KNMI
Research Programme
2003-2007

Climate Research

Seismology

Meteorological Research

Contents

0. Introduction

Scientific research at KNMI has been divided into three categories:

- Climate research
- Seismological research
- Meteorological research

For each of these three components, a research programme for the upcoming years is formulated periodically. Taken together, these programmes represent the Research Programme of KNMI. Details of this research programme are presented every year in KNMI's Annual Plan.

1. Climate Research Strategy

December, 2002

Summary

As national research and information centre for climate and climate change, KNMI deals with observation, investigation and prediction of the climate system. Starting point for this strategy are the current state of international climate research and the questions that are posed by public authorities and the general public, namely: 1. How is climate changing; 2. Why is climate changing; 3. What will the future climate be.

This has led to the formulation of the following research objectives for the period until 2007:

1. To acquire the necessary data through observations (monitoring);
2. To obtain better understanding of the climate system and the causes of climate variations and their predictability;
3. To achieve the ability to make more accurate predictions of climate (including climate extremes) on regional scales, as far as predictable, and considering both natural and anthropogenic effects.

Results of the research will be communicated to policy makers (mitigation and adaptation) and the general public. The research is integrated into the international efforts.

1.1 Introduction

This document contains an outline and global objectives of the climate research conducted by the Climate Research and Seismology Department (KS) of KNMI, the Royal Netherlands Meteorological Institute. The programme will be further detailed in annual work plans. The research strategy aims to provide answers to questions from public authorities and the general public, as well as to offer a high quality contribution to international scientific research efforts. A better understanding of climate and climate change will be the main research outcome. This knowledge is an instrumental part of all policy decisions that aim to achieve sustainable development in a safe environment. The recommendations issued in 2000 by an international review committee were taken into consideration when drawing up this research programme.

1.2. Mission statement

The mission of KNMI's climate research is:

To act as national research and information centre for climate and climate change at a high scientific level.

This mission prompts a number of questions: what information does KNMI wish to be able to provide; what research do we conduct and what level do we try to achieve. Below, we shall answer these questions.

1.3. Questions and main lines of research

The questions most often asked by public authorities and the general public (see Annex 1.1) can be split into three categories:

(i) *How is climate changing*: questions related to the observation and description of today's climate and that of the past, both in the Netherlands and elsewhere on earth.

(ii) *What is the cause of climate change*: How well do we understand the causes of natural and anthropogenic climate change?

(iii) *What will the future climate be like*: climate forecasts for the short term, ranging from seasons to several years, as well as longer-term predictions, mainly with a focus on Western Europe.

These three categories of questions correspond to three areas of research.

1.3.1 How is climate changing?

Research that focuses on answering this question includes *monitoring* and *description* of the actual climate. *Climate monitoring* is the sustained and homogeneous observation of climate variables, and parameters that determine the behaviour of the climate system. The objective of monitoring is to establish climate variations on time-scales ranging from seasons to centuries. In addition, it is important to observe more rapid processes relevant for climate variability. Since the climate system is a globally interconnected system, climate monitoring is an international activity (through GCOS, the Global Climate Observing System, and GAW, the Global Atmosphere Watch). These global observation systems make use of in-situ measurements, and ground and satellite-based remote sensing. *Climate description* includes data interpolation in space and time and the calculation of normals and extreme statistics.

In this context, KNMI will undertake the following initiatives:

- Observation and description of climate variables on the basis of the Dutch operational networks, as well as the monitoring and description of the atmospheric profile at KNMI's research station at Cabauw, which is to be upgraded into an international reference station.
- Reconstruction of past observational series and the reconstruction of the climate in Northwest Europe.
- Global and regional monitoring and analysis of the composition and radiation climate of the atmosphere. In this context, the focus will be on the interpretation of satellite measurements of vertical distributions of ozone, other greenhouse gases and aerosols, in conjunction with ground-based measurements at Paramaribo that fill a blind spot of the observing system in the tropics.
- Continuation of KNMI's contribution to international operational networks, such as the network of voluntary observation ships (VOS) and the European Group of Ocean Stations (EGOS). In addition, KNMI intends to strengthen site-based observations in the North-Atlantic Ocean, by contributing to the buoy network.
- Contribution to the development of novel assimilation techniques, and the retrieval and assimilation of observations in models (analysis), along with the verification of reanalysis products.

These research goals coincide in part with those of WM, the Observations and Modelling department of KNMI. Part of the work will be carried out in this department.

1.3.2 What is the cause of climate change?

Climate change as a result of human actions can only be understood and established against the background of natural climate change. This makes it necessary to study and model climate processes and to investigate interactions in the climate system. KNMI will contribute to the international activities in this field by performing research in the following three areas:

- The *functioning of the climate system* is investigated through studies of processes in the coupled atmosphere/ocean/sea-ice system.
- *Observed climate changes* are studied through the reconstruction of natural and anthropogenic climate forcing and the climate system's response to these forcings.
- *Research into climate predictability* focuses on the question whether the observed changes were predictable and to what extent the climate system, both globally and regionally, is predictable.

1.3.3 What are the predictions for the near future?

The future of our climate is of great socio-economic relevance, especially for the Netherlands. Global climate predictions are made with the aid of complex, coupled climate models. The prediction horizon varies from seasons to centuries. While developments on the seasonal time-scale are mainly determined by dynamic interactions between the oceans and the atmosphere, the development of radiative forcing is an important factor for longer time-scales. KNMI research in this area has the following focal points:

- In the field of *seasonal forecasts*, KS will carry out research in co-operation with the European Centre for Medium-range Weather Forecasts (ECMWF) in Reading (UK).
- The emphasis in KNMI's climate prediction research will be on *regional climate*. The aim is to make more accurate predictions of the climate in the Netherlands and its immediate surroundings (including adjacent seas and river basins), and in particular more accurate estimates of possible changes in extremes. In this kind of research, the outcomes of global models are rendered more precise by means of a combination of statistical methods and a regional climate model.
- KNMI will closely monitor international activities in the area of *global climate predictions*, and will work together with RIVM (the Dutch National Institute of Public Health and the Environment) in the development of assessment models.

1.3.4 Limitations

KNMI's research is focused on the climate system itself. It will not directly address the question of the consequences of climate change, nor will it investigate policy options. However, it will provide information that caters for the needs of impact researchers and policy makers.

1.4. Implementation

Since in-depth knowledge is essential and of strategic importance for the Netherlands, research will be carried out in a number of specialised divisions.

1.4.1 Atmospheric research

Work in this division focuses on the observation, modelling and understanding of the heat and water balance of the atmosphere. Research into the heat balance includes studies of the natural and anthropogenic greenhouse effect, i.e. of radiation transports in relationship to greenhouse gases, clouds and aerosols, and of heat transports linked to small-scale dynamics. Research into the water balance relates to the evaporation of water on the earth's surface, the formation of clouds and rain and the water balance of both soil and rivers. A major part of the work focuses on the development and application of new remote-sensing systems for observations related to the atmosphere's heat and water balance, both from satellites and on the ground. The Cabauw ground station will be developed into a national and international measuring station in the field of clouds, radiation, boundary layer structure, dynamics, greenhouse gases, their precursors, and aerosols (in co-operation with the Atmospheric Composition Division). Model research centres on a Regional Atmospheric Climate Model (RACMO). This model is related to the regional weather prediction model HIRLAM. The objective is to apply RACMO for the development of regional climate scenarios. Global model development is carried out mainly in co-operation with third parties (ECMWF, ECHAM).

1.4.2 Oceanographic research

The ocean plays an important role in the climate system. Work in this division focuses on large-scale ocean circulation, the variability of ocean currents, the large-scale interactions between the ocean and the atmosphere and on the processes that play a role in air/sea interaction. Experimental research into small-scale air/sea exchange is carried out at the Noordwijk Platform. KNMI plans to contribute to the in-situ observations in the North Atlantic Ocean of the ARGO buoy network. Modelling and theoretical work of the division supports and uses experimental work of the Royal Netherlands Institute of Sea Research. Research objectives include: a better understanding of large-scale

ocean circulation, a better understanding of the contribution of thermal expansion to sea level rise, improvement of relevant parameterisations, a better understanding of ocean variability and of the influence exerted by the ocean on the coupled climate system, as well as the development of data assimilation methods for seasonal forecasting systems.

1.4.3 Atmospheric composition research

The changing composition of the atmosphere is an important factor in anthropogenic climate change. Research in this field includes modelling, process studies and the observation of the global atmospheric composition, in particular from satellites. The launch of new instruments such as SCIAMACHY, OMI and GOME-2 makes this a particularly dynamic field of research. A closely related activity is the observation of present and the reconstruction of past radiative forcing, particularly relevant for the reconstruction, detection and attribution of natural and anthropogenic climate variations. Specific research objectives include the detection and projection of changes in the composition of the troposphere and the stratosphere, as well as climate interactions between these two atmospheric compartments.

1.4.4 Variability research

Research within this division focuses on large-scale atmospheric dynamics and related physics, and on the coupled atmosphere/ocean system. Specific research objectives are: the study of variability patterns and their underlying mechanisms, understanding climate change both in the recent geological past and as a result of anthropogenic forcing, and the study of the climate system's predictability. Work includes the development of a global so-called Intermediate Complexity Model.

1.4.5 Climate analysis

This division works on climate analysis, the reconstruction of the climate of the past on the basis of historical data, and on the development of climate scenarios for the benefit of impact studies. The methodology used is that of statistical climatology. Climate analysis and scenario work focuses on variability and extremes; climate reconstruction has a focus on high time-resolution. Both the analysis of the present climate and the construction of climate scenarios is carried out in close co-operation with the institutes responsible for water management policies in the Netherlands, in particular RIZA and RIKZ.

1.4.6 Interdivisional activities

In order to improve synergy between divisions, and following recommendations of the review committee, three interdivisional themes have been selected, each of which is linked to the three main areas of research described above. The interdivisional themes are:

- *Observation of, and research into, the atmospheric column at Cabauw*: The development of Cabauw into an international observation and research station, capable of supplying continuous observations related to a large number of climate system parameters.
- *Detection and attribution*: the detection of climate change and the quantification of the relative contribution of natural and human causes to the changes detected (attribution). This approach requires research into the patterns of climate change and the mechanisms that lead to large-scale climate variability.
- *Regional climate of Northwest Europe and adjacent waters*: analysing the present climate in Northwest Europe, making projections and answering questions raised by society regarding the regional consequences of human influences on climate.

The activities to be carried out will be detailed in the annual work plans.

1.4.7 Climate models

Numerical models are essential aids in climate research. A joint model development strategy will promote both the coherence of the research programme and the co-operation between divisions. The selection of models and the priorities in model development should follow from the general research strategy. Special attention will be given to the selection of models,

and the way in which they will be obtained or developed. Generally, one distinguishes three types of model:

- Component models, for instance models of the atmosphere, the ocean, atmospheric chemistry or radiative transport.
- Coupled global climate models, for which a distinction should be made between 1-dimensional models (1-D), Intermediate Complexity Models and Global General Circulation Models.
- Regional high-resolution climate models.

A model support project, provisionally funded by the Ministry of Education and Science through COACh, is already bearing fruit and is leading to greater coherence in model development, both within KS and between CKO (the Centre for Climate Research) partners. The aim is to continue or perhaps step up this effort within the context of CKO.

1.5. External relations

KNMI's research focuses on two categories of users: 1. Those who use its information and advice (specifically the public authorities and the general public); and 2. The international scientific community and associated (inter)national networks.

1.5.1 Users of information and advice

KS provides support to governmental policy on the climate and the environment by issuing scientific reports and advice memorandums. The main partners being naturally our own Ministry of Transport and Public Works and the Ministry for Housing, Spatial Planning and the Environment. KS itself does not contribute to the development of policies but monitors the quality of the scientific underpinning of policies. Co-operation with our own Ministry will be strengthened in the next few years, especially in the areas of water management and coastal protection. On a European and global level KS participates in international scientific assessments and coordinates national contributions.

In addition, KS provides information to other public and private organisations and to the general public on climate and climate change, by means of reports, press releases, and contributions within the field of education. Activities will be carried out on the basis of a more detailed communication plan.

1.5.2 The international scientific community

Publication of research results in leading international scientific journals was well as presentations at international conferences are important for recording and distributing the knowledge developed at KNMI. These activities also provide the basis for monitoring research quality and productivity.

The World Climate Research Programme (WCRP) provides the main framework for tuning KS's climate research efforts. In addition, KS offers contributions to the International Geosphere Biosphere Programme (IGBP) as well as to the Global Climate Observing System (GCOS) and Global Atmosphere Watch (GAW), both programmes run by the World Meteorological Organisation (WMO) in the field of observation and monitoring of the climate system. KNMI will continue to carry out its duties as national representative with the Global Climate Observing System (GCOS), Global Atmosphere Watch (GAW) and the Intergovernmental Panel on Climate Change (IPCC). KS intends to promote the visibility of its own research in the IPCC reports, and encourages direct participation of its staff in the drafting of IPCC reports, either as authors, contributors or reviewers.

Through the international activities, KNMI contributes to the international pool of scientific knowledge and obtains access to international data, knowledge and models. Participation in the bodies of these organisations is therefore essential to the fulfilment of our mission. KS will continue to participate in the activities of those organisations that offer a demonstrable contribution to answering the main questions formulated in this research programme.

Model development is done within national and international frameworks. To this end, KNMI co-operates with sister organisations both in the Netherlands and abroad, including ECMWF.

There is an increasing trend to establish European networks (the so-called European Research Area of Eurocommisioner Busquin). KNMI aims to secure a role in relevant networks in the areas of climate modelling and climate monitoring.

1.5.3 National co-operation

KNMI is a member of the Centre for Climate Research (CKO), the formal body for co-operation with the Institute for Marine and Atmospheric research Utrecht (IMAU) and the National Institute of Public Health and the Environment (RIVM). It will pursue an evaluation and, if necessary, adaptation of the CKO agreement in order to stimulate scientific co-operation and synergy in the best possible way.

Within the framework of programmes such as the third sequel to the National Research Programme on Climate Change (NOP), the Earth and Life Science Board of NWO, and the Knowledge Infrastructure Programme of the Interdepartmental Committee for the Strengthening of Economic Structures (ICES/KIS), KNMI intends to intensify its strategic relations with other national institutes, such as the Climate Change and Biosphere Programme (CCB) at Wageningen, the Netherlands Space Research Foundation (SRON) and the Netherlands Institute for Sea Research (NIOZ), and especially with its departmental sister institutes, the National Institute for Coasts and the Sea (RIKZ), and the National Institute for Integral Fresh Water Management and Waste Water Processing (RIZA).

In addition to these broad collaborations, more specific associations have been set up in connection our measuring facility in Cabauw (CESAR: Cabauw Experimental Site for Atmospheric Research) and the Ozone Monitoring Instrument (OMI) project.

1.5.4 Universities

A good co-operation with universities is of major importance. KNMI recruits graduates and post-doctorate students from universities and, together with universities, has access to the subsidies granted by the Netherlands Organisation for Scientific Research (NWO). In exchange, KS supervises graduate and Ph.D. students and gives researchers access to data and facilities. KNMI is an associate member of the Buys Ballot research school. In addition, KNMI strives to acquire or maintain part-time posts at the level of University Lecturer or Professor.

1.6 Synergy within KNMI

1.6.1 Within KS

Research in the three interdivisional themes will strengthen synergy within KS.

1.6.2 Within KNMI

In order to fulfil its mission, KS needs support from the Observation and Modelling (WM) and Measuring Instruments and Infrastructure (MI) departments. At the same time, KS has considerable knowledge in atmospheric research, weather prediction and measurement methods, which is potentially useful for other departments. In practice there are many joint activities. KNMI's management team has commissioned the development of a KNMI-wide strategy for research and development, which will further indicate how these joint activities can be strengthened and structured.

1.7 Staff, organisation and internal communications

1.7.1 Staff

Since climate research is an international issue, KNMI strives to achieve a high scientific level as measured by international standards. Recruitment, training, career and mobility planning of staff is thus of the utmost importance. KNMI intends to further improve its human resource policy by means of several measures. To this end, training plans will be drawn up for new and young staff. Within the framework of the planning cycle, an annual staff

plan will be formulated, taking care of the deployment of regular and temporary staff, on the basis of the quality and ambitions of existing employees and the needs of the organisation. The capabilities and ambitions of staff will be tested regularly against the possibility and desirability of KNMI-wide mobility. Managers and project leaders are expected to train and develop themselves.

1.7.2 Organisation

KS wants to create a dynamic and inspiring research environment with minimum administrative overhead. The divisions are at the basis of the organisation. Work in each division is structured into a number of product clusters. Specific objectives, and financial and human resource plans will be laid down in annual work plans. The Division Heads will monitor progress and the expenditure of the budget; they will take action whenever needed. Overall responsibility rests with the Head of Department, who will also supervise progress in the interdivisional activities, jointly with the Division Heads involved.

The acquisition of additional funding will be encouraged, provided that it strengthens KNMI's mission and this research programme, and also provided that the necessary housing and supervision can be made available.

KS strives for simple and effective administrative procedures, and sound administrative and financial management.

1.7.3 Internal communications

Good internal communication is essential for the well being of staff and for the quality of their work. Due attention will be given to this issue:

- The annual performance review (*evolutiegesprek*) with all staff is compulsory.
- Decisions taken in the Department Consultative meeting will be communicated through intranet.
- KS will continue the recently started weekly electronic Newsletter.
- Temporary staff will periodically be informed about their position.

Annex 1: Examples of questions by policy-makers and the general public

(Between brackets: the party asking the question)

1. Is the weather today really different from what it used to be? Is a couple of degrees warmer really such a big problem? (media, general public)
2. What are the likely changes in concentrations of greenhouse gases, aerosols and ozone depleting substances in the future? (general public, V&W, RLD, National Aviation Service, VROM, impact researchers)
3. What changes will the future bring in global and regional climates? How will temperature, precipitation and sea level change? What are the uncertainty margins in climate predictions? (general public, V&W, RWS, VROM, LNV, impact researchers)
4. What is the effect of (our) measures against climate change and ozone depletion, such as emission reductions? (general public, V&W, VROM)
5. What sudden irreversible changes may occur in the climate system in the future? (general public, V&W, VROM)
6. How high must the sea dykes be for a 1% per century chance of flooding? (RWS, RIKZ)
7. How high must the river dykes be at a 1% per 10-year chance of flooding? What is the chance of the country being covered in ice, low water levels and extreme precipitation intensity? (RIZA, RWS, water management boards, sewerage system managers)
8. Will we have 'superstorms' in the future? How will the likelihood of high water levels be affected by the greenhouse effect? (general public, V&W, RWS, RIKZ, insurance companies)
9. What will happen to weather extremes in the future? (general public, insurance companies, V&W)
10. In what way will the ozone layer, and the hole in it, change in the future? Is it possible for a hole in the ozone layer to develop in our region? What are the consequences in terms of UV-load? How dangerous is all of this? (general public, V&W, VROM, VWS)
11. What will be the future influence of aviation on the atmosphere and clouds? (general public, National Aviation Service, V&W, VROM, airline companies)
12. What is the influence of traffic and shipping emissions on the atmosphere and the climate? (general public, V&W)
13. What are the feasibility limits to seasonal forecasts? (agriculture, the business community, general public)
14. What is the outcome of forest fires and changes in land use on the climate? (general public, VROM, LNV)
15. What is the significance of a possible anthropogenic climate change in the light of major natural climate variations that occurred in the past?
16. Why would it not be possible to have another Little Ice Age in the near future?
17. What is the influence of volcanic eruptions and changes in solar activity on the climate of the future?
18. Will water shortages and low river flows recur more frequently in the future? (Water management boards, V&W, LNV, drinking-water companies and waterworks?

2. Seismology Research Strategy

November, 2002

Summary
The Royal Netherlands Meteorological Institute is a knowledge based research centre and observatory for earthquakes and related events. On the basis of seismological and other geophysical observations like infrasound, KNMI is active in fundamental and applied research in the field of seismology and furthermore hosts the European centre for exchange and coordination of seismological data (ORFEUS). The research is focused on seismic hazard and risk in the Netherlands. Divided generally by geographical location, natural earthquakes are observed in the southern part of the Netherlands and induced earthquakes as a result of the exploitation of gas reservoirs are observed in the north. Research is also carried out in the context of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The observations and subsequent research are published to serve both a general audience and scientific professionals.

2.1. Introduction

This research programme presents the main targets of research and observations in the field of seismology at KNMI. A more detailed version will be written as part of an annual workplan. This strategic research programme focuses on answering questions from government and society as well as on a high level contribution in the field of seismology. The main result of the described research will be a better understanding of the occurrence of earthquakes in the Netherlands and its effects. This knowledge is a basic requirement for the development of policy regarding hazard and risk.

The research is conducted in the Division of Seismology (SO) of the Department of Climate Research and Seismology. The Division is organized as a small independent unit of the Department for Climate Research and Seismology. It is responsible for the operational tasks (seismic observations and public information) and seismic research. The embedding in a meteorological institute is based on historical decisions and on the traditional division in geophysics, atmosphere, oceans and solid earth. In the middle of the 1980's, seismology was selected to represent the physics of the solid earth at KNMI.

2.2. Mission

The Division of Seismology is the operational knowledge and information centre in the Netherlands for earthquakes and related phenomena. It carries out high-level applied and more fundamental research based on seismological and other observations such as of infrasound. Furthermore, it functions as a European centre for the exchange and coordination of seismological data (ORFEUS). The research focuses on causes, effects and risks of earthquakes in the Netherlands. With this mission, the Division formulates an annual workprogramme and a budget is attached accordingly.

The relevance of seismology for the Netherlands government is high given the positioning of the KNMI as a centre for information on hazard and risk. In the current programme choices are made and clear research questions are posed. It allows tuning the level of research and observations with the available resources. The purpose of this strategic research programme is to show the choices made. In addition, the relation to other related research institutes is described.

2.3. Seismology in the Netherlands

The importance of seismology in the Netherlands can be answered through the geographical distribution of earthquakes in our country. In the south natural earthquakes occur with an estimated maximum local magnitude of 6.3. Paleoseismic studies might indicate sporadic occurrence of larger shocks. The recurrence frequency of tectonic earthquakes is not changing, but the vulnerability of society is increasing. Therefore, the risk for earthquakes in the Netherlands is increasing. The determination of the seismic risk in the Netherlands is the kernel of the seismic research programme.

In the northern provinces of the Netherlands induced earthquakes occur. They are associated with the extraction of natural gas in the area. The maximum expected local magnitude is estimated at 3.8. The recurrence frequency of magnitude 3.0 shocks is once every 5 years. The gas production will proceed until far in the 21st century.

As a moderate European state, the Netherlands is in support of a ban on nuclear explosions. With the signature of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) on September 10 1996, a milestone has been reached. During the past 25 years the Division of Seismology advised the ministry of foreign affairs on this issue. Internationally, seismologists have largely been involved with the detection and identification of nuclear test explosions. It contributed greatly to the development of seismology.

Besides these topics in seismology specific for the Netherlands, there are more fundamental subjects in the field. These subjects, such as the tectonic history, have a more international character. Moreover, there is overlap with other fields such as (structural) geology. It is clear, that for a proper study of seismology in the context of the Netherlands these more academic aspects also deserve attention.

The basis for observational seismic research is the data. The KNMI is the institute in the Netherlands responsible for the production and archiving of the seismic data, both broad-band and continuous. The Division of Seismology is integrated with ORFEUS, the European initiative for digital broad-band seismic data exchange and collaboration. As a result, an international functionality is added to the KNMI. The open availability of large data volumes to all researchers is essential. All digital seismic data from both KNMI and ORFEUS are easy accessible without cost.

2.4. Seismology at KNMI

In 1904 the first experimental seismic observations at KNMI began. In 1908, routine observations started. For the first time the available seismometers in this period were able to record earthquakes at large distances. The Netherlands belongs to the group of European countries that were interested in instrumental seismology in the early stages of the field. The seismic station at De Bilt (DBN) has a long, almost continuous dataset. Seismology at a meteorological institute is worldwide no exception. Geophysics can be divided in solid earth geophysics and the physics of the oceans and the atmosphere. The particular function of an observatory with continuous labour intensive duties and overall focus on geophysics is the most important overlap between seismology and meteorology. This accounts for the historic decision to have seismology at KNMI. In a period of 100 years, seismology at KNMI has developed greatly. The instrumentation is up-to-date, and the focus of attention has been shifted from observatory work to applied research in the field.

Today, in the tradition of observational seismology, KNMI focuses on the daily analysis of recorded seismic data and other observations. Research can be subdivided by the geographic distribution of earthquakes. In the southern part of the Netherlands the effects of natural earthquakes are studied. In the northern part, the effects of gas production induced earthquakes are the subject of research. All the research is made available with clear knowledge of the public function of the institute. Another research subject is the study of infrasound with has many elements in common with seismology. The

relevance of infrasound research is that the effect of low frequency/inaudible sound waves mimic seismic vibrations. The public cannot distinguish the two. Besides this, the observation and research of infrasound have become increasingly important in the context of detection and identification of nuclear explosions.

Seismic research and observations at KNMI are supported by the Division for Measurement Systems and Infrastructure. This support is essential for modern seismology with a marked technological dependence.

2.5. Related research institutions

The Division of Seismology at KNMI is not the only research group in the field. The University Utrecht (UU) has a faculty of earth sciences which houses a research group on seismology. This group focuses on aspects that are more fundamental in nature. There is an agreement of cooperation between KNMI and UU and the two research institutions are complementary in their research efforts.

The Division of Seismology has a regular contact with the geophysicists of the Free University of Amsterdam. This group studies mainly large-scale tectonophysics. The group is interested in incorporating seismology in their large scale modelling

Concerning earthquakes in the northern part of the Netherlands there is regular contact with the research department of the group for applied earth sciences of Delft University. This group models the deep subsurface using high frequency seismics; including the modelling of gas reservoirs that were subject to induced earthquakes.

With respect to geodesy, there are sparse contacts with researchers of Delft University. These are often of a general nature. A few times KNMI facilities, such as seismic stations, have been used for geodetic work. The use of Synthetic Aperture Radar (SAR) could be a possible future research item. With this technique, a static displacement after an earthquake or after fast subsidence can be measured.

In the field of infrasound, contact has been made with the Laboratory for Applied Acoustics and Seismics of Delft University. Here the aim is a PhD study of one of our staff members.

Regular contacts are common with the Geological Survey of the Netherlands (NITG-TNO), and there exists a memorandum of understanding. There is cooperation on five subjects: a. site responses for the northern part of the Netherlands, b. mechanical modelling of the Roswinkel gas reservoir, c. in the field of paleoseismology, d. development of a very dense seismic network, e. in the area of seismic hazard and risk analysis. In the past, volcanic monitoring of the islands Saba and St Eustatius has been investigated, but this project has ended due to the political unwillingness to support the monitoring. Together with the department of TNO, responsible for construction research (TNO-Bouw), KNMI and NITG operate a telephone answering service 'Geophone' for questions concerning (earthquake) vibrations and subsidence. The website of this service is of growing public interest.

2.6. Facets of general seismology

The general term seismology is often used to describe different aspects of the field. In order to explain the context of the research at KNMI, a short description is given in this section of seismology as a whole. Guided by the events during and after an earthquake a four step sequence can be described. The focus or source of earthquake and wave propagation through the solid earth are classical subjects in seismology. Then, the effects on the surface to people and buildings and the seismic measurements themselves follow. In order to be serious with respect to our public task as a centre of knowledge all facets of seismology deserve attention. Since this knowledge can be more externally oriented (to society) or focussed on the field itself, KNMI does not devote equal time to all aspects. The focus is on applied research

concerning earthquakes in the Netherlands and seismic observations.

2.6.1. The earthquake source

The study of the earthquake source is one of the most difficult subjects in seismology. The background is that the source is only visible in a convoluted way, through the filters of path effects and response at the surface and seismometer response. Moreover, the complex processes in the source are not in direct reach of instruments. The elastic properties of the fault zone are often disrupted by the process of fracturing. The process of rupture itself is complex and the movement along the fault seems to be a critical process, were chance plays a role. Sound conclusions concerning the source processes can only be drawn if the processes are understood and a good picture is available of the deep and shallow subsurface. At this time it is not clear to what extent the total slip along a fault is due to earthquakes or due to other more slow aseismic processes. This is important knowledge for the estimation of seismic risk.

The current data set of the KNMI allows localisation of the earthquake source with good accuracy; sometimes relative hypocenter determinations are used. Comparison with the geology from 3D-seismics can lead to conclusions concerning the source when these studies are reinforced with finite element model studies. The ultimate aim is a better understanding of the source. In this complex are of study, the Division of Seismology cooperates with interested oil companies, the Geological Survey and universities. The subject will remain of importance for years to come.

2.6.2. Wave propagation and structure of the earth

Wave propagation and structure of the earth are subjects that are intimately connected in seismology. Most of the fundamental questions are resolved now. For KNMI two problems remain of interest for further research. This concerns the structure between 5 and 30 kilometres, the depth of the 'Moho', which is the contrast in velocity due to a change in chemical composition of the crust. The structure above 5 kilometres is very well known in the Netherlands, since the oil industry applied 3D-seismics to large parts of the country. The data exists, but not always freely available. The structure between 5 and 30 kilometres can be studied with a technique that calculates 'receiver functions'. Here the conversions from P to S-waves at velocity contrasts generate the structural information. Deep profiles by NITG also provide means to infer deep structure. Recently, ideas have been put forward to shoot even some new profiles.

The second subject that is of importance is the wave propagation in the solid earth in connection with the accurate determination of hypocentra of earthquakes in the Netherlands. It is still an open question, whether the distribution of seismic stations in the Netherlands is adequate to use simple, one-dimensional velocity models or if a more complicated three-dimensional model is needed. In principle three-dimensional models are available along with the algorithms (UU) to perform efficient hypocentre calculations.

The Division of Seismology performs studies in the field of receiver functions and velocity models to contribute to more accurate hypocentre determinations.

2.6.3. Effects of earthquakes

The effects of earthquakes are documented in the European Macroseismic Scale (EMS). In the Netherlands, a maximum of VII-VIII on this scale is expected to occur. This was actually reached during the Roermond earthquake of 1992. The damage from this earthquake was considerable, yet a severe winter storm or flooding can cause even more damage and they are considered more frequent. In the Netherlands the dikes are brought to a height were a one in 1250 years chance of flooding seems acceptable. A Roermond type of earthquake has a recurrence period of 500-1000 years. In the northern part of the Netherlands, the situation is that in small areas intensities of VI-VI+ can occur. In this part, it is not so much the damage itself but the attribution of the

damage to the induced events that causes unrest among the population. Research with respect to the circumstances that can lead to damage as a result of earthquakes are of importance for the Netherlands as a whole. This concerns mainly the study of the subsoil to depths up to 100 metres. The details of the structure of these shallow layers determine the site response. Earthquake wave amplitudes can be strongly influenced by the site response. Previous research at two sites in the Netherlands showed that site response is of importance and that more experimental field work is necessary to develop a more founded vision on the subject.

The research is also directed to the detailed effects after an earthquake (damage, risk) in the Netherlands. The degree of detail is determined to a large extend by questions put forward by the society as a whole. At the moment these question reach beyond what seismologists can answer. Here a challenge lies ahead. A separate line of research is the determination of seismic hazard. First estimations have been made based on the Netherlands catalogue of earthquakes. In the coming years this research will be continued for the Netherlands as a whole, including induced seismicity and the North Sea area. The estimations will be improved by using measured peak ground accelerations in several sites in the Netherlands, instead of relying on macro seismic inquiries. Recently, research has been initiated in cooperation with Belgium, Germany and NITG on earthquakes in the geologic past. This paleoseismic research can result in estimates of severe earthquakes in the Holocene (the past 10,000 years). This line of research will be continued.

2.6.4. Earthquake recording

The daily care of recording earthquakes and the subsequent analysis of the signals constitute approximately 50% of the total programme of the Division of Seismology. This forms the basis of the research. In the coming period, KNMI can rely on data that was collected in the past period and on results from experimental observations such as those for the determination of S-wave velocities in the shallow (100 metres) subsurface.

The task in the context of the Comprehensive Nuclear-Test-Ban Treaty will be focussed on the analysis of seismic and infrasound signals. In this respect, a Netherlands National Data Centre will be initiated. In the data centre, data of several monitoring techniques will be brought together such as seismology, infrasound, hydroacoustics and radionuclide measurements. The KNMI research is directed to the waveform technologies only.

In addition to the active data collection of KNMI, the ORFEUS Data Centre (ODC) is another data related activity hosted by KNMI. The ODC collects digital broadband seismic data from European stations and makes these easily available to a wide range of researchers. In addition, ORFEUS coordinates the establishment of digital broadband stations and their technical details throughout Europe by way of working committees and workshops. Communication with the researchers is mainly via the Internet. ORFEUS is supported by 13 European countries (Belgium, Denmark, Germany, France, Greece, Great-Britain, Italy, Netherlands, Norway, Austria, Spain, Sweden en Switzerland).

2.7. Users of seismological knowledge

In formulating the strategic plan for the Division of Seismology, the users of seismic knowledge are recognized. The produced and acquired knowledge will be used in several ways. First to support the work in the Division itself and second in the role of centre of expertise. In this role, knowledge generated elsewhere is also made available and easy accessible for users in society as a whole. The identification of users is an important step in this process. Users can be found among professionals and non-professionals such the media and the general public. For a specialised field such as seismology translation of knowledge in common terms is needed for all users. They are summarised in the following list.

Government: V&W, Foreign Affairs, Economic Affairs, Defence (Air force)
Industry: AMOCO, ELF, NAM, building companies, assurance companies, TNO-Bouw, NITG-TNO
Media: TV, radio, writing press, schoolbook publishers, musea
Public: concerned citizens, school pupils, travellers, amateurs
Researchers: national and international

2.8. Symbiosis of observations research and experimental studies

The Division of Seismology hosts a suite of activities, observational work and analysis of data as a basis for applied research. The symbiosis of observations and research has a number of synergies that can be further exploited in the future.

The experimental work in the Division can be subdivided into routine observations, data collection, development of instrumentation, some ad hoc experiments and modelling work on earthquake source parameters. There is little experience in the Division with real experimental work such as reflection and refraction seismics. Yet there is an increasing demand for results of such experimental work, for instance in experiments concerning determination of site responses, infrasound measurements, measurements of tilt and paleoseismicity. In particular, the developments of array technologies such as those currently being used in infrasound may be a valuable contribution to seismic array measurements in the Netherlands.

2.9. Conclusion

This research programme provides the focus of work in the near future. That focus is mainly on the study of hazard and risk in the Netherlands. This applies to the northern parts where induced events occur with a lot of public attention and for the southern part of the country where the risks are highest. A research structure build around this theme shows clearly where gaps in current knowledge exist. This is the guidance for further detailing of the research programme.

The seismological research at KNMI uses a multitude of data that is available today, both from own sources such as from seismic instrumentation throughout the Netherlands as from results from specialized experiments. Site responses and modelling of the earthquake source are examples of studies that are of importance for the northern part of the Netherlands. For the southern part of the Netherlands the identification of active faults and the determination of seismic risk are important goals. The work will build on a number of studies that are already set in motion. The impact on society as a whole is central in the choice of priorities.

3. Meteorological Research Strategy

February, 2003

Summary
The aim of meteorological research at KNMI is to support the institute in fullfilling its public tasks on behalf of security, national economic interests and sustainable development of the environment in an optimal manner – as measured by international standards and present-day demands

In the definition of the relevant research issues, the demands of Dutch society on meteorology are taken as leading. Formulated in a generic way, these demands can be formulated as:

- What is the weather going to be?
- What is the weather at present?
- What was the weather like, and what can be considered normal?
- What impact does the weather have on my activities?
- How do I get the meteorological information that I need?

Based on these demands of society, several strategic choices concerning the main research objectives have been made and a number of critical success factors have been identified:

- Ensure a detailed description of weather and climate in the Netherlands, particularly for conditions of severe (life-threatening) weather
- Tailor weather information to the needs of specific important user groups
- Improve the accessibility of meteorological and climatological data and knowledge
- Maintain or improve the quality and efficiency of the operational systems
- Cooperation and strengthening of external (international) relations

3.1 Introduction

The aim of this research programme is to provide insight into the goals, strategy and main priorities of *meteorological research* at KNMI for the coming years. In addition, information is supplied on national and international co-operation, contacts with users and the way in which the R&D activities are organized. Meteorological research is mainly carried out within the Observations and Modelling Department.

Scientific research at KNMI can be divided into three categories:

- Meteorological research
- Climate research
- Seismological research

For each of these three components, a research programme for the upcoming years is formulated periodically. Taken together, these programmes represent the Research Programme of KNMI. Details of this research programme are presented every year in KNMI's Annual Plan.

3.2 Objectives

KNMI's mission is to contribute to the *safety, economic interests* and *sustainable development of the environment* of the Netherlands. It does so by making available *data*, *knowledge* and *information* on *weather*, *climate* and *seismology* to the Dutch government, the general public and specific user groups. The main objective of meteorological

research at KNMI is derived directly from this mission:

3.2.1 Mission

Meteorological research provides knowledge which contributes to the public tasks of KNMI in two ways:

- Research and development activities are undertaken primarily in order to ensure that the quality of basic meteorological data (observations and model data, both actual and historical) remains optimal and up to international standards, and that scientific and technological developments are pursued and exploited in operational practice.
- Secondly, this knowledge is made available to external users as part of the public knowledge infrastructure. This is usually done in the form of externally commissioned contracted research.

The aim is to make meteorological data and knowledge available to external users as widely and effectively as possible. In this respect, KNMI positions itself as the centre for meteorological data and expertise in the Netherlands.

3.2.2 Characteristics of meteorological research

- Meteorological (weather-related) research primarily aims at maintaining the quality, availability and accessibility of basic meteorological data (observations and model data) at a high level, and improve them wherever necessary.
- Knowledge and expertise are made available to both internal and external users.
- The main subjects of research are: observations and observational systems, numerical weather modelling, climatology and the meteorological data infrastructure.
- The research is strongly applied in character, in the sense that all scientific results should eventually be put to use in operational practice, either within or outside of KNMI.
- A balance is sought between exploiting new opportunities offered by scientific and technological developments (science/technology push), and meeting the needs of users of basic meteorological data (user pull). In this respect, the interests and needs of *external* users of KNMI data are now given greater weight in determining research plans and priorities than was previously the case.

3.2.3 Key questions from society

The main subjects of research are defined largely by the demands of society on meteorology. These demands can be summarized in the following generic key questions:

- **What is the weather going to be like?** The time scales considered here range from very short (minutes) to several days, weeks or even months ahead.
- **What is the weather like at present?** Is the weather at a specific location such that certain operations and activities can take place there?
- **What was the weather like, and what can be considered normal?** For example, the recently past weather contributes to the condition of the soil or to the amount of river runoff. Climatology is derived from archived observations. This supplies us with both information on which weather conditions can be considered "normal", and on the probability of extreme events happening.
- **What impact does the weather have on my activities?** Many professional users are insufficiently aware of how meteorological information may impact on their own business and decision processes.
- **How do I get the meteorological information that I need?** Meteorology is useless if interested parties are not able to access relevant information, data and expertise, or cannot obtain them in a timely fashion.

The aim of the meteorological research at KNMI is to contribute to the provision of scientifically valid answers to these questions.

3.3 Strategic choices and critical success factors

Given the key questions above, the scope of meteorological research can be very broad indeed. With limited resources available, strategic choices have to be made. These choices

are determined on the one hand by the needs of the users of meteorological information in the Netherlands, and on the other by scientific potential and developments. In setting research priorities, the consequences of participation in (inter)national research programmes need to be taken into account. Several critical success factors also contribute to the definition of R&D plans and priorities. The main strategic choices and success factors for the research plan are identified and described below.

3.3.1 Detailed description of weather and climate in the Netherlands

There is a need for a greater level of spatial and temporal detail in the description of weather systems over the Netherlands and its immediate surroundings, particularly in the case of hazardous weather conditions. Meteorological research activities are therefore strongly focussed on these small spatial scales and (very) short forecast times, and on extreme (small-scale) meteorological events and the consequences thereof.

In the search for more reliable methods for the detection and prediction of severe weather, the highest priority in the coming years will be given to the development of more accurate observation and prediction methods for (extreme) precipitation and severe convection. To an increasing extent, use will be made of probabilistic forecasts as tools for the interpretation of mesoscale phenomena, particularly in cases of severe (local) weather (thunderstorms, fog, road icing).

3.3.2 Tailoring weather information towards specific user groups

A second aim is to improve the tailoring of meteorological information to the particular needs of several important user groups. This is done by studying the ways in which meteorological information can best be used in the applications of these users, and by investigating which data and knowledge are of specific interest there.

Particular attention will be paid to the following groups of end users:

- coastal and harbour authorities,
- inland water management,
- aviation,
- environmental agencies.

3.3.3 Accessibility of meteorological and climatological data and knowledge

Another major objective is to increase the ease of access to meteorological information for users from government services, commercial enterprises and Dutch society in general, using modern ICT technology.

KNMI strives towards an open data policy: optimal availability of meteorological observations and model data (and climate and seismological information as well) for all users. The institute positions itself as the operational data centre for information on weather, climate and seismology in the Netherlands (KODAC = KNMI as Operational Data Centre).
Meteorological knowledge derived from research should be optimally accessible as well, both in a passive sense (providing knowledge by means of publications, a library, internet etc.) and actively (by carrying out external projects).

3.3.4 Quality and efficiency of operational systems

One of KNMI's main tasks is to maintain an adequate and cost-effective infrastructure for meteorological observations, forecasting and data processing. Hence, to optimise the effectiveness of the operational systems used for the collection, processing and dissemination of weather information as far as possible within the available means is a major target of, and a critical success factor for, meteorological research.
Quality assurance of the near-real-time and historic meteorological observations and model data is an item which will receive continuous care. Activities in this area will focus on the improvement of automatic observation quality control, the registration of metadata and best practice methods, and an extensive verification of operational models. Resources will be allocated to strengthen the scientific support to the

management of the operational observation and forecasting systems.

3.3.5 Co-operation and strengthening of external (international) relations

A continuous, strong focus on international co-operation and collaboration is of critical importance to KNMI's meteorological research. Selective participation in carefully chosen research groups and networks allows for an effective use of limited resources and for avoidance of duplication of effort. A swift, direct access to knowledge originating elsewhere can be ensured this way as well.

Meteorological research at KNMI is firmly embedded in international research collaborations and networks, mostly on a European scale. In this context, the organization of European weather services, EUMETNET, plays an increasingly active role. Other focal points for research cooperation are the EUMETSAT Satellite Application Facility (SAF)-projects, the international HIRLAM research projects and the EU Framework and COST programmes. At a global level, KNMI contributes to several programmes of the World Meteorological Organization (WMO), in particular the World Weather Watch (WWW) programme. Nationally, KNMI participates in many projects on a bilateral basis with other government services, universities and research institutes.

3.4 Key questions and associated research

Above, the boundary conditions within which meteorological research at KNMI takes place have been outlined, and the strategic choices defining research priorities have been described. Below, the consequences of these choices for research activities in the coming years are described in more detail. The research subjects have been ordered along the five key questions to meteorology mentioned earlier.

3.4.1 What is the weather going to be? (Modelling)

There is a need for a greater level of spatial and temporal detail in the description of predicted weather over the Netherlands and its immediate surroundings, particularly in cases of severe weather. Because of this, the research on numerical weather prediction models is concentrated on improving forecast accuracy on small spatial scales, very short forecast times and for extreme weather conditions.

The priority issues in the research on the numerical models used in operational forecasting are:

- To obtain spatially and temporally detailed short-range (up to 48h ahead) predictions of the weather and the sea state for the Netherlands and its surroundings. In the spring of 2002, the operational atmospheric forecast model HIRLAM has been renewed and its horizontal and vertical resolution considerably improved (to ~10km and 40 layers), by means of a significant increase in computing power. Research activities to further enhance the forecast quality at this resolution will focus on the assimilation of more types of (remote sensing) data and improving the description of precipitation and boundary layer processes. For the storm surge model WAQUA and the ocean wave model NEDWAM, very fine scale model versions (2-5km) are being developed for the Dutch coastal waters and Lake IJssel.
- The possibilities of forecasting at even higher resolutions (of ~1km) will be explored further. In the context of the HIRLAM-6 research project (2003-2005), a start will be made with the development of a non-hydrostatic meso-gamma model, capable of frequent assimilation of high-resolution data, and containing physical parametrizations suitable for use at 2-3km horizontal resolution. Particular attention will need to be paid to the description of cloud processes and turbulence. Additionally, statistical and physical post-processing techniques have been developed to transform short and medium range NWP forecasts to local predictions and wind forecast fields of a resolution of 1km or less. In the next few years it will be investigated how these downscaling methods should be combined to the best effect.

- A major objective is to improve methods for the detection and prediction of severe weather, for warnings to the general public and government services ("weeralarm") and for aviation safety. Emphasis will be put on enhancing the forecast quality of the position and intensity of (extreme) precipitation (on behalf of more accurate predictions of river water levels and local flooding), and the description of strongly convective weather conditions.
- Increasingly, information on the uncertainty of the weather situation and its predicted development will be made available in the form of probabilistic forecasts. In this respect, particular attention will be paid to applications in predictions of extreme or hazardous weather, e.g. heavy precipitation. Also, the possibilities and limitations of short-range (0-48h) ensemble forecasting will be explored further.
- Finally, quality assurance of the model is an item which will receive continuous care. Activities in this area will focus on continuous and extensive monitoring and verification, on the improvement of real-time quality control procedures, and a strengthening of the scientific support to the management of operational forecasting systems. Special attention will be paid to the issue of the verification of mesoscale phenomena.

3.4.2 What is the weather at present? (Observations and observational systems)

Similar to the research on numerical models, the main focus of the research on observations and observational systems is on obtaining a greater level of spatial and temporal detail in the description of the weather over the Netherlands and its direct environment. An increasingly important role in this respect is being played by high-resolution remote sensing observations from ground-based platforms and from space.

A key R&D issue for the coming years will be to achieve the exploitation of the full potential of the two Dutch precipitation radars, by implementing and using their Doppler velocity information and by improving the quantitative accuracy of the radar precipitation data. Other non-conventional observational systems which will be investigated closely are e.g. the Meteosat Second Generation (MSG) satellite, moisture observations from the GPS and wind profilers.

The main objectives of the research on observations and observational systems for the next few years are as follows:

- Strengthening of the European co-operation to achieve an optimal and cost-effective European synoptical observing system (EUCOS). In the period 2002-2006, a initial version of the EUCOS design is to become operational. In the context of EUCOS, KNMI will continue to contribute to the collection of observations from voluntary observing ships (VOS), drifting buoys, aircraft observations (AMDAR) and to the automatic launching of radiosondes from ships and platforms (ASAPs).
- Continued modernisation and restructuring of the Dutch meteorological observing system. It is aimed to achieve a "Composite Observing System for the NEtherlands (COSNED)", in which new, fully automated observing techniques and sensor types are to be deployed. An important subject of investigation is the optimal design of observational networks, on behalf of both operational meteorology and climate monitoring. Much attention will be required to fully automate the visual observations, in close contact with the present users of these data.
- Increased availability and use of new satellite observations, e.g. by means of participation in the EUMETSAT SAF projects.
- Increased deployment of high resolution ground-based remote sensing instruments for the mesoscale description of (potentially hazardous) weather in the Netherlands. It is planned to start making full use of the Doppler radar wind information and of improved quantitative radar precipitation data in the first half of the planning period. Also, a national network of boundary layer wind profilers is to be set up.

- The infrastructure for the collection and processing of remote sensing image information will undergo a complete redesign and be prepared for the reception of new data types (MSG, radar Doppler wind data, GPS, METOP/EPS, etc.).
- Finally, quality assurance of the observations is an item that will receive continuous care. Activities in this area will focus on the improvement of automatic real-time quality control procedures, the registration of meta-data, the recording of best practice methods, and a strengthening of the scientific support to the management of operational observing systems.

3.4.3 What was the weather like, and what can be considered normal? (Climatological research)

The questions "What was the weather like?", "What can be considered normal?" and "What is the probability that certain limits are exceeded?" belong to the realm of climatological research. Similar to the research on modelling and observations, climatological research at KNMI aims at achieving a more detailed description of the climate of the Netherlands and Europe. Particular attention is devoted to the study of the statistical probability of extreme (hazardous) events.

The main objectives of climatological research for the next few years are:

- To improve, and make more detailed, the description of the Dutch historical climate, and employ this knowledge on behalf of various government policy issues (e.g. safety against flooding).
- To further improve the extreme statistics of the Dutch wind climate. Also, the climate of precipitation and evaporation will be made up-to-date and determined with more spatial detail.
- To homogenize and make accessible long time series of Dutch climatological data on behalf of climate research.
- To exchange and interpret high-resolution climatological data on a European scale.
- To provide access to high-quality historical data for users at KNMI and elsewhere, in a cost-effective manner. The systems used for archiving and de-archiving historical observations will be renewed and extended with more types of data with high temporal resolution.
- Finally, quality assurance of the climatological data is an item which will receive continuous care.Activities in this area will focus on the improvement of real-time quality control procedures, the registration of meta-data and best practice validation methods, and a strengthening of the scientific support to the management of the climatological system.

3.4.4 What impact does the weather have on my activities? (Tailoring to user groups)

An important aim is to improve the tailoring of meteorological information to the particular needs of several important user groups. This is done by studying the ways in which meteorological information can best be used in the applications of these users, and by investigating which data and knowledge are of specific interest there. In the coming years, specific attention will be paid to the following groups of end users: coastal and harbour authorities, inland water management, aviation, and environmental agencies:

- **Coastal and harbour authorities**: For coastal safety and for the routing of shipping in the narrow traffic lanes along the Dutch coast, there is a need for spatially more detailed weather information, particularly wind speed and direction, on scales of approximately 1km. To enable the production of forecasts on such a fine scale, so-called downscaling techniques are being developed and tested, in close collaboration with services from Rijkswaterstaat.
- **Inland water management**: On behalf of hydrological users, much research is devoted to the improvement of the quantitative description of the observed and predicted precipitation, and the precipitation climate, over the Netherlands. New statistical methods are put to use for deriving probabilistic and regional precipitation

forecasts (on the scale of the Dutch Water Boards). The possibilities to allow hydrologists to make better use of available information on the probability of certain meteorological events are being explored.

- **Aviation**: On behalf of aviation safety, improved prediction methods for poor visibility, gusts and hazardous turbulence and convection will be deployed. The use of downscaling techniques will enable the production of highly detailed analyses and prognoses for wind at or in the vicinity of the Schiphol runways. This information can be used for runway allocation policy, or for the modelling of noise pollution in the environment of the airport. The observational system around Schiphol is to be renewed; present visual observations will become fully automated.
- **Environmental agencies:** More attention will be given to a better use of weather information on behalf of environmental issues. Highly detailed wind information can be used for example for the determination of the local transport and diffusion of air pollution or the propagation of noise. In co-operation with partners involved with energy research, it is being investigated what the potential contribution of improved and more detailed meteorological information could be to more accurate production forecasts for durable (wind and solar) energy sources.

Although somewhat different in nature, in this context we can also mention a research project on "The economic value of meteorology in the Netherlands" which will start in 2003. This project should result in an adequate set of performance indicators, by means of which the value of operational meteorology for the Netherlands can be determined and monitored in an objective manner. It may also yield answers to the question which (potential) improvements in meteorology are of most interest from an economic point of view.

3.4.5 How do I get the meteorological information that I need? (Access to data and knowledge)

A fifth major strategic objective of the meteorological research at KNMI is to increase the ease of access to meteorological data for users from government services, commercial enterprises and Dutch society in general. KNMI strives towards optimal availability of meteorological observations and model data (and climate and seismological information as well) for all users. The institute positions itself as the operational data centre for information on weather, climate and seismology in the Netherlands (KODAC = KNMI as Operational Data Centre).

Meteorological knowledge derived from research should be optimally accessible as well, both in a passive sense (providing knowledge by means of publications, a library, internet etc.) and actively (by carrying out external projects).

It is aimed to achieve these objectives by means of:

- Consistently following and advocating an open data policy, both nationally and internationally.
- Increasing employment of internet to provide access to meteorological data, making use of new ICT techniques such as GRID technology.
- Providing improved access to KNMI's meteorological knowledge through internet.
- Making more or more detailed types of data available by means of suitable databases that can easily be approached by external users.
- Deploying more widely known (not meteorologically specific) data formats, in addition to standard meteorological formats such as GRIB, BUFR etc.

3.5 External orientation and cooperation

Meteorological research activities at KNMI are mostly firmly embedded in international collaborations. Intensive contacts are also maintained with various national research institutes. As the R&D activities are often strongly applied in character, contacts with

external users are considered of high importance. Hence, users of data, knowledge and advice from government services, meteorological service providers and aviation authorities are consulted as to their experiences and needs on a regular basis.

Water management
In research activities on behalf of water management and coastal security, a close and long-standing cooperation exists with research institutes and users from Rijkswaterstaat: the National Institute of Coastal and Sea Management (Rijksinstituut voor Kust en Zee, RIKZ), the National Institute for Inland Water Management and Waste Water Treatment (Rijksinstituut voor Zoetwaterbeheer en Afvalwaterbehandeling, RIZA), the Storm Surge Warning Service (Stormvloed Seindienst; SVSD) and various regional services. In several projects, investigations are carried out in support of water policy development, particularly on flood safety issues. Researchers and operational forecasters jointly work on improving the meteorological information and services on behalf of the operational water management tasks of the regional services of Rijkswaterstaat. Contacts are maintained with the Union of Water Boards and the STOWA foundation concerning the development and use of meteorological expertise and services on behalf of hydrological users.

Commercial service providers
Nationally, KNMI provides basic meteorological data to commercial service providers such as MeteoConsult and Holland Weather Services. These providers are consulted regularly on the products provided by KNMI and more generally on data policy. Some of the larger service providers have expressed an additional need for meetings focussing more on scientific and technological developments. A scheme for this will be elaborated in the course of 2003.

Aviation
Meteorological research for aviation is based on the agreements and norms used within the international organisation ICAO. Regular contacts are maintained with Air Traffic control (Luchtverkeersleiding Nederland; LVNL) and Schiphol Airport on meteorological services. KNMI furthermore provides the airport authorities with advice on the impact that the intense building activities on the airport may have, on both the observational infrastructure and flight safety. Several research projects are aimed at improving and extending KNMI's meteorological services to civil aviation. Furthermore, meteorological expertise is provided for research on aviation policy issues, initiated by the programme board Flyland on behalf of the Ministery of Public Transportation and Water Works.

Research institutes within the Netherlands
In the context of its public tasks, KNMI maintains a close research collaboration with various government centres of expertise: with RIKZ in the field of storm surge risks and coastal zone research; with RIZA in the area of river flooding risks and water management; and with the National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu,RIVM) for the transport of chemical pollutants and warnings in cases of nuclear or chemical disasters.

A good co-operation with Dutch universities is considered to be of high importance. KNMI employs graduates and post-docs from the universities, and collaborates with various university research groups in projects subsidised by NWO and STW. Conversely, KNMI provides research opportunities for the thesis work of graduate and Ph.D. students, and gives several universities access to meteorological data. Active research co-operations exist with Delft University (remote sensing and maritime research), Wageningen University (boundary layer research), Leiden University and Twente University (high performance computing), the Dutch Institute for Nuclear and High Energy Physics (NIKHEF) and the computational centre SARA (ICT research).

Co-operation in the form of joint R&D activities and projects is aimed at with non-university technological institutes and research companies

as well. In the field of remote sensing research a good collaboration exists with NLR and Dutch Space Systems. In the development of maritime models, WL/Delft Hydraulics and Alkyon are important research partners. Together with ECN research is carried out on the optimisation of local weather predictions for the use of production prognoses for wind and solar energy.

Other forms of national cooperation
Jointly with RIVM, models are developed and tested for the prediction of the dispersion of toxic material emanating from nuclear or chemical accidents.
The Ministery of Defence is an important partner of KNMI in the area of meteorological infrastructure. A close collaboration exists in particular with the Royal Dutch Airforce (Koninklijke Luchtmacht, KLu) concerning the exploitation and renovation of the Dutch observational network.

International cooperation
At a global level, KNMI contributes to the activities of the World Meteorological Organisation (WMO), in particular to the World Weather Watch (WWW) programme. In addition, co-ordination and execution of meteorological research increasingly takes place at a European level. In this context, EUMETNET, an informal association of 18 European weather services, plays an important role, among others by initiating collaborative programmes such as EUCOS and ECSN. Many research initiatives in the field of satellite observations in which KNMI participates are launched by EUMETSAT (e.g. by means of the Satellite Application Facilities (SAF) projects) and ESA (e.g. the development of new types of instruments for the Earth Explorer Missions). For the development of numerical weather prediction, the HIRLAM project, a scientific collaboration between eight European countries, is of crucial importance. Finally, in the context of the EU Framework en COST programmes, R&D projects are initialized and carried out on a bilateral basis together with other weather services or research institutes.

3.6 Internal relations
The meteorological research of the Observations and Modelling Department (Waarnemingen en Modellen; WM) is carried out in synergy and co-operation with all other departments within KNMI.
In setting the research priorities, a balance is sought between exploiting new opportunities offered by scientific developments, and meeting the needs of operational users. Wherever possible, research results are implemented as innovations in the operational production processes. For these reasons, the research staff maintains close contacts with operations managers from WM and from the Weather Forecast Department (Weersverwachtingen en Adviezen; WA), and with operational forecasters.
The Instrumental Division (MI/INSA) is WM's main partner in the field of research on observational systems such as the radar, and on the renewal and redesign of the Dutch observational network. Research activities focussing on the development of the meteorological data infrastructure are co-ordinated on a project-to-project basis with the Automation Division (MI/AUT).
In its research on remote sensing systems and parameterisations for numerical models, WM regularly makes use of the expertise of research staff from the Climate and Seismology Department (Klimaatonderzoek en Seismologie; KS). Conversely, WM researchers play a facilitating role in R&D projects of KS concerning e.g. the data infrastructure for satellite information and the provision of historical observations and model data. Also, there are joint activities from WM and KS staff in the area of climatology and the statistics of extreme events, and in air-sea interaction research.

3.7 Organisation

3.7.1 Organisational structure
Meteorological research is mainly carried out within the Observations and Modelling Department. This department consists of four divisions, with the following number of staff

members active in research, on permanent basis (PB) and funded by project income (PI):

	PB	PI
• Operational Data (OD)	0	0
• Climatological Service (KD)	5	3
• R&D Numerical Modelling (RM)	14	3
• R&D Observations (RW)	6	13

Research activities are roughly distributed over the various divisions in the following manner:

- Observations and observational systems: research in this field is mainly carried out within the R&D Observations Division
- Numerical modelling: mainly carried out within the R&D Numerical Modelling Division
- Climatological research: mainly carried out within the Climatological Service
- Data infrastructure: mainly carried out within the R&D Observations Division

The Operational Data division is primarily responsible for the operation and maintenance of the automated processes concerned with the collection, production and dissemination of basic meteorological data. This division takes on board the innovations derived from research activities in its operational production systems.
The Climatological Service is responsible for maintaining the climatological archive (in both paper form and electronic databases), and for the provision of climatological products and advice.

3.7.2 Staffing policy and management of expertise

On the basis of the long-term research strategy and agreements between individual researchers and the management in yearly performance reviews, an overall education plan is drawn up annually. In this plan, attention is paid both to the keeping up-to-date of required professional expertise and to the development of personal skills. A vulnerable area of expertise in which the available capacity and level of knowledge needs to be strengthened in the coming years by recruitment, education and "training on the job", is the field of the quality assurance and interpretation of meteorological observations. Other areas of expertise that will continue to require careful attention are physical meteorology, numerical methods, statistical interpretation and ICT.
The policy to offer employment on a permanent basis to a limited number of staff who are funded from external projects is to be continued (see below).

3.7.3 Financial policy

Nearly one half of the research budget is funded by external sources, through externally commissioned research or participation in subsidised R&D projects. The turnover of such externally funded projects for 2003 is expected to be slightly more than 1,2 million Euro. Our policy is to keep this turnover stable for the coming years. These funds are used to finance the positions of 15 to 20 project staff members. The Department has a limited number of project staff members employed on a permanent basis, who are to be financed from a continuous flow of external funding. This approach has proven necessary in order to guarantee the continuity of specific scarce expertise.
Externally commissioned research or subsidised projects are only undertaken when the research involved fits within the Department's meteorological research programme.

Annex A: Acronyms

AMDAR	Aircraft Meteorological Data Relay
AUT	Automatisering (Automatisation Division (division within KNMI))
CCB	Climate Change and Biosphere Programme
CESAR	Cabauw Experimental Site for Atmospheric Research
CKO	Netherlands Centre for Climate Research
COACh	Cooperation on Oceanic Atmospheric and Climate Change studies
COSNED	Composite Observing System for the Netherlands
COST	Coordination of Science and Technology (EU programme)
ECMWF	European Center for Medium-range Weather Forecasts
ECSN	European Climate Support Network (Eumetnet programme)
EGOS	European Group of Ocean Stations
EUCOS	Eumetnet Composite Observing System (Eumetnet programme)
EUMETNET	European Meteorological Network (cooperative network)
EUMETSAT	European Meteorological Satellite Organisation
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GPS	Global Positioning System
HIRLAM	High Resolution Limited Area Model
HYDRA	Hydraulisch Randvoorwaarden (Hydraulic Boundary Conditions; project)
ICAO	International Civil Aviation Organisation
ICES/KIS	Knowledge Infrastructure Programme of the Interdepartmental Committee for the strengthening of Economic Structures
IGBP	International Geosphere Biosphere Programme
IMAU	Institute for Marine and Atmospheric research Utrecht
INSA	Instrumentele Afdeling (Instrumental Division (division within KNMI))
IPCC	Intergovernmental Panel on Climate Change
Klu	Koninklijke Luchtmacht (Royal Dutch Air Force)
KNIOZ	Royal Netherlands Institute for Sea Research
KNMI	Koninklijk Nederlands Meteorologisch Instituut (Royal Dutch Meteorological Institute)
KODAC	KNMI Operationeel Data Centrum (KNMI as Operational Data Center; research programme)
KS	KNMI's Climate Research and Seismology Department
LNV	Ministry of Agriculture and Fisheries
LVNL	Luchtverkeersleiding Nederland (Air Traffic Control the Netherlands)
METOP/EPS	Meteorological Operational Polar-orbiting satellite / EUMETSAT Polar System
MI	Measuring systems and Infrastructure (KNMI department)
MSG	Meteosat Second Generation (satellite)
NEDWAM	Nederlands Wave Model (operational ocean wave model)
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium (National Aerospace Laboratory)
NWO	Netherlands Organisation for Scientific Research
NWP	Numerical Weather Prediction
NWP SAF	Numerical Weather Prediction Satellite Application Facility
OC&W	Ministry of Education and Science
OMI	Ozone Monitoring Instrument
O&SI SAF	Ocean and Sea Ice Satellite Application Facility
RACMO	Regional Atmospheric Climate Model

RIKZ	Rijksinstituut voor Kust en Zee (National Institute for Coastal and Marine Management)
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (National Institute for Public Health and the Environment)
RIZA	Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling (National Institute for Inland Water Management and Waste Water Treatment)
RLD	National Aviation Service
RWS	Rijkswaterstaat
SAF	Satellite Application Facility
SRON	Netherlands Space Research Foundation
STOWA	Stichting Toegepast Onderzoek voor de Waterschappen (Foundation for applied research for the Water Boards)
STW	Stichting Technische Wetenschappen (Technology Foundation)
SVSD	StormVloed Sein Dienst (Storm surge warning service)
VOS	Voluntary Observing Ship
VROM	Ministry for Housing, Spatial Planning and the Environment
V&W	Ministry of Traffic, Public Works and Water Management
WA	Weersverwachtingen en Adviezen (KNMI department)
WAQUA	Water Quality model (operational storm surge model)
WCRP	World Climate Research Programme
WM	Waarnemingen en Modellen (Observations and Modelling; KNMI department)
WMO	World Meteorological Organisation