Hawaiian Islands

The scope of this section includes the US-affiliated islands of the Caribbean and Pacific. In the Caribbean, this includes Puerto Rico and the US Virgin Islands. In the Pacific, it includes the Hawaiian Islands, American Samoa, the Commonwealth of the Northern Mariana Islands, Guam, the Federated States of Micronesia, the Republic of the Marshall Islands, and the Republic of Palau.

KEY ISSUES

- **Freshwater Resources**
- **Public Health and Safety**
- **Ecosystems and Biodiversity**
- **Sea-level Variability**

ISLANDS IN THE CARIBBEAN AND THE PACIFIC

The Caribbean and Pacific islands that are affiliated with the US provide a unique setting for consideration of climate variability and change. Islands contain diverse and productive ecosystems,and include many specialized and unique species. After centuries of depending on subsistence agriculture and fishing,island economies are now based heavily on tourism,tuna processing and transshipment, and agricultural production for export (including sugar cane,bananas,pineapple, spices,and citrus fruits),making them highly responsive to external economic forces. The stability of these economies is also dependent on the health of the unique natural resources,all of which are sensitive to climate.

Many islands are facing the stresses of rapid human population growth,increasing vulnerability to natural disasters,and degradation of natural resources.Droughts and floods are among the climate extremes of most concern as they affect the amount and quality of water supplies in island communities and thus can have significant health consequences.Due to their small size and isolation,many islands face chronic water shortages and problems with waste disposal. Some are facing a species extinction crisis; for example,the Hawaiian Islands have the highest extinction rate of any state in the nation. For most island communities,infrastructure and economic activities are located near the coast,making them highly vulnerable to storm events and sea-level fluctuations.

Observed Climate Trends

In the Pacific,tropical storms and typhoons are common between May and December, but can occur in any month. In the Caribbean,the hurricane season spans the months from June to November. The El Niño Southern Oscillation (ENSO) cycle affects sea level, rainfall,and cyclone activity (hurricanes or typhoons, depending on the region). In the Caribbean, Atlantic hurricanes are suppressed during El Niño,while they increase during La Niña. In the Pacific,during El Niño events,Hawaii,Micronesia,and the islands of the southwest tropical Pacific often receive below normal rainfall. Additionally, areas of above normal precipitation, along with greater tropical cyclone activity, typically shift eastward towards French Polynesia. The region of greater tropical cyclone activity includes the central Pacific (Hawaiian waters),eastern Marshalls and Guam,and northern Marianas.

Over the last century, average annual temperatures in the Caribbean islands have increased by more than 1ºF (0.5ºC). Average annual temperatures in the Pacific Islands have increased by about 0.5ºF (0.25ºC). Globally, sea level has risen by 4 to 8 inches (10-20 cm) in the past 100 years with significant local variation. Relative

The Value of Climate Forecasts

The 1997-1998 El Niño event offers a vivid example of how information about potential consequences can be used to support decision making and benefit society. In 1997, the Pacific ENSO Applications Center (based in Hawaii and Guam) provided early forecasts of El Niño-related droughts in Hawaii, Micronesia, and the tropical southwest Pacific. The Applications Center subsequently pursued an aggressive program of government briefings, public education, and outreach. As a result, many Pacific Island governments established "drought task forces" and developed mitigation plans. In addition to addressing governmental actions, these drought task forces helped inform the public about strategies to conserve water, prevent outbreaks of diseases associated with droughts, and reduce the risk of wildfires that often increase during droughts.

These task forces employed radio and television announcements, information hotlines, brochures, and presentations on El Niño and drought in local schools. In response to the public information campaign, water

sea level,which also takes into account natural and human-caused changes in the land elevation such as tectonic uplifting and land subsidence (sinking),is also showing an upward trend (3.9 inches, about 10 cm,per 100 years) at sites monitored in the Caribbean and Gulf of Mexico. Although absolute sea level is also rising in the Pacific,trends vary greatly from island to island due to the fact that some islands are rising;ENSO and other short-term variations further complicate the picture. Low-lying islands that are not rising are very likely to be at risk from sea-level rise.

Some models suggest more persistent El Niño-like conditions across the Pacific. This would lead to a reduction of fresh water resources.

Scenarios of Future Climate

Pacific and Caribbean islands will possibly be affected by: changes in patterns of natural climate variability (such as ENSO); changes in the frequency, intensity, and tracks of tropical cyclones;and changes in ocean currents. These islands are very likely to experience increasing air and ocean temperatures and changes in sea level (including storm surges and sustained rise). Some recent climate model studies also project that ENSO extremes are likely to increase with increasing greenhouse gas concentrations. Some models suggest more persistent El Niño-like conditions across the Pacific. This would lead to a reduction of fresh water resources in areas of the western Pacific, Micronesia,and the southwest tropical Pacific,and a reduction in Atlantic hurricane frequency.

One hurricane modeling study suggests that peak wind speed will increase by 5-10% by the end of the 21st century along with significant increases in peak precipitation rates. Apart from the linkage with ENSO, there is significant uncertainty about how increasing global temperatures will affect hurricane and typhoon frequency and tracks.

Islands are home to unique ecosystems and species, with unsurpassed biodiversity. These resources are already threatened by invasive non-native plant and animal species, as well as urban expansion and various industrial activities, resulting in the highest extinction rates of all regions of the US. They can also be highly climate-sensitive.

Endangered Hawaiian hakalau.

Coral reef ecosystem.

Mangrove.

management agencies implemented water conservation plans and repaired their systems; residents repaired their water catchment systems; and local vendors supplied new catchment systems and new water storage tanks.

Even with these precautionary measures, the 1997-1998 El Niño produced such extensive drought conditions that water rationing became necessary, limited hours of water use were imposed on most islands, and eventually water augmentation was required on several Pacific islands.

Agriculture suffered from the droughts everywhere except on Guam, where there was ample water for irrigation.

Still, the consequences could have been worse. Advance warning through emerging forecasting capabilities and a focused program of education and outreach clearly helped mitigate the negative impacts. These actions prevented death and greatly reduced suffering to less than occurred during the 1983 El Niño.

ISLANDS IN THE CARIBBEAN AND THE PACIFIC KEY ISSUES

Freshwater Resources

Adequate water supplies are critical for the well-being and economic security of the islands and are needed for tourism, agriculture, fish processing,and urban/municipal users,as well as natural ecosystems. On many islands, water resources or access to them are already limited and subject to competing demands. It is possible that climate change and the resulting sea-level rise will adversely affect water supplies in the future through more frequent droughts, floods,and salt water intrusion into freshwater lenses. The populations of the Pacific Islands are primarily concerned with future conditions that are likely to exacerbate drought. In Puerto Rico and the US Virgin Islands drought is also a concern,as are flooding and landslides associated with heavy precipitation events.

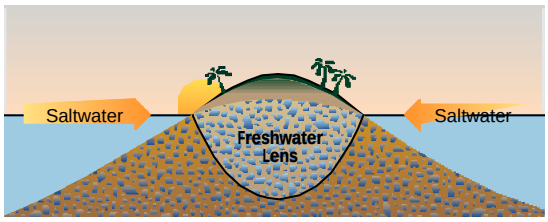
Adaptations: Strategies for providing adequate water resources include improved rainfall catchment; improved storage and distribution systems;development of under-utilized or alternative sources,better management of water supply and infrastructure;increased water conservation programs;construction of groundwater recharge basins for runoff;more effective use of ENSO forecast information;and application of new technology, such as desalinization. For agriculture,strategies include exploring the feasibility of planting more drought-resistant crops.Consideration of the effects of climate change and variability on freshwater resources should be integrated into community planning and tourism develpment.

Public Health and Safety

Both coastal and inland island populations and infrastructure are already at risk from climate extremes. Storms can damage or destroy buildings,damage infrastructure,and disrupt public services. Both the Pacific and Caribbean regions are familiar with severe cyclones,which have caused billions of dollars in damage from the destruction of housing, agriculture, roads and bridges,and lost tourism revenue. In both regions,a large percentage of people,infrastructure,and economic activities are located near the coast,leading to dense areas of vulnerability. The unique topography of Puerto Rico and the Virgin Islands makes them susceptible to floods and landslides often resulting from severe storms. It is possible that the frequency of extreme events may increase over the next few decades to a century thereby increasing the risk to public health and safety.

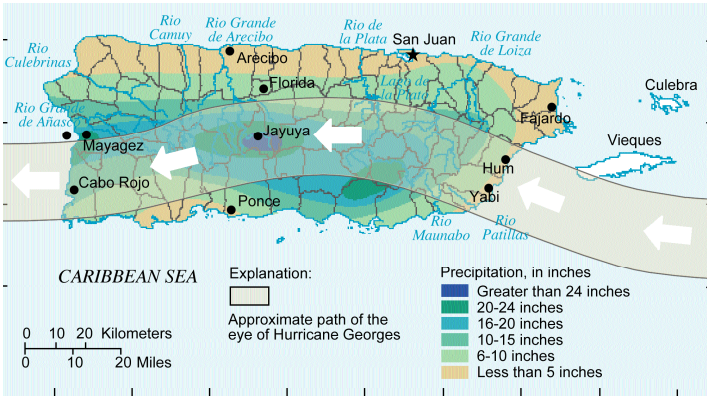
Adaptations: Strategies include upgrading and protection of infrastructure,comprehensive disaster management programs, changes in land use policies,and adoption and enforcement of more stringent building codes. For reducing public health risks,strategies include improved sanitation and health care infrastructure, emergency plans,and public education about health risks posed by floods and droughts.

Freshwater Lens Effect in Island Hydrology



On many islands, the underground pool of freshwater that takes the shape of a lens is a critical water source. The freshwater lens is suspended by salt water. If sea level increases, and/or if the lens becomes depleted because of excess withdrawals, salt water from the sea can intrude, making the water unsuitable for many uses. The size of the lens is directly related to the size of the island: larger islands have lenses that are less vulnerable to tidal mixing and have enough storage for withdrawals. Smaller island freshwater lenses shrink during prolonged periods of low rainfall, and water quality is easily impaired by mixing with salt water. Short and light rainfall contributes little to recharge of these sources. Long periods of rainfall are needed to provide adequate recharge.

Path of Hurricane Georges in Relation to Puerto Rico with Precipitation Totals



On September 21, 1998, Hurricane Georges swept across Puerto Rico. The eye of the hurricane was 25-30 miles wide and passed within 15 miles of the capital, San Juan, leaving a trail of devastation in its wake. The path of the hurricane and rainfall totals are shown here. Some areas received up to 26 inches of rain within 24 hours. Flooding, landslides, and catastrophic losses in infrastructure resulted.

Ecosystems and Biodiversity

The isolation of islands has made them living laboratories for understanding species adaptation and evolution,but has also made them extremely vulnerable to invasive species and other stresses. Islands are home to unique ecosystems and species,with unsurpassed biodiversity. These resources are already threatened by invasive non-native plant and animal species,as well as urban expansion and various industrial activities, resulting in the highest extinction rates of all regions of the US. They can also be highly climate-sensitive. For example,coral bleaching associated with El Niño events and the long-term warming of surface waters has become widespread in both the Pacific and Caribbean since the 1990s. During the El Niño of 1997-98,coral bleaching in Palau, known for its spectacular coral reefs, was extensive.

Other possible concerns include increased extinction rates of mountain species that have limited opportunities for migration;increased rates of changes in mangrove ranges and health;and declines in forests due to floods,droughts,or increased incidence of pests,pathogens,or fire. It is possible that increases in the frequency or intensity of hurricanes would generally favor invasive species. In addition,the unique "cloud forests"located on some of the islands occupy a narrow geographical and climatological niche. A slight shift in temperature or precipitation patterns would possibly cause this zone to shift upwards enough to be eliminated.

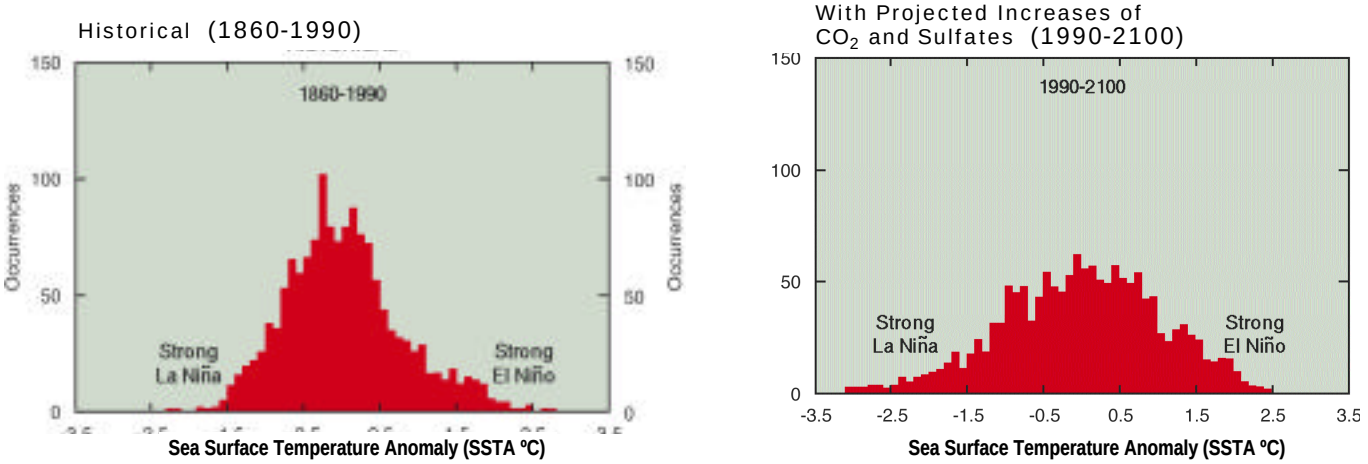
Adaptations: While options are limited,strategies include efforts at slowing biological invasions,strengthening and enforcing policies that protect critical habitats,improving understanding of the local effects of climate variability and change,and increasing the awareness of tourists and the public concerning the value of species and biodiversity.

Sea-level Variability

Sea-level rise,both long-term and episodic,is already an extremely important issue for many of the islands.Sea-level rise results in coastal erosion.inundation,and salt water intrusion into freshwater lenses and coastal agricultural zones (where taro,pulaka,and yams are grown). Future sea-level rise,both global and due to episodic events (such as extreme lunar tides,ENSO-related changes,and storm-related wave conditions) will increasingly contribute to negative consequences for island populations and ecosystems. Most at risk are low-lying islands and atolls. Examples of sites that are already close to sea level include the Republic of the Marshall Islands in the Pacific and much of the metropolitan area of San Juan in Puerto Rico.

Adaptations: Strategies include efforts to protect coastal infrastructure,transportation and water systems, agriculture,and communities; integrated coastal zone management; and crop diversification and the use of salt-resistant crops. Retreat from risk prone areas is likely to be necessary in some cases,but will be complicated due to land ownership,and could have significant consequences for social and cultural identity.

El Niños and La Niñas
Observed and Projected Sea Surface Temperature Anomalies



Some model projections suggest more frequent El Niño-like conditions and stronger La Niñas as a result of climate change. Sea surface temperature (SST) deviations from normal in the equatorial Pacific are used to measure the strength of El Niños and La Niñas. These high resolution model projections by the Max Planck Institute suggest more SST deviations from normal and thus more frequent El Niños and stronger La Niñas in the future. The high bars in the center are occurrences of normal SSTs. In the projections in the right hand graph, these normal temperatures occur less frequently, while lower (La Niña) and higher (El Niño) SSTs occur more frequently. The Max Planck model is used here because it has been able to reproduce the strength of these events better than other models due to its physics and ability to resolve fine scale structure in the ocean.