Hydroclimate variability and change: A tale of three current droughts

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Papers, highlights, etc. at http://www.ldeo.columbia.edu/res/div/oce/glodech/
Greenhouse warming will amplify and alter the pattern of precipitation less evaporation, P-E

20th Century P-E (colors) 925 mb Wind (vectors)

P-E (2021-2040) - (1951-2000)

P-E as it is now
- dry gets drier
- wet gets wetter
- subtropical dry zones expand

the coming change

Is this happening? How important re natural decadal variability?
Climate model projections for 2080-99 of two common drought indices: Palmer Drought Severity Index and Standardized Precipitation-Evaporation Index due to changes in precipitation, temperature, humidity, surface radiation.

- Due to changes in precipitation, temperature, humidity, surface radiation
- Due to changes in precipitation only
- Due to changes in temperature, humidity and surface radiation only

Increasing drought risk widespread - due to both T and P changes

Cook et al. (2014)
Causes of the 2011-14 California Drought: An unfortunate series of weather, ocean-forced variability and/or climate change?

Seager et al., NOAA Drought Task Force Report, December 2014

ASSESSMENT REPORT
Causes and Predictability of the 2011-14 California Drought
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% of normal precipitation
October 2012 to April 2013

October 2013 to April 2014

Seager et al., NOAA Drought Task Force Report, December 2014
California has a rich history of droughts. Current drought appears as one of many such events both in terms of amplitude and duration, but, because of steady warming, it is the worst, or close to.
sea surface temperature, 200mb height and precipitation anomalies averaged over Nov-Apr of 2011-14

models reproduce northeast Pacific ridge and dry west coast as a response to SST anomalies alone and of likely natural origin
In addition, the 1997/98 decadal precipitation shift observed GPCP

The 97/98 shift to more La Nina-like tropical Pacific state has favored drying across southwest North America.


GEOS-5 model

NCEP CFSv2 model

Convective precipitation rate [M/S]
Models project California wetter winters/drier springs due to rising greenhouse gases. Current drought mostly natural but shorter wet season, warming, less snow will seriously stress CA water resources.

CMIP5, (2021-2040) - (1979-2005)

$\Delta \overline{P}$ DJF

$\Delta (\overline{P} - \overline{E})$ DJF

$\Delta \overline{P}$ MAM

$\Delta (\overline{P} - \overline{E})$ MAM
Eastern Mediterranean
Significant wintertime drying occurred in most of the land regions surrounding the Mediterranean Sea from the 1960s to the 1990s. Some areas along the southern coast saw small increases in precipitation. Can this trend be attributed to anthropogenic forcing?
The trend pattern in the Mediterranean displays a similar (but not identical) pattern to the leading pattern of cold-season precipitation variability, which explains 25% of the variance.
According to various methods, rising GHGs should have led to a 10-15% reduction in annual average rainfall in the eastern Mediterranean and northwest Africa, increasing extreme drought risk.
Figure 1: Timeseries of six-month winter (November–April mean) for a) the Syria only area mean, using CRU3.1 gridded data at .5x.5 resolution, and b) and c) the Kamishli and Deir ez-Zor station records taken from the GHCN dataset. Red dots indicate years that were below the time mean based on the lengths of the respective records. For the Syria mean (a) the linear least squares fit is also shown, along with the time mean (dashed line).

Boxplots are of running five-year means with black asterisks representing the recent five-year drought (2004/05–08/09).

SYRIA IS ONE COUNTRY THAT HAS DRIED AND IT HAD A RECORD THREE YEAR DROUGHT IN 2006-8 FOLLOWED BY DRY YEARS IN 2009-11
Drought, crop failure and migration played a role in the events that led up to the beginning of the Syrian revolt in 2008.

Timeline of Events
Prior to the 2011 Uprising

1970s-1990s
Agricultural policies promote production of staple crops, leading to increase in number of groundwater wells and use of inefficient and outdated irrigation methods


12 March, 1971
Hafez al-Assad becomes president of Syria

Syria achieves self-sufficiency in wheat production

Drying of the Khabur River in NE Syria

Winter 2007-08
Driest in observed record

March 2011
Uprising in Syria

Syrian Urban Population Increase, 2003-2010

End 2002 urban population
8.9 million

By end 2010 pop. increase from natural birthrate (2.5% /yr)
1.5 million

Since 2005
Apartment prices in Damascus have more than doubled

Since 2007
Wheat, rice, and feed prices have doubled

2003-2010: Iraqi and Syrian Refugee Net Urban Influx (in Millions)

Syrian Refugees

Iraqi Refugees

Since the drought had a climate change component this might well be a case of human-induced climate change contributing to social conflict.
persistent drought since 1999, 2011 worst year

drought plus war

Ethiopia, Somalia, Djibouti, Kenya affected

First declaration of famine by UN in 30 years

tens of thousands dead, malnutrition affecting millions

East Africa drought and famine

Famine Early Warning System projection Jul-Sep 2011
Observed precipitation history over East Africa since 1900. Lots of decadal variability but recent drought appears unprecedented.

Relation of East Africa precipitation to ocean temperatures

Sea surface temperature composite for dry years

Drought driven by Pacific Ocean decadal variability (see also Lyon and DeWitt 2013)
But have no fear! Climate models project East Africa will get wetter!

But, model-projected precipitation change is nothing like ....

the actual recent trend. Mostly that's 'cos of natural decadal variability but ....
Atmosphere models forced by the ocean do OK but coupled atmosphere-ocean models do a lousy job simulating the East Africa seasonal cycle.

SST-forced atmosphere models

coupled atmosphere-ocean models

Rising temperatures, more variable precipitation implicated.

However the climate analysis in the 400+ page report is poor.
Conclusions

Do not assume that all current extreme climate events are caused by human-driven climate change. Sometimes there is a strong influence (Syria), sometimes not (California/western North America) and sometimes we don’t know (East Africa).

Future changes in drought and flood risk will depend on:
   (i) evolving natural variability,
   (ii) human-induced climate change,
   (iii) their interaction which can intensify both droughts and floods.

Human-induced climate change is steadily tipping odds to intensified aridity in southwest North America and the Mediterranean region.

The how, why and when of human-induced changes to drought and flood risk depends on much currently poorly understood atmosphere-ocean dynamics.