GNOME™

GENERAL NOAA OIL MODELING ENVIRONMENT

WORKBOOK

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

OFFICE OF RESPONSE AND RESTORATION

HAZARDOUS MATERIALS RESPONSE DIVISION

Contents

Introduction

This workbook contains example scenarios to help you learn to use **GNOME**, the General NOAA Oil Modeling Environment. GNOME was developed by the Hazardous Materials Response Division of **NOAA Office of Response and Restoration** (**OR&R**). Most users will want to use GNOME with its **Location Files**, which are files containing prepackaged tide and current data for a particular region. A mini-expert system in each Location File helps you translate environmental conditions into model parameters, making it easier to work with GNOME.

Both GNOME and its Location Files are available for free at the GNOME section of the NOAA OR&R Web site. If you haven't yet downloaded a copy of GNOME, use your browser to navigate to **http://response.restoration.noaa.gov/software/gnome/gnome.html,** and follow the instructions to download and install GNOME. To complete these examples, you will need to download GNOME and the Location File associated with a particular group of problems. The GNOME Location Files are available at **http://response.restoration.noaa.gov/software/gnome/locfiles.html**. If you want to complete the GIS Output Mode examples provided in this workbook, you will also need to download the ArcView extension file (gnome.avx) to view your GNOME trajectories in ArcView. The extension, and instructions for downloading it, are available at **http://response.restoration.noaa.gov/software/gnome/tools.html**.

This workbook assumes that you are somewhat familiar with GNOME's features and capabilities. If you are a first-time user of GNOME, you may want to start with the step-by-step example scenario described in Chapter 2 of the GNOME **User's Manual**. (The User's Manual is available in PDF format at **http://response.restoration.noaa.gov/software/gnome/gnome.html**.)

Some scenarios are designed to be modeled in GNOME's **Standard Mode**, and other examples should be completed in GNOME's **GIS Output Mode**. For each problem, you will be given the conditions (such as the date, the model and spill start time, the wind speed and direction, type of pollutant spilled, etc.) that exist for each example, then you will set up GNOME and answer the questions. Sometimes, you will be given hints or procedures to assist you in setting up the model. For each example, you'll also be given an answer to the problem.

Keep in mind that when you set a spill in GNOME, you can

(1) click *anywhere* within the water area of the map to set an approximate location of the spill. (In the Spill Information window that opens next, you can adjust the latitude and longitude settings to match the ones given in the example.) Or
(2) double-click the Spill Tool on the GNOME toolbar, then enter the details of your spill and its location.

As you work through the problems, you can get help in a number of ways:

Use GNOME's Online Help

1. Click a Help button.

- Most GNOME windows offer a **Help** or **More...** button you can click to get help on entering information into GNOME, or to get more information about a particular feature of GNOME.

- GNOME also provides references, and data relating to wind, river flow, and current patterns, to help you enter appropriate information into the model. In some GNOME windows, you will see buttons, such as **Finding Wind Data**, **Finding Flow Data**, and **How to Select a Current Pattern**. Click the appropriate button to get help with the weather and oceanographic conditions for your region of interest.

2. Use GNOME's Help menu.

- If you're using GNOME on a Macintosh, select **Topics...** from the **Help** menu to view an alphabetical listing of GNOME Help topics. Highlight a topic name, then click **Select** to view a discussion of that topic.

- If you're using Windows, select **Contents** from the **Help** menu to view the Help contents. Click any of the underlined topics to view the discussion of that topic.

Refer to the GNOME User's Manual

- Chapter 3 (**Working with GIS**) of the GNOME User's Manual describes the additional output options that GNOME offers GIS users.

- The manual's **Reference** chapter (Chapter 4) offers explanations of the main components of GNOME: Location Files, the Map Window, and the GNOME toolbar and menus.

- Chapter 5 offers **Troubleshooting** tips that can help you if you encounter a problem and are unsure how to solve it.

- The manual's **Glossary** provides explanations of terms you may encounter as you work in GNOME.

Take a Training Class

NOAA OR&R occasionally offers GNOME training classes at its facilities in Seattle. Two types of training are offered. A two-day course is provided to teach GNOME's Standard and GIS Output Modes. Trajectory modeling and GNOME's Diagnostic Mode are covered in a four-day course. For more information, contact NOAA OR&R at training@hazmat.noaa.gov or (206) 526-6317.

Email the GNOME Wizard

Email your question to the GNOME Wizard at gnomewizard@hazmat.noaa.gov.

Central Long Island Sound

For this set of problems, use the Central Long Island Sound Location File. This problem set will help you see how the phase of the tide, the effect of forecast wind, and the uncertainty of forecasts can all affect spills.

Standard Mode

Conditions:
Date: December 1, 1998
Model and Spill Start Time: 5:00 A.M. (0500)
Model duration: 2 days
Uncertainty: Not included, unless specified in a particular example.
Wind: No wind, unless specified in a particular example.
Pollutant type: Non-weathering, unless specified.

Use GNOME's Standard Mode to answer the following questions:

1. Tides are an important part of the circulation in Central Long Island Sound. To see how the phase of the tide (e.g. ebb, flood, slack before ebb, and slack before flood) affects a spill, place **four instantaneous spills** at 41° 13.71' N, 72° 44.78' W. Each one should start at a different time, as follows:

Spill a **0525** (5:25 A.M.) Maximum flood tidal current
Spill b **0832** (8:32 A.M.) Slack current before ebb tide
Spill c **1054** (10:54 A.M.) Maximum ebb tidal current
Spill d **1509** (3:09 P.M.) Slack current before flood tide

Note the farthest longitudes east and west that each spill reaches. Which spill moves the farthest east? The farthest west?

Hint: You may want to zoom in to the spill location before running the model. Spills at this location move primarily east-west. When the spills appear to stop moving and look more like "bees swarming", pause the model. You can move (but don't click!) the cursor to the point that appears to be the center of the spill and read the latitude and longitude in the lower left corner of the Map Window. Don't worry about matching the answers exactly.

Answer:

Spill	Farthest West	Farthest East
a	72° 47.71' W	72° 40.69' W
b	72° 45.77' W	72° 38.90' W
c	72° 47.18' W	72° 40.63' W
d	72° 49.37' W	72° 43.97' W

Spill b, set on the slack current before the ebb tide, moves the farthest east, while Spill d, set on the slack current before the flood tide, moves the farthest west. You can now see that knowing the timing of a spill relative to the tides (to within a few hours) can make a big difference in spill trajectories. (Winds can make a big difference to spill trajectories also! If the wind had been blowing onshore when these spills occurred, very different coastal areas would be threatened, even though the spills occurred in the same location.)

Note that the date chosen for this example is during a spring tide period, when the flood and ebb currents are greatest. During neap tide conditions, the differences would not be as great.

2. The effects of forecast wind and the uncertainty of forecasts are important to trajectory modelers. Using only **Spill b** from the first example, set a constant wind of **15 knots from the south** and include the **"Minimum Regret" (Uncertainty) solution** in your model run.

Is your "Minimum Regret" solution very different from your "Best Guess" solution?

Hint: You can remove the spills that you don't need by selecting them one at a time in the left section of the Map Window, then selecting Delete from the Item menu. To input the constant wind, double-click Constant Wind in the left section to bring up the Constant Wind box. To include the "Minimum Regret" solution, check the "Include the Minimum Regret solution" box in the left section to turn on the "Minimum Regret" splots.

Answer: The coastal areas that could be impacted by the oil spill in the "Minimum Regret" solution (the most conservative estimation) are almost three times greater than in the "Best Guess" solution. Responders need this information in order to balance the value of a resource with the possibility of it being oiled. For example, a nesting site for a rare bird species may need to be protected even if it is not in an area likely to be oiled, because the consequences of exposing the birds to oiling could be devastating.

Columbia River Estuary

Use the Columbia River Estuary Location File to work through these examples. In these problems, you will explore how the changing river flow alters the estuary's apparent tidal currents and an oil spill's trajectory, and how wind can move a spill in a different direction from the currents.

Standard Mode

Conditions:
Date: December 6, 1998
Model and Spill Start Time: 4:00 P.M. (1600)
Run duration: 1 day
Wind: No wind, unless specified in a particular example.
Pollutant type: Non-weathering.

Use GNOME's Standard Mode to answer these questions:

1. To see the effects of river flow on the tidal currents, use each of the three given Columbia River flow rates in the Location File with a wind speed of zero (0). Set a non-weathering spill of any amount at 46° 14.087' N, 123° 42.708' W (an interesting portion of the deeper channel).

How long does it take for some of the leading "best guess" (black) splots to leave the estuary?

> **Hint:** To find the time elapsed, stop the model using the Pause button, and then subtract the time shown on the run bar from the start time.
>
> **Answer:** The order from fastest to slowest is

High	7 hours
Medium	15 hours
Low	18 hours

> As you watch the slick move during each model run, the movement of the slick up-river during the flood tide will increase as the Columbia River flow decreases. When the river flow is low, the tides move the oil back and forth as the oil is moving out of the estuary. Under high river flow conditions, flood tides only slow the river flow, and there is no current reversal or reversal in the oil's direction of travel. This is because the river flow is greater than the tidal flood currents during a longer time period of the tidal flood cycle.

2. Rerun the fastest and slowest scenarios above with the addition of a 10-knot (kt) wind from the north. **What happens to the spill?**

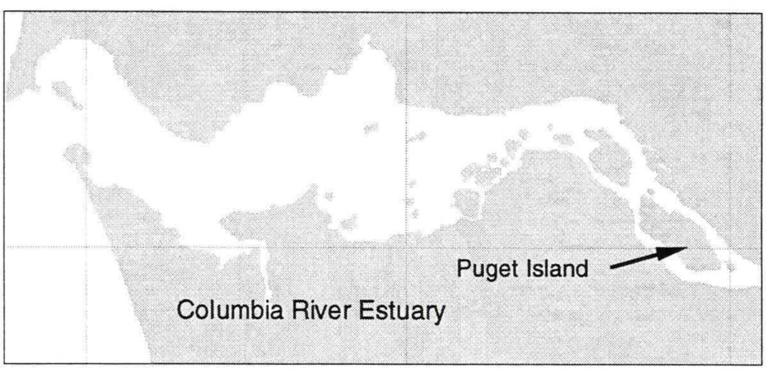
Answer: Even light winds can dramatically change the trajectory of a spill. In both the fastest and the slowest cases, a 10-kt wind from the north will cause most of the oil to beach on the southern shore of the estuary before leaving the estuary. This beaching happens because the wind both moves the oil directly (by pushing it) and generates surface waves that move the oil.

3. GNOME chooses between two different methods for estimating total river flow at Astoria, depending on the value you enter for the flow rates at Bonneville Dam and for the Willamette River. If both your values are small enough, the low flow method is used; otherwise, the high flow method is used (check the Technical Documentation section of the Columbia River Estuary **User's Guide** to learn more). To see the difference, set a spill at 46° 12.02' N, 123° 51.65' W. Run the spill using 200 kcfs for the Bonneville Dam flow rate and 90 kcfs for the Willamette River at Portland flow. Rerun the spill with 210 kcfs for the Bonneville Dam flow rate and 100 kcfs for the Willamette River at Portland flow, respectively.

Can you see a difference in how fast the spill moves down river?

Answer: Yes, when you increase river flow, you should be able to see a difference in how the oil moves, because a high river flow rate overwhelms the tidal currents. When the river flow is low, the tides move the oil back and forth as the oil is moving out of the estuary. Under high river flow conditions, flood tides only slow the river flow, and there is no current reversal or reversal in the oil's direction of travel. The first scenario (200 and 90 kcfs) leads to a total transport of 352 kcfs at Astoria. The second scenario (210 and 100 kcfs) leads to a substantially higher total transport of 506 kcfs. The large difference in oil movement that you saw when you ran the two scenarios shows that GNOME may not accurately model oil movement in the Columbia River Estuary near transitions between high and low flow conditions.

4.(a) Suppose there is a bird rookery on the southeastern portion of Puget Island.



The rookery extends from 46° 09.03'N, 123° 22.2' W to 46o 09.19' N, 123° 20.58' W. An oil spill occurs across the entire river at the right (eastern) edge of the map from a sunken boat. The river flow is low (125 kcfs) and you are concerned about immediate (within a few hours) impacts to the rookery.

Remember that the wind can be an important influence on oil trajectories. Experiment by changing the wind speed and direction to find the wind conditions that would keep all of the oil away from the rookery for the first hour of the spill.

From what direction must the wind blow to keep the rookery oil-free for the first hour? What is the minimum wind speed that would keep the rookery oil-free for that time?

Hint: Try zooming in to the area before you start. Select the Zoom In tool and use it to outline the new desired map area.

Hint: To set a line spill, click and drag the Spill Tool from the starting point to the end point of your spill.

(b) Suppose that you were responding to this spill, and the wind forecast was the same as your answer to part (a). **Would you anticipate any oil reaching the bird rookery?**

Hint: Try including the "Minimum Regret" solution to see if it makes a difference in the results.

Answers:
(a) A wind of 20 kts from the north should keep all splots off the bird rookery area.
(b) Though the "Best Guess" splots will probably not hit the bird rookery, the "Minimum Regret" splots will indicate more impacts to the rookery, showing you how important it is to consider the uncertainty solution when you want to understand the full range of possibilities. This is because forecasts are not likely to be perfect, and the "Minimum Regret" splots take into account how forecasts most commonly err. For more information, refer to the Uncertainty and "Minimum Regret" GNOME Help topics.

GIS Output Mode

Conditions:
Date: June 14, 1999
Model and Spill Start Time: 4:00 A.M. (0400)
Model duration: 2 days
Uncertainty: Not included, unless specified in a particular example.
Wind: As specified in each example.
Pollutant type: Diesel

Use GNOME's GIS Output Mode to answer these questions. (To change to GIS Output Mode, from the File menu, choose Preferences, click the Mode tab, then click GIS Output.)

1. A diesel spill occurs at approximately 0400 on Monday, June 14, 1999. The spill is estimated to be 1,000 barrels and located at 46° 15.11' N, 123° 40.81' W. The Columbia River is estimated to be running low, but exact numbers are not yet available. Examine how the spill trajectory changes as the constant wind varies between 0 knot (kt), 5 kt SW, 10 kt SW, and 15 kt SW.

Hint: To change the wind speed and direction (keeping all other Location File settings the same), double-click "Constant Wind" in the Summary List to the left of the Map Window. In the Constant Wind window, change the wind speed and direction as needed, then rerun the model.

Answer: With no wind, very little oil impacts either coastline. As the wind increases, the Washington coast is impacted by oil more quickly. Note that the winds in the area usually have a southerly component, so oil is more likely to come ashore in Washington than in Oregon.

2. The weather forecast is for winds from the SW at 15 kts. The U.S. Coast Guard would like printouts of the expected trajectory for today's overflights at 6:00 A.M. and 7:00 P.M., and their next morning overflight at 6:00 A.M. **Be sure to include the Minimum Regret solution in your trajectory products for the Coast Guard. Save your trajectories in GNOME Analyst (TAT) format, then use GNOME Analyst to print the oil concentration contours and uncertainty bound for these three times. NOTE:** In anticipation of Question 3, once you have run the 7:00 P.M. trajectory, save it in both **GNOME Analyst Splot Files** format (to use in this question) and in **NOAA Standard Splot Files** format on a **disk** (to use in Question 3).

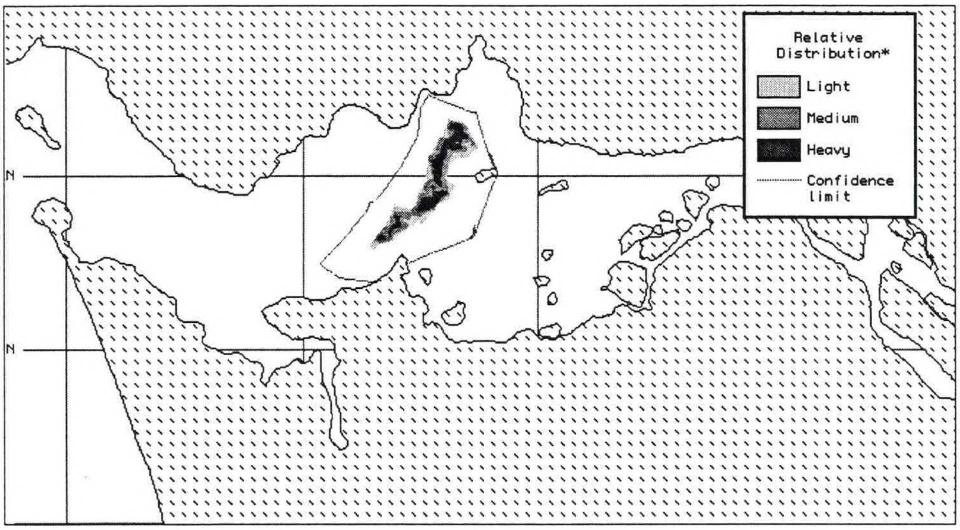
Hint: To print your trajectories, stop the model at the appropriate times by using the **Pause** control on the toolbar or the **Run Until...** item in the Model menu.

Hint: When you save your trajectories, you will create fewer files if you save them in the single output format, **GNOME Analyst Splot Files**, rather than the hourly output format, GNOME Analyst Splot File Series.

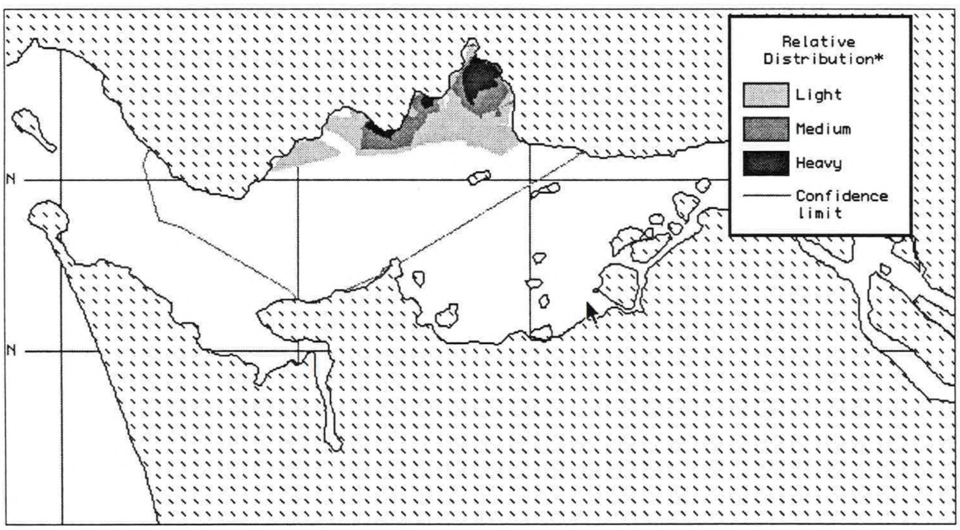
Procedure: After you have run each trajectory and saved it as GNOME Analyst Splot Files, open GNOME Analyst. You will need to open (1) a map file for the Columbia River Estuary (Columbia River Estuary.bna), (2) your Best Guess (Forecast) splot file, and (3) your Minimum Regret (Uncertainty) splot file. Print the resulting contours and boundaries.

Answer: Your GNOME Analyst trajectories should look something like these.

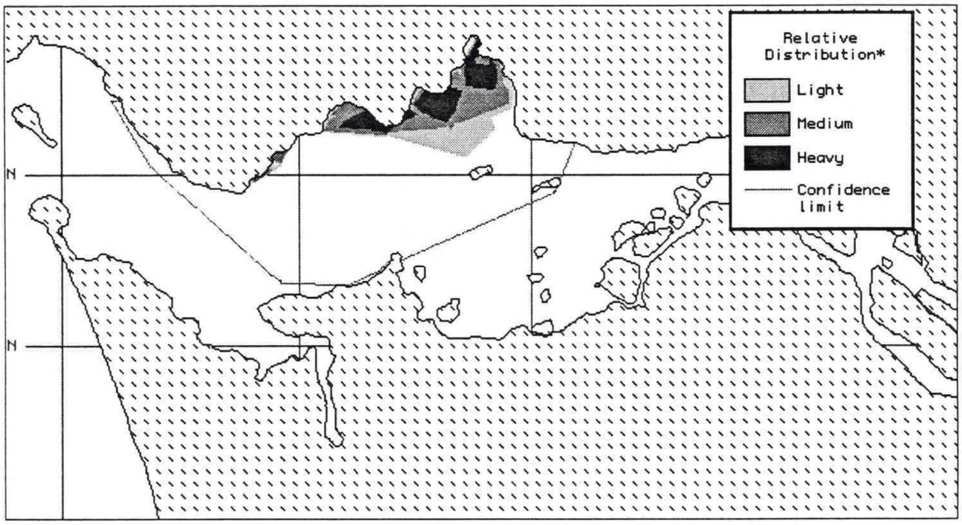
6/14/99 6:00 A.M. Trajectory



6/14/99 7:00 P.M. Trajectory



6/15/99 6:00 A.M. Trajectory



3. Members of the Biological Assessment Team would like the 7:00 P.M. forecast shown as oil concentration contours with an uncertainty boundary for their GIS system, **ArcView**. Use the NOAA Standard Splot Files (.ms*n*) that you saved on a disk in Question 2. A classroom PC is equipped with ArcView and the ArcView extension (gnome.avx), which will allow you to view your files.

Hint: See the Appendix to learn what GIS-compatible files each application produces.

Prince William Sound

For these problems, you will need to use the Prince William Sound Location File. These problems explore how wind can move an oil spill in a direction different from the currents, and how model and observation limitations can be overcome by considering both the "Best Guess" and the "Minimum Regret" (Uncertainty) solutions.

Note that the Location File for Prince William Sound includes an area larger than most of the Location Files, so the model may run rather slowly. If you don't want to wait for the model to run, you can review the results when it is finished by slowly dragging the carat under the Run Bar to see the hourly trajectory pictures, or you can create a movie of the results to view as needed.

Standard Mode

Two sets of example problems are provided below. Use GNOME's Standard Mode and the Prince William Sound Location File to complete them.

Example Set I

Conditions:
Date: February 24, 1999
Model and Spill Start Time: 12:00 noon (1200)
Run duration: 2 days
Uncertainty: Not included, unless specified in a particular example.
Wind: No wind, unless specified in a particular example.
Pollutant type: Non-weathering, unless specified.

Initial Report:
A crude oil spill of 1,000 barrels is reported to have occurred at 1200 February 24, 1999, located at 60° 25.44' N, 146° 49.62' W. Winds at this time are from the NW at 15 knots and are forecast to remain the same for the next 48 hours.

1. What is the difference in beach impacts between the "Best Guess" and Uncertainty model runs for 2 days?

> **Answer:** The "Best Guess" shows primarily the northwestern part of Hinchinbrook Island with oiling. The Uncertainty results show potential oiling of Montague Island and increased oiling of Hinchinbrook Island.

2. If this spill were gasoline in the same amount, what would your trajectory show?

> **Procedure:** Run a "Best Guess" gasoline spill, then examine the Mass Balance when the model is completed. (You may want to have the "Minimum Regret" (Uncertainty) solution turned off to make the model run faster.)

Answer: By the end of two days, almost all of the gasoline has evaporated (less than 5 splots are left). For the crude oil spill, only about a third of the splots have evaporated in two days. Much less shoreline is oiled because the gasoline isn't around long enough to travel very far.

3 . If the wind shifts to 15 knots from the north at 11:00 P.M. (2300) on the first day (Feb. 24), how will your trajectory change? (Go back to a non-weathering spill.)

Procedure: Be sure to choose Variable Winds in the "Choosing Wind Type" section. (If you have chosen a constant wind, you can change it to variable winds by double-clicking the name of your Location File, "Prince William Sound," in the Summary List. The Location File Welcome window will appear with all the settings you had previously chosen. You only have to enter information that you are changing, so in the "Choosing Wind Type" window, choose "Variable" from the pull-down menu.)

Answer: Now the beach impacts of the "Best Guess" trajectory affect both Hinchinbrook and Montague Islands. In problem 1, the "Best Guess" only impacted Hinchinbrook, while the Uncertainty trajectory showed that Montague could possibly be affected as well. In this problem, you can see how a small shift in the wind has a dramatic effect on the spill's trajectory.

Example Set II

This set of examples is designed to show you differences in the circulation patterns within Prince William Sound and how they affect oil trajectories. You will also explore how wind and different oil types affect spill trajectories and see how modeling the uncertainty in wind, currents and other model inputs leads to a more complete picture of potential oil impacts.

The following conditions hold for this example set:
Date: November 10, 1999
Model and Spill Start Time: 9:00 AM (0900)
Run duration: 1 day
Uncertainty: Not included, unless specified in a particular example.
Wind: No wind, unless specified in a particular example.
Pollutant type: Non-weathering, unless specified.

1 . Two spills, each 1000 bbl of Fuel Oil #6, have occurred in Prince William Sound at the following locations:

Spill #1: the north-central portion of the sound at 60° 40' N, 147° 0' W
Spill #2: between Green Island and Knight Island at 60° 20' N, 147° 32' W

How do the trajectories of these spills differ after 24 hours? What is the mass balance of each spill?

Hint: To quickly set the spill location, double-click the Spill Tool. In the Spill Information window that opens, you can enter the exact location of the spill.

Mass Balance	Spill #1 (bbl)	Spill #2 (bbl)
Floating		
Beached		
Evaporated		

Answer: The currents within the central sound are much weaker than in the western passages, so the northern spill spreads out more uniformly with some net movement to the north. The more southern spill spreads out in the direction of the current and travels much further. The mass balances for your trajectories should be similar to these results:

Mass Balance	Spill #1 (bbl)	Spill #2 (bbl)
Floating	837	777
Beached	0	52
Evaporated	163	171

2. Rerun the above spills with the following change: Add a 15 kt wind from the east.

How does the wind affect the trajectories? Note the changes in the mass balances.

Hint: To add the wind condition to your model, double-click "Wind" in the left section of the Map Window (the Summary List). Enter the speed and direction of the wind in the Constant Wind window that opens.

Mass Balance	Spill #1 (bbl)	Spill #2 (bbl)
Floating		
Beached		
Evaporated		

Answer: The wind makes the spills move in an easterly direction. Both spills have significantly more beach impacts with the wind blowing the oil onshore.

Mass Balance	Spill #1 (bbl)	Spill #2 (bbl)
Floating	599	117
Beached	238	712
Evaporated	163	171

3. Rerun the same spills with the following addition: Turn on the Minimum Regret (Uncertainty) solution (red splots).

How does this information change your forecast for potential beach impact areas?

Hint: To quickly turn on the Minimum Regret solution, click the box labeled "Include the Minimum Regret solution" in the Summary List.

Answer: Spill #1 could impact more beaches on Naked Island and other islands in the vicinity. Spill #2 shows impacts on more beaches of Knight Island, and now Evans Island and Latouche Island show some oiling and/or significant threat of oiling.

4. Rerun the same spills once more with the following change: Make both spills gasoline spills (keep the wind from the east at 15 kt).

Note the trajectories and the mass balances.

Hint: To change the pollutant type of a spill, double-click its description under "Spills" in the Summary List. (In this case, your two spills are described as "Fuel Oil #6: 1000 barrels.") In the Spill Information window that opens, choose gasoline from the Pollutant menu.

Mass Balance	**Spill #1 (bbl)**	**Spill #2 (bbl)**
Floating		
Beached		
Evaporated		

Answer: Lighter products evaporate more quickly than heavier products. These gasoline spills have few beach impacts because the product is evaporating so quickly.

Mass Balance	**Spill #1 (bbl)**	**Spill #2 (bbl)**
Floating	15	19
Beached	0	3
Evaporated	985	978

GIS Output Mode

Conditions:
Date: June 13, 1999
Model and Spill Start Time: 7:00 am (0700)
Run duration: 24 hours
Uncertainty: As specified in each example.
Wind: As specified in each example.
Pollutant type: Non-weathering.

Use GNOME's GIS Output to answer the following questions. (To change to GIS Output Mode, from the File menu, choose Preferences, click the Mode tab, then click GIS Output.)

1. You are asked to explore potential impacts from a spill at the mouth of Port Wells (let's say 60° 46.13' N, 148° 7.95' W). Oil spill trajectories change depending on which way the tide is moving when the oil is spilled. Even though the tidal exchange in Port Wells is relatively small, we still would like to examine effects for all possible tidal conditions (flood, ebb, slack before ebb, etc.). To do this, we can start the spill at one time and have it continue through one complete tidal cycle so that some oil is released at every possible tidal phase.

Have the spill start at 0700 and end at 2000. June 13, 1999 has some particularly strong spring tides to help the oil move around. Set the spill as 1000 barrels of non-weathering pollutant. (By using a non-weathering product, we won't lose splots as the oil evaporates or changes as it's exposed to the elements.) Run the model with no wind, then with a 20-knot wind up and down the channel (ESE and WNW). Be sure to run the model with the Minimum Regret solution for the no wind case, and compare it with the wind-influenced Best Guess solutions. **How do the shoreline impacts change with the wind? Do the Minimum Regret splots from the "no wind" case impact the shoreline in areas where the wind-influenced splots beach?**

> **Hint:** To set the spill to leak over time, in the Spill Information window, check the "Different End Release Time" box, then enter 2000 in the End Time item that appears below it.
>
> **Hint:** To change the wind speed and direction for the second and third scenarios, double-click "Constant Wind" in the Summary List to the left of the Map Window. In the Constant Wind window, change the wind speed and direction as needed.
>
> **Hint:** To quickly add or cancel the Minimum Regret solution, click the "Include the Minimum Regret solution" box under Model Settings in the Summary List.
>
> **Answer:** Without wind, the oil does not travel as far, nor does it impact as much shoreline as the wind-influenced spills. The Minimum Regret splots from the "no wind" case show beach impacts that occur only during the wind-influenced Best Guess trajectories. So, the uncertainty calculations for the wind are working! We see effects from other possible winds.

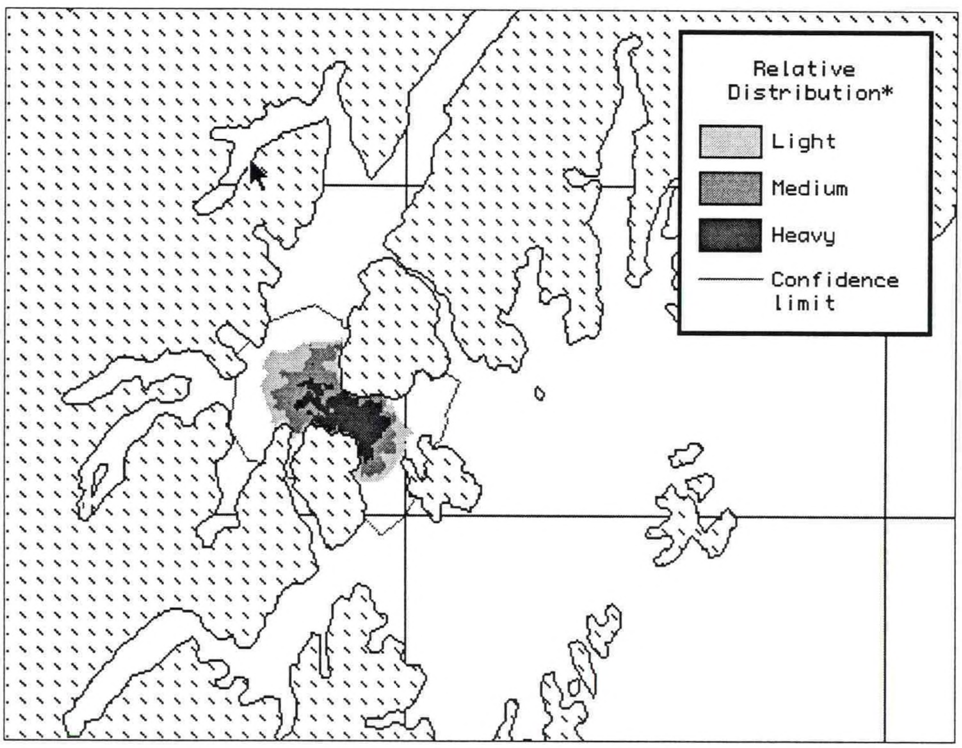
2. Create GIS-compatible output to display the 24-hour trajectory for each of the three scenarios. Run the model with the Minimum Regret solution turned on.

> **Procedure:** Run each trajectory, and save it in the single output format, **GNOME Analyst Splot Files**. Then, in GNOME Analyst, open the map file for Prince William Sound (Prince William Sound.bna), and for each scenario, open your Best Guess (Forecast) splot file and your Minimum Regret (Uncertainty) splot file. (Compare your contour concentrations and boundaries with the ones shown in the Answer below.)

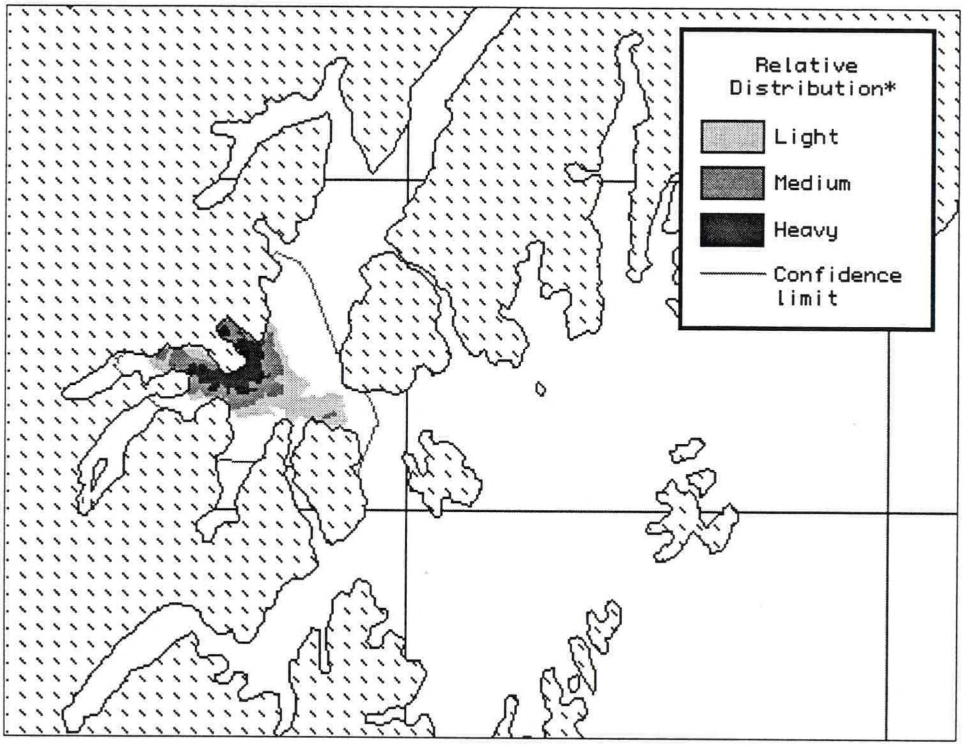
Next, save each of your GNOME Analyst results on a disk as **NOAA Standard Trajectory Files** (.ms*n*). (To learn more about the GIS-compatible files that GNOME and GNOME Analyst produce, see the Appendix.) Take your disk to the classroom PC that is equipped with ArcView and the ArcView extension (gnome.avx). You can then view and use these files in the GIS program.

> **Answer:** Your contour concentrations in GNOME Analyst should look something like these.

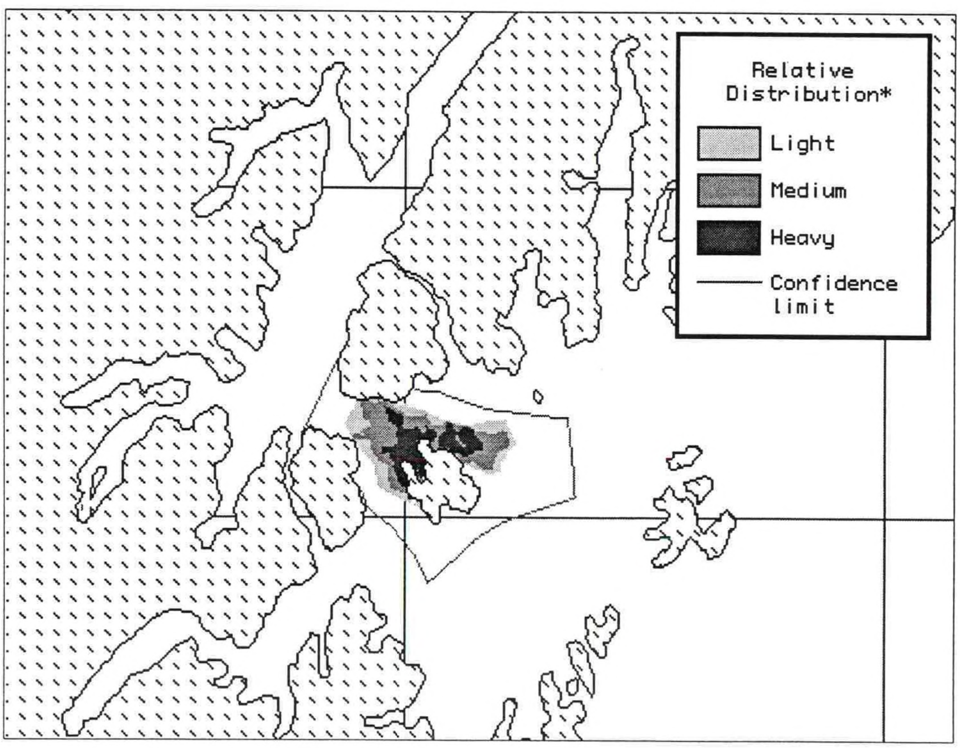
Oil Concentrations with No Wind



Oil Concentrations with 20-knot Wind from ESE



Oil Concentrations with 20-knot Wind from WNW



San Diego Bay

For this set of problems, use the San Diego Bay Location File. This problem set will help you see how spills can be affected by (1) the phase of the tide, (2) the forecast wind, (3) the type of pollutant, and (4) the uncertainty of forecasts.

Standard Mode

Conditions:
Date: January 19, 2000.
Model and Spill Start Time: As specified in each example.
Model duration: 1 day, unless specified in a particular example.
Uncertainty: Not included, unless specified in a particular example.
Wind: No wind, unless specified in a particular example.
Pollutant type: Non-weathering, unless specified in a particular example.
Spill size: 1000 barrels (bbls).
Spill: (Example 1-3) Linear source extending from 117° 13.55' W to 117° 16.5' W along 32° 39.5' N.
(Example 4) Point source in the center of San Diego Bay.

Use GNOME's Standard Mode to answer the following questions:

1. Tides are an important part of the circulation in and near San Diego Bay. To see how the tides affect a spill's trajectory, we will start the spill at different times in the tidal cycle. Run the spill in GNOME twice, once before the ebb tide (Start Time = 0740) and once before the flood tide (Start Time = 1500).

What is the difference in beach impacts (amount and areas) between the two spills?

> **Hints:** To quickly set a linear spill at a particular location, click and drag the Spill Tool from the *any* starting point to *any* end point on the water. In the Spill Information window that opens, you can then enter the exact location of the starting point and end point of the spill.
>
> When you change the start time of the spill, you will want to change both the *spill* start time and the *model* start time. To do this, double-click the description of the spill ("Non-Weathering: 1000 barrels") under Spills in the Summary List (the left section of the Map Window). In the Spill Information window, change the Release Start Time to 1500. GNOME will then prompt you to change the model start time to match the spill start time. Click Change.
>
> **Answer:** When the spill starts just before the flood tide, the entrance channel to San Diego Bay receives heavy beach impacts. When the spill starts just before the ebb tide, the oil drifts southward, away from the mouth of San Diego Bay. When the tide shifts back to flood, much less oil moves into the bay.

2. Wind both moves the oil along the water's surface and drives currents. Rerun the spill that started at 1500 with the addition of a 15 knot (kt) wind from the NW.

How does the oil's trajectory change from the previous example?

Hint: To add wind to your model, double-click Wind in the Summary List, then enter the wind speed and direction in the Constant or Variable Wind window.

Answer: Now very little oil impacts the entrance to San Diego Bay, and then only on the eastern side. Most of the oil now beaches south of 32° 38' N.

3. Different types of oil weather differently. In the previous examples you were using an imaginary type of oil that did not change with time. Now, rerun the spill from example #2 with 1,000 bbls of medium crude and then with the same amount of gasoline. You can record your results from the mass balance in the table below.

	Medium Crude (bbls)	**Gasoline (bbls)**
Released	1000	1000
Floating		
Beached		
Evaporated		
Off map		

Answer: Heavier oils remain in the environment longer than lighter refined products.

	Medium Crude (bbls)	**Gasoline (bbls)**
Released	1000	1000
Floating	58	0
Beached	536	20
Evaporated	211	971
Off map	195	9

4. Forecasts of environmental parameters are inherently uncertain. For example, wind and weather forecasts can be "off" in the speed, direction, or timing of winds. GNOME supports a "Minimum Regret" solution in addition to the "Best Guess" solution that you have been running. The "Minimum Regret" solution takes into account our uncertainty in wind, horizontal mixing, and currents.

Set a point source spill of non-weathering pollutant in the center of San Diego Bay. Set a start time of 0720 and a model duration of 2 hours. Run the model without winds and then with a 25 kt wind from each of the cardinal directions (N, S, E and W).

Zoom in to your spill area and briefly discuss the difference between the "Best Guess" (black) and "Minimum Regret" (red) trajectories. Why do you think this type of information would be useful?

Hint: To remove the old linear spill, select its description ("Non-Weathering: 1000 barrels") in the Summary List. Under the GNOME Item menu, select Delete. Then, use the Spill Tool to set a point source spill in the center of the bay.

To change the model duration, double-click "Duration: 24 hours" under Model Settings in the Summary List. In the Model Settings window, change the Model Run Duration to 2 hours. In this window, you can also include the Minimum Regret (Uncertainty) solution.

Answer: The "Minimum Regret" solution always covers a bigger area than the "Best Guess" solution. This indicates to responders and planners that they must consider oil impacts to be a possibility over a larger area than just the Best Guess of the solution.

Santa Barbara Channel

Use the Santa Barbara Channel Location File to work through these examples. This Location File uses six current patterns to represent the most common combinations of northern and southern currents in the Santa Barbara Channel. This set of problems will help you identify the current patterns that the Location File depicts, will show you how the choice of current pattern affects the spill trajectory, and will help you investigate the effect of wind on oil spill movement.

Standard Mode

Conditions:
Run duration: 24 hours or less.
Wind: No wind, unless specified in a particular example.
Pollutant type: Non-weathering.

Use GNOME's Standard Mode to answer the following questions:

1. Make a linear spill extending across the channel (in a north-south direction) near the channel's east-west center.

How does your choice of current pattern affect the spill trajectory in the first 24 hours? (Pay particular attention to the difference between the Cyclonic and Milling patterns.)

> **Hint:** To set a line spill, click and drag the spill tool from the starting point to the endpoint of your spill.
>
> **Hint:** To change the current pattern, but keep all other Location File settings the same, double-click the name of your Location File, "Santa Barbara Channel," in the left section of the Map Window (the Summary List). The Location File Welcome window will appear with all the settings you had previously chosen. You only have to enter information that you are changing. You can then rerun the model with the same spill, under the same conditions, but with a new current pattern.
>
> **Answer:** The direction and speed of currents along the northern and southern boundaries change with each current pattern, while few changes take place in the middle of the channel. This is because Santa Barbara Channel is wide enough that the northern and southern currents can act independently. The six current patterns in the Location File represent the most common combinations of northern and southern currents.

2. To investigate the effects of wind on oil spill movement, choose the Flood West pattern and set a spill at 34° 25.54'N, 120° 05.01'W. Gradually increase the wind from the south (by 10 knots each time) and examine where the oil impacts the beach.

How does changing the wind speed change the distance the spill travels before beaching?

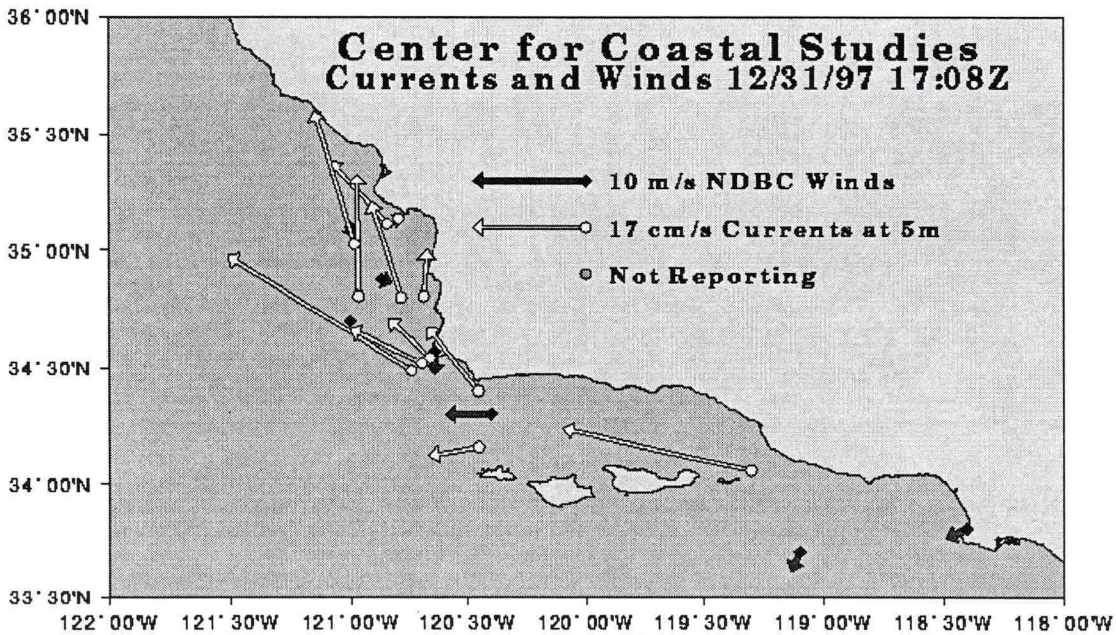
Hint: To quickly set a spill at a particular location, simply double-click the Spill Tool on the GNOME toolbar. You can then enter the *exact* latitude and longitude of the spill in the Spill Information window. (This method is much easier than moving your mouse around the map and watching its location in the lower left corner of the window!)

Answer: With no wind, the spill follows the coast, but does not impact the coastline. As the wind is increased, the impacts occur sooner after the spill occurs and closer to the spill site.

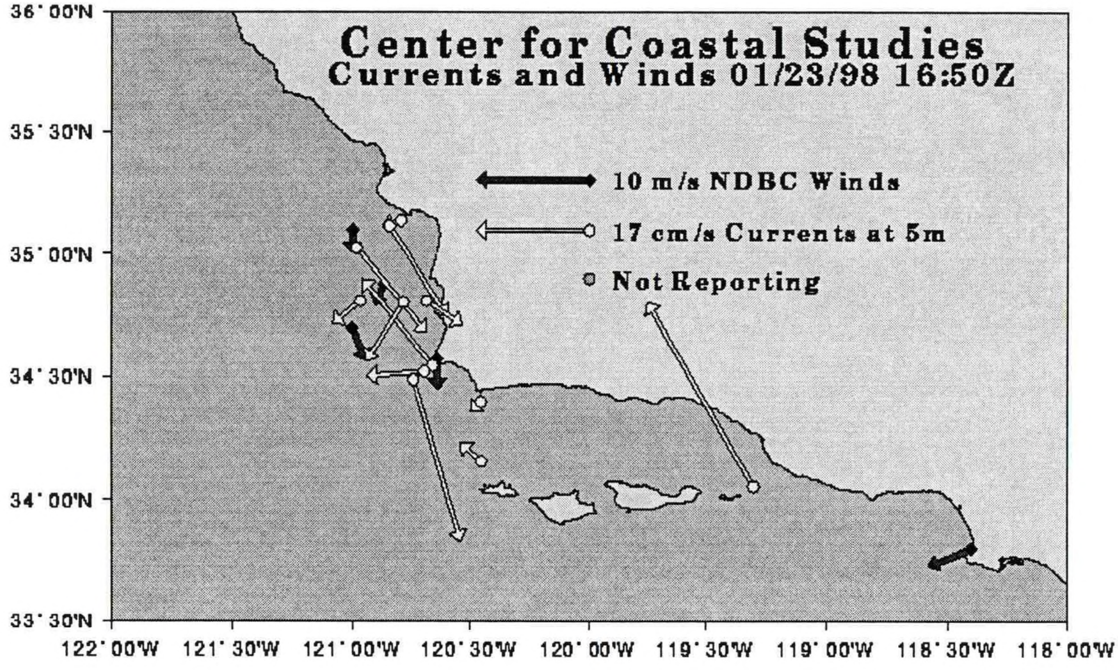
3. Below are some pictures of Santa Barbara Channel winds and currents (courtesy of the Center for Coastal Studies at the University of California at San Diego, and the Dept. of the Interior Minerals Management Service). **Use the pictures of the six current patterns in the Santa Barbara Channel Location File and the information in the "Selecting a Current Pattern" Help topic in the Location File to help you identify the current pattern in each picture.** You don't have to do all six examples in order to get an idea of how to do this task. As in real spill conditions, you may not have enough information to make an exact match, or the real conditions may vary from the classic definitions. In particular, the winds can change quickly, while the circulation and currents adjust to changes much more slowly.

Hint: The arrows on the pictures point in the direction that the wind or current is flowing. **The longer the arrow, the faster the flow.** To determine upwelling or downwelling conditions, orient the paper so that you are looking down the wind arrow from tail to point. The water flow due to Ekman transport (caused by the wind and the earth's rotation) will be to your (and the arrow's) right. Water moving toward the coast will cause downwelling; water moving away from the coast will cause upwelling.

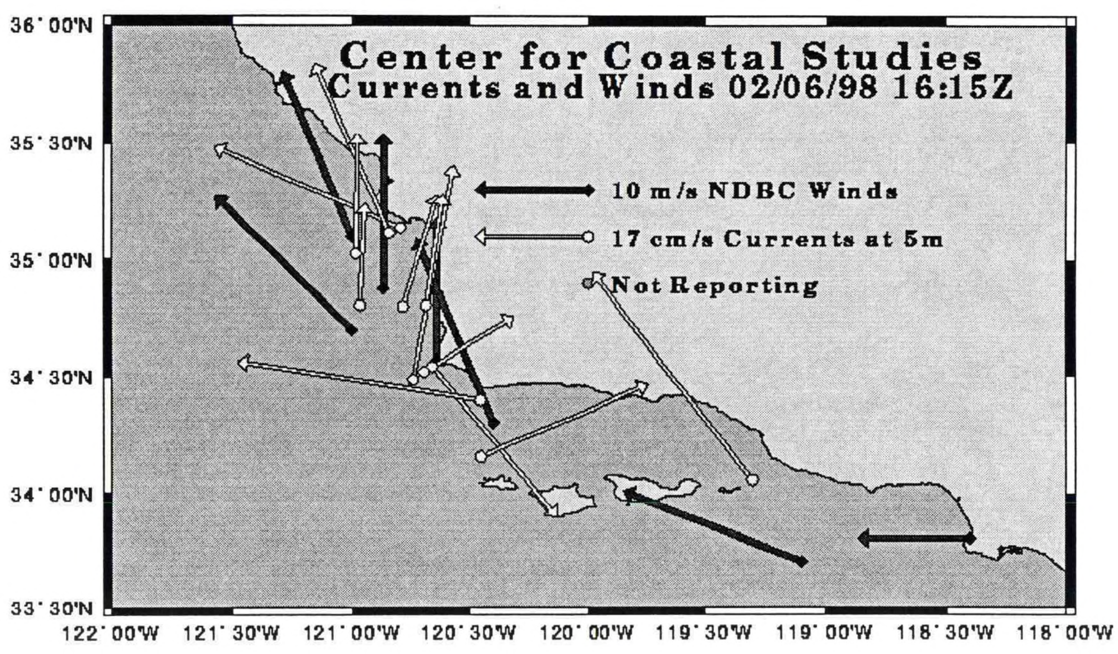
a. December 31, 1997



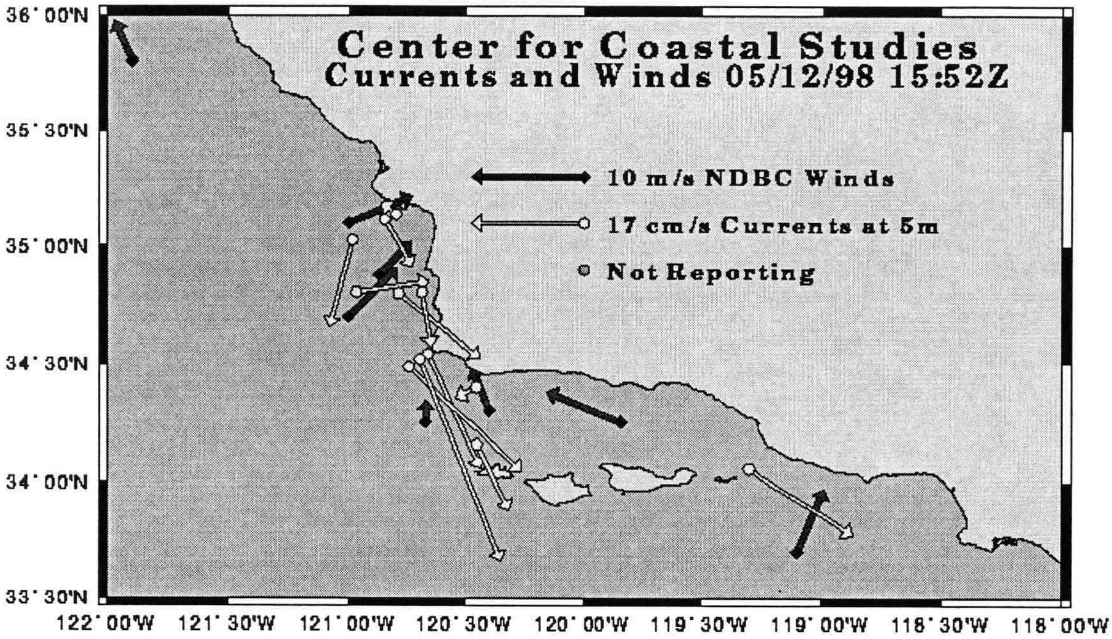
b. January 23, 1998



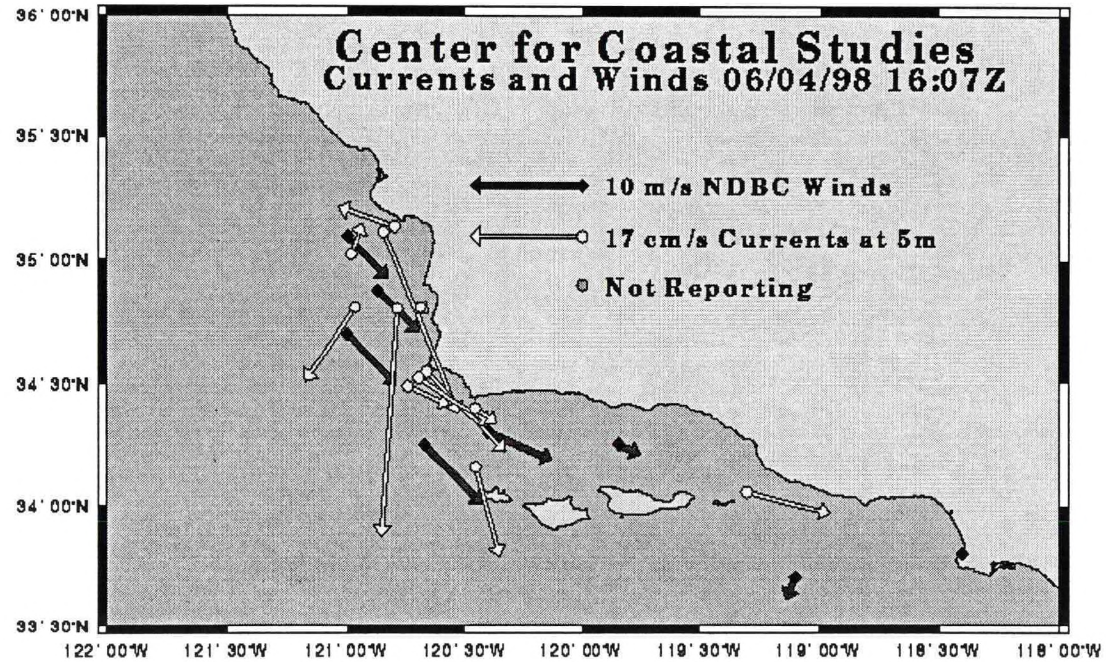
c. February 6, 1998



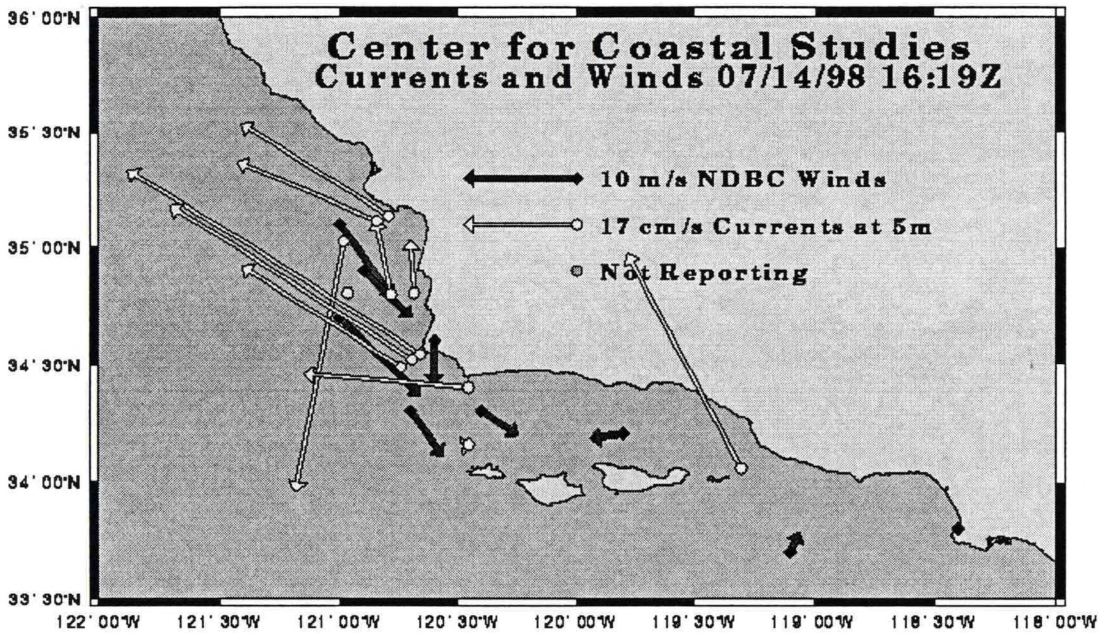
d. **May 12, 1998**



e. **June 4, 1998**



f. July 14, 1998



Answer:

a. December 31, 1997 - Flood West
Currents in the channel are directed along the coast toward the west. In this example, the wind stress is light and downwelling favorable, while the classic FLOOD WEST conditions have stronger winds.

b. January 23, 1998 - Milling
Although the flow is nominally all in the same direction, the difference between the **strength** of the currents at the eastern and western entrances is striking. Flow through the eastern entrance is inward; the currents in the western entrance are of similar small magnitude, however, they are in different directions. This could be due to small eddies, which would fit the MILLING definition. Also, the winds are weak and upwelling favorable. Another possibility is FLOOD WEST, although the coastal flow to the west of the channel appears too disorganized. You may want to look at the pictures leading up to these conditions to make a more informed decision.

c. February 6, 1998 - Cyclonic
The currents in the channel are all strong, with the flow inward at the eastern entrance, and in different directions between the two stations at the western entrance. This matches well with the CYCLONIC circulation pattern. The winds, however, are strong and downwelling favorable.

d. May 12, 1998 - Upwelling
The southern channel currents are eastward and stronger than the northern westward circulation. This matches the UPWELLING current pattern. The winds, however, are weak to moderate and downwelling favorable.

e. June 4, 1998 - Flood East
The water flow is nominally inward to the channel at the western entrance, and outward at the eastern entrance. This indicates the FLOOD EAST current pattern. Winds are strong and upwelling favorable, which matches the classic definition.

f. July 14, 1998 - Relaxation
The westward current in the northern portion of the channel is much greater than the eastward current that is barely detectable in the southern portion of the channel. The winds are moderate and upwelling favorable near the western entrance, which matches the classic definition.

Tampa Bay

Use the Tampa Bay Location File to work through these examples. In these problems, you will explore how wind, the changing tides, and different spill products can all affect a spill trajectory. You will also see how model and observation limitations can be overcome by considering both the "Best Guess" and the "Minimum Regret" (Uncertainty) solutions.

Standard Mode

Conditions:
Wind: Constant wind at 0 knot (kt), unless otherwise specified in a particular example.
Spill size: 1000 gallons.
Pollutant type: Non-weathering, unless specified.

Use GNOME's Standard Mode to answer these questions:

1. To see how changing winds affect an oil slick's trajectory, set up the model for a spill to occur on December 15, 1999 at 2100 located at 27° 34' N, 82° 53' W. Run the model for 6 hours and watch how the spill moves. Next, add a 20 knot (kt) wind from the SW and rerun the model.

What is the difference between the oil slick trajectory with and without the wind?

> **Hint:** To easily set a spill at a particular location, simply double-click the Spill Tool on the GNOME toolbar. You can then enter the *exact* latitude and longitude of the spill in the Spill Information window. (This method is much easier than moving your mouse around the map and watching its location in the lower left corner of the window!)
>
> To add wind to your model, double-click **Wind** in the left section of the Map Window (the Summary List), then change the wind speed and direction in the Constant Wind window.
>
> **Answer:** Offshore of Tampa Bay, the north-south component of the wind sets up a current running north or south. The wind also moves the oil on the surface of the water. As a result, the slick does not move very much without wind, and begins to move more as the wind increases.

2. To see how the changing monthly (spring to neap) and daily tides can affect the movement of a spill, change the spill location to the mouth of Tampa Bay at 27° 34.81' N, 82° 40.34' W. Change the model duration to 24 hours to see more of the tidal transport. Start the spill and see how far the spill moves in 24 hours.

> **Hint:** To move a spill, simply double-click the description of the spill in the Spills section of the Summary List. (In this case, the spill description is "Non-Weathering: 1000 gallons".) In the Spill Information window, change the position data to that shown above.

To change the model duration, double-click the item "Duration: 6 hours" in the Summary List. In the Model Settings window, change the Run Duration to 24 hours.

Next, change the start date and time to December 22, 1999 at 0030 and rerun the model for 24 hours.

Hint: You will need to change the start date and time for both the *model* and the *spill*. You can make these changes from the Summary List.

How did the spill trajectory of the second spill compare with the first? Note the differences in the tidal currents in the information below:

Date	Time	Tidal Current
12/15/99	2058	slack before ebb
12/15/99	2347	0.7 kt ebb
12/16/99	0252	slack before flood
12/16/99	0536	0.6 kt flood
12/22/99	0029	slack before ebb
12/22/99	0417	2.7 kt ebb
12/22/99	0835	slack before flood
12/22/99	1104	2.0 kt flood

Answer: The first spill starts during neap tides, when the tidal exchange is minimal, whereas the second spill starts during spring tides, when the tidal currents are maximal. The stronger the tidal currents, the farther the oil slick will travel and spread.

3. To see how uncertainty in model input (such as the uncertainty in weather forecasts) is modeled in GNOME, you will create a new spill with same model start time as the last spill on December 22, 1999. Change the model duration to 12 hours, and the spill location to 27° 46' 0.3" N and 82° 32' 22.2" W, and include the Minimum Regret solution. Run the three cases below and compare how the extent and amount of beached pollutant changes as the wind increases.

Case 1: 0 kt wind
Case 2: 5 kt wind from S
Case 3: 20 kt wind from S

Answer: As the wind increases, larger amounts of oil beach on the shorelines. Although the overall length of impacted shoreline is less with increased wind, the shoreline that is oiled has a higher density of oil.

	Wind	Amount Beached (%)
Case 1	0 kt wind	< 5
Case 2	5 kt wind from S	15 – 25
Case 3	20 kt wind from S	> 30

Note that the Minimum Regret solution (red splots) indicates how the beach impacts and oil location could change with different inputs (e.g., the weather forecast was not correct). This allows people using GNOME to alert decision-makers of potential impacts beyond the "Best Guess" of the spill location.

4. Rerun the last scenario (20 kt wind from S) twice more with new spill products: **gasoline** and **medium crude oil**.

How does the extent of the oil slick and the mass balance change with each product?

Hint: To change the pollutant type, double-click the description of the spill ("Non-Weathering: 1000 gallons") in the Summary List.

Answer: The extent of the oil slick does not change from one product to another, but the mass balance does change dramatically. Gasoline is a light, refined product that evaporates quickly. Medium crude is a much heavier product that persists much longer. Your answers may differ slightly from the ones shown below:

	Gasoline	**Medium Crude**
floating (%)	2	29
beached (%)	7	58
evaporated (%)	91	13

Appendix

The following table shows the GIS-compatible files that are produced by GNOME and GNOME Analyst. GNOME produces .ms6 and .ms7 files when the uncertainty solution is included. GNOME Analyst outputs files .ms1 through .ms7 in all instances, regardless of whether the files contain data.

Files	GNOME		GNOME Analyst
	Best Guess	Best Guess and Uncertainty	
.ms1			X[1]
.ms2			X[1]
.ms3	X	X	X
.ms4	X	X	X[2]
.ms5	X	X	X[2]
.ms6		X	X[3]
.ms7		X	X[3]

[1] Empty files if there are no contours.
[2] Empty files if there are no forecast splots.
[3] Empty files if there are no uncertainty splots.