STORMS

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WINDSTORMS ASSOCIATED WITH EXTRATROPICAL CYCLONES

John F. Weaver

INTRODUCTION

Historically, the term *extratropical cyclone* (ETC) has been taken to mean a large, mid-latitude region of low pressure at or near the Earth's surface in which air spirals cyclonically inward to try to fill the depressed region. In a broader sense, an ETC is a three-dimensional, migratory atmospheric disturbance which is found entirely outside of tropical latitudes. Its horizontal dimensions are on the order of $(10)^3$ km. Large temperature gradients (fronts) provide the primary energy source for the system as the potential energy created by these density differences are converted to kinetic energy. (See Chapter 10 for a more detailed description of dynamical aspects.) In a well-developed ETC the surface low pressure region is associated with an upper-level trough, and there is a near three-dimensional balance, such that air rushing into the system at lower levels is forced upward to high altitudes, where it diverges out and away from the cyclone's center (Figure 23.1). This rising motion often gives rise to inclement weather.

The rate at which low-level air spirals in towards the center is controlled by the relative intensity, or depth, of the low pressure. Windspeeds associated with this inward rushing air sometimes become quite intense.

Severe ETC-related winds can develop anywhere in the mid-latitudes. They occur most frequently during the winter and early spring (e.g., Golden and Snow 1991) when hemispheric temperature contrasts are greatest, and are typically most intense along coastlines, such as the Atlantic coast of the USA, where the contrast between warm water and cold continental air acts to enhance the total energy input into the storm. Though inland areas are not immune to severe ETC winds, coastal areas are particularly susceptible, due to this enhanced temperature gradient. Furthermore, reduced friction over the water allows greater surface windspeeds to develop along and near coastlines. Windspeeds in ETCs only occasionally exceed 50 m s^{-1} (100 kt), but adverse effects – just as with hurricanes – can be significant due to the widespread nature of the affected area, and the long period of time that a given location might be exposed.

A FEW HISTORICAL HIGHLIGHTS

Near the turn of the century, the standard suite of meteorological observations in the United States consisted of surface observations that were taken at about seventy locations around the country, three times each day. According to a book written by a British visitor to the USA in the late 1800s (Abercromby 1888), these data were telegraphed to the Signal Service Headquarters in Washington, DC, where they were plotted onto large surface charts by hand. A weather forecast consisted almost entirely of tracking and extrapolating significant surface features such as cyclones or troughs. Sometimes inferences were made regarding the future of an encroaching system by studying temperature and pressure *trends*. However, since no upper air soundings were available at the time, little was known about the important role played by the upper atmosphere in the behavior of the surface cyclone. Storms undergoing rapid cyclogenesis typically caught weather forecasters by surprise.
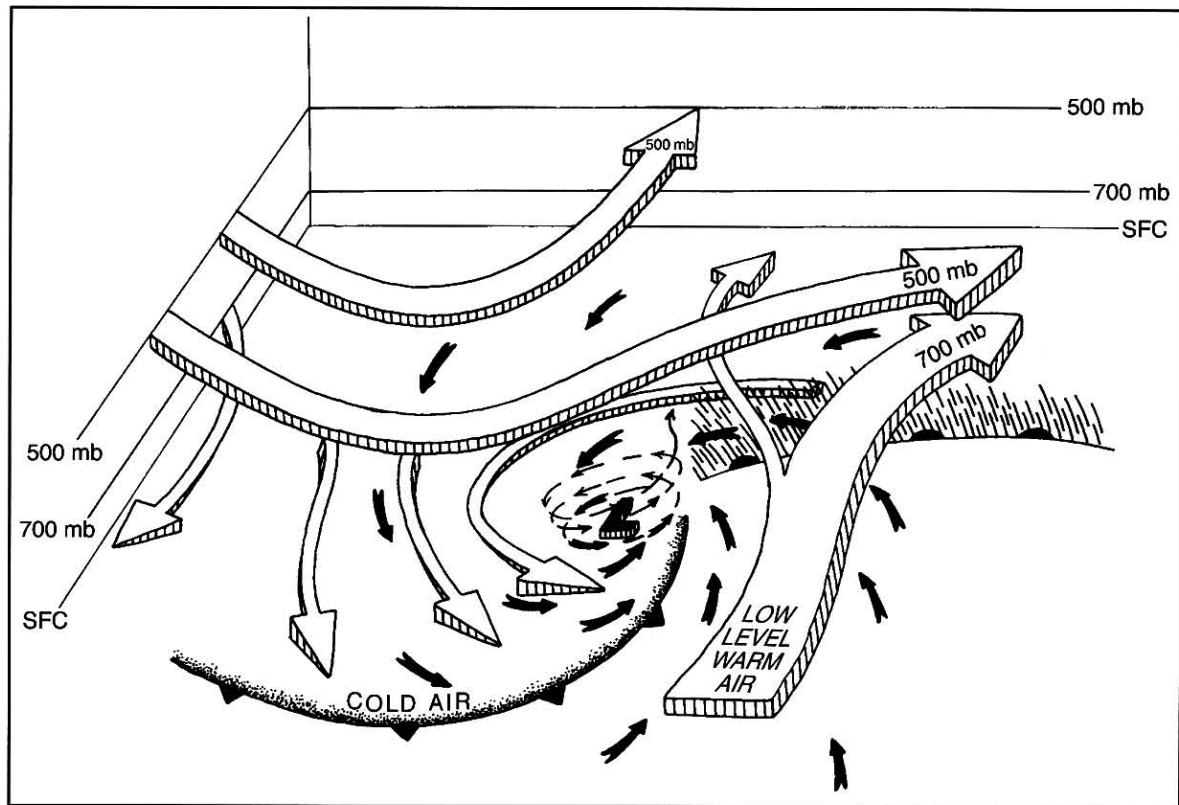
Figure 23.1 Conceptual drawing of a maturing extratropical cyclone showing idealized mean wind flow at various levels. Dark arrows represent flow at the surface. The intense circulation draws cold air from the north around behind itself, and pushes warm, southerly air northward. Air behind the system is generally subsident, that ahead generally ascendant. Graphic by Freda Weaver

Furthermore, the west coast was left virtually without advance warning, since most ETCs travel from west to east in the Northern Hemisphere, and few observations were available from over the Pacific.

With the accumulation of upper-air observations, and the development of the Norwegian conceptual model of the extratropical cyclone (Figure 23.2), a better theoretical understanding of the complex nature of ETCs became possible. This deeper grasp of atmospheric physics, together with the development of automated computational capabilities which began in the late 1940s (Charney 1949), have allowed for increasingly successful predictions of the movement and evolution of these sometimes troublesome events.

A POTPOURRI OF EXAMPLES

In the United States, the east coast has been most frequently affected by severe ETC-related weather. A study by Sanders and Gyakum (1980) provides some insight. Their research looked at cyclones which deepen very rapidly (at least 24 mb in 24 hours) and found that these so-called "bombs" seemed to occur along the western rims of oceans (Figure 23.3). It was found that this explosive development occurred when strong upper-level divergence associated with an upper-level trough, met up with strong gradients of low-level temperature along eastern coastlines. They also identified a separate region of rapid intensification over the Pacific Ocean situated roughly between 37–42°N latitude and 160–170°W longitude.

Figure 23.2 An idealized extratropical cyclone as visualized by Bjerknes and Solberg (1922), presenting a plan view and vertical cross-section

Severe extratropical cyclones pepper the history of the eastern United States. A fascinating chapter in the book *American Weather Stories* (Hughes 1976) describes a blizzard which, in March of 1888, severely affected the region from southern New England to Washington, DC. The account describes winds which knocked pedestrians off their fe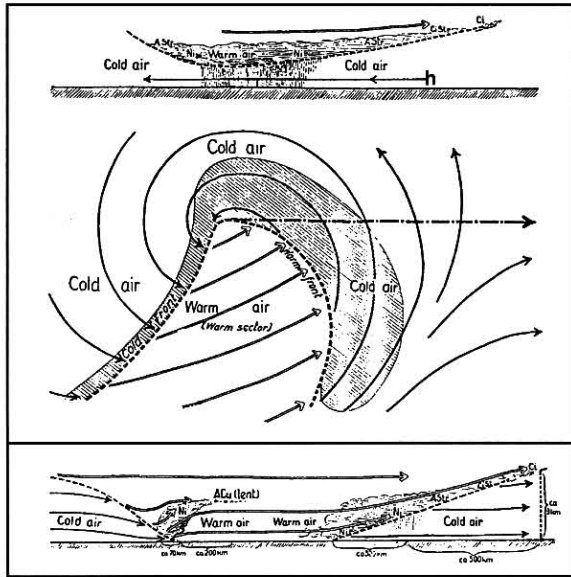et, forcing them to crawl to shelter. Winds approaching hurricane force sank over 200 vessels along the coastline, and piled 100–125 cm (40–50 in) of snow into 9–12 m (30–40 ft) drifts inland. Over 400 people were killed, 200 in New York City alone. Many of the deaths occurred when people, caught outside in "white-out" conditions, walked or crawled blindly till they succumbed to hypothermia. Most of these were dug out of deep drifts days, or even weeks, later.

Another spectacular storm occurred on 25 November 1950 when a surface low developed off the Carolina coast (Figure 23.4) and deepened rapidly, dropping to a central pressure of 978 mb as it moved inland into Ohio. The strength of the resulting winds over the next two days, as well as the size of the area affected, were enhanced by the fact that a massive

surface high pressure area had set up over Labrador. The central pressure of the high reached 1,049 mb. Record snowfalls, and hurricane-force winds, with gusts as high as $50 \, m \, s^{-1}$ (100 kt) at Concord, New Hampshire, affected all of New England, New York, New Jersey and Pennsylvania. Seas were pushed a mile inland in the New York City metropolitan area. A summary of the storm by Smith (1950) reports that more wind damage was produced by this incident than large hurricanes which affected the area in 1938 and 1944.

One of the most intense extratropical cyclones to ever hit the United States affected regions of the eastern United States from the Gulf coast to New England on 12–14 March 1993. Dubbed the "Storm of the Century", the central pressure of the surface low dropped to 961 mb on 13 March, driving winds in excess of $50 \, m \, s^{-1}$ from Florida to New Hampshire. Coastal flooding in Cuba was responsible for damage estimated at $1 billion, with total property damage in the United States estimated to be in excess of $2 billion. This storm is described in great detail in a two-part series of articles in the *Bulletin of the American Meteorological Society* (Kocin *et al.* 1995; Uccellini *et al.* 1995).

The western coastal states of the United States – in particular those in the northwest – are also vulnerable to severe ETC-associated windstorms. It is likely that the severe storms which plague these coastal areas (especially between northern California and Washington state) are a direct result of the explosive central Pacific cyclogenesis area described by Sanders and Gyakum (1980). Local forecasters in Washington and Oregon refer to a time-tested forecast rule regarding severe winds; namely, one looks for cyclones that deepen well out over the Pacific Ocean, just south of latitude 40°N. The severe wind-producing storms in this region typically approach the west coast on a west-to-east path, just south of 40°N, then curve northward beginning around 130°W longitude (Figure 23.5).

Nearly forty years ago, on Columbus Day, 12 October 1962, an intense extratropical cyclone struck the Washington–Oregon coast. At the time, the storm was the most destructive in US history. A central pressure of 960 mb was recorded just off the Oregon coast bringing wind gusts as high as $55 \, m \, s^{-1}$ (105 kt) in northern California. Observing stations in western
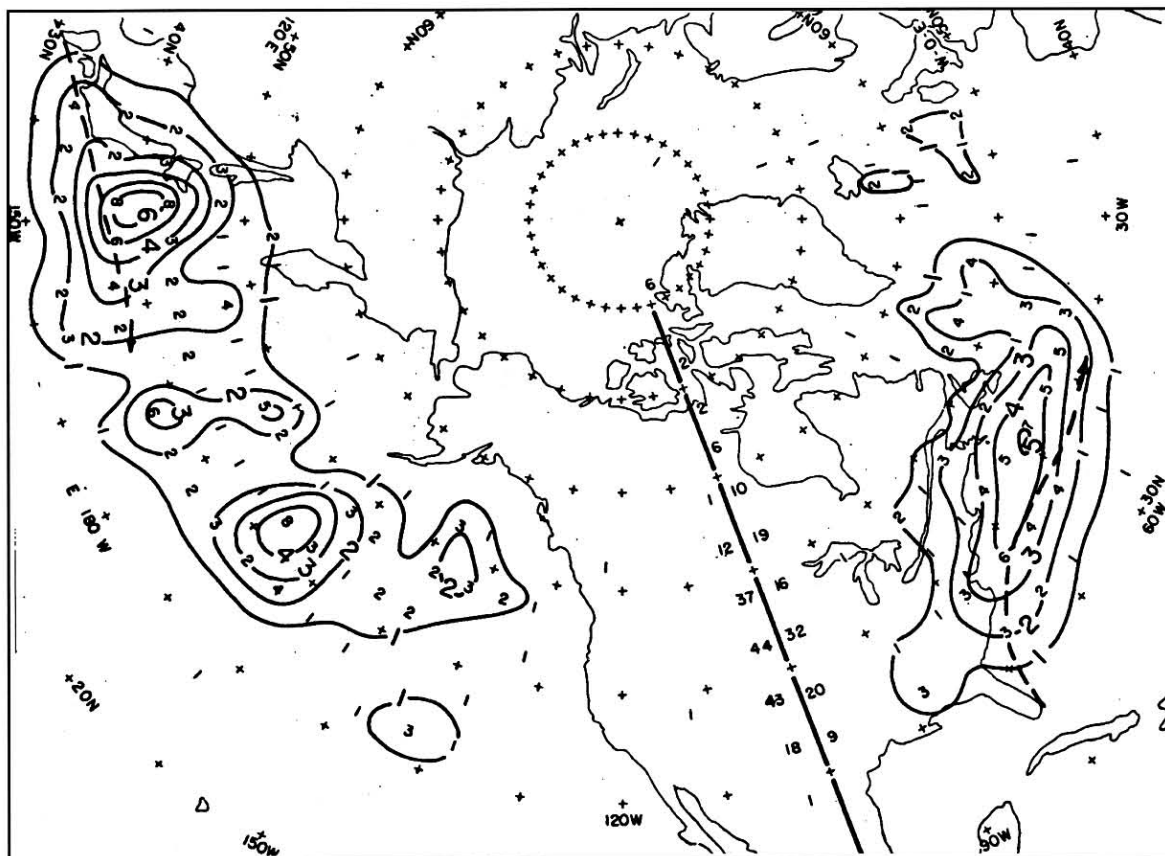
Figure 23.3 Distribution of ETC "bomb" events during three cold seasons. Raw non-zero frequencies appear in each 5° × 5° quadrangle of latitude and longitude. Isopleths are smoothed frequencies, obtained as one-eighth of the sum of four times the raw central frequency plus the sum of the surrounding raw frequencies. The column of numbers to the left and right of the heavy line at longitude 90°W represent, respectively, the normalized frequencies for each 5° latitude belt in the Pacific and Atlantic regions, with a normalization factor of (cos 42.5/cos ϕ). Figure is from Sanders and Gyakum (1980)

portions of both Oregon and Washington state all reported gusts in excess of 45 m s⁻¹, with several reporting gusts in excess of 55 m s⁻¹. Twenty-four people died, and hundreds were injured. Eighty-four homes were completely destroyed, 5,262 severely damaged, and 46,672 received at least minor defacement. Thousands of public and industrial buildings were affected; some were de-roofed, others received collateral damage from falling trees, or flying debris. Additionally, because this area is heavily forested, nearly 2,638,000,000 board feet of timber were lost when trees blew down. Further accounts of this major disaster can be found in Lynott and Cramer (1966),

as well as in internal reports on file at the Portland, Oregon, National Weather Service Office, and from detailed accounts in the area newspapers in the weeks following the event.

Examples of severe west coast windstorms since that time include 27 March 1963, 2 October 1967, 26 March 1971, 15 December 1977, 5 January 1978, 13–14 November 1981, and 10–14 December 1995. Accounts of these, and other severe windstorms around the country, can be found in the publication *Storm Data* (see reference list) which provides a state-by-state listing of all US severe weather on a monthly basis – including a brief description of individual events.

Figure 23.4 Surface analysis from 1230 UTC on 26 November 1950. Central pressure of the surface low at this time is 987 mb. Central pressure of the blocking high to the east is 1047 mb. Thin, black lines are constant pressure analysis lines called isobars. Thicker black lines with triangles and hemispheres show fronts. Multiple isobars over a region indicate strong winds. Here strong southeasterly winds are indicated. (Figure from Smith 1950)
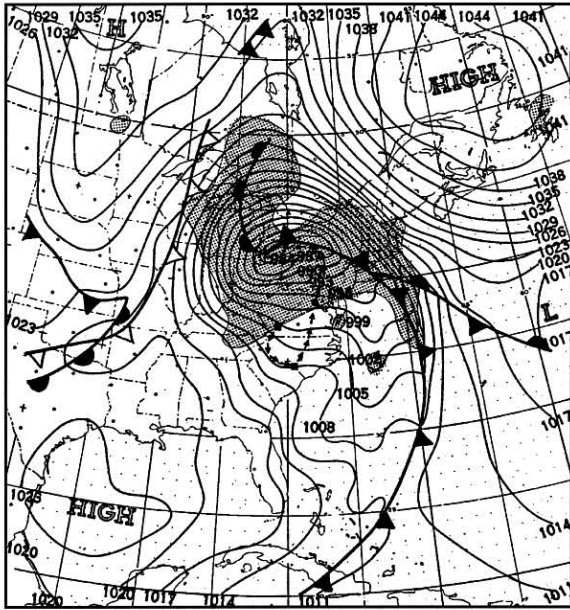
Topography can force significant changes in atmospheric flow patterns, including the formation, or intensification, of cyclones in the lee of mountain ranges. Air flowing from mountainous regions is warmed adiabatically as it moves to lower elevations. This warming leads to divergence aloft, which brings about a reduction in the surface pressure. The downslope motion also stretches the column of air, causing its rotational tendency to increase. When a pre-existing cyclone is present, intensification can occur.

During the winter and early spring, lee slope effects become even more a factor when frigid air moves out of Canada, into the Rockies. During these so-called "Bora" episodes, there is typically a mixing downwards of stronger winds from aloft as the cold air advection occurs. Also, as the frigid air moves eastward onto the Plains, the descending airstream can be locally more dense than that which it is replacing, and experiences a certain amount of gravitational acceleration. The cold air advection may reduce the effects of compressional heating somewhat, but the accelerating air can pour out of the mountains onto the Plains with hurricane force. When an ETC moves away from the mountains during Bora events, strong winds can act to increase the intensity of the temperature gradient in the vicinity of the cold front, thereby creating further intensification of the ETC.

Plate 23.1 shows a large system which intensified in the lee of the Rocky Mountains on the morning of 2 April 1982, bringing severe weather to the entire central Plains. It is the quintessential severe weather-producing extratropical cyclone. A squall line is indicated along the eastern edge of the system. This line of severe thunderstorms produced 56 tornadoes that killed 30 people and injured 383. Hailstones with diameters ranging from 2.5 to 4.5 cm (1 to $1\frac{3}{4}$ in) were common. One of the tornadoes was an F5 – the most intense on the well-known Fujita scale (Fujita 1971). Blowing dust in Colorado (northern plume) was raised by winds gusting from 45 to 55 m s^{-1} at many locations along the lee slopes. All stations in eastern Colorado reported winds of at least 25 m s^{-1}. The southern region of blowing dust (initiating in western Texas) was associated with winds which brought about nearly $2 million in damage.

Cotton *et al.* (1995) describe an out-of-season downslope wind event which affected the Front Range of the Colorado Rockies on 3 July 1993. Though the highest gusts reported during this event reached only 43 m s^{-1} (or 82 kt – modest for this type of event), the damage was unusually severe, because all of the trees had their complete complement of leaves. A full 30–60 per cent (depending on location) of all the trees in northern Front Range cities were affected, and the damage to trees, combined with collateral damage to automobiles, houses, etc., reached into the millions (Plate 23.2).

ECONOMIC AND SOCIAL CONSEQUENCES

Although not as locally severe as the damage produced by tornadoes or hurricanes, the adverse effects from strong straight-line winds in ETCs can be significant. Witness the variety and magnitude of damage
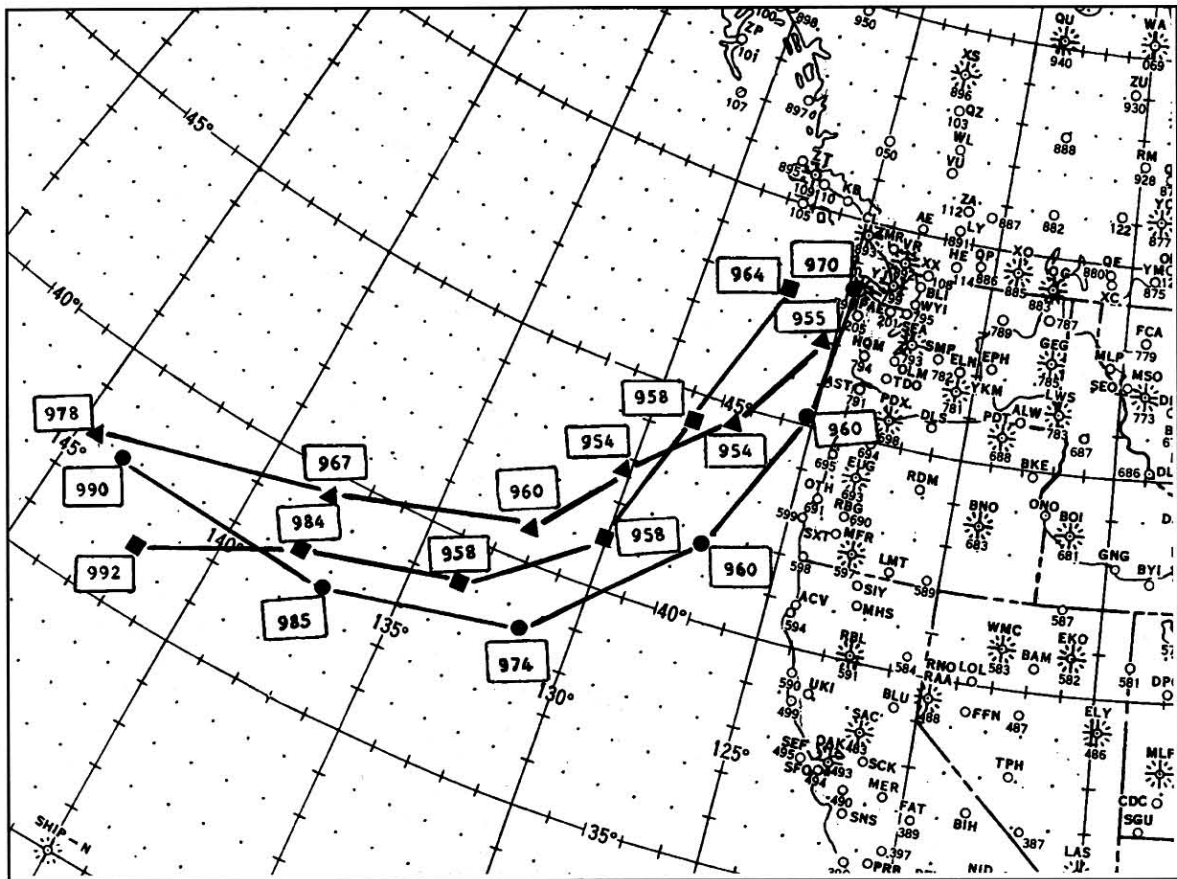
Figure 23.5 Tracks of three extratropical cyclones (ETCs) that produced severe winds in the northwestern United States. The track marked by circles is that of the infamous Columbus Day storm of 12 October 1962 (recorded gusts in excess of 115 kt), squares denote the track of 13–14 November 1981 storm (gusts to 90 kt), and triangles represent the storm of 12 December 1995 (maximum gusts to 110 kt). Central pressures are given in millibars. (Figure courtesy of Dave Willson, National Weather Service Forecast Office, Portland, Oregon)

described in the preceding paragraphs. Adverse effects encompass a wide range of outcomes including deaths, injuries, structural damage, enhancement of other hazard variables, damage to wildlands, interruptions to communications and transportation, and (in some cases) the initiation of adverse physiological and psychological reactions.

Injuries and deaths often occur as a direct result of the wind. For example, gusting winds can cause serious falls that injure, or even kill. Severe winds break branches, snap power lines, and topple trees. These falling objects, and other blowing debris, can result in serious injuries. Strong winds and cold temperatures

lower the *effective* temperature, making hypothermia more likely. Skin has a microscale boundary layer which erodes quickly as wind speeds increase (Rosen 1979). This layer of protection is roughly 4 mm thick in calm conditions, decreases to 1 mm at 5 mph, and is essentially non-existent on exposed skin at windspeeds over 20 mph. Porous clothing is of limited help in reducing these effects. Thus, heat can be transported away from the body very efficiently when winds are strong. This chilling effect is quantified through the variable known as the *wind-chill factor* (Figure 23.6).

Structural damage may have been more a problem
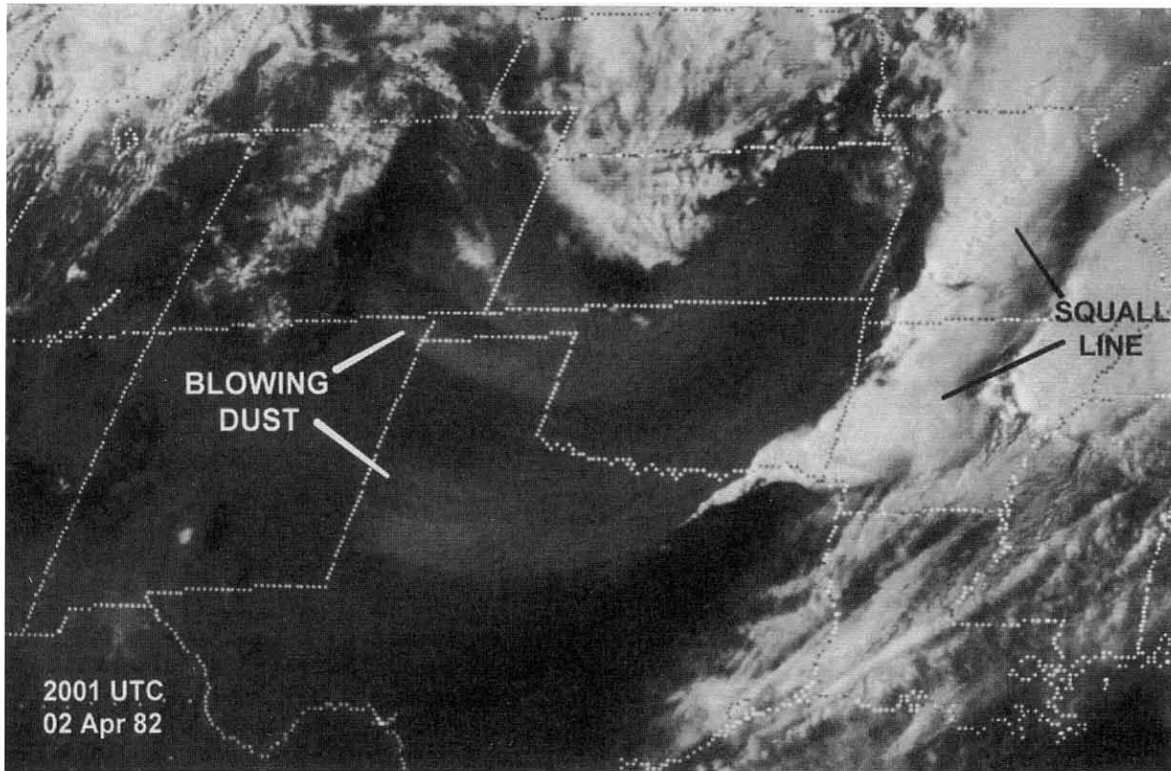
Plate 23.1 Visible wavelength image taken by the Geostationary Operational Environmental Satellite, GOES-East, on 2 April 1982. The picture shows a large extratropical cyclone centered along the northwest Kansas/southwest Nebraska border. Wind gusts as high as 115 kt were reported on the west side of the cyclone (in Colorado). Strong winds to the west through south of the system raised dust plumes that traveled hundreds of miles eastward. In this case, the cold air had wrapped all the way around to the east side of the system, causing a line of thunderstorms that produced tornadoes, large hail and damaging winds. (Photograph courtesy of the National Oceanic and Atmospheric Administration, NOAA)

in the past than it is today. This is because the manner in which strong winds cause damage to buildings did not begin to come under close scrutiny until 1970 when the discipline of wind engineering emerged (Cermak 1993).

Figure 23.7 is a schematic showing how the wind causes stress on certain preferred spots on an idealized building. This example represents a "typical" residential, wood-frame structure. As the wind envelops this building, increased pressure occurs almost immediately on the windward wall, and on the soffit above the wall. Additionally, there is an overall upward acting force on the peaked roof due to the increase of speed as wind is forced around that "obstacle" (similar to the lift on an aircraft wing). There is also

a small upward acting component induced on the upwind edge of the roof when the air is deflected by the roof edge. This is known as the separation pressure. If an upwind window is open the problem is worsened, since air pressure inside the structure fluctuates, intermittently increasing the upward pressure on the roof. However, this latter effect is more important in tornadoes where accelerations are sudden. In straight-line winds, pressure increases resulting from open windows usually have sufficient time to equalize before becoming a factor.

Structures most often fail first at the roof. Once the roof is gone, the lateral strength offered the structure by the roof-to-wall connections is gone, and both exterior and interior walls may collapse. The

Plate 23.2 Photograph of one of several dozen houses in Fort Collins, Colorado, which sustained damage when large, fully-leafed trees were blown down by a moderately intense, out-of-season downslope windstorm on 3 July 1993. (Photograph by author)

sequence can be accelerated by blowing debris from neighboring structures, or miscellaneous objects such as tree limbs, signs, etc. Building codes for residential and low-profile, engineered structures are aimed primarily at keeping the building's roof intact, and walls from buckling. This is accomplished by understanding the forces that winds can be expected to induce on a building through a combination of direct and indirect pressures. Thanks to a better understanding of wind engineering – and to newer building codes based upon that knowledge – much of the damage to structures in ETC wind situations has been reduced, although there is still a disturbing lag in the application of newer techniques (Perry 1987).

Strong winds can have secondary, and sometimes harmful, outcomes through their effect on other elements of nature. For example, along and near coastlines strong winds interact with the oceans,

Equivalent Temperature (°F)

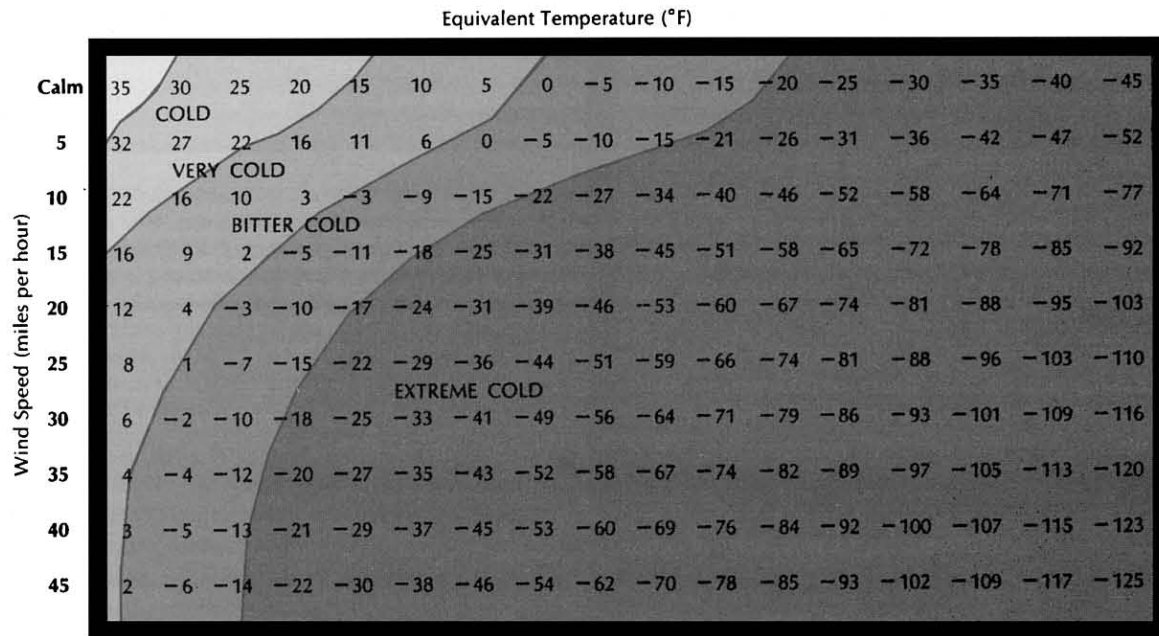| Wind Speed (miles per hour)	35	30	25	20	15	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40	−45
Calm	35	30	25	20	15	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40	−45
	COLD																
5	32	27	22	16	11	6	0	−5	−10	−15	−21	−26	−31	−36	−42	−47	−52
	VERY COLD																
10	22	16	10	3	−3	−9	−15	−22	−27	−34	−40	−46	−52	−58	−64	−71	−77
	BITTER COLD																
15	16	9	2	−5	−11	−18	−25	−31	−38	−45	−51	−58	−65	−72	−78	−85	−92
20	12	4	−3	−10	−17	−24	−31	−39	−46	−53	−60	−67	−74	−81	−88	−95	−103
25	8	1	−7	−15	−22	−29	−36	−44	−51	−59	−66	−74	−81	−88	−96	−103	−110
	EXTREME COLD																
30	6	−2	−10	−18	−25	−33	−41	−49	−56	−64	−71	−79	−86	−93	−101	−109	−116
35	4	−4	−12	−20	−27	−35	−43	−52	−58	−67	−74	−82	−89	−97	−105	−113	−120
40	3	−5	−13	−21	−29	−37	−45	−53	−60	−69	−76	−84	−92	−100	−107	−115	−123
45	2	−6	−14	−22	−30	−38	−46	−54	−62	−70	−78	−85	−93	−102	−109	−117	−125

Figure 23.6 Table of wind-chill factors. To determine the wind-chill find the outside air temperature on the top line, then read down the column to the measured wind speed. For example, if the outside temperature is 0° and the wind speed 20 mph, the rate of body heat loss for a normally clothed person is equivalent to −39° under calm conditions. (Figure from NOAA 1991)
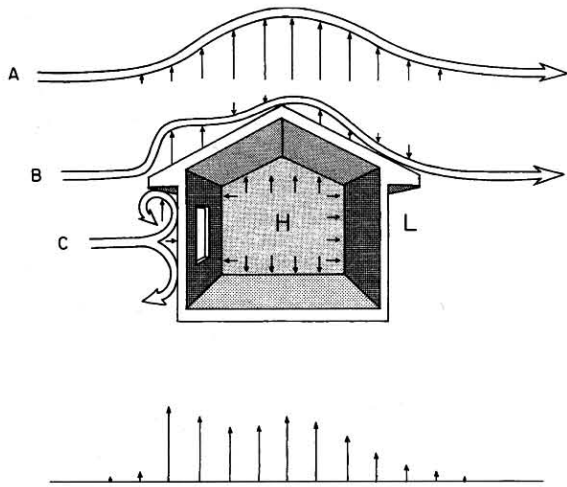
Figure 23.7 Schematic diagram showing how wind-induced, dynamic pressures cause stress at preferred spots on an idealized building. The example represents a "typical" residential-type structure. "A" represents an overall "lift" induced by the aerodynamic pressure (similar to that acting on an airplane wing); "B" is a separation pressure induced by the deflection of the wind as it interacts with the edge of the roof; "C" is a form of stagnation pressure that pushes inward on the wall, and upward on the soffit. Vectors at the bottom are the approximate sums of A, B, and C. Actual vector lengths and their relative sizes depend on the speed of the wind and its angle of attack, as well as on the aspect ratio and shape of the roof. (Figure by author)

bringing dangerously high tides and destructive waves. Damage to shipping and coastal structures can be significant (see Chapter 22). Winter winds can change even modest snowstorms into blizzards, generating "whiteouts" that make driving extremely dangerous, and piling snow into drifts that make road or airport runway clearing operations difficult, or even impossible. Blizzards frequently cause businesses and schools to close, transportation systems to grind to a halt, and may even result in injury or death for those unfortunate enough to be caught outside, away from shelter.

Blowing dust in the western states can also be a problem. Reduced visibility is a frequent cause of automobile accidents, and the damage to vehicles by the blowing dust can be significant. Blowing dust can wreak havoc with paint finishes, and fine dust particulates can destroy machinery if the particles

infiltrate places where moving metal parts are in contact with one another. Furthermore, blowing dust represents soil erosion, a destructive process in which valuable topsoil may be taken from farmers' fields and redeposited elsewhere. For some fascinating articles on duststorms and their hazards the interested reader is referred to Mattice (1935), Choun (1936), or Tannehill (1947).

Interruptions in the transportation and communications systems occur with some regularity in severe windstorms. High winds overturn high-profile vehicles, blow-down telephone and power lines, or (as noted) close roadways due to blowing and drifting snow. At times, even railroad lines can be blocked. Since most workers commute to work by bus, train, or automobile such closures can impact the entire business community. Also, many modern retail businesses run their inventories on a "just-in-time" replacement system, and highway closures can dissipate existing supplies throughout a region very quickly. High winds may even result in airport closures, disrupting the entire country's air carrier network should the closure occur in key cities, such as Chicago, Illinois, or Denver, Colorado.

We have already noted the massive amounts of timber toppled in Oregon on Columbus Day, 1962. But tree breakage is not the only threat to wildlands when strong winds occur. High winds can unexpectedly accelerate small wildland fires into roaring infernos that quickly consume thousands of acres. Such fires can bring extensive structural damage if the fire occurs in populated, or semi-populated, regions. The following is one of many examples.

On Sunday morning, 20 October 1991, in the heavily populated foothills west of Oakland, California, remnant embers from a relatively minor, five-acre brush fire which had been extinguished the previous afternoon were blown onto bone-dry brush and nearby residential shake-shingle roofs. The winds were associated with a weak, but intensifying extratropical cyclone in southern California. Thick, dry underbrush, combined with winds which gusted to as high as 65 kt, fanned a conflagration which left twenty-five people dead, and more than 150 injured. A total of 3,354 single-family dwellings, 456 apartment houses, and more than 2,000 automobiles were completely destroyed, along with 1,600 acres of wildland. The

strong winds had allowed a small incident to grow into the most costly urban-wildland fire in the nation's history, with damage estimates in excess of $1 billion. Furthermore, efforts to fight the fire with airplanes and helicopters were hampered by the winds.

It should not be surprising to learn that direct and indirect monetary damages due to ETC-related windstorms are significant. Though windspeeds most often range from 30 to 50 m s^{-1}, they do occur over broad areas, and the myriad of relatively minor to moderate damage reports can add up to significant dollar amounts. A report from the Property Claims Service – an American insurance industry service group (see reference list) – tallies disasters in terms of estimated dollar loss. According to their listing, of the top twenty-five weather catastrophes from 1965 to 1995, eleven were associated with hurricanes, seven with severe thunderstorm outbreaks (hail, tornadoes, flooding), and seven with winter and springtime extratropical cyclones which included wind as one of the mechanisms of damage. If one were to include the Oakland fire disaster as part of this listing, it would fall number eight in total dollar damage, displacing one of the severe thunderstorm events from the top twenty-five.

EFFECTS ON MOOD AND PHYSIOLOGY

As noted earlier, obvious adverse physiological effects brought about by severe extratropical windstorms include falls, trauma from blowing debris, and increased risk from hypothermia due to the wind-chill. But there are a myriad of less direct effects to consider as well. Some of these are quite subtle, and may have to do with a person's "weather sensitivity."

In many cases the line separating the weather's *physiological* versus *psychological* effects is hard to identify. Part of the confusion between the two has to do with the fact that weather elements actually do induce varying degrees of physiological reactions in the body (Persinger 1980). For example, temperature changes sensed by receptors in the skin cause the hypothalamus to signal other portions of the body to make physiological changes. Blood vessels in the skin constrict when the temperature turns cold – adrenaline levels may increase. High winds can cause adrenaline and serotonin levels to change (Sulman 1976). In fact, the human body's sensory system is *designed* to help the body react quickly to its changing environment. Individual reactions to small changes in bodily chemistry, however, may be substantially different.

Felix Sulman, in his book *Health, Weather and Climate* (Sulman 1976), summarizes results from a wide variety of biometeorological studies. Several are of interest to the current discussion. For example, that researcher notes that only about 30 per cent of the people in an average population group tend to be sensitive to extreme weather, or weather changes. This sensitivity is found to be dependent upon age. At the age of 13–20 years weather affects only about 24 per cent of the people psychologically, at 20–50 years it goes up to 33 per cent, and at 50–60 years the total of those affected can be as high as 50 per cent. Beyond this age, the percentage recedes. Sulman discusses a variety of physiological changes (e.g., hormonal variations, health complaints, etc.), and presents a very interesting listing of thirty-seven illnesses that seemed to occur more frequently in weather-sensitive people during foehn winds. More recently, Brandstatter *et al.* (1988) showed that differing personality types reacted to weather differently. In particular, their study found that "people who describe themselves as nervous, depressed, excitable, tense, or restrained, also report many symptoms of weather sensitivity."

Whether they are induced by internal physiological changes, or not, unusual weather can produce psychological reactions in a significant number of people. Positive correlations have been found between hotter temperatures and feelings of irritation or aggression (Rotton and Frey 1985, or Harries *et al.* 1984), though evidence exists that these aggressive tendencies diminish as heat becomes extreme (Fisher *et al.* 1984). Aggressive feelings have also been correlated with cold temperatures in some individuals (Howarth and Hoffman 1984). Relationships have been shown to exist between high humidity and "bad mood" (Persinger 1975, or Sanders and Brizzolara 1982). However, high humidity seems to act most efficiently when combined with high temperatures, since the body's cooling mechanism (evaporative cooling through sweating) becomes less effective as the air becomes more moist (Persinger 1980).

Studies of the effects of high wind on the human

psyche are less definitive. Howarth and Hoffman (1984) show a direct relationship between higher winds and a reduction in the self-control and cooperative attitude for certain individuals. Sulman (1976) found both physiological and psychological effect associated with the *Sharav* winds in Israel. However, he did not separate the effect of various weather variables within these hot, dry, and gusty desert wind events. In general, results from studies on high winds versus human behavior are inconsistent (Fisher *et al.* 1984), and much work is left to be done in this arena.

With caveats for personal prejudices, this author has read a plethora of literature on the subject of weather versus mood, and summarizes those readings as follows. High winds can affect the mood of "weather-sensitive" individuals on several levels. First, nervousness due to the threat of injury to self or damage to property (from debris and falling objects) may induce higher levels of adrenaline production. Even small amounts of this powerful chemical can foster nervousness and irritability. Since most windstorms associated with ETCs occur during the winter months, wind-chill may also become a factor. Remember that some subjects can become more aggressive at colder temperatures. Finally, there may be an added stress brought on by difficulties encountered when trying to perform even simple tasks outdoors in a strong wind (Poulton *et al.* 1975).

COMMUNITY PREPAREDNESS

The community's ability to deal with severe weather events begins with an awareness of the multitude of effects that accompany weather-related disasters, and formulating specific plans in advance to deal with them. Hazards associated with intense ETC windstorms seem best fitted to advanced preparation as the primary solution. The following are a few examples which address the hazards discussed above.

1 Emergency response systems in most modern cities are more than capable of handling injuries effectively in this type of windstorm, since the total number of injuries is small. Furthermore, ETC winds are normally not strong enough to block more than a few access roadways at a time.
2 Better building codes have mitigated much of the

structural damage which seems to have occurred with great frequency in the past, though notable exceptions still occur.
3 In blizzard-prone regions, drift fences and plowing strategies are being used to reduce those problems to manageable proportions. In regions where drifting snow is so severe that it becomes unmanageable, the best response may be to wait until winds calm somewhat. In such areas plans must include shelters for stranded travelers and, perhaps, snowmobiles as a part of the emergency rescue fleet.
4 The best advance-planning for fires such as that which occurred in Oakland is in the management of excessive undergrowth through controlled burns. Many of the residents in semi-wilderness regions around the country have become aware that burning small, carefully chosen areas *now* can prevent large-scale catastrophes in the *future*.
5 Many cities have begun requiring that power and phone lines be installed underground. This not only makes for better-looking neighborhoods aesthetically, it also reduces the number of interruptions to critical services during unusual weather events.
6 Modern clothing (which has evolved appreciably as a result of the increased understanding of the way heat is lost by the body) is now designed to not only provide layers of insulation, but also to prevent the wind from disturbing the warm protective layer covering the skin. Thus, it is possible to "dress for the wind-chill." Care must still be taken to make sure that clothing and foot gear are waterproof, and sufficient to the event, but clothing is available to mitigate most of the threat. Though people continue to find themselves victims of exposure, the tools are available to prevent most such incidents.
7 Since nothing definitive has been established with respect to the wind and adverse psychological effects, there are no standard responses in place to deal with this aspect of the event. If a person experiences unusual annoyance, nervousness, or agitation during high wind events, the best solution might be to plan indoor activities whenever possible, so that the worrisome sights and sounds are minimized. Well-engineered houses or commercial buildings can provide a sense of security,

and alleviate some, if not all, of the sense of imminent danger.

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