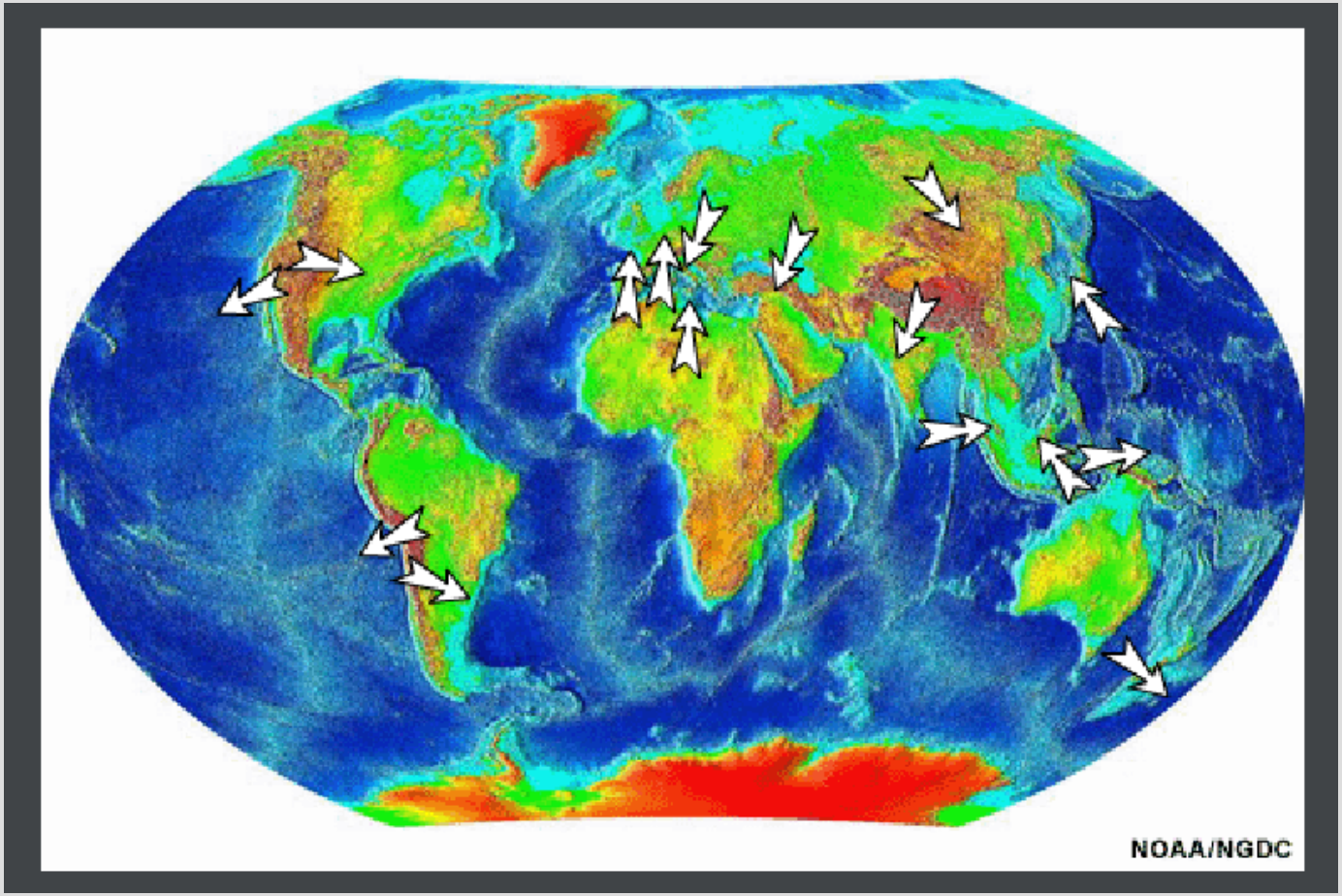
NATS 101
Section 13: Lecture 19

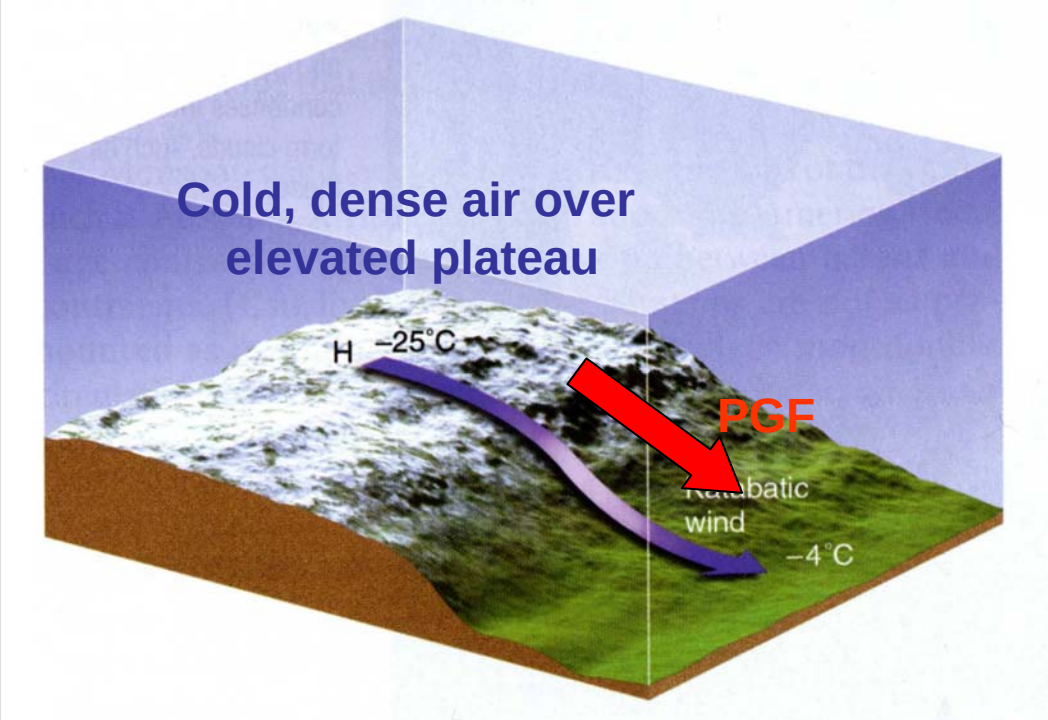
Katabatic Winds
and Monsoons

***Katabatic Wind*: Any downslope wind that is not due to diurnally-forced mountain-valley circulation**



They have many regional names, so we'll just stick to the ones relevant to the ones in our part of the world.

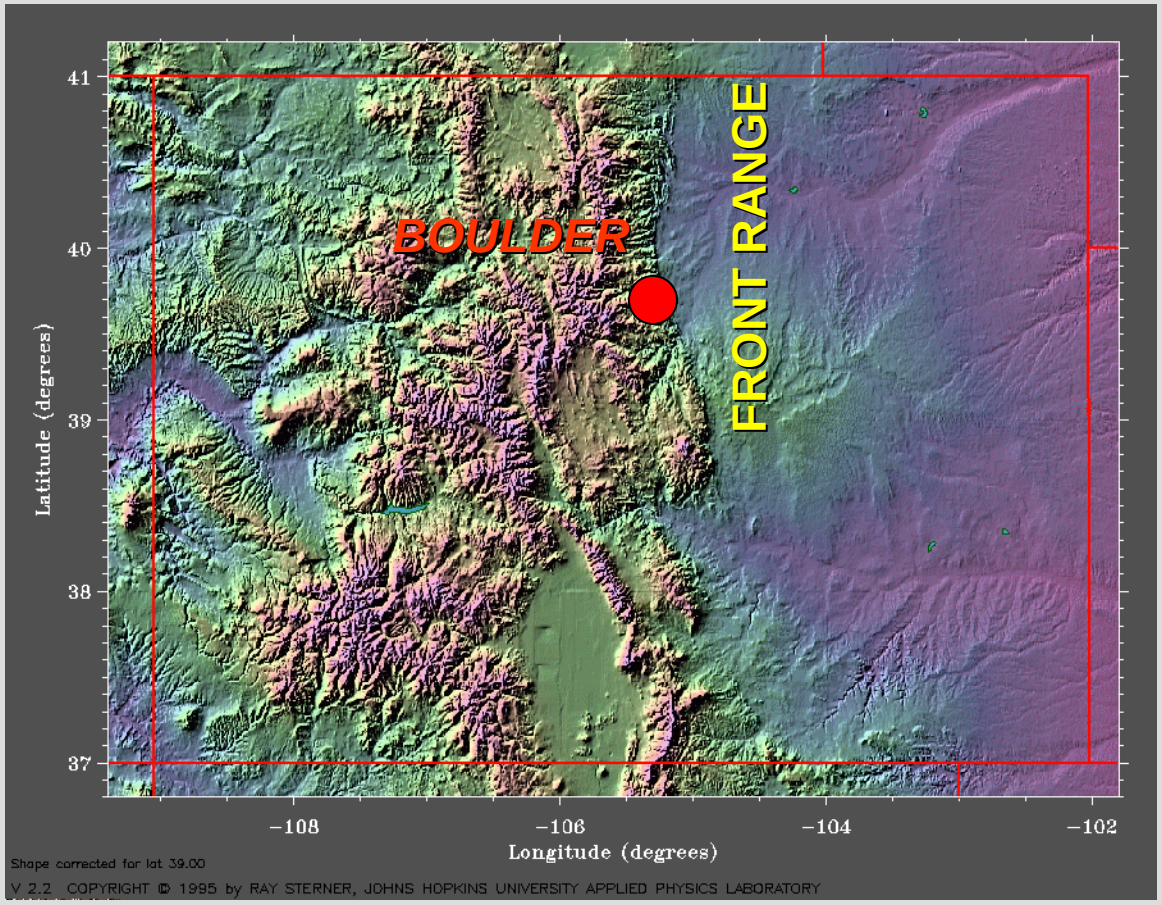
Bora: Cold Downslope Wind



Cold, dense air over an elevated plateau blows downslope.

If the slope is steep and/or the wind is forced through a narrow passage, a bora can be very strong.

Downslope windstorms Colorado Front Range



Topographic Map of Colorado

Factors

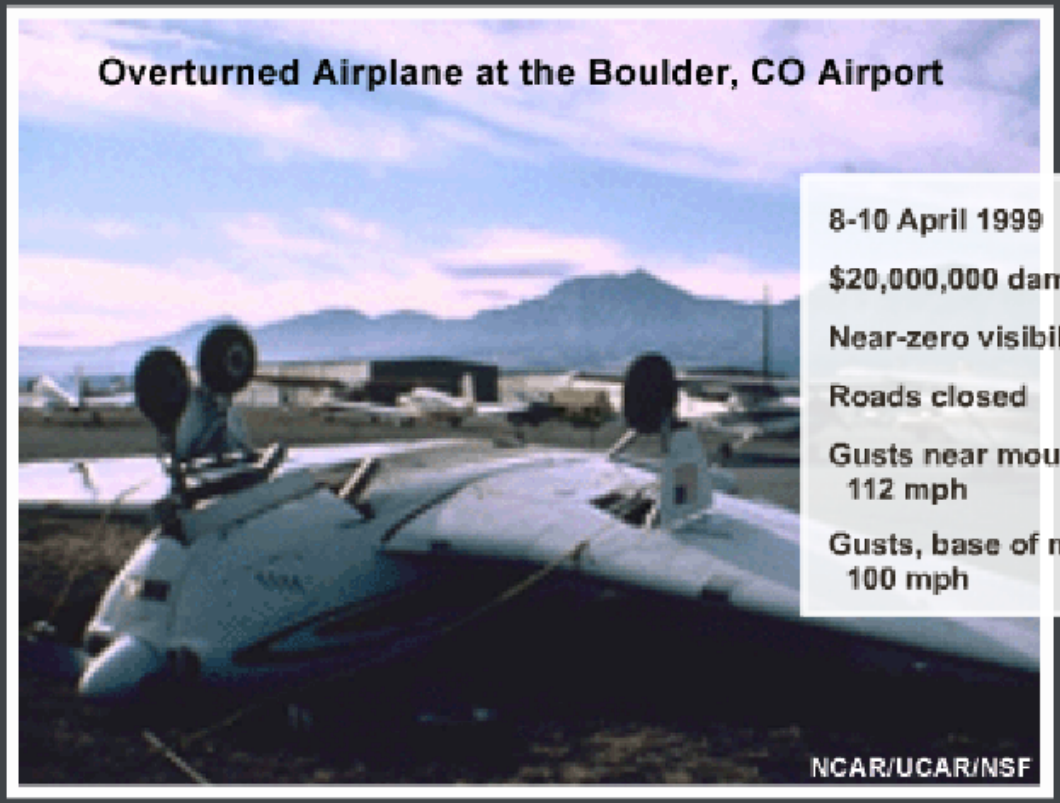
High elevated plateau to west with mountain peaks upwards of 14,000 ft.

Steep sloped topography in the foothills.

Narrow canyons which can channel the wind.

Result: Windstorms which can have hurricane force winds!

April 1999 Colorado Front Range Windstorm



Chinook: warm downslope wind

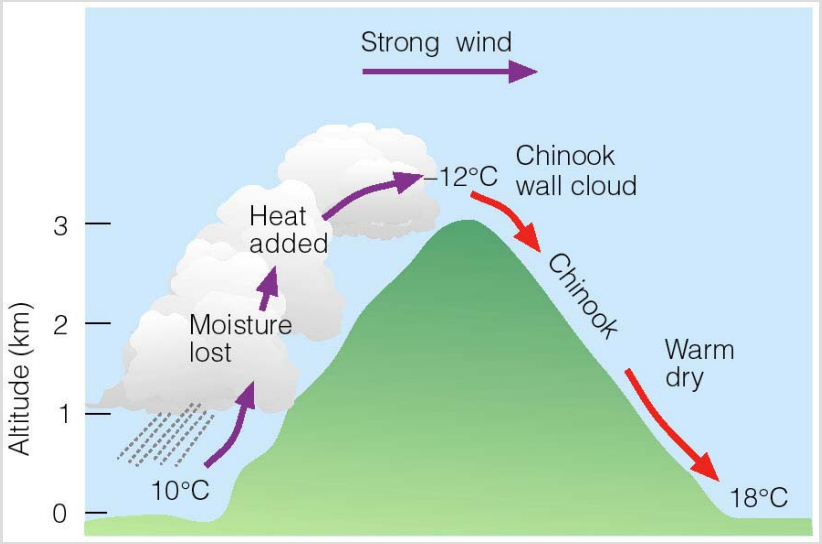
Windward side

Air is forced upslope

Air reaches its lifting condensation level

Clouds forms and precipitation

Heat is added to the air due to latent heat release (i.e. diabatic)



Leeward side

Air flows downslope

As it descends the pressure increases

Air is compressed and warms adiabatically.

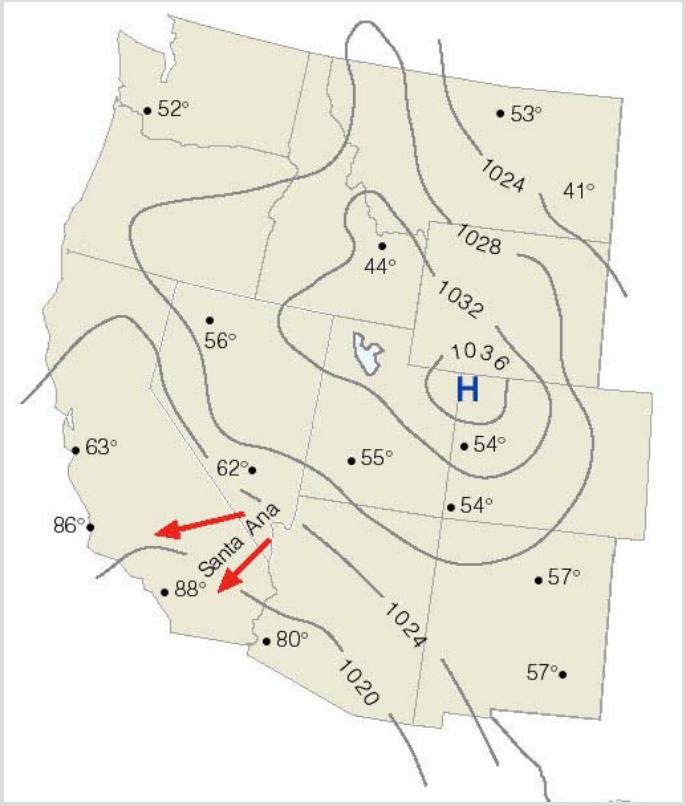
The word "chinook" is derived from the Chehalis Indians (Pacific Northwest) and means "snow eater." It is the reason why snow doesn't last east of the Rockies for very long.

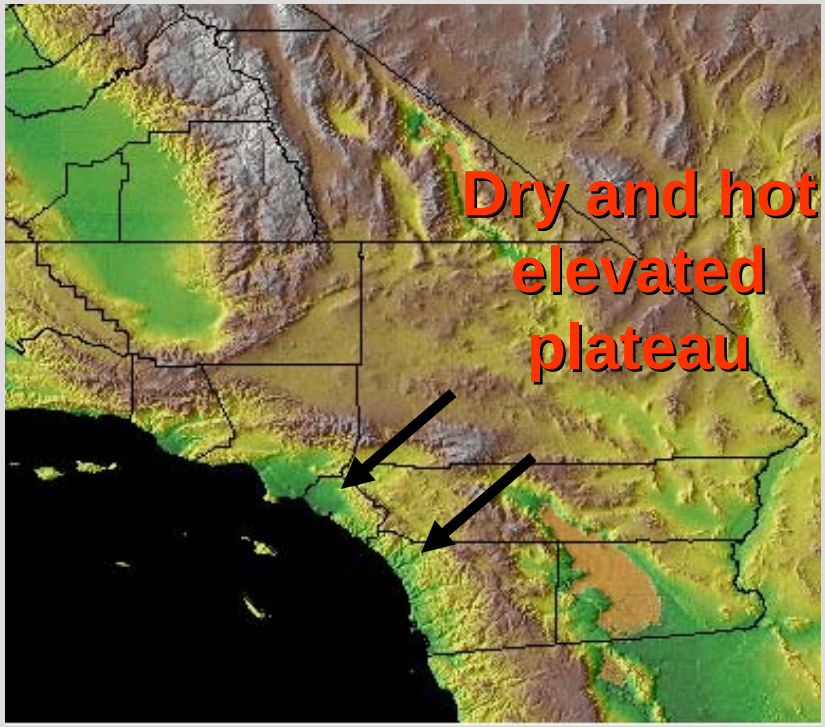
Chinook wall cloud

Cloud stops when the air begins to descent adiabatically on the leeward side of the mountain range (e.g. the Front Range in CO).

It's a pretty good bet it's snowing up in the mountains if you see this!

Santa Ana Wind



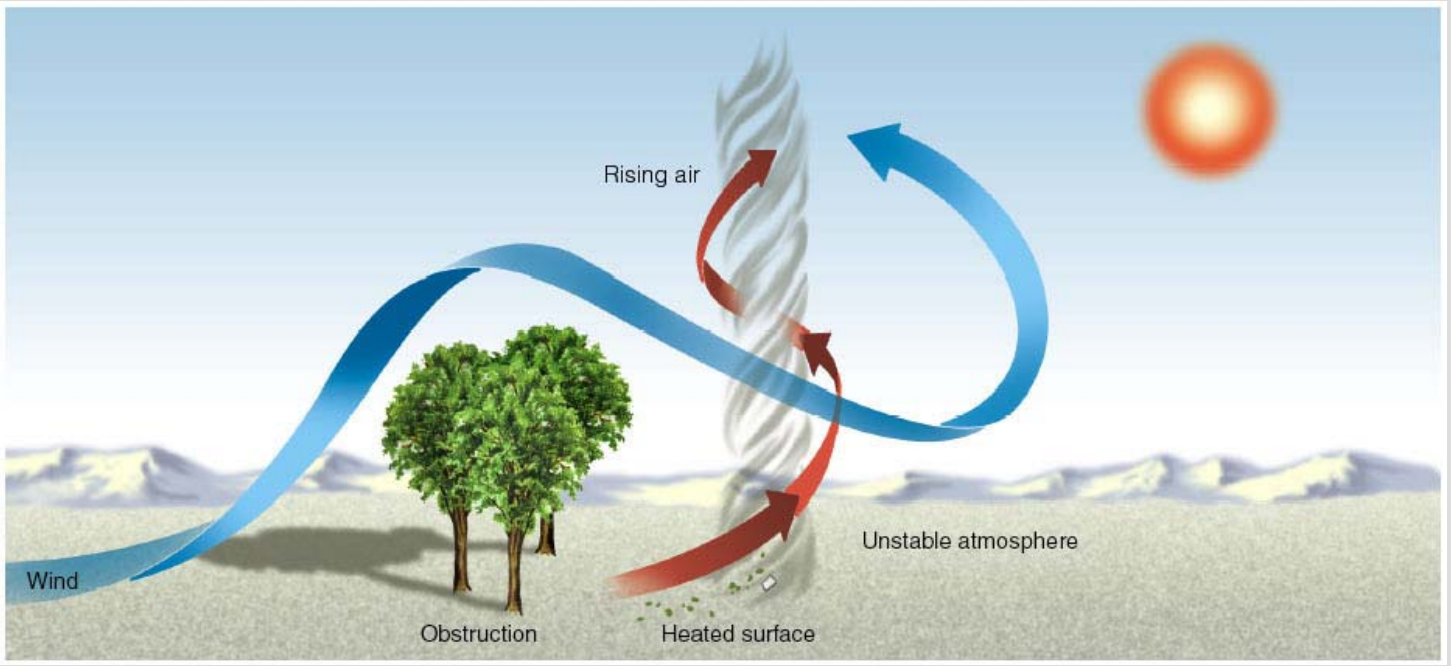


East wind from the Mojave desert is forced through narrow canyons in the mountains east of Los Angeles and San Diego.

Rapid warming due to adiabatic compression occurs.

Other interesting wind phenomena particular to Arizona and desert places…

Dust Devils



Wind is obstructed by a barrier which disturbs it enough to cause turbulent eddies, which rise in the thermal.

Another example of cyclostrophic balance—their rotation does not depend on whether they happen in Australia or Arizona!

Haboob: Dust or sand storm

Phoenix, Arizona

Caused by rapid movement of air associated with the gust front of a thunderstorm. Common during the monsoon, particularly just as it starts because the preceding months are dry.

Yet another danger our troops have to deal with in Iraq…

Fallujah, Anbar province, Iraq

Monsoon
A seasonal shift in winds and rainfall

It is also a thermally direct circulation, but on much larger continental scale.

They occur on every continent, except Europe and Antarctica, but the strongest by far is in Asia—specifically India.

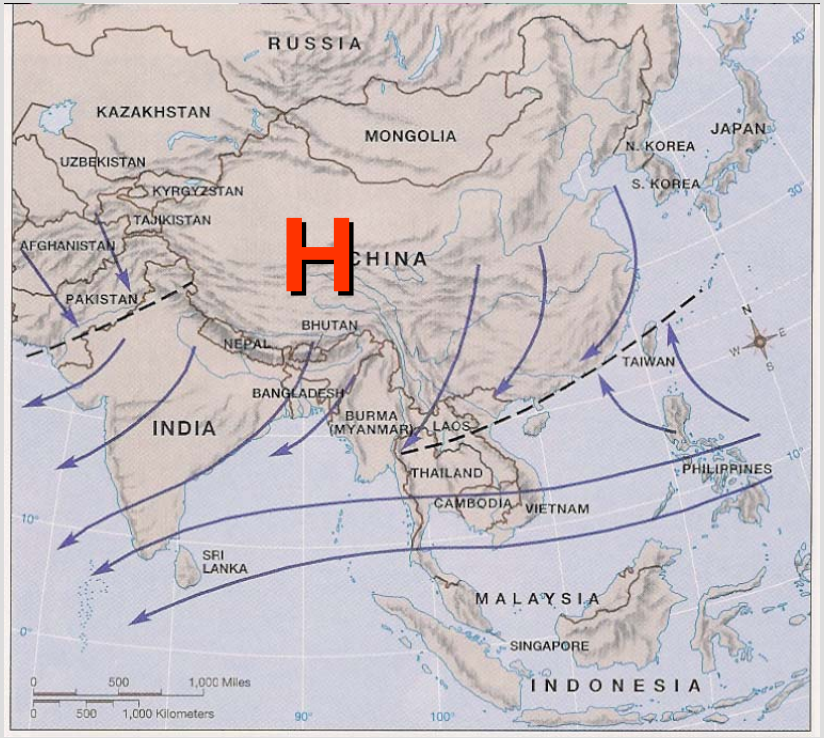
Why is the strongest monsoon in India?

To the north of India is the Himalaya Mountains and the Plateau of Tibet, with an average elevation of over 15,000 ft. and a horizontal extent of more than 1000 miles.

Contrast between the elevated plateau and the surrounding bodies of water south of India sets up a giant thermally direct circulation.

The Indian Monsoon: Winter Dry Season

WINTER LOW LEVEL CIRCULATION



(Aguado and Burt)

Tibetan Plateau is relatively cooler than the surrounding ocean off Asia

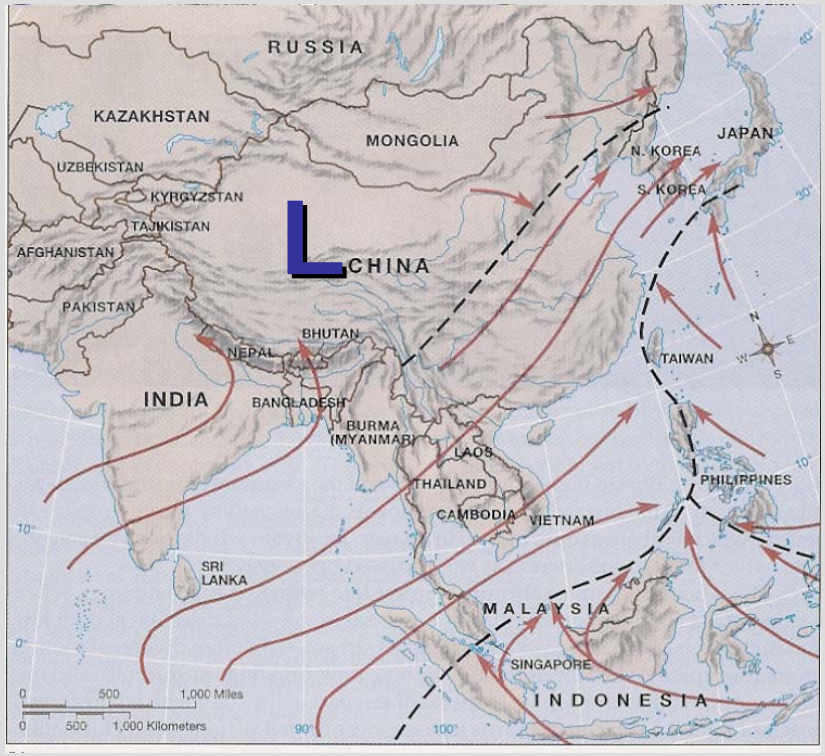
Cold air over the Tibetan Plateau is relatively more dense

Wind flows from the off the Tibetan Plateau to the ocean.

Offshore flow, no moisture transported to the interior of Asia.

Indian Monsoon: Summer Wet Season

SUMMER LOW LEVEL CIRCULATION



(Aguado and Burt)

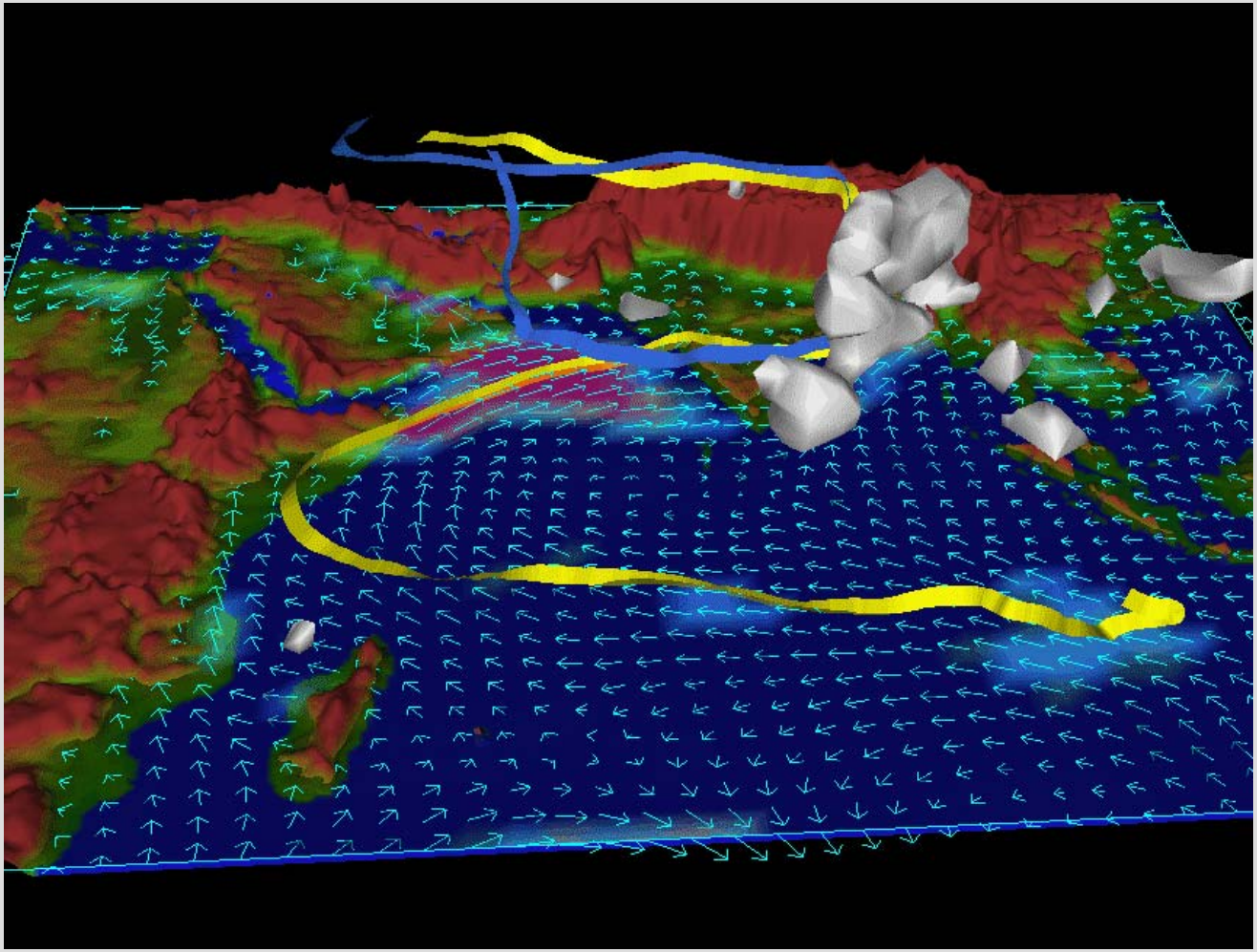
Tibetan Plateau is relatively warmer than the surrounding ocean off Asia

Warm air over the Tibetan Plateau is relatively less dense

Wind flows from the ocean to the Tibetan Plateau.

Onshore flow transports moisture to the interior of Asia.

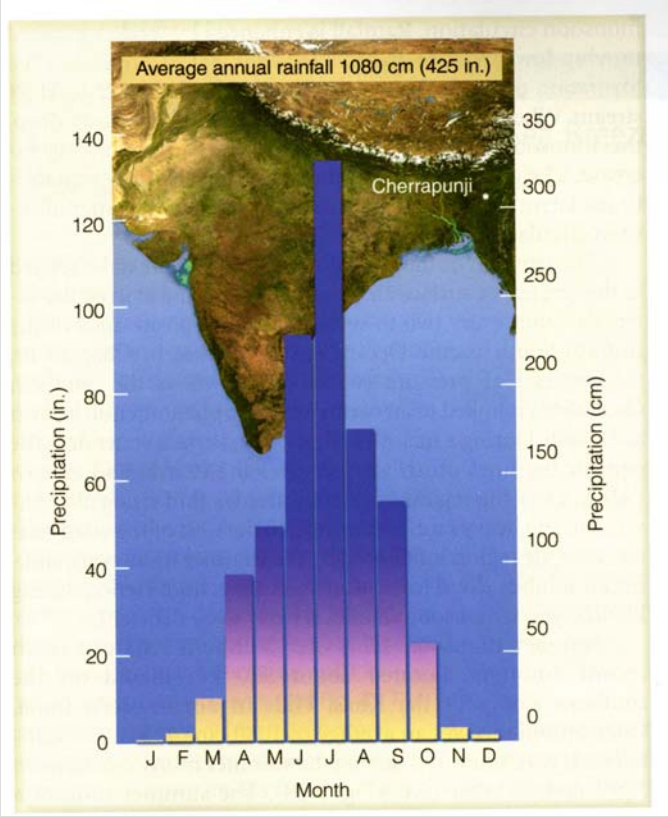
A Three-Dimensional View of the Indian Monsoon during the wet season



www.nassmc.org

The monsoon in India is REALLY WET!

Monthly rainfall
Cherrapunji, India



ONE OF THE WETTEST SPOTS ON EARTH!

New Delhi, India

If the Indian monsoon is too dry or too wet it can be a very big deal for rapidly growing Asian countries.

Consider that India and China alone have a combined population of over two billion people…

North America has a monsoon too--and it affects the Southwest U.S. and Mexico in a very big way!

Today: Monsoon climatology

Later: Monsoon interannual variability and severe weather

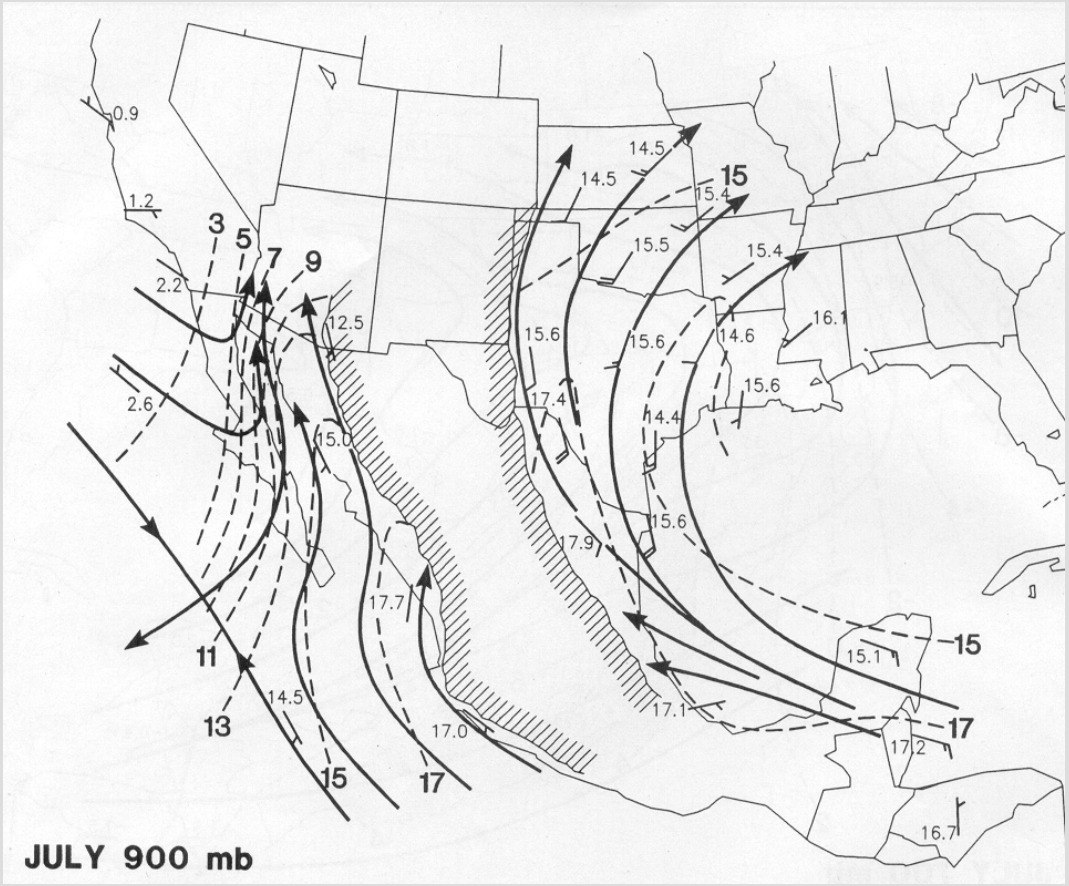
Why a North American Monsoon?

Similar to Asia, North America has a giant elevated plateau in the western U.S. and Mexico.

However, in our case, the Mexican plateau is only about 4000-7000 ft. in elevation, depending on where you are.

Though it is not as high as Tibet, it IS high enough that there is a regular seasonal reversal of circulation.

Average Low-Level Flow: July



Low level winds (900-mb) are directed onshore.

East of the Rockies, moisture is transported at low-levels from the Gulf of Mexico

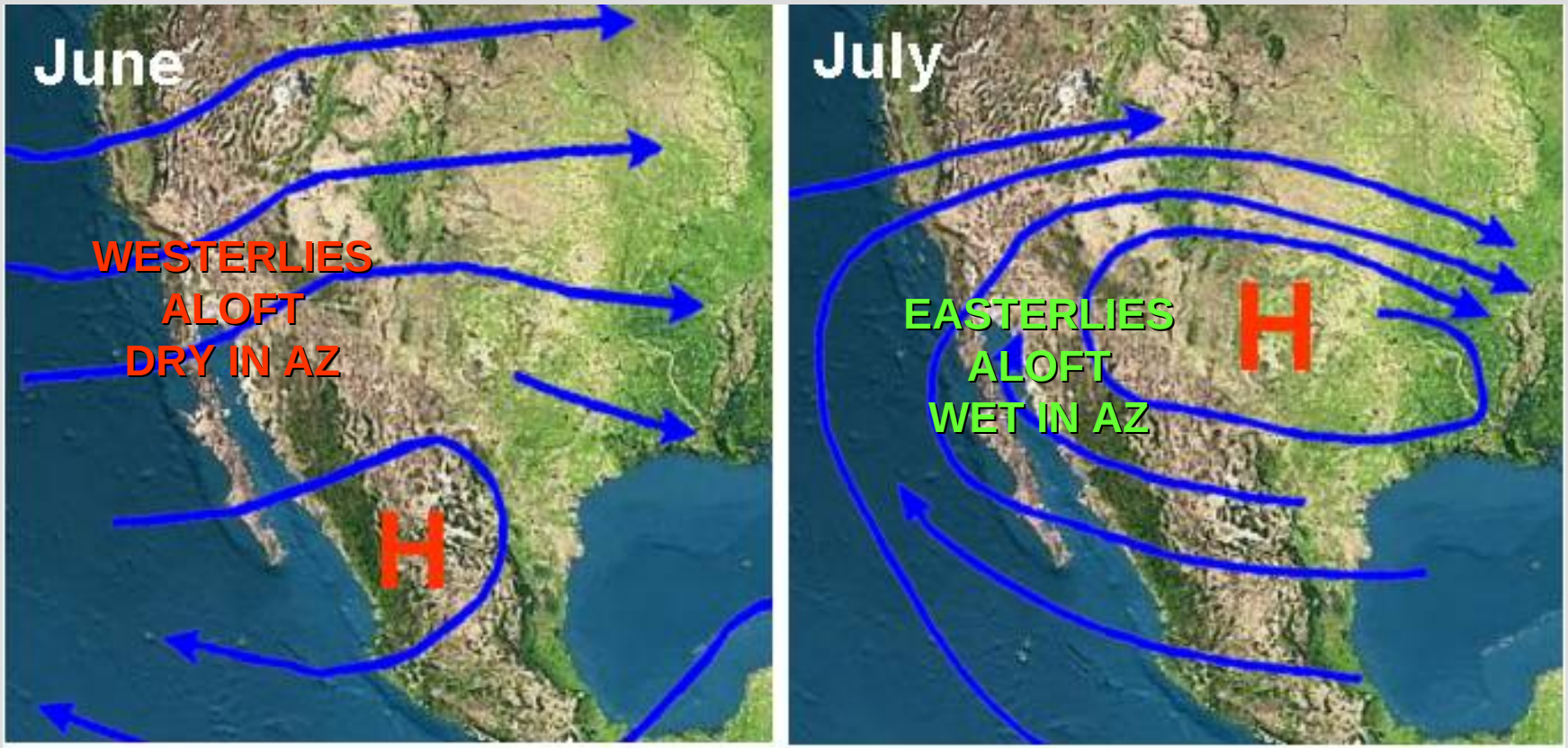
West of the continental divide, low-level moisture transport from the Gulf of California and East Pacific.

(Douglas et al. 1993)

Upper-level flow (500-mb)

Before monsoon

During Monsoon

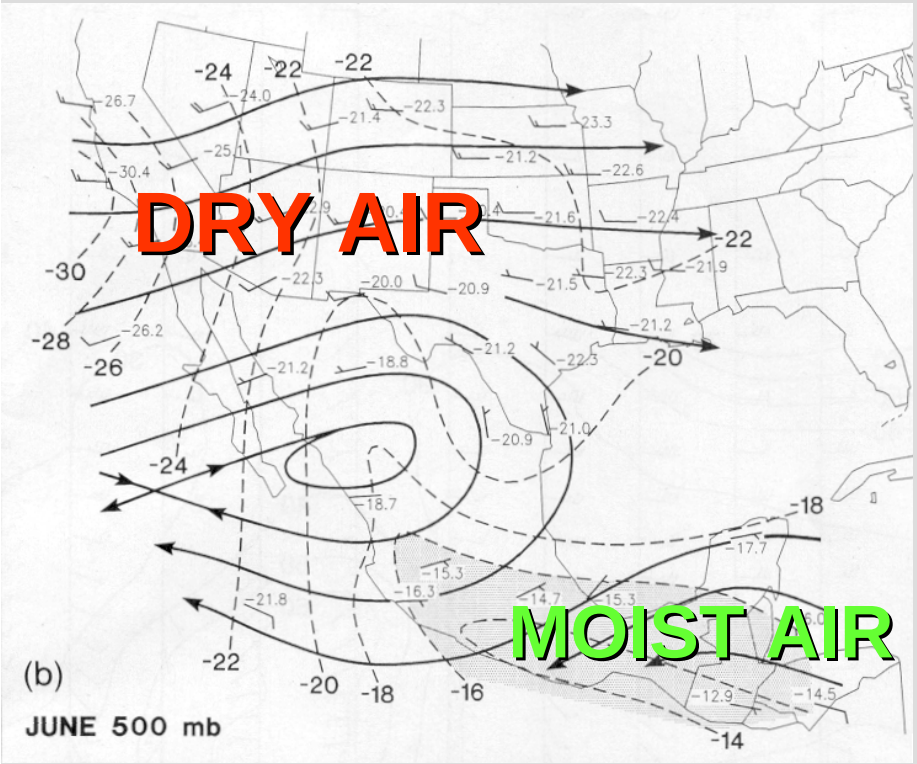


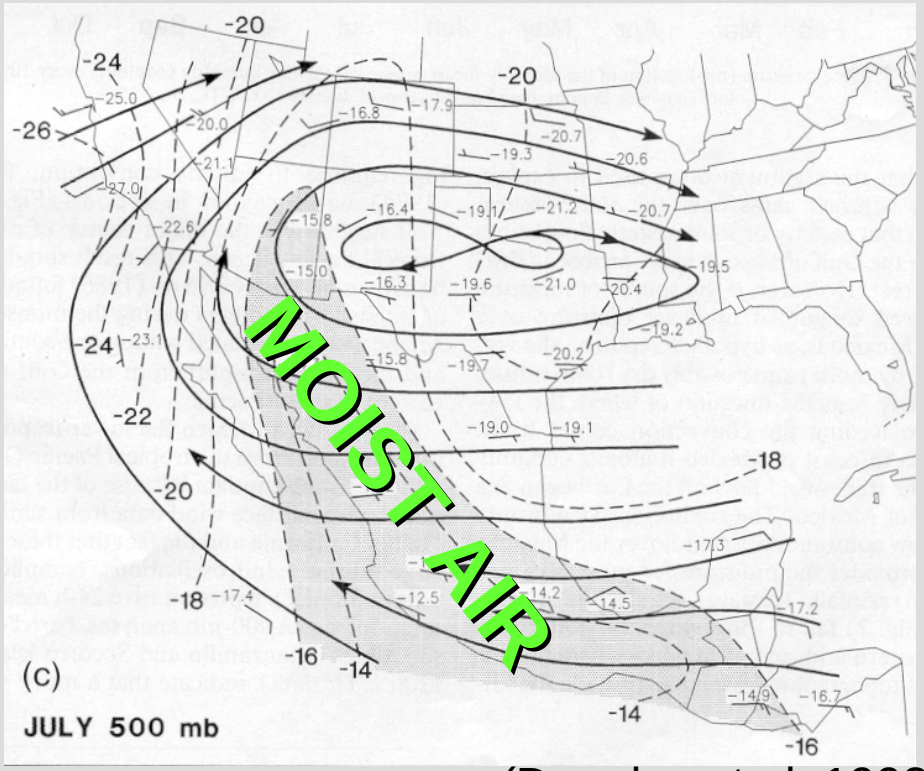
Mean 50 kPa Flow Patterns over SW North America

Westerlies aloft.
High pressure ridge to the south.
Little moisture at upper levels.

Easterlies aloft.
High pressure ridge to north (and east)
Moisture transport from Gulf of Mexico

Evolution of Monsoon Ridge and Upper-Level Moisture

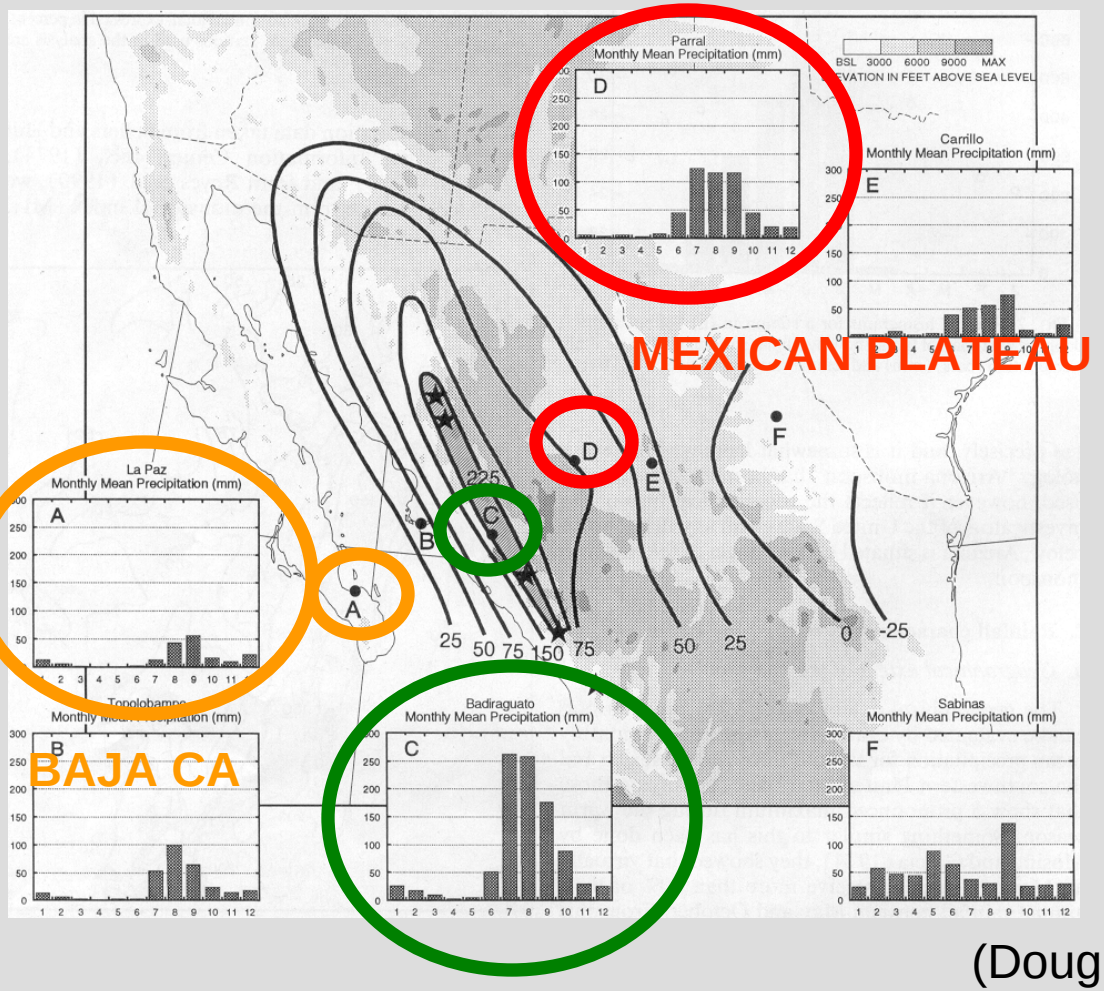




(Douglas et al. 1993)

Shaded areas indicate region of relatively high mixing ratio (i.e. atmospheric moisture content)

Monthly rainfall in western Mexico



The core of the North American monsoon is in Mexico, not Arizona

It accounts for about 60-70% of the rainfall there, so it is a pretty big deal for the country and its population, as a relatively large percentage of the population depends on subsistence agriculture.

(Douglas et al. 1993)

SIERRA MADRE OCCIDENTAL

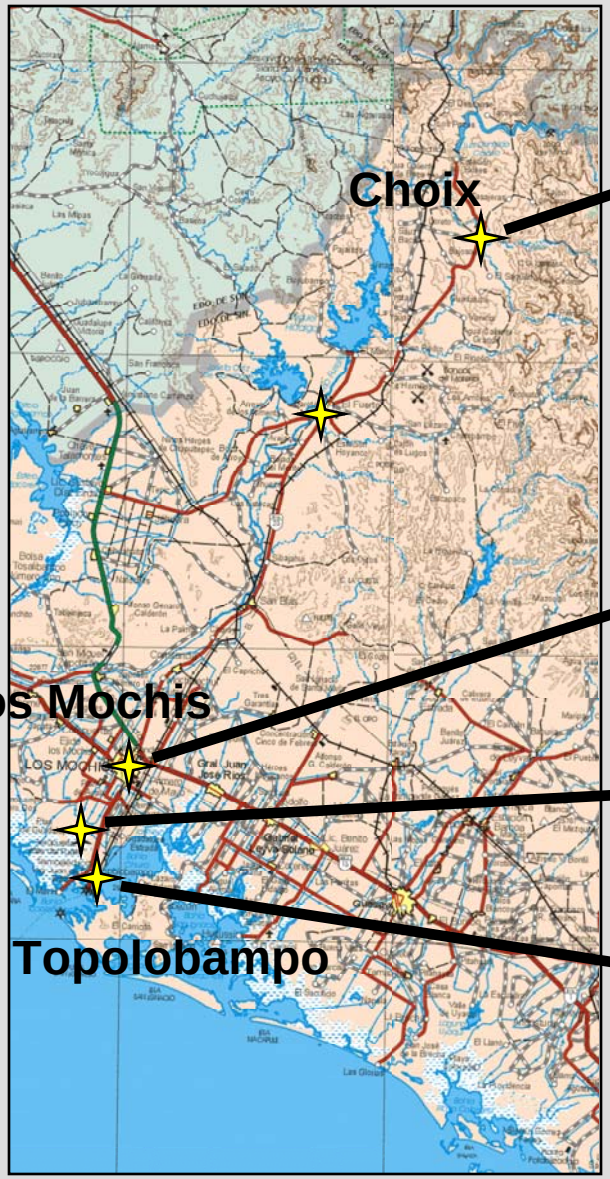
Sierra Madres in Mexico: Before and After Monsoon Onset

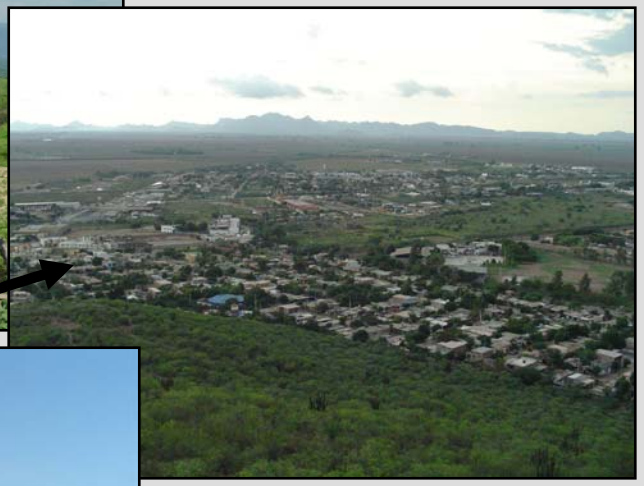
Before Monsoon Dry Season (May-June)

During Monsoon Wet Season (July-August)

(Chris Watts, Univ. of Sonora)

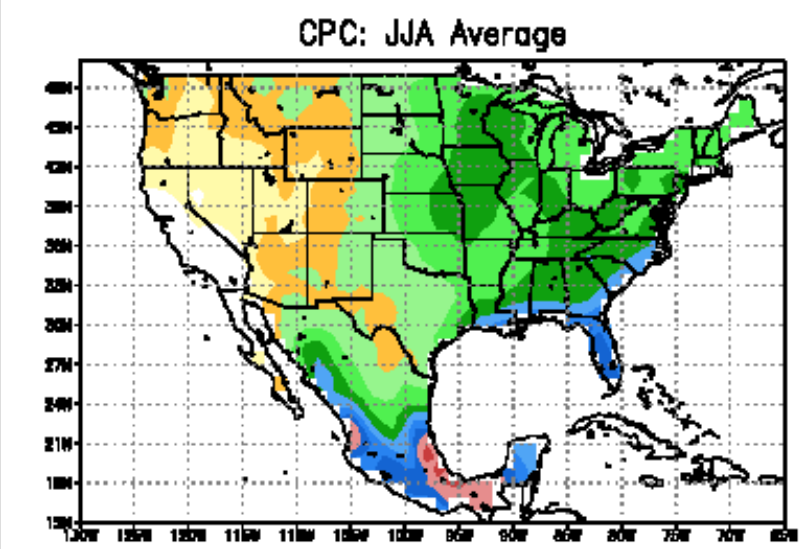
A trip from the coast into the Sierra Madre
From Los Mochis to Choix in Sinaloa, Mexico



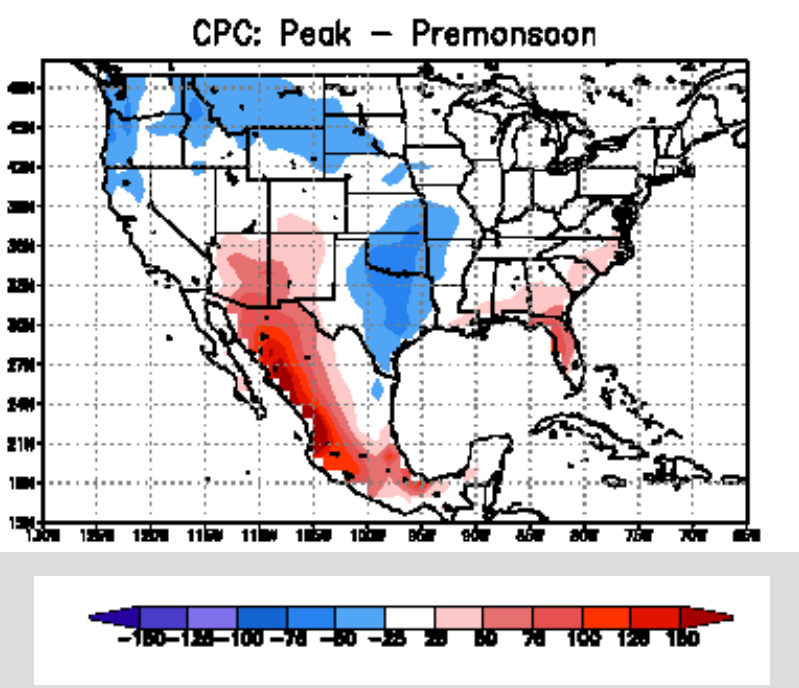


Continental Scale Shift in Rainfall (mm)

Summer Average Rainfall



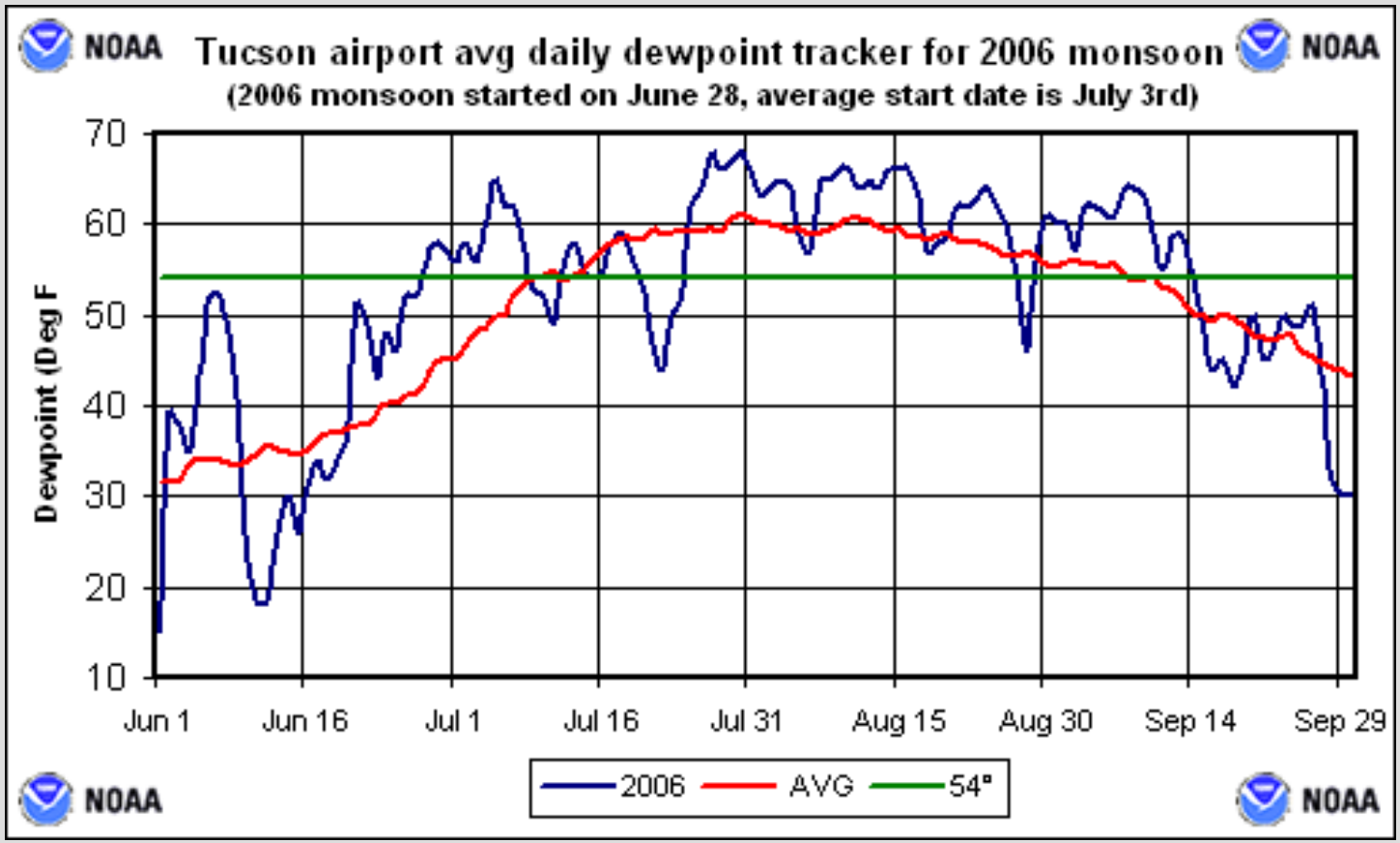
During monsoon – before monsoon



(Castro et al. 2007)

As the Southwest U.S. and western Mexico get wet, it dries out in the central U.S.

Monsoon in Tucson



Old definition: monsoon onset defined as when dew point exceeds 54°F for three consecutive days.

The monsoon from Kitt Peak…

Summary of Lecture 19

A katabatic wind is any downslope wind that is not due to a mountain-valley circulation.

Bora: cold downslope wind
Chinook: warm downslope wind

Katabatic winds can be very strong if the topography is steep and the wind can be channeled.

Dust devils and haboobs are examples of wind phenomena particular to desert regions.

A monsoon is a seasonal shift in winds and rainfall. It is caused by thermally direct circulation which reverses between winter (dry) and summer (wet).

The biggest monsoon is in India because of the strong thermal contrast between the Tibetan Plateau and surrounding ocean south of Asia.

The North American monsoon is much weaker than India's because the Mexican Plateau is only about one-third as high, but it is still a very important factor in the climate of western Mexico and the Southwest U.S.