MET 4300

Lecture 17
Mountain Windstorms (CH17)

Downslope Winds

--Hurricane force winds

•**Foehn** in the European Alps (a general term for warm, dry downslope windstorms –Latin: west wind)

•**Bora** in the Adriatic Sea SE of the Dinaric Alps (a general term for cold downslope windstorms—Greek: north wind)

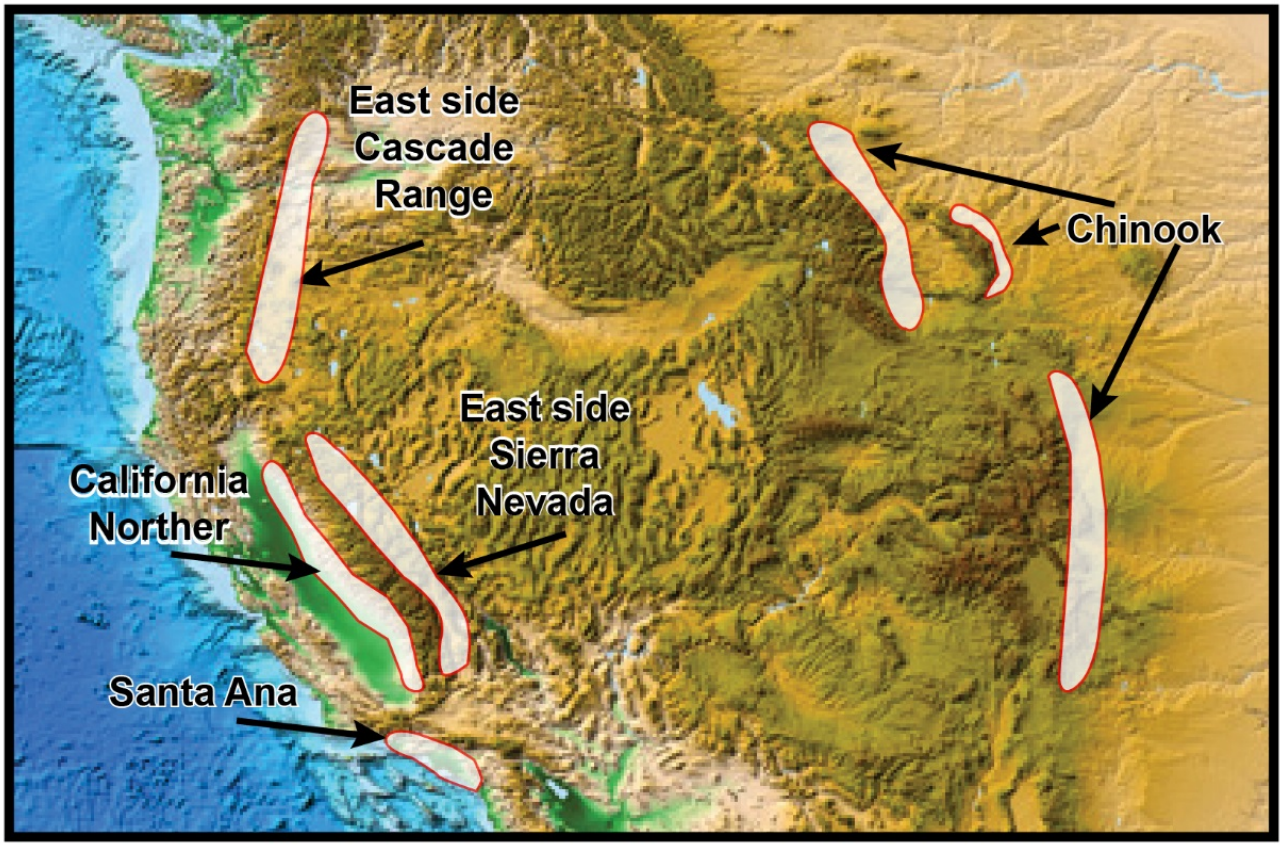
•**Katabatic Winds**: in high-latitude icefields in Alaska, Greenland and Antarctica (very cold winds)

In US:

•**Chinook** or Snow Eater in the east slope of the Rockies

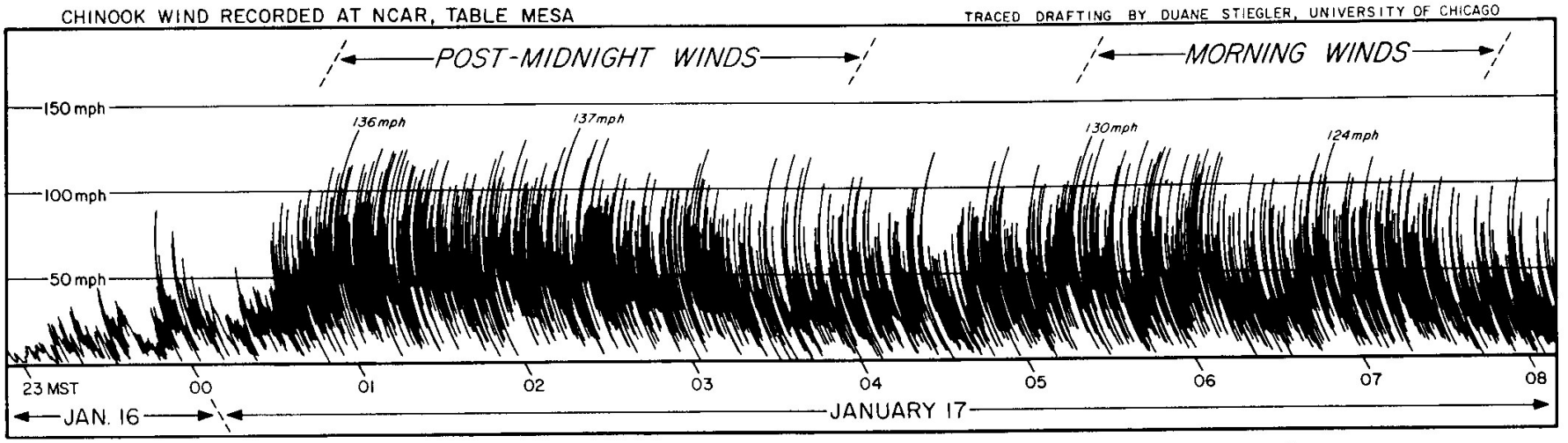
•**Santa Ana** in California: west slope of the San Bernardino, Santa Ana, and San Gabriel Mountains

Downslope Winds in Western North America



•**Chinooks:** can be extremely gusty (>100 kts), occur every year, mainly in late fall & winter. Chinooks extends from north to south along the plains of eastern Colorado from Fort Collins to Colorado Springs, including Denver and Boulder. The worst downslope winds are in Boulder.

An example of Chinook Winds



Jan 16-17, 1982 Chinook Wind Measurement at NCAR Boulder CO

Chinooks are warm (or hot), strong and gusty, blowing from a fixed direction, generally away from the mountains

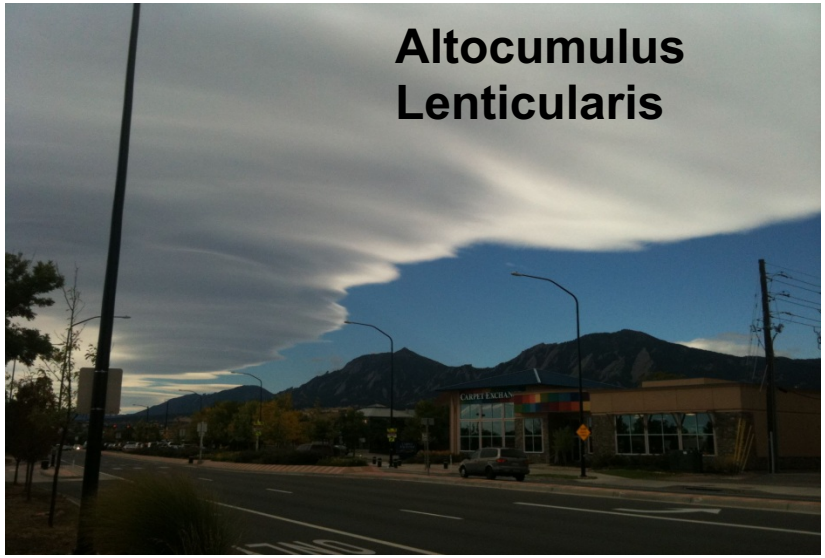
Gusts may exceed 100 kts. Influence the plains of eastern CO, mainly Boulder.

Gustiness (from 100mph to 10 mph within a minute) can cause a lot of roof damages, and psychological problems.

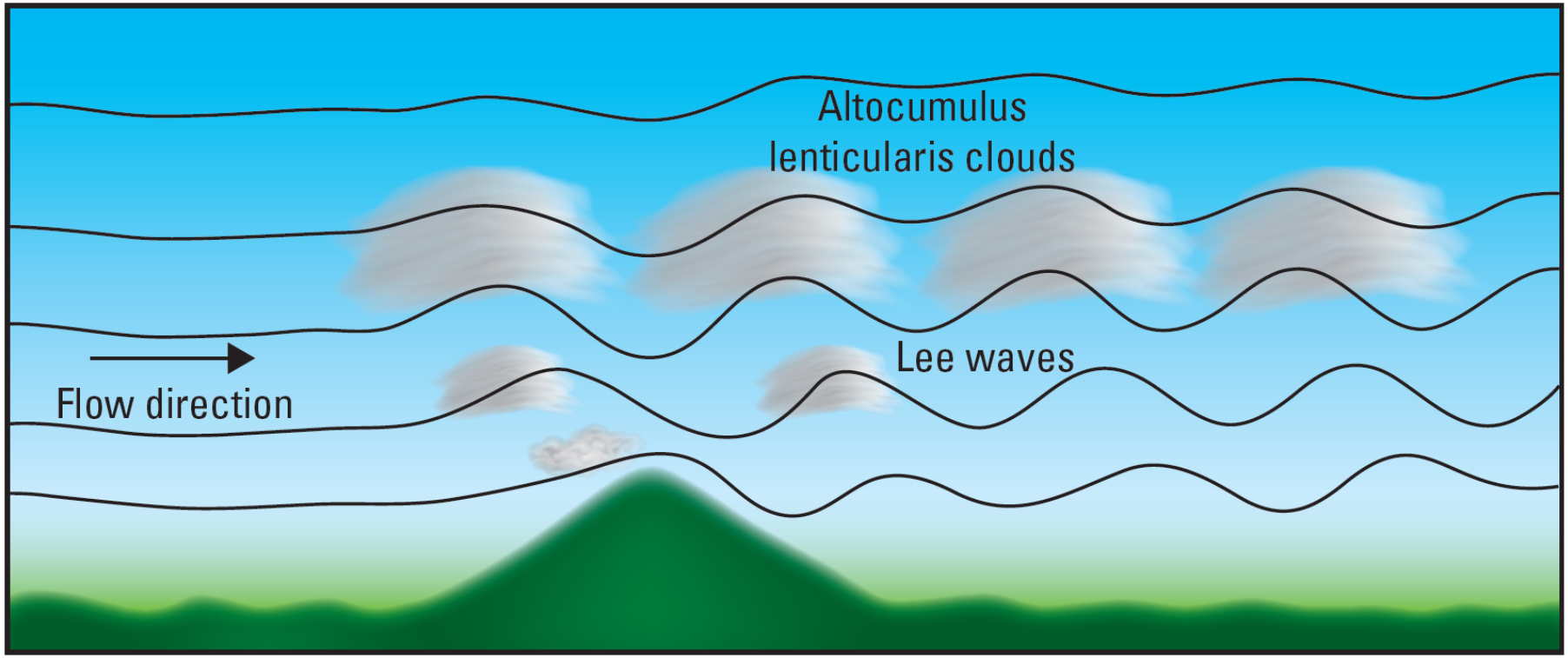
Dynamics of Downslope Windstorms:

Chinooks & Santa Ana are Dynamically-Driven

Mountain Waves and Lenticular Clouds



Dynamics: winds driven by strong pressure gradients that develop across mountain ranges; air rise on windward side and descend on the leeward side.

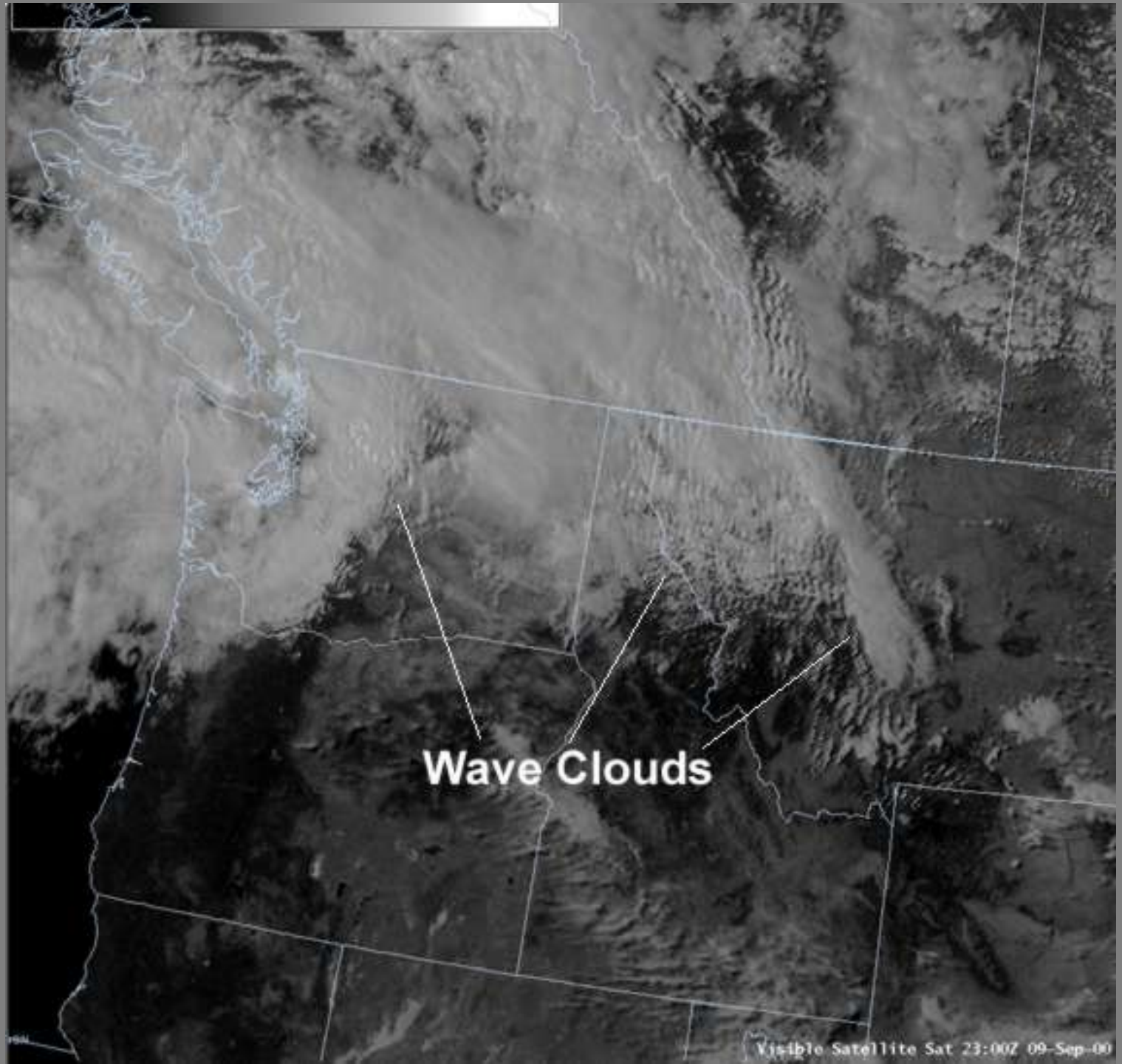


Altocumulus Lenticularis

Lenticularis Clouds

Lenticular Clouds, Probably Vertically Propagating

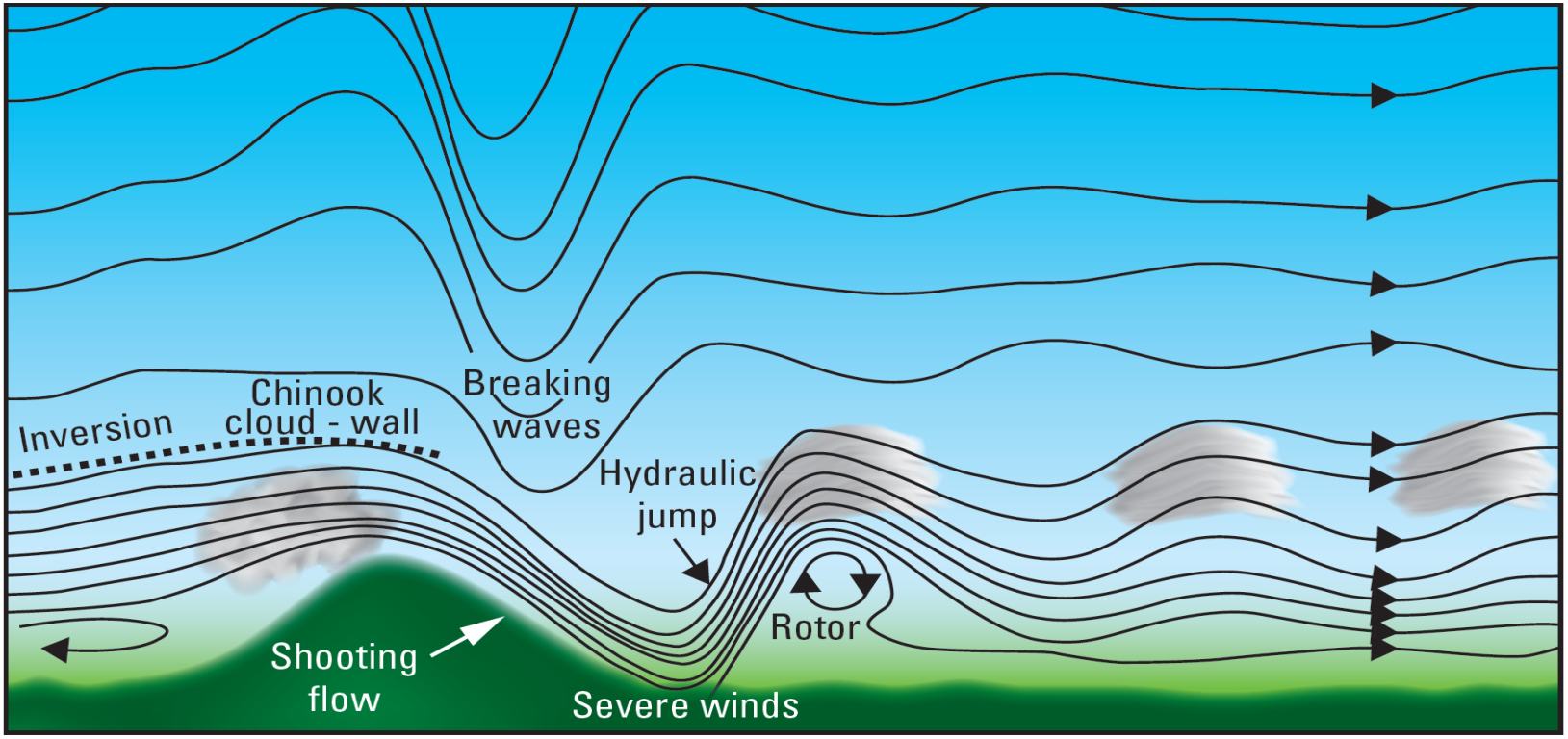
Trapped Mountain Waves


Wave Clouds
Visible Satellite Sat 23:00Z 09-Sep-00


BY STEVE J. SMITH

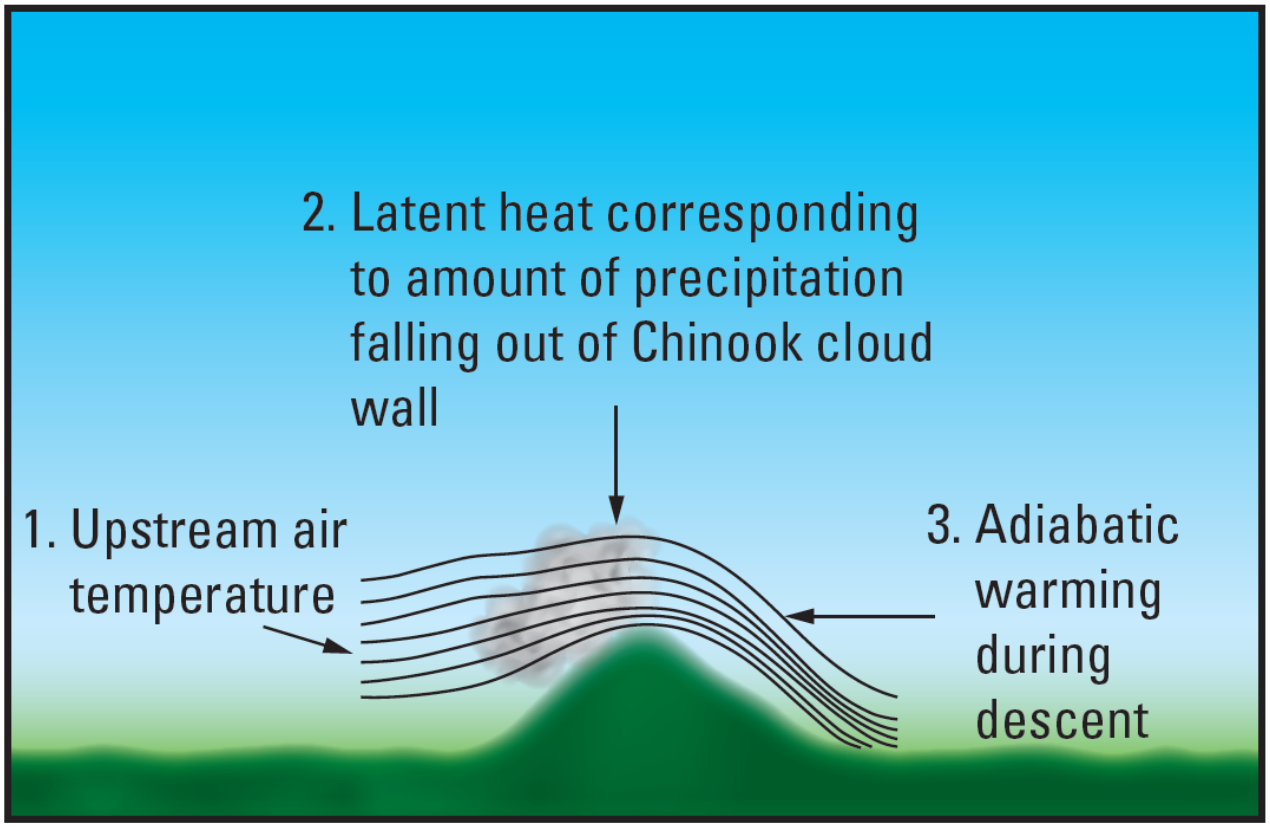
Hydraulic Jump

(when the wind is strong and an inversion exists upstream)



- **Shooting flow: large volume of air must pass between the inversion and mountain top; strong pressure gradients**
- **Jump: near or beyond the mountain base, the flow abruptly rises (jump) to adjust within the deeper layer (without inversion) –sharp; >25m/s**
- **Breaking waves: air above the inversion spills over the mountain, creating breaking waves – turbulent eddies**
- **Rotors: east of the jump or sometime between the mountain and the jump – dangerous to aircraft**

Chinook Windstorms of the Rocky Mountains



Factors that determine the temperature of air in downslope windstorms:

1) Upstream air temperature: can be warm (from Pacific) or cold (from Canada)

2) Latent heat: heat the air (some of them will be canceled out by cloud evaporation)

3) Adiabatic warming: dry adibatic lapse rate: 10 degree/km, so a 1.5 – 2.0 km descending can warm 15C to 20C, this T increase causes a lot of drying. Causing rapid snow melting on the plains.

The Chinook Wall

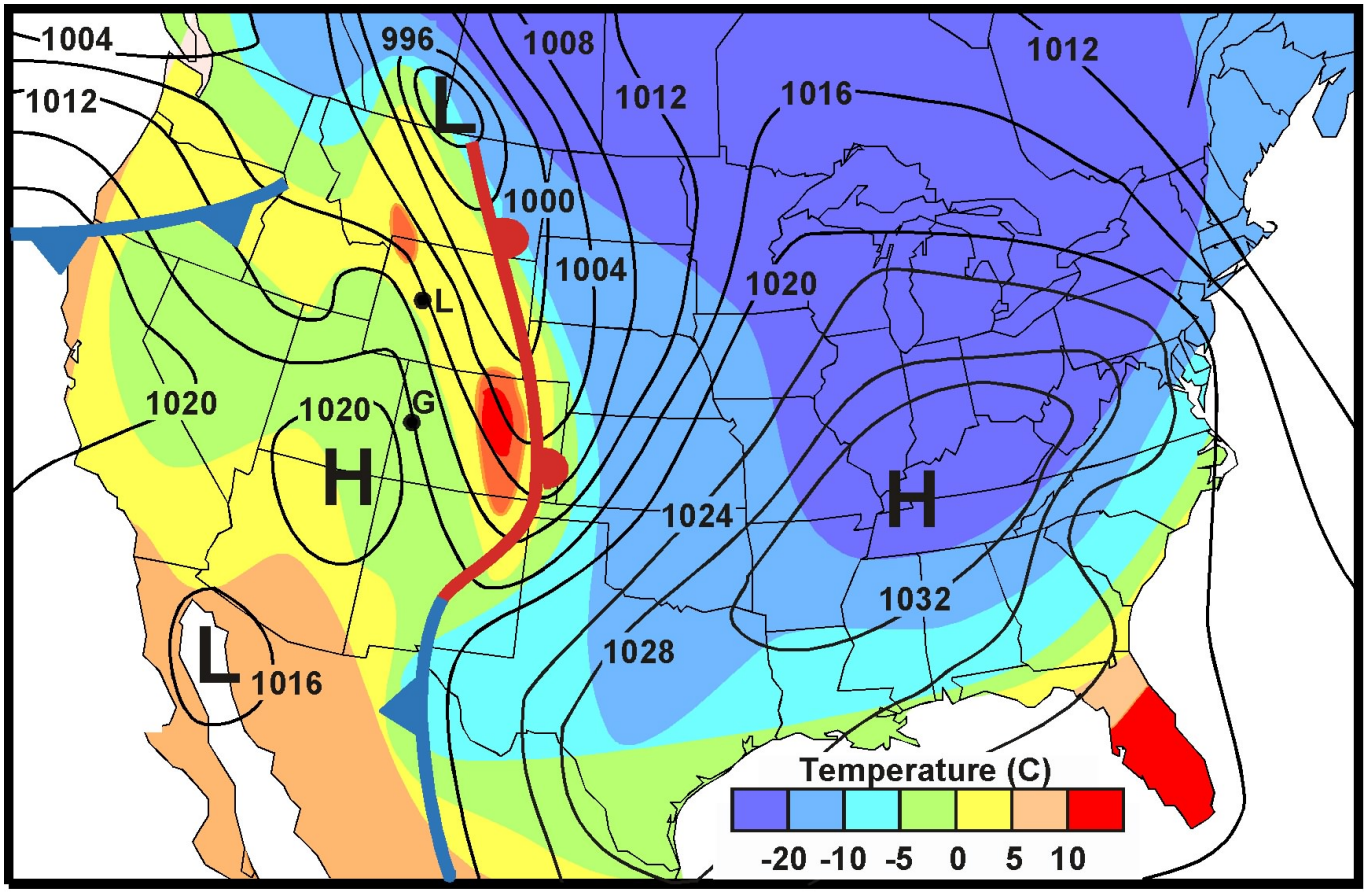
A wall of clouds that follows the mountain crest during downslope windstorms: View from the east side of the Rockies: cloud on the windward slopes and snow near the crest, clouds evaporate rapidly at east side.

Forecasting Chinooks: 3 Common features of Chinooks

- **A stable layer** upstream of the mountain 1-2 km above the mountain top: this stable layer appears as an inversion, creating wave structure above the inversion, and shooting flow and hydraulic jump on the lee side.
- **A strong pressure gradient** across the mountain: a sfc high pressure system to the west and low (center or lee trough) on the plains.
- The **background air flow** at levels near mountaintop (~ 700mb for the Rockies) is typically **strong & westerly**.
- A strong upper-level jet stream is not required. If it exists, it may be unfavorable to Chinook development.

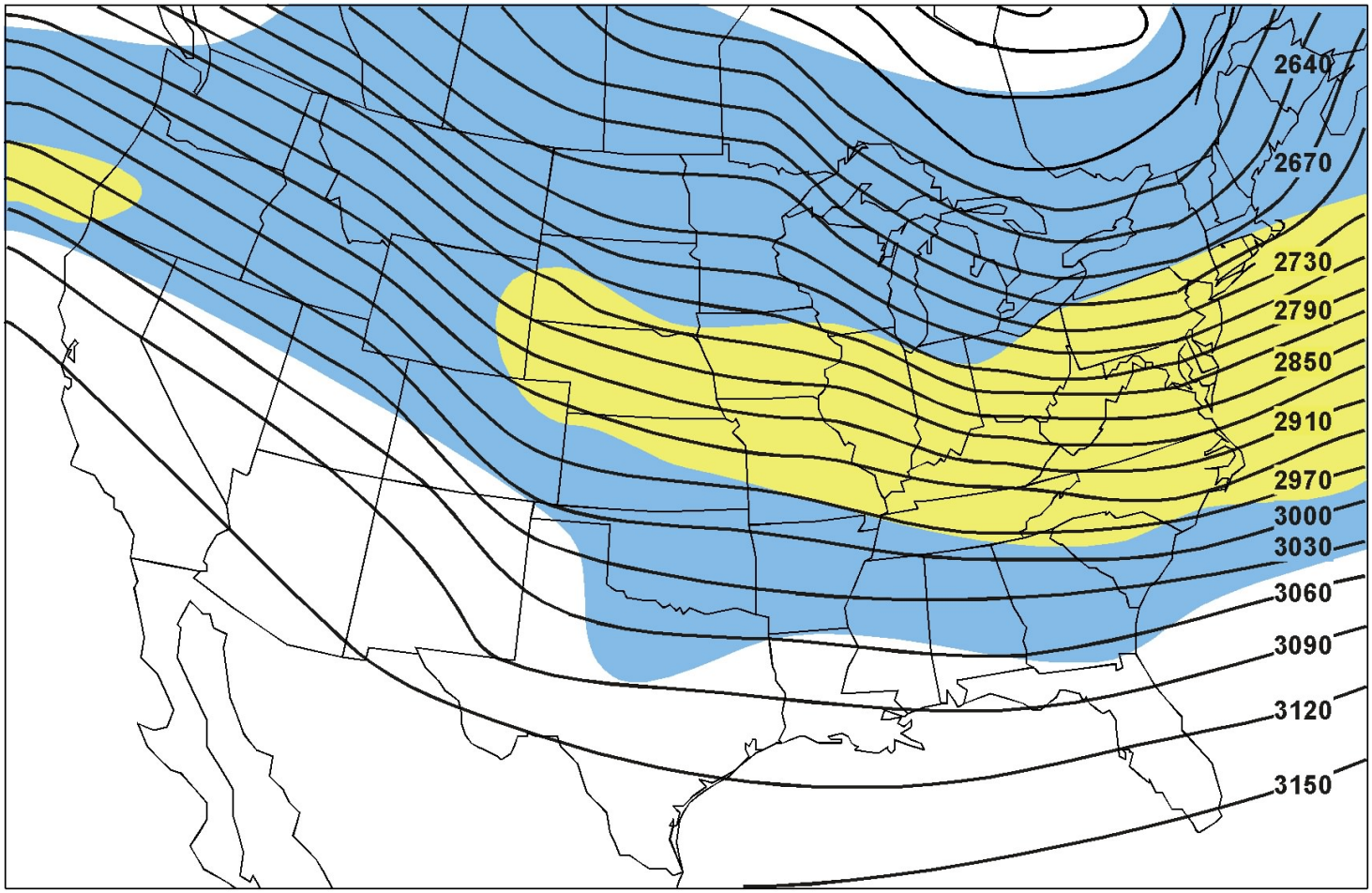
Chinook Surface Conditions:

Jan 16-17, 1982 Chinook Wind Boulder CO



- On 12 UTC Jan 17, 1982, 130mph gust occurred 20 mins after the time of this map
- Strong pressure gradient between the high pressure over Utah and the lee trough just east of the Rockies
- Warming appeared along the east side of the Rockies, where the downslope winds reached the surface. Denver 11 C, a sharp contrast to -7 C in western Kansa.

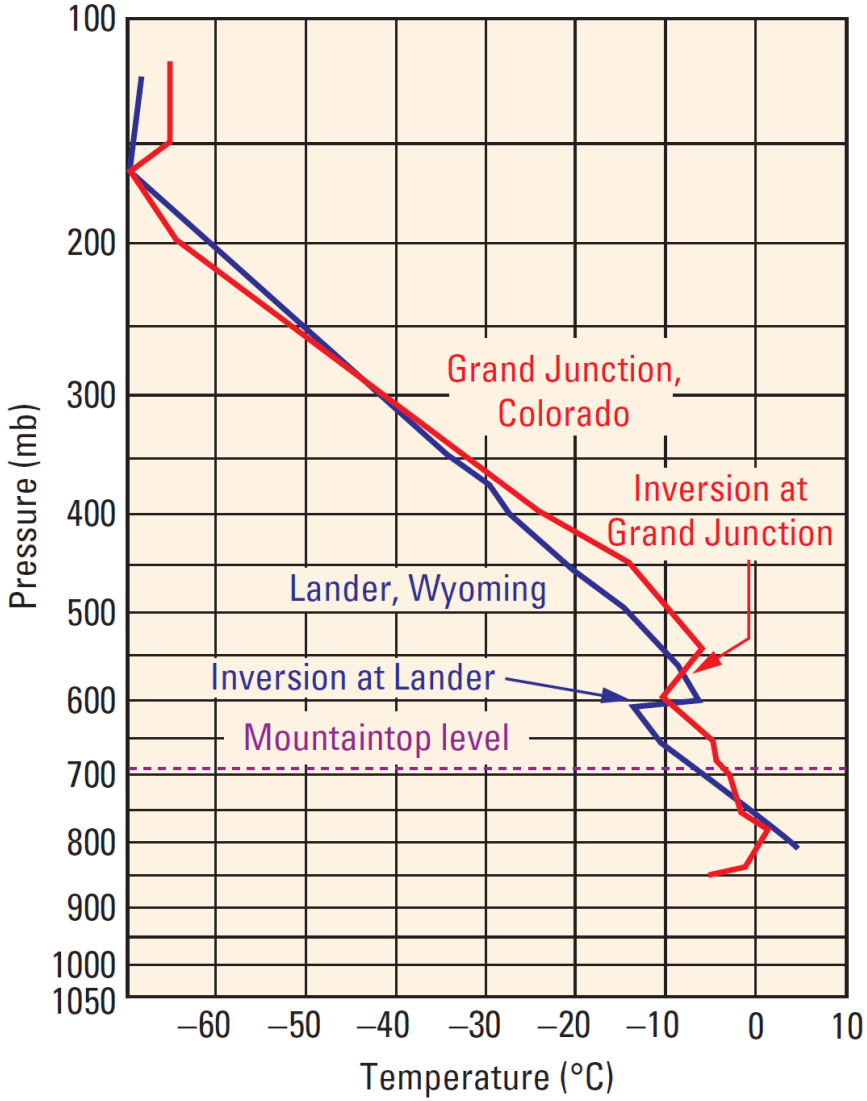
Chinook 700 mb Conditions



- **Blue shaded: winds>= 40 kts (46 mph), yellow: >=50kts (58 mph)**
- **Strong gradient in the 700 mb height (near mountaintop) field between the northern and southern borders of the US, indicative of strong background winds at mountaintop.**

Chinook Conditions

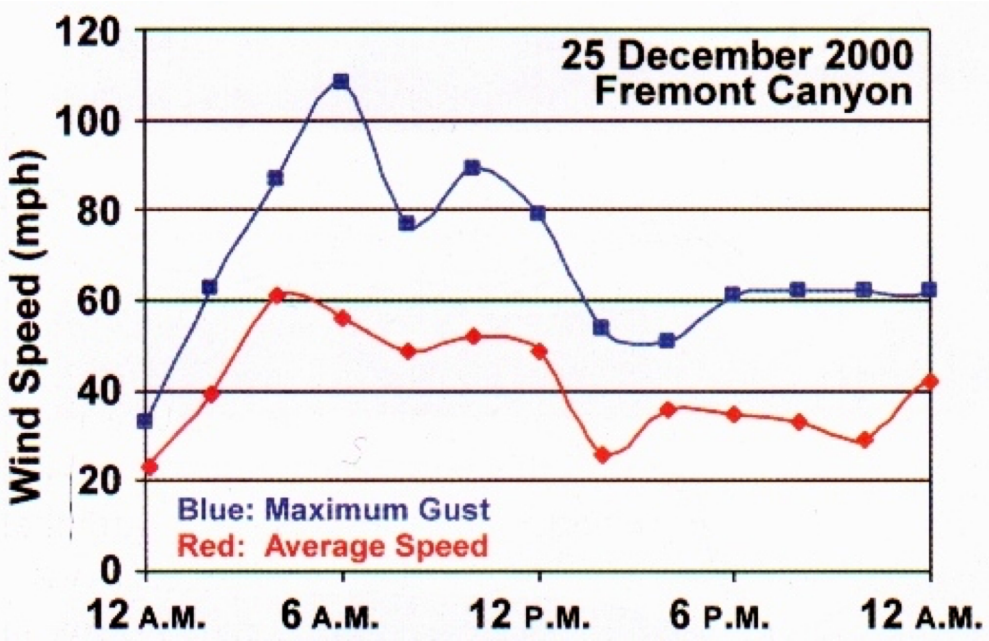
- Stable layer (inversion) to act as a lid above
- High pressure upwind
- Moderate flow across the mountains at mountain top level (700 mb)
- Lee trough forms on the downwind side of the mountains
- Strong jetstream is generally unfavorable



Soundings at 12 UTC Jan 17, 1982 (Grand CO & Lander WY are labeled as G & L on the surface map)

Santa Ana Windstorms of the Southern California

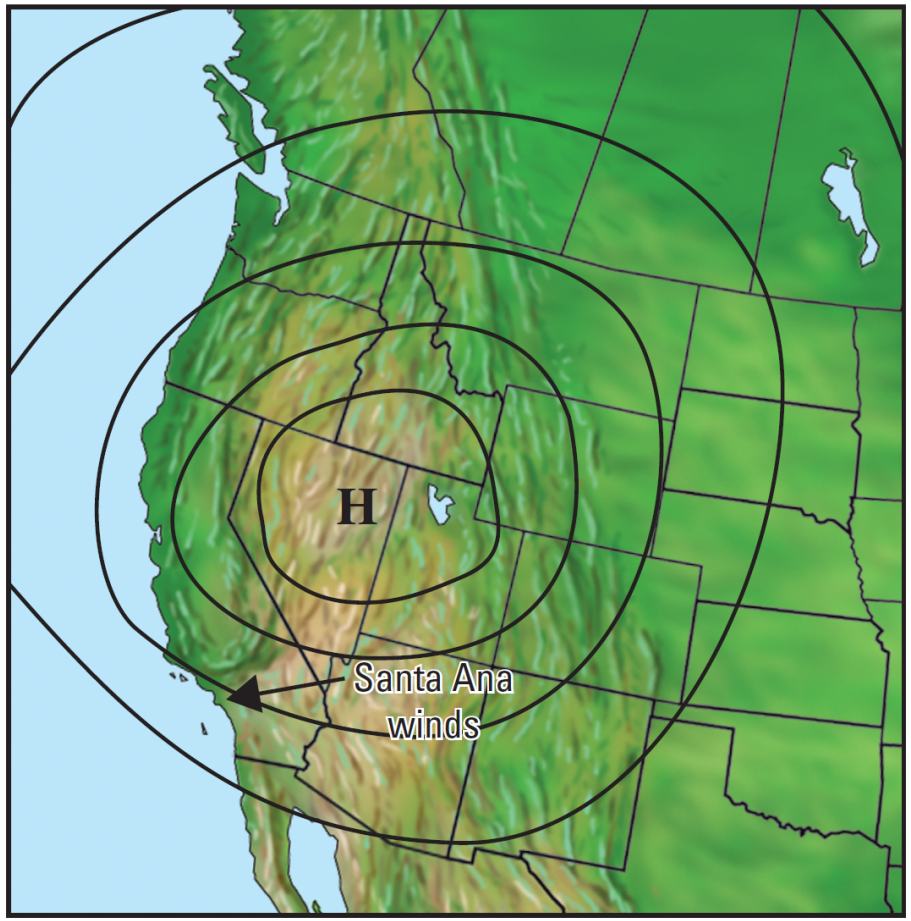
- Santa Ana has an Easterly component
- Not as strong as Chinooks, but dangerous because of their ability to spread wild fires
- Occur in southern CA's dry season (Apr-Nov), about 20 events per yr
- Humidity very low
- Beneficial to local fisheries (winds blow out to the sea, promoting upwelling)



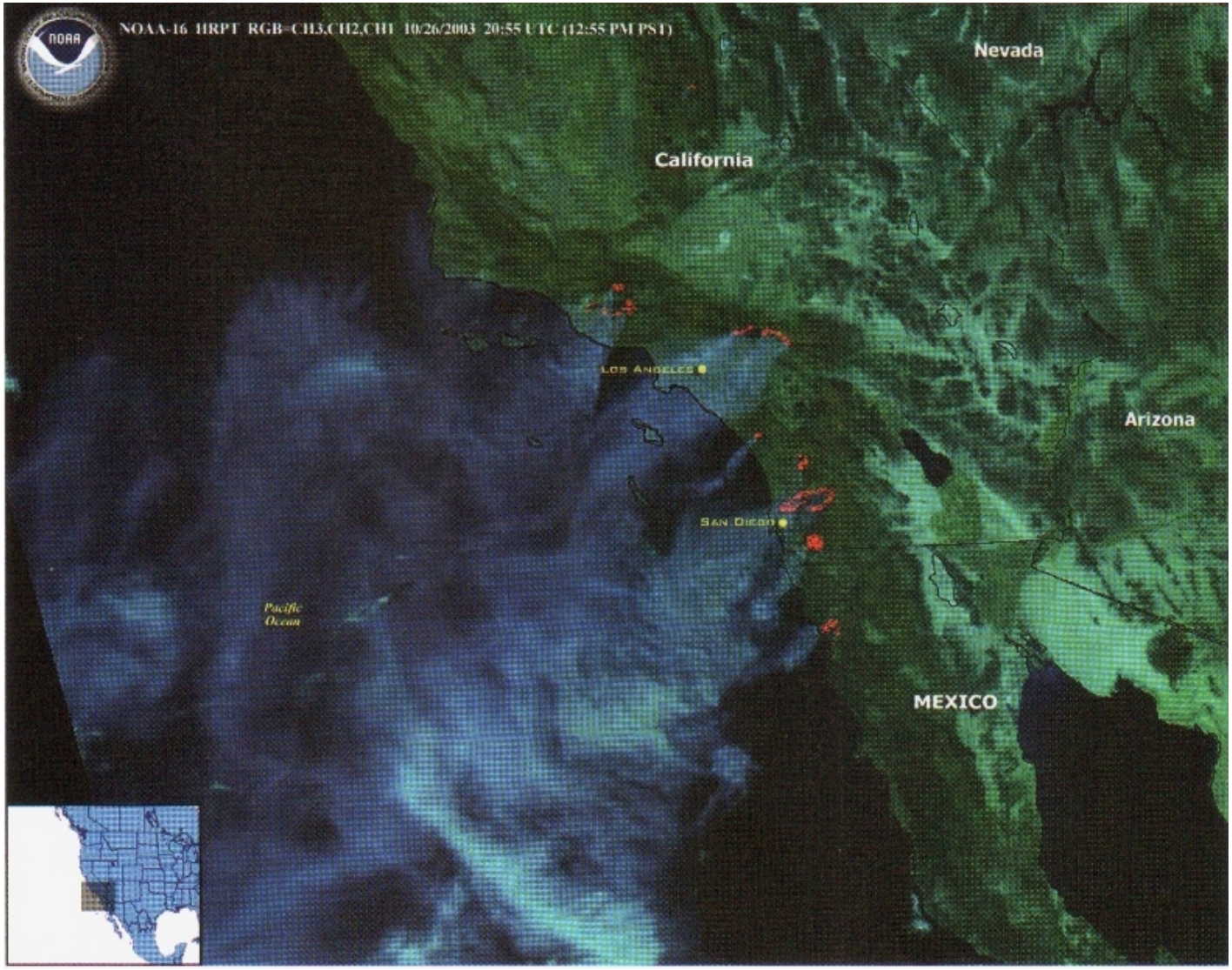
A Santa Ana Wind Example

Typical Santa Ana Conditions

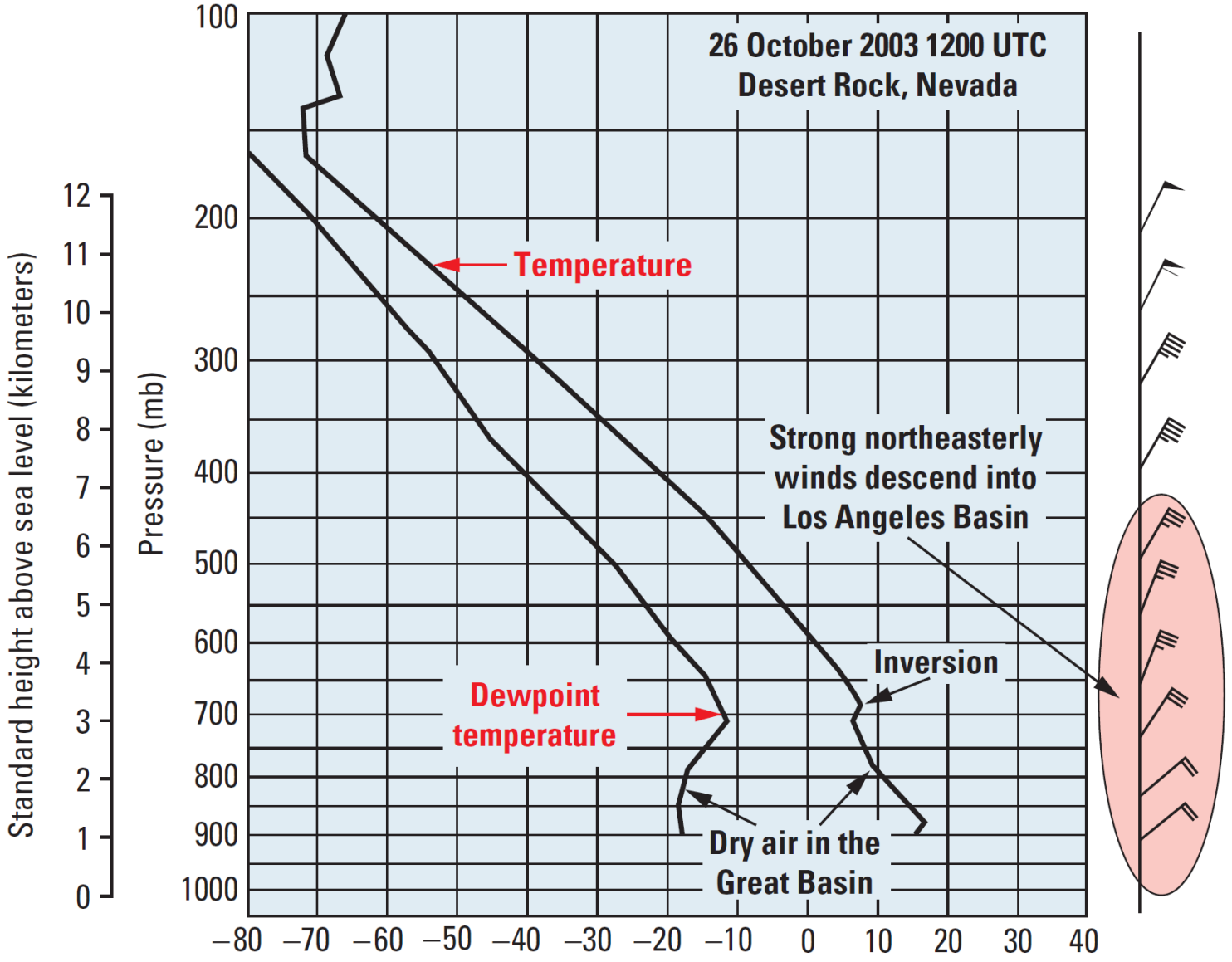
- **A strong high-pressure system** over the Great basin of Nevada and Utah, causing a strong N-S pressure gradient along the south California mountains. The strong pressure gradient drives an easterly wind to the Los Angeles basin.
- **A low** over Baja California
- **An inversion layer** at 700 mb
- As the air descends, it warms (could exceed 25 -30 C) at Los Angeles basin.



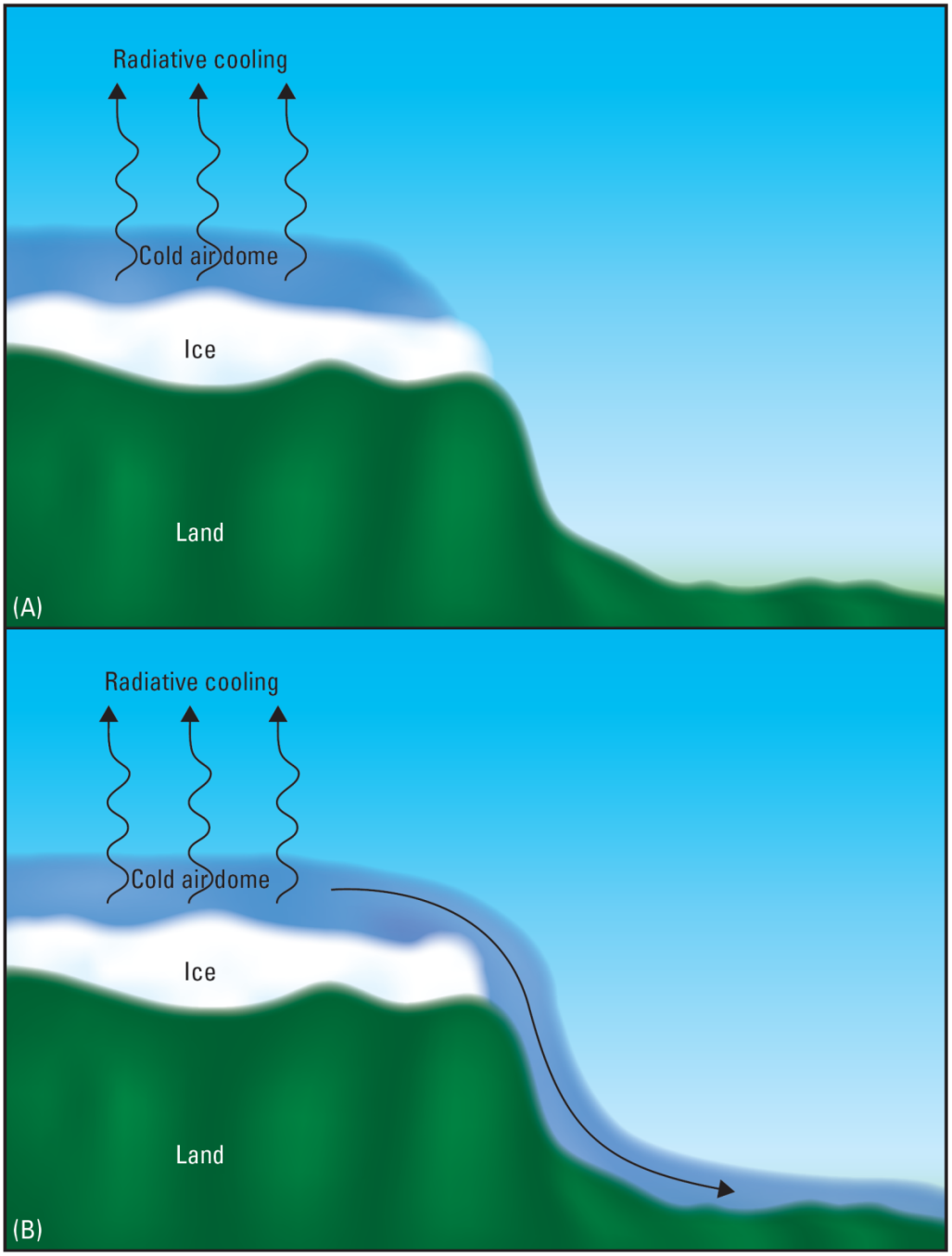
An Example: Smoke plumes associated with the Santa Ana driven wildfires in the LA basin in 26 Oct 2003 (fires over 200K acres, 16 deaths, loss of 1,900 homes)



Santa Ana Soundings in Nevada before descending the canyons



Non-Dynamically-Driven Winds:
Katabatic winds (radiatively driven)



Katabatic Winds in Antarctica

- Occur in the cold regions, icefields, typically in **Antarctic continent, & coast of Greenland**.
- Can occur any time, but mostly during winter
- Gusts > 100 kts
- Severe katabatic winds develop following a period of relative calm over ice sheets
- Strong radiative cooling during the calm period; the cold air spills down the slope off the ice sheet due to gravity force
- In spite of adiabatic warming, it arrives at the base as a cold wind.
- Turbulent, creating ground blizzards

Summary

- Downslope winds are gusty, warm or cold, can reach hurricane force (Chinook in Rockies, Santa Ana in CA, Foehn & Bora in Europe)
- Temperature of downslope air depends upon: T on windward side, heating by condensation, and adiabatic warming of the descending air.
- Chinnok winds are favored by moderate westerly flow at mountaintop level, a stable layer somewhat above the mountaintops, and generally a high upwind of the mountains
- Sanata Ana: Downslope low from the east over the mountains into LA. Favored by a high over Arizona and southern Nevada
- Radiatively driven Katabatic winds from Ice Caps in Antarctica and Greenland