Module 3 – Atmospheric Moisture

Lecture Outline

# Defining Moisture and Saturation

## What is “Air”?

* + - Many think that “air” is just made up of oxygen, but it is actually made up of many different gases.
      * Some gases have a constant concentration, while others are variable.
      * [Provide image showing percentage concentration of main gases]
    - The most common gases in our atmosphere are Nitrogen, Oxygen, and Argon.
      * Nitrogen (N2): 78%
        + Liquid Nitrogen used as a coolant (and can make ice cream)
      * Oxygen (O2): 20.9%
        + Oxygen tanks used by scuba divers to breath underwater
      * Argon (Ar): 0.94%
        + Argon used in welding as a shield against high-temperature metals
    - Although variables gases generally make up a small percentage of air, they can a big influence on what happens in our atmosphere and environments.
      * Carbon Dioxide (CO2): ~0.04%
      * Water vapor (H2O): ~1-4%
      * Methane (CH4): ~0.0018%
    - Water vapor is the most important variable gas because it is a major factor in heat transport between the surface and the atmosphere.
      * The location and amount of water vapor in the air depends on liquid water and heat at the surface because it comes from evaporation.
      * We cannot see water vapor because it is a gas, but we can see liquid water (clouds, fog, mist).

## The Three Phases of Water

* + - A phase change is a change from one state to another without a change in the chemical composition of the matter.
      * Same material but in a different form: solid, liquid, or gas.
    - There are three different phases, which means there are six types of phase changes:
      * [Show three phases with labeled arrows showing the direction and name of phase changes]
    - Water (liquid) will change into ice (solid) through deposition or freezing.
      * Deposition is the change from a gas to a solid, and leads to ice crystals (i.e., snow and frost).
      * Freezing is the change from a liquid to a solid, and leads to hard ice.
    - Water vapor or ice will change to a liquid through condensation or melting.
      * Condensation is the change from gas to liquid.
      * Melting is the change from solid to liquid.
    - Water or ice will change to water vapor through sublimination or evaporation.
      * Evaporation is the change from liquid to gas.
      * Sublimation is the change from solid to gas.

## What is “Humidity”?

* + - Humidity is the amount of water vapor in the air, measured either by volume, percentage, or mass.
      * Water vapor holds a lot of energy; therefore, humidity also indicates how much heat is available through phase changes.
      * Since we sweat to cool off, higher humidity means it can “feel” warmer even though the temperature may be lower.
    - Different environments have different amounts of available water, which in turn affects humidity.
      * Deserts are dry (and often hot) locations that have a lower humidity since there is less surface water.
      * Tropical rainforests have lots of rain so there is a large amount of water vapor and higher humidity.
    - Clouds form when water that evaporates from the surface condenses in the atmosphere.
      * This also helps to transfer heat from the surface, similar to the process of sweating cooling us off.
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# Measures of Moisture and Saturation

## Measures of Atmospheric Moisture

* + - Meteorologists measure the actual amount of water in the air based on various factors:
      * Vapor pressure (based on pressure)
      * Mixing ratio (based on mass)
      * Specific humidity (based on volume)
    - There are other measures that describe different aspects of humidity:
      * Relative humidity (percent saturation)
      * Dew point (temperature at saturation)
    - All of these measures are used in different ways.
    - Vapor Pressure: The total pressure of a mixture of gases is equal to the sum of the pressures of the individual gases.
      * Vapor pressure is the pressure exerted by just the water vapor.
    - Mixing Ratio: The mixing ratio describes the mass of water vapor in an area relative to the total mass of all the other components of the air.
      * Similar to listing water vapor as a single component of a recipe!
    - While vapor pressure and mixing ratio describe *how much* water vapor is in the air, the number doesn’t make much sense by itself.
      * Usually, the values are compared to potential values if the air were saturated.
    - Let’s meteorologists know how much water is needed before saturation is reached.

## Relative Humidity

* + - Relative Humidity is a ratio between the amount of water vapor currently in the air relative to the amount of water vapor if the air were saturated.
      * Relative humidity does not tell us anything about the actual water vapor content of the air, only the percent saturation.
      * A relative humidity of 100% tells us that the air is saturated with water vapor.
    - The amount of water vapor that can exist in the air before saturation occurs depends on temperature.
      * Higher temperaturesincreasethe amount of water vapor that can be in the air, without changing the actual amount of water in the air.
    - Since relative humidity depends on temperature, it is not a good measure to compare moisture levels at different locations.
    - Relative Humidity is used by meteorologist to communicate how close the air is to saturation, which is important for describing things such as comfort level and the potential for fog.

## Dew Point

* + - Dew point is the temperature at which the air needs to be cooled to achieve saturation.
      * At the dew point, relative humidity is 100%.
    - The dew point can never exceed the temperature the air is at. If the temperature drops or water vapor is added to the air, condensation must occur.
      * This condensation can appear as clouds or dew, or if the dew point is below freezing, snow or frost.
    - Meteorologist use dew point to estimate how much water vapor (humidity) is in the air. A higher dew point means more moisture and a lower dew point means less moisture.
      * On cooler (warmer) days, we need less (more) moisture in the air for it to feel humid.
    - Since dew point is an absolute measure (only depends on humidity), values can be compared at different points.

# 3D Patterns of Moisture in the Atmosphere

## Global Moisture Distribution

* + - Open IDV, then open file “GlobalMoisturePatterns.xidv”.
      * This will import 12 1°x1° GFS files corresponding to the 1st day of each month for 2018 @ 0000 UTC (“gfsanl\_3\_20180101\_0000\_000.grb2”, etc.).
        + File available from: <https://www.ncei.noaa.gov/data/global-forecast-system/access/historical/analysis/>
      * The following displays will be loaded:
        + Maps: Blue Marble (underlay), World country outlines.
        + Plan Views: Relative humidity (%) of the full atmosphere.
        + Plan Views: Relative humidity (%) at 850 and 500 hPa.
    - Features to note:
      * Relative humidity (and atmospheric moisture in general) is highest in the tropics despite the high temperatures, primarily because of the high rates of evaporation over the oceans.
        + Cycle through the monthly values of relative humidity of the full atmosphere.
      * Moisture patterns show a high variability over space and time since atmospheric water vapor increases and decreases due to phase changes with the surface and in the atmosphere (through clouds and precipitation). Also, winds can transport moisture large distances in the atmosphere.
        + Cycle through the monthly values of relative humidity of the full atmosphere.
        + Have students note when relative humidity is highest/lowest in their region.
      * Although temperature decreases with height, moisture content also decreases with height since the surface is the primary source of water vapor through evaporation.
        + View relative humidity at 850 hPa and 500 hPa and notice the difference in values with altitude.
        + Students can change their viewing angle with both surfaces visible to see how moisture changes both vertically and horizontally.

## Visualizing Clouds

* + - Open IDV, then open file “VisualizingClouds.xidv”.
      * This will import the 1°x1° GFS file for June 5, 2020 @ 0000 UTC (“gfs\_3\_20200605\_0000\_000.grb2).
        + File available from: <https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/global-forcast-system-gfs>
      * The following displays will be loaded:
        + Maps: Blue Marble (underlay), World country outlines.
        + Plan View: Relative humidity (%) at 500 hPa.
        + Vertical Cross Section: Relative humidity (%).
        + Isosurface of relative humidity at 95% colored by height (m).
    - Features to note:
      * Moisture varies widely both horizontally and spatially; therefore, it’s tough for meteorologists to make sense of where moisture is highest in the atmosphere. Since relative humidity is dependent on temperature (which also changes), this makes relative humidity touch to interpret.
        + Visualize the relative humidity vertical cross section and plan view at 500 hPa.
        + Have students interpret any patterns they see and figure out what might be causing them (i.e., high moisture, low temperature).
      * Since relative humidity is a measure of how close the air is to saturation, it is a much better variable to use for estimating where clouds may exist. This also allows for a 3D view of atmospheric moisture.
        + Visualize clouds by looking at an isosurface of relative humidity at 95% (which takes into account air at or near saturation).

## 3D Structure of Moisture Transport

* + - Open IDV, then open file “MoistureTransport.xidv”.
      * This will import 5 12-km NAM files corresponding to 00Z for April 30 – May 4, 2010 (“namanl\_218\_20100430\_0000\_000.grb”, etc.).
        + Files available from: <https://www.ncei.noaa.gov/data/north-american-mesoscale-model/access/historical/analysis/>
        + This time period corresponds to the historic flooding over northern Mississippi and Alabama and Tennessee.
      * The following displays will be loaded:
        + Maps: Blue Marble (underlay), World country outlines.
        + Plan View: Dewpoint (°C) at 2-meter height.
        + Plan View: Wind vectors at 10-meter height.
        + Isosurface of mixing ratio at 14 g/kg.
    - Features to note:
      * Atmospheric moisture primarily comes from the surface through evaporation; therefore, it is generally highest over warm ocean waters and then transported by atmospheric winds.
        + Visualize 2-m dewpoint and 10-m winds and note how the high dewpoint air is transported off the Gulf of Mexico into the central US.
        + Note the lack of moisture transport over Mexico, which is a result of the topography blocking the flow, while the lack of topography across the Southeastern US lets moisture flow freely.
      * While moisture is most commonly visualized at the surface, there does exist a 3D moisture plume that often extends off the Gulf of Mexico due to passing cyclones. Meteorologists refer to this feature as a “moisture tongue”, and it is a key feature when forecasting precipitation.
        + Visualize the isosurface of mixing ratio and note the horizontal and vertical extent of the moisture tongue.
      * Dew point and mixing ratio are different measures of moisture, and describe different features of atmospheric water vapor.
        + Note the difference in the patterns of dew point and mixing ratio.

Knowledge Test Questions

1. What are the primary components of air?
2. Roughly how much water vapor is in the air over different types of environments (i.e., deserts, rainforests, etc.)?
3. What are considered “constant” components of air, and what are considered “variable” components?
4. What does vapor pressure measure, and how is it related to the amount of water vapor in the air?
5. What does relative humidity measure, and what is it “relative” to?
6. What does the dew point describe?
7. Which measure of moisture is best used to show the amount of water vapor over a region? Why?
8. What is the main source of atmospheric water vapor over the United States?
9. Why does it feel more humid over Mississippi in the summer than in the winter?
10. Why is the southwest US drier than the southeast US?