



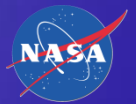
What Do Climate Models Tell Us: Western United States & Spain

Soroosh Sorooshian

*Center for Hydrometeorology and Remote Sensing
University of California Irvine*



*The Botin & Rosenberg workshop :
Adapting Water Rights to Face Climate Change Impacts
Botín Foundation, Calle de Castelló,
Madrid, Spain 25 April, 2019*



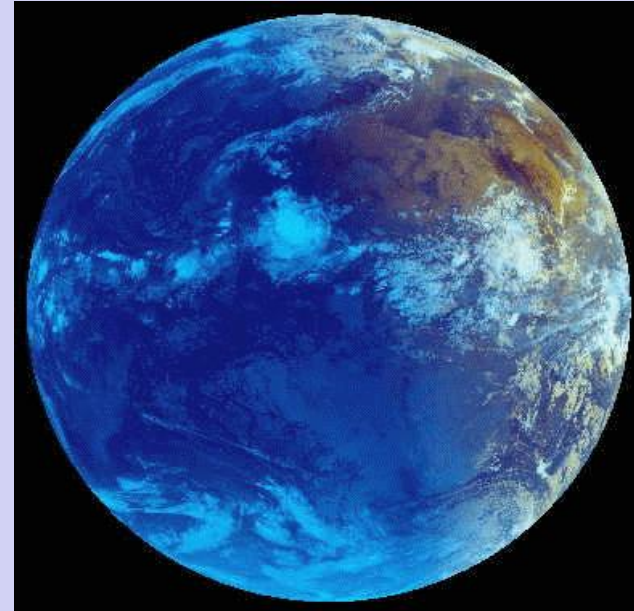
University of California Irvine (UCI) Past



and many more ...

Climate, Hydrology and Water Resources

- How will Climate change effect precipitation variability and water Availability?*
- Can we predict the future changes which are responsive to “user” needs?*



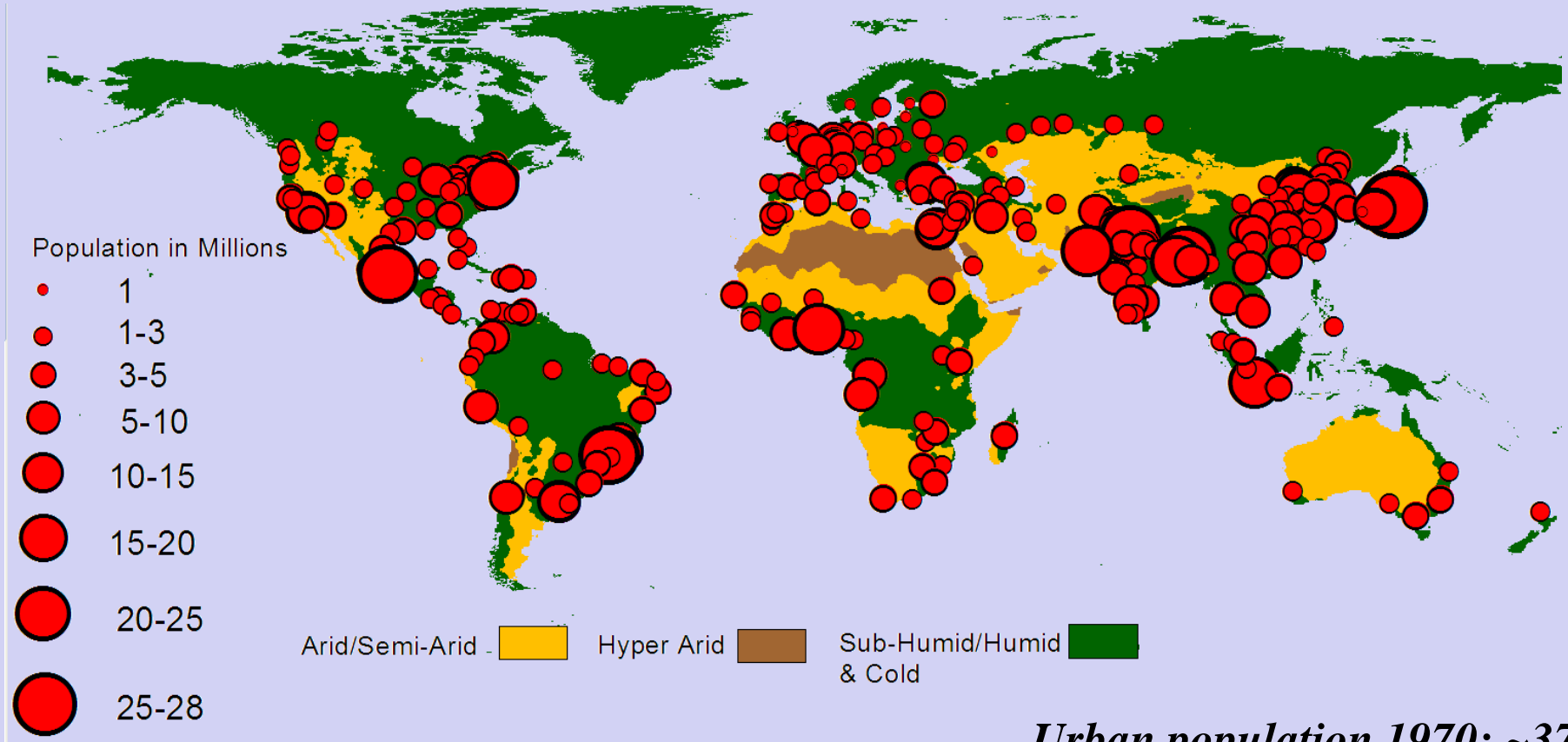


Stresses On Water Resources and Related Ecosystems:

- ***Population Impact*** (*More Predictable!*)
- ***Climate Impact*** (*Less Predictable!*)

Increasing Population: Number of Mega Cities

Projected Global Population: 8.3 Billion by 2025



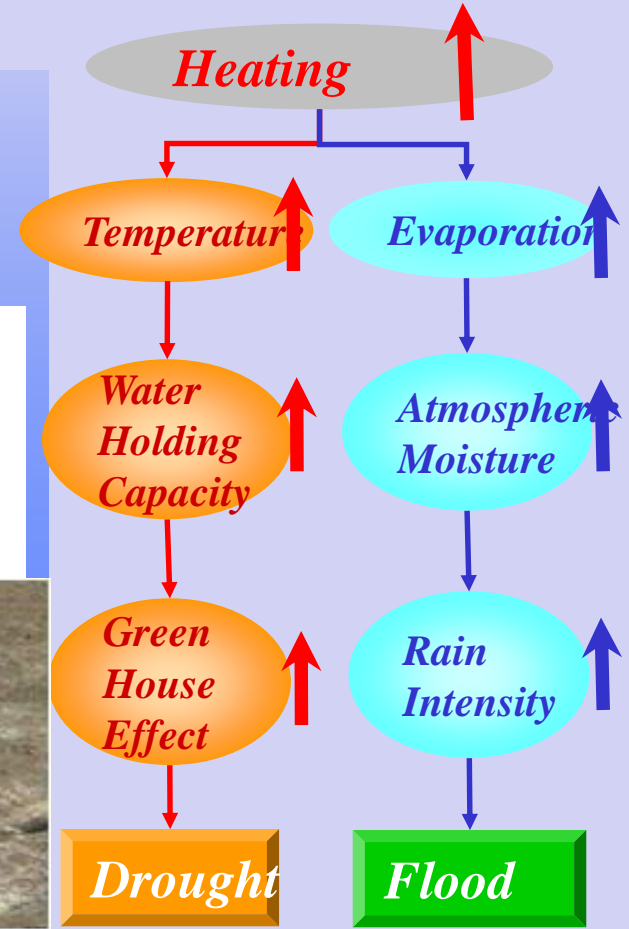
Urban population 1970: ~37%
2010: ~53%

**Took 200,000 years of human history for world's population to reach 1 billion;
and only 200 years more to reach 7 billion plus.**



Center for Hydrometeorology and Remote Sensing, University of California, Irvine

Global Warming And Hydrologic Cycle Connection



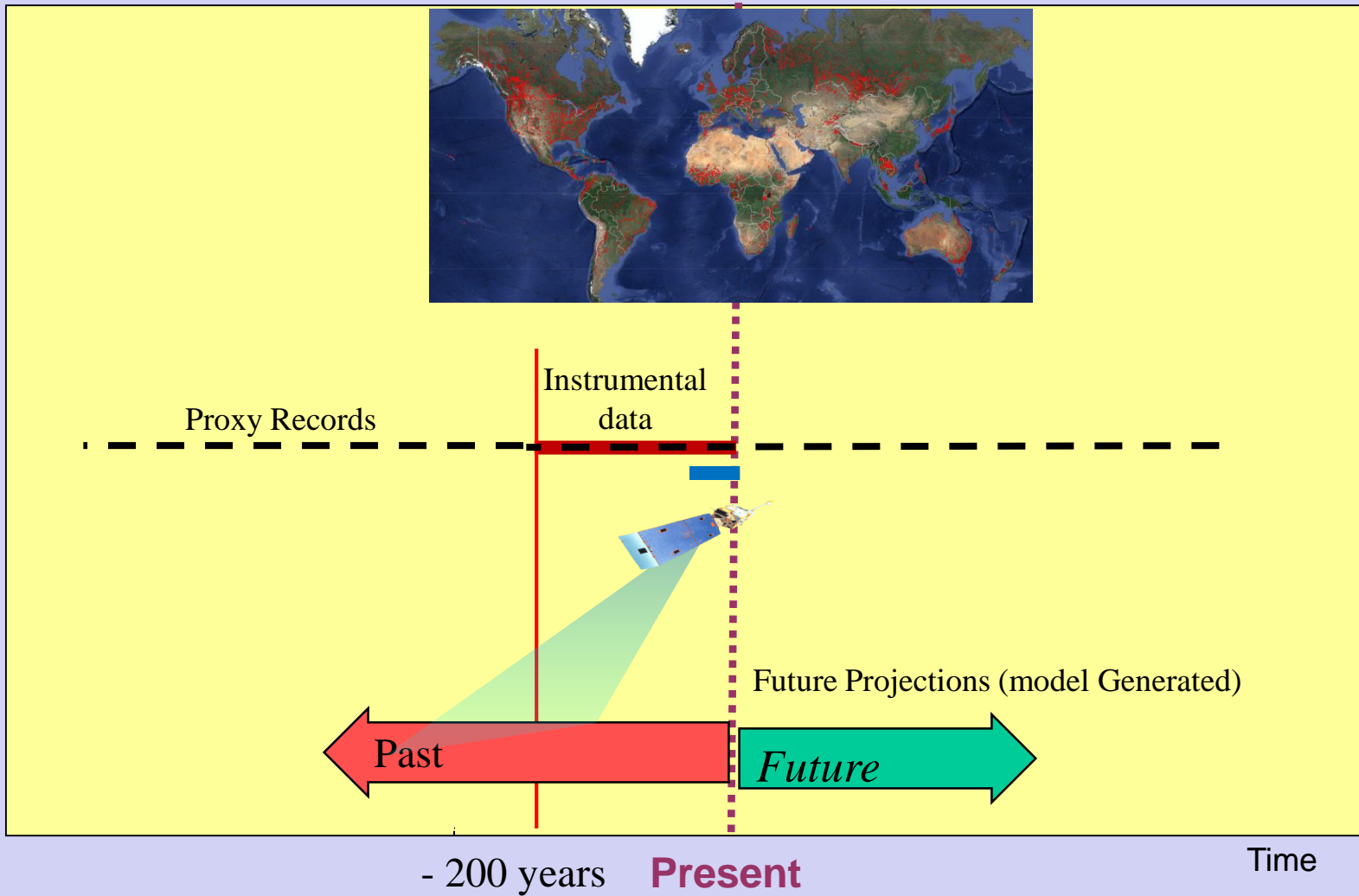
Information Relevant to Water Resources Planning

- Observations

- Models Projections



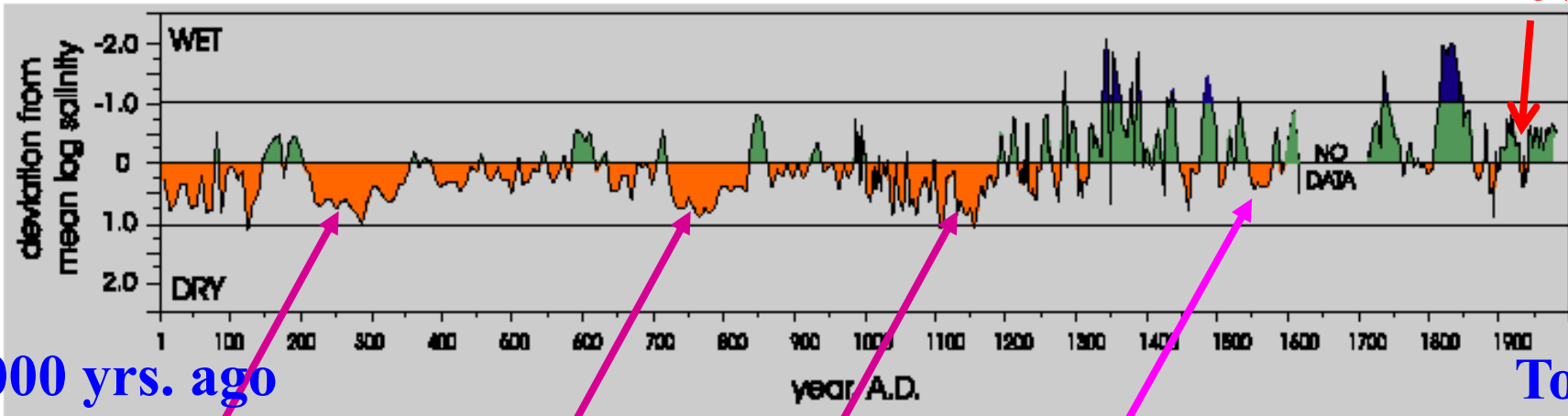
Hydroclimate of the Past and Future: Observation & Modeling



2000-year Climate history of central U.S.

The US Mid-West

Dust
Bowl



2000 yrs. ago

Today

>100 year "megadroughts"

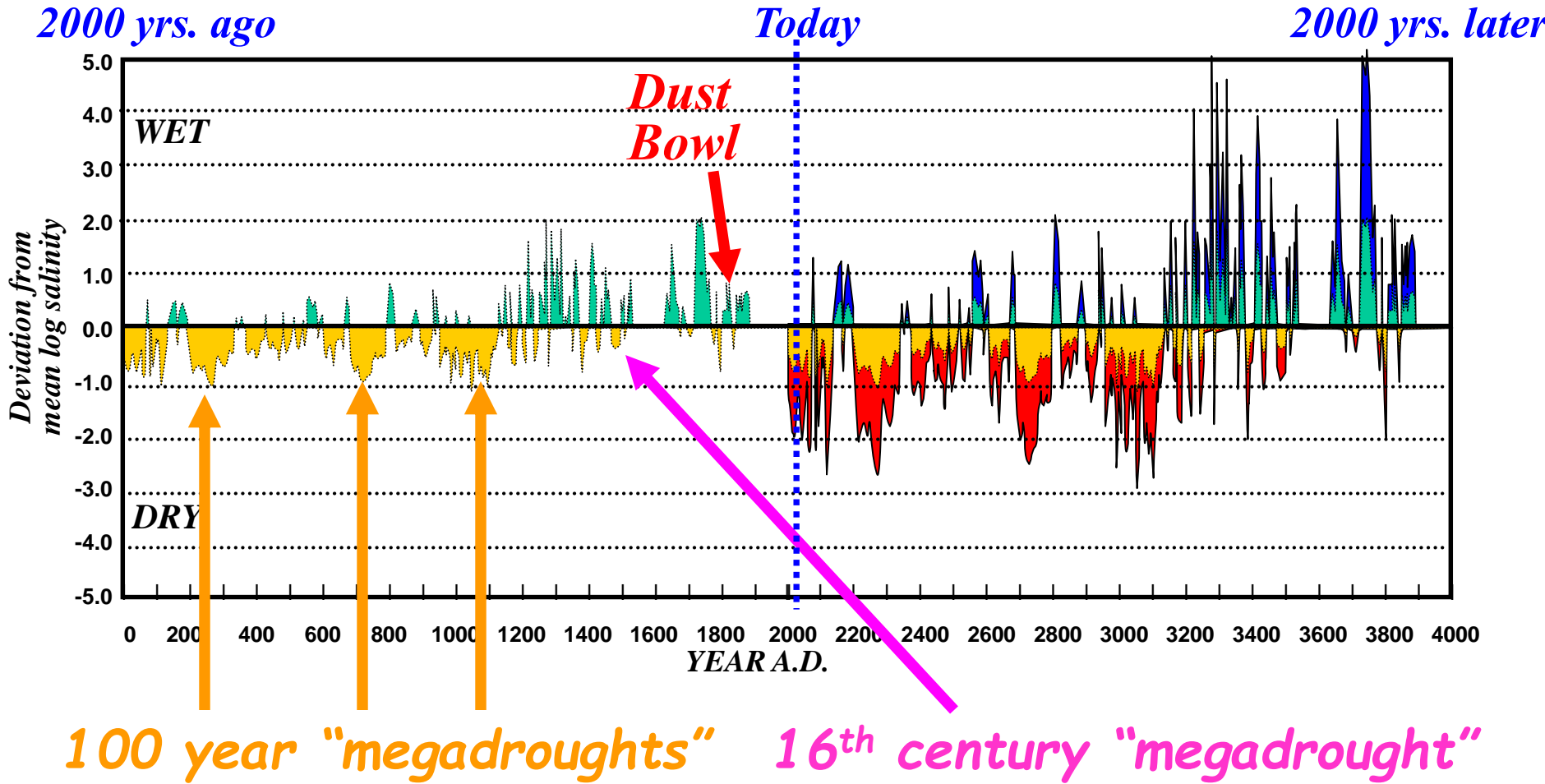
1930's dustbowl
16th century "megadrought"



Source: Overpeck 2004

Will Nature Repeat Itself ??????

The US Breadbasket: The Mid-West



Prediction Requirements for Water Resources

Short Range -----> Long Range
hours -----> days -----> weeks -----> months -----> seasons -----> years -----> decades

Flash Flood Warning

Flash Flood Guidance

Headwater Guidance

Flood Forecast Guidance

Reservoir Inflow Forecasts

Spring Snow Melt Forecasts

Water Supply Volume

Short-range

Mid-range

Long-range

Forecast Requirements



Climate-Scale approaches to addressing hydrologic extremes

Short Range — → Long Range
hours ———→ days ———→ weeks ———→ months ———→ seasons ———→ years ———→ decades

Flash Flood Warning

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Spring Snow Melt Forecasts

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Hydrologically-Relevant Climate Variables

*What Do Climate Models
Tell Us About the Future?*



Western U.S. future model projections



Dr. Chiyuan Miao - BNU



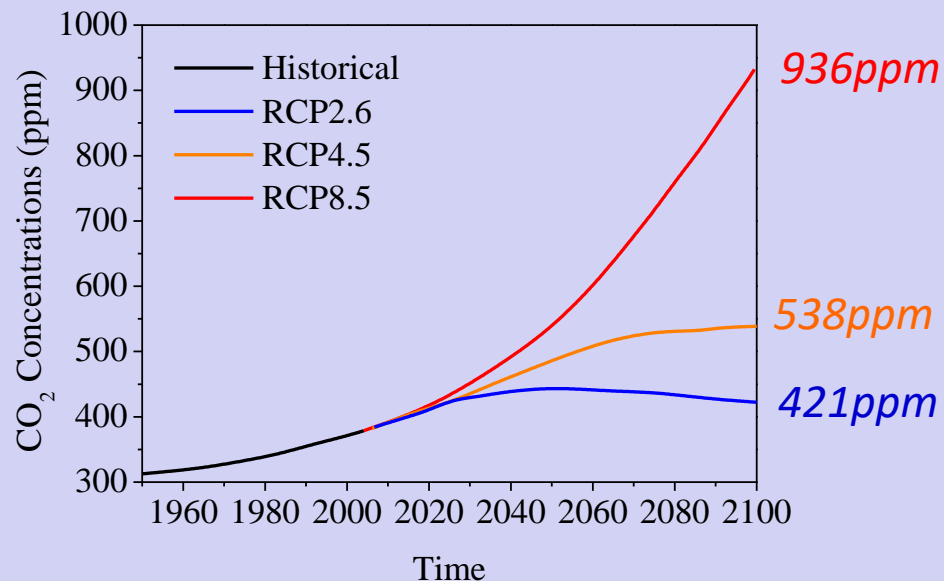
Future Modeling Scenarios – IPCC AR5

Representative Concentration Pathways (RCP) Scenarios:

RCP2.6: represent 'low' scenarios featured by the radiative forcing of 2.6 W/m^2 by 2100, the resulting CO_2 -equivalent concentrations is 421 ppm in the year 2100.

RCP4.5: represent 'medium' scenarios featured by the radiative forcing of 4.5 W/m^2 by 2100, the resulting CO_2 -equivalent concentrations is 538 ppm in the year 2100.

RCP8.5: represent 'high' scenarios featured by the radiative forcing of 8.5 W/m^2 by 2100, the resulting CO_2 -equivalent concentrations is 936 ppm in the year 2100.



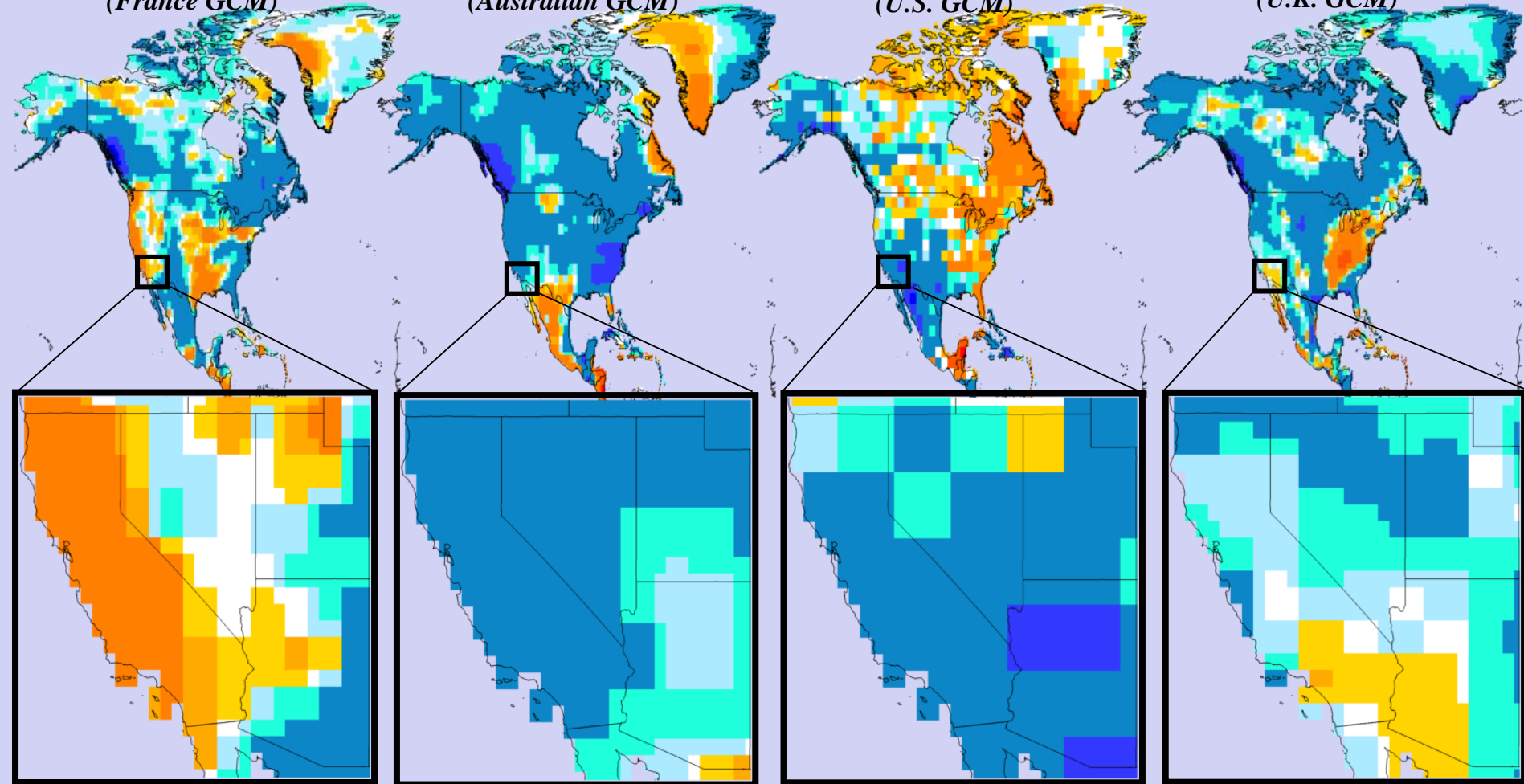
RCP2.6 ("High": 2.6 W/m², Equivalent CO₂ conc. 421 ppm by 2100)

CNRM-CM5
(France GCM)

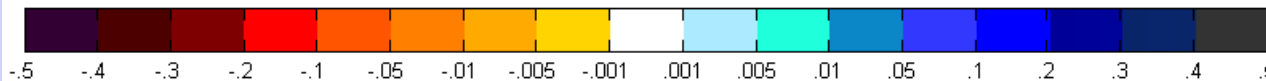
CSIRO-MK-3.6.0
(Australian GCM)

GISS-E2-R
(U.S. GCM)

HadGEM2-ES
(U.K. GCM)



Precipitation change (mm per day per decade)



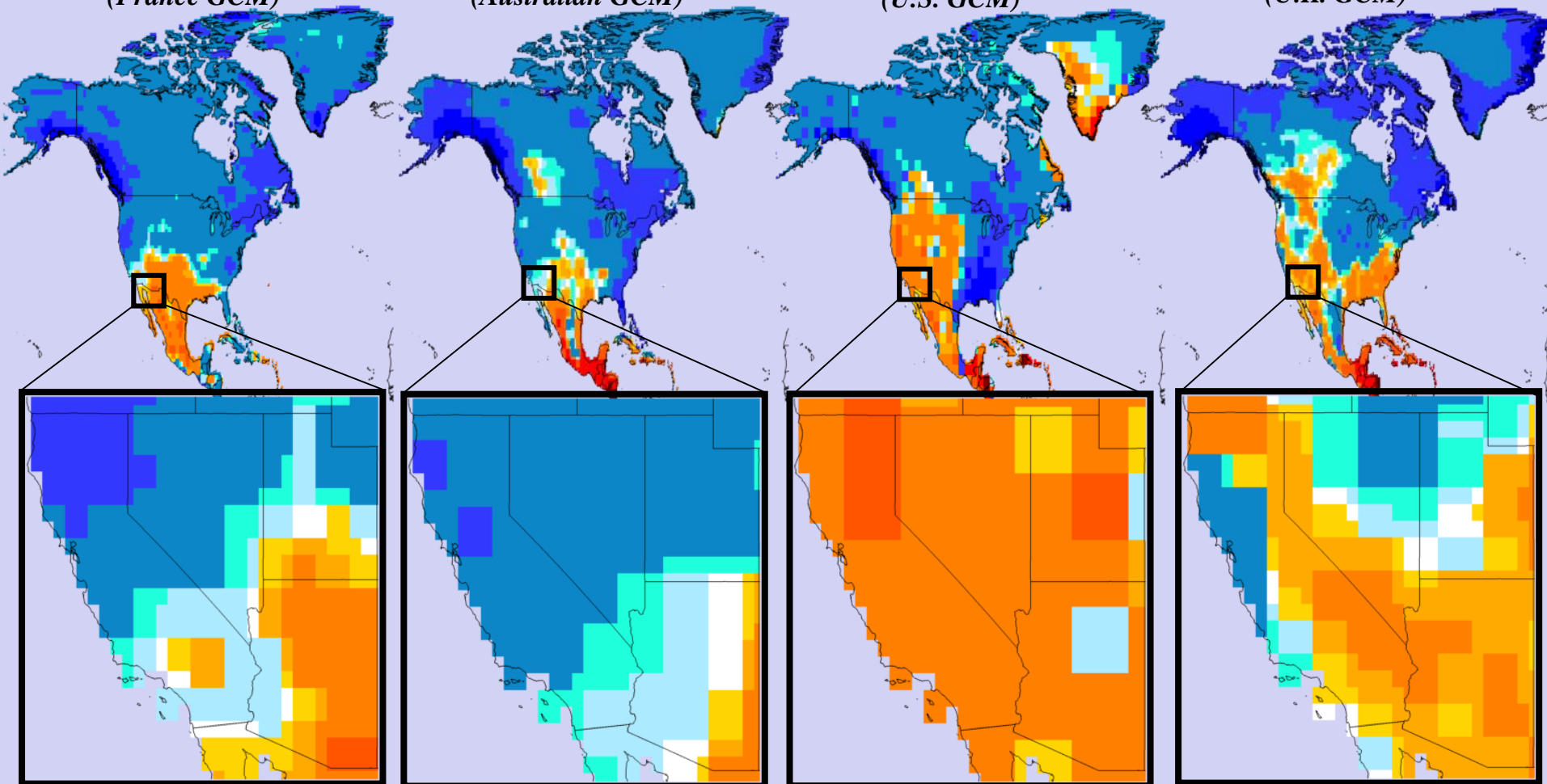
RCP8.5 ("High": 8.5 W/m², Equivalent CO₂ conc. 936 ppm by 2100)

CNRM-CM5
(France GCM)

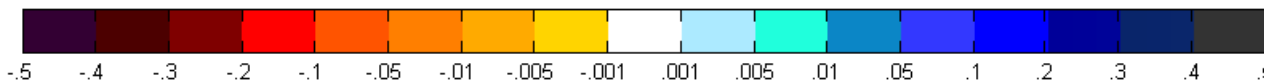
CSIRO-MK-3.6.0
(Australian GCM)

GISS-E2-R
(U.S. GCM)

HadGEM2-ES
(U.K. GCM)

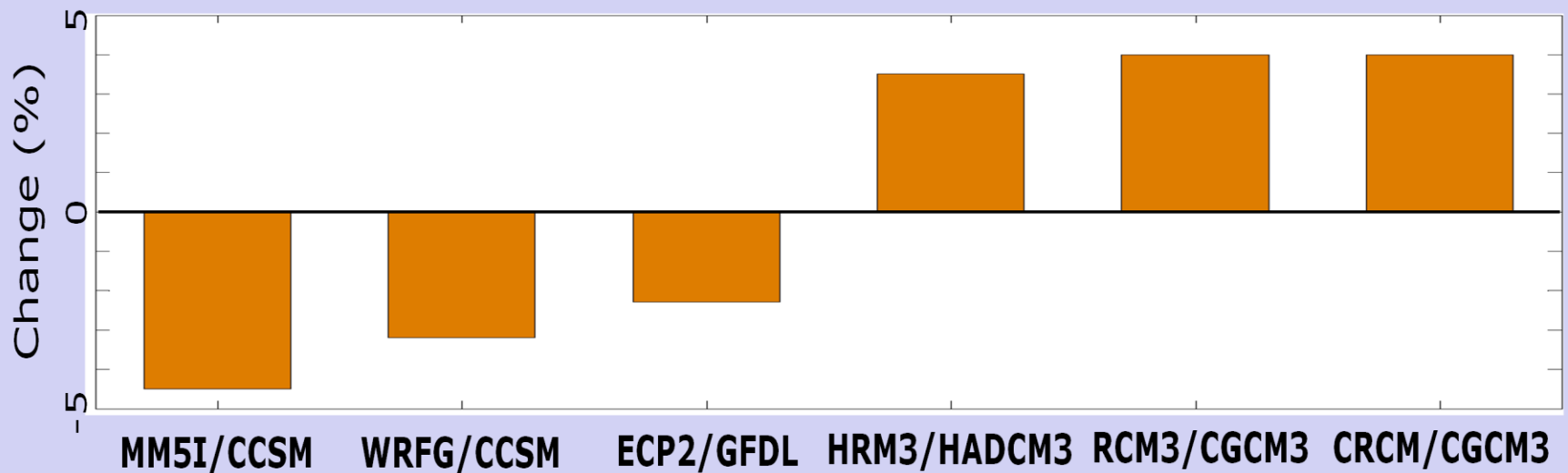


Precipitation change (mm per day per decade)



Recent Evaluation of RCM/GCM over Western U.S.

Models indicate different signs and magnitudes of changes in the mean precipitation over the Western U.S. under the SRES A2 emissions scenario.



Trend of area-average precipitation (comparing 2040-2070 with 1970-2000)

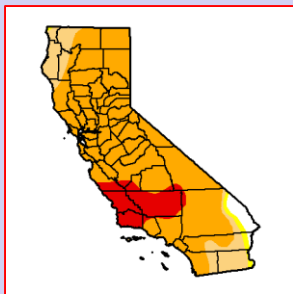
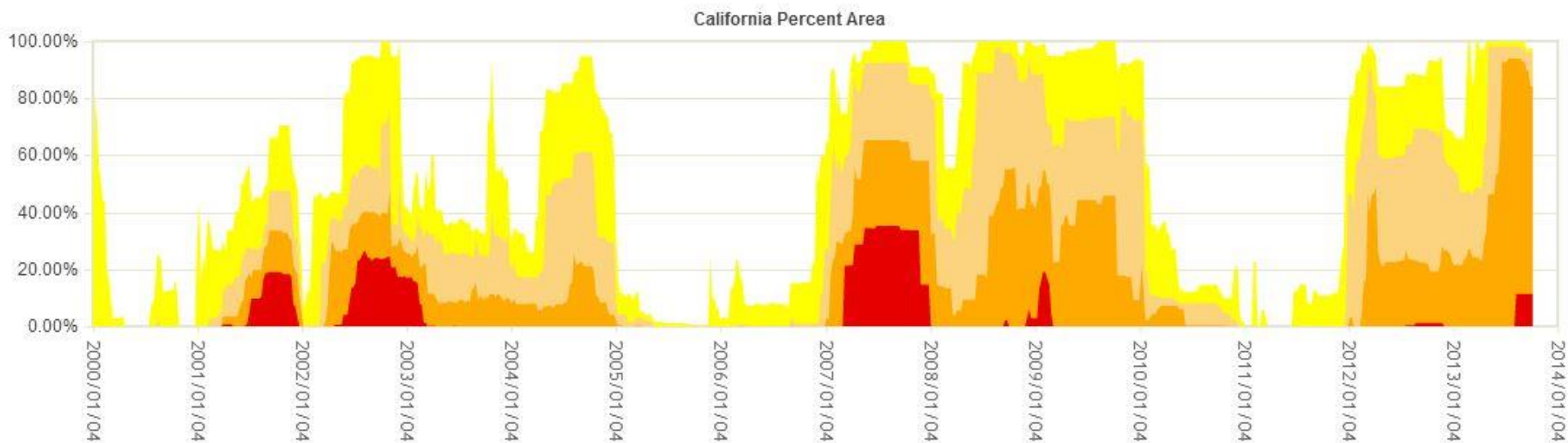


Wei Chu 2011



California Drought Conditions (2000 ~ Present): high variability but no trend

“The U.S. Drought Monitor, a composite index that includes many indicators, is the drought map that policymakers and media use in discussions of drought and in allocating drought relief.”



Drought Severity

D0 - Abnormally Dry

D1 Drought - Moderate

D2 Drought - Severe

D3 Drought - Extreme

D4 Drought - Exceptional

U.S. Drought Monitor for California –
Oct.8 2013

Data Source: <http://droughtmonitor.unl.edu/DataArchive.aspx>

Center for Hydrometeorology and Remote Sensing, University of California, Irvine



Spain + Portugal

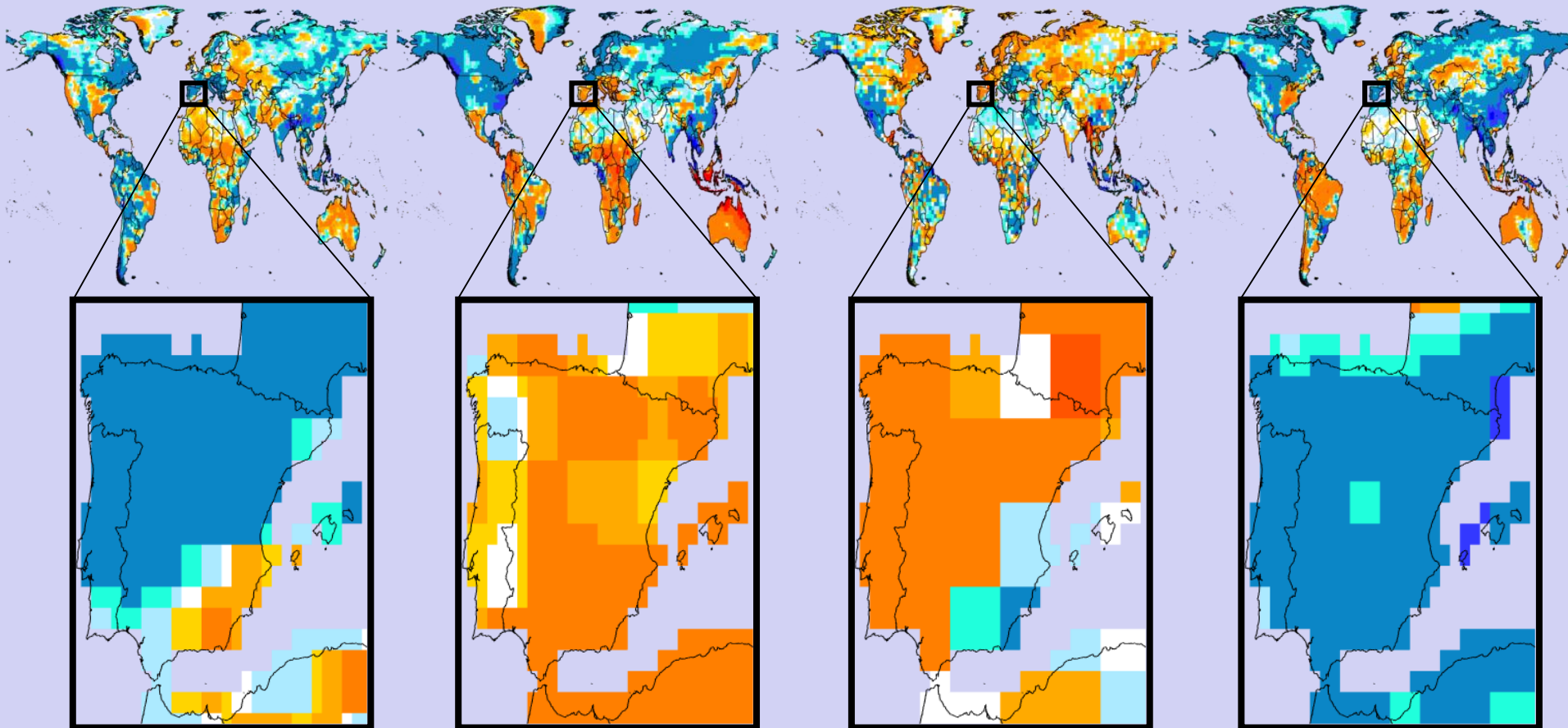
RCP2.6 ("High": 2.6 W/m², Equivalent CO₂ conc. 421 ppm by 2100)

CNRM-CM5
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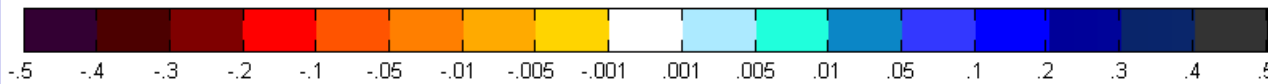
CSIRO-MK-3.6.0
(Australian GCM)

GISS-E2-R
(U.S. GCM)

HadGEM2-ES
(U.K. GCM)



Precipitation change (mm per day per decade)



Resolution: 0.5°x0.5°

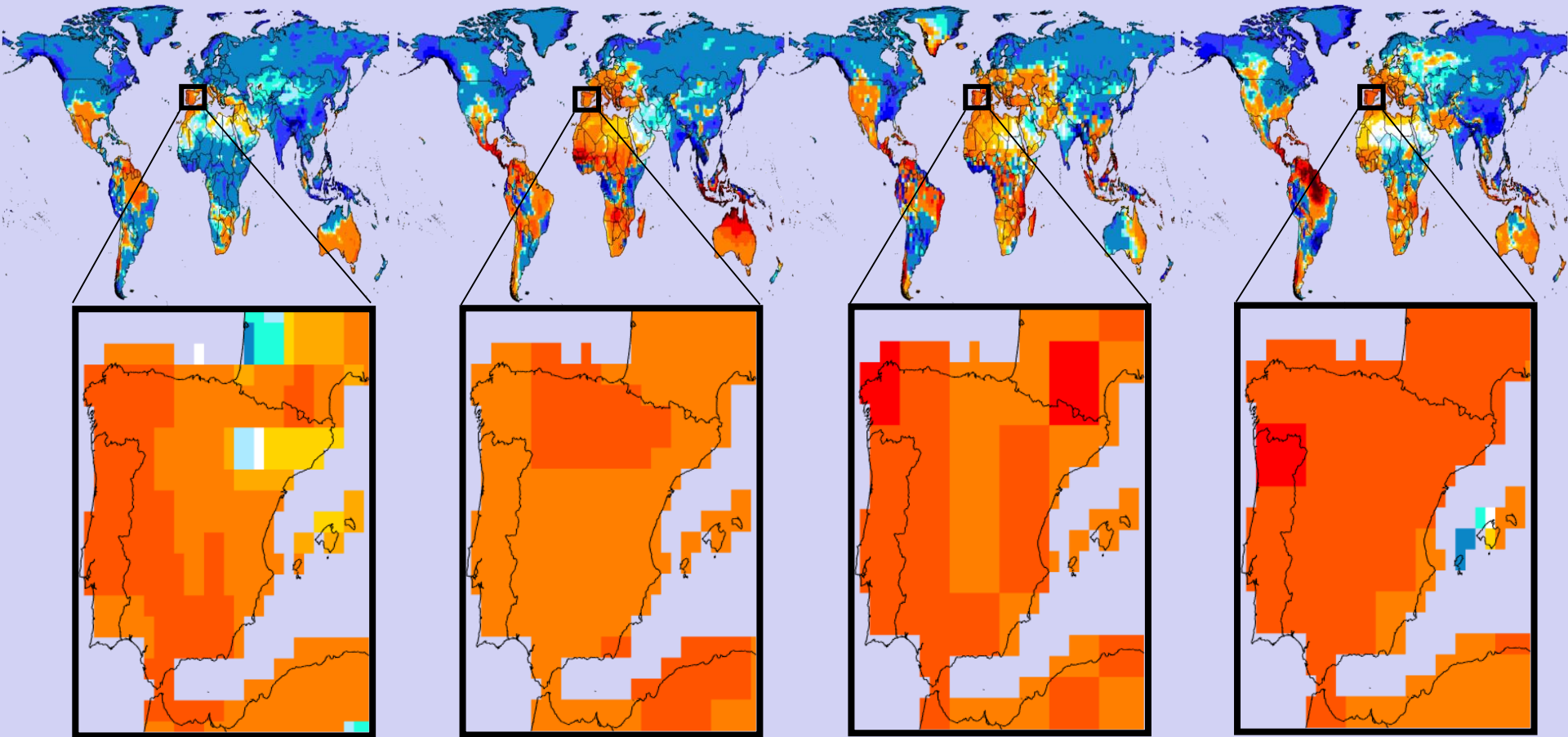
RCP8.5 ("High": 8.5 W/m², Equivalent CO₂ conc. 936 ppm by 2100)

CNRM-CM5
(France GCM)

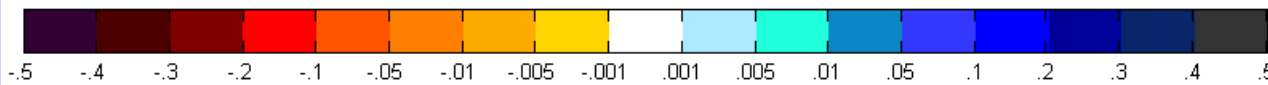
CSIRO-MK-3.6.0
(Australian GCM)

GISS-E2-R
(U.S. GCM)

HadGEM2-ES
(U.K. GCM)



Precipitation change (mm per day per decade)



Resolution: 0.5°x0.5°



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Flash Flood Guidance

Headwater Guidance

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Reservoir Inflow Forecasts

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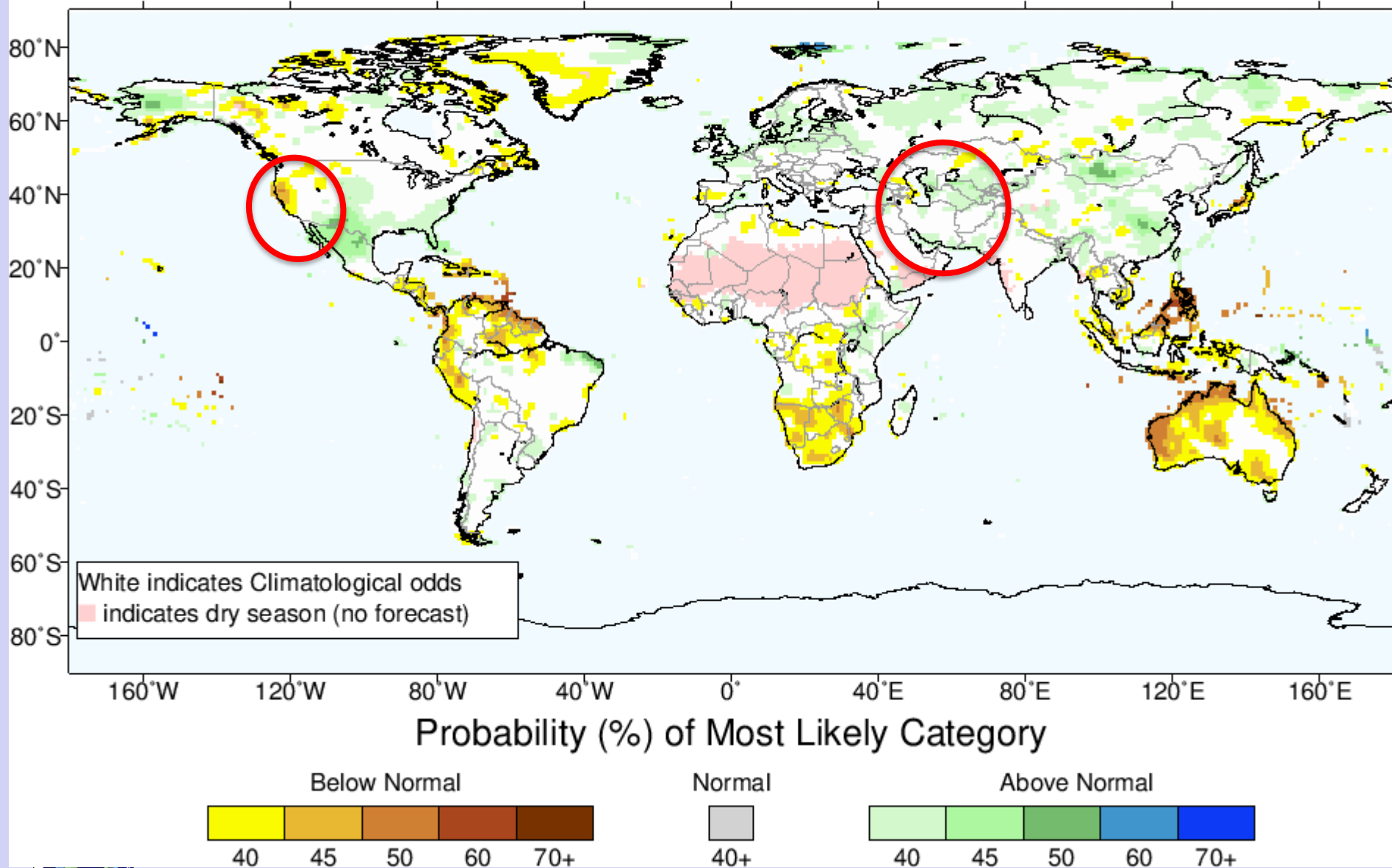
Water Supply Volume

Mid-range

Forecast Requirements



IRI Multi-Model Probability Forecast for Precipitation for January-February-March 2019, Issued December 2018



Information Relevant to Water Resources Planning

How About Recent Observations?

The Past 35 years (1983-2017)



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

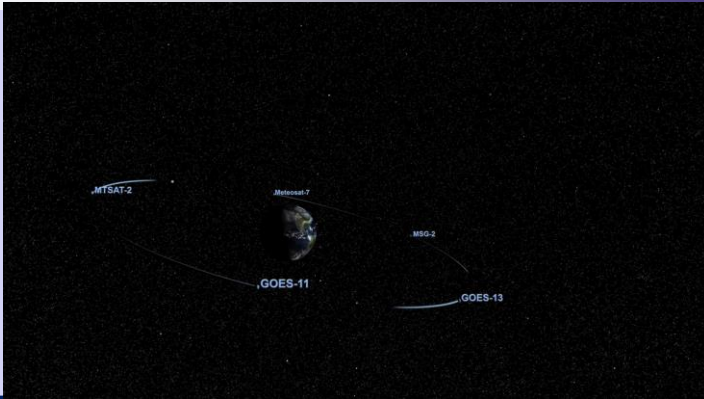


PERSIANN System

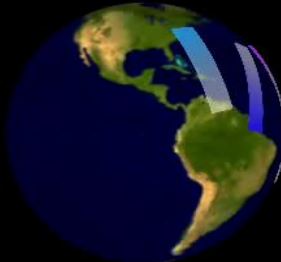
Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks



Satellite Data for Precipitation estimation



*Geostationary IR
Cloud top data
15-30 minute temporal
resolution*




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



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



PERSIANN Websites and Apps

- 
- *CHRS iRain*
 - *CHRS RainSphere*
 - *CHRS Data Portal*



PERSIANN-CDR

<http://www.ncdc.noaa.gov/cdr/operationalcdrs.html>

NOAA'S NATIONAL CLIMATIC DATA CENTER

NOAA's Climate Data Record (CDR) Program

PRECIPITATION ESTIMATION FROM REMOTE SENSING INFORMATION USING ARTIFICIAL NEURAL NETWORK

PERSIANN



PERSIANN CLIMATE DATA RECORD SPECIFICATIONS

- 0.25-deg * 0.25-deg (60°S–60°N latitude and 0°–360° longitude)
- Daily Product
- 1980–present
- Updated Monthly

SOME USES OF THE PERSIANN CLIMATE DATA RECORD

- Climatologists can perform long-term climate studies at a finer resolution than previously possible.
- Hydrologists can use PERSIANN-CDR for rainfall-runoff modeling in regional and global scale, particularly in remote regions.
- Performing extreme Event Analysis (intensity, frequencies, and duration of floods and droughts).
- Water Resources Systems Planning and Management

INPUTS TO THE PERSIANN CLIMATE DATA RECORD

- GridSat-B1 CDR (IRWIN)
- GPCP 2.5-deg Monthly Data

PERSIANN CLIMATE DATA RECORD
<http://www.ncdc.noaa.gov/cdr/operationalcdrs.html>

CLIMATE DATA RECORD PROGRAM INFORMATION
<http://www.ncdc.noaa.gov/cdr/index.html>

www.climate.gov
www.ncdc.noaa.gov

Preserving the past... Revealing the future
September 2013



- *Daily Precipitation Data*
- *Data Period: 1983~2018*
- *Coverage: 60°S ~ 60°N*
- *Spatial Resolution: 0.25°x0.25°*

Volume 96 Issue 1
(January 2015)

< Previous



A 30+ Year Global, Daily Precipitation Dataset

Ashouri, Hsu et al., BAMS, 2015.



PERSIANN Extensions: Climate-Related



CHRS RainSphere

*An Integrated System for Global Satellite Precipitation Data
and Information*



CHRS RainSphere

Rainsphere.eng.uci.edu



CHRS RainSphere

An Integrated System for Global Satellite Precipitation Data and Information

Inspiring research on hydroclimate and water resources

Home Info Tutorial Products About Us Lat: 55.179, Lon: -154.160

Map Layers

Country Pol. Division
 Cont. Basin Major River
 Tributary Watershed

Rain Information

Historical Satellite Observation
 Future IPCC Projection

Rain Layers

Accumulative Yearly
 Average Monthly

Year: Climatology
Submit Legend ON

Climatology (Yr)

Rain Layers Comparison

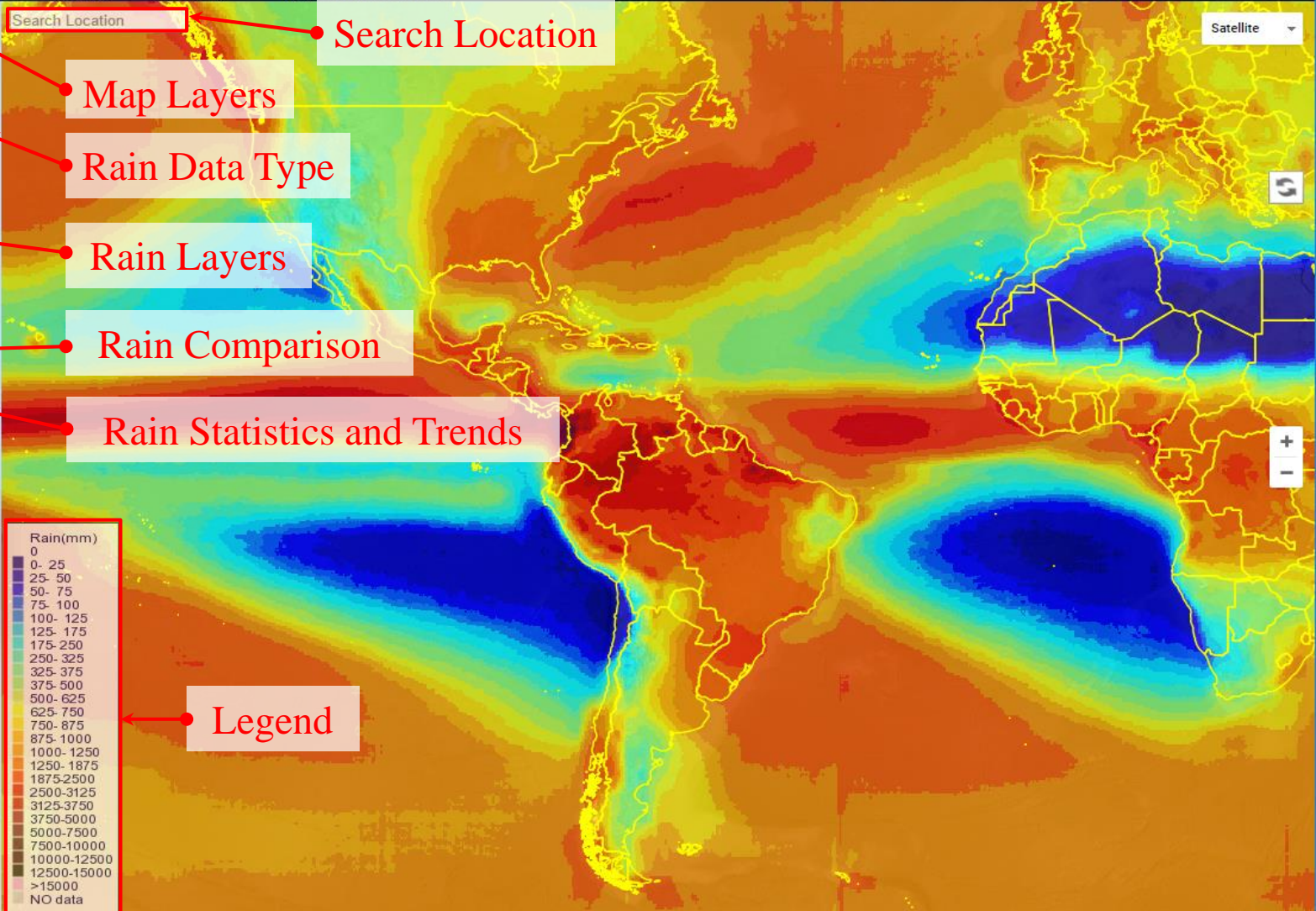
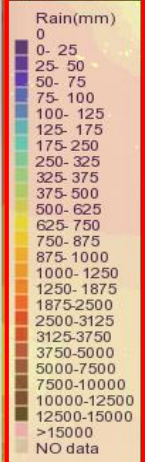
Side by Side Compare

Rain Statistics Rain Trend

Query By: Location
Date Type: Select Type

Select Type
Yearly
Monthly
Monthly by Year
Daily

Location
Country
Political Div
Cont. Basin
Major Basin
Trib. Basin
Watershed



Search Location

Map Layers

Rain Data Type

Rain Layers

Rain Comparison

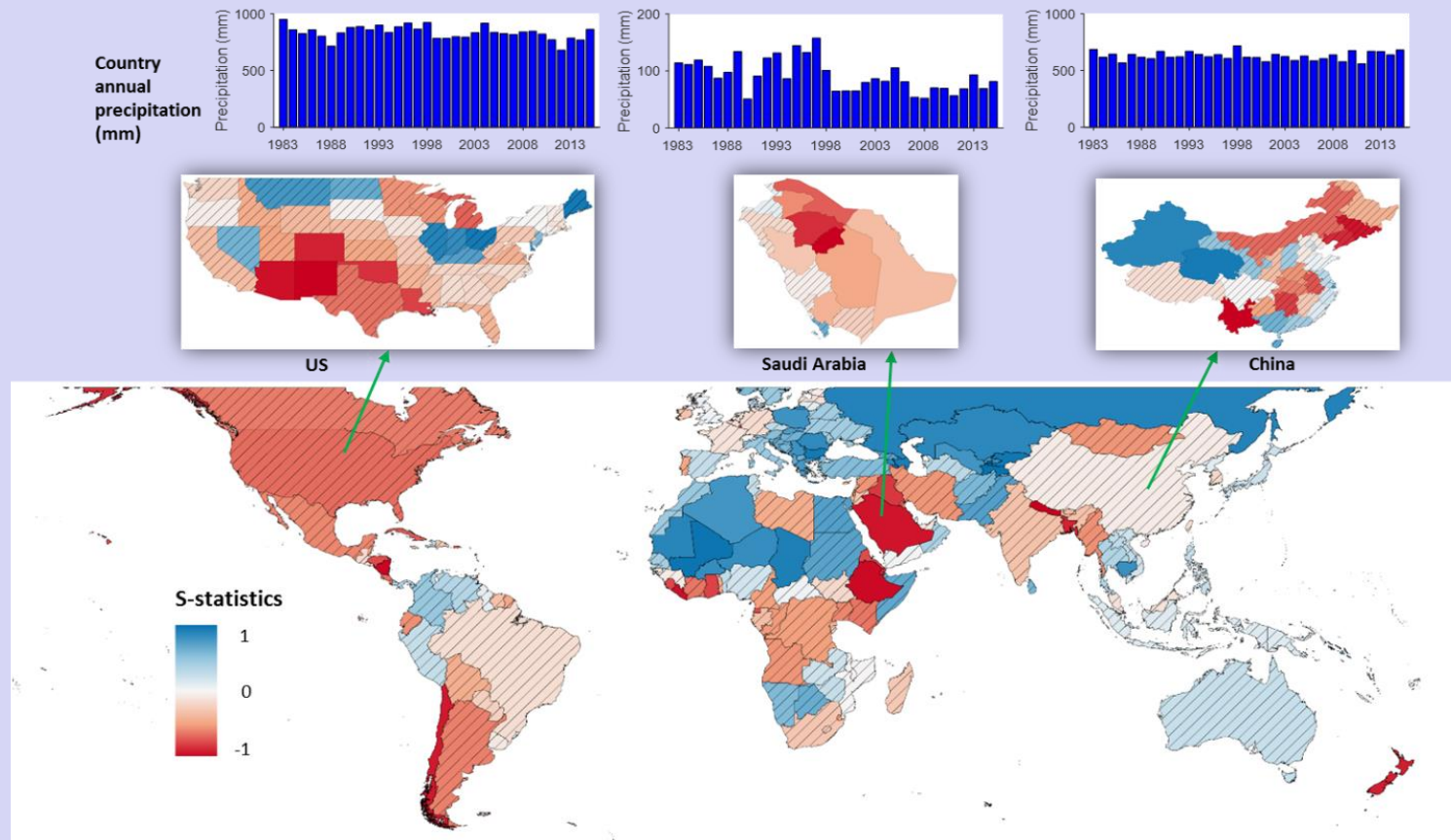
Rain Statistics and Trends

Legend



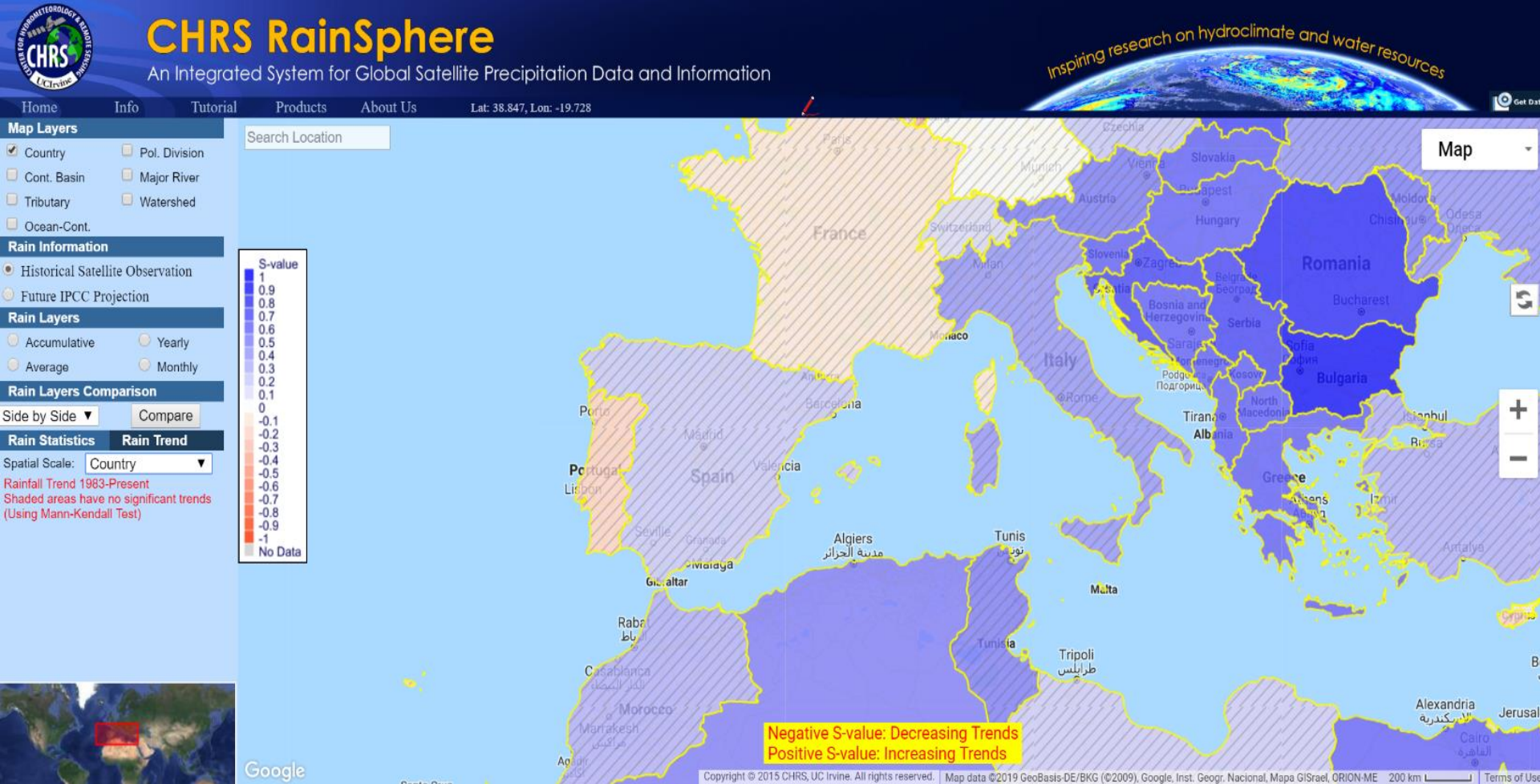
Google

Rainfall Trend Analysis: Countries and Political Divisions



Precipitation trends from 1983 to 2017 over 201 countries (60°N - 60°S) and state/province political divisions of US, Saudi Arabia and China

Rainfall Trend Analysis By Countries: Spain and Portugal



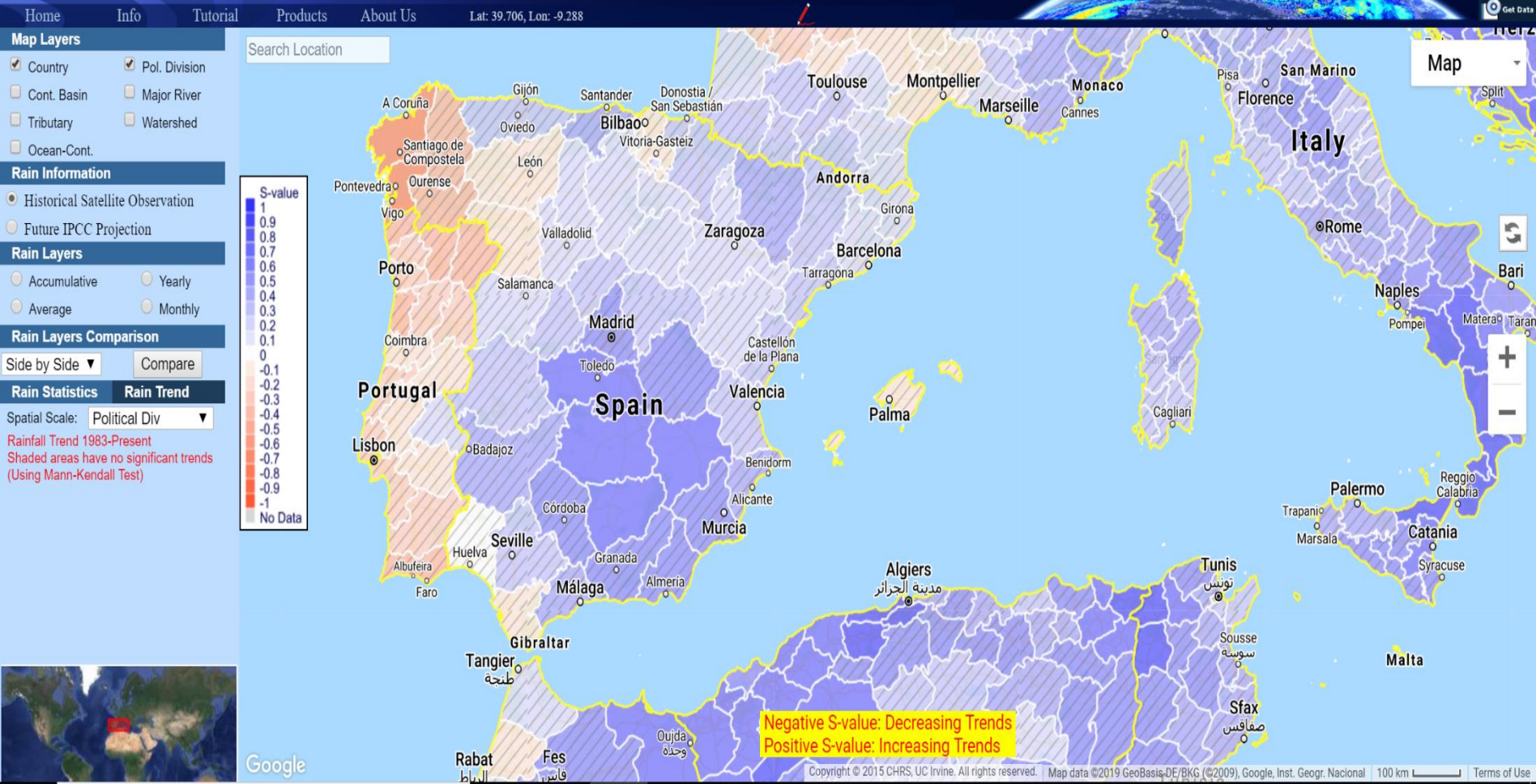
Rainfall Trend Analysis: By Political Divisions Spain & Portugal



CHRS RainSphere

An Integrated System for Global Satellite Precipitation Data and Information

Inspiring research on hydroclimate and water resources



34 Years of Satellite Annual Rainfall Obs. Over Spain Showing No Trend.



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Home Info Tutorial Products About Us Lat: 35.235, Lon: -11.535

Map Layers

- Country
- Pol. Division
- Cont. Basin
- Major River
- Tributary
- Watershed
- Ocean-Cont.

Rain Information

- Historical Satellite Observation
- Future IPCC Projection

Rain Layers

- Accumulative
- Yearly
- Average
- Monthly

Rain Layers Comparison

Side by Side


Rain Statistics **Rain Trend**

Query By:

Date Type:

From: To:

Please select a point on the map



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<http://rainsphere.eng.uci.edu>

RainSphere Country Query

Country/Territory: Spain

Area: 506,286 km²

Population: 47,066,402



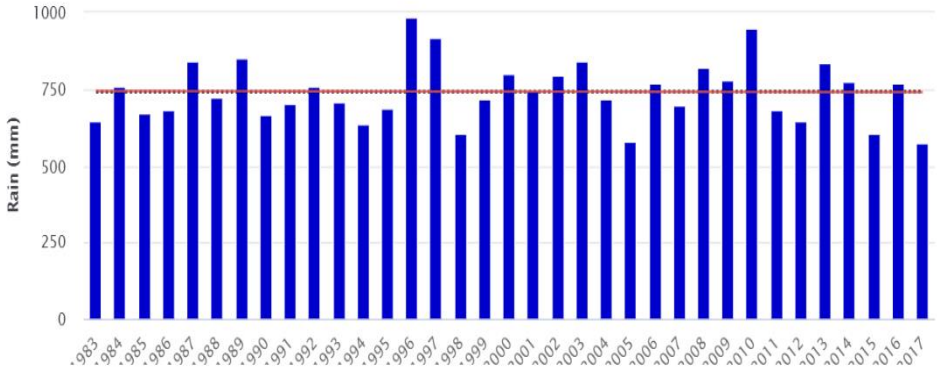
Yearly Rain

— Linear Trend $y = -0.11x + 743.41$

.... Average (741.57 mm)

MKT: **NO TREND**, alpha: 0.05, P: 0.91

← Temperature



Year	Rain (mm)
1983	650
1984	750
1985	650
1986	650
1987	850
1988	700
1989	850
1990	650
1991	700
1992	750
1993	650
1994	600
1995	650
1996	950
1997	900
1998	600
1999	700
2000	750
2001	700
2002	750
2003	850
2004	700
2005	550
2006	750
2007	650
2008	800
2009	750
2010	900
2011	650
2012	600
2013	800
2014	750
2015	600
2016	750
2017	550



CHRS RainSphere – Dailey Rainfall Madrid WY 2018



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Home Info Tutorial Products About Us Lat: 41.316, Lon: -3.523

Map Layers

- Country
- Cont. Basin
- Tributary
- Ocean-Cont.
- Pol. Division
- Major River
- Watershed

Rain Information

- Historical Satellite Observation
- Future IPCC Projection

Rain Layers

- Accumulative
- Average
- Yearly
- Monthly

Year: Climatology Month: 01

Submit

None

Rain Layers Comparison

Side by Side Compare

Rain Statistics Rain Trend

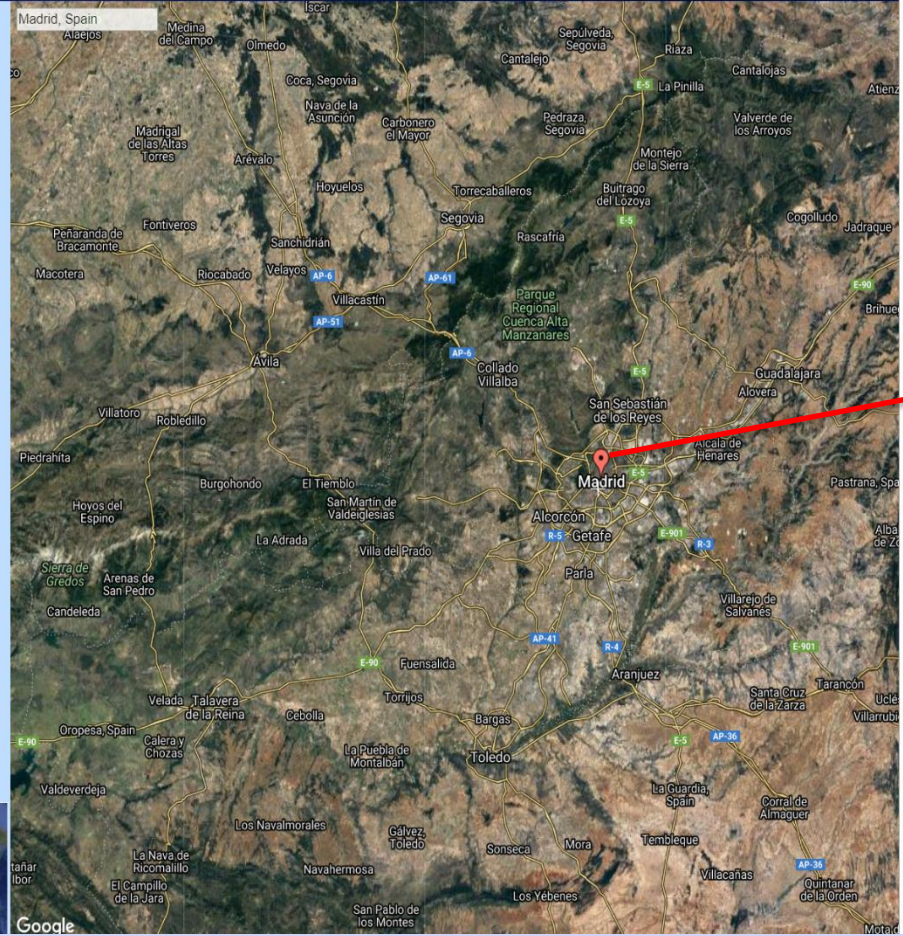
Query By: Location

Date Type: Daily

Select Date (limit 366 days)

2017-10-01 2018-09-30

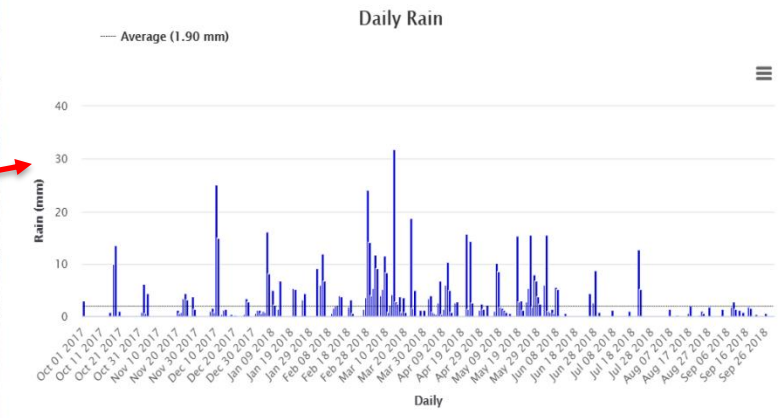
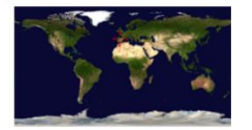
Please select a point on the map



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<http://rairsphere.eng.uci.edu>

Inspiring research on hydroclimate and water resources

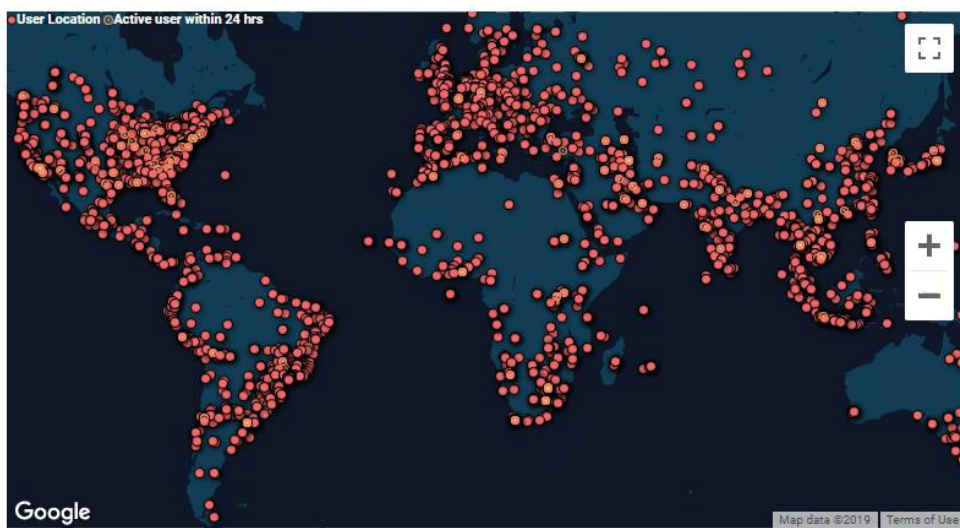
RainSphere Location Query
Location: Madrid, Comunidad de Madrid, Spain
Longitude: -3.712
Latitude: 40.400
Mean 0.04° Elevation: 671 Meters
Land Cover: Urban and Built-up



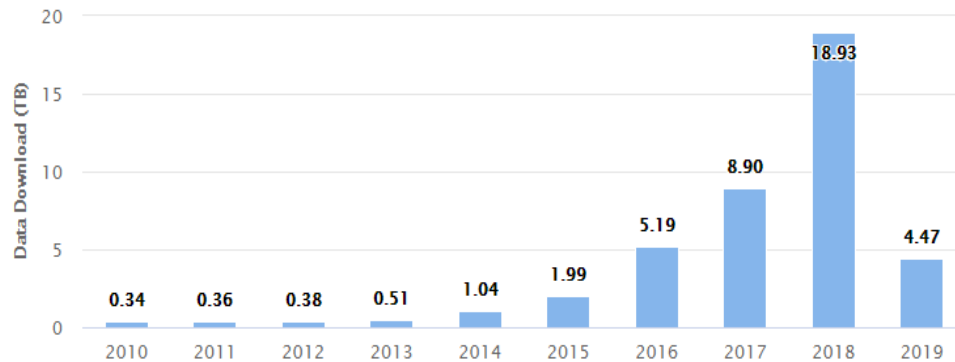
Usage of CHRS's products



CHRS User Statistics



Data Download

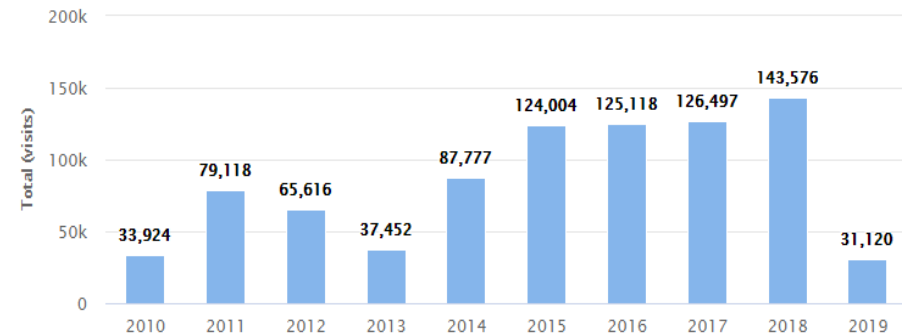


Overall CHRS Homepage iRain RainSphere Data Portal CONNECT

Total Visits: 855,414 since 01-Jan-2010
Countries: 205 countries registered

#	Country	Total Visits
1	United States	482,900
2	China	45,060
3	Israel	37,950
4	Thailand	32,000
5	Private IP	26,370
6	France	22,350
7	Iran, Islamic Republic Of	18,730

User Visit



Take Home Message

- *Despite advances to date, predicting the future Hydro-Climate variables will remain a major challenge:*

- *Future is complex and observing and modeling its*

Factoring in Resiliency in water resources system's design and planning is still the safest approach!

will to avoid
“generated” by models.

- *Long-term and sustained observation programs are critical, especially for model verification. Without some degree of verifiability, hard to expect their use*

From one Extreme to Another: Lake Urmia Iran

February 5, 2019



April 12, 2019





*Thank You for Hosting us
and Listening*

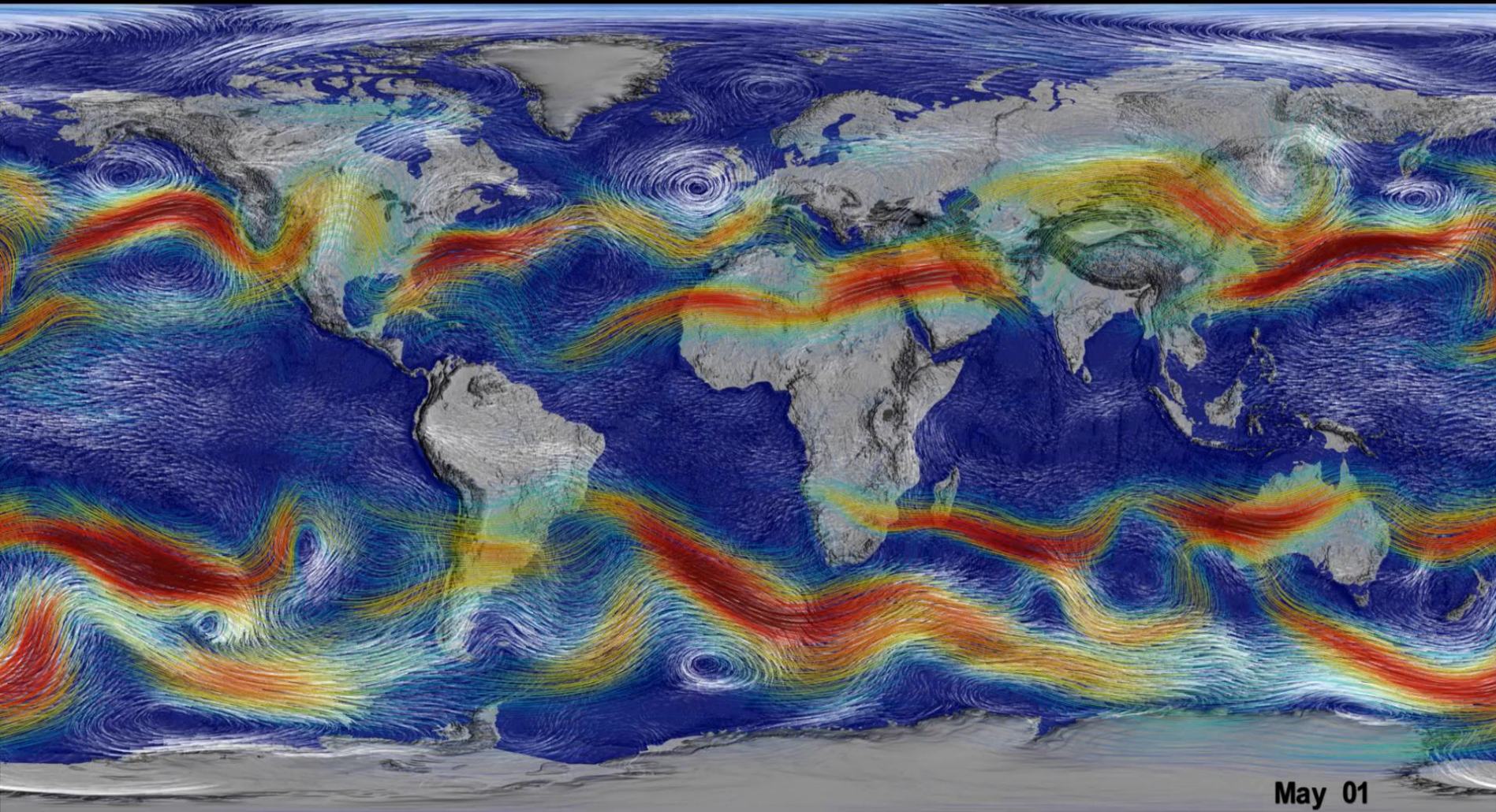
08/14/2009

Somewhere in New Mexico, USA - Photo: J. Sorooshian

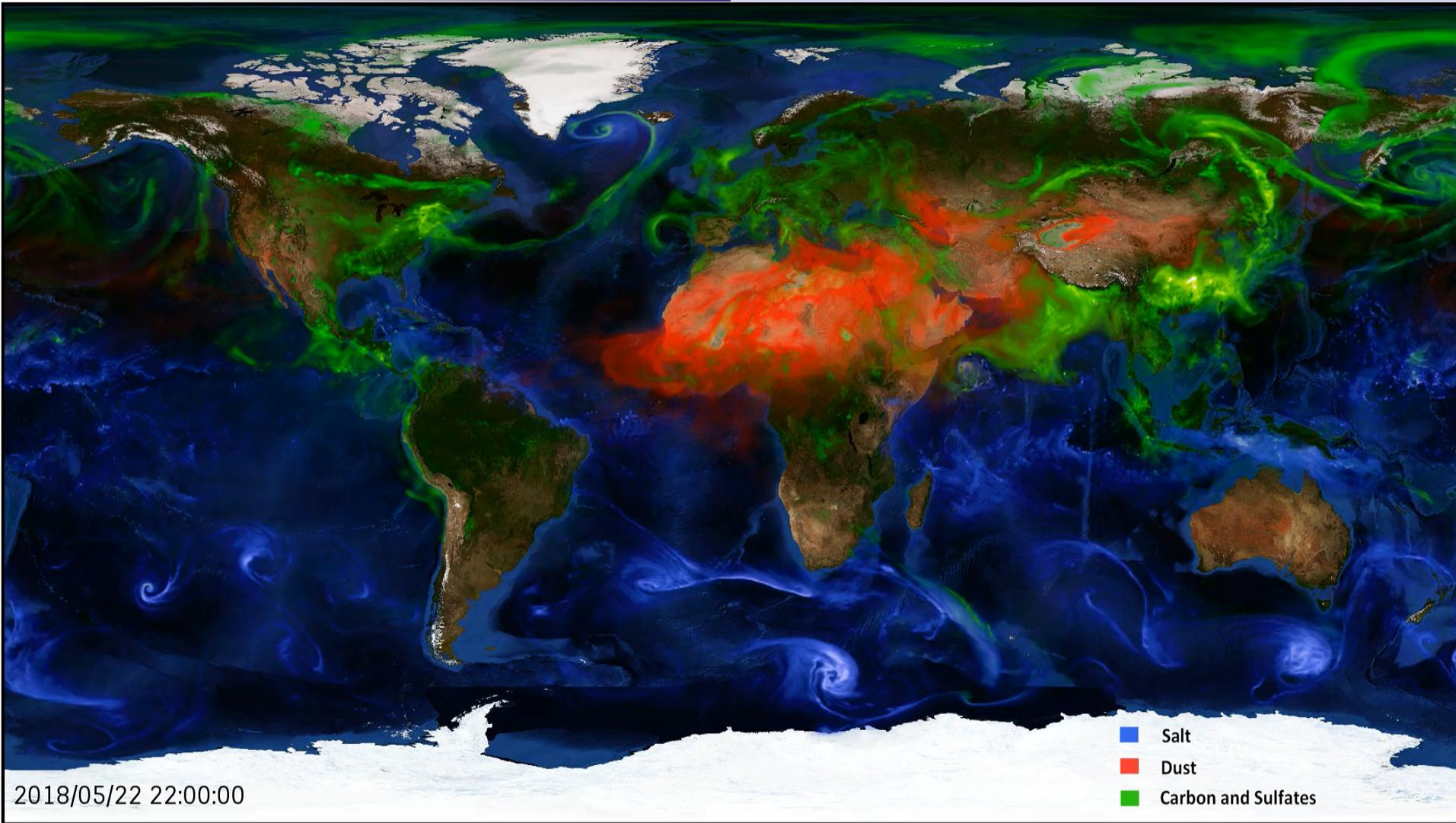
BACK up Slides



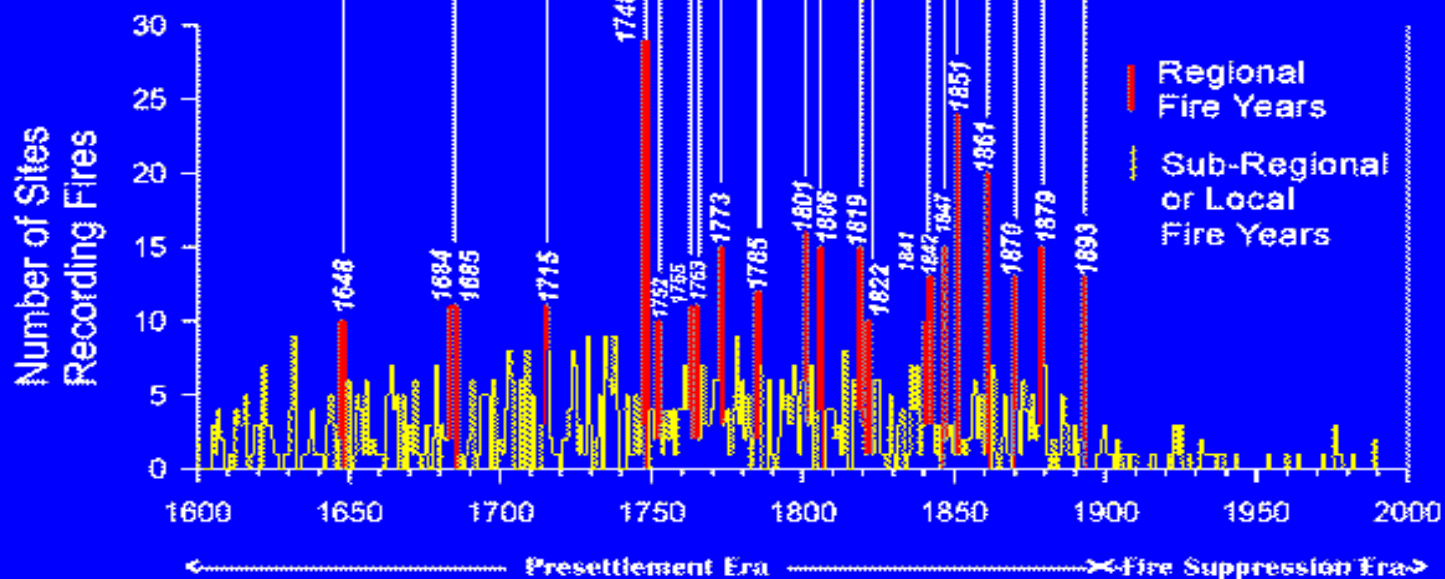
Atmospheric (Air) Circulations



A snapshot of Aerosol and other Pollutants' Movement Around the Globe



Composites of Fire-Scar Chronologies From Southwestern U.S. Forests



Seasonal-Scale Predictions

Short Range -----> Long Range

hours -----> days -----> weeks ----> months --> seasons --> years -----> decades

Flash Flood Warning

Flash Flood Guidance

Headwater Guidance

Flood Forecast Guidance

Reservoir Inflow Forecasts

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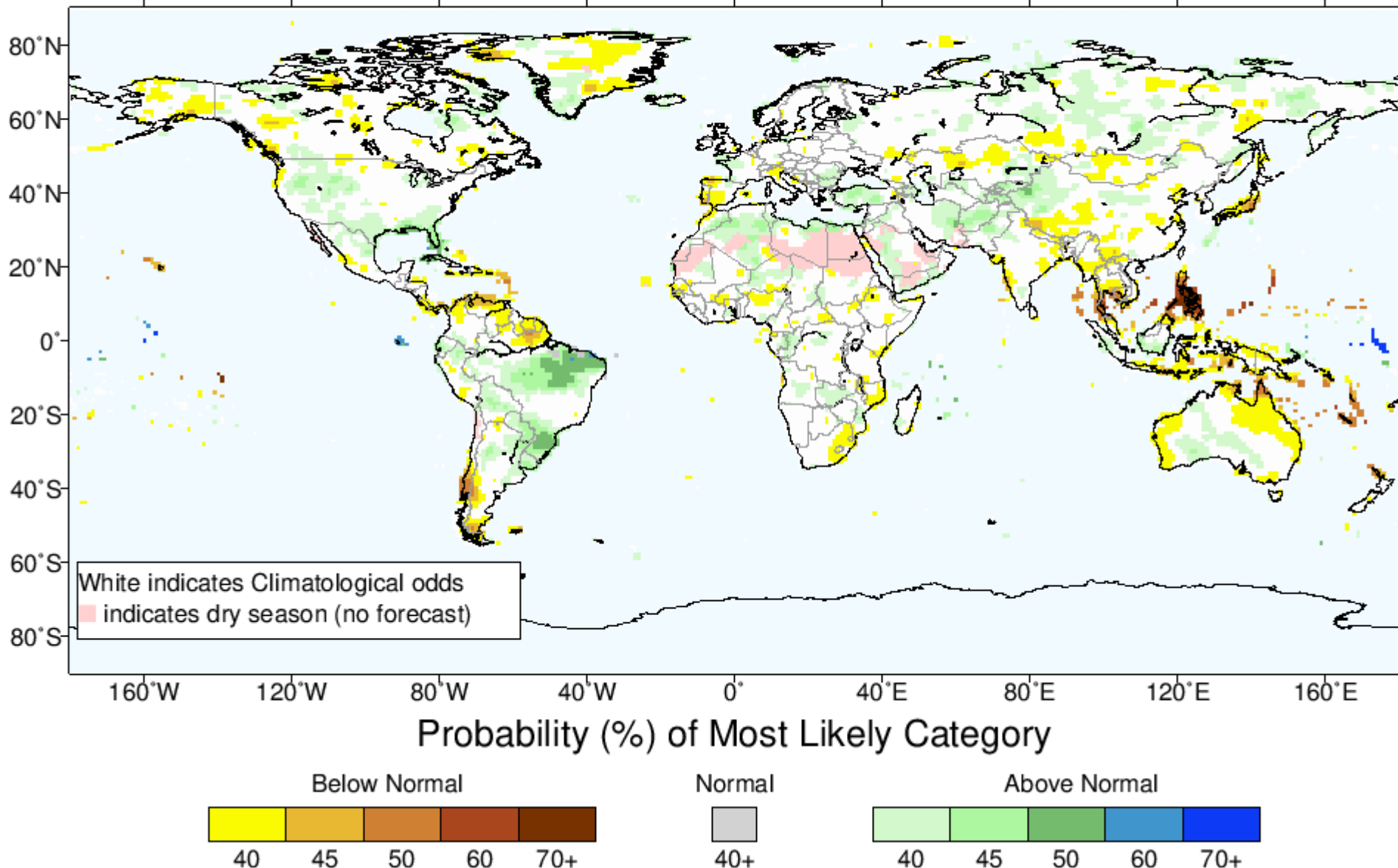
Water Supply Volume

Mid-range

Forecast Requirements



IRI Multi-Model Probability Forecast for Precipitation for April-May-June 2019, Issued March 2019



Recent Evaluation of RCM/GCM over Western U.S.







Wei Chu 2011

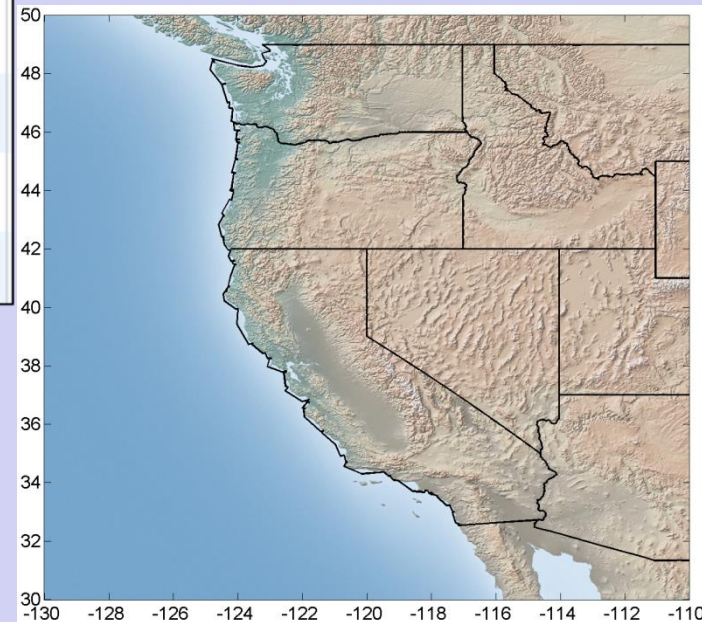
Current period: 1971-2000

Future period: 2041-2070

Spatial Res.: 50 km

Temporal Res.: daily

Regional Models	Climate Models			
	GFDL	CGCM3	HADCM3	CCSM
CRCM	_____		_____	_____
ECP2		_____	_____	_____
HRM3	_____	_____		_____
MM5I	_____	_____	_____	
RCM3	_____		_____	_____
WRFG	_____	_____	_____	



study region

Outputs of six RCM/GCM sets:

North American Regional Climate Change Assessment Program (NARCCAP)

Emissions Scenario:

A2: regionally oriented and fast economic growth

