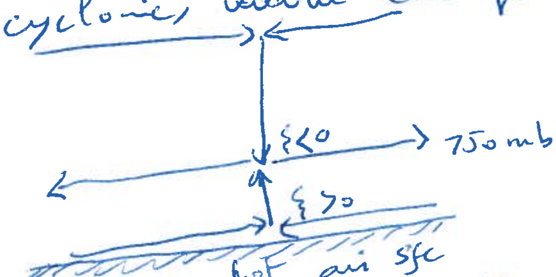
Question: How does the Indian monsoon influence the existence of subtropical deserts

Answer: Based on my tropical notes, Blake (1979) Blake (1983), Kshudiram book (Tropical Circulation systems and monsoons)

Charney (1975) noted that in general the incoming minus the outgoing radiation is positive over the tropics and negative over the high latitudes. A major exception occurs over the desert regions where satellite measurements show that the outgoing radiation exceeds the incoming radiation.

Let's consider the experiment done over the Saudi Arabian desert during May 1979. The heat low associated with the Saudi Arabian desert is a shallow, cyclonic, warm low pressure area in the lowest kilometer of the atmosphere.



lower cell: this is a shallow cell, has surface convergence, rising air and divergence at 850 mb

upper cell: this is a deeper cell starting with divergence at 850 mb, has descending air with weak convergence above this level.

Heat budget:

$$\frac{d\theta}{dt} = \frac{1}{c_p}\left(\frac{p_0}{p}\right)^{R/c_p} \sum_j H_j \quad \leftarrow \text{first law of thermodynamic}$$

The equation is averaged over the domain of interest [exp]

$$\frac{d[\theta]}{dt} = -[v]\cdot[\nabla\theta^*] - [w]\frac{\partial[\theta]}{\partial p} + \frac{1}{c_p}\left(\frac{p_0}{p}\right)^{R/c_p}\left[\sum H_j\right]$$
$$- [\nabla \cdot v^*\theta^*] - \frac{\partial}{\partial p}[w^*\theta^*]$$

↙ Energy budget.

Each term is computed during midday hours and pre-sunrise hours [period 9, 10, 12 May 1979]

One of the findings is a net radiative heat loss during a 24h period at all levels except for a slight gain around 550-450 mb. Furthermore at 250 there is a net upward radiative flux during a 24 hr period which requires that energy from other sources be supplied to ~~this~~ domain if the potential temperature profile is to be maintained. It appears that heat is imported into the upper troposphere and transported downward.

The downward motions are associated with mass convergence and energy supply in the upper troposphere; they enhance the drying of the troposphere which in turns alters the strong radiative forcing. It is suggested that the downward motions are in fact part of a large scale vertical overturning which associated with the Hadley and east-west circulations. These circulations tend to favor regions of the large surface albedo for their descent.

General Case: Co-existence of monsoon with desert circulation

The world's principal monsoons co-exist with subtropical deserts on their poleward sides. In the Northern hemisphere, the great central asian desert, the great Saharan desert in African, the Mojave-Sonoan desert in central america and the adjoining southwestern North America, all lie on the poleward sides of monsoons in the respective regions. Similar co-existence of monsoons with desert on their poleward sides is also observed in the Southern hemisphere in all the continents; for example, Gibson and western desert in Australia, Kalahari desert in South Africa and the Patagonia desert in South America all lie on the poleward sides of their respective monsoons.

Ramage (1966) observed a seasaw type inverse relationship between surface pressure anomaly in the 'heat low' over Thar desert in Pakistan and monsoon rainfall anomaly over the neighboring Arabian Sea off Bombay. He observed that a fall/rise of surface pressure in Thar Desert over Pakistan was correlated with increase/Decrease of rainfall over the neighboring Arabian Sea

In a theoretical study Charney (1975) observed that to maintain the radiative equilibrium of the atmosphere over a surface with high albedo, such as sandy soil surface, against radiative heat loss, air must descend and that it is this descent or adiabatic subsidence and warming of the air that leads to continued dryness and maintenance of the desert. He also recognized the contribution of the descending branch of the Hadley circulation to the desertification process.

Saha (2001b) using NCEP reanalysis data, computed the mean vertical circulation along the Greenwich meridian over the western part of the Saharan desert at 12 GMT during August and showed how the monsoon and the Hadley circulation coexist with the desert circulation and are linked to one another.

In this figure is the meridional circulation, while the monsoons winds converge into the ITCZ along about 12 deg N at low levels producing strong penetrative convection with diverges in the upper troposphere both equatorward as well as poleward, there is strong sinking motion over the desert area. It is so strong that it prevents the thermally direct low level desert convection from rising beyond 700 mb.