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Cross-references

Adaptation
Climate Change
Costs (Economic) of Natural Hazards and Disasters
Desertification
Disaster
Dust Bowl
Hazard
Historical Events
Land Degradation
Loess
Mitigation
Models of Hazard and Disaster
Natural Hazard
Risk
Vulnerability

CASE STUDY

DUST BOWL

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Definition

Dust Bowl. A period of drought, soil erosion, and intense dust storms that impacted the Great Plains of the United States during the 1930s.

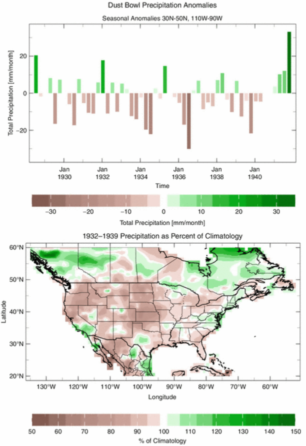
Introduction

The Dust Bowl refers to the years of drought and dust storms that affected the Great Plains of the United States during the 1930s. The term "Dust Bowl" was proposed by a reporter writing an article 1 day after "Black Sunday" – April 14, 1935 – which was one of the worst days of dust storms. The term originally referred to some of the worst affected regions in Texas, Oklahoma, Colorado, and Kansas. "Dust Bowl" is now used to refer more generally to the entire catastrophe in the 1930s comprising drought, crop failure, soil erosion, dust storms, economic collapse, and human migration.

Meteorological origins of the dust bowl

The Dust Bowl began with drought. Rain gauge data show that average precipitation over the Great Plains was less than normal for two thirds of the seasons between 1932 and 1939. Averaged over the core years of the Dust Bowl, 1932–39, the precipitation was less than 80% of normal in most of the Great Plains (Figure 1). Droughts of this length and severity are normal features of the climate in the Plains and several had occurred since European settlement with the most recent occurring in the early to mid-1890s. What made the Dust Bowl different from these earlier droughts was the widespread soil erosion and dust storms. In the period after World War I, the Plains were transformed by the expansion of agriculture (primarily wheat, much of it for export to Europe) and the removal of drought-resistant prairie grasses (Worster, 1979). During the 1920s, adequate rains allowed for bountiful crops, thereby encouraging more new planting. When the drought struck in the early 1930s, the non-drought-resistant strains of wheat that had been planted died, exposing bare soil that was easily eroded from the surface by the wind, creating the dust storms that were characteristic of the period. The scale and magnitude of wind erosion and dust storm activity during the Dust Bowl was fairly unique and did not occur during the earlier droughts.

In the mid-2000s, computer simulations with atmosphere models forced by ship-observed historical sea



Dust Bowl, Figure 1 The precipitation anomaly (mm/day), relative to a 1900–2007 climatology, averaged over 30–50°N and 110 to 90°W, by season for the decade of the 1930s and adjacent years (*top*). The 1932–39 averaged precipitation over North America as a percent of climatology (*bottom*). Data are from the Global Precipitation Climatology Centre.

surface temperatures (SSTs) demonstrated that small variations of tropical Pacific and Atlantic SSTs forced the sequence of multiyear, persistent droughts over the Plains and Southwest North America, including the Dust Bowl drought (Schubert et al., 2004a, b; Seager et al., 2005). North American drought is particularly common when the tropical Pacific Ocean is colder than normal (referred to as a La Niña-like state) and the tropical North Atlantic is warmer than normal. This was the case during the 1930s, and again during the early to mid-1950s when a separate drought struck southwest North America (Seager et al., 2008). These SST anomalies arise naturally from ocean-atmosphere interaction and cause drought over North America through changes in the circulation and thermal structure of the atmosphere. The end result is subsidence (sinking air) over the Plains, suppressing precipitation.

The role of dust storms in modifying and intensifying the drought

Typical SST-forced droughts, however, tend to be centered in the southern Plains, southwest USA, and Mexico, whereas the Dust Bowl drought extended up into the northern Plains and the Canadian prairies. Because of this, some researchers have argued that the Dust Bowl drought was largely forced by internal atmosphere variability and not related to anomalous SSTs (Hoerling et al. 2009). An alternative theory is that the dust storms were so frequent, widespread, and intensive that they actually altered the regional climate. Climate model simulations have been performed in which an atmosphere model was forced by observed 1930s SSTs but also with bare soil placed at the surface where contemporary maps indicated wind erosion occurred. The model created dust storms that interacted with the solar radiation. By reflecting radiation to space, the dust storms induced subsiding air and suppressed conversion of water vapor into precipitation and intensified the drought (Figure 2). Since the dust transport was north and east from the Plains, the modeled drought center also shifted north with the dust, bringing the spatial pattern of the Dust Bowl drought into better agreement with observations (Cook et al., 2009).

Impacts of the Dust Bowl drought and efforts to control the soil erosion

At the peak of dust storm activity, the Plains were emitting dust at a rate equivalent to current dust emissions in the most productive areas of the Sahara (Cook et al., 2008; Laurent et al., 2008). Dust was transported eastward to coastal cities and the Atlantic Ocean, creating widespread health problems related to dust inhalation and choking of the lungs. This became known as "dust pneumonia" and led to an uncertain number of deaths (Egan, 2005). In 1935, after the wind erosion and dust storms had been ongoing for several years, the Soil Conservation Service was created specifically to address the problem of soil erosion. In 1936, the Service completed a map showing the full extent of wind and water erosion during the Dust Bowl, an area extending through the Great Plains from the Gulf of Mexico to Canada (see Hansen and Libecap, 2004).

Soil Conservation Service scientists diagnosed the cause of wind erosion to lie in a combination of drought and poor cultivation practices (i.e., lack of fallowing of land and strip cropping and the absence of shelterbelts and vegetative residue to protect soils) (e.g., Chepil, 1957). Consistently, soil erosion from cultivated land in the 1930s greatly exceeded the erosion from pasturelands (Chepil, 1957). Hansen and Libecap (2004) also noted that the small size of Dust Bowl farms encouraged farmers facing drought to plant as much area as possible to compensate for reduced yield, instead of instituting erosion control measures that would reduce erosion risk but also take land out of cultivation. In many cases, eroded soil from one farm would be transported to neighboring farms, causing a chain reaction of crop failures and wind erosion within an area. To counter such destructive practices, the Soil Conservation Service created Soil Conservation Districts that, through a mix of incentives and coercion, encouraged farmers to cooperatively practice soil conservation techniques. In addition, some marginal lands were purchased by the Federal government and allowed to return to natural grasslands. Soil conservation techniques achieved some gains against erosion, but by 1941, rains were above normal and the drought and Dust Bowl had ended.

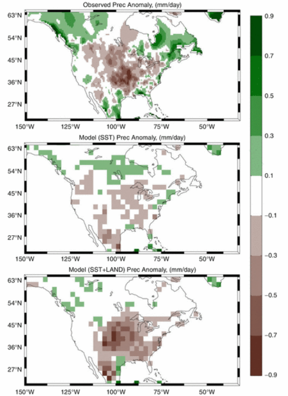
Crop failure put many farmers into debt and forced farm sales and abandonment. According to Worster (1979), by the end of the Dust Bowl, about three million people had left their farms and about 0.5 million migrated entirely out of the affected areas, with about half of those moving to California.

Legacy of the Dust Bowl

The Dust Bowl permanently altered the agricultural economy and farming of the Plains and directly led to the widespread adoption of soil conservation techniques in the United States. Out-migration led to farm consolidation. When drought returned to the Great Plains in the 1950s, the soil erosion and dust storms were more limited than in the 1930s and the social disruption was minor by comparison. Federal farm support policies and the beginning of irrigation also helped alleviate the impact of the 1950s drought on farmers (Hansen and Libecap, 2004; Worster, 1979).

Summary

The 1930s drought was, by meteorological standards, a multiyear drought of the kind the Great Plains had experienced previously and thereafter. It was forced by a combination of cold tropical Pacific and warm tropical Atlantic sea surface temperature anomalies that in turn generated changes in atmospheric circulation that suppressed precipitation in the drought region. Poor agricultural practices, such as expansive cropping of non-drought-resistant plants with little regard for soil erosion



Dust Bowl, Figure 2 Observed (*top panel*) and climate model simulated warm season (April–September) precipitation anomalies for the Dust Bowl period (1932–1939). When the model is forced with observed SSTs only (*central panel*), a weak drought is simulated that is centered too far south. If the effect of the dust storms is integrated into the model in addition to the SSTs (*bottom panel*), the drought intensifies and moves northward into the central Great Plains.

potential, turned the drought into the Dust Bowl as crops failed, bare soil was exposed, and wind erosion led to dust storms. The dust storms intensified the drought and moved its center northward. In response, the Soil Conservation Service was created and put in place conservation measures to limit the erosion. The drought ended when normal levels of rainfall returned in the early 1940s. The Dust Bowl led to a permanent transformation of Plains agriculture in terms of farm size, farming practices, and farm support policies. Subsequent droughts have not led to the same scale of soil erosion because of these changes and the introduction of irrigation.

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Cross-references

Drought
Dust Storm
El Niño/Southern Oscillation
Global Dust/Aerosol Effects
Hydrometeorological Hazards
Land Degradation

DUST DEVIL

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Synonyms

Convective vortex; Whirlwind

Definition

Warm-core vortices, normally less than 100 m high formed at the base of convective plumes often appearing as a well-defined dust funnel.

Overview

Dust devils are low-pressure, warm-core vortices with typical diameters ranging from 1 to 10 m, and heights of less than 100 m (Figure 1). However, occasionally, they can be larger or taller by more than an order of magnitude. Dust devils form at the bottom of convective plumes. Since their sources of angular momentum are local wind shears, caused either by the convective circulation itself or by larger scale phenomena, they can rotate clockwise or anticlockwise with equal probability. A distinctive feature of intense dust devils is their well-defined dust funnel. Theory indicates that dust is focused around the funnel by a dynamic pressure drop caused by increases in the speeds of the air spiraling toward the vortex.

Like waterspouts, tornadoes, and hurricanes, dust devils can be idealized as convective heat engines. They are the smallest and weakest members of this class of weather phenomena. The intensity of a dust devil depends on the depth of the convective plume and the transfer of heat from the ground into the air. When the surface is composed of loose particles, they might become airborne and make a dust devil visible. Dust particles are indirectly lifted from the surface by a process known as saltation. In this process, the larger particles are forced to move by the wind and bounce along the surface, lifting the smaller, harder to lift (because of strong cohesion forces) dust particles into the air. When loose particles are not present, intense vortices may exist and may not be visible to the observer. When a dust devil crosses a cold terrain, the dust column is cut off, and the vortex dissipates.

The abrupt increase in wind speed around dust devils is what creates a hazard; more than 10% of the accidents with light airplanes and helicopters are caused by visible or invisible dust-free dust devils. However, the abrupt reduction in visibility caused by them can also be a hazard.

Dust devils are more frequent in hot desert regions, but they also have been observed in colder regions such as the subarctic. Dust devils move with the ambient wind and slope with height in the wind shear direction. When the wind is strong, their diameters are biased toward large values.

The occurrence of dust devils increases abruptly from nearly zero at around 10 am to a maximum value at around 1 p.m. Then, dust devil activity slowly decreases toward nearly zero at the end of the afternoon. The abrupt increase at around 10 a.m. is due to increases in the solar radiation and abrupt increase in the depth of the boundary layer. The decrease to nearly zero at the end of the afternoon is due to the decrease in solar radiation and therefore convective activity.

Charge transfer occurs when sand and dust particles collide with each other and the surface. In this process, the smaller particles charge negatively and the surface and large particles positively. Then, the convective updrafts cause charge separation by carrying the smaller particles upward and electric fields of the order of 10,000 V/m can be generated. There are suggestions that