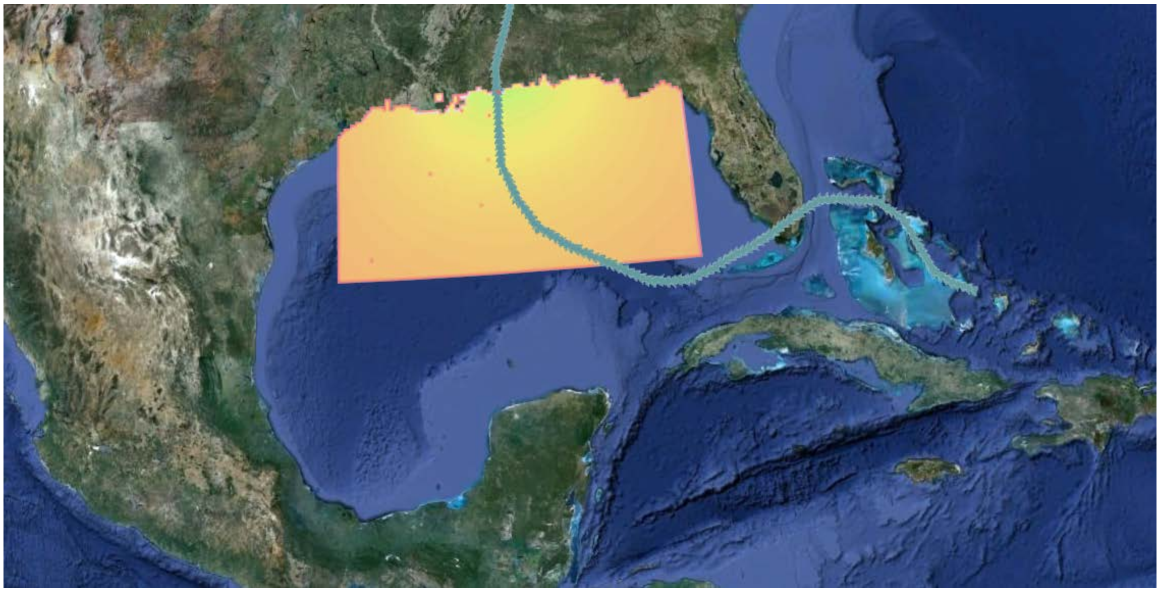
SMS

v. 11.1

SMS 11.1 Tutorial

WAve prediction Model (WAM)



Objectives

This tutorial will show how to create various WAM simulations from 2d Cartesian grids.

Prerequisites

- Overview Tutorial
- Wind field

Requirements

- WAM
- STWAVE
- Map Module
- Scatter Module
- Cartesian Grid Module

Time

- 60-90 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. This tutorial includes an optional section which runs STWAVE using spectra from WAM.

In this exercise, we will use wind data previously generated.

2 Loading Input Data Files

The WAM model requires a wind field to drive the simulation. For this case, we will load a previously computed wind field for a simulation of a simulated storm which mimics the path of hurricane Katrina from 2005.

1. Select File | Open and open the file 'WAMin.sms'. This project includes a grid covering the Northern Gulf of Mexico with data sets which define the wind directions at 10m 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 (7 days). Several coverages and a shapefile depicting the shoreline are also part of the project.
2. Click on the "Synthetic KATRINA" Scatter data and the "Sea level pressure" scalar data in the project explorer to activate it so you can visualize the wind data. The storm enters the domain around 6 pm on the 26th of August, so you will need to select time steps in that range to see the wind and pressure fields.

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, we will create this grid. 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, we will use the same domain.

First we need to create a new WAM coverage. We could do this by creating a new coverage, or by copying the PBL coverage. We don't need the storm track information from the PBL coverage, but we do want the grid frame. To create the coverage:

1. Right-click on Map Data and select New Coverage from the menu.
2. Select WAM as the coverage type and name the new coverage "WAM KATRINA".

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 application WAM will use this same resolution. The two resolutions do not need to match. The WAM grid should also 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, you can adjust the grid frame from which SMS will generate the grid. To set the grid frame properties:

1. Select the coverage named "WAM KATRINA" to make the Map module active.
2. Using the Create 2-D Grid Frame tool , define a grid roughly the same size and location as the grid containing the wind data. There is no need to be very precise since we will edit the grid. Simply click on three of the corners of the wind grid.
3. Using the Select 2-D grid Frame tool , double click on the icon in the middle of the grid (or right click and select "Properties"). The Grid Frame Properties will open. Make the following changes accordingly:
    - Origin X to -95.0
    - Origin Y to 25.0
    - I size to 11.5
    - J Size to 6.5
    - Cell Size in both directions: 0.1^{o}
    - Click OK.

3.2 Interpolating to Cartesian Grid

With a grid frame defined, you can now generate the WAM domain. To do this:

1. Right click on the "WAM KATRINA" coverage and select "Convert | Map -> 2D Grid" from the drop down menu. The "Map -> 2D Grid" dialog will appear.
2. Under Depth Options, set the "Source" to "Scatter Set". Click on the Select button and the Interpolation dialog will appear.

    - Under the wnat_bathy scatter set, select "z" as the data set on the top right portion of the dialog.
    - Change the Single Extrapolation Value to -2.0. This assigns a negative depth (land) to WAM cells created outside of the scatter set.
    - Click OK to return to Map -> 2D Grid dialog

3. Click OK in the Map -> 2D Grid dialog to create the WAM grid. A message will appear indicating that isolated cells have been found in the land region. Click OK to the message and you will see at the bottom right of the graphics window that 6 cells are selected. WAM does not really care about these isolated cells, so just ignore this message.
4. Toggle off the display of the "WAM KATRINA" coverage. (Now we have the grid to represent WAM. We don't need to display the grid frame.)
5. Select the "Synthetic_Katrina scatter data to make it active. Then click on the "Scatter" menu and select "Interpolate to Cartesian Grid". Select "Wind velocity at 10m" in the 'Scatter Set to Interpolate From' section.
6. Toggle on "All Time Steps", then click OK.

4 WAM Parameters

We have now created the WAM grid, but we have not yet assigned parameters to it. In order to better see the WAM grid, click on the "WAM KATRINA" grid to make it active, and then right click on it and select "Zoom to Grid". SMS will refresh the display centered on the WAM grid. The contours of bathymetry should be displayed as well. Now we will assign WAM parameters to the simulation.

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 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.

Right click on the "WAM KATRINA" grid and select the "Options..." command from the drop-down menu.

4.1 General Grid 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 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 longer run times, so the time step should be selected to maintain stability in as short a run time as possible.
In the Grid Options dialog, you will find 3 tabs: "General", "Output" and "Spatial Input". In the "General" tab, make the following changes:

- Set the "Title:" to "Sample WAM KATRINA".
- Set the "Water depth model" under "Model options:" to "Deep". The model options affect model stability. See the WAM documentation to get an explanation of the differences between the deep and shallow water options.
- The WAM model includes the capability to simulate refraction of waves caused by interaction with the ocean bottom and interaction with currents. For speed, these options will be left off in this tutorial.
- WAM can simulate wave breaking. Leave the "Breaking" flag set to enable this calculation.
- The "Test level" is a control for output diagnostics and is mostly used for model debugging. For now leave this set at 0 which is the minimal diagnostic output level.
- Leave the "Create restart file" option on. This causes WAM to create a restart file to continue analysis at a future time.
- Under "Model time steps:", you will see a display of the "Max CFL" number. At this point it is displayed as a red number and has a value of 2.34. SMS computes the maximum CFL value based on the propagation time step, cell size, refraction model and the water depth model. All three parameters are interconnected. If the computed maximum CFL is above the threshold of 1.0, these parameters should be changed to make sure that a stable condition is achieved. As you change model parameters and time steps, SMS re-computes the "Max CFL" number for the simulation. The most easily controlled parameter is the propagation time

step. It should be reduced until the CFL number is acceptable. The default time step is set at 900 seconds (15 minutes). As mentioned above, this results in a computed CFL of 2.34 which is unacceptable. Decrease the time step from 900 seconds (15 minutes) in increments of one minute, down until the CFL is less than 1.0. The number will turn green when it is acceptable. (You can change the units from seconds to minutes if desired.) The result will be a propagation time step specified as "360 seconds" or "6 minutes" with a computed Max CFL of 0.93. This indicates that 6 minutes is an acceptable time step for stability purposes. For simplicity and to have a round number for the timestep for this tutorial, change the propagation time step to “300 seconds” or “5 minutes” which will give us a Max CFL of 0.78.

- Also under "Model time steps:" set the "Source" value to "300 seconds" or "5 minutes" to match the propagation. It is not required that this time step match. We are just doing it here for convenience. Normally you would use a time step to smoothly transition the wind fields. This time step controls how frequently the WAM simulation updates the forcing terms. The input wind files were saved at 60 minute output. WAM interpolates between these intervals to attain a smaller forcing time step.
- Set the "Output wind" under "Model time steps" to 60 minutes or 1 hour. (You can use either time unit.)
- Under "Output time steps", set "Spatial Datasets:" to 1 hour. This controls how frequently WAM will save the spatially varied quantities. Viewing these quantities give feedback on the WAM simulation.
- Set the "Spectra:" output to 1 hour as well. This controls the interval between times that WAM saves spectral output at specified locations. (These spectra will be used to drive STWAVE in later simulations.)
- Set "Close / reopen files:" to 12 hours. This tells WAM to group the output data into files containing 12 hours worth of output each. These files will be created in the directory for the WAM grid and will be named "IntOutYYYYMMDDHH" and "SpectraOutYYYYMMDDHH".

4.2 Output Options

WAM supports a variety of output options. These are specified in the Output tab of the grid options dialog. Switch to the output tab, and scroll down to the bottom of the options list, you will see 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.

For production models, the WAM developers recommend that all the output options be left on. This results in large output files. In order to keep file sizes smaller for this tutorial we are only going to run with a subset of the options. 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

4.3 Spatial Input Options

The third tab in the "Grid Options" dialog allows specification of spatially varied input to the WAM model. Switch to the Spatial Inputs tab and make the following changes:

- Since the simulation is for the Gulf of Mexico, we do not need any data for Ice Cover.
- Currents can be fed into WAM to include the impact of currents on wave generation. This can be ignored for this exercise since WAM does not need Currents dataset to run but mainly a Wind dataset.
- Under "Wind data" section, click on the "Select" button and select the "Wind velocity at 10m" dataset.

Click OK to exit the Grid Options dialog.

5 WAM Simulation

With the WAM grid constructed and the grid options specified we are now ready to create a simulation. With SMS you can create multiple WAM simulations 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 the project explorer and select “New Simulation” | "WAM". A "WAM" entry is made in the tree with a folder named "Simulations". A default simulation, named "Simulation" is also created.

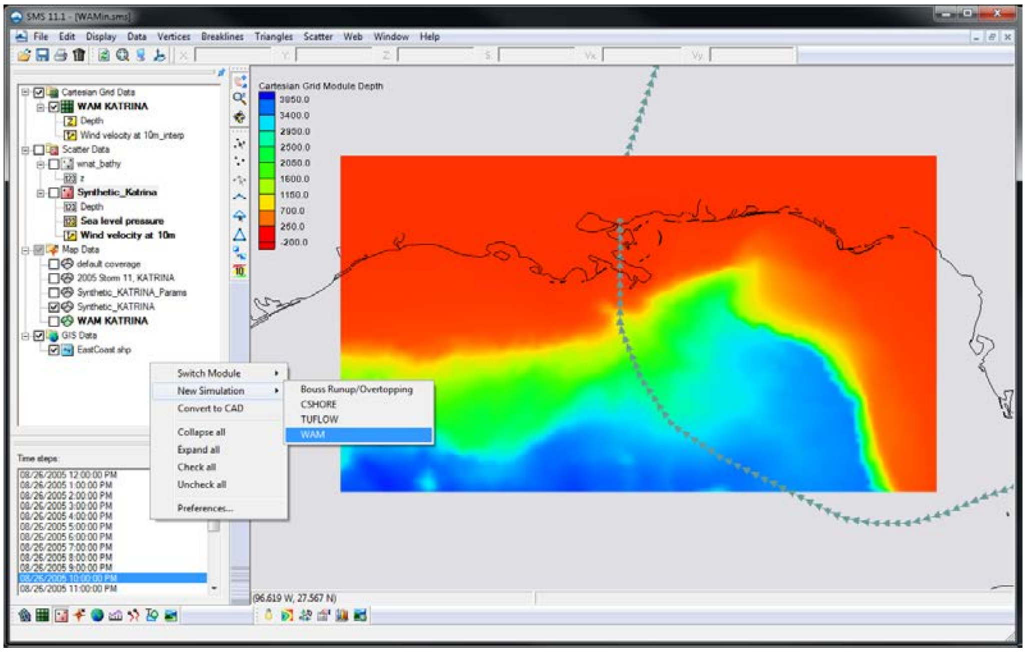


Figure 1 Creation of the WAM simulation by right clicking in the project explorer.

2. Rename the simulation by right clicking on "Simulation". Give the new simulation the name "WAMKATRINA".
3. Click on the "WAM_KATRINA" grid object in the project explorer. Don't let up on the button and drag this object into the newly named "WAMKATRINA" simulation. (Note: The same grid could be used in other simulations.) A link to the WAM KATRINA grid appears below the simulation name in the project explorer.

5.2 Simulation Parameters

Now we need to set up the simulation.

1. Right click the "WAMKATRINA" simulation and select "Model Control..." from the drop down menu. The "Simulation Model Control" dialog, which contains 2 tabs will appear.
2. In the "General" tab, we define the resolution and range of the spectral grids that will be created by WAM. The starting frequency band defines all the frequencies in the grid. Each frequency is defined by the frequency before it, so this is an important parameter. We will use the default value of 0.0417728. This corresponds to approximately a 24 second wave. It is the minimum recommended value (longest wave period). The WAM documentation has some guidance in choosing the right starting frequency band. The parameter for "Number of frequencies:" defines the extent of the spectral grid. Each frequency is 10% larger than the previous frequency. With 25 frequencies the maximum frequency is 0.4114 which corresponds to approximately a 2.5 second wave.
3. The "Number of directions" determines the size of the directional bin in the spectra. The default of 24 corresponds to a 15 degree bin.
4. Change the Start Simulation run time to 08/26/2005 1:00:00 PM. This corresponds to about the time the storm is approaching the domain. If currents are being used, you may wish to include more time before the storm arrives.
5. In order to expedite the run times in this exercise, make the "End" time to 08/28/2005 9:00 AM instead of going the full length of the storm. The seven day simulation takes just over an hour to run on a typical desk top machine. Reducing the run time will allow you to run a model for yourself and see the output. (Note: If time permits you can rerun the model with longer time ranges. Remember to stay inside the range of times for which wind data exists.)
6. Switch to the Spectra tab and make sure that the "Run type:" is set to "Cold Start". If a previous run is being used as a starting point and a hot start file was saved, you could choose the hot start option.
7. Leave the other model parameters at default values. Click OK to exit dialog.

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, we need to save the project. This is where the run information will be stored.

1. Select File | Save Project (WAMout.sms).
2. Right click on the “WAMKATRINA” simulation and select "Export WAM Files". This command creates a folder named "WAM" in your project folder. This “WAM” folder will contain a folder for each simulation, named for the simulation. In this case, we only have one simulation and it is named "WAMKATRINA" so the WAM folder includes a single folder named WAMKATRINA. This folder includes folders for each input grid and the wind input. Since the WAMKATRINA simulation includes only a single grid, two folders are created. The first is named “WAM KATRINA” which is the name of the grid we created and second is “WindInput” which contain all wind files. The process will take up to a minute because SMS resaves the wind data formatted for WAM to use.

6.2 Running WAM

Now that the project has been saved we can run WAM.

1. Right Click on the WAMKATRINA simulation and select Launch WAM.

   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 2.

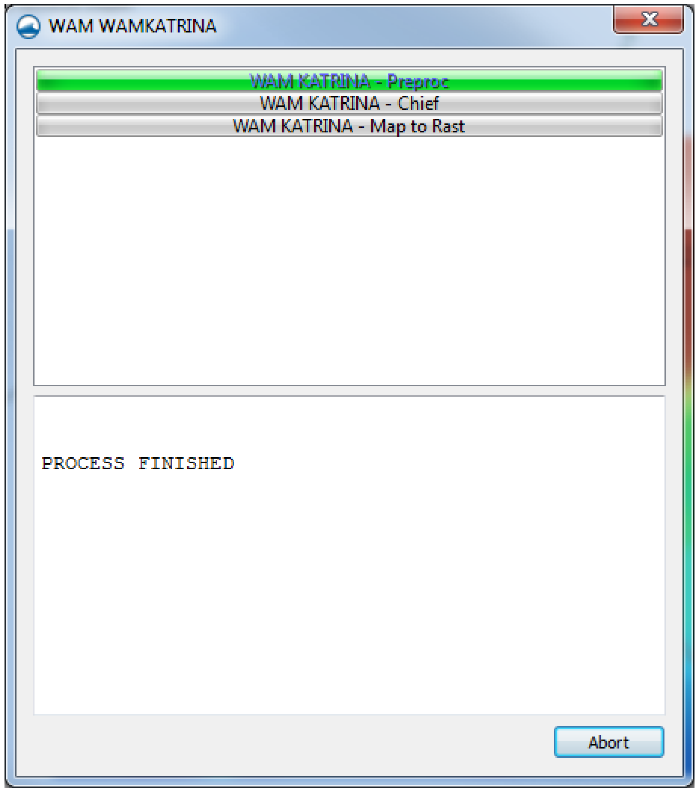


Figure 2 WAM Simulation Run showing the different WAM executables.

"WAM_Preproc" reviews the grid and creates two files, "Grid_info" and "Preproc prot". The "prot" file is an ascii dump of the model process. You can open this in an editor to verify that the model was executed and didn't detect problems. The "Grid_info" file is used in the next phase of the simulation.

"WAM_Chief" is the main process of WAM and takes the bulk of the run time. Unfortunately, the process does not output any diagnostics as it runs, so the model wrapper can not pass along progress information as the model runs. This process creates a "prot" file which is an ascii dump of the model process that can be reviewed in an editor. It also outputs three series of solution files. Each of these includes a particular type of output for a specified simulation interval. In this case, we specified that the "Close / reopen files:" interval should be 12 hours. Therefore, each solution file will contain 12 hours of data. The filename will include the time at the end of the simulation interval contained in that file. So the string "20050824060000" would indicate 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 file are:

- "IntOut###" - this is the interval output file. It contains the spatially varied data sets computed by WAM.

- "SpectraOut####" - this is the spectral output file. It contains the spectra at each spectral site, at the output frequency specified for spectral output.
- "Restart###" - this is a series of files which contain information to restart the simulation at a specific point if needed.

  "MAP_TO_RASTER" is a utility that 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 data sets. SMS writes a script (fort.10) that instructs this utility to name the solution file "wam_output.h5".

2. Click Exit once the simulation run is done.

WAM creates all of its output files in the folder for the grid. In this case that is the "WAM KATRINAGrid" folder.

7 Viewing WAM Simulation Results

SMS automatically loads the spatial data sets (from "wam_output.h5") and the spectral output when you exit the simulation run window. If the files do not open automatically, the datasets can be opened by selecting File | Open and browsing to the grid folder and selecting "wam_output.h5". This simulation did not include any spectral output. This option is discussed in section 9.

7.1 Viewing data sets on the grid

To view the output from WAM:

1. Make sure that the "WAM KATRINA" grid is selected. You should see 5 scalar and 2 vector data sets loaded on the grid where before we had only the depth. Clicking on a data set makes it the active, or viewed data set. One vector and one scalar can be active at a time (Figure 3).

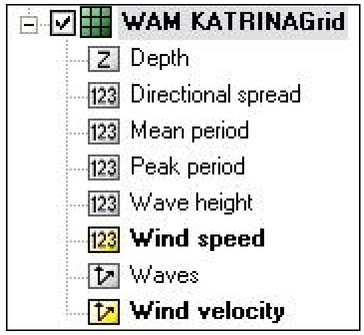


Figure 3 Datasets loaded from "wam_output.h5"

2. To illustrate how to view the output of the WAM model, select "Wave Height" as the active scalar dataset and "Wind velocity" as the vector set. (If you changed your display options, you may want to make sure that both contours and vectors are on.) Select 08/26/2005 2:00:00 PM as the time step. This is one hour after the start of the simulation. The model did not save anything before this time step. As you step through the time steps in the "Time steps:" window SMS will update the display showing how wind field changes and the wave heights vary over the domain. (Figure 4 shows the solution for 8/27/2005 7:00:00 AM).

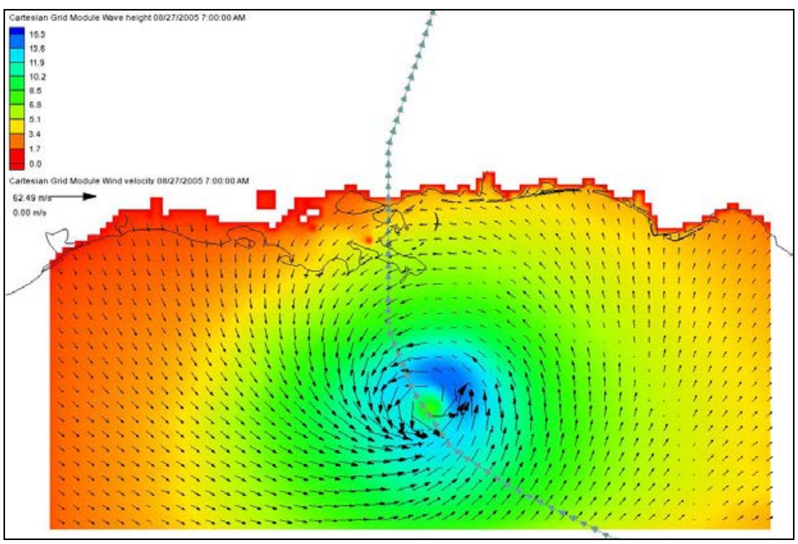


Figure 4 Sample of WAM spatial data set output

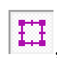
Spend a few minutes stepping through the various data sets created by the WAM model.

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. We must first create a grid frame. Right-click on "Map Data" and select "New Coverage" from the drop-down menu.
2. Select the type of coverage as WAM and change the name of the grid to "Nested WAM". Click OK.
3. Select the newly created "Nested WAM" to make it active.
4. Using the Create 2-D Grid Frame tool , click out a grid roughly in the same area as shown in Figure 5.

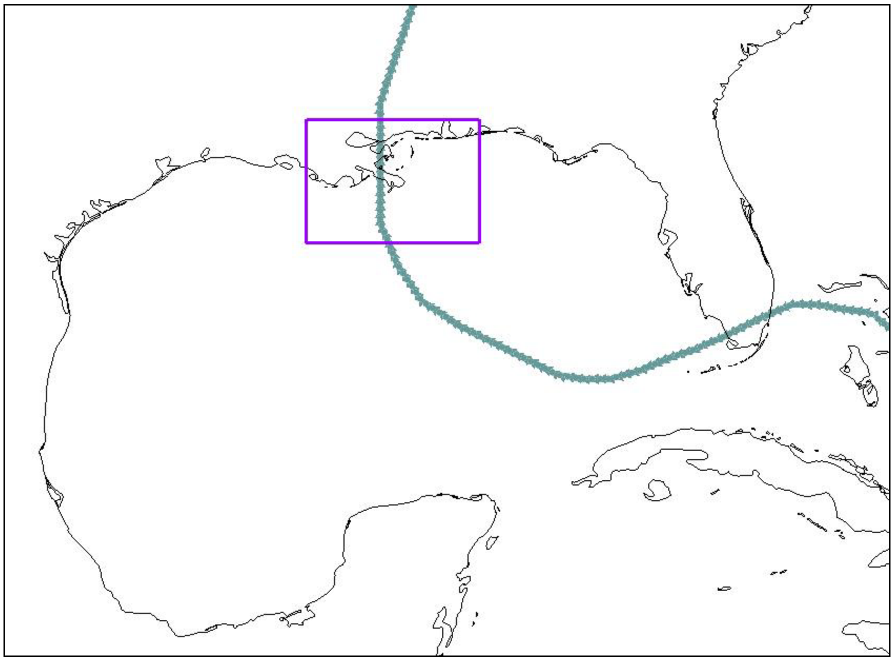


Figure 5 Nested Grid Frame

5. Right-click on the "Nested WAM" coverage and select "Convert | Map -> 2D Grid". This will create a grid named "Nested WAM".
6. Make the following changes:
   - Toggle on "Fine Grid" under "Grid Nesting".
   - Make sure the "Coarse Grid" is set as "WAM KATRINA" which is the name of our 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.
   - Double the resolution by setting the cell size in both I and J directions to 0.05^{o}.
   - Under "Depth Options", select the Scatter Set as Source and click on the Select… button.
   - Select "z" as the "Scatter Set to Interpolate From" and change the "Extrapolation" single value to -2.0. Click OK twice to interpolate grid.

NOTE: If you are prompted that some isolated water cells were found on the grid, click OK in dialog as these will not affect any results.

8.2 Grid Options

Now we need to set the grid options for this nested grid. To do this:

1. Select the grid "Nested WAM" to make it active.
2. Right-click on the "Nested WAM" grid and select "Options" to open the "Grid Options" dialog.
3. In the "Grid Options" dialog, "General" tab, make the following changes:
   - Set the "Title:" to "Nested WAM Sample".
   - Set the "Water depth model" under "Model options:" to "Deep".
   - Under "Model time steps:", set the "Propagation" time step to 150 seconds.
   - Set the "Source" time step to 5 minutes.
   - Set the "Output wind" under "Model time steps" to 30 minutes.
   - Under "Output time steps", set "Spatial Datasets:" and "Spectra" to 1 hour.
   - Set "Close / reopen files:" to 12 hours.
4. Switch to the Output tab and 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.
5. Switch to the "Spatial Inputs" tab and click on the "Select" button for the Wind dataset. Select the "Wind velocity at 10m" dataset under the ‘Synthetic

KATRINA' Cartesian grid. (As with the coarse grid, "Ice cover" and "Currents" are not needed.)

6. 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 the "WAMKATRINA" simulation and select "Duplicate".
2. Right-click on the new simulation and rename it as 'Nested WAM'.
3. In a similar fashion as before, drag the grid 'Nested WAM' into the simulation. The coarse parent grid named 'WAM KATRINA' should already be linked to the simulation.

8.4 Simulation Model Control

To set the parameters for this new simulation:

1. Right click the 'Nested WAM' simulation and select "Model Control" from the drop down menu.
2. In the "General" tab, change the "Start" time to 08/27/2005 5:00 AM and the "End" time to 08/28/2005 5:00 AM. (The high resolution grid will focus on the day around landfall for the storm.)
3. Switch to the "Spectra" tab and make sure that the "Run type" is set as "Cold Start".
4. Click OK to ext 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… and save the new project under the name 'NestedWAM.sms'.
2. Right click on the simulation and select Export WAM Files.

3. Right Click on the WAM simulation and select Launch WAM. (The model wrapper will now include items for both the parent and child grids and the processes will run for both.) Click Exit once the simulation run is done. (The run may take a few minutes.)

8.6 Viewing WAM Simulation Results for 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.

1. The solution files for the Nested grid will be loaded in SMS. In the Cartesian Grid data folder named 'Nested WAM' there will be several new datasets similar to the ones for the parent WAM grid.
2. Select the scalar dataset called 'Wind speed' and the vector dataset 'Wind velocity'. Go through the different times. Figure 6 shows the nested grid at time 08/27/2005 6:00:00 PM.

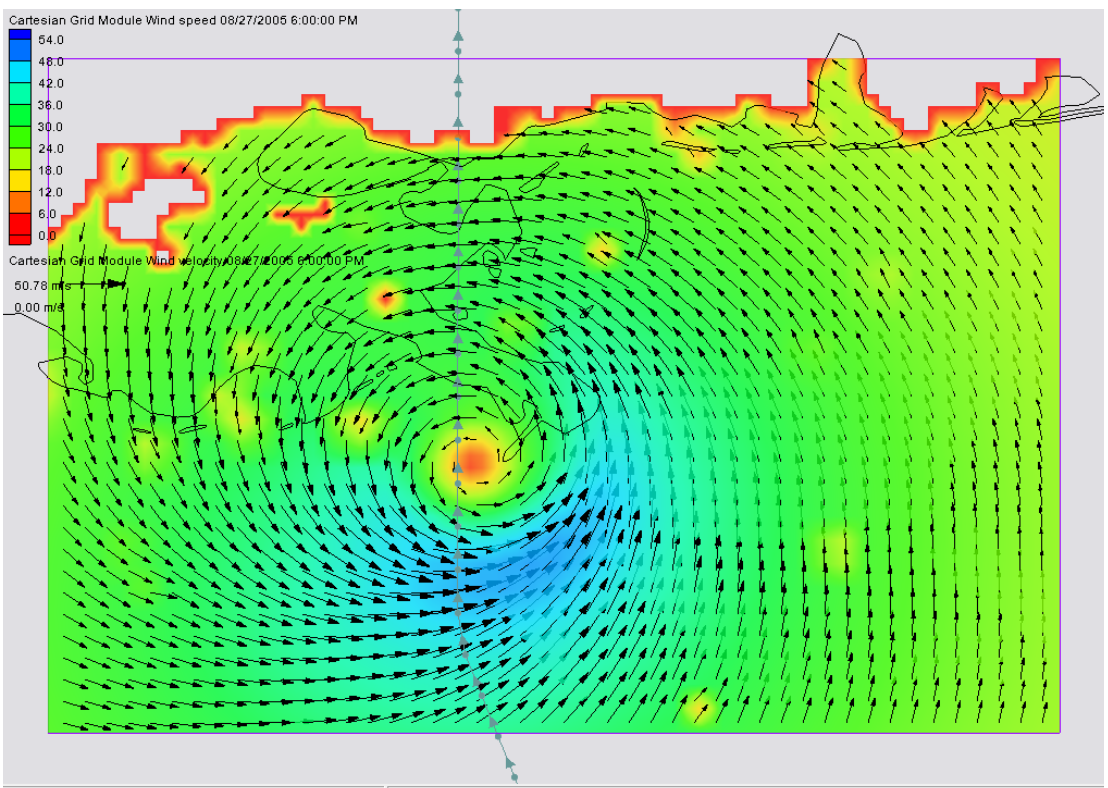


Figure 6 Nested Grid results for wind speed.

9 WAM Spectral sites Specification (Optional Exercise)

WAM supports the option of creating wave energy spectra at selected locations and time steps. The model could output an energy spectra at each cell at each time output interval. However, this would take an unreasonable amount of disk space and time. Therefore, WAM requires that the modeler define the locations (any cell in the Cartesian grid) and time frequency for saving wave energy spectra. (You specified the frequency in the previous section.) The output locations, associated with specific cells, will be referred to as spectral sites and can be specified in a couple of ways within the SMS interface. Since one of the principal applications of spectral output is for near shore wave models, the first method of defining spectral sites is to have SMS define them for a near shore model domain. This will be illustrated in the next section using an STWAVE domain. Spectral sites may also be defined manually.

9.1 Defining the near shore wave model domain

For this example, we will use STWAVE as a near shore wave model, which requires that we work in rectilinear space. Each Cartesian grid in SMS is associated with the projection that was in use when it was created. This is stored as part of the SMS project. While working in SMS, the current working projection (or display projection) may not be the same as the projection used to define a grid. In this situation, SMS transforms (or reprojects) the grid for display in the working projection.
We wish to define a near shore domain for STWAVE in the "Louisiana South (FIPS 1702)" projection. To do that, we need to change the working projection to this setting.

1. Select "Display | Projection".
2. Click on the "Set Projection" button and set the projection to be "State Plane Coordinate System" with the datum set to "NAD83", the units set to meters and the zone to "Louisiana South (FIPS 1702)".
3. SMS redisplays the data in the state plane projection. (Note: The WAM grid distorts since it is a geographic grid.)

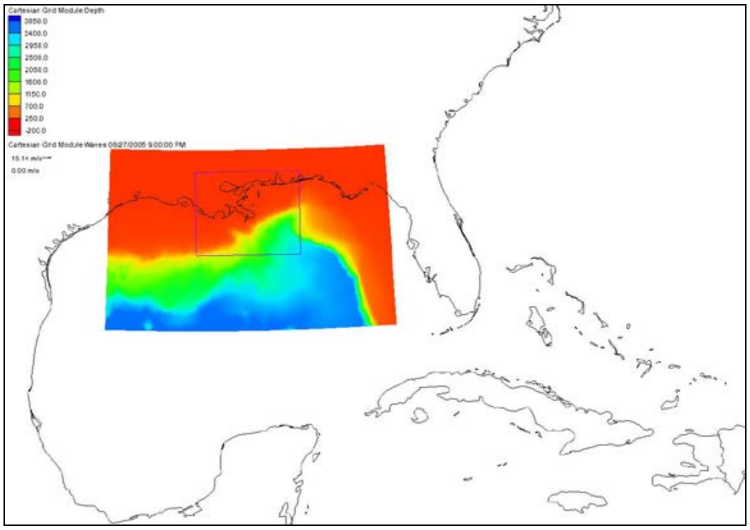
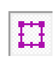


Figure 7 Domain reprojected to Louisiana South State Plane

In Louisiana South, we want to define an STWAVE domain. To do this, follow these steps:

1. Zoom into the area of Southern Louisiana.
2. Create a new coverage by right clicking on the "Map Data" item in the tree and selecting the "New Coverage" command. Set the type to Models | STWAVE and the name to "MsAl". Click OK to create the new coverage.
3. Right click on this coverage and select Projection. Set the projection to be "State Plane Coordinate System" with the datum set to "NAD83", the units set to meters and the zone to "Louisiana South (FIPS 1702)"
4. Select the "Create Grid Frame" tool  and click out a grid frame (three clicks) starting with an offshore point, going towards shore and then along the coastline (as seen in Figure 8). (This order is important for a near shore model like STWAVE, but not a regional model like WAM.)

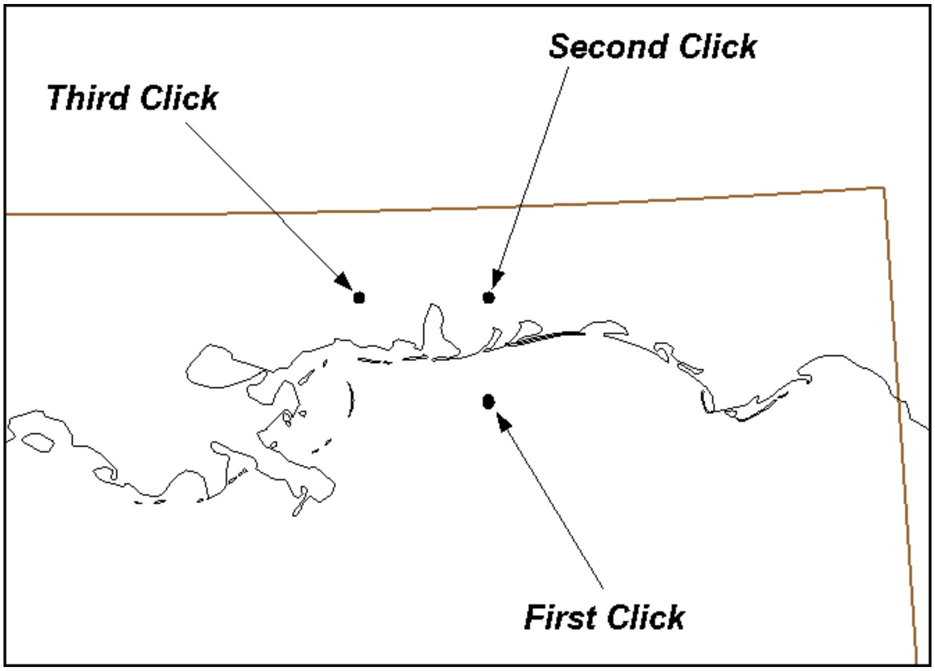


Figure 8 Grid Frame for Lake Ponchartrain

5. Click on the "Select Grid Frame" tool and double click on the grid frame you just created. Change the grid frame properties as shown in Figure 9.

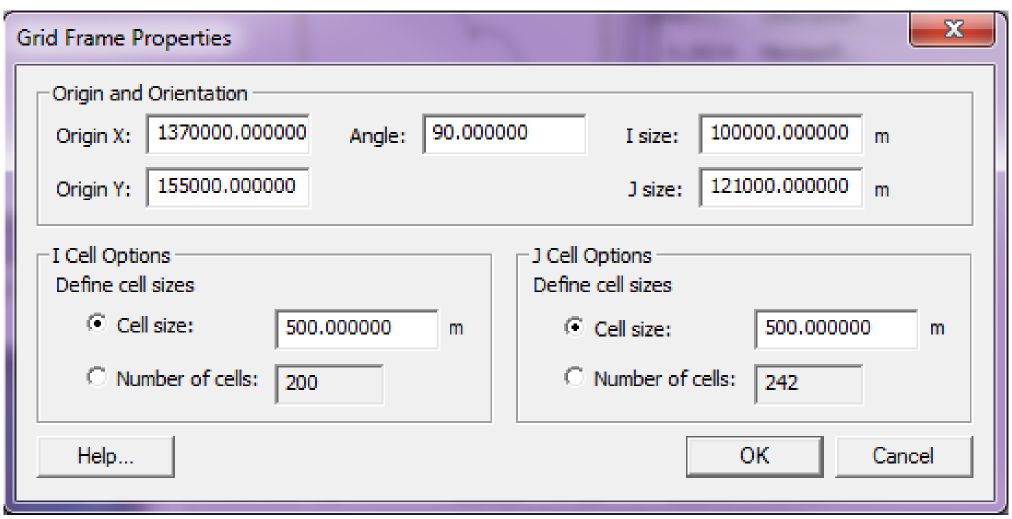


Figure 9 Grid properties for the Pontchartrain STWAVE grid frame.

6. To create the grid for this area, right click on the "MsAl" coverage and selecting "Convert | Map -> 2D Grid". The depth options will match those used for the WAM grid. Click OK to create the grid. (When the new grid is created, SMS will frame all the data. To see the new grid right click on the "MsAl" grid object and select "Zoom to Grid".)

9.2 Assigning STWAVE Input Boundaries

At this point, we need to define the locations where WAM will generate output spectra. This is specified for the WAM simulation, and since that simulation uses geographic coordinates, we need to change the working projection back to geographic. To do this:

1. Select Display | Projection and set the projection back to Geographic (Latitude/Longitude) with the datum to NAD 83. SMS will reframe the data.
2. Right click on the "WAM KATRINA" grid object and select "Zoom to Grid" to zoom into the WAM grid. The STWAVE grid is now the distorted grid (non rectangular).

STWAVE requires at least one spectra as a boundary condition for each open boundary. Two or more spectra may be used along such an STWAVE boundary to allow for spatially varying conditions. The location of the spectral sites should correspond with the open boundary locations in STWAVE, so it makes logical sense that the STWAVE grids would exist, and their boundary edges be defined (this means specifying which edges will have spectral inputs) before defining the spectral sites.

SMS supports a manual (explicit) approach for defining spectral sites and an automated method. In this manual method, the user selects a cell (or cells) in the WAM grid using the "Select Grid Cell tool" and then selects the "WAM | Assign Cell Attributes..." menu command. This command brings up the "Cell Attributes" dialog which allows the user to specify that this cell (or cells) is (are) a spectral site(s) and allows the user to specify a name for the selected site(s). (Note: the same dialog can be used to unassign cells as spectral sites.)

To experiment with this method of assigning spectral sites:

1. Select the MsAl coverage to be the active coverage. This makes its grid frame display so that we will see the grid extents.
2. Go to "Display Options" and select the "Cartesian Grid" options. Turn on "Cells", “Land Cell” "Ocean cell", "Spectra Site" and "Inactive grid boundaries". (Some of these may already be on.) Turn off the display on contours and vectors. Click OK.

3. Right click on the 'MsAl' grid object and select "Zoom to Grid". This zooms the display to the region around the STWAVE domain.
4. Select the ‘WAM KATRINA’grid to make it active. With the display of cells turned on, SMS will update the graphics window to appear like Figure 10.

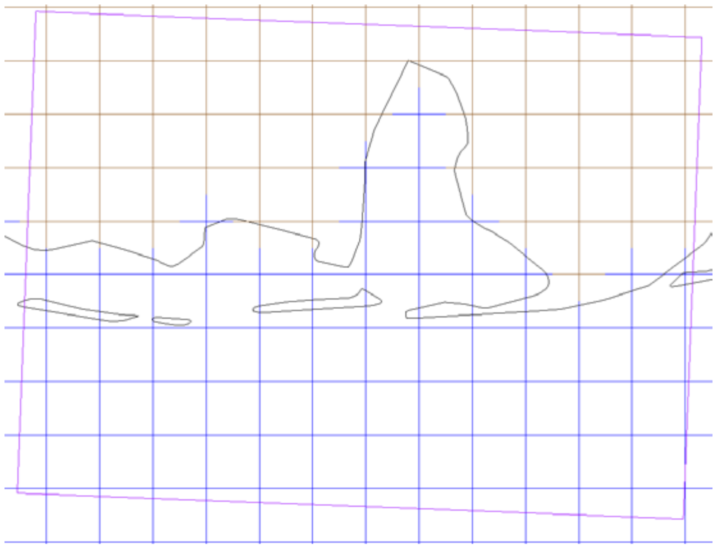
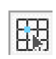


Figure 10 Gridframe for the STWAVE domain over the WAM cells.

5. Select the "Select Grid Cell" tool  and click on a few cells (in the WAM grid) that lie near the offshore boundary of the STWAVE grid. You can select multiple cells by holding down the "Shift" key. (See Figure 11)

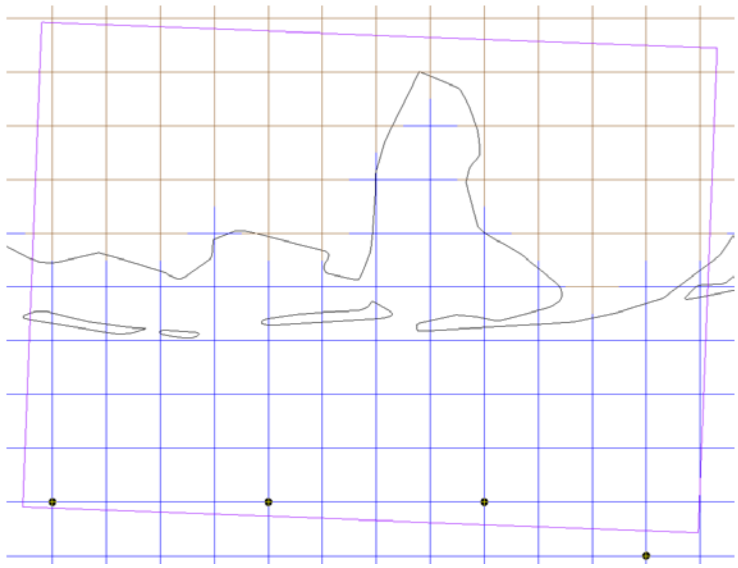


Figure 11 WAM cells selected along STWAVE grid boundary.

6. Select the "WAM | Assign Cell Attributes..." command to bring up the "Cell Attributes" dialog. Select the toggle box to define the cells as spectral sites and enter the name "site" in the edit field. SMS will name each site with this base name and a number. Click "OK" to exit the dialog. The display will refresh and the spectra site symbol will be drawn at each of the selected cells. This means that these cells are now spectra sites.
7. Make sure the cells are still selected (reselect if necessary), go back into the "Cell Attributes..." dialog and turn off the toggle. Click "OK" and the cells are no longer spectra sites.

This approach is straight forward, but if there are multiple STWAVE grids, or there are large domains, the process may be tedious. Another tool has been included to automatically define the spectral sites for an STWAVE grid.

9.3 Creating Spectral Sites

The boundary conditions for the grid has not yet been defined. If the boundary condition type is known, SMS can extract the best locations for spectral sites.
To create spectral sites along the STWAVE boundaries,

1. Select the STWAVE grid named 'MsAI'. The display will change to show this grid instead of the WAM grid.
2. Select menu item STWAVE | Model Control.

3. In the "STWAVE Model Control", select "Half Plane" for "STWAVE Plane Mode". In half plane mode the purpose of each edge of the domain is defined. The I = 1 edge is the only open edge. This edge needs at least one spectra.
4. Click OK to exit the "STWAVE Model Control" dialog.

Now that the STWAVE boundary locations have been defined, we will create the spectral sites.

1. Select the WAM grid named ‘WAM_KATRINA’ to make it active.
2. Right click on the grid and select "Create Spectral Sites..." from the drop down menu. The "WAM Spectral sites from STWAVE" dialog appears.
3. Toggle on the STWAVE grid named ‘MsAI’.
4. Under Spacing Options, select Space every 2 candidate points.
5. Click "OK". The spectral sites symbol will appear along the offshore boundaries of the STWAVE grid.

9.4 Running WAM and Viewing spectra at the spectral sites

In order to see the spectra data created by WAM,

1. Right click on the WAMKATRINA simulation and select "Export WAM Files". This will update the WAM simulation to include the spectral sites we just created.
2. Right click on the WAMKATRINA simulation again and select Launch WAM. This time the model wrapper includes a fourth component named "Print Spectra". Since we have spectral sites, WAM will create additional output files named "SpectraOut###" for each output interval. The "SpectraOut" files include the sea, swell and total spectra at each spectral site. After all three spectra at each site are stored, it stores the spectra at the next time value. The "PrintSpectra" utility converts the data files in these files from binary to ascii and organizes the spectra by spectral site. The utility saves the total spectra at a single spectral site for all the output times in a single file. This file can be used to create the boundary conditions for STWAVE.
3. Once WAM is finished running, click the "Exit" button to leave the model wrapper. SMS will read in the solution data for the grid as well as the spectra created at the spectral sites. You may get a message from SMS telling you that the spatial data sets have been updated because WAM overwrote the old solution files from the first run. Now you can view the spectra sites results.
4. Select one of the cells that is a spectral site with the "Select Grid Cell" tool .

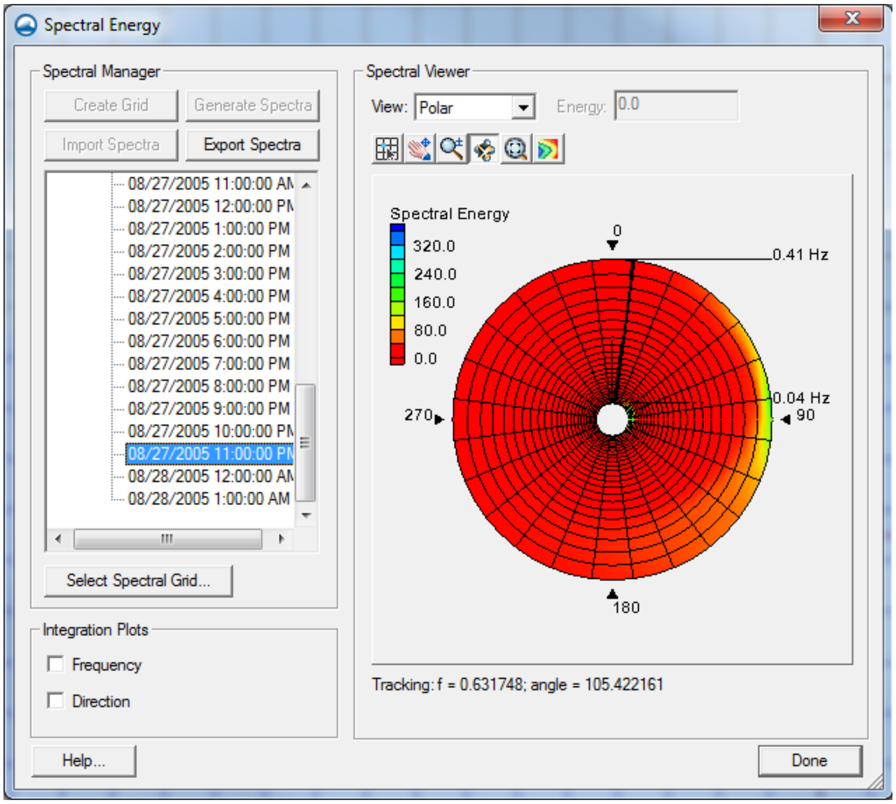


Figure 12 Spectral Energy dialog for spectral site.

5. Right click on the selected cell and select "Spectral Energy..." from the menu. The spectral energy dialog for that specific site will appear. Step through the time steps to see how the spectral energy at this site changes with time.

6. You can repeat these steps for each of the spectral sites. Figure 12 shows the spectral energy for the first (far right) spectral site for the date and time 08/27/2005 11:00:00 PM.

10 Conclusion

It is important to mention that for the purpose of this tutorial and because of the big 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 exercise. You may now keep looking around or close SMS