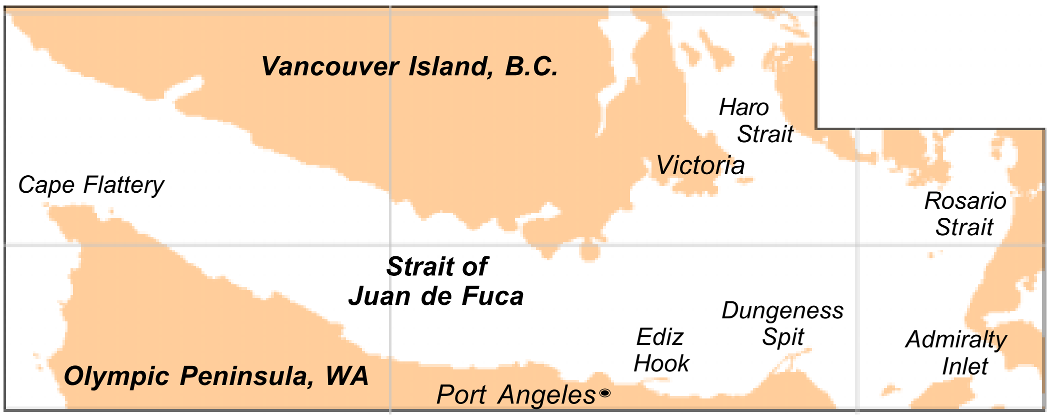
User's Guide

Welcome to the Location File for the Strait of Juan de Fuca. The Strait of Juan de Fuca is located in western Washington, along the border between Canada and the United States.



NOAA has created Location Files for different U.S. coastal regions to help you use the General NOAA Oil Modeling Environment, GNOME. In addition, on a case-by-case basis, NOAA develops international Location Files when working with specific partners. Each Location File contains information about local oceanographic conditions that GNOME uses to model oil spills in the area covered by that Location File. Each Location File also contains references (both print publications and Internet sites) to help you learn more about the location you are simulating.

As you work with the Location File for the Strait of Juan de Fuca, GNOME will prompt you to:

1. Choose the model settings (start date and time, and run duration).
2. Select the conditions at the entrance to the Strait.
3. Input the wind conditions.

GNOME will guide you through each of these choices. Each window has a button that leads you to helpful information and the general Help topic list. Click the Help button anytime you need help setting up the model. For example, you can choose whether or not to simulate a reversal of the surface flow at the entrance to the Strait. To get more information about this surface reversal, click the button More information about current reversals in the Set Strait Entrance Conditions window, or check the More information about current reversals Help topic. Similarly, when you need to input the wind conditions in GNOME, you can click the Finding Wind Data button to see a list of web sites that publish wind data for this region.

More information about GNOME and Location Files is available at http://response.restoration.noaa.gov/software/gnome/gnome.html .

Technical Documentation

Background

The Strait of Juan de Fuca is a glacially carved fjord lying between Washington State and Vancouver Island, British Columbia. The western entrance to Juan de Fuca is about 200 m deep. Near Victoria, the shelf is about 60 m deep and extends southward to separate the Strait into eastern and western sections. The eastern Strait separates about 135 km east of the mouth into a northern portion and a southern portion. The northern portion goes through the San Juan Archipelago (via Rosario Strait, Haro Strait and San Juan Channel) into the Strait of Georgia. The southern portion enters Puget Sound through Admiralty Inlet. The Strait of Juan de Fuca is a major transportation lane for Canadian and U.S. commercial and recreational ships and boats. There are oil refineries in Padilla Bay (off of Rosario Strait) and the Strait of Georgia.

Freshwater sources and estuarine circulation

The waters of the Strait of Juan de Fuca are partially mixed and weakly stratified. The primary freshwater source (approximately 75%) is the Fraser River in British Columbia (Herlinveaux and Tullly, 1961). The Fraser river flow has a strong seasonal cycle, with a maximum flow rate in early June at the peak of the high altitude snowmelt. The remaining fresh water enters the Strait through Puget Sound (Washington rivers), along the Olympic Peninsula, and along Vancouver Island. Rivers on Vancouver Island are a freshwater source an order of magnitude smaller than the Fraser River, with a peak in the winter during heavy rains (Masson and Cummins, 1999).

Vigorous mixing occurs at entrances/exits to the Strait--in Rosario Strait, Boundary Pass (linking the Straits of Georgia and Juan de Fuca) and Admiralty Inlet (connecting the Strait of Juan de Fuca with Puget Sound). This vigorous mixing, caused primarily by high currents flowing over sills, serves to mix salty and fresh water, decreasing overall salinity gradients of the Strait of Juan de Fuca waters.

Tides

Tides account for 83%-86% of the current variability in the Strait of Juan de Fuca (Holbrook et al., 1980b). Tidal currents are superimposed on a mean estuarine circulation with fresher, warmer water exiting the Strait overlying cooler, more saline water flowing into the Strait. Tidal currents become more complicated in the eastern part of the Strait, where there can be significant asymmetries between flood and ebb tides (Ebbesmeyer et. al., 1991; Frisch and Holbrook, 1980). There are numerous eddies in the eastern Strait of Juan de Fuca.

Winds, storms and surface current reversals at the entrance to the Strait

Local winds appear to play an insignificant role in surface currents in the Strait of Juan de Fuca. On the other hand, **coastal winds** are highly correlated with pulses of relatively warm, fresh water that enter the Strait during offshore storms and southwesterly winds (Hickey et al., 1991; Holbrook et al., 1980a; Holbrook et al., 1980b). These pulses occur most often in winter, typically at a rate of 2-3 times a month and lasting 2-7 days (Holbrook and Halpern, 1982; Holbrook et al., 1980a; Holbrook et al., 1980b). These pulses can be sufficiently strong to overcome the mean estuarine currents and cause surface currents in the Strait to reverse direction as far inland as Dungeness Spit (Ebbesmeyer at al., 1990; Frisch et al., 1981; Holbrook et al., 1980b). Occasionally, a storm will occur in the summer and reverse currents as well (Frisch et al., 1981; Hickey et al., 1991; Holbrook et al., 1980b).

Typical surface currents in the western Strait are 20-40 cm/s, with little variability in the summer and high variability in the winter. Sometimes, wintertime surface currents in the western Strait are 30 cm/s *inbound*. The region where mean, outgoing estuarine currents meet incoming, storm-induced currents can have convergence zones and strong currents that flow across the Strait (e.g. Hodgins, 1994). This has important implications for any surface pollutants, which can be pushed on shore from this convergence of opposing surface currents.

Current Patterns

The Strait of Juan de Fuca Location File contains five current patterns: a tidal pattern, a surface current reversal pattern at the western entrance to the Strait, a pattern for the local circulation in the Port Angeles area, and one pattern each for flood and ebb tide induced eddies. All current patterns were created with the NOAA Current Analysis for Trajectory Simulation (CATS) hydrodynamic application.

Tidal Currents

The tidal current pattern is scaled to the tidal predictions 7.6 miles SSE of Discovery Island, in the eastern Strait of Juan de Fuca (48¡ 18 N, 123¡ 10 W). The tidal currents at the Discovery Island station include mean estuarine circulation.

Surface Current Reversal

The surface current reversals at the entrance to the Strait of Juan de Fuca are represented by a current pattern that is scaled in the middle of the western entrance (48¡ 27 N, 124¡ 35 W). This pattern is then scaled according to the user-selected entrance conditions. The user's velocity choices include the following:

Reversal Condition	Velocity (m/s)
normal	0.0
mild	0.1
moderate	0.35
strong	0.5

This scaling was estimated from the data presented in Hickey et al., 1991, Holbrook et al., 1980a, and Holbrook et al., 1980b.

Port Angeles Coastal Flow

A particular area of concern in this Location File is Port Angeles. In addition to regularly scheduled traffic in the port, tankers may pull into the port while waiting for berths at the refineries in the Anacortes and Bellingham areas. Tidal eddies spin off the tips of both Dungeness Spit and Ediz Hook. Residual tidal currents between Port Angeles and Dungeness Spit result in a mean eastward surface current near the coast, with a convergence zone near the northern end of Dungeness Spit. (Note that Dungeness Spit is also the location of a National Wildlife Refuge).

Different studies have led to different conclusions regarding mean surface currents in Port Angeles Harbor. Ebbesmeyer et. al. (1979) concluded that the mean circulation within the harbor itself could not be determined. The complexity of the region, coupled with the potential high spill-risk, have spawned many studies. Surface currents have been analyzed from drift cards, pulp mill effluents, the 1985/86 T/V Arco spill, and a hydraulic model (Ebbesmeyer et. al., 1979; Ebbesmeyer et. al., 1981; U. S. Coast Guard, 1986).

Surface currents in the Port Angeles eddy pattern are scaled to 0.7 m/s just northeast of Dungeness Spit (48¡ 10 n, 123¡ 11 W). The spatial pattern of the Port Angeles eddies are modeled after current patterns presented in Ebbesmeyer et. al., 1979, Ebbesmeyer et. al., 1981, and the 1986 Port Angeles Arco Anchorage spill (U. S. Coast Guard, 1986). The scaling is based on the experimental runs of the Location File and the time periods for oil transport in the Port Angeles Arco Anchorage spill (U. S. Coast Guard, 1986).

Eastern Strait Eddies

The eastern Strait of Juan de Fuca has many eddies. These eddies can significantly alter predictions of surface currents (Ebbesmeyer et. al., 1991; C. Ebbesmeyer, personal communication; Mitsuhiro Kuwase, personal communication). The GNOME Location File for the Strait of Juan de Fuca simulates only the major eddies in the eastern straits: #2, #3 and #6 from Ebbesmeyer et al. (1991). Other eddies were considered either too small or their effects were created by the tidal current reversals and current shear. For example, historical data from an oil spill in the Port Angeles area indicated a consistent eastward drift in the currents along the shoreline between Port Angeles and Dungeness Spit. When this is simulated with the reversing tide, the cyclonic circulation resembling Ebbesmeyer et al. s eddy #10 is simulated. Also, the tidal current shear in Haro Strait creates additional mixing that could be interpreted as Ebbesmeyer et al. (1991) eddy #4.

Eddies were simulated in two separate patterns: one for the time period after the maximum flood currents and one for the time period after the maximum ebb currents. Ebbesmeyer et al. (1991) eddies #2 and #6 were simulated for the period after the maximum flood, and eddy # 3 and a version of eddy #6 further offshore (as produced in the University of Washington PRISM circulation model) were simulated in the period after the maximum ebb. A time series was created from the tidal current time series so that the eddy pattern started at zero amplitude at the previous appropriate tidal current maximum, increased to maximum by the next slack water period, and then decreased to zero at the opposite tidal current maximum. This was intended to simulate the eddies spinning up from the momentum of the previous tidal current maximum. The time series was then separated into flood and ebb components and each time series was scaled so that the maximum amplitude was one (1). This allowed us to simulate the currents in the patterns scaled to match the Canadian Current Atlas and have the amplitude change as the tidal exchange changed. The table below illustrates this process. (Note that this example uses a single day of data and assumes that the local maxima are the maxima for scaling purposes).

Time (6/13/01)	Original Time Series Velocity	Offset Time Series	Scaled Time Series	After Maximum Flood Time Series	After Maximum Ebb Times Series
00:19	0.0	+0.7	1.0	0.0	1.0
03:37	-0.8	0.0	0.0	0.0	0.0
08:54	0.0	-0.8	-1.0	-1.0	0.0
09:06	+0.0	0.0	0.0	0.0	0.0
10:05	0.0	+0.0	0.0	0.0	0.0
14:46	-0.7	0.0	0.0	0.0	0.0
18:11	0.0	-0.7	-0.875	-0.875	0.0
21:13	+0.7	0.0	0.0	0.0	0.0

The eddy circulation patterns were tested by setting up the Strait of Juan de Fuca in GNOME to produce data for the NOAA Trajectory Analysis Planner (TAP) model. Trajectories were run with and without the eddy circulation pattern (all other physics, such as diffusion and tides, were set up as in the Location File). The addition of the eddy patterns significantly improved the simulation of known collection zones within the Strait.

References

You can get more information about the Strait of Juan de Fuca from these publications and web sites.

Oceanographic

Canadian Hydrological Service. Current Atlas/Atlas des Courants: Juan de Fuca Strait to/a Strait of Georgia, 1983.

Ebbesmeyer, C. C., C. A. Coomes, J. M. Cox, and B. L. Salem, 1991. Eddy Induced Beaching of Floatable Materials in the Eastern Strait of Juan de Fuca, *Oceanography in Puget Sound*, pp. 86-98.

Ebbesmeyer, C. C., J. M. Cox, J. M. Helseth, L. R. Hinchey, and D. W. Thomson, 1979. Dynamics of Port Angeles Harbor and Approaches, Washington. U. S. Environmental Protection Agency Interagency Energy/Environment R&D Program Report No. EPA-600/7-79-252, 50 pp.

Ebbesmeyer, C. C., J. M. Cox, and B. L. Salem, 1990. 1875 Floatable Wreckage Driven Inland through the Strait of Juan de Fuca, *Oceanography in Puget Sound*, pp. 75-85.

Frisch, S. and J. Holbrook, 1980. HF Radar Measurements of Circulation in the Eastern Strait of Juan de Fuca, U. S. Environmental Protection Agency Interagency Energy/Environment R&D Program Report No. EPA-600/7-80-096.

Frisch, A. S., J. Holbrook, and A. B. Ages, 1981. Observations of a Summertime Reversal in Circulation in the Strait of Juan de Fuca, *Journal of Geophysical Research*, **86 (C3)**, pp. 2044-2048.

Herlinveaux, R. H. and J. P. Tully, 1961. Some Oceanographic Features of Juan de Fuca Strait, *Journal Fish. Res. Board Canada*, **18**, pp. 1027-1071.

Hickey, B. M., R. E. Thomson, H. Yih, and P. H. LeBlond, 1991. Velocity and Temperature Fluctuations in a Buoyancy-Driven Current off Vancouver Island, *Journal of Geophysical Research*, **96 (C6)**, pp. 10,507-10,538.

Hodgins, D. O., 1994. Surface Current Measurements in Juan de Fuca Strait Using the SeaSonde HF Radar, unpublished report of the Environment Canada, Environmental Protection Service, 70 pp.

Holbrook, J. R. and D. Halpern, 1982. Winter-time near-surface currents in the Strait of Juan de Fuca, *Atmos. Ocean*, **20**, pp. 327-339.

Holbrook, J. R., R. D. Muench, and G. A. Cannon, 1980a. Seasonal Observations of Low-Frequency Atmospheric Forcing in the Strait of Juan de Fuca. In: *Fjord Oceanography*, Plenum, New York, pp. 305-317.

Holbrook, J. R., R. D. Muench, D. G. Kachel, and C. Wright, 1980b. Circulation in the Strait of Juan de Fuca: Recent Oceanographic Observations in the Eastern Basin, *NOAA Technical Report ERL 412-PMEL 33*, 42 pp.

Masson, D. and P. F. Cummins, 1999. Numerical Simulations of a Buoyancy-Driven Coastal Countercurrent off Vancouver Island, *Journal of Physical Oceanography*, **29**, pp. 418-435.

U. S. Coast Guard Marine Safety Office Puget Sound On-Scene Coordinator's Report, Major Oil Spill Clean Up, T/V Arco Anchorage at Port Angeles, Washington, 21 December 1985 - 28 April 1986.

Weather and Online Information

National Weather Service (NWS) Western Region Forecast
http://www.wrh.noaa.gov/wrhq/javaLinks/index.html
An interactive map providing current observations and the latest forecasts for the northwestern U.S.

National Data Buoy Center Station Information: Western Washington
http://www.ndbc.noaa.gov/data/Forecasts/FZUS56.KSEW.html
The latest National Weather Service marine forecast for coastal and inland waters of western Washington.

National Data Buoy Center U. S. Northwest Regional Map
http://seaboard.ndbc.noaa.gov/stuff/northwest/nwstmap.shtml
Map of moored buoy and C-MAN stations in the U.S. Northwest. Click a station on the map (TTIW1, for example, at Tatoosh Island, WA) to view current conditions at that station.

The Weather Underground, Inc. weather page
http://www.wunderground.com/US/WA/
Weather conditions for cities in Washington State.

University of Washington Land-Margin Ecosystem Research Project (LMER)
http://depts.washington.edu/cretmweb/frasflow.html
Ten-year flow rates for the Fraser River at Hope, B.C.

River Forecast and Snow Surveys
http://www.elp.gov.bc.ca/rib/wat/rfc/
A B.C. Ministry of Environment, Lands, and Parks web site that provides snow, meteorological, and streamflow data from around the province.

http://www.elp.gov.bc.ca/rib/wat/rfc/river_forecast/graphs/hydrofrs.html
2001 Hydrograph of the Fraser River at Hope, B.C.

http://www.elp.gov.bc.ca/rib/wat/rfc/river_forecast/runoff.htm
A discussion of current runoff conditions throughout the province.

Environment Canada and the Province of British Columbia River Data
http://www.weatheroffice.com/water/Map.asp
An interactive interface that provides river flow and lake level data for B.C. waters.

Oil Spill Response

NOAA Hazardous Materials Response Division (HAZMAT)
http://response.restoration.noaa.gov
Tools and information for emergency responders and planners, and others concerned about the effects of oil and hazardous chemicals in our waters and along our coasts.