

NATS 101
Section 13: Lecture 10

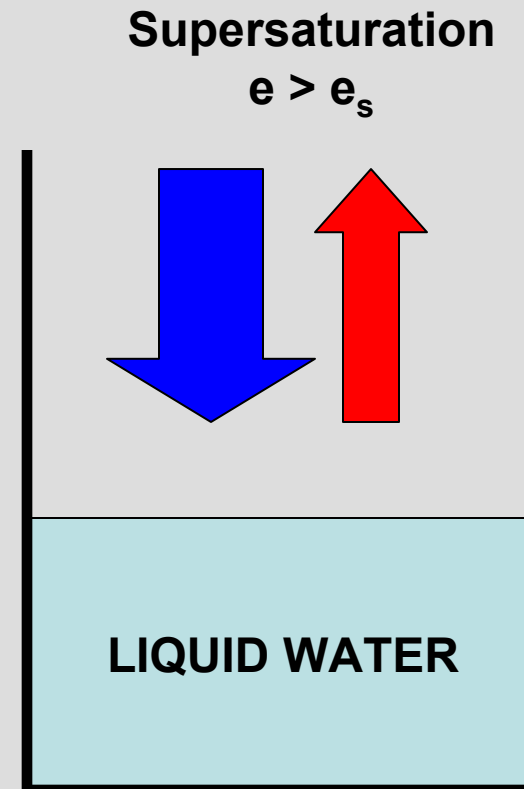
**Condensation, Cloud Formation,
and Fog**

Last time we focused on measures of atmospheric moisture which assumed the atmosphere is either saturated or unsaturated.

What happens in the case where the atmosphere is supersaturated?

What is happening when liquid water condenses?

Definition of supersaturation from last time?



If the **rate of evaporation** < **rate of condensation**, the air is said to be supersaturated with respect to water vapor.

The key idea is that water needs some sort of surface to condense on when the air is supersaturated, like the example of dew on grass.



In the atmosphere, this “surface” is a cloud condensation nuclei.

Cloud condensation nuclei (CCN)

Tiny aerosol particles upon whose surfaces condensation of water vapor begins in the atmosphere, or heterogeneous nucleation.

Cloud condensation nuclei ultimately originate from the Earth's surface, from both natural and man-made sources such as:

- Dust**
- Volcanoes**
- Smoke**
- Ocean spray (salt particles)**
- Biological processes**
- Industrial processes**

Classification of Cloud Condensation Nuclei

TABLE 6.1 >> Characteristic Sizes and Concentration of Condensation Nuclei and Cloud Droplets			
Type of Particle	Approximate Radius (micrometers)	No. of Particles (per cm ³)	
		Range	Typical
Small (Aitken) condensation nuclei	<0.2	1000 to 10,000	1000
Large condensation nuclei	0.2 to 1.0	1 to 1000	100
Giant condensation nuclei	>1.0	<1 to 10	1
Fog and cloud droplets	>10	10 to 1000	300

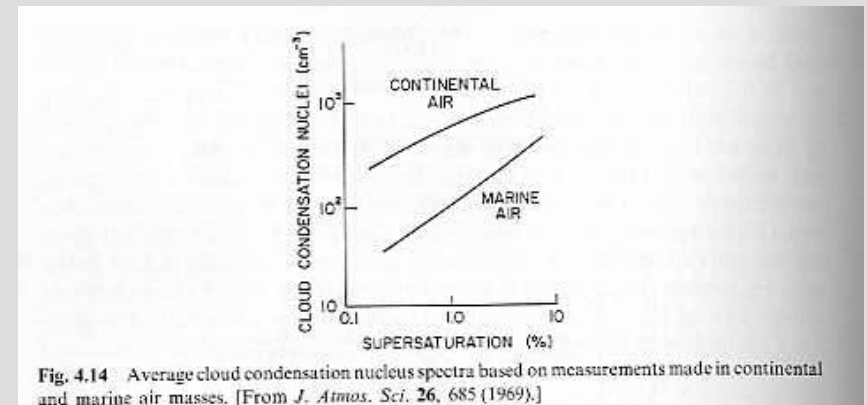


Fig. 4.14 Average cloud condensation nucleus spectra based on measurements made in continental and marine air masses. [From *J. Atmos. Sci.* 26, 685 (1969).]

(Wallace and Hobbs, 1977)

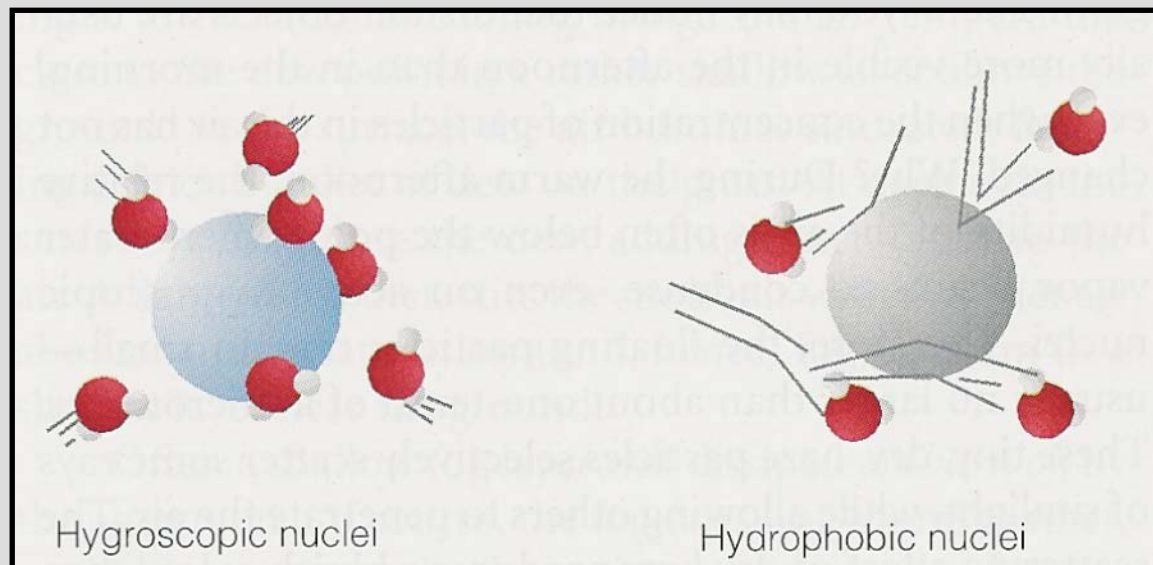
The wide range in cloud condensation nuclei concentration occurs because more aerosol pollutants occur over continents than oceans.

Continental air → more CCN

Maritime air → less CCN

What types of particles are good CCN?

Particles must be *hygroscopic*, or water seeking, so condensation will occur at or near the point where the relative humidity is 100%



Hygroscopic: condenses easily

- Salt
- Sulfuric and nitric acid

Hydrophobic: resists condensation

- Oil or gasoline
- Waxes

Haze (Weather Symbol = ∞)



Washington, DC, in summer.

Haze forms when dust or salt particles ($\sim 0.1 \mu\text{m}$) are suspended above a region.

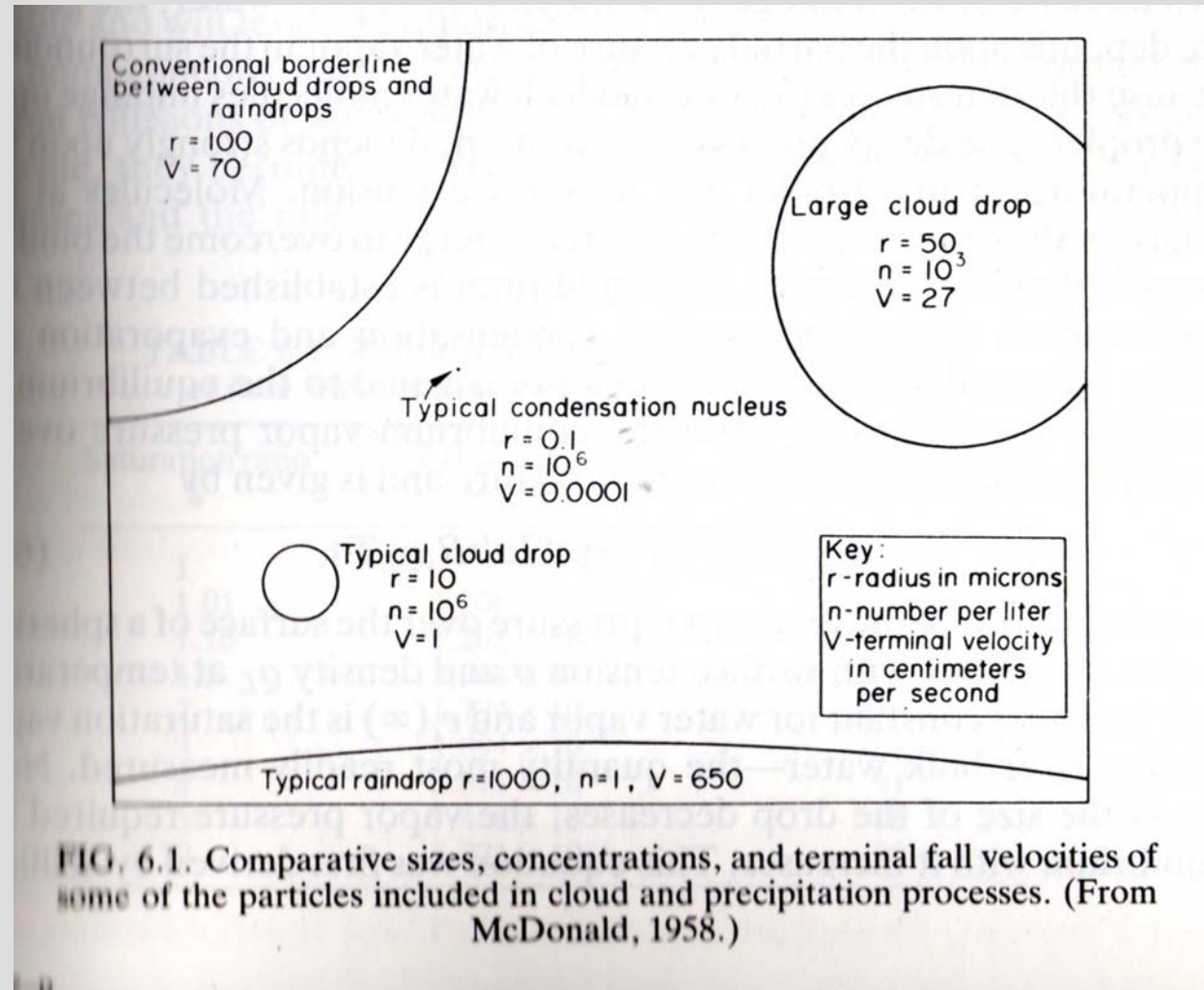
If the atmosphere is relatively humid, then the water begins to condense on these, forming tiny droplets which scatter light equally in all wavelengths

So on hot, humid days in summer (like in DC), this “wet” haze makes the sky appear dull gray or white.

Cloud droplets

Cloud droplets occur when enough water has condensed on the CCN to form a drop with a radius of about $10\ \mu\text{m}$.

How big is a typical CCN compared to a cloud drop or raindrop?



(Rogers and Yau, 1989)

Cloud drop concentration and size Maritime vs. Continental Environment

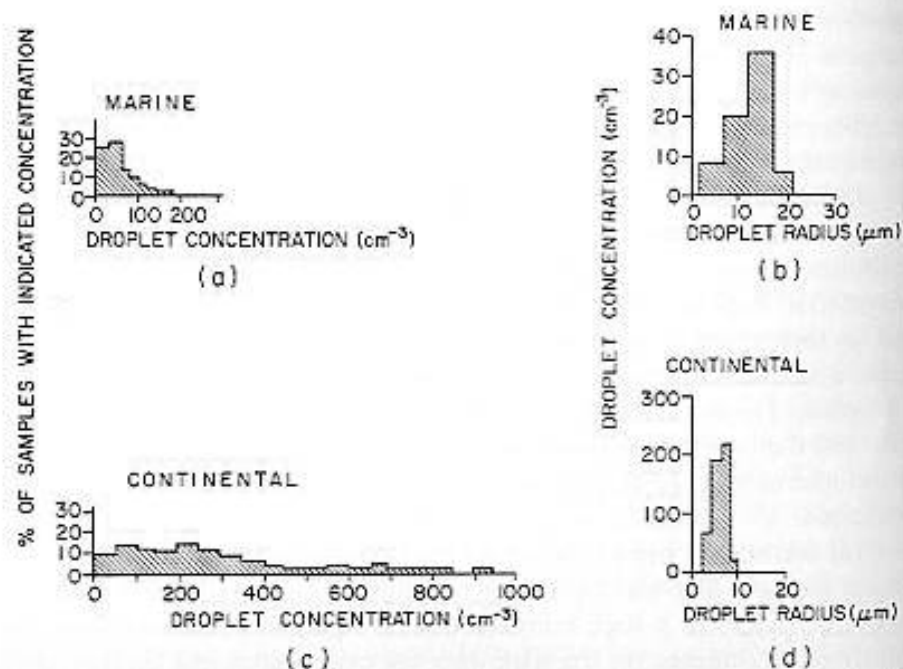


Fig. 4.15 (a) Percentage of marine cumulus clouds with indicated droplet concentrations. (b) Droplet size distributions in a marine cumulus cloud. (c) Percentage of continental cumulus clouds with indicated droplet concentrations. (d) Droplet size distributions in a continental cumulus cloud. Note change in ordinate from (b). [From *Tellus* 10, 258-259 (1958).]

(Wallace and Hobbs, 1977)

Marine Environment

Less CCN

Less total number of drops

Larger drops

Continental environment

More CCN

More total number of drops

Smaller drops



Rain cloud in Hawaii

The difference in the drop size distribution between marine and continental environments explains why rainfall can occur with very shallow clouds in tropical islands like Hawaii.

Though there are a relatively _____ number of drops in the cloud, those drops grow into raindrops a lot faster!

What is fog?

Fog: A cloud which forms at the ground, lowering the visibility to less than 1 km (or about two-thirds of a mile).

Fog Types:

Radiation Fog

Advection Fog

Upslope Fog

Steam Fog



London, England is infamous for foggy weather. What are some reasons it is so prone to fog?

Formation of Radiation Fog in Clear, Calm Nighttime Conditions

T_{ground} decreases

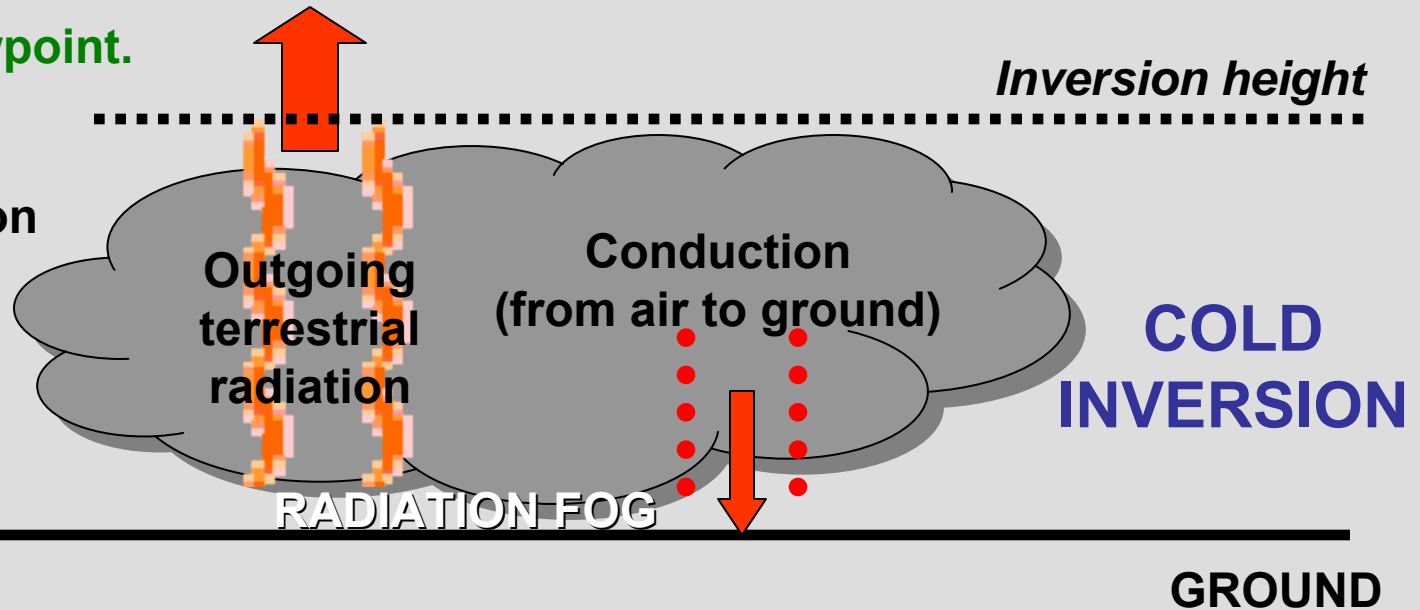
T_{air} decreases and inversion forms

T_{air} reaches dewpoint.

WARM ABOVE

Inversion height

Solar radiation
shut off



If conditions are clear and calm and the temperature cools to its dew point, water will begin to form on CCN. This is called radiation fog because it occurs as a result of radiative surface cooling.

Radiation Fog



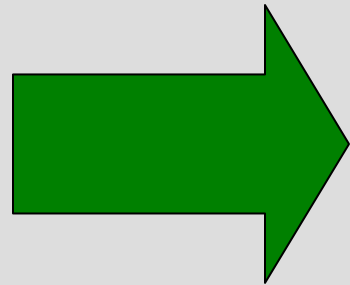
NASA image.

Radiation fog commonly forms in valley bottoms. It typically dissipates, or burns off shortly after sunrise when the ground begins to warm and the inversion goes away.

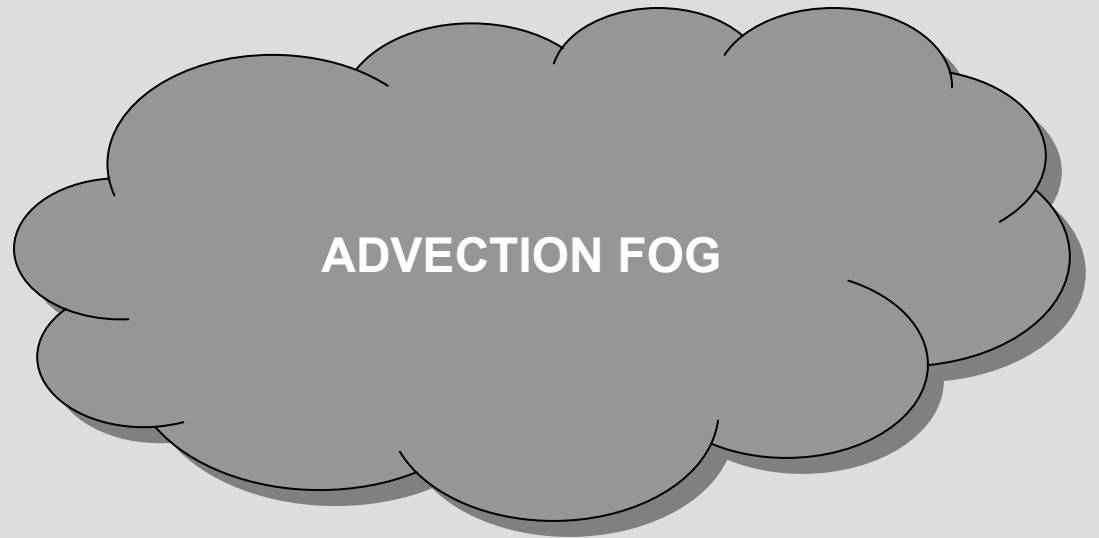
However, for big valleys, like the Central Valley of California, a strong inversion and thick fog (called Tule fog in CA) may persist for days or weeks.

Advection Fog

Warm moist air moves over a cooler surface. The air cools to its dew point and fog forms. May occur in combination with radiation fog.



**WARM, MOIST
AIR**



COLD SURFACE

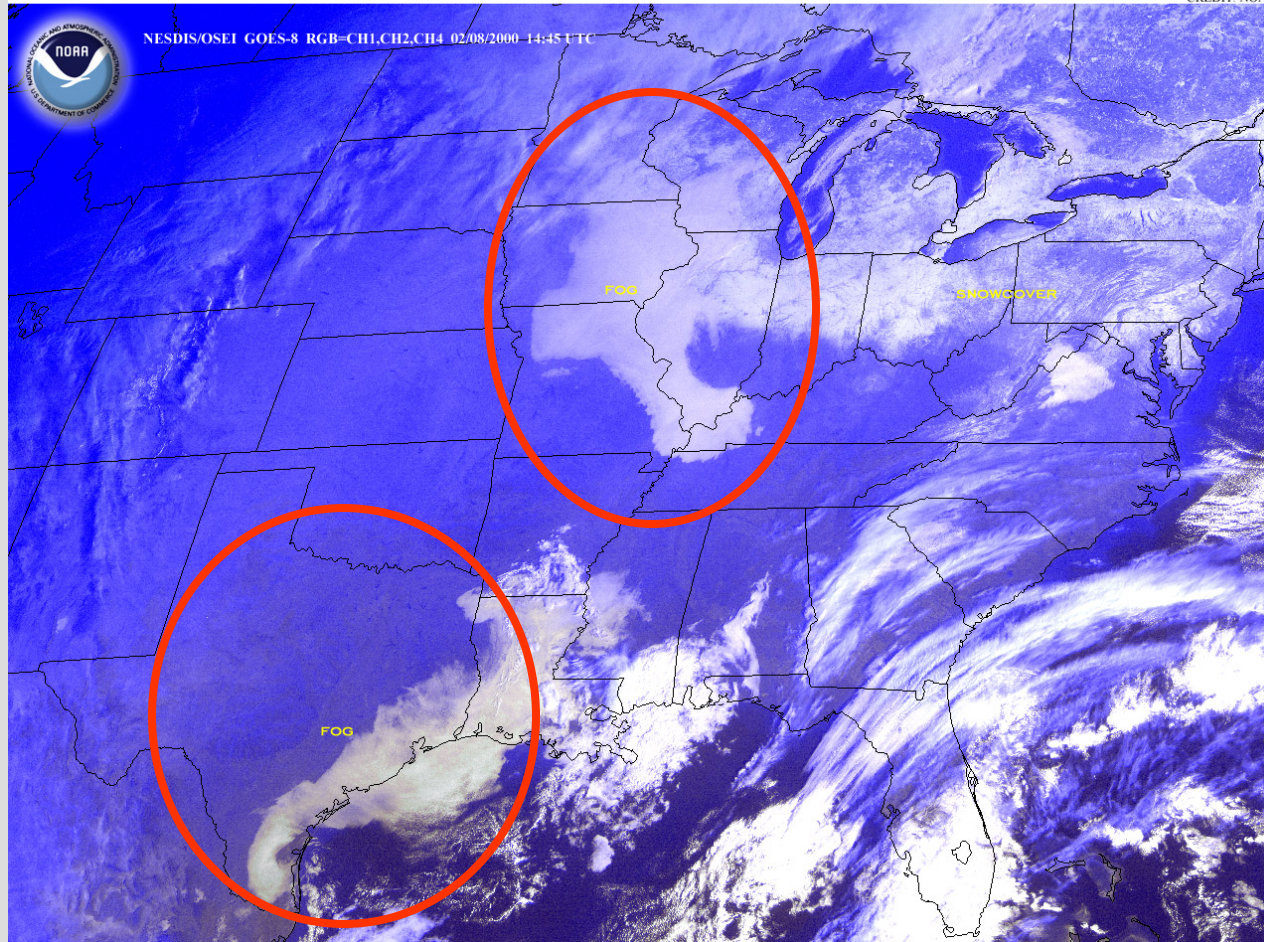
Advection Fog



Pacific coast example: Why does this happen more there?

Snow cover in the Midwest and Northeast regions of the United States and two areas of dense fog. One of these fog areas extends southward from Minnesota through Iowa, Illinois, Missouri and Kentucky, the other is along the Texas Gulf Coast and into Louisiana.

CREDIT: NOAA

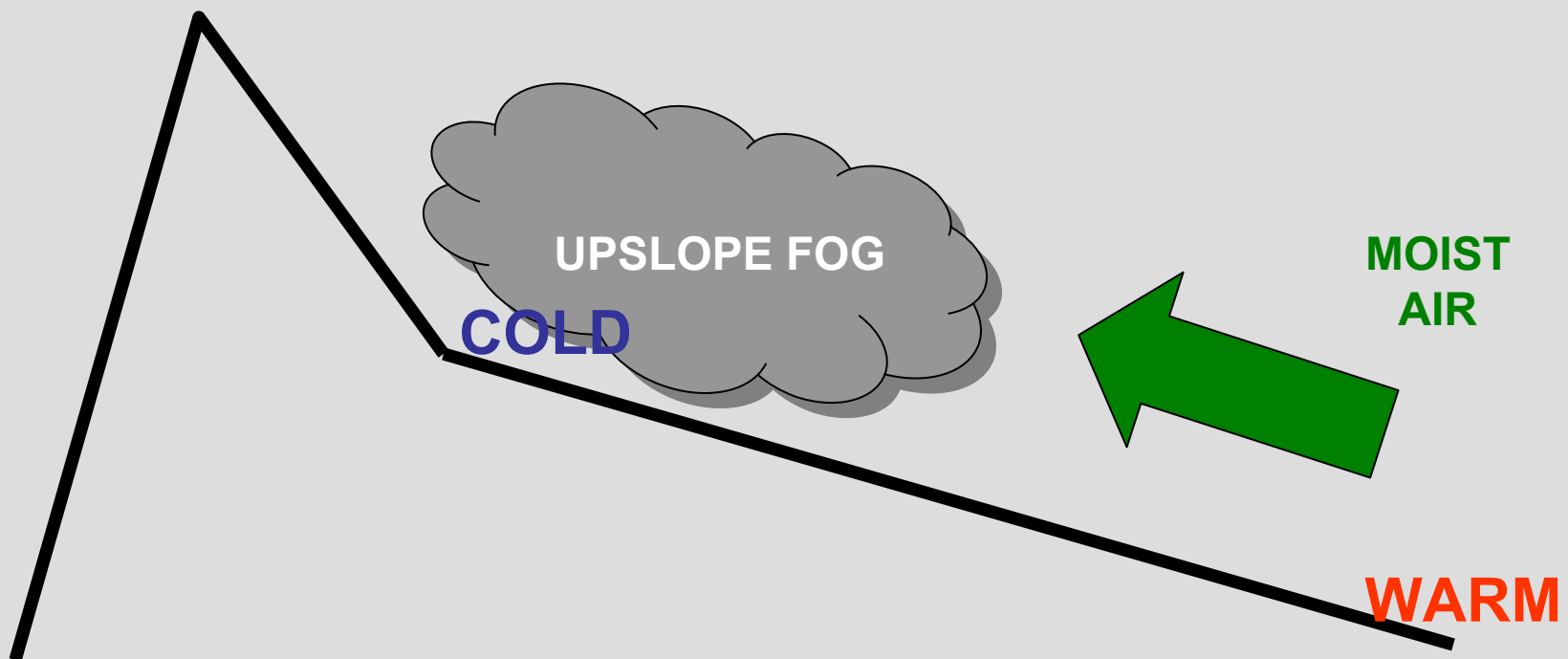


NOAA Imagery

Warm air from the Gulf of Mexico travels north over the central and eastern U.S. (February 2000). Advection fog forms in the Midwest over snow cover and Texas coast.

Upslope Fog

Moist air is forced upslope. Because the temperature decreases with elevation, the air cools to its dew point and fog forms.



A good example is the Front Range of Colorado.



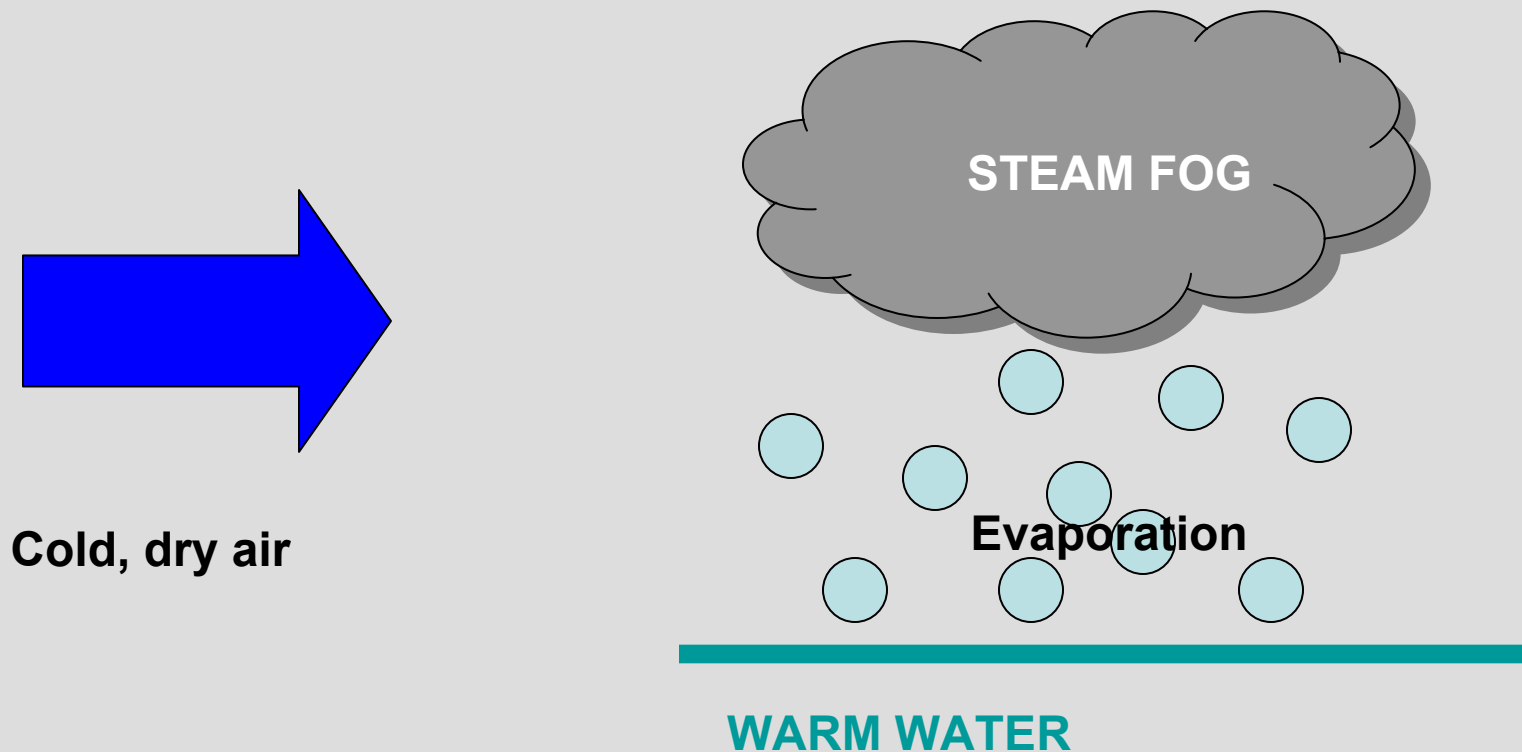
<http://meteo.pr.erau.edu/atlas/fog.html>

Photo by G. Hyland

Upslope fog on Granite Mountain, near Prescott, Arizona, in January 2001.

Steam or Evaporation Fog

Cold dry air travels over warm water (or a warm, moist surface). Water evaporates into the air, raising the dew point. If saturation occurs, fog forms.



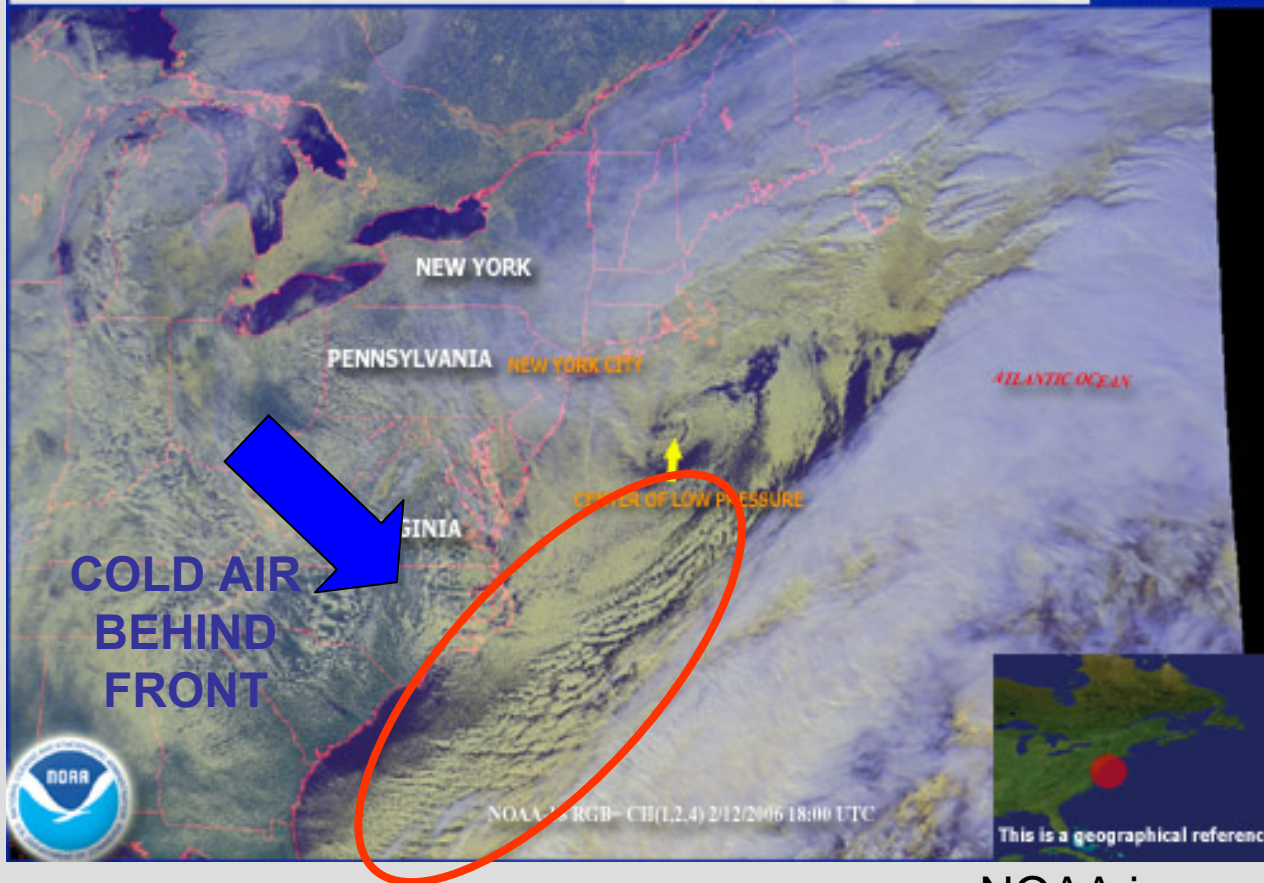


www.physicalgeography.net

Steam fog typically forms over lakes in cold, winter weather. Does this process warm or cool the water? Why?

The center of low pressure associated with the blizzard impacting New England was located 250 km (173 mi) to the southeast of New York City at 1 pm EST. Nearly 25 inches of snow had fallen in New York City by 1 pm, making this second only to the December 26-27 storm of 1947 which produced 26.4 inches.

Credit: NOAA



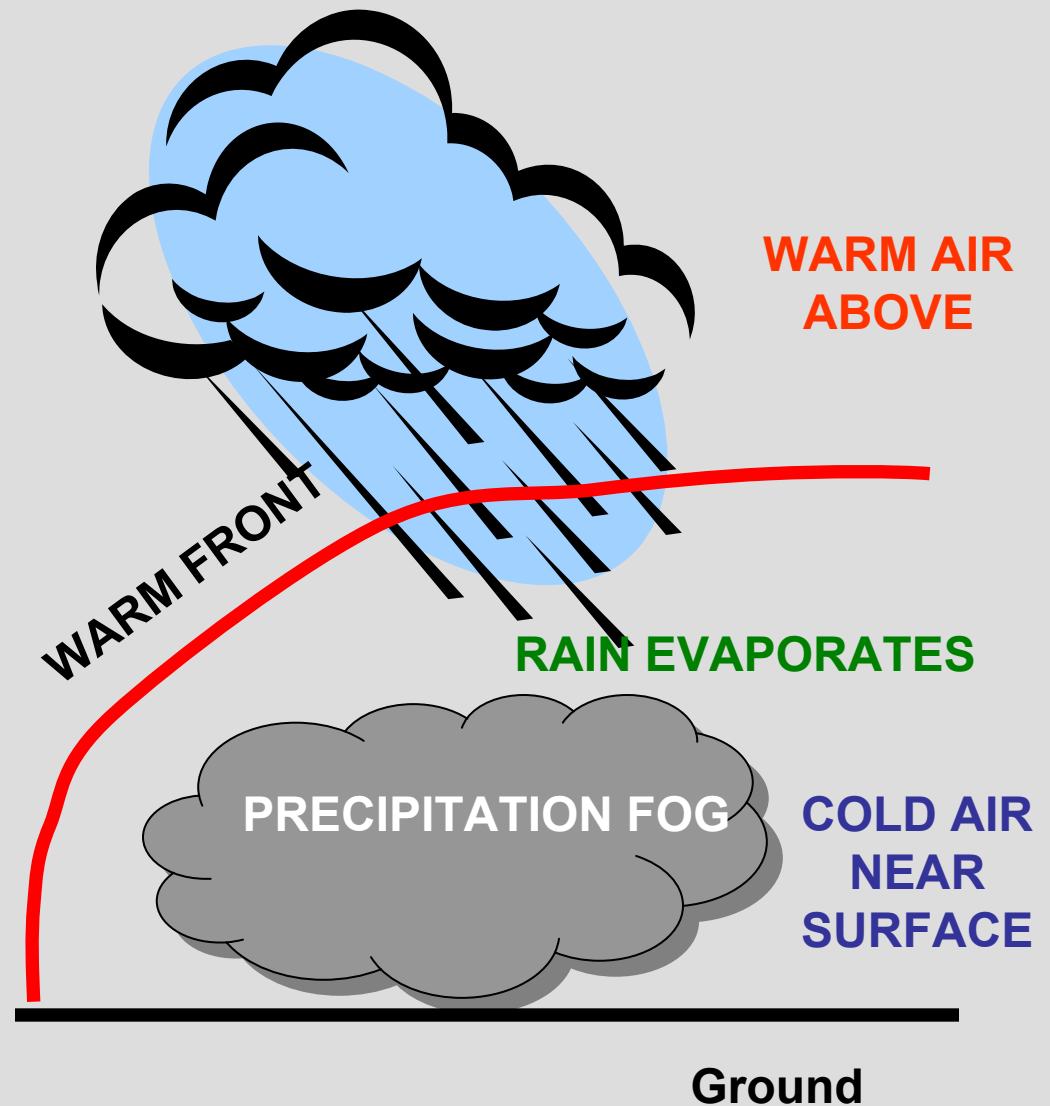
NOAA imagery

East coast storm in February, 2006. In the wake of the storm, evaporation fog is forming behind the cold front over the warm Gulf Stream. This is typical in wintertime.

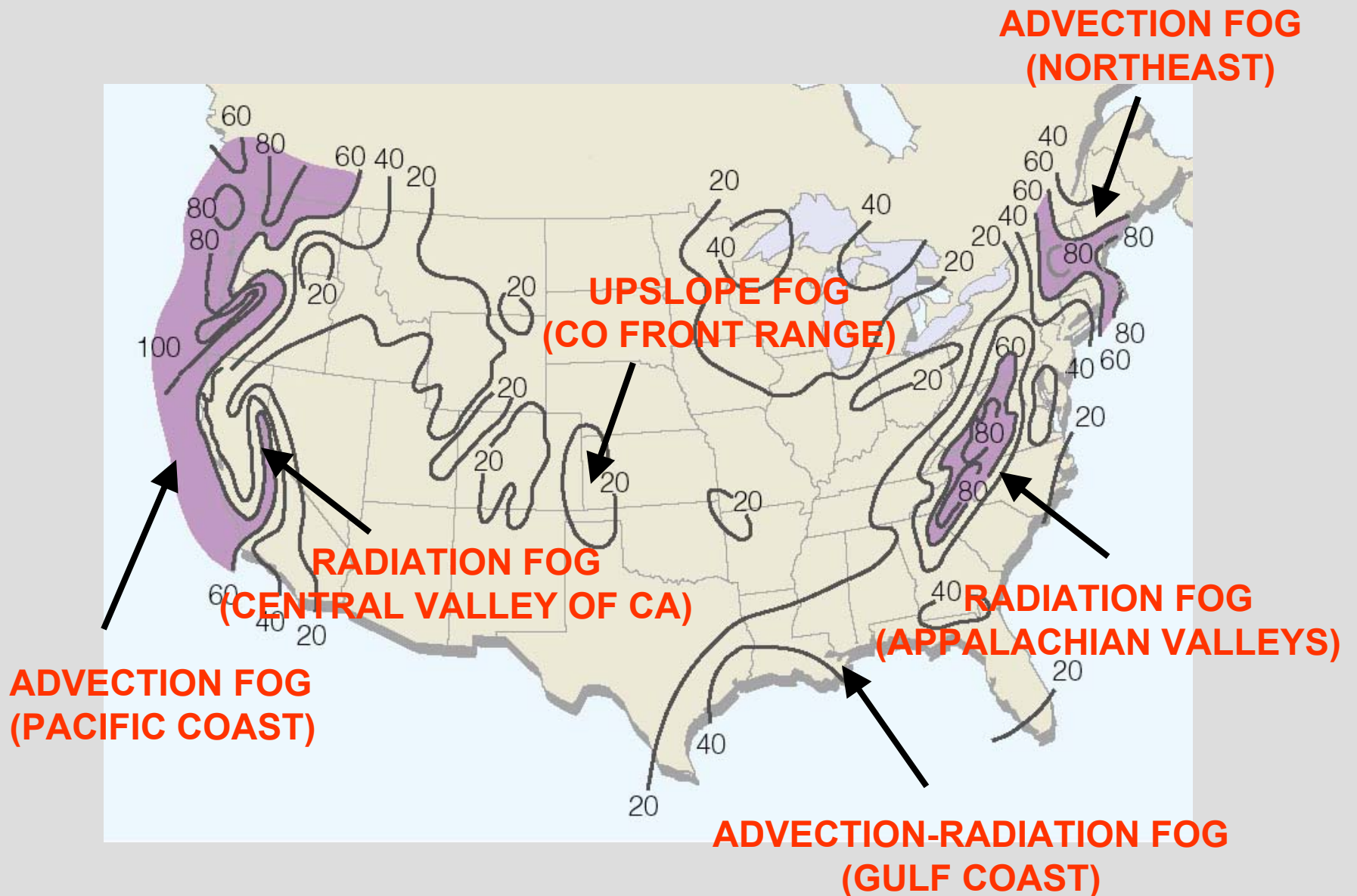
Precipitation or Frontal Fog

Warm rain falls through a layer of cold, moist air. Water evaporates into the cold air, raising the dew point. If the air reaches saturation, fog may form. It is a type of steam fog.

Common situation in warm fronts (which we'll talk about later), so it is also called frontal fog.



Foggy Areas in the U.S.



Summary of Lecture 10

Supersaturation occurs when the rate of condensation exceeds the rate of evaporation. In order for condensation to proceed a condensation surface is necessary.

The condensation surface in the atmosphere is a cloud condensation nuclei (CCN) which originate as aerosol particles from the Earth's surface. In order to be good CCN, the aerosols must be hydroscopic.

More CCN are found over continents than oceans.

Haze forms when water condenses on dust or salt particles, and it makes the sky appear gray or white due to Mie scattering.

Cloud droplets are about 10 μm or greater.

Fog is a cloud which forms near the ground and reduces visibility. The four types of fog are radiation, advection, upslope and steam. Know the physical mechanism for each of these and where they're most likely to occur.

Reading Assignment and Review Questions

Chapter 5: pp. 117-135 (8th ed.)

pp. 122-138 (9th ed.)

Cloud Chart at the back of the book.