and landings, the 1950s aircraft would have flown about 300 feet before the engines responded; today's aircraft fly about 1,500 feet. And today's runways, about 10,000 feet long, twice the length required for a typical piston-engine aircraft, indicate the extended exposure of modern commercial aircraft to boundary-layer phenomena during takeoff and landing.

The variation of wind divided by the distance over which the variation occurs is the wind shear: mathematically, the shear is a tensor whose nine components correspond to the three orthogonal directions in which the wind variations can occur, combined with the three directions from which the wind can be blowing. The pilot is most interested in wind and its variations in the directions of flight, and in the vertical wind, because these produce the principal lift forces. Small-scale shears, termed turbulence, can produce discomfort, but if an aircraft enters a region of much reduced headwind during takeoff or during approach to landing, loss of lift is a serious safety concern. This is exacerbated when a downdraft is encountered along with a sudden unfavourable change of horizontal wind speed. In a severe downdraft outflow, with wind variation around 20 m.p.h per 1,000 feet, decline of headwind and downdraft can cause irreversible loss of altitude to the point of a crash. This is most likely during takeoff or landing when a thunderstorm is over or near the airfield, but can also occur with solitary atmospheric waves.

As a result of several incidents beginning in the late 1960s, the Federal Aviation Administration (FAA) issued a series of advisory circulars on the hazards of thunderstorms and wind shear, and developed new instrumentation for use at airports. Until the late 1970s, surface winds at air terminals were reported by a single centrally located anemometer. Guidance from a single device is inadequate in the jet age, especially when winds vary by 50 m.p.h or more from one side of an airport to the other, and such variations can even occur in clear air and without local visual clues. In 1976, the FAA developed the Low Level Wind-shear Alert System — a system of multiple anemometers with a display and alarm system that notifies the control tower operator when any one of the anemometers indicates a wind speed different from the centre field wind[2]. The efficacy of the system is suggested by the fact that only one fatal accident (in July 1982 at New Orleans) has been attributed to wind shear in an airfield with the equipment. About 60 airfields now have the basic system, and there are plans for installation at 50 more. The installations at Denver and New Orleans are being upgraded by adding extra, more closely spaced anemometers.

Substantial study continues to refine our knowledge of low-level wind-shear events, their individual and statistical characteristics, climatology and predictability. Downbursts and microbursts are being studied in the Chicago area[3,4], at laboratories of the National Center for Atmospheric Research and the National Oceanic and Atmospheric Administration (NOAA) at Denver, Colorado[5], and at NOAA's National Severe Storms Laboratory at Norman, Oklahoma[6,7]. Downdraft outflow phenomena are unusually frequent and intense at ground level in the Denver area. There they are often abetted by a layer of rather dry air on and near the ground, having a steep lapse rate of temperature. Such a boundary layer tends to amplify any thunderstorm or shower downdraft, especially with the strong evaporative cooling that accompanies precipitation from scattered showers. Findings from the Denver-based projects JAWS (Joint Airport Weather Studies) and CLAWS (Classify, Locate and Avoid Wind Shear) have both theoretical and practical implications. Downdrafts strong enough to be classified as microbursts around Denver are often 0.5-1 mile in diameter, and typically last 5-15 minutes, although occasionally they develop significantly within one minute. The difference between peak winds on opposite sides of outflow on the ground at the time of maximum development is about 55 m.p.h. In summer, there is on average one microburst a day within 14 miles of Denver airport.

Further work seek to develop cost-effective systems, both for observing hazardous microbursts in appropriate detail and for communicating the information to pilots at the time of landing and taking off, so that accidents will be avoided and economies are achieved in the use of time and fuel. Observed atmospheric extremes are also being programmed in flight simulators to evaluate aircraft control strategies for mitigating effects of extreme shear during unforeseen encounters.

Other atmospheric phenomena hazardous to flights at low altitudes include solitary waves, strong vertical shear of the horizontal wind and vortices rotating around vertical axes along gust fronts. Solitary waves can retain significant intensity while propagating for hundreds of miles in a stable boundary layer; when the air is dry they may be practically invisible, but under suitably moist conditions they are marked by a line of cloud that may have a deceptively innocuous appearance. They have been especially targeted for research in northeastern Australia, where they are known as 'morning glories' and are quite common before noon[8]. In the United States they sometimes develop from thunderstorm gust fronts that propagate in a stable air layer ahead of the originating disturbance[9].

Intense warm frontal shear — a variation of the horizontal wind with height — especially when accompanied by poor visibility in rain and fog, can cause a descending aircraft to land short of the runway — as happened on 17 December 1973 at Logan Airport, Boston[10]. This outcome of extreme conditions can usually be averted by timely advice to the pilot on wind speed and direction at different altitudes. Doppler radars can provide this and other detailed wind information routinely, at intervals of a few minutes[11,12]

Future weather-surveillance systems for airports will probably include surface anemometers and Doppler radar, and possibly a lightning-locating system. It will be essential to collect data at a central location and to process them there for communication to pilots. As technology advances, we can expect an improved match between timely displays of processed meteorological data, actual wind and weather, aircraft capabilities, and pilot performance[13-15]. ☐

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100 years ago

Paradise Found. The Cradle of the Human Race at the North Pole. A Study of the Prehistoric World. By William F. Warren, S.T.D., LL.D., (London: Sampson Low and Co.)

It has come to be an understood thing that when geologists or biologists propound theories as to past stages of life on the earth, and these theories attain to a certain popularity, some theologian shall twist the words of the Book of Genesis into a new interpretation, to show that this was what the inspired author meant all the time. A fresh musician has set Moses to dance to a new scientific tune. Since the publication of well-known modern views as to the diffusion of plants and animals from the Polar Region, it was to be expected that we should have a book proving that man was created in an Arctic Paradise with the Tree of Life as the North Pole; and here the book is. Other ancient cosmologies, such as the Greek and Indian, are made to bear their not always willing testimony. The commendatory letters published from Professors Sayce, Tiele, and Whitney do not at all imply that these eminent scholars countenance the Polar Paradise doctrine. The author seems to have sent them a paper on "Ancient Cosmology and Mythical Geography," their acknowledgements of which they are now perhaps hardly delighted to find as certificates in a "Paradise Found."

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