U. S. Army Engineer Research and Development Center
Coastal and Hydraulics Laboratory

StormSim-JPM:

Stochastic Storm Simulation System's Joint Probability Method

Quick Start Guide

Version 0.3 Alpha

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Table of Contents

1. Content of the StormSim-JPM Tool package

- Script Interface_StormSim_JPM.m
  - Principal script that runs the StormSim-JPM Tool. Allows users to define inputs and view outputs. Includes an example of the input arguments and settings to evaluate peak events from an ADCIRC simulation over more than 400 virtual gages.
- File StormSim_JPM_Tool.p is the StormSim-JPM Tool.
- Folder "INPUT" contains three .mat files with example input data:
  - ProbMass_per_Event.mat – probability masses per event
  - Response_per_savepoint.mat – responses per savepoint
  - VG_info.mat – savepoint ID number
- Folder "JPM_output" contains the output generated for the example input file.
- Quick start guide (this document)
- Feedback form

2. Outline of the script Interface_StormSim_JPM.m

The script is divided in six sections, as follows. To run the tool with the provided example just click the "Run" button (green triangle in the Editor tab). The expected output can be found in the folder JPM_output.

1. **%% HEADER**
   - Contains the disclaimer, licensing details, authors, and history of revisions.

2. **%% Input data files**
   - This is an example on how to load the .mat files with the input data.

3. **%% General settings**
   - The general settings control the following:
     - virtual gauges to evaluate
     - confidence limits to compute
     - the integration methodology to apply
     - hazard definition: frequencies or probabilities
     - enable use of parallelized code
     - path to output folder
     - vector of responses to interpolate hazard from curve

4. **%% Uncertainty settings**
   - The uncertainty settings control the features related to the incorporation of the uncertainty, as follows:
     - values for absolute and relative
     - type and value of tide uncertainty
     - how to incorporate or apply the tide uncertainty
     - uncertainty treatment

5. **%% Plot settings**
   - Plot settings to control the view and label of hazard plots when these are required.

6. **%% USER: DO NOT CHANGE ANYTHING BELOW THIS LINE**
   - In this section, the StormSim_JPM_Tool.p file is called to perform the evaluation with the user-provided input arguments.

3. Description of the StormSim-JPM Tool

The current implementation of StormSim's Joint Probability Method (StormSim-JPM) tool estimates the hazard curve (HC) and confidence limits (CLs) of a response dataset of one or multiple virtual gauges. The HC can be expressed in terms of annual exceedance frequency (AEF) or annual exceedance probability (AEP). The *response* may refer to a tropical cyclone or hurricane's hydrodynamic response like, for instance, storm surge, significant wave height, and peak wave period, or to an atmospheric response such as wind or rainfall. Riverine discharge and other coastal compound flooding responses can be evaluated with this tool. In the context of the JPM, a vector of probability masses must exists and has one value for each response value in a virtual gauge.

The JPM tool offers three different integration methods to estimate the hazard (Section 3). Settings are provided in this tool so the user can specify the different types of uncertainty and associated values depending on the integration method selected. Detailed descriptions of available input arguments and settings are provided in the Section 5. This tool will return the computed HCs and two hazard tables. The *hazard table* is a summary of interpolated values interpolated from the HCs and corresponding to specific AEF or AEP values. A description of the different output arguments is included Section 6.

StormSim-JPM will also evaluate the number of virtual gages represented in the response input data to determine if this has to be split into smaller files. This feature will activate when more than 5000 virtual gauges are entered, creating a new folder in the current directory and automatically parsing and processing the new files.

4. Integration methodologies

Built-in in the StormSim-JPM tool are the following integration methodologies:

1. Probabilistic Coastal Hazard Analysis (PCHA) with Augmented Tropical Cyclone Suite (ATCS) (approach with augmented storm suite in the order of 10^4 to 10^6 TCs); outputs a best-estimate HC and CLs conveying uncertainty.
2. PCHA Standard (approach with a smaller storm suite of 100 to 1,000 TCs); outputs a best-estimate HC and CLs conveying uncertainty.
3. Joint Probability Method (JPM) Standard (storm suite size similar to No. 2); outputs a single HC which incorporates uncertainty.

These three approaches share the same integration equation but differ in the way uncertainty is incorporated into the HCs.

The PCHA with ATCS methodology is preferred when the hazard curve with associated CL curve are to be estimated using the synthetic storm suite augmented through Gaussian process meta-modelling (GPM). Under this method, the different uncertainties are incorporated into either the response or the CLs, depending on the settings specified for the uncertainty treatment. Uncertainties are randomly distributed before application. This methodology has been applied in the following studies:

- South Atlantic Coast Study (SACS) - Phases 1 (PRUSVI), 2 (NCSFL) and 3 (SFLMS)
- Coast Protection and Restoration (LACPR) Study
- Coastal Texas Study (CTXS) – Revision

When hazards with CLs are to be estimated using the synthetic storm suite "as is" (not augmented), the PCHA Standard methodology is preferred. In this case, the absolute and relative uncertainties are initially partitioned. Then, the different uncertainties are incorporated into either the response or the CLs, depending on the settings specified for the uncertainty treatment. Uncertainties are normally distributed using a discrete Gaussian distribution before application. The PCHA Standard method has been used in the following studies:

- North Atlantic Coast Comprehensive Study (NACCS)
- Coastal Texas Study (CTXS) - Initial study

Contrary to the PCHA with ATCS and PCHA Standard methodologies, the JPM Standard method incorporates all uncertainties into a single hazard curve. This method cannot generate CL curves. The uncertainties are applied and/or combined depending on the uncertainty treatment settings. Under this approach, uncertainties are normally distributed using a discrete Gaussian before application.

In any of the three methods, the uncertainty associated to the astronomical tide can be specified in the form of either a skew tide or a standard deviation. While skew tides are simply added to the hazard, the standard deviation tide uncertainty is distributed before application as stated before for each methodology.

5. Description of input arguments and settings

The following is a description of the input arguments and available settings of the StormSim-JPM tool.

5.1 Input data and files

- Resp: Response data; specified as a numerical array. Each row represents an event (e.g., storm). Each column represents a location (e.g., virtual gauge, savepoint, or node).

- ProbMass: Probability mass per event; specified as a vector or a matrix. Each row represents an event. Each column represents a virtual gauge.

- vg_id: ID number to label the virtual gauge to be evaluated; specified as a positive scalar or vector of positive integers. Must have one value per column of the input argument Resp. Otherwise, leave empty [ ] to automatically generate the IDs. Example: sp_id = [1 2 3 4 5 10 100 1500];

5.2 General settings

- vg_ColNum: Specific virtual gauges (columns in input Resp) to be evaluated; specified as a positive scalar or vector of positive integers. Otherwise, leave empty [ ] to evaluate all locations. Example: if input Resp has 1000 columns (virtual gauges) but only want to evaluate columns 1, 5, and 100, enter vg_ColNum = [1 5 100];

- prc: Percentage values for computing the percentiles; specified as a scalar or vector of positive values. Leave empty [ ] to apply default values 2.28%, 15.87%, 84.13%, 97.72%. User can enter 1 to 4 values. Example: prc = [2 16 84 98];

- integrate_Method: Integration method; specified as a character vector. Currently, the tool can apply one of the three integration methodologies described in Section 4. They share the same integration equation but have unique ways of incorporating the uncertainties. Current options are:

    - integrate_Method = 'PCHA ATCS'. The different uncertainties are incorporated into either the response or the percentiles, depending on the settings specified for U_tide_app and uncert_treatment. With the exception of when U_tide_type = 'Skew', the uncertainties are distributed randomly before application.

    - integrate_Method = 'PCHA Standard'. The different uncertainties are incorporated into either the response or the percentiles, depending on the settings specified for U_tide_app and uncert_treatment. With the exception of when U_tide_type = 'Skew', the uncertainties are normally distributed using a discrete Gaussian before application.

    - integrate_Method = 'JPM Standard'. The uncertainties are applied and/or combined depending on the settings specified for U_tide_app and uncert_treatment. With the exception of when U_tide_type = 'Skew', the uncertainties are normally distributed using a discrete Gaussian before application.

- ind_aep: Enter one (1) to express the hazard in terms of AEP; or zero (0) to use AEF.

- apply_Parallel: Enter one (1) to perform the evaluation in parallel; enter zero (0) otherwise.

- path_out: Path to output folder; specified as a character vector. Leave empty [ ] and the tool will create a folder named JPM_output in the current directory.
    - The tool will search for the default JPM_output output folder and will not create another one if it already exists.

- HC_tbl_rsp_y: user-defined vector of response values used to summarize the HC. Corresponding probabilities interpolated from the HC will be stored in HC_tbl_rsp_x.

5.3 Uncertainty settings

- U_a: Absolute uncertainty associated to the response. This uncertainty has same units of the response. The tool will apply this uncertainty depending on the value of inputs uncert_treatment and integrate_Method. Specified as a non-negative scalar. Otherwise, leave empty [ ]. Example: U_a = 0.20 meters;

- U_r: Relative uncertainty associated to the response and is dimensionless since is a fraction. The tool will apply this uncertainty depending on the value of inputs uncert_treatment and integrate_Method. Specified as a non-negative scalar. Otherwise, leave empty [ ]. Example: U_r = 0.15;

- U_tide_app: Indicates how the tool should apply the tide uncertainty. This uncertainty will be applied differently depending on the selected integration method (integrate_Method) and uncertainty treatment (uncert_treatment). Available options are as follows:

    - U_tide_app = 0: The tide uncertainty is not applied, regardless of the values of inputs integrate_Method and uncert_treatment.

    - U_tide_app = 1:

        - When integrate_Method = 'PCHA ATCS' or integrate_Method = 'PCHA Standard', the tide uncertainty (as a standard deviation) is combined with U_a, U_r or both, depending on the value of input uncert_treatment, and then applied to the confidence limits.

        - When integrate_Method = 'JPM Standard', the tide uncertainty is combined with U_a, U_r or both, depending on the value of input uncert_treatment, and then applied to the response.

    - U_tide_app = 2: The tide uncertainty is applied to the response before any of the other uncertainties, regardless of the values of inputs integrate_Method and uncert_treatment. The value of input U_tide_type determines how it is added, as follows:

        - When U_tide_type = 'Skew': the tide uncertainty is added to the response.

        - When U_tide_type = 'SD': the tide uncertainty is distributed and then added to the response. The distribution is random when integrate_Method = 'PCHA ATCS'. Otherwise, the uncertainty is distributed using a discrete Gaussian distribution when integrate_Method = 'PCHA Standard'.

- U_tide: Uncertainty associated to tides. Current options for this input vary depending on the value of input argument U_tide_type, as follows:
    - When U_tide_type = 'SD', input U_tide represents the tide uncertainty in the form of a standard deviation. Can be specified as a non-negative scalar when only one value applies to all locations. Can also be specified as a vector of non-negative values, with one value per location. Cannot be a matrix array.
    - When U_tide_type = 'Skew', input U_tide represents the tide uncertainty in the form of a skew or offset, and is superimpose to the responses. In this case, U_tide must be specified as a matrix array with one value per storm per location provided in input Resp.
    - Otherwise, set U_tide = [ ] when no tide uncertainty is needed.
- U_tide_type: Type of tide uncertainty; specified as a character vector. Current options are:
    - 'SD' = tide uncertainty in the form of a standard deviation, which is distributed and added to the responses. This can be combined with the absolute and relative uncertainties.
    - 'Skew' = tide uncertainty in the form of a skew or offset, which is added to the responses. Skew tides cannot be combined with other uncertainties.
    - Otherwise, set U_tide_type = [ ] when this is not applicable.
- uncert_treatment: Indicates the uncertainty treatment to use; specified as a character vector. Determines how the absolute (U_a) and relative (U_r) uncertainties are applied. Current options are:
    - uncert_treatment = 'absolute': only U_a is applied
    - uncert_treatment = 'relative': only U_r is applied
    - uncert_treatment = 'combined': both U_a and U_r are applied
    - These uncertainties can also be combined with the tide uncertainty depending on the values of inputs U_tide_app and integrate_Method.
- SLC: Magnitude of the sea level change associated to the responses; specified as a positive scalar. Otherwise, leave empty.

5.4 Plot settings

- plot_results: Enter one (1) to generate the hazard plots; enter zero (0) otherwise.

- yaxis_label: Parameter name/units/datum for label of the plot y-axis; specified as a character vector. Example: 'Still Water Level (m, MSL)'

- yaxis_Limits: Lower and upper limits for the plot y-axis; specified as a vector. Leave empty [ ] otherwise. Example: yaxis_Limits = [0 10];

6. Description of output arguments

The following is a description of the output arguments provided by the StormSim-JPM tool.

- HC_plt_x: predefined vector of probabilities used to define and plot the full HC. The type is:
    - AEP when ind_aep = 1
    - AEF when ind_aep = 0

- HC_tbl_x: predefined vector of probabilities used to summarize the HC. The type is:
    - AEP when ind_aep = 1
    - AEF when ind_aep = 0

- HC_tbl_rsp_y: vector of response values used to summarize the HC; could be predefined or user-specified.

- JPM_output: structure array containing the output data of the StormSim-JPM Tool. The following is a description each available field:

    - vg_id: identifier of the virtual gauge as specified by the user

    - HC_plt_y: full HC in the form of a double-type array with the following format:
        - col(01): mean or best estimate values
        - col (02): values of 2% percentile or 1st percentage of input prc
        - col (03): values of 16% percentile or 2nd percentage of input prc
        - col (04): values of 84% percentile or 3rd percentage of input prc
        - col (05): values of 98% percentile or 4th percentage of input prc

    - HC_tbl_y: interpolated response values corresponding to the values in HC_tbl_x. Stored in the form of a double-type array with the following format:
        - col(01): mean or best estimate values
        - col (02): values of 2% percentile or 1st percentage of input prc
        - col (03): values of 16% percentile or 2nd percentage of input prc
        - col (04): values of 84% percentile or 3rd percentage of input prc
        - col (05): values of 98% percentile or 4th percentage of input prc

    - HC_tbl_rsp_x: interpolated hazard values corresponding to the responses specified in HC_tbl_rsp_y. Stored in the form of a double-type array with the following format:

        - col(01): mean or best estimate values
        - col (02): values of 2% percentile or 1st percentage of input prc
        - col (03): values of 16% percentile or 2nd percentage of input prc
        - col (04): values of 84% percentile or 3rd percentage of input prc
        - col (05): values of 98% percentile or 4th percentage of input prc

- Removed_vg: Message in the form of a cell array, with the list of virtual gauges not evaluated when:
    - the number of response values or events in the input dataset is less than 0.05 times the sample size.

7. History of revisions

- 20210405 – released version 0.1 Alpha
- 20210601 – released version 0.2 Alpha
- 20210809 – released version 0.3 Alpha

8. Feedback form

Please use the "Feedback form" to report any errors found and send to the following email addresses:

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