Coastal Processes

OCN 210

This lecture includes selected slides kindly provided by: Prof. Chip Fletcher

Department of Geology and Geophysics, University of Hawaii

Boca del Drago, Bocas del Toro, Panama

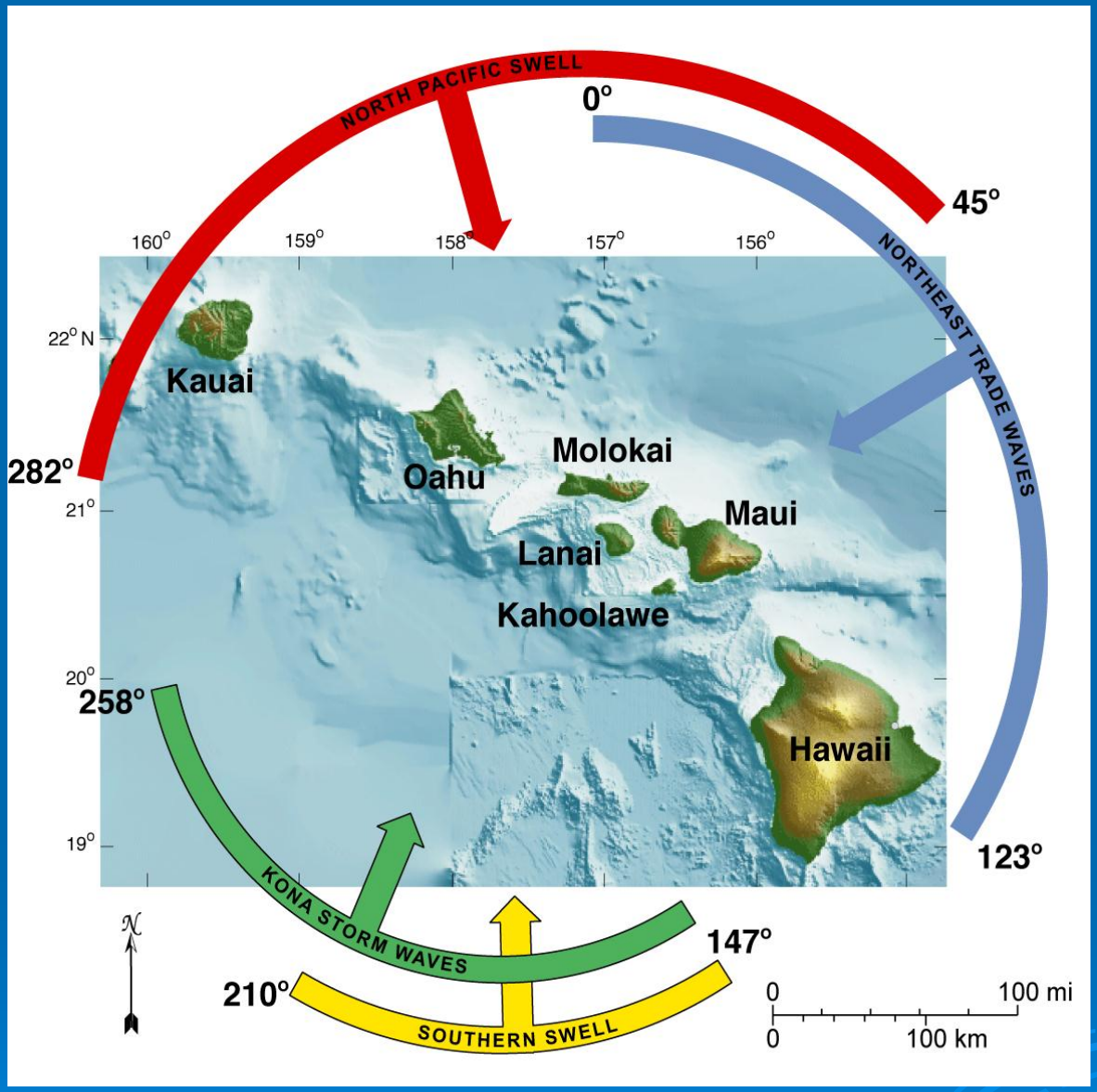
- Coastal populations are placed at risk from:
  - Large waves and storm surge
  - Extreme tides
  - Hurricanes
  - Tsunami
  - Sea Level Rise (global and local)

- The above processes cause changes in the coastline and threaten billions of dollars ($\$10^9$) of coastal infrastructure annually

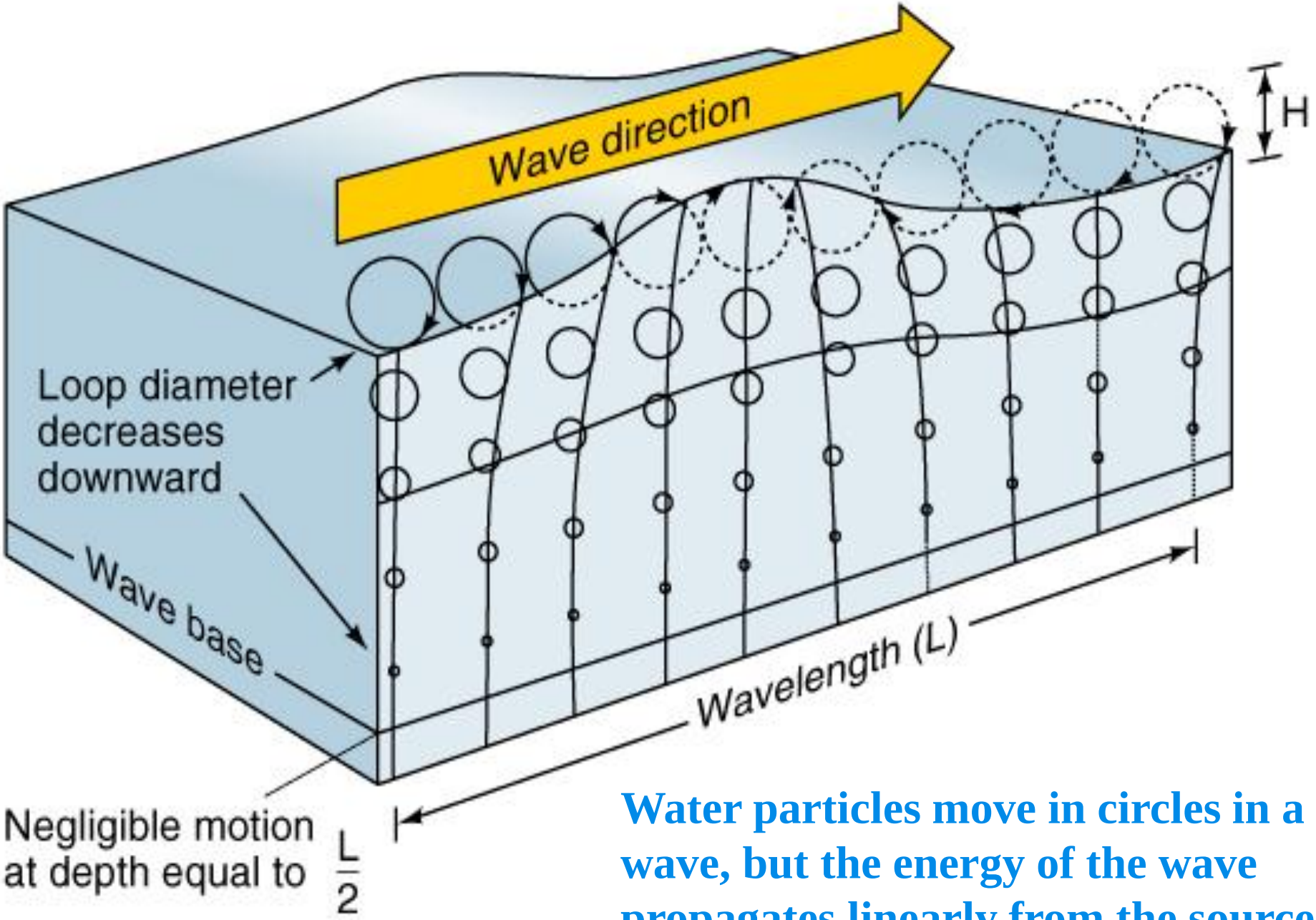
More than half of the US population lives on the narrow coastal strip that covers 17% of the total land area of the country

In 2003, 53% of the US population lived in the 673 coastal counties.

Much of the population of other countries along the sea also lives within a small distance from the coast



Swells coming from various directions impact the coastal zone in the Hawaiian island chain



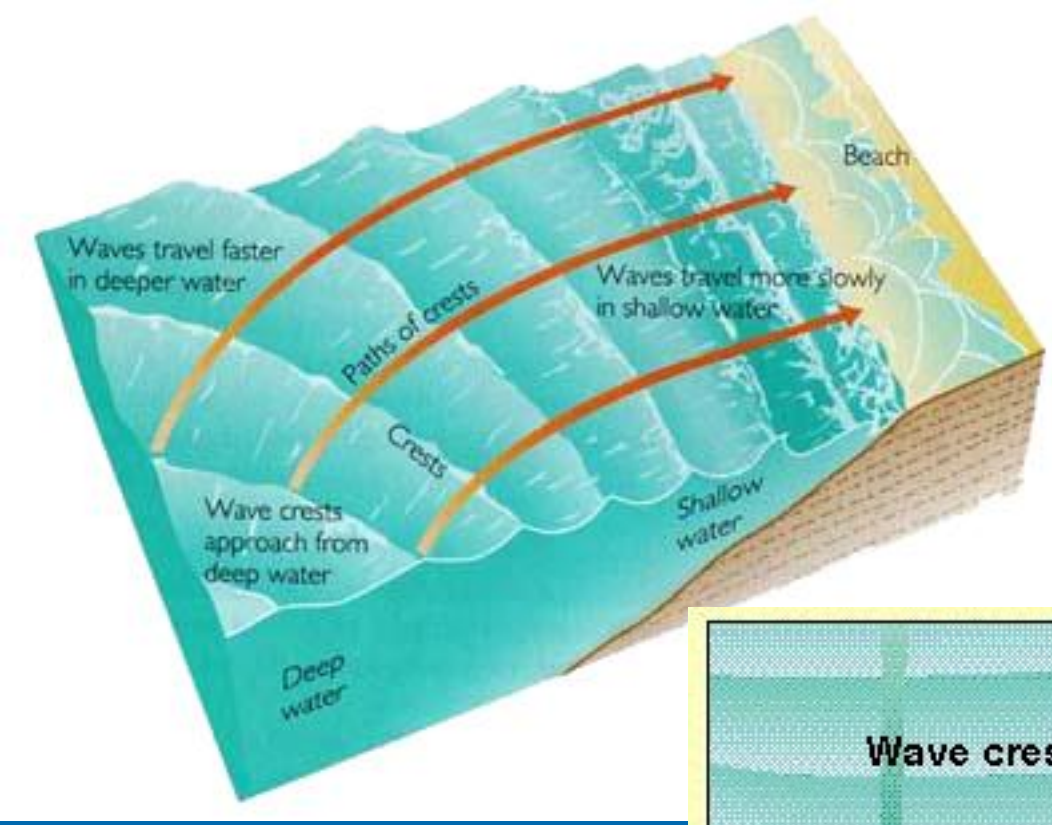
Water particles move in circles in a wave, but the energy of the wave propagates linearly from the source

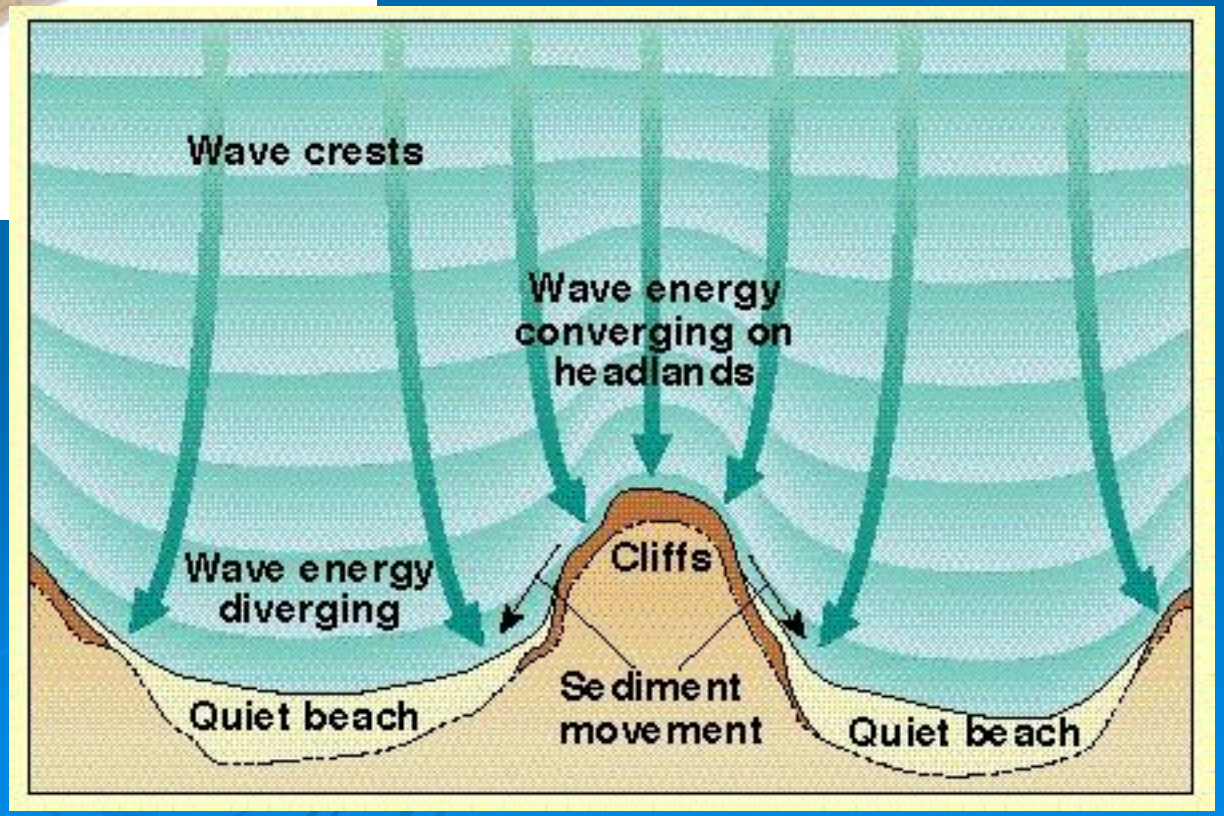
Sea State (or "seas"

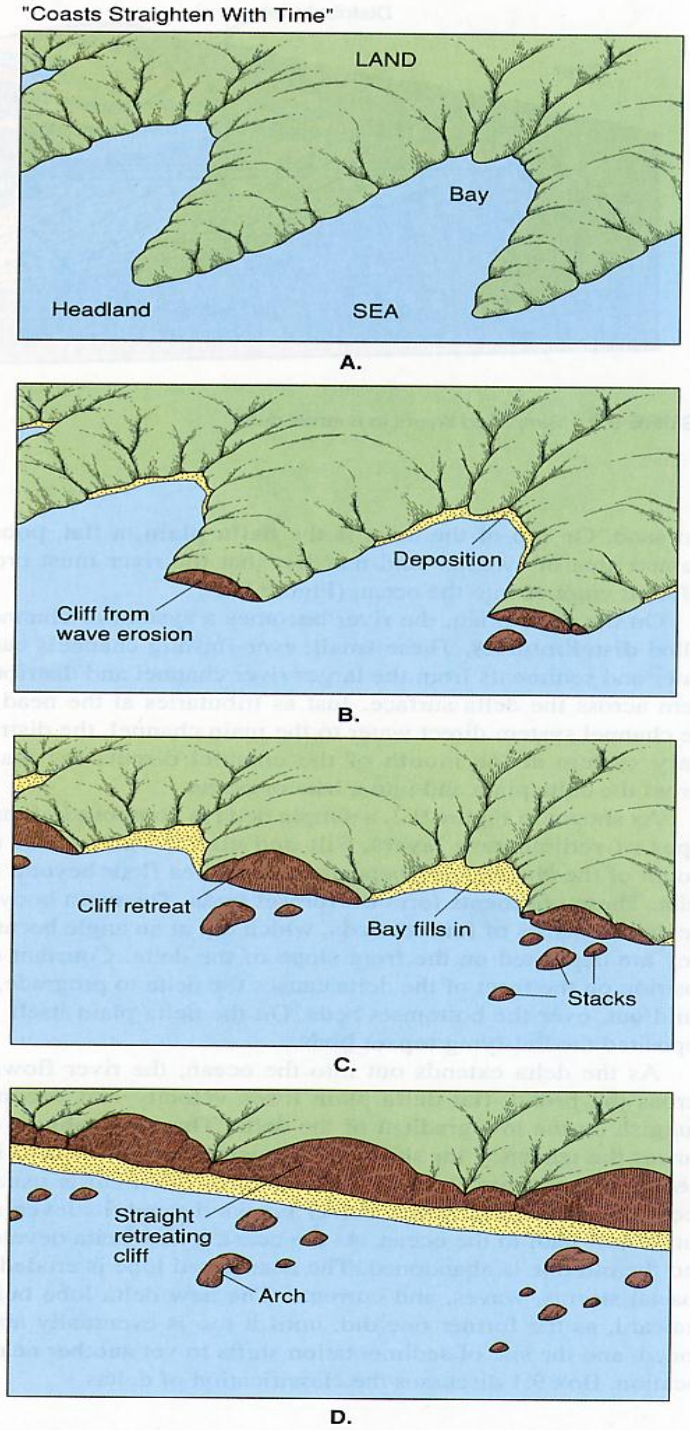
Swell

Wind blowing across the sea surface makes waves

Refraction affects how waves hit the coast

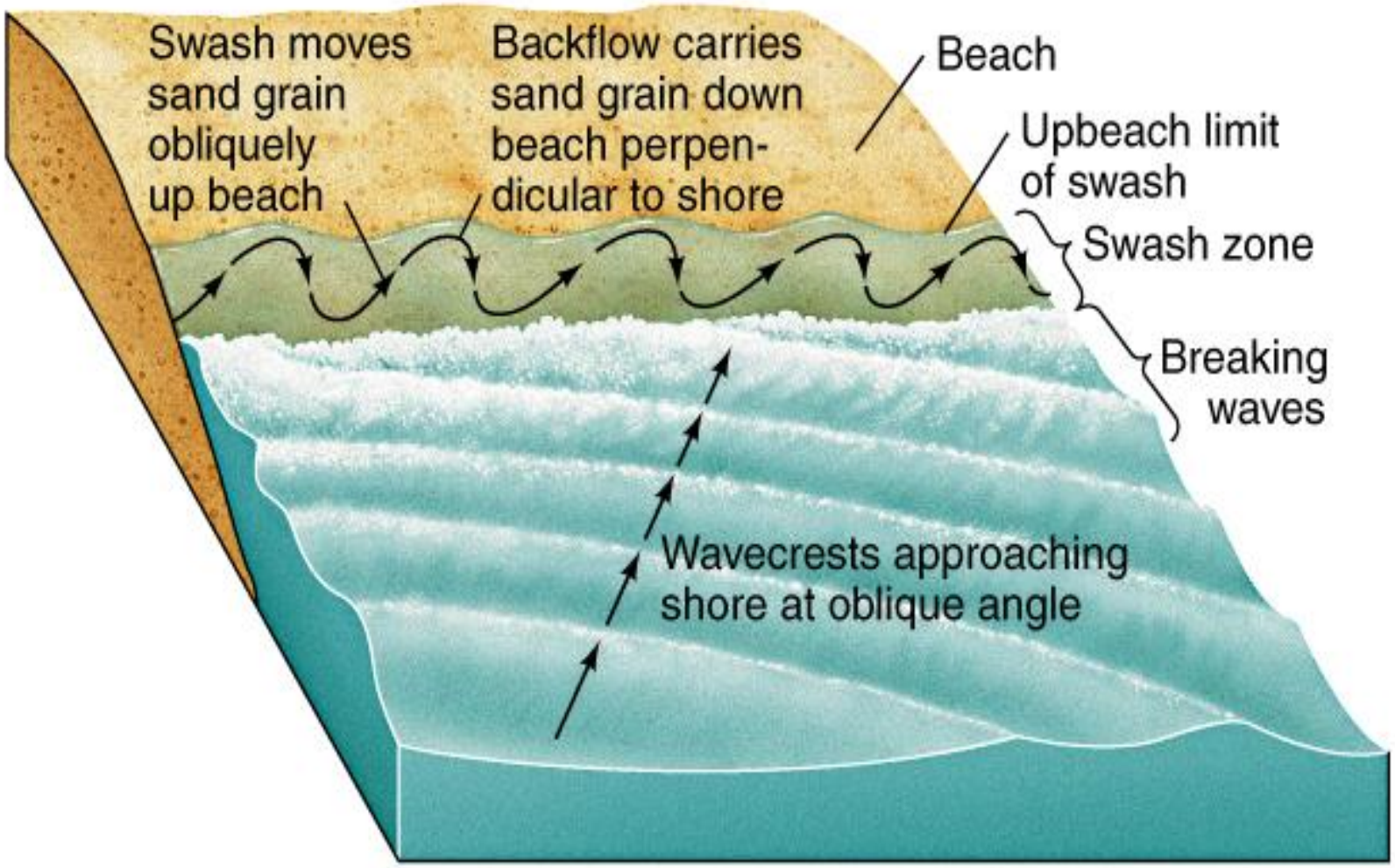


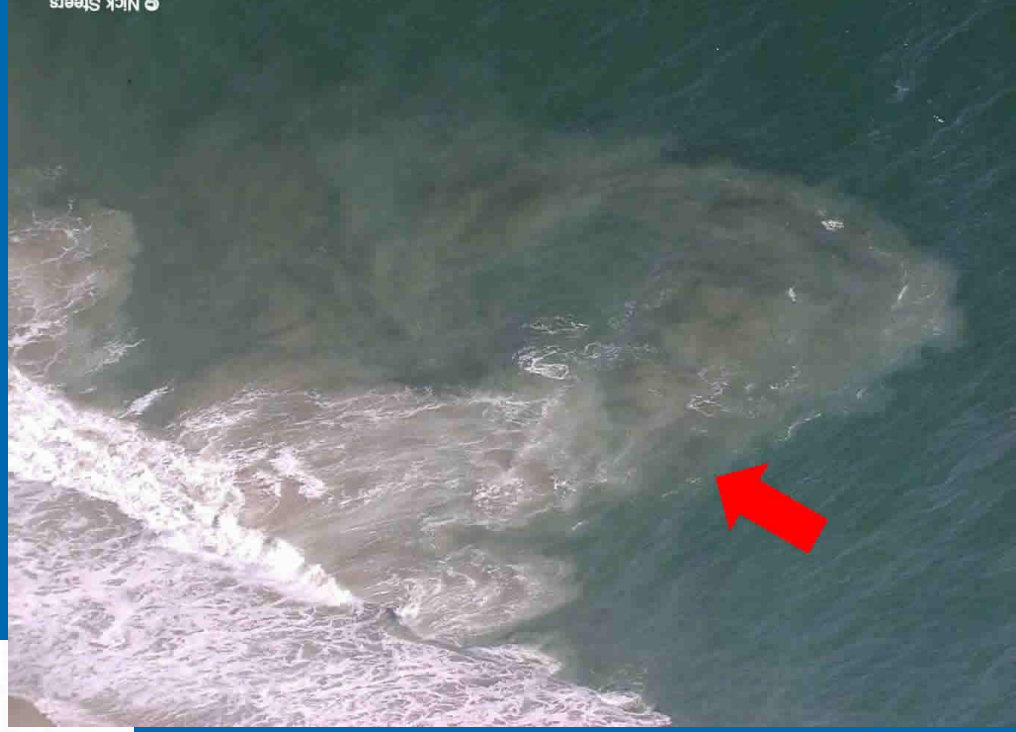


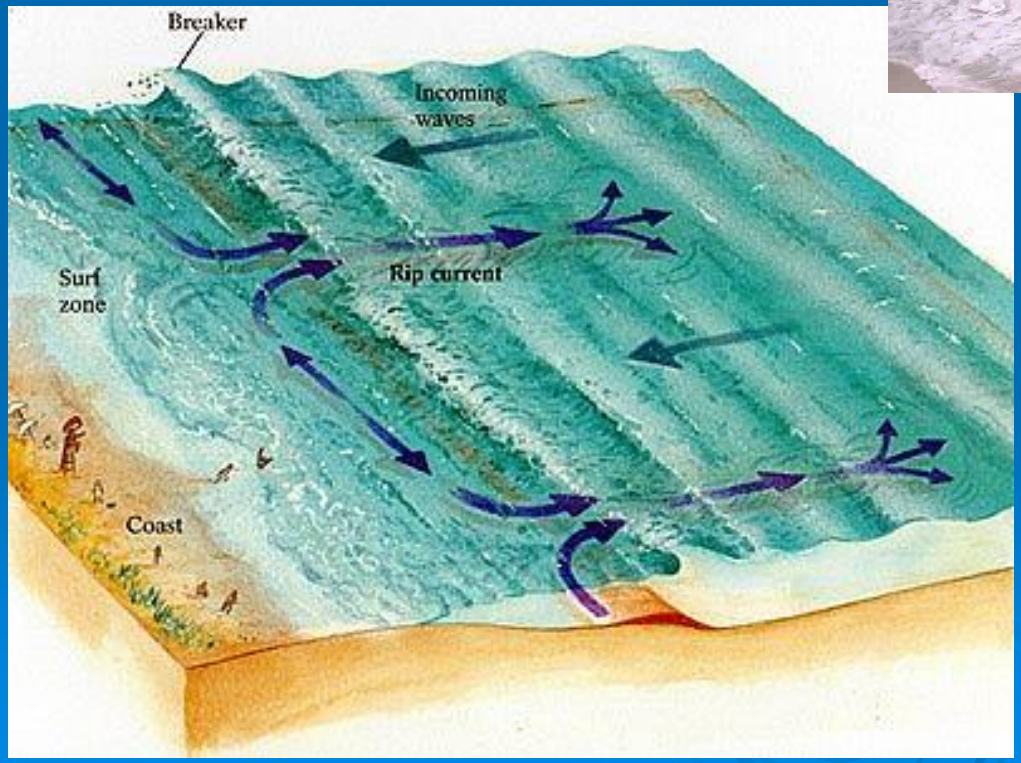


Over extended periods of time, shorelines are straightened by wave erosion

Longshore Transport
(result of waves hitting coast at an angle)

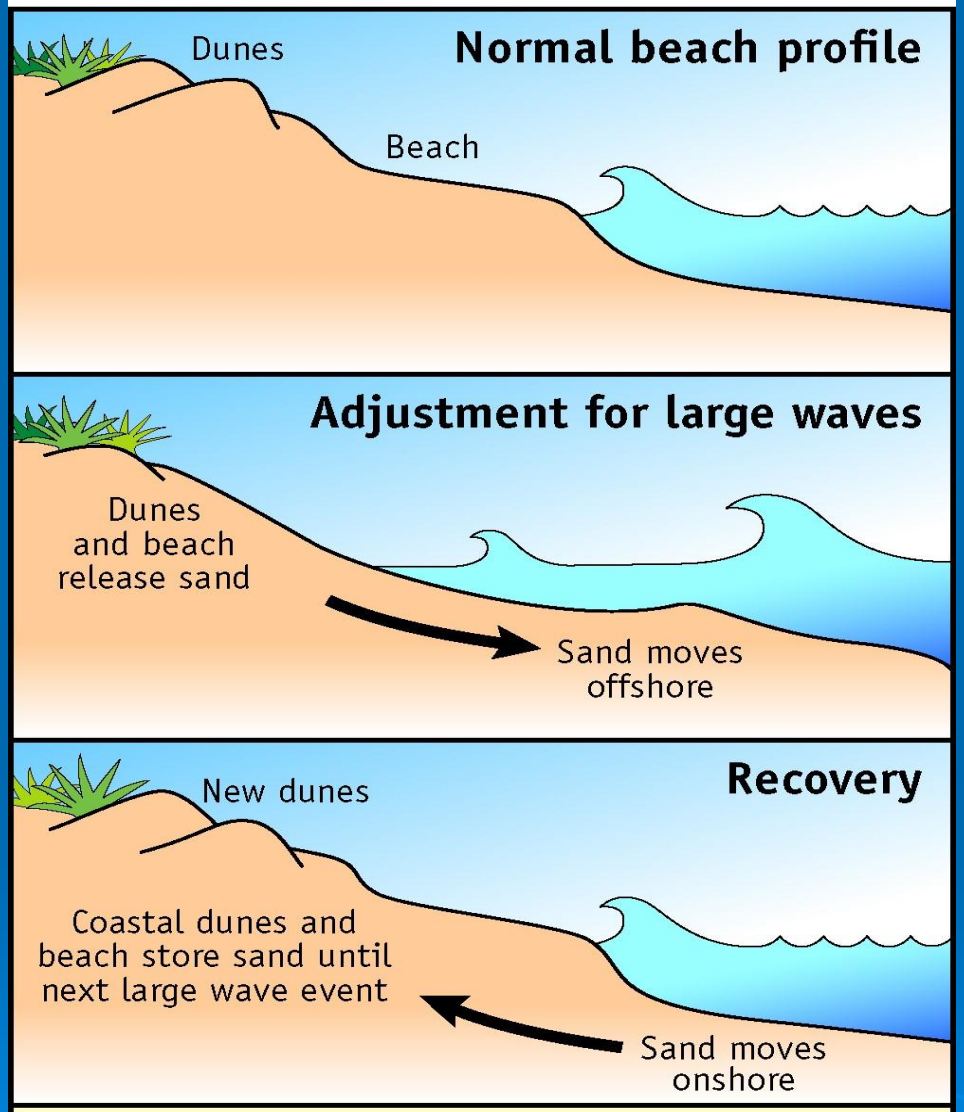






Rip Currents occur when water forced up the beach returns out to sea (these also provide a mechanism for moving sand offshore)

Seasonal beach profile adjustments



Large waves, which tend to occur seasonally in Hawaii, cause a beach to temporarily change its profile.

Dunes store sand until high waves move it to the beach

Beach=checking account

Dunes= savings account

High Swell

Tides are generated by the Earth-Moon system and deform the "water envelope" on Earth.

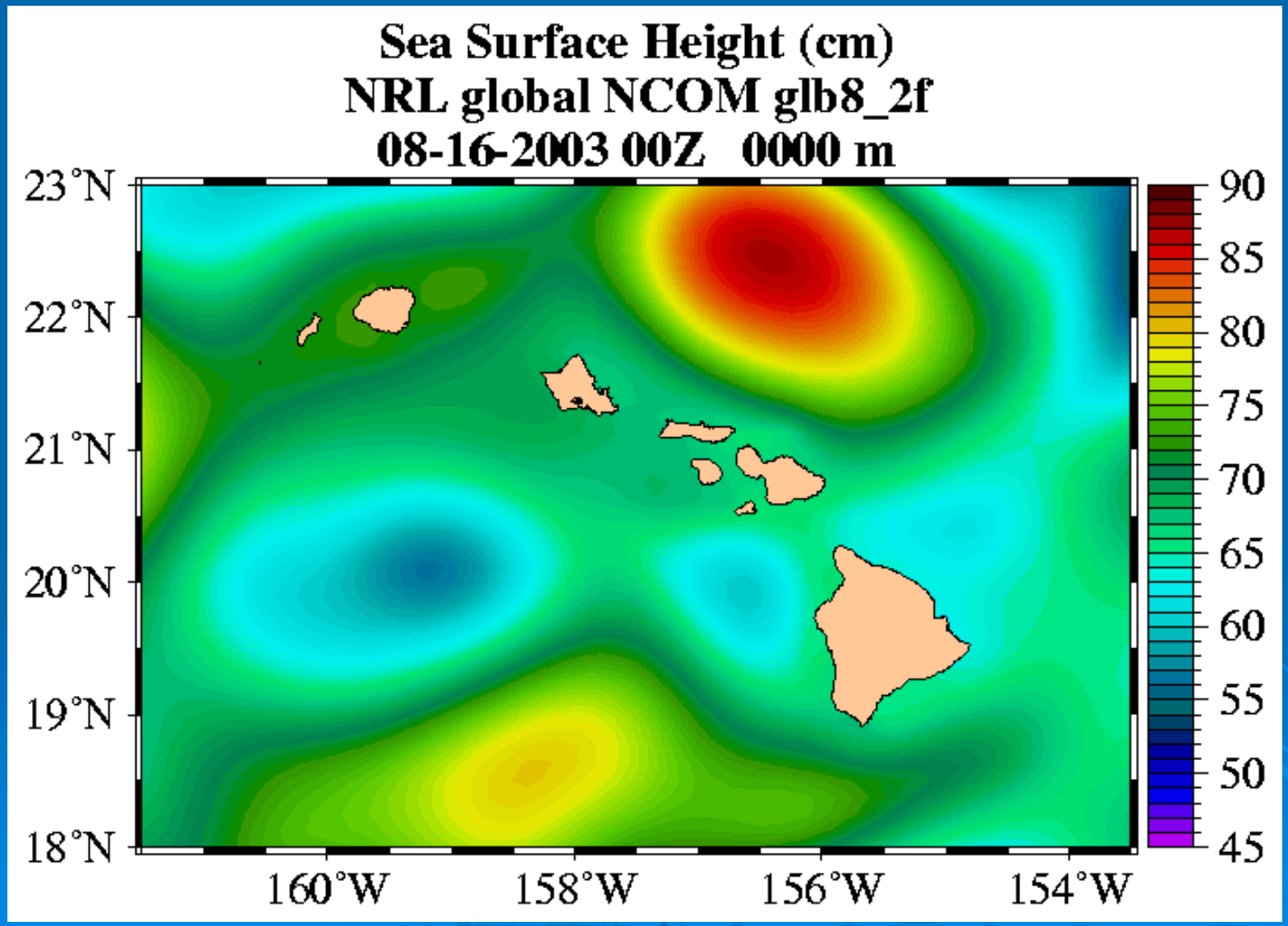
Smaller tides also result from the Earth-Sun system.

The tides result from the Earth literally "sliding" under its deformed water envelope during its daily rotation.

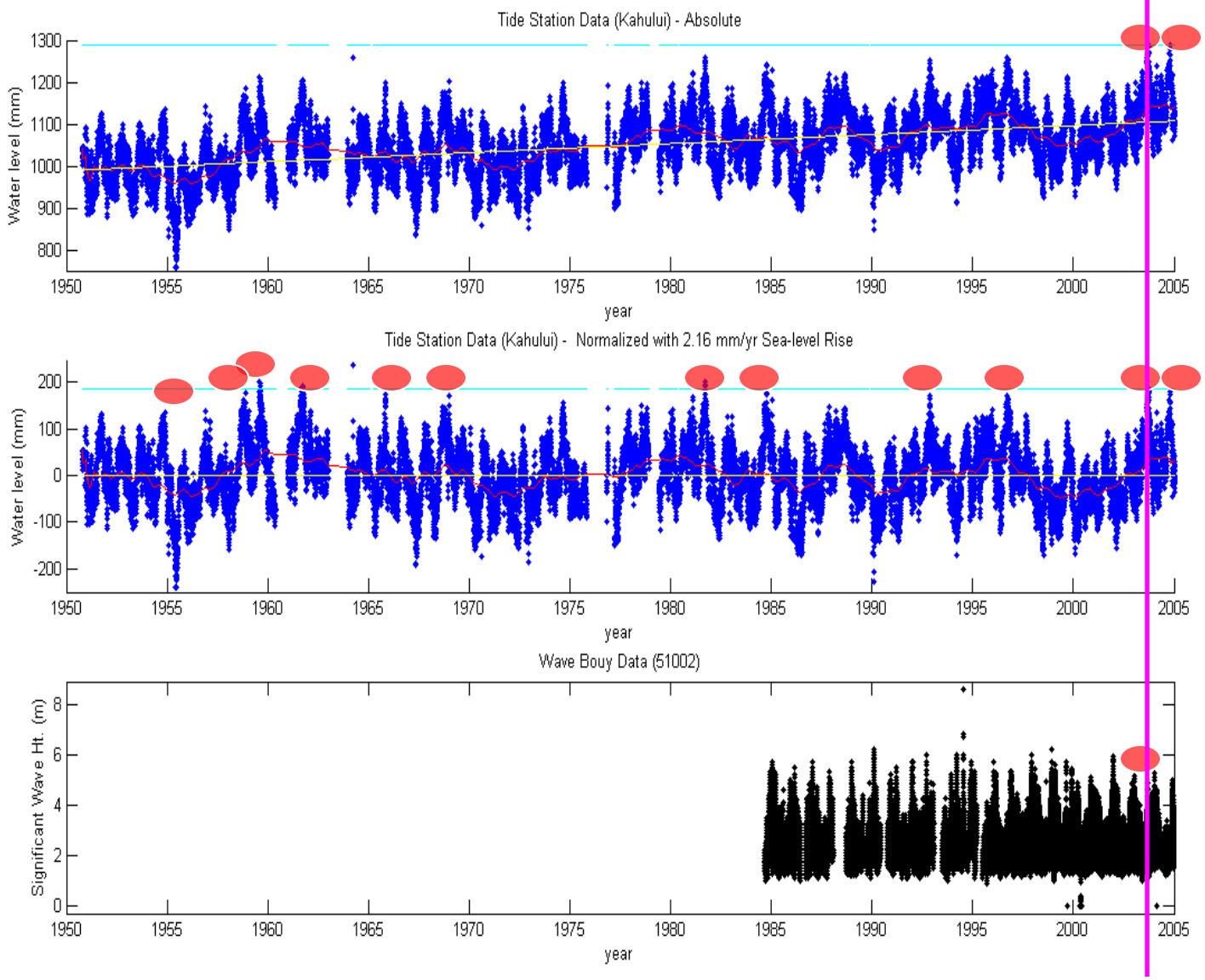
The tides (highly variable range depending on location) cause locally rising and falling sealevel

If high tides coincide with other processes that cause sea level to rise at the coastline, then the destructive impact of the latter will be greater than in the absence of the tide.

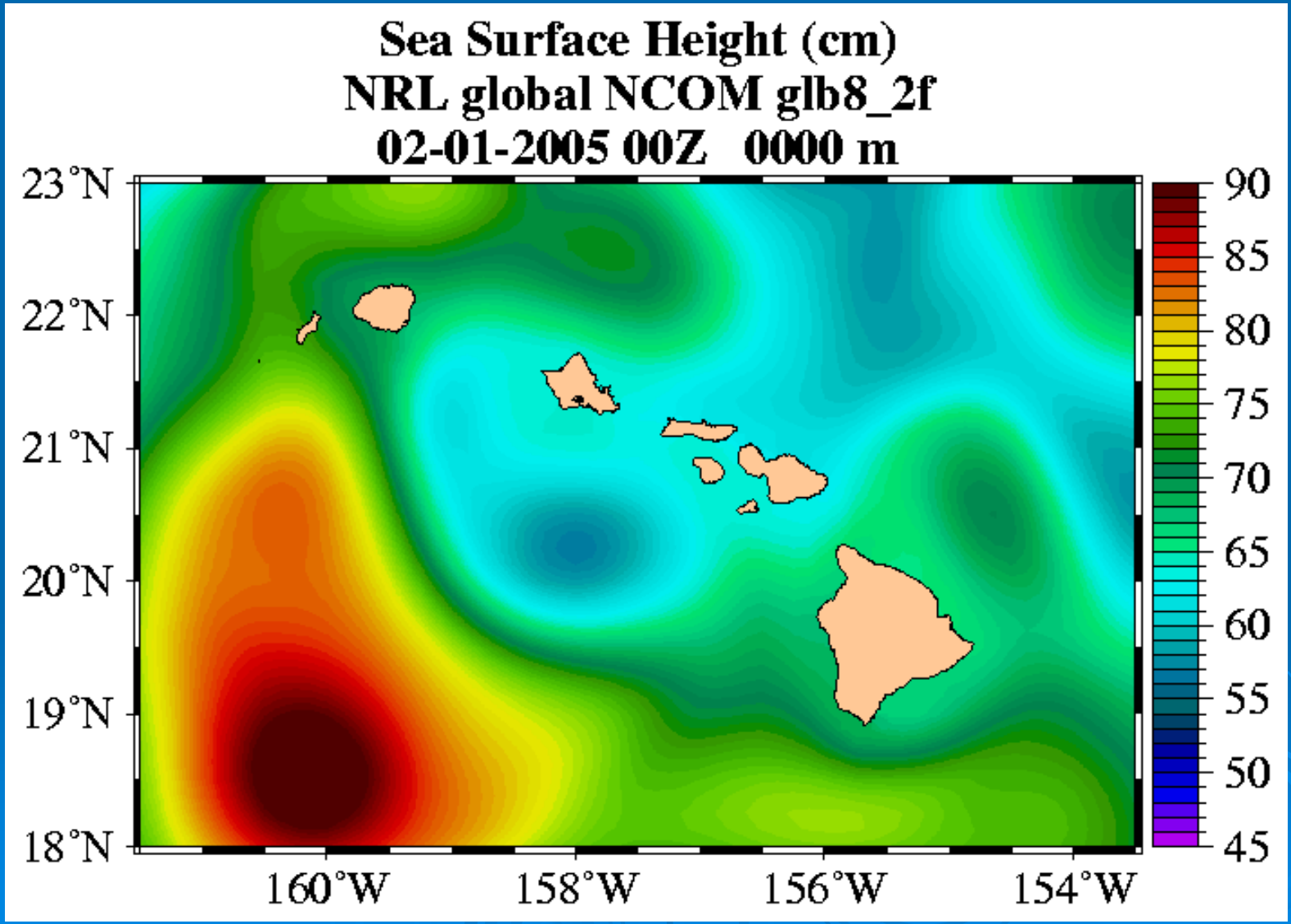
Extreme Tides



Extreme Tides



Mesoscale Eddies

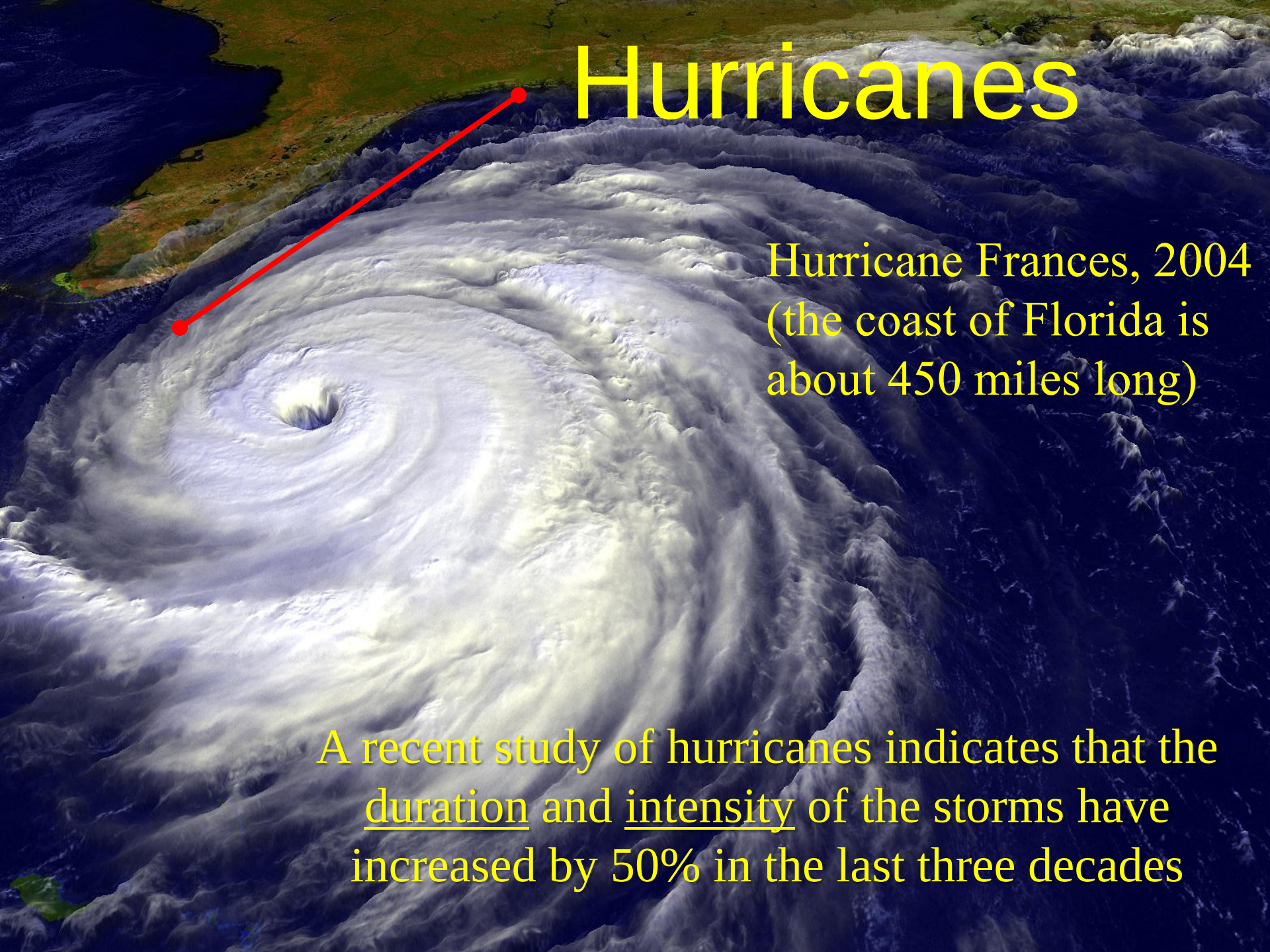


Effect of waves and tides

Top left to bottom right… October-January-February in Capitola, California

Extreme Tides

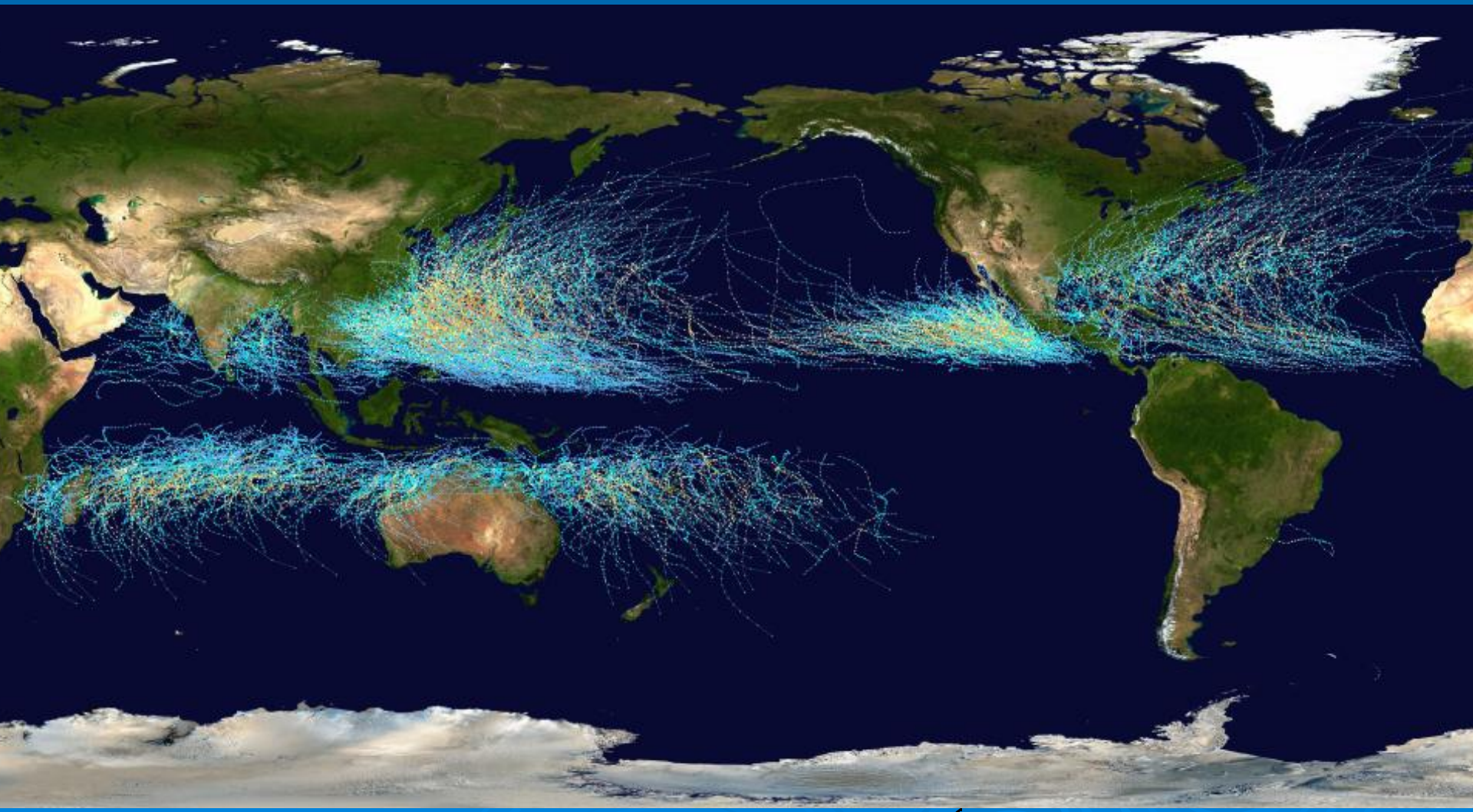
Hurricanes



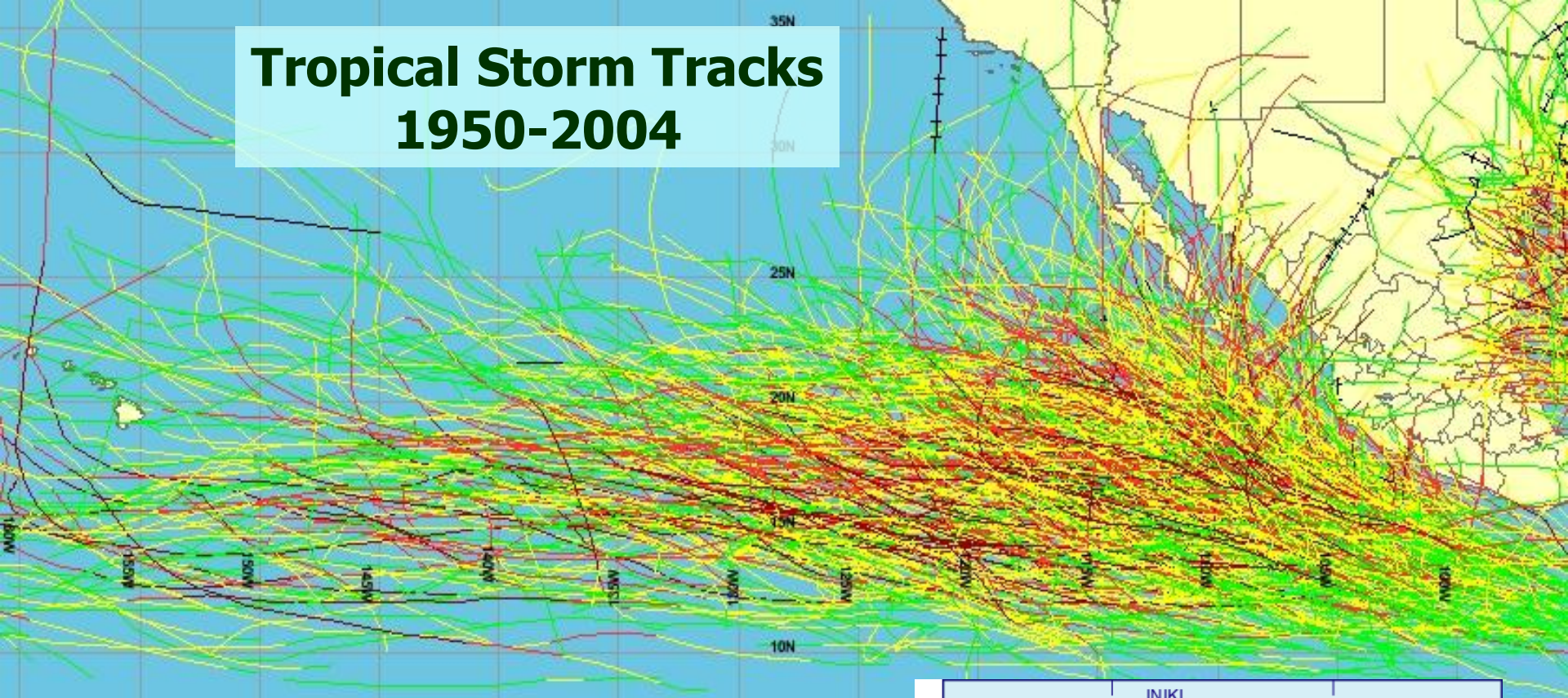
Hurricane Frances, 2004 (the coast of Florida is about 450 miles long)

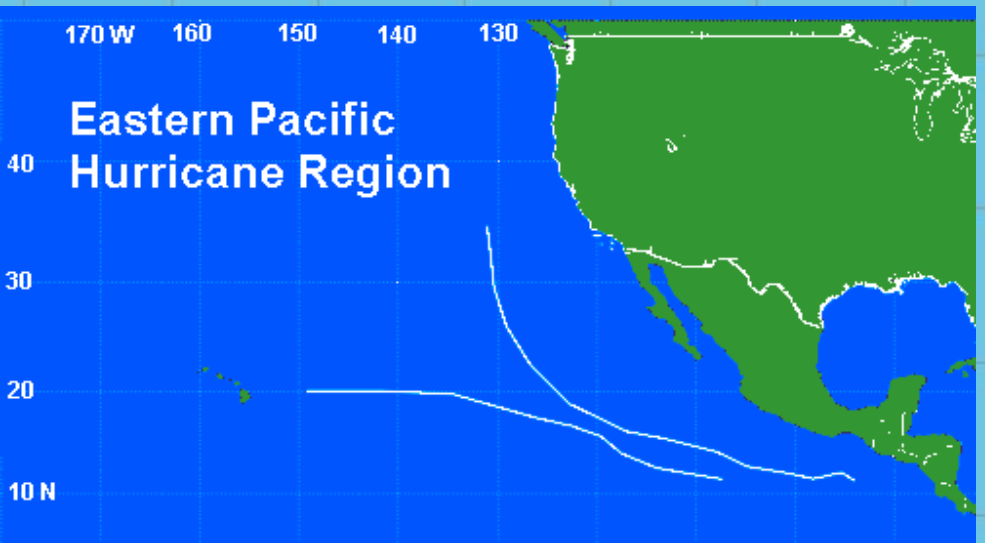
A recent study of hurricanes indicates that the <u>duration</u> and <u>intensity</u> of the storms have increased by 50% in the last three decades

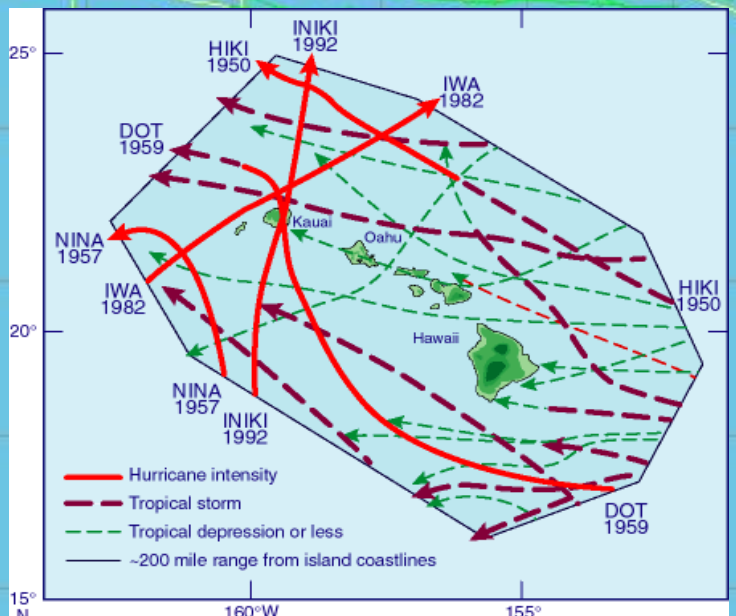
Hurricane Tracks



Tropical Storm Tracks 1950-2004

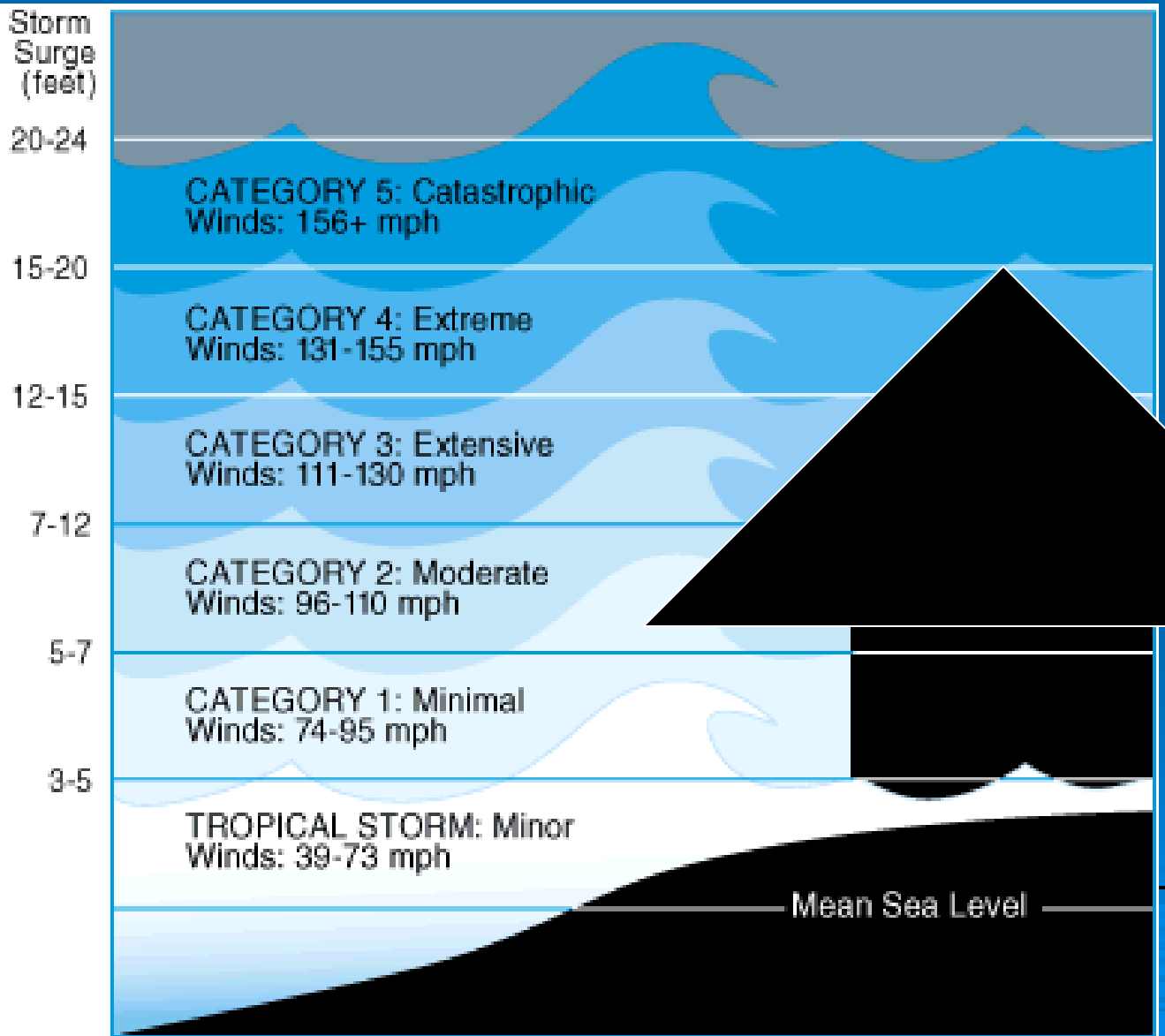







Hurricane Iniki storm surge debris line

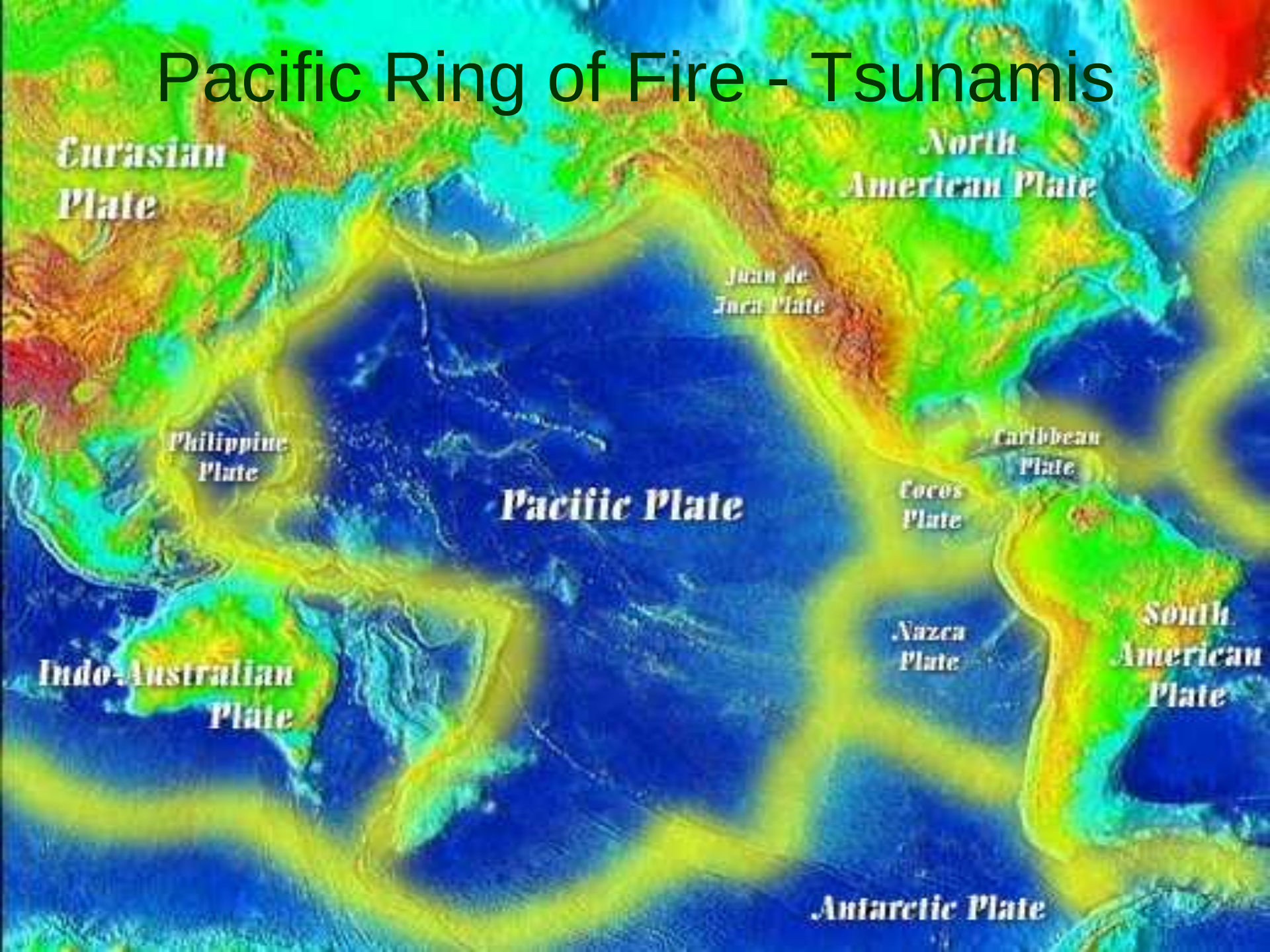
Storm Surge and Wind Damage



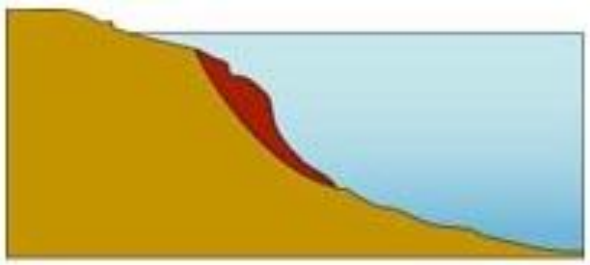
Storm surge claims 9 out of 10 hurricane victims

- **Tide level**
- **Wind shear**
- **Atmospheric pressure**
- **Wave height**
- **Wave set-up**

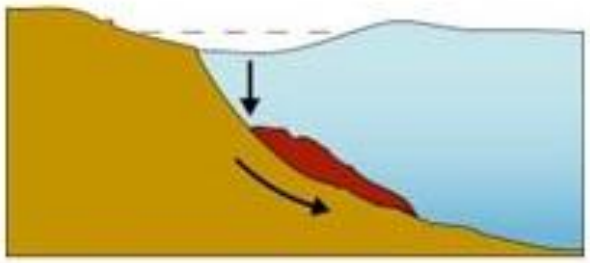
Pacific Ring of Fire - Tsunamis

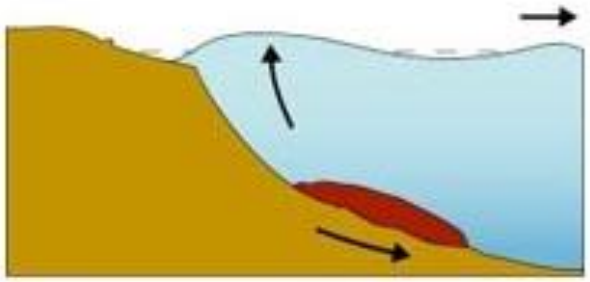


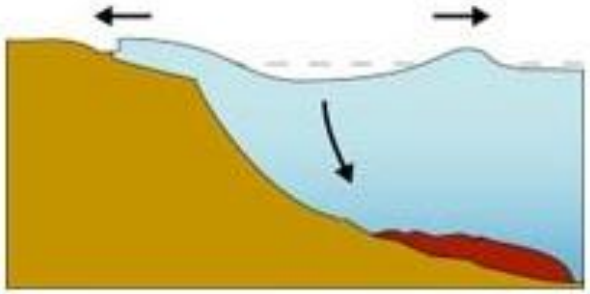
Tsunami – caused by any sudden movement of the seafloor



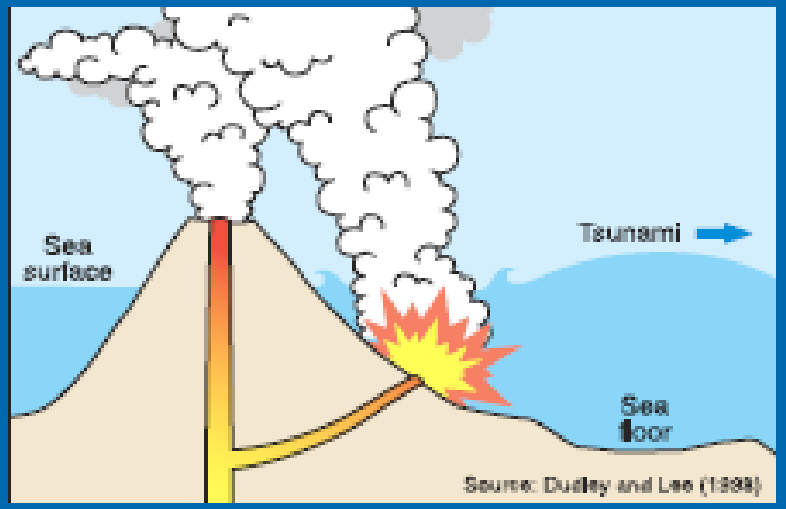
Submarine landslide



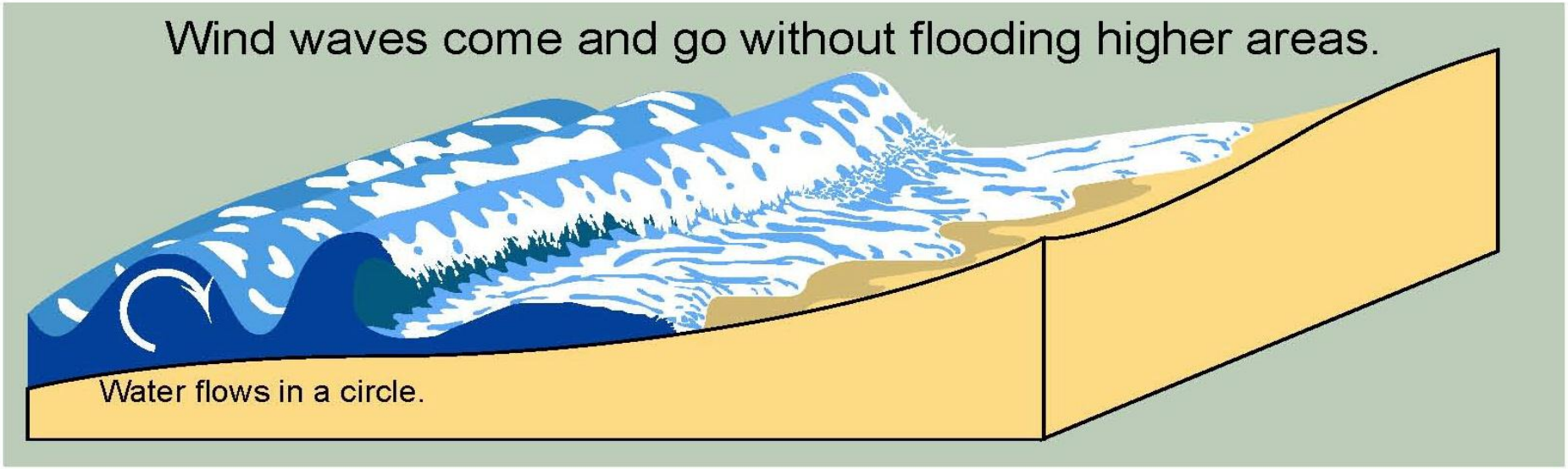


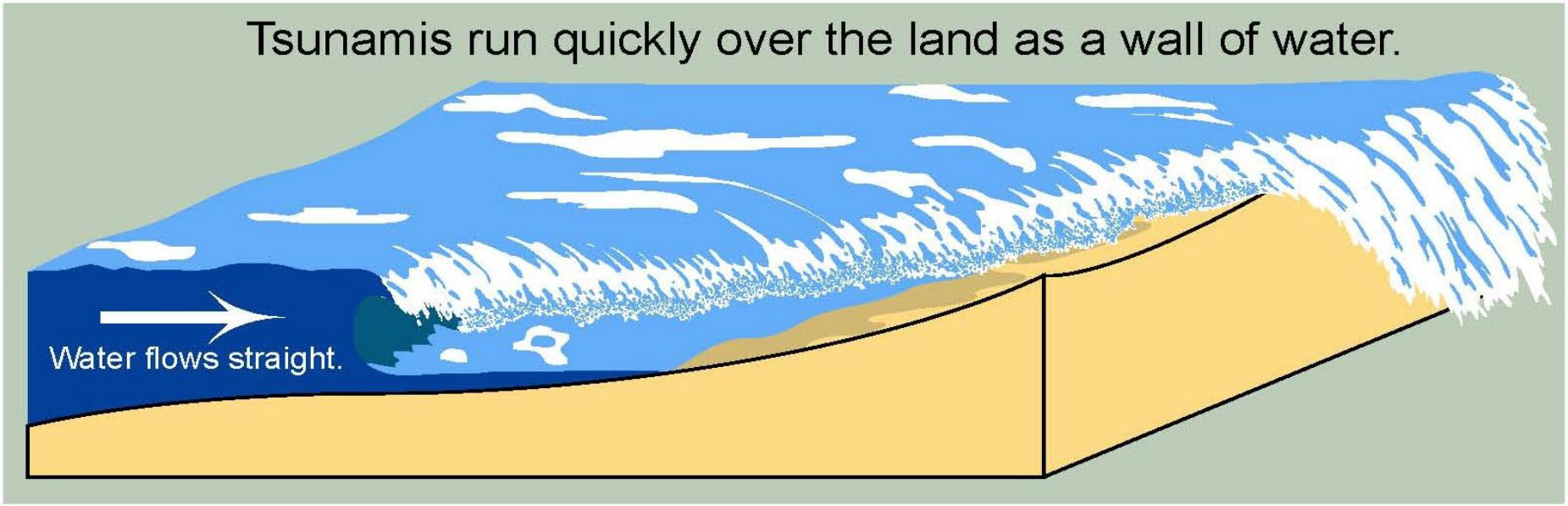


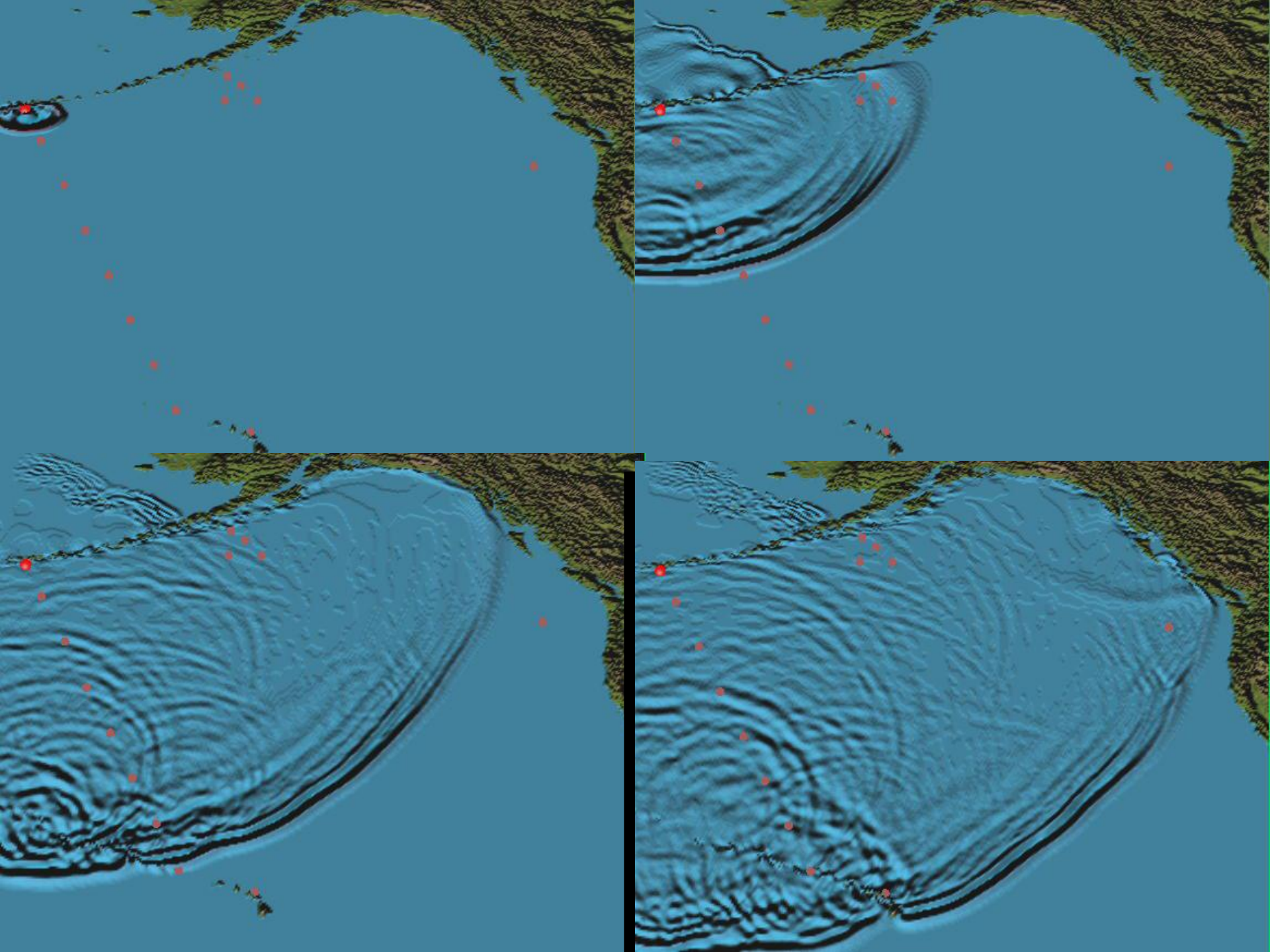
Submarine eruption

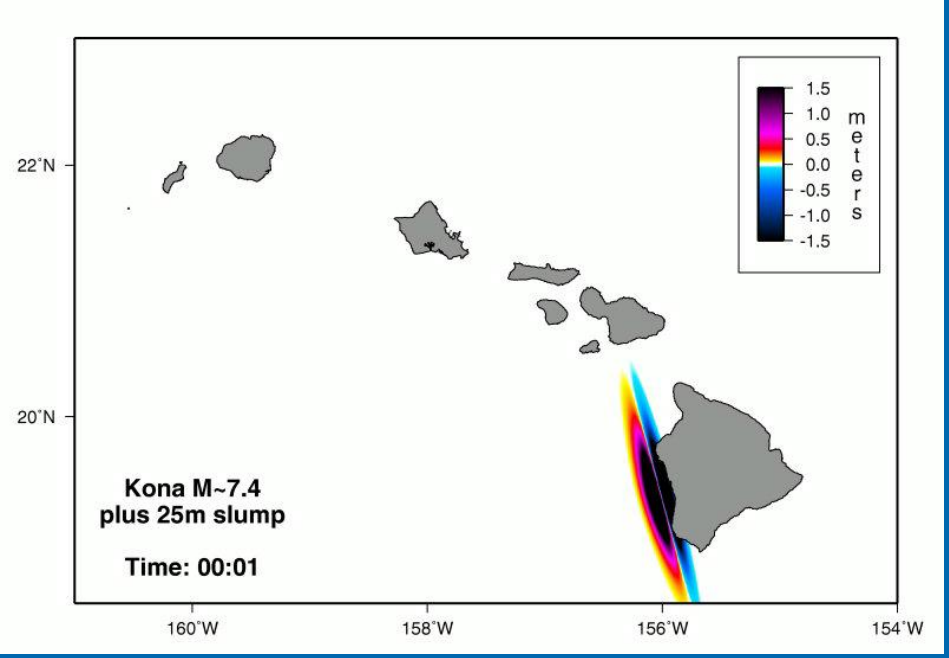


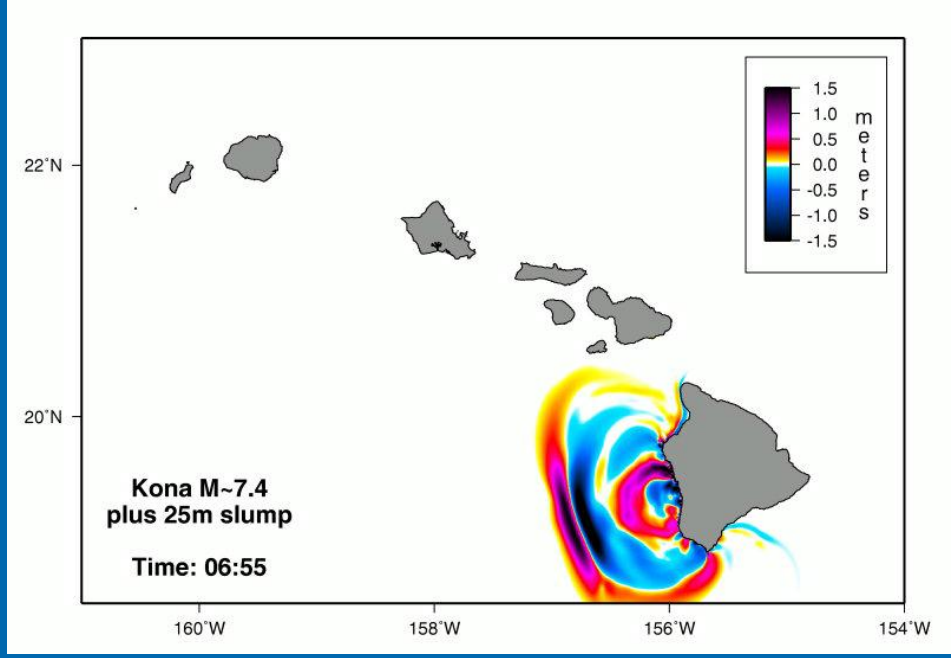
Shaking
Jolting
Faulting


Wind waves come and go without flooding higher areas.
Water flows in a circle.

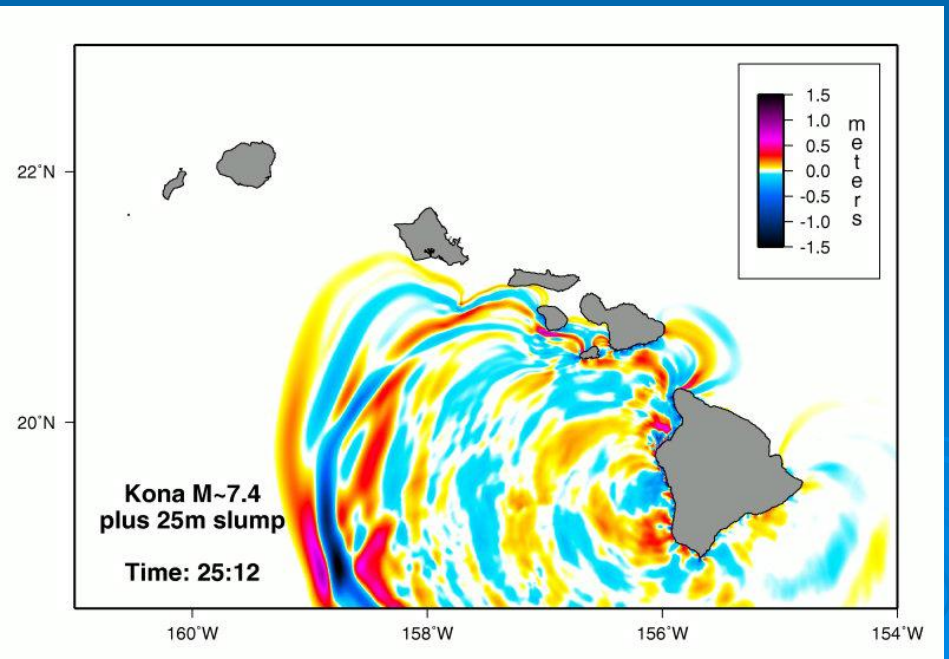

Tsunamis run quickly over the land as a wall of water.
Water flows straight.

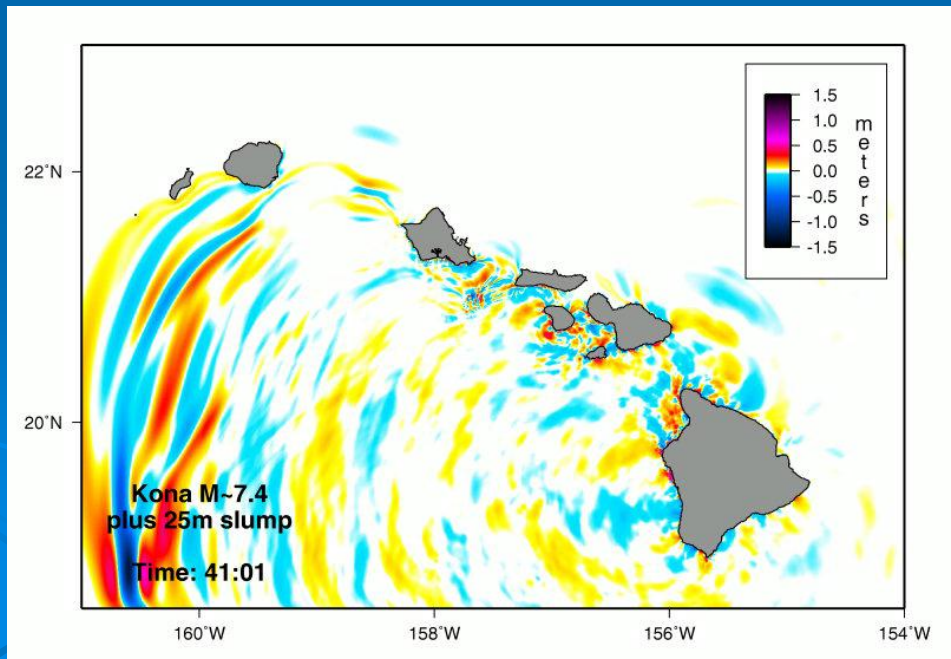


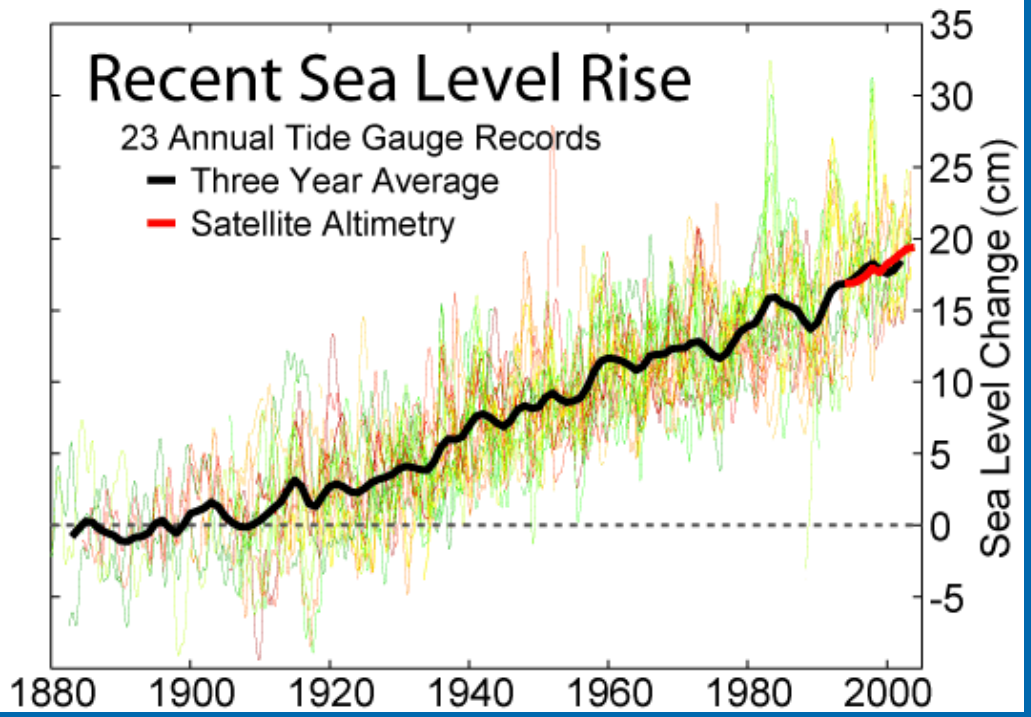




An earthquake in Kona could generate a wave hitting Waikiki in 30 minutes.

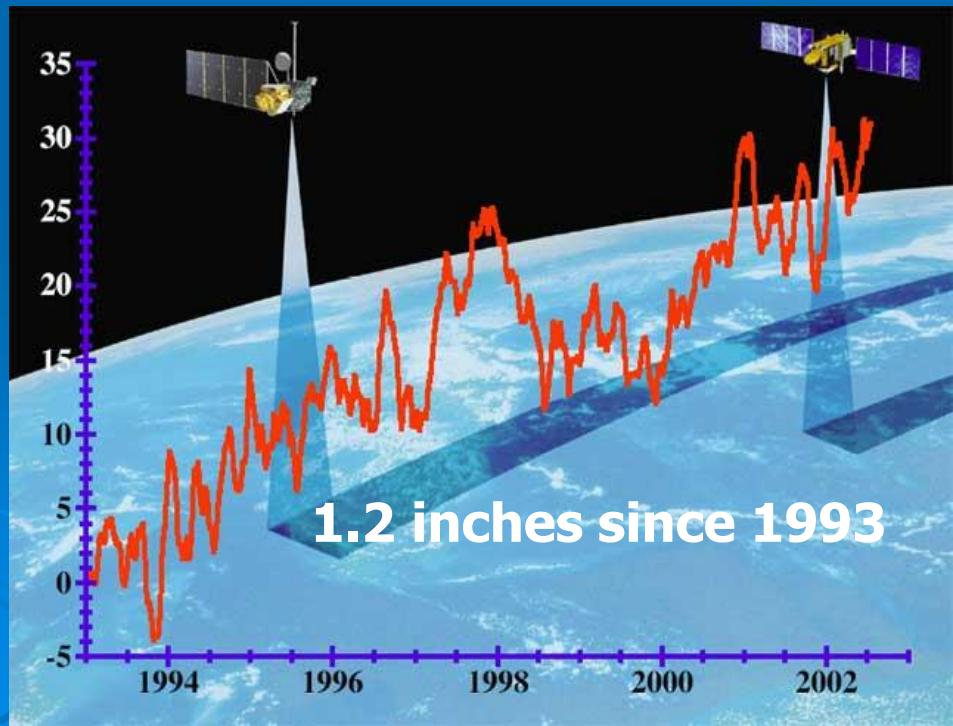






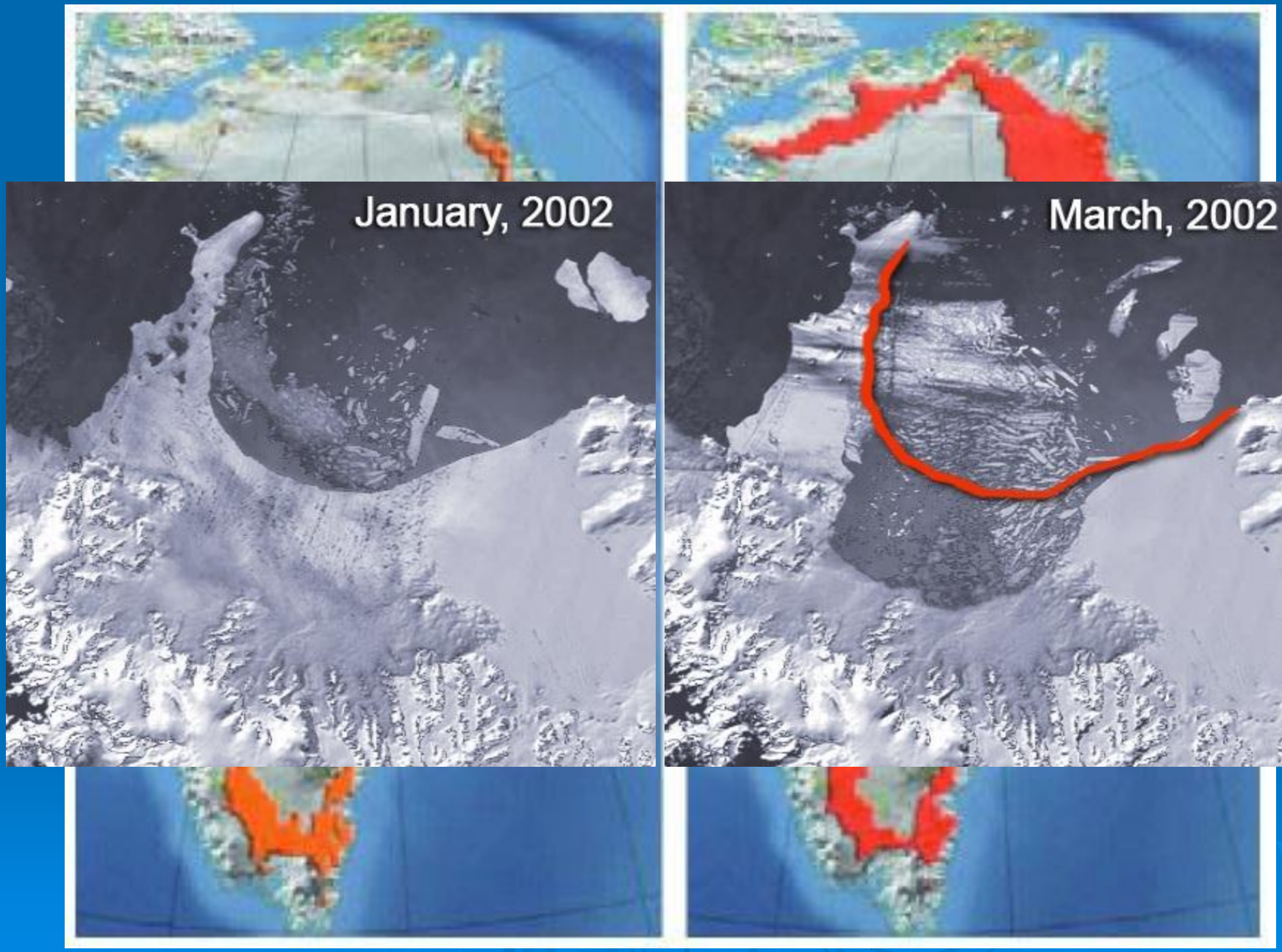
Sea level has been rising for several centuries…

…and will continue to rise for several centuries into the future

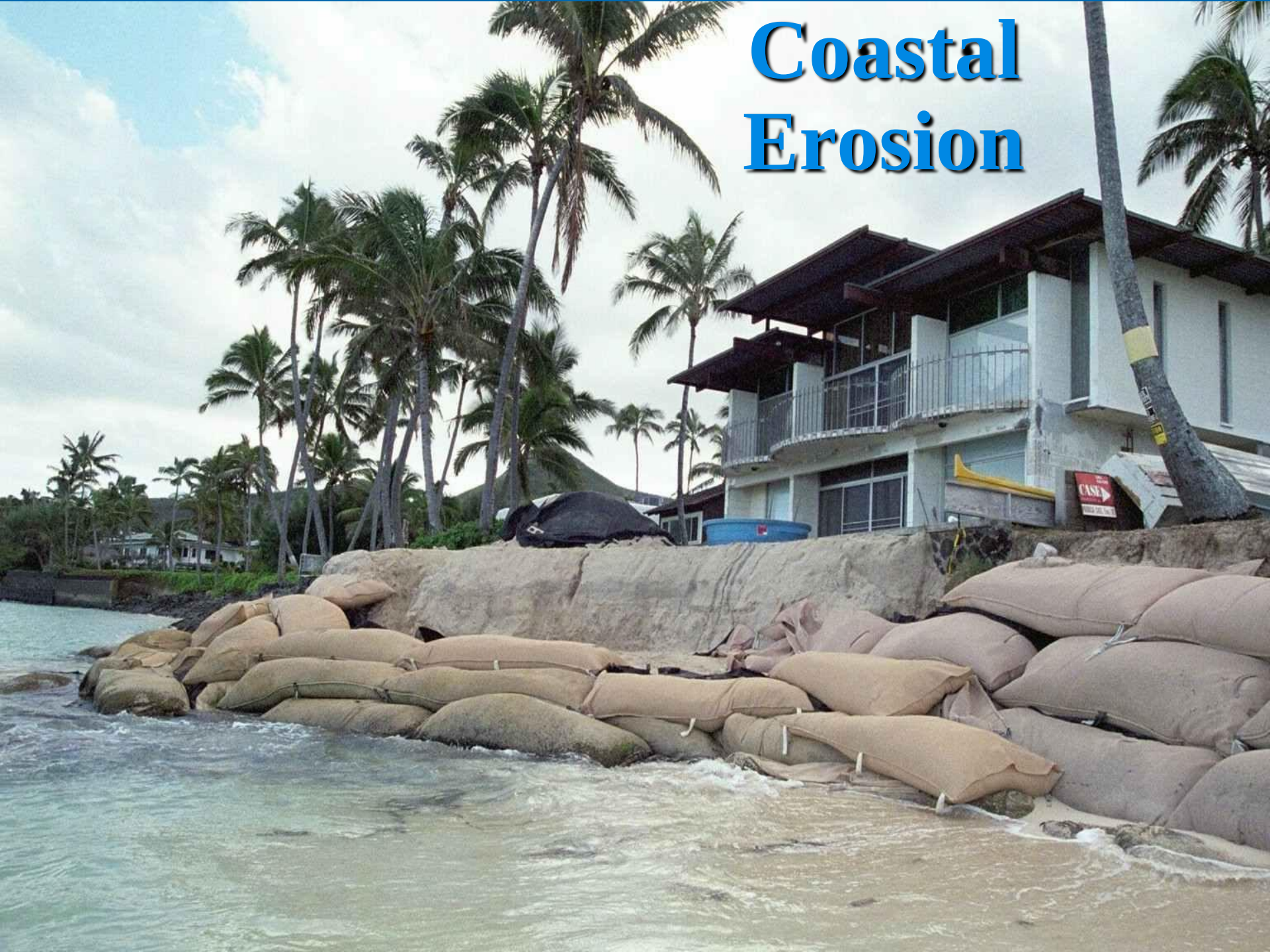


Sandy shorelines erode ~100 increments for every 1 increment of sea-level rise.

For a 1 m rise by 2100, beaches will recede ~100 m (over a football field!)


January, 2002
March, 2002

Coastal Erosion



Erosion of Coastal Areas Occurs:

- where a beach has an insufficient supply of sand to replenish loss from coastal processes
- when large (seasonal) waves and storm surge remove sand, some of which is not returned when waves subside
- when rising sea level causes a beach to migrate landward and erode the dune/land behind it
- when humans interfere with the natural sand supply, often resulting in sand starvation of the beach

All of the above drive a beach to seek new sand, usually by eroding the adjacent land

When erosion affects a coast, the traditional reaction has been to build a seawall or a groin.

When seawalls are built on coasts experiencing chronic erosion, the beach will disappear

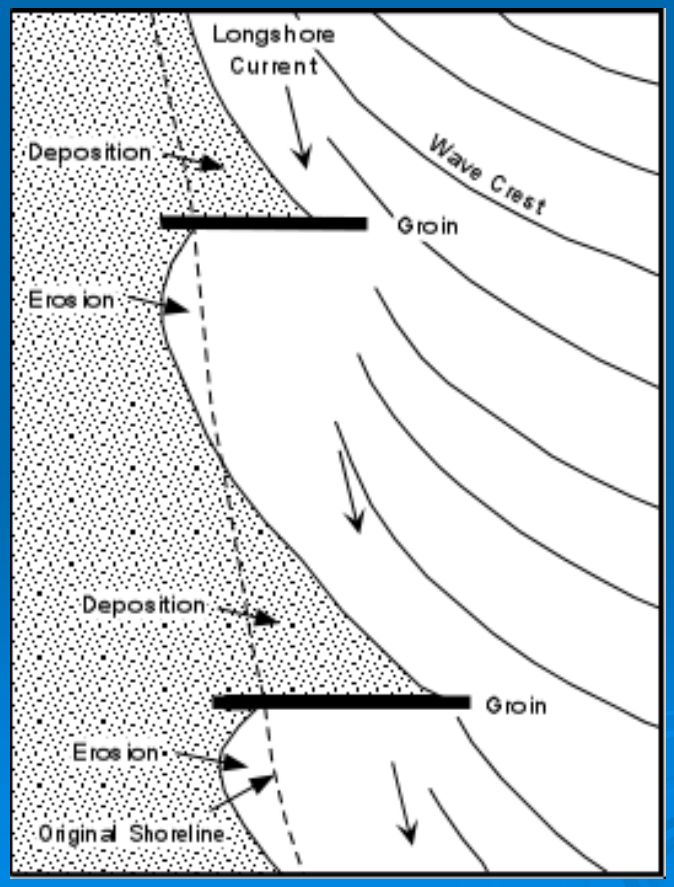
Seawalls worsen erosion by impounding dune sand.

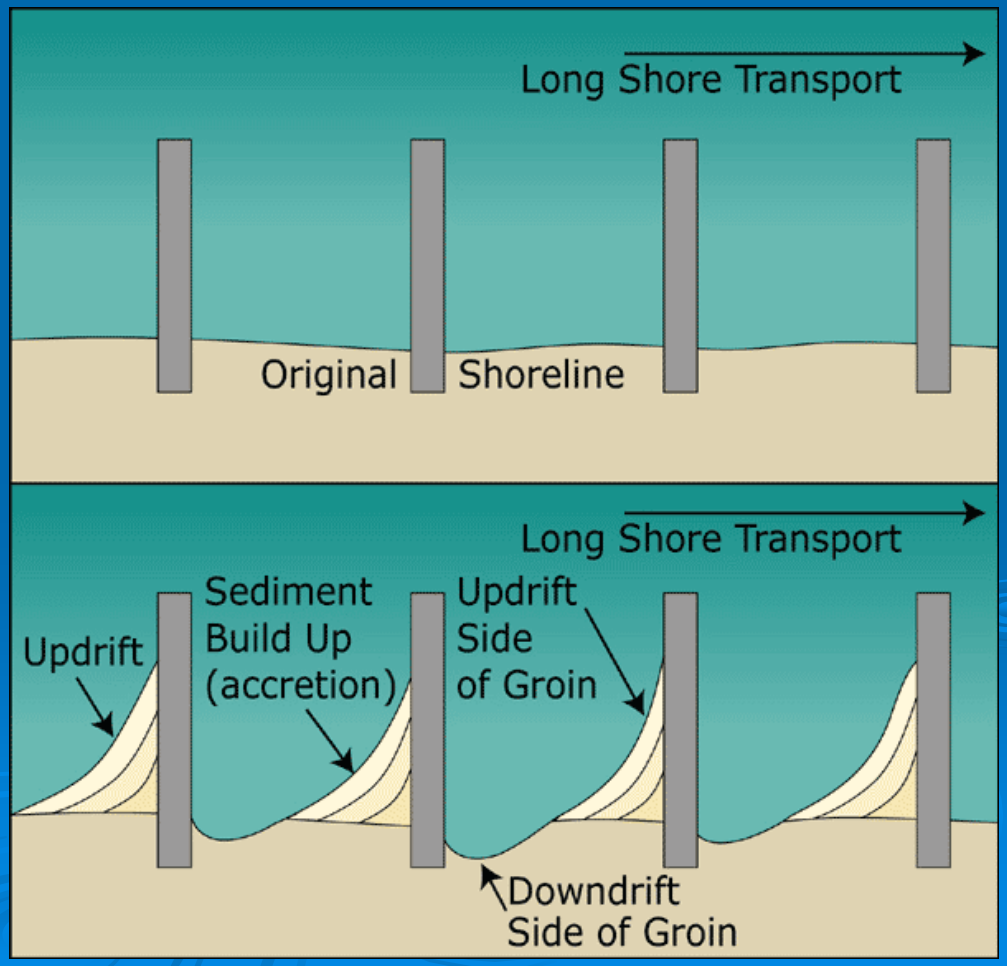
This starves the beach, often leading to accelerated erosion on adjoining beaches – widespread beach loss can develop

Coastal dunes are a storehouse of sand that can replenish the beach

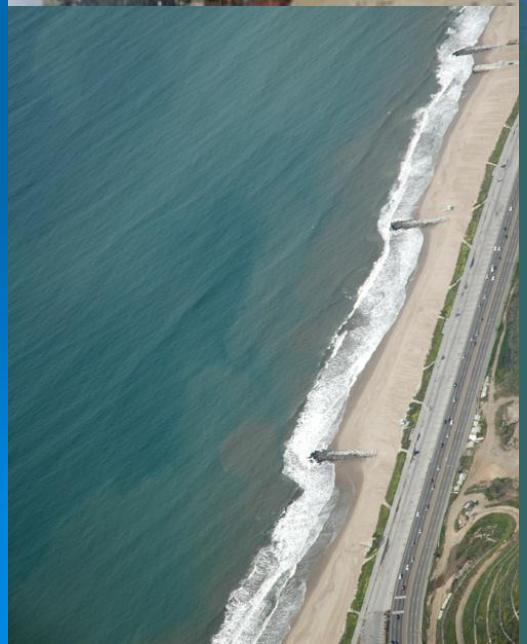
Groins

- Groins cause differential erosion because of how they impact water flow and interrupt longshore transport of sand





Groins on Continental Beaches



Mitigating Coastal Hazards

Avoidance-
Build up and away from the beach

Mitigating Coastal Hazards

Beach restoration-
Nourish with sand


Kona waterfront, restored


Kona waterfront

Coastal Erosion on O`ahu

Oahu 60 yr Erosion Hazards: Selected sites

Sunset Beach

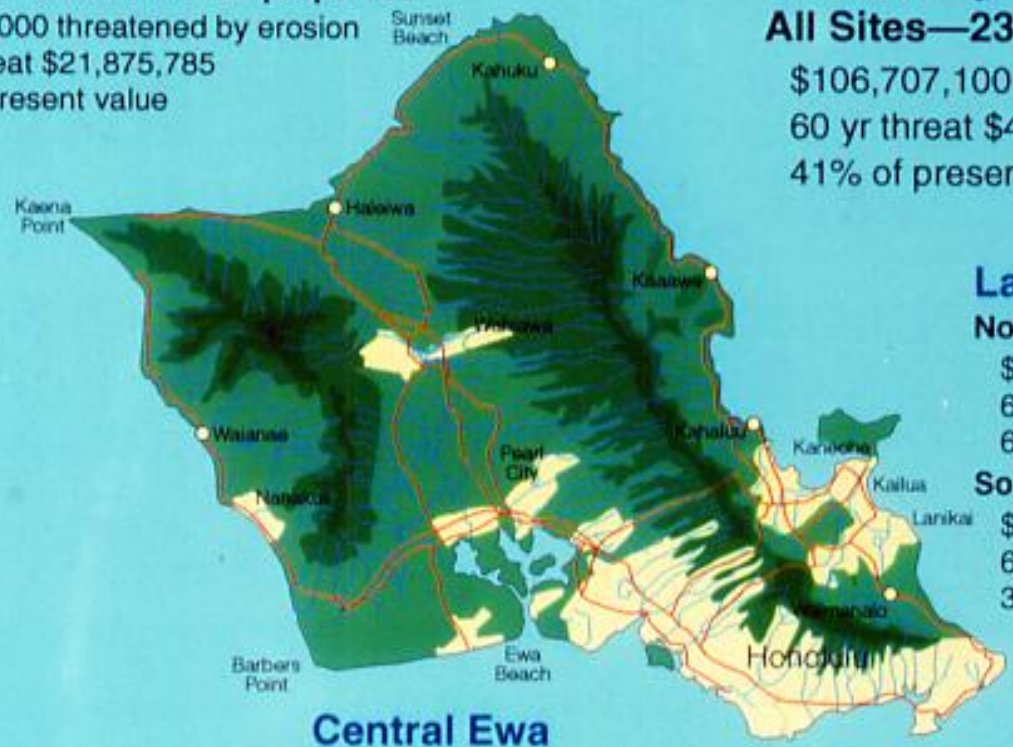
Pupukea to Sunset Pt—121 properties

$47,568,000 threatened by erosion
60 yr threat $21,875,785
46% of present value

Summary

All Sites—232 properties

$106,707,100 threatened by erosion
60 yr threat $43,452,805
41% of present value



Lanikai

North Lanikai—17 properties

$9,453,500 threatened by erosion
60 yr threat $6,212,660
66% of present value

South Lanikai—31 properties

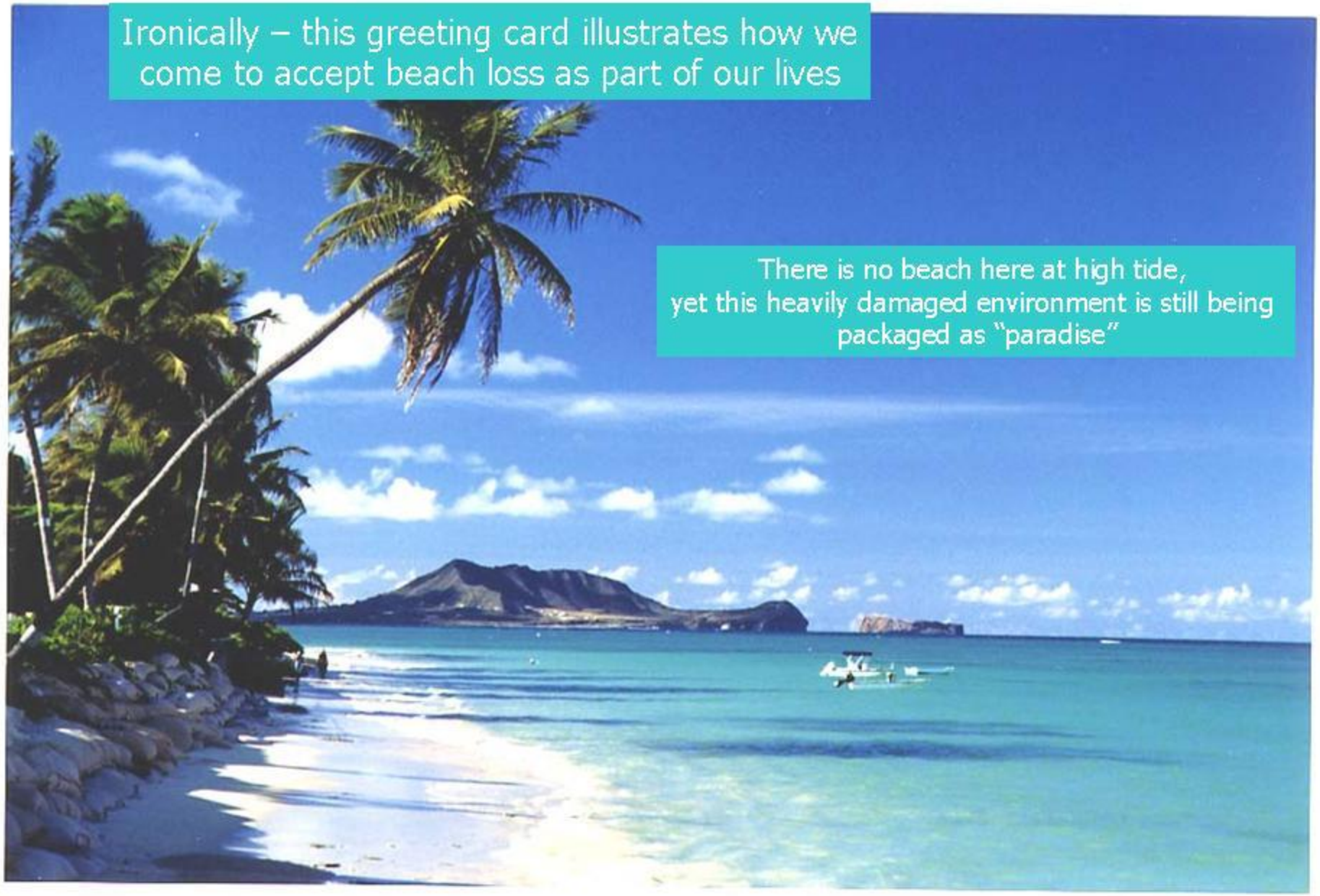
$25,137,500 threatened by erosion
60 yr threat $8,600,320
34% of present value

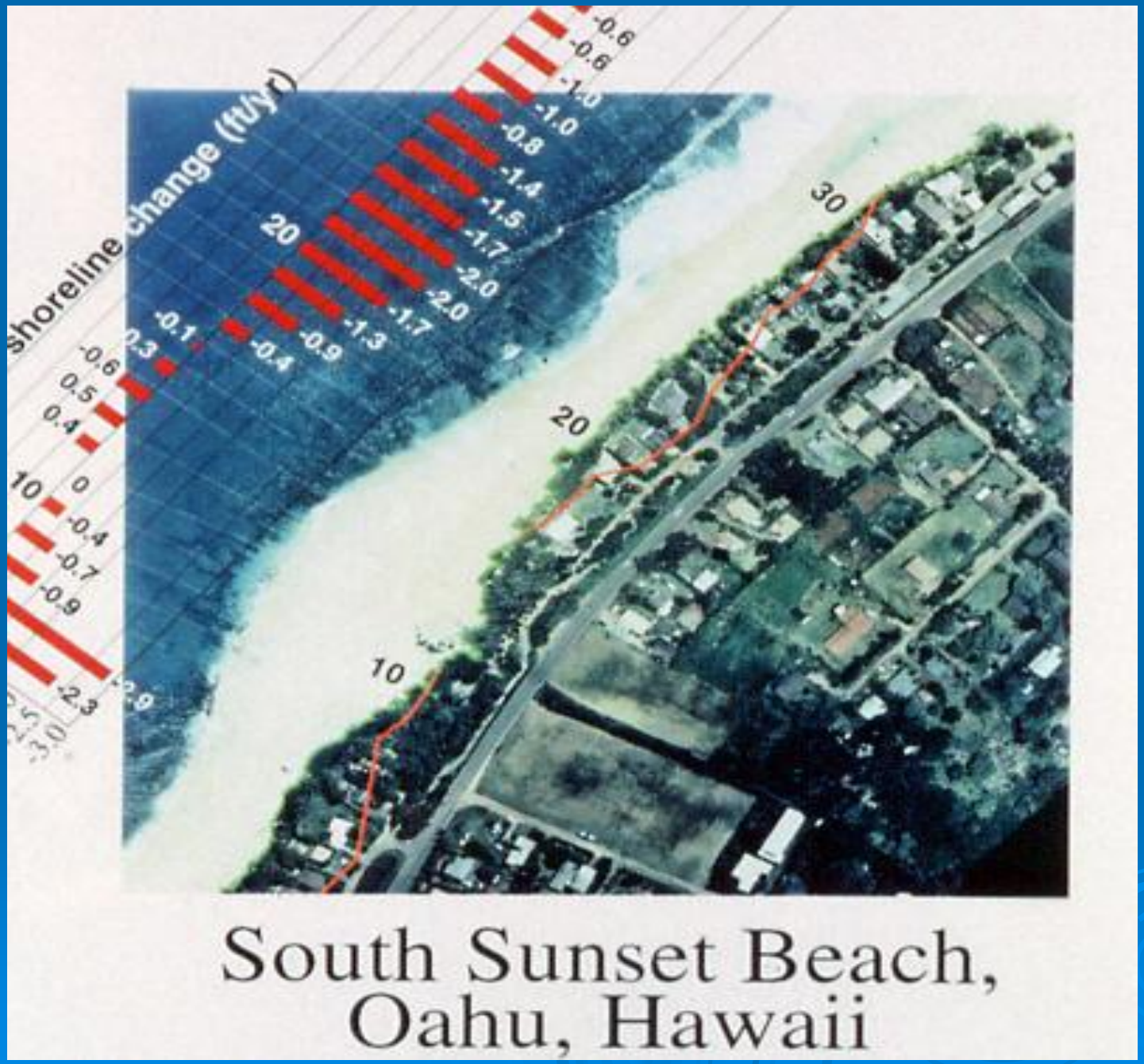
Central Ewa

Ewa Beach Road— 63 properties

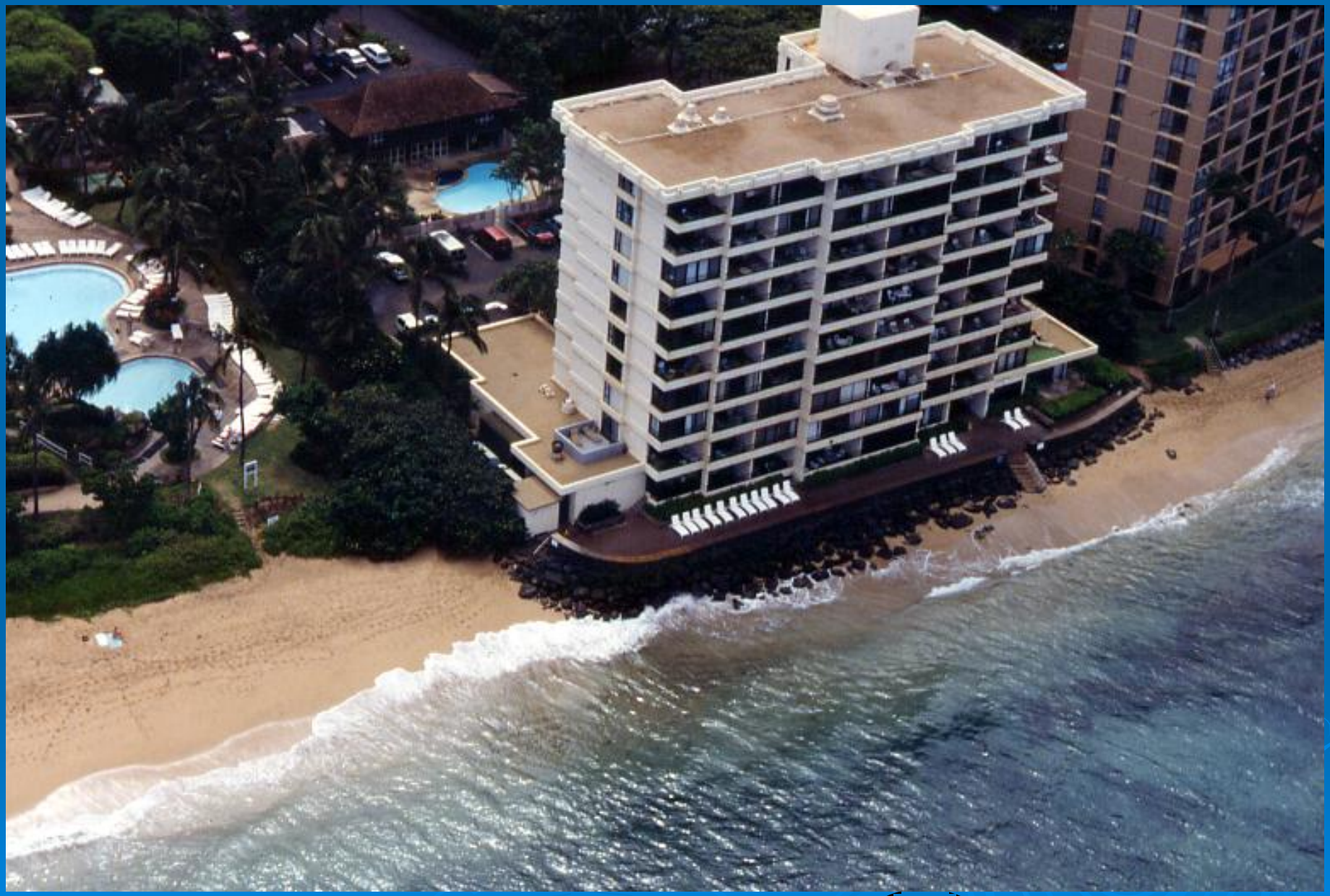
$24,548,100 threatened by erosion
60 yr threat $6,764,040
28% of present value

Note: Land values as of ~2000 (ten years ago)

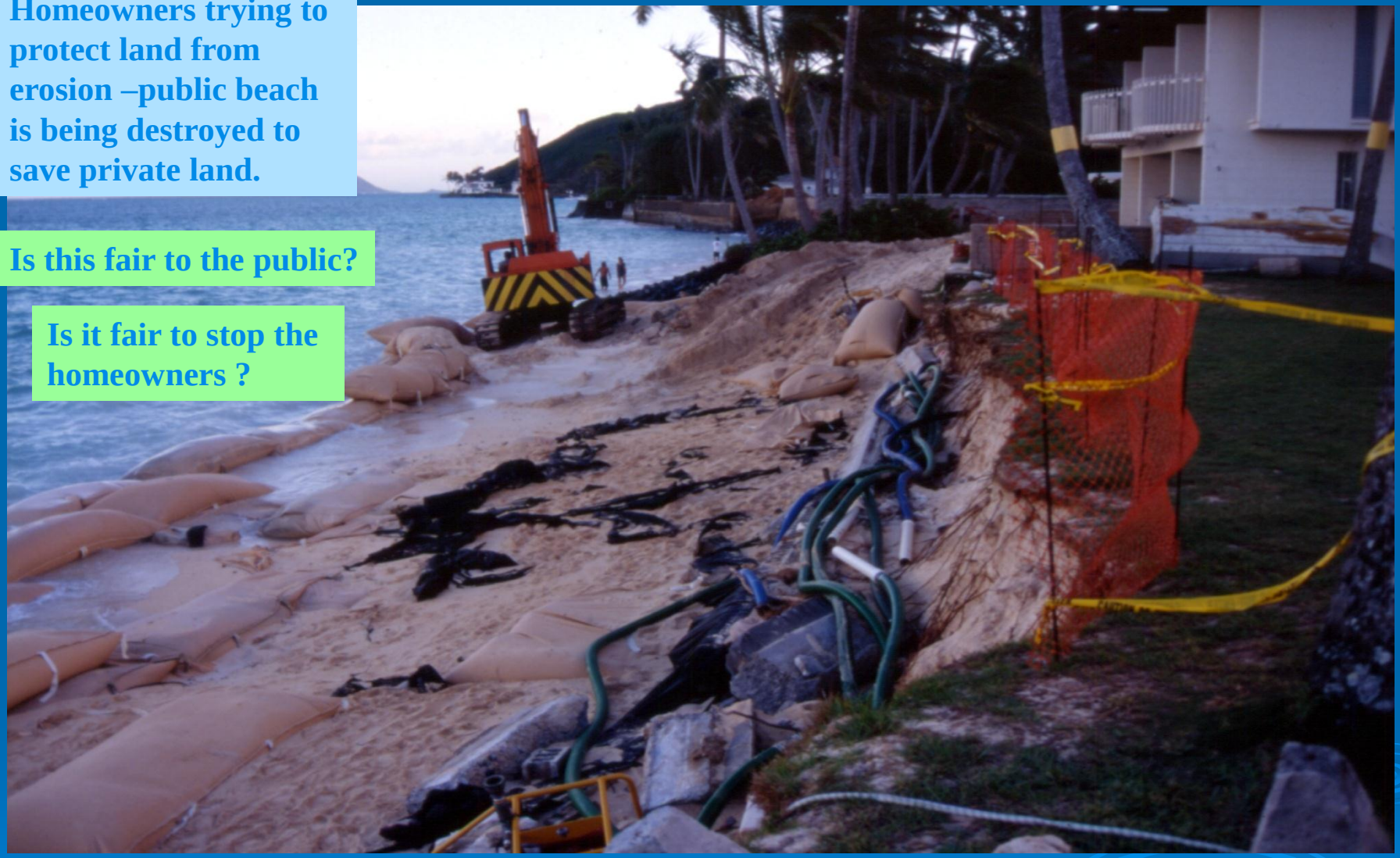

Ironically – this greeting card illustrates how we come to accept beach loss as part of our lives
There is no beach here at high tide, yet this heavily damaged environment is still being packaged as "paradise"
Lanikai Beach
Kailua



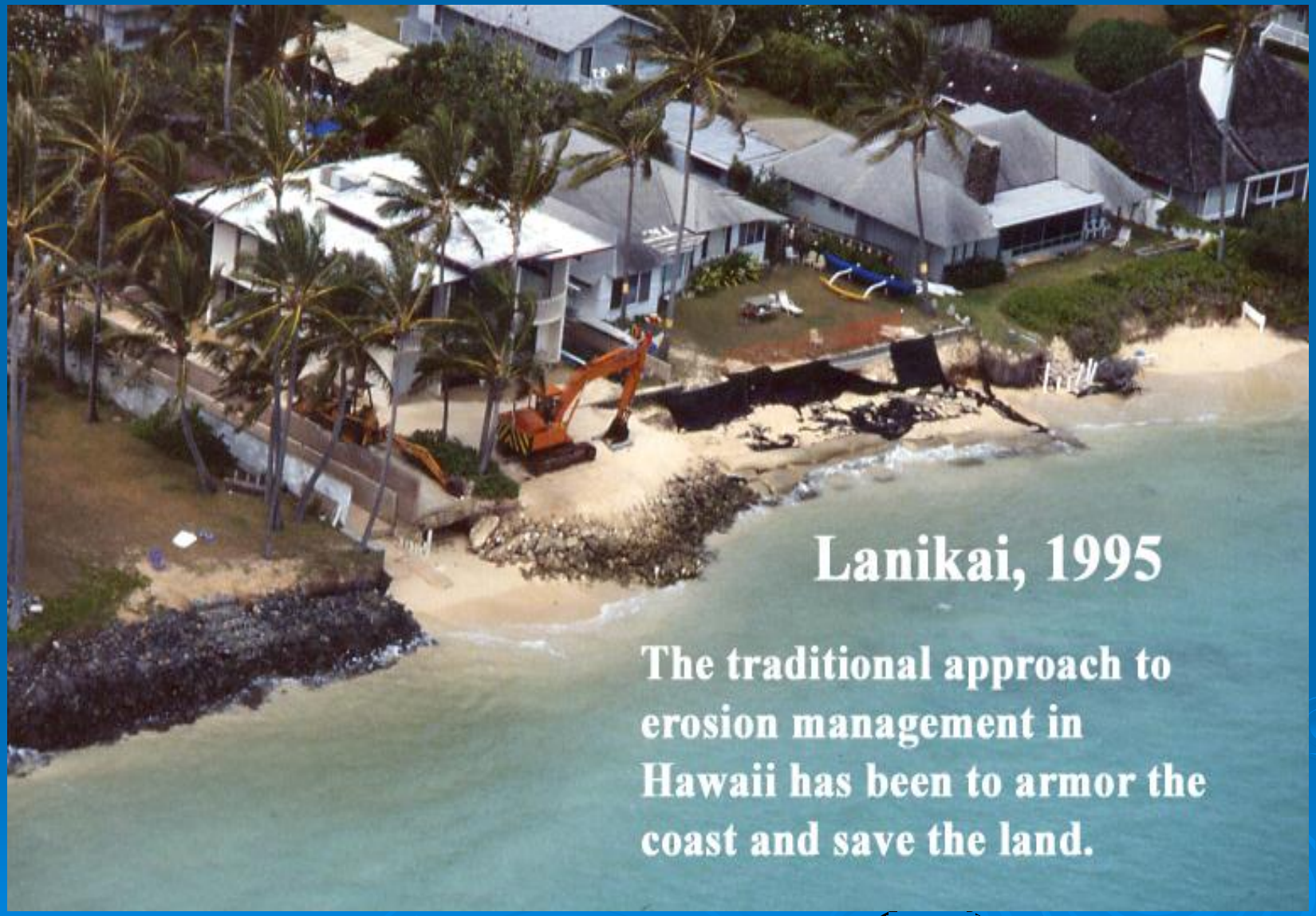
FEMA National coastal erosion study of 60 year erosion hazard, 1996



An example of chronic coastal erosion



Chronic coastal erosion is a statewide problem


Lanikai, 1995
The traditional approach to erosion management in Hawaii has been to armor the coast and save the land.

This beach is eroding because the wall traps sand.

Hardening

Seawalls are constructed where there is erosion, but they do not solve the erosion, they simply protect the land without protecting the beach.

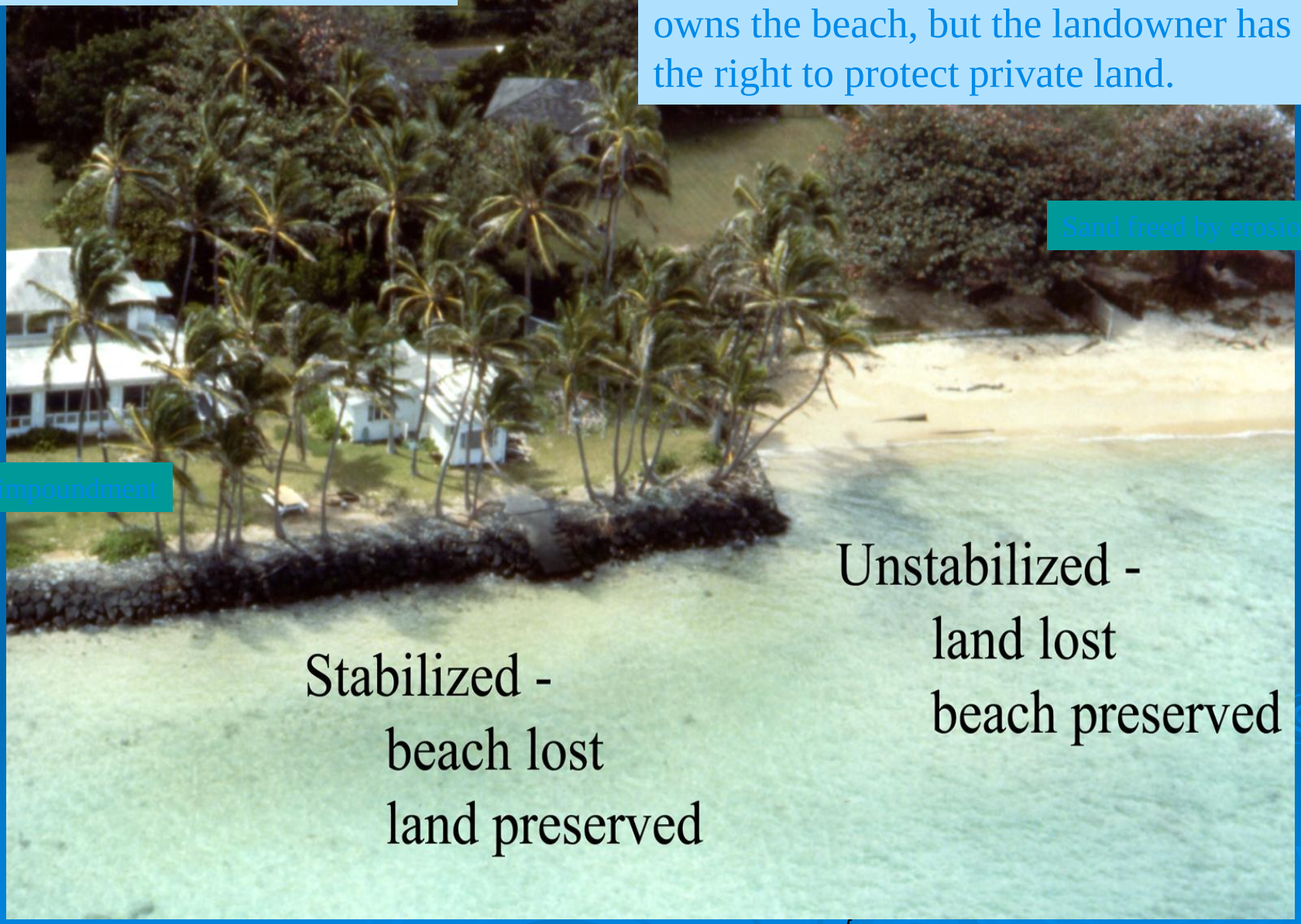
This would be a wide beach without the wall.

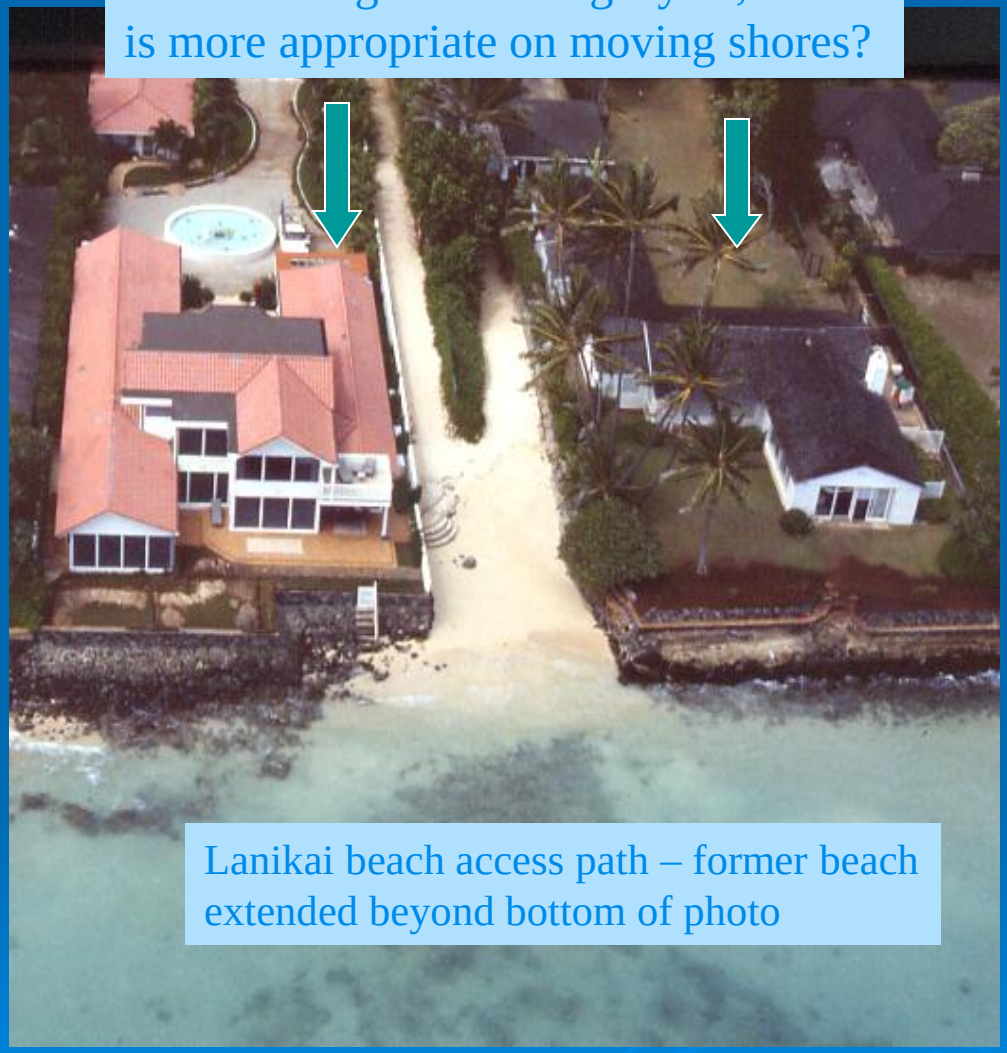
Many Hawaiian beaches suffer erosion because their dunes were destroyed (even before seawalls were built)

Coastal dunes are a storehouse of sand that can replenish the beach

Private rights vs. public rights

Whose rights should prevail? The public owns the beach, but the landowner has the right to protect private land.



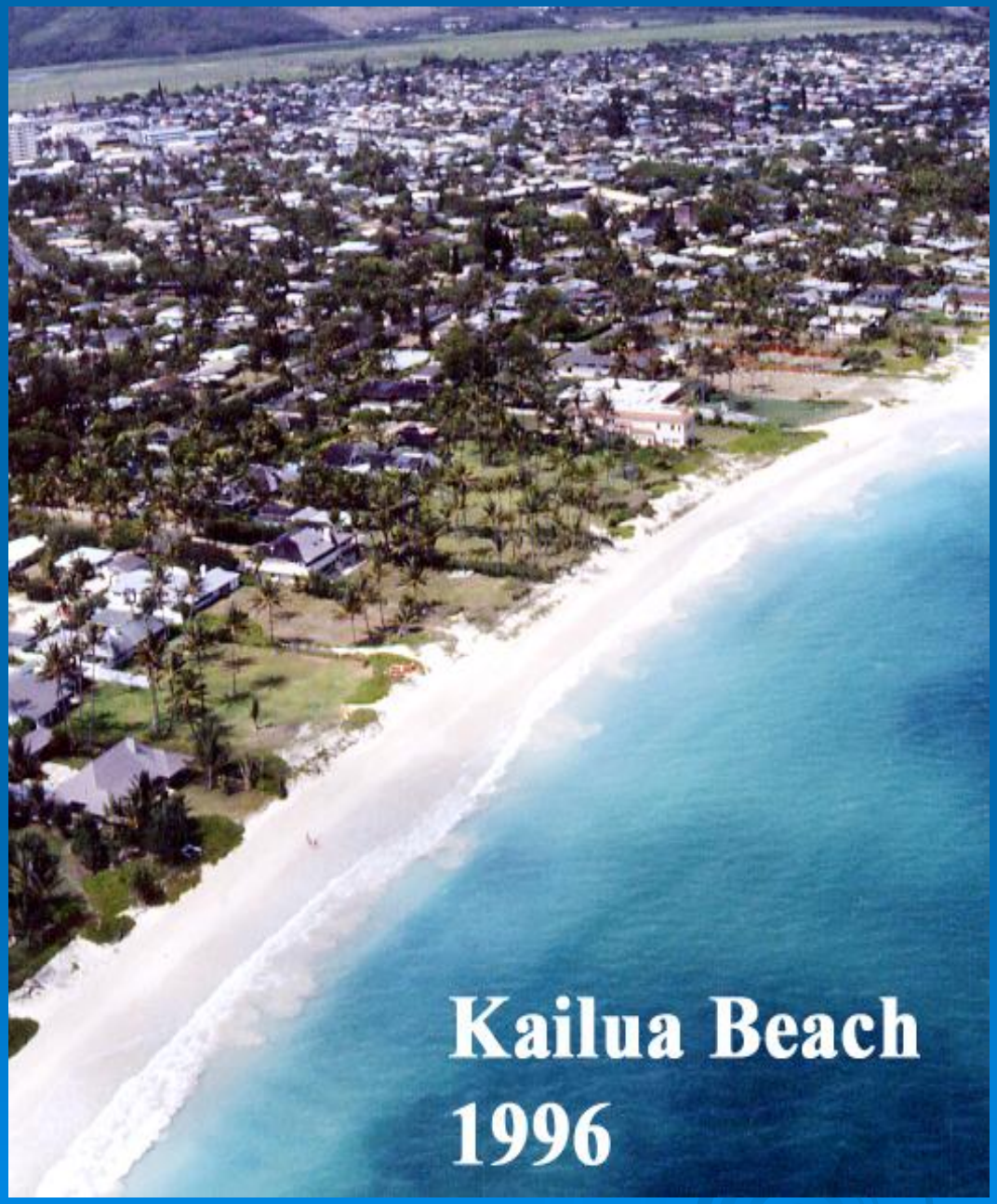


Beach Loss

17 miles on Oahu
9 miles on Maui
Beaches are 50-75% narrower in front of walls

Impacts

Access to the Ocean is lost
Marine ecosystem is damaged
Dune plants and ecosystem damaged
Cultural practices with Ocean are lost
Tourism economy impacted



Present setbacks do not offer adequate protection

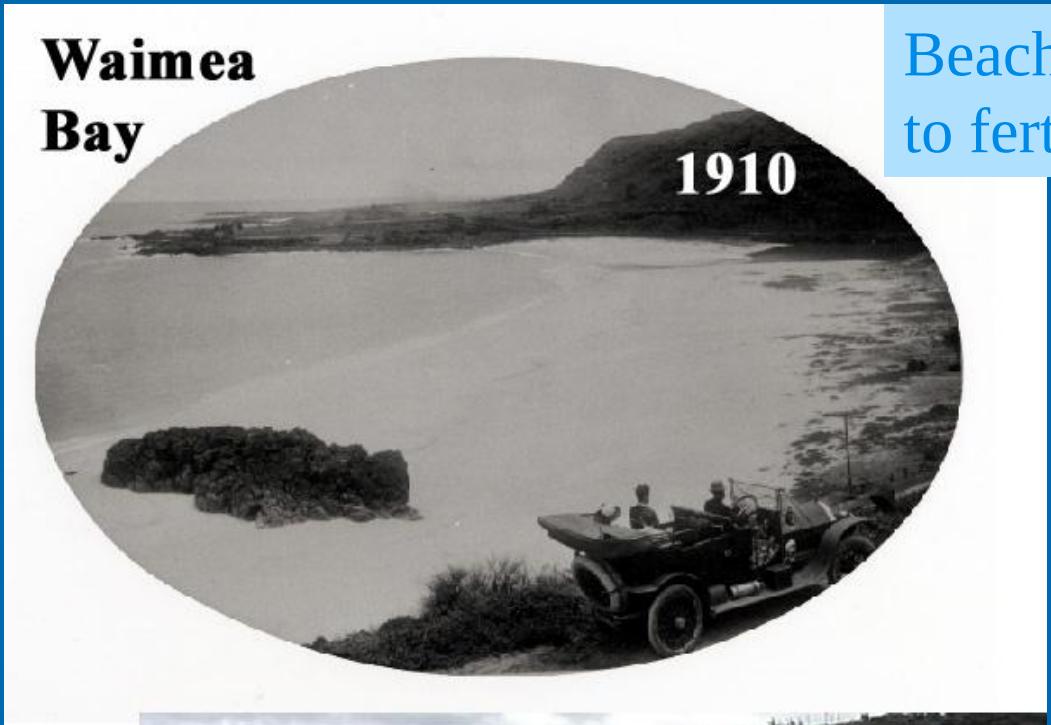
Older lots are being subdivided, development density continues to rise on all shores

Despite recommendations of many studies, SMA rules still fail to discriminate chronically eroding shores, and zoning ordinances make no allowance for long-term erosion trends and rates

Tourism supports over 60% of Hawaiian jobs.
As visitors see beaches disappearing, they may not return.

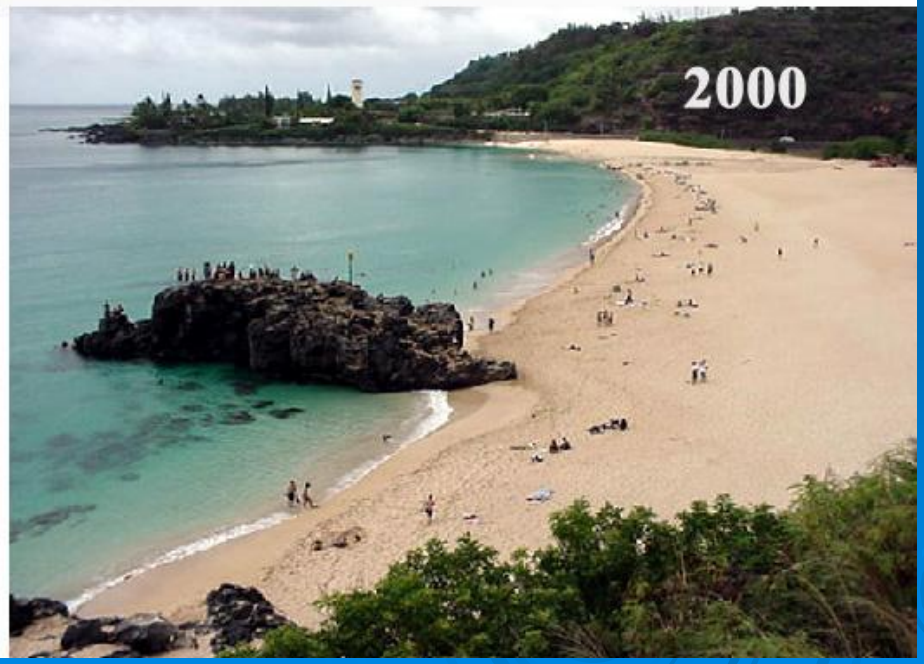
Erosion is caused by

1. Human impacts to sand availability
2. Waves and currents moving sand
3. Sea-level rise, forcing shoreline retreat

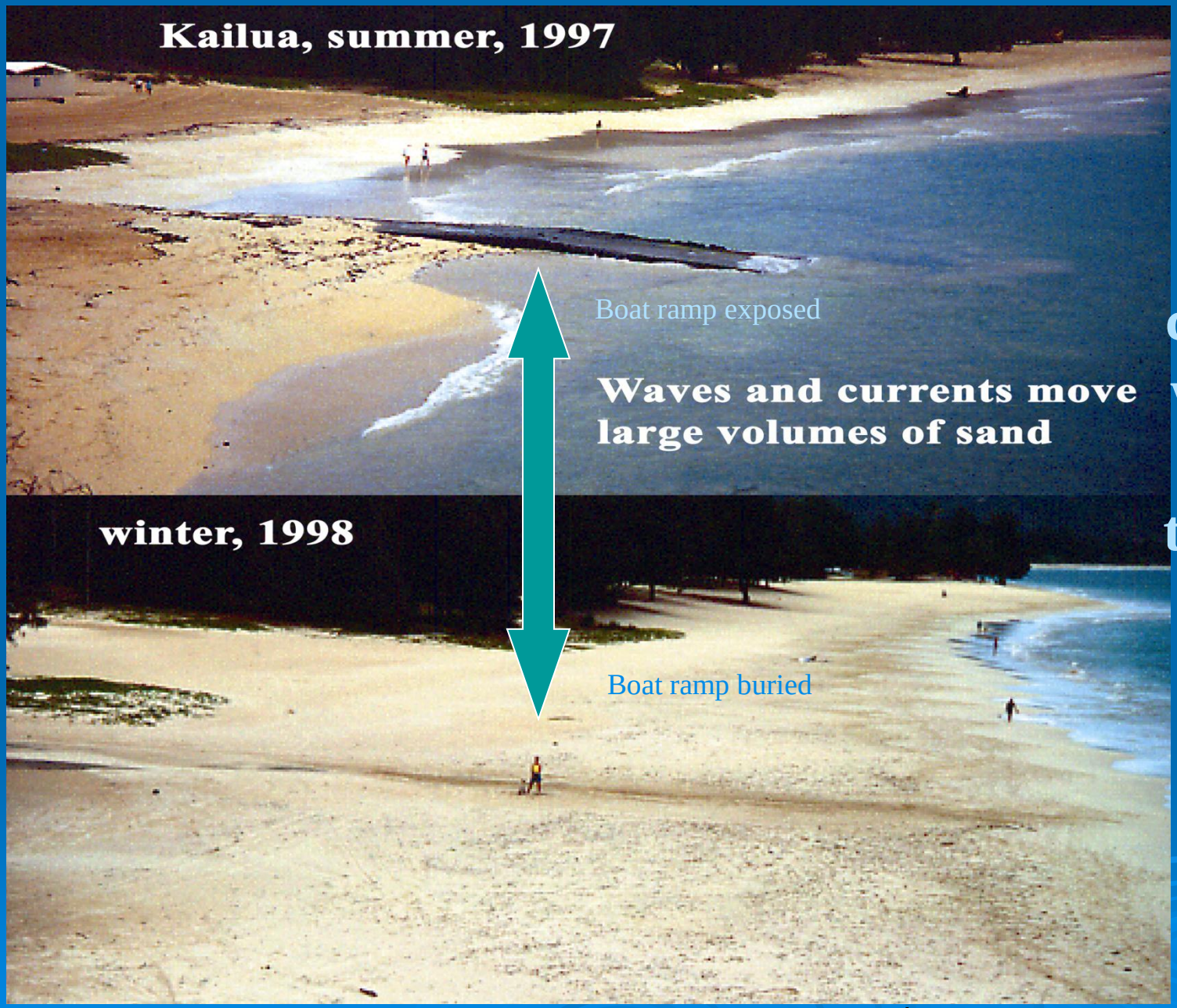


Beach sand was used as lime to fertilize sugar cane crops

Jump rock used to be buried in sand



Sand mining at Waimea Bay caused over 200 ft of erosion



Seasonal changes in waves can cause temporary erosion

Sandy shorelines erode 100-150 increments for every 1 increment of sea-level rise.

For a 0.24 m rise by 2050, beaches will recede by 24-36 m (~80-130 ft)

(Leatherman et al., 2000)

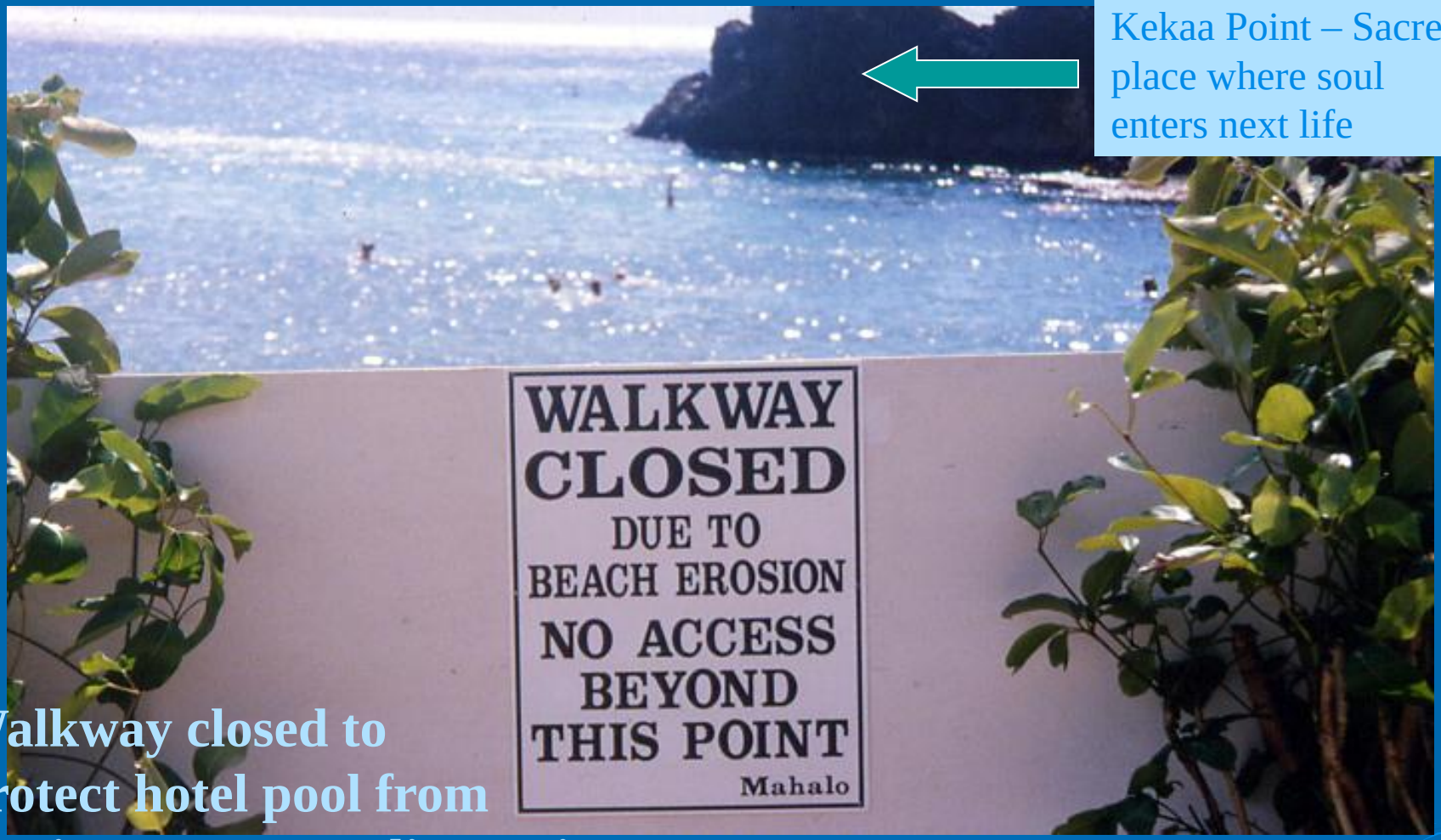
Water quality suffers on armored shores

High turbulence from wave reflection

Fleshy algal growth

Septic discharge

Tidal ecosystem heavily damaged



Kekaa Point – Sacred place where soul enters next life

Walkway closed to protect hotel pool from erosion – Kaanapali, Maui

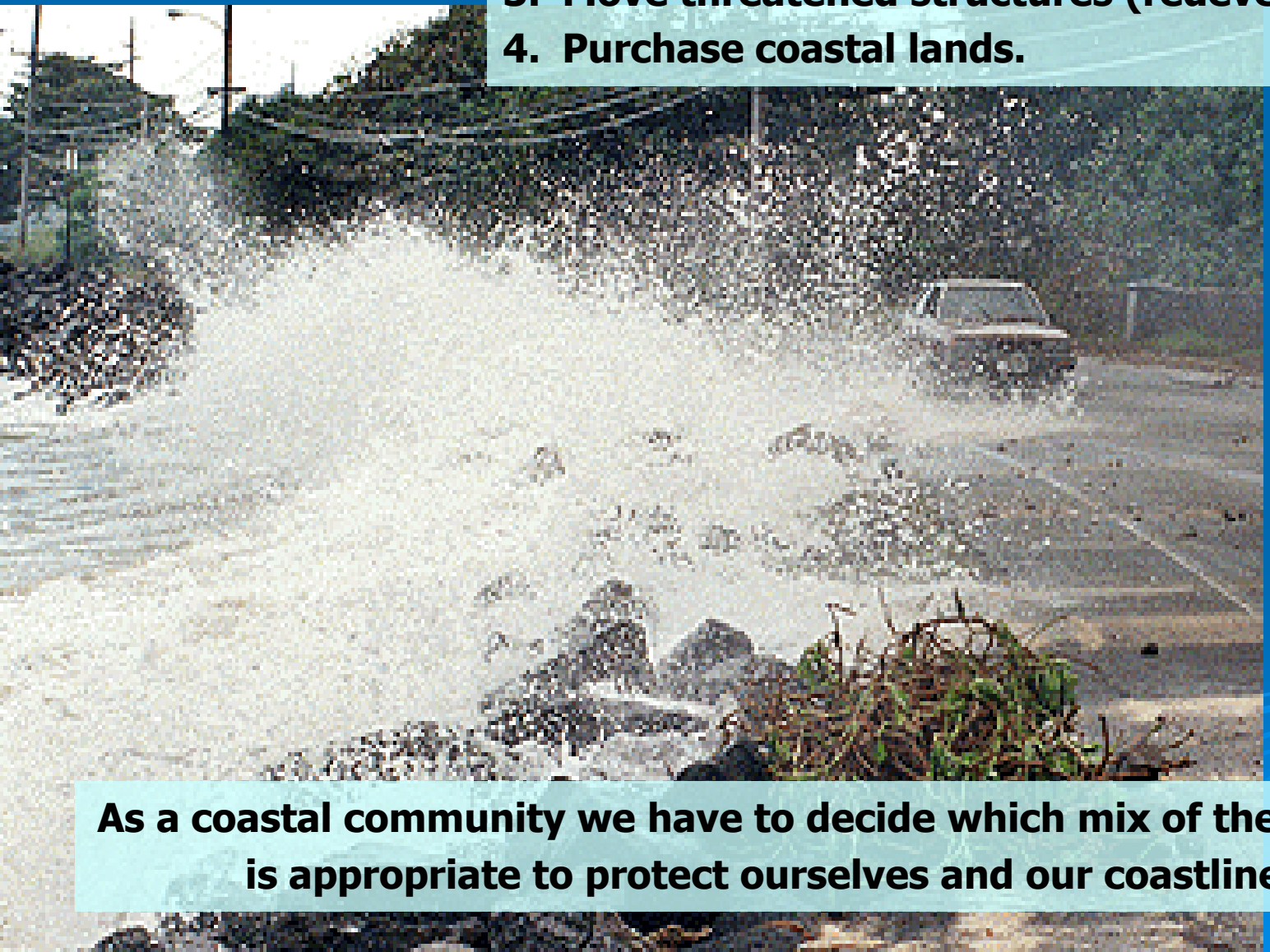
Erosion problems and complexities lead to conflicts (politics).

Department of Health – OEQC
EA for Shoreline Armoring

- Historical shoreline analysis
- Causes of erosion
- Shoreline type, site maps, beach profiles, existing walls
- Coastal hazard history, waves and currents, sediment movement
- 30-yr erosion hazard
- Seal of professional engineer

A combination of solutions exists:

1. **Avoid building near the shore (avoidance),**
2. **Restore beaches and dunes (restoration),**
3. **Move threatened structures (redevelopment),**
4. **Purchase coastal lands.**



As a coastal community we have to decide which mix of these tools is appropriate to protect ourselves and our coastline.

Political problems can never be resolved, only managed. The way to manage them is through education, demonstration, information and leadership.

Leadership can be displayed by involved citizens and active state and county government – elect people who truly care about the environment

POLICY DEVELOPMENT

Avoid development of eroding lands

Discourage additional development in erosion hazard zones

Plan at the littoral level

Acquire high value coastal lands

Construction guidelines for hazard areas

Nourish eroding shores