A Relational Database for Climatological Data

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ABSTRACT

Haigh, R. and J. Schnute. 1999. A relational database for climatological data. Can. Manuscr. Rep. Fish. Aquat. Sci. 2472: 26 p.

This report documents a climate database containing oceanographic and atmospheric information intended for use in fisheries stock assessments. The core data are supplied by the Institute of Ocean Sciences (IOS), where regularly updated text files are available on their network. We have also collected and incorporated additional climatological information posted on the Internet by various external agencies. In this report we describe the contents of the database and provide instructions on how to update the data tables. Staff members of Fisheries and Oceans Canada can access an electronic image of the database, documentation, and links to relevant Web sites at the Intranet site: http://stad.pbs.dfo.ca/Climate/.

RÉSUMÉ

Haigh, R. and J. Schnute. 1999. A relational database for climatological data. Can. Manuscr. Rep. Fish. Aquat. Sci. 2472: 26 p.

Ce rapport documente une base de données climatologiques contenant des informations océanographiques et atmosphériques qui pourront être utilisées pour l'évaluation des stocks halieutiques. La majorité des données proviennent de l'Institut des Sciences de la Mer (ISM). Ces données sont régulièrement mise à jour par ISM et disponible dans des fichiers textes sur leur réseau. Nous avons aussi recueilli et intégré des informations climatologiques supplémentaires affichées sur Internet par d'autres organismes. Dans ce rapport, nous décrivons le contenu de la base de données et donnons des instructions sur la manière de mettre à jour les tableaux de données. Les membres du personnel de Pêches et Océans Canada peuvent avoir accès à l'image électronique de la base de données, à la documentation ainsi qu' à des liens avec des sites Web pertinents, à l'adresse : http://stad.pbs.dfo.ca/Climate/.

1. INTRODUCTION

This report documents a climatological database containing oceanographic and atmospheric information intended for use in fisheries stock assessments. Mike Jensen and Jon Schnute at the Pacific Biological Station (PBS, Nanaimo, BC) designed an early version of this database in 1995 to house data compiled into text files by Howard Freeland and his associates at the Institute of Ocean Sciences (IOS, Sidney, BC). These data include (1) mean monthly sea surface temperatures (SSTs) and sea surface salinities (SSSs) recorded at various British Columbia (BC) lighthouses, (2) sea level heights at selected west coast ports, (3) climatological indices describing atmospheric teleconnection patterns, and (4) hemispheric temperature anomalies. The current database includes all these data, plus additional climatological indices, particularly various oceanographic indicators affected by El Niño/Southern Oscillation (ENSO) events. To assist the reader with numerous abbreviations used throughout this report, we have included a list of all acronyms used (Table 1).

We have designed the climate database as a tool for use by fisheries researchers and stock assessment biologists. It provides an accessible source of oceanographic and atmospheric information that may be useful in the assessment of BC fish and invertebrate stocks. For instance, temperature anomalies appear to affect stock recruitment, ocean survival, and migration routes of many fish species (e.g., Mysak 1986, Beamish 1993). Fluctuations in SST and SSS can influence the development of red tides (e.g., Taylor and Haigh 1993), and these can have significant impacts on aquaculture (Taylor 1993). Ocean primary and secondary productivity is known to fluctuate in tandem with decadal shifts in atmospheric pressure patterns (Venrick et al. 1987, Brodeur and Ware 1992, Francis et al. 1998).

The climate data have been loaded into a Microsoft ACCESS 97 relational database called CLIMATE.MDB. Where possible, we obtain our data from a network connection to IOS or from reliable Internet sources. Although a recently populated copy of the database is available, individual users may wish to maintain a copy for themselves. To this end, macros have been written to facilitate periodic updating. The user's main effort is to download text files from various network or Internet sources. Once the appropriate data files have been procured, a macro within the database completes the updating process automatically. We describe this process completely in Section 3.

1.1. El Niño/ Southern Oscillation (ENSO)

Our database contains several indices of atmospheric/oceanic interactions. The most widely known and perhaps most widely felt is an episodic fluctuation at the equator called El Niño/ Southern Oscillation (ENSO). As the name suggests, this process is defined by two components: the oceanic El Niño (EN) system and the atmospheric Southern Oscillation (SO) system.

The term "El Niño" was originally used by fishermen to describe the annual warming of surface water off the coast of Ecuador and northern Peru at Christmas by a southward current that disrupts regular upwelling. The warm surface waters usually disappear by March or April. Occasionally, however, the warming persists for over a year due to the ENSO process, and it is this larger warming event that has become known as El Niño.

Table 1. Acronyms used in the document.

Indices		Institutions	
Acronym	**Name**	**Acronym**	**Name**
AAS	Annual data ASCII file	BC	British Columbia, Canada
ALPI	Aleutian Low Pressure Index	BOM	Bureau of Meteorology, Australia
AS	Asian Summer (pattern)	CDC	Climate Diagnostics Center, Boulder CO
EA	East Atlantic (pattern)	CHS	Canadian Hydrographic Service, IOS
EA_JET	East Atlantic Jet (pattern)	COADS	Comprehensive Ocean-Atmosphere Data Set, CDC
EA_WR	East Atlantic/ West Russia (pattern)	CPC	Climate Prediction Center, Washington DC
ENSO	El Niño/ Southern Oscillation	CRU	Climate Research Unit, University of East Anglia
EP	East Pacific (pattern)	DNR	Department of Natural Resources, Queensland, Australia
EUR	Polar/ Eurasia (pattern)	DPI	Department of Primary Industries, Brisbane, Queensland
HAS	Sea level height ASCII file	FNMOC	Fleet Numerical Meteorology & Oceanography Center, Monterey CA
IAS	Climatological indices ASCII file	IOS	Institute of Ocean Sciences, Sidney BC
MEI	Multivariate ENSO index	JISAO	Joint Institute for the Study of the Atmosphere and Ocean, Seattle WA
N_HEM	N hemisphere land air temperature	NCEP	National Centers for Environmental Prediction, 9 US centres
N_HEM_LM	N hemisphere land + marine surface temperature	NOAA	National Oceanic and Atmospheric Administration, Washington DC
NAO	North Atlantic Oscillation	NODC	National Oceanographic Data Center
NP	North Pacific (pattern)	OSAP	Ocean Science and Productivity (Division), IOS
OAS	Oceanographic indices ASCII file	PACS	Pan American Climate Studies
PDO	Pacific Decadal Oscillation	PBS	Pacific Biological Station, Nanaimo BC
PNA	Pacific North American (pattern)	PFEG	Pacific Fisheries Environmental Group, Pacific Grove CA
PT	Pacific Transition (pattern)	PFEL	Pacific Fisheries Environmental Laboratory, Pacific Grove CA
S_HEM	S hemisphere land air temperature	PMEL	Pacific Marine Environmental Laboratory, Seattle WA
S_HEM_LM	S hemisphere land + marine surface temperature		
S_OSC	NOAA Southern Oscillation Index		
SAS	Sea surface salinity ASCII file		
SCAN	Scandinavia (pattern)		
SLP	Sea level pressure		
SOI	Southern Oscillation Index		
SOI_T	Troup's Southern Oscillation Index		
SSS	Sea surface salinity		
SST	Sea surface temperature		
TAS	Sea surface temperature ASCII file		
TNH	Tropical/ North Hemisphere (pattern)		
WP	West Pacific (pattern)		

Concurrent with El Niño events, atmospheric pressure fluctuations occur between the tropical W Pacific–E Indian Ocean and the tropical SE Pacific Ocean. This fluctuation pattern (period ~3.8 y) was termed the Southern Oscillation by Sir Gilbert Walker. Today it is measured by the Southern Oscillation Index (SOI, see Sections 2.1.3.12 and 2.5.1 for calculation details). Normally, the Australian-Indonesian region experiences low sea level pressures (SLPs) with ascending air and rainfall while the SE Pacific experiences high SLPs with descending air and dry conditions. These pressure gradients result in east-to-west trade winds which foster oceanic advection between the E and W Pacific Ocean. Air arriving in Indonesia is diverted up to the troposphere, from where it descends to the SE Pacific (Walker circulation). These are normal conditions characterized by positive SOI values.

The normal SLP differential drives easterly trade winds that pile warm water up in the western Pacific, depressing the thermocline. Off the coast of Peru, winds toward the equator cause a strong upwelling of cold, nutrient-rich water that drives high marine productivity. The heat build-up in the western Pacific cannot go on indefinitely. Eventually atmospheric instabilities, such as anomalous bursts of westerly winds in the western equatorial Pacific, initiate an ENSO response. The SLP differential reverses (SOI becomes negative) and the trade winds weaken. The warm water piled up in the western Pacific now flows eastward along the equator as a large, subsurface wave, and in 2-3 months hits western South America (Ramage 1986). More importantly, this wave deepens the thermocline in the eastern Pacific so that upwelling does not bring cool, nutrient-rich water to the surface. Consequently, surface water temperatures can increase by 7-9°C in the eastern tropical Pacific.

ENSO is a complex, coupled ocean-atmosphere process that has been somewhat simplified here to give the reader a general overview. Once initiated, the ENSO process typically lasts for approximately 18 months and varies chiefly in amplitude. It is important to note that ENSO events are usually associated with both negative SOI and positive SST anomalies. Our database includes an ENSO index derived from multivariate sources (Section 2.6.1).

Atmospheric/oceanic interactions such as ENSO are an important factor in the fluctuation of fisheries. Traditionally, over-fishing, habitat destruction, and pollution have been blamed for abundance declines; however, there is mounting evidence that environmental oscillations on the order of ENSO or longer can enhance or suppress abundance by affecting recruitment, juvenile survival, and food availability. Fisheries researchers and stock assessment biologists need to utilize environmental data, such as those contained in this database, to better understand fish population dynamics.

2. DATA SOURCES

Data in CLIMATE.MDB originate from five agencies that provide widely available information:

(i) the Institute of Ocean Sciences (IOS), which supplies SSTs and SSSs averaged monthly, from 19 stations along the British Columbia coast, monthly sea level height data from 26 ports, 12 climatological indices, and 4 hemispheric temperature anomalies;

(ii) the Pacific Fisheries Environmental Laboratory (PFEL); which supplies upwelling indices and anomalies from 15 stations along the west coast of North America;

(iii) the Climate Prediction Center (CPC), which supplies sea level pressure at Darwin and Tahiti;

(iv) the Joint Institute for the Study of the Atmosphere and Ocean (JISAO), which supplies the Pacific Decadal Oscillation index; and

(v) the Long Paddock, an Australian government site which supplies Troup's Southern Oscillation Index.

Appendix A provides details on these institutions and the corresponding websites or networks to visit for information and data. CLIMATE.MDB also contains data from two research sources:

(vi) Klaus Wolter of the Climate Diagnostics Center (CDC), who has given us the Multivariate ENSO Index; and

(vii) Dick Beamish of the Pacific Biological Station (PBS), who has provided the Aleutian Low Pressure Index (ALPI).

The series (vi) and (vii) are static in the database, and updates must be obtained directly from the researchers.

2.1. Institute of Ocean Sciences (IOS)

The Institute of Ocean Sciences, in Sidney, British Columbia, is one of Canada's largest marine institutes. IOS is the primary source of ocean science information for the coastal waters of British Columbia, the North Pacific Ocean, the western Canadian Arctic and navigable fresh waters west of the Manitoba-Ontario border. Within IOS the Ocean Science and Productivity Division (OSAP), currently headed by Dr. Howard Freeland, provides the scientific basis for assessing the effect of natural or large-scale changes in ocean conditions on fish stocks, fish habitat and marine activities.

2.1.1. Lighthouse SST and SSS

The lighthouse data have traditionally been obtained by lighthouse keepers, who go to the water's edge every day and sample the surface water. SST is obtained by immersing a thermometer in the water, in an insulated rubber bucket using techniques recommended by the UK Meteorological Office (accuracy ± 0.1°C). SSS is obtained by taking a water sample and measuring its density using glass hydrometers (accuracy ± 0.15 ppt). The data are recorded on a monthly log sheet and mailed to IOS once per month, then entered onto a spreadsheet that automatically updates files. One exception is that data from Amphitrite Point are called in to IOS every few days and updated in near real-time. Lighthouse locations are shown in Fig. 1. In recent years, the data acquisition process has been automated at some sites.

SSTs are collected from 17 BC coastal lighthouses, 2 federal government research facilities, 1 central N Pacific station, and 3 Peruvian coastal stations. SSSs are available from 17 BC lighthouses, 1 government station, and 1 central N Pacific station.

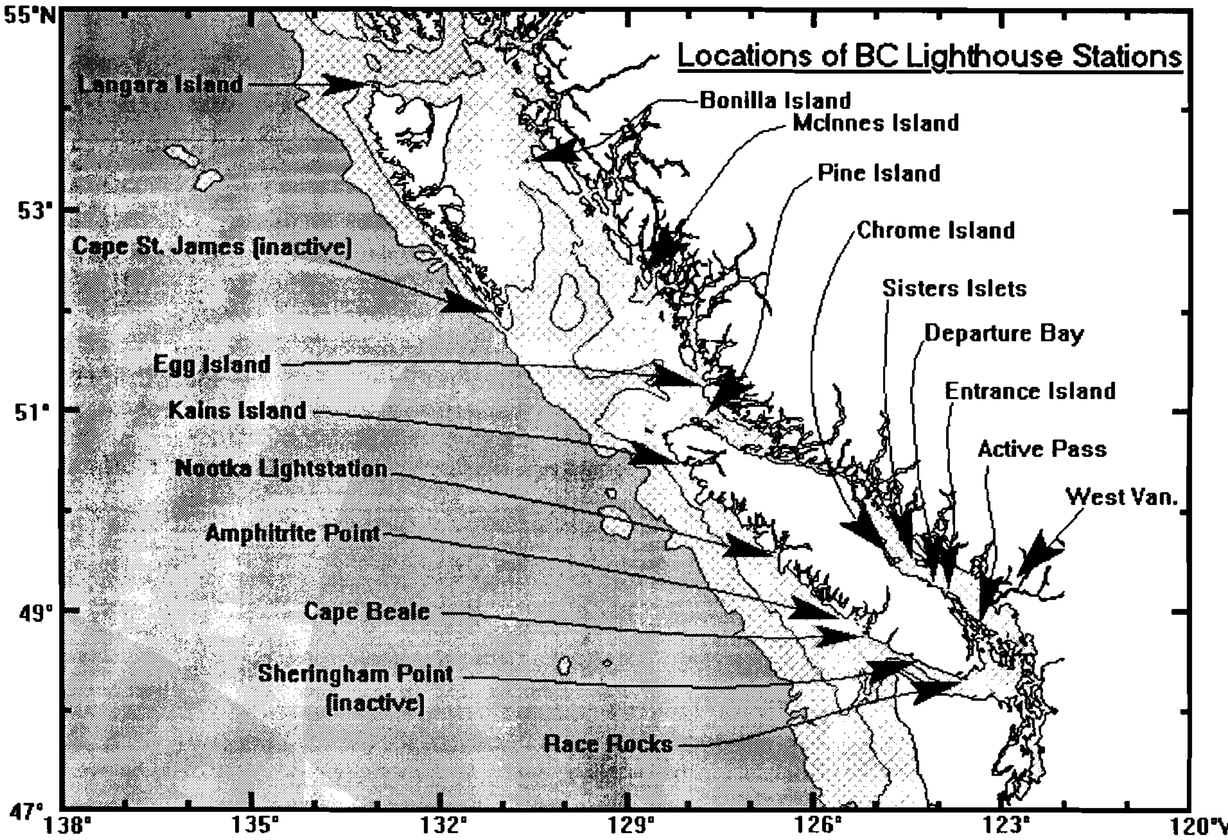

Figure 1. Lighthouse station locations. Source: IOS website – http://www.ios.bc.ca/ios/osap/data/lighthouse/lights.htm

2.1.2. Sea Level Height

The Canadian Hydrographic Service (CHS) monitors sea level height at various stations along the Pacific coast. Once a month, the monthly means are calculated and e-mailed to Dr. Freeland who updates the files. For details on protocols contact George Eaton at CHS, a division of IOS.

2.1.3. Atmospheric Indices

Dr. Freeland updates various atmospheric indices approximately every 6 months, except for the SOI, which is updated monthly. Numbers for all indicators arrive in a magazine called "Climate Diagnostics Bulletin" and are computed by the National Oceanic and Atmospheric Administration's (NOAA's) Climate Prediction Center (CPC). These indices measure "teleconnection patterns" between distant points on the planet, evidenced by recurring, persistent, large-scale patterns of pressure and circulation anomalies. The southern SLP oscillation between Darwin and Tahiti illustrates the most familiar teleconnection. Most of the indices available in the IOS files can also be found at CPC's website (Appendix B). Here we present descriptions almost verbatim from the CPC website, where we indicate approximate quotations with a reduced sans-serif font (such as this).

2.1.3.1. Northern hemisphere teleconnection patterns

CPC routinely monitors the primary teleconnection patterns and is involved in continuing research to better understand their role in the global climate system. Thirteen prominent teleconnection patterns can be identified in the Northern Hemisphere extratropics throughout the year. Although these patterns typically last for several weeks to several months, occasionally they can be prominent for several consecutive years, thus reflecting an important part of both the interannual and interdecadal variability of the atmospheric circulation. Many of the teleconnection patterns are also planetary-scale in nature, and span entire ocean basins and continents. For example, some patterns span the entire North Pacific basin, while others extend from eastern North America to central Europe. Still others cover nearly all of Eurasia.

All teleconnection patterns are a naturally occurring aspect of our chaotic atmospheric system, and can arise primarily as a reflection of internal atmospheric dynamics. Additionally, some of these patterns, particularly those over the North Pacific, are periodically forced by changes in tropical sea-surface temperatures and tropical convection associated with the ENSO cycle. Teleconnection patterns reflect large-scale changes in the atmospheric wave and jet stream patterns, and influence temperature, rainfall, storm tracks, and jet stream location/intensity over vast areas (Table 2).

http://nic.fb4.noaa.gov/data/teledoc/teleintro.html

2.1.3.2. North Atlantic Oscillation

One of the most prominent teleconnection patterns in all seasons is the North Atlantic Oscillation (NAO). The NAO exhibits little variation in its climatological mean structure from month to month, and consists of a north-south dipole of anomalies, with one centre located over Greenland and the other centre of opposite sign spanning the central latitudes of the North Atlantic between 35°N and 40°N. The positive phase of the NAO reflects below-normal geopotential heights and pressures across the high latitudes of the North Atlantic and above-normal geopotential heights and pressures over the central North Atlantic, the eastern United States and western Europe. The negative phase reflects an opposite pattern of height and pressure anomalies over these regions. The NAO exhibits considerable inter-seasonal and interannual variability, and prolonged periods (several months) of both positive and negative phases of the pattern are common.

http://nic.fb4.noaa.gov/data/teledoc/nao.html

Table 2. Prominent northern hemisphere teleconnection patterns.

Region	Abbrev	Teleconnection	Prominence
North Atlantic	NAO	North Atlantic Oscillation	all months
	EA	East Atlantic Pattern	Sep-Apr
	EA_JET	East Atlantic Jet Pattern	Apr-Aug
Eurasia	EA_WR	E Atlantic/ W Russia Pattern	Sep-May
	SCAN	Scandinavia Pattern	Aug-May
	EUR	Polar/ Eurasia Pattern	Dec-Feb
	AS*	Asian Summer Pattern	Jun-Aug
N Pacific / N America	WP	West Pacific Pattern	all months
	EP	East Pacific Pattern	Oct-Jul
	NP	North Pacific Pattern	Mar-Jul
	PNA	Pacific/North American Pattern	Aug-May
	TNH*	Tropical/ N Hemisphere Pattern	Nov-Jan
	PT	Pacific Transition Pattern	May-Aug

*Not included in current database

2.1.3.3. East Atlantic Pattern

The East Atlantic (EA) pattern is the second of three prominent modes of low-frequency variability over the North Atlantic, appearing in all months except May-August. The pattern is structurally similar to the NAO, and consists of a north-south dipole of anomaly centres which span the entire North Atlantic Ocean from east to west. However, the anomaly centres in the EA pattern are displaced southeastward to the approximate nodal lines of the NAO pattern. For this reason, the EA pattern is often mistaken as simply a slightly 'southward-shifted' NAO pattern. Also, the lower-latitude centre contains a strong subtropical link, reflecting large-scale modulations in the strength and location of the subtropical ridge. This subtropical link also makes the EA pattern distinct from its NAO counterpart.

http://nic.fb4.noaa.gov/data/teledoc/ea.html

2.1.3.4. East Atlantic Jet Pattern

The East Atlantic Jet (EA_JET) pattern is the third primary mode of low frequency variability found over the North Atlantic, appearing between April and August. This pattern also consists of a north-south dipole of anomaly centres, with one main centre located over the high latitudes of the eastern North Atlantic and Scandinavia, and the other centre located over Northern Africa and the Mediterranean Sea. A positive phase of the EA_JET pattern reflects an intensification of westerlies over the central latitudes of the eastern North Atlantic and over much of Europe, while a negative phase reflects a strong split-flow configuration over these regions, sometimes in association with long-lived blocking anticyclones in the vicinity of Greenland and Great Britain.

http://nic.fb4.noaa.gov/data/teledoc/eajet.html

2.1.3.5. East Atlantic / West Russia Pattern

The East Atlantic/ West Russia (EA_WR) pattern is one of two prominent teleconnections that affect Eurasia during most of the year. This pattern is prominent in all months except June-August. In winter, two main anomaly centres, located over the Caspian Sea and western Europe, make up the EA_WR pattern. A three-celled pattern is then evident in the spring and fall seasons, with two main anomaly centres of opposite sign located over W-NW Russia and over NW Europe. The third centre, having the same sign as the Russian centre, is located off the Portuguese coast in spring, but exhibits a pronounced retrogression toward Newfoundland in the fall. The most pronounced and persistent negative phases of the EA_WR pattern tend to occur in winter/ early spring while pronounced positive phases of the pattern are less common.

http://nic.fb4.noaa.gov/data/teledoc/eawruss.html

2.1.3.6. Scandinavia Pattern

The Scandinavia (SCAN) pattern consists of a primary circulation centre which spans Scandinavia and large portions of the Arctic Ocean north of Siberia. Two additional weaker centres with opposite sign to the Scandinavia centre are located over W Europe and over the Mongolia/ W China sector. The SCAN pattern is a prominent mode of low frequency variability in all months except June and July. The positive phase of this pattern is associated with positive height anomalies, sometimes reflecting major blocking anticyclones, over Scandinavia and W Russia, while the negative phase of the pattern is associated with negative height anomalies over these regions.

http://nic.fb4.noaa.gov/data/teledoc/scand.html

2.1.3.7. Polar/Eurasia Pattern

The Polar/ Eurasian (EUR) pattern appears only in the winter, and is the most prominent mode of low-frequency variability during December and February. The pattern consists of one main anomaly centre over the polar region, and separate centres of opposite sign to the polar anomaly over

Europe and northeastern China. Thus, the pattern reflects major changes in the strength of the circumpolar circulation, and reveals the accompanying systematic changes which occur in the midlatitude circulation over large portions of Europe and Asia.

http://nic.fb4.noaa.gov/data/teledoc/poleur.html

2.1.3.8. West Pacific Pattern

The West Pacific (WP) pattern is a primary mode of low-frequency variability over the North Pacific in all months. During winter and spring, the pattern consists of a north-south dipole of anomalies, with one centre located over the Kamchatka Peninsula and another broad centre of opposite sign covering portions of southeastern Asia and the low latitudes of the extreme western North Pacific. Therefore, strong positive or negative phases of this pattern reflect pronounced zonal and meridional variations in the location and intensity of the entrance region of the Pacific (or East Asian) jet steam.

In the summer and fall, the WP pattern becomes increasingly wave-like, and a third prominent centre appears over Alaska and the Beaufort Sea, with a sign opposite to the centre over the western North Pacific. This wave structure is most evident in fall, when it extends downstream along a quasi great-circle route into the western United States. The time series of the WP pattern indicates considerable intermonthly and interannual variability, and persistence of a particular phase of the pattern is relatively common.

http://nic.fb4.noaa.gov/data/teledoc/wp.html

2.1.3.9. East Pacific Pattern

The East Pacific (EP) pattern is evident in all months except August and September, and reflects a north-south dipole of height anomalies over the eastern North Pacific. The northern centre is located in the vicinity of Alaska and the west coast of Canada, while the southern centre is of opposite sign and is found near, or east of, Hawaii. During strong positive phases of the EP pattern, a deeper than normal trough is located in the vicinity of the Gulf of Alaska/ western North America, and positive height anomalies are observed farther south. This phase of the pattern is associated with a pronounced northeastward extension of the Pacific jet stream toward western North America, and with enhanced westerlies over the Pacific NW States, northern California, and sometimes southwestern British Columbia.

In contrast, strong negative phases of the EP pattern are associated with a pronounced split-flow configuration over the eastern North Pacific, and with reduced westerlies throughout the region. This circulation is accompanied by a confinement of the climatological mean Pacific trough to the western North Pacific, and possibly with a blocking flow configuration farther east.

http://nic.fb4.noaa.gov/data/teledoc/ep.html

2.1.3.10. North Pacific Pattern

The North Pacific (NP) pattern is prominent from March through July. This pattern consists of a primary anomaly centre which spans the central latitudes of the western and central North Pacific, and weaker anomaly region of opposite sign which spans eastern Siberia, Alaska and the intermountain region of North America. Overall, pronounced positive phases of the NP pattern are associated with a southward shift and intensification of the Pacific jet stream from eastern Asia to the eastern North Pacific, followed downstream by an enhanced anticyclonic circulation over western North America, and by an enhanced cyclonic circulation over the southeastern United States. Pronounced negative phases of the NP pattern are associated with circulation anomalies of opposite sign in these regions.

http://nic.fb4.noaa.gov/data/teledoc/np.html

2.1.3.11. Pacific North American Pattern

The Pacific North American (PNA) pattern is one of the most prominent modes of low-frequency variability in the Northern Hemisphere extratropics, appearing in all months except June and July. The PNA pattern reflects a quadripole pattern of height anomalies, with anomalies of similar sign located south of the Aleutian Islands and over the SE United States. Anomalies with sign opposite to the Aleutian centre are located in the vicinity of Hawaii, and over the intermountain region of N America (central Canada) during the winter and fall (spring).

The spatial scale of the PNA pattern is most expansive in winter. During this period, the Aleutian centre spans most of the northern latitudes of the North Pacific. In spring, the Aleutian centre contracts and becomes confined primarily to the Gulf of Alaska. However, the subtropical centre near Hawaii reaches maximum amplitude during the spring. The PNA pattern then disappears during June and July, but reappears in the late summer and fall. During this period, the midlatitude centres become dominant and appear as a wave pattern emanating from the eastern North Pacific. The subtropical centre near Hawaii is weakest during this period.

http://nic.fb4.noaa.gov/data/teledoc/pna.html

2.1.3.12. Southern Oscillation Index

The Southern Oscillation Index was devised to quantify SLP differences between the Indonesian region and the SE Pacific Ocean. This version of the index (S_OSC) is calculated as the difference between standardized SLP anomalies at Tahiti and Darwin. The SLP time series at both locations, along with the corresponding computed values of S_OSC, are available from the Climate Prediction Center's website (Appendix B).

The calculation of S_OSC begins with data T_{ij} and D_{ij} for SLPs at Tahiti and Darwin, respectively, in year i and month j. A base period of N years starting in year I ($i = I, I+1, \ldots, I+N-1$) is chosen to standardize these measurements. Typically, $I = 1951$ and $N = 30$, so that the base period spans the 360 months in 1951–80. Monthly means from the base period are

$$\overline{T}_j = \frac{1}{N}\sum_{k=0}^{N-1} T_{I+k,j} \text{ and } \overline{D}_j = \frac{1}{N}\sum_{k=0}^{N-1} D_{I+k,j}$$

for Tahiti and Darwin, respectively. Corresponding variances can then computed from all monthly deviations as

$$\tau^2 = \frac{1}{12N}\sum_{k=0}^{N-1}\sum_{j=1}^{12}\left(T_{I+k,j} - \overline{T}_j\right)^2 \text{ and } \delta^2 = \frac{1}{12N}\sum_{k=0}^{N-1}\sum_{j=1}^{12}\left(D_{I+k,j} - \overline{D}_j\right)^2 .$$

The difference between SLP anomalies, standardized for the base period, can now be defined as

$$\Delta_{ij} = \frac{T_{ij} - \overline{T}_j}{\tau} - \frac{D_{ij} - \overline{D}_j}{\delta} .$$

Over the base period, these have mean 0 and variance

$$\sigma^2 = \frac{1}{12N}\sum_{k=0}^{N-1}\sum_{j=1}^{12}\Delta^2_{I+k,j} \ .$$

Finally, the southern oscillation index (S_OSC) is defined as the normalized anomaly

$$S_{ij} = \frac{\Delta_{ij}}{\sigma}$$

for every year i and month j, inside or outside the base period.

SOI has positive values when pressure is low over Darwin and high over Tahiti. This pressure differential indicates strong easterly winds along the equator. When SOI becomes negative, the pressure differential is reversed and equatorial winds are weakened and, in some localities, become westerlies. It should be noted that SLP in the SE Pacific typically begins to fall a few months before SLP rises in the Australia-Indonesia region.

2.1.4. North/South Hemisphere Temperatures

The monthly means of northern and southern hemisphere averaged temperatures are computed by Dr. Phil Jones at the Climate Research Unit, University of East Anglia. These temperature series are periodically sent, as a courtesy, to Dr. Freeland who updates the IOS files annually. Average hemispheric and global temperature time series are also available on the Climate Research Unit website (Appendix B).

2.2. Pacific Fisheries Environmental Laboratory (PFEL)

The Pacific Fisheries Environmental Laboratory is a research unit of the U.S. National Marine Fisheries Service's Southwest Fisheries Science Center. It is home to the Pacific Fisheries Environmental Group (PFEG). The group was formed in 1969 to develop databases and to conduct research on fishery-related effects of natural environmental variability over a broad range of scientific, management, and operational concerns of the U.S. government and fishing industry. In addition to its research mission, PFEG distributes environmental index products and time series databases to cooperating researchers, taking advantage of its long association with the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC), Monterey, CA.

2.2.1. Upwelling Indices and Anomalies

PFEL provides a variety of oceanographic data products; however, we have chosen to incorporate only the mean monthly upwelling indices and their anomalies. On a monthly basis, PFEG generates indices of the intensity of large-scale, wind-induced coastal upwelling at 15 standard locations along the west coast of North America (Fig. 2). The indices are based on estimates of offshore Ekman transport driven by geostrophic wind stress. Geostrophic winds are derived from six-hourly synoptic and monthly mean surface atmospheric pressure fields, provided by FNMOC. Ekman mass transport is calculated as wind stress divided by the Coriolis parameter (a function of latitude and the Earth's rotation). In the northern hemisphere, advection of water occurs to the right of the wind direction. Therefore, equatorward winds result in offshore advection from the Pacific coast. The amount of water displaced by offshore advection is assumed to be replaced by upwelling. Similarly, onshore advection results in downwelling.

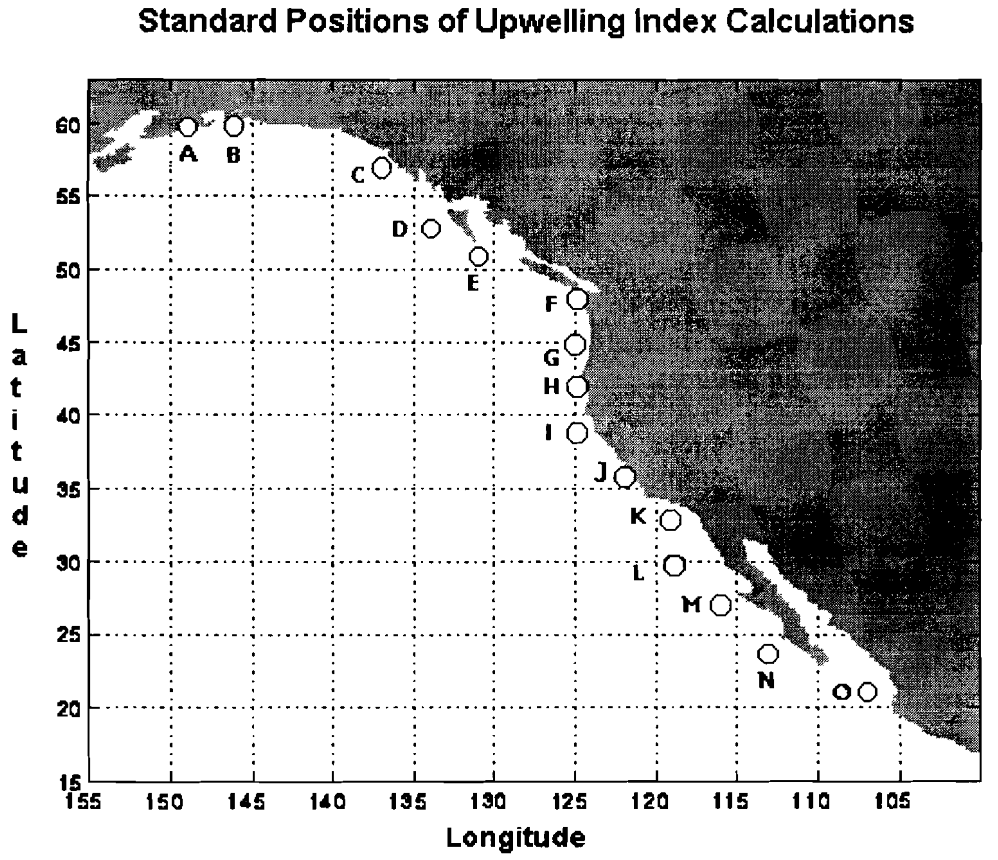

Figure 2. Upwelling station locations. Source: PFEL website – http://www.pfeg.noaa.gov/products/upwell.html

2.3. Climate Prediction Center (CPC)

The Climate Prediction Center is one of nine centres making up the U.S. National Centers for Environmental Prediction (NCEP). The mission of the CPC is to maintain a continuous watch on short-term climate fluctuations and to diagnose and predict them. These efforts are designed to assist agencies both inside and outside the U.S. federal government in coping with such climate-related problems as food supply, energy allocation, and water resources.

2.3.1. Sea Level Pressure

The CPC provides data on winds, sea level pressure, SOI (same as that in Section 2.1.3.12), SST, long wave radiation, northern hemisphere teleconnection patterns (same as those in Sections 2.1.3.1 – 2.1.3.11), and snow cover (Appendix B). We have added SLP at Darwin and Tahiti into the climate database because there are various methods of calculating SOI. With the raw SLP data, researchers can re-calculate SOI in whatever fashion suits their requirements (e.g., interval over which mean monthly anomalies is determined can be chosen).

2.4. Joint Institute for the Study of the Atmosphere and Ocean (JISAO)

JISAO is a cooperative institute between NOAA and the University of Washington, and complements the research at the Pacific Marine Environmental Laboratory (PMEL) in climate variability, environmental chemistry, estuarine processes and interannual variability of fisheries recruitment. PMEL carries out interdisciplinary scientific investigations in oceanography, marine meteorology, and related subjects. PMEL programs focus on coastal and open ocean observations and modeling to improve our understanding of the physical and geochemical processes operating in the world oceans, to define the forcing functions and the processes driving ocean circulation and the global climate system, and to improve environmental forecasting capabilities and other supporting services for marine commerce and fisheries.

2.4.1. Pacific Decadal Oscillation

Mantua et al. (1997) discuss the origins of an index called the Pacific Decadal Oscillation (PDO) which identifies a coherent, interdecadal time scale ocean-atmosphere co-variance. PDO is derived as the leading principal component of monthly SST anomalies in the North Pacific Ocean, poleward of 20°N. The monthly mean global average SST anomalies are removed to separate this pattern of variability from any "global warming" signal that may be present in the data. PDO reflects interdecadal ("climate regime shifts" in 1925, 1947, 1977) fluctuations in winter-time intensity of the Aleutian Low pressure system which dramatically affects fish production (e.g., Beamish 1993, Beamish & Bouillon 1993). Although PDO is related to ENSO, researchers have found that the former is a much better predictor of salmon production on the west coast of N America (Francis and Hare 1994, Hare and Francis 1994, Mantua et al. 1977). The original data sources used by Dr. Mantua are the UK Meteorological Office SST data set for 1900-81 and Reynold's Optimally Interpolated SST for 1982-97 (Appendix B).

2.5. The Long Paddock

During recent years, both the Queensland Department of Natural Resources (DNR) and the Department of Primary Industries (DPI) have conducted considerable research and development aimed at improving management for climatic variability. An Australia-wide climatic database has been established and a wide range of decision-support information services/ tools/ training developed to help clients better manage climatic risks and opportunities.

2.5.1. Troup's Southern Oscillation Index

DNR/DPI provide historical (1900-98) index values of Troup's SOI (SOI_T), which is the standardized anomaly of the mean Sea Level Pressure difference between Tahiti and Darwin. This differs somewhat from the CPC index defined in Section 2.1.3.12. The Troup index is computed relative to a long term average, which (from trial calculations) appears to use a base period from 1900 to the present. For example, the index to the end of 1998 would use $I = 1900$ and $N = 99$, in our earlier notation. Let

$$X_{ij} = T_{ij} - D_{ij}$$

denote the pressure difference between Tahiti and Darwin in year i and month j. Define a monthly mean $\overline{X}_j$ and variance σ_j^2 as

$$\overline{X}_j = \frac{1}{N}\sum_{k=0}^{N-1} X_{I+k,j}\,, \quad \sigma_j^2 = \frac{1}{12N}\sum_{k=0}^{N-1}\left(X_{I+k,j} - \overline{X}_j\right)^2 .$$

SOI_T is then

$$S_{ij} = 10\frac{X_{ij} - \overline{X}_j}{\sigma_j} .$$

This calculation obviously differs from that for S_OSC in Section 2.1.3.12. Here, the differences X_{ij} come directly from pressure measurements, and the mean $\overline{X}_j$ and variance σ_j^2 both depend on month j. Also, a factor of 10 is introduced into the index definition. The earlier calculation involved differences Δ_{ij} between anomalies, and all variances were calculated independent of month j. We should mention that the formulas in this report have come partly from numerical experimentation, and that these formulas generally, but not precisely, reproduce the series obtained from official sources. On the Internet, at least, it can be difficult to find mathematically precise descriptions of index calculations.

2.6. Climate Diagnostics Center (CDC)

The CDC identifies the nature and causes of climate variations on time scales ranging from months to centuries, with the goal of developing the ability to predict important climate variations on these time scales.

2.6.1. Multivariate ENSO Index

The multivariate ENSO Index (MEI), developed by Klaus Wolter of the CDC, uses six main observed variables over the tropical Pacific: sea-level pressure, zonal and meridional components of surface wind, sea surface temperature, surface air temperature, and total cloudiness fraction of the sky. These observations have been collected and published in COADS for many years. In the words of Wolter:

The MEI is computed separately for each of twelve sliding bi-monthly seasons (Dec/Jan, Jan/Feb,...,Nov/Dec). After spatially filtering the individual fields into clusters (Wolter 1987), the MEI is calculated as the first unrotated Principal Component (PC) of all six observed fields combined. This is accomplished by normalizing the total variance of each field first, and then performing the extraction of the first PC on the co-variance matrix of the combined fields (Wolter and Timlin 1993, 1998). In order to keep the MEI comparable, all seasonal values are standardized with respect to each season and to the 1950-93 reference period. The MEI is extended during the first week of the following month based on near-real time marine ship and buoy observations (courtesy of R.W. Reynolds at NCEP) summarized into COADS-compatible 2-degree monthly statistics at CDC. Caution should be exercised when interpreting the MEI on a month-to-month basis, since the input data for updates are not as reliable as COADS, and the MEI has been developed mainly for research purposes. Positive values of the MEI represent the warm ENSO phase, a.k.a. El Niño.

These data are not currently available on the Internet. For future updates of MEI and/or computed index values prior to 1950, contact Klaus Wolter (kew@cdc.noaa.gov). Any recent MEI file obtained by the user should be added to the text file MEI.OAS, following the format outlined in Section 3, Step 2. The new data will then be incorporated into CLIMATE.MDB automatically.

2.7. Pacific Biological Station (PBS)

The Pacific Biological Station is one of a network of nine major scientific facilities across Canada operated by the Department of Fisheries and Oceans (DFO). PBS studies the coastal and inland fish of BC, the North Pacific Ocean, the western Canadian Arctic and the fresh waters east to the Manitoba/Saskatchewan border.

2.7.1. Aleutian Low Pressure Index

The Aleutian Low Pressure Index (ALPI) measures the intensity of winter low pressure over the Aleutian region. Explicitly, it is expressed as the average monthly area (10^6 km^2) of low pressure in the north Pacific Ocean, less than or equal to 100.5 kPa, from December to March (Beamish et al. 1998). ALPI is converted to an anomaly by subtracting a 47-year mean (1950-97). Unlike all other datasets in CLIMATE.MDB, the ALPI data are annual rather than monthly. Any recent ALPI file obtained by the user should be added to the text file ALPI.AAS, following the format outlined in Section 3, Step 2. The new data will then be incorporated into CLIMATE.MDB automatically.

3. INSTRUCTIONS ON POPULATING THE DATABASE

Staff members of Fisheries and Oceans Canada can obtain the most recent version of the database and documentation from the Intranet site:

http://stad.pbs.dfo.ca/Climate/

The zipped file CLIMATE.ZIP includes:

- the Microsoft Access 97 database (CLIMATE.MDB),
- the most recent version of this report (CLIMATE.PDF) in Adobe Acrobat format,
- a zipped file of text files with data compiled at least up to the time of writing this report (CLIMDATA.ZIP),
- a current description of all available files (01README.TXT).

We suggest using a directory and subdirectory to maintain the files. First, unzip CLIMATE.ZIP into a working directory, such as C:\Climate. Then move CLIMDATA.ZIP into the subdirectory C:\Climate\ClimData, and unzip the data files there.

Populating the CLIMATE.MDB database with new or updated data tables is a predominantly automated process. Follow the steps outlined below:

1. Copy CLIMATE.MDB, FIXFILES.BAT, FORMAT1.EXE, FORMAT2.EXE , and DOSCVT.EXE from the working directory C:\Climate to the data subdirectory C:\Climate\ClimData. Retain the original text files in the data directory, unless they are updated from sources outlined in Section 2 as described in steps 2–6 below.

2. Copy the latest lighthouse SST/SSS files, sea level height files, and index files from IOS to C:\Climate\ClimData:

   a) If not connected to IOS, either go to your Windows desktop and right click on My Computer or go to Windows Explorer and click the menu item Tools. Choose Map Network Drive. Choose a drive letter not currently used and in the Path box type \\CCS\LIGHTPUB. This path may not work for some users, in which case try \\IOSCCS\LIGHTPUB. This will connect you to the IOS network server. Here, we assume that this remote drive is installed as L: (a natural letter for lighthouse data).

   b) Go to L:\ARCHIVE\MONTHLY and copy all the files there to C:\Climate\ClimData. If the latter already contains these files, overwrite them.

   The IOS text files comprise four groups: *.TAS = SST, *.SAS = SSS, *.HAS = sea level heights, and *.IAS = atmospheric indices. Each file name is prefixed with the site/index code, e.g., KAINS for Kains Island, S_OSC for Southern Oscillation Index. Consequently, KAINS.TAS contains SST at Kains Island while S_OSC.IAS contains index values of SOI. Furthermore, our text files of monthly data from other sources have the extension OAS, and files of annual data have the extension AAS. Appendix C details the files available.

   File format:

   The format of the IOS files has been standardized and is assumed to be the same for all ASCII data files, whether they come from IOS or external Internet sources. The PASCAL program *Format1.exe* performs this standardization on files from external Internet sources. The format of the files is important for successful processing by the PASCAL program *Format2.exe* (see Step 9c) which splits the files into sub-files containing site information (line 2 of the original file) and table information (comprising lines 3 on). The first line of the data file, which usually describes the file contents, is irrelevant to the climate database. Line 2 contains a description of the site/index code (file name prefix) followed by a latitude and longitude. Latitudes must be decimal-centered on column 36, longitudes on column 45. Line 3 contains field names: "Year, Jan, … , Dec" for monthly data and "Year, Annual" for annual data. Lines 4 on contain the data. All IOS text files are comma-delimited from line 3 on.

3. Download the latest upwelling indices and anomalies from the PFEG website to C:\Climate\ClimData:

   a) Go to http://www.pfeg.noaa.gov/data/data_download.html

b) Click on MONTHLY MEAN UPWELLING INDICES AND ANOMALIES.

c) Right click Monthly Anomalies For All 15 Positions and save target as **upa.txt**.

d) Right click Monthly Index Values For All 15 Positions and save target as **upx.txt**.

Accessing this website for the first time requires that a user register so that PFEL has some idea for what reason the person/agency may be using the data. Typically, the user ID is the first part of an e-mail address before the @ symbol and the password is simply the e-mail address.

The downloaded files, **upx.txt** and **upa.txt**, are not in a format suitable for importing to the climate database. The text files must first be processed by the PASCAL program *Format1.exe* (Step 9b) which splits each file into 15 files with formatting similar to that outlined in Step 2. The first two fields, containing latitudes and longitudes, are deleted and the geographic coordinates are copied to line 2, decimal centered on columns 36 and 45, respectively. The newly created files will have names incorporating the upwelling stations (A to O) with the extension "OAS" (e.g., UPX_A.OAS = upwelling index values at Station A, UPA_F.OAS = upwelling anomalies at Station F).

4. Download the latest SLPs from the CPC website to C:\Climate\ClimData:

   a) Go to http://nic.fb4.noaa.gov/data/cddb/

   b) Right click Darwin (SLP) 1882 - 1950: Data and save target as **darwin.txt**.

   c) Right click Darwin Sea Level Pressure (1951 - Present): Data and save target as **darwin2.txt**.

   d) Right click Tahiti (SLP) 1882 - 1950: Data and save target as **tahiti.txt**.

   e) Right click Tahiti Sea Level Pressure (1951 - Present): Data and save target as **tahiti2.txt**.

   The SLP data are split into two files for both Tahiti and Darwin. The first set (downloaded as **darwin.txt** and **tahiti.txt**) contains information from 1882 to 1950 and the SLPs have been transformed by subtracting 1000 from the mean monthly pressures and multiplying by 10 to express the values in tenths of a mbar. The second set (downloaded as **darwin2.txt** and **tahiti2.txt**) contains information from 1951 to the present and the SLPs have been transformed by subtracting 1000 (Note that these data have not been converted to tenths of a mbar). Additionally, the second set contains three time series: mean monthly SLPs, monthly SLP anomalies, and standardized monthly SLP anomalies. We use only the SLPs. *Format1.exe* (Step 9b) concatenates the first and second sets, converts the second set of data to tenths of a mbar, and creates the files DARWIN.OAS and TAHITI.OAS.

5. Download the latest PDO data from Nathan Mantua's ftp site at the University of Washington to C:\Climate\ClimData:

   a) Go to ftp://ftp.atmos.washington.edu/mantua/pnw_impacts/INDICES/

   b) Right click PDO.latest and save target as **pdo.txt**.

The PDO data are downloaded as a text file called **pdo.txt** which is then processed by *Format1.exe* (Step 9b) to remove any header/footer information. The resulting output file is called PDO.OAS.

6. Download the latest Australian SOI from the Long Paddock website to C:\Climate\ClimData:
   a) Go to http://www.dnr.qld.gov.au/longpdk/lpsoidat.htm
   b) Highlight data from 1900 on and copy to windows clipboard.
   c) Copy data to Windows notepad or other text editor and save as **soi_t.txt**.

   Unfortunately, there is no way to download a previously-defined data file. Instead, the user must highlight the tables and save the information as a text file called **soi_t.txt**. The data are organized in blocks of 20 years. *Format1.exe* (Step 9b) puts the data into one block and creates the file SOI_T.OAS.

7. In ACCESS 97 open the copy of CLIMATE.MDB in C:\Climate\ClimData. Be sure that the default directory seen by ACCESS is C:\Climate\ClimData. (Check this by trying to open a database.) Then run the macro *** BUILD DATABASE *** which makes the following calls automatically:
   a) Runs the DOS batch file *Fixfiles.bat*, which performs the following:
      i) Changes the attributes of all files in the directory so that none are read-only (attrib -r *.*). This allows renaming and altering.
      ii) Changes the extension of N_HEM, N_HEM_LM, S_HEM, and S_HEM_LM from TAS to IAS. These IOS files contain N and S hemisphere mean monthly temperature anomalies which are not SSTs. We have chosen to treat them as index files.
      iii) Deletes ALL.TAS/SAS (summary files of all TAS/SAS files) and TEST.TAS/SAS (contain no useful information).
      iv) Runs *doscvt.exe* to change any Internet files in UNIX format to DOS format.

      Note that the user may need to close the DOS window after this batch file has run.
   b) Runs the PASCAL program *Format1.exe*, which converts the downloaded Internet text files to the IOS format. *Format1.pas* may need to be updated periodically depending on how often the Internet files change format. *Format1.exe* performs the following transformations on various indices:

      UPX/UPA-- Input: **upa.txt**, **upx.txt**;
      Creates 3-line header – description, latitude/longitude, column headers;
      Deletes latitude/longitude fields;
      Introduces Station names A to O, from north to south;
      Introduces comma-delimitation;
      Splits file into 15 files, one for each station.
      Output = UPA_A.OAS to UPA_O.OAS and UPX_A.OAS to UPX_O.OAS.

      SLP---------- Input: **darwin.txt**, **darwin2.txt**, **tahiti.txt**, **tahiti2.txt**;
      Creates 3-line header – description, latitude/longitude, column headers;
      Concatenates files with 1882-1950 data and files with 1951-98 data;
      Deletes anomalies and standardized values from 1951-98 data;

Multiplies 1951-98 SLPs by 10 to make data compatible with earlier data;
Introduces comma-delimitation;
Output = DARWIN.OAS and TAHITI.OAS.

PDO--------- Input: **pdo.txt**;
Creates 3-line header – description, latitude/longitude, column headers;
Deletes supplementary header/footer information;
Introduces comma-delimitation;
Output = PDO.OAS.

SOI_T------- Input: **soi_t.txt**;
Creates 3-line header – description, latitude/longitude, column headers;
Deletes supplementary header/footer information;
Introduces comma-delimitation;
Output = SOI_T.OAS.

c) Runs the PASCAL program *Format2.exe* which reads in all files with the extension TAS, SAS, HAS, IAS, OAS, and AAS. The program then strips off header information to create 6 files called SITES_T/S/H/I/O/A.TXT, and uses the rest of the data to create 6 files called TABLE_T/S/H/I/O/A.TXT. These 12 files are now ready for import to CLIMATE.MDB.

d) Runs the macro *Import text files into B_Tables* which empties existing B tables and repopulates them with data contained in the SITES and TABLE files (see Step 7c).

e) Runs the macro *Flatten Tables* to create the A Tables where month is made a field variable with values from 1 to 12. User will be prompted to replace A Tables if any exist.

f) Runs the macro *Modify Field_4* to change the name of field 4, change the type of field 3 (Month) from text to integer, and enter field descriptions.

g) Runs the macro *Make A_All_Sites* which runs a series of queries to create the temporary table "T_All_Sites", containing descriptions and geographic position of all the sites. Another query sorts "T_All_Sites", finds unique records, and puts the results into the table "A_All_Sites". The macro finishes by entering field descriprions in "A_All_Sites". Note: because sites that are actually indices have no specific geographic position, latitudes and longitudes are set to 0.

h) Runs the macro Clean A_Tables to replace null codes (99.9, -999, etc.) with NULLs.

i) Runs the macro *Make T_Tables & G_Tables* which runs a set of queries to make summary tables of mean monthly and annual SST and SSS at various lighthouses and coastwide. These summary tables are used primarily for graphing routines.

j) Runs the macro *Clean G_Tables* to modify the properties of the G Tables.

8. When you are sure that the updated copy of CLIMATE.MDB is complete, move it to C:\Climate, replacing the previous version.

9. Update the zipped archive *ClimData.zip* in C:\Climate\ClimData with all TXT, TAS, SAS, HAS, IAS, and OAS files. Update the archive *Climate.zip* in C:\Climate with the updated files *ClimData.zip* and CLIMATE.MDB.

4. DATABASE STRUCTURE

After running the macro *** BUILD DATABASE ***, the text files described above will be loaded into "B" data tables, where the original cross-tabulated format (12 columns corresponding to months of the year) is maintained, and "B" site tables which contain site descriptions (geographic or index) and a physical location, if applicable. Tables with the prefix "A" are flattened versions of the "B" tables, i.e., the 12 months are encoded in the single field Month. "T" and "G" tables are used for temporary and graphics purposes (Section 5). Although the climate database contains final tables (Table 3), it is wise to retain tables at all levels (A, B, G, T) to ensure the proper execution of the *** BUILD DATABASE *** macro.

Table 3. Final tables in CLIMATE.MDB

ACCESS Table	Description of contents
A_All_Sites	Site/index codes and descriptions
A_Annual	Annual data from files *.AAS
A_Indices	Atmospheric index data from files *.IAS
A_Ocean	Oceanographic data from files *.OAS
A_Salinities	Salinity data from files *.SAS
A_Temperatures	Temperature data from files *.TAS
A_Tides	Sea level height data from files *.HAS
G_CoastWide Sal_Annual	Annual coastal salinities – average, minimum, maximum
G_CoastWide Sal_Monthly	Monthly coastal salinities – average, minimum, maximum
G_CoastWide Temp_Annual	Annual coastal temperatures – average, minimum, maximum
G_CoastWide Temp_Monthly	Monthly coastal temperatures – average, minimum, maximum
G_Salinity by Site (Annual)	Annual salinities, coastwide and by site
G_Salinity by Site (Monthly)	Monthly salinities, coastwide and by site
G_Temp by Site (Annual)	Annual temperatures, coastwide and by site
G_Temp by Site (Monthly)	Monthly temperatures, coastwide and by site

Code contained in PASCAL programs, ACCESS modules, and ACCESS macros are not presented in this document as users can view this code elsewhere. Occasionally, code will need to be altered as software evolves or data file format changes. The IOS data files will presumably retain their structure; however, this cannot be assumed for the Internet files. Executable PASCAL programs can be re-created by altering the code in *Format1.pas* and *Format2.pas*. At present, the macro *** BUILD DATABASE *** contains calls to a mixture of routines, including DOS-based programs, ACCESS macros, and Visual Basic functions. Perhaps in time all processing will be performed in Visual Basic.

5. GRAPHICS

The database can be perused visually by opening the form 00_GRAPHICS_MENU. Upon doing so, a menu containing 5 choices appears:

1) "Map: Lighthouse Positions" – location map of the BC coastal lighthouses from which SSTs and SSSs are collected.

2) “Lighthouse Pictures” – menu of lighthouse photographs, choose a lighthouse.

3) “Map: Upwelling Stations” – location map of stations along the west coast of North America from which data are used to calculate upwelling.

4) “Temperature Graphs” – choose “Annual Graphs” or “Monthly Graphs”, then click the down arrow of the “Select Sites” box and choose a site.

5) “Salinity Graphs” – choose “Annual Graphs” or “Monthly Graphs”, then click the down arrow of the “Select Sites” box and choose a site.

An annual SST/SSS graph for a selected site will plot six time series: (i) average annual SST/SSS for the site, (ii) maximum annual values for the site, (iii) minimum annual values for the site, (iv) average annual SST/SSS for the BC coast (comprising all lighthouses north of 47°N and east of 135°W), (v) maximum annual values for the coast, and (vi) minimum annual values for the coast. Similarly, a monthly SST/SSS graph will plot six curves (not time series) of monthly averages, maxima, and minima for a selected site and for the BC coast.

The graphics menu routines use data stored in the “G” tables, which were previously created by “G” queries called by the automatic macro *** BUILD DATABASE ***. The “T” tables (“T” for “temporary”) are an intermediate step in building the “G” tables, and are built by “T” queries. “T” tables contain averaged annual values for each site and averaged annual values for the coast, restricted to coastal lighthouses north of 47°N and east of 135°W. We define annual averages only in years with at least 10 months of data available.

Note: at the time of writing, the graphics menu will be disabled if any of the subforms (level 02 and 03) accessed by 00_GRAPHICS_MENU are accessed directly by the user.

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We thank all the researchers whose efforts have produced the data included in our database. Without their contribution, this work obviously would have been impossible. In particular, Howard Freeland's data compilation at IOS inspired our first attempt at a climatological database. Dick Beamish, Jackie King, and Klaus Wolter have generously provided the research data discussed in Sections 2.6–2.7. Mike Jensen and Trevor Crosse leant their considerable technical skills to the database design and programming.

REFERENCES

Beamish, R. J. 1993. Climate and exceptional fish production off the west coast of North America. Can. J. Fish. Aquat. Sci. 50: 2270-2291.

Beamish, R. J. and D. R. Bouillon. 1993. Pacific salmon production trends in relation to climate. Can. J. Fish. Aquat. Sci. 50: 1002-1016.

Beamish, R. J., D. Noakes, G. A. McFarlane, L. Klyashotrin, V. V. Ivanov and V. Kurashov, 1998. The regime concept and natural trends in the production of Pacific salmon. Can. J. Fish. Aquat. Sci., in press.

Brodeur, R. D. and D. M. Ware. 1992. Long-term variability in zooplankton biomass in the subarctic Pacific Ocean. Fish. Oceanogr. 1: 32-38.

Francis, R. C. and S. R. Hare. 1994. Decadal scale regime shifts in the large marine ecosystems of the North-east Pacific: a case for historical science. Fish. Oceanogr. 3: 279-291.

Francis, R. C., S. R. Hare, A. B. Hollowed, and W. S. Wooster. 1998. Effects of interdecadal climate variability on the oceanic ecosystems of the NE Pacific. Fish. Oceanogr. 7: 1-21.

Hare, S. R. and R. C. Francis. 1994. Climate change and salmon production in the northeast Pacific Ocean, p. 357-372. *In* R.J. Beamish [ed.] Climate Change and Northern Fish Populations. Can. Spec. Publ. Fish. Aquat. Sci. 121.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bull. Am. Meteor. Soc. 78: 1069-1079.

Mysak, L. A. 1986. El Niño, interannual variability and fisheries in the northwest Pacific Ocean. Can. J. Fish. Aquat. Sci. 43: 464-497.

Ramage, C. S. 1986. El Niño. Sci. Amer. 254: 76-83.

Taylor, F. J. R. 1993. Current problems with harmful phytoplankton blooms in British Columbia waters, p. 699-703. *In*: T.J. Smayda and Y. Shimizu [ed.] Toxic Phytoplankton Blooms in the Sea: Proceedings of the Fifth International Conference on Toxic Marine Phytoplankton, Elsevier Science Publishers, Amsterdam.

Taylor, F. J. R. and R. Haigh. 1993. The ecology of fish-killing blooms of the chloromonad flagellate *Heterosigma* in the Strait of Georgia and adjacent waters, p. 705-710. *In*: T.J. Smayda and Y. Shimizu [ed.] Toxic Phytoplankton Blooms in the Sea: Proceedings of the Fifth International Conference on Toxic Marine Phytoplankton, Elsevier Science Publishers, Amsterdam.

Venrick, E. L., J. A. McGowan, D. R. Cayan, and T. L. Hayward. 1987. Climate and chlorophyll a: long-term trends in the central north Pacific Ocean. Science 238: 70-72.

Wolter, K. 1987. The Southern Oscillation in surface circulation and climate over the tropical Atlantic, Eastern Pacific, and Indian Oceans as captured by cluster analysis. J. Climate Appl. Meteor. 26: 540-558.

Wolter, K. and M. S. Timlin. 1993. Monitoring ENSO in COADS with a seasonally adjusted principal component index, p. 52-57. *In*: Proc. of the 17th Climate Diagnostics Workshop, Norman, OK, NOAA/N MC/CAC, NSSL, Oklahoma Clim. Survey, CIMMS and the School of Meteor., Univ. of Oklahoma.

Wolter, K. and M. S. Timlin. 1998. Measuring the strength of ENSO – how does 1997/98 rank? Weather 53, in press.

Appendix A. Data sources for tables in CLIMATE.MDB

Institution	Contact	Information and Data
Institute of Ocean Sciences 9860 West Saanich Road Sidney, BC V8L 4B2	Dr. Howard J. Freeland Head, Ocean Science and Productivity Division e-mail: freelandhj@dfo-mpo.gc.ca	Info: http://www.ios.bc.ca/ios/osap/ Data on IOS network (available to DFO only): \\CCS\LIGHTPUB\ARCHIVE\MONTHLY Data on Internet (available to public): http://www.ios.bc.ca/ios/osap/data/
Pacific Fisheries Environmental Laboratory 1352 Lighthouse Ave. Pacific Grove, CA 93950	Jerrold Norton Tel: (408)648-8515, Fax: (408)648-8440 e-mail: jnorton@pfeg.noaa.gov	Info: http://www.pfeg.noaa.gov/ Data: http://www.pfeg.noaa.gov/data/data_download.html
Climate Prediction Center World Weather Building 5200 Auth Road, Room 800 Washington, DC 20233		Info: http://nic.fb4.noaa.gov/ Data: http://nic.fb4.noaa.gov/data/cddb/ http://www.nnic.noaa.gov/data/cddb/ (mirrored site)
Joint Institue for Study of the Atmosphere & Ocean Box 354235, University of Washington Seattle, WA 98195-4235	Dr. Nathan Mantua e-mail: mantua@atmos.washington.edu	Info: http://www.atmos.washington.edu/~mantua/ http://www-jisao.atmos.washington.edu/ Data: ftp://ftp.atmos.washington.edu/mantua/pnw_impacts/INDICES/
Queensland Department of Natural Resources Resource Sciences Centre 80 Meiers Road Indooroopilly, Queensland, Australia 4068	Ken Brook, Principal Research Scientist Risk Management and Drought e-mail: rouseabout@dnr.qld.gov.au Fax: 61-7-3896 9606	Info: http://www.dnr.qld.gov.au/longpdk/longpdk.htm Data: http://www.dnr.qld.gov.au/longpdk/lpsoidat.htm
NOAA-CIRES Climate Diagnostics Center University of Colorado Campus Box 449 Boulder, CO 80309-0449	Klaus Wolter Phone: (303) 492-4615 Fax: (303) 492-2468 e-mail: kew@cdc.noaa.gov	Info: http://www.cdc.noaa.gov/~kew/MEI/mei.html Data: Obtained by personal communication
Pacific Biological Station Fisheries and Oceans Canada 3190 Hammond Bay Rd. Nanaimo, BC, V9R 5K6	Dick Beamish Tel: (250) 756-7029 Fax (250) 756-7053 e-mail: beamishr@dfo-mpo.gc.ca	Info: http://www.pbs.dfo.ca Data: Obtained by personal communication

Appendix B. Information of interest on the Internet

Information	**Website**
BC lighthouse data, IOS	http://www.ios.bc.ca/ios/osap/data/
Climate Diagnostics Bulletin, CPC	http://nic.fb4.noaa.gov/products/analysis_monitoring/bulletin/
Climate Diagnostics Center, NOAA	http://www.cdc.noaa.gov/
Climate Prediction Center, NOAA	http://nic.fb4.noaa.gov/
Climate Research Unit, University of East Anglia	http://www.cru.uea.ac.uk/
COADS-based SOI, PACS	http://tao.atmos.washington.edu/pacs/additional_analyses/soi2.html
COADS-based SOI, updated	http://tao.atmos.washington.edu/data_sets/soicoads2/
Coastwatch, NOAA	http://cwatchwc.ucsd.edu/elnino.html
Comprehensive Ocean-Atmosphere Data Set, CDC	http://www.cdc.noaa.gov/coads/
Darwin & Tahiti SLP, SOI	http://nic.fb4.noaa.gov/data/cddb/
Dept. Natural Resources, Queensland	http://www.dnr.qld.gov.au/
Dept. Primary Industries, Queensland	http://www.dpi.qld.gov.au/
doscvt.exe (download doscvt27.zip), Oakland Univ.	ftp://oak.oakland.edu/pub/simtelnet/msdos/txtutl/
ENSO - Columbia University	http://ingrid.ldgo.columbia.edu/SOURCES/.Indices/ensomonitor.html
ENSO - Environment Canada	http://www1.tor.ec.gc.ca/elnino/english/elnino.html
ENSO - John L. Daly	http://www.vision.net.au/~daly/elnino.htm
ENSO - Office of Global Programs, NOAA	http://www.ogp.noaa.gov/enso/
ENSO - PMEL	http://www.pmel.noaa.gov/toga-tao/el-nino/home.html
Fleet Num. Meteorology & Oceanography Center	http://www.fnmoc.navy.mil/
Hemispheric & global temperature anomalies, CRU	http://www.cru.uea.ac.uk/cru/data/temperat.htm
Institute of Ocean Sciences	http://www.ios.bc.ca/ios/
Joint Institute for Study of Atmosphere & Ocean	http://www-jisao.atmos.washington.edu/
Multivariate ENSO Index, CDC	http://www.cdc.noaa.gov/~kew/MEI/mei.html
Nathan Mantua, JISAO	http://www.atmos.washington.edu/~mantua/
National Centers for Environmental Prediction	http://www.ncep.noaa.gov/
National Oceanic & Atmospheric Administration	http://www.noaa.gov/
National Oceanographic Data Center	http://www.nodc.noaa.gov/
NOAA's calculation of SOI, CPC	http://nic.fb4.noaa.gov/data/cddb/cddb/Readme.index
NOAA's SOI, CPC	http://nic.fb4.noaa.gov/data/cddb/
OAK Software Repository, Oakland University	http://oak.oakland.edu/
Pacific Biological Station	http://www.pbs.dfo.ca/
Pacific Decadal Oscillation, JISAO	ftp://ftp.atmos.washington.edu/mantua/pnw_impacts/INDICES/
Pacific Fisheries Environmental Laboratory	http://www.pfeg.noaa.gov/
Pacific Marine Environmental Laboratory	http://www.pmel.noaa.gov/
Pan-American Climate Studies	http://tao.atmos.washington.edu/pacs/
Reynold's optimally interpolated SST, CDC	http://www.cdc.noaa.gov/cdc/data.reynolds_sst.html
Teleconnection Indices, CPC	http://nic.fb4.noaa.gov/data/teledoc/telecontents.html
The Long Paddock, Queensland	http://www.dnr.qld.gov.au/longpdk/longpdk.htm
Tropical Atmosphere Ocean (TAO) Array	http://www.pmel.noaa.gov/toga-tao/
Troup's SOI calculation	http://www.bom.gov.au/climate/glossary/soi.shtml
Troup's Southern Oscillation Index	http://www.dnr.qld.gov.au/longpdk/lpsoidat.htm
Upwelling indices and anomalies, PFEL	http://www.pfeg.noaa.gov/data/data_download.html

Appendix C. Text files used to populate CLIMATE.MDB

File	Site/Index Name	Lat	Lon	File Extension*					
				AAS	HAS	IAS	OAS	SAS	TAS
ACTIVE	Active Pass	48.52	123.17				+	+	+
ALBERNI	Port Alberni	49.14	124.49		+				
ALERT	Alert Bay	50.35	126.56		+				
ALPI	Aleutian Low Pressure Index	0	0	+					
AMPHITRI	Amphitrite Point	48.55	125.32					+	+
ATKINS	Pt. Atkinson	49.2	123.15		+				
BAMFIELD	Bamfield	48.5	125.08		+				
BELLA	Bella Bella	52.1	128.08		+				
BONILLA	Bonilla Island	53.3	130.38					+	+
CAMPBELL	Campbell River	50.01	125.14		+				
CBEALE	Cape Beale	48.47	125.13					+	+
CHARLOTT	Charlotte City	53.15	132.04		+				
CHICAMA	Point Chicama, Peru	-7.75	79.333						+
CHIMBOTE	Chimbote, Peru	-9	78.583						+
CHROME	Chrome Island	49.28	124.41					+	+
CMUDGE	Cape Mudge	50	125.12					+	+
CSTJAMES	Cape St. James	51.56	131.01					+	+
DARWIN	Darwin Sea Level Pressure	0	0				+		
DEPARTUR	Departure Bay	49.13	123.57					+	+
EA	East Atlantic Pattern	0	0			+			
EA_JET	East Atlantic Jet Pattern	0	0			+			
EA_WR	East Atlantic/W Russia Pattern	0	0			+			
EGG	Egg Island	51.15	127.5					+	+
ENTRANCE	Entrance Island	49.13	123.48					+	+
EP	East Pacific Pattern	0	0			+			
ESQUIM	Esquimalt Lagoon	48.26	123.28		+				
EUR	Eurasian Index	0	0			+			
FRIDAY	Friday Harbor	48.33	123		+				
FULFORD	Fulford Harbour	48.46	123.27		+				
GOLD	Gold River	49.41	126.07		+				
HARDY	Port Hardy	50.43	127.29		+				
KAINS	Kains Island	50.27	128.02					+	+
KELSEY	Kelsey Bay	50.24	125.58		+				
LANGARA	Langara Island	54.15	133.03					+	+
LITTLE	Little River	49.44	124.54		+				
MCINNES	McInnes Island	52.16	128.43					+	+
MEI	Multivariate ENSO Index	0	0				+		
N_HEM	N. Hemisphere Land Air T	90	0			+			
N_HEM_LM	N. Hem. Land+Marine Sfc T	90	0			+			
NAO	North Atlantic Oscillation	0	0			+			
NEAH	Neah Bay	48.22	124.37		+				
NOOTKA	Nootka Point	49.23	126.33					+	+
NP	North Pacific Pattern	0	0			+			
PAITA	Paita, Peru	-5.083	81						+
PATRICIA	Patricia Bay	48.39	123.27		+				

*AAS = Annual data, HAS = Sea level height at ports, IAS = Atmospheric indices, OAS = Oceanographic indices, SAS = Sea surface salinity at lighthouse stations, TAS = Sea surface temperature at lighthouse stations

Appendix C cont'd. Text files used to populate CLIMATE.MDB

File	Site Name	Lat	Lon	File Extension*				
				HAS	IAS	OAS	SAS	TAS
PDO	Pacific Decadal Oscillation	0	0			+		
PINE	Pine Island	50.58	127.44				+	+
PNA	Pacific North American Pattern	0	0		+			
RACEROCK	Race Rocks	48.18	123.32				+	+
RENFREW	Port Renfrew	48.33	124.25	+				
RUPERT	Prince Rupert	54.19	130.2	+				
S_HEM	S. Hemisphere Land Air T	-90	0		+			
S_HEM_LM	S. Hem. Land+Marine Sfc T	-90	0		+			
S_OSC	Southern Oscillation Index	0	180		+			
SCAN	Scandinavian Pattern	0	0		+			
SEATTLE	Seattle	47.36	122.2	+				
SHERINGH	Sheringham Point	48.23	123.55				+	+
SISTERS	Sisters Island	49.29	124.26				+	+
SOI_T	Troup's Southern Oscillation Index	0	0			+		
SOOKE	Sooke	48.22	123.44	+				
STEVES	Steveston	49.08	123.12	+				
STN_P	Station Papa (salinity at 10m)	50	145				+	+
TAHITI	Tahiti Sea Level Pressure	0	0			+		
TOFINO	Tofino	49.09	125.55	+				
UPA_A	Upwelling Anomalies - Stn A	60	149			+		
UPA_B	Upwelling Anomalies - Stn B	60	146			+		
UPA_C	Upwelling Anomalies - Stn C	57	137			+		
UPA_D	Upwelling Anomalies - Stn D	54	134			+		
UPA_E	Upwelling Anomalies - Stn E	51	131			+		
UPA_F	Upwelling Anomalies - Stn F	48	125			+		
UPA_G	Upwelling Anomalies - Stn G	45	125			+		
UPA_H	Upwelling Anomalies - Stn H	42	125			+		
UPA_I	Upwelling Anomalies - Stn I	39	125			+		
UPA_J	Upwelling Anomalies - Stn J	36	122			+		
UPA_K	Upwelling Anomalies - Stn K	33	119			+		
UPA_L	Upwelling Anomalies - Stn L	30	119			+		
UPA_M	Upwelling Anomalies - Stn M	27	116			+		
UPA_N	Upwelling Anomalies - Stn N	24	113			+		
UPA_O	Upwelling Anomalies - Stn O	21	107			+		
UPX_A	Upwelling Indices - Stn A	60	149			+		
UPX_B	Upwelling Indices - Stn B	60	146			+		
UPX_C	Upwelling Indices - Stn C	57	137			+		
UPX_D	Upwelling Indices - Stn D	54	134			+		
UPX_E	Upwelling Indices - Stn E	51	131			+		
UPX_F	Upwelling Indices - Stn F	48	125			+		
UPX_G	Upwelling Indices - Stn G	45	125			+		
UPX_H	Upwelling Indices - Stn H	42	125			+		
UPX_I	Upwelling Indices - Stn I	39	125			+		
UPX_J	Upwelling Indices - Stn J	36	122			+		

*HAS = Sea level height at ports, IAS = Atmospheric indices, OAS = Oceanographic indices,
SAS = Sea surface salinity at lighthouse stations, TAS = Sea surface temperature at lighthouse stations

Appendix C cont'd. Text files used to populate CLIMATE.MDB

File	Site Name	Lat	Lon	File Extension*				
				HAS	IAS	OAS	SAS	TAS
UPX_K	Upwelling Indices - Stn K	33	119			+		
UPX_L	Upwelling Indices - Stn L	30	119			+		
UPX_M	Upwelling Indices - Stn M	27	116			+		
UPX_N	Upwelling Indices - Stn N	24	113			+		
UPX_O	Upwelling Indices - Stn O	21	107			+		
VANCOUV	Vancouver	49.17	123.07	+				
VICTORIA	Victoria	48.25	123.22	+				
WA	Western North Atlantic Index	0	0		+			
WESTVAN	West Vancouver	49.2	123.11					+
WP	West Pacific Pattern	0	0		+			
ZEBALLOS	Zeballos	49.59	126.51	+				

*HAS = Sea level height at ports, IAS = Atmospheric indices, OAS = Oceanographic indices,
SAS = Sea surface salinity at lighthouse stations, TAS = Sea surface temperature at lighthouse stations