Performance of the JPM and EST Methods in Storm Surge Studies

David Divoky, Donald T. Resio

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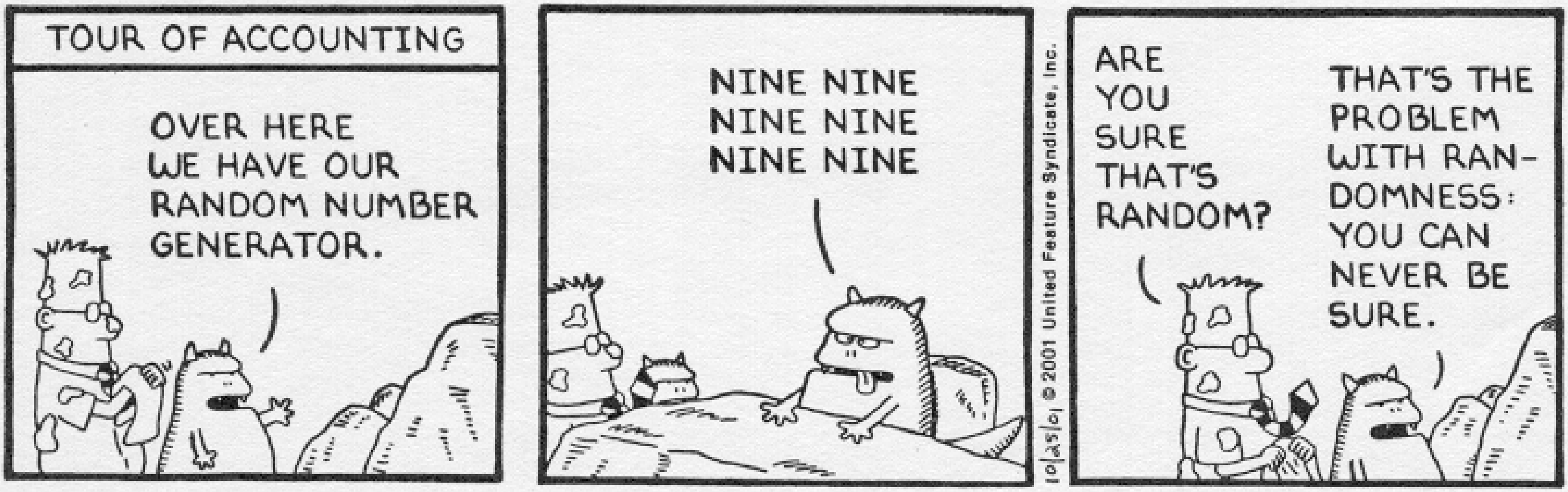
TOUR OF ACCOUNTING
OVER HERE WE HAVE OUR RANDOM NUMBER GENERATOR.
NINE NINE NINE NINE NINE NINE
ARE YOU SURE THAT'S RANDOM?
THAT'S THE PROBLEM WITH RANDOMNESS: YOU CAN NEVER BE SURE.
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DESCRIPTION AND MOTIVATION

Goal: Provide insight into performance of the Empirical Simulation Technique (EST) and the Joint Probability Method for hurricane storm surge studies.

Motivation: Urgent new post-Katrina studies by the Corps (LaCPR, IPET) and FEMA, needing reliable surge frequency estimates.

Pros / Cons: Questions of accuracy and economy (storm surge simulations being very expensive)

OVERVIEW OF THE METHODOLOGY

IDEA: Play nature's game

1 -- Adopt "hidden" distributions for storm parameters

2 -- Generate multiple samples drawn from those distributions

3 -- Evaluate surge frequency based on each sample using both EST and JPM

4 -- Compare

SUMMARY OF TENTATIVE CONCLUSIONS

The expectations that led to selection of JPM for the LaCPR, IPET, and new FEMA studies seem to be confirmed:

- EST appears to be sensitive to sample error (sample variation)
- JPM appears to be remarkably (surprisingly) robust against sample variation

METHODOLOGY - 1

Describe nature's rules parametrically using conventional distributions

Adopt storm descriptions which, as far as we can tell, are consistent with the truth, following

Resio's Whitepaper, Toro's Mississippi study

Simulate a realistic period of record

METHODOLOGY - 2

Simplify the methods to eliminate confounding factors, and to focus on the essential problems

Key factors:

hurricanes are small bullets, with a limited coastal footprint for the largest surge level

hurricane occurrence is extremely sporadic at any given site

Taken together, these factors suggest very large sample variation from place to place.

METHODOLOGY - 3

Important simplifications:

- Assume a straight shoreline
- Assume homogeneity over an extended region
- Assume stationarity over an extended period

But preserve:

- Relative footprint size of the response
- Sporadic character of random occurrence

METHODOLOGY - 4

Key simplification:

Adopt a surrogate for storm surge, maintaining key surge features

In this study, the selected surrogate was *the square of the shore-normal component of wind speed*

Consequently, the problem is reduced to advection of a specified wind field over the hypothetical study region, while recording the shore-normal peak at the study site.

METHODOLOGY - 5

To help alleviate the concerns of the wary, an unnecessarily detailed wind representation was adopted (as used in old NOAA and FEMA flood studies). The wind description included the vectorial addition of forward speed, for example, but not incurvature angle, Holland's B, along-track parameter variations, and so forth.

A simple annular top-hat wind distribution of unit height would have been perfectly adequate, but might have been accepted reluctantly.

PARTICULAR ASSUMPTIONS - 1

The homogeneous sample region was taken to be a uniform straight line (coast) 1000 nm long.

The storm density in space and time was selected for consistency with observed values in the northern Gulf of Mexico

The adopted storm parameters were the usual suspects:

- central pressure depression
- radius to maximum winds
- forward speed
- storm track direction
- landfall point

PARTICULAR ASSUMPTIONS - 2

For the basic simulation to be discussed here, the parametric distributions for the storm parameters were taken to be:

central pressure depression -- gumbel

radius to maximum winds – gaussian, conditional on pressure

forward speed – gaussian (but not conditional on angle)

storm track direction -- gaussian

landfall point -- uniform

PARTICULAR ASSUMPTIONS - 3

Storm occurrence was assumed to be Poisson-distributed, with the mean annual number over our 1000 mile "coast" taken from observations in the northern Gulf

For very long periods of record, all statistical methods should be good; for very short periods none are. In order to be pertinent to ongoing work, a period of record of 65 years was chosen, corresponding to the period of available high quality hurricane data (WWII and later).

SCHEME - Part1

Take 65 years to constitute a record.

For each year, obtain the Poisson number of storms.

For each storm, draw randomly from the 5 parameter distributions to obtain pressure, radius, forward speed, angle, and landfall point.

Determine the moving windfield, and advect it across the “coast” from a distance offshore to a distance on shore.

Record the peak surge surrogate (normal component of peak wind squared, divided by 1000).

SCHEME – Part2

For this example, repeat Part 1 10 times, giving 10 65 year records.

Pass these results to both EST and JPM

For EST, only the parameters and responses are needed.

However, for JPM, the parameters are assumed to be samples from unknown distributions. Consequently, the "observed" parameters are first used to fit appropriate distributions, from which the JPM simulation set will be derived.

For both EST and JPM, the storm density is taken to be the sample density.

SCHEME – Part 3

For EST, we have (in this example) applied the basic method restricted to “historical” storms. Hypothetical storms will be considered later.

For JPM, we have first determined the sample moments for each storm parameter using Hosking’s method of Linear Moments, and from these the distribution parameters.

In this example, while nature’s radii are conditional upon pressure, the JPM analysis assumes independence; conditional estimates will be considered later.

SCHEME – Part 4

The JPM simulation set was selected by the process of "Slicing and Dicing," not by any intelligent application of JPM-OS methods which would be difficult to automate.

For each of the 10 example records discussed here, pressure was sliced into 10 pieces, radius into 5, forward speed into 4, path angle into 4, and landfall point into 7 (with 5 to the left and 1 to the right of the sight). This gives 5600 as the number of JPM simulations per 65 year set.

Additional simulations have been done using an even sharper knife, as discussed later.

SCHEME – Part 5

Each of the 5600 “storms” gives a response at the site. Each of these has an associated rate of occurrence given by the product of the fractional rates of pressure, radius, forward speed, and angle, multiplied by the track-normal spacing between tracks (taken to equal the radius), and finally all multiplied by the sample storm density (events per nm per year)

SCHEME – Part 6

The rate of occurrence of a specified response was obtained by first accumulating each storm's rate into a histogram with 0.1 unit bins (this will be discussed again in a later paper this afternoon). The result is an empirical estimate of the response density function.

Finally, by summing the bins from the top down, one can find the response associated with any chosen rate. For example, the 100 year response corresponds to the bin for which the summation reaches 0.01.

FINDING THE "TRUE" VALUES

By the foregoing methods, one arrives at estimates of, say, the 100 year response for each of the 10 records, and for the EST determination.

In order to find the truth, JPM is implemented again using the *a priori* distributions rather than the sample distributions. For this, 5600 simulations were made, as well as a set of 22,400 simulations (slicing pressure into 20 slivers, and radius into 10).

For the basic example being discussed here (in 5600, 22400 pairs):

Z10 = 0.1, 0.0	Z50 = 5.7, 5.7
Z100 = 7.1, 7.1	Z500 = 9.8, 10.0

THE JPM ESTIMATE

For each of the 10 sample records, the JPM findings were (in 10, 50, 100, and 500 year columns):

2.1000	6.3000	7.8000	10.6000
0.0000	5.9000	7.4000	10.4000
0.0000	5.5000	7.1000	10.1000
0.0000	6.1000	7.7000	10.7000
0.0000	6.1000	7.7000	10.8000
2.0000	6.2000	7.7000	10.7000
0.0000	5.8000	7.3000	10.4000
1.8000	6.4000	7.9000	10.7000
0.1000	6.0000	7.7000	11.0000
2.2000	6.0000	7.3000	9.8000

THE EST ESTIMATE

These are the 100 year estimates from both JPM and EST:

7.8	10.1
7.4	---
7.1	11.4
7.7	7.9
7.7	9.6
7.7	15.3
7.3	7.2
7.9	8.2
7.7	9.5
7.3	7.1

(But note that the EST results may be improved by the addition of hypothetical tracks, now in preparation to be included in the paper)

DISCUSSION

The resistance of the JPM estimates to sample variation is remarkable, considering the variation in the 10 samples. Some of the variation is readily attributable to differences in storm density (ranging from 0.738E-4 to 1.08E-4)

The EST estimates show the sort of sample variation to be expected with the historical tracks, and should be improved with hypothetical tracks. Still, the variation is dramatic and it must be kept in mind that the addition of hypothetical tracks is based on the historical tracks, serving mainly to smooth alongshore variations.

CONCLUDING REMARKS

The tentative conclusions described here are being reviewed and will be recorded in the published version of the paper, as part of the Workshop proceedings

Additional comparisons with alternate assumptions will be shown there, including especially

- The influence of hypothetical tracks in an EST study
- JPM estimates using sample correlations (should improve things)
- Sensitivity to the period of record
- Influence of additional records

(And thanks to Norm Scheffner for all his help with EST)