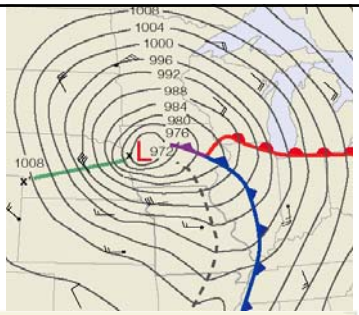
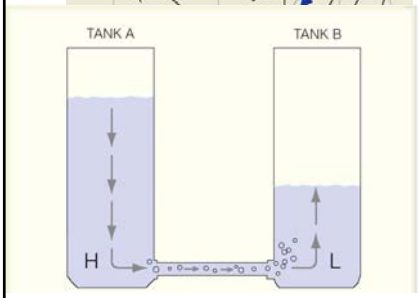
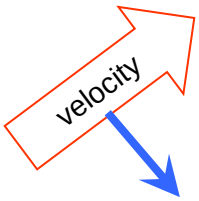




Pressure gradient force:
Pressure diff/distance

The key to solving the mystery that winds blow around, instead of towards, the low pressure center.



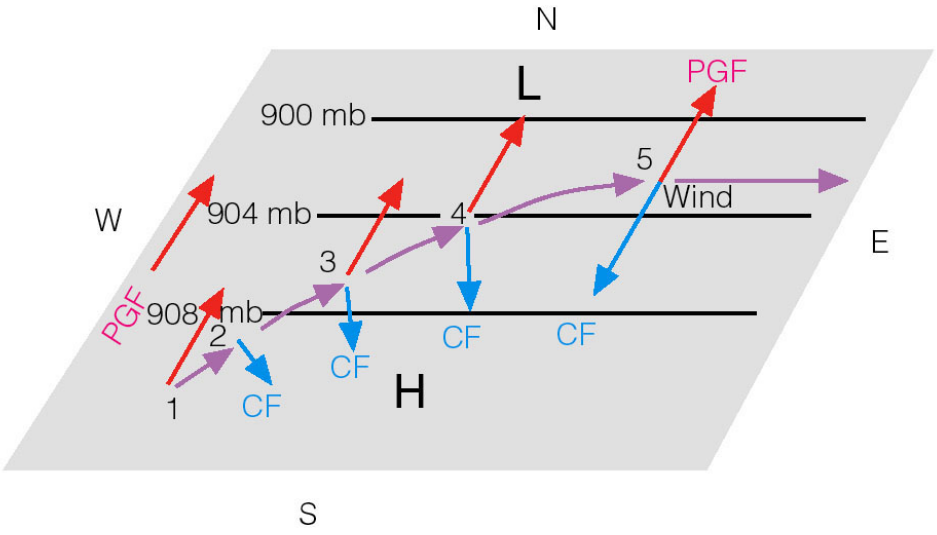
Coriolis Force

= 2 x Earth Rotation Rate x sin (latitude) x velocity

The Coriolis force (CF) turns wind in parallel to isobars

→ Geostrophic wind

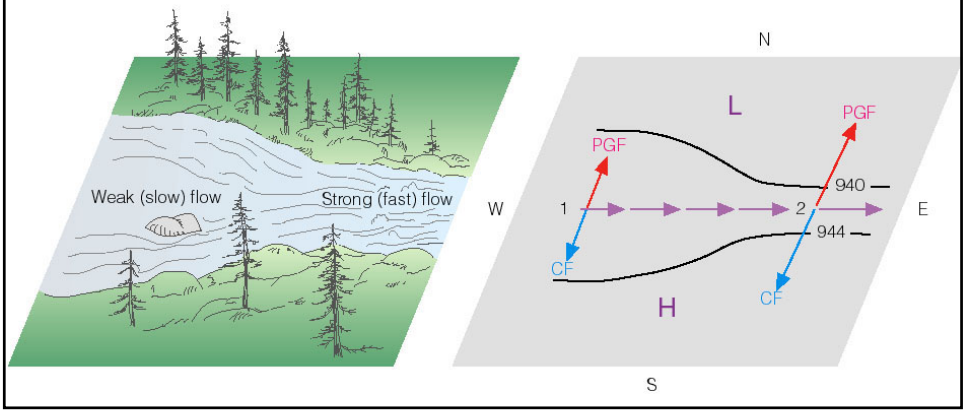
A balance between PGF and CF



Geostrophic wind

(William Ferrel, 1856; Buys Ballot, 1857)

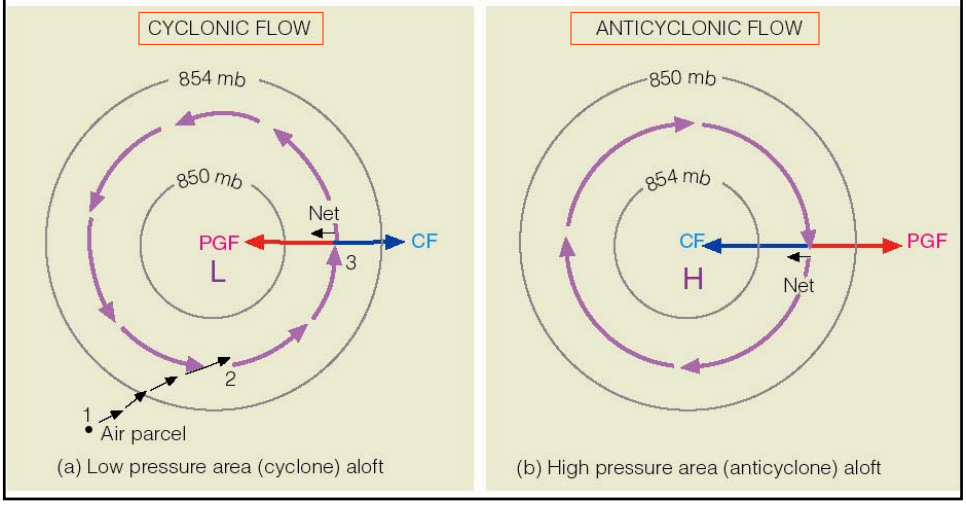
- Direction: in parallel to isobars, with high pressure to the right and low to the left in the Northern Hemisphere (opposite in the Southern Hemisphere)
- Magnitude: proportional to the spacing of isobars (analogous to river flow)



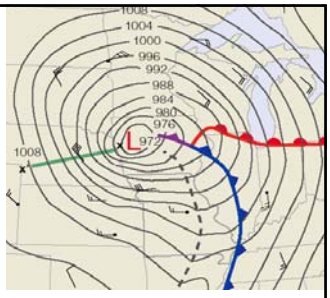
Gradient wind

a better approximation for curved wind than geostrophy, important in hurricanes

Balance among the pressure gradient force, Coriolis force, and centrifugal force due to curved flow



Bottom-line points

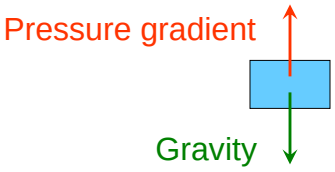


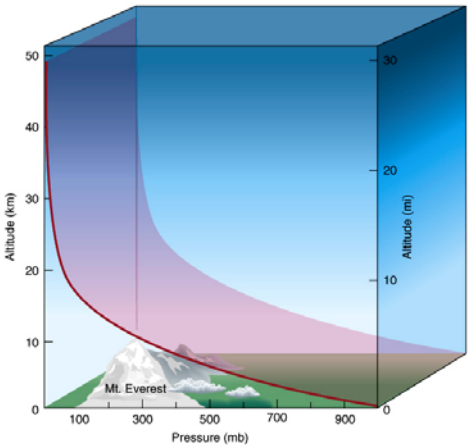
- Why is there wind? Horizontal variations in temperature (pressure gradient force).
- In NH, wind blows counter-clockwise around a low pressure, and clockwise around a high. (Facing the direction wind blows, high pressure to the right and low to the left.) Empirical
- Why does it blow the way it is? Balance of pressure gradient and Coriolis forces. Physical/dynamical
- Coriolis force: An apparent force due to Earth's rotation, directing to the right of the wind vector and proportional to the wind speed in magnitude.
- Surface friction helps the wind to gain a component from high toward low pressure.
- In SH, all the rules remain the same except reversing the direction.

Hydrostatic Balance

What keeps air from rising due to the upward pressure gradient force?

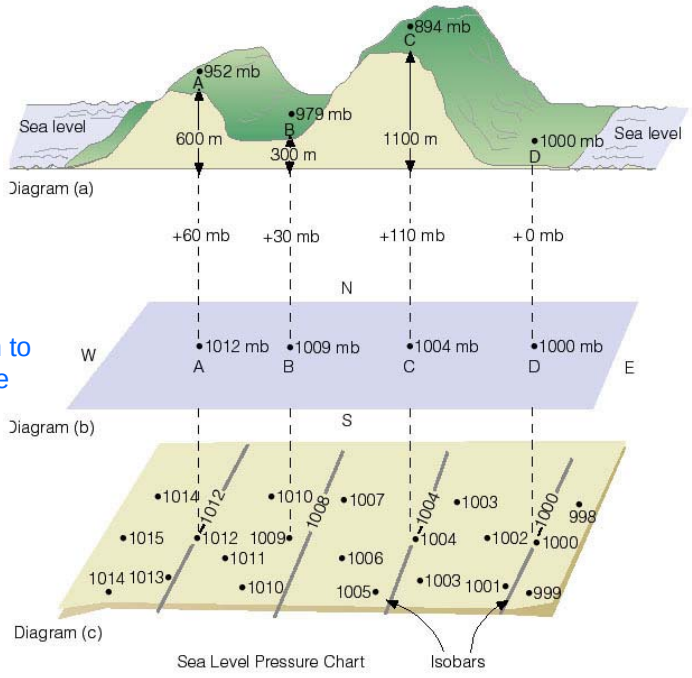
A balance between gravity and the pressure gradient force.





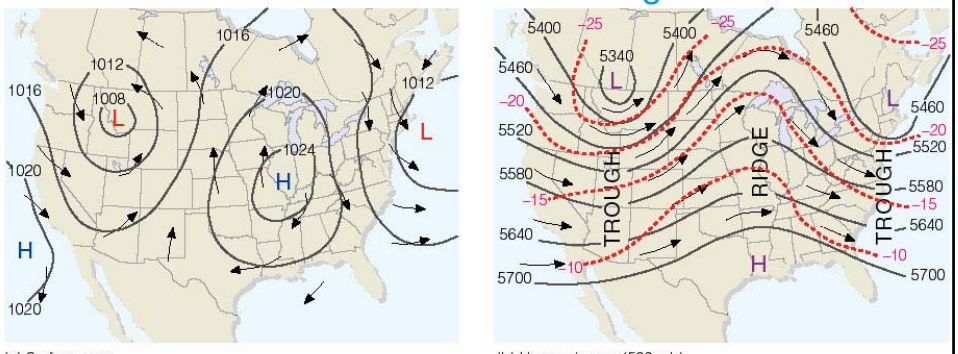
Station pressure

Altitude correction to
Sea level pressure



Trough

Ridge



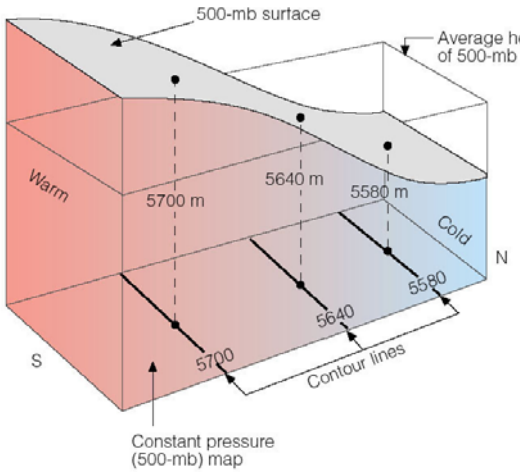
(a) Surface map

(b) Upper-air map (500 mb)

Isobaric Maps:

Measuring height on surfaces of constant pressure

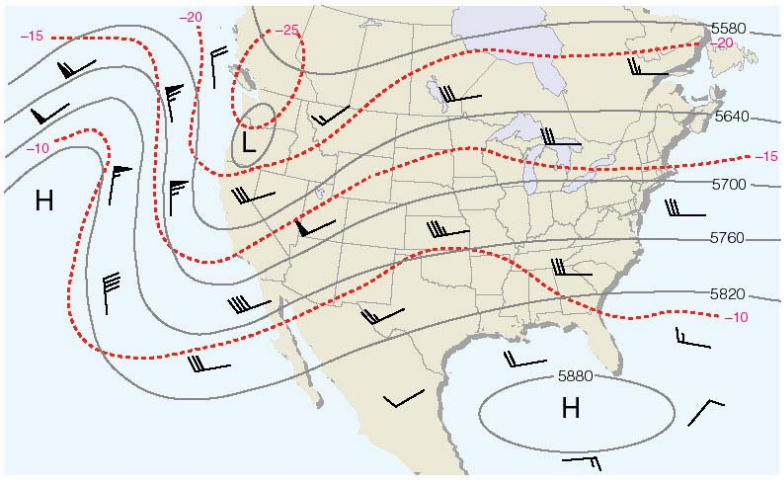
A vertical coordinate transformation
to simplify mathematical equations for atmospheric motion

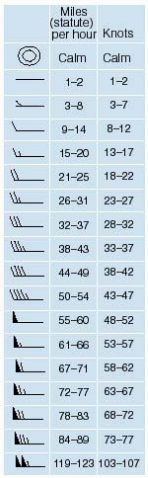


- Height contours on isobaric maps are equivalent to pressure contours at sea level.
- Warmer air column expands in volume/vertical → the 500 mb isobaric surface is taller than a cold air column.

Meridional wind

Zonal wind

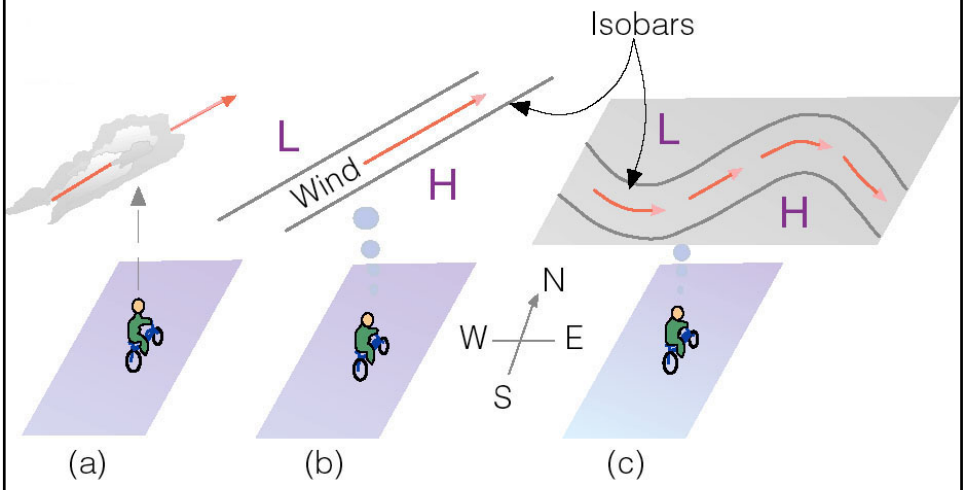


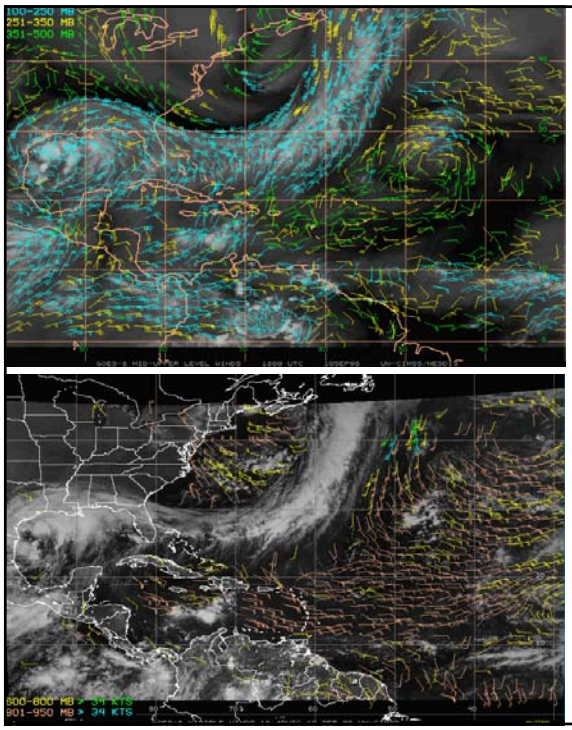


500 hPa map: wind, geopotential height, & temperature

The westerly jet stream → longer westward-bound flights.

Read cloud for wind direction and pressure patterns





Read Clouds II

GOES upper-level winds from cloud drift, water vapor Imager & Sounder

September 10, 1998

GOES Visible Winds at low levels

http://cimss.ssec.wisc.edu/tropic/

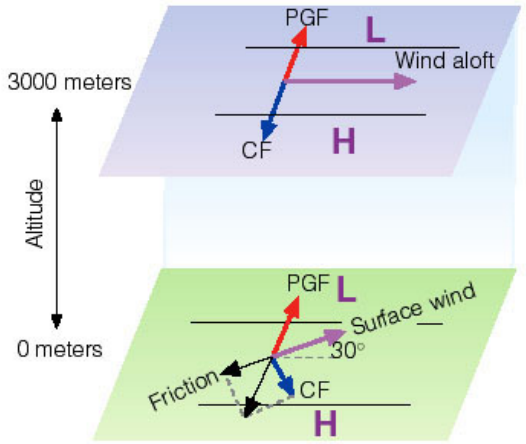
Friction

- Air in contact with the surface experiences frictional drag, effectively slowing the wind speeds.
  - Magnitude: depends upon wind speed and surface roughness
  - Direction: opposite to the movement of the air parcel
- Planetary Boundary Layer (PBL) – the lowest ~1-2 km of the atmosphere which experiences friction.
- Free Atmosphere – the remaining atmosphere which is free from frictional effects above the PBL.

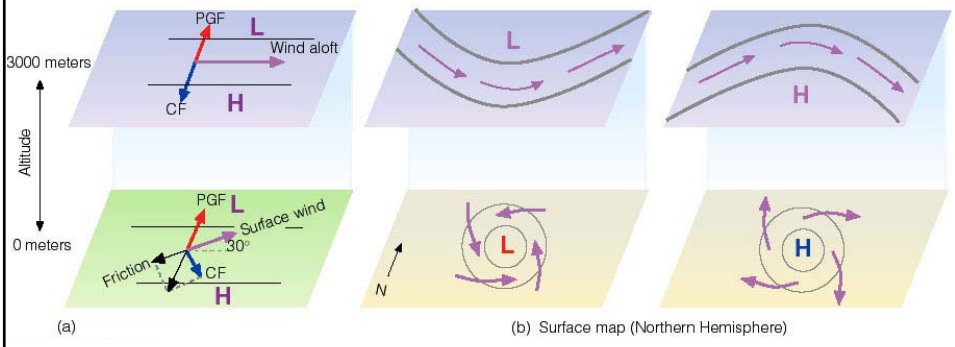
Effect of surface friction?

If the wind speed is reduced by friction, the Coriolis force will decrease and not quite balance the pressure gradient force

→ Force imbalance (PGF > CF) pushes wind in toward low pressure



Friction allows surface wind to attain a cross-baric component directing from high to low.

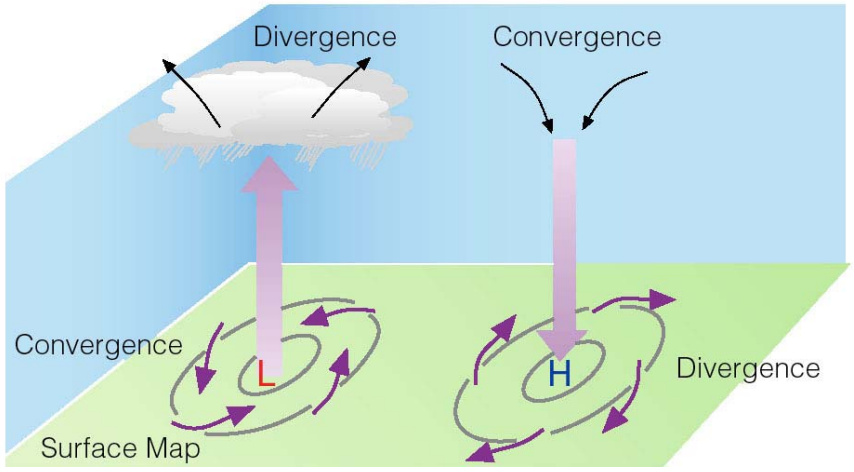


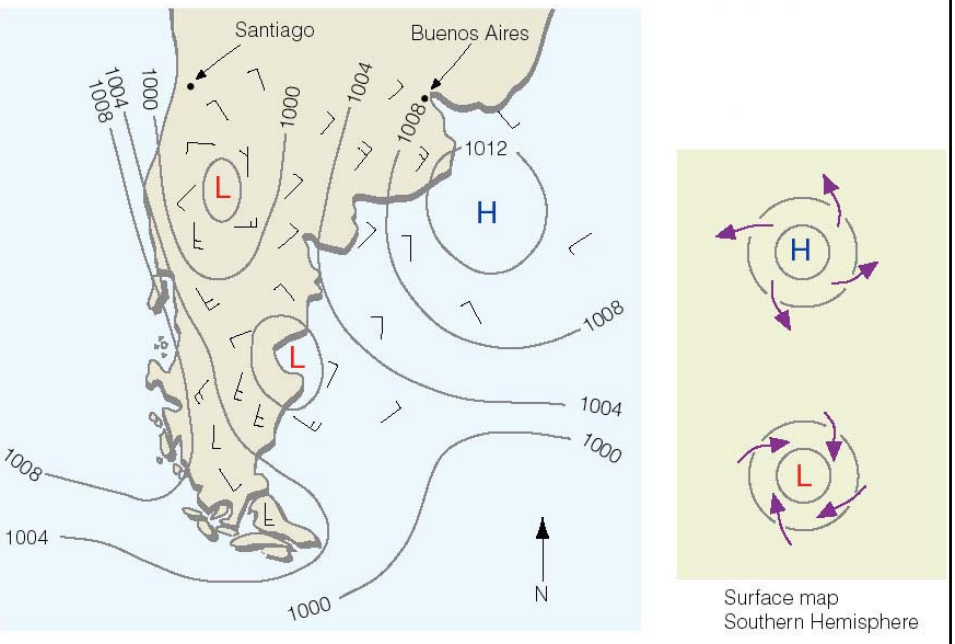
Inflow converging onto the low

Outflow diverging from the high

Upward motion in lows
→ Rain & other severe weathers
→ Hurricanes always have low-pressure centers (latent heat of condensation fuels the growth of storm)

Subsidence in highs
→ Fair weather and dry





Review of Forces

1. Pressure Gradient Force – changes in pressure over a distance causes air to move.
2. Gravity – only acts in the vertical direction
3. Coriolis Force – due to Earth's rotation
4. Centrifugal Force – when there is curved flow
5. Friction – only important near the Earth's surface

Only the first two forces listed above can cause winds in air that is initially at rest, and the last three are in action only when there is relative motion.

Review of Force Balances

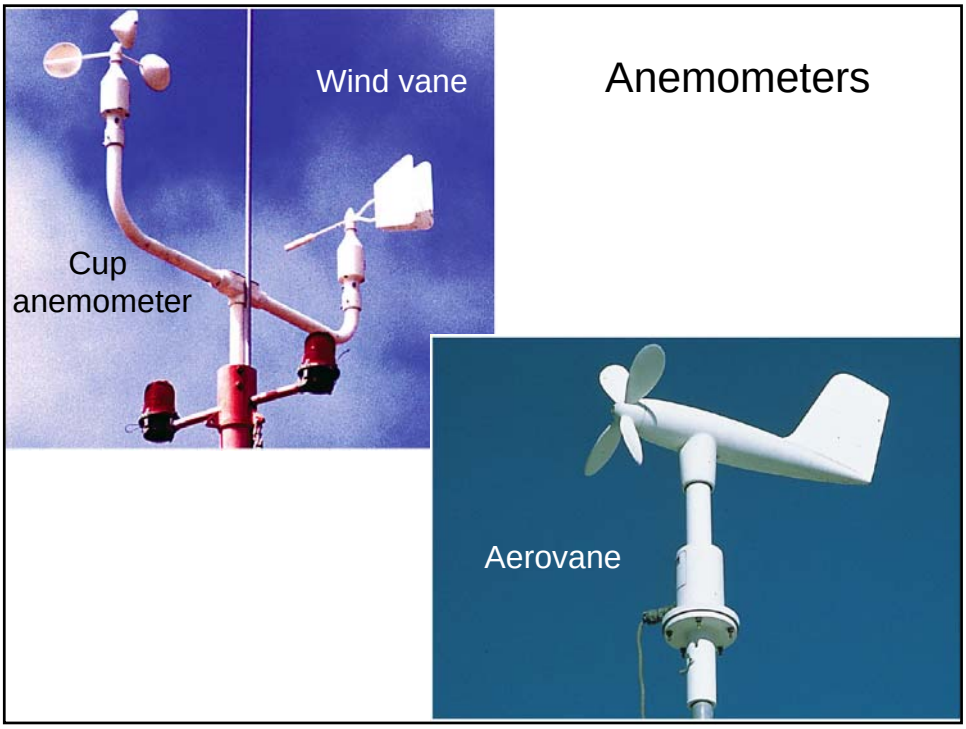
- Geostrophic Balance

  Pressure Gradient Force = Coriolis Force

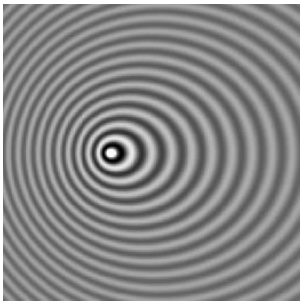
  (+ friction in PBL)
- Gradient Wind Balance

  Pressure Gradient Force = Centrifugal + Coriolis Forces
- Hydrostatic Balance

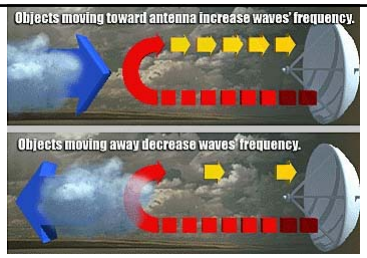
  Pressure Gradient Force = Gravity

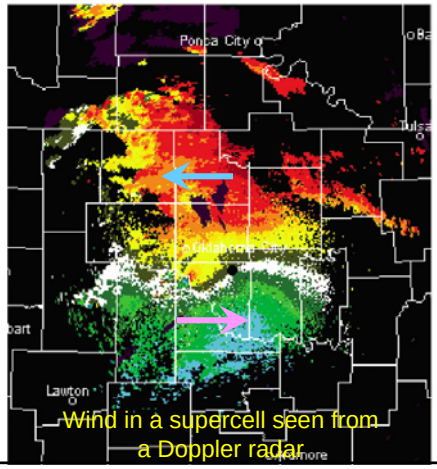


Doppler (1842) effect



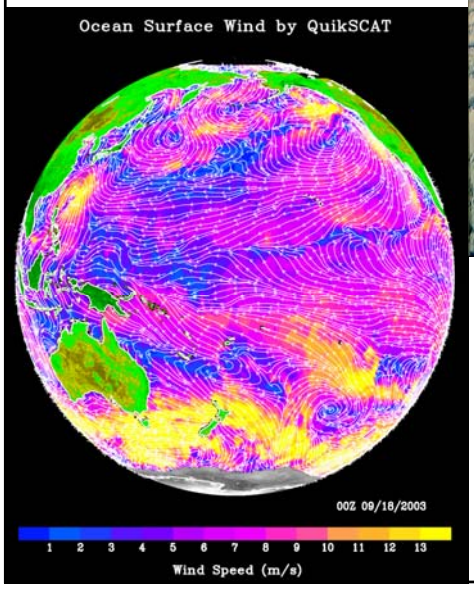
A source of waves moving to the left. The frequency is higher on the left, and lower on the right. → High-pitch sound from an approaching car.

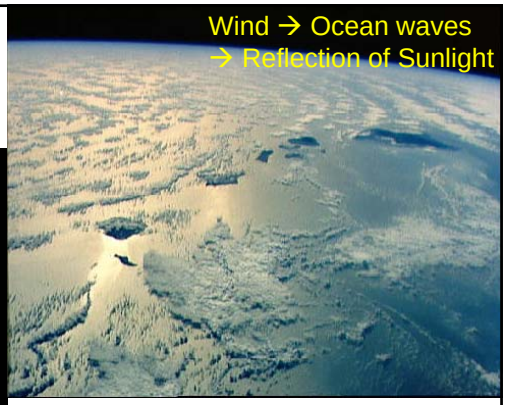




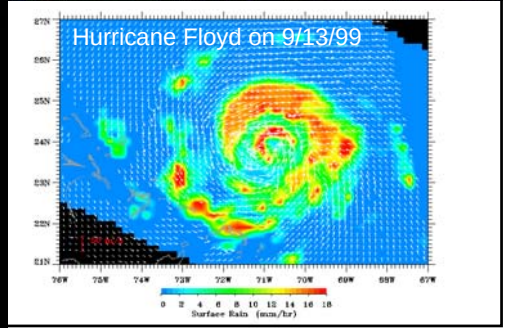
Wind in a supercell seen from a Doppler radar

All-weather global wind observations by **satellite-borne microwave scatterometer**



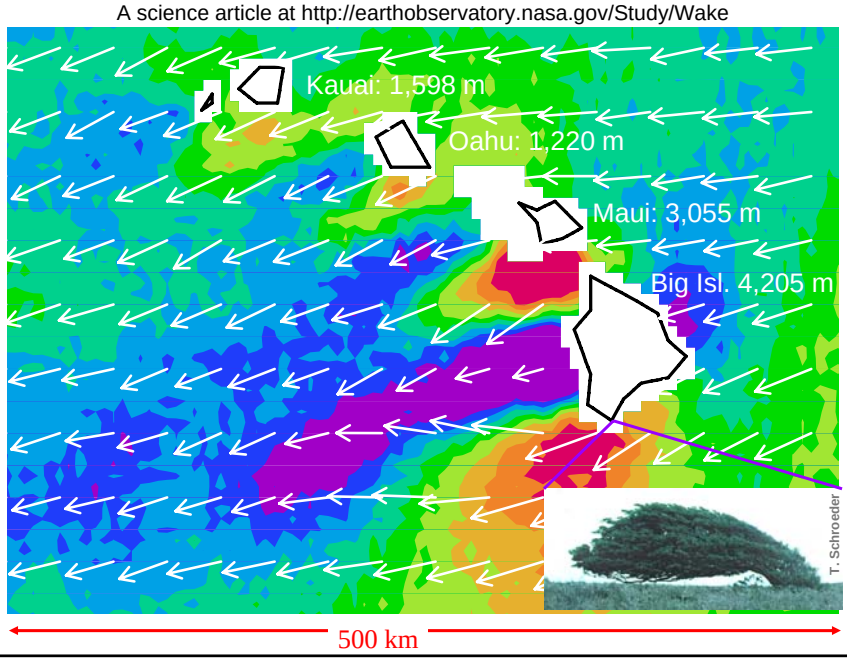


Wind → Ocean waves → Reflection of Sunlight



Wind near Hawaii (high in red & low in blue) from satellite scatterometer

A science article at http://earthobservatory.nasa.gov/Study/Wake



Key Words

- Station pressure, sea level pressure
- Isobar, surface map, isobaric map
- Mid-latitude cyclone, anticyclone
- Trough, ridge
- Pressure gradient & Coriolis forces
- **Geostrophic wind**
- Gradient wind, contripetal force
- Zonal and meridional wind
- Friction layer (difference in weather between lows and highs)
- Hydrostatic equilibrium