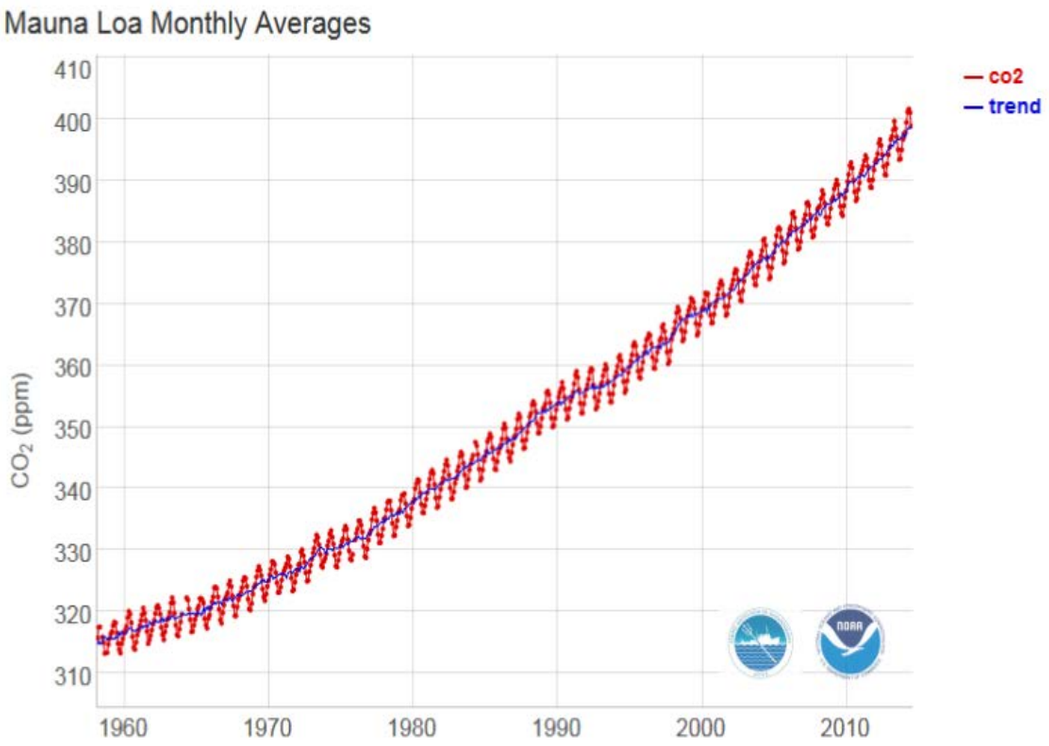
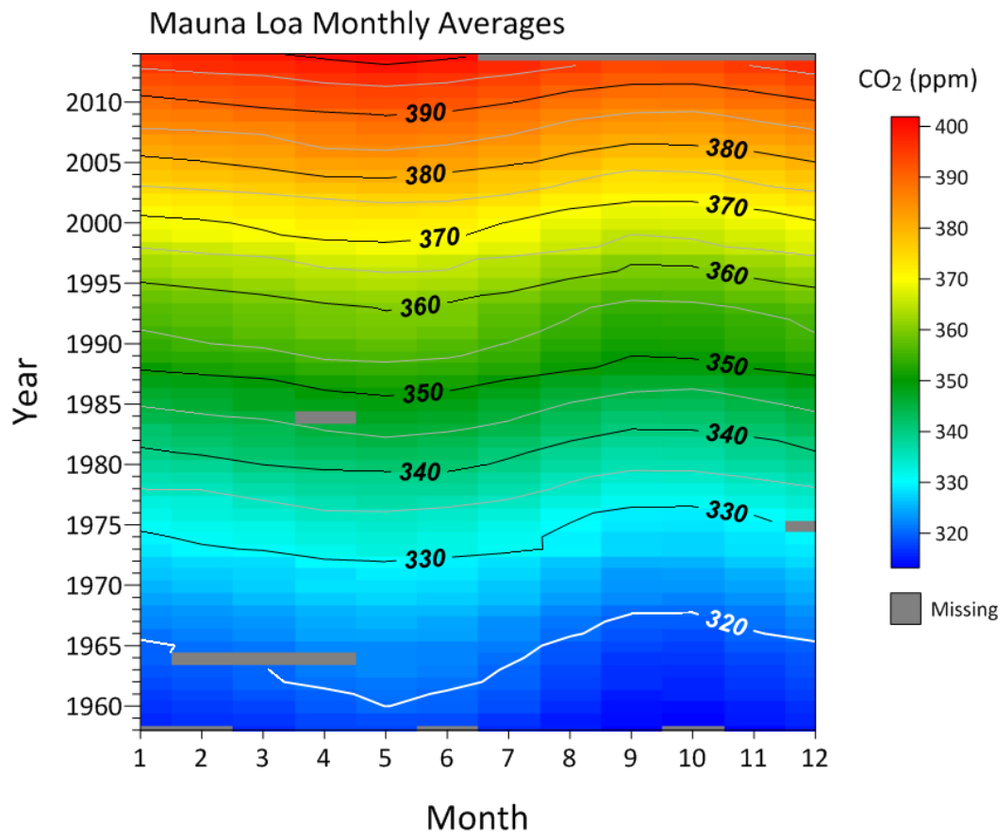
Innovative Ways to Visualize and Analyze Environmental Time-Series Data





Brown Bag webinar
NOAA Central Library
August 20, 2014

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NWS Training Division
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Webinar outline

- Visualization criteria
- Composition vs configuration metrics
- Examples and applications
- Analysis techniques
- Users
- Questions

Criteria for time-series visualization

- Show all data
  - Display large datasets
  - Handle wide data ranges
  - Clearly show each data point
  - Don’t hide/cover/clump points
- Identify patterns
  - Allow for easy comparisons
  - Spot outliers and artifacts
  - Show both short and long-term patterns
  - Identify natural vs artificial patterns

Data sources and challenges

- Observations

  Data collected for any number of environmental sciences

    Hydrology, engineering, oceanography, biology/ecology, meteorology, limnology, …

- Model output

  HEC-RAS, HEC-GeoRAS, HEC-HMS, PHABSIM, SEFA, ELOHA, WaterFALL, WFET, SWAT, CrEAM, ABF, NEABF, SAM2, IHA,…

- Big Data

  Obstacles to understanding

  Identify temporal signatures

  Need different display techniques

Time-series metrics (for hydrology)

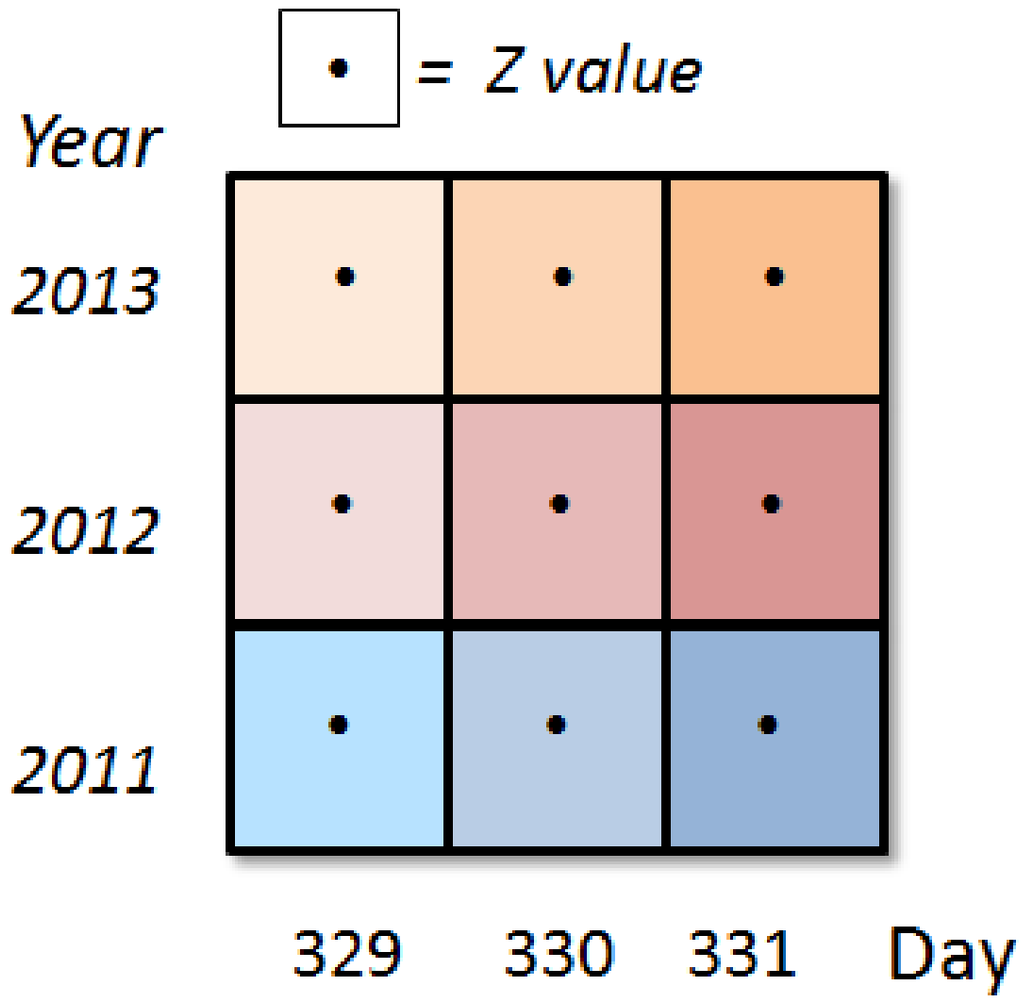
- Most indices are simple[1]
- Need time-scale analysis to find patterns[1]
- Hundreds of indices exist[2]

Magnitude	**55%**	**Composition**	
Frequency	**8%**		
Duration	**26%**		*Temporal*
Timing	**6%**	**Configuration**	*component*
Change	**5%**		

- Visualization overlooked as analysis method

[1] Long, K. S. 1994 [2] Olden, J.D., and N.L. Poff. 2003

Temporal map approach (raster graph)



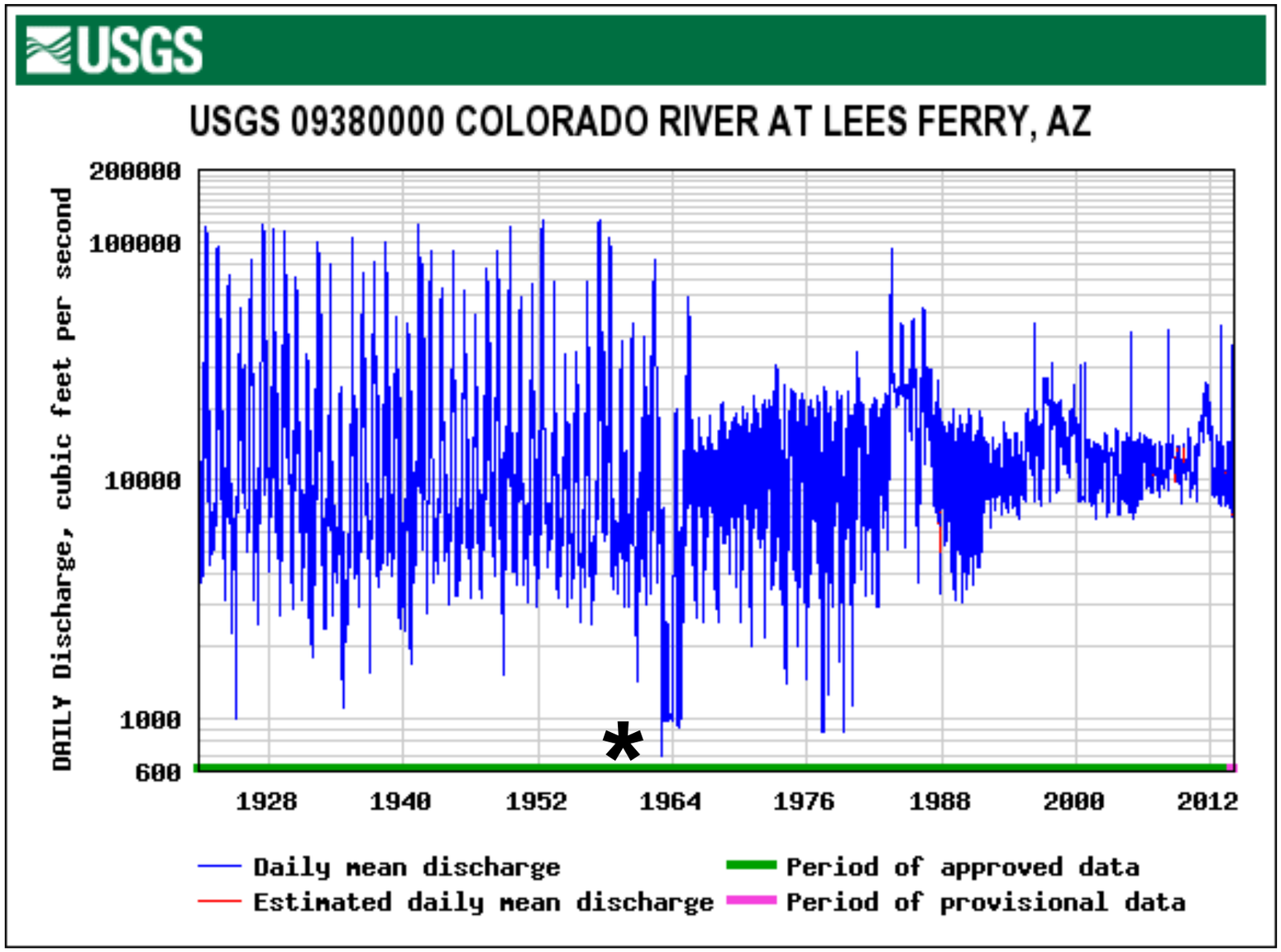
X = Short-term coordinate

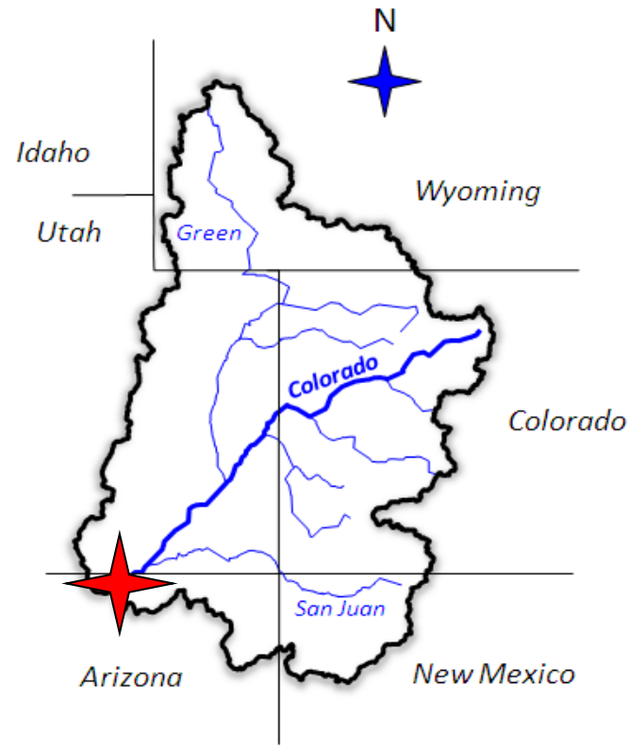
Y = Long-term coordinate

Z = Value (cell color)

Traditional hydrograph

92 years daily data (33,700 points)

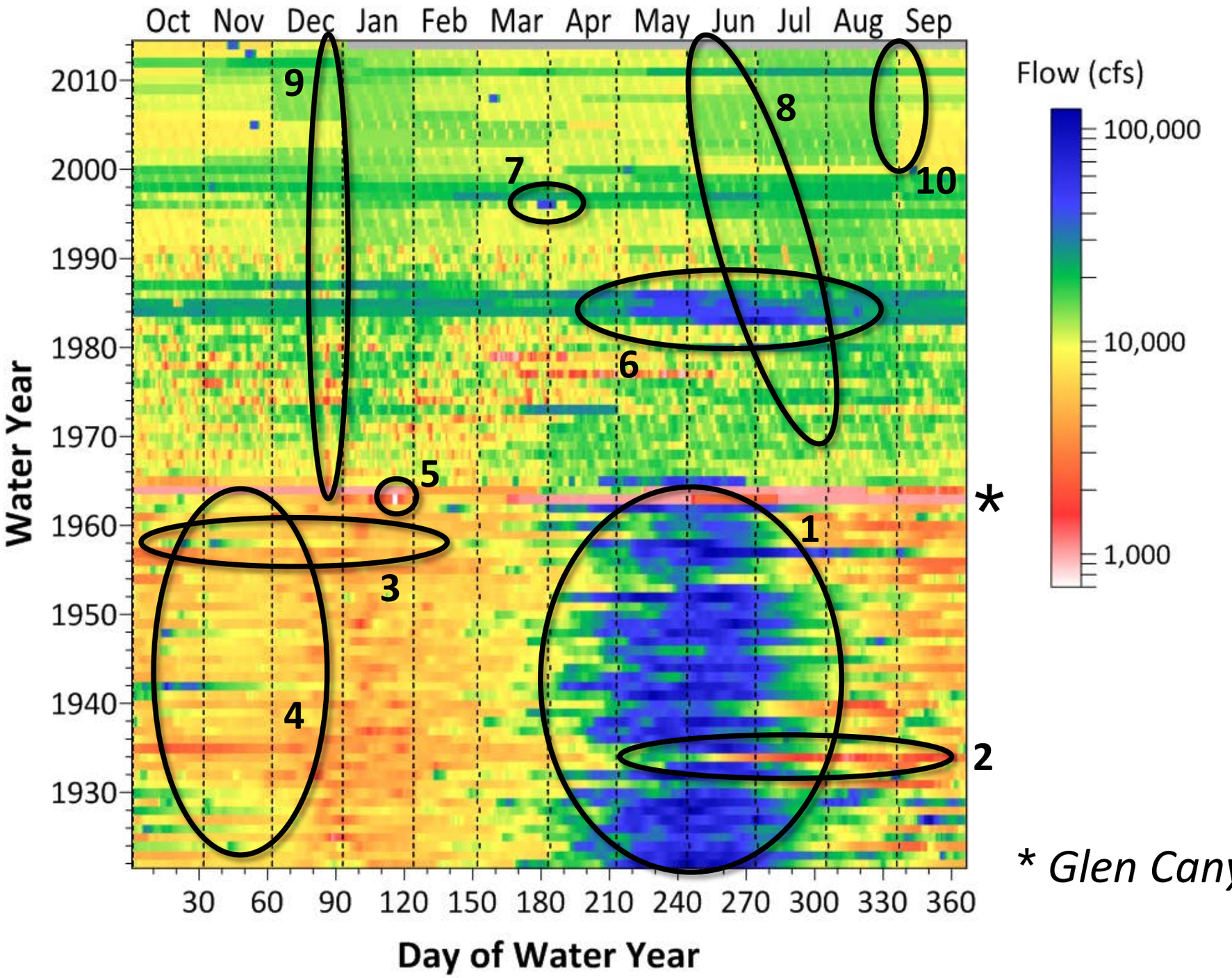




**** Glen Canyon Dam***

Raster hydrograph

Colorado River at Lees Ferry, AZ
92 years daily data (33,700 points)



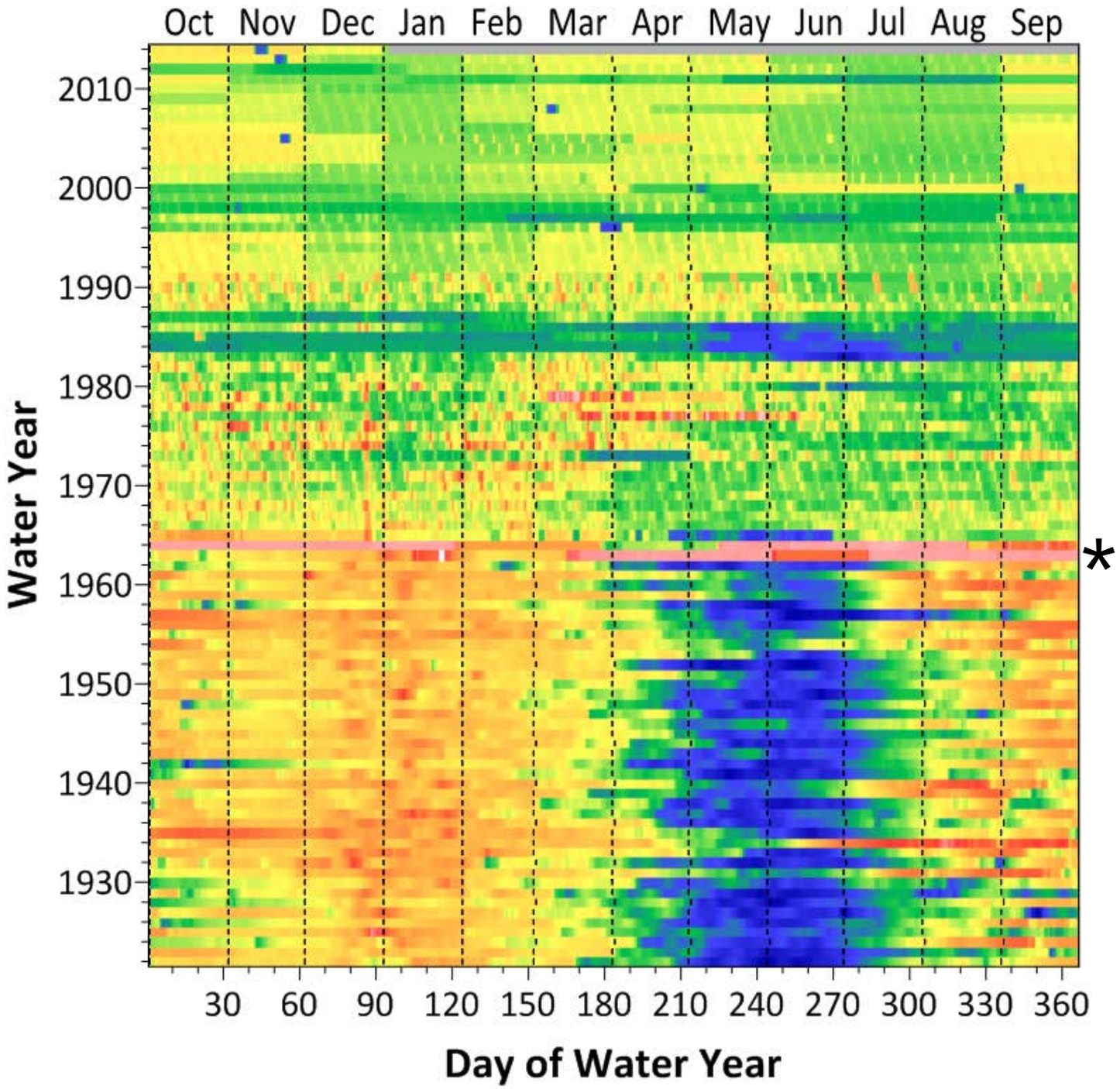
Temporal patterns

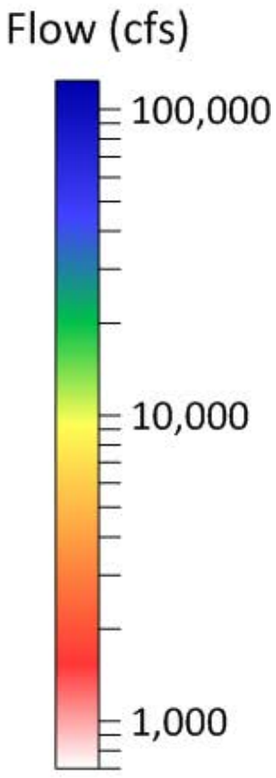
1. *Snowmelt runoff*
2. *Drought*
3. *Storm flow*
4. *Vegetation signal*
5. *Tunnels closed*
6. *El Nino*
7. *Artificial flood*
8. *Sundays*
9. *Christmas*
10. *Monthly change*

* *Glen Canyon Dam*

Raster hydrograph

Colorado River at Lees Ferry, AZ
92 years daily data (33,700 points)





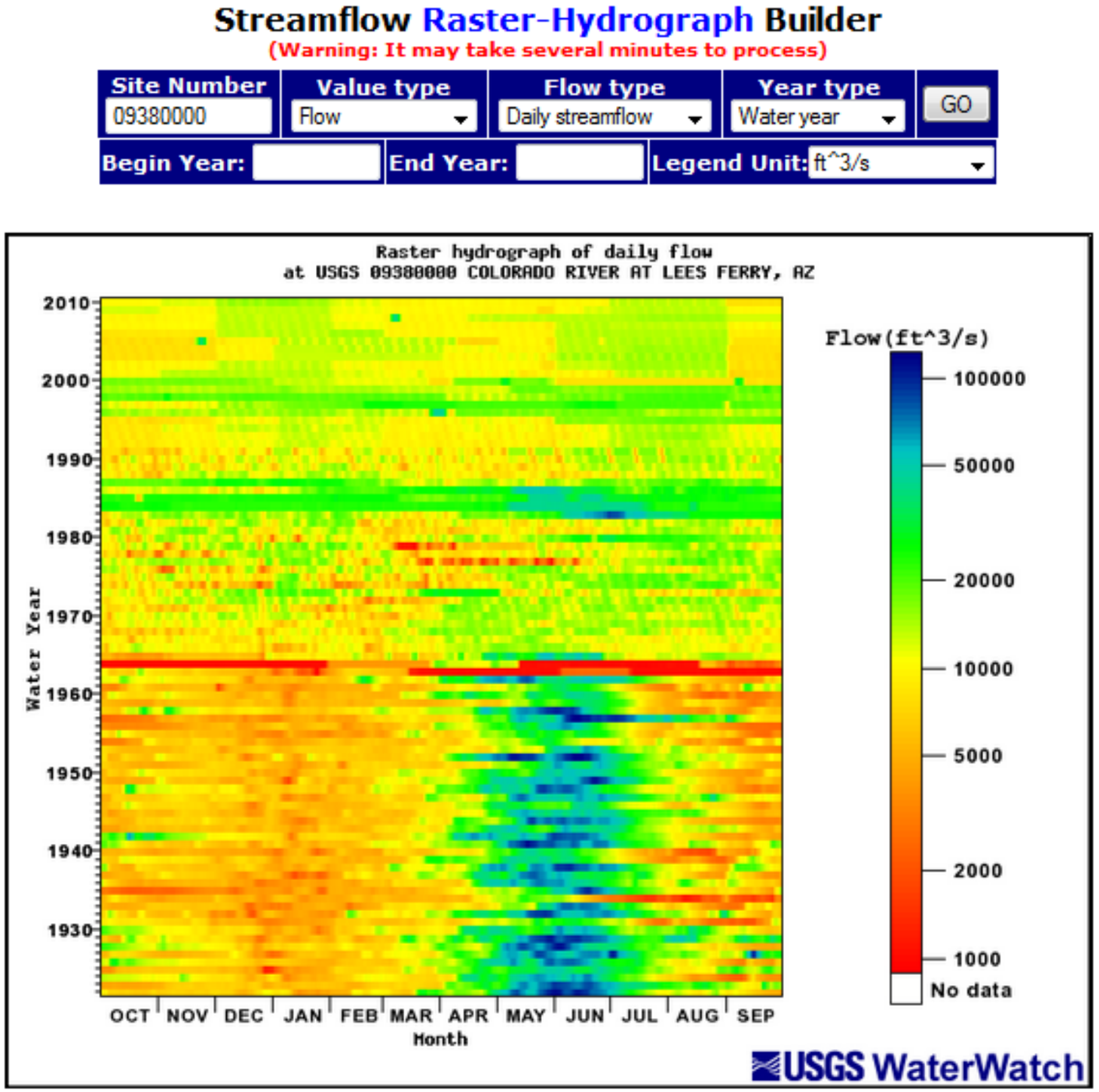
Color	Magnitude
Number	Frequency
Size	Duration
Coordinate	Timing
Color diff	Change

Connectivity,
Distribution,
Persistence

Temporal signature

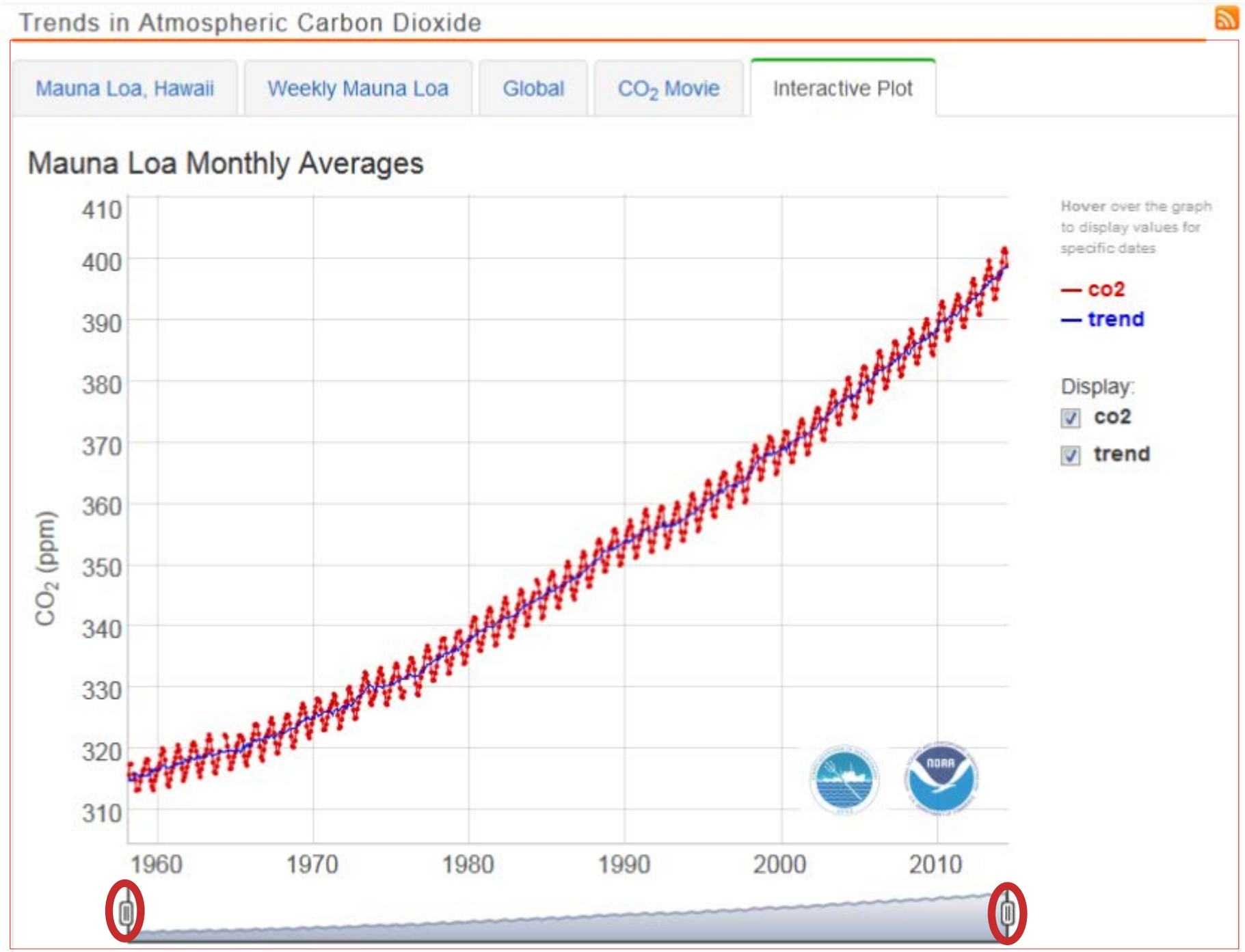
* *Glen Canyon Dam*

Adopted by the USGS



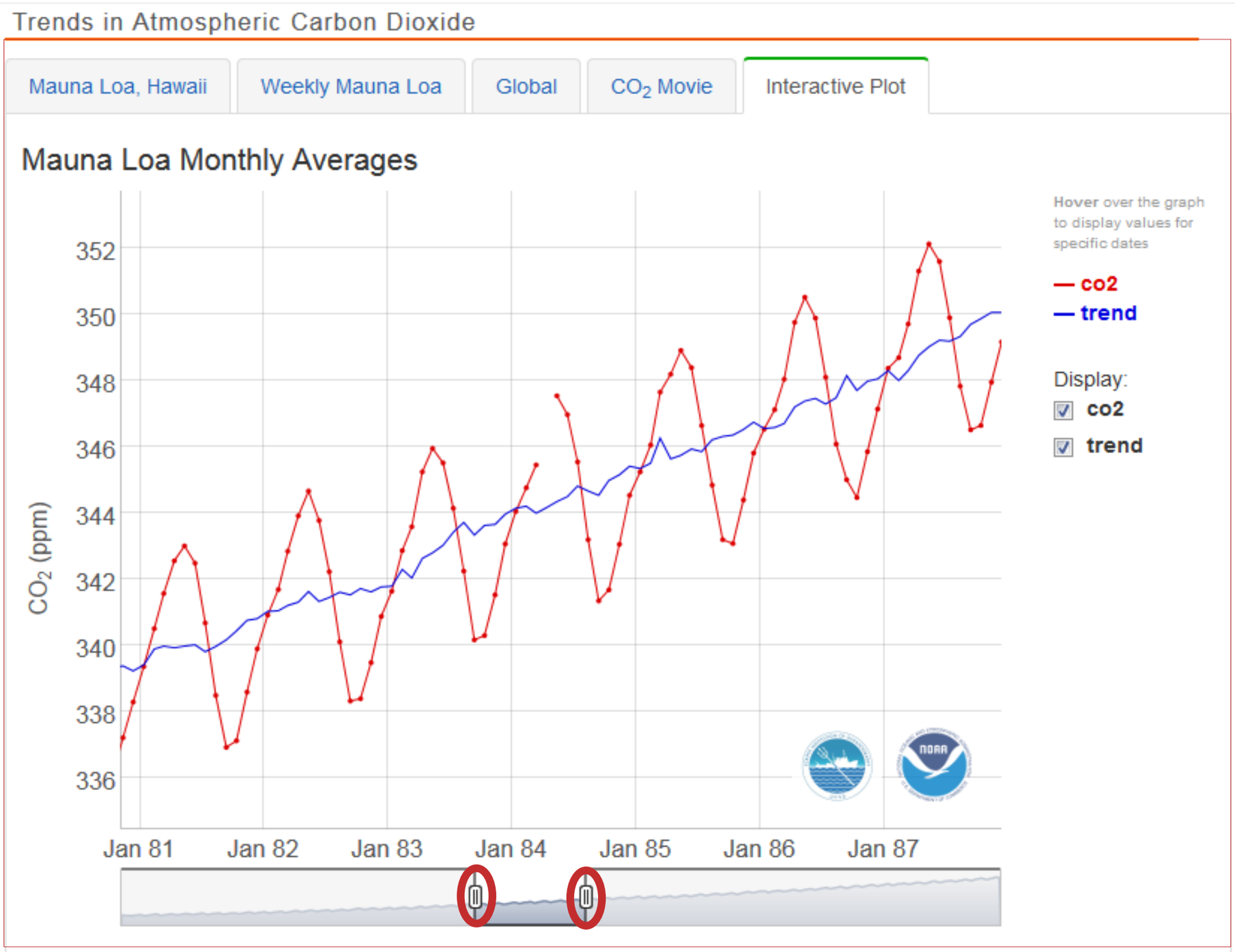
Traditional display

CO_2 dataset



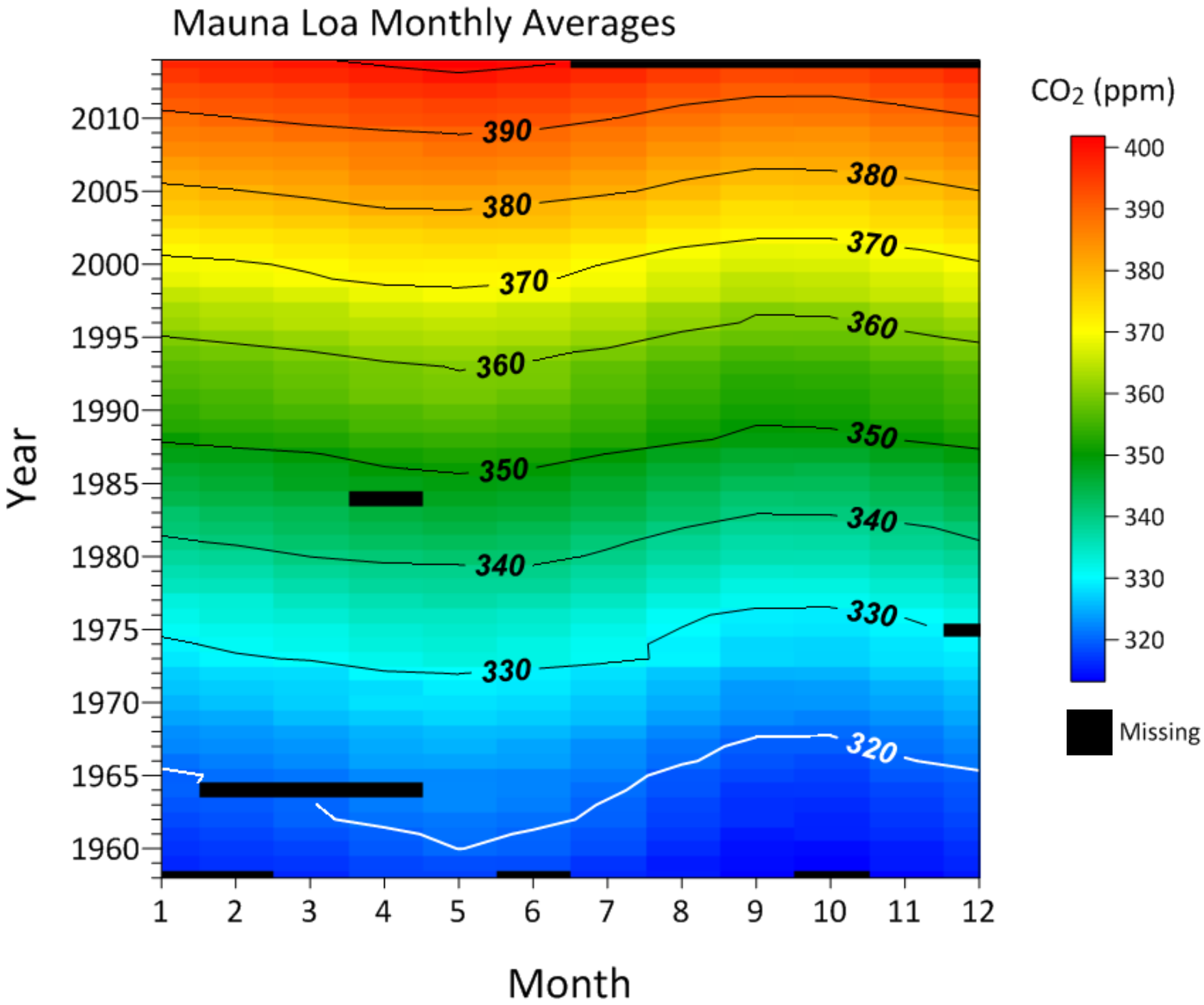
Zoom feature

CO_2 dataset

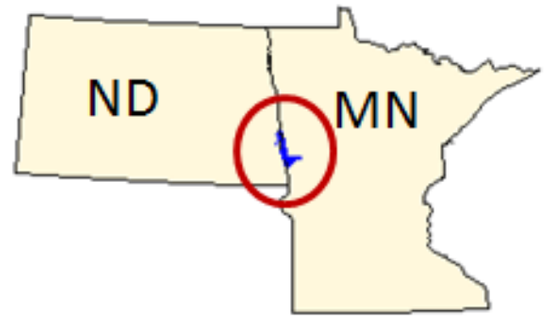


Application: Raster display

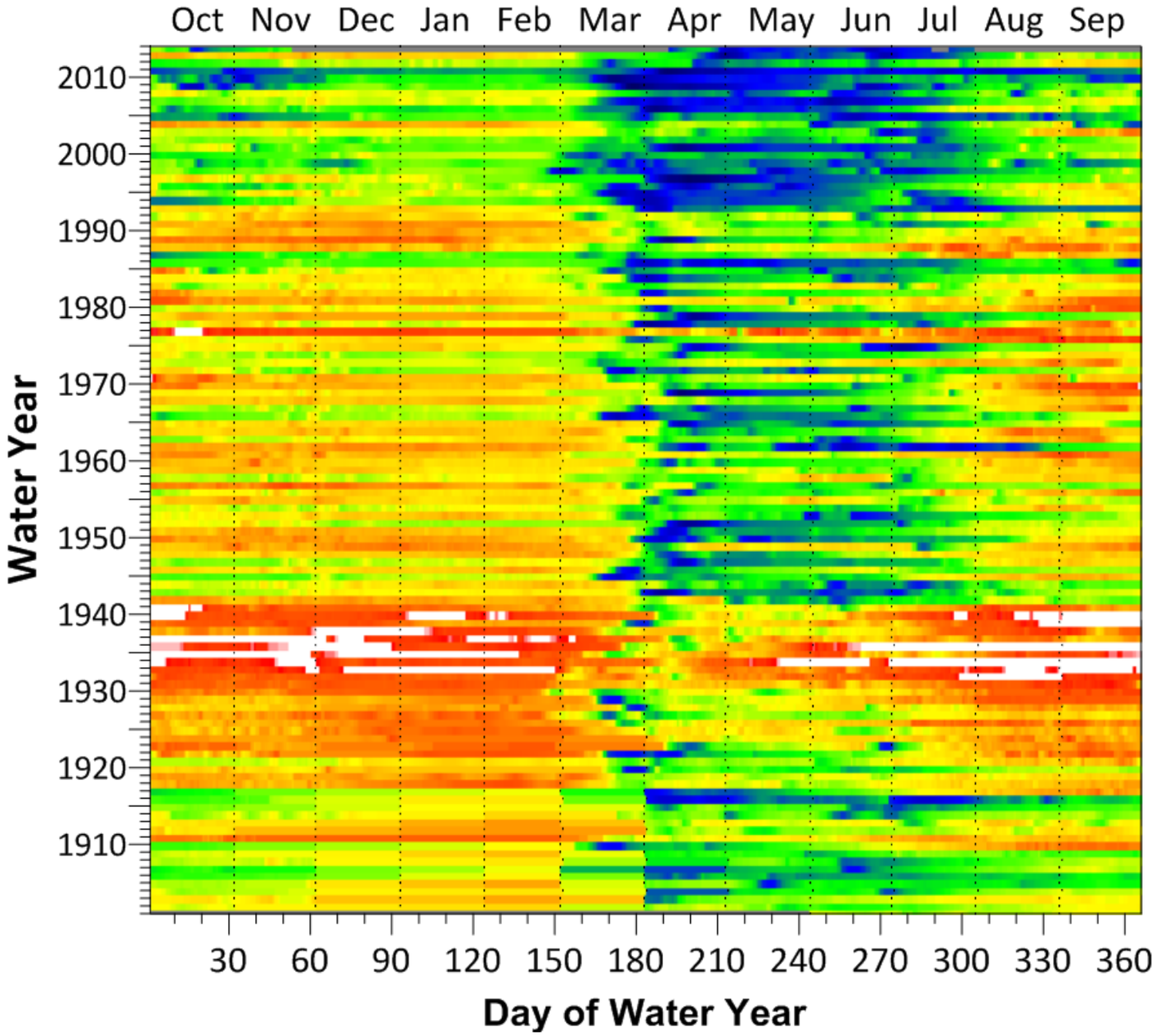
CO_2 dataset

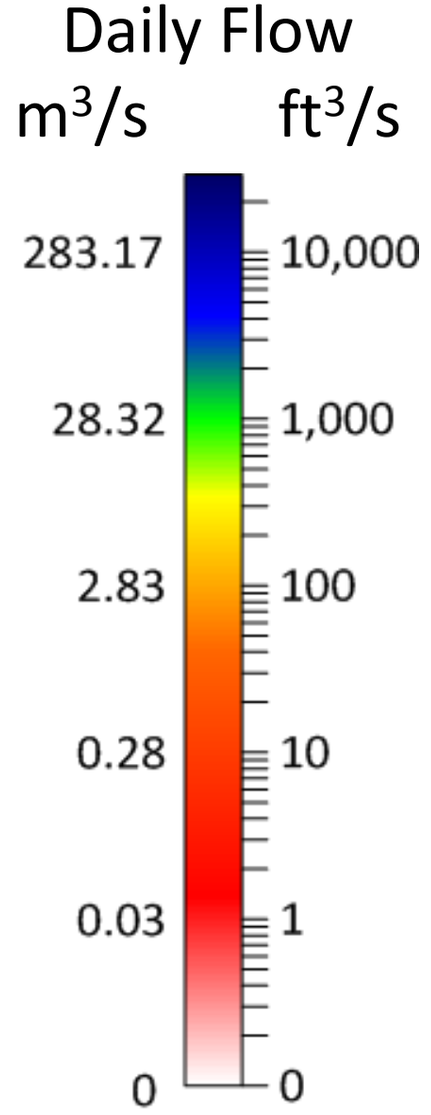


Application: Trends

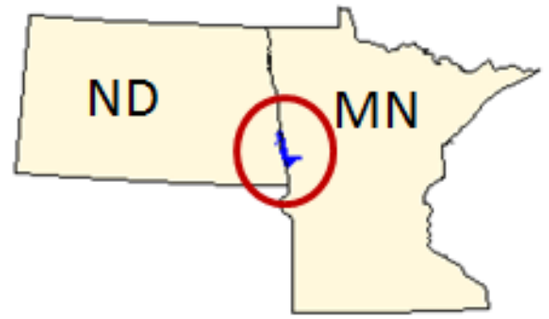


Red River of the North, Fargo, ND

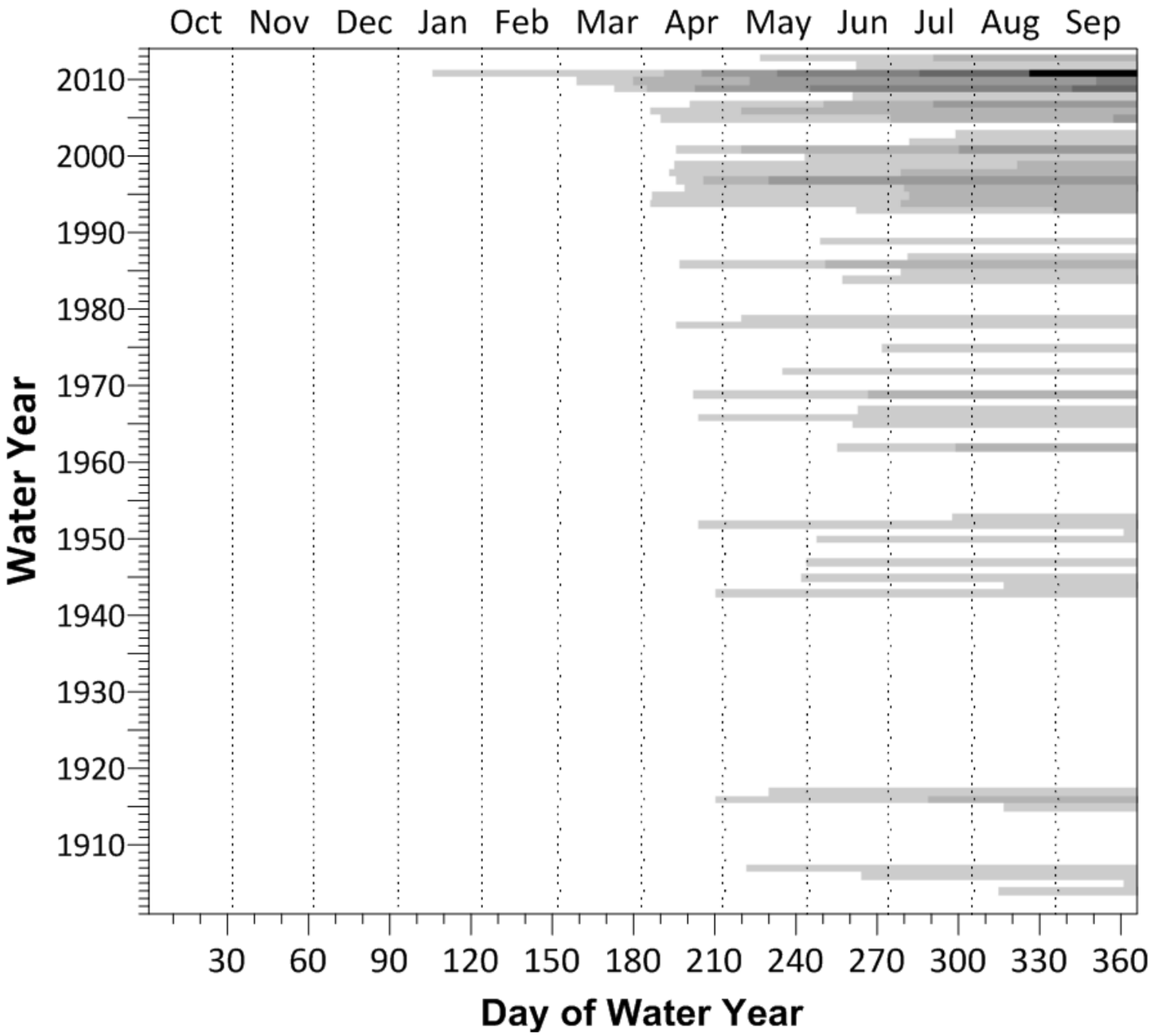


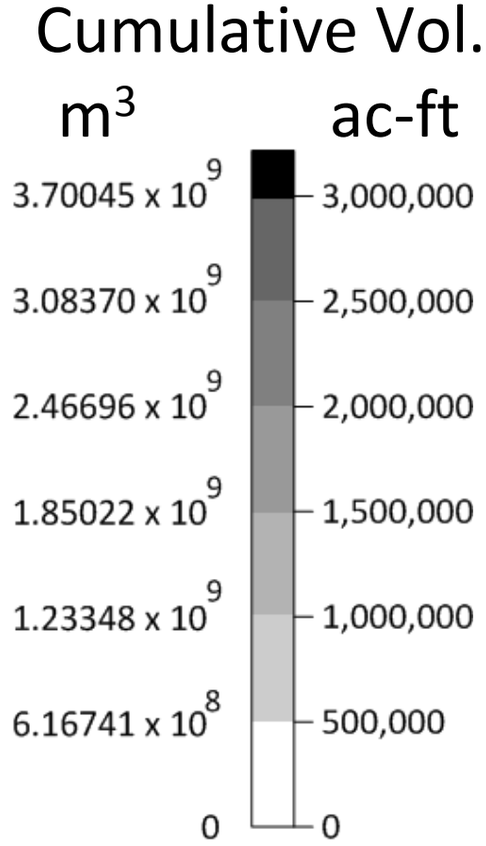


Application: Yearly volume



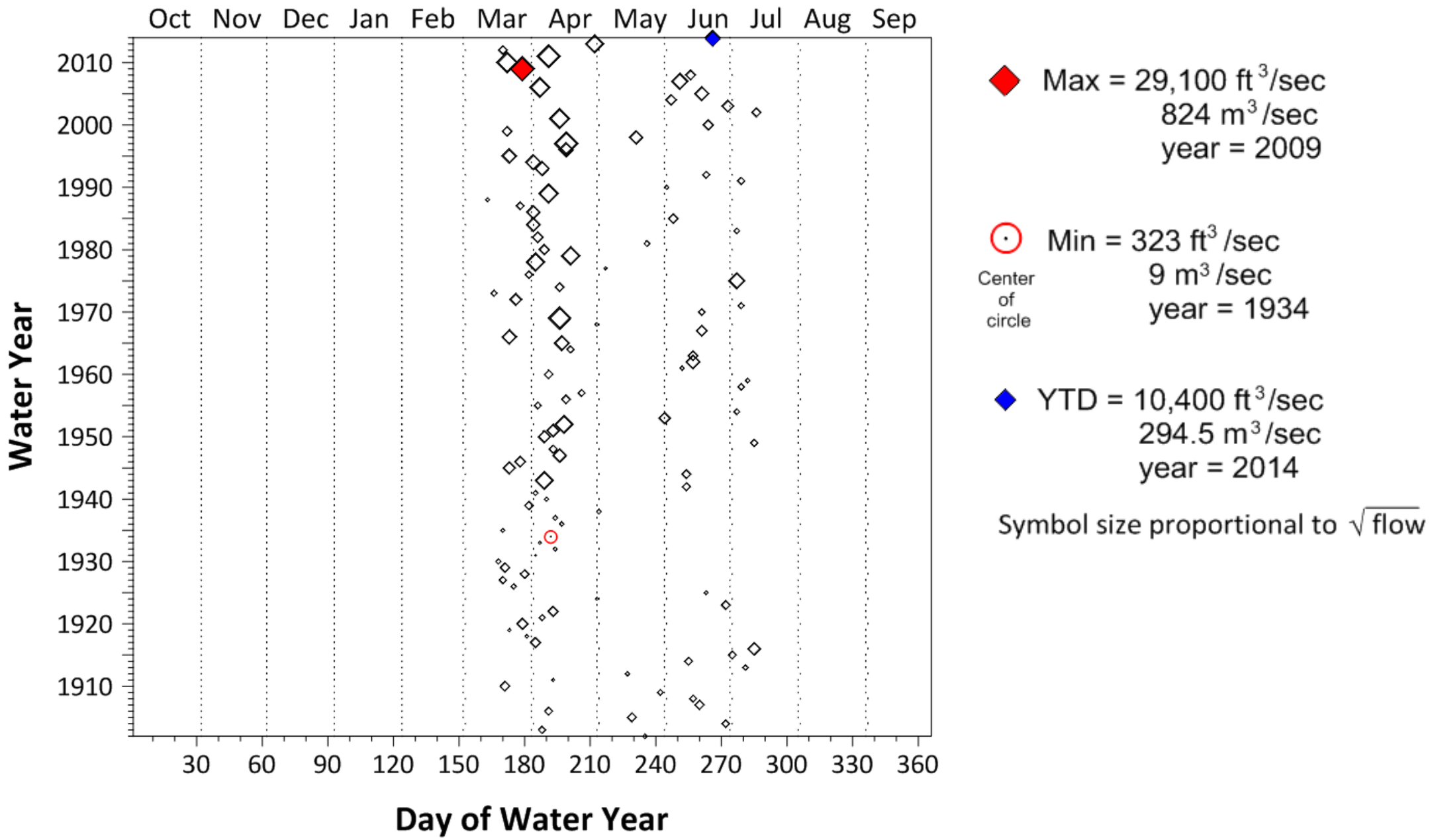
Red River of the North, Fargo, ND





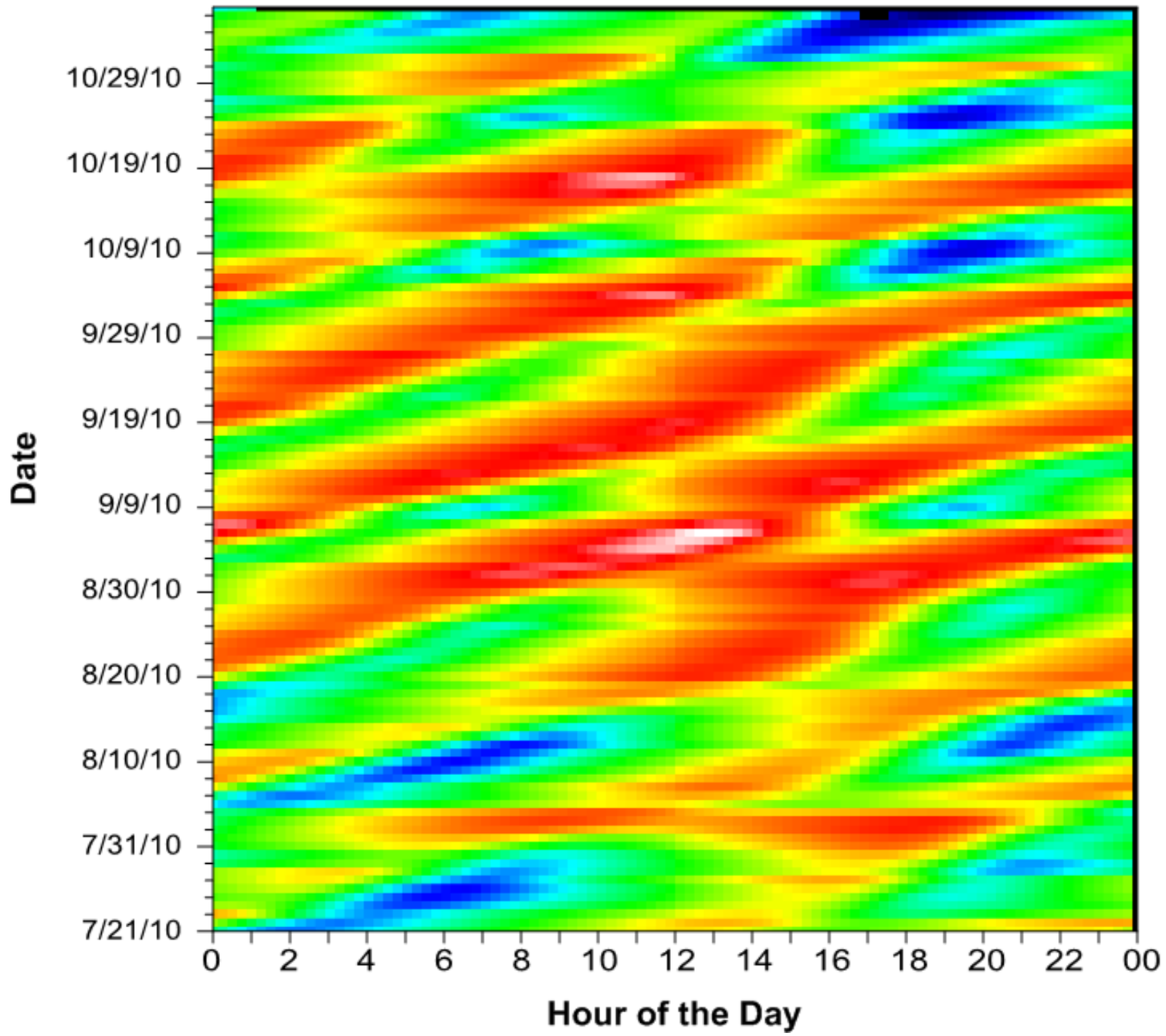
Application: Annual maximum flow

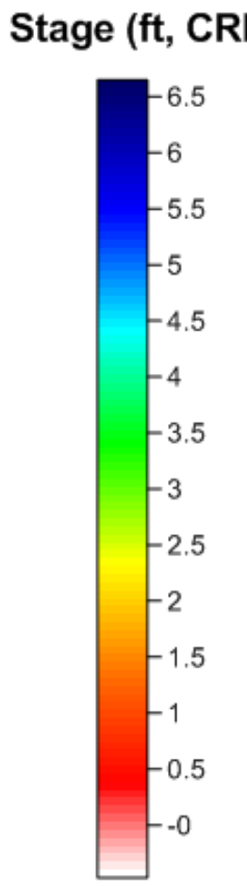
Red River of the North, Fargo, ND



Application: QA/QC

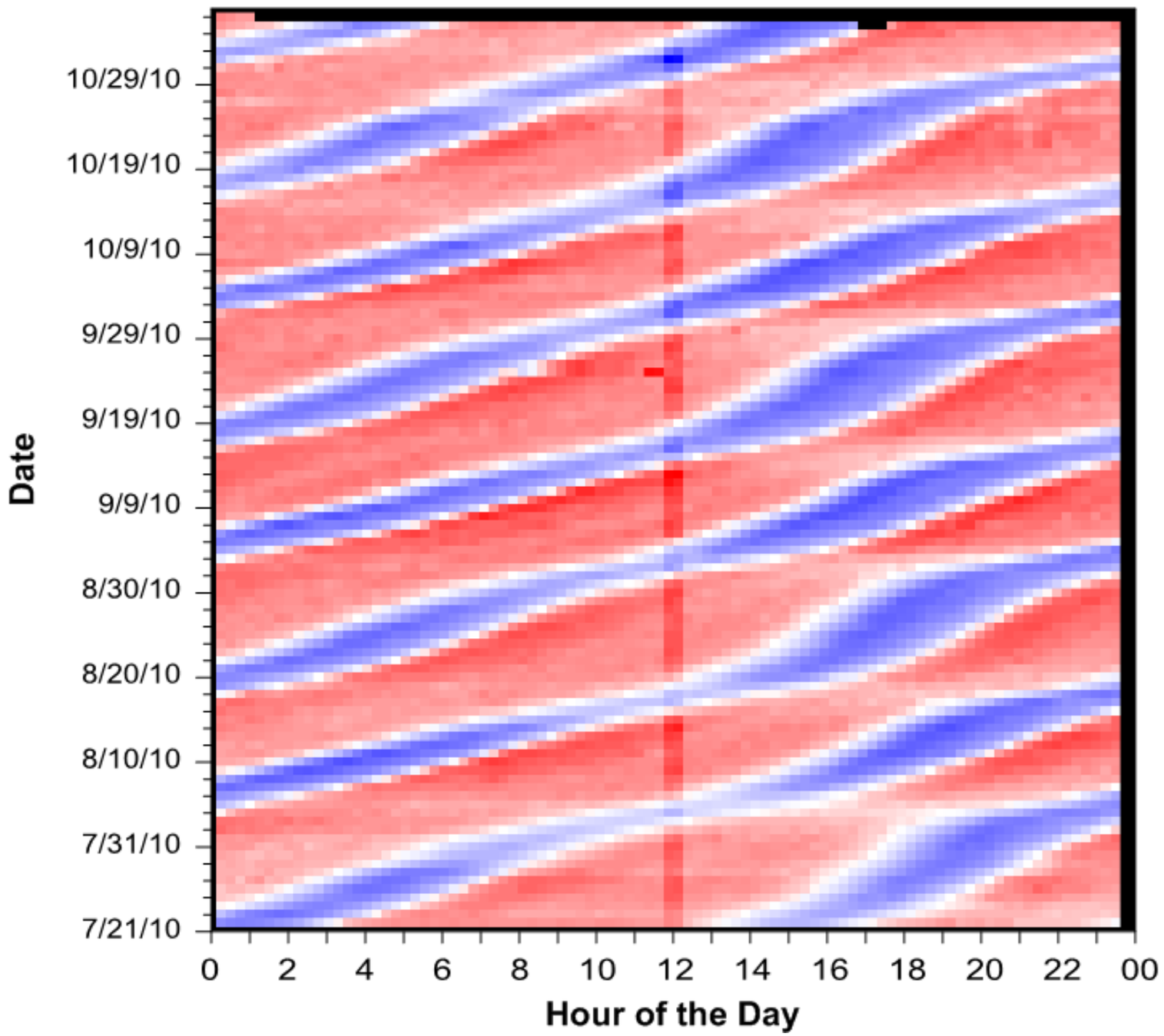
Columbia River at Vancouver, WA
15 minute stage data

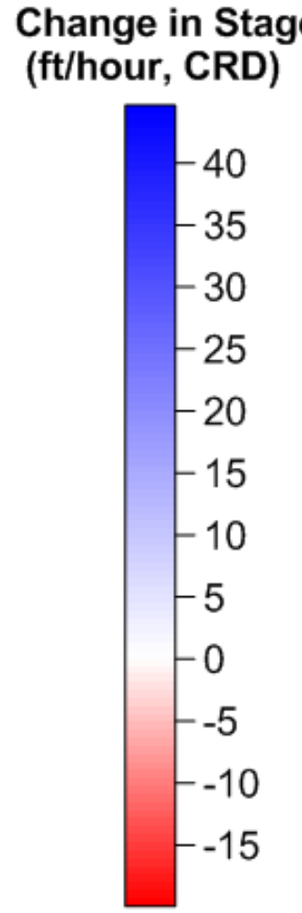




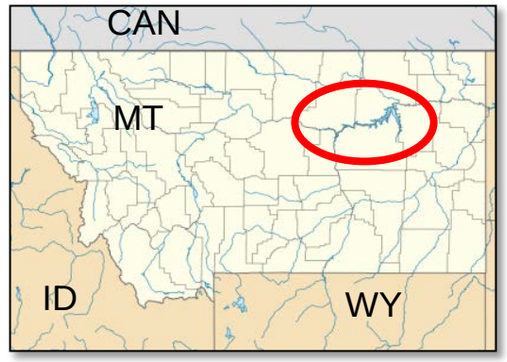
Change in stage

Columbia River at Vancouver, WA
Hourly rate of stage change

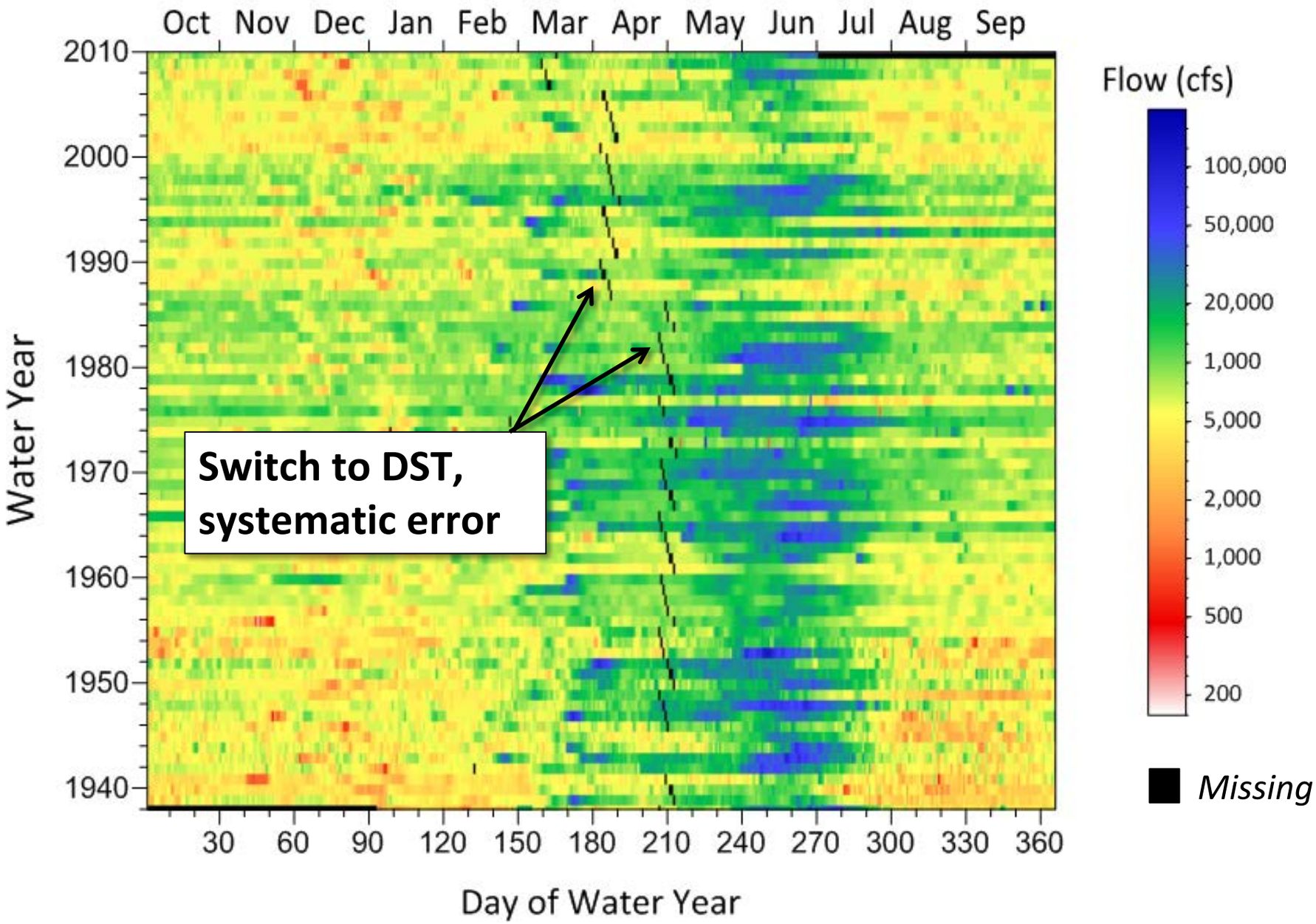




Application: QA/QC

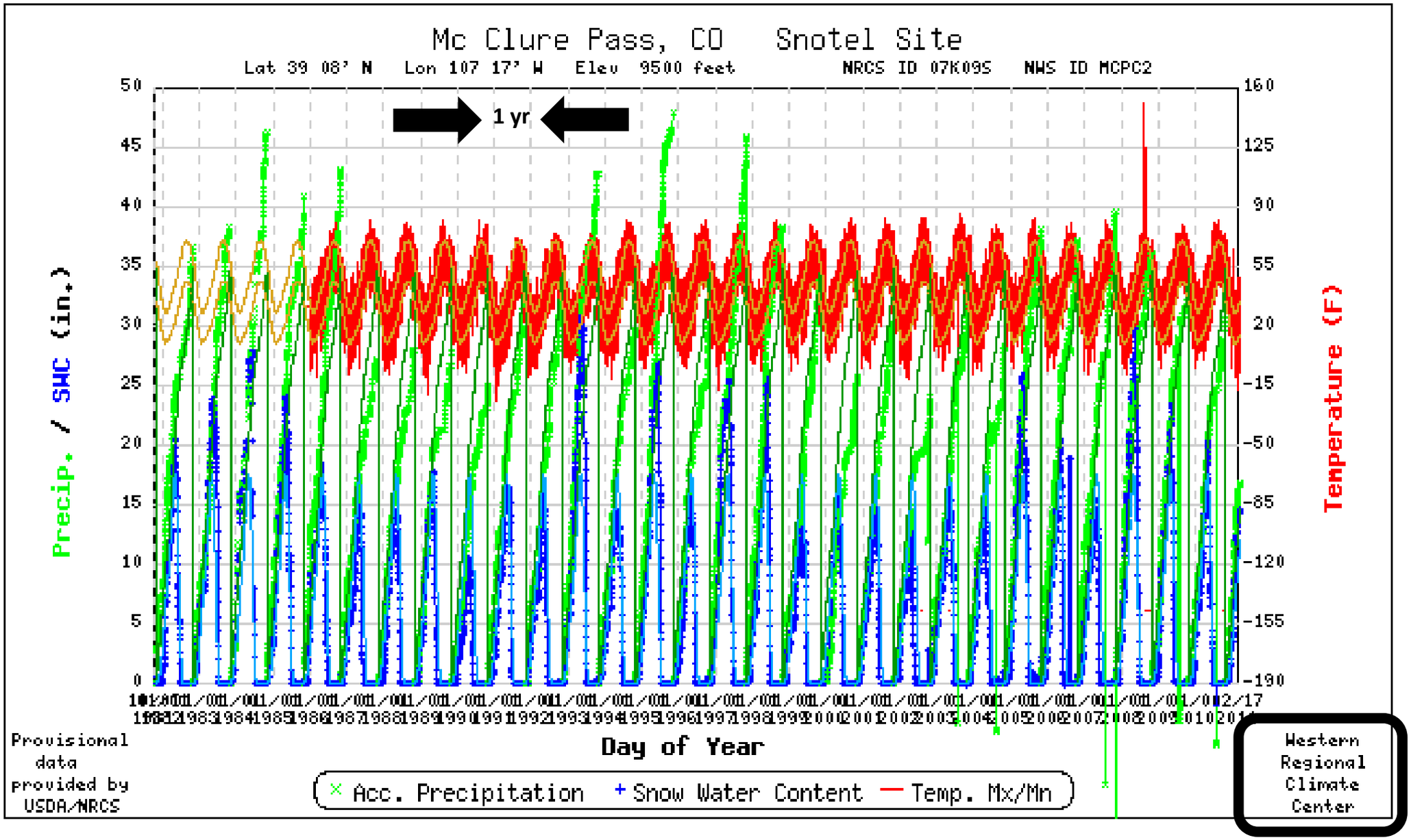


Fort Peck computed daily inflow
~72 yrs, 26,300 values

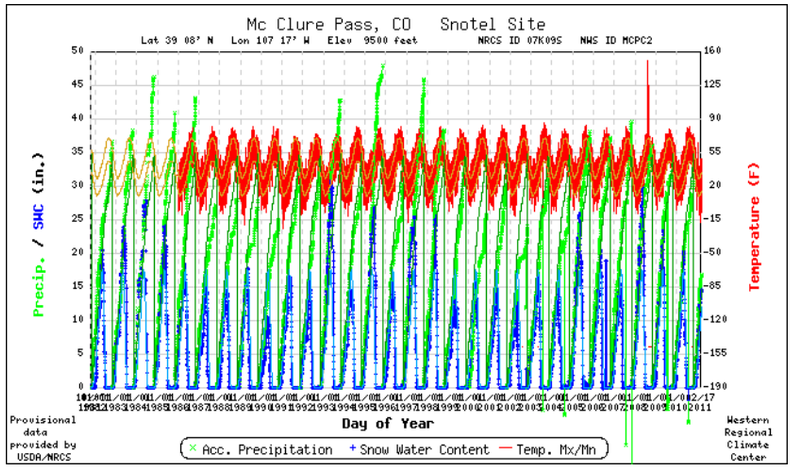


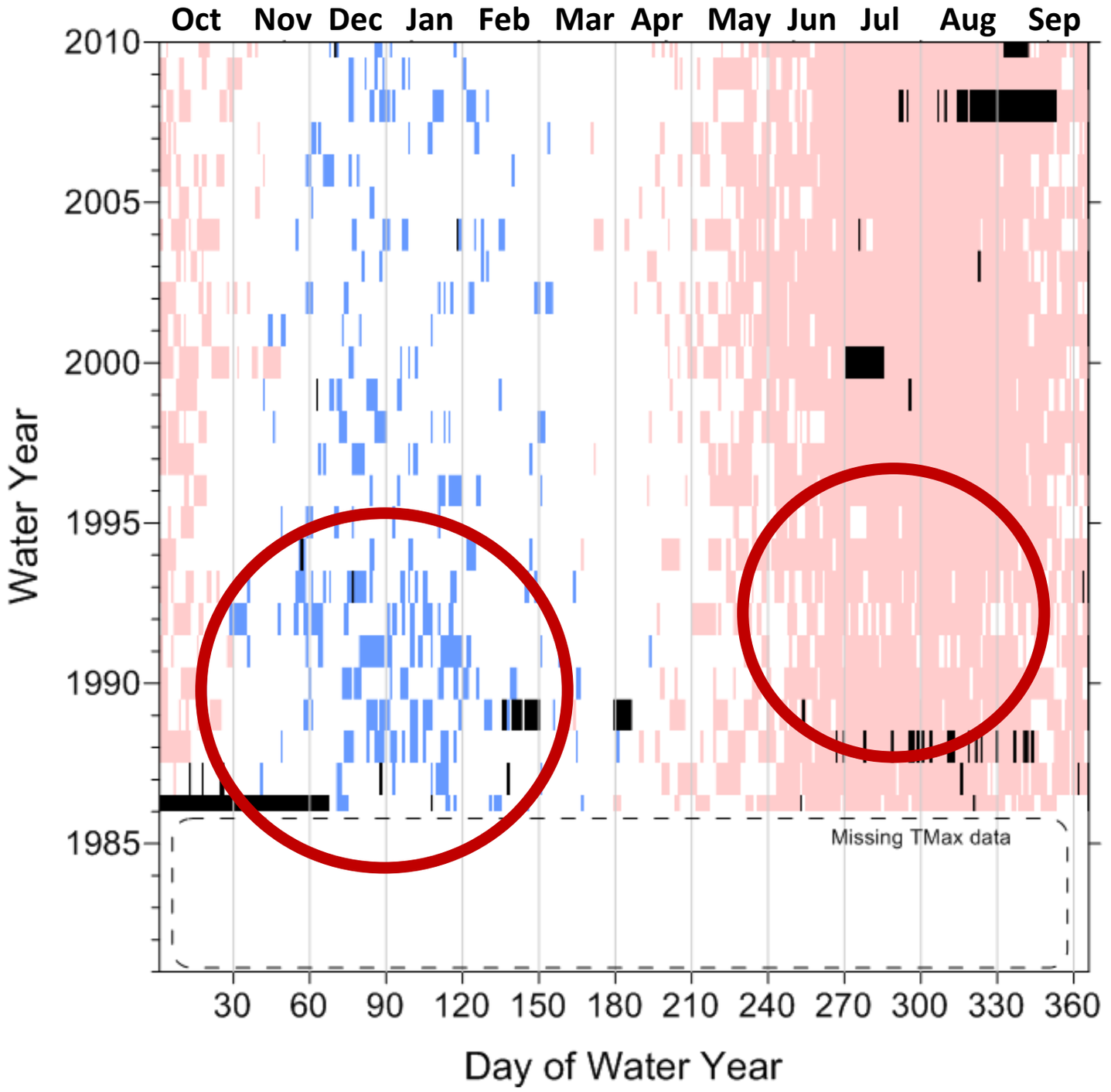
Application: pattern comparison

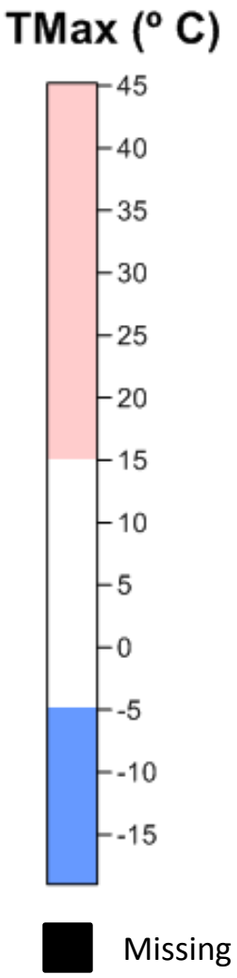
Temperature, Snow Water Equivalent, Precipitation



Temp

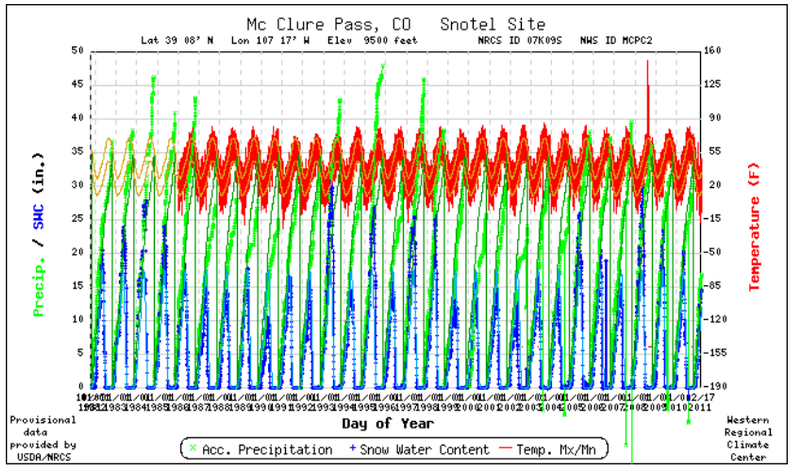


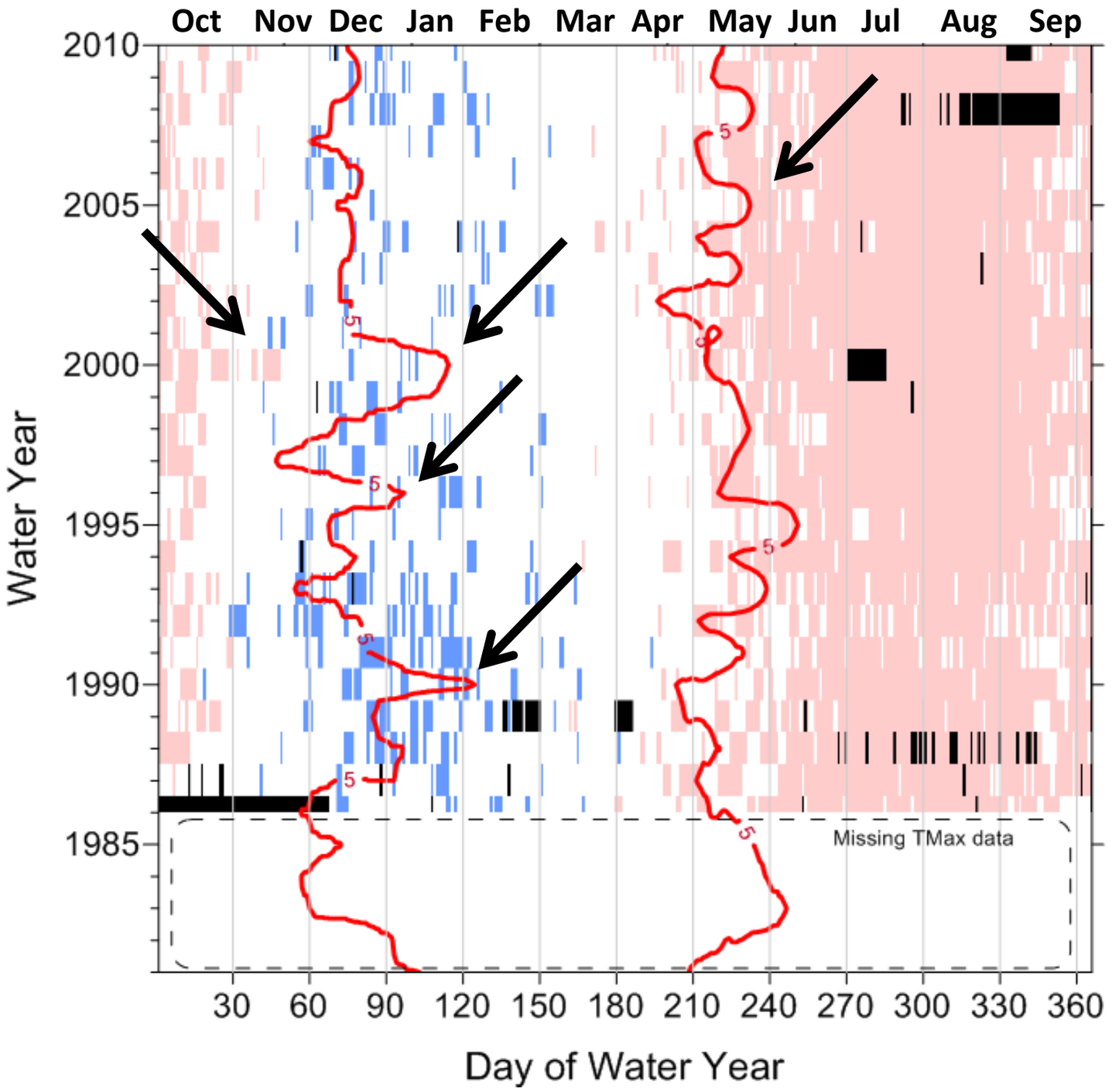


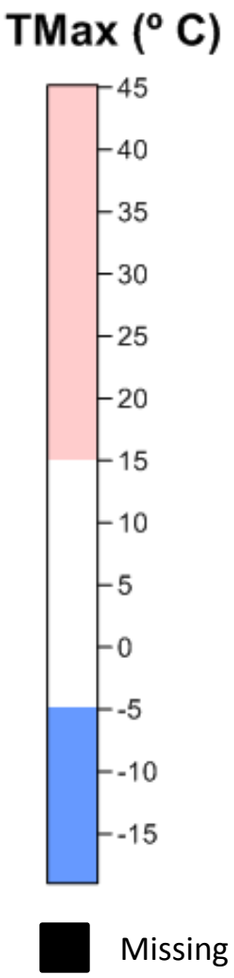


Temp threshold
-5° C, 15° C

Temp, SWE



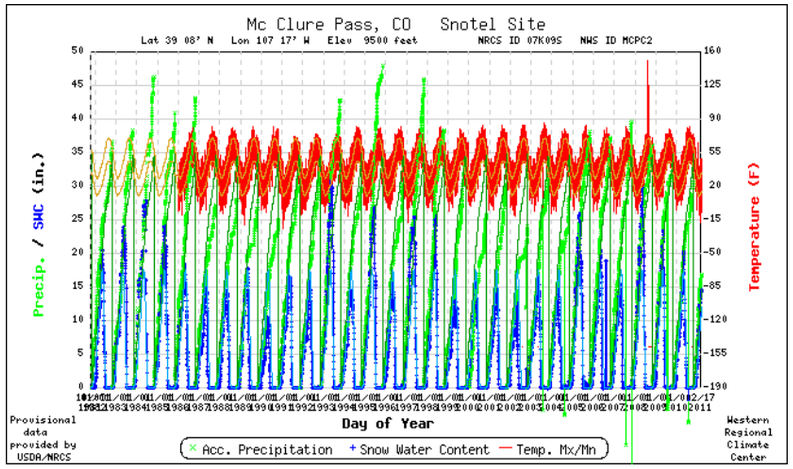


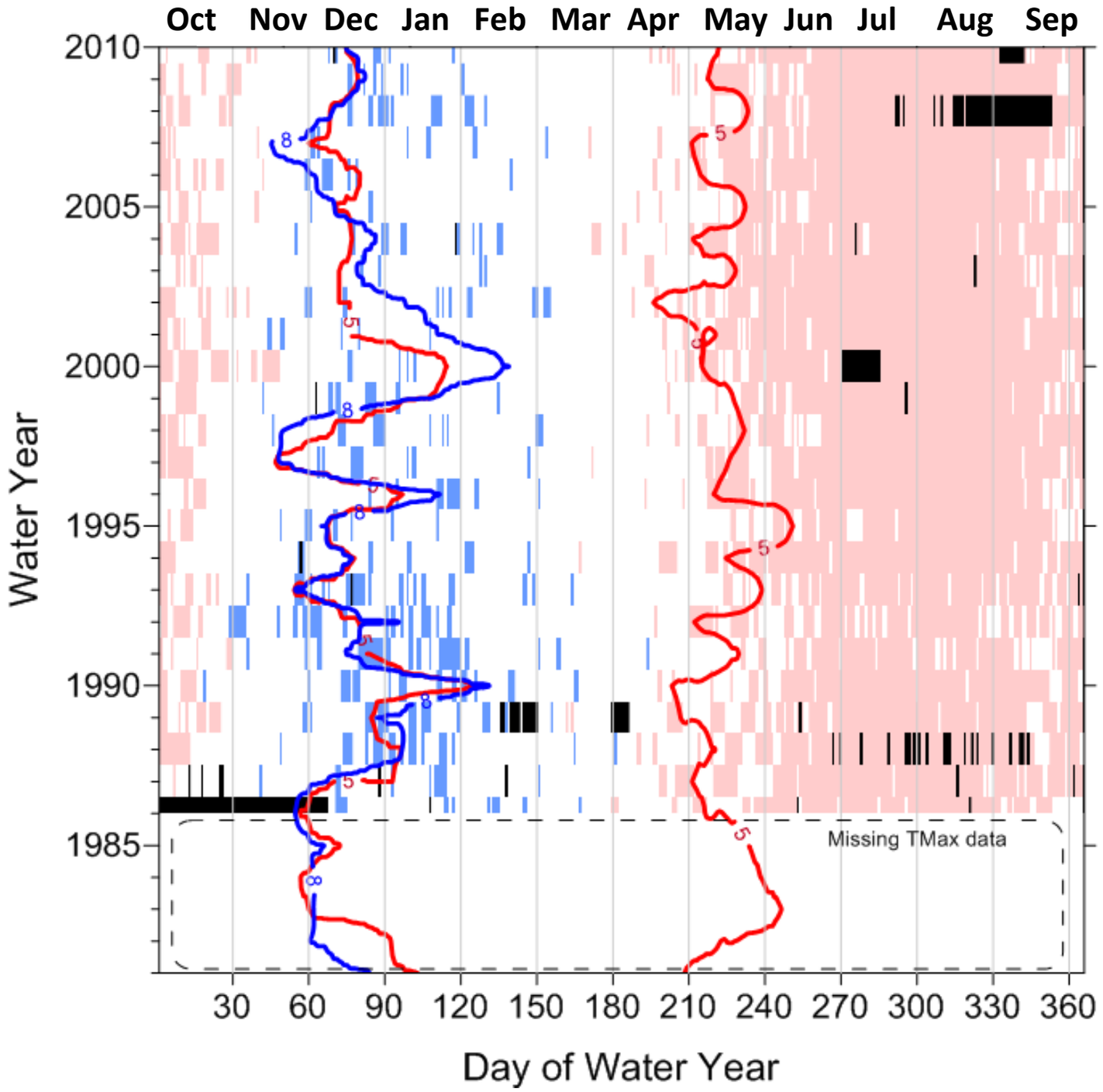


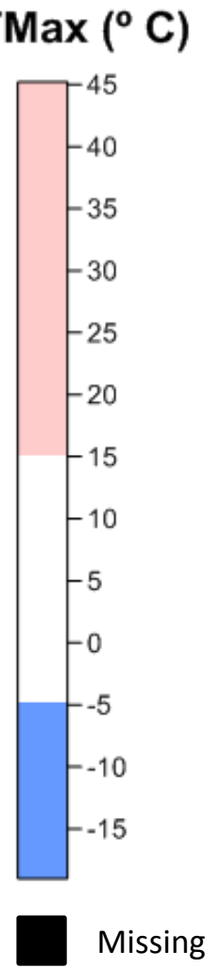
Temp threshold
-5° C, 15° C

SWE = 5 inches

Temp, SWE, Precip





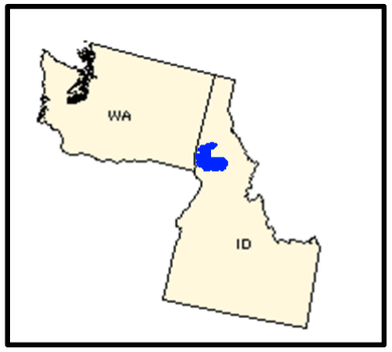


Temp threshold
-5° C, 15° C

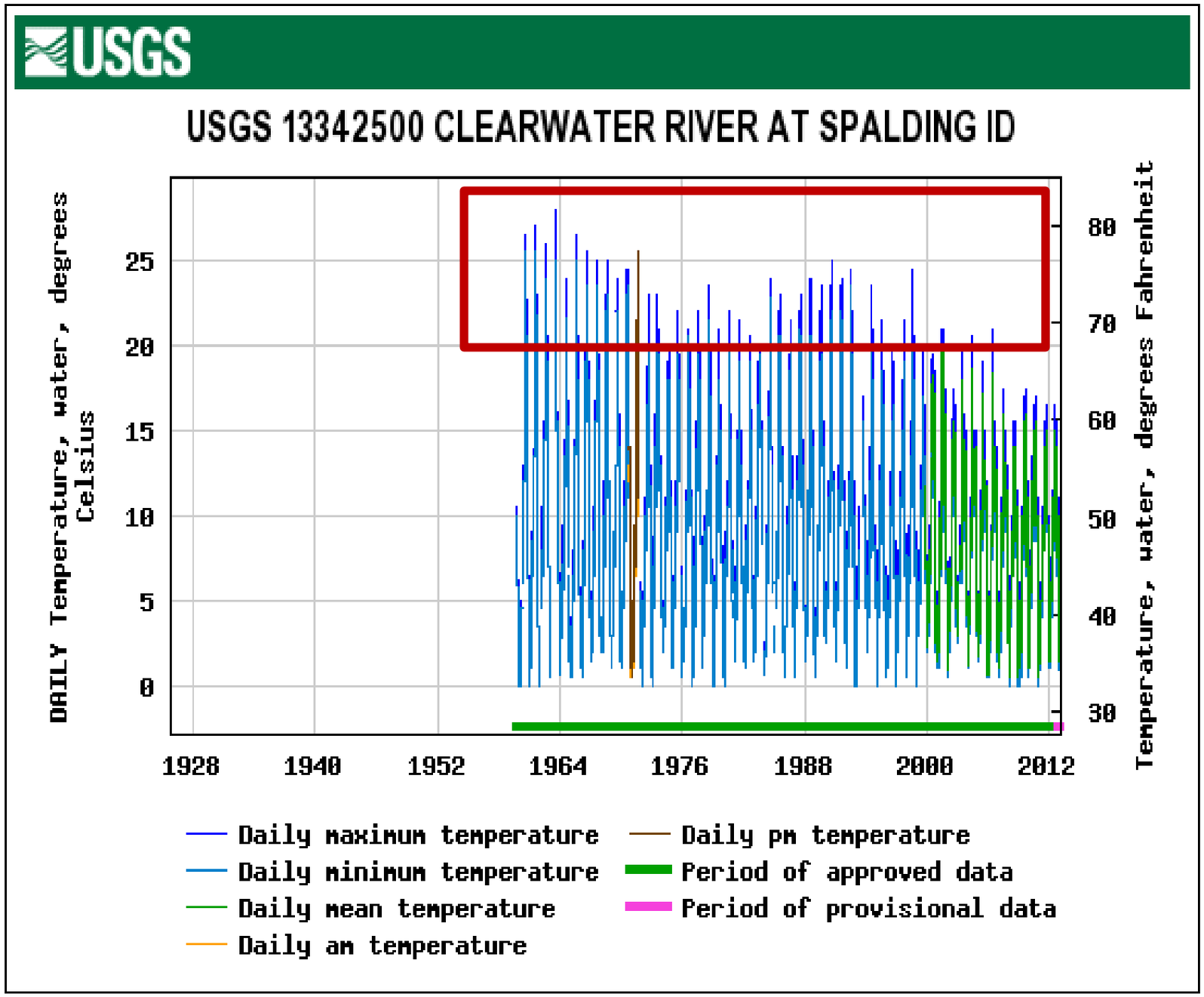
SWE = 5 inches

Σ precip = 8 inches

Application: Water temp

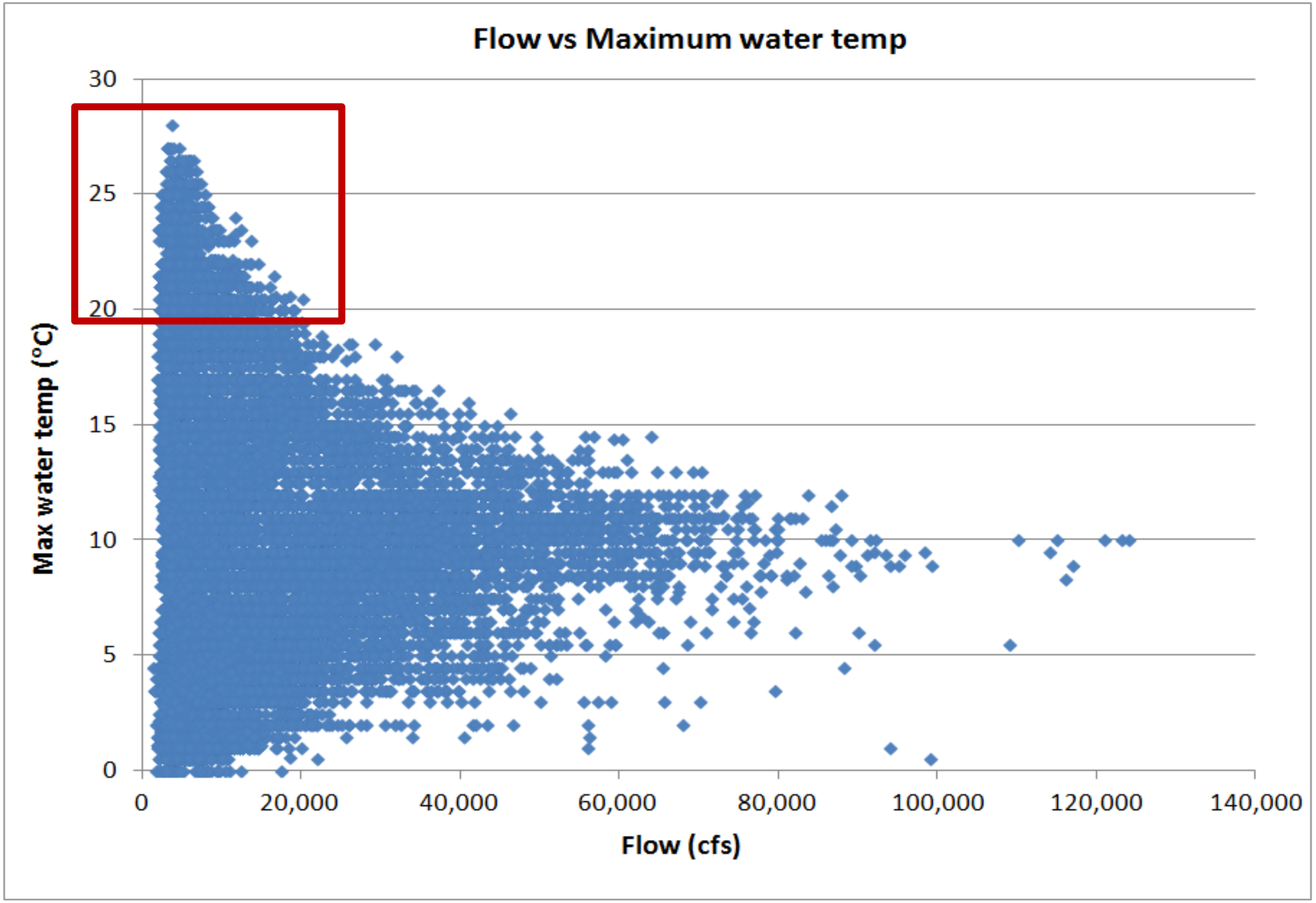


Indentify flows with maximum water temperature $\geq 20°$ C (68° F)



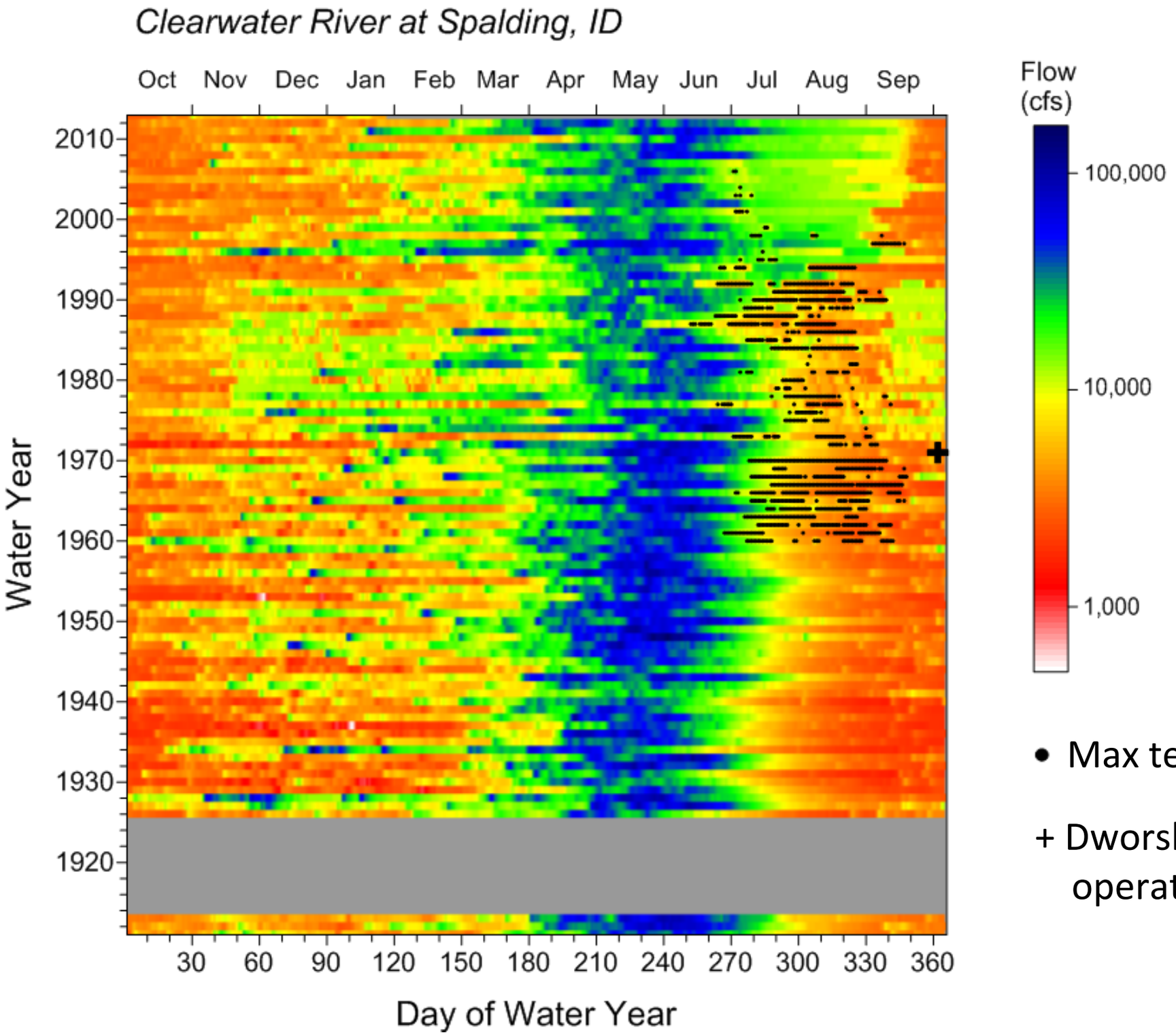
Max water temp vs flow

Indentify flows with maximum water temperature ≥ 20° C (68° F)



Max water temp vs flow

Flow, critical temperature and time

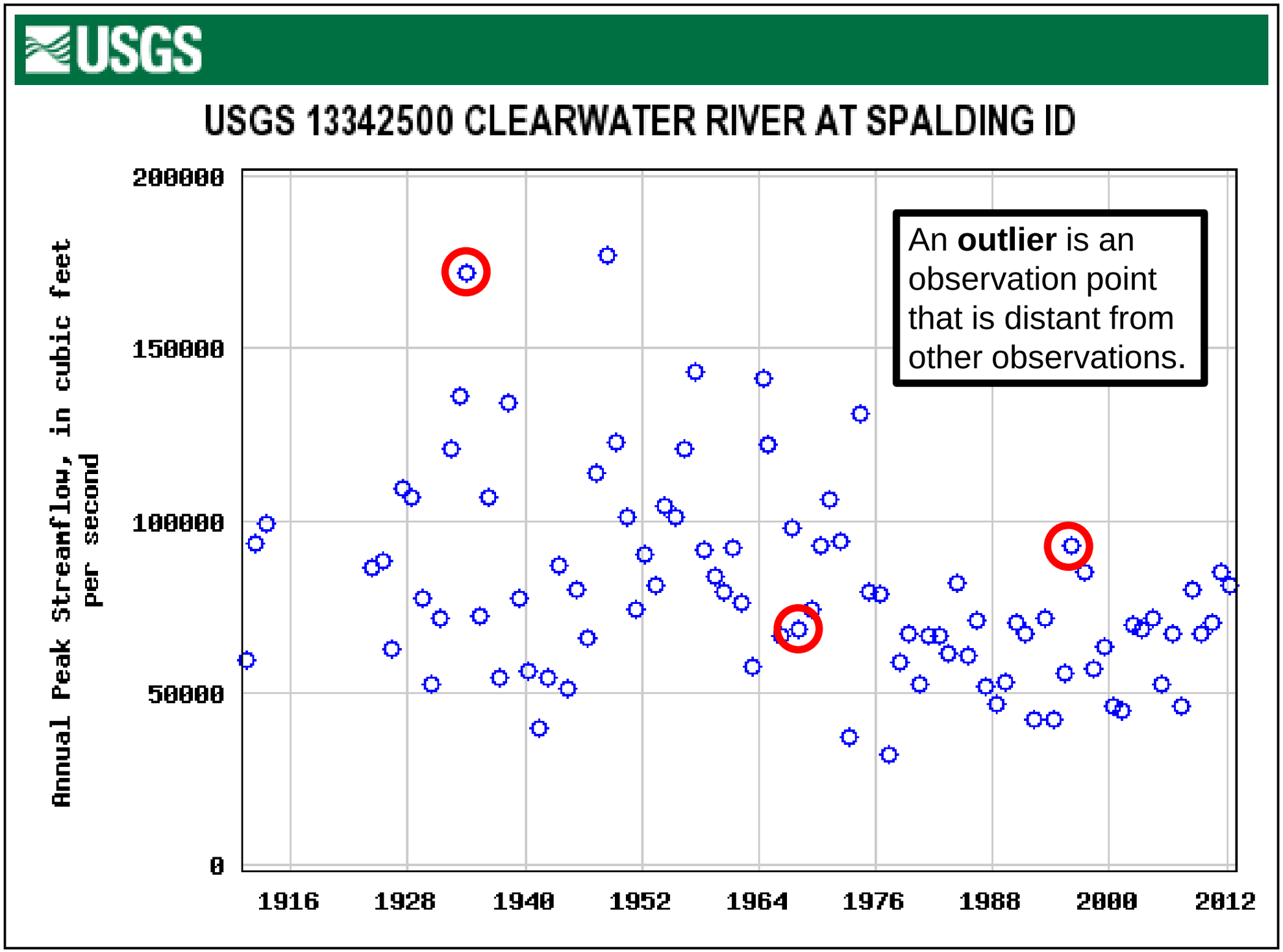


- Max temp $\geq 20^{\circ}$ C

+ Dworshak Dam operational

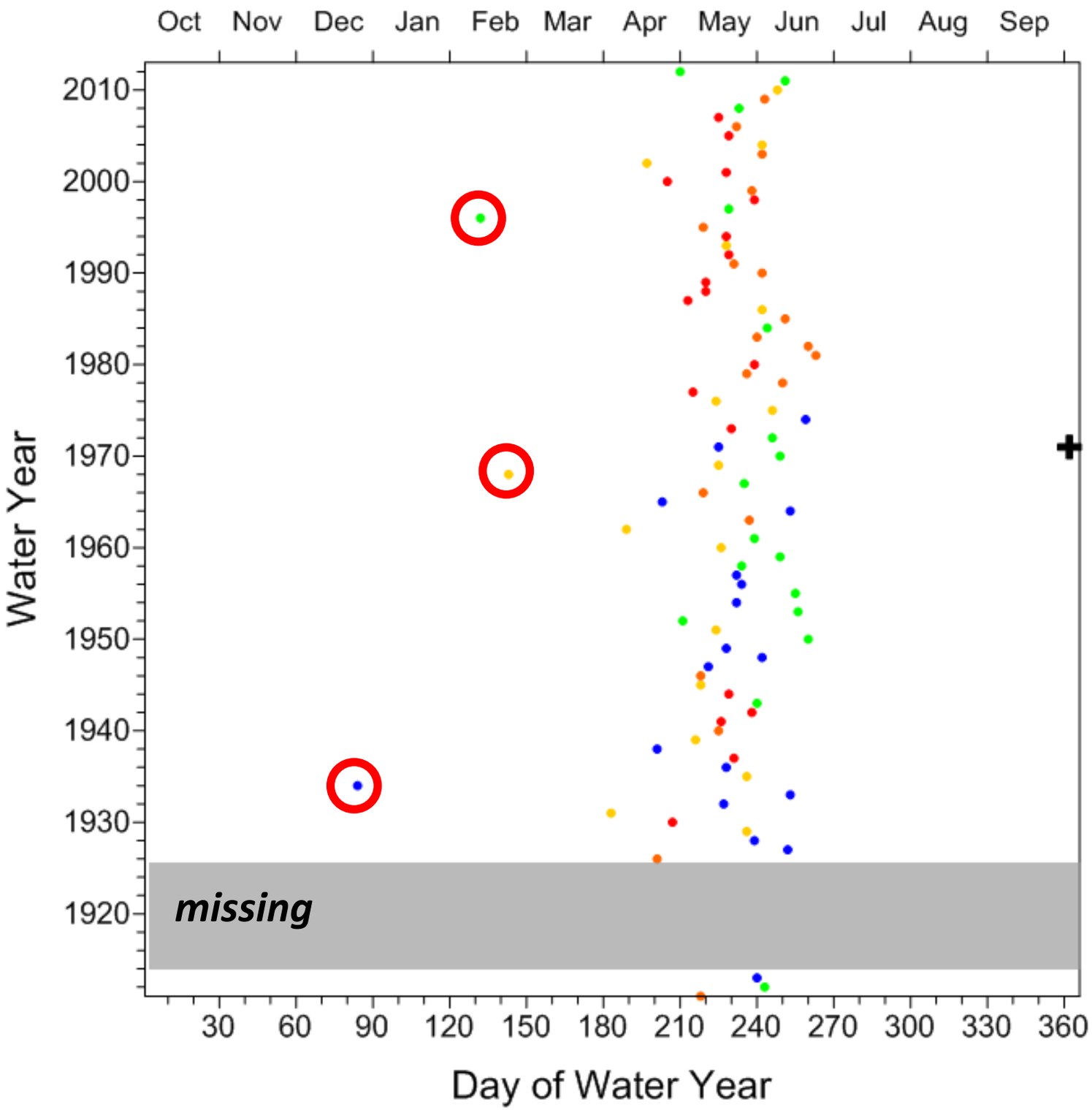
Application: Outlier detection

Annual maximum daily mean flow (cfs)



Outlier identification

Clearwater River at Spauling, ID



Streamflow (cfs)

- 97,600 to 166,100
- 75,600 to 97,600
- 65,200 to 75,600
- 53,400 to 65,200
- 28,500 to 53,400

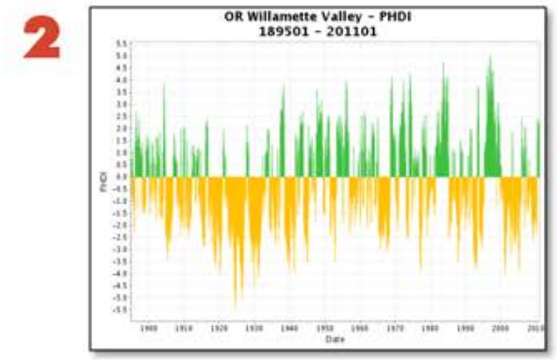
An **outlier** is an observation point that is distant from other observations.

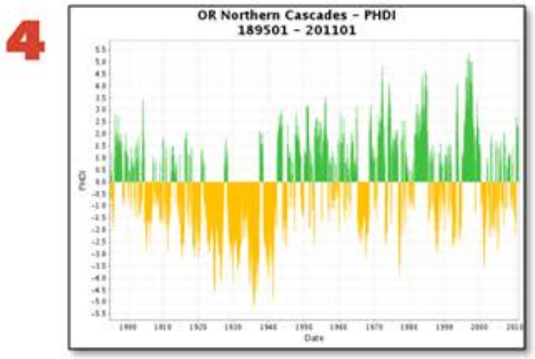
○ Temporal outliers

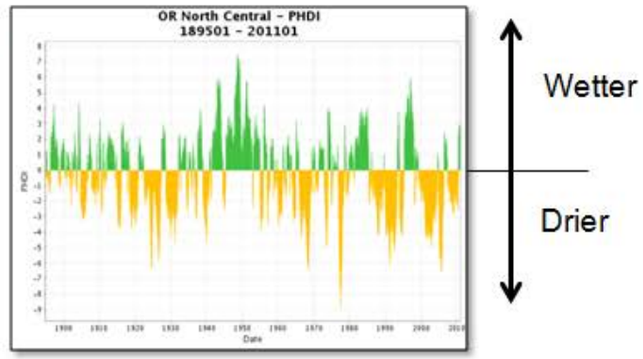
\+ Dworshak Dam operational

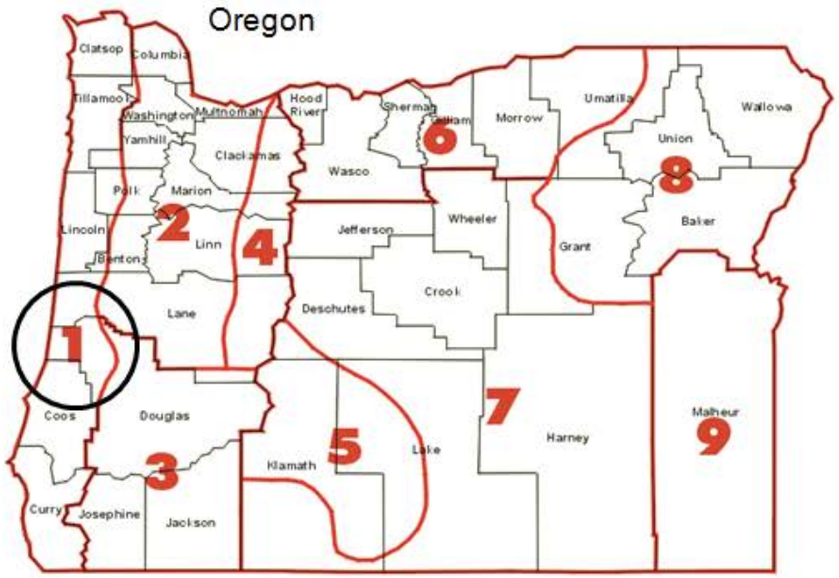
Application: Multi-site comparison

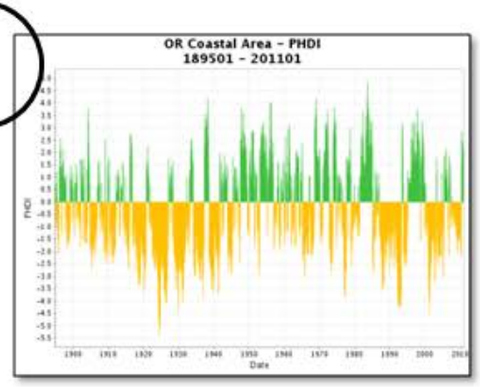
Drought index

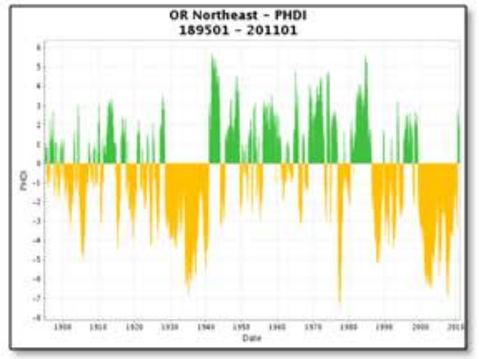


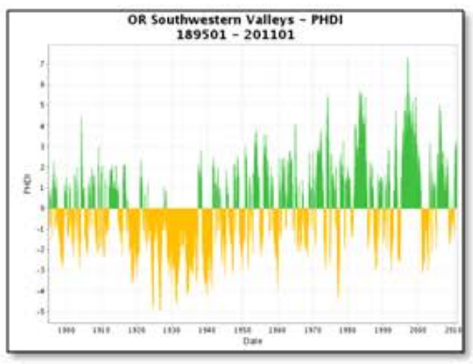


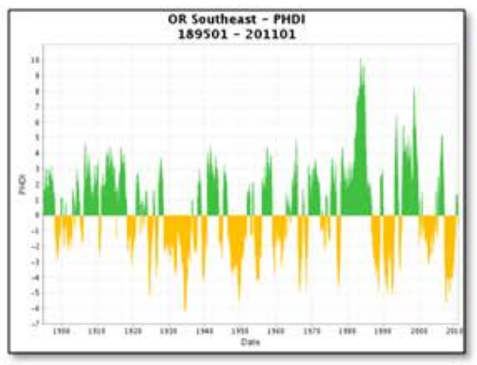


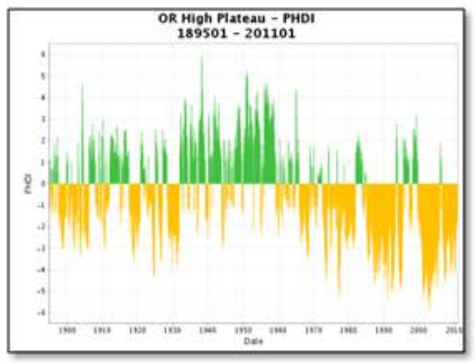


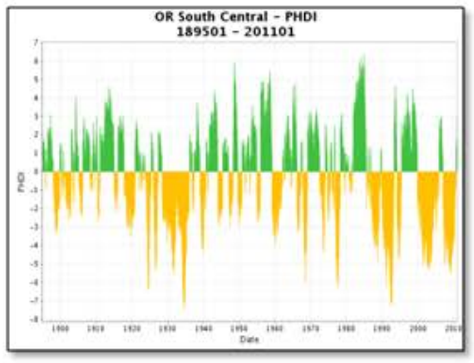




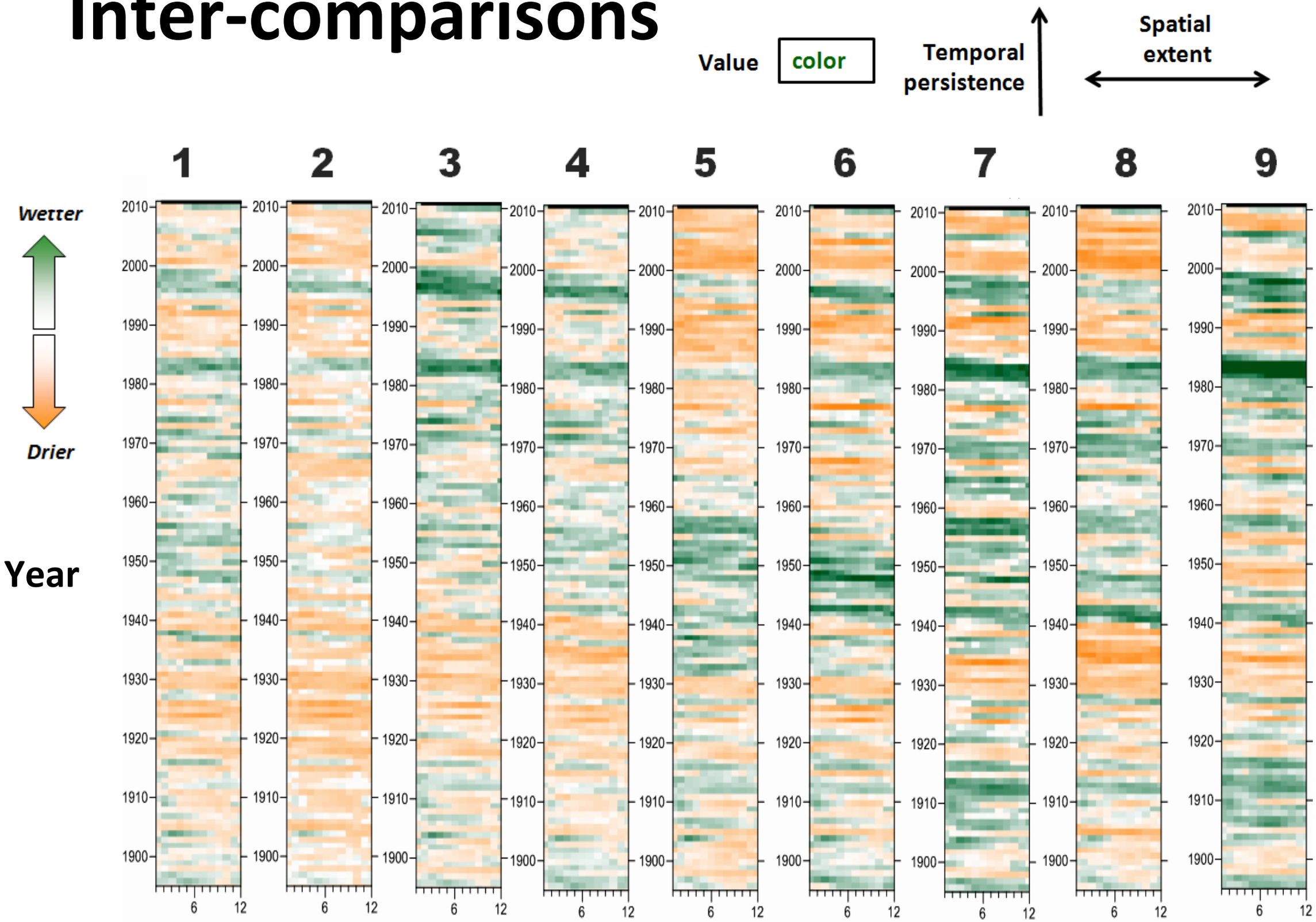






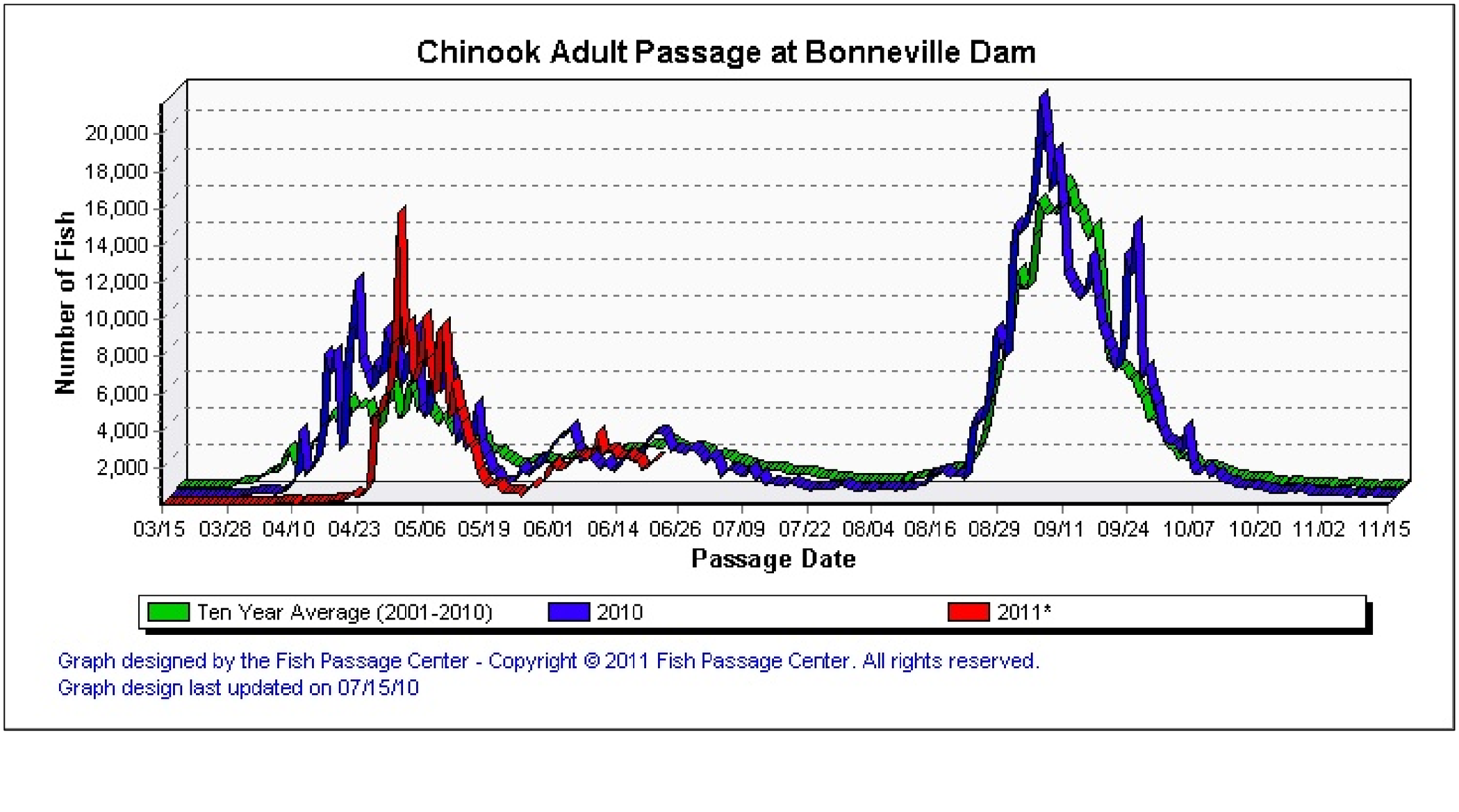


Inter-comparisons



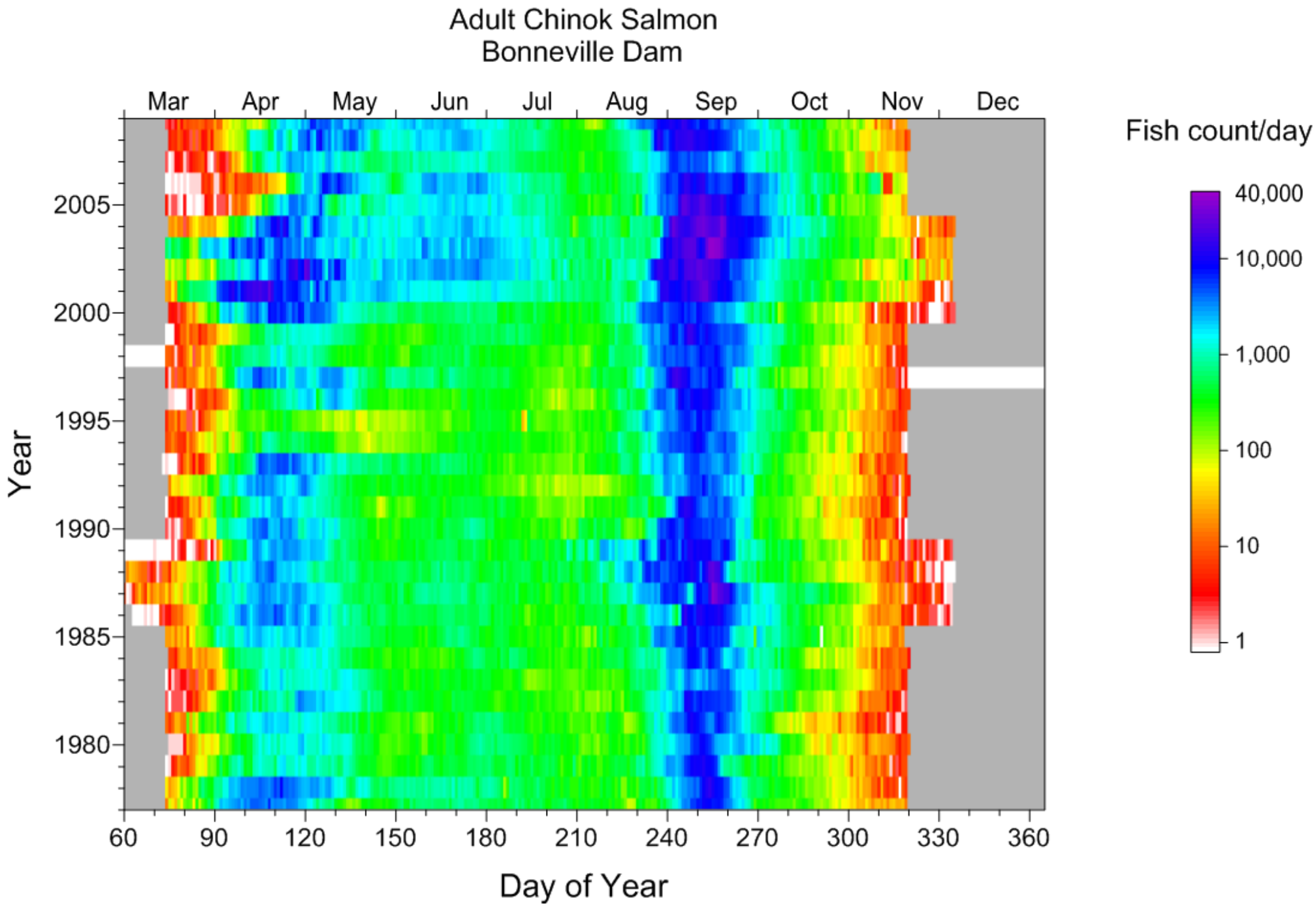
Application: salmon migration

Existing Bonneville Dam fish count plot



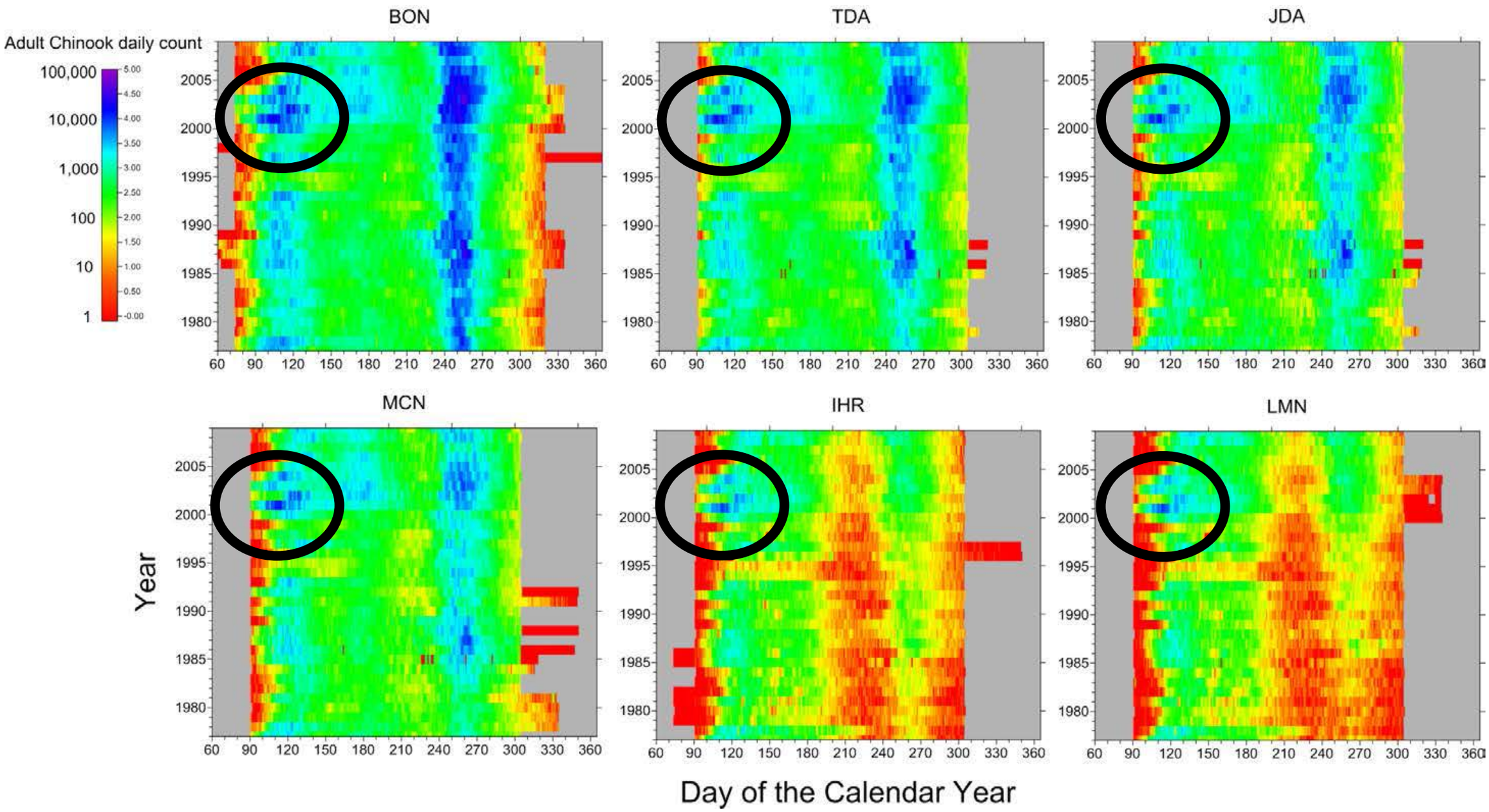
Site salmon migration

Bonneville Dam fish count – entire record



System salmon migration

Lower Columbia System fish count – entire record



Case study

Paralytic shellfish toxins in Puget Sound*

How can multiple environmental time-series be integrated into a single summary plot?

<u>Topics</u>

Water quality

Habitat monitoring

Hydrometeorology

Oceanography

Public health

Economics

Climate change

Decision support

Ecological forecasting and trends

Data visualization

* Moore, S.K., et al., 2009.

Aquatic habitat

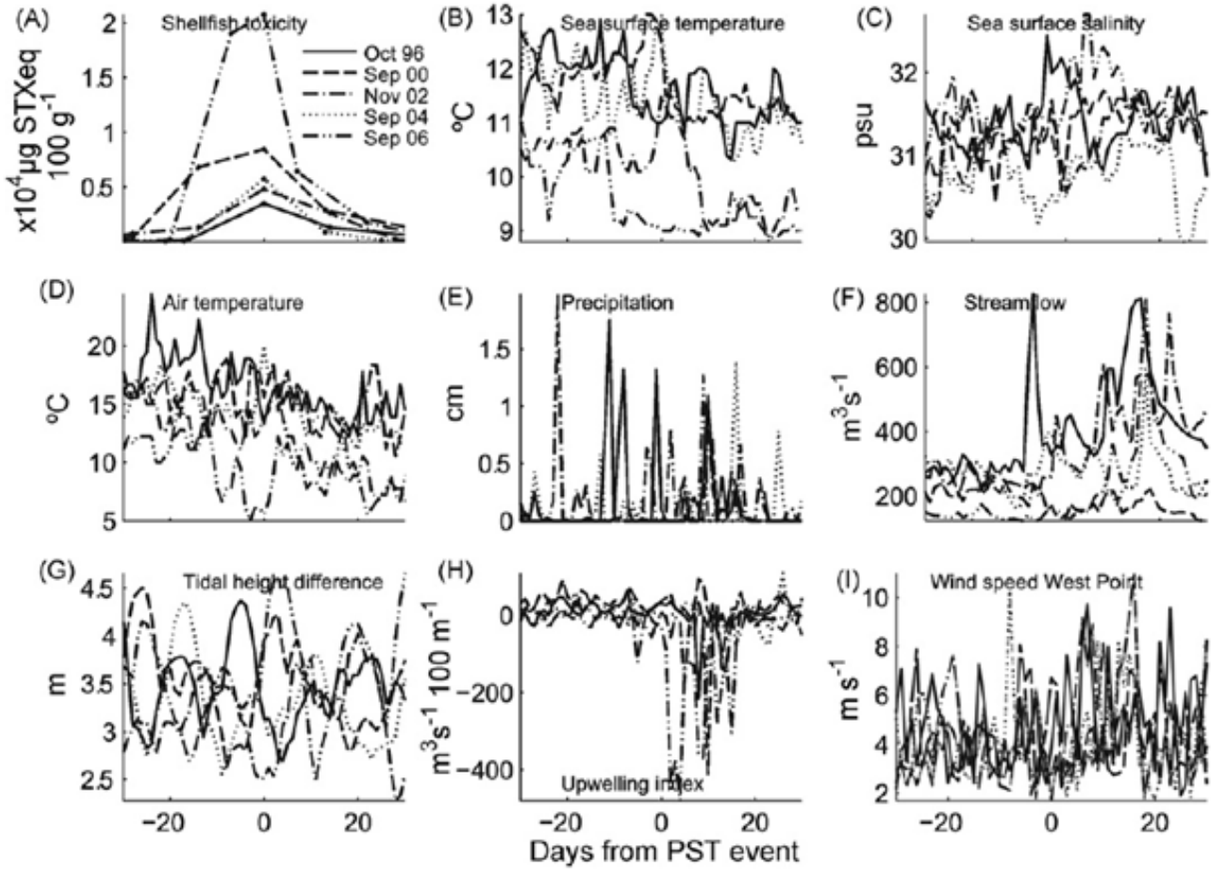
Background information

Time-series datasets:

Environmental factors

1. *Sea surface temp (°C)*
2. *Sea surface salinity (psu)*
3. *Air temp (°C)*
4. *Precipitation (cm)*
5. *Streamflow (m^3s^{-1})*
6. *Tidal height difference (m)*
7. *Upwelling ($m^3s^{-1}100\ m^{-1}$)*
8. *Wind speed (ms^{-1})*

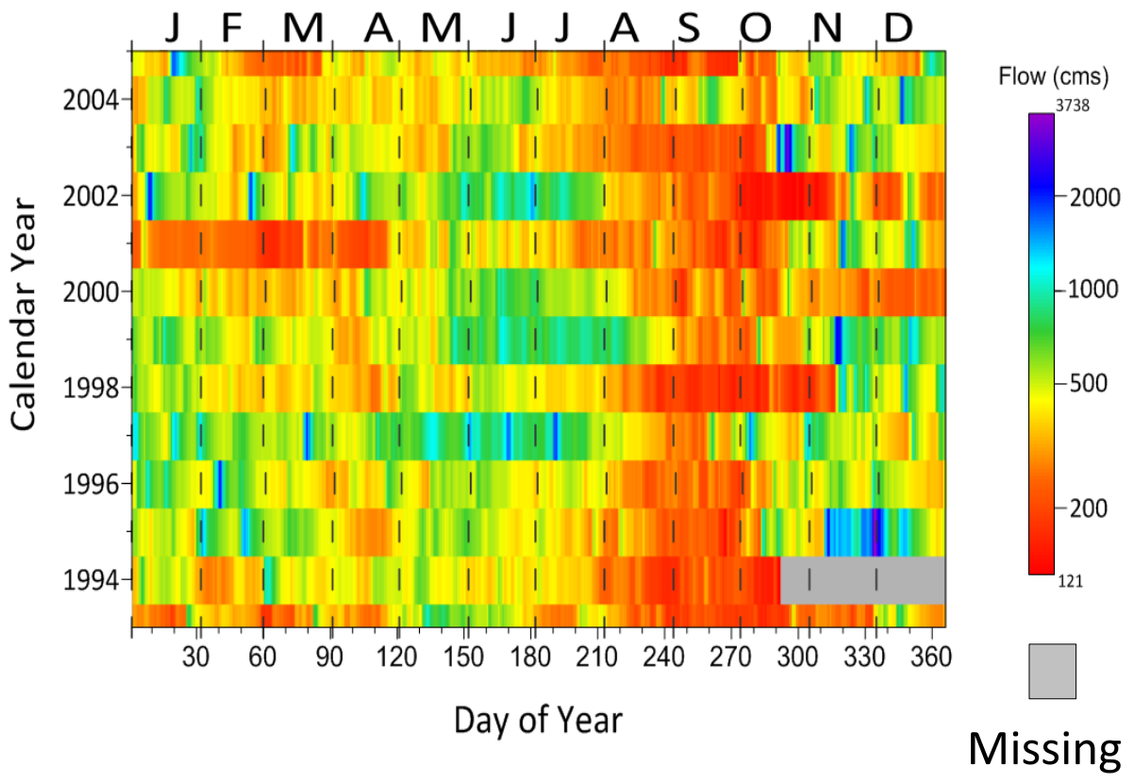
Traditional plots:



Criterion approach

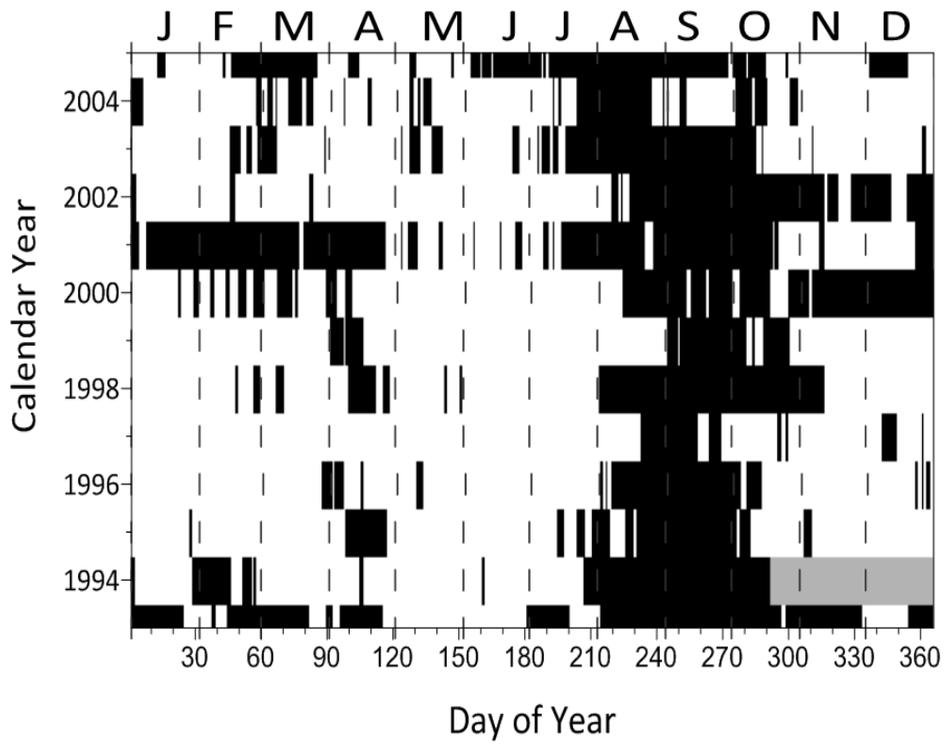
Binary filter

Observed streamflow



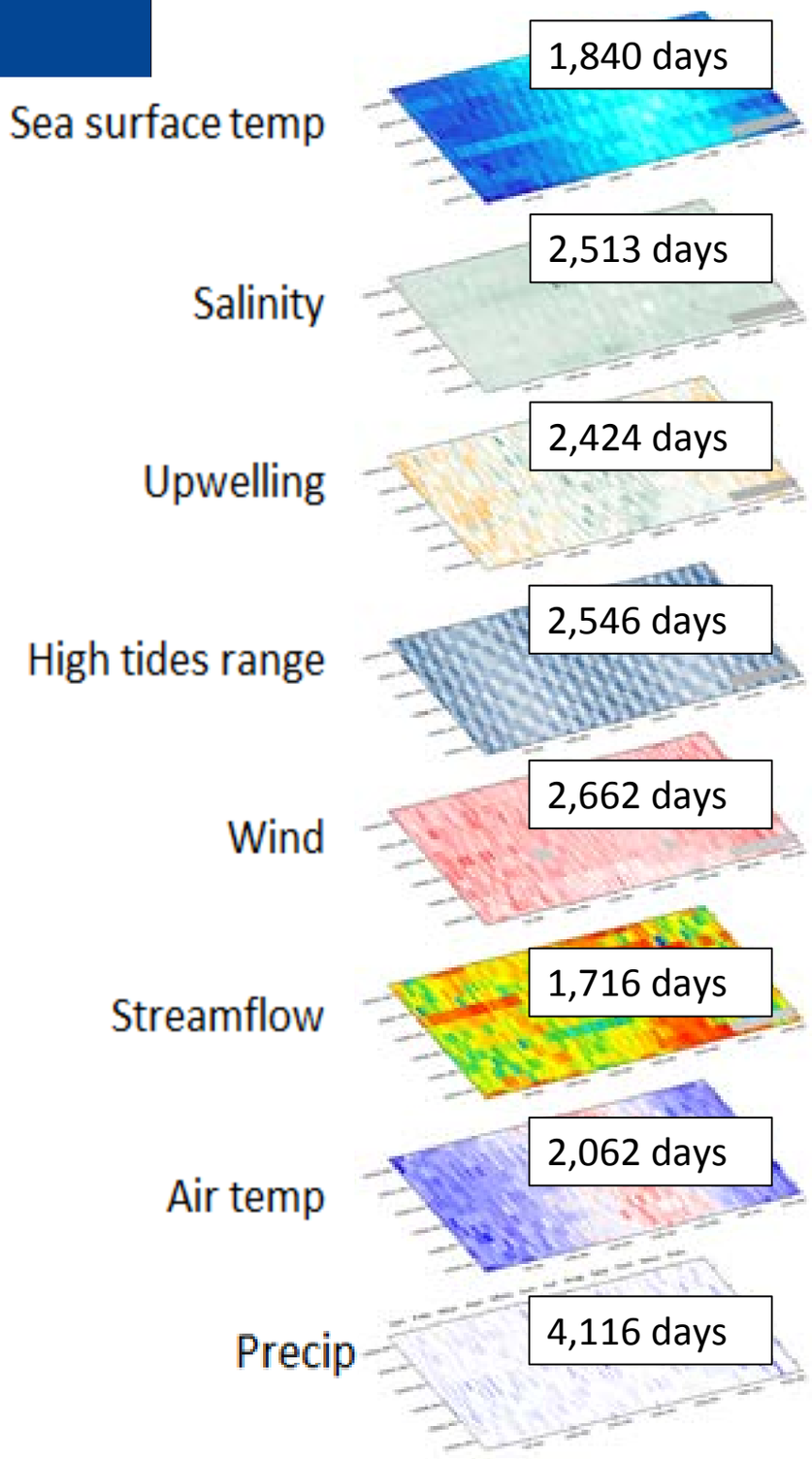
Flow ≤ 350 m^3s^{-1}

■ *Met = 1,* □ *Not met = 0*



1,716 days or "event windows"

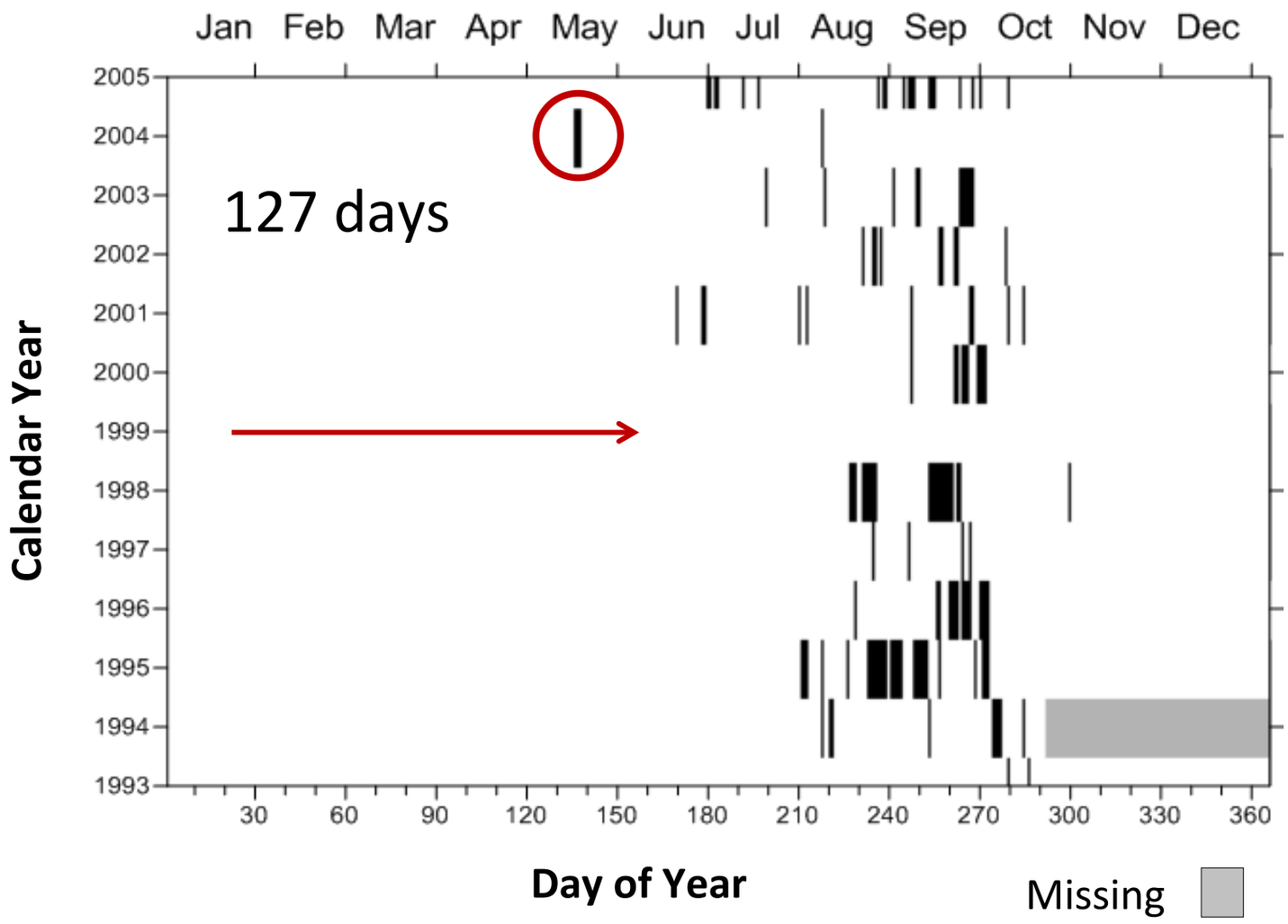
Analysis results



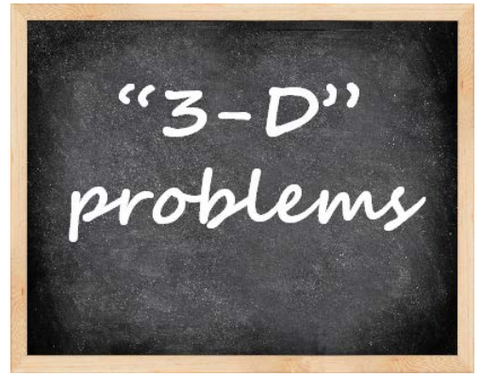
Apply specific criterion to specific layer

If Σ layers = 8 for specific day;
Then event window present

Potential Event Windows

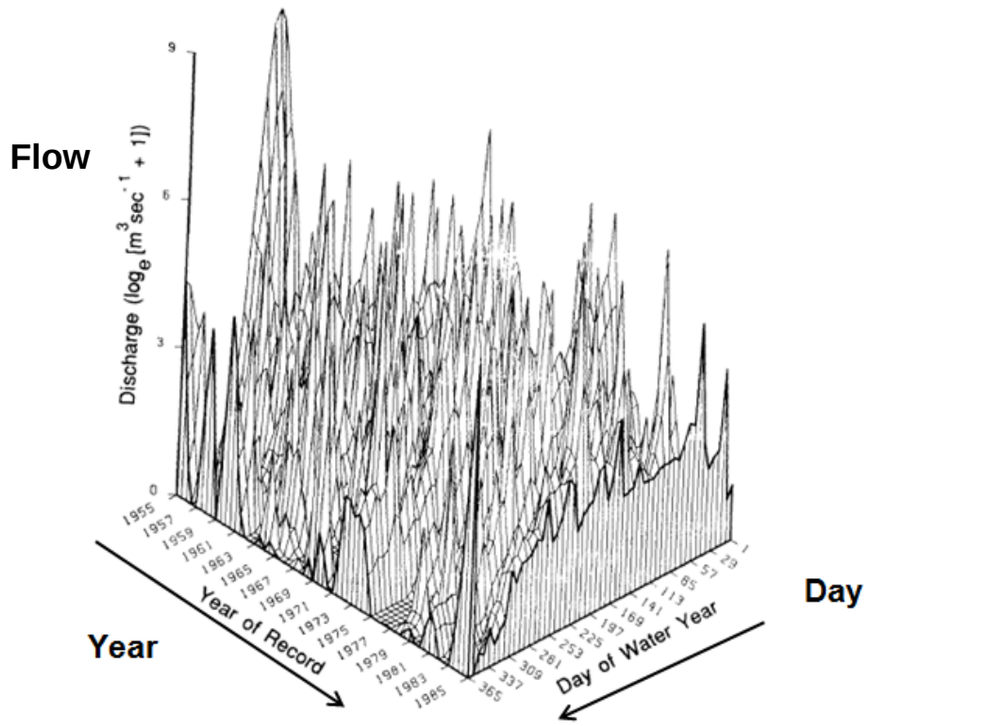


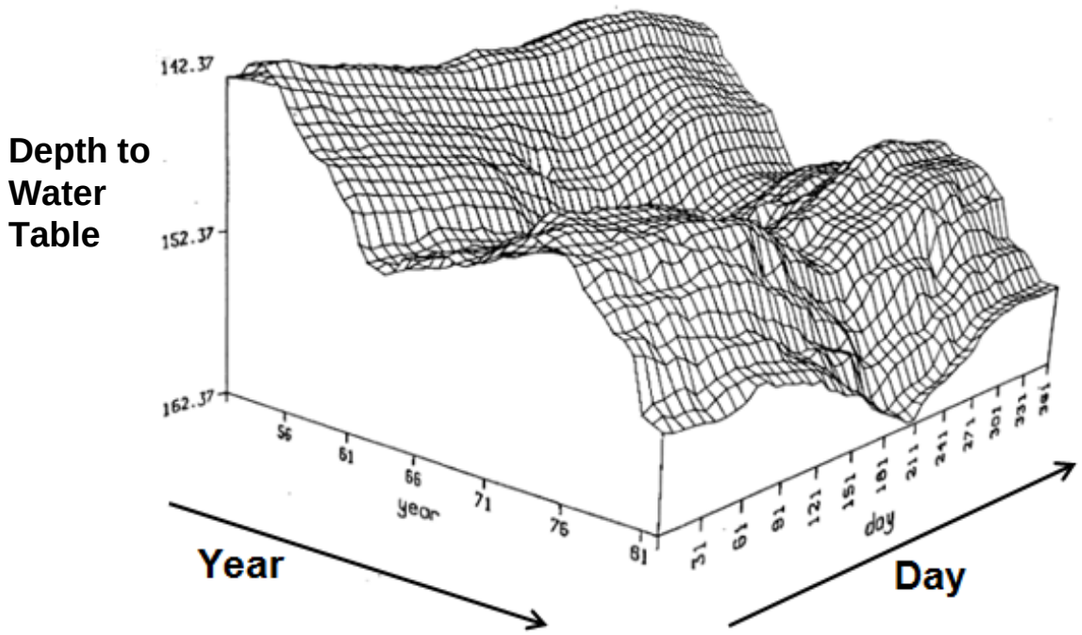
Problematic: 3-D plots

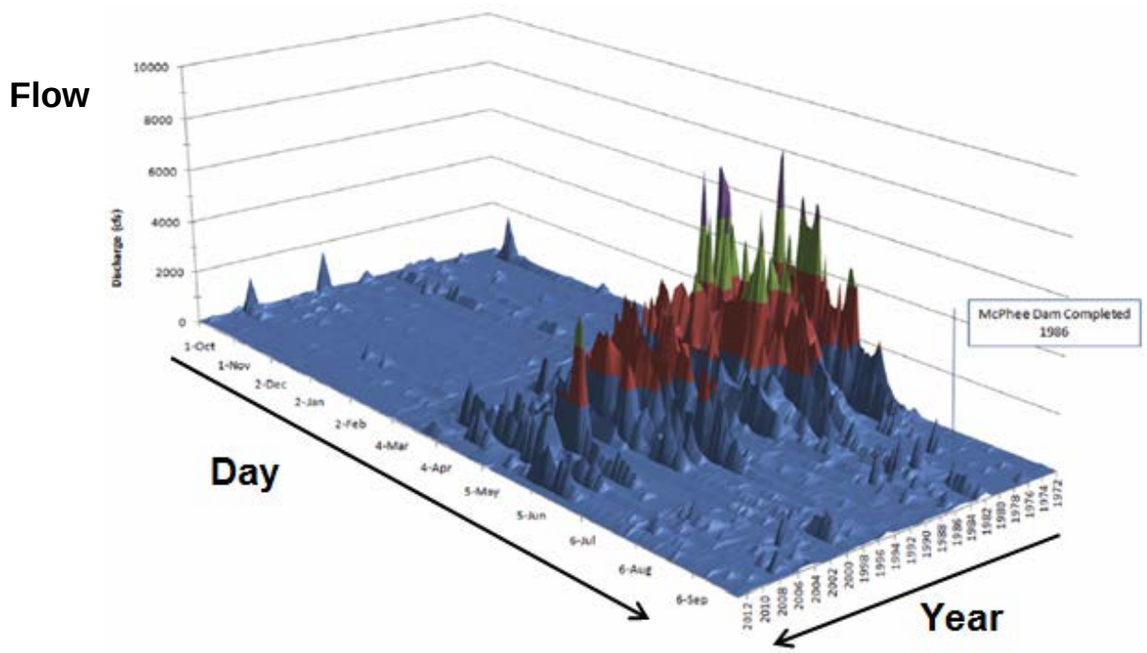


- **Perspective**
  - View direction
  - Hidden data
  - Lighting angle
  - Surface texture
- **Graph display issues**
  - Axis labels
  - Axis direction
- **Limited analysis**

- **Temporal data ≠ Spatial data**







Raster Users

Bureau of Land Management
National Park Service
NOAA
US Army
US Fish and Wildlife Service
US Forest Service
USDA – Agricultural Research Service
US Geological Survey

Idaho – WRRI
New Hampshire – Environmental Services
Hood River, OR – Water Planning Group

Brazil - National Water Agency
Republic of Ireland - EPA

Arizona State University
Fort Lewis College
Juniata College
Kent State University
North Dakota State University
Oregon State University
Texas A &M
University of Massachusetts - Amherst
University of North Carolina - Charlotte
University of Arizona
University of Oregon
Virginia Tech University

Nat. Center for Atmospheric Research
The Nature Conservancy
Normandeau and Associates, Inc

Brazilian National Water Agency (ANA)

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RMetS
Royal Meteorological Society

Pluviometric ID: precipitation characteristics at a glance

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Abstract

This article proposes the Pluviometric ID, a graphic representation of the main precipitation characteristics from a given dataset. The Pluviometric ID exceeds the traditional depiction of rainfall data as it allows a fast and simultaneous perception of parameters such as seasonal and interannual precipitation pattern changes, historic data series (length and integrity), cumulative and distributed (daily) long-term mean precipitation, among others. When plotted on a web map, the Precipitation ID quickly projects the regional precipitation patterns and trends towards a particular visually chosen direction. Non-standard patterns may eventually arise and be easily spotted.

Keywords: **precipitation data analysis; precipitation visualization; pluviometric ID**

Summary

- Natural way to view large datasets
- Quickly review and interpret
- Develop new types of products and analyses
- Cost effective and time efficient method

References

de Pessôa, J. A. 2014. Pluviometric ID: precipitation characteristics at a glance. Atmosph. Sci. Lett.. doi: 10.1002/asl2.501

Koehler, R. B., 2004. Raster Based Analysis and Visualization of Hydrologic Time - Series. Ph.D. dissertation, University of Arizona. Tucson, AZ, 189 p.

Long, K. S. 1994. Time Scale Analysis Can Assess Hydrologic Cumulative Impacts. WRP Technical Note HY-IA-2.2. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Moore, S.K., et al., 2009. Recent trends in paralytic shellfish toxins in Puget Sound, relationships to climate, and capacity for prediction of toxic events. Harmful Algae 8, 463–477. doi:410.1016/ j.hal.2008.1010.1003.

Olden, J.D., and N.L. Poff. 2003. Redundancy and the choice of hydrologic indices for characterizing streamflow regimes. River Research and Applications 19, 101-121.

Thank you!

Questions?

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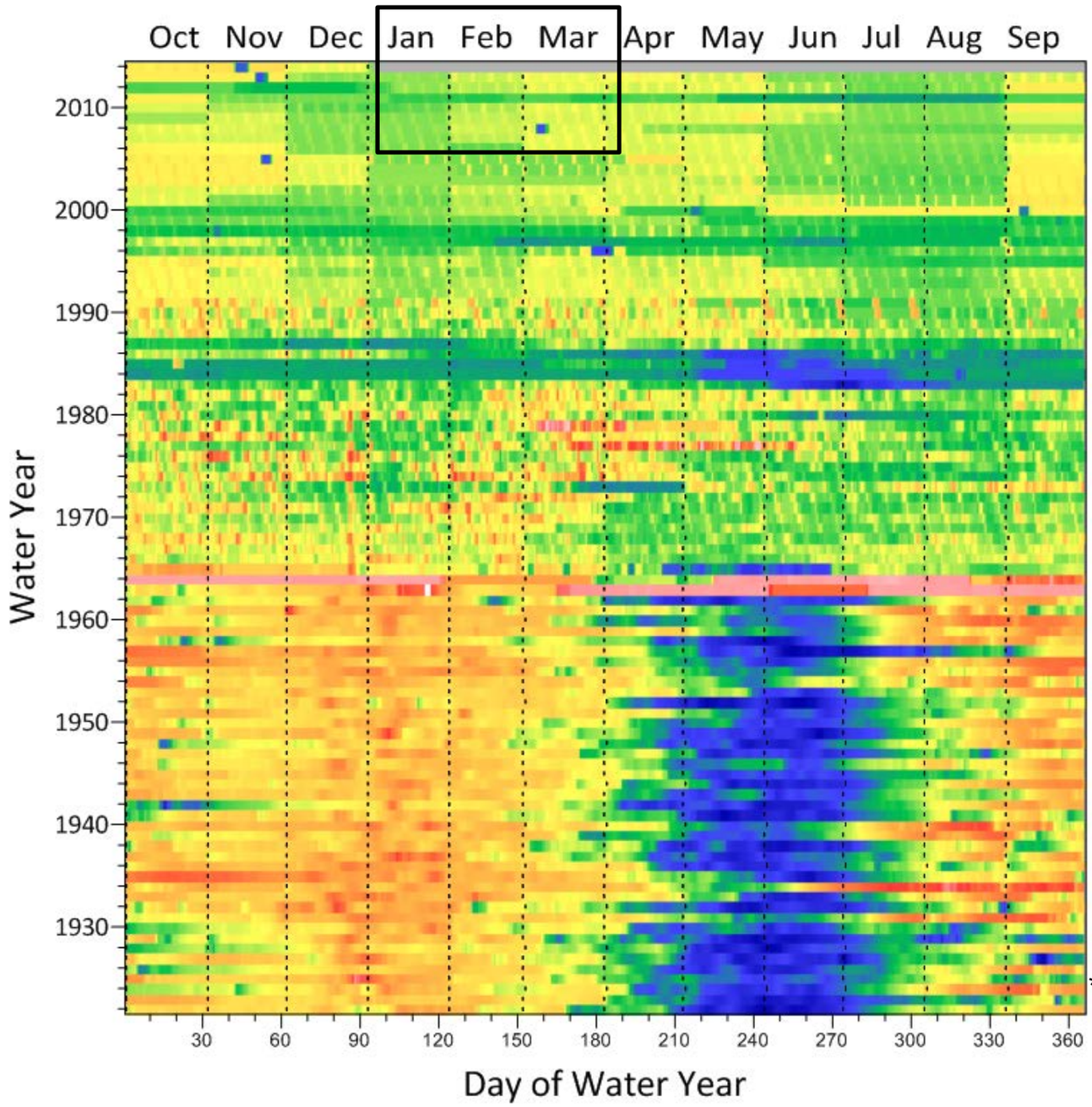
Extra slides

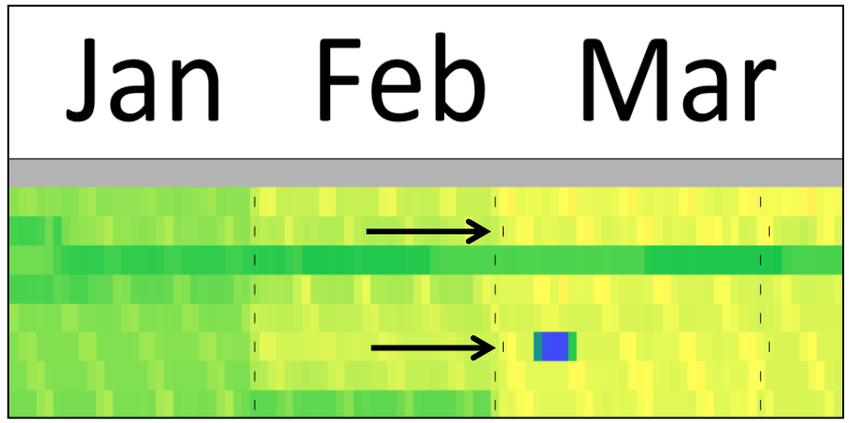
Raster hydrograph

Colorado River at Lees Ferry, AZ

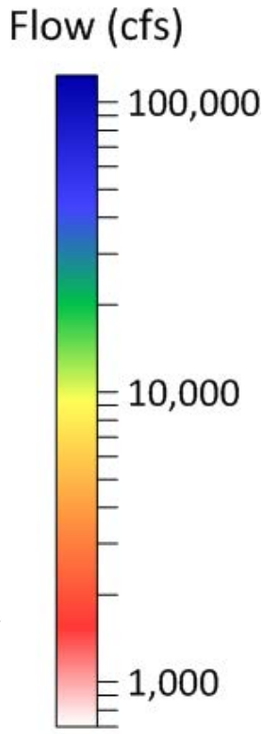
92 years of daily data (33,700 values)



*



Leap years



* *Glen Canyon Dam*