overall end of heat and drought for most of the affected areas. But hurricane “Isaac”, which made landfall by Wednesday morning (August 29, 2012) near the mouth of the Mississippi river, brought much rain not only to New Orleans. During the following days “Isaac” caused heavy precipitation and even flooding all along its path towards the Great Lakes area. At least for some areas in parts of the Mid West the drought came to an end.

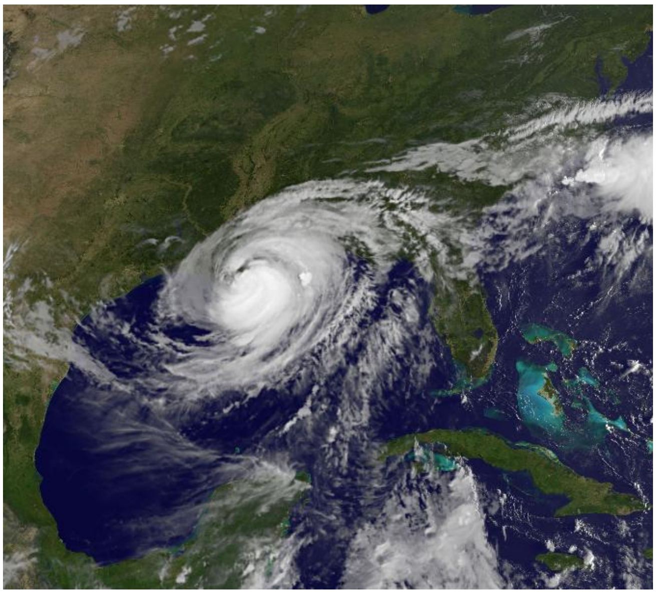

Figure 27:
Satellite image, GOES13, August 29, 2012, 11:31 UTC
Image Credit: NASA GSFC GOES Project

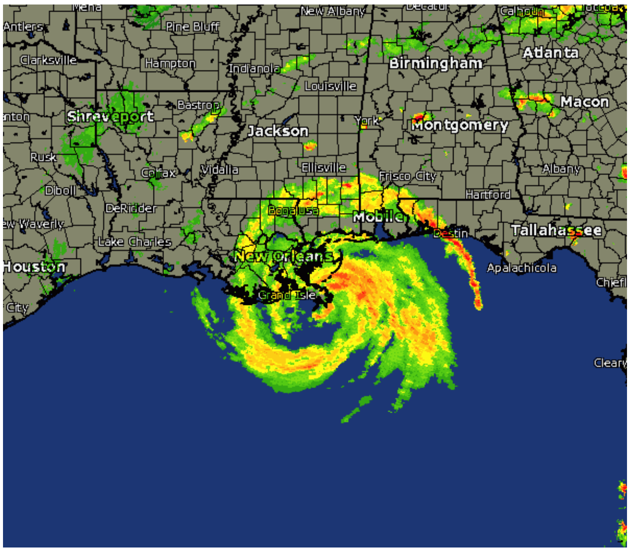

Figure 28:
Radar image (New Orleans) with “Isaac” making landfall, August 28, 2012, 11 UTC
Image Credit: wunderground.com

5.2 Evolution of hurricane "Isaac"

By mid-August, "Isaac" developed from a tropical wave that started near the West African coast moving westwards. On August 21 the system was upgraded to a tropical depression, after convection intensified and showed an organized structure as well as a strong near-surface circulation roughly 1000 kilometers east of the Lesser Antilles. This ninth tropical depression of the 2012 North Atlantic hurricane season was a so called "Cape Verde system". These systems form from a tropical wave off the west coast of Africa, mainly in the area of the Cape Verde Islands; hurricanes evolving from these systems are often among the strongest storms of the season.

On August 28, the central pressure of the tropical system dropped below 970 hPa and the sustained winds exceeded 70 kt (130 kph) - "Isaac" was classified into a hurricane of the first category.

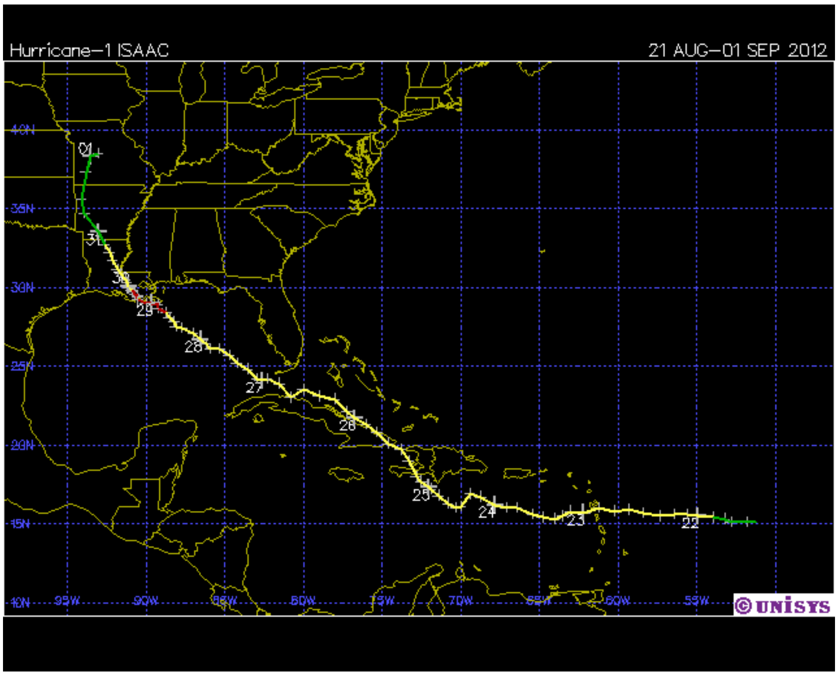

Figure 29:
Track of Hurricane "Isaac", 21 August - 1 September 2012
Image Credit: weather.unisys.com

On the morning of August 29, the hurricane arrived at the Mississippi Delta, about 100 kilometers south of New Orleans. Immediately before landfall "Isaac" reached its maximum intensity; the minimum central pressure was 968 hPa, the maximum sustained winds were at 80 kt (148 kph). Due to its pretty slow movement of only 13 kph "Isaac" was responsible for considerable rain amounts along Gulf coast areas. With further rapid weakening "Isaac" moved across Louisiana and into Arkansas, eventually dissolving over Missouri on September 1, 2012.

5.3 Precipitation amounts

On August 29, "Isaac" approached the U.S. Gulf Coast and entered southeastern Louisiana and southern Mississippi being associated with heavy precipitation and gale force winds. The slow movement of "Isaac" favored the unloading of huge amounts of rain and a storm surge at the eastern edge of the hurricane. The area between the Mississippi Delta, Mobile and Montgomery (AL) received over 200 mm of rain. In New Orleans, 261.1 mm fell between August 29 and 31, Mobile (AL) got 249 mm. On its way north, "Isaac" was responsible for rain amounts exceeding 100 mm in the states of Arkansas, Missouri and Illinois.

Please note: 1 inch is equal to 25.4 mm.

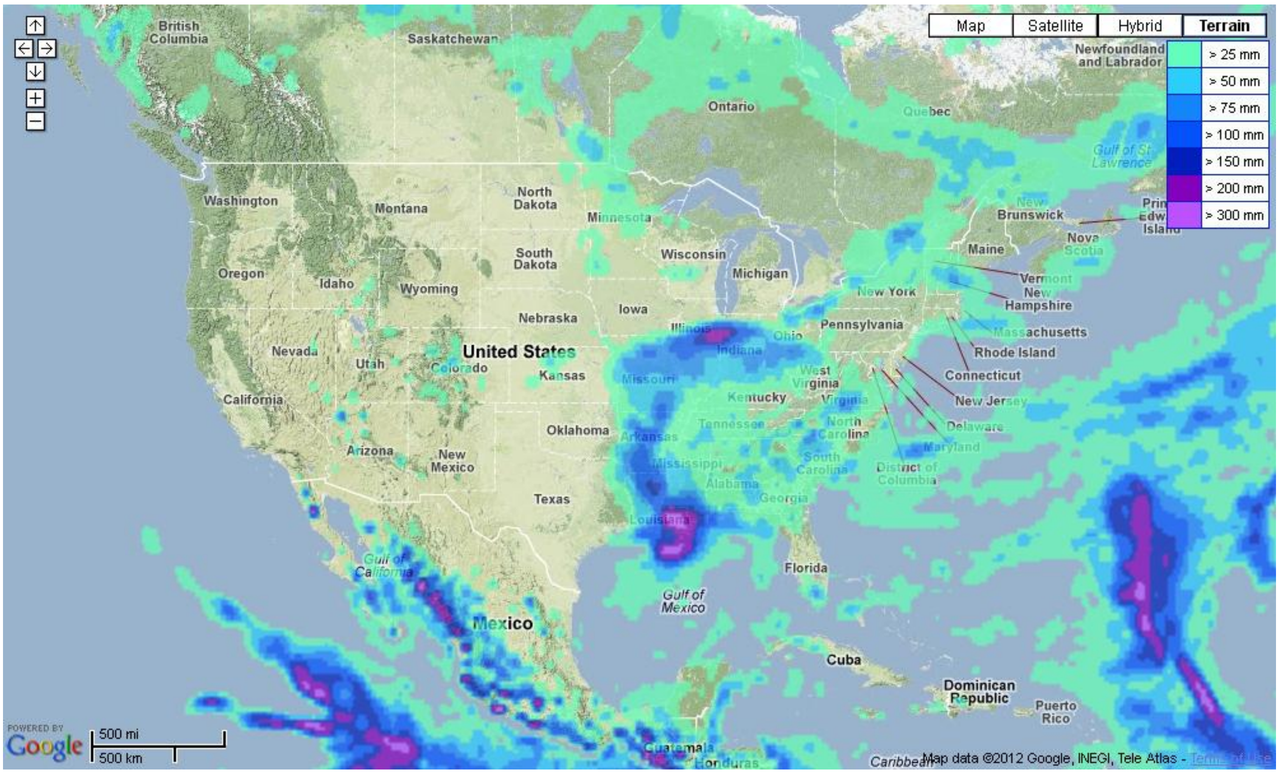

Figure 30:
Precipitation forecast (mm), 29 August - 6 September, 2012 – issued August 29, 2012
Image Credit: Wettergefahren-Frühwarnung

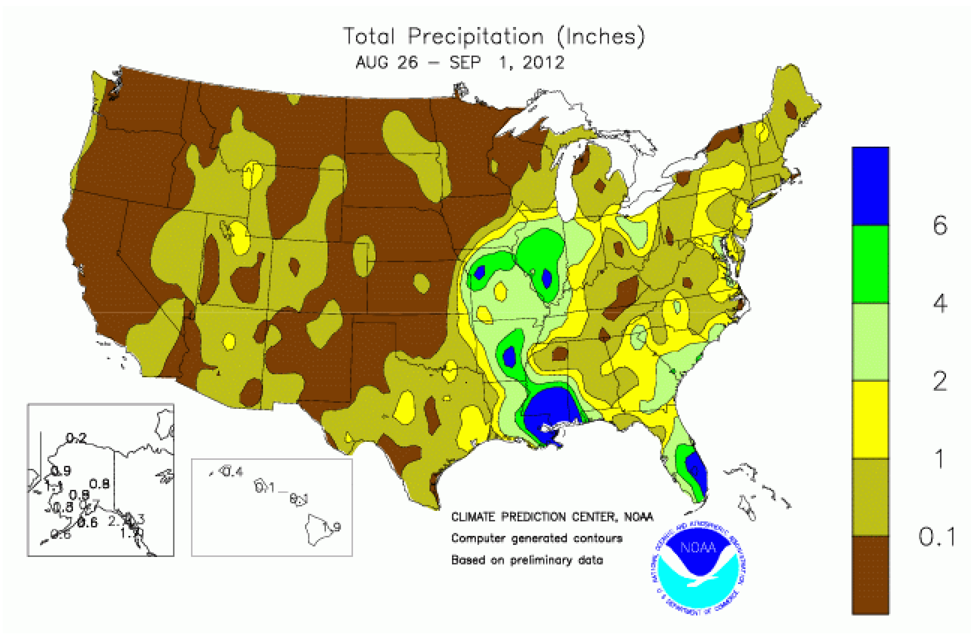

Figure 31:
Total precipitation (inches), August 26 - 1 September 2012
Image Credit: NOAA / CPC

6 The current impact of the drought in the U.S. on crops and livestock

According to the U.S. Department of Agriculture, the 2012 drought is the “most severe and extensive drought in at least 25 years” and “is seriously affecting U.S. agriculture, with impacts on the crop and livestock sectors and with the potential to affect food prices at the retail level” (USDA 2012). Media reported that as of August 17, “1,692 counties across 36 states in the U.S. have been legally declared primary natural disaster areas as the drought continues to cover 62% of the contiguous U.S. (cbs news).

6.1 The economic impact of the drought on the U.S.

To gauge the economic impact the drought in the U.S. could have, first a drought score was calculated using the data of the U.S. Drought Monitor and assigning a value in percentage per county. In the Drought Monitor, each county is given a combination classification of None, Level 0 (Abnormally dry), Level 1 (Drought – Moderate), Level 2 (Drought – Severe), Level 3 (Drought – Extreme) or Level 4 (Drought – Exceptional)”. The drought score first gives a value of 0 for nothing, Level 0 = 1, Level 1=2, Level 2 = 3, Level 3 = 4, Level 4 = 5, then an average value is given based on the percentage of drought-affected area per level per county. Figure 32 shows the obtained drought score in the U.S. past Hurricane Isaac.

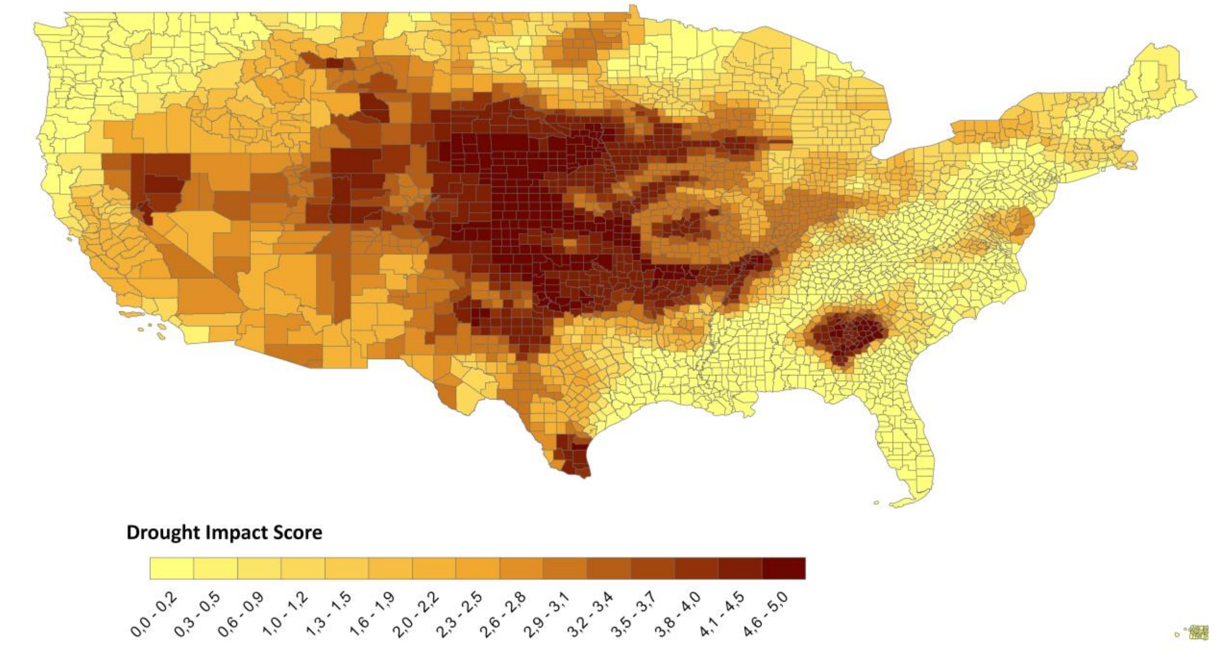

Figure 32: Drought Impact Score, post Hurricane Isaac (data as of 4 Sep 2012, reasonably unchanged as of 11 Sep 2012.)

The drought score can then be used to estimate the possible impact of the drought. Essentially to then determine the damage potential by the drought impact score, the exposed assets such as crops and livestock must be looked at, as well as a factor to look at the potential damage ratio.In essence, the relationship seems to be logarithmic with a value of the following giving a good mean damage ratio.

$$MeanDamage = 0.33 * \frac{(15^{(DroughtScore)})}{15^5} * CropValue$$

6.2 State impacts of crop value

The following diagram shows the percentage of total crop value affected in each state by drought from U.S. statistics (red= most severe, level 4; orange= less severe, level 3).

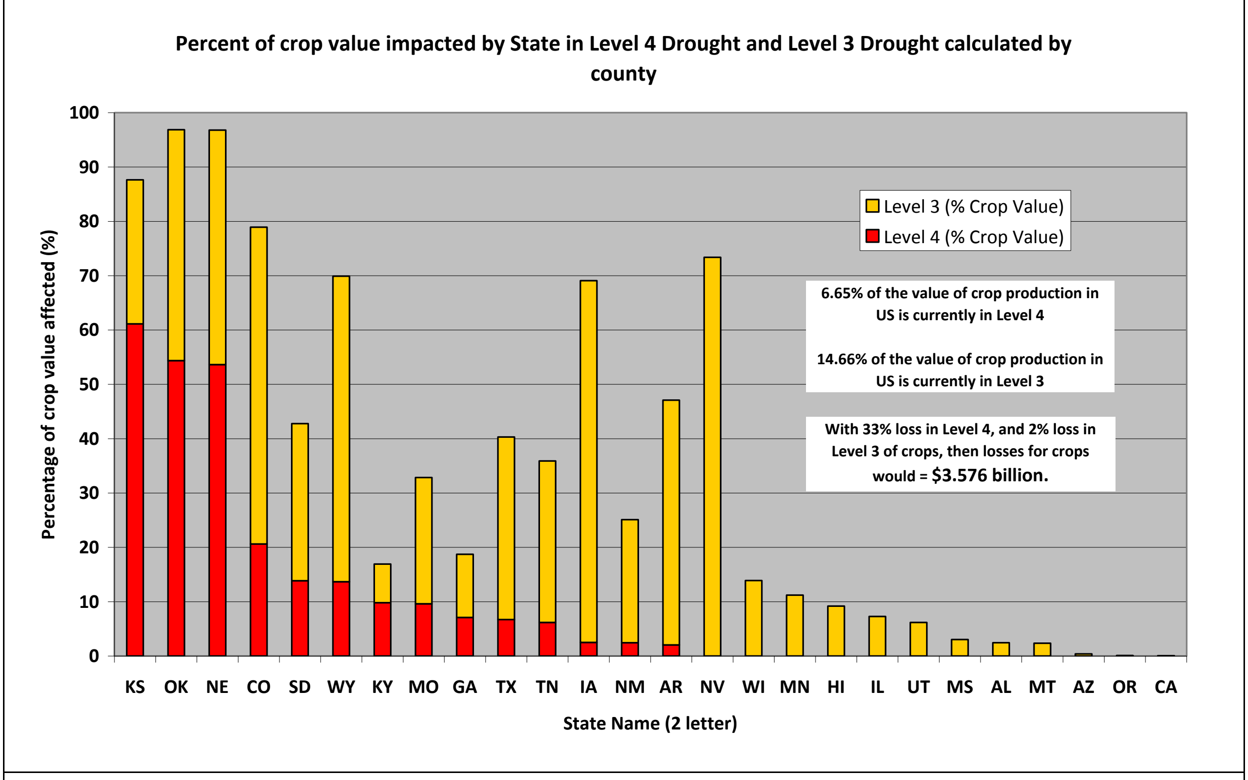

Figure 33: Percentage of crop value affected by State calculated by county.

6.3 The calculation of possible loss in the livestock and crop sectors of the U.S.

In the following diagram (Figure 34), the combined livestock and crop value of production per year in 2010 is shown in million U.S. dollars per county. It can be seen that there are high exposures through the central U.S. which, once affected, can lead to major losses. The total exposure is $296 billion per year.

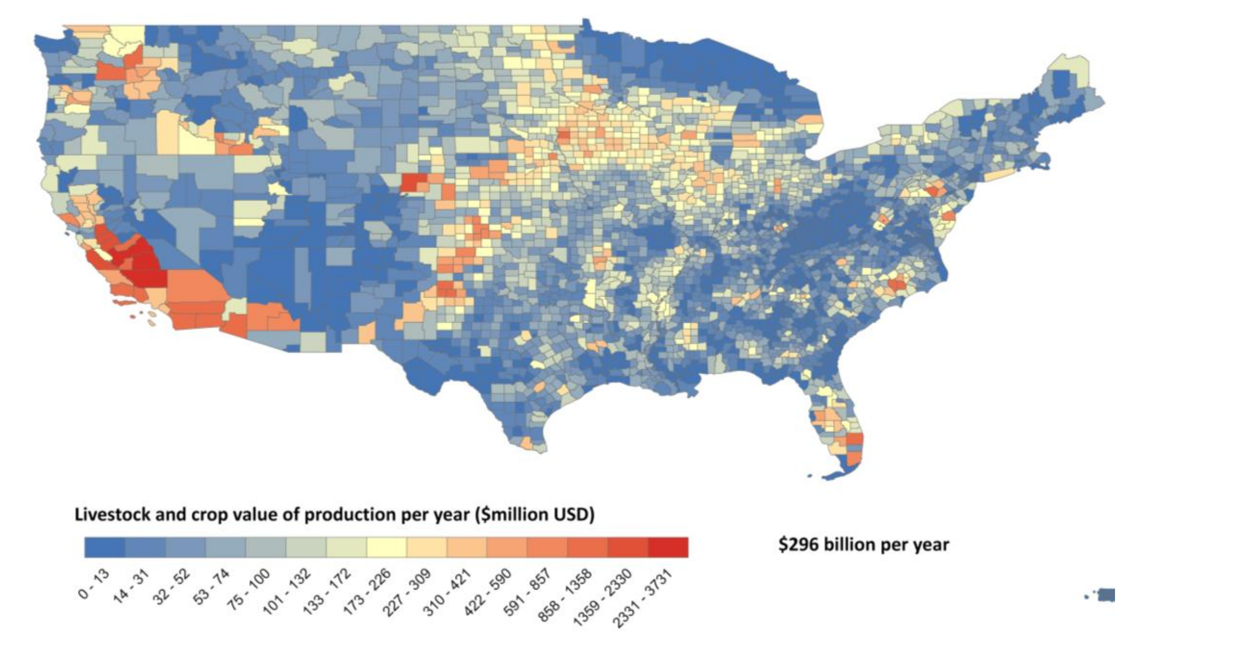

Figure 34: Livestock and crop value of production per year.

Livestock: Using a mean loss ratio of 15% of the total value of the 2012 livestock for Level 4 drought affected counties (in terms of percentage of a county) and a value of 1% for Level 3, there is a potential $3.27 billion loss in the livestock section. It can be seen that most losses in livestock would occur in the central United States.

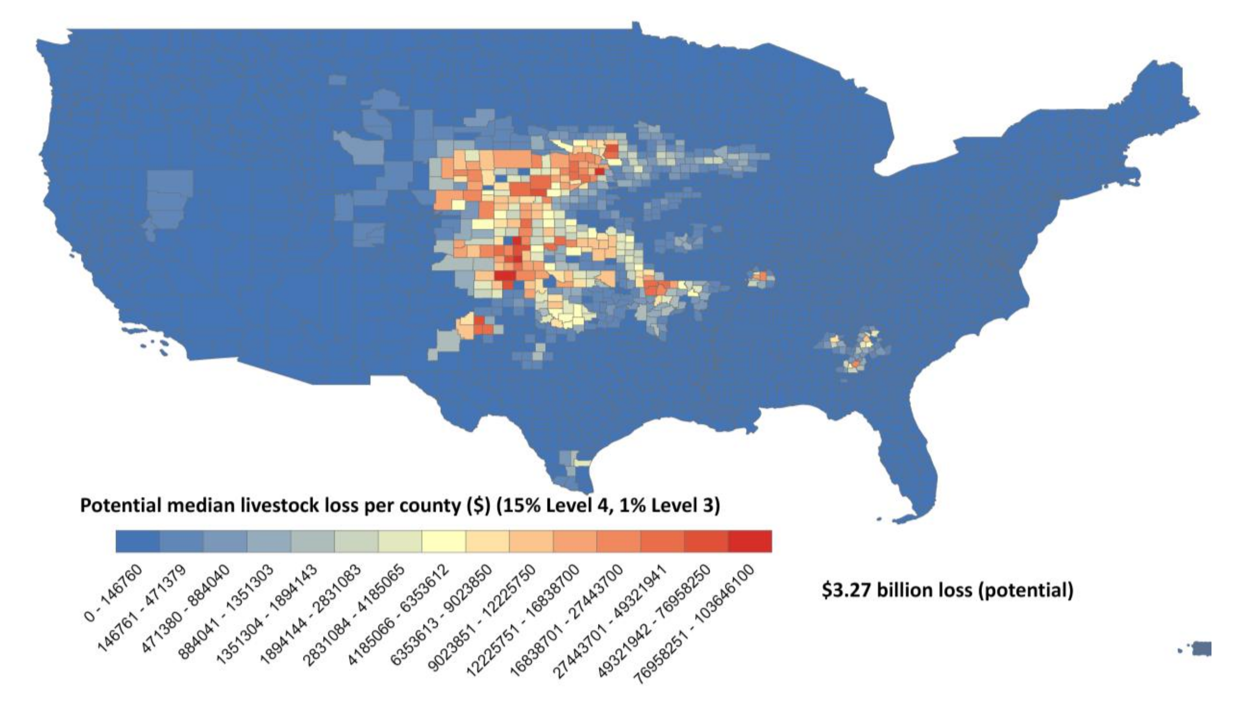

Figure 35: Livestock potential losses of production per county

Crops: Using a mean loss ratio of 33% of the total value of the 2012 crop for Level 4 drought affected counties (in terms of percentage of a county) and a value of 2% for Level 3, there is a potential $3.6 billion loss in the crop section. It can be seen that most losses would also occur in the central United States but in slightly different counties compared to those of the high intensities of livestock production.

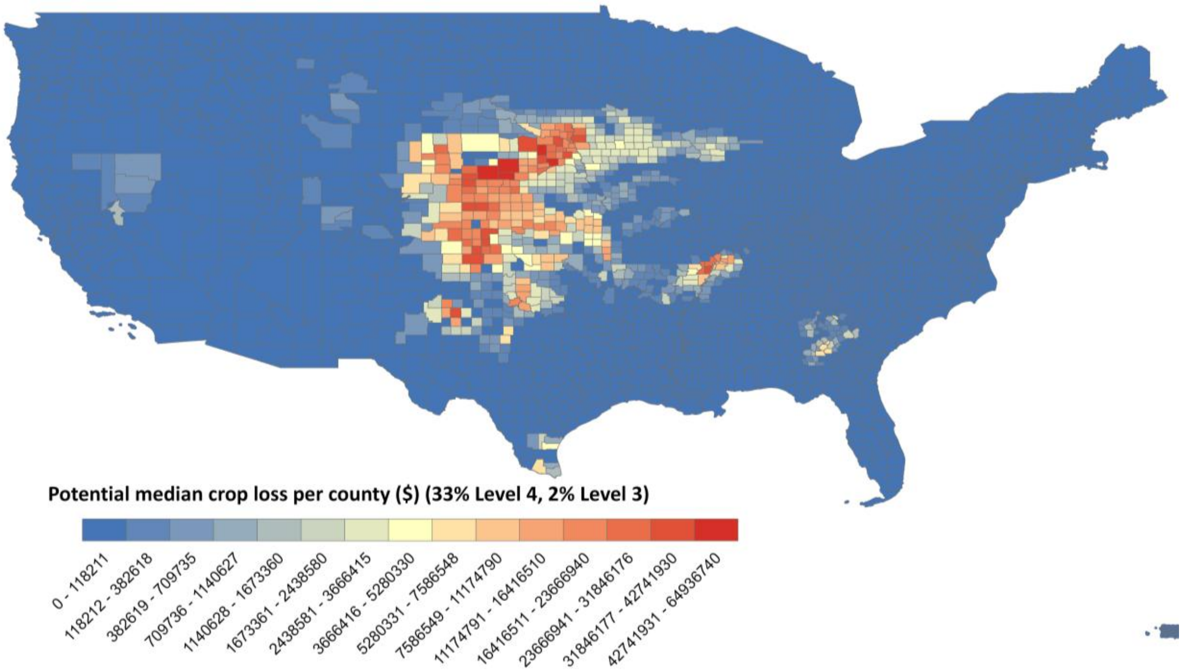

Figure 36: Crop potential losses of production per county

Using these rough percentages, **crop and livestock loss could be equal to around $7 billion** out of a total of $296 billion, thus about 2-3% of the total productive sector.

However, since in the U.S., 7% of the total production is currently under Level 4 drought and 15% is under Level 3, working out different levels of loss can give very different values, especially if the drought affects more than a year and also affects yearling production and/or crop production in the future. Different scenarios can be played out i.e. such that if all Level 4 is lost then this would total around $21 billion in losses for the U.S., and also cause many flow-on effects in terms of lost farms, houses and livelihoods.

6.4 Comparison with recent droughts in the U.S.

How is the 2012 drought likely to impact the U.S. compared to prior droughts? Back in 2005, Wilhite and Buchanan-Smith wrote that in the U.S., droughts "have produced far-reaching impacts on many economic sectors while also resulting in serious social hardships, especially in the agricultural community, and significant environmental consequences. Impact estimates for the last 2002 drought exceeded $20 billion, although there has not been a systematic assessment conducted at the national level" (Wilhite and Buchanan-Smith 2005). As a number of 1995, the average annual loss from drought in the U.S. has been estimated at $6-8 billion (FEMA, 1995 according to U.S. Drought Portal).

Table 3: Droughts in the U.S. 1980-2012 – National Climatic Data Center, estimated damage in U.S. $ billions where yearly loss exceeds $1bn:

Year	Description	Losses event year	Adj. 2012 CPI*
2011	Southern Plains/Southwest Drought & Heat Wave - Texas, Oklahoma, New Mexico, Arizona, southern Kansas, and western Louisiana	12	**12.2**
2009	Southwest/Great Plains Drought - 2009: Drought conditions occurred during much of the year across parts of the Southwest, Great Plains, and southern Texas causing agricultural losses in numerous states (TX, OK, KS, CA, NM, AZ). The largest agriculture losses occurred in TX and CA.	5	**5.4**
2008	Widespread Drought - 2008: Severe drought and heat caused agricultural losses in areas of the south and west. Record low lake levels also occurred in areas of the southeast. States of CA, TX, NC, SC, GA, and TN.	2	**2.1**
2007	Plains/Eastern Drought - Summer/Fall 2007: Severe drought with periods of extreme heat over most of the southeast and portions of the Great Plains, Ohio Valley, and Great Lakes area, resulting in major reductions in crop yields, along with very low stream-flows and lake levels. Includes states of ND, SD, NE, KS, OK, TX, MN, WI, IA, MO, AR, LA, MS, AL, GA, NC, SC, FL, TN, VA, WV, KY, IN, IL, OH, MI, PA, NY.	5	**5.6**
2006	Widespread Drought - Spring-Summer 2006: Rather severe drought affected crops especially during the spring-summer, centered over the Great Plains region with other areas affected across portions of the south and far west -- including states of ND, SD, NE, KS, OK, TX, MN, IA, MO, AR, LA, MS, AL, GA, FL, MT, WY, CO, NM, CA.	6	**6.8**
2005	Midwest Drought - Spring, Summer 2005: Rather severe localized drought causes significant crop losses (especially for corn and soybeans) in the states of AR, IL, IN, MO, OH, and WI.	1	**1.2**
2002	Widespread Drought - September 2002: Moderate to extreme drought over large portions of 30 states, including the western states, the Great Plains, and much of the eastern U.S.	10	**12.8**
2000	Drought/Heat Wave - Spring-Summer 2000: Severe drought and persistent heat over south-central and southeastern states causing significant losses to agriculture and related industries;	4	**5.3**
1999	Drought/Heat Wave - Summer 1999: Very dry summer and high temperatures, mainly in eastern U.S., with extensive agricultural losses.	1	**1.4**
1998	Southern Drought/Heat Wave - Summer 1998: Severe drought and heat wave from Texas/Oklahoma eastward to the Carolinas;	7.5	**10.6**
1996	Southern Plains Drought - Fall 1995-Summer 1996: Severe drought in agricultural regions of southern plains—TX and OK most severely affected;	5	**7.3**
1993	Southeast Drought/Heat Wave - Summer 1993: Southeast Drought and heat wave across Southeastern U.S.	1	**1.6**
1989	Northern Plains Drought - August 1989: Severe summer drought over much of the northern plains with significant losses to agriculture;	1	**1.9**
1988	Drought/Heat Wave - Summer 1988: 1988 drought in central and eastern U.S. with very severe losses to agriculture and related industries;	40	**77.6**
1986	Southeast Drought Heat Wave - Summer 1986: Severe summer drought in parts of the southeastern U.S. with severe losses to agriculture;	1.3	**2.7**
1980	Drought/Heat Wave - June-September 1980: Central and eastern U.S. drought/heat wave caused damage to agriculture and related industries.	20	**55.6**

* losses in event year adjusted to Consumer Price Index (CPI) 2012.

Comparing the impact of the current drought with recent droughts, however, is complex: for the 2012 drought, there are so far only estimations as the harvest is still ongoing. For the droughts in the U.S. in the last decade, loss estimations for the same events show huge spreads which makes a comparison difficult: for example the 2002 drought was mentioned above with an impact of U.S. $20 billion (Wilhite and Buchanan-Smith 2005) with NCDC & CATDAT preferring a value around $10 billion and EM-DAT giving $3.3 billion. The possible causes for these huge differences (definition of drought, classification of damages as drought-related, consideration of direct and indirect losses, insured losses, aggregation methods, etc.) will not be discussed here.

For the 2012 drought, several loss figures by insurers and re-insurers were reported in the economics media in mid-August. For the U.S. National Crops Insurance, it was "becoming apparent that the amount of crop insurance losses from this drought could eclipse the $11 billion total crop insured loss of 2011", and it was expected that "there will be as much as $20 billion of insured crop losses this year" (Artemis, 12-08-2012). This would concur with much higher loss ratios in the level 4 and level 3 affected regions.

In the quarterly financial statements of August 7th, Munich Re anticipated a net burden of approximately 160 million euros ($200 million) [before tax] from losses under crop failure covers, as a consequence of the persistent drought in large agricultural areas in the U.S. (Munich Re 2012, cnbc). Given these loss expectations by August, it was concluded in the economics media that the drought "is fast becoming the largest single weather related insurance loss of the year in the U.S." (Artemis, 12-08-2012).

Compared to these numbers, our estimations of damage in agricultural industry of U.S. $7 billion may appear to be average in terms of an AAL (Annual Average Loss) sense in the last 31 years ($6.9 billion U.S. [2012 adjusted from NCDC data]), however in terms of years this would be the 7th highest loss since 1980 (after years 1980, 1988, 1996, 1998, 2002, 2011).

As mentioned in the beginning of the section, we used a simple method to estimate the loss, and therefore a number of effects are not considered that have an influence on the total economic impact of the 2012 drought including comparison of different crop types in terms of losses. Some additional effects may include:

- impacts of high corn prices that reduces livestock production compared to the years before
- global financial crisis and housing crisis in the U.S. already has the economy on a knife-edge
- impacts of low water levels in parts of the Mississippi affecting trade and commerce
- possible decrease of wealth of farm equipment as it may be expected that some farmers are forced to sell
- long-term effects on next year's production.

7 Social vulnerability to drought

7.1 A Social Vulnerability Index (SoVI) for drought

Given the same level of drought exposure in two different counties of the U.S., the impact of the drought will not be the same in these counties, but commensurate with the social capacity to anticipate, cope with and respond to the drought in each county. We adopted the basic principles of the generic SoVI of Cutter et al. (2003) and built and modified index for social vulnerability to drought. The SoVI is a relative index to compare the social vulnerability to environmental hazards in different counties and states of the U.S. It should be noted that the SoVI was not developed for evaluating social vulnerability to drought, but developed as a generic index to represent how the social structure including social inequality in different counties – represented by several socio-demographic and socio-economic indicators of the U.S. Census – could lead to an aggravating effect of environmental hazards. We modified the indicator structure to represent both social and economic characteristics that represent social inequality and different capacities to cope with drought and both indicators that represent the agricultural activity in the counties as an element of people’s livelihood which is affected by drought. Therefore we replaced some of the original SoVI indicators that relate to the economic and occupational structure (occupation in service industries, employed in transportation, communication, and public utilities) by indicators representing the agricultural production and employment in agriculture. The following five indicators were selected to come up with the composition of a modified *Social Vulnerability Index for Drought (SoVD)*:

1. **Median Age** (original SoVI dominant indicator for the dimension “age”) whereby we assume that a higher median age increases vulnerability to drought.
2. **Per Capita Income** (original SoVI dominant indicator for the dimension “personal wealth”) whereby we assume that a lower per capita income increases vulnerability.
3. **Race and Ethnicity** (original SoVI comprises four dimensions for race and ethnicity): we used a composed indicator of the ratio of Hispanic, African American, Asian, and Native American population in each state for our modified social vulnerability index to drought, whereby a higher ratio of Hispanic, African American, Asian, and Native American population increases vulnerability to drought.
4. **Agricultural Production:** developed as the product of farmland area and the value of farm products sold - including both crops and livestock and poultry.
5. **Agricultural Employment**, developed as the percentage of population employed in farming and the farm earnings in each state:

   The higher the agricultural production and the agricultural employment of one state in comparison with other states, the more important is the agricultural sector for the state and for people’s livelihood in this state and therefore the more vulnerable is the state to drought.

The five indicators were populated with data available from the U.S. 2010 Census. The weight given to each indicator will determine the final relative value rankings in the index. Thus, two scenarios were developed; all indicators are valued equally under *Scenario 1*, and in *Scenario 2* the demographic indicators (median age, per capita income, and race and ethnicity) are given 50% of the weight, while the agricultural productivity and employment component are given the other 50% of the weight (Figure 6).

Social vulnerability index for drought SoVD

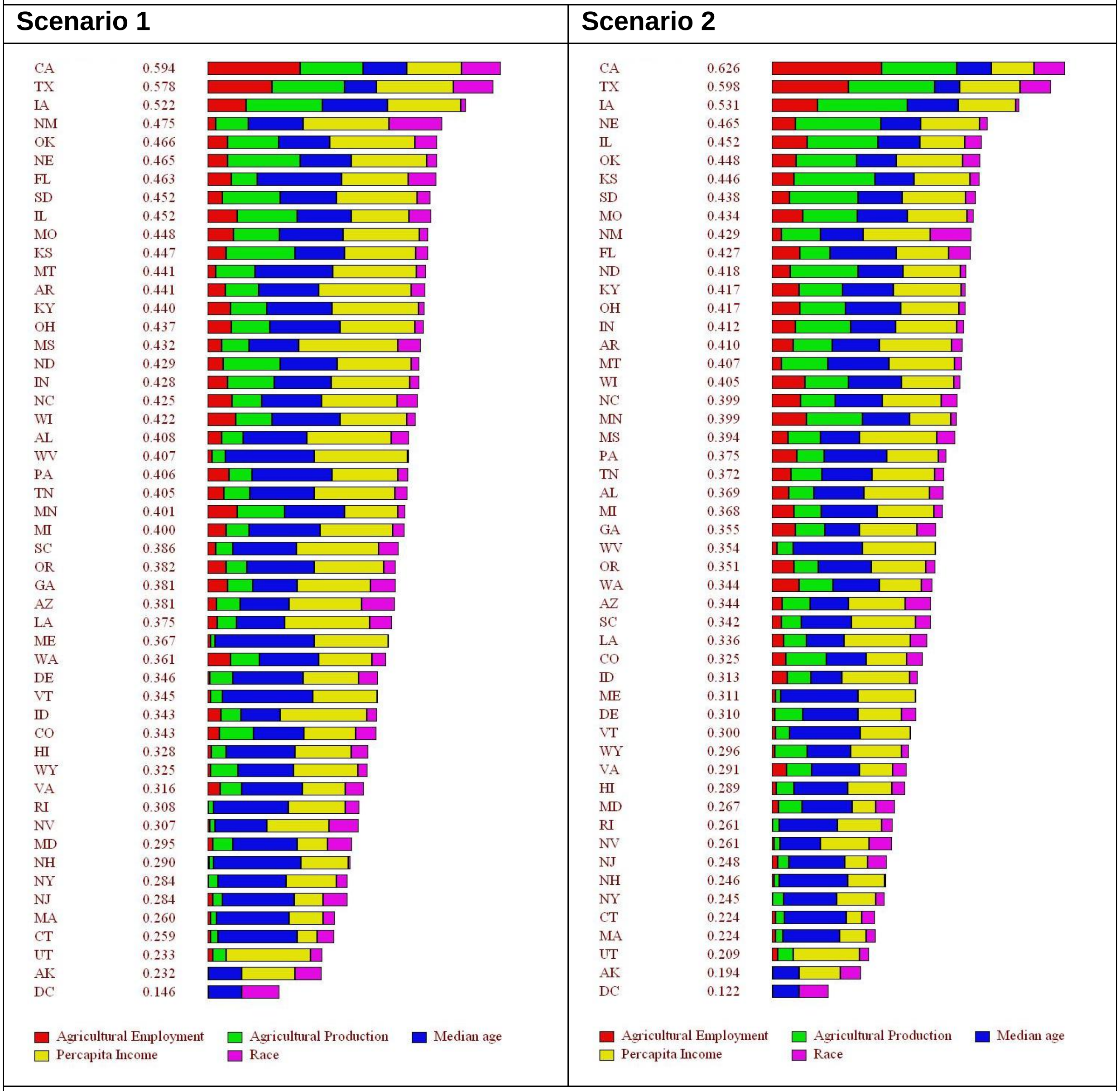

Figure 37: Social Vulnerability Index for Drought SoVD in U.S. (state-level) based on two scenarios for the weighting of indicators. Red: agricultural employment, green: agricultural production, yellow: per capita income, blue: median age, pink: race and ethnicity, Data: U.S. Census 2010.

It can be seen that the top three states regarding social vulnerability to drought – California, Texas and Iowa – are robust to the change in weights of the indicators, however, some states such as New Mexico are much more sensitive to changes in weight; ranking very high in social vulnerability to drought under the equal weight scenario 1 (4th position) and moving downwards in ranking (19th) position under scenario 2 indicating that agriculture is a less important dimension for social vulnerability in this State. It is interesting to note that the States with the top rankings under both scenarios are also the predominant States affected by historic droughts in the U.S. with the highest losses, shown in Table 3.

7.2 Aggravated drought impact

The potential aggravated impact of the 2012 droughts in the U.S. can be estimated by considering how the overall impact to areas experiencing extreme (level 3) and exceptional (level 4) droughts are amplified by the aggravating factors of the social vulnerability index to droughts previously explained. Thus, first a drought intensity score is obtained as the weighted sum of two indicators for each state: percentage of area affected by level 4 drought (weight of 0.75) and percentage of area affected by level 3 drought (weight of 0.25). Then, the aggravated drought impact (ADI) can be obtained by multiplying the drought intensity score by an indirect impact factor, based on the indicators representing the social vulnerability to droughts of each state (SoVD), according to the expression below:

$$\mathrm{ADI} = \sum_{i=1}^{n} \mathrm{DIS} \times (1 + \mathrm{SoVD})$$

The results are shown in Figure 38 as relative ranking. Another way to represent the data is through a scatterplot shown in Figure 39, where the impact factor or social vulnerability index for drought (SoVD) for scenario 1 of equal weights is shown on the Y-axis and the areas affected by level 3 and 4 droughts are shown on the X-axis.

Aggravated drought impact

Scenario 1

Scenario 2

Figure 38: Results for aggravated drought impact using two scenarios for the impact factor social vulnerability SoVD. Red: drought level (drought intensity) and green: impact factor as given by social vulnerability index.

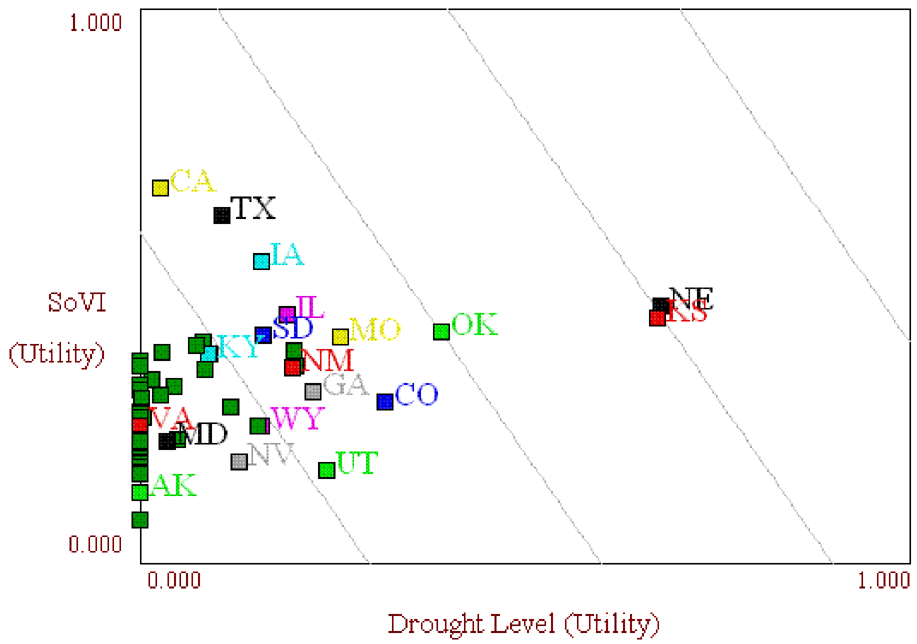

Figure 39: Scatterplot of aggravated drought impact with social vulnerability index for drought (SoVD) for scenario 1 of equal weights is shown on the y-axis and drought intensity on the x-axis.

In the resulting ranking of the states on the Drought Risk Index (Figure 38 and 39), it can be seen that for states such as Kansas and Nebraska both the social vulnerability against drought as well as the drought levels, i.e. the actual areas affected by droughts are high, giving these states their high rankings in the aggravated drought impact score. On the other hand, states such as California, Texas and Iowa have very high levels of social vulnerability to droughts, but were / are not impacted as high as some other states in the 2012 drought as their drought level is much lower.

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9 Contact

KIT Public Relations
Monika Landgraf
E-mail: monika.landgraf@kit.edu
Tel: +49-72160848126

GFZ Public Relations
Franz Ossing
E-mail: ossing@gfz-potsdam.de
Tel: +49-3312881040