METR/ENVS 113

Lecture 7: Air Pollution Meteorology

SJSU Fall Semester 2020

Module 3: Outdoor Air Pollution (Ozone and PM2.5)

Frank R. Freedman (Course Instructor)

Module 3: Outline

- **Air Pollution Meteorology** (Lecture 7)
- **Outdoor Air Pollution – Ground Level Ozone** (Lecture 8)
- **Outdoor Air Pollution – PM2.5** (Lecture 9)

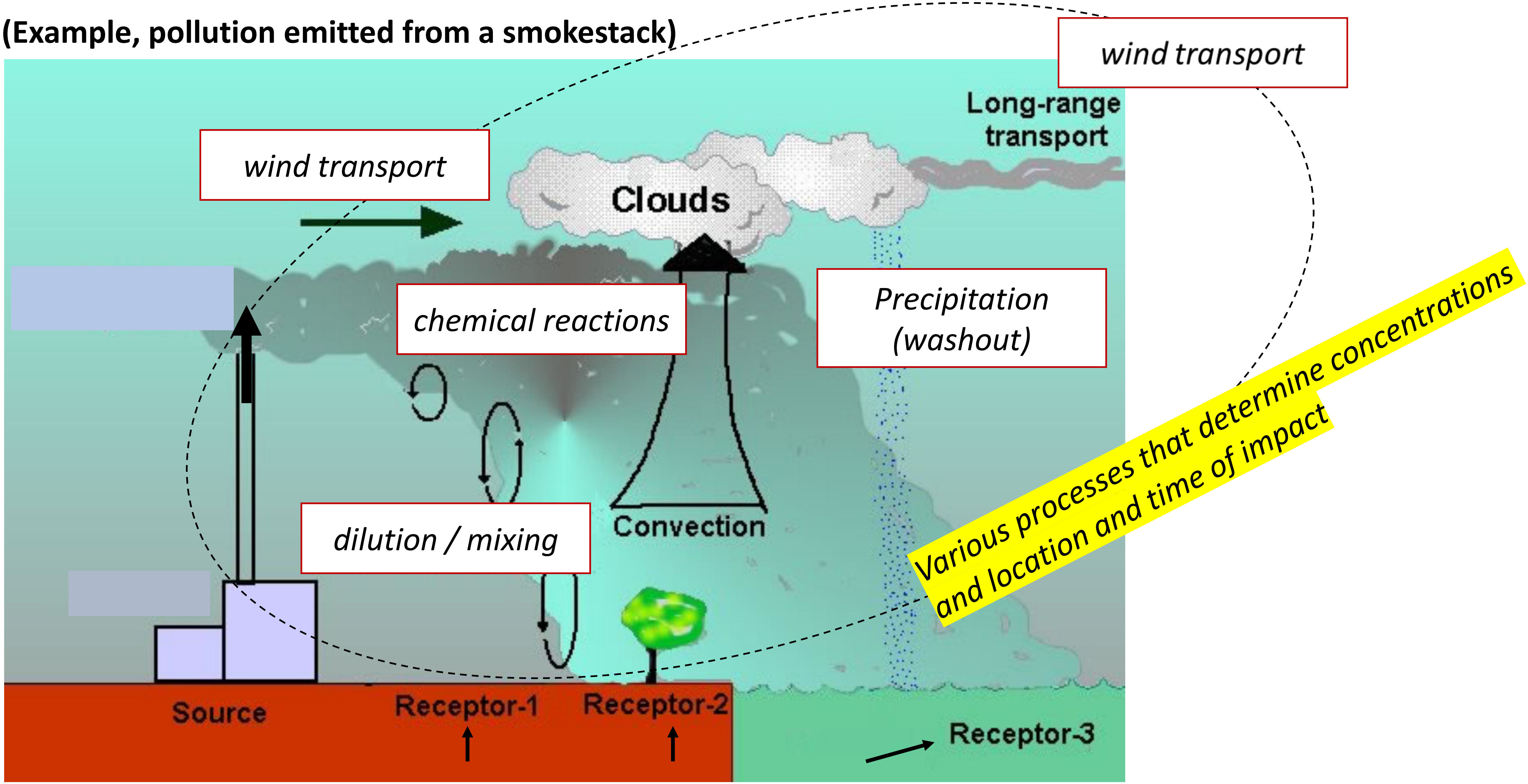
Lecture 7: Air Pollution Meteorology (Outline)

- **Air Pollution Meteorology: Processes & Variables**
- **Focus Topic 1: Winds and Pressure Systems**
- **Focus Topic 2: Temperature Inversions**

Air Pollution Meteorology
(Processes & Variables)

Processes that Affect Pollution Emitted from a Source

(Example, pollution emitted from a smokestack)



Processes & Meteorological Variables: Summary (1)

- Wind Transport
  - Air movement. Transports air pollution downwind away from emission source.
  - Meteorological Variables: Wind Speed, Wind Direction, Pressure
- Dilution / Mixing
  - Caused by “turbulence” (wind gustiness) in the air
  - Mixes polluted air with adjacent cleaner “unpolluted” air
  - Pollution spreads out, covers greater area as mixing increases
  - Peak air concentrations are reduced as mixing increases
  - Meteorological Variables: Wind speed, temperature (day vs. night), temperature inversions, high versus low pressure systems

Processes & Meteorological Variables: Summary (2)

- Chemical Reactions (gas phase)
  - Reactions of an emitted species with others in the air
  - Reduces concentrations of emitted species
  - Can form new pollution species as products of chemical reactions ("secondary air pollutants").
  - Example air pollutants: Ground-level ozone, photochemical smog
  - Meteorological Variables: Temperature and Sunlight
- Chemical Reactions (aqueous phase)
  - Reactions involving air species in presence of liquid water in air (haze, fog, clouds)
  - Gaseous air pollutants dissolve and dissociate into ionic compounds in liquid water.
  - Can form new pollution species as products of chemical reactions ("secondary air pollutants").
  - Example air pollutants: nitrate & sulfate PM2.5, acid fog, acid rain.
  - Meteorological Variables: Humidity, cloud coverage, precipitation

Processes & Meteorological Variables: Summary (3)

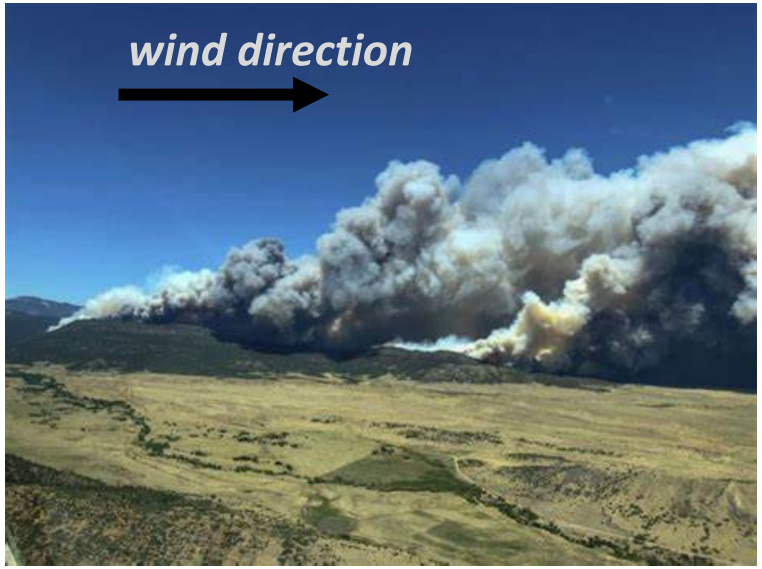
- Atmospheric Removal ("Washout", "Scavenging", "Wet Deposition")
  - Removal of air pollutants from air due to absorption into precipitation (rain, snow, etc …)
  - Affected pollutants: Particulate (PM2.5, PM10, etc …) and gases that are subject to aqueous phase chemistry (e.g. SO2, NO2).
  - Meteorological Variables: Precipitation
- Long Range Transport
  - Movement long distances (100s of kilometers or more) with wind transport
  - Affected pollutants (1): Relatively inert species, those that do not chemically react readily in air (gaseous or aqueous).
  - Affected pollutants (2): Species that are emitted through depth of troposphere. Examples, wildfire smoke, volcanic eruptions.
  - Meteorological Variables: Wind speed and wind direction throughout troposphere.

Air Pollution Meteorology
(Focus Topic 1: Winds and Pressure Systems)

Wind Direction & Air Pollution Transport

Pollution from a smokestack emission

Pollution from an industrial accident



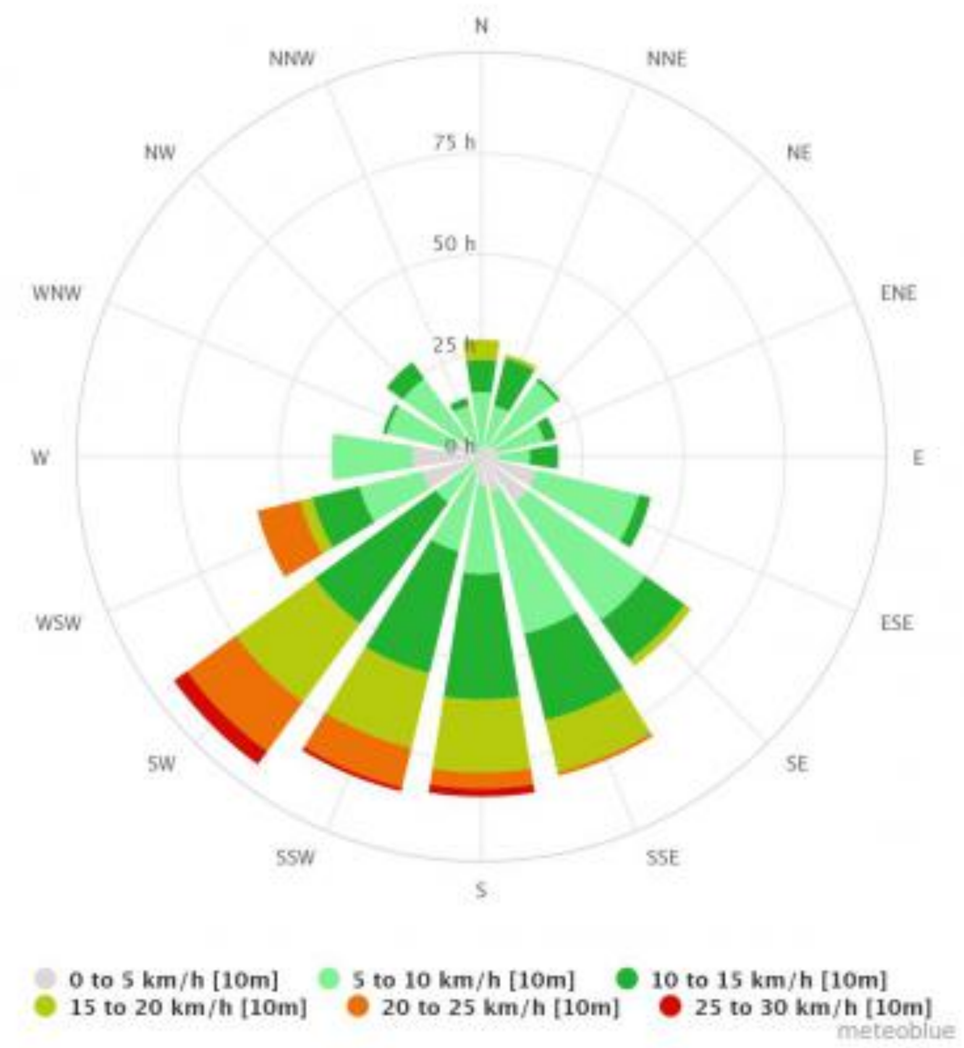
Wildfire smoke

Wind Rose

- Way of depicting winds measured at a location over long periods of time
- Depicts the frequency of winds of certain speeds from certain wind directions
- Length of flag – how frequently wind blows from direction that flag is pointing towards
- Hatches along flag – subdivides frequency according to wind speed.

<u>Wind Rose: Example 1</u>

- Winds blow most frequently from SW, SSW, S and SSE
- Fastest winds from SSW and SW

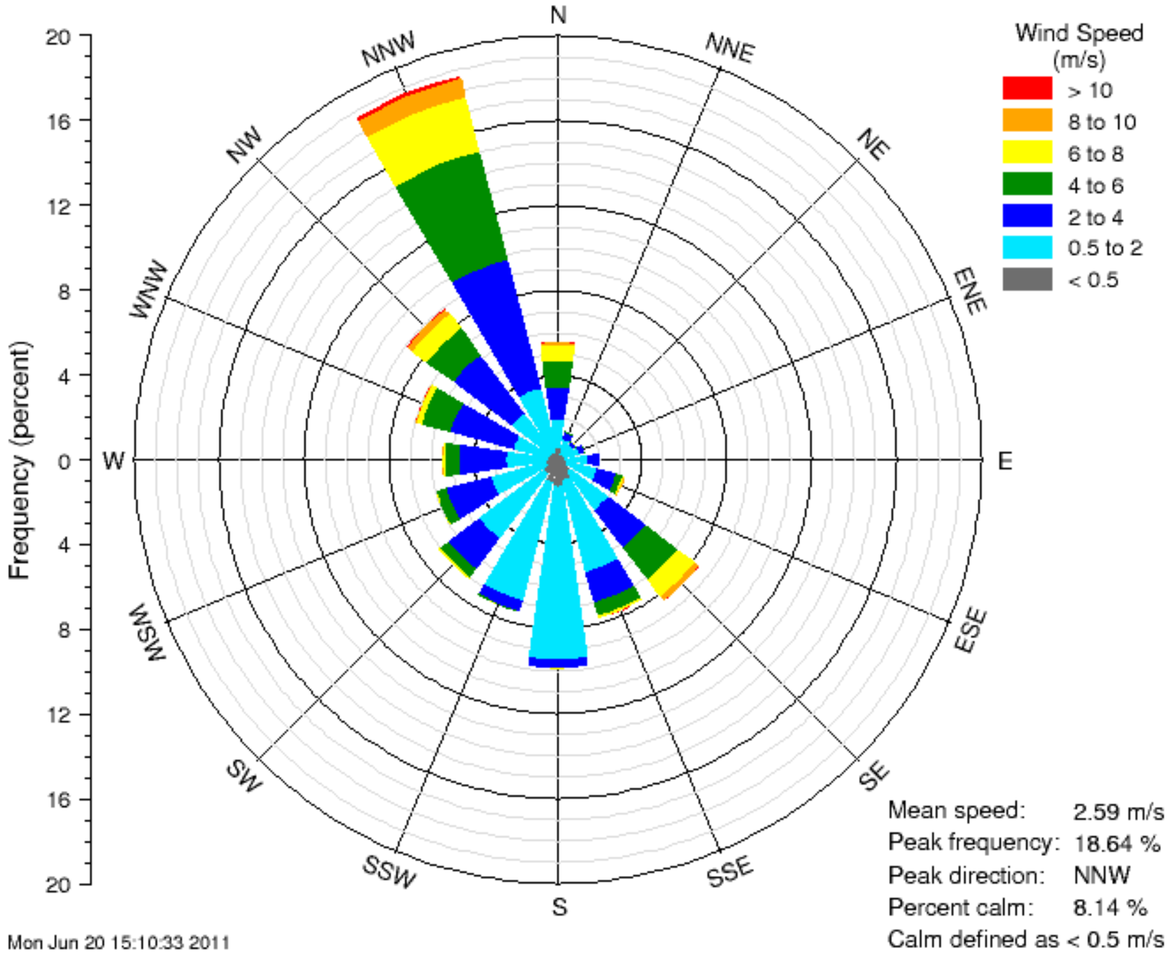


Wind Rose

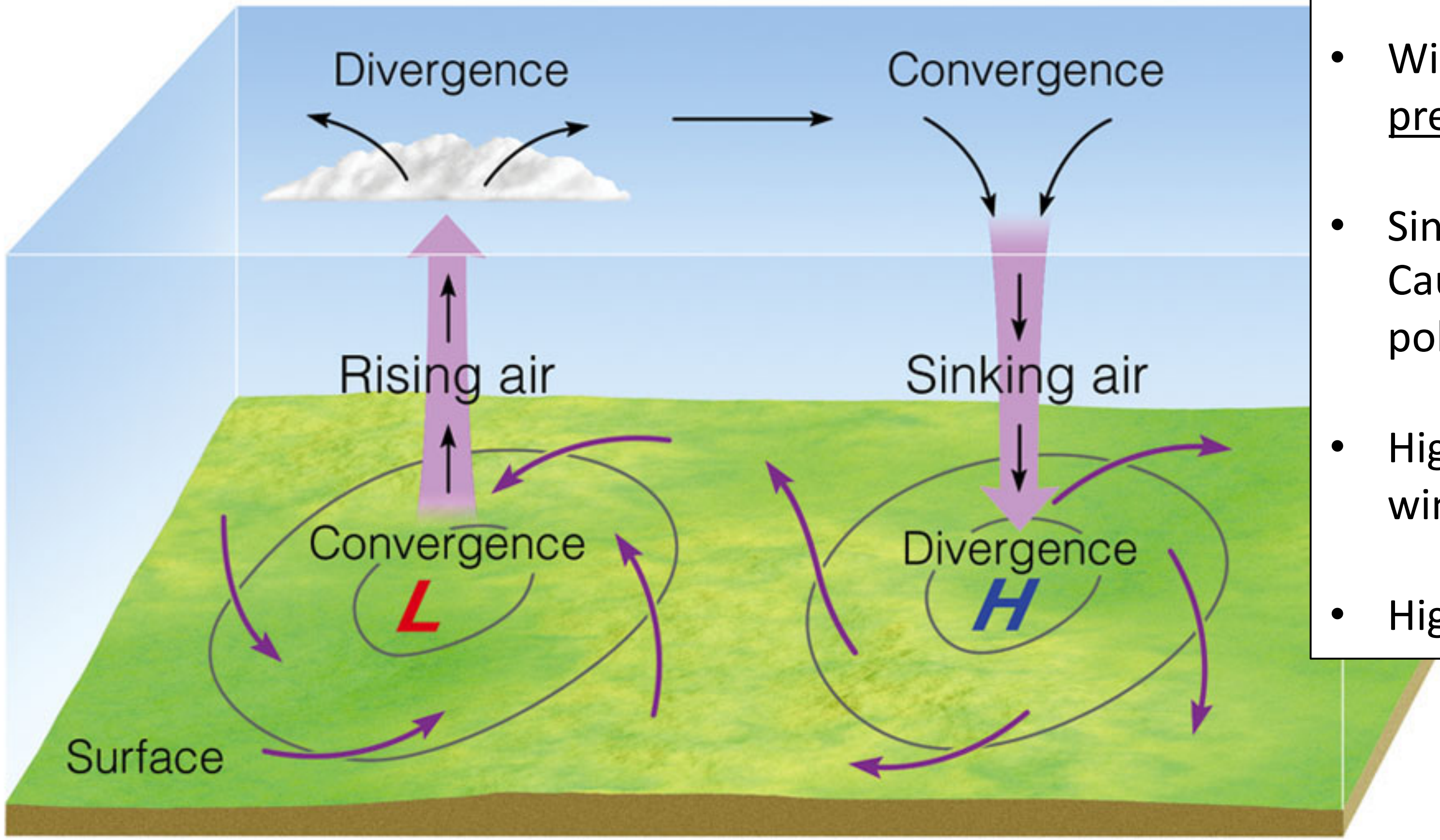
- Way of depicting winds measured at a location over long periods of time
- Depicts the frequency of winds of certain speeds from certain wind directions
- Length of flag – how frequently wind blows from direction that flag is pointing towards
- Hatches along flag – subdivides frequency according to wind speed.

<u>Wind Rose: Example 2</u>

- Winds blow most frequently from NNW
- Fastest winds from NNW
- Secondary peak frequency from SSW, S, SSE, SE
- Weak winds from SSW and S



Winds Around Surface High and Low Pressure

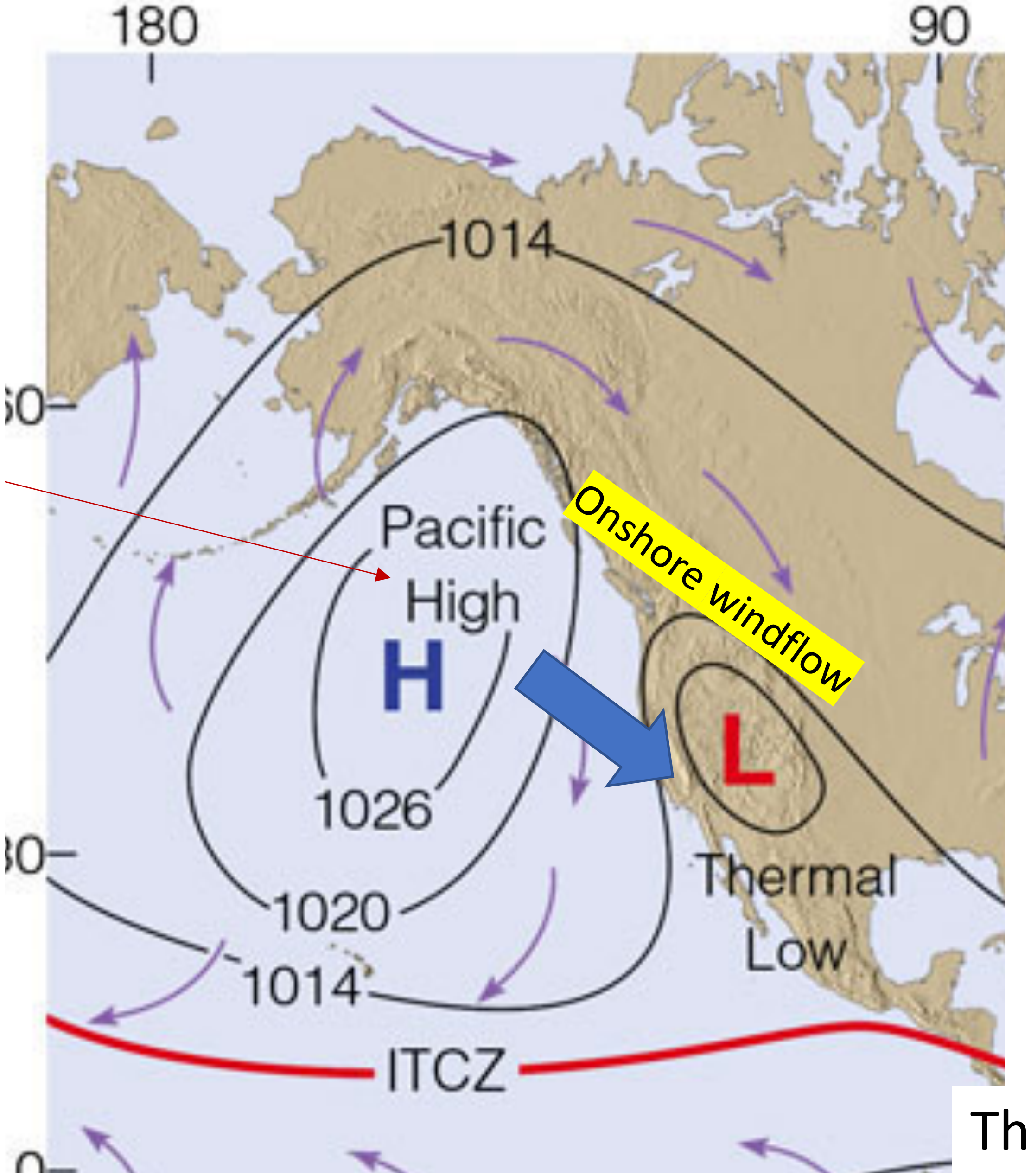


Key Points:

- Winds typically blow from high to low pressure.
- Sinking air associated with high pressure. Causes temperature inversions that trap air pollution (slides explaining this to come …).
- High pressure generally associated with weaker winds, and stagnation periods
- High pressure typically worse for air pollution

Typical Surface Pressure for summer off California Coast

PACIFIC HIGH
(offshore)



Thermal Low
(inland valleys)

Typical Summertime Daytime Wind Pattern (Bay Area)

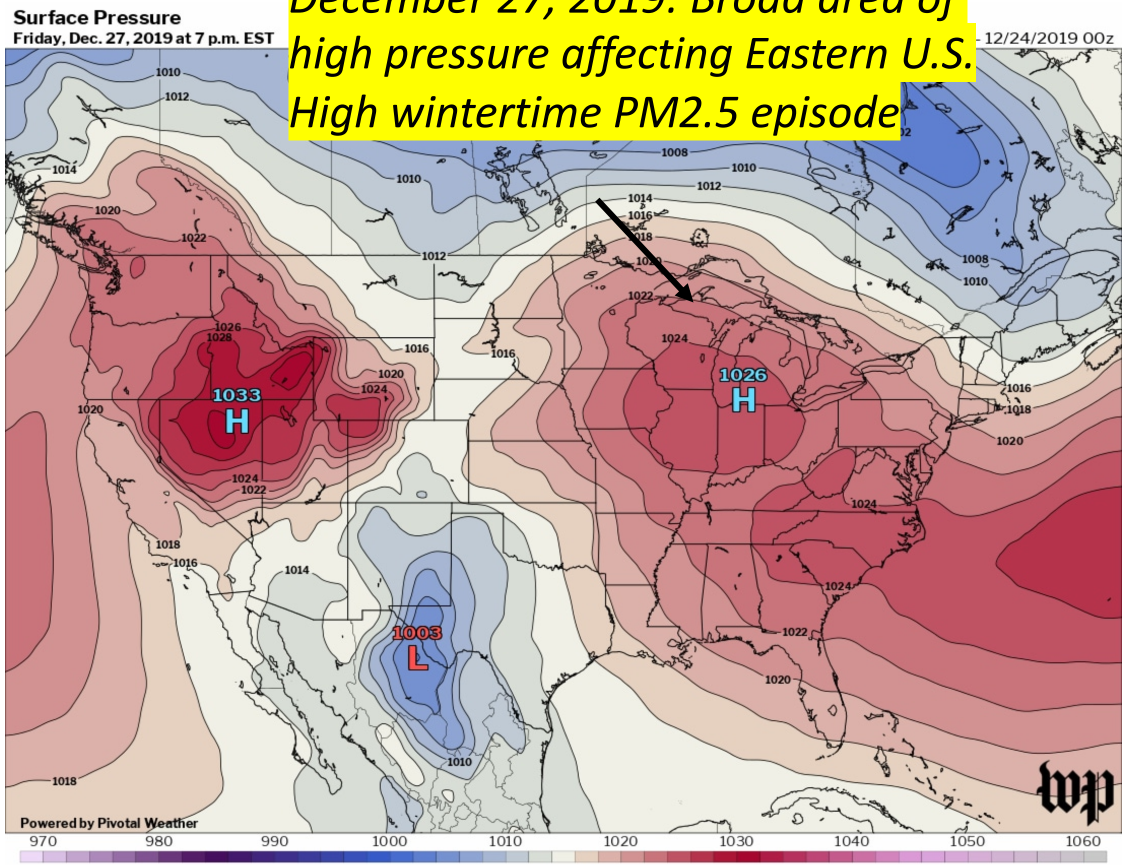
FIGURE 3.4-5
Ozone Transport from the BAAQMD

Key Points:

- Example of typical bay area summer wind flow patterns.
- Wind travels generally onshore, forced by Pacific High offshore towards thermal low covering inland valleys.
- Moves pollutant towards and get trapped in inland valleys

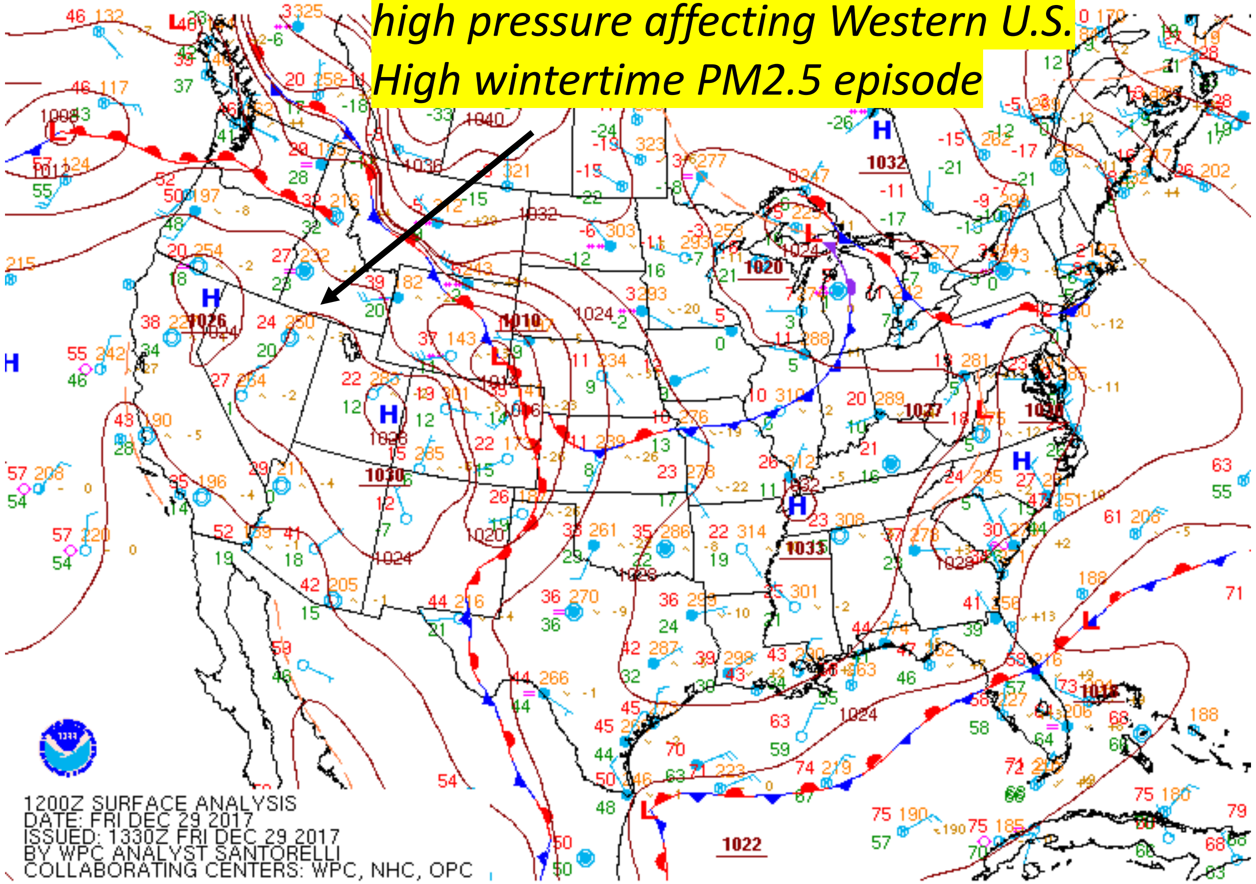
High Air Pollution Episodes: Stagnation Periods

December 27, 2019: Broad area of high pressure affecting Eastern U.S. High wintertime PM2.5 episode



https://www.washingtonpost.com/weather/2019/12/24/stagnant-air-brings-unhealthy-pollution-levels-washington/

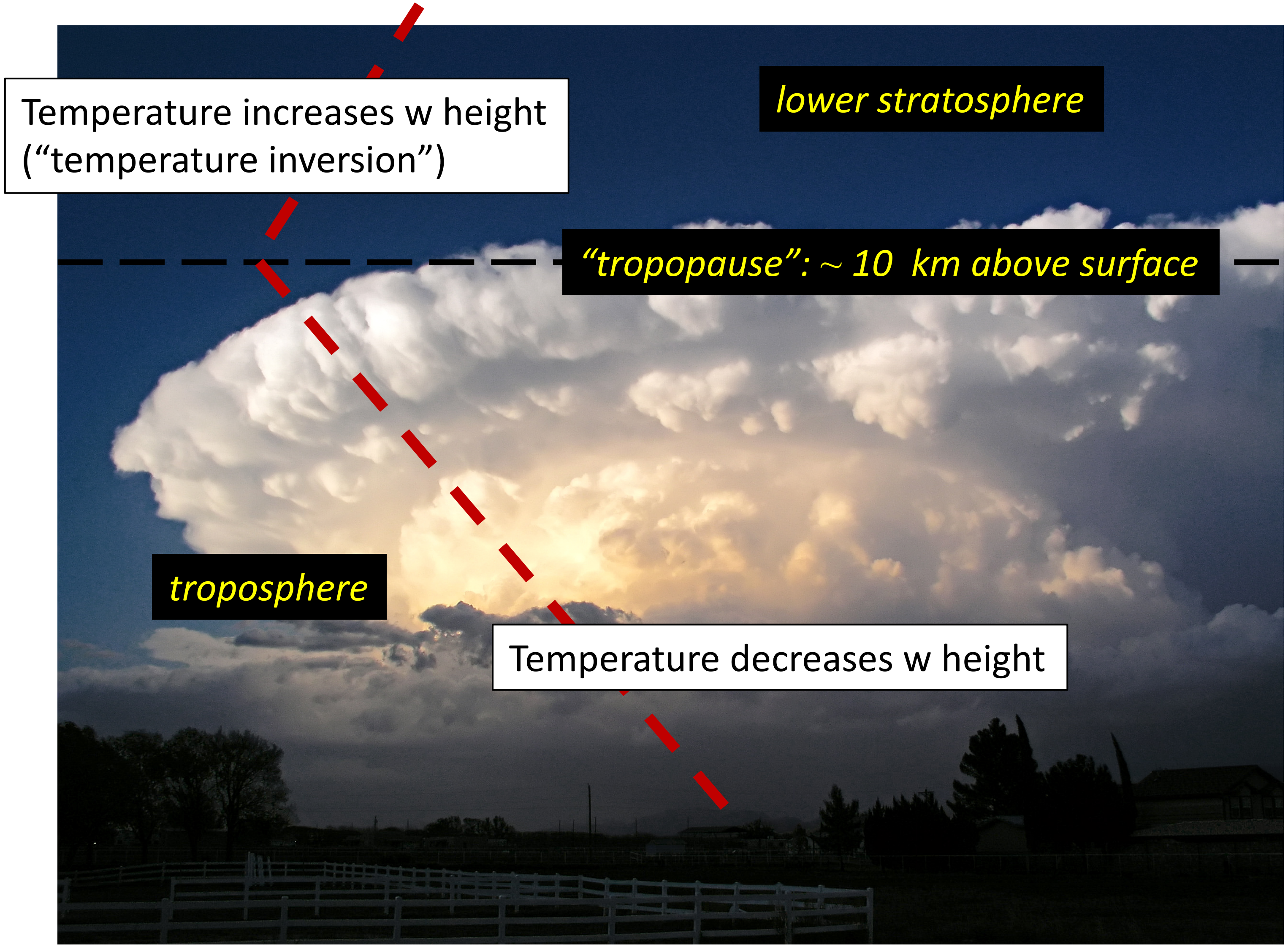
December 29, 2017: Broad area of high pressure affecting Western U.S. High wintertime PM2.5 episode



https://www.bakersfield.com/news/air-district-blames-atmospheric-stagnation-for-wintertime-pollution-spikes/article_acb6f950-1da5-11e8-a175-77fd45139ccc.html

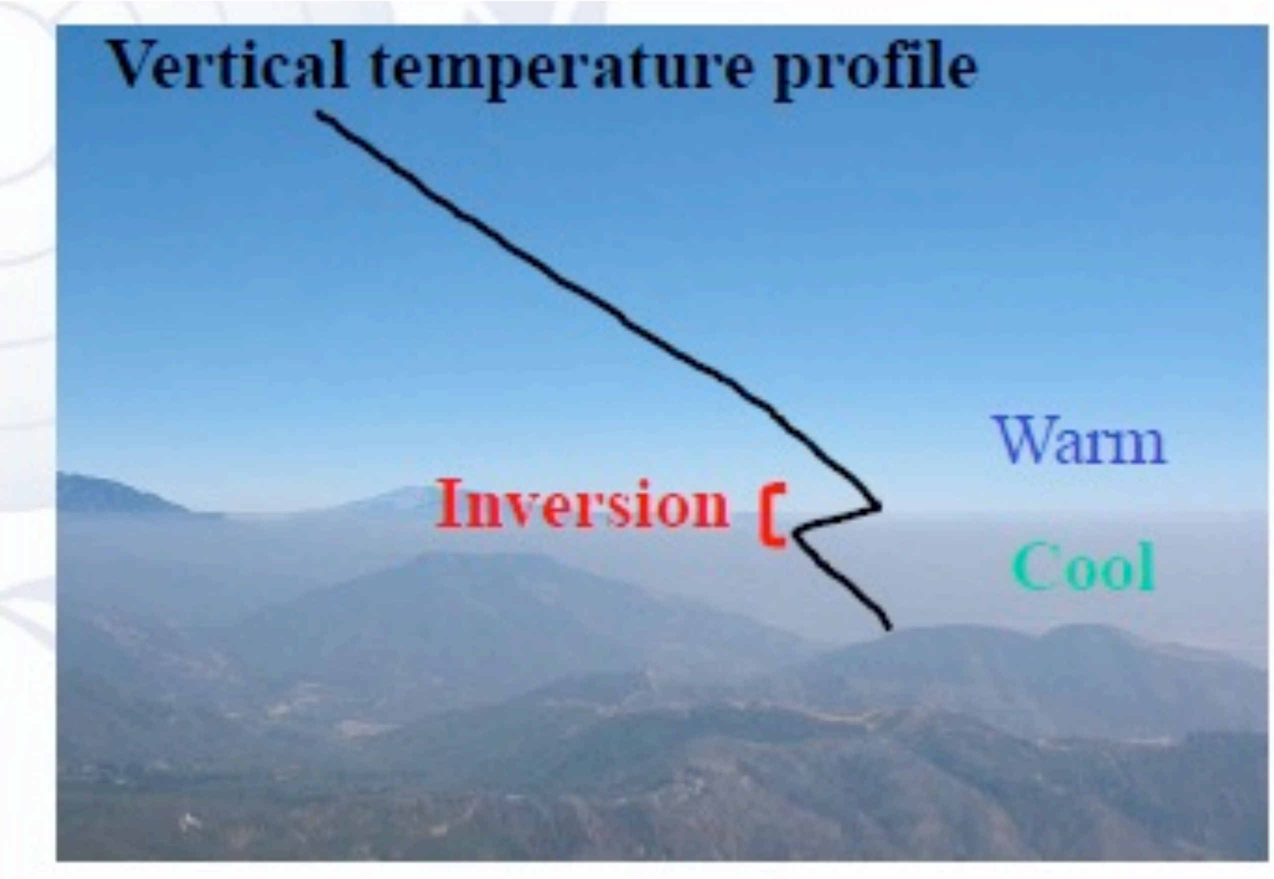
Air Pollution Meteorology
(Focus Topic 2: Temperature Inversions)

Stratospheric Temperature Inversion and Tropopause (from Lecture 1 …)



cumulus nimbus cloud
(thunderstorm)

Inversions at low elevations (near surface) that affect air pollution

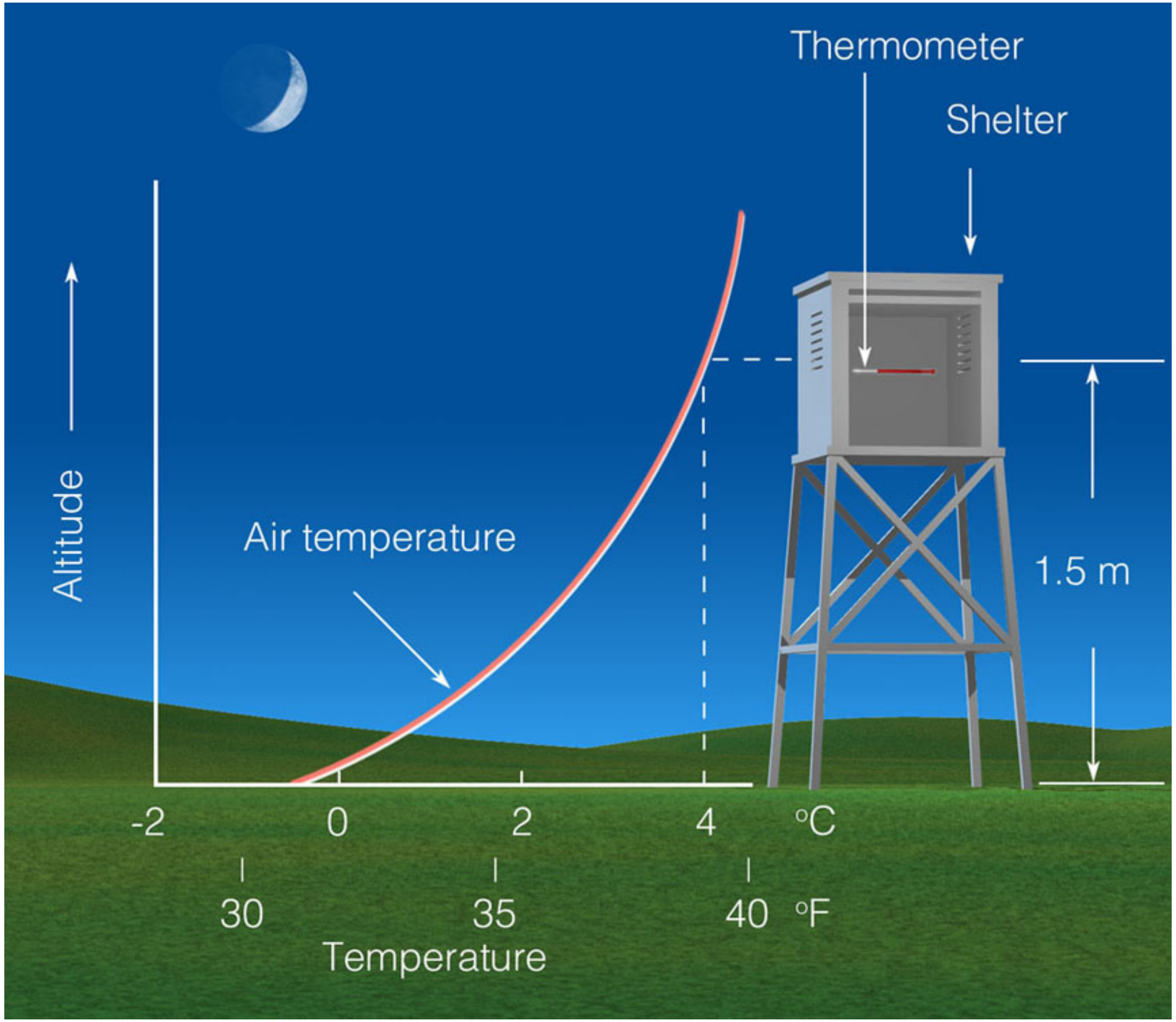


above the base of the inversion layer, while the smog remains below.

Temperature Inversions

1. Ground-based inversions (wintertime)
2. Subsidence inversions (summertime)

1. Ground-Based (Radiation) Inversions



Key Points

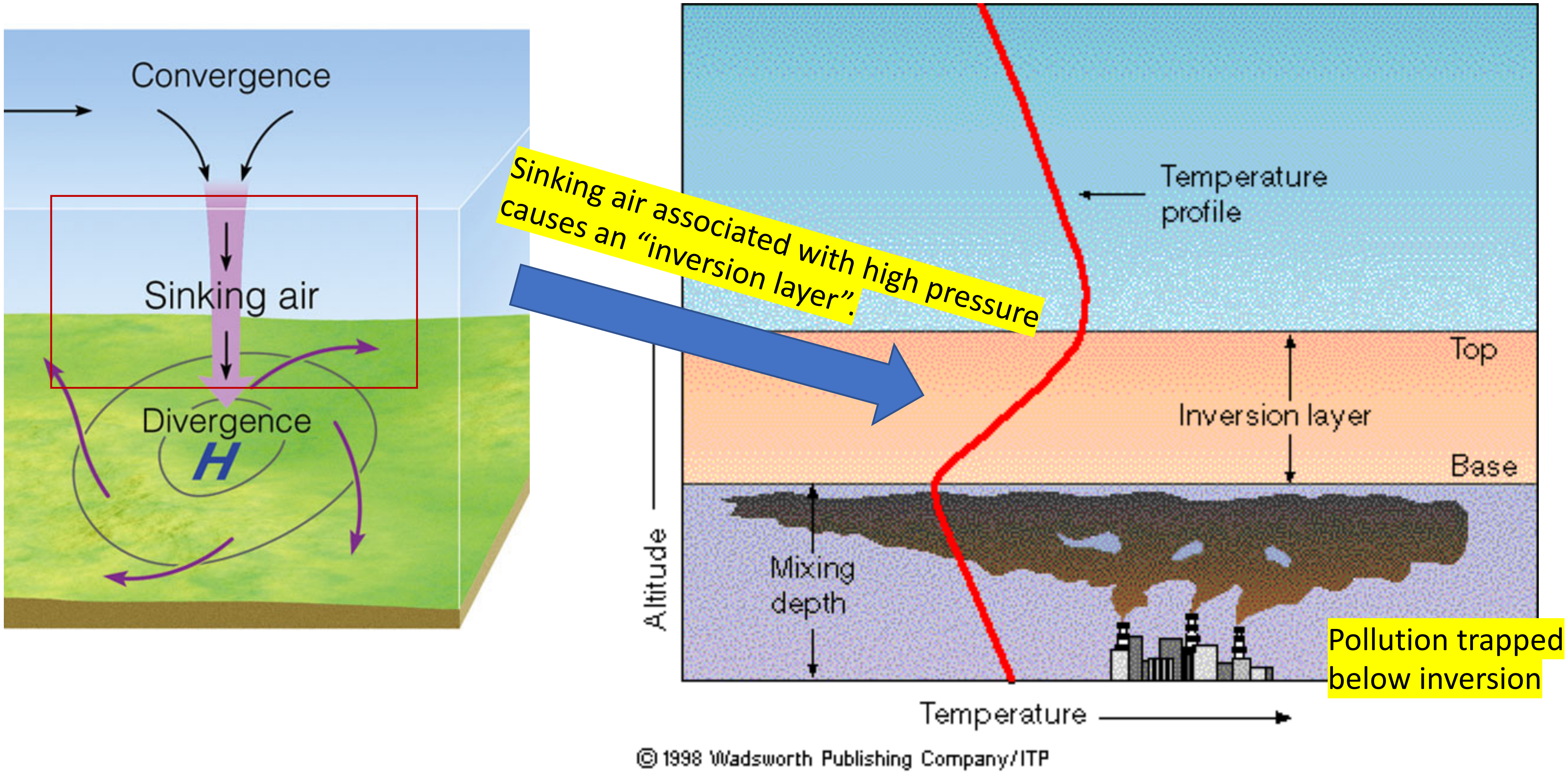
- Caused by sustained, infrared radiational cooling of the surface.
- Develop most strongly during long nights (wintertime) during clear skies.
- Ground-based inversion is shallow – within lowest 100s of meters above surface.
- Traps wintertime pollution emissions … leading to high concentrations.
- Common during stagnation episodes mentioned earlier.

Example: Nighttime Radiation Inversion w cold air trapped in valley ("Cold Air Pools")

Example: Urban pollution trapped within wintertime ground inversion (Salt Lake City, Utah)

Steve Griffin, Salt Lake Tribune

2. Subsidence Inversion



Example: Summertime air pollution trapped below subsidence inversion