

How does the rainfall change over Hawaii in the future? Convection permitting regional climate simulations of the Hawaiian Islands

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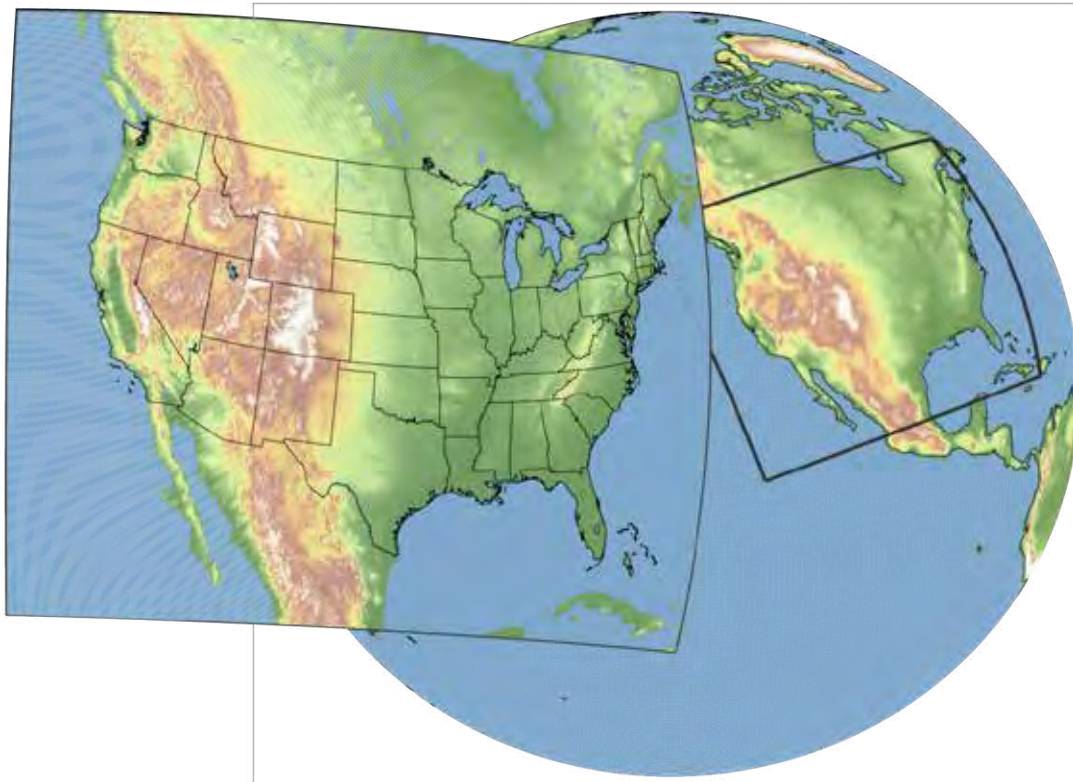


Outline

- Background
 - CONUS simulation
 - Motivation
- Experimental setup
 - HaRP tests
- Validation of historical results
- Future (PGW) results
- Summary

CONUS simulation

WRF 4 km | 1359 x 1015 grid cells
13 years (2001-13)
ERA-Interim



Liu et al. 2016, Clim. Dyn.

Physics

- **Microphysics**
[Thompson and Eidhammer 2014]
- **Radiation RRTMG**
[Iacono et al. 2008]
- **Land-surface model NOAH-MP**
- **Boundary layer YSU**
[Hong et al. 2006]

Spectral Nudging

U, V, T, and ZG above the PBL

Model Evaluation at SNOTEL Sites

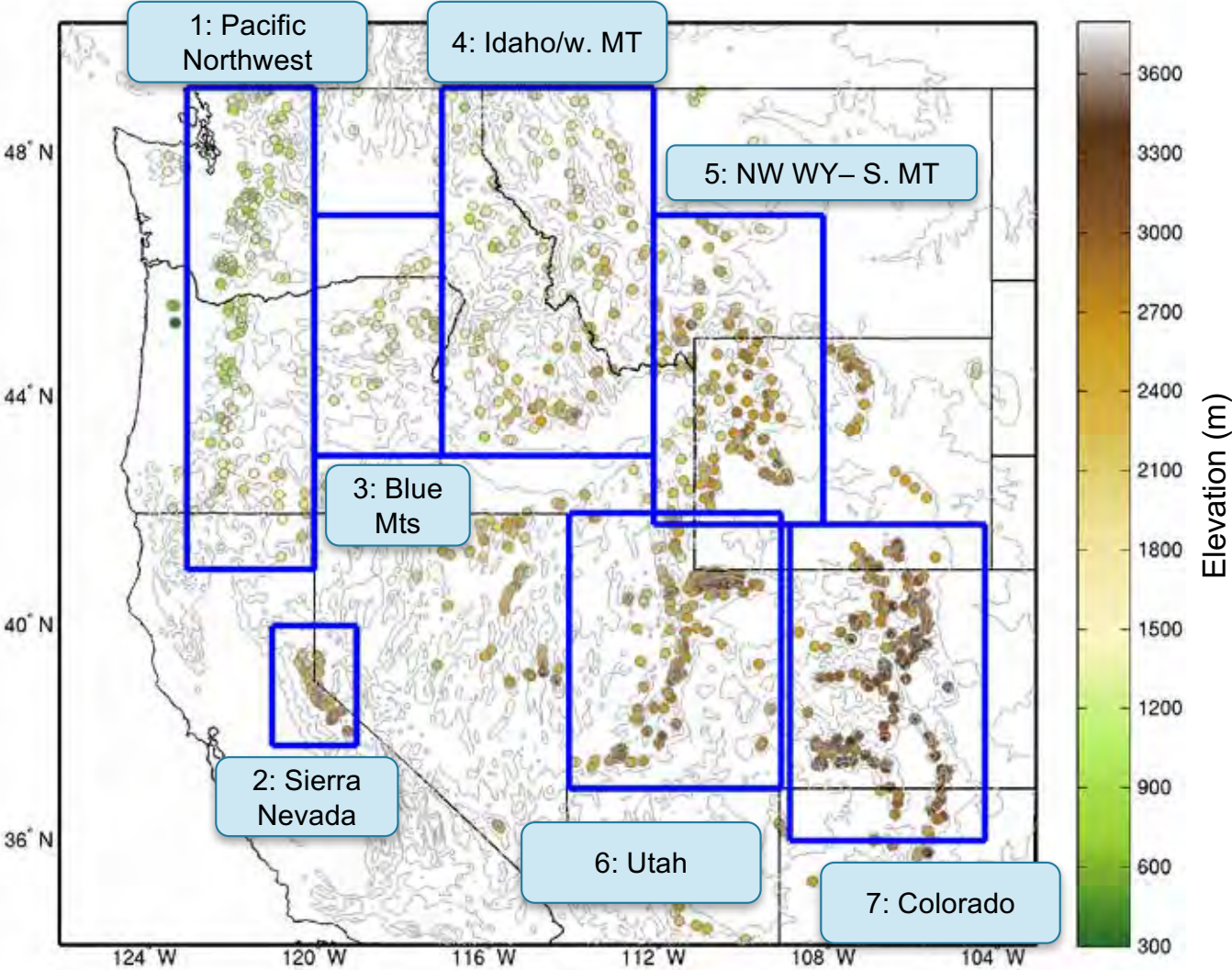
SNOTEL site at
Brooklyn Lake, WY



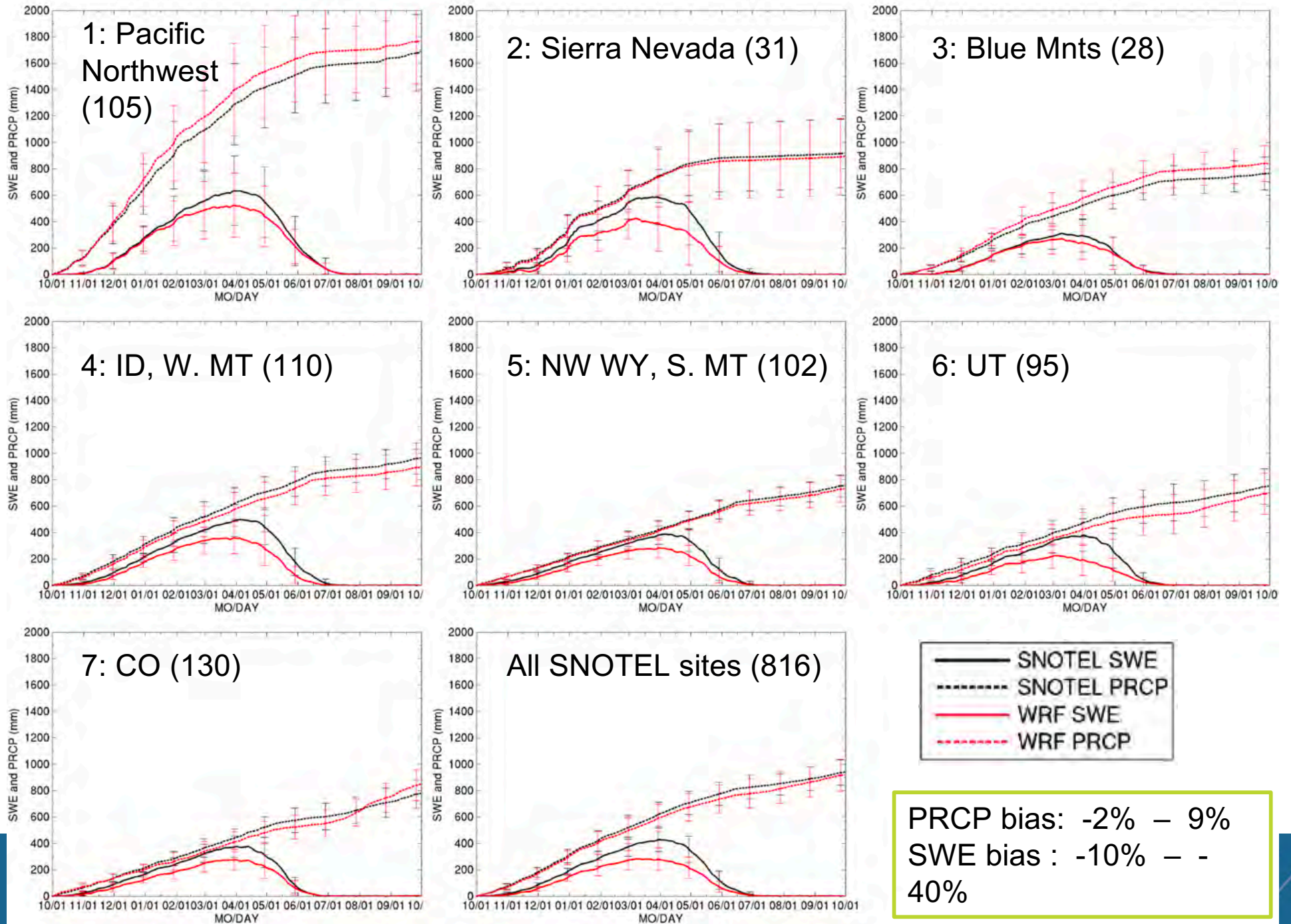
Snow gauge



Snow pillow



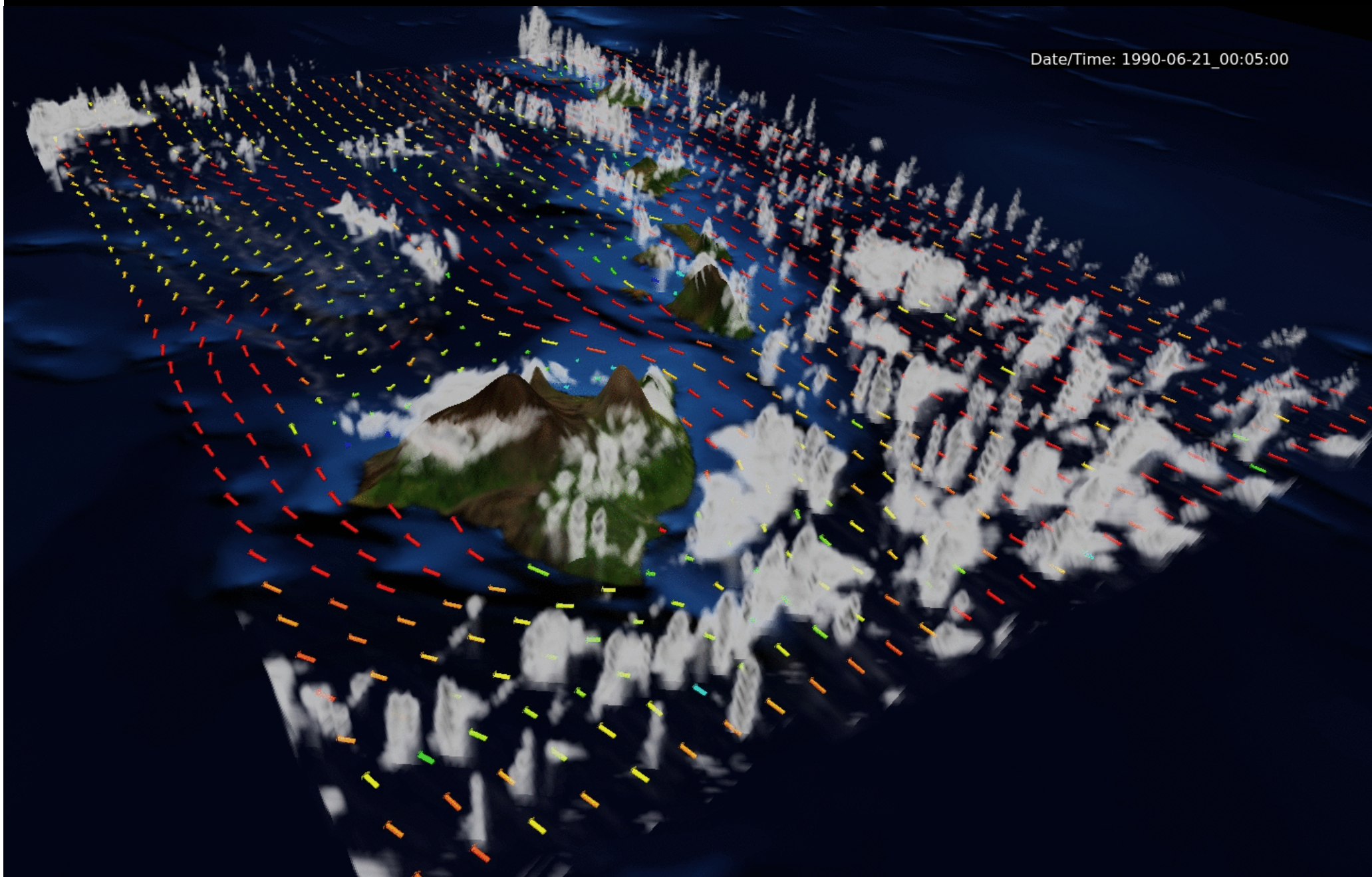
SNOTEL vs WRF at SNOTEL sites: 13-year climatology



Motivation

- High-resolution regional climate simulation has been carried out for the contiguous US (CONUS).
- No data with a similar quality exists for Hawaii and Alaska.
- In order to assess impacts of climate change on precipitation processes and consequent hydrology responses in Hawaii and Alaska, high-resolution regional climate simulations are carried out for these regions.

Date/Time: 1990-06-21_00:05:00



Experimental setup

- Simulation should be long enough to assess the climatology and extreme events ($> \sim 10$ years)
- Horizontal resolution should be high enough to resolve flow-terrain interactions that are important to the orographic clouds and precipitation ($< \sim 2$ km)
- Vertical resolution should be fine enough to resolve the trade-wind inversion - TWI ($< \sim 100$ m at TWI)

HaRP experiment tests

- Hawaiian Rainband Project (Jul.-Aug. 1990):
 - To study the sea-island-trade wind interactions
 - To better understand the forcing and organization of precipitation
 - NCAR Electra
 - 50 PAM sites
 - 2 Radars
 - Sondes

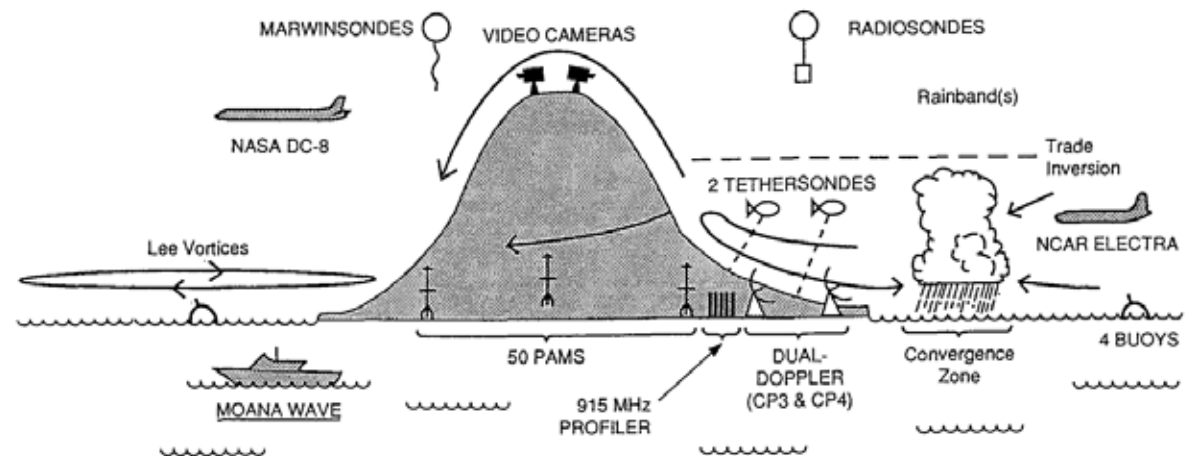
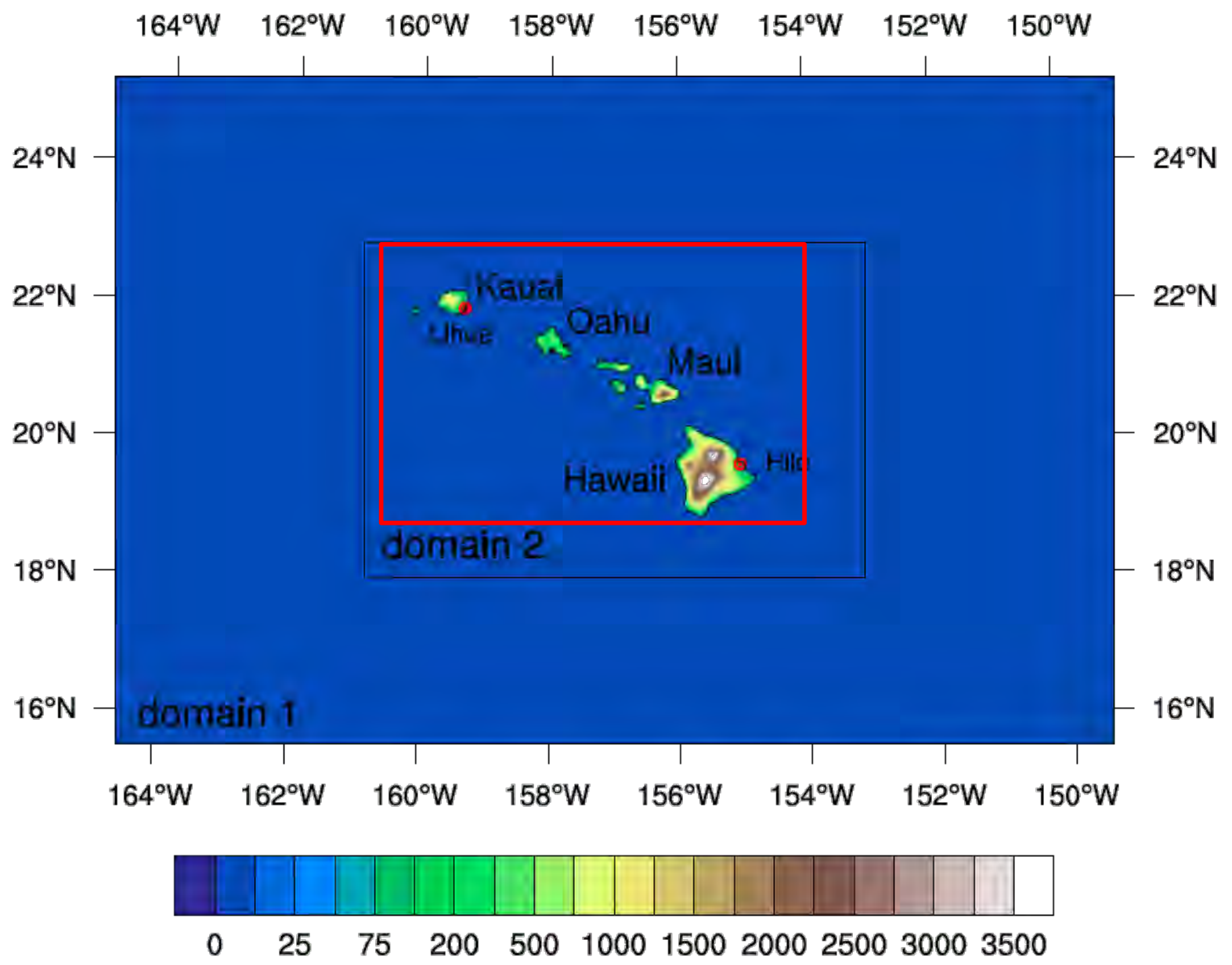


FIG. 1. Schematic representation of the airflow pattern and the observing systems used in the HaRP. Observing systems were deployed all around the island with emphasis on the windward (east) side.

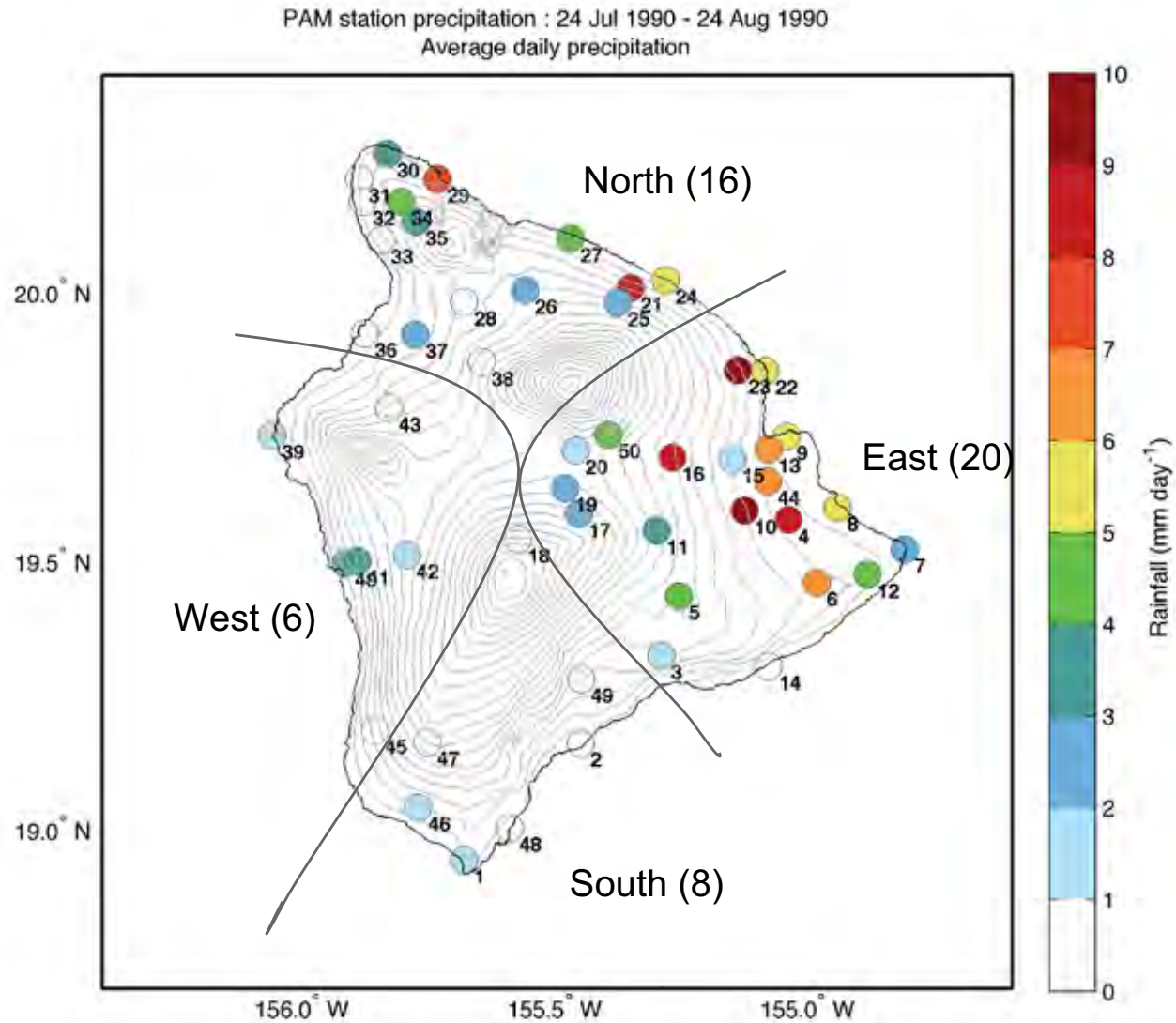
9 Experiments of HaRP simulation

Data	Case name	Original D2	Large D2	R2 SST	Noah MP	81 levels	CN50	CN75
ERA-I	ERA-I	X						
	ERA_LD2		X					
	ERA_R2SST		X	X				
	ERA_MP		X	X	X			
	ERA_CN50		X	X	X		X	
	ERA_81L		X	X		X		
	ERA_FINAL			X	X	X	X	X
CFSR	CFSR	X						
R2	R2	X						

The default cloud number concentration (CN) is 100/cc.

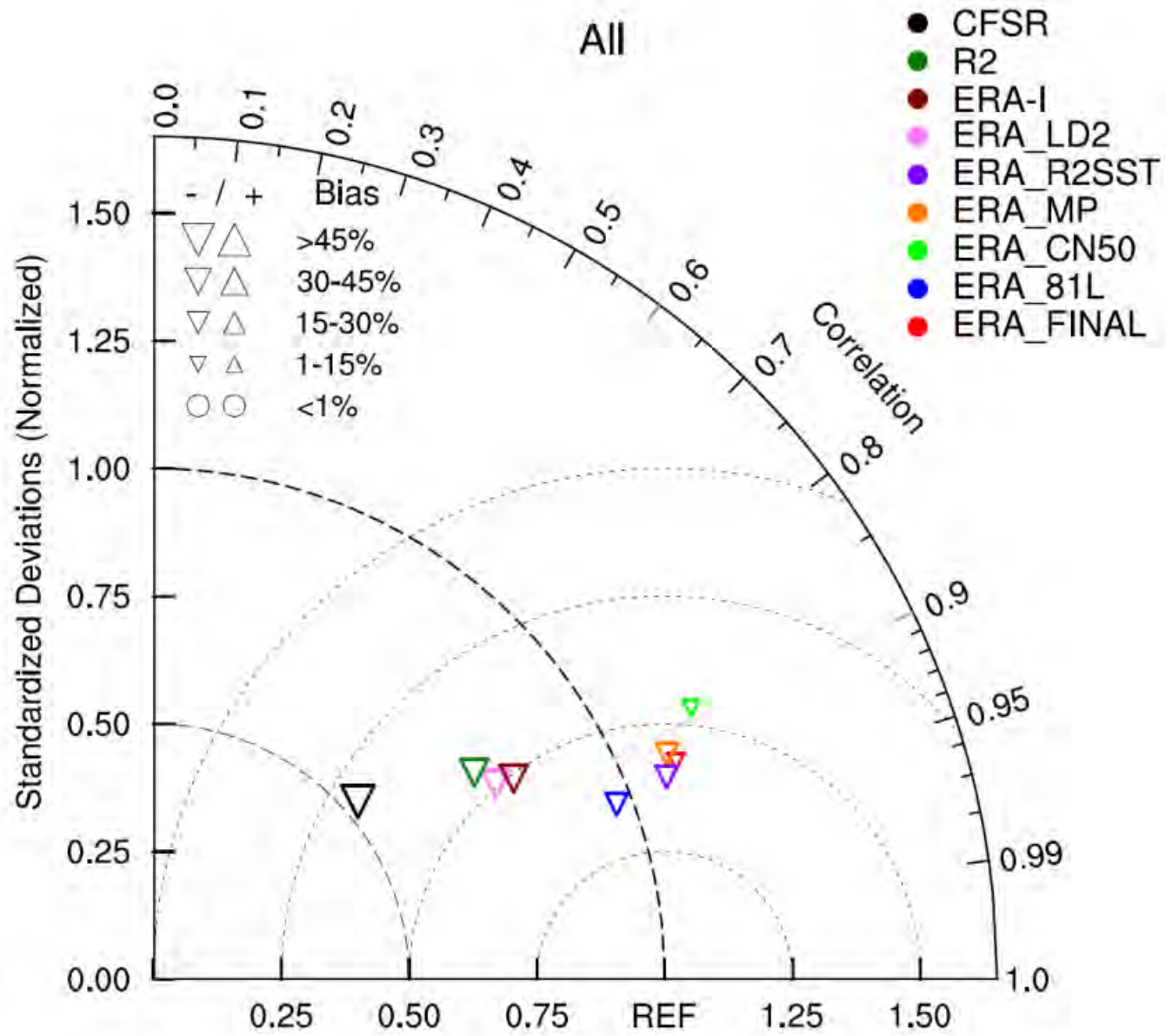


PAM and group locations



/Volumes/d1/kyoko/harp/matlab/map_PAM_diurnal_prop.r

17-Jul-2015



WRFV3.7.1 model configurations

Domain	4.5 km domain D01	1.5 km domain D02
Horizontal grids	360 x 240	540 x 360
Vertical levels	81 vertically stretching eta levels	
Time step	1 - 30 s	1 - 6 s
Microphysics	Thompson microphysics scheme (CN=75/cc)	
Land surface model	Noah Multiple Physics (MP)	
PBL scheme	MYNN 2.5 order scheme	
Horizontal diffusion	Evaluate mixing terms in physical space	
Turbulent closure	Horizontal Smagorinsky 1 st order closure	

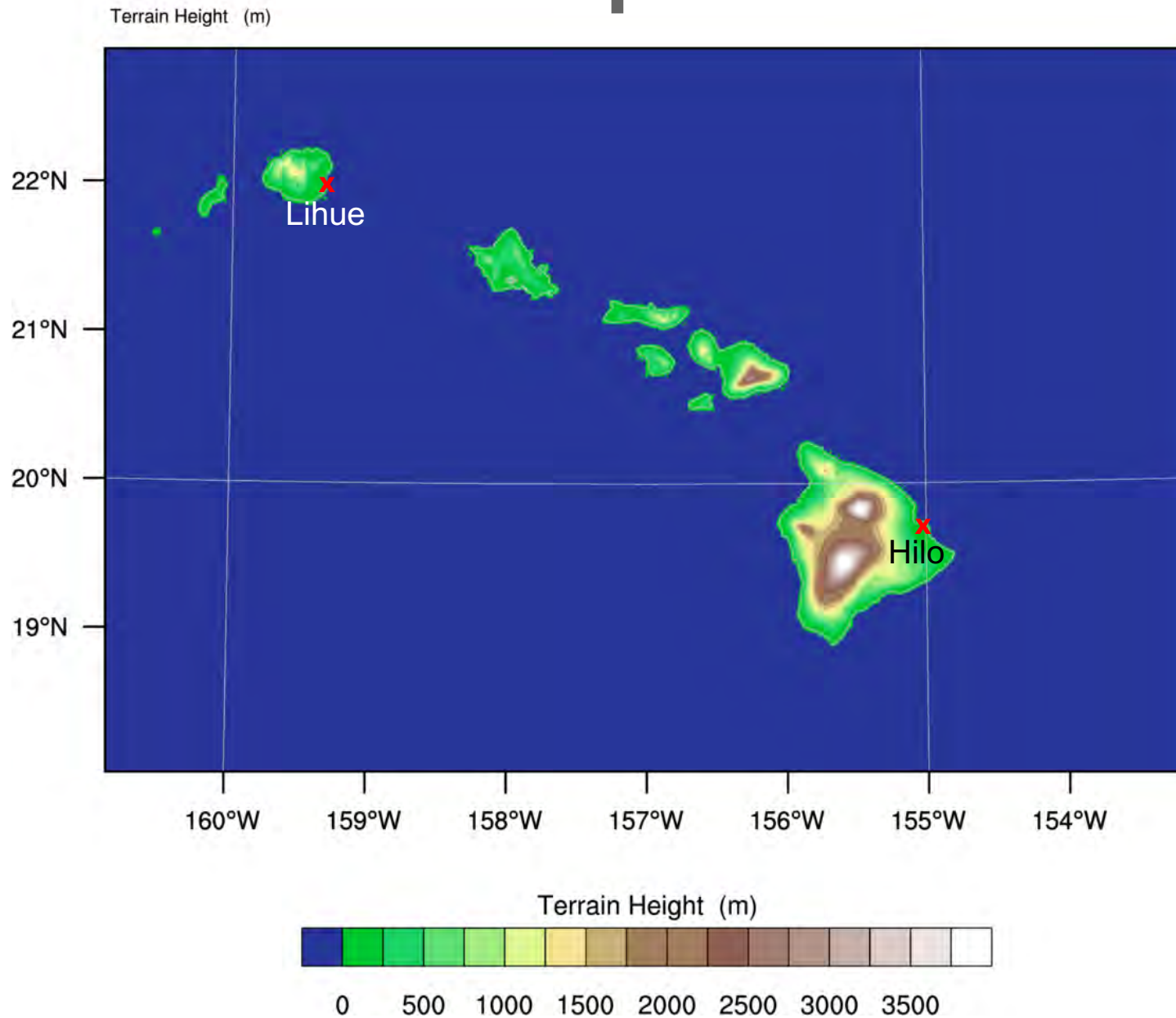
Validation of historical results

- 10-year Hawaii WRF simulation of the historical period (June 2002 to September 2012) is carried out using ERA-Interim and MUR SST inputs
- Results from October 2002 to September 2012 in D02 are validated against observations from various sources

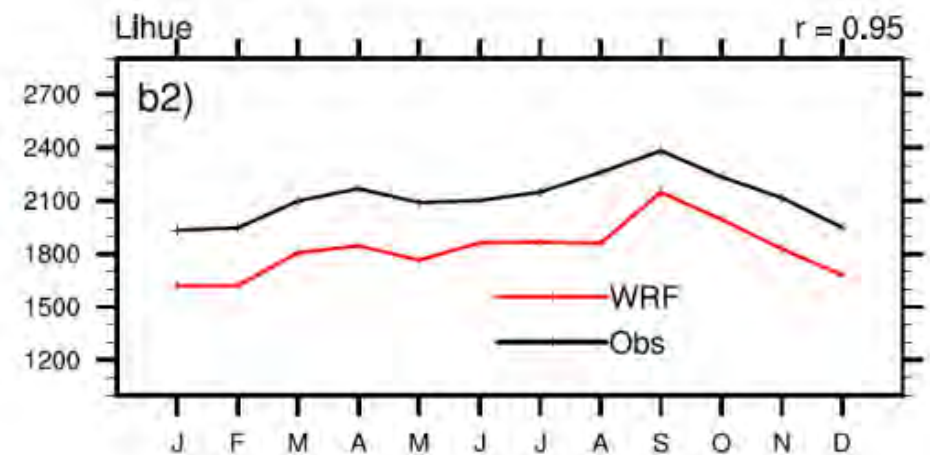
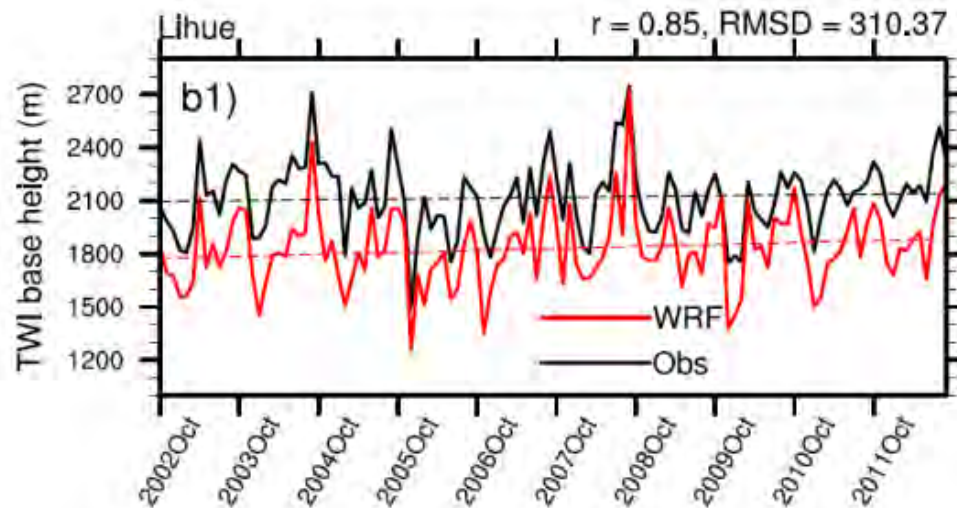
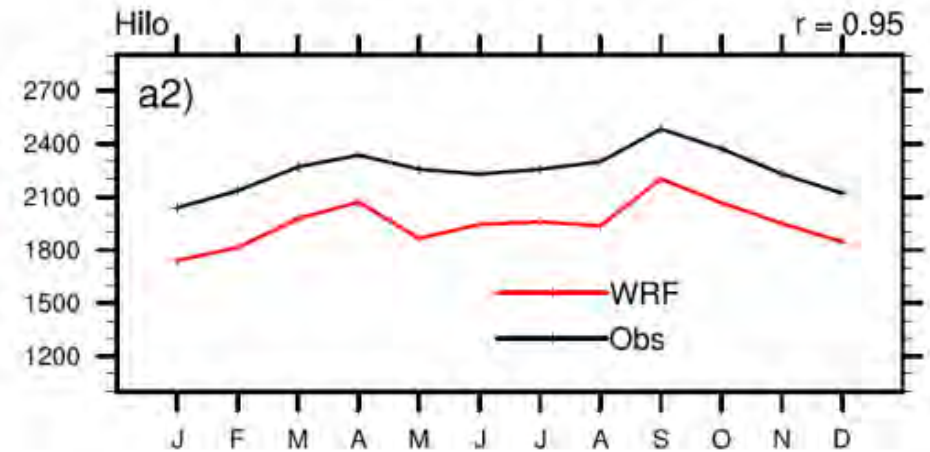
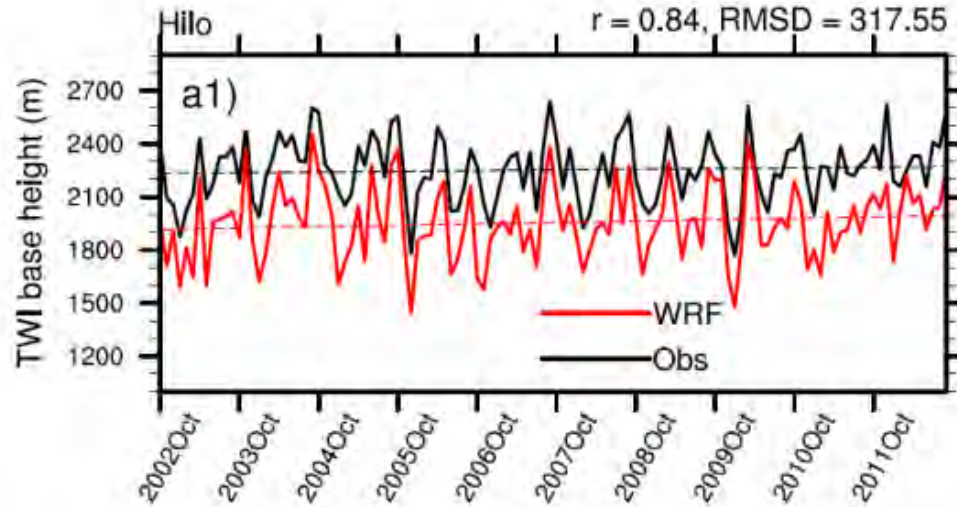
Observational Data Sources

- Hourly and daily station data
 - Environmental data from weather stations
 - Rainfall from NWS COOP, ASOS/AWOS, HydroNet (NWS network), RAWs (Dept. of Transportation), HaleNet (U. of Hawaii), SCAN (Soil Climate Analysis Network), USGS gauges, and other local networks from Hawaii (e.g. sugar plantations)
- Sounding data
 - 00 and 12 Z soundings from Hilo and Lihue
- Gridded data
 - Rainfall: <http://rainfall.geography.hawaii.edu/> (Giambelluca et al. 2013 and Frazier et al. 2015)

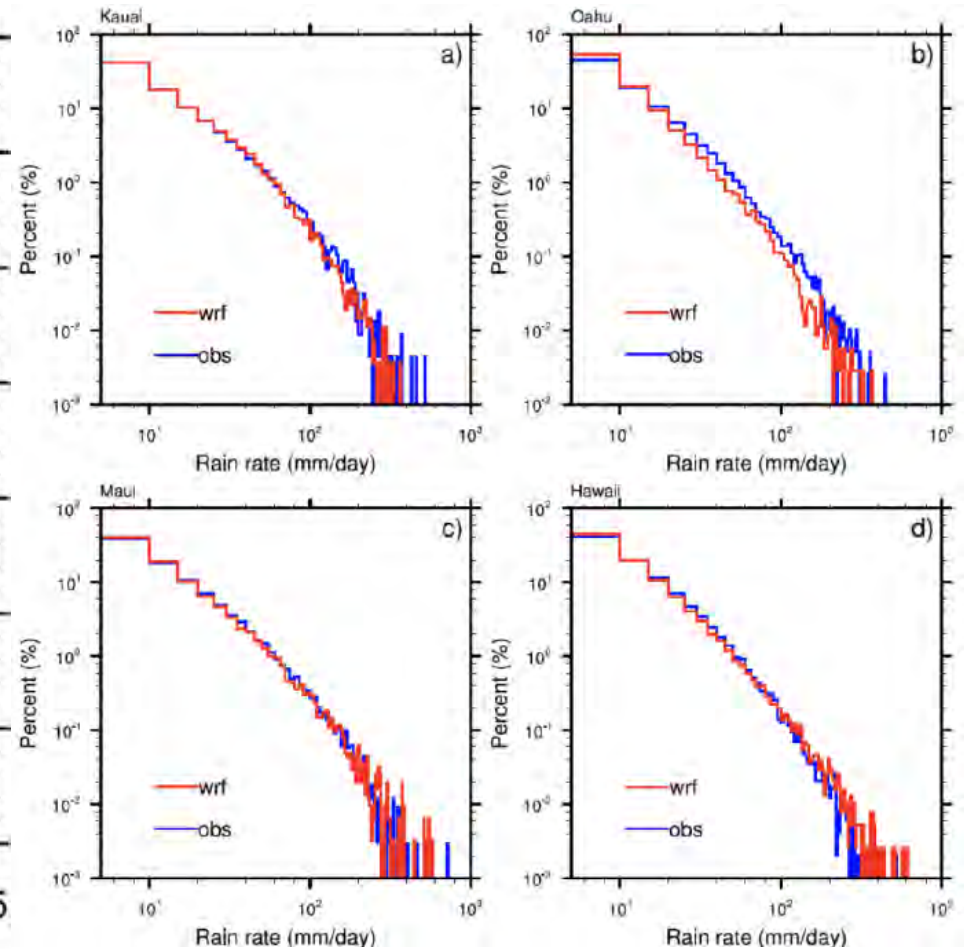
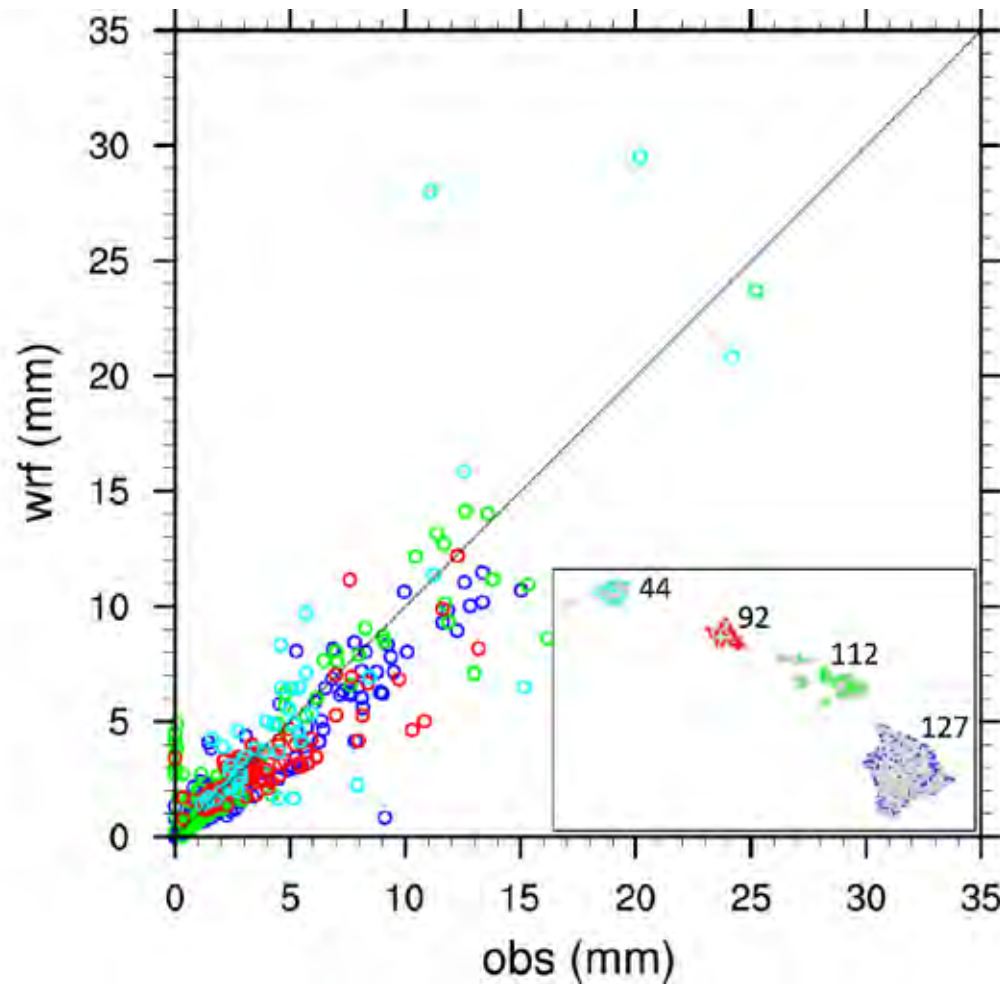
TWI comparisons



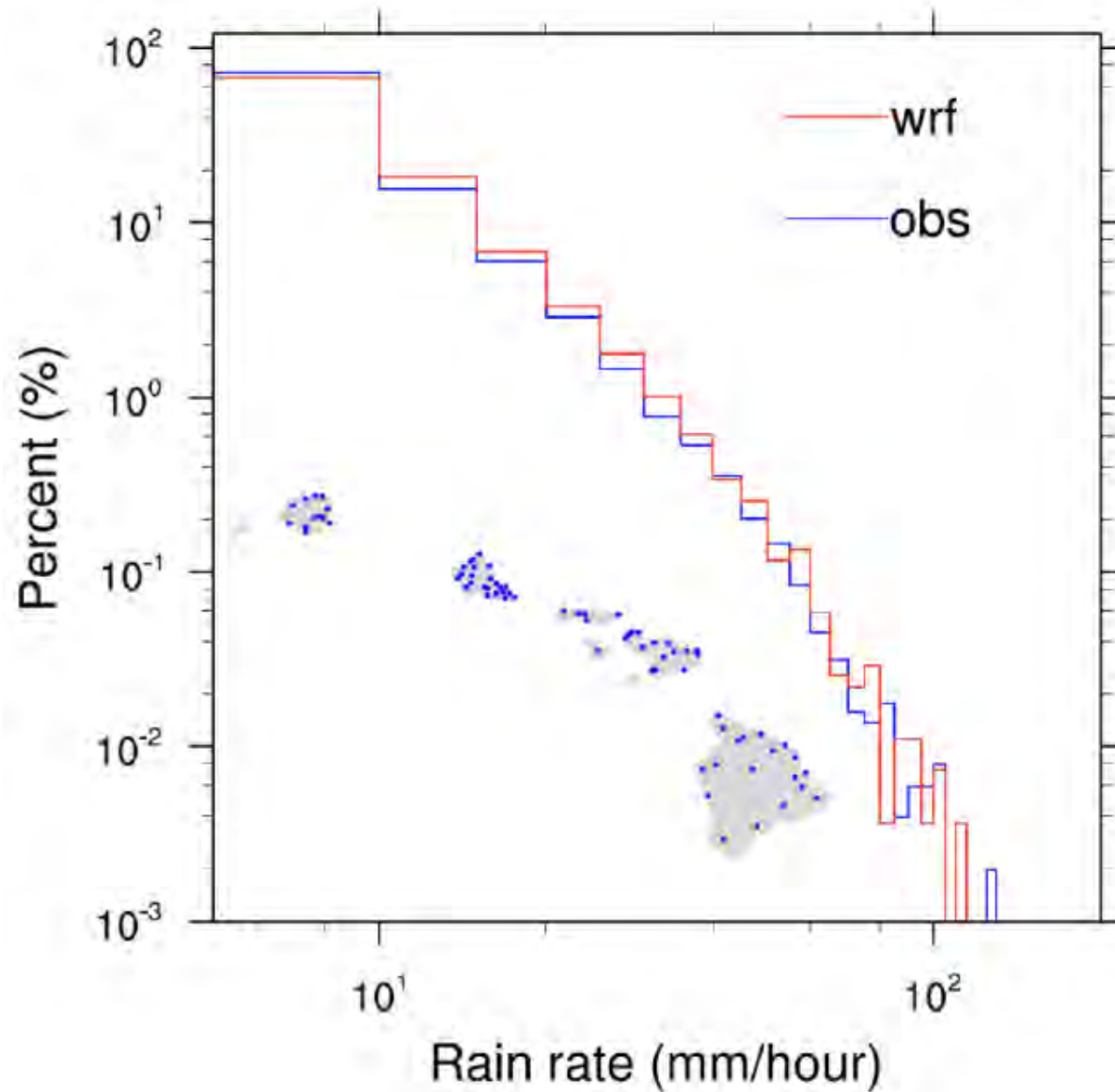
TWI base height



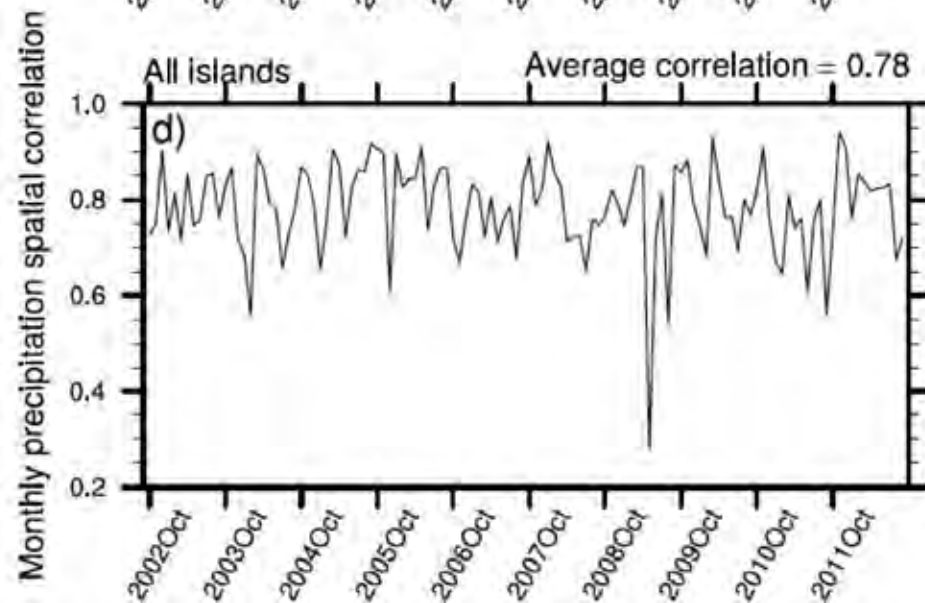
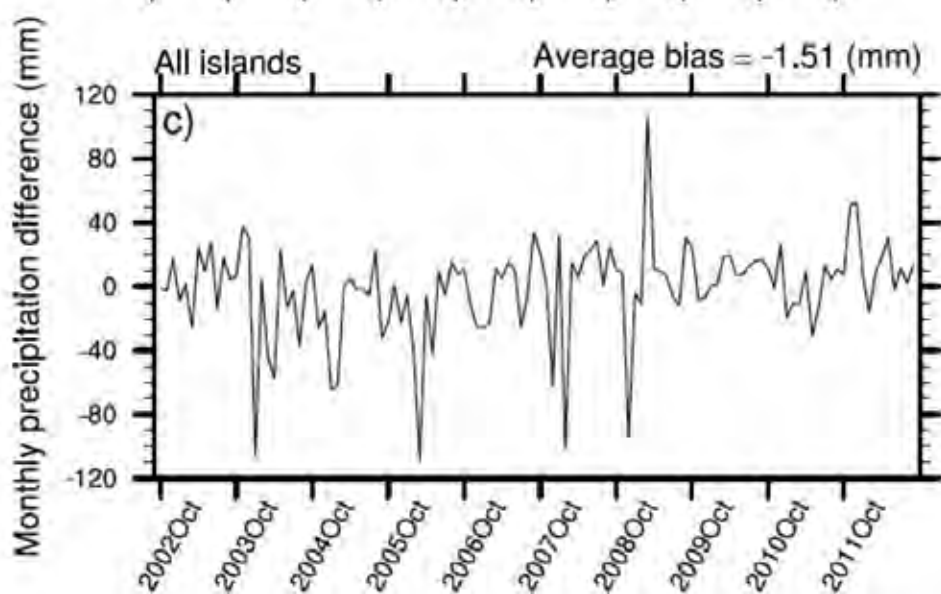
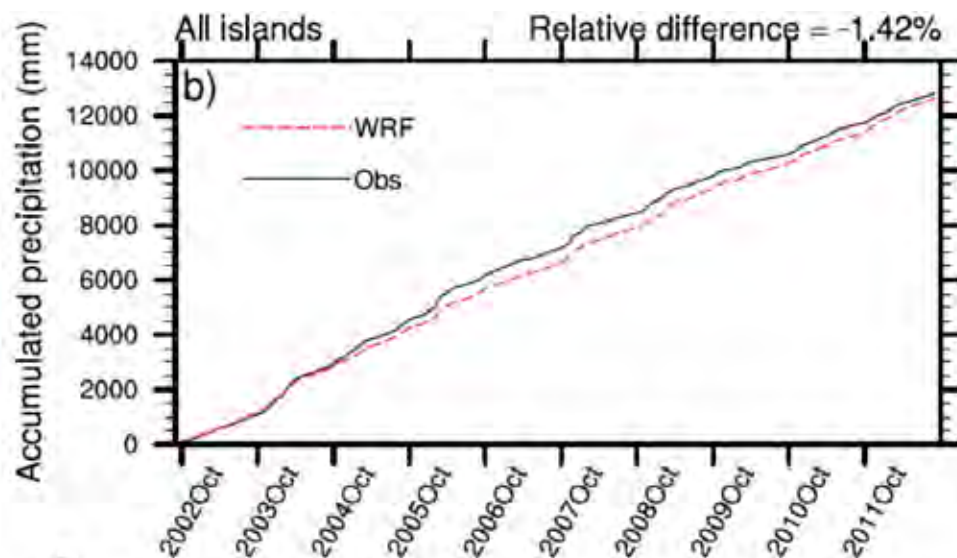
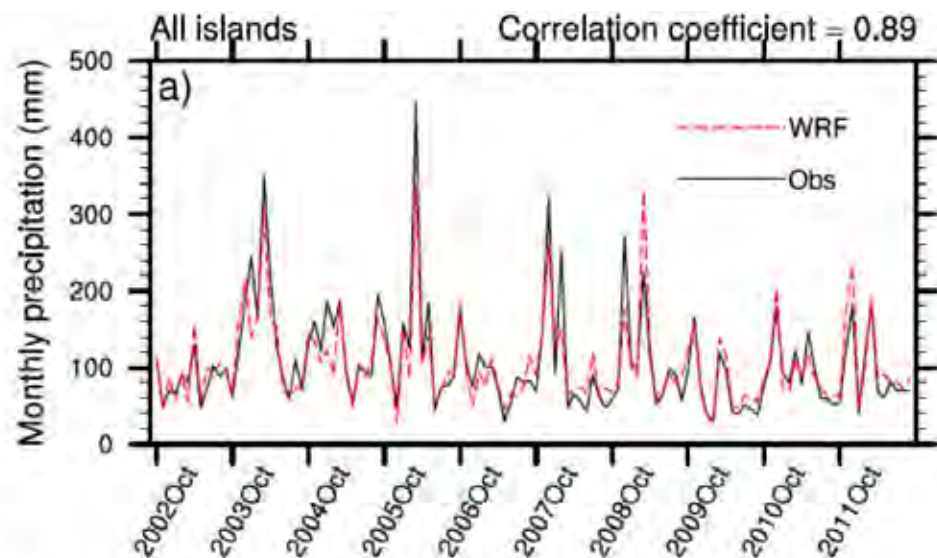
Daily rainfall comparisons



Hourly rainfall comparison



Gridded rainfall comparison



Pseudo Global Warming (PGW) Climate Simulation Forcing Data

Hawaii Historical Climate Simulation

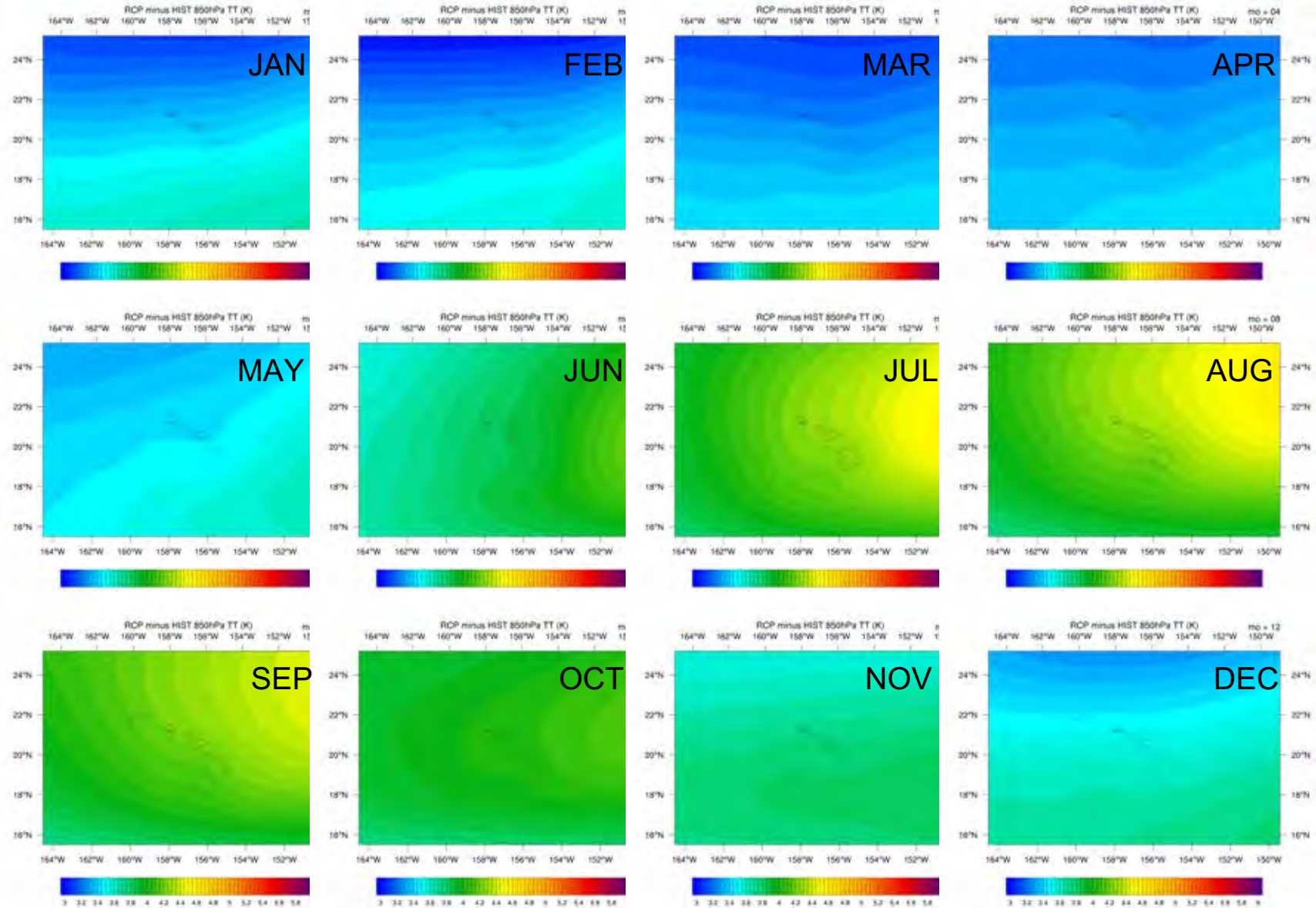
$$WRF_{input} = ERA-I$$

Hawaii RCP8.5 Future Climate Simulation (PGW)

$$WRF_{input} = ERA-I + (\overline{CMIP5}_{2071-2100} - \overline{CMIP5}_{1976-2005})$$

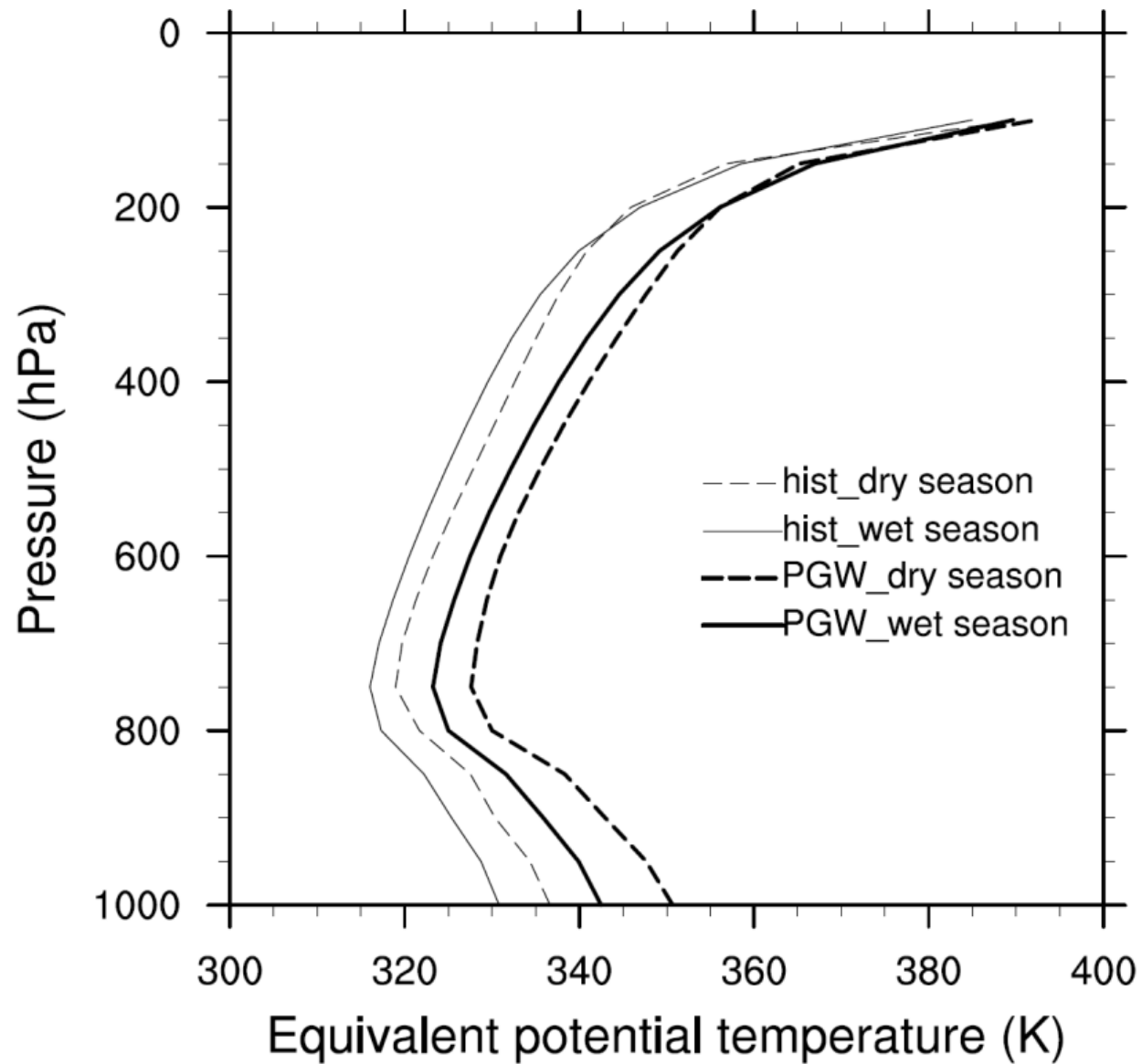
- 30-year monthly mean climate change signals from 19 ensembles from CMIP5 GCMs were added to 6-hrly ERA-interim data (T, RH, Geopotential height, U, and V)
- Minimal storm track change
- No spectral nudging is applied above boundary layer for both

850 mb delta T from CMIPS5

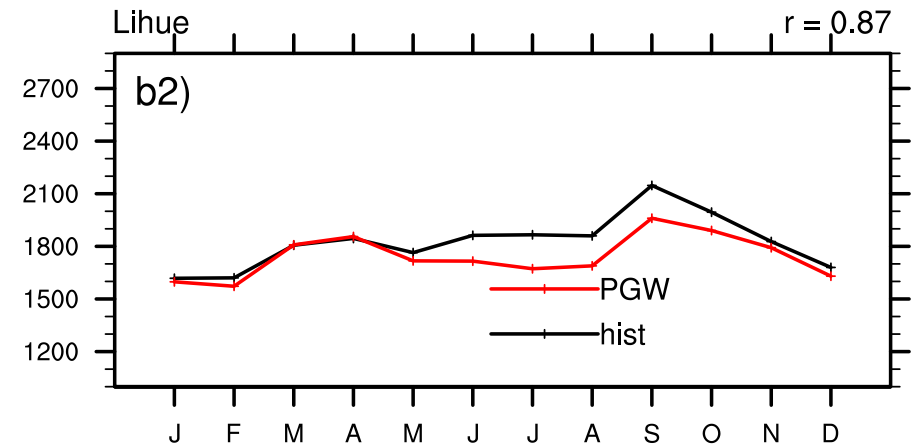
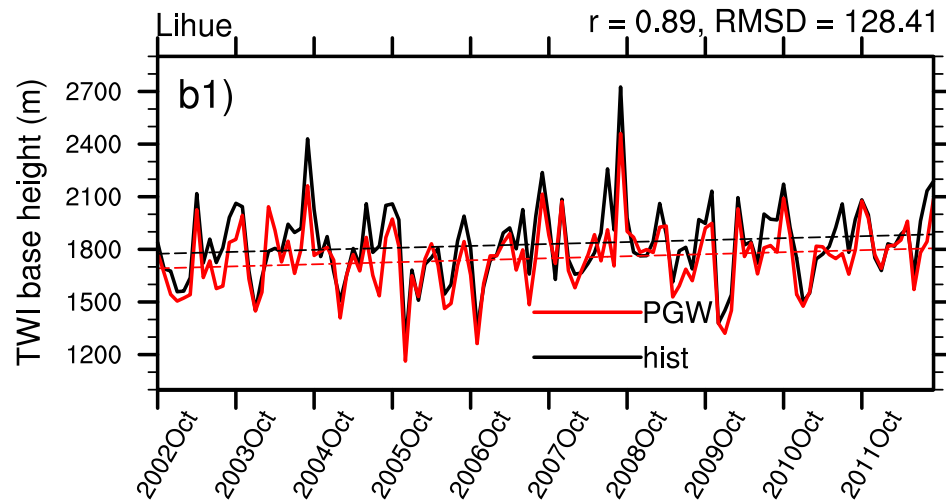
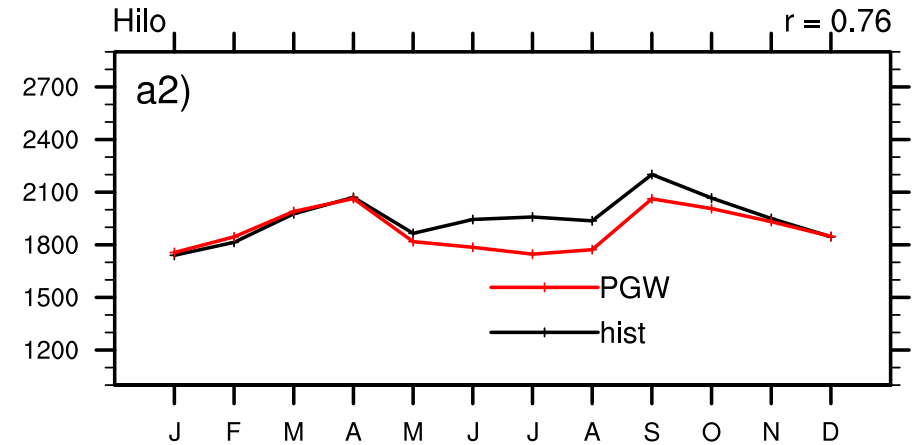
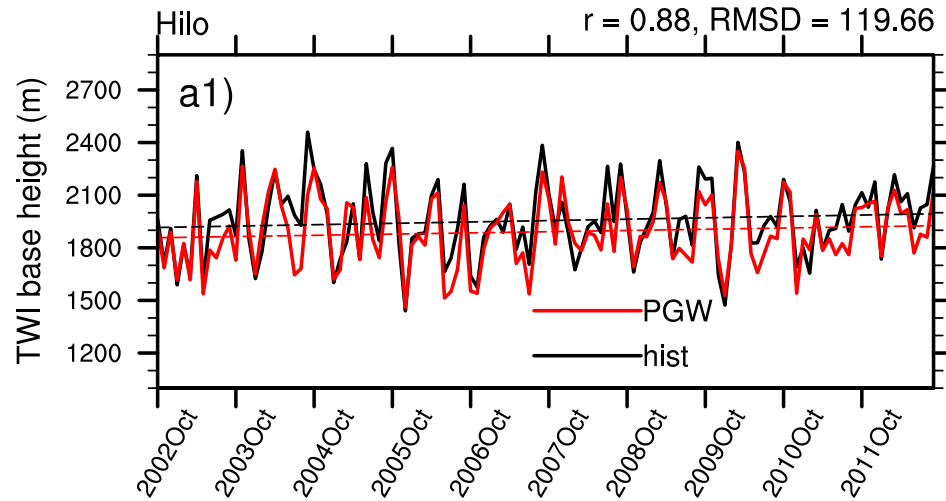


Temperature differences of monthly climatology (K)

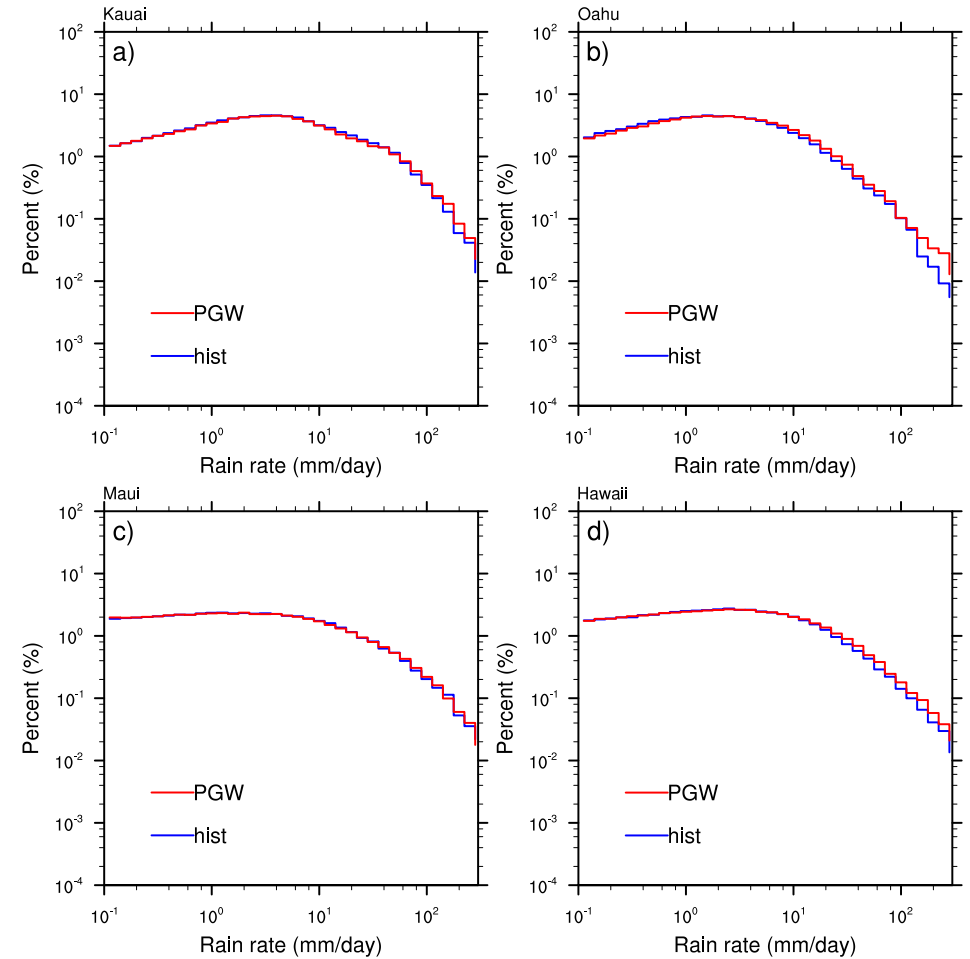
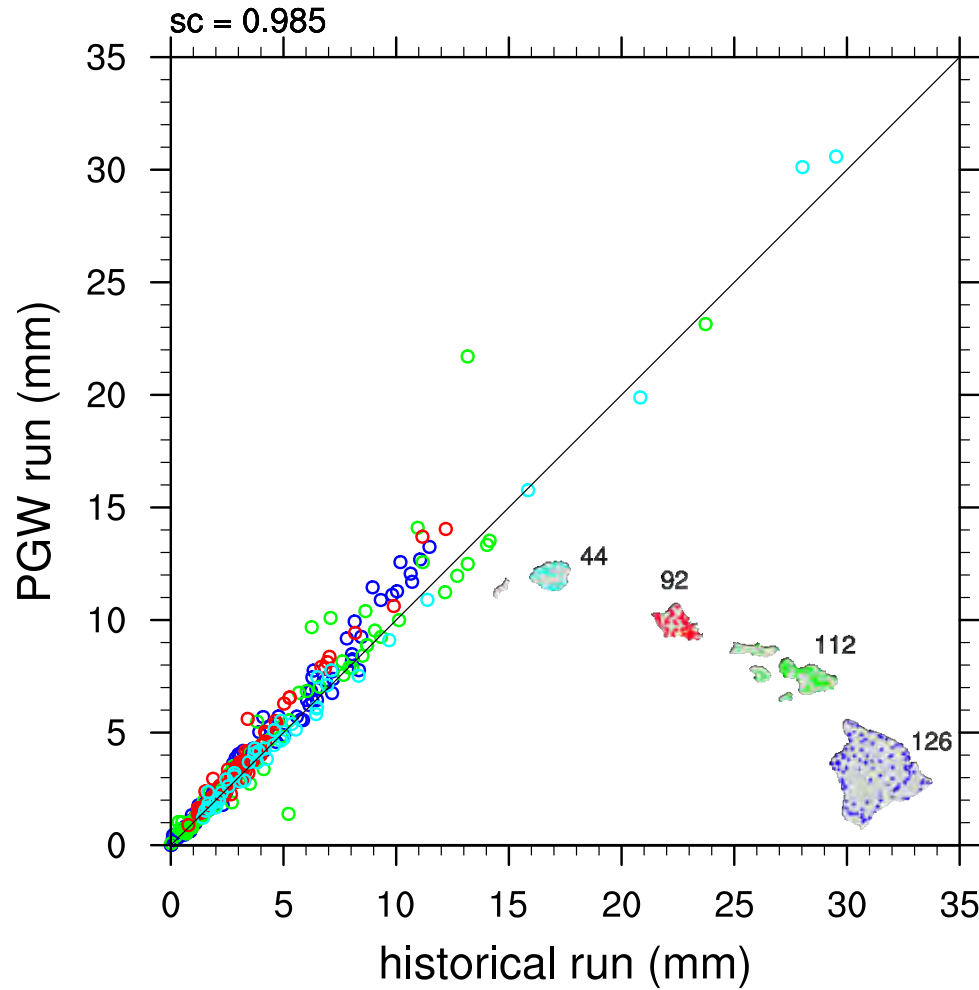
Thermo-structure change



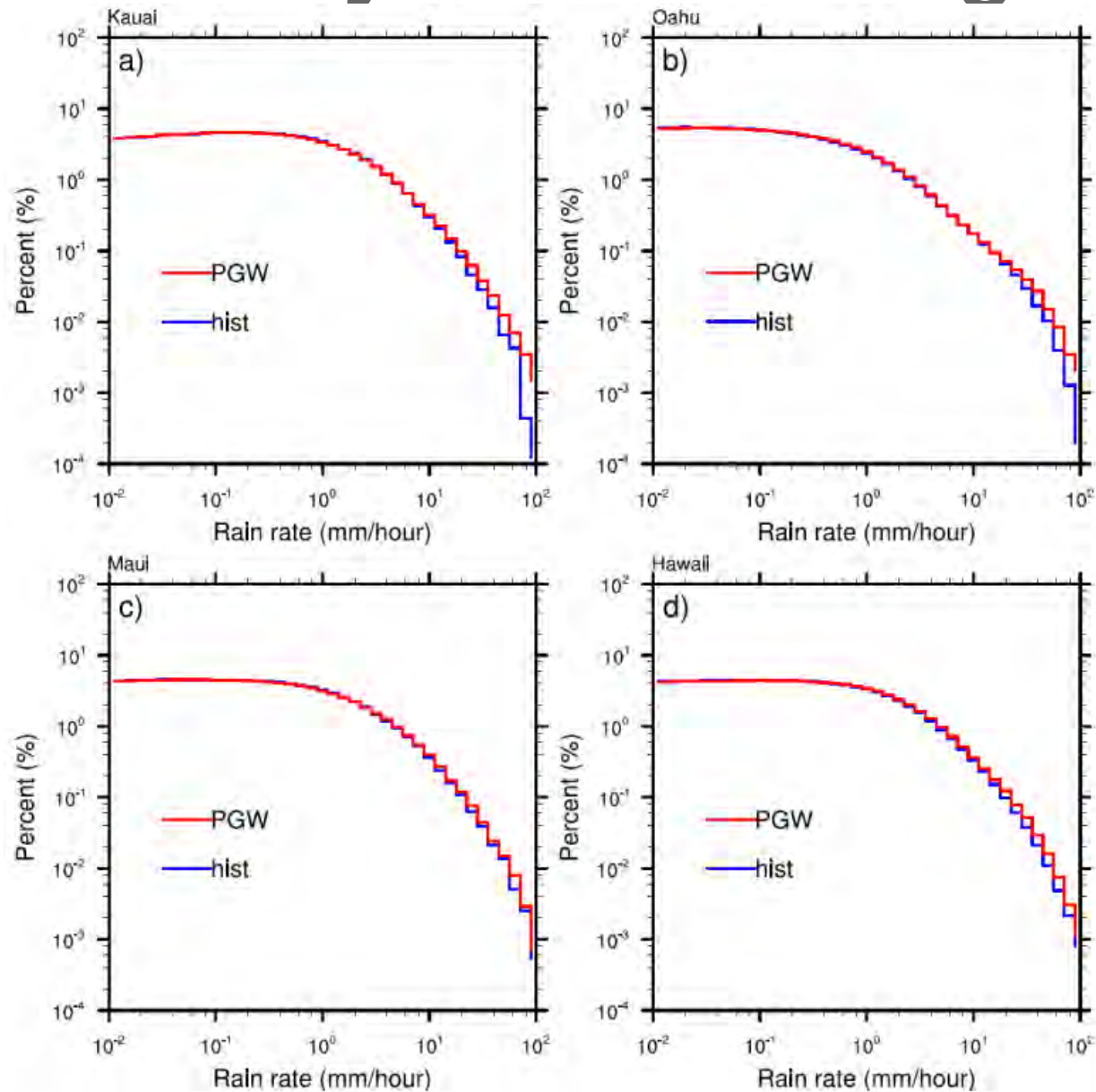
TWI base height change



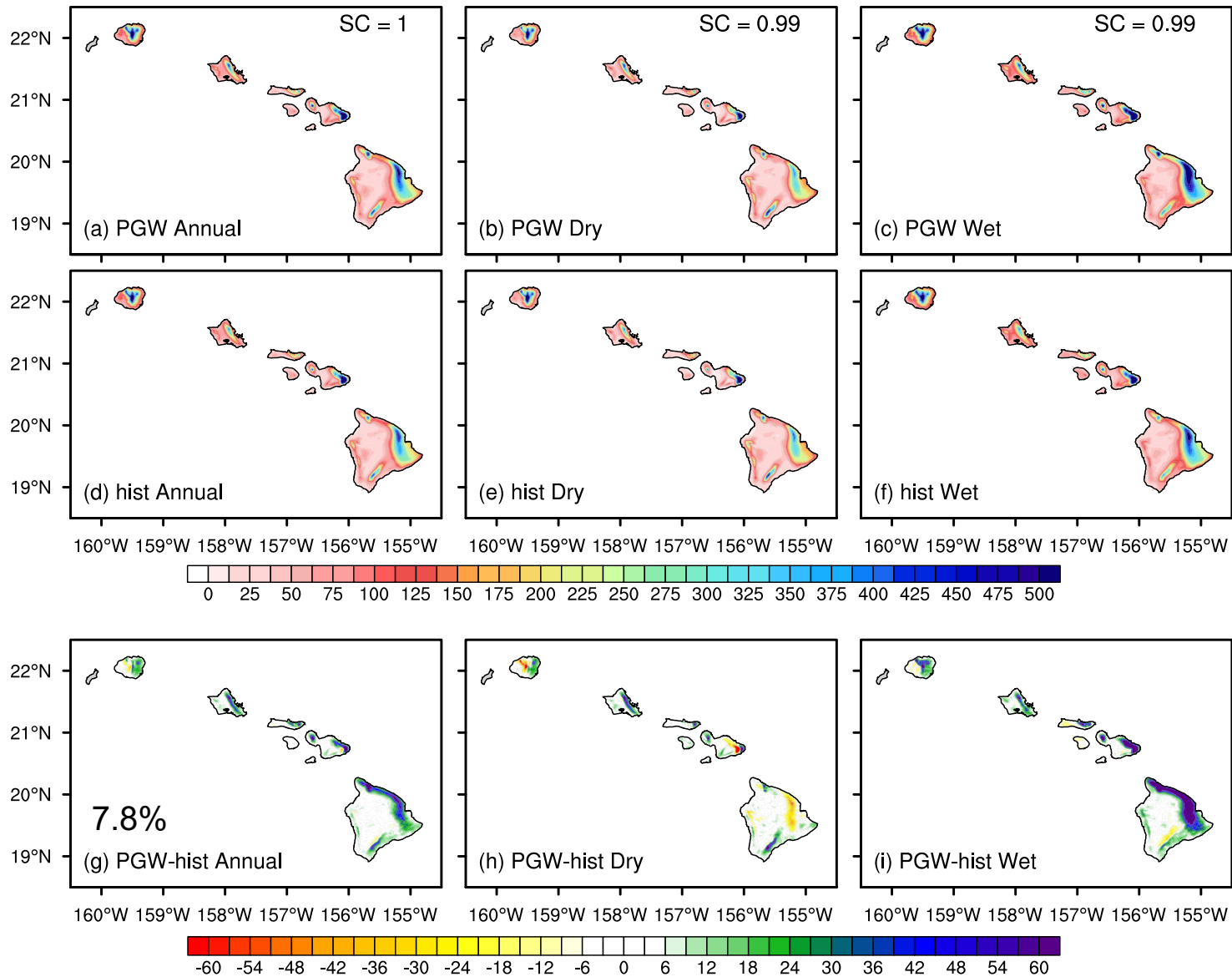
Daily rainfall change



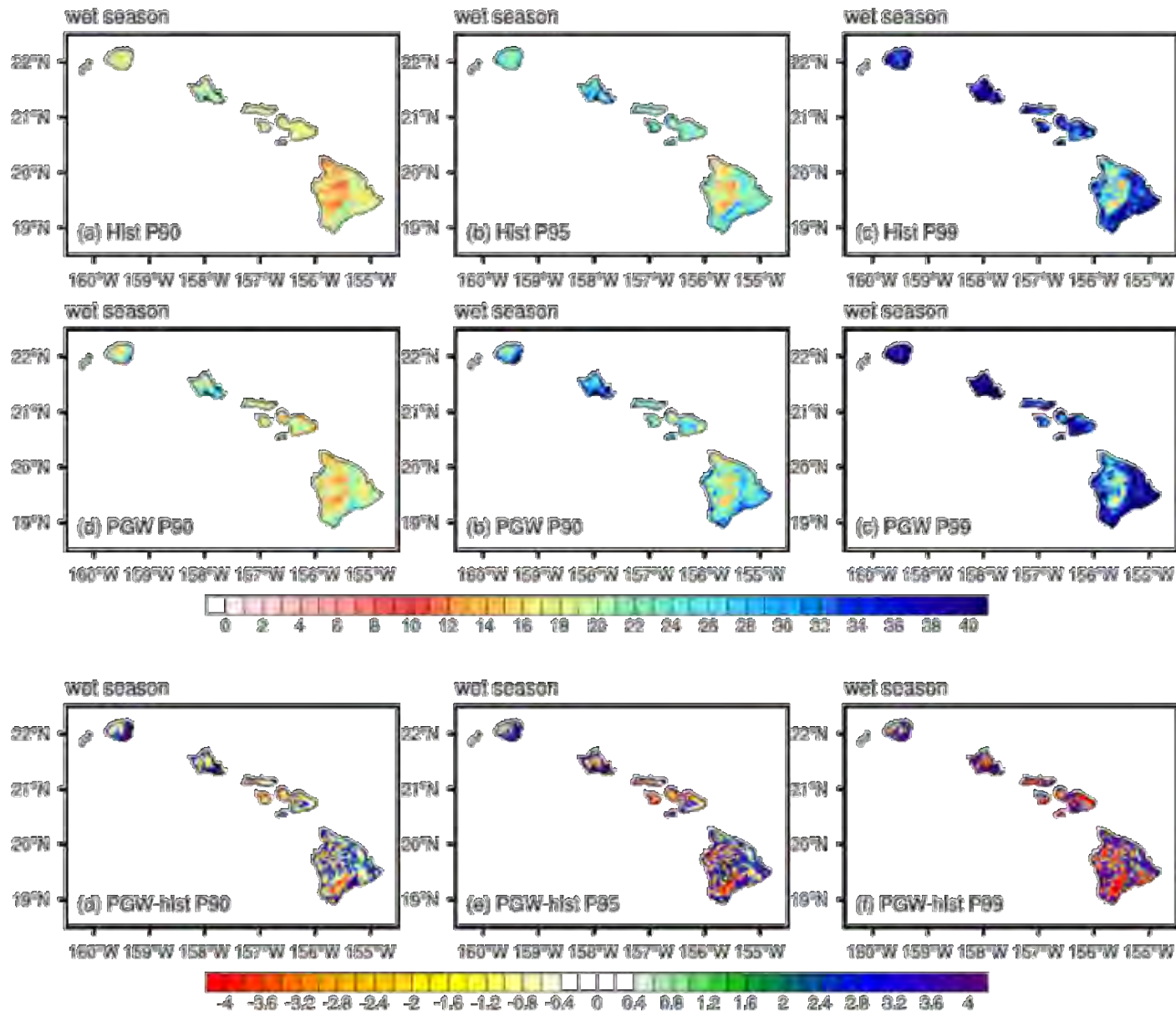
Hourly rainfall change



Spatial distribution change



Extreme precipitation change

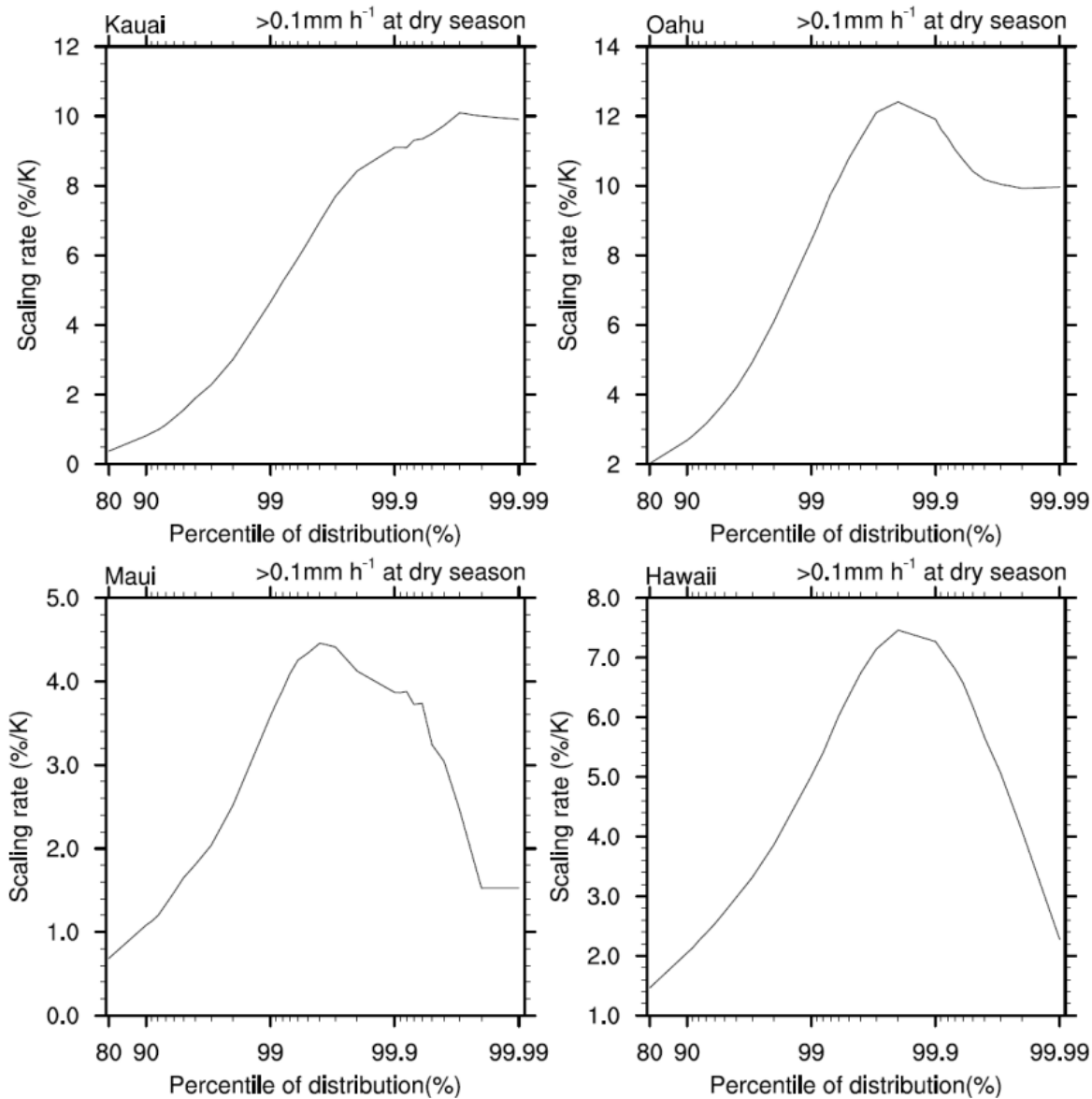


Summary



- ERA-Interim and MUR SST are used to drive the 10-year Hawaii historical climate simulation from June 2002 to September 2012 using WRFV3.7.1 based on HaRP test model configurations
- Validation of results from October 2002 to September 2012 using observations from various sources shows that WRF simulation captures the environment, TWI and precipitation features reasonably well
- The PGW simulation shows a decrease of TWI base height during the dry season leading to reduced rainfall in eastern Hawaii and at peaks in Maui and Kauai during the same dry season
- The PGW run also indicates that rainfall and rain rate increase in most of the Hawaii state mostly through the thermodynamic response
- The relative increase of the total rainfall is less than what the C-C relationship indicates
- The rainfall extreme changes in the future are related to topography

Rainfall scaling rate



Rainfall scaling rate

