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"
"The effects of a large island upon the trade-wind air stream"

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.**

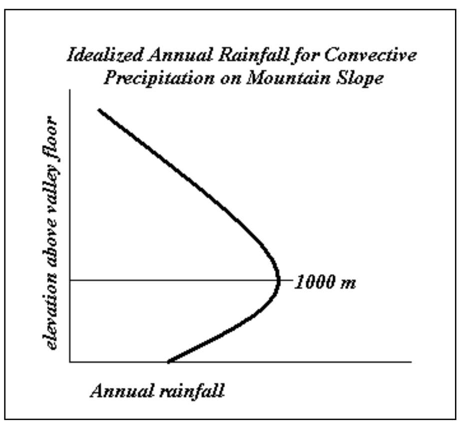
- **Coriolis helps to limit the horizontal effects of the land-sea breeze by turning the wind and therefore limiting its inland-offshore influence.**
- **In the tropics the radius of deformation is nearly an order of magnitude larger than in the midlatitudes, so a circulation such as the sea breeze can 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.**



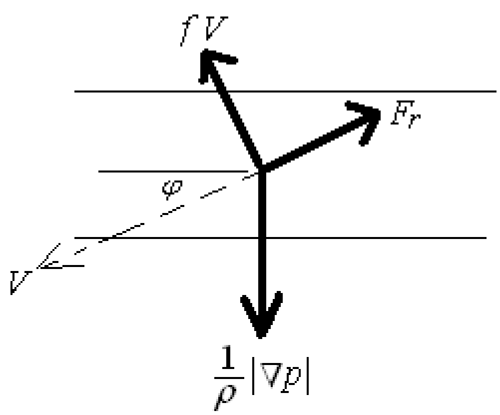
- **This is mainly associated with areas where convective clouds dominate the rainfall.**
  - **Lower slopes don't experience as much orographic lift, and also experience evaporation of rain below cloud base.**

- ○ **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,**

$$\tan\varphi = F_r / fV$$

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

$$\tan\varphi = C_D / f$$

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.**