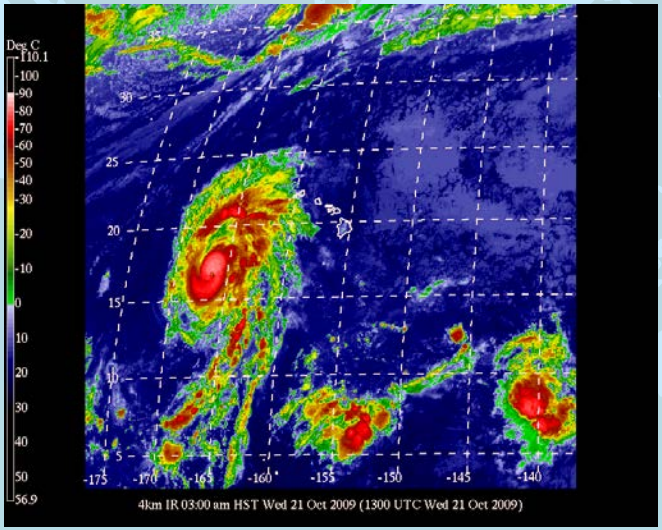
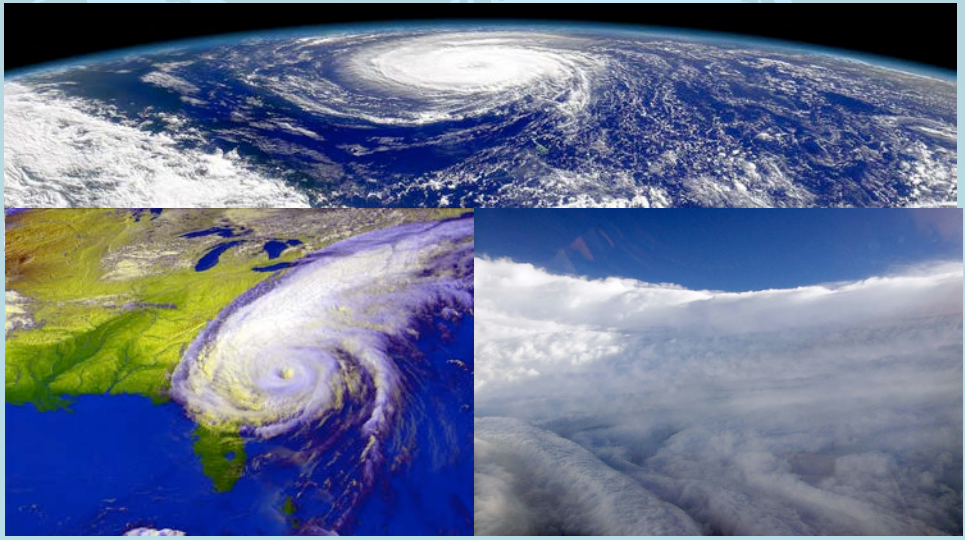
MET 200 Lecture 16 Hurricanes in Hawaii Hazards, and Forecasting

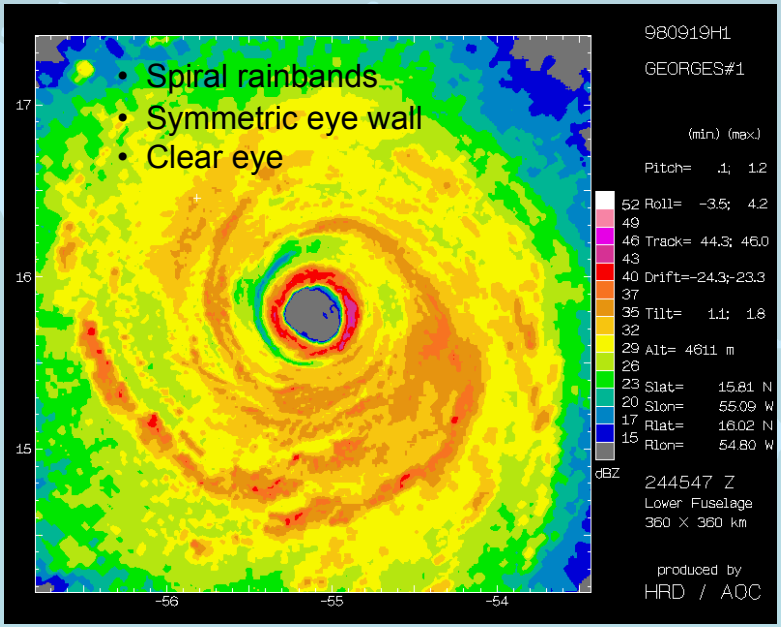


Sunset Last Night

Previous Lecture
Hurricane Structure and Climatology

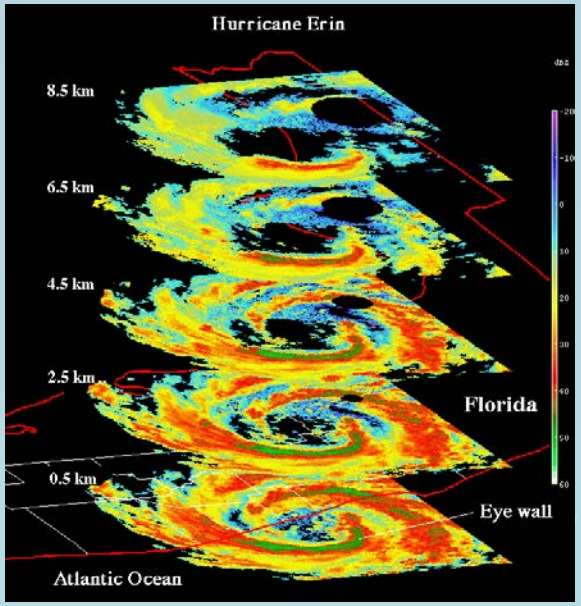


Radar Observations



Hurricanes weaken with height

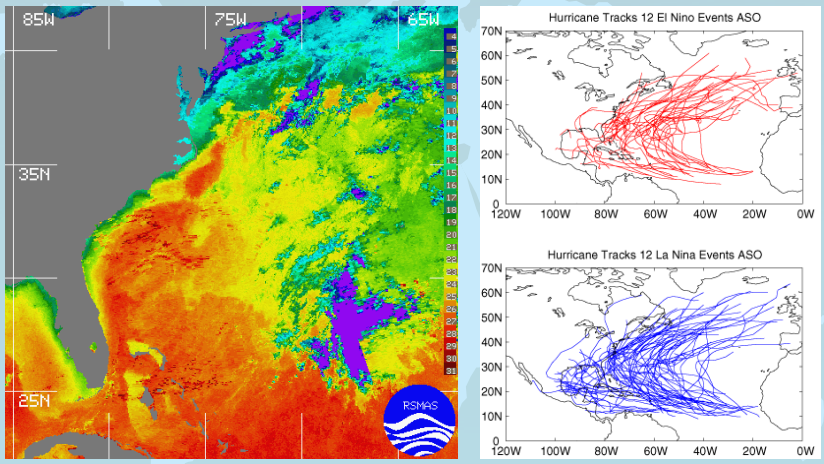
Structure in the rainfall seen in radar data.



Prerequisites for Hurricane Formation

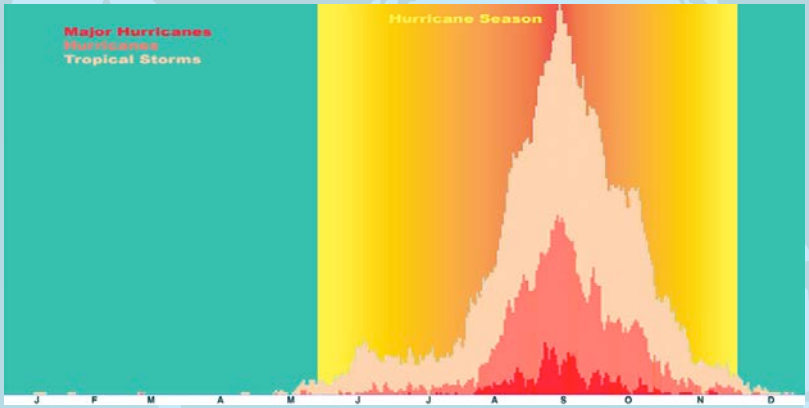
1. Warm ocean water with a temperature > 80˚ F (26˚ C) to a depth of ~50 m, so that cooler water cannot easily be mixed to the surface by winds. (Deep thermocline)
2. A pre-existing disturbance with cyclonic circulation (large low-level vorticity) persisting >24 hrs. As the air in the disturbance converges, angular momentum is conserved and the wind speed increases.
3. Small wind shear or little change in the wind speed or direction with height in the vicinity of the developing storm. (dv/dz<10 m/s from 850-200 mb)
4. Unstable troposphere characterized by enhanced thunderstorm activity. CAPE>1000 (Final CAPE in eyewall rather modest.)
5. Large relative humidity in the middle troposphere (no strong downdrafts). Moist air weighs less than dry air, contributing to lower surface pressures.

Hurricane Climatology



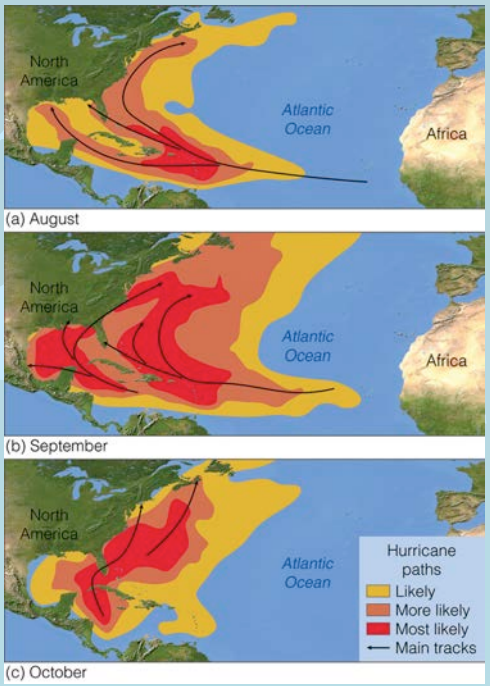
Hurricanes travel the warm Gulf Stream

Atlantic Hurricane Climatology

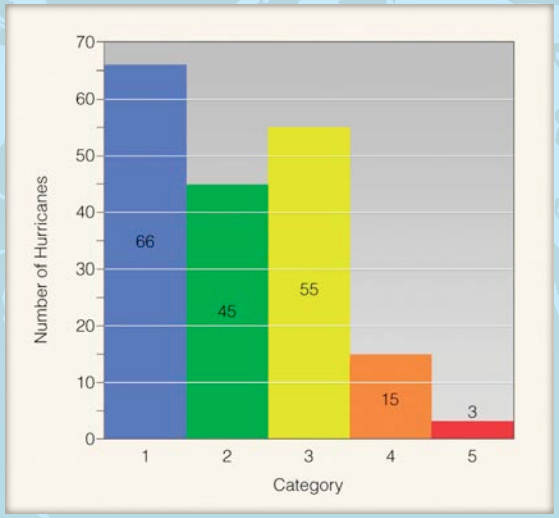


Number of hurricanes per month in the Atlantic Basin.

Likely Tracks

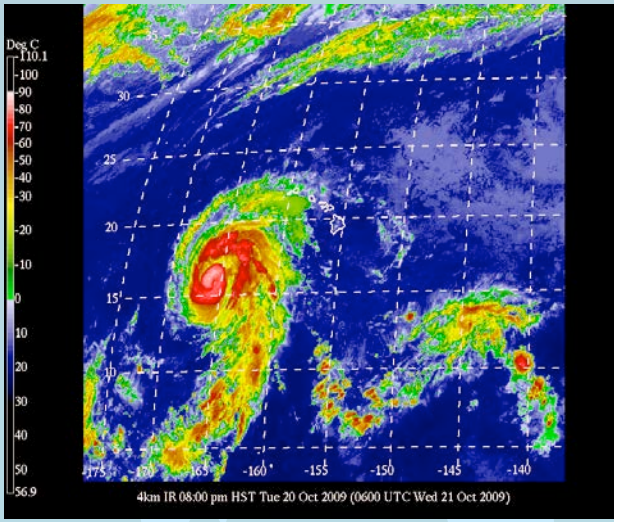


US Hurricane Climatology



- Category of US hurricanes at the time of landfall.

Hurricanes in Hawaii Hazards and Forecasting



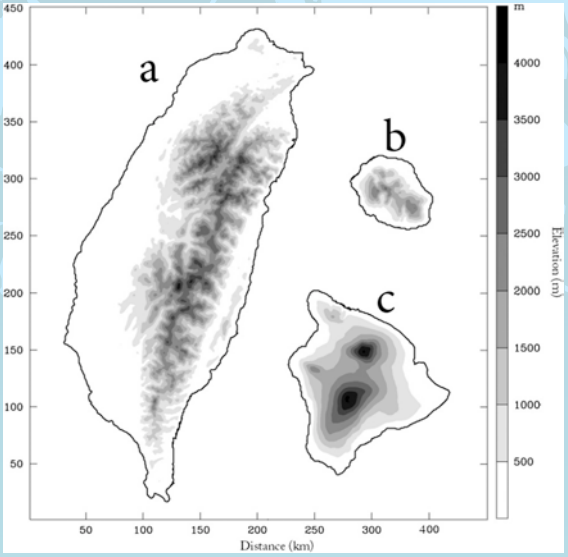
Hurricane Neki

- Hurricane's in Hawaii
- Hurricane hazards
- Hurricane forecasting

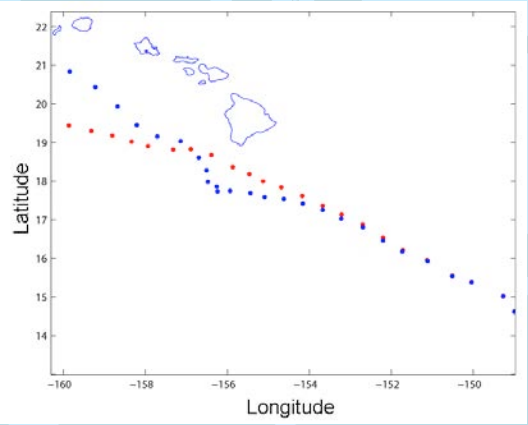
Some Common Comments

- No hurricane has made landfall on Oahu.
- Only Kauai gets hit
  - The Big Island and Maui were struck by a hurricane in 1871
  - Dot 1959, Iwa 1982, and Iniki 1992 all impacted Kauai
- Mountains protect us
  - If so, why don't the mountains of Puerto Rico or Taiwan protect them?
- There is no Hawaiian word for hurricane
  - No "Hawaiian Term" actually is not a surprise, since words such as Hurricane and Typhoon arise from local words for the winds observed.
  - David Malo (1843) defined five different Kona Winds.

Hawaii vs Taiwan and Reunion Isand

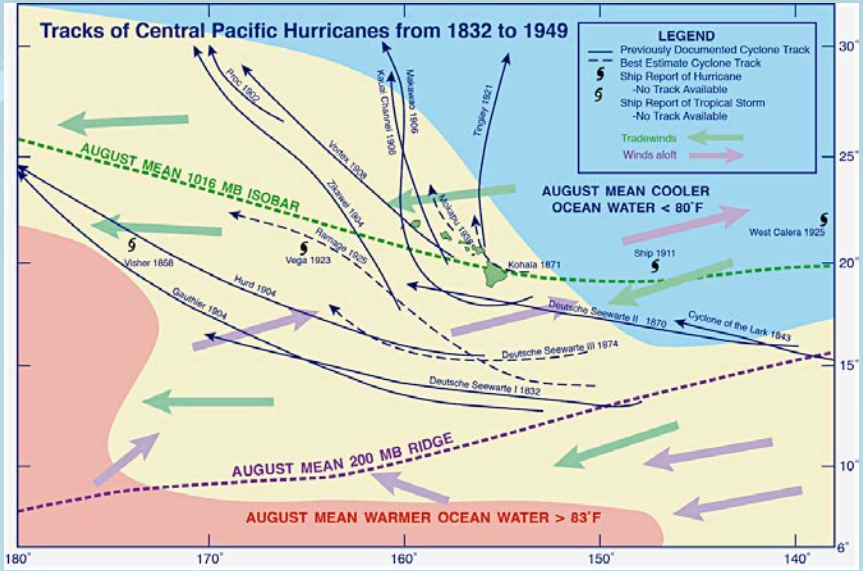


Impact of Hawaii Island on Track



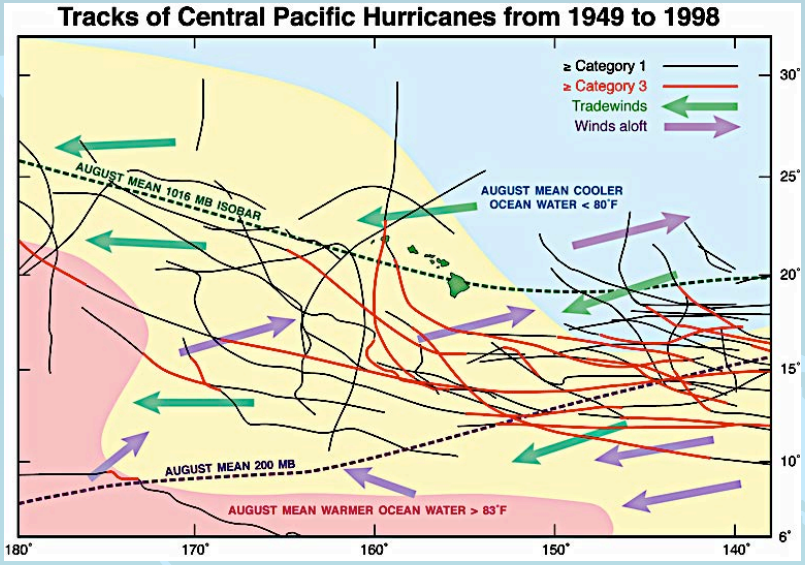
Simulated tracks with dots every 3 hours for Hurricane Flossie. The track of the blue (red) dots represents the case with (without) the Big Island present.

Hawaii Hurricane Climatology



Hurricane tracks in the central Pacific from 1832 to 1949

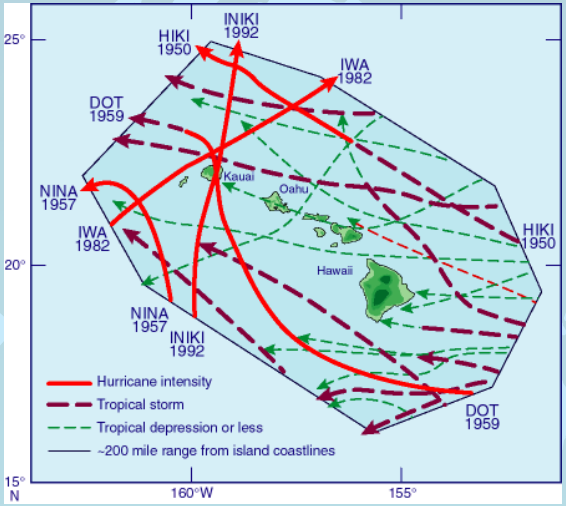
Hawaii Hurricane Climatology



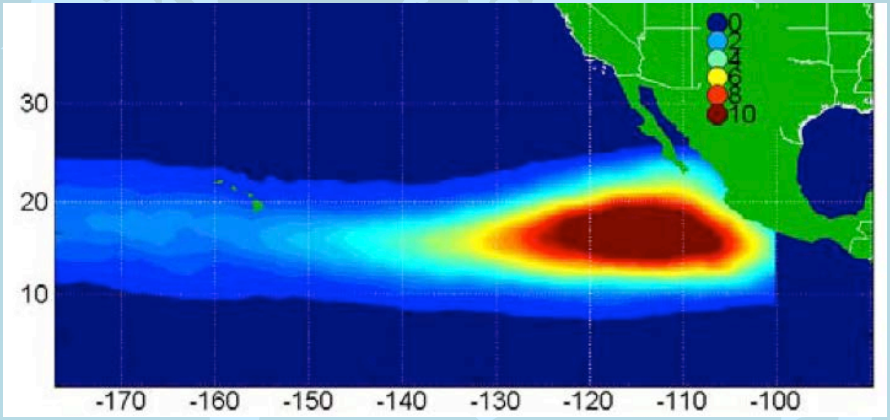
Hurricane tracks in the central Pacific from 1949-1998

Hawaii Hurricane Climatology

Tropical Cyclone tracks within 200 miles of the Hawaiian Islands since 1949.



Eastern Pacific Hurricane Climatology

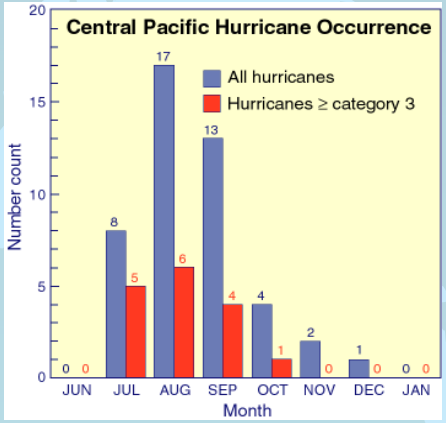


Monte Carlo Stochastic Simulation showing the number of times a hurricane passes within 75 nautical miles per 10 years in the Eastern and Central Pacific.

Central Pacific Hurricane Climatology

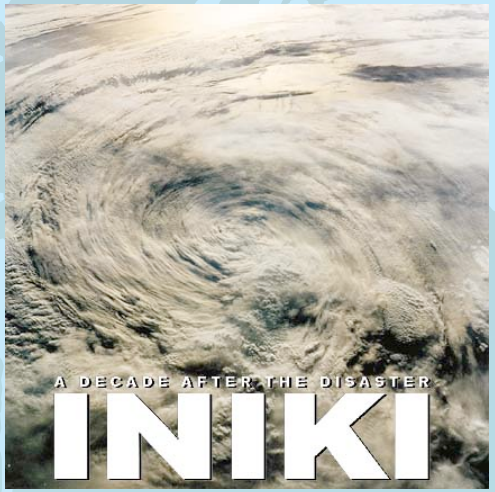
Note: more hurricanes occur in the central Pacific during strong el niño years.

Why?



Number of hurricanes per month in the central Pacific.

Hurricanes Impacting Hawaii



Iniki 11 September 1992



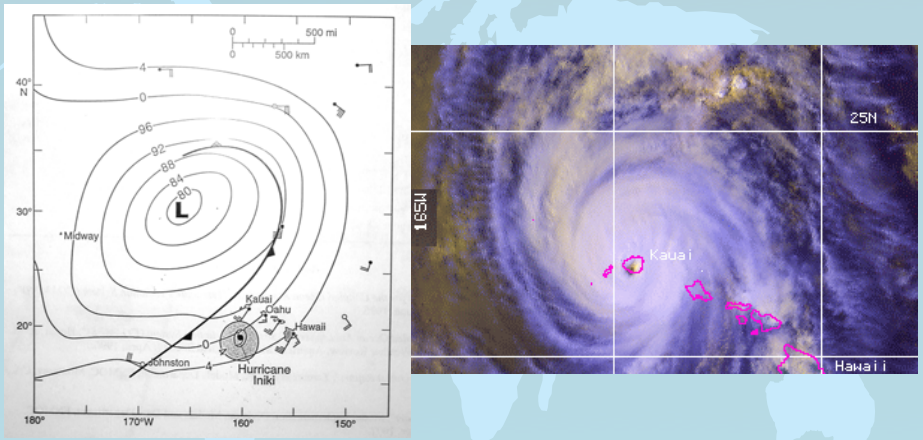

http://helzhalfacre.com/iniki/

Iniki Impacts

- 90% of structures on Kauai affected
- 14,118 damaged or destroyed
- 30% telephone poles down
- 3 years later unemployment 12%
- Social fabric altered-10% move away

- REMEMBER: This coincided with the bursting of the Japan Bubble Economy of the late 1980's.

A Question of Size



1980 Winter Storm vs. Hurricane Iniki,
2 PM HST on September 12, 1992

Hurricane Impact

- Energy of winds = wind velocity squared: $E = V^2$
- A doubling of the wind speed (e.g., from 70 to 140 mph) results in four times the destructive energy.

Saffir/Simpson Hurricane Scale

Category 1	74 - 95 mph	Storm surge 4 - 5 ft
Category 2	96 - 110 mph	Storm surge 6 - 8 ft
Category 3	111 - 130 mph	Storm surge 9 - 12 ft
Category 4	131 - 155 mph	Storm surge 13 - 18 ft
Category 5	> 155 mph	Storm surge > 18 ft

- Energy of winds = wind velocity squared: $E = V^2$
- A doubling of the wind speed (e.g., from 70 to 140 mph) results in four times the destructive energy.

Triple Threat

1. Storm Surge and Large Surf

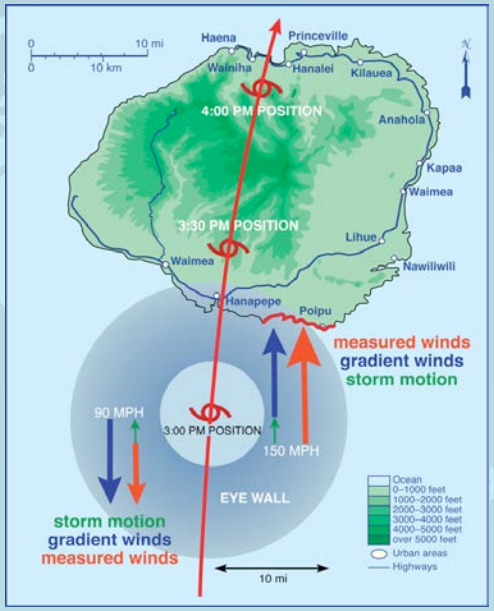
2. Heavy rains – Floods, flash floods, and landslides

3. High winds – flying debris

Hurricane Hazards in Hawaii

The winds, storm surge, and storm waves are all greatest just to the right of the storm track.

Why?

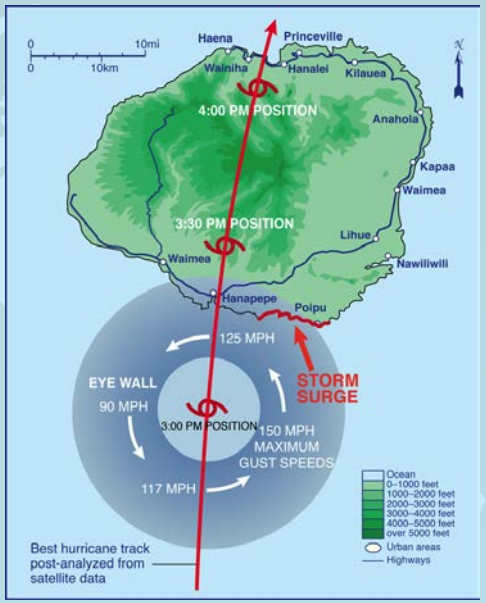


Hurricane Hazards in Hawaii

The storm surge and storm waves are greatest just to the right of the storm track.

Wind hazard is greatest on exposed ridges and mountain slopes.

Flash flood hazard is greatest near steam beds.



TRIPLE THREAT FROM TROPICAL CYCLONES

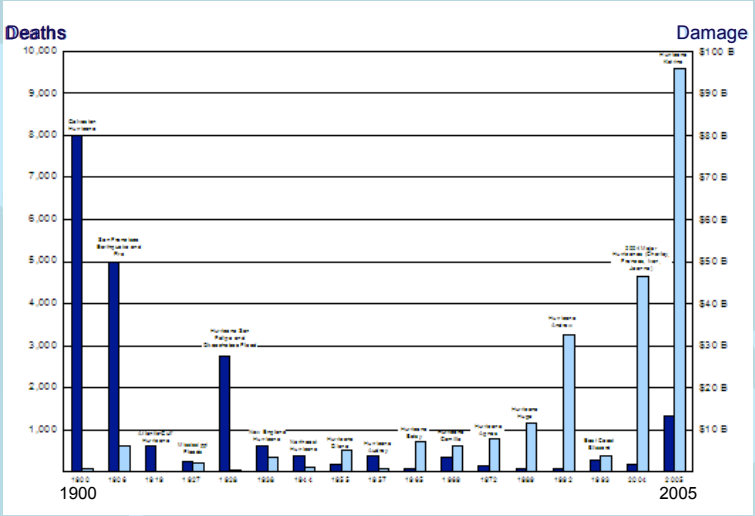
TRIPLE THREAT

Storm Surge (winds & low pressure) → Injuries and Loss of Life; Structural Damage; Destruction of vegetation/crops; Flooding of coastal areas; Erosion of Beaches; Saline Intrusion–loss of fertility

High Winds → Loss of Power/Communications; Fires - Urban and Brush

Heavy Rains → Contamination of Water Supply; Land Subsidence; Flooding of Inland Areas; Mud and Landslides

Past Hurricane Impact: Death vs Damage

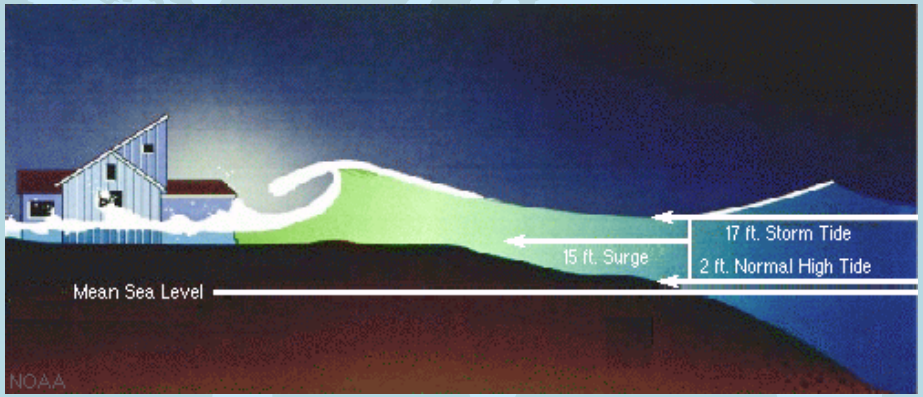


The record is dominated by a few extreme events: Galveston hurricane of 1900 and Katrina in 2005 (2005 Dollars)

Storm Surge - Elevated Sea-Level

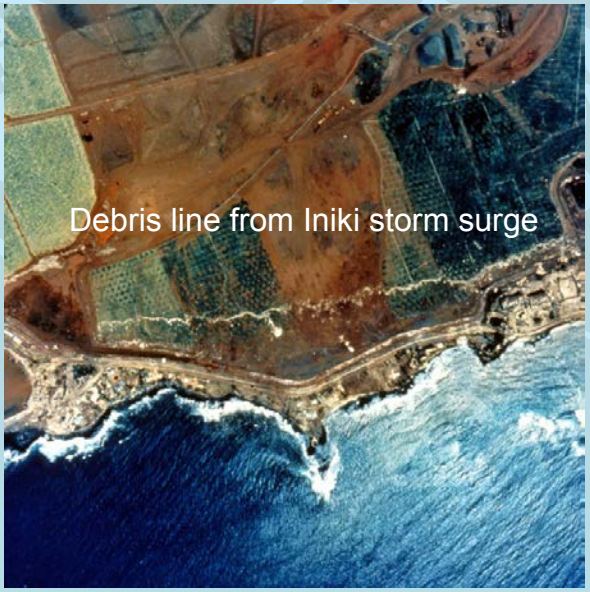
Flooding of coastal areas
Erosion of Beaches
Saline Intrusion–loss of fertility

Storm Surge - Elevated Sea-Level



Storm surges are historically responsible for the greatest numbers of deaths and they cause some of the worst damage.

Storm Surge



Storm Surge

±8000 people died in the storm surge

Storm Surge

Storm surge: before and after hurricane Camille, 8/17-18/1969.

Ivan Aftermath Storm Surge

9/24/2004

52 deaths in US

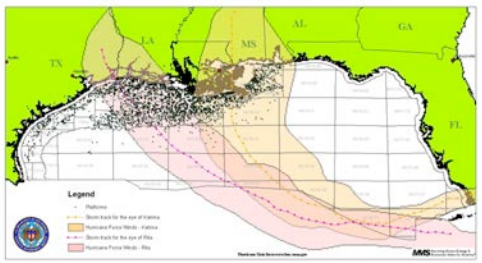
70 deaths in Caribbean

Katrina ±1800 deaths in US

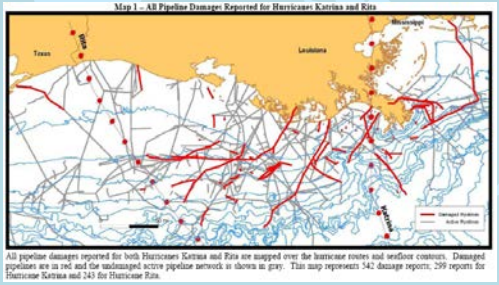
25 August 2005

Katrina Aftermath of Storm Surge

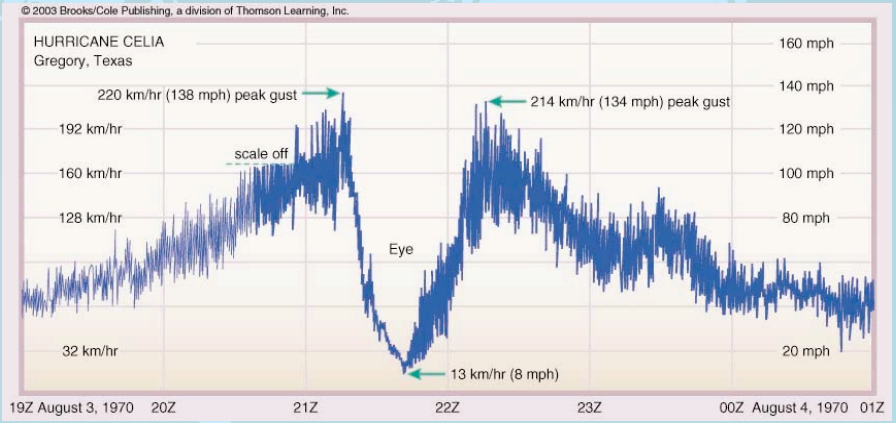
Katrina Aftermath



Oil production takes a hit from Rita and Katrina.



Hurricane Wind Damage



Wind Speed in hurricane Celia as it passed Gregory, TX.

Hurricane Wind Damage

Iniki Wind Damage

Hurricane Wind Damage

Wind damage to Darwin, Australia from cyclone Tracy. Made landfall on Christmas Eve 1974. Similar wind damage occurred in Andrew.

Hurricane Rains and River Flooding

Landslides

> 1000 deaths in Hurricane Mitch due to rain induced landslides.

Ivan 2004 Aftermath

Heavy rains &
Flooding in NC
US Death Toll 25

Irene 2011 Aftermath

Widespread Heavy Rains & Flooding

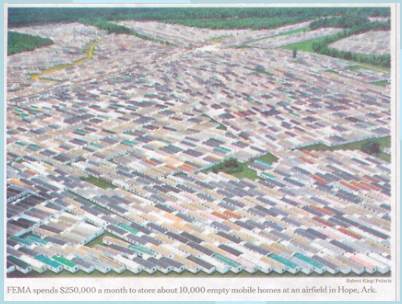
US Death Toll 44

North Carolina Flooding

Slow moving tropical cyclones result in very large rainfalls.

Hurricane Forecasting

Hurricane Mobile Homes



FEMA spends $250,000 a month to store about 10,000 empty mobile homes at an airfield in Hope, Ark.

Hurricane Gridlock

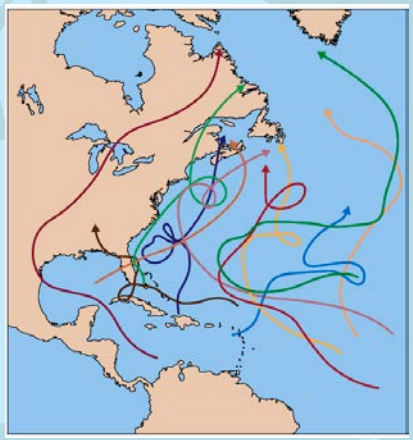
Hurricane forecasting involves predicting the future track and intensity of a hurricane.

Hurricane Forecasting

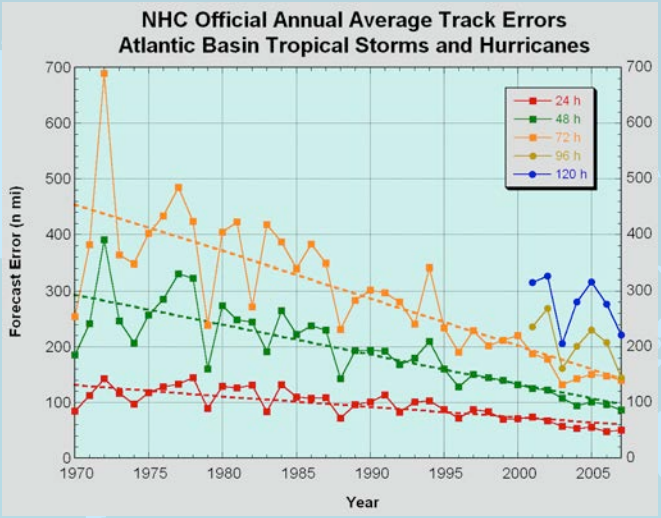
Hurricane forecasting involves predicting the track and intensity of a hurricane.

A combination of observations, numerical model output, and climate data are used to forecast hurricanes.

Hurricane tracks can be erratic and difficult to predict.



Hurricane Forecasting

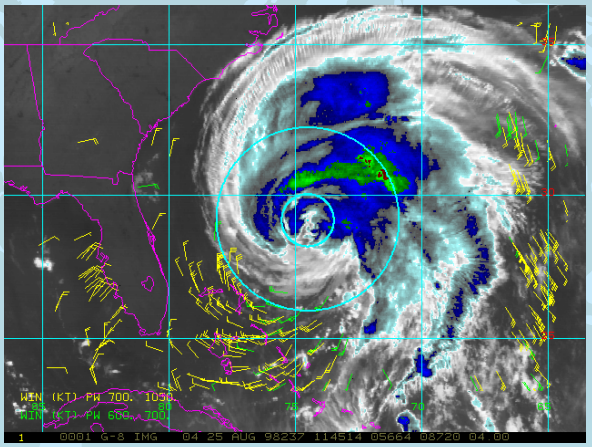


More progress has been made in hurricane track forecasting than in forecasting hurricane intensity change.

NWS Hurricane Advisories

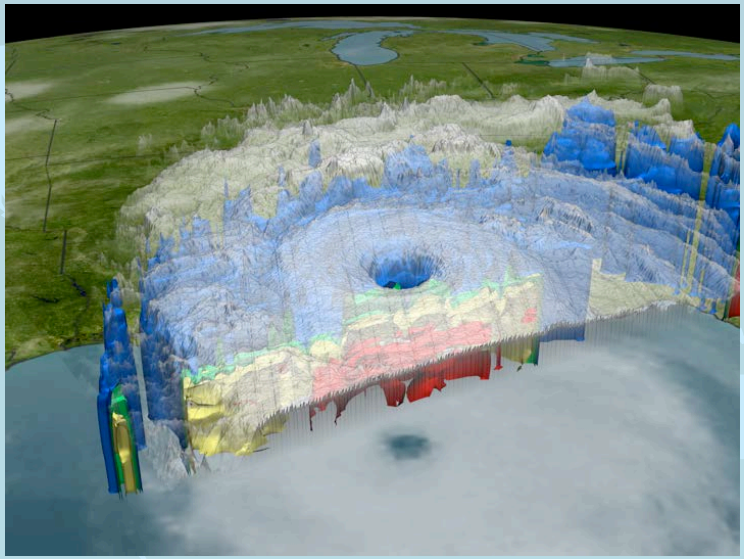
- Hurricane Watch - Hurricane may threaten the coast. Issued ~ at least 36 hours in advance
- Hurricane Warning - Hurricane conditions are expected within 24 hours. Issued ~12-24 hours or more in advance.

Cloud Drift Winds



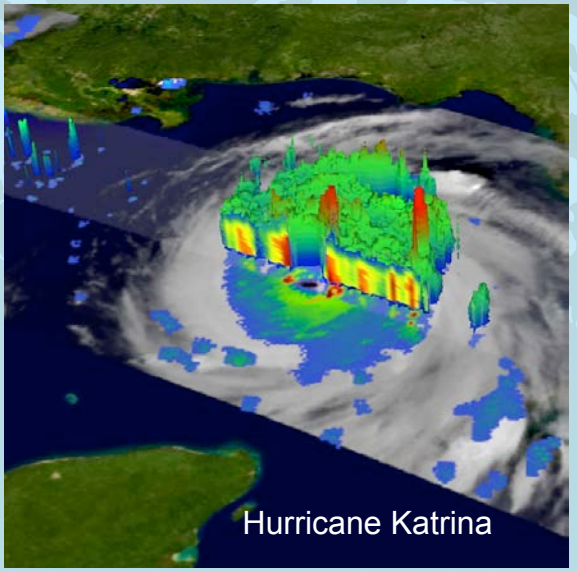
IR Imagery from Bonnie 8/25/98 1145 UTC
(Blue Rings at 100 and 350 km Radius)

Satellite Rainfall Measurement



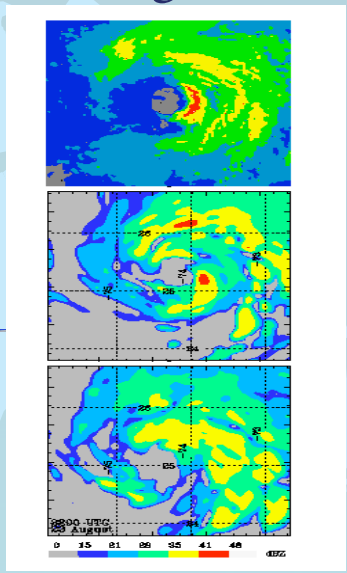
- Hurricane Katrina

Satellite Rainfall Measurement

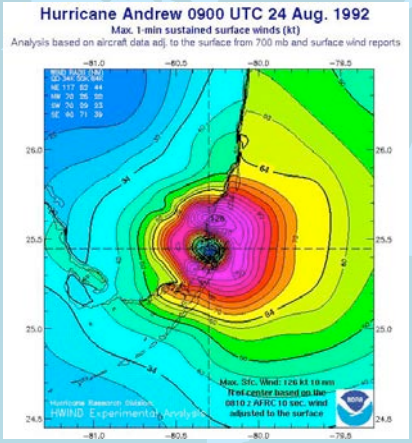


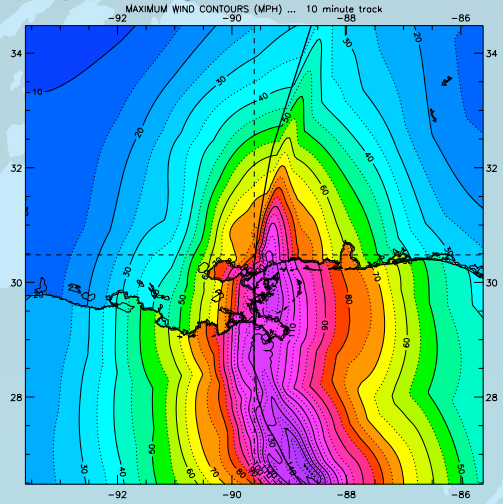
Hurricane Forecasting

- Radar Observed Rainfall
- 48-h model forecast with satellite observations
- 48-h model forecast without satellite observations



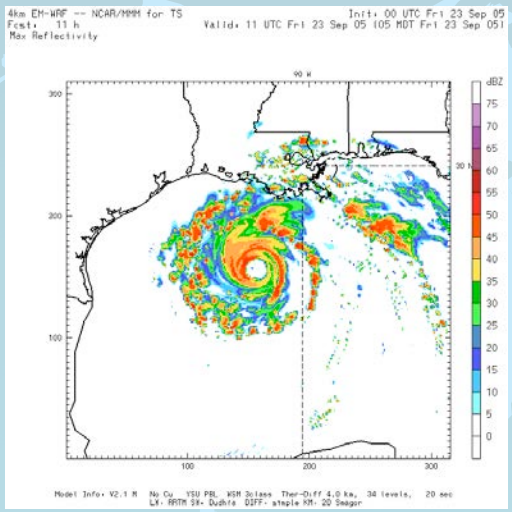
Wind Observations

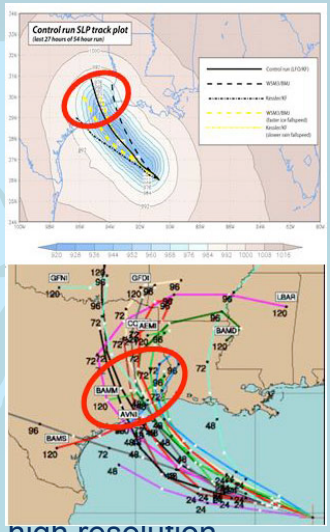




Wind distributions in Andrew and Katrina

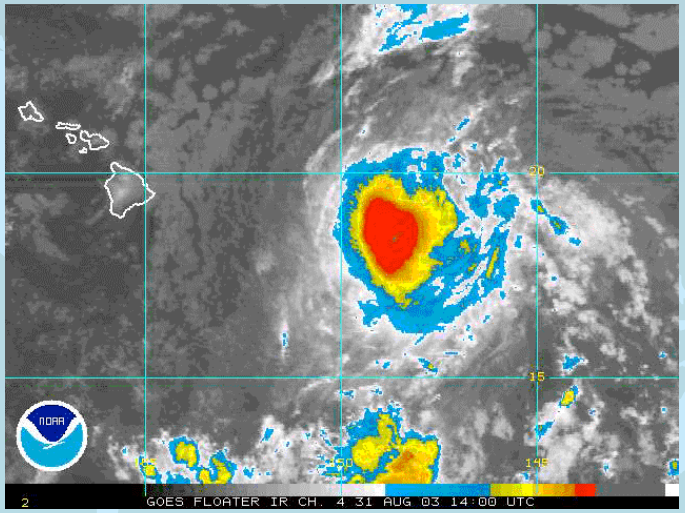
Hurricane Forecasting





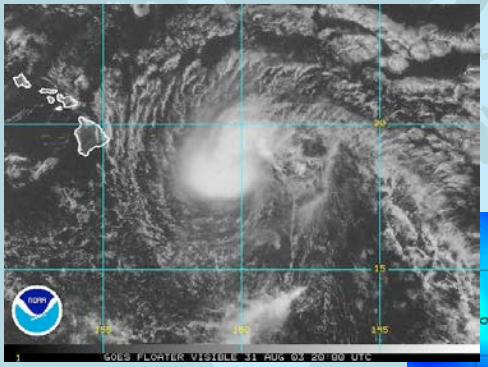
- Hurricane Rita Simulation using a high resolution model with data assimilation

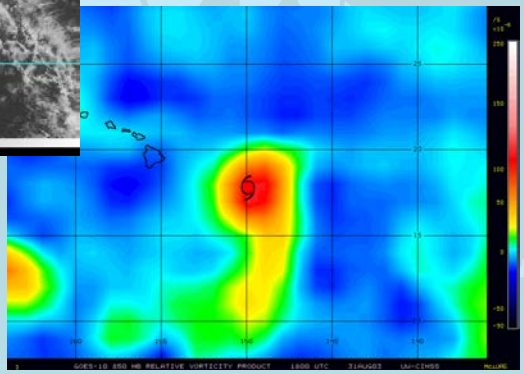
Hurricane Jimena



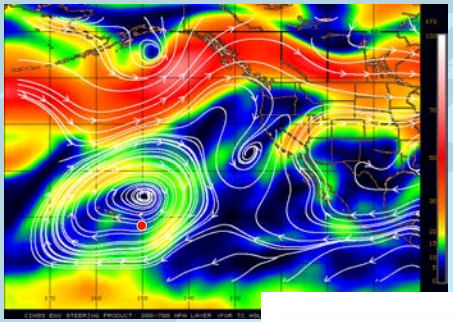
How can we estimate where this hurricane is going and how strong it will be?

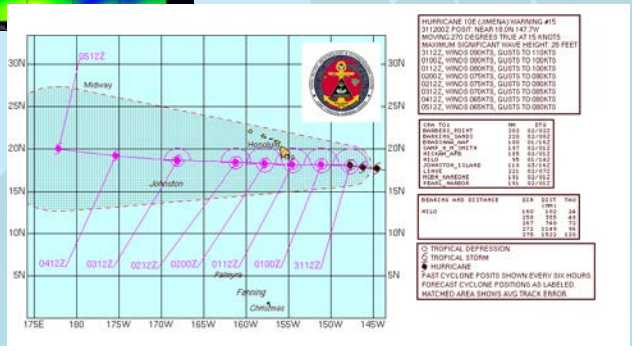
Locating Hurricane Jimena



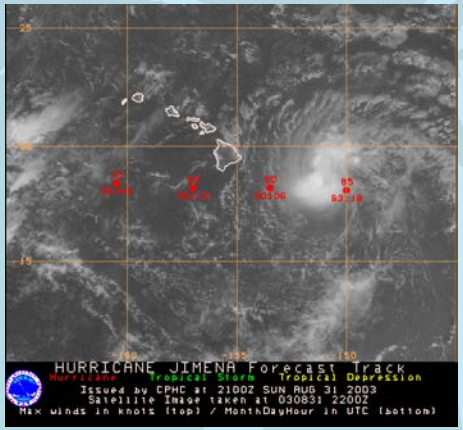


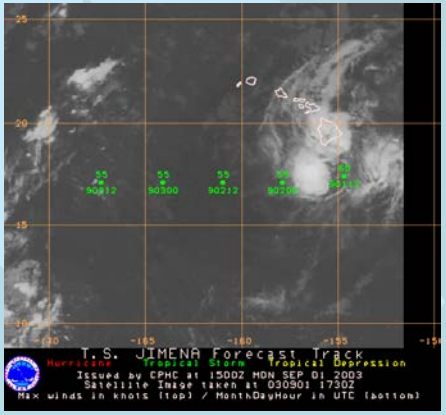
Layer-Mean Winds Steer the Storm



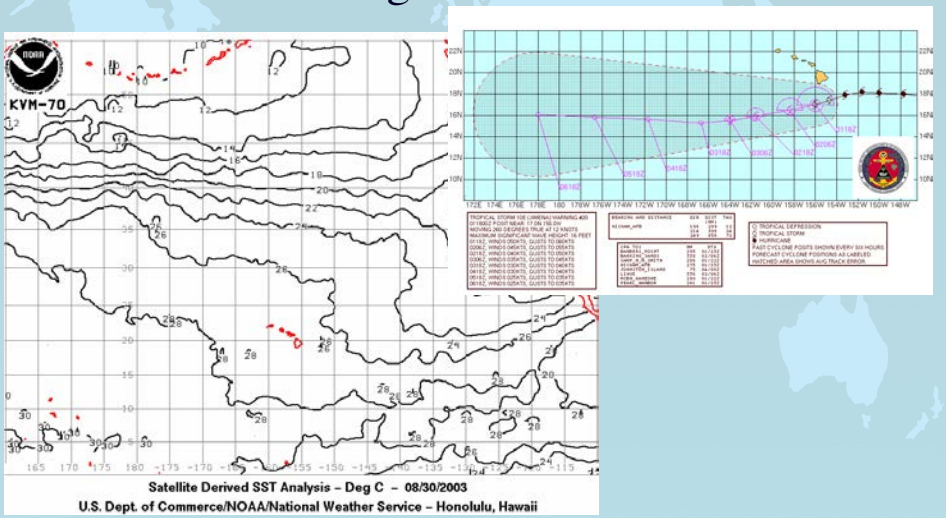


Track Forecasting

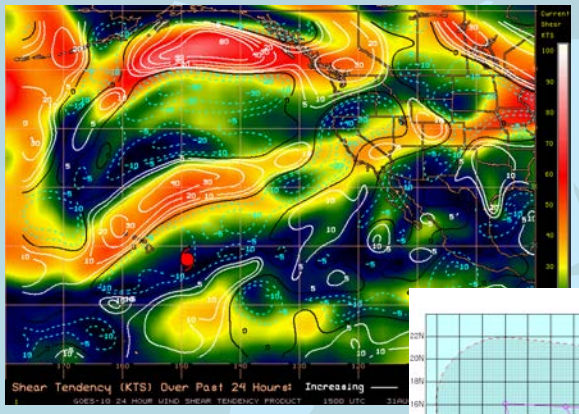


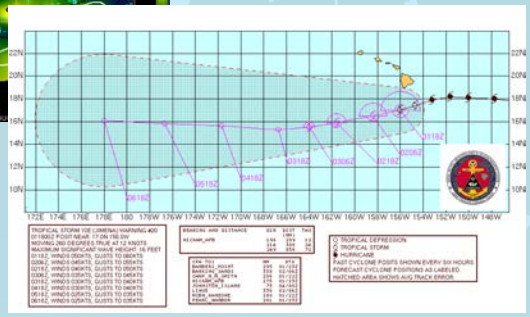


Sea Surface Temperature Important Factor for Hurricane Strength

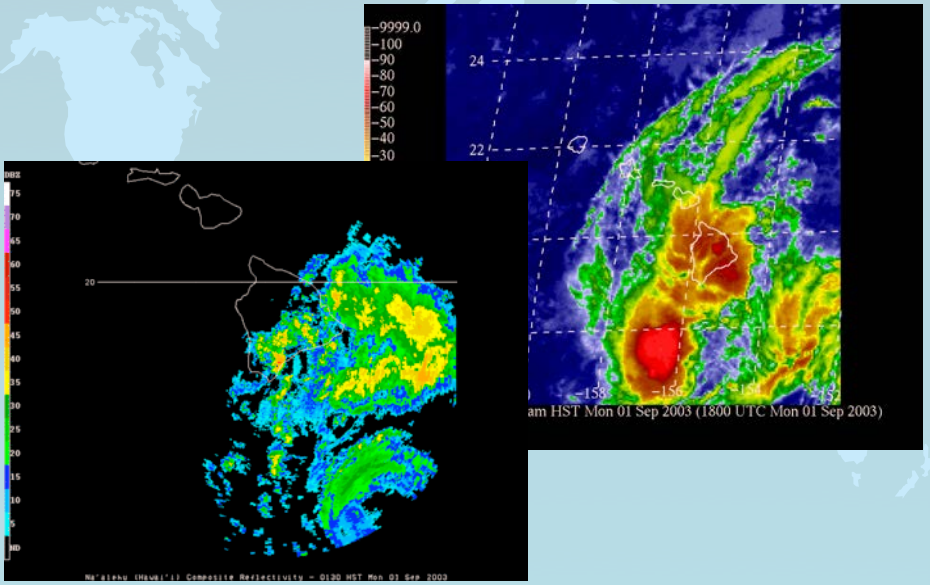


Wind Shear Weakens Storm





Thunderstorms and Flooding

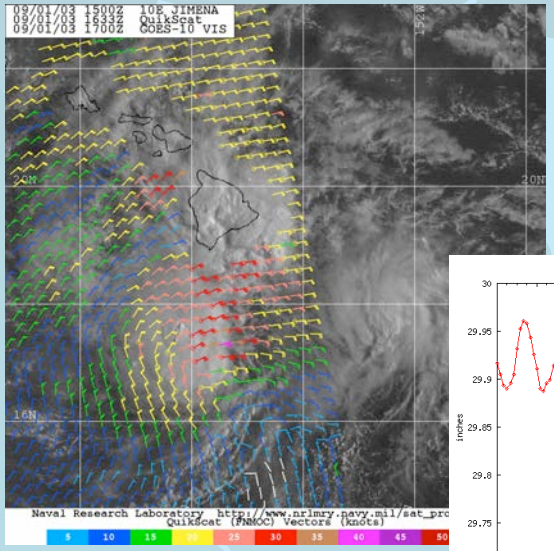


Thunderstorms and Flooding

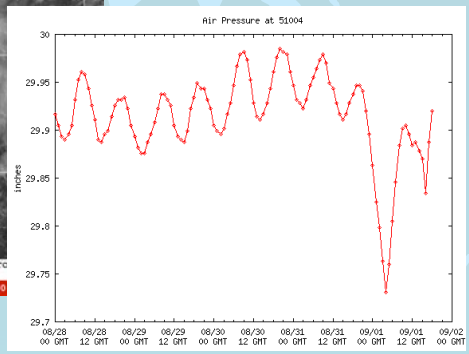
Rains turned out to be moderate and mostly beneficial to drought stricken Big Island.

The heaviest rainfall was in Upper Puna, where 8.43 inches were recorded in Glenwood and 6.09 inches in Mountain View in the 24 hours ending at 2 p.m. yesterday. Pi'ihonua recorded 5.75 inches, while Waiakea Uka had 5.79 inches.

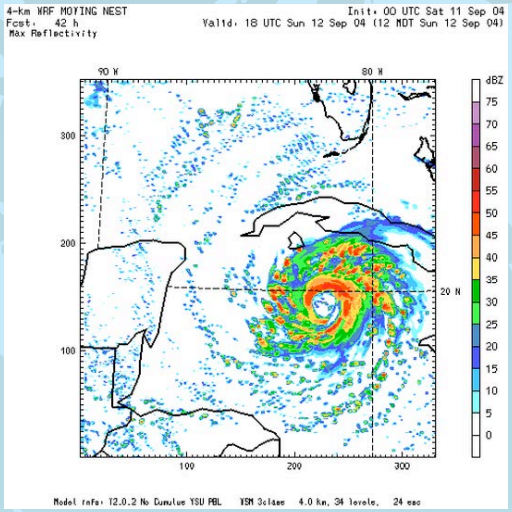
Winds in Hurricane Jimena



Officials with Hawai'i Electric Light Co. scrambled to repair downed power lines and remove tree branches tangled in lines, especially in Puna and Waimea.



Questions?



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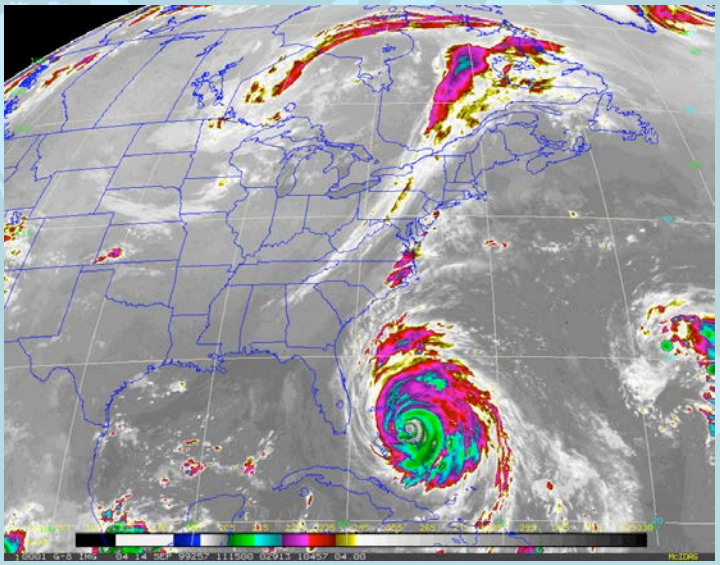

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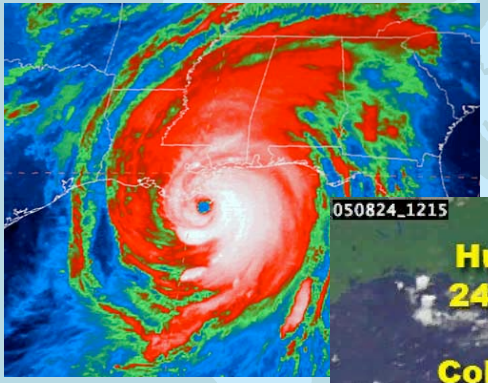

Hurricane Katrina