The influence of greenhouse gases on the 1930s Dust Bowl heatwaves across central United States

Tim Cowan[1,2,3], **Sabine Undorf**[3,4], Gabi Hegerl[3], Friederike Otto[5], Luke Harrington[5]

[1]University of Southern Queensland, Queensland, Australia

[2]Bureau of Meteorology, Melbourne, Victoria, Australia

[3]University of Edinburgh, Edinburgh, United Kingdom.

[4]Stockholm University, Stockholm, Sweden

[5]University of Oxford, Oxford, United Kingdom.

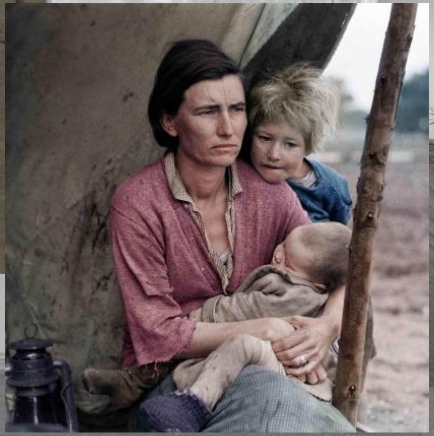
An abandoned farm in Coldwater District, north of Dalhart, Texas (June 1938).

Oklahoma, 1936

Taylor, Texas. April 1939

Sioux County, Nebraska, Spring 1936

The Dust Bowl was a period of devastating dust storms, mostly from 1933 through to 1935. Around 65% of Great Plains damaged by erosion in 1934 (Cook et al. 2014 *GRL*).



Oklahoma Panhandle, 1936

Williams County, Nth Dakota, 1937

Texas Panhandle, March 1936

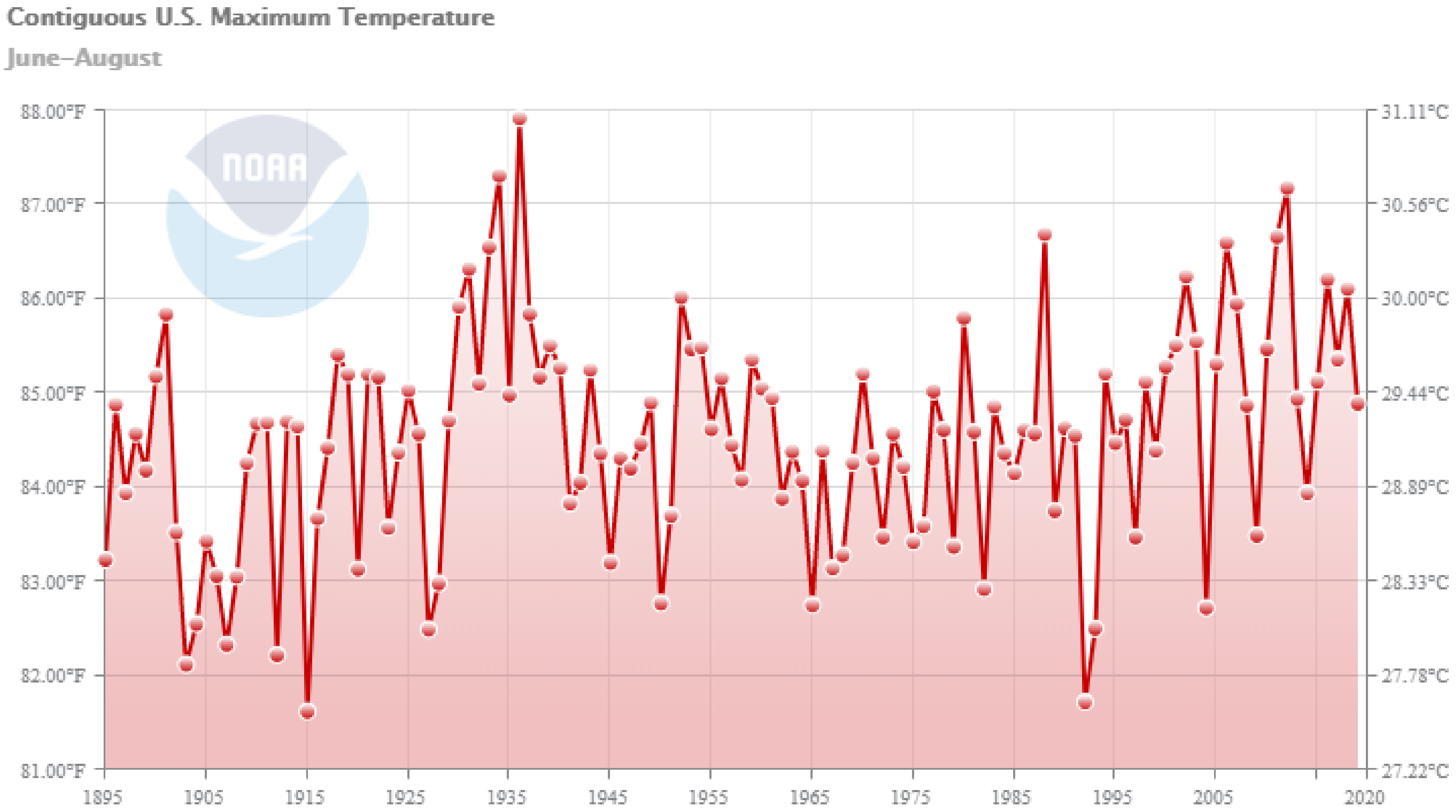
The Dust Bowl coincided with The Great Depression (~1929 – late 1930s);

- Wheat price dropped by two-thirds in 2 years (1929-1931) with huge oversupply (production up 300% in the 1920s).
- Drought Impacts: millions of residents displaced (~10% out-migration), dust pneumonia, crop failures, starvation, rioting.
- **Record-breaking heat!**

Photo credits: Russell Lee, Arthur Rothstein, Dorothea Lange (The Library of Congress, Prints & Photographs Division), Matt Loughre (The Sun UK)

Breaking heat records during the Dust Bowl

- 1936: the hottest US summer on record. Also hottest day/night for central US, southern Canada
- 1934: second hottest US summer. The 1930s were the hottest decade of summers on record.
- Heatwave durations exceeding 20 days, temperatures > 44°C (Cowan et al. 2020, Nat. Clim. Change).



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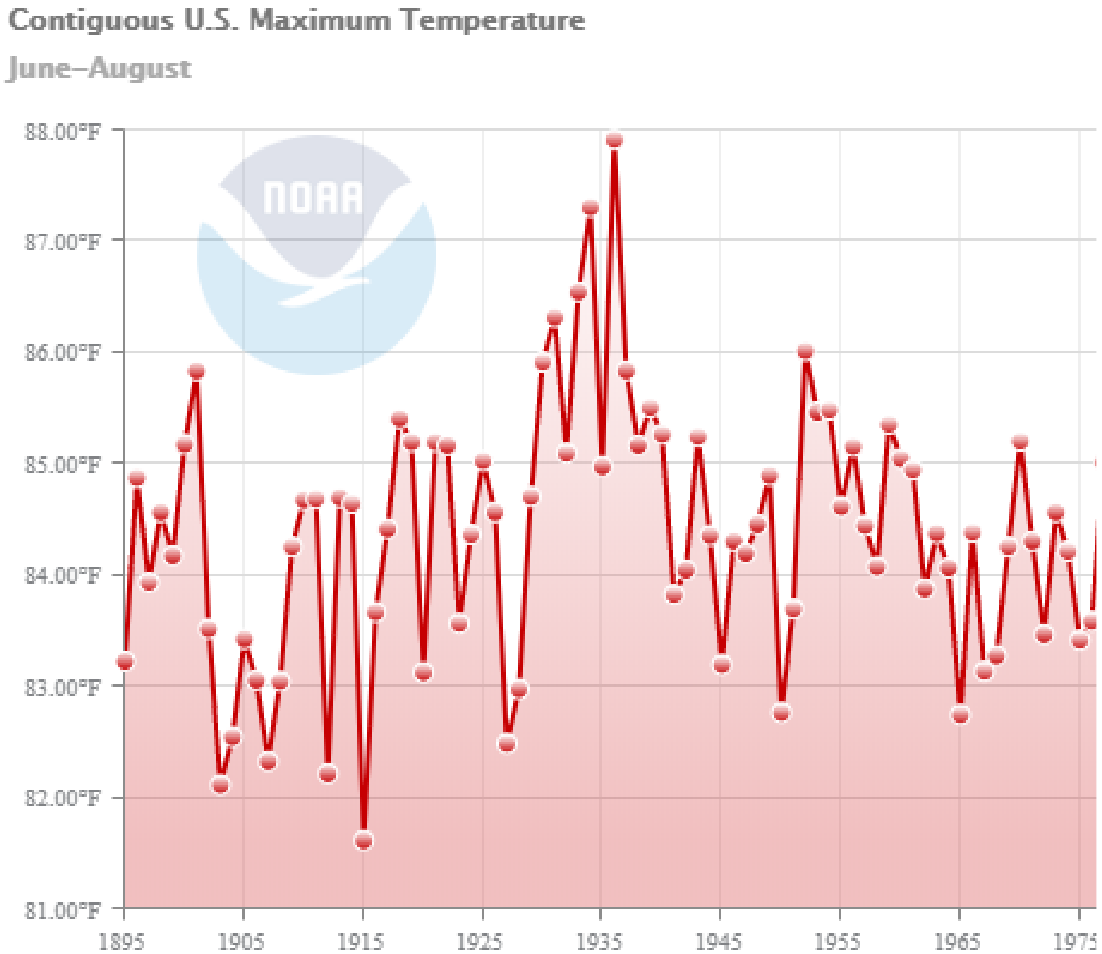
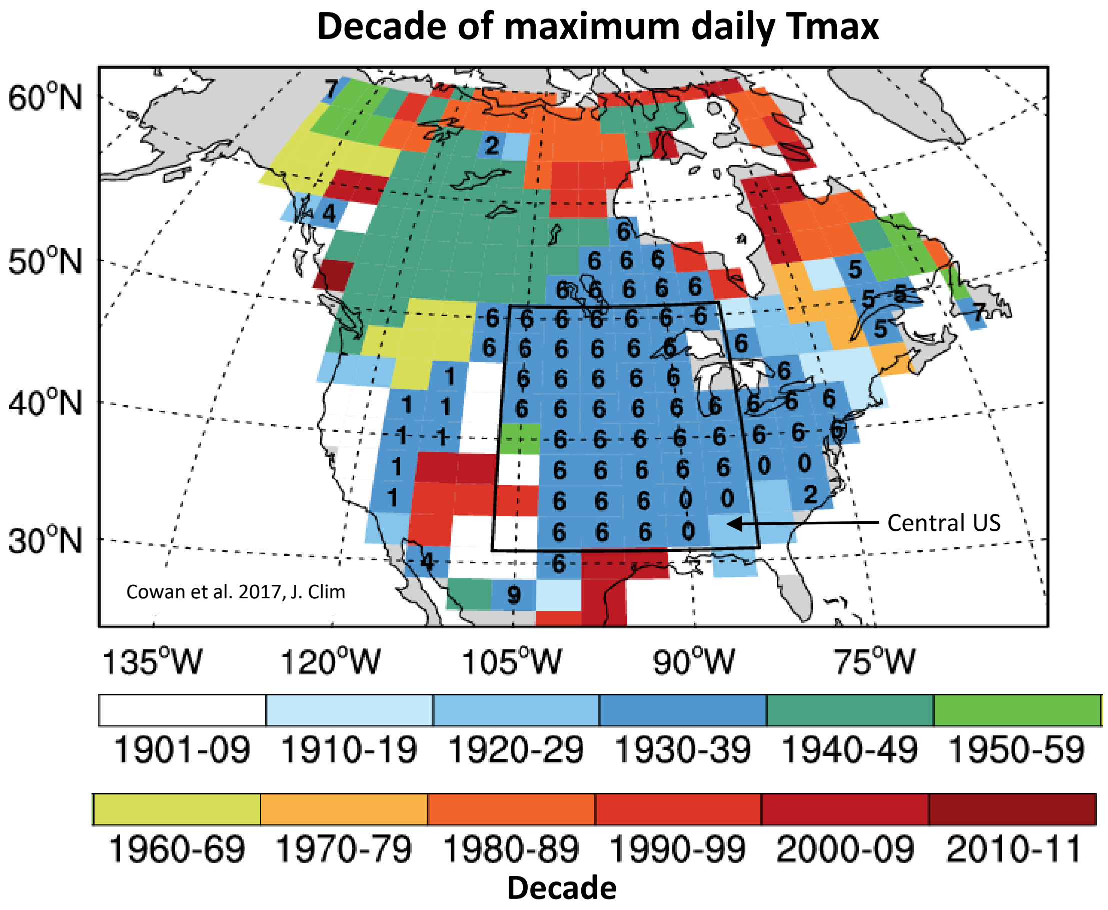




Objectives / Data / Methods

Obj. #1: Did greenhouse gas levels contribute to the 1930s Dust Bowl heatwaves?

Obj. #2: How extreme would the 1930s heatwaves be if they occurred under present day greenhouse gas levels?

Data: Observations ⇨ stations records (GHCN-Daily), homogenized daily temperatures.
Model runs ⇨ weather@home2 (WAH2) attribution experiments using HadAM3P.

Methods:

(1) Calculate heatwave metrics based on daily Tmax and Tmin.

For 1934 & 1936, conduct WAH2 simulations with:

(2) 1930s SSTs, GHGs [$WAH2_{1930s}$, 1550+ runs for both years]

(3) Remove human-induced warming, pre-industrial GHGs [$WAH2_{NAT}$]

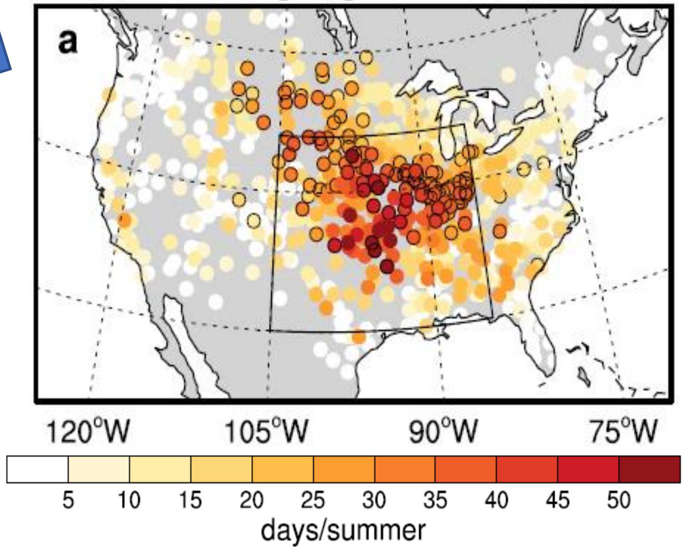
(4) 1930s SSTs with present day GHGs [$WAH2_{PD}$, 1200+ runs]

(5) 2015 SSTs with 2015 GHGs [$WAH2_{2015}$, 1200+ runs]

(6) Determine return periods.

Most recent year to the 1930s in terms of similar SST pattern

Example of total number of observed heatwave days in 1936



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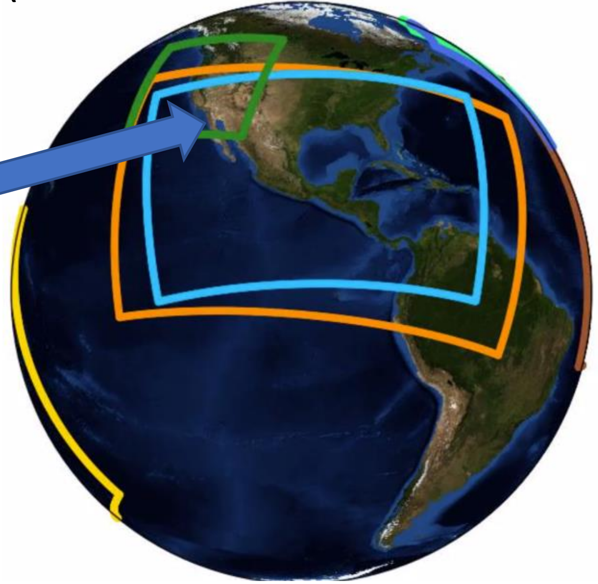
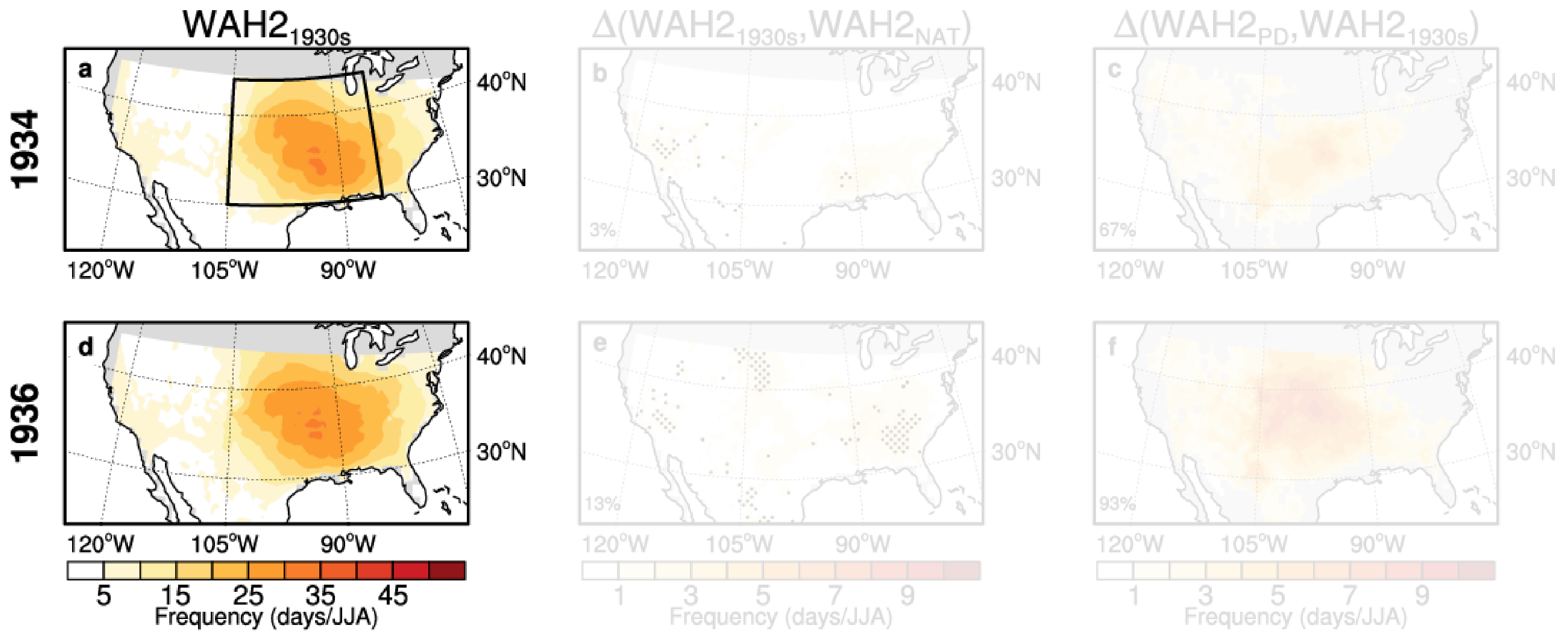
The domain of the regional model (southern US and central America)



Heatwave frequency in WAH2 for 1934, 1936



- **Left:** ensemble mean heatwave frequency (i.e., total number of summer heatwave days) based on the 200 simulations with the most heatwave days over central US.

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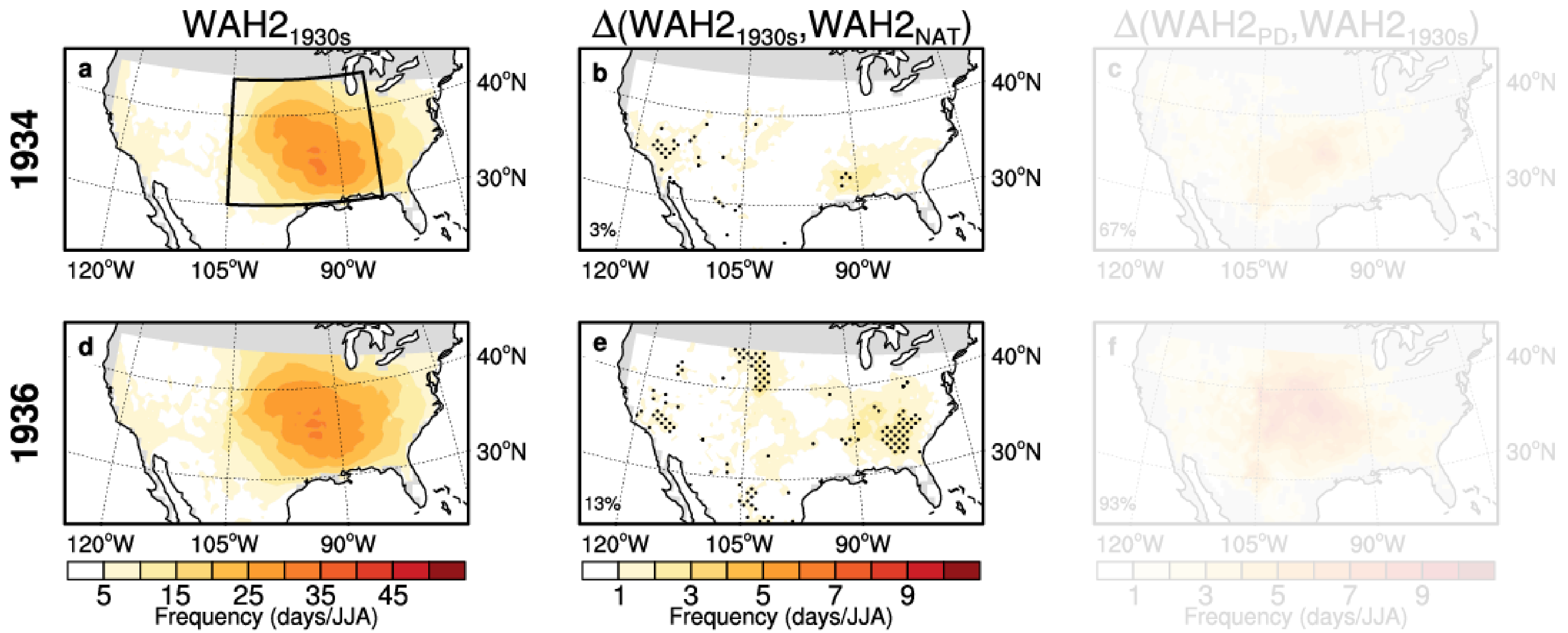

- **Left:** ensemble mean heatwave frequency (i.e., total number of summer heatwave days) based on the 200 simulations with the most heatwave days over central US.

- **Middle:** 1930s GHG forcing leads to a small increase in number of heatwave days over southeast US in 1934 (~ 2 days) and slightly more in 1936. Stippling = significant differences at 5% level.

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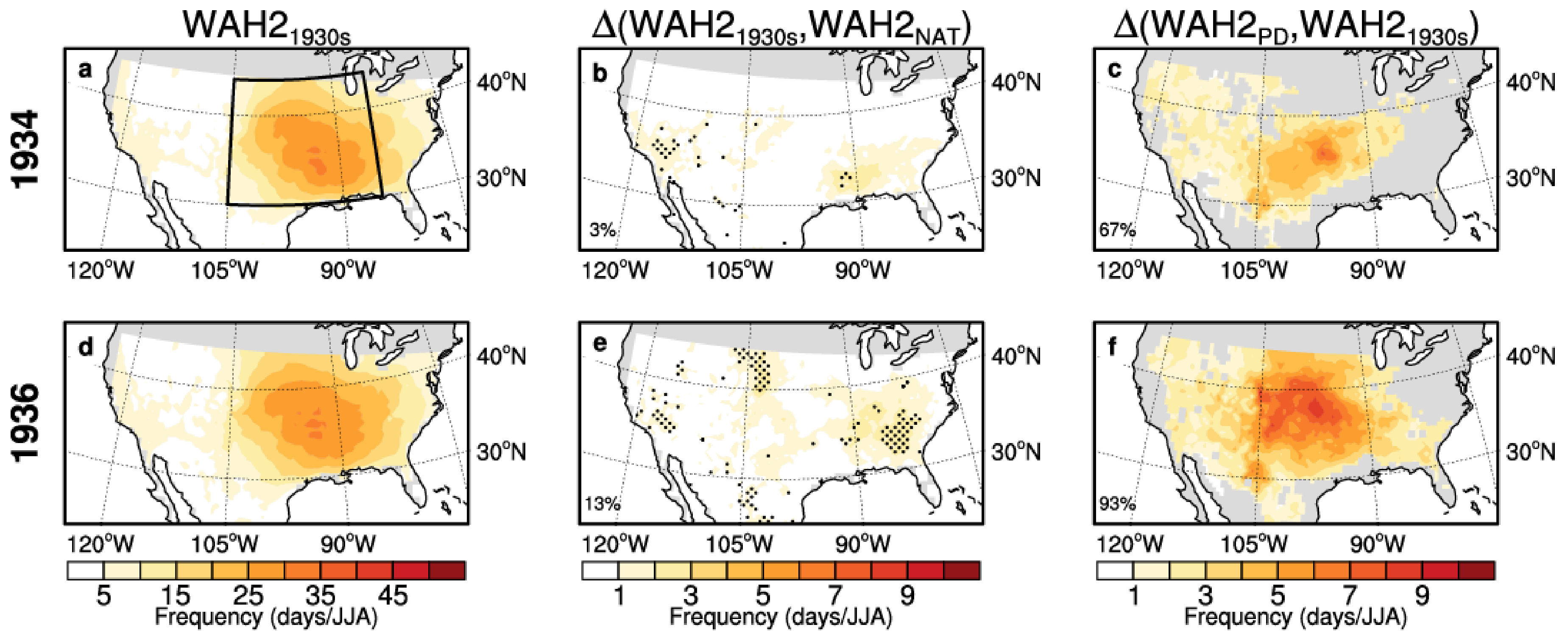
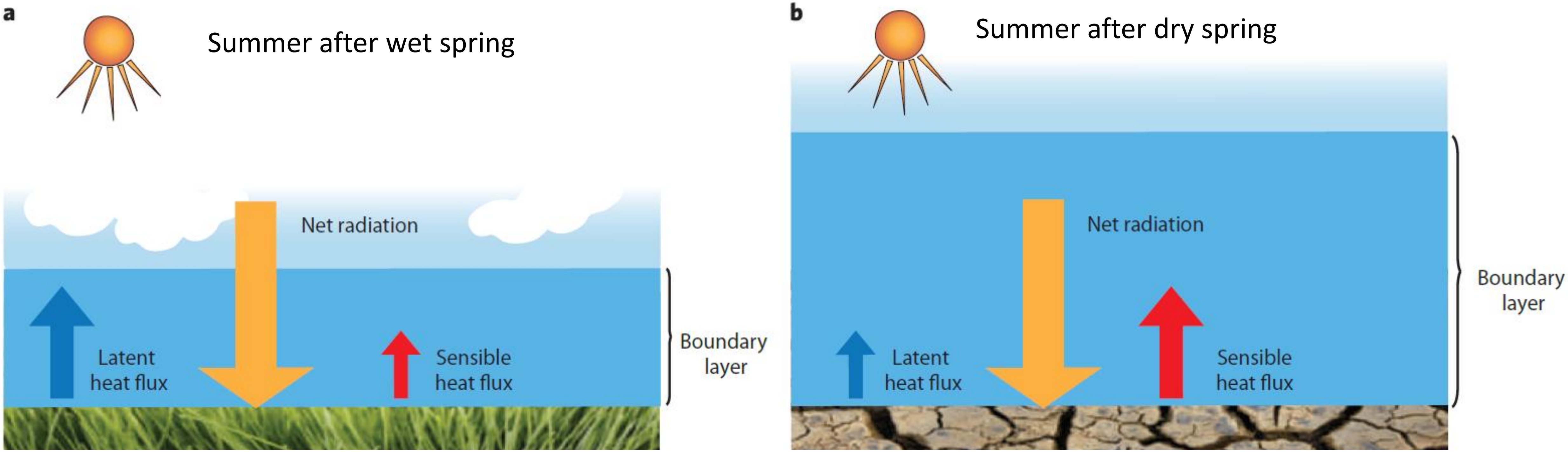


- **Left:** ensemble mean heatwave frequency (i.e., total number of summer heatwave days) based on the 200 simulations with the most heatwave days over central US.

- **Middle:** 1930s GHG forcing leads to a small increase in number of heatwave days over southeast US in 1934 (~ 2 days) and slightly more in 1936. Stippling = significant differences at 5% level.

- **Right:** under present day GHGs, there is a simulated increase of ~5-8 heatwave days over the central US. All changes are significant and robust to ensemble size and resemblance to observed circulations.

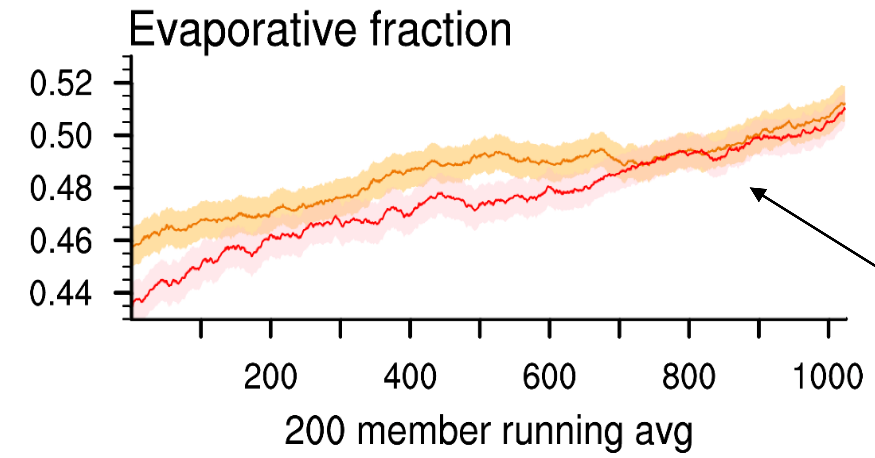
Spring drought, pre-conditioning summer heatwaves

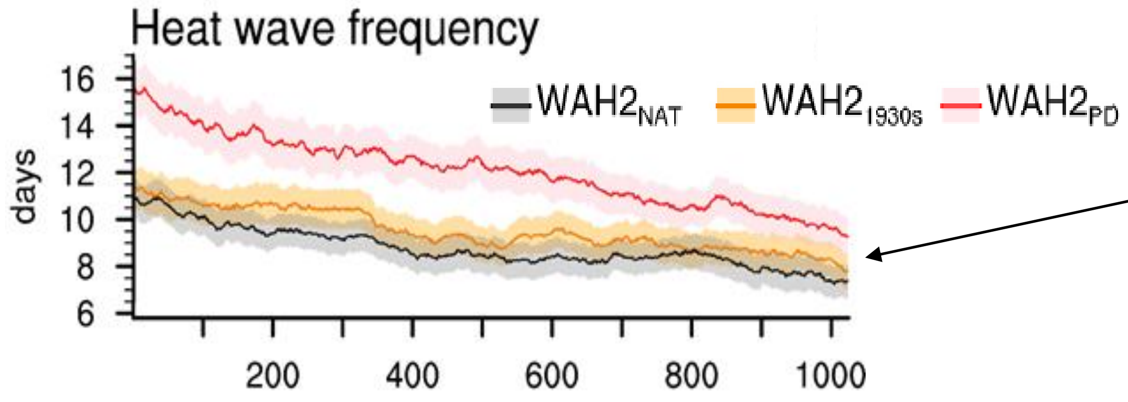


Alexander (2011), Hirschi et al. (2011), *Nature Geoscience*

Spring drought, pre-conditioning summer heatwaves

1936





Proxy for soil moisture

$$EF = Q_e/(Q_e + Q_h)$$

Latent heat flux

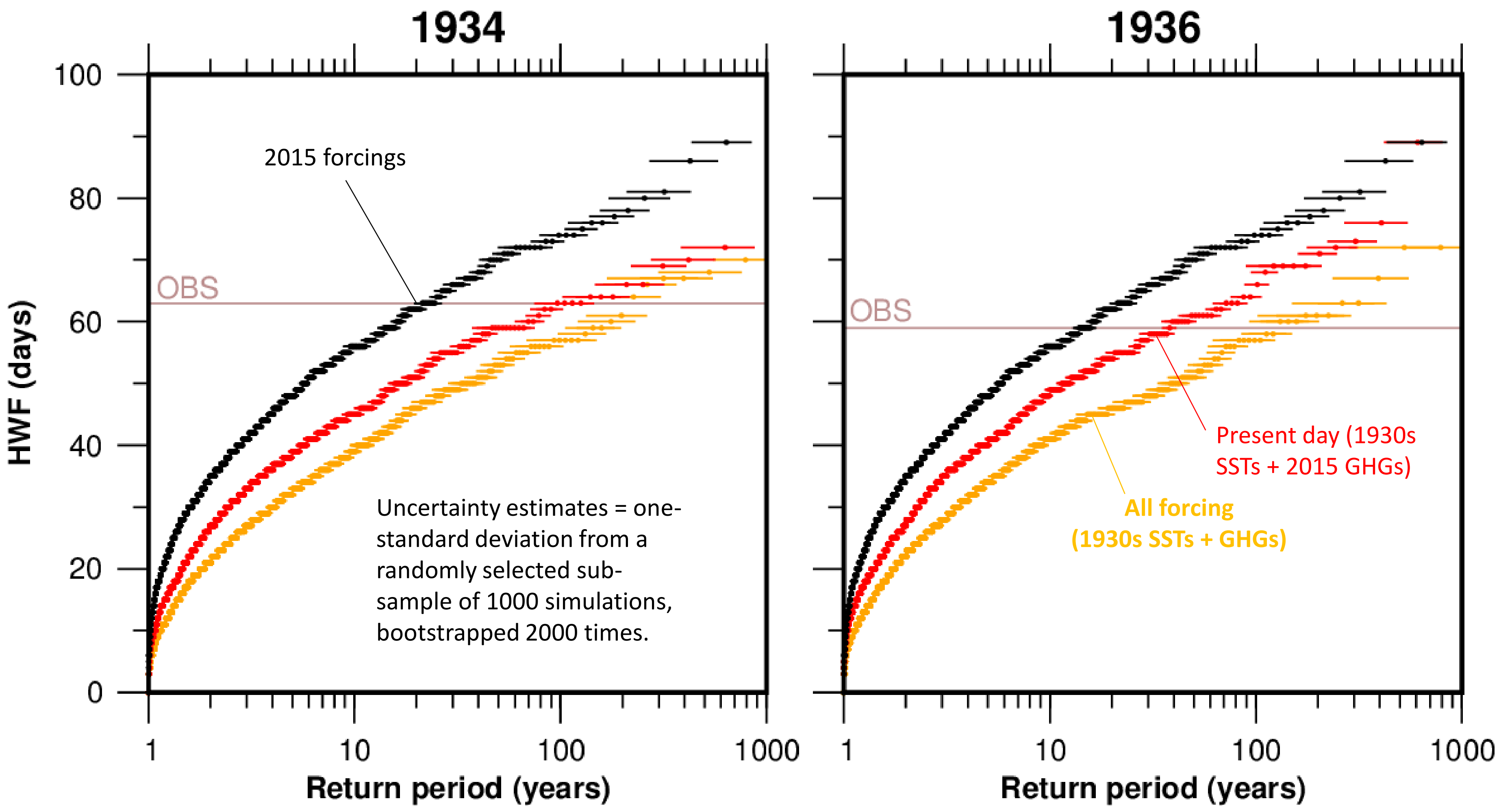
Sensible heat flux

Simulations re-ordered by spring precipitation from driest (left) to wettest (right) over central US. Outcome is considerably drier soils (EF) in the spring in WAH2PD compared to WAH21930s.

Drier soils amplify the summer heatwaves! There is only a marginal increase in heatwave activity due to 1930s GHGs, however under present day GHGs heatwave activity greatly increases, particularly in 1936 and less so in 1934 (not shown)

The likelihood of Dust Bowl-like heatwaves today

Plot showing the return period for maximum heatwave frequency over the central US for each WAH2 experiment.
Risk ratios = change in likelihood of heatwave activity



For (left) 1934, a **1-in-100-year event** becomes a **1-in-40-year event** today [risk ratio > 2.5]

For (right) 1936, a **1-in-100-year event** becomes a **1-in-30-year event** today [risk ratio > 3.4]

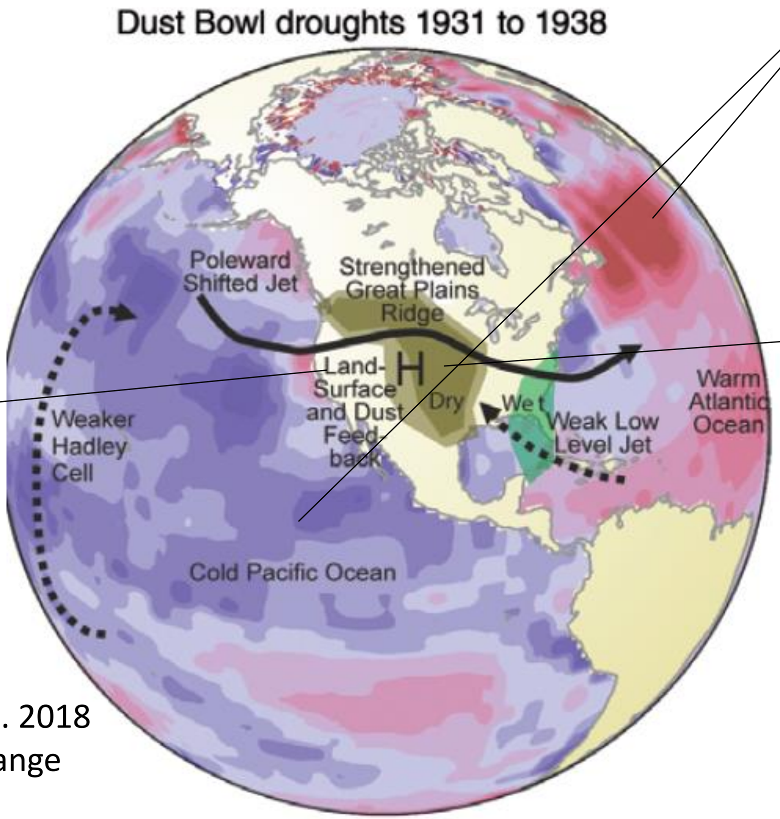
For 2015, a **1-in-100-year event** 1930s event becomes a **1-in-12-year event.**

Overview of the Dust Bowl period

Great Depression

1. Leading up to the 1930s, settlers transformed around 30% of the Great Plains to drought intolerant crops (e.g., wheat), using unsustainable farming practices to prevent erosion.

2. During the 1930s, cool tropical Pacific SSTs and warm North Atlantic SSTs triggered the drought.



Hegerl et al. 2018
Climate Change

3. Severe spring dust storms blocked sunlight, produced subsidence adiabatic warming, reduced convection and precipitation (e.g., more severe drought), leading to further crop failure.

4. Dry springs resulted in warmer summers through an increase in sensible fluxes.

5. Greenhouse gases from early 20th industrialisation intensified the Dust Bowl (e.g., extra 2 heat wave days).

With present day GHGs, there is a 2-3 times increase in the likelihood of a Dust Bowl-like heatwave activity over the central US. Before the end of the century, human-induced global warming is likely to be the dominant influence on heatwaves across the US (Lopez et al. 2018, Nature Clim. Change).

Further reading

Cowan, T., S. Undorf, G. Hegerl, L. Harrington, and F. Otto (2020), Present-day greenhouse gases could cause more frequent and longer Dust Bowl heatwaves, Nature Climate Change, doi:10.1038/s41558-020-0771-7.

Cowan et al. (2020). Human influence on the record-breaking Dust Bowl heat waves across central United States, Nature Communications (accepted).

Hegerl, G.C., S. Brönnimann, T. Cowan, A. R. Friedman, E. Hawkins, C. Iles, W. Müller, A. Schurer and S. Undorf (2019), Causes of climate change over the historical record, Environmental Research Letters, 14, 123006, doi: 10.1088/1748-9326/ab4557.

Hegerl G. C., S. Brönnimann, A. Schurer, and T. Cowan (2018), The early 20th century warming: Anomalies, causes, and consequences. WIREs Climate Change, e522, doi:10.1002/wcc.522.

Cowan, T., G. Hegerl, I. Colfescu, A. Purich and G. Boschat (2017), Factors contributing to record-breaking heat waves over the Great Plains during the 1930s Dust Bowl, Journal of Climate, 30, 2437-2461, doi: 10.1175/JCLI-D-16-0436.1.

Trees stripped bare by drought and grasshoppers on farm near Saint Anthony, North Dakota (July 1936)