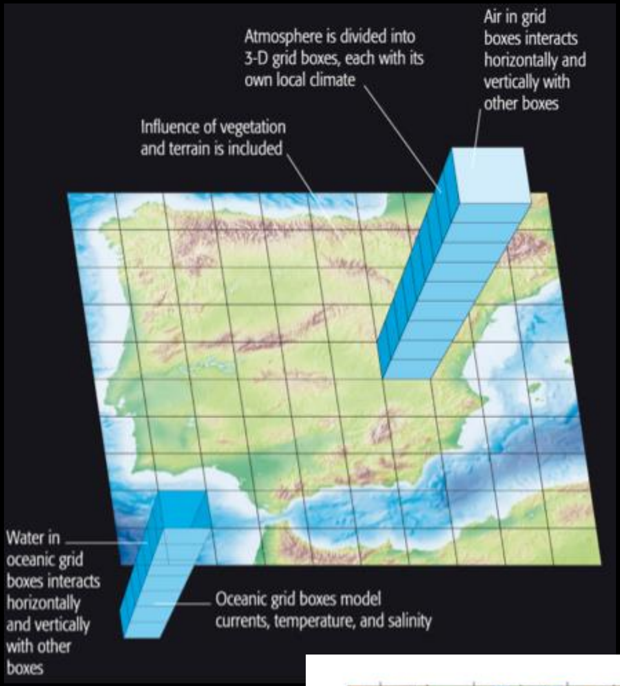
Climate Downscaling 201
(with applications to Florida Precipitation)



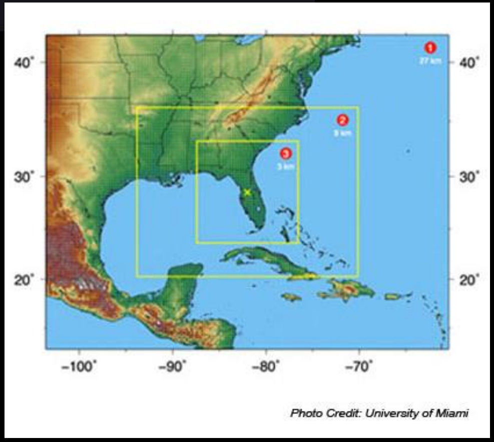


Photo Credit: University of Miami

Michael E. Mann

Departments of Meteorology & Geosciences; Earth & Environmental Systems Institute

Penn State University

USGS-FAU Precipitation Downscaling Technical Meeting

Florida Center for Environmental Studies (CES)

Florida Atlantic University

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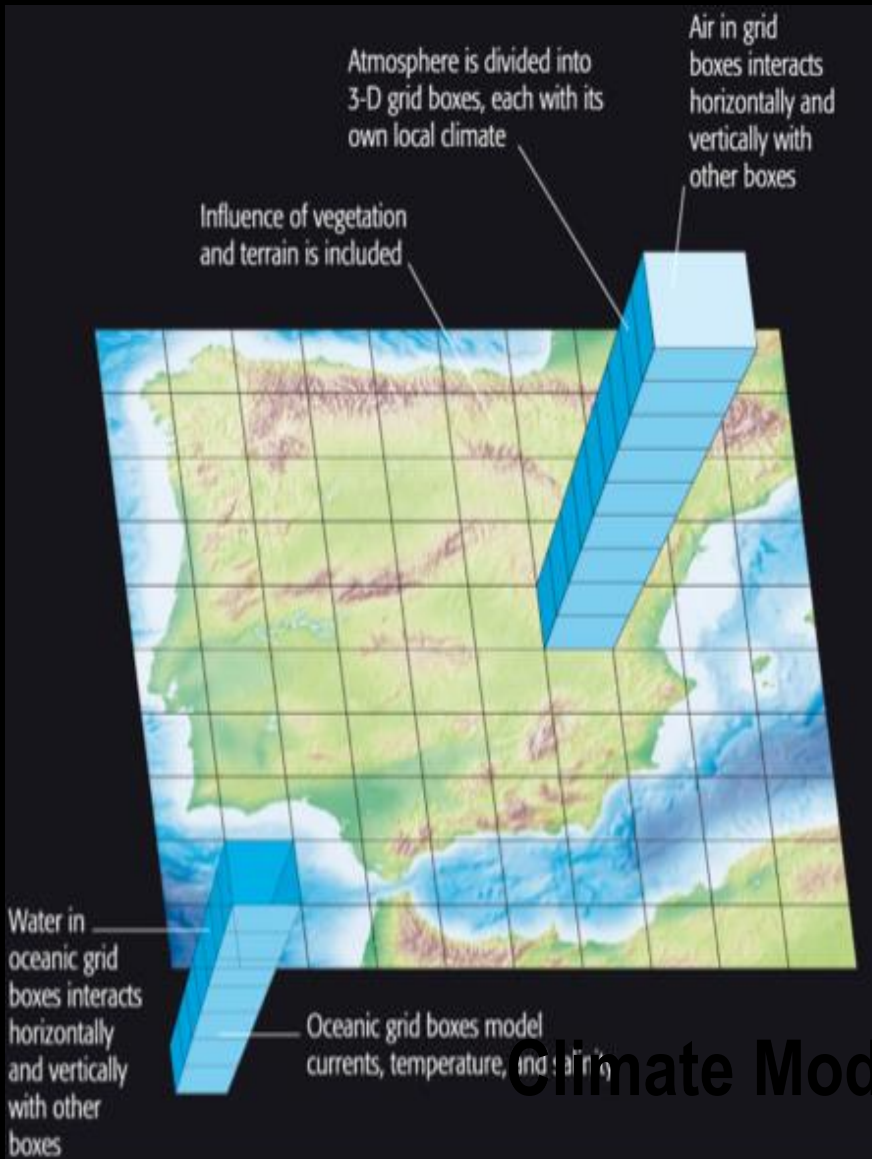
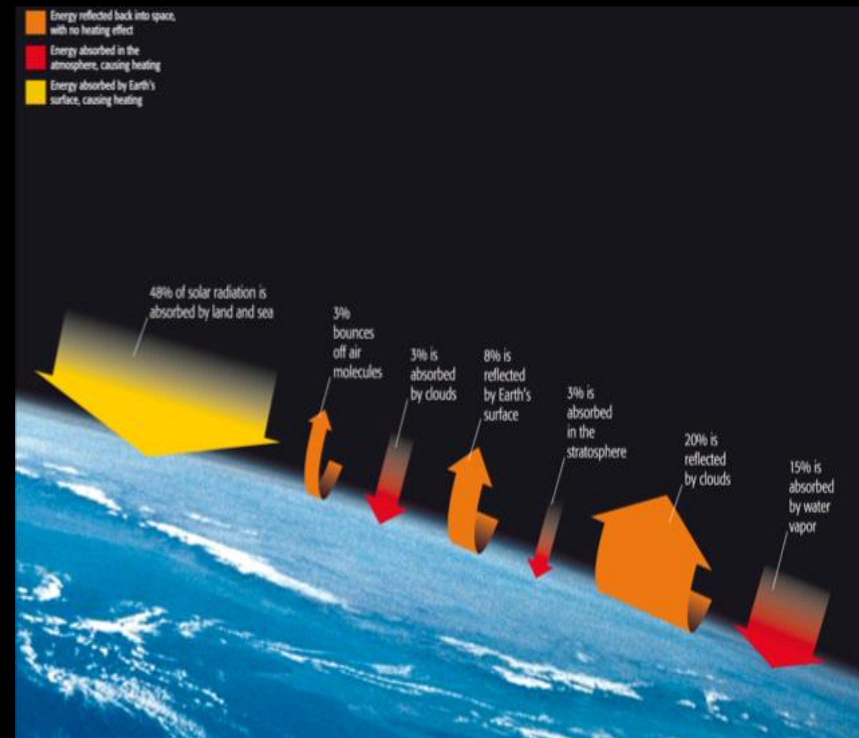
Jun 22, 2015

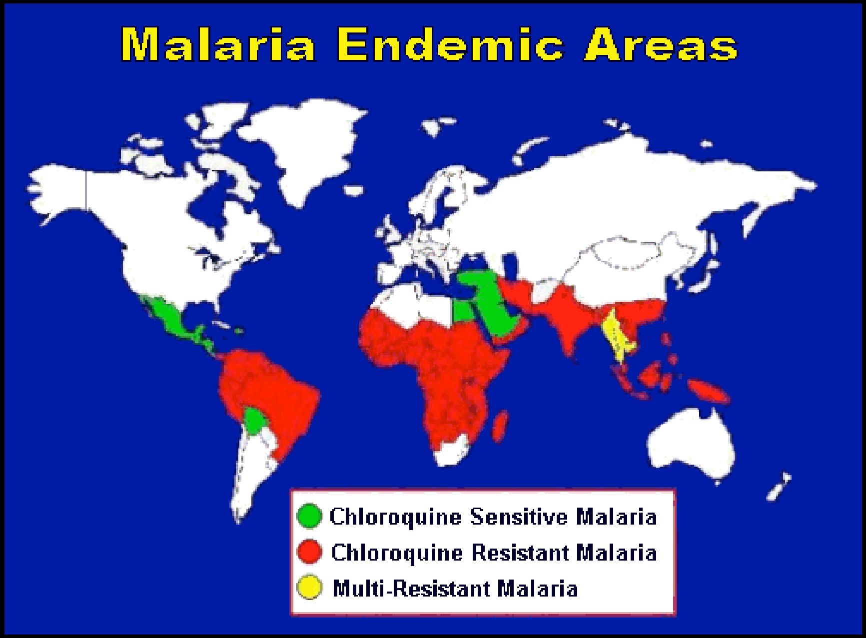
Climate Change Impacts

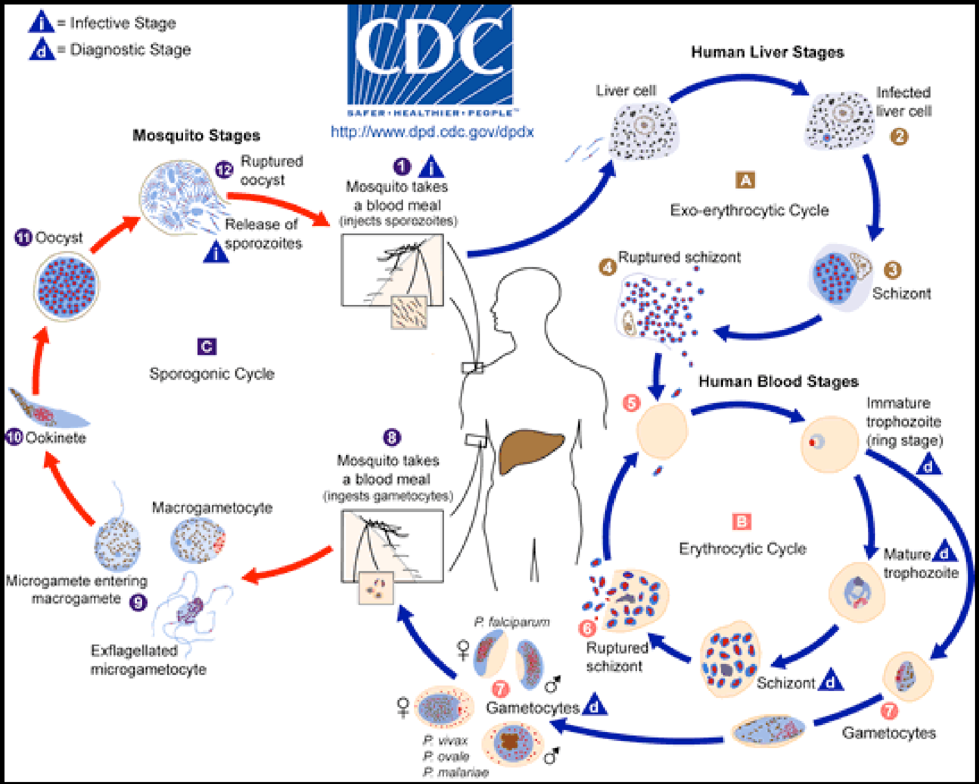


Climate Mod



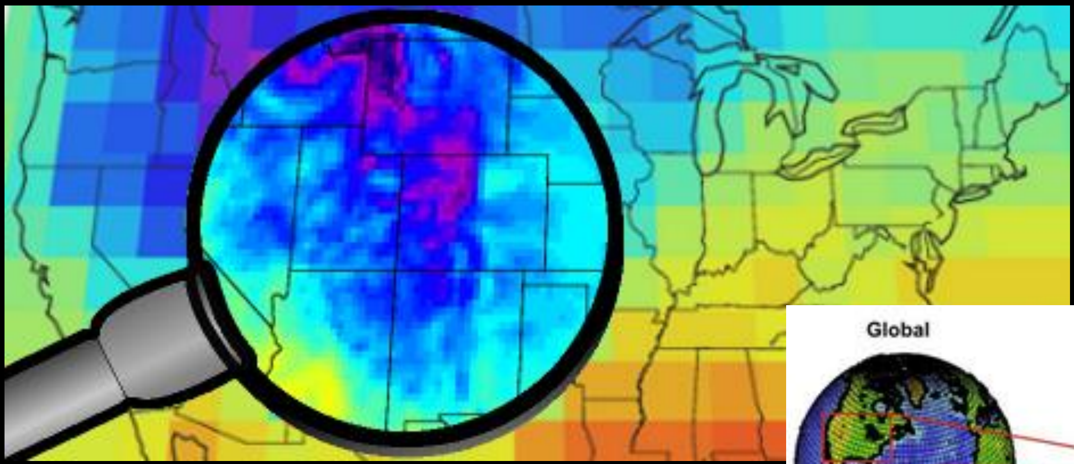
Human Health

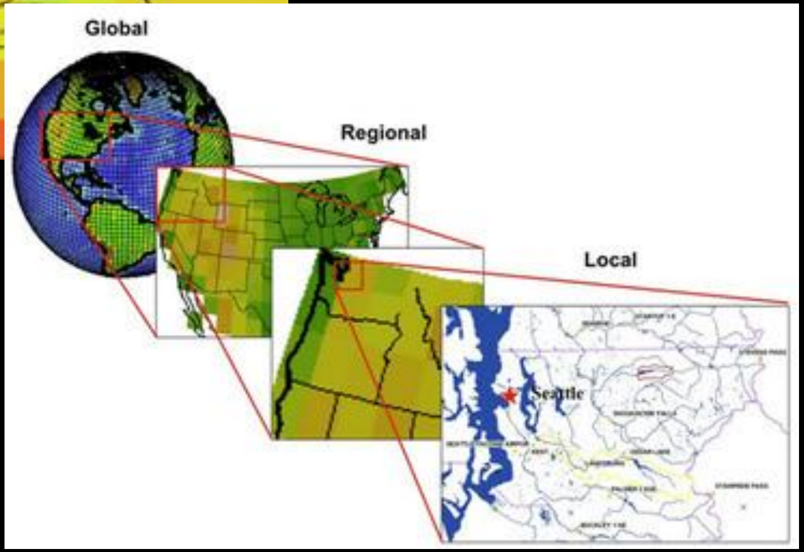




Energy & Water

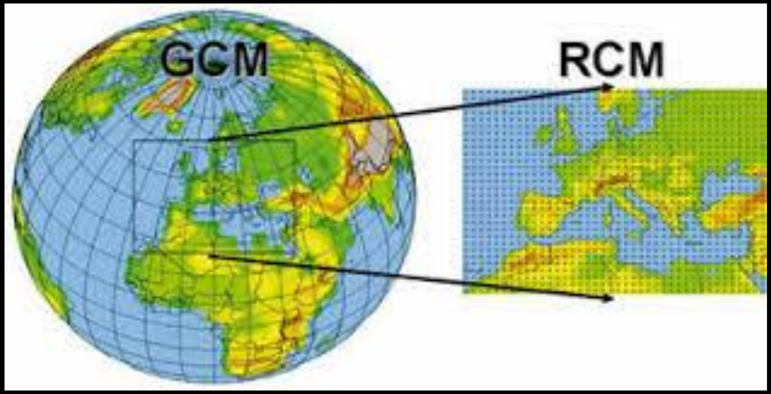
Downscaling!

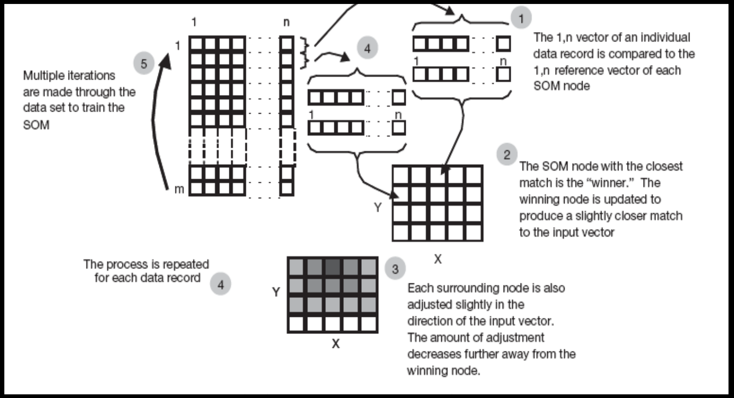




Dynamical or Statistical?

Downscaling!





Dynamical or Statistical?

Self-Organizing Maps

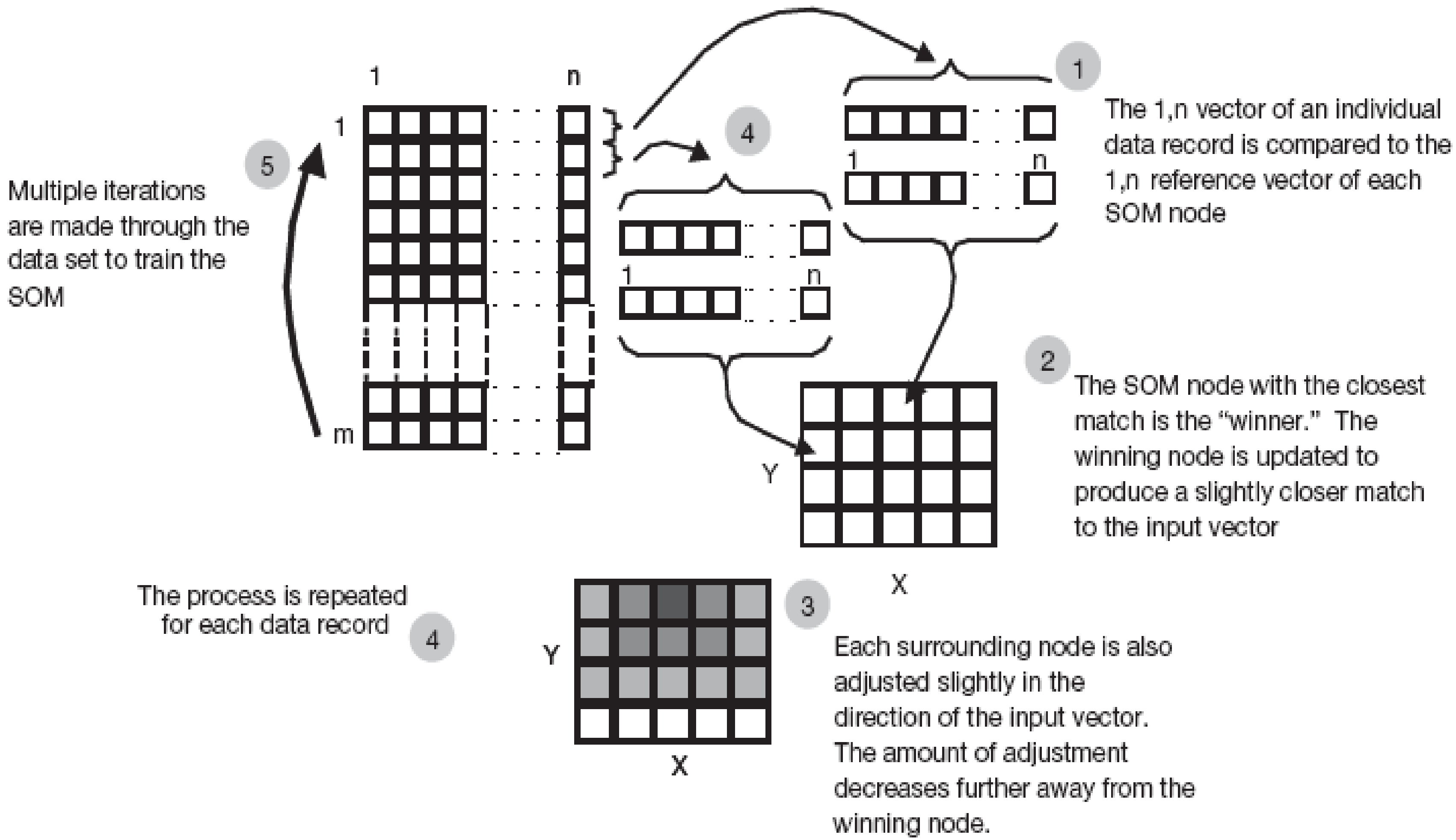
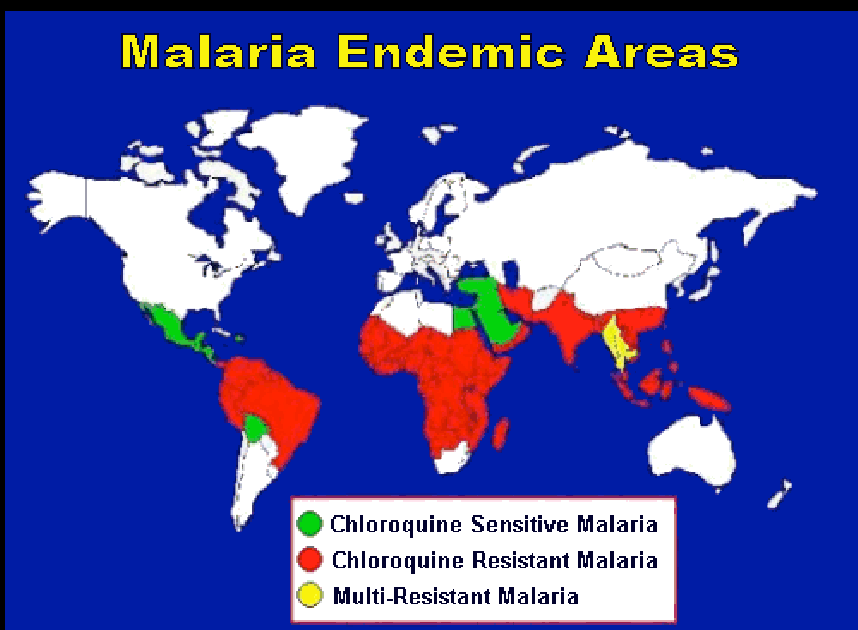
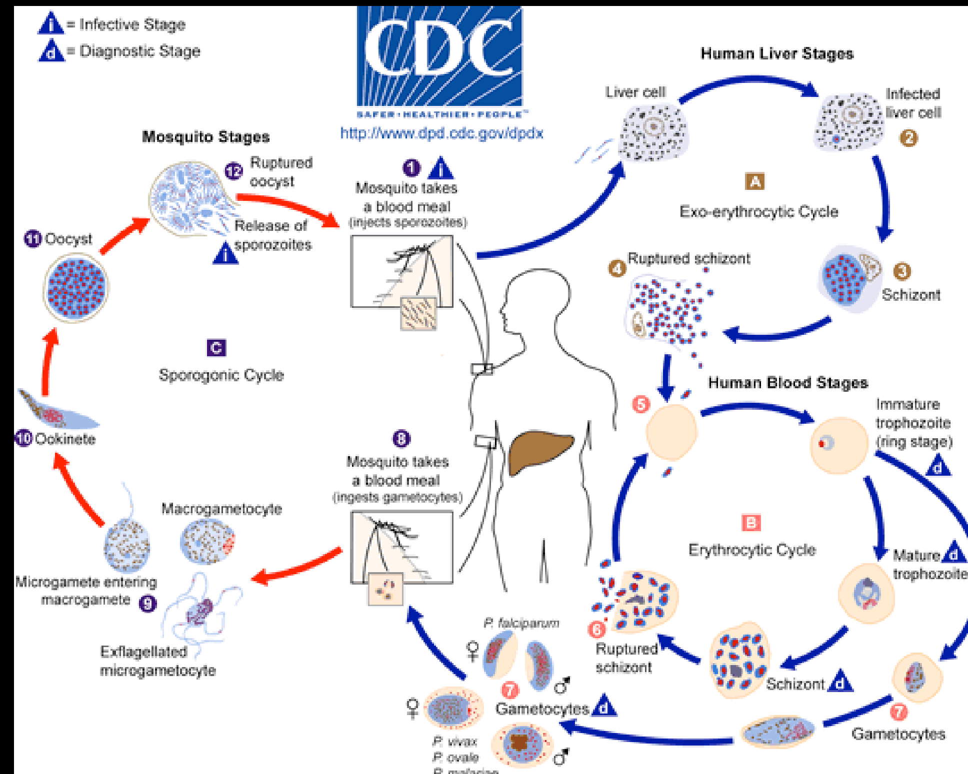


Fig. 1. The iterative self-organizing map (SOM) training procedure

(Crane and Hewitson, 2003)

Human Health





Downscaling: spread of Malaria in Africa

Quantifying the Influence of Environmental Temperature on Transmission of Vector-borne Diseases

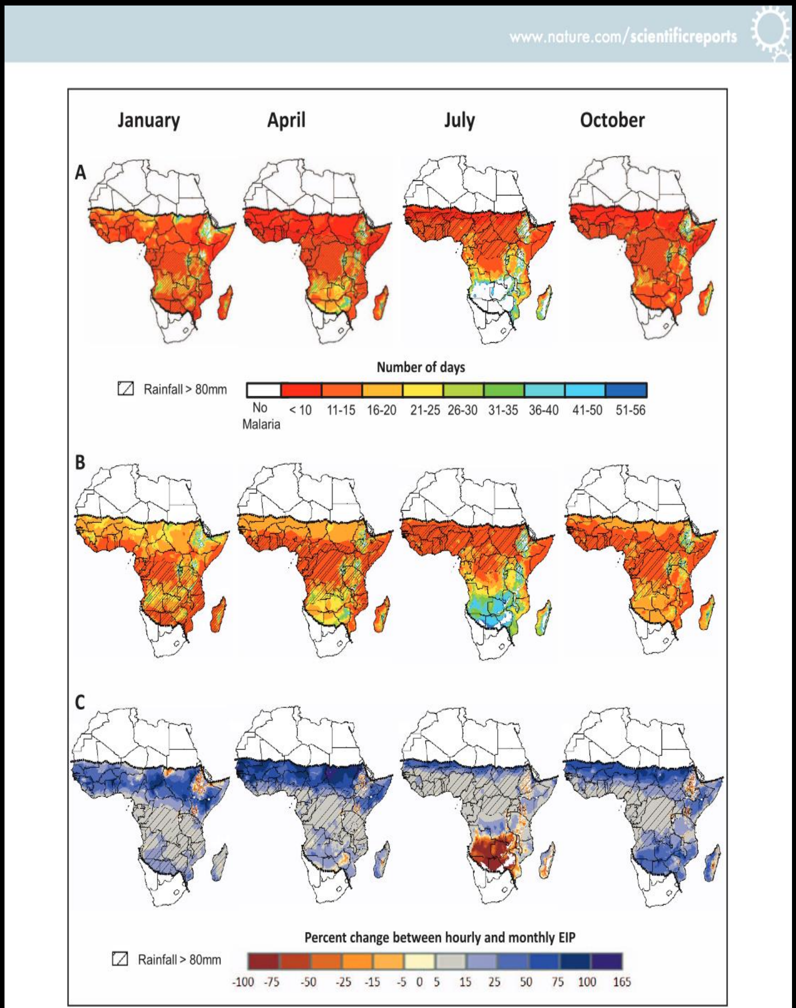
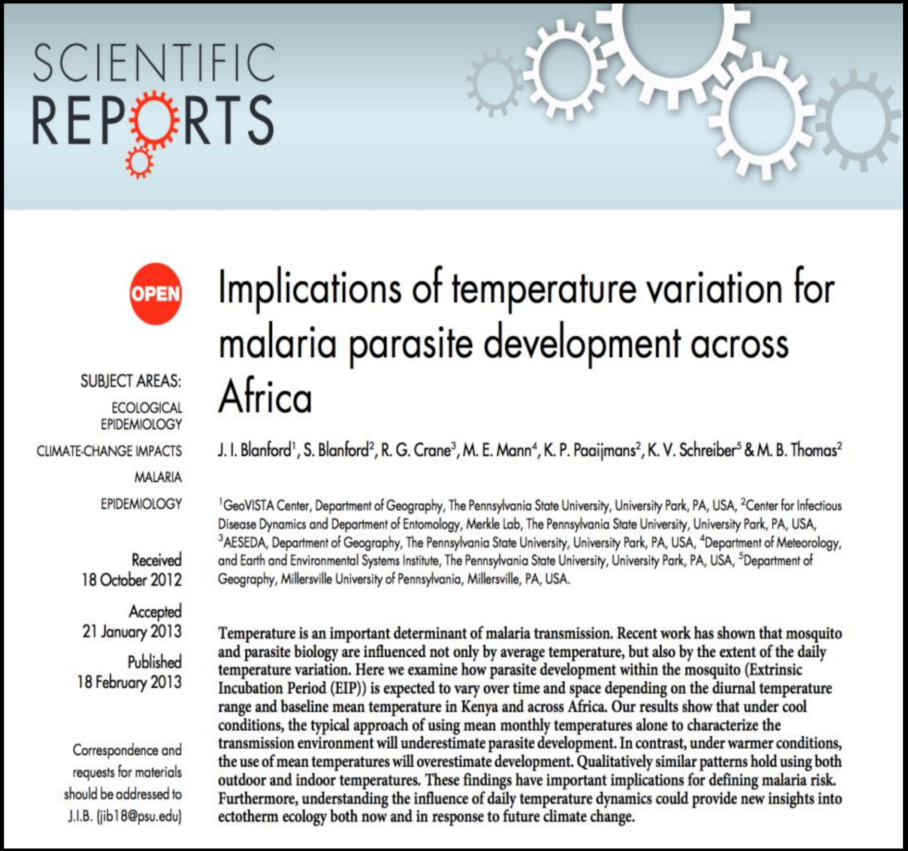


Figure 5 | Maps illustrating number of days for malaria to become transmittable across Africa within the defined malaria transmission zone utilizing outdoor temperature. Maps A, B and C as in Figure 4.



SCIENTIFIC REPORTS

OPEN

Implications of temperature variation for malaria parasite development across Africa

SUBJECT AREAS:
ECOLOGICAL EPIDEMIOLOGY
CLIMATE-CHANGE IMPACTS
MALARIA
EPIDEMIOLOGY

Received
18 October 2012

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J. I. Blanford[1], S. Blanford[2], R. G. Crane[3], M. E. Mann[4], K. P. Paaijmans[2], K. V. Schreiber[5] & M. B. Thomas[2]

[1]GeoVISTA Center, Department of Geography, The Pennsylvania State University, University Park, PA, USA, [2]Center for Infectious Disease Dynamics and Department of Entomology, Merkle Lab, The Pennsylvania State University, University Park, PA, USA, [3]AESEDA, Department of Geography, The Pennsylvania State University, University Park, PA, USA, [4]Department of Meteorology, and Earth and Environmental Systems Institute, The Pennsylvania State University, University Park, PA, USA, [5]Department of Geography, Millersville University of Pennsylvania, Millersville, PA, USA.

Temperature is an important determinant of malaria transmission. Recent work has shown that mosquito and parasite biology are influenced not only by average temperature, but also by the extent of the daily temperature variation. Here we examine how parasite development within the mosquito (Extrinsic Incubation Period (EIP)) is expected to vary over time and space depending on the diurnal temperature range and baseline mean temperature in Kenya and across Africa. Our results show that under cool conditions, the typical approach of using mean monthly temperatures alone to characterize the transmission environment will underestimate parasite development. In contrast, under warmer conditions, the use of mean temperatures will overestimate development. Qualitatively similar patterns hold using both outdoor and indoor temperatures. These findings have important implications for defining malaria risk. Furthermore, understanding the influence of daily temperature dynamics could provide new insights into ectotherm ecology both now and in response to future climate change.

Downscaling: spread of Malaria in Africa

Climatic Change (2014) 125:479–488
DOI 10.1007/s10584-014-1172-6

Downscaling reveals diverse effects of anthropogenic climate warming on the potential for local environments to support malaria transmission

Krijn P. Paaijmans • Justine I. Blanford • Robert G. Crane • Michael E. Mann • Liang Ning • Kathleen V. Schreiber • Matthew B. Thomas

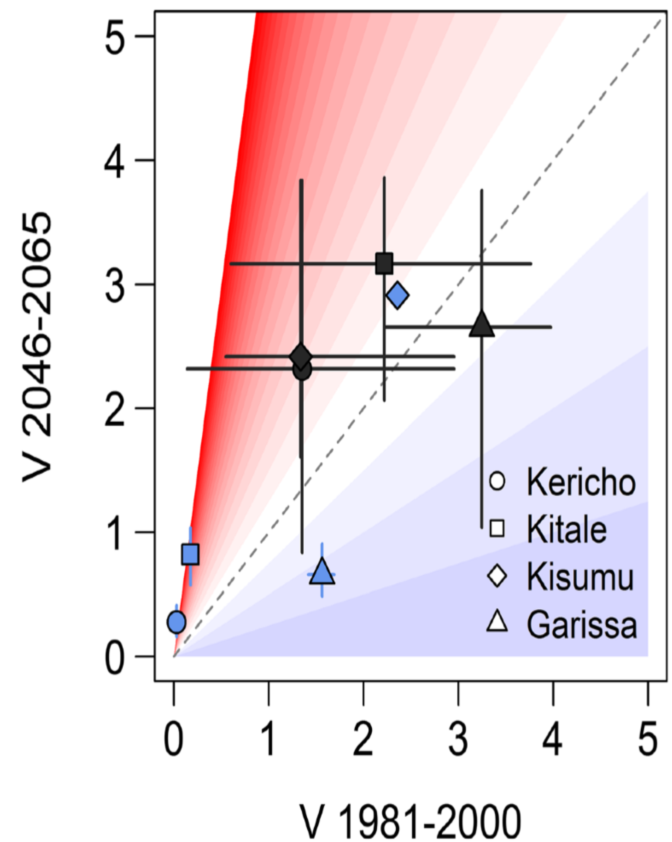
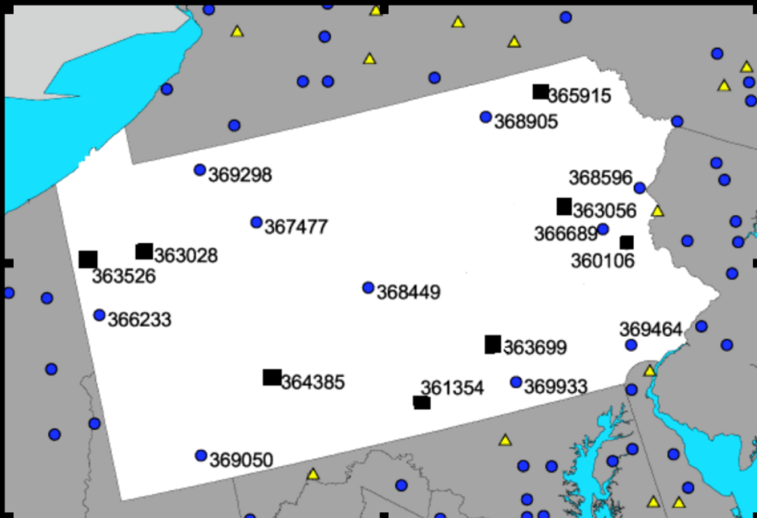
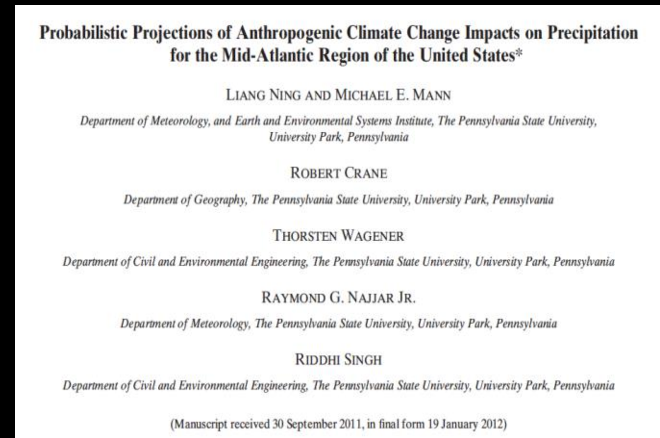


Fig. 3 Scatter plot of Lifetime Transmission Potential (*V*) for present day (x-axis) vs future (Y-axis) as predicted by raw GCMs based on mean temperatures (*black symbols*) and downscaled climate models based on DTRs (*blue symbols*) for 4 sites across Kenya. Data points represent 20-years average from the ensemble of models, the bars represent the range between lowest and highest average predicted by an individual model. Data above the dashed grey diagonal line indicate an increase in *V* as a result of warming, while data below the line indicate a decrease. Colored contours indicate increases (*red*) or decreases (*blue*) in *V* at 25% intervals (contours read vertically). The last red contour line represents a 500% increase

Energy & Water

Downscaling Precipitation in PA




Probabilistic Projections of Anthropogenic Climate Change Impacts on Precipitation for the Mid-Atlantic Region of the United States*

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Department of Meteorology, and Earth and Environmental Systems Institute, The Pennsylvania State University, University Park, Pennsylvania

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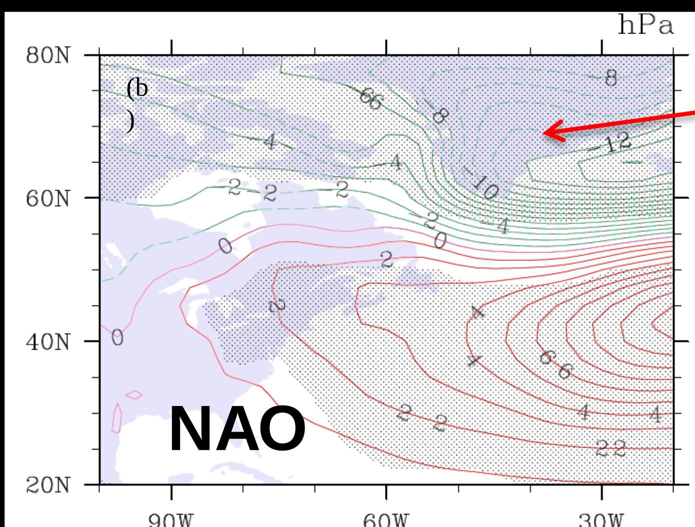
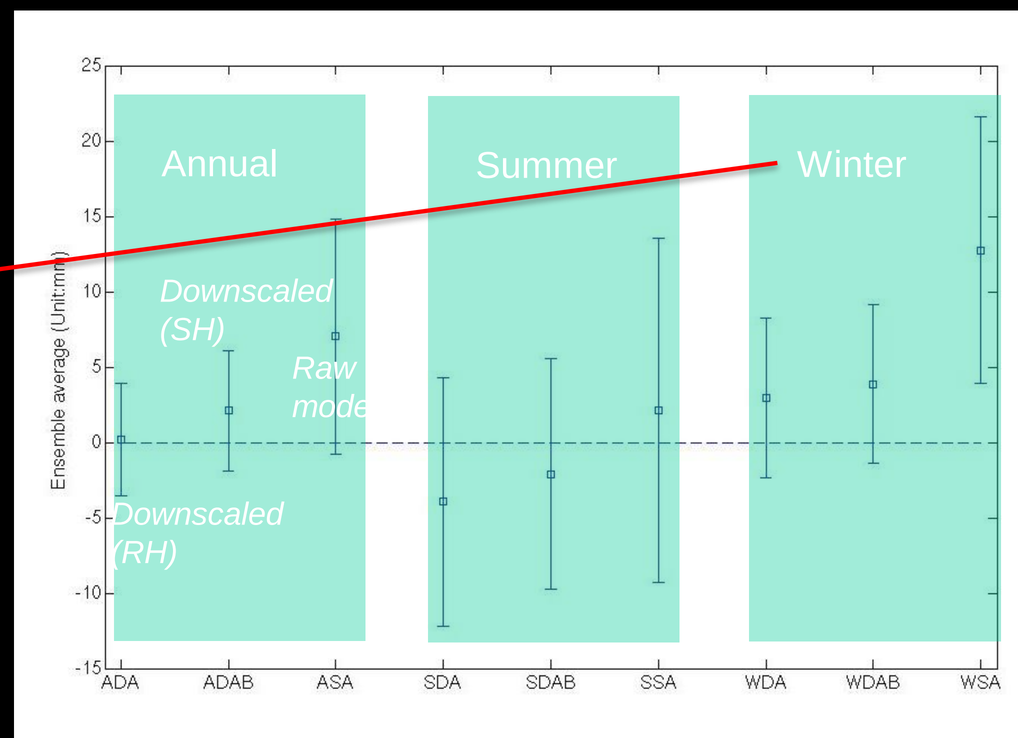
RIDDHI SINGH

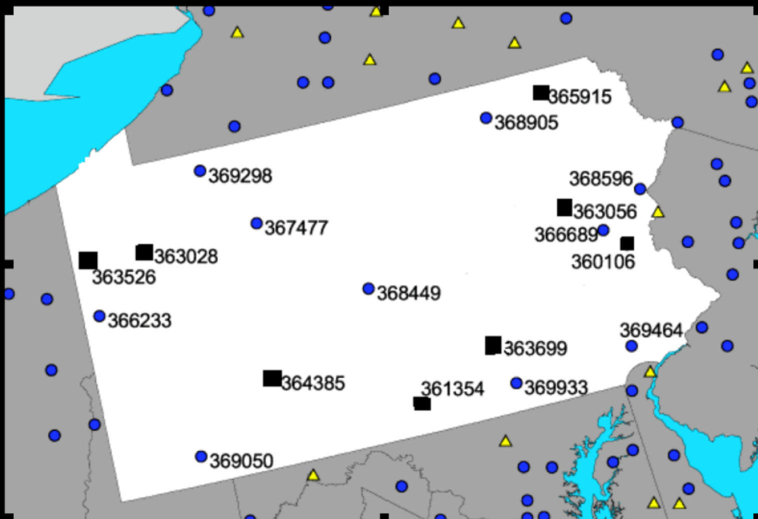
Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, Pennsylvania

(Manuscript received 30 September 2011, in final form 19 January 2012)





Downscaling Precipitation in PA



Hydrol. Earth Syst. Sci., 15, 3591–3603, 2011
www.hydrol-earth-syst-sci.net/15/3591/2011/
doi:10.5194/hess-15-3591-2011

Hydrology and Earth System Sciences

A trading-space-for-time approach to probabilistic continuous streamflow predictions in a changing climate – accounting for changing watershed behavior

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[2]Systech Water Resources, Inc., Walnut Creek, CA, USA
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Received: 24 June 2011 – Published in Hydrol. Earth Syst. Sci. Discuss.: 1 July 2011
Revised: 27 September 2011 – Accepted: 9 November 2011 – Published: 29 November 2011

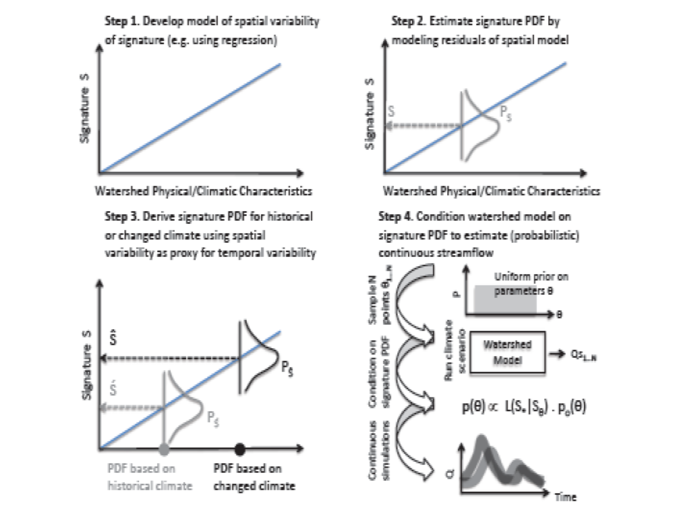


Fig. 1. The four step procedure for deriving probability distributions of streamflow for climate scenarios. In Step 2, S a signature and P_S is the probability associated with a signature value. In Step 3, $\acute{S}$ and $P_{\acute{S}}$ correspond to the distribution based on historical climate and $\hat{S}$ and $P_{\hat{S}}$ correspond to the distribution based on changed climate. In Step 4, θ represents the model parameters, $Qs_{1...N}$ represents the model simulations, S_* is the expected value of the signature derived from the regionalized relationship and S_θ is the value of the signature for the parameter θ.

Downscaling Precipitation in PA

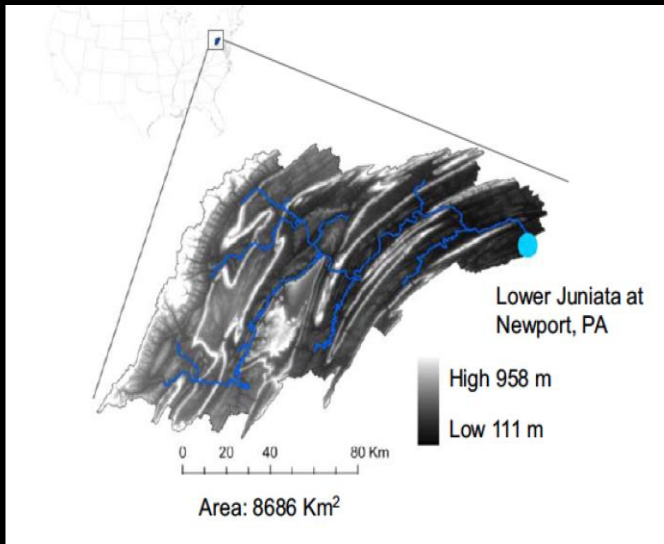


Figure 4. Study area: The Lower Juniata watershed and the location of the streamflow gauge.

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2013WR014988

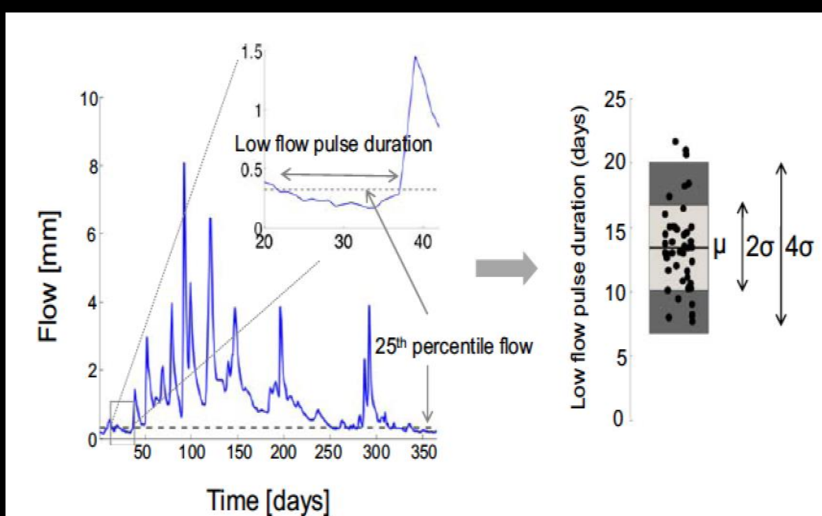
Key Points:

- Method provides valuable information to decision maker in large uncertainties
- Stakeholders define critical thresholds for hydrologic indicators of interest
- We identify land use and climate change combinations that cause vulnerability

A vulnerability driven approach to identify adverse climate and land use change combinations for critical hydrologic indicator thresholds: Application to a watershed in Pennsylvania, USA

R. Singh[1], T. Wagener[2], R. Crane[3], M. E. Mann[4], and L. Ning[5]

[1]Earth and Environmental Systems Institute, Pennsylvania State University, University Park, Pennsylvania, USA, [2]Department of Civil Engineering, University of Bristol, Bristol, UK, [3]Department of Geography, Pennsylvania State University, University Park, Pennsylvania, USA, [4]Department of Meteorology, Pennsylvania State University, University Park, Pennsylvania, USA, [5]Northeast Climate Science Center, Department of Geosciences, University of Massachusetts-Amherst, Amherst, Massachusetts, USA



For warming within the projected range of 3-6C, even very small decreases in summer precipitation (5% or so) could push runoff into a vulnerable regime, with substantially more frequent low-flow conditions that, along w/ warmer stream temperatures, threaten nuclear & fossil fuel energy plants.

Downscaling Procedure

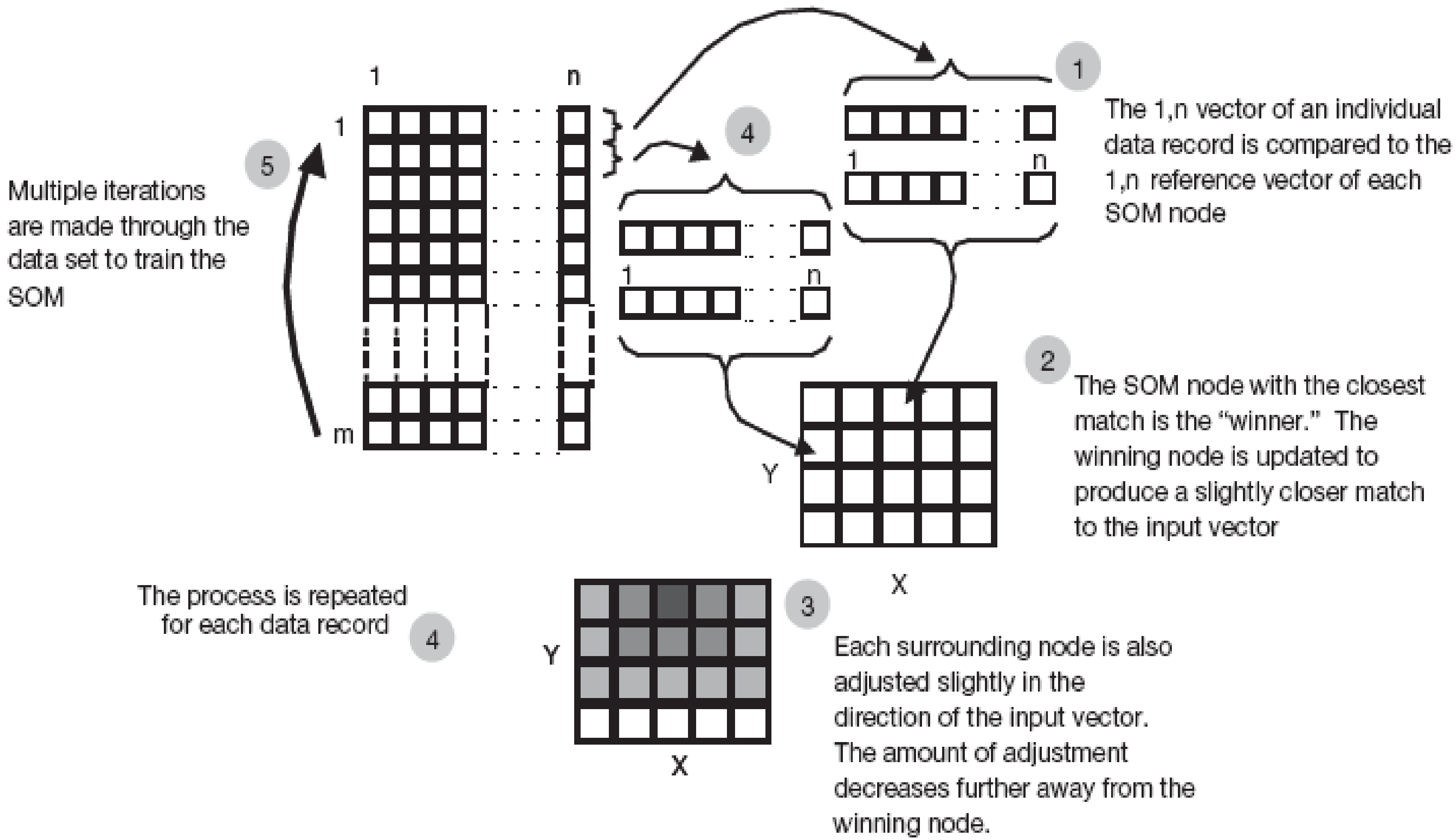


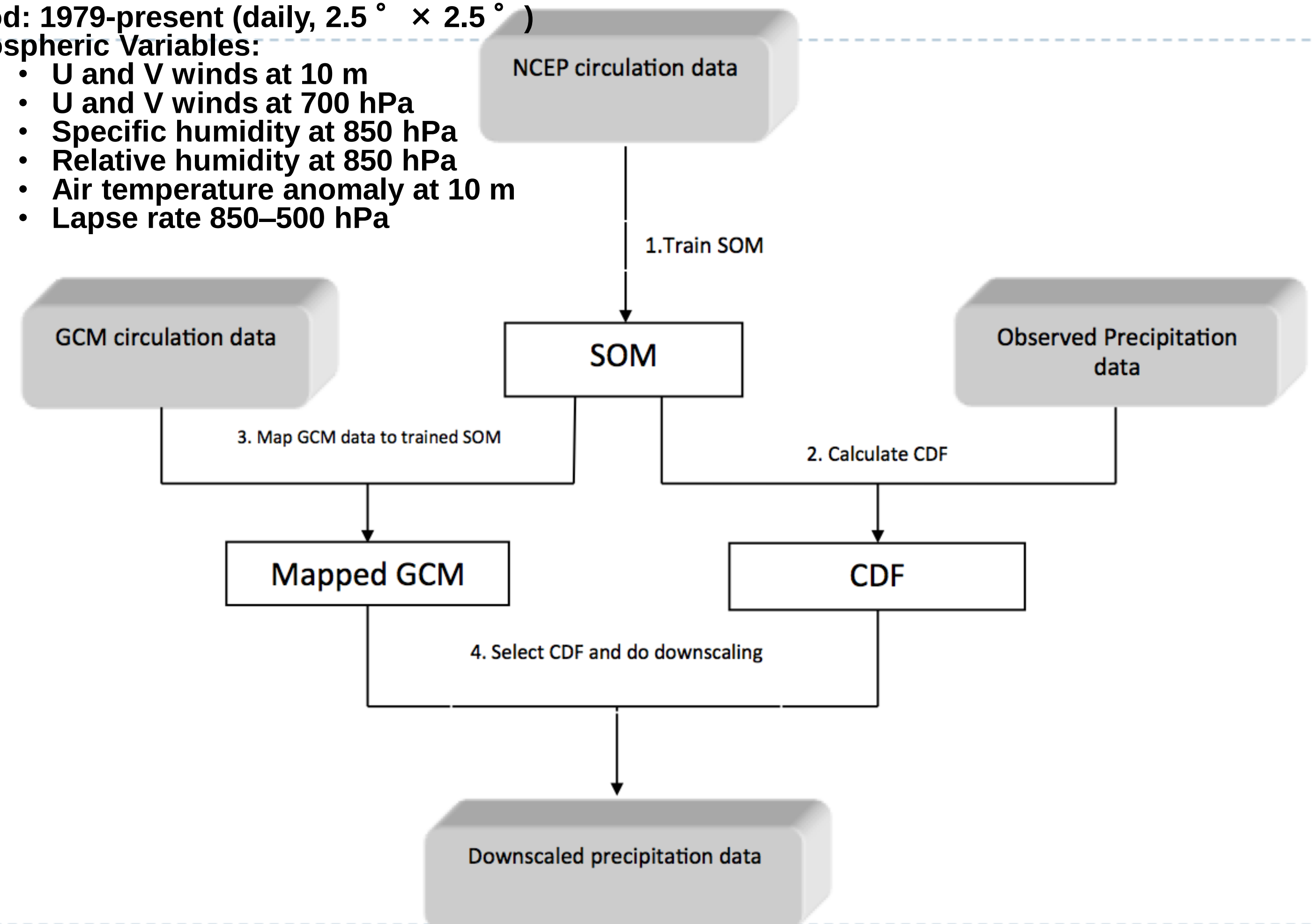
Fig. 1. The iterative self-organizing map (SOM) training procedure

(Crane and Hewitson, 2003)

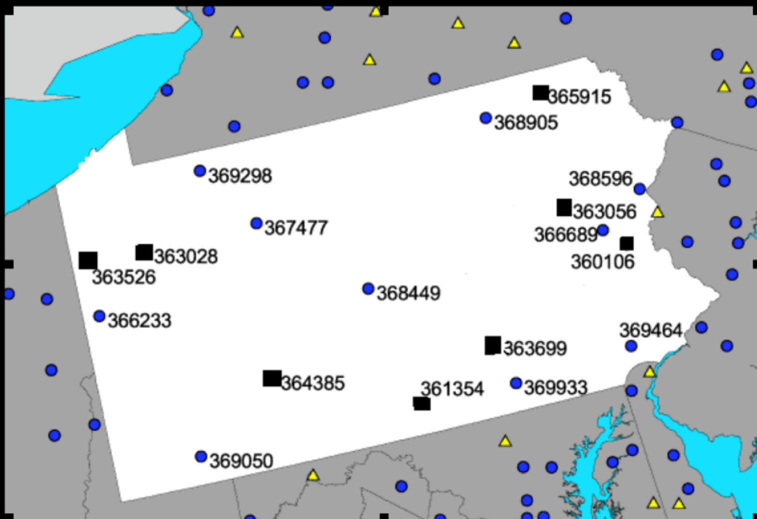
Downscaling Procedure

Period: 1979-present (daily, 2.5° × 2.5°)
Atmospheric Variables:

- U and V winds at 10 m
- U and V winds at 700 hPa
- Specific humidity at 850 hPa
- Relative humidity at 850 hPa
- Air temperature anomaly at 10 m
- Lapse rate 850–500 hPa



Downscaling Precipitation in PA



15 January 2012 NING ET AL. 509

Probabilistic Projections of Climate Change for the Mid-Atlantic Region of the United States: Validation of Precipitation Downscaling during the Historical Era*

LIANG NING AND MICHAEL E. MANN

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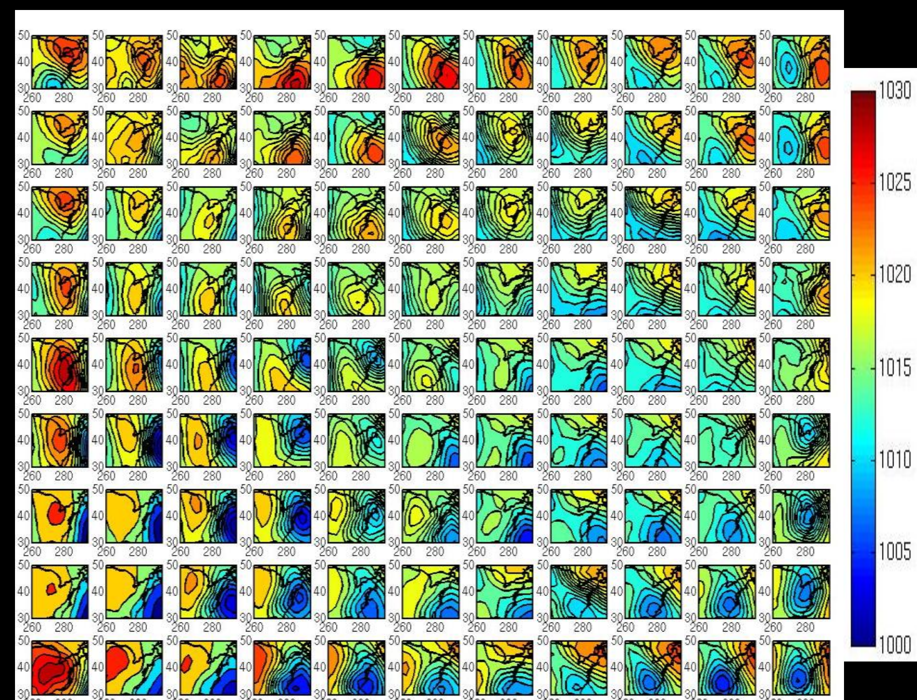
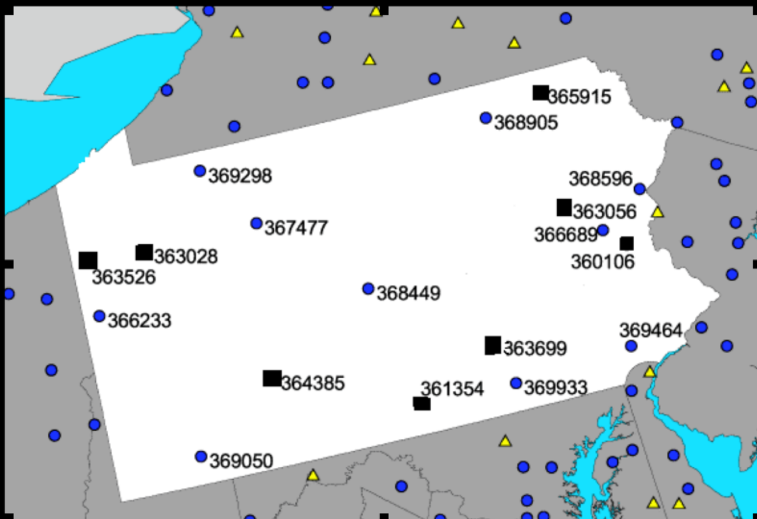


Self-Organizing Maps ("SOM"s) – SLP Patterns

Downscaling Precipitation in PA



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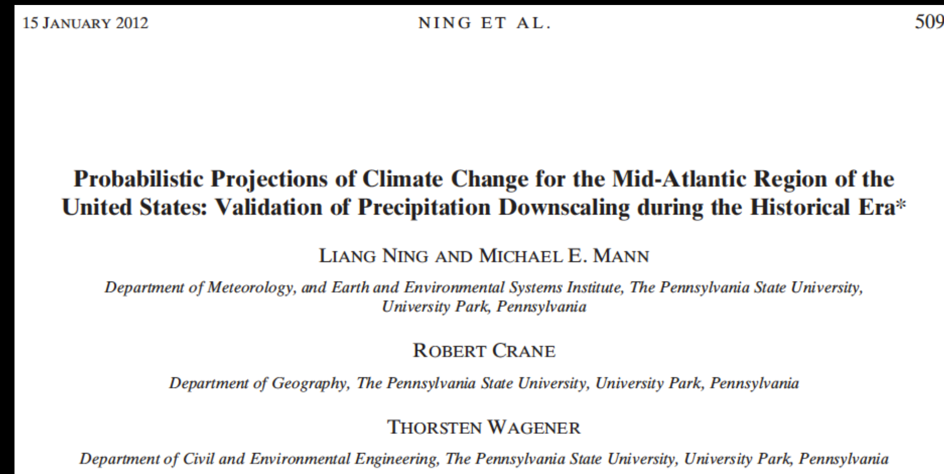
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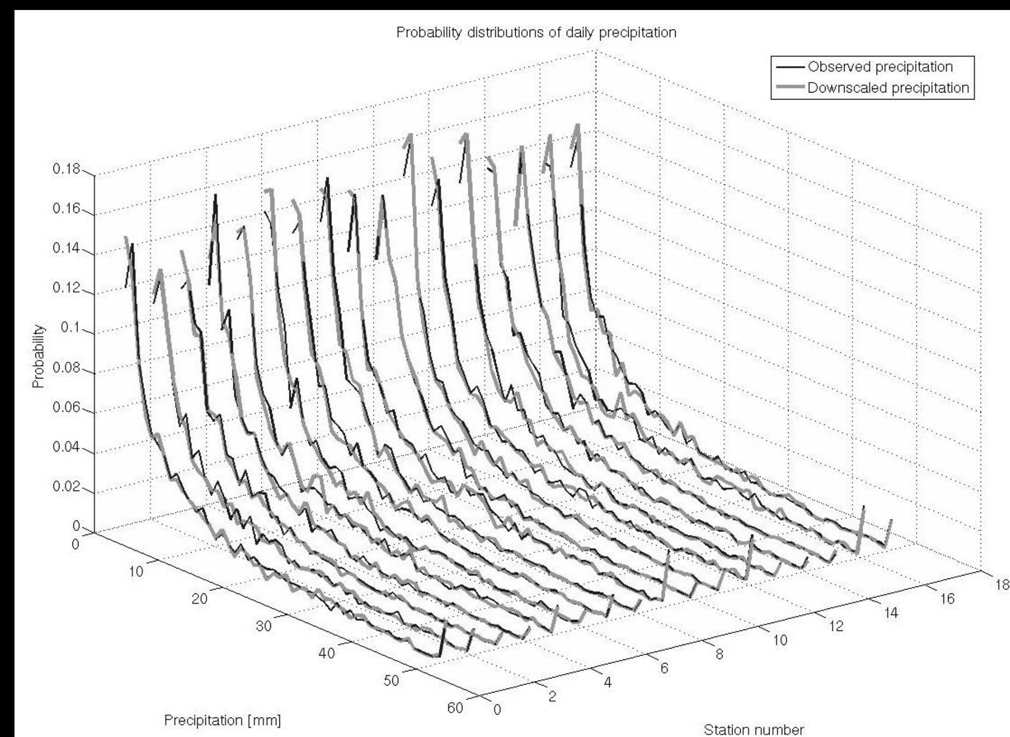
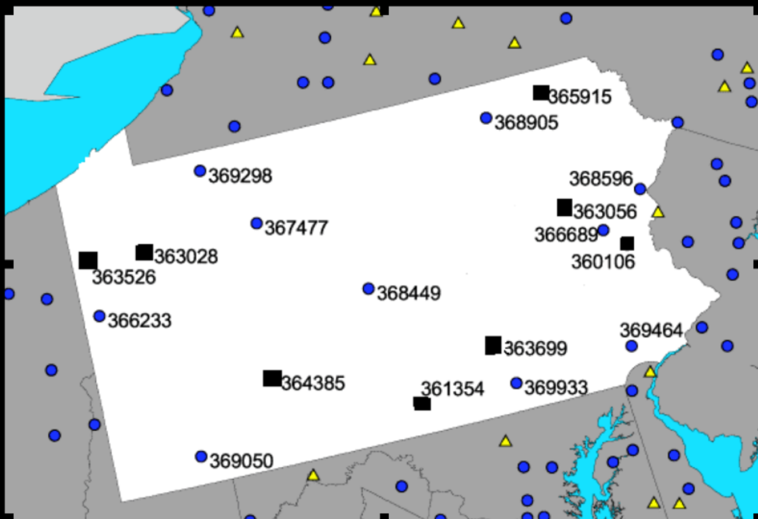


Downscaling Precipitation in PA



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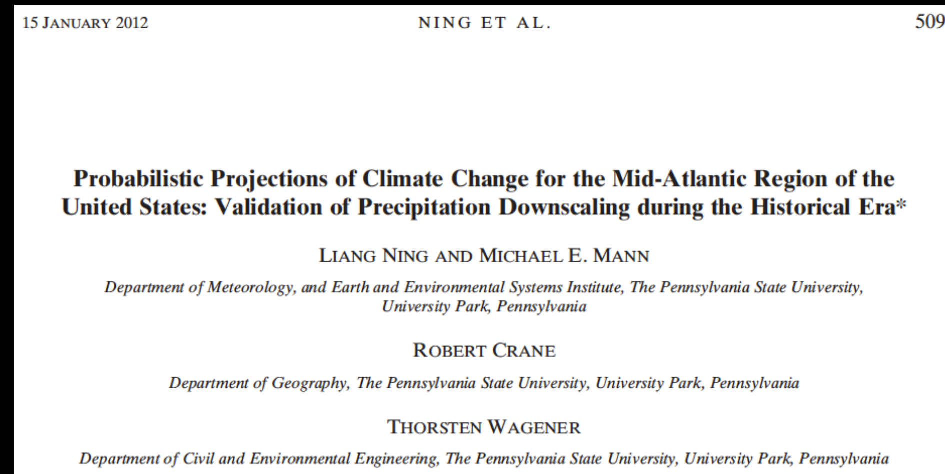

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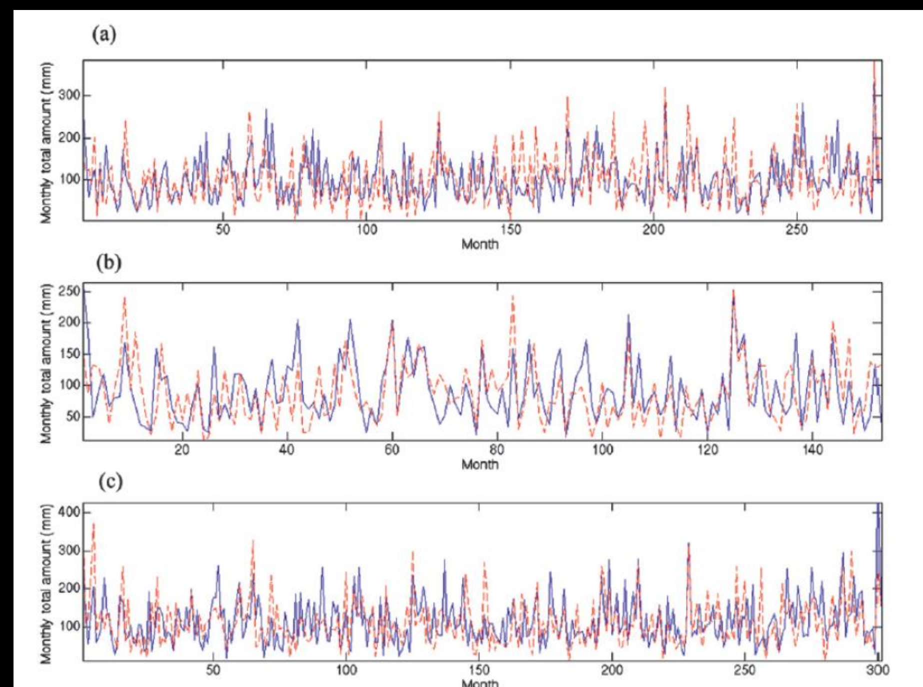
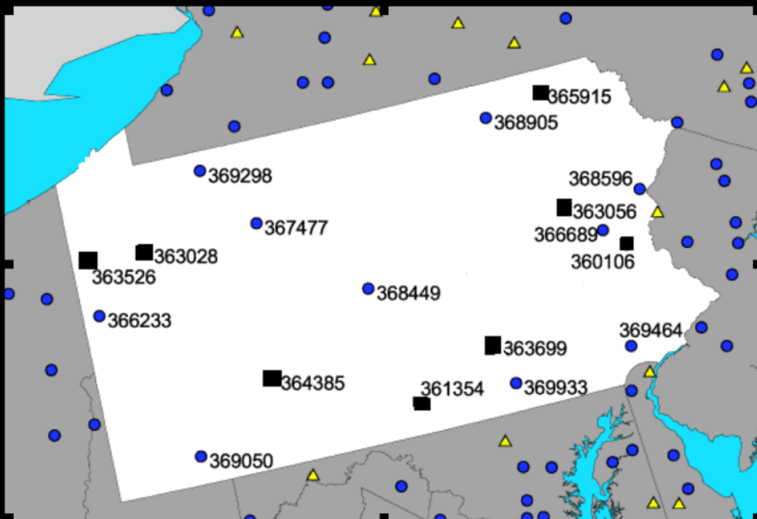
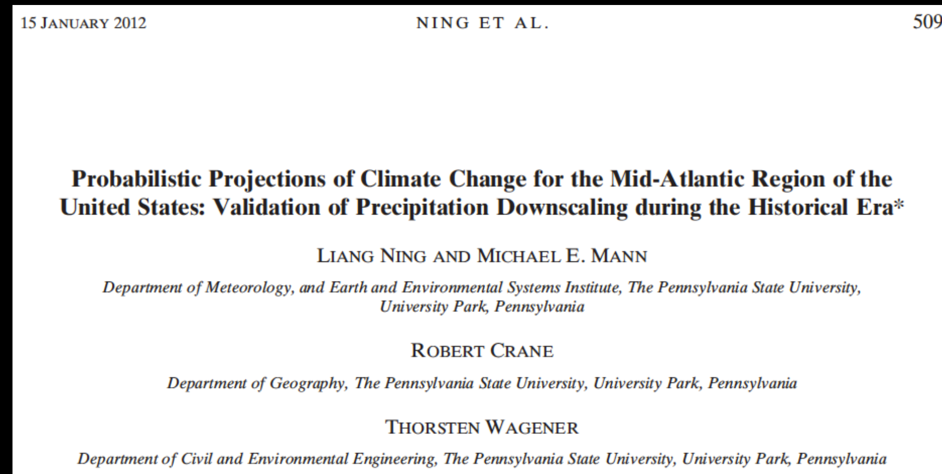


FIG. 9. Observed (blue) and downscaled (red) monthly precipitation amount time series for period 1979–2005 over stations (a) Allentown, (b) Harrisburg, and (c) Towanda (mm).

Downscaling Precipitation in PA

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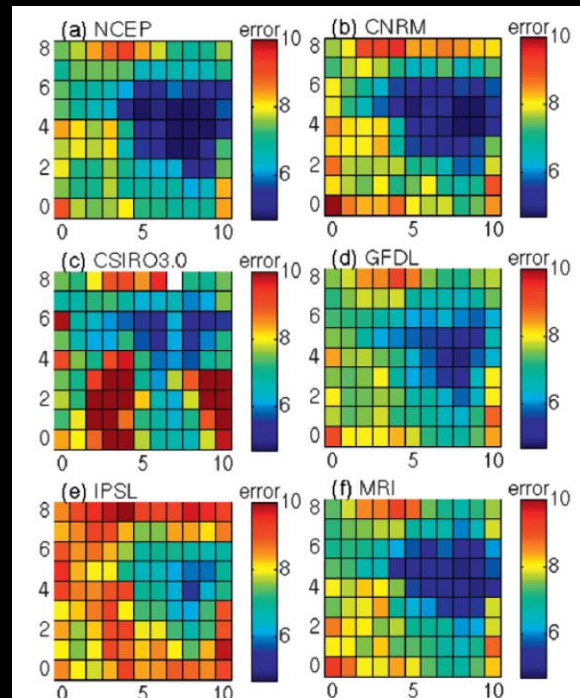
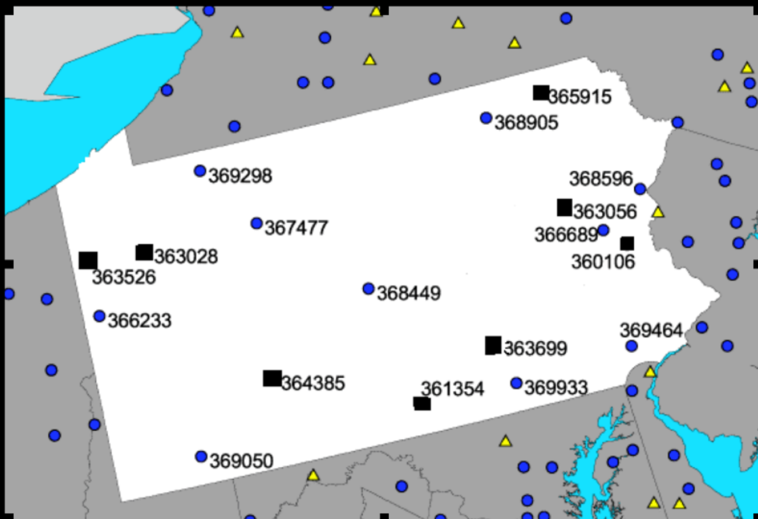


Fig. 4. Average quantization error distributions across the SOM nodes for atmospheric circulation from (a) NCEP and models (b) CNRM, (c) CSIRO, (d) GFDL, (e) IPSL, and (f) MPI centered on 40.0°N, 76.5°W.

Downscaling Precipitation in PA



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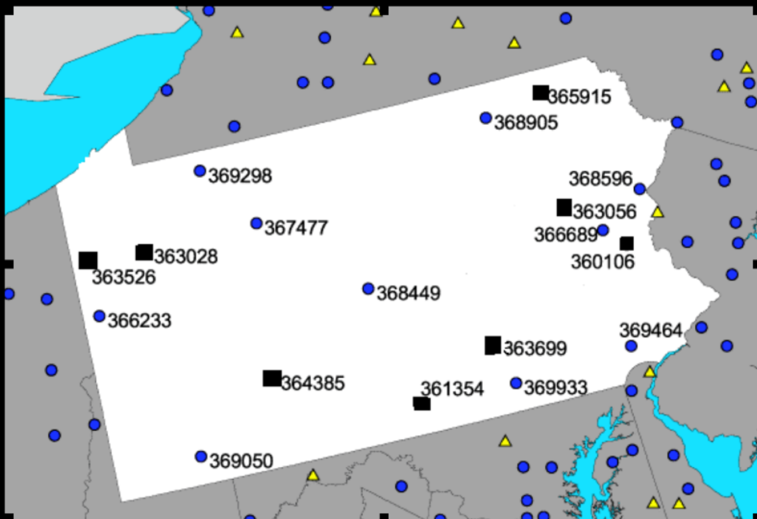
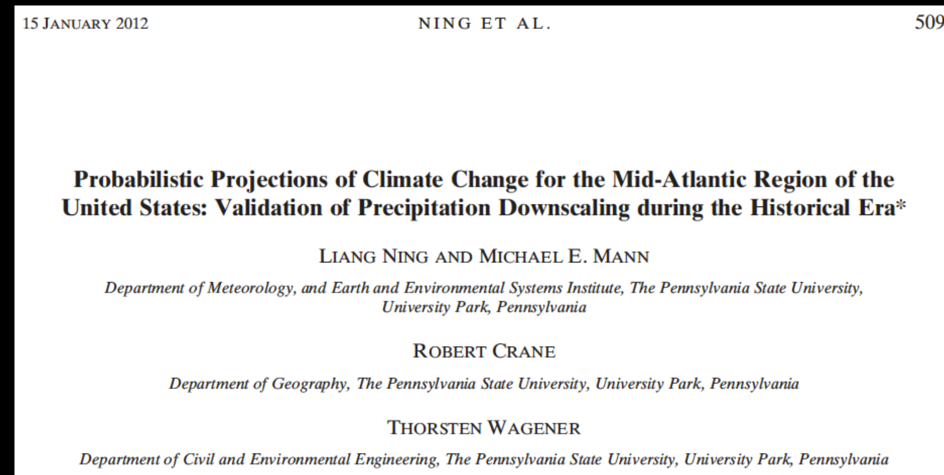
Liang Ning

TABLE 2. Ratio of mean-square errors (MSEs) (relative to the observed daily precipitation values) using mean downscaled estimates and climatological mean values.

Station	Spring	Summer	Autumn	Winter	Annual
Allentown	0.72	0.90	0.77	0.70	0.78
Chambersburg	0.77	0.87	0.78	0.72	0.78
Franklin	0.82	0.88	0.83	0.79	0.84
Greenville	0.82	0.85	0.82	0.81	0.83
Harrisburg	0.75	0.91	0.76	0.71	0.78
Johnstown	0.79	0.88	0.81	0.84	0.84
Montrose	0.75	0.86	0.78	0.81	0.79
New Castle	0.83	0.88	0.86	0.80	0.85
Palmerton	0.78	0.89	0.78	0.70	0.80
Ridgway	0.81	0.86	0.81	0.79	0.83
State College	0.85	0.86	0.81	0.80	0.83
Stroudsburg	0.70	0.86	0.73	0.70	0.74
Towanda	0.81	0.87	0.81	0.81	0.82
Uniontown	0.83	0.88	0.78	0.84	0.84
Warren	0.80	0.85	0.81	0.80	0.82
West Chester	0.77	0.85	0.80	0.78	0.80
York	0.71	0.87	0.74	0.72	0.76
Avg	0.78	0.87	0.79	0.77	0.81
95% CI	(0.780, 0.788)	(0.870, 0.873)	(0.791, 0.796)	(0.769, 0.776)	(0.806, 0.811)

Downscaling Precipitation in PA





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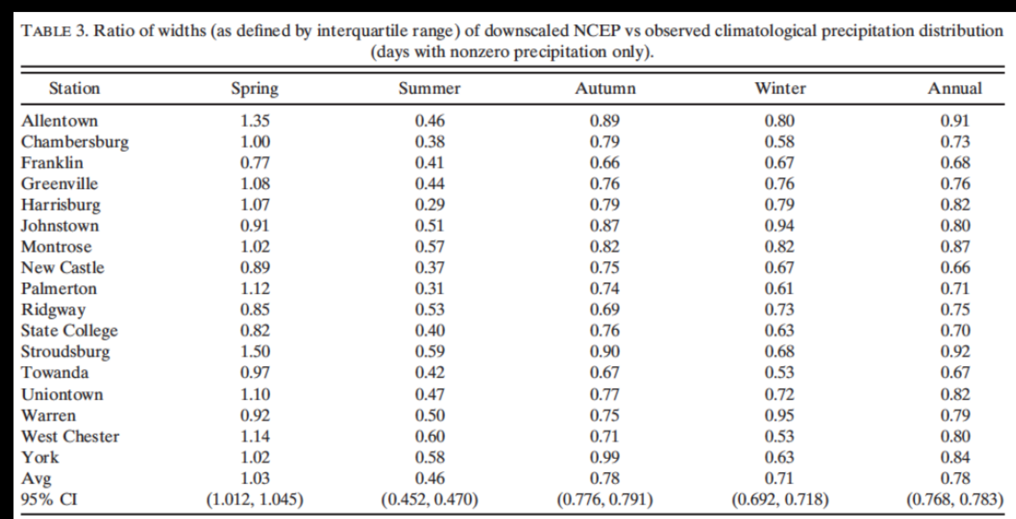

TABLE 3. Ratio of widths (as defined by interquartile range) of downscaled NCEP vs observed climatological precipitation distribution (days with nonzero precipitation only).

Station	Spring	Summer	Autumn	Winter	Annual
Allentown	1.35	0.46	0.89	0.80	0.91
Chambersburg	1.00	0.38	0.79	0.58	0.73
Franklin	0.77	0.41	0.66	0.67	0.68
Greenville	1.08	0.44	0.76	0.76	0.76
Harrisburg	1.07	0.29	0.79	0.79	0.82
Johnstown	0.91	0.51	0.87	0.94	0.80
Montrose	1.02	0.57	0.82	0.82	0.87
New Castle	0.89	0.37	0.75	0.67	0.66
Palmerton	1.12	0.31	0.74	0.61	0.71
Ridgway	0.85	0.53	0.69	0.73	0.75
State College	0.82	0.40	0.76	0.63	0.70
Stroudsburg	1.50	0.59	0.90	0.68	0.92
Towanda	0.97	0.42	0.67	0.53	0.67
Uniontown	1.10	0.47	0.77	0.72	0.82
Warren	0.92	0.50	0.75	0.95	0.79
West Chester	1.14	0.60	0.71	0.53	0.80
York	1.02	0.58	0.99	0.63	0.84
Avg	1.03	0.46	0.78	0.71	0.78
95% CI	(1.012, 1.045)	(0.452, 0.470)	(0.776, 0.791)	(0.692, 0.718)	(0.768, 0.783)

The Everglades

Project Overview

SFWSC

SOUTH FLORIDA WATER, SUSTAINABILITY, AND CLIMATE

Robust decision making for South Florida water resources by ecosystem service valuation, hydro-economic optimization, and conflict resolution

The goal of the National Science Foundation and United States Department of Agriculture Water, Sustainability, and Climate (WSC) Program is to "... understand and predict the interactions between the water system and climate change, land use, the built environment, and ecosystem function and services..."

Motivation

With multiple competing water allocation targets, exposure to extreme climate variability, and vulnerability to sea level rise (SLR), South Florida faces a unique severity and diversity of challenges that lie at the heart of the WSC program.

Every day in South Florida about 7.7 million people, companies, and farms use more than 3 billion gallons of water. With expected population growth and potential climate change impacts, different water use optimization strategies are needed. In order to investigate various strategies, a 5-year $5M WSC project focused on South Florida (the SFWSC) was initiated in 2013. Project researchers seek to develop hydrological and economic criteria for evaluating current and future water use and provide new insights into the value of water resources in the region. With this knowledge, the trade-offs decision-makers face under various climate change, economic, population, and SLR scenarios can be evaluated.

Novel investigations on the behavioral dimensions (e.g., risk perceptions) of decision-making in water resource management and land use planning under different economic and climate scenarios are also being explored.

Objectives

The project's objectives are to: 1) Develop a hydro-economic model for South Florida that optimizes water allocations based on the economic value of water; 2) Develop new information on the economic value of ecosystem services to be incorporated into model formulations; 3) Test management schemes designed to increase the resilience of water resources to climate variability, climate change, and SLR; 4) Engage stakeholders to improve understanding of the cognitive and perceptual biases in risk management and decision-making; and 5) Develop recommendations for adaptive water management that optimize economic and ecological productivity and foster sustained public support.

Approach

A hydro-economic optimization model utilizing a network design, such as the one pictured here (Figure 1) will be developed. The model will be used to examine the hydrologic, economic, and ecological trade-offs inherent to competing management objectives.

Figure 1. Schematic of SFWSC hydro-economic model

Project Support

National Science Foundation
WHERE DISCOVERIES BEGIN

USDA NIFA United States Department of Agriculture National Institute of Food and Agriculture

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Participants

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sfwsc.fiu.edu/Participating_Organizations.html

Water

February 15, 2015

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- Timelines and meetings
- Useful Links
- Post-doc and student opportunities
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Participating Organizations

Florida International University
University of Miami
Michigan Tech
Univertsity of Pennsylvania
Pennsylvania State University
University of Hawaii
University of Florida
Geodesign Technologies
University of South Florida
University of Central Florida
Florida State University
United States Geological Survey
South Florida Water Management District
Geodesign Techechnologies
Lanier Consulting, LLC

coastal Everglades changed in the past century?

Graduate student webinar, 1:30 pm March 28, 2014: Ross Boucek/FIU, *Does freshwater flow alter the distribution, behaviors, and catchability of an*

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Sunday, February 15, 2015

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Researchers to investigate Everglades ecosystem, climate change

February 4, 2013

UNIVERSITY PARK, Pa -- Water management in the Florida Everglades is the focus of a National Science Foundation grant awarded to Jose Fuentes, professor of meteorology.

The project will explore the hydrologic, ecologic and economic impacts of management strategies designed to increase the resilience of the Everglades ecosystem to climate variability, climate change and sea level rise. This research is part of a larger, ongoing project at Florida International University looking at coastal ecology and hydrology. The Penn State award is for five years at $300,514.

With southern Florida's population of 6 million projected to grow to 10 million in 20 years, management of urban fresh water becomes critical. Sea level rise and salt-water intrusion into the water table already impact drinking water supplies and threaten low-lying environments as diverse as Miami Beach and the Everglades.

Fuentes, working with Michael Mann, distinguished professor of meteorology, Penn State, will use regional climate change scenarios to develop management strategies that ensure the resilience of water supplies. The researchers will assess approaches to ensuring effective communication of scientific information to stakeholders in the face of potential biases in cognition and perception. They will also try to determine how regional climate change and variability, and sea level rise will affect the future water supply and its management.

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Mann honored with 2014 Pongo Environmental Award

Mann receives Conservation Achievement Award

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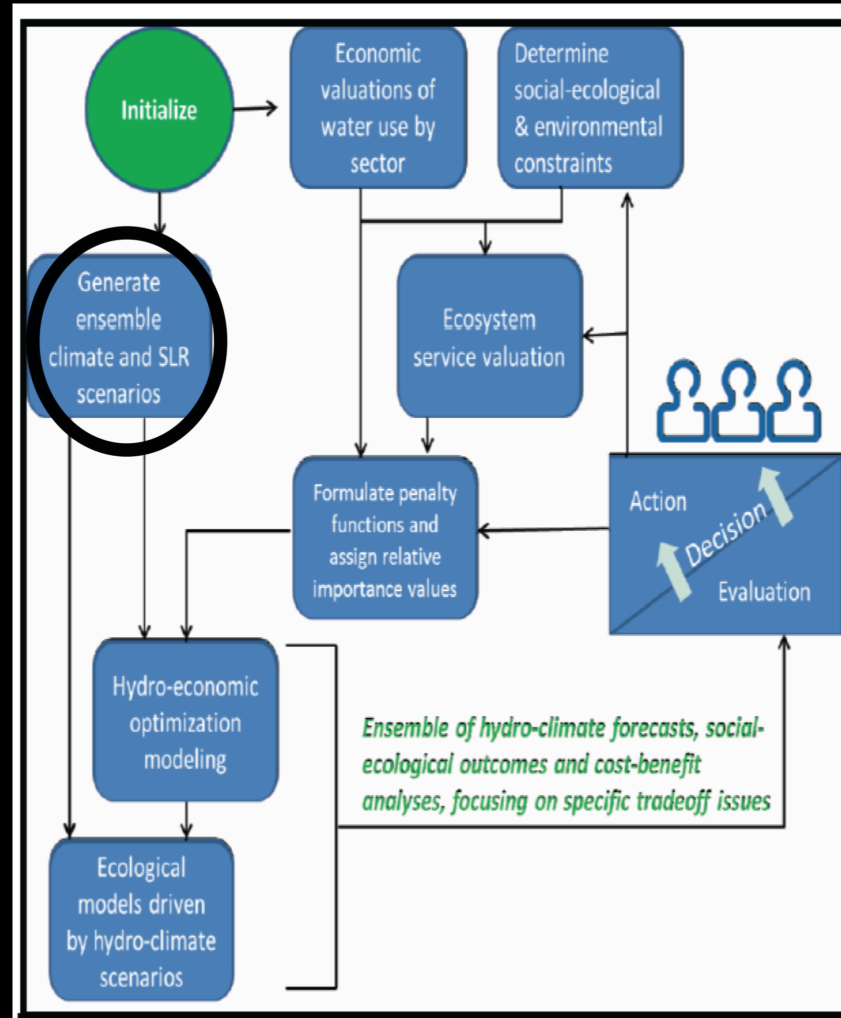
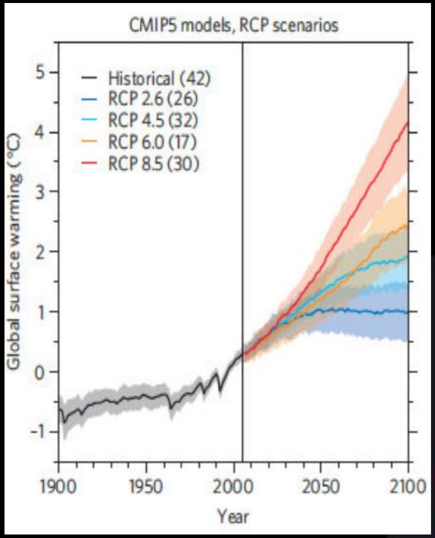
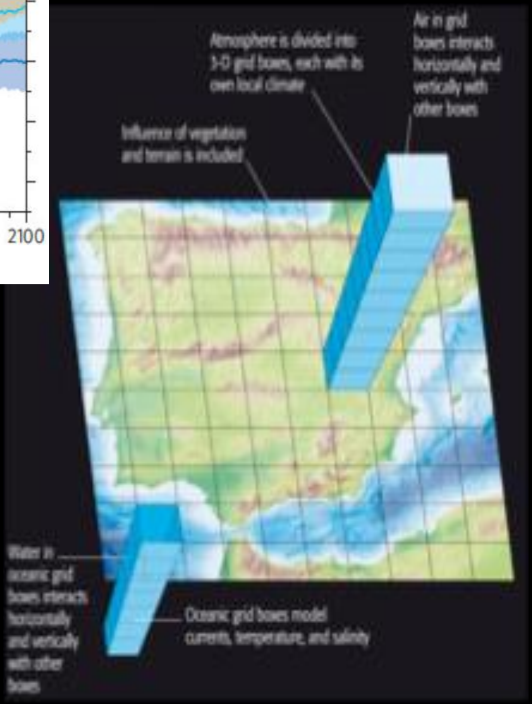


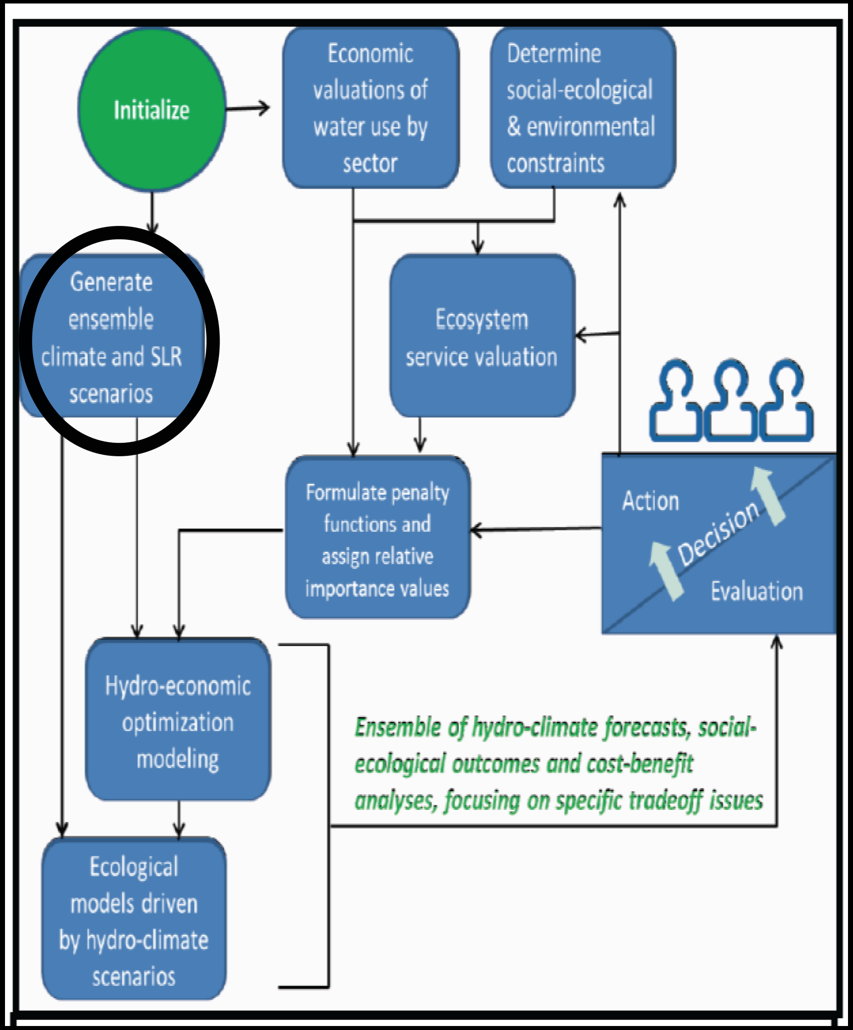


CMIP5 models, RCP scenarios
Historical (42)
RCP 2.6 (26)
RCP 4.5 (32)
RCP 6.0 (17)
RCP 8.5 (30)
Global surface warming (°C)
5
4
3
2
1
0
-1
1900
1950
2000
2050
2100
Year

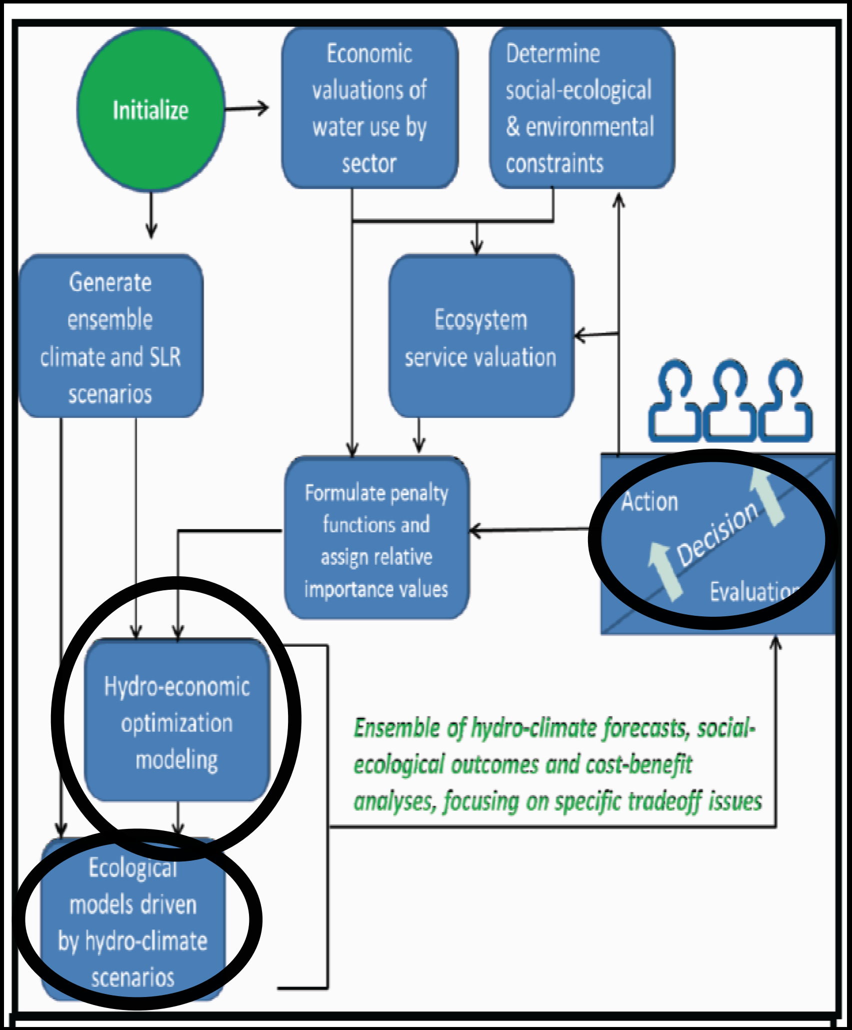


Atmosphere is divided into 3-D grid boxes, each with its own local climate
Air in grid boxes interacts horizontally and vertically with other boxes
Influence of vegetation and terrain is included
Water in oceanic grid boxes interacts horizontally and vertically with other boxes
Oceanic grid boxes model currents, temperature, and salinity

ipcc
INTERGOVERNMENTAL PANEL ON climate change
CLIMATE CHANGE 2013
The Physical Science Basis
WG I
WORKING GROUP I CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
WMO
UNEP



Initialize
Economic valuations of water use by sector
Determine social-ecological & environmental constraints
Generate ensemble climate and SLR scenarios
Ecosystem service valuation
Formulate penalty functions and assign relative importance values
Action
Decision
Evaluation
Hydro-economic optimization modeling
Ensemble of hydro-climate forecasts, social-ecological outcomes and cost-benefit analyses, focusing on specific tradeoff issues
Ecological models driven by hydro-climate scenarios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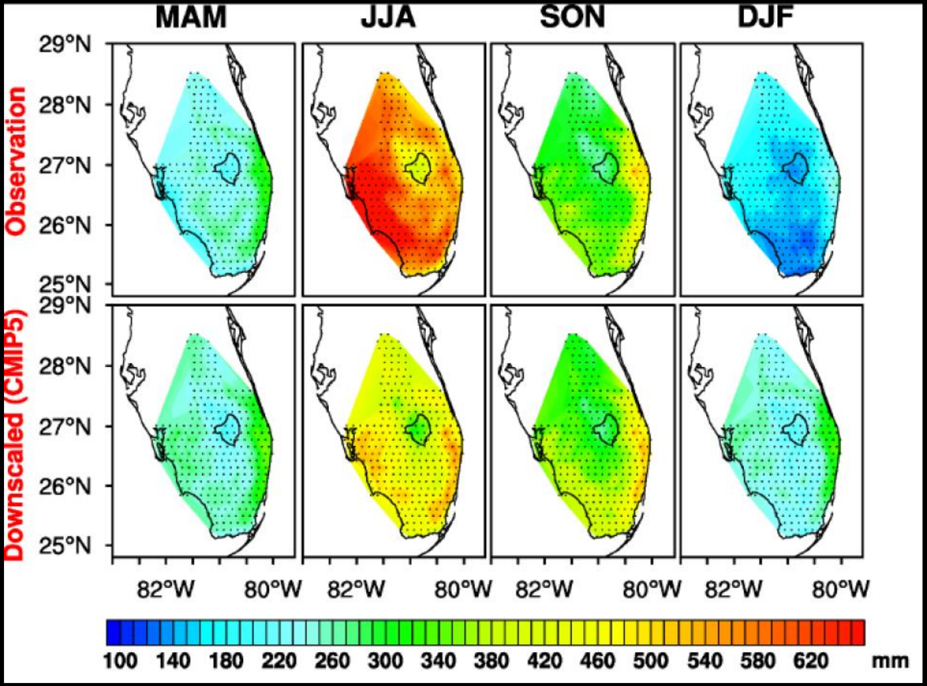
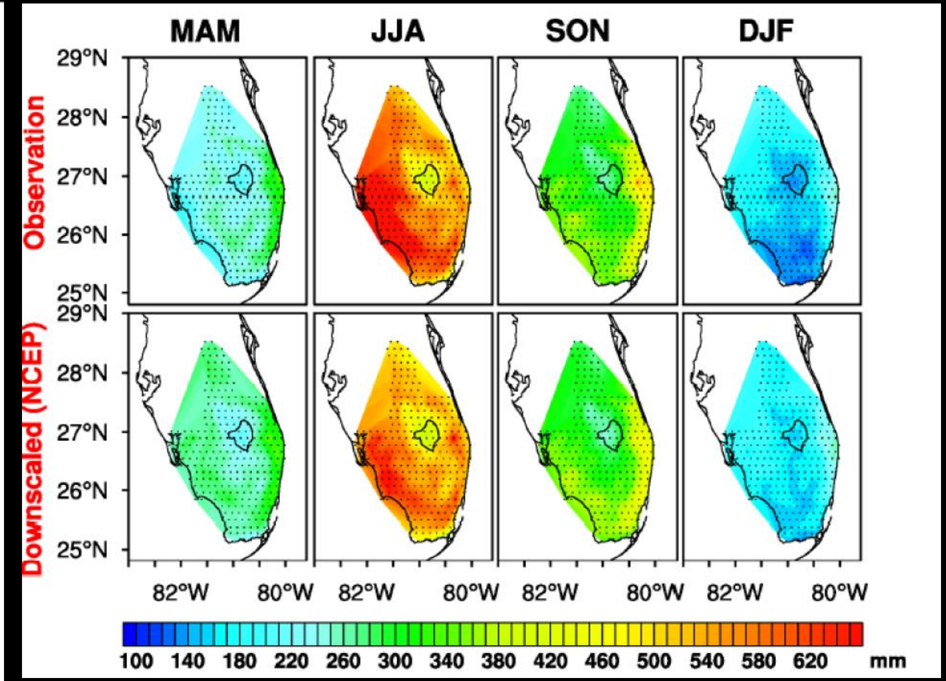
Philip LEVINE
Alton Rd

Downscaling Precipitation for Southern Florida



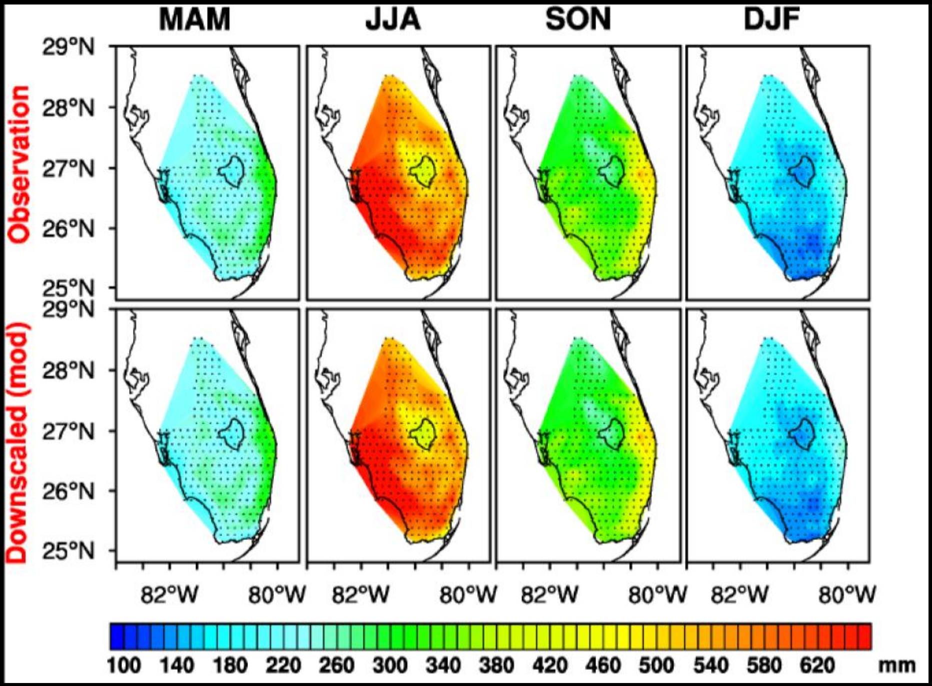
Downscaled precipitation – CMIP5 ensemble



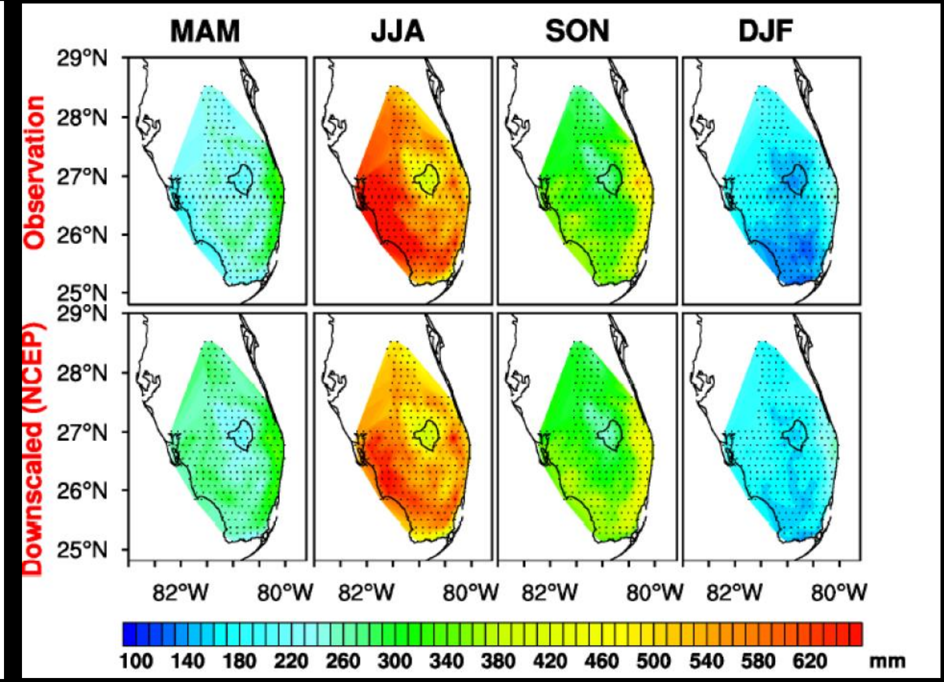
Downscaled precipitation - NCEP

Climatological Rainfall

Downscaling Precipitation for Southern Florida



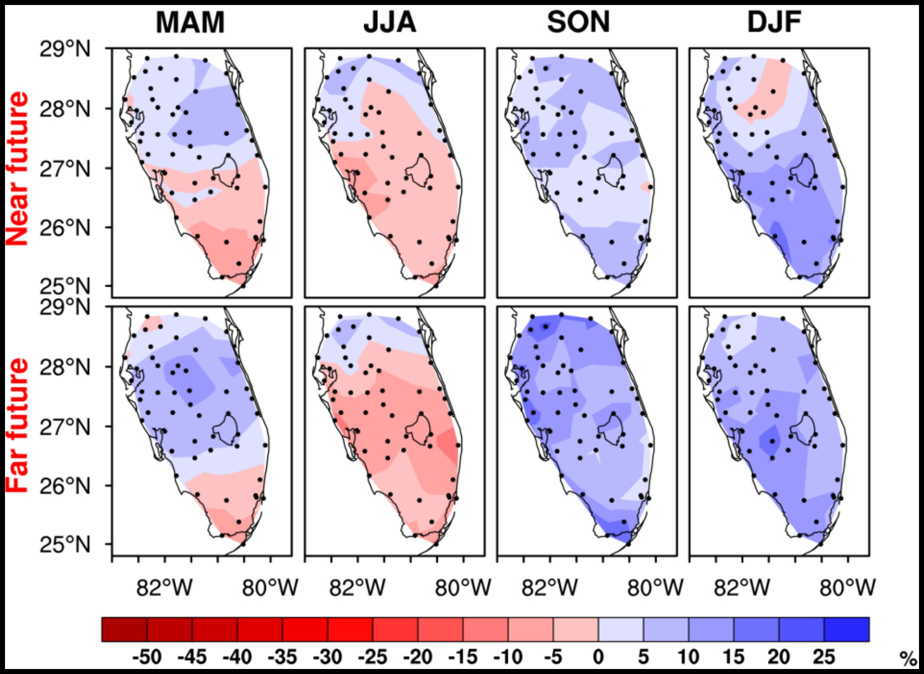
Downscaled precipitation – CMIP5 ensemble
(bias corrected)



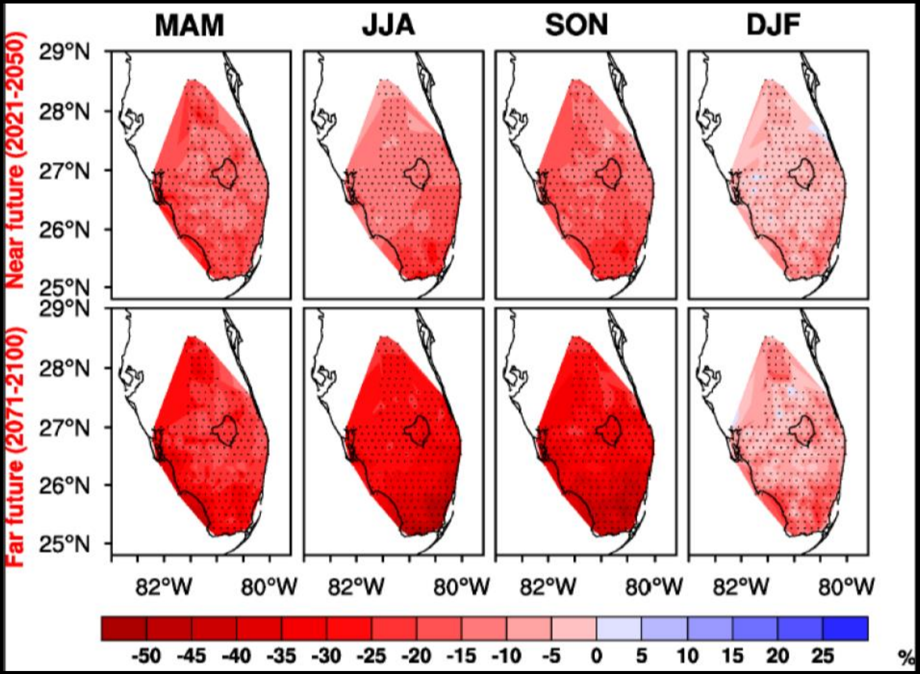
Downscaled precipitation - NCEP

Climatological Rainfall

Downscaling Precipitation for Southern Florida



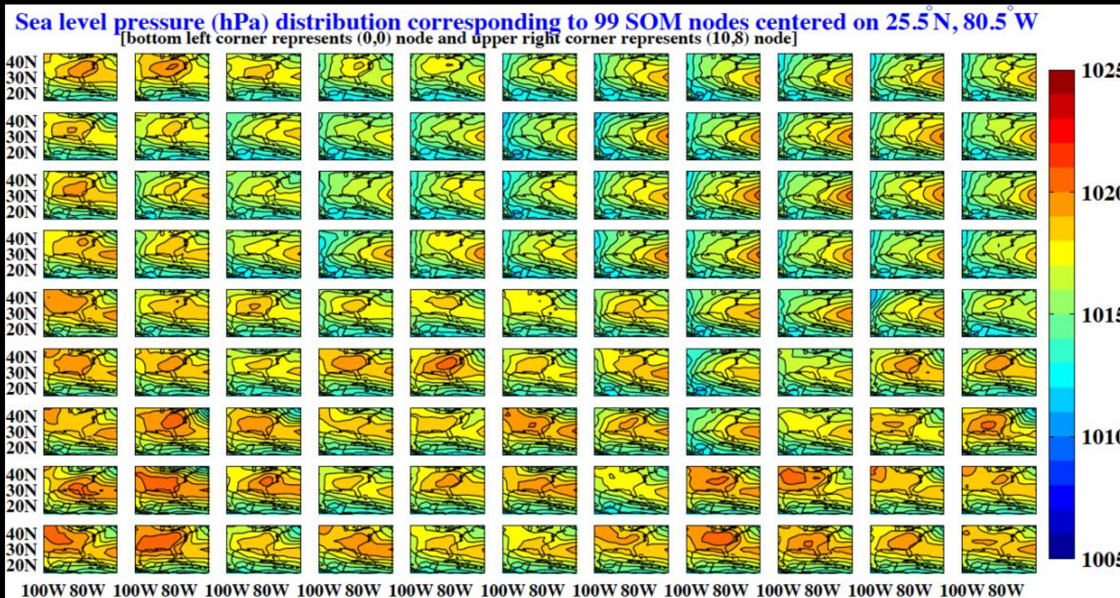
Raw model precipitation – CMIP5 ensemble

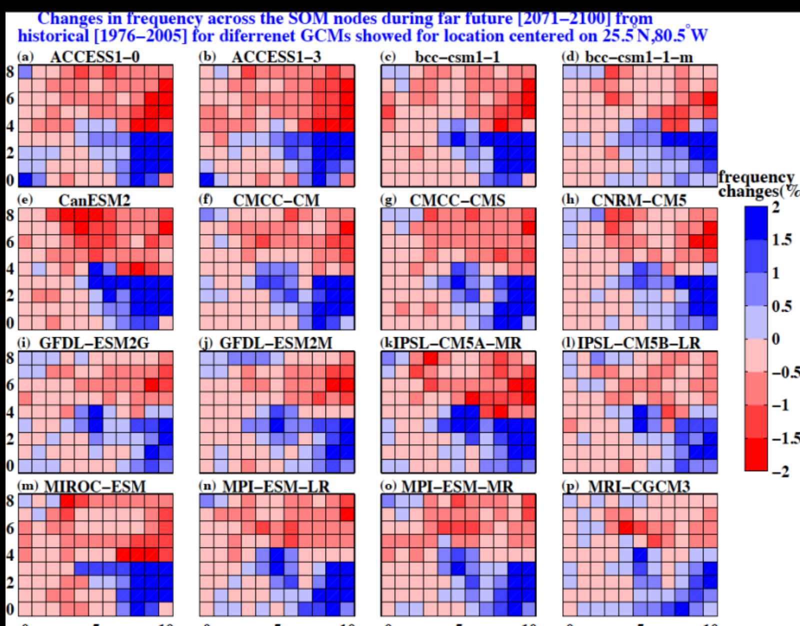


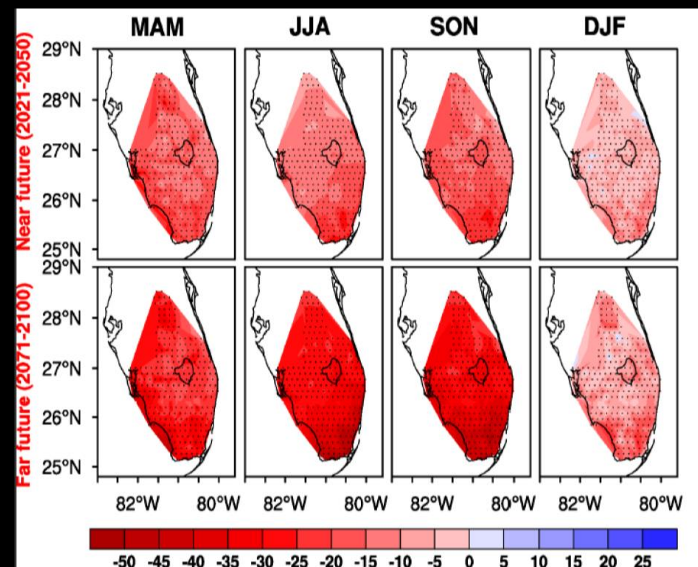
Downscaled precipitation – CMIP5 ensemble

Projected Change in Rainfall

Downscaling Precipitation for Southern Florida

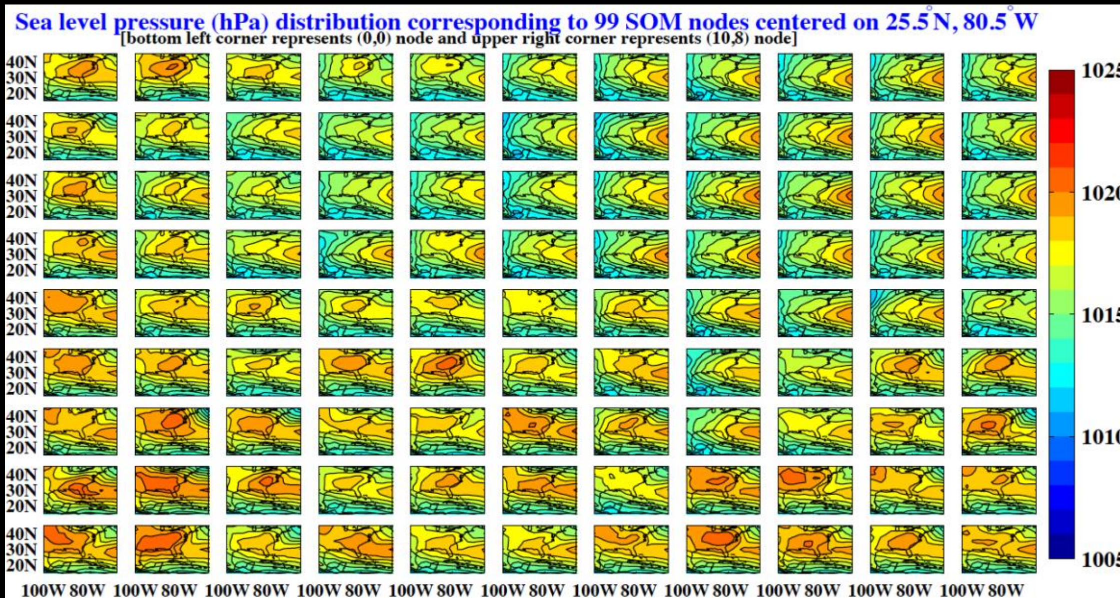


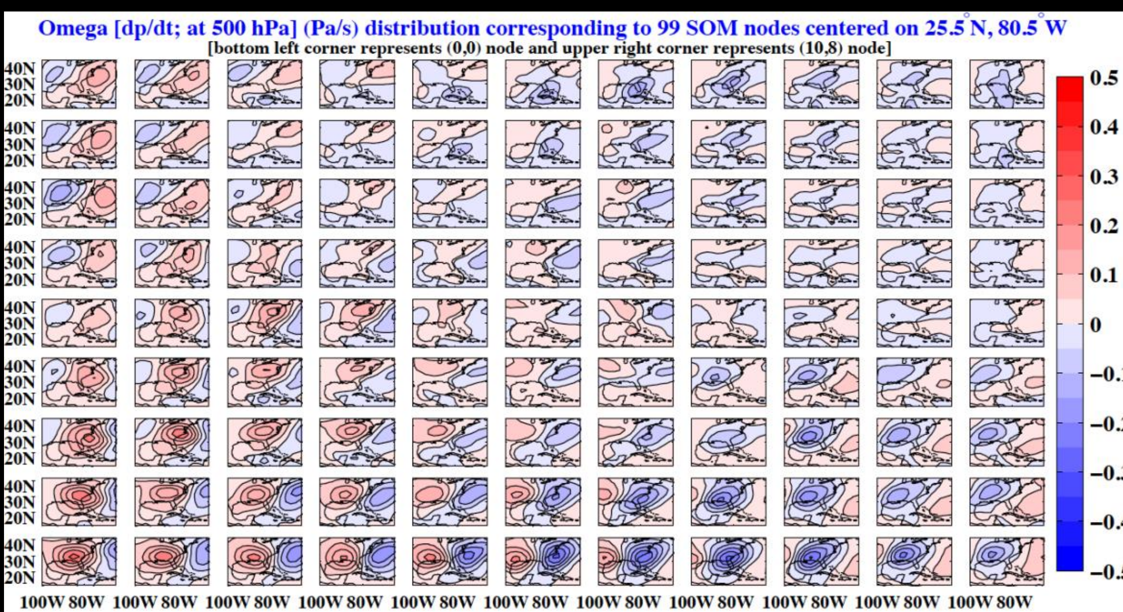


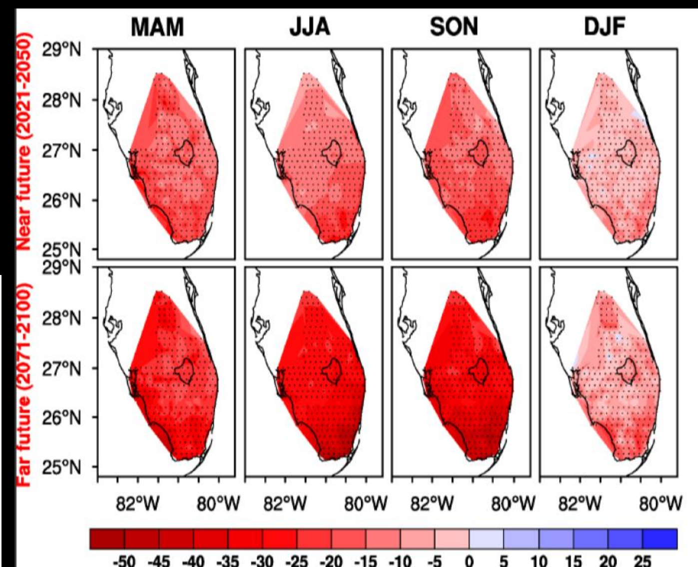


Downscaled precipitation – CMIP5 ensemble

Downscaling Precipitation for Southern Florida







Downscaled precipitation – CMIP5 ensemble

CONCLUSIONS

- *Climate Downscaling* is critical for assessing climate change impacts at regional and local scales.

- *Statistical downscaling* uses empirical relationships between large and local scales to downscale climate model simulations.

- Statistical downscaling techniques offer the the advantage of (a) being highly efficient and (b) circumventing potential physical limitations of models w.r.t. e.g. convective parameterizations, etc.

- On the other hand, they invoke certain types of statistical stationarity assumptions that can be circumvented with dynamical/physics-based approaches.

- Downscaled climate model simulation results can play a critical role in integrated assessment tools for assessing climate change impacts and mitigation strategies.

- Application of appropriate climate downscaling methods is likely to play a critical role in evaluating climate change impacts on the critical southern Florida region.

- How to downscaling?
- Dynamical downscaling
- Higher resolution numerical model constrained in GCMs
- Statistical downscaling
- Transfer functions between synoptic states and the parameters of interest
- Advantages and disadvantages

Step 1: Train SOMs

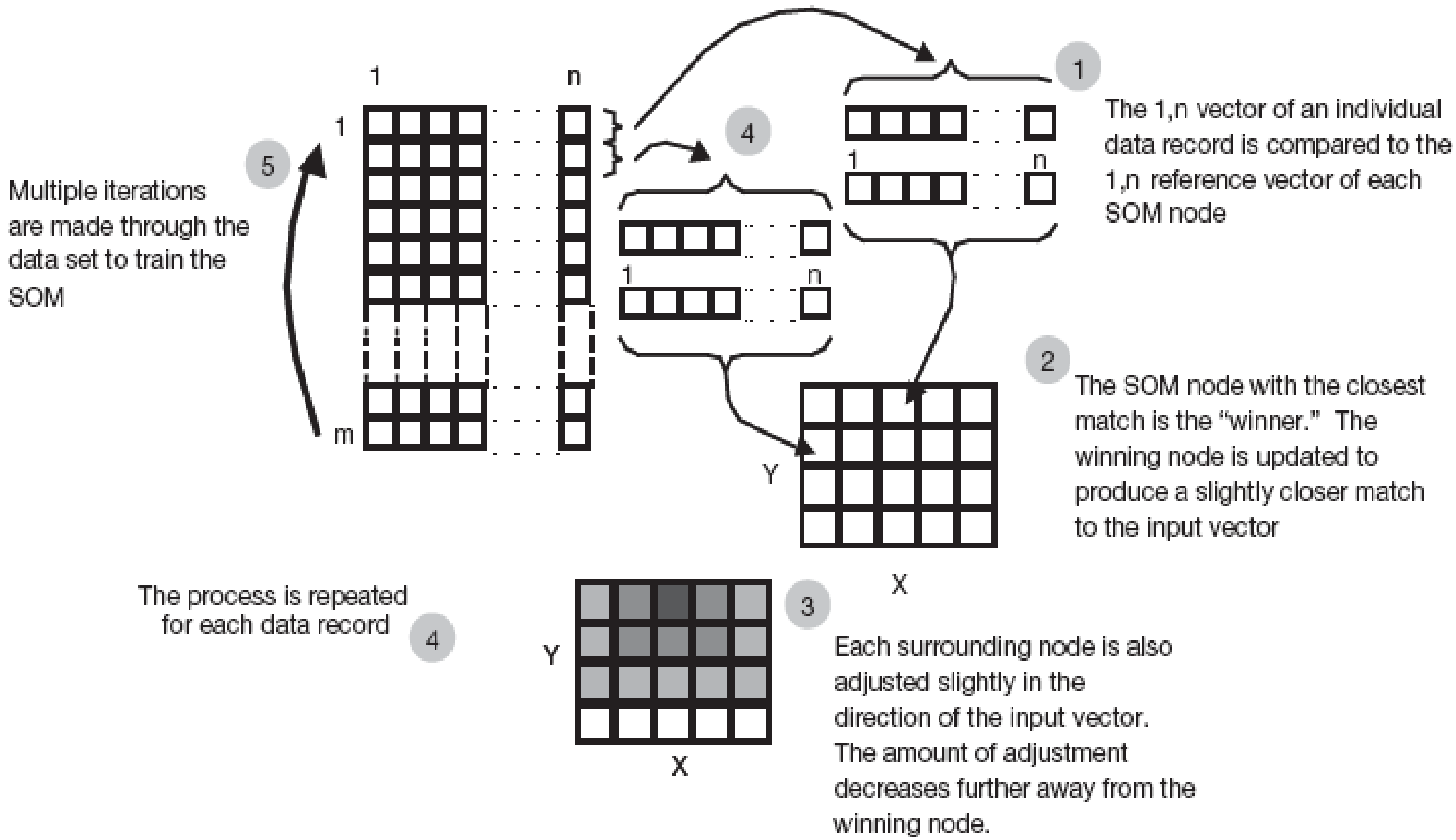


Fig. 1. The iterative self-organizing map (SOM) training procedure

(Crane and Hewitson, 2003)

Step 2: Calculate Cumulative Distribution

- Map synoptic state of each day from NCEP data to one node of the already trained SOM
- For each node:
- Rank the precipitation on those days mapped to this node from low to high
- Fit a spline to the ranked precipitation data
- Interpolate off spline to 100 ranks
- Each station is described by 99 different CDFs related to 99 characteristic synoptic states

Steps 3&4: Map GCMs data and do downscaling

- Map synoptic state of each day from NCEP or GCMs data to one node of the already trained SOM
- For each step:
- A precipitation value is generated by multiplying 100 with *r* between 0 and 1 determined by randomly selecting from the associated CDF for that synoptic state.
- Persistence of rainfall accomplished by modifying *r.* If rain occurs on the first day, then for the second day $\sqrt[1.2]{r}$ is used.
- Generate 1500 time series

PRECIPITATION DOWNSCALING OVER PENNSYLVANIA

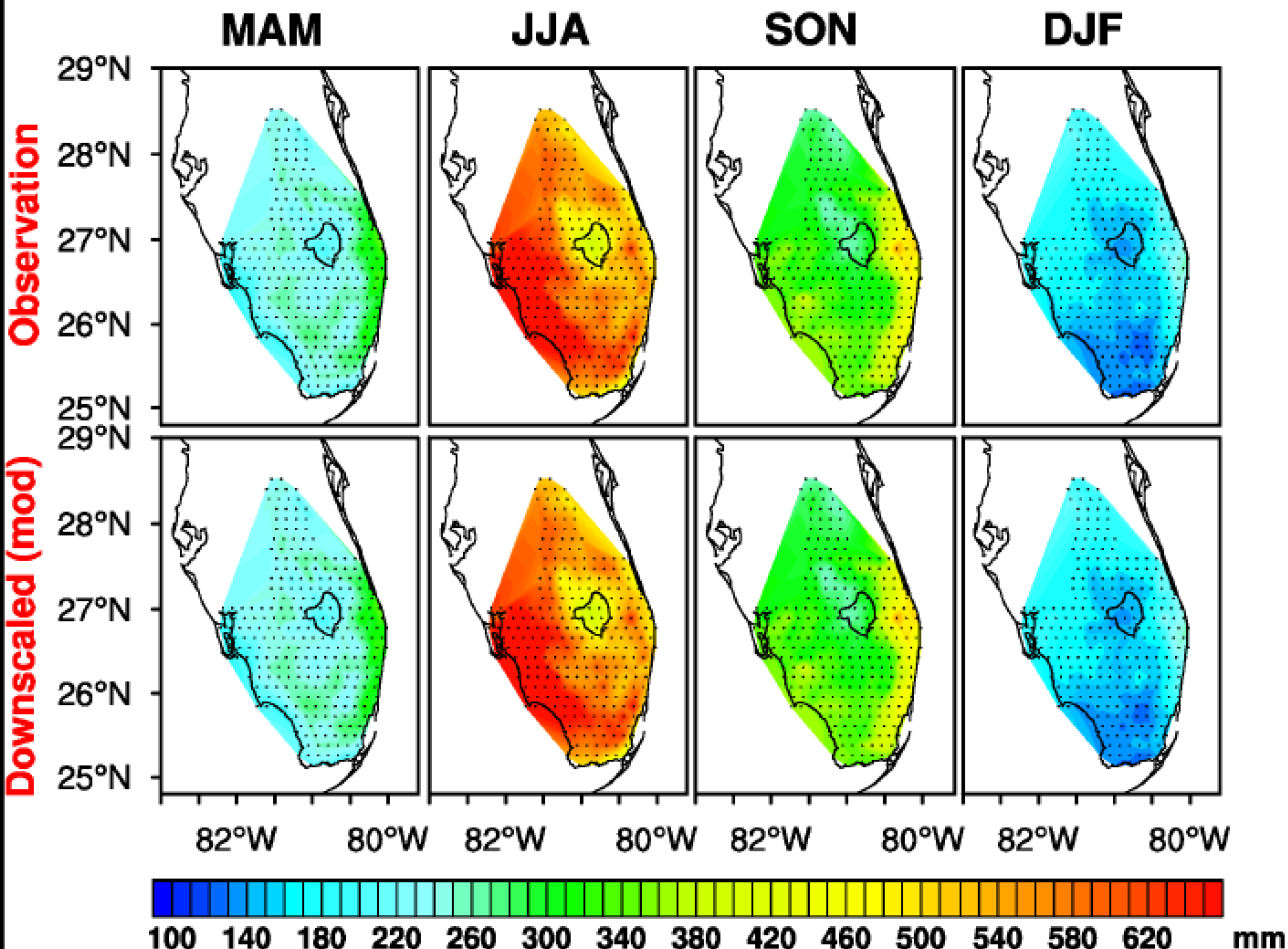


Figure 3: Same as Figure 1, but we employ a bias correction for each season in the final product that is constructed using CMIP5 downscaled precipitation.

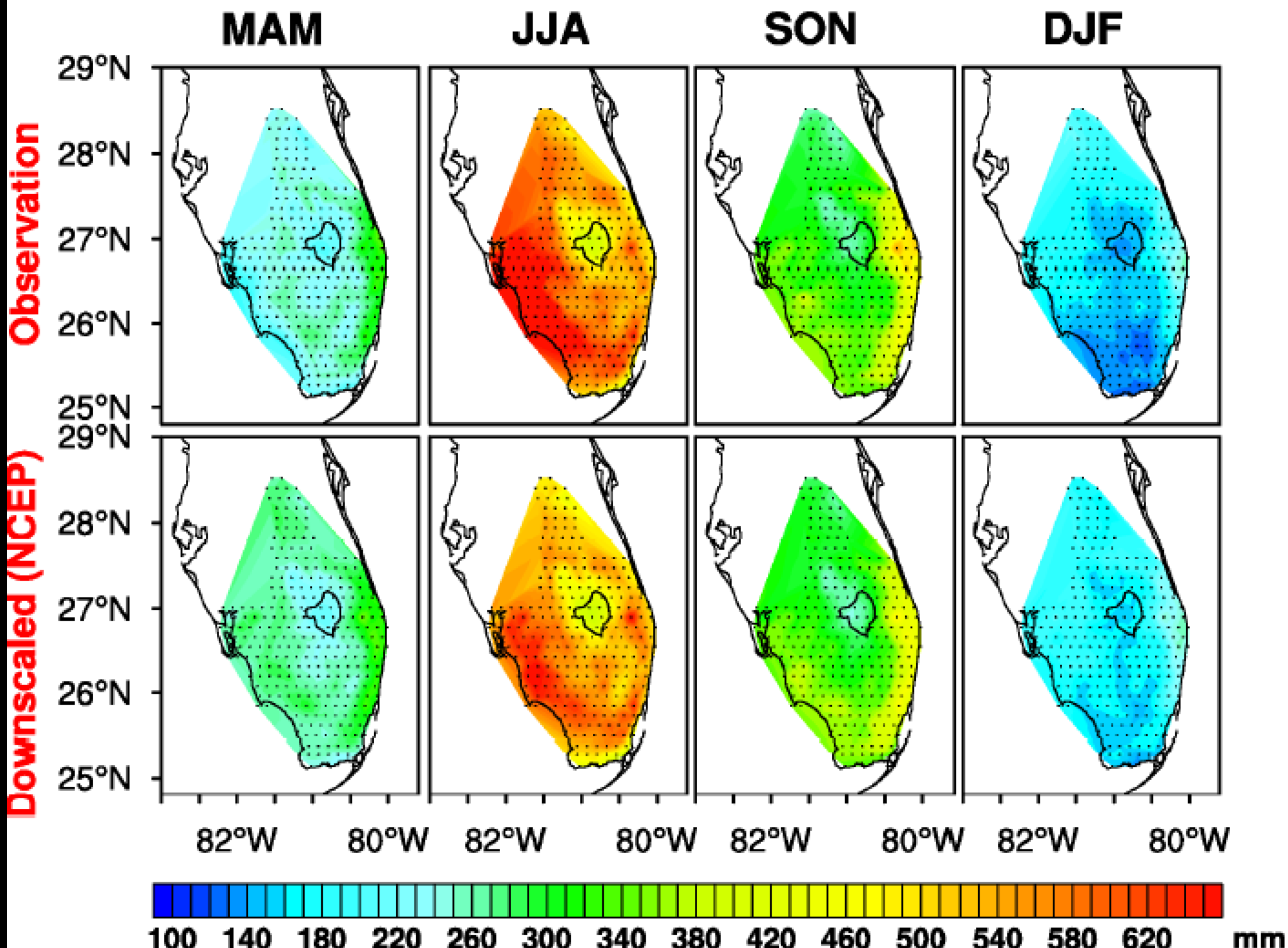


Figure 2: Same as Figure 1, but using NCEP downscaled precipitation.

Outline

- Introduction to the downscaling
- Data sets
- Downscaling procedures
- Validation of Downscaling over the Historical Era
- Evaluation of GCMs circulation data
- Evaluation of the downscaling method
- Comparisons between observed and downscaled precipitation data

Three data sets:

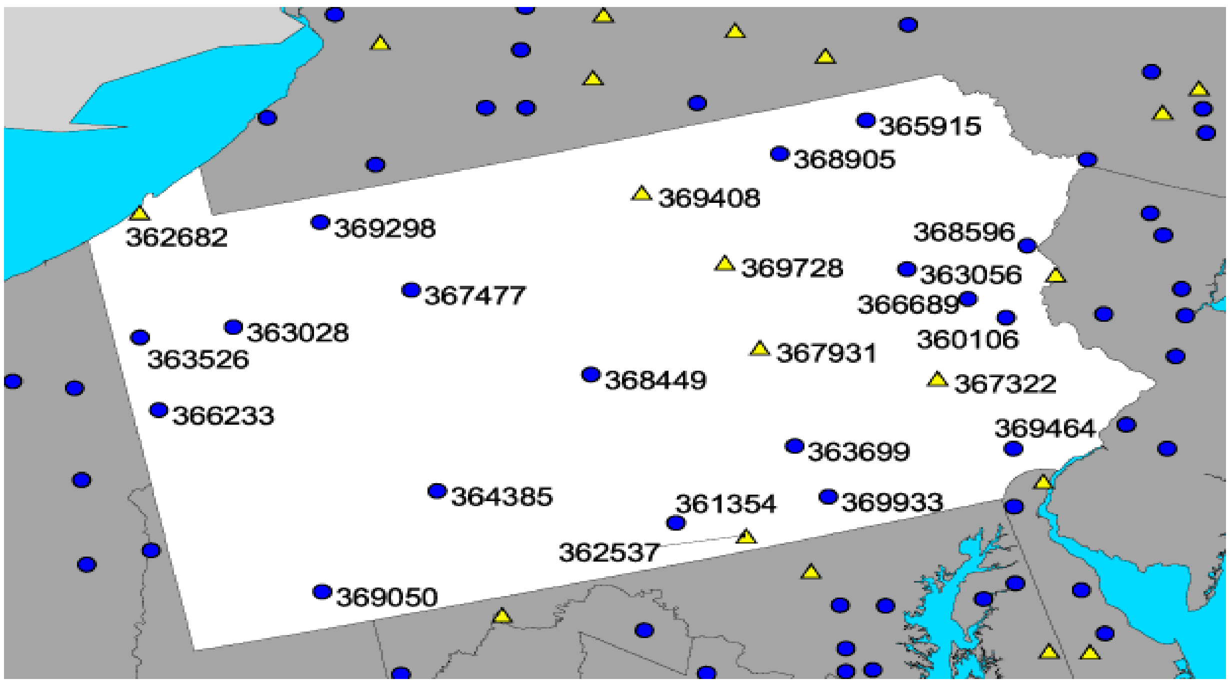
- NCEP reanalysis data
  - Period: 1979-present
  - 6-hourly averaged to daily
  - 2.5 °× 2.5 °
  - Variables:
    - U and V winds at 10 m
    - U and V winds at 700 hPa
    - Specific humidity at 850 hPa
    - Relative humidity at 850 hPa
    - Air temperature anomaly at 10 m
    - Lapse rate of temperature 850–500 hPa

Why downscaling?

Model ID, Vintage	Sponsor(s), Country	Atmosphere Top Resolution[a] References
1: BCC-CM1, 2005	Beijing Climate Center, China	top = 25 hPa T63 (1.9° x 1.9°) L16 Dong et al., 2000; CSMI 2005; Xu et al., 2005
2: BCCR-BCM2.0, 2005	Bjerknes Centre for Climate Research, Norway	top = 10 hPa T63 (1.9° x 1.9°) L31 Déqué et al., 1994
3: CCSM3, 2005	National Center for Atmospheric Research, USA	top = 2.2 hPa T85 (1.4° x 1.4°) L26 Collins et al., 2004
4: CGCM3.1(T47), 2005	Canadian Centre for Climate Modelling and Analysis, Canada	top = 1 hPa T47 (~2.8° x 2.8°) L31 McFarlane et al., 1992; Flato, 2005
5: CGCM3.1(T63), 2005		top = 1 hPa T63 (~1.9° x 1.9°) L31 McFarlane et al., 1992; Flato 2005
6: CNRM-CM3, 2004	Météo-France/Centre National de Recherches Météorologiques, France	top = 0.05 hPa T63 (~1.9° x 1.9°) L45 Déqué et al., 1994
7: CSIRO-MK3.0, 2001	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia	top = 4.5 hPa T63 (~1.9° x 1.9°) L18 Gordon et al., 2002
8: ECHAM5/MPI-OM, 2005	Max Planck Institute for Meteorology, Germany	top = 10 hPa T63 (~1.9° x 1.9°) L31 Roeckner et al., 2003
9: ECHO-G, 1999	Meteorological Institute of the University of Bonn, Meteorological Research Institute of the Korea Meteorological Administration (KMA), and Model and Data Group, Germany/Korea	top = 10 hPa T30 (~3.9° x 3.9°) L19 Roeckner et al., 1996
10: FGOALS-g1.0, 2004	National Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG)/Institute of Atmospheric Physics, China	top = 2.2 hPa T42 (~2.8° x 2.8°) L26 Wang et al., 2004
11: GFDL-CM2.0, 2005	U.S. Department of Commerce/ National Oceanic and Atmospheric Administration (NOAA)/Geophysical Fluid Dynamics Laboratory (GFDL), USA	top = 3 hPa 2.0° x 2.5° L24 GFDL GAMDT, 2004
12: GFDL-CM2.1, 2005		top = 3 hPa 2.0° x 2.5° L24 GFDL GAMDT, 2004 with semi-Lagrangian transports
13: GISS-AOM, 2004	National Aeronautics and Space Administration (NASA)/ Goddard Institute for Space Studies (GISS), USA	top = 10 hPa 3° x 4° L12 Russell et al., 1995; Russell, 2005
14: GISS-EH, 2004		top = 0.1 hPa 4° x 5° L20 Schmidt et al., 2006
15: GISS-ER, 2004	NASA/GISS, USA	top = 0.1 hPa 4° x 5° L20 Schmidt et al., 2006
16: INM-CM3.0, 2004	Institute for Numerical Mathematics, Russia	top = 10 hPa 4° x 5° L21 Alekseev et al., 1998; Galin et al., 2003
17: IPSL-CM4, 2005	Institut Pierre Simon Laplace, France	top = 4 hPa 2.5° x 3.75° L19 Hourdin et al., 2006
18: MIROC3.2(hires), 2004	Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	top = 40 km T106 (~1.1° x 1.1°) L56 K-1 Developers, 2004
19: MIROC3.2(medres), 2004		top = 30 km T42 (~2.8° x 2.8°) L20 K-1 Developers, 2004
20: MRI-CGCM2.3.2, 2003	Meteorological Research Institute, Japan	top = 0.4 hPa T42 (~2.8° x 2.8°) L30 Shibata et al., 1999
21: PCM, 1998	National Center for Atmospheric Research, USA	top = 2.2 hPa T42 (~2.8° x 2.8°) L26 Kiehl et al., 1998
22: UKMO-HadCM3, 1997	Hadley Centre for Climate Prediction and Research/Met Office, UK	top = 5 hPa 2.5° x 3.75° L19 Pope et al., 2000
23: UKMO-HadGEM1, 2004		top = 39.2 km ~1.3° x 1.9° L38 Martin et al., 2004

(Randall et al, 2007)

- Observed precipitation data
  - Period: 1979-2005
  - Daily
  - 17 stations (39°-42°N, 75°-82°W)



△ Monthly data available ● Daily and monthly data available

http://cdiac.ornl.gov/epubs/ndp/ushcn/state_PA.html

- GCMs data
  - 10 GCMs forced by 20c3m scenario
  - Periods: 1961-2000
  - Daily
  - Regridded to 2°× 2°
  - Variables: same as NCEP data

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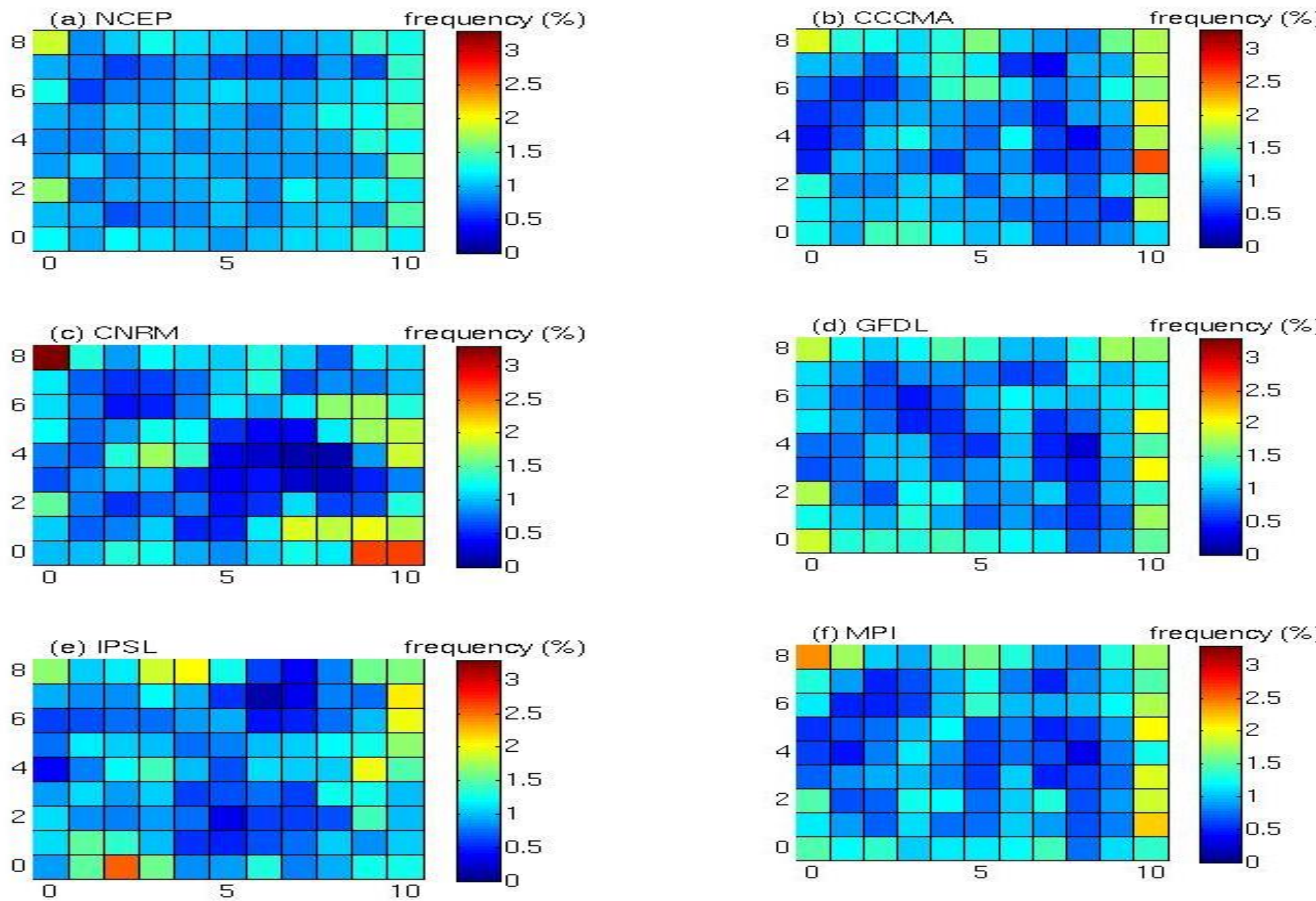
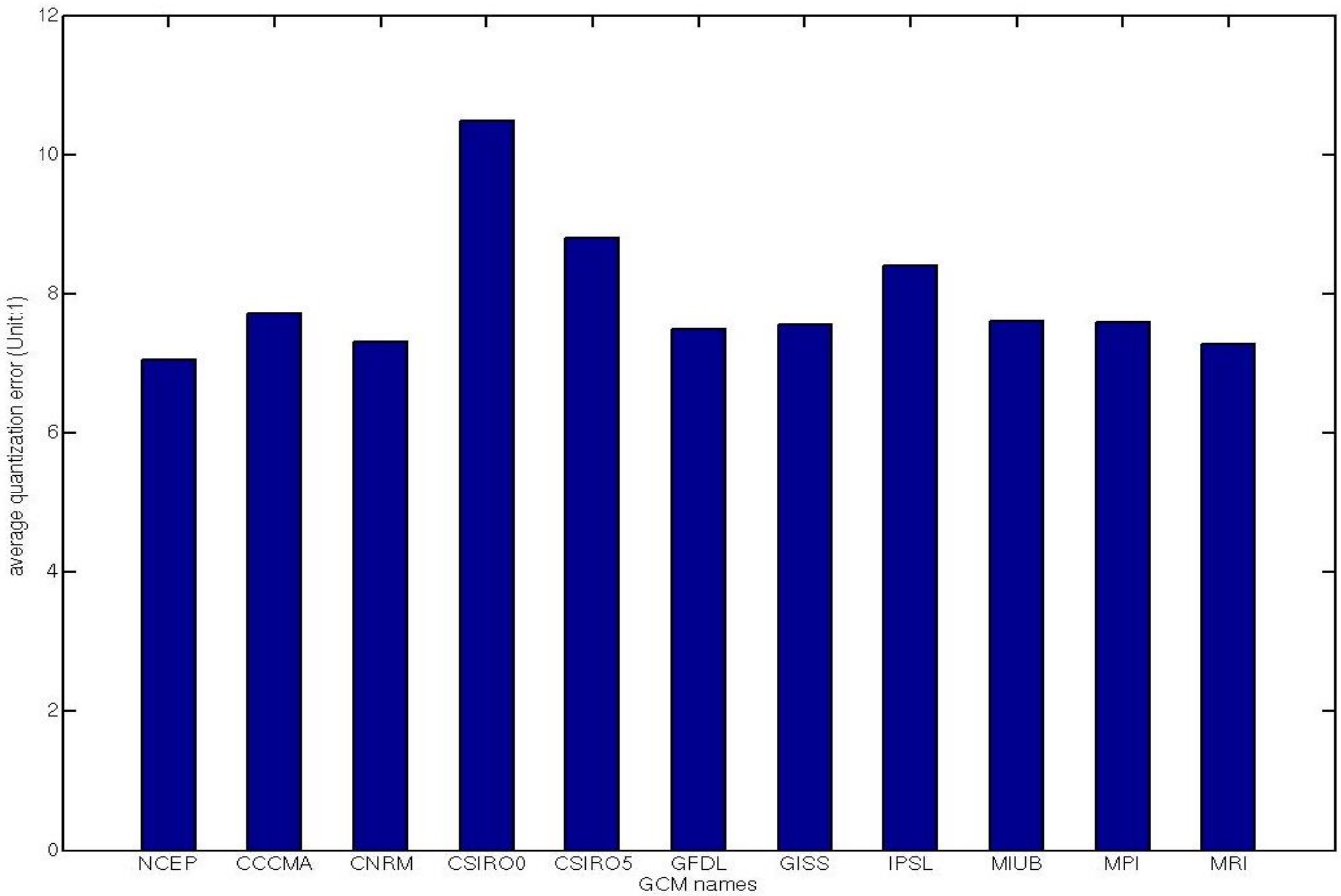
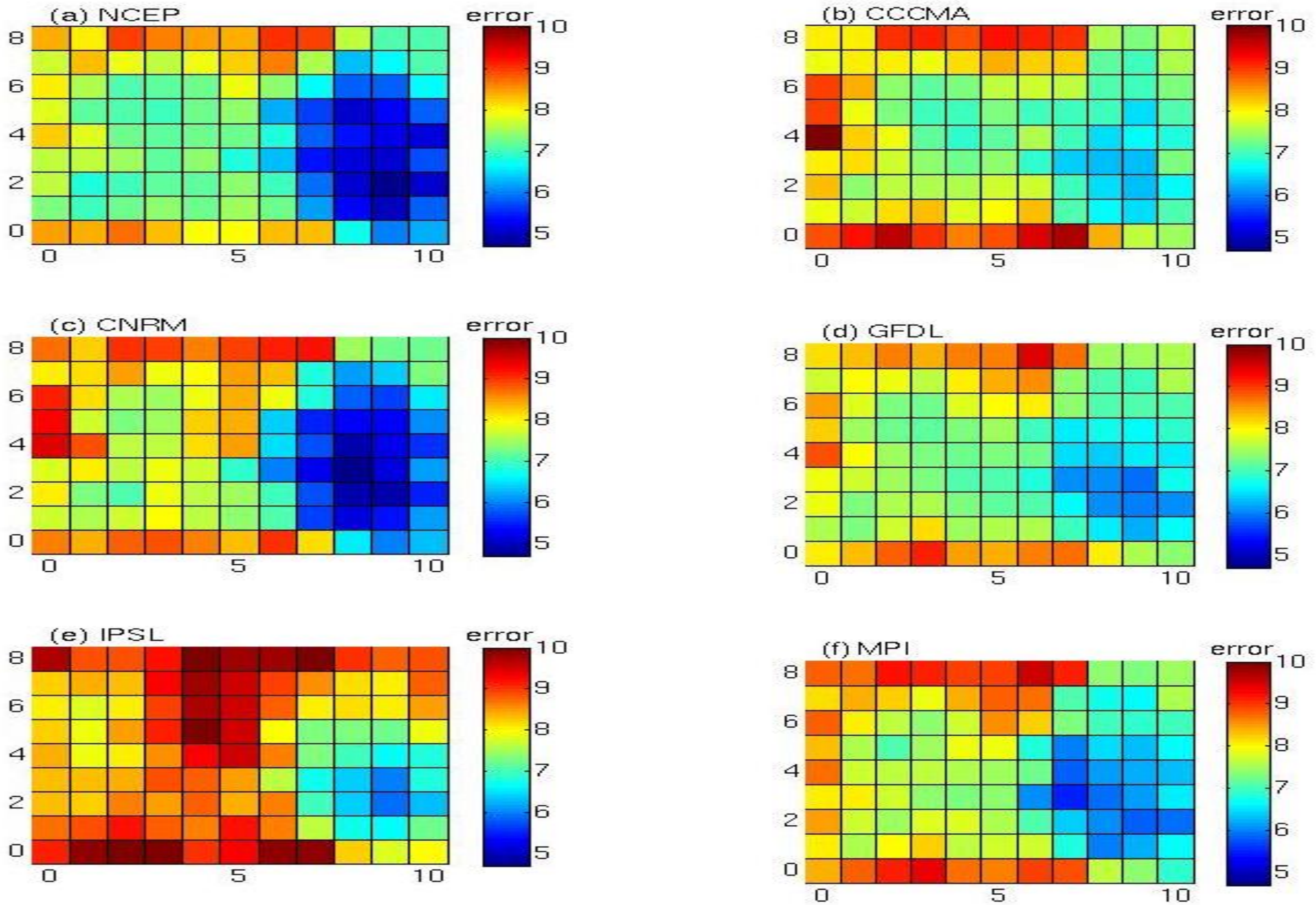


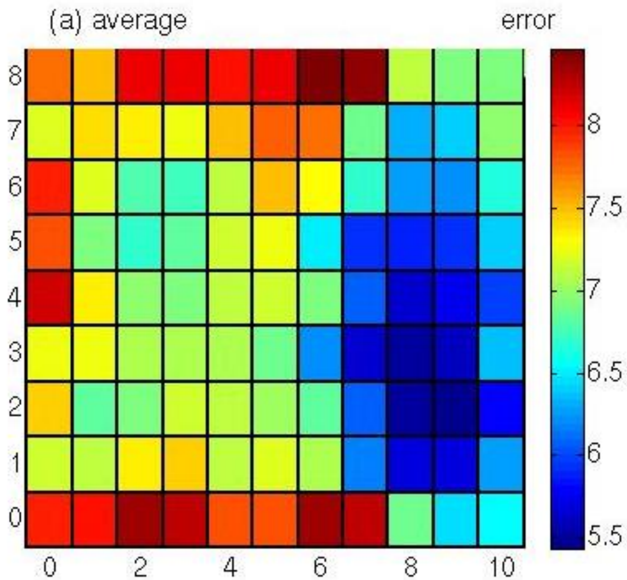
Frequency distributions across the SOM nodes for atmospheric circulation from NCEP (a), models CCCMA (b), CNRM (c), GFDL (d), IPSL (e), MPI (f) centered on 40.0° N and 76.5° W (Unit: %)



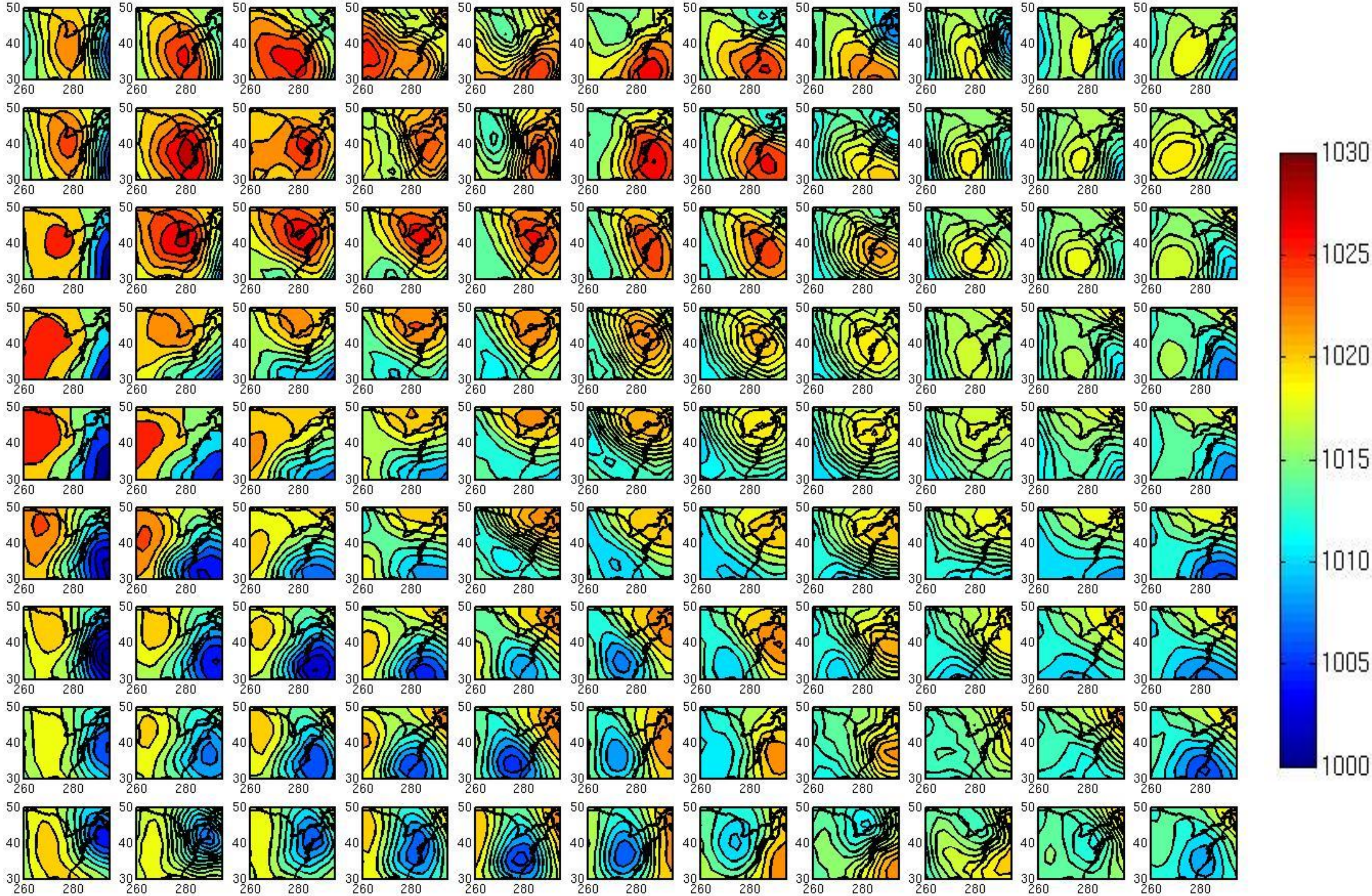
The average of the averaged quantization errors over all the SOM nodes for NCEP and 10 GCMs circulation data centered on 40.0° N and 76.5° W



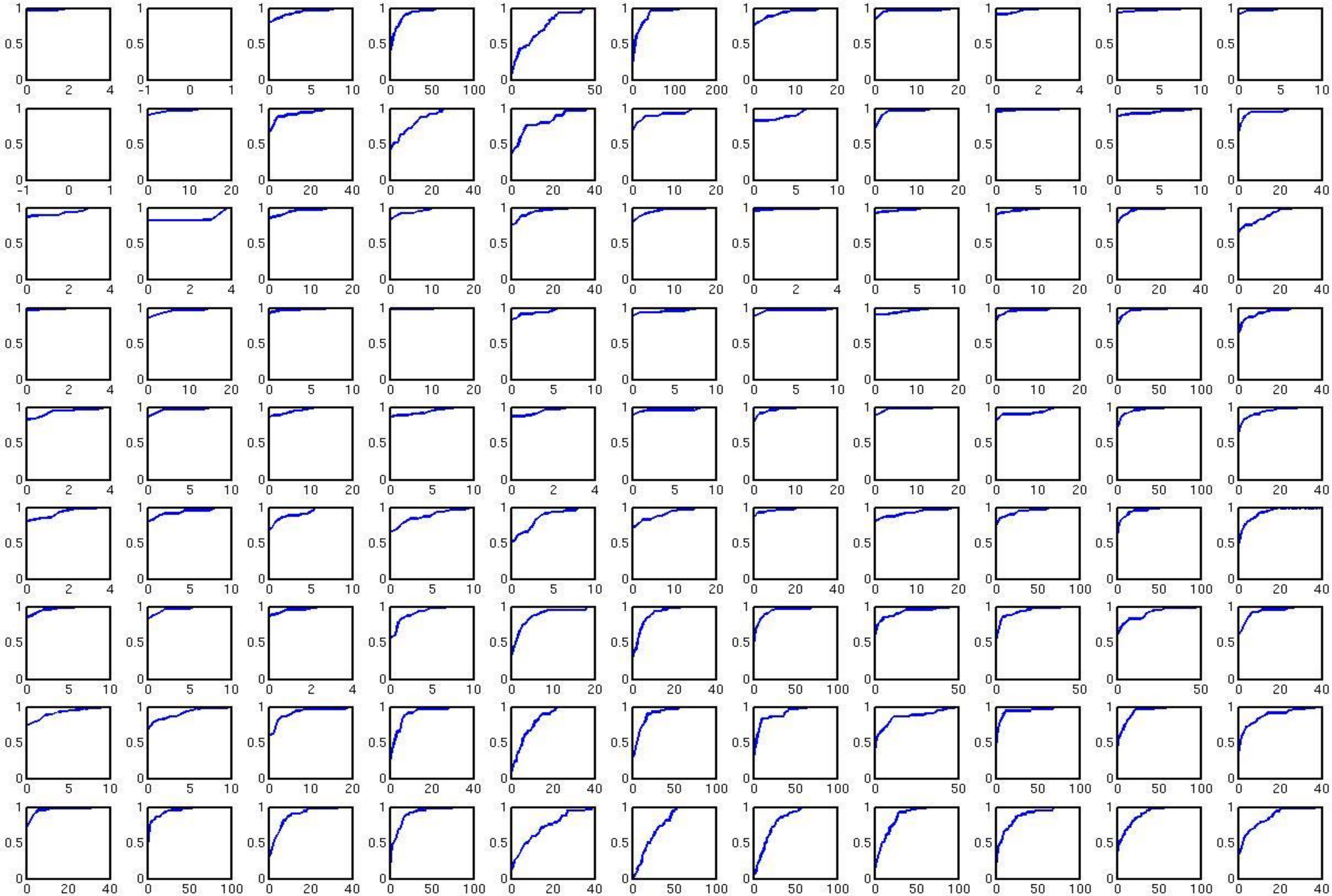
Average quantization error distributions across the SOM nodes for atmospheric circulation from NCEP (a), models CCCMA (b), CNRM (c), GFDL (d), IPSL (e), MPI (f) centered on 40.0° N and 76.5° W



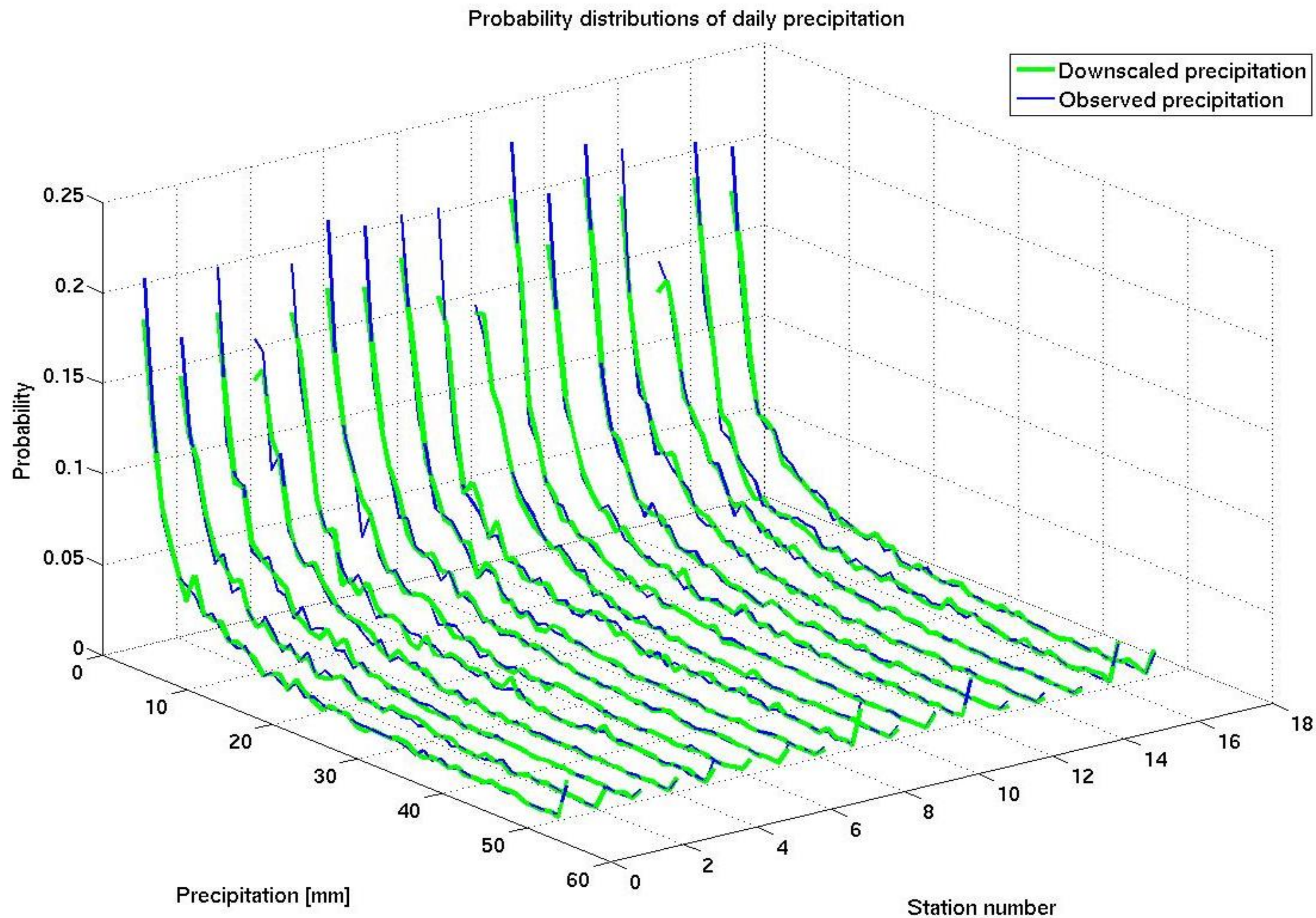
The average (a) and standard deviation (b) of the averaged quantization errors across the SOM nodes for NCEP and 10 GCMs circulation data centered on 40.0° N and 76.5° W



Sea level pressure distribution corresponding with 99 SOM nodes (Unit: hPa)



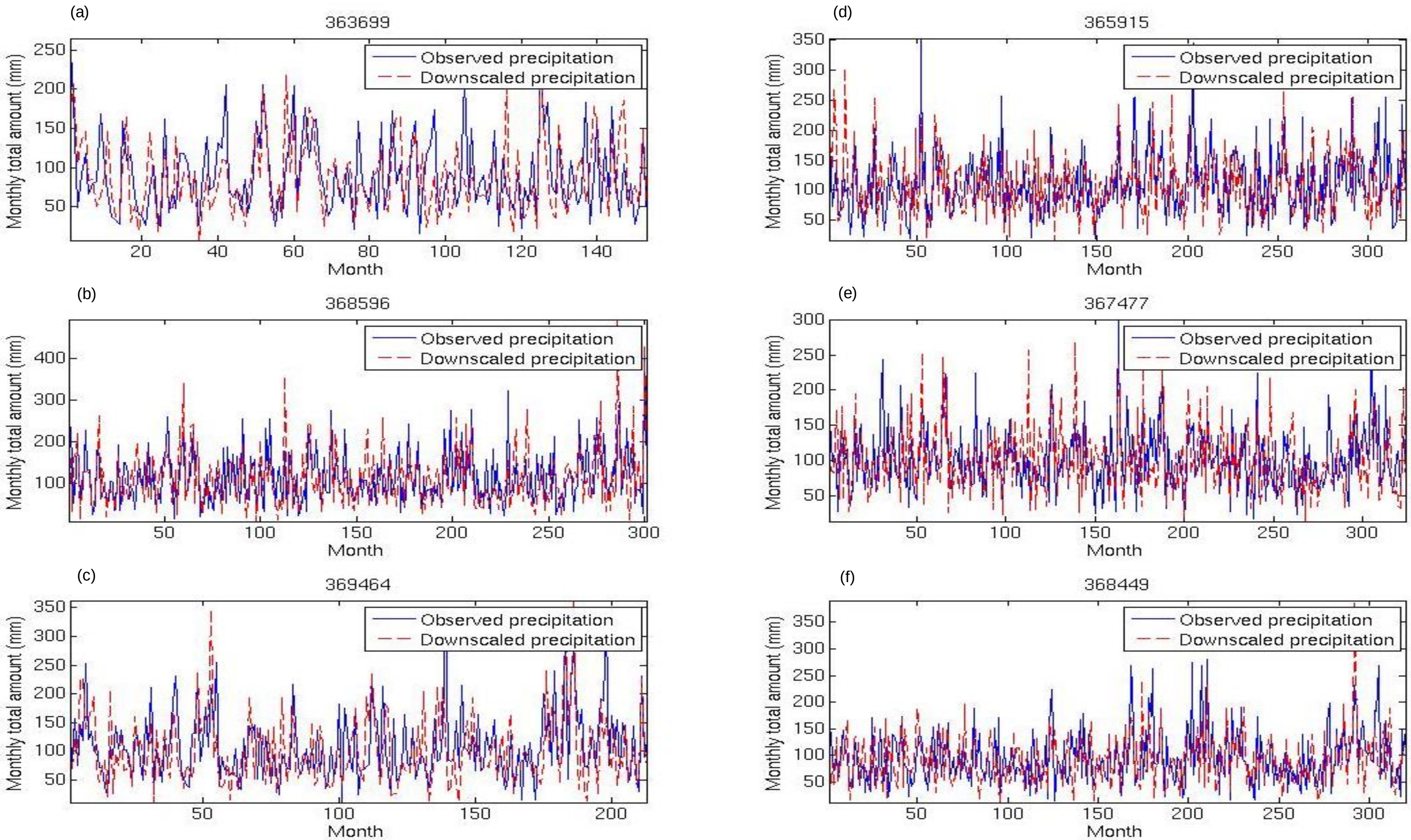
The cumulative distribution functions of daily precipitation values corresponding with 99 SOM nodes
(Unit of X-axis: 1, unit of Y-axis: mm)



The probability distributions of observed and downscaled daily precipitation for 17 stations in Pennsylvania during the period 1979-2005

The correlation coefficients between observed and downscaled monthly precipitation amounts over 17 stations during period 1979-2005
The bold indicate that those correlation coefficients can meet 99% significant confidence level

Station ID	Number of months	Number of years	Correlation coefficient of monthly precipitation amounts
360106	279	25	**r=0.50**
361354	313	27	**r=0.47**
363028	309	27	r=0.43
363526	217	19	r=0.50
363699	153	13	r=0.55
364385	170	15	r=0.49
365915	321	27	r=0.42
366233	307	27	r=0.44
366689	218	19	r=0.47
367477	324	27	r=0.40
368449	320	27	r=0.41
368596	301	27	**r=0.53**
368905	313	27	r=0.43
369050	292	27	r=0.44
369298	320	27	**r=0.45**
369464	213	20	**r=0.52**
369933	321	27	**r=0.49**



Observed and downscaled monthly precipitation amount time series for period 1979-2005 over station 363699 (a), 368596 (b), 369464 (c), 365915 (d), 367477 (e), and 368449 (f) (Unit: mm)

The absolute and average deviations between observed and downscaled climatology indices over all months and all 17 stations, and the corresponding percentages

Deviations of climatology indices	values
Absolute deviation of median monthly precipitation amount (mm)	10.96 (12.02%)
Average deviation of median monthly precipitation amount (mm)	0.17 (0.19%)
Absolute deviation of average monthly precipitation amount (mm)	8.95 (9.05%)
Average deviation of average monthly precipitation amount (mm)	-1.77 (-1.79%)
Absolute deviation of standard deviation (mm)	8.37 (17.65%)
Average deviation of standard deviation (mm)	-0.71 (-1.51%)
Absolute deviation of monthly number of rain days (day)	0.89 (7.51%)
Average deviation of monthly number of rain days (day)	-0.46 (-3.87%)

Conclusions

- SOMs is an effective method to extract the characteristic synoptic circulation patterns
- The GCMs simulated synoptic circulation patterns are similar to the observed patterns
- The downscaled precipitation can capture the main characters of the observed precipitation on probability distributions, and varieties on different time scales with close climatology indices

Future work

- Validation of the downscaling on precipitation over the future era
- Assessment of downscaled maximum temperature and minimum temperature
- Continue to improve the downscaled precipitation, especially for those months with large monthly precipitation amounts

Acknowledgment

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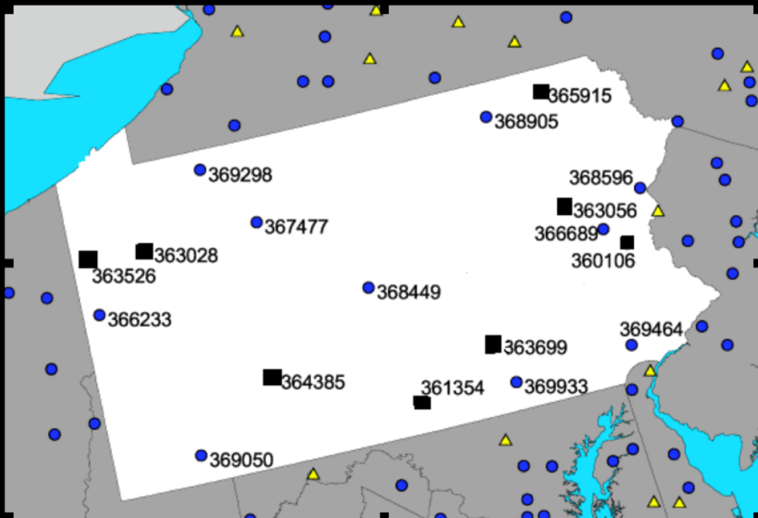
Downscaling Precipitation in PA



Probabilistic Projections of Climate Change for the Mid-Atlantic Region of the United States: Validation of Precipitation Downscaling during the Historical Era*

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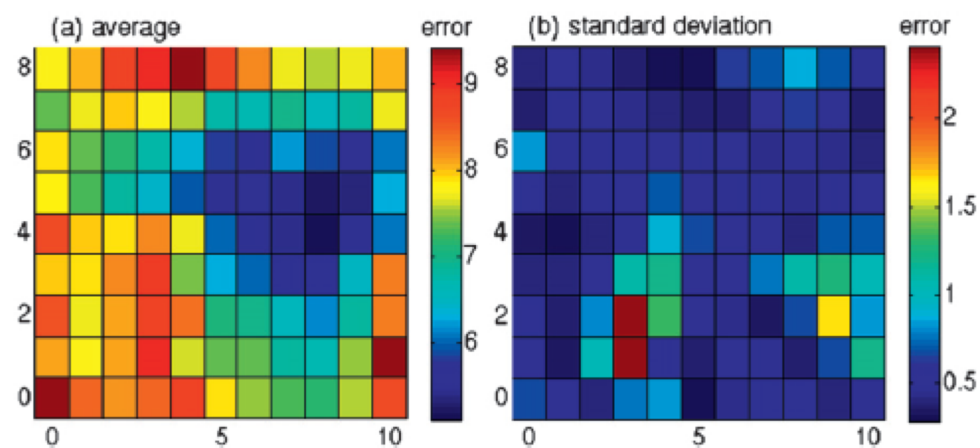

FIG. 5. The (a) average and (b) standard deviation of the averaged quantization errors across the SOM nodes for NCEP and nine GCMs' circulation data centered on 40.0°N, 76.5°W.