Air Masses and Fronts

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1 Introduction

From an average point of view, air seems to be uncomplicated. After all, for most intents and purposes, the atmosphere is an invisible and homogenous mixture of various uninteresting gasses. However, this perception of the atmosphere could not be further from the truth. In reality, everything from the temperature to the water content of a mass of air affects its behavior and interactions with other masses, resulting in the myriad weather and cloud systems we can observe from day to day. Read on to find out more about this constantly shifting sphere.

2 Temperature and Humidity

When the sun heats the Earth, it does so *unevenly*. This is because air and water require different amounts of energy to be raised to the same temperature, meaning continents heat faster than oceans. (Note that this ties in to the concept of *specific heat*; water has a high specific heat, meaning it takes relatively more energy to warm one unit of mass by 1°C.)

Additionally, different latitudes get different amounts of sun, due to a shallower angle of insolation nearer the poles. Passing through more atmosphere and spreading across a greater area means sunlight reaching each unit on the surface is less intense, as shown below.

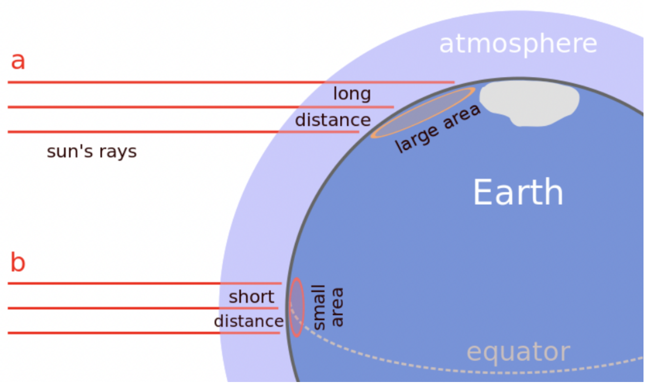

Figure 1: Insolation angle affecting surface intensity. (Credit: Wikimedia Commons)

This is important because the air above the planet's surface is almost entirely heated by the ground below it. Incoming solar insolation is largely in the form of shortwave radiation (visible, ultraviolet, etc.), which passes through the atmosphere without being absorbed (this region of the spectrum is known as the *atmospheric window*. Once it's taken in by the land or ocean, though, the energy is re-radiated in the form of longwave radiation - heat - which can be transferred into the surrounding air.

The closer to the equator and the more land underneath it, the hotter an air mass will get. But temperature is not the only thing that characterizes an air mass! Humidity plays a large part in determining how a parcel of air interacts with the environment. This is largely determined by whether the mass forms over a continent or over the sea; if it's formed over an ocean, it's likely to contain more water vapor than one that forms over dry land.

The temperature and humidity of air determines how it moves. Warm air rises, as higher temperatures mean more movements of the molecules that make up the air itself. This makes the air spread out, expand, and become less dense than cooler air.

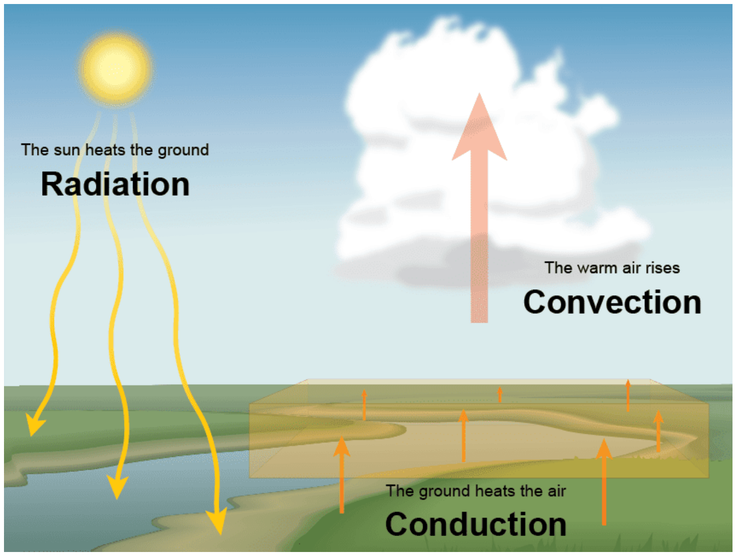

Figure 2: Radiation and convection (Credit: https://scied.ucar.edu/learning-zone/earth-system/conduction)

Humid air is also less dense than dry air. The largest components of the atmosphere are nitrogen and oxygen gas, with atomic masses of about 28 and 32 amu respectively. Water is H2O, which has an atomic mass of about 18 amu. Recall that the formula for density is

$$D = \frac{m}{v}$$

When humidity is higher, water takes up a larger percentage of the air mass, decreasing its total atomic mass and therefore decreasing its density.

In short, warm, humid air is the least dense, while cool, dry air is the most dense. You generally won't have to worry about humidity and how it relates to density, so this can be further reduced to the idea that warm air rises and cold air sinks.

2.1 Pressure and Weather

Clouds are produced when warm air rises. As you increase in altitude in the troposphere, temperature decreases. As cold air holds less water vapor than warm air, as an air parcel rises and cools, water condenses out of it to form clouds.

When an area of low pressure forms, it means that the air there is warm, as there is air flowing *away* from the area. When there is an area of high pressure, that indicates cold air, as there is air flowing *towards* the area.

Accordingly, low pressures correspond to warm, rising air, which in turn correspond to clouds and bad weather. Inversely, high pressures are associated with cool, sinking air, meaning clear skies and stable atmosphere.

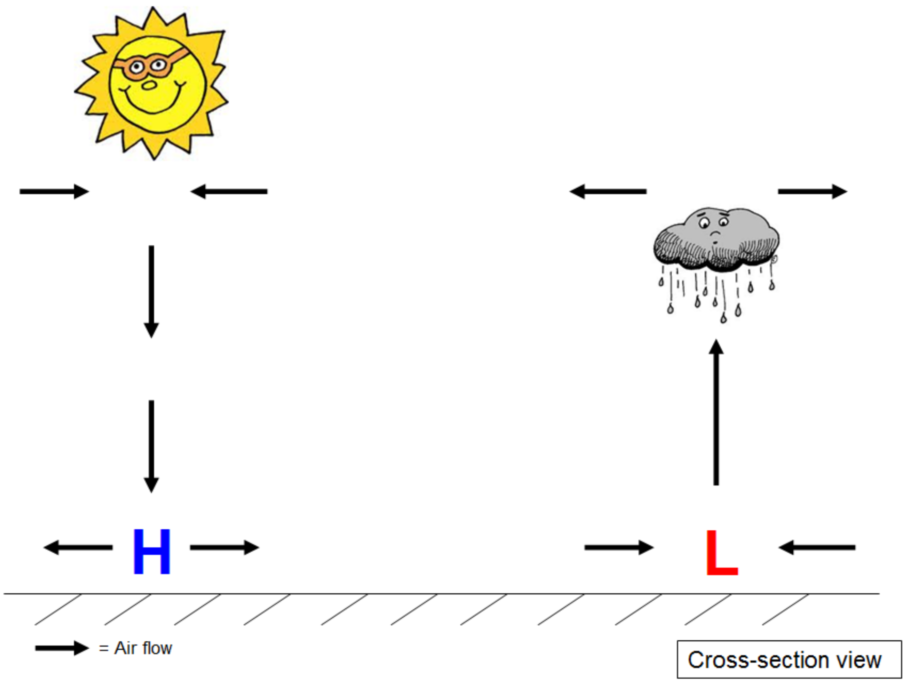

Figure 3: High and low pressures (Credit: https://weatherworksinc.com/news/high-low-pressure)

2.2 Types of air masses

- Continental Polar (cP)
  - Air that forms in high latitudes over dry land is classified as Continental Polar. These air masses are typically cold and dry.
- Continental Tropical (cT)
  - Air that forms in low latitudes over dry land is classified as Continental Tropical. These air masses are typically warm and dry.
- Maritime Polar (mP)
  - Air that forms in high latitudes over dry land is classified as Maritime Polar. These air masses are typically cold and wet.
- Maritime Tropical (mT)
  - Air that forms in high latitudes over dry land is classified as Maritime Tropical. These air masses are typically warm and wet.

- Equatorial, Arctic, Antarctic (E, A, AA)
  - Equatorial and Arctic/Antarctic air masses are reserved for those that form at the highest or lowest latitudes - around 90^o and 0^o respectively.

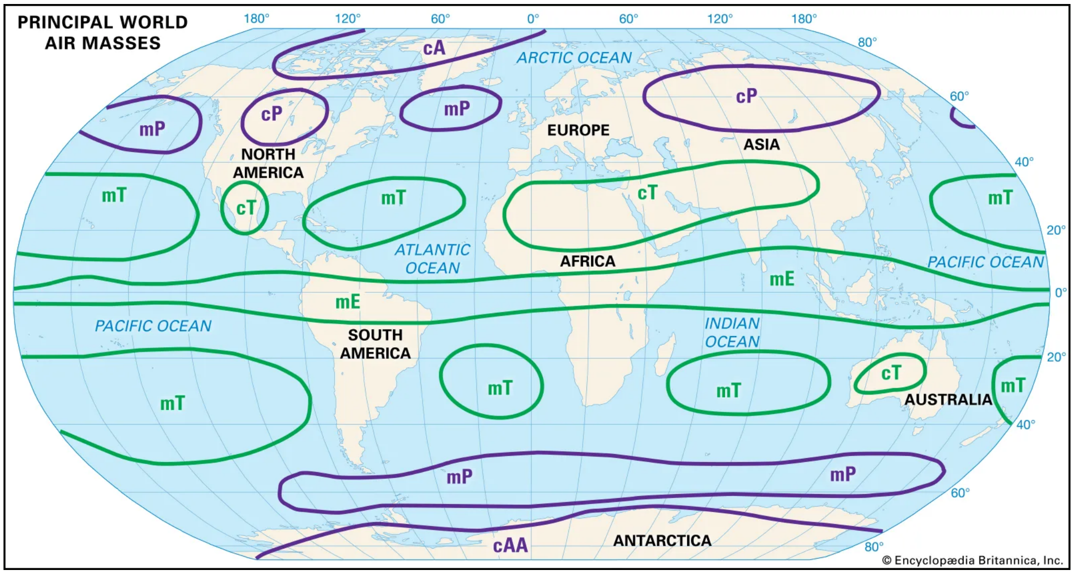

Figure 4: Where different masses form (Credit: https://www.britannica.com/science/air-mass)

2.2.1 Weather conditions in air masses

A hot, muggy day means that you're likely in the midst of a maritime tropical air mass. Conversely, cold and dry conditions indicate continental polar air. What happens when different air masses collide? The next section goes into further detail about these interactions.

3 Fronts

A front is the area of contact between two different air masses. The type of front resulting from an interaction depends on both the direction and the types of masses that collide, and can produce a variety of weather in response. Below is a list of the four types of meteorological fronts.

3.1 Types of fronts

- Warm
  - A warm front occurs when a warm air mass catches up to the gently sloping tail end of a cool air mass. The warm air, which can't mix with the cooler air, is forced up the slope and slowly forms clouds. This kind of front is known for producing milder and persistent rains, with nimbostratus clouds. Refer to the picture below.

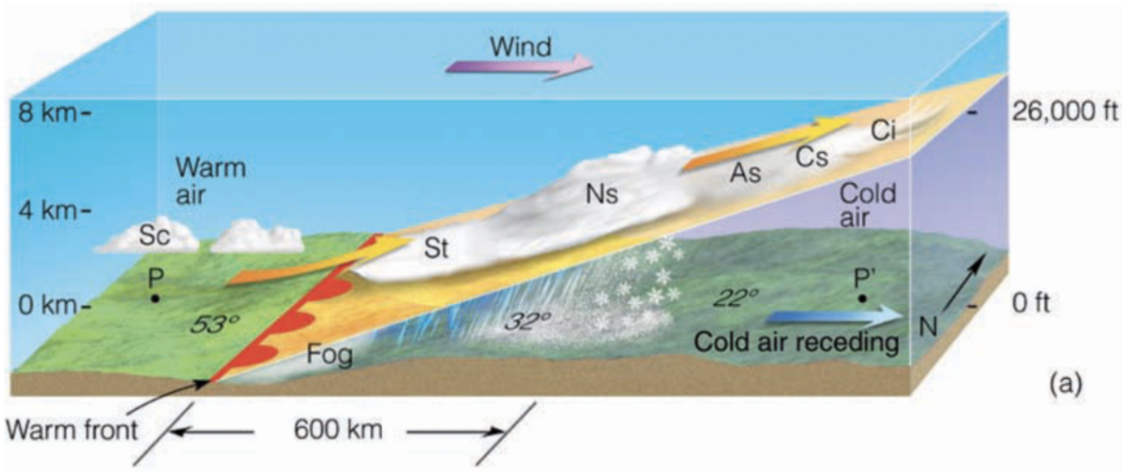

Figure 5: Warm front schematic (Credit: *Ahrens*)

- They are represented on weather maps with a series of semicircles on a line.

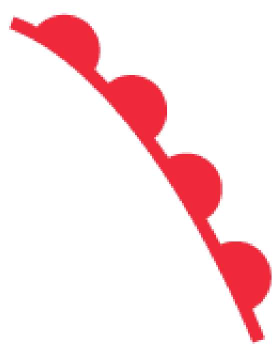

Figure 6: A warm front indicator (Credit: https://www.weather.gov/jetstream/wxmaps)

- Cold
  - A cold front occurs when a cool air mass pushes into a warm air mass. The warm air is forced upwards by the rounded front of the cooler mass, often creating heavy and temporary rains as well as cumulonimbus clouds. Refer to the picture below.

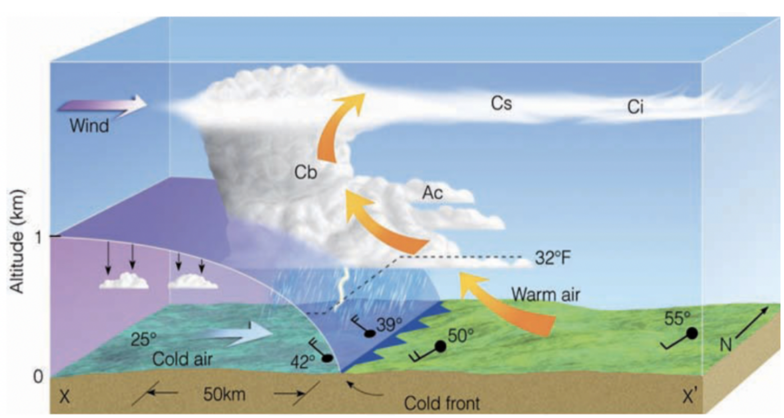

Figure 7: Cold front schematic (Credit: *Ahrens*)

  - They are represented on weather maps with a series of triangles on a line.

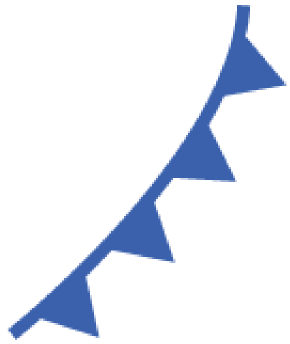

Figure 8: A cold front indicator (Credit: https://www.weather.gov/jetstream/wxmaps)

- Stationary
  - A stationary front occurs when a cool and a warm air mass collide, and neither has the energy to push into the other. This situation can be helped by winds blowing parallel to the front and not perpendicular. This front often causes lingering cloudy and rainy or snowy conditions. They are represented on weather maps with a series of alternating semicircles and triangles in opposing directions.

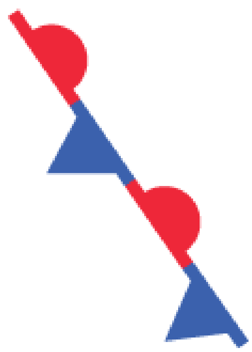

Figure 9: A stationary front indicator (Credit: https://www.weather.gov/jetstream/wxmaps)

- Occluded
  - An occluded front occurs when two cool air masses surround a warm air mass, forcing it out of contact with the ground. This often occurs around well-established low pressure areas. Occluded fronts can cause towering thunderstorms and cumulonimbus clouds, but a variety of other weather conditions may exist. Refer to the picture below.

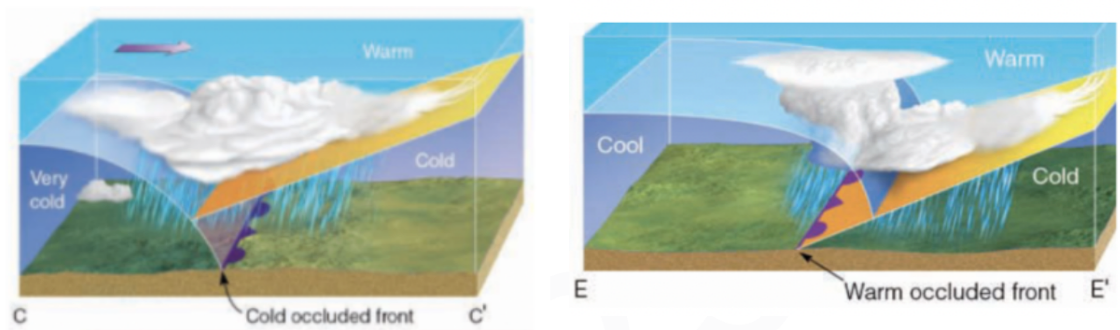

Figure 10: Occluded front schematic. Notice that two types of occluded fronts exist: warm and cold. (Credit: *Ahrens*)

– Occluded fronts are represented on weather maps with a series of triangles on a line.

Figure 11: An occluded front indicator (Credit: https://www.weather.gov/jetstream/wxmaps)

A common feature of an occluded front is a sort of "zipper"-like structure, where only part of the warm air mass has been forced off the ground as the cold air mass chases it in a circular pattern. They are represented on weather maps with a series of alternating semicircles and triangles in the same directions.

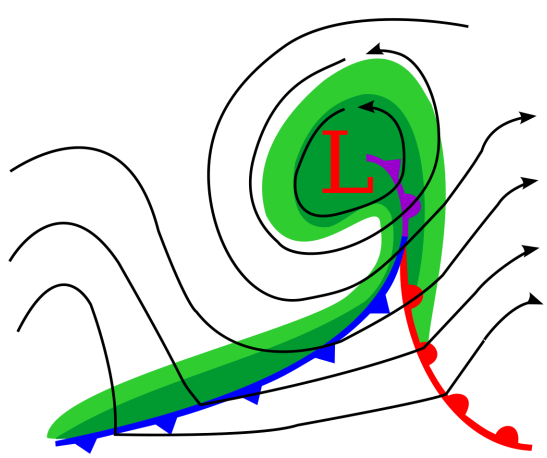

Figure 12: A "zipper"-like structure (Credit: https://skybrary.aero/articles/occluded-front)

4 Conclusion

Air masses are what drive our atmosphere and our weather. By learning to understand, recognize, and categorize these masses' interactions and formations, we can better interpret the world around us. Information about air masses helps meteorologists predict dangerous storms or sunny days, as well as see how air circulates in the atmosphere. With so many real world applications, it is clear that learning about air masses and fronts is critical to a well-rounded model of the environment.