

Rainfall Atlas of Hawai'i



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Commission on Water Resource Management
Department of Land and Natural Resources
State of Hawai'i

21 December 2011



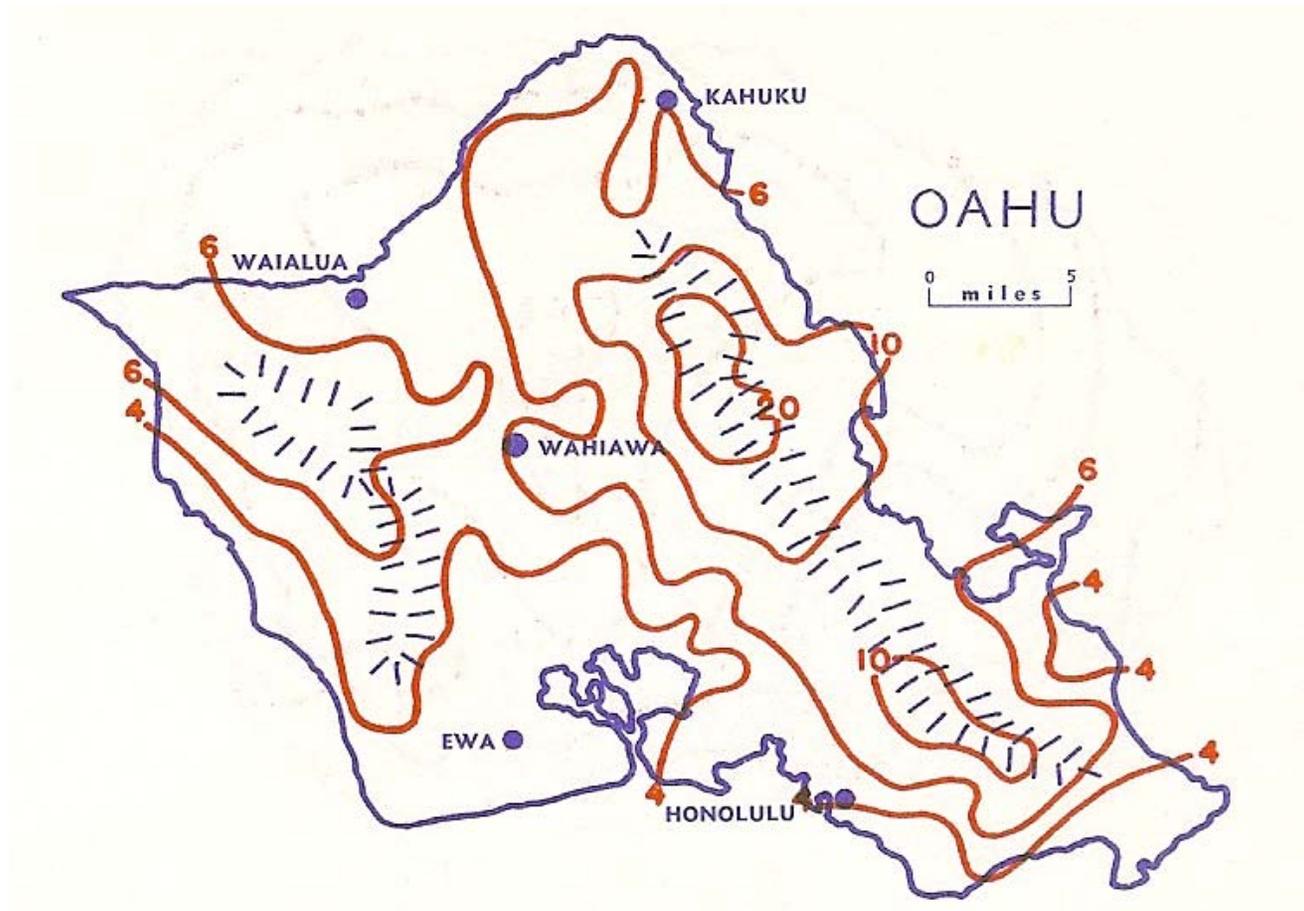
Measurement and Mapping of Hawaiian Rainfall

- Earliest known RF observations taken in 1837 at Nu‘uanu Avenue and Beretania Street
- 106 stations by 1900
- Number of stations increased with the growth of plantation agriculture
- 422 stations by 1920
- Mapping of rainfall patterns began in earnest in the 1920s



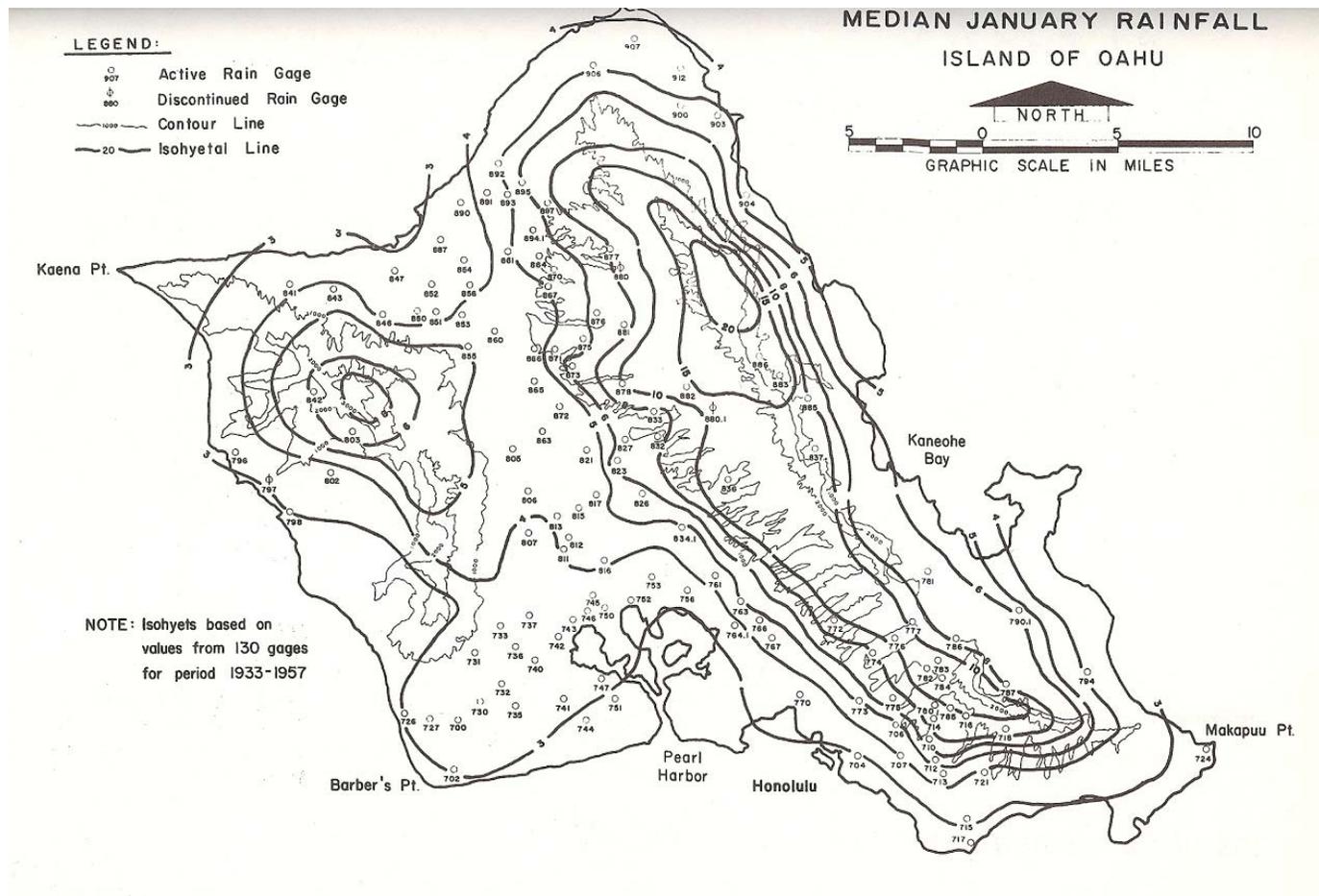
Previous Efforts to Map Hawaiian Rainfall

Mordy and Price (1955)



Previous Efforts to Map Hawaiian Rainfall

Taliaferro (1959)



Previous Efforts to Map Hawaiian Rainfall

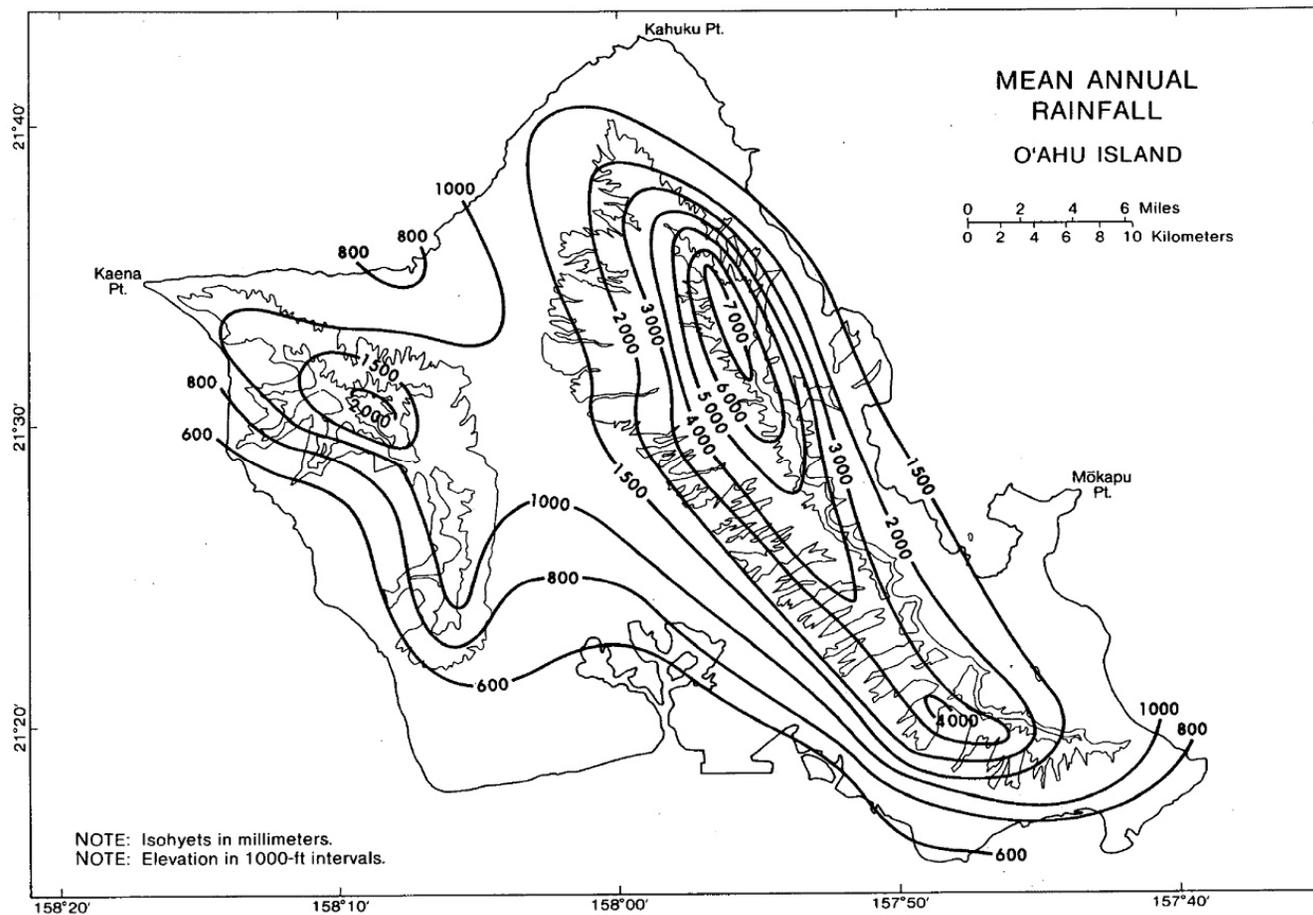
Meisner et al. (1982)



Previous Efforts to Map Hawaiian Rainfall

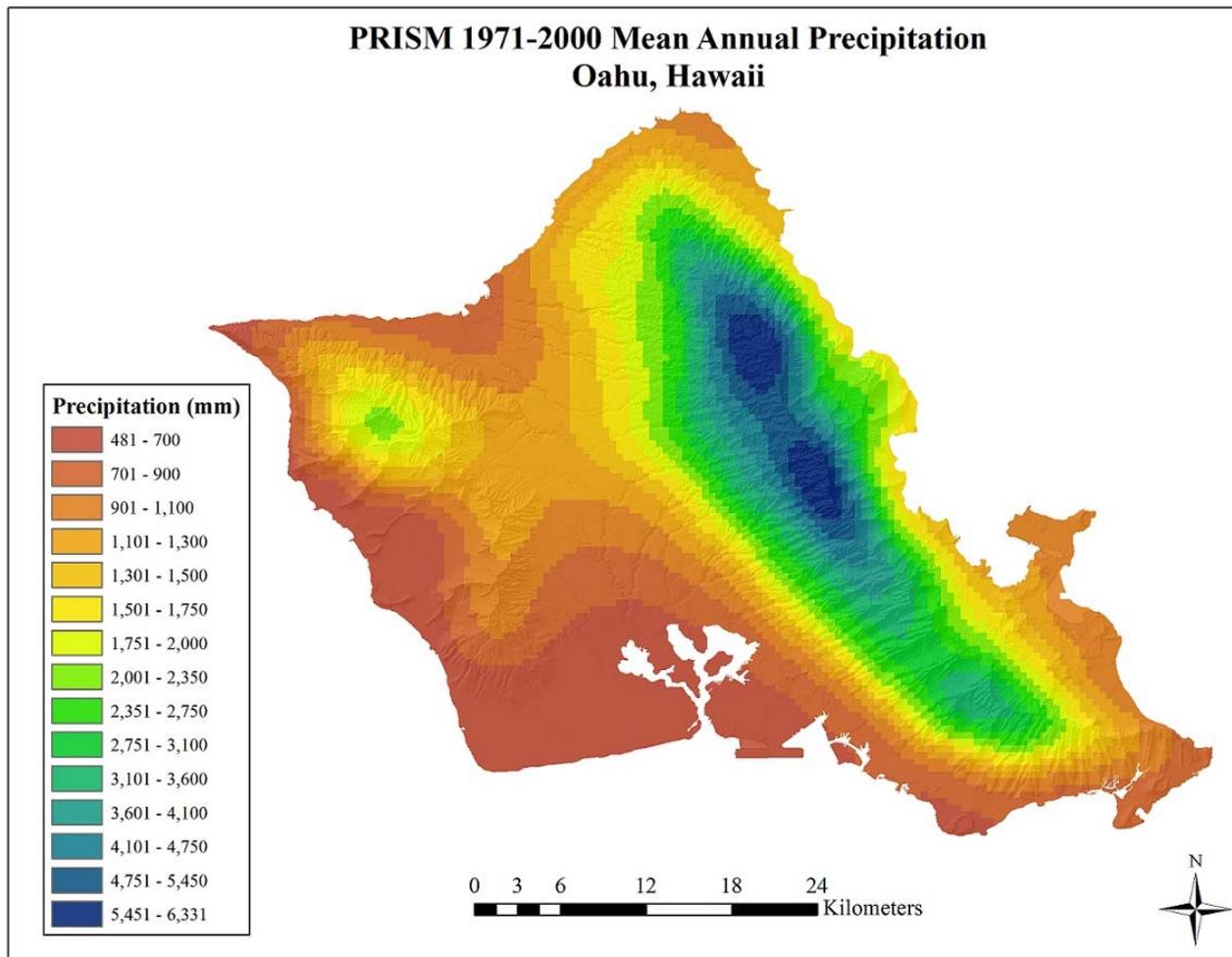
The Original Rainfall Atlas of Hawai'i

Giambelluca et al. (1986)



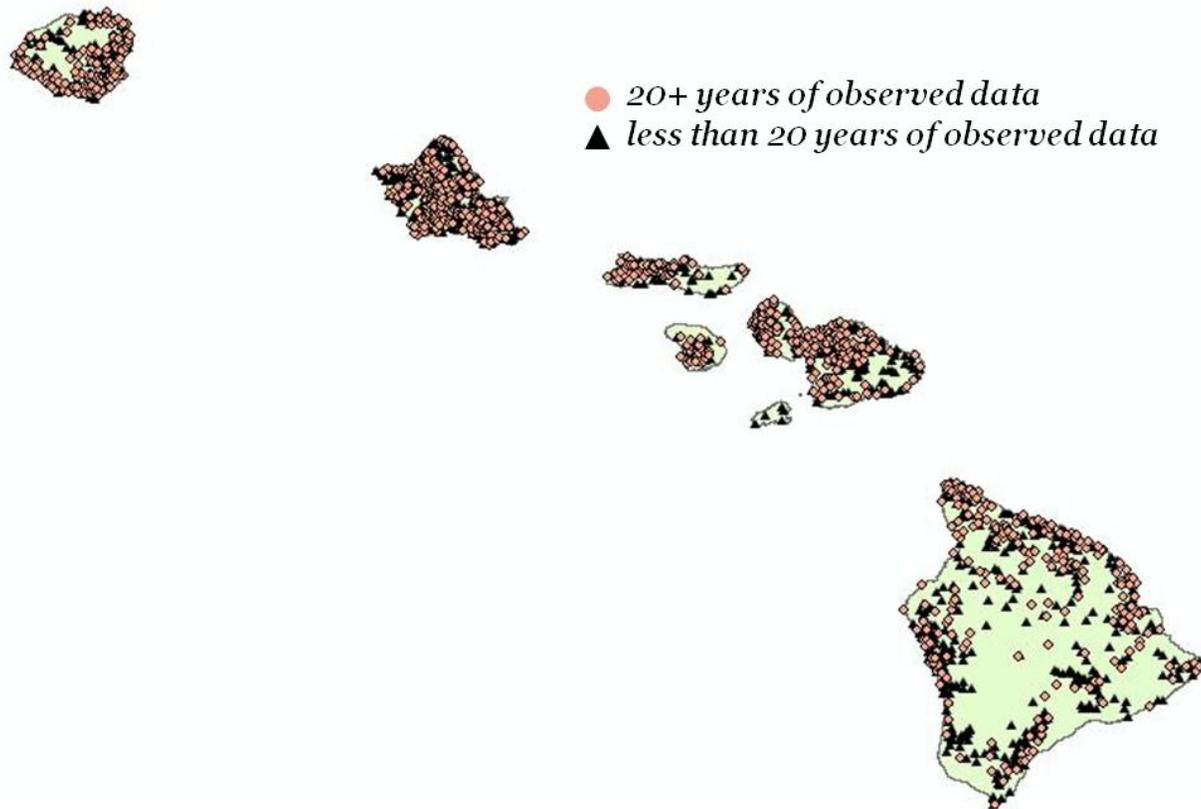
Previous Efforts to Map Hawaiian Rainfall

Daly et al. (2006)



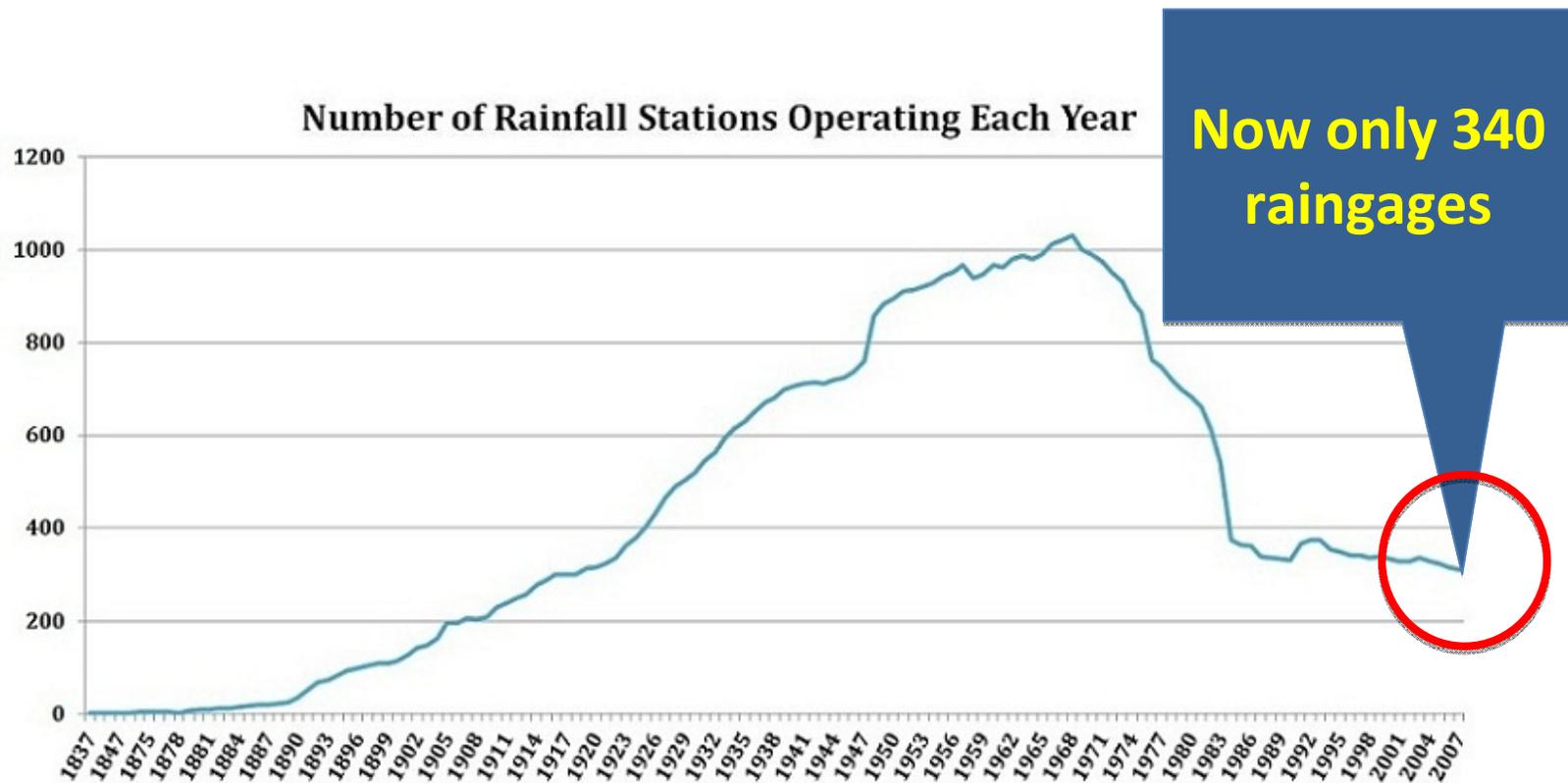
The Rainfall Network

- We compiled a monthly RF database of 2,188 raingage sites
- 517,017 station-months (43,085 station-years) of data
- Average length of record: 40 years



The Rainfall Network

Number of station operating at any given time peaked at 1030 stations in 1968



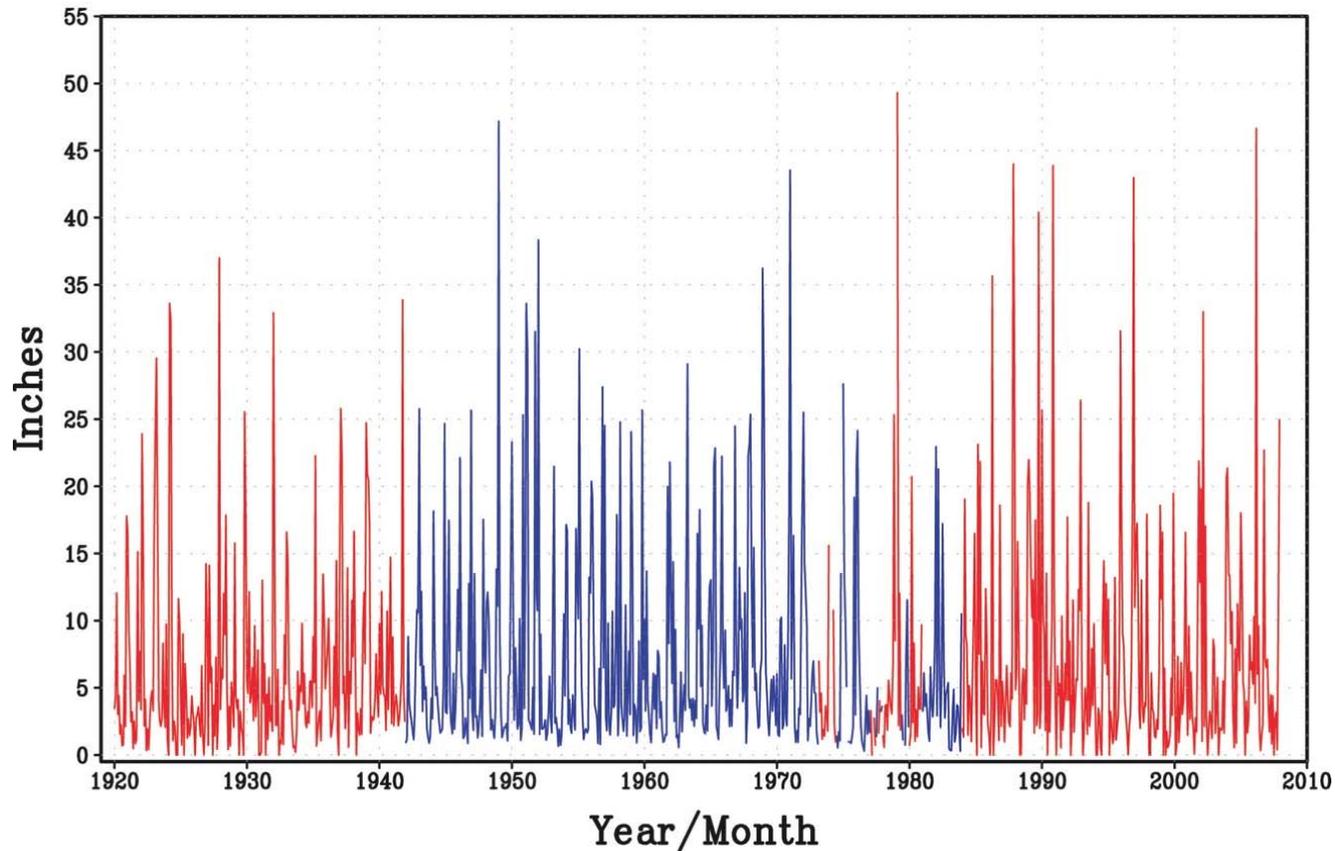
The Rainfall Network

- Large number of stations, but . . .
- Stations active during different periods
 - Need to have common base period for calculating means
 - Previous efforts adjusted means
 - We chose to do gap filling
- Not evenly distributed spatially
 - Most previous efforts relied strictly on subjective, expert knowledge
 - We supplemented raingage stations with “**virtual raingage stations**” based on patterns of natural vegetation
 - We used independent spatial predictor datasets:
 - **PRISM**
 - **MM5**
 - **Radar**

Gap-Filling Station Data

Numerous statistical techniques were used to fill gaps, including periods before and after a station's period of operation

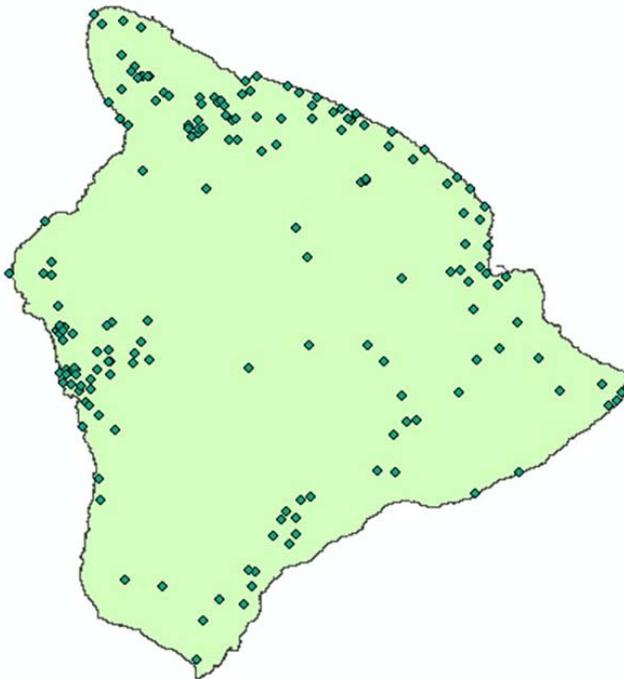
Ainahou (58): 19.3°N; 155.2°W



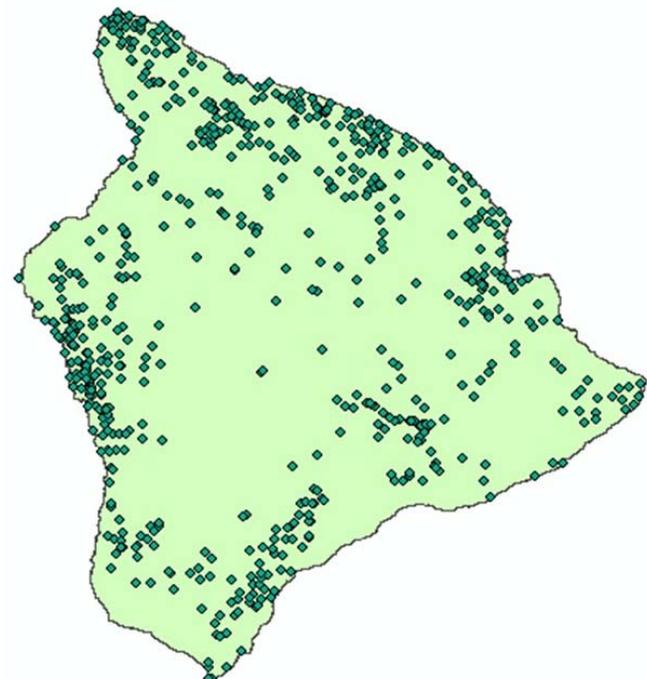
Gap-Filling Station Data

- Resulting estimates were rigorously tested and gap-filling estimates were rejected in many cases
- Results greatly improve the spatial distribution of stations for any given period

Raingages Operating in 1980

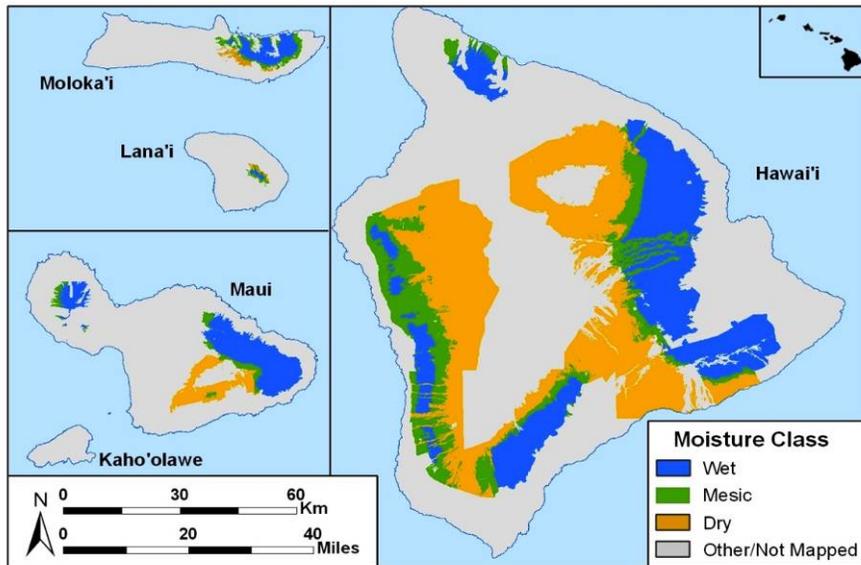


All Raingages

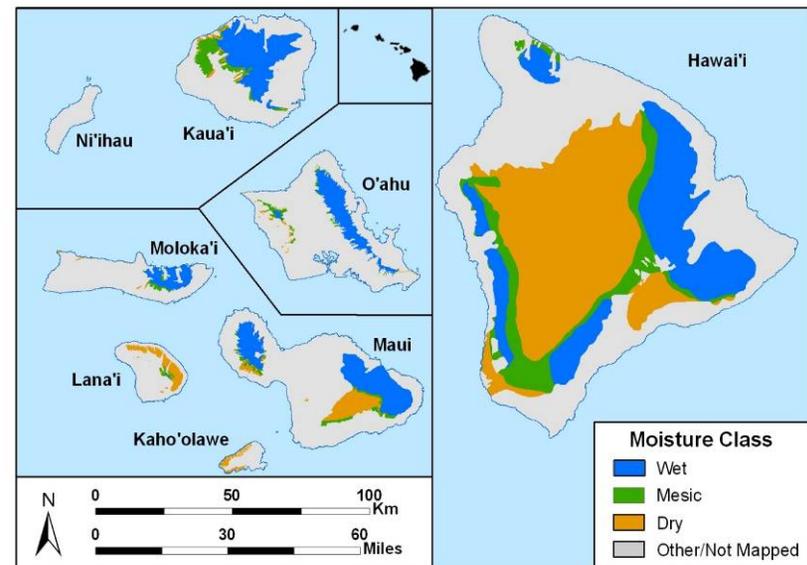


Estimating Mean Rainfall for Virtual Raingage Stations

Moisture zones determined by patterns of natural vegetation



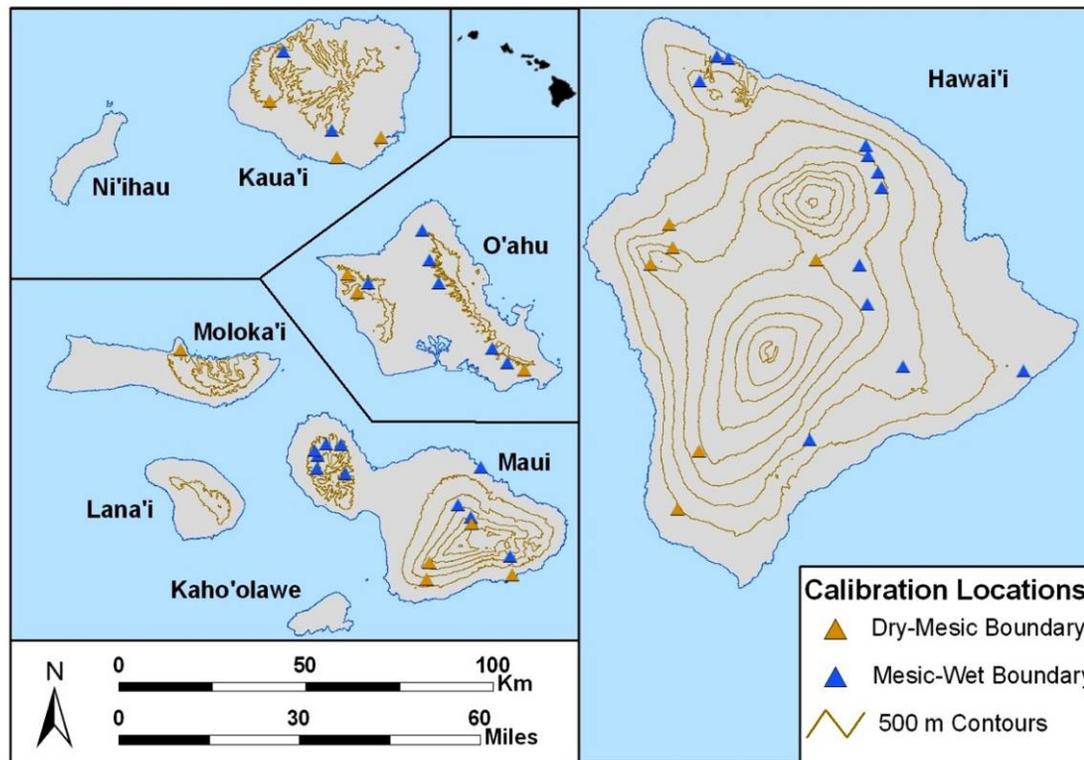
Jacobi (1989)



Gon et al. (1998).

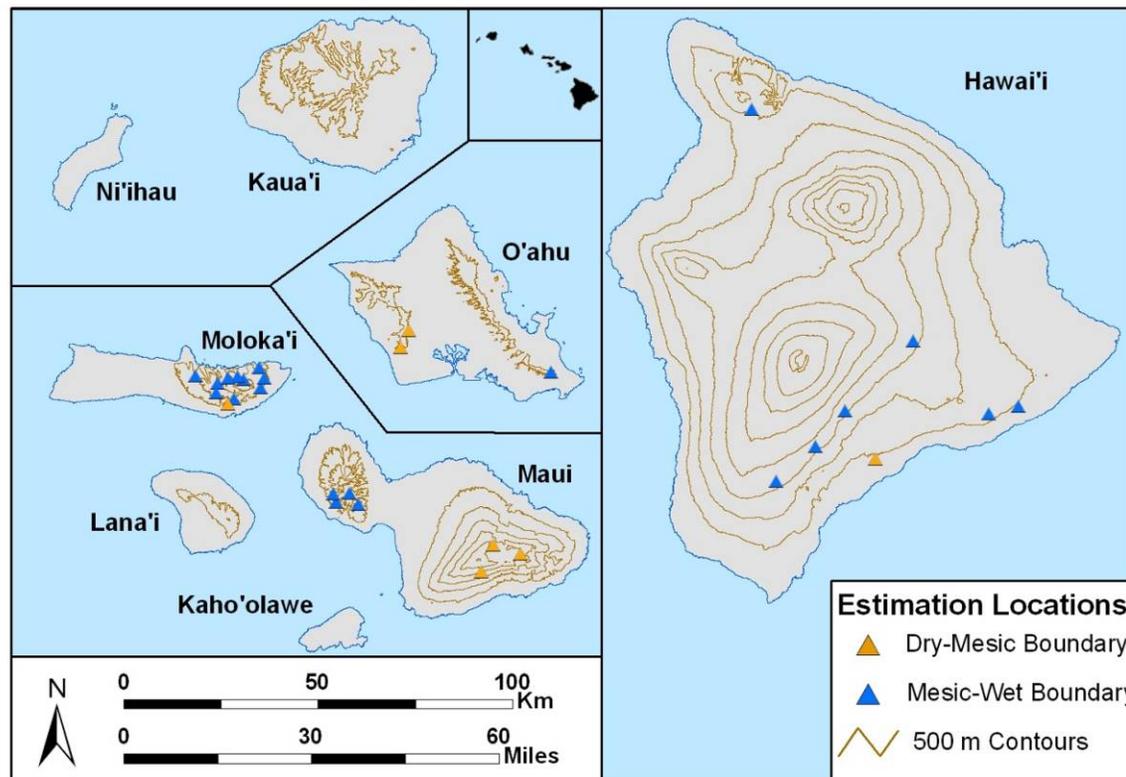
Estimating Mean Rainfall for Virtual Raingage Stations

Sites with known mean rainfall used to calibrate the model



Estimating Mean Rainfall for Virtual Raingage Stations

Mean rainfall estimated for sites with no nearby raingages



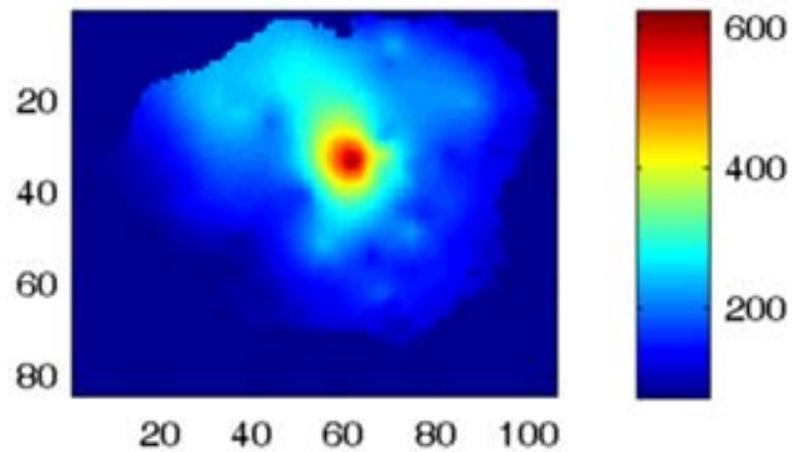
Base Period

- Natural multi-decadal rainfall fluctuations suggest using a long base period
- Long-term secular trends in rainfall suggest using a short, recent base period
- NOAA standard for computing normals: 30 years
- Our choice: Use the most recent available 30 year period:

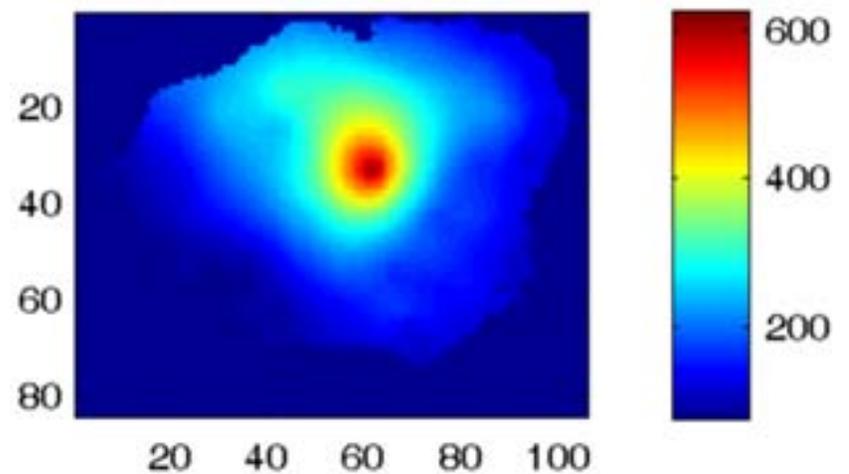
1978-2007

Spatial Interpolation of Raingage Data

Ordinary Kriging



Ordinary Kriging with Variable Observation Uncertainty

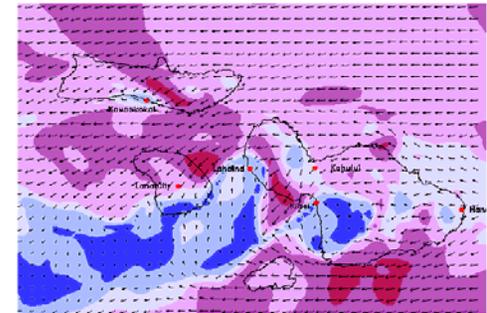


Predictor Spatial Datasets

PRISM: Mapping system relying on statistical relationships between rainfall and terrain



MM5: Mesoscale meteorological model used for operational weather forecasting

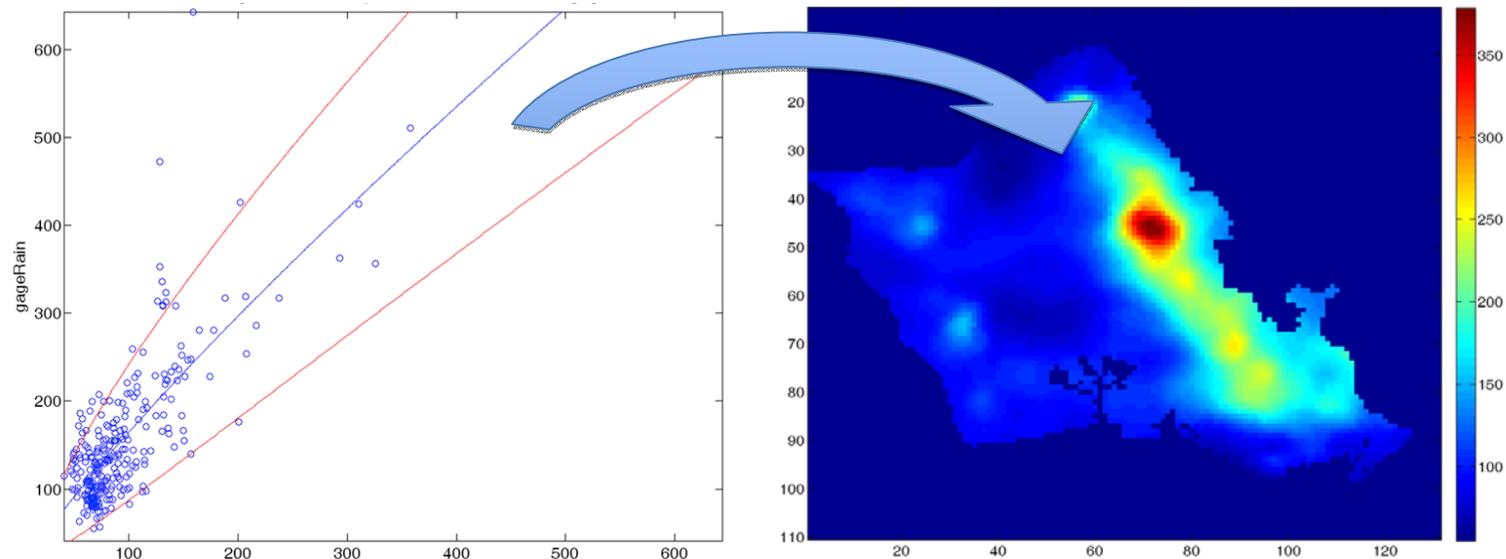


Radar Rainfall: Radar used to monitor rainfall and to identify intense rainfall approaching the islands



Adjusting Predictor Maps Using Observations

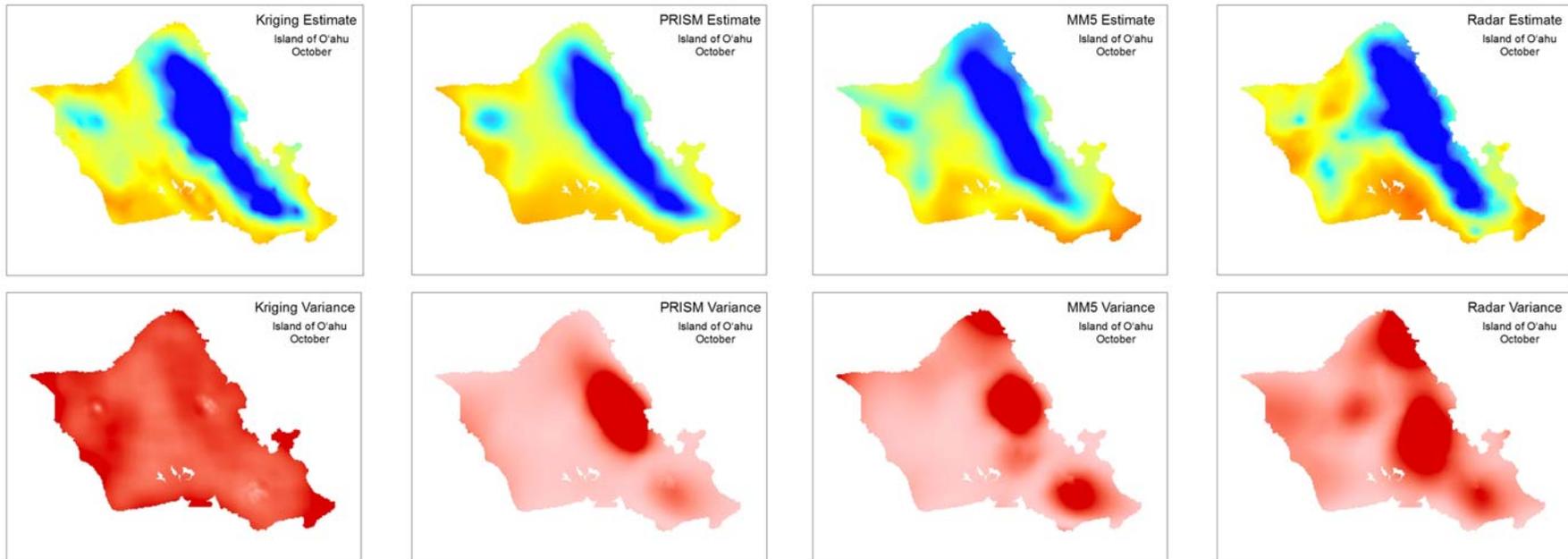
Non-linear regression between raw predictor rainfall and observed rainfall are used to produce adjusted predictor maps and maps of uncertainty.



Regression modeling of PRISM and rainfall at a given month (left) and its associated conditional mean rainfall map (right).

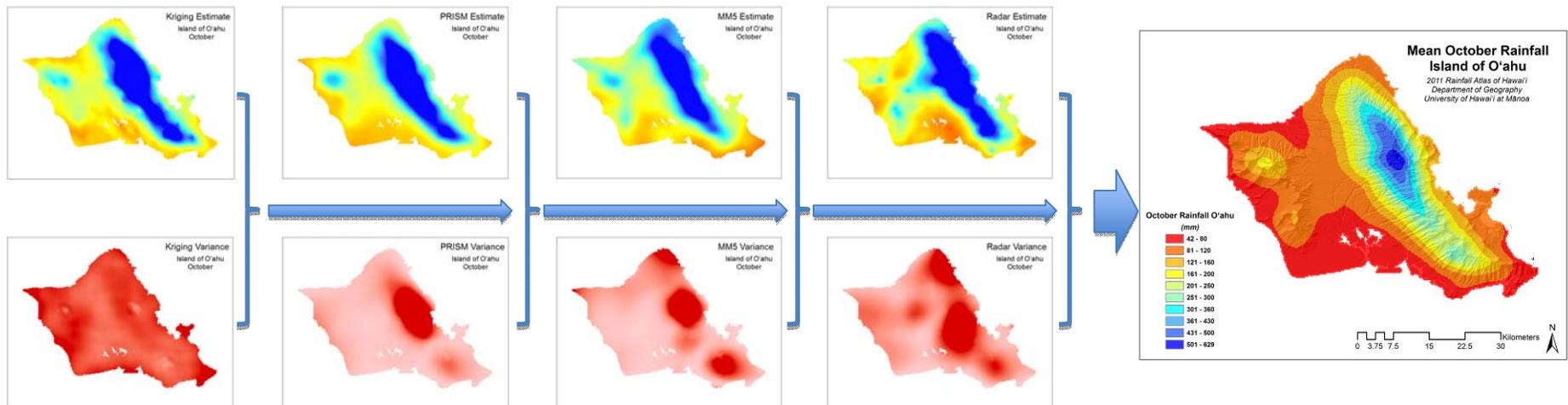
Fusing Interpolated Maps and Predictor Datasets

- Uncertainty used to weight the different estimates



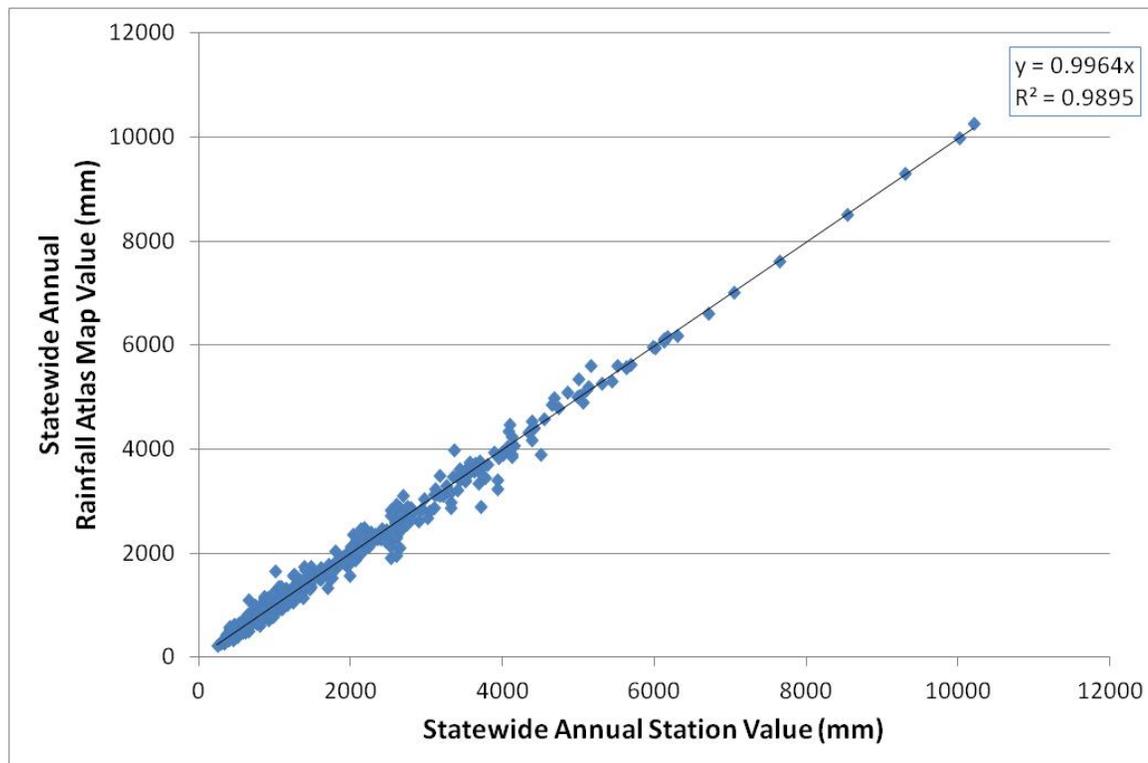
Fusing Interpolated Maps and Predictor Datasets

Bayesian statistics are used to fuse the estimates to produce the final maps



Checking the Final Maps

Mapped and observed mean rainfall lie along the 1:1 line



The Web Site

With the help of the EPSCoR Cyberinfrastructure Team at UH Hilo, we developed a web platform for the new rainfall atlas

Rainfall Atlas of Hawai'i
Geography Department - University of Hawai'i at Mānoa

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What is the Rainfall Atlas of Hawai'i?

The Hawaiian Islands have one of the most diverse rainfall patterns on earth. The mountainous terrain, persistent trade winds, heating and cooling of the land, and the regular presence of a stable atmospheric layer at an elevation of around 7,000 ft. interact to produce areas of uplift in distinct spatial patterns anchored to the topography. The resulting clouds and rainfall produced by this uplift lead to dramatic differences in mean rainfall over short distances. Knowledge of the mean rainfall patterns is critically important for a variety of resource management issues, including ground water and surface water development and protection, controlling and eradicating invasive species, protecting and restoring native ecosystems, and planning for the effects of global warming.

Be sure to check out the [interactive map!](#) It may need a few minutes to load on your first visit.

MODIS Image of Hawai'i, NASA Earth Observatory

Mean Annual Rainfall State of Hawai'i

2011 Rainfall Atlas of Hawai'i
Department of Geography, University of Hawai'i at Mānoa

Annual Rainfall (mm)

| |
|----------------|
| 204 - 750 |
| 751 - 1,200 |
| 1,201 - 2,000 |
| 2,001 - 2,750 |
| 2,751 - 3,500 |
| 3,501 - 4,400 |
| 4,401 - 5,400 |
| 5,401 - 6,400 |
| 6,401 - 7,300 |
| 7,301 - 10,275 |

0 25 50 100 150 200 Kilometers

The Rainfall Atlas of Hawai'i is a set of maps of the spatial patterns of rainfall for the major Hawaiian Islands. Maps are available for mean monthly and annual rainfall. The maps represent our best estimates of the mean rainfall for the 30-yr base period 1978–2007. However, for many reasons, it is not possible to determine the exact value of mean rainfall for any location. Therefore, for every map of mean rainfall, we provide a corresponding map of uncertainty. Uncertainty tends to be greatest where we have the poorest information about rainfall, for example in remote locations far from the nearest raingage.

This web site was developed to make the rainfall maps, data, and related information easily accessible. The maps depict rainfall patterns by color and/or by isohyets (lines of equal rainfall). The [interactive map](#) allows users to see the patterns of mean monthly and annual rainfall and corresponding uncertainty, zoom in on areas of particular interest, navigate to specific locations with the help of a choice of different base maps, and click on any location to get the mean annual rainfall and a graph and table of mean monthly rainfall. The locations of stations can also be shown on the interactive map. Clicking on a station gives both station and mapped estimates of monthly rainfall along with station metadata.

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Mean Monthly Rainfall (mm)

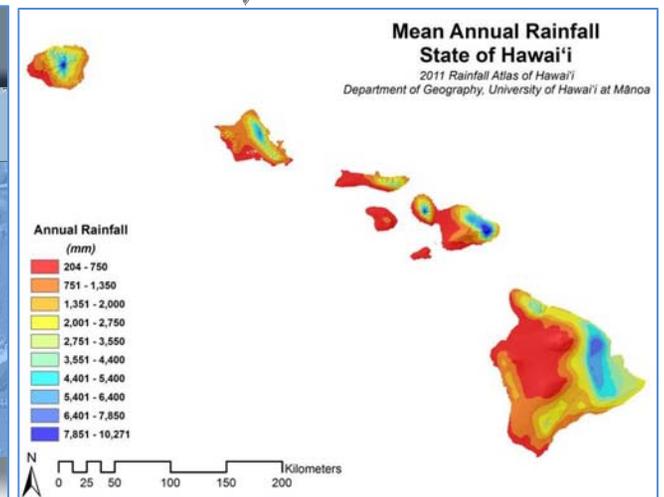
Map: 21.4562° N, 157.9817° W
Station: Kaha 18

| Month | Map | Uncert. | Station | Uncert. |
|-----------|--------|---------|---------|---------|
| January | 248.4 | 52.3 | 282.8 | 35.0 |
| February | 168.8 | 24.1 | 186.1 | 24.7 |
| March | 252.2 | 47.4 | 299.4 | 40.0 |
| April | 220.1 | 51.2 | 279.7 | 32.7 |
| May | 178.9 | 37.0 | 214.1 | 18.1 |
| June | 220.3 | 49.4 | 269.4 | 20.0 |
| July | 224.1 | 40.0 | 257.0 | 20.0 |
| August | 193.9 | 35.1 | 219.2 | 24.1 |
| September | 194.1 | 47.8 | 218.0 | 28.0 |
| October | 235.5 | 62.0 | 253.4 | 34.4 |
| November | 220.0 | 39.7 | 214.1 | 48.0 |
| December | 222.2 | 38.5 | 274.1 | 35.1 |
| Annual | 2684.6 | 147.8 | 2684.6 | 91.1 |

Station Information

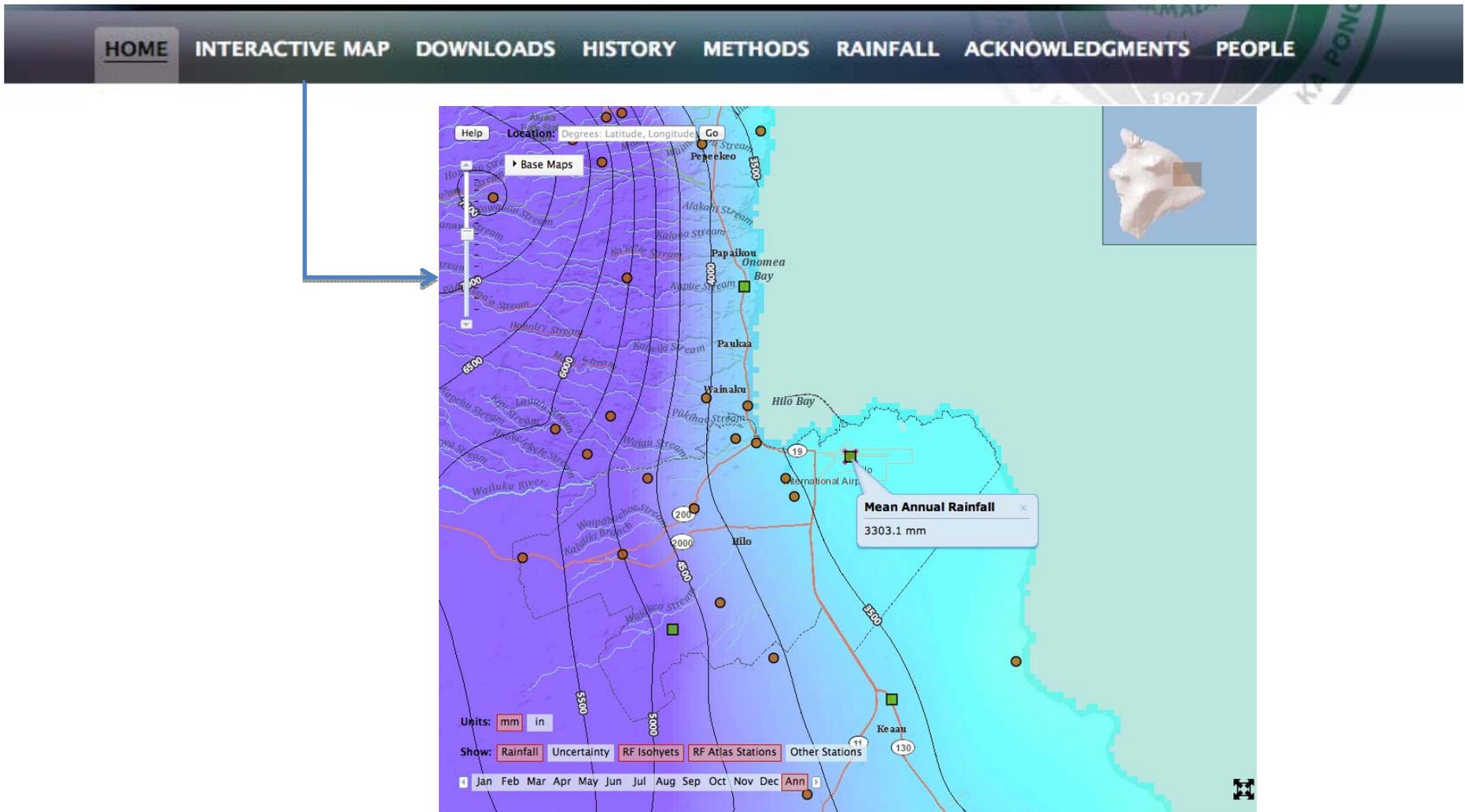
Site: 811
Name: Kaha 18
Observer: US ARMY
Date: 21.4562° N, 157.9817° W
DMS: 21° 27' 42.1" N, 157° 58' 8.7" W
UTM: 48QUR, 65876, 227429
Elevation: 471.9 meters / 1547 feet
Record Period: 1947 - 1999
Data Sources: FSL, NCDC, NWS, SAGE, SAGE/NCDC

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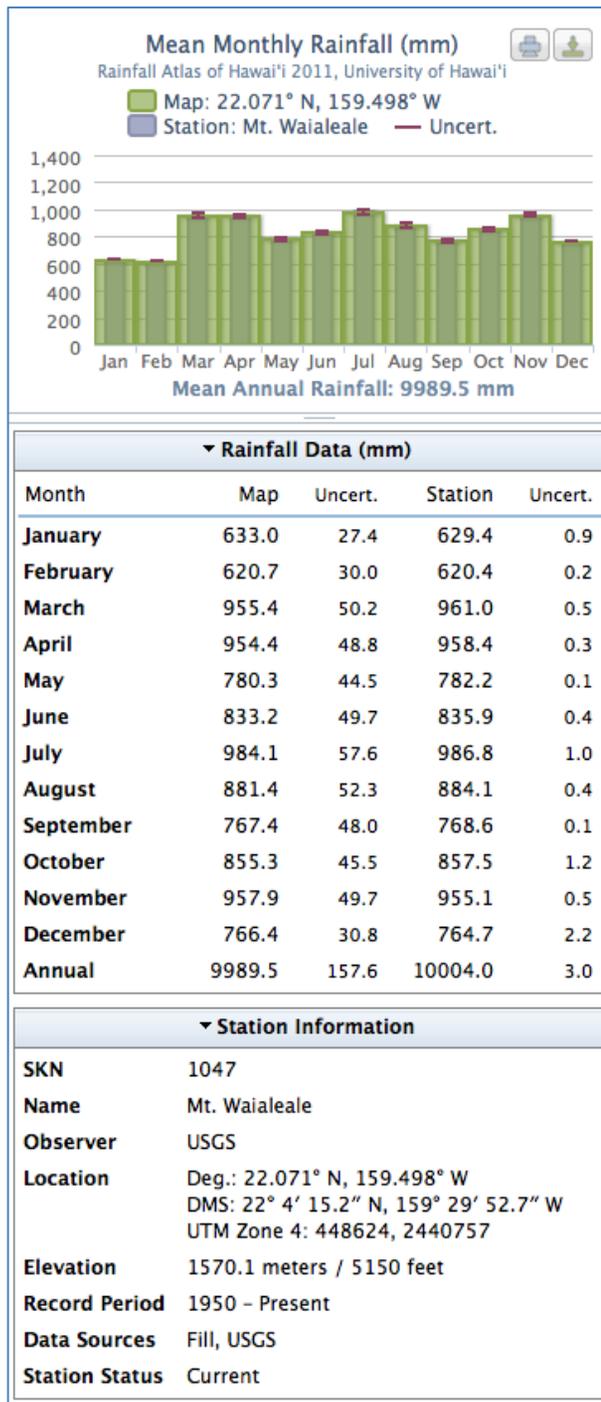


The Web Site

Locate any point of interest on the interactive map and click to get mean annual and monthly rainfall statistics



The Web Site



Clicking on a station gives both map and station estimates of mean annual and monthly rainfall statistics

The Web Site

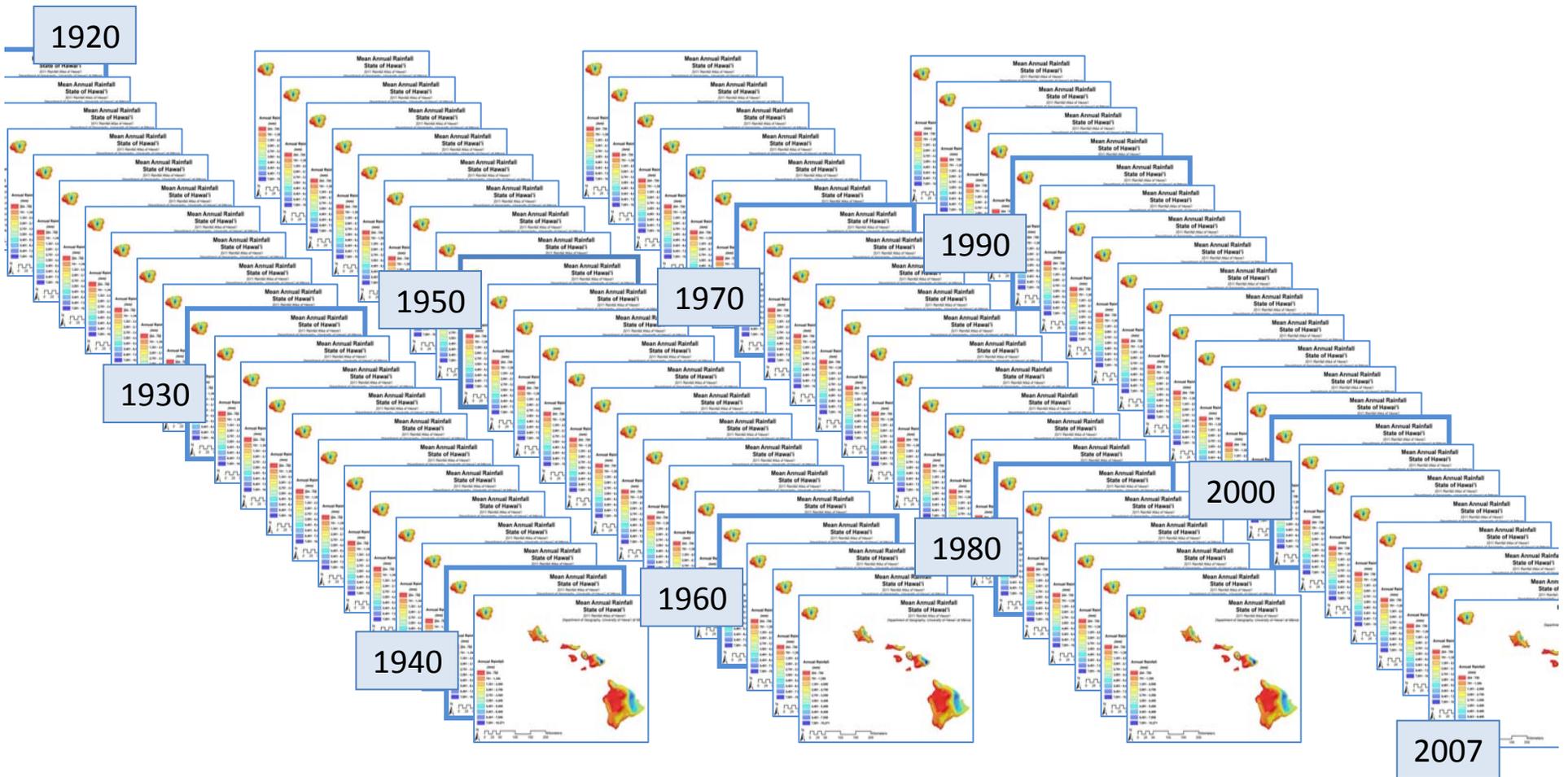
The Rainfall Atlas of Hawai'i Web Site is up and running.

Check it out:

<http://rainfall.geography.hawaii.edu/>

Coming Soon

Month/Year Maps from 1920 to 2007



Thank You

