Oceanology
Crossing the Atlantic
on the Akademik Ioffe

Text and photos
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"The subject of oceanology is the study and research of the totality of events taking place in oceans, seas and lakes," wrote geographer, academician and founder of Russian oceanology, Juli Shokalskiy, in 1917. Oceanology, or oceanography[1] as it is more commonly called in the West, is an integral part of natural sciences. The ratio of water to land on the planet Earth is approximately 71 to 29 percent. Furthermore, water surface is not only greater in square kilometres, but it is also continuous—whereas, land surface is finite and presented by separate parts washed over by the world's oceans. So, in essence, oceanography studies this one continuous body of water, the World Ocean!

By this point in history, nobody had yet taken the responsibility of determining the validity of oceanography as a science. Historically, if not considering Moses from the Bible to be the first oceanographer (as he parted the Red Sea, allowing his people to escape their pursuers at the right moment)[2], exploration of the oceans was conducted by "Homo Curious"—from the very first people to venture out into the open sea up to the great explorers of the Imperial Age.

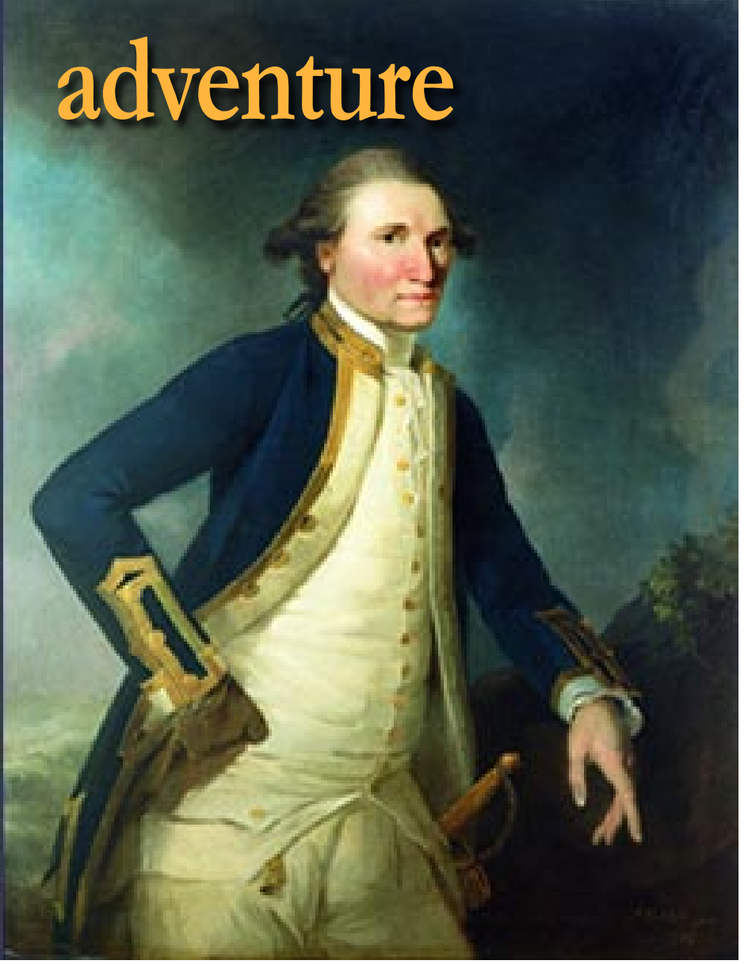
The exploration of the oceans occurred in parallel with the development of other sciences, cartography in particular. Every new heroic expedition acquired new data, descriptive at first (as in the early period of the great geographic discoveries) rather than numerical, such as depth measurements and ocean bottom relief views, grounds, temperatures, salinity, transparency and colour of oceanic water as well as direction and velocity of oceanic currents.

British expeditions led by James Cook in the late 18th century were considered to be the first scientific voyages. Three journeys taken by Cook, aimed at finding the southern continent, enriched the era's geographical knowledge greatly, both directly and marginally. On one hand, new lands were discovered (the eastern shores of New Zealand and eastern Australia), geographic maps were created, detailed reports were made and oceanographic data collected on the physical features of oceans and water movements.

On the other hand, the expeditions served as a challenging push for further expeditions. During the first voyage, for instance, no traces of an expected polar continent in the moderate latitudes of the Pacific Ocean were found. As a result, new French expeditions were sent there.

Crew members and research staff at work on bow of the *Akademik Ioffe*

Crossing the Atlantic



Portrait of Captain James Cook RN 1782, by John Webber. Collection: National Portrait Gallery, Canberra, Australia. Purchased in 2000 by the Commonwealth Government with the generous assistance of Robert Oatley and John Schaeffer

Great Britain was the first to estimate the importance and dominant position of the sea, including its scientific significance. The idea was actively accepted by France and also Russia from the beginning of the 19th century. After Cook's enterprises and until 1872, there were 29 expeditions undertaken around the globe, 11 of which were British and eight Russian. All in all, the number of scientific marine expeditions during that period amounted to 75.

The first round-the-globe trip by Russian sailors was made on board the ships *Nadezhda* and *Neva* in 1803-1806 under the leadership of Lieutenant Captain Ivan Kruzenshtern. The expedition ships parted company after rounding Cape Horn. *Nadezhda* turned to Kamchatka to explore Okhotskoe and the Japanese seas, and *Neva*, lead by Captain-lieutenant Juri Lisianski went to the Northern Pacific and to Alaska. The ships met up later and returned back around the Cape of Good Hope.

During that three-year journey, depth temperatures were measured as well as the first observations of vertical ranges at ocean depths made. Geographic discoveries in high Southern latitudes were accomplished within the Pacific archipelagos.

In 1819-1821, the Russian Marine Department organized the first Russian Antarctic expedition on board the military boats *Vostok* and *Mirnyi* under the general leadership of Captain 2nd rank Faddey Bellinsgauzen (Fabian Gottlieb von Bellingshausen who later rose to admiral). *Mirnyi* was captained by Michael Lazarev.

Their journey reached 69 degrees of Southern latitude when they discovered lands lying to the East of Cape Horn and made remarkable descriptions of geophysical aspects of the Southern Polar province.

The British round-the-globe oceanographic expedition of the *Challenger* (1872 -1876) was a key event in the development of oceanography. The expedition had vast aims: to study the ocean bottom landscapes and relief as well as observe physical, chemical and biological features on the surface and at depth. The composition of officers was selected with respect to the oceanographic research-oriented character of the expedition. Detailed "field" tasks were prepared, special devices were invented and designed, and laboratories were constructed.

The Naval wooden corvette *Challenger*, having clocked 68,900 sea miles, made 362 deep stations and determination at every point of depth and grounds. Bottom water samples were taken and temperature measured

Faddy Bellinsgauzen, 1778-1852
(Fabian Gottlieb von Bellingshausen)

on the bottom and at different depths. Surface currents were observed as well as some underwater currents. Meteorological observations were made every hour.

Challenger's accumulated data and reports (50 volumes!) appeared to be a special epoch in the development of oceanography. With *Challenger* came the understanding of the necessity of planned explorations. Since then, oceanographic studies have been part of obligatory programs for nearly every marine venue enterprise.

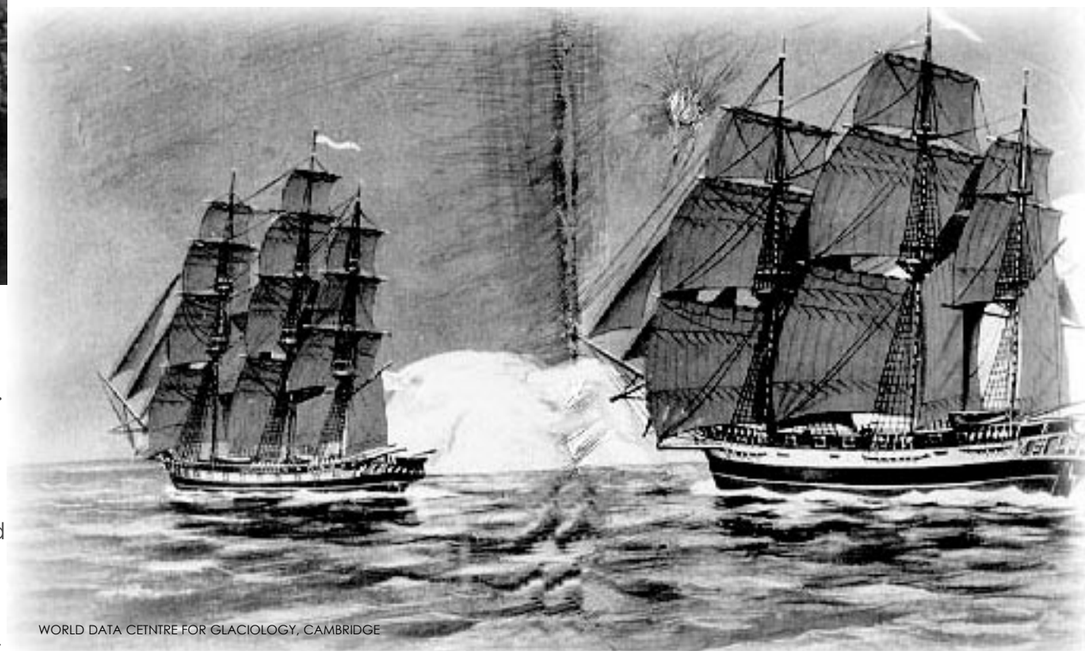
It is evident that a revolutionary change in the very approach to ocean science and to data collection has taken place during the last 100 years. This change is a transition from data collection by separate expeditions to global systematization of data collection and management of rational collection strategy.

The appearance of new technology—distant satellite research, computer processing of giant data files, new high precision measuring devices—all these provided the possibility of a qualitative jump in the 1960s, from a view of the ocean as an environment with features slowly changing in time and space to an understanding of the fact that in the ocean there exist lots of comparatively narrow zones with sharply changing parameters, oceanic fronts many kilometres wide whirling like atmospheric cyclones and anticyclones, which appear all the time—they appear, move and disappear. We now know that a so-called "thin structure" exists, which are steady layers of water having vertical dimensions of several meters and horizontal dimensions of several kilometres.

HMS Challenger, 1872. By William A. Herdman. Courtesy of the Freshwater and Marine Image Bank

Modern exploration of oceans

It is true that nowadays research vessels sailing under various flags are steadily tracing the World Ocean, from the



Vostok (East) and *Mirnyi* (Peaceful), 1819-1821

ABOVE: The churning Atlantic
RIGHT: Hoisting the carousel aboard

Equator to the Arctic and the Antarctic. There are nearly no "white spots", or unexplored areas on the map of our planet. But in the abyss, strikingly blue or iron-grey, there are lots of them. Moreover, all the processes taking place within the oceans are still not an open book for scientists at all.

Modern research is differentiated and multi-directional with sometimes fundamental and, at other times, applied importance.

First of all, there is the problem of climate and its variability. Knowledge of the nature of climate and the ability to forecast weather gives us the possibility to make sound decisions in the choices of prospective methods of development that are harmonious with the environment. Trade forecasts are also very important with regard to economic concerns as well as space and defence issues.

During research voyages, studies are made from the deck of the ship by remote methods. The practice of expedition study includes current velocity measurements, observation of light regimes and biotic factors of environment as well as measurements of hydro-chemical parameters. It is during the sea journey that one can touch "live" the main hydrological parameters that characterize sea water such as salinity, temperature and pressure—the so-called CTD parameters. They are some of the main topics of interest in physical oceanography. (See Block 1).

Cast off!

It is the summer of 2005, and I am heading out across the northern Atlantic Ocean on board the Russian research vessel, *Akademik Ioffe* (Block 2), which can not, of course, be compared with the *National* expedition that took this route in 1889[3]. It is practically regular now, this short scientific cruise. Russian oceanographers are completing it for the fifth time. The last three times took place annually, which consequently makes it possible to obtain a series of data with reliable observations for study of the variability of water masses, adding to repeated data gathering of sections by WOCE–CLIVAR in the North Atlantic Ocean[4].

ABOVE & INSETS: Sonding devices

The planned duration of this journey is a little less than three weeks. That much time is needed to head out of port from Gdansk, Poland, journey across the Baltic Sea, put out to the North Sea via the straits of Kattegat and Skagerrak around Denmark, reach 60 degrees northern latitude and cross the Northern Atlantic, record the oceanographic section from the Faroe Islands to Greenland, and then, turn to the south to reach Newfoundland.

Now out to sea, I see that the Gdansk port cranes disap-

LEFT: The windmills of Denmark
INSET: The port of Copenhagen

Denmark to Canada

peared from sight long ago, as well as the Danish wind mills producing electricity—the symbol of modern Denmark. The huge hull of our white ship breaks waves under the sunny blue skies of summer upon the North Sea. I see the stoic silhouette of the captain's bridge and steering deck-cabin where one can take in a grand view of all the space out to the very horizon, a forest of antennas on the upper deck and the navigator deck... Everything looks reliable and instills a sense of confidence.

But excitement is still palpable on deck. Anticipation is an essential component of the sailor's profession. And research always has a lot to consider.

A day in the life of *Ioffe*

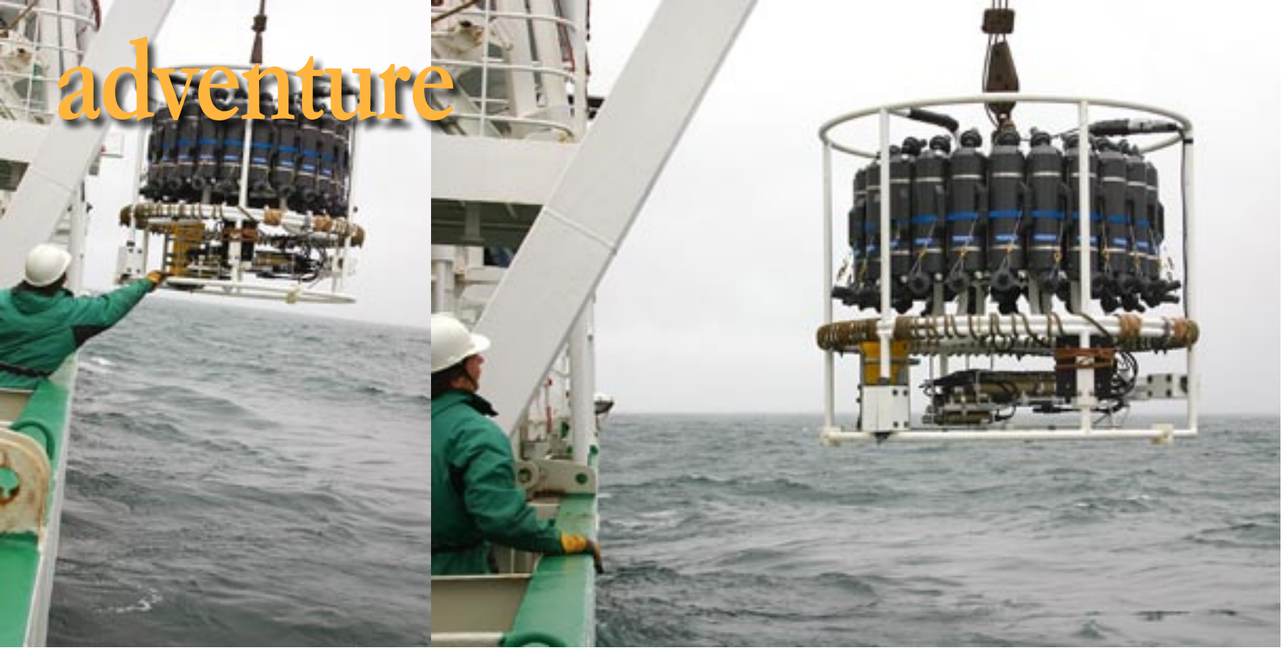
When the ship reaches 60 degrees latitude, work in the open sea begins. The scientific crew now labours in permanent round-the-clock shifts, and the chief of the expedition becomes the main director on board (after the captain, of course). The chief scientist is the person responsible for deciding whether to continue working or miss intermediate stations under severe weather and sea conditions.

The target: to collect data until we get to the very end of this ocean section. It may sound a bit dramatic, but obtained data—input of this expedition and the whole Russian national oceanographic science community—goes to the international cooperation and research effort.

The ship sails along a marked course and makes stops at points where deep measurements are planned. These are stops for hydrological stations with CTD-

In Russia, scientists play different roles at the same time—they are researchers, managers, providers, etc.. In foreign countries, it is not the same. Special managers are responsible for the technical provisions of the project and equipment. In Russia, all responsibilities are carried out by the chief of the expedition and the chiefs of various departments. Transportation of all the loads on board, winding of new rope to the operational winch, set-up of the research camp including unpacking and checking high-precision devices, preparation of work places, reliable fastening of computers and other devices onto tables —nobody can rule out roughness at sea. Vira slow!

Arriving in St. Jones, Newfoundland



THIS PAGE: Carousel deployment

Crossing the Atlantic

sensing ability (determining vertical profiles of electrical conductivity, temperature and depth) and water sampling (See Block 3).

Current ship time is 16:41:01, which means GMT (Greenwich) is 18:41:01. *Akademik Ioffe* slowly but steadily reaches the position of the planned stop for station #1152 (#36 according our section schedule), and the level of "scientific" activity on board increases dramatically.

Coordinates of this ocean section are 59 degrees 50 minutes Northern Latitude and 39 degrees 20 minutes Western Longitude. Supposed depth is 2,840 meters. Supposed duration of labour at this station is 2 hours 10 minutes.

The ship slows down. A monitor showing the parameters of our movement reveals steadily decreasing speed: 6.7 knots…. 5.6….. 1.6. One knot really means that the ship has come to a "stop". We have reached the station position, but the engines must continue to work. The captain cannot stop the engines completely under such rough conditions.

The water temperature is 9.6˚C. Air temperature is 7.3˚C. The deck is wet, splashed by the salty sea.

A complex device nicknamed "carousel" is prepared for deployment. Ropes that secure it on board are undone. The winch is readied. "Vira!"—Upwards!

The rosette of devices, guided carefully by strong men's hands, loses contact with the deck and moves forward above the gunwale and over board to hang above the water. Now, the trick is to catch the next wave. This construction weights 200 kg, but in the water, it achieves amazing buoyancy, so one must be extremely careful. Done. Slowly giving the rope to the winch, the carousel, looking like a turquoise jelly-fish, descends... disappearing from sight.

When deploying and raising up the sonde, it is very important that the process be very smooth, without jerking and bumping the deck, since it is upon these factors that the future fate of the rope, devices and cruise results depend.

In order to measure currents precisely, the rope with the devices, which reaches depths up to 3,000 meters, must be kept in a vertical position. This can be achieved only by the fine work of the navigator, especially with the wind velocity equalling 20 meters per second and swells as high as 6-8 meters while the ship moves in a direction opposite the wind.

At this time, any unfastened objects on the ship tend to float freely in space, so wet table clothes are placed on the tables in the saloon to avoid the "running away" of plates and covers. But the deck hands continue to work.

The men on duty watching corresponding data on a monitor screen, guide the winch-men: "Winch, 1,000 m passed... Continue to descend... Continue to descend." The ship goes up and down on the waves. Velocity is 1 knot, winds are 15.8 m/sec. The monitor shows the line of the rope with sonde deployment. The two kilometre mark is passed. "Winch, 500 meters to the bottom. Maina slow!". One must be extremely careful, even knowing that the ship is above a plain (lower terrain) and not above the Reykianess Range (oceanic ridge), for example.

...400 meters to the bottom... 200 meters to the bottom... "Winch, half... hundred meters to the bottom... Maina dead slow, 50 meters to the bottom, winch to stop! ...Winch here—stop."

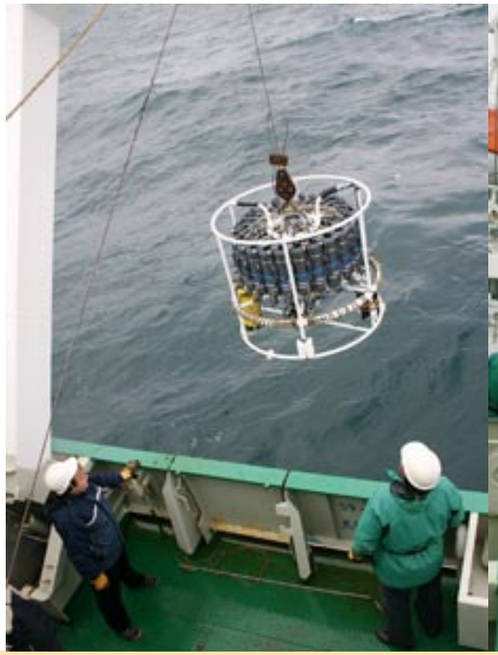
The signal to close the "deepest" bottle is sent by a simple movement of the computer mouse. Then, a smooth ascent begins with stops at previously planned depth values. Bottles, one by one, are forced to close after being filled with ocean water. Stops occur on levels that correspond with various water masses in order to get a uniform picture of samples along all water thicknesses and to determine the position of the nucleus of each water mass and the frontiers between them.

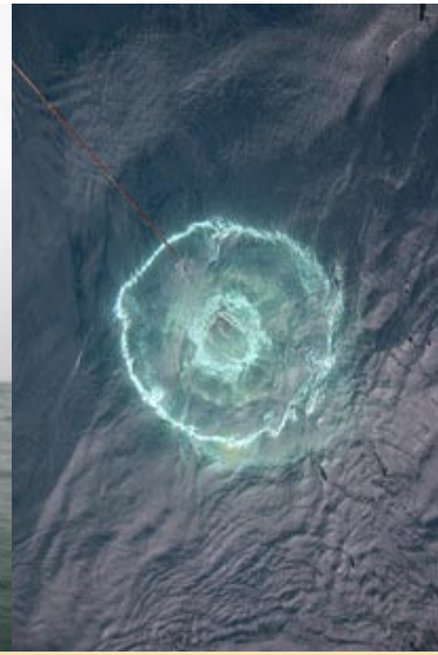
The next exciting moment is the instant when the carousel shows itself! The winch is ordered, "Vira slow!" The sonde is pulled over board by the hook, and the men carefully hoist the device onto the deck. Hydro-chemists hurry to take necessary quantities of deep ocean water for laboratory tests.

Gathering ocean water for investigation

The station is done, and the captain's bridge receives the order to continue moving ahead. The ship steadily increases its speed, and we move onward to the next planned station.

During this cruise, oceanographic section as long as 1,164 sea miles was completed. Complex measurements of sea water parameters from the surface to the bottom of the ocean were made at 40 points. At these stations, meteorological observations were made and gigabytes of information about acoustic features of the bottom were registered. The





Researchers working in labs and on deck

The P-Frame, a lifting device on the stern

data will be processed later when we return home.

Everything was okay. No extraordinary situations arose. Greenland glaciers appeared in the fog, and *Akademik Ioffe* turned to south towards St. Jones. Sometimes, to the left and to the right of the deck, little fountains appeared. Then humped backs appeared—whales were passing by heading in their own direction.

We met no ships coming or going—60 degree latitude is not the most popular route. It was just us and the ocean, which changed its colour from bright silver to mysterious blue. And the people on board were still not yet tired of looking into the very depths of the ocean. They are true romantics of oceanography who dreamt of sea journeys since their college days and consider scientific data obtained on these journeys to be more precious than publication in a foreign magazine or academic status.

International cooperation

Alex Sokov is the deputy director of the P.P. Shirshov Institute of Oceanology of the Russian Academy of Science and principal investigator of the Russian interdepartmental project "Meridian–Plus" of the Federal special program "World Ocean". Russian oceanographic research lies within the sphere of interests of international programs led under the patronage of the IOC UNESCO (International Oceanographic Commission), the WMO (World Meteorological Organization) and other intergovernmental organizations.

The North Atlantic research cruise is a good example of Russian participation in international research. Indeed, the North Atlantic is the very place that hosts one of the world's main regions for intensive energy exchange between ocean and atmosphere, which determines the moderate climate of Western Europe and the climate of the European part of Russia.

It is also here, where the Atlantic branch of the so-called "global convective circulation of the World Ocean" locks—turning from a northerly to southerly direction and heading downward. This circulation is similar to the ocean conveyor belt on the planetary scale, which transfers giant volumes of water masses between high and low latitudes of the main oceans—the Pacific, Indian and Atlantic.

The fact that European climate is determined by the character of energy exchange between ocean and atmosphere in the Northern Atlantic and the intensity of the conveyor belt at work has been known for several decades already, but many important details of this connection still need more quantitative specifications.

One of the problems that needs to be settled for the forecasting of climatic changes is: What factors cause fluctuations in the intensity of the conveyer belt activity within ten-year periods, and what atmospheric processes are "reliable" for that fluctuation? The

answers to these questions are very important just now when, during the past decade, unprecedented warming of the North Atlantic and Arctic Oceans have been observed.

That's why transatlantic cruises are so important. They are the Russian contribution to international programs such as CLIVAR (Climate Variability), NORDIC WOCE (North Ocean Circulation Experiment) and ASOF (Arctic Sub Arctic Ocean Fluxes). Not every state can afford to conduct full-scale oceanographic research on independent cruises. A full day's work on one of the ships belonging to the Institute of Oceanology, such as the *Akademik Ioffe* or *Akademik Mstislav Keldysh*, costs several tens of thousands of US dollars. To satisfy these costs, people in the Russian Institute of Oceanology, with the support of the Ministry for Economy of the Russian Federation, created and brought to life a successful pattern of partial funding of research cruises using recruited funds from tourist companies.

The results of every independently accomplished expedition enrich Russian science not only directly through research procedures and data obtained, but also indirectly. By contributing its input into international cooperation, Russia possesses equal rights to use the results obtained by other countries that accomplish programs within the framework of international projects—and that is necessary for acquiring an integral picture of the world.

Heading for the Antarctic

Measurements in the World Ocean are not limited by sonding from our ship's board. Data obtained during the

The *Akademik Ioffe*

Crossing the Atlantic

North Atlantic cruise of the research vessel *Akademik Ioffe* is being processed. Meanwhile, the other ship of the Institute of Oceanology, *Akademik Sergey Vavilov*, went out in October 2005 to complete the next cruise along another route: Kaliningrad (Russia) – Cape Town (SAR) – Antarctica – Ushuaia (Argentina). The Chief of Expedition was Dr Sergey Gladyshev, Russian coordinator of the international experiment researching the South Ocean for which such countries as Russia, France, Germany, SAR and USA participated and placed their research programs on board.

During this expedition and in addition to complex oceanographic measurements taken by the research staff, two autonomous floating buoys were launched supplied with navigational instruments and CTD sensors. The buoys are to float for the next two years in the rarely investigated region between the southern part of the Atlantic and Indian Oceans. Devices on the buoys will "shuttle" from the surface to a depth of 2,000 m and back scanning CTD parameters of water masses and transmitting the data via satellite upon surfacing. Satellite information will come to the data collection centre ashore.

After the successful launch of these two buoys, Russia gained operation of several similar devices in the World Ocean, which enables Russian scientists to use results from all the other buoys and a half-thousand similar devices (belonging to other countries) floating in other parts of the World Ocean.

Acoustic research in the Arctic

Dr Sergey Pisarev, coordinator of the Russian-American project ATOC (Acoustic Thermometry of Ocean Climate), is a leading research scientist of the P.P. Shirshov Institute of Oceanology of the Russian Academy of Science. He said that two original systems of acoustic thermometry have worked for more than one and a half years, all in all, in the Arctic Basin—the least accessible location for traditional oceanographic "contact" measurements.

The deep regions of the Arctic Ocean, the Arctic Basin, play a major role in forming global climate. Furthermore, these regions are very sensitive to fluctuations and possible climatic changes.

Acoustic thermometry is a method of remote observation of large-scale variation of temperature in the ocean. The method of acoustic thermometry of the ocean is based upon the almost linear dependence of the speed of sound underwater upon temperature. The system includes a fixed source (acoustic transmitter) and a receiver (array) in the ocean.

The first Arctic acoustic thermometry experiment took place in April 1994. Due to the efforts of the employers of several research bodies of the Russian Academy of Science, ice camp Turpan was established 300 km north of Spitsbergen. During the whole month, powerful Russian acoustic transmitters sent signals at 20 Hz across the entire Arctic Ocean to receiving arrays located at ice camp Narwhal in the Lincoln Sea and ice camp SIMI in the Beaufort Sea, covering distances of 2,100 and 1,200 km.

It became possible to measure, with great precision, the main parameters of the signals describing features of ocean water and sea ice cover. Acoustic monitoring in the Arctic was regarded as worthwhile by administrators, and in October 1998, within the frames of first-hand actions of the Russian Federal special program, "The World Ocean", a new and autonomous acoustic source was deployed by the Russian team at the sea bottom close to the shelf border northwest of the Franz-Joseph Land archipelago. This source, together with an American autonomous receiving array, worked nearly one and a half years. The processing of the enormous amount of data received from the device is only now being finished.

In particular, it was found that increasing temperatures of the Atlantic Layer in the Arctic ocean, which have been observed since the early to mid-1990's up to the present, did not take place uniformly, but occurred with arrivals to the Arctic Basin, from time to time, of anomalous warm "spots" of Atlantic origin. ■

COMMENTS

[1] In Russia, despite the fact that discussion about the application of the terms, *oceanology*, study of the ocean, and *oceanography*, description of the ocean, continues within the scientific community, both terms are used nearly equally nowadays. In foreign literature, the term *oceanography* is most often used.

[2] Munk, Walter. *The evolution of physical oceanography in the last hundred years.* Scripps Institution of Oceanography, La Jolla, California, USA.

[3] The German expedition on board the *National*, which investigated the Northern part of the Atlantic Ocean in 1889 accomplished the journey from Northern Europe approximately along the 60th degree Northern Latitude to Greenland, and further to the south, Newfoundland, then continued on to the Bermuda Islands.

[4] This hydrological section is assigned to Russia within the framework of the international program CLIVAR (Climate Variability). In 2005, 40 stations along 1,164 sea miles were checked. Measurements enable scientists to determine year-to-year variations of water features in the investigated region according to their thermohaline (variations of temperature and salinity) and hydrochemical parameters in the moment of sharp climate changes as well as changing of borders between separate water masses in the section by means of comparing the results with data received during previous sections in 1997, 2002, 2003, 2004.

LEFT: Carousel deployment
BELOW: Water sampling

Crossing the Atlantic

Block 1. CTD PARAMETERS

CTD parameters include conductivity, salinity, temperature and depth. Salinity is calculated through conductivity, and in fact, not the depth, but hydrostatic pressure is measured. Water temperature changes are usually accompanied by changes in other factors, most importantly in currents, which determine the physical features of water masses. CTD parameters serve as a basis for calculating important features of ocean water such as density, vertical stability, ductility, temperature of freezing, sound velocity and refraction of light coefficient. CTD parameters can be regarded as a signature, since they are the most independent group of parameters, different from the other environmental factors, which depend more or less upon salinity, temperature and pressure.

Salinity

Salinity is the saltiness or dissolved salt content of a body of water. Prior to 1978, salinity or halinity was expressed as ‰ ("promille"). In 1978, oceanographers redefined salinity in Practical Salinity Units (psu). Salinity depends on atmospheric precipitation, river drainage and evaporation from water surfaces. Changes in salinity influences changes in water density, thus participating in peculiarities in the formation and movement of water masses, influencing the character, direction and intensity of currents.

Temperature

Temperature depends on the quantity of solar heat meeting the water surface, water-atmosphere heat-exchange, closeness of big ice formations and oceanic currents. Ocean water temperature is measured directly with metallic resister thermometers and thermostats. Temperature influences the instrument error (faults, mistakes) of other sensors that have direct contact with water, which causes the necessity to introduce amendments to the results of measurements of other parameters.

Hydro-static pressure

Hydro-static pressure is needed for the determination of the depth to which measuring devices are deployed and at which other parameters are measured. At the same time, hydro-static pressure data are an inevitable part in the process of the determination of salinity and density of ocean water, sound velocity within water and some other water characteristics. The dependence between hydro-static pressure and the depth of device deployment is rather complicated, but for practical purposes, relatively simple equations connecting absolute pressure and depth are used.

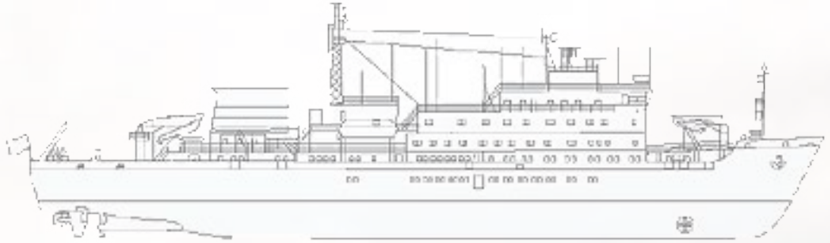
Block 2. *AKADEMIK IOFFE*

Akademik Ioffe is one of the research vessels of the P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences (IO RAS), sister-ship of the *Akademik Sergei Vavilov* based in Kaliningrad. It was built in Finland in 1989. Velocity: 10.5 knots (max – up to 15 knots). 6,700 tons displacement. Max length is 117.1 m, width 18.2 m, 6 m set. Board height is 10 m. The vessel is autonomous regarding fuel and water for 60 days. It can host 117 passengers on board with 43 crew members. There are various weight-lifting devices on board (i.e. cranes, winches), research instruments and equipment for complex studies of the ocean: deep water, multi-radial and parameter echo-sounders, side hydro-scanner, a system of dynamic positioning, modern navigational system GPS, automatic meteorological station, acoustic Doppler current gauge (measurement device), special hydro-acoustic complex, CTD's and water sampling devices, a station of registration and processing of satellite information. There are 12 laboratories on board—their general area is 300 square meters.

Block 3. DEVICES: CTD Sondes

CTD sondes are used widely to measure CTD parameters. Nowadays, it is the main device used during expedition research cruises. At every station of the section, a measuring complex is deployed practically to the sea bottom: a carousel with 24 5l-volume bottles (these are special vessels made of a chemically pure material for water sampling from

Crossing the Atlantic



Schematic of *Akademik Ioffe*

separate depth levels in order to examine salinity, dissolved oxygen contents, silicon and phosphates); oceanographic sonde, which continuously registers temperature, electrical conductivity, pressure, transparence; acoustic current speed and direction profiler; and an altimeter showing the distance between the deployed device and the sea bottom. CTD sondes make it possible to receive profiles (during vertical descent and ascent) of the vertical distribution of temperature and conductivity (salinity). Depending on the model, CTD sonde transfers information to an on board computer via special cables on-line or accumulates data in memory blocks of the sonde itself, to be retrieved after sonde ascent. The main producers of these devices are the American companies, Sea-Bird Electronics, Inc. and Falmouth Scientific, Inc., and Italy's IDRONAUT S.r.l.

Hydrological measurement complex

The 911plus is a premier real-time CTD accurate to the highest international standards. It features high resolution sampling (24 Hz), pump-controlled T-C ducted flow up to 10,500 meters (15,000 psi) depth capability, maximum auxiliary sensor flexibility and optional modem channel for Water Sampler control. The 911plus has eight 12-bit A/D channels, and supports redundant C&T sensors or custom auxiliary digital inputs. The 911plus consists of the 9plus underwater unit and the 11plus V2 Deck Unit.

The underwater unit for the 911plus CTD includes modular temperature and conductivity sensors with TC Duct, SBE 5T submersible pump, redundant T and C input channels, 8 differential inputs, low pass-filtered A/D channels, a water sampler modem channel, stainless steel guard cage and SEASOFT software.

The standard SBE 9plus underwater unit has an aluminium housing rated to 6,800 meters (22,300 ft) and is supplied with one conductivity and one temperature sensor (fitted with a TC Duct and constant-flow pump) and an internally mounted temperature-compensated Paroscientific Digiquartz pressure sensor for 6800 meters (10,000 psi) full-scale range. Input channels and bulkhead connectors are provided for an optional second (redundant) pair of temperature and conductivity sensors. Other standard features include an 8-channel, 12-bit A/D converter with differential inputs and low pass filters and high-power capability for support of commonly used auxiliary sensors (e.g., SBE 43 dissolved oxygen, SBE 18 or SBE 27 pH, transmissometer, fluorometer, ambient light, altimeter), a modem channel for real-time water sampler control and a port for connection of an optional bottom contact switch.

SBE 11plus V2 Deck Unit includes RS-232 and IEEE-488 computer interfaces, a modem channel for real-time water sampler control (including water sampler control push buttons and status lights), NMEA 0183 interface for adding GPS position to CTD data, 12-bit A/D input channel for surface PAR sensor, switch-selectable 115/230 VAC operation, audio tape interface (data backup), LED read out for raw data and audible bottom contact (or altimeter) alarm. The 11plus V2 also provides a remote pressure output (useful as an input signal for towed vehicle control) and a programmable serial ASCII data output containing up to seven variables in computed engineering units. Calibration coefficients are stored in EEPROM, and a separate micro controller converts raw CTD data to temperature, depth, salinity, etc. The 11plus V2 is shipped in a free-standing cabinet with a hardware kit for mounting in a standard 19-inch electronics rack.

Dr Sergey Pisarev on the *Akademik Ioffe* in Copenhagen

Receiving CTD data

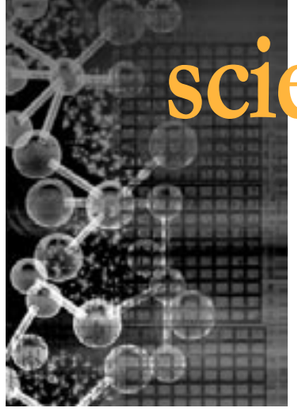
SEASAVE software is used to receive CTD data. It enables one to set the connection of the board unit and computer. This software makes it possible to determine ports and data transmitting velocity from the carousel, the order of bottles closing (one by one or in a given order). The software also provides the possibility to register GPS data into a CTD file or separately. During data transmission, one can see on one diagram the distribution of four given parameters with depth range.

Precision

Modern science demands measurement precision to the millesimal regarding temperature and salinity. During measurements in the ocean, precision of CTD measurements are lost mostly because of different inertia (Inertia: the time needed for the sensor to change its data, or testimony, due to penetration into new water layers with new dimensions of the measured environment parameters) of temperature and conductivity sensors. SBE company found the way to overcome different inertia of their sensors. The sondes are washed by water in a different regime—not like in real time, depending on descending sonde velocity, but uniformly, with fixed speed. The fixed speed is provided by a special pump that circulates sea water via sensors during sonding.

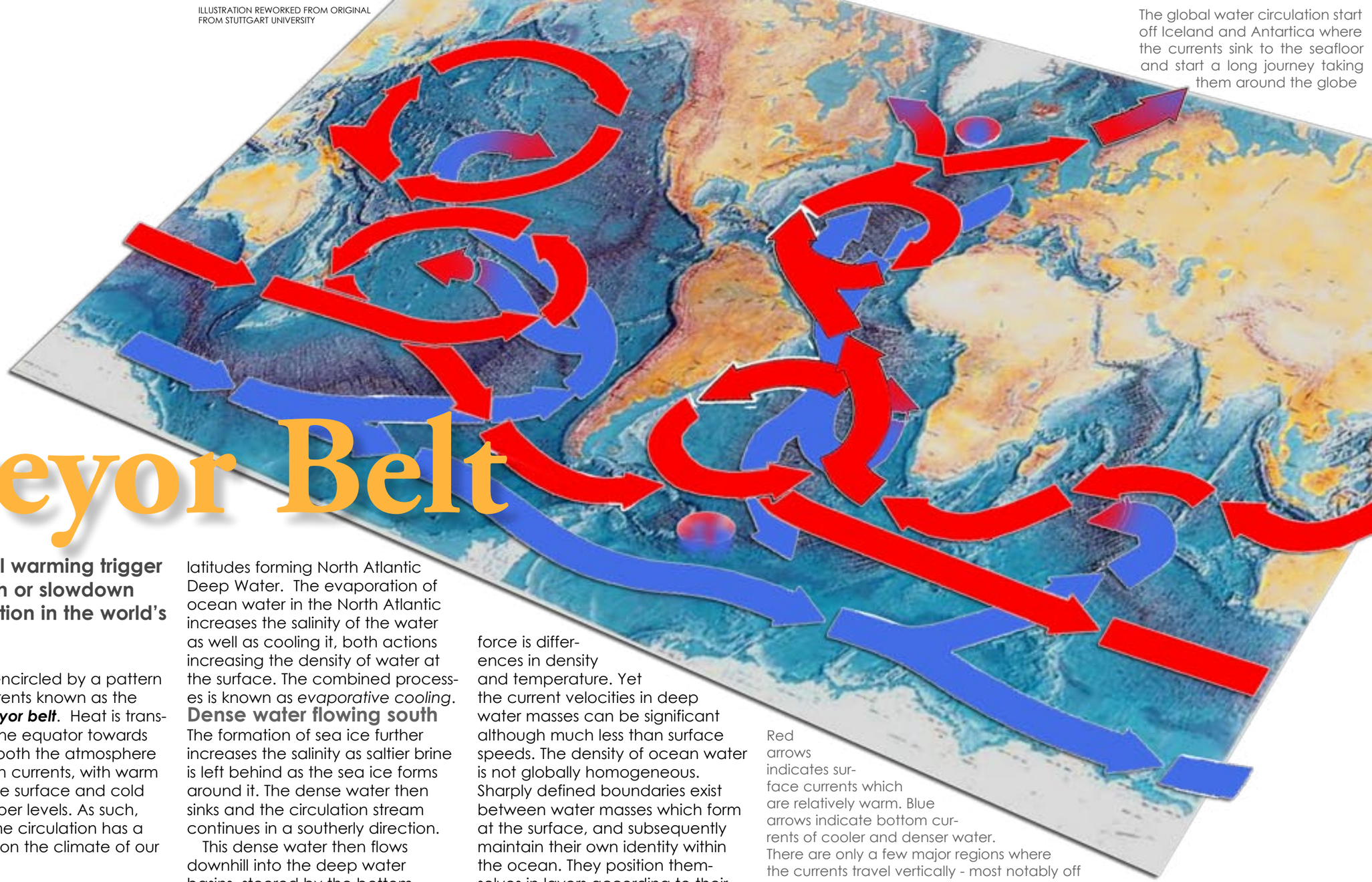
CTD data processing

Data processing is made with the assistance of SBE Data Processing software. Data processing consists of data levelling regarding pressure; data averaging in the given interval regarding pressure, depth and time of registration; introducing amendments; calculation of all parameters; filtration of data and creation of graphs and diagrams. ■



By Peter Symes

ILLUSTRATION REWORKED FROM ORIGINAL FROM STUTTGART UNIVERSITY



The global water circulation start off Iceland and Antartica where the currents sink to the seafloor and start a long journey taking them around the globe

The Thermohaline Circulation Conveyor Belt

The **thermohaline circulation** is the term for the global density-driven circulation of the oceans. Term is derived from *thermo* (heat) and *haline* (salt), which together determine the density of sea water.

The vertical exchange of dense, sinking water with lighter water below it is known as *overturning*. Hence, another name, emphasizing the vertical nature and pole-to-pole character of this kind of ocean circulation, is the **meridional overturning circulation**.

Can global warming trigger a shutdown or slowdown the circulation in the world's oceans?

The globe is encircled by a pattern of ocean currents known as the ***ocean conveyor belt***. Heat is transported from the equator towards the poles by both the atmosphere and by ocean currents, with warm water near the surface and cold water at deeper levels. As such, the state of the circulation has a large impact on the climate of our planet.

Gulf Stream

The best known segment of this circulation is the Gulf Stream, a wind-driven gyre, which transports warm water from the Caribbean northwards where its effect in warming the atmosphere contributes to warming Europe, cooling all the while and eventually sinking at high latitudes forming North Atlantic Deep Water. The evaporation of ocean water in the North Atlantic increases the salinity of the water as well as cooling it, both actions increasing the density of water at the surface. The combined processes is known as *evaporative cooling*.

Dense water flowing south

The formation of sea ice further increases the salinity as saltier brine is left behind as the sea ice forms around it. The dense water then sinks and the circulation stream continues in a southerly direction.

This dense water then flows downhill into the deep water basins, steered by the bottom topography, only resurfacing in the northeast Pacific Ocean some 1200 years later. Extensive mixing therefore takes place between the ocean basins, reducing differences between them and making the oceans one global system.

In the deep ocean, where wind is absent, the predominant driving force is differences in density and temperature. Yet the current velocities in deep water masses can be significant although much less than surface speeds. The density of ocean water is not globally homogeneous. Sharply defined boundaries exist between water masses which form at the surface, and subsequently maintain their own identity within the ocean. They position themselves in layers according to their density, which depends on both temperature and salinity. This is known as "stratification"

Deep water masses

The dense water masses that sink into the deep basins are formed in quite specific areas of the North Atlantic and in the Southern Ocean. In the Norwegian Sea evaporative cooling predominates, and the resulting sinking water mass, called the North Atlantic Deep Water starts a slowly southward flowing current. The route of the deep water flow is through the Atlantic Basin around South Africa and into the Indian Ocean and on past Australia into the Pacific Ocean Basin. There is no corresponding flow from the Arctic Ocean Basin into the Pacific as the narrow Bering Strait is too shallow. By contrast in the Weddell Sea off the coast of Antarctica near the

Red arrows indicates surface currents which are relatively warm. Blue arrows indicate bottom currents of cooler and denser water. There are only a few major regions where the currents travel vertically - most notably off Greenland and Antartica where the currents sink

It is not the thermohaline circulation that is the primary reason Western Europe is so temperate. Europe is warm mostly because it lies downwind of an ocean basin. However, the thermohaline circulation does warm Western Europe by about 2 °C relative to the similarly located west coast of Canada.

edge of the ice pack, the effect the sinking water masses is predominantly caused by brine exclusion when the surface waters freeze. The resulting water mass, the Antarctic Bottom Water, then sinks and flows north into the Atlantic Basin. It is so dense it actually flows under the North Atlantic Deep Water. Once, flow into the Pacific is blocked, this time by the Drake Passage between the Antarctic Peninsula and the southernmost tip of South America forcing the current eastward.

Upwelling

What goes down must come up elsewhere. All these dense water masses sinking into the ocean basins displace the water above them, so that elsewhere water must be rising in order to maintain a balance. However, because this thermohaline upwelling is very widespread and diffuse, it has proven quite tricky to measure where upwelling occurs using current speeds, given all the other wind-driven processes going on in the surface ocean.

Deep waters do however have their own chemical signature and tracking trace elements of silicon from deep water there is clear indications, though not solid evidence, that the bulk of deep upwelling occurs in the North Pacific. A number of other models of ocean circulation place most of the deep upwelling in the Southern Ocean, associated with the strong winds in the open latitudes between South America and Antarctica. ■

So, Will The Gulf Stream Close Down?

In 2004 an analysis of satellite data demonstrated the North Atlantic Gyre, the northern swirl of the Gulf Stream, has been slowing markedly over time. Also The National Oceanography Centre in the UK found a 30% reduction in the warm currents that carry water north from the Gulf Stream from the last such measurement in 1992.

There is, however, presently no evidence for cooling in northern Europe or nearby seas but for quite the reverse. The bulk of available evidence seem to point that the Gulf Stream is relatively stable, whereas there is possibly a weakening of the North Atlantic drift.

In May 2005, investigations under the Arctic ice sheet found that the giant columns of sinking water, in which the cold dense water normally sinks down to the sea bed and is replaced by warm water, in turn generating the North Atlantic Drift had virtually disappeared. Out of normally seven to twelve giant columns, only two were found, both extremely weak.

This has led to some fear that global warming may be able to trigger the type of abrupt massive temperature shifts which occurred during the last ice age. It is also thought that it was large influxes of low density meltwater from the Greenland ice sheet leading to a disruption of deep water formation and subsidence in the extreme North Atlantic that eventually caused the climate period in Europe known as the Big Freeze which lasted for about 70 years in the 1300's.

It is very unlikely

It is, however, by no means clear that sufficient freshwater could be provided to interrupt thermohaline circulation. Present climate models indicate that it is not the case. While previous prehistoric shutdowns have caused cooling, the current overall climate is different; and sea-ice formation in particular is less because of overall global warming. Modelling also suggests that increase of fresh water flows large enough to shut down the thermohaline circulation should be at least an order of magnitude greater than currently estimated - and such increases are unlikely to become critical within the next hundred years.

In coupled Atmosphere-Ocean models the Termohaline Calculation tends to weaken somewhat rather than stop, and the warming effects outweigh the cooling, even locally. The North Atlantic is, actually, currently warmer than in the earlier measurements suggesting that either the circulation is not weakening, or that it does not have the hypothesised cooling effect - or that other factors are able to outweigh any cooling. ■

Maldives

Sea Laboratory of Banyan Tree Vabbinfaru

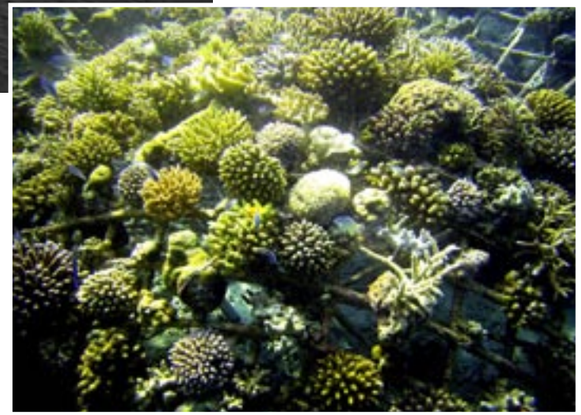
Text by Andrey Bizyukin, PhD
Photos by Andrey Bizyukin, Alexander Andrians and courtesy of the Marine Lab archives

What are the Maldives in a nutshell? Astonishing lagoons of turquoise and completely transparent water, dazzling white sands under a tropical sun, lush fig trees and coconut palms... all of these elements conspire to create this world renowned tropical paradise. Hundreds of thousands of divers and other holiday-makers aspire to come to the Maldives. Now imagine all these islands with all their sunbathers, snorkellers and divers, most of whom want to experience the wonders of the underwater realm, the corals, colourful tropical fishes, turtles, dolphins, and for a few brave souls, perhaps a shark or two. Needless to say, this constant year-round influx of humans has an effect on the coastal ecosystems of these tiny islands. How long this romantic legend, this tropical paradise with a worriless life under palm trees, cloudless blue skies and an ocean full of fish, can withstand the pressure remains an open question.

Sunset on the pier

◄ The islands of the Maldives with their long jetties stretching out over the reefs are surrounded by crystal blue waters. BELOW THREE PHOTOS: Measurements are taken in the coral growth study

Maldives



Enter the sea laboratory Banyan Tree Vabbinfaru, which, under the skillful direction of Abdul Aziz Abdul Nakim, is already working on solving some of these problems.

Very few individuals among the visiting divers seem to reflect much upon the fact that this wonderful underwater world can be destroyed in an instant. We need only to recollect the event of 1998 when excessively warm water brought to the islands by a very pronounced El Niño raised the temperatures of the surface layers of the ocean from 28-29° C to 30-31° C even in the area of the Maldivian islands, which lie in open ocean.

Just this seemingly insignificant increase in temperature of a couple of degrees causes bleaching, which ultimately, within a few weeks, leads to mass destruction of corals down to a depth of five meters.

The sea laboratory is located only 20 minutes by speedboat from Male, the capital of the Republic. But as you take the first step onto the island, it seems like you have reached another world.

This unorthodox scientific laboratory works in close collaboration with visiting divers. It is a very far cry from the usually dry and, at times, seemingly geriatric academia. Here, marine science is laid out bare for everyone to see and partake. Yet, researchers who are famous in their fields come here to conduct their research and to offer popular lectures on the latest scientific advances in straight-forward language.

The Maldivian archipelago is an unique underwater world where the ecosystem has had millennia to evolve and enter a steady state. However, they still remain fragile and prone to outside disturbances.

The sea laboratory is set to study all aspects of sea life and is simultaneously working in several key directions at once, explains Abdul Aziz.

The project: an artificial reef

The biggest flower in Banyan Tree Vabbinfaru is not something that grows on a stalk or a tree, but on a metal construction, 12 meters in diameter and four meters deep, welded from metal rods.

The structure has been nicknamed *Lotus* due to its superficial similarity to the famed flower, which in fact, does not grow on the island.

The Lotus sits on a shoal 20 meters west of the sunset jetty on the island. A constant electrical current of 3 volts flows through the metal, keeping a slight negative charge in relationship to the surroundings. Titanium plates with a positive electric charge of plus 3 volts are located around the perimeter of the metal construction, at a distance of 1 meter.

With the exception of the Lotus construction, most experiments here have been done with small metal pyramids welded from rods. Initially these structures look very much out of place and without an obvious purpose, but soon enough they start to perform their small miracles.

With the aid of electrolysis, the growth of small corals is stimulated and the framework turns into structures of corals with remarkable speed.

Fragments of corals are stuck in place with plastic fasteners to the metal lattice where the weak current induces rapid growth in the corals. They soon grow to cover the whole structure. Even slices of coral that were very sick, or almost dead, seem to liven up and start a phase of rapid regrowth once fastened to the structure. The symbiotic algae, the zooxantellea, which lives symbiotically within the coral, soon return to their hosts giving them their vibrant colours.

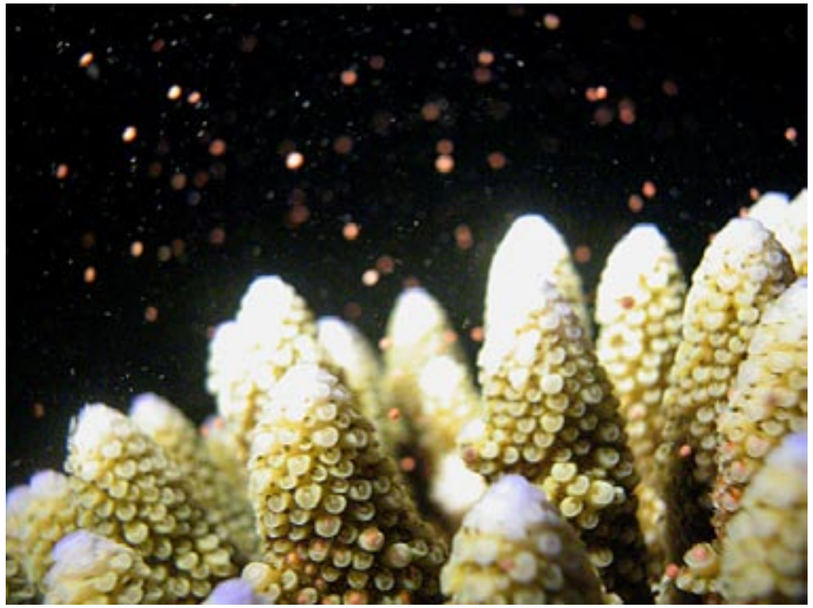
The results of the experiments have surpassed all expectations. The new corals, grown under somewhat artificial conditions, seem to be stronger and more resilient against the ravages of disease, pollution and the rising ocean temperatures.

Their apparent health is a testament to the successful growth of coral gardens even in the presence of certain other inhabitants of the sea. The predatory starfish, crown of thorns, for example.

Abdul Aziz Abdul Nakim

Maldives

A diver inspects the coral growth found on the 12m diameter and 4 meter deep metal construction, *Lotus*, created to stimulate coral growth with a constant low current of electricity. BELOW: Coral spawning



These starfish live off coral polyps and have ravaged huge areas of the Great Barrier Reef off Australia. Consequently, divers on the Maldives have always been keen to collect them and take them ashore and out of harms way in order to protect the corals.

In addition to the rapid growth of corals, huge congregations of butterfly fish also signals a healthy coral colony.

In order to manage the development of coral plantation at Banyan Tree Vabbinfaru, a technique is employed whereby hundreds of meters of cable are laid underwater to form the basis of artificial reefs. In this underwater laboratory, it is possible for eco-conscious visiting divers to participate in surveys.

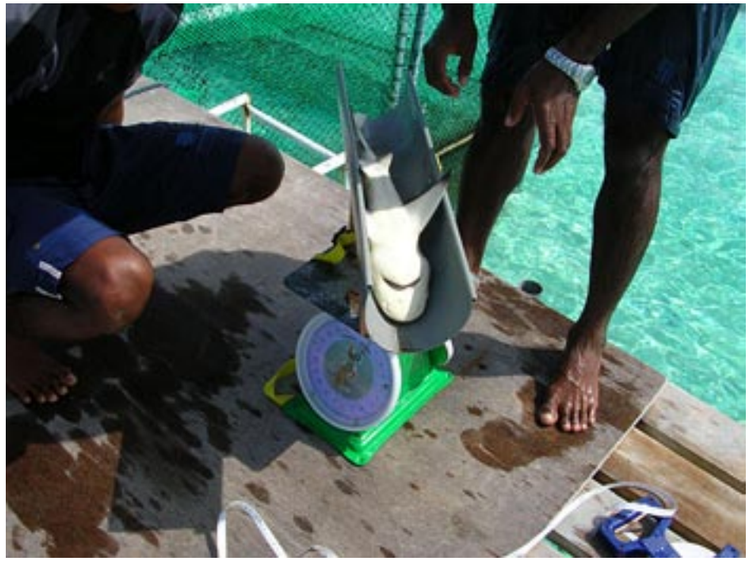
Divers quantify these new inhabitants of the sea by diving along these cables writing down their observations on slates. All the data collected this way aids in monitoring the development of the corals in more detail. For this reason, every helping hand is much welcomed. In return, the visitor gets an insight into a very interesting and promising scientific project and a rare opportunity to dive with a greater purpose.

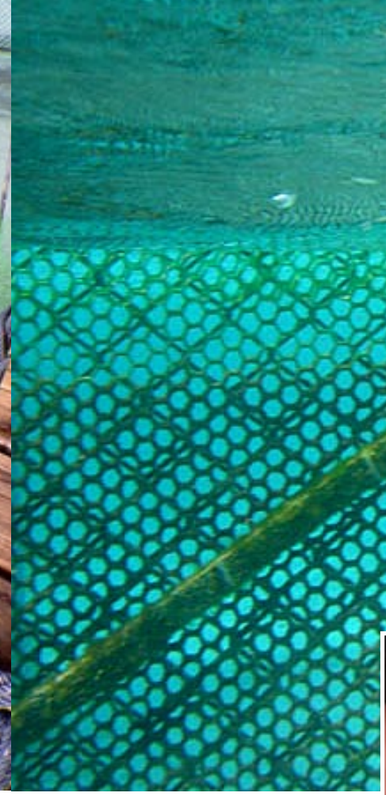
Around the island of Banyan Tree Vabbinfaru and across a house reef in a depths to up to 30 meters, we find a lot of small flat cement tiles, now overgrown with young corals, and near which a lot of electronic temperature gauges are spread out.

Scientists, volunteer divers or visitors who are simply inquisitive, regularly dive down to photograph and measure the sizes of new coral polyp colonies growing on the tiles. Thus, the laboratory staff can study the relationship between growth rate of corals and depth and temperature fluctuations of water.

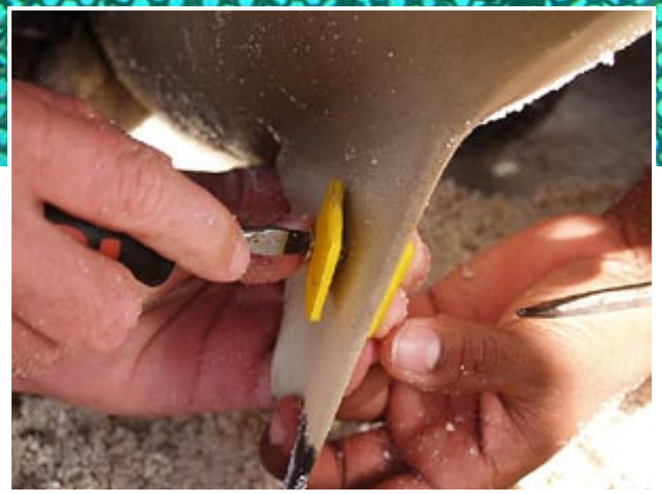
An event that is exciting even for seasoned scientists is the spawning of the planted corals, which has previously only been described in Australia and Okinawa. Not until now has it been witnessed and described in the Indian Ocean.

A diver emerges from a coral formation near the pier





Scenes from the shark cage: research staff captures, weighs and measures Blacktip sharks



◀ Tagging a shark

Under the full moon on March 23, under Abdul Aziz' watch, the corals of the project spawned in unison. On this unique night, which only occurs once per year, all the polyps in a colony, as if they have all entered an agreement or following some command, spawn huge quantities of eggs and sperm giving life to new coral reefs.

"Probably in the future, our knowledge and techniques will allow us to accelerate growth to restore or even to increase the quantity of coral reefs in various areas of world ocean. We need only time and help from both experts and regular divers engaged in the sea environment to achieve a better understanding of the wildlife of coral reefs," said Aziz.

The research into artificial reefs has been taking place here for only a short number of years, but the project has already drawn a lot of attention from the government and has been rewarded a special prize by the Republic's President Maldivskoj.

The shark study

In the sea, approximately 200 meters off the coast, we find mesh wire fencing off a small area in the water. This is a holding cage for Blacktip sharks. We are going to dive into it.

As we gingerly descend down a slippery rusty ladder, we grip hard onto our cameras. We enter the opposite world.

Usually divers are protected from sharks by being in a cage, but here in this research experiment, it is not the case. Sharks and people will study each other, face to face, in the enclosed space. It is going to be interesting to see who will be frightened, or God forbid, who will suffer from the close encounter.

Rule no. 1: Above all, do not give the sharks an opportunity to attack. For this reason, I lie down heavily upon the bottom as I am overloaded with photographic equipment.

It is not a good idea to reason out the many different ways a shark might bite you. But it is necessary to lay easily on the sea floor and confidently repeat to oneself the same words over and over again, "I am not afraid of sharks. I adore sharks. They are white and fluffy."

At this moment, the sharks merge. Unbenownst to us, the sharks have gathered together in a flight response, hammered up into a corner and observing us. I take a deep breath and take the first series of pictures.

My self-confidence rises and I decide to aggravate the situation a bit—I begin by confidently moving toward in their small party.

The sharks are nervous and rush at me. I fade back, nestling on a sea floor again with the continuos descent of my camera.

I notice that the sharks are led by an individual. One of them, which is larger, flies directly by my right ear.

Ah-h!!! My adrenaline flies off the scale! What was that? A practice attack or a gesture of despair? I check my camera chamber and correct the position of the flash. I am again enveloped—this time by two sharks.

Rule no. 2: Do not exhaust and pin an animal in a corner—do not create a desperate situation for the animal. Contradicting logic, it will strike out with the most desperate actions. Therefore, I decide not to come near to the sharks anymore. But I ask Shahid, our dive-guide, to provoke the sharks to move in a shelter. If the expert often feeds the the sharks, they apparently act like old friends and understand each other.

Obeying orders, Shahid, moves the sharks as if with a magic wand, and aligns them all in a line like trained circus animals, which begin moving clockwise, circulating in an open-air cage. Here that common language means!

Rule no. 3: Do not test fate more than once. Therefore, after having finished shooting a film, I finish the dive and politely bowing, indicate that I am retiring from the shark house with a trouser full of unforgettable impressions.

"Blacktip sharks are a very rare kind in our waters. Therefore, we study them.

◀Mugshot of a sea turtle
BELOW: A Sea turtle heads to the sea with technology on its back to track its movements

Maldives

Some sharks live continuously in our open-air cage-cell. We feed them, we study their habits, we catch them periodically to measure and weigh them and when they have grown enough, we tag them with special labels and we set them free in the sea," said Aziz.

Sharks are absolutely amazing creatures. For example, when a couple of sharks are mating, the male holds the female with his teeth with all its force, causing some absolutely awful wounds. Any other animal would be lost from such traumas, but the phenomenally powerful immune system of sharks allows them to cope with any problems. There is a Russian saying about healing of this sort, one would say: "heals like a dog". On the Maldives, one would probably say, "heals like a shark".

To catch sharks, harmonious direction, work and skill is required, handling sharks with the magic of a conjurer. The main skill is to correctly seize a shark and confidently turn its belly up. If one manages to get the shark upside down, a sharp change of blood-pressure places the shark into almost instant relaxation. In such a sleepy state, you can do anything with a shark, pull it out of the water, measure its length from the nose to a tail, weigh it and place labels under fins.

We also were not kept from the temptation to hold a live shark in our hands. It was surprisingly warm with gentle rough leather skin. It is simply an unforgettably pleasant sensation. The white skin of a shark is most similar to the white enamel of the teeth of mammals, only it has, of course, elastic properties.

Aziz marks the sleeping sharks, pinning an inker into their skin with a standard sized tetracicline ring. The antibiotic tetracicline stays a long time in the skin of a shark. By repeatedly catching a shark over the long term, on increased at a rate of tetracicline ring, it is possible to calculate the growth rate of an animal in its natural environment and dwelling.

In order not do too much harm to an animal, all scientific procedures are completed in no more than 20 minutes. After that, the shark is put back into the water, belly turned downwards. The hunter quietly pats it, trying to wake it up from its sleepy, drowsy state. Gently woken, the shark starts to move, at first languidly, but then, as if having regained consciousness from a dream, it moves confidently back into its native element, the sea. It is simply a miracle.

Green turtle study

It is considered that green sea turtles can become a dieing breed. Therefore, the work of collection by a laboratory is connected with educational lectures among the population

Above and below shot of the lagoon at the Banyan Tree resort, Vabbinfaru

ABOVE: Safe from predators and other dangers, juvenile sea turtles enjoy a free swim in clear waters

BELOW: Research staff have opportunities to relax on the beach in comfy hammocks. BOTTOM RIGHT: The shark pens where researchers study Blacktip sharks

A sea turtle soars through the shallows

of atolls and the study of the ways of the migration of these ancient animals. For this purpose, special labels of laboratory with the instruction of date, a place and Banyan Tree Vabbinfaru address which fasten in axillary areas of the turtle fins are used. For the same purposes, a portable radio beacon fixed on back armour of an animal is sometimes used.

If you meet such a turtle somewhere in the Indian Ocean, inform Aziz about it. Regular divers have been very helpful with the work of scientists. Observers found one of the endangered turtles near the Seychelles and another off the African coast. Now, we know that the migration routes of Maldive's turtles can be vast.

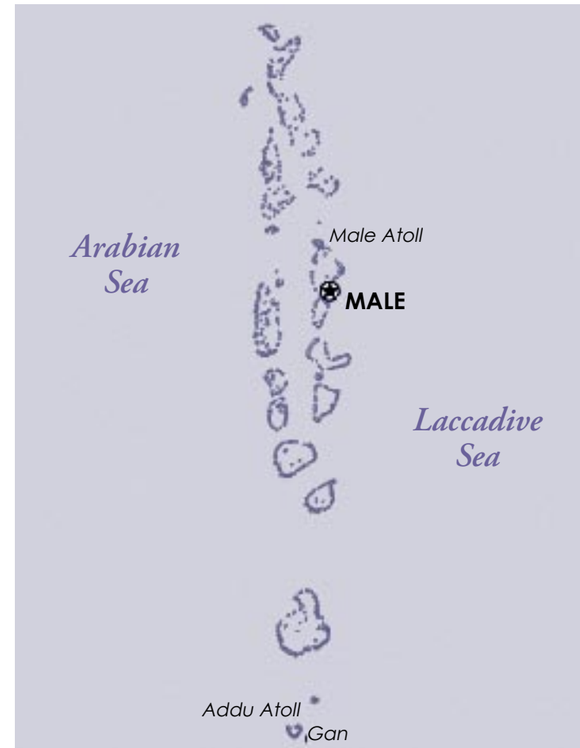
Life at Banyan

Scientists at Banyan Tree Maldives Vabbinfaru are not isolated within the precincts of the laboratory. They give lectures at schools, invite visitors to the islands to participate in their projects. "Support us in our scientific research. Come to us and you will get closer and more acquainted with the life of reefs and sharks. Be accurate and close to the sea. Do not collect corals and cockle shells. Help us maintain the unique underwater world of the Maldives. We are always glad for visitors," said Aziz to finish the story. For more information, email: **Abdul.azeez@banyantree.com**

A diver inspects the *Lotus*, an electrified artificial reef

fact file

Maldives



History The Maldives was long a sultanate, first under Dutch and then under British protection. It became a republic in 1968, three years after independence. Since 1978, President Maumoon Abdul GAYOOM - currently in his sixth term in office - has dominated the islands' political scene. Following riots in the capital Male in August 2004, the president and his government have pledged to embark upon democratic reforms, including a more representative political system and expanded political freedoms. Tourism and fishing are being developed on the archipelago. Government: republic; Legal system: based on Islamic law with admixtures of English common law primarily in commercial matters; has not accepted compulsory ICJ jurisdiction; the US does not have an embassy in Maldives; Capital: Male

Geography Southern Asia, group of atolls in the Indian Ocean, south-southwest of India (3 15 N, 73 00 E). 1,190 coral islands grouped into 26 atolls (200 inhabited islands, plus 80 islands with tourist resorts); archipelago with strategic location astride and along major sea lanes in Indian Ocean. Coastline: 644 km. Terrain: flat, with white sandy beaches; lowest point: Indian Ocean 0 m ; highest point: unnamed location on Wilingili island in the Addu Atoll 2.4 m; Natural resource: fish ; Natural hazards: low level of islands makes them very sensitive to sea level rise; Environmental issues: depletion of freshwater aquifers threatens water supplies; global warming and sea level rise; coral reef bleaching

Climate tropical; hot, humid; dry, northeast monsoon (November to March); rainy, southwest monsoon (June to August)

Population 359,008 (July 2006 est.) Ethnic groups: South Indians, Sinhalese, Arabs; Religion: Sunni Muslim; Internally displaced persons: 11,000 (December 2004 tsunami victims) (2005)

Languages Maldivian Dhivehi (dialect of Sinhala, script derived from Arabic), English spoken by most government officials

Economy Tourism, Maldives' largest industry, accounts for 20% of GDP and more than 60% of the Maldives' foreign exchange receipts. Over 90% of government tax revenue comes from import duties and tourism-related taxes. Fishing is a second leading sector. The Maldivian Government began an economic reform program in 1989 initially by lifting import quotas and opening some exports to the private sector. Subsequently, it has liberalized regulations to allow more foreign investment. Agriculture and manufacturing continue to play a lesser role in the economy, constrained by the limited availability of cultivable land and the shortage of domestic labor. Most staple foods must be imported. Industry, which consists mainly of garment production, boat building, and handicrafts, accounts for about 18% of GDP. Maldivian authorities worry about the impact of erosion and possible global warming on their low-lying country; 80% of the area is one meter or less above sea level. In late December 2004, a major tsunami left more than 100 dead, 12,000 displaced, and property damage exceeding $300 million. Over the past decade, real GDP growth averaged over 7.5% per year. As a result of the tsunami, the GDP contracted by about 5.5% in 2005. Agriculture: coconuts, corn, sweet potatoes; fish; Industry: fish processing, tourism, shipping, boat building, coconut processing, garments, woven mats, rope, handicrafts, coral and sand mining

Currency rufiyaa (MVR); Exchange rates: 1 USD =12.6 MVR; 1 EUR = 16.09 MVR; 1 AUD = 9.55 MVR; 1 SGD = 7.95 MVR; 1 CAD = 11.26 MVR

Visa Valid passport, onward/return ticket and sufficient funds required for entry. 30-day no-cost visitor visa issued upon arrival. Extension 90 days with sufficient funds staying at a resort or hotel or present a letter from a local sponsor. Stays over 60 days face heavy fines and deportation. Airport departure tax charged. Yellow fever immunization required if travelling from infected area.

Local Customs Alcohol, pork, images or worship and pornography are prohibited. Alcohol is available at resorts and on safari boats.

Diving The Maldives compromise of 7000 low-lying coral islands in a 1200-mile chain Southeast of India. About 200 of the islands are inhabited (although visitors have very little interaction with the 175,000 predominantly-Muslim residents), and several are devoted entirely to small resorts that offer average to excellent tropical reef diving with big fish action if the resort has a knowledgeable staff that knows where and when to find it. However, the Maldives are best dived from live-aboards to get to the pristine dive sites in the more remote locations.

Decompression Chamber Two recompression chambers are available in the Maldives. One is on Bandos Island (fifteen minutes by speedboat from Male) and the other is in Kuramathi (one hour by speed boat and about twenty minutes by air taxi from Male.)

Health Immunisation against typhoid, hepatitis A and polio is recommended. Precautions should be taken to avoid sunburn and dehydration. There is a good private hospital on Malé and first aid facilities are available on all the resort islands. Food and water in the resort hotels is generally risk-free. Medical insurance is advised.

Websites
Maldives Tourism
www.visitmaldives.com
Banyan Tree Vabbinfaru
www.banyantree.com/maldives