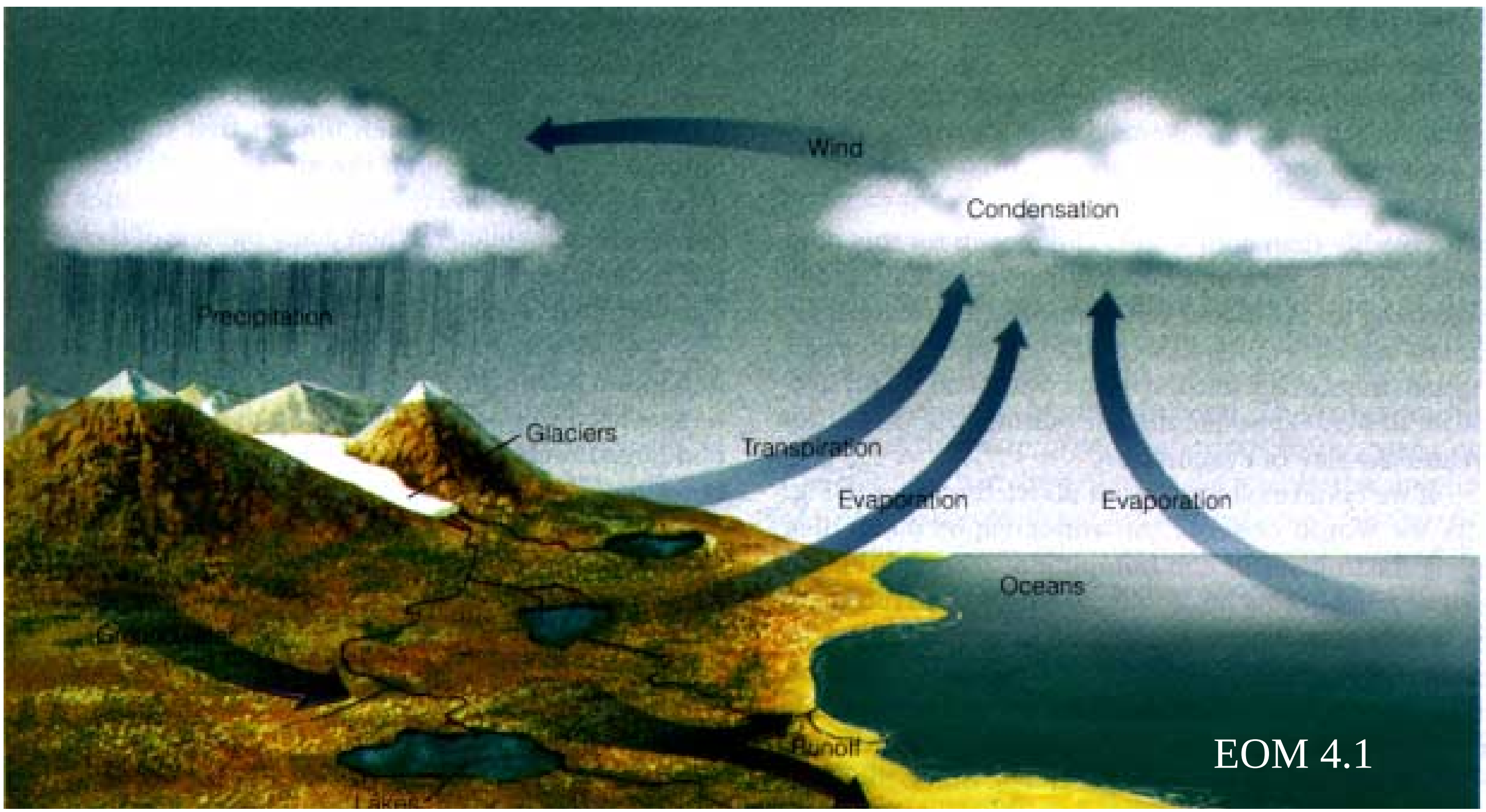
Lecture 17 Humidity

The Hydrologic Cycle (EOM fig 4.1)

- 85% of water in atmosphere evaporates from oceans
- Of precipitation that falls over continents, about half runs off in rivers into oceans, half is transpired/evaporated
- A water vapor molecule is typically rained out after a week in atmosphere.



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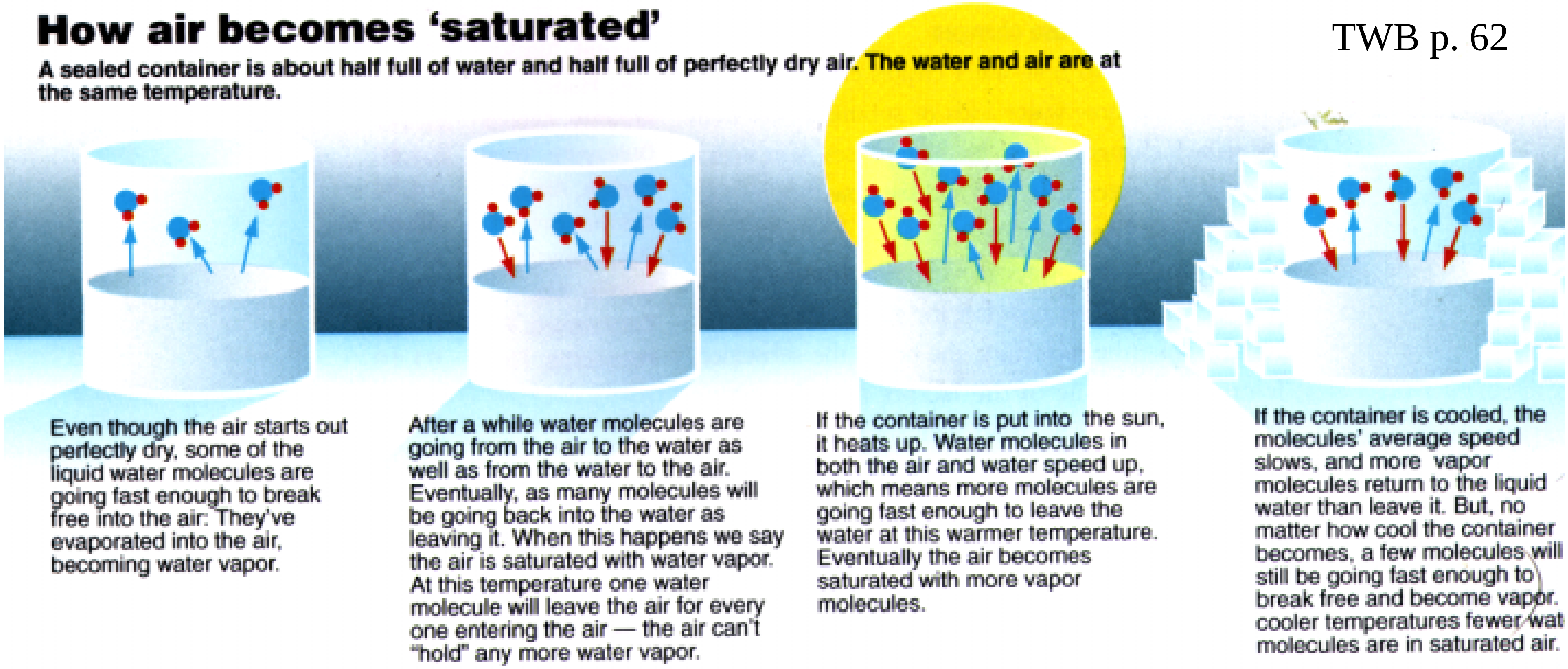
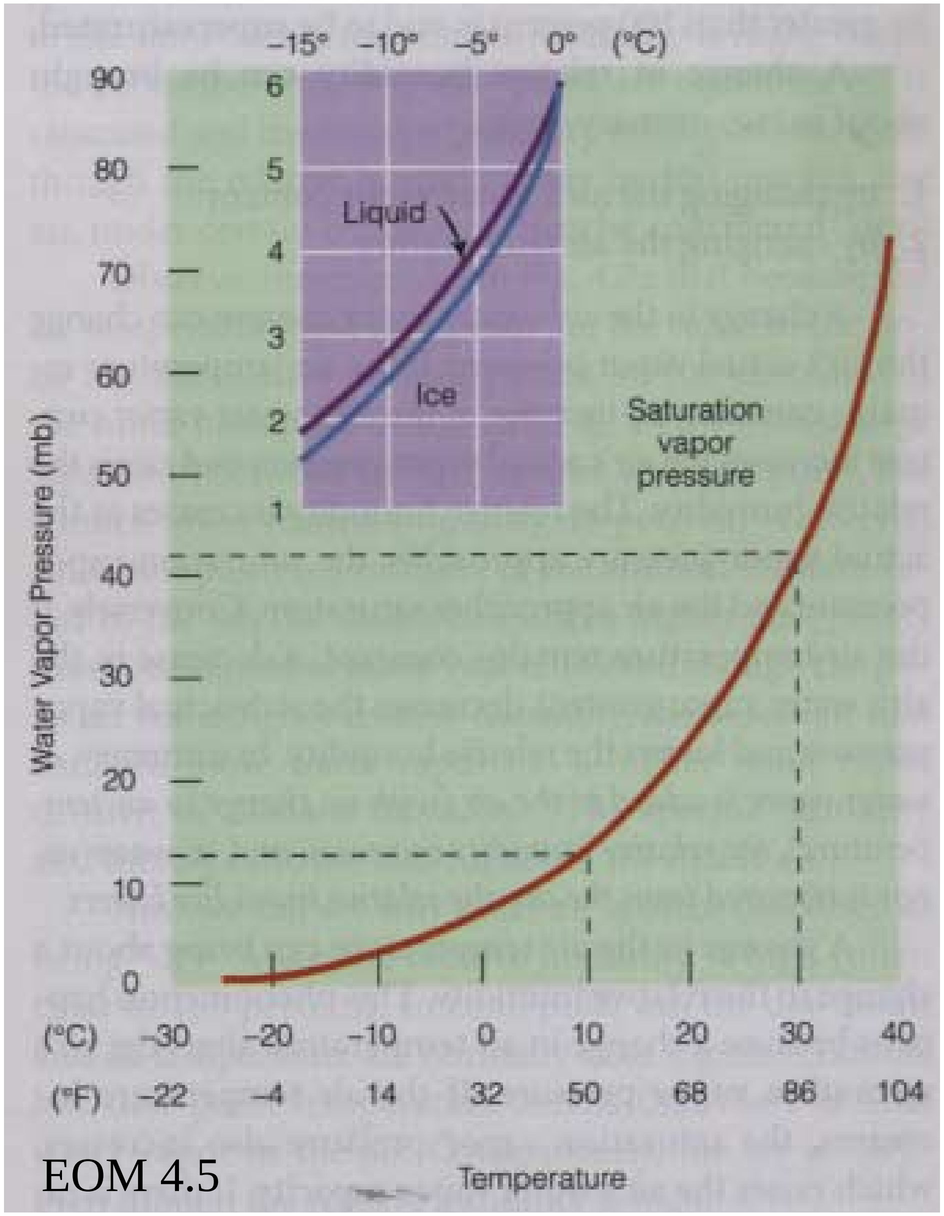


- The saturation vapor pressure of water depends only on the temperature, not the air pressure.
- If temperature is below 0 C, the above pictures would also apply to an ice surface. Since water molecules are more tightly locked together in an ice crystal, saturation vapor pressure over ice is lower.

Saturation Vapor Pressure (SVP) vs. Temperature

- SVP doubles for each 10 C increase in temperature.
- Cloud water droplets a few microns in diameter can be ‘supercooled’ down to -40 C before freezing, even though larger rain-size drops freeze readily below 0 C.
- Below 0 C, SVP over ice is slightly lower than over water (10% lower at -10 C, 30% lower at -30 C).



EOM 4.5

Humid Air

Humid air is a mixture of the molecules that make up dry air (mainly N_2 (molecular weight MW=28) and O_2 (MW=32)), and lighter water vapor molecules (MW=18).

The *specific humidity* is the mass fraction of water vapor in the air. As humid air is compressed or expanded, its specific humidity remains unchanged.

Consider a container of humid air. Each type of molecule bounces off the container walls, contributing a *partial pressure* to the air pressure proportional to the number of molecules per unit volume (and temperature). The partial pressure of water vapor is called the *vapor pressure.*

Relative Humidity

$$\text{RH} = \frac{\text{Vapor Pressure}}{\text{Saturation Vapor Pressure}} \times 100\%$$

- Note that RH depends on temperature as well as the vapor pressure.
- When RH reaches 100% we say the air is *saturated*.

Consider air that is saturated at 0 C, then heated to various temperatures.

Temperature	VP	SVP	RH
0 C	6 mb	6 mb	100%
10 C	6 mb	12 mb	50%
20 C	6 mb	23 mb	28%
30 C	6 mb	42 mb	14%

This is why we have low RH in houses, in which cold outside air is heated to room temperature.

Dewpoint

Dew point: Temperature to which air would have to be cooled for it to become saturated (depends only on vapor pressure - 0 C for all cases above).

Frost point: Temperature for saturation wrt ice, slightly higher than dewpoint. From chart,

Vapor pressure	Dew point	Frost point
12 mb	10 C	
6 mb	0 C	0 C
3 mb	-10 C	-8.5 C

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Dew and Frost

- At night, the ground and exposed objects (cars, roofs, etc.) cool by emission of longwave radiation faster than the air, and by conduction form a ‘skin’ of cold air next to them.
- As this skin cools below its dew point (or frost point if below 0 C), water vapor condenses out of the air onto the nearby surface as dew or frost.
- If the skin of cold saturated air becomes more than a few cm thick, water drops also condense in the air to produce fog

More about dew and frost

Dew/frost are *less* likely if:

- The surface is warmed by longwave radiation from a cloud layer or even when it is below a tree covered with leaves or needles, since the ground may not cool below the dew point.
- Turbulence produced by wind mixes the air at the ground with warmer air above.

Night time air temperatures (at 5.5 feet) rarely fall much below the dew point of the previous evening, if the night is calm. As they cool to dew point, dew or frost, then possibly fog, form. The condensation releases latent heat, which inhibits further cooling.

If early evening temperatures are less than 5 C above dew point, and the night is clear and calm, fog is likely as the air cools overnight.

Condensation (or frost) on inside window panes occurs if the glass temperature is below the dew (or frost) point of the inside air (can be moister than outside air due to humidity from cooking, showers, etc.)

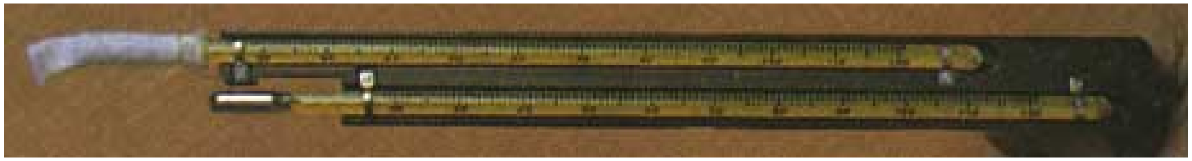
Wet-bulb temperature and psychrometers

Wet bulb temperature: Coldest temperature to which air can be cooled by evaporating water into it until the air is saturated. Warmer than dew point because moisture is added to the air to cool it, raising the dew point.

Wet-bulb temperature is roughly 30% of the way from the dew point to the temperature, e. g.:

If temperature is 20 C and dew point is 13 C, wet-bulb temperature is 15.5 C (EOM Appendix D)

Humidity can be measured using a psychrometer, which combines temperatures measured from a regular thermometer and from a'wet bulb' thermometer in which the bulb is covered with a damp cloth and ventilated by motion or a fan.



Wet bulb thermometer
Regular thermometer

EOM 4.9

Humidity Slightly Reduces Air Density

Consider a volume containing 1000 molecules of dry air at room temperature and pressure 1000 mb. The mass of the air in this volume is:

	MW	
780 molecules N_2	x 28 =	21840
210 molecules O_2	x 32 =	6720
10 molecules Ar	x 40 =	400
Total Mass	=	28960 daltons

By Avogadro's Law, a mixture of 990 molecules of dry air and 10 of water vapor at above temperature and pressure will occupy same volume as above. Vapor pressure will be 10 mb. Mass change is:

+ 10 molecules	H_2O x 18 =	180 daltons
- 8 molecules	N_2 x 28 =	-224
- 2 molecules	O_2 x 32 =	- 64
Net Mass Change		-108 daltons (-0.37%)

$\Rightarrow$ Humid air (10 mb VP) is 0.37% less dense than dry air, like warming 1 C.