Innovative ways to visualize and analyze environmental time-series data

Source: nps

Source: nrcs

Source: noaa

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Why this talk?

Big Data!

- Critical for ecosystem management

  Understand/restore/protect
  Forecast/predict/monitor
  Budget time and resources

- Expand data analytics

  Observed and generated data sources
  Data configuration

Focus on time-series

Tools – both qualitative and quantitative

- Interpretation

  Visual data exploration – pattern identification

  Summarize situation for management

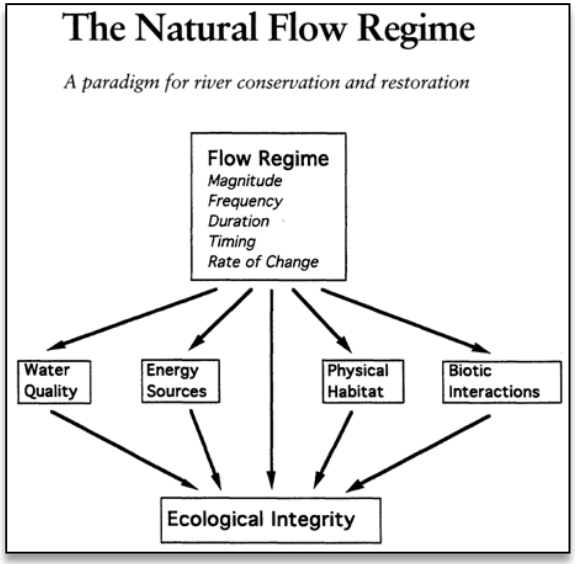
- Analysis

  Quantify patterns

  Use GIS to evaluate data configuration

- Actionable results

  Defendable decision support



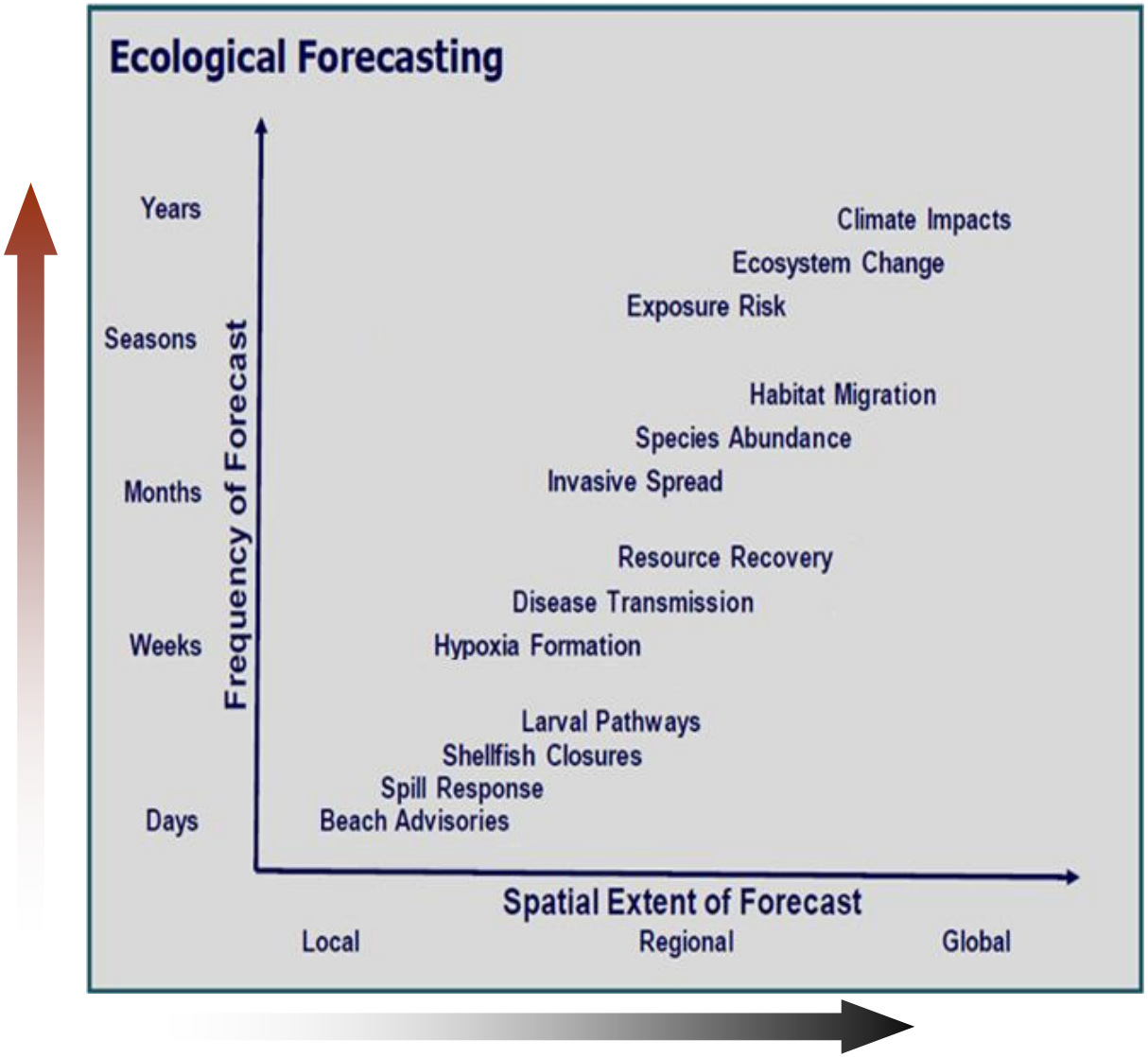
Data visualization goals

- Show all data – don’t hide or distort
- View multiple timescales simultaneously
- Compare within and between datasets
- Display a large range and amount of data
- Identify trends and patterns - natural and artificial
- Locate outliers and anomalies

Patterns - training your eyes to see

Source: http://www.coolbubble.com

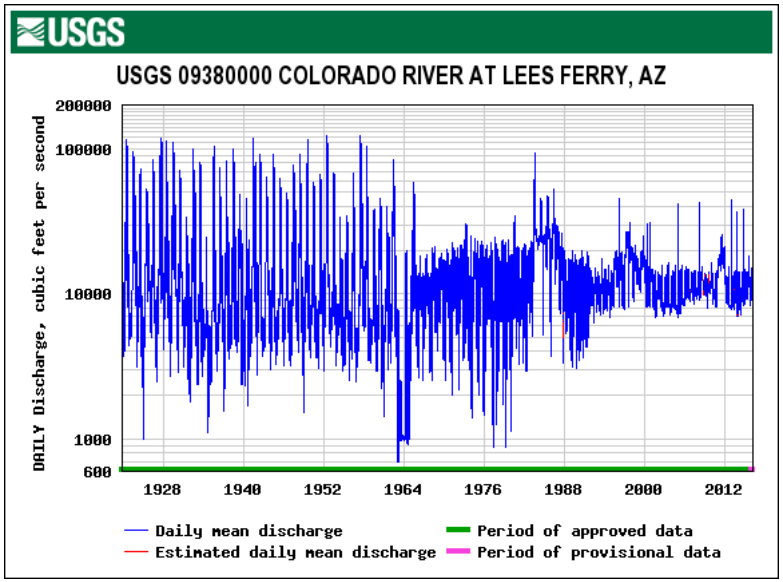
Time and space scales - ecology

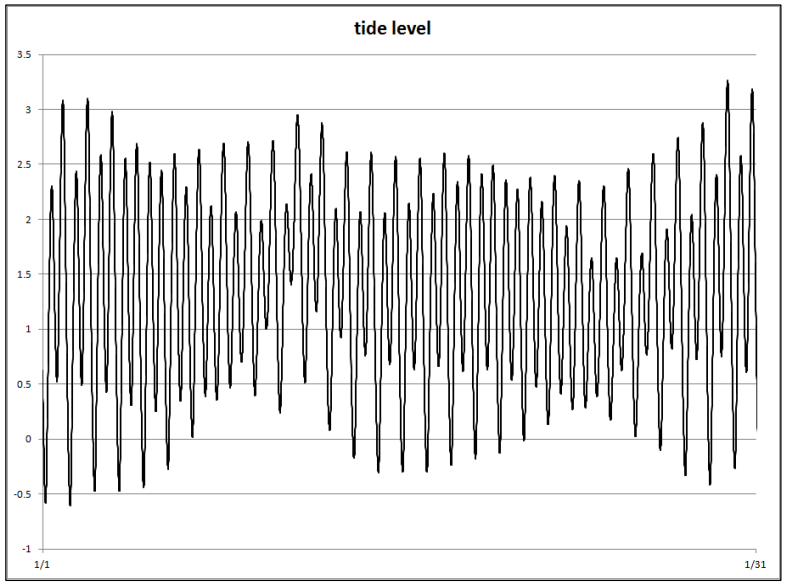


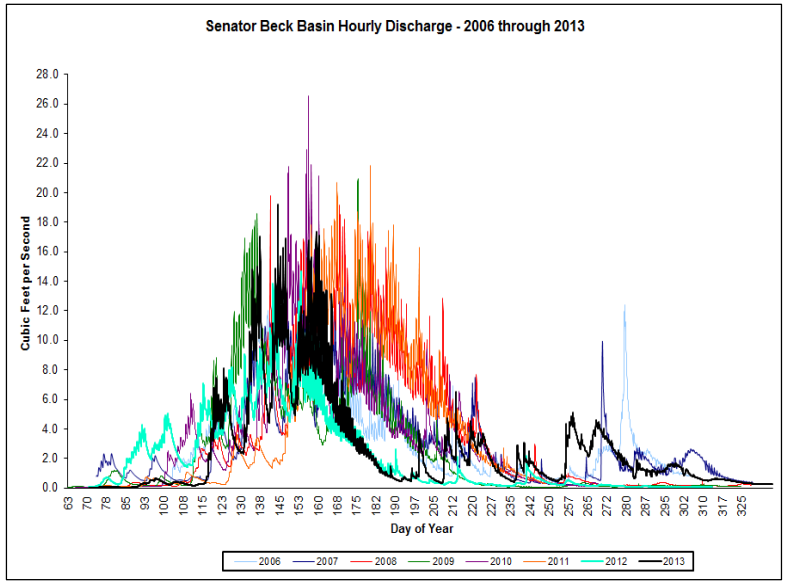
Source: NOAA

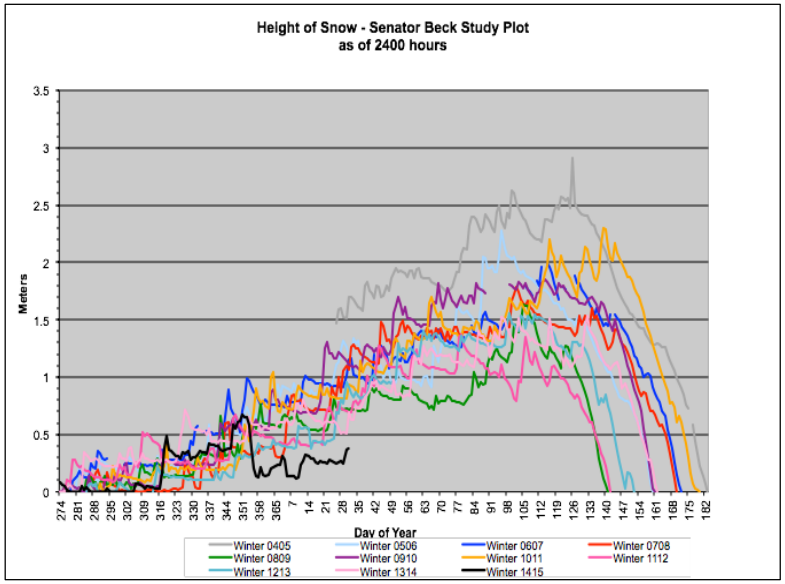
Time-series data displays

Source: USGS, NOAA, CSAS









Issue: Composition vs Configuration

(order is not a factor) ***(order is fundamental)***

- Time-series are sequential
- Most metrics are composition-based

  Mean, median, count, percentile, min, max, flow duration,…

- Configuration-based metrics needed

  Attributes of data arrangement

  Reflect data order

  Sequence information

- Example: 60 years of record, 60 years at a time

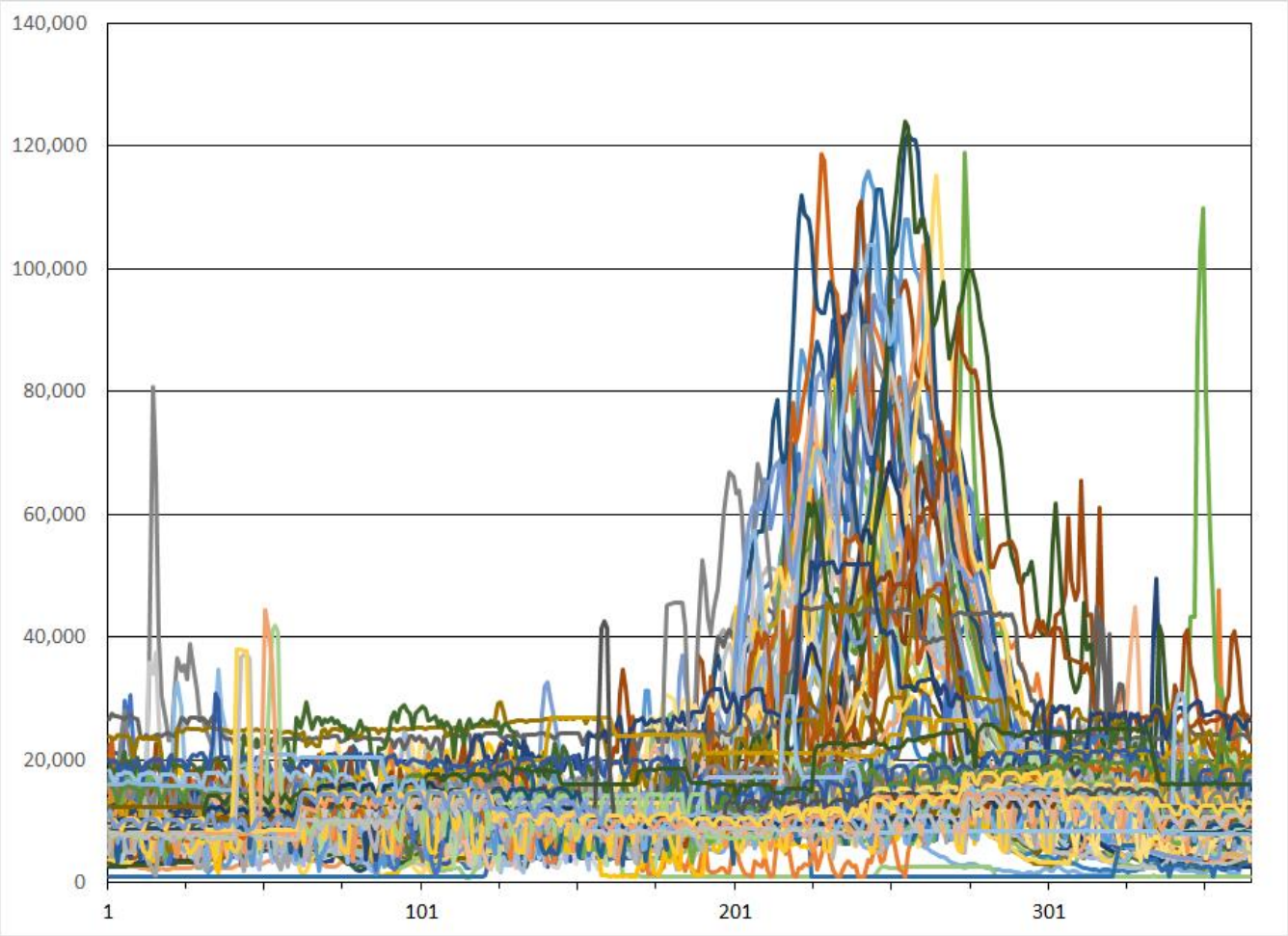
  Combinations = C(60,60) = 1

  Permutations = P(60,60) = 8.32×10^{81}

Spaghetti plot

Assumption: Lines are within a single plane

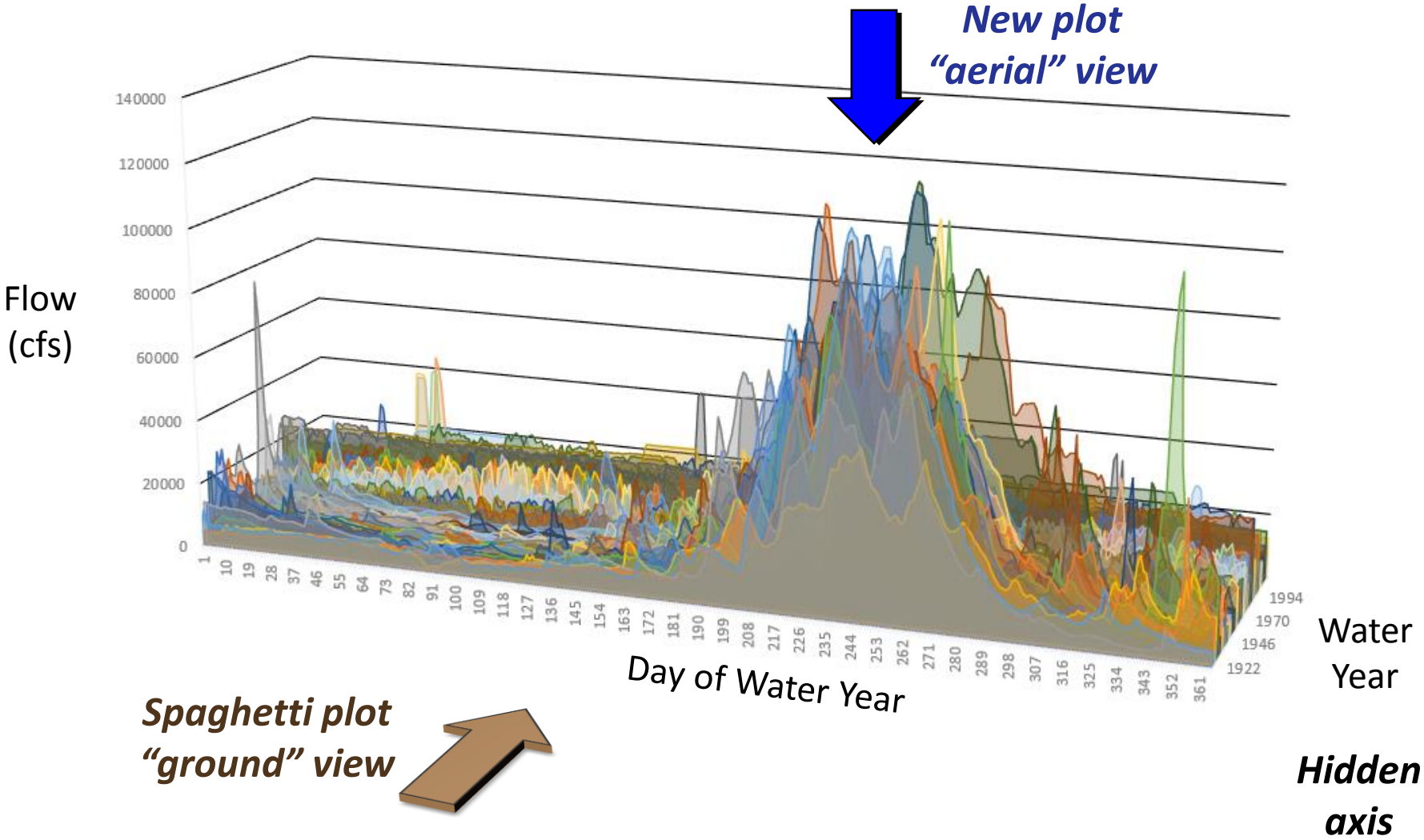
Flow (cfs)



Day of Water Year

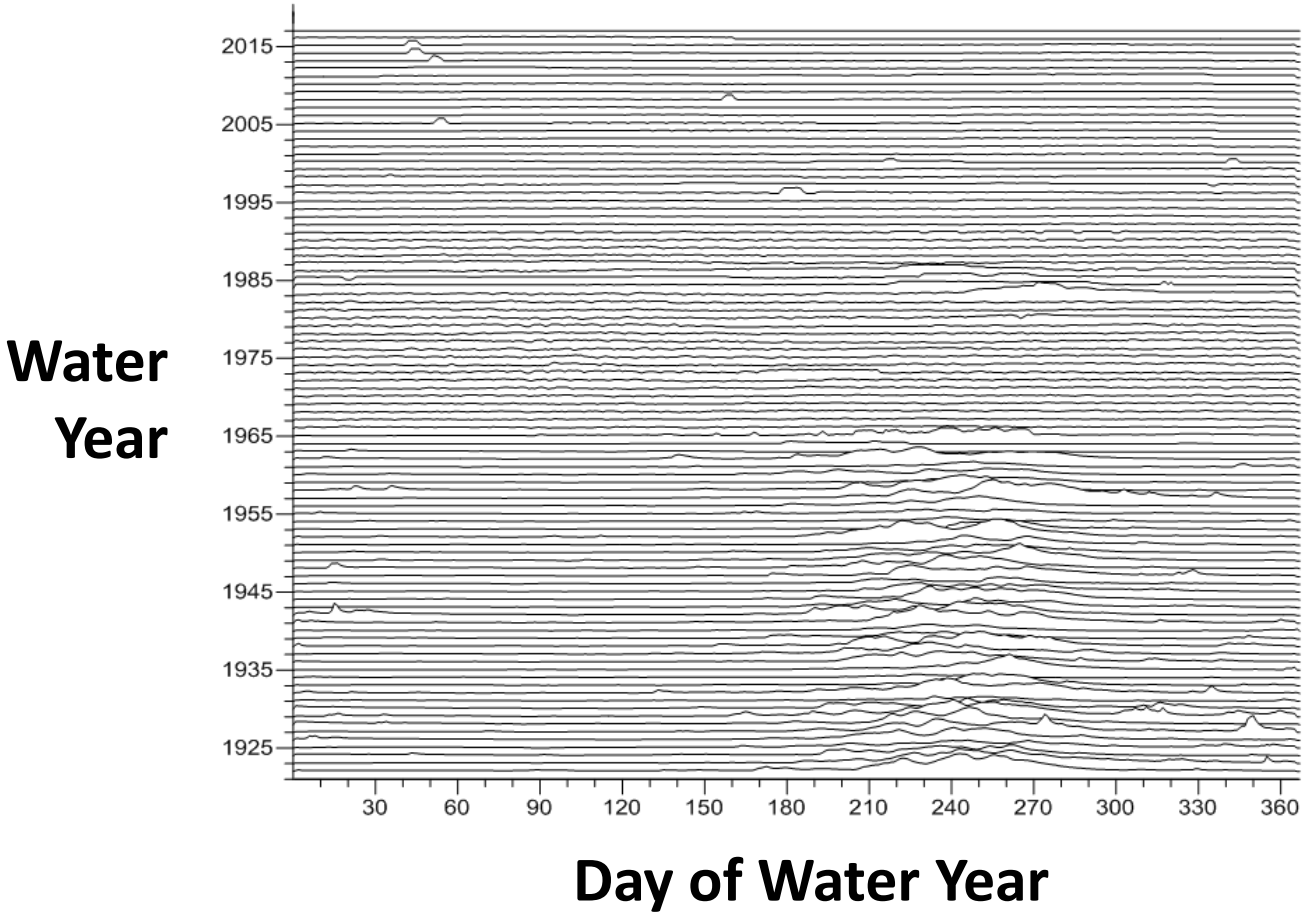
New approach

Change the assumption: Lines are stacked planes



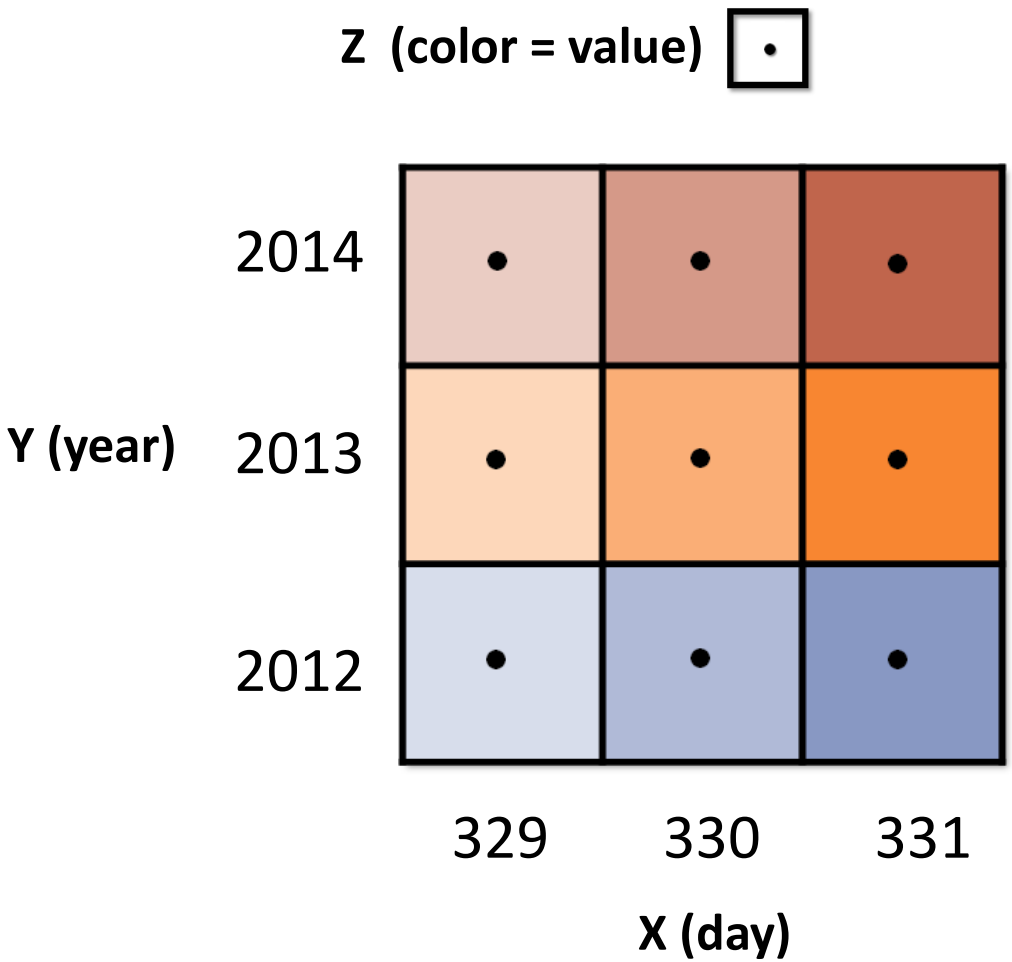
“Time map”

- Dual timescale coordinate system
- Common framework for visualization and layering data



Timescape of data

- GIS-like raster grid



Example datasets:

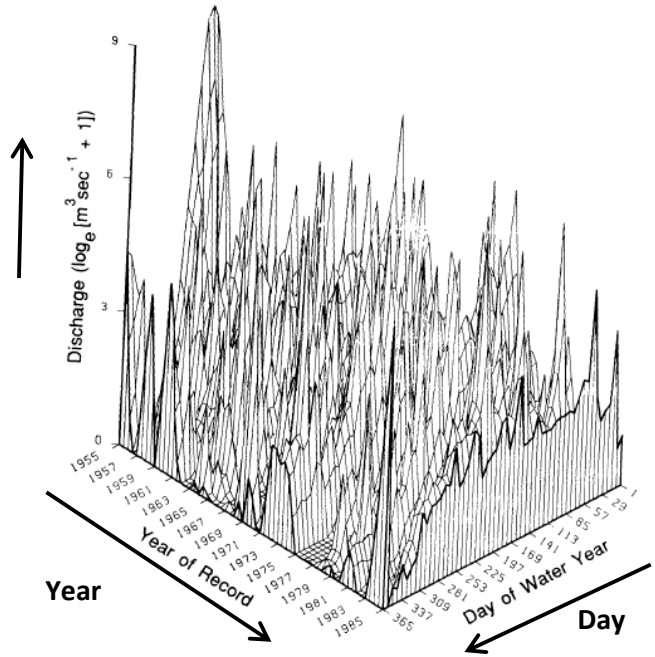
Streamflow, stage
Water temp, quality
Power production
Tides and currents
El Nino, La Nina, PDO
Sunrise, sunset
Model output, scenarios
Fish count
Park visitors

Plus even more

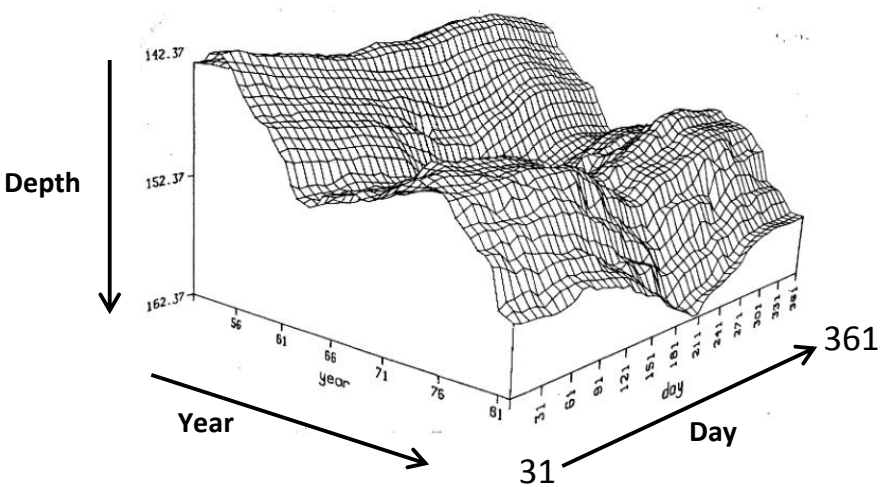
3-D surface plot problems

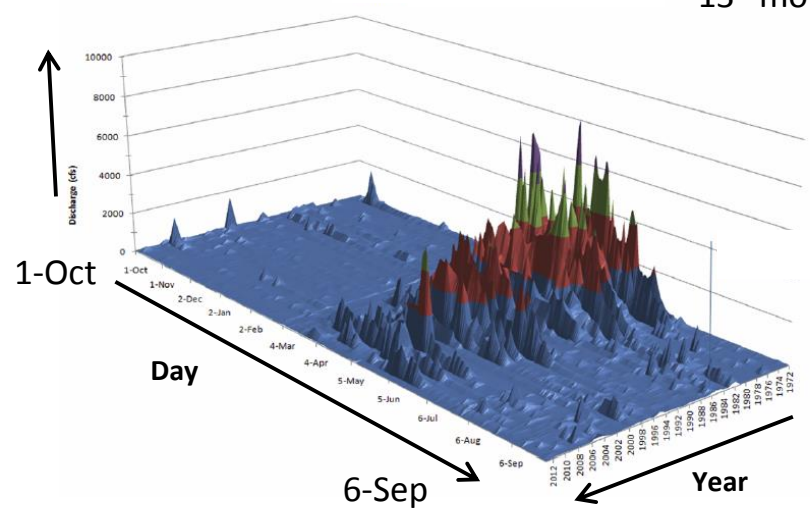
Hidden data	Perspective
View angle tilt	View direction
Lighting angle	Surface texture
Axis label	Axis direction
Limited analysis	Layer issues

Temporal data ≠ Spatial data



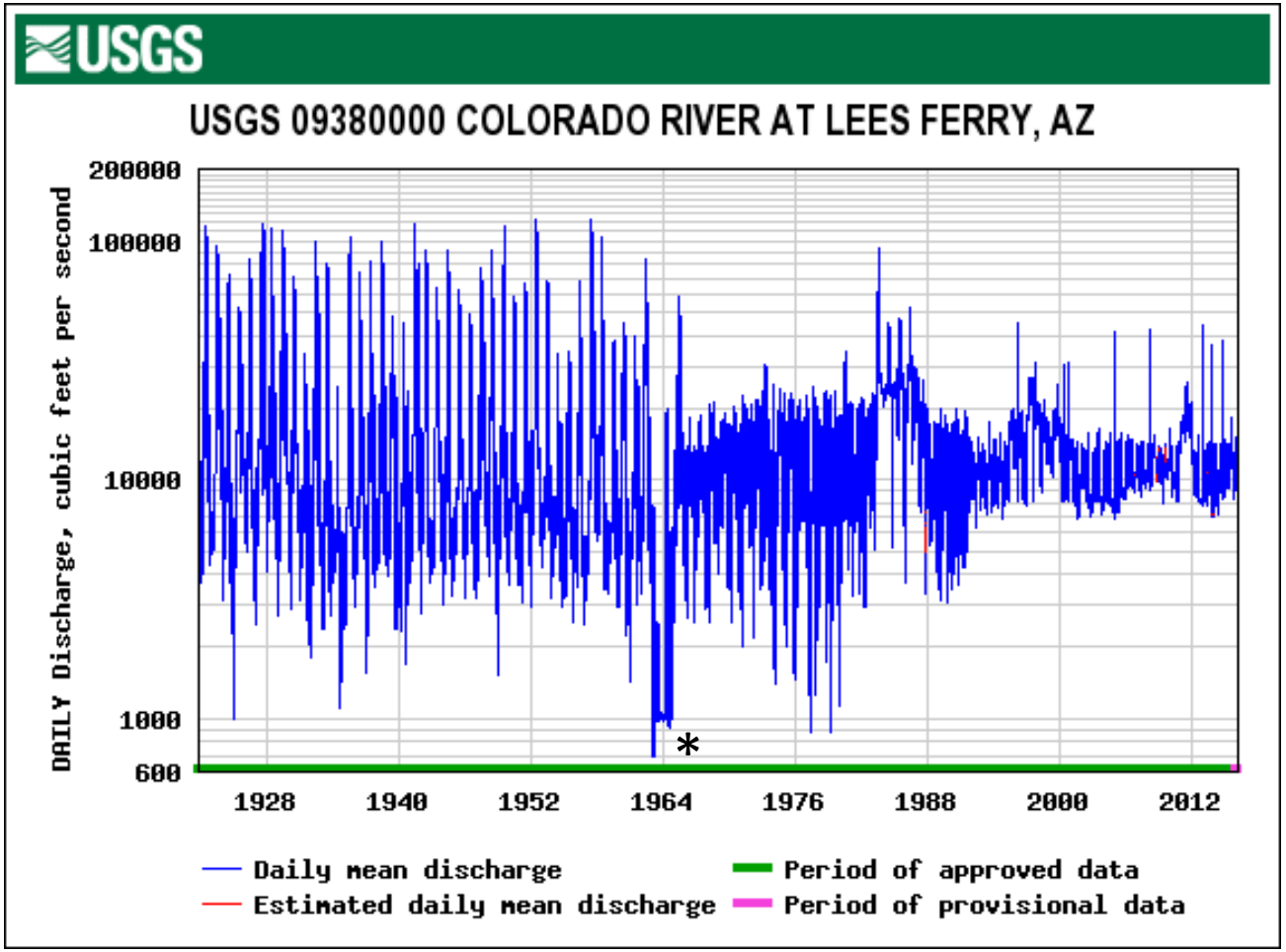
13 “months”





Streamflow examples

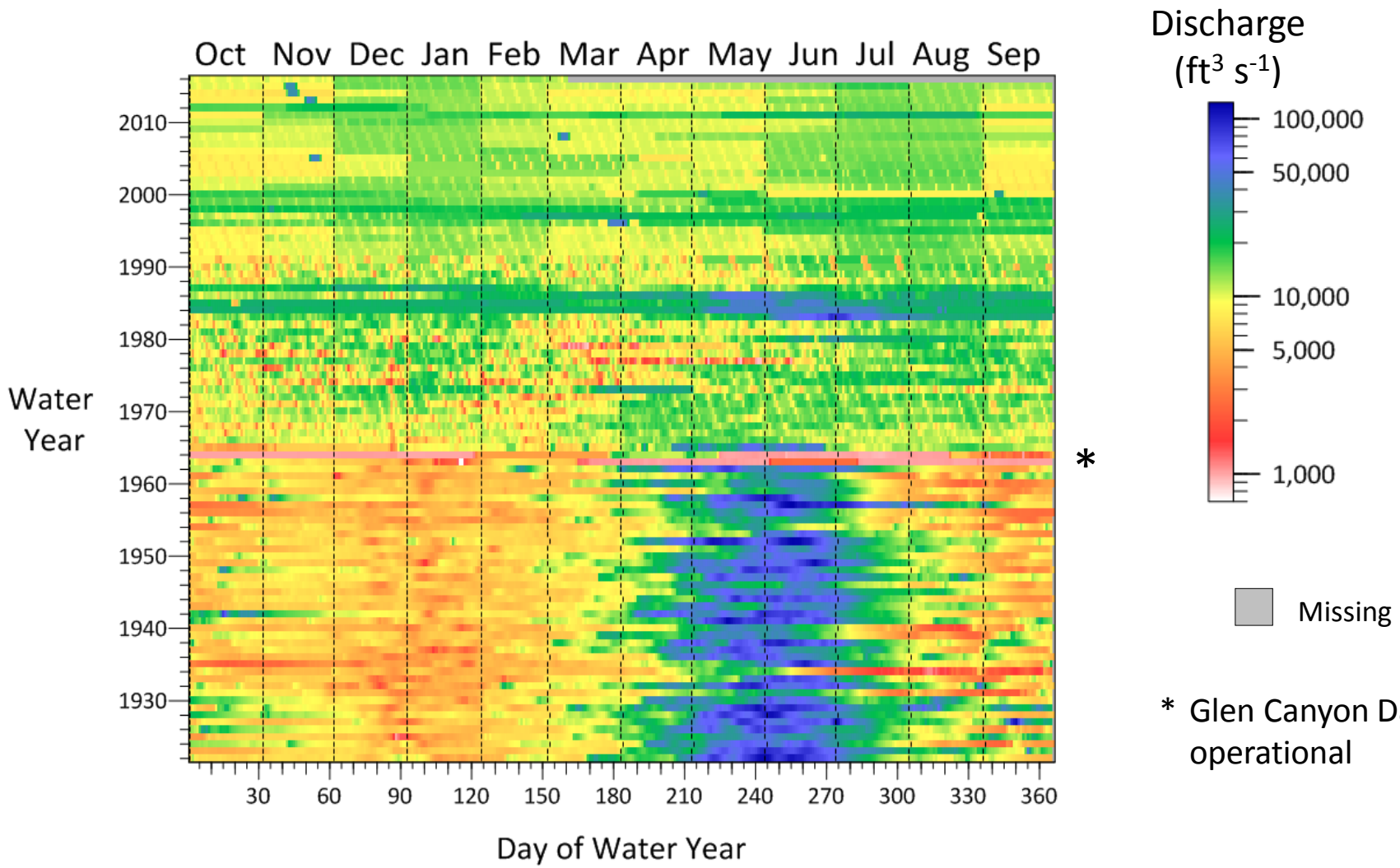
Traditional hydrograph



* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

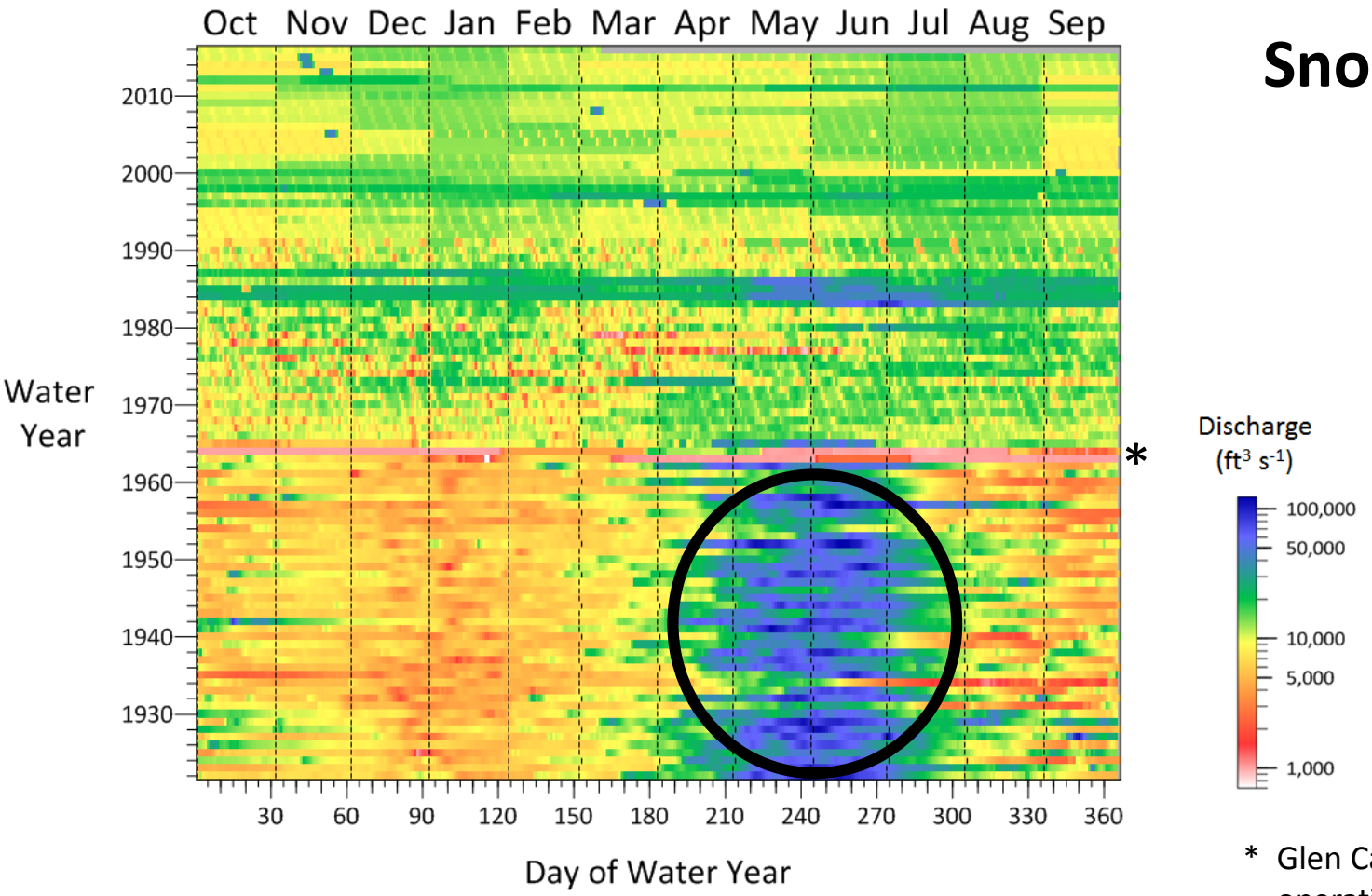


* Glen Canyon Dam operational

Data source: USGS

Raster hydrograph

Colorado River at Lees Ferry, AZ

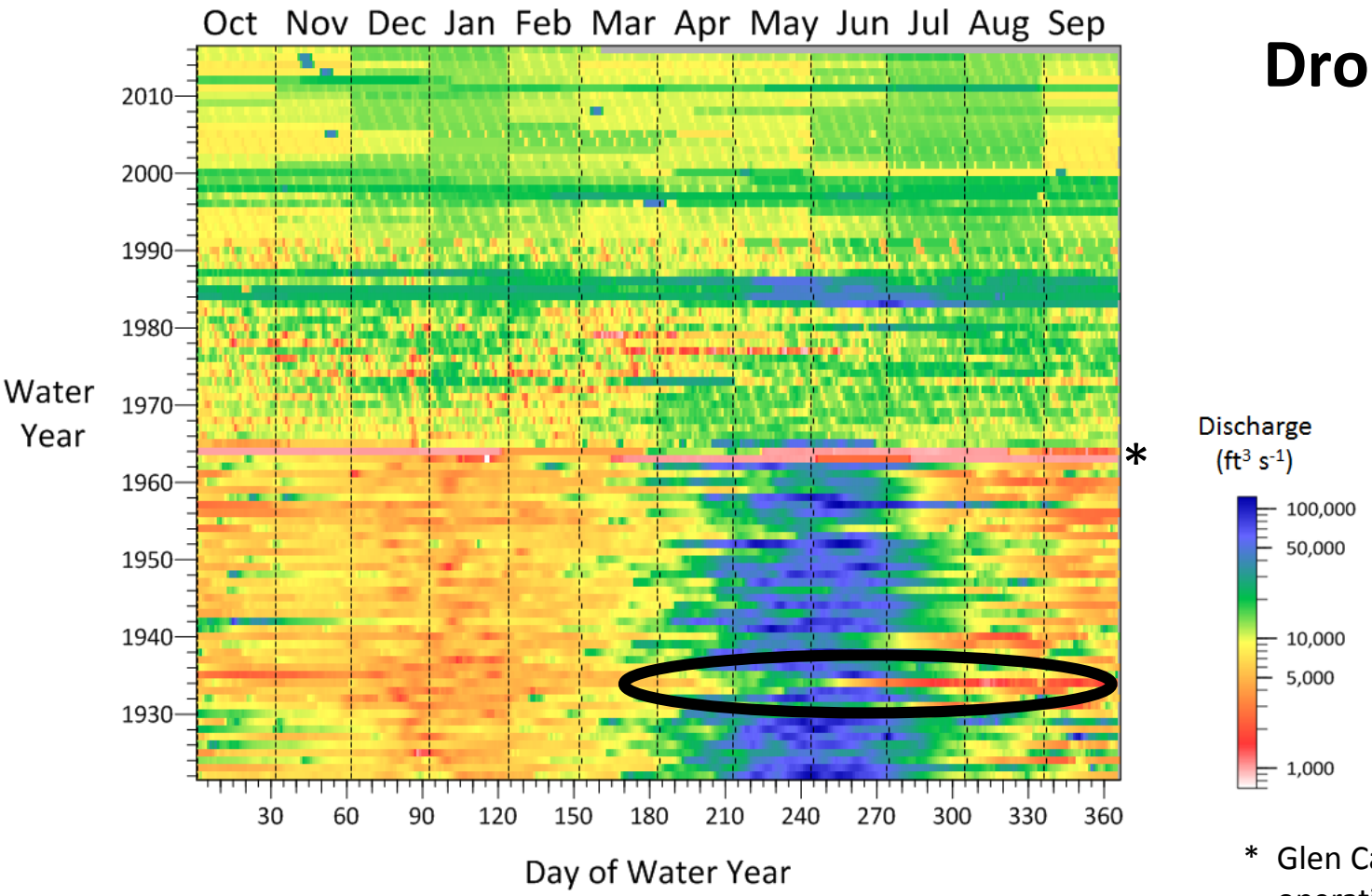


Snowmelt

* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

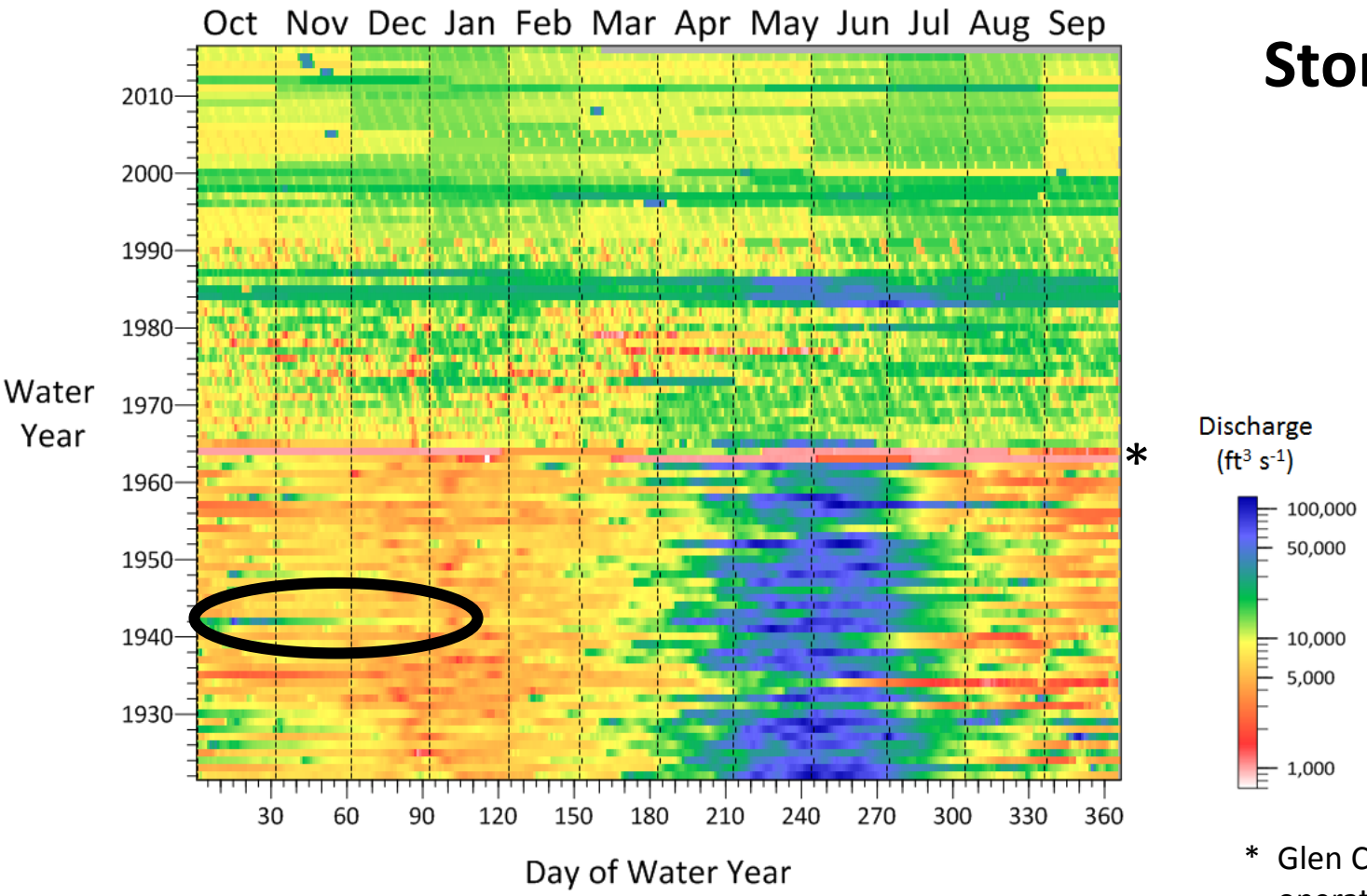


Drought

* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

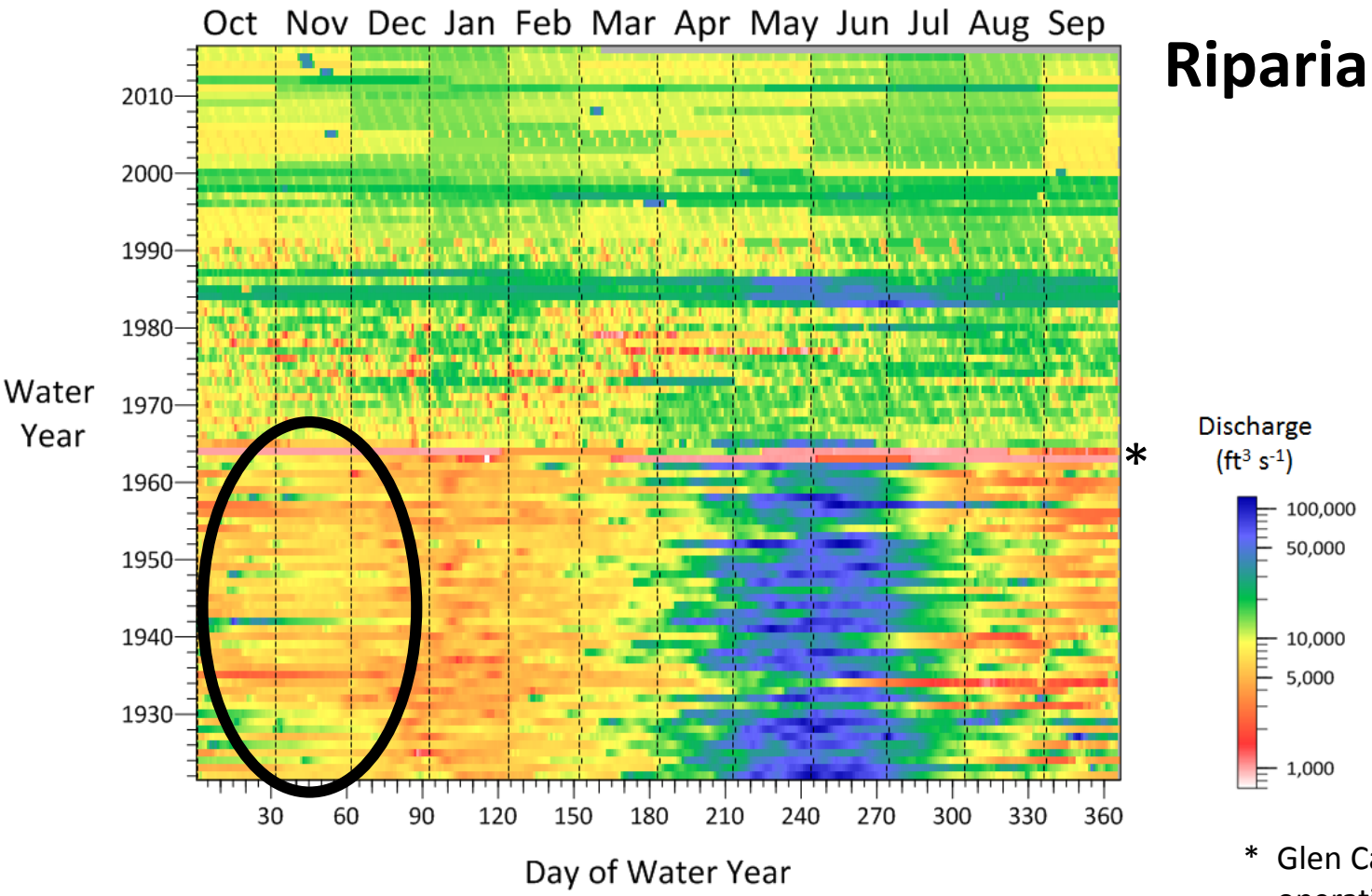


Stormflow

* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

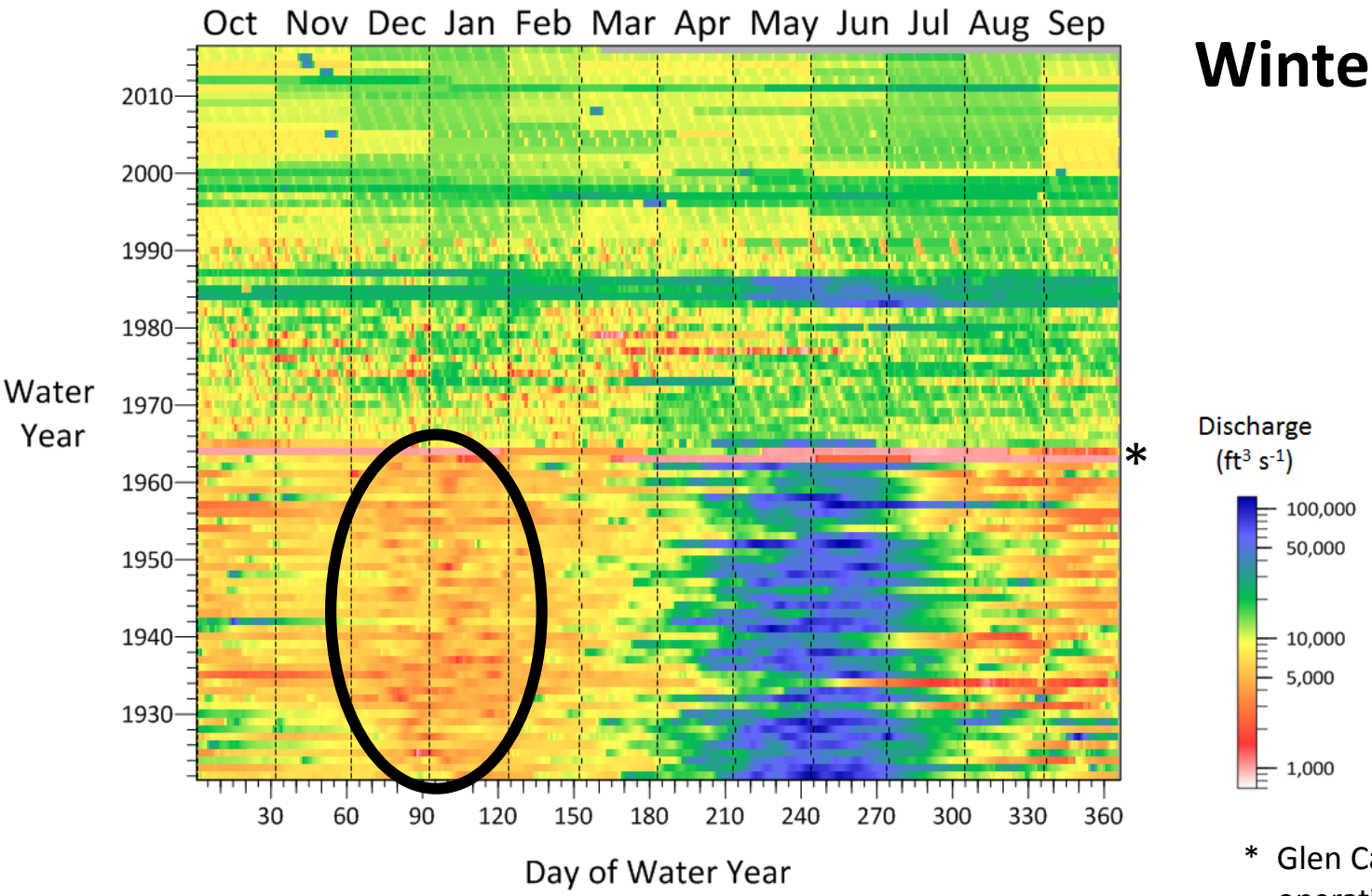


Riparian water use

* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

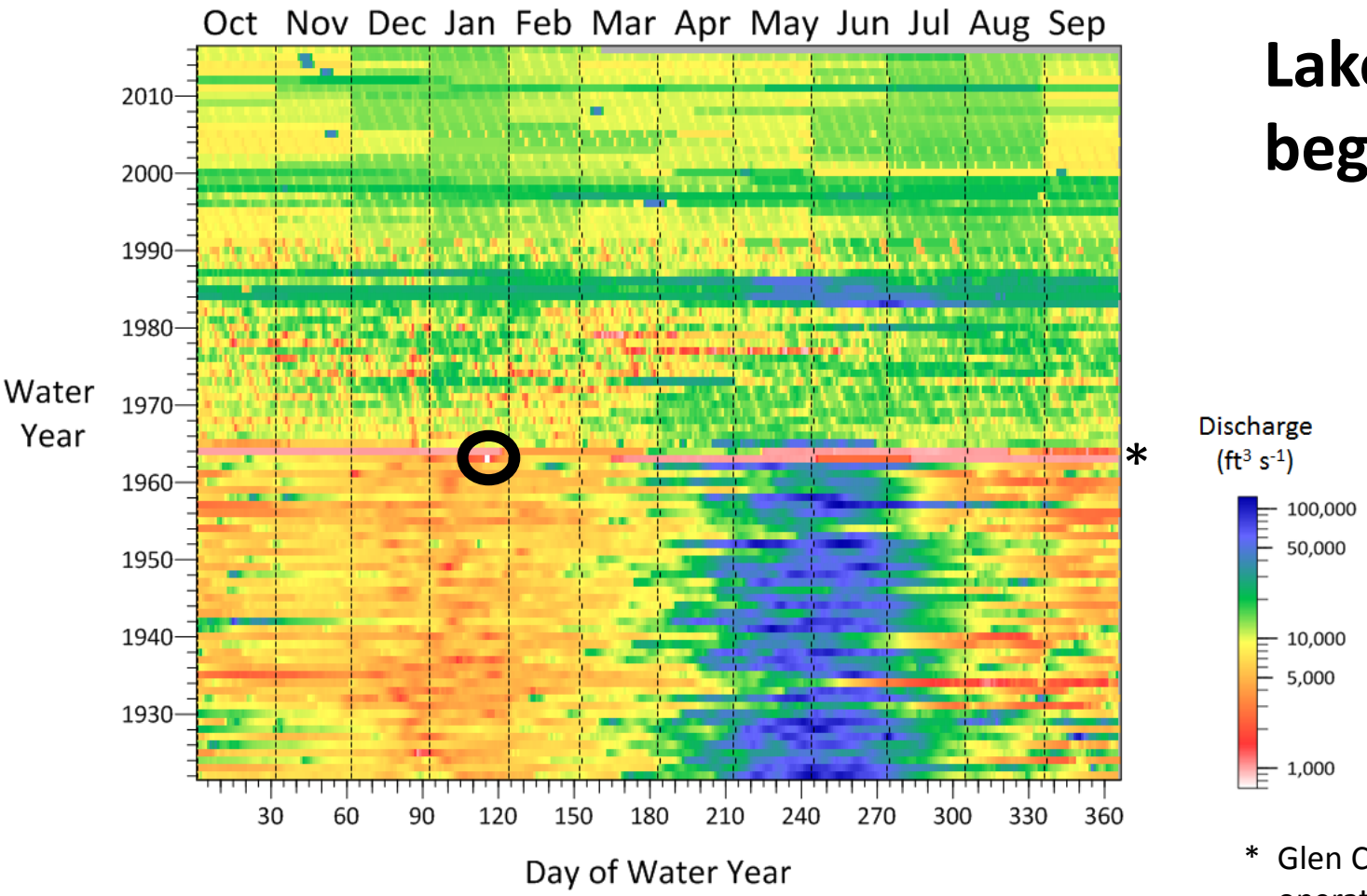


Winter low flow

* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

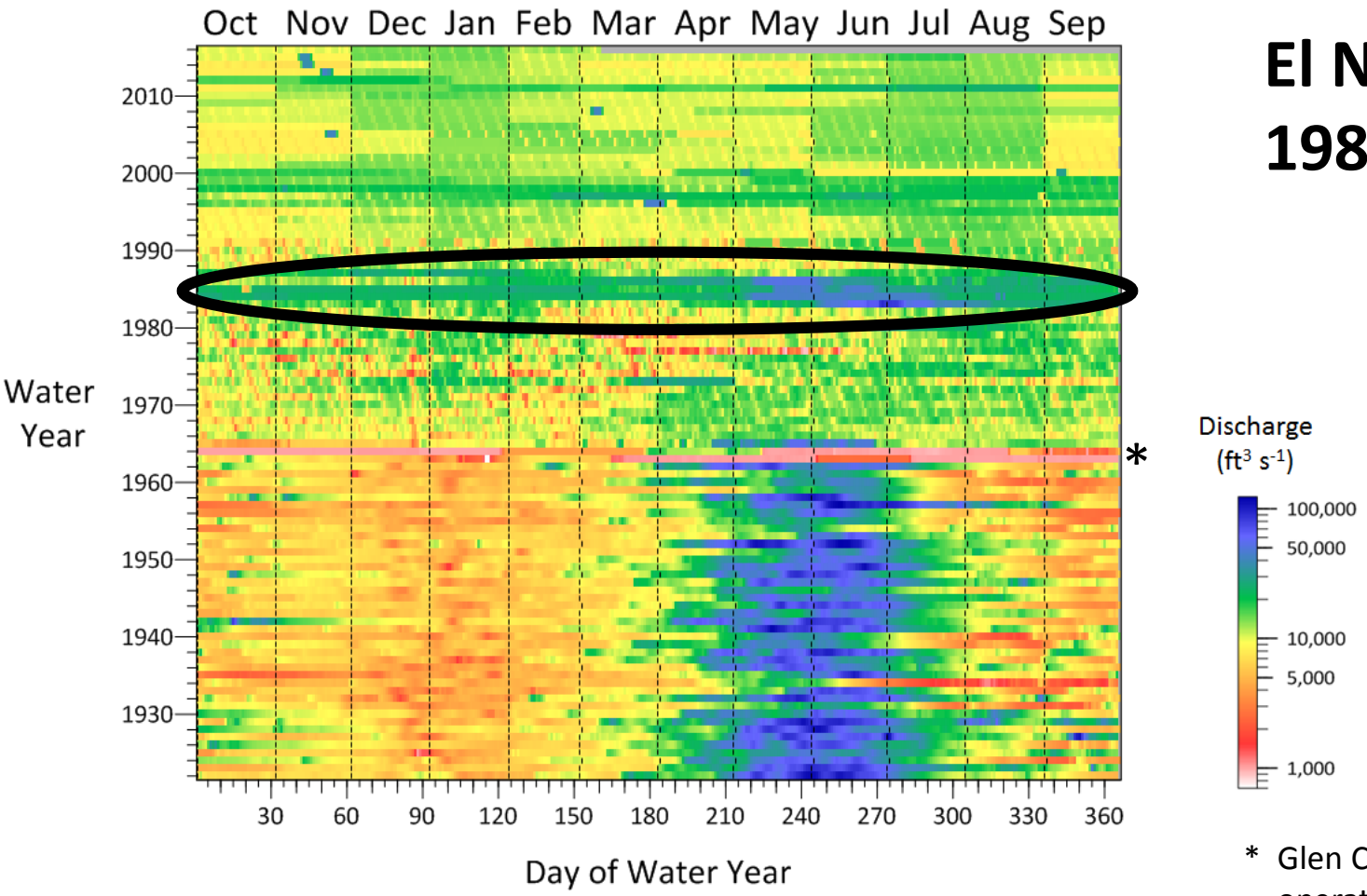


Lake Powell begins filling

* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

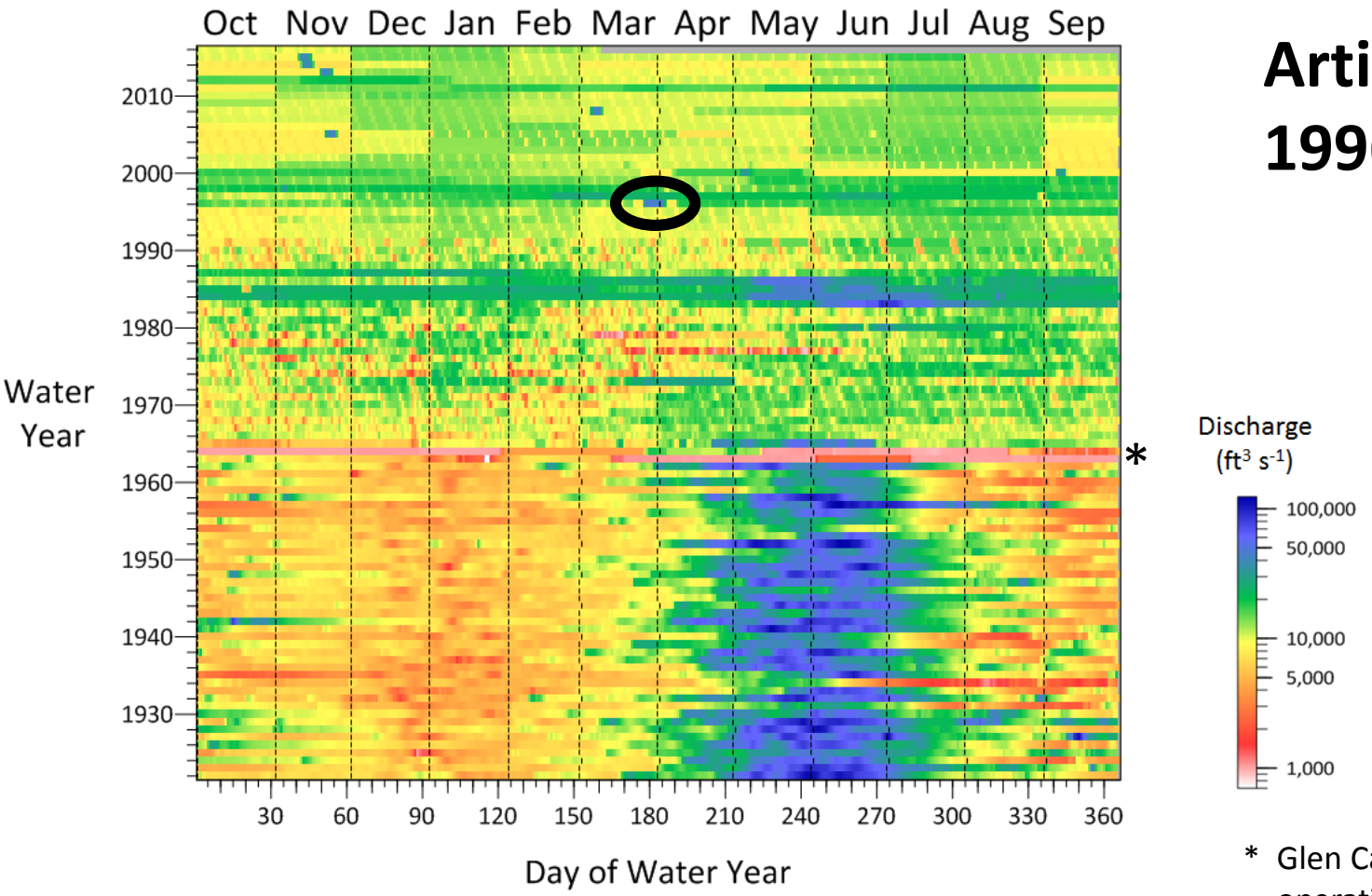


El Nino
1983 – 1985

* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

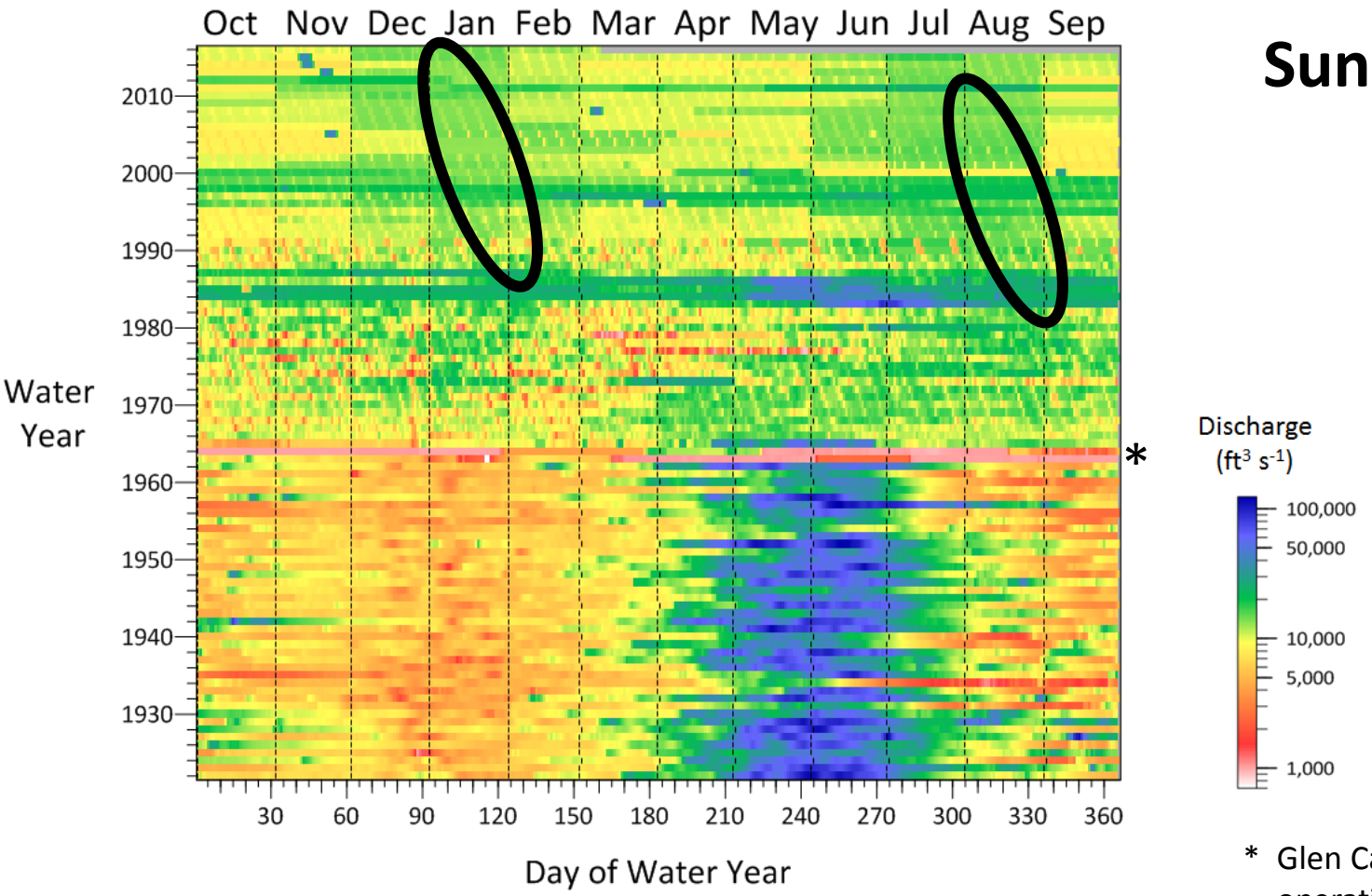


Artificial flood 1996

* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

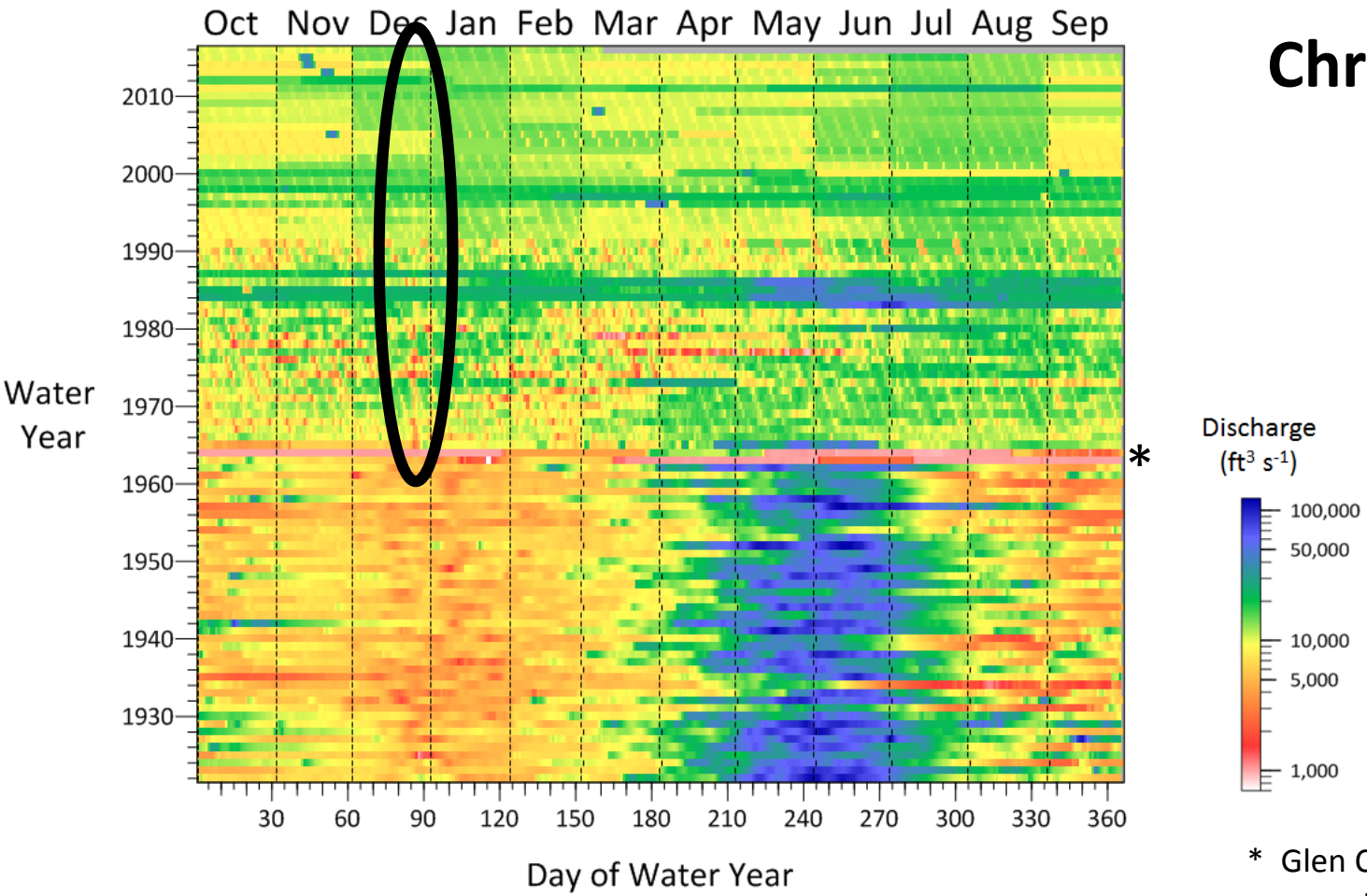


Sundays

* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

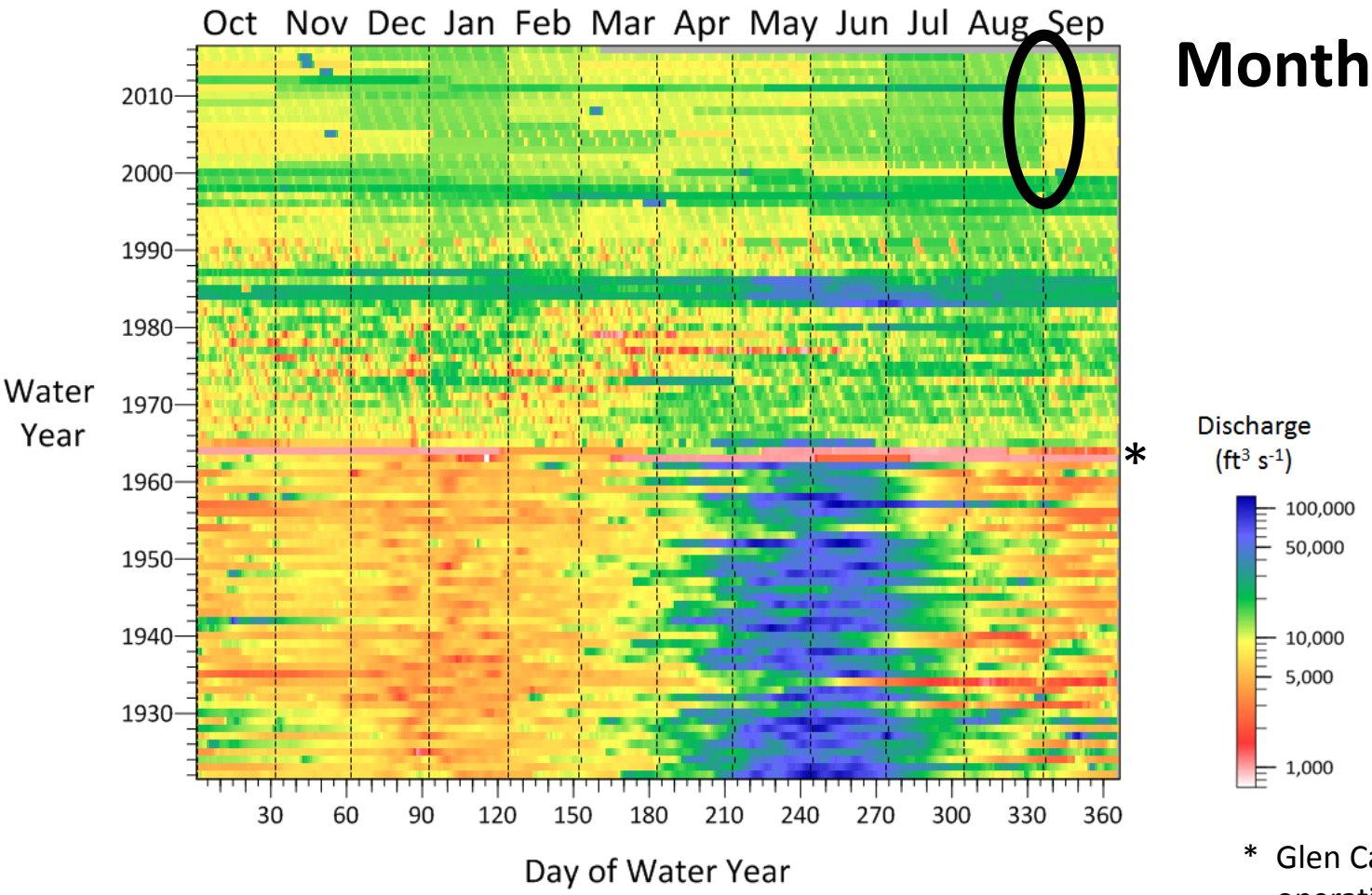


Christmas

* Glen Canyon Dam operational

Raster hydrograph

Colorado River at Lees Ferry, AZ

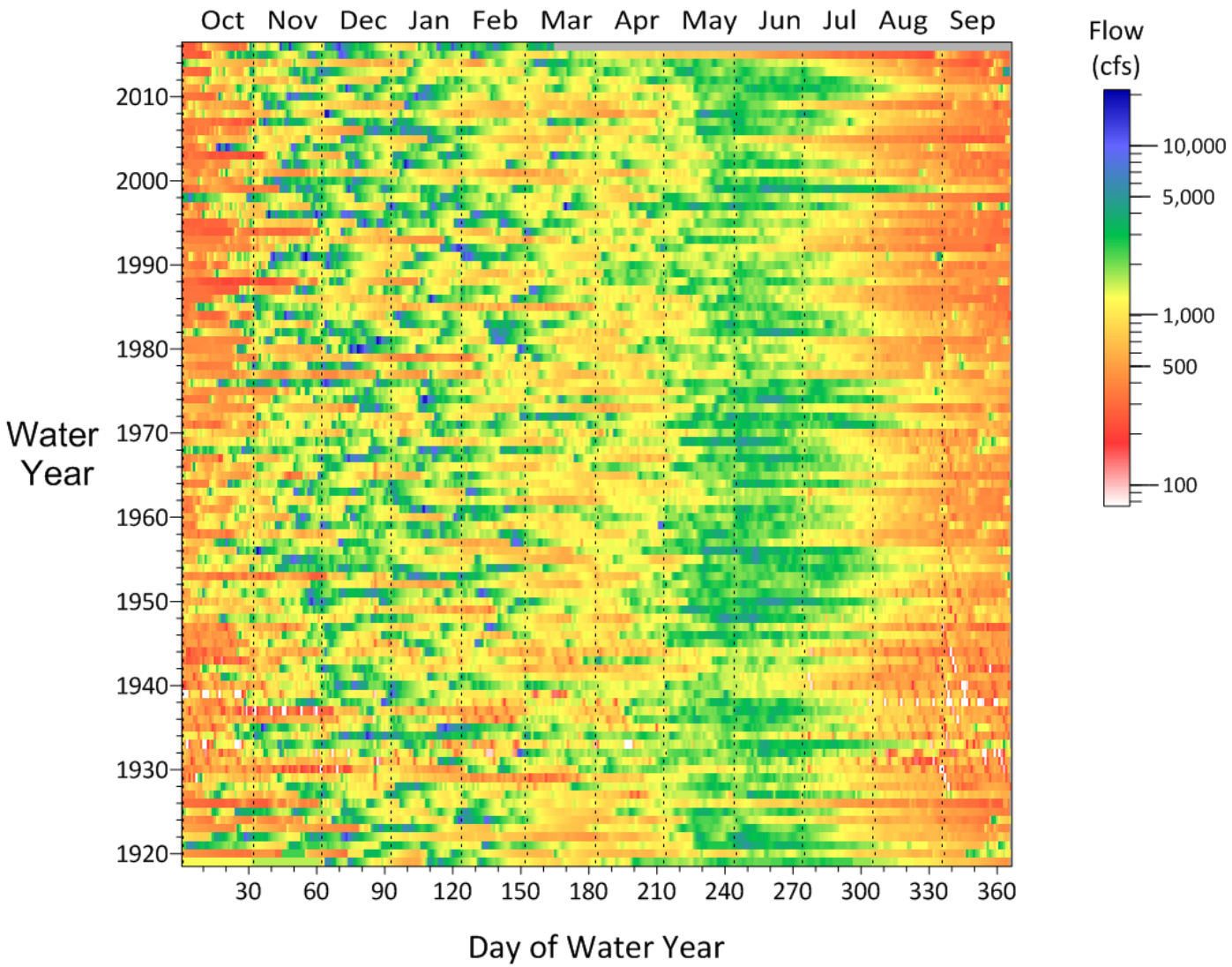


Monthly change

* Glen Canyon Dam operational

Raster hydrograph

Elwha River at McDonald Br near Port Angeles, WA



Similar plots

Plot name:

Heat map

Temporal raster plot

Raster image

Waterfall plot

Chromogram

Pixel graph

Image map

Raster hydrograph

Software:

Graphics

Excel, Matlab, OriginLab, SAS,

Surfer, ArcGIS, R, Google Docs, QGIS, Python

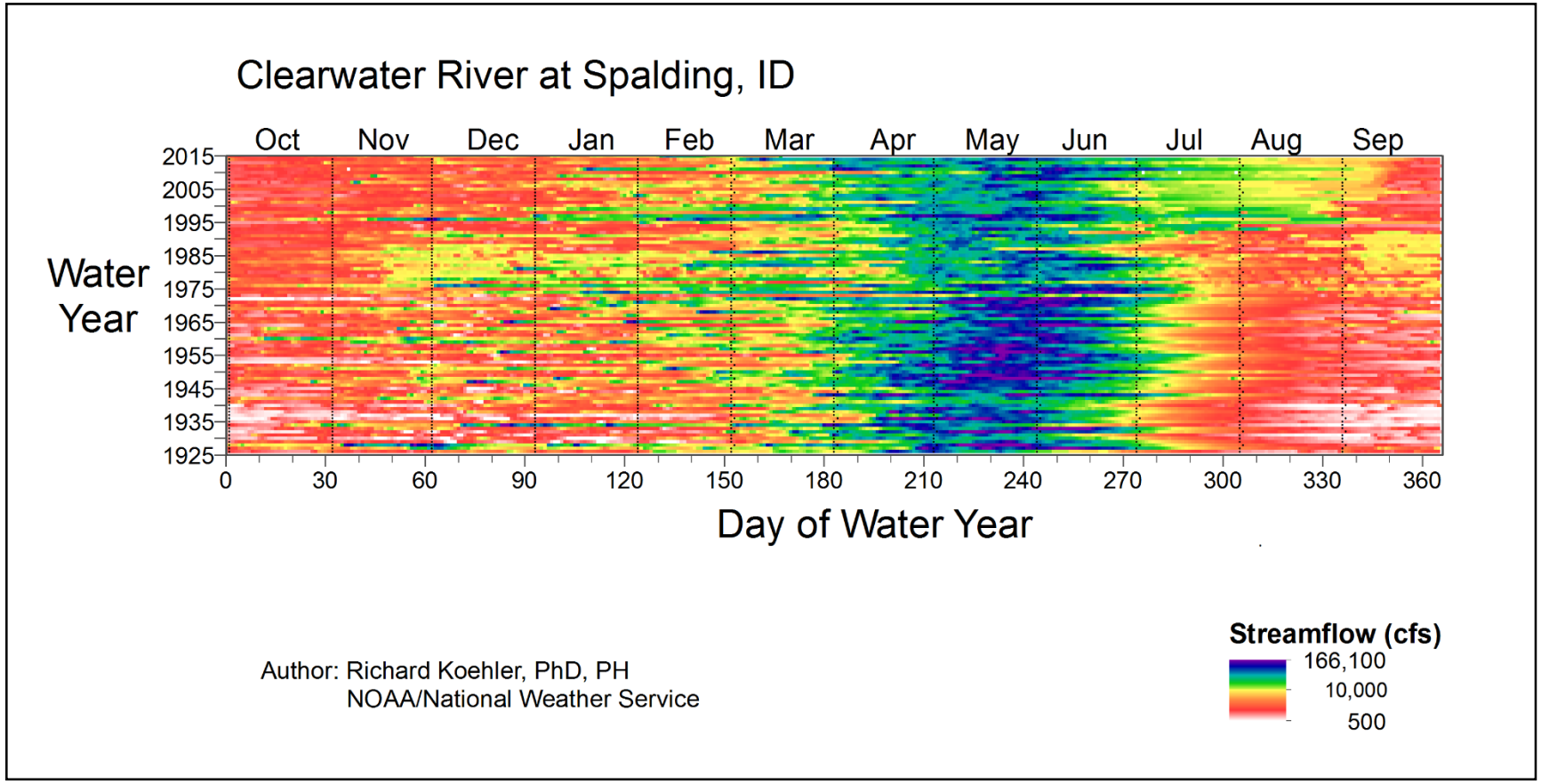
Quantitative tools

Surfer, ArcGIS, Mathematica,

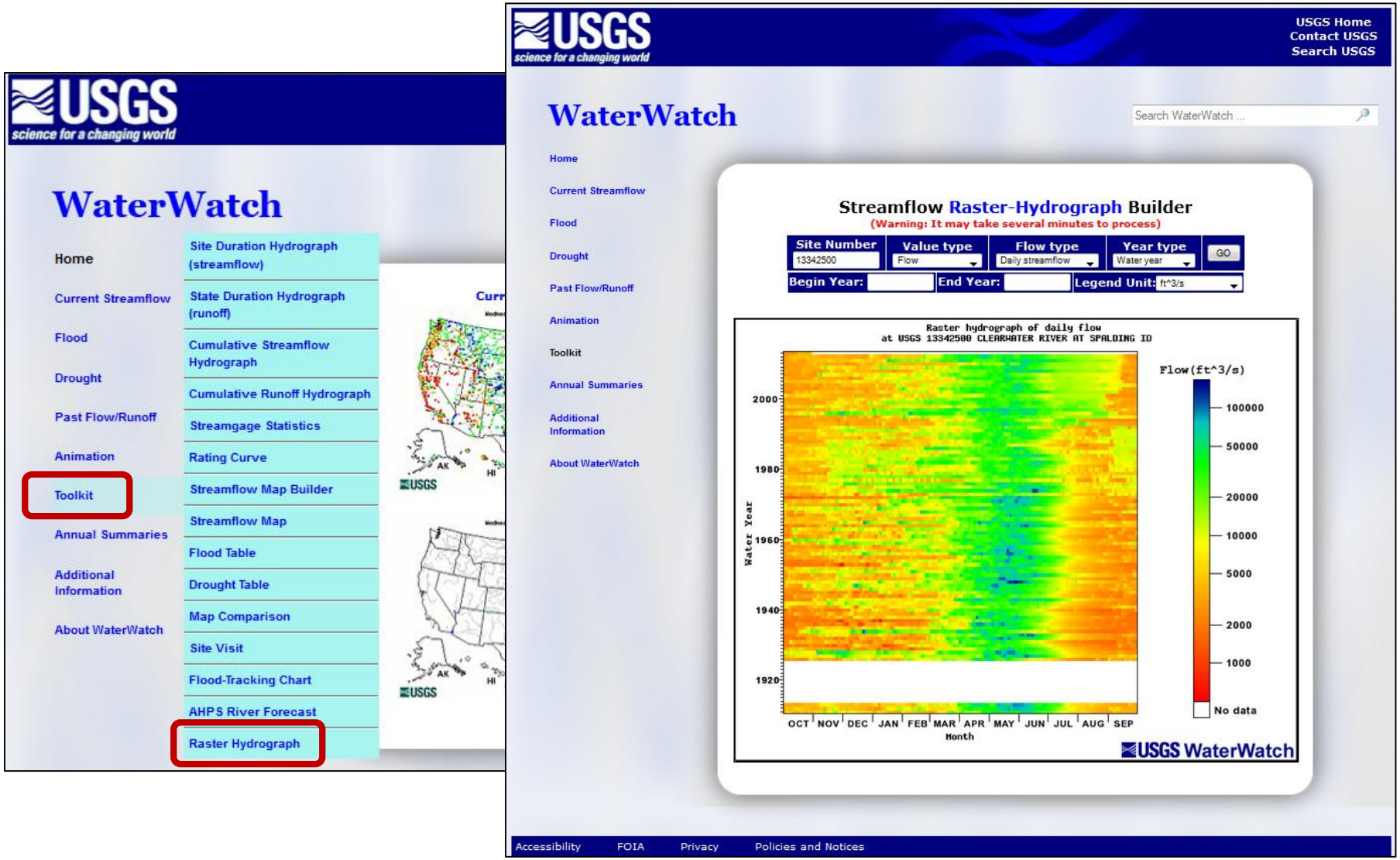
QGIS, FRAGSTATS

ArcGIS plot

Raster hydrograph created in ArcMap

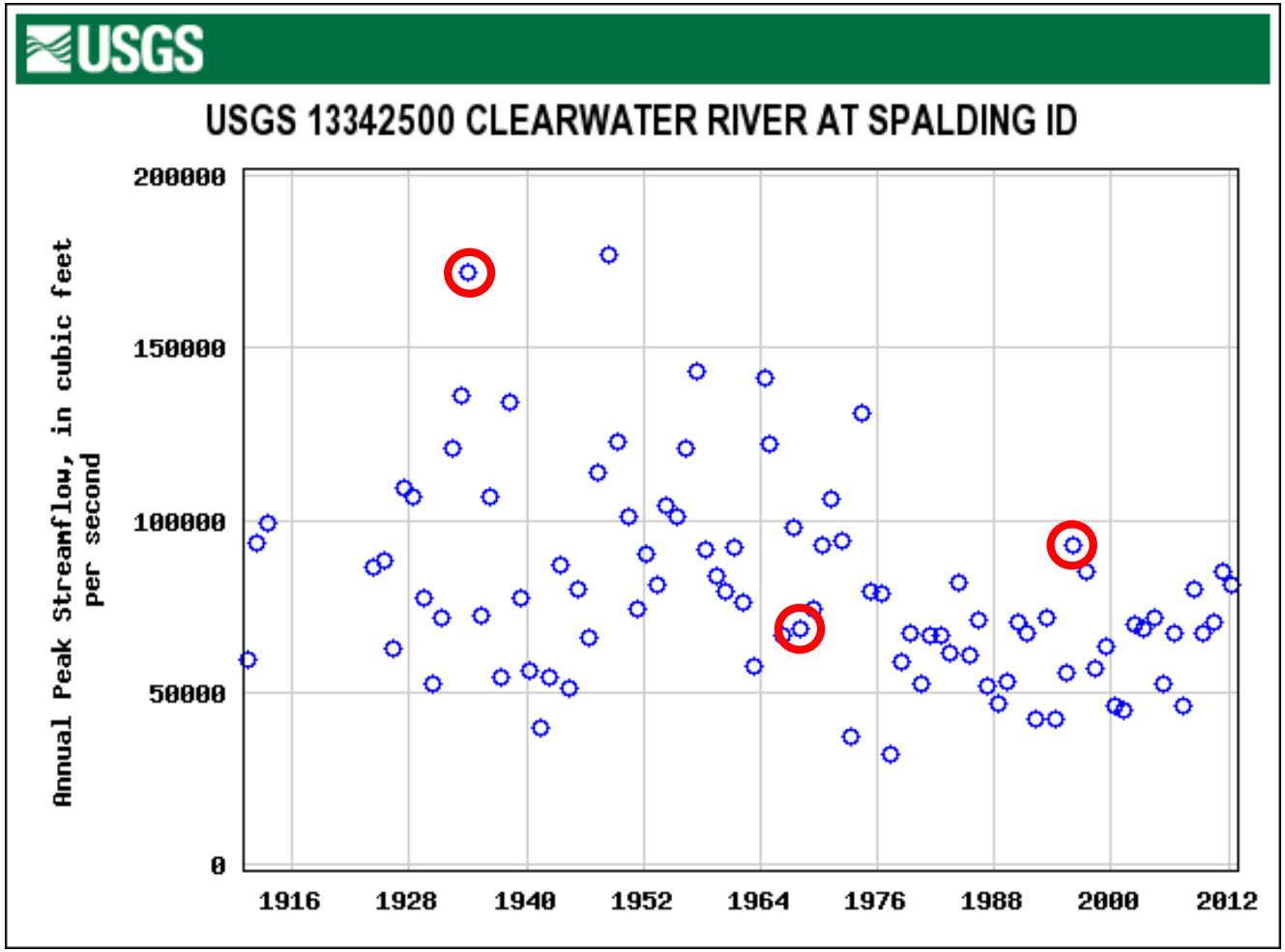


Online resources



Outlier detection

Annual maximum daily mean flow (cfs)

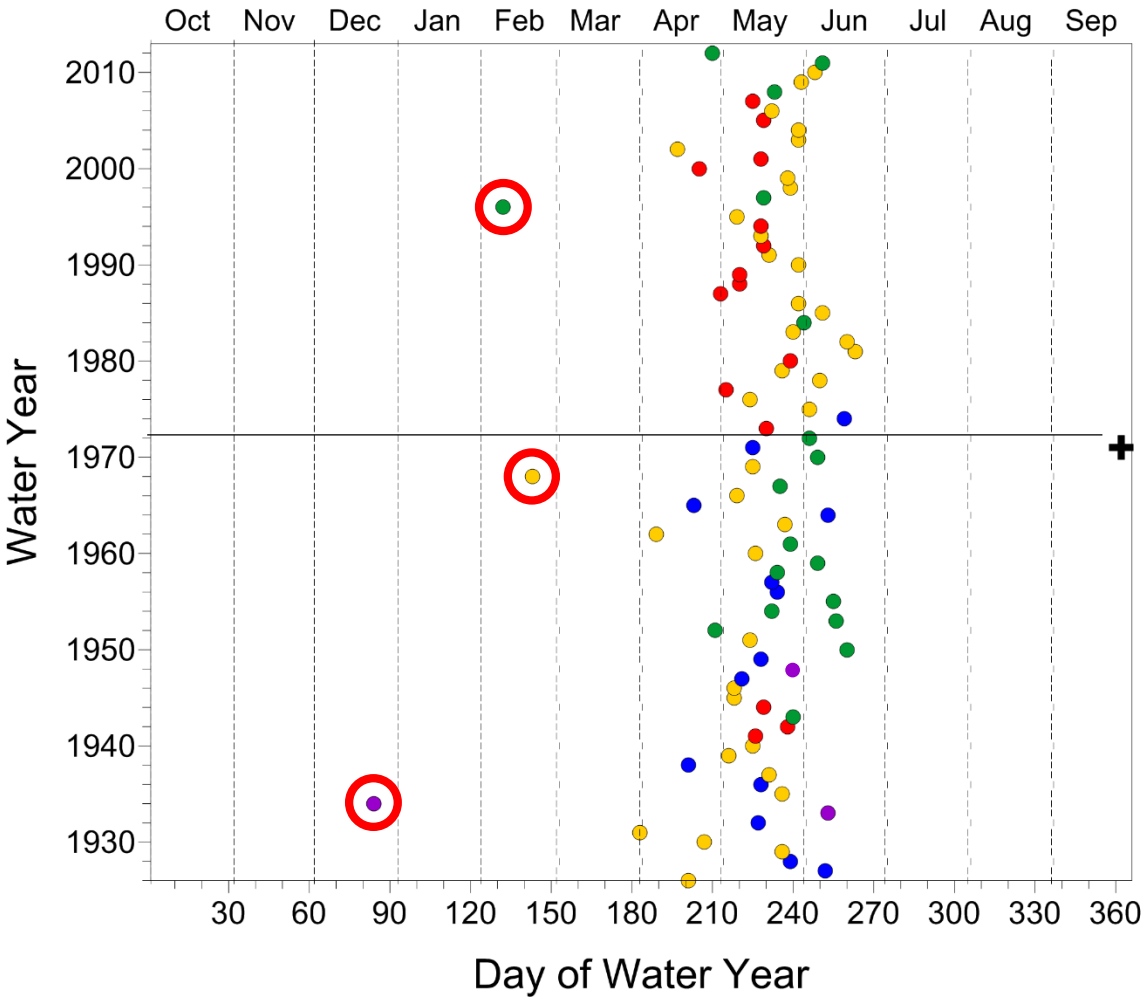


An **outlier** is an observation point that is distant from other observations.

Outliers

Outlier identification

Annual maximum daily mean flow (cfs)



28,500 to 50,000
50,000 to 75,000
75,000 to 100,000
100,000 to 125,000
125,000 to 166,100

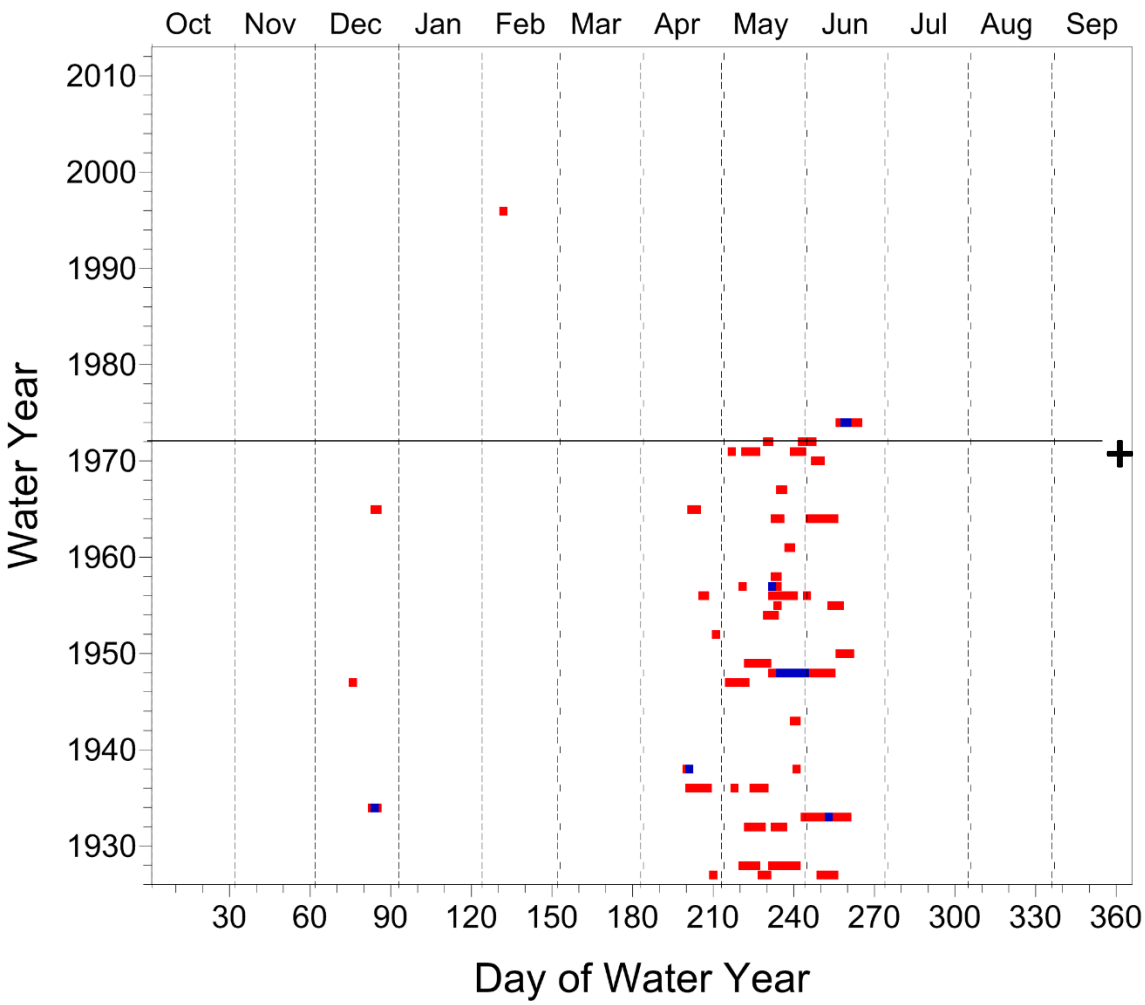
An **outlier** is an observation point that is distant from other observations.

Temporal outliers

\+ Dworshak Dam operational

Flood frequency flows

Return period flows



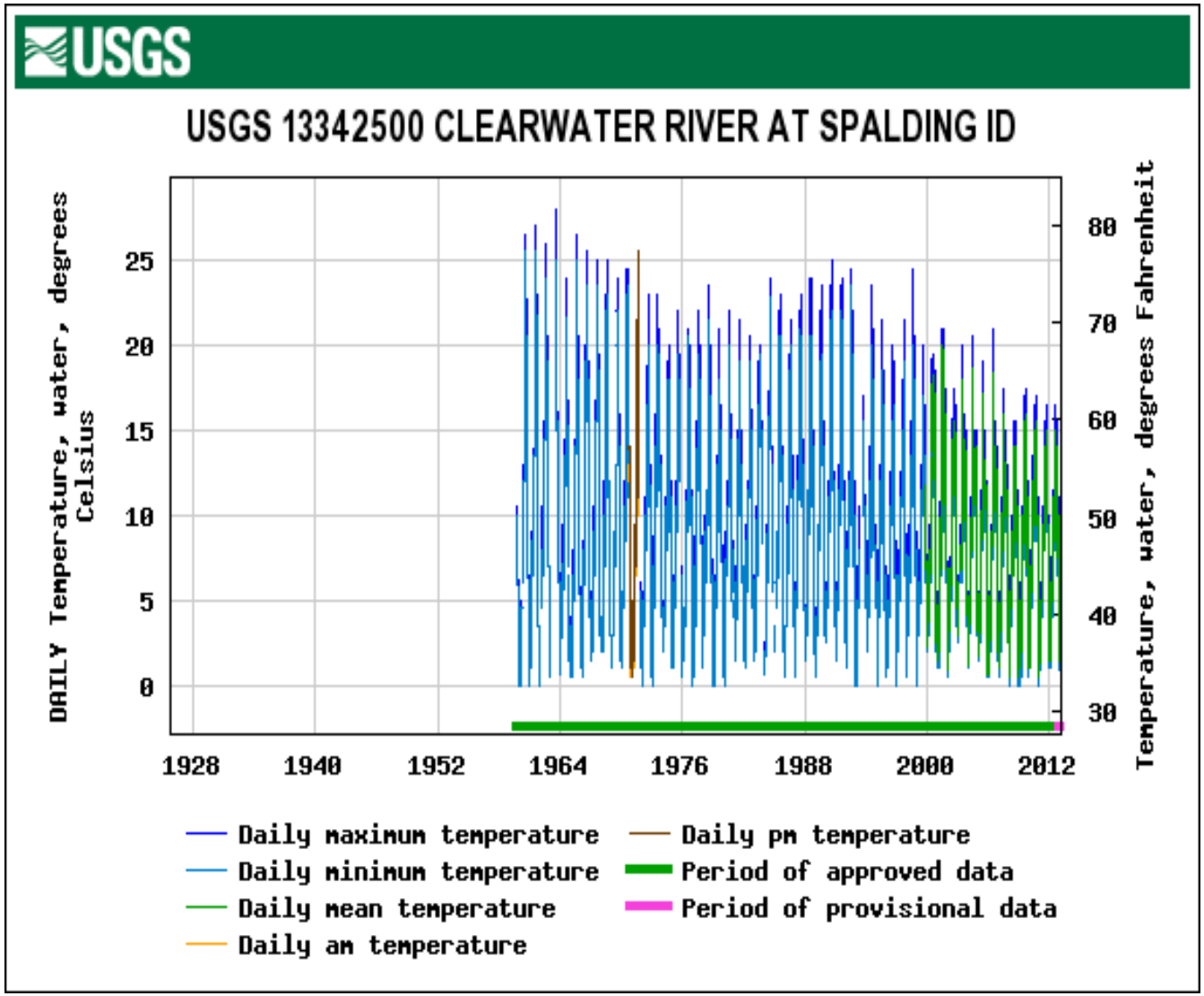
10+ year return period
122,900 cfs to 166,100 cfs

2+ year return period
82,700 cfs to 122,899 cfs

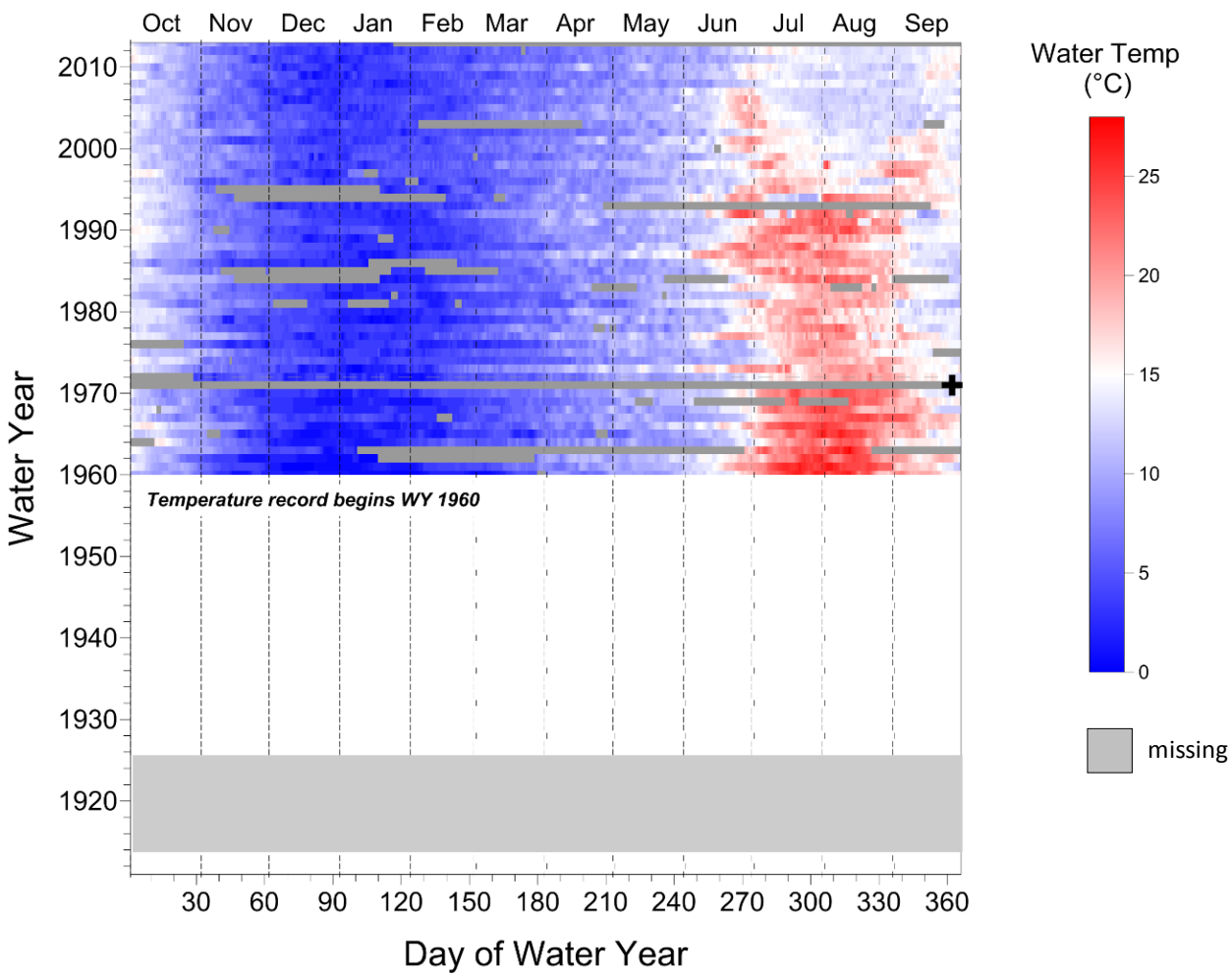
\+ Dworshak operational

Pre-dam record used to compute flood frequency design flows

Traditional plot – water temperature



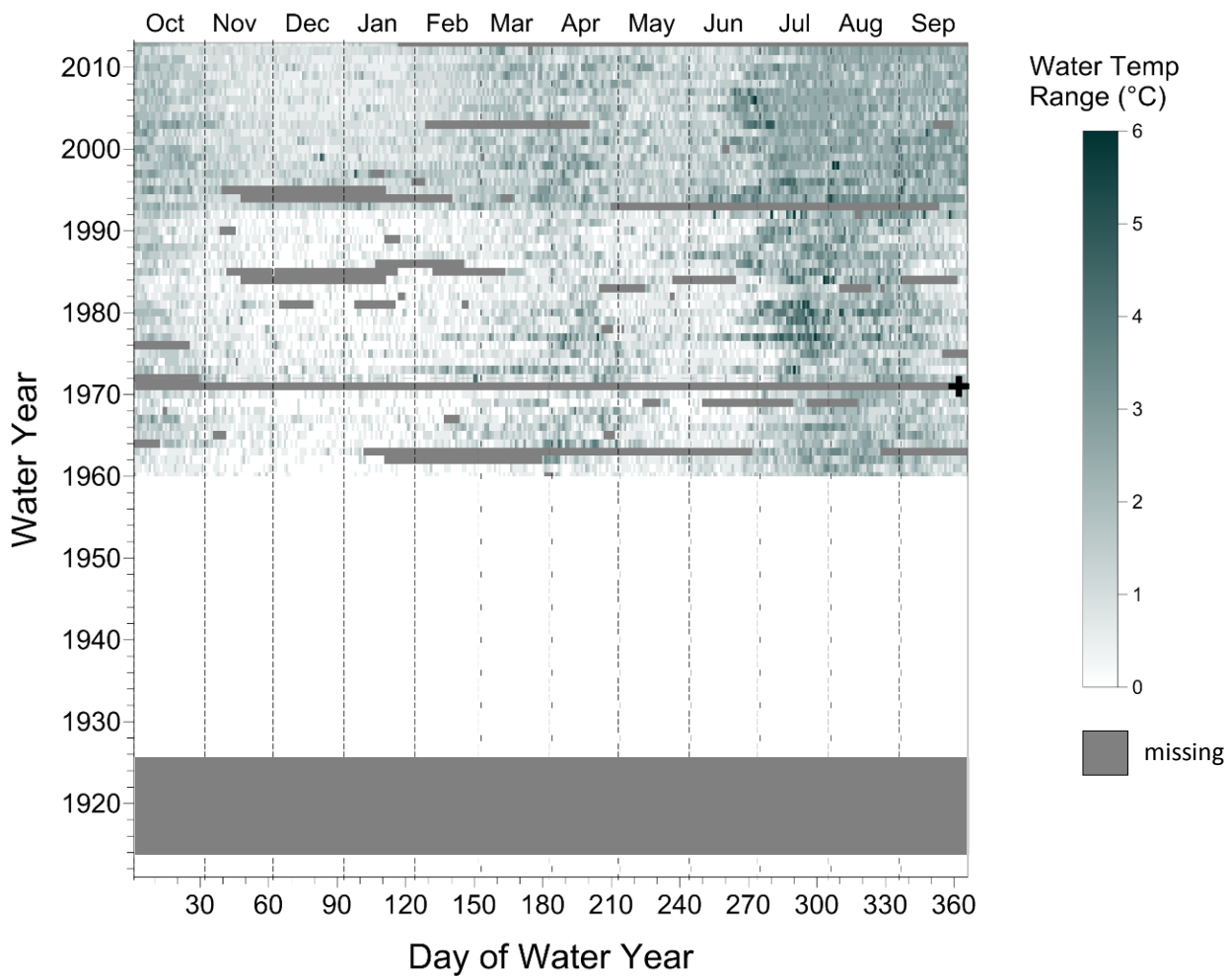
Daily maximum water temperature



Temperature synced with summer flow, except for recent years.

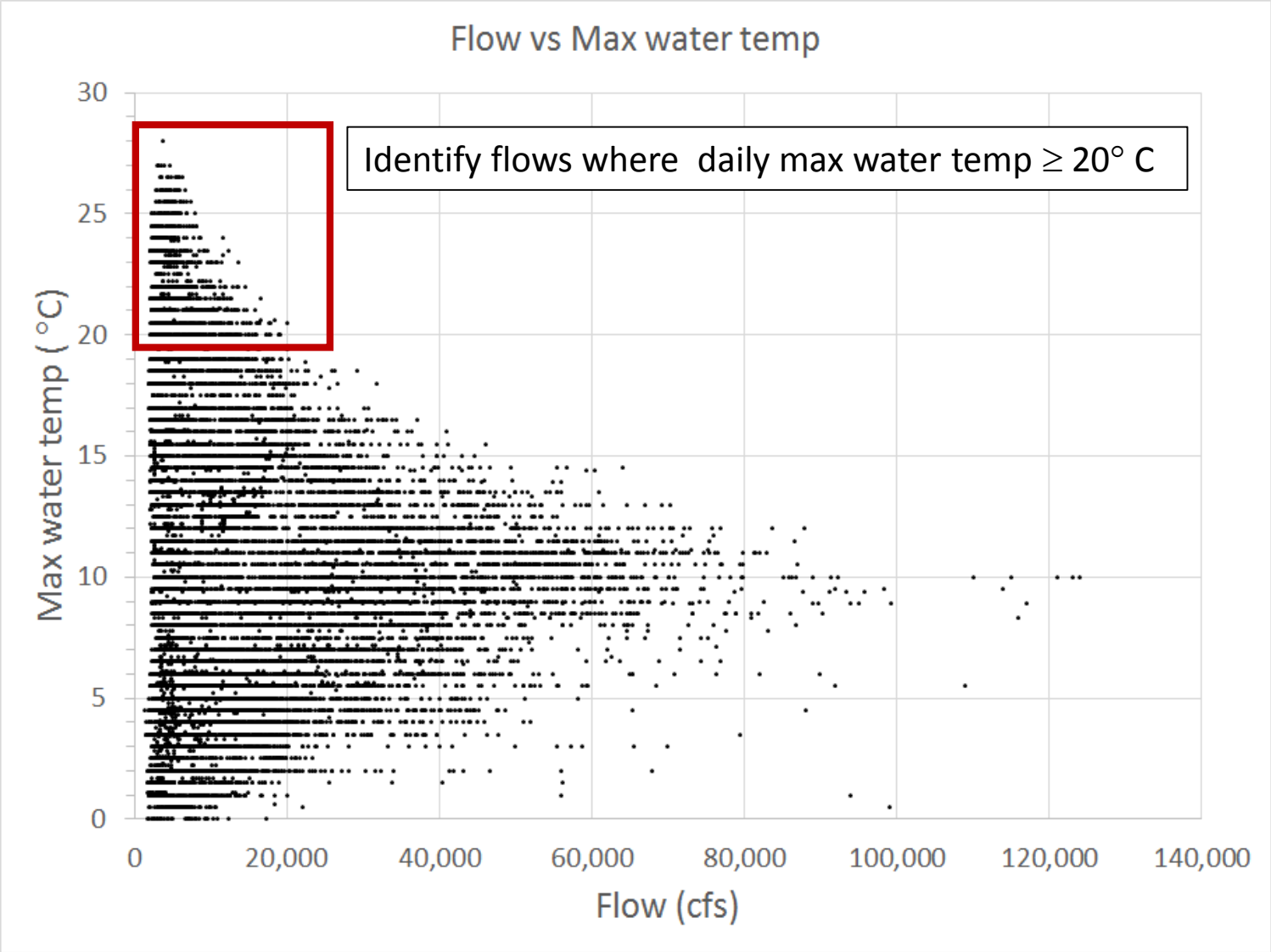
Note link with power production.

Water temperature range (max – min)



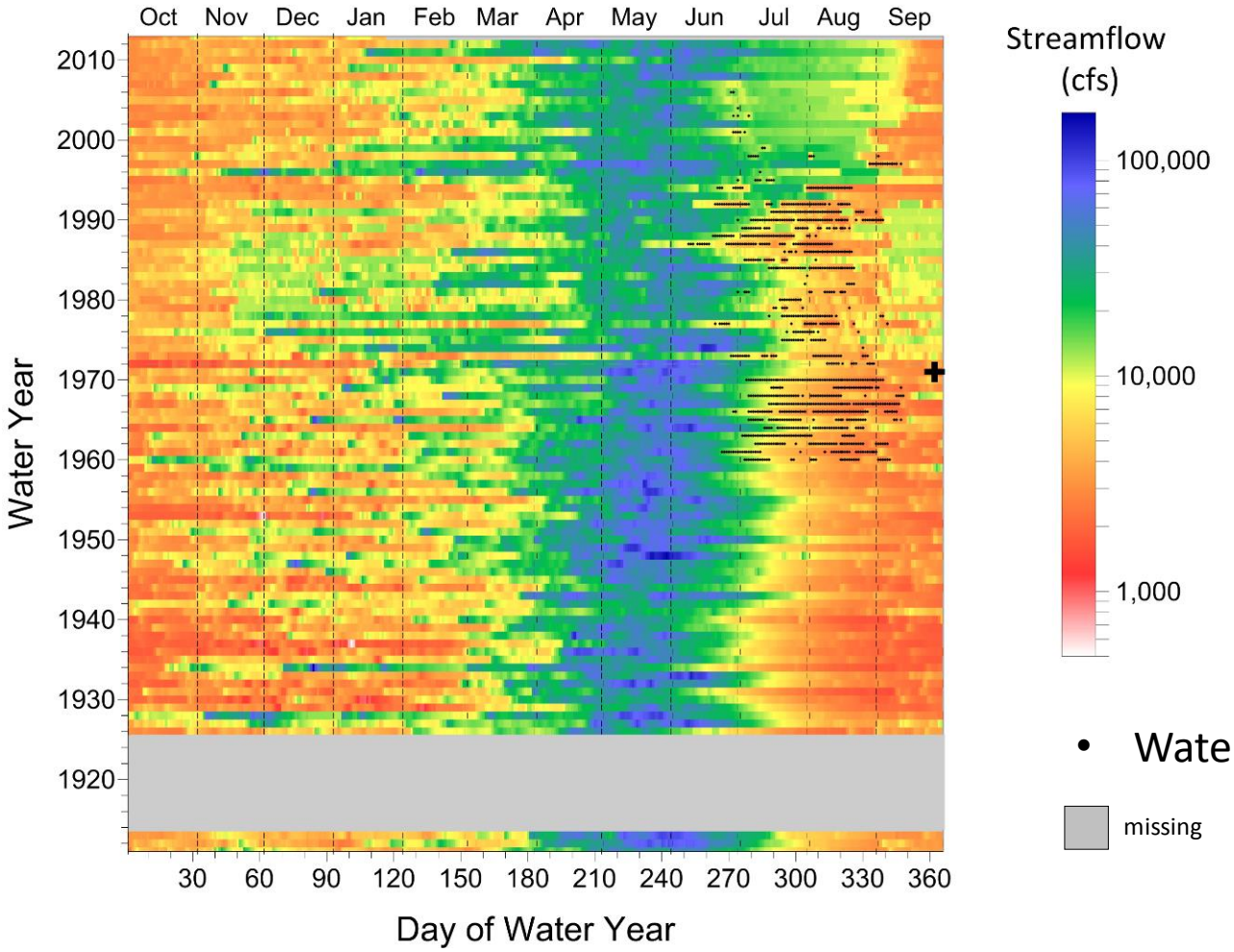
Additional patterns

Flow vs daily max water temp



Overlay multiple datasets

Flow and max water temp



Overlays helps identify coincidence

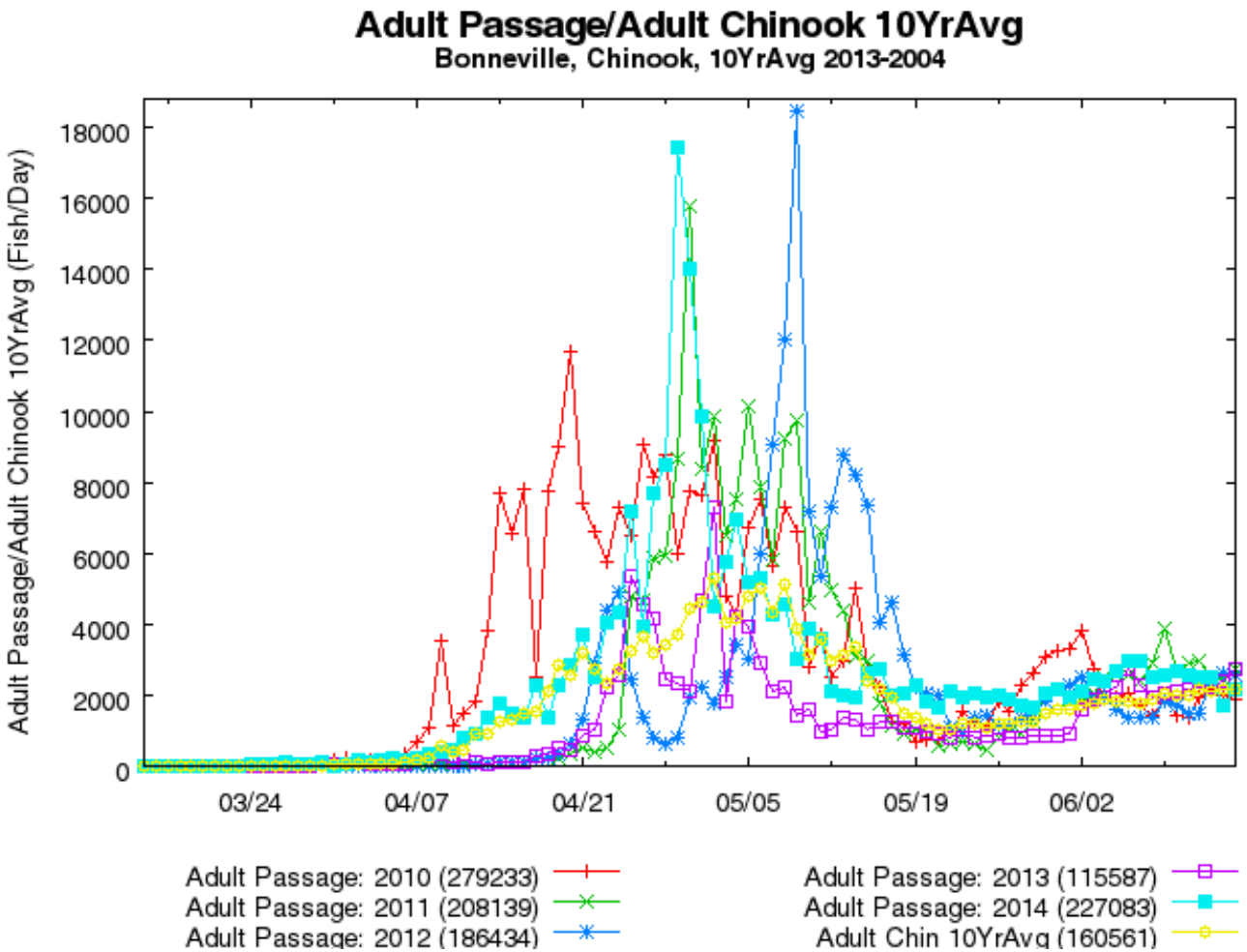
Warning: Coincidence does not always imply a connection.

- Water temp ≥ 20° C

missing

Bonneville adult chinook

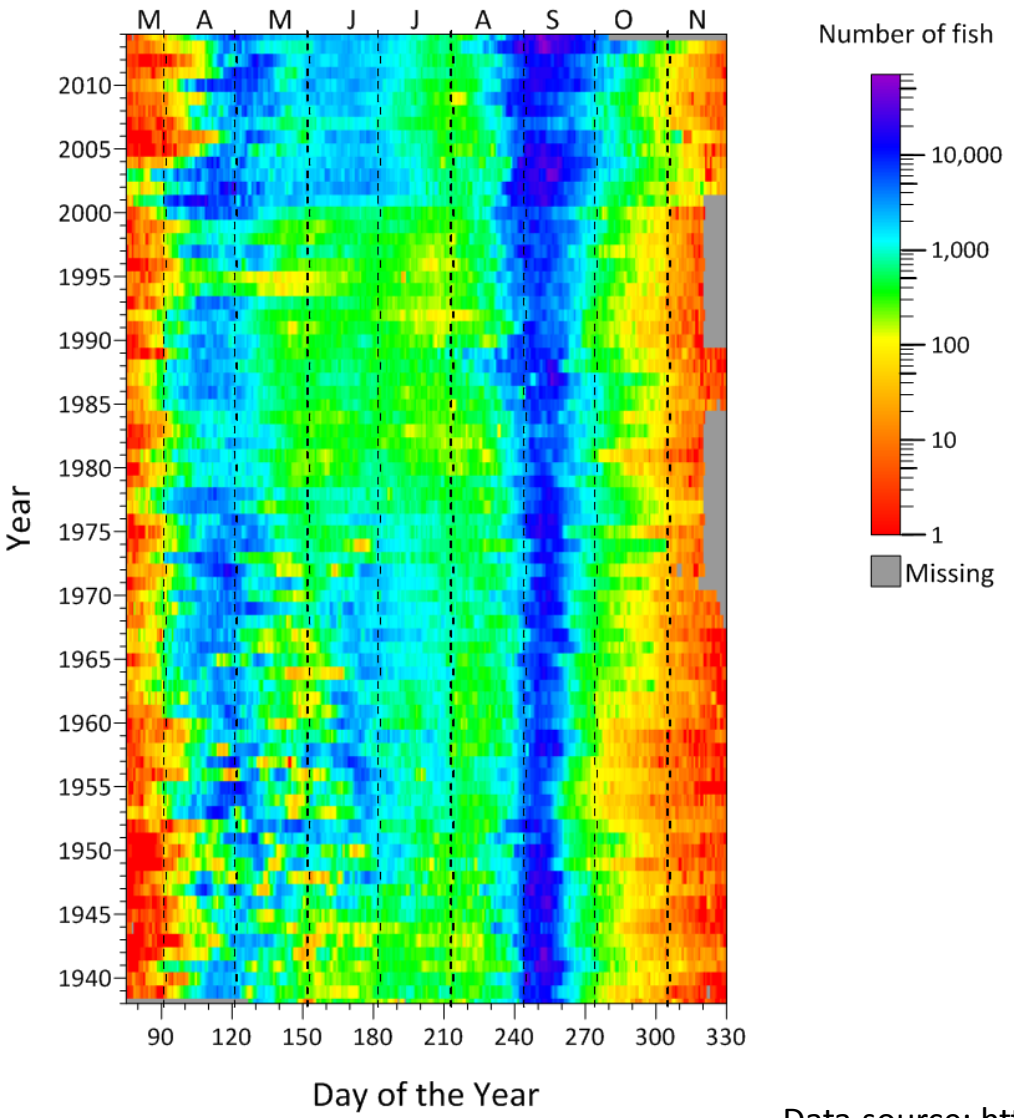
Daily Count, (2010 – 2014, 5 years)



Source: http://www.fpc.org/

Bonneville adult chinook

Daily Count, (1938 – 2014, 76 years)



Data source: http://www.nwd-wc.usace.army.mil/

Flow regime and geology

Dr. Gordon Grant USFS - OSU study

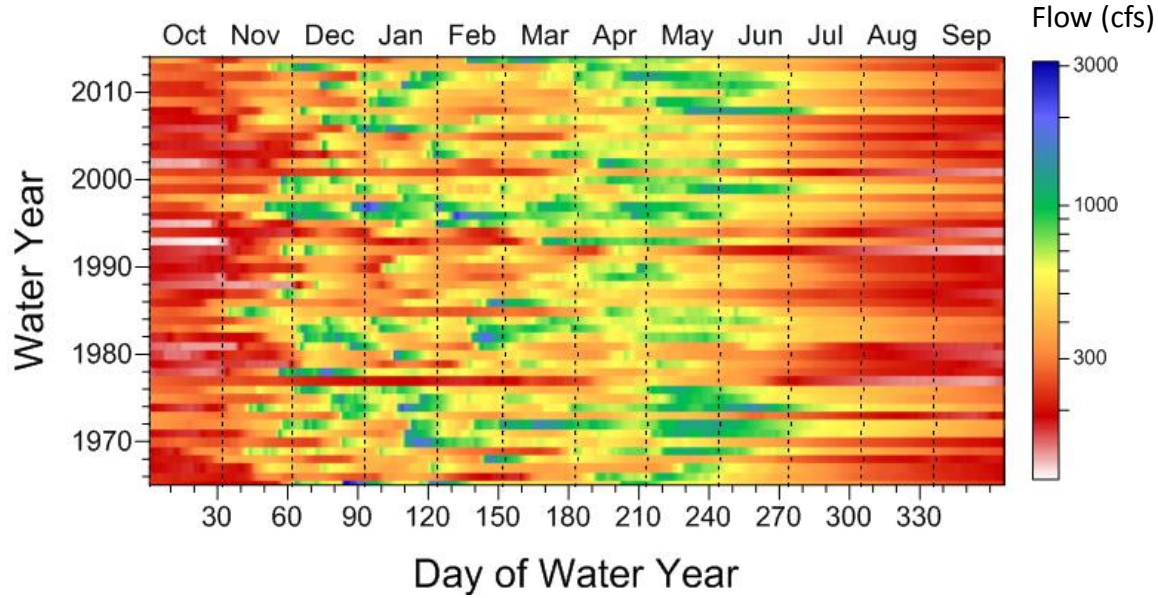
McKenzie River at Outlet of Clear Lake, OR
Elev = 3,015 ft,
Drainage area = 92.40 mi^2
High Cascade geology
High bedrock perm, Mtn/Trans terrain
Moderate/High soil perm

Lookout Creek near Blue River, OR
Elev = 1,378 ft
Drainage area =24.10 mi^2
Western Cascade geology
Low bedrock perm, Mtn terrain
Low soil perm

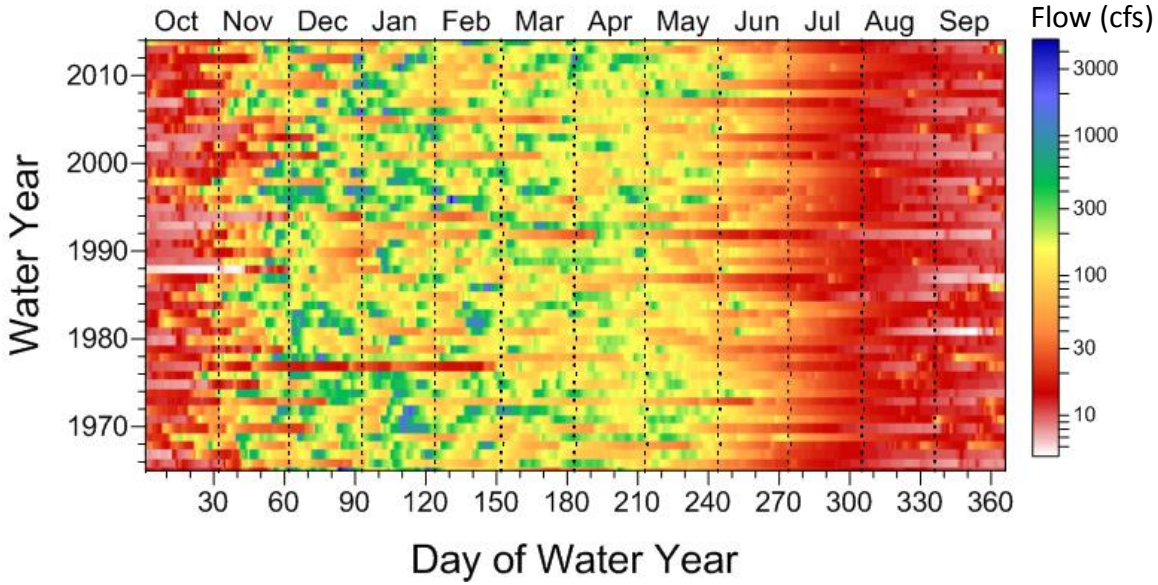
Source: Grant et al., 2010. Streamflow response to climate warming in mountain regions: Integrating the effects of snowpack and groundwater dynamics. http://www.fs.fed.us/psw/cirmount/meetings/mtnclim/2010/talks/pdf/Grant_Talk2010.pdf

Flow regime and geology

Clear Lake, OR
High soil perm
Winter: longer duration
Summer: higher baseflow



Lookout Creek, OR
Low soil perm
Winter: shorter duration
Summer: low baseflow



SNOTEL example – Crater Meadow, ID

United States Department of Agriculture
NRCS Natural Resources Conservation Service

National Water and Climate Center

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- Surface Water Supply Index

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- SNOTEL & Snow Course Data
- SCAN Data
- Other Climate Data
- 30 Year Normals

Quick Links
- Report Generator Data Search
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- Weekly Water & Climate Update

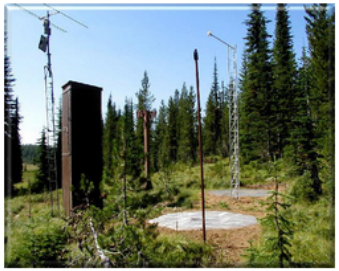
Help Centers
- Report Generator
- Web Service

- Snow Survey Programs by State

SNOTEL Site: Crater Meadows
State: Idaho
Site Number: 425
County: Clearwater
Latitude: 46 deg; 34 min N
Longitude: 115 deg; 17 min W
Elevation: 5960 feet
Reporting since: 1984-08-03

Questions about this site.

View Daily Sensor Descriptions
View Hourly Sensor Descriptions
View Sensor History



Site notes:

- **Data is provisional and subject to revision.**
- More site notes.
- Photograph is of the Crater Meadows SNOTEL site.
- *2015-March-29 National Water and Climate Center*
- **To Obtain the Daily Normals for the Period 1981-2010:**
- Daily Snow Water Equivalent Medians
- Daily Accumulated Precipitation Averages

Site Reports:

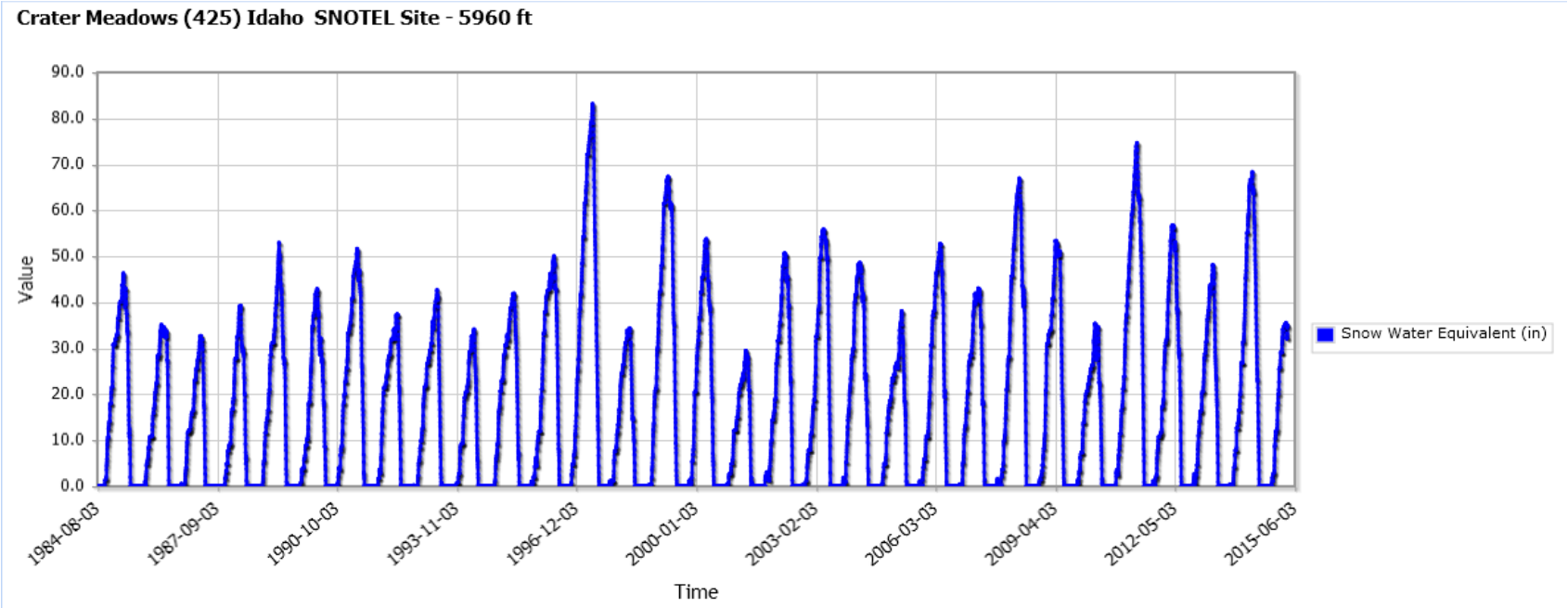
Report Type	Daily	Current Water Year*	Historical	Hourly
Standard Sensors† (*Most Current Data*)	Last 7 Days	Daily Readings	Daily (Csv Delimited)	Last 7 Days
Precipitation, Accumulated	Last 7 Days	Daily Table	Daily Table	Last 7 Days
Snow Depth	Last 7 Days	Daily Readings		Last 7 Days
Snow Water Equivalent	Last 7 Days	Daily Table • Daily Graph	Daily • Monthly	Last 7 Days
Temperature	Last 7 Days	Max • Min • Avg	Max • Min • Avg	Last 7 Days
Soil Moisture/Temperature				Select # of Days

Element Reports:

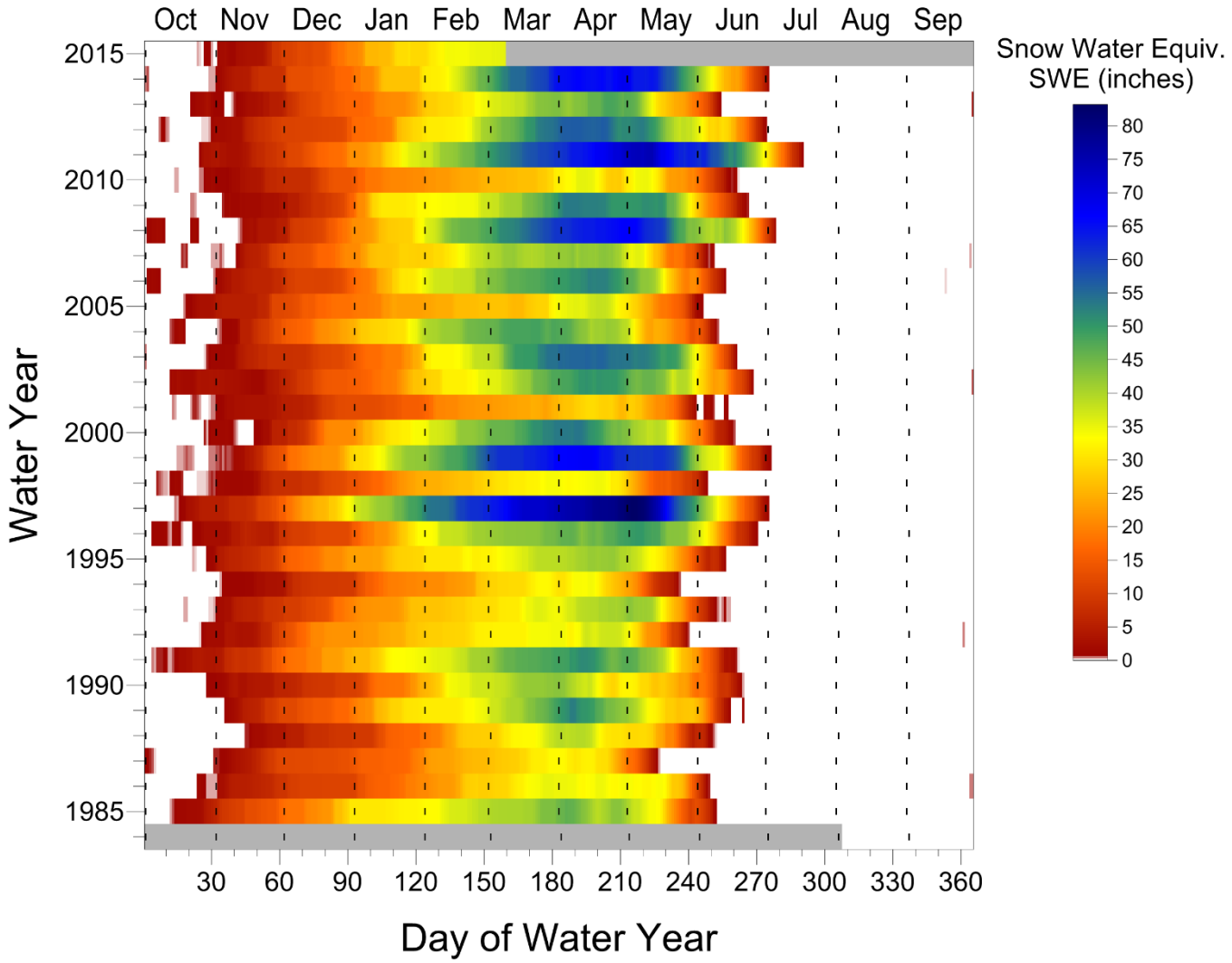
☐ Check to view temperatures in degrees Fahrenheit. Default is degrees Celcius.

Select Report Content	Select Time Series	Select Format	View Current	View Historic		
Standard SNOTEL (1984-08-03)	Daily	table	Last 30 days	1984	Calendar Year	All days
All Sensors (no chart)	Hourly	csv	Last 7 days	1985	Water Year	01
Soil Moisture & Temperature (2011-08-15)	12 AM	chart	Last 24 hours	1986	January	02
Soil Moisture (2011-08-15)	3 AM		Water Year	1987	February	03
Soil & Air Temperature (2011-08-15)	6 AM		Calendar Year	1988	March	04
Accumulated Precipitation (1984-08-03)	9 AM			1989	April	05
Accumulated Precipitation & Snow (1984-08-03)	12 PM			1990	May	06
===Individual elements===	3 PM			1991	June	07
Air Temperature (1983-10-01)	6 PM			1992	July	08
Diagnostics (2011-03-28)	9 PM			1993	August	09

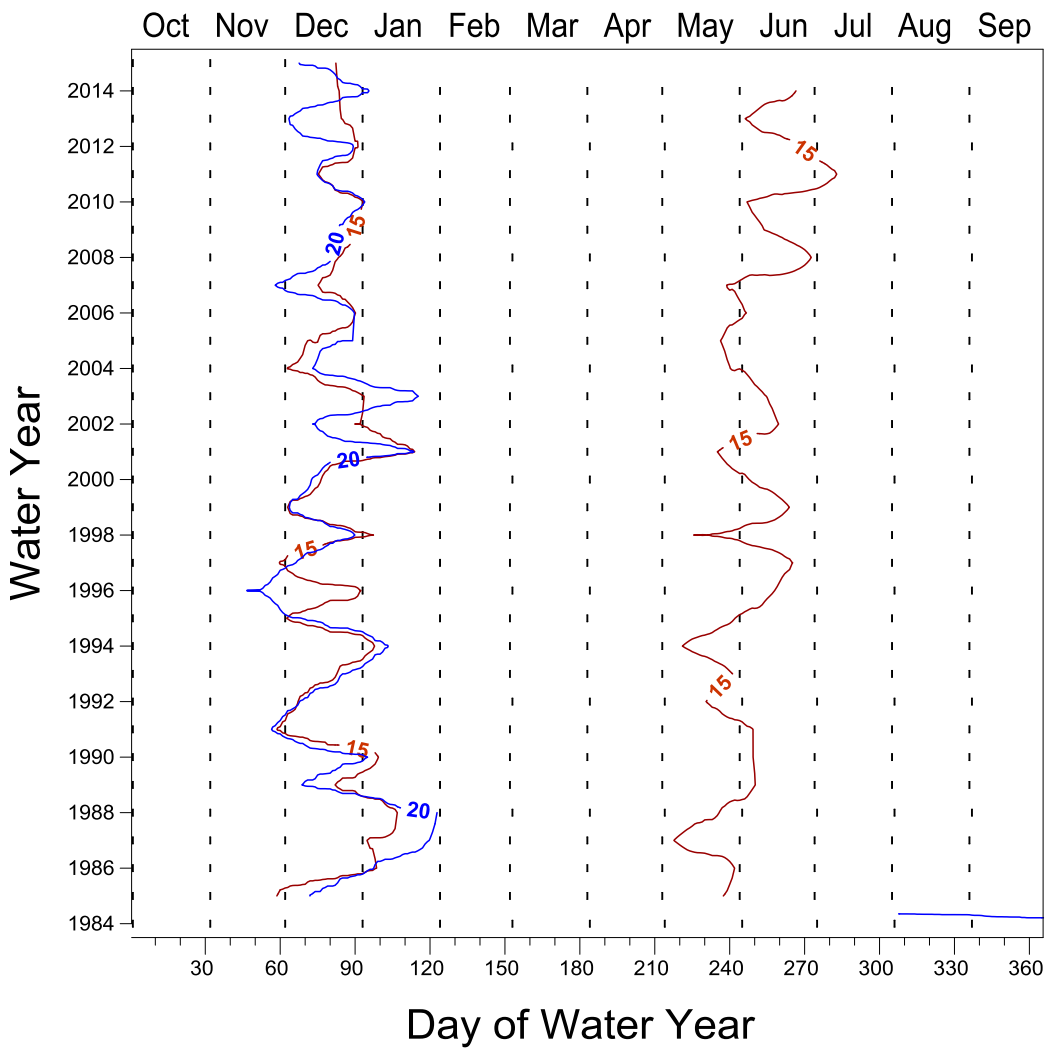
Snow Water Equivalent



Snow Water Equivalent



SWE and Precipitation

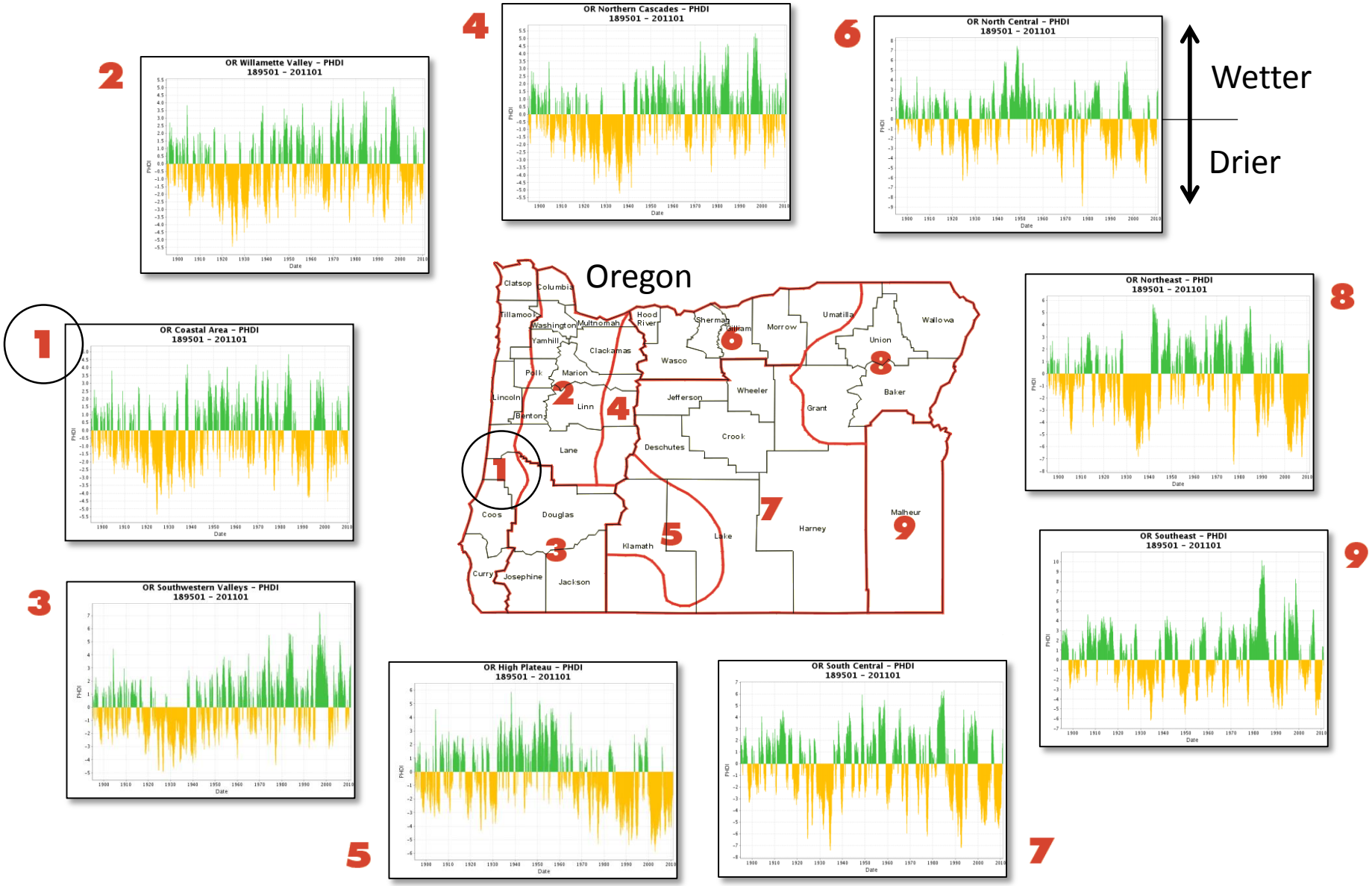


SWE (15 inches)

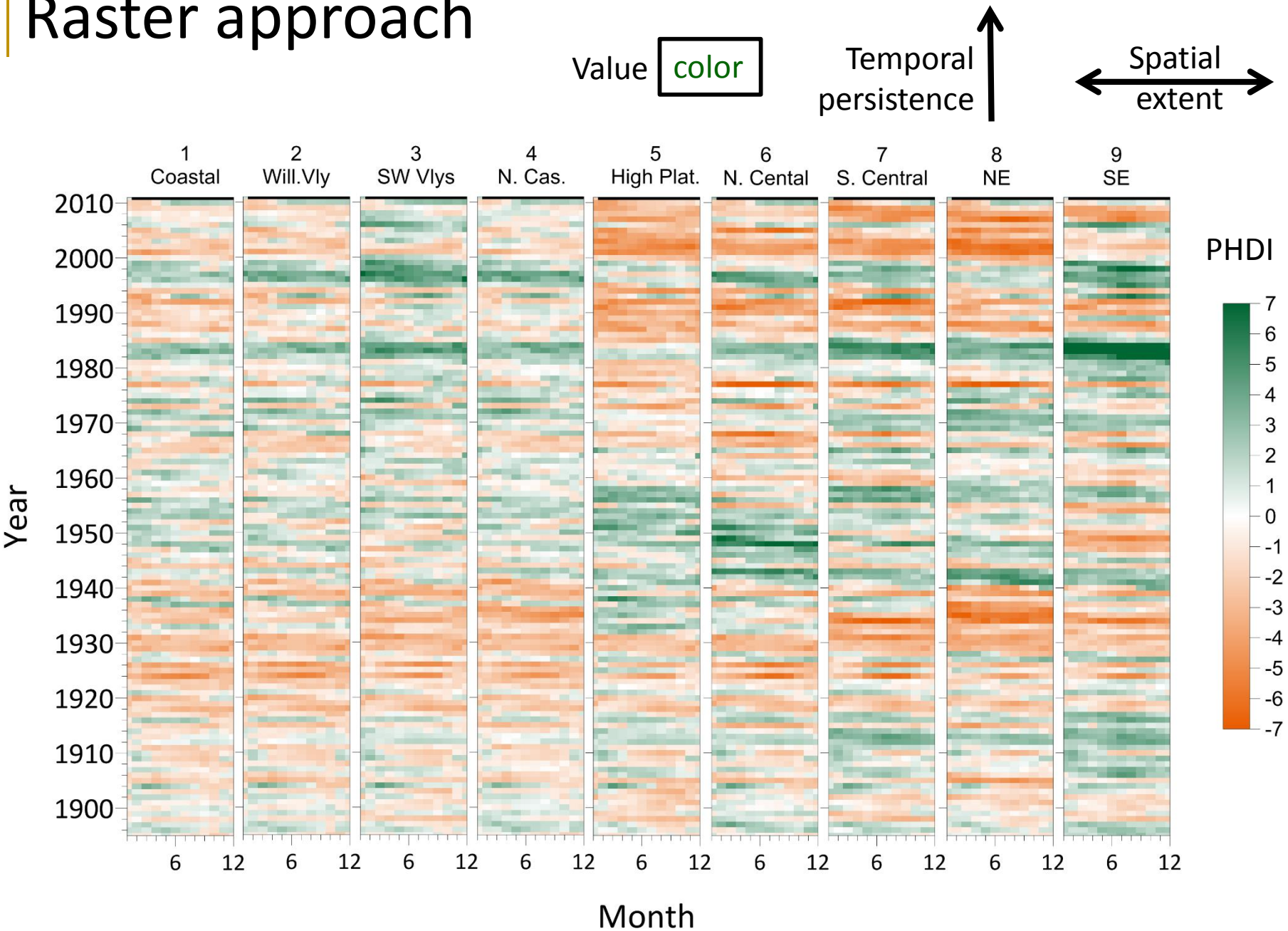
Precip (20 inches)

Drought map comparisons

Palmer Hydrologic Drought Index (PHDI)



Raster approach



GIS-like analysis

Puget Sound

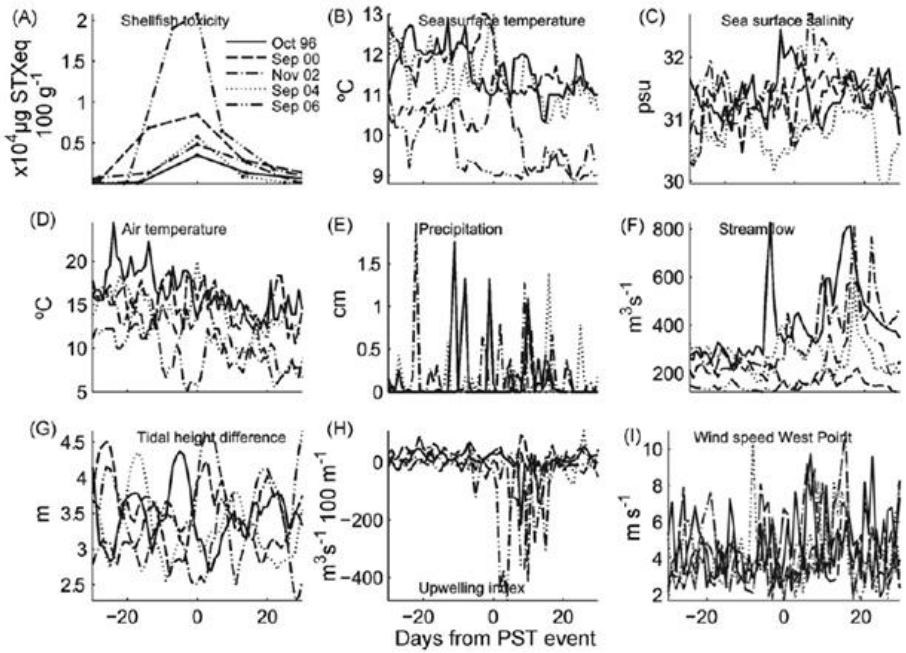
Puget Sound paralytic shellfish toxins

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:



Source: 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.

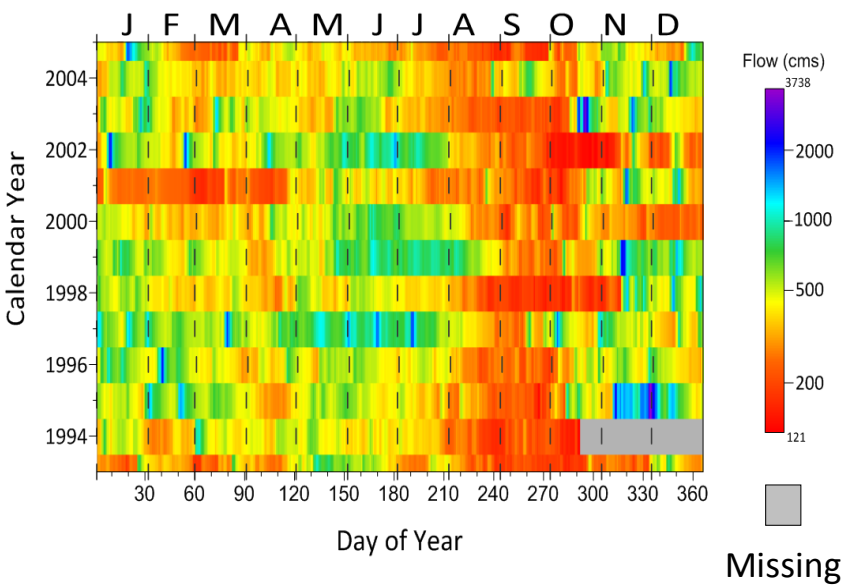
Criterion evaluation

Find days with favorable streamflow conditions

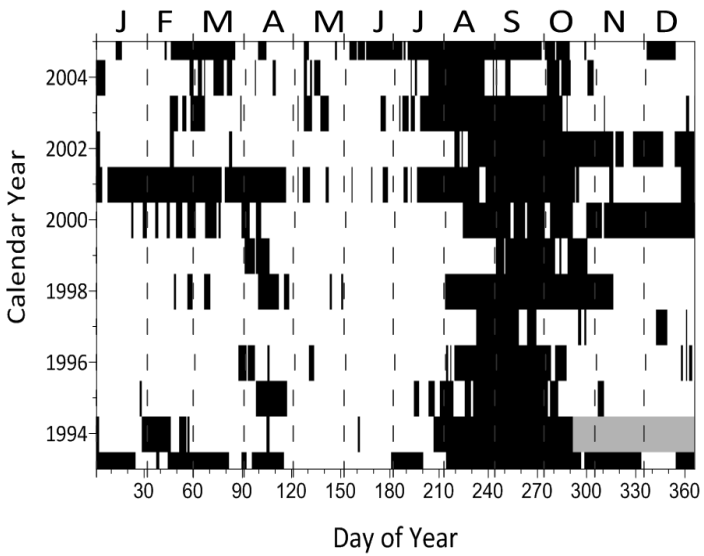
Criterion: Flow ≤ 350 m^3s^{-1}

■ *Met = 1* □ *Not met = 0*

Observed streamflow

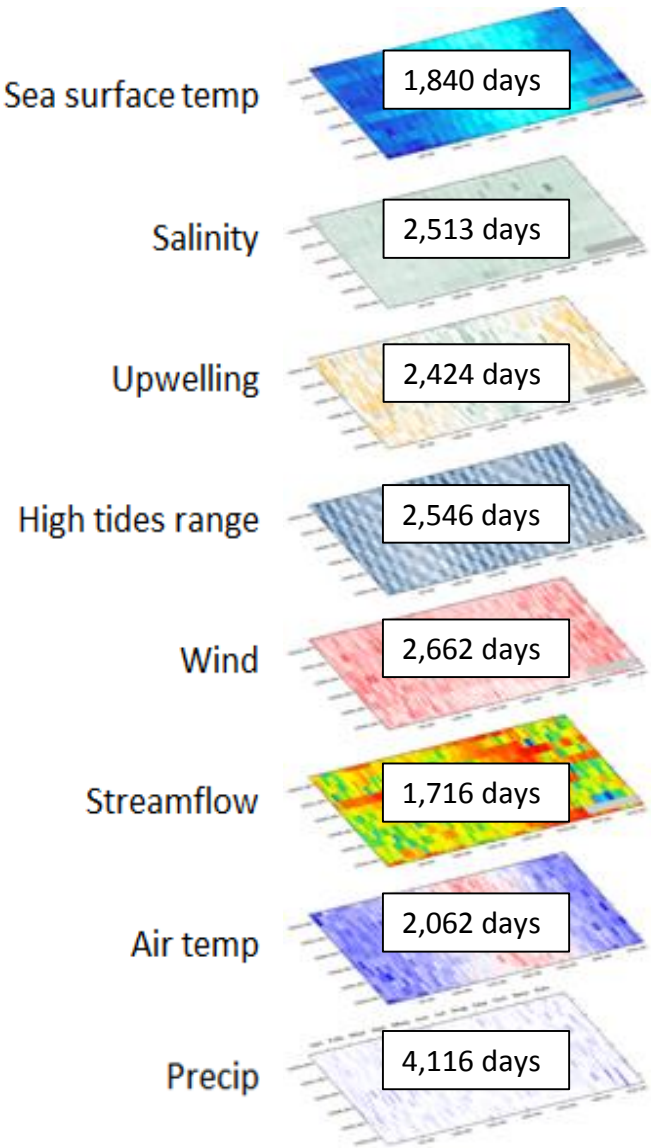


Binary filter



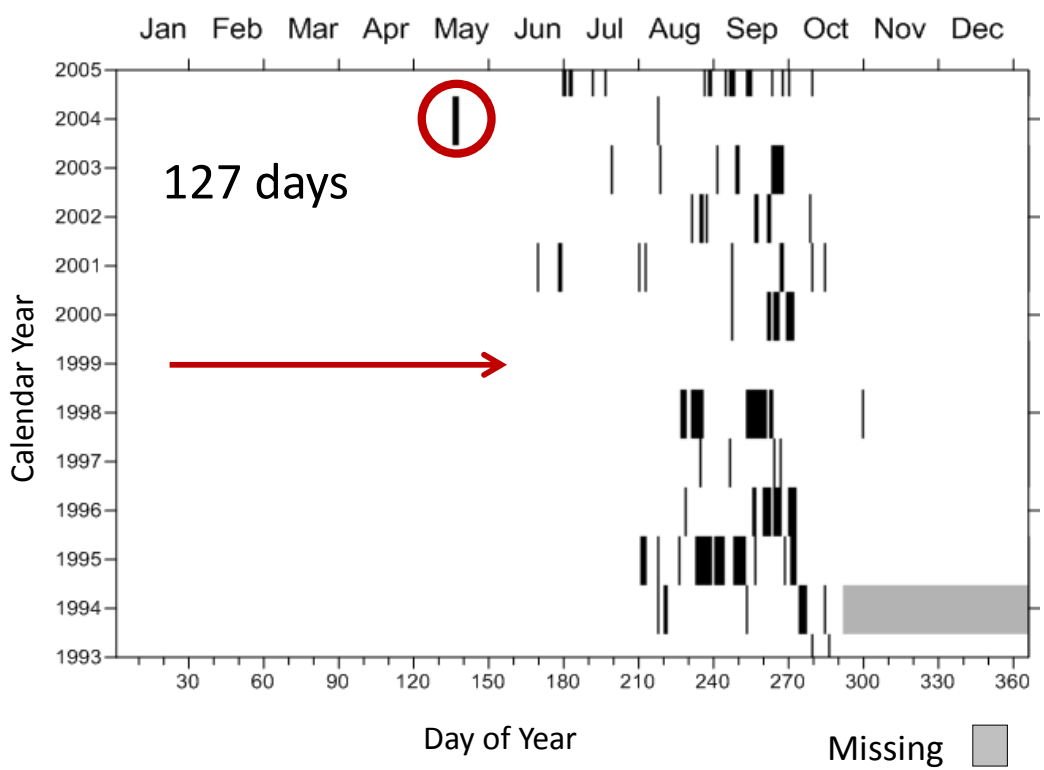
1,716 days or "event windows"

Habitat analysis results



IF (Σ layers = 8 for specific day)
THEN (All factors favorable for an event)

Potential Event Windows



Summary

Alternate display of data

Online resources

Multiple applications

Variety of plots and combinations

Questions?