

**ESCI 344 – Tropical Meteorology**  
**Lesson 6 – Local and Diurnal Circulations**

**References:** *Forecaster's Guide to Tropical Meteorology* (updated), Ramage  
*Climate Dynamics of the Tropics*, Hastenrath  
*Climate and Weather in the Tropics*, Riehl  
“The interaction of trade wind and sea breeze, Hawaii,” Leopold,  
*J. Meteor.*, **6**, 312-320, 1949  
“The effects of a large island upon the trade-wind air stream,” Malkus,  
*Quart. J. Roy. Meteor. Soc.*, **81**, 538-550, 1955

**Reading:** “The interaction of trade wind and sea breeze, Hawaii” (e-reserve)  
“The effects of a large island upon the trade-wind air stream” (e-reserve)

**GENERAL**

- **Diurnal variation of solar radiation and temperature in Tropics is much larger than annual variation.**
  - In midlatitudes, annual variation is larger than diurnal variation.
- **Diurnal and mesoscale process are very dominant in the Tropics.**

**LAND-SEA BREEZE**

- **Land-sea breezes caused by the differential heating across land-water boundaries occur both in the midlatitudes and the tropics. However, the influence of land-sea breezes is generally more pronounced in the tropics.**
- **Inland or offshore extent of land-sea breeze is greater in the tropics compared with the midlatitudes (~100 km, vs. ~10 km).**
- **The difference in extent is explained by the weaker Coriolis acceleration in the tropics.**
  - *Rossby radius of deformation* is the ratio of the gravity wave speed divided by the Coriolis parameter,

$$\lambda_R = c/f .$$

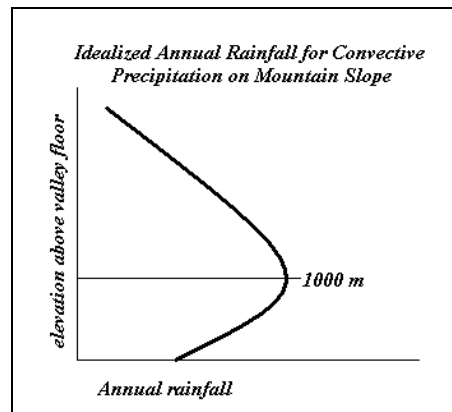
- **The radius of deformation is essentially a measure of how large a circulation must be in order for the effects of the earth's rotation to be important.**
- **Circulation smaller than the radius of deformation are not affected by the earths rotation.**

- Coriolis helps to limit the horizontal effects of the land-sea breeze by turning the wind and therefore limiting its inland-offshore influence.
- In the tropics the radius of deformation is nearly an order of magnitude larger than in the midlatitudes, so a circulation such as the sea breeze can have a much larger horizontal extent without being turned by the Coriolis acceleration.
- The type of cloudiness and/or precipitation associated with the land-sea breeze depends on the orientation of the coast with respect to the prevailing wind, as well as the inland topography.
- In a 1949 study, Leopold categorized four main types of land-sea breeze interactions with the trade winds over islands. His four categories are:
  - *Lanai type* – Appropriate for small, low island in which the trade winds blow up and over the peaks, and do not split.
    - Sea-breeze front is narrow and perpendicular to trades.
  - *Maui type* – Appropriate when peaks are tall enough to split trade wind flow.
    - Flanks of sea-breeze front exhibit shear lines trailing downwind.
  - *Mauna Kea type* – Appropriate for windward side of island with very tall peaks.
    - Cloudiness forming on windward side during daytime as trades are reinforced by sea breeze.
    - At night, land breeze front causes convergence offshore, with offshore cloudiness and showers.
  - *Kona type* – Appropriate for leeward side of islands with very tall, broad peaks.
    - During daytime, sea breeze moves in unimpeded by trade flow, which has been blocked by tall, broad peaks.
    - Convective showers form inland as sea breeze brings in moist air that is heated from below.
    - At night, down-slope land breeze suppresses clouds.
- Leopold's categories likely apply to other islands besides Hawaii.

- Land-breeze interaction with trades has been documented as producing enhanced rainfall at night and early morning on the east coasts of Brazil and the Ivory Coast.
- Large, mountainous islands (such as Puerto Rico) often have a clear ring of suppressed cloudiness surrounding them in the afternoon.
  - This is due to the compensating subsidence from the vigorous convection over the interior.
- *Land-lake breeze* circulations occur over and around large lakes, such as Lake Victoria in Africa.

### MOUNTAIN CIRCULATIONS

- Mountain-valley breezes are common in the tropics.
  - Valley breezes occur in afternoon, leading to cloudiness over mountains, with clear skies in subsiding air over valleys.
  - Mountain breezes occur at night, leading to clearing over the mountains, and cloudiness in valleys.
- Mountain rainfall patterns in tropics often show a band of maximum rainfall somewhere at around 1000 meters above the valley floor, with decreasing rainfall at the foot or toward the top of the mountain.

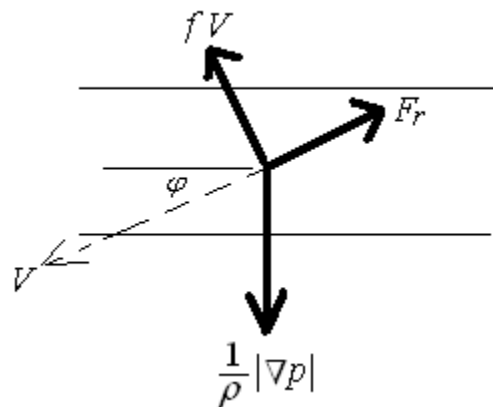


- This is mainly associated with areas where convective clouds dominate the rainfall.
  - Lower slopes don't experience as much orographic lift, and also experience evaporation of rain below cloud base.

- Upper slopes suffer from lower moisture availability.
- Where stratiform clouds dominate, the rainfall maximum tends to be near the top of the mountain.

### STRESS-DIFFERENTIAL INDUCED DIVERGENCE

- An abrupt change in friction (surface stress) can result in convergence or divergence and impact rainfall and cloudiness patterns.
- The force balance for steady flow with friction is shown in the diagram



- In order to balance the friction and Coriolis terms, the following relation must hold,

$$\tan \phi = F_r / fV$$

where  $F_r$  is the deceleration from friction. If friction is considered to be linear in  $V$ , then

$$\tan \phi = C_D / f$$

where  $C_D$  is the drag coefficient.

- Where the drag coefficient is larger, the cross-isobar angle is larger.
- For the same drag coefficient, the cross-isobar angle is larger at low latitudes than at higher latitudes.
- An air stream paralleling a coast-line will result in
  - Divergence and drier conditions over the coastline if the lower pressures are inland.

- **Convergence and moister conditions over the coastline if higher pressures are inland.**
- **This may partially explain the dry conditions over certain coastal regions such as the North coast of Venezuela, and other locations in the Tropics.**