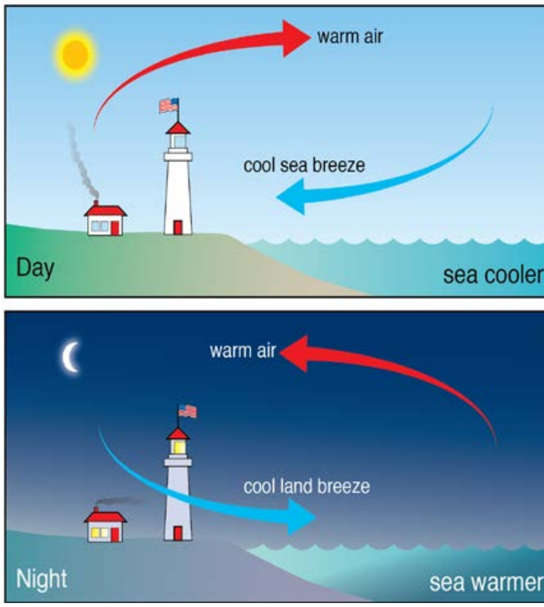

Local Winds and Rains of Hawai‘i:

I Kama‘āina I Nā Makani A Me Nā Ua

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Figure 1 Sea breeze and land breeze circulations are driven by differential heating.

Title: Local Winds and Rains of Hawai‘i: ***I Kama‘āina I Nā Makani A Me Nā Ua***

Grades: 6-8, modifiable for 3-5, 9-12

Time: 2 - 10 hours

***Nā Honua Mauli Ola*, Guidelines for Educators, *No Nā Kumu*:** Educators are able to sustain respect for the integrity of one’s own cultural knowledge and provide meaningful opportunities to make new connections among other knowledge systems (p. 37).

Standard: Earth and Space Science 2.D ESS2D: Weather and Climate
Weather varies day to day and seasonally; it is the condition of the atmosphere at a given place and time. Climate is the range of a region’s weather over one to many years. Both are shaped by complex interactions involving sunlight, ocean, atmosphere, latitude, altitude, ice, living things, and geography that can drive changes over multiple time scales—days, weeks, and months for weather to years, decades, centuries, and beyond for climate. The ocean absorbs and stores large amounts of energy from the sun and releases it slowly, moderating and stabilizing global climates. Sunlight heats the land more rapidly. Heat energy is redistributed through ocean currents and atmospheric circulation, winds. Greenhouse gases absorb and retain the energy radiated from land and ocean surfaces, regulating temperatures and keep Earth habitable. (A Framework for K-12 Science Education, NRC, 2012).

Hawai‘i Content and Performance Standards (HCPS) III
http://standardstoolkit.k12.hi.us/index.html

STRAND THE SCIENTIFIC PROCESS	
Standard 1: The Scientific Process: SCIENTIFIC INVESTIGATION: Discover, invent, and investigate using the skills necessary to engage in the scientific process	
Topic: Scientific Inquiry	**Benchmarks:** **SC.8.1.1** Determine the link(s) between evidence and the conclusion(s) of an investigation. **SC.8.1.2** Communicate the significant components of the experimental design and results of a scientific investigation.
Standard 2: The Scientific Process: NATURE OF SCIENCE: Understand that science, technology, and society are interrelated	
Topic: Science, Technology, and Society	**Benchmark SC.8.2.1** Describe significant relationships among society, science, and technology and how one impacts the other
Topic: Unifying Concepts and Themes	**Benchmark SC.8.2.2** Describe how scale and mathematical models can be used to support and explain scientific data.
STRAND PHYSICAL, EARTH, AND SPACE SCIENCES	
Standard 8 EARTH & SPACE SCIENCE: Understand the Earth and its processes, the solar system, and the universe and its contents.	
Topic: **Forces that Shape the Earth**	**Benchmarks:** **SC.ES.8.1** Describe how elements and water move through solid Earth, the oceans, atmosphere, and living things as part of geochemical cycles **SC.ES.8.4** Describe how heat and energy transfer into and out of the atmosphere and their involvement in global climate. **SC.ES.8.6** Describe how winds and ocean currents are produced on the Earth's surface. **SC.ES.8.7** Describe climate and weather patterns associated with certain geographic locations and features. **SC.8.8.4** Explain how the sun is the major source of energy influencing climate and weather on Earth **SC.8.8.6** Explain the relationship between density and

	convection currents in the ocean and atmosphere.

To the Teacher: Connections to Place & Culture(s)

I Kama‘āina I Nā Makani A Me Nā Ua:
One is seen as a local native by one's knowledge of the winds and rains.

Local winds and clouds are the result of the influence of complex terrain and the daily or diurnal heating cycle of the Hawaiian Islands on the large-scale winds and moisture arriving from over the open ocean. Large scale winds here refers to surface winds arising over the open ocean as a result of surface high and low pressure systems that have a scale of ~1000 km, such as the Hadley circulation or Kona lows. Each of the main Hawaiian Islands has many local wind regimes that depend critically on the height of the mountains and the areal size of the islands.

The mountains of Hawai‘i have a profound impact on the weather, both on the wind field and on the climatology of cloud and precipitation. As moist air is forced upslope, it cools and since cool air can hold less moisture, some moisture condenses. As a result clouds and then rain form, which are sometimes referred to as *orographic* clouds and rain. As the undisturbed flow over the ocean approaches the Hawaiian Islands, the mountains and daily heating cycle over the islands disturbs the flow, resulting in “local” winds. The direction of the flow at large scales interacts with the topography to produce gradients in cloud and rainfall, that in turn help define the local climate; e.g., wet windward and dry leeward slopes. The height of the mountains and the strength of the flow determine if the flow can pass over the top of the mountain or if the flow is forced to split and go around the mountain (see Figs. 2 and 3). Mountains can act both to trigger and anchor thunderstorms that can produce prodigious rainfall rates up to 8 inches (200 mm) per hour.

The fact that topographic features are fixed makes the interaction between large-scale storms systems and mountains somewhat easier to anticipate. The greatest accuracy in weather forecasting is associated with the largest scale systems, so if one has detailed knowledge of topography, it is fairly straightforward to forecast the general character of the topographically forced winds, clouds, and rainfall that will occur with various large-scale weather systems. For example, UH scientists using O‘ahu rainfall data, statistics, and General Circulation Models predict more frequent heavy rainfall events but reduced rainfall intensity through 2040 for the south shoreline of O‘ahu as Earth undergoes unprecedented warming. Heavy rainfall and flash floods have economic and environmental costs: slope and coastal erosion, pollution of marine environment, and damage to coral reefs (http://www.hawaii.edu/news/article.php?aId=4710).

Hawai‘i's Local Winds and Rains

The Hawaiian Islands are diverse in terms of topography and geographic extent. Each island has unique combinations of mountains, valleys, sea, land, and windward and leeward features that influence the local circulation of air and the distribution of rain. The local circulations or “local winds” have very different characteristics from the large-scale wind circulation over the open ocean. The several hundred local Hawaiian wind and rain names result from and reflect the diverse topography, cultural traditions, and ecological settings that have a defining role in how people think and talk about Hawaiian weather.

The oral and written literature of Hawaiʻi reveal deep interest in and knowledge of winds, rain, and the water cycle, for example, see *Water of Kāne*, p. 30. We can see the cultural importance of knowledge of the weather in the following tradition. To be considered a local or *kamaʻāina* (child of the land), you may be called upon to recite the winds or rains of that place. If you could name them, you were then deemed to be a *kamaʻāina*; if not, you would be considered a *malihini*, a stranger. The chants listing winds and rains were often published in the newspapers as part of stories, or to simply inform the public about the nature of the winds in a certain area. At times these would even be challenged and disputed, with a reply such as, "No, that person was wrong, for they are only a *malihini*. I am the true *kamaʻāina*, and these are the correct winds of this area." Our ancestors valued this information, as it was crucial in the everyday lives of a sea-faring and farming people.

Many names of local winds can be found in the story of the *Wind Gourd of Laʻamaomao*, (Nākuʻina, 1902, 2005) which tells of a boy named Pākaʻa, whose mother gives him a gourd that contains the bones of his grandmother, Laʻamaomao. With this gourd, and the chants of wind names that his mother teaches him, Pākaʻa is able to control the winds. Pākaʻa then passes on this knowledge to his son, Kūapākaʻa, and a key moment of the story is when Kūapākaʻa chants to impress the chief Keawenuiaʻumi, naming winds from Hawaiʻi island to the tiny island of Kaʻula, out past Kauaʻi. (A calabash named the Wind Gourd of Laʻamaomao is in the Bishop Museum.)

There were over 300 names for the different winds and breezes that blow near and over the islands. These names are important because they reflect our ancestors' emphasis on keen observations and their deep knowledge of the local topography, for the wind names describe their nature and often convey natural and cultural information specific to the place. People shared knowledge about weather in more than 100 Hawaiian language newspapers published between 1834 and 1948 (http://seagrant.soest.hawaii.edu/hawaiian-language-newspaper-translation-project).

Articles reveal the names of local winds often provide information on characteristics, direction, origin, force, and timing. The keen observations of ancestors recognized the wind-rain relationship in naming a wind of Hilo the *ʻAlahonua kiʻi ua*, the "fragrant earth wind that fetches the rain" (Nogelmeier, 2007). Navigation close to Hawaiʻi Island is affected by the wind from the mountains, the Mumuku, while the Hoʻolua wind comes from the shore. An article in *Ke Koo o Hawaii*, 29 August 1883 (attached below) tells of the *Kulaʻipau*, a strong wind of Kona that has capsized the ship ʻIwalani. The name *Kulaʻipau* is a warning—it means to completely knock over. The wind between Lahaina and Molokaʻi is called the Kaomi. If this wind is strong, then a great deal of rain is expected in Kāʻanapali. The Kona wind originating in Kona storms, a cold upper level storm that develops around Hawaiʻi during Hoʻoilo, the winter season, is mentioned many times throughout Hawaiʻi nei.

An excerpt from an article describing an unusually windy night in Kona, Hawaiʻi not only gives insight into the culturally embedded traditions of Kūapākaʻa, son of Pākaʻa, but also compares the windy weather conditions of Hilo to calm Kona. The writer hypothesizes the wind may have come from Hilo, referring to the tradition of kite flying in Hilo made possible by its consistent winds. The article (attached below) is entitled "*Hele Uluulu Ka Makani* (The Wind Blew Violently)" (*Ka Nupepa Kuokoa*, 18 December 1869).

> [T]he wind blew extremely violently, shaking things, and our sleep was startled by the terrible blowing of this great wind. We are used to a pleasant sleep at night in our land embraced by calm, so where did this despicable one come from to startle our sleep? Perhaps from Hilo, since that is a windy land where the children fly kites, or perhaps Kūapākaʻa has come with his wind gourd.

In a series of articles related to the story of the wind gourd, Pākaʻa tells his son Kūapākaʻa to call the winds. He calls the winds of Hawaiʻi Island, one of which is the Uahiapele wind of Kīlauea, literally the smoke of Pele. This name is very fitting, for it dwells in Kīlauea, the famous home of Pele. He also calls the Nāulu sea breeze of Kawaihae, interpreted as "sudden shower." In another article, Kūapakaʻa calls the wind of Puna the Moaniʻala, meaning the light, fragrant wind. The name reveals the connection of local wind names to local plants as Puna is often referred to in songs and chants as *Puna paia ʻala i ka hala* [Puna, the forest bower fragrant with pandanus].

We see descriptive wind names of Kauaʻi in an article (attached below) by S. K. Kuapuʻu (1902). The area of Manenene on Kauaʻi has the *Onehali* wind, the "carried sands" wind. The recognition of the wind-rain relationship is seen in the name of Wailua's *Waiʻōpua* wind, the "water-bearing cumulus cloud" wind. *Hiʻiakaikapoliopele* (Nogelmeier, 2007) tells of Līhuʻe's Pāhola wind, *ke kiu holo kiʻi makani lele kula o Līhuʻe* the scout that fetches the winds sweeping the Līhuʻe plains. The word Pāhola itself means "to extend; to spread about."

Hawaiʻi's Sea-Land Breezes

The contrast between the ocean and the island temperatures drives sea-land breeze circulations on each of the Hawaiian Islands (Fig. 1). Sea and land breezes exist due to the difference in temperature over land and sea during the day and night. During the day the land heats up more rapidly than the sea, so for the same altitude the temperature over land will be warmer than over the sea. Because air that is warm relative to its surroundings rises, this generates a difference in the pressure between the air over the land and the sea, specifically, with lower pressure over the land and higher pressure over the sea. Therefore, the rising warm air is replaced by cool moist air from over the sea. The influx of air from the sea is called a sea breeze, and it often produces clouds and showers over the mountains.

During the night, especially when there are no clouds, both the land and ocean radiate heat to space, but the land loses its heat much faster than the sea because water has such a high heat capacity (ability to store heat in a given mass of substance) and wind driven motions in the water mix warmer water up from just below the surface. Therefore, the land cools faster than the sea.

Pretty soon the relatively warmer air over the ocean begins to rise. Air that is cooled over the land flows downslope toward the ocean to form a land breeze.

The strength of the sea-land breezes varies from island to island, depending on the height of the island's mountains and the overall size of the islands, and the strength of the large-scale winds. The taller volcanoes on Maui and the island of Hawaiʻi block the large-scale flow, allowing heat to build up on the leeward sides even when the large scale winds are moderately strong and thus increasing the strength of the daily sea breeze over the lee slopes of these islands (Figs. 2 and 3). Conversely, the taller mountains also produce cooler air at altitude and a stronger land breeze at night. Note the flow splitting in Figs. 2 and 3. The smaller islands such as Kauaʻi and Oʻahu have lower mountains that do not block the flow. Therefore, these islands only experience well-developed sea-land breezes under lighter large-scale winds conditions.

If you study the winds at Keāhole Airport, you find there is a daily cycle in wind direction (http://www.weather.gov/data/obhistory/PHKO.html) that includes all compass directions! The winds at Keāhole Airport are characteristic for winds in general along the leeward side of the island. The forecast winds for the Island of Hawaiʻi can be viewed at http://weather.hawaii.edu/. Click on the lower right thumbnail to access WRF model output. Then change field to surface winds and domain to Big Island to get a detailed view the impact of the large volcanoes on the flow and the diurnal sea-land breeze cycle across the island.

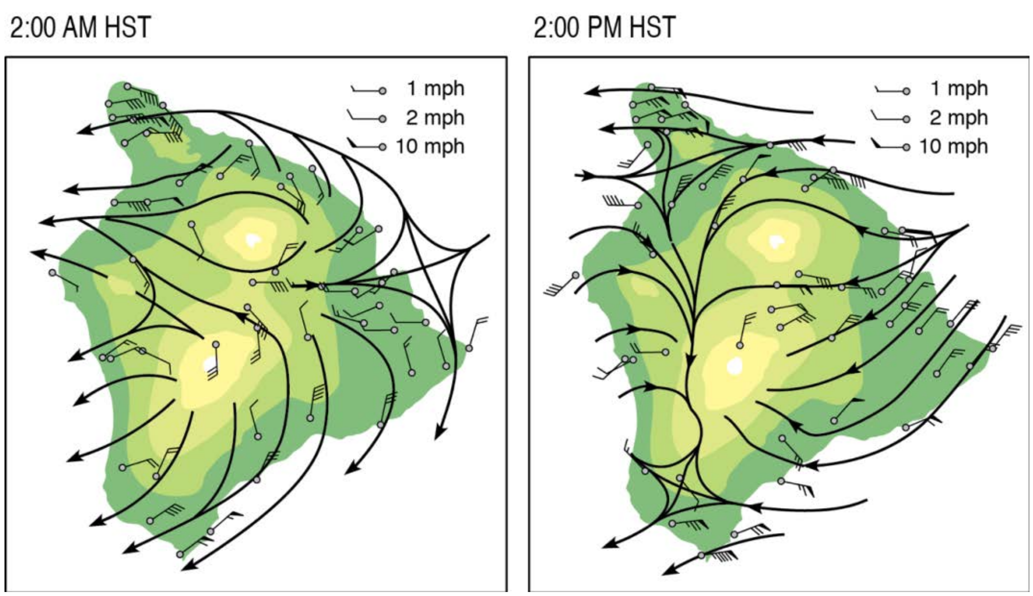

Figure 2 Island of Hawaiʻi with color shading indicating elevation (colors change every 3000 ft) and average winds (mph) during a six-week period during July and August 1990.

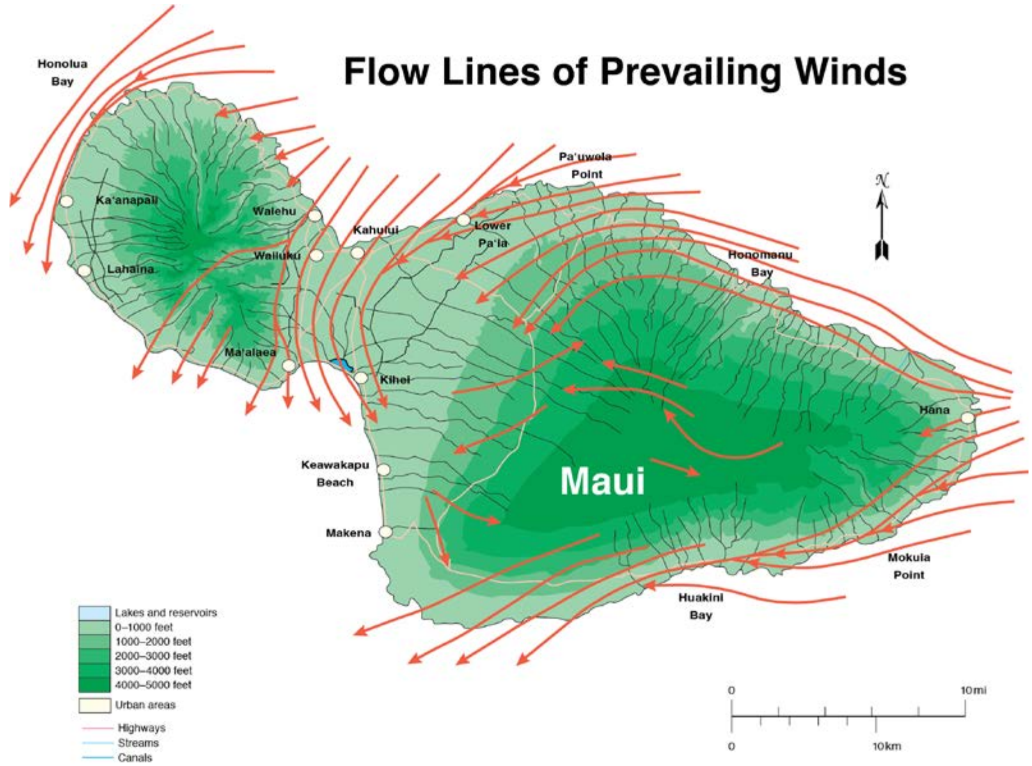

Figure 3 Stream or flow lines (red lines) are drawn everywhere parallel to the local wind direction and show the impact of the mountains on the flow during the afternoon on a typical trade-wind day.

Several Hawaiian newspaper articles mention the channel between Moloka‘i and Lahaina, Maui. The channels between the Hawaiian Islands are sometimes dangerous for navigating. This is because the trade winds are funneled through the narrow area between two islands causing the pressure gradient to increase between the entrance and exit of the channel, which in turn causes the wind speed to increase. The waves generated by these higher winds can interact with ambient swells, particularly those coming up from the south, to produce very steep standing waves. This is the reason why many boating accidents occur in the island channels.

Moloka‘i is considered by Hawaiians to be the island of the winds. This is partly due to the fact that the mountains play a less important role in affecting winds here than on the other islands. The winds can pass easily over the lowest parts of this island without having to split or even rise very far. The western half of Moloka‘i is dry because it lacks orographic rainfall, rainfall that occurs when moist air is forced to rise over mountains, cooling and therefore condensing and precipitating (See Fig. 4). The forced ascent by terrain is the reason why the windward sides of all the Hawaiian Islands are lush and green with vegetation in the satellite view in Fig. 4. Conversely, air that has already lost much moisture becomes even drier as it descends and warms along the lee slopes, thus the lee areas of all the islands are relatively dry. The exception is the Kona coast of the Island of Hawai‘i where the trade winds are blocked by Mauna Loa, and a well-developed (and almost daily) sea breeze brings clouds and rainfall upslope there (see Figs. 4 and 5).

Figure 4 NASA true-color satellite image of the Hawaiian Islands showing the influence of the mountains on rainfall and vegetation.

Another location that is often referenced is Hāna, on the windward side of the Maui at its eastern end. There is a headland at this point that causes the winds to split, swirl around and break in many directions (see Fig. 3). This is the major reason why the prevailing trades have so many different names according to speed and direction at Hāna in the newspaper references, such as an article published in *Ke Au Okoa* on 12 June 1865 (attached below). Being on the windward side of Maui, Hāna also receives copious rainfall (Fig. 5).

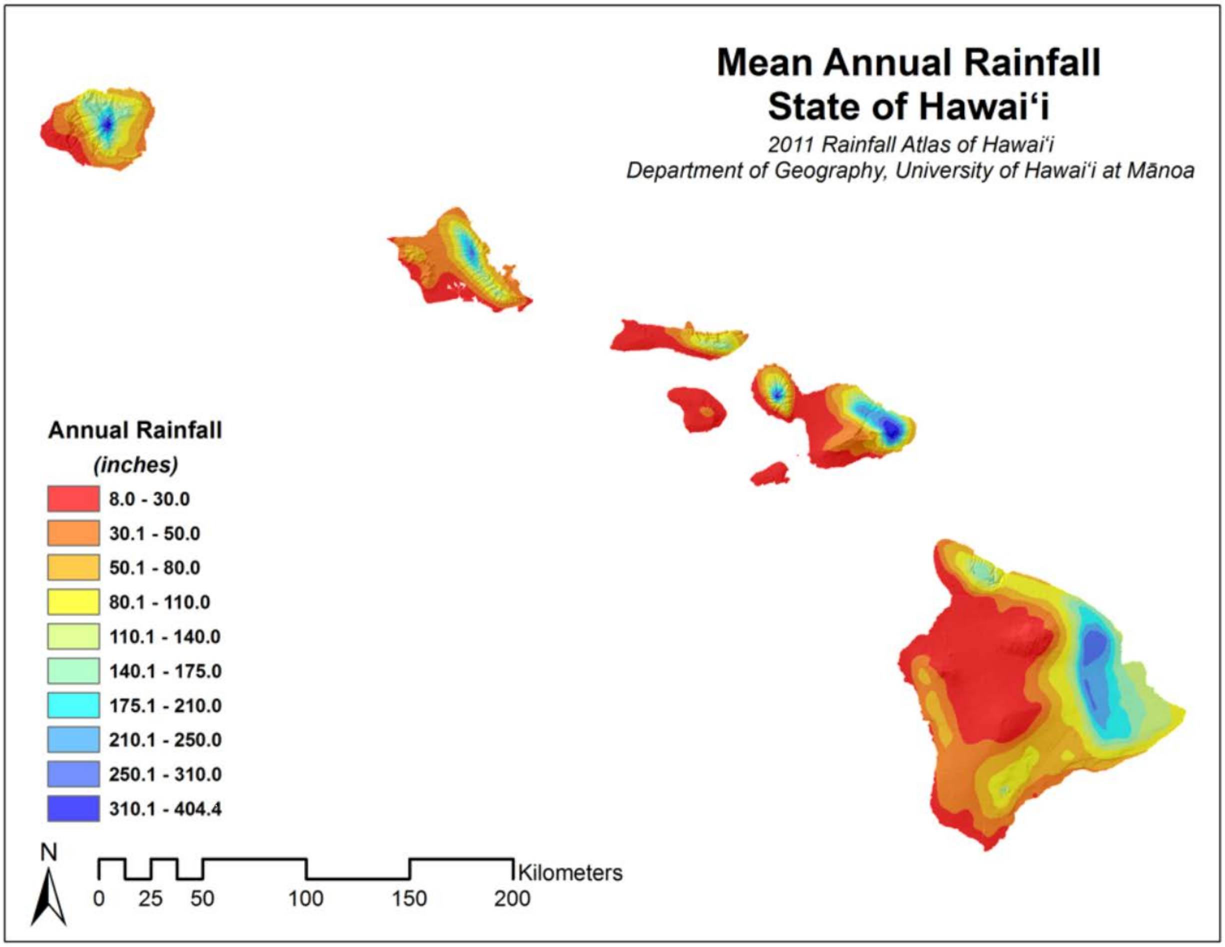

Figure 5 Mean annual rainfall map of the State of Hawai‘i

Instructional Activities:

1. **Engage**:

- Hawai‘i has over 300 named winds. Why do you think there are so many?
- Where have you experienced strong winds in Hawai‘i? What do think causes them?
- It is common in Hawai‘i, but not elsewhere, to say windward and leeward when giving directions. To a long-time resident, what information about winds, rains, and vegetation is included in these simple words?
- Share a story you know about local winds or rain.

2. **Explore:**

- Draw a sea-land breeze system. When does the sea breeze occur? When does the land breeze occur?
- Which sides of the islands are more likely to have sea land breezes? Why?
- What physical mechanism generates a sea-land breeze system?
- Why are the windward areas of most of our islands greener than the leeward areas?

3. **Explain:**

- Explain why channels between islands may be hazardous for navigation.
- Choose one of the winds described in this lesson then explain the science conveyed in its Hawaiian name.
- How do local winds affect rainfall and vegetation on windward and leeward areas?
- What is orographic rain? Can you identify a place where and why we can see it almost every day?
- Do one of the “Hands on Science” activities and explain how it relates to winds or rain.
- Why is it important to know and name the winds for a navigator? a farmer? a fisherman?

4. **Elaborate/Extend:**

- Research at least one wind on your island and explain its pattern and its origin. If the name is unknown, what would you name it?
- Design a project to investigate the winds and rains where you live.
- How can we take the knowledge that we gained about specific winds in our area and use this to utilize and maximize wind-powered energy?

5. **Evaluate:**

- Can students explain the relationship between local winds, rainfall, and orography?
- Can they explain why some areas around the islands are easier to navigate than others?
- Can students explain why Kona and Hilo have such different winds?

Hands on Science

In this section we will explore key concepts through experiments that will help us understand the science in more depth.

Winds

Wind is the word we use to describe horizontal movement of air. Whenever we want to speak about vertical movement of air we say *updraft* when the air is moving up, and *downdraft* when the air is moving down. Wind exerts a force and just like any other force it has intensity and direction. These two quantities describe the wind itself at any given point and time. We use an anemometer to measure wind intensity, and a wind vane to detect which direction the wind is blowing from. Winds are usually described by the direction they are blowing *from*, not by the direction they are blowing to.

In physical terms, winds are the balance between different forces in the atmosphere. There are five different forces active in the atmosphere, pressure gradient, centrifugal force, Coriolis force, gravitational force and frictional force. The balance between these five forces generates a wind vector for that precise location and time. So for each time, there is a balance of all the forces.

Let's begin by investigating local winds with two simple instruments that indicate direction and wind speed.

Lab 1: Measuring Wind Speed and Direction

HCPS III Std. 1 Scientific Inquiry, **SC.8.1.1**, **SC.8.1.2**

Let's go outside with a compass and a hand held anemometer and record wind direction and speed. Then compare your observation with those collected at the same time by the National Weather Service (see http://www.prh.noaa.gov/hnl/pages/obs.php).

Location and Time	Wind Speed	Wind Direction

Plot the winds on a map of your island and see how the mountains affected your results. Repeat this exercise at school and at home several times during the day. Does a pattern emerge to the local winds and does that pattern change with time of day?

Lab 2: Surface Heating (Land Sea Breezes)

HCPS III Std. 1 Scientific Inquiry, **SC.8.1.1**, **SC.8.1.2**
HCPS III Standard 2: The Scientific Process, SC.8.2.2
HCPS III Std. 8 Earth & Space Science, SC.8.8.4, SC.8.8.6

We've all walked across hot black top in a parking lot with our bare feet in the summer. Similarly, it is cooler to wear a white shirt in the hot sun than a black one. Why is this so and what affect does it have on the world around you?

The darker a surface is, the more light it absorbs and the faster it heats up. Conversely, a surface appears light when it has a relatively high reflectivity (albedo) for visible light. The relative ability of different surfaces to absorb light is referred to as absorptivity. The higher a surface's absorptivity the more light it absorbs and is converted to heat. A perfectly black surface absorbs 100 percent of the light that strikes it (albedo = 0). A perfectly white surface reflects 100 percent of the light that strikes it (albedo = 1).

The air above a warm surface is heated as the surface absorbs increasing amounts of light. As the air heats, it becomes less dense and rises. A *convection current* forms as cooler air replaces the warmer air and then is subsequently heated as well. This convective motion contributes to the formation of winds.

When adjacent air over the ocean remains much cooler than that over the land, the warm air rises over the land and it is replaced by cooler air from over the ocean. The resulting circulation is referred to as a sea breeze. The temperature contrast from sea to land can be large due the fact that the ocean has a much larger specific heat than the land, and sunlight is absorbed through a greater depth of water. The opposite of a sea-breeze circulation often develops at night when the land cools more quickly than the ocean, and the resultant wind blowing off shore is called a *land breeze*.

OBJECTIVE: The objective of this activity is to investigate the phenomena of differential heating of surfaces.

MATERIALS:
§ reflector lamp with 100-Watt bulb
§ 2 black cups
§ 1 white cup
§ two insulated lids with slits
§ two thermometers
§ ruler or meter stick
§ sand
§ water
§ piece of glass or Plexiglas

PROCEDURE:

1. Slide the thermometers through the slits in the insulated lids so that the bulb of each will be about half way down in the cups.
2. Place the lids on the cups and put the cups side by side, about 10 cm from the lamp as shown in Fig. 6.

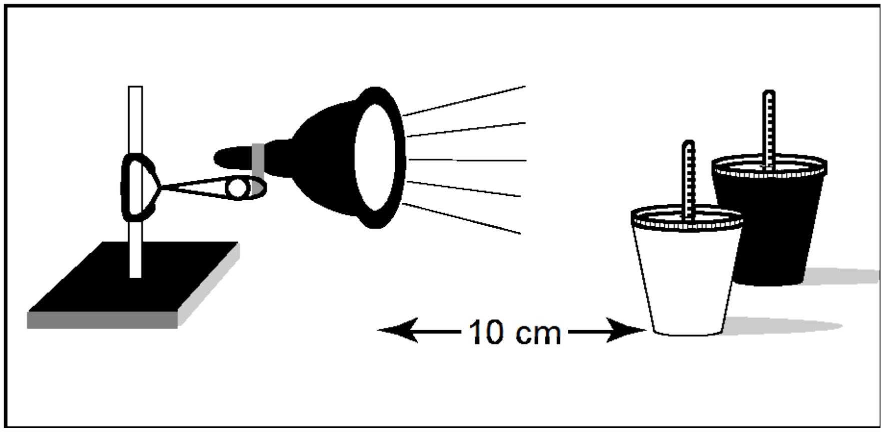

Figure 6: Schematic diagram

3. Record the initial temperature of each cup in the Data Table. In the space below predict what will happen to the temperature in each cup when the light is turned on, and explain your prediction. *Will there be any differences between the cups?*
4. Turn on the light and record the temperatures every two minutes for ten minutes.
5. Table 1. Record your results in Table 1 below and graph your results on graph paper.
6. Table 2: Place a piece of glass between the light source and the thermometers and repeat steps 3, 4, and 5. If there are any differences in the rate of temperature change with the glass inserted explain briefly below.
7. Table 3: Fill one black cup with dry sand and the other black cup with wet sand. Repeat steps 1 through 4 above. In the space below predict *any differences between the cups* when the light is turned on, and explain your prediction.

TABLE 1. AIR ONLY

	TEMPERATURE (˚ F) vs TIME (MINUTES)					
	0	**2**	**4**	**6**	**8**	**10**
BLACK						
WHITE						

TABLE 2. GLASS BETWEEN CUPS AND LIGHT

	TEMPERATURE (˚ F) vs TIME (MINUTES)					
	0	**2**	**4**	**6**	**8**	**10**
BLACK						
WHITE						

TABLE 3. BLACK CUPS WITH DRY OR WET SAND

	TEMPERATURE (˚ F) vs TIME (MINUTES)					
	0	**2**	**4**	**6**	**8**	**10**
DRY SAND						
WET SAND						

QUESTIONS:

1. What happened to the temperature measured in the two cups as variables changed? Were your predictions correct?

2. How, if at all, would the results differ if a silver cup is used instead of a white one?

3. Predict how temperature would change if you left the cups under the light for a longer time.

4. A glider is an airplane with no engine. To stay aloft, glider pilots sometimes look for fields that have been recently plowed. Explain why based on your results above.

5. How can you relate this experiment to land-sea breezes?

6. Why do you expect land to heat up faster than the ocean?

7. Sea land breezes are only noted at certain locations of Hawai‘i. Explain what causes this.

Lab 3: Recycled Water-The Hydrologic Cycle

HCPS III Std. 1 Scientific Inquiry, **SC.8.1.1**, **SC.8.1.2**
HCPS III Std. 8 Earth & Space Science, SC.ES.8.1, SC.8.8.4

In considering the hydrology of the Earth, remember that the oceans cover about 70% of the Earth's surface and that they represent more than 97% of the Earth's water. Another 2.2% is locked up in ice caps and glaciers. As global temperatures increase or decrease, the quantity of land-held ice decreases (by melting) or increases (by precipitation), resulting in important changes of sea level. The atmosphere contains only 0.001% of the planet's water, but this water crucially affects the lives of people, animals, and plants.

In this activity, a distillation apparatus is used to model the hydrologic cycle. Keep in mind the distinctions between the distillation model and the hydrologic cycle as it occurs in nature.

Reading: Water of Kāne (pp. 30-31)

OBJECTIVE: The objective of this activity is to investigate the hydrologic cycle.

MATERIALS:
§ clear plastic shoebox with lid
§ small plastic cup
§ Baggie filled with sand or soil
§ water
§ ice
§ lamp with reflector

PROCEDURE:
1. Set up the apparatus shown in Fig. 7.
2. Cut a hole in one corner of the lid of the shoebox, just large enough for the cup to fit halfway through the lid.
3. Add enough water to cover the bottom of the clear shoebox, a depth of about one inch.
4. Position the sandbag at one end of the box, directly under the opening of the cup.
5. Fill the small plastic cup with ice and place it in the opening of the lid.
6. Position a gooseneck lamp so that its light is shining onto the water inside the box.
7. Periodically check the set-up to observe the progression of events. Record your observation over the course of the class and diagram the movement of the water through the set-up.

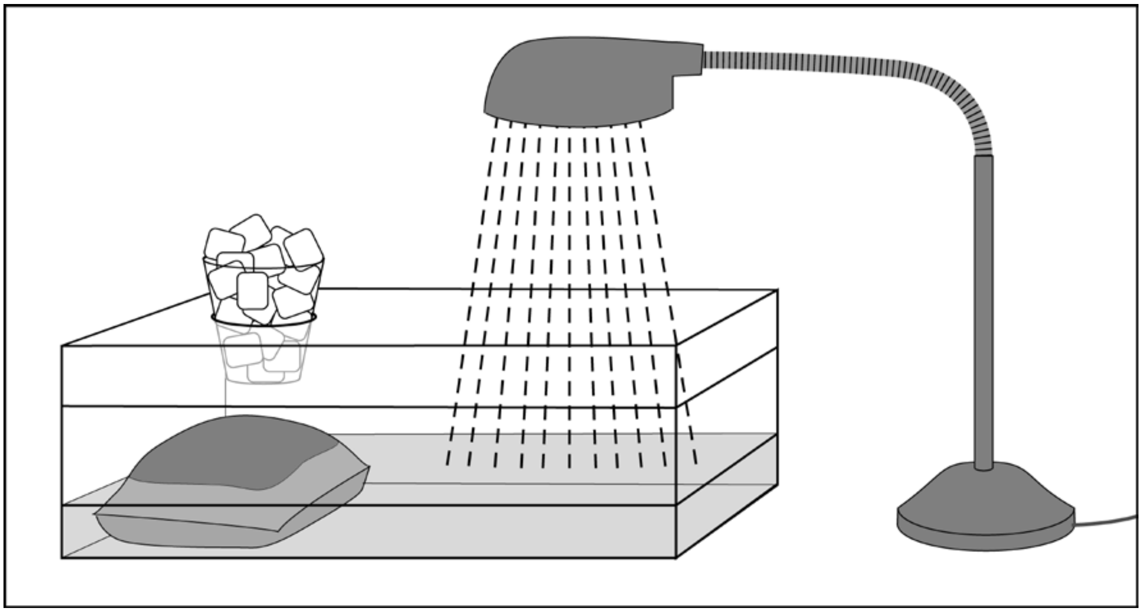

Figure 7 Schematic diagram

QUESTIONS:

1. Where in this activity does evaporation occur? Condensation?

2. What causes water droplets to form on the outside of the cup that is in the shoebox?

3. Where in the Earth's hydrologic cycle does evaporation occur? Condensation?

4. From what you observed in this activity, what are the key processes in the hydrologic cycle?

5. Was water lost from the system in any part of this activity? If so, where?

Lab 4: Formation of Clouds

HCPS III Std. 1 Scientific Inquiry, **SC.8.1.1**, **SC.8.1.2**
HCPS III Std. 8 Earth & Space Science, SC.ES.8.1, SC.8.8.4

There are three conditions in the atmosphere that are met before a cloud forms. First, there must be sufficient moisture in the air. Secondly, the air must cool so that it becomes saturated and condensation can occur. And finally, there must be some type of particulate or condensation nuclei suspended in the air such as dust, smoke, or pollen for the excess water to condense on.

OBJECTIVE: The purpose of this experiment is to investigate the conditions which must be present in order for clouds to form.

MATERIALS:
§ 32-oz. clear glass jar with lid
§ ice cubes or crushed ice
§ hot water
§ matches
§ can of aerosol spray (air freshener is best)
§ black construction paper
§ safety goggles
§ flashlight (optional)

PROCEDURE:

1. Fill the jar with hot water.
2. Pour out the hot water leaving only ~2 cm of water in the bottom of the jar. Place the jar in front of the upright construction paper.
3. Turn the lid of the jar upside down and fill it with ice. Place the lid on the jar as shown in Fig. 8. Observe the jar for three minutes. Darken the room and shine the flashlight on the jar as you make your observations. Record your observations in the Data Table.
4. Pour the water out of the jar and repeat steps 1 and 2.
5. Move all loose papers away from the jar. Wearing your safety goggles, strike a match and drop the burning match into the jar.
6. Immediately cover the mouth of the jar with the lid full of ice as you did in step 3 and observe what happens for three minutes. Record your observations in the Data Table.
7. Pour out the water and repeat steps 1 and 2.
8. Spray a very small amount of aerosol in the jar and immediately cover the mouth of the jar with the ice-filled lid. Observe for three minutes and record the observations in the Data Table.

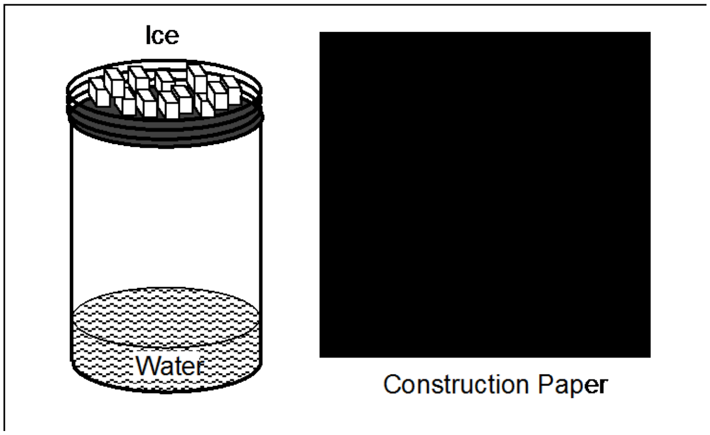

Figure 8 Schematic diagram

Data Table

TRIAL	OBSERVATIONS
No match or aerosol	
Match	
Aerosol	

QUESTIONS:

1. Comment on the differences on your observations, and the reasons for these differences.

2. If a layer of sand were on the bottom of the jar instead of water, would a cloud form? Why or why not?

3. What would have happened if cold water had been used instead of hot water? Why?

4. Describe any motion observed inside the jar. Explain your observation.

Lab 5. Rain Makers (Orographic Rain)

HCPS III Std. 8 Earth & Space Science, SC.ES.8.7

As discussed in the introduction, the mountains of Hawaiʻi have a profound impact on the weather, both on the wind field and on the climatology of cloud and precipitation. As moist air is forced upslope, it condenses and first forms clouds, and then rain. The direction of the flow at large scales interacts with the topography to produce gradients in cloud and rainfall, that in turn help define the local climate; e.g., wet windward and dry leeward slopes. The height of the mountains and the strength of the flow determine if the flow can pass over the top of the mountain or if the flow is force to split and go around the mountain (see Figs. 2 and 3).

Reading: Water of Kāne (pp. 30-31)

OBJECTIVE: The goal of this activity is to learn about the impact of mountainous terrain on the climatological distribution of wind and rainfall by analyzing wind and rainfall data collected during an extended field experiment called the Hawaiian Rainband Project (HaRP). You will also learn about orographic lifting and discover the relationship between rainfall amounts and islands terrain.

MATERIALS: Two maps are provided with contours for elevation plotted every 3000 ft and wind data plotted in knots (kt) per hour (Fig. 9), and rainfall data in mm (Fig. 10). (1 knot, or nautical mile, is 1.15 mile per hour.)

PROCEDURE:

1. Draw streamlines on Fig. 9. Streamlines are everywhere parallel to the instantaneous wind direction. Unlike contours, streamlines have no numerical value and can join other streamlines and even cross each other at **col or saddle points** in the wind field.
2. Label the leeward and windward sides of the island.
3. On Fig. 3 draw *isohyets* (contours of equal rainfall) every 20 mm (i.e. 20, 40,...160).
4. Label all your isohyets and label the areas of maximum and minimum rainfall with a large ‘MAX’ or ‘MIN’.

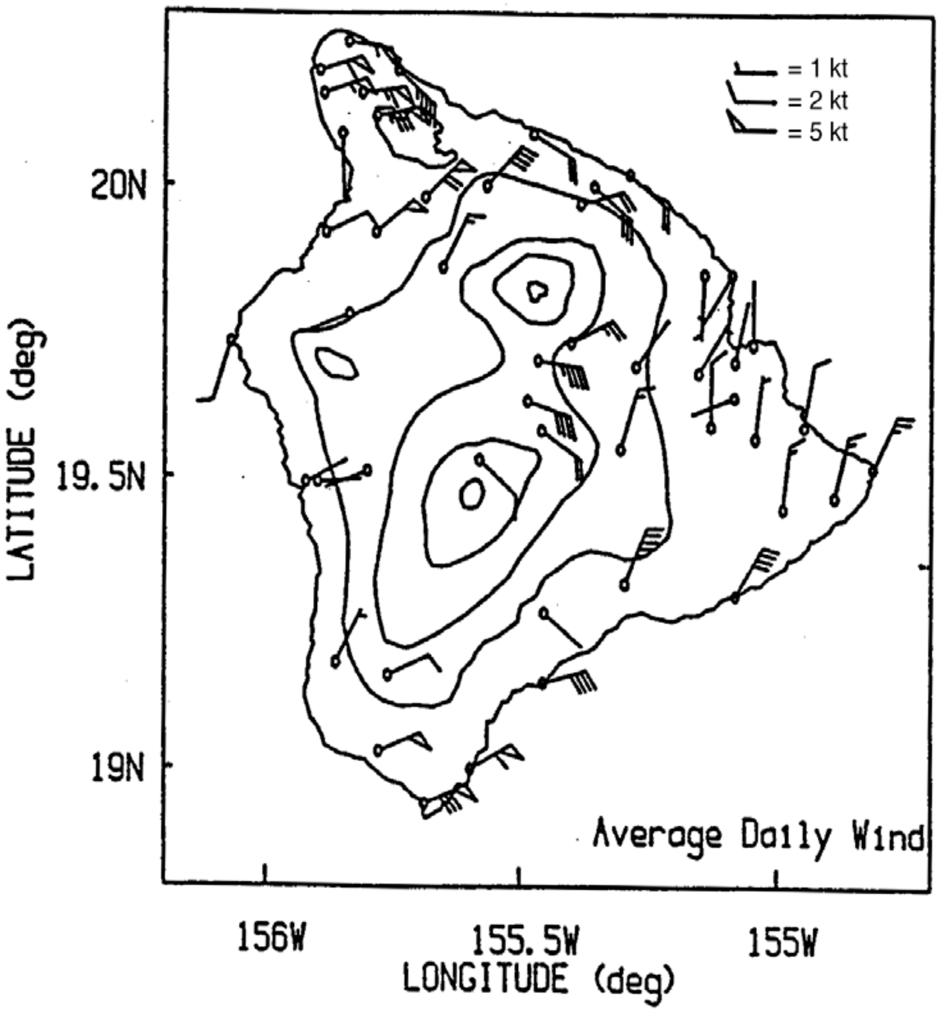

Figure 9 Island of Hawai'i with contours for elevation plotted every 3000 ft. and average winds (kt = knot) during a six-week period during July and August 1990.

QUESTIONS (pertaining to Fig. 9):

1. Do your streamlines indicate flow splitting is taking place? If it is, explain why?

2. Where on average is the wind speed the greatest? Why?

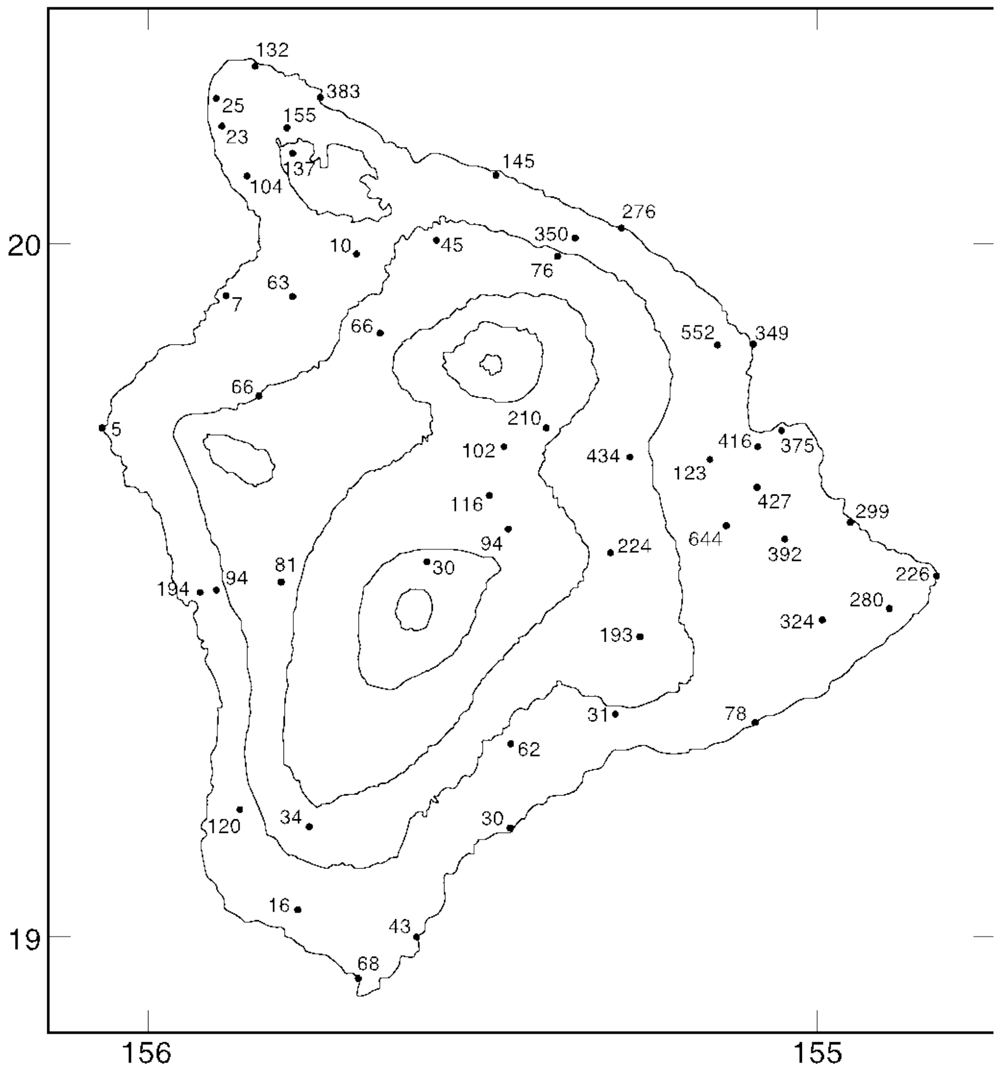

Figure 10 Island of Hawai‘i with contours for elevation plotted every 3000 ft. and average rainfall (mm) during a six-week period during July and August 1990.

QUESTIONS (pertaining to Fig. 10):

1. Did you find the minimum rainfall where you expected to? What about the maximum rainfall? Explain.

2. Why are there no maxima in rainfall at the summits of Mauna Kea and Mauna Loa?

3. Identify the wettest regions. Identify the driest. Relate Kona’s rainfall to Hilo’s rainfall. Please mention everything you know.

Summary of Local Winds and Rains of Hawaiʻi: *I Kamaʻāina I Nā Makani A Me Nā Ua*

After completing this lesson it should be easier to understand the interaction of the winds and the mountains to create the weather we experience in Hawaiʻi. You can now understand why the local winds are important to Hawaiʻi, not only for agriculture, but also for navigation. Navigators had to know more than the general circulation (Hadley Cell) and the prevailing trade winds that are the surface branch of the Hadley Cell because many local wind patterns develop, some of which can be hazardous to sailing. In areas where the trades are blocked then the local diurnal circulation becomes the dominant wind pattern.

In recognizing and utilizing these winds, their names and nature, we are perpetuating the great legacy that was left by our ancestors. In these articles and excerpts from the epic of *Hiʻiakaikapoliopele*, these winds are recognized because they have a unique nature and help describe the places in which they reside. A reference to a wind could also be a reference to that particular place. Or perhaps a wind was especially cold, strong or abrupt; one may be referring to this quality that is also exemplified in us as people. Therefore, let us follow in the footsteps of those before us and recognize and learn about the many winds here in Hawaiʻi.

We hope you have enjoyed this lesson, and are inspired to know and teach more about our islands' weather phenomena and features.

Article 1: *Home Rula Repubalika.* 15 March 1902, pg. 1

I ko Laamaomao manawa e ola ana, ua kaulana oia no ka hoolohe o na makani iaia, a hiki iaia ke kahea aku i na inoa, a i kona make ana, ua hooili oia i ka mana kahea makani i kana keiki.

E ka mea heluhelu, eia keia mau helu eono o ka hae, nolaila, ke hoopokole nei au a mahope aku, aka, e hai e aku nae au ia oukou i kekahi mau makani i kaheaia e Kuapakaa, oia hoi ka Pakaa keiki ana i moe ai me ke alii o Molokai, a ua a'o aku o Pakaa iaia i na hana a pau ana i imi ai no Keawenuiaumi, a ua ike mua no hoi kakou ma ka Hokuloa i na makani o Hawaii. Nolaila, ke hai aku nei au i ko Kauai mau makani a me Niihau, na inoa a me ko lakou mau wahi, penei:

"A-la i ka nana mai e oe,
Ka' makani a Laamaomao,
Ka'u i waiho aku——
Ke uwalo 'la i ke kini i ka pae mauna,
He ao hoailona makahi puaa,
He makani hono ia no Kapaa,
Aia ka makani la i Kauai,
He Moae ko Lehua,
He Mikioi ko Kawaihoa,
He Naulu ko Niihau,
He Naulu ko Kaulakahi,
He Lawakua ko na Pali,
He Lanikuuwa ko Kalalau,
He Lauae ko Honopu,
He Aikoo ko Nualolo,
He Makani Kaehukai ko Milolii,
He Pukapele ko Mana,
He Moeahua ko Kekaha,
He Waipao ko Waimea,
He Kapaahoa ko Kahana,
He Maka'upili ko Peapea,
He Aoao ko Hanapepe,
He Unulau ko Wahiawa,
He Kiu Anu ko Kalaheo,
He Ae hoi ko Lawai,
He Malanai ko Koloa,
He Kuiamanini ko Weliweli,
He Makahuena ko Kapaa,
He Onehali ko Manenene,
He Koomakani ko Mahaulepu,
He Puapua ko Kipu,
He Alaoli ko Hulaia,
He Waikai ko Kalapaki,
He Kaao ko Hanamaulu,
He Waikua-aala ka Makanikulai
Hale no Konolea,
He Waiopua ko Wailau,
He Waiolohia ko Nahanahanai,
He Inuwai ko Waipouli,
He Hooluamakani ko Makaiwa,
He Kehau ko Ka-Paa,
He Malamalamaiki ko Kealia,
He Makanihulilua ko Hanaikawao,
He Amu ko Anehola,
He Kololio ko Moloaa,
He Kiuinuwai ko Koolau lele ma
waho,
He Maheu ko Kalihiwai,
He Nau ko Kalihikai,
...
Pae ae la aia i uka—e pae he ino,
I nehinei ka la malie,
I holo ia mai ina ua pae.

O keia ae la na inoa a ua keiki 'la i kahea ai, a o ua inoa io no ia a hiki i keia wa i ko laila poe keiki papa, ua like pu no. Nolaila, ma ka Helu 2 o keia moolelo, e hoomakaia ke kaao i ka hoowahawaha ana o Keawenuiaumi i kana kauwa.

—*Na S. K. Kuapuu.*

(Aole i pau.)

Article 1 Translation: *Home Rula Repubalika.* 15 March 1902, pg. 1

When Laʻamaomao was living, she was famous because the winds obeyed her, and she could call their names. When she died, her child inherited the power to call the winds.

O reader, here are these six issues from the newspaper *Ka Hae*, so I am shortening this for later. However, I will tell all of you some of the winds that were called by Kūapākaʻa, the child of Pākaʻa from his union with a Molokaʻi chiefess. Pākaʻa taught him all the duties that he sought out on behalf Keawenuiaʻumi, and we already saw the winds of Hawaiʻi in the newspaper *Ka Hokuloa*. So I recite to you the winds of Kauaʻi and Niʻihau, their names and the places in which they reside, as follows:

"Awaken and take heed, O you,
The wind of Laʻamaomao,
The secret observer of Koʻolau, woman of Kauaʻi,
This is what I have to present before you—
I call out to the multitude on the row of mountains,
Clouds of omen, pressing a bank of clouds,
There is a bad-smelling wind at Kapaʻa,
The wind is at Kauaʻi,
Lehua has a Moaʻe wind,
Kawaihoa has a Mikiʻoi wind,
Niʻihau has a Nāulu wind,
Kaʻulakahi has a Nāulu wind,
Nāpali has a Lawakua wind,
Kalalau has a Lanikuʻua wind,
Honopū has a Lauaʻe wind,
Nuʻalolo has an ʻAikoʻo wind,
Miloliʻi has a Makani Kaʻehukai wind,
Mānā has a Puʻukapele wind,
Kekaha has a Moeāhua wind,
Waimea has a Waipao wind,
Kahana has a Kapaʻahoa wind,
Peʻapeʻa has a Makaʻupili wind,
Hanapēpē has an ʻAoʻao wind
Wahiawā has an Unulau wind,
Kalāheo has a Kiu Anu wind,
Lāwaʻi has an Aʻe wind,
Kōloa has a Malanai wind,
Weliweli has a Kuiamanini wind,
Kapaʻa has a Makahūʻena wind,
Manenene has an Onehali wind,
Māhāʻulepū has a Koʻomakani wind,
Kīpū has a Puapua wind,
Hulāʻia has an Alaʻoli wind,

Kalapakī has a Waikai wind,
Hanamāʻulu has a Kāʻao wind
Waikuaʻaʻala is the house-tumbling wind from Konolea,
Wailua has a Waiʻōpua wind,
Nāhanahanai has a Waiolohia wind,
Waipouli has an Inuwai wind,
Makaīwa has a Hoʻoluamakani wind,
Kapaʻa has a Kēhau wind,
Keālia has a Mālamalamaiki wind,
Hanaikawao has a Makanihulilua wind,
Anahola has an Amu wind,
Moloaʻa has a Kololio wind,
Koʻolau has a Kiuinuwai wind that flies beyond,
Kalihiwai has a Maheu wind,
Kalihikai has a Nau wind,
Hanalei has a Luha wind,
Waiʻoli has a Waiamau wind,
Waipā has a Kuʻunahele wind,
Lumahaʻi has a Haukoloa wind,
Wainiha has a Lūpua wind,
Naue has a Pahelehala wind,
Hāʻena has a Limahuli wind,
The Kawaikūʻauhoe waters on the cliff,
The tip of that wind,
It grasps like a whirlwind and then rushes out to sea,
When it comes ashore, it will come as a storm,
Yesterday was calm,
To be overrun, should it come ashore."

These are the names that this child called, and they are indeed the true names to this day. According to the natives of those places, the names are the same. So, in the second volume of this story, the legend starts with Keawenuiaʻumi reviling his servant.

—By S. K. Kuapuʻu.

(To be continued.)

Article 2: *Ka Nupepa Kuokoa*. 18 December 1869, pg. 3

HELE ULUULU KA MAKANI.—Ke i mai nei ko makou hoa oiaio G. W. P. o "Kona kai opua i ka lai;" a penei kana: "Ma ka wanaao o keia kakahiaka Poalua, Dekemaba 7, hele uluulu loa ka makani e hoonaueue ai, a puiwa ana ko makou hiamoe i ka hele ino a keia makani nui. Ua maa no makou i ka moe lea o ka po i ko makou aina a ka lai i hoohihi ai; a mai hea mai la keia haukae o ka hele ana mai, a hoopuiwa i ko makou hiamoe? Ma'ia paha mai Hilo mai, oiai he aina makani ia wahi a kamalii hoolele lupe; a i ole ia, ua hiki mai nei paha o Kuapakaa me ka hokeo makani ana."

Article 2 Translation: *Ka Nupepa Kuokoa*. 18 December 1869, pg. 3

THE WIND BLEW VIOLENTLY—Our true friend G. W. P. of "Kona of the calm seas that mirror the cumulus clouds " writes in, and here is what he says: "At dawn this morning, Tuesday, December 7, the wind blew extremely violently, shaking things, and our sleep was startled by the terrible blowing of this great wind. We are used to a pleasant sleep at night in our land embraced by calm, so where did this despicable one come from to startle our sleep? Perhaps from Hilo, since that is a windy land where the children fly kites, or perhaps Kūapāka‘a has come with his wind gourd."

Article 3: *Ke Au Okoa*. 12 June 1865, pg. 4

Na inoa o na makani o Hana.

Eia malalo nei na inoa o na makani o Hana, Maui Hikina, e hoike ana i ko lakou nui, a me ka lakou mau hana. Oia hoi kahi a'u i hookamaaina iho ai ia'u iho mai ko'u wa i hanau ai a loaa mai ia'u na makahiki he 10. A he mau la opiopio no keia a'u e noho nei, aka, aole au e kuhe a kanalua no ka hai aku i keia mau makani. Ua ike no au, o na makani mau no ia o keia mau pali kahakai.

He Kaomi. He makani mau a he makani kamaaina keia no Hana. He malie ke kai, aohe nui o ka ua, he oluolu ka aina a pau o Hana, a he mahana maikai ka la.

O ke Koholalele. O ka lua keia o na makani maikai o Hana, ua like iki no keia makani me ke Kaomi, aka, he wahi ano e a huli ko keia ma kai mai, a o ka poe e holo ana i Hawaii ma ka waa, ua maikai loa keia makani.

O ke Koholopehu. He makani huhu hala ole keia, he nui kona ikaika, na keia makani no e hoohuli i ka lau o na laau iuka, a he ao kaumaha maluna o na mauna, a he kuaua mai ka moana mai, alaila, e hele huhu auanei ka wai me ka opala i kai. Hookahi la, e pau no keia makani.

O ke Kapae. He makani kapae ma kai pono mai, nou pono mai i ka aina, he oloku ke kai, a he anuanu ka aina a pau o Hana, a he mau la, e pau no keia makani.

O ka Hoolua. He makani ino loa keia, ua pa mai keia makani ma ka hikina mai. O nei makani ka mea nana e hoopae i na moku e ku nei ma ke awa o Hana, he makani kii wai no keia, he nui ka ua, a he anu ka aina a pau o Hana.

O ka Aimaunu. He makani maikai, keia, he malie ke kai, i ka wa kakahiaka nae, he oloku ke kai, a he amaamau ka haule ana o ka ua, a he kawahawaha ka ale o ka moana. O keia na kumu e aiia'i ka maunu o ka mea e make ai o ka ia, a he makani ai maunu keia no Hana,

O ka Lauawaawa. He makani malie wale iho no keia mauka mai o ka aina.

O ka Paiolopaowa. He makani keia mauka mai o ka aina, hele pu mai no nae me na kulu wai a ka ua, e hoopulu ana i na onohi maka a ka ipoahi.

O ka Halemauu. He makani keia maluna pono mai o na mauna, he wahi ikaika no kona i ka wa kakahiaka nui, a mahana mai ua pau.

O ke Kiu a me ke Kona. He mau makani malihini keia, aka, o keia na makani nana i hoopololi i na palikahakai o Hana, ku wale no lakou aole mea hana, a o na kai poi e noke hala ole ana i na paia paa o ke ala ua malu loa ia.

Ua pau, ke hoi nei maua me ka ua Oninipuaio i ka moana. Owau me ka mahalo,

L. S. Kailiehu.

Honokalani, Maui, Iune 2, 1865.

Article 3 Translation: *Ke Au Okoa*. 12 June 1865, pg. 4

The names of the winds of Hāna.

Here below are the names of the winds of Hāna, East Maui, explaining their importance and what they do. That is the place where I lived from when I was born until I was ten years old. I am still in the days of youth, and yet I am not uncertain or doubtful in telling of these winds. I know that these are the regular winds of these shore cliffs.

A Kaomi wind. This is a regular wind and a familiar wind for Hāna. The sea is calm, there is not a lot of rain, the entire expanse of Hāna is comfortable, and the sun has a pleasant warmth.

The Koholālele wind. This is the second of the good winds of Hāna. This wind is a little like the Kaomi, but there is a different quality, and this one changes out over the ocean. For people sailing to Hawaiʻi by canoe, this wind is excellent.

The Koholāpehu wind. This is a wind of endless wrath, and quite forceful. This wind turns the leaves of the upland trees; there are heavy clouds on the mountains, and sudden rain showers from the ocean, and then the water eventually rushes, filled with flotsam, down to the sea. After one day, this wind is done.

The Kāpae wind. An angled wind from right offshore, buffeting the land. The sea is stormy and entire land of Hāna is cold; after a few days, this wind is done.

The Hoʻolua wind. This is a terrible wind. This wind blows from the east. This is the wind that pushes the ships in the Hāna harbor to shore. This is a water-fetching wind, with lots of rain, and the entire land of Hāna is cold.

The ʻAimaunu wind. This is a good wind. The sea is calm, although in the morning the sea is rough, the rain falls in continual showers, and the ocean is furrowed with swells. These are the reasons that the bait of the one who wants fish is eaten, this is a bait-eating wind of Hāna.

The Lauʻawaʻawa wind. This is a quite gentle wind down from the inland areas.

The Paiolopāʻowā. This is a wind from the upland, but it comes with drops of rain, drenching the eyes of the ardent lover.

The Halemauʻu wind. This is a wind right above the mountains. It has some force in the early morning, and then when the day warms, it ends.

The Kiu and Kona winds. These are rarely-seen winds, but these are the winds that starve the shore cliffs of Hāna. When they come, no one works, and the waves break unceasingly, and where the paths are bordered by bowers, they are sheltered.

That is the end, I am returning with the ʻŌninipuaʻiʻo rain to the ocean. Yours gratefully,
L. S. KAILIEHU.

Honokalani, Maui, June 2, 1865.

Article 4: *Ke Koo o Hawaii.* 29 August 1883, pg. 5

Na Hoaui Ana.

Heaha ke mele e himeni mau ia ai uo ka poe Pakalaki? Eia ka Puali Inuwai e kalokalo ia ai no ua poe la: .

"He lokoino ka Hala he wawau ka Lehua,
Hana kupaha ka wai o Kehoi,
E hoi ke kupa o Lihue ua pa i ka neo,
Akahi no ka nele o ka la waiwai."

Pehea hoi oe e olelo ai no ka poe Lawaia paoa? He pono lakou e pule i ka poe Makapaa, ke akua o ka poe Moewaa, penei:

"Powa hewa ka lihi i ke ko'a-namu,
Nana kee-ka Ia i ka maunu ekaeka,
Hoopa-u ka a ka Lawaia paoa,
Hoanuanu ili o ka hele maunu."

Heaha kau e kaena ai ke ike ka malihini i ke kai o Punaluu? He hiki ia'u ke pule i ka makani o Kona i hulihia o Iwalani.

"Aia i Punaluu ko'u aloha,
I ke kai haohao a ka malihini,
No Kona ka makani he Kulaipau,
Kikii kapakahi o ka Iwalani,
A waho makou o Kailua,
Hiki ana ka makani wili ahiu."

Article 4 Translation: *Ke Koo o Hawaii.* 29 August 1883, pg. 5

The Passing of Time.

What is the song that is always sung for people struck with bad luck? Here is what the Water-Drinking League prays for such people:

> “The Hala is evil-hearted, the Lehua is unfriendly,
> The Kehoʻi waters do wondrous deeds,
> The native of Līhuʻe returns, struck by emptiness,
> For the first time to have no rich day.”

What would you say for the unlucky fishermen? They must pray to the one-eyed people, the god of those with bad luck, like so:

> “Plundering on the border of the fishing ground where fish bite,
> The fish look at the foul bait with disdain,
> The unlucky fisherman's belongings are soaked,
> Chilling the skin of the bait carrier."

What do you brag about when the visitor sees the ocean of Punaluʻu? I can pray to the wind of Kona that capsized the ʻIwalani.

> “My love is at Punaluʻu,
> In the ocean that astonishes the visitor,
> The Kulaʻipau wind is from Kona,
> That heels the ʻIwalani to one side,
> We reach outside of Kailua,
> The wildly twisting wind will arrive.”

WATER CYCLE READING: *KA WAI A KĀNE*

He ui, he nīnau: E ui aku ana au iā ʻoe, Aia i hea ka Wai a Kāne?
Aia i ka hikina a ka Lā, Puka i Haʻehaʻe,
Aia i laila ka Wai a Kāne.

E ui aku ana au iā ʻoe, Aia i hea ka Wai a Kāne?
Aia i Kaulana a ka lā, I ka pae ʻōpua i ke kai,
Ea mai ana ma Nīhoa, Ma ka mole mai o Lehua;
Aia i laila ka Wai a Kāne.

E ui aku ana au iā ʻoe, Aia i hea ka Wai a Kāne?
Aia i ke kuahiwi, I ke kualono, I ke awāwa, I ke kahawai;
Aia i laila ka Wai a Kāne.

E ui aku ana au iā ʻoe, Aia i hea ka Wai a Kāne?
Aia i kai, i ka moana, I ke Kualau, i ke ānuenue, I ka pūnohu, i ka ua koko, I ka ʻālewalewa;
Aia i laila ka Wai a Kāne.

E ui aku ana au iā ‘oe, Aia i hea ka Wai a Kāne?
Aia i luna ka Wai a Kāne. I ka ‘ōuli, i ke ao ‘ele‘ele, I ke ao panopano, I ke ao pōpolo hua mea a Kāne la, e!
Aia i laila ka wai a Kāne.

E ui aku ana au iā ‘oe, Aia i hea ka Wai a Kāne?
Aia i lalo, i ka honua, i ka Wai hū, I ka wai kau a Kāne me Kanaloa, He waipuna, he wai e inu,
He wai e mana, he wai e ola,
E ola nō, ea!

WATER OF KĀNE

A query, a question, I put to you: Where is the water of Kāne?
At the Eastern Gate, Where the Sun comes in at Ha‘eha‘e;
There is the water of Kāne.

A question I ask of you: Where is the water of Kāne?
Out there with the floating Sun, Where cloud-forms rest on Ocean's breast. Uplifting their forms at Nihoa, This side the base of Lehua;
There is the water of Kāne.

One question I put to you: Where is the water of Kāne?
Yonder on mountain peak, On the ridges steep, In the valleys deep, Where the rivers sweep;
There is the water of Kāne.

This question I ask of you: Where, pray, is the water of Kāne?
Yonder, at sea, on the ocean, In the driving rain, In the heavenly bow, In the piled-up mist-wraith, In the blood-red rainfall, In the ghost-pale cloud-form;
There is the water of Kāne.

One question I put to you: Where, where is the water of Kāne?
Up on high is the water of Kāne, In the heavenly blue, In the black piled cloud, In the black-black cloud. In the black-mottled sacred cloud of the gods;
There is the water of Kāne.

One question I ask of you: Where flows the water of Kāne?
Deep in the ground, in the gushing spring, In the ducts of Kāne and Loa, A well-spring of water, to quaff,
A water of magic power - The water of life!
Life! O give us this life!

Unwritten Literature of Hawaii: The Sacred Songs of the Hula (1909). N. S. Emerson, translator. Smithsonian Institution, Washington, D.C.

Questions about Local Winds for Students

Now the causes of local winds and rains should be a bit clearer. We hope you can express in your own words the concepts you have learned and share with family and friends the knowledge and wisdom you have gained. Let’s check your knowledge with a few questions.

1. What have you observed and learned about the local winds in your and community?
2. How would you describe the behavior of winds around your neighborhood?
3. If you explain local winds to your parents or friends, what examples can you provide?
4. In what ways are local winds you observed different than large-scale winds over the ocean?
5. Can you explain in your own words why mountains are so important for rainfall?
6. How are sea and land breezes formed?
7. If you wanted to observe sea and land breezes in the Hawaiian Islands, which island and location would you choose for the sea and land breeze? Briefly explain.
8. When and where do you expect showers to occur during sea and land breezes circulations? Why?
9. Why does it rain so much in Hilo while Waikoloa on the Kona side is so dry?
10. If you go sailing for great distances what would be the most important, large scale or local winds? What if you were just going to sail around your island for a day?
11. Can you explain how the Hawaiian names of winds reveal a lot of science?
12. What learning activities did you like the most? Please share what you learned with us!

Waiānuenue, Rainbow Falls

Rainbow Falls, 80 ft. (24 m) tall and almost 100 ft. (30 m) in diameter is in Wailuku River State Park, Hilo, Hawai‘i.

At Waiānuenue the Wailuku River plunges into a large pool, flowing in front of a natural lava cave, considered the mythological home of Hina. Its Hawaiian name Waiānuenue literally means rainbow water.

Waiānuenue derives its name from rainbows seen in the mist on sunny mornings.

Source: http://en.wikipedia.org/wiki/Rainbow_Falls_%28Hawaii%29

LESSON 2 – LOCAL WINDS – KEY

Lab 2: Surface Heating (Land Sea Breezes)

1. What happened to the temperature measured in the two cups as variables changed? Were your predictions correct?

   A In the first and second trials, the temperature in the black cup was greater than the temperature in the white cup. The black cup absorbs more energy than the white cup.

2. How, if at all, would the results differ if a silver cup is used instead of a white one?

   A Theoretically, the temperature of the two cups would show an even greater difference. The silver surface of the cup would effectively reflect all the energy hitting its surface. This process would allow less energy to be absorbed than with a plain, white surface. However, in practice the difference would be hard to detect.

3. What would happen if you were to leave the cups under the light for a long period of time, say 24 hours?

   A The temperatures of the two cups would stabilize once radiative and thermal equilibrium was reached. They would however, not become equal. The black cup would still show a greater temperature.

4. A glider is an airplane with no engine. In order to stay in the air, glider pilots sometimes look for large paved areas or fields which have been recently plowed. Explain why.

   A Glider pilots need updrafts to keep their planes in the air longer. Large paved areas or fields which have been recently been plowed are great sources for updrafts. These surfaces absorb a lot of energy and transfer it to the air right above their surfaces. This heated air then rises and is replaced by adjacent cooler air. This cycle is constantly repeated and creates an updraft.

5. How can you relate this experiment to land-sea breezes?

   It relates to land-sea breezes in a sense that land and sea heat up at different rates. The land heats up faster and more than the sea and this causes a rising convection current over land replaced by air from the sea. This generates a sea breeze.

6. Why do you expect land to heat up faster than the ocean?

   A I expect land to heat up faster than the ocean because land has a lower heat capacity than the sea, meaning solar radiation is absorbed faster than in the sea.

7. Sea-land breezes are only noted at certain locations of Hawai'i. Explain what causes this.

A In regions where the trade winds are strong enough to overcome local winds, weaker sea-land breezes are not apparent. If volcanoes and size of islands are great, such as on Maui and Hawai'i, mountains block the large-scale flow, allowing heat to build up on the leeward sides even when the large scale winds are moderately strong. This increases the strength of the daily sea breeze over the lee slopes of these islands (Figs. 2 and 3). At night, the taller mountains also produce cooler air at high altitudes and a stronger land breeze.

Lab 3: Recycled Water-The Hydrologic Cycle

1. Where in this activity does evaporation occur? Condensation?

A In this activity evaporation occurs at the surface of the water in the shoe box. Evaporation will occur at a faster rate on the surface of water directly below the lamp. Condensation occurs on the surface of the cup holding the ice.

2. What causes water droplets to form on the outside of the cup in the shoe box?

A The ice in the cup cools the air in the shoe box around the bottom of the cup. When the dew point temperature of the air is reached condensation starts to form on the cup.

3. Where in the Earth's hydrologic cycle does evaporation occur? Condensation?

A Evaporation occurs at the surface of oceans, lakes, and rivers. Evaporation also takes place on land. Water evaporates from soils and plants. A lot of precipitation evaporates even before it hits the ground. The highest evaporation rates occur over subtropical oceans in the trade-wind belt. Condensation occurs in clouds in the troposphere typically as air rises and cools. Water can also condense on the leaves of plants and other surfaces when the temperature at the surface reaches the dew point. In a study by Giambelluca, DeLay, Nullet, Scholl and Gingerich (2011) on Haleakalā, occult precipitation (not measured by conventional rain gauges) was 32% of total precipitation. Hawaiians knew this and protected forests.

4. From what you observed in this activity, what are the key processes in the hydrologic cycle?

A The key processes in the hydrologic cycle are evaporation (aided by the input of solar radiation), transport of the water vapor by air currents, condensation into clouds, and precipitation back to the surface. Once it reaches the surface again it may enter lakes, rivers or ground water and may make its way to the ocean before evaporating again.

5. Was water lost from the system in any part of this activity? If so, where?

A As long as the cover of the plastic shoe box fits tightly, little water will be lost in this system. The water will cycle through different phases and be present in a different state than it was initially.

Lab 4: Formation of Clouds

1. Comment on the differences in your observations, and the reasons for these differences.

   A When no aerosol was introduced into the jar, water preferentially condensed on the surface of the lid and the sides of the jar. When an aerosol was introduced into the jar from the match, water vapor preferentially condensed onto the surface of the aerosol particles and a visible cloud formed. The large size of the smoke particles from the match made them effective cloud condensation nuclei.

2. If a layer of sand were put on the bottom of the jar instead of water, would a cloud form? Why or why not?

   A Nothing would have happened if a layer of sand was put in the jar instead of water. The water is the source of the vapor in the jar. No water...no vapor...no clouds.

3. What would have happened if cold water had been used instead of hot water? Why?

   A Clouds will not form if the water used is near room temperature or cooler. The hot water evaporates into the cooler room temperature air and results in a relative humidity that slightly exceeds 100%. This is a prerequisite for cloud formation.

4. Describe any motion observed inside the jar. Explain your observation.

   A A slight upward motion is seen in the center of the jar as heated air just above the surface of the hot water rises toward the top of the jar due to its positive buoyancy. As air cools at the top of the jar and along its sides, a downward circulation develops along the walls of the jar. This circulation is analogous to the motions observed in cumulus clouds in nature.

Lab 5. Rain Makers (Orographic Rain)

QUESTIONS (pertaining to Fig. 9):

1. Do your streamlines indicate flow splitting is taking place? If it is, explain why?

A Yes, the streamlines split or deviate, around the two largest volcanoes that make up the island of Hawai‘i.

2. Where on average is the wind speed greatest? Why?

A The strongest winds occur at the northern and southern tips of the island of Hawai‘i. See Figure 2, numbers of flags on wind arrows indicate speed. Each full line represents ten knots (1 kt =1.15 mph). Shorter lines represent wind speed increments of 5 knots. Blocking on the upstream side of the island results in slightly higher surface pressure, while lower surface pressure forms on the downwind side of the island. This results in an acceleration of the flow along the two sides of the island.

QUESTIONS (pertaining to Fig. 10):

1. Did you find the minimum rainfall where you expected to? What about the maximum rainfall? Explain.

A Yes. Kona side of the island of Hawai‘i is the driest region as it is the region with the least trade wind influence. The top of Mauna Loa and Mauna Kea follow because they above the trade wind inversion which traps moisture underneath and therefore prevents cloud formation above it. Without cloud formation there is no rain. Maximum rainfall is found on the upper slopes of mountains on the windward side of islands exposed to prevailing trade winds.

2. Why are there no maxima in rainfall at the summits of Mauna Kea and Mauna Loa?

A Moist air, which originates near sea level, does not usually have sufficient kinetic energy (wind speed) to reach the summit, instead the airflow splits and flows around the summits. Then during the few events when the air has enough speed to be able to reach the summit, most of the rain has already fallen out of the cloud along the slopes of the volcano.

3. Identify the wettest regions. Identify the driest. Relate Kona’s rainfall to Hilo’s rainfall. Please mention everything you know.

A The wettest regions, such as Hilo, famous in legend (see Hawaiian newspaper article 2) for its kite-flying wind and rains lie in the windward areas where the trade winds constant blow to form clouds and rain. The driest regions on the island the Hawai‘i are the Kona side of where trade winds are blocked by tall volcanoes and above the trade wind inversion on the tall mountains. Above the inversion, warmer air traps cooler moist air below it so clouds do not form.

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