0.1 C

caballing See cabbeling.

cabbeling In physical oceanography, a phenomenon that occurs when two water masses with identical densities but different temperatures and salinities mix to form a third water mass with a greater density than either of its constituents. This is hypothesized to be a major cause of sinking in high northern latitudes. See McDougall [1987b].

cabbeling coefficient A quantity given by

$$d = \frac{1}{\beta}\frac{\partial\beta}{\partial\theta} - \frac{1}{\alpha}\frac{\partial\alpha}{\partial\theta} + \frac{\alpha}{\beta^2}\frac{\partial\beta}{\partial S} - \frac{1}{\beta}\frac{\partial\alpha}{\partial S}$$

where *beta* is the saline contraction coefficient, α is the thermal expansion coefficient, θ is the potential temperature, and S is the salinity. This describes changes of the isopycnal slope along isopycnals. See Muller [1995].

CABEX Acronym for Cascadia Basin Experiments, an underwater acoustics experiment performed jointly by the APL at the University of Washington School of Oceanography and the Acoustical Oceanography Research Group at the IOS. In this experiment acoustic arrays are designed to record images of sea surface zone backscattering in order to distinguish between rough surface scattering and scattering from bubble distributions near and beneath the surface. The hypothesis being tested is whether the small void fraction bubble clouds are responsible for the observed increase over simple rough surface backscattering predictions at moderate to high wind speeds. See the CABEX Web site[12].

calcareous Of or containing calcium carbonate or another, usually insoluble, calcium salt.

calcareous ooze A fine-grained, deep-sea deposit of pelagic origin containing more than 30% calcium carbonate derived from the skeletal material of various plankton. It is the most extensive deposit on the ocean floor but restricted to depths less than about 3500 m due to the carbon compensation depth.

CALCOFI Acronym for California Co-operative Fisheries Investigations.

`[http://www-mlrg.ucsd.edu/calcofi/]`
`[http://www.sio.ucsd.edu/explorations/calcofi/]`

CalCOOS Acronym for the California Coastal Ocean Observation System, the mission of which is to provide an observation–based description of the resources of California's coastal ocean in support of science, coastal resource management and emergency response.

`[http://www.calcoos.org/]`

caldera The official IHO definition for this undersea feature name is "a collapsed or partially–collapse seamount, commonly of annular shape."

California Current The eastern limb of the clockwise flowing subtropical gyre in the North Pacific. The California Current flows equatorward throughout the year offshore from California from the shelf break to about 1000 km from the coast. The current is strongest at the surface and extends over the upper 500 m of the water column, with seasonal mean speeds of about 10 cm s^{-1}. It carries relatively colder fresher subarctic water equatorward. Within about 300 km of the coast, some of the fresher water in the upper 20 m is associated with the Columbia River plume. South of Point Conception a

[12] http://wavelet.apl.washington.edu/CABEX/top.html

portion of the Current turns southeastward and then shoreward and poleward. This is known as the Southern California Countercurrent (SCCC) during times when the flow successfully rounds the Point, and as the Southern California Eddy when the flow recirculates within the Bight.

From April until September northerly winds prevail which leads to upwelling and equatorward surface flow through the spring and summer months. This leads to an extremely large temperature gradient between a few kilometers offshore and the land surface with concomitant condensation and the sort of heavy fogs for which San Francisco is notorious. See Hickey [1979], Hickey [1993], Tomczak and Godfrey [1994] and Hickey [1998].

California Undercurrent One of the two narrow, poleward–flowing boundary currents in the California Current system (the other being the Inshore Countercurrent). The CU appears as a subsurface maximum of flow between 100 and 250 m deep over the continental slope and transports warm, saline equatorial waters. It flows within 150 km of the coast as opposed to the 850–900 km extent of the southward flowing CC. The flow seems to be continuous for distances of 400 km or more, and has been observed at locations ranging from Baja California to Vancouver Island. Current measurements off Central California indicate continuous, year–round flow over the upper slope at around 350 m with an average speed of 7.6 cm s^{-1}. See Collins et al. [2000].

CALK Acronym for Carbonate ALKalinity, a function of carbonate and bicarbonate ion concentration.

CAMBIOS A French program to monitor the Azores front and the flow of meddy across that region. This is to be done via acoustic tomography using three sound transceivers as well as with a series of CTD/ADCP stations and some XBT deployments. See the CAMBIOS Web site[13].

Camotes Sea A small sea within the Visayan Islands that comprise the middle portion of the Philippines. It is centered at about 124.5° E and 10.5° N and is connected to the Visayan Sea to the northwest (between the islands of Cebu and Leyte), and to the Bohol Sea to the south via the Tanon Strait and a passage between the islands of Bohol and Leyte. The Camotes Islands are prominently features in the midst of this sea.

Canadian Arctic Archipelago See Collin and Dunbar [1964].

Canadian Basin Deep Water (CBDW) A water mass ... See Hansen and Osterhus [2000].

CANALES An oceanographic experiment taking place in the Balearic Sea from 1996 to 1998 to investigate the interannual, seasonal and mesoscale variability of the circulation in the Balearic Channels. The experiment consisted of four parts:

- 13 hydrographic cruises from March 1996 to June 1998;
- 14 vector–averaging mechanical current meters deployed on four mooring lines from May to November, 1996;
- analysis of daily composite infrared SST images of the western Mediterranean; and
- the use of an inverse model to obtain transport estimates from the data collected.

See Pinot et al. [2002].

Canary Basin An ocean basin located to the west of the Canary Islands in the eastern North Atlantic Ocean. This is bound to the north by the Azores Rise and is mostly composed of the Madeira Abyssal Plain, although a smaller depression called the Seine Abyssal Plain is also found there. This has also been called the Monaco Deep. See Fairbridge [1966] and Barton et al. [1998].

[13] http://www.cms.udel.edu/woce/field/french_atlantic.html

Canary Current See Hill et al. [1997] and Barton et al. [1998].

CANIGO A European Union research project whose goal is to understand of the marine system in the Canary–Azores–Gibraltar region of the Northeast Atlantic Ocean and its links wit the Alboran Sea. The project objectives are to obtain improved knowledge about the physical processes controlling the subtropical gyre and related mesoscale circulations through observations and modeling; to study the carbon cycle in the pelagic system and estimate the carbon flow from this system to deeper waters; to quantify the influence of coastal upwelling and Saharan dust on particle fluxes in the Canary region and its change through the last glacial and interglacial periods; and to quantify, understand and model the exchange system thorugh the Strait of Gibraltar, the processes of formation, evolution and fate of the Mediterranean outflow, and to measure the biogeochemical fluxes accompanying the water exchanges.

The program, scheduled to start in August 1996 and to last for 38 months, consists of observations with ships, moored instrumentation, drifters, and acoustic tomography. Laboratory experiments, satellite data, and numerical models will also be used. The project is coordinated by the Instituto Espanol de Oceanografia in Spain and the participants include Portgual, the UK, France, Germany, Norway, Sweden, Italy, Austria, Switzerland, Ireland and Israel.

From Parrilla et al. [2002a]:

> Canary Islands Azores Gibraltar Observations (CANIGO) is an European research project that was carried out as a target study in the European Union's Marine Science and Technology (MAST) III program from 1996 to 1999. Its general objective was to gain a better understanding of the physics, biogeochemistry and paleoceanography of the eastern subtropical North Atlantic. The study region of CANIGO encompassed the subtropical frontal system of the Azores, the Gibraltar exchange, the northern Canary Islands region and the transition zone of the NW African upwelling margin. CANIGO included scientists of 45 institutions from 12 countries (Austria, France, Germany, Israel, Italy, Ireland, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom). More than 300 scientists, technicians and students dedicated about 4000 months of work to the project. The disciplines of physics, chemistry, biology and geology were included in a combined observational and modeling program.
>
> The specific goals of CANIGO were: (1) to obtain an improved knowledge of physical processes controlling the North Atlantic subtropical gyre and the related mesoscale circulation through observations and nested circulation models; (2) to study the carbon cycle in the pelagic system in nutrient limited (oligotrophic) and nutrient-rich (productive) waters and to estimate the carbon flow through and from the pelagic system to deep waters; (3) to determine, quantitatively, the influence of coastal upwelling and Saharan dust on the magnitude and composition of particle flux in the Canary region, and to investigate how this influence changed through the last glacial and interglacial period; and (4) to quantify, understand and model the water mass exchange system through the Strait of Gibraltar, the processes of formation, evolution and fate of the Mediterranean Outflow, including the associated submesoscale eddies, and to measure the biogeochemical fluxes (in terms of carbon, nitrogen, trace metals and metalloids) accompanying these water exchanges.
>
> The work program consisted of observations with ships, moored instrumentation, drifters, floats and acoustic tomography, laboratory experiments, the use of satellite data, numerical modeling and the processing and joint analysis of data. Cruises with research vessels were generally multidisciplinary and multinational. The ship time in CANIGO, including research vessels and ships of opportunity, added up to almost two years, distributed in 48 cruises of variable duration. Around 1700 time series records were obtained from 38 moorings.

See Parrilla et al. [2002a] and Parrilla et al. [2002b].

[http://www.cms.udel.edu/woce/field/spain_atlantic.html]

Cantabrian Sea See Gil et al. [2002].

canyon The official IHO definition for this undersea feature name is "a relatively narrow, deep depression with steep sides, the bottom of which generally deepends continuously, developed characteristically on some continental slopes."

capacitance matrix method An algorithm for imposing additional conditions on the solution of a boundary value elliptic problem at specified grid points in the interior of the computational domain. It effectively determines a modification to the right-hand side of the governing elliptic equation which will precisely satisfy the additional interior boundary conditions. Pragmatically it allows the inclusion of island and irregular coastal boundaries while retaining the use of fast and accurate elliptic solving routines at a modest additional computational expense. See Wilkin et al. [1995].

CAPE Abbreviation for convective available potential energy.

CAPE Acronym for Circumpolar Arctic PaleoEnvironments, an organization within IGBP–PAGES to provide the vehicle through which international and national Arctic paleo–programs can be linked. The primary emphasis of CAPE is to facilitate the scientific integration of paleoenvironmental research on terrestrial environments and adjacent margins covering the last 250,000 years of Earth history, particularly those tasks that cannot easily be achieved by individual investigators or even regionally focused research teams. See CAPE Project Members [2001].

[http://www.ngdc.noaa.gov/paleo/cape/cape.html]

Cape Basin An ocean basin located to the west of South Africa at about 35° S in the South Atlantic Ocean. This includes the Cape Abyssal Plain which is fed by the Orange River. This has also been called the Walvis Basin. See Fairbridge [1966].

Cape Horn Current (CHC) A current found south of approximately 42°S along the coast of Chile. The west wind drift of the subtropical gyre veers south and becomes the Cape Horn Current at this latitude. The lower salinity and higher oxygen values found in the upper part of the current as it moves south indicate interaction with the estuarine circulation in the complex fjords along the coast. These properties are limited to the region next to the coast at 42°S, but extend to around 100 km offshore at 51°S. See Strub et al. [1998].

Cape Verde Basin An ocean basin located at about 15° N off the west coast of Africa in the North Atlantic Ocean. It includes the Cape Verde Abyssal Plain, separated from the Madeira Abyssal Plain to the north by a belt of abyssal hills, and the Gambia Abyssal Plain. This has also been known as the North African Trough, the Chun Deep, and the Moseley Deep. See Fairbridge [1966].

Cape Verde Frontal Zone A major discontinuity in the warm water sphere in the eastern tropical Atlantic named as such by Zenk et al. [1991]. It marks the boundary between the North and South Atlantic Central Waters (NACW, SACW) that form a strong thermohaline front north of the Cape Verde Islands. See Zenk et al. [1991] and Klein and Siedler [1995].

capillary wave A wave on a fluid interface for which the restoring force is surface tension. See Dias and Kharif [1999] and Perlin and Schultz [2000].

carbon-14 dating A radioisotope dating method wherein a radioactive isotope of carbon, also called radiocarbon, is used to date materials containing carbon. Carbon-14 is produced in the atmosphere by a reaction between slow cosmic ray neutrons and stable nitrogen-14 and subsequently becomes incorporated into molecules of carbon dioxide by reactions with oxygen or by exchange reactions with stable carbon isotopes in molecules of carbon monoxide or carbon dioxide. These molecules are rapidly mixed through the atmosphere and hydrosphere to reach a constant level of concentration representing a steady-state equilibrium, maintained by the constant production of carbon-14 and its continuous decay to stable carbon-12.

The carbon-14 molecules enter plants tissues via photosynthesis or by absorption through roots and the concentration subsequently remains constant due to a balance between incorporation and decay. Animals feeding on such plants have a similar constant radiocarbon level. When the plants and animals die, the incorporation of carbon-14 stops while the decay into carbon-12 continues with a half-life period of 5570 years. Thus if the radiocarbon activity in a living plant or animal is known, its activity in the dead tissues of a similar plant or animal can be used to calculate the time elapsed since its death by measuring the ratio of carbon-14 to carbon-12. This is known as the carbon-14 date of the sample. See Bowen [1991] and the Radiocarbon Web site[14].

carbon compensation depth The level in the ocean below which the solution rate of calcium carbonate exceeds its deposition rate. This is also called the carbonate compensation depth.

carbon cycle Refers to the cycling of carbon in the form of carbon dioxide, carbonates, organic compounds, etc. between various reservoirs, e.g. the atmosphere, the oceans, land and marine biota and, on geological time scales, sediments and rocks. The largest natural exchange fluxes occur between the atmosphere and the terrestrial biota and between the atmosphere and the surface water of the oceans.

carbon dating See carbon-14 dating.

carbon dioxide This is the most important of the greenhouse gases with an atmospheric concentration of 353 ppm (in 1990), up from an estimated 260-290 in pre-industrial times (pre-1880). This gas plays a very large part in the natural carbon cycle, with the amount of carbon taken out of the atmosphere each year by plant photosynthesis being almost perfectly balanced by the amount put back into the atmosphere by the processes of animal respiration and plant decay.

The chief natural sources the burning of coal, oil and natural gas, the so-called fossil fuels, and the cutting down and burning of forests, with the latter contributing about a third as much as the former. See Revelle and Fairbridge [1957].

carbonate pump The name given to the cycling of CaCO3 in the ocean. Plants and animals living in the euphotic zone have CaCO3 skeletons (tests) which they precipitate from dissolved calcium and carbonate ions. The CaCO3 formed this way eventually sinks and is dissolved back to calcium and carbonate ions in the deeper parts of the water column and in the sediments. The ocean circulation closes the loop by transporting the ions back to the surface waters. This pump creates a surface depletion and a deep enrichment of both DIC and alkalinity. An increase in the strength of this pump will serve to increase atmospheric CO2 since the pump variations have twice as great an effect on alkalinity as on DIC. See Najjar [1991].

Cariaco Basin The Cariaco Basin is a 1400 m deep depression within the continental shelf of Venezuela, connected to the southeastern Caribbean Sea across a sill that reaches approximately 140 m at its deepest point. See Richards [1975] and Astor et al. [2003].

[14] http://www2.waikato.ac.nz/c14/webinfo/index.html

Caribbean Current One of two downstream branches into which the confluence of the Guiana Current and the North Equatorial Current split when encountering the Lesser Antilles. The Antilles Current flows northward along the eastward side of the Antillean Island Arc to eventually merge into the Florida Current, while the Caribbean Current flows west–northwesterly through the various passages between the Windward Islands of the Lesser Antilles.

The characteristics of the Carribean Current derived from the observed annual average density field show it to be a warm, persistent, and powerful current with a gentle increase in velocity as it flows from the Windward Islands to the Yucatan Channel. The axis of the main flow is about 20 km wide, extends from the surface to a few tens of meters below, and streams about 200–300 km off the coast of Venezuela. It then veers northwest across, over and beyond the various submarine channels of the Jamaica–Honduras Ridge and exits through the Yucatan Channel. The axis of the current has an annual average velocity of 0.50 m/s, with the spring–summer velocity (0.80 m/s) greater than that of autumn–winter (0.40 m/s). Maximum velocities greater than 2.0 m/s have been measured, and the velocities decrease with depth to speeds not greater than 0.05 m/s at 1000 m. The annual average volume transport is estimated at 30 Sv.

The trajectories of satellite–tracked drifters indicate that the trajectory of the Caribbean Current is most correctly referred to in a statistical sense, e.g. Gallegos [1996] refers to "the loops, cusps, meanders and reversals, the presence of eddies, filaments of currents and countercurrents, and other typical motions, including turbulence, within a wide range of time and space scales." See Gallegos [1996].

Caribbean Sea The largest marginal sea of the Atlantic Ocean, with a surface area of 2.52×10^6 km^2 and a volume of 6.48×10^6 km^3 (twice that of the Mediterranean Sea). The north and eastern boundaries are the Greater and Lesser Antilles, and the southern extent is bounded by the irregular coasts of Venezuela, Colombia and Panama. The western boundary is Central America. It is located between 8–22°N latitude and 60–89∘W longitude, i.e. about 3000 km east to west and 1500 km south to north.

The average depth of the Caribbean is 4400 m, and it consists of five principal basins. They are, from east to west (with average depths):

- the Grenada Basin (3000 m);
- the Venezuela Basin (5000 m), the largest of the basins;
- the Columbia Basin (4000 m);
- the Cayman Trench (6000 m), with a maximum depth of 7100 m; and
- the Yucatan Basin (5000 m).

The major sills and ridges (with maximum depths) separating the basins from each other, the Atlantic, and the Gulf of Mexico are, from east to west:

- the Grenada (740 m), St. Vincent (890 m), St. Lucia (980 m), Martinique (950 m), Dominica (950 m) and Guadaloupe Passages connecting the Grenada Basin with the Atlantic;
- the Aves Ridge (1800 m) connecting the Grenada and Venezuela Basins;
- the Jungfern (1815 m), Anegada (1910 m) and Mona (475 m) sills connecting the Venezuela Basin to the Atlantic;
- the Beata Ridge (3600 m) separating the Venezuela and Colombian Basins;
- the Jamaica–Haiti Passage (1475 m) and various channels across the ridge between Jamaica and the Honduras–Nicaragua continental shelf (1600 m) separating Columbia Basin and the Cayman Trench;

- the Windward Passage (1690 m) connecting the Cayman Trench with the Atlantic;
- the Cayman Ridge (4000 m) separating the Cayman Trench from the Yucatan Basin; and
- the Yucatan Channel (2040 m) connecting the Yucatan Basin with the Gulf of Mexico.

The water masses and circulation of the Caribbean have been summarized by Mooers and Maul [1998]. Their summary is repeated here in slightly modified form:

> The IAS [Intra–Americas Sea, i.e. the coastal, estuarine, riverine, continental shelf and deep waters of the Gulf of Mexico, Caribbean Sea, Guianas and Bahamas (including the Straits of Florida)] contains the "roots" of the Gulf Stream system, and its circulation is consequently dominated by throughflow, with a volume transport estimated to be about 30 Sv. The inflow is derived from the tropical and subtropical North Atlantic Ocean. For example, the Guyana Current is a major source of inflow from the tropical Atlantic Ocean. The majority of the inflow enters the Caribbean Sea through several passages, of variable sill depth, between the Antilles Islands and, to a lesser estent, the Windward Passage. The remainder bypasses the Caribbean Sea via the Antilles Current, some of which flows through the Bahamas Islands and enters the Straits of Florida.
>
> Associated with the throughflow regime is the thermohaline–driven lower branch of the meridional overturning circulation known as the Deep Western Boundary Current (DWBC), which flows equatorward at a depth of about 3 km along the periphery of the IAS continental slope. This intense, deep flow is part of the Global Conveyer Belt in the Atlantic and has a volume transport of about 15 Sv. Although little DWBC water spills directly into the IAS through the major deep passages, it mixed with the ambient middepth Atlantic waters to form the remarkably uniform bottom water in the Caribbean Sea Basin. Dynamically, the role of the DWBC on IAS circulation is essentially unknown.
>
> Surface waters of the tropical Atlantic Ocean ($T \approx 28°C$, $S \approx 36$ ppt) flow into the IAS through the Antilles Passages, and except for extreme winters, flow out the Straits of Florida with almost the same general T–S properties. Below the surface, at typically 200 m, the subtropical underwater (SUW) dominates the shape of the T–S curve ($T \approx 22°C$, $S \approx 36.7$ ppt) in the main flows of the Gulf Stream system. Outside the current, the salinity is typically reduced to $S \approx 36.2$ ppt, due to mixing with the ambient waters, usually of riverine origin but also due to excess of precipitation (P) over evaporation (E), particularly in the northern Gulf of Mexico. SUW is formed in the central tropical Atlantic where $E > P$ and sinks along an isopycnal surface before and during IAS passage.
>
> The next 500 m or so of the water column is dominated by Western North Atlantic Central Water (WNACW) with a typical temperature range of $20°C > T > 8°C$ and salinity range of $36.3 > S > 35.2$ ppt. At about 700 m, the characteristic salinity minimum of Antarctic Intermediate Water (AAIW) near $S \approx 34.8$ ppt and $T \approx 7°C$ can be traced from the northern Straits of Florida through the IAS, including the western Gulf of Mexico (where SUW is only found in Loop Current anticyclonic edies), through the Caribbean Sea and eventually of course to its ($E < P$) source off Antarctica. Finally, in the deepest waters, >1000 m or so, the mid–depth waters of the Atlantic (slightly increased salinity) are generally recognized. The deep waters of the IAS are remarkably uniform ($T \approx 4°C$, $S \approx 35$ ppt) and created by overflows of the sills in the deeper passages (especially the Anegada and Windward Passages).
>
> The surface flow through the island passages organizes into the Caribbean Current that flows westward off the northern coast of South America and then northward along the eastern coast of Central America. Subsequently, it becomes known as the Yucatan Current as it flows through the Yucatan Channel and then becomes known as the Loop Current as it penetrates northward into the eastern Gulf of Mexico. It then turns anticyclonically southward to exit to

the east through the Straits of Florida, where it is known as the Florida Current and its volume transport is about 30 Sv. The persistent cyclonic Panama–Colombian Gyre (PCG), located in the southwestern Caribbean Sea, where it interacts with the plume of the Magdelena River, is the other major component of the surface general circulation.

The flow through the Antillean Passages is spatially complex (i.e. undercurrents and countercurrents; bottom trapping) and temporally variable on time scales of months and years wit no clear annual cycle.

The deep circulation is largely unexplored but there are dynamical reasons to anticipate a mean cyclonic flow along bottom topography in both the Caribbean Sea and the Gulf of Mexico. ... The Caribbean Sea is composed of several basins that divide the deep circulation. Geochemical data provide some estimates of deep–water age and residence times, but the physical processes involved (i.e. flow over the deep sills of the island passages) are onlly now being investigated theoretically and observationally.

The macroscale, seasonal wind forcing (which is regional as well as remote, i.e. from the North Atlantic, in nature) modulates the general circulation of the open basins by approximately 10% and may lead to flow reversals over shelves. For example, the summertime intensification of the trade winds leads to ecologically significant coastal upwelling and westward shelf flows along the northern coasts of South America, the Yucatan Peninsula and Cuba.

See Wust [1964], Gordon [1967], Kinder et al. [1985], Gallegos [1996] and Mooers and Maul [1998].

Caribbean Surface Water (CSW)

See Corredor and Morell [1999].

[http://cima.uprm.edu/cats/cats.htm]
[http://cima.uprm.edu/~morelock/mor2.htm]

Caroline Basin

See Siedler et al. [2004].

Carpenter, William (1813–1885)

See Peterson et al. [1996], p. 93.

Carruthers residual current meter

A current meter designed to measure and record the residual current over a longer period of time. In a manner similar to that of the Ekman current meter, a device drops small metal balls into a compass box after a certain number of turns of the propeller. The average velocity and direction are obtained by counting, after an extended period of time, the number and distribution of balls dropped (of over 22,000 available) into the slots of the compass box. See Sverdrup et al. [1942].

CARUSO

Acronym for CARbon dioxide Uptake by the Southern Ocean, an experiment undertaken from January 1988 to December 2000 to test the hypothesis that "the carbon dioxide uptake by the Southern Ocean is being dominated by synergistics of light and iron regulating the photosynthetic carbon dioxide fixation of large diatoms and carbon export into deeper Antarctic waters." The specific objectives of the program were:

- estimation of the biological and physical carbon dioxide pumps in the Southern Ocean via application of transient tracers such as chlorofluorocarbons, $^{3}He/^{4}He$ and tritium;
- investigation of the co–limitation of light and iron of bloom forming diatoms;
- quantification of iron sources to Antarctic surface waters via the use of natural isotopic tracers (^{228}Ra and $^{143}Nd/^{144}Nd$);
- field observations and an in situ iron fertilization experiment; and

- a modeling study of the biological, chemical and physical systems in the Antarctic.

[http://kellia.nioz.nl/projects/caruso/]

Caspian Sea See Zenkevich [1957] and Zenkevitch [1963].

Catalan Sea See Balearic Sea.

CATCH Acronym for the Couplage avec l'ATmosphère en Conditions Hivernales experiment, which took place in the North Sea in January and February 1997. See Eymard [1999].

CATO Expedition See Scripps Institution of Oceanography [1979a].

CCD Abbreviation for Calcite Compensation Depth, defined as the depth at which the CaCO3 content of sediments reaches 20%.

CDW Abbreviation for Circumpolar Deep Water.

CEAREX Acronym for Coordinated Eastern Arctic Experiment, a multi-national and multi-platform field program carried out in the Greenland and Norwegian Seas (north to Svalbard) from Sept. 1988 through May 1989. It was a collaboration between Canada, Denmark, France, Norway and the United States and consisted of four phases: the Polarbjorn Drift Phase, the Whaler's Bay/SIZEX Phase, the Oceanography Camp Phase, and the Acoustic Camp Phase. See Pritchard and et al. [1990].

[http://nsidc.org/NSIDC/CATALOG/ENTRIES/nsi-0020.html]

Celebes Sea Alternate name for the Sulawesi Sea.

Celtic Sea A shallow embayment of the eastern North Atlantic bounded by Southern Ireland, southwest Wales, Cornwall and Brittany. It is usually separated from the Irish Sea by a line drawn from Ramsey Island to Carnsore Point and from the English Channel by a line drawn from Ushant to Lands End. The seaward limit is usually set at the slope break at about 165–185 m. See Cooper [1967], Fairbridge [1966], Pingree [1980] and Simpson [1998].

Celtic Seas A term used for the European shelf seas to the west and south of the British Isles. These include the Hebrides and Malin shelves west of Scotland, the Irish Shelf, the English Channel, the Celtic Sea and the Irish Sea. See Simpson [1998].

Cenderawasih Bay A bay on the northern coast of Irian Jaya centered at approximately 135° E and 2.5 deg. S at the southwestern edge of the Pacific Ocean. It connects with the Pacific via the Woinui and Yapen Straits and is bordered immediately to the north by the New Guinea Trench.

belcentersofaction

centers of action Large semipermanent belts of high or low sea level pressure distributed around the Earth that largely control the general circulation of the atmosphere and the concomitant long-term weather patterns. The term was originally used by Teisserenc de Bort in 1881 to describe maxima and minima of pressure on daily charts, but has evolved to have the more global meaning. These centers include the Icelandic Low, the Aleutian Low, the Pacific High, the Azores High, the Siberian High, and the Asiatic Low. See Herman and Goldberg [1985].

Central South Equatorial Current One of three distinct branches into which the South Equatorial Current splits in the western South Atlantic. See Stramma [1991].

Central Water In physical oceanography, a term used to identify thermocline water masses in all three oceans. The water arrives at the thermocline via a process known as subduction. Central Water is characterized by T-S relationships that span a large range that is nonetheless well-defined by the method of formation. The term was originally introduced to differentiate between thermocline water of the central north Atlantic Ocean (now known as NACW) and water from the shelf area to west, but now has the abovementioned broader meaning. See Tomczak and Godfrey [1994].

CEPEX Acronym for Central Equatorial Pacific Experiment, conducted in March and April 1993 with the goal of establishing the respective roles of cirrus radiative effects and surface evaporation in limiting maximum surface temperatures in the equatorial Pacific. It examined the validity of a hypothesized thermostat effect which may limit greenhouse warming. Deep intensive convection is observed to occur when tropical SSTs exceed about 27° C. This produces cirrus (ice particle clouds) anvils that spread out over millions of square kilometers. It is hypothesized that while these clouds trap outgoing infrared radiation, they also reduce incoming solar radiation, the net effect being to stabilize SSTs, thereby acting in effect as a thermostat.

CEPEX employed surface, airborne, and space-borne platforms to measure radiation fluxes, cirrus radiative and microphysical properties, vertical water vapor distribution, evaporation from the sea surface, and precipitation. The specific objectives were:

- to measure the vertical structure of the water vapor greenhouse effect;
- to measure the effect of cirrus on radiation fluxes over the equatorial Pacific Ocean;
- to measure the east–west gradients of SSTs and the evaporative and sensible heat fluxes from the sea surface along the equatorial Pacific Ocean;
- to measure the east–west gradients of vertical distribution of water vapor along the equatorial Pacific Ocean; and
- to explore the microphysical factors contributing to high albedo of widespread cirrus layers.

See Ramanathan et al. [1995].

`[http://www-c4.ucsd.edu/~cids/cepex/]`
`[http://www.joss.ucar.edu/cgi-bin/codiac/projs?CEPEX]`

CEPTE Acronym for Central Equatorial Pacific Tomography Experiment, a long–term, 1000 km scale tomography experiment taking place from Dec. 1998 to Dec. 2000. The purpose is to measure the shallow overturning of a meridional circulation cell, i.e. a subtropical circulation cell (STC) that has been hypothesized as one mechanism by which El Nino/La Nina events in the tropics are connected to the subtropical ocean. CEPTE involved five JAMSTEC tomography moorings deployed in an array about 1000 km across just north of the equator at about 180°W.

Ceram Sea See Seram Sea.

CESNA Acronym for the Climate Expert System for the North Atlantic, part of a project to develop a practical system that can manipulate qualitative information in a way that facilitates insights into observed and anticipated climate changes. At present CESNA can be used to estimate changes in mean winter and annual climatic characteristics with a one year lead time in the region that includes eastern North America, the North Atlantic, the adjacent Arctic seas and much of Europe. See the CESNA Web site[15].

CFC See chlorofluorocarbon.

[15] http://www.cs.colorado.edu/ sergei/cesna.html

CFL Abbreviation for Courant, Friedrichs, and Levy, the discoverers of a time step limitation for numerical simulations of partial differential equations.

Chain Fracture Zone One of the pathways (along with the Romanche Fracture Zone) for AABW and lower NADW from the western to the eastern trough of the equatorial Atlantic Ocean across the Mid–Atlantic Ridge. To the west of the CFZ sill, the AABW and NADW cores are separated by a deep thermocline marking the vertical transition between them. This thermocline erodes eastward and vanishes in the eastern basin. See Mercier and Morin [1997] and Messias et al. [1999].

Challenger Expedition (1872-1876) A three and a half year voyage starting in 1872 that laid the scientific foundation for every major branch of oceanography. The ship, captained by George S. Nares and later Frank T. Thomson, took over 350 stations in all the oceans except the Arctic and logged 68,890 nautical miles. Perhaps the only ultimately unsatisfying aspect of the expedition was that the ship, a spar-decked vessel with auxiliary steam power, was slow and clumsy and had the habit of rolling about 50° to either side. The expedition was led by Sir Wyville Thompson, with his chief assistant John Murray and the expedition's chemist J. Y. Buchanan also playing major roles.

The observations and records obtained aboard the Challenger furnished data for charting the main bathymetric contours of the ocean basins, established the cold and relatively constant nature of temperatures at great depths, located the exact position of many islands and sea mounts, established that there was no zone in the sea in which life did not exist, and enabled the construction of accurate charts of the principle surface (and some subsurface) currents in the world ocean. The deep sea data were obtained with trawls lowered on hemp ropes. The ship dragged for samples in water as deep as 4,475 fathoms and trailed as much as eight miles of line in trawls that took 12 or 14 hours to complete.

The foundations of marine geology were laid by Murray with his study of the deep-sea sediments obtained in the trawls. The sediments discovered were newly classified as globigerina, radiolarian or diatom oozes or red clay, and their spatial distribution was mapped. The plankton nets, simple bags of muslin or silk attached to iron rings one foot in diameter captured many new planktonic forms, permanently changing that branch of marine biology. Many new and different forms of life were dredged from great depths, permanently dispelling the notion that these depths were lifeless and founding deep-sea biology. The expedition's chemist Buchanan took seventy-seven water samples throughout the oceans, deriving data from these that formed the foundation of chemical oceanography. He also dispelled the myth of Bathybius.

The scientific results of the expedition were published in fifty large volumes over fifteen years, edited first under the direction of Thompson and, after his death, by Murray. The best artists in England were hired to create the illustrations. The funding for this publishing endeavor was not included as part of the budget of the expedition and it was a constant struggle for Thompson and Murray to obtain financial resources to complete the endeavor, so it might also be said that the foundations for the difficulty of obtaining funds for oceanographic research were also laid by this expedition.

The Challenger Expedition probably contributed more to the science of oceanography than any single expedition before or after. It marked the beginning of oceanography as a disciplined science, with the scientists establishing a pattern of scrupulously precise observations and efficiency. While the quality of ships and of sampling and measuring devices have greatly improved since 1872, it is doubtful that the standards set by the Challenger Expedition will ever be exceeded. It was truly a landmark in oceanography. See Thomson and Murray [1884–1895].

Challenger Report A fifty volume set of reports on the results of the Challenger Expedition. The six main sections of the report were narrative, physics and chemistry, deep–sea deposits, botany, zoology and a summary. A more detailed breakdown is:

I. Narrative. Three bound volumes.

- Vol. 1 (1172 pp.)
  Narrative of the cruise of H.M.S. Challenger, with a general account of the scientific results of the expedition (in two volumes) – T. H. Tizard, H. N. Moseley, J. Y. Buchanan and John Murray

- Vol. 2 (823 pp.)
  - Magnetical results – Commander Maclear, Lieutenent Bromley, Staff–Commander Tizard, E. W. Creak (305 pp.)
  - Meteorological observations – Staff–Commander Tizard (
  - Pressure errors of the Challenger thermometer – P. G. Tait
  - Petrology of St. Paul's Rocks (Atlantic) – A. Renard

II. Physics and Chemistry. Two bound volumes.

- Vol. 1 (325 pp.)
  - Part I – Composition of ocean water – W. Dittmar
  - Part II – Specific gravity of samples of ocean water – J. Y. Buchanan
  - Part III — Deep–sea temperature observations – Officers of the Expedition
- Vol. 2 (633 pp.)
  - Part IV – On some of the physical properties of fresh–water and of sea–water – P. G. Tait
  - Part V – Atmospheric circulation, based on the observations made on board H.M.S. Challenger and other meteorological observations – A. Buchan
  - Part VI – Magnetical results - E. W. Creak
  - Part VII – Petrology of oceanic islands – A. Bernard

III. Deep–Sea Deposits. One bound volume. (583 pp.)

- Deep–sea deposits – John Murray and A. Renard
- Analytical examination of manganese nodules, with special reference to the presence or absence of the rarer elements – J. Gibson
- Chemical analyses of marine deposits, manganese nodules, phosphatic concretions, zeolitic crystals, volcanic lapillae, glauconite, bones of cetaceans, teeth of sharks, etc. – Brazier, Dittmar, Renard, Sipocz, Anderson et al.

IV. Botany. Two bound volumes.

- Vol. 1. (910 pp.)

  - Introduction. – Present state of knowledge of various insular floras, being an introduction to the botany of the Challenger Expedition – W. B. Hemsley

  - Part I. – Botany of the Bermudas and various other Islands of the Atlantic and Southern Oceans.–The Bermudas – W. B. Hemsley

  - Part II. – Botany of the Bermudas and various other Islands of the Atlantic and Southern Oceans.–St. Paul's Rocks, Fernando–Noronha and contiguous islets, Ascension, St. Helena, South Trinidad, the Tristan da Cunha Group, Prince Edward Group (Marion Island), the Crozets, Kerguelan Island, Macdonald Group (Heard Island), Amsterdam and St. Paul Islands – W. B. Hemsley

  - Part III. – Botany of Juan Fernandez, south–eastern Moluccas, and the Admiralty Islands – W. B. Hemsley

- Vol. 2 (214 pp.)

  - Part IV. – Diatomaceae - C. A. F. C. degli Antelminelli

V. Zoology. Forty bound volumes.

- Vol. 1 (553 pp.)

  - General introduction to the zoological series of reports – C. Wyville Thomson

  - Part I. – Brachiopoda. – T. Davidson

  - Part II. – Pennatulida. – A. v. Kölliker

  - Part III. – Ostracoda. – G. S. Brady

  - Part IV. – Cetacea. Bones of. – W. Turner

  - Part V. – Green turtle (Chelone viridis, Schneid.). Development of the. – W. K. Parker

  - Part VI. – Shore fishes. – A. Günther

- Vol. 2 (422 pp.)

  - Part VII. – Certain Hydroid, Alcyonarian, and Madreporarian corals. – H. N. Moseley

  - Part VIII. – Birds. – P. L. Selater

- Vol. 3 (496 pp.)

  - Part IX. – Echinoidea. – A. Agassiz

  - Part X. – Pycnogonida. – P. P. C. Hoek

- Vol. 4. (558 pp.)
  - Part XI. – Petrels. Anatomy of the. – W. A. Forbes
  - Part XII. – Deep–sea Medusae. – E. Haeckel
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- Vol. 5 (587 pp.)
  - Part XIV. – Ophiuroidea. – T. Lyman
  - Part XVI. – On some points of the anatomy of the Thylacine (Thylacinus cynocephalus), Cuscus (Phalangista maculata), and Phascogale (Phascogale calura); with an account of the comparative anatomy of the intrinsic muscles and nerves of the Mammalian Pes. – D. J. Cunningham
- Vol. 6 (486 pp.)
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  - Part XVII. – Tunicata. Firs part.–Ascidiae Simplices. – W. A. Herdman
- Vol. 7 (493 pp.)
  - Part XVIII. – Spheniscidae. Anatomy of the. – M. Watson
  - Part XIX. – Palegic Hemiptera. - F. Buchanan White
  - Part XX. – Hydroida. First part.–Plumularidae. – G. J. Allman
  - Part XXI. – Orbitolites. Specimens of the genus. – W. B. Carpenter

VI. Summary. Two bound volumes.

- Summary of the scientific results obtained at the sounding, dredging, and trawling stations of H.M.S. Challenger. – J. Murray (1665 pp.)
  With appendices, viz.:–
- Spirula. – T. H. Huxley and P. Pelseneer (32 pp.)
- Oceanic circulation based on the observations made on board H.M.S. Challenger and other observations. – A. Buchan (38 pp.)

CHAMP Acronym for the Coral Health And Monitoring Program, a NOAA project to provide services to help improve and sustain coral reef health throughout the world. The goals include establishing an international network of coral reef researchers to share information about and monitor coral health,

providing near real-time data products derived from satellite images and monitoring stations at coral reef areas, providing a data repository for historical data, and adding to the general fund of coral reef knowledge. See the CHAMP Web site[16].

chaos That which we should be mindful of.

Charlie Gibbs Fracture Zone See Saunders [1994].

Jule Charney (1917-1981) A dominant figure in atmospheric science and geophysical fluid dynamics in general in the three decades following WWII.

`[http://www.nap.edu/readingroom/books/biomems/jcharney.html]`

chemical oceanography The most thorough and complete series of reviews on the topic can be found in the *Chemical Oceanography* series. The chapters to date are:

1. Ocean and estuarine mixing processes - K. F. Bowden
2. Sea water as an electrolyte solution - M. Whitfield
3. Chemical speciation - W. Stumm and P. A. Brauner
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6. Salinity and the major elements of sea water - T. R. S. Wilson
7. Minor elements in sea water - P. G. Brewer
8. Dissolves gases other than CO_2 - D. R. Kester
9. The dissolved gases–carbon dioxide - G. Skirrow
10. Chemistry of the sea surface microlayer - P. S. Liss
11. The micronutrient elements - C. P. Spencer
12. Biological and chemical aspects of dissolved organic material in sea water - P. J. Le B. Williams
13. Particulate organic carbon in the sea - T. R. Parsons
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16. Reducing environments - W. G. Deuser
17. Marine pollution - E. D. Goldberg
18. Radioactive nuclides in the marine environment - J. D. Burton
19. Analytical chemistry of sea water - J. P. Riley et al.
20. The electroanalytical chemistry of sea water - M. Whitfield
21. Extraction of economic inorganic materials from the sea - W. F. McIlhenny
22. Seaweed in industry - E. Booth
23. Marine drugs: chemical and pharmacological aspects - H. W. Youngken, Jr. and Y. Shimizu
24. Oceanic sediments and sedimentary processes - T. A. Davies and D. S. Gorsline
25. Weathering of the Earth's crust - G. D. Nicholls
26. Lithogenous material in marine sediments - H. L. Windom

[16] http://coral.aoml.noaa.gov/

27. Hydrogenous material in marine sediments: excluding manganese nodules - H. Elderfield
28. Manganese nodules and other ferro–manganese oxide deposits - D. S. Cronan
29. Biogenous deep sea sediments: production, presentation and interpretation - W. H. Berger
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31. Factors controlling the distribution and early diagnosis of organic matter in marine sediments - E. T. Degens and K. Mopper
32. Interstitial waters of marine sediments - F. T. Manheim
33. The mineralogy and geochemistry of near–shore sediments - S. E. Calvert
34. The geochemistry of deep–sea sediments - R. Chester and S. R. Aston
35. Sea–floor spreading and the evolution of the ocean basins - E. J. W. Jones
36. Sea–floor sampling techniques - T. C. Moore, Jr. and G. R. Heath
37. Suspended matter in sea–water - W. M. Sackett
38. Aerosols chemistry of the marine atmosphere - W. M. Berg Jr. and J. W. Winchester
39. The organic chemistry of marine sediments - B. R. Simoneit
40. Determination of marine chronologies using natural radionuclides - K. K. Turekian and J. K. Cochran
41. Estuarine chemistry - S. R. Aston
42. Coastal lagoons - L. D. Mee
43. Influence of pressure on chemical processes in the sea - F. J. Millero
44. The Geochemical Ocean Sections Study–GEOSECS - J. A. Campbell
45. Trace elements in sea–water - K. W. Bruland
46. The chemistry of interstitial waters of deep sea sediments: interpretation of deep sea drilling data - J. M. Gieskes
47. Hydrothermal fluxes in the ocean - G. Thompson
48. Natural water photochemistry - O. C. Zafiriou
49. Organic matter in sea–water: biogeochemical processes - C. Lee and S. G. Wakeham
50. Marine pollution - M. R. Preston
51. Electroanalytical chemistry of sea water - C. M. G. Van Den Berg

Compare to biological, geological and physical oceanography. See Holland [1978].

chemical tracers See England and Maier-Reimer [2001].

Chile Current Another name used for the Peru Current.

Chile–Peru Current Another name used for the Peru Current.

China Coastal Current A southward flowing current along the Chinese coast in the Yellow Sea. This current brings low salinity water from the northern parts of the Yellow Sea, particularly the Bohai Gulf, to the south and on into the East China Sea where part of it continues along the coast and another part joins and turns eastward with the northward flowing Taiwan Current.

chlorine titration The method developed by Knudsen and others in 1902 to determine the chlorinity and therefore salinity of a sea water sample. See Dietrich [1963].

chlorinity A concept originally defined (circa 1900) to circumvent the difficulties inherent in attempting to directly measure the salinity of sea water. It was determined by volumetric titration using silver nitrate and originally defined as "the weight in grams (in vacuo) of the chlorides contained in one gram of seawater (likewise measured in vacuo) when all the bromides and iodides have been replaced by chlorides." This was defined in terms of the atomic weights known in 1902 and as such was dependent on any changes in their determinations. The weights did change so the definition was kept in terms of the 1902 atomic weights until a new definition was determined in 1937. The new definition of chlorinity as "the mass of silver required to precipitate completely the halogens in 0.3285234 kg of sample seawater" was free of this limitation.

The chlorinity was later defined in terms of electrical conductivity when it was determined that density may be predicted from conductivity measurements with nearly an order of magnitude better precision than from a chlorinity titration. This change was also predicated on the development of precise and reliable electronic instruments in the 1950s to perform the measurements. This led to the present method of calculating the chlorinity (and thence salinity) by experimental determination of a relationship between chlorinity and the conductivity ratio of a sample at atmospheric pressure and 15° C to that of a standard seawater. See Lewis [1980] and Lewis and Perkin [1978].

chlorofluorocarbon (CFC) Any of a group of exceptionally stable compounds containing carbon, fluorine, and chlorine, which have been used especially as refrigerants and aerosol propellants. CFCs are climatically significant for their ability to break down ozone molecules in the atmosphere. There are several kinds of CFCs, the most common being CFC-11, CFC-12, CFC-113, CFC-114 and CFC-115, having ODPs of, respectively, 1, 1, 0.8, 1 and 0.6. They are also significant as a greenhouse gas since, molecule for molecule, they are 10,000 times more efficient in trapping heat in the atmosphere than carbon dioxide. The GWPs of CFC-11 and CFC-12 are, respectively, 5000 and 8500.

chlorosity The number of grams of chloride and chloride equivalent to the bromide in one liter of sea water at 20° C. See Riley and Chester [1971].

Chukchi Sea One of the seas found on the Siberian shelf in the Arctic Mediterranean Sea. It is located to the east of the East Siberian Sea, to the north of the Bering Strait, and adjoins the Arctic Ocean proper to the north. This has also been called the Chukotsk Sea. See Zenkevitch [1963], Weingartner et al. [1998] and Münchow et al. [1999].

Chukotsk Sea See Chukchi Sea.

CICAR Acronym for Cooperative Investigation of the Caribbean and Adjacent Regions, an IOC Coordination Group.

CINCS A project to study pelagic–benthic coupling in the oligotrophic Cretan Sea. The primary aim of the study was to study biogeochemical exchanges between the Cretan continental shelf and the adjacent open marine ecosystem of the oligotrophic Cretan Sea. The CINCS program ran in parallel and was complementary to the PELAGOS program.

Tselepides and Polychronaki [2000] provide the details of the study:

> The scientific and administrative coordination of the project was undertaken by the Institute of Marine Biology of Crete and involved collaboration with 40 scientists from seven other laboratories (Netherlands Institute for Sea Research, National Centre of Marine Research in Athens, University of Genova, University of Tromso, Southampton Oceanography Centre, University of Crete and the Laboratory of Marine Microbiology in Marseille) representing six of the European Union countries. The study area was a 30 by 40nm area in the south Cretan

Sea contiguous to the northern coast of the island of Crete and cover a bathymetric depth range of 40 to 1570 m. Sampling was conducted at a grid of stations which were intensively sampled on eight bimonthly oceanographic cruises between May 1994 and September 1995. Two research vessels (the R/V *Aegaeo* and *Philia*) were used simultaneously to cope with the intensive sampling schedule and a number of technologically advanced sampling gears (including benthic landers, time lapse cameras and a submersible) were used for the first time in the Eastern Mediterranean.

See Tselepides and Polychronaki [2000].

[http://www.ncmr.ariadne-t.gr/frame/CINCS.html]
[http://bali.cetiis.fr/mtp/MTP1/Projets/cincs.html]

circalittoral zone This has also been called the outer sublittoral zone.

circle of mean temperature A concept advanced by Sir James Clark Ross in 1847 in which he posited that there is a latitude circle where the mean temperature of the sea is constant through its entire depth. North of this line, located at 56° S and having a temperature of 39.5° F, the sun warms the sea to temperatures above this mean temperature such that at 45° S the mean temperature line has descended to 600 fathoms. The limit of the sun's influence was ascertained to be 1200 fathoms, at which latitude the surface temperature was 78◦ F. Similarly, the mean temperature line descends to the south of the circle where it exists at a depth of 750 fathoms at 70° S, above which the temperature decreases to a surface minimum of 30° F. The latitude of the circle corresponds closely to the mean position of what is now known as the Antarctic Convergence, thus leading to Ross identifying an important oceanic feature for the wrong reasons. The figure of 39.5° F was used because Ross, throughout his 3 year voyage, consistently measured temperatures at depths as great as 1200 fathoms but never record a temperature lower than 39.5° F due to pressure distortion effects on his thermometers. See Deacon [1971].

Circumpolar Deep Water (CDW) The most extensive water mass found in the ACC, CDW is usually further split into Upper Circumpolar Deep Water (UCDW) and Lower Circumpolar Deep Water (LCDW). UCDW is characterized by an oxygen minimum and nutrient maxima (with sources in the Indian and Pacific Oceans) as well as by a relative minimum in temperature south of the Subantarctic Front (SAF) induced by the overlying Antarctic Intermediate Water (AAIW) and Winter Water. LCDW is characterized by a salinity maximum and nutrient minima derived from North Atlantic Deep Water (NADW).

The source region of the split (and LCDW) is in the southwest Atlantic where relatively warm, salty, oxygen rich and nutrient poor NADW meets the ACC just below the oxygen minimum therein, thus splitting the CDW into two parts. The upper branch of this split retains the oxygen minimum layer present before the split, with the lower branch also showing an oxygen minimum induced by high oxygen concentrations in both the overlying NADW and the underlying Antarctic Bottom Water. The latter minimum has been eroded via mixing by the time the LCDW reaches the Greenwich Meridian, to be replaced by a general increase in oxygen from the UCDW minimum to the bottom.

The oxygen minimum of the UCDW lies slightly below the phosphate and nitrate maxima. At the Drake Passage the concentrations in this minimum increase from 3.7 mL/L in the Subantarctic Zone (SAZ) to 4.1 mL/L in the Antarctic Zone (AZ). The NADW influx to the east of this reverses this trend such that concentrations decrease to the south at the Greenwich Meridian, e.g. from 4.2 mL/L near the SAF to less than 4.1 mL/L near the PF. The mean concentrations of the nutrient maxima at the Drake Passage or 2.42 μmol/L for phosphate and 35.4 μmol/L for nitrate. The phosphate maximum is eroded by NADW north of the PF such that it is reduced to 2.36 μmol/L at the Greenwich Meridian,

although it is unchanged south of the PF. The nitrate concentration erodes slightly to 34.8 μmol/L north of the SAF at the Greenwich Meridian, while it increases to as high as 36.8 μmol/L near the PF.

The mean salinity at the LCDW salinity maximum at Drake Passage is 34.729, the lowest in the Southern Ocean since there it is most remote from the NADW source of the maximum. The phosphate minima concentration at Drake passage is about 2.25 μmol/L while the nitrate minima is 32.5 μmol/L. That are reduced to, respectively, 1.98 μmol/L and 29.9 μmol/L, north of the PF at the Greenwich Meridian, with the concentrations reduced even south of the PF, although to a lesser degree.

The paths of LCDW in the Atlantic are summarized by Onken [1995]:

> In the Atlantic, LCDW is found in all basins. From the Argentine Basin it flows north and invades the Brazil Basin via the Vema and Hunter Channels and the Lower Santos Plateau. At the northern end of the Brazil Basin, the flow splits into an eastward branch through the Romanche Fracture Zone and a northwestward one, which spills over the broad equatorial sill into the Guiana Basin and finally into the North American Basin, where it can be identified up to 40°N. The eastern North Atlantic, that is, the Cape Verde, Canary and Iberian Basins, are supplied via the Vema Fracture Zone at ≈11°N. Here LCDW influence has been traced northward up to ∼32°N. The Sierra Leone and Angola Basins get their LCDW contribution through the Romanche Fracture Zone from the Brazil Basin; however, the abyss of the southwesternmost corner of Angola Basin is also partly influenced by LCDW, which originates from the Cape–Agulhas Basin and spills over deep sills in the Walvis Ridge named the Walvis Passage.

See Reid et al. [1977], Whitworth and Jr. [1987] and Onken [1995].

CIRFZ The Circulation in the Romanche Fracture Zone experiment took place in November–December 1994. It was a cooperative effort between American and French scientists aboard the N/O Le Noroit to study the movement of Antarctic Bottom Water (AABW) through the Romanche Fracture Zone. During the 20 day experiment 55 HRP profiles and more than 30 CTD stations were completed, with most of the work concentrated in and around the Zone. Twelve more HRP dives comprising two equatorial sections were made after the work in the Zone to examine the structure of the deep equatorial jets. It was found that very strong eastward velocities in the deepest part of the Zone were responsible for high levels of turbulent mixing of the AABW. See Polzin et al. [1996] and Montgomery [1996].

CITHER Acronym for CIrculation THERmohaline, a French program to study the South Atlantic equatorial and meridional boundary regions. This was part of the French contribution to WOCE and was funded by CNRS, IFREMER and ORSTROM, and was carried out by scientists from CEN/Saclay, Université de Bretagne, Occidentale, IIM/Vigo (Spain), Univeristy of Bremen (Germany) and BNPL/Sequim (USA). According to the web site:

> CITHER is an experimental programme in physical and geochemical oceanography aiming at a better description and understanding of the general circulation of the South and Equatorial Atlantic, and the contribution of this oceanic region to the global thermohaline circulation. It rests on the realization of five large scale hydrographic lines of the WOCE Hydrographic Programme (WHP) and their analysis both in themselves for local studies, and in association with other hydrographic lines and Lagrangian measurements for more synthetic approaches of the whole South Atlantic region.

See Arhan et al. [1998].

`[http://www.ifremer.fr/lpo/cither/]`

C–LAB Acronym for Communication–Linked Automatic Buoy, a moored oceanographical and meteorological buoy system operating in Prince William Sound, Alaska since late 1991. This started out as part of the CFOS project but became part of the SEA project in 1994. The buoy is moored to the southeast of Naked Island, Alaska in water 190 m deep. It is usually deployed in late February or early March and recovered in late November. C–LAB consists of a suite of meteorological instruments to measure wind speed and direction, air temperature, and barometric pressure. Water temperature measurements are made at 11 different depths, and there is a fluorometer at 10 m depth to measure the fluorescence of microscopic phytoplankton. Data are collected 12–18 times per day via the ARGOS system. See the C–LAB Web site[17].

clapotis More later.

Clausius-Clapeyron equation An equation expressing rate of change of the saturation vapor pressure with temperature. It is given by

$$\frac{de_w}{dT} = \frac{L_v}{T(v_v - v_w)}$$

where e_w is the saturation vapor pressure, T the temperature, L_v the latent heat of vaporization, v_v the specific volume of the vapor phase, and v_w the specific volume of the water phase. This is given approximately by

$$L_v(T) \simeq 2.5008 \times 10^{-6} - 2.3 \times 10^3\, t \; J\,\mathrm{kg}^{-1}$$

where t is the temperature in degrees Celsius.

CLIMAP Acronym for Climate: Long-Range Investigation Mapping and Prediction, a project started in 1971 by a consortium of scientists from many institutions to study the history of global climate over the past million years, particularly the elements of that history recorded in deep-sea sediments. One goal of CLIMAP, the Last Glacial Maximum Project, was to reconstruct the boundary conditions for the climate 18,000 years ago to serve as boundary conditions for atmospheric GCM simulations. See Project [1976] and Project [1981].

climate Traditionally defined in terms of the mean atmospheric conditions at the earth's surface. Peixoto and Oort [1992] offer the more technical and broader "set of averaged quantities completed with higher moment statistics (such as variances, covariances, correlations, etc.) that characterize the structure and behavior of the atmosphere, hydrosphere, and cryosphere over a period of time." Any definition as least implicitly involves some sort of averaging procedure to distinguish the climate from that more instantaneous quantity we call the weather.

climate drift The divergence of a coupled atmosphere-ocean numerical model simulation from an initial or observed state due to imbalances between the components. See also systematic errors and flux correction. The origin of this drift is the mismatch between the externally-prescribed air-sea surface fluxes used to drive each model during the spin-up phase and the surface fluxes computed by the coupled model once the ocean and atmosphere components are joined. Sources for this difficulty involve shortcomings in the simulation of extensive layers of marine stratocumulus clouds in tropical and sub-tropical regions, errors in surface fluxes, insufficient model resolution, spin up and initialization difficulties, sea ice representation problems, and the treatment of the vertical penetration of heat into the ocean. This has also been called solution drift. See Sausen et al. [1988], Manabe and Stouffer [1988], and Meehl [1992].

[17] http://murre.ims.alaska.edu:8000/~eslinger/CLAB/clab.html

climate forcing agents Any of several factors which can change the balance between the energy (in the form of solar radiation) absorbed by the Earth and that emitted by it in the form of long-wave infrared radiation, i.e. the radiative forcing of climate. Examples include changes in the amount or seasonal distribution of solar radiation that reaches the Earth due to Milankovitch forcing, changes in the albedo due to desertification, deforestation, or changes in ice area, and the absorption of solar radiation by aerosols in the atmosphere.

Clyde Sea See Simpson and Rippeth [1993].

CME Abbreviation for Community Modeling Effort, a WOCE component to design and execute a series of baseline calculations of the wind- and thermohaline-driven, large-scale ocean circulation, to make comparisons of these simulations with observations, and to evaluate the performance of the models and identify needed improvements. See the CME Web site[18].

CMICE See Current Meter Intercomparison Experiment.

CMIP Abbreviation for Coupled Model Intercomparison Project, an analog of AMIP for global coupled ocean–atmosphere general circulation models. It began in 1995 under the auspices of CLIVAR and is supported (as is AMIP) by PCMDI. The purpose of CMIP is to examine climate variability and predictability as simulated by the models, and to compare the model output with observations where available. See the CMIP Web site[19].

CMO Abbreviation for Coastal Mixing and Optics program, a project to study the mixing of ocean water on the continental shelf, and the effect of the mixing on the transmission of light through the water.

`[http://wavelet.apl.washington.edu/CMO/]`
`[http://www.whoi.edu/science/AOPE/cofdl/cmo/]`

cnoidal wave A periodic wave that can have widely spaced sharp crests separated by wide troughs, not unlike the wave froms just outside the breaker zone near the shore. Limiting cases of cnoidal waves include solitary waves (when the wave period becomes infinite) and Airy waves, although the mathematical difficulties of the theory have kept it from such wide application. The cnoidal wave profile is given by

$$\eta = H \,\mathrm{cn}^2 \left[2K(\kappa) \left(\frac{x}{L} - \frac{t}{T} \right), \kappa \right]$$

where L is the wavelength, T the period, H the wave height, $K(\kappa)$ the complete elliptic integral of the first kind of modulus κ, η the coordinate of the water surface above the trough level at the horizontal coordinate x, and $\mathrm{cn}(r)$ the Jacobian elliptic function of r (from whence comes "cnoidal" analogous to "sinusoidal"). See Komar [1976] and LeMehaute [1976].

COADS Acronym for Comprehensive Ocean Air Data Set, a CGCP program to update and enhance the most extensive and widely used set of surface marine data available for the global ocean over the past 150 years. See the COADS Web site[20].

COAMPS Acronym for Coupled Ocean Atmosphere Mesoscale Prediction System, a numerical weather prediction model of the NRL.

COARE Acronym for Coupled Ocean-Atmosphere Response Experiment, a TOGA experiment conducted in thr equatorial western Pacific from November 1992 through February 1993. The stated aims of COARE were to describe and understand:

[18] http://www.ucar.edu/oceanmodel.html
[19] http://www-pcmdi.llnl.gov/covey/cmip/cmiphome.html
[20] http://www.ncdc.noaa.gov/onlinedata/coads/coads.html

- the principal processes responsible for the coupling of the ocean and atmosphere in the western Pacific warm pool system;
- the principal atmospheric processes that organize convection in the warm pool region;
- the oceanic response to combined buoyancy and wind stress forcing in the western Pacific warm pool region; and
- the multiple scale interactions that extend the oceanic and atmospheric influence of the western Pacific warm pool system to other regions and vice–versa.

Additional information can be found at the TOGA COARE Web site[21]. See Webster and Lukas [1992] and Godfrey et al. [1998].

COAST A 5–year interdisciplinary research project on cross–shelf transport processes in a wind–driven system. This is sponsored by the NSF and part of the CoOP program. The program consists of field experiments off the Oregon coast along with coordinated ocean circulation, ecosystem and atmospheric modeling. COAST started in early 2000, with major field work taking place in summer 2001 and winter 2003. The major participants are Oregon State University, the University of North Carolina and LDEO.

`[http://damp.oce.orst.edu/coast/]`

COAST Acronym for Coastal Observation and Simulations with Topography, a PMEL program. COAST was conducted from Nov. 30 to Dec. 15, 1993 and the purpose was to collect the observations needed to document and ultimately anticipate the influence of orography on mesoscale weather phenomena in coastal environments. The objectives were:

- to identify conditions that contribute to the development of coastally trapped disturbances during periods of strong but relatively uniform onshore flow; and
- to observe the mesoscale structure of fronts and other features associated with baroclinic cyclones over the open sea, and describe their evolution as they come under the influence of orography.

See Bond et al. [1997].

`[http://www.atmos.washington.edu/~gcg/MG/coastsum.html]`

Coastal Mixing and Optics Project (CMO) A project funded by ONR and performed by the Ocean Physics Laboratory at ICESS. The objective is to determine how particles and optical properties respond to physical forcing under various oceanic conditions on a broad continental shelf off the east coast of the U.S. This will be done by collecting time series of optical and physical data from several depths using a variety of newly developed optical and physical instruments placed on a mooring at a mid–shelf location. See the CMO Web site[22].

coastal trapped wave To be completed.

COASTWATCH See Espedal et al. [1998].

COBSEA Acronym for Co-ordinating Body of the Seas of East Asia.

CODAR Acronym for Coastal Ocean Dynamics Applications Radar.

[21] http://www.coare.ucar.edu/
[22] http://www.icess.ucsb.edu/opl/cmo.html

CODE Acronym for Coastal Ocean Dynamics Experiment, a program to study shelf processes that took place north of San Francisco during the summers of 1981–1982. The program employed drifters, hydrographic measurements, Doppler–acoustic surveys, wind measurements, and remote sensing to study a prominent, persistent filament near Point Arena. It was notable for the first integrated use of remote sensing for a study of this magnitude, the first coastal use of the ADCP, and the introduction of a new generation of high quality near–surface drifters. It led to a clear understanding of regional scale wind driving and provided a moored array data set still uses as the standard to test models. See Davis [1985], Winant et al. [1987] and Lentz and Beardsley [1991].

COHMAP The Cooperative Holocene Mapping Project (COHMAP) was an initiative to assemble a global array of well-dated paleoclimate data and use a GCM to identify and evaluate causes and mechanisms of climate change over the last 18,000 years. See Project [1988].

COLD Acronym for Coupled Ocean–Ice Linkages and Dynamics, a research program whose components include LTER, RACER and SANTA CLAuS. See the COLD Web site[23].

cold start problem In climate modeling, this is a problem that results from beginning a model simulation at a point in time when the climate response to natural and anthropogenic forcing that happened before the start of the simulation is already in progress. An example would be specifying 1950 initial conditions for a simulation of the effects of anthropogenic CO2 increases when the CO2 increases although the CO2 increases started in the latter half of the 19th century. This results in a simulation that is missing at least 50 years of the time evolution of the modeled system's response to increasing atmospheric CO2, which can be vital to the prediction of future states of a system with components that change on time scales greater than 50 years, e.g. the ocean.

Columbia Current (CC) According to Strub et al. [1998]:

> The Columbia Current flows to the north next to the coast off northern Ecuador and Columbia and is strongest in austral winter (August). It is confined to the top 100 m, reaches velocities of order 1.0 m s^{-1} and stays within 100–200 km of the coast. During most periods, it forms the eastern limb of a cyclonic gyre that fills the Panama Bight.

See Wooster [1959] and Strub et al. [1998].

Columbia River Estuary See Sherwood et al. [1990].

COMAR Acronym for Coastal Marine Program, a UNESCO project.

Comprehensive Ocean Air Data Set This is an extensive data set that was created by combining, editing and summarizing global in situ marine data from many sources. It covers the period 1854-1992. It is a cooperative project among ERL, NOAA, the NCDC, CIRES and NCAR. Extensive hypertext documentation[24] is available. There is also a further processed version of this data set called UWM/COADS. See Woodruff et al. [1987].

computational grid A mapping of discrete points onto a continuum (e.g. the ocean, the atmosphere, etc.) to comprise a grid-like structure. This is done to enable a numerical solution of the equations governing the specific continuum in cases where analytical solutions are impossible or infeasible due to irregular boundary conditions, nonlinearities in the governing equations, or some combination thereof. A discretized version of the equations is solved at each point in the grid, and the collection of these

[23] http://hahana.soest.hawaii.edu/hotcold.html
[24] http://www.ucar.edu/dss/pub/COADS.html

solutions is combined (usually graphically) to recover a continuum-like solution. It is hoped that this solution well approximates the hypothesized correct solution.

computational mode An artifact of numerical solution procedures that use a centered scheme for temporal advancement, i.e. one that requires information at three time levels. Starting such a scheme requires two independent initial conditions, one specified and the other calculated from this using a temporal scheme requiring only two time levels. This results in a solution that is actually the sum of two solutions, one related to the actual physics of the problem and the other purely an artifact of the numerical procedure. The numerical solution usually alternates at each time step, resembling a sawtooth wave over time, and can be damped by averaging the solution over two consecutive time steps at suitably chosen intervals. See Kowalik and Murty [1993].

concentration basin See mediterranean sea.

cone See fan.

CONFLUENCE A program to investigate the upwelling region and mixing of the Rio Plata into the southwest Atlantic Ocean.

conservation laws More later.

consistency In numerical modeling, a numerical computational scheme is said to be consistent if the discrete algebraic equations created by the process of discretization recover or reduce to the original continuum differential equations as the spacing in the computational grid is shrunk to zero. The scheme is said to be unconditionally consistent if the above is true no matter how (i.e. in what order, etc.) the grid is shrunk. Thus consistency deals with relations between equations in their continuum versus discrete forms, as opposed to convergence.

continental margin The official IHO definition for this undersea feature name is "the zone, generally consisting of shelf, slope and continental rise, separating the continent from the deep sea floor or abyssal plain; occasionally a trench may be present in place of a continental rise."

continental rise The official IHO definition for this undersea feature name is "a gentle slope rising from the oceanic depths towards the foot of a continental slope."

continental shelf See shelf.

continental slope The relatively steep slope usually found between the continental shelf and the abyssal plain. Continental slopes range from 3 to 6° in slope (with 4° being about average), range in depth from 100-300 m to 1400-3200 m, range in width from 20-100 km, and occupy about 8.5% of the ocean floor if the 2000 m contour is taken as the deeper border. The continental shelf and slope are said to comprise the continental margin.

Continental Slope Current A persistent poleward flow over the continental slope region off northwestern Europe. It is thought to originate as far south as the Armorican Slope region off the west coast of northern France, and flows north past the exit of the Faroe–Shetland Channel. This current supplies the saltiest and warmest water exchanged over the Greenland–Scotland Ridge, a water mass known as North Atlantic Water. See Hansen and Osterhus [2000] and the references therein.

continental shelf oceanography See Allen et al. [1983], Brink [1987], Walsh [1988], Brink [1991] and Huyer [1990].

continental shelf wave To be completed.

Continental Water Boundary (CWB) In physical oceanography, a frontal region in the Southern Ocean located at around 61-62° S that separates the Continental Zone to the south and its separate water mass of uniform temperature and low salinity in the upper 500 m from the Antarctic Zone to the north. The term was introduced to demarcate the northern limit of a cold water mass (colder than about 0°C) near the South Shetland Islands having a subsurface isothermal layer extending from about 150 m depth to more than 500 m. See Tomczak and Godfrey [1994], pp. 76. This is also known in the Weddell Sea region as the Weddell Gyre Boundary.

Continental Zone In physical oceanography, a region in the Southern Ocean between the Southern ACC Front and the continent of Antarctica. It is characterized hydrographically by a water mass of uniform temperature and low salinity in the upper 500 m. The CZ is one of four distinct surface water mass regimes in the Southern Ocean, the others being (to the north) the Antarctic Zone (AZ), the Polar Front Zone (PFZ) and the Subantarctic Zone (SAZ). See Orsi et al. [1995].

continuity equation See Sander [1998].

continuous plankton meter A device used by biological oceanographers to provide continuous qualitative and quantitative records of plankton distribution and patchiness when studying swarms over large areas. The meter is a square or round torpedo-shaped tube about 1 m long that is towed behind a ship underway at full speed. There is a small entrace hole in the front end which leads to a wider tunnel across which a band of silk gauze is stretched. This gauze is slowly wound from one spool to another via a propeller mechanism attached to the outside of the meter, thus being linked to the speed of the meter and therefore the distance it has traveled. Data gathered with the meter is considered supplementary to other types of net tow data gathered separately at individual stations. See Sverdrup et al. [1942].

contra solem A term introduced by V. W. Ekman in 1923 to describe motion turning to the left (right) in the northern (southern) hemisphere, i.e. cyclonic motion. This is the reverse of cum sole.

contrail cirrus A type of cloud hypothesized to form when water vapor within jet aircraft plumes undergoes homogeneous and/or heterogeneous nucleation processes upon which ice particles form and grow. They persist for only a short time if the ambient air is dry, but may last for minutes to hours and spread into linear formations a few kilometers in width and tens of kilometers in width if humid conditions prevail. They also tend to cluster in groups. Various investigations attempting to show a connection between them have at least showed a correlation between increased use of jet fuel in some regions and the average annual number of clear days. See Liou [1992].

convective adjustment In the numerical modeling of ocean circulation, this is a process wherein, after each time step, the vertical potential density gradient is calculated and, if densier water anywhere overlies lighter water, the densities are mixed such that a state of either a neutral or slightly positive stability is created. This process numerically mimics the convective overturning processes observed and inferred in the real ocean at locations such as the Weddell Sea, although the real process takes place at spatial scales on the order of a kilometer or less while the model resolution is such that the spacing between grid points is usually much greater than this.

convergence In numerical modeling, a numerical computational scheme is said to be convergent is the solutions to the discrete algebraic equations created by the process of discretization approach the solutions of the original continuum differential equations as the spacing in the computational grid is shrunk to zero. Thus convergence deals with relations between solutions of equations in their continuum versus discrete forms, as opposed to consistency.

CONVEX–91 Acronym for CONtrol Volume EXperiment, 1991, a survey designed to investigate the shape and strength of the Northeastern sector of the North Atlantic subpolar gyre, and to examine the exchanges between the upper and deep waters of the area. This was part of the Gyre Dynamics Experiment, itself part of WOCE core project 3. See Read [2001].

conveyor belt A simple model of a closed global thermohaline interbasin exchange circulation scheme introduced by Broecker [1987], Broecker [1991], and Gordon [1986]. Cold and salty deep water formed in the Norwegian/Greenland Sea (called NADW) flows southward as a deep current where around 30% is transported via the ACC to the Indian and Pacific Oceans. The flow travels northward along the western boundaries of these oceans and upwells in the northern portions. This drives a warm, shallow return flow that travels from the Northern Pacific through the Indonesian Archipelago and the Indian Ocean (gaining the water upwelled there) towards the South Atlantic via the southern tip of Africa. There it is joined by the remaining 70% that mixed with AAIW and returned to the South Atlantic via the Drake Passage. A general northward flow returns the water to the North Atlantic. The regions of deep water formation around Antarctica form AADW which flows under and mixes with the NADW, forming another component in the mixture. This is a simple (and to some an overly simplistic) view of the thermohaline circulation, but it is useful as a first order description. A more complete and accurate version of the interbasin exchange circulation pattern has been developed.

cooscillating tide The tide created in an estuary caused by the ocean tide at the entrance to the estuary acting as a driving force. See Officer [1976].

COPE Acronym for Coastal Ocean Probing Experiment, a NOAA ETL experiment which took place in 1995. The objectives were to determine how environmental conditions affect observations of internal waves with active and passive microwave sensors, to develop improved instrumentation and techniques for observation of the air–sea interface, and to evaluate new scattering theories. See Trokhimovski et al. [2000]. See the COPE Web site[25].

COPS Acronym for Coastal Ocean Prediction Systems Program.

coral bleaching A phenomena wherein coral reefs bleach as a result of high temperatures or other environmental stresses, e.g. pollution episodes. Observations indicate that since 1979 bleaching episodes have coincided with El Nino war events and suggest that the scale of bleaching since 1979 is unprecedented since 1870. See Goreau and Hayes [1994] and Glynn [1993].

coral reef A limestone structure found in relatively shallow water composed of corals, organisms that secrete limestone foundations to provide structural support and protection. There are three geomorphologically distinct types of coral reefs, fringing reefs, barrier reefs, and atolls, although there are gradations between these types. All these types have the same basic biological structure and result from the same processes of accretion. See Wells [1957] and Barnes and Hughes [1988].

Coral Sea A marginal sea located in the southwest Pacific centered at about 155° E and 14° S off of the northeast coast of Australia. It is also bordered by the Solomon Islands and Papua New Guinea to the north and west, New Caledonia and the New Hebrides Islands to the east, and abuts the Tasman Sea to the south. The bathymetry is essentially composed of the Solomon Basin to the northwest, the Coral Sea Basin in the center, and the New Hebrides basin to the east. It has a mean depth of about 2400 m with a maximum depth of 9140 m in the New Britain Trench. The shallowest parts are found on the continental shelf off of Queensland. See Rotschi and Lemasson [1967].

[25] http://www6.etl.noaa.gov/projects/cope.html

core layer method A systematic attempt to apply hydrography to describe the waters of the ocean as developed by Wust and his students in the 1930s. In this method he distinguished between different core layers characterized by maxima or minima in their oxygen, salinity or temperature fields. While of unquestioned descriptive value, this method has some significant limitations. The number of layers that can be identified using this techique is limited, e.g. Wust identified just seven such layers in the North Atlantic, a shortcoming ameliorated by the development of the isopycnal method. Also, these layers were too often uncritically assumed to be the main paths of ocean circulation, an assumption that has been proven to be incorrect on more than one occasion.

Coriolis acceleration An acceleration, the magnitude of which for a particle moving horizontally on the surface of the Earth is $2\Omega V \sin\phi$ where Ω is the angular velocity of the rotation of the Earth, V the vector velocity relative to the Earth's surface, and ϕ the latitude. This acceleration is directed perpendicular to the direction of V and to the right (left) in the northern (southern) hemisphere. There are other terms for three-dimensional motion in GFD, but they are generally negligible.

Coriolis effect The denotes the effect of the Coriolis force to deviate a moving body perpendicular to its velocity.

Coriolis force The force which, acting on a given mass, produces the Coriolis acceleration. It is a fictitious force introduced to facilitate the application of Newton's second law of motion to a rotating reference frame. See Persson [1998].

Coriolis parameter This is defined by

$$f \;=\; 2\Omega \sin\phi$$

where Ω is the angular velocity of the rotation of the Earth and ϕ the latitude. This gives the Coriolis acceleration on a moving particle when multiplied by that particle's velocity.

CORK Acronym for Circulation Obviation Retrofit Kit, a device that allows boreholes to be isolated from the ocean water above the seabed and conditions in the hole to be monitored for long periods of time. CORK's purpose is to provide a long–term seafloor observatory intended to allow a monitored and accessible borehole to return to its pre–drilling state.

The CORK data logger can record temperature and pressure data for five years, and store it in memory for an additional five years until it can be retrieved via either a manned submersible or a ROV. The data is obtained by a string of sensors hanging from CORK at the bottom of the borehole. It also has fittings for recovering samples from inside the hole and allows fluid to be injected into the hole for certain kinds of tests.

`[http://www-odp.tamu.edu/sciops/labs/downhole/cork.html]`
`[http://www-odp.tamu.edu/dsd/TOOLS/CORK.HTM]`

COROAS Acronym (in Portuguese) for Oceanic Circulation in the Western Region of the South Atlantic, a Brazilian research program whose objective was to determine the seasonal mean fields of velocity, heat and mass transport by the Brazil Current and the AAIW flowing into the coastal region of southeastern Brazil. The specific objectives included:

- estimating the baroclinic and barotropic components of the circulation along the Brazilian coast, including the continental shelf and shelf break regions, between Ubatuba and Cananéia;
- continuously monitoring the velocity field and heat and mass transports of the Brazil Current and AAIW along the southeastern Brazilian coast;
- determining the importance of mesoscale vortices to the heat and mass transport of the Brazil Current;

- determining the response of the continental shelf water to the forcing of intrusions by the Brazil Current and AAIW; and
- studying the deep circulation in the Brazil Basin, including its interaction with the Argentine Basin.

The experiment took place from November 1992 through February 1994.

[http://www.labmon.io.usp.br/projects/coroas/coroas.html]

CORSA Acronym for Cloud and Ocean Remote Sensing around Africa, a project which aims to provide a quality controlled data set of surface, atmospheric and cloud parameters over a time period and at a resolution not available from any other source. The data are derived from NASA AVHRR GAC level 1b data products, with over 13,000 of these products having been processed. See the CORSA Web site[26].

COSNA Acronym for Composite Observing System for the North Atlantic.

Costa Rica Coastal Current (CRCC) A current found entirely in the eastern tropical Pacific. It begins just offshore of the Panama Bight where the North Equatorial Countercurrent (NECC) ends to the east of the Galapagos, and turns to the north off the coast of Central America and Mexico. It meets the southward flowing California Current around the mouth of the Gulf of California. The position of this confluence varies seasonally, with the meeting occurring off Tehuantepec during March and April, and off Baja California during September and October. After this confluence, it turns west to become part of the North Equatorial Current (NEC). The presence of this current is inferred mostly from large–scale hydrographic measurements. The northern part of this is sometimes called the Mexican Current.

During the winter months, strong winds cross Central America through several isthmuses, e.g. Tehuantepec and Papagayo. These disturb the Costa Rica Coastal Current by spinning up a wind jet across the shelf, and intense cooling of the sea surface beneath the jet results from the upwelling and entrainment of subsurface water. Large anticyclonic warm core eddies develop to the right (north) of the wind jet, along with weaker, short–lived cyclonic counter–eddies to its left (south). An average of five of the anticyclonic eddies are spun off each year. See Badan-Dangon [1998].

Costa Rica Dome A region centered to the west of Central America around 8–10°N and 88–90°W and about 200 to 400 km wide. Open ocean upwelling causes a domelike configuration of the local well–defined thermocline, bringing nutrients to the photic zone and sustaining increased biological productivity. This cyclonic gyre is located between the North Equatorial Countercurrent (NECC) to the south, the Costa Rica Coastal Current (CRCC) to the east and north, and the extension of the California Current and beginnings of the North Equatorial Current (NEC) to the north and northwest. See Wyrtki [1964], Umutani and Yamagata [1991] and Badan-Dangon [1998].

cotidal line Lines joining the points where high water occurs at the same time. The lines show the lapse of time between the moon's transit over a reference meridian (usually the Greenwich meridian) and the occurrence of high water for any point lying on the line.

coupled model In climate modeling this refers to the combination of an atmospheric GCM with some sort of ocean model rather than the simple specification of SSTs as a lower boundary condition. From simple to complex, the ocean model hierarchy used proceeds from swamp ocean models to slab ocean or mixed-layer models to oceanic GCM models. See Meehl [1992] and Bye [1996].

Cox number See McDougall et al. [1987].

[26] http://me-www.jrc.it/CORSA/SST/corsa.html

CPOP Abbreviation for complex principal oscillation pattern, a generalization of the POP concept into the complex domain. Although this was introduced to extend the POP technique to the modeling of standing wave oscillations, it was also found the CPOPs evolve more regularly and with less noise than POPs. Also, prediction skills are significantly stronger than with the POP model. See Burger [1993].

CPR Abbreviation for continuous plankton recorder. See Reid et al. [2003].

CREAMS Acronym for Circulation Research of the East Asian Marginal Seas.

`[http://hikari.riam.kyushu-u.ac.jp/creams.html]`
`[http://sam.ucsd.edu/onr_jes/onr_jes.html]`

Cretan Arc Straits According to Kontoyiannis et al. [1999]:

> The Cretan Arc is the region that extends from the southern part of Peloponissos (at Elafonisos), through the islands of Kithira and Antikithira, along Crete to the islands of Kassos, Karpathos and Rhodes, and ends at the Asia Minor Coast to the north of Rhodes. It consists of a series of straits with complex bathymetry, which are gateways connecting the South Aegean Sea with the Ionian Sea to the west and the Levantine Sea to the east. On the eastern side, there are the Kassos Strait (∼65 km width, ∼900 m sill depth), the Karpathos Strait (∼40 km width, ∼850 m sill depth), and the Rhodes Strait (∼15 km width, ∼350 m sill depth). On the western side are the Antikithira Strait (∼30 km width, ∼700 m sill depth), the Kithira Strait (∼35 km width, ∼160 m sill depth) and the Elafonisos Strait (∼10 km width, ∼180 m sill depth).

The results of their flow measurement program in the straits contradict the traditional characterization of typical inflow/outflow at the surface/bottom, i.e.

- a deep, persistent outflow of Cretan Deep Water (CDW) ($\sigma_\theta > 29.2$), with a total annual mean of ∼0.6 Sv through the Antikithira and Kassos Straits at depths below 400 m and 500 m, respectively, with the highest outflowing transports (∼0.8 Sv) in April–June and the lowest (∼0.3 Sv) in October–December;
- a weakly varying (from 1.7 to 2.1 Sv) inflow in the upper 400–500 m of the Rhodes and Karpathos Straits, which is affected by the Asia Minor Current;
- a net outflow in the upper 400 m of the Antikithira and Kithira Straits, which is influenced by the Mirtoan/West Cretan Cyclone and varies seasonally from ∼2.5 Sv in early winter to ∼0.8 Sv in summer/early autumn.
- a complex and highly variable flow regime in the Kassos Strait, governed by interactions among the East Cretan Cyclone, the Ierapetra anticyclone, and the westward extension of the Rhodes Gyre, e.g. a net inflow of ∼0.7 Sv in autumn/early winter of one year and a net outflow of 0.5 Sv in the early spring/summer of the next year.

See Kontoyiannis et al. [1999].

Cretan Intermediate Water (CIW) A modified form of Levantine Intermediate Water (LIW) that enters the southern Aegean Sea as LIW via the eastern Cretan Straits and is ventilated and transformed by convective processes to become a slightly denser intermediate water mass. See Theocharis et al. [1999].

Cretan Sea According to Georgopoulos et al. [2000]:

> The Cretan Sea is the southernmost, largest in volume and deepest (2500m) basin of the Aegean Sea. It communicates with the Levantin Basin and the Ionian Sea through the eastern and western straits of the Cretan Arc respectively, through sills that are no deeper than 700m. To the north of the Cretan Basin is the shallow (<200 m) shelf of the Cyclades Plateau. The hydrology and the water mass dynamics of the south Aegean Sea have been known from the historic works of Lacombe et al. [1958] and Ovchinnikov [1966], and were reviewed by Malanotte-Rizzoli and Hecht [1988].

This is supplemented by Theocharis et al. [1999]:

> The Cretan Sea constitutes the larger and deepest basin of the south Aegean with an average depth of 1000 m and contains two depressions in the eastern part reaching 2500 m. To the northwest the Mirtoan basin reaches 1000 m. Between the Mirtoan and Cretan Sea depths are of the order of 600 m. The Cretan Sea is bounded to the north by the Kiklades Plateau at a depth of 400 m and to the south by the Cretan Arc islands. It communicates with the Ionian and the Levantine Seas through a series of six Straits, namely the Cretan Arc Straits. These are characterized by high relief and have sill depths ranging from 150 to 1000 m. Outside the Straits the sea bed plunges towards the deep basins of the Hellenic Trench (depth ∼3000-4000 m).

Theocharis et al. [1999] summarize the water mass pathways and dynamics in the Cretan Sea region:

> Modified Atlantic Water (MAW) comes from the western Ionian and is carried within the surface and/or sub-surface layers by the Mid–Mediterranean Jet (MMJ) and its branches; it enters the Cretan Sea mainly through the Antikithira Strait but occasionally through the Kassos Strait. Black Sea Water (BSW) flows in at the surface from the north and west Aegean and reaches the Mirtoan Sea. At times its influence can be traced as far as the Kitherian straits. The Asia Minor Current (AMC) carries the surface saline waters of Levantine origin towards the south Aegean that subsequently extend over large areas of the Cretan Sea. This input leads to the formation of highly saline Cretan Intermediate Water (CIW) within the Cretan Sea. Variability in the salinity of CIW can be attributed to the extent to which MAW participates in the formation process. However, we also detected less saline intermediate water being formed within the Cretan Basin, as well as intermediate waters with deeper characteristics most probably having their origin in the Mirtoan Basin.
>
> Thus, the intermediate water masses are represented at different areas in the θ-S diagram. Consequently, we clearly distinguish the typical LIW that enters the Aegean through the straits both from the Levantine and the Ionian Seas, as well as the more saline CIW and the colder and denser Mirtoan Intermediate Water (MIW). Interestingly, the latter flows southwards and, being dense enough, sinks in the deep troughs of the western Cretan Sea, thus probably contributing to the formation of the new very dense Cretan Deep Water (CDW) in the Cretan Sea. Moreover, a well-defined intermediate 'minimum temperature and salinity' Transition Mediterranean Water (TMW) layer in the south Aegean Sea is a new and important structural feature. Its appearance might be related to the CDW outflow towards the deep and bottom layers of the eastern Mediterranean. TMW enters the south Aegean through the Cretan Arc Straits, follows two opposite paths and fills the entire Basin. Recently, the CDW has been making a considerable contribution to the formation of the new, warmer, saltier and denser Deep Water observed in the Eastern Mediterranean, that has been displacing the Eastern Mediterranean Deep Water (EMDW) of Adriatic origin, not only in the adjacent open sea regions outside the Aegean Sea, but also more distantly in the Ionian and Levantine Seas. Thus the Cretan Sea is the unique source of the new type of EMDW.

> Finally, we have identifed the densest water mass of the south Aegean, Mirtoan Deep Water (MDW), that is almost totally isolated in the deep and bottom layers of the Mirtoan Basin. Both MIW and MDW possibly have their origins in the neighbouring Kiklades Plateau. The new hydrological vertical structure of the Cretan Sea is characterised by the superposition of three or four basic water masses, which develops significant thermohaline gradients between them. This new structure is limiting the depth to which convective mixing extends to $<\sim$250 dbar; in the past it was considered that homogenisation of the entire water column was possible. This also indicates that the 'new' CDW has its origin in the surrounding areas, as the Kiklades Plateau and/or the Mirtoan Basin. The persistence of the basic circulation elements and the vertical hydrological structure throughout the observation period indicate that a rather stable regime is reached. However, in the context of the drastic changes occurred during the last seven years in the deep thermohaline cell of the eastern Mediterranean, we would consider this regime transitional.

This body of water has also been (mostly historically) called the Sea of Crete and the Sea of Candia. See Theocharis et al. [1999], Balopoulos et al. [1999] and Georgopoulos et al. [2000].

Cretan Sea Overflow Water (CSOW) A designation proposed for a new deep water mass formed in the Cretan Sea. CSOW is warmer ($\theta > 13.6°$C) and more saline (S > 38.80) than Eastern Mediterranean Deep Water (EMDW). The formation of CSOW is an event of relatively recent origin, and is part of recent overall changes observed in the thermohaline circulation of the Eastern Mediterranean. The transition is mainly from a system with a single source of deep water in the Adriatic Sea (EMDW) to one with an additional source in the Aegean Sea (CSOW).

Other observed changes have been (according to Klein et al. [1999]):

> All major water masses of the Eastern Mediterranean, including the Levantine Intermediate Water (LIW), have been strongly affected by the change. The stronger inflow intoxi the bottom layer caused by the discharge of CSOW into the Ionian and Levantine Basins induced compensatory flows further up in thexi water column, affecting the circulation at intermediate depth. In the northeastern Ionian Sea the saline intermediate layer consisting ofxi Levantine Intermediate Water and Cretan Intermediate Water (CIW) is found to be less pronounced. The layer thickness has been reduced by factor of about two, concurrently with a reduction of the maximum salinity, reducing advection of saline waters into the Adriatic. As a consequence, a salinity decrease is observed in the Adriatic Deep Water. Outside the Aegean the upwelling of mid-depth waters reaches depths shallow enough so that these waters are advected into the Aegean and form a mid-depth salinity-minimum layer. Notable changes have been found in the nutrient distributions. On the basin-scale the nutrient levels in the upper water column have been elevated by the uplifting of nutrient-rich deeper waters. Nutrient-rich water is now found closer to the euphotic zone than previously, which might induce enhanced biological activity. The observed salinity redistribution, i.e. decreasing values in the upper 500–1400 m and increasing values in the bottom layer, suggests that at least part of the transition is due to an internal redistribution of salt. An initiation of the event by a local enhancement of salinity in the Aegean through a strong change in the fresh water flux is conceivable and is supported by observations.

See Klein et al. [1999].

Cromwell Current See Equatorial Undercurrent.

cryosphere That part of the climate system consisting of the ice fields of Antarctica and Greenland, other continental snow and ice fields, sea ice and permafrost. At present the Antarctic ice sheet holds 89.3%

of the total global ice mass, with the Greenland ice sheet holding 8.6% and mountain glaciers and permafrost holding 0.76% and 0.95%, respectively. The remaining 0.39% is distributed among seasonal snow and sea ice. See Untersteiner [1984], Hibler and Flato [1992], and Van der Veen [1992].

CRYSYS Acronym for CRYospheric SYStem, a Canadian interdisciplinary science investigation under the NASA EOS program. The goals of CRYSYS are to develop capabilities for monitoring and understanding regional and North American variations in cryospheric variables, to develop and validate local, regional and global models of climate/cryospheric processes and dynamics, and the assemble, maintain and analyze key historical, operational and research cryospheric data sets. See the CRYSYS Web site[27].

C–SALT Acronym for Caribbean–Sheets and Layers Transect, a combined mesocale, fine– and microstructure survey of the well–ordered thermohaline staircase in the tropical North Atlantic east of Barbados. Such staircases are thought to be the sites of enhanced vertical mixing by the salt finger form of double–diffusive convection. The C–SALT program was a coordinated attempt to measure the intensity of salt finger convection, monitor the finescale shear and density environment, establish the lateral extent of the layered structure, and collect velocity, hydrographic and tracer data needed to evaluate the role of the fingering processes in the regional evolution of water properties. The experiment was carried out in the spring and autumn of 1985 in an area centered at about 57°W, 12°N at the confluence of the high salinity Subtropical Underwater (SUW) at 150 m depth and the fresher Antarctic Intermediate Water (AAIW) at 750 m depth. The superposition of these two extrema gives rise to a strongly destabilizing vertical salinity gradient, i.e. the main determining factor for staircase formation.

The C–SALT program found a large, coherent, and long–lived thermohaline staircase in its study area. The occurrence of mixed layers at the minimum density ratio and the observed water mass transitions within layers indicate that salt fingers make a substantial contribution to both maintenance of the staircase and vertical mixing. See Schmitt et al. [1987].

CSCS Abbreviation for Chukchi Sea Circulation Study.

CSEC Abbreviation for Central South Equatorial Current.

CSR Abbreviation for Cruise Summary Report. See ROSCOP.

CSW Abbrevation for continental shelf wave.

CTD In oceanography, an abbreviation for Conductivity-Temperature-Depth, an instrument for performing oceanographic measurements. The CTD measures (either directly or indirectly) the three most important oceanographic parameters for describing the distribution of water in the ocean: temperature, salinity, and pressure.

CTDO Abbreviation for Conductivity-Temperature-Depth-Oxygen profiler.

CTW Abbreviation for coastal trapped wave.

CTZP Acronym for the Coastal Transition Zone Program, a research program that took place in 1987 and 1988 off the northern coast of California. The important questions this program attempted to address were the physical and biological nature and structure of cold filaments, what causes a filament to form, and the physical and biological characteristics of a filament. In order to address these questions the program included a modeling effort and divided the field effort into a pilot and a main program.

[27] http://www.dow.on.doe.ca/CRYSYS/

The pilot program took place in 1986–1987 and had the goals of gaining some three–dimensional information about biological, chemical, and turbulent processes in a filament as well as to gain further background information about the detailed physical structure. It included four large–scale, coarsely resolved surveys from San Francisco to northern California, taking place in both winter and summer. The goal was to see if filaments or related currents could be identified when upwelling was not present, thus confirming or denying the hypothesis that filaments are related to coastal upwelling.

The main program took place in summer 1988 and consisted primarily of a time series of repeated maps meant to chart out the time dependence of a single filament near Point Arena, California. It also allowed for well–sampled repeat sections of microstructure variability and detailed biological process measurements. The objective was to characterize the detailed temporal evolution of a filament and the processes that maintain its structure. See Brink and Cowles [1991].

CU Abbreviation for California Undercurrent.

CUE Acronym for Coastal Upwelling Experiment, an IDOE project.

CUEA Acronym for Coastal Upwelling Ecosystems Analysis, an IDOE project. See Smith [1981] and Barber and Smith [1981].

cum sole Descriptive of rotation in the same sense as a vector that points toward the sun, i.e. motion turning to the right (left) in the northern (southern) hemisphere, i.e. anticyclonic motion. This term, along with the opposite contra solem, was coined by V. W. Ekman in 1923.

curl The curl of a vector field is a measure of its rotational motion, i.e. when applied to the velocity vectors of air or water motion, the curl is nonzero if the parcel is spinning. In mathematical terms, the divergence of a vector function is defined by

$$\nabla \times A$$

where ∇ is the gradient operator that operates with a vector (or cross) product on the vector field A. See Dutton [1986].

current A flow of water within the sea which is coherent at least in a time–averaged sense. The currents identified as such in the world ocean include: Agulhas Current, Agulhas Return Current, Alaska Coastal Current, Alaska Current, Aleutian Current, Algerian Current, Anadyr Current, Angola Current, Antarctic Circumpolar Current (ACC), Antilles Current, Azores Current, Baltic Current, Benguela Current, Bering Slope Current, Brazil Current, California Current, Canary Current, Caribbean Current, Central South Equatorial Current, Chile Current, China Coastal Current, Cromwell Current, Davidson Current, Davidson Inshore Current, Delware Coastal Current, East Australian Current, East Arabian Current, East Africa Coast Current, East Auckland Current, East Cape Current, East Greenland Current, East Icelandic Current, East Indian Current, East Korea Current, East Spitsbergen Current, Equatorial Countercurrent, Equatorial Intermediate Current, Falkland Current, Florida Current, Gaspe Current, Guineau Current, Guyana Current, Haida Current, Hopen–Bjornoya Current, Humboldt Current,

current meter See Gould [2001] for a historical overview.

Current Meter Intercomparison Experiment (CMICE) See Beardsley et al. [1981].

CW Abbreviation for Central Water.

CWB Abbreviation for Continental Water Boundary.

cyclone An atmospheric pressure distribution in which there is a low central pressure relative to the surroundings. The circulation around the center is anticlockwise (clockwise) in the northern (southern) hemisphere.

cyclonic The direction of rotation around a center of low pressure. This is counter-clockwise in the northern hemisphere and clockwise in the southern. The term originates from the circulation observed around tropical cyclones.

cyclosonde A device that allows the profiling of the water column by alternately rising to the surface and sinking to a predetermined depth. It does so by adjusting its buoyancy. This device can be used as a platform for a variety of instruments. See Van Leer et al. [1974].

cyclostrophic wind A theoretically hypothesized wind that would exist, when blowing around circular isobars, as a balance between the pressure gradient and the centrifugal force. The Coriolis force is neglected, and as such this is a useful approximation only in low latitudes, e.g. in tropical cyclones.

CZCS Abbreviation for Coastal Zone Color Scanner, a scanning radiometer with six spectral channels centered at 0.443, 0.520, 0.550, 0.670, 0.750 and 11.5 micrometers and selected to allow measurement of ocean color and temperature, suspended sediment and chlorophyll concentrations, and ocean pollutants. It works by measuring the ratio of different colors of visible light, with the basic idea being that the higher the concentration of chlorophyll-a in the water column, the greater the proportion of light in the peaks of its absorption spectrum that will be missing. This measurement is used as a proxy for the amount of phytoplankton primary production going on in the water column.

The CZCS sensor operates in the visible portion of the spectrum so it can only collect data in clear sky conditions. This leads to the necessity of taking multi-year averages over some areas, e.g. the Indian Ocean, to get useful images. The device resolution is 800 m. This instrument flew aboard the NIMBUS-7 satellite and was active between November 1978 and June 1986. Other ocean color sensors are being launched between 1996-1998, including NASA's SeaWiFs, NASDA's OCTS, and DLR's MOS.

The CZCS data is classified into various product levels depending on the processing of the data and what type of ancillary data is include. Level 0 data is the raw binary sensor counts recorded for radiation at 6 wavelengths. A Level 1 data product is the raw binary sensor counts cut into 2 minute scenes and bundled with orbital and atmospheric data. A Level 2 data product is a processed product where a sensitivity loss correction, atmospheric correction, and chlorophyll derivation algorithm have bee applied to a level 1 product to calculate surface reflectances, land/cloud flags, subsurface reflectances, atmospheric signals, and chlorophyll concentration.

A Level 3 Primary product is generated by remapping a number of level 2 products from the same day to a fixed geographical area, with the areas known as basins. This uses the orbital and geo-referencing data from the Level 1 product and applies a coastline feature matching algorithm. The basins are calculated in Alber's equal area projection with a 1 km pixel size. A Level 3 composite product is generated by calculating the average cholorophyll value for each pixel over a number of Level 3 Primary products. See the CZCS Dataset Guide Document[28].

[28] http://daac.gsfc.nasa.gov/DATASET_DOCS/czcs_dataset.html