Oceanographic Research

Oceanographic

General • The Oceanographic Research Division studies the role of the ocean and air-sea interaction in climate variability and climate change. The general objective is to contribute to the understanding of natural climate variability, the prediction of climate and the assessment of anthropogenic climate change. Efforts focus on understanding natural climate variability and its causes. Research in the division is structured in two themes: ‘Air-sea interaction and climate’ and ‘Ocean modelling and climate’.

The division has continued experimental work at the Research Platform Meetpost Noordwijk (MPN). Results from previous campaigns were analysed, while preparations for new experiments were being made. The analysis concerned turbulent fluxes of momentum, latent and sensible heat as well as CO_2 fluxes. Among the preparations for new experiments the development of a wave following platform and its instrumentation played a central role.

An effort was made to link results of the experimental micro-meteorological work to larger-scale studies. This was done in collaboration with the European Centre for Medium-range Weather Forecasts (ECMWF) as part of its Re-analysis projects and in the framework of a National Research Programme on global air pollution and climate change (NOP) project. From our expertise we also contributed actively to the joint World Climate Research Programme/Scientific Committee on Oceanographic Research (WCRP/SCOR) Working Group on Air-Sea Fluxes. An important source of information about past global air-sea fluxes is the Comprehensive Ocean Atmosphere Data Set (COADS) database, which is partly based on observations of Dutch Voluntary Observing Ships. In the framework of the KNMI programme Historical Climate (HISKLIM) we made efforts to assess the quality of these data and to make them better available.

With support from the Netherlands Organisation for Scientific Research (NWO) in the framework of its Dutch contribution to the Climate Variability and Predictability Research (CLIVARNET) programme we collaborated with the Netherlands Institute for Sea Research (NIOZ), the Institute for Marine and Atmospheric Research Utrecht (IMAU) and the University of Capetown in the Mixing of Agulhas Rings Experiment (MARE), which can be seen as a direct contribution of the Netherlands to the international Climate Variability and Predictability Research (CLIVAR) programme. Another international project (jointly with the Southampton Oceanography Centre and others) studied particle trajectories in the thermohaline circulation in a high-resolution ocean model.

We continued the study of tropical ocean variability, in particular also the variability related to El Niño, in a two-prong approach aimed at better predictions and at better understanding of the underlying physics.

We continued our close collaboration with the National Institute of Public Health and the Environment (RIVM) and the University of Utrecht in the framework of the Netherlands Centre for Climate Research (CKO) and the Co-operation on Oceanic, Atmospheric and Climate Change studies (COACh). The Head of Division accepted a part-time professorship in Climate Dynamics at the Faculty of Physics and Astronomy of the University of Utrecht. Several PhDs were granted for research carried out under guidance of division staff members, and several new PhD projects were approved. Staff members lectured at national and international schools. Two staff members made extended research visits abroad (Scripps and Lamont Doherty.)

Research is the main activity of the division, but in addition a considerable amount of energy is put into informing policy makers and the general public about climate issues. The division played a major role in the writing of a Fact Sheet on climate and climate change, which was distributed widely in the Netherlands. Staff members also made contributions to the review of the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) Working Group I.

We kept close contact with a number of international programmes such as CLIVAR, World Ocean Circulation Experiment (WOCE), Global Ocean Observing System (GOOS) and International Geosphere Biosphere Programme (IGBP). On a European level we contributed to the implementation of the EUROCLIVAR recommendations for Climate Variability and Predictability research in Europe. On a national level we represented CLIVAR in several committees (NWO, Royal Netherlands Academy of Arts and Sciences (KNAW)).

Mathematical physics

Van Duin

At the sea surface various waveforms may be observed. Among the periodic waves, the so-called Stokes wave proves to be unstable to perturbations with long wavelengths. Ultimately, this instability may lead to disintegration of the wave. Among the periodic waves, there also exists a class of weakly non-linear cnoidal waves. In the case of shallow water waves, these satisfy the Korteweg-de Vries equation and are known to be stable in general. However, when the water is deep with respect to the wavelength, the results are quite different. In contrast with the previous case, unstable wave perturbations then exist if certain conditions are satisfied. The properties of these waves have been studied. Earlier work on the effect of non-uniformity of modulated wave packets on the mechanism of Benjamin-Feir instability was published in the Journal of Fluid Mechanics.

The physics of air-sea exchange

Jacobs, Oost, Van Oort, Wallbrink, Worrell, Komen

The physical description of the microscale aspects of air-sea interaction remains the focus of our group. The research programme has an important experimental component in which we measure the exchange of momentum, heat, water vapour and CO_2 near the water surface, as well as the flux-related environmental parameters. The experimental work is performed at MPN, owned and operated by Rijkswaterstaat (Directorate-General of Public Works and Water Management). Experimental work at sea requires special strategies and instruments designed to withstand the exacting environment close to the water surface.

The Air-Sea GAs exchange / MAGE project (ASGAMAGE)

In the preceding period, the EU-supported project ASGAMAGE, for which KNMI was project co-ordinator, has been formally finished. However, analysis of the extensive data set from the ASGAMAGE field experiments is still continuing.

The main aim of the ASGAMAGE project, as far as the KNMI contribution was concerned, was the intercomparison of the values for the transport coefficient k_w for the exchange of CO_2 between the oceans and the atmosphere, found with various techniques. Until 1996, results from those techniques showed order-of-magnitude discrepancies. Improved confidence in k_w and insight in its measurement is important for our understanding of the global carbon budget.

The ASGAMAGE experiments bridged a significant part of the existing gap. The results from eddy correlation measurements, carried out by KNMI, and those from the differential tracer method, performed by colleagues from the Plymouth Marine Laboratory (PML) and the University of Newcastle upon Tyne (UNT), UK, the method that so far has yielded most values cited in the literature, are comparable to within a factor of 2-3 now. However, because the gap is still too large, the research into the remaining differences by means of data analysis and model studies has been continued, in co-operation with the Risø National Laboratory (Denmark), the PML (UK) and the UNT (UK). This study suggested that much of the remaining differences and the scatter in the eddy correlation data could be explained in terms of the assumptions made in the various measurement techniques and the degree to which these assumptions are fulfilled in practice. The earlier suggestion that near-surface vertical gradients may be an important error-source in the differential tracer method has been further explored. There are indications, especially from model studies, that this may indeed have been at least partly the cause of the discrepancies. Additional analyses showed that the eddy correlation method is more likely to be affected by instationarity and inhomogenity of the CO_2 concentration field in water and air, which may cause a lot of scatter in the data.

An analysis of the transport coefficients for heat and moisture, C_H and C_E, has been completed. C_H and C_E are both key variables in the coupling between atmosphere and sea. The analysis of the ASGAMAGE data uncovered a so far unknown dependence of these coefficients on wind speed and atmospheric stability. The results raise some doubt as to the validity of the almost universally applied Monin-Obukhov surface layer similarity theory over the sea.

The ASGAMAGE database also provided the opportunity to further analyse the transport of momentum as influenced by the wave field. An important result from Humidity Exchange over Sea (HEXOS), an earlier, well-known international experiment conducted at MPN, was confirmed. A pronounced correlation between inverse wave-age and the Charnock parameter could be established using the ASGAMAGE data. Once again, at a given wind speed the momentum fluxes were found to be much higher near MPN than over the open ocean, but it could be shown that the North Sea data are fully consistent with open ocean results by taking wave-age differences into account. The limited depth at MPN (18m) appeared to have no effect on the momentum flux data from ASGAMAGE, and must therefore be ruled out as a factor of importance to the air-sea momentum fluxes.

The wave follower

The construction of the wave-follower continued to be the main item for the technical activities within the group. The instrument has now successfully been tested in the wave flume facility in De Voorst, owned by Delft Hydraulics, and in the North Sea, at MPN. The tests have confirmed the potential of the wave follower to enable micrometeorological observations within the wave boundary-layer. During the latest test, wind observations were made well within that layer, at about 50 and 150 cm above the sea surface, in the presence of waves with heights up to 2 m. Momentum flux measurements were made with miniature versions of the pressure anemometer during this test. These instruments were developed with the special purpose to mount them on the wave follower and to observe the wind field in the wave boundary-layer, i.e. at distances down to 20 cm above the water surface. The special mechanical provisions at MPN functioned very well, and the software programme that has been developed to control the wave follower operation was also applied with success. Special provisions that were introduced to safeguard the functional use of the instrument under adverse conditions performed well. See also the highlight in this report.

Global air-sea fluxes and ocean waves

Sterl, Bonekamp, Komen, Caires, Wallbrink

Work on global air-sea fluxes has been centred around ECMWF's Re-Analysis projects ERA15 and ERA40, and around the comparison of different flux products.

A NOP supported project aiming at the validation of the ERA15 air-sea fluxes has been finished. Two major results from this project obtained during the reporting period concern the development of an adjoint ocean model and an assessment of surface drag parameterisations. The adjoint model is used to assimilate hydrographic observations into the ocean model and from that to adjust the surface forcing of the ocean. The work on drag parameterisations also contributed to the preparation of ERA40, which started production in July 2000. KNMI is involved in this new re-analysis and will assess its ocean wave results.

Assimilation of ocean observations

A 4DVAR data assimilation scheme developed as part of the El Niño research (see below) was used to study the possible adjustment of air-sea fluxes with the help of upper ocean observations. Identical-twin experiments and an experiment with real observation show that adjusting wind stress with the 4DVAR scheme is an effective way to correct errors in the upper ocean analysis and in the wind stress over the tropical ocean.

In the equatorial Pacific, a large reduction in wind stress and upper ocean temperature misfits can be achieved by assimilating hydrographic data. The main reason is that the equatorial region combines a high ocean model sensitivity to short term disturbances with a high number of observations, which are uniformly distributed. Off-equatorial regions of the Pacific lack this combination and the performance of the 4DVAR method is not that well there.

An intercomparison of wind stresses as obtained from ERA15 and from the Research Vessel Moana Wave during the Tropical Ocean Global Atmosphere - Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) identified discrepancies between the two. On average, the ERA15 zonal wind stress is too weak for the first leg of the RV Moana Wave (November 11, 1992 to December 3, 1992) and too strong for the second leg (December 17, 1992 to January 11, 1993). Assimilating the upper ocean observations reduces the discrepancy between ERA15 and observed wind stress. Therefore, the wind stress estimate adjusted by the 4DVAR scheme seems to be more realistic than the original ERA15 wind stress for the considered region and period.

Drag coefficients

In preparation of ERA40 different wind stress parameterisations have been compared with wind stress measurements over the open ocean. The comparison reveals some clear differences in the mean drag coefficient or, equivalently, the mean dimensionless aerodynamical surface roughness (or Charnock parameter) for all wind speed ranges greater than 6 m/s (Figure 1). These differences are significant and need to be resolved.

In addition, three alternative wind stress parameterisations have been compared by statistical means using the Royal Research Ship (RRS)

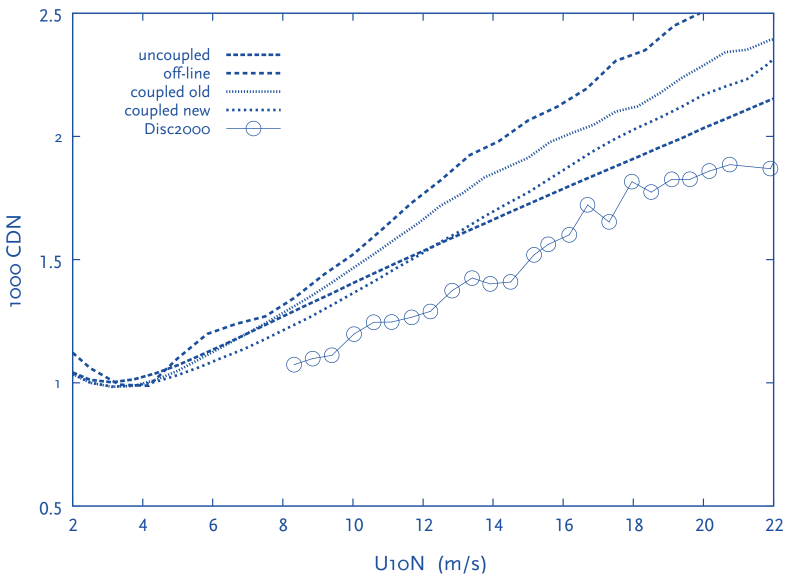

Figure 1. The mean drag coefficient CDN as a function of wind speed at 10 m. From the five curves shown, four are from different model versions and one from observations. The dashed, dashed-dotted, dotted and solid line are from ERA15 (constant Charnock parameter), an uncoupled wave model run, and two versions of a coupled atmosphere-wave model, respectively. The line with open circles is for the Discovery data as described by Taylor and Yelland.

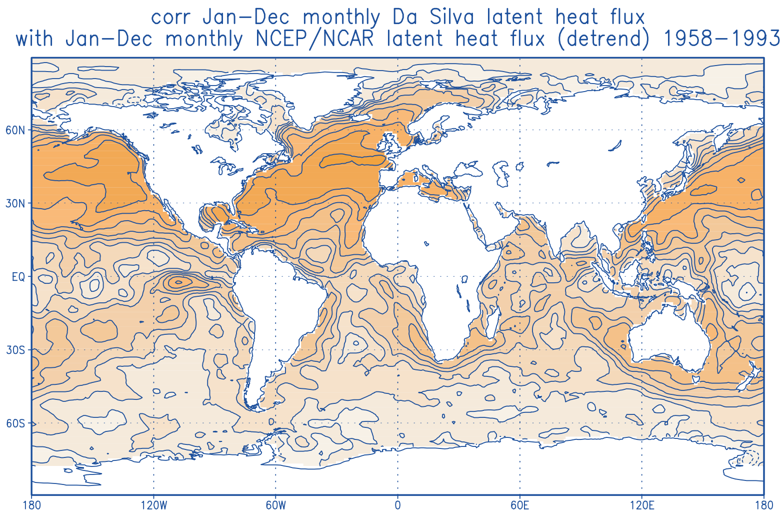

Figure 2. Correlation's between the latent heat fluxes from the NCEP re-analysis and the reconstruction of DaSilva.

Discovery wind and wind stress measurements. The parameterisations are characterised by a constant Charnock parameter, a linear dependence of the drag coefficient on the near-surface wind ($CD_{10} = a + b \bullet U_{10}$) and a wave-age dependent Charnock parameter. On the basis of the statistical tests and published estimates of the random errors an order of preference could be given. The wave age dependent parameterisation provides the best description of the observed wind stresses. A very good second is the above linear relationship. For wind speed bin averaged neutral drag coefficients this parameterisation gives at least a description as good as the wave-age dependent one, but the description of the wind stress variability is slightly poorer. By far the poorest representation of the surface drag is provided by the constant Charnock parameter case.

These results have helped in establishing details of the drag parameterisation to be used in ERA40, in which the constant drag coefficient as used in ERA15 is replaced by a sea-state dependent one.

Intercomparison of fluxes

Global fields of historical surface fluxes can be obtained by three methods, re-analysis, reconstruction, and satellite observations. In a re-analysis an atmospheric model is run and constrained by atmospheric observations. The result is a time history of the state of the atmosphere from which the surface fluxes can be deduced. In a reconstruction fluxes are calculated from in-situ measurements made from buoys and ships. These observations are subsequently inter- and extrapolated to obtain global coverage. Satellites measure some surface variables from which fluxes can be calculated with near-global coverage.

As it turns out, fluxes obtained form these three methods differ widely, not only between methods (re-analysis vs. reconstruction, say), but also within one method (e.g., reconstruction's made by different scientists). Intercomparing different flux products can teach us something about the errors inherent in each of the products as well as in the method used.

For the reconstruction's the biggest problem is the inhomogeneous coverage of observations. Especially in the Southern Hemisphere large areas are essentially data-void, making extensive extrapolation necessary to obtain global coverage. Figure 2 shows a map of the pointwise correlation of latent heat flux as obtained from the National Centers for Environmental Prediction (NCEP) Re-Analysis and the reconstruction of DaSilva. While the correlations are very high in the data-rich Northern Hemisphere, they are poor in the Southern Hemisphere. A similar comparison between the NCEP and the ERA15 reanalyses shows very high correlation's in the extratropical regions of both hemispheres, but poor correlation's in the Tropics, indicating problems in at least one of the reanalyses in these regions.

Recovery of historic marine observations
An important source of information about past global air-sea fluxes is the COADS database, which is partly based on observations of Dutch Voluntary Observing Ships. In the framework of the KNMI HISKLIM project we made efforts to assess the quality of these data and to improve their availability. This involved recovery of lost metadata and the reconstruction of the fate of 20 000 meteorological ships journals that had disappeared in the Second World War. See also chapter Climate Analysis and Scenarios.

El Niño Southern Oscillation (ENSO) and data assimilation in ocean models

Burgers, Van Oldenborgh, Bonekamp, Vossepoel, Appeldoorn, Zelle

El Niño Southern Oscillation (ENSO) research at KNMI aims both at gaining a better understanding of the causes and effects of the phenomenon and at contributing to the improvement of seasonal forecasting systems. Software for the systematic investigation of teleconnections has been developed and a strong teleconnection between El Niño winters and spring precipitation in Europe was found and documented. An important activity is data assimilation for improving the initialisation of forecast models. A technique for combining satellite altimeter measurements with in-situ sub-surface buoy measurements has made possible improved estimates of salinity in the Equatorial Pacific. A 4D-VAR assimilation scheme has been developed for making better use of sub-surface data.

Whenever there is a big weather event, questions reach KNMI about how unusual this is and whether it is connected to El Niño and/or greenhouse warming. Because answering these questions took more and more time, a system has been developed for investigating teleconnections in a systematic way. This web-based 'climate explorer' allows one to make plots of correlation's between a large number of fields and time series from a large database. Because researchers outside KNMI showed considerable interest, it has been put on the public KNMI web:
http://www.knmi.nl/onderzk/oceano/special/nino/nino.html. Now climate researchers are using it all over the world.

The climate explorer was used in establishing the El Niño teleconnection between winter El Niño events and high precipitation in Europe in a band from southern England eastward to the Ukraine. Lagged correlations suggest that south-east Asian surface temperature anomalies may act as intermediate variables. In a joint project with the Meteorological Service of the Netherlands Antilles, the seasonal predictability of the Dutch Caribbean is being documented, again using the climate explorer.

Predictability was studied in the context of the simple stochastic oscillator system. It was shown that if 'ocean data' are assimilated the gain in predictability of this system depends on details of the noise that drives the system, illustrating the need for a proper representation of small-scale processes if one wishes to assess the predictability of the ENSO system.

A method for estimating salinity in the equatorial Pacific from comparisons of satellite altimetry sea-level observations with sub-surface buoy temperature observations had been developed before. Now this method has been incorporated in a version of the NCEP model. It is a three-dimensional variational method that uses sea-level observations and sub-surface temperature observations for obtaining both temperature and salinity corrections to the model state at a given time, in contrast to the operational NCEP scheme which only corrects temperature. The scheme has been tested on real data in a four-year model run. The new scheme clearly improves the simulation of salinity variability and of displacements of the Western Pacific fresh pool. In addition, it improves the simulation of sea-level variability without degrading the temperature field.

A four-dimensional variational scheme (4D-VAR) has been developed for the Hamburg Ocean Primitive Equation (HOPE) model that is used by the seasonal forecasting group at ECMWF. The driving wind stress field has been used as a control field, guaranteeing dynamical consistency of the ocean fields. The adjoint of the HOPE model, which is necessary for the 4D-VAR method, had been developed and tested at KNMI before. In the runs made so far, sub-surface data have been assimilated. Both synthetic experiments and a run with real observations over 14 weeks have been done. The scheme is able to reduce errors in the ocean analysis which originate either from the wind-stress forcing or the initial state. First results indicate a better reconstruction of equatorial zonal currents than a standard Optimal Interpolation (OI) scheme.

Variability of the wind driven and thermohaline circulation

Donners, Drijfhout, Hazeleger, Katsman, Sterl, De Vries

Limited knowledge of the ocean and limited ability to model ocean processes still form critical issues in climate modelling. Therefore, we have carried out process studies as well as large scale modelling studies.

An isopycnic model of an idealised North Atlantic subtropical gyre, coupled to a mixed layer model and an atmospheric anomaly model, was used to study variability in Subtropical Mode Water formation. The response to deterministic (North Atlantic Oscillation (NAO)) and stochastic forcing has been investigated, as well as internally generated variability. Finally, subduction processes and the role of eddies have been studied. We have studied mechanisms for decadal variability in watermass formation and its impact on the North Atlantic subtropical gyre. Another series of process studies focuses on eddy parameterisations. The effect of eddies is to mix properties along surfaces of constant density. In coarse resolution models used in climate studies these processes are parameterised. We study mixing of thickness and potential vorticity in the same idealised isopycnic model, but now within a configuration that comprises both a subtropical and subpolar gyre and in which diabatic processes have been neglected. Although potential vorticity is a conserved quantity, while thickness is not, it appears that the mixing by eddies of thickness is better captured by a down-gradient diffusion scheme than the mixing of potential vorticity, especially when the flow becomes strong and unstable. At present, we evaluate the skill of various parameterisation schemes in a coarse resolution model with a similar configuration as the high-resolution model.

With an idealised quasi-geostrophic model mechanisms for interannual to decadal variability of the wind driven circulation have been studied. In particular we focus on the role of deep western boundary currents in selecting or enhancing decadal timescales in the wind driven gyres. To this end a continuation method is used that calculates stationary solutions as a function of a critical parameter, that is, the strength of the forcing or dissipation. Also the stability characteristics of the stationary solutions are determined in order to describe the transition to time dependence and the associated unstable oscillatory modes. In the purely wind driven configuration the flow becomes unstable to oscillatory instabilities with timescales in the order of months. Low-frequency variability occurs naturally when a deep western boundary current is present. The perturbations with intermonthly timescales stabilise when a deep western boundary current is added, and different perturbations with near-annual to decadal timescales become important. This research is performed in co-operation with IMAU.

Despite progress made in the World Ocean Circulation Experiment, there is still an enormous lack of ocean observations. Therefore, the analysis of numerical simulations is a useful approach to a better understanding of ocean circulation. This work is done with global ocean models developed elsewhere. The response of the Atlantic overturning circulation to South Atlantic sources of buoyancy, characteristic for the impact of Agulhas Rings in the South Atlantic, has been investigated within the Large Scale Geostrophic model. This work is part of a PhD-study carried out at IMAU. It appears that the Atlantic overturning circulation is sensitive to the parameterised inflow of Agulhas eddies. In co-operation with the Lamont Doherty Earth Observatory simulations with a basin-scale model of the Pacific have been analysed. The interaction between the subtropical and tropical Pacific ocean was investigated as a possible mechanism for decadal variability in ENSO. Also, a parameterisation of the impact of atmospheric transient eddies (the storm track) was applied to a coupled atmospheric mixed-layer Ocean Model to study the effect on sea surface temperature, heat fluxes and the thermocline in the Pacific. A further study addressed the role of the ocean in tropical Atlantic decadal variability. This work was carried out at Lamont. With the global high-resolution ocean general circulation model OCCAM (developed at the Southampton Oceanographic Centre) the meridional overturning cells in the tropics have been evaluated. In particular, the role of the eddy mass transport in the overturning circulation was studied. It appears that the eddies compensate the mean flow in the meridional plane.

The route of the North Atlantic Deep Water (NADW) and its return flow has been investigated by following Lagrangian trajectories simulated by a high resolution ocean general circulation model (OCCAM). This work is carried out in a co-operation with the Southampton Oceanography Centre, Southampton (UK), Meteorologiska Institutionen Stockholms Universitet, Stockholm (Sweden) and Laboratoire de Physique des Océans, Brest (France) in the EU-funded project 'Tracing the Water Masses of the North Atlantic and the Mediterranean (TRACMASS)'. The upwelling zones of NADW have been traced by forward integrating trajectories released in the equatorial Atlantic until NADW upwells. The same method has been applied to the NADW-return flow, now by backward integrating trajectories. Most trajectories upwell in the Southern Ocean, which implies that wind driven upwelling is more important in connecting the upper and lower branch of the conveyor belt than was previously thought. Much work has been carried out on more fundamental and methodological aspects of the trajectory method in a drifting, high-resolution z-co-ordinate global ocean model. In particular the time averaged eddy-induced transport velocity was estimated, a separate assessment was made of the impact of the seasonal cycle and of the higher frequencies, a method was developed to correct the divergent part of the velocity field for drift and spurious diapycnal mixing while securing mass conservation and finally an evaluation was carried out of the mass budget on density surfaces by transforming all diabatic processes into separate diapycnal velocities. As the net diapycnal velocity forces the overturning or thermohaline circulation correct assessment of this velocity is of highest importance. Also, we used the trajectory method to depict the pathway of the various water masses that constitute the NADW outflow and return flow on the World Ocean by calculating the horizontal streamfunction for each separate watermass.

Large climate models are very time consuming to run, and therefore less suitable to study inter-decadal variability. Therefore, KNMI has chosen to develop a fast-coupled model of intermediate complexity: ECBILT. See also chapter Predictability Research. A study has been performed to isolate the role of the ocean in inducing atmospheric variability. On interannual timescales the oceans do not affect the patterns of atmospheric variability, nor their explained variance. But the spectra change. The oceans act to redden the spectra, especially the atmospheric temperature spectra. When the atmosphere is coupled to a slab mixed layer this reddening is strongly overestimated. Ocean dynamics make the temperature spectra above sea to deviate from that of a first-order auto regressive process. No preferred timescales arise for the dominant patterns of atmospheric variability. The dominant patterns of ocean/atmosphere covariability, however, do show the existence of preferred timescales. The latter only occur when the atmosphere is coupled to a dynamically active ocean. Also, a simple isopycnic model of an idealised Atlantic together with a similar configured z-co-ordinate model (GFDL) has been used to study the role of wind driven upwelling in the Southern Ocean versus interior diapycnal mixing in connecting the upper and lower branch of the thermohaline circulation. This is a co-operation with institutes from the US and the UK. The role of wind driven upwelling can be significant, but depends on the strength of the interior mixing and the eddy return flow in the Southern Ocean. Both processes are parameterised in climate models and still largely unknown. This result strongly suggests an increased effort to better determine and parameterise eddy transports and the interior diapycnal mixing in the ocean.

In co-operation with IMAU and NIOZ and the university of Cape Town the consorted observational and modelling experiment 'Mixing of Agulhas Rings Experiment (MARE)' has been formulated. It is financed by the Netherlands' CLIVAR programme. Its main goals are to estimate the proportion of Agulhas Ring leakage that contributes to the upper branch of the Conveyor Belt and to identify the dominant mixing processes that determine that proportion. Also, we assess the impact of varying

Indian-Atlantic interocean exchanges on variability on regional scales as well as on the strength of the Atlantic overturning circulation and associated climate fluctuations over the North Atlantic sector. Two cruises have been carried out with active participation of KNMI scientists. The KNMI contribution to MARE consists of a series of modelling and observational studies. At present we have started an analysis of coupled and oceanic South Atlantic variability from both re-analysis data sets (NCEP/ECMWF) and hydrographic data (NODC). A hindcast of this variability using a South Atlantic isopycnic model (Miami isopycnic co-ordinate ocean model (MICOM)) coupled to an atmospheric anomaly model has been made. An analysis of the spreading of Indian Ocean Water in the South Atlantic model using particle-tracking techniques is done. Finally we analyse secondary circulations and watermass exchange in a model of the observed Agulhas Ring. We also contribute to the cruise-data analysis carried out at NIOZ.

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Number of international presentations: 1999: 35, 2000: 18.

Externally funded projects: national 5, international 5.

Educational, organisation of workshops:
G. Burgers was lecturer at the Vening Meinesz Research School of Geodynamics at the Technical University of Delft, 13 January 1999. Modelling the dynamics of El Niño.
S.S. Drijfhout organised a TRACMASS meeting at NIOZ, Texel, 17 - 20 May 2000.
S.S. Drijfhout guided a student from France. Report: The Conveyor Belt the OCCAM model; tracing watermasses by a Lagrangian methodology, 15 June - 15 September 2000.
W. Hazeleger organised a CKO (Netherlands Centre for Climate Research) meeting on Subtropics - Tropical interaction in the Pacific at KNMI, 11 January 2000.
W. Hazeleger, G.J. Komen, C. Severijns and P. de Vries participated in the Buys Ballot Symposium , Rolduc Abbey, Kerkrade, 27 October 2000.
G.J. Komen was lecturer at the Vening Meinesz Research School of Geodynamics at the Technical University of Delft, 13 January 1999. Climate variability and climate changes.
G.J. Komen was lecturer at the Centro de Investigación Científica y

Educación Superior de Ensenada (CICESE), Ensenade, Mexico, 22-28 August 2000.
G.J. Komen organised a Clivar meeting at KNAW, Amsterdam, 16 March 2000.
G.J. Komen is professor at the University of Utrecht, Faculty of Physics and Astronomy.

Other activities:
J. Donners and S.S. Drijfhout went on the Mare-II cruise, 18 July - 9 August 2000.
S.S. Drijfhout prepared and supervised the Mare-I cruise, 21 February - 18 March 2000.
G.J. Komen, G. Burgers and G.J. van Oldenborgh, 1999, contributed to the preparation of a KNMI/NOP Fact sheet on Climate and Climate Change.
G.J. Komen, member of the Netherlands IGBP/WCRP Committee, Royal Netherlands Academy of Arts and Sciences.
G.J. Komen, member of the Netherlands SCOR Committee, Royal Netherlands Academy of Arts and Sciences.
G.J. Komen, chairman of the Program Board CKO.
G.J. Komen, member of the Scientific Board of SRON.
G.J. Komen, chairman of the Clivarnet.
G.J. Komen, associate editor, Journal of Physical Oceanography.
G.J. Komen, member of the Advisory Board of the National Geographic Magazine for the Netherlands and Belgium.
G.J. Komen, member of the Advisory Committee Marine Facilities, NWO.
A. Sterl, member of the JSC/SCOR Working group Air-Sea Fluxes.