Weather and Climate Extremes over Canada: Science and Adaptation,
Winnipeg, Canada, February 7-9, 2011

Application of Remotely Sensed Precipitation Data in Monitoring and Analysis of Extremes: Challenges and Opportunities

Amir AghaKoucak

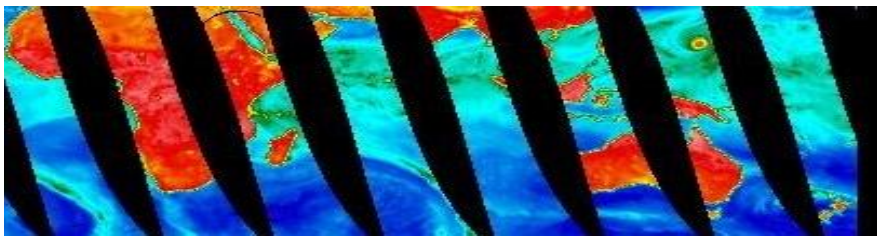
Kuolin Hsu & Soroosh Sorooshian

Center for Hydrometeorology & Remote Sensing
Department of Civil & Environmental Engineering
University of California Irvine

SATELLITE PRECIPITATION DATA

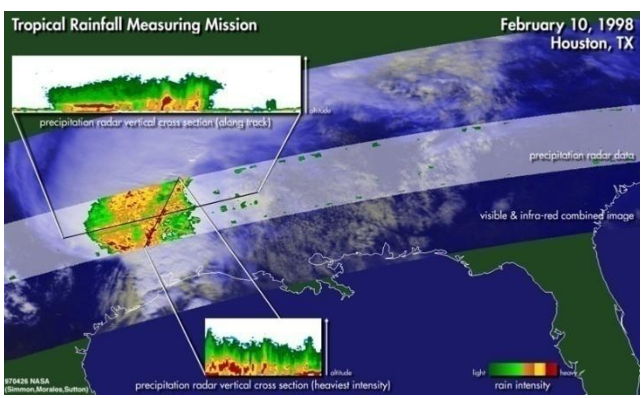
Meteosat 7 (EUMETSAT)

Geostationary IR
Cloud top data
15-30 minute temporal resolution



SSMI 85GHz (DMSP)

Passive Microwave (SSM/I)
Some characterisation of rainfall
~2 overpasses per day per spacecraft, moving to 3-hour return time (GPM)

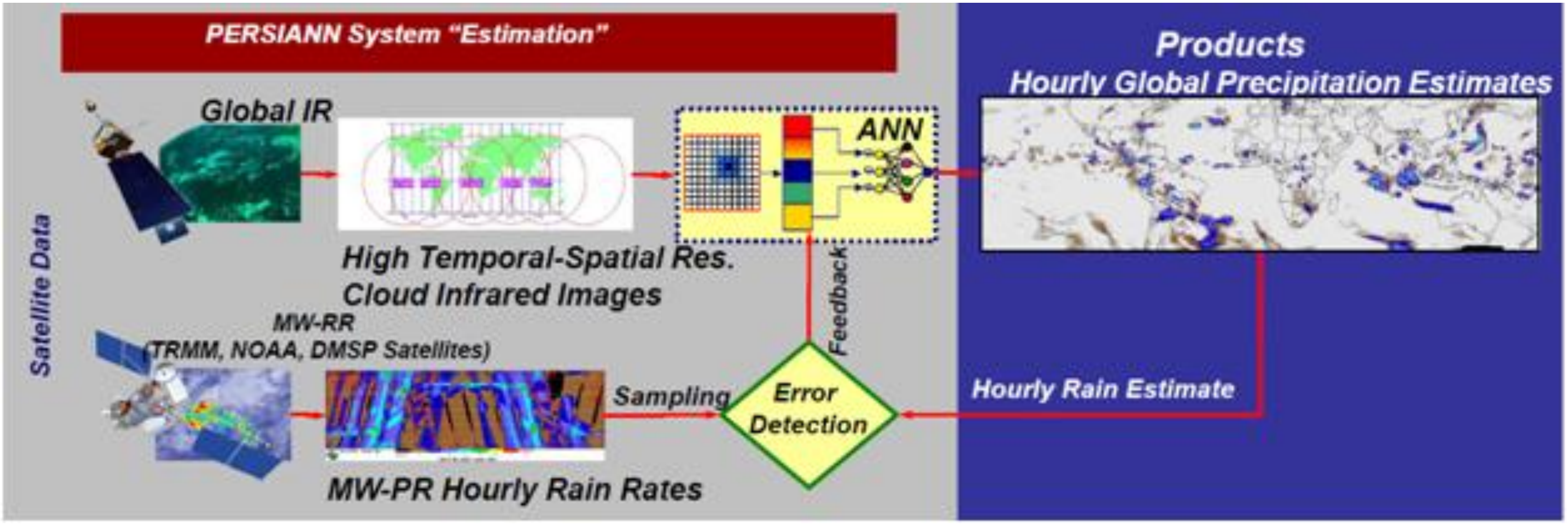


TRMM PR (NASA/NASDA)

TRMM precipitation RADAR
3D imaging of rainfall
1-2 days between overpasses
(S-35° N-35 °)

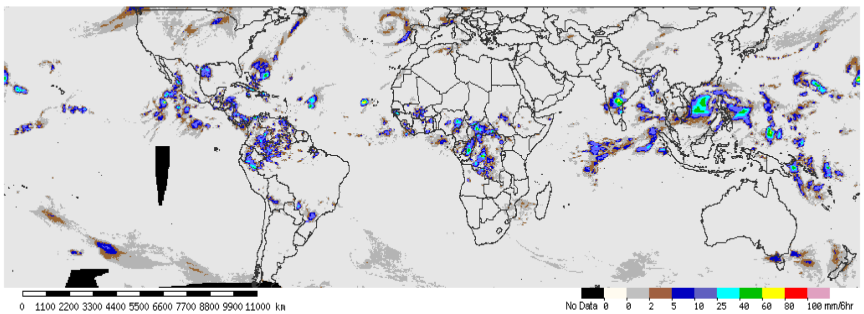
Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)

The algorithm utilizes a neural network classification and approximation approach to derive precipitation estimates based on IR data calibrated with microwave estimates.

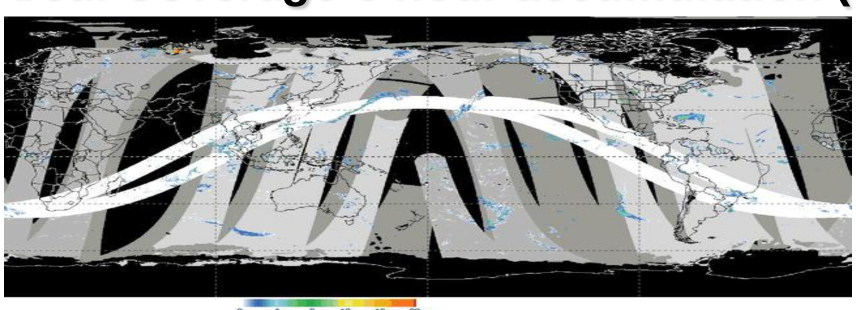


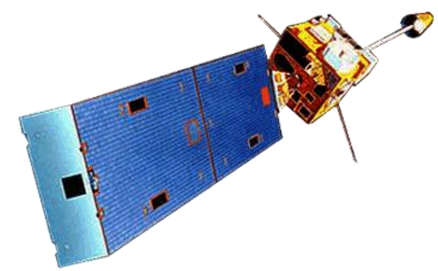
PERSIANN ALGORITHM

GEO (VIS/IR):
- Less accurate estimates
- Good global areal coverage with high temporal sampling



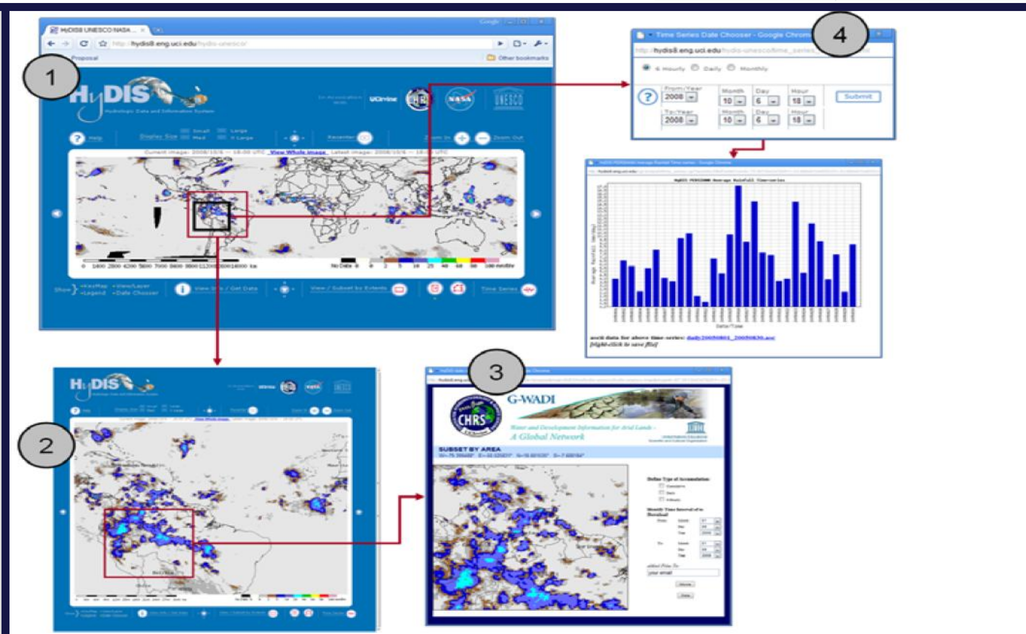
LEO (PMW):
- More accurate and less frequent estimates
- Areal Coverage 3 hour accumulation (Regional gaps)



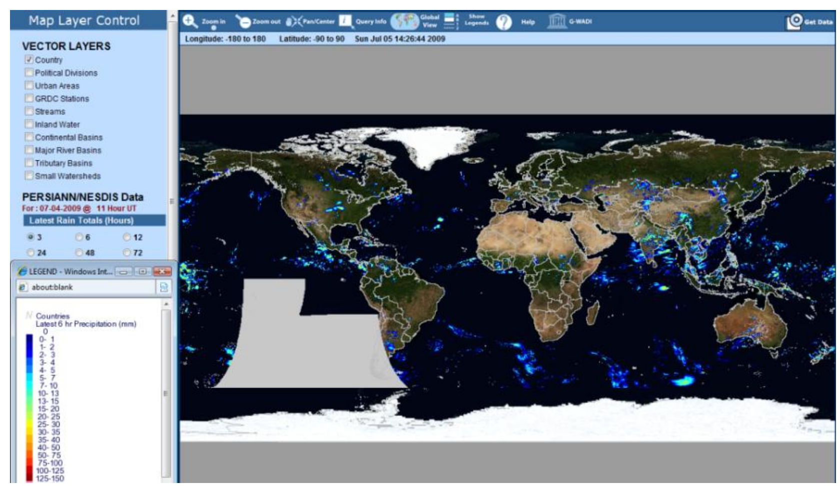


PERSIANN ALGORITHM

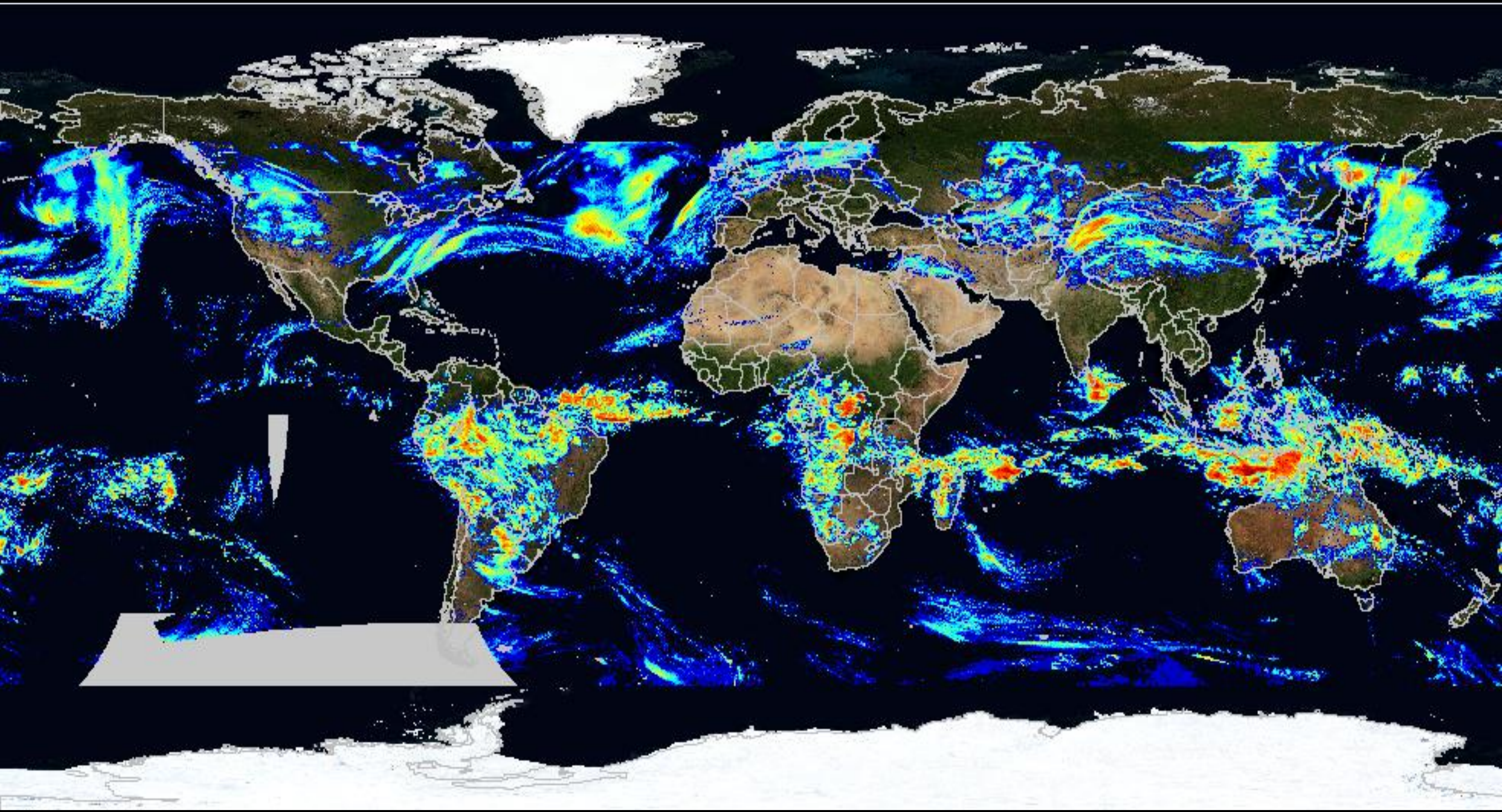
PERSIANN data
Spatial Resolution: 0.25º degree
Temporal Resolution: 3-hour
Source: HyDIS
http://hydis8.eng.uci.edu/hydis-unesco/



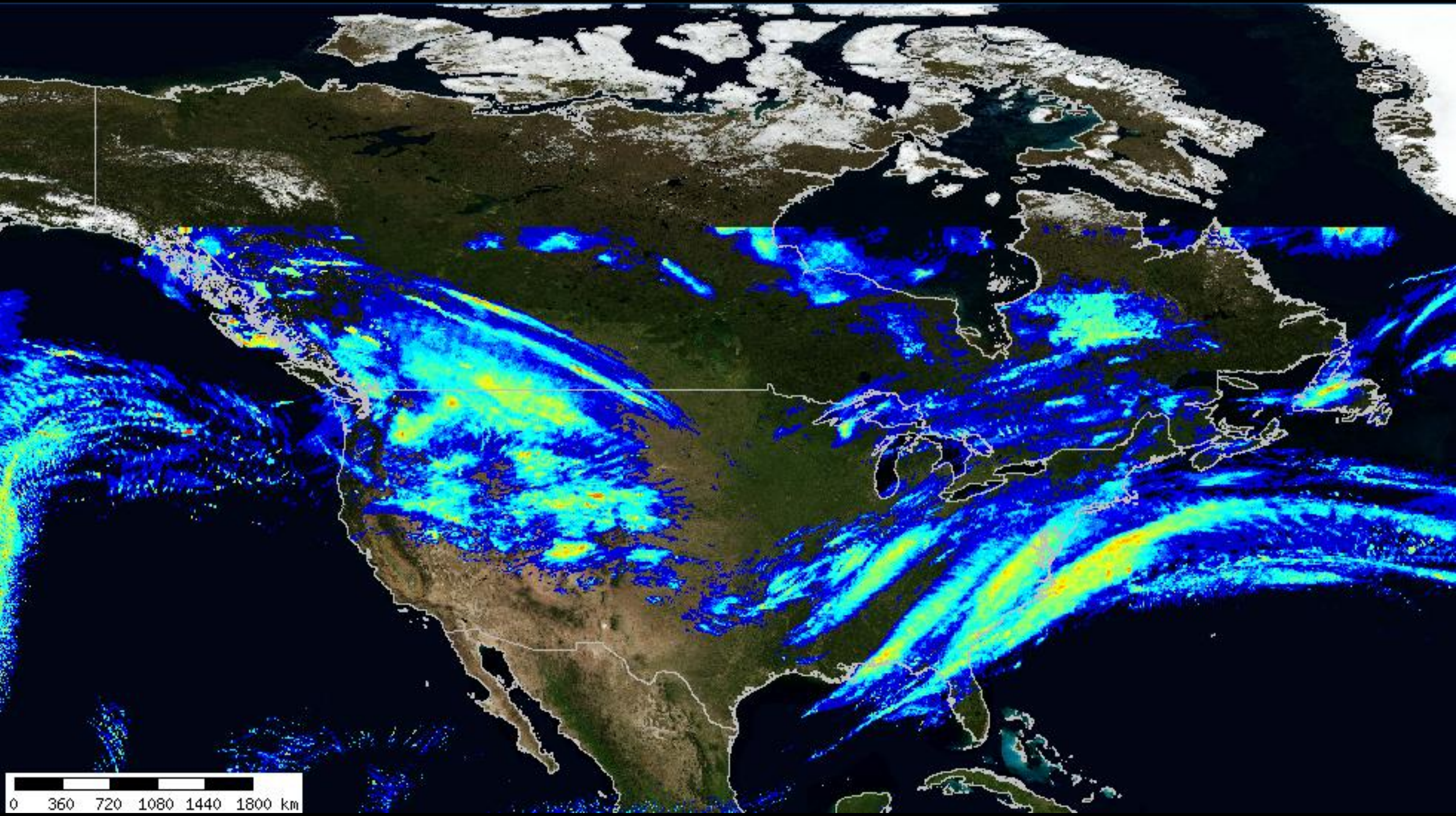
PERSIANN-CCS data
Spatial Resolution: 0.04º degree
Temporal Resolution: 1-hour
Source: GWADI
http://hydis.eng.uci.edu/gwadi/



PERSIANN ALGORITHM

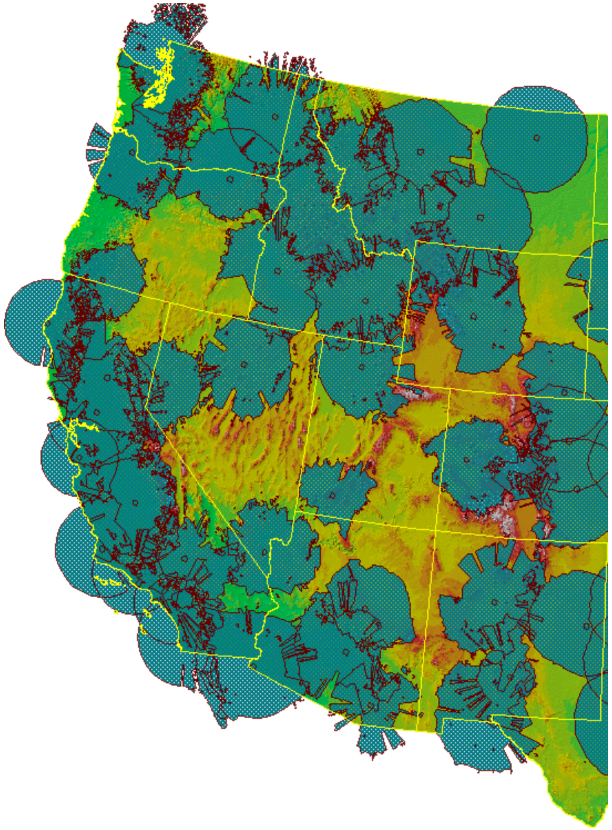


PERSIANN ALGORITHM



WHY SATELLITES?

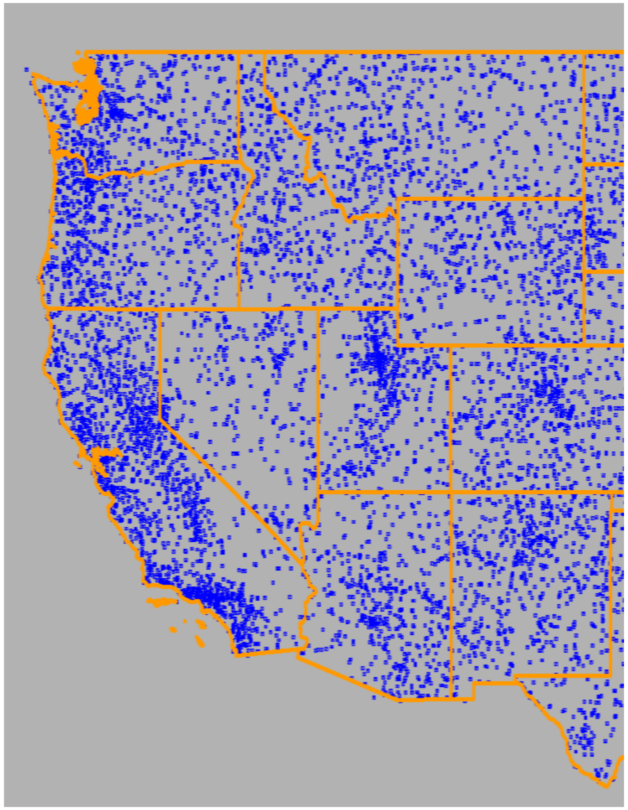
WSR-88D Radar Coverage



3 km Above Ground Level

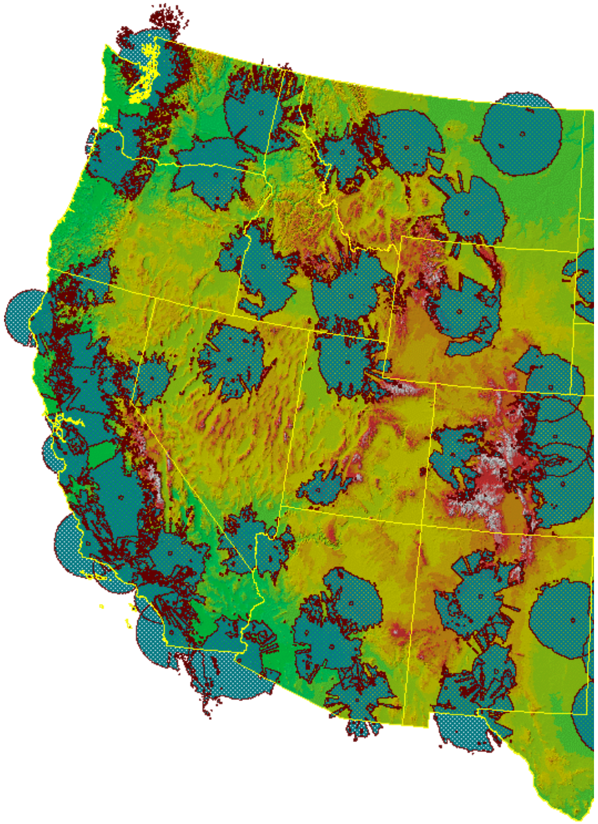
Maddox, et. Al., 2002

Gauge Network



WHY SATELLITES?

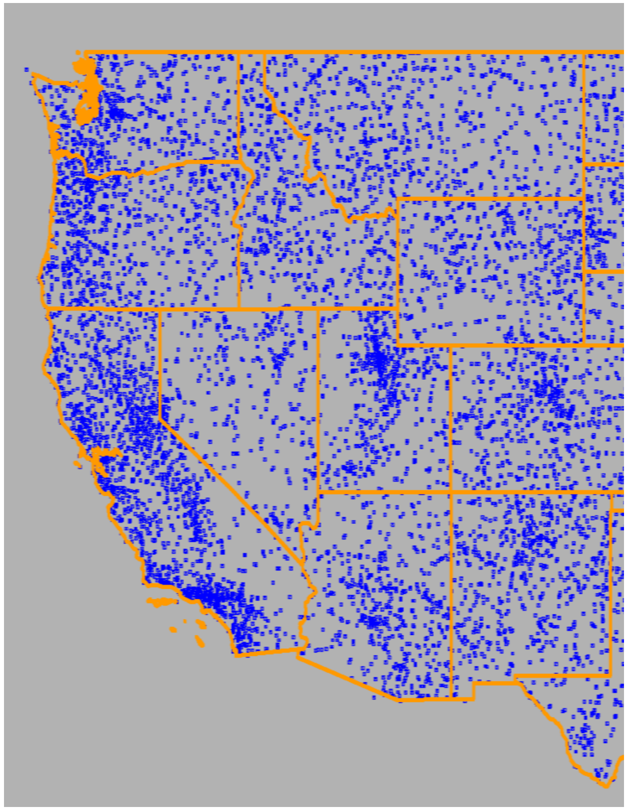
WSR-88D Radar Coverage



2 km Above Ground Level

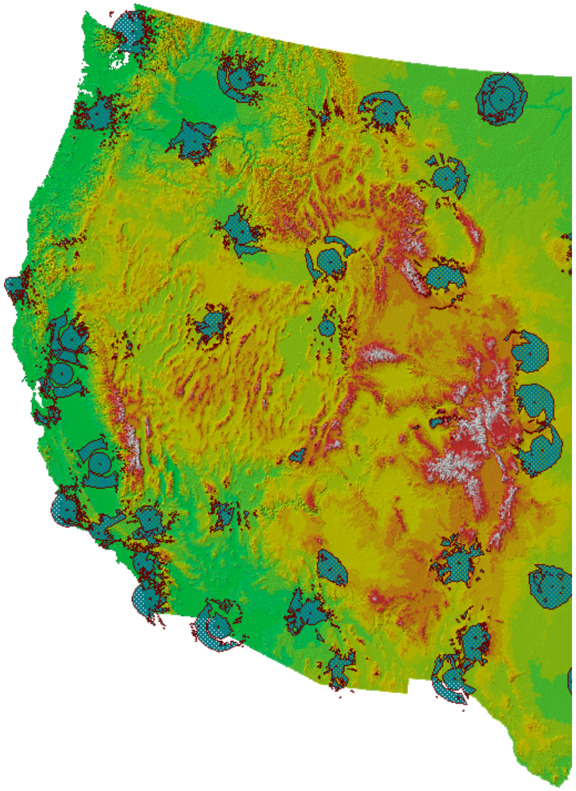
Maddox, et. Al., 2002

Gauge Network



WHY SATELLITES?

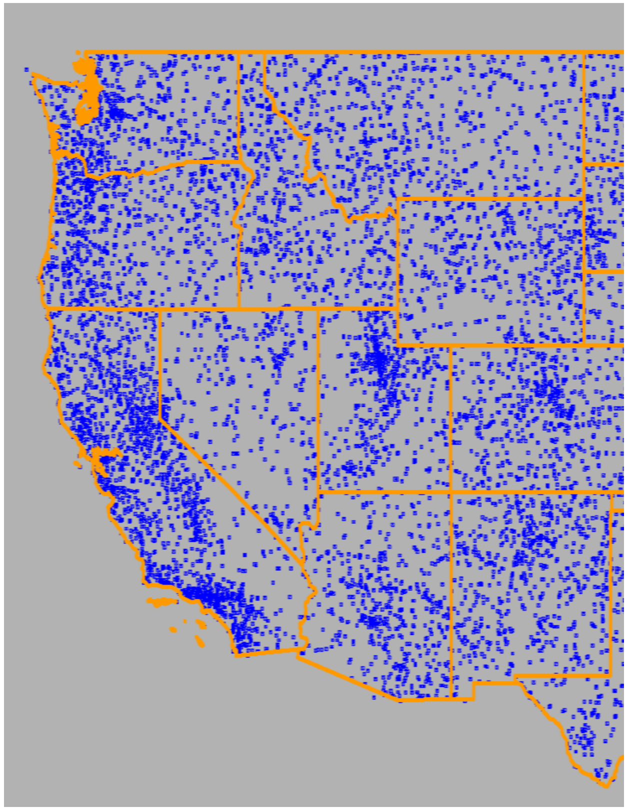
WSR-88D Radar Coverage



1 km Above Ground Level

Maddox, et. Al., 2002

Gauge Network

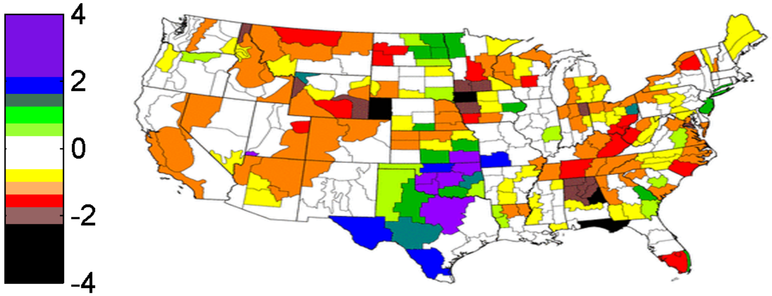


Drought Analysis Based on Standard Precipitation Index (SPI) Using Remotely Sensed Precipitation Data

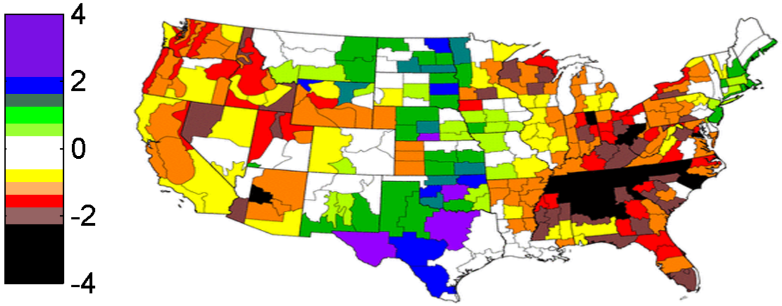
DROUGHT ANALYSIS

SPI Estimates: NCDC Gauge Precipitation Data

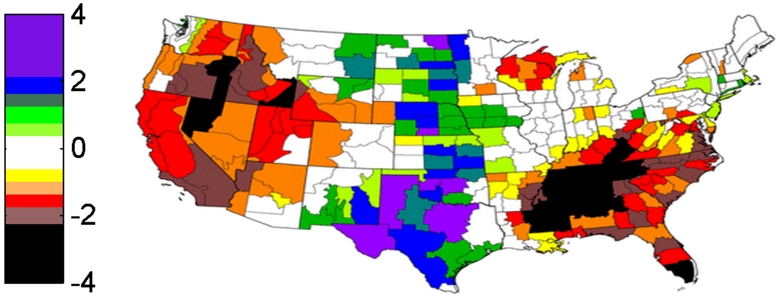
1-Month SPI Index; June 2007



3-Month SPI Index; April-June 2007



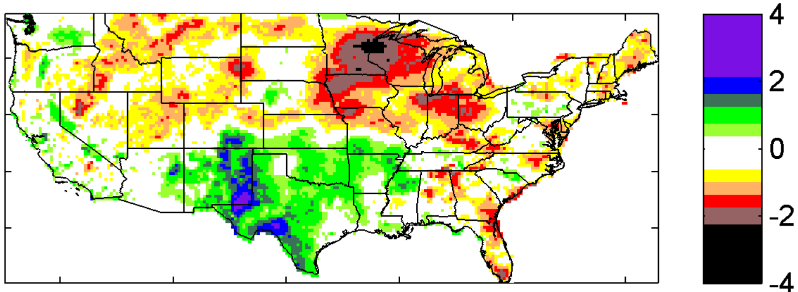
6-Month SPI Index; January-June 2007



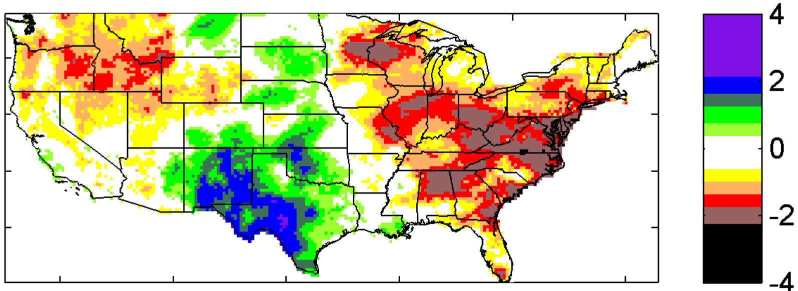
DROUGHT ANALYSIS

SPI Estimates: PERSIANN Satellite Precipitation Data

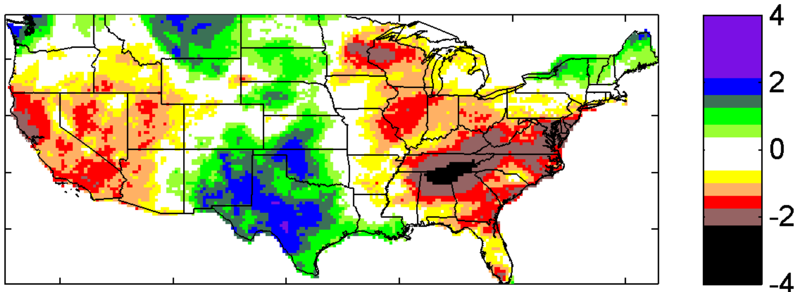
1-Month SPI Index; June 2007



3-Month SPI Index; April-June 2007

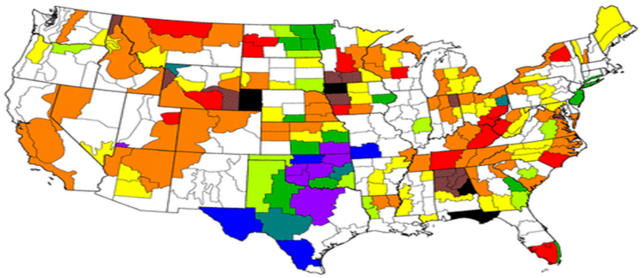


6-Month SPI Index; January-June 2007

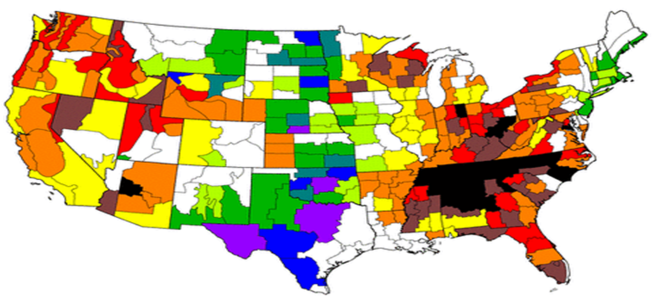


SPI Estimates: NCDC Gauge Precipitation Data

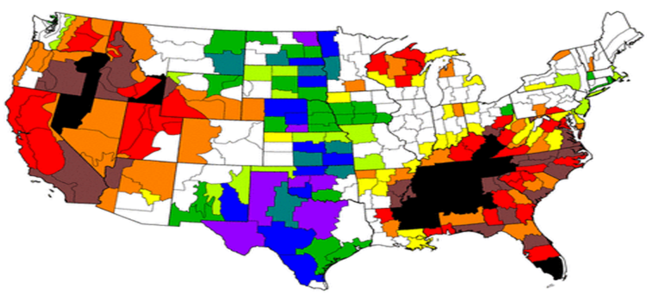
1-Month SPI Index; June 2007



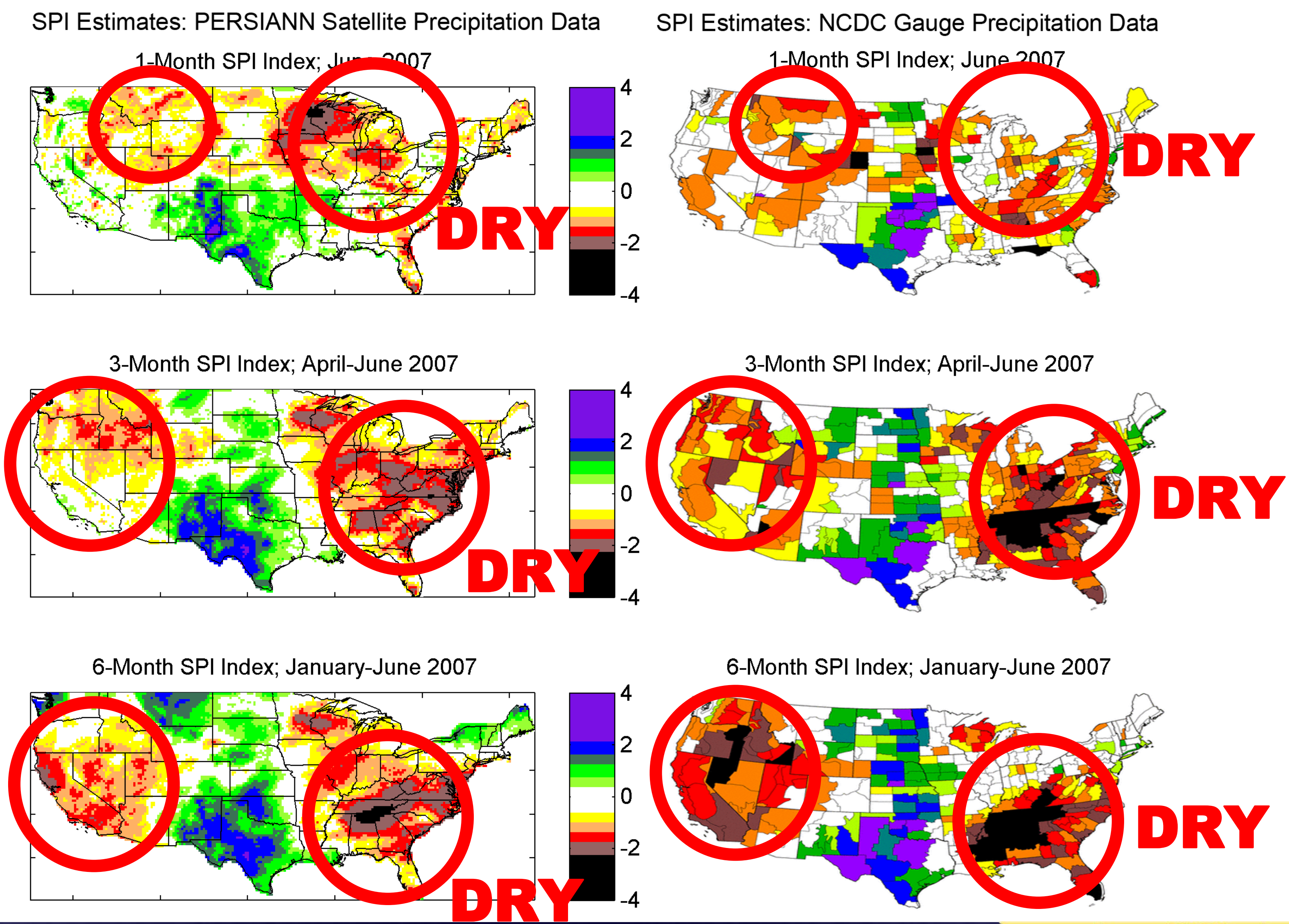
3-Month SPI Index; April-June 2007



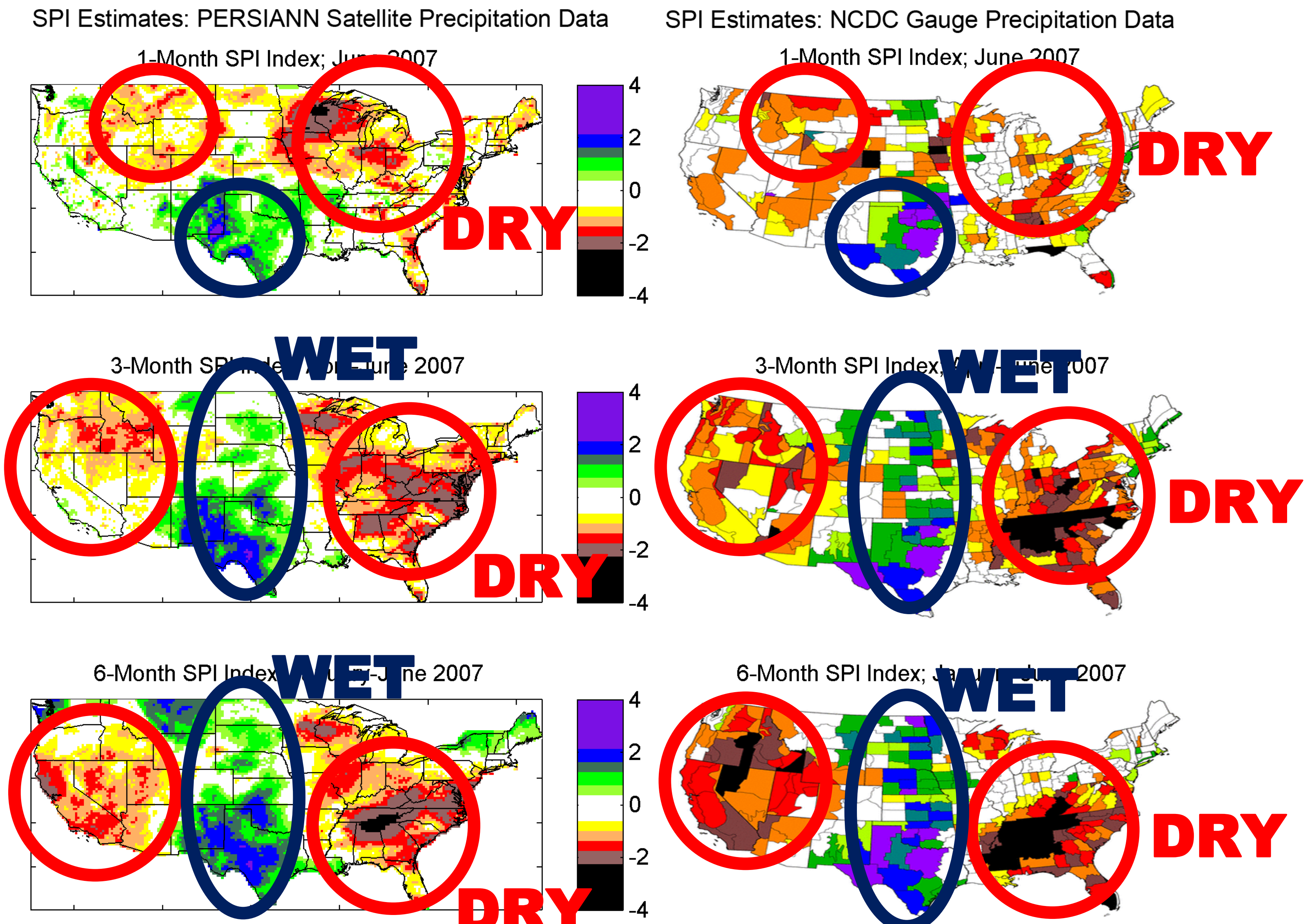
6-Month SPI Index; January-June 2007



DROUGHT ANALYSIS



DROUGHT ANALYSIS

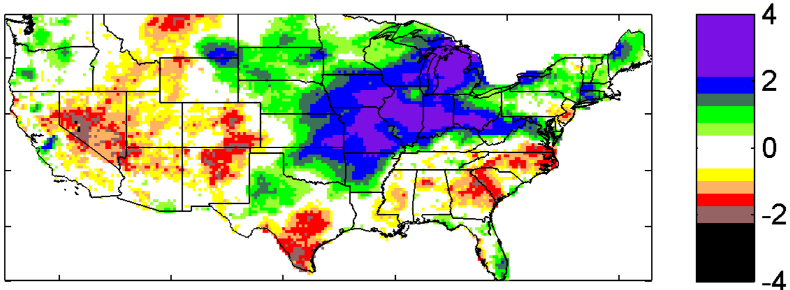


DROUGHT ANALYSIS

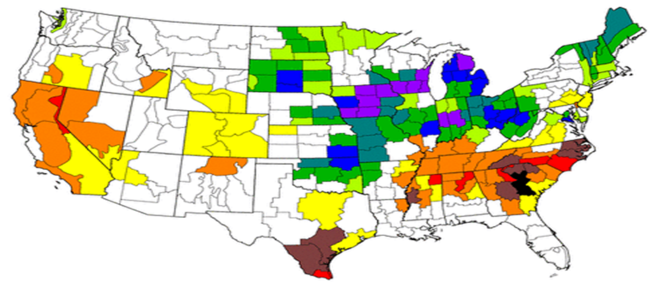
SPI Estimates: PERSIANN Satellite Precipitation Data

SPI Estimates: NCDC Gauge Precipitation Data

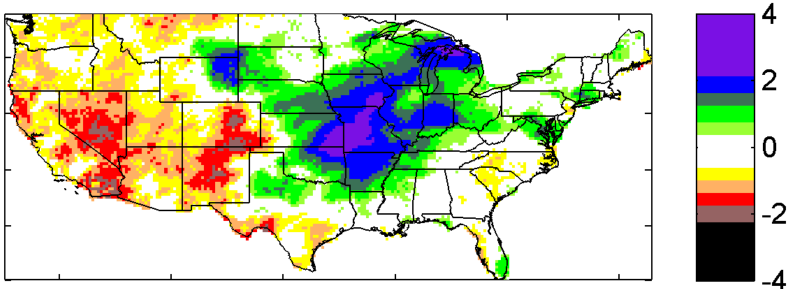
1-Month SPI Index; June 2008



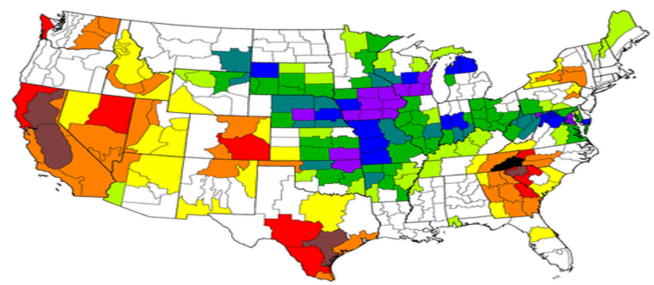
1-Month SPI Index; June 2008



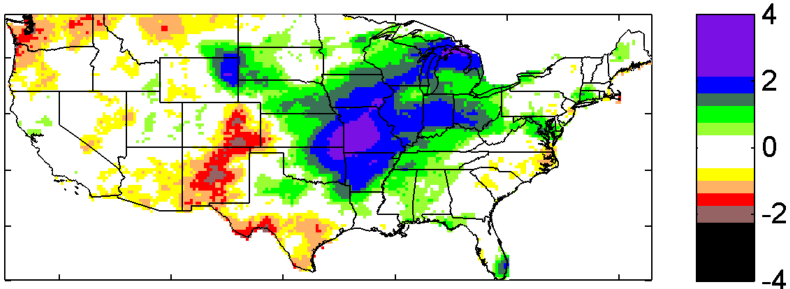
3-Month SPI Index; April-June 2008



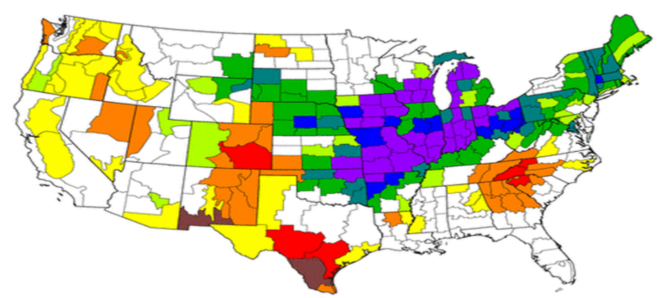
3-Month SPI Index; April-June 2008



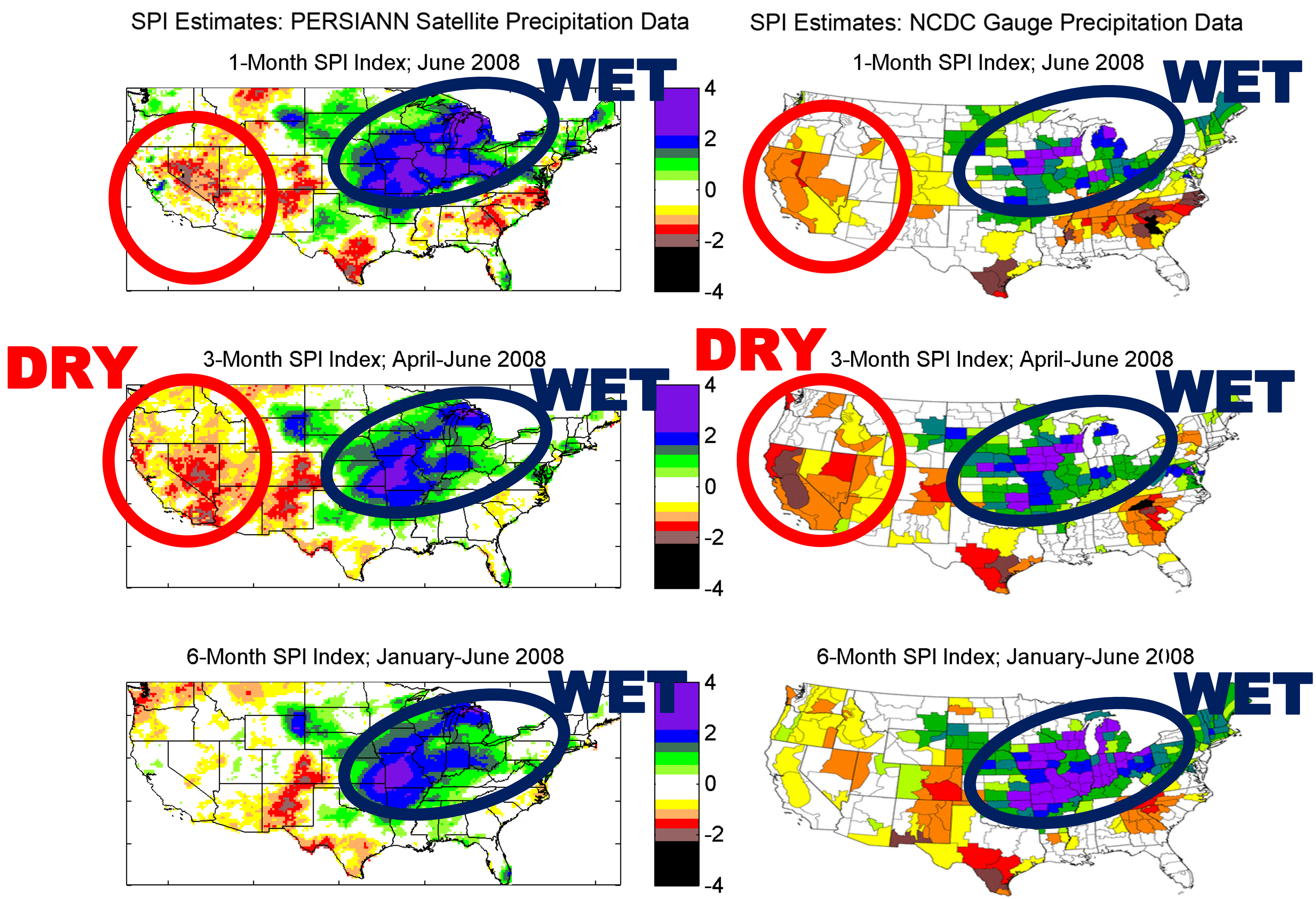
6-Month SPI Index; January-June 2008



6-Month SPI Index; January-June 2008

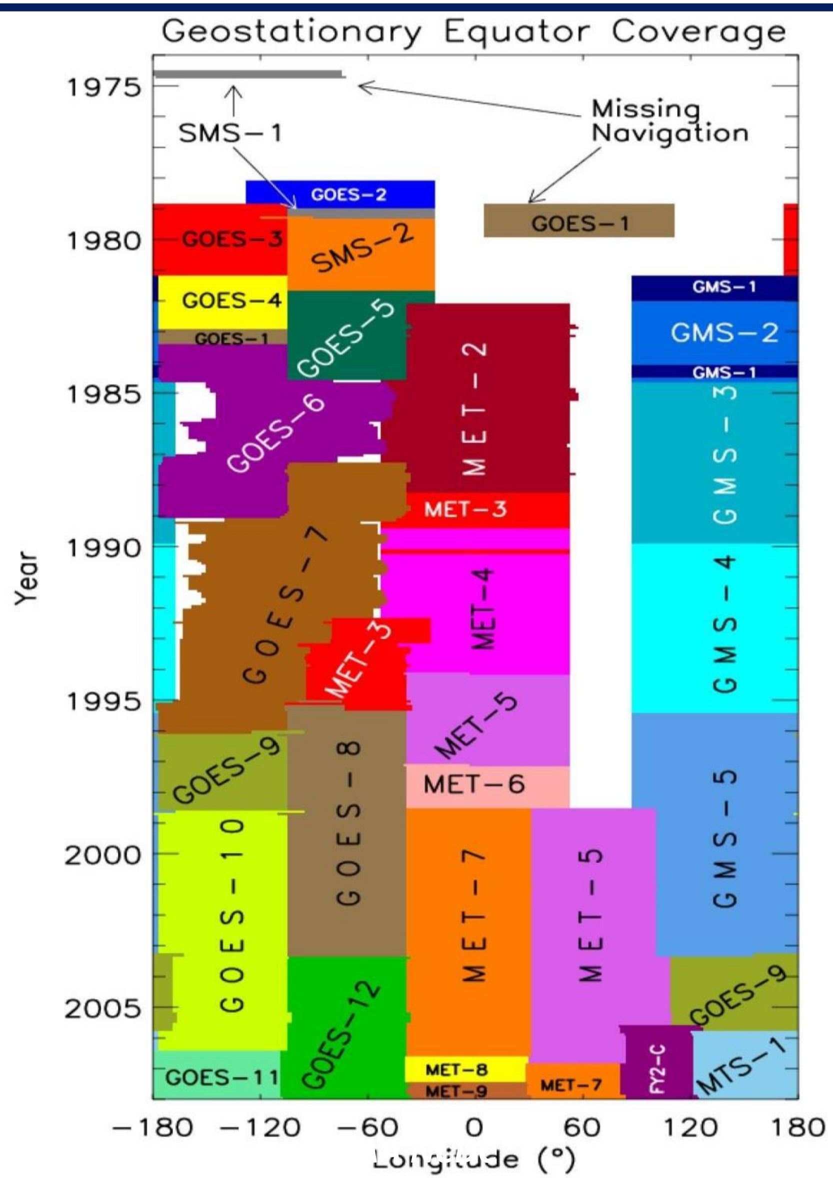


DROUGHT ANALYSIS



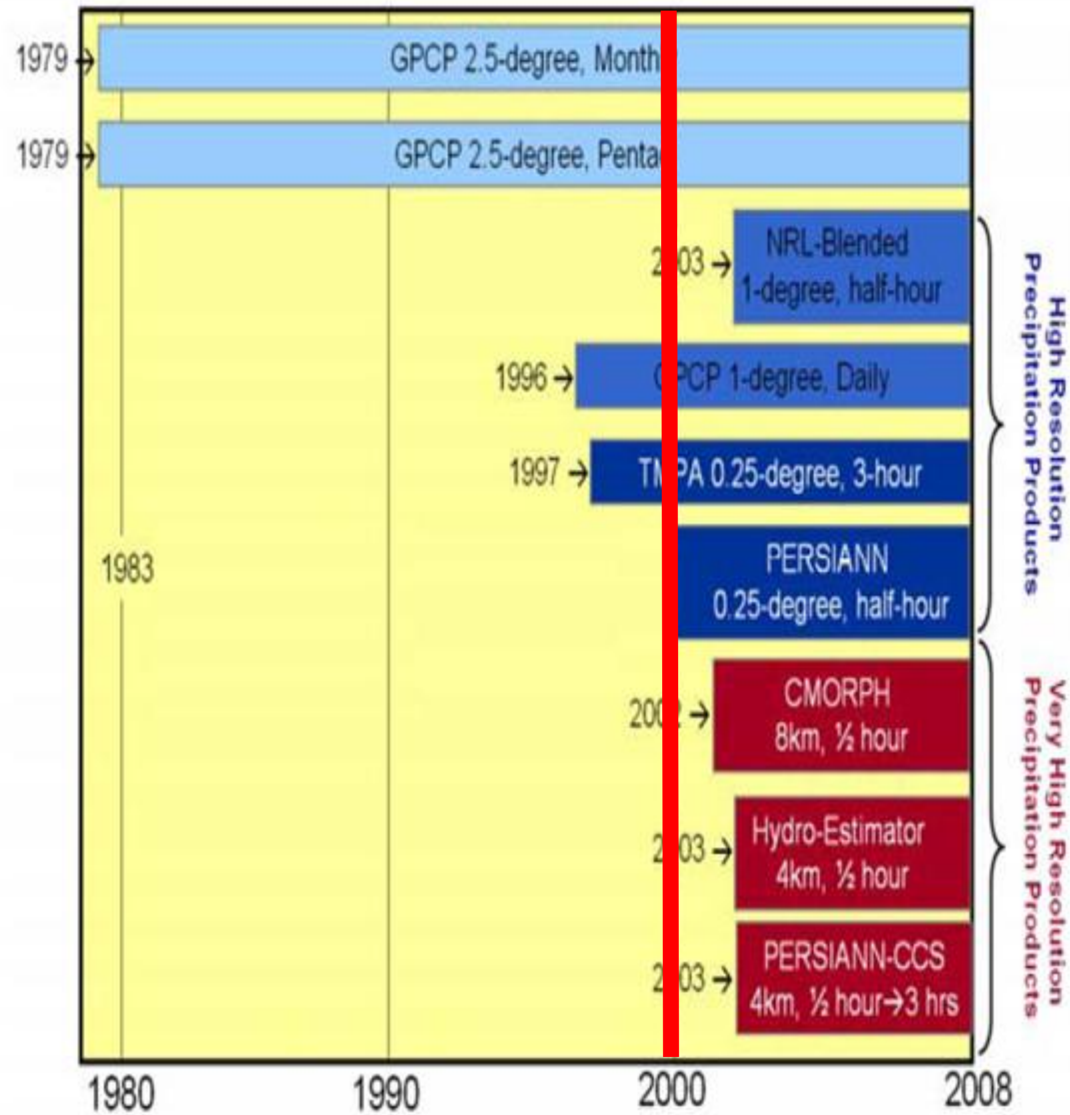
RECONSTRUCTION OF LONG-TERM DATA

Reconstruction of PERSIANN rainfall data back to 1983 based on the available Inferred (IR) data from GEO



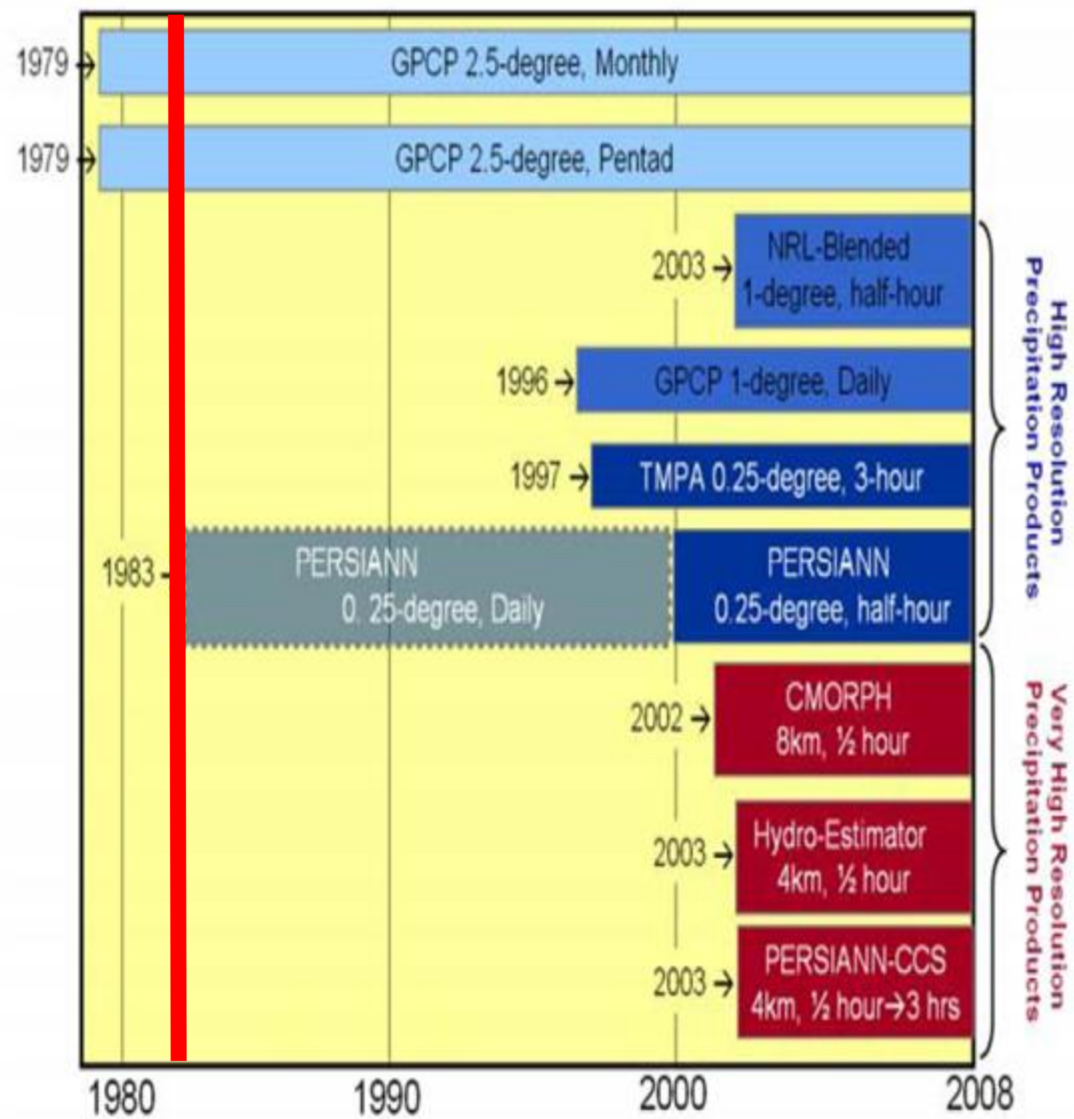
RECONSTRUCTION OF LONG-TERM DATA

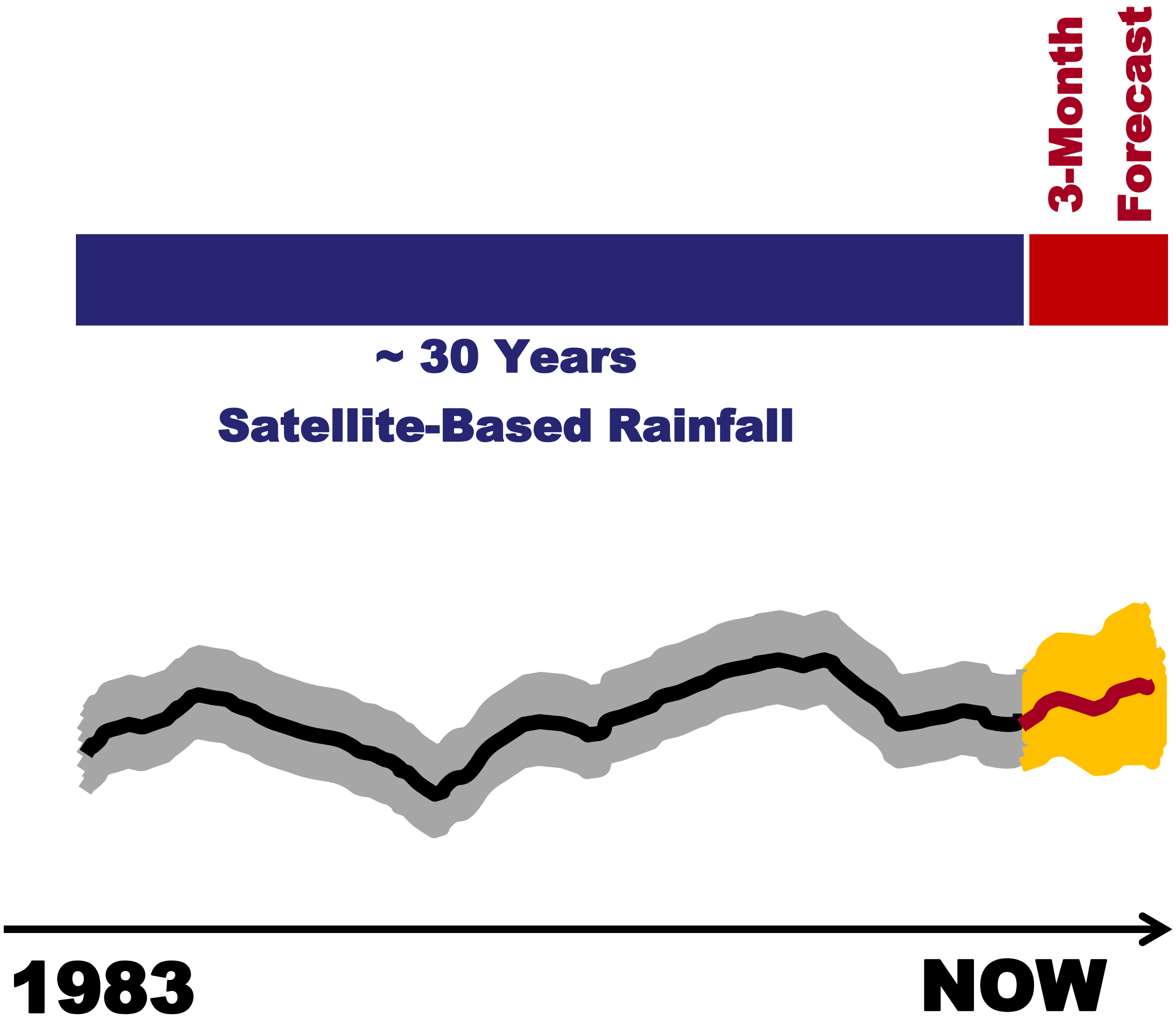
Reconstruction of PERSIANN rainfall data back to 1983 based on the available Inferred (IR) data from GEO



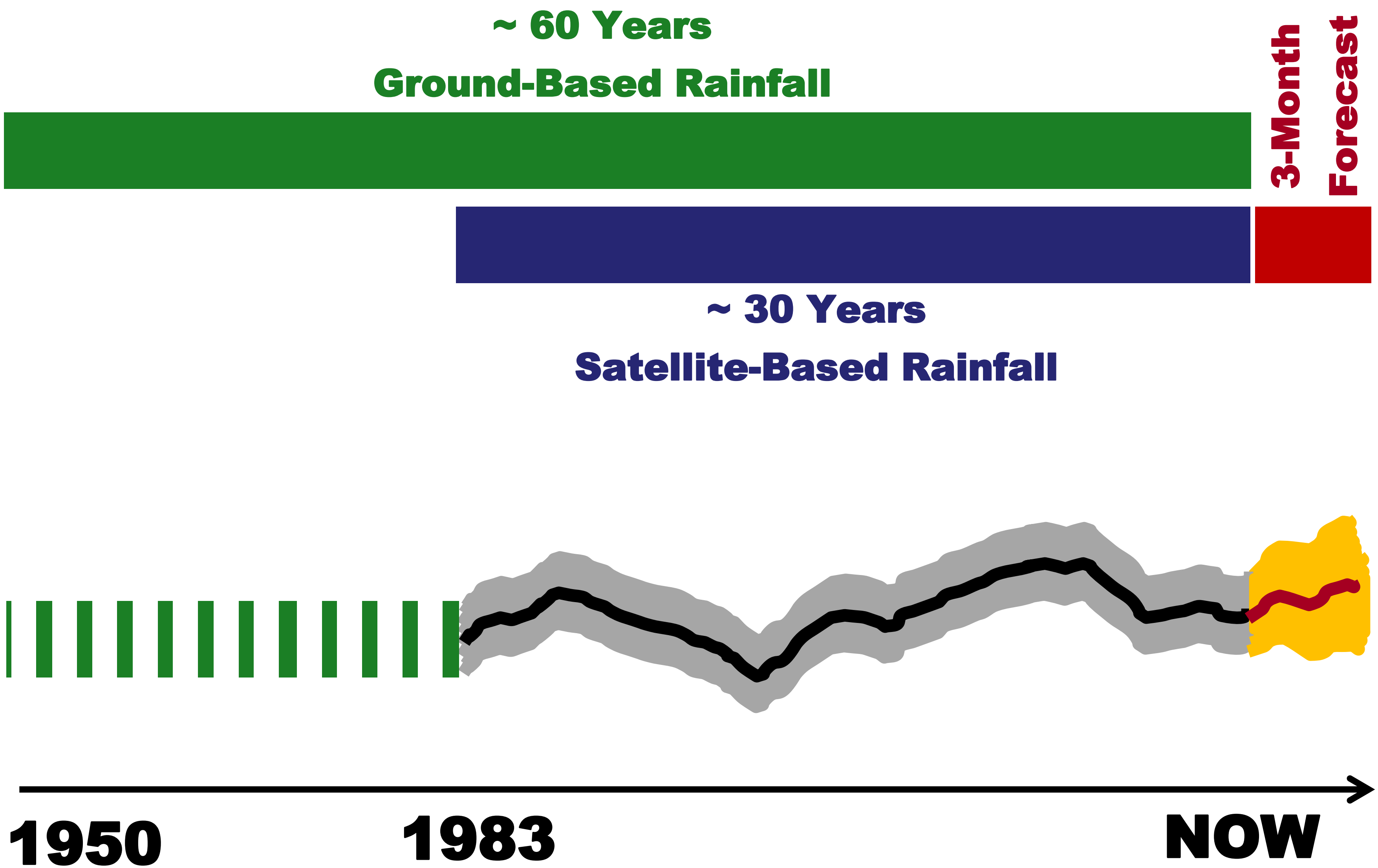
RECONSTRUCTION OF LONG-TERM DATA

Reconstruction of PERSIANN rainfall data back to 1983 based on the available Inferred (IR) data from GEO




3-Month Forecast
~ 30 Years
Satellite-Based Rainfall
1983
NOW

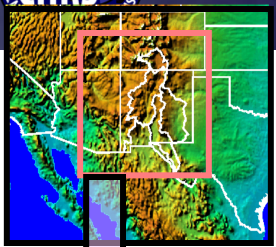
DROUGHT ANALYSIS



Application of Satellite Precipitation Data to Flood Warning

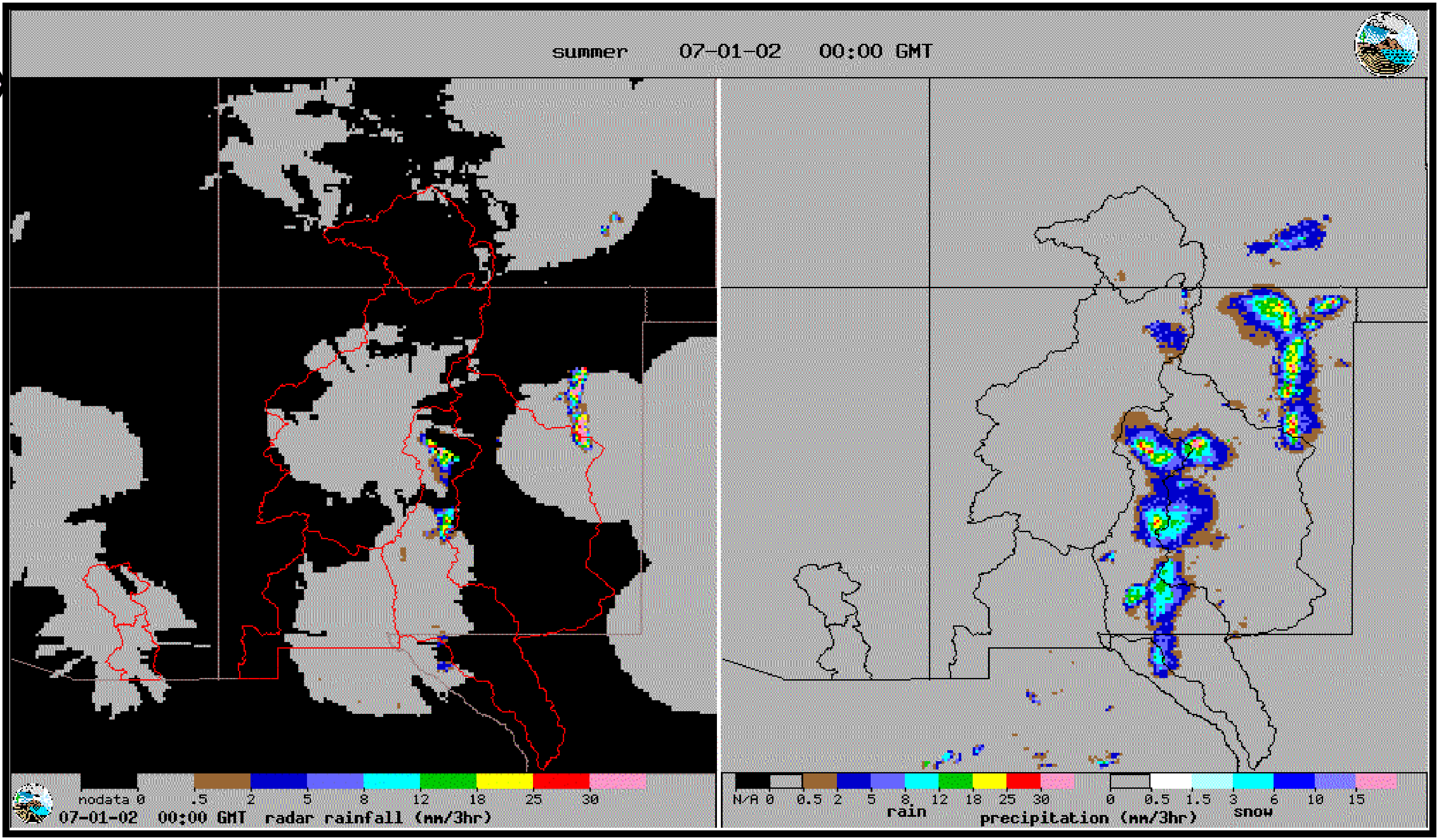
High Resolution Data from Satellites

Study Area



Radar Observation (2 km AGL)

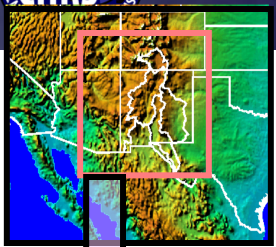
PERSIANN-CCS Estimates



4km x 4km, 3-hour accumulated precipitation

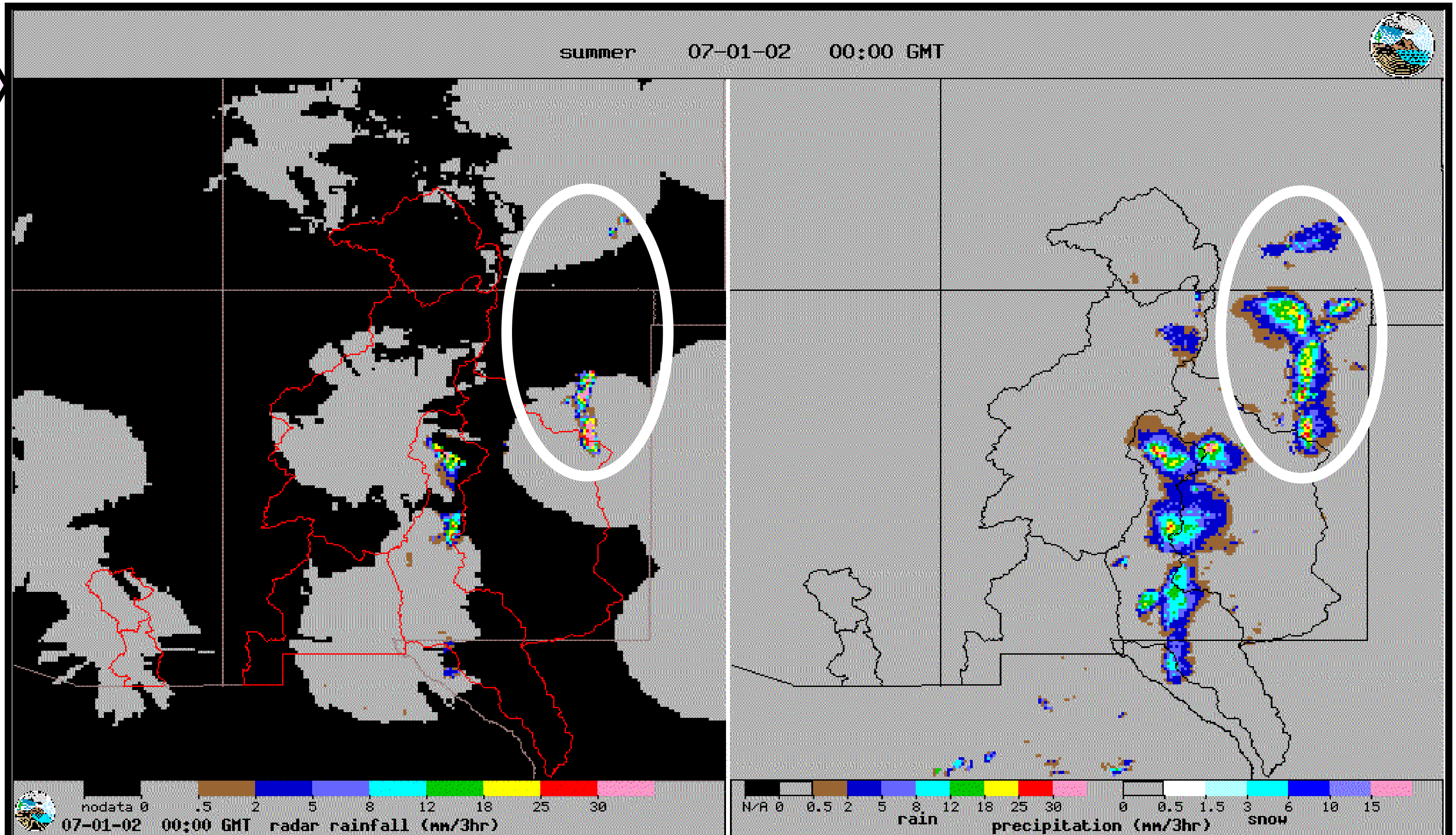
High Resolution Data from Satellites

Study Area



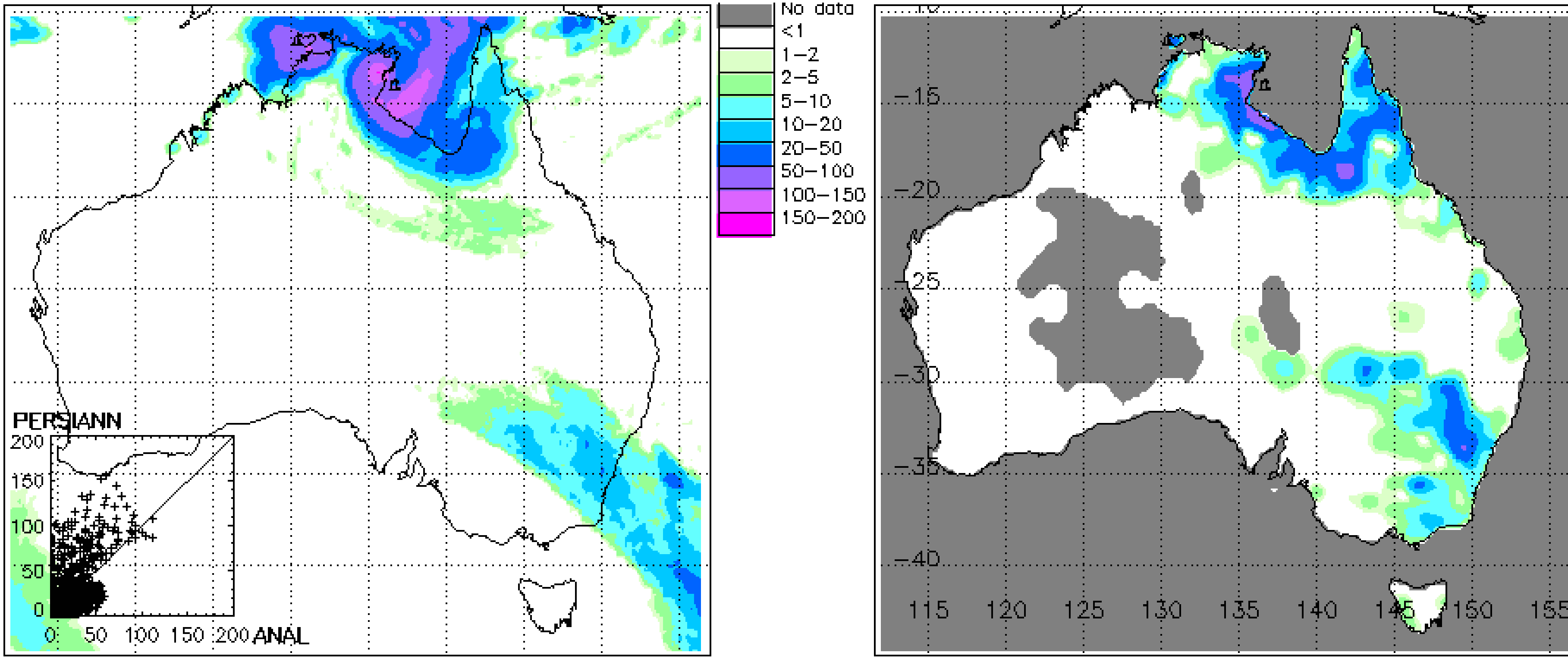
Radar Observation (2 km AGL)

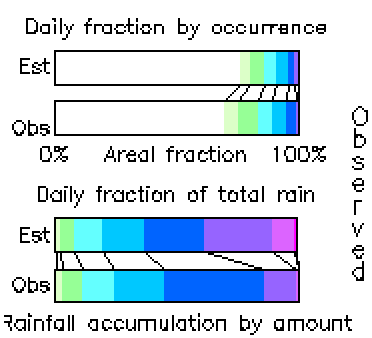
PERSIANN-CCS Estimates



4km x 4km, 3-hour accumulated precipitation

SATELLITE VS. GAUGE





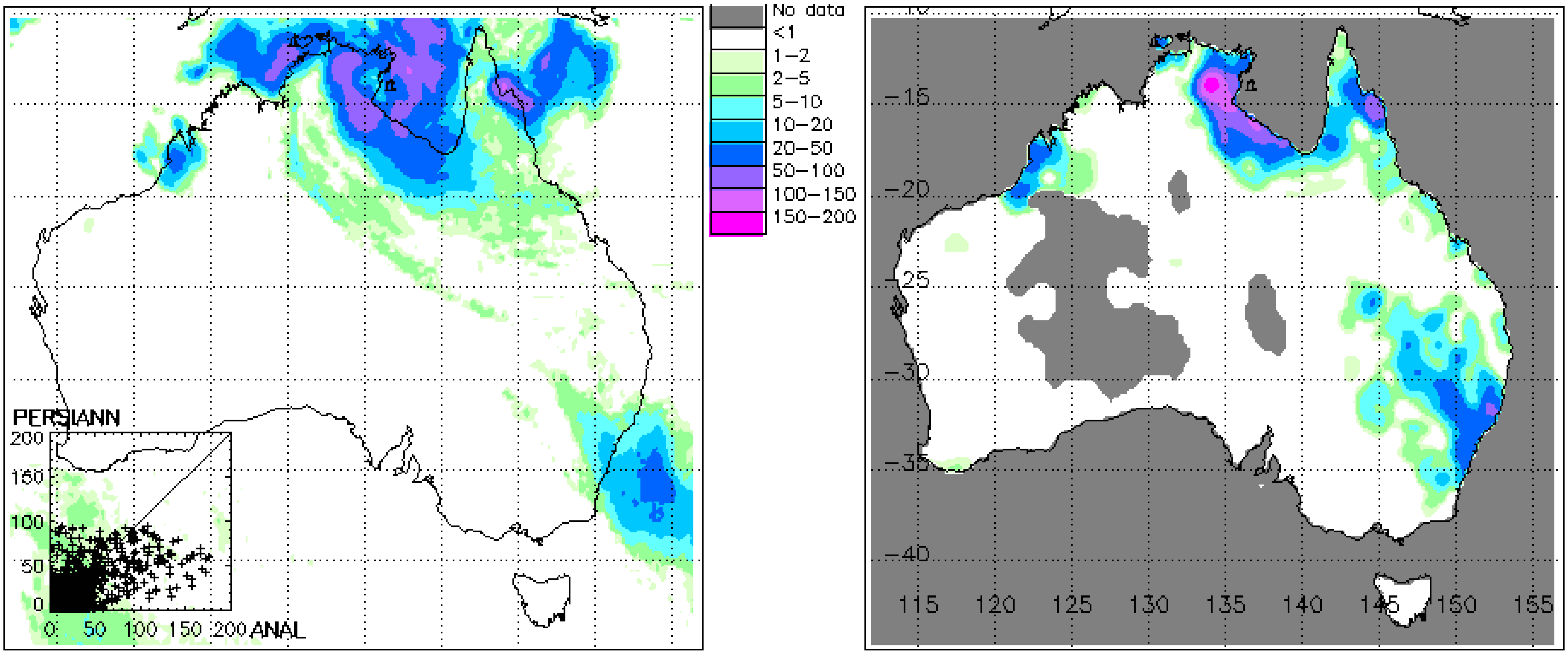
		PERSIANN <1	PERSIANN ≥1
Observed	<1	6231	670
Observed	≥1	1250	1684

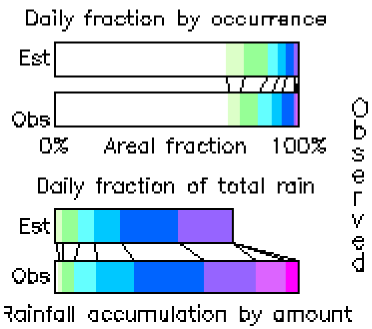
Verification statistics for 20100329 n=9835 Verif. grid=0.25° Units=mm/d

	Analysed	PERSIANN
# gridpoints raining	2934	2354
Average rain	3.4	3.4
Conditional rain	11.4	14.1
Rain volume ($mm*km^2x10^6$)	22.9	22.8
Maximum rain	112.6	155.0

Mean abs error = 3.0
RMS error = 8.4
Correlation coeff = 0.710
Frequency bias = 0.802
Probability of detection = 0.574
False alarm ratio = 0.285
Hanssen & Kuipers score = 0.477
Equitable threat score= 0.338

SATELLITE VS. GAUGE





		PERSIANN <1	PERSIANN ≥1
Observed	<1	5857	1173
Observed	≥1	1116	1689

Verification statistics for 20100330 n=9835 Verif. grid=0.25° Units=mm/d

	Analysed	PERSIANN
# gridpoints raining	2805	2862
Average rain	4.5	3.3
Conditional rain	15.8	11.3
Rain volume (mm*km²x10⁹)	30.4	22.1
Maximum rain	175.7	95.1

Mean abs error = 3.5
RMS error = 10.0
Correlation coeff = 0.736
Frequency bias = 1.020
Probability of detection = 0.602
False alarm ratio = 0.410
Hanssen & Kuipers score = 0.435
Equitable threat score= 0.276

FLOOD WARNING

Precipitation

Rainfall (R)

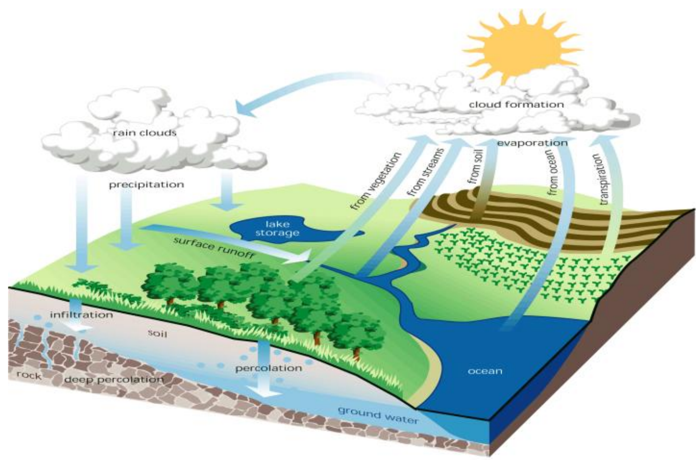
Snow

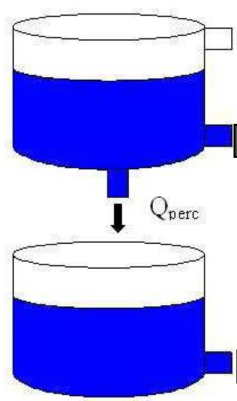
Snowmelt (S_m)

$R+S_m$

Soil Moisture

Evapotranspiration





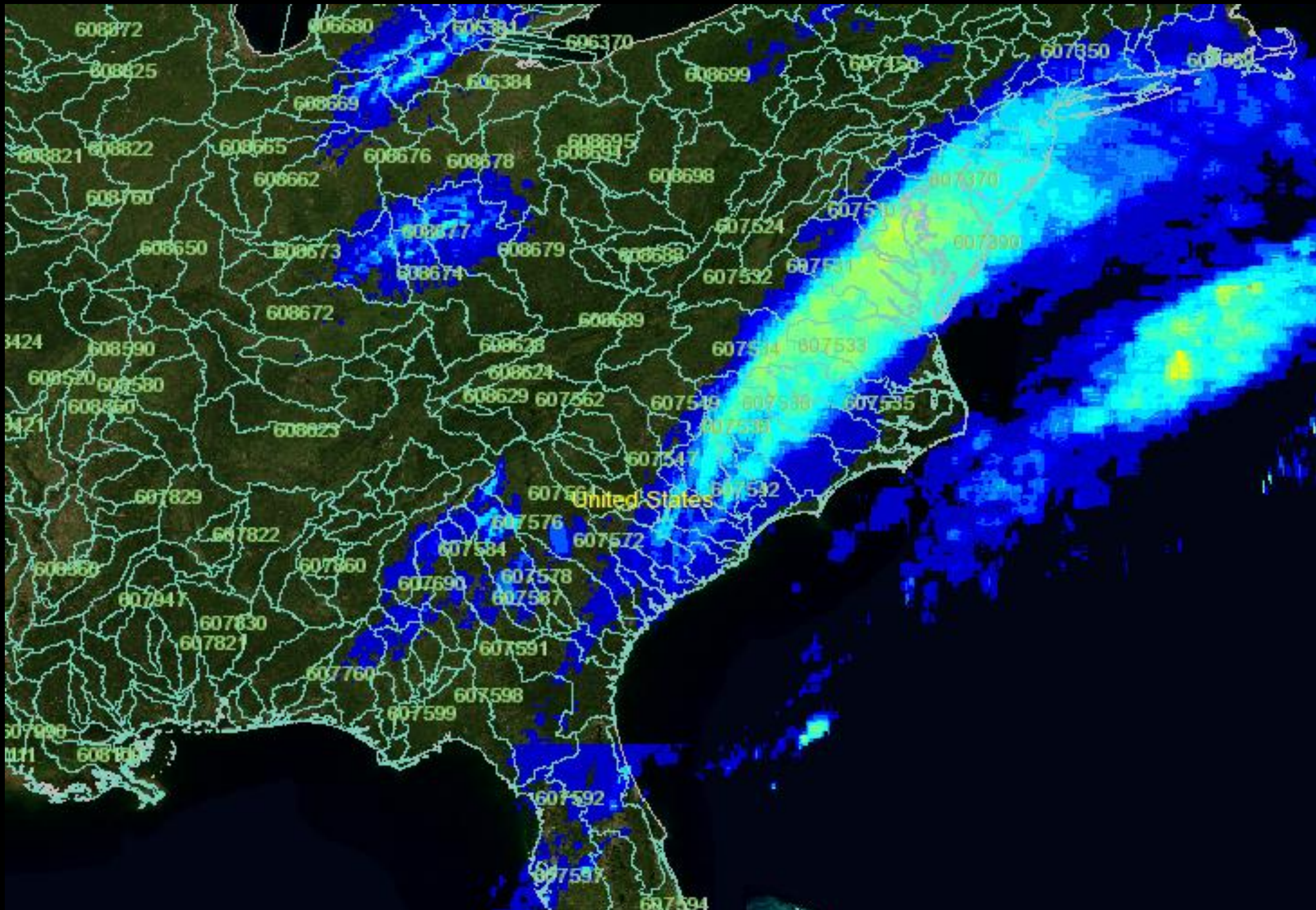
Surface Flow

Interflow

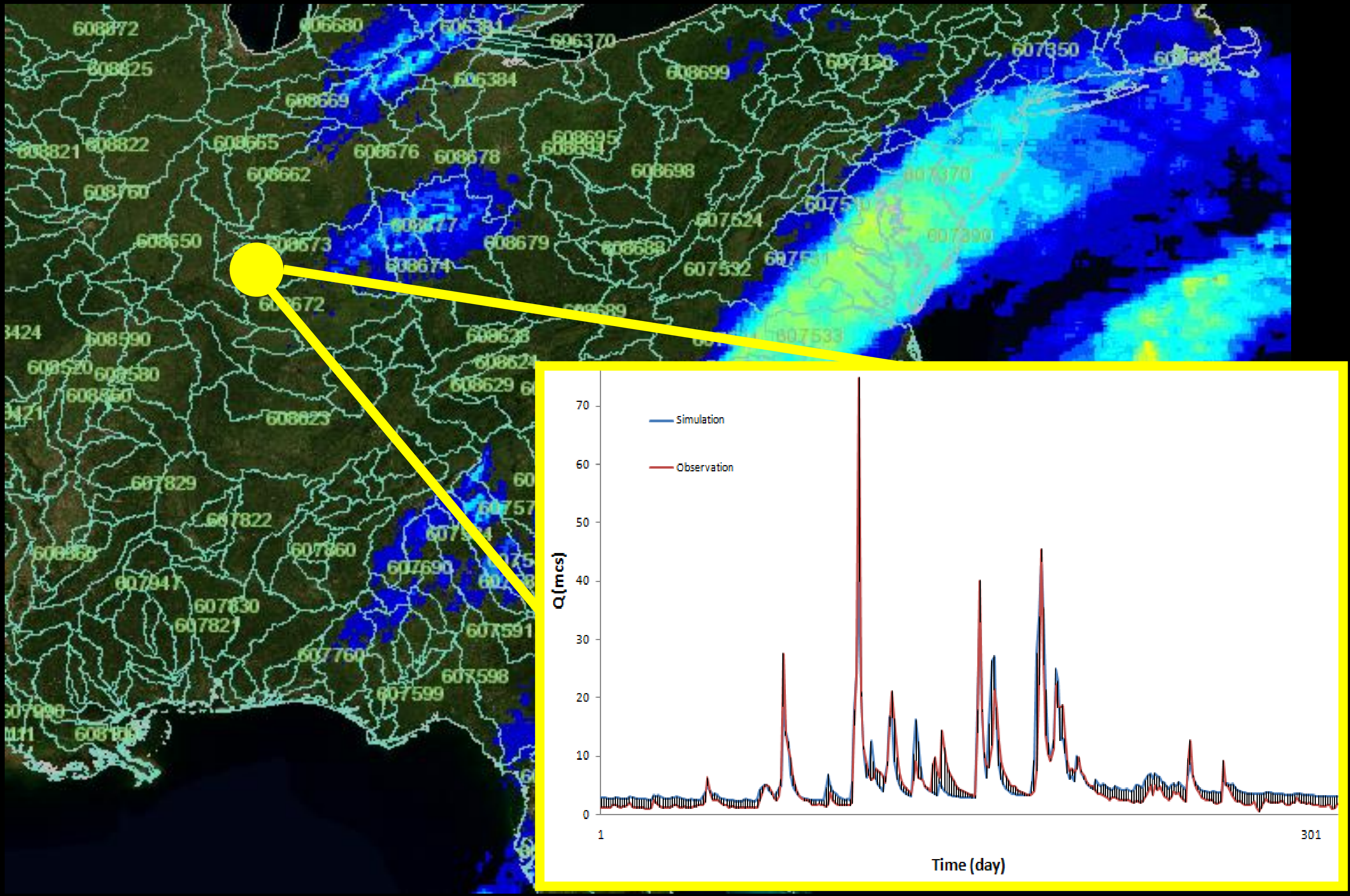
Base Flow

Runoff

FLOOD WARNING



FLOOD WARNING



QPOD

Quantile Probability of Detection (QPOD)

$$QPOD = \frac{\Sigma_{i=1}^{n}\mathbf{I}\left(P_{sat}|P_{sat} \geq t \& P_{ref} \geq t\right)}{\Sigma_{i=1}^{n}\mathbf{I}\left(P_{sat}|P_{sat} \geq t \& P_{ref} \geq t\right) + \Sigma_{i=1}^{n}\mathbf{I}\left(P_{ref}|P_{sat} < t \& P_{ref} \geq t\right)}$$

P_{sat} = satellite estimates

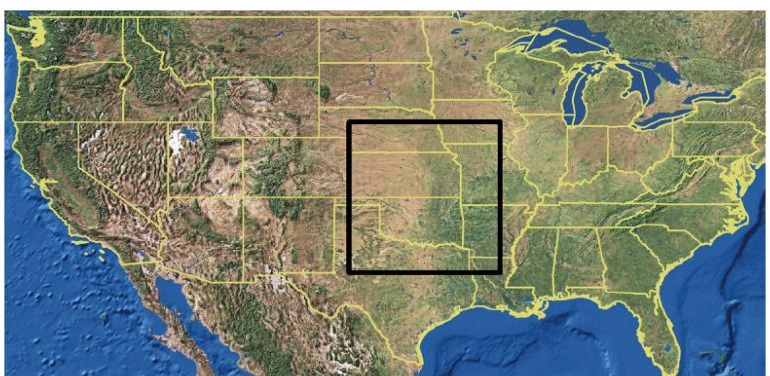
P_{ref} = reference measurements (e.g., STIV data)

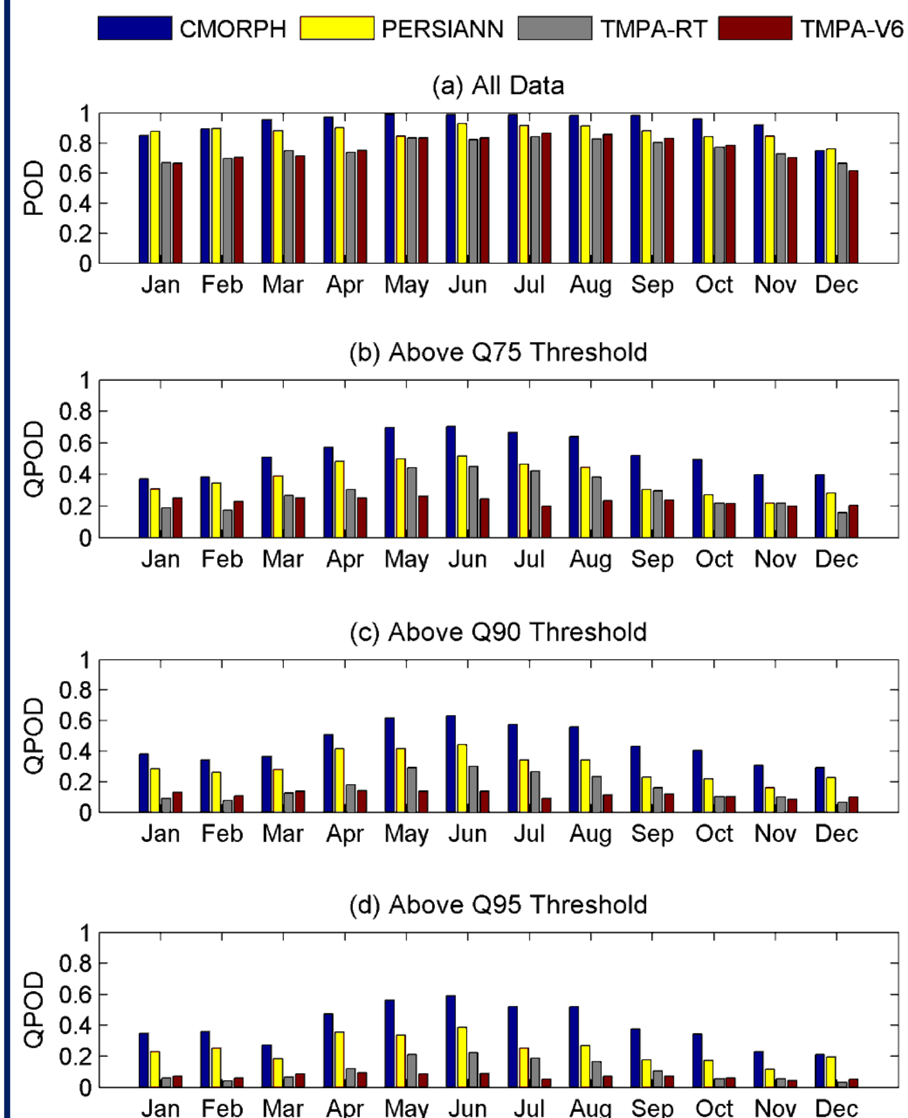
t = extreme threshold (e.g., 75, 90, 95 percentiles of data)

n = number exceedances

Period of Analysis: 2005-2008

Reference data: Stage IV radar-based gauge adjusted data





QFAR

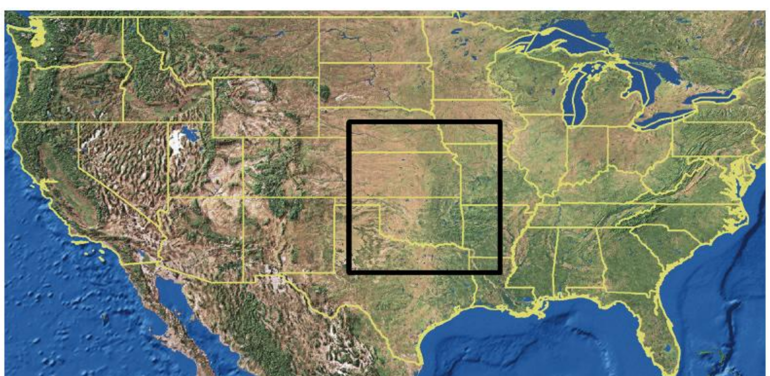
Quantile False Alarm Ration (QFAR)

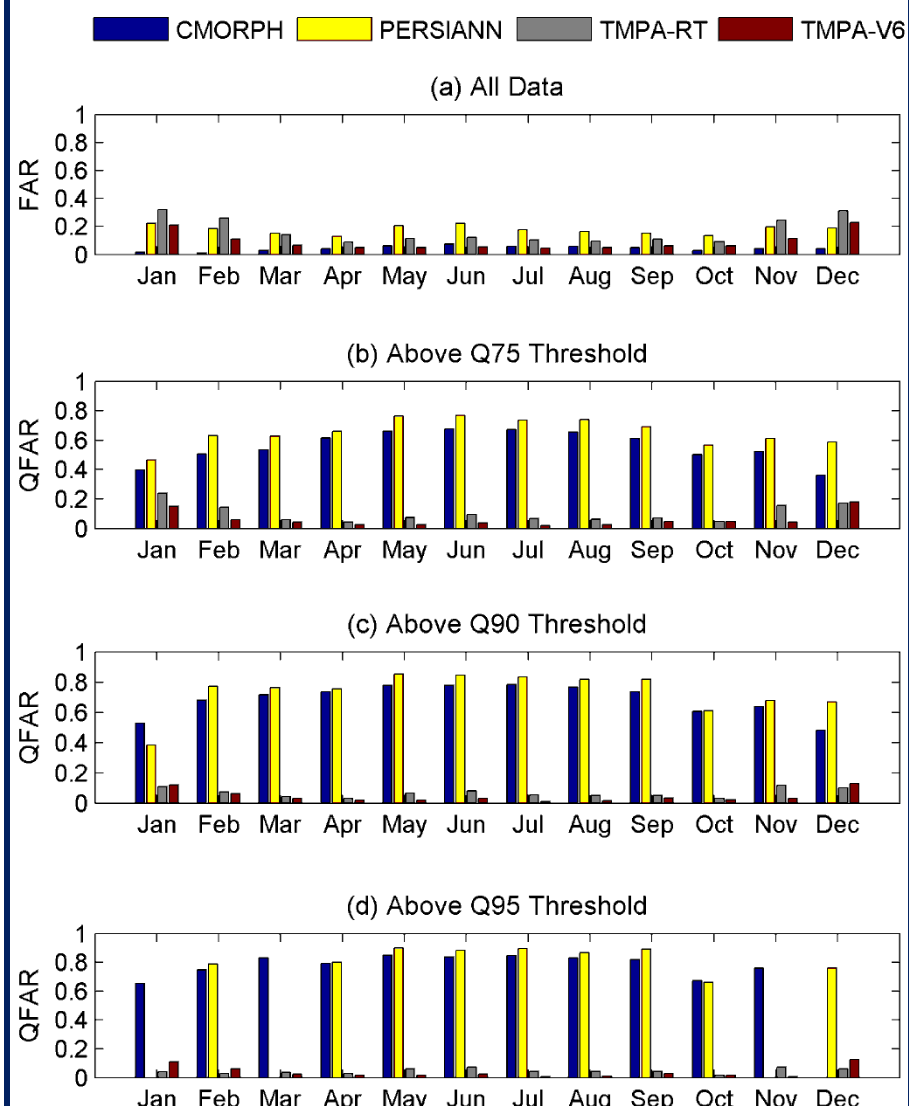
$$QFAR = \frac{\Sigma_{i=1}^{n} \mathbf{I}\left(P_{sat}|P_{sat} \geq t \& P_{ref} < t\right)}{\Sigma_{i=1}^{n} \mathbf{I}\left(P_{sat}|P_{sat} \geq t \& P_{ref} \geq t\right) + \Sigma_{i=1}^{n} \mathbf{I}\left(P_{ref}|P_{sat} \geq t \& P_{ref} < t\right)}$$

$$\begin{aligned} P_{sat} &= \text{satellite estimates} \\ P_{ref} &= \text{reference measurements (e.g., STIV data)} \\ t &= \text{extreme threshold (e.g., 75, 90, 95 percentiles of data)} \\ n &= \text{number exceedances} \end{aligned}$$

Period of Analysis: 2005-2008

Reference data: Stage IV radar-based gauge adjusted data





MONTHLY QUANTILE BIAS

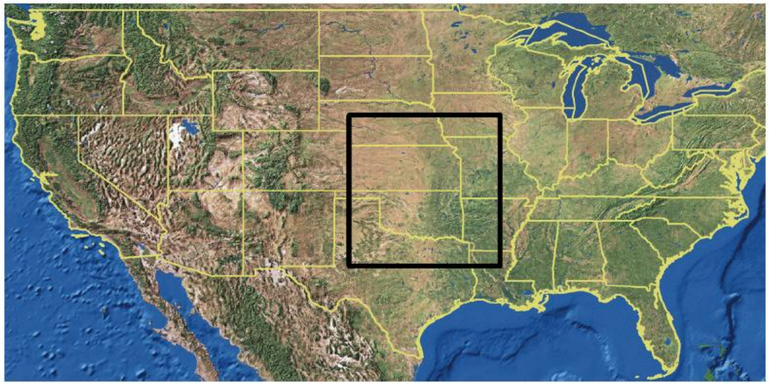
Monthly Quantile Bias

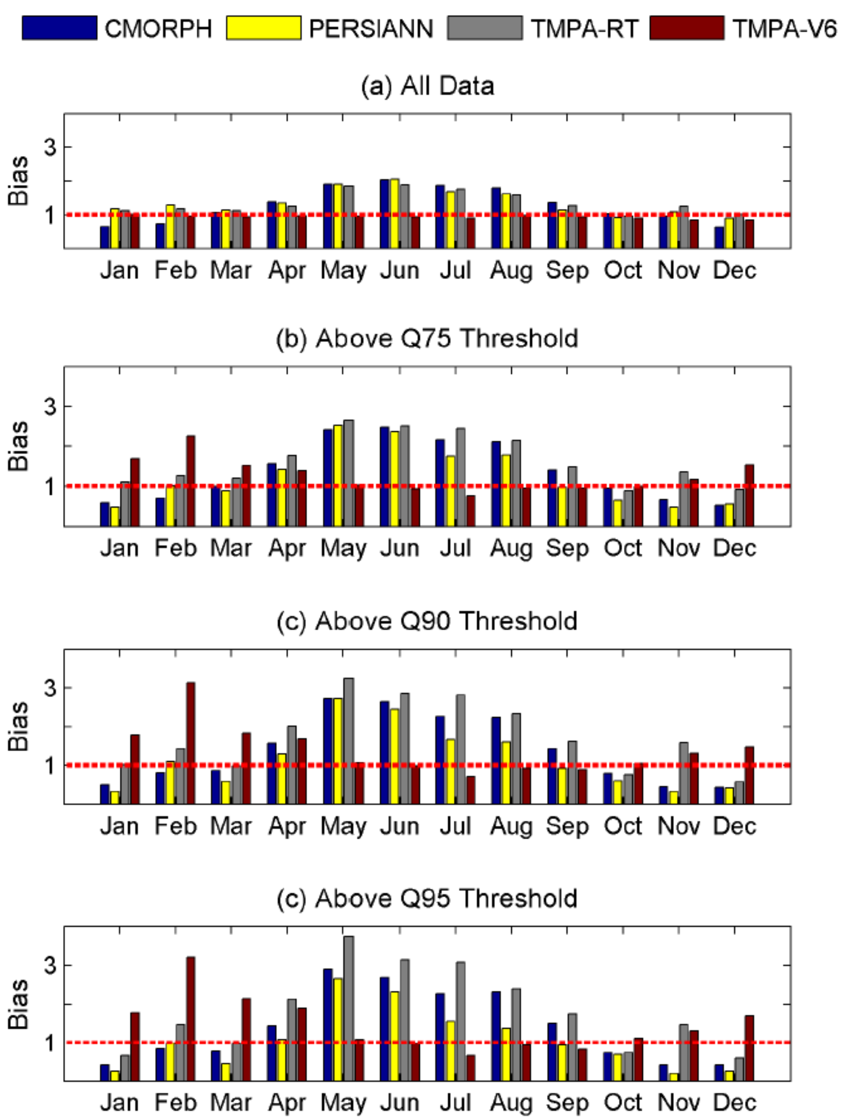
$$MQB = \frac{\Sigma_{i=1}^{n}\left(P_{sat}|P_{sat} \geq t\right)}{\Sigma_{i=1}^{n}\left(P_{ref}|P_{ref} \geq t\right)}$$

P_{sat} = satellite estimates
P_{ref} = reference measurements (e.g., STIV data)
t = extreme threshold (e.g., 75, 90, 95 percentiles of data)
n = number exceedances

Period of Analysis: 2005-2008

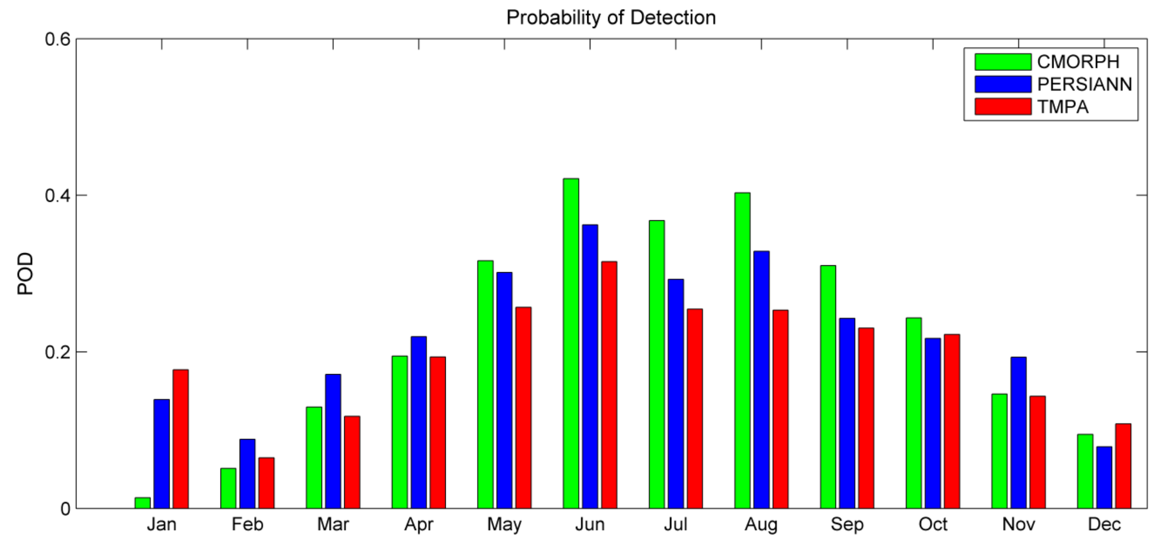
Reference data: Stage IV radar-based gauge adjusted data

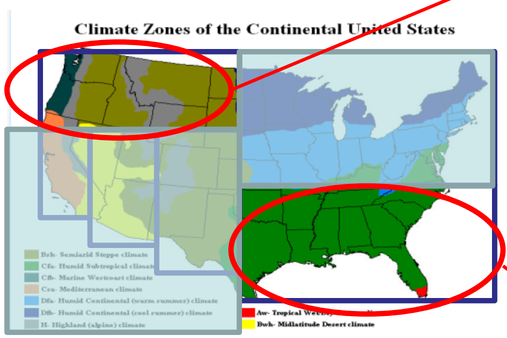




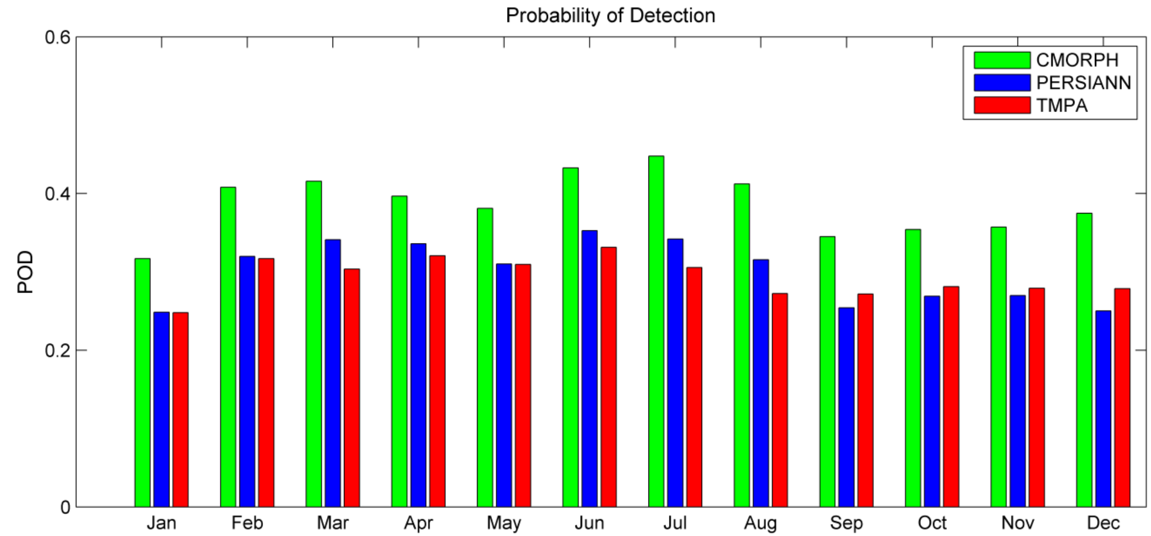
ADAPTING ALGORITHMS FOR CLIMATE REGIONS

North Western United States



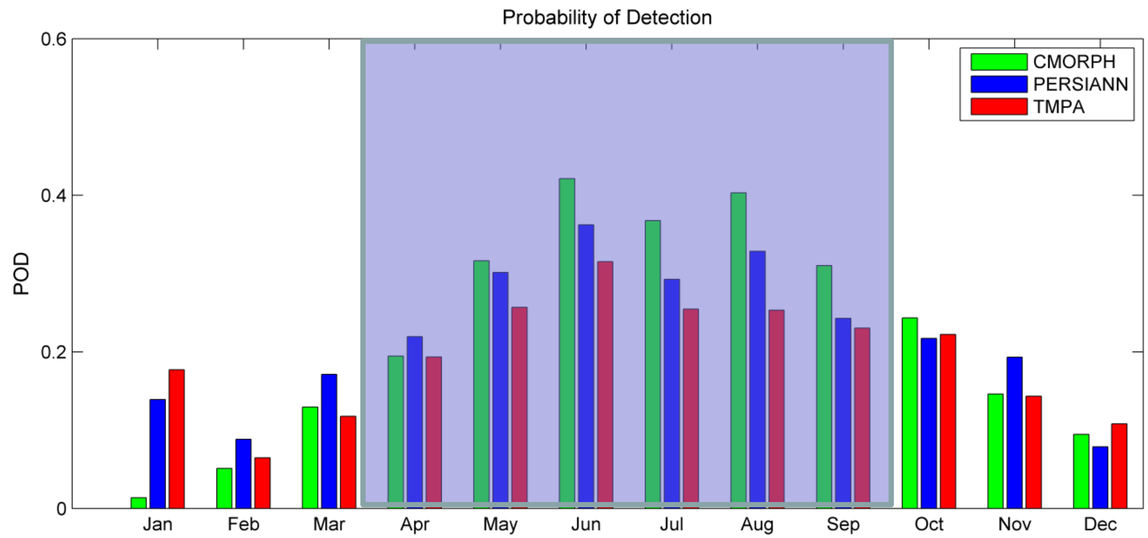


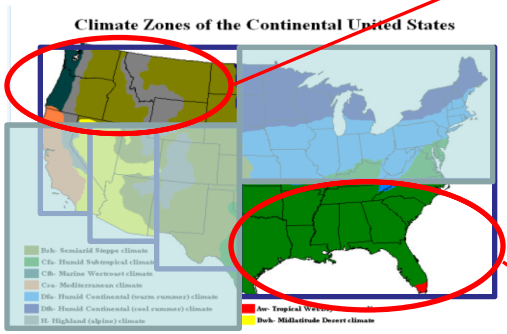
South Eastern United States



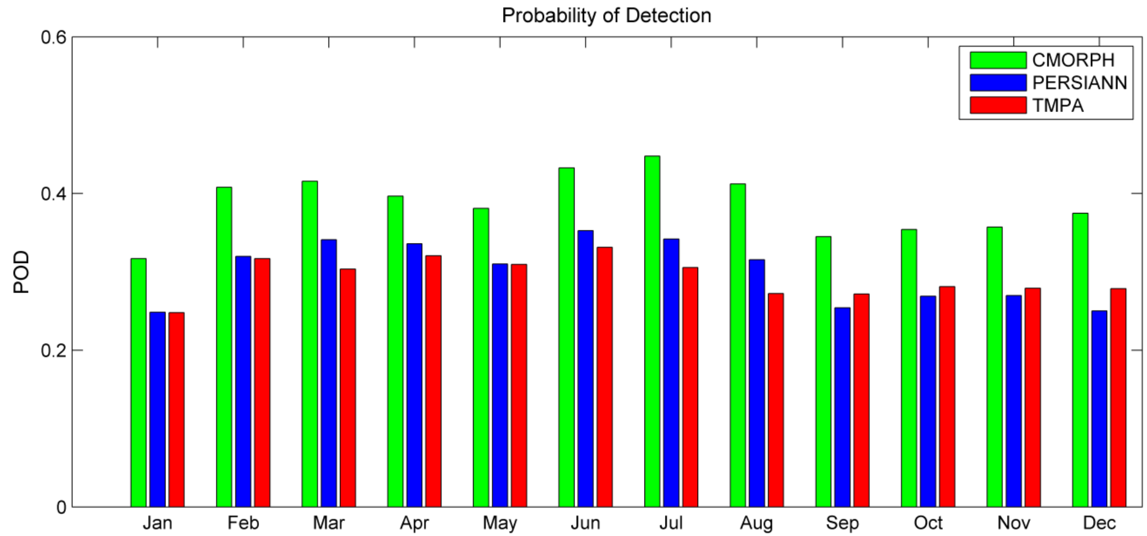
ADAPTING ALGORITHMS FOR CLIMATE REGIONS

North Western
United States



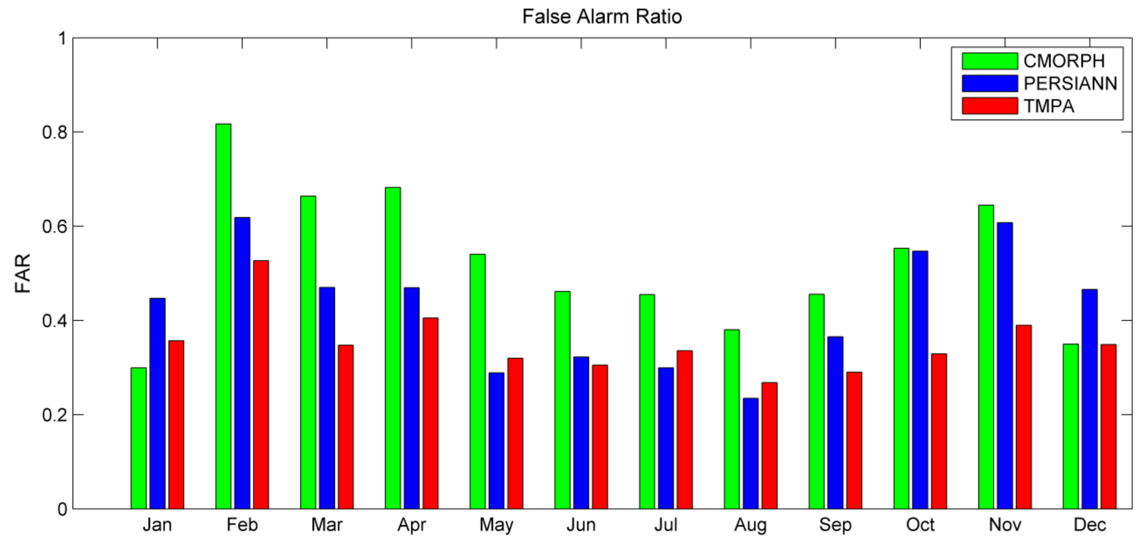


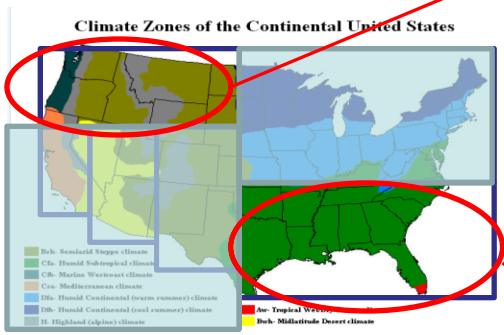
South Eastern
United States



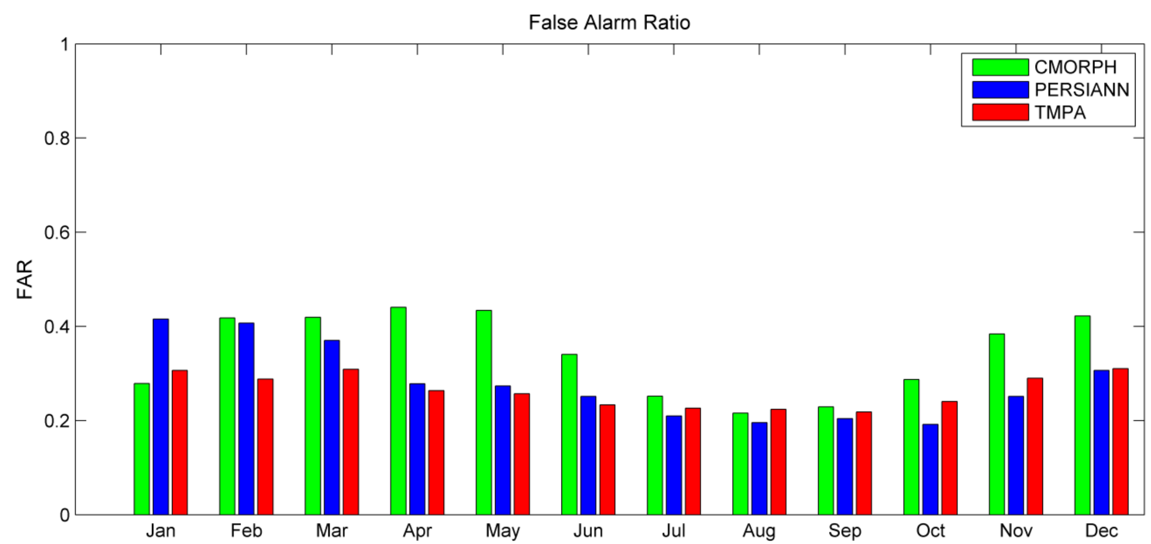
ADAPTING ALGORITHMS FOR CLIMATE REGIONS

North Western United States





South Eastern United States



ERROR DECOMPOSITION

Following Willmott (1981, 1982):

$$MSE = \frac{\sum_{i=1}^{n}\left(P_{sat} - P_{ref}\right)^2}{n}$$

MSE: Mean Squared Error

P_{sat} : Satellite Estimates

P_{ref} : Reference Measurements

Total MSE		Systematic MSE		Random MSE
$\frac{\sum_{i=1}^{n}\left(P_{sat} - P_{ref}\right)^2}{n}$	$=$	$\frac{\sum_{i=1}^{n}\left(P^*_{sat} - P_{ref}\right)^2}{n}$	$+$	$\frac{\sum_{i=1}^{n}\left(P_{sat} - P^*_{sat}\right)^2}{n}$

$$P^*_{sat} = a\,P_{ref} + b$$

P^*_{sat} : Linear regression to reference measurements

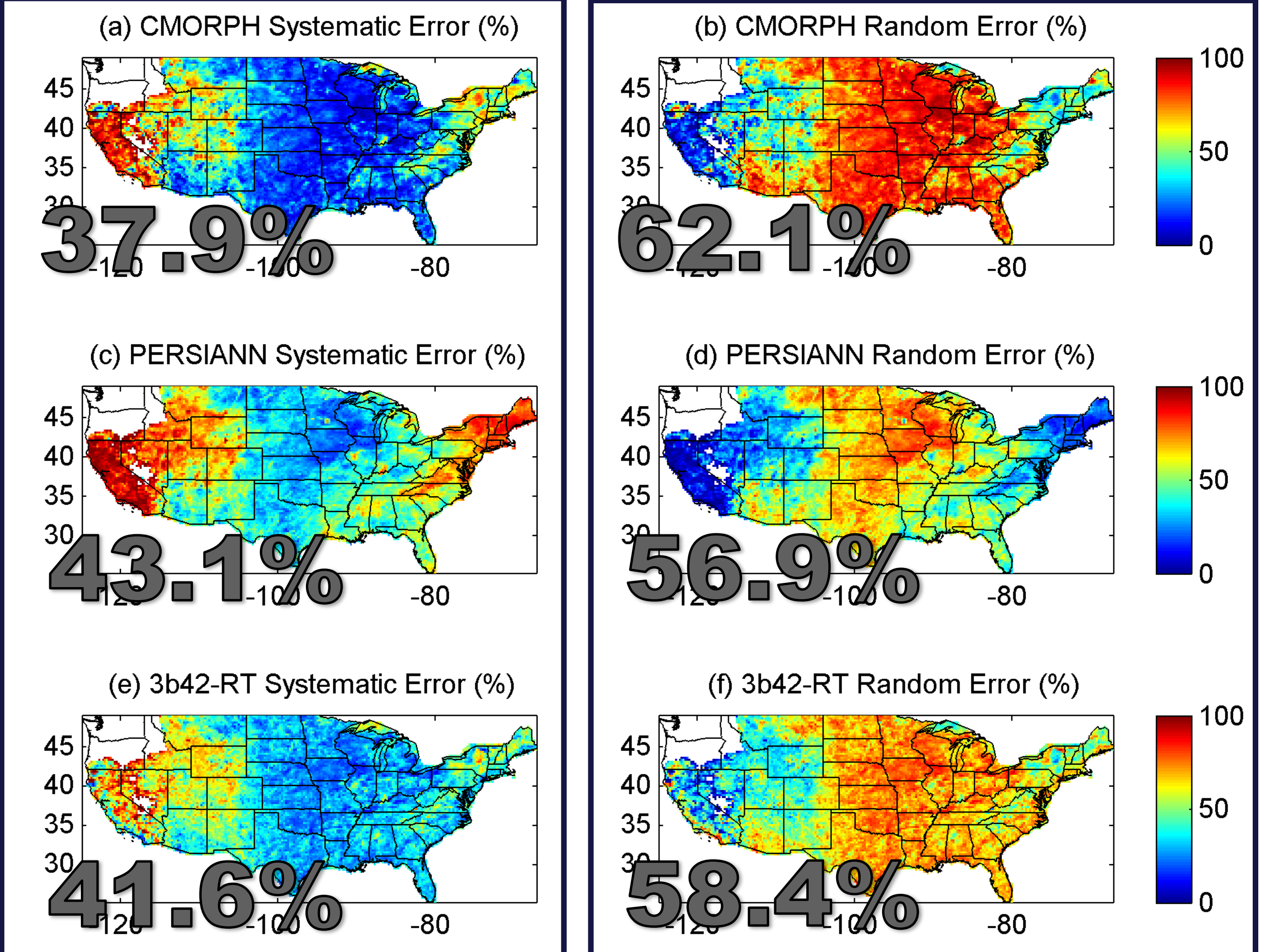
a : Slope

b : Intercept

ERROR DECOMPOSITION

3-hr Data

	Systematic Error (%)	Random Error (%)
CMORPH		
PERSIANN		
3b42-RT		



ERROR DECOMPOSITION

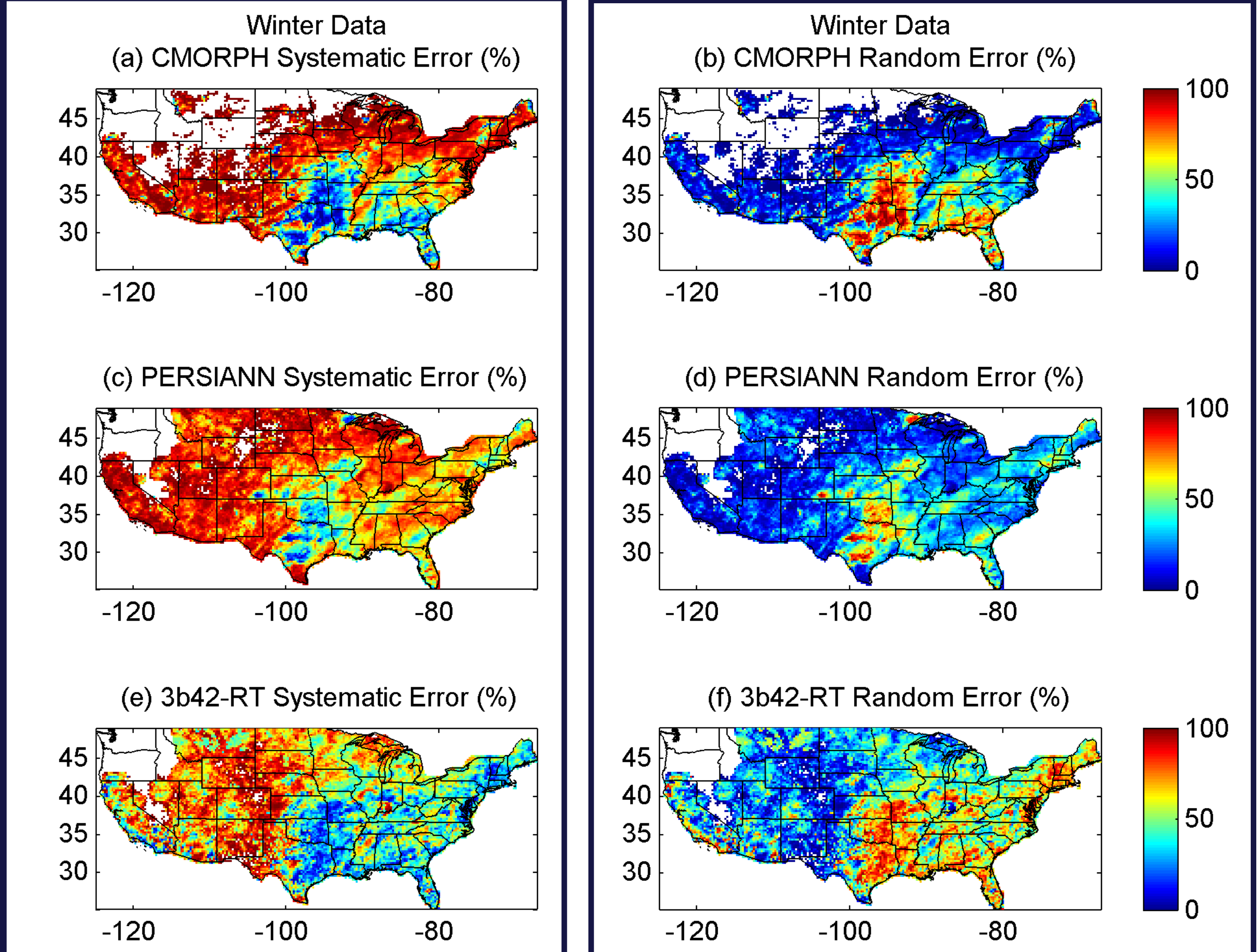
Systematic Error (%)

Random Error (%)

CMORPH

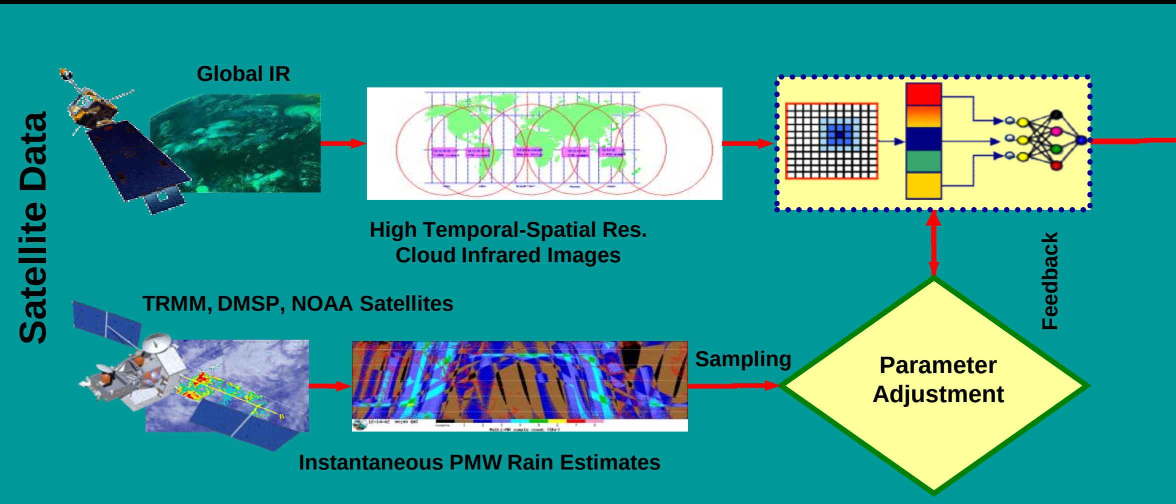
PERSIANN

3b42-RT

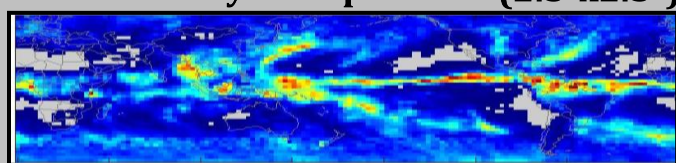


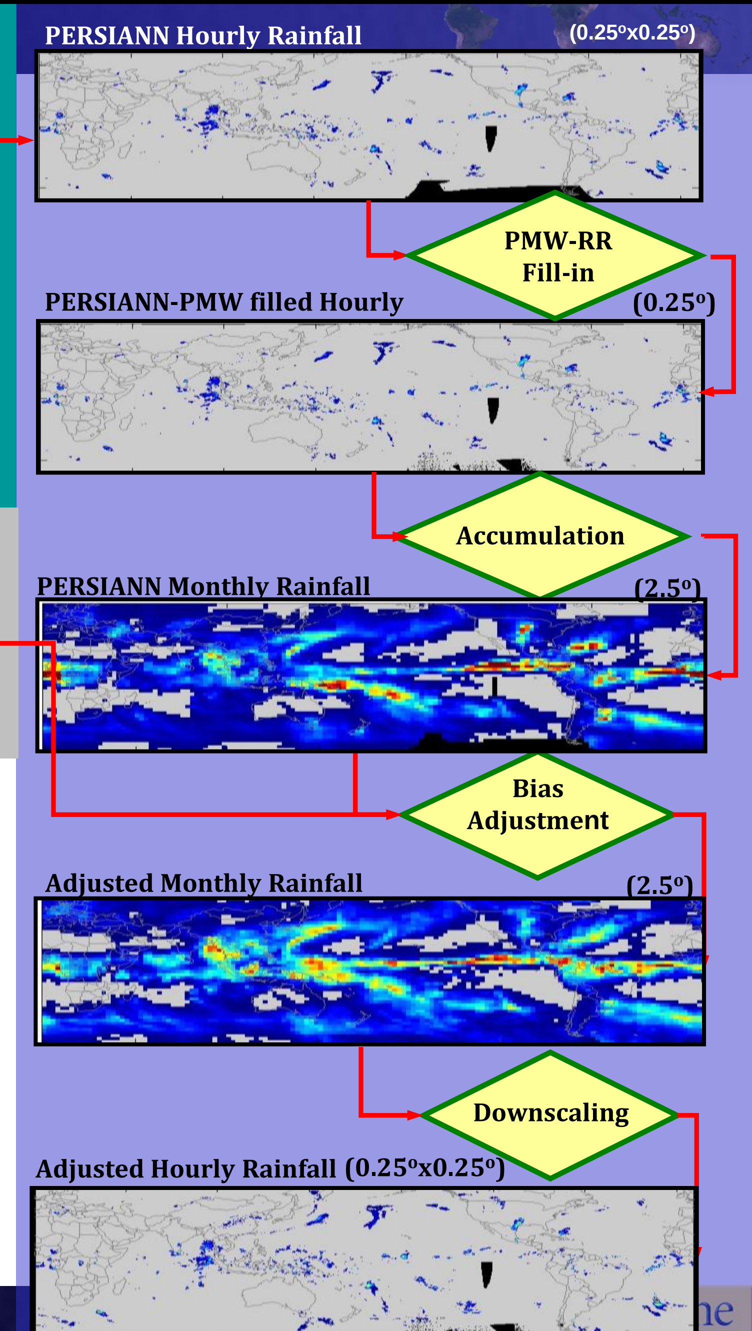
3-hr Data

Winter



GPCP Monthly Precipitation (2.5°x2.5°)





Bias adjustment of PERSIANN rainfall:

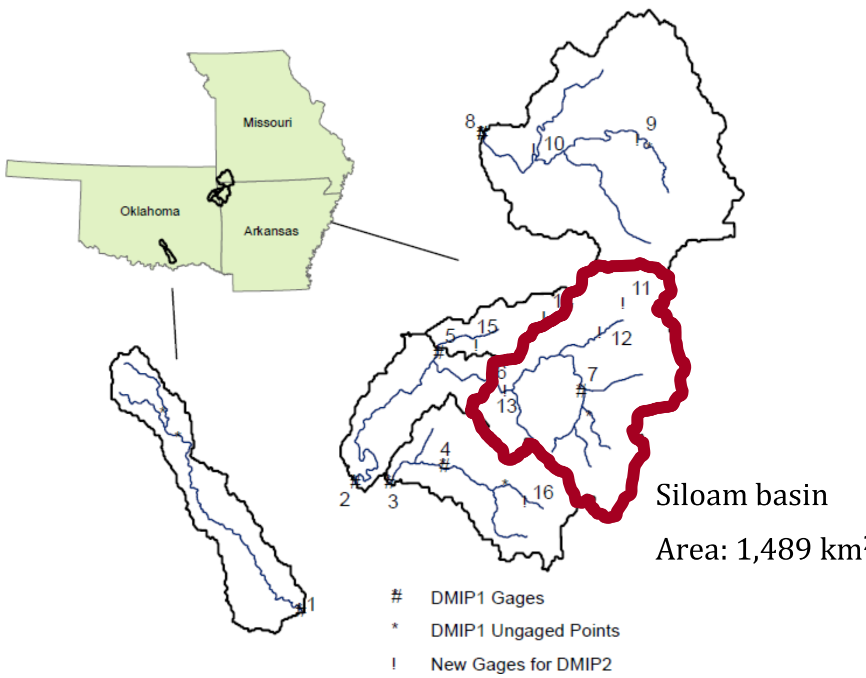
Stage I: Fill-in missing PERSIANN rainfall by PMW-rainfall.

Stage II: Accumulation and Adjustment of PERSIANN rainfall based on GPCP monthly rainfall measurement.

Stage III: Spatial and temporal downscaling of PERSAINN bias estimates from monthly rainfall at 2.5 degree to hourly at 0.25 degree.

HYDROLOGIC APPLICATIONS

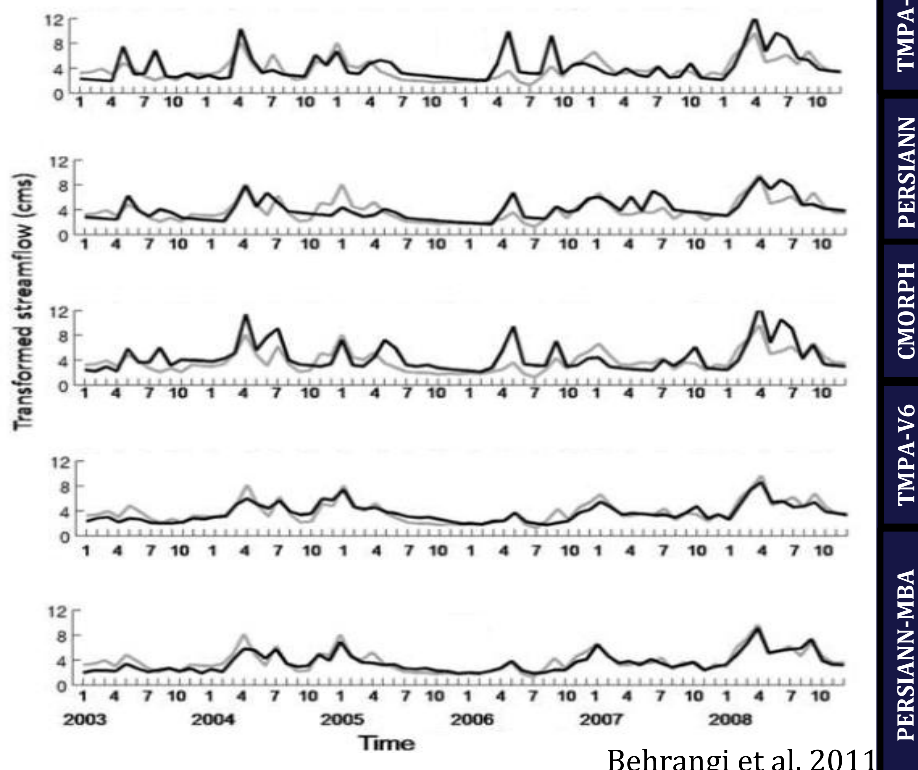
Distributed Model Intercomparison Project (DMIP)



Siloam basin

Area: 1,489 km^2

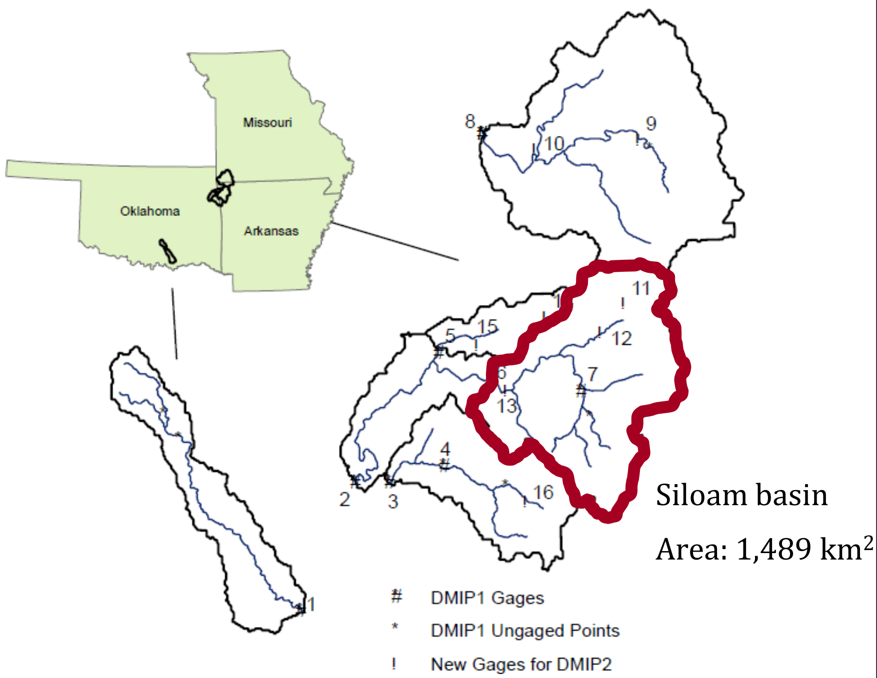
Hydrologic Modeling



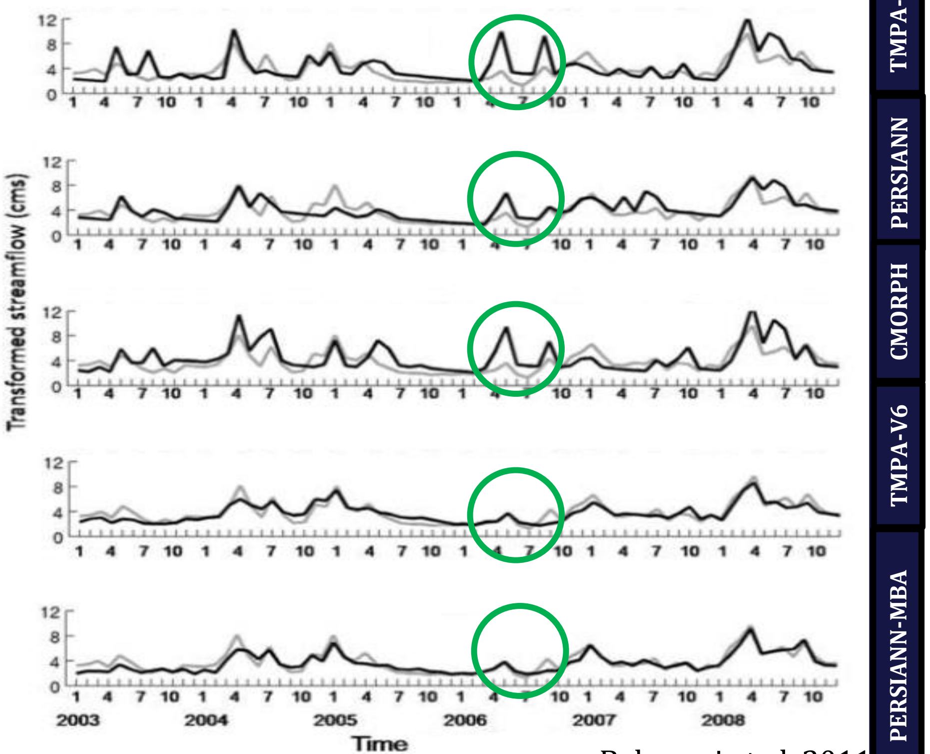
Behrangi et al. 2011

HYDROLOGIC APPLICATIONS

Distributed Model Intercomparison Project (DMIP)



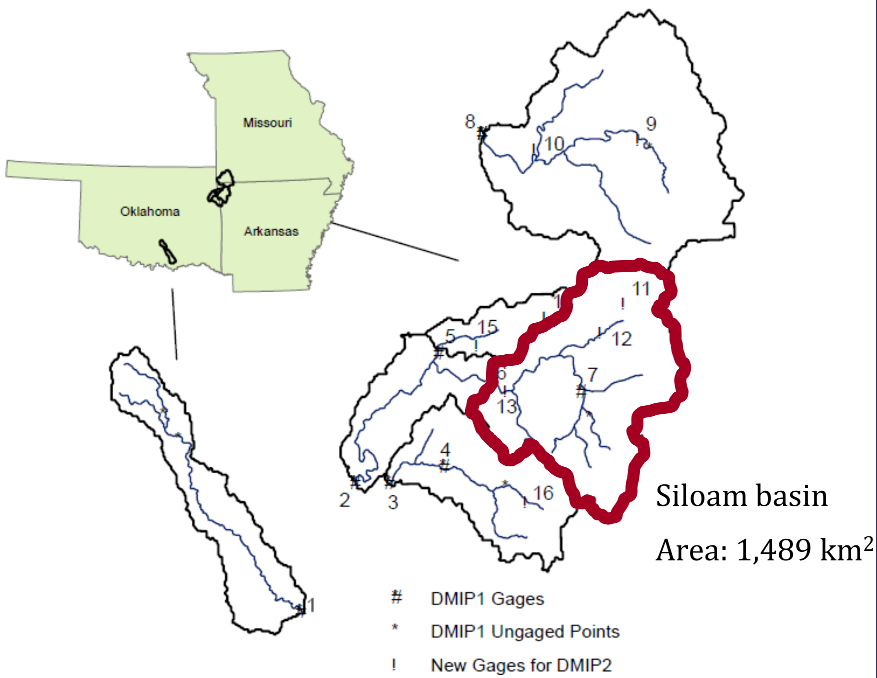
Hydrologic Modeling



Behrangi et al. 2011

HYDROLOGIC APPLICATIONS

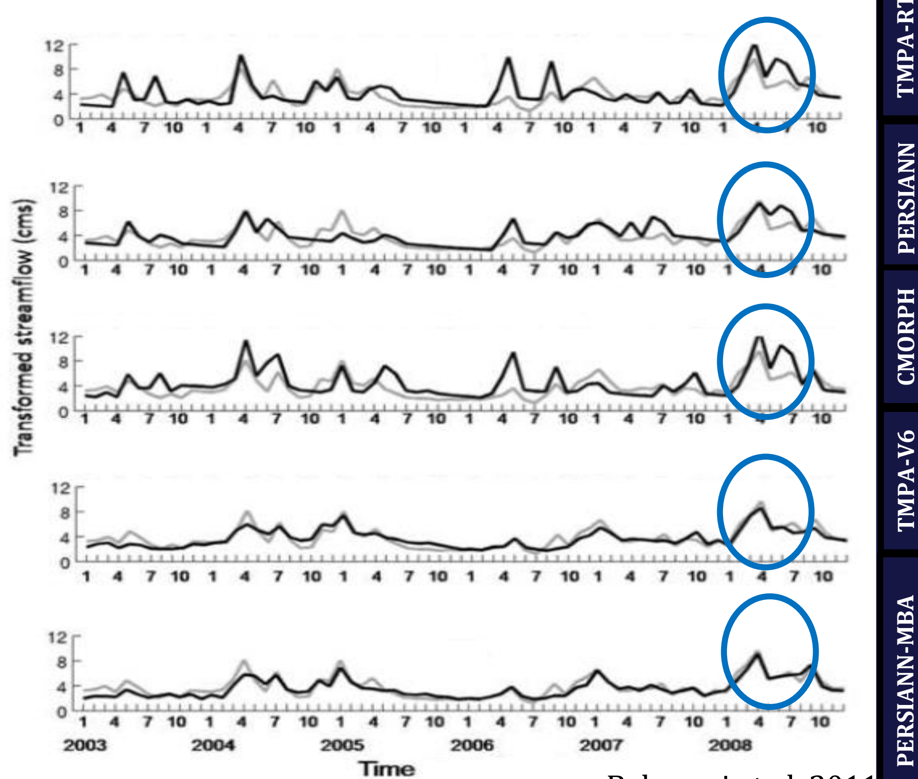
Distributed Model Intercomparison Project (DMIP)



Siloam basin

Area: 1,489 km^2

Hydrologic Modeling



Behrangi et al. 2011

THANK YOU FOR YOUR ATTENTION

Amir AghaKoucak
University of California, Irvine
amir.a@uci.edu