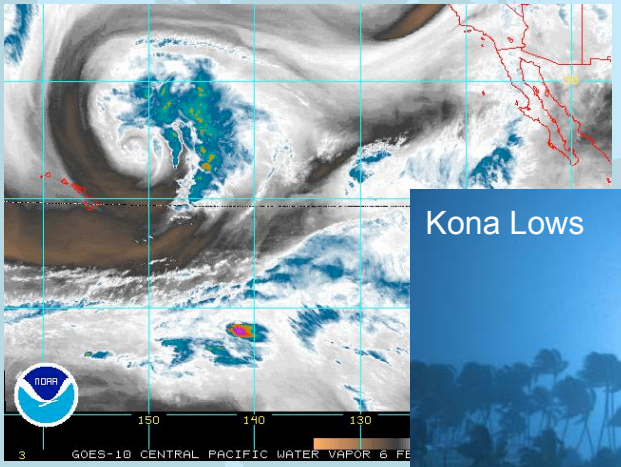
MET 200 Lecture 24 Flooding in Hawaii and Intro to Severe Thunderstorms



Kona Lows

Cause more flash floods in Hawaii than any other storm system

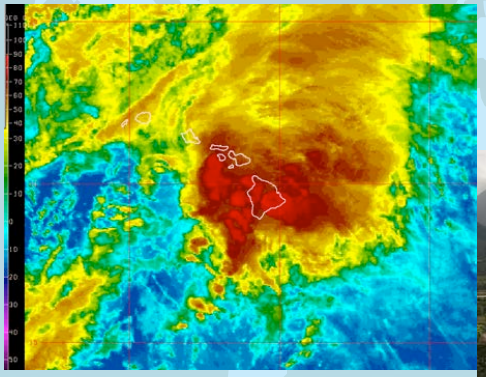
$Billion Tornados

Strongest storms this far north in more than 100 years

1000 homes destroyed in Washington, Illinois

Cold front spawned 68 tornados on Sunday

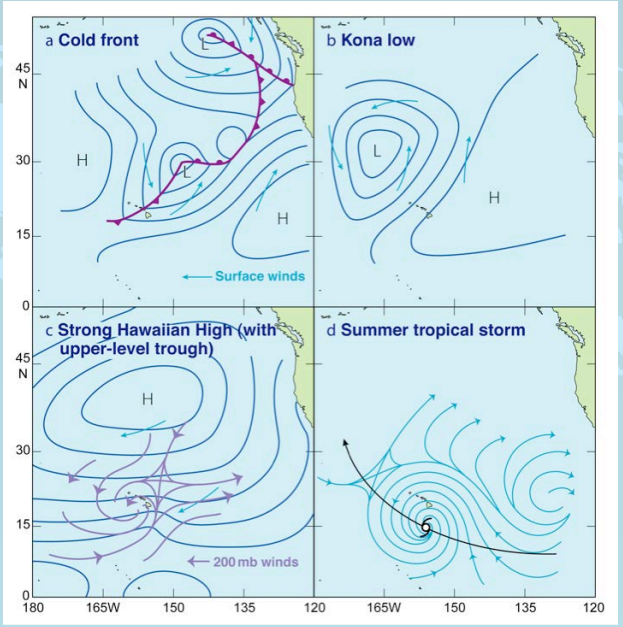
Previous Lecture: Hawaii Weather Hazards and Air Mass Thunderstorms



Hilo Flood November 2000

Hanalei Flood November 2009

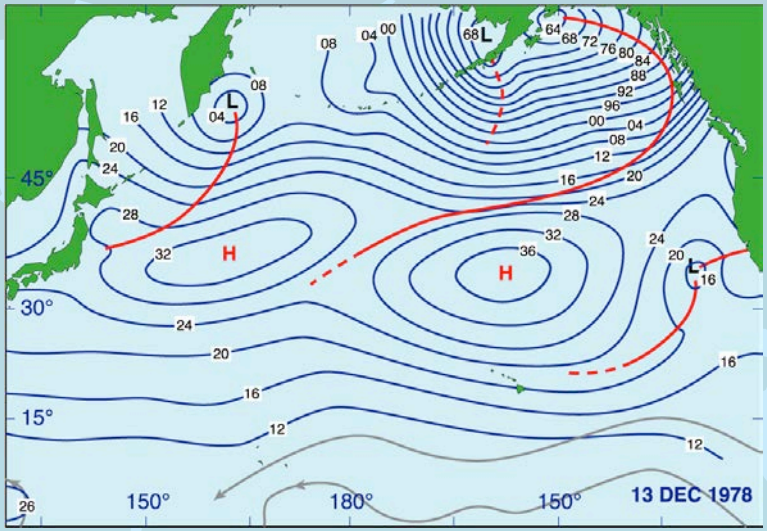
Four Hazardous Weather Patterns in HI



Sources of Weather Hazards in Hawaii

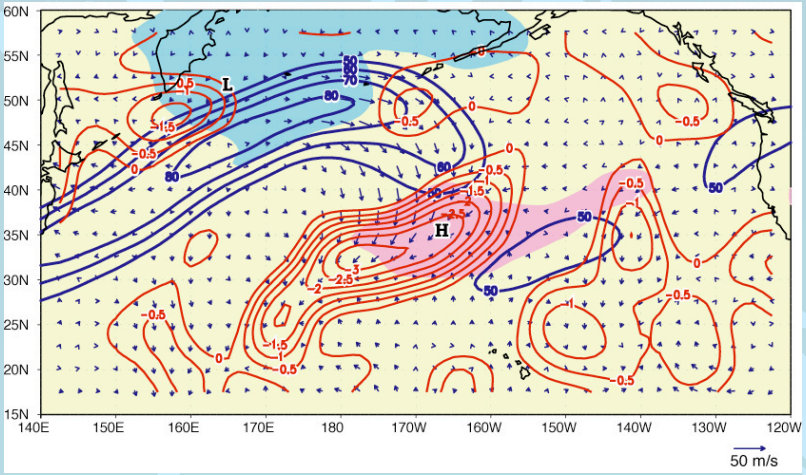
1. Midlatitude cyclones - cold fronts
   - heavy rains and flash floods
   - strong winds
   - large waves and swell*
2. Kona lows
   - heavy rains and flash floods*
   - strong winds
   - large waves and swell
3. Extra strong Hawaiian highs
   - high trade winds*
   - large waves and swell
   - heavy rains and flash floods
4. Tropical cyclones
   - strong winds
   - large waves and swell
   - storm surge*
   - heavy rains and flash floods

Strong Hawaiian High



Sea-level pressure analysis for 13 December 1978.

Dynamics of a Hawaiian High



Divergence aloft over the N. Pacific out of a winter storm causes converge over the Hawaiian High and ridge building.

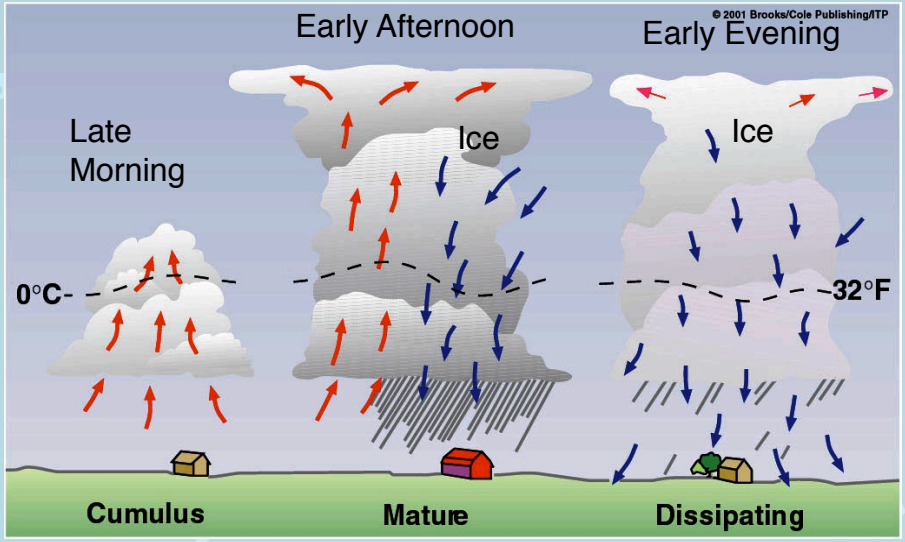
Air Mass Thunderstorms

Environment: Air Mass thunderstorms are triggered by lifting.

Lifting is provided by

- Sea-breeze circulations
- Land-breeze circulations
- Mountain-valley circulations
- Solar heating
- Outflows from earlier thunderstorms

Air Mass Thunderstorms



Three stages in the life cycle of an air-mass thunderstorm.

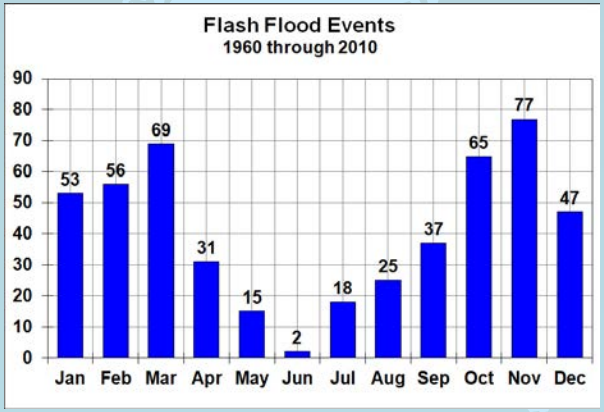
Heavy Rain and Flooding in Hawaii

- Sources of Hazardous Weather in Hawaii
- The Flash Flood Problem
- Flood Ingredients
  - Lots of Water Vapor
  - Terrain effects
  - Saturated soils
- Some Past Events
- Observations and Forecasts
- NWS Advisories

Manoa Valley flood, Halloween 2004

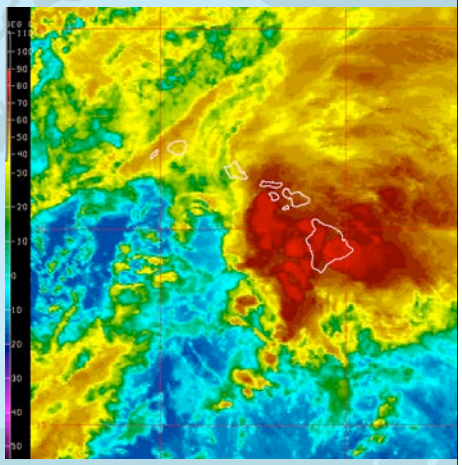
When do Flash Floods Occur in Hawaii?

- 495 events in 41-year period
- 9.7 per year
- Causes most of the direct wx-related fatalities
- November is the worst month for storms (1-2 flash floods)
- June has the best weather



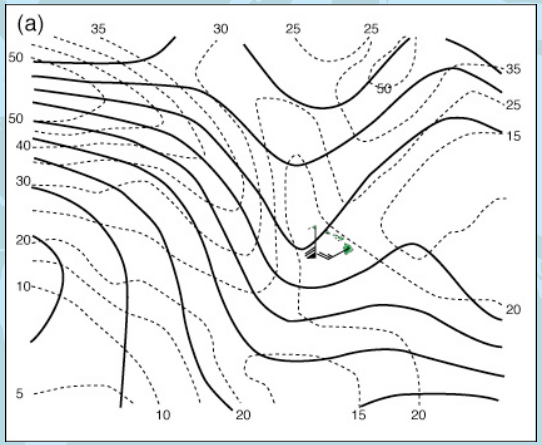
Ingredients for Heavy Rain

- Moisture – lots of water vapor
  - Large amounts of moisture results in unstable air and more rainfall
- Large upward motion
  - Low level convergence & upper level divergence needed for heavy rainfall.
- Slow storm motion (i.e. long duration)
  - Increases total rainfall over basin
  - terrain anchoring



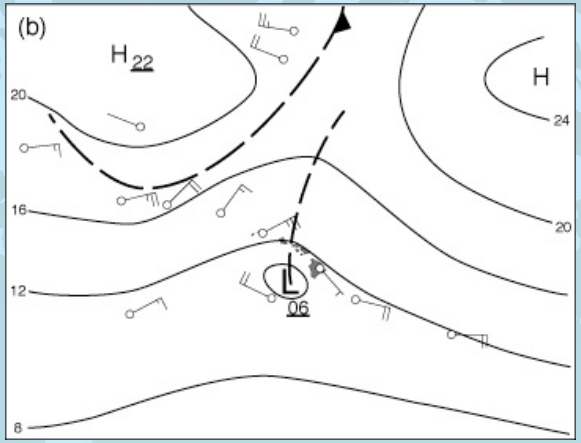
Enhanced IR image during peak rainfall period of the Nov. 2000 Big Island flood event.

Upper Level Divergence of Winds



- Analysis for 1200 UTC 25 January 1996 of 250 mb streamlines and isotachs (every 5 m/s).

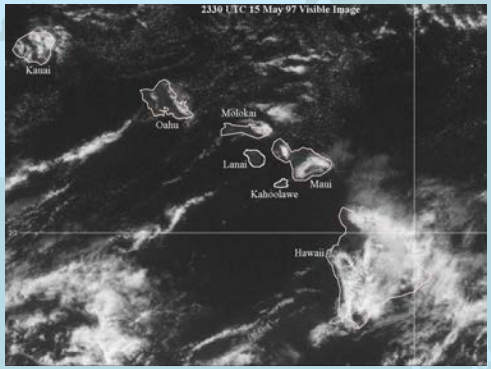
Low Level Convergence of Winds



- Analysis for 1200 UTC 25 January 1996 of sea-level pressure (mb).

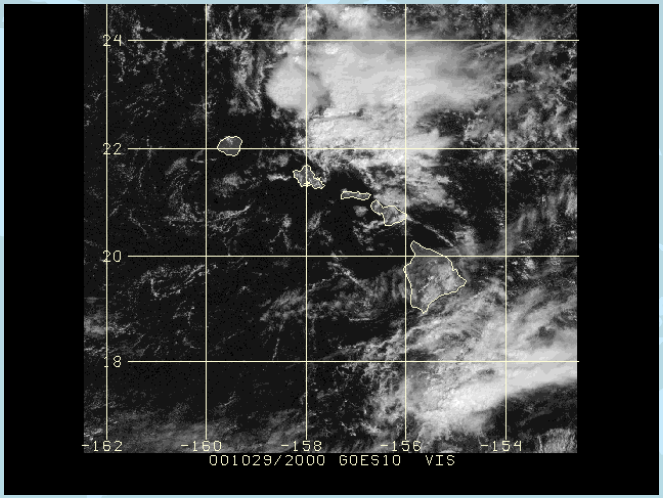
Terrain Affects

- Terrain lifting and anchoring
  - Ideal lifting mechanism for prolonged heavy rains
  - Rain maxima often over slopes exposed to low level flow
- Lee-side convergence zones (a.k.a. “plumes”)
  - Enhanced low level convergence.
  - Southeasterly flow causes “plume” to drift over downstream islands



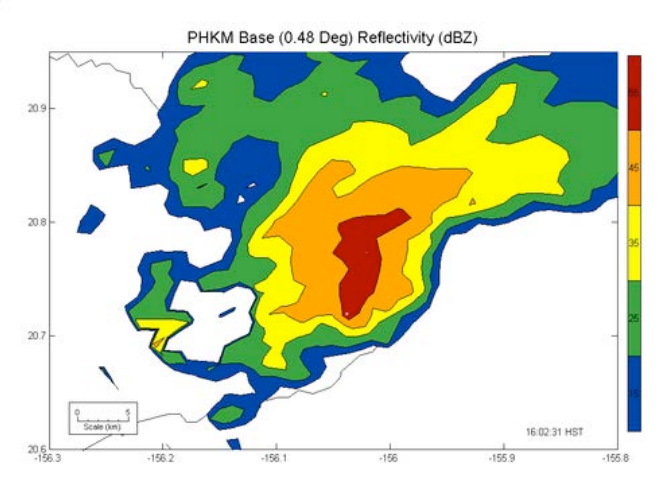
Visible image showing plumes

Hana Flood



Big Island Plume and Terrain Anchoring

Hana Flood

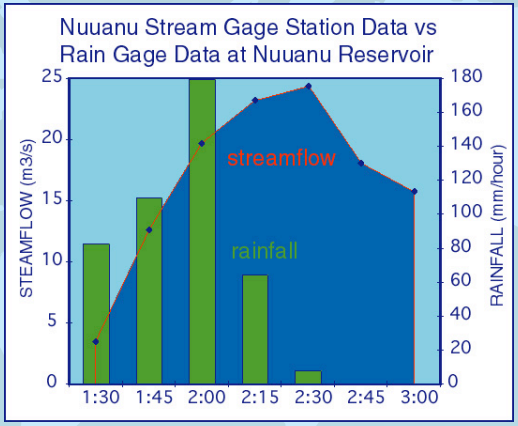


Big Island Plume and Terrain Anchoring

Factors that Contribute to Flood Problem

1. Small Watersheds result in short response time.
   - Steep slopes increase speed of runoff
   - Shallow soils quickly become saturated
2. Urbanization increases runoff.
   - debris dams commonly form in urban culverts
   - storm water and sewers share plumbing - result is sewage spills.

Small Basins mean Short Response Time



Small basins with steep slopes and shallow soils make the time between peak rain and peak discharge short, as little as 15 minutes. Half of the State is within 5 miles of the shore, therefore lead time for a response time is very short.

Contributing Factor - Saturated Soil

Paauau Stream overtopping Belt Highway at Pahala during Nov. 2000 Big Island flood event.

- Soil moisture content from previous rains
- Previous Rainfall: Rate, duration, pattern
- Soil type, depth and stratification: determines infiltration rate & flow type

Contributing Factors - Land Use

- Land use affects basin response
  - Agriculture
  - Natural forest
  - Urbanized
- Basin slope & size
  - Small, steep, shallow soils: < 1 hr response time
- Channel condition
  - Debris dams?

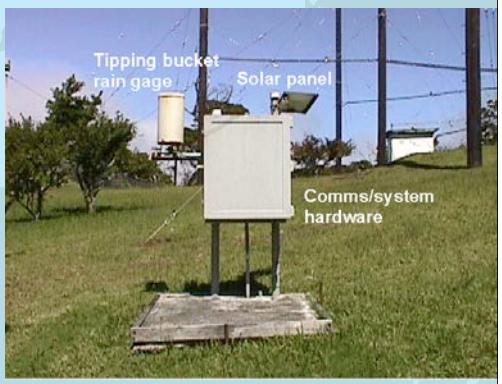
Aerial view of Kaneohe, Oahu. Note encroachment of urban areas within small, steep-walled basins.

Observations & Forecasting Tools

- Rain gage data
- Satellite Imagery and products
- Radar Imagery and products
- Balloon and Aircraft Soundings
- GPS total water vapor
- Stream gage data
- Numerical models
- Spotters
- Experience

Flash Flood Detection – Rain Gages

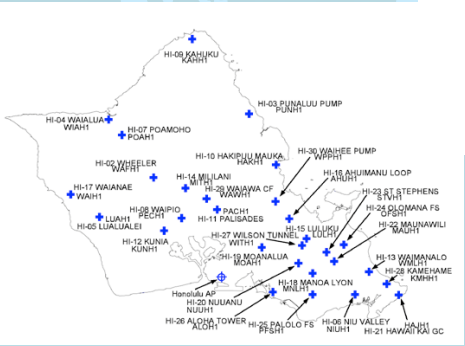
- Automated system provides alarm for intense rain.
- "Ground truth" on actual rainfall…but
  - Wind bias
  - Intense rainfall low bias
  - Spatial coverage limitations
- Provides some lead time
- 2 to 4 in/hr is significant



Automated rain gage with phone telemetry at Kokee radar station.

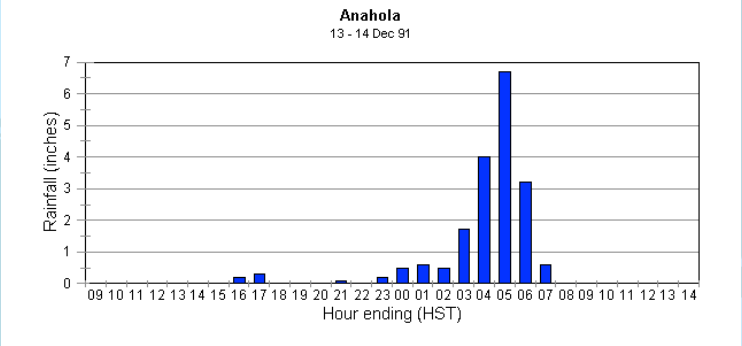
Rain Gage Networks on Oahu

Cooperative Stations



Automated Hydronet Stations

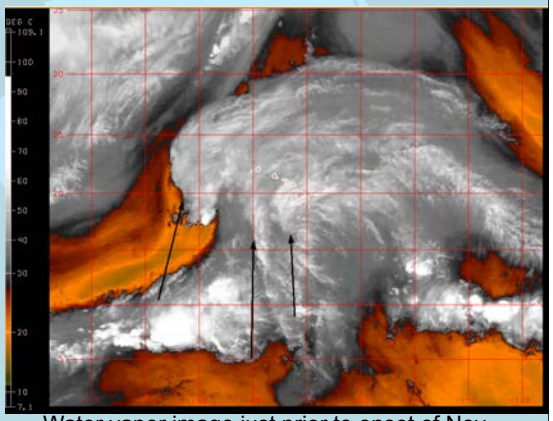
Anahola Flood 13-14 December 1991



Hourly rainfall from gage at Anahola during the 1991 Anahola flood.

Satellite Products

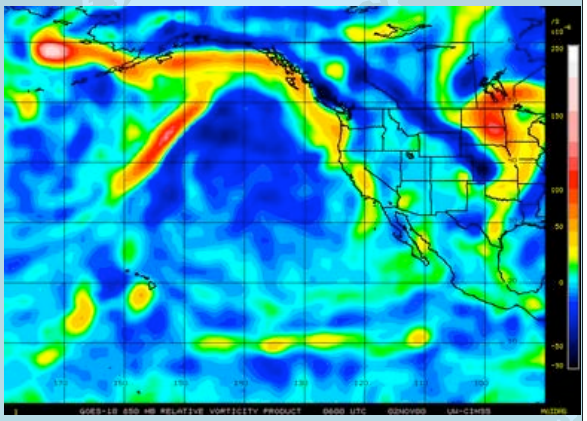
- Visible: Sharp views of circulations and low level boundaries during day
- IR: provides cloud top temperature - cold clouds with sharp edges mean heavy rainfall
- WV: Useful for tracking upper-level motion
  - Jets, cyclonic circulations, short waves



Water vapor image just prior to onset of Nov. 2000 Big Island flood event

Satellite Products

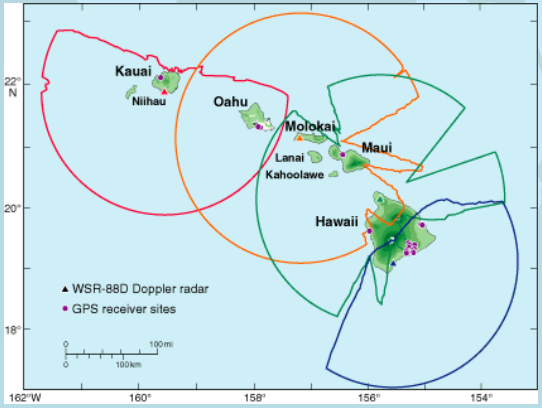
- A growing number of derived products aid forecasters
- GOES products
  - Total Water Vapor
  - Stability
  - Winds
  - Low tracking
- Polar orbiter products
  - Water vapor
  - Rain rate
  - Surface winds



850 mb low tracking product

Doppler Radar

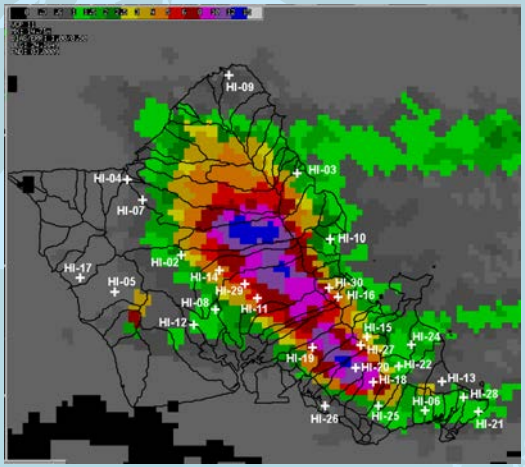
Doppler radar measures rainfall rates, wind speeds. These observations are most useful for short-term forecasting (6-12 hours).



Radar antenna

Radar Data & Derived Products

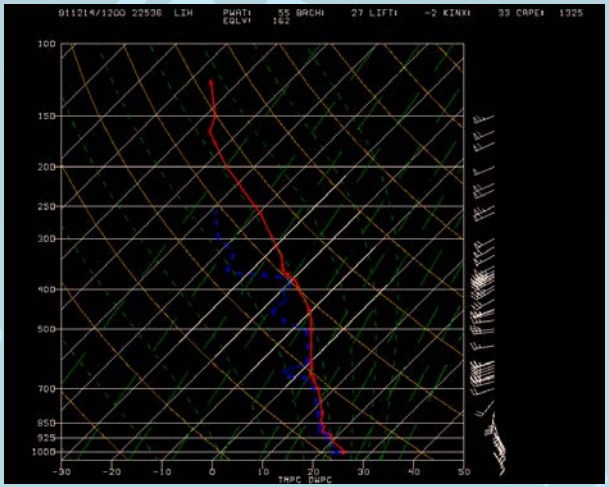
- Provides good spatial and temporal resolution
- Excellent for cell motion
- Cross-sections for vertical structure
- Rainfall estimates



Storm total rainfall from Molokai WSR-88D covering December 1999 flood event.

Soundings

Balloon and Aircraft soundings provide information on moisture content and stability of air.



Lihue sounding just prior to heavy rains from Dec. 1991 Anahola flood event

Stream Gages

- Real-time capability on growing number of sites
- 1- to 4-hour routine transmission interval
- Emergency broadcast capability available if flood threshold known
- Excellent “ground truth” of flood conditions
- Limited lead time for operations
- Data used for rainfall/flood threshold calibration

USGS stream gage at Kahana Stream

Applying Forecast Tools

- Radar data
  - Short term forecast tool
  - Look for signs of heavy rain - cells and rainbands
  - Terrain will amplify rain rates
- Surface data
  - Watch for changes in wind speed/direction, dew point, and 24-hr pressure trend
- Experience
  - Years of looking at numerical and observational data improves skill in most cases
- Spotters
  - “Eyes and ears” of NWS in the field
  - Trained volunteers
  - Law enforcement and emergency management officials

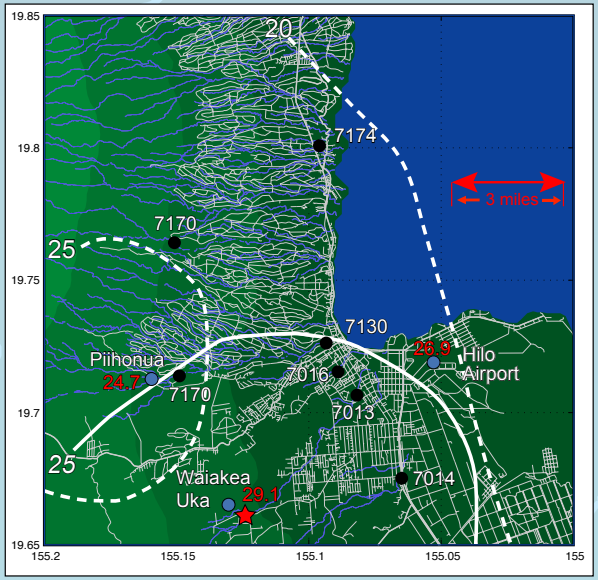
Some Notable Flood Events

- November 2000
  - SE and E Big Island
  - $70 Mil.
  - 37 inches/24-hrs (22 in./6-hr)
- Dec 1991 Anahola Flood
  - East Kauai
  - $5 Mil. & 4 fatalities
- Dec 1987/Jan 1988 “New Years Flood”
  - East Oahu
  - 22 inches/24-hrs
  - $34 Mil.
- March 2006
  - Kaloko Dam Break - seven deaths

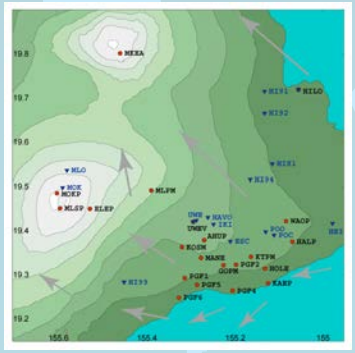
Bridge washout on Komohana St. in Hilo the day after the Nov. 2000 Big Island flood event.

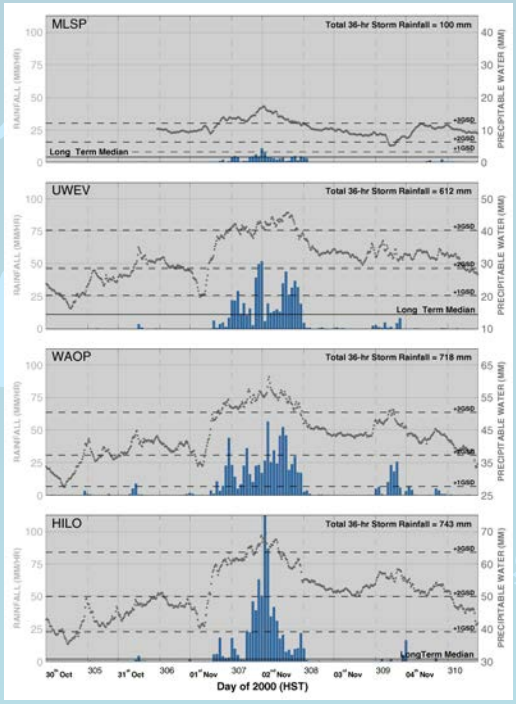
Hilo Flood 1-2 November 2000

24-hr rainfall (solid) and 100-yr flood rainfall (dashed).



Rainfall vs Water Vapor





Hilo Flood 1-2 November 2000

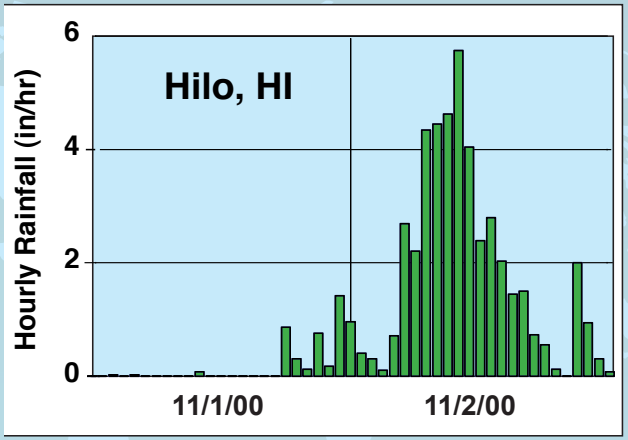
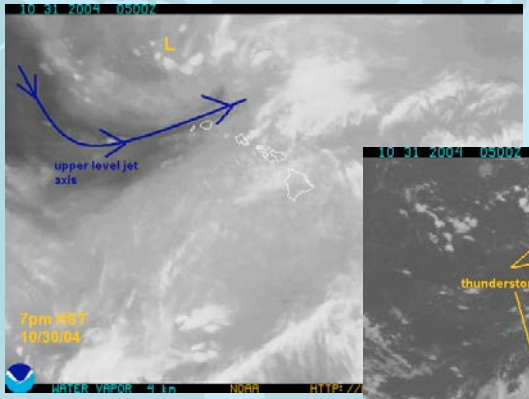


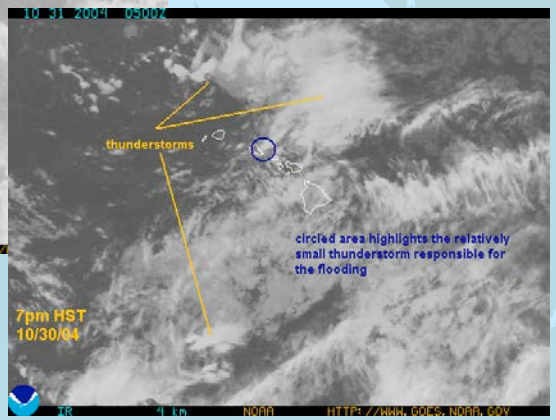
Figure 1 Hourly rainfall rate (inches per hour) for Hilo for the period 1 to 2 November 2000.

Manoa Halloween Flood

Manoa Halloween Flood 2004

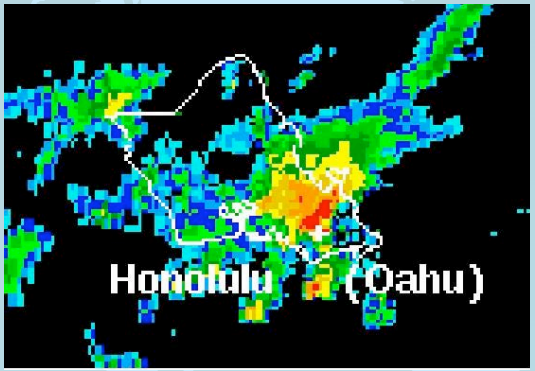


Upper-level divergence over converging NE trade winds.



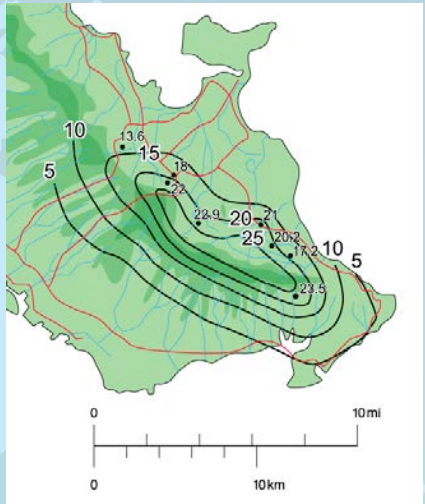
Manoa Halloween Flood 2004

Rainfall Rates
15min: 1.29 inches
1-hr: 3.72 inches
2-hr: 4.38 inches
3-hr: 5.73 inches
6-hr: 8.71 inches
A once in 50-yr storm



Oahu New Year's Eve Flood

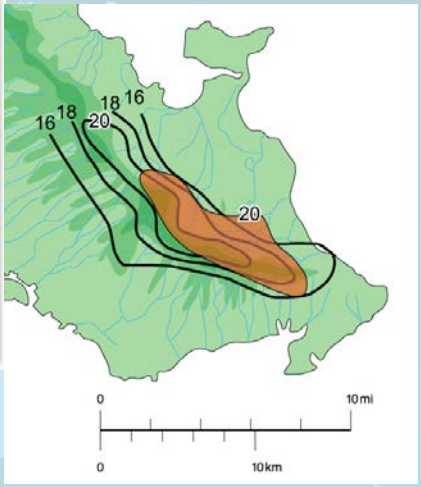
Kahena Street, Hahaione Valley on January 2, 1988. Flood waters gouged a 10–20 ft channel in the roadway. (Photo courtesy of T. Giambelluca).



24-hour rainfall in inches. Distribution determined by the terrain.

Rainfall Distribution: New Year's Storm

Our islands have narrow coastal transportation corridors that can have large sections isolated by debris flows. This occurred on Oahu on New Years Eve, 1987 when all transport to East Oahu was severed.



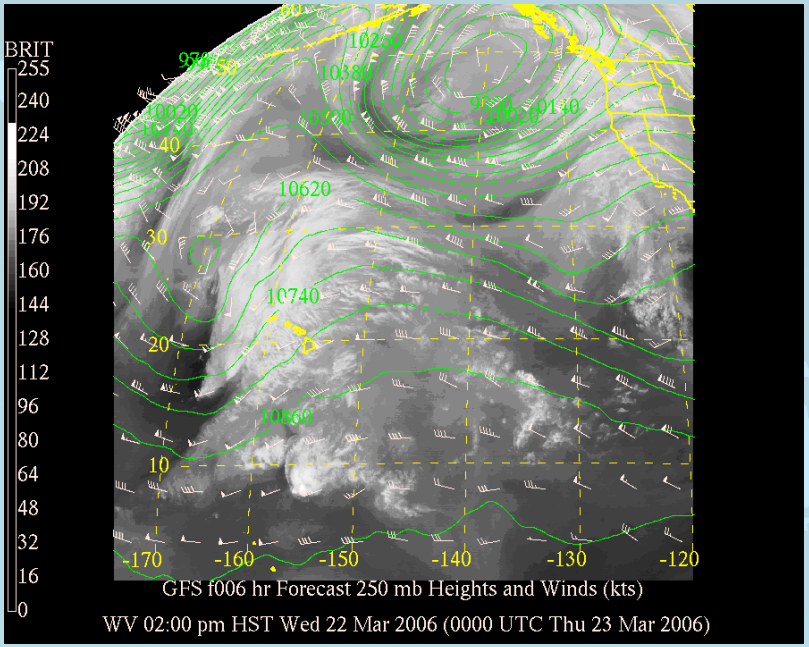
Contours for a 100-yr rainfall event with overlay of 20" rainfall contour.

Oahu Floods February and March 2006

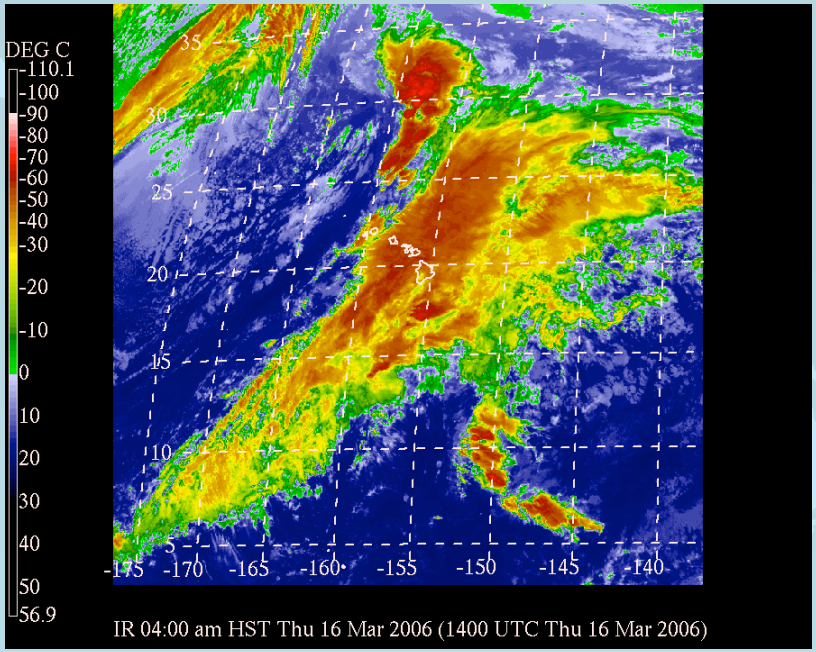
Laie Flood

The Deja Vu Kona Low

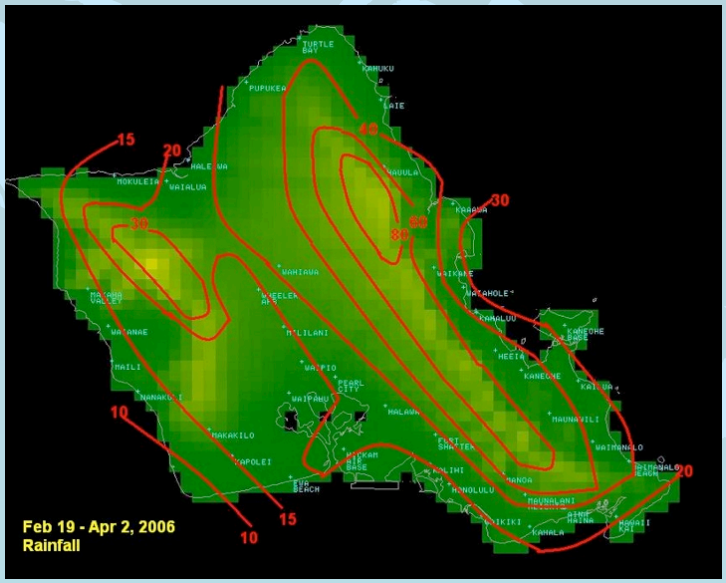
The Deja Vu Kona Low



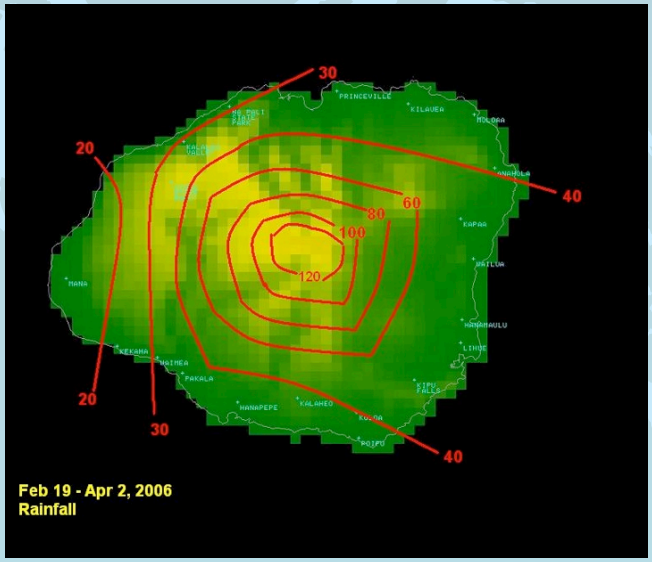
The Deja Vu Kona Low



The Deja Vu Kona Low



The Deja Vu Kona Low



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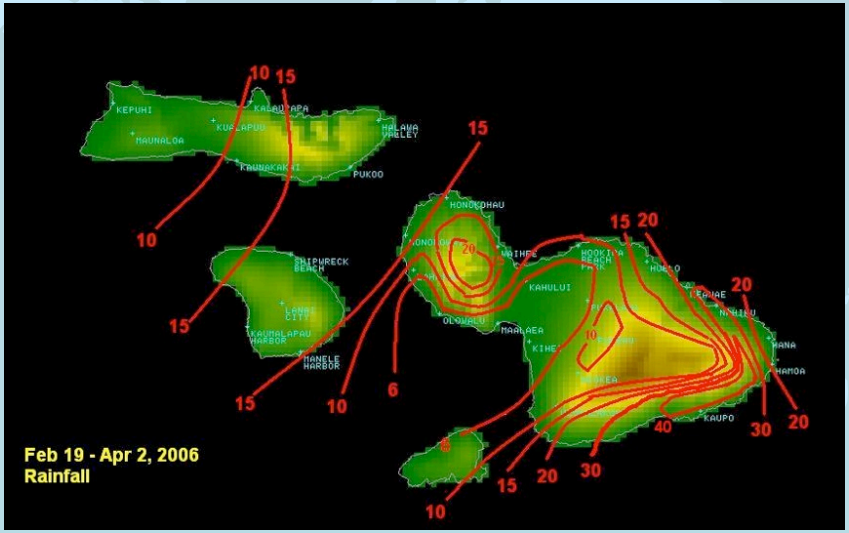

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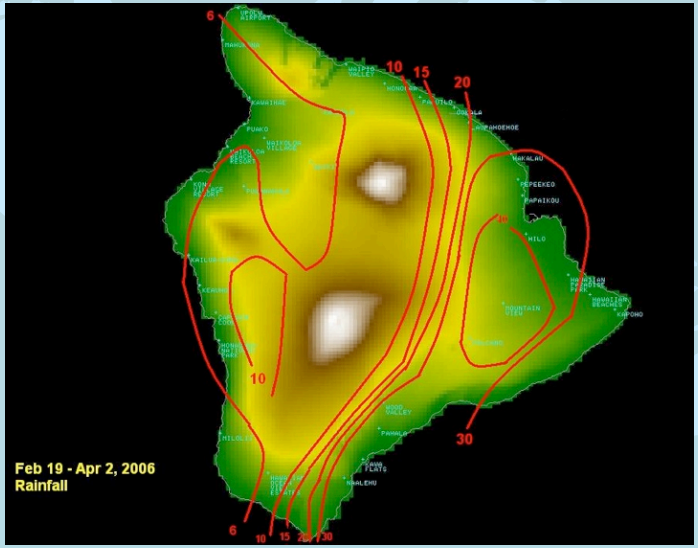


Kaloko Dam Break

- Caused seven deaths
- Over 120 dams in the State of Hawaii
- Most are earthen dams, 70 to 90 years old, built to support agriculture

Kaloko Reservoir, Kauai

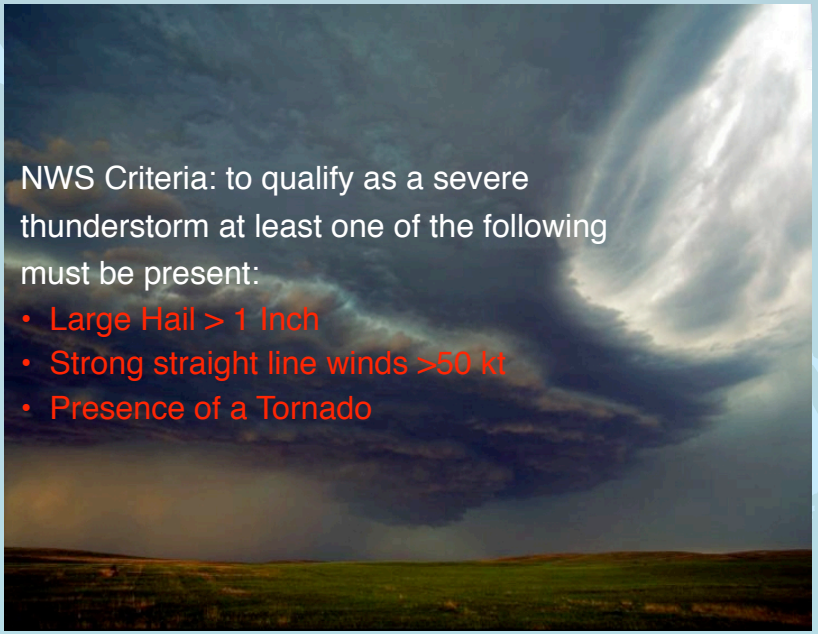
Kaloko Dam Break

Kaloko Dam Break

Severe Thunderstorms

- NWS Criteria
- Environment
- Severe thunderstorms In Hawaii

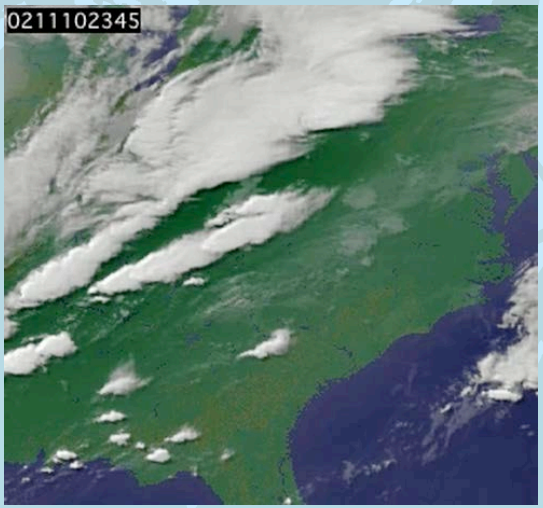
Severe Thunderstorms: NWS Criteria

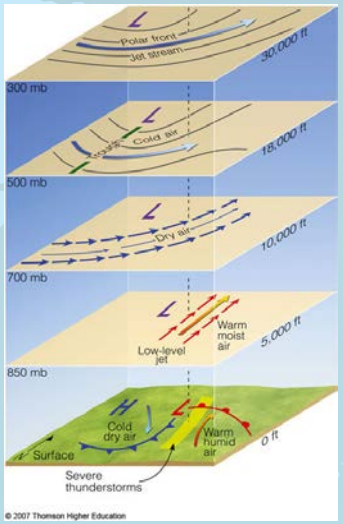


NWS Criteria: to qualify as a severe thunderstorm at least one of the following must be present:

- Large Hail > 1 Inch
- Strong straight line winds >50 kt
- Presence of a Tornado

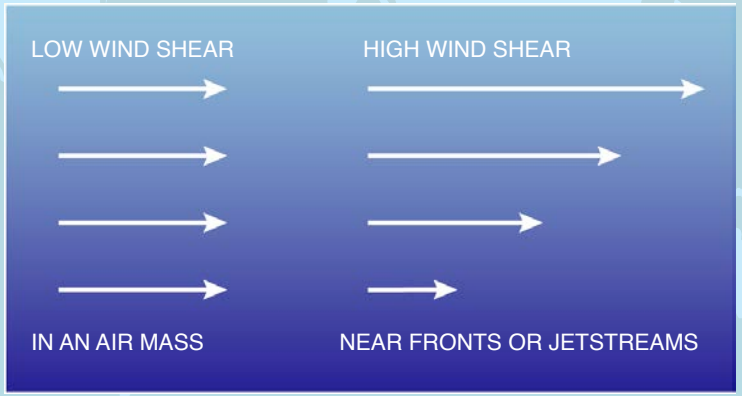
The Severe Thunderstorm Environment





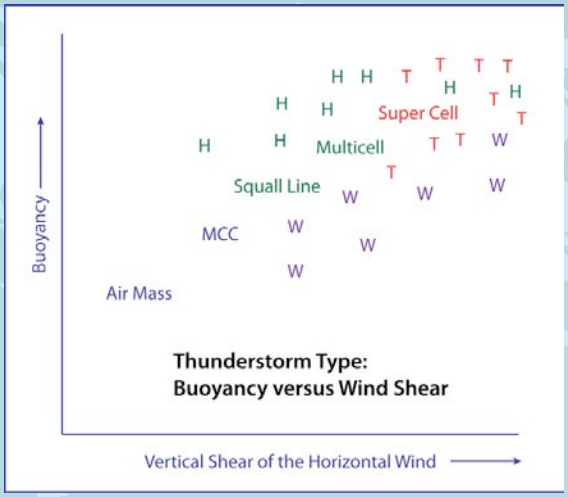
Air Mass vs Severe Thunderstorms

Environment: Severe thunderstorms form in regions of relatively strong winds and large wind shear. Thus they form near fronts and jet streams.



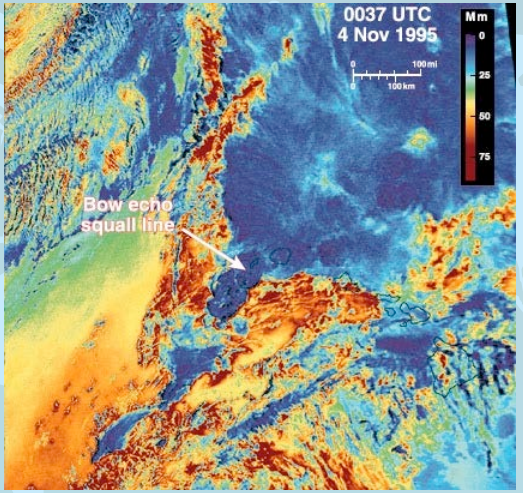
Air Mass Thunder Storm Severe Thunderstorm

The Thunderstorm Environment



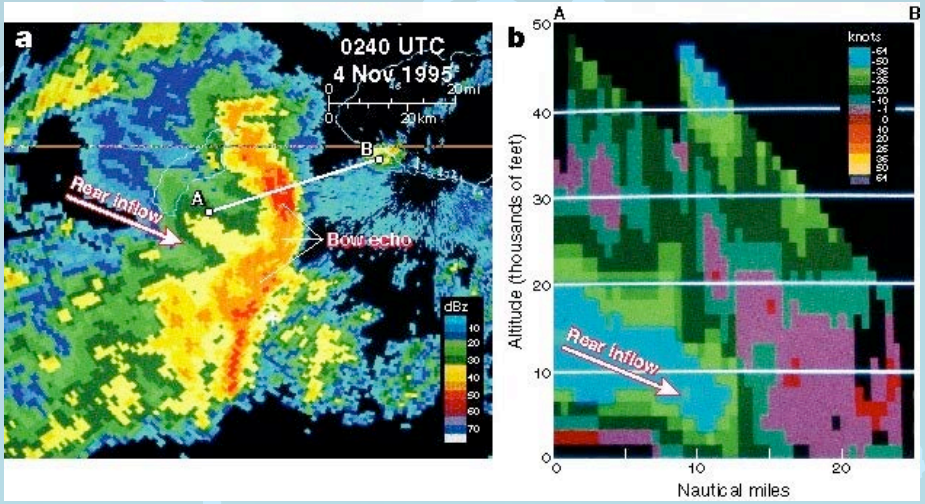
The type of thunderstorm development depends on the magnitude of the horizontal wind shear with height and the buoyancy.

Rainbands in Kona Lows



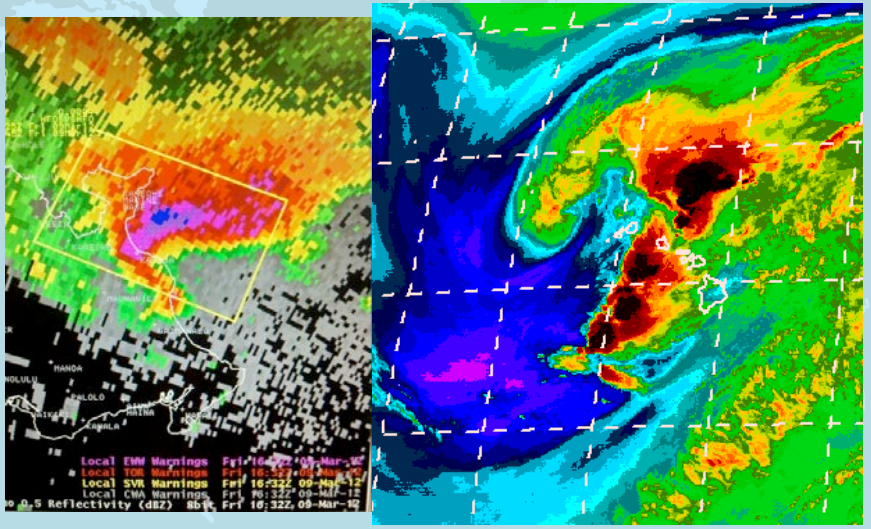
This water vapor image shows moist air associated with squall line (line of thunderstorms).

Squall line Passage and High Winds

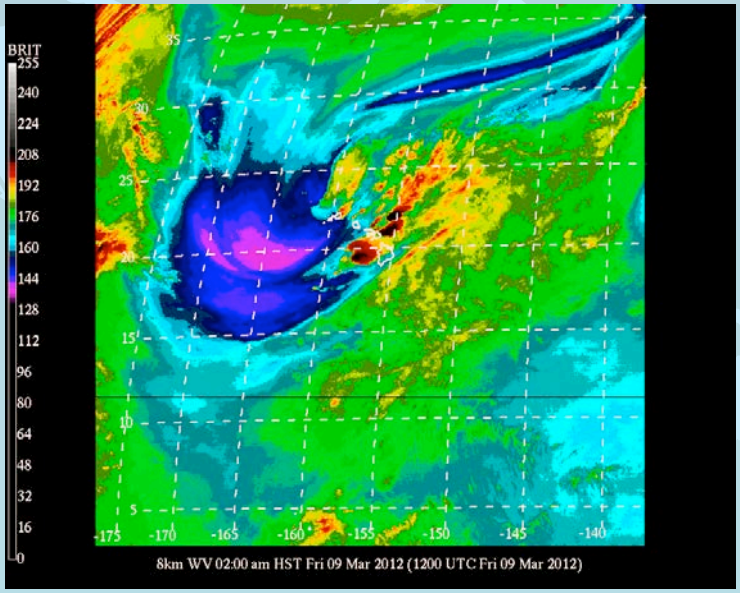


Squall line at left is bowed by strong NW winds. Wind speeds of 90 mph were observed in Lihue when the squall line passed.

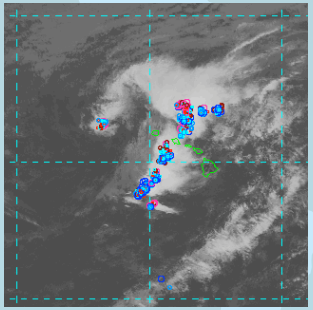
Oahu Hailstorm – March 2012



Water Vapor Loop 3-10-12



Oahu Hailstorm – March 2012

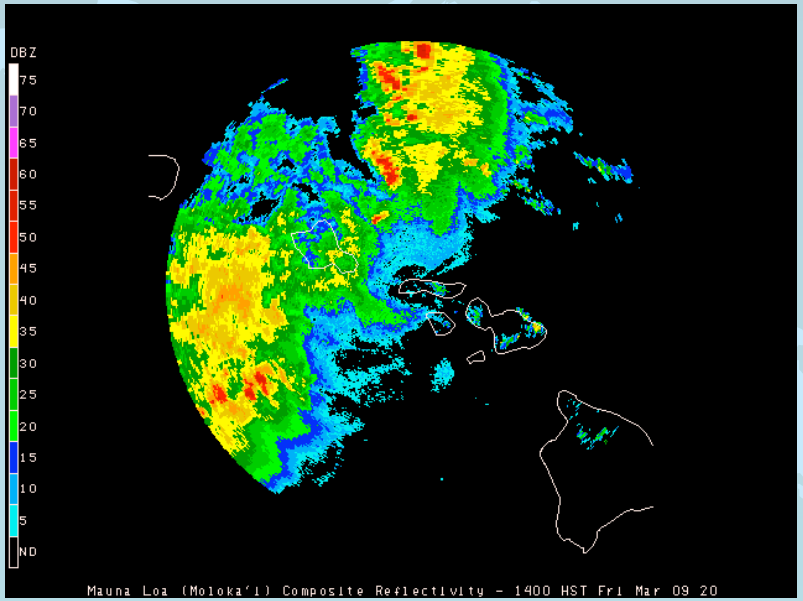


Oahu Hailstorm – March 2012

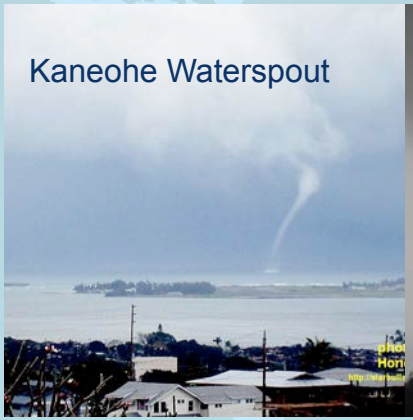
Hail was recovered in Kaneohe measuring 4.25 inches!

Oahu Hailstorm – March 2012

Oahu Hailstorm – March 2012



Hawaii Waterspouts and Tornados



- Waterspouts and funnel clouds are fairly common in Hawaii. Tornados > F1 are rare.

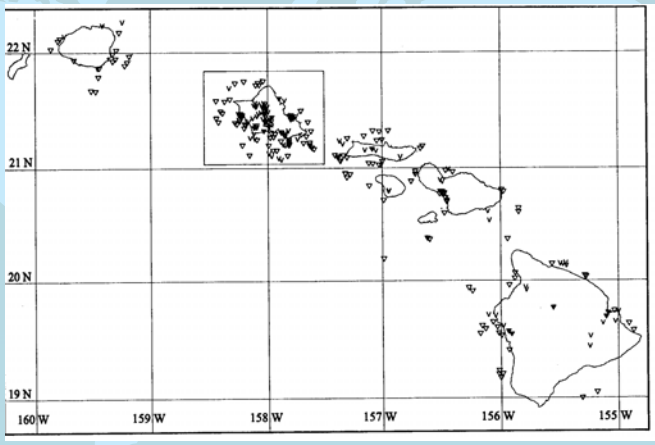
Tornados over Oahu

Crazy Weather in Honolulu

Crazy Weather in Honolulu

Crazy Weather in Honolulu

Observations



Locations of reported funnels, waterspouts and tornados for period 1976-1997.

Questions?