Flood Hydroclimatology and Extreme Events in the Southwest: A Streamflow Perspective

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Overview

• Prologue
• “Flood Hydroclimatology” Revisited
• Flood Heterogeneity & the Complexities of Predictability
• “Catastrophic Flooding” Revisited
• Postscripts: On Tree-Rings, Floods & the Future
“The persistence of climatic departures implies that the assumption of randomness-over-time, which is basic to most techniques currently employed by federal and state agencies . . . . is frequently not valid.”

Knox et al. 1975
Newspaper advertisement . . . .

$99 just $8 a month*
Cuisinart flood processor
Reg. $130. Model DLC-10E with expanded feed tube; includes steel chopping, medium slicing and grating blades plus plastic mixing blade.
THE FLOOD PROCESSOR

Expanded feed tube
– Combines floods of different types together

Chopping, slicing & grating blades
– Chops up climatic cause information and slices off extreme high outliers

Plastic mixing blade
– Mixes up unique statistical properties of individual floods
FLOOD HYDROCLIMATOLOGY

... is the analysis of flood 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

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Hirschboeck, 1988
Generalized Seasonality of Peak Flooding in the Southwest

Hirschboeck, 1991
after figure in USGS Ground Water manual
FLOOD HYDROCLIMATOLOGY

FLOOD-CAUSING MECHANISMS = WEATHER embedded in CLIMATE
“Flood Hydroclimatology” REVISITED: The Streamflow Perspective
Flood Hydroclimatology Approach

- “Bottom-Up” Approach (start in the watershed to link to atmosphere)
- Observed Gage Record
- Meteorological / Mechanistic / Circulation-Linked
- Flood Hydroclimatology Framework / Link to Flood Frequency Distribution
Watershed Boundaries

The Arizona Flood Hydroclimatology Project

Streamflow Gauges
Flood Heterogeneity & the Complexities of Predictability: Flood Type Matters!
COMPLEXITY DUE TO: 3 main types of Flood-Producing Mechanisms Interacting with Diverse Physiographic Regions

- TROPICAL CYCLONES and/or REMNANTS
- SUMMER CONVECTIVE STORMS
- WINTER SYNOPTIC-SCALE STORMS
FLOOD TYPES BASED ON CAUSATIVE MECHANISM:

TROPICAL CYCLONE FLOODS

Floors caused by rainfall associated with dissipating tropical cyclone remnants

Santa Cruz River Flood Hydrograph for Tropical Storm Heather, Oct 1977

Santa Cruz River Flood flow for Tropical Storm Octave, Oct 1983

Based on Hirschboeck (1991)

National Hurricane Center and noaa.gov

FLOOD TYPES BASED ON CAUSATIVE MECHANISM:

SUMMER CONVECTIVE FLOODS

Sabino Creek Flow, July 2006

Floods caused by rainfall from isolated thunderstorms or organized mesoscale convective systems

McCollum et al. (1995)

Santa Cruz River Flood Hydrograph
Summer Convective thunderstorm

July 24 1990
AZ floods

McCollum et al. (1995)
FLOOD TYPES BASED ON CAUSATIVE MECHANISM:

**WINTER SYNOPTIC-SCALE FLOODS**

Flood caused by precipitation from fronts, closed lows & atmospheric rivers

**Santa Cruz River Flood Hydrograph**
Winter Synoptic Storm January, 2010

- **Gradual Rise** in Discharge;
- **Long-Duration** Events

**Total Volume:** 175,800 ft³/sec

Sequence of AR moisture influx events that preceded January 2010 floods:

Jan - Feb 1993: Statewide Peaks of Record due to multiple winter storms

Jan 1993 AR

- Jan 9-19, 1993
- Feb 19-20, 1993

SORTING OUT THE COMPLEXITIES OF FLOOD HETEROGENEITY . . .

TC floods are rare & vary in size
Both Synoptic & Convective floods are numerous
Convective floods on average are smaller

All Peaks above base

Standardized Discharge

Agua Fria River near Mayer, AZ

- Annual max peak
- Other peaks over threshold

Source: Zamora-Reyes 2014
ANOTHER SOURCE OF COMPLEXITY:

In any three year period in Arizona watersheds, streamflow can vary from low flow to extreme peak flow in response to the 3 main meteorological mechanisms . . .
Agua Fria River near Mayer, AZ

All Peaks above base

Tropical Cyclone

Summer Convective

Winter Synoptic

YET
ANOTHER SOURCE OF COMPLEXITY:

The mixture of flood types can shift over time!

Source: Zamora-Reyes 2014
**Verde River abv Horseshoe Dam**

**GEOGRAPHIC COMPLEXITIES:**

Contrast in dominance of flood type due to location; in southern basin, the largest floods of record are due to rarer types.
EVEN MORE COMPLEXITY!

Neighboring watersheds do not share the same big floods!

Summer Convective Flows dominate

Santa Cruz at Tucson Annual Peak Flow

1926 1983 1993

San Pedro at Charleston Annual Peak Flows

1926 1983 1993

Summer Convective Flows dominate
Spatial distribution of the DOMINANT FLOOD-PRODUCING MECHANISM

Spatial distribution of the flood-producing mechanism that generated the HIGHEST PEAK FLOW IN EACH STATION

Diana Zamora-Reyes M.S. 2014
WHAT FRACTION OF FLOOD PEAKS ARE INFLUENCED BY ARs?

AR fraction = \frac{\text{total \# AR peaks}}{\text{total \# observed peaks}}
“Catastrophic Flooding” REVISITED

Ingredients of the Big Ones!
Paleoflood evidence for a natural upper bound to flood magnitudes in the Colorado River Basin

Is there a natural upper bound to flood size? Could it change?

Paleoflood Envelope Curve

Enzel et al. 1993 WRR
Paleofloods compared to a major observed flood event (1993 flood peaks and paleoflood estimates plotted)

Envelope curve for peak flows during extreme 1993 FLOOD + paleofloods

House & Hirschboeck (1997)
What causes the MOST EXTREME FLOODS?

after Costa (1985)
Extreme Floods of Record evolved from:

I. uncommon (or unseasonable) locations of typical circulation features (future manifestation of climate change?)

II. unusual combinations of atmospheric processes

III. rare configurations in circulation patterns (e.g., extreme blocking, cutoff lows, atmospheric rivers)

IV. exceptional persistence of a specific circulation pattern
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)
THE IMPORTANCE OF RESPECTING THE DRAINAGE DIVIDE
DOWNSCALING

Hirschboeck 2003 “Respecting the Drainage Divide”
Water Resources Update UCOWR
“Scaling up from local data is as important as scaling down from globally forced regional models.”

— Pulwarty, 2003
COMPLEMENTARY APPROACH:

- Atmospheric Circulation Processes
- Small basin
- Large basin
- Combined Hydroclimatic Flood-type Distributions
- Process-sensitive upscaling
- Downscaling
- GCM Grid Scale
- Regional Model Grid Scale
- Hydrological Model Grid Scale
- Streamflow Processes in individual Basins
To summarize . . .
FLOOD TYPE MATTERS!
&
RESPECT THE
DRAINAGE DIVIDE!
THANK YOU!