I. Wind Movement

1. Things moving on a moving sphere move to the right in the N hemisphere and to the left in the S hemisphere
2. objects accelerate when they change speed of direction.
3. The speed of a geostrophic wind is directly related to the PGF. If the different between isobars narrows, the speed of the wind (and the Coriolis force will increase.
4. A gradient wind blowing around a low pressure center is constantly accelerating because it is constantly changing direction. This is called CENTRIPETAL ACCELERATION and is directed at RIGHT angles to the flow of the wind.
5. If the wind is not very fast and the curvature is large (i.e. the radius is large) then the centripetal force is weak and compared to other forces is insignificant. If however the radius is small and the wind is strong as happens in tropical cyclones and tornados, then the force is large and becomes important.
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7. Winds around low pressure centers are called "cyclonic", while those around high pressure centers are called "anti-cyclonic"
8. Surface winds are impacted by both the Coriolis Effect and friction slows down the wind so wind speeds tend to increase with height. So winds aloft with the same pressure gradient blow faster than those on the surface and because of their sped are effected more by the Coriolis Effect. The layer of the atmosphere affected by friction is called the friction layer or the planetary boundary.
9. Winds around a low move counterclockwise on the surface, but aloft there is a trough and the gradient wind is moving toward the east (i.e. it is a west wind) A surface high has winds rotating clockwise, but in the air aloft there is a ridge and the gradient winds are again, moving eastward.

II Scales of Motion

1. There are four scales involved: Microscale, mesoscale, synoptic and plantary. He last two are sometimes grouped together as macroscale.
2. Friction arises in several ways and at different levels. It occurs when 2 surfaces seem to adhere to one another. It is more visible in water when small eddies form as water passes an obstruction. Fluid friction is known as "viscosity". When the slowing movement occurs in a gas of fluid, It is the random movement of molecules from one surface moving over to the other that causes the friction. If air is moving horizontally and smoothly (LAMINAR FLOW) over a stationary mass of air, the molecules are moving about – even in the stationary air. This is a minor kind of situation and if alone would only happen just above the boundary layer.
3. EDDY VISCOSITY MECHANICAL EDDIES
    - A. Eddie viscosity occur on a larger scale than molecular viscosity. The internal friction caused by whirling eddies is called "Eddy viscosity". This is caused by the roughness of the terrain – trees, buildings, and other obstructions. They occur hundreds of meters in the air. Frictional drag disappears rather rapidly and by 10 meters (33feet) above the surface winds may be twice as fast as on the surface although the effect of turbulence may be as high as 1000 meters (3,300 ft)

B. Mechanical Viscosity deals with turbulence that occurs from eddies formed by winds blowing specifically over over objects like houses.

III Thermal Turbulence

1. Surface temperature can also cause turbulence. The Earth heats, air rises and convection cells form. The motion is called “thermal turbulence”. It increases with the amount of heating and the degree of atmospheric instability. The more heat the greater in the instability. Turbulence may occur as high as the base of the stratosphere (10 k or 6.2 miles up)
2. Friction of air flow (viscosity) is a result of the exchange of air molecules moving at different speeds. The exchange happens by random molecular movement (molecular viscosity) at a very minor level. Turbulent motions (eddy viscosity) is more dramatic. The frictional aspects of air movement are therefore more influenced by mechanical and thermal turbulent mixing. The depth and hence the frictional result of the mixing depends on three main factors:
   (a) surface heating – which produces a steep lapse rate and strong thermal turbulence
   (b) strong wind speeds which produce strong mechanical turbulence
   (c) rough or hilly landscape which produces strong mechanical turbulence
   when these three factors occur simultaneously, the frictional effect of the ground is transferred upward quite high and the wind at the surface is strong and gusty

IV. Eddies

1. Eddies form on the LEEward side of an object. Any object regardless of size can cause them, although the larger the object and the faster the wind the greater the eddy. Rough terrain will produce more (and larger) than a smooth terrain.
2. winds of 40 knots and above passing over a mountain with atmospheric stability can produce several waves and eddies with eddies being produced under each wave. Eddies produced in this fashion are called “roll eddies” or “rotors”. They have a violent vertical motion and produce strong turbulence which is dangerous to planes.
3. Eddies often produce a wind flow on the surface that opposes the direction of the air above it.

V. Wind shear

1. Turbulent eddies occur not only near the surface but aloft as well when the wind suddenly changes speed or direction a (or both) very abruptly. Such a change is called “WIND SHEAR” and the shearing creates eddies along a mixing zone. If these occur in clear air it produces “clear air turbulence (CAT)”. (see slide) This turbulence can be extremely dangerous to aircraft. These down winds are sometimes called “air pockets”

VI. Wind Force

1. The force of the wind on an object is proportional to the wind speed squared. So a small increase in wind ups the force dramatically.
2. The generic formula for wind load is F = A x P x Cd where F is the force or wind load, A is the projected area of the object, P is the wind pressure, and Cd is the drag coefficient. The wind pressure = 0.00256 x V^2
3. Objects on the ground can be moved by the wind. Winds have been measured at more than 230 mph. Soil, silt, socks erode and alter landscapes. Snow has been rolled into barrel like shapes and moved along. These are called “snow rollers”. Moving sands produce dunes. Snow is moved from open areas and blows until it meets and object like a town where it may pile up.

4. Wind with sand can damage crops. It also causes plants to increase their rate of respiration and in warmer areas with low humidity this can actually dry out plants. Land where natural vegetation has been removed and there has been drought makes the soil ripe for erosion, The Dust Bowl of the 1930's was such an event.
5. Winds blow fires and spread forest fires and fires into areas with crops. The wind adds oxygen, blows sparks that spread the fire and imperils livestock and homes.
6. Crops are often protected by "windbreaks' or "Shelter belts" – usually a series of different kinds of trees planted perpedicIar to the prevailing winds. Air traveling through the breaks is "broken down" into smaller eddies. Trees planted too closely together may cause downdrafts which can damage crops.

VII Wind and Water

1. Wind has an effect on water as well. It makes most waves. Frictional drag on the water creates ripples which create larger surfaces for the wind to act on.
2. The wind transfers energy to the water. The wave is not actually moving, the energy is moving through the water as you can see if you watch something floating in the water near the shore. The object simply rises and falls as the energy lifts the water as it passes by
3. The waves are dependent on three things:
   (a) wind speed
   (b) wind duration
   (c) fetch
4. A 50 knot wind blowing over a distance of 2600 km (1600 miles) can raise a wave some 15m (49 feet high) Thus a stationary storm system centered in the open sea can generate a wave measuring more than 31 m or 100 feet high.
5. When waves (called "seas" when they are in the area of the wind that created them) move to less windy areas, the waves become more rounded and are known as "swells"
6. Waves reaching the shore can transfer their energy to the land and can do serious damage to beaches and homes built along them.
7. Winds across lakes may change direction because the friction over the land is greater than over the ocean and as a result, the winds speed up as the start over the water. The increased speed causes a stronger Coriolis Force and there is a change in wind direction.
8. Winds moving over large lakes can cause seiches (water that moves back and forth like water in a tub)

VIII. Local Wind Systems

1. The same isobaric pressures appear at different heights in low pressure and high pressure centers.
2. The air to the north is cooler and hence denser and the result is the isobaric surfaces are at lower levels where than in the warmer highs.
3. Notice that the isobar surfaces are lower over surface highs than over surfaces lows. As a result, air aloft has a lower pressure (at the same altitude) over highs than over lows. As a result, the pressure gradient remains from higher pressure to lower pressure, except the higher pressure aloft is over the surface low and the lower pressure aloft is over the surface high!
4. So at both levels of these cells the air moves with the PGF from higher to lower pressure.
5. This is known as a THERMAL CIRCULATION. The regions of SURFACE HIGH AND LOW pressure created as the atmosphere either cools or warms are called THERMAL (COLD-CORE) CELLS and THERMAL (WARM-CORE) CELLS. They are usually shallow systems no more than a few kilometers above the surface. They weaken with height.

6. Thermal pressure systems are characterized by being shallow, weakening with height, and being maintained by local surface heating and cooling.
7. Sea and lake breezes

   The sea breeze is a kind of thermal circulation caused by the uneven heating of the land and water causes these "MESOSCALE" winds.

8. Mountain and Valley Breezes

a. During the day sunlight warms the valley walls ad the air above them. The heated air being less dense than the surrounding air rises forming a gentle up slope breeze – a valley breeze. At night the situation reverse. The mountain slopes cool quickly chilling the air so it becomes dense and sinks into the valley producing a mountain breeze (gravity breeze or drainage breeze are other names for it). These are more common in summer and upslope winds start early and reach their peak around midday. If they have a lot of moisture, they may cause cumulus clouds above the summits and in the early afternoon, showers or thunderstorms might occur. Downslope winds start in the late evening and continue until just before sunrise.

9. Katabatic winds. Any downslope wind is a katabatic wind, although the term is used for stronger winds than the breezes. These may tear down elevated slopes at hurricane speeds (more than 74 mph) although many are about 10 knots or less.
10. Chinook (Foehn) Winds

    Chinook winds are warm dry downslope winds that slip down the eastern slope of the Rockies. These also occur in many places. In the European Alps they are called *Foehn* and in Argentina, *azonda.*

11. Santa Ana Winds
    a. These are warm dry winds that blow downhill from E or NE into Southern California. The air comes down from a high desert plateau and funnels through mountain canyons in the San Gabriel Mountains and over L.A. into the San Fernando Valley and thence out over the Pacific. The winds blow as fast as 90 knots in the Santa Ana Canyon. They result from a high pressure over the Great Basin. Clockwise circulation around the anticyclone forces air downslope from the Basin. Thus compressional heating is responsible for the warmth. Since it originates in the desert it is already warm to begin with and so is hotter than one might expect.
12. Similar to Santa Ana winds are "CALIFORNIA NORTHERS" which impact the northern half of California's Central Valley. These downslope winds are heated by compression and on Aug 8. 1978, Red Bluff California (a town on a line with Philadelphia, recorded a high of 119^0F for 2 consecutive days
13. Desert Winds
    a. All size winds develop over the deserts. Some are huge – one as big as Spain formed in Feb 2001 over the Sahara. It moved westward along the African Coast then northward for thousands of miles.
    b. During the 1930's large dust storms formed over parts of the Great Plains and some, lasting as long as 3 days, spread dust for hundreds of miles over the Atlantic.
    c. The "HABOOB" is a dust or sandstorm whose name comes from Arabic. It forms as cold downdrafts form along the leading edge of a thunderstorm. These lift dust and sand into a huge tumbling dark cloud that may extend horizontally for over 100 km and rise vertically to the base of the thunderstorm. They are most common in the African Sudan, but occur elsewhere as well. Southern Arizona and other parts of the desert southwest see them on occasion.

14 Dust Devils

a. On a small scale wind may produce rising spinning columns of air that pick up dust or sand from the ground. These are called “dust devils” or ”whirlwinds” . They normally form on clear hot days over a dry surface where most of the sunlight goes into heating the surfaces rather than evaporating water from vegetation. The atmosphere above becomes unstable, convection sets in and heated air rises often lifting dust, sand and dirt high into the air. Wind, often deflected by small surface barriers, flows into the area, rotating the rising air. Depending on the nature of the deflecting object the spin may be cyclonic or anti cyclonic.