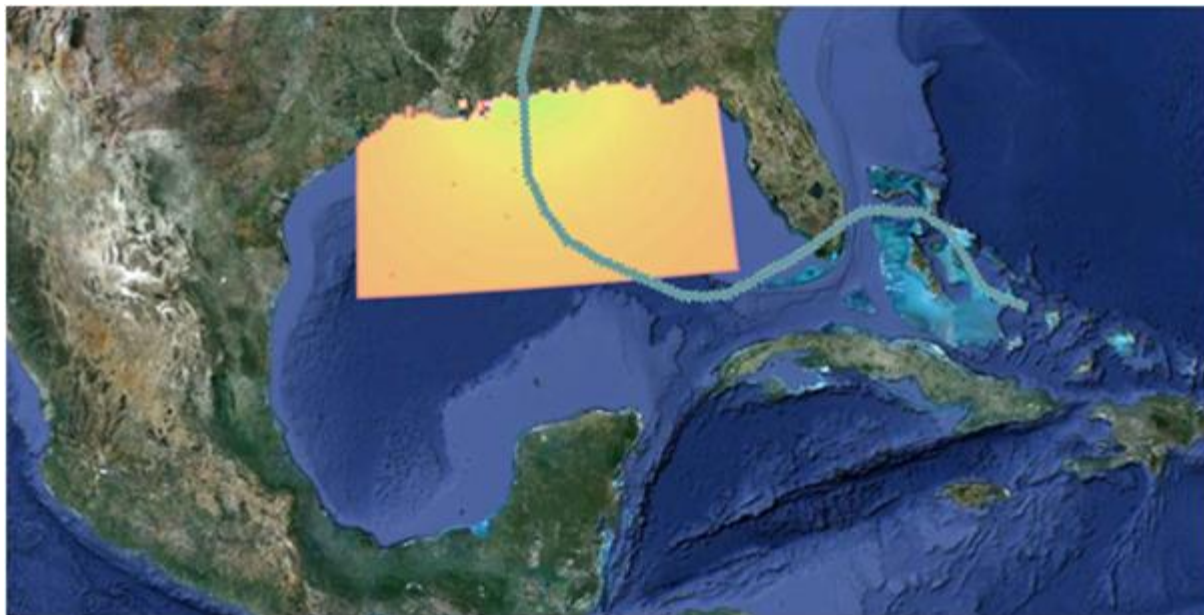




SMS 14.0 Tutorial

WAM

WAve prediction Model (WAM)



Objectives

Learn how to create various WAM simulations from 2D Cartesian grids.

Prerequisite Tutorials

- Overview

Required Components

- SMS Core
- WAM Model & Interface

Time

- 40–50 minutes

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1 Introduction

The global ocean WAve prediction Model (WAM), developed and maintained in part by the Engineering Research and Development Center (ERDC) of the United States Army Corps of Engineers (USACE) is a third generation wave model. WAM predicts directional spectra as well as wave properties at user specified output locations in the model domain throughout a simulation. The model requires a wind field for the desired simulation period as input.

Given these wind fields, WAM can predict the directional spectra generated by coastal storms at locations near the shore or engineering structures. These wave spectra can play a significant role in the flooding and damage caused by coastal storms as they are compounded on surges associated with the storm.

WAM is designed for large scale domains and runs in geographic coordinates. WAM can be used to generate spectral boundary conditions for a nearshore wave model.

In this tutorial, previously-generated wind data will be used.

2 Loading Input Data Files

The WAM model requires a wind field to drive the simulation. For this case, a previously-computed wind field will be imported for a simulation of a synthetic storm mimicking the path of Hurricane Katrina from 2005.

1. Select **File | Open...** to bring up the *Open* dialog.
2. Select "Project Files (*.sms)" from the *Files of type* drop-down.
3. Browse to the *data files* folder for this tutorial and select "WAMin.sms".
4. Click **Open** to import the file and exit the *Open* dialog.

The project should appear similar to Figure 1.

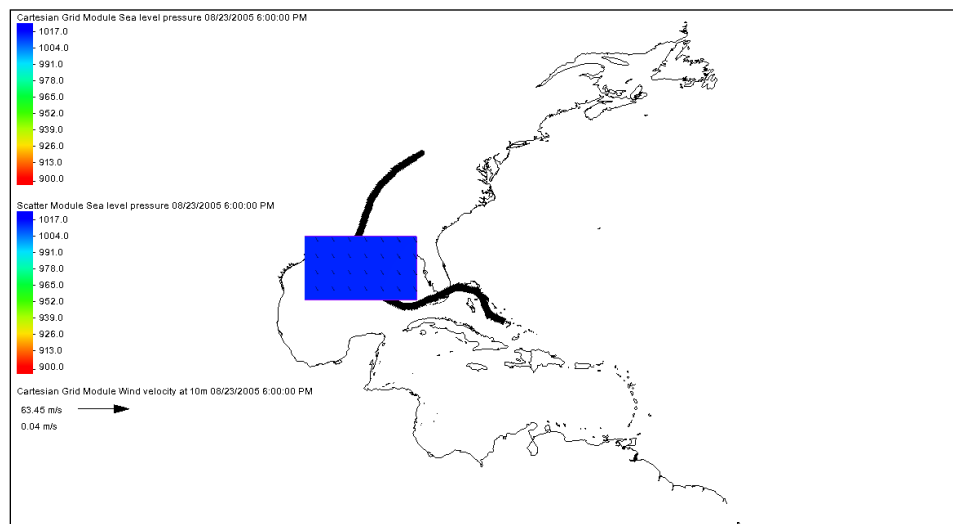


Figure 1 Appearance of initial project

This project includes a grid covering the northern Gulf of Mexico, with datasets which define the wind directions at 10 meters and the sea level pressures for each hour for a period of time from August 23, 2005 at 6 pm to August 30, 2005 at 6 pm (seven days). Several coverages and a shapefile depicting the shoreline are also part of the project.

5. Select “ Sea level pressure” in the Project Explorer to make it active.
6. The storm enters the domain around 6 pm on August 25, so select and step through time steps around that time to see the wind and pressure fields.

The wind and pressure fields at time step “08/27/2005 6:00:00 AM” should appear similar to Figure 2.

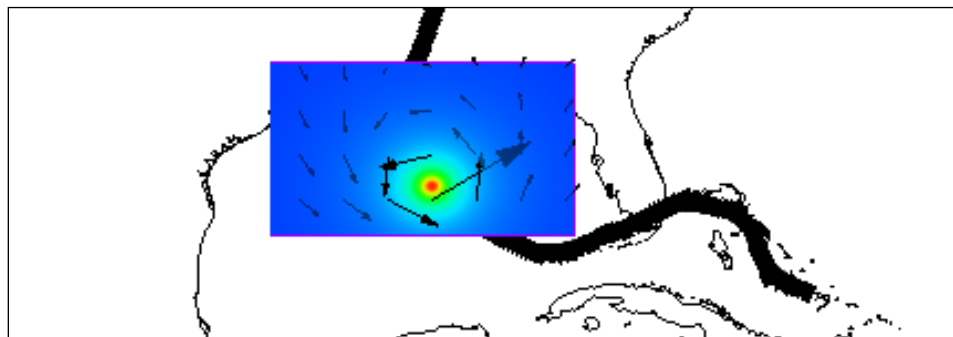


Figure 2 Wind and pressure fields at 6 am on August 27, 2005

3 Defining the WAM Domain

A WAM simulation requires a Cartesian grid in geographic coordinates to define the scope of the computations. In this section the grid will be created. The wind data drives the WAM simulation, so the domain of this model must lie within the grid which defines the wind field.

For this example, the same domain will be used. First it is necessary to create a new WAM coverage. This can be done by creating a new coverage, or by copying an existing PBL coverage.

To create the coverage:

1. Right-click  "Map Data" and select **New Coverage** to open the *New Coverage* dialog.
2. In the *Coverage Type* section, select *Models* | **WAM** (near the bottom of the list).
3. Enter "WAM_Katrina" as the *Coverage Name*.
4. Click **OK** to close the *New Coverage* dialog.

The new  "WAM_Katrina" coverage will appear in the Project Explorer.

3.1 WAM Grid Frame Properties

The grid on which the wind data is defined consists of cells with dimensions of 0.1 x 0.1 degrees. For this tutorial, WAM will use this same resolution, though the two resolutions do not need to match. The WAM grid should be the same size or slightly smaller than the grid with the wind data so that every cell in the WAM grid contains wind data.

To specify the WAM grid position, size, and resolution adjust the grid frame properties from which SMS will generate the grid by doing the following:

1. Select  "WAM_Katrina" to make the **Map**  module active.
2. Using the **Create 2-D Grid Frame**  tool, click out a grid frame in the same general area where the  "Synthetic_KATRINA" grid is located.
3. Using the **Select 2-D Grid Frame**  tool, double-click on the icon in the middle of the grid frame to open the *Grid Frame Properties* dialog.
4. In the *Origin, Orientation and Dimensions* section, enter "-94.9" as the *Origin X*.
5. Enter "25.1" as the *Origin Y*.
6. Enter "11.3" as the *I Size*.
7. Enter "6.3" as the *J Size*.
8. Enter "0.1" as the *Cell size* in both the *I Cell Options* and *J Cell Options* sections.
9. Click **OK** to close the *Grid Frame Properties* dialog.

3.2 Interpolating to Cartesian Grid

With a grid frame defined, the WAM domain can now be generated by doing the following:

1. Right-click  "WAM_Katrina" and select *Convert* | **Map** → **2D Grid** to bring up the *Map → 2D Grid* dialog.
2. In the *Depth Options* section, select "Scatter Set" from the *Source* drop-down.
3. Click **Select...** to bring up the *Interpolation* dialog.
4. In the *Scatter Set To Interpolate From* section, select "z".
5. In the *Interpolation Options* section, enter "-2.0" as the extrapolation *Single Value*.

This assigns a negative depth (land) to WAM cells created outside the scatter set.

6. Click **OK** to close the *Interpolation* dialog.

7. Click **OK** to close the *Map → 2D Grid* dialog.
8. Click **OK** when advised that isolated water cells were found on the grid.
9. Turn off “ WAM_Katrina”.

The grid to represent WAM is needed, but the grid frame doesn't need to be displayed. The project should appear similar to Figure 3.

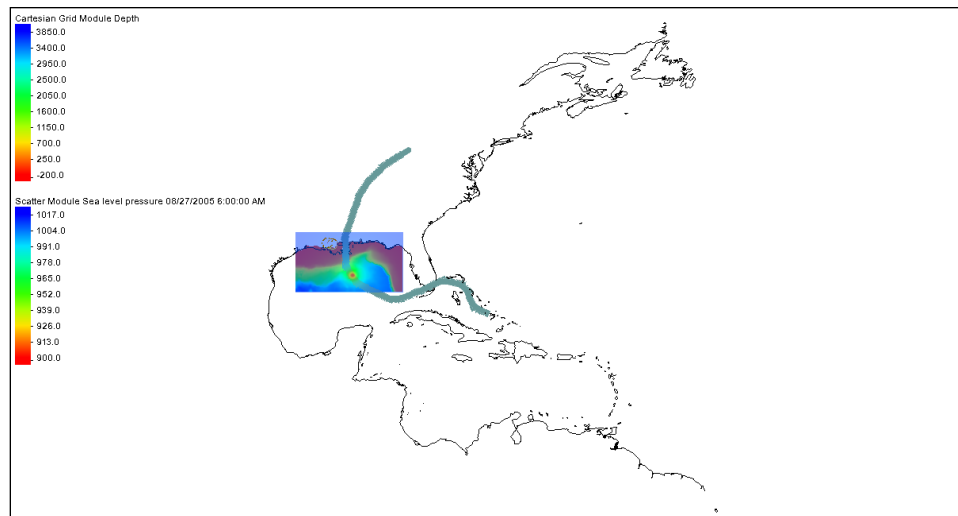


Figure 3 After defining the WAM domain

4 WAM Parameters

The WAM grid has been created, but has not had parameters assigned to it. Most of the parameters for running WAM are specified on a grid level and a few others are specified on a simulation level (when using multiple grids, as shown later). The grid options include computation parameters, time steps, output times, output field types, and spatial input options. The output field types and spatial inputs have their own sections below.

4.1 General Options

The computation parameters include several options that can affect the quality of the simulation and runtimes. Using the shallow water depth model, depth refraction, or depth and current refraction model requires a smaller time step and increases runtime.

The WAM model is subject to what is referred to as the CFL condition. A larger time step results in shorter run times, but lower stability. The Courant–Friedrichs–Lewy (CFL) condition is a measure of anticipated stability and a prediction for convergence in solving partial differential equations numerically. The time step must be small enough to assure that input energy from the wind and transferred wave energy can more cleanly pass from cell to cell and does not skip cells as the input fields change.

If the time step is too large, energy may be moved through cells without being tracked appropriately. Decreasing the time step resolves this problem but results in a longer run time, so the time step should be selected to maintain stability in as short a run time as possible.

In order to better see the WAM grid and assign WAM parameters, do the following:

1. Select  "WAM_Katrina_Grid" to make it active, then right-click on it and select **Zoom to Grid**.

SMS will refresh the display and center it on the WAM grid. The contours of bathymetry should be displayed as well.

2. Right-click  "WAM_Katrina_Grid" and select **Options** to bring up the *Grid Options* dialog.
3. On the *General* tab, enter "WAM_Katrina" as the *Title*.
4. In the *Model options* section, select "Deep" from the *Water depth model* drop-down.

The model options affect model stability. See the WAM documentation to get an explanation of the differences between the deep and shallow water options.

5. Select "Not used" from the *Refraction model* drop-down.
6. Turn on *Breaking* and *Create restart file*.

The *Test level* is a control for output diagnostics and is mostly used for model debugging. The minimal diagnostic output level is "0", the default setting.

Under *Model time steps*, *Max CFL* is displayed in red with a value of "2.33". If the computed maximum CFL is above the threshold of "1.0", it will appear in red and these parameters should be changed until a stable condition is achieved (it will appear green when this happens). Each time the model parameters and time steps are changed, SMS recomputes the *Max CFL* for the simulation. The settings for this tutorial keep the simulation simple.

7. In the *Model time steps* section, enter "300" as the *Propagation* and select "seconds" from the drop-down.

This changes the *Max CFL* to "0.78", making it green.

8. Enter "300" as the *Source* and select "seconds" from the drop-down to match the propagation.

It is not required that this time step match, but they match here for simplicity and convenience. Normally, a time step would be used to smoothly transition the wind fields. The input wind files were saved at 60 minute output. WAM interpolates between these intervals to attain a smaller forcing time step.

9. Enter "60" as the *Output wind* and select "minutes" from the drop-down.
10. In the *Output time steps* section, enter "1" as the *Spatial Datasets* and select "hours" from the drop-down.
11. Enter "1" as the *Spectra* and select "hours" from the drop-down.
12. Enter "12" for *Close/reopen files* and select "hours" from the drop-down.

These last three settings control the output time steps. *Spatial Datasets* controls how frequently WAM saves the spatially varied quantities. Viewing these quantities gives feedback on the WAM simulation. *Spectra* controls the interval between times that WAM saves spectral output at specified locations.

Close/reopen files tells WAM to group the output data into files each containing 12 hours of output. These files will be created in the directory for the WAM grid and will be named "IntOutYYYYMMDDHH" and "SpectraOutYYYYMMDDHH".

13. Select the *Output* tab.

4.2 Output Options

The *Output* tab of the *Grid Options* dialog lists a variety of output options for WAM. At the bottom of the options list are different descriptions of swell and sea waves.

Sea waves are generated in a local area by the wind that is currently blowing. Swell waves are waves that have traveled into an area after being generated by previous winds in other areas. There may be swell present even if there is no wind and no sea waves. These options are on by default.

For production models, the WAM developers recommend all the output options be left on, resulting in large output files. Some of these will be turned off in order to make this tutorial go faster.

1. In the *Model options* section, turn off everything except the following :
 - Wind speed at 10m
 - Wind direction
 - Significant wave height
 - Wave peak period
 - Wave mean period
 - Wave direction
 - Directional spread
 - Spectra of total sea
 - Sea spectra
 - Swell spectra
2. Select the *Spatial Inputs* tab.

4.3 Spatial Inputs Options

The *Spatial Inputs* tab in the *Grid Options* dialog allows specification of spatially varied input to the WAM model. No changes will be made to the *Ice cover data* and the *Currents data* sections as they are not needed for this tutorial.

1. In the *Wind data* section, click **Select...** to bring up a *Select Dataset* dialog.
2. In the *Select* section, select the "Wind velocity at 10m" dataset.
3. Click **Select** to close the *Select Dataset* dialog.
4. Click **OK** to exit the *Grid Options* dialog.

5 WAM Simulation

With the WAM grid constructed and the grid options specified, it is time to create a simulation. In SMS, multiple WAM simulations can be created in the same project. Each simulation must be associated with a WAM grid, but more than one simulation can use the same grid.

5.1 Simulation

To create the WAM simulation:

1. Right-click in a blank spot at the bottom of the Project Explorer and select *New Simulation* | **WAM**.

A “ WAM” folder should appear, containing a “ Simulations” folder with a default “ WamSimulation” in it.

2. Right-click “ WamSimulation” and select **Rename**.
3. Enter “WAM_Katrina” and press *Enter* to set the new name.
4. Drag “ WAM_Katrina Grid” onto the new “ WAM_Katrina” simulation.

A link to the “ WAM Katrina Grid” appears below “ WAM_Katrina” in the Project Explorer.

5.2 Simulation Parameters

To set up the simulation, do the following:

1. Right-click the “ WAM_Katrina” simulation and select **Model Control...** from the drop-down to bring up the *Simulation Model Control* dialog.

For this simulation, the settings in the *Frequency and direction grid* section on the *General* tab should be left at the defaults. *Number of frequencies* defines the extent of the spectral grid. *Number of directions* defines the size of the directional bin in the spectra. *Lowest frequency* defines all the frequencies in the grid. The XMS Wiki discusses these in more detail.¹

2. In the *Simulation run times* section, enter “08/26/2005 01:00:00 PM” as the *Start* and “08/28/2005 09:00:00 AM” as the *End*.

This start time corresponds to the approximate time the storm is approaching the domain. More time before the storm arrives may be included if currents are being used. To expedite the run times in this tutorial, *End* is set to a shorter time instead of going the full length of the storm.

The seven-day simulation can take just over an hour to run, depending on the speed of the computer. Reducing the run time allows running a model more quickly in order to see the output. If time permits, models can be rerun with longer time ranges. Remember to stay inside the range of times for which wind data exists.

3. On the *Spectra* tab, in the *Parameters of initial spectrum* section, select “Cold Start” from the *Run type* drop-down.

If a previous run was being used as a starting point, and a hot start file had been saved, the hot start option could be chosen.

4. Leave the other model parameters at default values and click **OK** to exit the *Simulation Model Control* dialog.

¹ See https://www.xmswiki.com/wiki/SMS:WAM_Simulation_Model_Control

6 Exporting WAM Files, Saving Project and Running WAM

Now all the necessary information for a WAM simulation run has been entered into SMS. It is time to save the project and run WAM.

6.1 Exporting WAM Files and Saving Project

Before exporting the WAM files and running WAM, save the project. This is where the run information will be stored.

1. Select **File | Save As...** to bring up the **Save As** dialog.
2. Enter "WAMout.sms" as the **File name**.
3. Click **Save** to save the project under the new name and close the **Save As** dialog.
4. Right-click  "WAM_Katrina" and select **Export WAM Files**.

This command creates a folder named "WAM" in the project folder. This "WAM" folder contains a folder for each simulation, named for the simulation. In this case, there is only one simulation, named "WAM_Katrina", so the WAM folder includes a single folder named "WAM_Katrina". This folder includes folders for each input grid and the wind input.

Since the  "WAM_Katrina" simulation includes only a single grid, two folders are created. The first is named "WAM_Katrina Grid", which is the name of the grid previously created, and second is "WindInput", which contains all wind files. The process time can vary, depending on the speed of the computer being used, because SMS resaves the wind data formatted for WAM to use.

6.2 Running WAM

Now that the project has been saved, it is time to run WAM.

1. Right-click  "WAM_KATRINA" and select **Launch WAM** to bring up the **WAM WAM_Katrina** model wrapper dialog.

There are three WAM executables including "WAM_Preproc", "WAM_Chief", and "MAP_TO_RASTER". The model wrapper launches each of these in turn (they are order specific) as seen in Figure 4. Once each process is complete, the bar for that process will turn green.

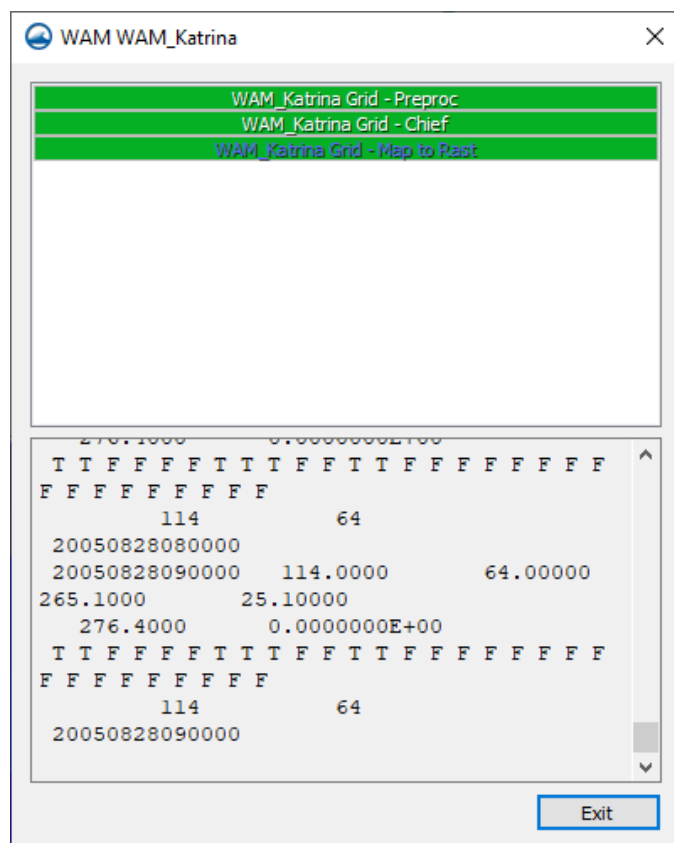


Figure 4 WAM Simulation Run showing the different WAM executables

In this case, with a specified “Close / reopen files:” interval of 12 hours, each solution file will contain 12 hours of data. The file name includes the time at the end of the simulation interval contained in that file. Therefore, the string “20050824060000” indicates the file contains data with time values from 2005 August 23 at 7 pm through August 24 at 6 am.

The three types of output files are “IntOut”, “SpectraOut####”, and “Restart####”. The “Map to Rast” utility converts the data in the “IntOut####” solution files into an HDF5 format so that SMS can read them. This allows for post processing of the datasets. SMS creates a script, “fort.10” (placed in the “WAM_KATRINA Grid” output folder), that instructs this utility to name the solution file “wam_output.h5”.

2. Once all three processes are complete, click **Exit** to close the *WAM_WAM_Katrina* model wrapper dialog.

WAM creates all of its output files in the folder for the grid. In this case that is the “WAM_KATRINA Grid” folder. The XMS Wiki describes this process in greater detail.²

7 Viewing WAM Simulation Results

SMS automatically loads the spatial datasets (from “wam_output.h5”) and the spectral output when exiting the simulation model wrapper dialog. If the files do not open automatically, the datasets can be opened by selecting *File* | **Open...**, browsing to the

² See https://www.xmswiki.com/wiki/SMS:WAM_Graphical_Interface#Model_Wrapper

grid folder, and selecting “wam_output.h5”. This simulation did not include any spectral output.

7.1 Viewing datasets on the grid

To view the output from WAM:

1. Select “ WAM_Katrina Grid” to make it active.

Five scalar () and two vector () datasets should be listed under the grid, where before there was only the depth (). Selecting a dataset makes it the active, or viewed, dataset. One vector and one scalar dataset can be active at a time (Figure 5).

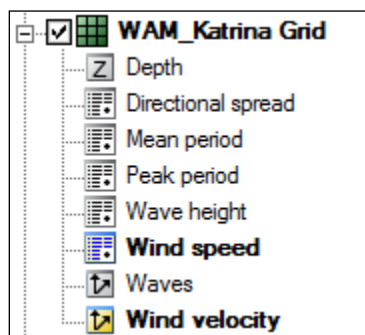


Figure 5 Datasets loaded from “wam_output.h5”

To illustrate how to view the output of the WAM model, do the following:

2. Select “ Wave Height” as the active scalar dataset and “ Wind velocity” as the active vector set.
3. Turn off “ Scatter Data” in the Project Explorer.
4. Click **Display Options**  to open the *Display Options* dialog.
5. Select “Cartesian Grid” from the list on the left.
6. Turn on *Contours* and *Vectors*.
7. Click **OK** to close the *Display Options* dialog.
8. Select “08/26/2005 2:00:00 PM” as the time step and step forward through the time steps.

This is one hour after the start of the simulation. The model did not save anything before this time step. While stepping through the time steps in the *Time steps* section, SMS updates the display to show how wind field changes and the wave heights vary over the domain. Figure 6 shows the solution for “8/27/2005 7:00:00 AM”.

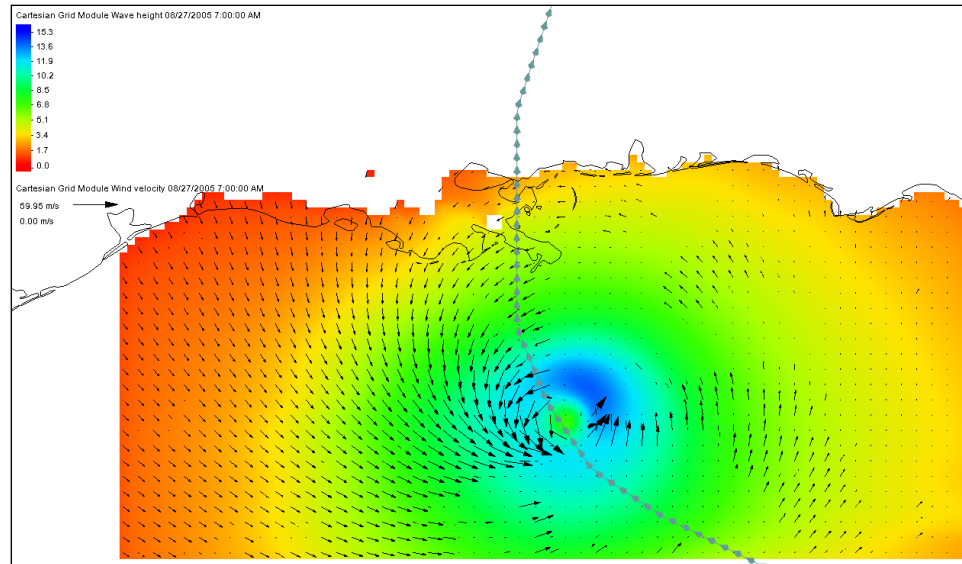


Figure 6 Sample of WAM spatial dataset output

8 Nested Simulation

WAM supports the ability to create a coarse grid to cover a large domain, and then define smaller, high resolution grids in specific areas of interest. SMS refers to the coarse grid as a “parent” grid and the small grids as “child” grids. These “nested” child grids allow high resolution investigation of a region of interest without the computational expense of a high resolution grid over the entire basin.

8.1 Nested Grid

To create a nested grid:

1. Right-click on “ Map Data” and select **New Coverage** to bring up the *New Coverage* dialog.
2. In the *Coverage Type* section, select *Models* | **WAM** and enter “Nested WAM” as the *Coverage Name*.
3. Click **OK** to close the *New Coverage* dialog.
4. Select the new “ Nested WAM” coverage to make it active.
5. Using the **Create 2-D Grid Frame**  tool, click out a grid roughly in the same area as shown in Figure 7.

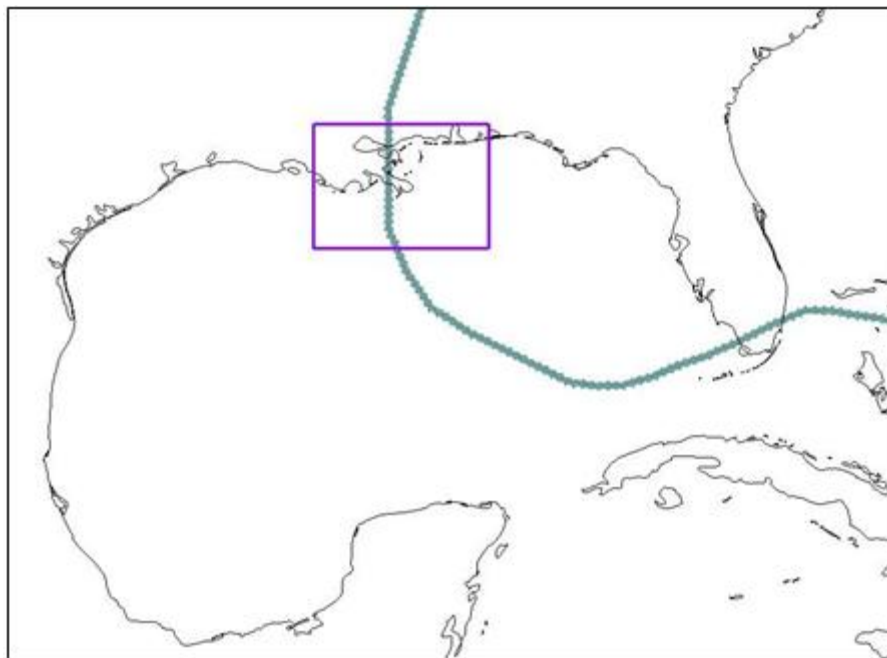


Figure 7 Nested grid frame

6. Right-click on “ Nested WAM” and select **Convert | Map → 2D Grid** to bring up the *Map → 2D Grid* dialog.

The default grid name is “Nested WAM Grid”. The default will be used for this tutorial.

7. In the *Grid Nesting* section, turn on *Fine Grid*.
8. Select “WAM_Katrina Grid” as the *Coarse Grid*.

This is the name of the parent grid. This will change the values for the newly mapped grid, such as the origin and increment, to correspond to cells in the coarse grid.

9. In both the *I Cell Options* and *J Cell Options* sections, enter “0.05” as the *Cell size*.
10. In the *Depth Options* section, select “Scatter Set” from the *Source* drop-down.
11. Click **Select...** to bring up the *Interpolation* dialog.
12. In the *Scatter Set To Interpolate From* section, select “z” from the tree list.
13. In the *Interpolation Options* section, enter “-2.0” as the *Single Value*.
14. Click **OK** to close the *Interpolation* dialog.
15. Click **OK** to close the *Map → 2D Grid* dialog and generate the nested grid.
16. If prompted that some isolated water cells were found on the grid, click **OK**. These will not affect any results.

8.2 Grid Options

To set the grid options for this nested grid, do the following:

1. Select “ Nested WAM Grid” to make it active, then right-click it and select **Options** to open the *Grid Options* dialog.
2. On the *General* tab, enter “Nested WAM Sample” as the *Title*.

3. In the *Model options* section, select “Deep” from the *Water depth model* drop-down.
4. In the *Model time steps* section, enter “150” as the *Propagation* and select “seconds” from the drop-down.
5. Enter “5” as the *Source* and select “minutes” from the drop-down.
6. Enter “30” as the *Output wind* and select “minutes” from the drop-down.
7. In the *Output time steps* section, enter “1” and select “hours” from the drop-down for both *Spatial Datasets* and *Spectra*.
8. Enter “12” for *Close/reopen files* and select “hours” from the drop-down.
9. On the *Output* tab, turn off everything except:
 - Wind speed at 10m
 - Wind direction
 - Significant wave height
 - Wave peak period
 - Wave mean period
 - Wave direction
 - Directional spread
 - Spectra of total sea
 - Sea spectra
 - Swell spectra

As before, this is done in order to keep the file sizes more reasonable during the tutorial.

10. On the *Spatial Inputs* tab, in the *Wind data* section, click **Select...** to bring up the *Select Dataset* dialog.
11. In the *Select* section, select “Wind velocity at 10m” from tree list and click **Select** to close the *Select Dataset* dialog.

As with the coarse grid in this tutorial, *Ice cover data* and *Currents data* are not needed here.

12. Click **OK** to close the *Grid Options* dialog.

8.3 Nested WAM Simulation

In nested grid cases, both the nested (fine) grid and the parent (coarse) grid have to be added to the simulation.

1. Right-click on “ WAM_Katrina” and select **Duplicate**.
2. Right-click on “ WAM_Katrina (2)” and select **Rename**.
3. Enter “Nested_WAM” and press *Enter* to set the new name.
4. Drag “ Nested WAM Grid” onto “ Nested_WAM”.

The coarse parent grid, “ WAM_Katrina Grid”, should already be linked to the simulation.

8.4 Simulation Model Control

To set the parameters:

1. Right-click " Nested_WAM" and select **Model Control...** to bring up the *Simulation Model Control* dialog.
2. On the *General* tab, in the *Simulation run times* section, enter "08/27/2005 05:00:00 AM" as the *Start*.
3. Enter "08/28/2005 05:00:00 AM" as the *End*.

This makes the high resolution grid focus on the day around landfall for the storm.

4. On the *Spectra* tab, in the *Parameters of initial spectrum* section, select "Cold Start" from the *Run type* drop-down.
5. Click **OK** to exit the *Simulation Model Control* dialog.

8.5 Exporting WAM Files, Saving Project, and Running WAM

Saving the project and files works the same for nested simulations as it does with single grid simulations.

1. Select *File* | **Save As...** to open the *Save As* dialog.
2. Select "Project Files (*.sms)" from the *Save as type* drop-down.
3. Enter "NestedWAM.sms" as the *File name*.
4. Click **Save** to save the project under the new name and close the *Save As* dialog.
5. Right-click " Nested_WAM" and select **Export WAM Files**.
6. Right-click " Nested_WAM" and select **Launch WAM** to bring up the *WAM Nested_WAM* model wrapper dialog.

The model wrapper now includes items for both the parent and child grids, and processes will run for both. All six processes will turn green once completed.

7. Once all six processes finish, click **Exit** to close the *WAM Nested_WAM* model wrapper dialog.

8.6 Viewing WAM Simulation Results for the Nested Grid

The nested grid will now have its own solution data that can be viewed with the same methods used for the parent grid. The solution files for the " Nested WAM Grid" have now imported into SMS. In the " Cartesian Grid Data" folder named " Nested WAM Grid", there are several new datasets similar to the ones for the parent WAM grid.

1. Right-click " Nested WAM Grid" and select **Zoom to Grid**.
2. Under " Nested WAM Grid", select the " Wind speed" scalar dataset and the " Wind velocity" vector dataset.
3. Go through the different times, beginning at "08/27/2005 6:00:00 AM".

Figure 8 shows the nested grid at time step "08/27/2005 8:00:00 PM".

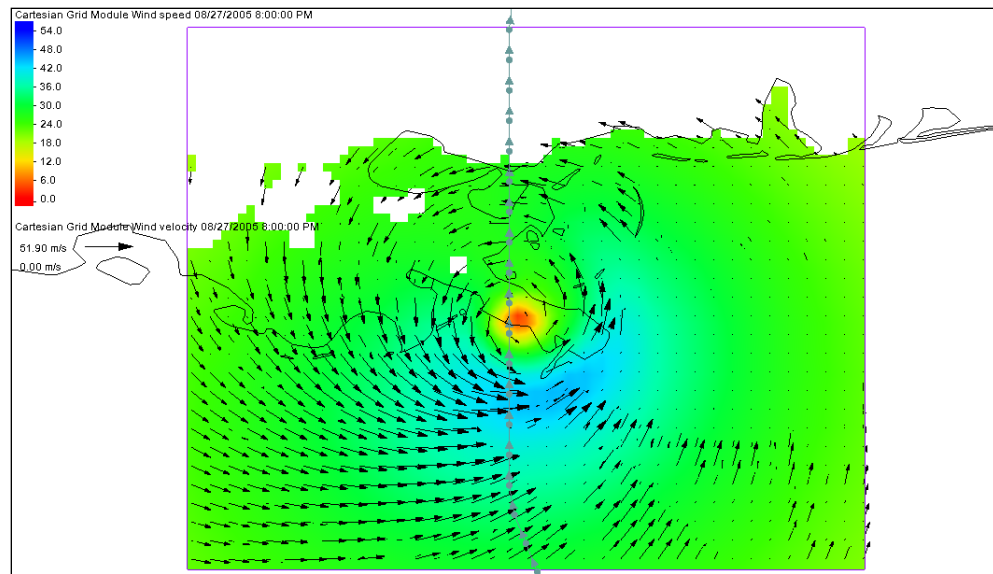


Figure 8 Nested grid results for wind speed

9 Conclusion

For the purpose of this tutorial, and because of the large sizes of the files created during WAM runs, the extent of the WAM domain was made smaller than would be realistic. For example, in a realistic situation for hurricane Katrina, one might want to extend the WAM domain to cover the whole Gulf of Mexico.

This concludes the "WAM" tutorial. Feel free to continue experimenting, or exit the program.