# Pressure Gradients 

GEOG/ENST 2331 - Lecture 7 Ahrens: Chapter 8
Lab 2

# Mechanics: $F=m a$ 

What exerts force in the atmosphere?
s Pressure gradients
m Gravity
: Coriolis effect
a Friction

Review: Pressure
*) Atmospheric pressure is force per unit area exerted by atmospheric gases (all directions)

- Commonly expressed in millibars or hectopascals
s. $1 \mathbf{h P a}=100 \mathrm{~Pa}=1 \mathrm{mb}$

3 Surface pressure is close to 1000 hPa
${ }_{4}$ Varies with time and place


Ideal Gas Law

- Pressure, density and temperature of air are related by the Ideal Gas Law:
: $P=\rho T C$
: $C$ is the gas constant
\& For air, $C=287[\mathrm{~J} / \mathrm{kg} \cdot \mathrm{K}]$
- See Ahrens pp. 228-229

A\&B: Figure 4-1

Partial Pressures

- In a mixture of gases, each individual gas exerts its own partial pressure
as. E.g. $\mathrm{pCO}_{2}$ or $\mathrm{pH}_{2} \mathrm{O}$
* Dalton's Law: the sum of the partial pressures equals the total pressure

Charting pressure

* Isobars - lines of constant pressure
* Pressure Gradient - the change in pressure over distance
s Zonal
Meridional
sor Vertical
al Blocking situations


Ahrens: Figure 8.10

# Pressure gradient force 

TANK A


- Tendency for fluids to flow from high pressure to low pressure

Ahrens: Fig. 8.17

## Horizontal pressure gradient force

Horizontal pressure differences are usually slight.

Strong pressure gradients indicate strong winds and storms.

Ahrens: Fig. 8.18


$$
\mathrm{PGF}=-\frac{1}{\rho} \frac{\Delta P}{\Delta x}
$$

## PGF

PGF is always perpendicular to isobars

Closely spaced isobars indicate stronger PGF

Ahrens: Fig. 8.19


## Vertical Changes in Pressure

- Pressure decreases with height
- Exponential: roughly $50 \%$ every 5.5 km


A\&B: Figures 4-2 and 4-3


## Coordinate system

Cartesian system ( $x, y$ )
$x$ - zonal (East/West) direction - East is positive $y$ - meridional (North/South) direction - North is positive $z$ - vertical - up is positive
$u$ - velocity in the $x$ direction
$v$ - velocity in the $y$ direction

Gravitational force
人) Force of attraction between two masses

- Earth approximation:
: GF $=m g, g=9.8 \mathrm{~N} / \mathrm{kg}$
* Vertical force (always pulls 'down')


## Hydrostatic Balance

A vertical balance of forces

- Pressure gradient force and gravity are equal
- No net vertical acceleration

$$
\Delta P=-\rho g \Delta z
$$



Higher pressure

Ahrens: Fig. 7, p. 250

## Vertical pressure gradients

Pressure always decreases with height
Vertical pressure gradients are balanced by gravity

Scale height, $H$, is a vertical distance over which the pressure drops by a constant factor

$$
\begin{aligned}
& P=\rho C T \\
& \Delta P=-\rho g \Delta z
\end{aligned}
$$

$$
H=\underline{C T}
$$

$g$
$T$ is the average temperature in the column of height $H$

## Scale Height

3) If $T$ is large, then $H$ is large and the pressure reduces more slowly with height.
s If $T$ is small the opposite is true.
(2) For example, the tropopause occurs at 250 hPa . The height of the tropopause is 8 km at the poles and 13 km at the equator.
m This is consistent with the scale height analysis

$$
H=\frac{C T}{g}
$$



## Temperature and scale height



A\&B: Figure 4-7

## Upper air

Height of constant pressure decreases with temperature


Ahrens: Figure 8.13

## Altimeters



Ahrens: Fig. 2, p. 237

Constant altitude surfaces


Ahrens: Figure 8.14

## Isobaric charts


(a) Surface map

Pressure (in hPa)

(b) Upper-air map (500 hPa)

500 hPa height contours (in m).

Ahrens: Figure 8.16b


Elongated zones of high and low pressure are called ridges (a) and troughs (b), respectively.

A\&B: Figure 4-20

## Atmospheric Pressure Examples

| mm Hg in Hg $832.6-32.78$ |
| :---: |
| 825.1-32.48 |
| 817.6-32.19 |
| 810.1-31.89 |
| 802.6-31.60 |
| 95.1-31.30 |
| 787.6-31.00 |
| 780.1-30.71 |
| 772.6-30.42 |
| 765.1 - 30.12 |
| 757.6-29.82 |
| 50.1-29.53 |
| 742.6-29.24 |
| 735.1-28.94 |
| 727.6-28.64 |
| 720.1-28.35 |
| 712.6-28.05 |
| 705.1-27.76 |
| 697.6-27.46 |
| 690.1-27.17 |
| 682.6-26.87 |
| 675.1-26.58 |
| 667.6-26.28 |
| 660.1-25.99 |
| 652.6-25.69 |
| 645.1-25.40 |
| 637.6-25.10 |

-1083.8 hPa: Highest recorded sea-level pressure: Agata, Siberia, associated with the Siberian High that forms over northern continental Siberia during dark, frigid winters. December 31, 1968.
-1079.6 hPa: Highest recorded Canadian sea-level pressure: Dawson, Yukon Territory. February 2, 1989.
« Strong high-pressure system
1013.25 hPa Standard sea-level pressure

Deep low-pressure system
970
960
950
$940 \sim 940.2 \mathrm{hPa}$ Lowest recorded Canadian sea-level pressure:
930
920
910
900
890
880
870
860
850
1100
1090
1080
1070
1060
1050

- 1040

1030
1020
1010
1000
990
980

$\leftarrow$ St. Anthony, Newfoundland. January 20,1977.
920 hPa: Hurricane Katrina during landfall. Buras, Louisiana, USA. August 28, 2005.

882 hPa (26.04 in.) Hurricane Wilma (October, 2005)
870.0 hPa: Lowest recorded sea-level pressure: In eye of Super Typhoon Tip, Pacific Ocean, $17^{\circ} \mathrm{N}, 138^{\circ} \mathrm{E}$ (between Guam and the Philippines). October 12, 1979.
hPa
1110



Ahrens: Figure 8.15

## Put the air in motion

- Horizontal pressure gradients cause the air to move
- The Earth's surface is a spinning frame of reference
- Push an object within that reference and it will not appear to travel in a straight line



## The Coriolis Effect



Ahrens: Fig. 8.21

Next lecture

- Coriolis "force"
- Geostrophic winds
- Cyclones and anticyclones
- More of Ahrens et al., Chapter 8

