

Local Winds

Kahua A'o Presentation — February 16, 2013
Steven Businger



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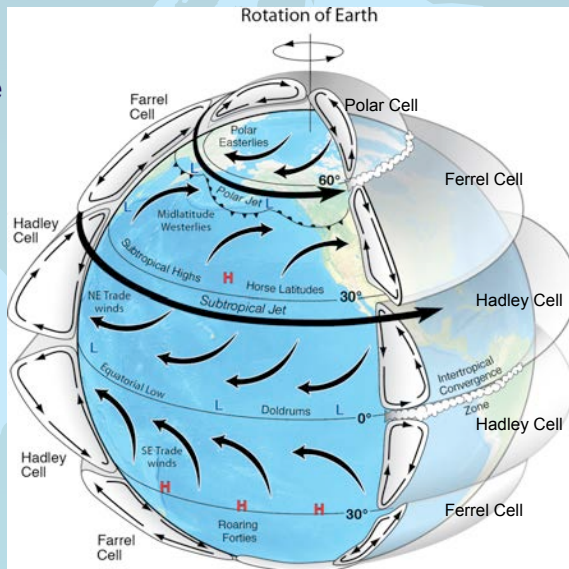
Hadley Circulation in Action



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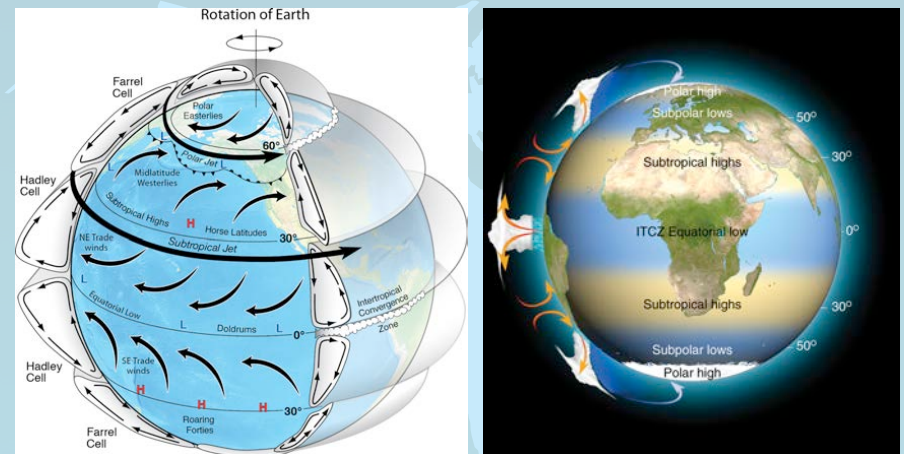
Idealized 3-Cell Model

A schematic of the Earth's weather machine. In Hawaii our weather is dominated by the Hadley Cell and northeast trade winds.



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Idealized 3-Cell Model



- Weak winds found near Equator (doldrums), 30 degrees (horse latitudes), and over poles.
- Boundary between cold polar air and mid-latitude warmer air is the *polar front*

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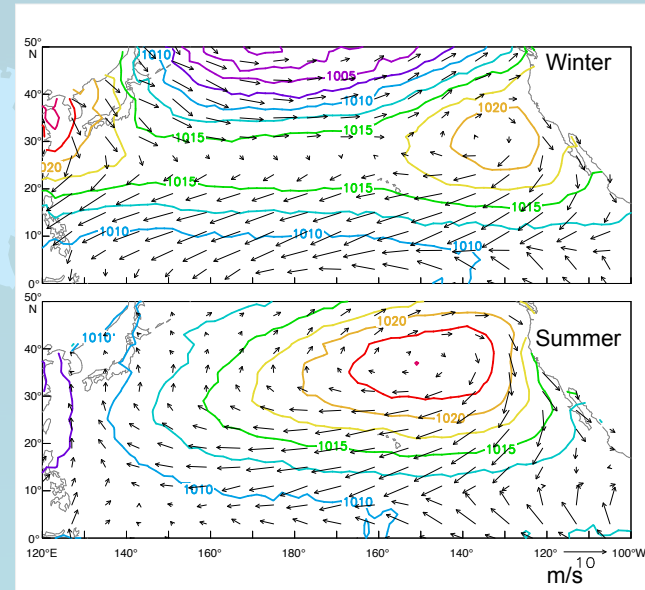
Trade Winds

Trade winds are the most common winds over Hawaiian waters, accounting for 70% of all winds in Hawaii.

These persistent winds, which blow from a NE to ENE direction, became known as trade winds centuries ago when trade ships carrying cargo depended on the broad belt of easterly winds encircling the globe in the subtropics for fast passage.

Winds blow from each of the other quadrants (SE, SW, and NW) 10% of the time.

Surface Pressure & Wind in Summer and Winter



Based on ship reports

Frequency of Trade Wind Days



Strong Trade Wind Days (25-33 kt)



Trade Winds

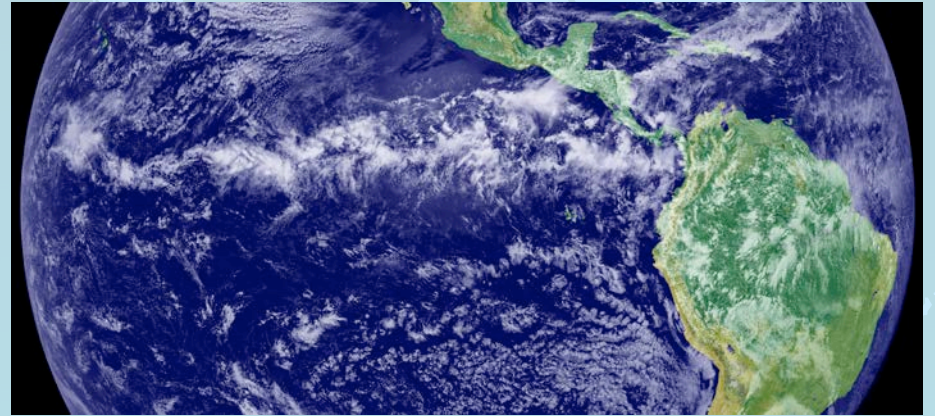
Though often refreshingly cool, strong, gusty trade winds can cause problems for Hawaii.

Blowing from the NE through East direction, these strong trades funnel through the major channels between the islands at speeds 5-20 knots faster than the speeds over the open ocean.

In addition, terrain enhancement of trade winds can cause even greater acceleration to more than hurricane force.

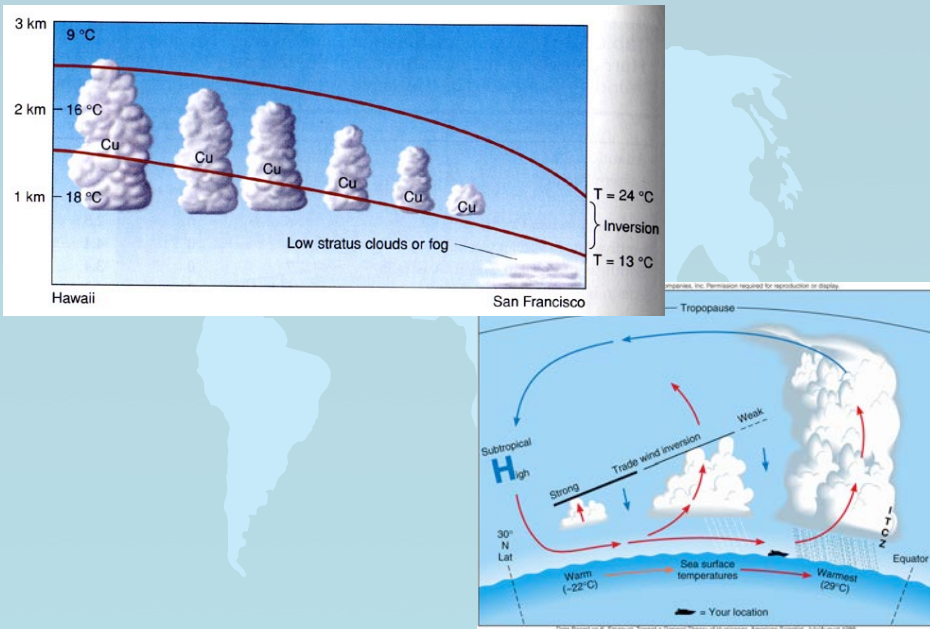
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Hadley Cell, Cumulonimbus, and Marine Stratus



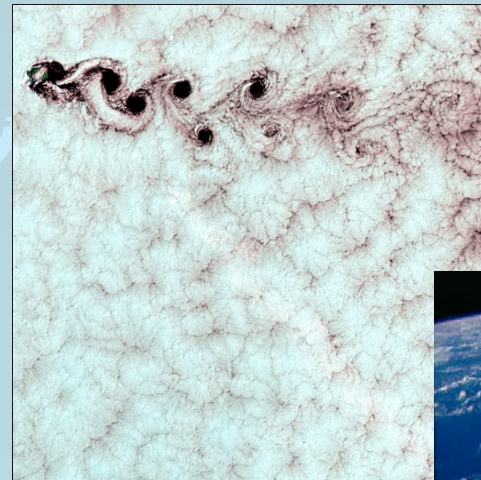
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Evolution of Trade Wind Inversion



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Friction Induced Eddies



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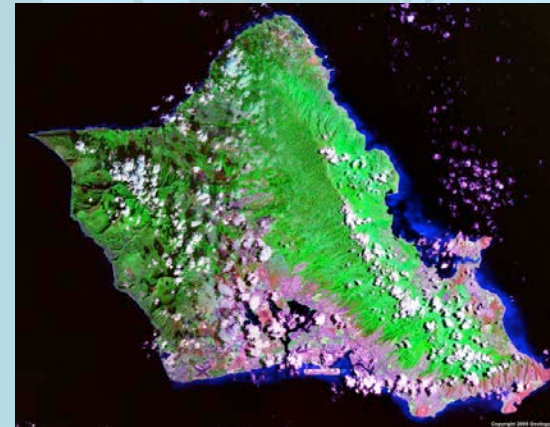
Sea and Land Breezes



- Local coastal winds
- Thermal circulations driven by differential heating/cooling of adjacent land and water surfaces
- Most prevalent when/where solar heating is strong

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Oahu Sea-Breezes Cause Clouds



Sea breeze front from pearl harbor to Waikiki.
Offshore sinking air over the North Shore and windward waters.

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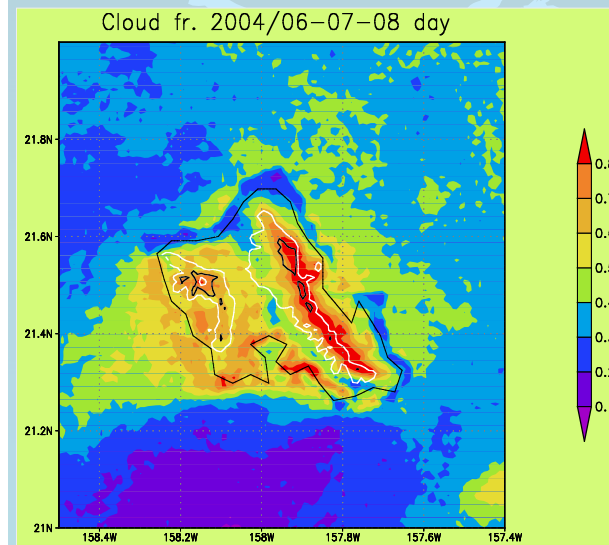
Oahu Sea-Breezes Cause Clouds



Sea breezes on Oahu are strongest on light trade wind days.

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Oahu Sea Breezes Cause Clouds

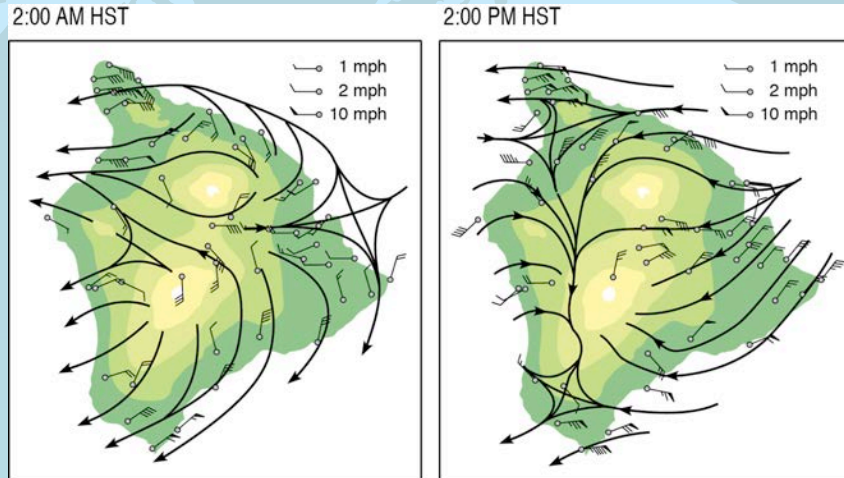


Daytime Cloud Fraction for Oahu

Sea breeze front from pearl harbor to Waikiki.
Offshore sinking air over the North Shore and windward waters.

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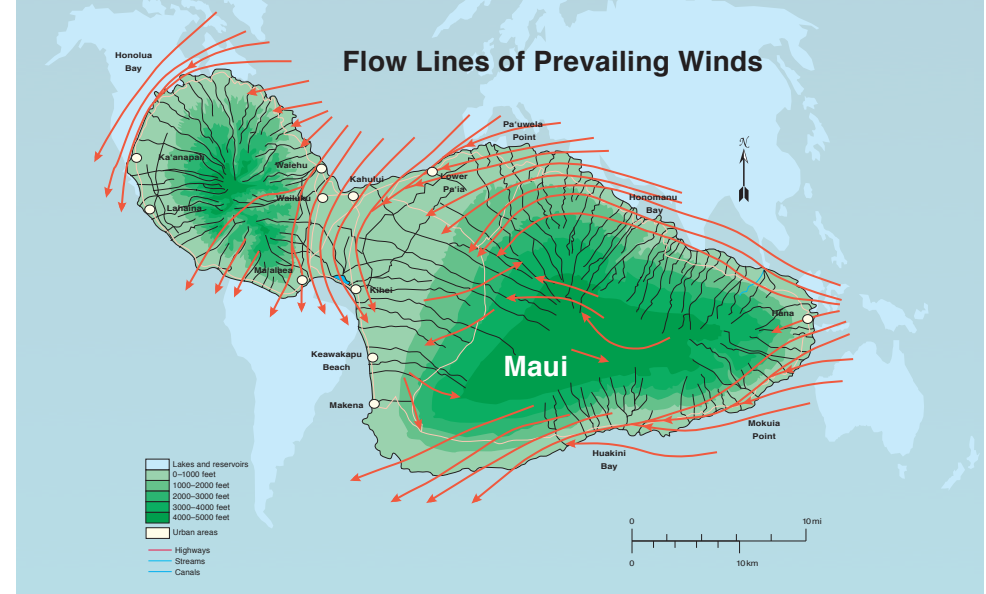
Island of Hawaii July Diurnal Winds



Island of Hawaii with contours for elevation plotted every 3000 ft and average winds (mph) during a six-week period during July and August, 1990.

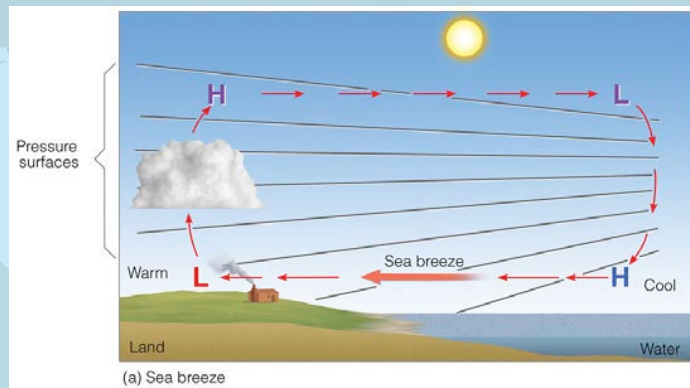
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Tradewinds and Maui



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Sea and Land Breezes



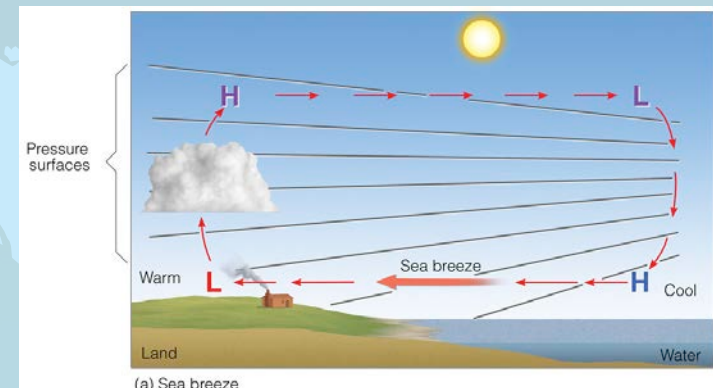
(a) Sea breeze

Sea breezes

- Cool coastal communities
- Bring more humid air
 - Haze
 - Fog
- Often produce summer thunderstorms inland from the coast

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Sea and Land Breezes



(a) Sea breeze

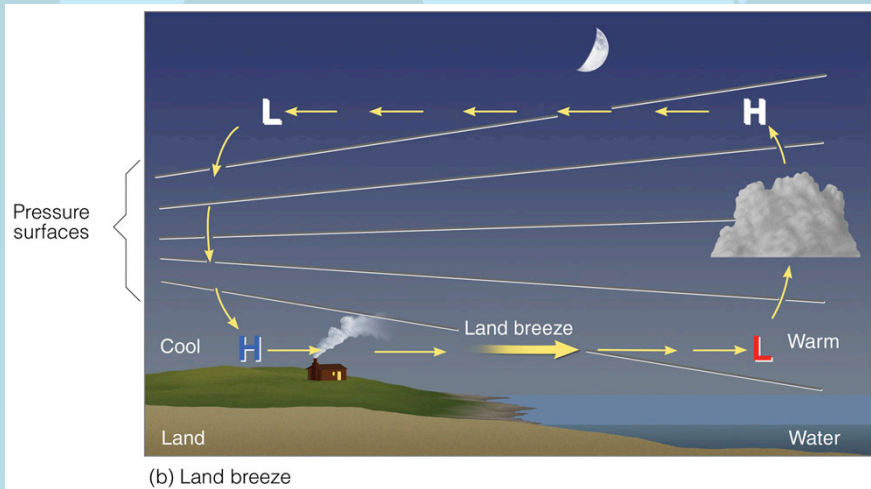
Sea breeze development summary

- Solar heating raises land temperature more than water
- Air in contact with land warms and rises
- Cooler (denser) sea air moves in to replace rising air over land
- Air sinks over the water in response to surface air movement, producing return circulation (land-to-sea breeze) aloft

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Land Breeze

Land breezes form at night due to stronger radiative cooling of the land surface leading to sinking and offshore flow of this cooler air mass with return flow aloft



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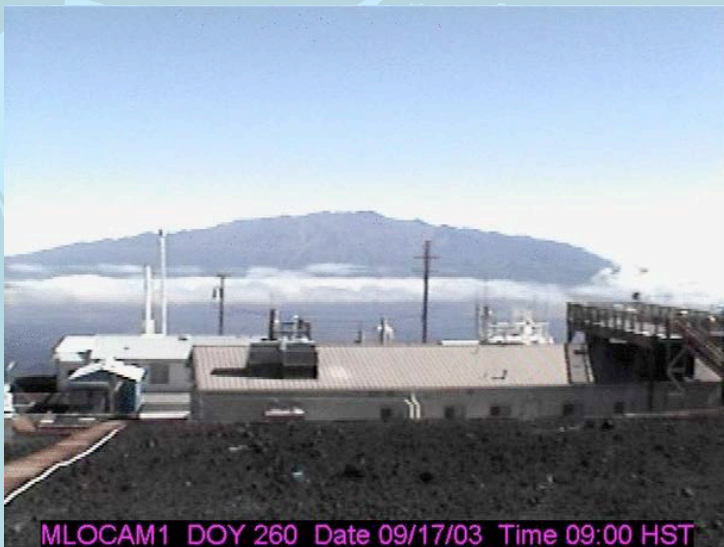
Land Breeze

Land breezes form at night due to stronger radiative cooling of the land surface leading to sinking and offshore flow of this cooler air mass with return flow aloft. Thunderstorms may form at night over the offshore waters.



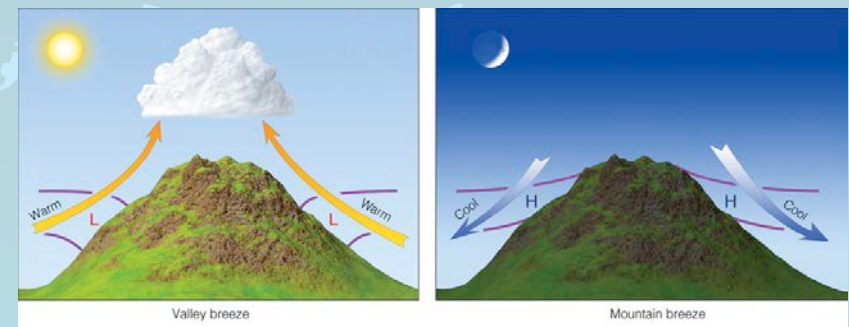
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Mountain/Valley Winds



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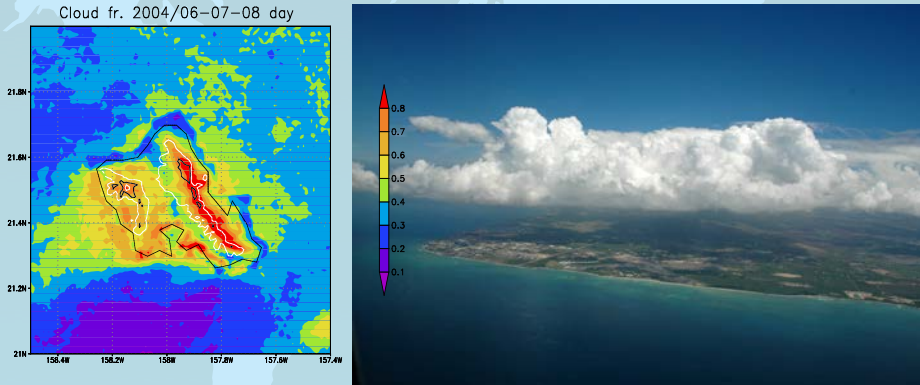
Mountain/Valley Winds



- Sunlight heats mountain slopes during the day and they cool by radiation at night
- Air in contact with surface is heated/cooled in response
- A difference in air density is produced between air next to the mountainside and air at the same altitude away from the mountain
- Density difference produces upslope (day) or downslope (night) flow
- Daily upslope/downslope wind cycle is strongest in clear summer weather when prevailing winds are light

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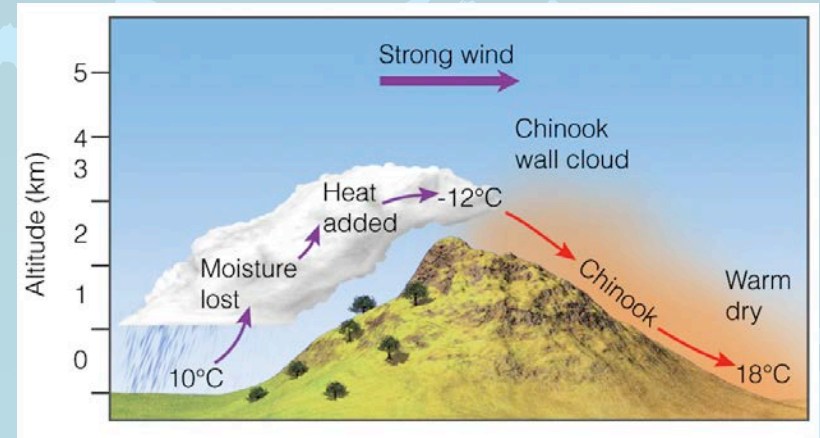
Combined Sea Breeze and Mountain - Valley Circulations



In Hawaii, the sea-breeze and mountain-valley circulations are combined to produce an island scale circulation that can be quite vigorous, especially when trade winds are light.

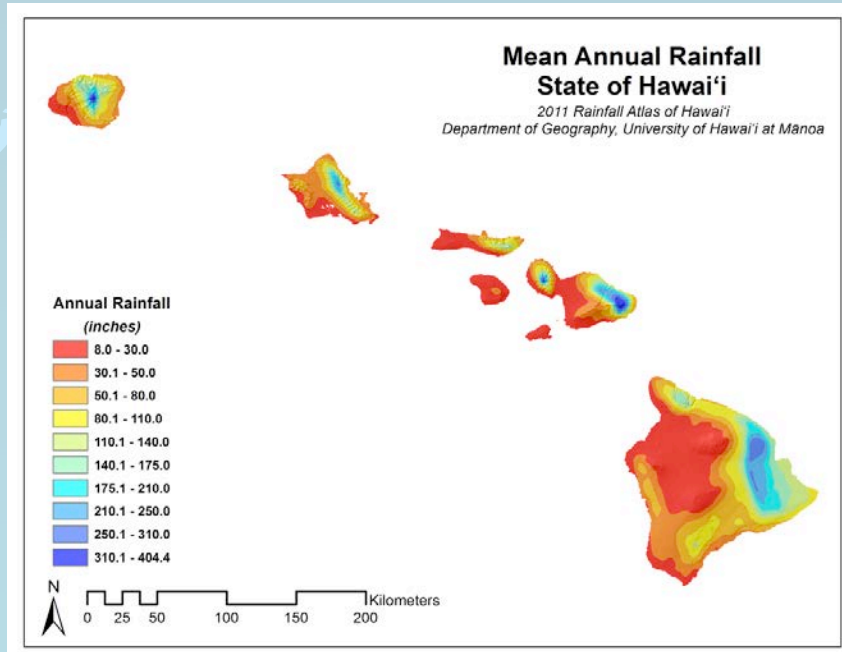
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Terrain-Induced Rain

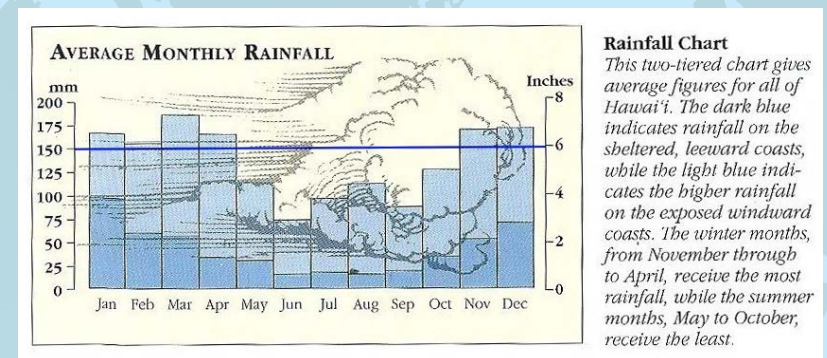


- Terrain lifts the air that blows off of the ocean in Hawaii. The lifted air cools as it expands, resulting in clouds and rain on the windward slope
- On the lee side the air warms as it descends due to compression, leaving warm drier conditions on the leeward side.

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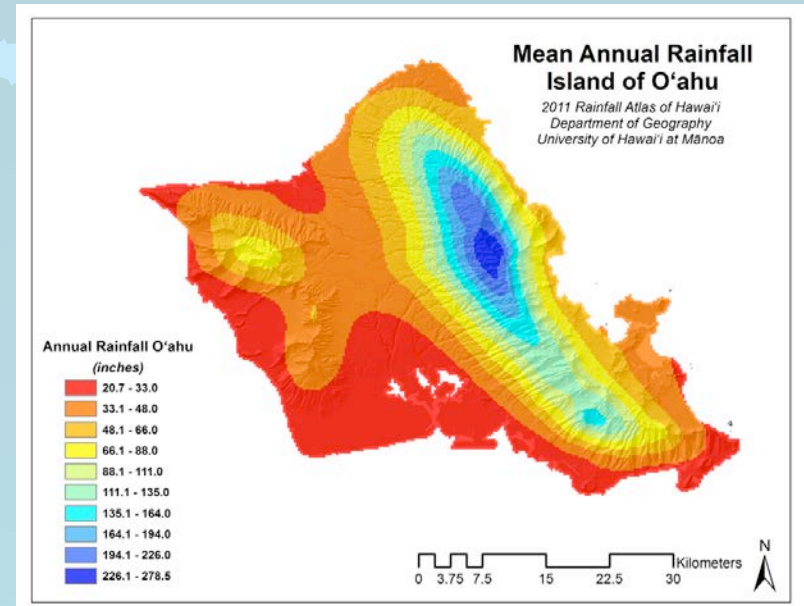
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NASA Image of Hawaii



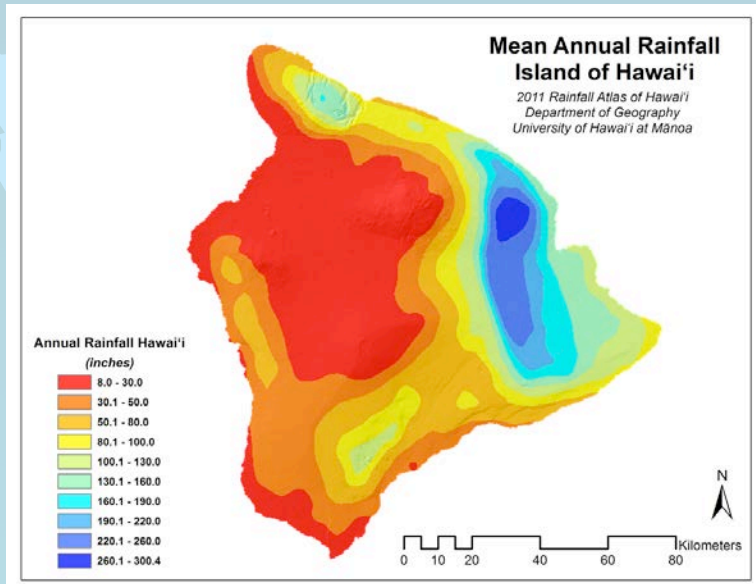
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Annual Rainfall for Oahu



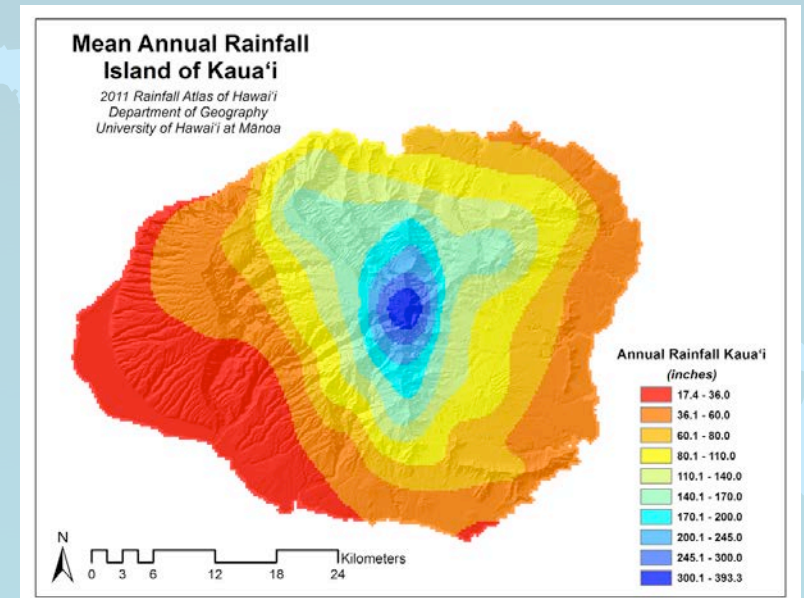
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Annual Rainfall for Island of Hawaii



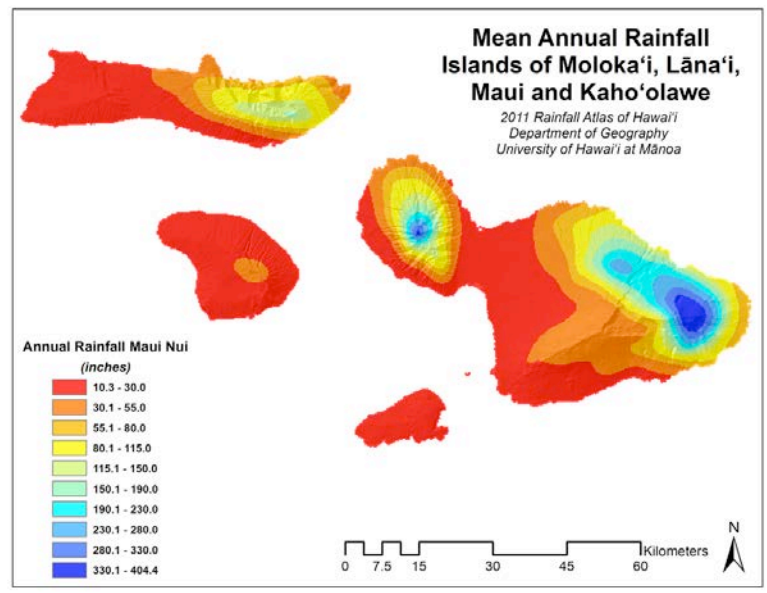
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Annual Rainfall for Island of Kauai



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Annual Rainfall for Maui & Molokai



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Questions?



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