Mapping Gridded Drought Index to Mitigate Drought Impacts on the Mountain West

Jae Ryu

Department of Biological and Agricultural Engineering

Mountain West Water Institute "Water Ways and Means"
May 15-16 2012
Hilton Garden Inn
Idaho Falls, Idaho

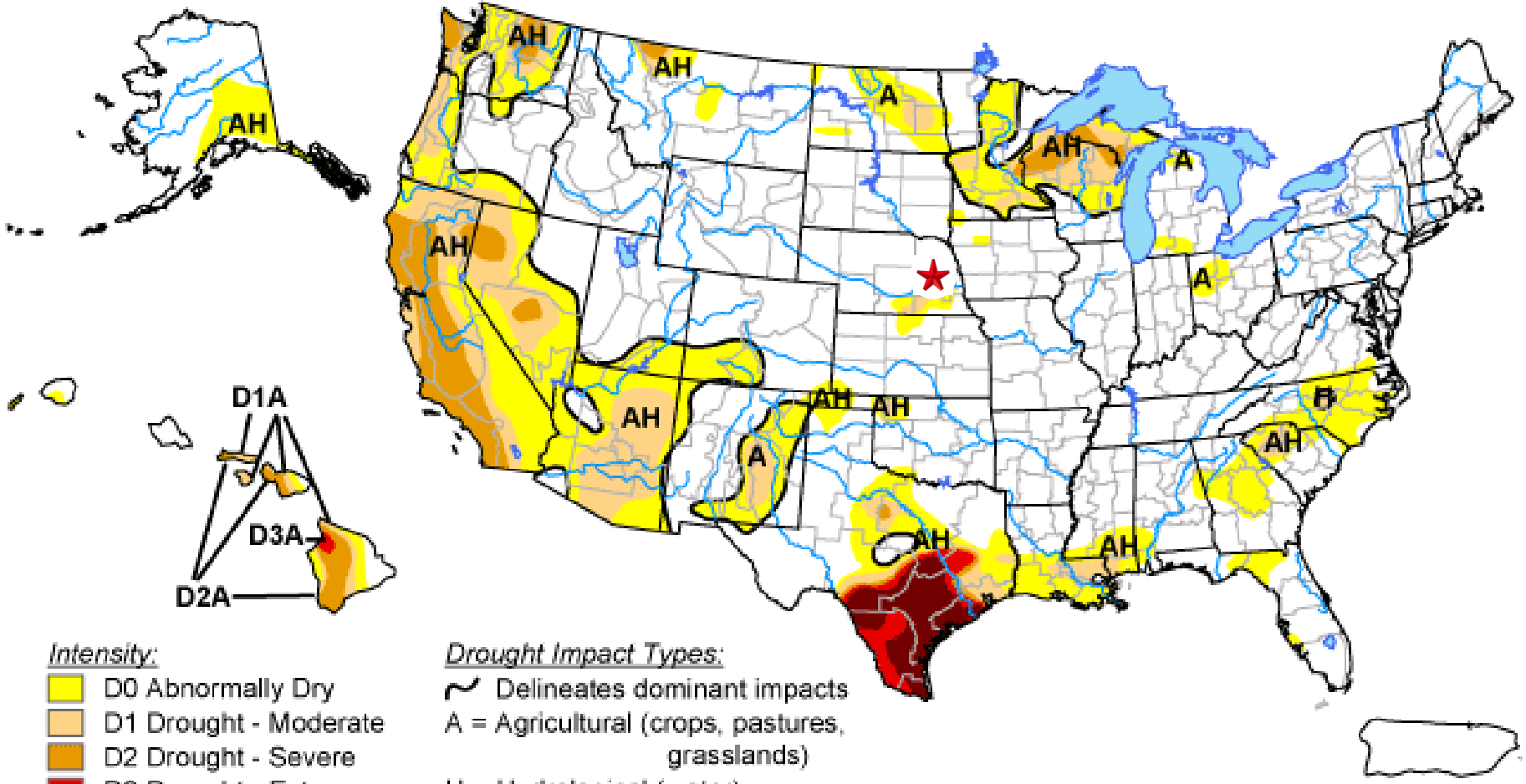
University of Idaho
A LEGACY OF LEADING

Presentation Outline

- Research at the previous institution
- Current and future research, and beyond to deal with Idaho water issues

U.S. Drought Monitor

August 25, 2009
Valid 8 a.m. EDT



Intensity:
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:
- ~ Delineates dominant impacts
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

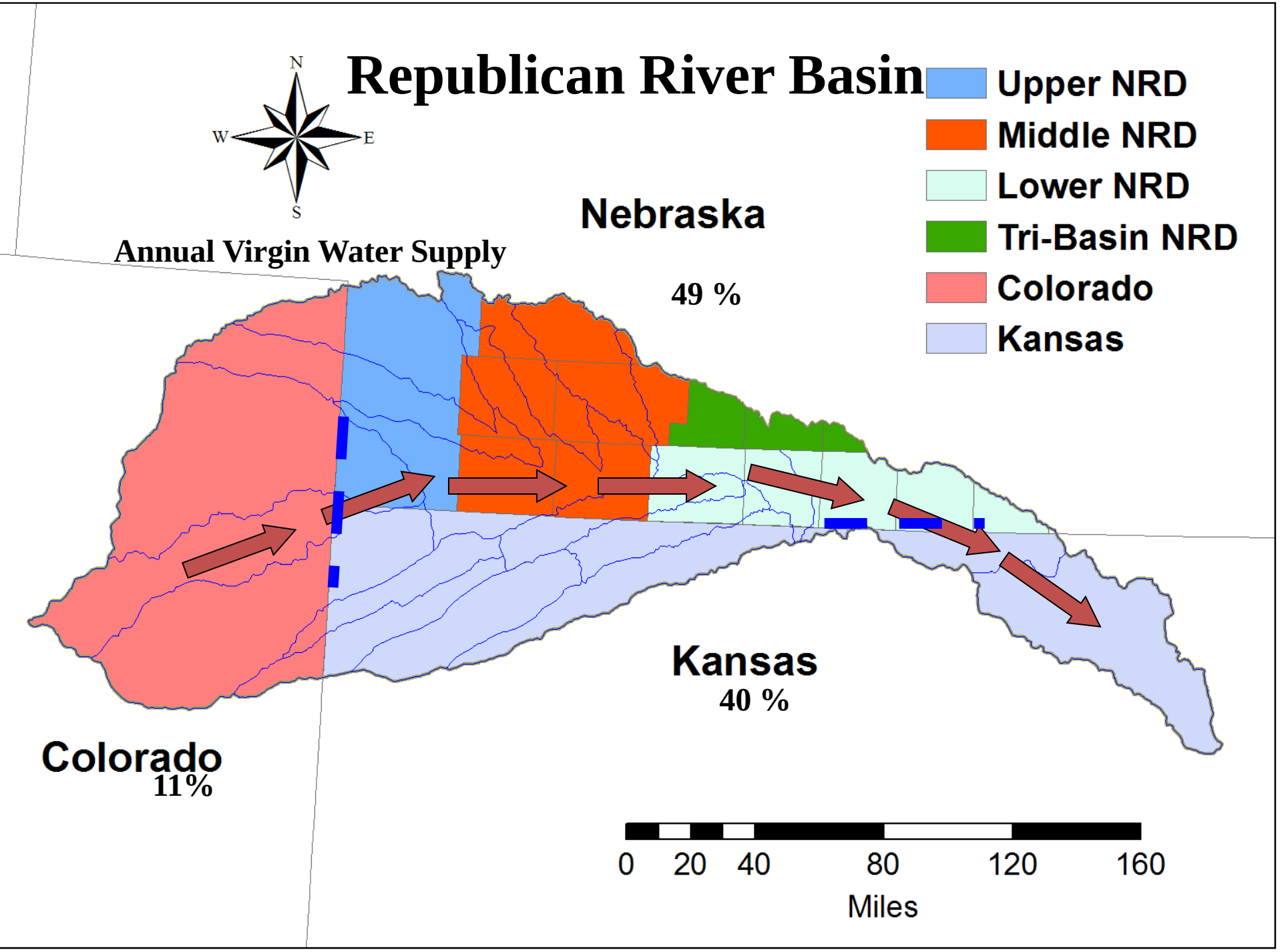
USDA National Drought Mitigation Center

Released Thursday, August 27, 2009

Author: Brad Rippey, U.S. Department of Agriculture

Research Experiences, NDMC

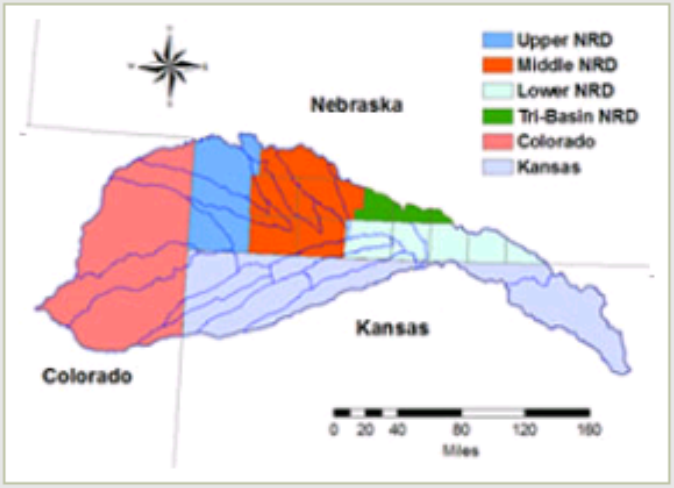
- Water and drought web portal for Republican River Basin, Nebraska (NOAA)
- Seasonal capability for US Drought Monitoring (NASA)
- US Drought Atlas Project (USDA)
- Distributed Model Intercomparision Project (DMIP)


Republican River Basin
N
W
E
S
Upper NRD
Middle NRD
Lower NRD
Tri-Basin NRD
Colorado
Kansas
Annual Virgin Water Supply
Nebraska
49 %
Kansas
40 %
Colorado
11%
0 20 40 80 120 160
Miles

Republican River Basin Water and Drought Portal

Welcome to Republican River Basin Water and Drought Portal

Water resources in the Republican River Basin are vital to the sustainability of the life that surrounds them. Not only is it important to the well being of people but it's also necessary for crop production, animal life, and the hydrological cycle. This portal was created to provide comprehensive information on emerging and ongoing water and drought issues for anyone that has an interest in the Republican River Basin. It will give stakeholders the planning information and tools needed to develop sustainable water strategies as well as information to better prepare for and respond to water shortage and drought.



The portal is part of the National Integrated Drought Information System (NIDIS), which is a national effort to provide enhanced access to drought-related information.

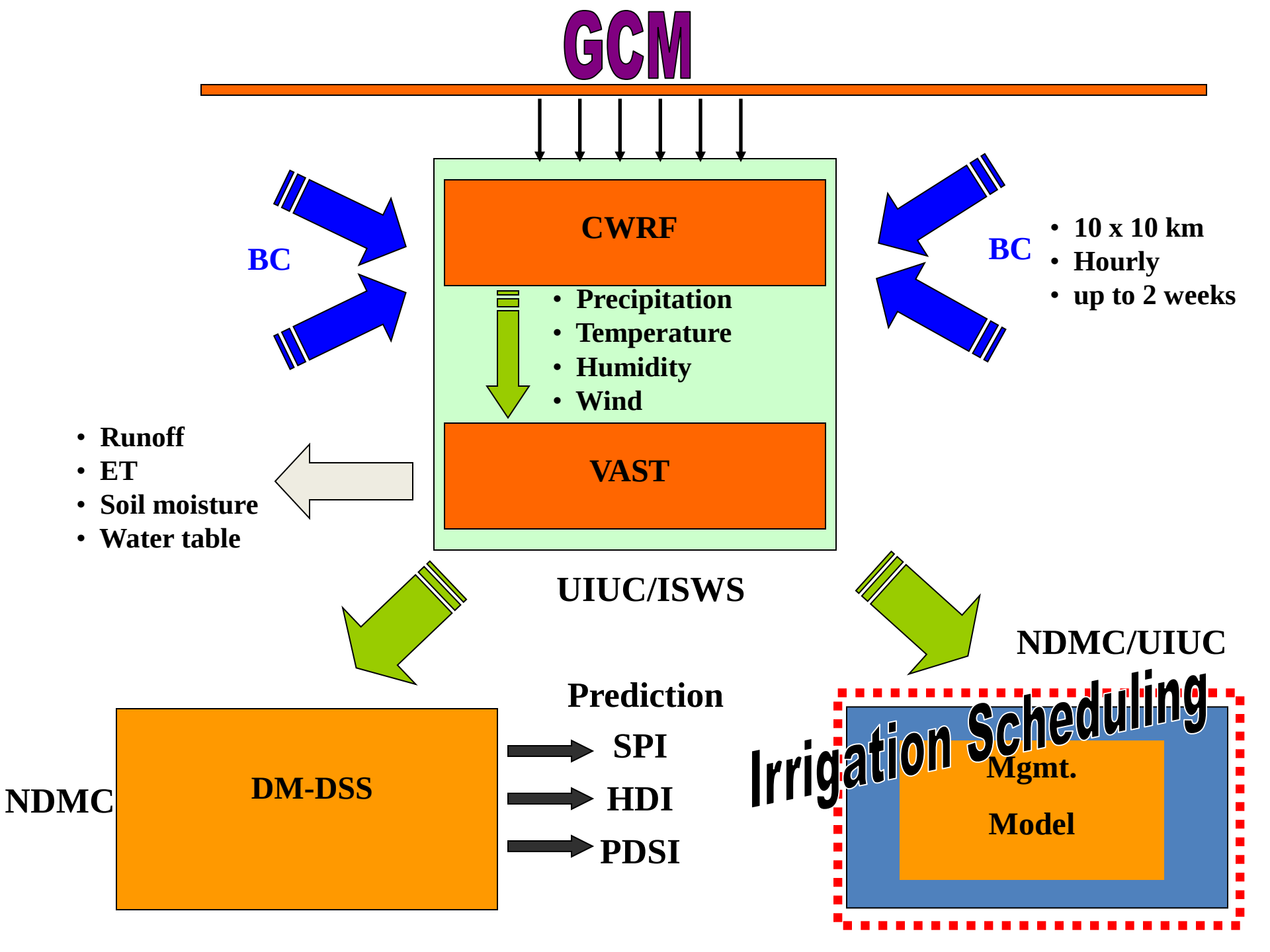
What's New

We will continue to add content to this website. Please visit us again to find more and updated information. Your feedback is important to us. Please send comments to 'cknutson1@unl.edu'.

Recent Drought News

"2007 was Tenth Warmest for U.S., Fifth Warmest Worldwide" - *NOAA (1.15.2008)*
(view article)

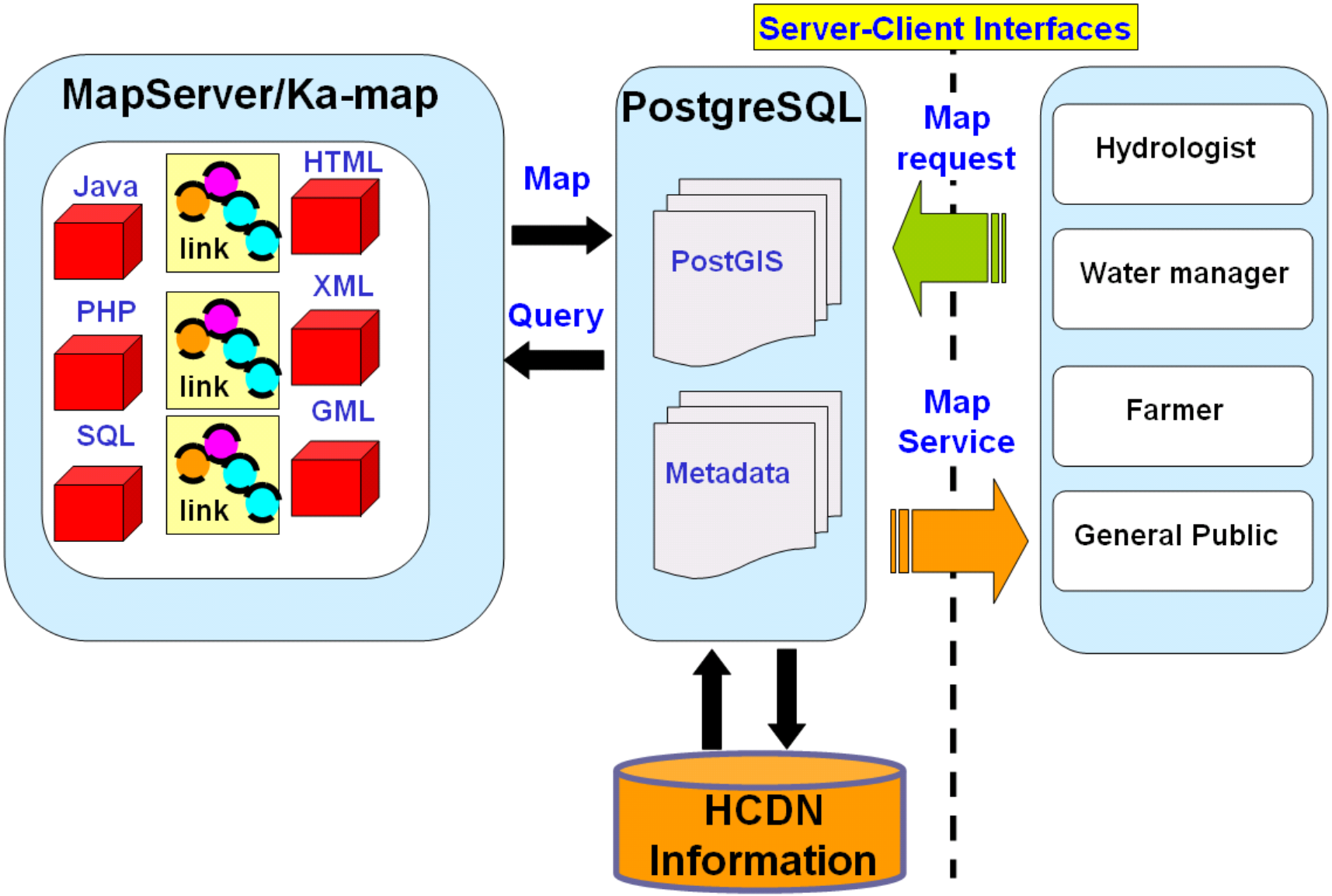
"Harvesting Rainwater by Not Letting it Go to Waste" - *NPR (1.10.2008)*
(view article)


GCM
CWRF
BC
BC
• 10 x 10 km
• Hourly
• up to 2 weeks
• Precipitation
• Temperature
• Humidity
• Wind
VAST
• Runoff
• ET
• Soil moisture
• Water table
UIUC/ISWS
NDMC/UIUC
Prediction
SPI
HDI
PDSI
NDMC
DM-DSS
Irrigation Scheduling
Mgmt.
Model

Web-GIS Visualization

- ArcIMS (ESRI): Commercial, cost, server license
- Google Map/Microsoft Virtual Earth: Commercial, free with condition, online key
- MapServer (UMN): Open source, free of charge, GNU License

A Framework of Open Source Web-GIS



U.S. Drought Atlas Demonstration - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://rainier.unl.edu/atlas/index.html

Most Visited | Customize Links | Free Hotmail | Windows Marketplace | Windows Media | Windows | mapserv.exe (PNG Im...

Google | office depot | Search | Bookmarks | Check | AutoLink | AutoFill | Send to | Settings

U.S. HYDRO DROUGHT ATLAS DEMONSTRATION

Ka-Map (AJAX) + Mapserver (GIS Server) + PostGIS (Geospatial Database) = Openso

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Atlas | 1:21000000

Search

Type in USGS gage station number (e.g. 6783500)

6783500

Search

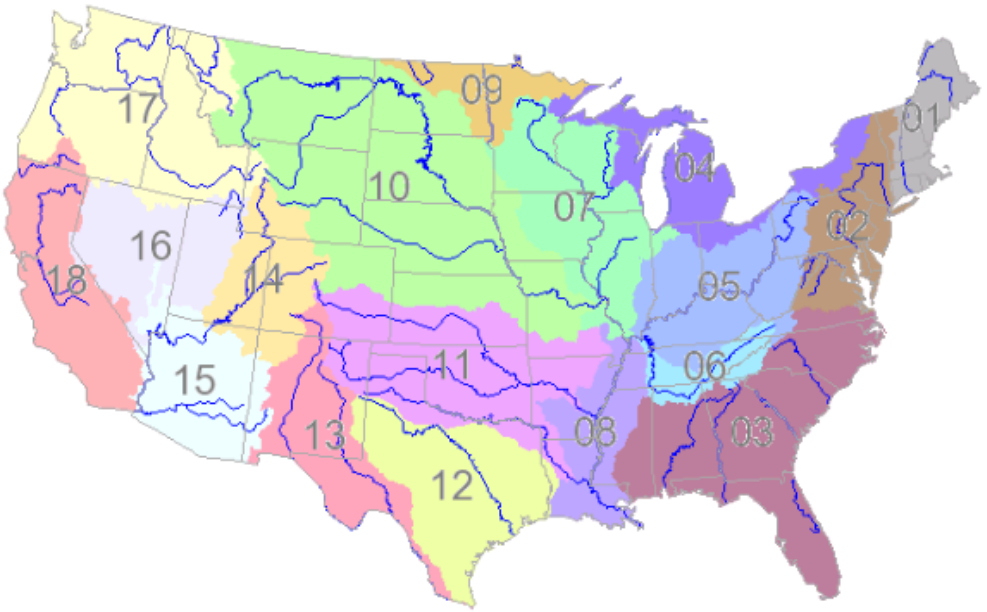
Search string:
6783500

Layer Name:
HCDN Gage Stations

results: 1

StationID	State	Zoom to	Streamflow
06783500	NE		

6783500



http://rainier.unl.edu/atlas

kilometers
0 400 800 1200

Find: | Next | Previous | Highlight all | Match case

Done

U.S. Hydro Drought Atlas Demonstration - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://rainier.unl.edu/atlas/flow_out.php?startyear=1980&endyear=1982&staid=06783500

Most Visited | Customize Links | Free Hotmail | Windows Marketplace | Windows Media | Windows | mapserv.exe (PNG Im...

U.S. Drought Atlas Demonstration | U.S. Drought Atlas Demonstration | U.S. Hydro Drought Atlas Demon...

U.S. HYDRO DROUGHT ATLAS DEMONSTRATION

Ka-Map (AJAX) + Mapserver (GIS Server) + PostGIS (Geospatial Database) = Opensource Framework

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2

Start Year 1980

End Year 1982

OK

Start Time Year Mon Day 1973 1 1

End Time Year Mon Day 1973 1 1

Start Year 1980

End Year 1982

Hydro Drought Index 6 months

Show Volume Bars

Vertical Grid

Horizontal Grid

Log Scale

Chart Type CandleStick

Moving Average Bollinger Band

Moving Averages Simple 10 Simple 25

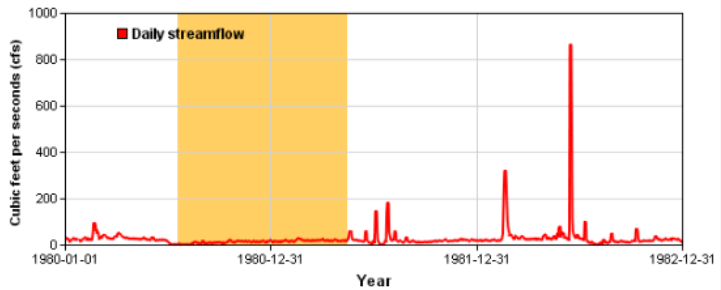
Technical Indicators None None None None

Update Chart

Station ID: 06783500 (USGS Link)
Name:MUD CREEK NEAR SWEETWATER, NE
State:NE
Latitude:41.0375
Longitude:-98.99305556
Elevation:2013.69
Period of Record: 1933/5/1 - Current

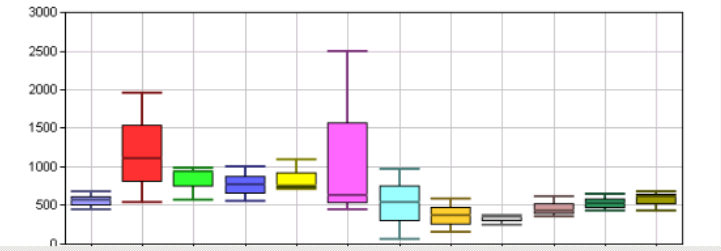
1

Historic Streamflow from 1980 to 1982 at 06783500



3

Monthly Streamflow from 1980 to 1982 at 06783500



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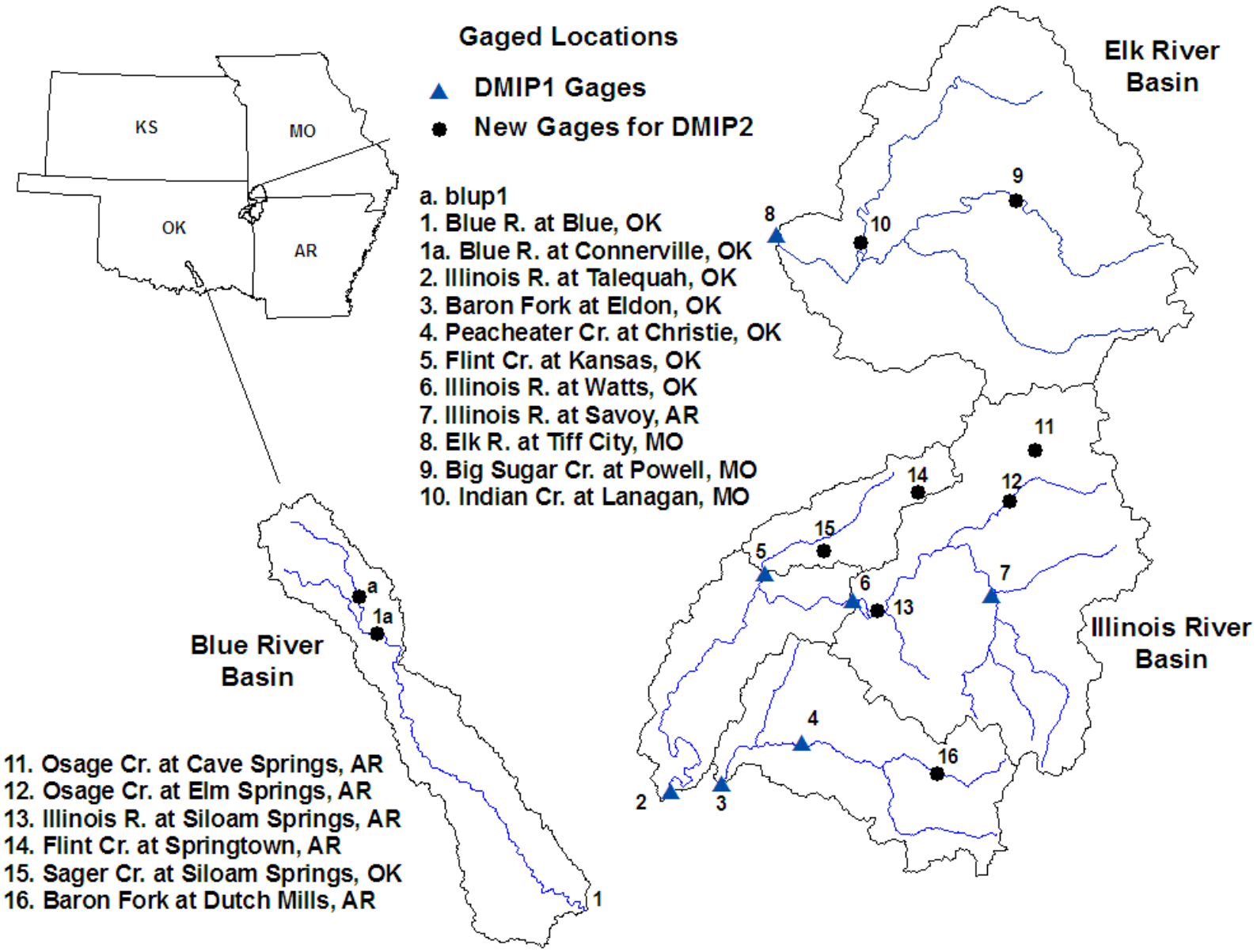
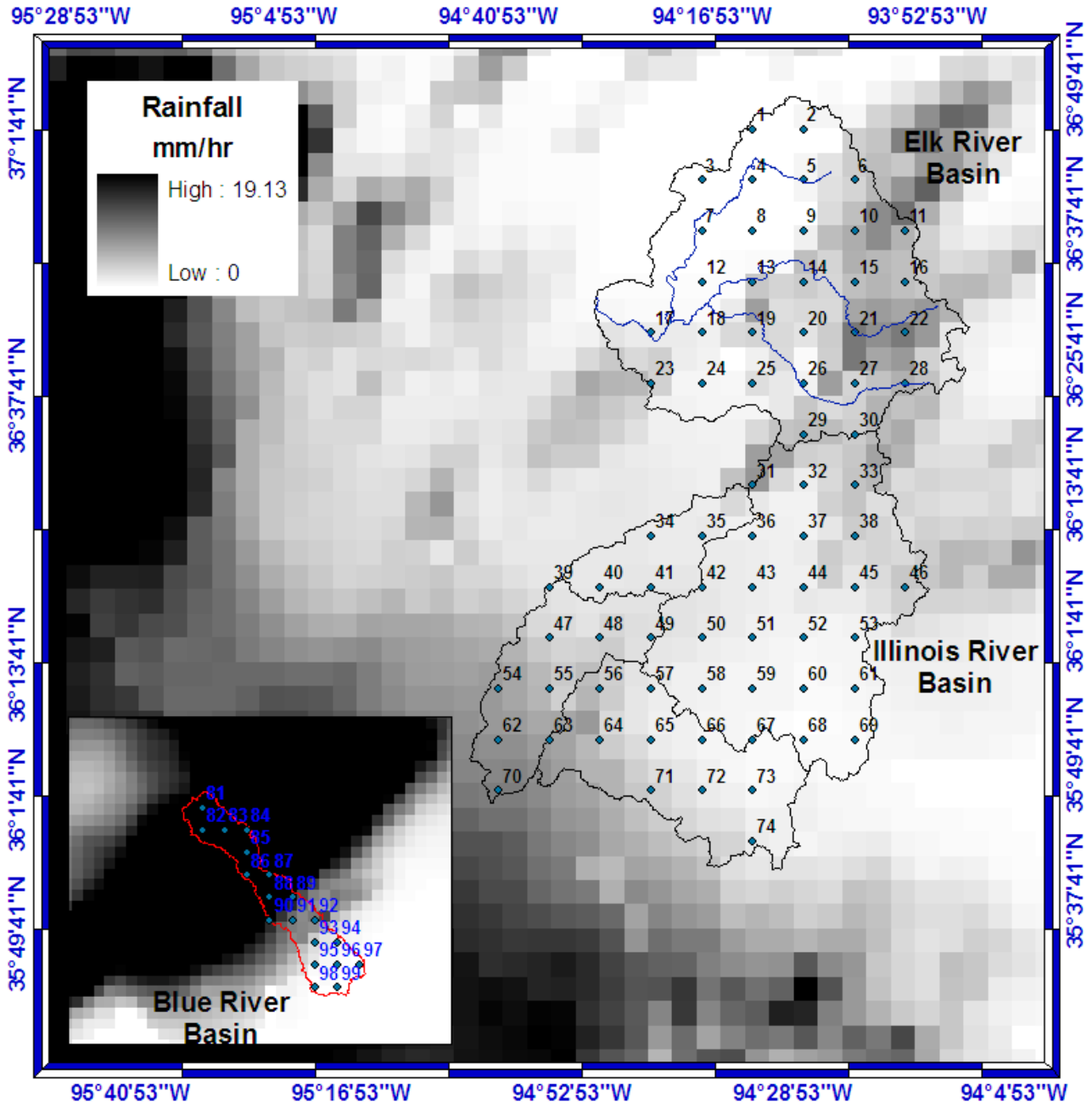
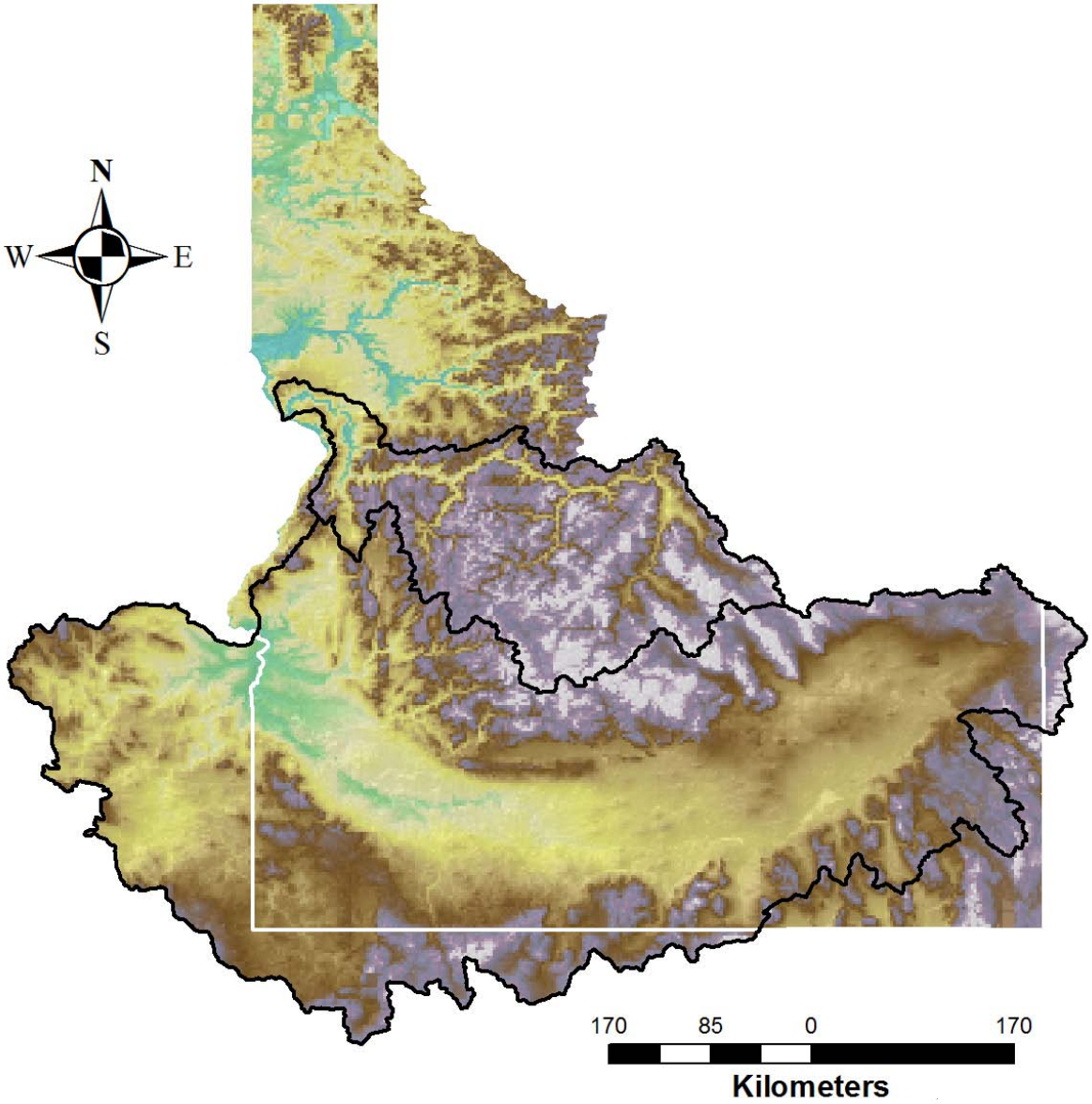


Figure 1 Study area of DMIP2 basins. Note that triangles represent USGS stream gages used for DMIP1 project and circles indicate new gages added for DMIP2 project

4 km x 4 km
Hourly



Journal of Hydrologic Engineering, 14(8), 847-857, ASCE, 2009



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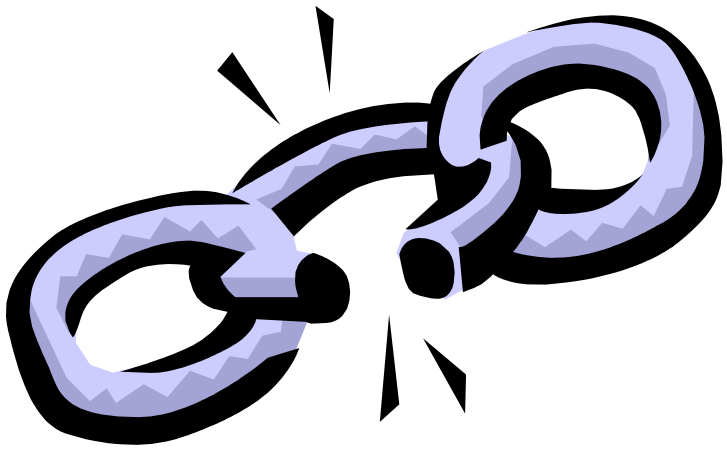
Climate Change



Human Dimensions


OUT. TEMP
AUTO
OFF
BRIGHT
OUT. TEMP
-22
MODE
A/C
6-DISC CD CHANGER
PUSH PWR·VOL
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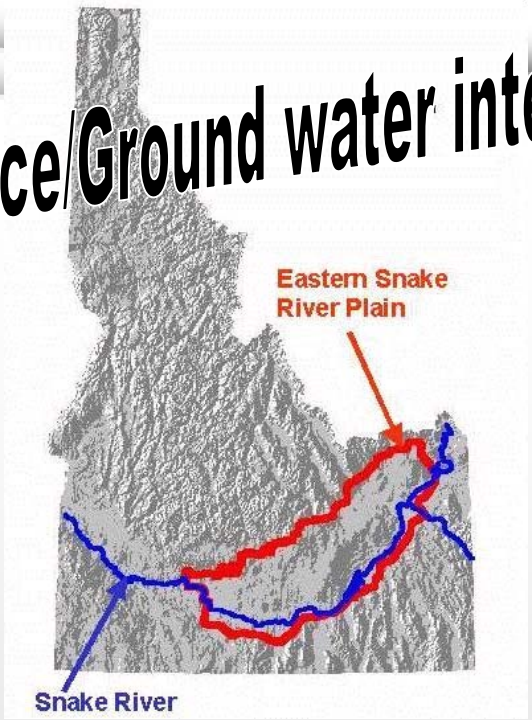
LOAD


I
MISS
GLOBAL
WARMING
I
MiSS
GLOBAL
WARMiNG
EFI
DODGE
HAROLD'S
Minnesota
Hill BROS.
hillbros.com

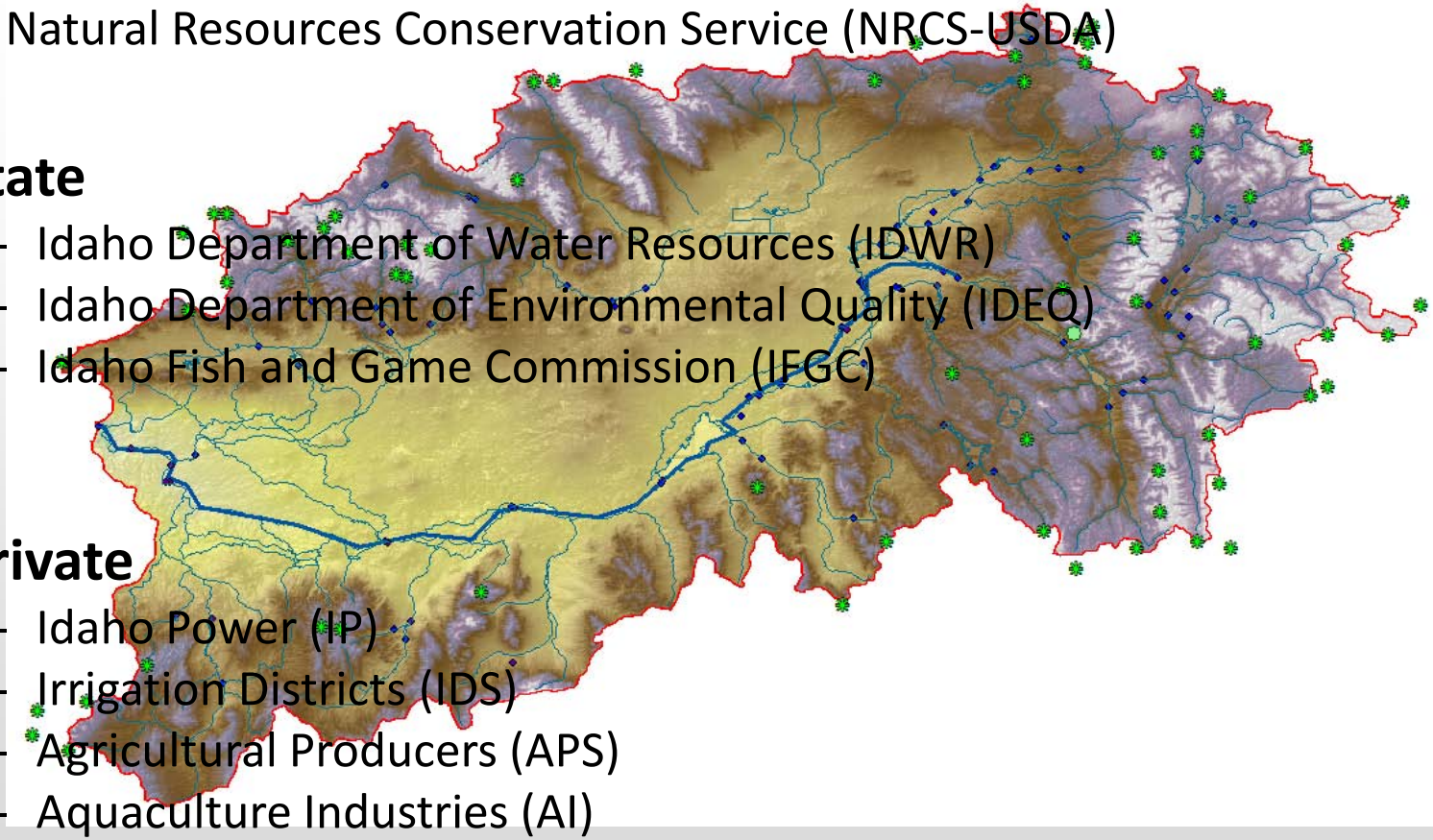
Surface/Ground water interaction



Irrigated agriculture

Climate change impacts

- **Federal**
  - U.S. Bureau Reclamation (USBR)
  - U.S. Geological Survey (USGS)
  - U.S. Army Corps of Engineers (USACE)
  - Natural Resources Conservation Service (NRCS-USDA)



- **State**
  - Idaho Department of Water Resources (IDWR)
  - Idaho Department of Environmental Quality (IDEQ)
  - Idaho Fish and Game Commission (IFGC)

- **Private**
  - Idaho Power (IP)
  - Irrigation Districts (IDS)
  - Agricultural Producers (APS)
  - Aquaculture Industries (AI)
  - Surface/Groundwater Irrigators (SGI)

Idaho Models

ESPAM (MODFLOW-Groundwater Model)

VIC (Vegetation Infiltration Capacity Model)

Snake River Planning Model (SRPM)
Movement: MODSIM → POWERSIM→ RIVERWARE

GIS-Based Accounting Model (IDWR)

GFLOW (Conceptual Groundwater Model)

GAMS (General Algebraic Modeling System)

Climate Change

Policy-Driven Decision Making
Adaptive Management Options
Water Dispute Resolution
Sustainable Water Resources Planning and Management

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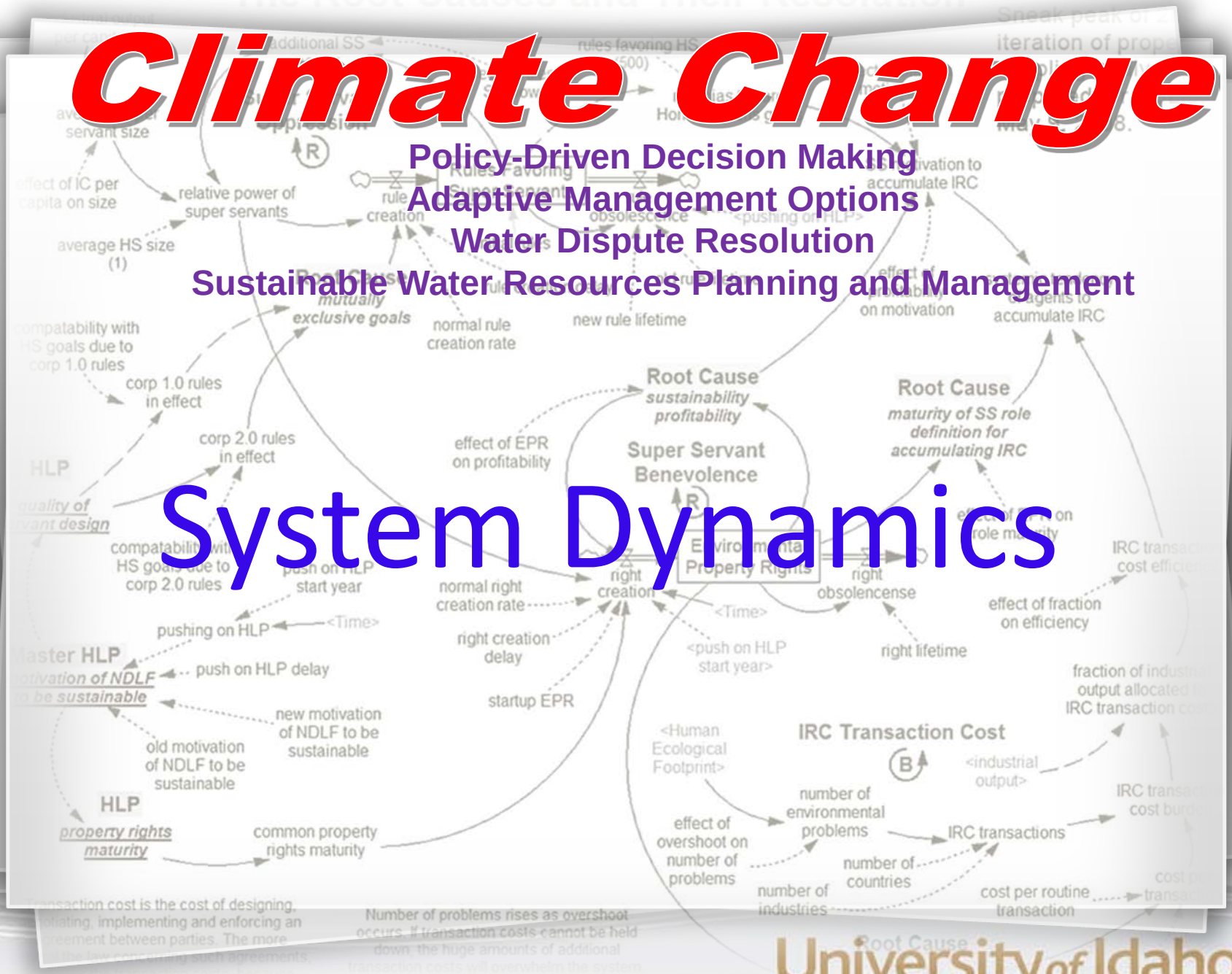
Climate Change

Policy-Driven Decision Making

Adaptive Management Options

Water Dispute Resolution

Sustainable Water Resources Planning and Management



System Dynamics

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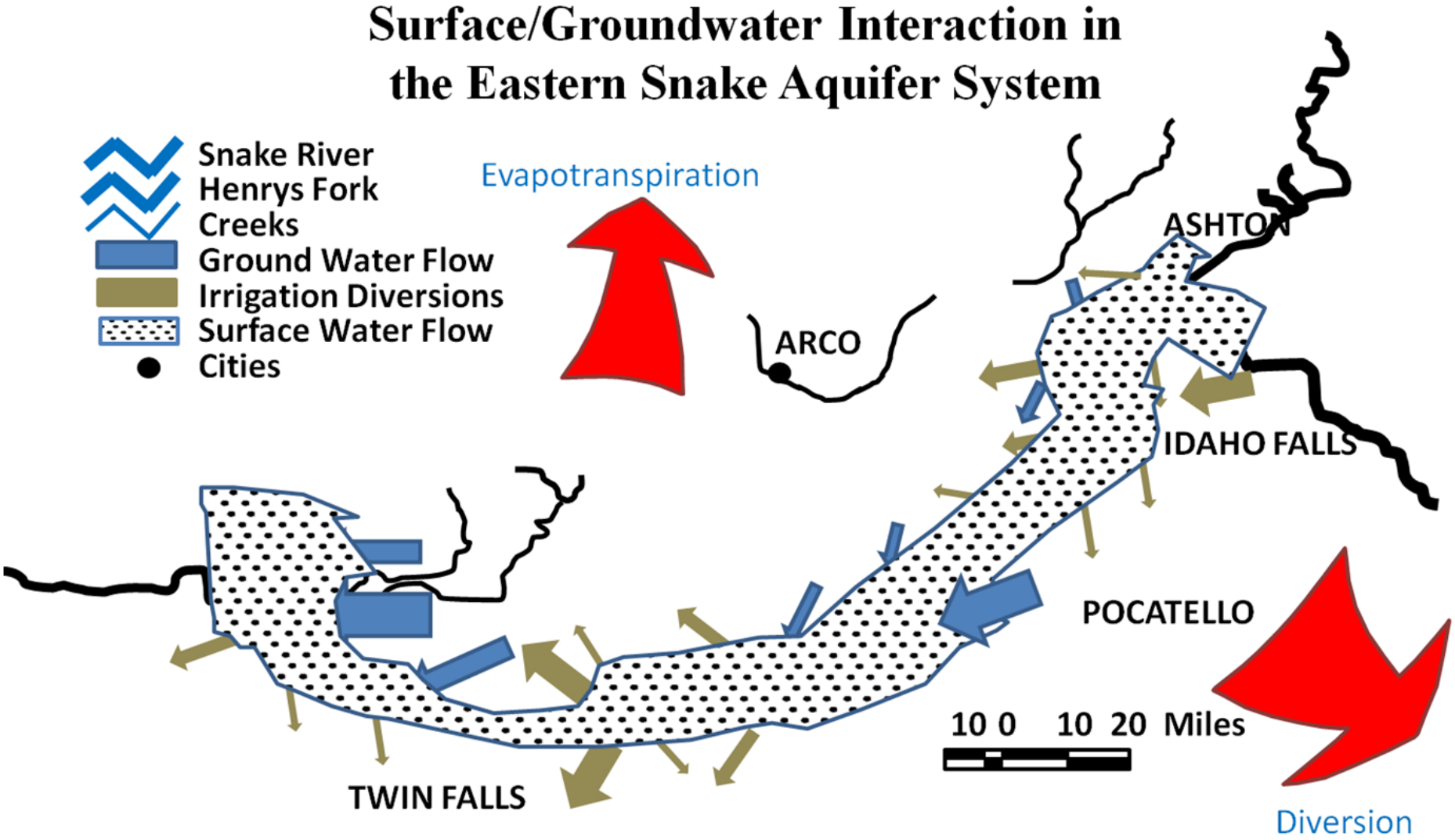
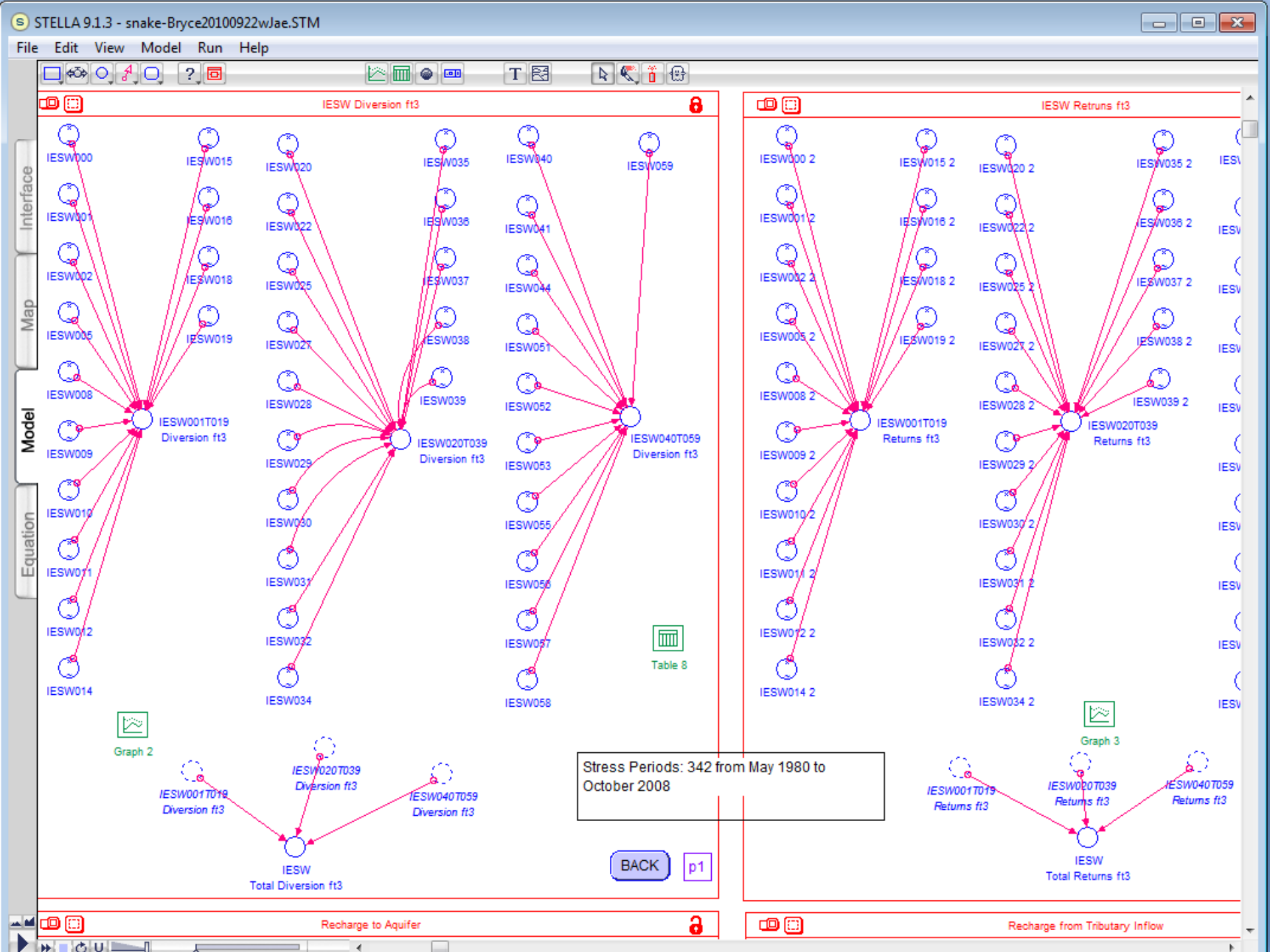


Figure 2. Flow in the Snake River is strongly affected by irrigation diversions and by inflow from springs (after Kjelstrom, 1986)


STELLA 9.1.3 - snake-Bryce20100922wJae.STM
File Edit View Model Run Help
Interface
Map
Model
Equation
IESW Diversion ft3
IESW000
IESW001
IESW002
IESW005
IESW008
IESW009
IESW010
IESW011
IESW012
IESW014
IESW015
IESW016
IESW018
IESW019
IESW001T019
Diversion ft3
IESW020
IESW022
IESW025
IESW027
IESW028
IESW029
IESW030
IESW031
IESW032
IESW034
IESW035
IESW036
IESW037
IESW038
IESW039
IESW020T039
Diversion ft3
IESW040
IESW041
IESW044
IESW051
IESW052
IESW053
IESW055
IESW056
IESW057
IESW058
IESW059
IESW040T059
Diversion ft3
Table 8
Graph 2
IESW001T019
Diversion ft3
IESW020T039
Diversion ft3
IESW040T059
Diversion ft3
IESW
Total Diversion ft3
Stress Periods: 342 from May 1980 to October 2008
BACK
p1
IESW Retruns ft3
IESW000 2
IESW001 2
IESW002 2
IESW005 2
IESW008 2
IESW009 2
IESW010 2
IESW011 2
IESW012 2
IESW014 2
IESW015 2
IESW016 2
IESW018 2
IESW019 2
IESW001T019
Returns ft3
IESW020 2
IESW022 2
IESW025 2
IESW027 2
IESW028 2
IESW029 2
IESW030 2
IESW031 2
IESW032 2
IESW034 2
IESW035 2
IESW036 2
IESW037 2
IESW038 2
IESW039 2
IESW020T039
Returns ft3
Graph 3
IESW001T019
Returns ft3
IESW020T039
Returns ft3
IESW040T059
Returns ft3
IESW
Total Returns ft3
Recharge to Aquifer
Recharge from Tributary Inflow

Evaluation Criteria

- System Reliability (97% threshold)

$$\alpha = \frac{S}{T}$$

Where, α =System reliability (probability), T= Total outputs (success and failure), S= the set of all satisfactory outputs

- System Vulnerability (magnitude)

$$\beta = \sum_{j \in F} s_j e_j$$

Where, β=Vulnerability indicator, s= the most unsatisfactory (severe impacts) among failures, e=probability of S in failure set

- System Resiliency (Back to normal)

$$\gamma = \frac{\phi}{\alpha}$$

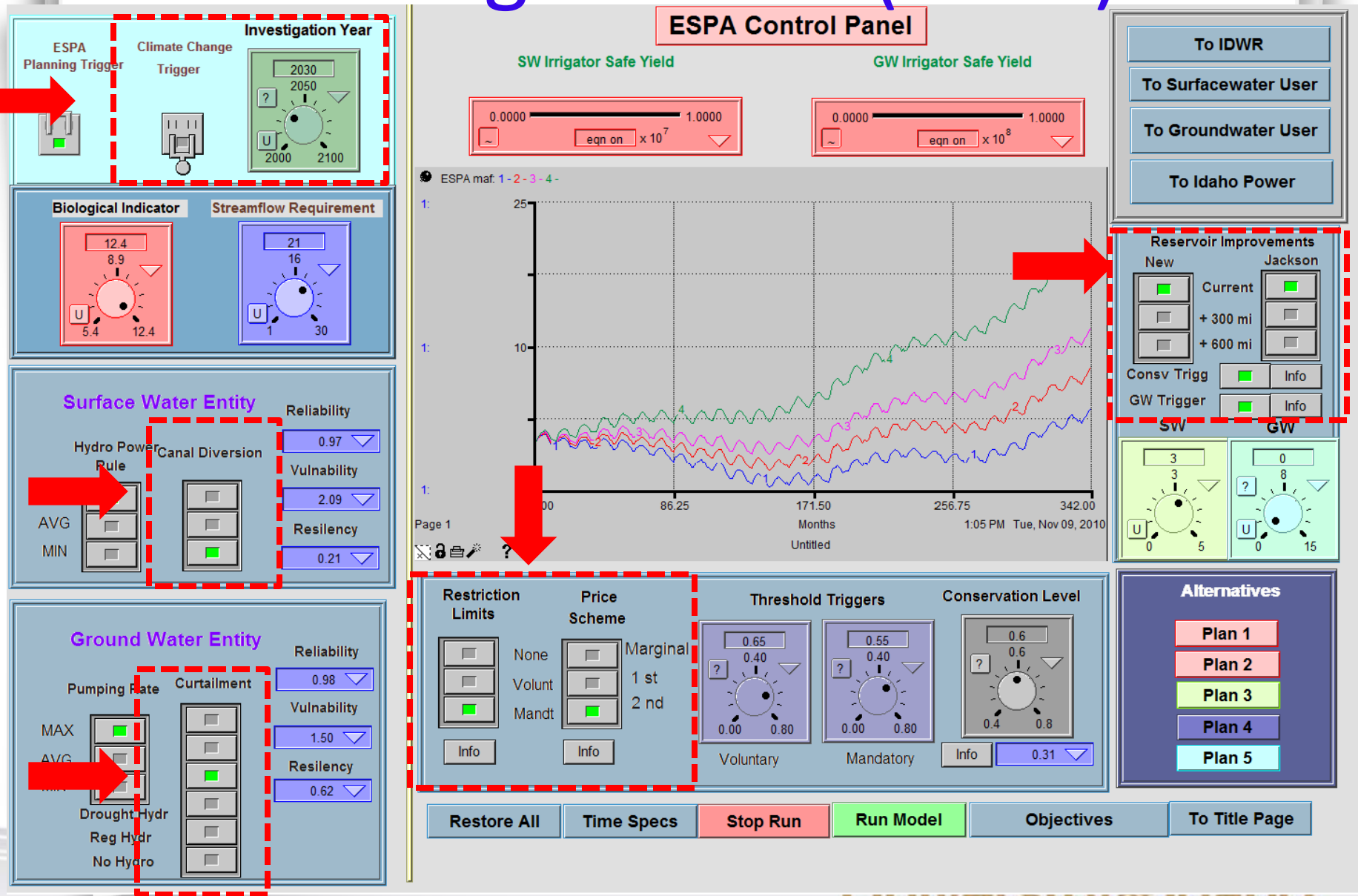
Where, γ=resiliency, α= system reliability

$$\phi = \lim_{n \to \infty} \sum_{t=1}^{n} W_t$$

Where, ϕ=probability of system recovery W_t=1 when random event X_t is failure and X_{t+1} is sucess; otherwise W_t=0

(Hashimoto et al., 1982; Ryu et al., 2009)

Planning Horizon (2100)



Salmon Tract Agricultural System Model

STELLA 9.1.3 - Salmon Falls ReservoirSD2000.STM

File Edit View Interface Run Help

Salmon Tract Agricultural Systems Model

Reservoir Calibration Parameters

Salmon Falls Dam, July 27, 2011 — Salmon River Canal Company, July 27, 2011

Agricultural Parameters

Irrigation on the Salmon Tract, July 29, 2011

Water Conservation Controls

An aspen grove near the headwaters of Wilson Creek in the Salmon Falls watershed, July 28, 2011

Economic Parameters

Grain Elevators near Amsterdam, July 29, 2011

Chevron Station in Hollister, July 28, 2011

Normal Conditions — Drought Conditions — Groundwater Pumping

WARNING LIGHTS

Forcast Selection

Irrigated Maximum Yield — Production Cost — Dry Land Maximum Yield

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Salmon Tract Agricultural System Model

Simulation : Salmon Tract

forio.com/simulate/hoek8591/salmontractpublished/run/

야후! 사전 Dictionary, Encyclop...

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Salmon Tract Agricultural Systems Model — Overview | Download Model | Run Simulation

Contact Info.

Salmon Tract Agricultural Systems Model: a story of water conservation

The Author

Model Introduction

To understand the model, new users should step through the buttons below by column from left to right.

Location/Climate | Model Calibration | Modeling Assumptions

A History of the Tract | Operating the Model | Data Sources

Salmon Tract Water Rights | Model Results | Acknowledgements & References

WATER CONSERVATION

Water Conservation has been accomplished thru three main methods, water supply forecasts, improvements in delivery effeciency (canal lining & piping laterals), and on-farm irrigation effeciency improvements.

April Supply Forecast Meeting, since 1955

Delivery Efficiency Canal Lining, 1973

On-farm effeciency/sprinklers, 1992-present

Author: David Hoekema

Discuss | Share | Embed

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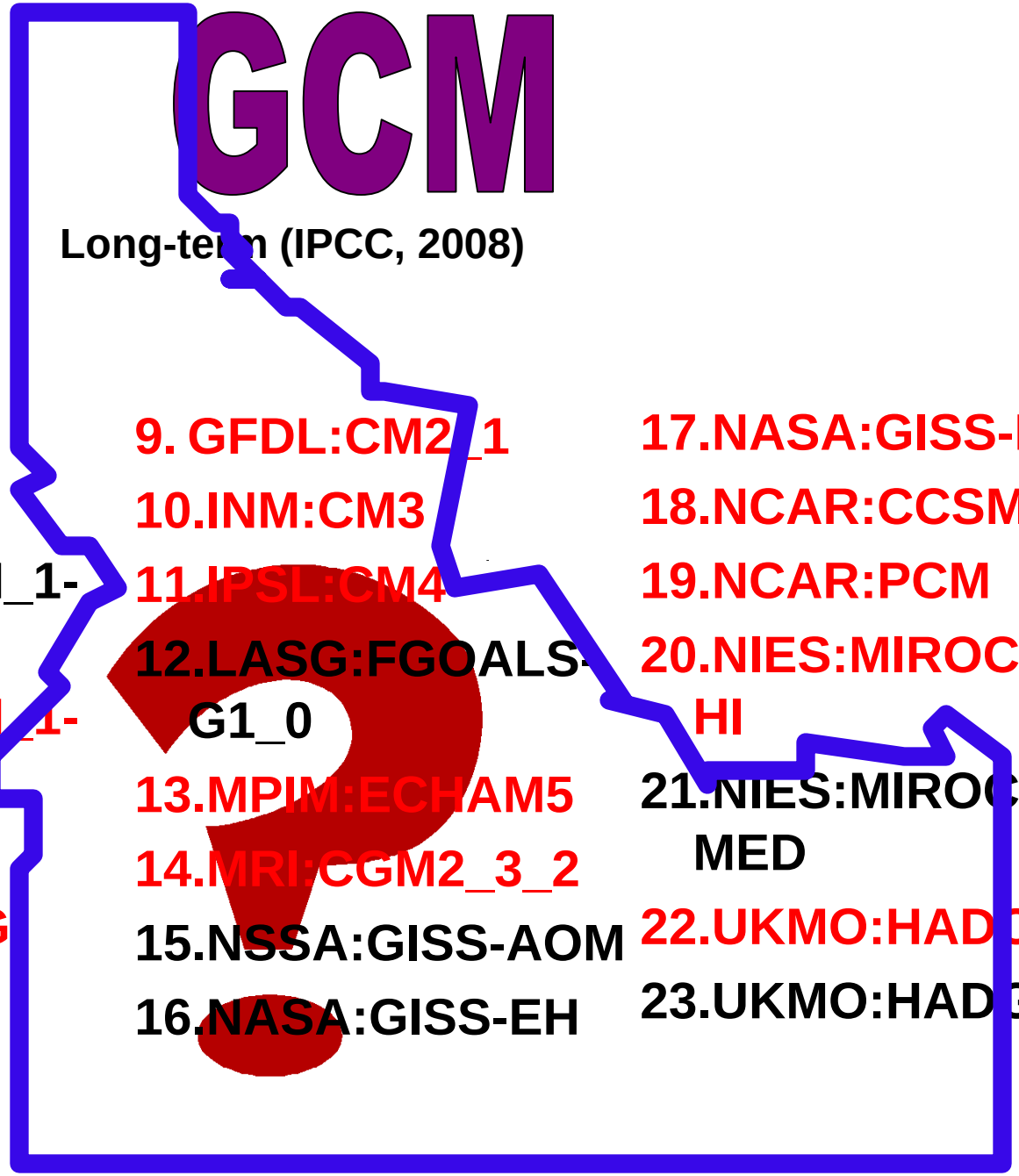
Mapping Gridded Drought Indicators Using Outcomes from GCMs (Long-term drought predictions)

GCM

Long-term (IPCC, 2008)

1. BCC:CM1
2. BCCR:BCM2
3. CCCMA:CGCM_1-T47
4. CCCMA:CGCM_1-T63
5. CNRM:CM3
6. CONS:ECHO-G
7. CSIRO:MK3
8. GFDL:CM2
9. GFDL:CM2_1
10. INM:CM3
11. IPSL:CM4
12. LASG:FGOALS-G1_0
13. MPIM:ECHAM5
14. MRI:CGM2_3_2
15. NSSA:GISS-AOM
16. NASA:GISS-EH
17. NASA:GISS-ER
18. NCAR:CCSM3
19. NCAR:PCM
20. NIES:MIROC3_2-HI
21. NIES:MIROC3_2-MED
22. UKMO:HADCM3
23. UKMO:HADGEM1

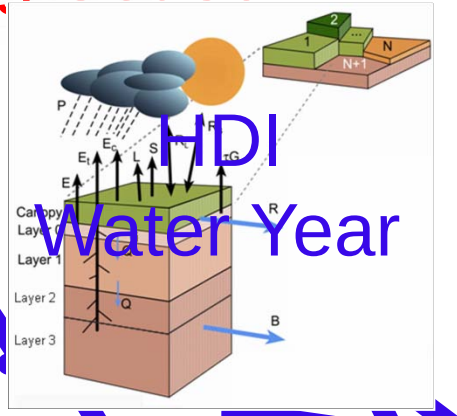


http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/

Models	A1B # of Ensemble	A2 # of Ensemble	B1 # of Ensemble
BCCR-BCM2	1	1	1
CCCMA-CGCM3.1	1...5	1...5	1...5
CNRM-CM3	1	1	1
CSIRO-MK3	1	1	1
GFDL-CM2	1	1	1
GFDL-CM2.1	1	1	1
GISS-ER	2,4	1	1
INM-CM3	1	1	1
IPSL-CM4	1	1	1
MIROC3.2	1...3	1...3	1...3
MIUB-ECHO-G	1...3	1...3	1...3
ECHAM5/MPI-OM	1...3	1...3	1...3
MRI-CGCM2.3.2	1...5	1...5	1...5
NCAR_CCSM3	1…3,5…7	1…4	1…7
NCAR_PCM	1…4	1…4	2…3
UKMO_HADCM3.1	1	1	1
Total # of Ensemble	**39**	**36**	**37**

3-M SPI Winter

PDSI Growing Season



Spatial Resolution:

- North America Land Data Assimilation Domain (Monthly), Western States (Daily)
- Contiguous US + S. Canada + N. Mexico (25.125N – 52.875N, -124.625E - -67.000E)
- 1/8 grid size (~ 12 km x 12 km)

Temporal Scale:

- Periods: 1950-2099
- Time step: Monthly (Daily)

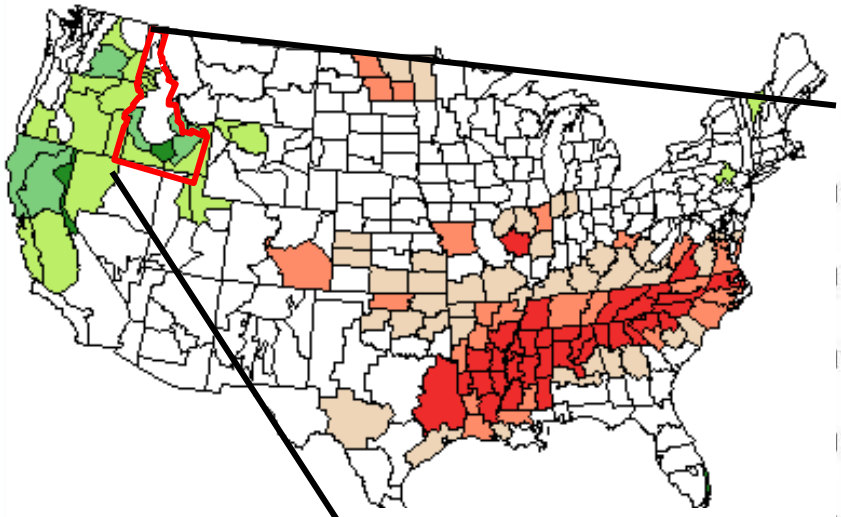
Wet Years (1986, 1993)

Normal Years (1988, 1999)

Drought Years (1987, 1992)

Idaho Droughts of the past

3-month SPI through the end of March 1986



+2.0 and above (Extremely Wet)
+1.50 to +1.99 (Very Wet)
+1.0 10 +1.49 (Moderately Wet)
-0.99 to +0.99 (Near Normal)
-1.00 to -1.49 (Moderately Dry)
-1.50 to -1.99 (Very Dry)
-2.0 and below (Extremely Dry)

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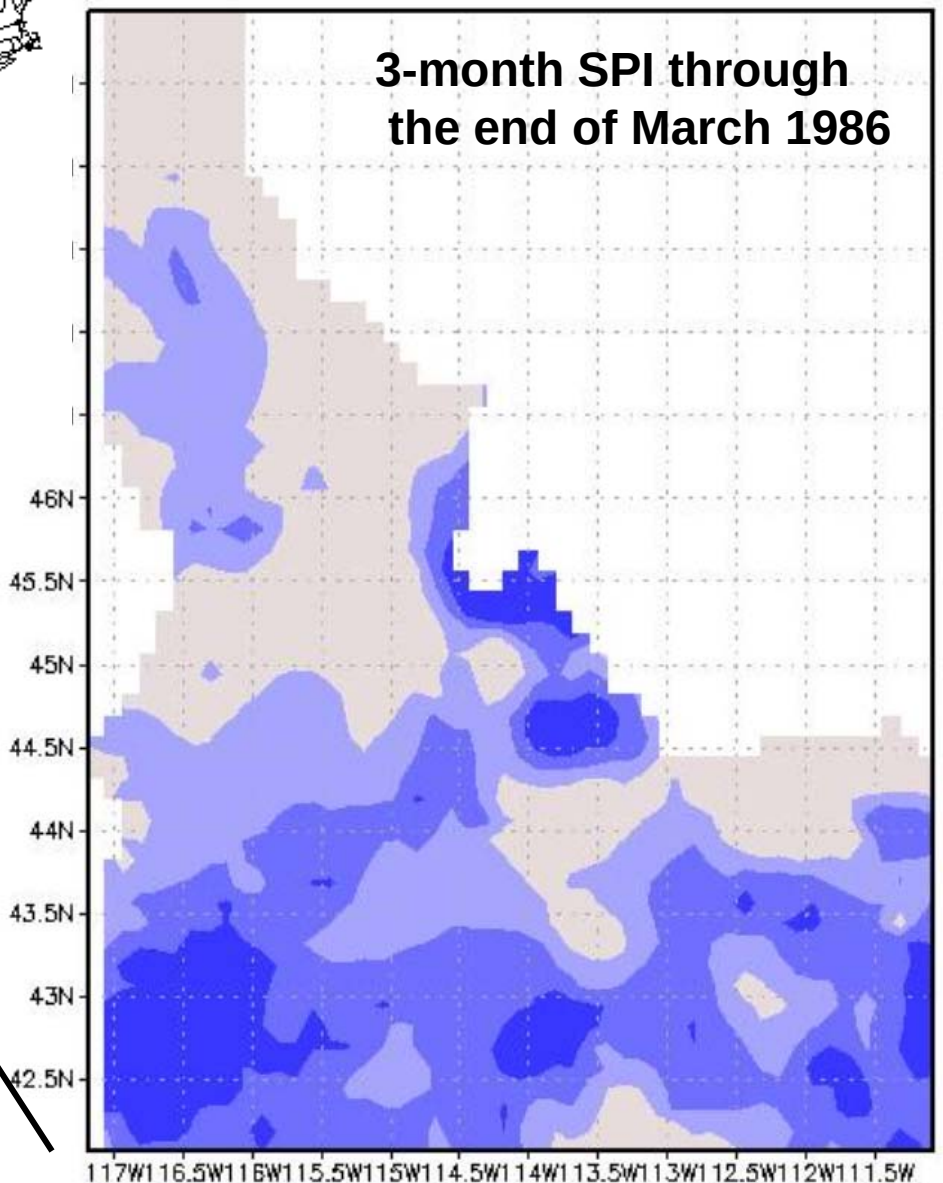
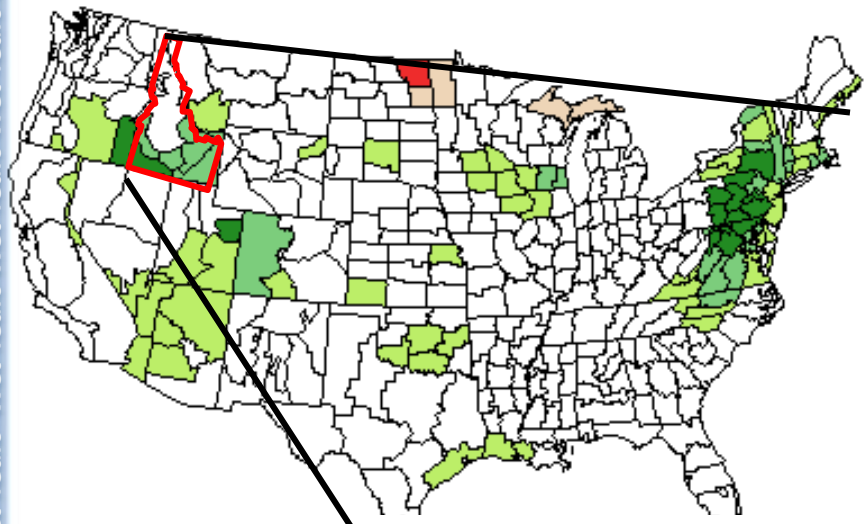
Wet Years (1986)

- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)



3-month SPI through the end of April 1993



- +2.0 and above (Extremely Wet)
- +1.50 to +1.99 (Very Wet)
- +1.0 10 +1.49 (Moderately Wet)
- -0.99 to +0.99 (Near Normal)
- -1.00 to -1.49 (Moderately Dry)
- -1.50 to -1.99 (Very Dry)
- -2.0 and below (Extremely Dry)

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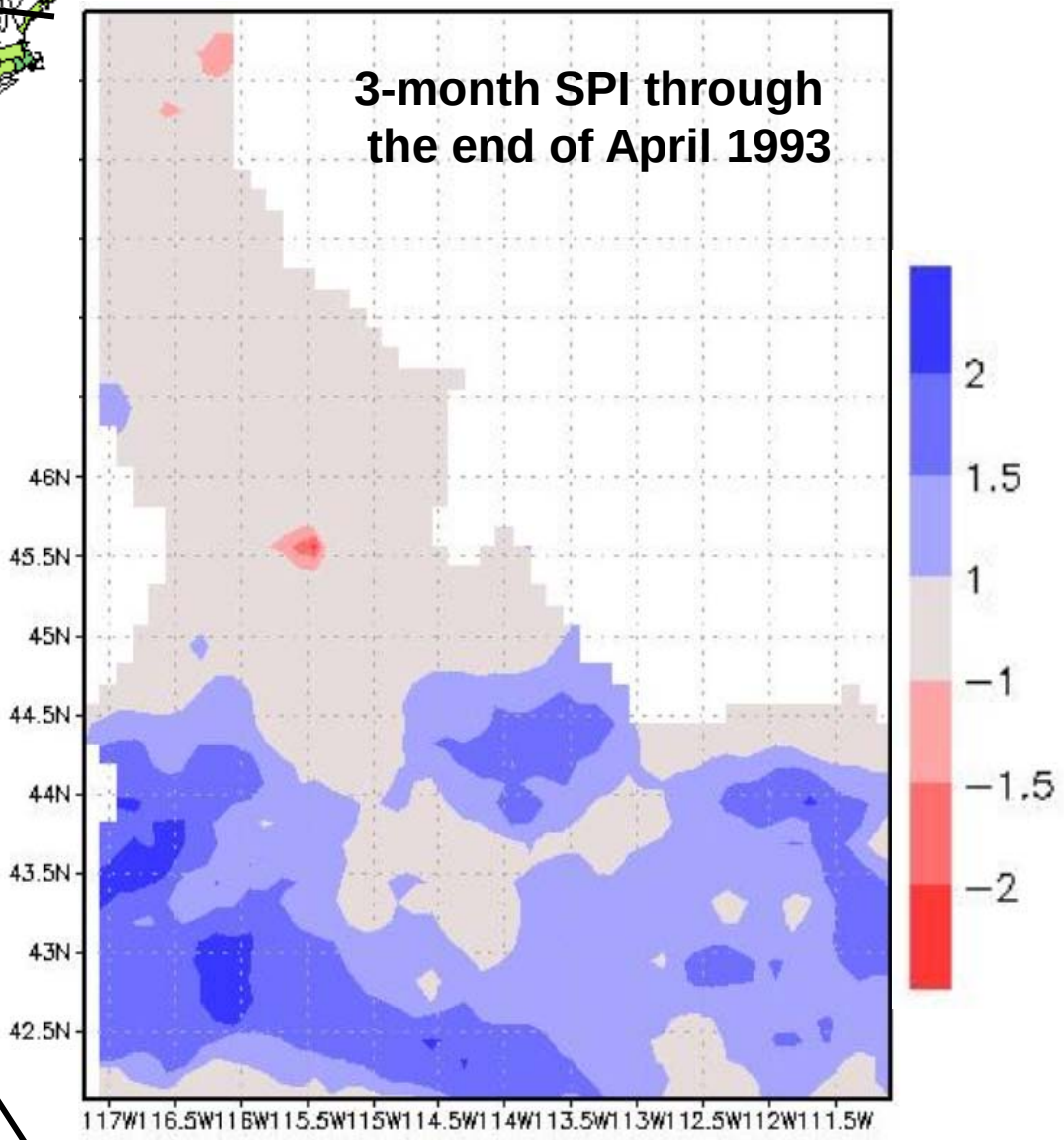
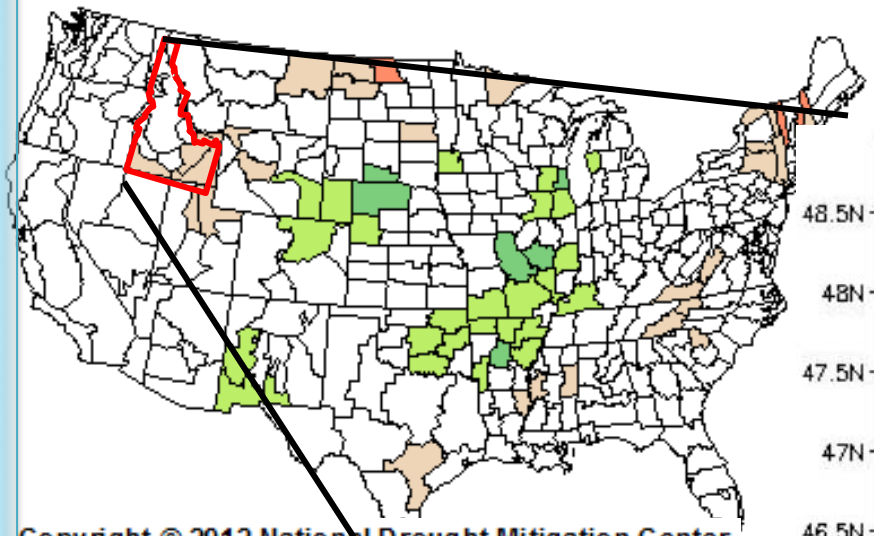
Wet Years (1993)

- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)



3-month SPI through the end of February 1988



- +2.0 and above (Extremely Wet)
- +1.50 to +1.99 (Very Wet)
- +1.0 10 +1.49 (Moderately Wet)
- -0.99 to +0.99 (Near Normal)
- -1.00 to -1.49 (Moderately Dry)
- -1.50 to -1.99 (Very Dry)
- -2.0 and below (Extremely Dry)

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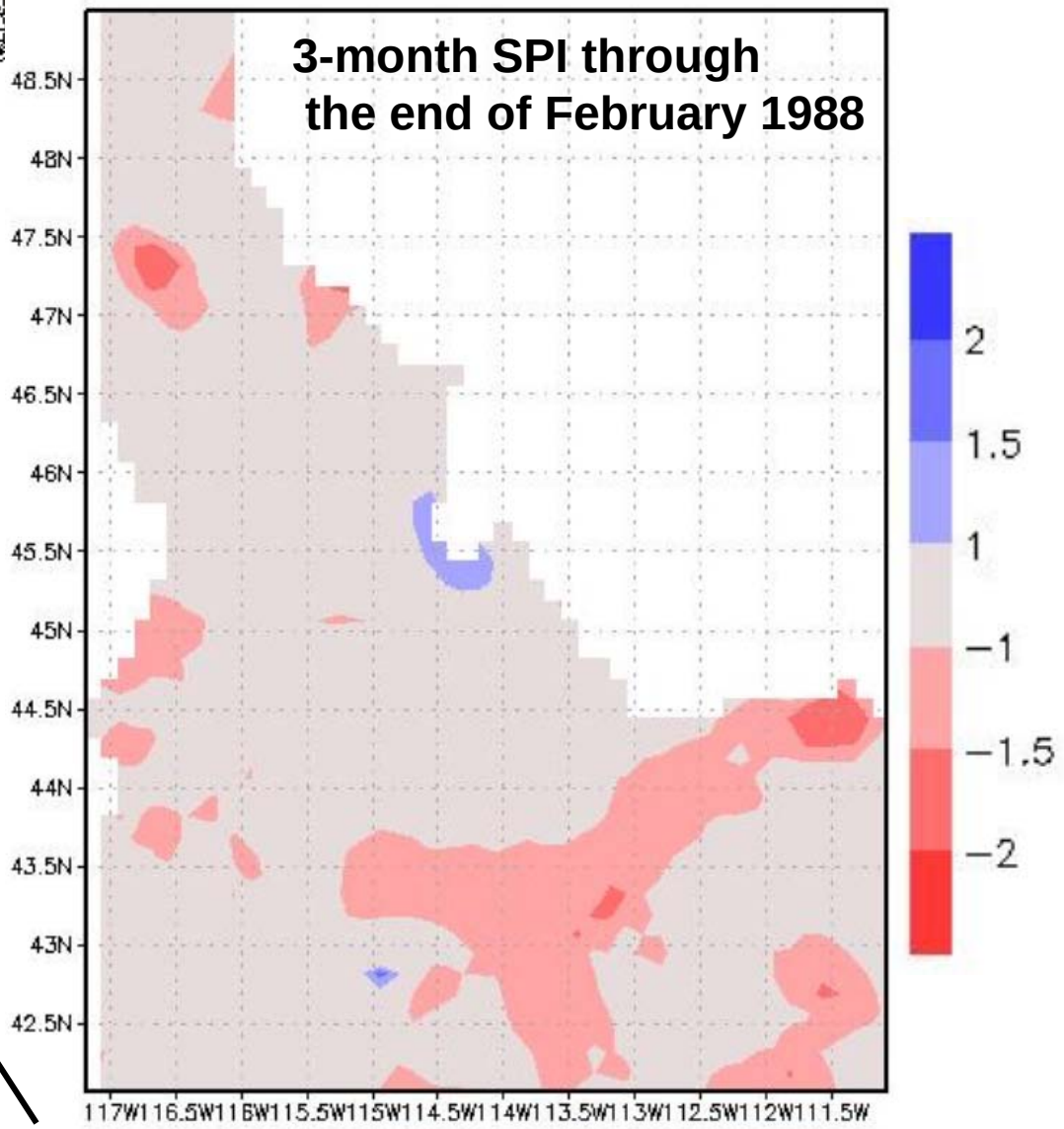
Normal Years (1988)

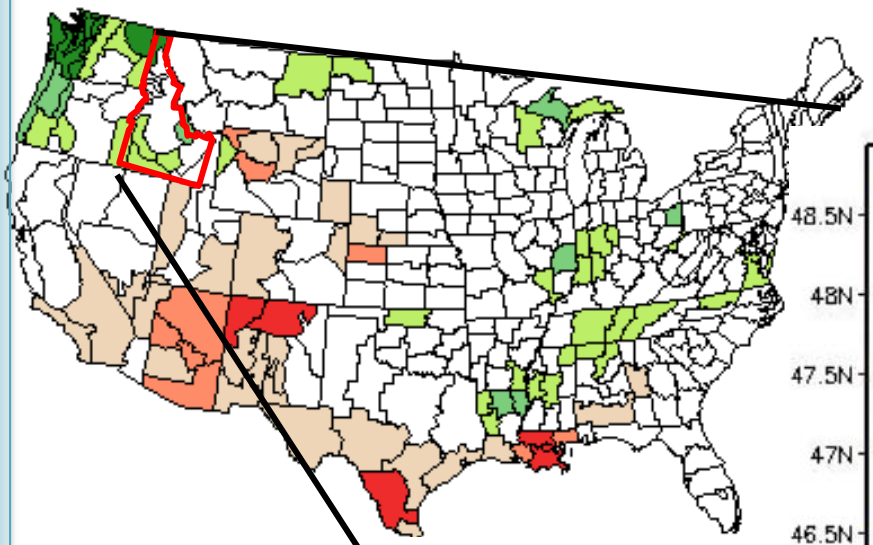
- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)



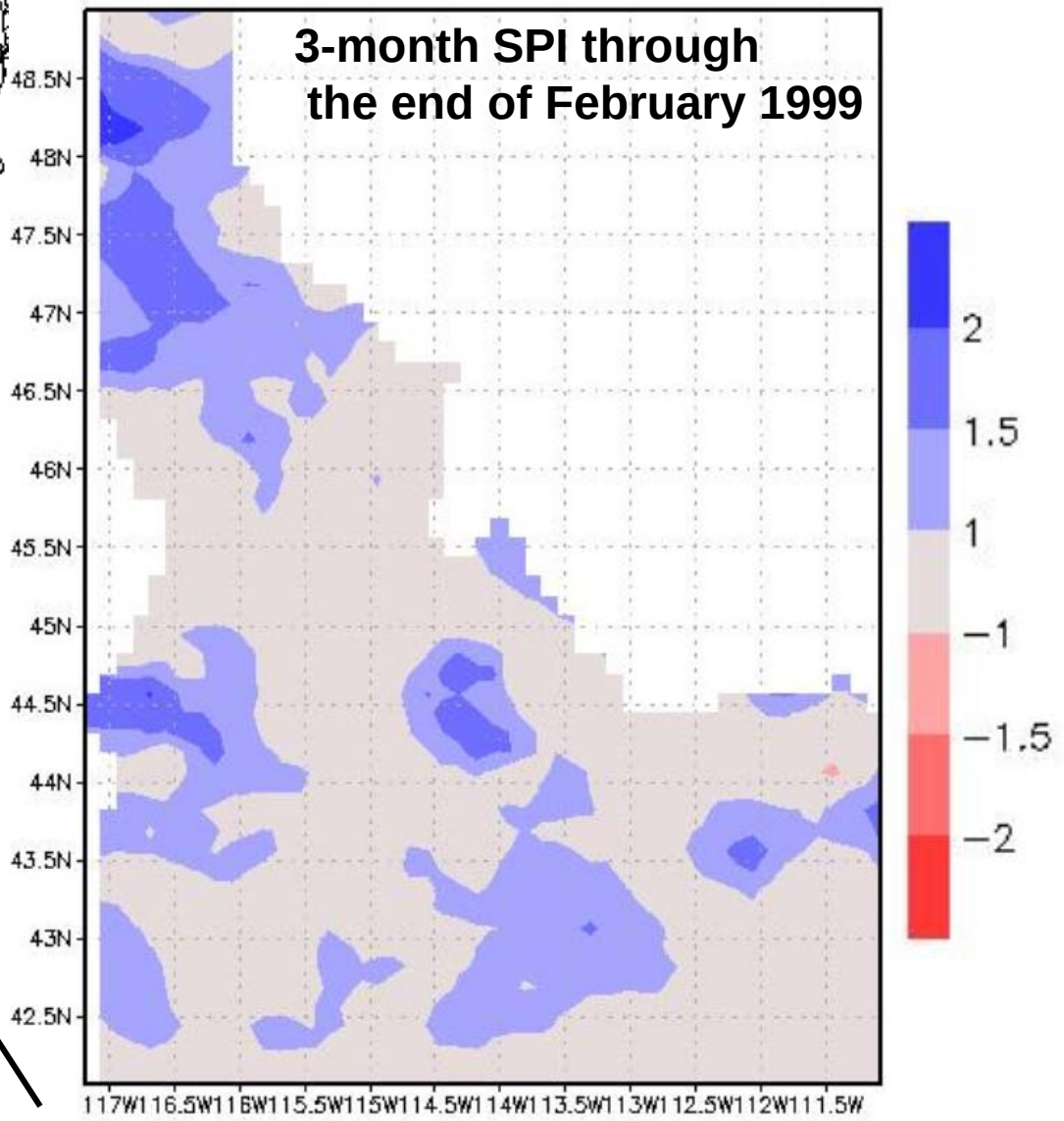
3-month SPI through the end of February 1999

Normal Years (1999)

- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)



- +2.0 and above (Extremely Wet)
- +1.50 to +1.99 (Very Wet)
- +1.0 10 +1.49 (Moderately Wet)
- -0.99 to +0.99 (Near Normal)
- -1.00 to -1.49 (Moderately Dry)
- -1.50 to -1.99 (Very Dry)
- -2.0 and below (Extremely Dry)



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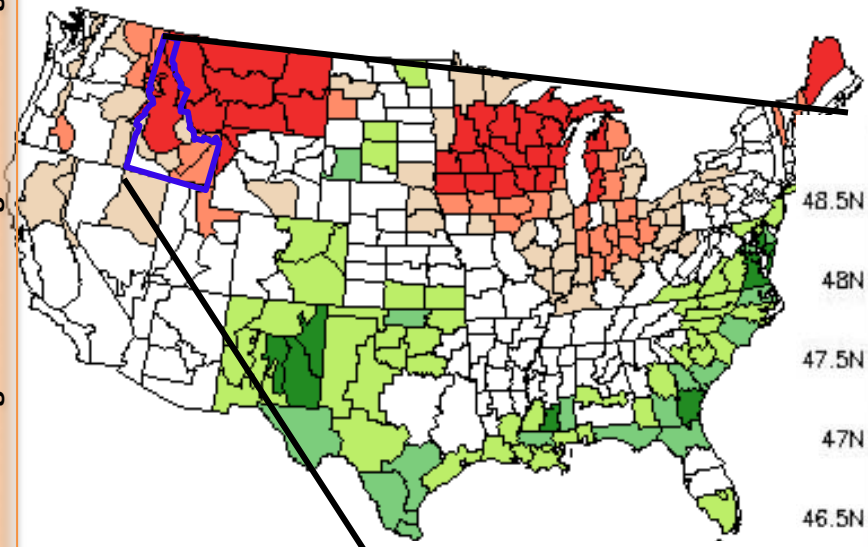
3-month SPI through the end of February 1987

Drought Years (1987)

- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)



- +2.0 and above (Extremely Wet)
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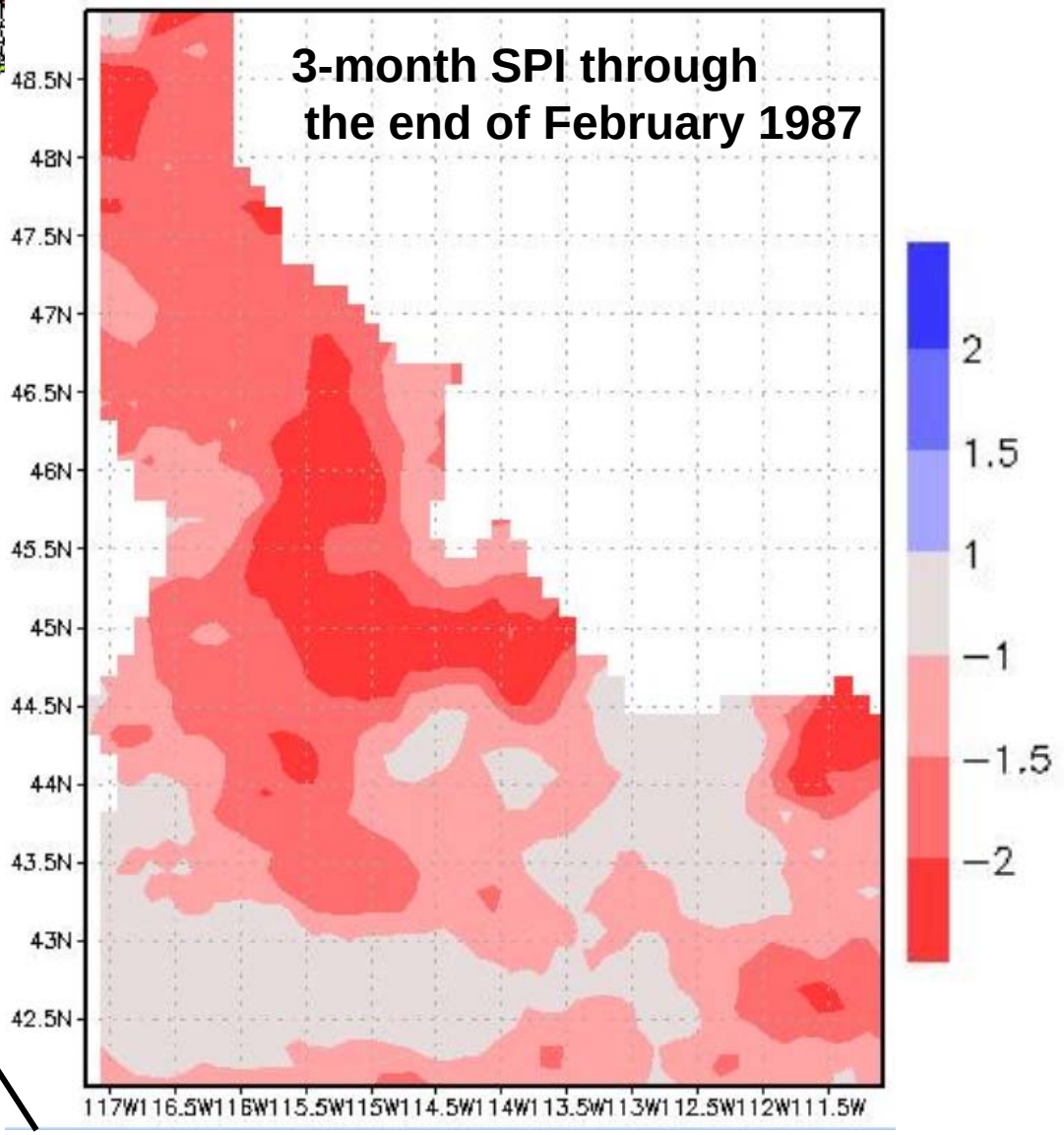
- -1.00 to -1.49 (Moderately Dry)
- -1.50 to -1.99 (Very Dry)
- -2.0 and below (Extremely Dry)



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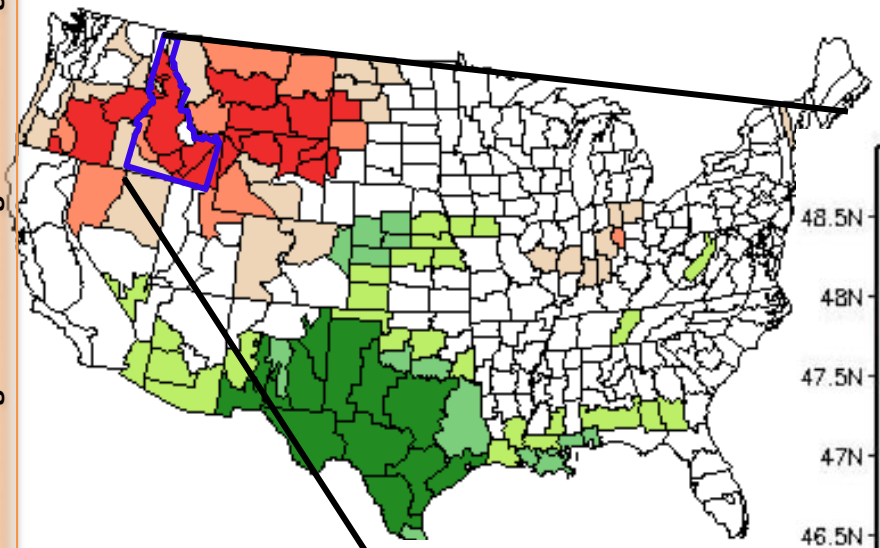
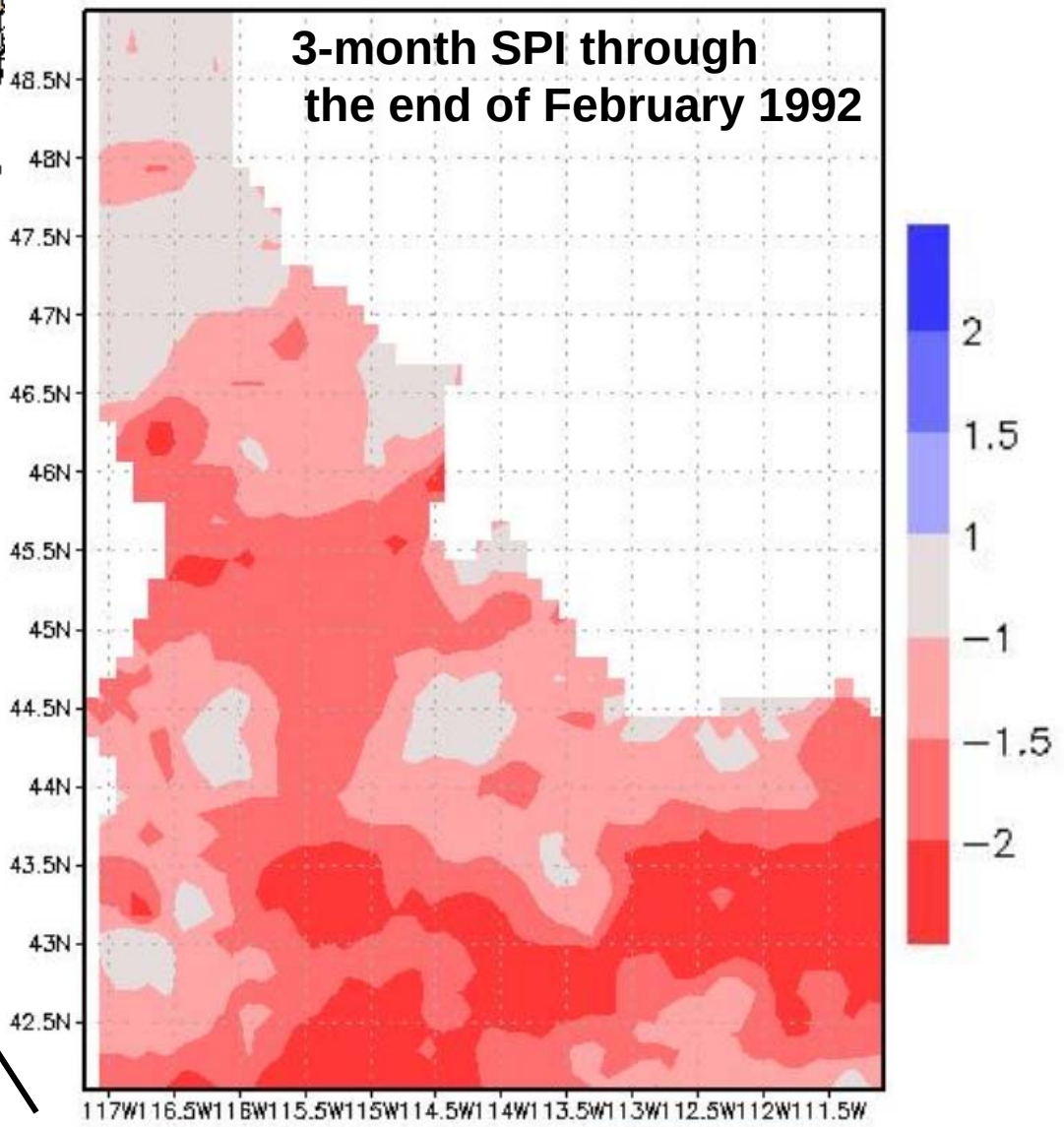
3-month SPI through the end of February 1992

Drought Years (1992)

- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)





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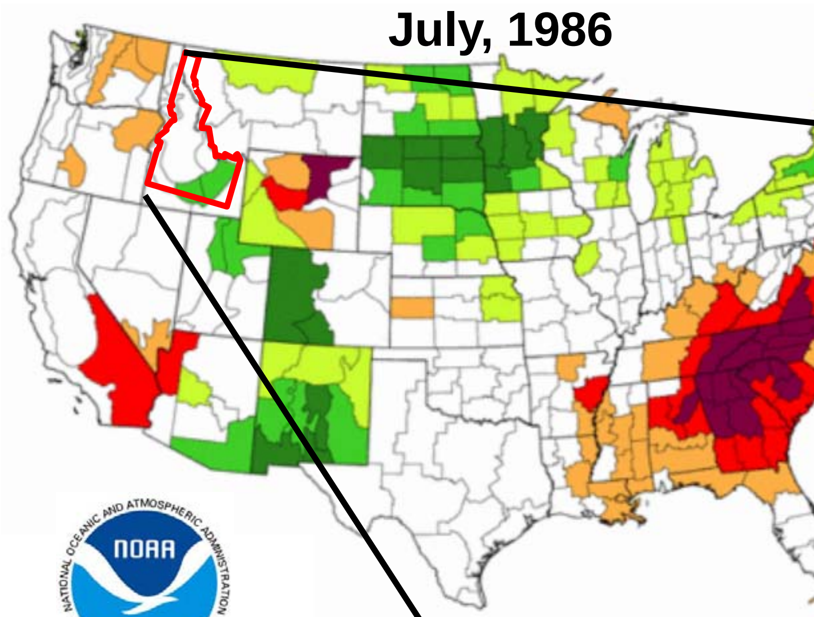
Palmer Drought Severity Index (PDSI)
July, 1986



NOAA

National Climate Data Center, NOAA

extreme drought	severe drought	moderate drought	mid-range	moderately moist	very moist	extremely moist
-4.00 and below	-3.00 and -3.99	-2.00 and -2.99	-1.99 and +1.99	+2.00 and +2.99	+3.00 and +3.99	+4.00 and above

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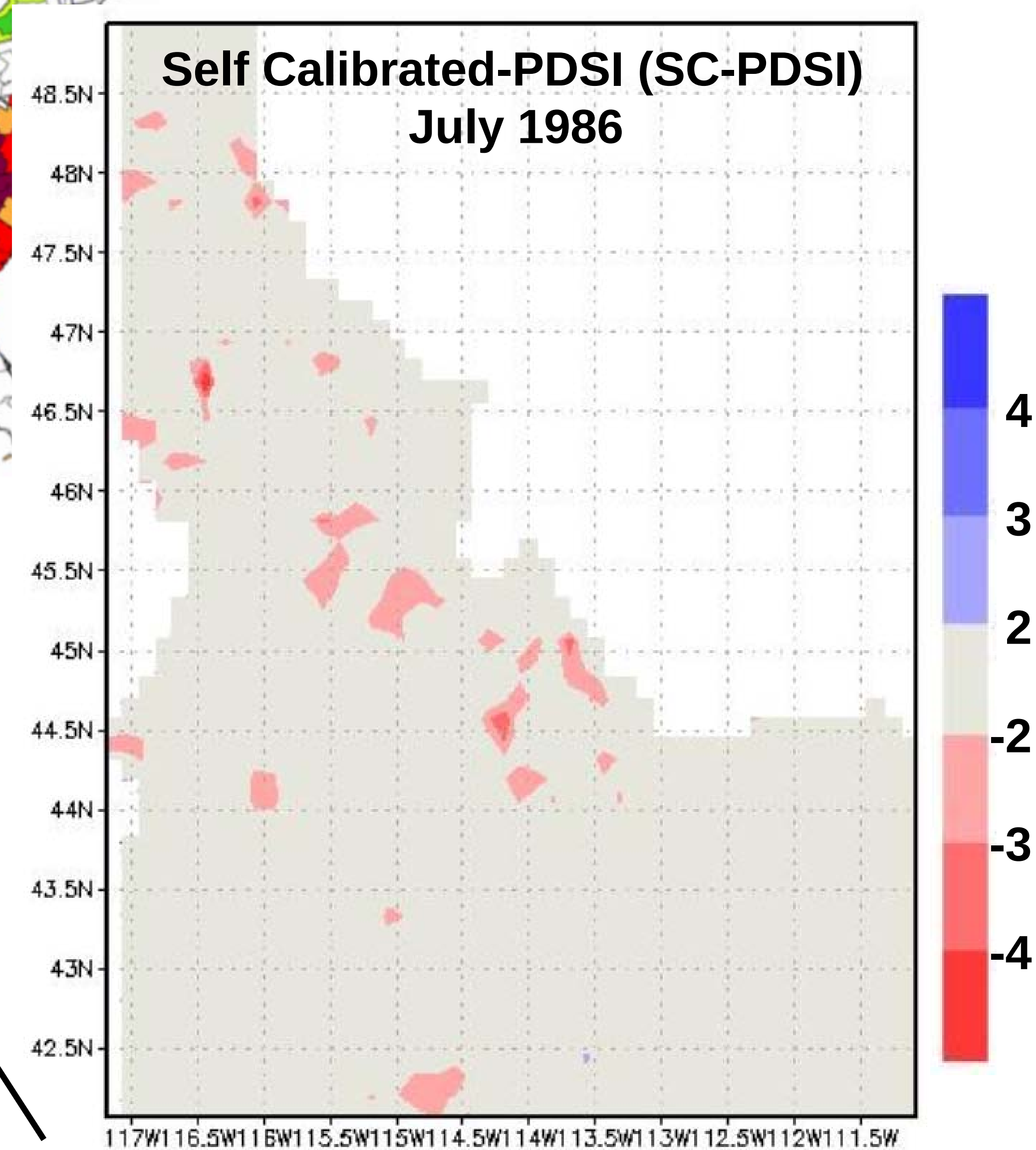
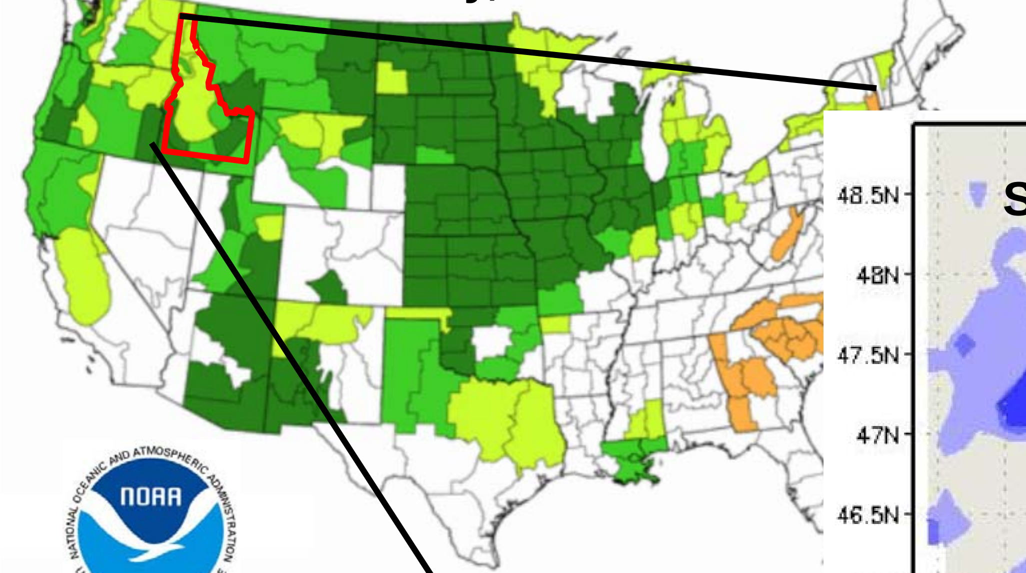
Wet Years (1986)

- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)



Palmer Drought Severity Index (PDSI)
July, 1993



National Climate Data Center, NOAA

extreme drought	severe drought	moderate drought	mid-range	moderately moist	very moist	extremely moist
-4.00 and below	-3.00 and -3.99	-2.00 and -2.99	-1.99 and +1.99	+2.00 and +2.99	+3.00 and +3.99	+4.00 and above

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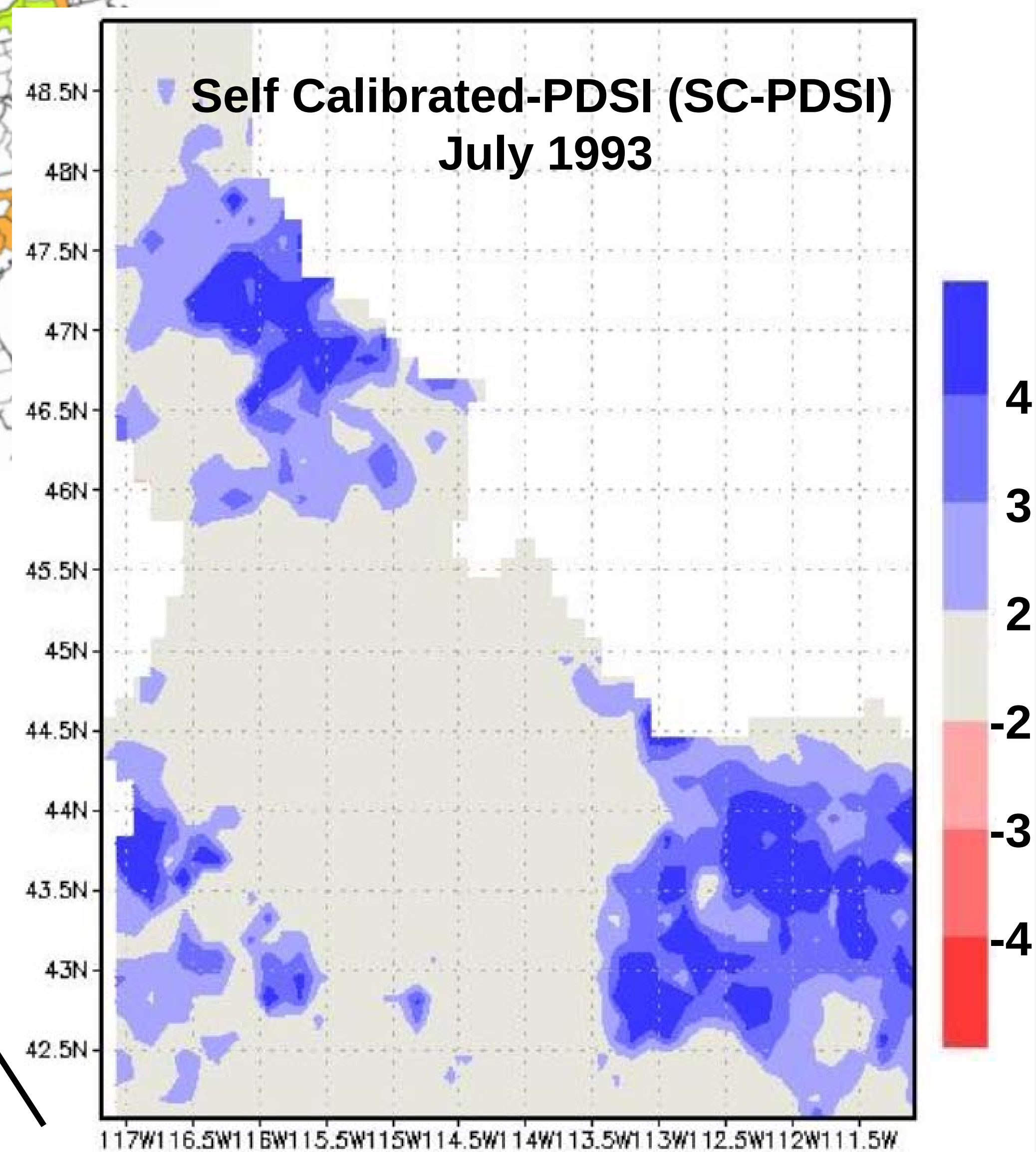
Wet Years (1993)

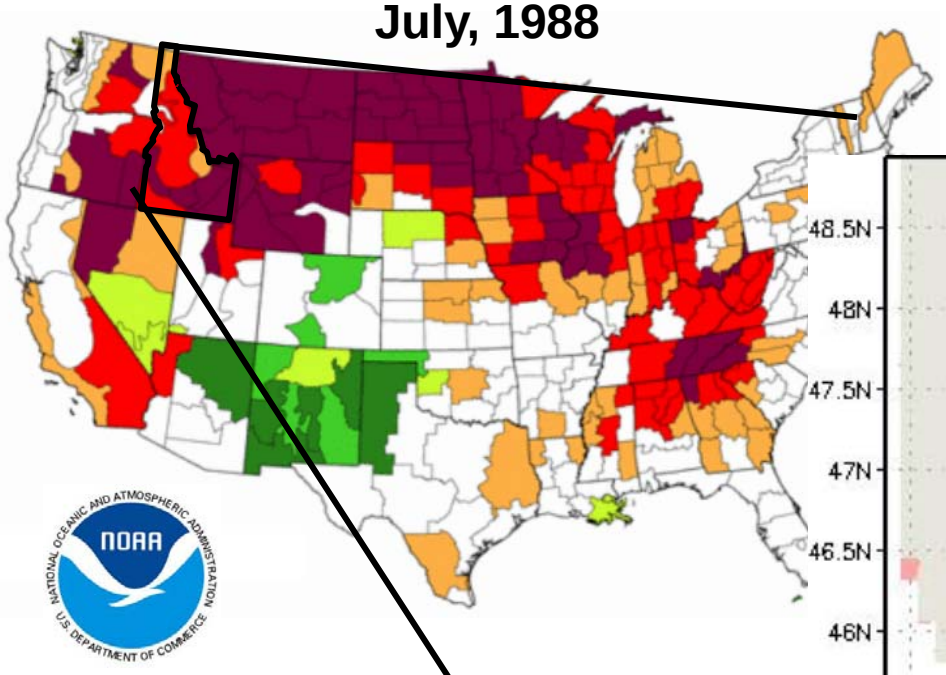
- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)



Normal Years (1988)

- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)

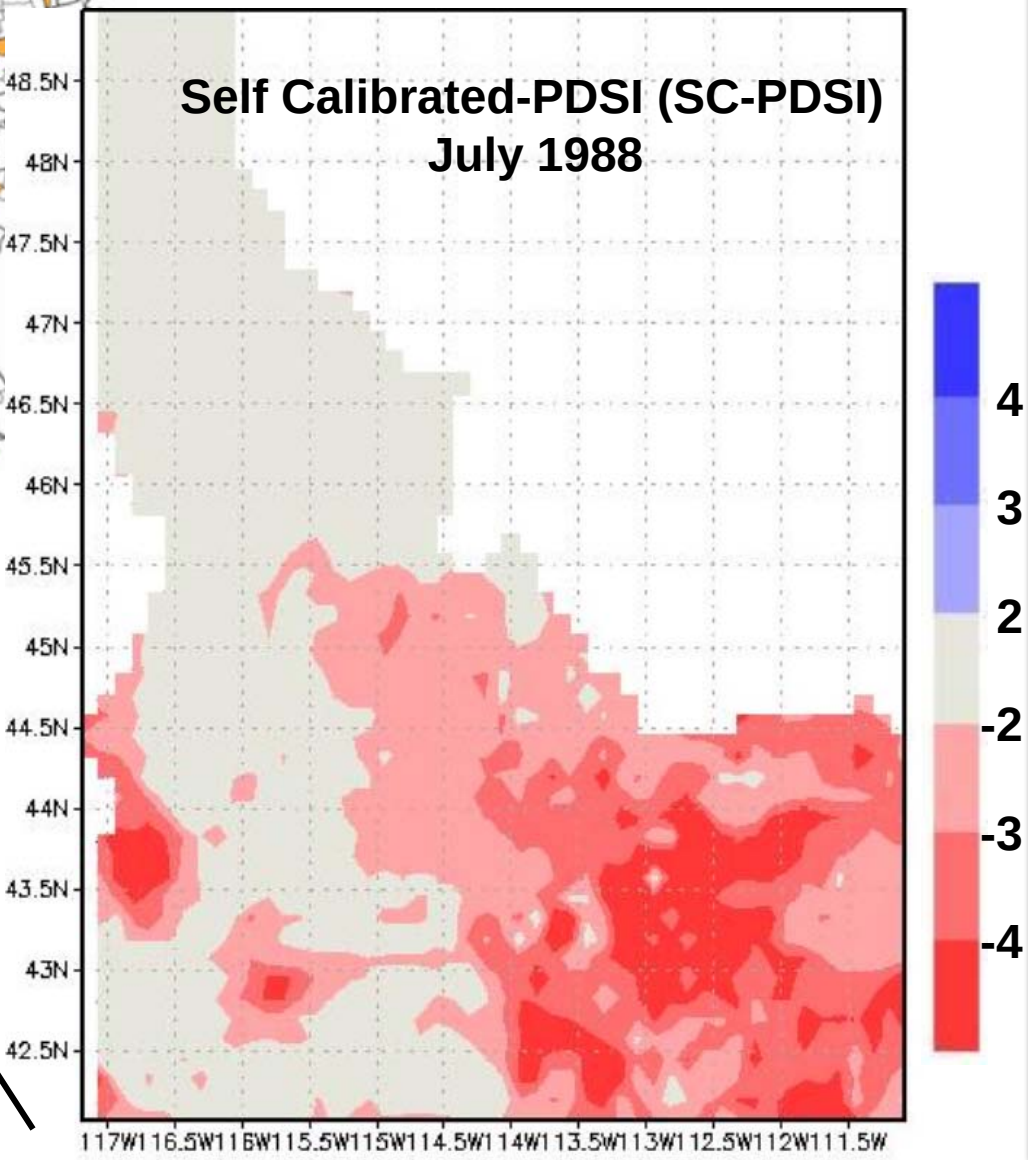
Palmer Drought Severity Index (PDSI)
July, 1988



National Climate Data Center, NOAA

extreme drought	severe drought	moderate drought	mid-range	moderately moist	very moist	extremely moist
-4.00 and below	-3.00 and -3.99	-2.00 and -2.99	-1.99 and +1.99	+2.00 and +2.99	+3.00 and +3.99	+4.00 and above

Self Calibrated-PDSI (SC-PDSI)
July 1988



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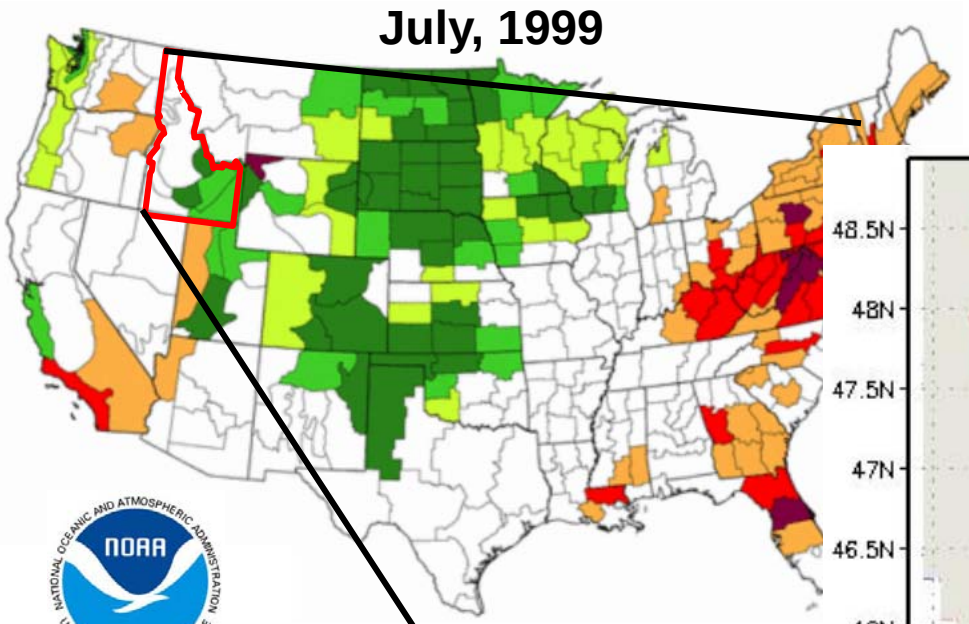
Normal Years Normal Years Normal Years Normal Years Normal Years Normal Years Normal Years Norm

Normal Years (1999)

- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)

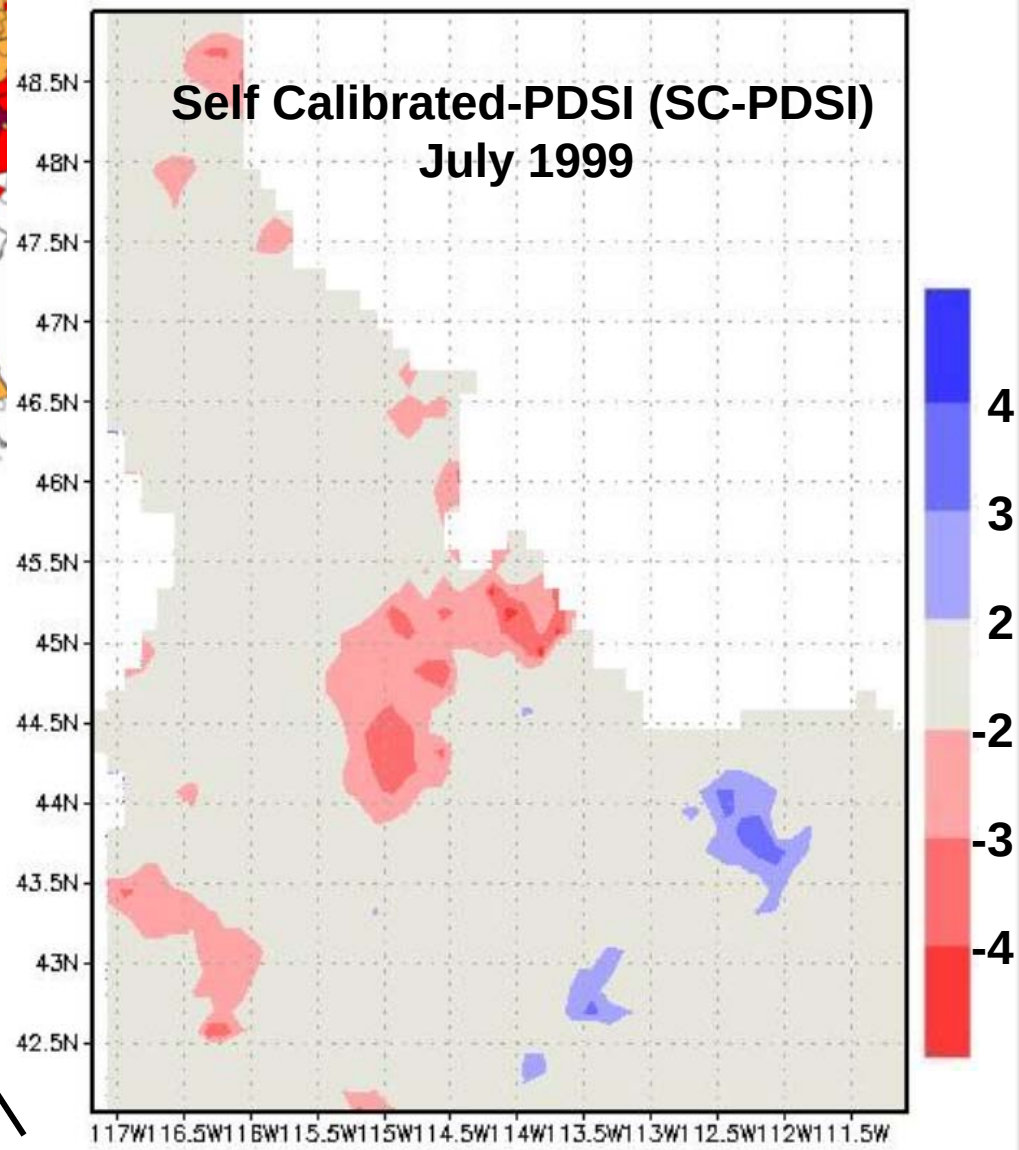
Palmer Drought Severity Index (PDSI)
July, 1999



National Climate Data Center, NOAA

extreme drought	severe drought	moderate drought	mid-range	moderately moist	very moist	extremely moist
-4.00 and below	-3.00 and -3.99	-2.00 and -2.99	-1.99 and +1.99	+2.00 and +2.99	+3.00 and +3.99	+4.00 and above

Self Calibrated-PDSI (SC-PDSI)
July 1999



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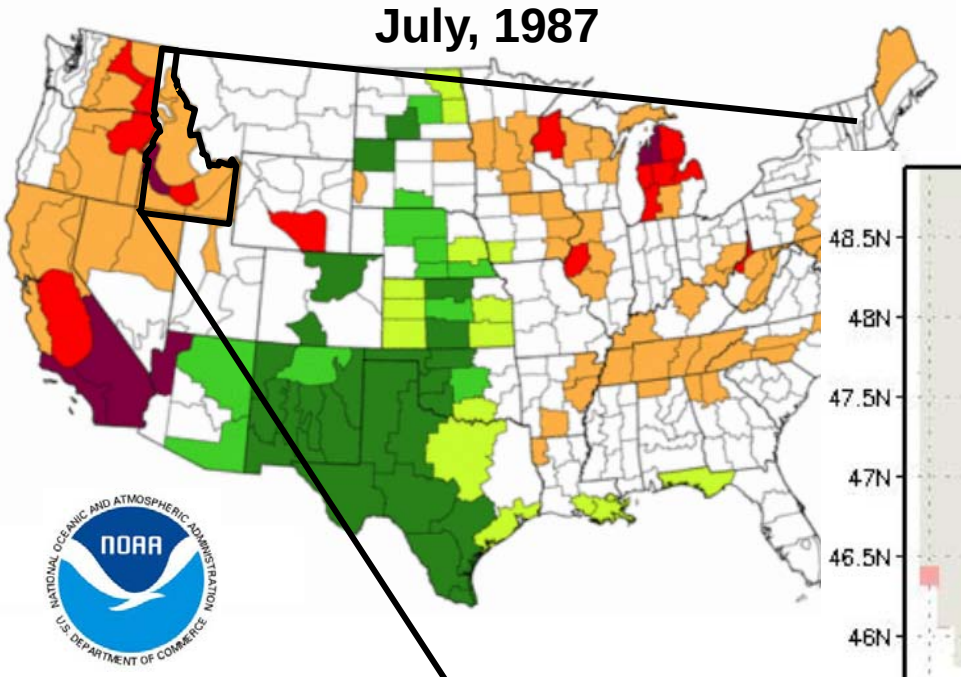
Normal Years Normal Years Normal Years Normal Years Normal Years Normal Years Normal Years Norm

Drought Years (1987)

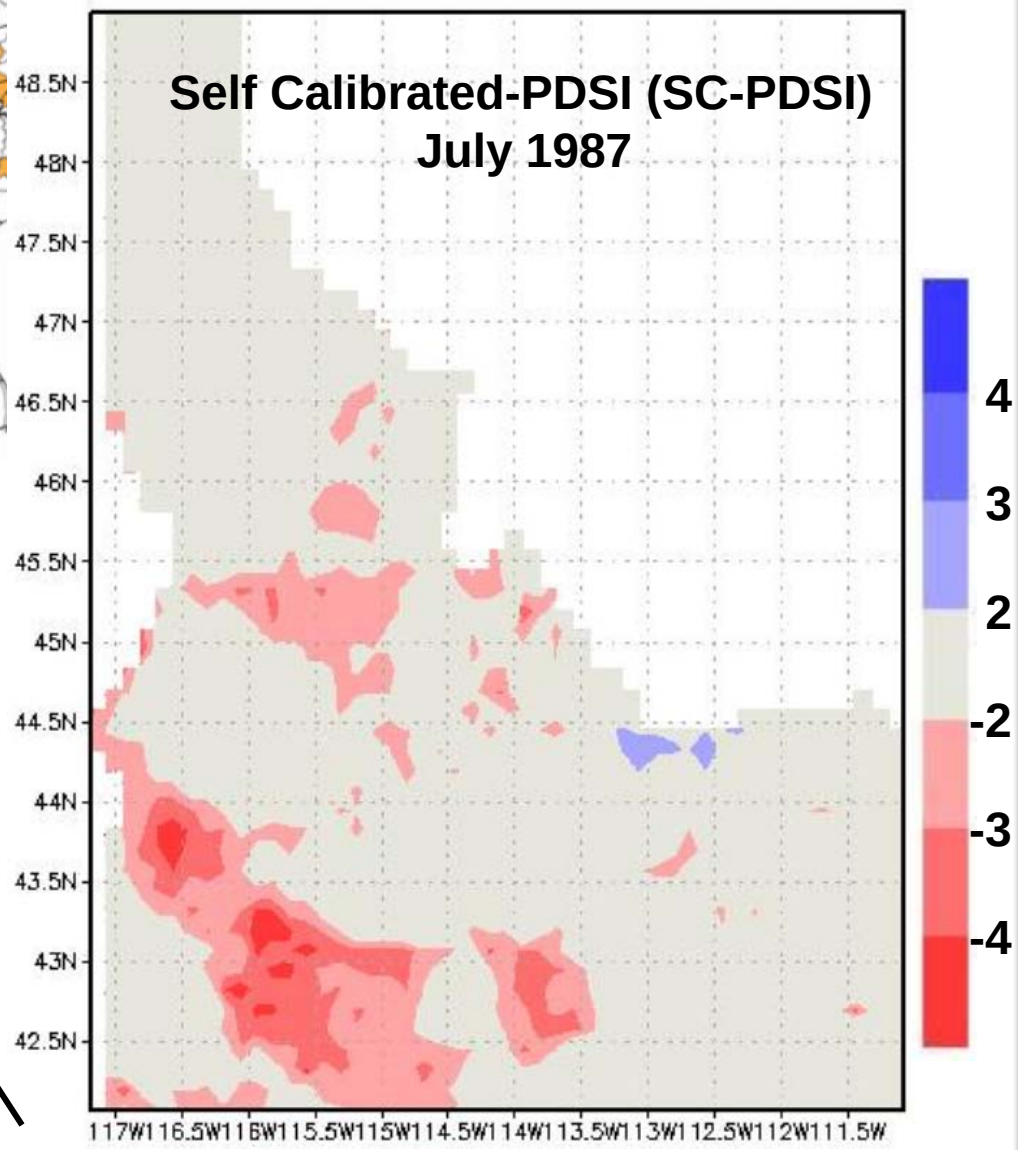
- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)

Palmer Drought Severity Index (PDSI)
July, 1987



National Climate Data Center, NOAA

extreme drought	severe drought	moderate drought	mid-range	moderately moist	very moist	extremely moist
-4.00 and below	-3.00 and -3.99	-2.00 and -2.99	-1.99 and +1.99	+2.00 and +2.99	+3.00 and +3.99	+4.00 and above



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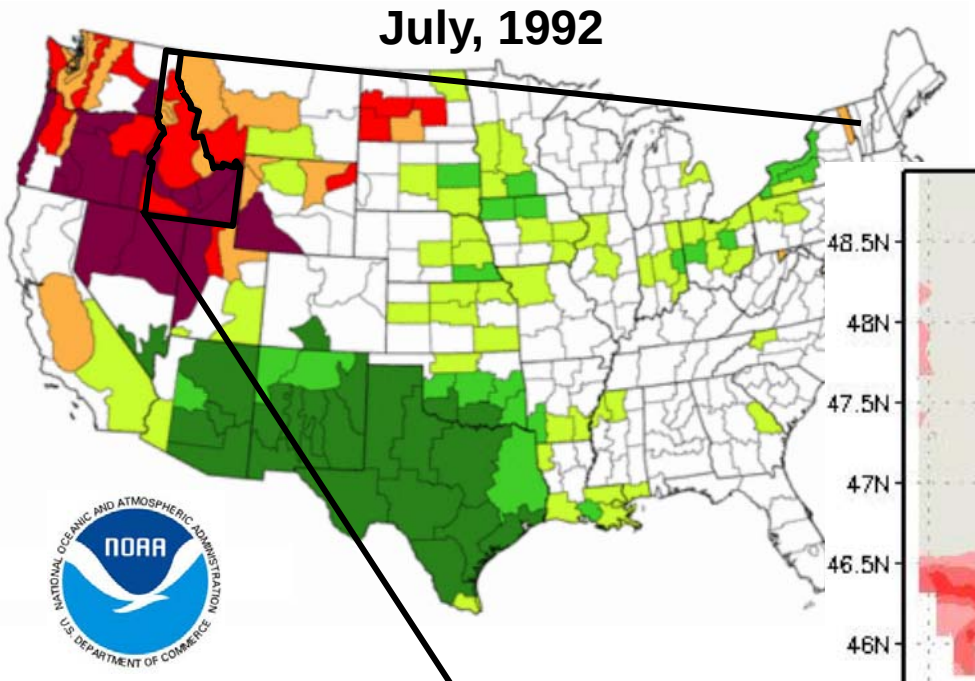
Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years

Palmer Drought Severity Index (PDSI)
July, 1992



National Climate Data Center, NOAA

extreme drought	severe drought	moderate drought	mid-range	moderately moist	very moist	extremely moist
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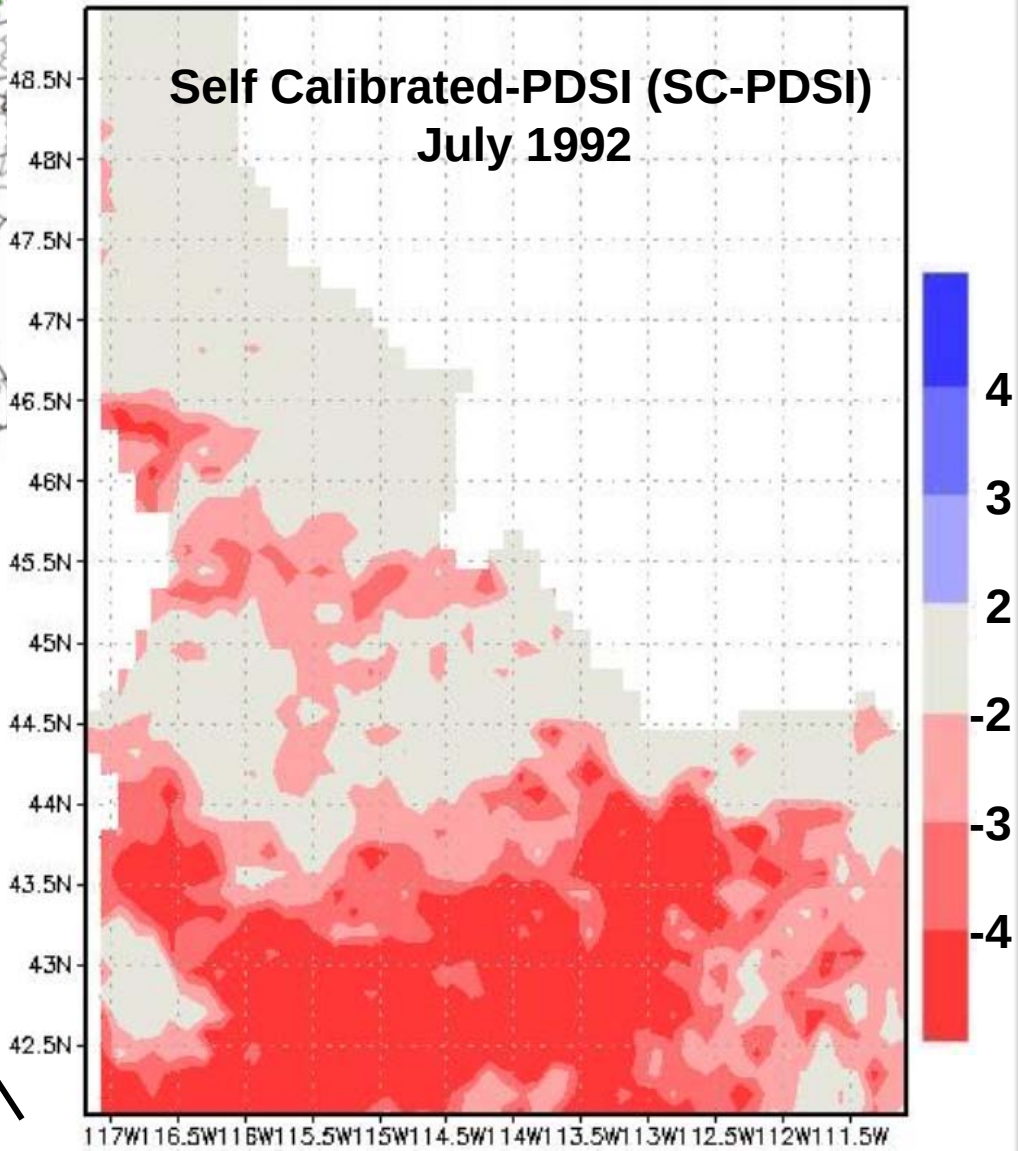
Drought Years (1992)

- NOAA/COOP
- PRISM (Daly et al., 1994, 1997)



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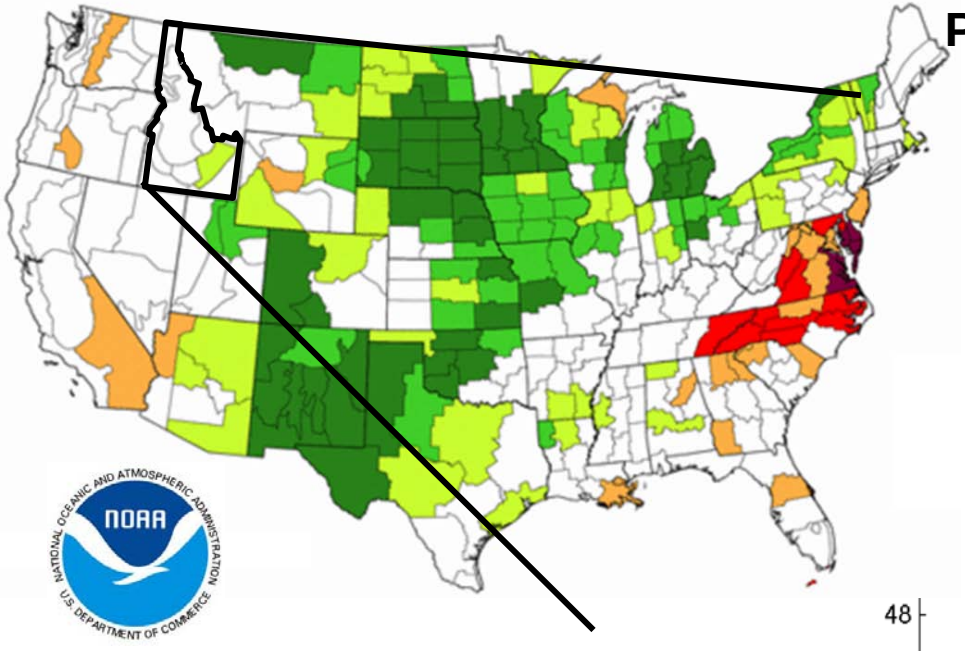
Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years

Palmer Hydrological Drought Index (PHDI)
November, 1986

Drought Years (1987)

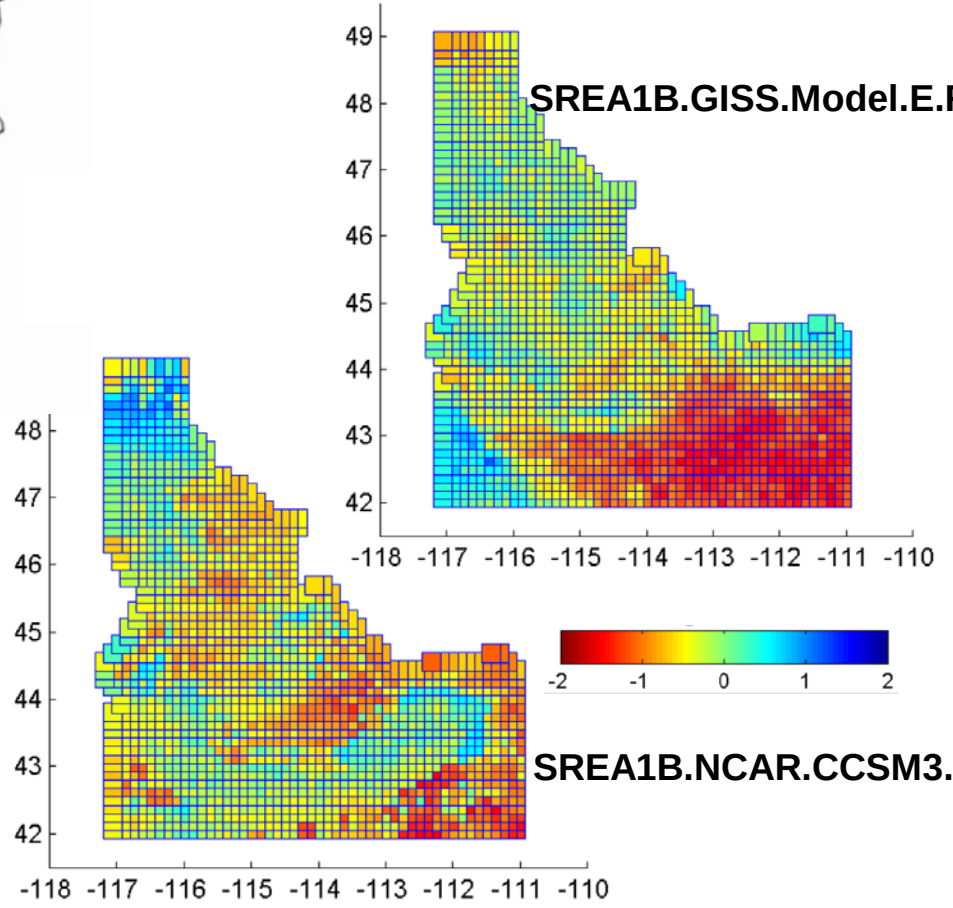


National Climate Data Center, NOAA

extreme drought	severe drought	moderate drought	mid-range	moderately moist	very moist	extremely moist
-4.00 and below	-3.00 and -3.99	-2.00 and -2.99	-1.99 and +1.99	+2.00 and +2.99	+3.00 and +3.99	+4.00 and above

Criterion	Description
SDI ≥ 0.0	Non Drought
-1.0 ≤ SDI < 0.0	Mild Drought
-1.5 ≤ SDI < -1.0	Moderate Drought
-2.0 ≤ SDI < -1.5	Severe Drought
SDI < -2.0	Extreme Drought

Palmer Hydrologic Drought Index (PHDI)
From VIC model
Water Year 1987 (Oct-Dec 1986)



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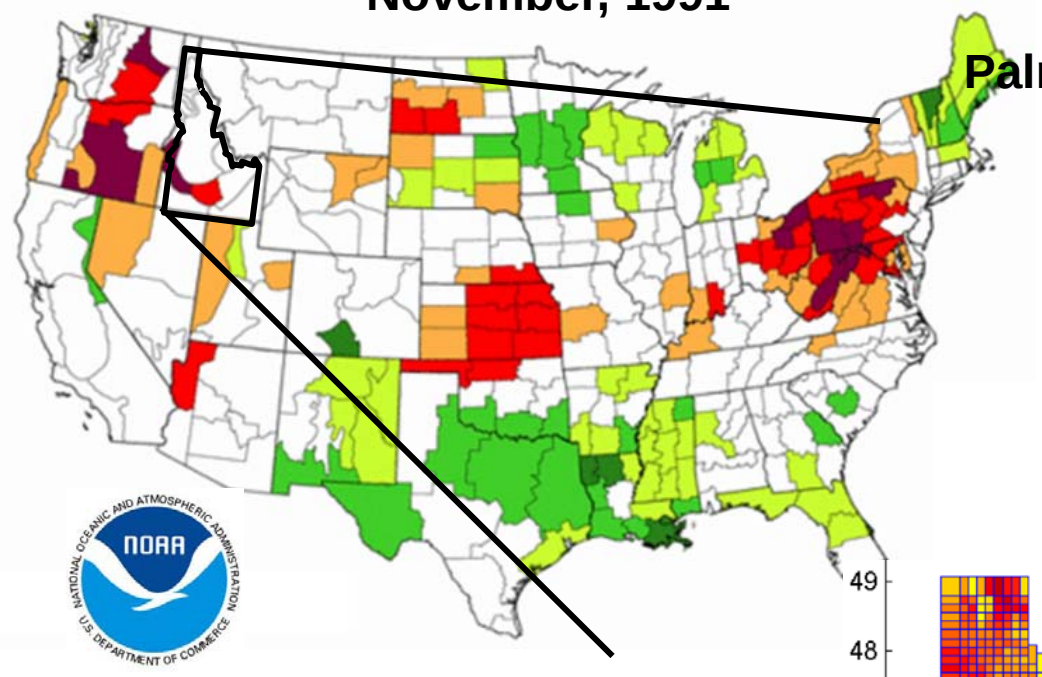
Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought

Palmer Hydrological Drought Index (PHDI)
November, 1991

Drought Years (1992)



National Climate Data Center, NOAA

extreme drought	severe drought	moderate drought	mid-range	moderately moist	very moist	extremely moist
-4.00 and below	-3.00 and -3.99	-2.00 and -2.99	-1.99 and +1.99	+2.00 and +2.99	+3.00 and +3.99	+4.00 and above

Criterion	Description
SDI ≥ 0.0	Non Drought
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-1.5 ≤ SDI < -1.0	Moderate Drought
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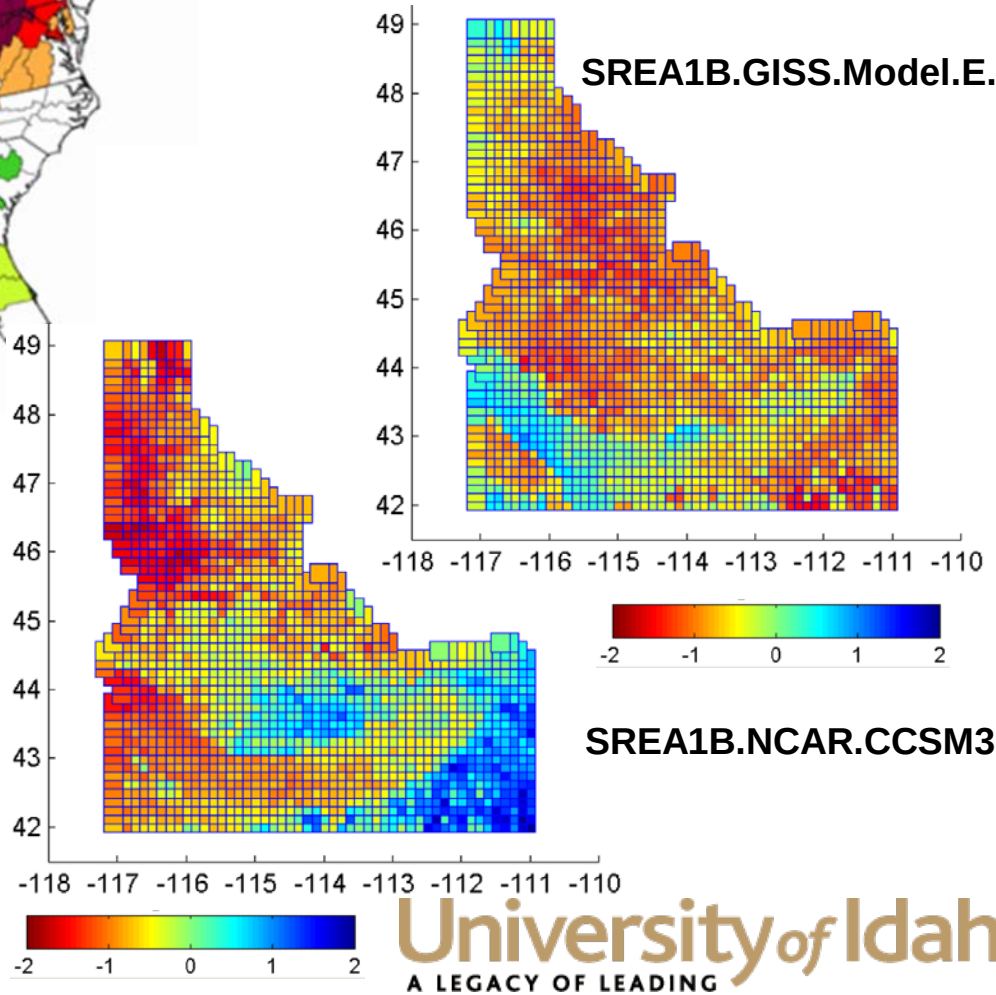
SDI < -2.0	Extreme Drought

Palmer Hydrologic Drought Index (PHDI)
From VIC Model
Water Year 1992 (Oct-Dec 1991)



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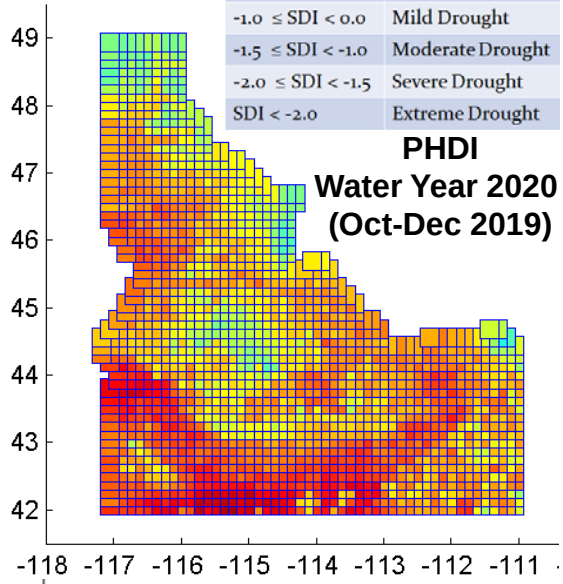
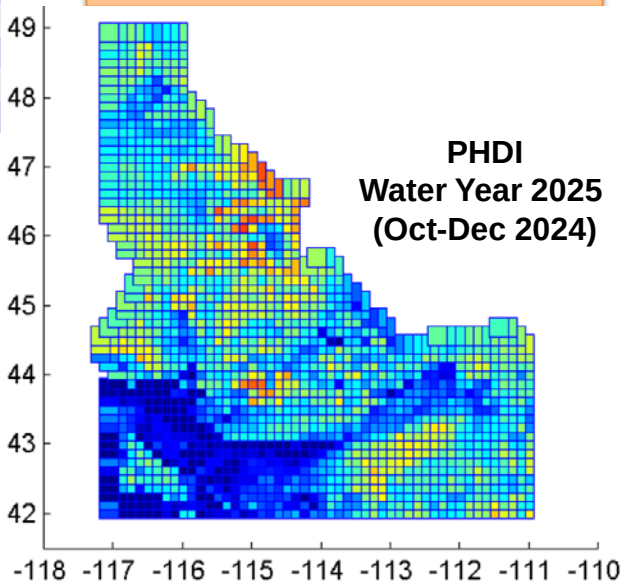
Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought

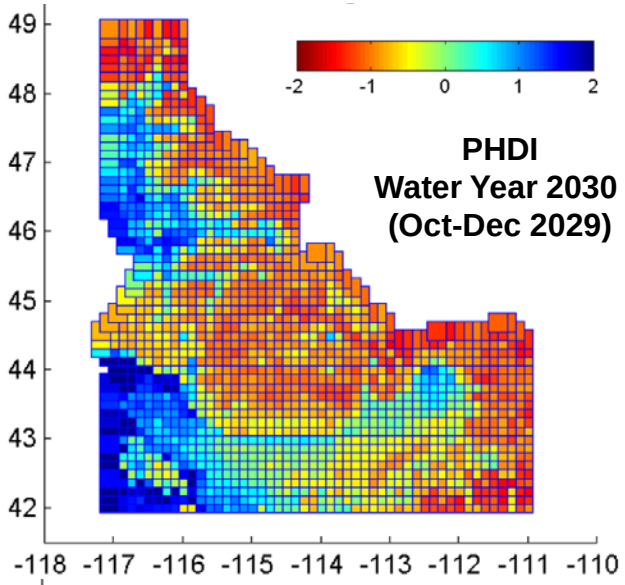
Future Droughts (2020, 2025, 2030)

Criterion	Description
SDI ≥ 0.0	Non Drought
-1.0 ≤ SDI < 0.0	Mild Drought
-1.5 ≤ SDI < -1.0	Moderate Drought
-2.0 ≤ SDI < -1.5	Severe Drought
SDI < -2.0	Extreme Drought

SREA1B.GISS.Model.E.R.4







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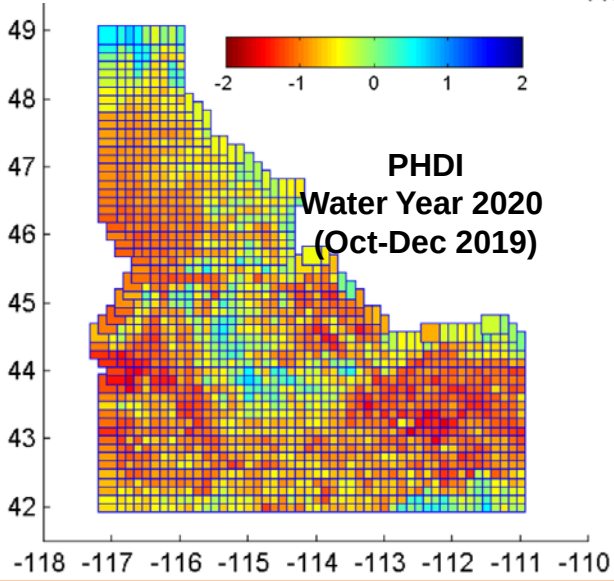
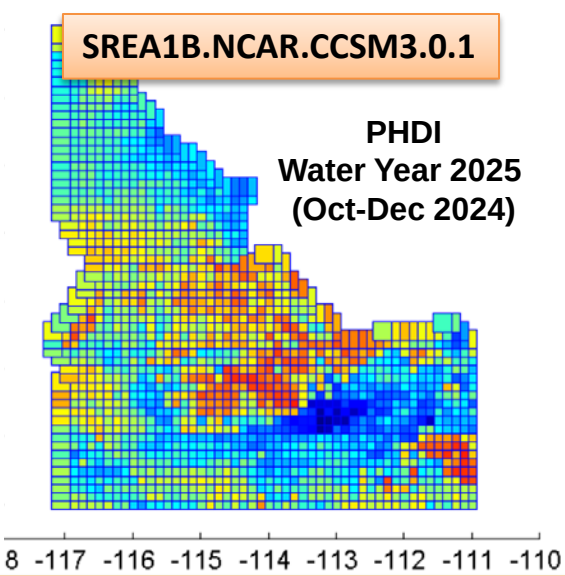
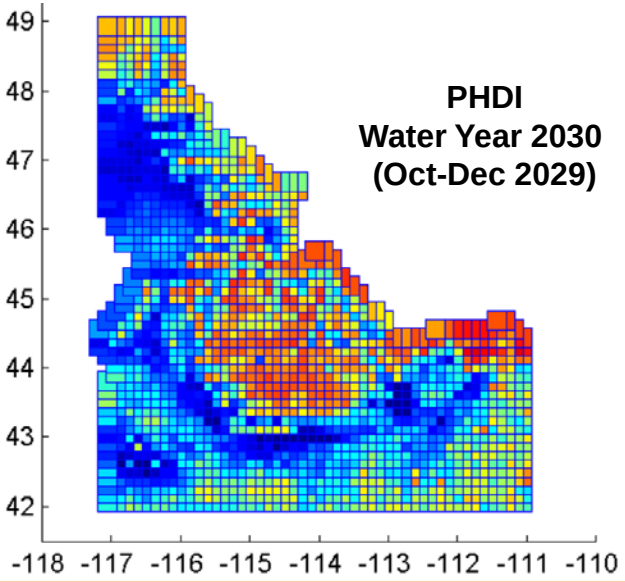






Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought Years Drought

Historic Drought

- SPI
  - 1-month (short-term)
  - 3-month (mid-term)
  - 6-month (mid-term)
  - 12-month (long-term)
- PDSI
  - 3-month window
  - 6-month window
  - 12-month window
- HDI

Future Drought

MODELS

1. BCCR:BCM2
2. CCCMA:CGCM_1-T63
3. CNRM:CM3
4. CSIRO:MK3
5. GFDL:CM2
6. GFDL:CM2_1
7. GISS-ER
8. INM:CM3
9. IPSL:CM4
10. NIES:MIROC3_2-HI
11. MIUB-ECHO-G
12. MPIM:ECHAM5
13. MRI:CGM2_3_2
14. NCAR:CCSM3
15. NCAR:PCM
16. UKMO:HADCM3

Scenarios

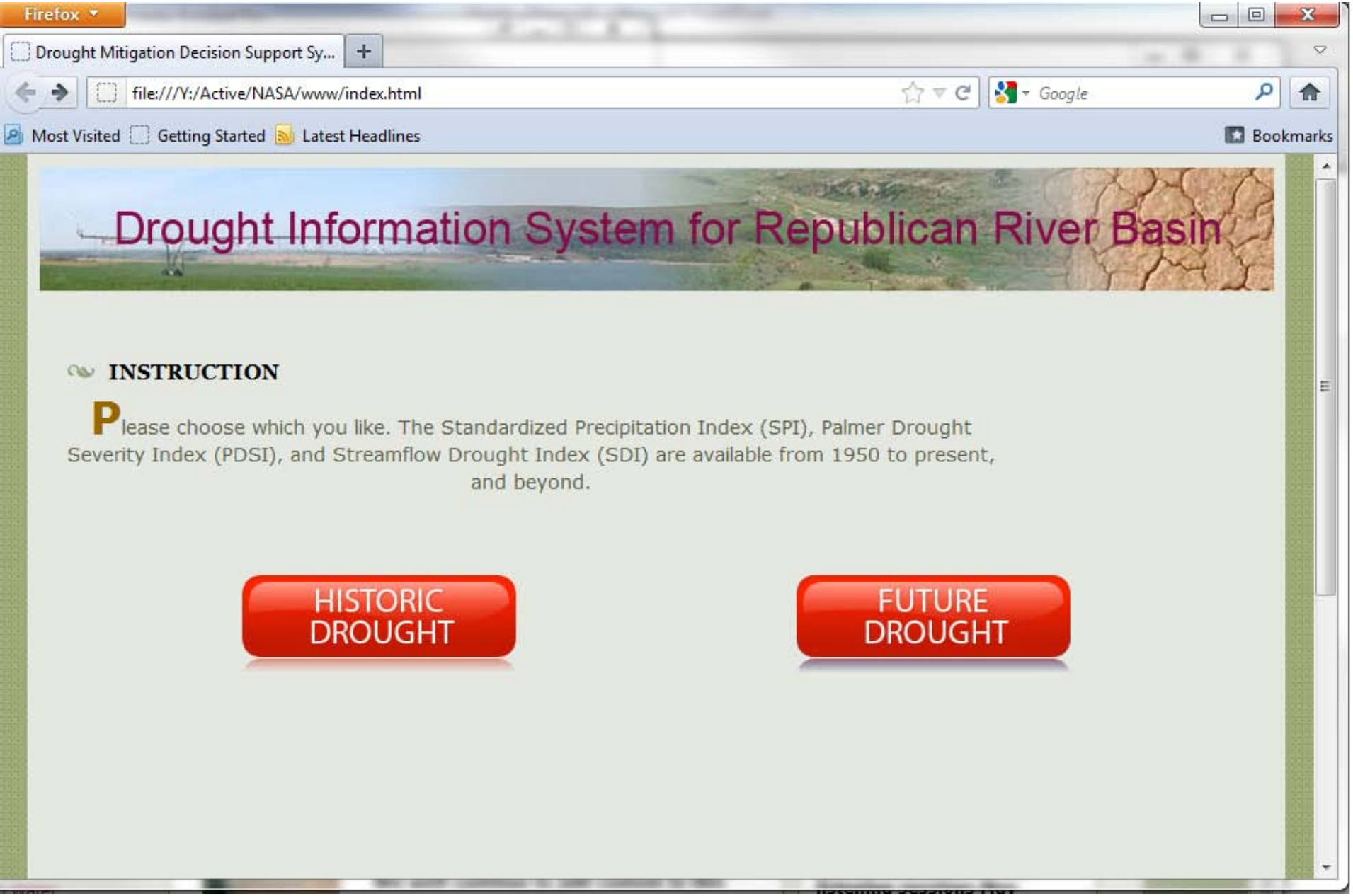
- A1B
- A2
- B1

ENS

- 3 (~2.5)

[4 (SPI) + 1 (PDSI) + (3 HDI)] * 50 years (1950-1999) * 12 months (Jan – Dec)
= 4,800 maps for historic drought

4,800 maps * 16 models * 3 scenarios * 3 ensembles = 691,200 maps for future drought


Firefox
Drought Mitigation Decision Support Sy...
file:///Y:/Active/NASA/www/index.html
Google
Most Visited
Getting Started
Latest Headlines
Bookmarks
Drought Information System for Republican River Basin
INSTRUCTION
Please choose which you like. The Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), and Streamflow Drought Index (SDI) are available from 1950 to present, and beyond.
HISTORIC DROUGHT
FUTURE DROUGHT

Thank you!

Jae Ryu

jryu@uidaho.edu