in which the wind shifts with the passage of a low, observations indicate that the shift frequently occurs at about the same time at all altitudes up to two miles. He expressed a desire for original research in this country independent of the work of Bjerknes and others.

On the Diurnal Variation of Wind Velocity

By Irving I. Schell

From the hourly amounts of wind travel observed for the months May, 1933-April, 1934 at Mount Washington, N. H. (6270 feet) and November, 1932-July, 1933 at Concord, N. H. (289 ft.), the diurnal wind velocity regimes were determined for different air masses and lapse rates and the results used in a general consideration of the cause of the diurnal course and range of wind velocity at different levels. The previous discussions and observations on the subject were reexamined in order to test the adequacy of the well known Espy-Köppen explanation involving simply the vertical transfer of momentum through mechanical and convective turbulence. It appears that the daily course is not determined, not even in the lower atmosphere, by turbulence alone, as claimed by Taylor and Iswekov, but is also influenced, especially in the upper layers, by diurnal oscillations of pressure gradient; but no further analysis of the latter factor was made. It was definitely shown, however, that since the diurnal range (amplitude of the diurnal variation) is to a large extent a function of the stability of the air mass, it varies characteristically with the air-mass type and season. In summer the amplitude is largest in Pc and Npc air masses, in winter in Npp air masses, while the smallest amplitude is in Npc. With stable conditions the amplitude is such that it cannot be due to turbulence alone, but once overturning of the layers takes place the amplitude is a function of the lapse rate of temperature (in the lowest 2 km layer). —R. G. S.

Discussion:

H. H. Clayton thought that the larger daily range of wind velocity associated with a steep lapse rate was due to the fact that ascending currents then reached higher levels, and swifter moving air from those levels was brought down. He added that the secondary maxima shown in some of the diagrams were probably a normal condition. At night there is a noticeable maximum of wind velocity at 500 meters; in the morning, when the ascending currents reach this level, the high velocity is brought down, and the velocity then decreases until the ascending currents reach a level where the air movement is swifter than at 500 meters. On some occasions, when the air is stratified, there might be several maxima of velocity shown in the daily curve of wind velocity at the ground. The speaker remarked that there were some irregularities that were due to the method used, and which would be eliminated by a better method.

Meteorological Features and History of Tornado at Norfolk, Va., Sept. 5, 1935

By John J. Murphy, Weather Bureau, Norfolk

Norfolk's first bona fide tornado, that of September 5, 1935, furnished some very interesting meteorological features, which are graphically shown on the record sheets of the various self-registering instruments at the
Hampton Roads Naval Air Station Aerological Office, which escaped the full force of the whirling monster by about one hundred yards.

The tornado first appeared about 3:45 p.m. in the Churchland section of Norfolk County and finally disappeared about two miles northeast of Willoughby Spit, withdrawing into the great mass of cumulonimbus cloud, after traversing about 13 miles of land and water surface, a combination tornado and waterspout.

It had its genesis in a dense mass of cumulonimbus cloud that formed in the southwest portion of the sky in mid-afternoon and developed into a thunderstorm of great intensity, characterized in its early stages by unusually vivid flashes of lightning of the zigzag type and violent crashes of thunder.

Shortly after the development of the thunderstorm, observers in the Churchland section noted the “funny-looking” cloud, described by some as looking like a funnel, and by others as like “an elephant’s trunk”, suspended from the mass of black, whirling cloud. A number stated that the funnel-cloud had an orange glow, and it was generally noted that the cloud whirled in a counter-clockwise direction and was preceded by a roaring noise similar to that made by a large fleet of airplanes.

The tornado cloud first touched the ground in a brier patch about 800 feet south of the Churchland boulevard. The brier bushes were flattened in an almost perfect circle about 50 feet in diameter, and all lay pointing in toward the center of the circle. Advancing in a northeast direction by leaps and bounds, it left a trail of destruction in its wake.

Growing crops were stripped from vines and stalks, which were flattened as though by a giant roller, the tops of huge pines were twisted off, hay stacks were whirled aloft, as also were small boats hurled up on the shores of creeks, small houses and sheds were unroofed, the bottom of a creek was plainly visible as the spinning cloud sucked up the water, and even some of the mud, in its passage. A huge bull was carried skyward and dropped to earth some 40 yards away, unscathed, but bellowing frantically.

Gathering momentum as it progressed northeastward, the tornado made its first transformation into a waterspout as it left the mainland on its journey to Craney Island, where it whirled through the area occupied by the U. S. Public Health Service as a quarantine station, with devastating effect. Striking the island about 4 p.m., the tornado developed full strength as attested by damage amounting to $18,000, all occurring in the twinkling of an eye.

It ripped off a large section of the heavily constructed pier, folding it back in the direction from which the storm came, unroofed the boiler house and fumigating station, a brick structure, and stripped a section of the roof off a small wooden storehouse.

A large one-story brick building, 100 by 50 feet, was the next victim of the storm’s fury, which completely demolished the structure that had withstood the ravages of storms for the past century. Eye witnesses said this building appeared to explode, the windows and doors blowing outward and the walls and roof caving in. The side walls of the building were 13 inches thick, and the end walls 18 inches. Timbers from it were found several hundred feet away, driven so solidly in the ground that they could not be moved by the combined efforts of several men.

Leaving Craney Island the tornado
again became a waterspout as it skirted the edge of Hampton Roads, and resumed its tornado characteristics on reaching land near the extensive terminals of the Norfolk Tidewater Company.

The writhing cloud descended here and forced an empty gondola car off its trucks, then bounded along, partially unroofing a small frame residence. As it crossed the road leading to the grain elevator it snapped six steel-reinforced concrete electric light poles, 38 inches in circumference, shearing them off about 12 feet above the ground; and all fell to the northward.

Continuing across Hampton Boulevard, main traffic artery between the city and the Naval Operating Base, it picked up a Dodge sedan, moving northward, and carried it 85 feet, dropping it in the opposing traffic lane undamaged.

It next struck the Virginian Railway yards and overturned three empty refrigerator cars weighing 60,000 pounds each, tearing the roof off one and carrying it 2000 feet.

Crossing Masons Creek it passed between a group of hangars at the Naval Air Station, whipping the huge steel doors off two hangars, and damaging two automobiles parked on the roadside.

It became a waterspout again as it passed from the Air Station area to Willoughby Bay, and in passing over Willoughby Spit demolished a small garage, after which it moved off into Chesapeake Bay, withdrawing into the mass of cumulonimbus cloud about two miles out in the bay.

The general course of the storm was from SW to NE and the width of the path of destruction varied from 50 to 300 feet. In all sections struck by the funnel cloud there was ample evidence of the rotary motion, as shown by the position of the scattered debris and fallen trees. In its initial stages the funnel cloud moved at a rate of about 20 miles per hour, but in the last half of its life it is estimated that its forward movement was at the rate of 50 miles per hour.

The micro-barograph record at the Air Station, which was inspected by the writer through the courtesy of Lieut. V. O. Clapp, U.S.N., Aeronautical Officer, shows a rather rapid fall in pressure between 4:00 and 4:03 p.m. as the tornado approached the station, and as it whirled past, about 100 yards to the eastward, the pressure fluctuated wildly, rising .14 in about a minute, followed by an abrupt drop of .13, then a quick uprush of .13, most of which was practically instantaneous. Then followed several less violent and more gradual oscillations as the tornado moved away from the station, and the pressure leveled off.

During these rapid pressure fluctuations the wind was also cutting capers, shifting entirely around the compass almost instantly from ENE, as the tornado approached, through E, S, W, and N, back to ENE, and then counterclockwise to S just as rapidly, as the twister passed the station.

Coincidental with the violent pressure fluctuations and rapid wind shifts, the wind developed great gustiness, the anemograph showing an instantaneous jump from 6 miles per hour to 45, followed by just as sudden a drop to 10, another quick jump to 42, and an abrupt drop to 14, all within a space of about 10 minutes.

The hygrograph trace showed quite a rapid rise in humidity from 64% just before noon to 100% at 2:30 p.m., with a sharp drop to 86% just before the arrival of the tornado, and
a corresponding sharp rise as the tornado arrived and passed. Temperature changes were insignificant.

The Norfolk tornado was apparently one of the series of tornadoes that swept through southern Virginia and northern North Carolina on a 180-mile front during the afternoon and early evening of September 5th. The tornadoes were first reported in Virginia in Pittsylvania County in mid-afternoon, and last reported at 10:30 p.m. in Middlesex County, 180 miles northeast of Pittsylvania County.1

It is not believed that the storm passed over the entire district as a perfectly formed tornado, but it is evident that a number of separate funnel clouds developed in the eastward passage of the storm.

While no attempt has been made by the writer to compile a list of the property damage over the area traversed by the tornadoes, an accurate survey was made in this section, where property was damaged to the extent of $22,000. A conservative estimate of the total damage suffered throughout southern Virginia, however, would fix the loss from the tornadoes as not less than $100,000. Two lives were lost in the Farmville section, and more than a score injured by a twister.

The statement that this was Norfolk's first bona fide tornado is offered despite Giles' "Compilation of Tornadoes in Virginia, 1814-1925," which lists two tornadoes as having occurred here, one on Aug. 23, 1875, and the other on July 13, 1876.

It is believed that the storms listed by Giles as tornadoes were but out-rushing thundersqualls. This seems borne out by the brief notations of the storms in the station Daily Journal, in which both are described as whirlwinds that did but slight damage.

The track of the 1935 tornado was traced carefully by the writer over practically its entire 13-mile course, and eye-witnesses were questioned at length in all sections from the point of inception to its disappearance.

1These storms occurred where a cold front joined the northeastern margin of an advancing tropical cyclone.—Ed.

A THUNDERHEAD AND RAINSQUALL NEAR PORTLAND, ORE.

By A. B. CARPENTER, Weather Bureau, Portland

July 7, 1935 was a day of showers at Portland, Oregon, with light showers in the morning and until 2:30 p.m. At that time occasional moderate showers reached Portland with the advance portion of a front. This was followed by clearing weather. Then followed the most interesting part of the day. Thunder was heard at 6:45 p.m. in the northwest, and another front became evident in the weather and barograph trace for Portland at 7:30 p.m.

At this time towering cumulus clouds were observed in the NNW, SW, and SE. The thunderhead in the NNW was most fascinating, as the setting sun behind the cloud gave it a beautiful silver fringe, and drew attention to the violent and rapid growth of the top. At 8 p.m., Don Smith, a local pilot, arrived at the airport from the north, with an exciting tale of the terrific updraft he experienced at the confluence of the Willamette and the Columbia Rivers, approximately eight miles NNW of Portland. The direction and distance checked very well with conditions observed from Portland, and the top was calculated at 13,886 feet, using an angle taken with the theodolite and the above mentioned base line. The pilot also reported very heavy