

Climate Change & Southwest Riparian Areas:

How “Connecting the Dots” between
the Past, the Present, and Processes
can help us address concerns of climate
change & variability in SW Riparian Areas

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**Laboratory of Tree-Ring Research
University of Arizona**



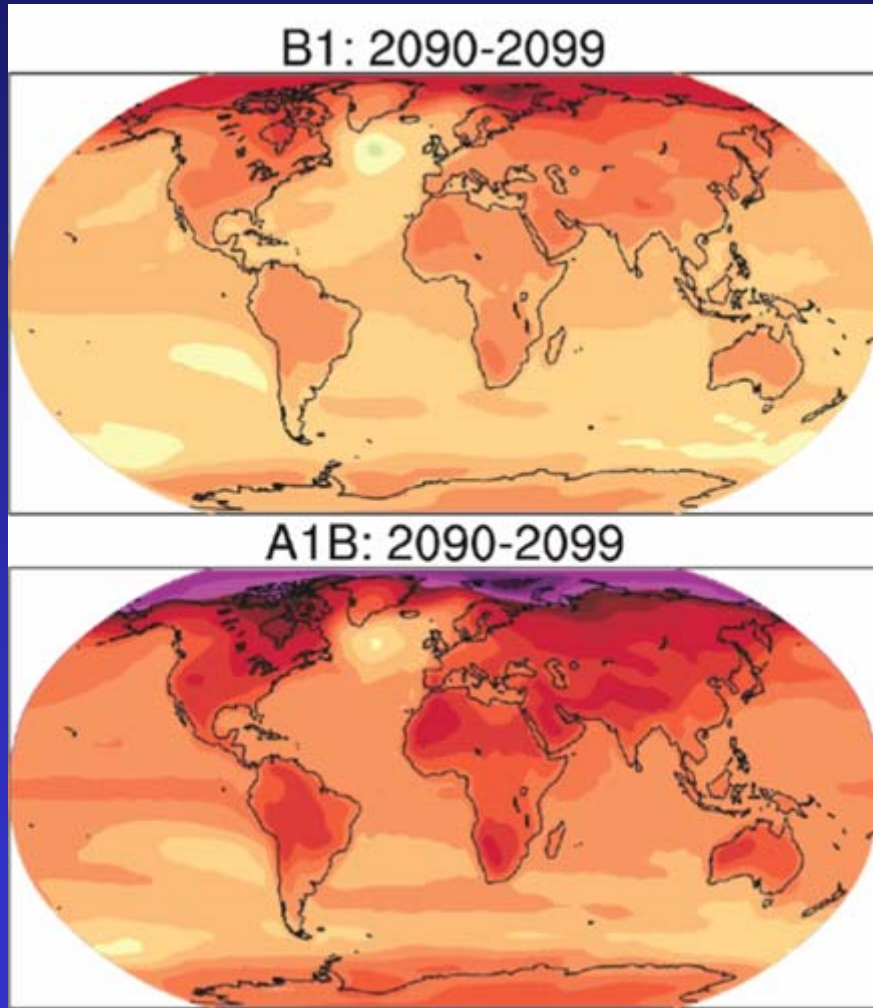
Climate and Riparian Areas Workshop
Connecting the Dots – Climate Change/Variability and
Ecosystem Impacts in Southwestern Riparian Areas –
April 11, 2007

The laboratory of
Tree-Ring Research

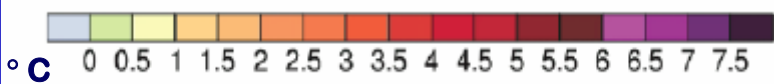
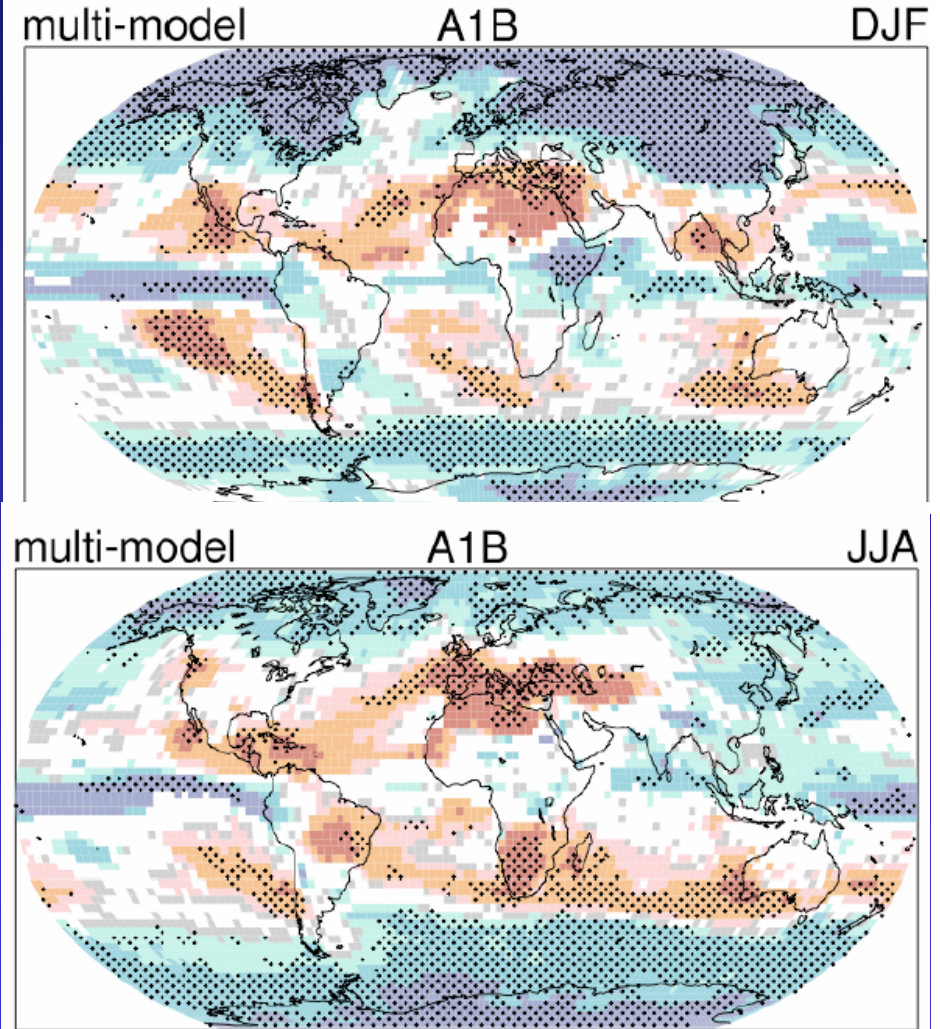


Some Global Temperature & Precipitation Projections:

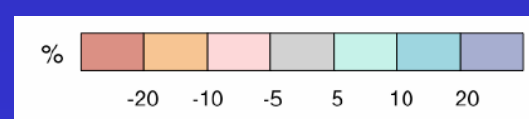
Projections of Surface Temperatures



Projected Patterns of Precipitation Changes



2007 IPCC WG I
Summary for
Policymakers



Arizona Daily Star[®]
www.dailystar.com[®] www.azstarnet.com[®]

Published: 04.06.2007

Study predicts dust-bowl Southwest

The New York Times
nytimes.com

March 27, 2007

Heat Invades Cool Heights Over
Arizona Desert

Arizona Daily Star[®]
www.dailystar.com[®] www.azstarnet.com[®]

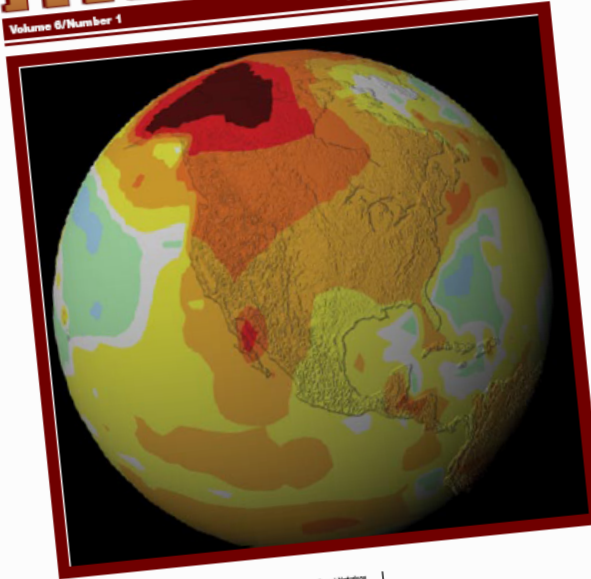
Published: 04.09.2007

SE Ariz. desert 1 of 10 'treasures'
at warming risk

Southwest The Resource for Semi-Arid Hydrology
HYDROLOGY

January/February 2007

Volume 8/Number 1



Inconvenient
Hydrology?

Southwest Hydrology
University of Arizona - TAMU
P.O. Box 210780-08
Tucson, AZ
85721-0788

Address Service Requested

A publication of SARA, an NSF Science and Technology Center - The University of Arizona.

Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America

Richard Seager et al., April 2007 *Science*

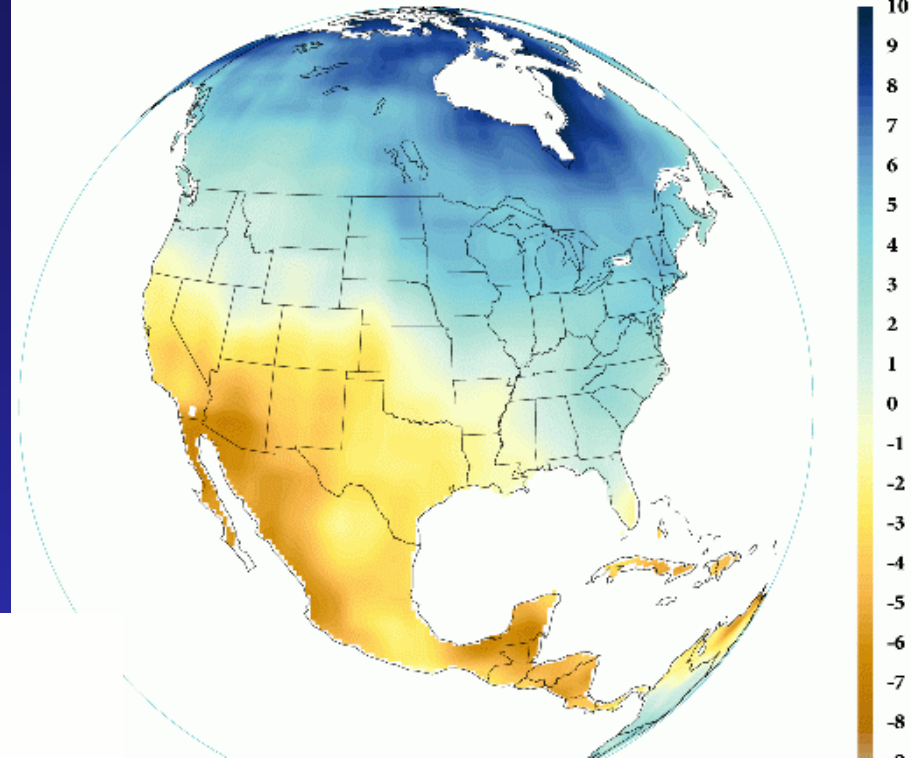
- 19 different climate modeling groups
- Widespread agreement that Southwestern North America [is] on a trajectory to a climate even more arid than now.
- Becomes marked early in the current century.

**“ In the Southwest the levels of aridity seen in the 1950s multiyear drought, or the 1930s Dust Bowl, become the new climatology by mid-century:
a perpetual drought.”**

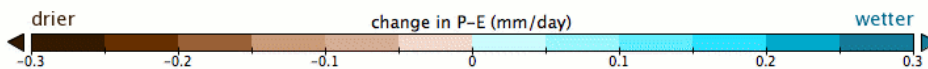
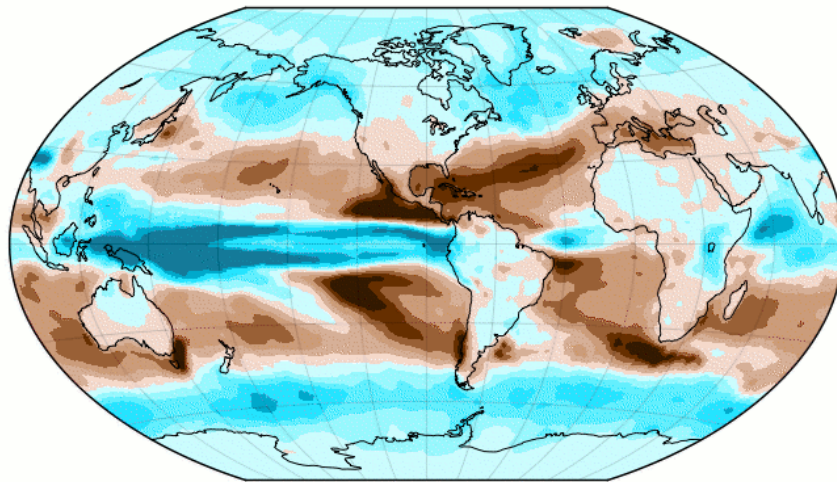
Seager et al. 2007:

- Hadley Cell expands poleward
- Descending air suppresses precipitation by drying the lower atmosphere
- subtropical dry zones expand

Projected Change in Precipitation 1950-2000 to 2021-2040
(Percent of 1950-2000)



Change in P-E (2021-2040 minus 1950-2000)

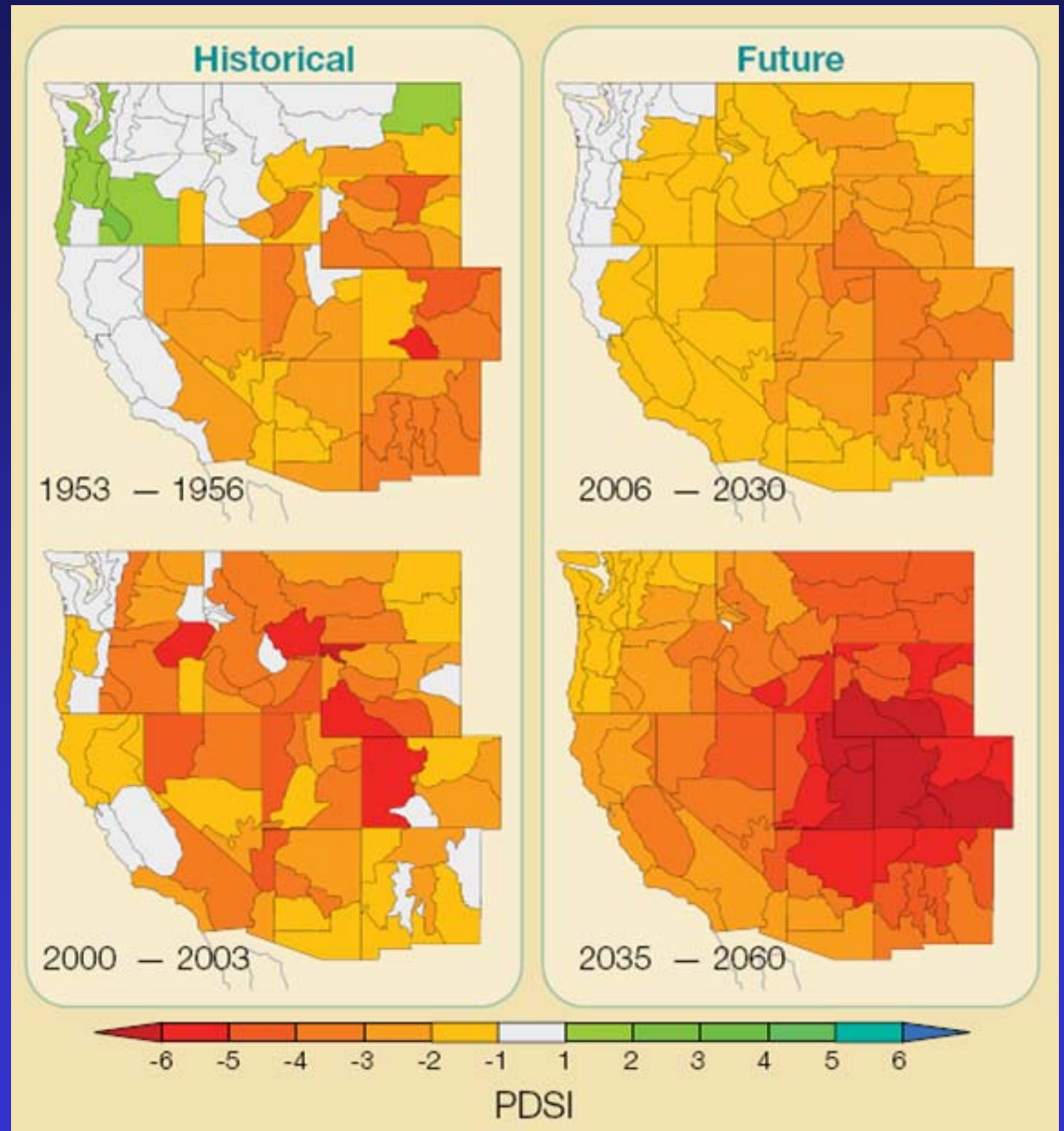


Winkler Tripel projection centered on -90.0°E

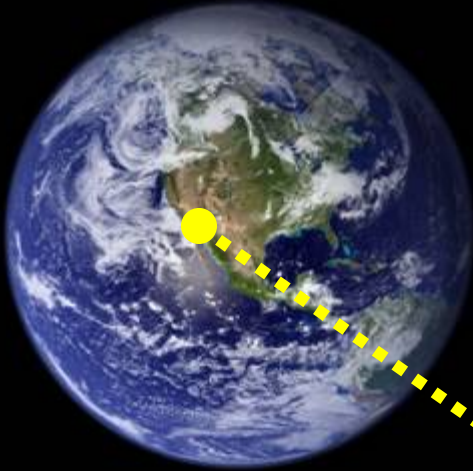
- Rain-bearing mid-latitude storm tracks shift poleward

- Both changes cause the poleward flanks of the subtropics to dry.

Typical scale of
future regional
projections:
based on
coupled ocean-
atmosphere-
land models



Source:
Hoerling & Eischeid 2007
in Southwest Hydrology



Key Question:

How do we transfer the growing body of knowledge and assertions about global climate change and variability to individual Southwestern watersheds and their riparian areas?

Issues of spatial and temporal scale are of key importance in understanding the processes involved in the delivery of precipitation and the resulting riverine response in individual watersheds.



This presentation argues:

... that attention to some very basic hydrologic and geographic elements at the local and regional watershed scale

-- such as basin size, watershed boundaries, storm type seasonality, atmospheric circulation patterns, and geographic setting

... can provide a basis for a cross-scale approach to linking GLOBAL climate variability with LOCAL hydrologic variations in riparian areas ...

... including **EXTREME EVENTS**
in the “tails” of streamflow
probability distributions,
such as floods and droughts.



In other words we will

**. . . let the rivers “speak for themselves”
about how they respond to climate .**



A systematic compilation of watershed-specific information about spatially and temporally varying hydroclimatic extremes is proposed as a starting place for making operationally useful decisions about prospective climatic changes.

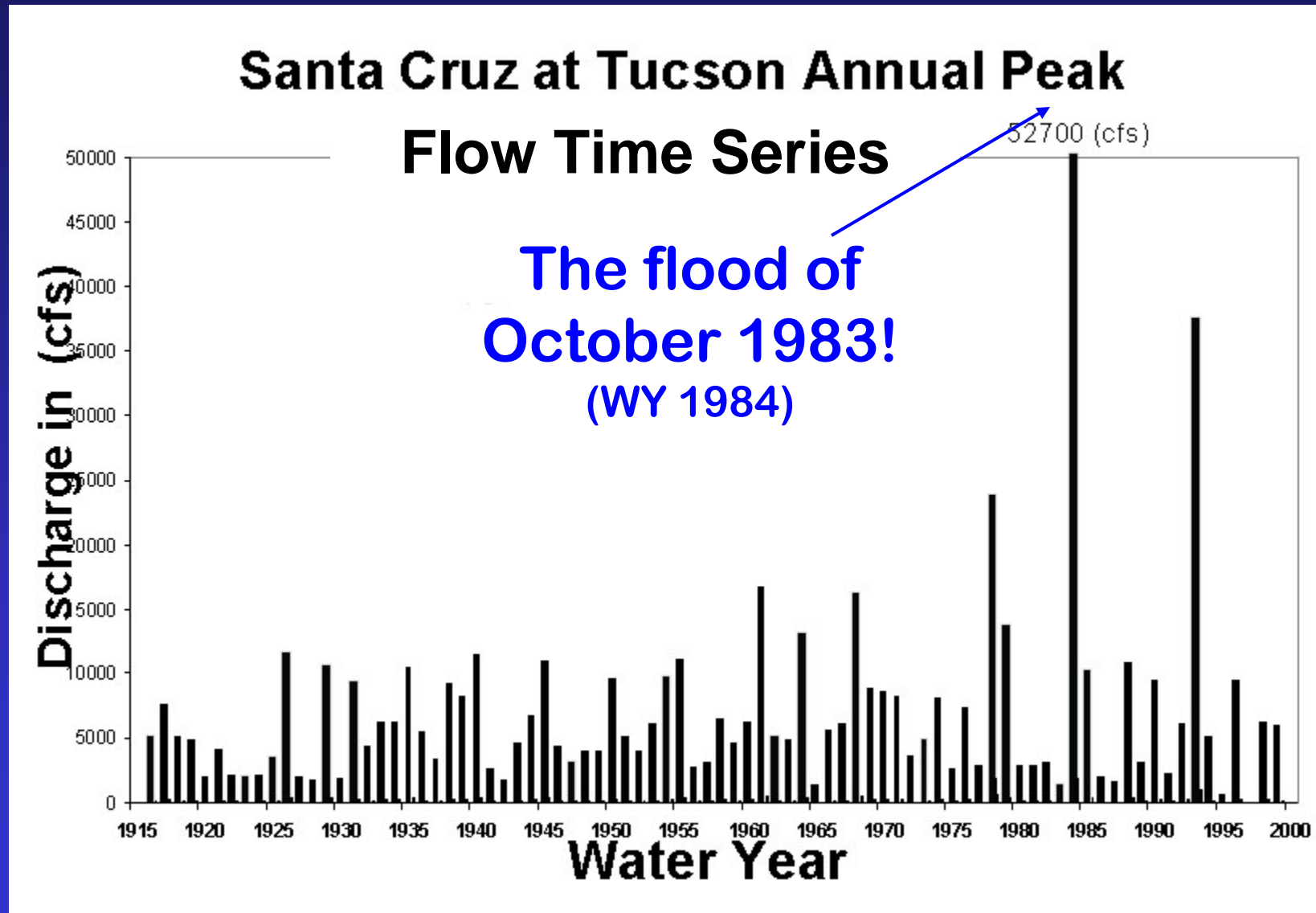
Climate Change & Southwest Riparian Areas “Connecting the Dots”

- I. Connecting across Time**
- II. Connecting across Scales**
- III. Connecting between streamflow, storms, circulation patterns, & climate variations**
- IV. Concluding Remarks**

Climate Change & Southwest Riparian Areas “Connecting the Dots”

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Rivers have histories peak flows:

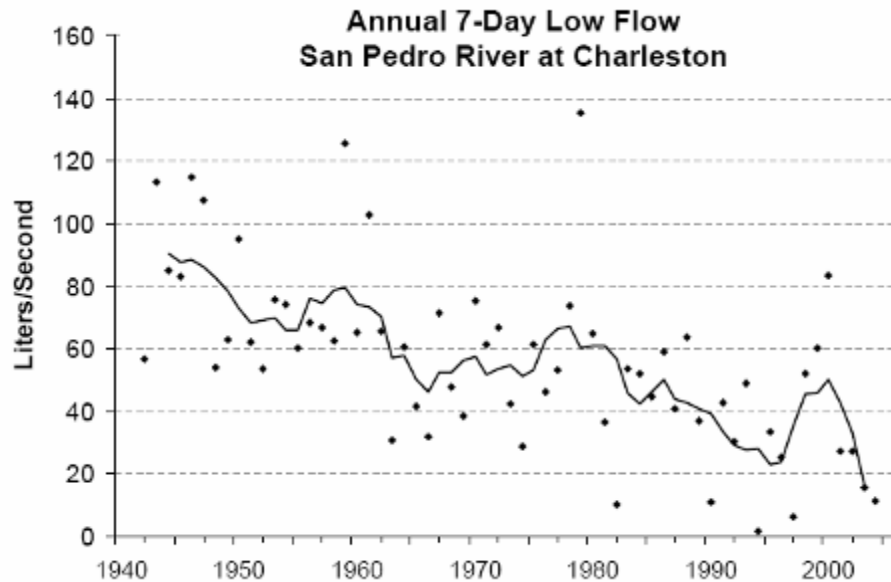
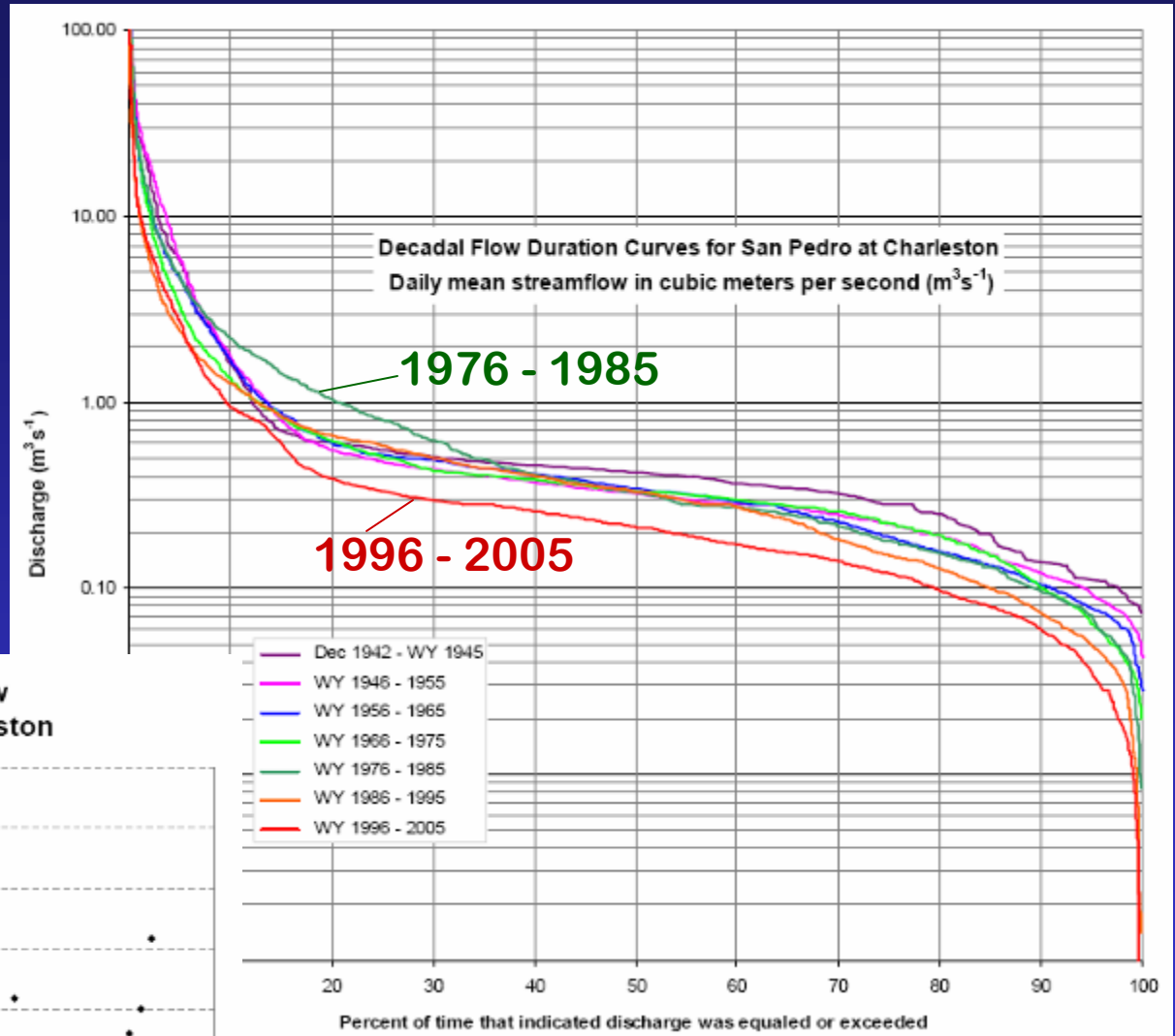


Rivers have histories mean and low flows

San Pedro River

Decadal differences in daily mean streamflow →

From: MacNish et al. "Hydrology of the San Pedro Basin" in Stromberg & Tellman, (forthcoming)



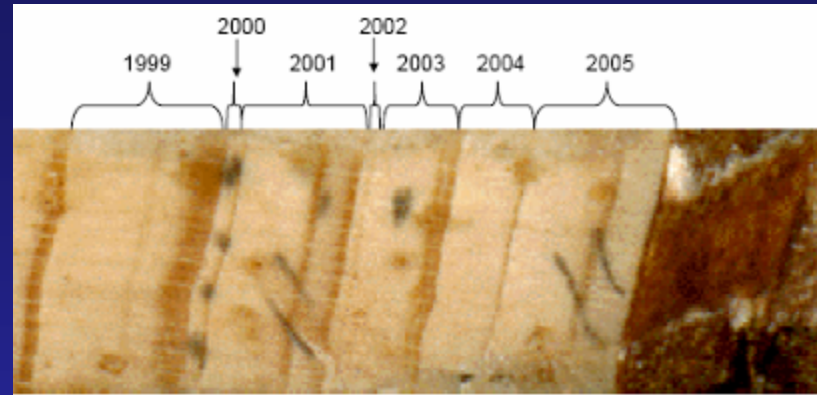
← Time series of 7-Day Low Flow from 1940 - 2002

As long a record as possible is the ideal . . . especially to understand and evaluate the extremes of floods and droughts:

By definition extreme events are rare, hence gaged streamflow records capture only a recent sample of the full range of extremes that have been experienced by a given watershed.

Information extracted from . . .

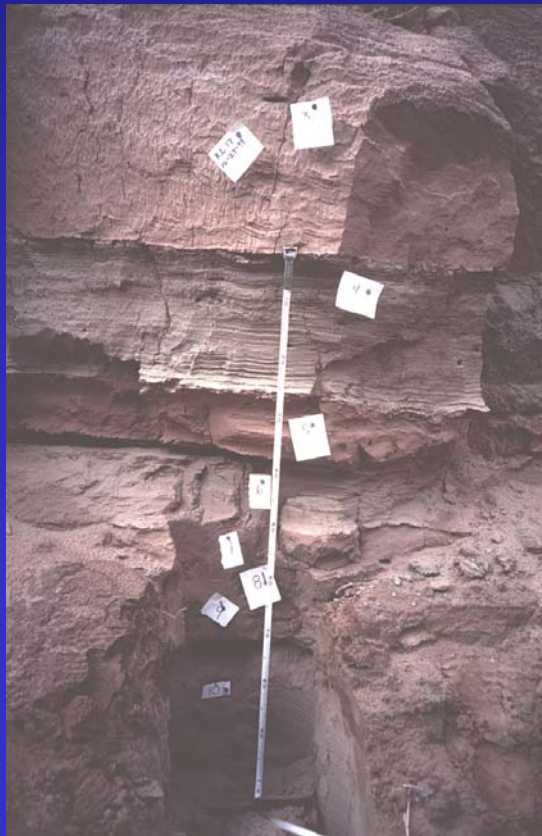
TREE RINGS



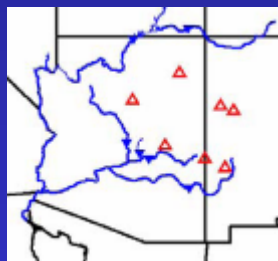
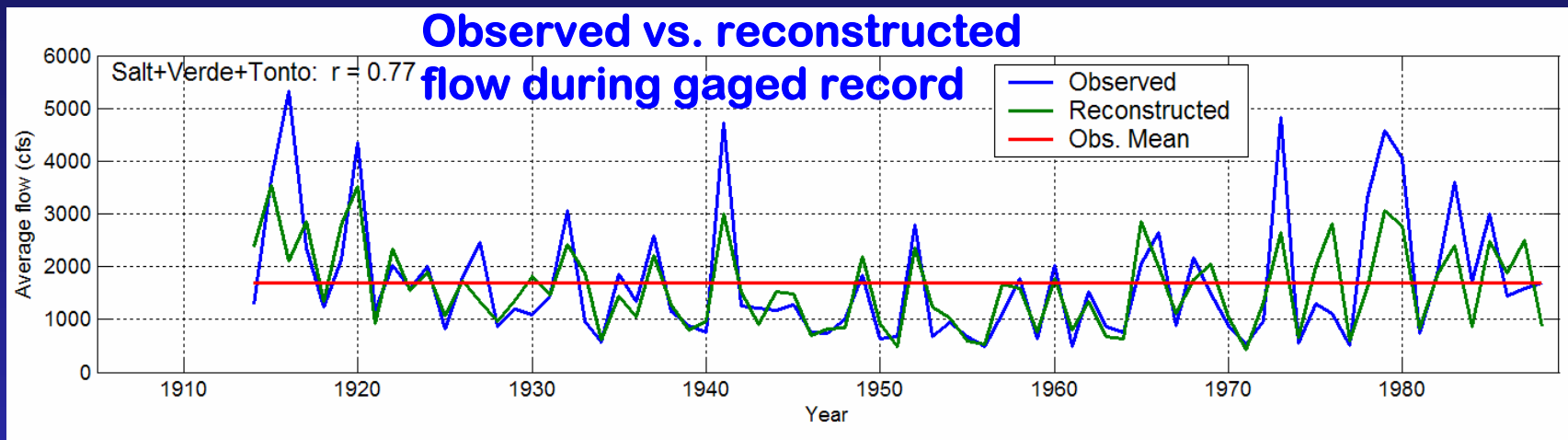
&

STRATIGRAPHIC PALEO - STAGE INDICATORS

can augment the gauged record
of extreme events in some
Arizona watersheds.



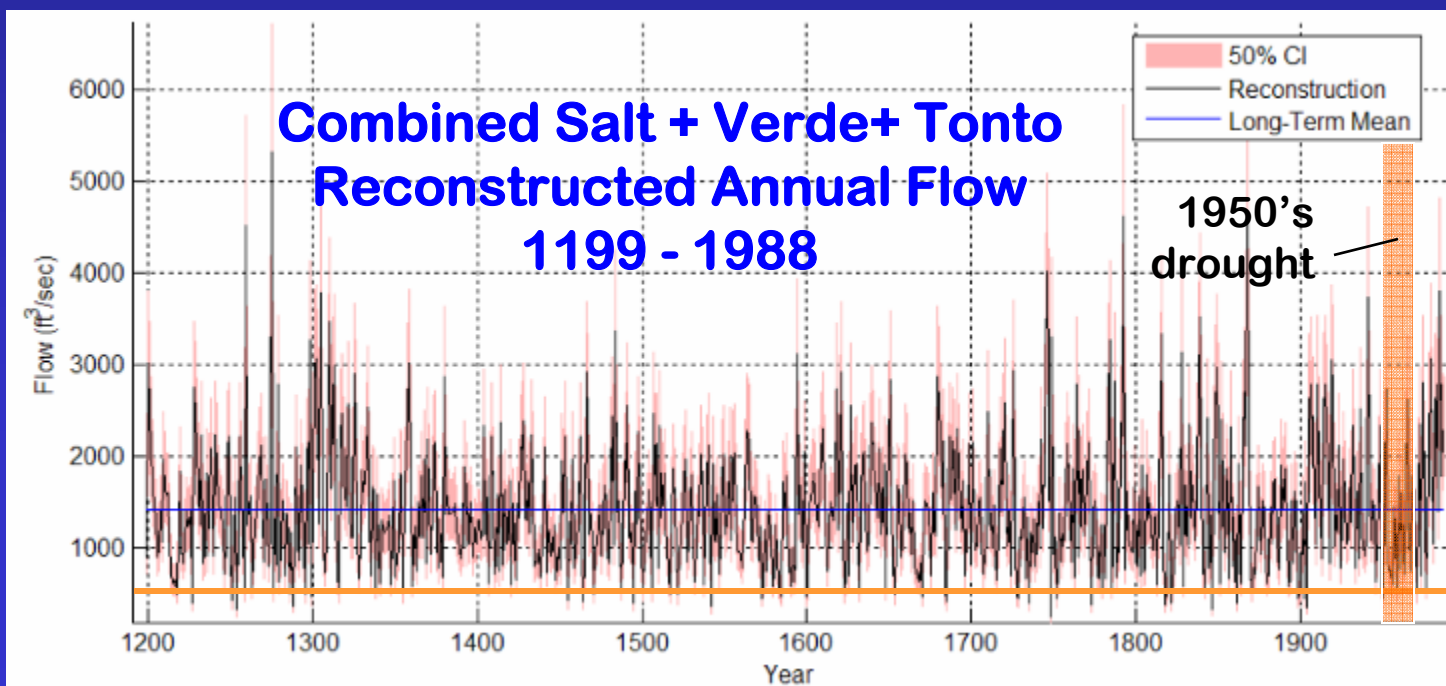
Tree-Ring Streamflow Reconstructions:



Tree-ring sites used in the reconstruction



Hirschboeck & Meko
 2005 SRP Final Report
www.ltrr.arizona.edu/srp



Paleo-Stage Indicators (PSI):

PALEOFLOOD (def)

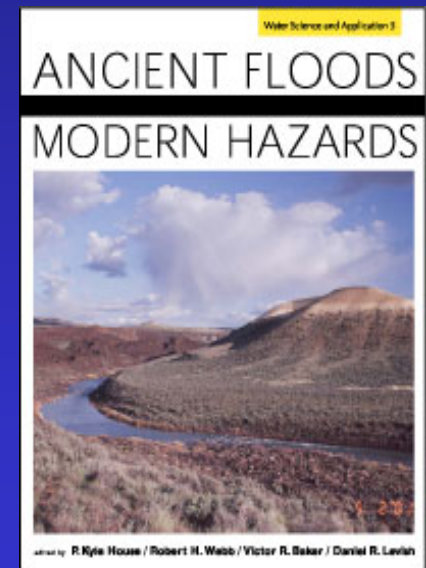
A past or ancient flood event which occurred prior to the time of human observation or direct measurement by modern hydrological procedures.

Recent or modern events may also be studied using paleoflood analytical techniques:

HISTORICAL FLOOD

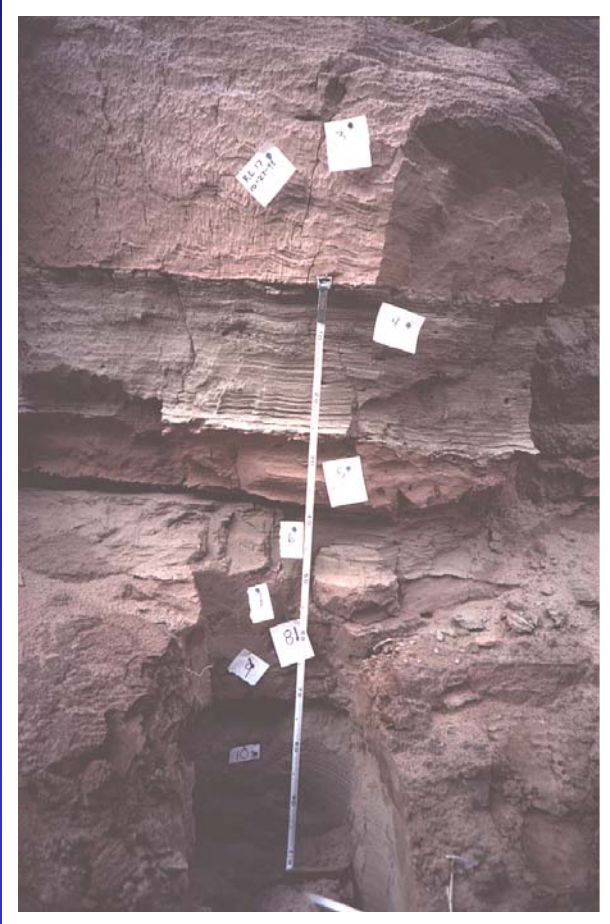
Flood event documented by human observation and recorded prior to the development of systematic streamflow measurements

EXTREME FLOOD IN UNGAGED WATERSHEDS



House, Webb, Baker
& LeVish (2002)
American Geophysical
Union

Paleoflood Deposits . . .



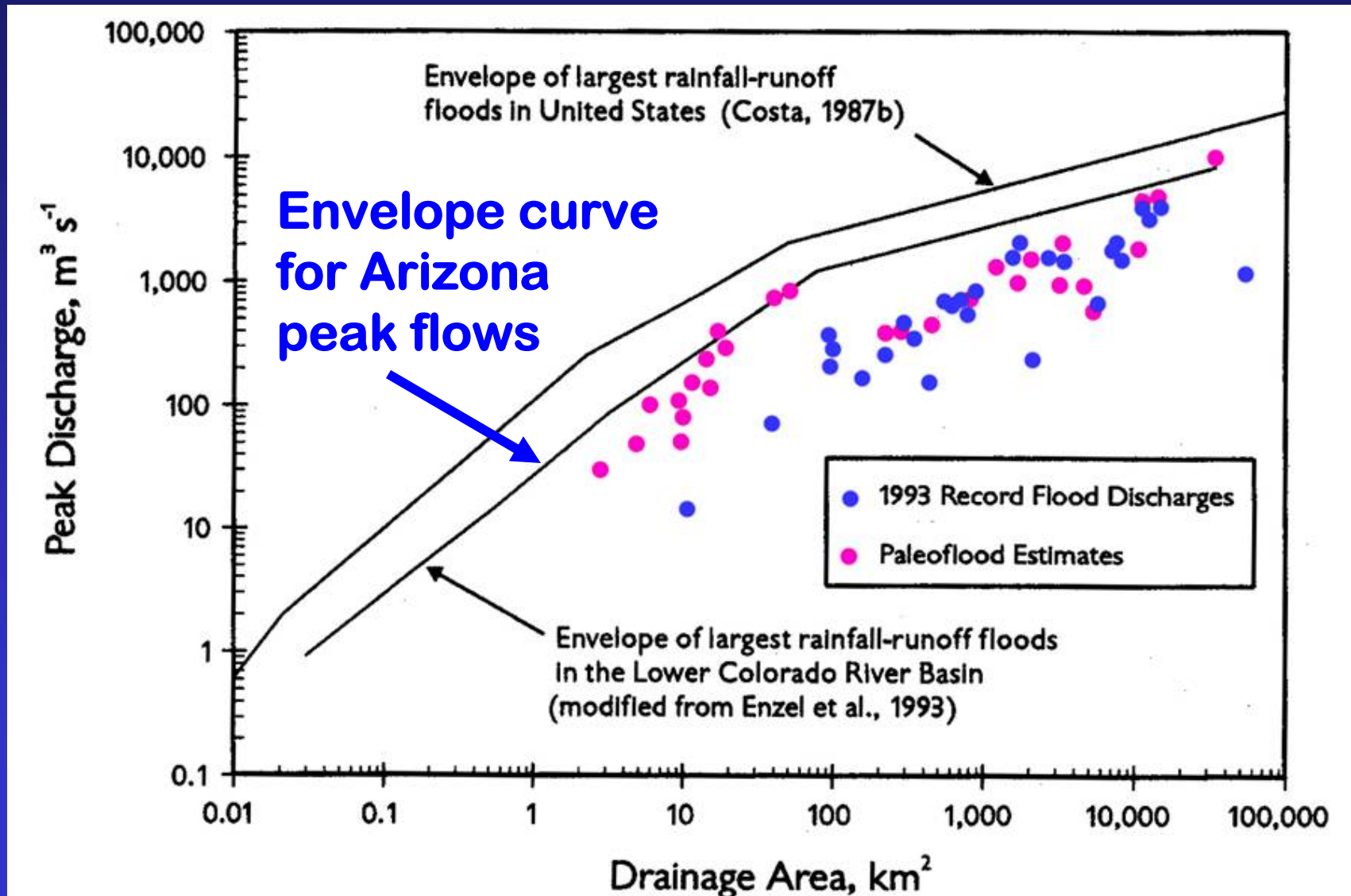
-- not filtered through a biological response (unlike tree rings)

-- direct physical evidence of extreme hydrologic events

-- selectively preserve evidence of only the largest floods . . .

. . . precisely the information that is lacking in the short gaged discharge records of the observational period

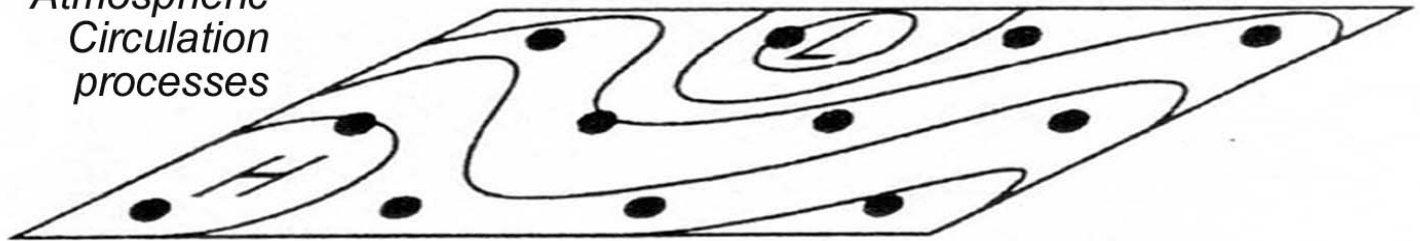
Compilations of **paleoflood records** combined with **gaged records** suggest there is a **natural, upper physical limit** to the magnitude of floods in a given region.



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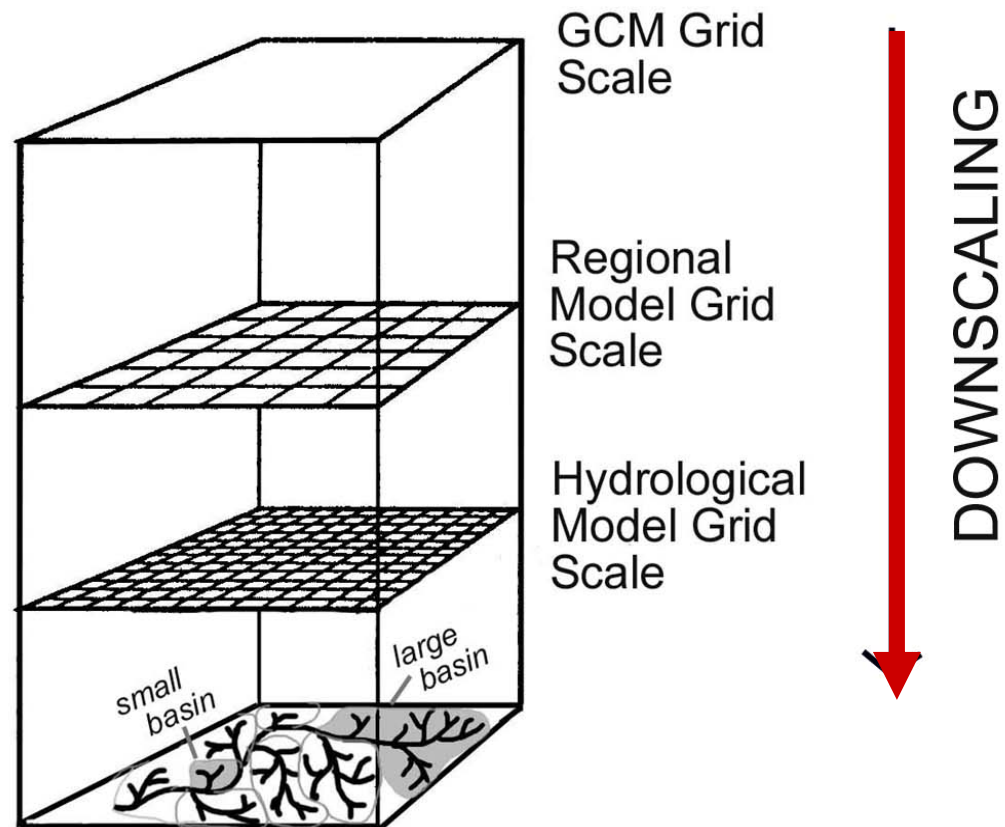
Atmospheric
Circulation
processes



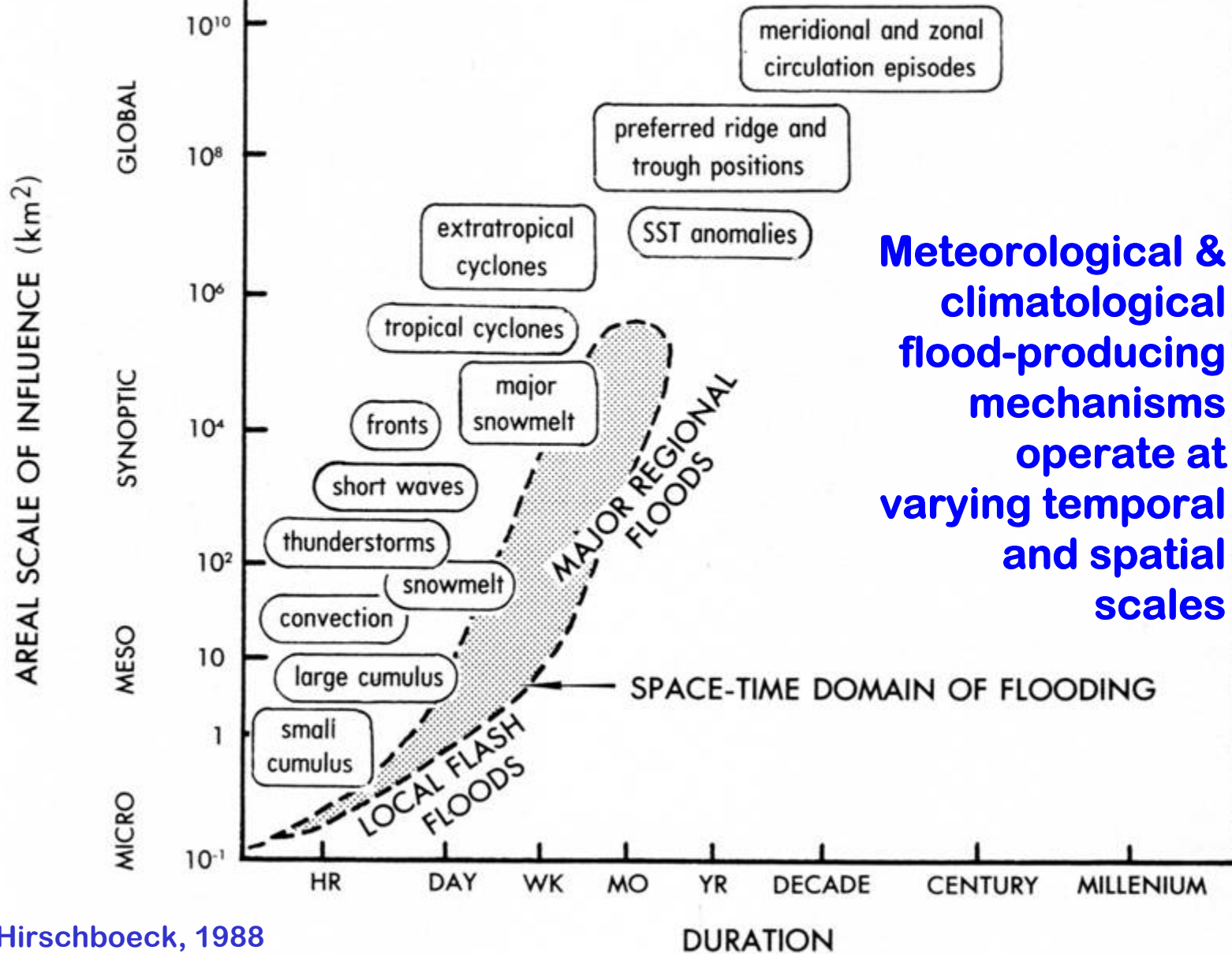
DOWNSCALING:

Interpolation of GCM results computed at large spatial scale fields to higher resolution, smaller spatial scale fields, and eventually to watershed processes at the Earth's surface.

Streamflow
Processes
in individual Basins



FLOOD-CAUSING MECHANISMS



Meteorological & climatological flood-producing mechanisms operate at varying temporal and spatial scales

Climate Change & Southwest Riparian Areas “Connecting the Dots”

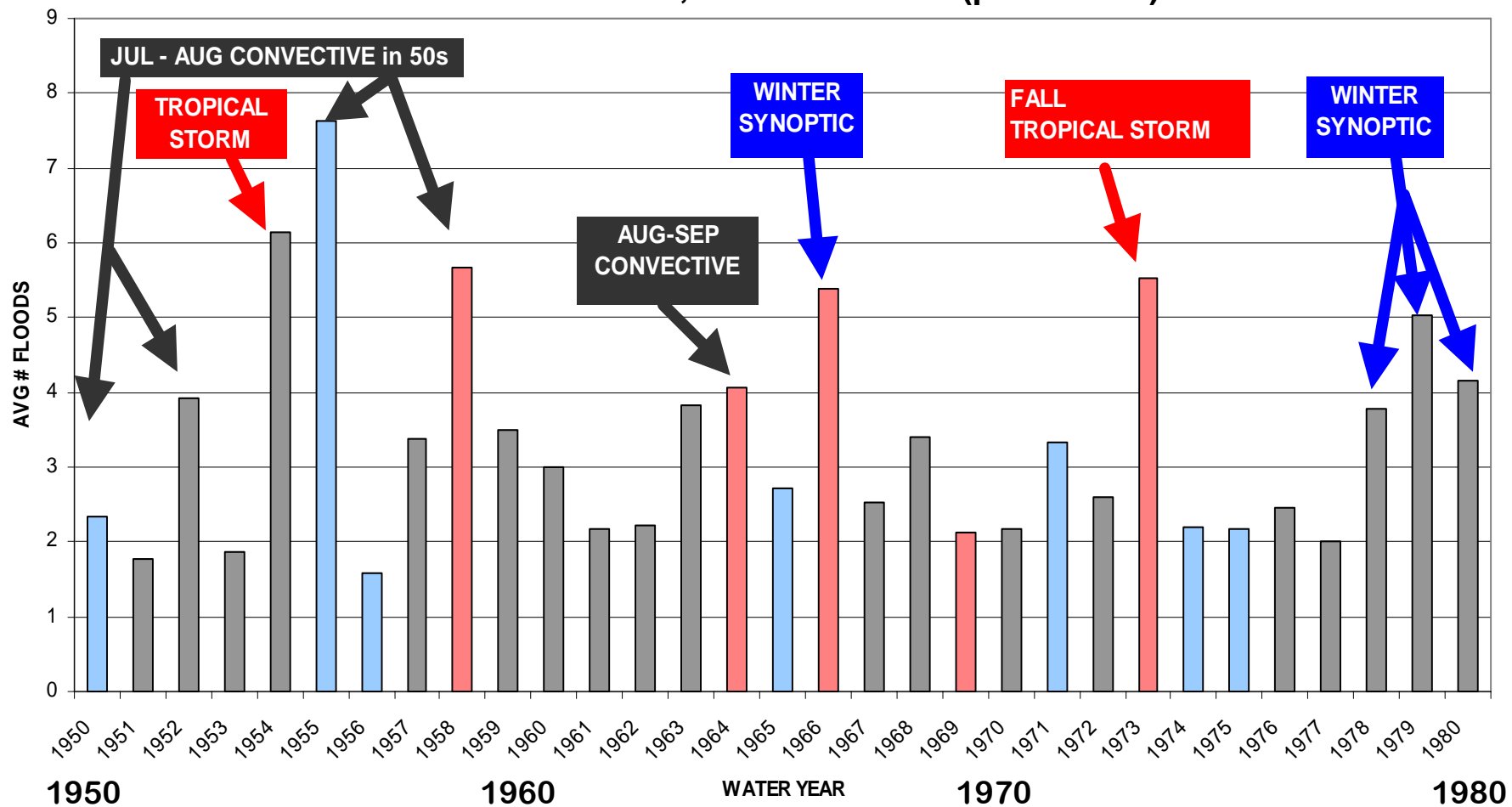
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Interannual Variability of # of Floods (WY 1950-80)

FREQUENCY OF FLOOD PEAKS PER YEAR

AVERAGE # OF PARTIAL DURATION SERIES FLOODS
in GILA RIVER BASIN, AZ EACH YEAR (per station)

Warm ENSO events
Cold ENSO events



FLOOD (DROUGHT) HYDROCLIMATOLOGY

Flood (drought) hydroclimatology is the analysis of flood (drought) events within the context of their history of variation

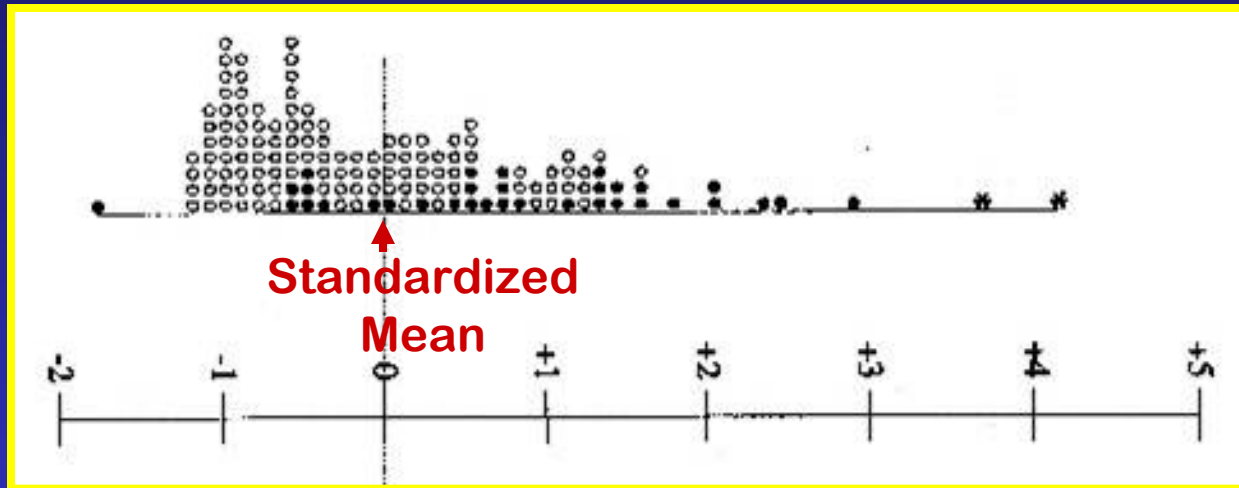
- in magnitude, frequency, seasonality
- over a relatively long period of time
- analyzed within the spatial framework of changing combinations of meteorological causative mechanisms

Adapted from Hirschboeck 1988
Flood Hydroclimatology

Gaged Flood Record -- Histogram

(Standardized Discharge Classes)

o = partial series
- = annual series

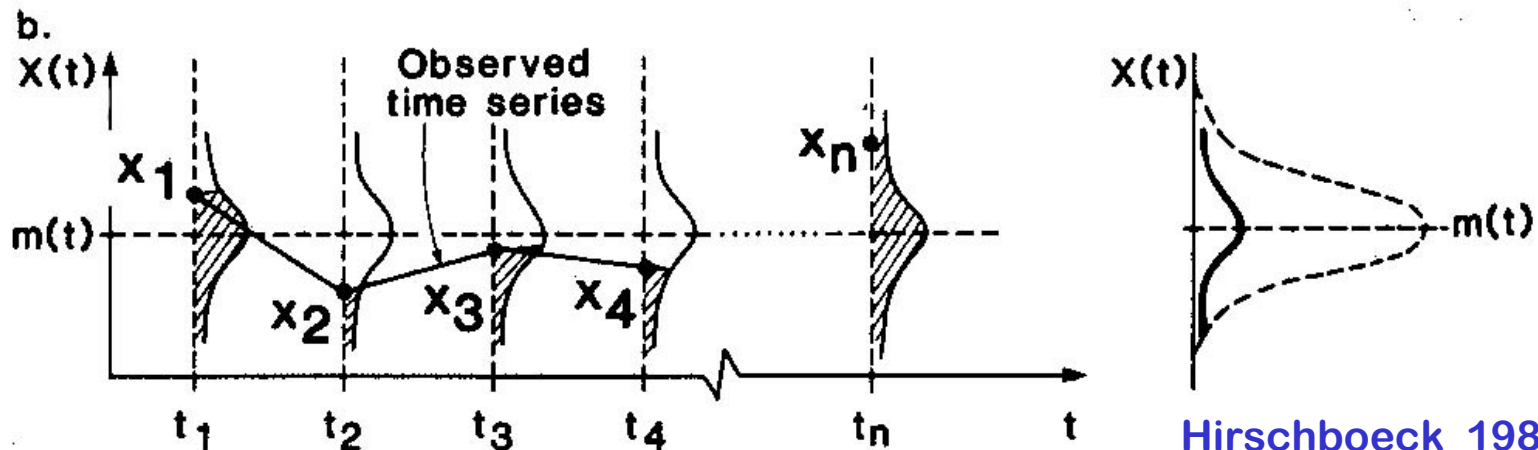
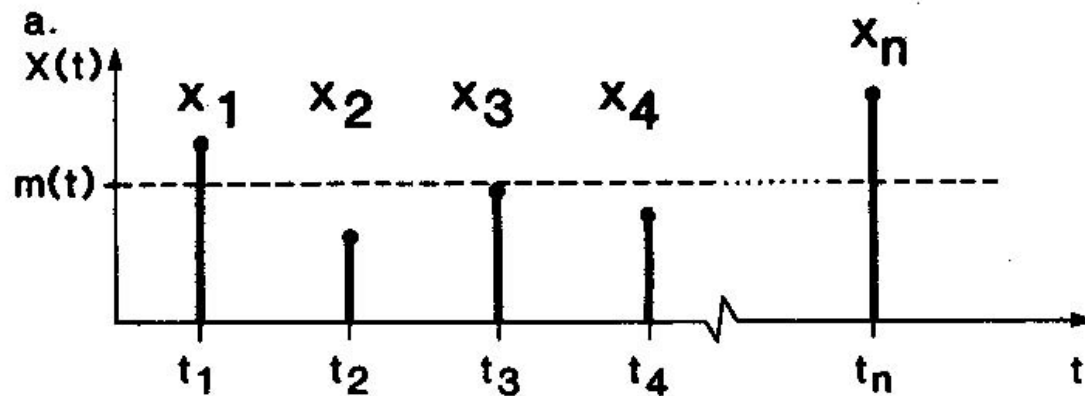


SKEWED DISTRIBUTION

Extreme events → tails of distribution

The Standard Time Series Assumption

The standard approach assumes stationarity and independent, identically distributed event probabilities

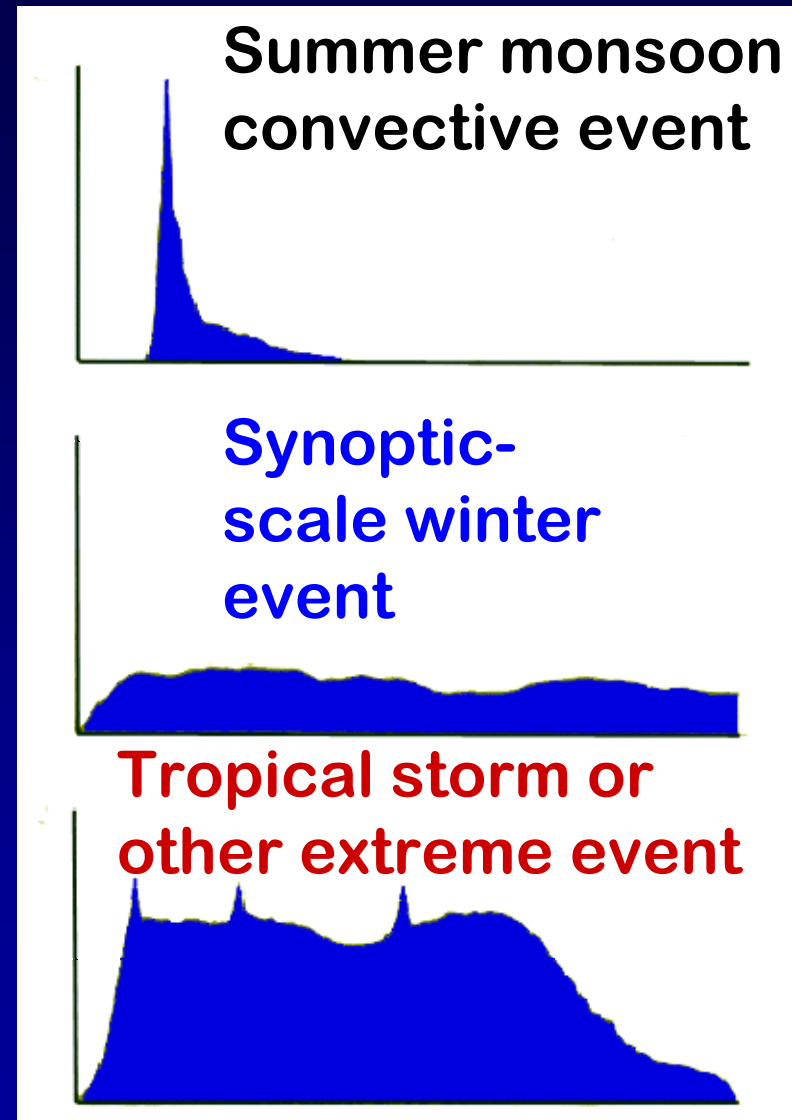


Events at each point in time emerge from independently, identically distributed probabilities

... but are all floods alike?

The type of storm influences the shape of the hydrograph and the magnitude & persistence of the flood peak

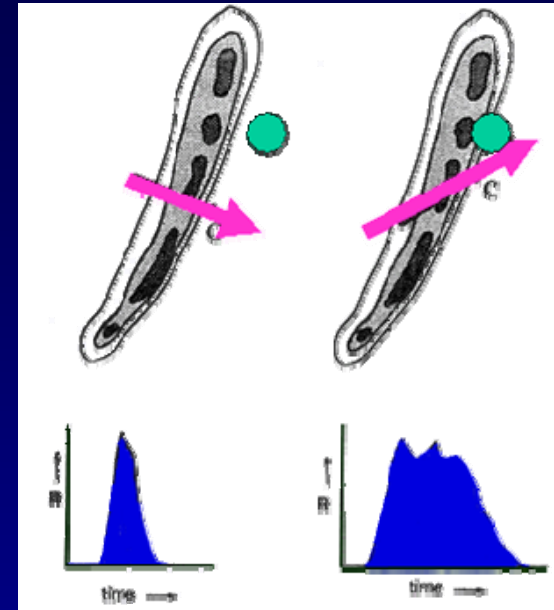
This can vary with basin size (e.g. convective events are more important flood producers in small drainage basins in AZ)



In addition, extreme flow events can emerge from synergism in:

The way in which rainfall is delivered

- in both **space** (e.g., storm movement, direction)
- and **time** (e.g., rainfall rate, intensity)
- over drainage basins of different **sizes** & **orographies**



from Doswell et al. (1996)



Therefore -- **hydroclimatic subgroups** may vary with drainage area in the same watershed

Causative mechanisms:

- precipitation type
- storm characteristics
- steering mechanisms
- synoptic pattern / storm track
- antecedent conditions

This framework of analysis allows a flood time series to be combined with climatic information

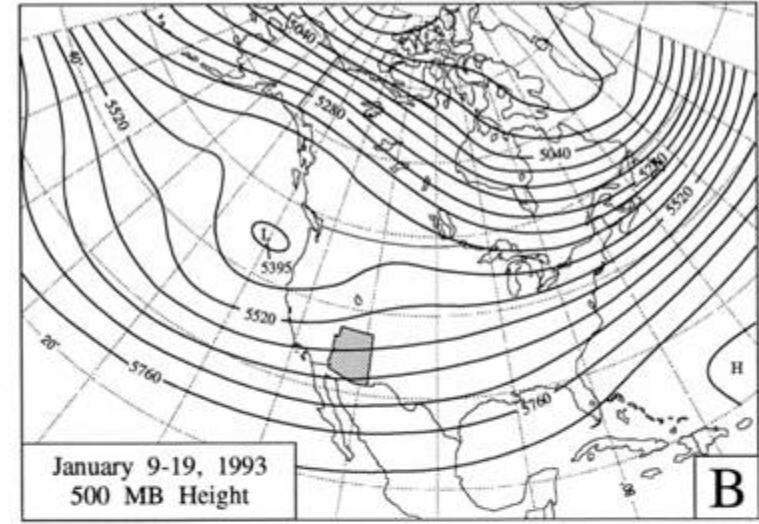
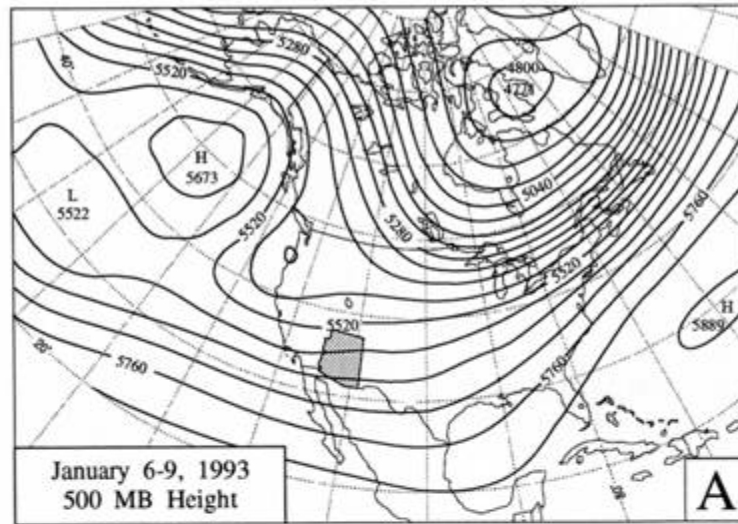
To arrive at a PROCESS-based mechanistic understanding of long-term flooding variability and its probabilistic representation.

(This can also be done with droughts.)

Example: SYNOPTIC “EDDY FLOW” ALONG DIFFERENT WINTER STORM TRACKS

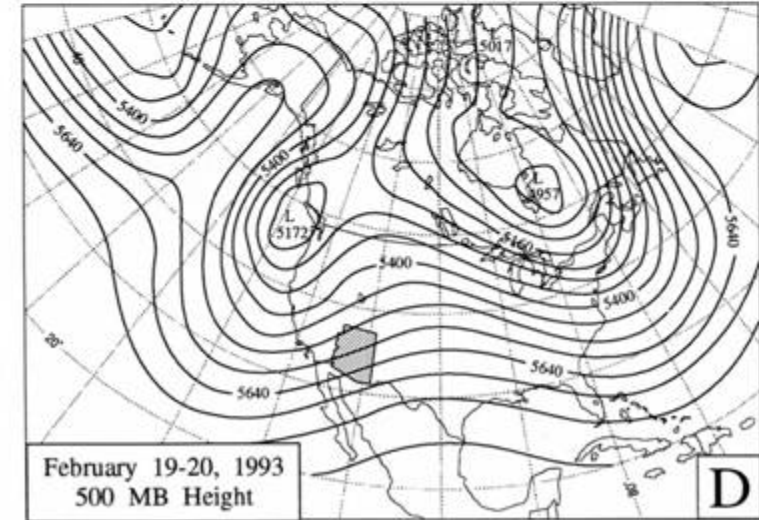
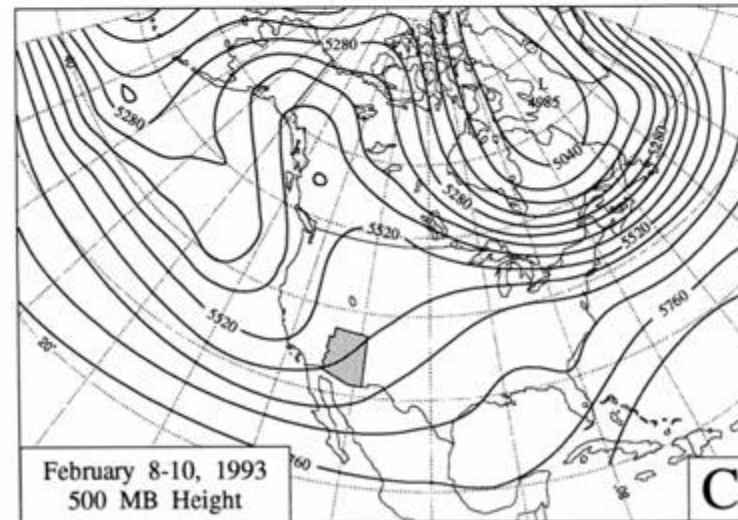
TRANSIENT
EDDIES:

Cold storm
sequence
on W-E
track
→ snow



Process-based understanding of flood origins

Warm storm
sequence
on SW-NE track
→ rain-on-
snow

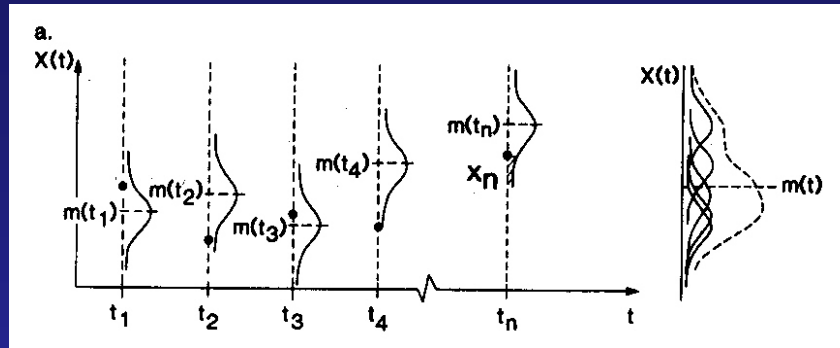


From: House &
Hirschboeck 1997

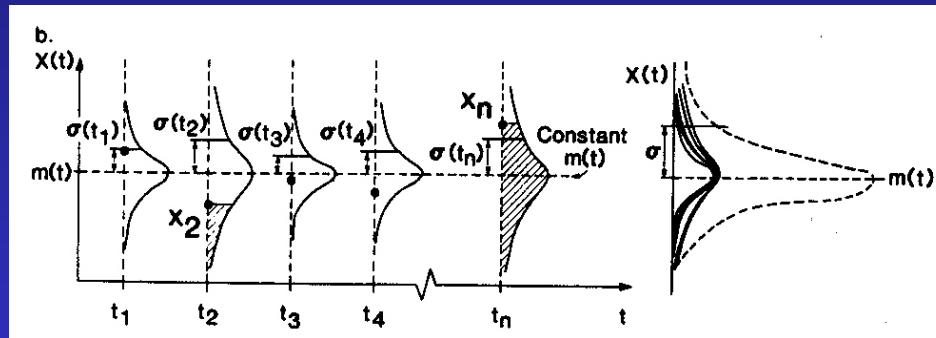
Record-breaking floods of winter 1992-93 in Arizona

Process-Based Conceptual Framework for Hydrologic Time Series:

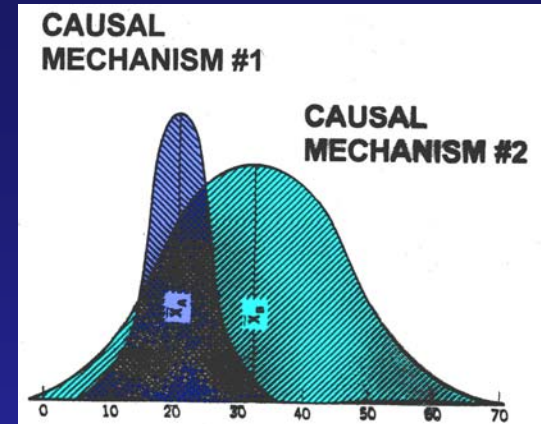
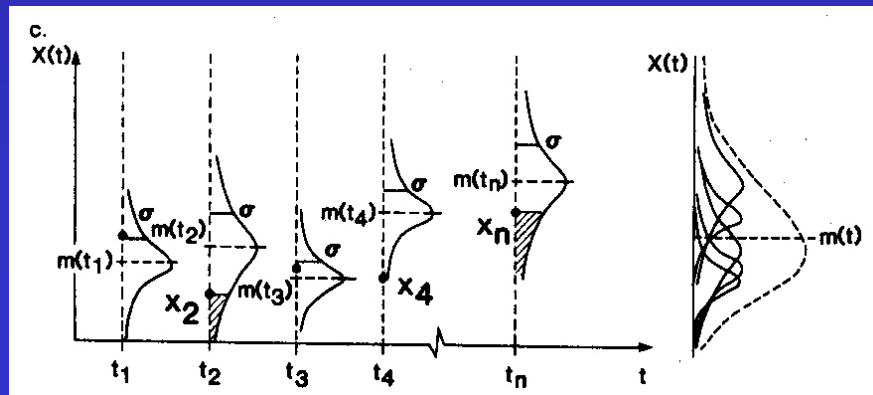
Time-varying means



Time-varying variances



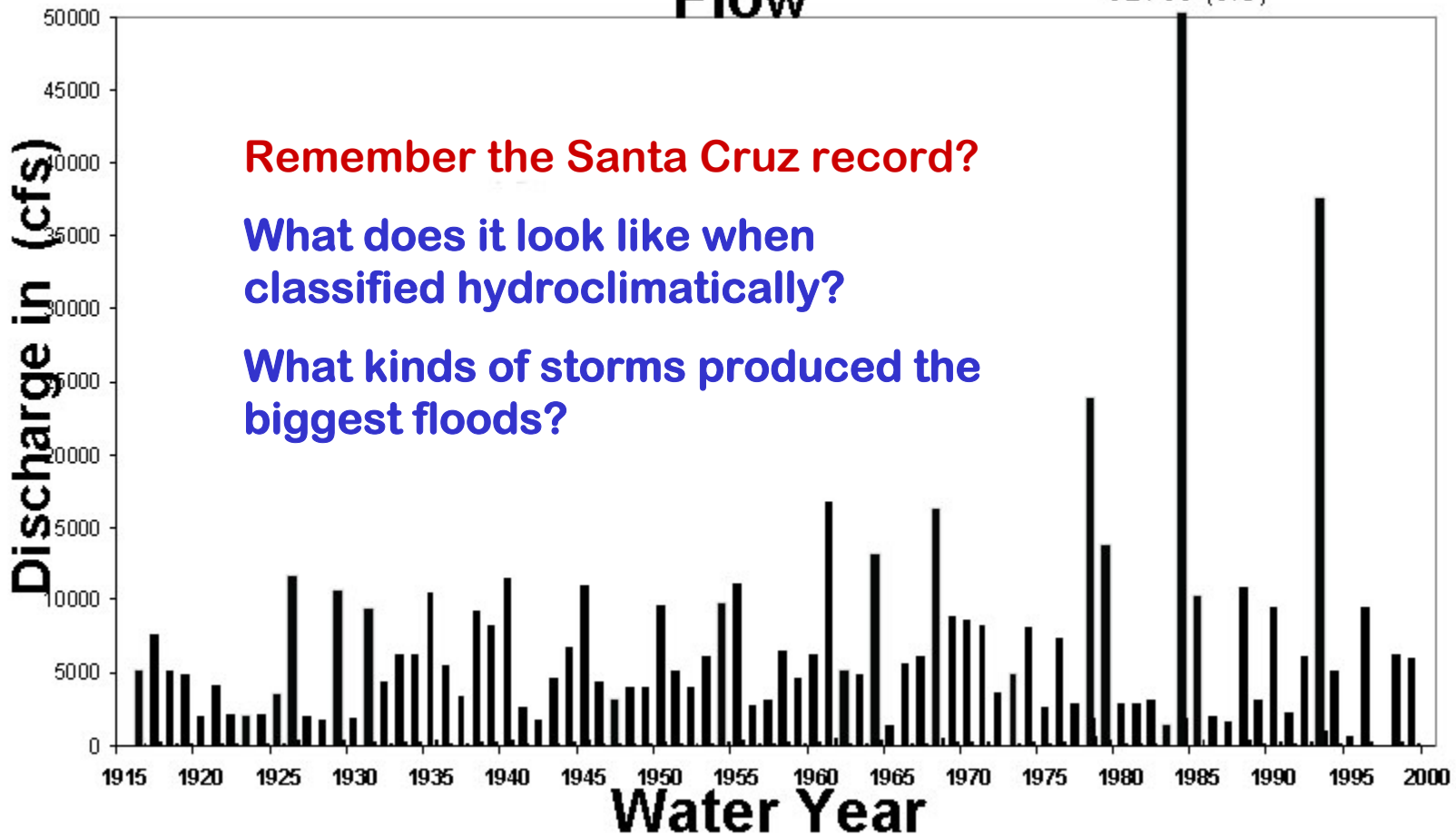
Both



Mixed frequency distributions may arise from:

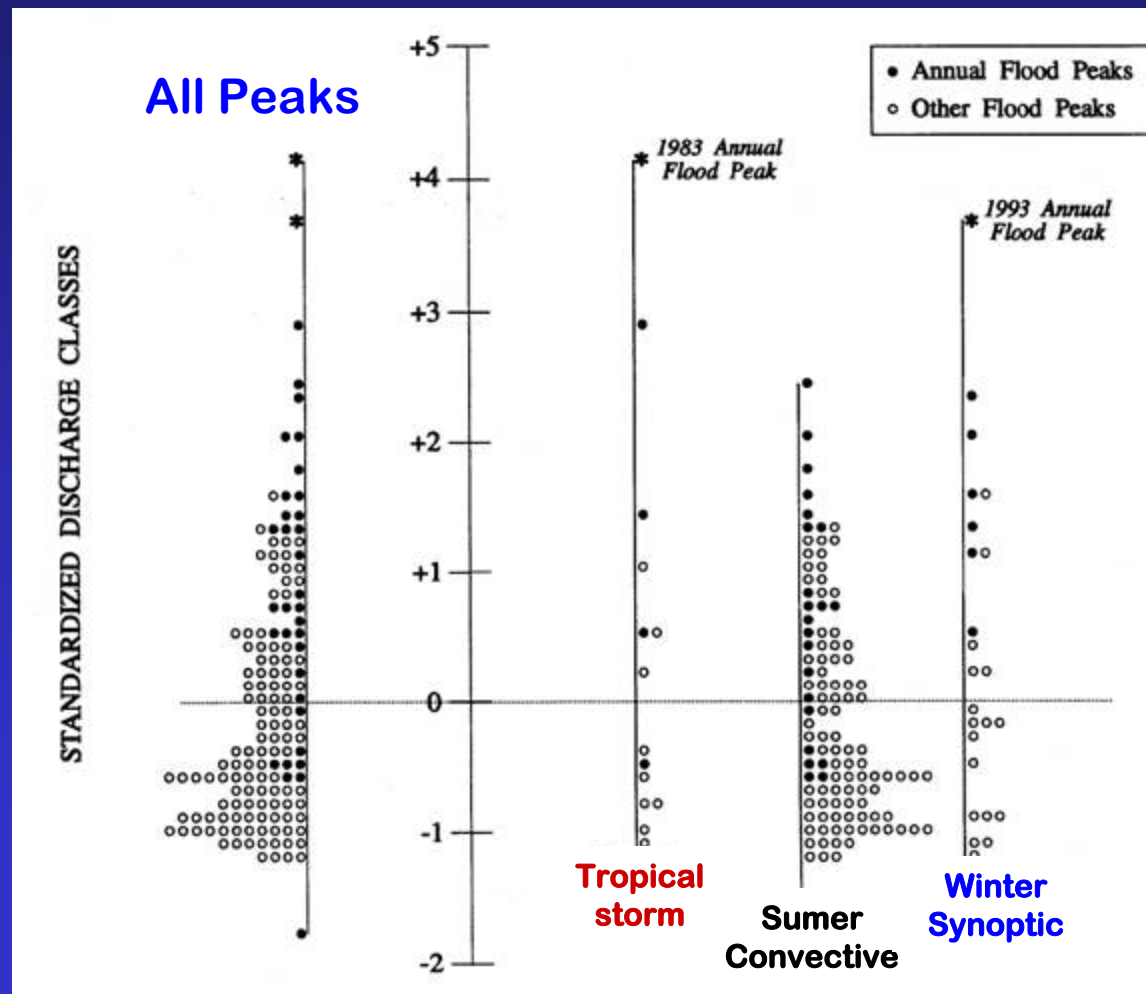
- storm types
- synoptic patterns
- ENSO, etc. teleconnections
- multi-decadal circulation regimes

Santa Cruz at Tucson Annual Peak Flow

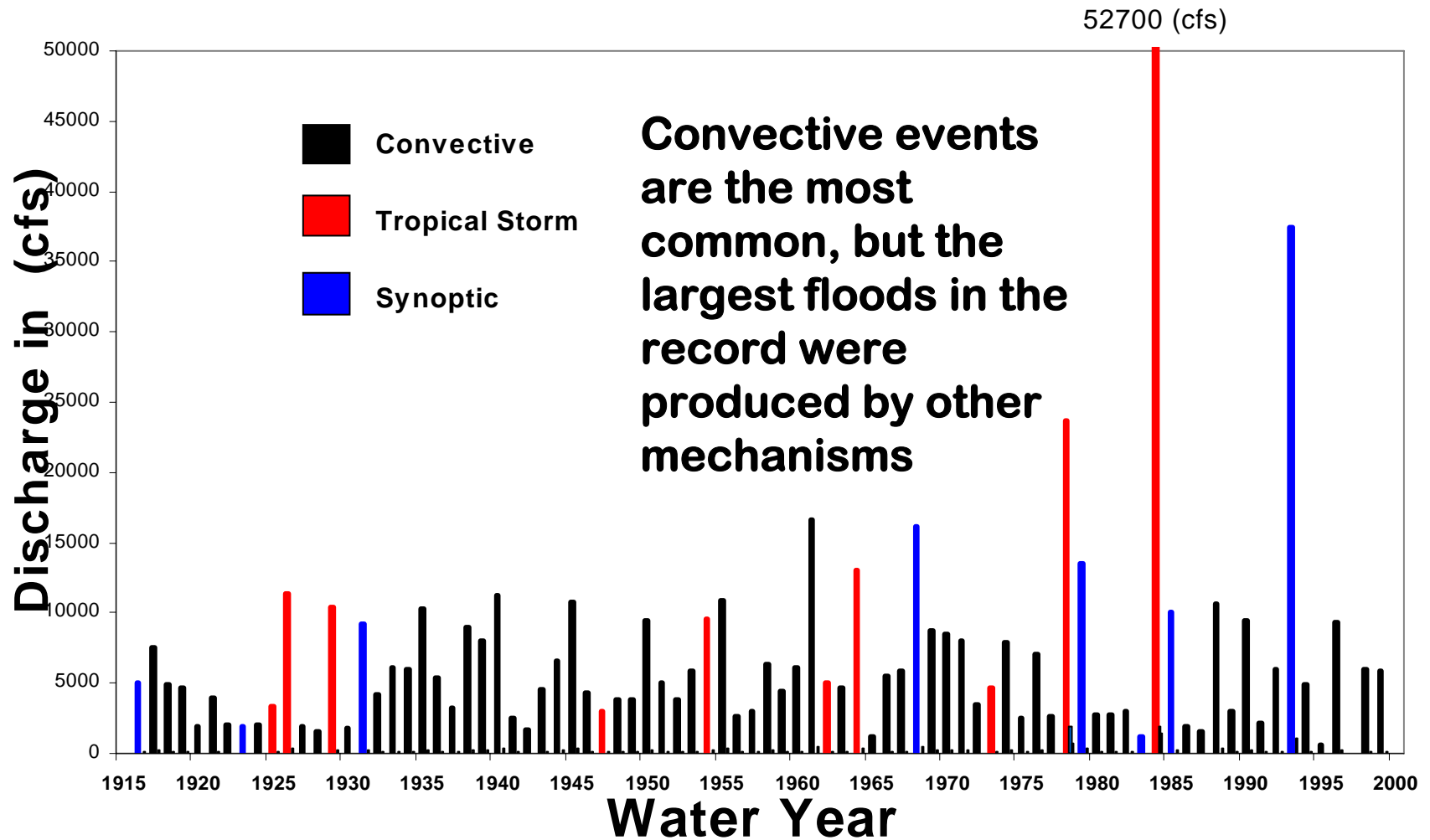


Santa Cruz River at Tucson

Peak flows separated into hydroclimatic subgroups

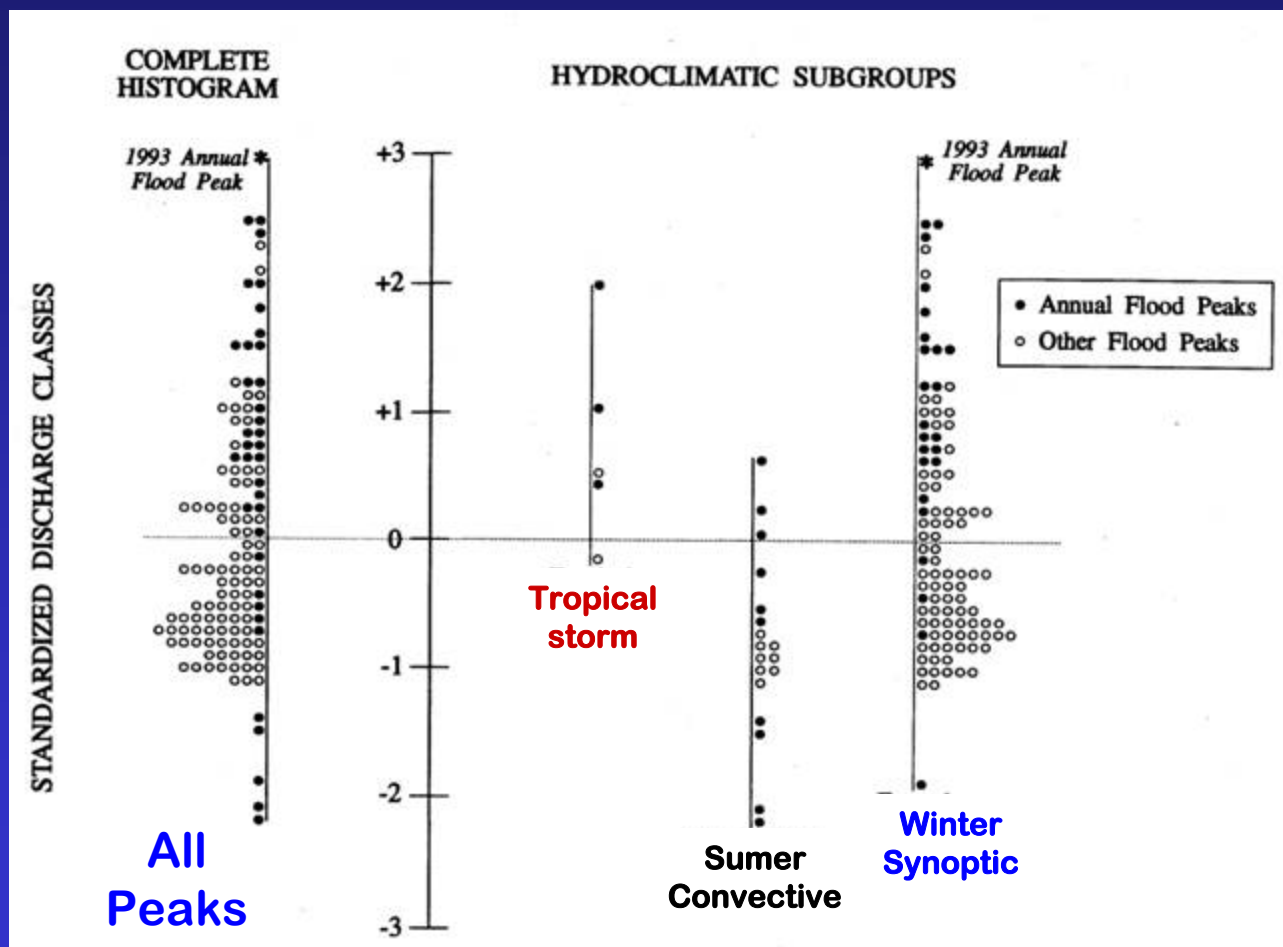


Santa Cruz at Tucson

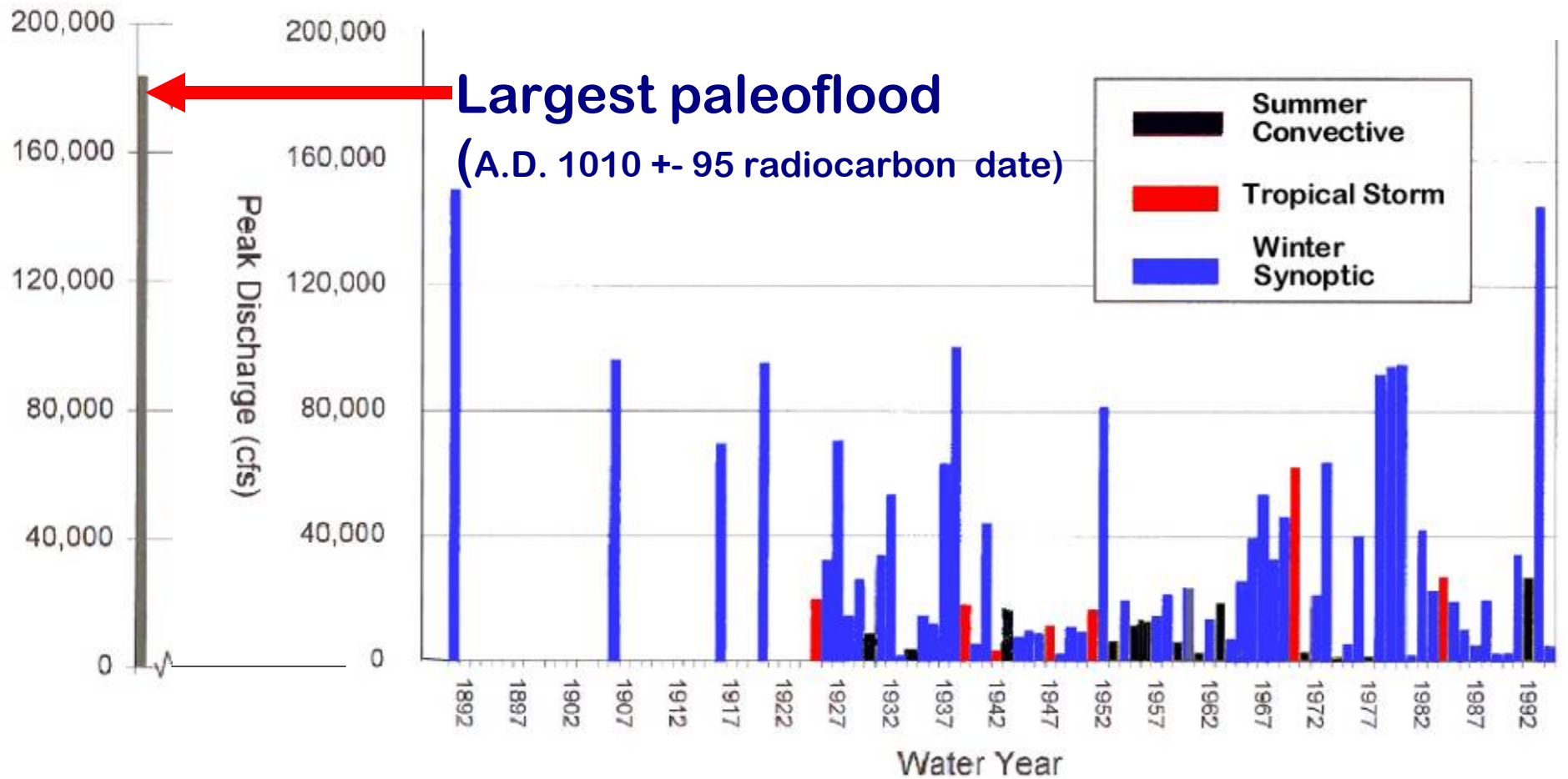


Verde River below Tangle Creek

Peak flows separated into hydroclimatic subgroups



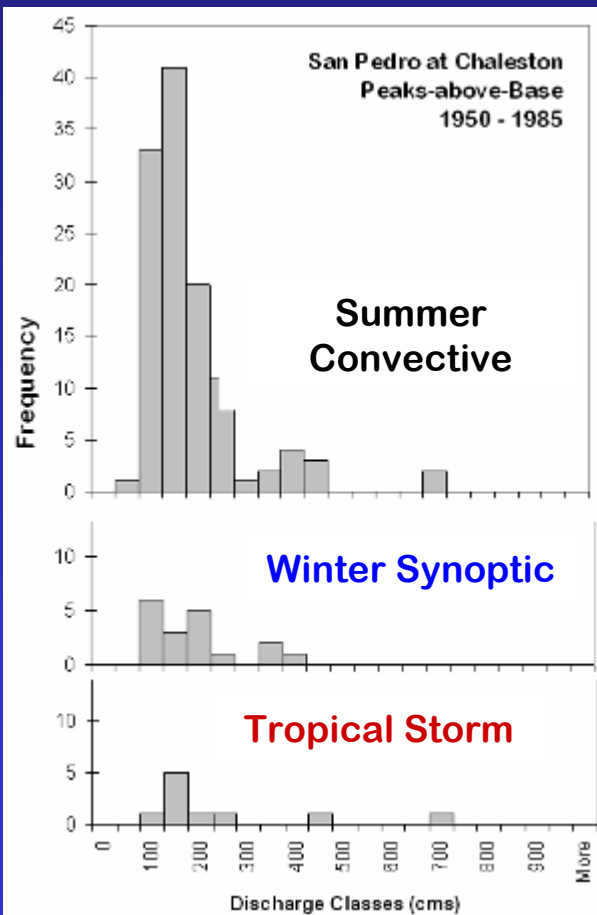
Annual Flood Series for the Verde River Below Tangle Creek Coded by Hydroclimatological Type



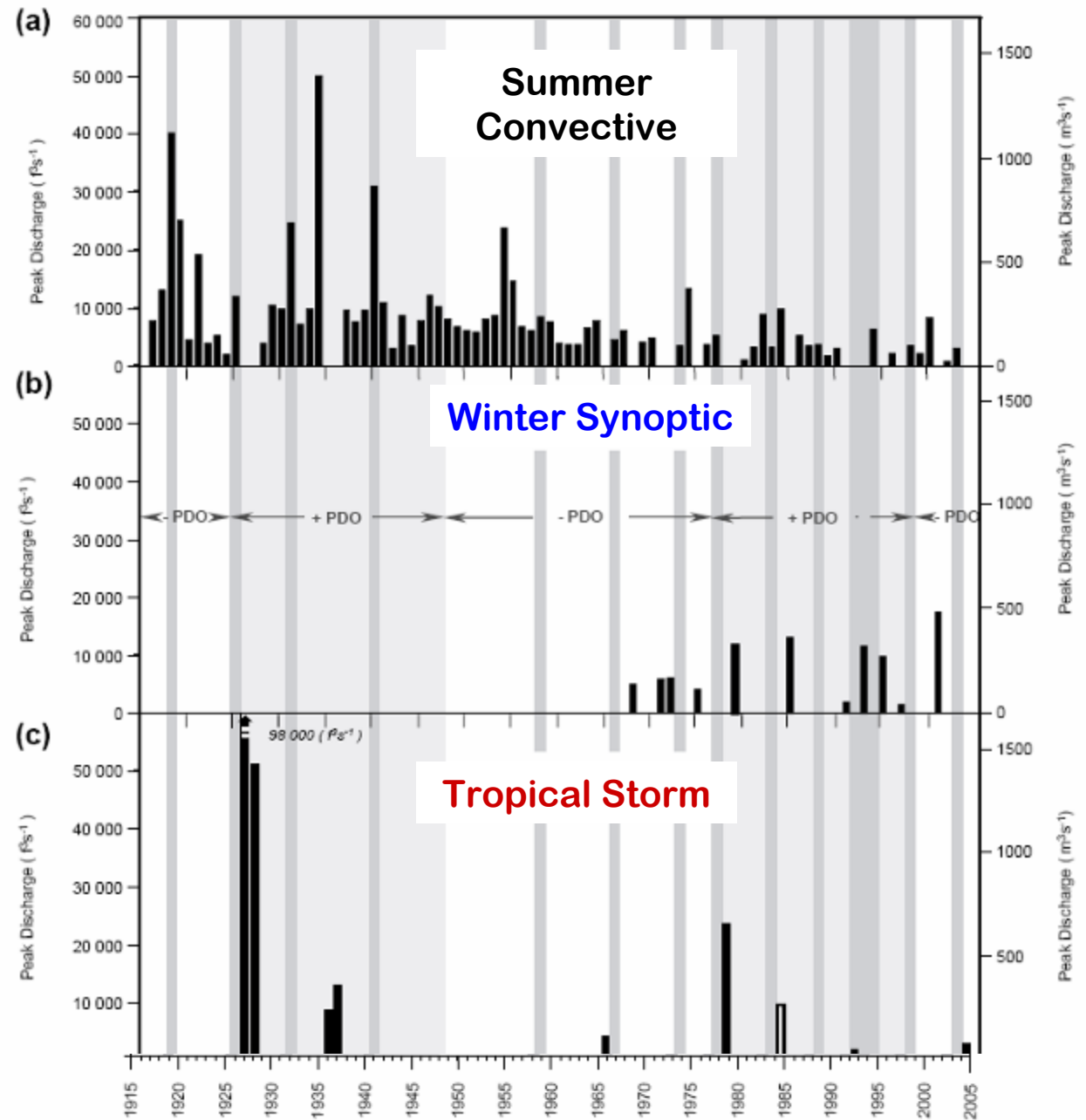
San Pedro at Charleston

Peak flows separated into hydroclimatic subgroups

from: MacNish, R, Hirschboeck, K., Baird, K., and Maddock, T. *in* Stromberg and Tellman (forthcoming)



El Nino years

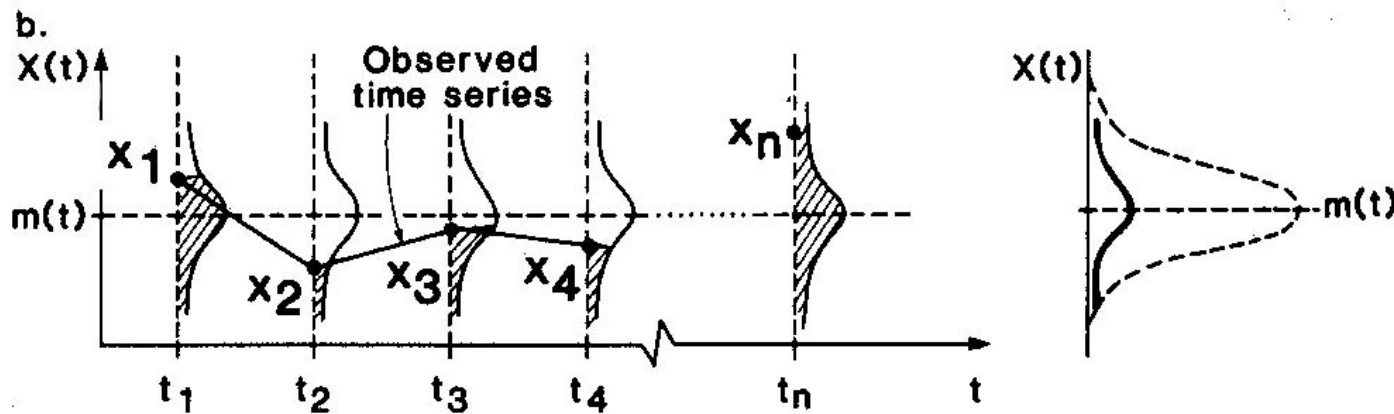
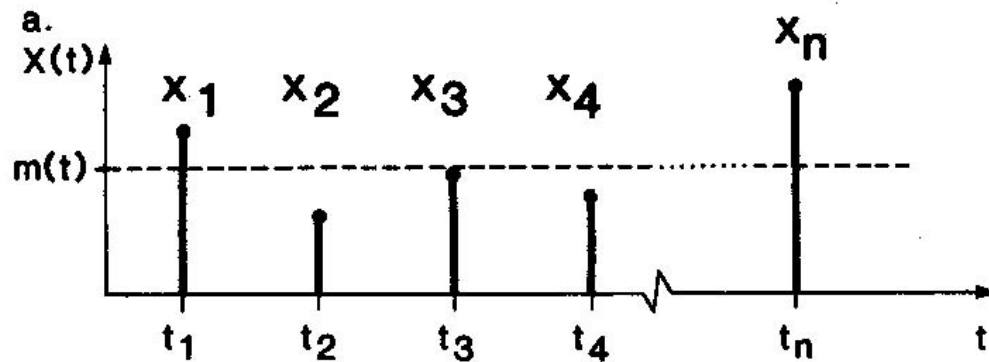


1915

1960

2005

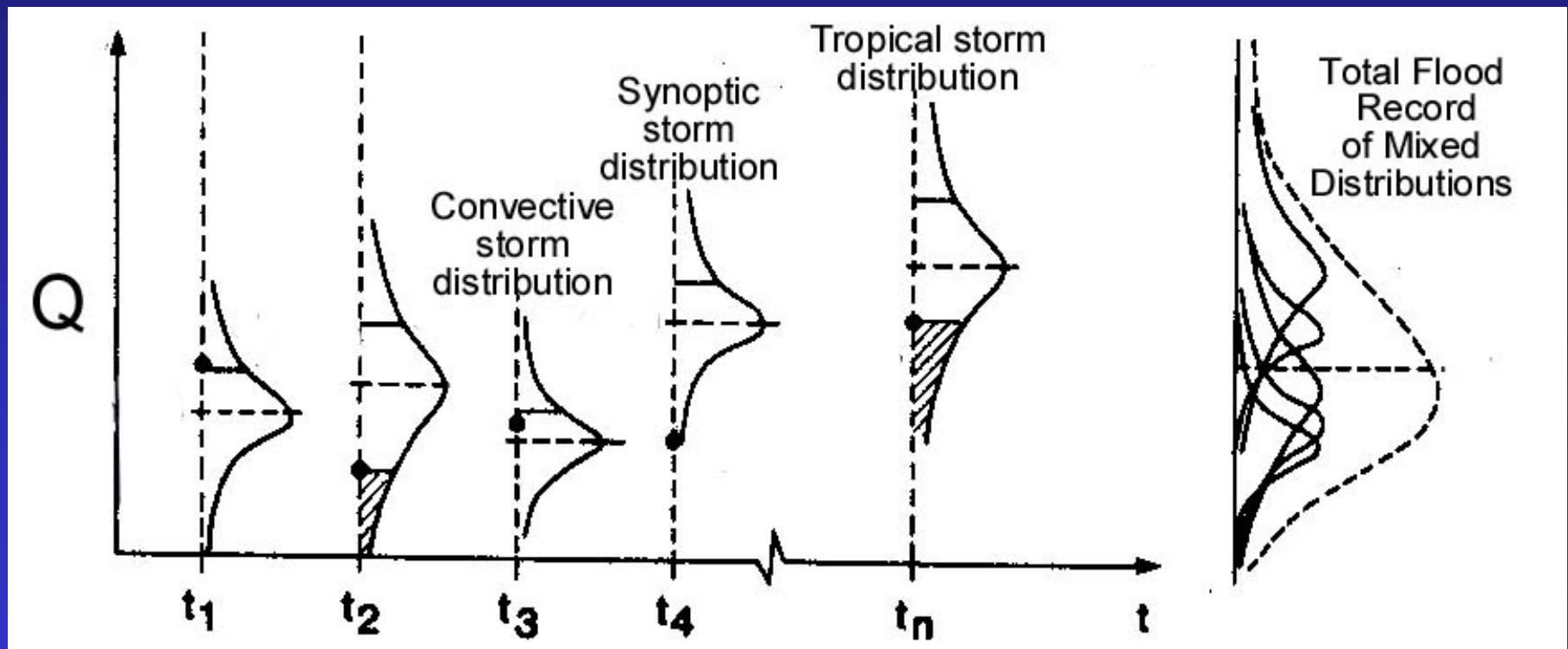
Based on these results we can re-envision the underlying probability distribution function for Gila Basin floods to be not this



... but this:

Alternative Model to Explain How Flood Magnitudes Vary over Time

Schematic for Arizona riparian systems based on different storm types

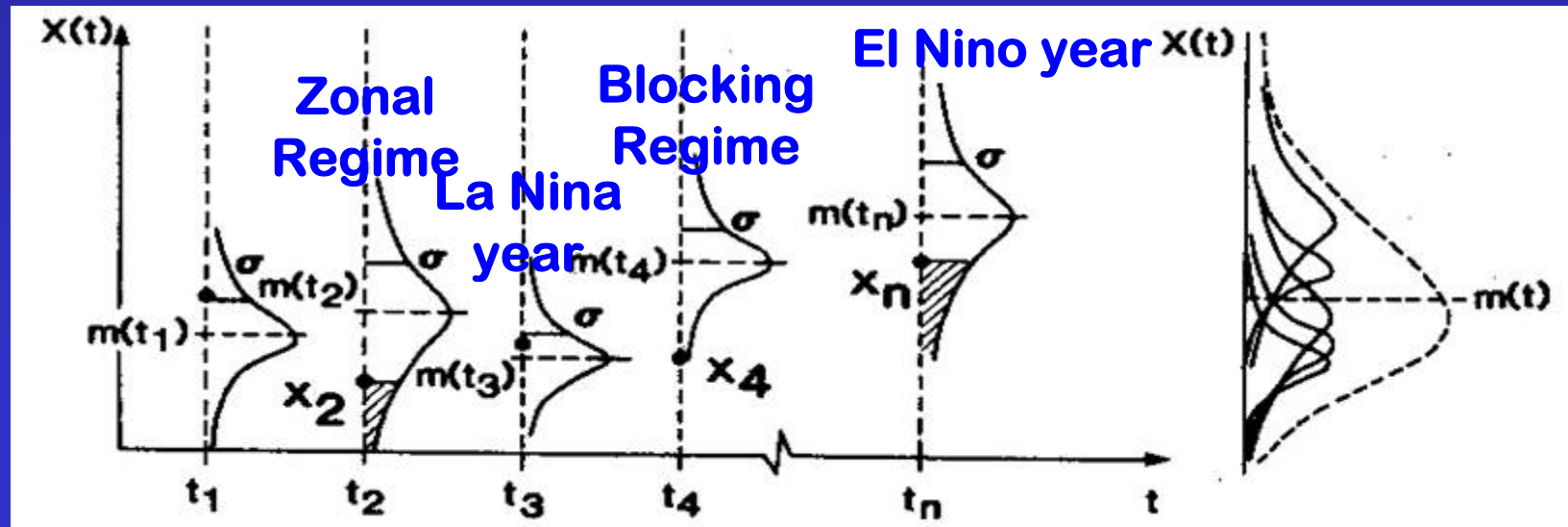


Varying mean and standard deviations due to different causal mechanisms

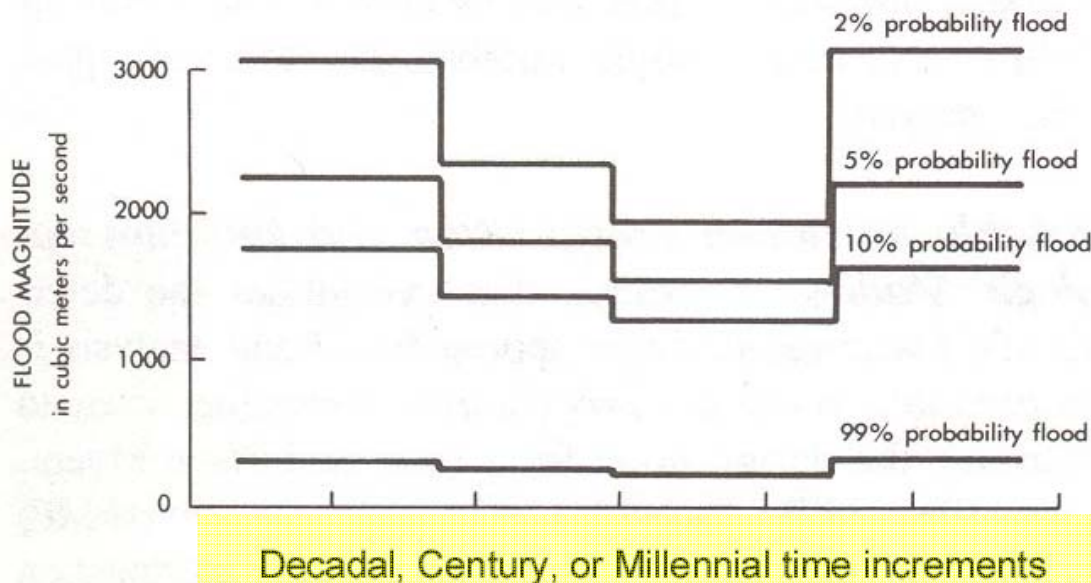
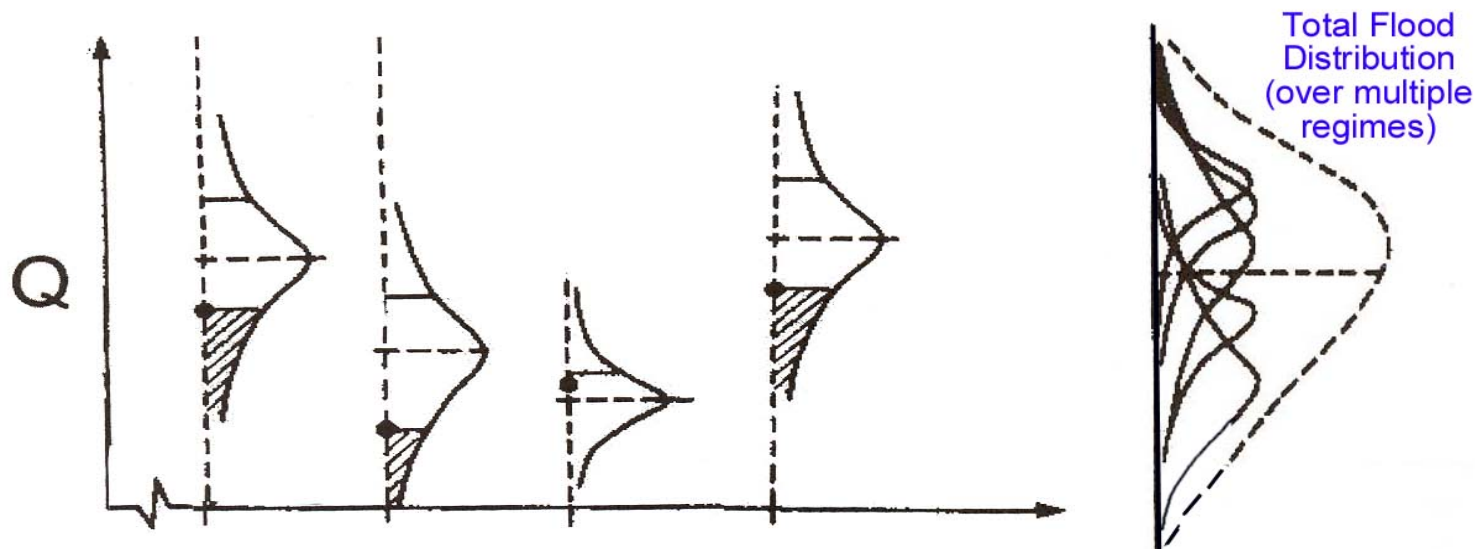
... or this:

Conceptual Framework for Circulation Pattern Changes

When the dominance of different types of flood-producing mechanisms or circulation patterns changes over time, the probability distributions of potential flooding at any given time (t) may be altered.



... or this: Conceptual Framework for Low-Frequency Variations and/or Regime Shifts:



A shift in circulation or SST regime (or anomalous persistence of a given regime) will lead to different theoretical frequency / probability distributions over time.

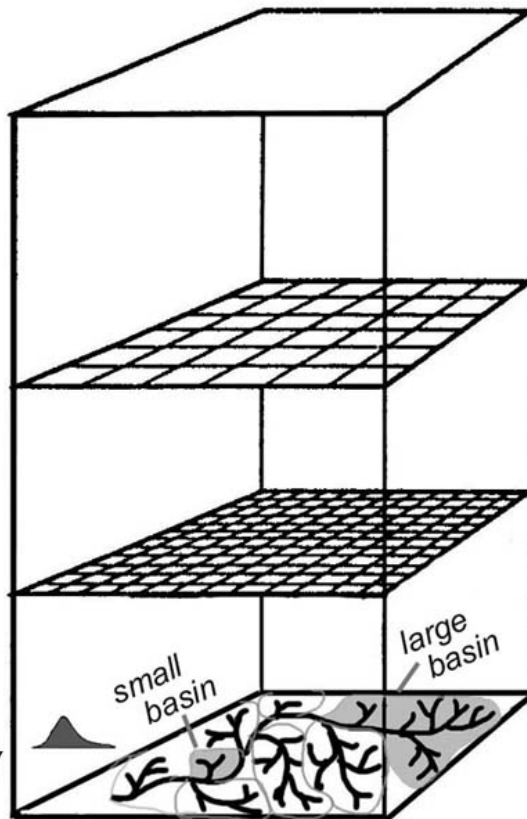
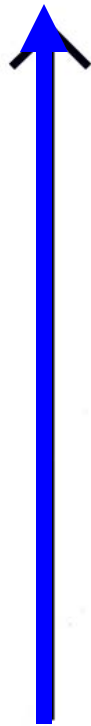
By associating seasonal and long-term variations in a stream's hydrograph with storm types and the synoptic atmospheric circulation patterns that deliver them . . .

. . . a **PROCESS-BASED “upscaling”** approach provides an alternative way to bridge the gaps between local, regional, and global scales of hydroclimate information and future climate projections.

Atmospheric
Circulation
Processes



PROCESS-SENSITIVE
UPSCALING



GCM Grid
Scale

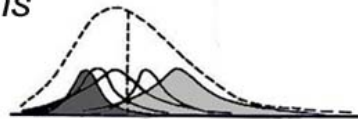
Regional
Model Grid
Scale

Hydrological
Model Grid
Scale

small
basin

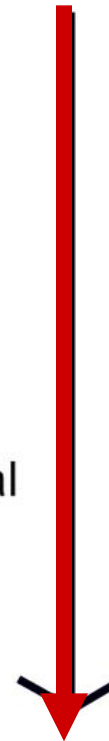
large
basin

Streamflow
Processes
in individual Basins



Combined
Hydroclimatic Flood-type
Distributions

DOWNSCALING



Climate Change & Southwest Riparian Areas “Connecting the Dots”

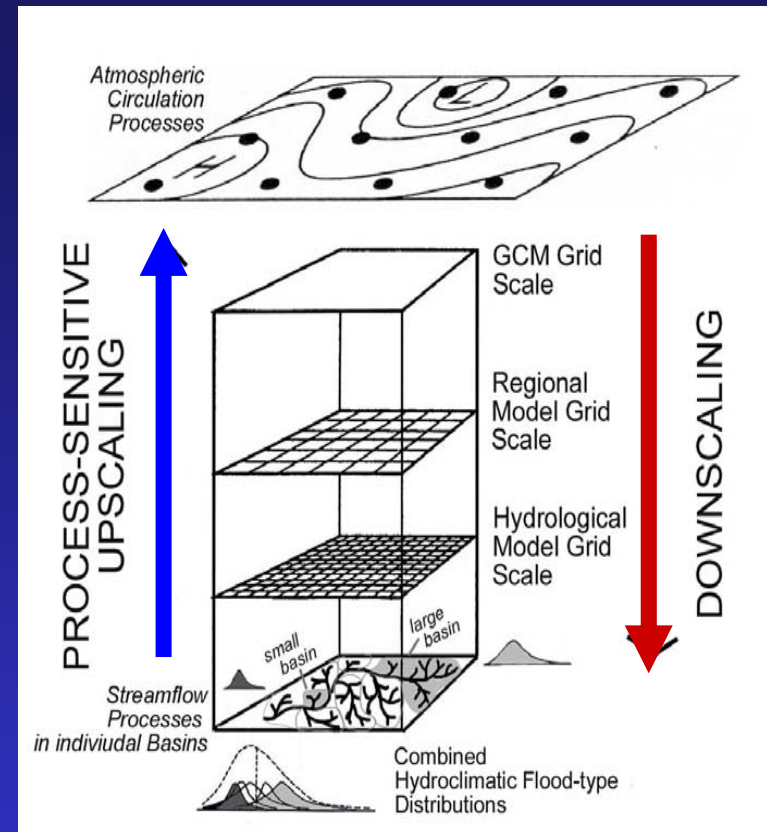
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Summary

Attention to some very basic hydrologic elements at the local and regional scale . . .

. . . . especially as they are manifested in a stream's past history and its present individual mix of storms and processes . . .

. . . can provide a basis for a cross-scale approach to linking GLOBAL climate variability with LOCAL hydrologic variations in riparian areas.



1.

Conceptual Framework → Process Upscaling

For floods, paleofloods, or droughts, climatic changes can be conceptualized as time-varying atmospheric circulation regimes that generate a mix of shifting streamflow probability distributions over time.

This conceptual framework – provides an opportunity to evaluate streamflow-based hydrologic extremes under a changing climate from the viewpoint of the riparian area itself, i.e. “process upscaling” in addition to “model downscaling.”

2.

Regional Basin Differences

The interaction between storm properties and drainage basin properties (e.g. area, aspect, slope) plays an important role in the occurrence and magnitude of large floods both regionally and seasonally – and may result in different combinations of mixed distributions.

Understanding these regional basin differences is precisely what is needed to assess how projected climate changes will impact a given watershed.

3.

Usefulness of Paleo-record

Extending a streamflow record back in time with paleo -information can provide deeper insights into the natural variability of the stream.

Compilations of paleoflood records combined with gaged records suggest there is a natural, upper physical limit to the magnitude of floods in a given region.

Will this be true in the future? An envelope curve can be a useful tool for investigating this type of regional change in streamflow extremes.

4.

Mean Flow vs Transient “Eddies”

Shifts in storm track locations and other anomalous circulation behaviors (transient eddy flow) are clearly linked to unusual flood and drought behavior.

The dire model projections in Seager et al. 2007 were driven mostly by the mean flow, not the transient eddies which are important for determining where precipitation will occur.

Shifts in winter storm tracks (& eddies) are likely to be the factors most *directly* responsible for projected increases – or decreases -- in hydrologic extremes under a changing climate.

5.

Natural Variability vs Anthropogenically Forced Model Projections

In contrast to historical droughts, future drying (in the models) is not linked to any particular pattern of change in sea surface temperature but seems to be the result of an overall surface warming driven by rising greenhouse gases.

El Niño and La Niña factors should still come into play . . . but will their influence and effects be the same?

6.

Summer Uncertainty

Future projections for the summer monsoon rainy season are still very uncertain.

-- will convective storms increase due to warmer temperatures and more precipitable water vapor?

-- or will subtropical drying suppress the rains?



Proposed project to add flood & drought hydroclimatology information for specific gages to this webpage:

Arizona Flood Warning & Drought Monitoring

Home Lakes/Dams Rivers/Washes Precipitation Weather Drought Tools Links

Welcome to the Arizona Flood Warning and Drought Monitoring Webpage



Webpage participants are committed to providing weather, precipitation and stream flow information in "real time" in order to monitor and assess the potential risk for flooding in areas within Arizona.

The gauges on this site are organized by county and watershed. Please [click here](#) to view a [county](#) or [watershed](#) map.

The engine behind this webpage is the Multi-Agency Task Force, a group comprised of federal, state, and local agencies working to enhance communication, particularly during times of severe weather. Read about the [background](#) of the Arizona Flood Warning System and see the list of [participating agencies](#).

Photo: Steve Waters, FCDMC

<http://data.afws.org/sui/frontPage.aspx>

