Question:

Compare and contrast Indian summer monsoon with the North American Monsoon.

Answer: Based on some tropical notes, reports from the climate prediction center,

Kshudiram Saha's book: "Tropical Circulation Systems and Monsoons"

North american monsoon:

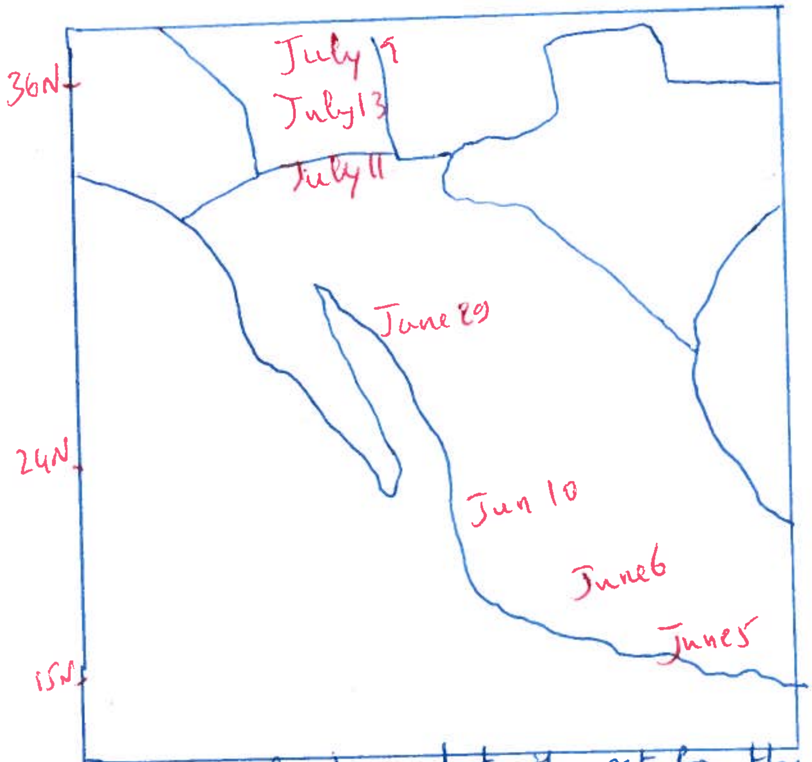
The North American monsoonal (Also called Southwest United States monsoon, the Mexican monsoon, or the Arizona monsoon) circulation is characterized by distinct rainfall maxima over western Mexico and the Southwestern United States and by an accompanying upper-level anticyclone over the higher terrain of northwestern Mexico. Heating over the mountains of Mexico and the western United States plays a major role in the development and evolution of the monsoon, in a manner similar to what is observed over the Tibetan Plateau and the Bolivian Altiplano. A low-level jets, from the Gulf of Mexico and the Gulf of California bring moisture to the continent and play an important role in the daily cycle of precipitation . Geographically, the NA monsoon precipitation region is centered over the Sierra Madre Occidental in the Mexican states of Sinaloa, Durango, Sonora, and Chihuaha. An "active" day during the monsoon in southeast Arizona will be as follow; At around 1:00 pm, thunderstorms are building in the mountains northeast, east and southeast of Tucson. By 5:30 pm, the storms have consolidated into a large mass and moved into the deserts, with the strongest deep storms. Underneath, a line of severe thunderstorms is detected by automated observing systems reporting 60-80 mph winds in the Tucson metro area, with a large dust storm forming underneath the clouds.

During May and June heavy rainfall begins over southern Mexico and quickly spreads northward along the western slopes of the Sierra Madre Occidental. Typical onset dates of the monsoon range from early June in Southwest Mexico to early July in Arizona and New Mexico. At any particular location the beginning of the monsoon is usually sudden, with the weather changing abruptly from relatively hot, dry conditions to relatively cool, rainy ones. Although the onset of the monsoon proceeds rapidly from south to north, the intensity of the monsoon rainfall decreases towards the north. As the monsoon spreads northward the daily cycle of precipitation grows more intense and strongly depends on elevation. The heaviest rains generally occur over the highest elevations during the afternoon and early evening, and at lower elevations later at night. Circulations linking coastal regions to the sea and mountains to nearby valleys become more prominent in the Gulf of California region, and are influenced by surges of moisture from tropical disturbances, such as tropical cyclones, further to the south.

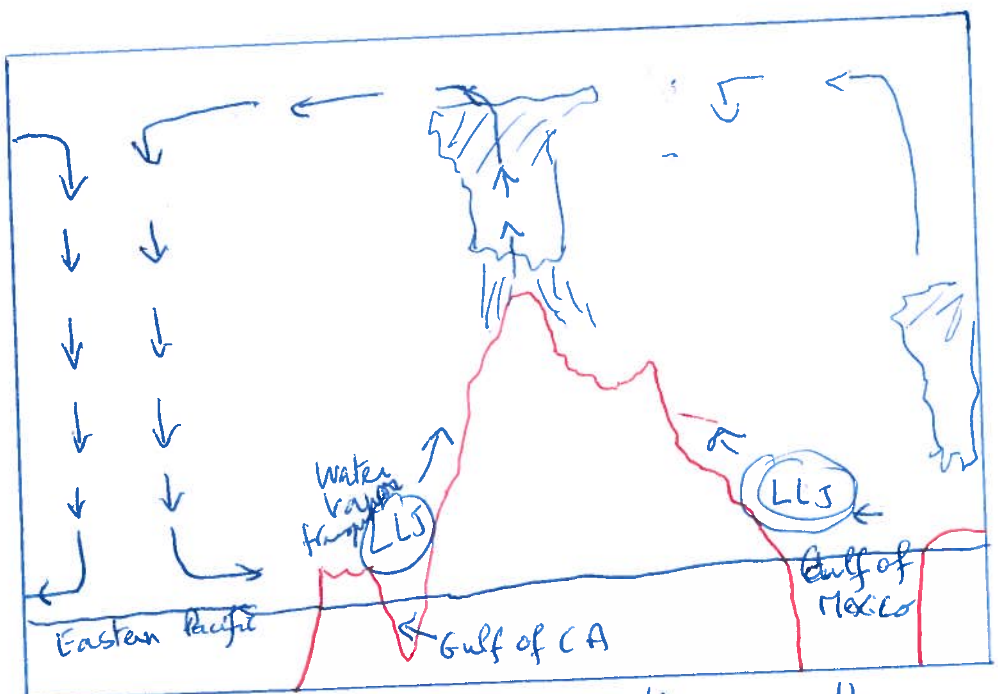
The North American monsoon reaches maturity in July and August. The northern edge of the monsoon extends into Arizona and New Mexico. The reversal of the surface winds over the northern Gulf of California from northwesterly to southeasterly is accompanied by an abrupt increase in moisture. During the mature phase of the monsoon season the heaviest precipitation remains west of the Sierra Madre Occidental in Mexico and near the southern end of the Gulf of Mexico. Mean monthly rainfall totals can exceed 30 cm along much of the western slopes of the Sierra Madre Occidental, causing the vegetation to evolve from near desert conditions to those typical of a tropical rain forest within several weeks. Surges of tropical moisture move northward along the Gulf of California and are linked to active and break periods of the monsoon rains over Arizona, southeastern California and southern Nevada. On average portions of western Mexico receive in excess of 70% of their annual precipitation during this period.

Tropical disturbances in the form of tropical depressions, tropical storms, and even hurricanes account for between 20 and 60% of the rainfall along the Pacific coast of Mexico, and can contribute as much as 25-30% to the seasonal rainfall in the western interior locations. The monsoon system decays in September and October, but generally at a slower pace than during development. The monsoon high over the western U.S. weakens, as the monsoon precipitation retreats southward into the deep tropics. However, as cold fronts associated with the polar jet stream begin to push into Arizona, the lingering moisture can trigger severe thunderstorm episodes in Arizona and northern Sonora. In addition, this time of year is the peak of tropical storm season in the eastern Pacific. Decaying tropical systems can become caught in the weakening monsoon flow and lifted into the deserts. The seasonal march may contain a double peak structure (wet- dry-wet) in the seasonal march of precipitation is found along the west coasts of Mexico and Central America . The dry period is called the mid-summer drought. The duration of the midsummer-drought varies from year-to-year.

The North American monsoon is affected on seasonal and longer timescales by complex interactions between the Pacific and Atlantic oceans, the North American landmass, and the atmosphere. The relative influences of each of these climate players determines the type of the monsoon in any particular year. There is some evidence that local ocean temperatures, unrelated to ENSO, may help to determine the regional timing, intensity and extent of the monsoon precipitation. Roughly 80% of the rainfall in Arizona and New Mexico occurs after water temperatures in the northern Gulf of California exceed 28.5°C. The wettest years in Arizona are associated with significantly higher temperatures (>29°C) while the driest years are associated with lower temperatures. Also when the upper-level monsoon anticyclone is located to the east of the region, wetter-than-normal conditions occur in the Southwest. Conversely, when the anticyclone is to the west of the region, drier-than-normal conditions occur.



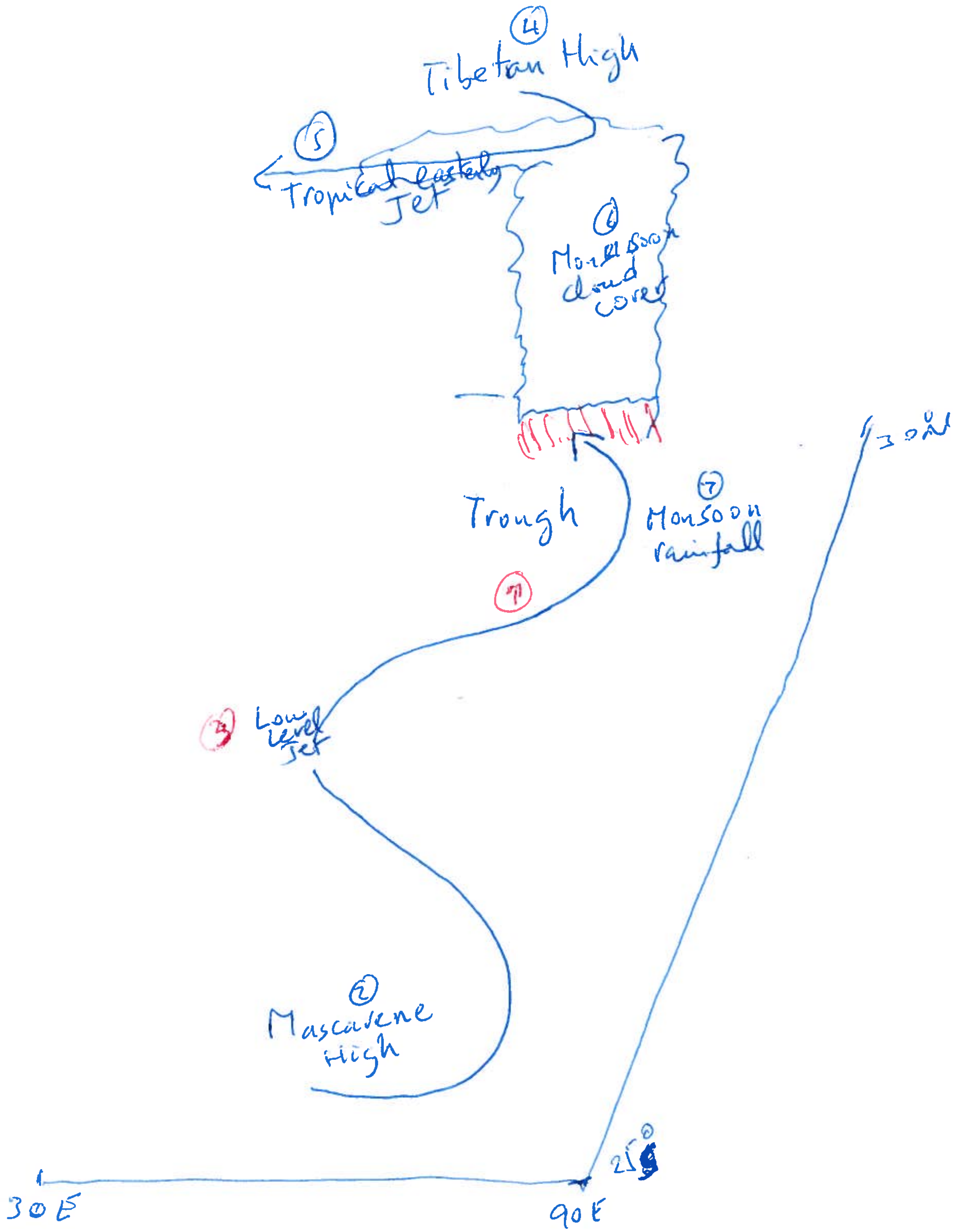
Mean calendar date of onset for the summer monsoon using daily precipitation.



Cross section through the north american monsoon system at 27.5°N.

Indian Summer monsoon:

The onset of the Indian summer monsoon (ISM) over the southern tip of the Indian peninsula [also known as monsoon onset over Kerala (MOK)] has been considered the beginning of India's rainy season. Over 70% of the annual rainfall in India occurs during the summer monsoon season from June to September. Two rainfall maxima with totals exceeding 1200 mm are observed over India and the surrounding Indian Ocean during the monsoon season. The first maximum is centered over the Bay of Bengal and extends northwestward into eastern and central India. The second maximum is located along the west coast of India on the windward side of the Western Ghats Mountains. A relative minimum in rainfall of less than 500 mm is found in the climatological mean between these two regions in the southeastern state of Tamil Nadu. Relatively low climatological rainfall totals of 400–600 mm are also observed across northern India, while the lowest totals (200–400 mm) are observed in northwestern India in the vicinity of the Great Indian Desert.The MOK is associated with a large area of organized rainfall caused by deep convection extending eastward a few thousand kilometers from the low-latitude regions of the Arabian Sea in the north Indian Ocean. The moisture required for this large area of rainfall is mainly produced in the south Indian Ocean and carried to the convective heat source associated with MOK by a strong cross-equatorial low-level jet stream (LLJ). The cyclonic shear vorticity region of the LLJ produces deep convection and monsoon rainfall by Ekman pumping of air, rich in moisture, from the atmospheric boundary layer.
Heavy rains lash south peninsula after the cross-equatorial low-level jet (LLJ) is established across the Somali coast into the near-equatorial Arabian Sea. The northward progression of the monsoon is symptomatic of a large scale transition of a deep convection from the equatorial to continental regions. By middle of July, monsoon covers the whole country. Large scale changes occur in the circulation features associated with the onset phase of Indian monsoon (Pearce and Mohanty 1984). At the date of monsoon onset, there is a band of deep convection in the east-west direction passing through southern tip of India, a maximum cloud zone . During the summer monsoon onset phase, major changes are also observed in the atmospheric wind flow at all levels. There is an appreciable acceleration of cross equatorial flow across the Somali coast and westerly zonal flow over the equatorial Indian Ocean . The westerly zonal flow extends up to 600 hpa. The relative humidity of the air also increases at least up to 500hpa (Rao 1976). At the upper tropospheric levels, the onset is generally associated with a northward shift in the subtropical westerly jet stream to the north of the Tibetan Plateau and the westward shift of the quasi-stationary trough at 500hpa, from about 90E to about 80E. Yin (1949) was the first to link the process of monsoon onset to the displacement of westerly troughs in the circumpolar westerlies and shift of the sub-tropical jet (STJ) to the north of the Himalayan periphery. A tropical easterly jet stream also appears over south India in association with the monsoon onset. Murakami and Ding (1982) have suggested that the onset is related to the warming of the Eurasian region by diabatic heating. Thus the onset of the monsoon over India is linked to a combination of regional and planetary scale changes over the entire Indian monsoon region.



4
Tibetan High
5
Tropical easterly Jet
6
Monsoon cloud core
Trough
7
Monsoon rainfall
3
Low level Jet
2
Mascarene High
30N
25S
30E
90E

In determining (modeling) the Oscillations of the Asian summer monsoon system (T.N. Krishnamurti 1976 Title: "Oscillation of a monsoon system"), the following 9 parameters are defined;
1) Monsoon Trough: This is the low-pressure trough at sea level that is a part of the global equatorial trought of the northermn summer season.
2) Mascarene high: This is a high pressure area south of the equator. Its name comes from the Mascarene Islands east of Madagascar. The center of this anticyclone is located near 30S and 50E.
3) Low level cross-equatorial jet: This is a northern summer low-level jet. Its importance has been recognized since the observational studies of Findlater. The jet has maximum winds near the 1.5km level.
It is know to occasionally have speeds of the order of 100kt near Madagascar and off the Somali coast .
It is a very narrow jet (both horizontally and vertically); The jet is confined close to the mountains and the western boundary effect of the east African highlands is recognized to be important for its dynamics.
The axis of the low-level jet begins to move north-westward in February and reaches the east African highlands
by June. Thereafter its position remains steady for several months. This jet becomes most intense during the
months of June, July and August. During these months the axis of the jet downstream from the Somali coast is
observed to split into two branches.
4) Tibetan High: This is a large anticyclone that is know to have its largest amplitude near 200mb during the
northern summer months.
5) Tropical easterly Jet: The upper tropospheric easterly jet is near 150mb. This jet has winds of roughly 80-100kts
with the strongest winds being found just to the southern tip of India over the Arabian Sea. The jet forms in the
monsoon month of June and is present until September.
6) Monsoon cloudiness and 7) Monsoon rainfall
8) Dry static stability: In the monsoon belt over northern India during active and inactive rainfall periods, the surface heating goes from small to very high values due to solar insolation. The dry static stability fluctuates near the surface from stable to less stable or unstable values during these periods.
9) Moist static stability: The parameter here is the change of moist static energy between the surface and 700mb.

We see from the above description that the North American monsoon is much smaller in its horizontal dimension and intensity than the Indian monsoon, it is not as strong or persistent. Also the seasonal reversals of the wind are less pronounced.