SESSION 1: WEATHER VARIABLES AT THE SURFACE

One Energy

June 21, 2022

QUICK DEFINITIONS…

- **Weather**: Short-term variations in the sensible state of the atmosphere. OR the condition of the atmosphere at a particular location and moment.

- **Climate**: "Average Weather" – 30 years min.

- **Meteorology**: The study of weather; Greek: *meteoron* (things high up) + *logia* (study of)

WEATHER VARIABLES

- What are the main variables? We will discuss:
  - Temperature
  - Atmospheric (Barometric) Pressure
  - Wind Speed / Direction
  - Humidity
- Predictions will be based on measurements of these variables.

TEMPERATURE MEASUREMENTS

- Per the World Meteorological Organization (WMO) standard, temperature is typically measured between 1.5 and 2 m above ground level.

- Instrument shelters are often used to reduce the influence of solar radiation and air stagnations

TEMPERATURE MEASUREMENTS

- The National Weather Service uses resistance thermometers, which measure the change in electrical resistance of a piece of metal (a function of temperature)

- Often sheltered by a white "Stevenson Screen", protecting thermometer from direct solar irradiation

- Well ventilated

TEMPERATURE MEASUREMENTS

ATMOSPHERIC PRESSURE

- Values of atmospheric pressure typically don't show up in a daily forecast.

- But this variable is very important to meteorologist.

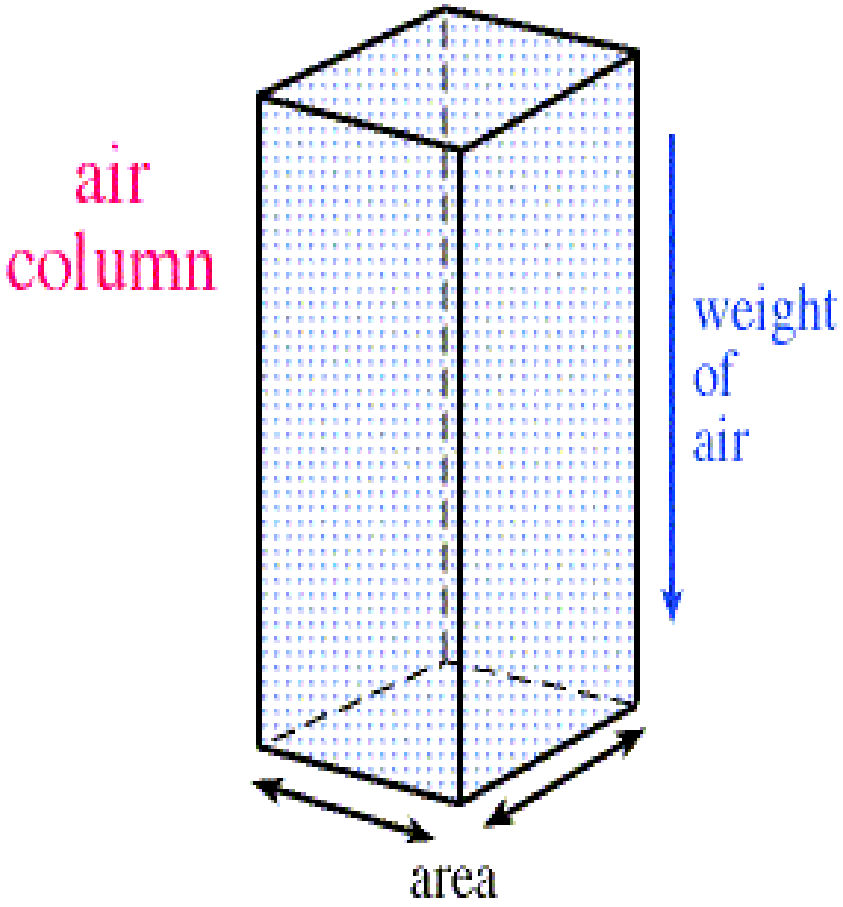
- Simple trend:
  - Low / Lowering Atmospheric Pressure = Storms

  - High / Rising Atmospheric Pressure = Nice Weather

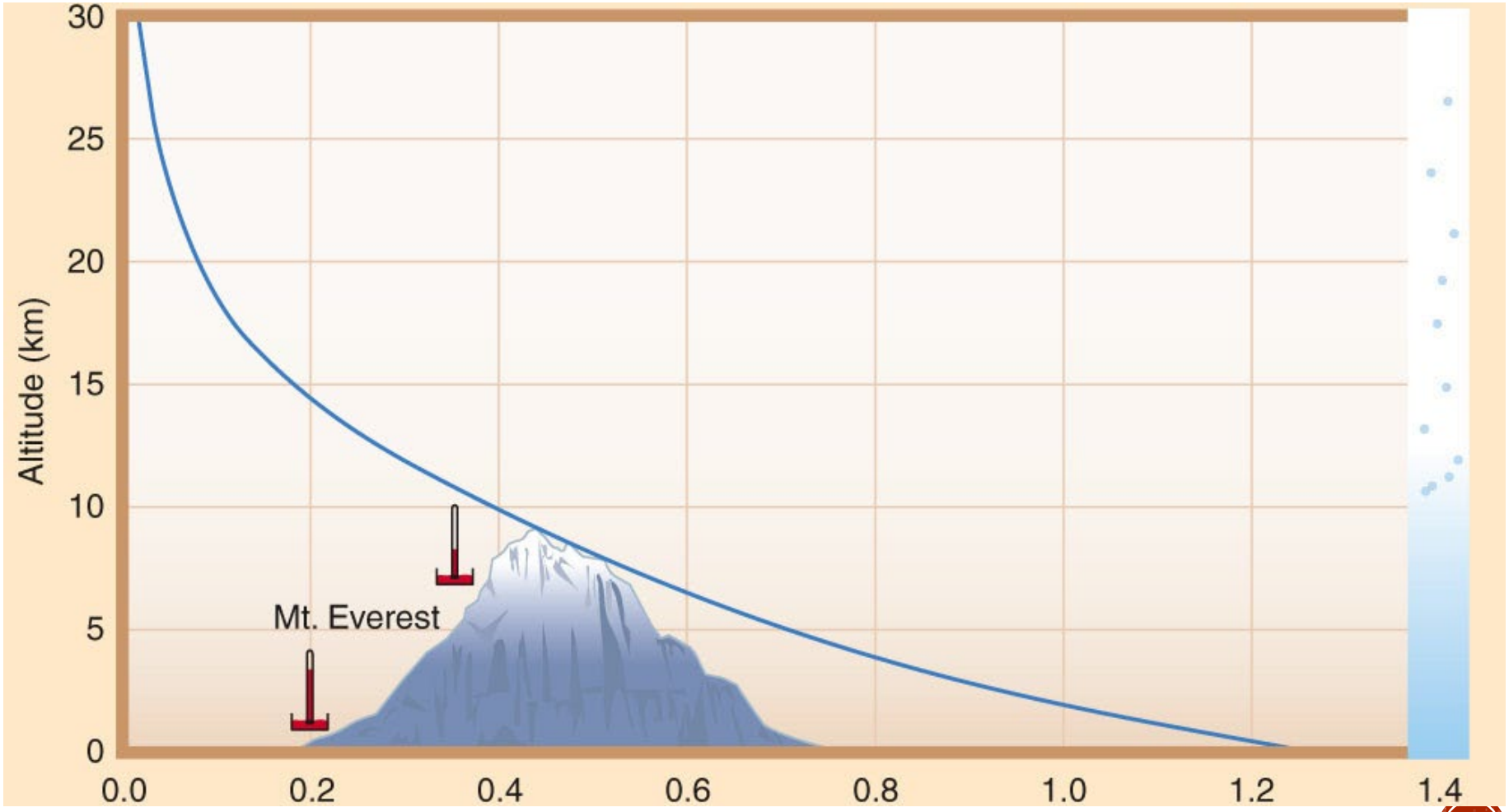
ATMOSPHERIC PRESSURE: WHAT IS IT?

- Pressure = Force per unit Area
- Related to Density
- Its how much "stuff" is above you

Stuff= atmosphere (gas molecules).



PRESSURE CHANGE WITH HEIGHT



PRESSURE THE VARIABLE

- It is helpful to think of pressure in two different ways:

1. Values of atmospheric pressure change in response to weather systems

2. Values of atmospheric pressure change (decrease) with height. As you go up in the atmosphere, there is less "weight" above you.

PRESSURE UNITS

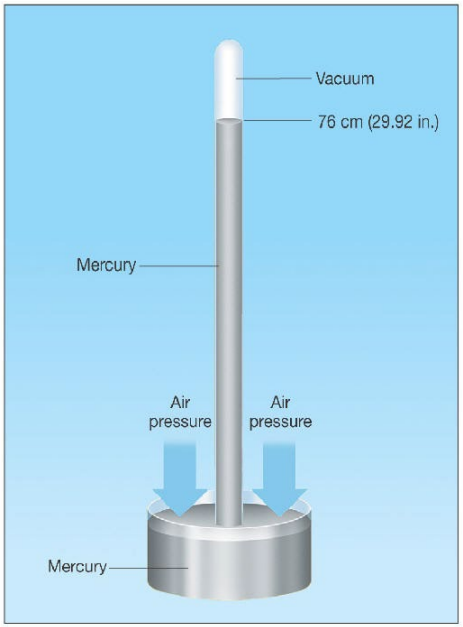
- Pressure can be expressed in many ways:
  - Car tires: PSI

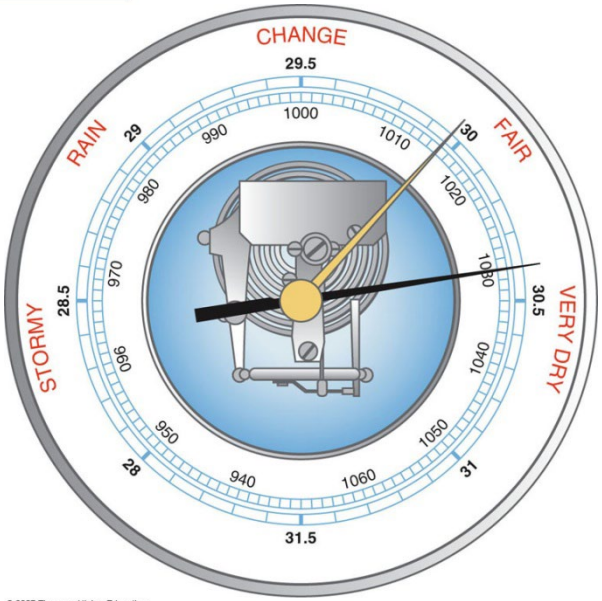
- In the atmosphere, we use millibars (mb) or hectopascals (hPa) as the units for pressure.

- 1 mb = 1 hPa

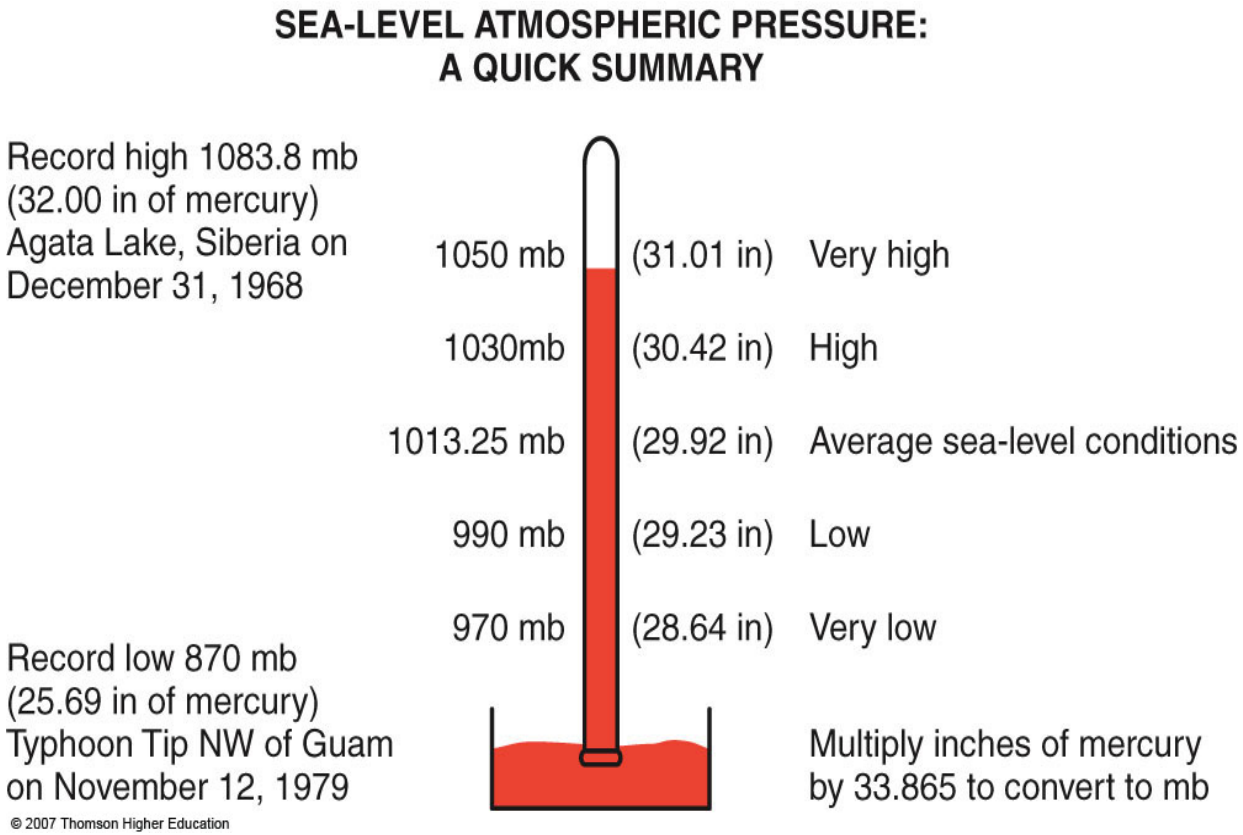
- The base units are bars and pascals respectively…

ATMOSPHERIC (BAROMETRIC) PRESSURE





- A barometer measures pressure.
- Mercury barometers (top) and aneroid barometers (bottom) are what we are used to.
- NWS uses electronic barometers.



New Records

- Highest surface pressure: 1085.7 mb, Dec 2001, Mongolia
- Lowest surface pressure in the Atlantic: 882 mb, Hurricane Wilma, 2005
  - Lower measurements have been made in tornadoes recently

Low Pressure = Fast Winds!

DESCRIBING WATER VAPOR CONTENT

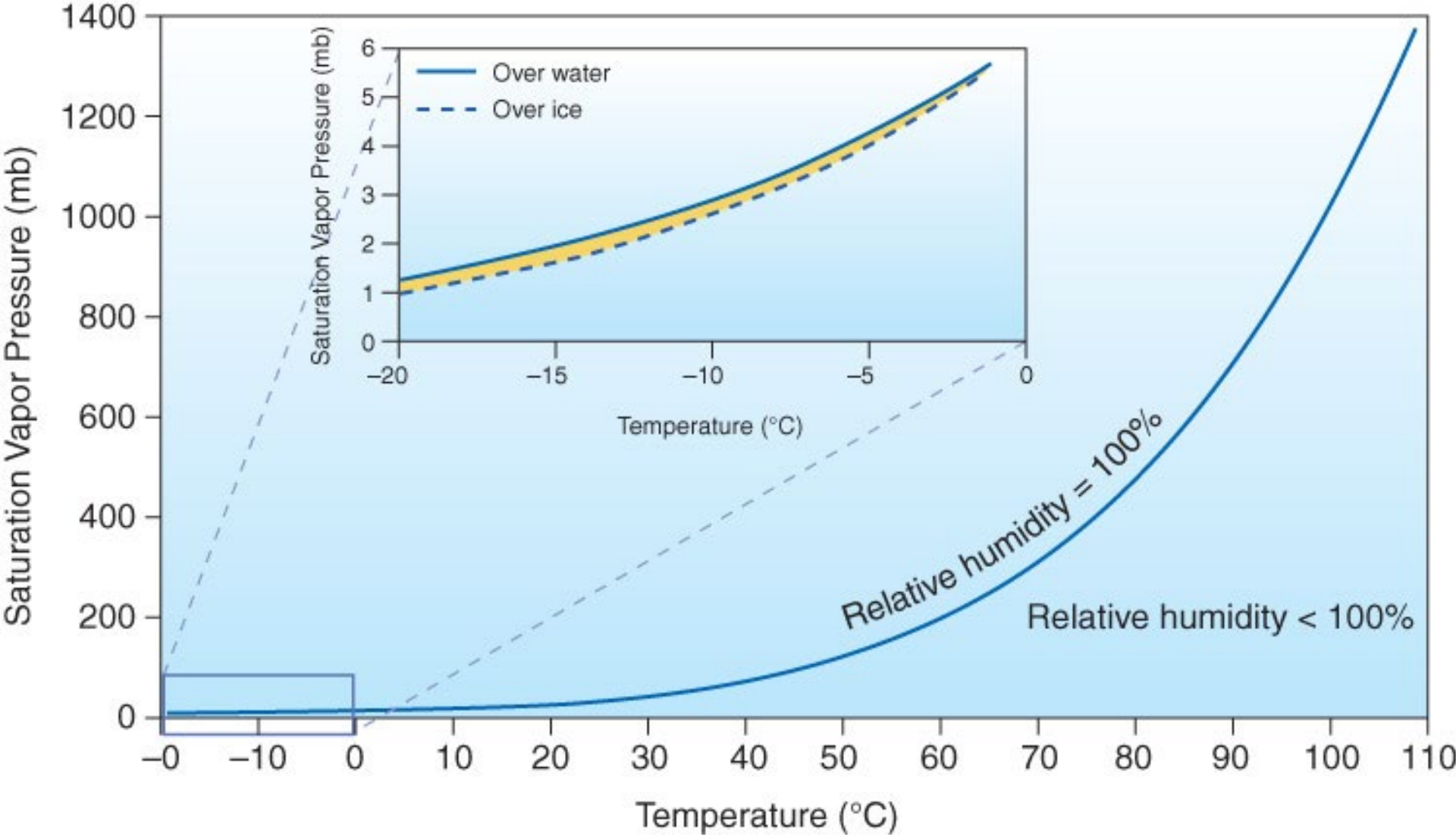
- **Humidity** – general term for the amount of water vapor in the air
- Humidity is expressed by:
  - *Vapor Pressure*
  - *Relative Humidity- we hear this one a lot*
  - *Dew Point Temperature*

- Most of these describe "distance" to saturation.

VAPOR PRESSURE

- Atmospheric pressure exerted SOLELY by water vapor molecules.
- Expressed in millibars (mb)
- Saturation vapor pressure – the pressure exerted by water vapor molecules at saturation
- Saturation vapor pressure increases as temperature increases → TEMPERATURE DEPENDENT.
  - "Warm air holds more water vapor" – sort of.

SATURATION VAPOR PRESSURE



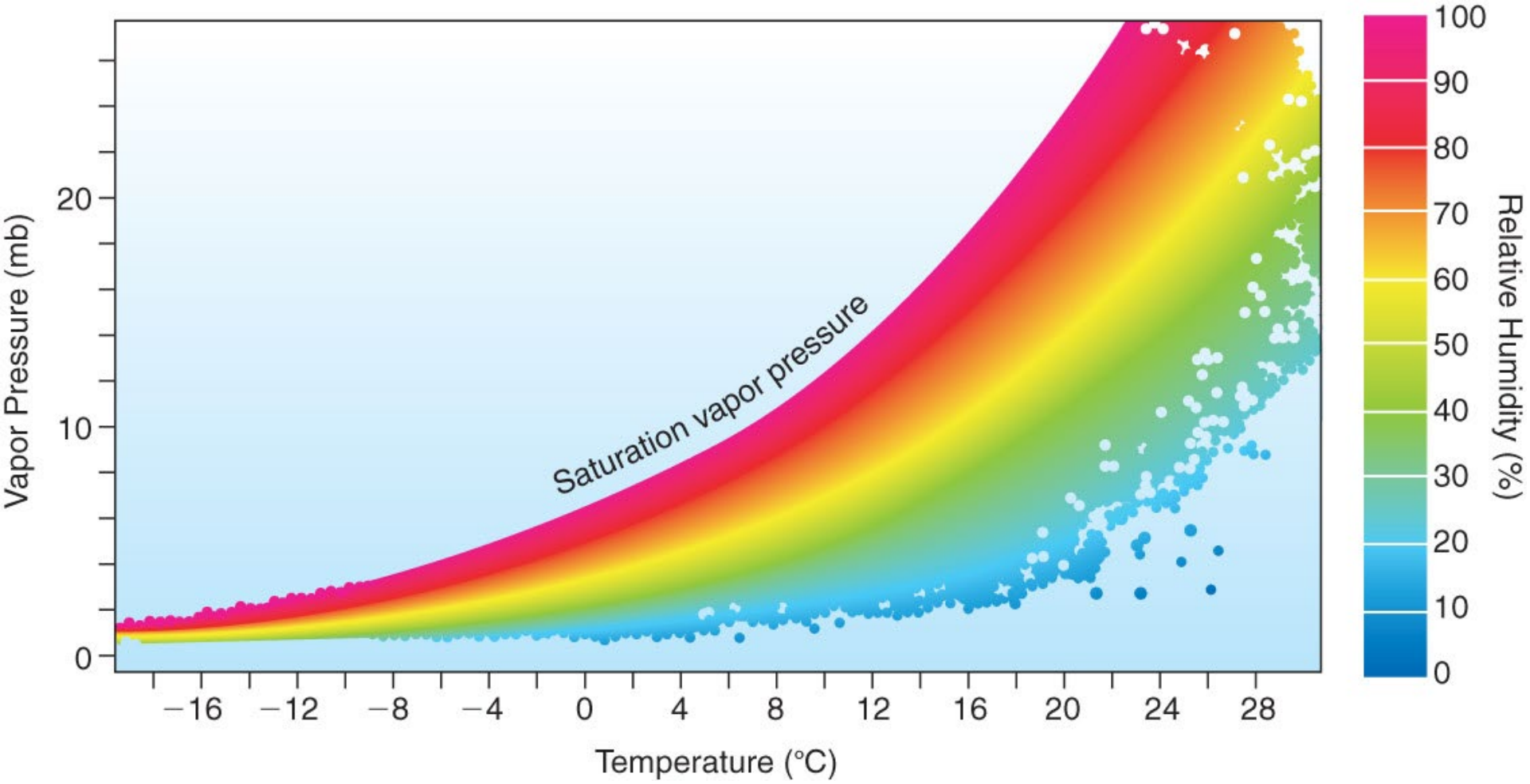
RELATIVE HUMIDITY

- Ratio of actual water vapor content to the maximum water vapor content possible (at saturation).
  - Expressed as a percentage

- $RH = 100\% \times \left(\frac{\text{VAPOR PRESSURE}}{\text{SATURATION VAPOR PRESSURE}}\right)$

- Does NOT tell you how much water vapor is in the air (therefore, can be very misleading).

SATURATION VAPOR PRESSURE



WAYS TO ACHIEVE SATURATION (RH=100%)

1. Add water vapor

   - Process: **Evaporation**

   - Example: Bathroom shower, Rain falling into dry air

WAYS TO ACHIEVE SATURATION (RH=100%)

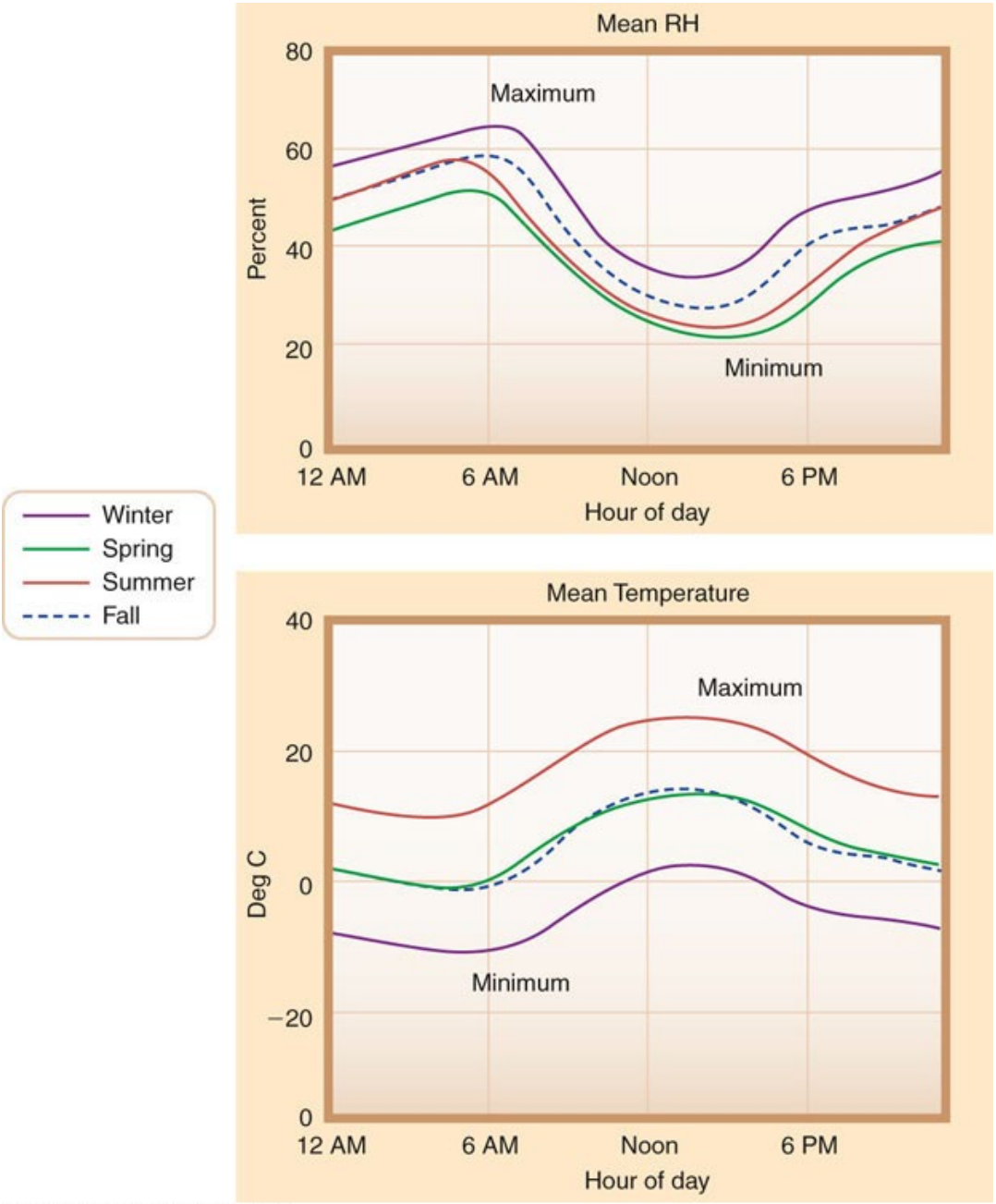
2. Cool the air
   - Process: recall temp lecture.

   - Example: Condensation on the outside of a cold glass or air conditioners

RELATIVE HUMIDITY VS. TEMP

- With NO change in water vapor content,
  - RH increases as temperature decreases
  - RH decreases as temperature increases

- So how might RH change through the course of a day? Through the seasons?



DEW/FROST POINT TEMPERATURE

- Temperature to which air must be cooled to reach saturation (at constant pressure)

- Like vapor pressure and mixing ratio, dewpoint temperature is an indicator of the *actual* water vapor content

- Whether is dew or frost depends upon whether or not the temp is < freezing.

DEW AND FROST

- Dew forms as a result of condensation.
- Frost forms as a result of deposition.
- Frost ≠ Frozen Dew!!

DEWPOINT TEMPERATURE

- Abbreviated T_D, it will always be less than the air temperature (and can be used to infer the overnight low temperature).

- We can relate the dewpoint to relative humidity by considering ambient temperature:

When the dew point is much lower than the air temperature, the relative humidity is low.

When the dew point is close to the air temperature, the relative humidity is high.

CONNECTING THE DOTS

- We can relate the dewpoint to relative humidity by considering ambient temperature:

When the dew point is much lower than the air temperature, the relative humidity is low.

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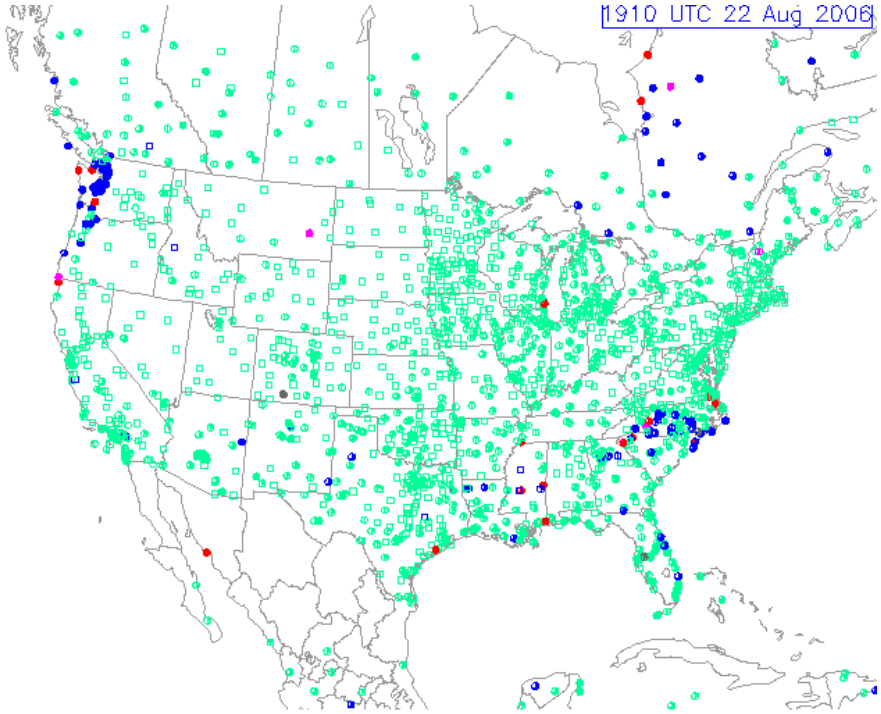
WIND SPEED / DIRECTION

- Anemometers measure wind speed and direction
- Cup anemometer used to measure wind speed
- Wind vane used to measure wind direction
- Also, there are sonic anemometers which measure how wind affects the propagation of sound waves (no moving parts!)

DIRECT MEASUREMENTS

- Automated Surface Observing System (ASOS) – Typically located at airports
- Automated Weather Observing System (AWOS)

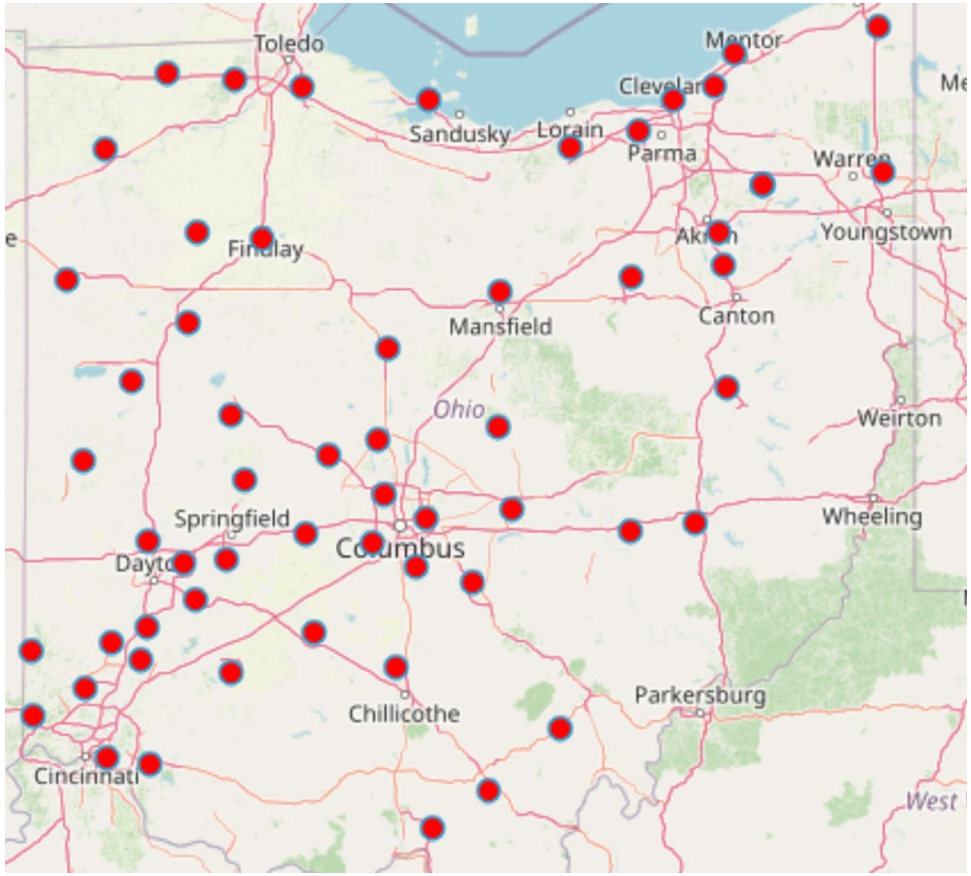
AUTOMATED SURFACE OBSERVING SYSTEM(ASOS) AND AWOS



- Over 900 ASOS sites across North America

- Measures and reports variables with a frequency of 1-60 minutes
  - Temperature
  - Dew point temperature
  - Pressure
  - Wind direction/speed
  - Rainfall
  - Cloud height
  - Visibility

AUTOMATED SURFACE OBSERVING SYSTEM(ASOS) AND AWOS



- Data resolution depends on the station and the file.

- ASOS 6405 – 1-minute resolution except for wind (2 min moving average)

- ASOS 6401 – 5-minute resolution.

METARS

KBWI 181754Z 31017G26KT 10SM BKN050 23/11 A2984 RMK AO2 PK WND 31029/1740 SLP102 T02330106 10233 20206 51012

KCLE 181751Z 35016G26KT 10SM CLR 19/06 A3017 RMK AO2 PK WND 34027/1656 SLP228 T01890056 10189 20150 53013

KCLT 181752Z 34013G24KT 10SM FEW070 FEW250 33/09 A2991 RMK SLP117 T03280089 10328 20244 50000

KCVG 181752Z 35009KT 10SM CLR 23/09 A3017 RMK AO2 SLP208 T02330094 10233 20178 50001

KDCA 181752Z 31020G31KT 10SM FEW047 BKN055 24/09 A2987 RMK AO2 PK WND 33035/1713 SLP115 T02390094 10244 20217 51010

KDEN 181753Z 28013G21KT 210V310 10SM FEW090 SCT140 BKN220 31/07 A3001 RMK AO2 SLP065 T03110072 10311 20189 58001

KDFW 181753Z COR 18006KT 10SM FEW050 SCT100 SCT250 34/19 A3002 RMK AO2 SLP154 TCU DSNT W MOV W T03440194 10350 20244 58008

KDTW 181753Z 01012G23KT 10SM FEW250 21/05 A3020 RMK AO2 SLP224 T02110050 10211 20150 50002 $

KEWR 181751Z 32017G24KT 10SM BKN045 22/08 A2972 RMK AO2 PK WND 32029/1713 SLP065 T02170083 10222 20200 50005

KFLL 181753Z 09009KT 10SM SCT030 31/24 A2994 RMK AO2 SLP138 T03110239 10311 20261 58000 $

KIAD 181752Z 33015G27KT 10SM BKN055 22/10 A2989 RMK AO2 PK WND 33031/1711 SLP118 T02220100 10228 20200 51012 $

SURFACE MEASUREMENTS IN WIND ENERGY

- Used for:
  - Resource Assessment
  - Turbine Selection
  - Real-time operations
    - Severe
    - Winter

- Hourly sufficient, but 10-min recommended.
  - True as long as maxes / mins are included

SURFACE MEASUREMENTS IN WIND ENERGY

Table 4-5. Derived statistics for basic and additional parameters

Measurement parameters	Recorded values
Wind speed, m/s	Average, standard deviation, min/max
Wind direction, degrees	Average, standard deviation, max gust direction
Temperature, °C	Average, min/max
Solar radiation, W/m^2	Average, min/max
Vertical wind speed, m/s	Average, standard deviation, min/max
Barometric pressure, kPa	Average, min/max
Delta temperature, °C	Average, min/max
Relative humidity, %	Average, min/max

SOURCES OF SURFACE MEASUREMENTS

- ASOS / AWOS :
  - NCEI (for 5 min to 1 min data)
  - IEM (pick and choose variables!)
- Mesonets
  - Regionally Variable
- RWIS
  - Road Weather Information Systems (DOT)
- Click here for list