From Here to Where?

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Outline

1. Updating Bulletin 17B
2. NRC(1999) – American River Conclude
3. Easy: Adding climate signal with LP3
4. Griffis - ENSO example
5. Mississippi - trend example
6. Concluding remarks
Bulletin 17B

• Uniform flood frequency techniques used by US Federal agencies

• Bulletin not updated in 20+ years
  – despite significant amount of research
  – additional 30 years of data for skew map
  – better statistical procedures for spatial data
Regional Skew Estimation

Regional skew $G_g$ from B17 skew map

$-0.5 \leq G_g \leq +0.7$

Map SE = 0.55

$\Rightarrow$ MSE[$G_g$] = 0.302

Effective record length = 17 yrs
Regional Skew Estimation

Tasker & Stedinger (1986)

- $\text{MSE mostly sampling error}$
- separate sampling error and model error

In Illinois, $\text{MSE}[G_g] = 0.100$

(Effective record length $\approx 60$ years)
2008 in Southeast: Skew Not Explained by Location, Drainage Area

(Courtesy Tim Cohn, 2008)
Regional Skew Southeast

1976 (MSE = 0.302)
2,972 sites nationally

2009 (MSE = 0.14) revised 1/09
342 independent watersheds

Maps claims to be as good as 17 years

γ = 0 as good as 40 years of record
Anticipated Changes to B17B

1. Appropriate & efficient statistical procedures [such as Bayesian GLS regional regression] for computation of regional skew and its precision recognizing that sample skewness estimators are relatively inaccurate.

2. Expected Moments Analysis (EMA) as consistent simple unifying statistical framework to simultaneously address
   (a) historical flood information
   (b) regional skew information
   (c) adjust for low outliers

3. Computation of confidence intervals for quantiles correctly reflecting uncertainty in at-site estimators of skewness coefficients based upon EMA.
I was asked to recall:

National Research Council,
*Improving American River Flood Flood Frequency*,
National Academy Press,
American River: Climate change?

Concern is Folsom dam releases and levees protecting the City of Sacramento, the capital of California.
NRC (1999) - American River

- ... little doubt that the observed frequency of large floods on the American River is much greater in the period from 1950 to the present than it was in the period from 1905 to 1950.

- Based on the present understanding of climate dynamics [and they considered many of possibilities], it is not possible to assess the relative contribution of natural and anthropogenic factors to this observed increase.

- More importantly, it is not possible to predict its likely persistence in time.

- The committee is very uncomfortable ....
Stationarity Is Dead: Whither Water Management?

P. C. D. Milly,1* Julio Betancourt,2 Malin Falkenmark,3 Robert M. Hirsch,4 Zbigniew W. Kundzewicz,5 Dennis P. Lettenmaier,6 Ronald J. Stouffer7

Science, Feb. 2008
“In view of the magnitude and ubiquity of the hydroclimatic change apparently now under way, however, we assert that stationarity is dead and should no longer serve as a central, default assumption in water-resource risk assessment and planning. Finding a suitable successor is crucial for human adaptation to changing climate.”
From Here to Where?

1. Does climate change mean we are not interested in historical records?

Of course not: it tells us what flood series look like and where we start.

Then we need to estimate the change.
From Here to Where?

2. Dr. Beth Faber’s remarks address next concern: with modest records, we do not know where we are now!
From Here to Where?

3. So how do we determine where we go from here?
Annual Floods (1950-1996) for Mississippi River at St. Louis

• Bulletin 17B can be modified to account for variability in flood risk by employing time-dependent parameters
• Most appropriate if relate variation to climate indices:
  PDO, NAO, ENSO, …
• Consider models for logs of flood peaks, $X = \log[ Q ]$
  1. $X_t \sim \text{P3}[ \mu(t), \sigma, \gamma ]$
  2. $X_t \sim \text{P3}[ \mu(t), \sigma(t), \gamma ]$
  3. $X_t \sim \text{P3}[ \mu(t), \sigma(t), \gamma(t) ]$
P3 = Pearson type 3 distribution with 3 parameters.
Incorporation of El Nino Effects

Linear model for mean $\mu$ (of logs) is:

$$\mu_t = \alpha + \beta \ c_t + \varepsilon_t$$

$\mu_t$: computed w/ all floods in observed record
$\alpha-\beta$: regression parameters (mean & slope)
$\varepsilon_t$: independent variation
$c_t$: climate index (i.e. ENSO, SST, NAO)

Adds only 1 parameter $\beta$ to the model.
If log-space $\sigma - \gamma$ fixed,
CV-Skew fixed for real-space floods.
Significant Relationships Between ENSO Indices and Annual Maximum Flood Series (5-month lag)

Source: Ashwini Kashelikar, Griffis Master’s Student
Incorporation of ENSO Effects

- One-year ahead forecast of the mean:
  \[ \hat{\mu}_{t+1} = a + b \hat{c}_{t+1} \]
  \( \hat{c}_{t+1} \): forecasted value of SST anomaly

- Forecast flood risk for next year using updated (forecasted) log-mean flood to reflect phase and intensity of ENSO/PDO event
One-Year Ahead Forecast of Flood Risk (New River, VA)

Forecasted SST = 0.23  (Neutral ENSO event)
Difference for 100-year event:  ~6,000 cfs

Source: Ashwini Kashelikar, Griffis Master’s Student
Forecasted SST = 1.2 (Strong El Niño Event)
Difference for 100-year event: ~13,400 cfs
Upper Mississippi River Trend

From Here to Where?
Mississippi River Trend

- Olson et al. (1999) found that reconstructed flood records for Mississippi River at Hannibal & St. Louis exhibit statistically significant trends.

- How might such variability be included in flood risk management and project design?
### Statistical Significance of Trend Models, 1898-1998

<table>
<thead>
<tr>
<th>Site</th>
<th>Slope*</th>
<th>p-value**</th>
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<tbody>
<tr>
<td>Hermann</td>
<td>0.0035</td>
<td>0.7%</td>
</tr>
<tr>
<td>Hannibal</td>
<td>0.0047</td>
<td>0.01%</td>
</tr>
<tr>
<td>St. Louis</td>
<td>0.0033</td>
<td>0.2%</td>
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</table>

*After logarithmic transformation

*Based upon a two-sided test.
Statistical Models of Flood Series

1) **LN-iid**: Lognormal distribution assumes floods are INDEPENDENT and IDENTIALLY distributed.

2) **LN-Trend**: Lognormal distribution around linear trend for log-flood series
   - Assume trend continues
   - Assume mean has year 2000 level

3) **LN-ARMA**: autoregressive-moving average time series model of log-flood series

Statistical Models

For Hannibal (log-space parameters)

1) LN-iid:
   \[ \mu = 12.3 \quad -- \quad -- \quad \sigma = 0.36 \]

2) LN-Trend:
   \[ \mu = 12.3 \quad \beta = 0.0047 \quad \sigma = 0.34 \]

3) LN-ARMA(2,1):
   \[ \mu = 12.3 \quad \varphi = 0.87 \quad \sigma = 0.36 \]

*Second model has smaller \( \sigma \), but \( \beta > 0 \).*
Forecasted Mean for Hannibal on Miss. River

1) LN-iid;  2) LN-Trend: continues or stops; 3) LN-ARMA
(flood flows in million cfs)
Forecasts Mean & 50-yr Flood for Hannibal

1) LN-iid; 2) LN-Trend, continues or stops; 3) LN-ARMA

(flood flows in million cfs)
Upper Mississippi Conclusions

Variation in flood risk is likely to affect flood-risk management if decision parameters can be adjusted on a year-to-year basis.

However, variations in flood risk are likely to have disappeared before major construction projects can be designed, authorized, and completed.

Not clear how to project a real change.
Climate change: time to start addressing the issue

“The picture’s pretty bleak, gentlemen. ... The world’s climates are changing, the mammals are taking over, and we all have a brain about the size of a walnut.”
Concluding Remarks

• We do not know present flood risk assuming annual floods are independent over time.

• If we allow for historical climate variability and/or year-to-year persistence, we know even less.

• With climate change, need to project from uncertainty of our current knowledge based upon the past record to estimate risk in the future.
Concluding Remarks

• Formulating models is easy, but are they credible?

• Adding trend in scale (LP3 log-space mean) is attractive and simple. Uncertainty can be added, but would such an addition be accepted?

• To be defensible we should base flood-risk forecasts upon change in climate-characteristics for which we have a physical-causal basis for multi-decadal projections.

• For at least a century people have changed and will continue to change landscape and hydrologic systems across United States: Change in flood risk is not new.
Decade-to-Century-Scale Climate Variability and Change (NRC, 1998):

The evidence of natural variation in the climate system -- which was once assumed to be relative stable -- clearly reveals that climate has changed, is changing, and will continue to do so with or without anthropogenic influences.

.... Furthermore, compounding the inevitable hazard of natural climate variations is the potential for long-term anthropogenic climate alteration.
Extra Slides
Bulletin 17 Development
&
Possible B17B changes
Development of Bulletin 17B

- Flood frequency analysis (FFA) for design of water-use, water-control projects, floodplain definition, B-C analyses
- Need for uniform FFA techniques recognized in mid-1960s
  - national flood insurance program
  - interaction between levels of government
Development of Bulletin 17B

• Bulletin 13 published April 1966
  summary of FFA techniques commonly employed by Federal agencies

• Congressional mandate in 1966 to:
  
  “present a set of techniques for frequency analyses that are based on the best of known hydrological and statistical procedures”

  [House Document No. 465, August 1966, p. 22]
Development of Bulletin 17B

• Bulletin 13 published April 1966
  summary of FFA techniques commonly employed by Federal agencies

• Congressional mandate August 1966

• Bulletin 15 published December 1967
  recommended use of LP3 distribution with regional skew information
Development of Bulletin 17B

• Bulletin 17 published January 1976
  – recommendations for handling low outliers, use of historical information
  – provided skew map

• Bulletin 17A published June 1977
  – revised method for historical information

• Bulletin 17B published March 1982
  – new method of combining sample skew with regional skew was introduced
  – revised test for low outliers
Recommendations

• As 25th anniversary of Bulletin 17B approaches, time for an update.

• New techniques now available correct known problems with Bulletin 17B.

• Seek to better use data in efficient and consistent statistical framework.
Changes Would Provide

1. Statistically appropriate and efficient procedures [such as Bayesian GLS regional regression] for computation of regional skew and its precision recognizing that sample skewness estimators are relatively inaccurate

2. Use of Expected Moments Analysis (EMA) as a statistically effective and flexible method for employing historical flood data (and associated plotting positions) with LP3 dist.
3. EMA as a consistent and simple unifying statistical framework to simultaneously address
   (a) historical flood information
   (b) regional skew information
   (c) adjust for low outliers

4. Computation of confidence intervals for quantiles correctly reflecting uncertainty in at-site estimators of skewness coefficients based upon EMA.
Key Bulletin 17B Research


Use a Window?

Use historical years that represent future flood risk distribution to eliminate bias.

• How do we select such a period?
  i) If use only last 10-20 years have too little record for planning. (Lack precision.)
  ii) If use only years with same size floods, then no gain in statistical precision.

• How would one capture transition to unconditional distribution? Risk varies!
## Metrics of Risk (probability)

<table>
<thead>
<tr>
<th></th>
<th>Risk 2000</th>
<th>Max Risk</th>
<th>Avg Risk</th>
<th>Prob. of Big Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LN-iid:</strong></td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.26</td>
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<tr>
<td><strong>LN-ARMA</strong></td>
<td>0.021</td>
<td>0.021</td>
<td>0.012</td>
<td>0.29</td>
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<tr>
<td><strong>LN-Trend:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>–2000 level</td>
<td>0.037</td>
<td>0.037</td>
<td>0.037</td>
<td>0.68</td>
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<tr>
<td>–Continues</td>
<td>0.037</td>
<td>0.084</td>
<td>0.058</td>
<td>0.83</td>
</tr>
</tbody>
</table>

30-year horizon