
Modeling Microclimates and Climate Change in Hawaii

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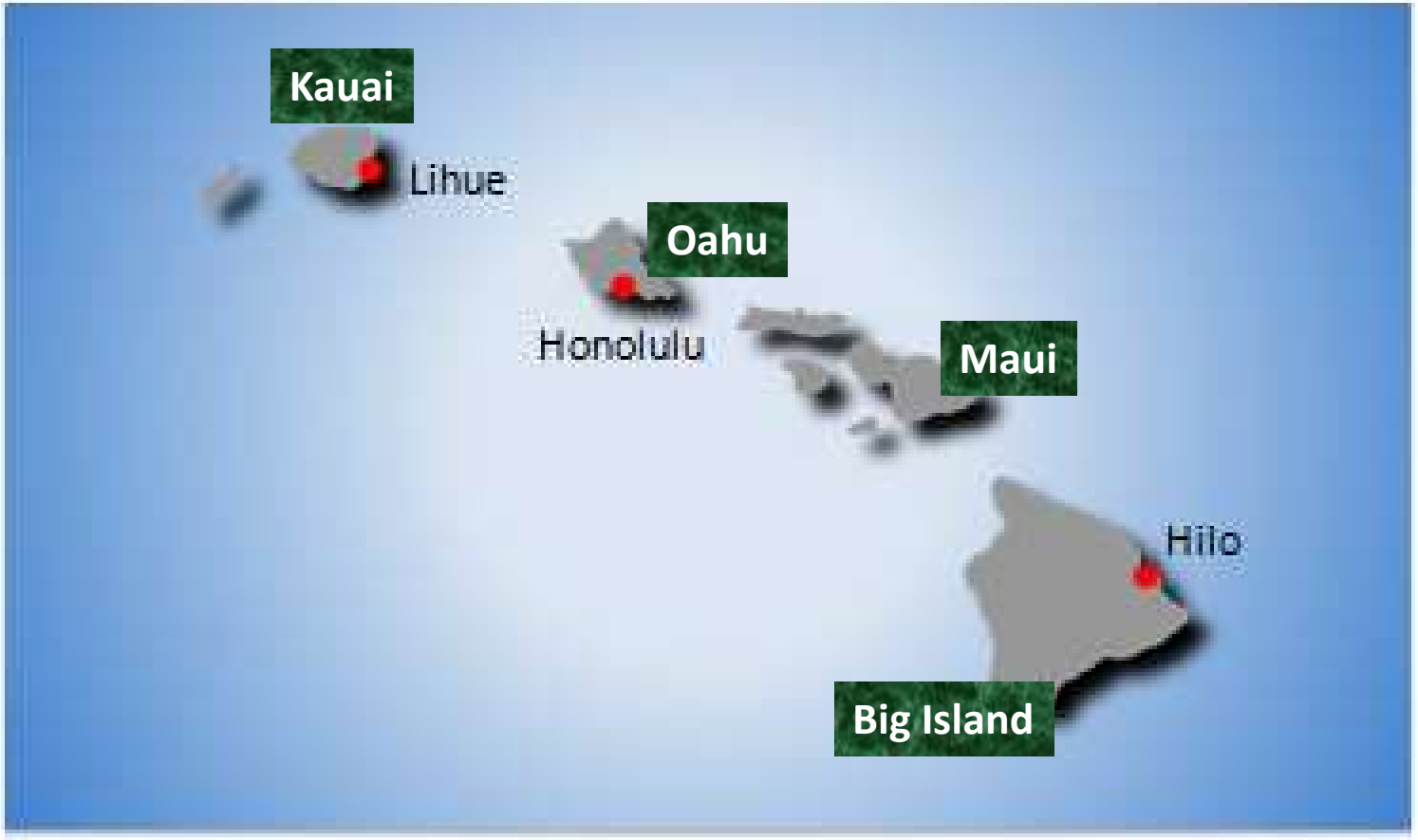
INTERNATIONAL PACIFIC RESEARCH CENTER

Chunxi Zhang, Yuqing Wang, Axel Lauer and Kevin Hamilton



Modeling Microclimates and Climate Change in Hawaii


Lihue
Honolulu
Hilo


Kauai
Lihue
Oahu
Honolulu
Maui
Hilo
Big Island

Why Worry About Climate Change in Hawaii ??

Why Worry About Climate Change in Hawaii ??

Help conserve water during Maui's serious drought

May 6, 2010
Lahaina News

Save | SHARE

Weeks before the start of summer, lawns are brown, hillsides are parched and Hawaii is experiencing some of the worst drought conditions in the country.

Due to the El Niño phenomenon, rainfall across the state has been well below normal. After an abnormally dry winter, Maui residents can expect an arid spring season, the state Commission on Water Resource Management (CWRM) reported last week.

"Hawaii is suffering from drought, and the current El Niño has exacerbated the situation," said Ken Kawahara, the commission's deputy director.

The panel wants Maui residents and businesses to be conscious of drought conditions, help conserve water and prevent potentially deadly wildfires.

Star Advertiser

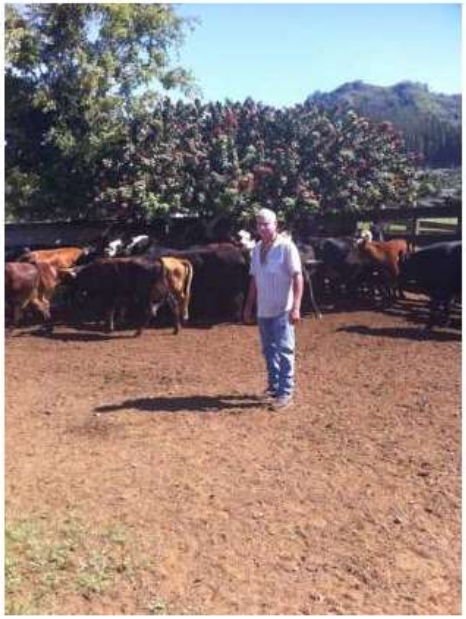
Saturday, June 16, 2012 82.0°F

Rain does little to ease drought

Farmers hope for relief with the wet season

By Gary T. Kubota

POSTED: 01:30 a.m. HST, Nov 22, 2010
LAST UPDATED: 12:33 p.m. HST, Nov 22, 2010



COURTESY PHOTO
Cattle rancher William Sanchez Sr. has had to cut his herd in half because of the drought on Kauai.

The statewide drought appears to be easing as cooler La Nina conditions bring more rain to Hawaii, according to the National Weather Service.

But farmers and ranchers said a protracted amount of rain is needed before they can recover from several years of extremely dry conditions.

Some areas, such as southwestern Kauai and leeward sections of the Big Island and Maui, did not receive significant rainfall in October, continuing extreme drought conditions, National Weather Service officials said Friday.

Late Thursday, thunderstorms along with lightning passed by Hawaii, and most of the anticipated heavy rainfall missed the islands.

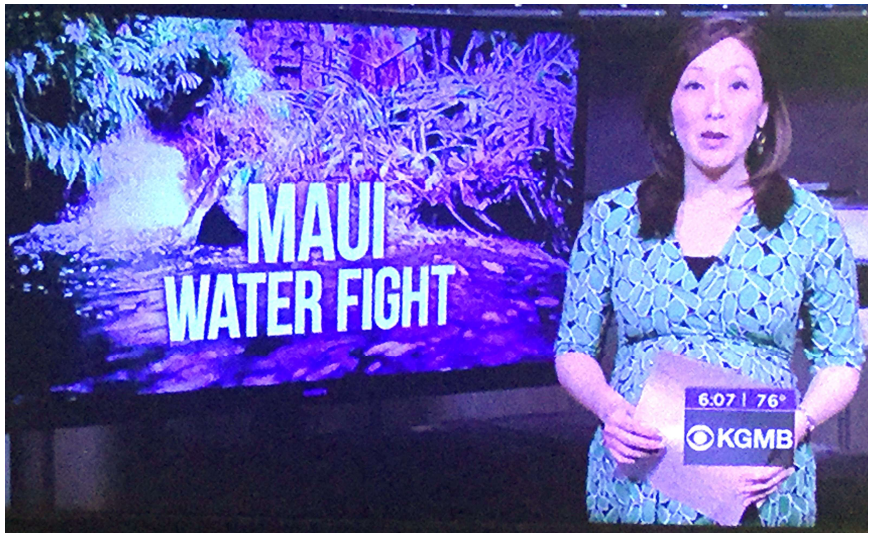
The weather service reported 0.15 inches of rain Thursday at Honolulu Airport and 0.6 inches at Lihue Airport but none for airports in Hilo and Kahului.

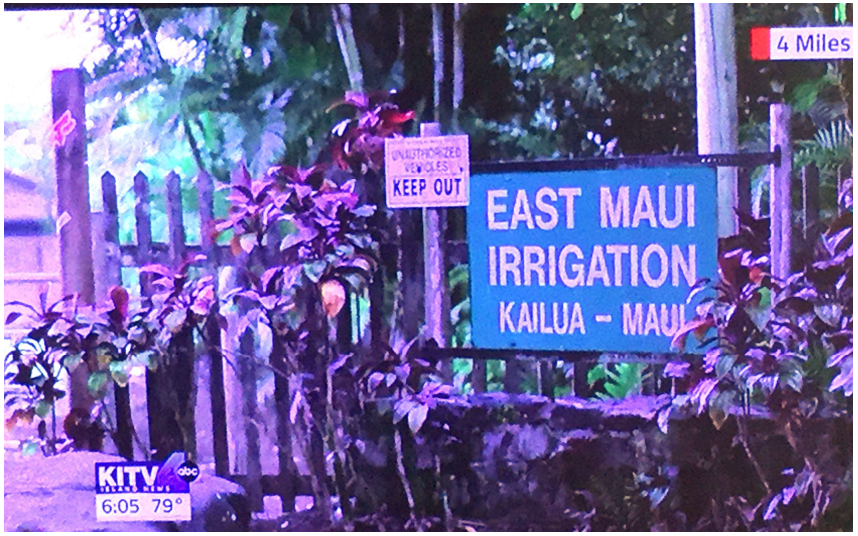
In October, while many places reported less than normal rainfall, some areas exceeded their normal monthly average, including Haiku on Maui with 5.71 inches -- 12 percent above normal -- and Honaunau on the Big Island with 5.54 inches of rain, 7 percent above normal.

A rain forest gauge on Oahu recorded 19.6 inches, or 15 percent more than normal, the weather service said.

Kauai rancher William Sanchez Sr. said he has had to cut his herd in half and is down to 1,000 head, and he has been buying cattle feed

Media coverage of controversy about water rights on Maui in March 2016





Waianae wildfire flare up, residents evacuate

Posted: Jun 07, 2012 5:26 PM HST
Updated: Jun 07, 2012 6:01 PM HST

WAIANAE (HawaiiNewsNow) - Firefighters were once again called to battle a persistent wildfire in Waianae Thursday afternoon.

The latest is a flare-up of a fire that first started last night in the Waianae mountain range off Piliuka place.

Reportedly at least half a dozen residents have voluntarily evacuated. The American Red Cross says it is opening a shelter at Waianae District Park for residents who are evacuating from their homes.

This fire is unrelated to Monday's fire began near Navy property in Lualualei Valley, then crawled over to Waianae Valley and spread into the Waianae Kai

March 26, 2015

STAN LEE / SLEE@STARADVERTISER.COM

A Honolulu Fire Department helicopter makes a water drop on a fire above the University of Hawaii-Manoa Friday afternoon.

Hawaii Plants and Birds

Hawaii is world's "hot spot" of biodiversity

Hawaii Plants and Birds

Hawaii is world's "hot spot" of biodiversity

Hawaii Plants and Birds

Hawaii is world's "hot spot" of biodiversity

Hawaii is world's "hot spot" for extinction

Hawaii Plants and Birds

Hawaii is world's "hot spot" of **biodiversity**

Hawaii is world's "hot spot" for extinction

Hawaii Plants and Birds

More than 90% of native Hawaiian plants and animals are *endemic*, meaning they exist nowhere else on earth.

75% of the United States' already extinct plants and birds once lived only in Hawaii even though its islands represent just 0.2% of the nation's total land area.

U.S. government lists 526 plant species and 88 bird species as threatened - more than a 1/3 third are found in Hawaii.

The New York Times
Tuesday, May 29, 2012

Science

Scientist at Work

May 29, 2012, 3:49 PM

The Extinction of Hawaiian Birds

By DAVID J. FLASPOHLER

Bennng et al. PNAS 2002

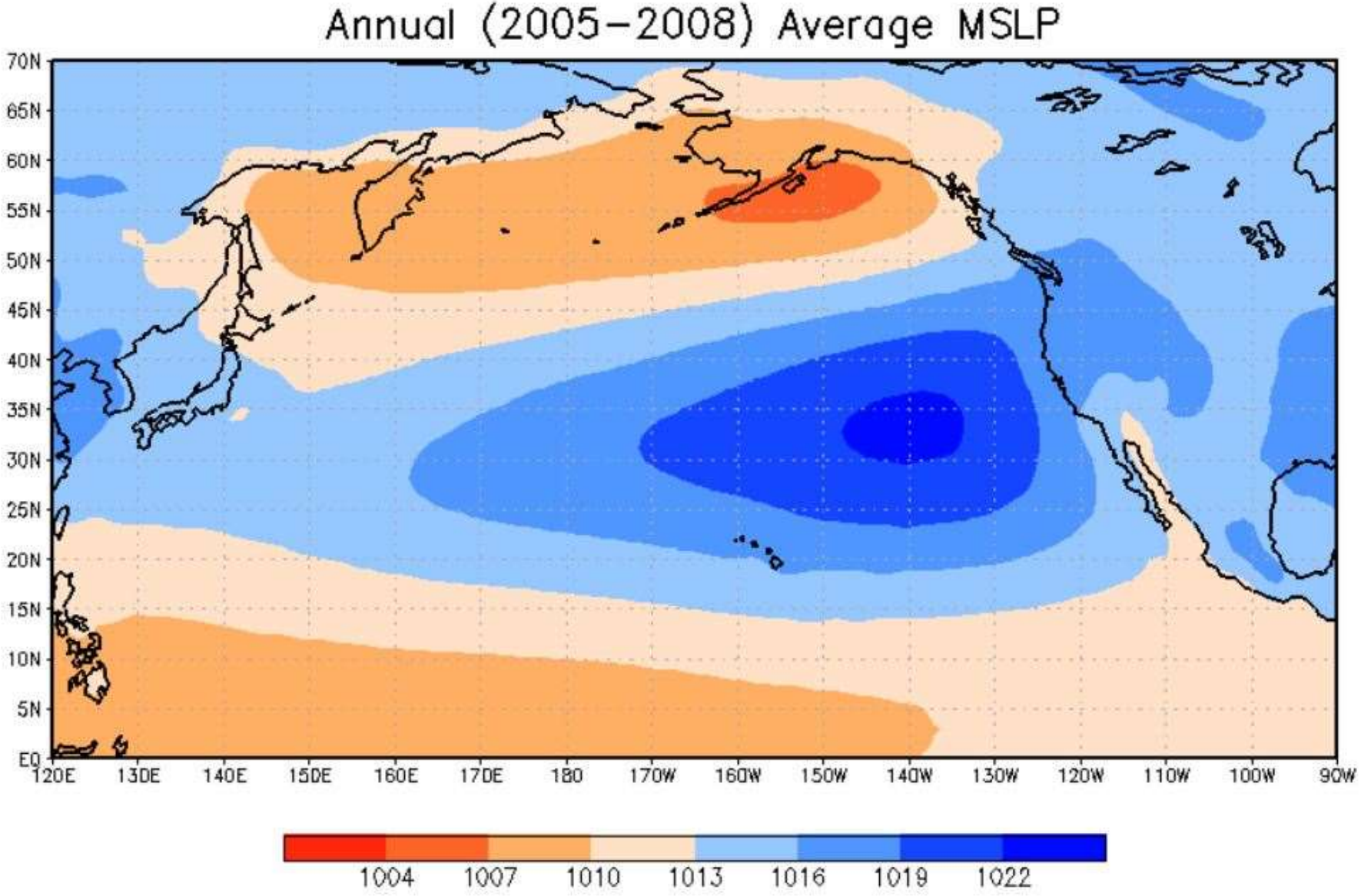
- **The Hawaiian honeycreepers (*Drepanidae*)**
- **29 species – many are already extinct**

Bennng et al. PNAS 2002

- **"Anthropogenic climate change is likely to combine with past land-use changes and biological invasions to drive several of the remaining species to extinction"**

Silversword

“Recent population declines in the silversword are associated with decreasing precipitation and increasing temperature”.


Annual (2005–2008) Average MSLP
70N
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
120E
130E
140E
150E
160E
170E
180
170W
160W
150W
140W
130W
120W
110W
100W
90W
1004
1007
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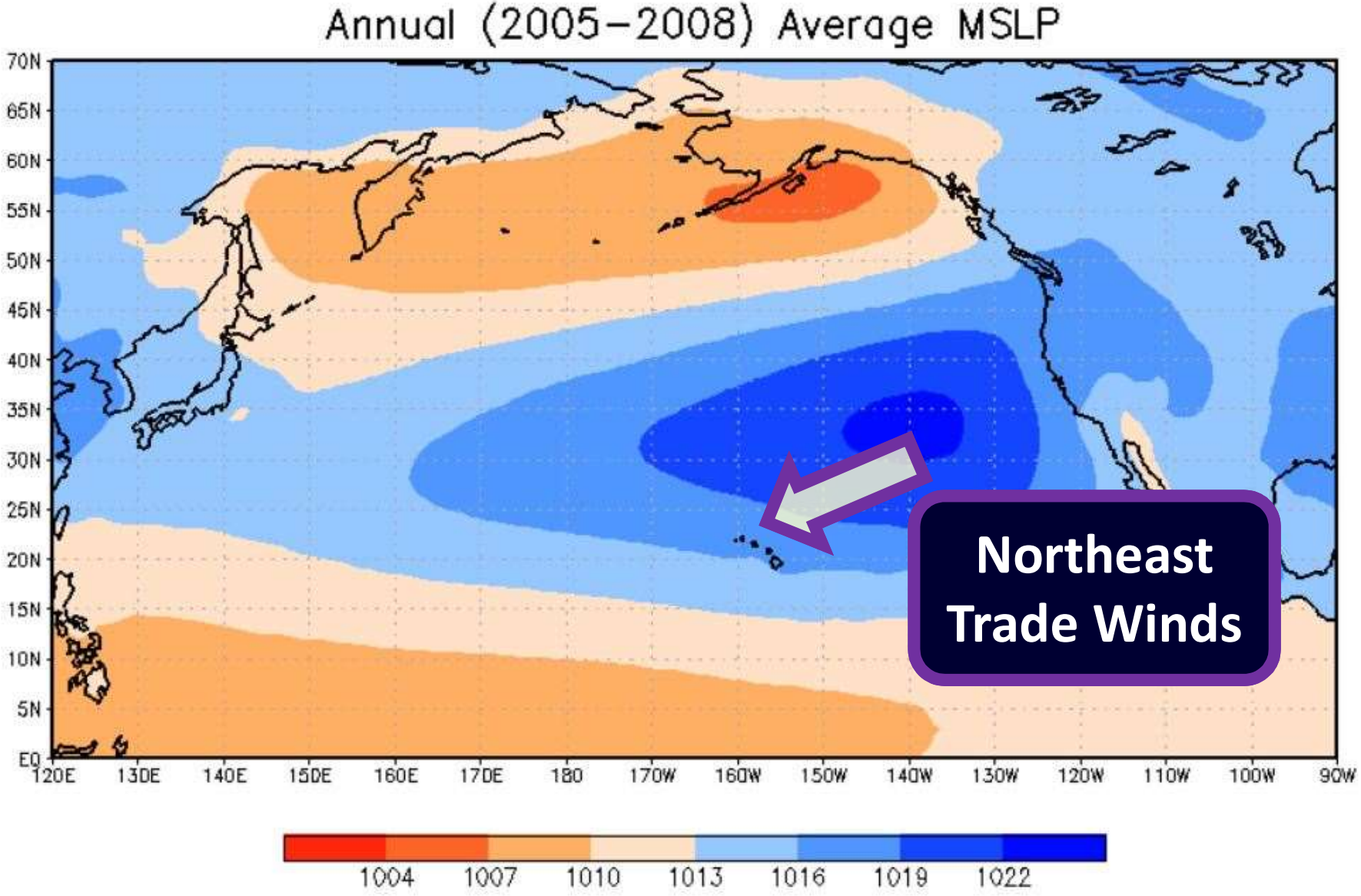
1016
1019
1022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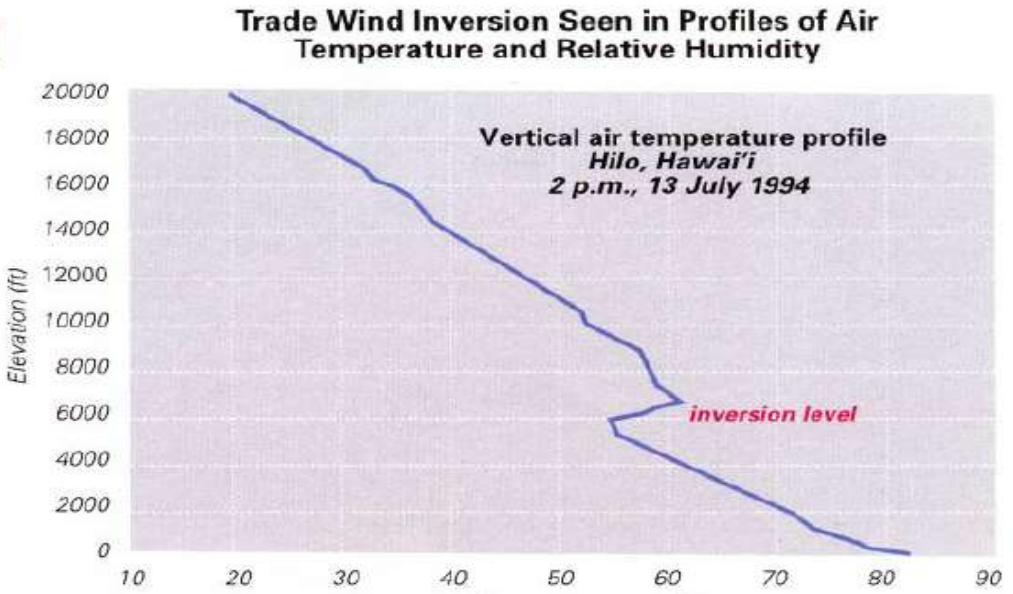
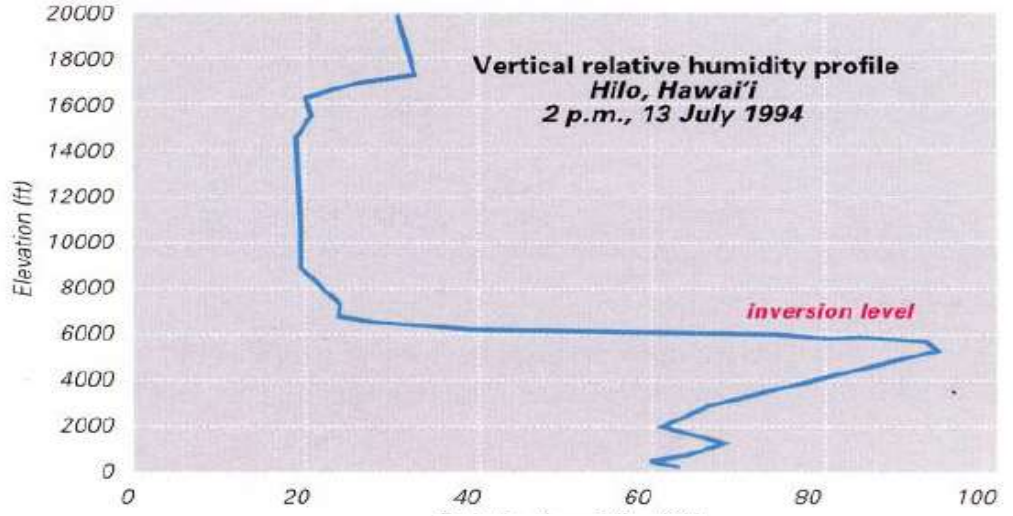
15N
10N
5N
EQ
120E
130E
140E
150E
160E
170E
180
170W
160W
150W
140W
130W
120W
110W
100W
90W
1004
1007
1010
1013
1016
1019
1022
Northeast
Trade Winds

Trade-Wind Inversion

- Mean altitude ~2200 m (7200 ft)
- Frequency ~80%

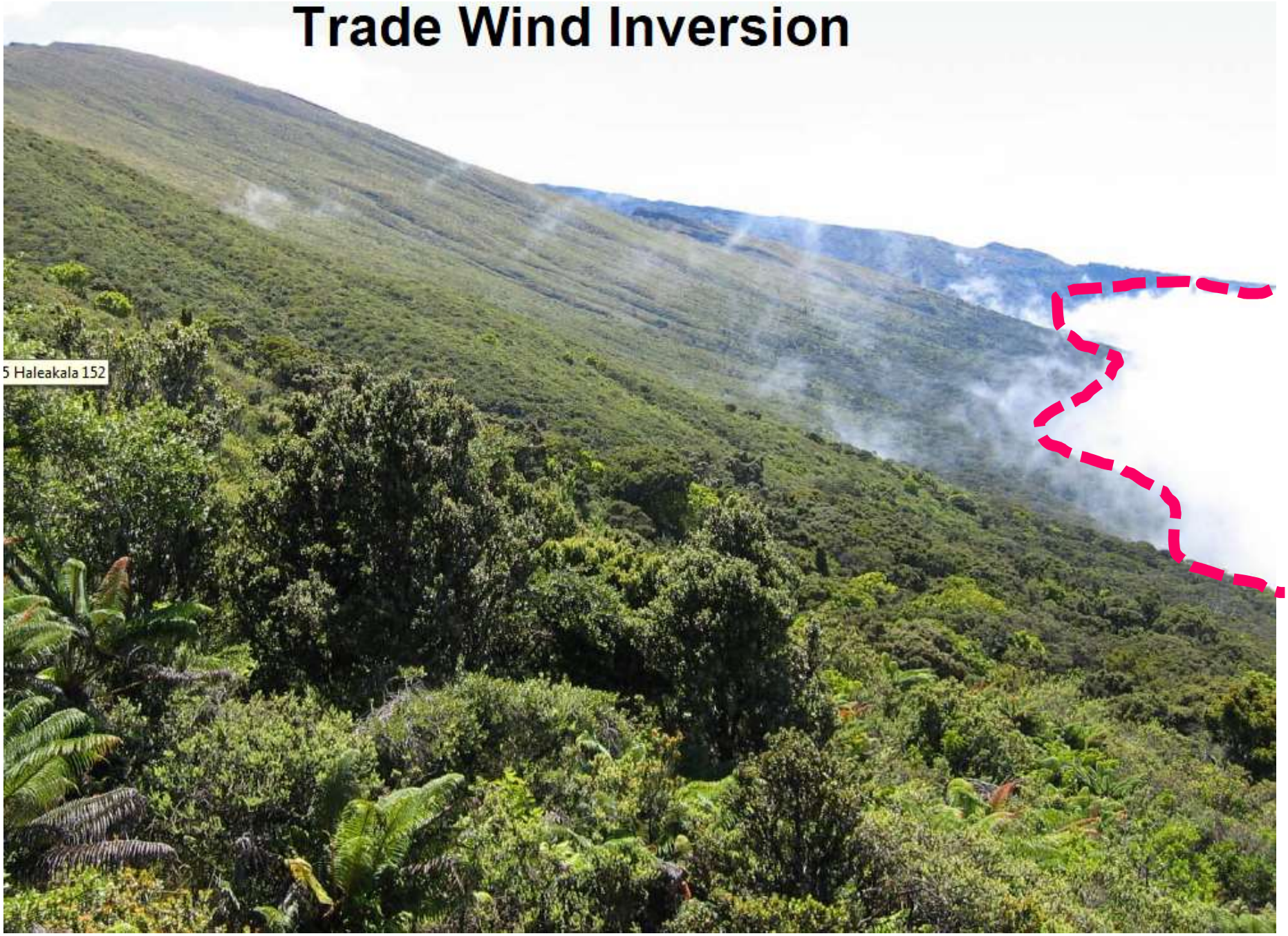


Air temperature

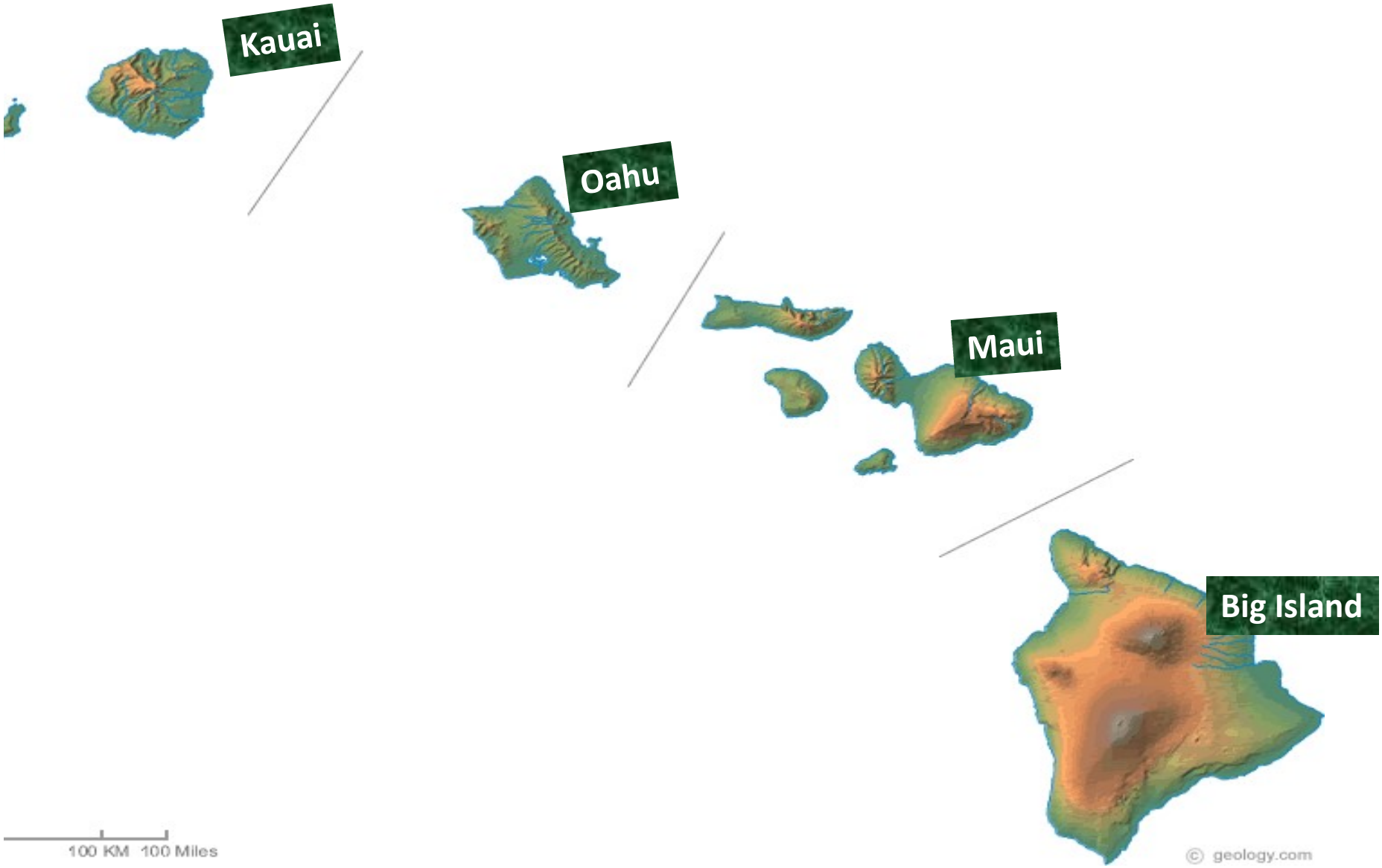


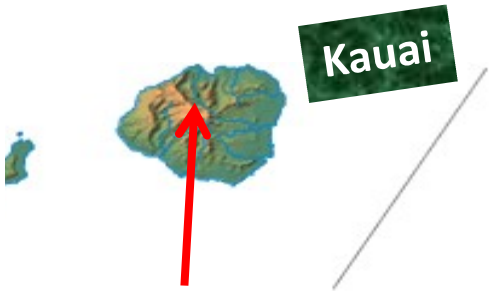
Relative humidity %

Trade Wind Inversion

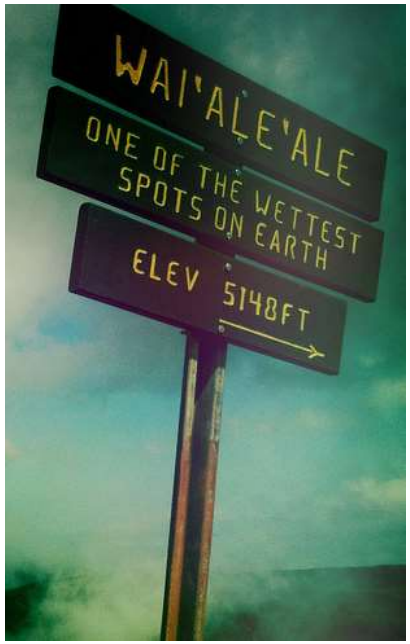


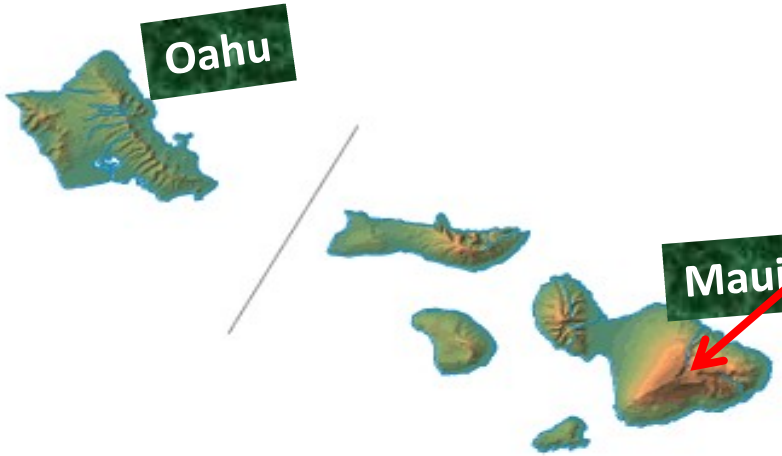

100 KM 100 Miles
© geology.com

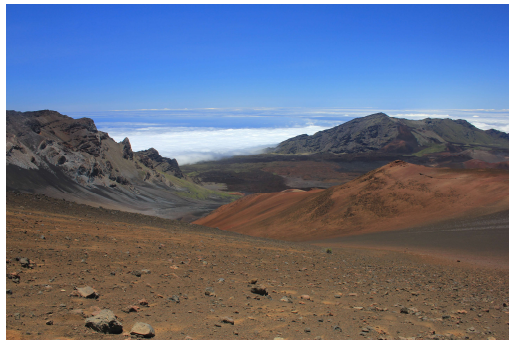

Kauai
Oahu
Maui
Big Island
100 KM 100 Miles
© geology.com



Waialeale
1570 m

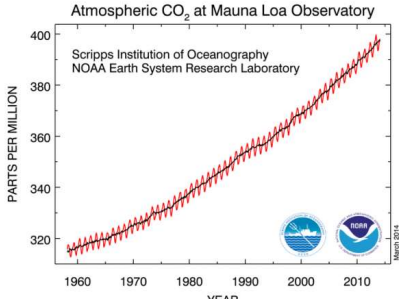






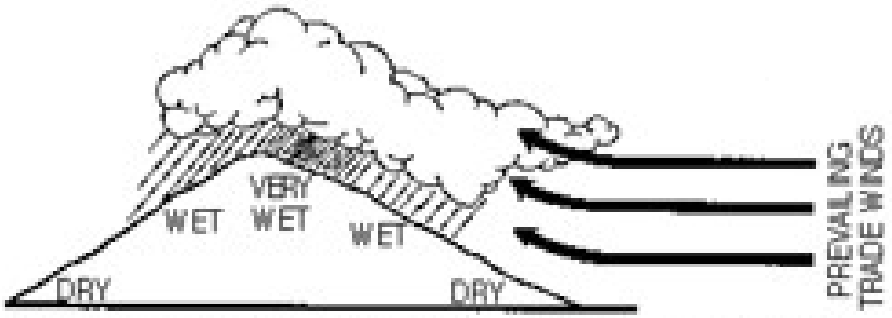
Haleakala
3050 m

Mauna Kea
4200 m



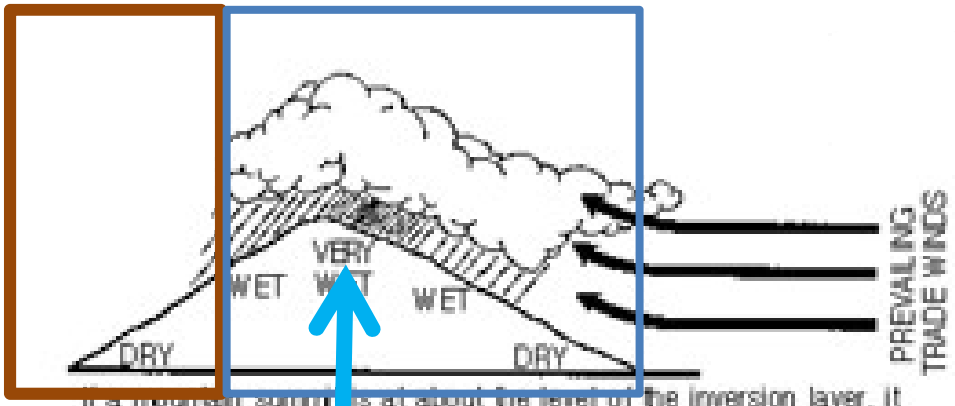
Mauna Loa
4170m

Typical Pattern of Orographic Rainfall



If a mountain summit is at about the level of the inversion layer, it receives a maximum amount of rainfall, which falls on the leeward side of the summit as well as on the windward side.

DRY WET

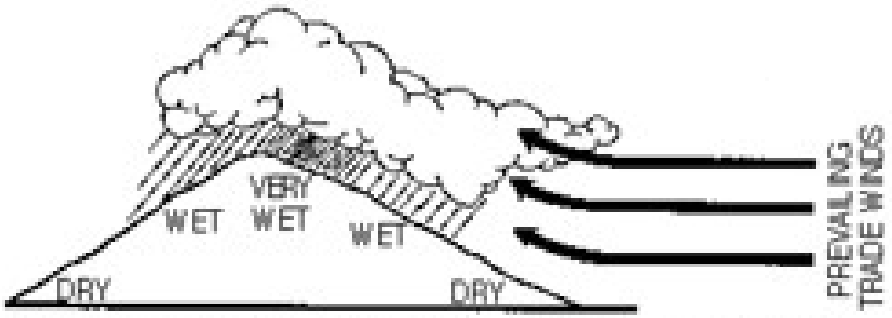


Typical Pattern of
Orographic Rainfall

receives a maximum amount of rainfall, which falls on the leeward
side of the summit as well as on the windward side.

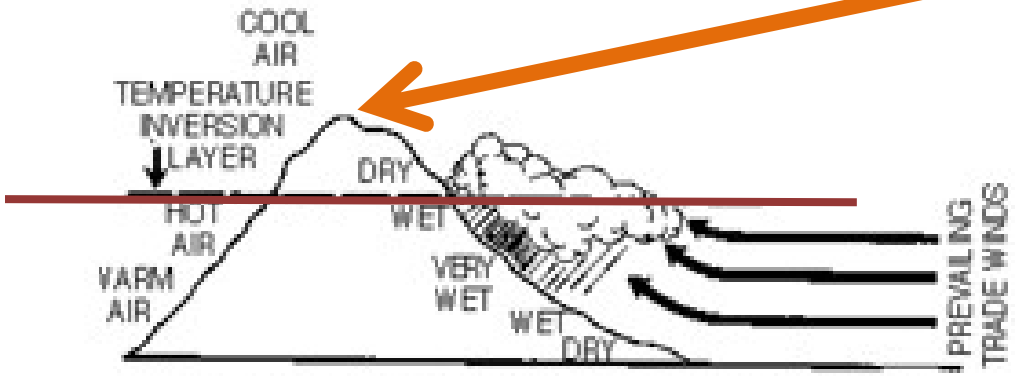
MOST RAIN
AT SUMMIT

Typical Pattern of Orographic Rainfall



If a mountain summit is at about the level of the inversion layer, it receives a maximum amount of rainfall, which falls on the leeward side of the summit as well as on the windward side.

VERY DRY



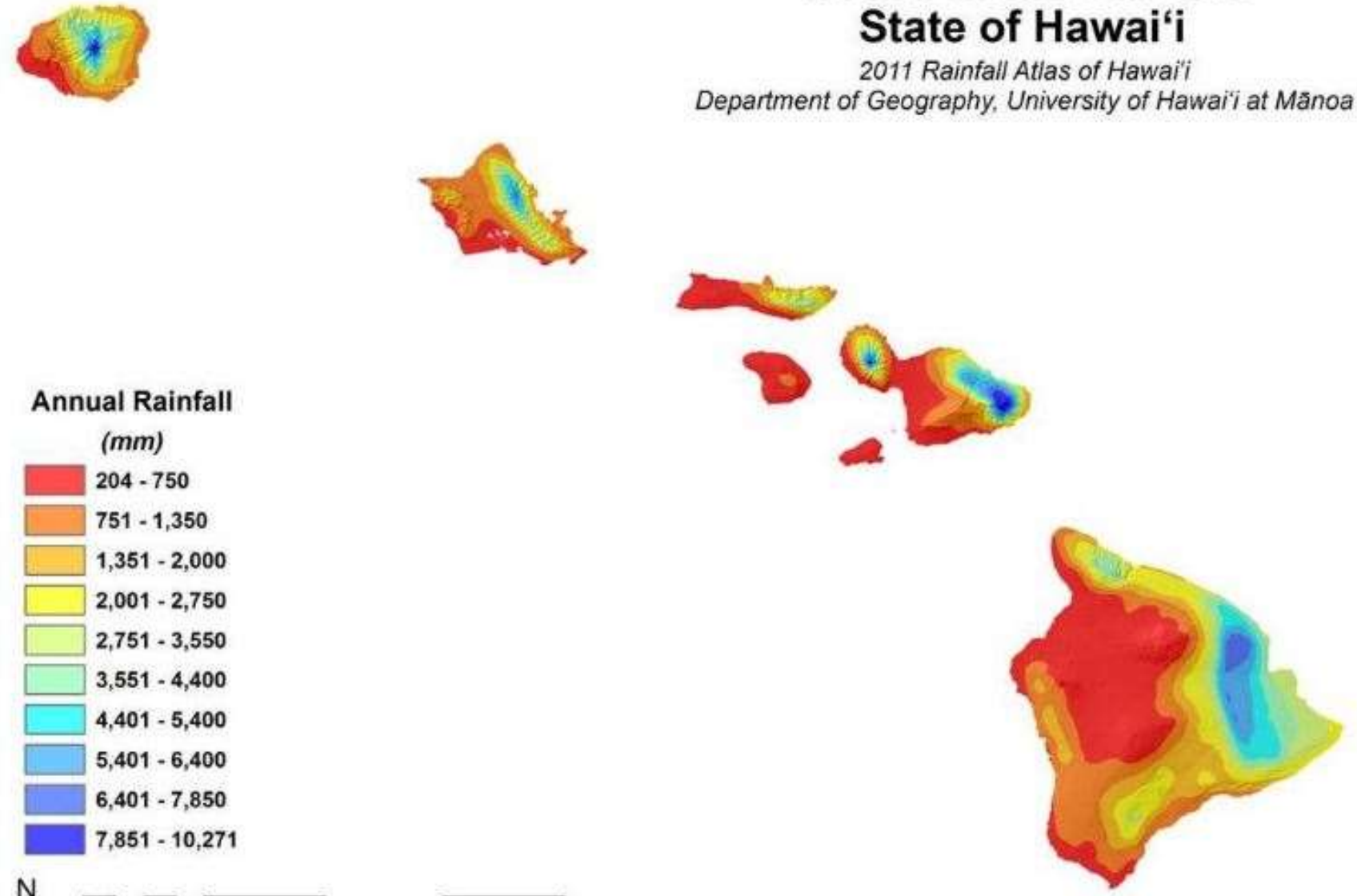
Trade winds are forced upward by mountain masses. When they penetrate cold air at the upper limit of a temperate inversion layer (air warmer than near ground level), they condense into rainfall on the windward side of an island.

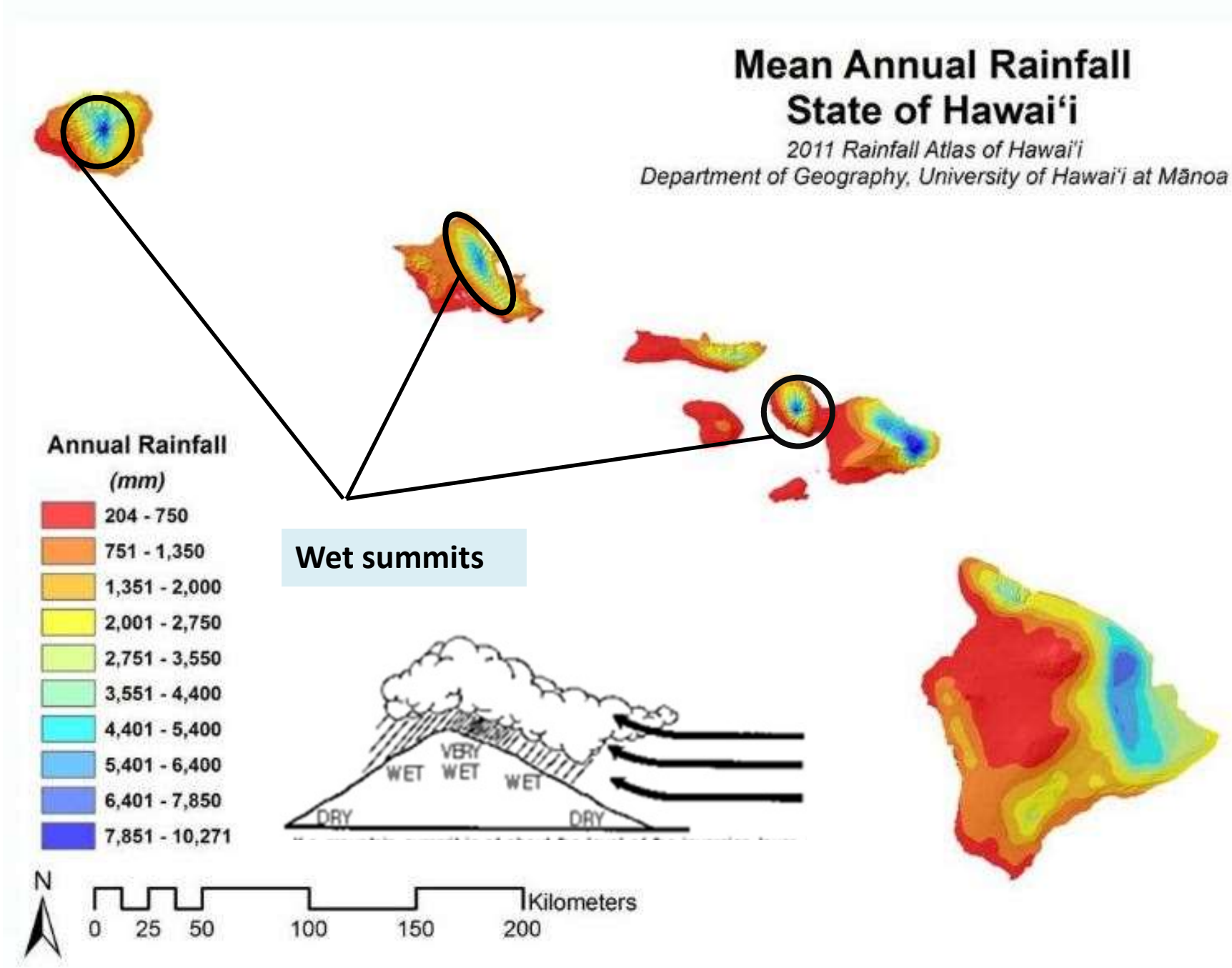
Mauna Kea, Mauna Loa & Haleakala


100 KM 100 Miles
© geology.com

Mean Annual Rainfall
State of Hawai'i

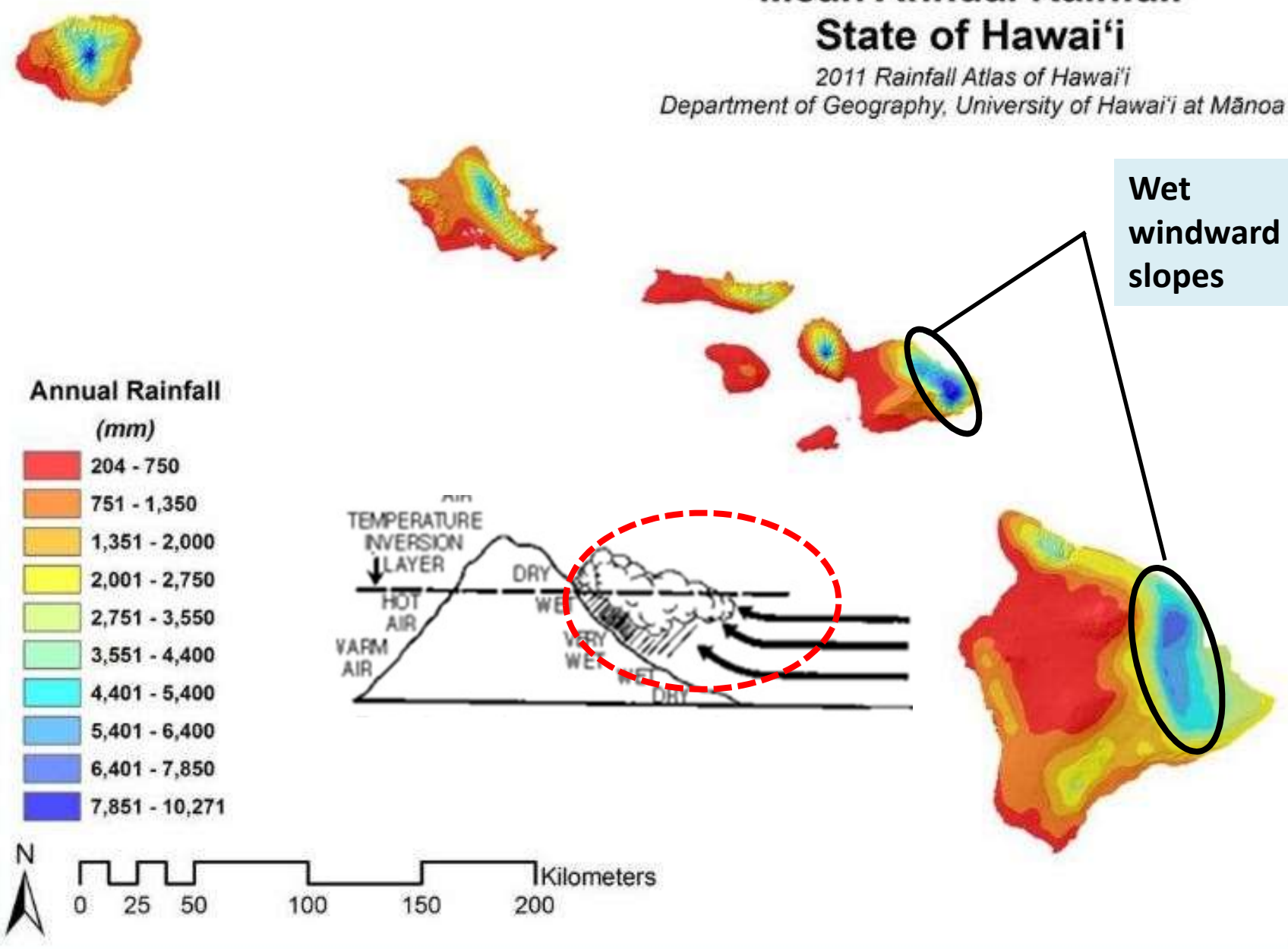
2011 Rainfall Atlas of Hawai'i
Department of Geography, University of Hawai'i at Mānoa




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 - 1,350
1,351 - 2,000
2,001 - 2,750
2,751 - 3,550
3,551 - 4,400
4,401 - 5,400
5,401 - 6,400
6,401 - 7,850
7,851 - 10,271
Wet summits
VERY WET
WET
WET
DRY
DRY
N
0 25 50 100 150 200
Kilometers

Mean Annual Rainfall
State of Hawai'i

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



Mean Annual Rainfall
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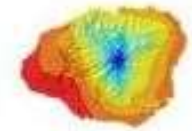
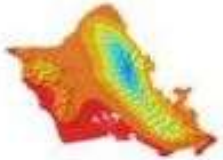
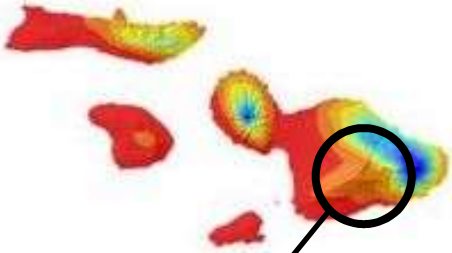






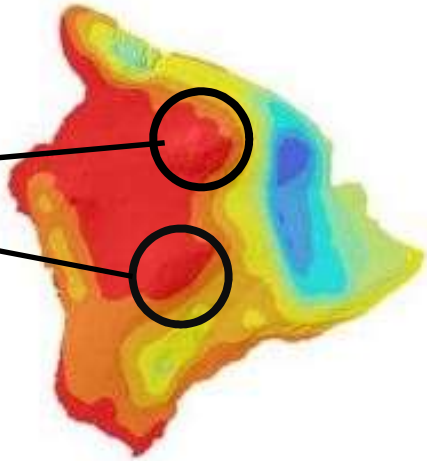
Annual Rainfall
(mm)

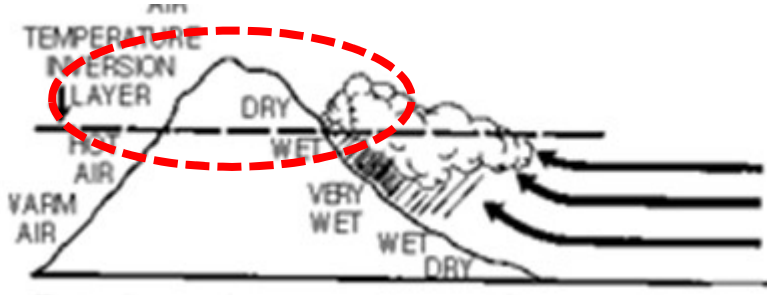
- 204 - 750
- 751 - 1,350
- 1,351 - 2,000
- 2,001 - 2,750
- 2,751 - 3,550
- 3,551 - 4,400
- 4,401 - 5,400
- 5,401 - 6,400
- 6,401 - 7,850
- 7,851 - 10,271

N

0 25 50

Dry summits





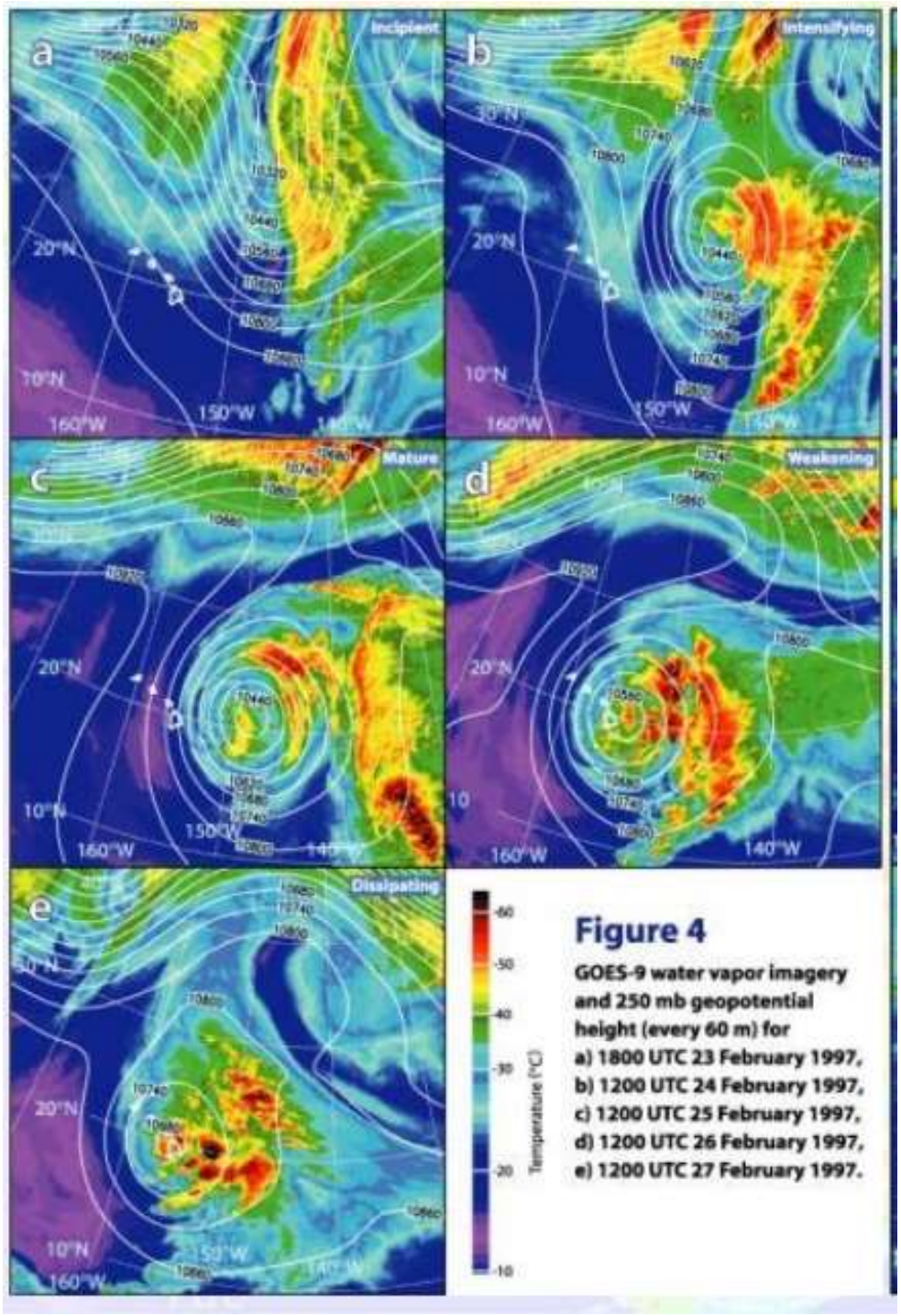


Figure 4

GOES-9 water vapor imagery and 250 mb geopotential height (every 60 m) for a) 1800 UTC 23 February 1997, b) 1200 UTC 24 February 1997, c) 1200 UTC 25 February 1997, d) 1200 UTC 26 February 1997, e) 1200 UTC 27 February 1997.

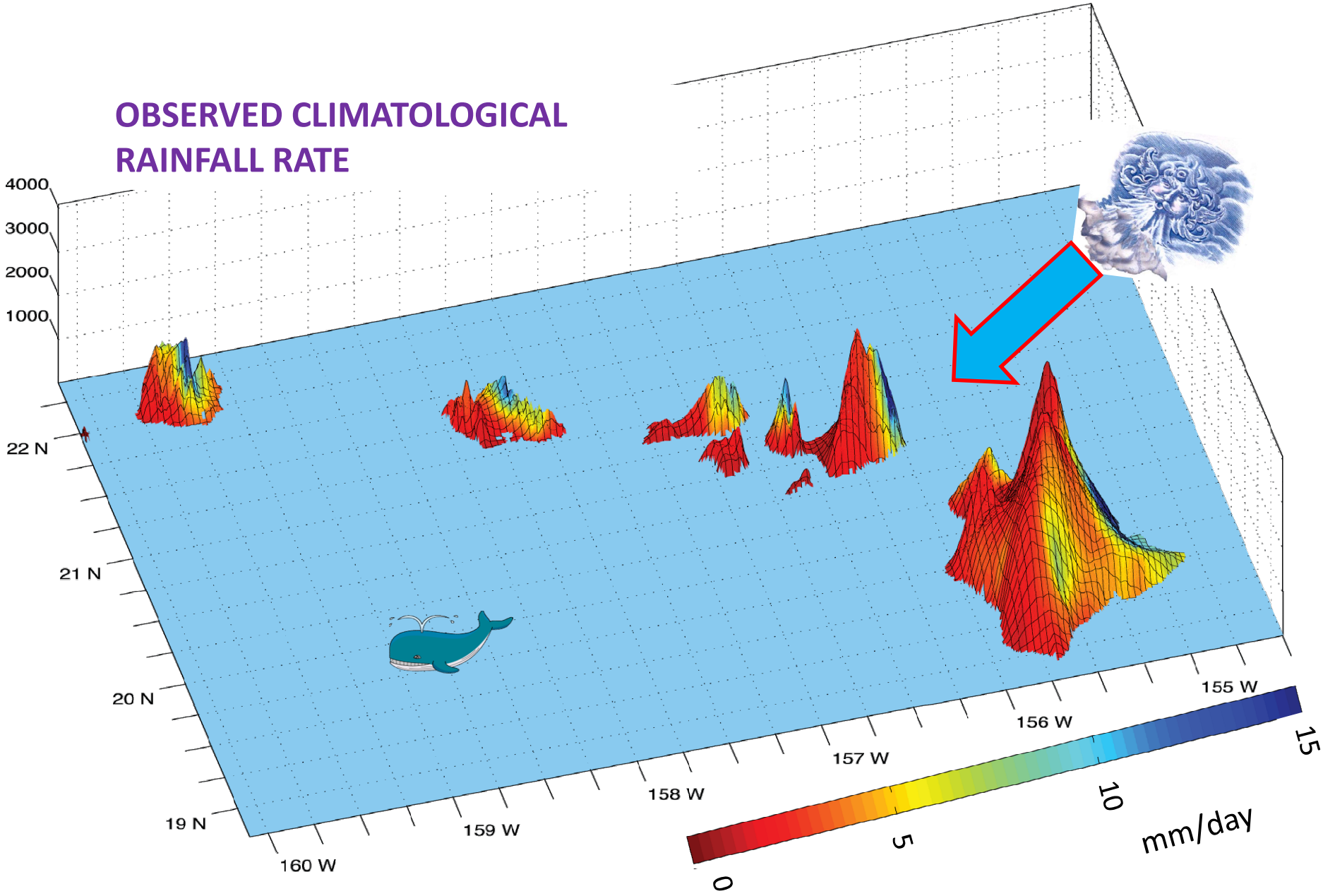
Sometimes, particularly in winter, the usual trade wind pattern breaks down and more active weather can lead to convective rain

This is how most of the rain in the "rain shadow" regions occurs.

March 2012
Oahu

The interaction of the atmospheric flow with the very tall and very steep topography in leads to fine structure in the microclimates

OBSERVED CLIMATOLOGICAL RAINFALL RATE



This leads to a big challenge for even the finest resolution global models for climate projections

Hydrological Research Letters 3, 49–53 (2009)
Published online in J-STAGE (www.jstage.jst.go.jp/browse/HRL). DOI: 10.3178/HRL.3.49

Projection of changes in future weather extremes using super-high-resolution global and regional atmospheric models in the KAKUSHIN Program: Results of preliminary experiments

Akio Kitoh, Tomoaki Ose, Kazuo Kurihara, Shoji Kusunoki, Masato Sugi
and KAKUSHIN Team-3 Modeling Group
Meteorological Research Institute, Tsukuba, Japan

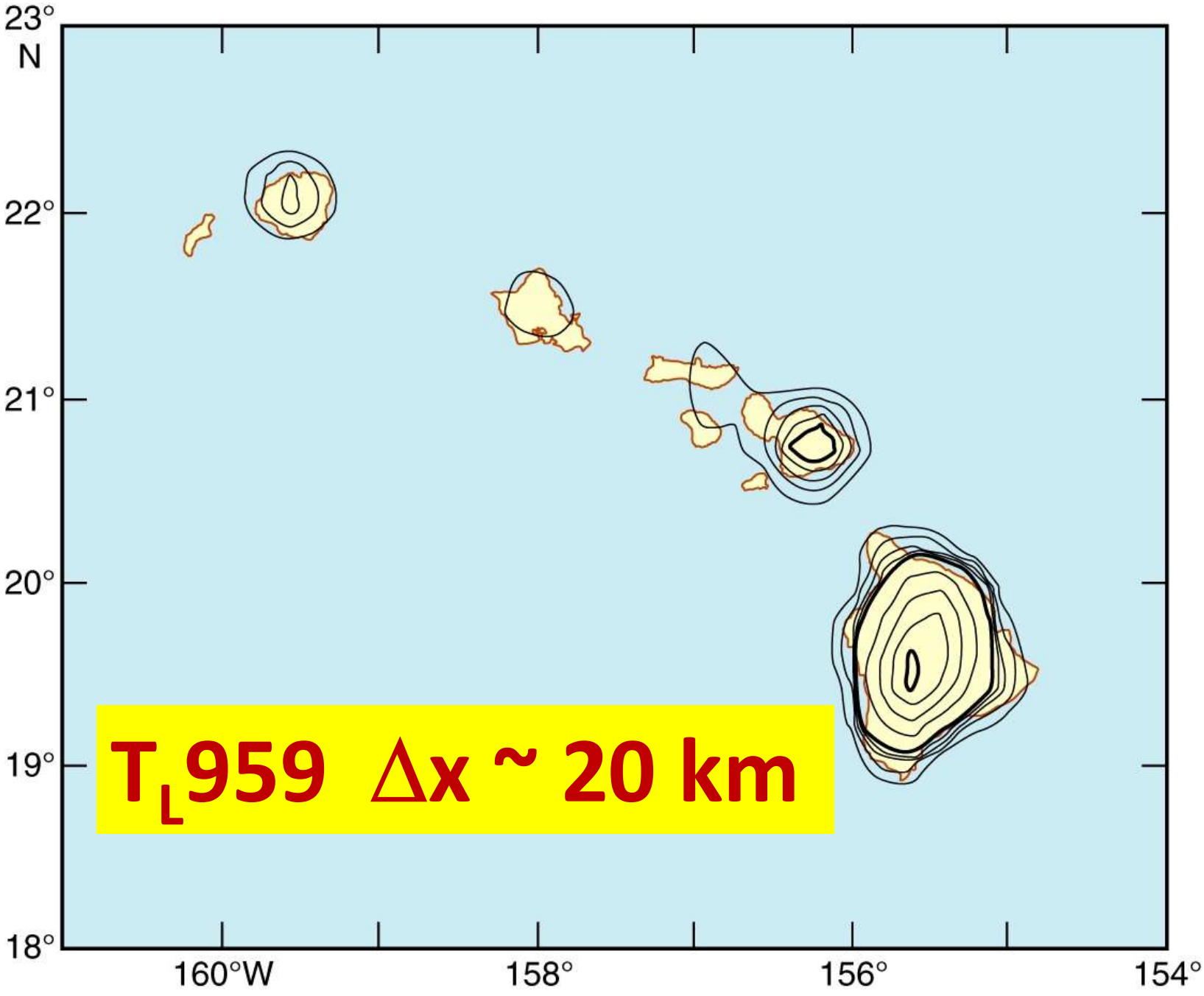
Abstract:

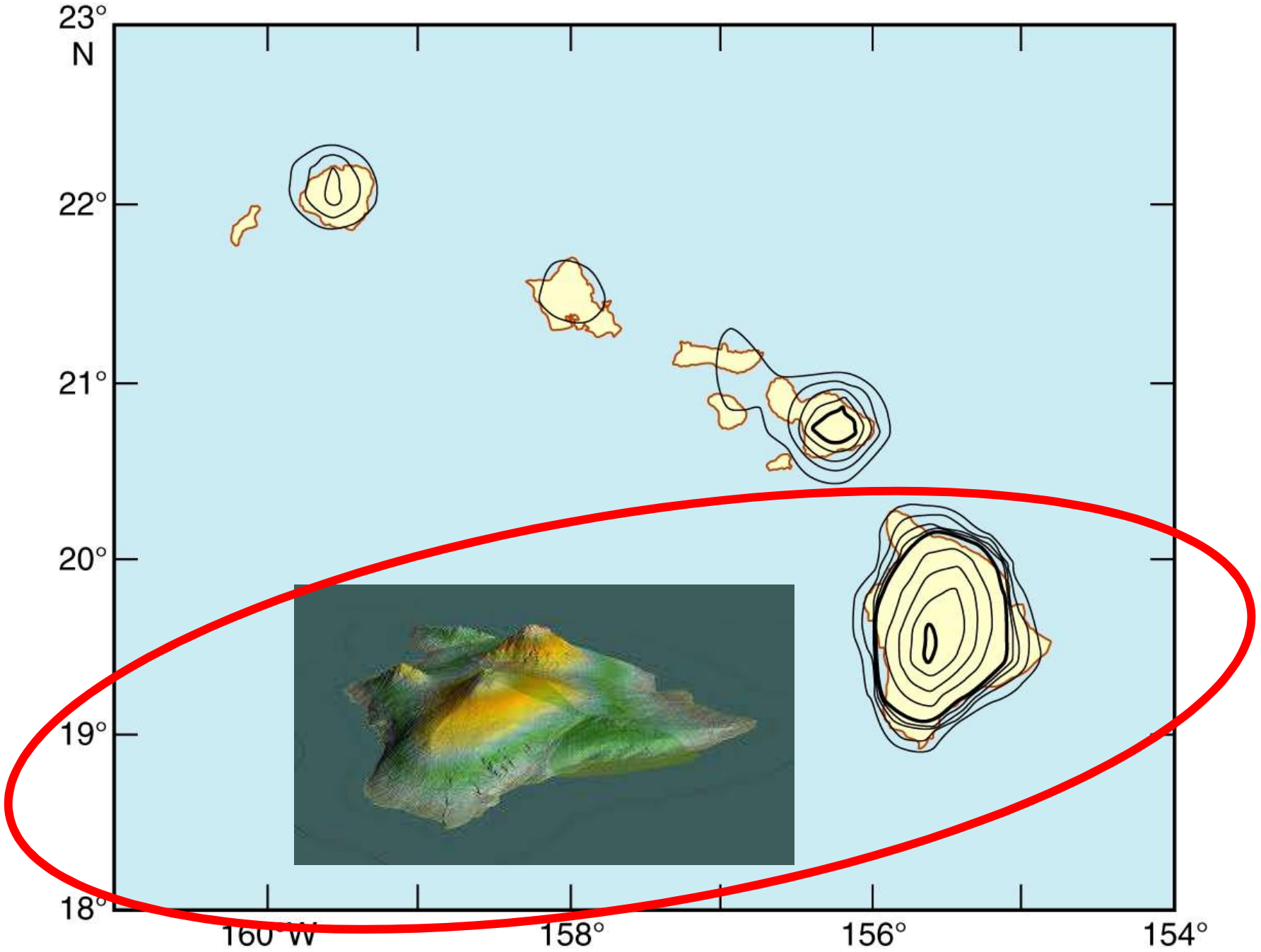
Changes in future weather extremes are projected using a global atmospheric general circulation model and a non-hydrostatic regional climate model under the global warming environment in the near future (2030s) and at the end of the 21st century. The global 20-km mesh model can simulate tropical cyclones more realistically in their strength, structure and geographical distribution together with associated heavy rainfall and strong surface winds as compared with lower resolution models. According to the SRES A1B scenario, it is projected that at the end of the 21st century there will be a 40%~60% increase in precipitation and a 15%~20%

climate change studies (Mizuta et al. 2006) based on the Japan Meteorological Agency (JMA) numerical weather forecast model. The grid size of this model is several times higher than that previously used in climate model simulations. In the previous experiment, we performed the present-day simulation using the observed sea surface temperature (SST) and the global warming simulation by adding the SST anomalies obtained by the Meteorological Research Institute AOGCM (MRI-CGCM). Utilizing the results of this experiment, Kusunoki et al. (2006) investigated the Baiu rain band changes over East Asia at the end of the 21st century, while Kitoh et al. (2008) showed future climate projections over the Middle East. Moreover, Kamiguchi et al. (2006) discussed changes in extremes in precipitation

~20 year long integrations

T_L959 $\Delta x \sim 20$ km


23°
N
22°
21°
20°
19°
18°
160°W
158°
156°
154°
T_L959 $\Delta x \sim 20$ km


23°
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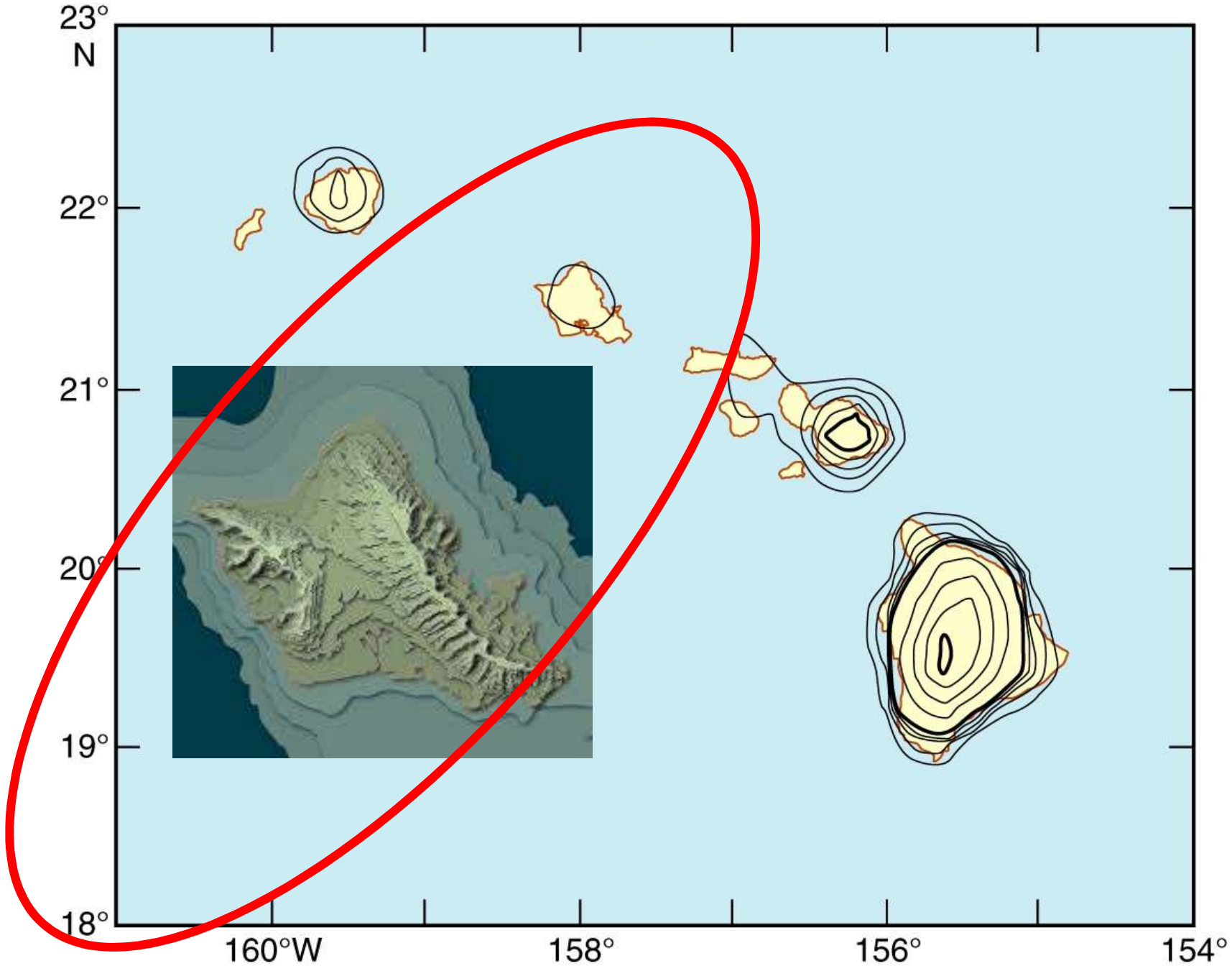
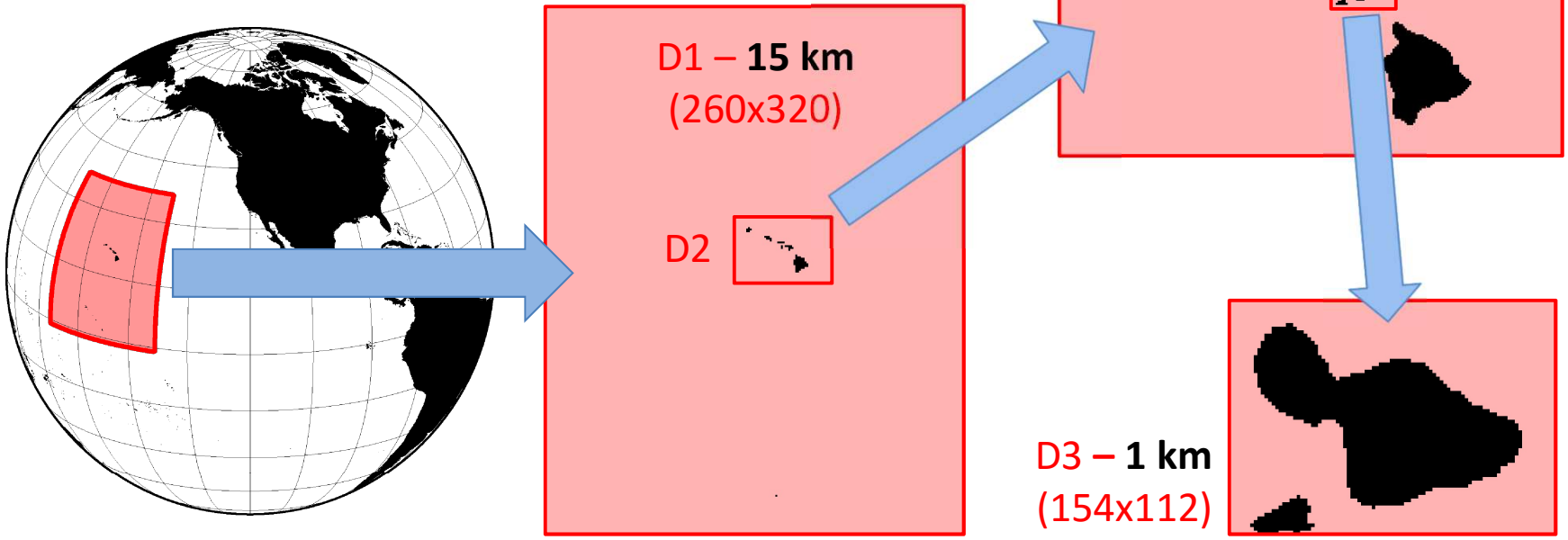
154°

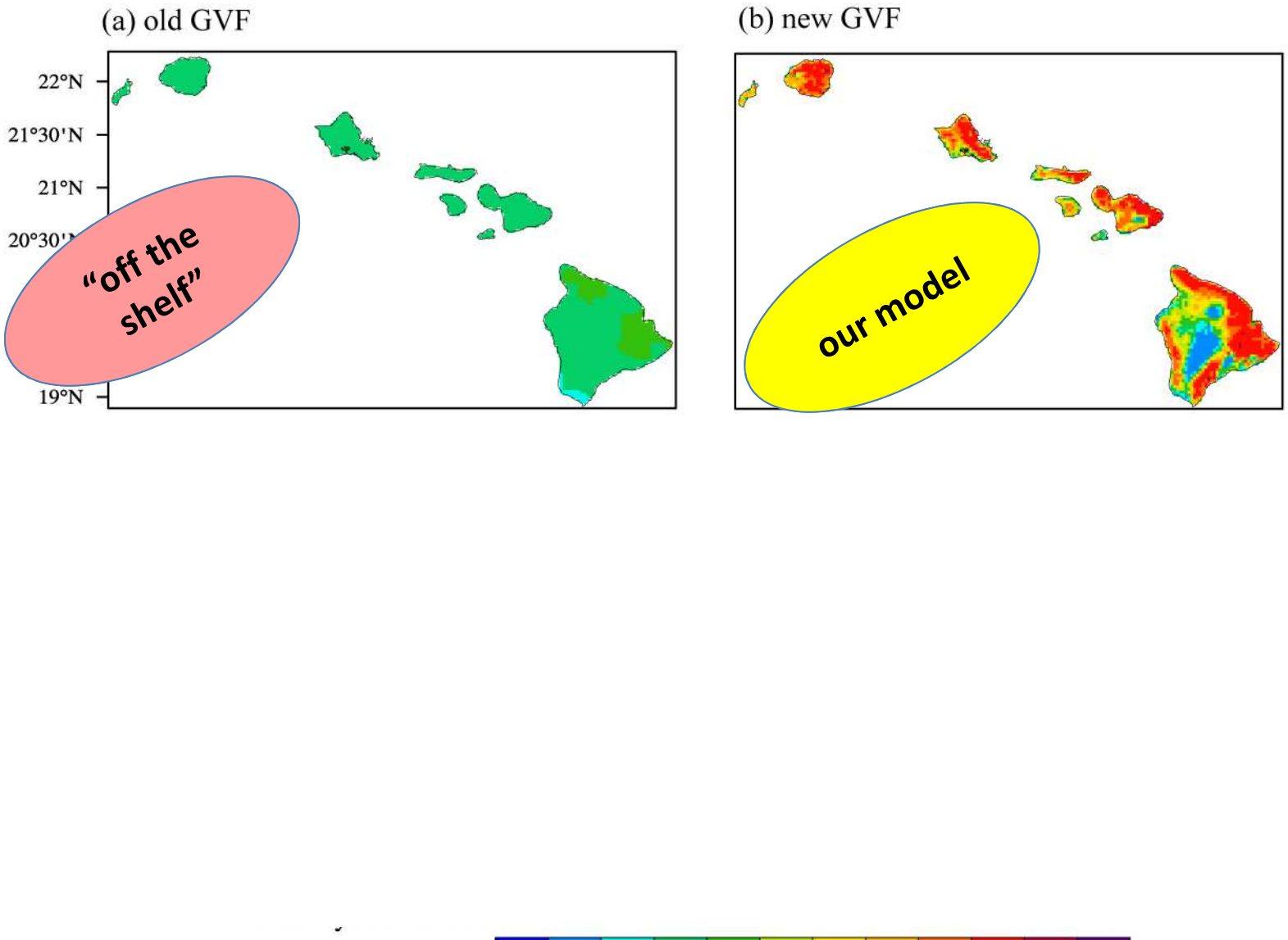

23°
N
22°
21°
20°
19°
18°
160°W
158°
156°
154°

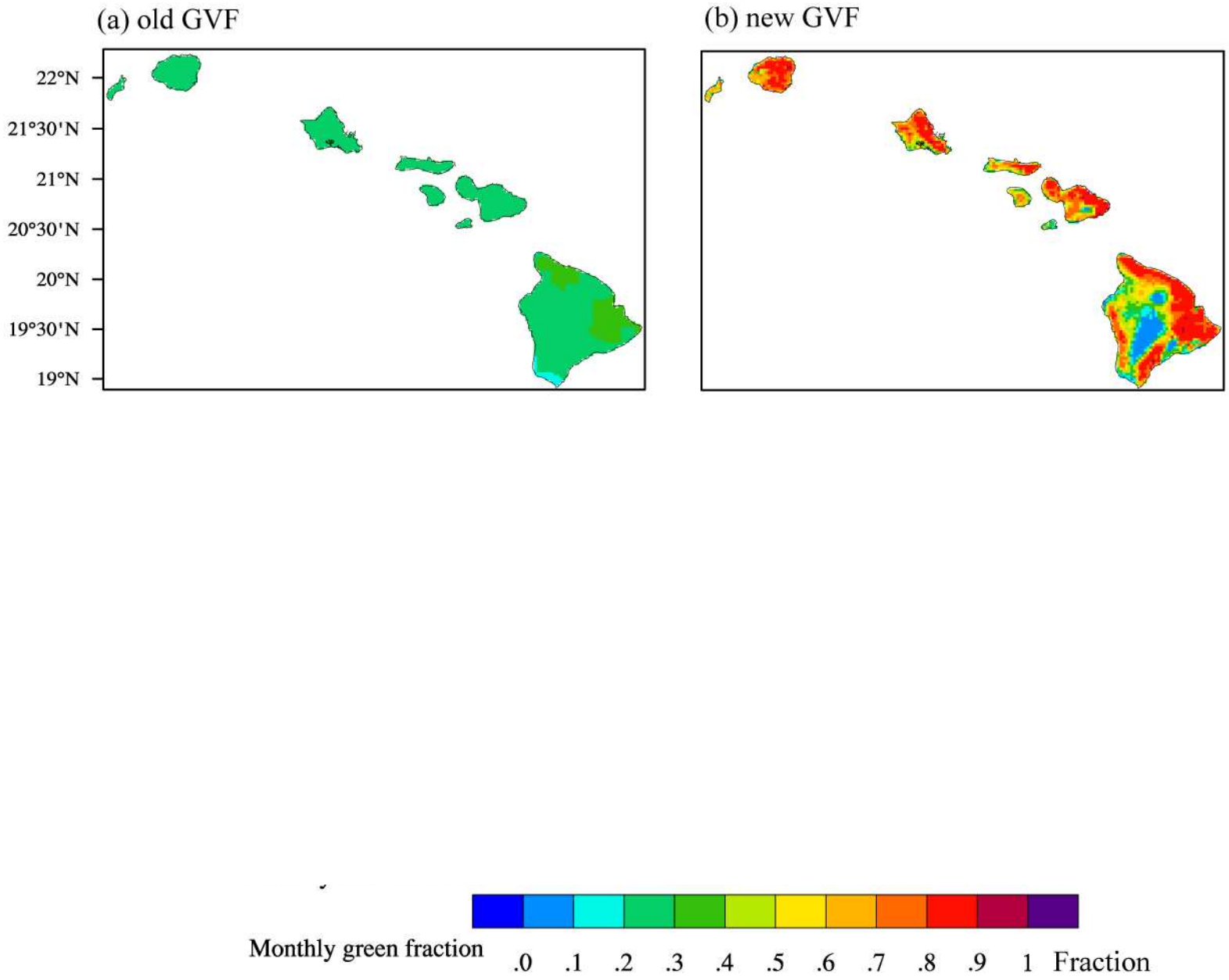
The Hawaii Regional Climate Model (HRCM)

- Adapted from **WRF** – community Weather Research & Forecast model
- 31 vertical levels (14 levels below 700 hPa)
- New data sets for: land cover/use (NLCD), surface albedo (MODIS), vegetation types/fraction and soil types (STATSGO2)
- MERRA (Modern-Era Retrospective Analysis for Research and Applications) reanalysis from NASA (6-hourly data @ 0.5°×0.67°)
- NOAA SSTs (daily data @ 0.25°x0.25°)
- 1-way nesting with up to 3 domains (D1, D2, D3)

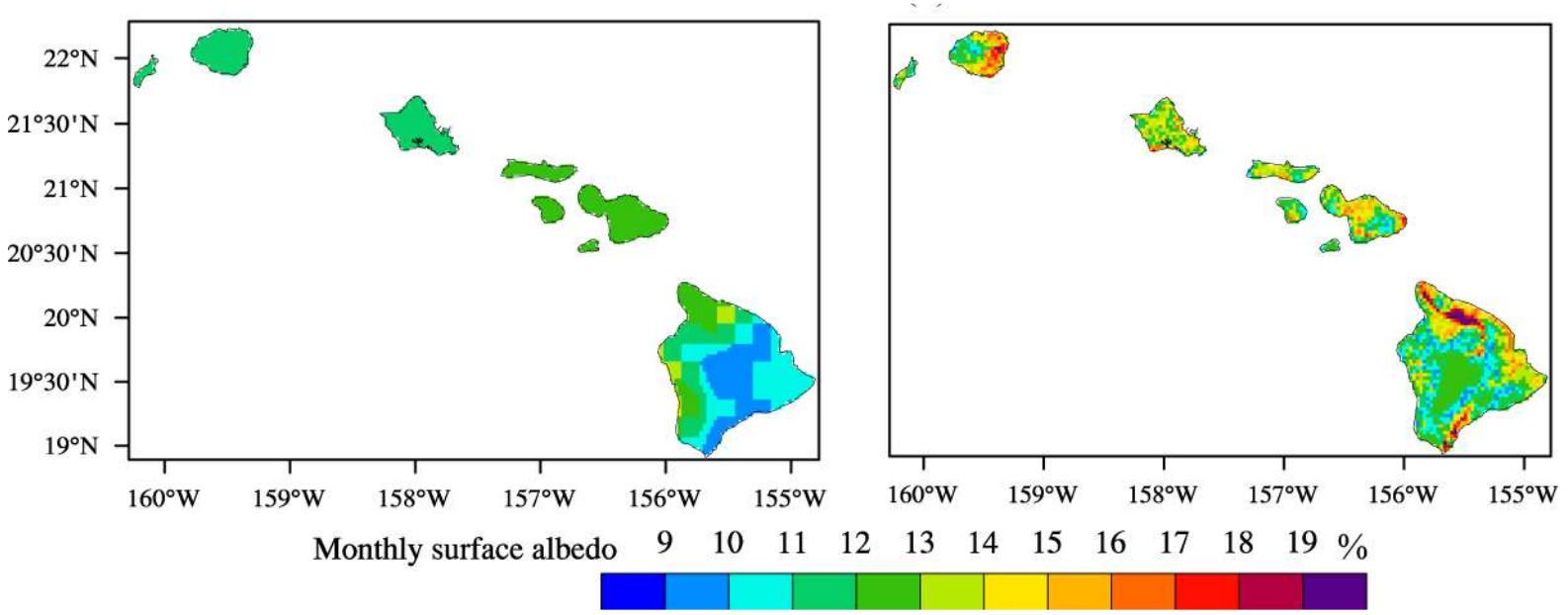


Green vegetation fraction in July

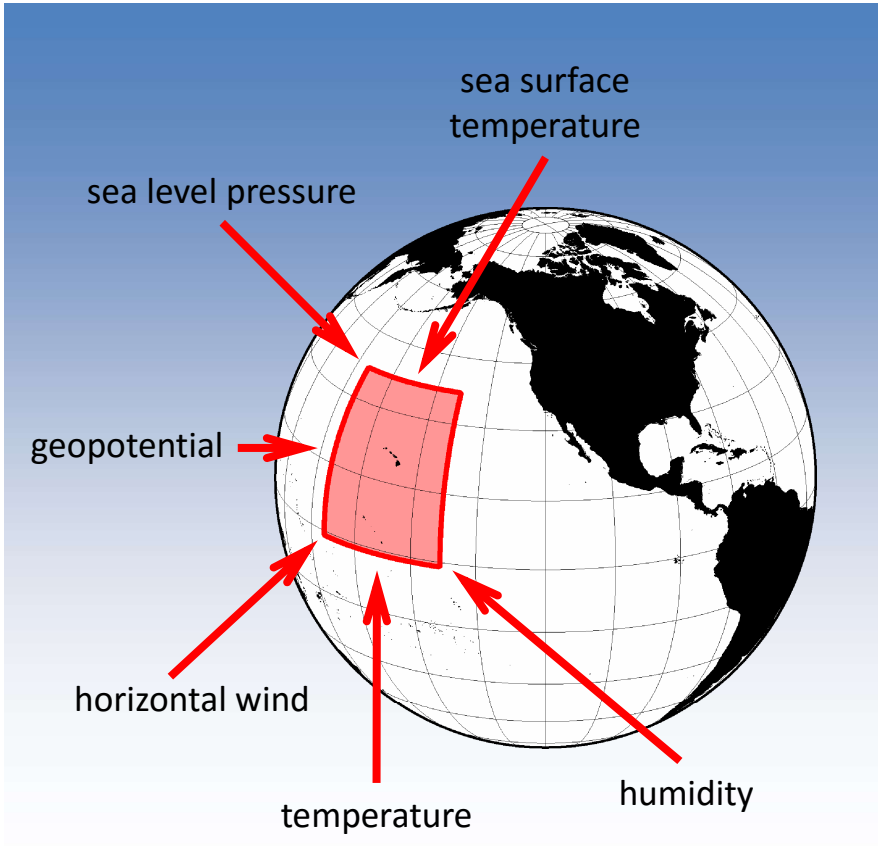



(a) old GVF
(b) new GVF
22°N
21°30'N
21°N
20°30'N
20°N
19°30'N
19°N
Monthly green fraction
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1 Fraction

Surface albedo in July



Specification of the boundary conditions

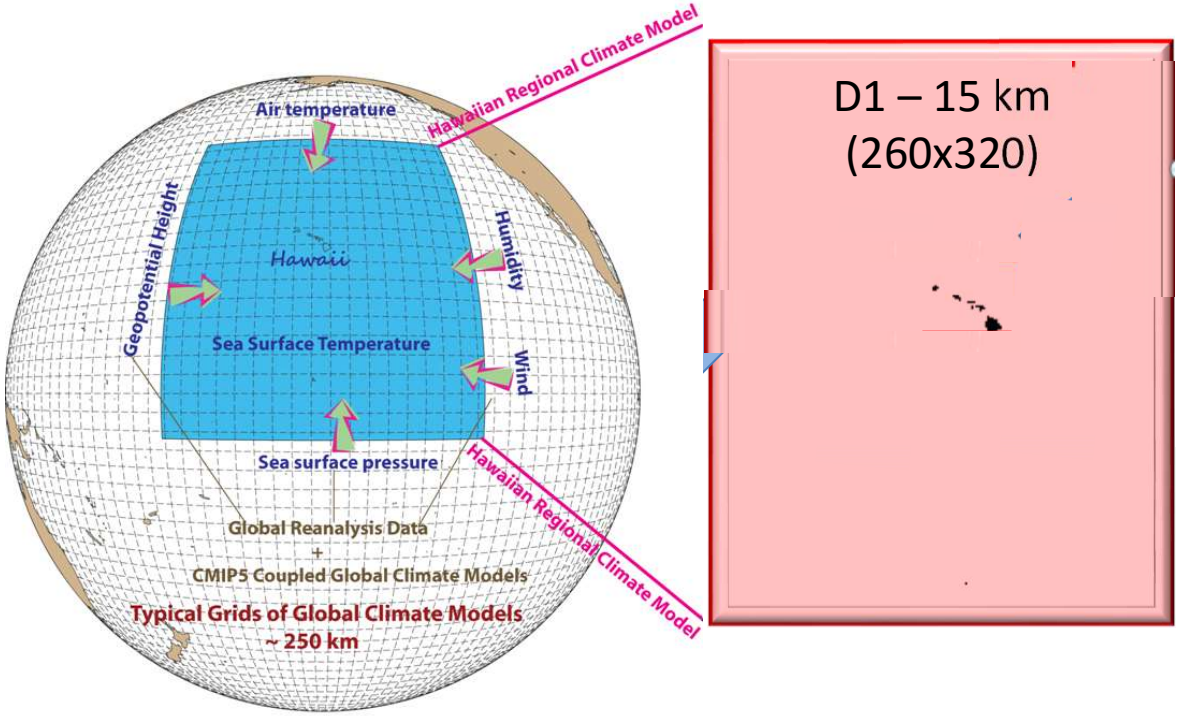


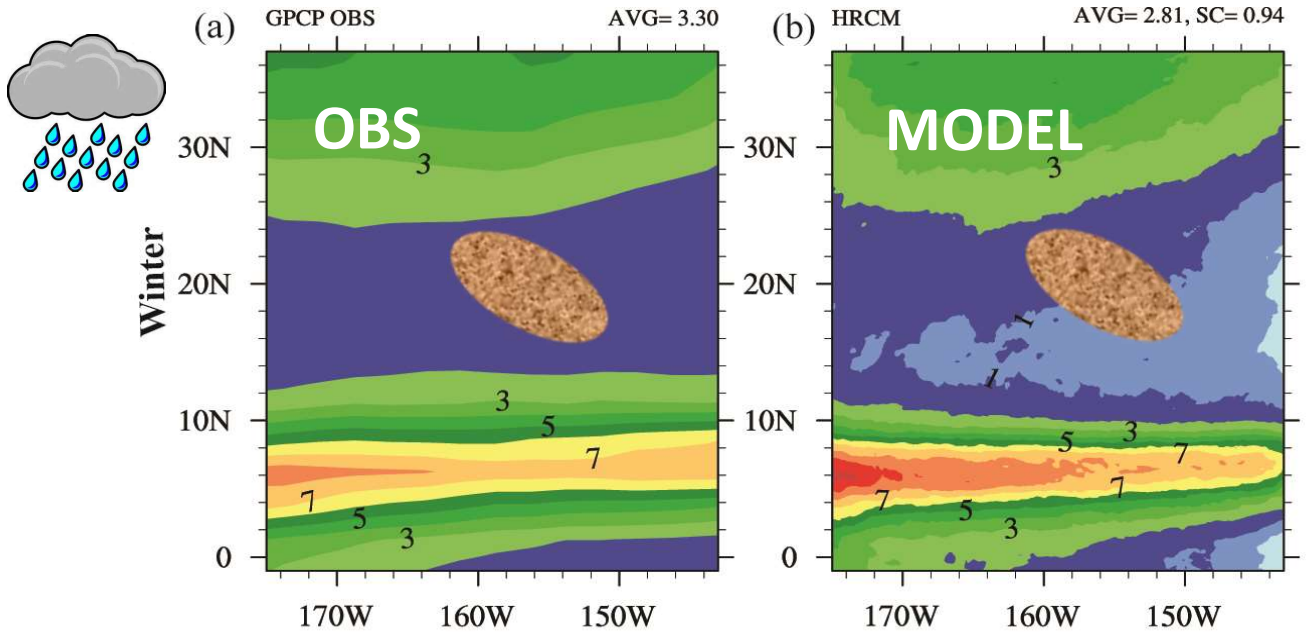
MERRA reanalysis data, NOAA SSTs

Present-day run

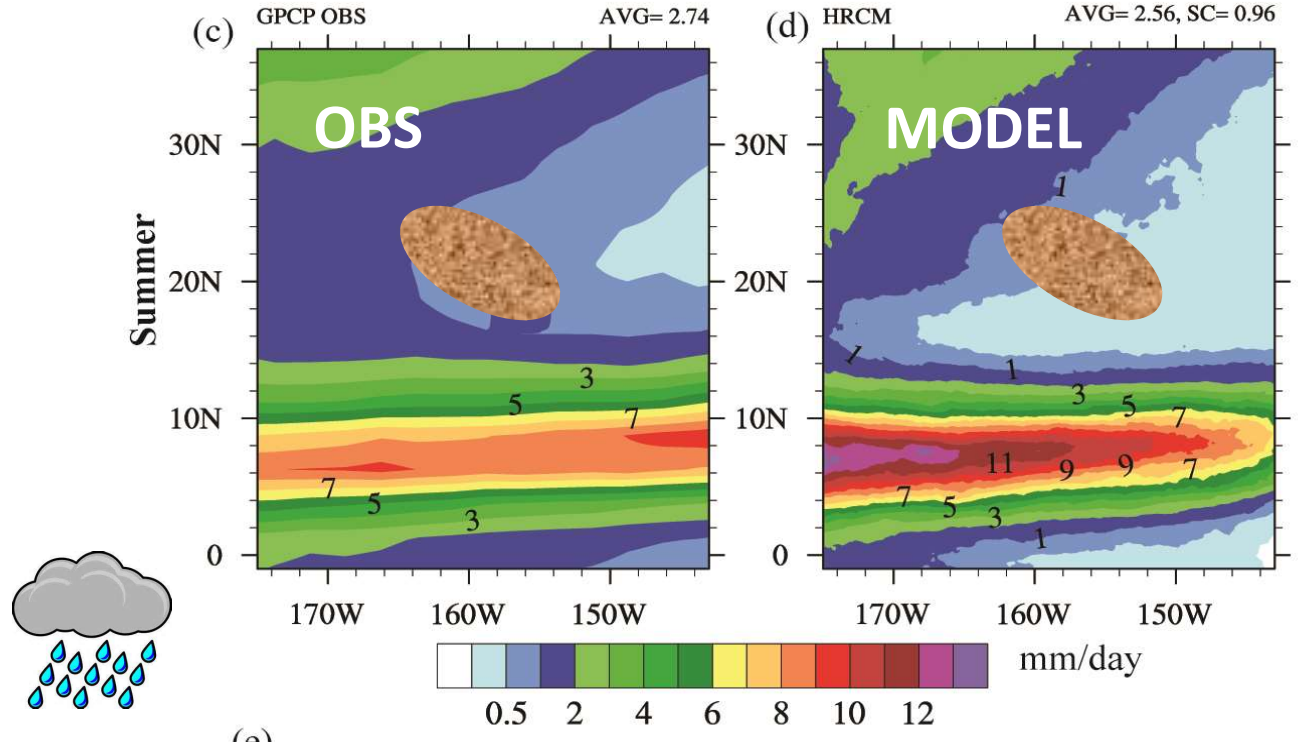
1990-2009

Results from the outer domain (D1) with 15 km spacing

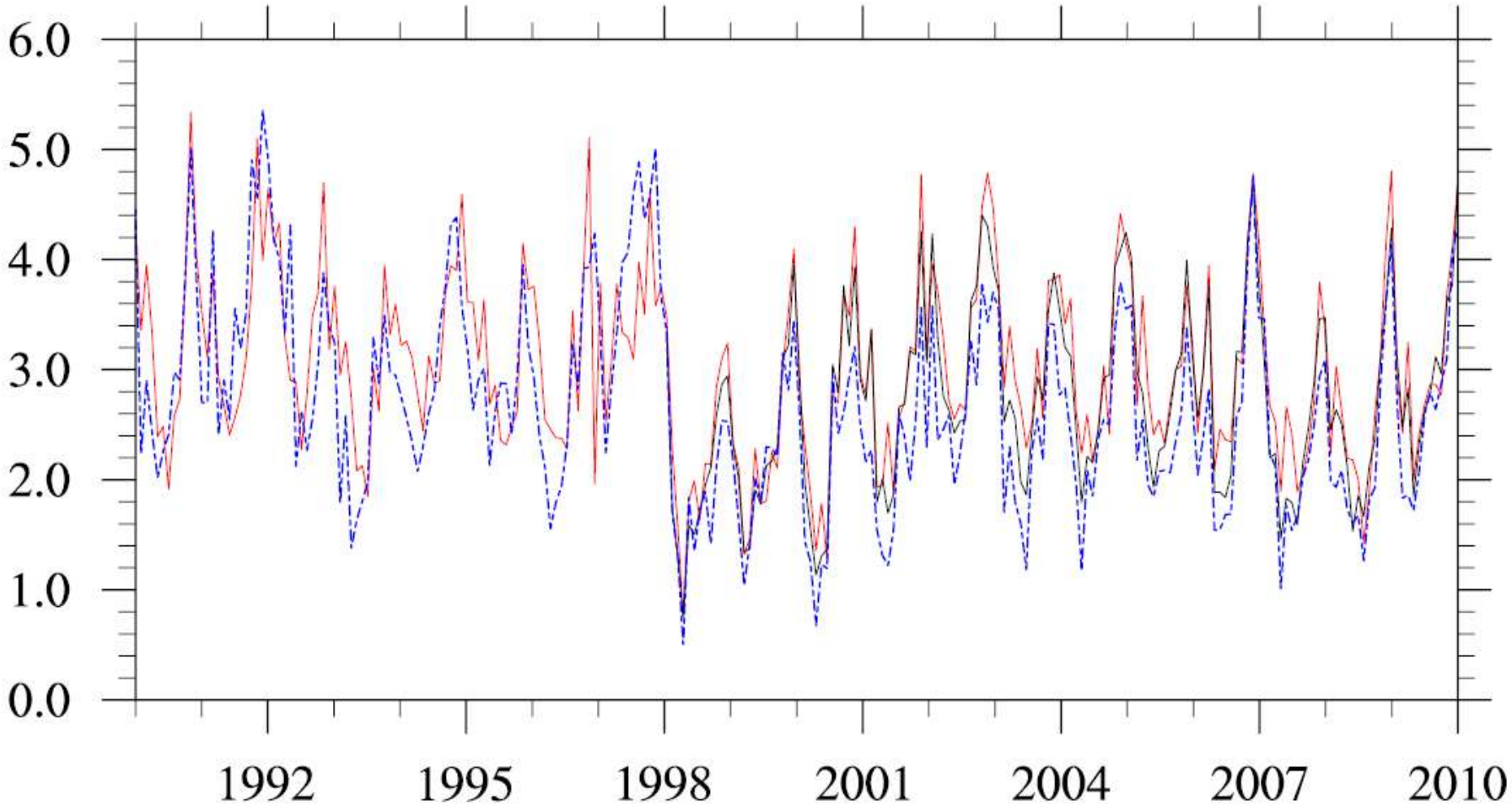




“Winter” Rainfall
November-April



“Summer” Rainfall
May-October



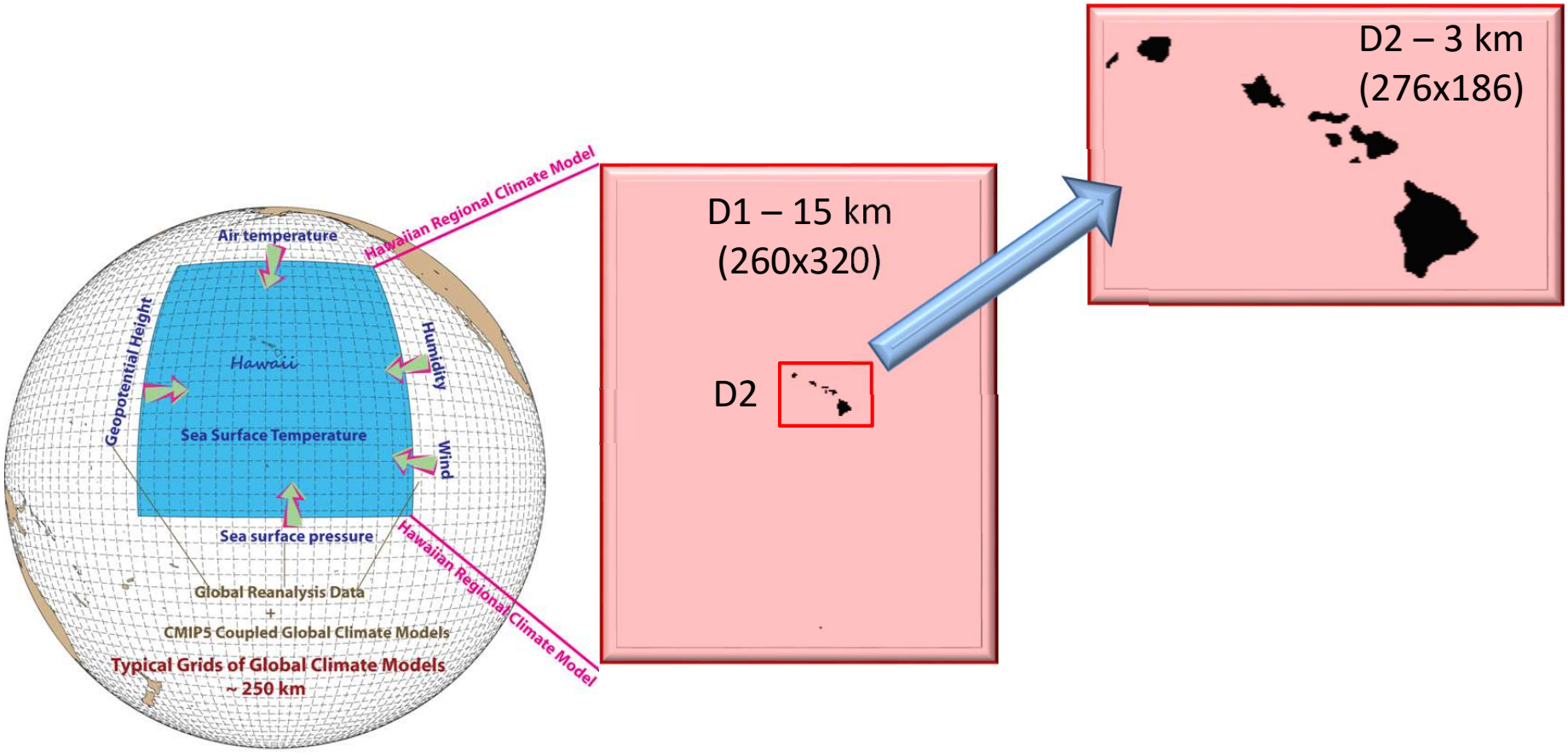
Time Series of Monthly Domain-Averaged Rainfall

Model Results in Blue

GPCP Observations in Red

TRMM Observations in Black

Results from the middle domain (D2) with 3 km spacing



observations

model

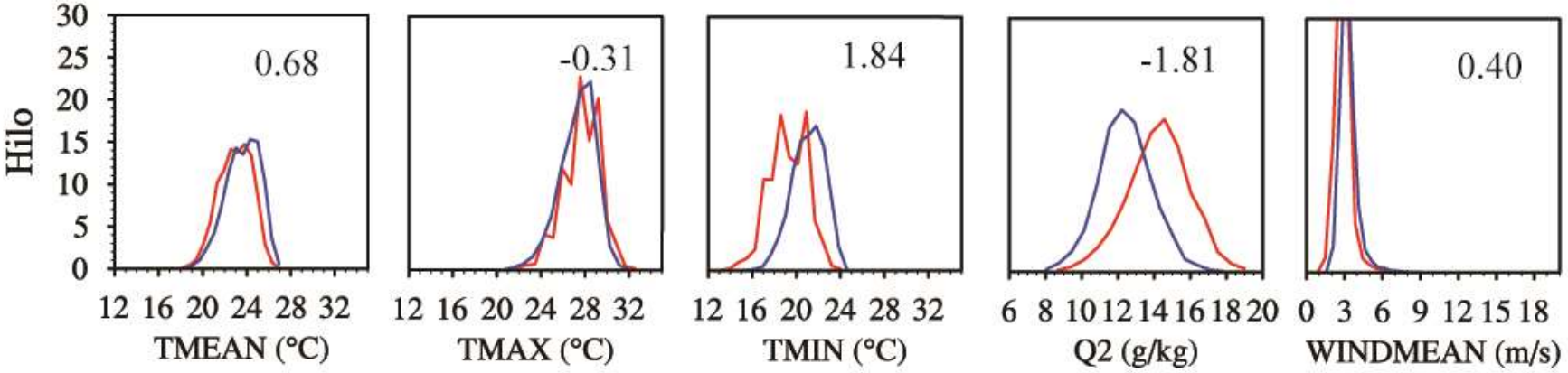
Daily mean surface air temperature

Daily mean maximum air temperature

Daily mean minimum air temperature

Daily mean surface humidity

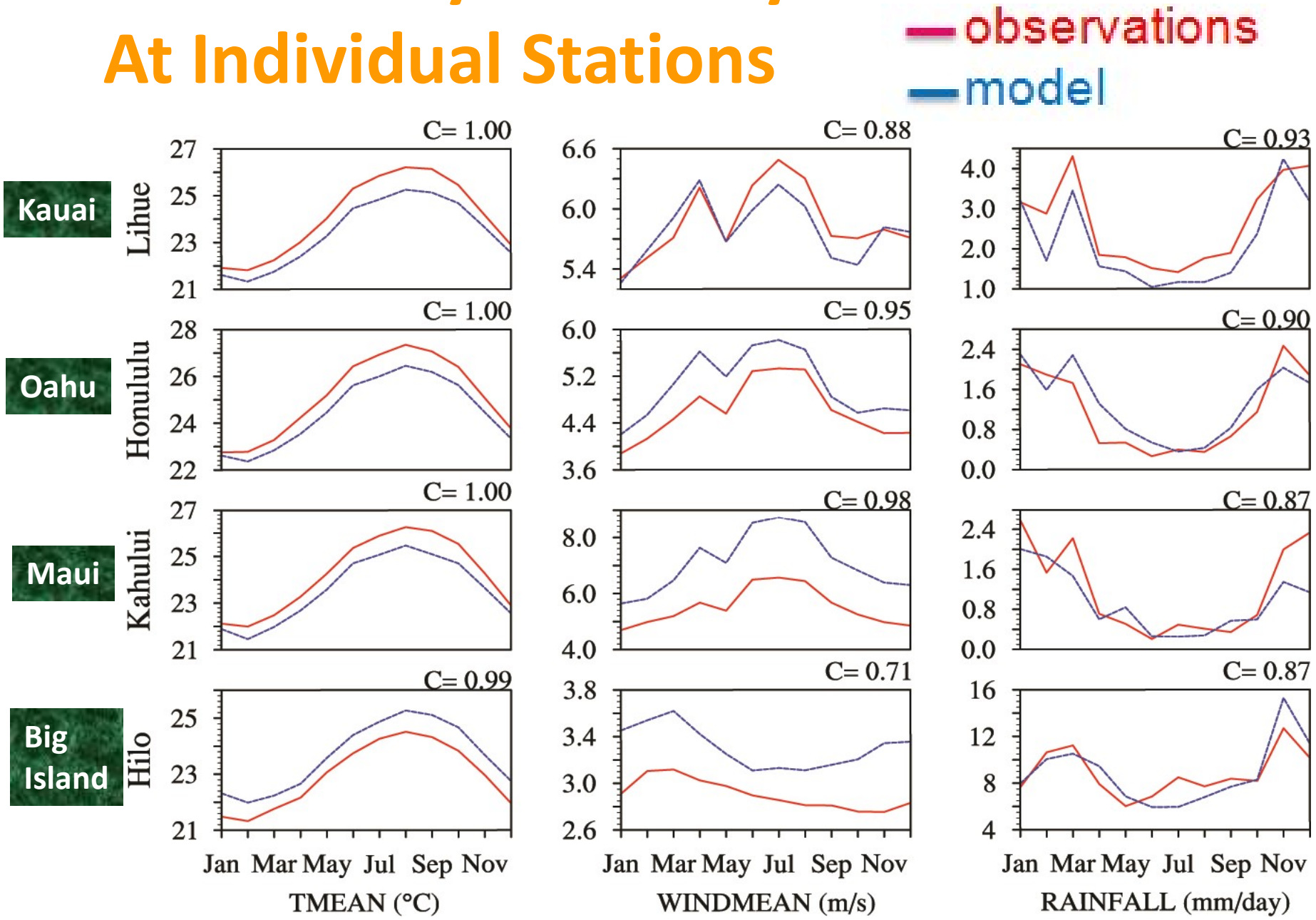
Daily mean surface wind speed

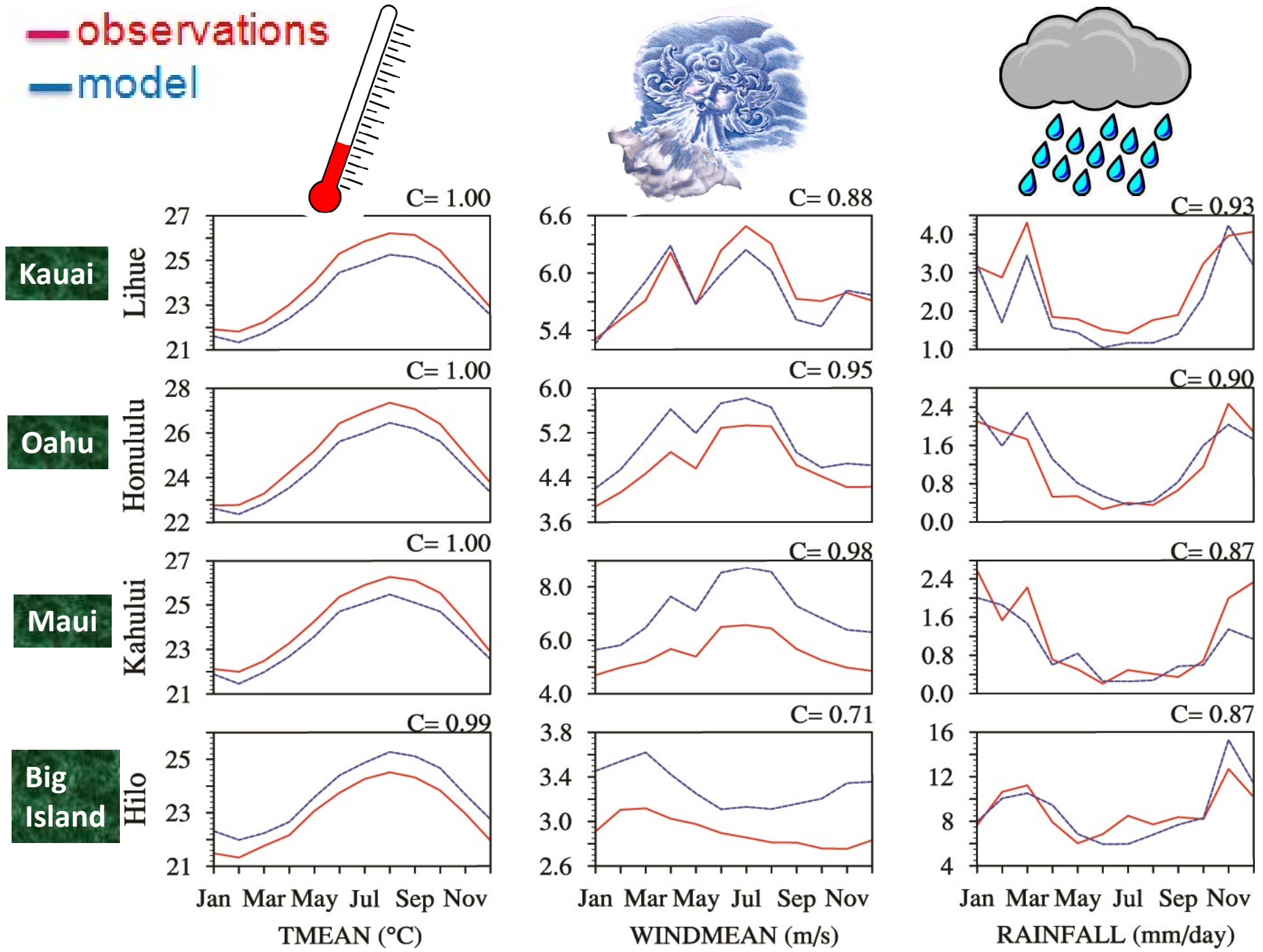


Domain 2

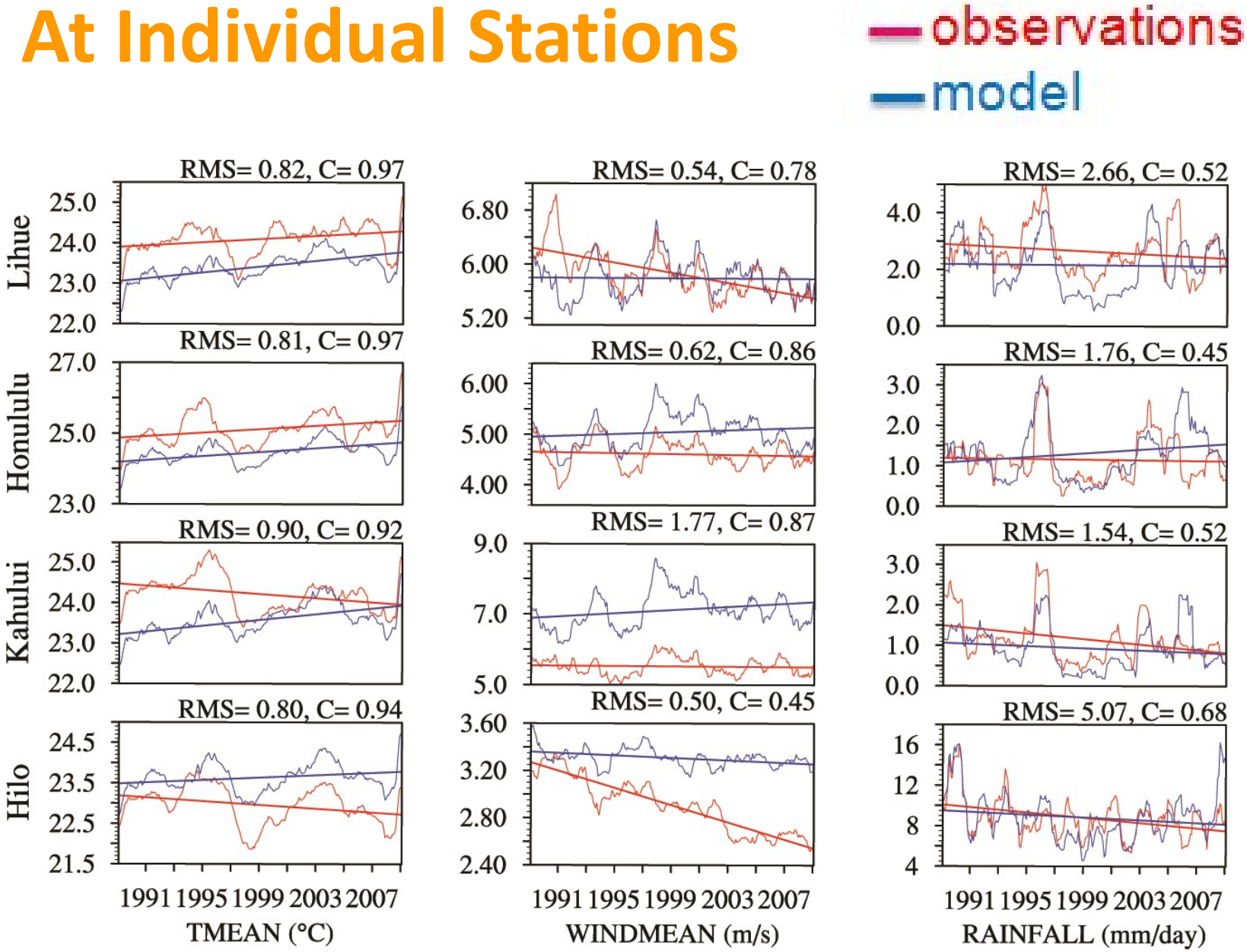
results Δx ~ 3 km

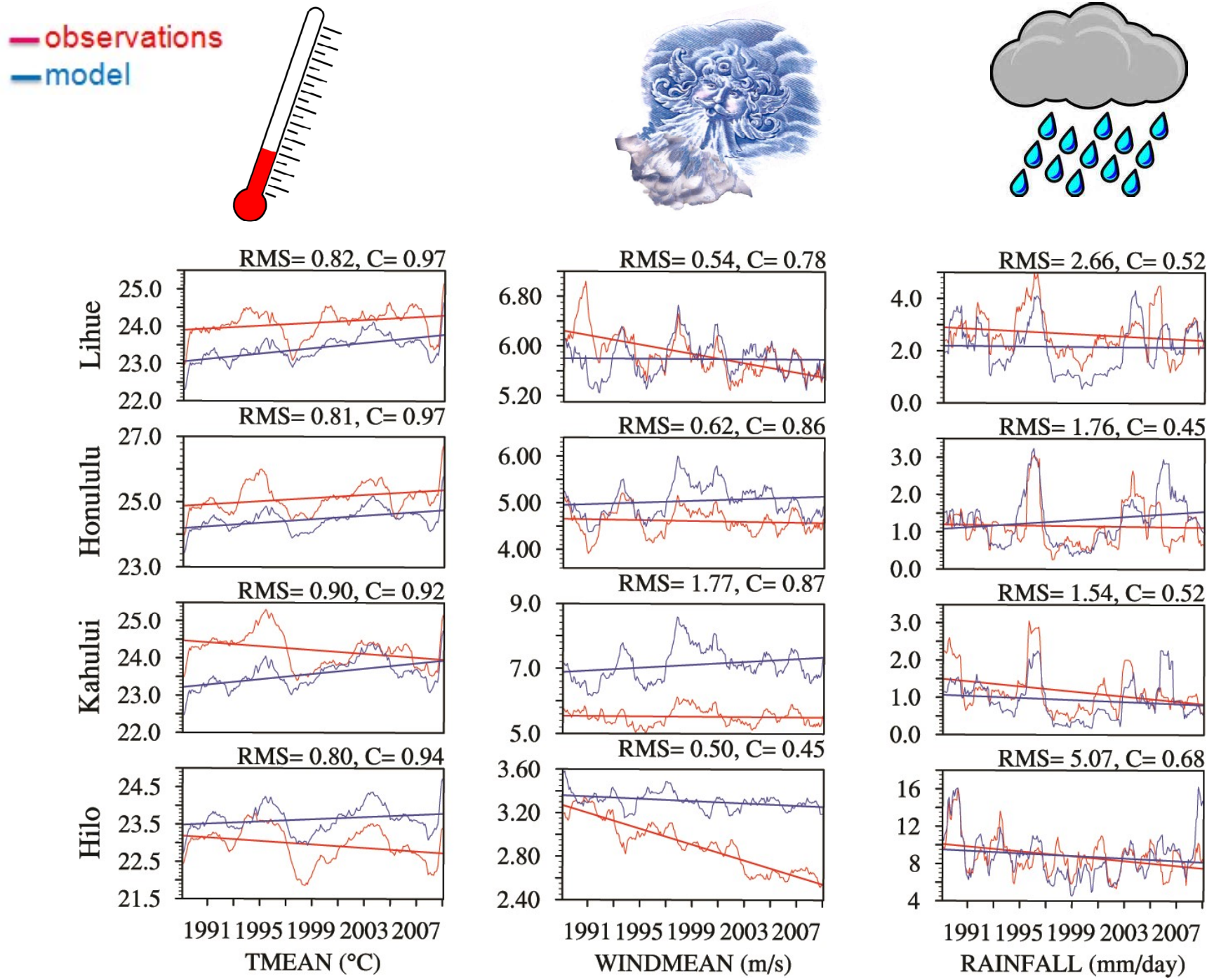
Seasonal Cycle in 20-year Mean Data At Individual Stations

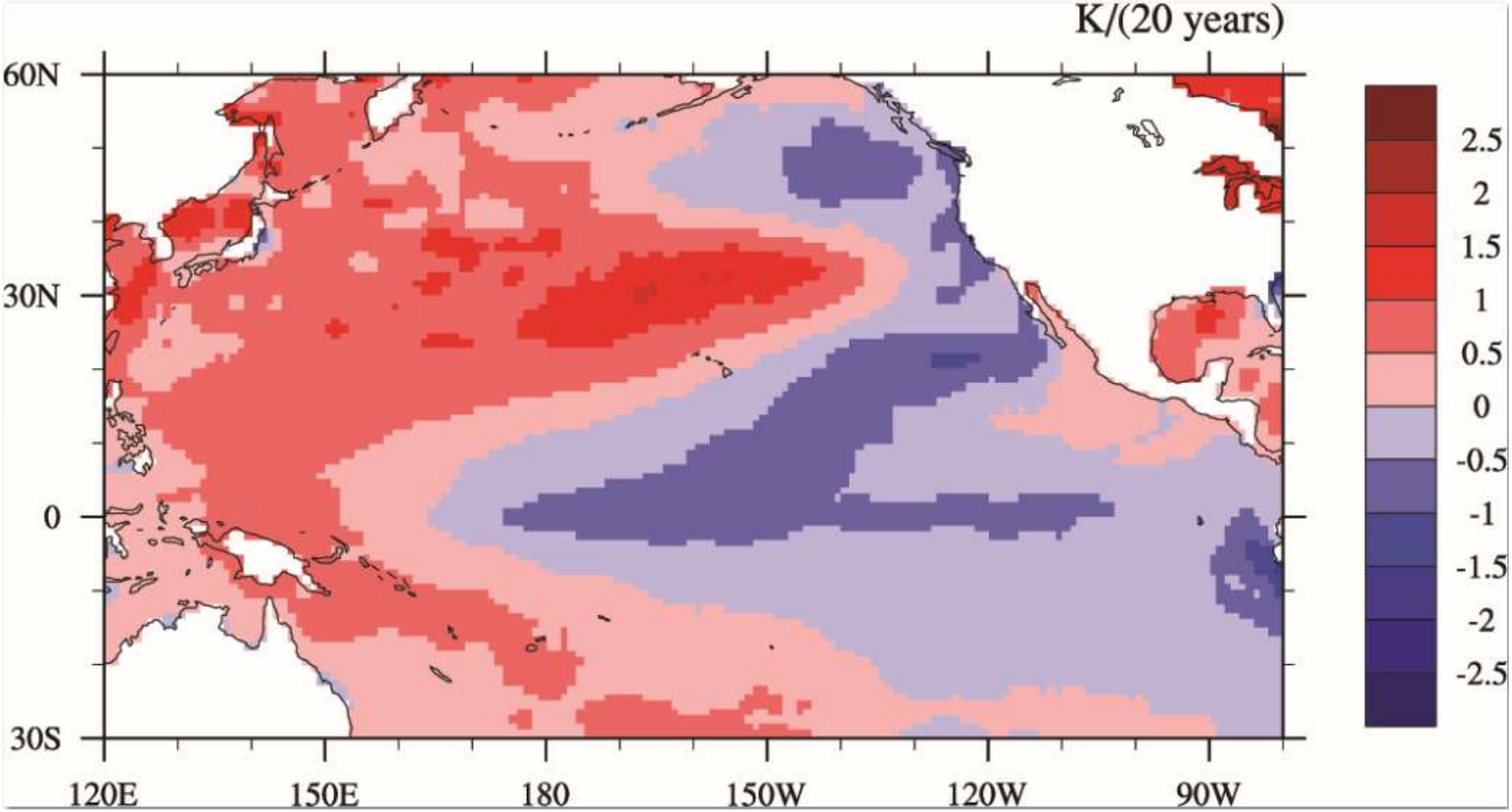



observations
model
Kauai
Oahu
Maui
Big Island
Lihue
Honolulu
Kahului
Hilo
C= 1.00
C= 1.00
C= 1.00
C= 0.99
C= 0.88
C= 0.95
C= 0.98
C= 0.71
C= 0.93
C= 0.90
C= 0.87
C= 0.87
Jan Mar May Jul Sep Nov
TMEAN (°C)
WINDMEAN (m/s)
RAINFALL (mm/day)

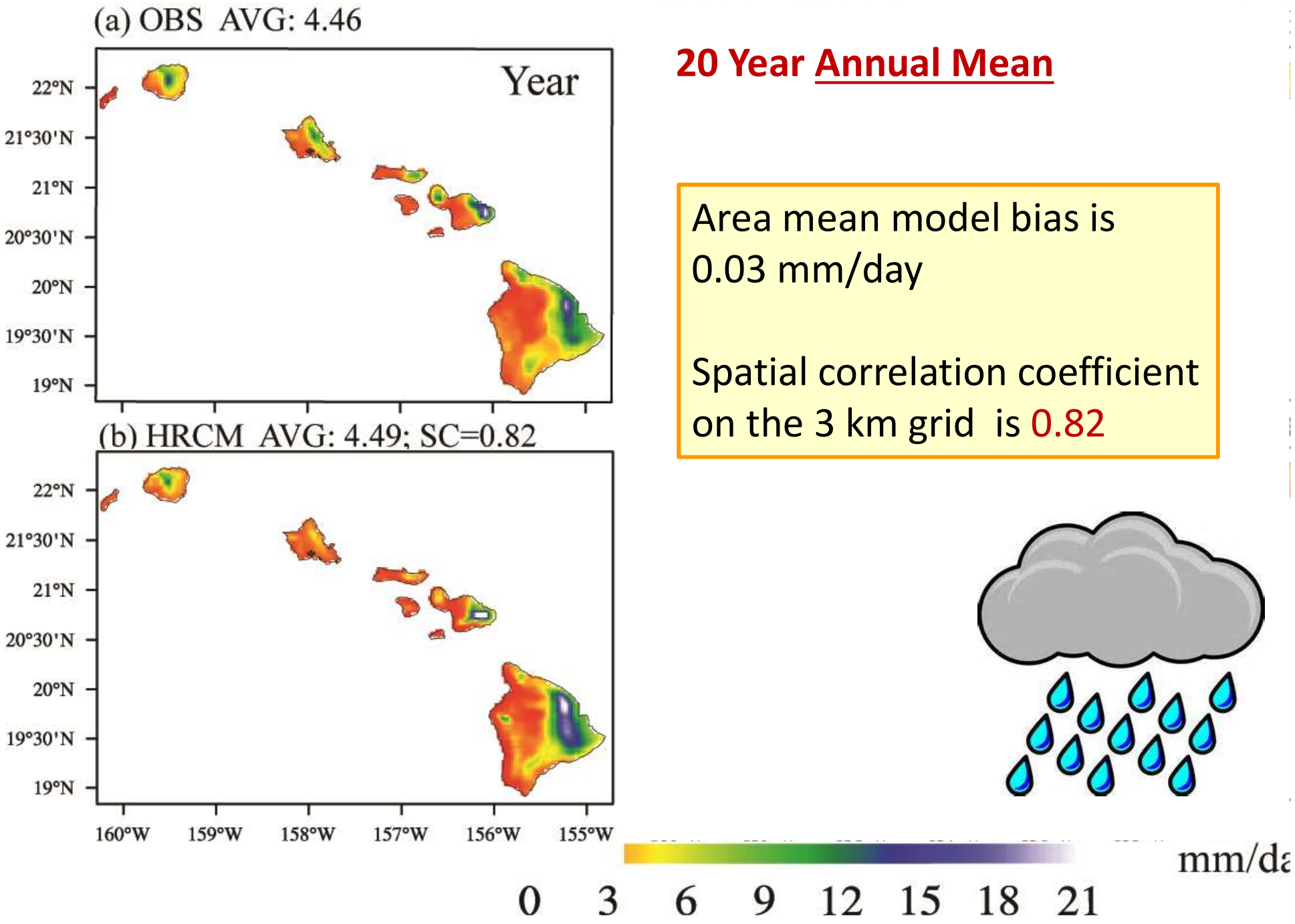
Time Series (6-Month Running Means) At Individual Stations




observations
model
RMS= 0.82, C= 0.97
RMS= 0.54, C= 0.78
RMS= 2.66, C= 0.52
Lihue
RMS= 0.81, C= 0.97
RMS= 0.62, C= 0.86
RMS= 1.76, C= 0.45
Honululu
RMS= 0.90, C= 0.92
RMS= 1.77, C= 0.87
RMS= 1.54, C= 0.52
Kahului
RMS= 0.80, C= 0.94
RMS= 0.50, C= 0.45
RMS= 5.07, C= 0.68
Hilo
1991 1995 1999 2003 2007
TMEAN (°C)
1991 1995 1999 2003 2007
WINDMEAN (m/s)
1991 1995 1999 2003 2007
RAINFALL (mm/day)



The linear regression trend in the observed SST over 1990-2009. The trend is expressed in degrees C over 20 years.



20 Year Annual Mean

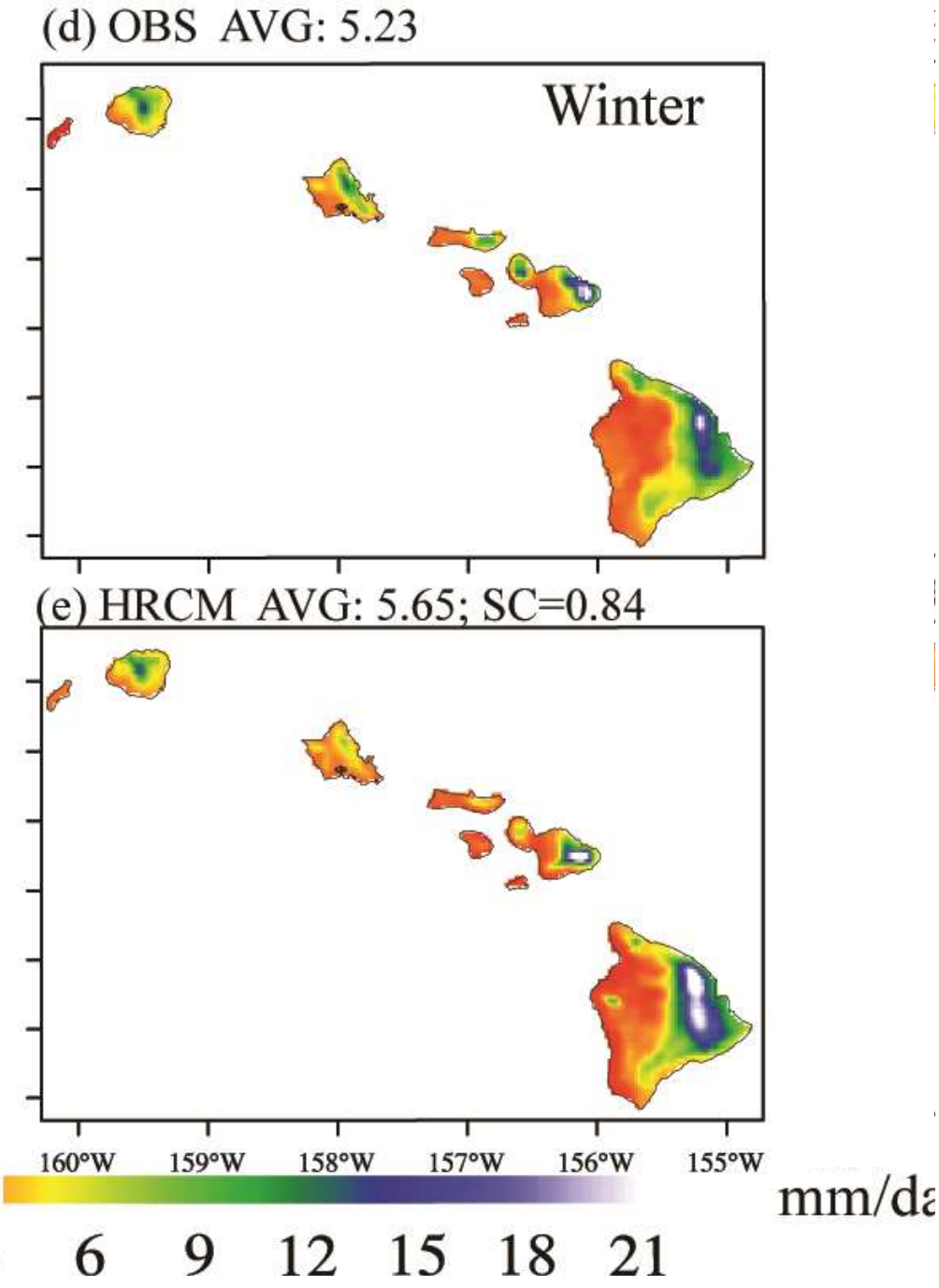
Area mean model bias is 0.03 mm/day

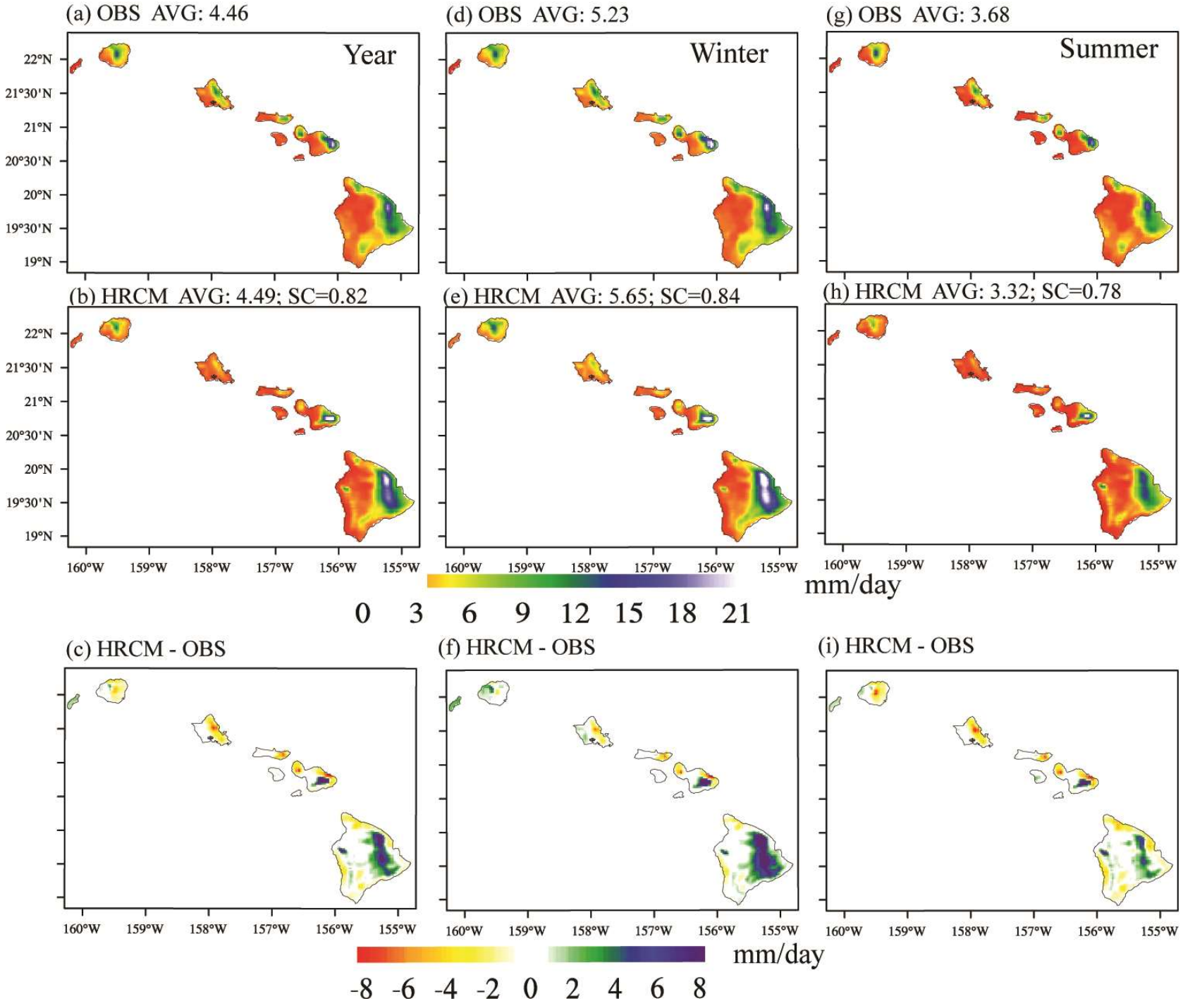
Spatial correlation coefficient on the 3 km grid is 0.82

20 Year November-April

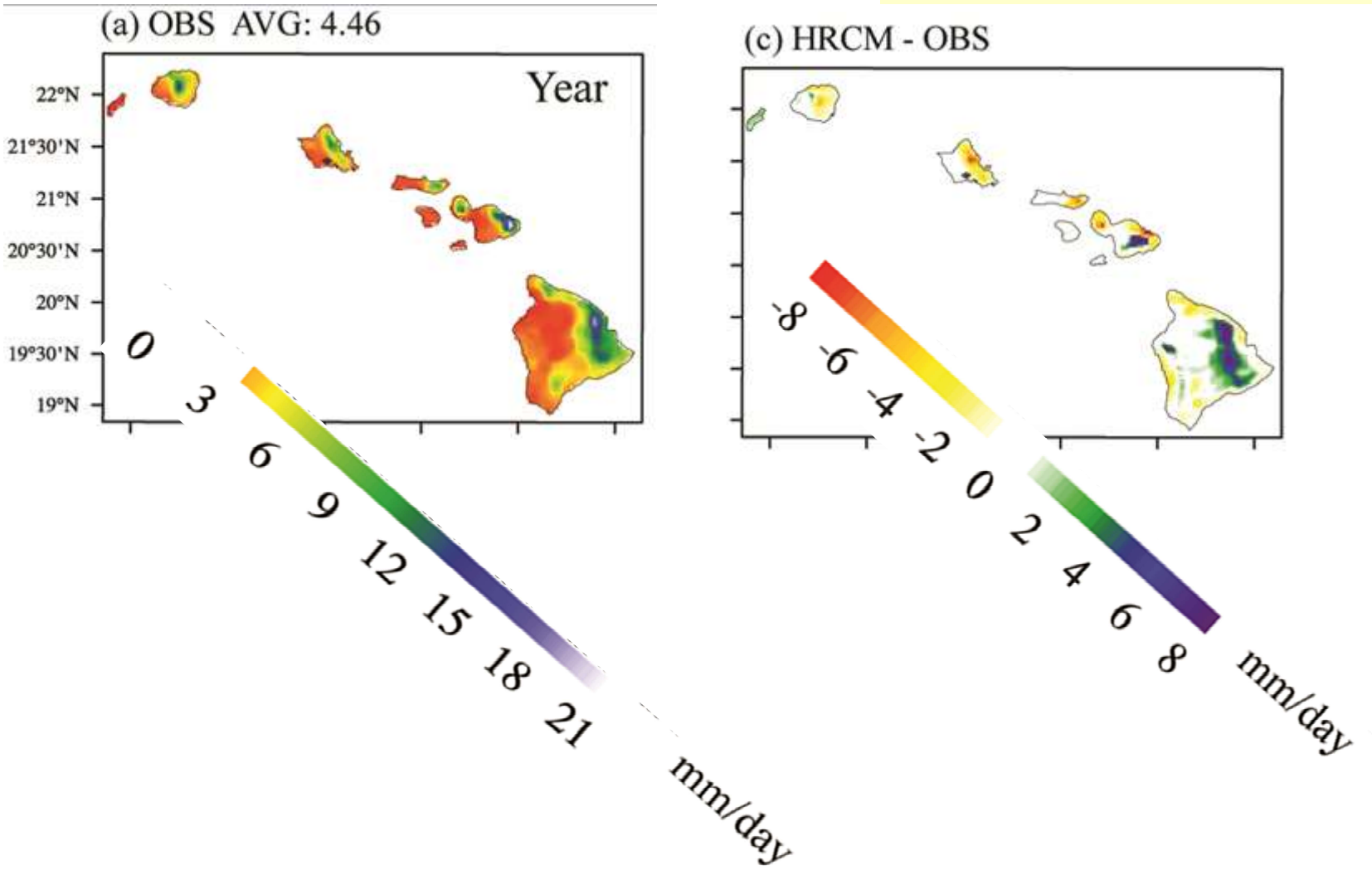
Area mean model bias is
0.42 mm/day

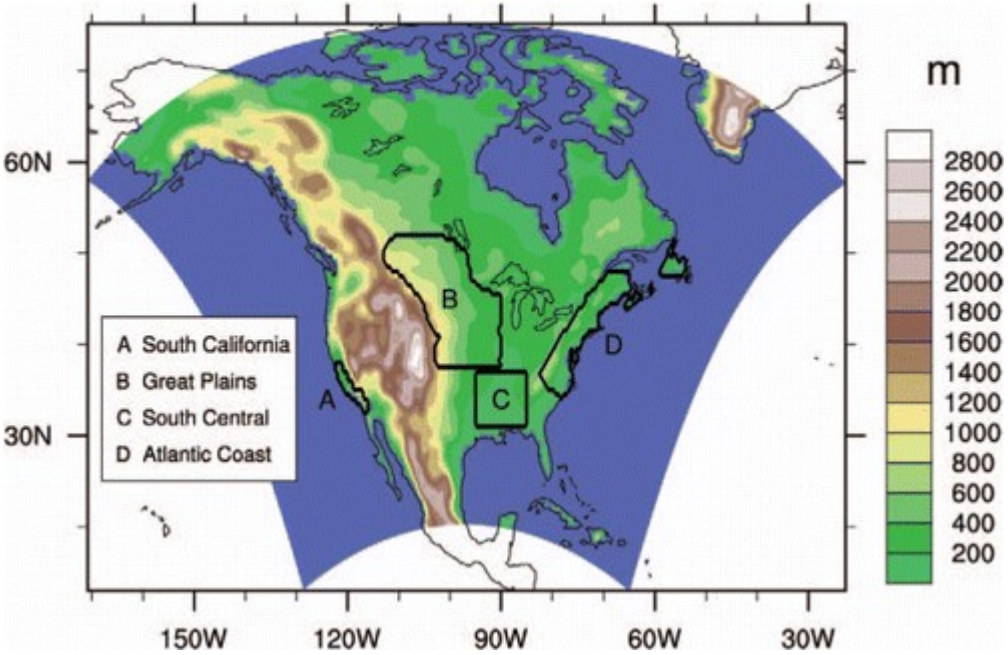
Spatial correlation coefficient
On the 3 km grid is 0.84

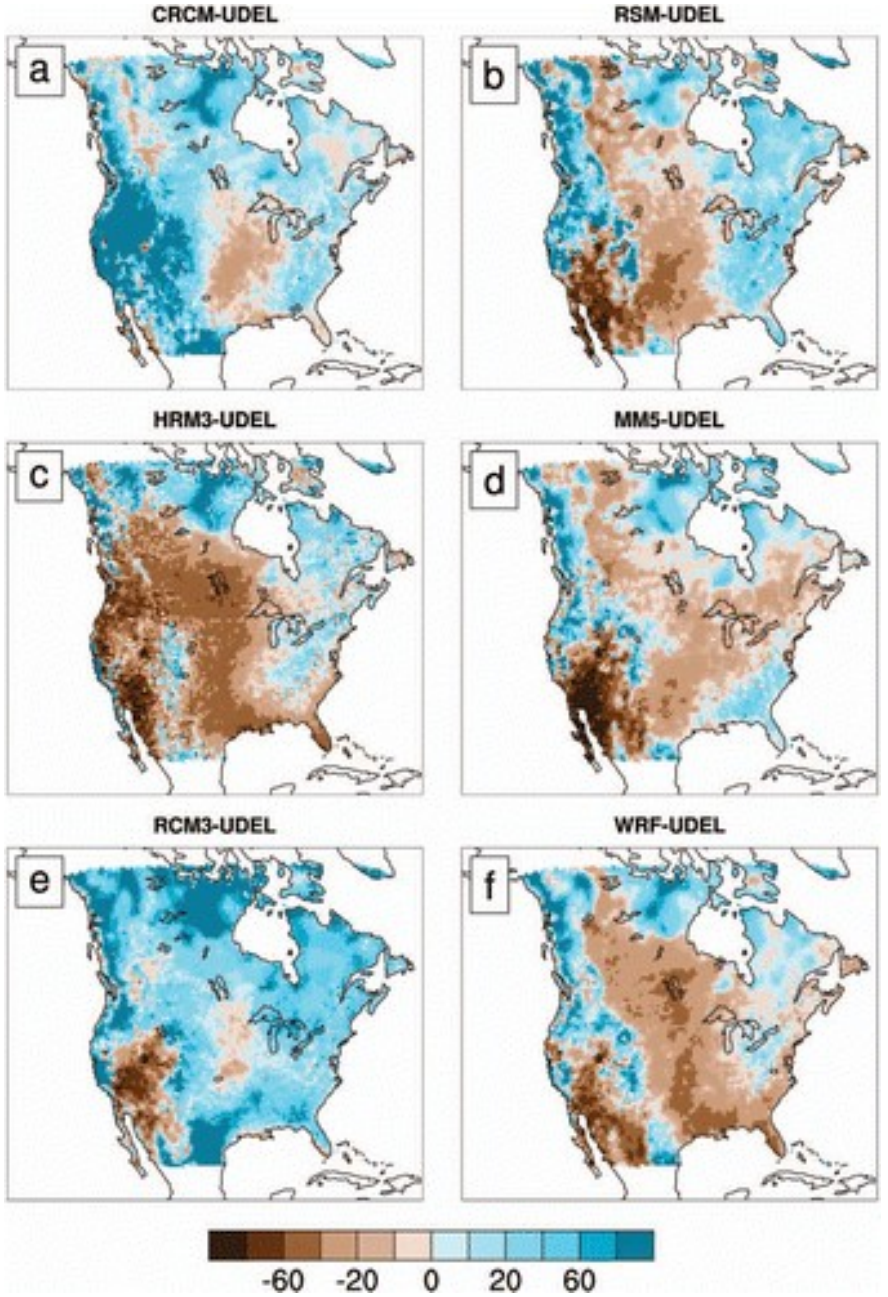



(a) OBS AVG: 4.46
Year
(d) OBS AVG: 5.23
Winter
(g) OBS AVG: 3.68
Summer
(b) HRCM AVG: 4.49; SC=0.82
(e) HRCM AVG: 5.65; SC=0.84
(h) HRCM AVG: 3.32; SC=0.78
22°N
21°30'N
21°N
20°30'N
20°N
19°30'N
19°N
160°W
159°W
158°W
157°W
156°W
155°W
mm/day
0 3 6 9 12 15 18 21
(c) HRCM - OBS
(f) HRCM - OBS
(i) HRCM - OBS
mm/day
-8 -6 -4 -2 0 2 4 6 8

BIAS IN MODEL SIMULATION





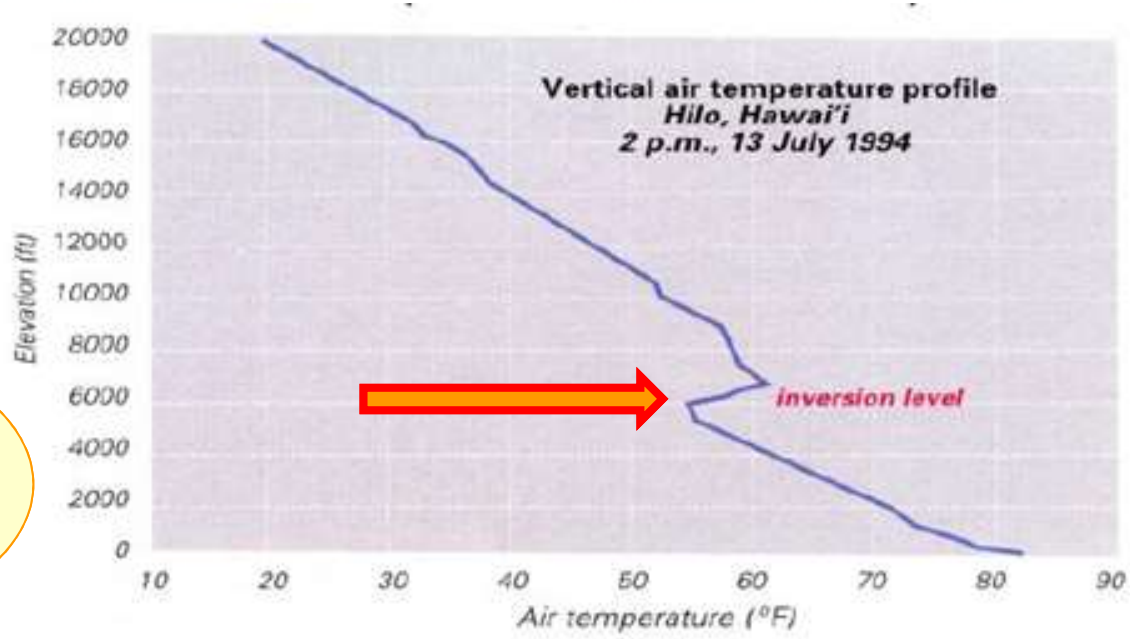


NARCCAP

20 year summer precipitation bias express as % of observed

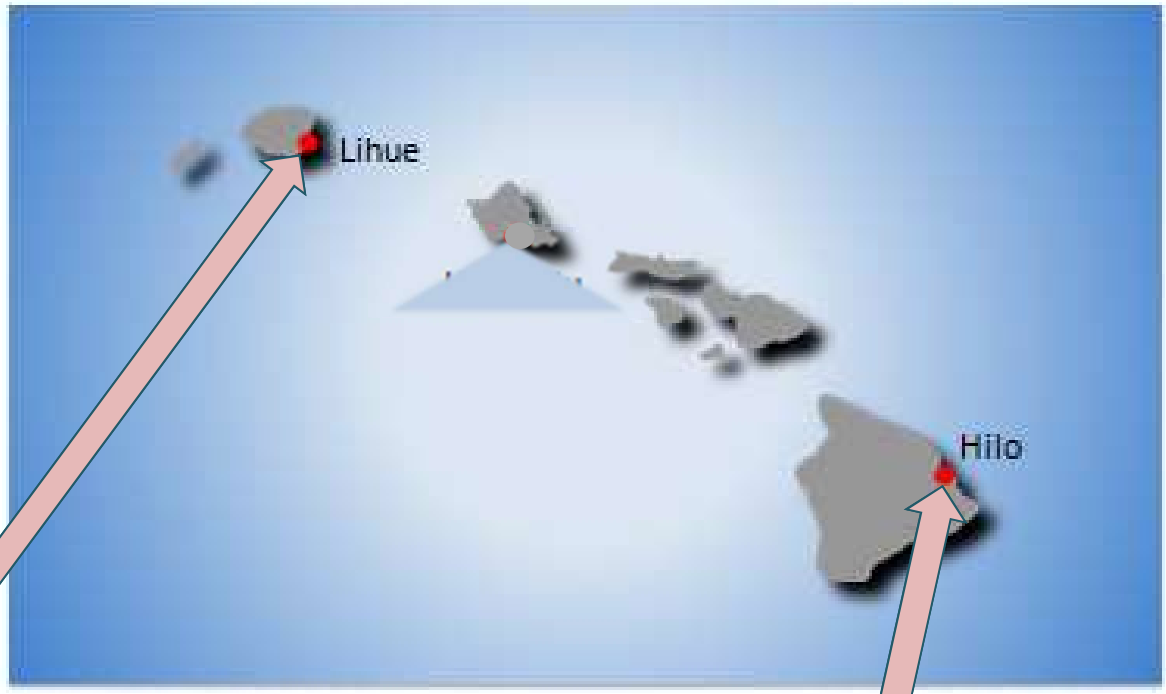
% bias

12-hourly operational soundings are taken at 2 stations – Lihue & Hilo

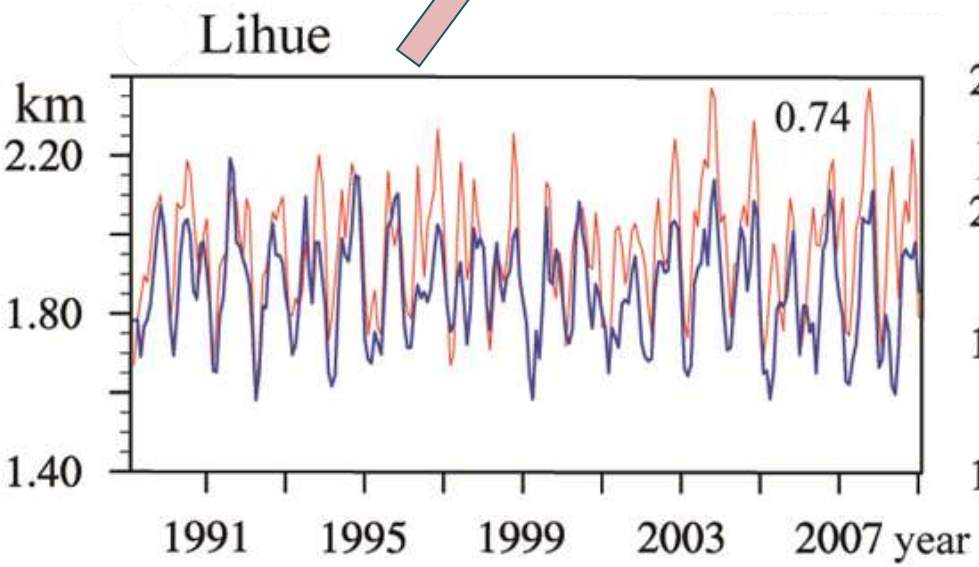


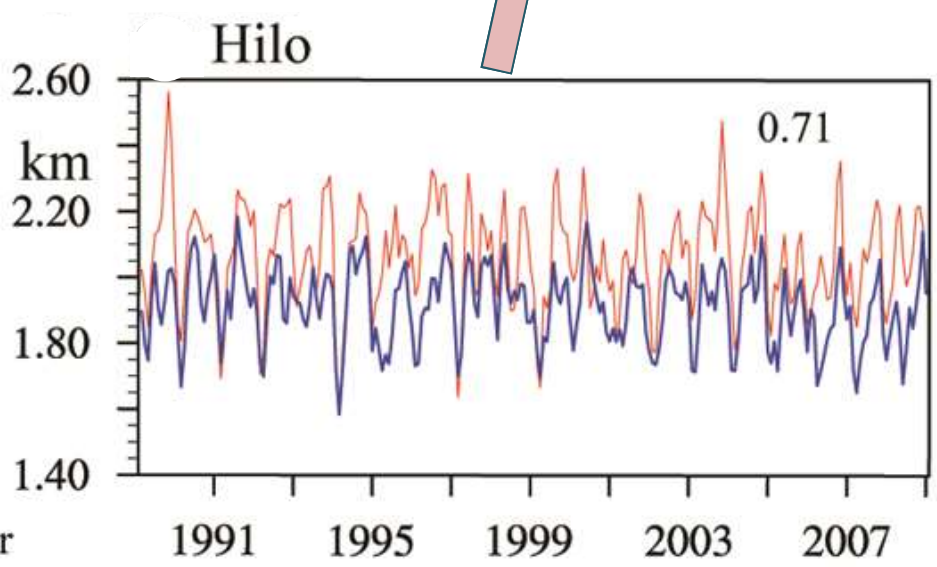
Trade Wind Inversion Base Height (TWIBH)

Model has a low bias of about 100-150 m in TWI height



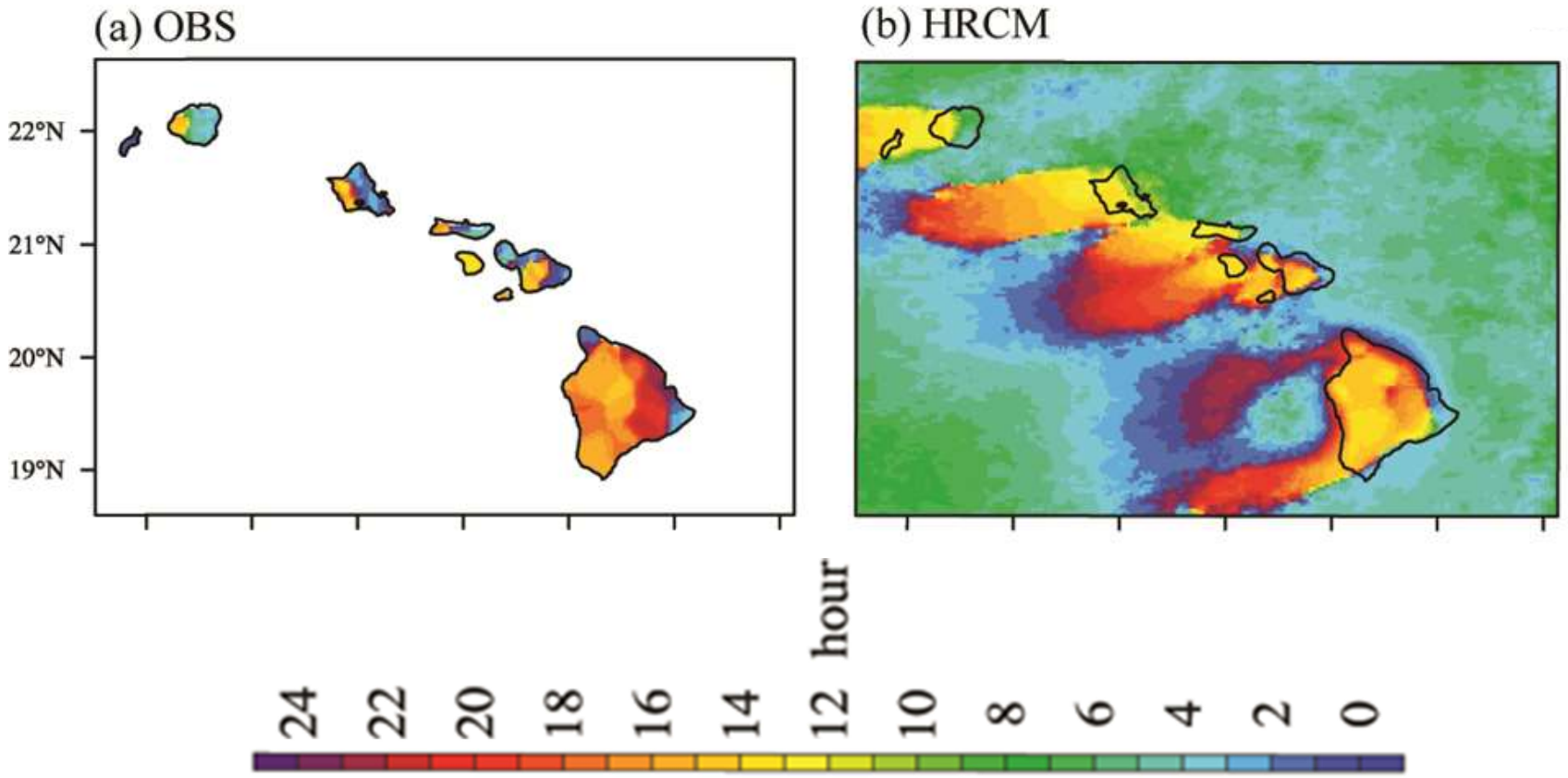
observations
model

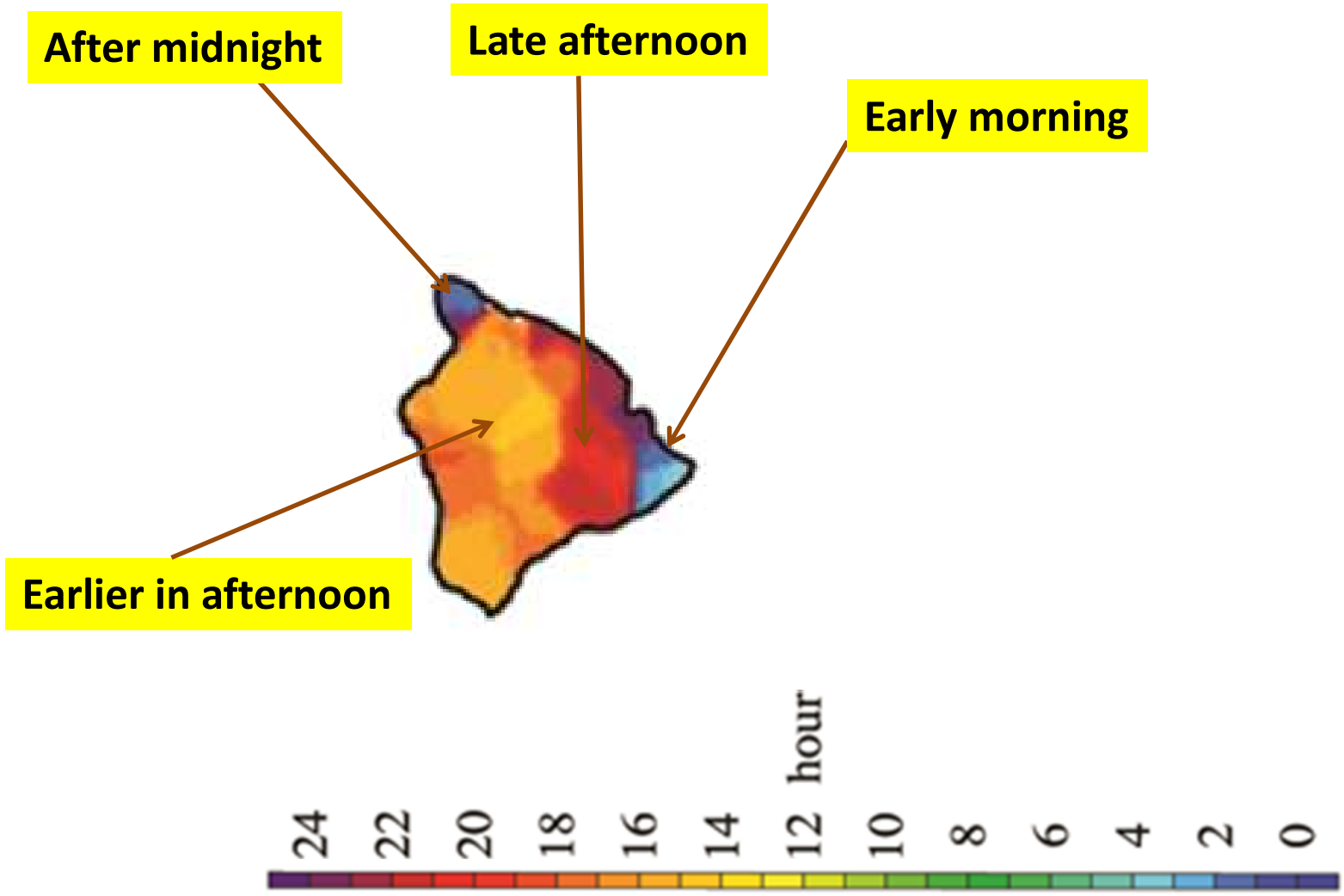


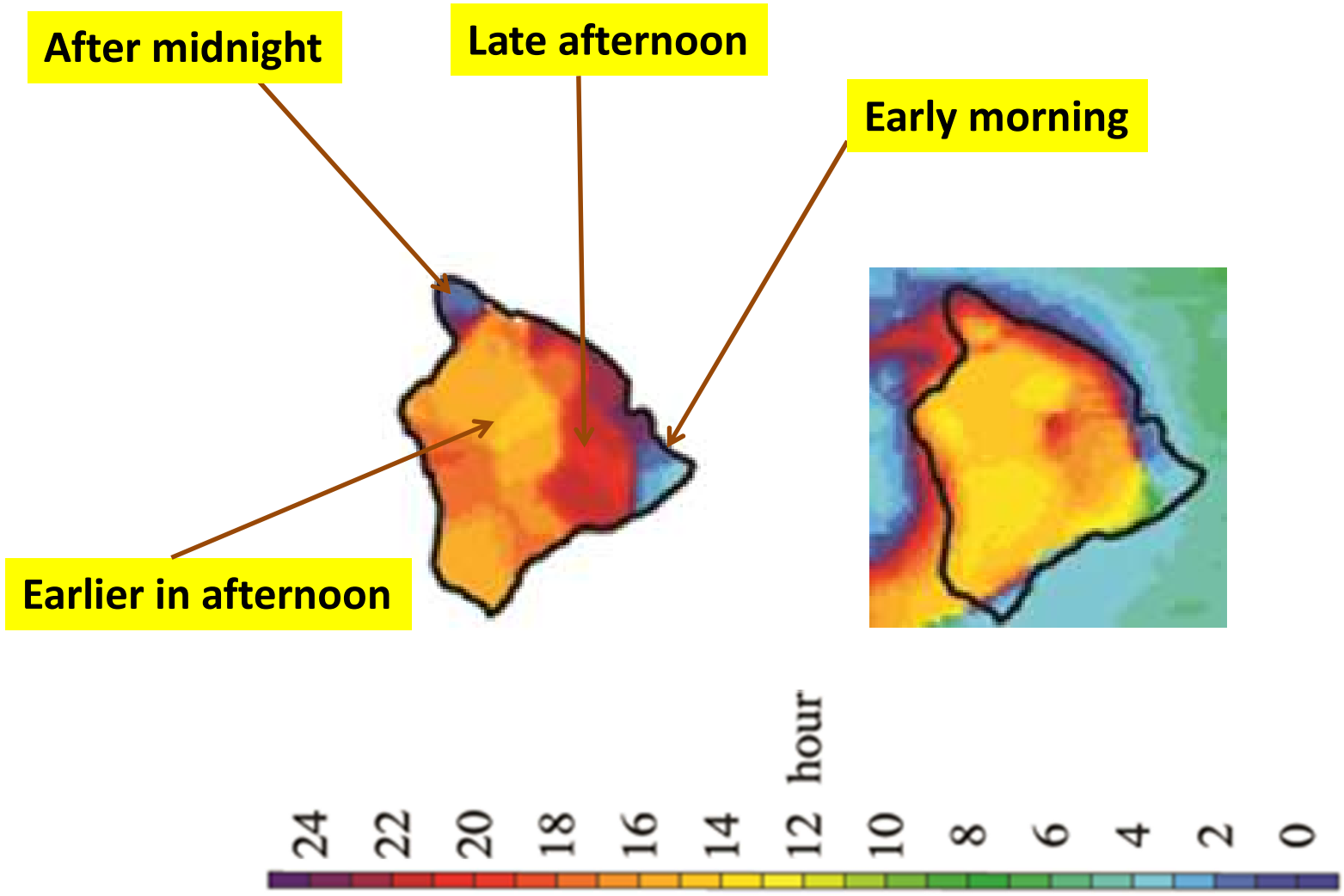


Diurnal Rainfall Variation

Time of Peak Climatological Rainfall Amounts

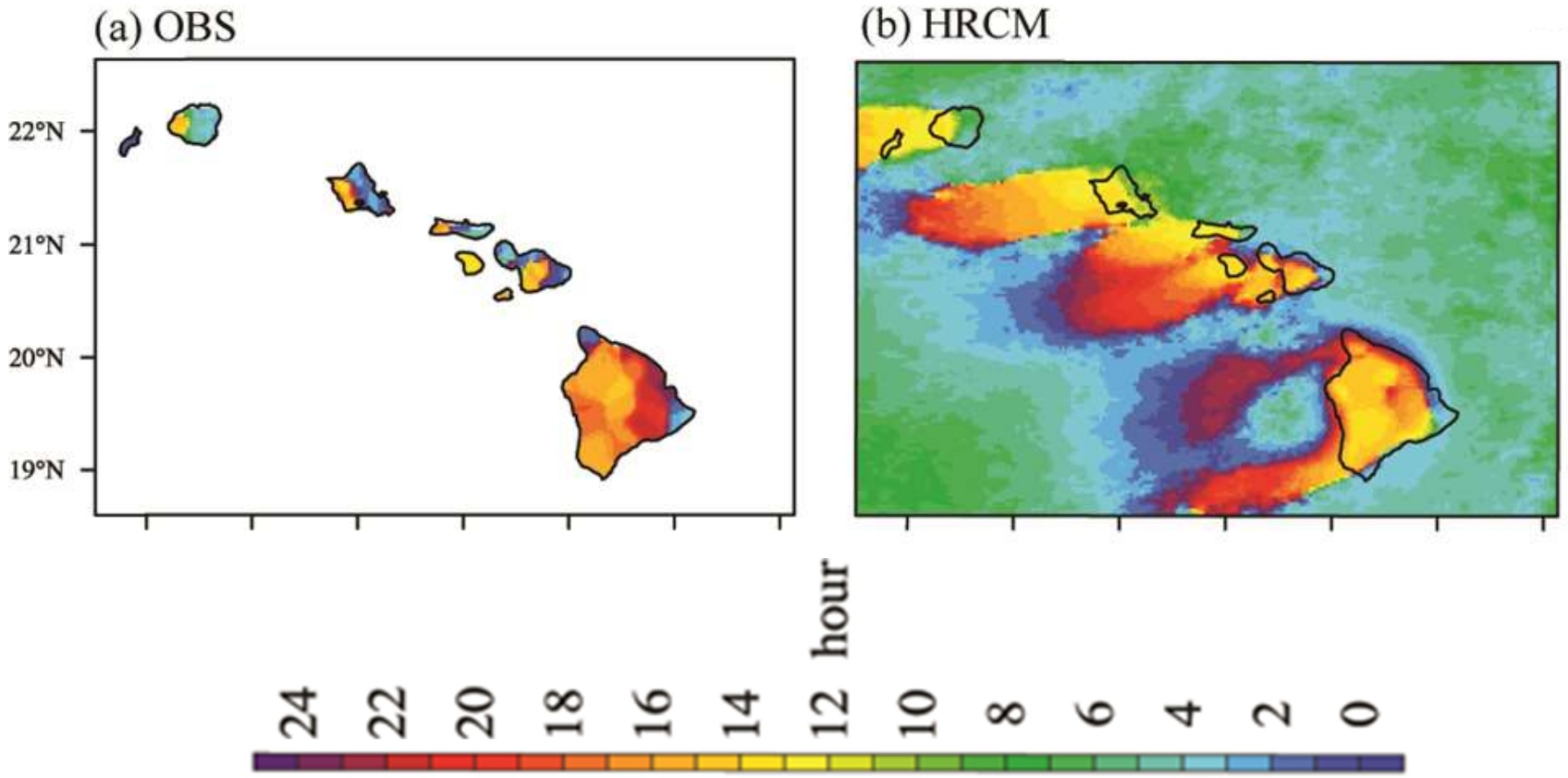


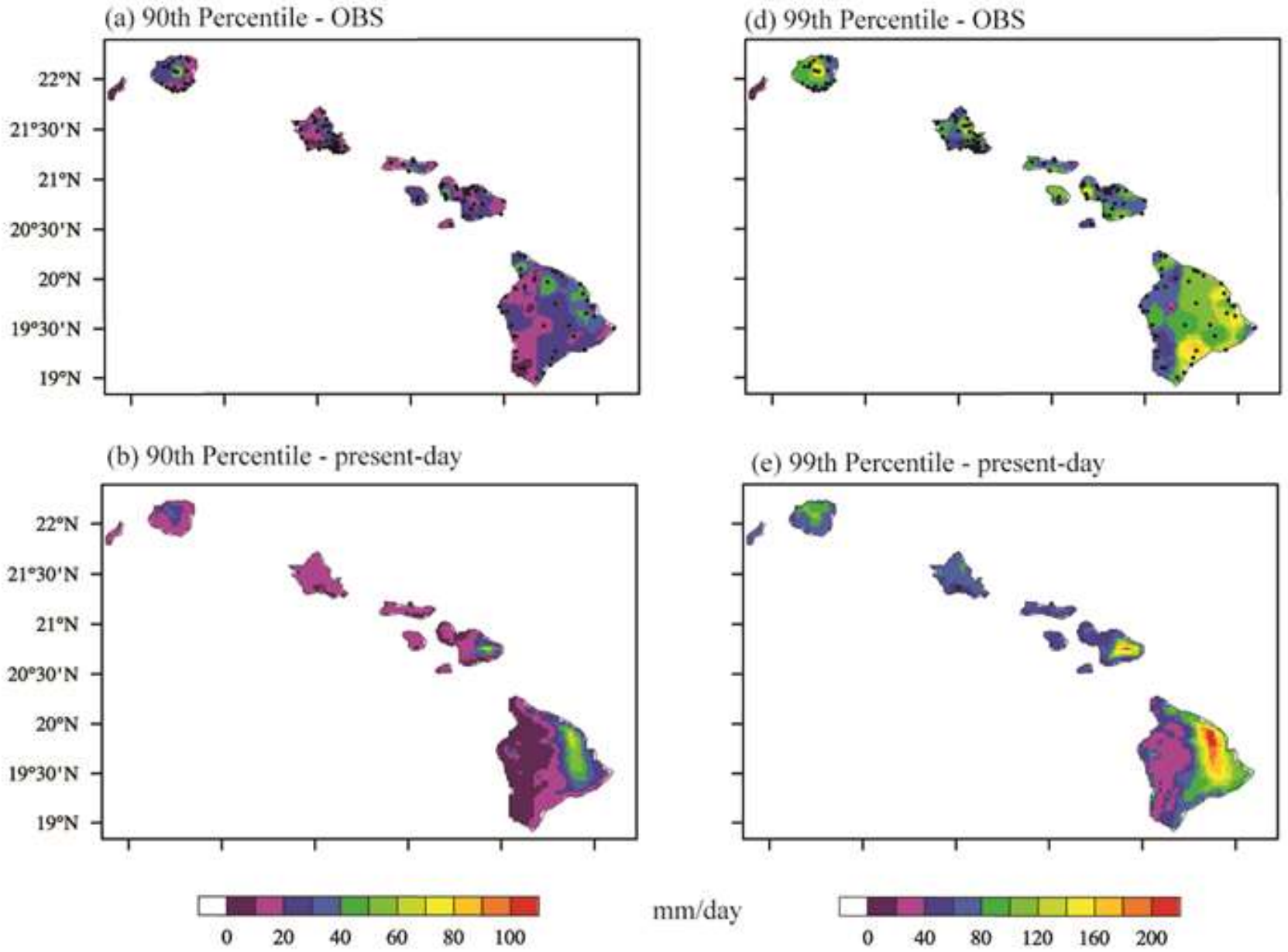

After midnight
Late afternoon
Early morning
Earlier in afternoon
hour
24
22
20
18
16
14
12
10
8
6
4
2
0


After midnight
Late afternoon
Early morning
Earlier in afternoon
hour
24
22
20
18
16
14
12
10
8
6
4
2
0

Diurnal Rainfall Variation

Time of Peak Climatological Rainfall Amounts

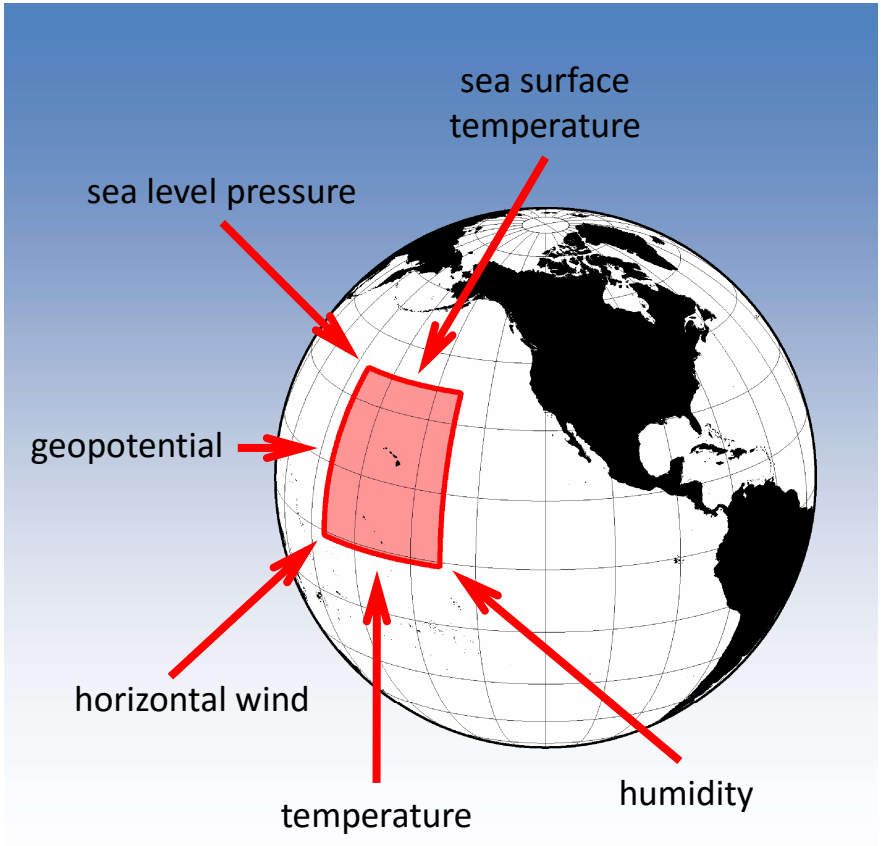



(a) 90th Percentile - OBS
(d) 99th Percentile - OBS
(b) 90th Percentile - present-day
(e) 99th Percentile - present-day
22°N
21°30'N
21°N
20°30'N
20°N
19°30'N
19°N
0 20 40 60 80 100
mm/day
0 40 80 120 160 200

Global Warming Projection for Late 21st Century

Specification of the boundary conditions

Pseudo-Global-Warming Method (*Kimura and Kitoh* 2007; *Sato et al.* 2007)



MERRA reanalysis data, NOAA SSTs

Present-day Run

MERRA reanalysis data, NOAA SSTs

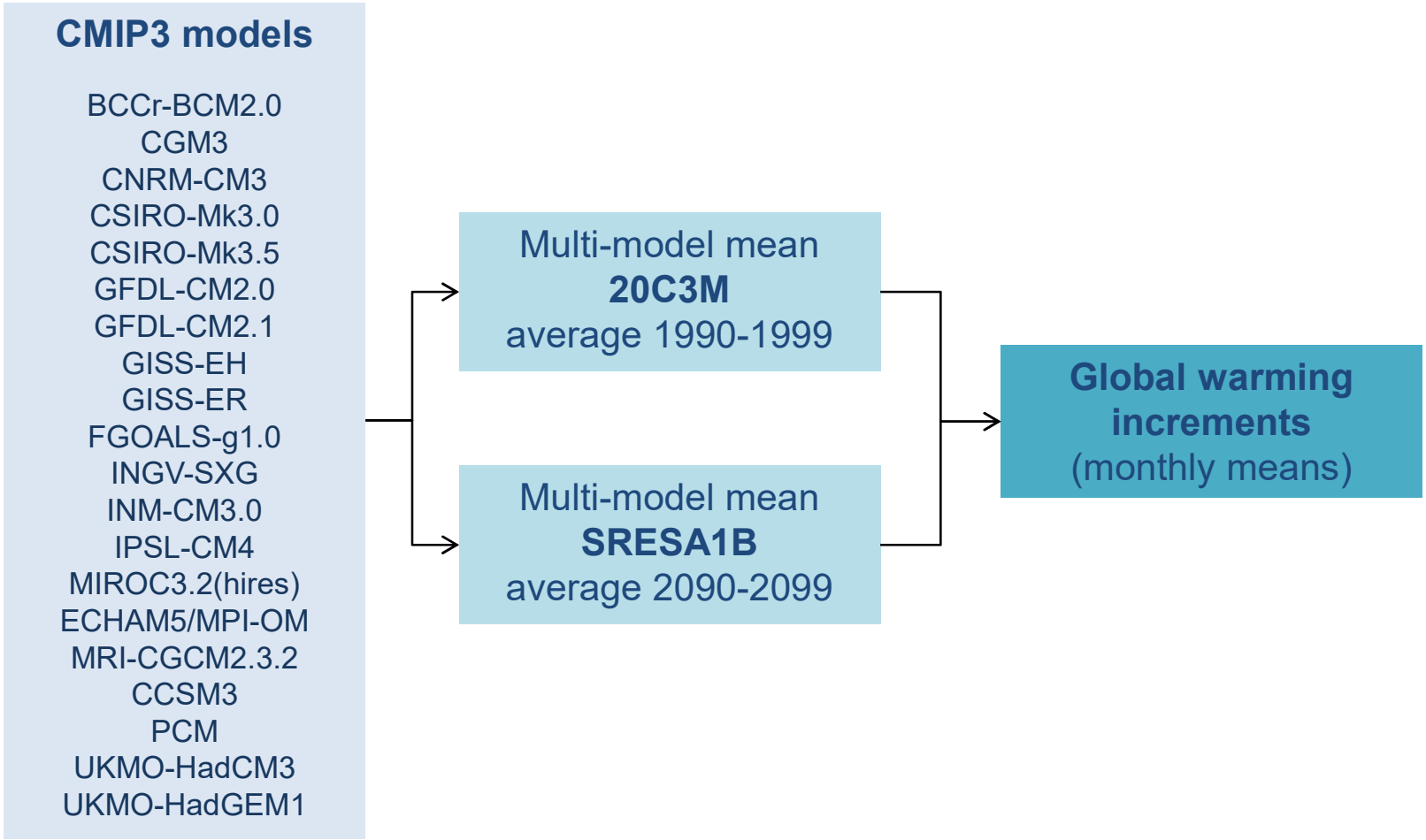
+

Global warming increment (monthly means)

Global Warming Run

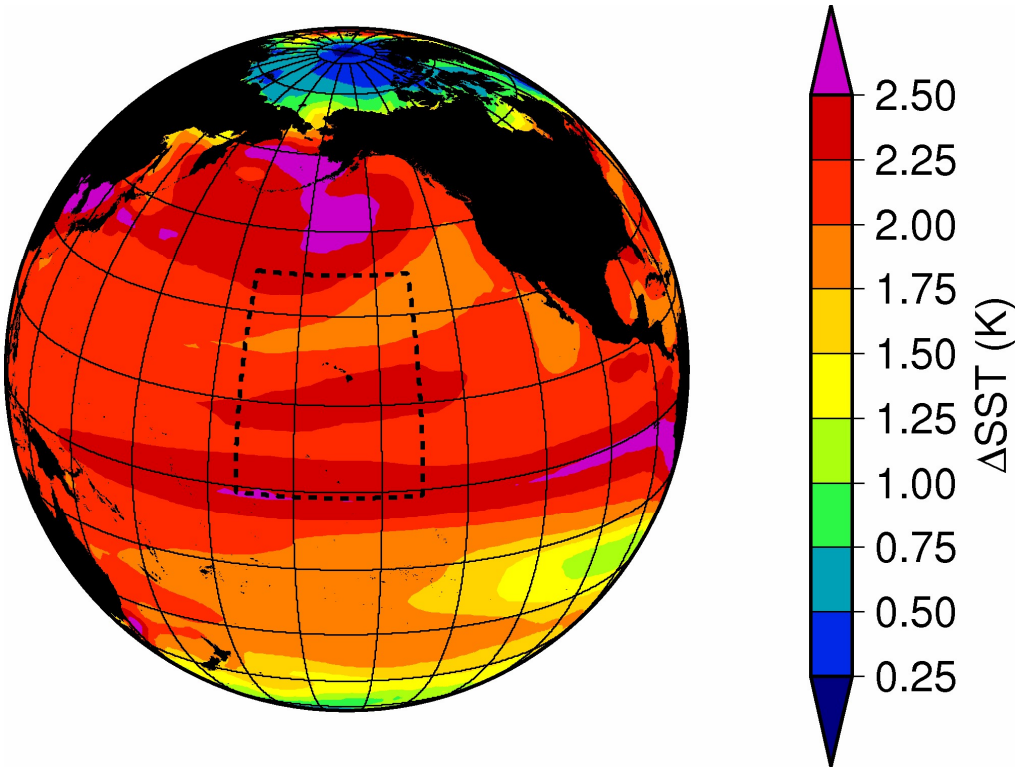
Specification of the boundary conditions

Pseudo-Global-Warming Method (*Kimura and Kitoh* 2007; *Sato et al.* 2007)

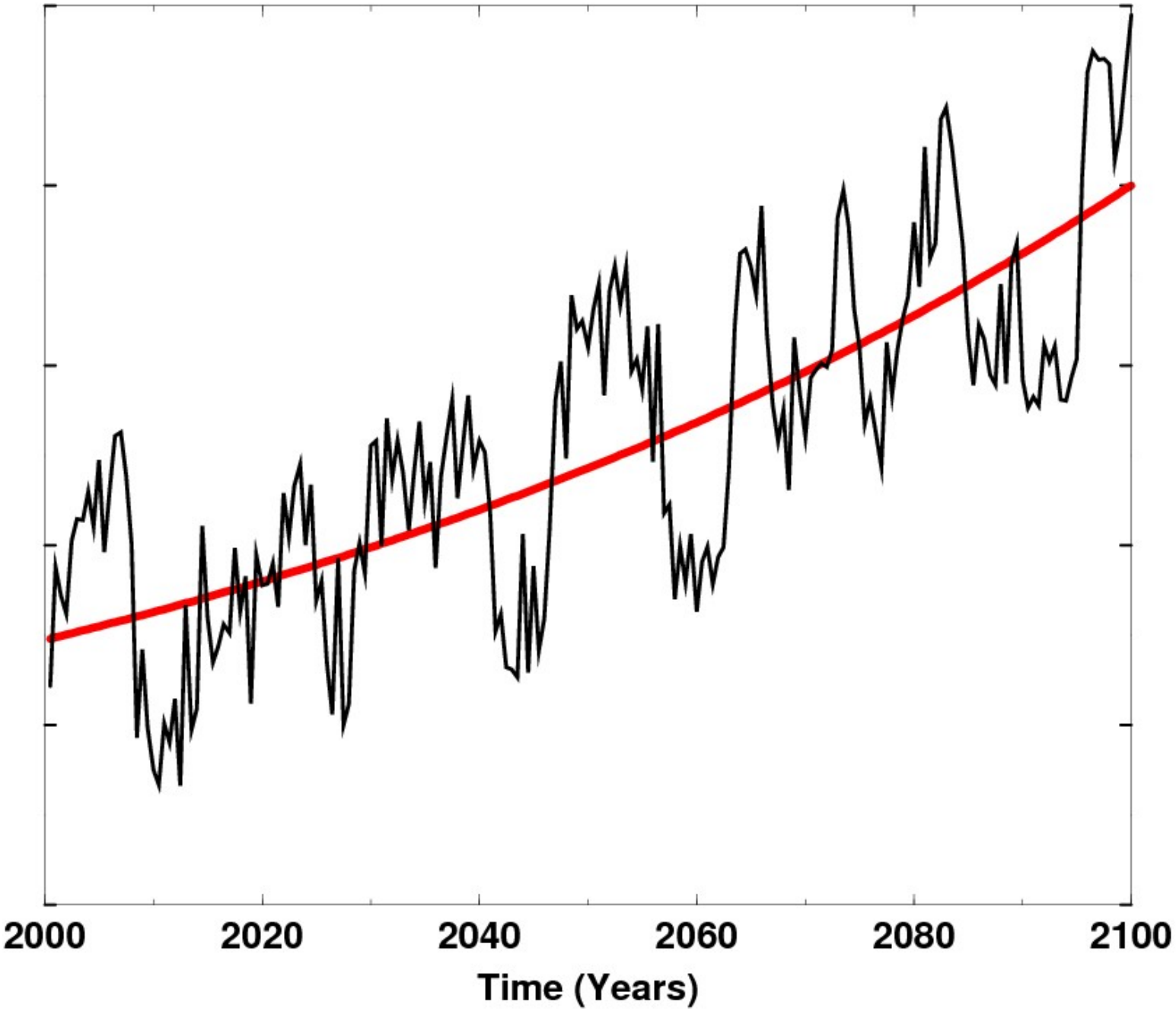


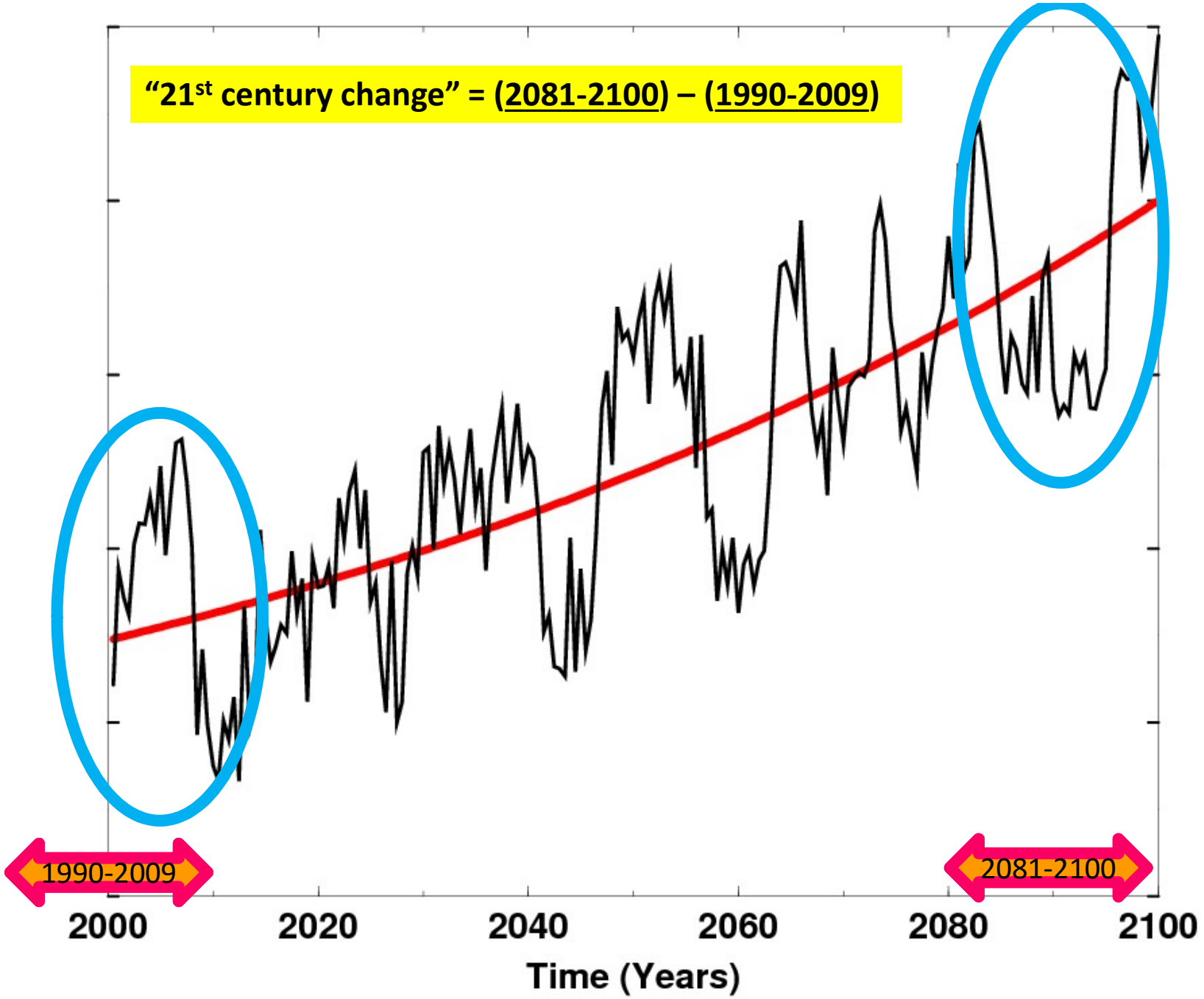
Global warming increment: SST

Future scenario (SRES A1B, 2090-2099) – present-day (20C3M, 1990-1999)



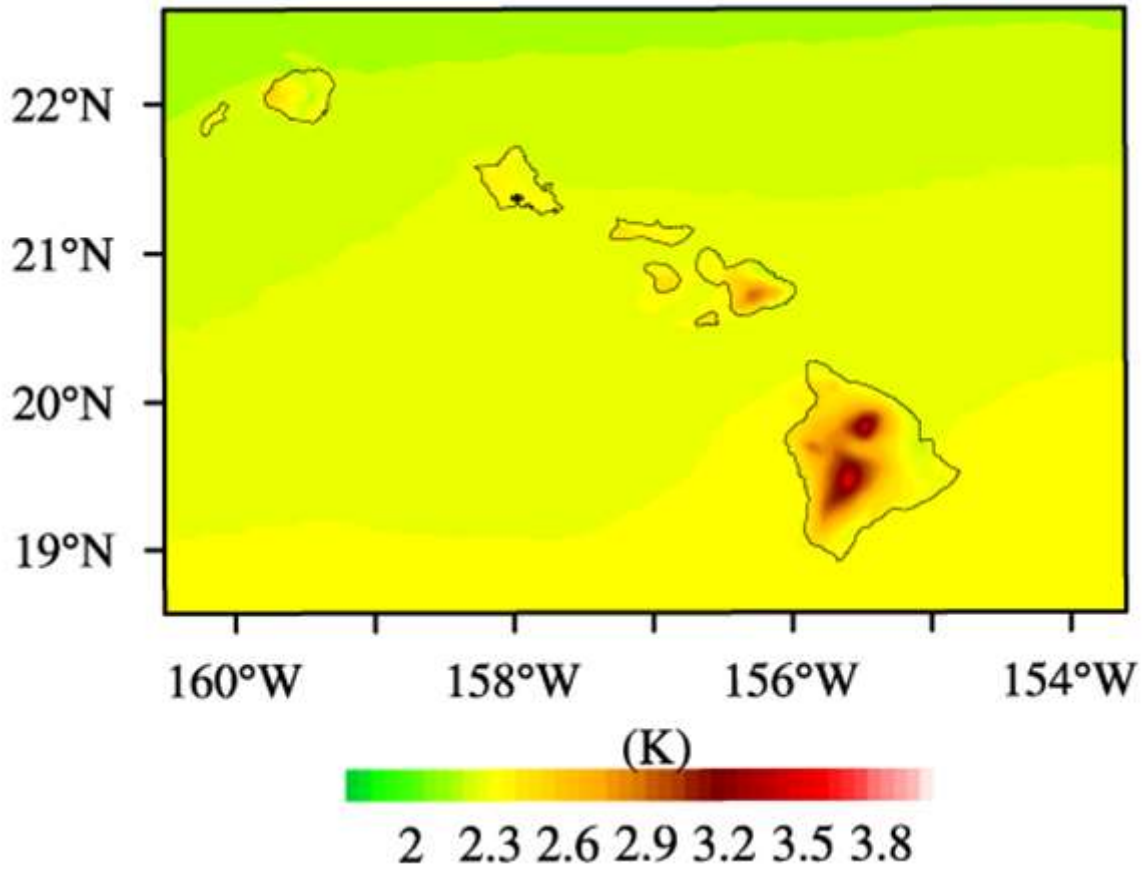
Multi-model mean (16 CMIP3 models)

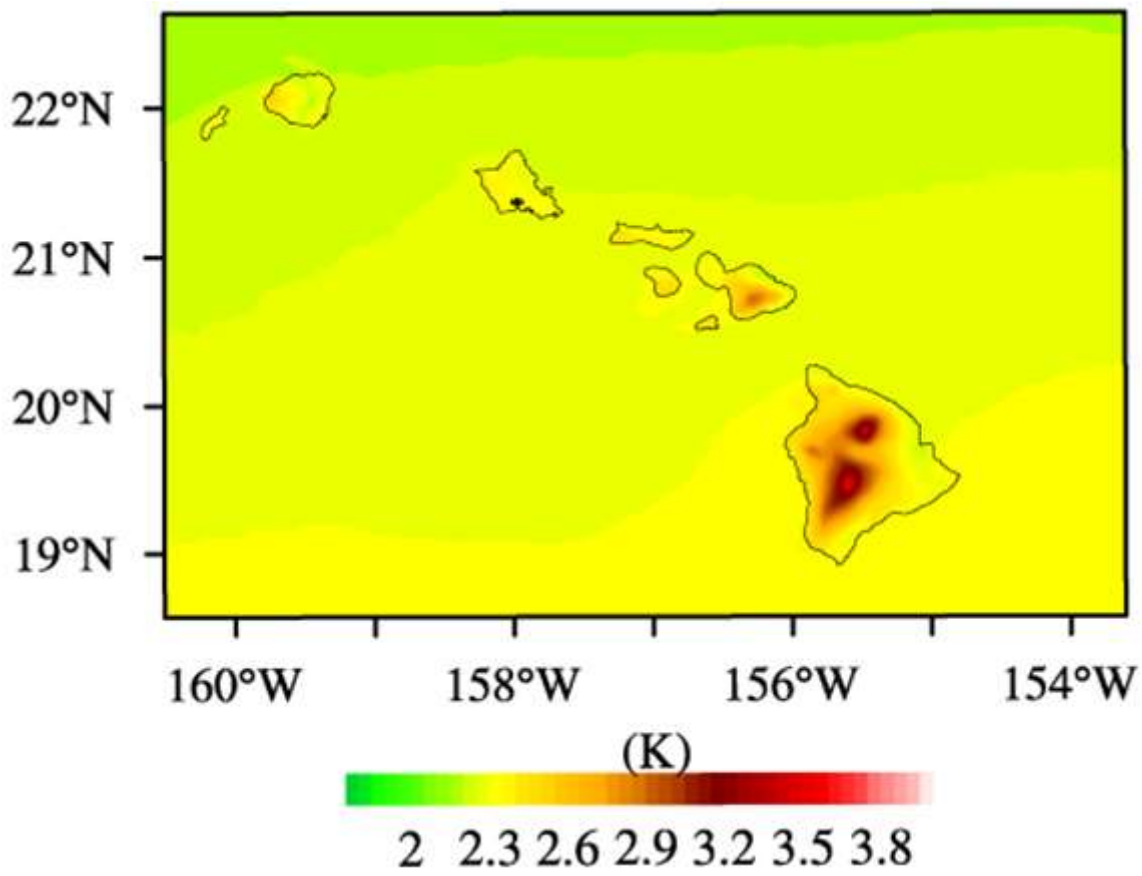

2000
2020
2040
2060
2080
2100
Time (Years)

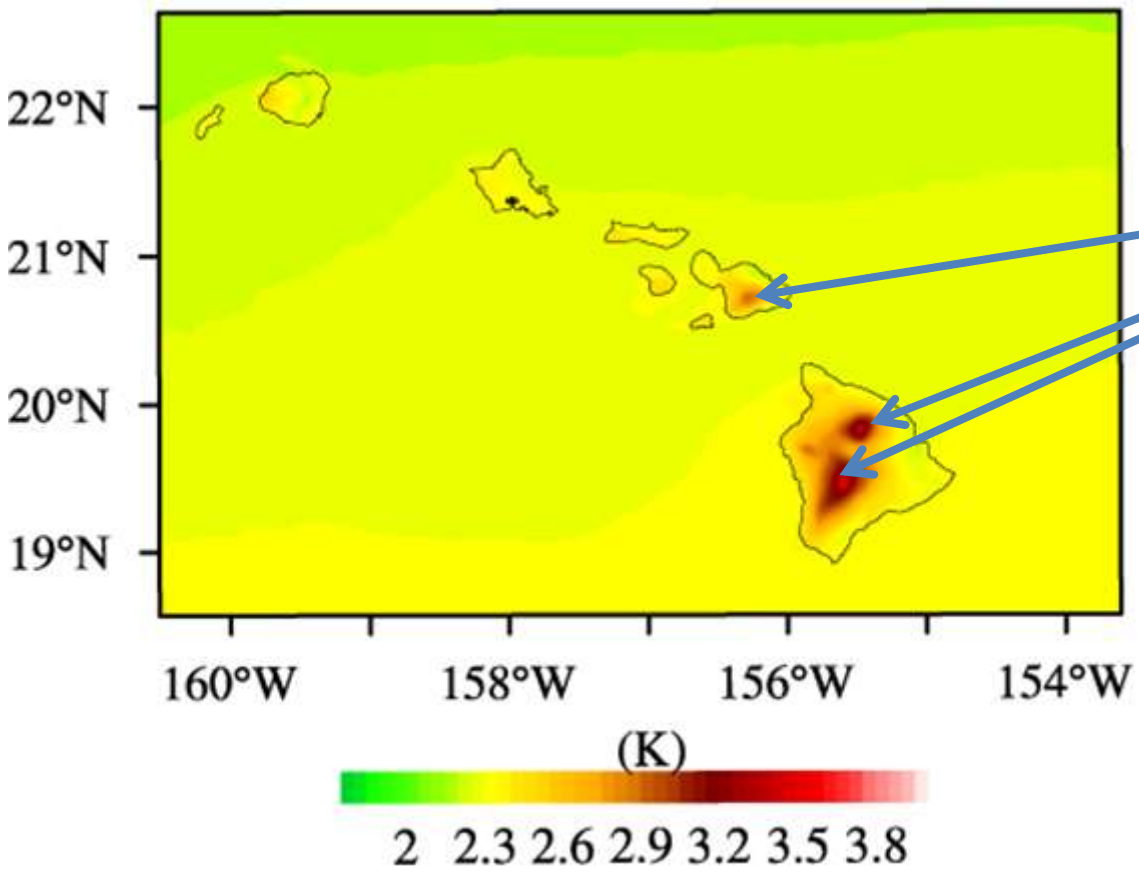

"21st century change" = (2081-2100) – (1990-2009)
1990-2009
2081-2100
2000
2020
2040
2060
2080
2100
Time (Years)

21st Century Change

surface air temperature

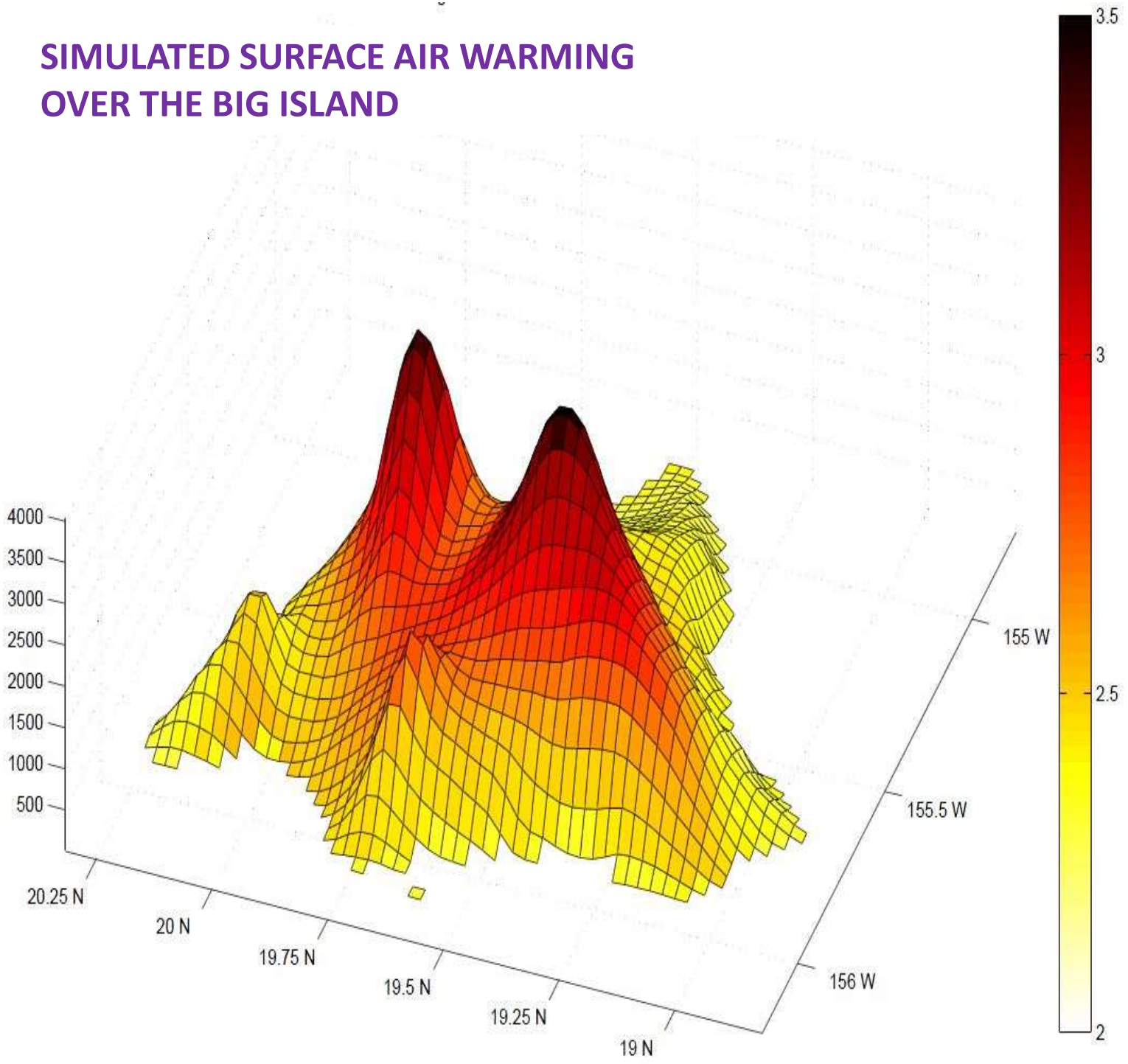


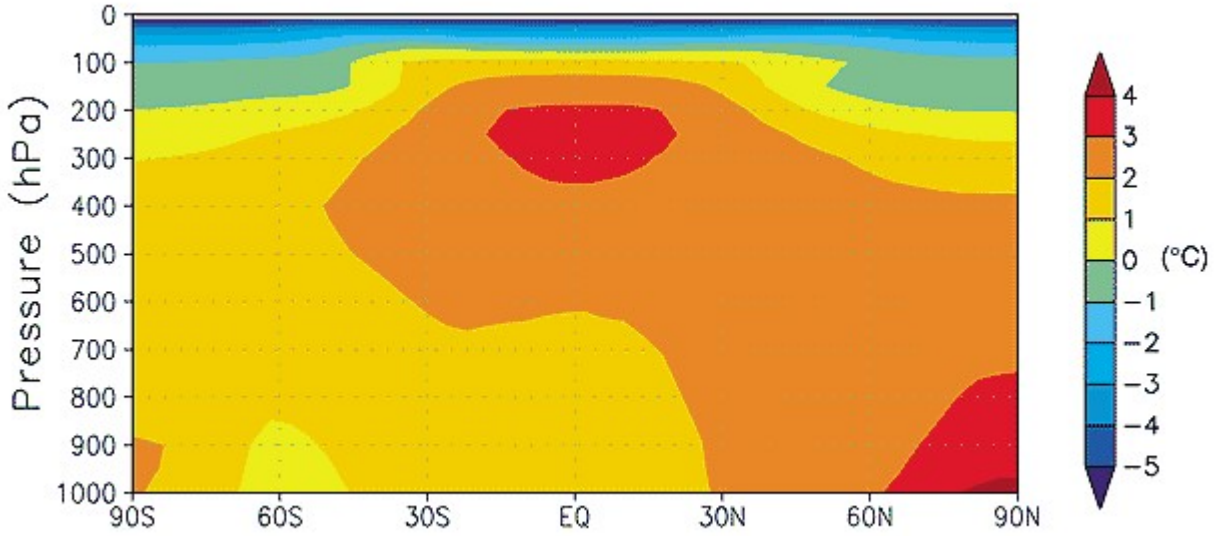

22°N
21°N
20°N
19°N
160°W
158°W
156°W
154°W
(K)
2 2.3 2.6 2.9 3.2 3.5 3.8



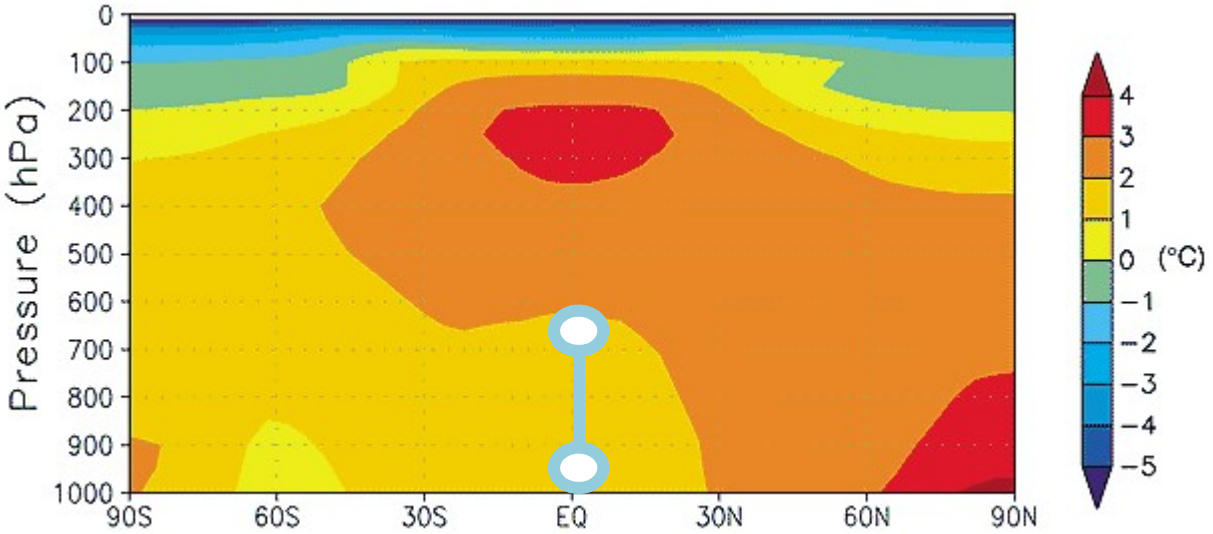
intensified warming at altitude

SIMULATED SURFACE AIR WARMING OVER THE BIG ISLAND



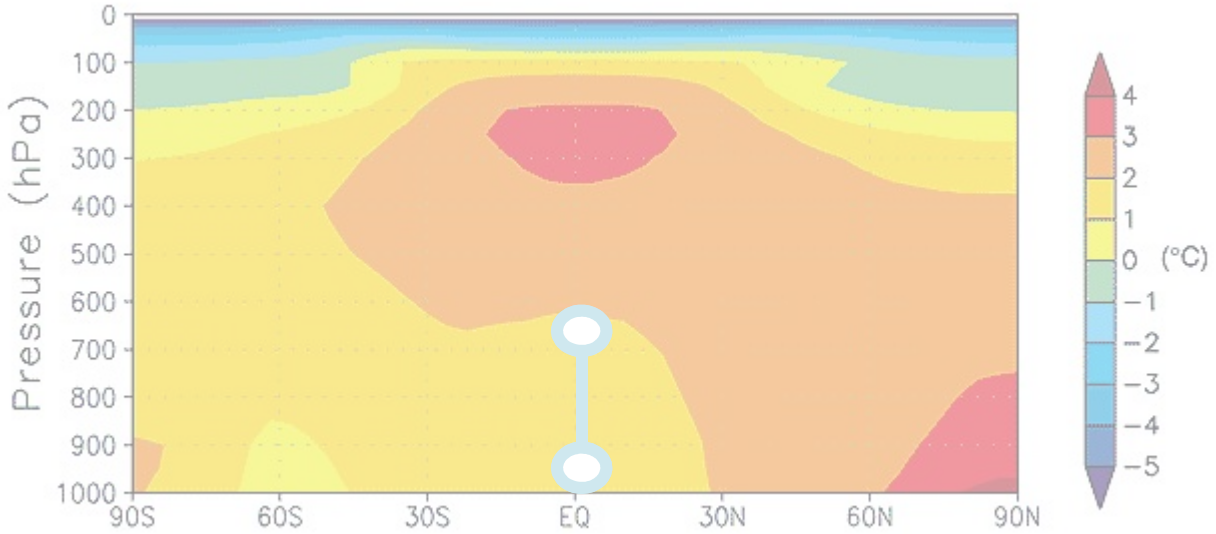


Multimodel Mean Zonal-Mean Temperature Change in A Greenhouse Gas Driven Warming



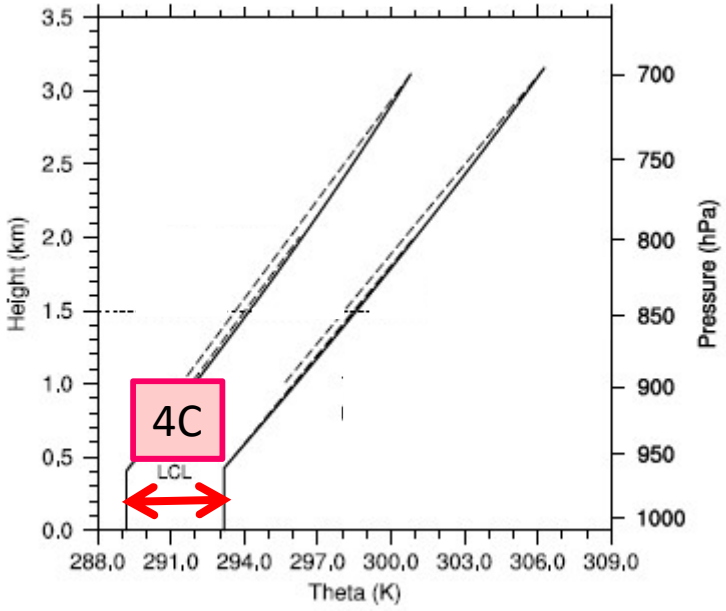
Multimodel Mean Zonal-Mean Temperature Change in A Greenhouse Gas Driven Warming

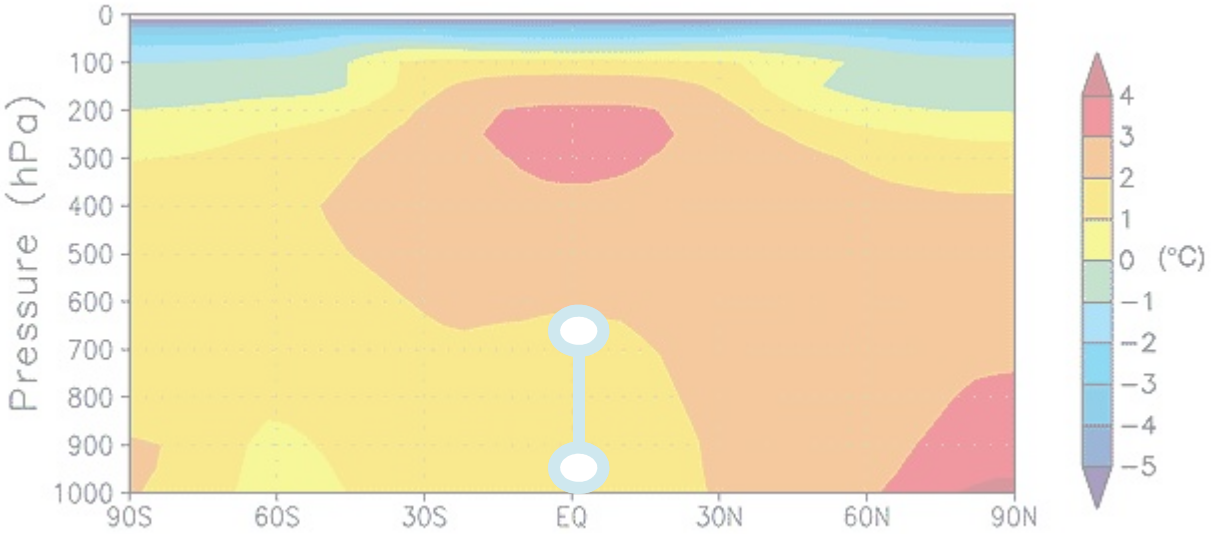
$$d(\Delta T)/dz > 0$$



Multimodel Mean Zonal-Mean Temperature Change in A Greenhouse Gas Driven Warming

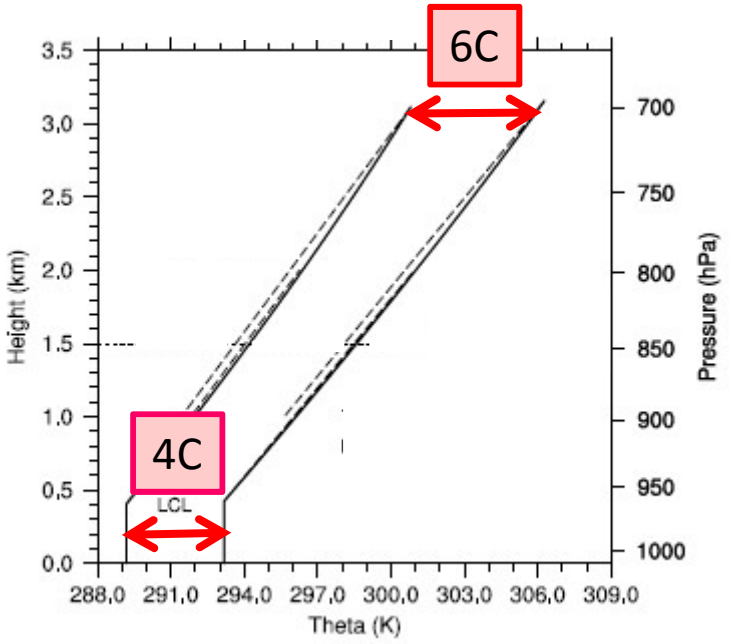
$$d(\Delta T)/dz > 0$$





Multimodel Mean Zonal-Mean Temperature Change in A Greenhouse Gas Driven Warming

$$d(\Delta T)/dz > 0$$

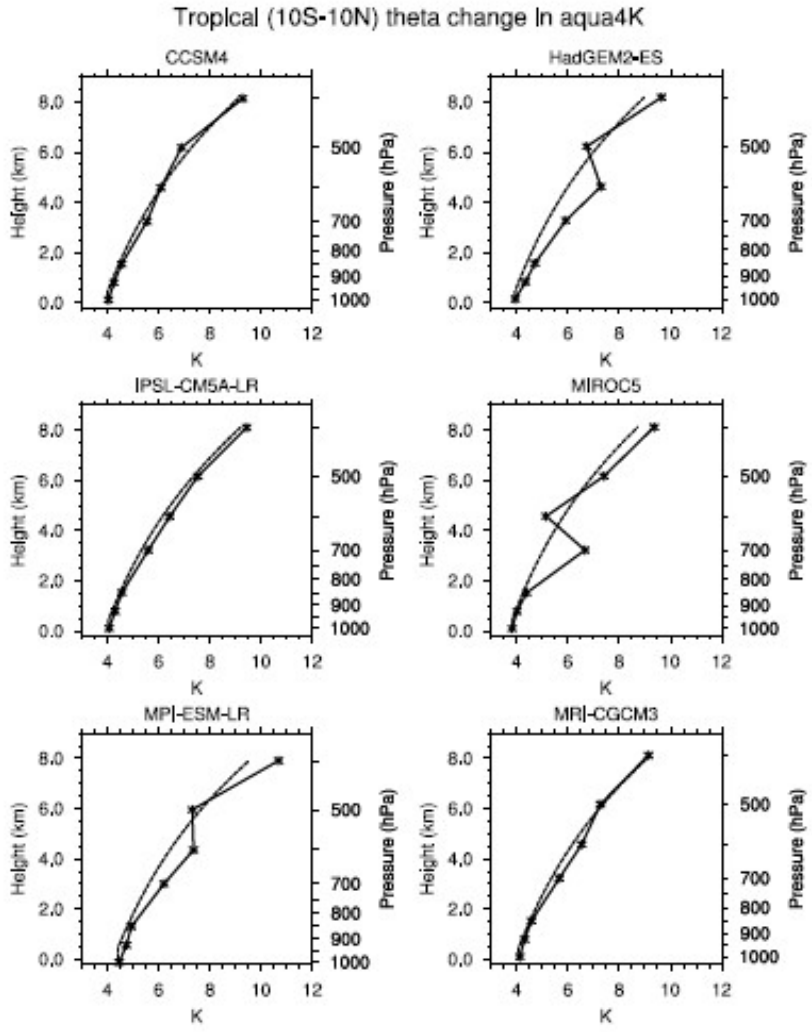


Clim Dyn
DOI 10.1007/s00382-014-2441-9

The strength of the tropical inversion and its response to climate change in 18 CMIP5 models

Xin Qu · Alex Hall · Stephen A. Klein · Peter M. Caldwell

Rate of increase in warming with height is even larger than expected based on changes in moist adiabat



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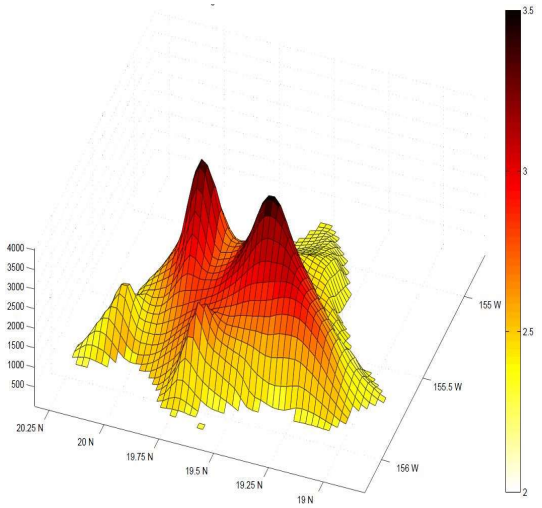
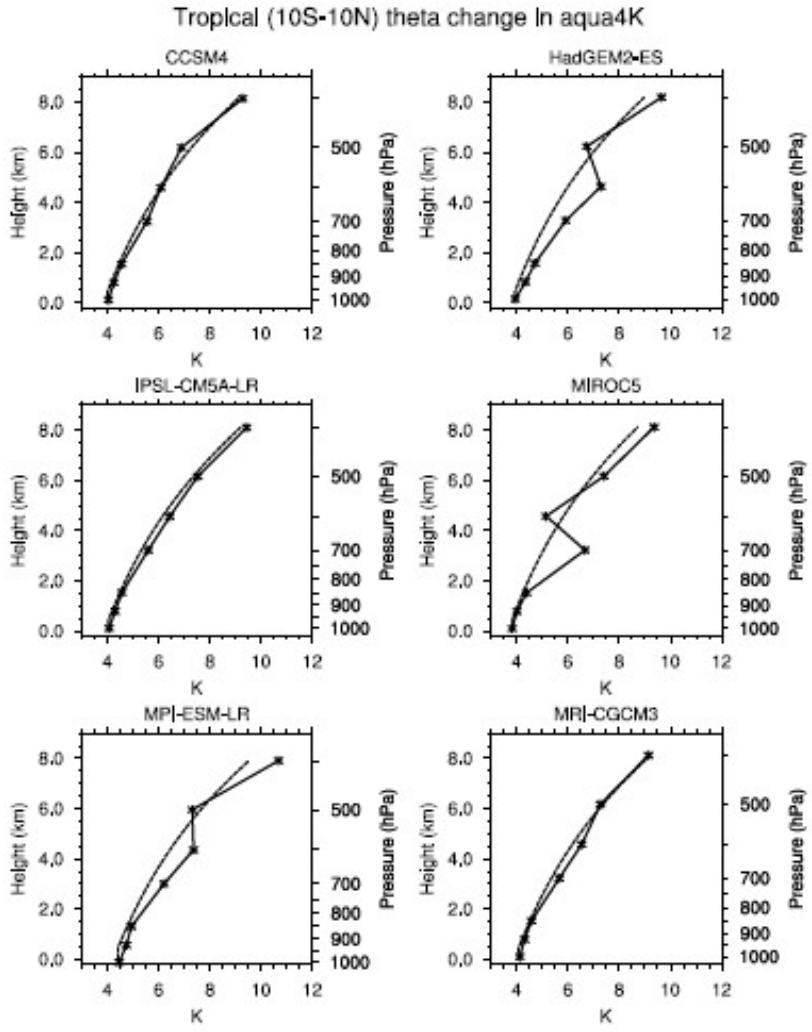
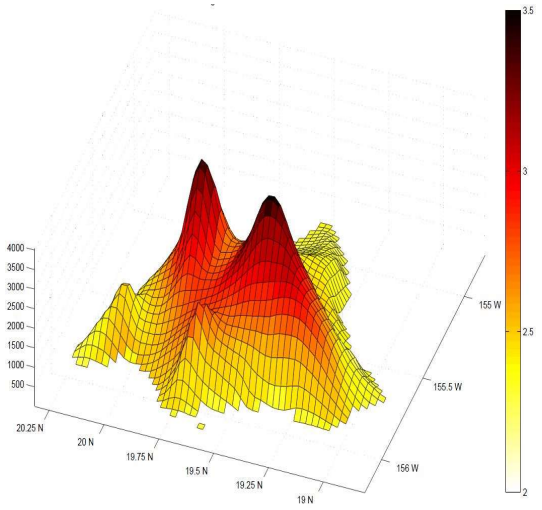




Tropical troposphere is stabilized on average by the global warming effects

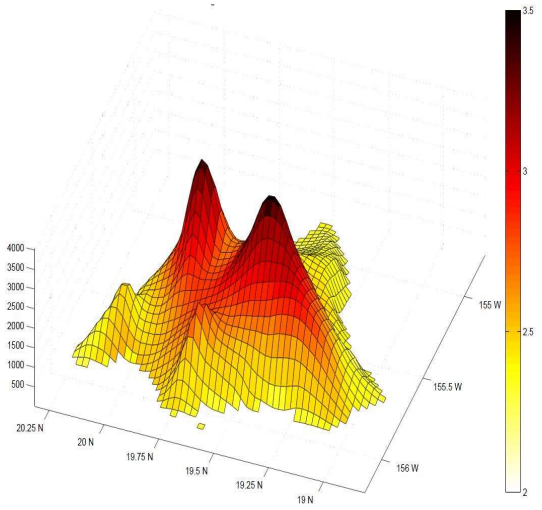
Rate of increase in warming with height is even larger than expected based on changes in moist adiabat



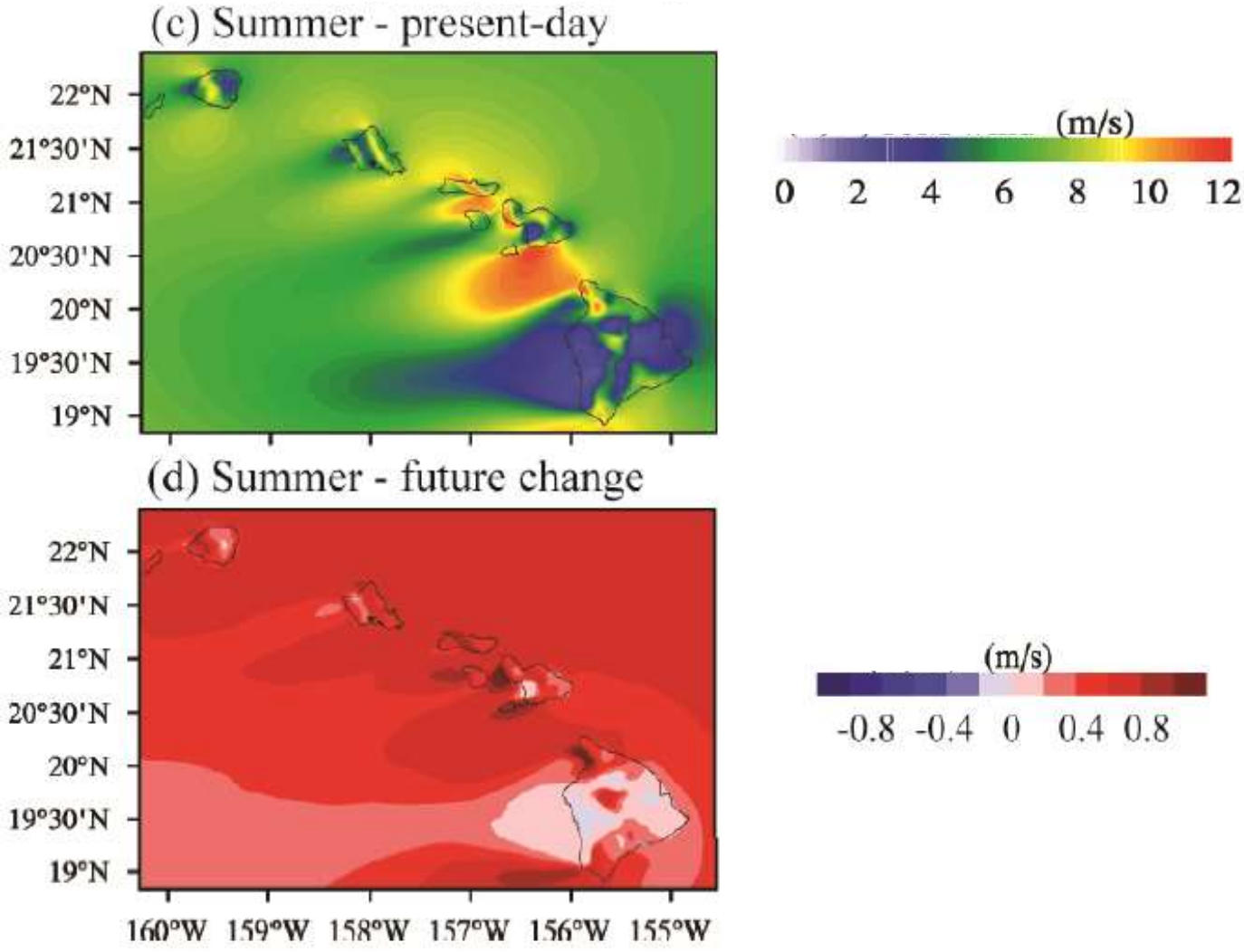
Tropical troposphere is stabilized on average by the global warming effects

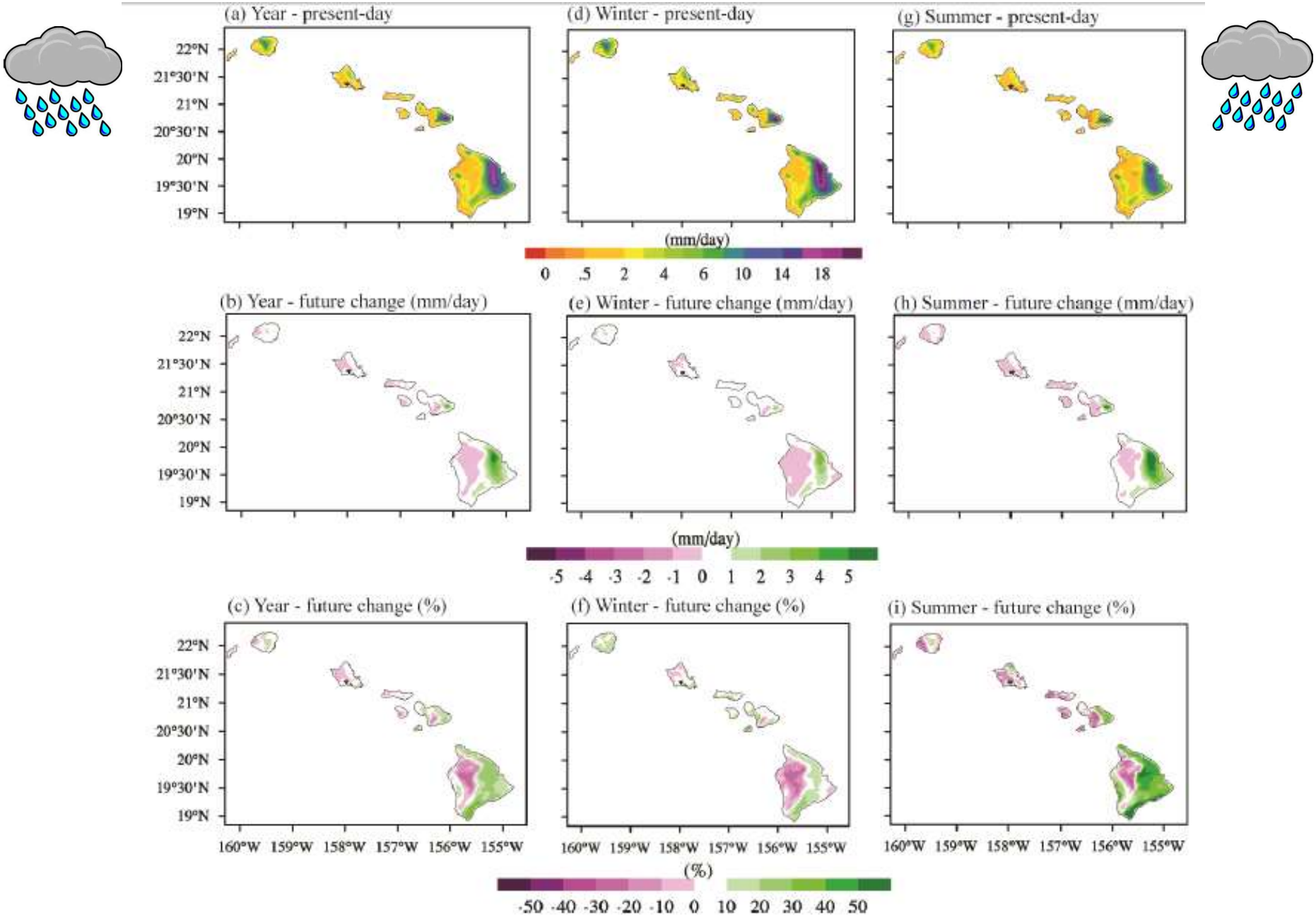
Perhaps less convective rainfall?

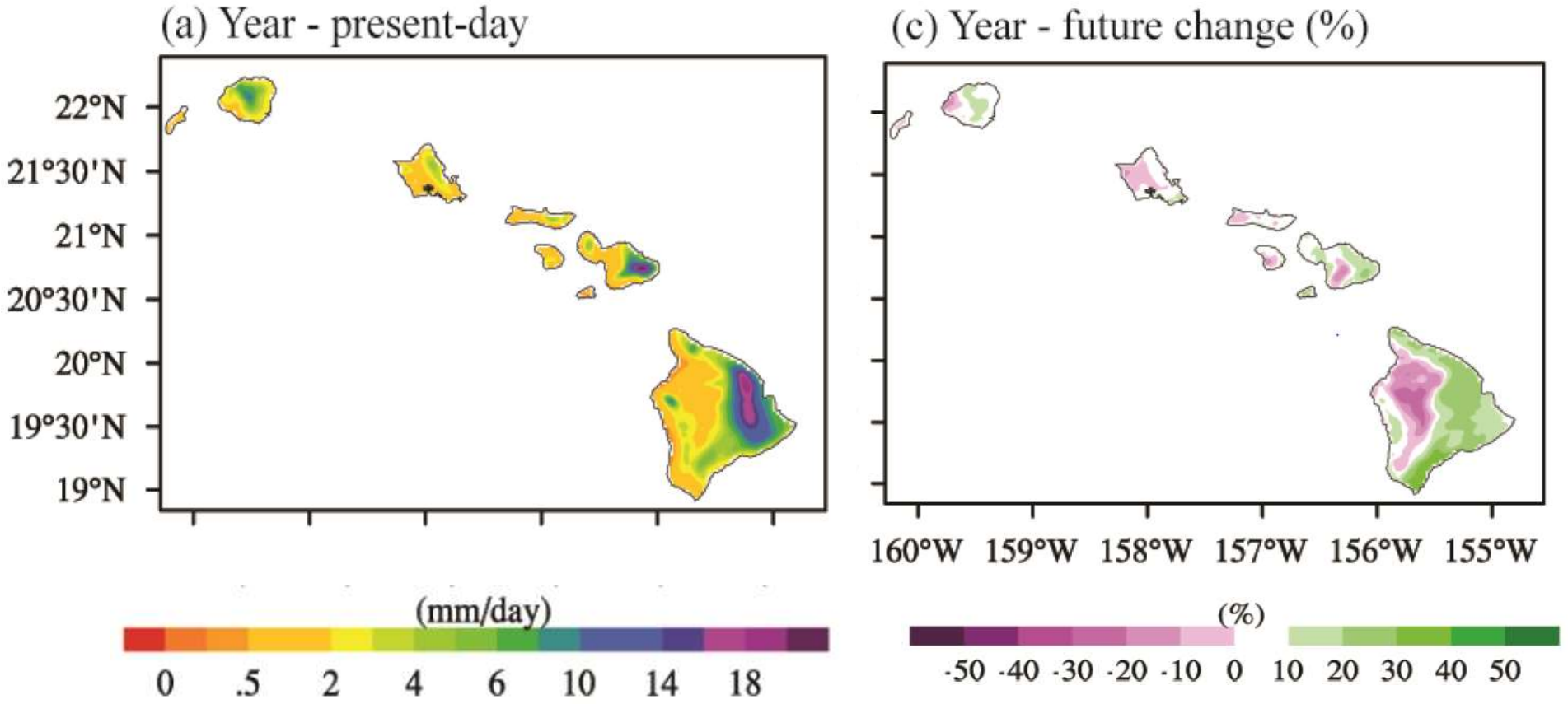
Rate of increase in warming with height is even larger than expected based on changes in moist adiabat

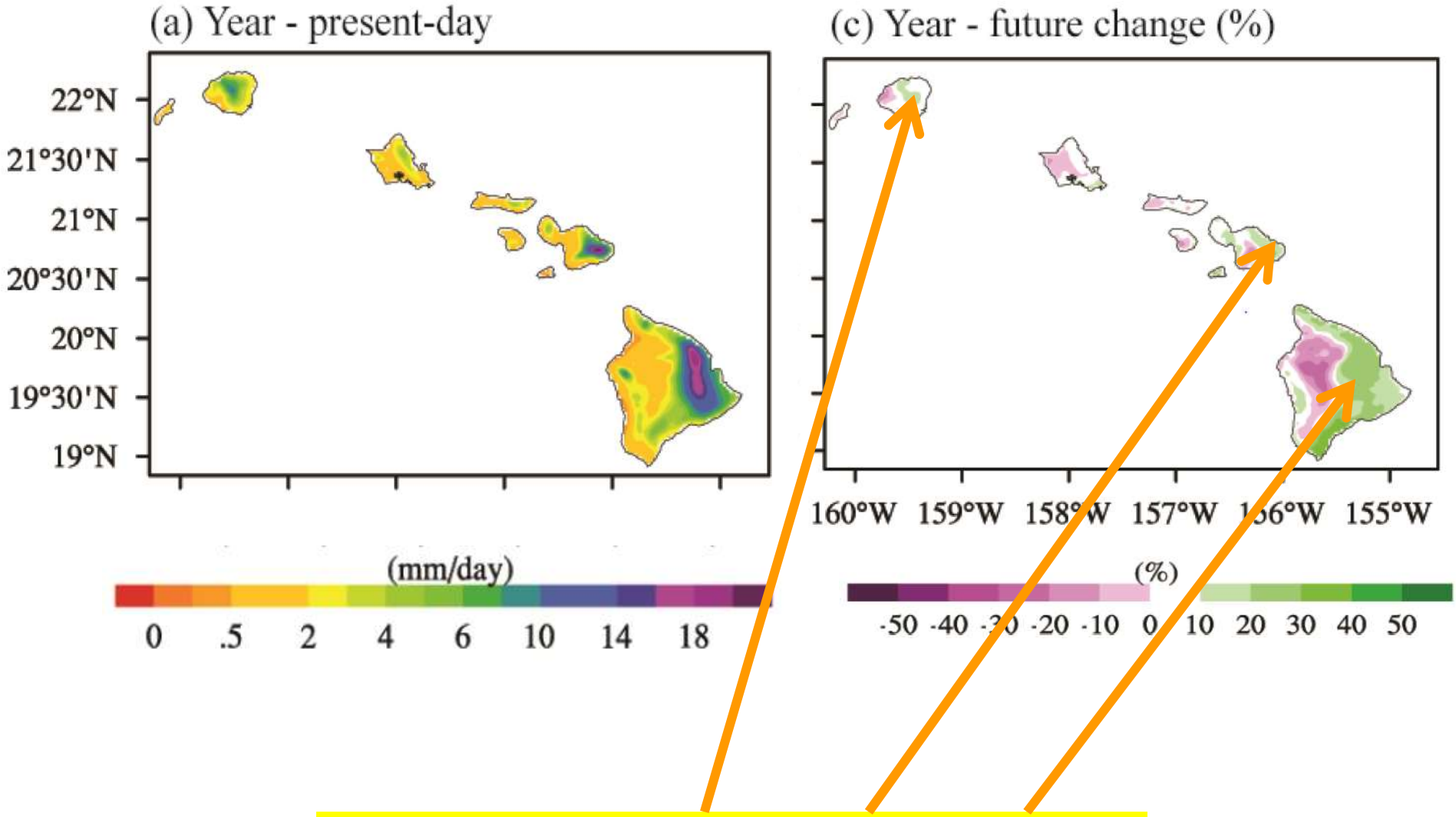


Surface Wind Speed

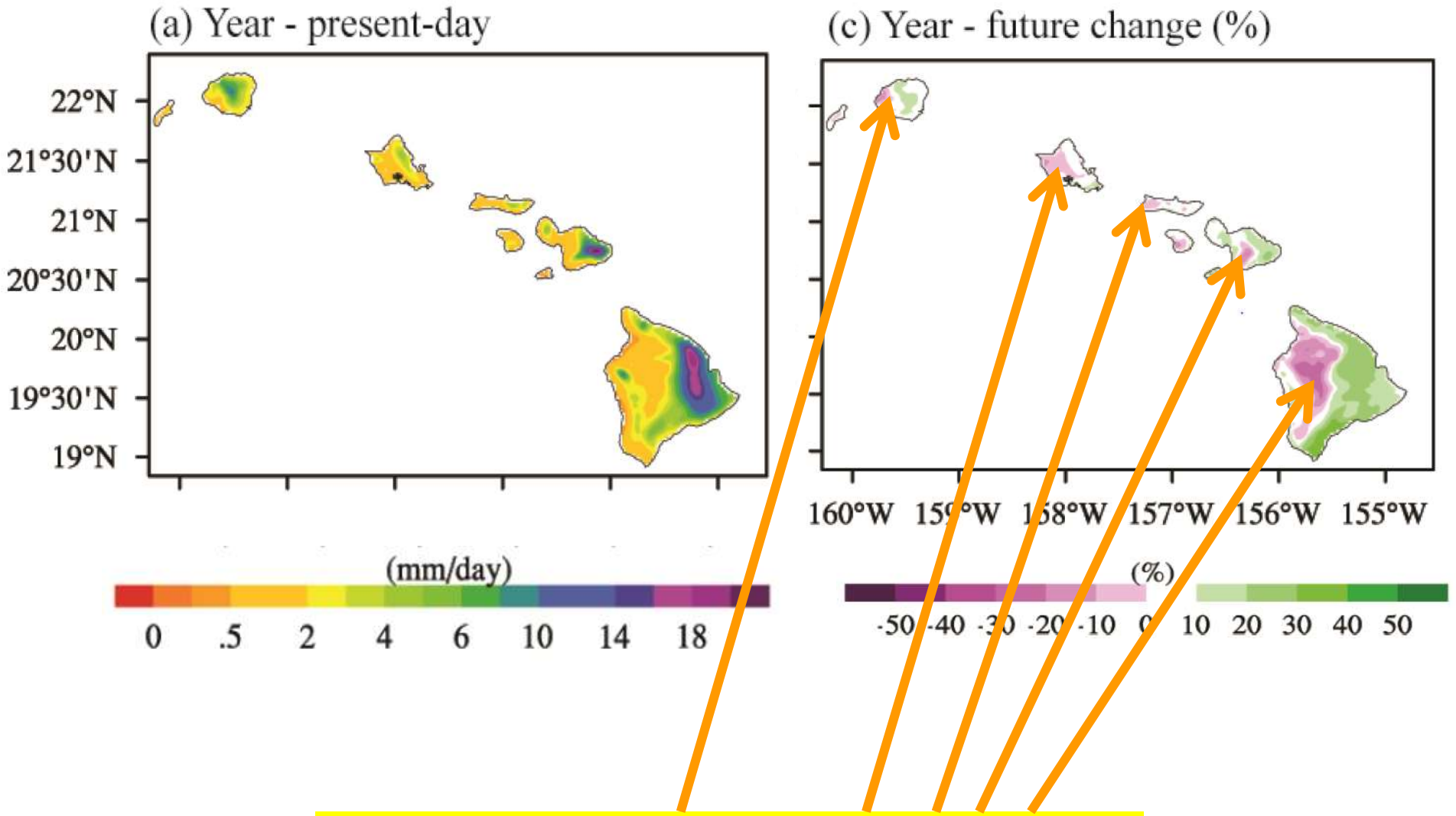



(a) Year - present-day
(d) Winter - present-day
(g) Summer - present-day
22°N
21°30'N
21°N
20°30'N
20°N
19°30'N
19°N
(mm/day)
0 .5 2 4 6 10 14 18
(b) Year - future change (mm/day)
(e) Winter - future change (mm/day)
(h) Summer - future change (mm/day)
(mm/day)
-5 -4 -3 -2 -1 0 1 2 3 4 5
(c) Year - future change (%)
(f) Winter - future change (%)
(i) Summer - future change (%)
160°W 159°W 158°W 157°W 156°W 155°W
(%)
-50 -40 -30 -20 -10 0 10 20 30 40 50

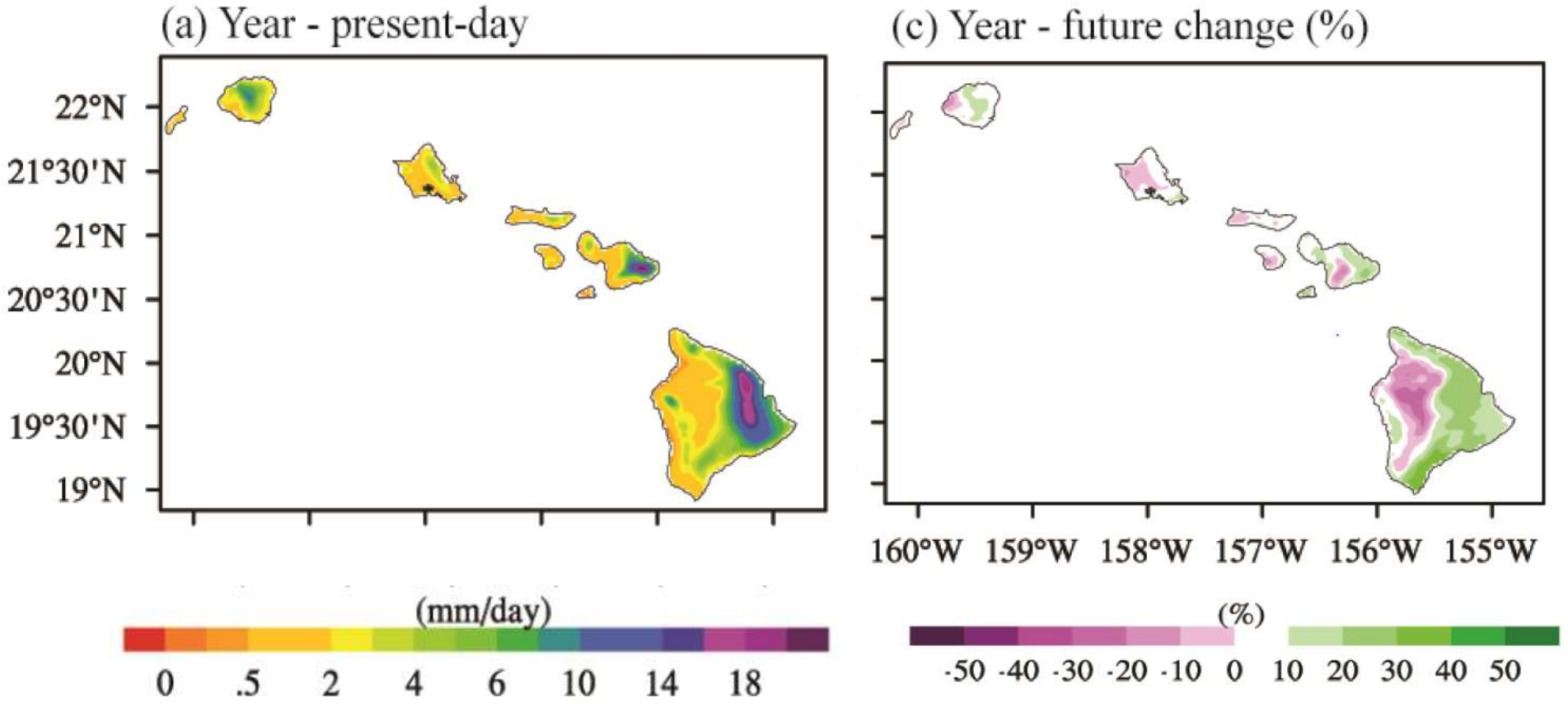

(a) Year - present-day
22°N
21°30'N
21°N
20°30'N
20°N
19°30'N
19°N
(mm/day)
0 .5 2 4 6 10 14 18
(c) Year - future change (%)
160°W 159°W 158°W 157°W 156°W 155°W
(%)
-50 -40 -30 -20 -10 0 10 20 30 40 50

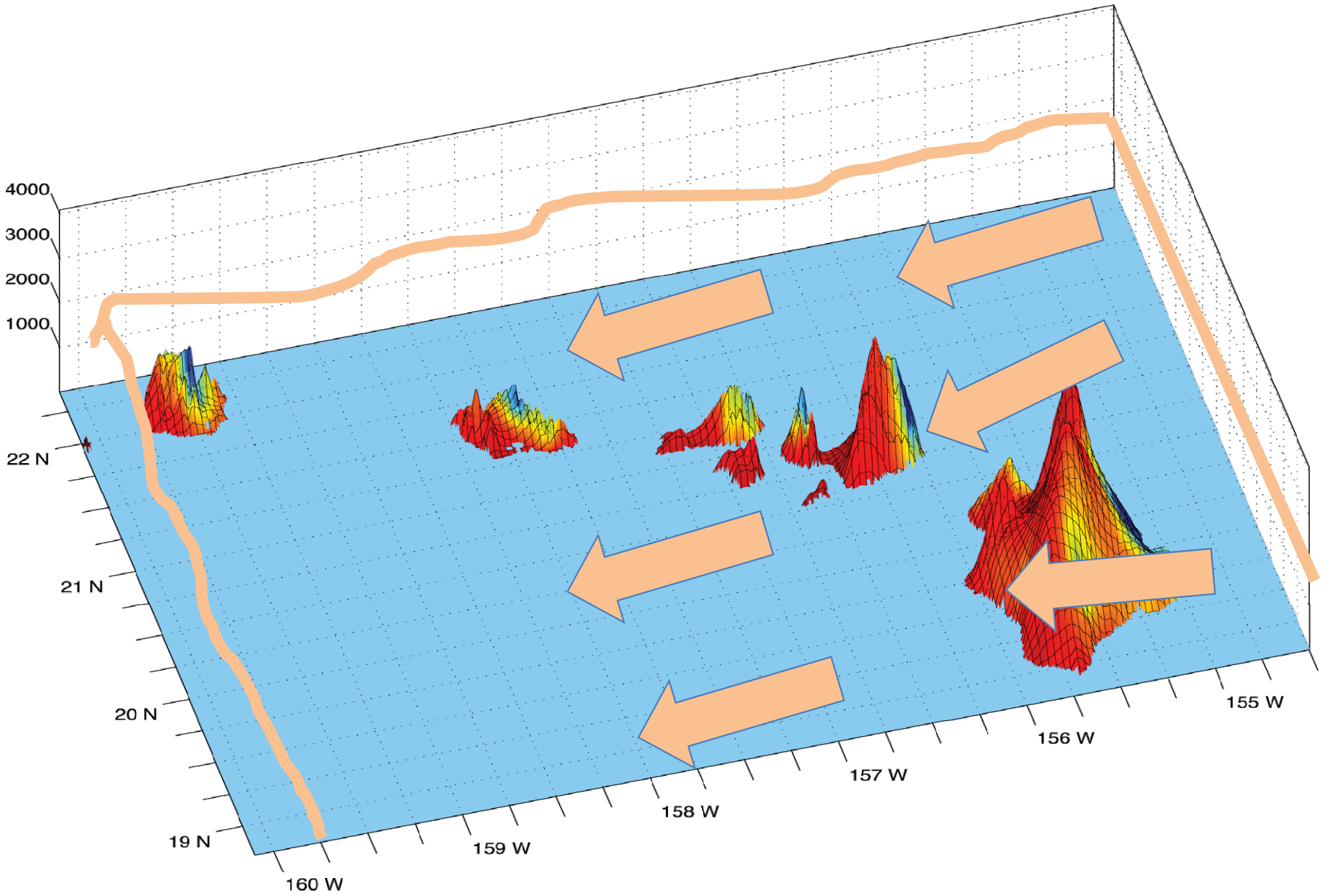


“WET BECOMES WETTER”

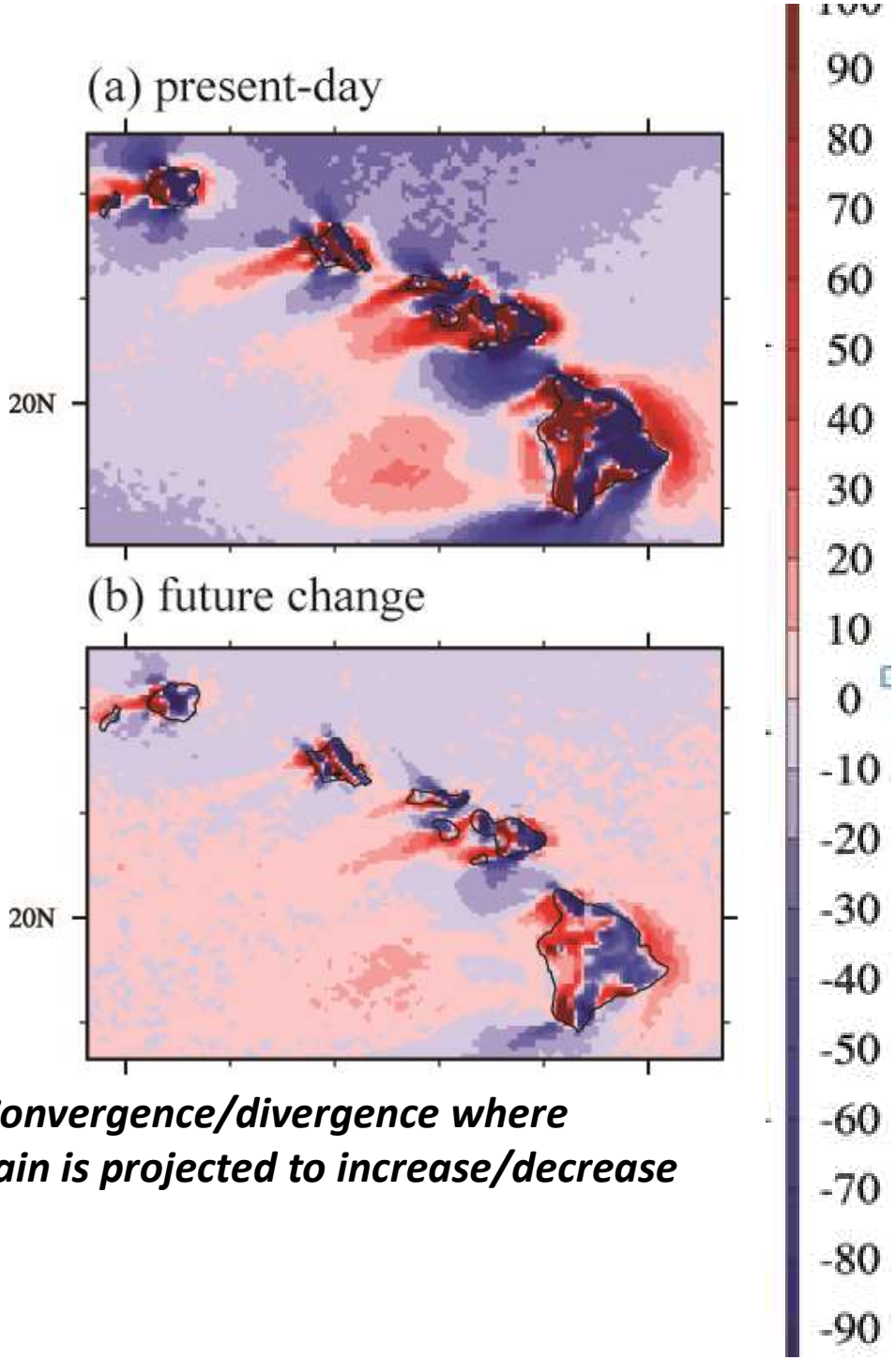


“DRY BECOMES DRIER”


(a) Year - present-day
22°N
21°30'N
21°N
20°30'N
20°N
19°30'N
19°N
(mm/day)
0 .5 2 4 6 10 14 18
(c) Year - future change (%)
160°W 159°W 158°W 157°W 156°W 155°W
(%)
-50 -40 -30 -20 -10 0 10 20 30 40 50



Boundary Layer Moisture Flux Convergence = $$MFC = -\frac{1}{g}\int_{P_{sfc}}^{P_{bl}} \nabla \cdot (qV_h)\,dp$$



Convergence/divergence where rain is projected to increase/decrease

Divergence of boundary layer moisture flux

humidity

$$q = \bar{q} + \acute{q}$$

horizontal wind

$$V_h = \overline{V_h} + \acute{V_h}$$

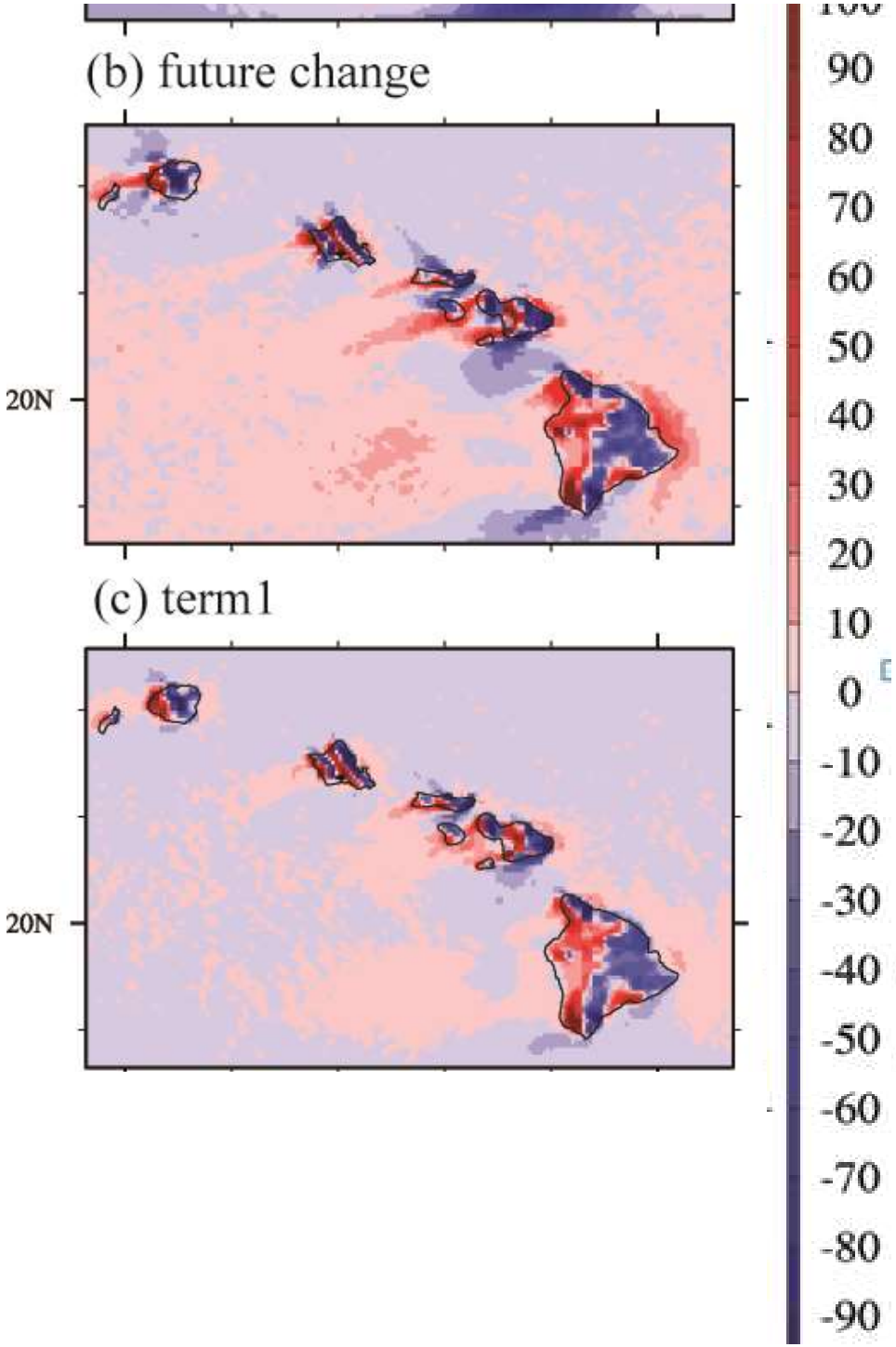
future present change

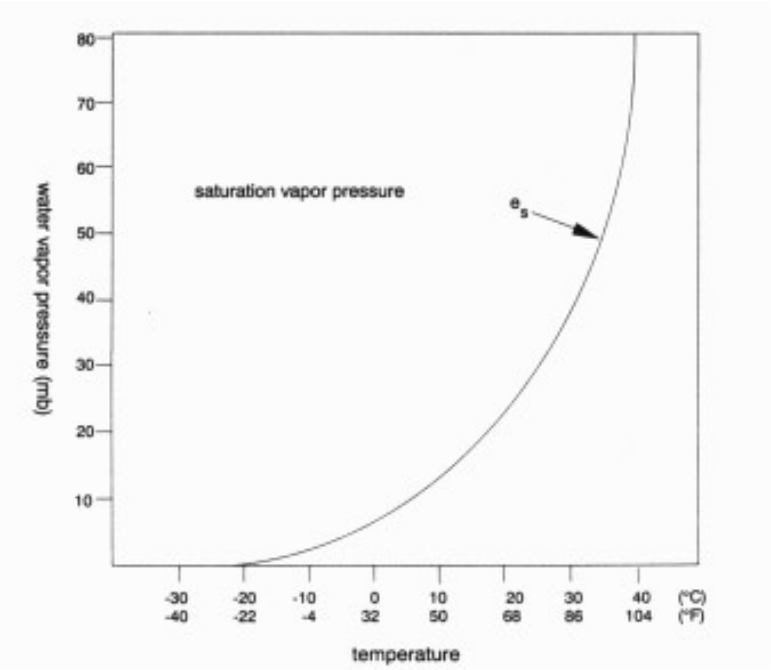
$$\underbrace{MFC_{future} - MFC_{present}}_{future\ change} = \left(\underbrace{-\frac{1}{g}\int_{Psfc}^{Pbl} \nabla \cdot (qV_h)dp}_{future}\right) - \left(\underbrace{-\frac{1}{g}\int_{Psfc}^{Pbl} \nabla \cdot (\bar{q}\overline{V_h})dp}_{present-day}\right) =$$

$$\underbrace{-\frac{1}{g}\int_{Psfc}^{Pbl} \nabla \cdot (\acute{q}\overline{V_h})dp}_{term1} \underbrace{-\frac{1}{g}\int_{Psfc}^{Pbl} \nabla \cdot (\bar{q}\acute{V_h})dp}_{term2} \underbrace{-\frac{1}{g}\int_{Psfc}^{Pbl} \nabla \cdot (\acute{q}\acute{V_h})dp}_{term3}$$

Change of humidity and same winds

Same humidity and change of winds

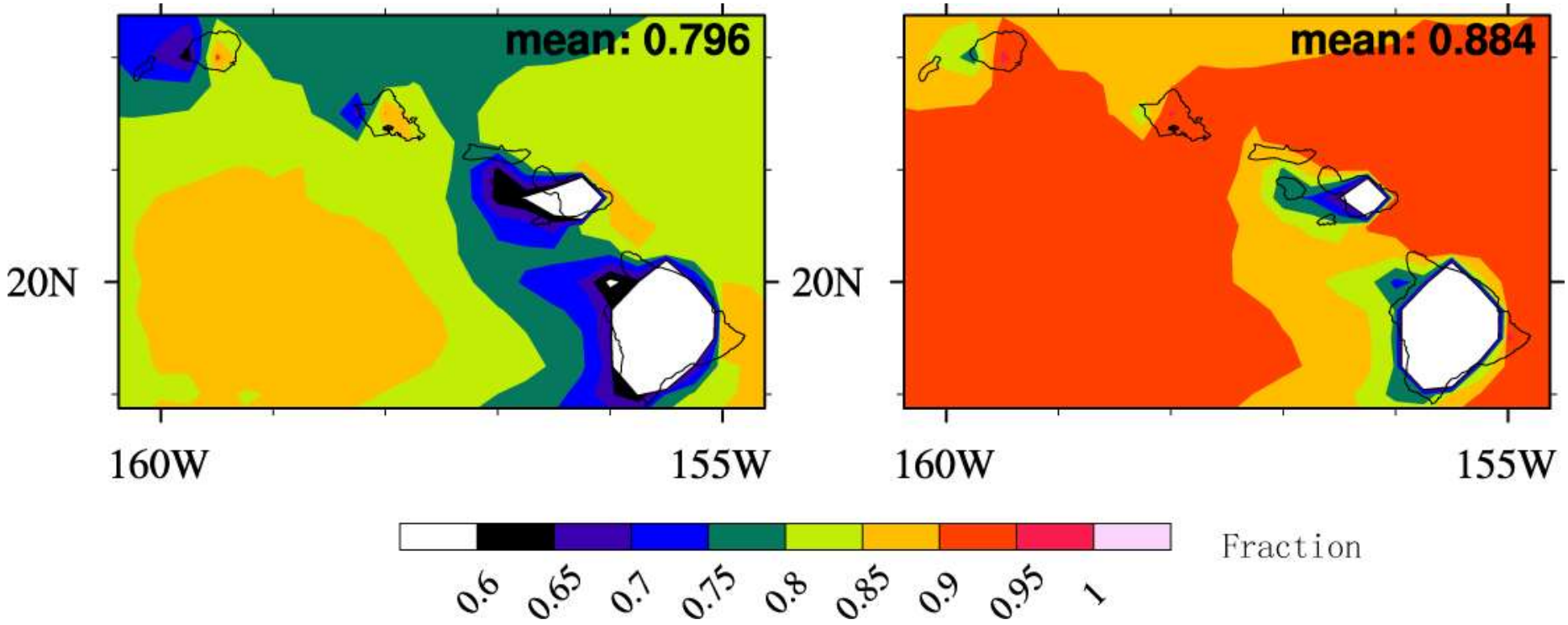




~7% saturation water vapor content per degree rise in temperature

Flux divergence change explained just by increase in boundary layer moisture content

Trade wind inversion frequency (fraction)



Present

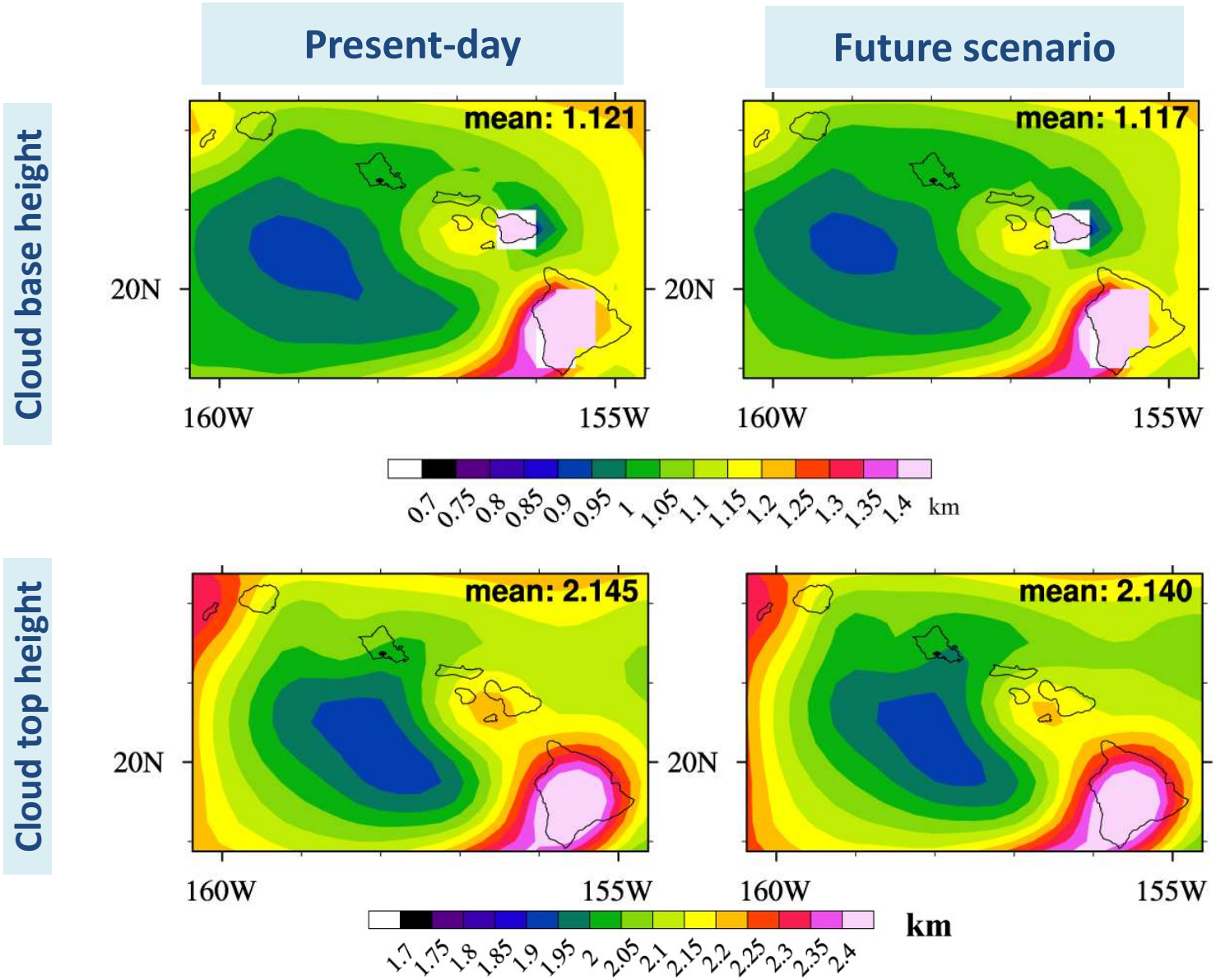
79.6%

Future

88.4%

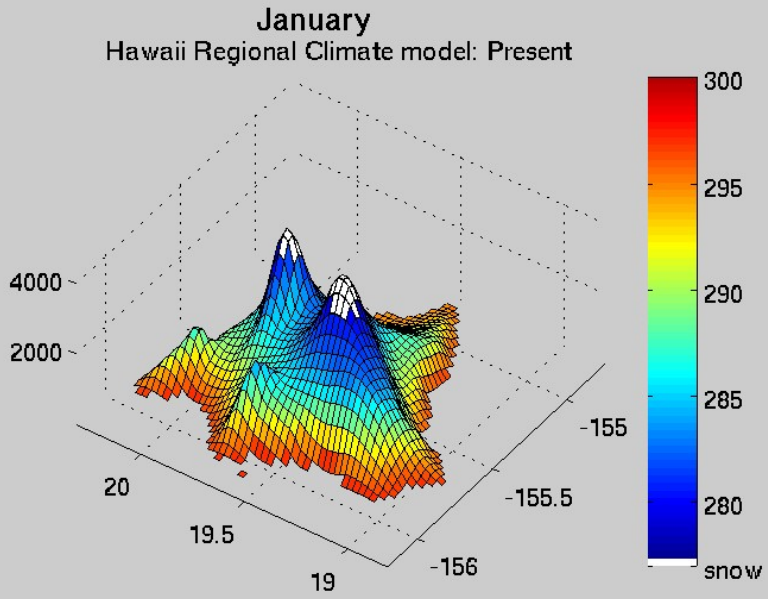
Days without trade wind inversion 20.4% → 11.6%

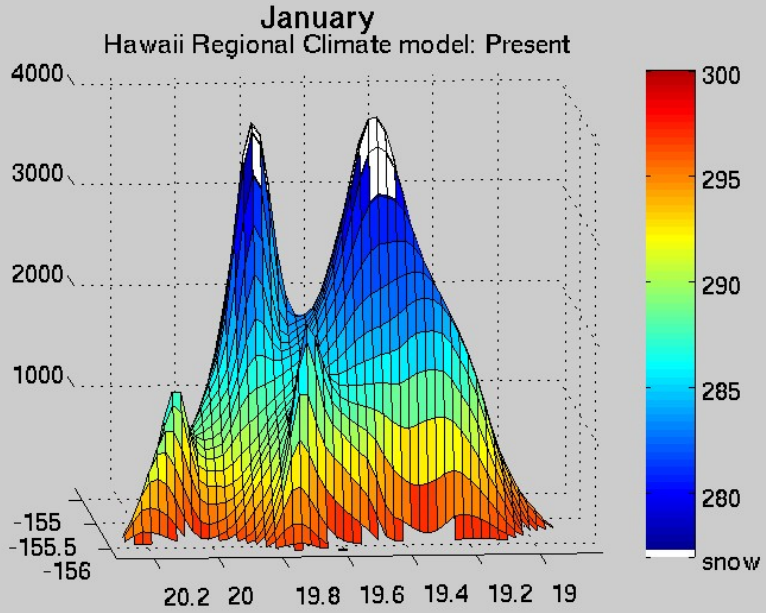
Cloud base and cloud top height (km)



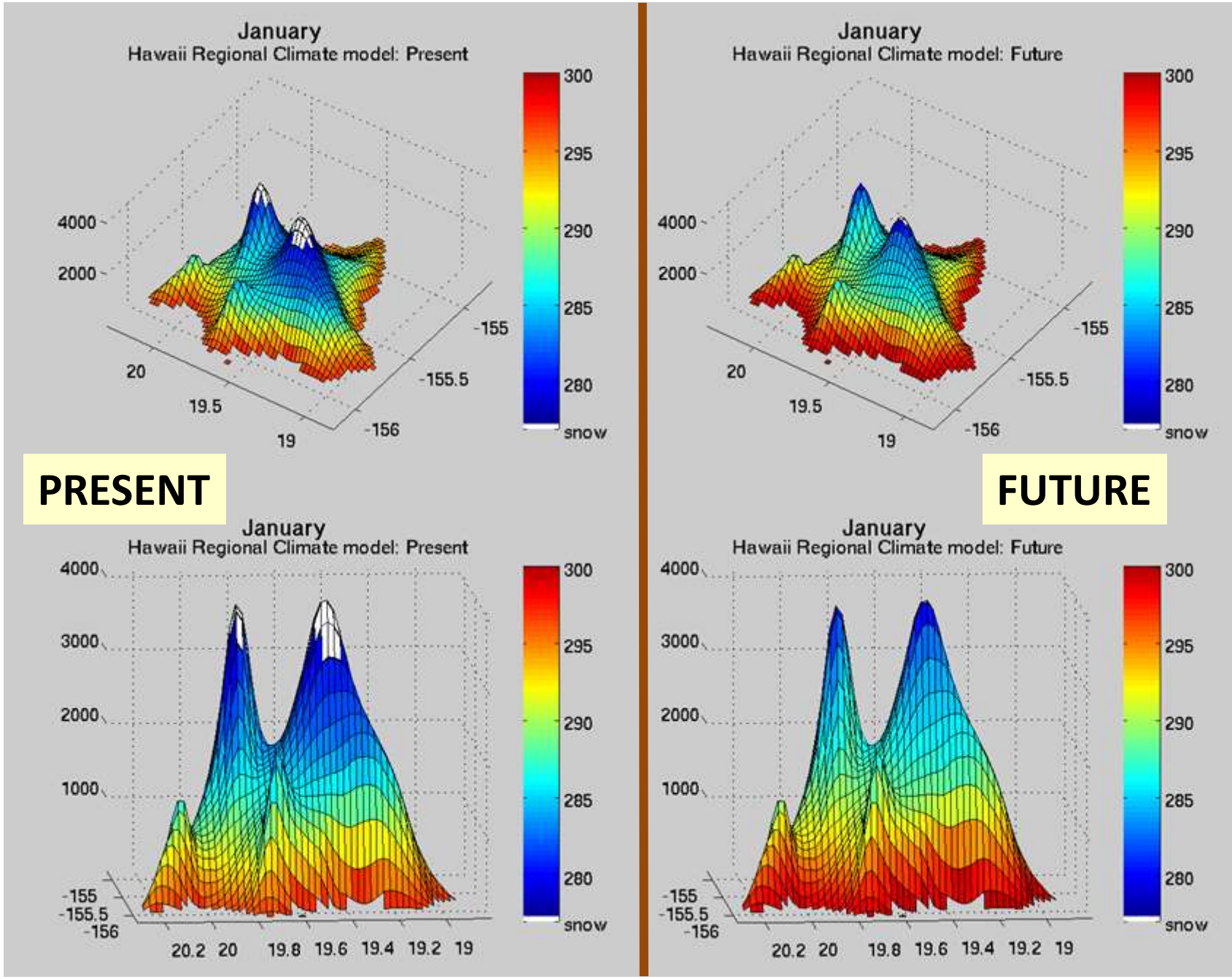
Snow capped Mauna Kea & Mauna Loa

This image was taken at Wednesday, April 2, 2014, 10:31:41 am HST.





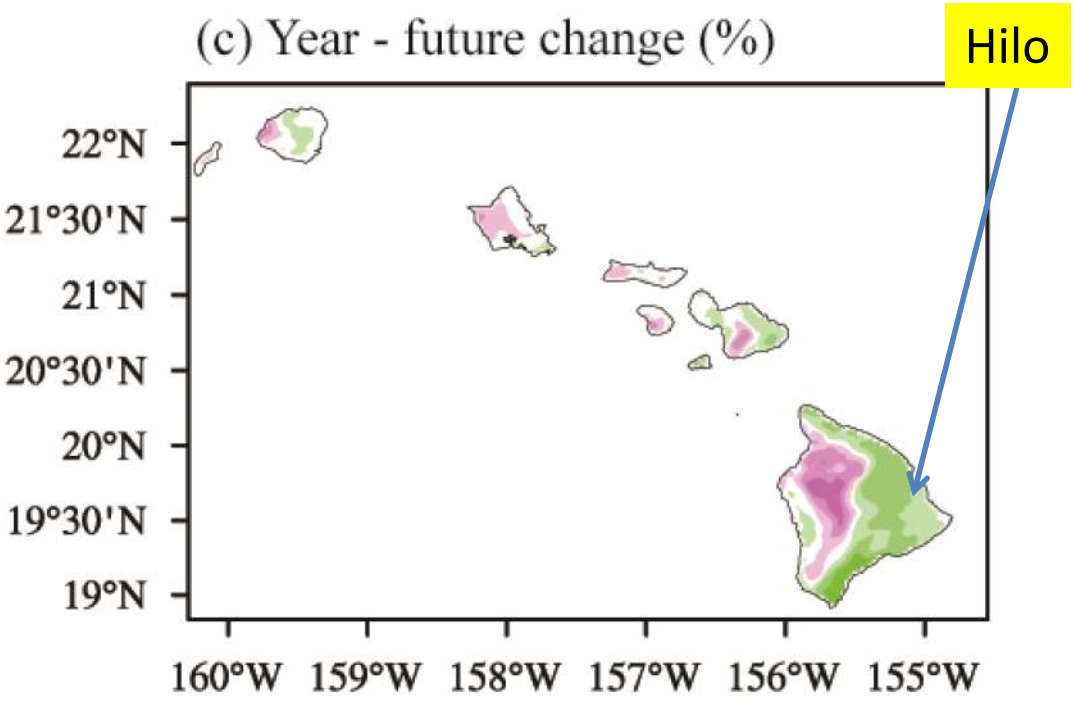
White color shows areas where 20 year mean snowfall for that month is more than 5 cm


January
Hawaii Regional Climate model: Present
4000
2000
20
19.5
19
-155
-155.5
-156
300
295
290
285
280
snow
January
Hawaii Regional Climate model: Future
4000
2000
20
19.5
19
-155
-155.5
-156
300
295
290
285
280
snow
PRESENT
FUTURE
January
Hawaii Regional Climate model: Present
4000
3000
2000
1000
-155
-155.5
-156
20.2 20 19.8 19.6 19.4 19.2 19
300
295
290
285
280
snow
January
Hawaii Regional Climate model: Future
4000
3000
2000
1000
-155
-155.5
-156
20.2 20 19.8 19.6 19.4 19.2 19
300
295
290
285
280
snow

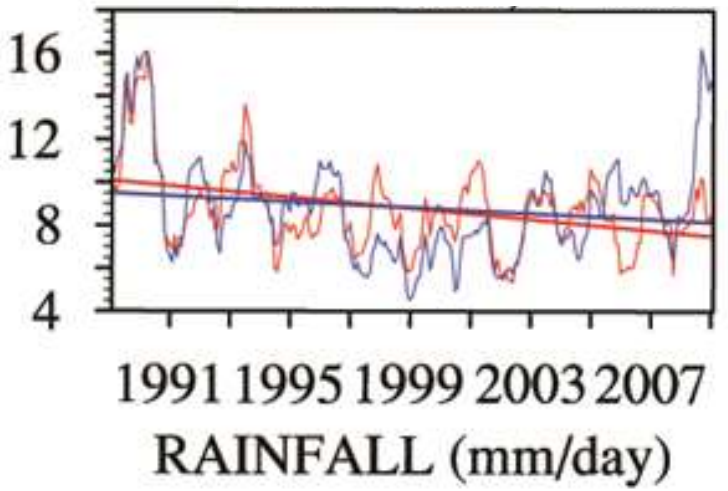
Snow capped Mauna Kea & Mauna Loa

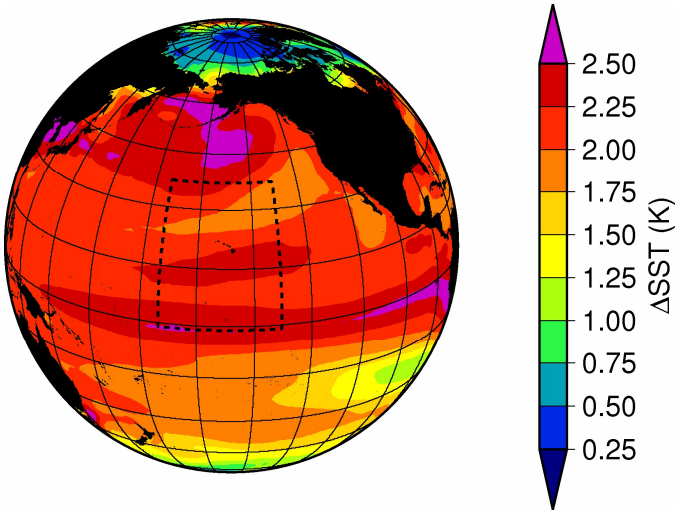
This image was taken at Wednesday, April 2, 2014, 10:31:41 am HST.

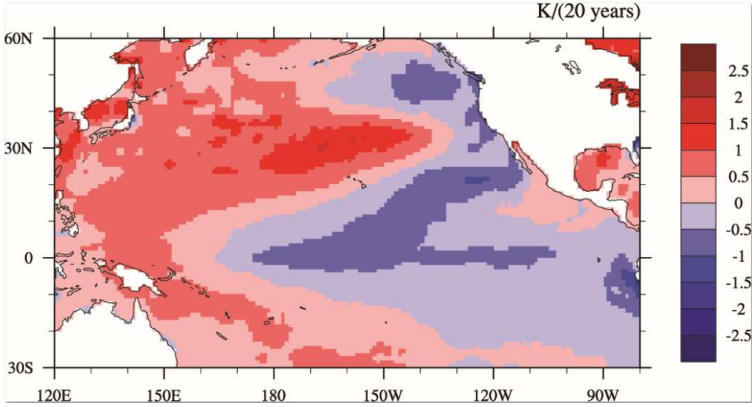
Snow will almost entirely disappear by end of 21st century

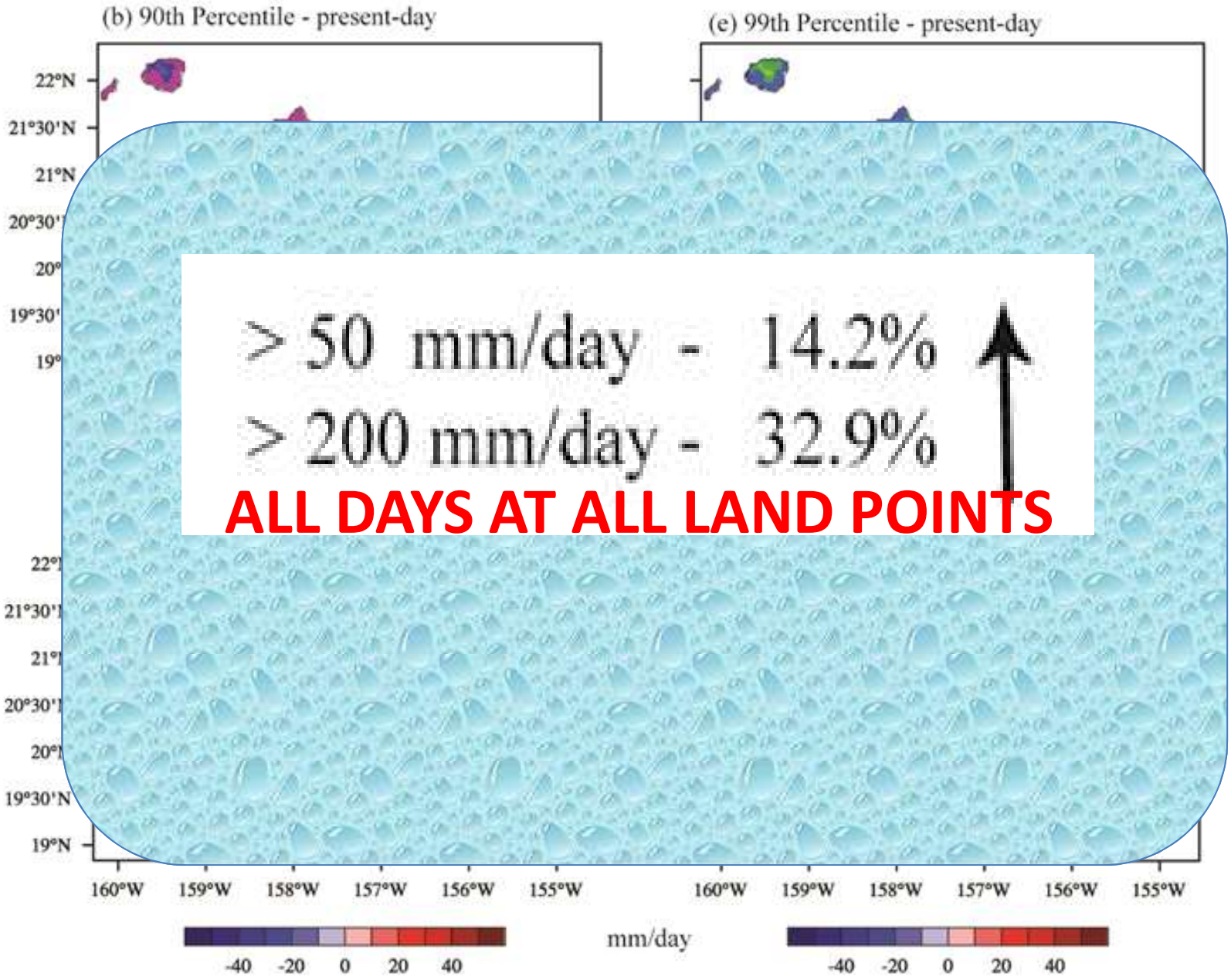


Observed and Modeled Rainfall Trends at Hilo

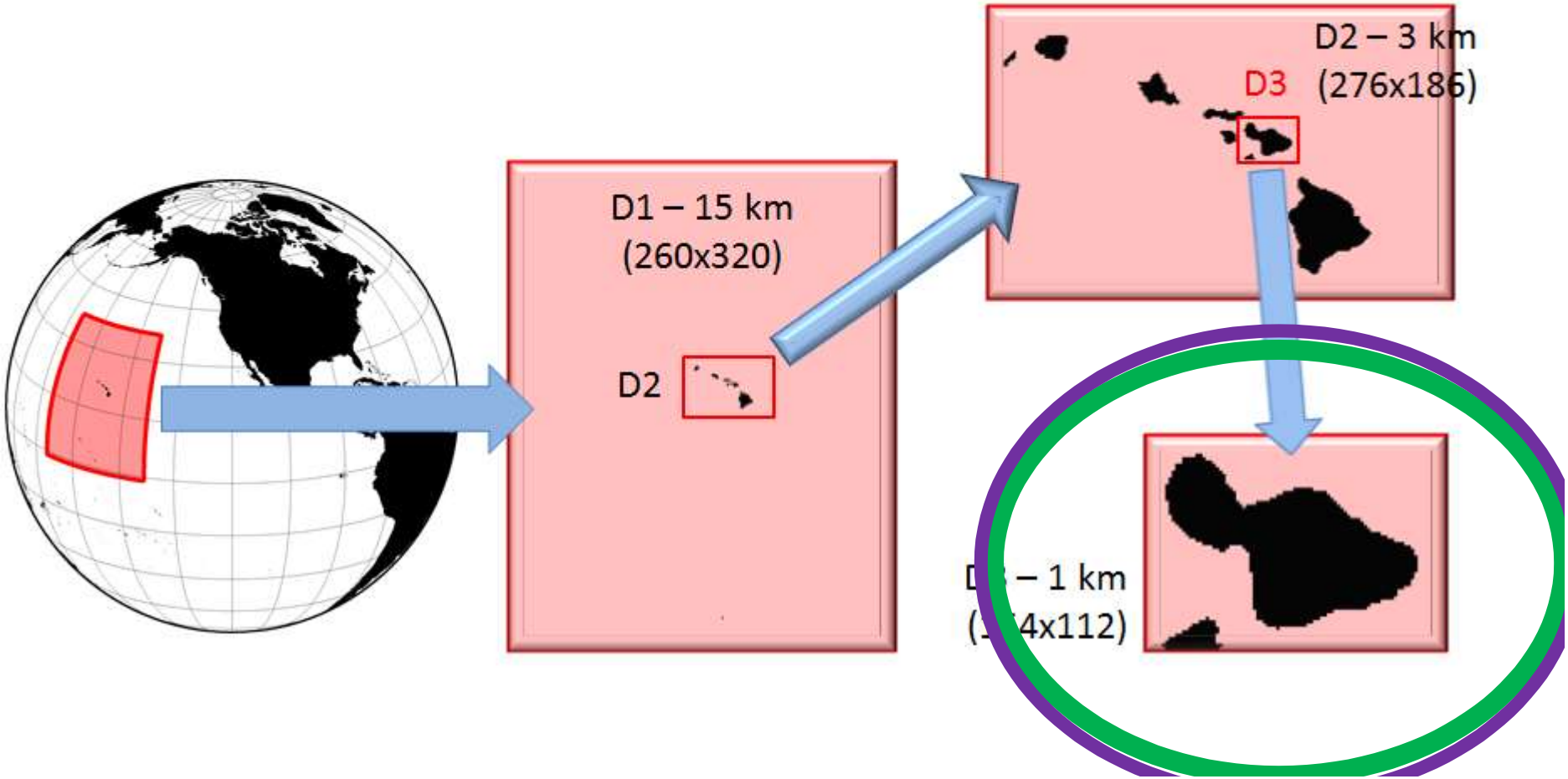






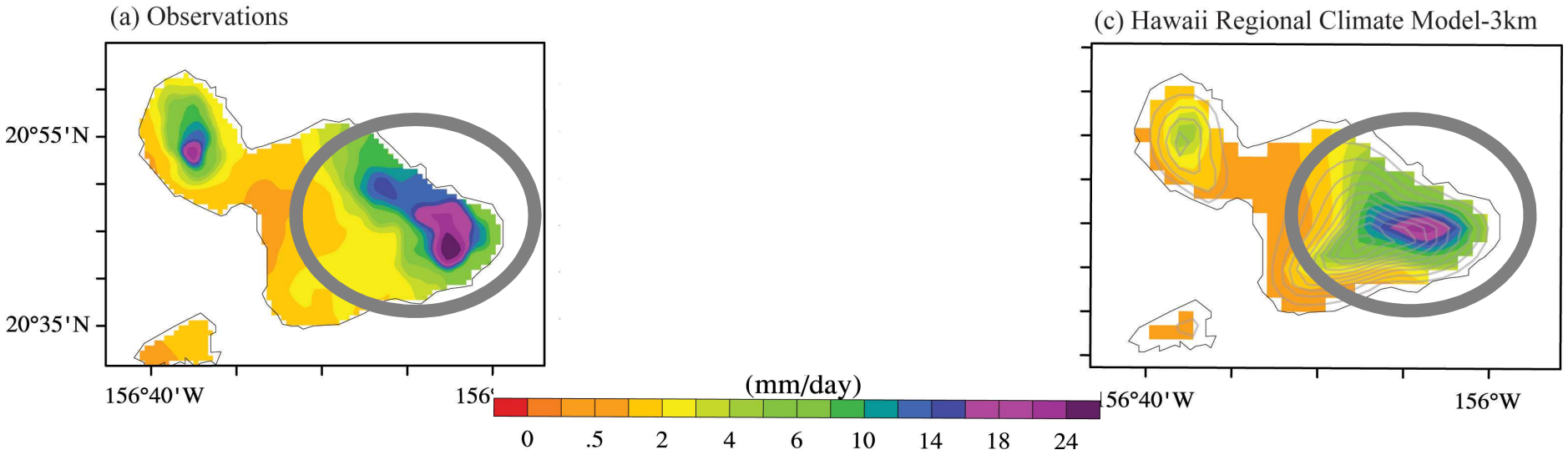

(b) 90th Percentile - present-day
(e) 99th Percentile - present-day
22°N
21°30'N
21°N
20°30'
20°
19°30'
19°
22°
21°30'
21°
20°30'
20°
19°30'N
19°N
160°W
159°W
158°W
157°W
156°W
155°W
-40
-20
0
20
40
mm/day
> 50 mm/day - 14.2%
> 200 mm/day - 32.9%
ALL DAYS AT ALL LAND POINTS

Results from the inner domain (D3) with 1 km spacing * for Maui *



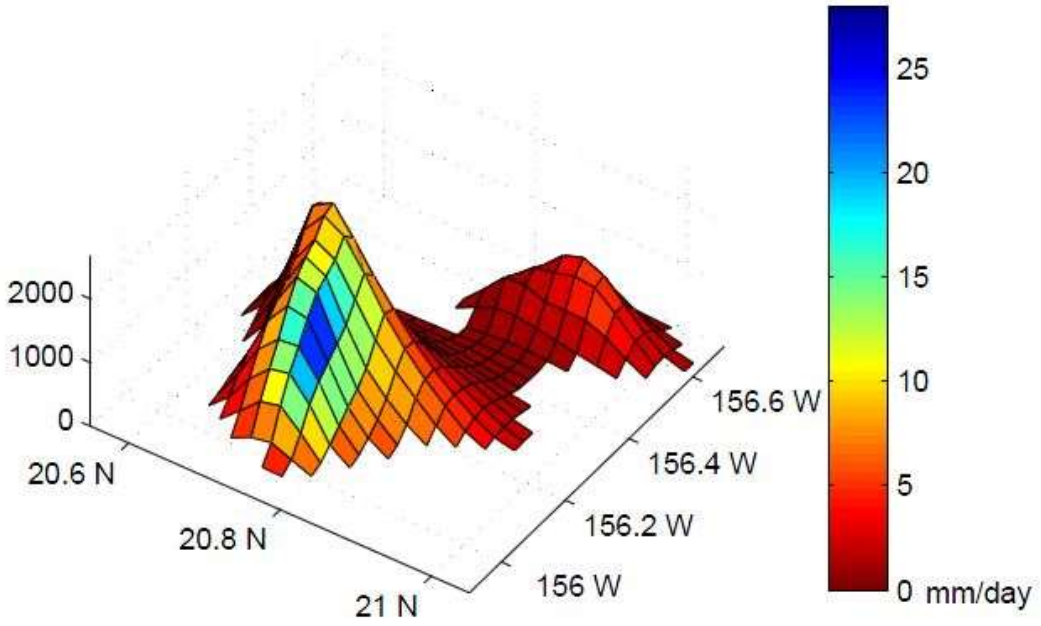
Observations

Δx = 3 km



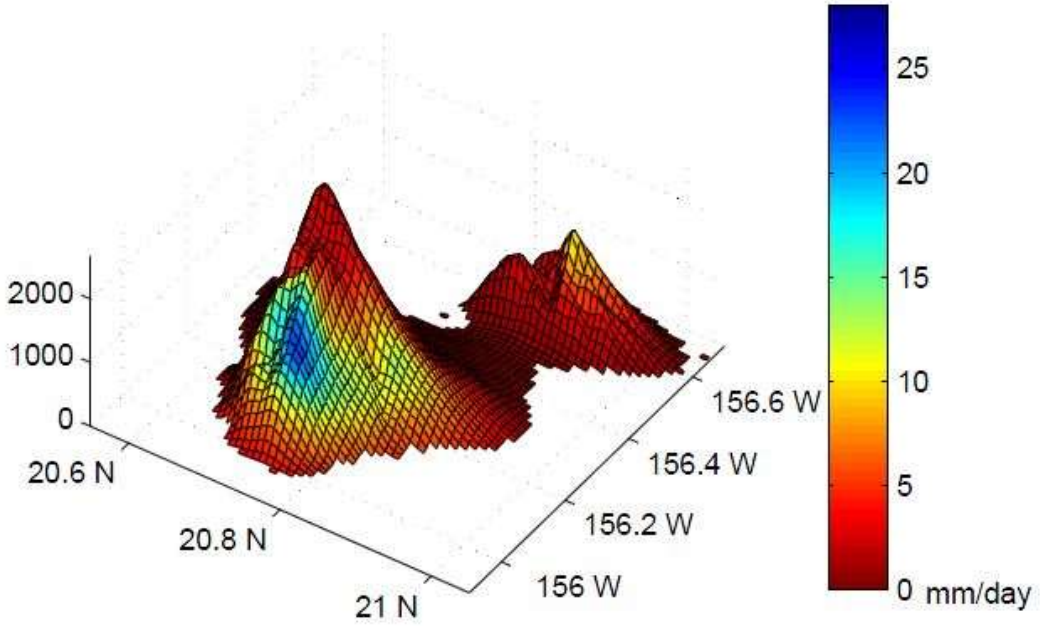
20 year (1990-2009) mean rainfall observed and in the 3km resolution nested grid in the Hawaii Regional Climate Model

$\Delta x = 3$ km



Unfortunately adequate simulation for Maui (and probably for Oahu and Kauai) requires quite fine horizontal resolution

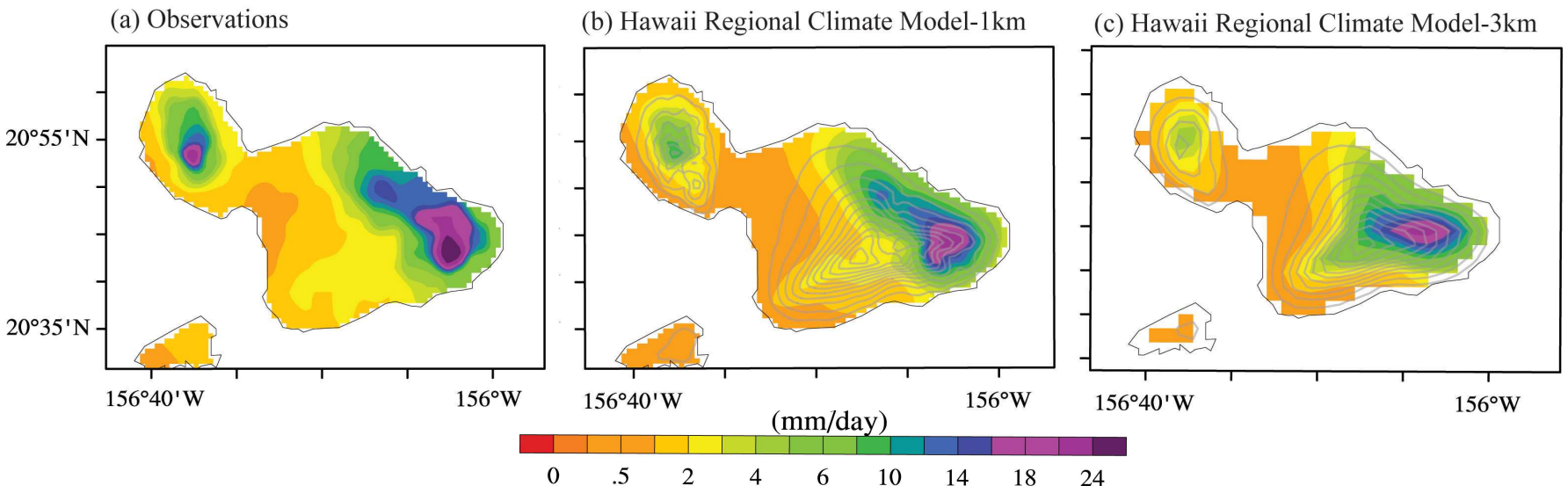
$\Delta x = 1$ km



Observations

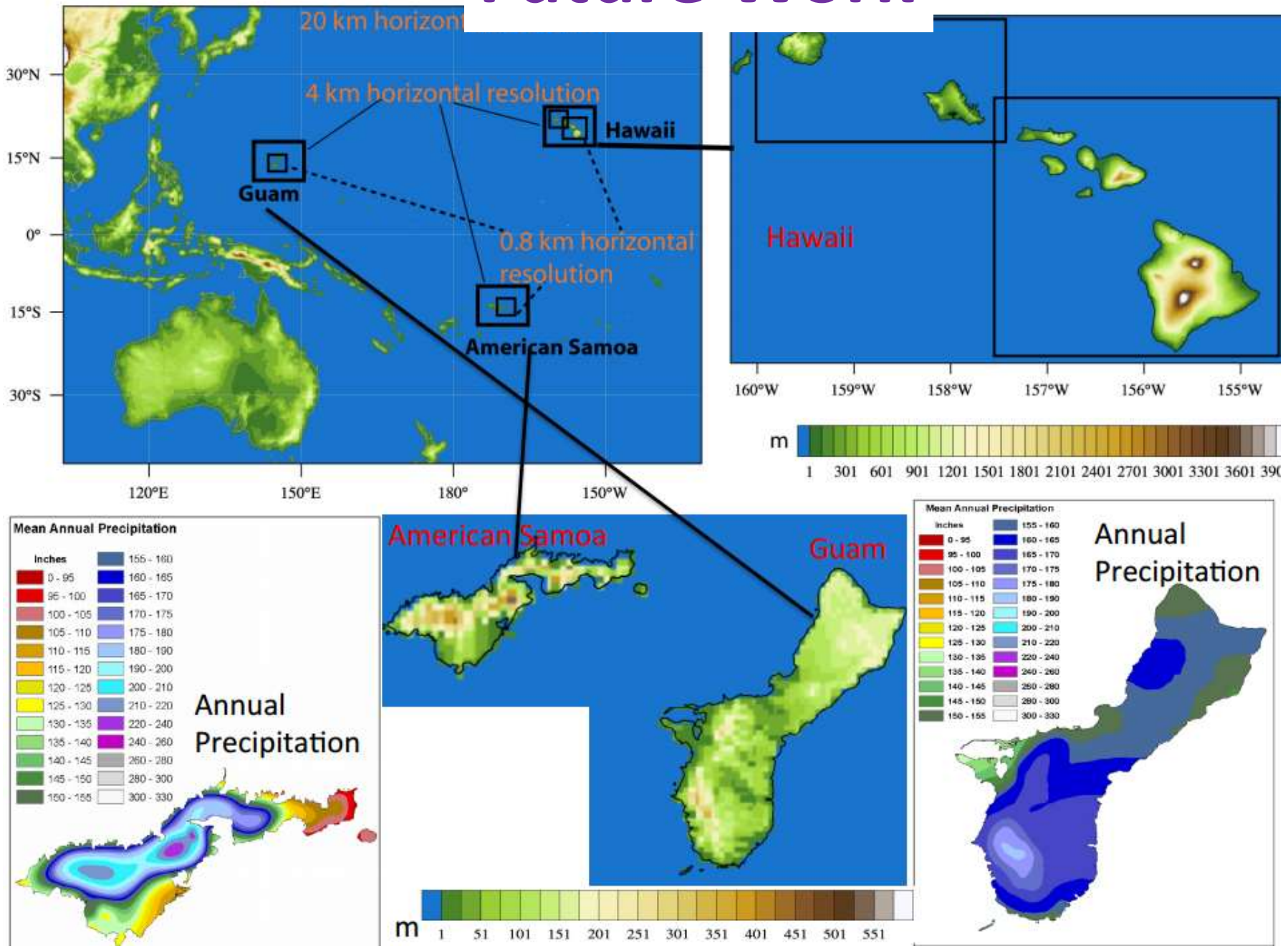
Δx = 1 km

Δx = 3 km



Unfortunately adequate simulation for Maui (and probably for Oahu and Kauai) requires quite fine horizontal resolution

Future Work


20 km horizont
4 km horizontal resolution
Hawaii
Guam
0.8 km horizontal resolution
American Samoa
30°N
15°N
0°
15°S
30°S
120°E
150°E
180°
150°W
Hawaii
160°W
159°W
158°W
157°W
156°W
155°W
m
1 301 601 901 1201 1501 1801 2101 2401 2701 3001 3301 3601
Mean Annual Precipitation
Inches
0 - 95
95 - 100
100 - 105
105 - 110
110 - 115
115 - 120
120 - 125
125 - 130
130 - 135
135 - 140
140 - 145
145 - 150
150 - 155
155 - 160
160 - 165
165 - 170
170 - 175
175 - 180
180 - 190
190 - 200
200 - 210
210 - 220
220 - 240
240 - 260
260 - 280
280 - 300
300 - 330
Annual Precipitation
American Samoa
Guam
m
1 51 101 151 201 251 301 351 401 451 501 551
Mean Annual Precipitation
Annual Precipitation

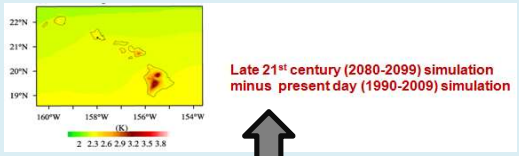
Plant Range Model Projections
Fortini (PICCC, PICSC FY13)

College of Tropical Agriculture and Human Resources
Carbon Storage in Terrestrial Biosphere
Hawbaker, Litton, Giardina

College of Tropical Agriculture and Human Resources
Crop Suitability Models for Hawaii & Implications of Climate Change
Gross, Miura

Climate Change and Avian Malaria
Samuel, Liao (PICSC FY12)

Fine-Resolution Climate Projections for Hawaii via Regional Modeling
Yuqing Wang, Zhang, Hamilton



Pac RISA
Finucane, Keener, Lewis

College of Tropical Agriculture and Human Resources
Valuing Climate Change Impacts on Coral Reef Ecosystem Services
Oleson (PICSC FY13)

Maui Biofuels Project
Sugimura, Kim

Ground Water Modeling for West Maui
Anthony, Mair, Al-Kadi

Conclusions

present day simulation

- HRCM forced with observed boundary fields can simulate the basic features of the mean as well as diurnal, seasonal and interannual variations of the precipitation in the Hawaiian Islands.
- Unfortunately really adequate simulation for Maui (and probably for Oahu and Kauai) requires quite fine horizontal resolution

Conclusions

climate change projection

- The surface and surface air temperatures are projected to have around 2-3.5°C degree increase over the 21st century in the SRESA1B scenario. The surface warming is intensified with height.
- Projected rainfall changes are significant (up to ~30%) and generally exhibit a wet-get-wetter, dry-gets-dryer pattern.
- The biggest practical effects may be increased drying (more evapotranspiration, less rainfall) in the already dry parts of each major island

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