The 1930s Dust Bowl heat waves: Were they Atlantic forced, and did anthropogenic climate change play a role?

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Coincided with The Great Depression (~1929 – late 1930s);
  ➢ Wheat price dropped by two-thirds in 2 years (1929-1931) with oversupply.
  ➢ Drought/dust impacts: over 2 million residents displaced (20-30% migration),
    dust pneumonia, rioting, crime sprees, starvation, madness.

Devastating dust storms in 1933, 1934, 1935; 65% of Great Plains damaged by erosion in 1934 (Cook et al. 2014 GRL);
Breaking heat records during the Dust Bowl

- Hottest day/night for central US, southern Canada;
- Largest areal extent of hot days in the 1930s (45% of US; Abatzoglou & Barbero, 2014 GRL).

Cowan et al. 2017; J. Climate
Heat waves in the ‘30s

- What role did SST anomalies play?
- Was the summer circulation important?
- How sensitive are the heat waves to devegetation?
- Was there a greenhouse gas signal in the 1930s?

HadGEM3 atmosphere-only model (idealised, sensitivity runs)
weather@home2 simulations
Sea surface temperatures and heat wave activity

1930s

HadGEM3 experiments
Five most active heat wave summers in the 1930s

Average temperature of heat waves (HWM)
Hottest temperature of hottest event (HWA)

HadGEM3 AMIP-experiments

8-9°C bias
Summer circulation (analogue technique)

Observed (7 days)

Corresponding circulation

Best matching model circulations

Comparison

HadGEM3

N=20 best analogues of each day of observed heat wave week per experiment

Adapted from Jézéquel et al. 2017, Clim. Dynamics
Contribution of atmospheric circulation to daily \(T_{\text{max}}\) during the hottest summer heat waves in the 1930s

Each point is made up of 200+ analogue patterns


- 25 warmest SST springs (NE Pacific)
- 25 warmest SST springs (N Atlantic)
- N Atlantic + NE Pacific combined

Frequency of Jul-Aug hot days
Spring drought (pre-conditioning)

Alexander (2011),
Hirschi et al. 2011,
Nature Geoscience
Spring drought (pre-conditioning)

(MSLP & Moisture advection (May))

Z500 anomalies

Moisture advection
Land cover changes

1. Devatation of grass (%)
   - 30% soil
   - 50% soil
   - 80% soil

2. Evaporative fraction
   - 30%
   - 50%
   - 80%

3. Great Plains
   - Surface Temperature
     - Cook et al. 2013, *J. Climate*
Impact of greenhouse gases (using weather@home2 experiments)

Heat wave frequency

Comparison of heat wave frequency between observations (OBS) and simulations (WAH2_ALL) over the Eastern USA. The heat wave frequency is represented in days, with different colors indicating the number of days a heat wave persists. The maps show an increase in heat wave frequency and duration due to GHG-induced changes.
Conclusions

• **Atmosphere-only experiments:**
  - Atlantic SSTs produce hotter, more active Dust Bowl heat waves;
  - Summer differences between experiments arise from spring drying.

• **Devegetation leads to significantly hotter and longer heat waves:**
  - Most likely underestimated in CMIP5 experiments;
  - HadGEM3 highly sensitive to grass removal exceeding 20-30% over central US.

• **Anthropogenic climate change played a small but significant role:**
  - Caution using “absolute” metrics of heat waves (i.e., amplitudes) due to overly warm model biases.

Brönnimann (2015), Advances in Global Change Research
Thank-you
Defining heat waves

Simple percentile definition
- $T_{max} > 90\text{th percentile}$ 3 consecutive days
- $T_{min} > 90\text{th percentile}$ on 2nd and 3rd (consecutive) nights
- Use daily percentiles, using a 15-day sliding window
  (Perkins & Alexander 2013, *J. Climate*).
- Similar to Excess Heat Factor (combines heat excess + stress)

Stations

Berkeley Earth Surface Temp.

Number (HWN)
(events per season)

Frequency (HWF)
(total days per season)

Duration (HWD)
(longest event per season)

Amplitude (HWAA)
(Temp. anomaly of hottest day of hottest event)

Time series over the Great Plains (105-85W, 30-50N)

Cowan et al. 2017, *J. Climate*
Figure S1: The precipitation anomalies averaged over the core Dust Bowl region (36°N-39°N, 99.5°W-105°W, see boxes in Fig. 4) for the period 1932-1938. The first two points compare the observed and C20C results (the bar denotes the ensemble spread measured by +/- one standard deviation). Points to the right of the dashed vertical line show the results from the various idealized SST runs and a repeat of the C20C value. Here the bars denote the 90% confidence intervals. Units are mm/day.
Simulating the Dust Bowl heat waves

- Oxford have carried out weather@home simulations over 1931, 1934 and 1936, using an atmospheric model + a regional model over southern North America; each year has ~1500-1600 simulations.

- One simulation set are driven by observed SSTs with GHGs and aerosol composition set at 1930s levels (ALL30s), one without anthropogenic forcing (NAT30s), and one with observed SSTs with GHGs set at present day levels (PD30s).

- Cautious of warm bias in the model.
Spread in HadGEM3
HIST spread in MSLP and Z500

Simulation #1
Simulation #2
Simulation #3
Simulation #4
Simulation #5
Simulation #6
Simulation #7
Simulation #8
Simulation #9
Simulation #10
HIST ensemble mean
20CR

Contour from -3 to 3 by 3
Spring/summer conditions in HadGEM3 & 20CR
Spring/summer Differences btw ATL and PAC.
1934 crop changes

Gutmann et al. 2016, Social Science History

A. 1934

Crop failure (%)

- 0% – 20%
- 20% – 40%
- 40% – 60%
- >60%
CMIP5 historical

Bare soil runs
HadGEM3
Weather@home2 simulations