Intergovernmental Oceanographic Commission

Workshop Report No. **84**

Workshop on Atlantic Ocean Climate Variability

Moscow, Russian Federation
13-17 **July 1992**

UNESCO

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SUMMARY REPORT

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1. OPENING

1.1 WELCOMING

The Atlantic Ocean Climate Variability Workshop was opened by Dr. Sergey Lappo, Director of the State Oceanography Institute, at 10.00, 13 July 1992. He identified the Atlantic Ocean as having significant influence on weather in the Russian Federation. There are various national research programmed which are studying the Atlantic Ocean, among them are the USA, Canada, Germany, France and Russia. He characterized the merging of these national programmed as important to our collective understanding of the ocean. There are a number of ongoing national oceanographic programmed which are not part of the internationally co-ordinated programmed such as the World Ocean Circulation Experiment (WOCE) and the Tropical Ocean and Global Atmosphere (TOGA) programme. These programmed have different research objectives, spatial and temporal scales, and funding sources. Examples include an upwelling study in the North East Atlantic, atmospheric synoptic variations investigations over the Gulfstream Separation Region and local acoustic experiments. One of the objectives of the Workshop would be to investigate opportunities for co-operation and co-ordination among these activities so as to contribute to the understanding Atlantic Ocean climate variability.

1.2 STATEMENT OF' THE HEAD OF THE HYDROMETEOROLOGY COMMITTEE OF RUSSIA

Mr. Youri Zubov, Head of the Hydrometeorology Committee (HYDROMET) of Russia, summarized HYDROMET's interest in this Workshop from two perspectives. First, the Atlantic Ocean contributes greatly to long-term variations of weather conditions over the Russian Federation. An understanding of that role is important to accurately predicting weather conditions for the Russian Federation. Second, the recently concluded United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, 3-14 June 1992 and the completed Framework Convention on Climate Change have focussed international attention on global atmospheric warming and climate change. The Atlantic Ocean plays a major role in that process.

The Russian HYDROMET is considering, as its highest priority, Atlantic Ocean climate variability from the point of view of long-term weather forecasting. But, this does not mean that investigations related to long-term climate programmed will be cancelled. He recognized that understanding the role of the ocean in climate change was a long and complicated process. He supported continued upper layer ocean studies, directly connected with weather forecasting and studies of deep ocean changes as well. He considered the contributions of HYDROMET, particularly SOI, to international climate change study as very important. Mr. Zubov wished the participants of the Workshop a very productive week and expressed his special thanks for the participation of the Western scientists.

1.3 STATEMENT OF THE SECRETARY SCOR-IOC COMMITTEE ON CLIMATIC CHANGES AND THE OCEAN (CCCO)

On behalf of the SCOR-IOC Committee on Climatic Changes and the Ocean (CCCO), Mr. Raymond Godin, Secretary CCCO, expressed his thanks for the opportunity to co-sponsor this Workshop. The Workshop has been organized to address activities within the entire Atlantic Ocean in order to address issues related to the oceanic conveyor belt and its variability on time scales from season to decades and longer. A scientific review of what is know about Atlantic Ocean climate variability, presentations of results from current studies and discussions of future programmed will be presented. The meeting should also afford an opportunity to explore the extent to which ocean models can integrate and give coherence to various oceanographic activities. There is a need for channels for the distribution of this information. Feedback to the modellers, from those who assess the results will contribute to model improvements and our understanding of Atlantic Ocean climate variability.

1.4 ADOPTION OF THE AGENDA

The draft agenda was modified and adopted as in Annex I. Participants are listed in Annex III.

2. SCIENTIFIC PRESENTATIONS

The scientific presentations covered the topics of (i) global processes and modelling; (ii) programmed concerned with Atlantic climate variability; and (iii) key-regions and key processes. The abstracts of the presentations are presented in Annex II. In addition, demonstrations of computer systems and data bases used in support of Atlantic climate studies by the State Oceanography Institute were also provided.

Most of the scientific presentations indicated the increasing interest in the study of interannual variations associated with the Atlantic Ocean. The most significant subject areas of Atlantic climate investigations are global and regional feedbacks and the variability and dynamics of physical oceanographic properties, including those of intermediate and deep water in specific key regions.

Processes of importance to climate variability were identified in a number of key regions, some of which already have some long time-series of data. From a climate change perspective, future investigations should benefit from regions where we already have climatic or fine resolution data sets. Several of these key regions along with their international, multinational and national programme affiliation were identified as follows:

* Newfoundland Basin (WOCE CP3, SECTIONS, CASP, Acoustic Tomography of IFREMER, etc.)
* Nordic Seas (all ICES programmed)
* North-East Atlantic (ASTEX, SEMAPHORE, SOFIA, ROME, various fisheries programmed, WOCE CP3/SUBDUCTION, etc.)
* Tropical Atlantic (TOGA and associated national efforts)
* Labrador current (WOCE CP3, OPEN, ACCP, SECTIONS)
* Brazil deep water basin (WOCE CP2/CP3, national Brazilian fisheries programmed)
* Agulhas current (WOCE CP2, national South African programmed)

3. CONCLUDING REMARKS

Noting that IOC co-sponsorship of the WCRP will result in the disestablishment of the CCCO on 31 December 1992, the participants discussed the importance of continuing the activities of the Atlantic Ocean Climate Studies Panel. The discussion is summarized as follows: (i) the importance of co-ordinating national, multinational, and international ocean research activities; and (ii) the need to advocate and encourage the wider national participation in Atlantic Ocean climate research by the IOC, WMO, ICSU and its SCOR through input provided by the Atlantic Ocean Climate Studies Panel.

3.1 ATLANTIC BASIN OCEANOGRAPHIC RESEARCH CO-ORDINATION

The significance of basin-wide Atlantic climate research co-ordination to national, multinational, and international oceanographic research was emphasized in the following areas:

(i) Co-ordination of future research. Opportunities need to be available by which oceanographers participating in various national and international programmed can interact and thereby involve national programmed in international Atlantic climate change studies. Relevant national programmed need not be limited to those focussed on climate, but all other related activities such as synoptic and mesoscale air-sea interaction, boundary layer modelling, acoustics, testing of satellite data, etc. Examples were given of how national research programmed could often be adjusted to serve both national and international research programme objectives.

(ii) Linkages among established ocean research programmed. Programme linkages need to be made between national, multinational, and international ocean climate research activities, e.g., WOCE CP1 and CP3 field activities with ongoing ICES programmed. ICES programmed are especially significant, because of the important role of the Nordic Seas processes in the formation of intermediate and deep waters. In general, the following are important functions which the Atlantic Climate Studies Panel is needed for:

a) Information exchange amongst national, multinational, and international Atlantic ocean climate programmed regarding the scientific content and status of programmed, experiments, and field activities;
b) Co-ordination of operational plans which result in the cost-effective use of national oceanographic resources; and
c) Association and coupling of ideas, people and data.

(iii) Encouragement of the establishment where needed of new programmed. From time to time a need to establish a new programme may evolve, e.g., the need for a future southern Atlantic analog to ICES or new international research activity which focusses on alternate sources of intermediate and deep water formation. Issues relating to the consequences of an unsuccessful implementation of WOCE CP3 could necessitate the organization of a similar future post-WOCE research activity.

(iv) Advances in regional and global ocean model development. Atlantic ocean climate studies provide the basis for a variety of modelling activities. Emphasis on the development of simple limited-parameter models can be used to develop, establish and test new working hypotheses. Atlantic Ocean experimental studies are then used to investigate and verify those hypotheses. Knowledge gained on those ocean climate processes from the simple models can then be incorporated in global general circulation models.

3.2 THE ATLANTIC OCEAN CLIMATE STUDIES PANEL

The continuation of the Atlantic Ocean Climate Studies Panel after the disestablishment of the CCCO was recommended. A strong advocacy group for encouraging wider national participation in Atlantic Ocean climate research is needed. The important linkages through the JSC or another subsidiary body of IOC, WMO, ICSU and its SCOR are important in developing and co-ordinating national ocean climate research capabilities in the region. The following points were also made regarding the continuation of the Atlantic Panel:

(i) Useful in getting nations (FSU) involved in international programmed.

(ii) A long-term standing panel is required to maintain a means of liaison to co-ordinate ocean research activities that are relevant to climate.

(iii) Necessary to maintain as a means to expose and consider scientific views which are not incorporated into international programmed.

(iv) With the disestablishment of the CCCO and the current large committee reporting structure of the JSC, a forum is required for scientific exchange discussion on Atlantic Ocean climate related issues.

(v) A strong. advocacy body consisting of active oceanographic researchers is required to adequately represent Atlantic Ocean basin oceanographic climate research interests.

4. CLOSURE

The Workshop participants conveyed their thanks and gratitude to Dr. S. Lappo and the State Oceanography Institute for hosting the Atlantic Climate Studies Workshop and to the CCCO and Prof. J. J. O'Brien for making arrangements for the participation of foreign scientists.

ANNEX I

AGENDA

13 July 1992

1. OPENING

   1.1 INTRODUCTION AND WELCOMING REMARKS BY THE DIRECTOR STATE OCEANOGRAPHY INSTITUTE, MOSCOW

   1.2 STATEMENT OF THE HEAD OF THE HYDROMETEOROLOGY COMMITTEE OF RUSSIA

   1.3 STATEMENT OF THE SECRETARY, SCOR-IOC COMMITTEE ON CLIMATIC CHANGES AND THE OCEAN

   1.4 ADOPTION OF THE AGENDA

2. SCIENTIFIC PRESENTATIONS

   2.1 GLOBAL PROCESSES AND MODELLING (Chaired by S. Lappo, J. O'Brien and S. Gulev)

   * Atlantic Ocean SST EOF reanalysis, 1949-1989 (J. O'Brien/ C. Jones)
   * Climatic variability of large-scale interaction processes in the North Atlantic (S. Gulev)
   * Variability of hydrographic properties of North Atlantic Ocean (S. Levitus)
   * Wave number-frequency spectrum of the large-scale disturbances in the atmosphere and sea surface temperature in the mid-latitudes of the North Atlantic (E. Kulikov)
   * Meridional fresh water transport in the World Ocean (S. Dobrolubov)
   * On the mechanism of long-term climate variability of the World Ocean circulation (S. Lappo)
   * Arctic ocean contribution to climate variations (G. Alexeev)
   * Climate variations at the Northern Hemisphere (V. Byshev)
   * Ocean data assimilation procedure based on joint equation technique (V. Zalesny)
   * Interdecadal variability of Atlantic Ocean meridional circulations in a linear, coupled ocean-atmosphere model (R. Metha)
   * The advective heat fluxes into the North Atlantic upper layer. Part 1: Direct and indirect estimates. Part II: Self-modelling solutions. (A. Nechvolodov, S. Popov, G. Safronov)

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   * Modelling of climate circulation and meridional heat transport in Atlantic Ocean (Y. Demin, R. Ibraev, A. Sarkisian)
   * Interdecadal variability in the thermohaline circulation in the coupled ocean-atmosphere model (T. Delworth, S. Manabe, R. Stouffer)
   * On the modelling of World Ocean climate circulation (Y. Resniansky, A. Zelenko)

- * Inter-calibration programme for North Atlantic circulation models (A. Sarkisian)
- * On interannual variability of the ocean-atmosphere characteristics of North Atlantic (V. Efimov, A. Prusov, A. Sizov)

2.2 PROGRAMMED CONCERNED WITH ATLANTIC CLIMATE VARIABILITY (Chaired by J. Merle)

- * The future of CCCO and its activities (R. Godin)
- * Comments (J. O'Brien)
- * TOGA in the tropical Atlantic Ocean (J. Merle)
- * Comments to TOGA contribution to Atlantic climate study (V. Efimov)
- * Recent French programmed in the North Atlantic (Y. Desaubies)
- * ROCC -- goals and objectives (S. Lappo)
- * Status of WOCE North Atlantic programmed (N. Fofonoff)
- * WOCE and CLIVAR (A. Clarke)
- * WOCE CP 3 observational plan and scientific objectives (J. Gould)
- * ACCP main ideas and status (S. Levitus)
- * Open discussion

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2.3 SOI SCIENTIFIC AND TECHNICAL FACILITIES DISPLAY: COMPUTER SYSTEMS AND DATA BASES IN SUPPORT OF ATLANTIC CLIMATE STUDY (Chaired by V. Tereschenkov)

- * North Atlantic ocean climatic variations: informational and technological aspects (K. Selemenov)
- * Monitoring of the climate active oceanic processes in the Greenland and Norwegian Seas (G. Alexeev, A. Korablev, V. Ivanov)
- * Regional hydrological data base at SOI (S. Grigoryev, V. Tereschenkov)
- * Data archaeology at the North Atlantic (Y. Sychov)

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2.4 KEY-REGIONS AND KEY-PROCESSES (Chaired by V. Efimov, A. Clarke and O. Mamaev)

- * Deep and intermediate waters and their circulation in the northern North Atlantic (A. Clarke)
- * Year-to-year variations of hydrological structure in the Newfoundland basin and North Atlantic climate variability (I. Yashayaev, V. Tereschenkov)
- * Multi-year changes in the Labrador Sea waters in the North-West Atlantic (J. Gould)
- * Seasonal and interannual variability of thermodynamical characteristics of North-West Atlantic, constructed using a four-dimensional analysis model K. Beliaev, A. Alexandrochkin)
- * Changes in conditions in the Labrador Sea (J. Lazier)
- * Circulation in the Gulf Stream delta area (Y. Ivanov, E. Morozov)

- * On the role of North Atlantic deep water circulation in climate changes - SOI plans and some recent results (A. Sokov)
- * On the long-term changes in the salinity fields at 48°N in the North Atlantic - a review and some ideas (P. Koltermann)
- * Heat and mass transport at 36°N in Atlantic (A. Andreev, V. Tereschenkov)
- * Observation of the Gulf Stream recirculation by acoustic tomography (Y. Desaubies, F. Gaillard)
- * Frontal structure of the North West Atlantic (I. Belkin)
- * Climatic variability of synoptic and sub-synoptic sea-air interaction processes in North Atlantic mid latitudes (S. Gulev)
- * Manifestation of subduction in the thermohaline fields at the Azores front (V. Zurbas)
- * Low-frequency variability of the hydrophysical fields of the tropical and subtropical Atlantic (A. Polonsky)

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- * Downstream changes of the Gulf stream transport (N. Fofonoff)
- * On climate space-time variability of Arctic deep waters (A. Popov)
- * Reanalysis of Gulf stream transport (T. Rossby)
- * Simulation of mixed layer and SSTA synoptic evolution during FGGE with flux correction procedure (N. Diansky, S. Moshonkin)

2.5 KEY-REGIONS AND KEY-PROCESSES/POSTER DISPLAY (Chaired by O. Mamaev)

- * On the possible deep water formation (P. Bogorodsky, I. Podgorni)
- * Numerical simulation of deep convection in the polar ocean gyre (A. Marchenko, P. Bogorodsky)
- * Monitoring and modeling of the frontal structures in the Nordic Sea (V. Ivanov, A. Korablev)
- * Generation of Gulf Stream rings and meanders due to non-stationary wind (M. Subbotina)

2.6 DISCUSSION AND CONCLUDING REMARKS (Chaired by R. Godin)

ANNEX II

ABSTRACTS OF PRESENTATIONS

ATLANTIC OCEAN SST EOF REANALYSIS, 1949-1989

J. O'Brien and C. Jones
(Florida State University, Tallahassee)

The British Meteorological Office gridded SST data on a 5° x 5° mesh from 1945-1990 is subjected to a principle component analysis for the Atlantic Ocean from 20°S to 60°N. We do not do the entire world.

The first 3 modes are very low frequency results. The first mode is the N-S oscillation. The second mode is a tropical pattern. The third mode is a Gulf Stream extension mode.

The conclusions are:

a) there is no evidence of global warming in the North Atlantic, and
b) there is no evidence of an El Niño (ENSO) mode in the Atlantic Ocean.

CLIMATIC VARIABILITY OF LARGE-SCALE INTERACTION PROCESSES IN THE NORTH ATLANTIC

S. Gulev
(State Oceanography Institute, Moscow)

Meridional heat fluxes for the North Atlantic were calculated on the basis of a meteorological North Atlantic data set (1957-1990). Meridional heat transport estimates were carried out for different periods. Visible variability can be figured out as well as different types of meridional heat transport behavior in mid-latitudes. Possible reasons of these phenomena are under consideration. Future activity in this field can be connected with comprehensive bulk calculations, based on sampling data sets.

WAVE NUMBER-FREQUENCY SPECTRUM OF THE LARGE-SCALE DISTURBANCES IN THE ATMOSPHERE AND SEA SURFACE TEMPERATURE IN THE MID-LATITUDES OF THE NORTH ATLANTIC

E. Kulikov
(State Oceanography Institute, Moscow)

Atmospheric pressure, surface air temperature and sea surface temperature (SST) data of the 22 yearly observations carried out by the Weather Ships in North Atlantic were used to estimate wave number-frequency spectrum of large scale variability in atmosphere and upper ocean. Meridional constituents of pressure and temperature waves with wavelengths of 6000 km and 4000 km respectively were detected by method of maximum likelihood. Previous theoretical study could explain the pressure spectrum as domination of quasi-stationary disturbances (external Rossby wave) which resonant generated by orographic or thermal forcing of steady westerly wind in mid-latitudes. Short temperature wave which detected by wave number spectral analysis could be likely explained by the existence of a quasi-stationary internal Rossby wave which is formed by the resonant conditions within lower layer of the

atmosphere. The SST spectrum is similar to air temperature one. It means that wave constituents in SST field are induced by air temperature influence.

MERIDIONAL FRESH WATER TRANSPORT IN THE WORLD OCEAN

S. Dobrolubov
(Moscow State University)

Different methods of calculating the meridional freshwater transport (MFWT) and reasons for large discrepancies between estimates of that parameter are discussed. A new method is proposed to correct calculations of the effective ocean surface evaporation by the divergence of water-vapor fluxes in the atmosphere and effective evaporation over the land. It is shown that MFWT in the World Ocean is directed from 20°N and 20°S to the equator and poleward with extreme values of order 0,5 Sv at 10 and 40 in both hemispheres. The errors of MFWT calculations by the proposed method in the individual ocean basins and the influence of water exchange in the Bering Strait and Indonesian seas are estimated. MFWT in the Atlantic and North Pacific is directed similar to the World ocean. In the Indian Ocean MFWT is directed northward at all latitudes and in the South Pacific - from 5°N to the Antarctic.

A simple inverse model is used to determine the role of different fresh water transport processes. In tropical and north subtropical regions the fluxes of subsurface high-salinity water masses determine the opposite MFWT direction. In south subtropical region both northward intermediate current of low-salinity water and western boundary current determine the sign of MFWT. Importance of freshwater flux variation in high latitudes is demonstrated by modelling of meridional thermohaline circulation. Some requirements for future observational programs are also proposed.

ARCTIC OCEAN CONTRIBUTION TO THE CLIMATE VARIATIONS

G. Alexeev
(Arctic and Antarctic Research Institute, St. Petersburg)

Ocean influences the climate owing to decrease of the planetary albedo, increase of the greenhouse effect, and changes in the heat impact on the atmosphere due to spatial-temporal redistribution of the incoming solar radiation.

The last mechanism is connected with a nonlinear relationship between surface temperature and outgoing long wave radiation. Its action results in raise of the mean annual temperature due to reduction of the radiation heat loss from the ocean-atmosphere-land system, that is connected with the ocean capability to pass the heat from summer to winter and from warm to cold regions.

Stronger changes in this ocean capability occur in high latitudes oceans and, in particular, in the Arctic Ocean where its changes occur in the upper freshened layer, in the extent of sea ice, in the inflow and transformation of the atlantic water, in run-off, and in the processes of deep and anomalously deep winter convection.

The theoretical and empirical estimates confirm the important climatic role of the ocean and its strong variations in high latitudes.

The goals of investigations in the Arctic Ocean are indicated. They include the monitoring of climatically active arctic processes and structures, modelling efforts and studies of interaction on the basis of international co-operation.

CLIMATE VARIATIONS AT THE NORTHERN HEMISPHERE

V. Byshev
(Shirshov Institute of Oceanology, Moscow)

Using the long time series (1891-1986) of average air temperature on the Earth surface for the latitude belts 25-85°N (Northern Hemisphere) and 65-85″N (Arctic region), the annual values and total dispersion of temperature were computed. It was found out, that there were high (2-6 years) and low (10 and more years) frequency variations of these parameters. The temperature and dispersion vary inversely in the Northern Hemisphere (25-85°N), the variation of temperature reaches 1°C and more, the dispersion - near $12(°C)^2$. It was obtained, that in the Arctic region (65-85°N) the air temperature on the Earth surface and its dispersion vary identically with the same as for the Northern Hemisphere periods, but the amplitude of these variation are more higher (4°C for temperature and $70(°C)^2$ for dispersion.

It was calculated the influence of averaging period on the values of average air temperature and its dispersion. It was found out that there are two intervals of stabilization -- 20 and 60 years. Then the high and low frequency signals were separated. So, there are the low frequency variations with period 60 years with amplitude about 0.56°C. There are two cold epochs with extremes in 1901-1911 and 1965-1976 and one warm epoch with extreme in 1938-1942. The high frequency variations have the same characteristics.

It was found out, that the variations of air temperature and its dispersion are highly correlated (-0.8). The same results were obtained for the Arctic region, but the amplitude of variations are more significant -- 1.36-l.66°C and $31(°C)^2$.

It can be declared, that the most representative averaging period is the period of 60 year, but the results have to be tested.

OCEAN DATA ASSIMILATION PROCEDURE BASED ON ADJOINT EQUATION TECHNIQUES

V.B. Zalesny
(Institute of Numerical Mathematics, Moscow)

Our goal is to construct a numerical Ocean Global Circulation Model (OGCM) to simulate high resolving ocean dynamics with low viscosity coefficients which could be used further in data assimilation and initialization procedure. For the solution of the data assimilation problem we use a coupled system of forward and adjoint equations. The coupled system is constructed with the help of Pontryagin's Principle for control problems. As a result we obtain a 4-dimensional time-space boundary-value problem, nonlinear in general case.

To solve the coupled system in effective way we apply the symmetrized from of governing equations and space-time energy conserving implicit numerical schemes using the splitting-up method. The ocean primitive equation model and the results of two sets of numerical experiments are presented. The model was used to investigate the short-term adaptation processes of density and velocity field in rectangular basin.

We have applied this model for the Arabian Sea variability study. The numerical experiments have been directed at the estimation of wind stress influence on the ocean dynamics and formation of SST anomaly.

INTERDECADAL VARIABILITY OF ATLANTIC OCEAN MERIDIONAL CIRCULATIONS IN A LINEAR, COUPLED OCEAN-ATMOSPHERE MODEL

V. Metha
(.NASA/Goddard Space Flight Center)

There are numerous observations of interannual to interdecadal variability of Atlantic region climate. Sea surface temperature (SST), sea level pressure (SLP), and surface winds have been observed to undergo oscillations at the above time scales. In the tropical Atlantic Ocean region, SST, SLP, and winds are observed to undergo cross-equatorial oscillations which have also been correlated with rainfall variability over the Sahel region of Africa and northeast Brazil. In the middle latitude Atlantic region, there are north-south oscillations in SST, SLP, and winds. The east- west structures of SST-SLP-winds oscillations are nearly zonally-symmetric (symmetric with respect to longitude) in the Atlantic region.

In earlier work (Mehta, 1991, 1992) with a global, primitive-equation, multi-level, coupled ocean-atmosphere model, I found that mean meridional circulations (MMC) in the atmosphere and ocean can have zonally-symmetric normal modes oscillating at interannual to interdecadal time scales. Ocean-atmosphere interaction resulted in large growth rates of the amplitudes of the oscillations. I am now applying the same ocean-atmosphere models to study normal modes of oscillation of the Atlantic region meridional circulations, primarily the ‘conveyor belt’ circulation in the Atlantic Ocean. For basic sates containing the ‘conveyor belt’ circulation and ‘realistic’ parameter values, zonally-symmetric modes oscillating at periods of several years to several decades are present in the coupled ocean-atmosphere model. Cross-equatorial SST-SLP perturbations oscillating at decadal time scales occur as normal modes of the coupled ocean-atmosphere model containing Atlantic region MMC. Zonal wind and ocean current perturbations are also associated with the SST-SLP oscillations. Oscillation periods and meridional structures of SST, SLP, and zonal wind in some of the decadal period coupled ocean-atmosphere modes are similar to the corresponding characteristics of the observed oscillations in the tropical Atlantic region.

In this presentation, observations of interdecadal variability in Atlantic region climate will be briefly reviewed. Then, the interdecadal variability of uncoupled and coupled ocean-atmosphere modes and the presence of idealized Atlantic Ocean ‘conveyor belt’ circulation will be discussed. Sensitivity of such oscillations to parameterized processes and ocean boundaries in the coupled model will also be discussed.

References:

Mehta, V.M. (1991). Meridional oscillations in an idealized ocean-atmosphere system, Part I: Uncoupled modes. Climate Dynamics, 6, 49-65.

Mehta, V.M. (1992). Meridionally-propagating interannual to interdecadal variability in a linear ocean-atmosphere model. J. Climate, 5, 330-342.

TEE ADVECTIVE HEAT FLUXES INTO THE NORTH ATLANTIC UPPER LAYER

A. Nechvolodov, S. Popov and G. Safr9n0v
(State Oceanography Institute, Moscow)

Part I: Direct and indirect estimates

Indirect estimates of the heat advection have been obtained from the heat balance equation for an unit water column, bounded by the ocean surface and the active layer lower boundary beneath with the assigned surface heat flux and temperature field evolution. A local two-layer model is used for calculating the vertical distribution of temperature in the ocean active layer. Indirect estimates of the monthly mean heat advection are compared with the direct estimates in the active layer. Direct estimates are calculated from the temperature and velocity fields, which have been obtained by the initialization. Three-dimensional primitive equation numerical model in vertical levels. Seasonal mean climatological data on temperature and salinity are taken from a numerical atlas of Levitus at 31 levels. Diagnostic results are used as an initial state for the integration of the prognostic equations. The fields of temperature and salinity from Levitus (1981) contain the observation errors and some mesoscale features which can not be resolved by the model. The procedure of adjustment correct some inconsistent details in temperature and salinity fields and improve the advective heat pattern. It is shown the agreement between the direct and indirect estimates in the summer and the discrepancy in the winter. The climatic monthly mean advective heat contribution into the temperature field evolution is small in Comparison with the surface heat flux contribution for about 70% of total area of the basin.

Part II : Self-Modelling Solutions

The self-modelling solution for advective transport has been founded. This solution was founded by the way of including of unknown function, which was evaluated with use of total system of hydrodynamical equations for the large scale moving (in the geostrophic and quasistatic approximations). This function exponentially depended on self-modelling parameter.

Tp identify those function several suggestions were used. Particularly, the relationship between referred function and heat flux at the sea surface as well as heat flux at fixed depth had been taken into account.

Thus, we can determine temperature advective transport just near ocean surface by the way of indirect approach (see Part I). To do it SST and atmospheric data can be used. By this way it is possible to figure out the integral heat transport by currents in the 400-500 meters thickness layer for every, if any time moment for each grid point. To obtain the estimates of seasonal and long-term variability of advective fluxes and meridional heat transport in the North Atlantic the numerical experiments with 15-year monthly averaged data set (10-65 N, 0-80 W) had been produced.

INTERDECADAL VARIABILITY IN THE THERMOEALINE CIRCULATION IN THE COUPLED OCEAN-ATMOSPHERE MODEL

T. Delworth, S. Manabe and R. Stouffer
(NOAA/GFDL, Princeton)

Variability of the thermohaline circulation (THC) in the North Atlantic on time scales of decades is investigated with the use of a 200-year integration of a low-resolution coupled ocean-atmosphere general circulation model. This model was developed at NOAA’s Geophysical Fluid Dynamics Laboratory.

The intensity of the model THC in the North Atlantic undergoes irregular oscillations, with a time scale of approximately 30-50 years and an amplitude of 1-2 Sverdrups. These fluctuation are closely related to changes in the large scale temperature, salinity and density fields in the North Atlantic. A more intense THC is associated with anomalously dense water between 54N and 72N, along with enhanced convection and sinking motion in that region. Both the vertical and meridional density and salinity gradients change in relation to the intensity of the THC. Density fluctuations at lower latitudes (30S-30N) are out of phase with density fluctuations at higher latitudes (50N-70N). The time series of vertically-averaged density and salinity in the sinking region of the THC are approximately in phase with each other, while the time series of vertically-averaged temperature lags the THC by approximately 90.

The fluctuations appear to be self-sustaining. Anomalous transports of heat act to stabilize the fluctuations through the effect of temperature anomalies on density. In addition, anomalous transports of salt play a substantial role in the fluctuations by altering the density field. The role of surface fluxes is also discussed.

ON THE MODELLING OF WORLD OCEAN CLIMATE CIRCULATION

Y. Resnyansky and A. Zelenko
(Hydrometeorological Center of Russia, Moscow)

The results of numerical experiments with an ocean general circulation model are being presented. The large-scale ocean motions are described using the primitive equations written in spherical co-ordinates. The discrete representation is constructed in a manner similar to Bryan's (1969) using the finite differencing on a staggered grid of the Arakawa's B type.

The effects of small scale mixing in the upper ocean are treated in the framework of the integral approach. The interaction of the processes incorporated in the circulation model with fixed vertical levels, and in the model of the upper mixed layer (UML) the lower boundary of which in the course of its evolution may fall at an arbitrary depth is allowed for via the special algorithm. The procedure of the alternate computations in either model conserves the integral heat and salt contents, while the parameterization of turbulent kinetic energy budget in the UML model ensures the feasibility for developing of penetrative as well as nonpenetrative convection modes. The existence of the latter mode is a necessary condition for the simulation of cyclic states of the upper ocean.

The solution of the mixed boundary problem is sought in the domain bounded by the ocean surface, by its floor and by the lateral walls where a no-slip condition is imposed and no flux of heat or salt normal to the boundary is allowed. Generally, the computational domain may be multiply connected.

At the ocean surface the rigid lid condition is assumed, and the fluxes of heat, salt and momentum are prescribed. At the bottom the flow is required to parallel the slope, and the fluxes of momentum, heat and salt are taken to be zero. The unknown constants specifying the transport stream function at the internal contours of the multiply connected domain are determined using the "hole" relaxation technique. To validate the model, the series of numerical experiments have been carried out. These experiments constitute the hierarchy of successively complicating conditions and expanding, grids. The initial testing involved the simulations of the simple regimes for which the control analytical solutions could be obtained.

The subsequent testing stage was based on the simulations of the wind-driven barotropic circulation in a rectangular flat bottom and uneven bottom reservoir, as well as in the multiply connected region. The estimates of the model's sensitivity to parameter variations have been obtained.

Finally, two experiments have been carried out with realistic geography. In each of the experiments the evolution of the world ocean circulation was computed over the time interval about a year. The experiments differed in values of certain parameters and in the distribution of the surface fluxes of momentum and heat.

The horizontal resolution corresponded to the Gaussian grid of the spectral atmosphere general circulation model T21, composed by 64 x 32 grid points over the Earth surface excluding the Arctic basin from the computational domain. The vertical structure was represented by 15 levels with varying steps monotonically increasing with depth.

In both of the experiments the integration started from ocean at rest and with climatological initial distributions of temperature and salinity (Levitus, 1982). The surface atmospheric forcing was maintained stable throughout the integration in a "permanent January" mode. The development of the motion was tracked by the temporal changes of mean kinetic energy (MKE). The fastest MKE changes were observed during the first 100 days representing the transient process of the mutual adaptation of density and motion fields. The subsequent far slower changes reflected the attenuation of the circulation's intensity due to the erosion of the initial density contrasts.

The model's fields obtained after the passage of the initial adaptation stage reasonably well reproduce the well known qualitative features of the ocean general circulation, such as the subtropical gyres in both hemispheres, the circumpolar flow and the major world ocean current systems.

The potentialities of the further model's applications are being discussed.

ANNUAL AND INTERANNUAL VARIABILITY OF THE OCEAN-ATMOSPHERE CHARACTERISTICS OF NORTH ATLANTIC

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Archive data of monthly averaged SST for 1957-1990 in 5-degree squares, monthly averaged position of Intertropical Convergence Zone (ITCZ) along 28 W for 1971-1987 and indexes of anomalies over North Atlantic have been analyzed.

It has been noted that indexes of winters for southern parts of United States are following the meridional movement of ITCZ with time legs near 6 months.

Maps of correlations of ITCZ position and SST over the North Atlantic are computed for interannual time scales. Maximums of absolute values of the correlations between them (negative values) are situated in the center of North Atlantic, in the Bermuda region, and in the eastern area (Biscay Bay), with SST advanced ITCZ on 21 months. Maximum positive values of the correlation are in the area of Newfoundland and zonal tropical band (centered near 10 N) with ITCZ advanced SST on 7-10 months.

The regions of the same correlation type are connected by long distance ties. The features of the correlation's maps between SST in those areas are discussed.

The connection between SST over North Atlantic and Rossby's circulation index are analyzed separately for small and large values of this index. Summer and winter anomalies for two types of the index are shown to have opposite signs.

TEE FUTURE OF CCCO AND ITS ACTIVITIES

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The SCOR-IOC Committee on Climatic Changes and the Ocean (CCCO) was given the responsibility to develop the oceanographic component of the WCRP in the early 1980s. The CCCO developed the World Ocean Circulation Experiment (WOCE) and the oceanographic component of the Tropical Ocean and Global Atmosphere (TOGA) Programme. The CCCO'S basin scale ocean panels co-ordinate regional climate research activities and establish linkages to the larger global climate research programmed. The Ocean Observing System Development Panel is developing a conceptual design for the climate component of the Global Ocean Observing System. The multidisciplinary Carbon Dioxide Advisory Panel is developing a global/gyre scale oceanic pCO_2 data base.

In 1992, the World Meteorological Organization, Intergovernmental Oceanographic Commission, and the International Council of Scientific Unions are to sign a new agreement for co-sponsorship of the World Climate Research Programme (WCRP). Development and management of all the oceanographic and meteorological aspects of the WCRP will be centralized with the Joint Scientific Committee (JSC) of the WCRP and its Joint Planning Staff (JPS) in Geneva. Both the JSC and the JPS will be expanded to include additional oceanographers. With the implementation of the Agreement, a transfer of the responsibility for planning the oceanographic component of the WCRP from the CCCO to the JSC will take place and the CCCO will likely be disestablished by 1 January 1993.

The implications of the disestablishment of the CCCO will be discussed. Among the issues to be addressed are (1) which of the CCCO activities will be continued under the JSC, SCOR or IOC?; and (2) will there be a new committee established to address multidisciplinary and other research planning not being addressed by the JSC?

TOGA IN THE TROPICAL ATLANTIC OCEAN

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The tropical Atlantic ocean exhibits a distinct but similar event to El Niño in the tropical Pacific Ocean. In 1984 such a warm event developed in the tropical Atlantic in response to a large amplitude trade winds oscillation induced itself by the 1982-1983 Pacific El Niño.

Thus TOGA includes also the Atlantic Ocean with a particular objective that is to test the feasibility of real time, near operational simulation of the thermal and dynamical state of its upper layers using a realistic primitive equations model with data assimilation. Another aspect of TOGA in the tropical Atlantic is the use of altimeter observations (GEOSAT and TOPEX/POSEIDON) to the current field and the depth of the thermocline which is also a signature of the warm/cold El Niño-like events that affects this region.

ROLE OF THE OCEAN IN CLIMATE CHANGES (ROCC): GOALS AND OBJECTIVES

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The Role of the Ocean in Climate Changes (ROCC) is a programme aimed at the study of ocean climate change developed by a group of scientists from the State Oceanographic Institute, Academy of Science of Russia, Academy of Science of the Ukraine and Moscow State University. ROCC is based upon a natural evolution of ideas and achievements from national and international ocean research projects such as SECTIONS, WOCE, TOGA, JGOFS and others.

The two primary goals of the ROCC programme are:

1. Quantitative description of the global interoceanic "conveyor" and its role in the formation of the large scale anomalies in the North Atlantic. The objectives on the way to this goal are:

   to obtain reliable estimates of year-to-year variations of heat and water exchange between the Atlantic Ocean and the atmosphere;

   to establish and understand the physics of long period variations in meridional heat and fresh water transport (MHT and MFWT) in the Atlantic Ocean;

   to analyze the general mechanisms, that form the MHT and MFWT in low latitudes (Ekman flux), middle latitudes (western boundary currents) and high latitudes (deep convection) of the North Atlantic; and

   to establish and to give quantitative description of the realization of global changes in SST, surface salinity, sea level and sea-ice data.

2. Development of the observational system pointed at tracing the climate changes in the North Atlantic. This goal merges the following objectives:

   to find the proper sites, that form the interannual variations of MHT ;

   to study the deep circulation in the "key" points;

   to develop the circulation models, reflecting the principle features of interoceanic circulation; and

   to define the global and local response of the atmosphere circulation to large scale processes in the Atlantic ocean.

During the last two decades major efforts were concentrated on quantitative experimental and model description of the ocean's role in global climate change. In particular, the significance of the oceanic key-regions in the ocean-atmosphere interaction processes was defined; the connections between sea surface temperature (SST) anomalies and the interannual variations of the global atmosphere circulation were established; the stability of the meridional ocean thermohaline circulation and its influence on global climate was carefully investigated. The results have proved the exclusively important role of the North Atlantic as a key feature in the formation of the global "conveyor" of interoceanic circulation, which determines the long-period variability of the entire climate system.

ROCC is comparable with the Atlantic Climate Change Programme (ACCP) which has been initiated by the USA (NOAA), from the viewpoint of principal ideas and general objectives. However, in contrast with ACCP, ROCC is more strongly concentrated on key-regions and establishes stronger links with ongoing programmed, like WOCE, TOGA, etc.

WOCE CP3 OBSERVATIONAL PLAN AND SCIENTIFIC OBJECTIVES

J. Gould
(Institute of Ocean Sciences, Wormley)

WOCE CP3 (The Gyre Dynamics Experiment) is a key element of WOCE and is important if we are to make significant developments in ocean modelling for climate research. Core Projects 1 and 2 will provide a “snapshot” of the ocean over the period of WOCE observations. It will provide a definitive data set against which the models' ability to reproduce the climatology of the ocean (mean circulation, distribution of water mass properties, distribution of eddy kinetic energy) can be assessed. For climate modelling we need ocean models that can reproduce the seasonal and interannual variability of the ocean and that can adequately parameterise the key processes (internal mixing, air sea fluxes, mode water formation, thermocline ventilation, etc.) .

CP3 has an observational programme aimed at addressing these issues and will far the most part be carried out in the North Atlantic. Constructive collaboration with other programmes, both national and international, is essential for the achievement of CP3 goals.

NORTH ATLANTIC OCEAN CLINATIC VARIATIONS: INFORMATIONAL AND TECHNOLOGICAL ASPECTS

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One of the principal problems in the ocean climatic variability investigations (especially in subsurface layers) is the scarcity of adequate hydrological information, its excessive irregularity in time and space. As a result the quantitative and even qualitative characteristics of climatic signal in real (not model) deep ocean often cannot be determined.

The problem of informational starvation can be partly soften with the help of proposed scheme of 'basis' data sets analysis. Historically intensive hydrological observations were realized in some selected regions of North Atlantic (ocean weather stations, standard hydrological sections, etc.), so 'basis' data sets can be formed to calculate statistically reliable parameters of large-scale ocean variability. Usage of regular surface information may help to join results of the 'basis' data sets analysis into more integral picture of North Atlantic.

Different aspects of the 'basis' data sets analysis are under consideration, such as data sets brief characteristics, technological problems (data control, gaps in data sets), regular seasonal variations and anomalies calculation. Some illustrative results dealing with quasi-annual variability in the surface and deeper layers in the OWS “C” region are discussed.

MONITORING OF THE CLIMATE ACTIVE OCEANIC PROCESSES IN THE GREENLAND AND NORWEGIAN SEAS

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During last two decades the Nordic Seas were under the AARI intensive investigation due to the significant role in the climate variability. The large-scale monitoring programme was started in 1976. For the present time the data set includes 42 surveys covering the area from 60 to 80N with hydrographic stations in the regular grid net. This archive allowed to determine the areas in the Nordic Seas were the variation of the oceanographic parameters is the highest. Such areas were explored by mesoscale surveys. In the center of Greenland Sea, where the deep water convection is supposed to be, the field measurements began in 1984, and now the total number of surveys here comes to 21. The special monitoring programme in the Lofoten basin was initiated in 1985. The data set includes 17 surveys. The other important regions under investigation were the straits, that connect Nordic Seas with the North Atlantic and the Arctic basin, hydrographic fronts.

The obtained data sets allow to construct the average annual and monthly average oceanographic fields for February, May, August and November. Year to year variability for the different types of the water masses shows that long period trends exist. For example, the mean potential temperature for the Greenland Sea Deep Water mass increased from 1982 to 1990 by approximately 0.09°C. This result was obtained from combined data base compiled from AARI and GSP (Greenland Sea Project) data. Temperature increasing illustrated that convection in the Greenland Sea reduced during 1982-1990, and mixing with surrounding water mass prevailed. The only exception is the data from ORV SHULEYKIN 1984 cruise. The properties distribution shows that deep convection event took place. The interesting conclusion derived from 1987 sequence surveys in the Lofoten basin. The small-scale anticyclonic gyre at deep water exists and its progressive movement is quasicyclonic.

YEAR-TO-YEAR VARIATIONS OF HYDROLOGICAL STRUCTURE IN NEWFOUNDLAND BASIN AND NORTH ATLANTIC CLIMATE VARIATIONS

I. Yashayaev and V. Tereschenkov
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The hydrological data collected by the research vessels of State Oceanography Institute in the Newfoundland Basin during 1982-1990 is analyzed. The waters of the survey area were divided into three water bodies, according to their T-S-Gradient properties, that is cold, warm and frontal waters. Seasonal and interannual variability of mean temperature and salinity characteristics of these hydrological structures are considered.

MULTIYEAR CHANGES IN LABRADOR SEA WATER IN THE NE ATLANTIC

J. Gould
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In summer 1991 the CONVEX-91 survey of the subpolar NE Atlantic as part of WOCE Core Project 3 revealed markedly different distribution of temperature and salinity distributions from those seen in TTO and on the IGY sections made by Erika Dan. The cooling seen is possibly related to changes in the source conditions in the Labrador Sea as documented by Lazier.

THE INTERANNUAL AND SEASONAL VARIABILITY OF INTEGRAL CHARACTERISTICS IN THE NORTH ATLANTIC SUBPOLAR FRONTAL ZONE CONSTRUCTED WITH THE HELP OF FOUR-DIMENSIONAL ANALYSIS

K. Beliaev and A. Alexandrochkin
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The report contains an analysis of seasonal and annual changes of integral characteristic in the period from 1981 to 1991 years. Means of heat and salt capacity are received for different water zones. Flow of heat, salt and masses are calculated cross 41 and 47 n.1., and the interaction between dynamic structures in the region is taken into account. The main instrument of investigation is the nonlinear model of thermohydrodynamic equations with the data correction.

We considered the system of primitive equations and open boundary conditions. On every time step the data assimilation is taking place. The mean fields of hydrophysical parameter are investigated.

CHANGES IN CONDITIONS IN THE LABRADOR SEA

J.R.N. Lazier
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Temperature and salinity data obtained in the Labrador Sea in 1966 and 1992 reveal that the average temperature and salinity of the 3500 m water column have changed by 0.46°C and 0.059 respectively. The change in salinity is a maximum at of 0.09 at 2000 m in the Labrador Sea Water which lies between 500 and 2000 m. The salinity difference decreases to 0.05 in the Denmark Strait Overflow Water near the bottom and to 0.03 in the North Atlantic Deep Water lying between the Labrador Sea Water and the Denmark Strait Overflow Water. Data from other years demonstrate that the salinity decrease in the Labrador Sea Water begins in the upper layer as two anomalous pulses of low salinity water in the late 1960s and mid 1980s. The low salinity tends to reduce vertical convection and isolate the underlying water mass. When convection resumes the low salinity water is mixed down to intermediate depths and serves to decrease the salinity of the intermediate Labrador Sea Water. Below the Labrador Sea Water the water column is strongly stratified and the changes in salinity are due to changes in the properties of incoming Denmark Strait Overflow Water.

CIRCULATION IN THE GULF STREAM DELTA AREA (April-June 1990)

Y. Ivanov and E. Morozov
(Shirshov Institute of Oceanology)

During April-June 1990 three ships made hydrographic research in the Newfoundland area. The objective of the measurements was to study the water transport and eddy dynamics in the Gulf Stream delta. The paths of the main jets in the area where the Gulf Stream approaches the Newfoundland ridge were mapped and the water transport calculated. The temporal variability of the current structure was studied during the three month period. The surveys pictured an intensive meander formed in the delta area which separated from the stream becoming a cold ring. The total amount of the water transport in the Gulf Stream did not vary greatly during the time of measurements. At the same time the water transport change in the resulting jets after the Gulf

Stream termination was significant. This fact is possible caused by the variation of the barotropic joint transport of the Gulf Stream and the slope water current.

HEAT AND MASS TRANSPORT AT 36N IN ATLANTIC

V. Tereschenkov and A. Andreev
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The meridional heat flux across 36N in Atlantic Ocean was estimated from the hydrological data using the method by Bryan (1962). The results are 0.8 pW for the IGY data and 1.13 pw for 1981 data. The advantages and disadvantages of the method used are discussed. The data, collected by the SOIN from 1971, are used for the heat flux variability estimations. The errors of computation are included.

The roles of various components of meridional heat flux are also described. It was computed that the greatest contribution to the total flux is made by the component of baroclinic flux, associated with the correlation between potential temperature and velocity in the vertical plane, but the most important from the variability point of view is another component of baroclinic flux, determined by the correlation in the horizontal plane.

The structure of baroclinic heat flux is examined. It shows, that the area to west of 60w is the most important for estimation of the baroclinic flux component connected with horizontal circulation. As for another component of baroclinic flux, it was found out that the greatest differences between two surveys were formed below the 2000 m level.

The influence of data grid is estimated. The meridional heat flux variability is examined. The possible connection between two components of the baroclinic heat flux is described.

OBSERVATION OF THE GULF STREAM RECIRCULATION BY ACOUSTIC TOMOGRAPHY

Y. Desaubies and F.Gaillard
(IFREMER, Brest)

An experiment to observe the Gulf Stream recirculation was conducted in 1988-89 around 40 N and 55 W. Five moorings equipped with tomographic transceivers were deployed south of the Stream, for a period of nine months. Preliminary results will be given on the acoustic propagation characteristics, the method of inversion, and the estimation of the barotropic and baroclinic fields of temperature, velocity, and vorticity. General comments on the usefulness of such tomographic measurements for the observation of the local circulation will be made.

CLIMATIC VARIABILITY OF SYNOPTIC AND SUB-SYNOPTIC SEA-AIR INTERACTION PROCESSES IN NORTH ATLANTIC MID LATITUDES

S. Gulev
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This study attempts to consider the role of short period synoptic processes in forming of climatic variability in mid latitudes of the North Atlantic on the basis of original sampled meteorological data. Data set consisted observations at the Ocean Weather Station C for the period 1953-1980. Additionally voluntary meteorological observations for the same region were used. Short period dispersions of meteorological observations were calculated for every individual month. Annual and interannual variations of them are discussed, as well as the possibility of SST forcing by short period sea-air interaction processes.

MANIFESTATION OF SUBDUCTION IN THERMOHALINE FIELDS AT THE AZORES FRONT/CURRENT

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Results of detailed CTD-mapping of a fragment of the Azores front/current, which was made October 9-12, 1991 using a towed undulating vehicle, are presented. On meridional sections across cyclonic frontal meanders the effects of sharpening and overturning of the front were found (an increase of horizontal thermohaline gradients in local, less than 5 km wide, regions of upper thermocline, the change in sign for salinity isolines tilt, and the displacement o salinity front at upper mixed layer to the south with respect to its position at underlaying thermocline), but such peculiarities were absent on sections across the anticyclonic one. Maps of root mean square fine structure salinity fluctuations calculated for different layers allow interpretation in framework of subduction mechanism.

LOW-FREQUENCY VARIABILITY OF THE METEOROLOGICAL AND HYDROLOGICAL FIELDS IN THE NORTH TROPICAL AND SUBTROPICAL ATLANTIC

A. Polonsky
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The goal of the present work is the description and discussion of the coupled air/sea variability in the North Atlantic with typical temporal scale from several months to one or two decades. The regions of the relatively strong interannual variability (in comparison with the average seasonal one) are documented using long-term routine and satellite observations. The equatorial evidences of the intense year-to-year variability are presented. Coupled air/sea variability reveals itself as the fluctuations of the average annual values as well as the annual/semi-annual harmonic parameter ones. There are two separated typical temporal scales namely about 3 years and about 1-2 decades. Part of the Atlantic variability is due to the Pacific ENSO events, but another one is not correlated with the Pacific variability. The equatorial year-to-year SST variations, generated both by the heat flux and wind stress anomalies, can influence efficiently the atmospheric circulation in the North Atlantic. Indeed, the low-frequency equatorial variability of the virtual heat fluxes with the typical temporal scale exceeding 3 years is due mainly to the large-scale SST fluctuations. They can reach about 2-2.5°C in the North Equatorial Atlantic at least once each 15 years and generate therefore the significant atmospheric response. Thus the SST low-frequency variations in the North Equatorial Atlantic can be the important element of the feedback in the coupled air/sea variability. ‘

The possible high-amplitude interannual fluctuations of the meridional heat fluxes at the Northern boundary of the Equatorial Atlantic and interannual structure variability of the western equatorial boundary layer are also discussed.

DOWNSTREAM CHANGES OF THE GULFSTREAM TRANSPORT

N. Fofonoff
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Based on two CTD sections across the Gulf Stream at 68 and 55 degrees W, transports in potential density classes and potential vorticity were calculated and compared to determine the downstream changes. The data show that five distinct layers and interaction with bottom topography are needed to describe adequately the transport and potential vorticity distribution and changes. These observations may have implications for developing numerical models of gyre-scale circulations including western boundary currents.

SEASONAL AND SECULAR CHANGES IN DYNAMIC HEIGHT ACROSS AND BAROCLINIC TRANSPORT *BY* THE GULF STREAM

O. Sato and T. Rossby
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In an earlier study Rossby and Rago (CCCO Technical Note, 1984) investigated the seasonal changes in the dynamic height on both sides of the Gulf Stream east of Cape Hatteras. They found that the dynamic height anomaly has a seasonal signal that reaches a maximum in September, a result that seemed to conflict with Worthington's (Johns Hopkins University, 1976) study of 32 hydrographic sections which showed a transport maximum in April. Since the Worthington and Rossby and Rago studies used similar data sets, we thought it would be instructive to redo the analyses. We were able to use 66 hydrographic sections for this study.

The September maximum in dynamic height anomaly is reconfirmed, and is due to the heating and cooling of the upper ocean, i.e., the seasonal thermocline. The baroclinic transport maximum, on the other hand, is found to be much weaker, - 3 Sv, than the 15 Sv previously reported, and accounts for only 2% of the total variance. There is no evident secular trend in transport when plotted against year (1932-1988), but there is some evidence for a 10 Sv decrease in transport between the late 1950s and late 1960s.

SIMULATION OF MIXED LAYER AND SSTA SYNOPTIC EVOLUTION DURING FGGE WITH FLUX CORRECTION PROCEDURE

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The evolution of Sea Surface Temperature Anomalies (SSTA) is a very important problem of the atmosphere-ocean interaction. The part of this problem connected with intra-seasonal variability of SSTA is not investigated well enough. Our goal was to study variability of mixed layer depth and SSTA in the North Atlantic in winter for 1978-79 according to FGGE data set.

In the model of the active ocean boundary layer the balance prognostic equations of temperature, salinity, turbulent energy and mean wind generated momentum are used with non-linear state equation for water density. The correction procedure of the heat flux in the upper mixed layer, used seasonal trends of water temperature, turbulent energy and short-wave solar radiation fluxes at the water-air interface, is applied for simulation of synoptic variability of the SSTA. A new method of determination of advection and meridional heat transport by currents in the ocean is suggested on the base of this procedure.

The model consequently takes wind trend with corrected heat flux, anomalies of heat and turbulent energy fluxes, advective fluxes by anomaly wind-driven and climatic currents at each time step. This procedure of dividing according to frequencies and physical processes gives reasonable results. It is shown that the quasi-homogeneous layer intensively interacts with atmosphere in winter only by approximately its upper one half that essentially influences ocean's heat-dumping properties.

Estimations of influence on synoptic SSTA by anomalous wind-driven advection and climatic currents was made. Contribution of anomalous wind- driven advection equals 30-40% on the average from this one of anomalies of heat fluxes at the ocean surface in the storm-track reqion. Climatic currents cause not more than 5-10% SSTA variability on the average over ocean and 15-50% in Gulf Stream.

MONITORING AND MODELLING OF THE FRONTAL STRUCTURE IN THE NORDIC SEAS

V. Ivanov and A. Korablev
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Using the results of 42 large scale oceanographic surveys, accomplished by AARI research vessels in the Norwegian and Greenland Seas in 1976-1990, the average positions of several main frontal zones were determined. Estimates of their climate characteristics and time variability were made. The hypothesis explaining the existence of the frontal system as a result of the interaction between the barotropic circulation field and the bottom topography was proposed. Mesoscale variability of the Arctic front at the Greenwich meridian was examined. Several suggestions about the possible reasons for the meandering and eddy-formation, based on the model results were made. By means of the numerical modelling the dynamical structure of the Iceland Gap front was investigated. Some conclusions about the relationship between the Gap front's structure and the overflow's mechanism were proposed.

GENERATION OF GULF STREAM RINGS AND MEANDERS DUE TO NON-STATIONARY WIND-STRESS

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Using barotropic model of an ocean of constant depth on the b-plane with free slip boundary conditions we can see that there is such cause of generating meanders and eddies in the model as non-stationary wind-stress action. The equations of motion for square basin of the width pL=1000 km after normalizing are transformed into non-dimensional form of vorticity equation and Poisson equation for stream function.

Numerical experiments have been carried out for broad range of external parameters and different kind of non-stationary wind component. When wind-stress is steady, no meanders or eddies are forming in the basin. Averaged over the basin kinetic energy approaches the steady state. When wind-stress is the sum of two components the stream line pattern sharply changes. A meander forms in the north-east region of the basin, then an eddy is cut-off from the meander. The eddy moves to the west. When the eddy reaches the western boundary it is trapped by western boundary current.

The process of generating and absorbing eddies is quasi-periodic in some interval of the periods. The averaged kinetic energy oscillates with a period which is about the period of non-stationary wind component. Forming eddies is when the energy decreases and trapping eddies is when the one increases. The energy reaches quasi-steady state for definite range of frictional parameter. Life time of eddies and their diameters depend upon external parameters.

Generating eddies takes place only in definite interval of the periods T (30 days < T < 150 days). Beyond this interval no eddies are forming. When the period is equal limit values of the interval the forming eddies are small and do not move, their life time is very short.

ANNEX III

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ANNEX IV

GLOSSARY OF ACRONYMS AND SPECIAL TERMS

AARI	Arctic and Antarctic Research Institute (Russia)
ACCP	Atlantic Climate Change Programme
ASTEX	Atlantic Stratocumulus Transition Experiment
CASP	Canadian Atlantic Storm Programme
CCCO	Committee on Climatic Changes and the Ocean (SCOR-IOC)
CP	Core Project
CTD	Conductivity, Temperature, Depth
ENSO	El Niño Southern Oscillation
FGGE	First GARP Global Experiment
FSU	Florida State University
GARP	Global Atmospheric Research Programme
GEOSAT	Geodetic Satellite Mission
GFDL	Geophysical Fluid Dynamics Laboratory (NOAA)
GSP	Greenland Sea Project
HYDROMET	Hydrometeorology Committee (Russia)
ICES	International Council for the Exploration of the Sea
ICSU	International Council of Scientific Unions
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
IPO	International Project Office (IPO)
ITCZ	Intertropical Convergence Zone
JGOFS	Joint Global Ocean Flux Study
JPS	Joint Planning Staff (WCRP)
JSC	Joint Scientific Committee for the WCRP (WMO-ICSU-IOC)
MFWT	Meridional Fresh Water Transport
MFWT	Meridional Fresh Water Transport
MHI	Marine Hydrophysical Institute (Ukraine)
MHT	Meridional Heat Transport
MKE	Mean Kinetic Energy
MMc	Mean Meridional Circulation
NASA	National Aeronautics and Space Administration (USA)
NOAA	National Oceanic and Atmospheric Administration (USA)
OGCM	Ocean Global Circulation Model
Ows	Ocean Weather Ship
ROCC	Role of the Ocean in Climate Changes
ROME	Résolution de la Circulation 0céanique à Moyenne Echelle
SCOR	Scientific Committee on Oceanic Research (ICSU)
SECTIONS	Energetically Active Zones of the Ocean and Climate Variability
SEMAPHORE	Mesoscale Ocean Circulation and Air-Sea Interactions Experiment
SLP	Sea Level Pressure
SOFIA	Surface de l'0céan, Flux et Interactions Avec l'Atmosphère
SOI	State Oceanography Institute (Russia)
SST	Sea Surface Temperature
SSTA	Sea Surface Temperature Anomalies
THC	Thermohaline Circulation
TOGA	Tropical Ocean and Global Atmosphere Programme (WCRP)
TOPEX/POSEIDON	Joint US/French Ocean Topography Experiment
UML	Upper Mixed Layer
UNCED	1992 United Nations Conference on Environment and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment